INTERNATIONAL ASSOCIATION FOR
THE PHYSICAL SCIENCES OF THE OCEAN
Association Internationale des Sciences
Physiques de l'Océan

INTERNATIONAL UNION
OF GEODESY AND GEOPHYSICS
Union Géodésique et
Géophysique Internationale

PROCES-VERBAUX No. 12
IAPSO MEETINGS
AT
MOSCOW

July - August 1971
PUBLICATIONS

The Association issues two series of publications, viz. Publications Scientifiques
and Procès-Verbaux.

The following numbers have appeared:*  

PUBLICATIONS SCIENTIFIQUES

No. 1. S. F. GRACE:
   I. Historical review of dynamical explanations of tides in non-elongated
      enclosed seas and lakes.
   II. Historical review of dynamical explanations of the tides of the Medi-
      terranean, the Baltic Sea, the Gulf of Mexico, and the Arctic Ocean
      (1931). Out of print.


No. 3. Bibliography on tides and certain kindred matters (Fourth instalment).

No. 4. PHIL E. CHURCH: Temperatures of the Western North Atlantic from

No. 5. Monthly and annual mean heights of sea-level, up to and including the
       year 1936. (1940).

No. 6. Bibliography on tides and certain kindred matters (Fifth instalment).

No. 7. J. P. JACOBSEN and MARTIN KNUDSEN: Unnormal 1937 or primary
       standard sea-water 1937. (1940).

No. 8. Report of the Committee on the criteria and nomenclature of the major
       divisions of the ocean bottom. (1940).

No. 9. B. HELLAND-HANSEN, J. P. JACOBSEN and T. G. THOMPSON: Chemi-
       cal methods and units. (1948).

No. 10. Monthly and annual mean heights of sea-level, 1937 to 1946, and unpub-
        lished data for earlier years. (1950).

No. 11. J. P. JACOBSEN, REX J. ROBINSON and THOMAS G. THOMPSON: A
        review of the determination of dissolved oxygen in sea water by the
        Winkler method. (1950).

No. 12. Monthly and annual mean heights of sea level, 1947 to 1951, and unpub-
        lished data for earlier years. (1953).


No. 18. Bibliography on generation of currents and changes of surface level in
       (1958).

*Available publications may be obtained from IUGG Publications Office: 39th Rue Gay-Lussac, 75 – Paris-V, France.


No. 28. The theory of oceanic circulation as developed in the USSR over the past fifty years, 1967.


PROCES-VERBAUX


No. 3. General Assembly at Washington, September 1939. (1940).


No. 5. General Assembly at Brussels, August 1951. (1952).


These publications form a continuation of the Bulletins de la Section d'Océanographie de l'Union Géodésique et Géophysique Internationale, of which there were 17 numbers, No. 1 being issued in 1921 and No. 17 in 1931. Out of print.

ADDITIONAL PUBLICATIONS

Reports and Abstracts of Communications:


EXTRA:


Standard terminology on optics of the sea. (Published in the Chronique de l'UGGI, No. 57, 1964).
FOREWORD

At the XV General Assembly of the International Union of Geodesy and Geophysics, held at the Moscow State University in Moscow, USSR, 30 July - 14 August 1971, IAPSO convened a number of interdisciplinary Symposia with other Associations of the Union. In addition, a special Symposium on "Some Problems in Physical Oceanography" was arranged by USSR colleagues, and a Symposium was convened by the Tsunami Committee.

Association business was conducted at the Opening and Closing Sessions for IAPSO participants and at meetings of the Executive Committee. Some Working Groups held their own meetings during the Assembly.

Because IAPSO had so recently held its General Assembly in Tokyo, Japan, 13-25 September 1970, the Moscow IUGG General Assembly was not considered an IAPSO General Assembly. Consequently, reports of Commissions, Committees and Working Groups were not presented. No elections were held. It was, however, decided to document the business and scientific meetings. Since most of the Symposia were held jointly with other Associations and covered a wide range of disciplines, abstracts of only those papers considered to be related to oceanography were selected for inclusion in this volume, No. 12 of IAPSO's Proce-Verbaux.

E. C. LaFond
Secretary, IAPSO

CONTENTS

Officers of the Association ........................................... xi
Presidential Remarks at the Closing Plenary Session of the Union .......... 1
Administrative Reports ............................................. 3
  Minutes of the Sessions for IAPSO Participants .................. 4
  Agenda for the Executive Committee Meetings of the Association ........ 6
  Minutes of the Executive Committee Meetings of the Association ........ 8
IUGG Resolutions of Special Interest to IAPSO ...................... 24
Statutes of the Association ....................................... 27
By-Laws of the Association ....................................... 29
IAPSO Registrants at the XV General Assembly of IUGG .................. 35
Symposia — Abstracts of the Scientific Papers Related to Oceanography
Presented at the IAPSO Sponsored or Co-Sponsored Symposia ............ 39

Symposium on Marine Geodesy .................................... 40
Symposium on Tsunami ........................................... 44
Symposium on Microseisms ....................................... 64
Symposium on Energy Fluxes over Polar Surfaces ...................... 70
Symposium on Air-Sea Interaction ................................ 79
Symposium on Air and Water Pollution ............................. 99
Symposium on Automatic Acquisition of Data and Time
Series Analysis .................................................. 103
Symposium on Remote Sensing Techniques .......................... 108
Symposium on Water Balance in Semi-Closed Sea Bays ............... 114
Symposium on Some Problems of Physical Oceanography ............... 122

Author's Index ................................................ 153
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PRESIDENTIAL REMARKS AT THE CLOSING PLENARY SESSION OF THE UNION
August 14, 1971

RAPPORT DE L’ASSOCIATION INTERNATIONALE DES SCIENCES PHYSIQUES DE L’OCEAN


Mais la proximité de la réunion de Tokyo a provoqué une baisse notable de l’effet de l’océanographes présents ici.

À Moscou, l’Association a participé à de nombreux symposiums et a tenu deux réunions administratives. Les résumés des communications présentées seront publiés par l’Association.

Le Bureau de l’Association, élu à Tokyo l’an passé, n’avait pas à être renouvelé.

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2. Le Comité Exécutif de l’Association à qui l’Assemblée Générale de Tokyo avait confié le soin d’organiser les prochaines réunions de l’Association a établi le programme suivant:

a) L’Association tiendra sa prochaine Assemblée Générale pendant celle de l’Union en 1975. À cette occasion, elle organiserà des réunions scientifiques spécifiques.

D’ici là, l’Association tiendra:

b) conjointement avec l’IAMAP, et avec son accord, un symposium sur les “couches limites dans l’air et dans la mer,” si les disponibilités financières le permettent. Il aura lieu à Melbourne en janvier 1974, au moment de l’Assemblée Générale de l’IAMAP. L’IAPSO organisera aussi à cette occasion une Assemblée Scientifique sur des sujets spécifiquement de son ressort;

c) un symposium sur invitation sur les “Aspects de l’Oceanographie Optique” en juin 1972 à Copenhague; animateur: Prof. Jerlov;

d) un symposium, conjointement avec la Commission de Géologie Marine de l’IUSG, sur la Contribution apportée par les forages profonds en mer à la Géologie (Deep Sea Drilling); il sera tenu à Montréal en août 1972, en même temps que le Congrès Géologique international;

e) un Symposium sur invitation sur “l’Oceanographie Physique de la Mer Rouge”; date et lieu ne sont pas encore décidés; animateur: Prof. Tchermin;


* * * * * * * *

Professor Henri Lacombe

ADMINISTRATIVE REPORTS

MINUTES OF THE OPENING SESSION FOR IAPSO PARTICIPANTS

August 2, 1971

1. The President of the Association, Professor Henri Lacombe, called the meeting to order and welcomed the participants.

2. During the last General Assembly of IAPSO (Tokyo, 1970), it was stated that the time and place of the next General Assembly should be discussed during the IAPSO business meeting in Moscow, and decided by the IAPSO Executive Committee. Thus, a schedule for future IAPSO meetings was discussed. One suggestion was:

   1971 Meeting of IAPSO participants during IUGG General Assembly
   1973 Summer or 1974 Winter: Scientific Assembly with IAMAP
   1975 General Assembly with IUGG
   1976 Joint Oceanographic Assembly (or Congress) with other organizations.

3. The President announced that several National Reports on Physical Oceanography have been received and are available for distribution in the IAPSO Office. Those countries having prepared National Reports were Argentina, Canada, France, German Democratic Republic, India, Italy, Japan, Mexico, Rumania and Yugoslavia.

4. Professor R. Stewart reported on the work of the IAPSO Commission on Physical Oceanography, pointing out that the Commission was planning three Symposia:

   Aspects of Optical Oceanography
   Effects of Various Kinds of Engineering Works on the Ocean Environment
   Physical Oceanography of the Red Sea

President Lacombe elaborated further on the proposed Red Sea Symposium.

5. Professor E. Simpson reported on a proposed IUGS/IUGG Symposium, Contribution of Deep Sea Drilling to Geology.

6. The President reported that an IUGG Working Group was being formed to consider the place of Geochemistry in IUGG. Those present felt that IAPSO should be represented in such a group. It was suggested that Dr. Ken Sugawara be nominated as IAPSO representative to this Working Group.

7. The President announced that an oceanographer was needed on an IUGG Commission on Theoretical Geophysics. The name of Professor Walter Hansen was proposed for this Commission.

8. The President requested consideration of a replacement for the IUGG Representative to SCOR, currently Professor R. Revelle. It was decided to inquire if Professor Revelle wished to continue in this capacity; if not, Professor A. S. Monin would be nominated.
MINUTES OF THE CLOSING SESSION FOR IAPSO PARTICIPANTS

August 12, 1971

1. The President of the Association, Professor Henri Lacoste, opened the Session by announcing the decision of the Executive Committee to hold its next General Assembly at the time and place of the next IUGG General Assembly. Suggested topics for Symposia for the 1975 Assembly were presented (document 15). The President pointed out that in the future IAPSO may hold three types of meetings, briefly:
   a. Those concerning specific subjects bearing on the physical sciences of the ocean; and to be held during General Assemblies or at other types of meetings; e.g., scientific assemblies or symposia.
   b. Those held jointly with other Associations of IUGG; and
   c. Those held jointly with organizations concerned with other fields of marine science (biology, chemistry, geology, etc.).

2. The President reported that IAPSO tentatively plans to hold a joint IAMAP/IAPSO Assembly in Melbourne, Australia, in January or February, 1974. It will be called IAPSO SCIENTIFIC ASSEMBLY ON AIR-SEA BOUNDARY LAYERS. Suggested symposia topics were presented (document 14). Negotiations with the Australian Government have been initiated.

   Professor J. W. Brodie pointed out that the Tsunami Committee is planning to meet in Wellington, New Zealand in February 1974 and participants may be able to attend both meetings if they are appropriately scheduled.

3. Other IAPSO Symposia were confirmed:
   a. Aspects of Optical Oceanography, to be held 19–22 June 1972 in Copenhagen, Denmark, with Prof. N. Jerlov the Convenor. This will be held in conjunction with SCOR/IAPSO/UNESCO WG 15 on Photosynthetic Radiant Energy. Dr. G. C. Van Dam pointed out that an ICES Symposium on Physical Processes of Dispersion of Pollutants in the Sea is planned for Aarhus, Denmark, 2–6 July 1972 and suggested that the Symposium on Optical Oceanography and the Meeting of SCOR/IAPSO/UNESCO WG 15 might be delayed by a week so that the participants may attend both meetings. (Optical Oceanography Symposium date could not be changed.)
   b. Physical Oceanography of the Red Sea, to be held in Kiel, Germany, or Paris, France, with Professor P. Teterina the Convenor; date not yet deecided upon.
   c. Contribution of Deep Sea Drilling to Geology, to be held in Montreal in August, 1972, with Drs. M. Peterson and B. Heezen the Convenors.
   d. Effects of Various Kinds of Engineering Works on the Oceanographic Environment, with Drs. L. M. Dickie and W. L. Ford the Convenors. Place and date have not yet been established.

4. Dr. R. Preisendorfer (USA) presented a proposal, initiated by several USSR delegates, for the establishment of an ad hoc IAPSO WG on Ocean Optics. The proposal was adopted and the following were appointed to the ad hoc Group, which plans to meet at the time of the Optical Oceanography Symposium in order to finalize Terms of Reference and the Program.

   Dr. N. Jerlov (Denmark), Chairman; Dr. A. Ivanoff (France); Dr. Yu. E. Ochakovsky (USSR); Dr. T. Sasaki (Japan); Dr. K. Shifrin (USSR); and Mr. J. Tyler (USA).

   It was pointed out that IAPSO could not financially support this Working Group.

5. It was proposed that a Special Joint IAG/IAPSO Study Group on Mean Sea Level be created. This would replace the present IAG Study Group 2-22, but with no change in membership.

6. The possible creation of a Joint IAG/IAPSO Committee on Marine Geodesy was discussed but no action was taken.

7. Dr. M. Uda proposed the formation of an ad hoc Working Group on Marine Pollution. This was discussed and it was decided that the proposed members of the WG should be contacted by Dr. Uda and asked to develop a Symposium on Marine Pollution for the 1975 General Assembly. At that time the matter of creating a Working Group on Marine Pollution should be reconsidered.

8. A statement, prepared by Dr. G. W. Lennon and the Executive Committee, endorsing continued support for the Permanent Service for Mean Sea Level by FAGS was read (document 7.1).

9. Appointments confirmed:
   a. Dr. Ken Sugawara was nominated an IAPSO representative to an IUGG Committee, to study the place of Geochemistry within the Union.
   b. Professor Walter Hansen was proposed as IAPSO representative on the IUGG Commission on Theoretical Geophysics.
   c. Professor June Partulio was proposed as IUGG representative on FAGS.

10. Professor Charnock reported on highlights of a meeting of IAMAP/IAPSO/SCOR Joint Committee on Air-Sea Interaction and presented two recommendations which were subsequently endorsed by the participants (document 8.1). He also suggested that the IAPSO Scientific Assembly in Melbourne be organized by Drs. Charnock, Stewart and Priestley.

11. Dr. S. A. Kitaigorodsky summarized the IAMAP/IAPSO Symposium on Air-Sea Interaction and stated that although it was a success, more papers pertaining to the sea, rather than the atmosphere, were needed. He hoped that in the next assembly more emphasis will be placed on wind waves and swell.

12. Professor Menúchá proposed, and the participants endorsed, the resolutions presented by the ICES/IAPSO/SCOR/UNESCO Panel of Experts on Oceanographic Tables and Standards at the IAPSO General Assembly in Tokyo (see p. 65, Proceedings, No. 11).

13. Professor A. Gougenheim requested that he be replaced by M. Eyries on the GEBCO Committee. This was approved.

14. A request by the ICSU Panel on World Data Centers (Geophysical and Solar) concerning any revisions or additions to the Guidelines for Data Collection and Exchange, and related New Proposals, was presented.
AGENDA
EXECUTIVE COMMITTEE MEETINGS OF THE ASSOCIATION
IUGG XV General Assembly
August 2–14, 1971

Document 1

1. Adoption of Agenda
2. Tabling of National Reports
3. Administration
   3.1 Report of Secretary for the period 1970–1971
4. Discussion of activities of IAPSO Commissions
   4.1 Commission on Marine Geophysics
   4.2 Commission on Marine Chemistry
   4.3 Commission on Physical Oceanography
5. Discussion of activities of IAPSO Scientific Advisory Committees
   5.1 Committee on Tides and Mean Sea Level
   5.2 Committee on General Bathymetric Charts of the Oceans
6. Discussion of activities of IAPSO Working Groups
   6.1 Working Group on Symbols, Units and Nomenclature in Physical Oceanography
7. Discussion of activities of IAPSO-related Services
   7.1 Permanent Services for Mean Sea Level
   7.2 Standard Seawater Services
8. Discussion of activities of IAPSO representatives on Inter-Association Committees or Working Groups
   8.1 IAPSO/UNESCO/UNESCO Joint Committee on Air-Sea Interaction
   8.2 IASH/IAPSO Working Group on Global Survey of the Fluctuation of Glaciers
9. Discussion of activities of IAPSO representatives to other Committees or Working Groups
   9.1 IUGG Committee on Tsunami
   9.2 IUGG Committee on Space Research
   9.3 IUGG Committee on the Problems of Geochemistry
   9.4 IUGG Committee on Critical Data
   9.5 IUGG ad hoc Committee on Science Teaching
   9.6 IUGG International Heat Flow Committee
10. Discussion of activities of Joint IAPSO Committees and Working Groups
    10.1 SCOR/IAPSO/UNESCO WG 15 on Photosynthetic Radiation Energy
    10.2 SCOR/IAPSO/UNESCO WG 21 on Continuous Current Velocity Measurements
    10.3 ICES/IAPSO/UNESCO Panel of Experts on Oceanographic Tables and Standards
    10.4 UNESCO IMCO/ISSC/IAPSO/WMO ad hoc Group for the Study of External Forces Affecting Ships
    10.5 IAPSO/SCOR/UNESCO Working Group 27 on Tides of the Open Sea
11. Establishment of Scientific Committees
    11.1 Re-establishment, disbandment, change in terms of reference or change in membership of existing committees
    11.2 Creation of new committees
12. Further Administration
    12.1 Adoption of resolutions
    12.2 Nomination of IAPSO Representatives to Inter-Association and other Committees and Working Groups
    12.3 Relationship between CMG and IAPSO
13. Scientific Symposia
    13.1 Joint IAPSO Symposia — IUGG Moscow
    13.2 Aspects of Optical Oceanography — Copenhagen, 1972
    13.3 CMG — Contribution of Deep-Sea Drilling to Geology — Montreal, 1972
    13.4 French National Commission, IAPSO/SCOR/IOC — Symposium on Physical Oceanography of the Red Sea
14. Other Meetings related to IAPSO
    14.1 Second International Congress on the History of Oceanography — 1972
    14.2 Inter-Union Commission on Geodynamics
    14.3 IOC Proposed International Advanced Institute for Physical Oceanography
15. Place and date of next IAPSO General Assembly
15.1 Invitations from countries
16. Place and date of next Executive Committee Meeting
17. Other business
MINUTES OF 1st MEETING OF THE EXECUTIVE COMMITTEE OF THE ASSOCIATION

August 2, 1971

Members present:
H. Lacombe, President
E. LaFond, Secretary
H. Grant, Member
E. Simpson, Member
M. Udai (Acting for K. Yoshida, Vice-President)

Members absent:
A. Monin, Vice-President
K. Grasshoff, Member
J. Rossiter, Member
B. Somayajulu, Member

1. President Henri Lacombe called the meeting to order and the agenda (document 1) was adopted.

2. (Item 2). Nine national reports on Physical Oceanography were tabled (Argentina, France, German Democratic Republic, India, Italy, Japan, Mexico, Rumania, Yugoslavia).

3. (Item 3). The Secretary reported that the past correspondence and records of IAPSO, formerly held by Dr. A. Maxwell, have now been transferred from Woods Hole to San Diego. The Committee recommended a letter of thanks to Dr. Maxwell for his efforts during his term of office as Secretary and for the efficient transfer of records, including a trip to San Diego to facilitate a smooth transfer of the secretarial duties.

Procès-Verbaux: The minutes, reports and scientific abstracts of the IAPSO General Assembly in Tokyo, prepared by Dr. Maxwell, were assembled and published in July 1971 as Procès-Verbaux No. 11. These will be distributed to the attendees of the IAPSO 15th General Assembly, IAPSO Committee Members, National Correspondents, and IUGG, ICSU, IOC, SCOR, and UNESCO officers.

Publications Scientifiques: A new Publication Scientifique No. 29, "Bibliography on Mean Sea Level 1959–1969 and Bibliography on Tides 1955–1969" was completed by the Permanent Services for Mean Sea Level. A translation of Publication Scientifique No. 22 in Japanese, Russian and Spanish has been printed. All publications are on sale at the IUGG Publications Office in Paris. It was recommended that older IAPSO publications now in short supply at the office be duplicated.

4. (Item 3.2). The Secretary distributed a financial report of the Association covering the period 1 January to 30 June 1971. The Association receives an allotment of $4,500 per year from IUGG. An additional $230 was received from the sale of publications during 1970. It was pointed out that a new budget has been submitted to IUGG which, if approved and implemented, will increase the IAPSO allotment.

5. (Item 4.3). The Secretary reported that the IAPSO Commission on Physical Oceanography is planning four symposia, one of which is entitled "Aspects of Optical Oceanography." Professor Jerlov, as Organizer, has invited several speakers and one had already requested travel funds from IAPSO. The Executive Committee endorsed the Symposium and authorized a small financial contribution.

Also endorsed were Symposia entitled: "Effects of Various Kinds of Engineering Works on the Oceanographic Environment," being planned by Drs. L. N. Dickie and W. L. Ford of Canada; "Physical Oceanography of the Red Sea," being developed by Professors P. Tchernia, G. Dietrich, and K. Wyrtki; and "Contribution of Deep Sea Drilling to Geology," which will be an IUGS-IUGG Symposium, to be held during the next International Geological Congress in Montreal, Canada, August 1972. Professor E. Simpson is involved in the organizing committee of Symposia.
MINUTES OF 2nd MEETING OF THE EXECUTIVE COMMITTEE OF THE ASSOCIATION
August 5, 1971

Members present:

H. Lacoste, President
E. LaFond, Secretary
H. Grant, Member
E. Simpson, Member
M. Uda (Acting for K. Yoshida, Vice-President)

Members absent:

A. Monir, Vice-President
K. Grasshoff, Member
J. Rossiter, Member
B. Somayajulu, Member

1. (Item 151). Mr. G. E. Hemmen reported that the UK Royal Society’s Physical Sciences of the Ocean Subcommittee recommends that IAPSO hold its General Assembly at the same time and place as the IUGG General Assembly.

2. (Item 5.2). The Secretary stated that a report on the activities of the GEBCO Committee from 1967 to 1971 has been prepared and submitted to IAPSO by Professor A. Gougenheim.

3. (Item 6.1). The Secretary reported that the former Working Group on Bibliography and Classification has completed its work and produced a document, “Titles of Journals with Abbreviations.” The Executive Committee recommended that this document be published as an IAPSO Publication Scientifique. It was further recommended that Drs. F. Model and L. Otto continue to represent IAPSO, with respect to Physical Oceanography (UDC 551.46), in the Federation Internationale de Documentation (FID).

4. (Item 7.1). Dr. G. W. Lennon reported that the financial support for the Permanent Service for Mean Sea Level through FAGS may be discontinued after 1972 if ICSU and UNESCO funds to FAGS are discontinued. The Executive Committee decided to write, with the help of Dr. Lennon, a statement to the Council of FAGS concerning the continued support of the Permanent Service for Mean Sea Level and emphasizing the importance of MSL information to IAPSO (Document 7.1).

The Executive Committee considered the Recommendations of its Scientific Advisory Group on Tides and Mean Sea Level, which met jointly with IAG Group 2-22 in a Symposium on Coastal Geodesy held in Munich 22–24 July 1970, and endorsed their recommendations Nos. 1, 2, and 3 (p. 38, 39, Proces-Verbaux No. 11).

The possibility of setting up an IAG/IAPSO Special Study Group on Mean Sea Level was discussed and its creation approved, providing arrangements could be made.

5. (Item 10.1). The Secretary reported that IAPSO representatives on SCOR/IAPSO/UNESCO Working Group 15 on Photosynthetic Radiant Energy, Dr. N. Jerlov and Mr. J. Tyler, plan to attend the Group Meeting in Copenhagen in 1972.

6. (Item 10.2). The Secretary reported that IAPSO representatives of SCOR/IAPSO/UNESCO Working Group 21 on Continuous Current Velocity Measurements, Mr. T. Kvinge and Dr. G. Seidler, will attend the Group meeting in Moscow, during the IUGG General Assembly.

7. (Item 10.3). The Secretary reported that Dr. K. Grasshoff, IAPSO Representative on ICES/IAPSO/UNESCO Panel of Experts on Oceanographic Tables and Standards, submitted a report on the work of the Panel.

8. (Item 10.5). The Secretary reported that IAPSO Representatives of IAPSO/SCOR/UNESCO Working Group 27 on Deep Sea Tides, Drs. Munk, Capurro, and Dohler, plan to meet in Venice, October 18–19, 1971.

9. (Item 11.2). In a letter to the Secretary, Professor A. Gougenheim proposed that IAPSO create a Commission on the History of Oceanography. After discussion the Executive Committee decided that SCOR may be a more appropriate place for such a body, since SCOR is concerned with all branches of Oceanography.
MINUTES OF 3RD MEETING OF THE EXECUTIVE COMMITTEE
OF THE ASSOCIATION
August 6, 1971

Members present:
H. Lacombe, President
A. Monin, Vice-President
E. Lefond, Secretary
H. Grant, Member
E. Simpson, Member
M. Uda (Acting for K. Yoshida, Vice-President)

Members absent:
K. Grasshoff, Member
J. Rossiter, Member
B. Somayajulu, Member

1. (Item 12.1). The Recommendations of the ICES/IAPSO/SCOR/UNESCO Joint Panel of Experts on Oceanographic Tables and Standards were endorsed (see p. 65, Procès-Verbaux No. 11).

2. (Item 12.2). In response to an invitation from Dr. M. Strong, General Secretary of the UN Conference on the Human Environment, to send an observer to its Conference, the Executive Committee nominated Dr. K. Grasshoff to be the IAPSO Observer.

3. (Item 12.2). At the request of Dr. K. Grasshoff, the Executive Committee endorsed the nomination of Dr. E. Goldberg to be Consultant to the Near Shore Environment to the SCOPE Commission on Monitoring.

4. (Item 12.2). In a letter from Dr. Hans-Tamb-Lyche, Secretary General, Conseil International pour l'Exploration de la Mer (ICES), IAPSO was asked to appoint an observer to the next ICES meeting in Helsinki, 27 September–6 October 1971. Dr. K. Grasshoff was appointed.

5. (Item 12.2). The newly formed SCOR Working Group on Coastal Upwelling Processes was discussed and it was suggested that Professor R. C. Dugdale would be a most suitable person to serve on this Working Group.

6. (Item 12.2). Dr. R. Dorrestein, IAPSO Representative on Joint UNESCO/IMCO/ISSC/IAPSO/WMO Group for the Study of External Forcings Affecting Ships, has been invited by Mr. A. Saveltov, Secretary of the Marine Safety Committee, to attend the fourth session of the group. The Executive Committee recommended Dr. Dorrestein to attend as IAPSO Representative.

7. (Item 12.2). The Secretary-General of IUGG has written that IUTAM is planning a symposium in 1973 on Turbulent Diffusion and Atmospheric Pollution and invited an IAPSO Representative to assist with the planning. Dr. K. Grasshoff was nominated.

8. (Item 12.3). At the request of the Secretary-General of IUGG, the relationship between CMG and IAPSO was clarified by Professor Simpson (Document 12.3).

9. (Item 13.1). The Joint Symposium of IAPSO with other Associations held during the IUGG General Assembly in Moscow were discussed. It was decided to include selected abstracts in the next Procès-Verbaux.

10. (Item 13.2). The Executive Committee endorsed the proposed symposium on Aspects of Oceanography and agreed to help with funding if it be required.

11. (Item 14.3). The Report of the IUC, Long Term Scientific Policy and Planning Group was discussed. Concerning item No. 1 of the Report, the majority of the Executive Committee felt it better to support existing laboratories rather than create the Proposed International Advanced Institute for Oceanography. There was one dissenting vote.

12. (Item 15.1). The time and place for holding the next IAPSO meeting, as well as type of meeting itself, were discussed at length. Suggestions from the Royal Society (UK) and Academy of Science (USSR) were considered.

The Executive Committee felt that IAPSO should hold three types of meetings (see item 1 in Minutes of the Closing Session for IAPSO Participants). It was agreed that the next General Assembly should be held jointly with the IUGG General Assembly, and symposia topics were suggested. It was further decided that the interval of four years between major IAPSO meetings was too long and that an intervening scientific assembly would be appropriate. IAMAP was approached regarding a joint meeting, since IAMAP plans a General Assembly in the interim. As a result, the Association has tentatively decided to hold an IAMAP/IAPSO Assembly in Melbourne, Australia, in January or February 1974. The proposed Assembly was discussed with Dr. C. H. B. Priestley of Australia and the Bureau plans to contact the Australian officials for final arrangements. IAPSO had received only one invitation from a country, Monaco, to hold its meeting there. However, several cities have offered facilities, with charges for meetings.

13. (Item 11.2). Professor A. Monin presented a proposal that the Association create an ad hoc Working Group on Ocean Optics, pointing out the importance and newness of optical research in the ocean, the fact that SCOR/UNESCO/IAPSO WG 15 is completing its work, and the various tasks confronting the proposed Working Group. He submitted 10 names of scientists who might make up the Working Group. He also suggested that the Working Group might be transformed into a Commission on Ocean Optics at the General Assembly in 1975, if so desired. The proposal was approved, but with a reduced number of members. It was pointed out that IAPSO has no funds to support such a group.
14. (Item 17). Professor A. Gougeon asked by letter which scale for GECBO charts would be the most useful for oceanographers. The Executive Committee felt that each program may require a different scale and no single scale could be specified.

15. (Item 16). It was decided to hold the next Executive Meeting in Edinburgh, Scotland, 19–20 September 1972.

STATEMENT FOR CONTINUED SUPPORT OF THE PERMANENT SERVICE FOR MEAN SEA LEVEL

Document 7.1

To Council of FAGS

The Executive Committee of IAPSO views with alarm the warning of the Secretary of FAGS that financial support from ICSU and UNESCO to the Permanent Services, through FAGS, might not be continued after 1972.

The Executive Committee of IAPSO is anxious that the interests of the Permanent Service for Mean Sea Level should not suffer due to lack of funds and in fact confirms that the services provided under this heading are essential for the future benefit of IAPSO and indeed other Associations of IUGG.

Accordingly, the Executive Committee of IAPSO strongly supports FAGS in its representation for continued funding to ICSU and UNESCO, and deplores the present threat to the future of the Permanent Services.
MINUTES OF THE 4th MEETING OF THE IAMAP/IAPSO/SCOR COMMITTEE ON AIR-SEA INTERACTION
August 1 and 7, 1971

Document 8.1

Present:
H. Charnock (Chairman)
S. A. Knaigorodskii (Representing A. S. Monin)
J. Namias
C. H. B. Priestley
R. W. Stewart
S. S. Zilitinkevich

By Invitation
Brooks, Burt, Busch, Coantic, Dobryshman (WMO), Foster, Kraus, Lacombe, Malone, Mitsuta, Miyake, Munn, Pond, Roth, Taylor, Zwang.

1. Apologies for absence
Apologies for absence were received from K. Bryan and P. Welander.

2. Minutes of the last meeting
The minutes of the 3rd meeting, held in Princeton on 21–23 January, 1969, were read and agreed.

3. Matters arising
Minute 3.4: It was reported that an Air-Sea interaction symposium was in progress at the XV General Assembly of UGGI.

It was noted that many of the papers were concerned with small-scale motion in the air over the sea; for future symposia an effort would be made to attract papers on a broader spread of topics, including more work on the upper layers of the ocean.

Minute 3.6: It was reported that further instrument intercomparison trials had taken place at Tsitlyanskiy, USSR between Australia, Canada, Soviet and United States scientists. These had again proved valuable but further work was desirable especially on humidity instruments. There also appeared to be a growing need for comparison of instruments used in aircraft.

It was agreed that on future occasions it was desirable that information was exchanged and that others involved were consulted before results were presented or published.

It was suggested that a land-based instrument comparison trial be held in Australia in June, July and August, perhaps in 1974. This would involve the estimation of heat flux and evaporation as well as stress, the need for analysis on site was recognised.

A comparison of aircraft turbulence sensing instruments was proposed for 1973. This could take place in Canada and be restricted to the lowest 1600 m of the atmosphere. A small group (Munk – Convenor, Miyake, Warner and Zwang) were asked to consider this possibility and make suggestions for implementing it.

(Note: The following resolution was subsequently passed by IUGG – The IUGG recognising the great value of the international comparisons made of turbulence instruments at Vancouver and Tsitlyanskiy and appreciating the need for further development in preparation for GARP and related programmes, recommends that further comparisons be arranged, emphasizing the importance of humidity sensors and of airborne instruments.)

4. Membership
It was reported that the membership of Messrs Bryan and Zilitinkevich, who had been coopted at the request of the JGC for GARP, would be ratified by IAMAP and IAPSO at their plenary session.

H. Charnock was re-elected as Chairman but gave notice that he would resign this office at the next meeting. The offices of Secretary and Treasurer were not filled.

(Note: At the subsequent meeting of IAMAP and IAPSO the membership of the Joint Committee was agreed as:

K. Brooks, C.H.B. Priestley, J. Namias, S.S. Zilitinkevich (IAMAP);

5. The transfer of gases between the ocean and the atmosphere, especially H₂O and CO₂

At the 10th SCOR General Meeting the following recommendation was made to the Joint Committee (which also joins SCOR WG 28):

"It was recommended that the Working Group give special attention to the question of direct eddy flux measurements of the water vapor transport. The adequacy and intercomparability of existing instrumentation should be evaluated, as should the distribution of measurements needed to establish reliable estimates of evaporation for any place on the surface of the world ocean."

The need for instrumental comparisons was readily agreed; the necessary action has already been agreed (see 3 above).

It was, however, unlikely that the necessary equipment would ever be usable routinely from merchant vessels. It would probably be used to establish relations between more easily observed elements which could then be used to make the estimates of evaporation needed.

This raised two general needs: for the improvement of ships' routine meteorological observations and for more work on the complicated processes which occur at the interfacial layer between the atmosphere and the ocean.

Various means of filling these general needs were discussed. The WMO and its CMM were continually trying to improve the quality of observations from merchant vessels. But ships were becoming more automated and some new development was becoming necessary. Even this would not produce observations outside shipping..."
lanes. The possibility of satellite observation depended on an increased knowledge of the interfacial layer as well as of surface sensors.

It was recognized that water vapour was not the only gas whose exchange between sea and air was important, carbon dioxide, lead tetraethyl and others were of concern. They would be considered by SCOPE and other international bodies.

It was agreed that work on these problems would be stimulated wherever possible and that at a joint meeting of IAMAP and IAPSO (now fixed for 14–25 January 1974 in Melbourne) one session should be devoted to discussing the mechanisms involved in the exchange of gases between the atmosphere and the ocean.

6. Air-Sea interaction in relation to ocean circulation projects

This was discussed briefly but it was agreed to defer detailed consideration to the next meeting when it was hoped Dr. Byron would report on recent developments. The question of monitoring the results was important and there was a brief discussion of the MODE and Polygon projects.

7. Air-Sea interaction in relation to GATE, GARP and other Meteorological projects

The details of projects for GATE would not be available until the end of 1971, and it was agreed that Dr. B.J. Mason, Chairman of the Tropical Experiment Board, should be invited to present an account of its present status.

(NOTE: Dr. Mason presented his account at a subsequent meeting, attended also by SCOR WG 21 and 34. It became clear that a coordinated oceanographic programme involving all the ships, would probably prejudice the meteorological objective. There would be an opportunity to do some oceanographic work but detailed planning could not be done until the GATE plans became firmer. The collaboration of oceanographers would be sought by publication of a general account of the proposed GATE project in oceanographic journals. The air-sea interaction aspects were important: It was thought they should deal with interactions which affected synoptic developments rather than with small-scale near-surface motions. Much depended on decisions about the station keeping required of ships, the navigational aids available for windfishing, etc.)

As regards GARP, little progress had been made since the last meeting in specifying the need for buoys. Various prototypes were being constructed in several countries. Professor Stewart reported that the University of British Columbia was collaborating with the French EOLE Project in studying the satellite location of drifting buoys. Concern was expressed that the IRIS system was being abandoned but no definite information was available. The general view was that satellite interrogation of buoys would prove desirable but that to transmit only the sea-surface temperature would not be adequate.

Professor Zilitinekevich reported that he has accepted an invitation from the Joint Organising Committee for GARP to provide a review on air-sea interaction in connection with GARP.

Dr. Mitsuta spoke briefly, about the 1974 AMTEX project to study air-sea interaction when cold air flows south over Japanese waters. The importance of this and other area studies was recognized and it was agreed that they should be fully supported.

8. Air-land interaction in relation to GATE, GARP and other Meteorological projects

This was discussed only briefly. Dr. Priestley reported on Australian work on this aspect. The views of the JOC for GARP were not yet clear. Nothing had been about a network to monitor the radiation surplus or to assess surface wetness.

9. Air-surface interaction in relation to seasonal and long-term development

This was acknowledged to be related to questions, discussed earlier, of the increased density and improved accuracy of observations, especially over the ocean. There seemed little hope of explicit modeling but the reality of the so-called teleconnection was now in little doubt. Dr. Dobryshman reported that the WMO Historical Sea Surface Temperature Project was still active.

10. Survey of relevant research activity

It did not seem necessary, or desirable, to produce a comprehensive survey of relevant research activity. Air-sea interaction was not a well-defined subject but had ramifications into most aspects of meteorology and oceanography. It was thought that the Joint Committee could most usefully concern itself with the interaction of the atmospheric and oceanic boundary layers.

11. Status report on WWW and IGÓSS

Dr. Dobryshman, though not an official WMO representative, spoke briefly about WWW, which was progressing satisfactorily and referred to various reports of progress which were available from WMO.

The development of IGÓSS had apparently been temporarily halted pending a more realistic specification of a practicable system.

12. Date of next meeting

It was agreed that the next meeting should be held in January 1974 during the joint meeting of IAMAP and IAPSO which it is hoped will take place in Melbourne, Australia, in January 1974.

Recommended subjects for symposia at that meeting are:

1) The determination and prediction of sea surface temperature;
2) Exchange of gases between atmosphere and ocean;
3) Mesoscale structure of the atmospheric and oceanic boundary layer; and
4) The role of air-sea interaction in synoptic and climatic development.
13. Any other business

The Joint Committee expressed its thanks to their Soviet hosts for allowing the meeting in Moscow University.

RELATIONSHIP BETWEEN IAPSO AND CMG

Document 12.3

The Executive Committee noted with approval that membership of the IUGS Commission for Marine Geology (CMG) had been enlarged, at the Tokyo meeting in September 1970, to include five marine geophysicists (A. S. Laughton, UK; X. le Pichon, France; A. E. Maxwell, USA; G. B. Udintsev, USSR; and S. Uyeda, Japan) whose affiliation lies mainly with IUGS. At the same time the Secretary of CMG was elected to the Executive Committee of IAPSO. All three core members of the IAPSO Commission for Marine Geophysics are now members of the reconstituted CMG, thus providing an informal liaison between the marine geoscience activities of IUGS and IUGS. Professor Simpson (Secretary of CMG) undertook to place the Secretary of IAPSO on his permanent mailing list for all reports on CMG meetings and other activities. A reciprocal arrangement is maintained by IAPSO, so that an informal though effective working arrangement exists between CMG and IAPSO.
Document 14

- Radiative budget of the atmosphere and ocean boundary layers.
- The thermocline and the microstructure of the upper layers of the sea.
- Structure of the 100–200 m lower atmosphere.
- Wind effect on the motion above the thermocline: friction at the thermocline.
- Effects of surface films on air and water.
- Fluxes of heat, water vapor and momentum, their parametrization.
- Ocean waves — surface and internal.
- Determination and prediction of sea surface structure.
- Exchange of gases across the sea surface.
- Mesoscale structure of atmospheric and oceanic boundary layer.
- Role of air/sea interaction in climatic changes.

Document 15

- Deep water formation
- Transport diffusion of pollutants in the sea
- Water motions under a moving atmospheric depression over a homogeneous, two-layer or stratified ocean
- Upwelling and vertical movements in the sea
- Tides and mean sea level
  - Deep Sea
  - Near Shore
- Internal motion
- Pollution (to be organized by Prof. M. Uda)
  - Air
  - Sea
- Oceanographic effects of man-made structures
- General circulation of the oceans
Resolution 3

The International Union of Geodesy and Geophysics

Recognising the great importance of boundary layer phenomena to the development of the GARP project and to ocean circulation projects and

Being aware of the value of international studies of regions of particular significance,

Recommends that such studies be supported, especially those concerned with
1) air mass modification in the Sea of Japan
2) wind/wave interaction in the North Sea and
3) boundary layer interaction in the Atlantic Ocean.

Resolution 4

The International Union of Geodesy and Geophysics

Recognising the great value of the international comparisons made of turbulence instruments at Vancouver and Tsushima and

Appreciating the need for further development in preparation for GARP and related programmes,

Recommends that further comparisons be arranged, emphasizing the importance of humidity sensors and of airborne instruments.

Resolution 17

The International Union of Geodesy and Geophysics

Desiring to establish an international framework for

a) the determination of variations of mean sea level in time with respect to a local fixed mark at a significant number of sea coast points,

b) the provision of oceanographic information for the commencement of a study of variations of mean sea level in space;

Recommends that each country, according to its capability, should give high priority to the establishment of a number of more sophisticated tide gauge installations run by scientific staff and observing all parameters associated with the perturbation of the sea surface and,

Recommends furthermore, that the Tide Gauge Bench Mark (Référence du Marigraphie) of each such site be connected to the first order leveling net of the Country.

Resolution 18

The International Union of Geodesy and Geophysics

Endorses the recommendation no. 1 of the Joint Panel on Oceanographic Tables and Standards dealing with the determination of the absolute density of pure water at 4°C and at least two different temperatures, preferably 0 and 20°C, to

obtain a sound basis for the determination of the absolute density of sea water, furthermore the accurate determination of the thermal expansion of water with the necessary precision between 0 and 40°C.

Resolution 19

The International Union of Geodesy and Geophysics

Taking into account the increasing use of instruments for in situ measurements of thermal conductivity, strongly recommends that:

a) high precision measurements of conductivity of sea water are carried out in the temperature range of 0°C to 14°C,

b) that high precision measurements are made of conductivity as function of temperature and pressure,

c) that high precision measurements are made of sound velocity as function of temperature, salinity and pressure.

Resolution 20

The International Union of Geodesy and Geophysics

Convened in its XVth General Assembly in Moscow in August 1971,

Conscious of its dedications to the study of the physical and chemical processes taking place on Planet Earth and in its environs and of its responsibility to provide scientific advice on practical problems of a geodetic or geophysical nature,

Recognising that man’s mastery of matter, energy and information handling, as well as his expanding knowledge of life processes have brought mankind to the threshold of an era within which the material necessities and esthetic amenities of human existence are within the reach of every person on this globe,

Aware that this elevated state of man is being jeopardized by a disturbing lack of harmony between man and his natural and social environment,

Persuaded that new knowledge, revised human values and new and renewed institutions are required to achieve the quality of human environment that is now within reach,

Noting that the United Nations is convening a Conference on Human Environment in Stockholm in June 1972 to focus the attention of governments and public opinion on the importance and urgency of this problem and to identify those aspects that could best be solved through international cooperation,

Recalling the advances in the understanding of Planet Earth that have been made through the series of international scientific programs beginning with the International Geophysical Year,

Persuaded that the time is propitious for a concerted effort by all nations and all disciplines to extend our understanding of the human environment,

Urges the Stockholm Conference to declare the interval 1975 to 1980 a Special International Environmental Period during which the nations of the world are called upon to set aside their differences and join together in a coordinated effort to start the process of bringing the environment and man into a harmonious state,
STATUTES OF THE ASSOCIATION

Adopted by the General Assembly at Berne, October 1967

I. Objects, Composition and Membership of the Association

1. The International Association for the Physical Sciences of the ocean (IAPSO) is a constituent of the International Union of Geodesy and Geophysics. The Association is subject to those articles of the Statutes and By-Laws of the Union which apply to Associations, and also to these Statutes.

2. The objects of the Association are:
   (a) To promote the study of scientific problems relating to the ocean and interactions taking place at its boundaries, chiefly insofar as such study may be carried out by the aid of mathematics, physics and chemistry;
   (b) To initiate, facilitate and co-ordinate research into and investigations of, those problems of the ocean which require international co-operation;
   (c) To provide for discussion, comparison and publications.

3. Those countries which adhere to the Union are Members of the Association.

By resolution of a General Assembly of the Association, other international organizations which are concerned with the study of physical sciences of the ocean may be admitted to Membership, with the status of guests.

II. Administration

4. The Authority of the Association shall be vested in the countries adhering to the Union, and exercised collectively by their delegates meeting in General Assembly of the Association.

5. The Association shall hold business meetings at the General Assemblies of the Union, to be held normally once every four years.

   The Association may recommend to the Executive Committee of the Union, at a General Assembly of the Union, arrangement of joint sessions of two or more Associations or of joint meetings of two or more Committees or Commissions, for the discussion of topics of an interdisciplinary character.

   With the concurrence of the Executive Committee of the Union, the Association may arrange General Assemblies and other meetings of its own in the interval between the General Assemblies of the Union, either singly to deal with topics of specific interest, or jointly with another Association or other Associations.

6. The General Assembly of the Association shall elect the President, the two Vice-Presidents, the Secretary and the Deputy-Secretary of the Association.
7. The Bureau of the Association shall consist of the President and Secretary. Its duties shall be to conduct the affairs of the Association in accordance with the decisions of the foregoing General Assemblies of the Association. It shall prepare the Agenda for General Assemblies.

8. The General Assembly of the Association shall elect, from countries which adhere to the Union, four persons who, together with the President, Vice-Presidents, Secretary and Deputy-Secretary, shall constitute the Executive Committee of the Association.

III. Voting

9. On scientific matters, each delegate present shall have one vote.

10. In questions of administration or of mixed, administrative and scientific character not involving questions of finance, voting shall be by countries, each country having one vote with the provision that its subscription shall have been paid up to the end of the year preceding the voting.

11. In questions involving finance, voting shall be by countries, with the same provision as for administrative questions. The number of votes for each country shall be one greater than the number of its category of membership to the Union.

12. In case of doubt as to which class a question belongs, and in all cases of equality of votes, the chairman shall decide.

13. A delegate shall represent only one Member Country. An adhering country not represented by a delegate may forward by post its vote on any specific question of an agenda.

14. Guests will not vote.

IV. General

15. These Statutes shall be changed only by a majority of two thirds of the votes cast at a General Assembly by delegates or by post.

16. The Association may make By-Laws which may be changed by a simple majority of the votes cast at a General Assembly by the delegates or by post.

17. This English text shall be the authoritative text of the Statutes of the Association.

BY-LAWS OF THE ASSOCIATION

Adopted by the General Assembly at Berne, October 1967

I. Membership of the Association

1. It is recommended that each adhering country shall form a National Sub-Committee for the Physical Sciences of the Ocean, to which correspondence may be addressed.

2. Each adhering country and each international member may contribute to the Agenda of General Assemblies of the Association.

II. Administration

3. (a) The President and Vice-Presidents of the Association shall be elected for one period, the term "period" being taken to mean the interval between the ends of two successive General Assemblies of the Association other than Union Assemblies, except that if no such General Assembly of the Association is held in the interval between two General Assemblies of the Union, the election of officers will take place at second General Assembly of the Union.

(b) The Secretary and Deputy-Secretary shall be elected for two periods, and may be re-elected for subsequent single periods.

4. The Secretary shall manage the routine business, conduct the correspondence, preserve the records, and arrange the preliminaries of General Assemblies.

5. Of the four persons referred to in Article 8 of the Statutes, two shall retire after each General Assembly where elections have taken place and they shall not be eligible for re-election until after the expiration of one period. Each retiring member shall have served at least as long as each non-retiring member.

6. The Executive Committee shall:

(a) Prepare for the Executive Committee of the Union recommendations concerning the arrangement, at a General Assembly of the Union, of scientific meetings to be confined to joint sessions of two or more Associations or of Joint meetings of two or more Committees or Commissions, for the discussion of topics of an inter-disciplinary character.

(b) Seek for the concurrence of the Executive Committee of Union, for the arrangement of General Assemblies and other meetings of the Association in the intervals between the General Assemblies of the Union, either singly to deal with topics of specific interest, or jointly with another Association or other Associations.

(c) Fill any vacancy which may occur among the officers of the Association between General Assemblies. Such appointments shall be subject to the subsequent approval of the next General Assembly. Tenure of
office for part of a period shall not be counted as a period for the purpose of these By-Laws.

(d) Consider matters of general administration and finance, and report thereon to the General Assembly.

(e) Make recommendations on matters of policy.

(f) Frame the budget for the ensuing period and report to the General Assembly of the Association and to the General Secretary of the Union. The budget period of the Association coincides with the budget period of the Union.

(g) Advise upon the distribution of funds.

(h) Consider proposals for changes in the Statutes and By-Laws, and report thereon to the General Assembly.

7. Officers designated by these By-Laws for special duties or for special committees may appoint substitutes in their stead. Notice of the intention to do so must be sent in writing to the President or Secretary. No substitute shall represent more than one officer.

8. Decisions and actions of the Officers and Committees of the Association, taken during and between General Assemblies, shall be subject to the sanction of the General Assembly.

9. Proposals for the Agenda of a General Assembly shall reach the Secretary six months before the General Assembly. The Secretary shall send the Agenda to adhering countries, through the National Sub-Committees where such exist, at least four months before the General Assembly. No question which has not been placed on the Agenda shall be discussed unless a proposal to that effect be approved by two-thirds of the votes of the countries represented at the Assembly.

III. Finance

10. The President and Secretary shall individually have power to sign documents on behalf of the Association.

11. The Secretary shall receive the allocations of funds from the Union, and administer the funds of the Association. At the end of the calendar year preceding a General Assembly of the Union he shall prepare and send to the General Secretary of the Union the Accounts of the Association.

12. Each Account shall be audited by a qualified accountant.

13. Travelling expenses may be paid by the Secretary, but only (a) in connection with meetings on specific Association business, and (b) when those concerned represent the Association and not adhering countries or other organizations, and (c) in cases where those concerned cannot draw proper allocations from their own national sources. Such payments may cover travelling costs and a reasonable contribution to other expenses while attending such meetings.

ASSOCIATION REPRESENTATIVES

COMMISSIONS, SCIENTIFIC ADVISORY COMMITTEES AND WORKING GROUPS OF THE ASSOCIATION

I. COMMISSIONS

1. Commission on Marine Geophysics
   Dr. G. B. Udintsev (USSR)
   Dr. B. C. Heeen (USA)
   Dr. A. S. Laughton (UK)

2. Commission on Marine Chemistry
   Prof. J. Gieskes (USA)
   Dr. B. A. Skopintsev (USSR)
   M. M. Menaché (France)

3. Commission on Physical Oceanography
   Dr. R. W. Stewart (Canada)
   Dr. K. Yoshida (Japan)
   Prof. Nils Jerlov (Denmark)

II. SCIENTIFIC ADVISORY COMMITTEES

1. Committee on Tides and Mean Sea Level
   Ing. M. M. Eyriès (France)
   Dr. J. R. Rossiter (UK)
   Dr. D. E. Cartwright (UK)

2. Committee on General Bathymetric Chart of the Oceans
   Dr. A. S. Laughton (UK)
   Dr. B. C. Heeen (USA)
   Dr. G. B. Udintsev (USSR)

III. WORKING GROUPS

1. Working Group on Symbols, Units and Nomenclature in Physical Oceanography
   Chairman: Mr. J. Crease (UK)
   Members: M. M. Menaché (France)
   Dr. G. N. Ivanov-Franzkevich (USSR)
IAPSO ad hoc Working Group on Ocean Optics

Chairman:
Prof. N. Jerlov (Denmark)

Members:
Dr. A. Ivanoff (France)
Dr. Yu. E. Ochakovsky (USSR)
Dr. T. Sasaki (Japan)
Prof. K. Shifrin (USSR)
Mr. J. E. Tyler (USA)

IAPSO RELATED SERVICES

Permanent Service for Mean Sea Level
Dr. J. R. Rossiter (UK)

Standard Sea Water Services
Dr. P. Hermann (Denmark)

IAPSO REPRESENTATIVES IN INTER-ASSOCIATION AND OTHER COMMITTEES AND WORKING GROUPS

IAMP/IAPSO/SCOR Scientific Committee on Air-Sea Interaction
Dr. K. Bryan (USA)
Prof. H. Charnock (UK)
Prof. R. W. Stewart (Canada)
Dr. L. R. Zwang (USSR)

IUGG Committee on Tsunami
Prof. R. O. Reid (USA)

IUGG Committee on Space Research
Ex officio: Secretary

IUGG Committee on the Problems of Geochemistry
Dr. E. D. Goldberg (USA)

IUGG Committee on Critical Data
M. M. Menaché (France)

International Heat Flow Committee
Ex officio: Secretary

IUGG ad hoc Committee on Science Teaching
Prof. P. Groen (Netherlands)

SCAR WG in Oceanography
Dr. G. E. R. Deacon (UK)

SCOR
a) Representative of IUGG: Prof. A. S. Monin
   Ex officio member of SCOR Executive:
   President
b) Representatives of IAPSO: Ex officio member of SCOR:
   Secretary

SCOR Working Group 15 (with IAPSO and UNESCO) on Photosynthetic Radiant Energy
Prof. N. Jerlov (Denmark)
Mr. J. E. Tyler (USA)

SCOR Working Group 21 (with IAPSO) on Continuous Current Velocity Measurements
Dr. T. Kvinge (Norway)
Dr. G. Siedler (FRG)

ICSU WDC Steering Committee
Dr. K. Voigt (GDR)

ICSU Scientific Committee on Water Research (COWAR)
Prof. E. Eriksson (Sweden)

Joint ICES/IAPSO/SCOR/UNESCO Panel of Experts on Oceanographical Tables and Standards
Prof. K. Grasshoff (FRG)

Joint IAPSO/SCOR/UNESCO Working Group 27 on Tides of the Open Sea
Dr. W. H. Munk (USA)
Dr. G. C. Dohler (Canada)
Dr. F. Schott (FRG)

Joint UNESCO/IMCO/ISCC/IAPSO/WMO ad hoc Group for the Study of External Forces Affecting Ships
Dr. R. Dorrestein (Netherlands)
IUGG Inter-Association Committee on Mathematical Geophysics

Dr. W. Hansen (FRG)

Joint IAG/IAPSO Special Study Group on Mean Sea Level

Dr. G. W. Lennon (UK)
Prof. L. Asplund (Sweden)
Dr. Z. Dziadziuszko (Poland)
Lt. Cdr. N. C. Glen (UK)
Frau Dr. E. Llisitzin (Finland)
Dr. W. Lohrberg (FRG)
Dr. Helge Thomsen (Denmark)
Ir. P. J. Wemelsfelder (Netherlands)

IAPSO REGISTRANTS

XV GENERAL ASSEMBLY OF IUGG
Moscow, USSR — 1971

BULGARIA

Galabov, J.

CANADA

Bottos, F. B.
Dohler, G. C.
Grant, H. L.
Neu, H. J. A.

DENMARK

Thomsen, H.

FEDERAL REPUBLIC OF GERMANY

Engel, M.
Schäfer, P.

FRANCE

Coantic, M. F.
Girard, G. G.
Gougouenheim, A.

GERMAN DEMOCRATIC REPUBLIC

Brosin, H.
Gohs, L.

ITALY

Frassetto, R. F.

JAPAN

Futu, H.
Hoshino, M.
Iwata, N.

Sugimura, Y.
Uda, M.
SYMPOSIA

Abstracts of the Scientific Papers Related to Oceanography Presented at the IAPSO Sponsored or Co-Sponsored Symposia

1. SYMPOSIUM ON MARINE GEODESY
   Sponsored by IAG (with IAPSO)
   Convenor: Dr. A. G. Mourad

9. SYMPOSIUM ON TSUNAMI
   Sponsored by IASPEI (with IAPSO/Tsunami Committee)
   Convenor: Mr. B. D. Zeller

10. SYMPOSIUM ON MICROSEISMS
    Sponsored by IASPEI (with IAPSO)
    Convenor: Dr. F. Benard

16. SYMPOSIUM ON ENERGY FLUXES OVER POLAR SURFACES
    Sponsored by IAMAP (with IAPSO/IASH)
    Convenor: Prof. S. Orvig

17. SYMPOSIUM ON AIR-SEA INTERACTION
    Sponsored by IAMAP (with IAPSO/IASH)
    Convenor: Prof. H. Charnock

19. SYMPOSIUM ON AIR AND WATER POLLUTION
    Sponsored by IAMAP (with IASH/IAPSO)
    Convenor: M. J. Jacquet and Prof. H. Schoeller

29. SYMPOSIUM ON AUTOMATIC ACQUISITION OF DATA AND TIME SERIES ANALYSIS
    Sponsored by IAGA (with all associations)
    Convenor: Dr. A. DeVuyyst

31. SYMPOSIUM ON REMOTE SENSING TECHNIQUES
    Sponsored by IASH (with IAPSO/IAMAP)
    Convenor: Dr. F. Bock

32. SYMPOSIUM ON WATER BALANCE OF SEMI-CLOSED SEA BAYS
    Sponsored by IASH (with IAPSO/IAMAP)
    Convenor: Dr. W. Ackermann

SYMPOSIUM ON SOME PROBLEMS OF PHYSICAL OCEANOGRAPHY
Sponsored by IAPSO
Convenor: Prof. V. G. Kort
1. MARINE GEODESY AND THE CHALLENGES OF THE OCEANS

A. G. Mourad
Battelle Memorial Institute, Columbus Laboratories, Columbus, Ohio, USA

Marine geodesy already has several techniques available that offer direct approaches to the solution of many oceanic problems. These techniques and past progress will be reviewed and assessed. Results of several experiments will also be presented. The role of marine geodesy in meeting the challenges of the oceans will be discussed. Illustrative examples will be given related to determination of boundaries, mapping and mean sea level, and to direct measurement of ocean spreading and open-ocean tides as well as to prediction and forecasting of certain environmental parameters.

2. GRAVIMETRIC DETERMINATION OF THE GEOID ALONG MERIDIAN 150° W

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**Atlantic Oceanographic Laboratory, Bedford Institute, Canada

Determination of the difference in height between the isobatic sea surface and the geoid gives the change in potential of an isobatic surface. From this can be calculated the potential of all other isobatic surfaces, wherein lies the key to ocean current transport. Orbital perturbation analysis of satellite track observations provides the low order harmonics of the geoid. At present the higher order harmonics may only be obtained at the sea surface. In order to determine the high harmonics of the geoid along the path of a polar orbiting satellite, a gravimetric determination of the geoid was made along 150° W between 63° S and 57° N. Future satellite altimeter profiling of the sea surface with reference to this geoidal section will enable an absolute dynamic section to be made.

3. COASTAL GEODESY, THE DEFINITION OF THE MEAN SEA LEVEL SURFACE

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A classical concept of the geoid is the unperturbed free ocean surface. A number of attempts have now been made to define this surface, particularly in Europe, using long-time series of sea level observations connected by terrestrial links of precise leveling.

Past procedures in the maintenance of coastal tide gauges and the quality of the instrumentation make it possible to determine time variations in the relationship
between land and sea levels with a limited precision, but create difficulties in establishing spatial differentials. Also conventional geodetic procedures, in particular those associated with precise leveling, do not preclude the presence of systematic error. Again a national leveling exercise is a lengthy and laborious procedure which can be accomplished only at infrequent intervals. Nevertheless attempts to define the mean sea level surface particularly in European waters have been made with some success.

Long tidal time series, prefiltered so as to remove most of the perturbations of tidal origin, have been reduced to annual mean levels. The latter have been subjected to regression analysis so as to identify: (a) a secular trend of linear, quadratic or cubic form; (b) influences of static barometric pressure; (c) perturbations due to annual residual wind-stress; (d) the nodal tide. Although designed primarily to investigate relative movements of land and sea levels at each station, the technique does allow the determination of the elevation of the mean sea level surface at any point in recent history, and also by certain inferences with respect to connections to the appropriate national leveling networks it is possible to interpolate the surface in space. Furthermore the regression process, in providing coefficients for the associated meteorological parameters, allows a definition of the surface for isobaric conditions which is remarkably compatible with the unified European leveling network. The surface shows a positive gradient to the north giving a level differential of some 30 cms. between the Mediterranean and the English Channel and a similar differential between the Channel and the northern North Sea. It should be noted that no account has been taken of the influence of water density differences in this evaluation.

Plans are afoot to make more precise deductions in the future by (1) improving the observational techniques applied to sea level for this purpose so as to increase accuracy and to enable corrections to be applied for appropriate perturbing parameters; (2) to conduct absolute gravity measurements at certain permanent tidal observatories so as to allow discrimination between eustatic changes in sea level and movements of the land surface in the vicinity of the gauge; (3) to improve procedures of both oceanography and geodesy so as to identify responsibilities and purify the data from past misinterpretations.

4. INTERACTION BETWEEN OCEAN AND EARTH TIDES

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There is close interaction between earth tides and oceanic tides. The objective of earth tide studies is to investigate the response of the earth as a whole to tidal forces. Several techniques are used:

1. Geophysical instruments installed on the earth’s crust.
2. Astronomical observations of nutations (which is the same phenomenon as tesserai diurnal tides); Chandler Wobble which is a tesserai tide of 430 days period; and secular retardation of the speed of rotation.
3. Satellite orbit perturbations. In each case there is a contribution from oceanic tides difficult to separate by simple analysis of observations because the frequencies are just the same. This is

why we must investigate more carefully the tidal processes.

1. In the case of geophysical instruments (gravimeters and horizontal pendulums) we measure simultaneously:
   a. the tidal response of the solid earth
   b. the attraction of periodically displaced oceanic waters
   c. the loading effects of these waters on the upper crust.

Our original objective was to remove these oceanic effects by calculation or by empirical separation process in order to restrict the investigation to the solid earth phenomena. At the present time, owing to the insufficient knowledge of the oceanic tides distribution and of the structure of the crust it is proposed to solve the inverse problem (Kuo): from a net of well selected stations derive a model of the crust.

Recent developments of this program are:
   European tidal gravity transverse profile (1970–1971)
   Astro Geo project Spitsbergen (1968–1970)

Numerical results will be presented during the Moscow Symposium.

2. An important part of the secular retardation of the speed of rotation is due to frictional processes in oceanic tides. New approaches are made to calculate as correctly as possible the amount of energy dissipated in this way. Then a comparison can be made between internal friction in solid earth tides (phase lags), friction in oceanic tides and the astronomical and paleontological data.

3. Tidal displacements of masses affects the orbital motion of artificial satellites. It is necessary to separate what is of solid earth tides origin and oceanic tides origin.

5. SATELLITE ALTIMETRY AND ITS APPLICATIONS TO MARINE GEODESY—THE GEOS-C AND SKYLAB PROGRAMS

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Interest in the inclusion of a radar altimeter on earth orbiting spacecraft has been expressed by geodesists, oceanographers, and others for a number of years. NASA has undertaken the development of such altimeters for inclusion in the proposed GEOS-C and SKYLAB Programs. This paper will outline the objectives both long range and immediately applicable to altimetry in general and to the SKYLAB and GEOS-C programs specifically.

The design tradeoffs necessary for the GEOS-C and SKYLAB altimeters will be presented. In addition, the ground truth and in-orbit calibration requirements will be discussed along with the total system error budget. The altimetry experiments planned for the SKYLAB and GEOS-C missions will be discussed showing how marine geodesy and oceanography can contribute to and benefit from them.
9: SYMPOSIUM ON TSUNAMI
Sponsored by IASPEI (with IAPSO/Tsunami Committee)
Tuesday, August 10
Chairman: K. Iida
Redefining Tsunami Magnitude
1. Z. K. Grigorash and L. A. Korneva
   The estimation of the Tsunami waves energy according to the tide gauge
   records and the refraction charts (using the example of the Black Sea
   tsunami)
2. L. N. Ikonnikova
   Investigations into the waves of tsunami on the basis of power principle
3. T. Hatori
   A method for determining the tsunami magnitude
4. K. Iida
   Review of tsunami magnitude
5. K. Iida
   Redefining tsunami magnitude
   Members of the IUGG Tsunami Committee Problems of redefining tsunami magnitude (discussion)

Wednesday, August 11
Chairman: G. Miller
Prediction of Tsunami inundation, Short Term
6. R. M. Garipov
   On the tsunami recognition by a seismic information
7. Hideo Watanabe
   Statistical studies on the wave-form and the maximum height of large tsunami
8. V. M. Jaque
   Hydrophysical method of tsunami prediction
9. A. A. Poplavsky, A. I. Ivaschenko and I. N. Tikhonov
   Some principal possibilities of improving of the seismological method of the tsunami prediction
10. J. C. Larsen
    The electromagnetic field of long and intermediate waves
11. O. T. Magoon and N. L. Arno
    Prediction of long-term tsunami inundation at Crescent City, California, USA
12. P. Mechler and Jacques Talandier
    Seismic T-phases and tsunami in French Polynesia
13. R. F. Henry and T. S. Murty
    Numerical resonance studies of a multi-branched coastal system: Rivers Inlet, British Columbia

    The response of the continental shelf and some inlets on the west coast of Canada to incoming tsunami
15. L. M. Balakina
    The source mechanism of tsunamigenic earthquakes, northwestern region of the Pacific Ocean
16. S. L. Solov'ev
    Recurrence of earthquakes and tsunamis in the Pacific and threshold magnitudes of tsunami-genetic earthquakes
17. Rudolf W. Preisendorfer
    Recent tsunami theory
    Report of the joint tsunami research effort on short-term prediction

Thursday, August 12
Chairman: S. S. Voyt
Prediction of Tsunami inundation, Long Term
19. R. D. Braddock
    On asymmetric tsunami generation
20. K. Kajiura
    The directivity of energy radiation of the tsunami generated in the vicinity of a continental shelf
21. S. S. Voyt and B. I. Sebekin
    Influence of the Coriolis force and geometrical characteristics of the disturbance source on the wave generation
22. L. V. Cherkesov, V. V. Kaysh, I. P. Lukina and V. S. Fedosenko
    Deformation of tsunami waves while they reach shallow water
23. A. V. Nekrasov, V. A. Makarov, R. V. Pyaskovsky and V. G. Buehte
    Studies of tsunami propagation and transformation by means of numerical computations and electrostimulation
24. L. A. Ostrovsky and E. N. Pelinovsky
    Nonlinear wave transformation on fluid surface of variable depth
25. G. F. Vasiliev and V. G. Sudobetich
    Numerical solutions to the problems of tsunami-type waves run-up on a sloping beach and their entering the estuary
26. Sh. Nakamura
    On hydraulic bore and its application: generation and propagation of tsunamis
27. G. E. Kononkova and A. E. Rehruzel
    Experimental investigation of rolling of solitary tsunami waves on the coast slope
1. THE ESTIMATION OF THE TSUNAMI WAVES ENERGY ACCORDING TO THE TIDE GAUGE RECORDS AND THE REFRACTION CHARTS (USING THE EXAMPLE OF THE BLACK SEA TSUNAMIS)

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When waves move shoreward from the tsunami origin the wave velocity, the wave direction, the initial form of the wave front are changed differently depending on the depth change character of the sea in various directions and the wave energy is transmitted in different directions irregularly. Owing to this the estimation of the whole tsunami wave energy released in the origin by the use of separate tide gauge records of tsunami waves in the various coast points can be either exceeded or reduced if the convergence or divergence of the wave rays in consequence of the wave refraction is not taken into account. It is desired to have the wave measurements at a set of tide gauge stations for the correct estimation of the tsunami energy in its origin. Then it would be possible to integrate the energy through the whole sea coast. But such wave measurements have not yet been put into practice to date. This paper deals with the method of estimation of the tsunami wave energy in the origin by using the tide gauge records at the separate coast points taking into account the wave refraction. The new suitable method for the construction of wave refraction charts for any sea is proposed using a special graph which gives the wave rays direction change depending on the sea depth change. The wave refraction charts are constructed, the wave energy distribution all over the sea basin is characterized, the tsunami energy flow in the direction of the separate coast points and the whole tsunami wave energy in its origin are determined on the basis of the tide gauge records at the Black Sea coast of the Crimea and Caucasus for the following tsunamis: 26 June and 11–12 September, 1927 and 12 July, 1966 which have occurred in the Black Sea. Besides the concrete results for the Black Sea small tsunami this paper is of scientific interest for carrying out the similar researches concerning the calculation of the tsunami energy and its distribution over the basin of the oceans and seas when the catastrophic tsunami occurs.

2. INVESTIGATIONS INTO THE WAVES OF TSUNAMI ON THE BASE OF POWER PRINCIPLE

L. N. Ikennikov
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The main formula for the estimation of tsunami height is obtained by solving the equation of the energy balance for the mathematical conditions relative to waves of tsunami. The formula obtained generalizes Green's law with regard for the energy losses for the friction of water particles on the bottom and for the deformation of the wave shape. The estimation of the energy losses of the tsunami wave with the variable numerical friction and deformation coefficients is given. The reliability of the assumed schematization and friction and deformation coefficients, corresponding to it, are
determined by the comparison of calculation results with the observational data. The energy losses of tsunami waves with different period in their travel way towards the coast in the ocean regions with different bottom slope and the energy variations due to refraction are shown. The numerical calculation of the tsunami heights in the coastal area is given.

Solution of the energy balance equation which the most completely takes account of the losses and variations of the energy on the way of tsunami towards the shore, stipulated by different factors forming the waves, will, on the author's opinion, be the best approximation to truth.

3. A METHOD FOR DETERMINING THE TSUNAMI MAGNITUDE
Tokutaro Hatori
Earthquake Research Institute, University of Tokyo, Tokyo, Japan

Based on the attenuation of the maximum wave amplitude with the distance along the continental shelf from the earthquake epicenter, a formula to determine the tsunami magnitude is found. The present tsunami scale follows the Imamura-Iida's magnitude. The magnitudes of 48 tsunamis (origin: Japan, 34; other countries, 14) are determined by this formula from tide gauge records at the circum-Pacific coasts except those of the stations near the tsunami source and the mid-oceanic islands. According to the present method, the tsunami magnitude can be estimated easily from a few records observed at distant stations even if the data near the tsunami source are scarce. For example, by making use of several records observed in Japan, the magnitudes of principal tsunamis generated in Alaska, Aleutian, and Kamchatka regions could be estimated within the accuracy of about ±0.5. The magnitude scale determined by the present formula is closely related to the total wave energy and the dimension of the tsunami source.

4. REVIEW OF TSUNAMI MAGNITUDE
Kumiz i Iida
Department of Earth Science, Nagoya University, Nagoya, Japan

The definitions of various tsunami magnitude scales are summarized. Tsunami magnitude scale has been formed to express the size of tsunamis in terms of a scale of their heights since Imamura's proposal in 1949. Imamura defined five discrete tsunami magnitude from 0 to 4 in terms of maximum height of tsunami inundation as measured along a coast taking some damaged area into consideration. This magnitude scale was extended one step at the small end by K. Iida (1956), who later (1961, 1965) provided other scales based on tsunami height, extended the scale at both ends, and changed the ratio between steps in the earlier scale. The scale which is continuous, for both height and magnitude, was adopted by K. Iida, D. C. Cox, and G. Pararas-carayannis (1967), based on maximum run-up heights measured on whatever coast line closest to the area of generation of tsunami.

The correlation between mean and maximum heights of tsunami inundation and grades of various scales by S. L. Soloviev (1970), who showed the difference of the magnitude from the intensity which was related fairly well to the mean heights from the analysis of the Imamura-Iida scale.

The relationships among these various magnitude scales will be described.

5. REDEFINING TSUNAMI MAGNITUDE
Kumiz i Iida
Department of Sciences, Nagoya University, Nagoya, Japan

This paper will describe the redefinition of tsunami magnitude. A formula to determine the tsunami magnitude scale is presented on the basis of the maximum wave amplitude at a certain depth line off the continent or island. The tsunami magnitude is obtained as a function of maximum wave amplitude and a distance from the source. Tide gauge records at the circum-Pacific stations were used for determining the tsunami magnitude. The present magnitude scale is related to the earthquake magnitude and the dimension of the tsunami source.

A magnitude scale of different form which has various tsunami parameters is discussed for the tsunami associated with near and distant earthquakes. The magnitudes of some principal tsunamis generated in Kamchatka, Alaska, Aleutian and Japan region are also estimated by various scales.

6. ON THE TSUNAMI RECOGNITION BY A SEISMIC INFORMATION
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In this paper the problem of the tsunami recognition by a seismic information is settled in a following way.

Let us suppose the tsunami wave to be initiated by the underwater earthquake. The motion near the epicenter is not known exactly to be of the class in H. A point A being at the seashore is the point of observation. The seismic signal, $C_s$, measured in a small neighborhood of $A$ is a function of the time. It is needed to forecast the wave height $TS_A$ of the tsunami in the point $A$ as a time-function using this seismic signal.

At the present time the parameters of the epicenter are determined at the first stage by a seismic information, $C_s$, and then the wave height of the tsunami. This intermediate operation is not necessary.

Of course the function $TS_A$ cannot be predicted uniquely by $C_s$. We show existence of the linear transformation $T$ such that the mapping $S: C_s \rightarrow T(TS_A)$ is one-valued. Nontrivial mappings $T$ and $S$ are constructed in some simple cases.

Those characteristics of $TS_A$ which cannot be determined exactly by $C_s$ can be predicted with a probability depending on $P$.

A priori we do not know the distribution of $P$. It can be determined only by the results of the tsunami's observations. The machine program of the recognition are discussed which precises the value $P$ and therefore it improves the "knowing" properties with increasing of the number of the tsunami's observations.
7. STATISTICAL STUDIES ON THE WAVE-FORM AND THE MAXIMUM HEIGHT OF LARGE TSUNAMIS

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Many tide-gage recordings of large tsunamis on the coasts of the Pacific Ocean area show such complicated wave-forms that no relationship from one wave-form to another seems to exist, especially for the maximum wave.

The purpose of this study is to clarify the features of the wave-form and the maximum height of large tsunamis by classifying the tide-gage recording in three types, A, B and C. The "A" type record is made up of an impulse wave which arrives directly from the tsunami source. The "B" type record consists of the edge wave which propagates along the continental shelf and island-arc side and often consists of two or three groups. The "C" type is the combination of "A" and "B" types. The data used in this study are four tsunamis: The Kamchatka Tsunami of Nov. 4, 1952; the Aleutian Tsunami of March 9, 1957; the Chile Tsunami of May 22, 1960; and Alaska Tsunami of March 28, 1964.

The "A" type occurs primarily at isolated islands in the Pacific Ocean. The "A" type at a continental coast is a result of the location of the tsunami source with respect to the tide-gage. The "B" type is distributed mainly on the continental coast and island-arc side. The distribution of the "C" type differs from tsunami to tsunami. These geographic distributions are closely related with the mechanism of the tsunami source.

The relationships between the delay time of maximum wave and travel time of initial wave are as follows:

1) The "A" type shows a constant delay time of about two hours as a mean value for all travel times.

2) The first group of "B" type shows constant delay time of about six hours or a slow decrease of the delay-time for an increase of the travel time. The second group of "B" type shows the definite decrease of the delay time for an increase of the travel time, and the third group of "B" type shows a more definite decrease than the second group.

The height of the maximum wave of "A" type generally shows decreasing height with increasing travel time. This is explained as the damping of a tsunami by several kinds of friction, although the damping coefficient is very small. The height of "B" type increases with an increase of travel time in all groups. This may be related to the increase of period in the edge waves of tsunami by the propagation over a long distance.

Although the results of these statistical analysis are quantitatively rough, the maximum height of a large tsunami and its arrival time after occurrence can be estimated by applying these results. The tsunami warning will be expected to issue better information on the tsunami height later.

8. HYDROPHYSICAL METHOD OF TSUNAMI PREDICTION

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The recording system of hydrophysical events with the help of bottom seismographs located on the shelf edge is described.

The results of observations conducted on the Shikotan shelf by means of mentioned system are discussed.

The possibility of tsunami recording on the shelf in advance and the proper time warning of its approaching to a coastal line is demonstrated.

9. SOME PRINCIPAL POSSIBILITIES OF IMPROVING THE SEISMOLOGICAL METHOD OF THE TSUNAMI PREDICTION

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The working conditions of the tsunami warning service along the Far East coast of the USSR require rapid deriving of earthquake information from observation data of a single station. Improving of the seismic part of the service should result in sharp increase of information obtained from observations. A necessity to use electronic digital computers in tsunami service is evident.

It is necessary to create earthquake parameter determination methods which would use digital records directly and would not require an interpreter to pick out and identify the necessary signals.

Some results of working out such methods (determination of an azimuth at an epicenter, epicentral distance) are presented in the paper.

Possibilities to distinguish tsunamiogenic and nontsunamigenous earth-quakes from their record spectrum forms are estimated.

Possibilities of long-term prediction of strong tsunamis in the north-western Pacific are discussed. Strong tsunamis show a tendency to group in time, the groups following one another every 5 to 6 years on the average. Presumable prediction of the time of beginning of the next group of strong tsunamis is given.

A possibility of giving a more precise definition of the magnitude criterion of tsunamiigenity of earthquakes by means of data on the focal depth is shown.
10. THE ELECTROMAGNETIC FIELD OF LONG AND INTERMEDIATE WAVES

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The electromagnetic field induced by long and intermediate water waves (e.g., tsunami) is dependent on the time variation and spatial variation of the water motion and on the earth's electrical conductivity structure. The water motion is approximated by a plane progressive wave on a nonrotating flat infinite ocean of uniform depth. The earth's conductivity is approximated by plane uniformly conductive layers that represent the ocean, the bottom sediments, and the highly conductive mantle. The analytical solution to the electromagnetic problem shows the important influence of frequency, wave number, and oceanic and mantle conductivity, all of which modify the field through both self-induction and mutual induction. Amplitudes of the electromagnetic field are tabulated for a range of tsunami frequencies.

11. PREDICTION OF LONG-TERM TSUNAMI INUNDATION AT CRESCENT CITY, CALIFORNIA, U.S.A.

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**Office, Chief of Engineers, Corps of Engineers, Department of the Army, USA

Crescent City is located in Northern California on the Pacific Coast of North America. In the last decade, the harbor and city have been damaged by tsunamis, the most severe occurrence being the tsunami associated with the Alaskan earthquake of March 1964.

Studies undertaken with a view toward prediction of long-term tsunami inundation and also to the design of protective structures to reduce tsunami damage have consisted of gathering historic information on tsunamis at Crescent City; preparation of detailed bathymetric and topographic surveys; wave refraction studies of propagation of tsunamis across the Pacific Ocean; detailed two-dimensional flume studies of tsunami runup with and without tsunami barriers; and studies of probability of tsunami occurrence including the effect of tides.

Based on the results of the above work, it was concluded that conceptually, protection may be provided for varying degrees of damage by construction of a coastal seawall or levee at Crescent City. Detailed design of the protective work would probably require additional model testing in a three-dimensional model basin.

12. SEISMIC T-PHASES AND TSUNAMIS IN FRENCH POLYNESIA

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The Ecole Normale Superieure and the Laboratoire de Detection et de Geophysique (Commissionat a l'Energie Atomique) installed, 10 years ago, a seismic network in French Polynesia, which operates, among other equipment, 10 short period vertical seismometers (5 on Tahiti-Moorea Islands, 4 on Rangiroa Atoll, 1 on Rikitea Island). The quality of these stations is surprisingly good (magnification: 110,000 at 1 cps, 500,000 at 5 cps, but a strong cutoff at 0.3 cps).

We record a very great number of T-phases, sonic waves which propagate in the SOFAR and become seismic waves near the stations. It was possible to correlate some of these T-phases with the arrival of Tsunamis in French Polynesia. This observation enables us to forecast Tsunamis.

We may describe our forecasting system by the following steps:

1) Each time we record a seism which magnitude is above a certain level we locate it immediately, to know if the epicenter is, or not, in a tsunamiogenic area. This is done with the only use of P-phases.

2) If yes, we wait until the arrival of T-phases, which is later than the P-phase arrival. If the T are above a certain level, then we give a Tsunami alarm. Since 1967 this forecasting procedure is in use, and we were able to give a warning for each tsunami observed in French Polynesia, without any false alarm.

13. NUMERICAL RESONANCE STUDIES OF A MULTI-BRANCHED COASTAL SYSTEM: RIVERS INLET, BRITISH COLUMBIA

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For an understanding of seiche action and tsunami response of a coastal inlet, it is necessary to estimate the frequencies of the first few normal modes of the free oscillation. This paper examines the difficulties which arise when these resonance frequencies are computed for multi-branched inlets by iterative search for successive normal modes. It is shown that, unless the boundary conditions are applied to each mode in an appropriate manner, spurious modes of oscillation may appear during the numerical computation and, further, that genuine modes may be overlooked. Essentially, the initial and final boundary conditions should be applied in branches of the system where there is appreciable motion.

An alternative method which requires considerably less programming effort is then discussed: the lower resonance frequencies of the system are found simultaneously from the difference-differential equations used to represent the system.
after the space dimension is discretized. The limitations of this method are
discussed.

Finally the so-called "impulse-response method" is considered. This appears
to be particularly suitable for the case of tsunami response prediction and can be
used with little modification for finding seiche frequencies also. In this case, the
resonance frequencies are determined by detecting peaks in the Fourier transform
of the time response of the system to an impulsive excitation.

14. THE RESPONSE OF THE CONTINENTAL SHELF AND SOME INLETS
OF THE WEST COAST OF CANADA TO INCOMING TSUNAMIS

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For any meaningful tsunami prediction on a given coast, a detailed knowledge
of its response to incoming tsunamis is necessary. Many complexities arise due to
interaction with other possible oscillations on the Shelf and in the inlets and rivers.
With this general aim in view, work is in progress on the following problems investi-
gated through mostly numerical methods to take the complex topography into
account. The response of the Continental Shelf off Queen Charlotte Islands,
Vancouver Island, Hecate Strait and Queen Charlotte Sound to tsunami approach-
ing from different directions is being investigated. A calculation is made of the
trapping of tsunami wave energy around the Queen Charlotte Islands. It has been
reported in the literature that the delay between the first wave and the maximum
wave at a tidal station may be due to the edge waves on the Continental Shelf.
For this reason a calculation of the edge waves, trapped and leaked modes on the
Continental Shelf has been made. The propagation of a tsunami as a bore through
the Fitz Hugh Sound complex and Alberni Inlet complex has been calculated using
numerical methods and also the method of characteristics.

15. THE SOURCE MECHANISM OF TSUNAMIC GENIC EARTHQUAKES,
NORTH-WESTERN REGION OF THE PACIFIC OCEAN

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1. The confrontation of source mechanism of tsunamigenic and non-
tsunamigenic earthquakes was carried out. There were considered 121 shocks
(1927–1965) which in the north-western region of the Pacific occurred, of them
24 were accompanied by tsunami.

2. As it appeared, the tsunamigenic earthquakes have the following source
mechanism. One of the possible fault planes, being apparently the main one,
steeply dips (dip angle is more or equal to 65°); the displacement on this fault
plane is mainly dip-slip (angle Y between displacement vector and the fault plane
dipping is not more than ~20°).

3. As a rule, steep fault planes within the sources of tsunamigenic shocks
had the strike along island arcs, and the oceanward dipping. In all cases the oceanic
sides, i.e., the hanging walls of these steep fault planes were relatively uplifted.

4. Non-tsunamigenic earthquakes in the most cases had either more gently
dipping fault plane or more significant strike component of displacement in the
source. However, some non-tsunamigenic shocks had source mechanism similar to
tsunamigenic ones. Tsunami occurs only when the magnitude of a shock is large
enough and focal depth is small, i.e., when steep fault plane, probably, reach oceanic
floor and leads to considerable deformation of it.

5. The source mechanism of tsunamigenic and non-tsunamigenic earthquakes,
which were considered, are in a good conformity with regularities of stress field in
the north-western region of the Pacific, established by the author in 1962 and 1967.

16. RECURRENT OF EARTHQUAKES AND TSUNAMIS IN THE PACIFIC
AND THRESHOLD MAGNITUDES OF TSUNAMIC GENIC
EARTHQUAKES

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The compilation of catalogs of strong earthquakes (M ≥ 6) for 1906–1967 and
of tsunami in the Pacific is completed. Magnitude M of all earthquakes is uni-
formly redetermined on the basis of observations of the Soviet seismic stations.
Magnitude-frequency relations for earthquakes is found in 60 zones. The average
value of the angular coefficient is obtained to be equal to 0.79 ± 0.11. The final
map of earthquake recurrence in the Pacific is compiled.

Frequency-intensity relation for tsunami in 26 Pacific zones is found, the
intensity of tsunami being estimated with the help of the modified Imamura-Iida
scale. The average value of the angular coefficient is obtained to be equal to 0.29
± 0.06. The final map of tsunami recurrence in the Pacific is compiled.

The parameter of tsunamigeneration defined as a ratio of tsunami and earth-
quakes frequencies is calculated for all zones. It is affirmed that this parameter has
high values in shelf zones with block tectonics and low values in arc zones.

Expressions for calculation of tsunami probability as function of magnitude
of an earthquake and the parameter of tsunamigeneration are deduced. The tables
of tsunami probability are calculated for some zones, and threshold magnitudes
of tsunamigenic earthquakes are found (these values vary from 6.5 to 7).

Threshold magnitudes of distant earthquakes to announce tsunami danger
on the Soviet shores are also found.
17. RECENT TSUNAMI THEORY

R. W. Preisendorfer
Joint Tsunami Research Effort, National Oceanic and Atmospheric Administration, USA


18. REPORT ON JOINT TSUNAMI RESEARCH EFFORT ON SHORT-TERM PREDICTION

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Joint Tsunami Research Effort, Pacific Oceanographic Laboratories, National Oceanic and Atmospheric Administration, USA

Research in various topics related to short-term or real-time prediction of tsunamis is being conducted at JTRE. Earlier works on 1) the use of a small aperture seismic array to determine epicenters and on 2) the location or identification of source regions by use of pattern recognition techniques are being combined. First results show that the array will always be sufficient to locate an epicenter to within a region of several degrees’ extent and that there may be a possibility of recognizing the fault system within that region.

Permanent tsunami recording systems have been installed at Minami Tori Shima and Wake Island. These pressure gages have been placed in deep enough water so that only the very longest period swell will appear in addition to tsunamis and tides. Records from these gages provide the least distorted wave form data available from shore-based stations. Such data will be the best input for nearshore run-up studies. Identical recording systems have been emplaced at Oahu and Amchitka Islands. All stations record pressure and temperature at the sea floor and atmospheric pressure at the shore.

Two complete permanent open ocean tsunami data transponding systems have been built. Both communicate with the surface acoustically on command. One unit is designed to be emplaced under a weather ship, the other system utilizes a buoy which provides data transmission to the shore. The bottom unit is battery powered with a lifetime of three years each of which a total of one month of data may be sampled.

A new wave form for which the analytic non-linear solution can be derived has been found. The initial condition is a stationary elevation of water level decaying monotonically from the shore. The sea floor has constant slope. This may be compared to the condition which exists at the time a wave has reached maximum run-up.

19. ON ASYMMETRIC TSUNAMI GENERATION

R. D. Bradock
Department of Mathematics, University of Queensland, Brisbane, Australia

The generation of a tsunami in water of constant depth is considered for the special case of an asymmetric distribution of bottom velocity. The resulting surface disturbance consists of a wave front followed by a dispersive wave train, but the important result concerns the orders of magnitude of these two wave systems. In the asymmetric case, the wave front is of lower order than the wave train, this order relationship being just the reverse to that obtained by other authors considering the symmetric case.

20. THE DIRECTIVITY OF ENERGY RADIATION OF THE TSUNAMI GENERATED IN THE VICINITY OF A CONTINENTAL SHELF

Kinjiro Kajura
Earthquake Research Institute, University of Tokyo, Tokyo, Japan

The radiation pattern of the tsunami generated by a broad crustal deformation on or near the continental shelf is examined analytically in the framework of the linear long-wave approximation.

The proportion of the energy trapped on the shelf as the edge wave modes relative to that radiated into deep water increases with the decrease of the long-shore dimension of the source. Also, the nearer the source to the coastline, the greater is the rate of the generation of edge waves.

The directivity difference of the energy radiation in deep water grows with the increase of the long-shore dimension of the source and/or the ratio of the deep water depth to that of the shelf water.

Due to the multiple reflections on the shelf, a train of waves with decreasing amplitudes propagates in deep water. The dominant "period" of this wave train is comparable with the period of the shelf oscillation but gradually decreases with the increasing angle of radiation from the direction perpendicular to the coastline.


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Shirshov Institute of Oceanology, Academy of Sciences, Moscow, USSR

The character of the tsunami waves connected with the source of the waves generation, its power, continuity of its acting and space extent, therefore, it is necessary firstly to investigate the waves generated by the concentrated point source
for construction of the various hydrodynamical models. Then, for the solving of
the problems with given space characteristics of the disturbance region it is possible
to use the solution obtained for concentrated point source.

In the study the different mechanisms of the generation of the unsteady long
waves are considered. Among them are the disturbances of the surface pressure,
the movements of the bottom, the forced changing of the free surface level of the
fluid and the source within fluid. The comparison of the waves picture generated
by this sources of disturbance is carried out and correspondence between investigated
influences of the disturbances is determined. The influence of the Coriolis force
on the directed waves propagation generated by the geometrical features of the dis-
turbance region is studied.

The reflection of the waves from straightline shore in conditions of the rotating
basin is explored and the asymmetry, influenced by the acting of the Coriolis force
and by the character of the disturbances source, is shown. The boundary effects pro-
duced due to rotation, and formation of the Kelvin-type waves are investigated.

The reflection and refraction of the long unsteady waves in the rotating basin
with the sharp variation of its depth are considered. The exact solution of the given
problem is obtained and the asymptotical investigation of the reflected wave is
 carried out. The unsteady waves considered as superposition of the harmonic in
the time waves with the various frequencies are captured by the discontinuity of the depth
in the low-frequency part of the spectrum. The width of the spectrum of the captured
waves depends from the value of depth jump and always is less than inertial frequency.

22. DEFORMATION OF TSUNAMI WAVES WHILE THEY REACH THE
SHALLOW WATER

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Sevastopol, USSR

The effect of a continuous change in the basin depth on the deformation of
long waves while they are moving from a deep-water region of the basin into a
shallow one is discussed.
1. Analysis of the effect of change in the bottom profile of the basin on
long waves arising from initial disturbances in a uniform ideal nonrotating fluid
is performed by numerical methods in a nonlinear statement.
2. The analytical solution to a problem of long waves arising from initial
disturbances in a basin, the depth of which changes in the transition zone according
to a certain law, is obtained in a linear statement. The analysis of the effect of depth
ratio of the shallow and deep-water regions on the wave deformation is given.
3. The effect of the change in the bottom relief of the basin on internal
waves, arising from atmospheric disturbances in a two-layer ideal fluid is investi-
gated by analytical methods under the assumptions of the linear theory.

23. STUDIES OF TSUNAMI PROPAGATION AND TRANSFORMATION
BY MEANS OF NUMERICAL COMPUTATIONS AND
ELECTROMOISTMULATION

A. V. Nekrasov, V. A. Makarov, R. V. Pyaskovsky and V. G. Bukhteev
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This work is based on the shallow water equations, both linear and nonlinear.
Some problems are solved for one-dimensional bottom profiles and for two-
dimensional domain having real depth distribution. The possibilities of intercom-
plementary numerical and electroanalogue methods are employed.

An electronic model has been constructed to simulate tsunami propagation
in the Japan Sea by means of which the Nigata tsunami of 1964 was investigated.
The main attention is paid to influence of initial source various forms and orientation
on the amplitudes, periods, duration of oscillations, energy characteristics, etc.,
in different parts of region in question. Results obtained are compared to observa-
tional data. Besides the studies of actual tsunami a number of general problems of
non-stationary wave electromimulation is discussed.

By means of numerical calculations the initial perturbation form in the source
of the Nigata tsunami is reconstructed and its energy amount is evaluated. The shelf
effect—in the first place reflection and resonance—are considered for various shelf
 types, schematic and real, in the Japan Sea and in the Kuril-Kamchatka region. It is
shown that the combination of concentrated local reflection and "spread" one may
lead to additional periods, shelf radiation and other effects, whose characteristics
can be determined. Methods and results reported on the Honolulu Symposium are
developed considerably.

24. NONLINEAR WAVE TRANSFORMATION ON FLUID SURFACE OF
VARIABLE DEPTH

L. A. Ostrovsky and E. N. Pelinovsky
USSR

The paper gives the summary of results concerning the nonlinear wave processes
in the coastal zone. The known solutions of hydrodynamic equations at constant
fluid depth ("coidal" and Reimann waves) are presented. The dependence of wave
processes in the coastal zone on the relation between the nonlinearity, dispersion and
inhomogeneity parameters is discussed. The evolution of a solitary wave in the
inhomogeneous medium is considered for the stepwise and the smooth variations
of the depth. The transformation of waves locally close to coidal ones is investigat-
ed. The deformation of a long wave on the beach slope is considered; the coordinate
of the wave breaking depending on the slopes of the bottom is found. It is shown that
the presence of large-scale statistical inhomogeneities of depth leads to
decreasing of the average distance of the wave breaking. The dissipation of the non-
linear wave is considered.
25. NUMERICAL SOLUTIONS TO THE PROBLEMS OF TSUNAMI-TYPE WAVES RUN-UP ON A SLOPING BEACH AND THEIR ENTERING THE ESTUARY

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Within the framework of one-dimensional nonlinear shallow water theory problems associated with run-up of tsunami waves on a sloping beach as well as with surge occurring in the estuaries during entering into them the tsunami waves are solved.

For the solution the bottom line is set continuously. If the problem of moving the wave into the estuary is considered, data on the cross-section of the channel are set. The friction is assumed to be quadratic and considered according to Shezy's hydraulic formula.

Disturbances of water surface are determined either by setting the curve at the boundary profile at some distance from the beach, or by setting the tsunami waves parameters in initial conditions.

When calculating the wave climbing on the beach the same conditions are set at the front of the wave as at the wave moving about the dry channel (depth equals zero). In this case the same nonlinear equations of shallow water theory are used for describing the flow.

For solving initial equations finite difference scheme constructed in terms of a mobile net is used, finite difference relations being compiled with the laws of conservation. Results for calculation following problems are presented in this paper:

1. Solitary wave run-up upon the sloping beach.
   Longitudinal water surface profiles and length speed distribution for various time moments are presented.
2. Solitary wave run-up and run-over across the dam.
3. Tsunami-type wave entering the estuary.
   An example for calculating the periodic run-up over inclined beach is also presented.

26. ON HYDRAULIC BORE AND ITS APPLICATION; GENERATION AND PROPAGATION OF TSUNAMIS

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Various researches have been carried out on tsunami generation and propagation for the purpose to find the characteristics of tsunamis and to predict the tsunami disaster, which were reviewed, for example, by B. W. Wilson (1964). This report is on a study of tsunamis from the point of view of hydraulic bore and its application. An uni-directional experiment on the hydraulic bore (Nakagawa, Nakamura and Ichihashi, 1969) is one of the references for this study.

The hydraulic bores are classified to four categories judging from the experimental result: a) parabolic water profile (for the initial condition, \( h_1/h_0 = 0 \)), b) moving hydraulic jump (0 < \( h_1/h_0 < 0.4 \)), c) unstable undular bores partly breaking (0.4 < \( h_1/h_0 < 0.56 \)), and d) stable undular bores (0.56 < \( h_1/h_0 \)). A theory for the steady hydraulic bores (for example, Stoker, 1957) is compared to the result of the experiment, i.e., the bore height and its celerity, for the transitional stage and for the quasi-steady state to find good agreement for the latter state.

The tsunamis generated at the deep sea will be expected to correspond to undular bores. The equivalent initial condition might be \( h_1/h_0 = 0.999 \) or so for the existing tsunami. A remark is necessary in the application that the existing tsunami propagates and transform three-dimensionally and that the reported experiment is carried out under the condition of uni-directional.

The tsunamis in coastal regions will be simulated for the depth conditions of small values of \( h_1/h_0 \). This simulation will be assured by the tsunami at the river mouth which were photographed at the Niigata Earthquake (1964) and by the result of the experiment.

27. EXPERIMENTAL INVESTIGATION OF ROLLING OF SOLITARY TSUNAMI WAVES ON THE COAST SLOPE

G. E. Kononikova and A. E. Reihndel
Moscow State University, Moscow, USSR

One of the most important aspects of the tsunami waves problem is the question of their run up on the coast. Here information about the border line and the level of flooding are of the utmost importance. The degree of coast flooding depends both on the parameters of the wave itself and on the conditions under which it propagates. To elucidate the principal regularities of the phenomenon of tsunami run up on the coast the problem was schematized: the propagation of a solitary wave in the channel of constant cross-section and the propagation of the wave on a flat slope of the coast were considered. The aim of the investigation was to find how the speed of run up as well as the speed of the vertical and horizontal components of the magnitude of the run up of a solitary wave on the coast are related to the angle at which the slope is inclined the height of the wave, the depth of the channel and the roughness of the bottom.

The experiments were made in the hydrophysics laboratory at the Moscow University.

In the experiments four angles of inclination (\( \tan \alpha = 5, 7, 10, 15 \)) of the coast were taken; the depths of the water were 16, 19, 22, 25 cm the heights of the waves were 3 cm to 8 cm. The parameters of the waves under investigation were well described by the solitary-wave theory. It has been established that under the same conditions of the performance of the wave producer, other things being equal, the height of the rising wave is inversely proportional to the depth of the water in the channel.

The length of the run up of the waves on the slope and the speed of run up, increase with the rising height of the wave. The roughness of the bottom greatly decreases the length and the speed of run up.

The increase of the angle of slope inclination leads to an increase of the vertical component of run up and to a decrease of the horizontal component. When the inclination of the slope is constant (\( \tan \alpha = 15 \)), the length of run up becomes greater when the depth of the water becomes greater.
28. NUMERICAL TIME-STEPPING OF A TSUNAMI INTO HILO BAY

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Joint Tsunami Research Effort, National Oceanic and Atmospheric Administration, USA

The town of Hilo, Hawaii, has been repeatedly inundated by tsunamis, and a breakwater had been proposed to protect the town. In connection with the breakwater proposal, the U.S. Army Corps of Engineers constructed a hydraulic model to scale 1:600 and of total size 19 m by 29 m. In this paper a parallel numerical model has been constructed. The present availability of very high-speed, large-core computers (IBM Model 360-65 with core storage of 2·10^6 bytes) has made detailed numerical modeling possible with the attraction of more flexibility and lower cost than is possible in hydraulic models. In this case a rectangular grid of 54 by 82 grid points is used. The linearized wave equations with a quadratic friction term are used:

\[ \frac{\partial \eta}{\partial t} = \left( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right), \]

\[ \frac{\partial u}{\partial t} = gh \frac{\partial \eta}{\partial x} - k \frac{u \sqrt{u^2 + v^2}}{h^2}, \]

\[ \frac{\partial v}{\partial t} = gh \frac{\partial \eta}{\partial y} - k \frac{v \sqrt{u^2 + v^2}}{h^2}, \]

where \( \eta \) is the water level, \( u \) and \( v \) are vertically integrated water velocities, \( g \) is 9.8 m/sec^2, \( k \) is a friction constant and \( h(x,y) \) is the undisturbed water depth. The numerical scheme uses central differences for all space and time derivatives. The grid points where \( u \) and \( v \) are calculated are interleaved with the grid points where \( \eta \) is calculated. In addition, velocities and water levels are calculated at alternate time steps. This system has proven to be very stable. The velocities are taken to be 0 normal to the coast, and input wave is specified in the two open boundaries. The program is written in such a way that the type of wave and the direction and speed of arrival are easily specified. In addition, provision is made for overtopping the breakwater and for flooding of the shoreline. All of the programs are written so that the calculations can be readily adapted to any coastal region. Results are presented showing the effect of direction of arrival on the amplification of a single-crested wave.

29. THE INVERSE TSUNAMI PROBLEM FOR ISLANDS OF GENERAL SHAPE

C. E. Knowles* and R. O. Reid**
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**Department of Oceanography, Texas A & M University, College Station, Texas, USA

The problem investigated here is that of estimating the deep water characteristics of a tsunami based on recordings made at a point or near an island shoreline. Based on work done previously by the authors for each of two cylindrical islands of simple shape, the extension and generalization of the analysis to more realistic symmetrical and real non-symmetric islands will be discussed. The basic assumption, as before, is that the incident tsunami in deep water is represented by a plane wave but that its signature in time at a fixed point in deep water is unknown. The study is limited to the linear theory for long waves and accordingly, the application requires that the observed water level signatures be at locations where non-linear effects and dispersion are minimal. The method is numerical.

For a given direction of the input wave train in deep water and a given observation point (P) near the island, the solution of the problem as posed rests on the determination of the transfer function for the response at P due to the input. If the transfer function can be established from a known pair of input-output time sequences having a broad band spectrum, then in principle, one can estimate the deep water input from other measured time sequences at the same point P.

The transfer function at P is estimated from a numerical model in which the island bathymetry is represented on a discrete grid and the wave equations are solved numerically for a given deep water input and the response at the point in question is obtained, subject to appropriate boundary conditions.

Results to date indicate that, given a very long input time sequence and spatial grid resolution sufficiently good to render the spectra accurately, a good estimate of the transfer function can probably be made.

30. THE METHOD OF ESTIMATION OF THE TSUNAMI HEIGHT REPETITION AT SOME PART OF THE COAST

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Sakhalin Complex Scientific Research Institute, Academy of Sciences, Novoalexandrovsk, USSR

One of the estimations of the degree of the tsunami danger is the calculation of the repetition of those waves of various intensity on the average within some zone (analogous to the graph of repetition of the earthquakes).  
The real heights of the tsunami waves of one and the same intensity at various parts of the coast depend upon the bottom relief on the way of their propagation and the coastline shape.

The method of estimation of the tsunami wave repetition of various heights at some part of the coast based on the knowledge of the tsunami repetition of various intensity on the average within the zone and the approximate control of the peculiarities of the distribution is suggested.
10: SYMPOSIUM ON MICROSEISMS
Sponsored by IASPEI (with IAPSO)
Convener: P. Bernard
Wednesday, August 4
Chairmen: E. F. Savarensk and R. A. Haubrich

1. A. D. Sytinsky
   On the hydrometeorological conditions of microseism generation

2. V. N. Tabulevich
   On the complex of occurrences arising simultaneously with the formation of microseism

3. L. P. Vinnik
   Origin of microseismic P waves

4. P. Bernard
   Variations des microseismes autour du Golfe de Gascogne

5. M. Bossolasco, G. Cicconi and C. Eva
   On the propagation of microseisms near a coast

6. L. J. H. Grinda
   Illustration d’une théorie des microseismes par quelques cas concrets

7. H. Bradner
   Microseism propagation via oceanic waveguide

8. H. Korhonen
   Spectral development of microseism storms at the Oulu seismograph station

9. T. A. Proskuriakova, L. N. Rykunov and E. F. Savarensk
   Some results of investigations on microseisms in the USSR

1. ON THE HYDROMETEOROLOGICAL CONDITIONS OF MICROSEISM GENERATION

A. D. Sytinsky
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The study of hydrometeorological conditions of microseism generation on the basis of the observations made at Mirny Station (Antarctica) and Pulkovo Observatory has shown:

1. The main microseism background is generated by the coastal effect in the stormy area causing on-shore wind.
2. Microseisms are generated by the wind and water surface interaction, microseism intensity increasing simultaneously with the wind speed increase.
3. According to the data obtained the ripple is not involved in this mechanism, however. The surf cannot be the cause of microseism generation either, since it is absent due to the ice belt near the Antarctic shores.
4. In a general case microseism amplitudes are directly proportional to the square of the wind speed and inversely proportional to the distance between the source and the observational point.
5. Comparison of long-term microseism data obtained at Pulkovo and Mirny seismic stations has shown that the rise of microseismic storms at these stations on the average occurs synchronously. This fact permits to consider atmospheric disturbances to be synchronously generated independent of a season in the southern parts of the Indian and Atlantic Oceans and in the Northern Atlantic.

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2. ON THE COMPLEX OF OCCURRENCES ARISING SIMULTANEOUSLY WITH THE FORMATION OF MICROSEISM

V. N. Tabulevich
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Earlier were known single fact and theories not uniting the whole complex of periodic infrasound and seismic fluctuations in a general physical system. There the simultaneous arising of microseismic fluctuations, the regions of standing sea waves and the infrasound are shown. It was seen that at a high velocity of the cyclone centre, the derivatives of amplitude and microseism period increase (∂A/∂t, ∂T/∂t). Statistically it is shown (observations of Perth for 1957–1959) that for ∂A/∂t > 0.15 m/sec, ∂T/∂t > 0.2 sec/sec, very strong magnetic storms are registered in Irkutsk.

Published in Monographie de FUGG, No. 31, 1972.
3. ORIGIN OF MICROSEISMIC P WAVES

L. P. Vinik
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Moscow, USSR

Origin of P waves detected earlier in microseisms of very quiet locations in the
USSR is discussed in detail. It appears that the most pronounced sources of P waves
are tropical cyclones in the Pacific. The amplitude of the force in the source for a
medium power typhoon is found to be $10^{17}$ dynes approximately. The effective
source area is estimated as $10^6 - 10^8$ km$^2$. The shape of the amplitude spectrum of
P wave corrected for the absorption in the mantle does not contradict the standing
wave theory of microseisms generation. Since Rayleigh wave is the strongest one
among those generated by the surface force, the possibility of extraction of P wave
depends on the rate of Rayleigh wave attenuation with epicentral distance. Results
of observations at various epicentral distances give strong evidences of the predomi-
nant attenuation of the fundamental Rayleigh mode as compared with higher Ray-
leigh modes in the frequency band of 0.3 - 0.15 cps. It is suggested that the P wave
method of typhoon detection may have almost unlimited range of operation.

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4. VARIATIONS DES MICROSEISMES AUTOUR DU GOLFE
DE GASCOGNE

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En 1969, trois stations ont été installées à Brest (Service hydrographique),
Hendaye (Observatoire d’Abbadia), et La Coruña (Observatorio meteorologico) avec
un matériel identique à celui de l’Observatoire du Parc Saint Maur (seismographe à
inscription visible et intégrateur du niveau microseismique moyen). La comparaison
peut-être étendue au Maroc, où des mesures d’amplitude et de période sont faites réguliè-
rement, et à València (Irlande) dont les seismogrammes sont fournis par le NGDC américain.

Les variations jour par jour de l’amplitude des microseismes à Brest sont presque
exactement semblables à celles de Saint Maur situé à la même latitude. Les diffé-
rences entre les deux années sont statistiquement en relation
avec la position des dépressions atmosphériques. A Hendaye, les mêmes max-
nima sont assez souvent suivis d’un deuxième paroxysme correspondant à l’arrivée
de la houle provenant de la dépression origine du premier maximum. Cet effet est
plus rare et moins marqué à La Coruña où on aurait pu s’attendre à le retrouver, mais
les maximums de cette station, parfois attribuables à des fronts locaux comme dans
les stations de la Méditerranée, précèdent souvent de 24 heures une pointe éolique
de la courbe de Rabat, ce qui correspond assez bien au temps de propagation de
la houle sur la distance séparant les deux stations.

Enfin, il apparaît que le dédoublement de l’isobare centrale des dépressions est
un facteur de renforcement de l’amplitude des microseismes.

Published in Pure and Applied Geophysics, 1972.

5. ON THE PROPAGATION OF MICROSEISMS NEAR A COAST

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Genova, Italy

Summary. In this paper two methods for analysing in real time or “on line”
microseisms, with the aim of the determination of the fundamental periods and
their evolution, are presented. With the first method the autocorrelation of micro-
seisms as a random signal is derived, whereas the second method consists in a fre-
cuential filtering of the seismic signal. The application of these methods is made
for simultaneously recorded microseisms at Genoa and Vesima-Arenzano (station
placed just on shore-line). The results show that at Genoa the amplitude ratio
between secondary and primary microseisms is varying in the range of 3 - 15, whereas
at Vesima this ratio is of the order 1 - 1.5. These different values of this ratio are
chiefly to be ascribed to the attenuation with the distance, as well as to the different
response of the ground to the travelling pressure waves. — The spectral band at
Vesima is larger than at Genoa, on account of the occurrence of high frequency
microseisms of great energy at the first station.

Published in Pure and Applied Geophysics, 1972.

6. ILLUSTRATION D’UNE THEORIE DES MICROSEISMES PAR
QUELQUES CAS CONCRETS

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Scientifique de Monaco, Principauté de Monaco

Au colloque de PARIS (1970) sur les MICROSEISMES (MS) l’auteur a formulé
les principes d’une théorie qui montre le rôle important, dans la génération des MS,
noté par:

- Les houles croisées et donc par les variations de la direction du vent sur
  la mer.
- L’effet sélectif de la réflexion de la houle par une côte.
- La réfraction de la houle.
- Le filtrage des houles arrivant à la côte par effet des petits fonds.
- La vitesse de propagation de la houle, généralement plus grande que
  celle des cyclones.

Le diagramme de rayonnement des sources,

et par conséquent par la bathymétrie comme par la morphologie des côtes proches de
la zone de génération.

Des cas concrets de MS bien étudiés en fonction des circonstances météoro-
logiques et océanographiques illustrent et justifient les principes originaires de cette
théorie, en particulier ceux qui font l’objet des travaux dont les titres suivent, con-
cernant les MS classiques de la bande de périodes de 2 à 18 secondes.
7. MICROSEISM PROPAGATION VIA OCEANIC WAVEGUIDE

Hugh Bradner
University of California, San Diego, California, USA

Experiments have been made to determine whether a significant amount of microseism energy in the open ocean can be carried in organ-pipe $\pi$ waveguide modes. A three-component seismometer in spherical aluminium container was balanced to float freely at midwater depth; a similar instrument was dropped on the ocean bottom. Simultaneous records from the two instruments were analyzed for peaks in coherence of their power spectra. Results indicate a substantial energy in $\pi$ modes in the ocean area of the observation.

Measurements at the same area, but widely separated in time, indicate that the frequencies of microseism peaks and the general shape of the microseism spectrum are characteristic of the geographical location, in agreement with the conclusions of Molokhov. We characterize the microseisms as motion in a waveguide that is excited by a non-white forcing function.

Published in Pure and Applied Geophysics, 1972.

8. SPECTRAL DEVELOPMENT OF MICROSEISM STORMS AT THE OULU SEISMOGRAPH STATION

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Abstract — In this study spectral development of microseisms at Oulu is discussed by means of power spectra computed from the recordings of a long period vertical seismograph. North Atlantic storm microseisms are found to be distinguished at peak frequencies in band 90–120 mHz while the main peaks of Norwegian microseisms occur at frequencies higher than 130 mHz. In both of these cases a low frequency side maximum is found at nearly the same frequencies as the main maximum in corresponding sea wave spectra. Fast moving storms associate with rapid changes in microseism spectra. A shift of peaks towards higher frequencies is found in connection with storm approach.

Published in Pure and Applied Geophysics, 1972.
16: SYMPOSIUM ON ENERGY FLUXES OVER POLAR SURFACES
Sponsored by IAMAP (with IAPSO/LASH/SCAR)
Convener: S. Orvig
Tuesday, August 3
Chairman: E. R. Pouder

Session 2: Wind Studies and Detailed Energy Fluxes Over Sea Ice
1. W. J. Campbell and L. A. Rasmussen
   A numerical model for sea ice dynamics incorporating three alternative ice
   constitutive laws
2. I. F. Allison
   A sample study of the energy fluxes preceding, accompanying, and following
   the formation of antarctic sea ice
3. M. P. Langleben
   The decay of a cover of sea ice

Wednesday, August 4
Chairman: N. Untersteiner

Session 3: Large-Scale Energy Fluxes, Regional Studies
   Microwave radiation of ice cover on the Cura Sea
5. M. P. Langleben
   Albedo of ice-infested waters in the channels of the Canadian Archipelago
6. E. Vovinckel and S. Orvig
   Synoptic energy budgets from the Beaufort Sea
7. R. M. Koerner
   Ice accumulation and ablation in, and ice export from the Arctic Ocean

Wednesday, August 4
Chairman: M. J. Rubin

Session 4: Large-Scale Energy Fluxes, Global Studies
8. M. I. Budko
   Energetic balance of polar areas and climate change
   Estimation of the energy balance elements for the atmosphere of the polar
   zone of the northern hemisphere (northward of 50°N)

Thursday, August 5
Chairman: A. F. Trebushnikov
Session 5: Interaction Between Ocean and Atmosphere
10. D. L. Laskhtman, K. L. Egorov, A. G. Pulugin, N. M. Lifshits and
    V. M. Radkevich
    Dynamic and thermal processes of ice-cover as a link in the interaction
    between ocean and atmosphere
11. S. D. Smith
    Wind stress and turbulence over a smooth ice floe
12. E. R. Pouder and O. M. Johannessen
    Ice movement in the Gulf of St. Lawrence
13. V. V. Bogorodsky, B. Ya. Gytshok and V. I. Trepelnikov
    Methods of remote measurements of drifting sea ice thickness and a photometric
    model of snow/ice cover
1. A NUMERICAL MODEL FOR SEA ICE DYNAMICS INCORPORATING THREE ALTERNATIVE ICE CONSTITUTIVE LAWS

W. J. Campbell and L. A. Rasmussen
U. S. Geological Survey, USA

A steady-state numerical model for sea ice dynamics is developed in which the ice is assumed to flow under the action of four forces: air stress, water stress, Coriolis force, and the internal ice stress. Brandt-type boundary layers are assumed at both ice surfaces, with the water boundary layer coupled to an Ekman Layer in which the vertical eddy viscosity is allowed to vary horizontally. Three different viscous ice constitutive laws are alternatively assumed for the internal ice stress: 1) quasi-anisotropic; 2) isotropic with a variable shear viscosity depending on the sign of ice divergence; 3) isotropic with constant shear and bulk viscosity (suggested by John Glen). The equations are solved using an iterative technique for the same stress field for each choice of constitutive law, with two ice parameters in each case: 1) a shear viscosity for compression at a point and a shear viscosity for tension at a point; 2) a shear viscosity for areas of ice convergence and one for areas of ice divergence; 3) a shear and bulk viscosity which are constant over the whole area. For reasonable choices of these parameters it was found that: a) all three models gave smaller values of ice convergence in the anticyclonic gyre (Beaufort Sea) than those obtained in the earlier uniform ice viscosity model (Campbell, 1968); b) models (1) and (2) yielded similar values of ice convergence and divergence but showed many small-scale differences in the field of sea ice, especially in the areas under and around an atmospheric cyclone; c) model (3) gave the smallest values of ice convergence and divergence.

2. A SAMPLE STUDY OF THE ENERGY FLUXES PRECEDING, ACCOMPANYING, AND FOLLOWING THE FORMATION OF ANTARCTIC SEA ICE

J. F. Allison
Antarctic Division, Department of Supply, Australia

During 1969 a micrometeorological station was operated on annual sea ice near Mawson (69° 34'S, 62°E). Continuous measurements were made of net radiation, global radiation, sea ice thickness, wind speed and air temperature at four levels, and ice and water temperatures at seven levels. Similar measurements were also made over open water from a raft during part of the summer. From the results various terms in the energy balance equation are estimated and discussed for short periods representative of the pre-formation, formation, and decay of the sea ice.

3. THE DECAY OF A COVER OF SEA ICE

M. P. Langleben
McGill University, Montreal, Canada

In his now classic book, Arctic Ice, Zubov discussed the melting of sea ice during the arctic summer by thermal interaction with the surrounding water. The model assumes a slightly broken ice cover, the solar radiation incident on the surface being absorbed solely in the narrow expanses of water between ice floes. From the method of mixtures, he derived an expression which indicated that the proportion of open water increased exponentially with time towards total ice-free conditions. The model predicts that the time to complete melting of a nine-months ice cover is 47 days for an initial ice thickness of 100 cm, and 70 days for an initial thickness of 150, assuming an incident radiation of 400 cal cm⁻² day⁻¹ and an albedo of 0.1 for the ocean water.

These times are appreciably longer than the period available for this process in the Arctic, considering that about a month of above-freezing temperatures are necessary beforehand to thin the ice cover to the stage where it can begin to break up under wave or wind action. The model therefore has been modified to include the effect of absorbed solar radiation. To deal with this more complex situation, two difference equations are set up for stepwise integration, using an increment of time of one day. In each step, one calculation determines the decrease in ice thickness by surface melting arising from absorption of solar radiation by the ice, and the other the decrease in lateral extent or surface area of the slightly thinned-down ice cover resulting from thermal interaction of the ice floes with the adjacent waters which too have absorbed solar radiation. This procedure is repeated, on a day-by-day basis, until such time as the ice cover is completely melted.

Using the above values for incident radiation, albedo of the water and ice thickness, and an albedo for the ice surface of 0.4, the revised model predicts the time to total disappearance of the ice cover as being reduced by a factor of about two in each case. A series of such computations has been performed by a range of values of incident radiation and ice albedo commonly observed during the arctic summer, and the families of curves showing the progressive decrease in the extent of the ice cover as a function of time are presented.

4. MICROWAVE RADIATION OF ICE COVER ON THE CARA SEA

A. E. Basharinov, A. A. Kurskaya and L. T. Tutchkov
Institute of Radio Engineering and Electronics, Academy of Sciences, USSR

Microwave emissivity for ice covers is determined by their absorbed and reflected properties and depends on the temperature, salinity, presence of moisture in liquid phase, the nature of lower surfaces, properties of upper snow layer, etc. The measurements of microwave ice cover radiation permits the estimate of their parameters.

The observation of ice cover microwave radiation of waves 3 cm; 30 cm; 60 cm have been made on the Cara Sea during 1964-1966. The radiation measurements of 3 cm have also been made with the radiometric receiver on a helicopter.
The variation of intensity and polarisations degree of micro-wave radiation, depending on the ice thickness, ice salinity and snow cover parameters, have been observed. The estimated value of the dielectric permeability of snow cover varied from 1.75 to 5.5 with changing the content of liquid water. The interferential oscillations during the changing of the ice thickness were observed. The processing of the measured intensity variations of the microwave radiation intensity permits the estimate of the values of dielectric permeability ~4 and less angle ~5 x 10^-4, then the thickness of ice cover was less than 20 cm.

5. ALBEDO OF ICE-INFESTED WATERS IN THE CHANNELS OF THE CANADIAN ARCHIPELAGO

M. P. Langleben
McGill University, Montreal, Canada

Values of the albedo of the ice cover in the waters of the Canadian Arctic have been calculated from observations of total hemispherical and of reflected short-wave radiation. The measurements were obtained between 24 June and 15 July 1970 in a series of ice-reconnaissance flights by the Ice Patrol aircraft of the Polar Continental Shelf Project within an area roughly bounded by the coordinates (83°N, 60°W), (78°N, 80°W), (74°N, 95°W), (70°N, 140°W) and by the southern limit of the permanent pack ice.

The aircraft, a twin-engine Beechcraft, was fitted with two Kipp pyranometers which were mounted outside on plates rigidly fastened to the top and bottom of the aircraft in the vicinity of the cabin rear area. The instruments were levelled on the ground with the Beechcraft jacked up to normal flying altitude. In flight, the thermopile outputs were recorded continuously. In addition, the ice cover was photographed at frequent intervals using a remotely-controlled camera equipped with a telephoto lens, the field of view being about 200 m x 300 m when the aircraft altitude was 1000 m.

Quantitative information on the nature of the ice cover, from these photographs and from the logged remarks of an ice observer who was aboard the aircraft, are presented alongside the graphs of incident radiation and albedo plotted against time for each of the flight tracks. Estimates are made of the average albedo of the ice cover during this period in many of the bodies of water surrounding the Canadian Arctic islands.

6. SYNOPTIC ENERGY BUDGETS FROM THE BEAUFORT SEA

E. Vowinckel and S. Orvig
McGill University, Montreal, Canada

The "oasis effect" in the surface energy balance is most pronounced in Polar Ocean conditions with restricted open water areas ("polynya"). The differences in energy budgets of sea and ice surfaces are then greater over short distances than anywhere in the world. In order to study these conditions, 1957–58 surface and radiosonde data have been used from the Soviet Station "North Pole 7," which drifted in the Beaufort Sea and which had been regarded as representative for the Central Polar Ocean. All terms in the surface energy budget have been calculated for every day of the year. All terms show pronounced differences over ice and water, the most conspicuous being in the sensible heat flux. In February, the open-water value is 63 times as large as the ice value, and is of opposite sign. In the middle of the summer, this term shows little difference between water and ice, but the directions of the fluxes remain opposite.

The latent heat flux also shows great differences over ice and water, but it is much smaller than the sensible flux, due to low air temperature and low-water-holding capacity.

The turbulent terms are partly determined by instability; as these increases, it becomes dominant. The heat exchanges from open leads are significantly higher than other published results, perhaps because daily values have been used. A few extreme synoptic situations have an important influence on the turbulent exchange over a longer period. This does not hold for radiative terms. Over the ice surface the synoptic influence operates essentially via cloud variations and thus via radiation. Over water surfaces, in addition to cloud effects, the wind and air-mass changes influence the surface heat budget.

Air-mass modification is calculated for various widths of open water leads and varies air temperature and humidity conditions. Surface energy budgets for large areas are found to be very sensitive to open water. Compared to this, the various ice thicknesses are of minor importance. That fraction of open water in the Polar Ocean is calculated which would be sufficient to contribute that amount of energy at present imported by atmospheric advection.

7. ICE ACCUMULATION AND ABLATION, AND ICE EXPORT FROM THE ARCTIC OCEAN

R. M. Koerner
Polar Continental Shelf Project, Department of Energy, Mines and Resources, Canada

During the crossing of the Arctic Ocean by the British Trans-Arctic Expedition (February 1968 and June 1969), a record of the type and frequency of ice forms was made. The greatest detail was recorded between the North Pole and Spitsbergen where 9.0 percent of the ice was ridged or hummocked at the surface, 17.0 percent was unridged ice less than a year old, 73.0 percent was unridged ice and 9.0 percent was ice-free; 14.5 percent of the ice-cover was keeled or hummocked. From the above observations and a set of 250 thickness measurements, the cross-sectional area of each ice-type has been calculated.

The mean thickness of the ice in April varies between 387 cm in the Trans-Polar Drift Stream and 456 cm in the Gyral. Ablation reduces the mean thickness by 58 cm during the summer in both areas.

The summer ablation in 1968 from a level area on a multi-year floe was 45 g/cm^2, 9 g/cm^2 of ice melted from under the floe. The melting rates of unridged, ponded and hummocked ice were determined by precise levelling in early July and mid-August 1968. Greatest melting took place on new hummocks, least on old smooth hummocks.
Ablation, accumulation and ice balance have been studied for a number of situations. The total ablation and accumulation of each ice-type was measured directly or has been calculated according to empirical formulae derived from the present or Russian data. For example, a winter ice growth of 26–56 cm/cm² has been calculated from measurements of new ice growth in fractures throughout a 25 km² area in the Gyral between October 1968 and February 1969. A similar new-ice growth figure of 41 cm/cm² has been calculated from the amount of new ice closed in the Gyral/Transition zone on the main journey.

For the period February 1968 to May 1969 the annual ice export was 5500 Km², 51 percent of this is from the Trans-Polar Drift Stream, 37 percent from the Pacific Gyral and 2 percent from a Transition zone. The low ice export from the Pacific Gyral is in part related to the dominance of convergent ice drift in that area, as a consequence there is a contrast between Gyral and Drift Stream topography. In the Gyral the multi-year floes include a large number of hummocks with characteristically smooth profiles. In the Trans-Polar Drift Stream the multi-year floes have fewer hummocks, almost all having a very angular (i.e., younger) profile.

8. ENERGETIC BALANCE OF POLAR AREAS AND CLIMATIC CHANGE

M. I. Budyko
Main Geophysical Observatory, Leningrad, USSR

As a result of using meteorological satellites it has been found out that the albedo of the earth-atmosphere system in polar areas, with the presence of ice cover, is approximately twice as large as its mean planetary value. It follows that the value of absorbed radiation in high latitudes is determined to a considerable extent by the influence of ice cover, which is an essential factor of the thermal regime of the atmosphere.

Consideration of ice cover influence on thermal regime leads to the conclusion of substantial instability of present climate, since small changes of solar radiation can result in appreciable changes of ice cover area on the land and the oceans.

The calculations have shown that comparatively small changes in atmospheric transparency and changes in radiation at the external boundary of the atmosphere, due to the variations of the Earth's orbit elements, were a sufficient reason for the development of quaternary glaciations.


Ye, P. Borisienkow and M. Sh. Chernomukhin
The Arctic and Antarctic Research Institute, Leningrad, USSR

The energy balance elements of the polar atmosphere have been calculated for every month of the 1-year cycle at the points of the regular geographic grid.

Mean values of effective potential and kinetic energy for different latitudinal zones have been evaluated. Year-to-year and inter-seasonal variations of the energy balance elements have been studied.

The estimation of the effective potential energy fluxes through different parallels has been made.

Energy balance elements have been compared with the heat balance components of the polar zone, arctic sea ice coverage, solar activity and large-scale circulation processes.

The polar zone of the Northern Hemisphere has been shown to be extremely dynamic zone of energy sink, which controls latitudinal exchange in the complex mechanism of the general atmospheric circulation.

It is inferred that the research and observations according to the proposed Polar Experiment Program (POLEX) are necessary.

10. DYNAMIC AND THERMAL PROCESSES OF ICE-COVER AS A LINK IN THE INTERACTION BETWEEN OCEAN AND ATMOSPHERE

Hydrometeorological Institute, Leningrad, USSR

1. A drift of the ice-cover is a result of its dynamic interaction with the boundary layers of the atmosphere and ocean adjoining its surfaces. Therefore a correct description of the mechanism of transfer of momentum of the atmosphere to the ice-cover and from ice to ocean has an important significance for obtaining qualitative and quantitative results.

2. In the present work a complete system of equations is used to describe the dynamical interaction of the atmospheric boundary layer-ice boundary layer system of the ocean. On the basis of the hypothesis of a semi-empirical theory of turbulence, a complete system of equations was obtained.

3. The analysis of the influence of external factors upon the ice-drift by wind has been carried out.

4. Stratification of boundary layers and thickness of ice play an important role. In connection with this, the problem of the dynamics of the system is considered together with the thermal processes.

11. WIND STRESS AND TURBULENCE OVER A SMOOTH ICE FLOE

Stuart D. Smith
Atlantic Oceanographic Laboratory, Bedford Institute, Dartmouth, Nova Scotia, Canada

During March 1970 the McGill University-Bedford Institute Ice Drift Study established a manned drifting station by freezing a small ship in a large, smooth, snow-covered ice floe in the Gulf of St. Lawrence. Three components of wind turbulence, and also temperature fluctuations, were measured using sonic anemometers. Thirty-nine data runs of 40 minutes average duration were recorded on magnetic tape. During most of these runs two sonic anemometers were operated, at various horizontal and vertical locations, in order to evaluate variations in the turbulence and stress with probe position.
Reynolds stresses, drag coefficients, roughness lengths and heat fluxes have been computed digitally using the eddy correlation method. Spectra of velocity components and of temperature, and co-spectra of Reynolds stress and of heat flux are examined.

The average drag coefficient for smooth ice, $C_D = 0.0013$, is about the same as for the sea surface and about half that observed over small, 30-cm high floes in the Gulf of St. Lawrence in 1969.

12. ICE MOVEMENT IN THE GULF OF ST. LAWRENCE
E. R. Poulsener and O. M. Johannessen
Marine Sciences Centre, McGill University, Montreal, Canada

A study of ice drift was carried out in 1970 in the Gulf of St. Lawrence (Canada) using as a base an ice-strengthened vessel M/V STEPHENVILLE, 140' long. She was escorted on March 3 into the ice pack between the Magdalen Islands and the Baie de Chaleurs in the Gulf of St. Lawrence by an icebreaker. Four buoys with radar reflectors, anemometers, and suspended current meters were placed on nearby floes. The STEPHENVILLE was allowed to freeze into a large floe and the vessel and buoys drifted for 27 days in a generally southerly direction towards Prince Edward Island.

Routine observations were made throughout the period of the position of the ship and buoys (by Decca navigator and radar), of wind velocity at different heights and locations, and of currents at 6 levels. A total of 450 hydrocasts were made using a STD (salinity, temperature, depth) recorder developed by the National Research Council, together with a few Nansen casts for calibration of the STD instrument.

Some results will be presented on the relations between the wind and current fields and the movement of the ice.

13. METHODS OF REMOTE MEASUREMENTS OF DRIFTING SEA-ICE THICKNESS AND A PHOTOMETRIC MODEL OF SNOW/ICE COVER
V. V. Bogorodsky, B. Ya. Gyskhokh and V. I. Trepolnikov
The Arctic and Antarctic Research Institute, Leningrad, USSR

The ice cover at sea effectively decreases the ocean-atmosphere heat exchange, reflecting solar radiation in summer and inhibiting ocean heat losses in winter. Therefore the presence or absence of sea ice essentially influences dynamic and thermodynamic ocean-atmosphere interactions. In this connection, ice cover thickness, compaction and temperature are of paramount importance. At present, methods of remote measurements of sea-ice thickness and temperature over vast areas are being developed in the USSR and abroad.

1. The physical principles of the methods of remote measurements of sea ice thickness and the equipment based on radio sounding principles are considered in the paper; performances of radars are included.

2. The problem of electromagnetic radiation transport through snow and ice is considered. The solution is given using a photometric model of snow/ice cover. The model is based on a rough solution of the radiation transport equation, the two-flow approximation.

The method permits calculation of the coefficients of diffuse transmission and reflection for a multi-layered plane-parallel model.

17: SYMPOSIUM ON AIR-SEA INTERACTION
Sponsored by IAMAP (with IAPSO/IASH)
Convenors: W. L. Godson and R. W. Stewart
Friday, August 6, a.m.
Chairman: H. Charnock

1. R. W. Stewart

2. L. R. Tsang and A. M. Yaglom

3. R. G. Fleagle

4. K. Brocks and L. Krugermeyer

5. Y. Mitsuta

6. M. Miyake

7. A. Takeda and K. Taira

8. L. Hasse

Friday, August 6, p.m.
Chairman: A. M. Oboukhov

9. B. B. Hicks

10. J. A. Businger

11. H. K. Tiefenau

12. W. M. Gray

13. P. A. Taylor


Intercomparison of air-sea interaction instrumentation

Spread of the data available on turbulence parameters in the atmosphere surface layer

Meso-scale structure of the planetary boundary layer

The aerodynamic roughness of the sea surface

Measurement of air-sea interaction on a cruising ship

Air-borne measurements of turbulent transport over the ocean surface

Shipboard measurements of turbulent fluxes across the sea surfaces

On the parametrisation of air-sea problems

Some eddy-flux measurements over water

On the determination of the total heat flux in the laminar surface layer of the sea

The specific ozone destruction rate of the ocean surface and its dependence on horizontal wind velocity

Observed wind veering over the oceans and implication for air-sea momentum exchange

Boundary-layer transition zones

The structure of near-water atmospheric layer and peculiarities of ocean-atmosphere interaction under a storm condition

79
15. K. Bernhardt

16. J. Namias

Monday, August 9, a.m.
Chairman: A. S. Monin

17. K. L. Davidson and D. J. Portman

18. N. Iwata

19. A. H. Schookey


21. I. Orlanski

22. T. P. Barnett et al

23. T. P. Barnett et al

24. O. H. Sitendin and R. J. Lai

Monday, August 9, p.m.
Chairman: J. C. Wyngaard

25. T. D. Foster

26. L. M. Brokhovskikh, V. V. Goncharov, V. M. Kurtepov and K. A. Naugolnykh

27. E. B. Kraus

28. C. W. Van Atta

On the influence of the planetary boundary layer over land and sea on the dynamics of the atmosphere
Climatic changes in atmosphere and ocean on the order of decades

The influence of water waves on the adjacent air flow
Angular spreading of wind waves
Water boundary layer within first ten millimeters below wind-driven waves
Generation of wind waves and velocity field structure in the air over a wavy water surface

Local generation of low frequency internal gravity waves in the ocean
Measurements of wind wave growth in the North Sea
Measurement of wind wave dissipation in the North Sea
Laboratory investigation of turbulence above waves

Convection induced by the evaporation of sea water
On sound generation by the ocean-atmosphere boundary layer
Pressure fluctuations originating in the marine planetary boundary layer
Higher-order structure functions and statistical self-similarity of turbulence near the air-sea interface

29. A. G. Kolesnikov, V. V. Efimov and A. A. Sizov

30. J. C. Kaimal

31. N. E. J. Boston

32. C. H. Gibson

Peculiarities of the turbulent structure of the near-water layer of the atmosphere
Characteristics of spectra and cospectra of atmospheric parameters in the first 22 m
An investigation of high wave number temperature and velocity spectra in air
Measurements of turbulence, humidity and temperature over the open ocean from a stable platform
1. INTERCOMPARISON OF AIR-SEA INTERACTION INSTRUMENTATION

R. W. Stewart
Institute of Oceanography, University of British Columbia, Vancouver, Canada

In 1966 the Joint Committee (IAMAP/IAPSO/SCOR) on Air-Sea Interaction recommended that an experiment be conducted in order to intercompare measurement and analysis techniques which were in use in various laboratories for the determination of boundary fluxes over water. The need for such an experiment had become evident because of significant discrepancies between reported results on these fluxes. Accordingly, following a preliminary trial in 1967, groups from Canada, USA and USSR gathered during the late summer of 1968 in Vancouver, Canada. The results of this experiment showed that although some sensors gave results in good agreement, there were important discrepancies in others. Different analysis techniques gave good agreement.

A follow-up experiment was conducted in the early summer of 1970 at the Soviet field station at Tsimlyansk, involving participation of groups from USSR, USA, Canada and Australia. Instruments modified on the basis of previous experiments were employed, as well as some new sensors—particularly of humidity fluctuation. Once more good agreement was obtained between results from some sensors, but important limitations were revealed in the performance of some others.

2. SPREAD OF THE DATA AVAILABLE ON TURBULENCE PARAMETERS IN THE ATMOSPHERE SURFACE LAYER

L. R. Tavang and A. M. Yaglom
Institute of Atmospheric Physics, Academy of Sciences, Moscow, USSR

The paper presents a survey of the data available on turbulence parameters in the surface layer of the atmosphere. The survey emphasizes the discrepancies in the data from different sources and indicates the spread in the values of "Universal" constants and functions determined at different locations and with different instruments. The possible reasons for the discrepancies are analysed. Special attention is paid to the sources of instrumental errors in the light of the results obtained during the international expedition on the intercomparison of turbulence-measuring techniques at Tsimlyansk (USSR) in the summer of 1970.

Some recommendations on future experimental investigations of turbulence in the surface layer of the atmosphere are proposed in the concluding part of the paper.

3. MESO-SCALE STRUCTURE OF THE PLANETARY BOUNDARY LAYER

R. G. Flesagle
University of Washington, Seattle, Washington, USA

Vertical fluxes of water vapor, heat, and momentum measured by independent methods have been compared in a series of field observations programs. Observations have been made over land and over the sea and several investigators from other institutions have participated. Profile measurements using a vertically traveling probe have been used as a basis against which to compare other methods. Covariances have been calculated using a number of different sensors and sensor systems. Data obtained during BOMEX from the Boundary Layer Instrument Package (BLIP) have been used to calculate surface stress by the geostrophic departure method. Vertical flux in the boundary layer is highly concentrated in periods of a few seconds duration; as a result, agreement of the independent measurements improves as the period of averaging increases. Individual comparisons for periods of 40 minutes have a standard deviation of roughly 25 to 35%.

4. THE AERODYNAMIC ROUGHNESSNESS OF THE SEA SURFACE

K. Brocks and L. Krugermeyer
Meteorologisches Institut, Universität Hamburg, Hamburg, Germany

The effects of density stratification on the wind profile within the maritime boundary layer are investigated. If wind profiles under neutral conditions are approximated by logarithmic functions, apparent roughness parameters $z_0$ and apparent friction velocities $u_*$ are obtained, but variations of $z_0$ of more than eight orders of magnitude result.

From more than 1000 simultaneous wind, temperature, and humidity profiles, measured in the Baltic and North Seas, values of $z_0$ are investigated as a function of wind speed. The apparent $z_0$ depends systematically on Richardson number, which in turn is related to wind speed, resulting in a widely scattered distribution of $z_0$.

This scattering was attributed to large-scale effects on the sea state (fetch and duration). 152 profiles under neutral conditions ($|R_i| < 0.01$, including humidity influence) were selected to determine a mean value of $0.015 \text{ cm}$ for $z_0$, and there was no significant variation of $z_0$ with wind speed. The mean value of the drag coefficient amounted to $C_D = 1.3 \cdot 10^{-3}$ for a reference level of 10 m. The values obtained by profile measurements in the Baltic and North Seas were almost the same as those in the equatorial Atlantic Ocean ($787$ neutral profiles) ($1.36 \pm 0.21$, $1.25 \pm 0.14$ and $1.23 \pm 0.25 \times 10^{-3}$, respectively). These results are consistent with direct measurements of the vertical momentum flux obtained by hot-wire, thrust, and sonic anemometers. It is concluded that the discrepancies amongst previous measurements are due to disturbing influences during observation and due to neglecting the influence of stability. Parameterization of the wind friction with the mean local wind speed within the maritime boundary layer appears to be possible.
5. MEASUREMENT OF AIR-SEA INTERACTION ON A CRUISING SHIP

Y. Minuta
Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan

An attempt to make air-sea eddy-correlation flux measurements on a cruising ship is described. Ships are the only platforms on which ocean-wide flux measurements can be made, since buoys, towers and airplanes are limited in their operation over oceans. A sonic anemometer-thermometer and a fine thermocouple psychrometer-hygrometer are installed on the top of the forecastle where the effect of the ship on the airflow is a minimum. The three-dimensional components of the wind relative to the moving ship are corrected for ship motion (detected by the motion sensors in the cabin) and then used to estimate the momentum, sensible heat and water vapor fluxes.

The test results, made a part of the Severe Rain Storm Project — GARP of Japan on the western part of the Pacific, are presented, together with error estimates. Dissipation spectra using a hot-wire anemometer on top of the mast were also computed to obtain independent values of the momentum flux. In addition, mean-state measurements were made for flux determinations by the bulk method.

This new method has proved to be a useful means of monitoring the ocean-wide distributions of fluxes, as it can be made on a cruising ship under various weather conditions, even though the accuracy of the wind estimates is a little lower than that obtained on a stabilized platform.

6. AIR-BORNE MEASUREMENTS OF TURBULENT TRANSPORT OVER THE OCEAN SURFACE

M. Miyake
Institute of Oceanography, University of British Columbia, Vancouver, Canada

Combining the information from fast response sensors for atmospheric turbulence and motion of aircraft; transport of momentum, heat and moisture from the ocean ship can be determined from an aircraft. Beechcraft Queen-Air have been used off-shore of the West Coast of Vancouver Island and over the tropical ocean off Barbados. The result of flux measurement from Flp will be discussed, along with the inferred structure of the Planetary Boundary Layer, from these measurements.

7. SHIPBOARD MEASUREMENTS OF TURBULENT FLUXES ACROSS THE SEA SURFACES

Atsushi Takeoka and Keisuke Taira
Ocean Research Institute, University of Tokyo, Tokyo, Japan

Direct measurements of turbulent fluxes with sufficiently high accuracy have been made on a conventional research vessel. A long low-boom, on the end of which is installed a three-dimensional sonic anemometer, permits the turbulent wind to be measured without artificial disturbances due to the hull of the vessel. Through the correction system for ship motion which consists of 3 accelerometers, 3 gyrosopes and a computer, each vector component of the wind is instantaneously transformed into a value related to a fixed Earth coordinate system. As a result of the correction system, the error in flux value can be reduced to less than 10% even under a 20 m/s wind.

8. ON THE PARAMETRISATION OF AIR-SEA INTERACTION PROBLEMS

L. Hasse
Meteorologisches Institut, Universität Hamburg, Hamburg, Germany

Recent results of air-sea interaction research at the Meteorological Institute of Hamburg University are reviewed. Topics are:

1) The relationship between geostrophic and surface wind, which may be described by $U = aU_s + b$, where $b$ depends significantly on the surface layer stability as measured by the air-sea temperature difference. The observed ratio $U/U_s > 1$ may be explained by the fact, that the surface wind is a local variable, and the geostrophic wind a meso-scale one.

2) The vertical flux of latent heat, parametrised by the product of wind speed and air sea temperature difference. Good agreement was obtained from measurements with different methods in temperate and tropic zones, the $q_u$ being somewhat less than $1 \times 10^{-3}$.

3) The dependence of the ocean skin temperature on the heatflux ($H$) through the air-sea interface and on wind ($U$) induced turbulence (Q short wave radiation): $T_s - T_a = C_1 \cdot H/U + C_2 \cdot Q/U$. Theoretical calculations from REICHARDT's universal temperature profile showed good agreement with observations.

9. SOME EDDY-FLUX MEASUREMENTS OVER WATER

B. B. Hicks
CSIRO, Division of Meteorological Physics, Victoria, Australia

Three recent experiments allow evaluation of the bulk transfer coefficients for momentum, water vapour and sensible heat over water bodies of different sizes. As part of a study of evaporation rates from a swamp, measurements of latent and sensible heat fluxes were made over Lake Wyangan in southern N.S.W., Australia. This lake is of several kilometres diameter. In a later experiment, Reynolds stress and sensible heat were measured from a natural gas platform standing in Bass Strait, south of mainland Australia. The most recent experiment involved the direct measurement of each of these turbulent fluxes from a fixed tower erected in Lake Michigan, USA.

Perhaps most important of the results is the finding that drag coefficients obtained in near-neutral conditions over Lake Michigan do not differ significantly from those obtained in similar conditions over open ocean, despite the obvious differences in depth, fetch, and hence surface wave structure. In both situations, the drag coefficients do not depart from those corresponding to aerodynamic smoothness at low wind speeds, but show an increase with higher velocities.
10. ON THE DETERMINATION OF THE TOTAL HEAT FLUX IN THE
LAMINAR SURFACE LAYER OF THE SEA

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The very attractive technique developed by McAlister to obtain the total heat
flux with radiometric measurements of the temperature gradient near the sea surface
requires a more careful analysis of the possible errors than are presented so far in the
literature. One correction stems from the fact that the ocean surface area is larger
than a horizontal plane, consequently the heat flux per unit horizontal area is larger
than the heat flux per unit sea surface area. A similar correction is required for the
determination of the temperature gradient with the radiometer. Those two corrections
may simply be combined and related to the average sea state.

A more serious error is introduced by the advection of water to the surface.
The turbulent state of both the atmosphere and ocean at both sides of the interface
induces a continuing stretching and shrinking of the surface. Although the flow
appears to be laminar near the surface a substantial amount of heat is being convection
to the surface, which is to be added to the amount that is being conducted to the
surface. Even at a distance of only 0.1 mm to the surface the convection term may
be a significant percentage of the conduction term. This analysis also sheds light on
the sharpness of the temperature discontinuity at the surface.

11. THE SPECIFIC OZONE DESTRUCTION RATE OF THE OCEAN
SURFACE AND ITS DEPENDENCE ON HORIZONTAL WIND
VELOCITY

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Vertical profiles of ozone concentration and temperature for various wind
velocities were determined at a lighthouse in the North Sea. Determination of the
ozone flux into the ocean surface resulting from the ozone concentration gradient,
taking the layer dependence of the transfer coefficients into account, yielded the
following results:

In the range from 1 m/sec to 10 m/sec the vertical ozone gradient is indepen-
dent of wind velocity. A slight decrease of the gradient for increasing wind
velocity turned out not to be significant. Thus the vertical ozone flux increases
linearly with the wind velocity. An increase of the gradient with increased stability
is compensated by the layer dependence of the transfer coefficients, within the
experimental errors.

We obtained the following relation between the sea surface destruction rate \(q\) and the wind velocity \(u_{10}\) at a height of 10 m:

\[ q = (1.7 \pm 0.6) \times 10^{-3} \times u_{10} \text{ [cm/sec]} \]

12. OBSERVED WIND VEERING OVER THE OCEANS AND
IMPLICATION FOR AIR-SEA MOMENTUM EXCHANGE

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A statistical survey of the wind veering in the lowest two km (resolved in 4 or 5
layers) has been made over the oceans. All available (over 80,000) ship rawin
and pibal runs of the U. S. Weather Records Center (Asheville) have been consulted. If
measurement and turbulent induced errors in the individual runs are mostly random
(as the author feels), then the statistical averages should be meaningful. Where wind
directions are highly variable, thermal wind effects should be largely eliminated.
Wind sounding runs are fairly evenly available from latitudes of 10 to 60°. Lesser
amounts of data are available in the 0-10 and 60-90° latitude belts.

Veering information has been statistically stratified by latitude season, wind
direction, wind speed, speed squared, and speed cubed. Reasonable veerings of
10-15° are observed in the lowest km and 0-5° in the second km. Veering asym-
luratic variation. Veering increases with wind speed in the middle
latitudes but not in the tropics. South winds show a average veerage of 20° more
than north winds in westerly latitudes (as expected from thermal wind considerations).
A general summary of this observational information will be given. A discussion of the
implications of this information for possible alteration of our current estimates of
air-sea momentum exchange will be made.

13. BOUNDARY-LAYER TRANSITION ZONES

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A numerical model of airflow above changes in surface conditions in the lowest
10 to 15 metres of the atmosphere has been developed based on boundary-layer approxi-
mations, a mixing-length hypothesis and empirical forms for \(\phi_M\), \(\phi_L\), and \(\phi_K\) (the non-
dimensional wind shear, temperature gradient and absolute humidity gradient). For
locally unstable thermal conditions the Businger-Dyer hypotheses are used

\[ \phi_M = (1 - 16.0 \frac{z_0}{z_L}) \phi_L; \phi_M = \phi_L = \phi_M^2 \]

where \(L\) is the Monin-Obukhov length while in stable conditions we use \(\phi_L = \phi_M = \phi_K = 1 + 5.2 (z_0/L)\) which is based on Web's work on the log-linear velocity
profile. The theoretical model is applied to several cases of flow from land to sea and

86

87
vice-versa by suitably specifying surface values of roughness length and sensible and latent heat fluxes. The model predicts that changes in surface sensible heat flux are an important factor in determining the flow and can lead to large increases or decreases in turbulence levels in the upper part of the transition zone or internal boundary-layer. Similar effects are predicted for airflow in mid-ocean above sharp changes in the water temperature.

14. THE STRUCTURE OF NEAR-WATER ATMOSPHERIC LAYER AND PECULIARITIES OF OCEAN-ATMOSPHERE INTERACTION UNDER A STORM CONDITION

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Based on pulsation measurements in the boundary layer over the sea, some data were obtained about the vertical distributions of turbulent structure characteristics and their relations with wave parameters. The possibility of dividing wind-speed dispersions into “wave” and “turbulent” components by evaluating spectra and cross-correlation functions is proved. It is shown that the vertical distribution of “wave” components is described by an exponential law: \( \sigma_w = \sigma_{w0} \exp(-z_0/\lambda) \), where \( z \) = height above sea level, \( \lambda \) = average length of wave sea. Dimensionless dispersions of “turbulent” fluctuations are 2.6 ± 0.6 and 0.9 ± 0.2 for horizontal and vertical components respectively.

These results have confirmed an opportunity to use some basic concepts of the boundary layer over a solid surface in the authors’ model for heat and momentum exchange between ocean and atmosphere.

All conclusions are correct for wind velocities less than 15 m/sec. Under storm conditions, specific non-turbulent mechanisms of vertical heat, mass, momentum transfer begin to act in association with the spraying of whitecaps and the accumulation of air bubbles in the upper ocean layer. Some evaluations of such transfer by spray drops are made. Calculated dependencies of exchange coefficients upon wind velocity correspond satisfactorily with scarce data from experiments both in the sea and in wind tunnels. An account of fast vertical flux amplification during storms may be important for ocean-atmosphere interaction climatological studies.

15. ON THE INFLUENCE OF THE PLANETARY BOUNDARY LAYER OVER LAND AND SEA ON THE DYNAMICS OF THE ATMOSPHERE

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The influence of the planetary boundary layer on the dynamics of the atmosphere is discussed briefly, considering especially the components of the total ageostrophic boundary layer flow and its significance for the vertical motions, the surface pressure pattern and the interdiurnal pressure changes, respectively.

Some effects of the marine atmospheric boundary layer are analyzed in comparison with the continental atmospheric boundary layer, taking into account various approaches to determine the dependence of the roughness parameter of the sea surface on the friction velocity.

Finally, a method is described to determine the geostrophic drag coefficient from routine rawinsonde data, and some preliminary results are given in comparison with theoretical conclusions.

16. CLIMATIC CHANGES IN ATMOSPHERE AND OCEAN ON THE ORDER OF DECADES

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This paper describes some of the large-scale aberrations in the general circulation of the atmosphere and its weather during the coherent periods of 1948–1957 and 1958–1969, and associates these aberrations with the comparable-scale thermal anomalies at the North Pacific sea surface. An air-sea coupling system is proposed to explain year-to-year coherence of both sea-surface temperatures and prevailing atmospheric flow patterns. Major breaks between the roughly decadal climate regimes are discussed in terms of changes, irreversible for years, which follow a few extreme seasons, changes which may be due to atmospheric instabilities forced by slowly evolving and long lasting thermal patterns in the ocean.

17. THE INFLUENCE OF WATER WAVES ON THE ADJACENT AIR FLOW

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**University of Michigan, Ann Arbor, Michigan, USA

Measurements of wind component and temperature fluctuations from 2 to 8 meters above waves in Lake Michigan and in the Atlantic Ocean have been analyzed in terms of similarity theory. Both energy of the fluctuations and spectral distributions show that turbulent air flow over waves is significantly influenced by the waves. Initial results indicate that the dimensionless root mean square measures of the fluctuations (\( \sigma_u/u^* \), \( \sigma_v/u^* \), \( \sigma_w/u^* \)) are in general agreement with the findings of Kitagorodskii and of Volkov with respect to their dependence on dimensionless height (z/L) and dimensionless phase speed (C/u^*). The results of these that correspond to the wave spectra maxima.

At the frequencies of the wave spectra maxima it is found that (1) spectra of the velocity components generally have energy concentrations, (2) cospectra that represent vertical fluxes of horizontal momentum have significant extreme, and (3) on several occasions downward flux was enhanced at an upper level at the same time that it was decreased at a lower level.
18. ANGULAR SPREADING OF WIND WAVES

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According to the linear theory, two-dimensional spectra of wind waves can be connected with those of turbulent pressure fluctuation in the lower atmosphere.

In the present paper, directional properties of wind waves are calculated from observations of surface elevations and induced horizontal orbital velocities of water particles, using an electric capacitance-type wave gauge and an ultrasonic current meter at the Marine Observation Tower constructed at the 20-m depth and about 1.3 km offshore.

By the observation system it is possible to get the first five coefficients of Fourier expansion of directional spectra of the surface waves. By these coefficients are then calculated the directional properties, that is, variance of angular spreading, spectral peakedness introduced by Longuet-Higgins and long-crestedness, etc., which are compared with the values from previously proposed empirical formulae.

It is noteworthy that the observed variance of angular spreading and spectral peakedness as well as long-crestedness are similar to those from the linear theory derived with empirically determined Priestley's spectra of turbulent pressure fluctuation, which are originally obtained on land surface.

19. WATER BOUNDARY LAYER WITHIN FIRST TEN MILLIMETERS BELOW WIND DRIVEN WAVES

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According to R. W. Stewart, the only thing that makes one wind driven wave different in any fundamental way from another is surface tension effects in waves that are less than about five centimeters long. Also, the force of a ten meter per second wind on a violently wavy sea is scarcely more than over smooth glass.

The near-surface boundary layer in the water below wind-generated waves has not received the attention that has been given to the flow of the air that generates the waves, particularly in the capillary-gravity transition region. A suspension of aluminum particles, having a long settling time, has been injected near-surface wind driven flow in a wind flume. Novel lighting and cinematography techniques are described that yield data on the distributions of water velocities in the horizontal and vertical directions within the first ten millimeters of the undulating water surface. Statistical boundary layer information for several wind speeds that generate water waves in the capillary-gravity transition region is presented for the first time. A short cine film, taken at sea, will be used to demonstrate that the techniques can be adapted for use in the ocean.

20. GENERATION OF WIND WAVES AND VELOCITY FIELD STRUCTURE IN THE AIR OVER A WAVY WATER SURFACE

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This work is devoted to the study of the generation of wind waves and the dynamic interaction of water surfaces containing progressive waves with the adjoining air layers. Investigation was carried out under natural conditions and in the laboratory.

In the reservoir of Rybinsk, frequency spectra of the wavelets at several wind velocities were obtained. The analysis of the wave spectra and the wind velocity profiles enables one to estimate some parameters in Miles' theoretical results.

The pressure field in the air flow above the waves was investigated in the laboratory. Pulsations of pressure in the air flow, synchronous records of the vertical speed of the water surface and the velocity profiles were obtained. Near the wavy water surface, a maximum in the pressure spectrum at a frequency corresponding to the frequency of the maximum in the spectrum of the vertical speed of the water surface was obtained. The coefficients of correlation and dispersion of pressure pulsations for various horizons were obtained. Dispersions of pressure which was in phase with the slope of the wave, and dispersions of the pressure which was displaced in phase at τ, in relation to the water surface elevation were selected from the total pressure dispersions.

The results of experiments on the determination of the kinematic structure and statistical characteristics of the velocity field over wavy water surface are presented.

The following cases have been examined:

a) the velocity field over wavy water surface in the absence of an outer wind stream (swell);
b) the velocity field of the wind stream over a water surface covered with mix roughness (swell and wind wave);
c) the velocity field of the wind stream over a water surface covered with wind waves during the initial stage of their development;

The air stream structure was studied using the thermoclinometry method and the method of the stream visualization by photography.

21. LOCAL GENERATION OF LOW FREQUENCY INTERNAL GRAVITY WAVES IN THE OCEAN

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The linear response at different layers of a stratified ocean were investigated as a function of an effective pressure applied at the bottom of the mixed layer. This effective pressure is the result of the motion in the mixed layer due to the wind stresses and atmospheric pressure. In the first part of this work, there is derived a
solution as a function of space and time for constant stratification showing the transient behaviour of low frequency waves. In the second part there is considered a more realistic stratification (density exponential increase with depth) and these results show a sharp peak at frequencies slightly higher than the inertial frequency when the time scale of the pressure fluctuations is smaller than 15 hours, the vertical distribution of these waves depends very much on the horizontal scale of the forcing. Storms with horizontal scales of the order of 100 km will excite inertial waves with concentration of energy mainly in the upper layers. Storms of the order of 20 km will excite inertial waves with the energy proportional to the local Brunt-Väisälä frequency.

22. MEASUREMENTS OF WIND WAVE GROWTH IN THE NORTH SEA


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Extensive measurements of the temporal and spatial features of an actively growing wind sea have been obtained. The data have been converted to two-dimensional spectral fields which in turn have been parameterized. The dependence of the resulting spectral parameters on environmental variables (e.g., wind, current, etc.) will be discussed. This discussion will illustrate the variation observed in the "equilibrium" range constant. The presentation will also demonstrate the importance of tide induced modulations on the wave field, the importance of non-linear wave-wave interactions to the wave energy budget, and the parameters influencing the over-shoot effect. The data also indicate that the directional spread of wave energy is much broader than the commonly assumed cos^4 cos^2 distributions.

23. MEASUREMENTS OF WIND WAVE DISSIPATION IN THE NORTH SEA


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***Deutsches Hydrographisches Institut, Hamburg, Germany
****National Institute of Oceanography, Surrey, England
*****Abteilung für Theoretische Geophysik, Hamburg, Germany

A large measurement array has been used to observe wave dissipation resulting from both an opposing wind field and/or bottom friction. The dissipation data obtained during opposing wind conditions appear to be the first of their kind and will be presented in detail. The dissipation due to bottom friction is reasonably well explained by the theory of Hasselmann and Collins. The interaction of long swell with the current field is found to be of such importance that good prediction of swell decay in marginal seas will require some knowledge of the local current regime.

24. LABORATORY INVESTIGATION OF TURBULENCE ABOVE WAVES

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The structure of turbulent shear flows above propagating waves is investigated experimentally in a wind and wave facility at the University of Florida. The existence of the wave-induced perturbations and their importance in transferring momentum to waves is a central question in this study.

The mean velocity profiles were measured by a pitot-static probe and a pressure transducer. The turbulent air velocities were measured in the horizontal and vertical directions by using a two-channel hot-film anemometer. Power-spectrum analyses of the turbulence measurements were conducted with the use of an analog power spectrum analyzer with special low-frequency and narrow-band pass capabilities. In addition, the turbulence measurements above mechanical waves were phase averaged with respect to the frequency of the mechanical wave by analog means in which the wave was used as a trigger.

The experimental program included measurements at two fetches 10 and 25 meters downstream of air intake and at many elevations above the mean water level in the range 10-50 centimeters. Four wind speeds with reference velocities U_e = 1.95, 2.86, 4.60, and 10.70 m/sec were investigated. For each test condition, turbulence measurements were obtained both in the presence and absence of mechanical waves with wave height = 8.9 centimeters and wave speed = 2.26 m/sec in a depth of water = 0.915 meter.

The power-spectrum results indicate the presence of significant wave-induced peaks in both the horizontal and vertical velocities at the frequency of the mechanical wave. The peaks disappear in the absence of mechanical waves. The wave-induced perturbations also appear as periodic signals after phase averaging signals which initially appear to be random turbulence. Calculations of momentum transfer to waves based on the wave-induced Reynolds stress and based on the measured growth rate of waves indicate that the wave-induced stress accounts for most of the momentum transfer to waves at C/U_e = 3.5. At C/U_e = 2.0 the wave-induced Reynolds stress is negative which suggests wave damping.
25. CONVECTION INDUCED BY THE EVAPORATION OF SEA WATER

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The evaporation of sea water produces fluxes of heat and water vapor from the top surface of the ocean. To a good degree of accuracy the change in water level induced by the evaporation can be neglected and the effect of the water vapor flux out of the ocean can be represented by a flux of salt into the ocean. The fluxes of heat and salt at the sea surface are thus coupled by the latent heat of vaporization. A theoretical analysis of the onset of convection induced by the combined effects of the heat and salt fluxes is made using Fourier analysis of the variables. It is found that the convective behaviour is primarily determined by the evaporation rate and the salinity of the sea water. For the usual range of oceanic salinities thermal processes dominate the convection and the spacing of convection cells is not too different from those produced by the evaporation of fresh water. Experiments using a schlieren optical system to visualize the flow show that the spacing of the convection is determined by the thermal boundary layer and that the salinity boundary layer is dragged along the edges of the thermally produced cells.

26. ON SOUND GENERATION BY THE OCEAN-ATMOSPHERE BOUNDARY LAYER

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The paper demonstrates that the motions in the ocean-atmosphere boundary layer as well as the interactions between these motions can lead to sound-wave radiation into the ocean as well as into the atmosphere. The analysis is carried out on the basis of the well-known theory by Lighthill. At great distances from the boundary layer and in certain conditions, the sound field is equivalent to the field of sources distributed along the interface. The distribution of sources is expressed through the interface disturbances.

A classification is made of the mechanisms of sound generation by the ocean-atmosphere boundary layer which takes account of motions of different types both in the ocean and in the atmosphere and interactions between these motions.

It is demonstrated that even when linear-approximation theory is used, the turbulent component of motions both in the ocean and in the atmosphere can lead to sound generation. Non-linear mechanisms of sound generation are related to interactions of the following: wave to wave, turbulence to turbulence and wave to turbulence; both oceanic and atmospheric turbulence being considered. The intensity of sound generated by each mechanism is estimated and the relative contribution is analysed of each sound-generating mechanism into the low-frequency noise in the ocean as well as into the infrasound oscillations in the atmosphere.

27. PRESSURE FLUCTUATIONS ORIGINATING IN THE MARINE PLANETARY BOUNDARY LAYER

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We have observed surface pressure fluctuations over the sea with an array of sensitive pressure sensors. The spectra of these fluctuations contains usually a broad peak characterized by frequencies of order 1/20 min \(^{-1}\), horizontal scales of a few kilometers and amplitudes of order 0.02 mb. The pressure anomalies can be demonstrated to translate approximately with the surface wind. Corresponding fluctuations have developed in a numerical model by Deardorff (Geophys. Fluid Dyn. 1970, Vol. 1, 377–410). They seem to be associated with fluctuations and "intermittencies" of the Reynolds stress and of the moisture flux through the boundary layer.

28. HIGHER-ORDER STRUCTURE FUNCTIONS AND STATISTICAL SELF-SIMILARITY OF TURBULENCE NEAR THE AIR-SEA INTERFACE

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Structure functions of longitudinal velocity fluctuations up to fourteenth order have been measured close to the water surface in the atmospheric boundary layer over the open ocean, and the results are compared with conflicting theoretical predictions for separations in the inertial subrange. The behaviour of the measured structure functions of fourth and higher order are in clear disagreement with that predicted by Kolmogorov's original theory. Good agreement is found up to eighth order with predictions of a later modification of the theory by Kolmogorov, Obukhov, and Yaglom, which accounts for the intermittency in the local dissipation rate. For higher orders the behaviour of the data and the modified theory are also not in agreement. Computations of the probability distribution of the increments of the fluctuating velocity at one point show that in the inertial subrange the increments are not self-similar in the sense defined by Mandelbrot and Van Ness, contrary to a previous conjecture of Dutton and Devene. The measured probability density function of the velocity difference increments continuously evolves from a strongly non-Gaussian form at small separations to a nearly Gaussian form at the largest separations, and the higher-order skewness and flatness factors approach values appropriate to a Gaussian joint probability distribution only for the largest values of the separation. Cross spectra of velocity fluctuations and the local wave height are examined in attempts to assess the influence of air-sea interactions on the measurements.
29. PECULIARITIES OF THE TURBULENT STRUCTURE OF THE NEAR-WATER LAYER OF THE ATMOSPHERE

A. G. Kolesnikov, V. V. Efimov and A. A. Sizov
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Turbulent structure of the near-water layer of the atmosphere depends on a large extent on the character of disturbances introduced into the air flow by moving waves. The greatest contribution of wave disturbances to the intensity of the turbulent flow occurs at the interaction between wind and waves of the swell. In this case, wave disturbances in the atmosphere resemble orbital ones and the field of mean velocity is rebuilt in such a way that acceleration of the air flow arises in the vicinity of propagating waves. The increase of Reynolds number of the flow leads to an intensification of the turbulent "closures" as well as to the negligible effect of the contribution of wave disturbances to the intensity of the turbulent flow. High correlation between turbulence intensity of the air flow and wave disturbances enables one to divide the interaction process into stages, determined from the value of the dimensionless parameter \( u' \sigma / \bar{C}_w \) (where \( \sigma_w \) is the phase velocity of wave components making a basic contribution to the dispersion of the wave surface elevation). It is shown that spectra of the longitudinal velocity component at this stage of interaction with developing wind waves satisfy the law of the inertial interval within the whole frequency band of surface waves. At stages of interaction with mixed waves, spectra of longitudinal velocity have peaks at frequencies of swell waves. The phase shear between the horizontal component of velocity and the elevation, determined for this stage of interaction at a frequency band of energy-carrying components of waves, is close to 180°, which does not contradict Miles’ quas-laminar theory (1957).

30. CHARACTERISTICS OF SPECTRA AND COSPECTRA OF ATMOSPHERIC PARAMETERS IN THE FIRST 22 m

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The paper discusses spectral and cospectra data obtained from recent boundary layer experiments conducted over a flat uniform site in southwestern Kansas and compares them with similar measurements made over ice floes and over water.

The Kansas data represent measurements from three heights, 5.66, 11.3 and 22.6 m, covering a range of z/L values from -2.1 to +3.3. They include spectra of \( u, v, w, \) and \( \theta \) and the cospectra of \( uw, w \phi \) and \( u \phi \). When plotted in appropriate non-dimensional coordinates, the spectral and cospectral curves collapse into single universal curves in the inertial subrange but spread out according to z/L at lower frequencies. In the inertial subrange the power spectra fall as \( n^{-5/3} \), the cospectra of \( uw \) and \( w \phi \) as \( n^{-7/3} \) and the cospectra of \( u \phi \) as \( n^{-1} \). The paper discusses how recent data obtained over land and water fit the composite spectral diagrams derived from the Kansas data and possible reasons for some of the observed departures.

31. AN INVESTIGATION OF HIGH WAVE NUMBER TEMPERATURE AND VELOCITY SPECTRA IN AIR

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Turbulent temperature and velocity fluctuations in air were measured at a height of 4 meters over a tidal mud flat. Particular attention was focused on the high wave number, small scale region of the spectra of these fluctuations. Velocities were measured with a constant temperature hot wire anemometer, the hot wire consisted of a platinum wire \( 5 \mu m \) in diameter and approximately \( 1 \mm \) in length. Temperature fluctuations were measured with a platinum resistance thermometer which consisted of a platinum wire \( 0.15 \mu m \) in diameter and about \( 0.30 \mm \) in length.

The velocity spectra results agree well with the classical results of Grant, Stewart and Mijllet (1962) and Pond, Stewart and Burling (1963). In addition, they extend the velocity spectrum in air to slightly higher wave numbers. The one-dimensional Kolmogorov constant \( \kappa' \) estimated from these data was 0.50.

The temperature spectra clearly show the shape of the one-dimensional temperature spectrum in air beyond the \(-5/3 \) region. These spectra show that in air there is no \(-1 \) region and that temperature and velocity spectra are very similar. The value of the scale constant \( \kappa'' \), which appears in the scale \(-5/3 \) law, computed from these data was 0.81. Direct measurement was made of all parameters that enter into the calculation of \( \kappa'' \).

32. MEASUREMENTS OF TURBULENCE, HUMIDITY AND TEMPERATURE OVER THE OPEN OCEAN FROM A STABLE PLATFORM

Carl H. Gibson
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Crossed hot wire anemometers, Lyman-\( \alpha \) hygrometer, and 0.6 micron resistance wires were positioned from zero to 30 meters above the sea from the Scripps Floating Instrument Platform (FLIP). Results from a series of expeditions are
discussed. Statistical analysis of the data was accomplished using on-board and land-based computers. Averaged viscous and diffusive dissipation statistics were studied for both velocity and temperature fields and compared to log-normal predictions of Kolmogoroff, Obukhov, Yaglom, Gurvich and others. The universal constant appearing in Kolmogoroff's third hypothesis was estimated from \( -\frac{\mathrm{d}f}{\mathrm{d}t} \) and found to be about 1/2, in agreement with values inferred from spectra of dissipation. Temperature and humidity fields were remarkably similar. Both displayed a ramp-like anisotropy, with sharp increases in the downwind direction. Spectra of the variables, derivatives, squared derivatives, etc., were calculated, normalized with mean dissipation rates and some six universal constants evaluated (most were about 1/2) characterizing the inertial subrange observed. Flux values were measured, inferred and compared to simultaneous measurements from an airborne two-frequency infrared radiometer system.

19: SYMPOSIUM ON AIR AND WATER POLLUTION

Sponsored by IAMAP (with IASH/IAPSO)

Convenors: J. Jacquet and H. Schoeller

Tuesday, August 10

Chairmen: J. Jacquet and H. Schoeller

1. O. S. Zudin, B. A. Nelepo and N. I. Popov  
   Part of physical phenomena in "self-purification" of surface ocean water

2. G. D. Sharma  
   Geochemical evolution of interstitial waters in arctic and sub-arctic marine sediments

3. D. C. Thorstenson and F. T. Mackenzie  
   Interstitial water chemistry of reducing carbonate sediments, Devil's Hole, Harrington Sound, Bermuda

4. P. Verdell  
   Relations between the karstic conduits and the sea in the Languedocian Littoral—resulting phenomena of the pollution
1. PART OF PHYSICAL PHENOMENA IN "SELF-PURIFICATION" OF SURFACE OCEAN WATER

O. S. Zudin, B. A. Nlepo and N. I. Popov
P. P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, USSR

Fall-out contaminations on the ocean surface are to be found involved in the processes of different nature and scale. Taking part in general circulation they are transported in the ocean, changing their concentrations under the influence of turbulence, sedimentation and others.

The investigations carried out during the recent years, showed that the information on statistical structure of the contamination fields may be used in analysing the "self-purification" process. In consequence, it turned out, that on the basis of the use of the optimal interpolation method realized with the help of electron digital computers (EDC) it is possible to recover the field of contaminant concentrations.

In the process of the analysis the limiting parameters were taken into consideration, determined by instrumentation sensitivity and permissible concentrations of the contaminant. The calculations carried out allow the influence of hydrophysical processes proceeding in the ocean on the contamination fields to be determined. It was also found, that it is possible to evaluate the efficiency of the forecast of these fields in accident situations.

One of the ways of "self-purification" on the ocean surface layer from the contaminants are the natural processes of separation of water and suspended matter. The contaminants can form the dispersive phase independently or as a result of interaction with natural suspension of sea water.

The separation of the sufficiently heavy particles—in the form of the sedimentation process—proceeds under the influence of the gravity. The influence of the Lorentz force on the particles of light emulsions in the natural conditions of the ocean was also considered.

The calculations showed that with existing value of geomagnetic field and current velocities observed, this force at some quite real charge of the suspended particles can reach the values equivalent to the weight increase of the latter on several orders. Consequently one can expect that the distribution field in the ocean, for example the field of oil emulsion, will possess the microstructure.

2. GEOCHEMICAL EVOLUTION OF INTERSTITIAL WATERS IN ARCTIC AND SUB-ARCTIC MARINE SEDIMENTS

Ghanshyam D. Sharma
Institute of Marine Science, University of Alaska, College, Alaska, USA

Glaciation plays an important role in providing sediments to the arctic and subarctic oceans. These mechanically weathered, rapidly deposited sediments provide an unparalleled natural laboratory to study sediment-seawater interaction and the geochemical evolution of pore waters.

The sediments in arctic and subarctic regions consist predominately of feldspar, quartz, illite-mica and chlorite. High feldspar content in sediments is indicative of lack of chemical weathering in this area. The sediments entering the environment rapidly react with seawater. Such interaction depends on the bulk mineralogy and particle size of the sediments, environment of deposition, and path length the sediments follow prior to deposition. During early stages of sediment-seawater interaction sodium and calcium ions are exchanged while sodium, magnesium and potassium become dominant exchangeable cations with prolonged interaction. Early stage of burial is characteristic of a chemical and biological adjustment between the mobile overlying water and the immobile sediments.

3. INTERSTITIAL WATER CHEMISTRY OF REDUCING CARBONATE SEDIMENTS, DEVIL'S HOLE, HARRINGTON SOUND, BERMUDA

D. C. Thorstenson* and F. T. Mackenzie**
*Department of Geological Sciences, Southern Methodist University, Dallas, Texas, USA
**Department of Geological Sciences, Northwestern University, Evanston, Illinois, USA

The interstitial water chemistry of fine grained anaerobic carbonate sediments in Devil's Hole, Harrington Sound, Bermuda, has been studied at intervals over the two years. Pore waters from shallow cores / 1 meter/ have been analyzed for Ca++, Mg++, Na+ or Cl-, titration alkalinity, pH, H2S, NH4, and dissolved CH4 and NO3.

A summer thermocline develops in Harrington Sound, and the water in Devil's Hole becomes anoxic, with production of H2S and NH3. In winter months, the sediments are overlain by normal seawater. These changes are accompanied by slight seasonal variations in the interstitial water chemistry. Changes in pore water chemistry with depth have been duplicated in experiments with anaerobic decomposition of algae in seawater, and can be modeled on a theoretical basis.

The theoretical models and experiments both indicate that the changes in pore water chemistry with depth can be produced in a closed system. Therefore, diffusion processes in the sediments are producing no major changes in the ratios of dissolved constituents in the interstitial waters. Theory, experiments, and field observation all indicate that decomposition of organic matter will not produce significant early diagenetic changes in carbonate sediments.

4. RELATIONS BETWEEN THE KARSTIC CONDUITS AND THE SEA IN THE LANGUEDOCIAN LITTORAL—RESULTING PHENOMENA OF THE POLLUTION

P. Verdel
Department of the Sciences of the Earth, Sciences School, University of Orléans, Democratic and Popular Republic of Algeria

The western border of the Gulf of Lions, in the part comprised between the Rhone delta and the pyrenne ridge, presents amid a widely exposed stratigraphic series, the numerous calcareous formations, which are important centres of karst phenomena.
The Karst appear therein as a milieu riddled by a series of channels circulating on variable levels and varying with their age and their relative speed of the rising in the ground.

Every karstic system moves on its proper basic level, signaling the current position of the sea level.

The oscillations of the Mediterranean in the course of geological time allowed the setting of exutoxor strata, whose relations to the present circulating system—whenever such relations exist—entail the presence of a mostly varied series of connections between the karstic flowings on the one hand, and the waters of the sea on the other hand.

Reciprocal pollution phenomena may occur in one of the following ways:
- Penetration of salt water into the underground water;
- on the level of the free karstic conduits;
- through the alluvial permeable formations, injected by the karstic conduits.

The phenomenon could be natural as well as provoked by intensive pumping, penetration of the underground polluted waters into the sea:
- on the level of the free karstic conduits
- through the alluvial formations.

The flowing may occur on the surface, on a positive altitude; or in depth, under the sea level; or following a mechanism involving both processes.

Simultaneous penetration of salt water into the underground water and of underground water into the sea:
- through a free conduit
- through the alluvial permeable complex.

Continuous alluvial deposit of underground water, constitutes the main material force governing the suction of sea water.

29: SYMPOSIUM ON AUTOMATIC ACQUISITION OF DATA AND TIME SERIES ANALYSIS
Sponsored by IAG (with all Associations)
Convenor: A. P. De Vuyst
Thursday, August 5, p.m.
Chairman: A. P. De Vuyst

   Hydrophysical “polygon” in the tropical Atlantic

2. A. D. Yampolsky
   Variability of the inertial oscillations as deduced from the machine treatment of long series of current measurements

3. K. S. Pomeranets and Y. V. Sustavov
   Internal oscillations of meteorological and tidal origin obtained from the long-term series in the ocean

4. V. V. Navrotsky
   Statistical analysis of velocity and temperature measurements in the sea

5. P. K. Guber and V. R. Fuks
   Correlation and spectral analysis of the ocean processes with a seasonal component

6. R. D. Grigorikina and V. R. Fuks
   Spectra of the intramonthly water temperature variations in the upper layer of the ocean
1. HYDROPHYSICAL "POLYGON" IN THE TROPICAL ATLANTIC

K. A. Chekotillo, V. D. Egorikhin, L. M. Fomin, G. N. Ivanov-Frantzkevich, V. V. Moroshkin, V. G. Neiman and V. B. Titov

P. P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, USSR

During February–September 1970 specialized investigations were carried out on a selected site ("polygon") at approximately 16°30'N and 33°30'W. This work was aimed at collecting long series of current measurements and detailed data on thermohaline structure of the ocean with a view to developing further the concept of such systematic studies and obtaining new data on the variability of oceanic currents. Six USSR research vessels took part in the work.

Currents were recorded by Alexeev's current meters suspended from 17 buoy stations set in a cross-like pattern within a square 120 x 120 nautical miles. The buoys were unequally spaced at preselected distances. Measurements were carried out simultaneously at 10 different depths with 30 min frequency. A great number of other hydrophysical, meteorological, geophysical, etc., observations were also conducted.

The analysis of records revealed that even the so-called "mean currents" which are the residual after filtering out the inertial and tidal components are highly variable both in time and in space. One can always find, within the complete six-months period of observations, a time-interval of one or two weeks which would produce a "mean current" of any direction desired. The mean current vector was found to be rotating with depth in an orderly fashion which suggests an influence of density stratification.

Spectral analysis demonstrated that the inertial and tidal components of the observed current are quite strong at the site. Both the inertial and tidal currents were largely baroclinic which fact confirms their oscillatory nature. The depth of the energy maximum for the inertial current coincides with that of the shallowest vertical density gradient.

Observations of the micro- and meso-scale processes, including internal waves and turbulence, gave valuable information on the origin and evolution of certain important features of the upper ocean thermohaline structure.

2. VARIABILITY OF THE INERTIAL OSCILLATIONS AS DEDUCED FROM THE MACHINE TREATMENT OF LONG SERIES OF CURRENT MEASUREMENTS

A. D. Yampolsky

P. P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, USSR

In 1967 sixty days long series of current measurements were conducted in the Arabian Sea at seven locations along two straight lines forming a right angle. Each branch of the array of buoys was approximately 60 miles long. Current directions and velocities were recorded by Alexeev's current meters every 30 minutes at 25, 50, 100, 150, 200, 300, 400, 600, 800, 1000 and 1200 m.

These series of measurements were treated on a computer according to the special programme designed to obtain characteristics of current oscillations with the period close to 1/2 pendulum day for the given latitude. The degree of variability is examined of the amplitudes and periods thus obtained in time and space. Dependence is considered of these characteristics upon certain parameters of the mean current field.

3. INTERNAL OSCILLATIONS OF METEOROLOGICAL AND TIDAL ORIGIN OBTAINED FROM THE LONG-TERM SERIES IN THE OCEAN

K. S. Pomerents and Y. V. Sustavov

State Oceanographical Institute, Leningrad Division, Leningrad, USSR

Results of the statistical analysis of oceanographical time series that have been obtained at the North Atlantic (Faroe-Shetland region) with two-month duration are described. Most attention was paid to the time variations of isotherms as they indicate internal waves.

The most significant fluctuations of oceanographical elements are detected in the seasonal and main thermocline. Deviations are most significant in the main thermocline from the normal distribution.

Cycles with long-term, multi-hour's and semi-diurnal periods are detected by the spectral analysis. The energy decreases from long-term to multi-hour's periods by the "5/3" law.

Oscillations with periods of 60 and 12 hours were selected with the aid of smoothing and filtration. Analysis of meteorological series (pressure, wind and main components of the pressure field) showed that the origin of detected regularities is meteorological and tidal accordingly.

The intensity of meteorological and tidal internal oscillations of isotherms is almost the same. In the upper ocean (over 200 m) intensity of internal oscillations of isotherms is the lowest. Cross spectral analysis of the time series for different isotherms showed that the closest connection between internal oscillations for both regularities is in the main thermocline. The obtained results testify that the thermocline is an undivided part of the vertical structure of the ocean.

Tidal oscillations of isotherms have practically the same phase as the external forces and the coherence is high. Internal oscillations of isotherms with meteorological period lag behind the fluctuations of meteorological elements, the connection between them being sufficiently close.

4. STATISTICAL ANALYSIS OF VELOCITY AND TEMPERATURE MEASUREMENTS IN THE SEA

V. V. Navrotsky

Atlantic Department of P. P. Shirshov Institute of Oceanology, Academy of Sciences, Kaliningrad, USSR

The velocity and temperature measurements here analysed are made at the buoy stations in the eastern part of Atlantic Ocean with readings 10 minutes discrete. In addition in several regions of Atlantic Ocean the temperature measurements were
made from the moving ship with help of thermistor chain. In the first part of the paper some methodical questions are considered, to wit: the more precise algorithms for the computation of probability distribution, of the moments and correlation function; the filtering with regard to the nature of the process; the peculiarity of the analysis with fast Fourier transformation (FFT) as in single so in coherent analysis. In the second part the results of direct measurements are analysed. One of the most interesting and noticeable phenomena in the upper layer of sea are internal waves, that's why great attention is given to the detection of their characteristics, to the analysis of their vertical and horizontal structure, to the problem of internal wave—turbulence interaction. The analysis of the measurement permits to obtain the estimations for horizontal and vertical fluxes of momentum and of heat, to check the usual assumptions about the values of horizontal mixing coefficients.

The very complicity of the processes in the upper layer of sea—anisotropy, nonstationarity, the variety of physical mechanisms—demand the special concentration of the efforts for their investigation. The simultaneous measurements at fixed points and at spatial sections are necessary. This will permit to check the existing, and to build up more reasonable theories for the processes in the upper layer of the ocean.

5. CORRELATION AND SPECTRAL ANALYSIS OF THE OCEAN PROCESSES WITH A SEASONAL COMPONENT

P. K. Gubser and V. R. Fuks
Department of Oceanology, The Leningrad State University, Leningrad, USSR

The seasonal component is dominant in the energy spectra of a number of the ocean processes. The useful information, obtained from the statistical analysis of variation of various oceanological characteristics, is often reduced to a minimum because of the large intensity and exact periodicity of the annual oscillation.

The analytic expressions for correlation, cross-correlation, spectral, and cross-spectral functions of the processes containing annual harmonics have been derived. The results of analytic filtration and polynomial smoothing which suppress the seasonal component are discussed. The effect of these transformations on the detached intramonth fluctuations of oceanological processes are studied with different energy relation between seasonal and high frequency fluctuations and also with different length of series and maximum lags of correlation function. The results of IBM estimation of both spectra and cross-spectra of the actual and designed test series are shown.

6. SPECTRA OF THE INTRAMONTHLY WATER TEMPERATURE VARIATIONS IN THE UPPER LAYER OF THE OCEAN

R. G. Grigorina and V. R. Fuks
Department of Oceanology, The Leningrad State University, Leningrad, USSR

The present paper deals with the study of variability of the structure of ocean processes with space and time in the Kuroshio water system in the range of insufficiently known time scales from 3 to 30 days. The study was based on 3-year series of daily water temperature fields, thermocline depths and gradients. The zones of the energy supply and turbulent energy decrease are distinguished in the spectra of these processes.

Characteristic spatial scales of certain energy fluctuations are determined by means of the cross-spectrum analysis.

Analytical approximation of the spatial-time spectrum of the temperature variations is suggested. Variability of the temperature conditions in the frequency range under study is explained by the advection of heat with currents.

A hypothesis on a significant role of Rossby waves and frontal waves in the Kuroshio water regime is suggested.
31: SYMPOSIUM ON REMOTE SENSING TECHNIQUES
Sponsored by IASH (with IAPSO/IAMAP)
Convenor: P. Bock

Tuesday, August 10, a.m.
Chairman: P. Bock

1. V. V. Bogorodsky and V. P. Tripolnikov
Distance methods of thickness measurements of sea drifting ice

Wednesday, August 11, p.m.
Chairman: N. K. Vinnichenko

2. D. Q. Wark and D. T. Hilleary
The satellite infrared spectrometer (SIRS) experiments on the Nimbus III and Nimbus IV satellites

Investigation of the atmospheric water content by means of the ground-based radio thermal location

4. V. E. Derr
The study of boundary layer processes by LiDAR remote sensing techniques

Thursday, August 12, p.m.
Chairman: P. Bock

5. A. S. Gurvich and N. S. Thieme
Measurements of turbulence spectra by laser's beam

6. W. Nordberg
Measurements of the microwave emission from terrain and sea surfaces

7. A. M. Obukhov, A. E. Basharinov, A. S. Gurvich and S. T. Egorov
The geophysical aspects of earth's microwave radiation investigations

8. A. E. Basharinov and A. M. Shutko
Effect of sea state on microwave radiation

The Nimbus F earth radiation budget (ERB) experiment

1. DISTANT METHODS OF THICKNESS MEASUREMENTS OF SEA DRIFTING ICE
V. V. Bogorodsky and V. P. Tripolnikov
Arctic and Antarctic Research Institute, Leningrad, USSR

Ocean and sea ice cover effectively decreases ocean-atmosphere heat exchange. It reflects solar radiation in summer and inhibits ocean water heat in winter. Therefore, the availability or the lack of sea ice essentially influences dynamic and thermodynamic ocean-atmosphere interaction not only in the polar regions but also likely all over the globe.

From this aspect the following ice cover parameters are acquiring paramount significance: thickness, compaction, and temperature. Ice cover thickness and its compaction is subjected to seasonal variations. Therefore, when the problems of ocean-atmosphere interaction are studied, the ice cover can be characterized by average values of thickness and temperature.

In order to obtain integral estimations of ice cover thickness it is necessary to make available data of detailed instrumental measurement of large water areas. Physical principles are discussed in the paper. Technical characteristics of sea ice of radars are also included in this paper.

2. THE SATELLITE INFRARED SPECTROMETER (SIRS) EXPERIMENTS ON THE NIMBUS III AND NIMBUS IV SATELLITES
D. Q. Wark and D. T. Hilleary
National Environmental Satellite Service, NOAA, USA

Two similar experiments to measure the temperature of the free air from the surface to 30 km have been carried on the NIMBUS III and NIMBUS IV spacecraft. The SIRS, the second instrument, observed spectral radiances in six additional intervals between 18 μm and 36 μm to obtain water vapor distributions; this spectrometer also scanned to each side of the orbital track. Both instruments were characterized by good signal to noise ratios and excellent stability of their radiometric response and wavelength calibrations in orbit. Some spectral channels failed in orbit, but the on-board calibration tests made such failures evident and confirmed proper performance of the other channels.

From the measured radiances and the known transmittances of carbon dioxide, temperature profiles have been deduced. Transmittances by water vapor are obtained from the temperature profiles and the radiances, and water vapor profiles are deduced. Systematic differences are noted when comparing the results with simultaneous measurements, which leads to adjustments in the theoretically computed transmittances. In the most opaque parts of the carbon dioxide band, the angular scan reveals increasing radiances with angle, from which one may imply mean lapse rates, and, to some degree, resolve the uncertainties in stratospheric temperatures. True optical properties of the gases are thus determined from observed radiances, and are employed in enhancing the accuracy of temperature and humidity profiles.

The implications of the SIRS observations in plans for future instruments are discussed.
3. INVESTIGATION OF THE ATMOSPHERIC WATER CONTENT BY MEANS OF THE GROUND-BASED RADIO THERMAL LOCATION

M. S. Malkevich, A. P. Naumov, V. M. Plechkov, Yu. A. Romanov and V. G. Snopkov
Institute of Atmospheric Physics, Institute of Oceanology, and Institute of Radio-Physics, Academy of Sciences, Moscow, USSR

Theoretical and experimental investigations are made to determine the integral water content and the height distribution of H₂O-vapor in the atmosphere by means of the ground-based thermal location within the rotational resonance of monomer molecules H₂O centred at the wave-length \( \lambda = 1.35 \) cm. The dependence between the vertical radio-wave absorption in this range of spectrum and the total mass of the water vapor in the atmospheric column is found. The influence of the dimer molecules of water vapor on the interpretation of the radiometric results is analysed. The experimental data on the integral water content in the atmosphere are given, obtained in different climatic zones of the Atlantic Oceans at the radiometric measurements (on the board of the scientific research ship Academician Kurchatov) and the corresponding results for a continental region. Time and latitude variations of the humidity and some correlation characteristics at simultaneous measurements of the atmospheric water content by radiometric and aerological methods are discussed. The solution of the inverse problem—the restoration of the humidity of the profiles over the measurements of the integral radio-absorption in the atmosphere at \( \lambda = 1.35 \) cm—is made by the method of the statistical regularization. The calculated profiles of the height humidity distribution are compared with the results of the atmosphere aerological sounding.

4. THE STUDY OF BOUNDARY LAYER PROCESSES BY LIDAR REMOTE SENSING TECHNIQUES

V. E. Derr
National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Boulder, Colorado, USA

By the use of on-frequency backscattering, off-frequency backscattering (Raman and fluorescent), and cross-correlation between multiple beams, a laser system has been used for the measurement of horizontal winds, the vertical profile of atmospheric water vapor, cloud heights and velocities, aerosol content, temperature profiles, and turbulence structure functions. The Raman lidar and the two-beam correlation method for wind sensing will be described in detail, and the application of these measurements to the study of fundamental atmospheric problems will be discussed. The measurement of humidity and wind profiles under a variety of conditions found in the lee of the Rocky Mountains will be reviewed. Preliminary turbulence spectra will be presented.

5. MEASUREMENTS OF TURBULENCE SPECTRA BY LASER'S BEAM

A. S. Gurvich and N. S. Thiem
Institute of Atmospheric Physics, Academy of Sciences, Moscow, USSR

Fluctuations arising in a light wave when it propagates through a turbulent medium enable to obtain the information on the characteristics of inhomogeneities. In the case when the relative fluctuations of the refraction index are small and its variation of at a distance of the order of the wave length is also small, the fluctuation spectrum of the intensity of a flat wave is connected with the spectrum of the refraction index by the Abel integral equation. The high frequency part of the spectrum of intensity proves to be sensible to the shape of the turbulence spectrum in the region of small scales.

In the experiment the He-Ne laser with the wave length 6328 \( \text{Å} \) was used as a source. The records of fluctuations of intensity in the centre of collimated beam propagating over the flat surface at a distance of 25 and 50 m was done. The beam diameter was chosen so that it hadn't influenced upon the frequency spectrum of intensity at the beam axis.

The spectra of power of intensity fluctuations were computed. The data obtained enabled to estimate the value of the internal scale of turbulence. The results have been compared with various known models of the temperature spectrum.

6. MEASUREMENTS OF THE MICROWAVE EMISSION FROM TERRAIN AND SEA SURFACES

W. Nordberg
NASA Goddard Space Flight Center, USA

Aircraft measurements have been made of emitted radiation at wavelengths ranging from 0.8 to 3 cm, over large areas of North America, the Pacific and Atlantic Oceans and the Arctic Sea Ice. Brightness temperatures of water surfaces of varying roughness of terrain with varying soil moisture and of sea ice of varying structure were observed. Radiation at 1.55 cm was mapped with an image forming radiometer over these areas.

Emission from sea surfaces was observed to increase with increasing wind speeds at a rate of about 1 percent per meter sec⁻¹. This increase was determined to be due to whitecaps and foam at higher wind speeds. Microwave radiance maps of densely vegetated terrain show nearly blackbody emissions; dry, unvegetated areas are distinguished by emissivities ranging from 0.8 to 0.9; and barren moist soils display emissivities of much less than 0.8. Ice-water contrasts have been mapped under all atmospheric conditions, including thick clouds, due to the very low (0.4) emissivity of water. Different types of sea ice can also be distinguished by their emissivities which vary according to the ice structure, especially in the 0.8 to 1.5 cm wavelength range. Smooth, undisturbed ice has an emissivity of about 0.75, compared to about 0.95 for strongly hammocked ice.

Imaging radiometers of this type will be flown on Nimbus satellites to map daily the distribution and structure of polar ice and to survey variations of soil
moisture on a global scale. Observations of microwave emission from sea surfaces with aircraft could provide better measurements of the energy exchange between the atmosphere and the sea surface.

7. THE GEOPHYSICAL ASPECTS OF MICROWAVE EARTH RADIATION INVESTIGATION

A. M. Obukhov, A. E. Basharinov, A. S. Gurvitch and S. T. Egorov
Institute of Atmospheric Physics and Institute of Radioengineering and Electronics, Academy of Sciences, Moscow, USSR

The satellite measurements of microwave Earth radiation can be realized under any atmospheric conditions and give additional possibility to obtain geophysical information by the comparison with the observations in infrared and optical frequency bands.

The measurements in the centimeter and decimeter frequency ranges where the atmosphere is almost transparent permit to determine the earth surface temperatures and to estimate the surface conditions (the existence of waves and foam on the sea and floating ice, the degree of soil moisture, etc.). The measurements in millimeter and centimeter frequency ranges in the centre and on the edge of absorption lines of water vapor and oxygen permit to estimate the water content in the atmosphere, the intensity of hydrometeors and temperature profiles in the atmosphere. The comparison of the results of satellite microwave measurements with the meteorological and hydrological observations shows that the accuracy of the earth surface temperature measurements is 1-3°F, the accuracy of atmosphere integrated water vapor content and of liquid water content of clouds is about 10%.

By microwaves satellite experiments were obtained many geophysical results: the variations of earth surface temperature and its emissivity in microwave region, the moisture and hydrometeors distribution.

8. EFFECT OF SEA STATE ON MICROWAVE RADIATION

A. E. Basharinov and A. M. Shutko
Institute of Radioengineering and Electronics, Academy of Sciences, Moscow, USSR

The results of experimental and theoretical investigations indicate that the properties of the thermal radiation of sea surface in the microwave region depend on sea state. As follows from observed data the intensity of the thermal radiation emitted by the sea surface at near nadir angles for example increases when surface is becoming more and more rough. This effect may be explained first of all by the formation of foam which emissivity is of large value in the microwave region. Floating ice may also increase the brightness temperature of sea surface because the emissivity of ice is known to be also of a large value.

Passive microwave measurements over the oceans at wavelengths 8.5, 3.4, 1.35, and 0.6 cm have been carried out from the satellite "Cosmos-243." These observations have detected many regions with large values of brightness temperature which exceed those for smooth surface. Complete analysis of the results of measurements obtained at different wavelengths and a comparison with meteorological data allowed to determine the nature of this effect namely to define stormy regions and areas with heavy cloudiness and precipitations and to indicate the areas with rough sea in the presence of cloudiness.

Some spectral peculiarities for different state of sea surface—calm sea, rough sea, sea with a presence of a floating ice—have been observed under this experiment.

The comparison of the experimental values of brightness temperatures with data of windspeeds obtained from the weather charts of the Meteorological Center of the USSR has exposed the dependence of the emissivity from the strength of wind.

9. THE NIMBUS F EARTH RADIATION BUDGET (ERB) EXPERIMENT

A. J. Drummond, J. R. Hickey, D. T. Hilleary and W. L. Smith
*Eqley Laboratory, USA
**National Environmental Satellite Service, NOAA, USA

The ERB experiment will provide, for the first time, precise monitoring of the Earth's radiation budgets on both synoptic and planetary scales, by simultaneous measurement of (1) incoming Sun radiation; and (2) outgoing Earth reflected and emitted radiation, separately, through concurrent fixed wide-angle sampling of the entire disc and scanning narrow-angle sampling of the angular dependent flux components. Solar spectral measurements, in the ultraviolet and visible regions, are included, as is also separation of visible from near infrared Earth reflectance. The scanning system will yield a series of coherent measurements of the radiances from relatively small terrestrial areas at a number of zenith and azimuth angles; it permits up to nine different angular views of an area. Independent in-flight calibration will correlate the different methods. The radiometer is designed to achieve measurement accuracies of better than 1.0 percent absolute and 0.5 percent relative.

Several methods of treating the ERB data, to obtain local regional and global budgets, will be reviewed. This paper is intended to announce the experiment to the cognizant scientific community and seeks the participation of atmospheric and solar scientists in suggesting any additional ways of interpreting and documenting the results of the experiment.
1. SOME RESULTS OF HEAT, WATER AND SALT BUDGET INVESTIGATIONS IN THE OSLOFJORD

Herman G. Gade
University of Bergen, Bergen, Norway

The principal findings of a four-year survey (1962–65) of the hydrography of the Oslofjord are reviewed with particular reference to the heat, water and salt budgets. Normally, stagnant conditions are encountered below sill level (19.5 m) of the inner basins. With intervals from one to several years spontaneous massive influxes of heavy water replace the deep water of the inner basins. During the stagnant intervals the salinity, temperature and other variables are subject to eddy diffusion leading to a nearly steady change of magnitude.

The appropriate heat, water and salt budgets have allowed a determination of vertical eddy diffusivities with such a high degree of accuracy that it has been possible to conclude that the thermal diffusivity in this case is from 2–4 times as high as that of salt. The diffusivity lies in the range from 0.5 to 10 cm$^2$/sec. In diffusivity is strongly coupled with the static stability.

2. DYNAMICS OF THE HYDROLOGICAL BUDGET OF THE DNIEPER-BUG BRACKISH LAGOON

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The Dnieper-Bug brackish lagoon is a reservoir with a retarded water exchange whose regime is determined by the fresh water inflow from the multiam Dnieper delta and by wind-water exchange with the Black Sea through open Kinburn Strait. The annual fresh water exchange coefficient ($u_{o}$) is between the fresh water inflow and the lagoon storage, makes up an average of 2.0 and changes within the limits from 3.9 (a wet year) to 9.0 (a dry year). The annual coefficient of the sea water exchange amounts to an average of 4.0 and ranges from 6.0 to 2.0. The relation between the inflow of fresh and salt water averages 1.1 and owing to this the lagoon average salinity of 1.5 – 2.0% is maintained.

Due to the run-off component decrease recently the fresh water exchanged has dropped to 15.0 (26.0–8.0) and the average lagoon salinity has increased from 1.9% (1955) to 3.1% (1969).

While using the Dnieper water with 95% annual probability the average fresh water exchange will decrease to 10.0 (23.0–0.0). In dry years the lagoon will be an evaporator without the inflow of fresh water. Since the wind-water exchange with the sea will be kept at the former level the lagoon water salinity will be 2–3% higher than that of the sea. The lagoon average salinity will make up 1.5% and will vary depending on the many-year and seasonal Dnieper run-off and on the wind-water exchange with the Black Sea from 6% (spring water softening in wet years) to 20% (in dry years).
3. TEMPORAL AND SPATIAL VARIABILITY IN GULF OF ST. LAWRENCE CURRENT PATTERNS

S. H. Sharaf El Din* and R. W. Trites**

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**Bedford Institute, Dartmouth, Nova Scotia, Canada

Currents measured for periods of about one month through a number of sections in the Gulf of St. Lawrence (e.g. Cabot Strait, Strait of Belle Isle, Gaspé, Pointe des Monts) commonly show marked variability in daily residual values. Investigations have noted similarity in many instances between fluctuation in daily mean current and atmospheric pressure gradients in the region. In 1967 moored meters were installed at 8 sites between Cabot Strait and Pointe des Monts and the currents recorded simultaneously in order to gain information on spatial coherence in flow variability and to shed more light on the correlation with meteorological parameters. Fluctuations in residual currents in Cabot Strait and Gaspé Passage are closely correlated, although there is little coherence with the currents measured in the central area of the Gulf. Relatively high correlations were found between atmospheric pressure gradients from selected meteorological stations and residual currents at many of the sites, but no simple pattern emerged. The correlation coefficient in general decreases horizontally from Anticosti Island to Pointe des Monts suggesting that estuarine processes dominate the flow pattern here. It is concluded that meteorological parameters play a significant role in determining the oceanographic features throughout much of the Gulf.

4. EFFECT OF SHORELINE IRREGULARITIES ON THE DISPERSION MECHANISM IN ESTUARIES AND OTHER EMBAYMENTS

A. Okubo
Chesapeake Bay Institute, The Johns Hopkins University, Baltimore, Maryland, USA

Irregularities in the shoreline of an embayment play the role of a trap for water properties. The exchange processes of water between the trap and the main body may lead to an effective longitudinal dispersion of the properties such as an introduced pollutant. For example, consider a tagged volume, produced by an instantaneous discharge, as tidal currents carry it up and down an estuary. Frequently eddies associated with shoreline irregularities will temporarily trap water containing a high concentration as the tagged volume is moved past the shore features by the current, while the material trapped is gradually redischarged out into the main stream. When the tide reverses, the process repeats itself, with a resulting dispersion on the opposite side of the tagged volume. The entire process may be called the "entrainment phenomenon." The problem is treated theoretically. A mathematical model for this phenomenon is developed, in which the exchange process of property between the trap and main body can be parameterized by the geometry of the system as well as by the exchange rate coefficient. In effect, the trap behaves as a localized source-and-sink of material for the main body of water.

The model enables us to discuss the moments of the material distribution. It is shown that, depending upon the values of parameters chosen, the presence of trap may enhance or suppress the rate of dispersion in the main stream. This study suggests that the entrainment phenomenon may be a process of practical importance in longitudinal dispersion of substance in estuaries and coastal waters.

5. WINTER SINKING IN THE WESTERN MEDITERRANEAN

H. Charnock
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The deep water of the Western Mediterranean is almost homogeneous, with well defined potential temperature and salinity. It is formed in winter at the surface but until recently little was known about when and where it formed, how it formed and the sinking mechanism generally.

This problem is of more than local interest; it is probably relevant to the sinking of Arctic and Antarctic bottom-water and so to the general circulation of the world ocean as well as to that of the Mediterranean.

Two multiple-ship expeditions have studied this problem, in operations MEDOC 1969 and MEDOC 1970.

In each winter bottom-water formation was observed in a restricted region about 50 km off the Gulf of Lyons. In this restricted region the whole water column became almost uniform, the normal structure (surface water, intermediate water, deep-water) being homogenized by strong mistral winds and the cooling and evaporation they produced.

In this symposium accounts of the work will be presented by some of those who took part in the work at sea. The ships concerned were Atlantia II (US), Bannock (Italy), Jean Charcot (France), Discovery (UK), Hydra (UK), Origny (France), and Maria Pia (Italy).

The arrangements for international cooperation were made informally and largely on the initiative of Professor P. Tchernia (Paris).

6. FORMATION D'EAU PROFONDE EN MEDITERRANEE NORD–OCCIDENTALE

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Le fait que prés de 75% des eaux des océans aient les caractéristiques relativement homogènes d'"eaux profondes" illustre leur importance et celle de la connaissance des mécanismes qui les forment. La présence, au large de la côte méditerranéenne française, d'une telle zone de formation d'eau marine profonde est à l'origine des campagnes "MEDOC" 1969 et 1970.

La petite échelle de temps et d'espace du phénomène qu'avaient révélée les travaux effectués par l'"ORIGNY" (Marine Nationale), pendant la période très froide de janvier à février 1963, exigait que l'on disposât, pour l'étude, de plusieurs navires ou plates-formes travaillant simultanément. C'est ainsi qu'à l'opération MEDOC 1969 ont participé les navires britanniques "HYDRA" et "DISCOVERY" (Dr. J. Swallow), le navire "ATLANTIS II" (Professeur Stommel pas Dr. Miller) et un avion DC4 d'observation météorologique de Woods Hole (Dr. Bunker). Le navire
italien "BANNOCK" (Professeur Frassetto), la "MARIA PAOLINA" (Slaclant Cen), enfin du côté français l'"ORIGNY" (M. Bonnot), le "JEAN CHARCOT" (Professeur Térentia) et la Bousée-Laboratoire (Dr. J. Gouell).


A la fin de janvier et au début de février 1969, existe sur ce méridien, entre 43° et 40°N, le système habituel à trois couches: eau de surface, eau intermédiaire, eau profonde; cependant, les conditions climatiques hivernales agissant sur les eaux relativement denses présentes près de la surface dans la zone centrale du tourbillon cyclonique de la circulation thermohaline, présent dans le secteur, font apparaître vers 42°15' Nord des eaux denses (g = 29.07) sous une couche d'environ 200 mètres, homogène en θ et S (12.82; 38.39).

Après qu'au printemps pendant près d'une semaine des vents violents de NW (Tramontane et Mistral), la structure à trois couches disparait au centre du tourbillon et des eaux homogènes sur des épaisseurs de plus de 1000 mètres apparaissent en des "chimères" qui coupent la couche d'eau intermédiaire antérieurement présente. Les caractères de la masse d'eau s'expliquent par le mélange de l'eau superficielle hivernale présente au début de février avec l'eau intermédiaire: il en résulte une apparition en surface d'une épaisse couche d'eau homogène, relativement chaude et salée qui peut servir à localiser ces "chimères." Plusieurs d'entre elles peuvent exister à des distances réciproques de l'ordre de 10 milles à 20 milles.

Au mois de mai, on constate le rétablissement graduel du système habituel à 3 couches et un fractionnement et une expansion des couches d'eau homogène formées pendant l'hiver.

Il semble que la majeure partie des processus constatés s'explique par pure instabilité statique, sauf peut-être les derniers stades d'homogénéisation très profonde, dans lesquels il est possible que des non-linéarités de l'équation de l'état de l'eau ou d'autres processus soient susceptibles d'intervenir.

Il est très net que les vents sont un facteur décisif dans l'extension verticale des mélanges et dans l'établissement des couches homogènes. Cependant, il n'apparaît pas nettement si le vent joue un plus grand rôle par ses effets dynamiques que par ses effets d'intensification du prélèvement de chaleur (et de vapeur d'eau) par l'air à la mer. Comme il semble que, en cette période d'eau homogène, il ne se manifeste pas de corrélation entre le vent et le courant superficiel (mesures de J. Gouell sur la Bousée-Laboratoire), le second effet (intensification des échanges) paraît avoir l'effet majeur. Le fait que la localisation de la zone homogène se trouve à la convergence des directions, au rivage, de la Tramontane (du NW à Narbonne) et du Mistral (de Nord dans la Vallée du Rhône) conduit à penser que les variations spatiales du vent ont la plus grande importance.

7. DEEP WATER RENEWALS OF SILL FJORDS, A STOCHASTIC PROCESS

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Investigations of deep water exchange in Norwegian fjords with sills have revealed that massive influxes are recurring phenomena with time intervals being essentially multiples of a full year.

A statistical theory is presented in which the event of influx may be predicted in terms of the yearly demand D of the homogeneous density of the resident water in the fjord basin together with the statistical properties of the density of the adjacent coastal water at sill depth. It is found that the frequency distribution f(S) of the density S of the water entering the basin may be obtained from

\[ \int_{0}^{\infty} f(S_{0}) \cdot F(S_{0}, S) \, dS_{0} = f(S) \]

where \( F(S_{0}, S) \) is the conditional frequency distribution for S when the previous influx had density \( S_{0} \).

\( F(S_{0}, S) \) is given by

\[ F(S_{0}, S) = \sum_{n=1}^{\infty} g_{n}(S) \cdot n \cdot O(S_{0}, n-1) \]

Here

\[ g_{n}(S) = g(S) \quad S > S_{0} \cdot mD \]

\[ g_{n}(S) = 0 \quad S < S_{0} \cdot mD \]

where \( g(S) \) is the frequency distribution of \( S_{\text{max}} \) of the adjacent coastal water and is presumed known; and

\[ O(S_{0}, m) = \int_{0}^{S_{0} \cdot mD} g(S) \, dS \]

Application of the theory to observed frequencies is in progress.
8. PROBLEM OF WATER BALANCE OF THE BALTIC SEA

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Knowledge of the Baltic Sea water balance is indispensable for right water
environment appreciation considering system and productivity of the sea. Although
the problem was already taken half century ago, and continued by the Baltic Hydro-
logical Conferences till now has not been worked out complete balance evaluation
based on uniform measurement observation material. At the Baltic Oceanographers
Conferences, Poland suggested the resumption of researches and expressed its readiness to coordinate them.

The paper contains general review of problems concerning water balance. The
author of the article points out the method and scope of the balancing. Other elements of balance against the background of the hitherto advancement of study on them
were covered. Further studies are indispensable in vertical water exchange between the
sea and the atmosphere/atmospherial precipitation and evaporation from water surface.
Water inflow from the basin was already estimated taking as the foundation the period 1951–1960; further ten-year period is under study. Much difficulty appears at
the attempt of estimation of water exchange between: the Baltic Sea and the North Sea.
Indispensable are regular measurements of streams in Danish sounds. At last, more adequate evaluation demands balance retention and water stage estimation.
Furthermore, the author of the paper exhorts to taking up wide collaboration within the Baltic Oceanographers Conferences having stressed the role of the Baltic
water balance as the background for extension research on the discussed sea and methodical significance of the undertaken work for the bases of balancing of the
semi-closed areas.

9. THE MAIN PRINCIPLES OF CALCULATION OF THE WATER AND
SALT BALANCE FOR SEMICLOSED AND CLOSED SEAS

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The characteristic feature of the water and salt balance for semiclosed and closed seas and of their hydrological and hydrochemical regime is their close dependence on the continental runoff and on the water exchange between the adjacent ponds.

The regime and the balance of such seas is greatly variable due to variations of the climate conditions in their basin and to the influence of the man economic activity.

It makes necessary to consider the water and salt balance and hydrological and hydrochemical regime of the seas as a non-stationary or quasi-stationary
process.

In case of the quasi-stationary processes while calculating the water and salt balance it is possible to use the possibility-statistic methods.

For the determination of possible variations of hydrological and hydrochemical
regime of seas with the non-stationary process the helio-geophysical relations between the
main components of the water and salt balance and the hydrological and hydrochemical characteristics of the sea are used.

For the more detailed investigation it is necessary to allow for the reactive influence of the variations of the morphometric seas parameters.

In case of calculation of the water and salt balance for the short periods of time (the year, the season, the month) the influence of the temperature stratification of the
atmosphere on the main expenditure component of the balance—the evaporation—is essential.

The lack of hydrometeorological informations on the open sea regions results in the
great difficulty of the calculation of the water and salt balance for the short periods. This deficiency can be partly made up by the zonation of the sea on the
basis of long-term data.

10. EXCHANGE OF PLANKTON IN SEMI-ENCLOSED MARINE BASINS

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In a study of the exchange of phytoplankton in a small semi-enclosed marine basin, plankton concentration has been shown to be an important water quality parameter, capable of giving information about the mixing processes in the basin. The ingoing and outgoing fluxes of phytoplankton were measured at three depths in the entrance of the basin every hour for 25 hours. Phytoplankton concentration at the entrance was correlated with the transport, since the water inside the basin is richer in plankton than the water outside. The regression of phytoplankton concentration on transport in a given depth zone describes the intensity of mixing at the mouth of the basin. Of the total phytoplankton export (which constituted 11% of the total stock in the basin), 35% was exchanged via the mean flow and 65% was exchanged via the fluctuations in the flow. A five-fold variation in phytoplankton concentration was observed at the entrance during the 25 hours. The fluctuations were about 2% hours out of phase with the tide. Time series observations in the
centre of basin revealed considerable short-term variability in phytoplankton concentrations, but the fluctuations there were smaller in amplitude than those observed at the entrance, and the phase lag with the tide was longer.

The data illustrate how the exchange properties of any quantity in a coastal
embayment depend on the distribution of the quantity with depth, and on the
relative speeds and thicknesses of the seaward and landward flowing layers. The
results have been used in a successful balance of the short-term phytoplankton
budget of this basin.
1. O. A. Goushchin and L. M. Krivelevich
   On the theory of ocean current in the low latitude area

2. B. I. Tjurjakov and L. N. Kuznetsova
   Wind and thermohaline currents and their variability as related to variations of macronosynoptic processes

3. R. P. Bulatov
   Oceanic gyres and geostrophic eddies in the water circulation of the Atlantic Ocean

4. L. M. Fomin and V. B. Titov
   Inertial oscillations in horizontally non-homogeneous field of current velocity in the ocean

5. A. E. Bukatov, L. V. Cherkasov and S. F. Dotsenko
   Internal waves from atmospheric disturbances in a continuously stratified ocean

6. Z. K. Abuzayrov
   A study on relationship between the fields of sea and atmospheric pressure fields in the North Atlantic

7. V. I. Cooksa
   On peculiarities of the formation and distribution of the Indian Ocean intermediate layers

8. V. S. Zlobin
   Formation of fields with higher oxygen concentration in the ocean and their interaction with atmosphere

   Indirect checking results of theoretical models of the development of sea waves in connection with their spectral structure

10. L. M. Fomin
    New data on a vertical structure of current velocity in the ocean

11. E. I. Serjakov and A. I. Smirnova
    Large-scale heat interaction of the atmosphere and the ocean in the North Atlantic

12. M. G. Glagoleva and L. I. Skriphtunova
    Forecasting of the ocean water temperature in the warm season of the year

13. G. N. Mileyko
    Calculation of water temperature distribution in Atlantic and Pacific Oceans in the cold season

14. V. V. Rossov
    On the influence of the temperature field in the North Atlantic on development of atmospheric processes

15. O. I. Shremetevskaya
    On correlations between sea surface temperature, heat fluxes and atmospheric circulation in the North Pacific

16. S. I. Kan
    Ocean temperature field and prediction of ice phenomena on seas

    Large oceanographic experiment in the North Atlantic

18. L. I. Boris
    On seasonal variability in the tidal waves
1. ON THE THEORY OF OCEAN CURRENT IN THE LOW LATITUDE AREA

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The purpose of this report is the investigation of the non-homogeneous fluid motion in the neighbourhood of the equator, the depth and boundary conditions of this fluid being in agreement with the real data.

Let the sea water motion be steady. The eddy friction due to vertical and horizontal transfer of momentum, horizontal pressure gradient, inertia forces and Coriolis forces are taken into account in balance forces in the horizontal direction. In the vertical direction, the hydrostatic condition is taken. The fluid is considered to be incompressible. The equation of density diffusion is taken in the form suggested by P. S. Linelkin.

Taking this into account we write the system of non-linear hydrodynamic equations in the form of

\[ \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} + \frac{\partial W}{\partial z} = -\frac{1}{\rho_0} \frac{\partial p}{\partial x} \]

\[ \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} + \frac{\partial W}{\partial z} = -\frac{1}{\rho_0 g} \frac{\partial p}{\partial y} \]

\[ \frac{\partial U}{\partial z} = \frac{\tau}{\rho} \]

\[ \frac{\partial U}{\partial z} = \frac{\rho}{\rho_0} (x, y) \]

For the following boundary and initial conditions when \( z = \xi \), where \( \xi \) is a free surface level

\[ \frac{\partial U}{\partial z} = \frac{\tau}{\rho} \]

\[ \frac{\partial U}{\partial z} = 0 \]

\[ \frac{\partial U}{\partial z} = \rho = \rho_0 \quad (x, y) \]

when \( z = H \)

\[ U = V = W = 0 \]

\[ \frac{\partial p}{\partial x} = 0 \]

On lateral walls

when \( x = 0 \)

\[ \rho = \rho_w (y, z) \]

\[ U = V = 0 \]

when \( x = L \)

\[ \rho = \rho_e (y, z) \]

\[ U = V = 0 \]

2. WIND AND THERMOHALINE CURRENTS AND THEIR VARIABILITY AS RELATED TO VARIATIONS OF MACROSYNOPTIC PROCESSES

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The results of the theoretical computation of the three-dimensional large-scale stationary fields of the wind and thermohaline currents in the North Atlantic and the data about their variability as related to the variations of the macrosynoptic processes in the atmosphere are given in this paper.

The computation was made according to the theoretical model proposed by P. S. Linekin based on the linear theory of the baroclinic layer of the ocean. The method used by the authors was supplemented with some new results. These are an approximate method of computation of the gradient current in the surface layer and a new form of the boundary condition for the basic differential equation to compute the thermohaline currents. The method used in the paper is sufficiently sensitive and is suitable for the study of the variability of the wind and thermohaline currents.

The relief of the free surface of the ocean, the wind and thermohaline perturbations of density, the velocities of currents and vertical motions were computed on the digital electronic computer, the program was written in ALGOL. All the computations were carried out for 14 levels in the vertical.

The wind currents were computed for three subtypes of the large-scale atmospheric processes \( W_1, W_2, W_3 \) (according to the typification proposed by M. A. Valerianova) using the mean monthly values of the wind stress for December 1957, April
and August 1958. The thermohaline currents are given for four seasons of the mean year for many years. They were computed using the average data for many years of the heat-and-moisture exchange.

Some results of the computation are shown in figures 1-3 by the schemes of the resulting (wind and thermohaline) currents for winter (subtype W3), spring (subtype E1), and summer (subtype E3).

The main part of the wind circulation in the surface layer is characterized by the enormous anticyclonic circulation of water (15°–45°N). The well-known currents of the North Atlantic appear clearly along the edges of it. The mean velocities of the wind currents are equal 30–40 cm/sec (W3) and 20–30 cm/sec (E1, E3), the maximal magnitudes, 80–120 cm/sec. The wind circulation in the deep layer consists of the vast cyclonic circulation of water with well-expressed counter-currents. The mean velocities are equal 5–10 cm/sec (W3) and 2–5 cm/sec (E1, E3).

The thermohaline circulation displays the rather complicated character differing from the wind circulation. During all the seasons of the mean year the transfer of water in the surface layer predominates in the direction from the Equator to the North Pole, in the deep layer — on the contrary. The mean velocities in the surface layer are equal 10–20 cm/sec in summer and 30–40 cm/sec in winter, in the deep layer, 2–5 cm/sec and 5–10 cm/sec respectively.

The obtained results show the variability of the wind and thermohaline currents. It is caused by the variations of the macroscopic processes and processes of the heat-and-moisture exchange between ocean and atmosphere. All the elements of currents and vertical motions are changeable. The variability of the wind and thermohaline currents caused by the variations of macroscopic processes in the atmosphere (the character of the transfer of air masses, the intensity of these processes, the season course of the heat-and-moisture exchange) is one of the consequences of the large-scale interaction between atmosphere and ocean.

A relative estimation of the role of the wind and thermohaline currents in forming the resulting ocean circulation in the North Atlantic is given in the paper too. The role of the wind circulation is predominant. The contribution of the thermohaline currents averages 20–30%. However their relative role increases to 50–60% in the air-sea interaction centres (by the coast of the North America and of the Northwest Africa). The role of the thermohaline circulation increases with a depth. At the depth 2000 m its contribution is equal to about 50%. In spite of the lesser intensity in comparison with the wind circulation, the thermohaline circulation is of importance in forming the resulting circulation. Many peculiarities of the ocean circulation are caused by the thermohaline currents.

The comparison of the obtained results with the data of the instrumental measurements of currents and of the observed distribution of phosphorus and oxygen was done in the paper. Satisfactory accordance takes place almost in all the links of the three-dimensional circulation.

The authors take an opportunity to report that Professor V. V. Timonov gave much attention to this investigation and they dedicate this paper to the memory of him.

Fig. 1. Calculated scheme of the resulting currents for the winter subtype W3:
(a) at the depth 100 m, (b) at the depth 2000 m.
The velocities are given in cm/sec. Inset maps in the right corners show the corresponding schemata of the vertical motions; the zones of the upwelling are shaded.
Fig. 1. Calculated scheme of the resulting currents for the summer subtype E4:
(a) at the depth 100m, (b) at the depth 2000m.
The velocities are given in cm/sec. The rest of the explanations are
given in text.

Fig. 2. Calculated scheme of the resulting currents for the spring subtype E5:
(a) at the depth 100m, (b) at the depth 2000m.
The velocities are given in cm/sec. The rest of the explanations are
given in text.
3. OCEANIC GYRES AND GEOSTROPHIC EDDIES IN THE WATER CIRCULATION OF THE ATLANTIC OCEAN

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Computations of geostrophic currents were carried out for different time space scales using averaged thermocline observations conducted from 1872 to 1967. As reference surface was taken the depth of 4000 db., near close to the boundary dividing the deep and bottom waters. The investigations show that the rearrangement of circulation takes place in the layer boundaries, between structural zones, therefore any one of them may serve as reference surface. Formerly these computations were made by the author from a reference surface of 1500 db., which lies the border line separating the intermediate and deep water, the basic features of dynamic topography obtained with different reference surface remained the same.

Extremal values of variances of dynamical heights obtained for one-degree and five-degree trapezia were used for eliminating small-scale disturbances and revealing reliable non-uniformities of dynamic topography. Right macrocirculation system succeeding one another in a meridional direction and placed symmetrically relative to the equator (four in each hemisphere). Within the boundaries of large-scale gyres eddies are traced with a diameter of nearly 500 km. Their total number in the Atlantic Ocean exceeds 50.

The rearrangement of horizontal geostrophic circulation can be traced on the charts. With the passage from surface to intermediate waters the northern subtropical anticyclonic gyre is transformed into two cyclonic gyres divided by the North Atlantic ridge. The other macrocirculation systems are preserved slightly displaced to the high latitudes and divided into smaller gyres. In deep waters the meridional component of water circulation increases considerably. Thus the zonal circulation, prevailing in the surface layers is gradually rearranged into a meridional one, which increases intensity with increasing depth.

4. INERTIAL OSCILLATIONS IN HORIZONTALLY NONHOMOGENEOUS FIELD OF CURRENT VELOCITY IN THE OCEAN

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1. Inertial oscillations of velocity are generally seen on data of long time measurements of current velocity in the ocean. As it follows from analysis of data they are irregular very much and their periods differ from a value corresponding to the latitude. They have also another interesting feature which brings them out a set of periodical phenomena in the ocean.

It is clear that inertial oscillations result from the Earth's rotation effect on nonstationary current velocity field. Their structure has to depend on current velocity structure as like as on variations which took place in the velocity field.

2. Influence of horizontal nonhomogeneity of current velocity field on inertial oscillations is discussed. Oscillations of velocity $u$, $v$ are described by an equation system

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} - \lambda v = 0,$$

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + \lambda u = 0.$$  

An averaged current velocity field $u_0$, $v_0$ is assumed to be known.

Terms $\frac{\partial u_0}{\partial x}, \frac{\partial v_0}{\partial y}$ have been neglected in (1) to avoid a functional dependence of $u_1, v_1$ on $x$ and $y$. It is known from measurements that a coherence of inertial oscillations vanishes rapidly with distance increase.

Solution of (1) is periodic if

$$\text{div} \mathbf{u}_0 < 2 \left( \lambda^2 + \lambda \text{rot} \mathbf{u}_0 + \frac{\partial u_0}{\partial x} \frac{\partial v_0}{\partial y} - \frac{\partial v_0}{\partial x} \frac{\partial u_0}{\partial y} \right).$$

(2)

Unequality (2) is a condition of existence of inertial oscillations in current velocity field.

As it follows from solution the inertial oscillations have a frequency

$$\omega^2 = \lambda^2 + \lambda \text{rot} \mathbf{r}_0 - \frac{1}{4} \left( \text{div} \mathbf{u}_0 \right) + \frac{\partial u_0}{\partial x} \frac{\partial v_0}{\partial y} - \frac{\partial v_0}{\partial x} \frac{\partial u_0}{\partial y}$$

(3)

being determined by Coriolis' parameter and horizontal nonuniformity of flow.

3. Such peculiarities of inertial oscillations follow from the solution of the problem:

a) Period of the oscillations differs from a value corresponding to the geographical latitude. A magnitude of difference of the period from $2\pi/\lambda$ is mainly determined by a current velocity vorticity: $T < 2\pi/\lambda$ if the vorticity is positive; $T > 2\pi/\lambda$ if the vorticity is negative.

b) The inertial oscillations of current velocity are unisotropical in a horizontal plane. Orbit deformation depends on a horizontal nonuniformity of current velocity field.

c) An amplitude of the oscillations varies in time. It increases if a divergence of current velocity is negative and it decreases if the divergence is positive. The amplitude is always reduced by a lateral friction.

d) Trajectories of water particles oscillating with inertial period are unlinked. The effect will be the same if a portion of oscillation energy transfuses into progressive movement. The translusion of energy is not large when current velocity divergence is positive but it can be significant if the divergence is negative.

4. Theoretical conclusions and results of current measurements carried out in the Indian Ocean, 1967, are compared. A coincidence seems to be quite satisfactory.
A period of oscillations and an orbit form correspond to horizontal structure of current velocity field.

The hypothesis is constructed that meanders of stream currents of the Gulf-stream type can be hypothetrical orbits of inertial oscillations of current velocity interacting nonlinearly with a current velocity field.

5. INTERNAL WAVES FROM ATMOSPHERIC DISTURBANCES IN A CONTINUOUSLY STRATIFIED OCEAN

A. E. Bukatov, L. V. Cherkesov and S. F. Dotsenko

Internal waves generated by atmospheric disturbances in a continuously stratified ocean are investigated. Three models of continuous density stratification are discussed: a one-layer model with density varying from the free surface to the bottom of the sea according to the exponential law; a two-layer model with the homogeneous lower layer and inhomogeneous upper one; a three-layer model with the density discontinuity layer in the upper and lower layers density is constant and in the middle transient layer it varies according to the exponential law.

1. An analytical solution to the problem of internal waves arising under the action of periodic in-time disturbances of the atmospheric pressure both concentrated in some (fixed) area of the ocean surface and travelling in the strip or on the whole free surface is obtained for the above density models under the assumptions of the linear theory of waves in a non-uniform fluid of finite depth (Fjelstov theory).

It is shown that internal waves can arise only at oscillation frequency less than that of Vissal-Brent. The relationship between the elements of arising internal waves and the vertical structure of velocity field and the character of density stratification, frequency of atmospheric disturbances, Coriolis parameter value and depth of the ocean is studied. It is proved that at long period oscillations the inhomogeneity of sea water intensifies exchange processes through the whole ocean thickness.

In the case of periodic travelling disturbances of the atmospheric pressure the presence of an infinite spectrum of resonance pressure wavelengths is indicated. The dependence of these lengths on the density drop and thickness of the layers is found out. It is shown that one can obtain a well pronounced phenomenon of "dead water" by the corresponding selection of wavelengths.

2. An investigation of the steady internal waves generated by baric disturbances applied in the strip travelling with constant velocity in the direction perpendicular to its generatrix is carried out for the above density models discussed. Coriolis force is not taken into account.

It is shown that the generated wave motion consists of two motions: one motion is present everywhere, attenuates exponentially while moving off the area of application of disturbing pressure, the other (wake) exists only in the area beyond the strip, it does not attenuate and is formed by the sum of harmonic components. Their quantity is dictated by the value of parameters of the problem for which the wave number is equal to zero. This conclusion allows one to divide the area of space of parameters into areas with the constant number of harmonic components of which an undamped wake is formed.

It is shown that the component with the least wavelength is weakly disturbed by a surface wave due to inhomogeneity. Its amplitude decreases exponentially with depth and is small in the ocean thickness. Internal wave motions are conditioned by other components. They are most intense in the vicinity of levels with maximum gradients of density. Criteria of the internal waves generation are found, their dependence on parameters of the problem are investigated.

A numerical analysis of velocity field along the vertical and horizontal is performed. Its dependence upon the velocity of travelling of baric disturbances, density stratification and layers thickness are studied.

6. A STUDY ON RELATIONSHIP BETWEEN THE FIELDS OF SEA AND ATMOSPHERIC PRESSURE FIELDS IN THE NORTH ATLANTIC

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The physical-statistical method has been elaborated at the Hydrometeorological Research Centre of the USSR for forecasting the fields of sea in the North Atlantic based on the visual observations of the state of sea.

The method is based on the simple physical conception that fields of sea depend on the fields of wind, which in their turn, are determined by the atmospheric pressure fields.

For the point analysis of changing atmospheric pressure fields and fields of sea, it is convenient to present the latter by expansion into series with respect to some functions, for example Chebyshev polynomials, as it is done in this study. Then the series coefficients can be used as arguments when constructing the prognostic equations.

Such approach makes it possible to take into account the development of wind waves with space and time.

As initial data for the construction of prognostic equations, synoptic charts of atmospheric pressure and state of sea were used for 1960—1961 winter which were issued at regular intervals four times a day. Data on pressure and state of sea were taken for analytical representation in the points of the grid determined beforehand.

For each of points by the method of least squares using computers, the linear equations were constructed as follows:

\[ h_{x,y} = \int (A_y, B_y) \]

where \( h_{x,y} \) projections of wave height (taking into account the direction) on the axes of coordinates at the moment of the forecast; \( A_y \) coefficient of series of atmospheric pressure fields taken at the moment of the forecast; and \( B_y \) coefficients of series of sea fields at the moment of forecast compiling.

Obtained correlation coefficients almost over all the calculated area have values ranging from 0.70 to 0.85. It is obvious that the greatest correlation coefficients are associated with regions where wind waves are prevailing.
The suggested method for forecasting the state of the sea was examined in the operational work. Unlike other methods of forecasts of wave parameters, it is convenient for the use of computers since it excludes direct determination of the fetch of wind and the duration of its action.

In practice, each time computing the forecast the forecaster must only take from the analyzed wave charts the values of initial heights of wave at the moment of compiling the forecast and after computing to map the results. The computation is made in steps of 6-hour intervals. The computed sea field after each step is assumed as initial for the next step, etc.

The calculations of prognostic sea fields using obtained equations have given satisfactory results. They are within the limits of the accuracy which it is possible to obtain from data of visual observations of sea.

7. ON PECULIARITIES OF THE FORMATION AND DISTRIBUTION OF THE INDIAN OCEAN INTERMEDIATE LAYERS

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In the Indian Ocean there are two main regions of formation of surface waters of such density as to enable them to spread at intermediate depths. The first region in the northwestern part of the ocean with its adjacent basins is the source of high salinity water, the second one — Antarctic zone — is source of low salinity water.

Each intermediate layer occupies a definite depth. Besides, the intermediate layers of the Indian Ocean, within the limits of their distribution, are characterized by rather constant density values especially in the core of these layers. Hence it is obvious that the water properties are transported at intermediate depths mainly along isopycnal surfaces by advection and large-scale horizontal diffusion.

Data from more than 8,000 hydrographic stations (from 1903 to 1965) have been averaged by 5 by 5° areas. Based on the averaged data the core layers and corresponding density values have been determined from T,S-curves. Density values were also determined for the vertical limits of the intermediate layers. The determinations made possible to establish the horizontal limits of the intermediate layers on the assumption of an isopycnal transport of water properties. It is also possible to consider these limits as boundaries between water masses structures of the North Indian Ocean.

Root-mean-square values were calculated for evaluating space variability of density values in the core layers and at their vertical limits. (See table.) Comparatively small root-mean-square values were in good agreement with the assumption that the water properties are transported at intermediate depths of the Indian Ocean mainly along isopycnal surfaces. The most favourable conditions for this process are found in the core of the intermediate layers. In the Persian-Arabian intermediate layer, the isopycnal distribution of water properties is less pronounced. We also came to the conclusion that the density values in the core and at the vertical limits of the intermediate layers are quasi-constant through the year north of 10° South Latitude.

8. FORMATION OF FIELDS WITH HIGHER OXYGEN CONCENTRATION IN THE OCEAN AND THEIR INTERACTION WITH ATMOSPHERE

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As it is known an increase of the relative oxygen content in sea water is specified by a spring-summer blooming of phytoplankton and water cooling during ice formation.

A greater part of the Norwegian Sea area is free of ice. In winter period the oxygen saturation by Fox in a 0–50 m layer of warm Atlantic waters at 63°00'–67°30'N corresponds to (97.1 ± 0.5)%, if n = 500. It is (95.9 ± 0.7)%, if n = 8 at a 0 m depth in cold waters of the East Icelandic Current. In spring-summer period the oxygen saturation at a 0 m depth on the section at 67°30'N in warm waters increases up to (107.7 ± 2.3)% (n=9), in cold waters — up to (113.1 ± 2.9)% (n=6), in mixed waters — up to (107.8 ± 2.8)% (n=6).
As for configuration of curves representing the relative oxygen content (Fig. 1), they are similar to those of normal value distribution and formally can be represented (e.g., 1968) by the following formula:

$$C_{ox} = 109.3 \cdot e^{-0.015(t-6.5)^2}$$

where $C_{ox}$ – oxygen concentration, %; $t$ – time, months $4 \leq t \leq 10$.

$\sigma = \pm 2\%$

Functional dependence between the height of sun above the horizon and oxygen production was determined on diurnal stations. A greater number of points is situated along ellipse or in the interval:

$$\min \{y_i\} \leq 0 \leq \max \{y_i\}$$

The decision of the mathematical model of phytoplankton system produced oxygen showed that velocity of $O_2$ production ($V_1$) might be greater than quadruple rate of biochemical consumption and diffusion ($V_2$), i.e., $V_1 > 4V_2$.

If we take the observed oxygen saturation ($97.1 \pm 0.5\%$ for zero, then while using the value $\Delta O_2$ ml/l, curves were characterized by superoxigenation in sea water in 1965–1970, after that the squares of obtained figures were measured with a planimeter. If we assume that the oxygen excretion across the boundary water–atmosphere is the predominant process, then we according to Bull (1947) express the concentration of $O_2$ by means of square and after that the diffusion coefficient $D$ was calculated by method of maximal ordinate ($y_m$)

$$D = \frac{S^2 \rho}{4n\pi(y_m)^2}$$

where $S$ – square, cm$^2$; $\rho$ – scale coefficient, $\sigma$ – time, day, $y_m$ – maximal ordinate, cm. Diffusion coefficients in warm, mixed and cold waters are $(5.9 \pm 2.5) \times 10^4$, $(5.4 \pm 1.4) \times 10^3$, and $(5.0 \pm 1.4) \times 10^3$ cm$^2$·sec$^{-1}$ respectively, while mean temperatures for 6 years are: $(7.34 \pm 0.62)^{\circ}\mathrm{C}$, $(5.22 \pm 0.71)^{\circ}\mathrm{C}$ and $(1.33 \pm 0.47)^{\circ}\mathrm{C}$.

Temperature coefficients calculated with allowance for molecular viscosity of sea water were to be equal to: $k_1 = 1.332$ and $k_2 = 3.510$. Redfield, A (1948) determined the exchange coefficient for summer period in the Gulf of Maine: $1.08 \cdot 10^4$ ml·sec$^{-1}$ through 1 cm$^2$ with mean water temperature of $16.3^{\circ}\mathrm{C}$. By introducing the temperature coefficient from 7.34$^{\circ}$ to 16.3$^{\circ}$ amounted to 1.745, we’ve obtained the respective coefficient $1.02 \cdot 10^4$, i.e., good coincidence of results of observations. Analogous values were theoretically obtained by Okubo, A (1957).

Therefore, the formation of the fields of higher oxygen content results from fast rates of its production by phytoplankton and fairly slow diffusion of $O_2$ across the boundary ocean-atmosphere.

9. INDIRECT CHECKING RESULTS OF THEORETICAL MODELS OF THE DEVELOPMENT OF THE SEA WAVES IN CONNECTION WITH THEIR SPECTRAL STRUCTURE

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1. Numerous results of empirical spectral analysis for different stages of wind waves growth and also data about changes of visible waves distribution moments were used for the study of correlation between the values of spectral density function and its time and space derivatives.

2. Following initial data have been used:
   - for calculations of two-dimensional spectra: 102 stereophotographs (from 150 x 350 sq.m to 300 x 600 sq.m) of wave surface for weak, moderate, stormy seas (mean wave heights up to 4 m);
These expressions were used for indirect model verification of wave growth and propagation proposed by Phillips and Miles in connection with the possibility of linear approximation \( S'(S) \).

5. Cases of stationary nonhomogeneous and nonstationary homogeneous changes of spectral characteristics were treated separately.

The calculations show that the correlation between \( S' \) and \( S \) is substantially nonlinear and may be formally expressed by the 4th power polynomial for the specific conditions of wave-forming. The input of linear component is equal to \((0.5 - 0.8) S'\).

The dependence of \((S' - S')_S\) on \( S \) is also nonlinear. Changes of \( S' \) caused by the nonlinear interactions in the wave spectra were calculated by approximative expression of Burnett which is based on the Hasselmann’s theory. The correlation between \((S' - S')_S\) and \( S \) may be approximated as linear only for the initial stages of wave growth. The free term \( \omega \) of the approximative dependence varies from \(10^{-5} \text{cm}^2\) for wind velocity \(10\text{m/sec}\) to \(10^{-7} \text{cm}^2\) for wind velocity \(20\text{m/sec}\) which is higher than its estimations by the Phillips’ theory. Angular coefficient \( \beta \) has the order of magnitude \(10^{-4}\) sec and increases with the growth of wind velocity. Its values are close to the Miles’ estimations but less than those obtained experimentally by Burnett and Wilkerson and Snyder and Cox (not counting nonlinear interactions in the wave spectra).

10. NEW DATA ON A VERTICAL STRUCTURE OF CURRENT VELOCITY IN THE OCEAN

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1. In order to find details of vertical distribution of current velocity in the ocean a number of measurements carried out in the Indian Ocean, in the Pacific, in the Atlantic Ocean, in the Black Sea and in the Mediterranean have been processed and analysed. The analysis has showed that there is a clearly seen tendency of alternating rotations of velocity vector to the left and to the right on a background of smooth decrease of averaged current velocity with depth. A current velocity vector turns against a visible movement of the Sun in a surface homogeneous layer and in the upper portion of a thermocline, it turns at opposite direction in lower portion of a thermocline if one looks downward. More compound picture of a current velocity distribution with depth – four and more layers with alternating direction of a velocity vector rotation, has been found there where an ocean thermocline includes intermediate homogeneous layers. Current velocity vector rotates at mutual reversed directions at the northern and southern hemispheres when another conditions are the same.

There are hopeful conditions to form an intermediate counter-current into a layer where two spirals drawing current velocity vector rotation are conjugated. Somewhere this condition is realized.

Smooth vertical profiles of current velocity correspond quite well to low following directly from Stockman’s density model.
2. Peculiarities of a current velocity structure described above are illustrated by observations collected in different areas of the ocean. Of the most interest is measurements carried out in a zone of the Equatorial undercurrent in the Atlantic near 1° of the southern latitude. As it is seen on figures the counter-current is brought into being by means of conjugation of two spirals having mutual reverse rotation. The spirals are drawn by ends of current velocity vectors.

3. An attempt is made to describe theoretically the vertical structure of current velocity observed in the ocean by a mechanism of nonlinear interaction between low frequency and high frequency components of water movement. Such model is adequate after averaging of basic equations to a frictional model including a variable coefficient of vertical viscosity. A scale analysis has shown an effective coefficient of vertical viscosity has to be somewhere as large as $10^{-3}$ to $10^{-4}$ cm$^2$ sec$^{-1}$ to satisfy this model. It is assumed that inertial oscillations of current velocity can be a spectral component of water movement which is able to set up a powerful vertical exchange of momentum in the ocean.

4. An attack of a problem concerning inertial oscillations of current velocity in the homogeneous ocean has shown that the oscillations bring into being a vertical flux of momentum. A vertical friction coefficient corresponding to this flux has a magnitude of a requisite order besides its vertical distribution is in harmony to vertical distribution of current velocity observed in the ocean.

11. LARGE-SCALE HEAT INTERACTION OF THE ATMOSPHERE AND THE OCEAN IN THE NORTH ATLANTIC

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The investigation of the problem on the interaction between the atmosphere and the ocean involves a study of thermal and dynamical processes occurring in the active oceanic layer and greatly affecting the results and the exchange mechanism in the atmospheric boundary layer.

In this work the heat characteristics are considered of the surface and deep waters of the northern part of the Atlantic Ocean and their relation to atmosphere circulation variability over the North Atlantic.

Heat budget components for the ocean surface heat advection and the active layer heat amount variations were calculated on the basis of hydrometeorological observational data, averaged over different space and time scales.

In this work an attempt was made to take into account the atmospheric stratification influence upon heat and water turbulent fluxes.

Values of advection and heat amount variations were calculated for the variable active layer depth. In the first place a classification of different regions of the North Atlantic was made according to active layer depths.

Many-year means of heat amount variations were calculated by means of the temperature on standard depth levels. To determine the variations of monthly means of active layer heat amount for individual years the method was used of calculation of heat amount according to variation of the surface water temperature.

The advection heat influx for every month of a "mean" year, was calculated by currents and temperature fields, and the advection heat influx for individual years was determined as the rest term from the heat balance equation for the ocean active layer.

Heat and water exchange through the sea surface is of different intensity in different regions. The variability of heat loss centers activity may be illustrated when investigating the large-scale ocean-atmosphere interaction, and so the especially active domains may be named the centers of ocean-atmosphere interaction.

In this paper such centers were pointed out for all the seasons of the year. The intensity of heat loss centers is maximum in cold season (36 kcal/cm$^2$ month) and decreases to 4–6 kcal/cm$^2$ month in warm season. The summary heat influence of the ocean upon the atmosphere in the winter season reveals considerable space differences in the North Atlantic.

One can clearly fix the heat loss center between 30° and 40°N. The second region of active heat loss is situated southeast of Newfoundland and the third is southwest of Greenland. The fourth heat loss center is in the Norway and Barents seas.

The results of the comparison of the summary heat loss to different synoptic characteristics allow us to conclude that the center formation in the cold period is evidently related to high wind speeds and to the spreading of cold air, coming from the continent over the warm waters of the Gulf Stream, North Atlantic current and their warm branches.

On the other hand, in winter, in the regions of ocean-atmosphere interaction centers places of intensive cyclone formation are situated; the principal cyclone travel paths go over the heat loss centers and cyclone depth in these regions is small. This coincidence seems not to be incidental and the main role in formation of cyclones in the center region belongs to the energy obtained by the atmosphere from the ocean.

The determined heat loss centers coincide to regions of action and formation of warm currents and it is in turn connected with thermal processes occurring in the ocean active layer.

The interannual variability of the atmospheric and oceanic interaction sources, heat content and advection were studied against the background of variations in the atmospheric circulation character. The comparison of typical distributions of heat balance components with peculiarities of the atmospheric circulation gave satisfactory results. The calculated active layer heat balance components, obtained up to now for the last 20 years, permitted to consider the inter-year oscillations of heat balance characteristics and to evaluate their role in the process of the large-scale thermal ocean-atmosphere interaction.

12. FORECASTING OF THE OCEAN WATER TEMPERATURE IN THE WARM SEASON OF THE YEAR

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The development of the water temperature forecasting methods is associated with the general problem of air-sea interaction. When solving this problem it is necessary to investigate the relations between atmospheric processes and water
circulation, the influence of currents and sea disturbance, the role of heat flows through the ocean surface, etc. The contemporary applicability limits of the theoretical studies for forecasting necessitates the development of methods based on the analysis of physical processes into account the local peculiarities of sea regions in question.

At the Sea Department of the Hydrometeorological Centre of the USSR the work is carried out dedicated to the methods of long-range, as well as short-range, forecasts of ocean water temperature; the basis of the methods has been laid in the investigations by Prof. Belinsky N. A.

The short-range method of water temperature forecasting is based on consideration of heat flows through the ocean surface and current heat advection. The components of heat budget that is insolation, back radiation, sensible heat and evaporation are calculated for evaluation of heat flows through the surface. In order to estimate advection immediately it is necessary to know the current velocity and water temperature gradients. In cases when the required information is not available the current influence is defined indirectly on the basis of the atmospheric pressure field.

Water temperature changes $\Delta t$ are defined by formula

$$\Delta t = f(B_q, \Sigma Q),$$

where:

$B_q$ — coefficients of series expansion according to the orthogonal function system of atmospheric pressure field;

$\Sigma Q$ — heat flows through the ocean surface.

To calculate the vertical water temperature curve formula is suggested:

$$t_h = t_{av} + \Delta t_1 e^{b(h-1)^n} - \Delta t_D e^{(D-b)m}$$

where:

$t_{av}$ — average layer temperature;

$\Delta t_1$ and $\Delta t_D$ — water temperature deviation at the surface and at the lower boundary of the layer from the average layer temperature;

$b, d, m, n$ — quantities depending on factors defining the features of heat flows propagation;

$h$ — normal coordinate.

While forecasting the water temperature distribution on the ocean surface the orthogonal function series are also employed for analytical description of temperature fields. In that case the forecast problem reduces to definition of series coefficients of the temperature field. On the basis of predicted coefficients temperature values are calculated in every point of the field.

The possibility of long-range ocean water temperature forecasting in the warm season is based on the hypothesis of predominant influence of winter processes on the water temperature. The latter is due to the fact that in winter the air-sea heat interaction is more pronounced than in summer. In winter the sensible heat and evaporation are of great significance. During the warm season these components are lower and insolation-minus-back-radiation value changes from year to year within small range.

Therefore water temperature anomalies are formed usually in the cold season at least in the upper sea layer. Thus the water temperature in summer can be calculated from initial data and heat losses in winter. Heat losses through the ocean surface may be defined indirectly on the basis of atmospheric pressure fields, since the thermal condition of the atmosphere and the character of its interaction with the ocean to a great degree are governed by intensity and direction of air currents.

Water temperature in summer months is predicted by the use of correlation between water temperature anomalies in regions of weather ships and the field of atmospheric pressure over North Atlantic and North America with account for initial conditions.

13. CALCULATION OF WATER TEMPERATURE DISTRIBUTION IN ATLANTIC AND PACIFIC OCEANS IN THE COLD SEASON

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This report deals with the methods of precalculation of water temperature and convection depth that is applied in the operational practice of the Hydrometeorological Centre of the USSR.

The calculation of the water temperature for the water column with cross-section of 1 cm$^2$ and height $H$ is reduced to the solution of the following equation:

$$\frac{dt_w}{dr} = \frac{\partial Q}{\partial r} - \frac{\partial t_w}{\partial r} \frac{df}{dr}$$

where $\partial Q$ — heat discharge through the surface, $H$ — the depth of convectional mixing, $\partial t_w/\partial r$ — the temperature gradient of water in the direction of the horizontal water transfer, $df/dr$ — the flow velocity in the horizontal surface, $C_p = 1$.

The calculations are made with the aid of numerical integration by a computer with a step of 1 day in the points of standard grid north of 15° N. The points are crossing of latitudes and longitudes in 25° and 5° respectively. To make the field more detailed the grid of double density is selected for the Newfoundland bank, Labrador shelf, Faeroes and Scotland region while in the Sea of Okhotsk and Bering Sea it is in 1°.

The heat losses can be calculated with sufficient accuracy by the difference between water and air temperatures.

The convection depth can be preliminarily determined with the density comparison methods by Zubov N. N., taking into account the density increase in the process of water mixing. To calculate the convection depth for the squatory we
used deep water hydrological observations data from 1750 observation stations in the Atlantic and 2600 observation stations in the Pacific Ocean, the Sea of Okhotsk and Bering Sea for the period of the maximum water heating from 1950 up to 1965 as the initial data. Chart’s album shows the convection depths calculated in intervals of 1° of the temperature decreases.

Interpolated values of depth convection for the points of standard grid were recorded in the external memory of the computer.

To obtain the calculated convection depth it is enough to get the values of the water temperature on the surface available. The water temperature on the surface in the cold season is assumed to be similar to the water temperature in the mixed layer.

Comparison of the calculated convection depth values and the actual bathithermographic observation data showed satisfactory coincidence.

Advection water temperature changes are taken into account approximately by their average values for many years calculated through the flow velocities and water temperature gradients. Advectional changes of water temperature are introduced to the calculated scheme with a ten-day period from the external computer memory.

Initial temperature field on the surface is represented by the ship, field and aircraft observations for 4–5 days.

Predictions of water temperatures are made for a month in advance. Both average monthly values and its values for the beginning of the ten-day period are calculated.

Long-range forecasts are precise with ten days forecast validity. This is performed taking into account air temperature anomaly precisions as well as the precisions of the water temperature distribution for the past 5-day period.

The data of the long-range forecast precisions are transmitted by the telegraph.

The effectiveness of this method make up about 20% as compared with a climatic forecast.

14. ON THE INFLUENCE OF THE TEMPERATURE FIELD IN THE NORTH ATLANTIC ON DEVELOPMENT OF ATMOSPHERIC PROCESSES

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The problem considered is not new, but in the present paper based on new observations an attempt has been made to obtain some new results. Our investigations carried out in the North Atlantic in 1968–1970 enabled us to analyse more detailed, than before, variability of position of the oceanic Polar Front. The data from previous observations, those on anomalies of air temperature in winter and meteorological charts for a series of years were used also in this work.

As Dietrich, we assumed that the oceanic Polar Front position is presented like the 10°C isotherm at a 200 m depth. In Fig. 1 it is shown that year by year variability of the Polar Front position is very great and it can exceed 300 miles. These variations cause great changes in the heat content of waters. Our draft hypothesis is based on the conception about the determining influence of temperature field of oceanic upper layers on the development of atmospheric processes. Therefore, the position of the oceanic Polar Front in North Atlantic determines the intensity of cyclonic activity and general direction of cyclones’ displacement. When the position of the Polar Front is abnormally northern the centre of cyclogenesis will be the Labrador Sea and the cyclones displace along the oceanic Front to North Europe and it is warm owing to Atlantic air masses in winter over the greater European part.

When the position of the oceanic Polar Front is abnormally southern the main area of cyclogenesis is situated southward of Newfoundland, cyclones displace along the Front to southern Europe and this causes lower winter temperatures of the air over North and Central Europe.

Unfortunately, the observations on the Polar Front position in North Atlantic are infrequent. In four cases of five processes developed in the way as it was supposed and only in one case (winter 1969/70) our hypothesis was not confirmed: position of the Polar Front being northern, the winter contrary to our expectation was cold. Meteorological charts show that in Dec. 1969–Jan. 1970 trajectories of filling cyclones with northern component passed through the Norwegian Sea and this caused positive temperature anomalies only over northernmost Europe; at the same time an extensive cold anticyclone was found over the greater part of European territory of the USSR. In February latitudinal air transport converted to longitudinal: cyclonic activity developed over Central Europe, where positive anomalies of air temperature were observed.

We consider that not only the middle or extremal position of the Front, but also some wave processes on it affect the development of the cyclonic activity. In summer 1969 a cold eddy started to form from the meander near 30°W. In spring 1970 two deep eddies to the southeast of the Front were well pronounced. They were 2–3°C colder than the adjacent waters, their square was about 100 thsd. km².

In winter, according to our calculations velocity of dissipation of energy of cyclones over Mid-North Atlantic is a value of the same order as turbulent heat inflow from the ocean to atmosphere. Therefore a sharp reduction of the latter value while displacement of cyclones into a vast zone of cold waters (areas of eddies) lead to exceeding of dissipation of cyclones energy its inflow and the cyclones are filled. It is precisely that process over Mid-North Atlantic was responsible for the development of meridional processes in the atmosphere in the winter 1969/70.

CONCLUSIONS. In most of investigated cases the abnormally northern position of the oceanic Polar Front corresponds to warm winters over Europe and, vice versa, its position being southern winters are cold. This regularity is broken if eddies develop in the southeastern part of the Polar Front. This calls for further investigation and specification. However, at present a rough forecasting of winter anomalies of air temperature with 4–6 months in advance is already possible. For this purpose regular surveying of the position of the oceanic Polar Front is extremely necessary.
The main reasons for changes in heat budget from day to day are the processes of insolation and evaporation. The variations of evaporation are caused by fluctuations of air temperature, humidity and wind velocity which, in turn, depend on physical properties of moving air flows. The variations of insolation depend both on astronomical and meteorological causes. The effect of astronomical factors is of little value in comparison with that of meteorological factors (cloudiness). The changes of cloudiness are closely connected with atmospheric circulation. As a result of such analysis and calculations the equations for prediction of heat budget values on atmospheric circulation were obtained with the help of multiple correlation. As an indicator of atmospheric circulation the pressure field data over the North Pacific represented in analytic form by natural orthogonal functions were used.

While compiling the sea surface temperature forecast the pressure field data for the previous day were used for the prediction of values of heat budget and advective changes of sea surface temperature for the next day. Summing up the changes caused by external heating and advection and taking into consideration the initial values of sea surface temperature the forecasts were made by extrapolation. Comparison of calculated sea surface temperature with the actual ones showed a satisfactory coincidence.

The study of the correlations between heat budget, sea surface temperature and atmospheric circulation in the different ocean areas have a good prospect in investigations of air-sea interaction and in making forecasting both in the ocean and over the ocean.

16. OCEAN TEMPERATURE FIELD AND PREDICTION OF ICE PHENOMENA ON SEAS

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Ocean-atmosphere interaction is one of the basic problems of modern oceanology. This problem is of prime importance for all sea forecasts and, in particular, for ice forecasts. Lately, physio-statistical methods have found increasing use in long-range forecasting. But considerable difficulty has been encountered in their application because of a very complicated interaction of the processes occurring in the atmosphere and the ocean.

In this paper only one aspect of the problem is discussed, namely the influence of the summer and partially spring and autumn ocean temperature field on ice conditions of non-arctic seas in winter.

To represent ocean temperature conditions, observations can be used, made either at the stationary points or over one or another area with sufficiently dense observation network. The advantage of the former type of observations is their reliability and regularity. The latter type makes it possible to take into account the characteristic features in the most “active” areas, such as, for example, the zones of hydrological fronts. The field can be expressed analytically by the expansion of water temperature into mathematical series which widens the possibilities of analysis and practical application. The paper presents both observations at stationary points (weather ships) and over the area.
The main characteristic feature of the ocean temperature field is the great stability of temperature anomalies and the extremes among them. It is such "carriers of memory" as heat content of oceans that have the most prolonged effect on the future weather.

The relationships were found between water temperature on the surface of the oceans and certain characteristics of the ice regime, such as the time of ice occurrence in ports, the amount of ice, the length of shipping route in the ice, the duration of ice, period, for almost all non-arctic seas of various physio-geographical conditions.

The water temperature in August, as well as the preceding and following months, has proved the main argument in forecast relationships. These relationships have turned out to be so close in a number of cases that they can be directly used in predictions.

For example, the relationships between normal amount of ice on the Sea of Azov and the Black Sea in January—February and the sum of water temperature anomalies in August according to A, B, C, D, E and M weather ships in the Atlantic Ocean have the correlation coefficients equal to 0.78 and 81% reliability; permissible error does not exceed 0.67σ, where σ is the mean-square error.

Two regions, big and small, were selected on the surface of the Pacific Ocean. These regions were chosen due to their location near the Sea of Okhotsk (for which the calculations were made), relatively adequate observations and peculiar thermal fields situated in the places where warm and cold oceanic currents meet.

Expansion into series with respect to Chebyshev polynomials was made for both regions. It was found out that the signs of anomalies coincide, that is the positive summer temperature anomalies in the Pacific correspond to warm winters on the Sea of Okhotsk and vice versa.

Temperature field was used to find out the influence of the ocean on the date of the first occurrence of ice at different points of the coast. The best results turned out to be for points situated nearer to the ocean, for example, Ust-Bolsheretsk, for which the coefficients of correlation reached 0.8.

The prediction of amount of ice early in winter, that is in December, when ice is only beginning to cover the sea still remained a complicated problem. A number of relationships with amount of ice in December were found from data on water temperature in the ocean in August. Using two or three variables, close relationships with the coefficients of correlation R = 0.74 were found, errors not exceeding 0.67σ equal to 88%.

17. LARGE OCEANOGRAPHIC EXPERIMENT IN THE NORTH ATLANTIC

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Such an experiment was carried out in 1970 in one of the regions of Tropical North Atlantic. A network of buoy moorings that held current and temperature meters was a technical basis of the experiment. Investigation of spatial and time structure of meso- and large-scale motions was the main objective of the studies. Determination of interaction between fluctuations and mean flow was a particular task of the experiment. Seventeen mooring stations arranged as a symmetric cross with the centre at the point of 16°30'N, 33°30'W. The sides of the cross 209 km each were meridionally and zonally oriented. The measurements of currents were made at 10 locations; temperature meters worked at depths of 50 and 200 m. The observations at the buoy stations began at the end of February and continued till early September.

The P. P. Shirshov Institute of Oceanology of the USSR Academy of Sciences was at the head of the sea investigations. The vessels of the Institute "Dmitry Mendeleev" and "Akademik Kurчатов" carried out the major part of the work. The R/V "Andrey Vilkitsky" has also fulfilled a considerable part of researches.

The scale of the experiment is unprecedented in the world oceanography. Suffice it to say that more than 1.5 million single recordings of current velocity and direction have been made. Tremendous work on technical preparation of the experiment preceded the investigations in the ocean.

The studies of currents obtained by averaging in time intervals from two days to some months show a distinct nonstationarity of large-scale motion at a point. The currents averaged for the period mentioned are essentially nonhomogeneous in space—both horizontally and vertically. These facts make one suppose that the current scheme is the consequence of superposition on the mean flow of low-frequency oscillations similar to planetary waves (Rossby waves) and eddies resulting from hydrodynamic instability of these disturbances. The estimates for 50 and 300 m depths indicate eddies of 100 to 200 km in diameter to move mostly to the West at a speed of 4–5 cm/sec. These eddies can be regarded as components of the so-called geostrophic turbulence.

One can notice a relationship between the distribution with depth of Brunt-Väisälä frequency and current character at different depths. Currents are most regular at a depth of 100 m corresponding to the depth of the pycnocline layer. Here the motion is mainly in the north-west direction, i.e., approximately in the direction of Trade wind. Currents become more irregular at lower and higher depths where Brunt-Väisälä frequency decreases. The hodograph of current velocity vertical distribution based on the data averaged for 160 days shows that in the interval of depths coinciding with the position of the pycnocline layer, water moves to the north-west at a speed of nearly 4 cm/sec. One can suppose that this order of current velocity is typical of quasi-stationary currents in central parts of the ocean. The current in general runs northward higher than the pycnocline depth and southward in the lower layers of the ocean. Such distribution of velocities is a resulting effect of the observed large-scale quasi-geostrophical disturbances. The latter were probably the mechanism which reduces potential energy of the inclined isopycnal surfaces through heat redistribution; in this case the intensive heat influx to the ocean was accompanied by a northward transport of warmer water and a southward transport of colder water.

The pulsation energy of the zonal and meridional components of current velocity calculated for the intervals of about a month indicate isotropy of the energy field of horizontal pulsations at intermediate depths. For instance in the 100–600 m layer the mean ratio of oscillation energy of the meridional velocity component to energy of the zonal component is 1.0; the ratio appreciably differs from unity at a depth of 25 m, as well as at depths of 1000 and 1500 m. These facts may indicate that at intermediate depths the characteristic period of low-frequency oscillations was more than a month, and the oscillation period in the uppermost layer and at great depths was relatively less and approached the month period.
18. ON SEASONAL VARIABILITY IN THE TIDAL WAVES

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The present paper is devoted to the analysis of the seasonal variability in the tidal internal waves and the associated currents for a mean year from the data by Fjelstad method.

The testing of the Fjelstad method as applied to the ocean has shown a fairly satisfactory agreement between computation data and observed data.

Density observations for great water areas which we have at our disposal at present, make it possible to analyse space-and-time variability of the internal waves and associated currents only for a mean year.

We shall consider the variability of the tidal internal waves for the North Atlantic. To calculate the parameters of the internal waves we have made use of the density data given in the paper on the principal features of the Atlantic Hydrology edited by Muromcev.

The parameters were computed for the months representative of the hydrological seasons, namely: January—February, June, August, October, November. For autumn and winter months the calculation was performed for ten degree quadrates for June and August with a grid of greater frequency.

Having compared the computation data with the data of observation, we came to the conclusion that it is sufficient for our purposes to compute the parameters of 4 waves. The addition makes a total computed wave in relative values. As we can see in our paper, one can safely perform a qualitative analysis of the variability of internal waves on the basis of relative values.

In our investigation we had at our disposal a number of data received from hydrologic stations performing long-period observations (up to several days); the data have been obtained recently from several parts of the North Atlantic for various months of the year.

The vertical distribution of the computed amplitude, and that of the observed amplitude coincide, which permits us to make a conclusion that in our theoretical computation we have considered all the main factors contributing to the formation of internal waves.

When observation data are used, we have to take into consideration the influence of other factors as well; the latter may be regarded as secondary factors. Thus the correlation between computed amplitudes and observed amplitudes obtained from several regions of the North Atlantic could be used for the whole area of the North Atlantic as well. This also enabled us to obtain a preliminary quantitative estimation of the amplitudes and velocities of the current, which is caused by semidiurnal internal waves.

In the Atlas on the seasonal variability of the tidal phenomena, and internal waves in the North Atlantic, one can see the maps of computed extreme amplitudes of internal waves, as well as the velocities of the current; their depth is also indicated. The data of quantitative estimation of semidiurnal internal waves are also listed here.

We have observed an appreciable variability of the internal waves from place to place for the period under review. The greatest variability of both amplitudes and current velocities in the area of the North Atlantic is observed in June (the amplitude during this period ranges between 15 and 50 m, the velocity of the current is from 10 to 45 centimeters per second).

We also note the pronounced character of the seasonal variability of internal waves. The seasonal variability of the currents, however, is less pronounced than that of the amplitudes.

It should be noted here that the velocities of the currents are characterized by greater variability with depth, as compared with the amplitudes. In a layer of 0 to 1000 metres one can observe two maximum values for the current. Two maximum values along the vertical for the amplitudes can be found only on a few areas of the central part of the North Atlantic.

The analysis of the value of the density gradient and its distribution along the vertical shows that the intensity and position of the layer of larger density gradients determine, to a great extent, the variability of the vertical structure of internal waves as well as their variability both seasonal and from place to place. It has been found out as a result of our investigation that the variability of vertical structure of internal waves is closely connected with stratification; this enables us to say that the data and conclusions as to the depth of the tidal waves, may be safely applied to other types of internal waves, such as inertia waves. The above-mentioned data of space-time variability may be used in analysing the variability of certain parameters of semidiurnal internal waves, such as component of vertical velocity, or the energy and turbulent effect of the internal waves.
<table>
<thead>
<tr>
<th>Author</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abuzyarov, Z. K.</td>
<td>133</td>
</tr>
<tr>
<td>Allison, I. F.</td>
<td>72</td>
</tr>
<tr>
<td>Anisimova, E. P.</td>
<td>91</td>
</tr>
<tr>
<td>Arno, N. L.</td>
<td>52</td>
</tr>
<tr>
<td>Balakina, L. M.</td>
<td>54</td>
</tr>
<tr>
<td>Barnett, T. P.</td>
<td>92</td>
</tr>
<tr>
<td>Basharinov, A. E.</td>
<td>73, 112</td>
</tr>
<tr>
<td>Bernard, P.</td>
<td>66</td>
</tr>
<tr>
<td>Bernhardt, K.</td>
<td>88</td>
</tr>
<tr>
<td>Bernstein, V. A.</td>
<td>63</td>
</tr>
<tr>
<td>Bogorodsky, V. V.</td>
<td>78, 109</td>
</tr>
<tr>
<td>Boris, L. I.</td>
<td>150</td>
</tr>
<tr>
<td>Borisenkov, Ye. P.</td>
<td>76</td>
</tr>
<tr>
<td>Bortkowski, R. S.</td>
<td>88</td>
</tr>
<tr>
<td>Bossolasco, M.</td>
<td>67</td>
</tr>
<tr>
<td>Boston, N. E. J.</td>
<td>97</td>
</tr>
<tr>
<td>Bouws, E.</td>
<td>92</td>
</tr>
<tr>
<td>Braddock, R. D.</td>
<td>57</td>
</tr>
<tr>
<td>Bradner, H.</td>
<td>68</td>
</tr>
<tr>
<td>Brekhovskikh, L. M.</td>
<td>94</td>
</tr>
<tr>
<td>Brocks, K.</td>
<td>83</td>
</tr>
<tr>
<td>Buchteev, V. G.</td>
<td>59</td>
</tr>
<tr>
<td>Budyko, M. I.</td>
<td>76</td>
</tr>
<tr>
<td>Butetner, E. R.</td>
<td>88</td>
</tr>
<tr>
<td>Bukatov, A. E.</td>
<td>132</td>
</tr>
<tr>
<td>Bulatov, R. P.</td>
<td>130</td>
</tr>
<tr>
<td>Busering, J. A.</td>
<td>86</td>
</tr>
<tr>
<td>Campbell, W. J.</td>
<td>72</td>
</tr>
<tr>
<td>Carlson, H.</td>
<td>92</td>
</tr>
<tr>
<td>Cartwright, D.</td>
<td>92</td>
</tr>
<tr>
<td>Carmock, H.</td>
<td>117</td>
</tr>
<tr>
<td>Chekotillo, K. A.</td>
<td>104, 148</td>
</tr>
<tr>
<td>Cherkesov, L. V.</td>
<td>58, 132</td>
</tr>
<tr>
<td>Chernukhin, M. Sh.</td>
<td>76</td>
</tr>
<tr>
<td>Cicconi, G.</td>
<td>67</td>
</tr>
<tr>
<td>Cooksa, V. I.</td>
<td>134</td>
</tr>
<tr>
<td>Davidian, I. N.</td>
<td>137</td>
</tr>
<tr>
<td>Davidson, K. L.</td>
<td>89</td>
</tr>
<tr>
<td>Dean, J. P.</td>
<td>41</td>
</tr>
<tr>
<td>Derr, V. E.</td>
<td>110</td>
</tr>
<tr>
<td>Dotsenko, S. F.</td>
<td>132</td>
</tr>
<tr>
<td>Drummond, A. J.</td>
<td>113</td>
</tr>
<tr>
<td>Efimov, V. V.</td>
<td>96</td>
</tr>
<tr>
<td>Egorikhin, V. D.</td>
<td>104, 148</td>
</tr>
<tr>
<td>Egorov, K. L.</td>
<td>77</td>
</tr>
<tr>
<td>Egorov, S. T.</td>
<td>112</td>
</tr>
<tr>
<td>Eva, C.</td>
<td>67</td>
</tr>
<tr>
<td>Ewing, J. A.</td>
<td>92</td>
</tr>
<tr>
<td>Fedosenko, V. S.</td>
<td>58</td>
</tr>
<tr>
<td>Fleagle, R. G.</td>
<td>83</td>
</tr>
<tr>
<td>Fomin, L. M.</td>
<td>104, 130, 139, 148</td>
</tr>
<tr>
<td>Foster, T. D.</td>
<td>94</td>
</tr>
<tr>
<td>Fuks, V. R.</td>
<td>106</td>
</tr>
<tr>
<td>Gade, H. G.</td>
<td>115, 119</td>
</tr>
<tr>
<td>Garipov, R. M.</td>
<td>49</td>
</tr>
<tr>
<td>Gibson, C. H.</td>
<td>97</td>
</tr>
<tr>
<td>Gienapp, H.</td>
<td>92</td>
</tr>
<tr>
<td>Glagoleva, M. G.</td>
<td>141</td>
</tr>
<tr>
<td>Go, Ch. N.</td>
<td>63</td>
</tr>
<tr>
<td>Goncharov, V. V.</td>
<td>94</td>
</tr>
<tr>
<td>Goptarev, N. P.</td>
<td>120</td>
</tr>
<tr>
<td>Gousshchin, O. A.</td>
<td>124</td>
</tr>
<tr>
<td>Gray, W. M.</td>
<td>87</td>
</tr>
<tr>
<td>Grigorash, Z. K.</td>
<td>47</td>
</tr>
<tr>
<td>Grigorkina, R. D.</td>
<td>106</td>
</tr>
<tr>
<td>Grinda, L. J. H.</td>
<td>67</td>
</tr>
<tr>
<td>Page</td>
<td>Page</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Guber, P. K.</td>
<td>106</td>
</tr>
<tr>
<td>Gurvich, A. S.</td>
<td>111</td>
</tr>
<tr>
<td>Gurvitch, A. S.</td>
<td>112</td>
</tr>
<tr>
<td>Gyskhojhy, B. Ya.</td>
<td>78</td>
</tr>
<tr>
<td>Hasse, L.</td>
<td>85</td>
</tr>
<tr>
<td>Hasselmann, D.</td>
<td>92</td>
</tr>
<tr>
<td>Hasselmann, K.</td>
<td>92</td>
</tr>
<tr>
<td>Hatori, T.</td>
<td>48</td>
</tr>
<tr>
<td>Haworth, W. T.</td>
<td>48</td>
</tr>
<tr>
<td>Henry, R. F.</td>
<td>53, 54</td>
</tr>
<tr>
<td>Hickey, J. R.</td>
<td>113</td>
</tr>
<tr>
<td>Hicks, B. B.</td>
<td>85</td>
</tr>
<tr>
<td>Hilleary, D. T.</td>
<td>109, 113</td>
</tr>
<tr>
<td>Iida, K.</td>
<td>48, 49</td>
</tr>
<tr>
<td>Ikonnikova, L. N.</td>
<td>47</td>
</tr>
<tr>
<td>Ivanova, V. S.</td>
<td>137</td>
</tr>
<tr>
<td>Ivanov-Frantsevich, G. N.</td>
<td>104, 148</td>
</tr>
<tr>
<td>Ivashchenko, A. I.</td>
<td>51</td>
</tr>
<tr>
<td>Iwata, N.</td>
<td>90</td>
</tr>
<tr>
<td>Jaque, V. M.</td>
<td>51</td>
</tr>
<tr>
<td>Johannessen, O. M.</td>
<td>78</td>
</tr>
<tr>
<td>Kaimal, J. C.</td>
<td>96</td>
</tr>
<tr>
<td>Kajijuara, K.</td>
<td>57</td>
</tr>
<tr>
<td>Kan, S. I.</td>
<td>147</td>
</tr>
<tr>
<td>Knowles, C. E.</td>
<td>63</td>
</tr>
<tr>
<td>Knysz, V. V.</td>
<td>58</td>
</tr>
<tr>
<td>Koerner, R. M.</td>
<td>75</td>
</tr>
<tr>
<td>Kolesnikov, A. G.</td>
<td>96</td>
</tr>
<tr>
<td>Konojkova, G. E.</td>
<td>61, 91</td>
</tr>
<tr>
<td>Korhonen, H.</td>
<td>68</td>
</tr>
<tr>
<td>Korneva, L. A.</td>
<td>47</td>
</tr>
<tr>
<td>Kraus, E. B.</td>
<td>95</td>
</tr>
<tr>
<td>Krivalevich, L. M.</td>
<td>124</td>
</tr>
<tr>
<td>Krugermeyer, L.</td>
<td>83</td>
</tr>
<tr>
<td>Krusman, P.</td>
<td>92</td>
</tr>
<tr>
<td>Kurskaya, A. A.</td>
<td>73</td>
</tr>
<tr>
<td>Nelepov, B. A.</td>
<td>100</td>
</tr>
<tr>
<td>Nordberg, W.</td>
<td>111</td>
</tr>
<tr>
<td>Okubo, A.</td>
<td>116</td>
</tr>
<tr>
<td>Obukhov, A. M.</td>
<td>112</td>
</tr>
<tr>
<td>Orlanski, I.</td>
<td>91</td>
</tr>
<tr>
<td>Orlov, A. S.</td>
<td>91</td>
</tr>
<tr>
<td>Orvig, S.</td>
<td>74</td>
</tr>
<tr>
<td>Ostrovsky, L. A.</td>
<td>59</td>
</tr>
<tr>
<td>Pasechnic, T. A.</td>
<td>137</td>
</tr>
<tr>
<td>Pelinovsky, E. N.</td>
<td>59</td>
</tr>
<tr>
<td>Platt, T.</td>
<td>121</td>
</tr>
<tr>
<td>Plechko, V. M.</td>
<td>110</td>
</tr>
<tr>
<td>Pomeranets, K. S.</td>
<td>105</td>
</tr>
<tr>
<td>Poplavsky, A. A.</td>
<td>51, 63</td>
</tr>
<tr>
<td>Popov, G. I.</td>
<td>91</td>
</tr>
<tr>
<td>Popov, N. I.</td>
<td>100</td>
</tr>
<tr>
<td>Portman, D. J.</td>
<td>89</td>
</tr>
<tr>
<td>Pouder, E. R.</td>
<td>78</td>
</tr>
<tr>
<td>Preisendorfer, R. W.</td>
<td>56</td>
</tr>
<tr>
<td>Preobrazhensky, L. Yu.</td>
<td>88</td>
</tr>
<tr>
<td>Proskaurokova, T. A.</td>
<td>69</td>
</tr>
<tr>
<td>Pulugina, A. G.</td>
<td>77</td>
</tr>
<tr>
<td>Pyaskovsky, R. V.</td>
<td>59</td>
</tr>
<tr>
<td>Radkevich, V. M.</td>
<td>77</td>
</tr>
<tr>
<td>Rasmussen, L. A.</td>
<td>72</td>
</tr>
<tr>
<td>Reid, R. O.</td>
<td>63</td>
</tr>
<tr>
<td>Rehrudell, A. E.</td>
<td>61</td>
</tr>
<tr>
<td>Richter, K.</td>
<td>92</td>
</tr>
<tr>
<td>Romanov, Yu. A.</td>
<td>110</td>
</tr>
<tr>
<td>Rossov, V. V.</td>
<td>144</td>
</tr>
<tr>
<td>Rozkov, V. A.</td>
<td>137</td>
</tr>
<tr>
<td>Rykunov, L. N.</td>
<td>69</td>
</tr>
<tr>
<td>Savarensky, E. F.</td>
<td>69</td>
</tr>
<tr>
<td>Schooley, A. H.</td>
<td>90</td>
</tr>
<tr>
<td>Sebekin, B. I.</td>
<td>57</td>
</tr>
<tr>
<td>Sell, W.</td>
<td>92</td>
</tr>
<tr>
<td>Name</td>
<td>Page</td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
</tr>
<tr>
<td>Trits, R. W.</td>
<td>116</td>
</tr>
<tr>
<td>Tsvang, L. R.</td>
<td>82</td>
</tr>
<tr>
<td>Tuteckov, L. T.</td>
<td>73</td>
</tr>
<tr>
<td>Van Atta, C. W.</td>
<td>95</td>
</tr>
<tr>
<td>Vasiliev, O. F.</td>
<td>60</td>
</tr>
<tr>
<td>Verderli, P.</td>
<td>100</td>
</tr>
<tr>
<td>Vinnik, L. P.</td>
<td>66</td>
</tr>
<tr>
<td>Vitousek, M. J.</td>
<td>56</td>
</tr>
<tr>
<td>Von Arx, W. S.</td>
<td>41</td>
</tr>
</tbody>
</table>