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Workshop Report No. 69



**IOC Workshop on Sea-Level
Measurements in Antarctica**

Leningrad, USSR, 28-31 May 1990

A Supplement to this Report, containing selected papers
presented at the Workshop, will be published separately, as
IOC Workshop Report No. 69 Suppl.

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1. OPENING

Dr. B. Krutskih, Director of the Arctic and Antarctic Research Institute (AARI, USSR State Committee for Hydrometeorology), welcomed the participants. He presented the main research activities conducted by the Institute in the Antarctic area and paid special attention to some basic problems of sea-level measurements at the Soviet Antarctic stations. He pointed out that the AARI has been dealing with sea-level research in polar zones for many years both at national and international levels. In conclusion, Dr. Krutskih expressed the hope that the Workshop would be scientifically fruitful and pleasant for the participants.

Dr. V. Jivago, GLOSS Technical Secretary, welcomed the participants on behalf of the Secretary IOC, Dr. G. Kullenberg, and expressed the sincere gratitude to the USSR State Committee for Hydrometeorology and the Arctic and Antarctic Research Institute for hosting the Workshop. He recalled some recent recommendations of IOC Governing bodies related to GLOSS, and in particular, a recommendation of the IOC Assembly at its Fifteenth Session (July 1989, Paris) calling for strengthening the GLOSS network in the Antarctic area. He also referred to IOC documents related to the development of GLOSS in the Southern Ocean. Dr. Jivago pointed out that this Workshop in Leningrad was a joint activity of the IOC Group of Experts on GLOSS (GE/GLOSS) and the IOC Regional Committee for the Southern Ocean (IOCSOC). The Scientific Committee on Antarctic Research (SCAR) was a co-sponsor of the Workshop.

Dr. D. Pugh, Chairman of GE/GLOSS, directed the attention of the experts to some specific conditions of sea-level measurements in Antarctica (ice movement hazards, problems of power at sites, shortage of well trained personnel, etc.). He repeated some recommendations of the first IOC Workshop on Sea-Level Measurements in Hostile Conditions (March 1988, Bidston, UK) and suggested that the meeting in Leningrad both review the progress achieved since then and also discuss the further development of the GLOSS network in the Antarctic area.

Dr. V. Ivchenko, Chairman of IOCSOC, enumerated some scientific and technical problems that the researchers face in the Antarctic area during the expeditions. He underlined that a very limited number of sea-level data have been received by all the countries in the Southern Ocean. He stressed the high cost of research in this distant region and called for further development of international co-operation there.

Dr. E. Korotkevich, Vice-Chairman of SCAR, welcomed the participants on behalf of SCAR. He also referred to problems in polar research and highlighted gaps in our knowledge of processes in Antarctic water. He emphasized that, despite long-term efforts at international level in Antarctica, we still have very limited and disconnected data about fluctuations of sea level there. Dr. Korotkevich pointed out the great importance of sea-level measurements in the Antarctic area, for and practical applications.

2. ADMINISTRATION ARRANGEMENTS FOR THE WORKSHOP

Dr. J. Vassie was designated as Chairman and Dr. J. Hannah as Rapporteur of the Workshop.

The participants considered and approved the Programme of the Workshop as given in Annex I. The List of Participants is given in Annex II.

3. RECENT AND FUTURE NATIONAL ACTIVITIES RELATED TO ANTARCTIC SEA-LEVEL MEASUREMENTS

Delegates from each country summarized the work undertaken by their respective nations in determining Antarctic sea levels. While the full content of most of the papers presented can be found in the Proceedings of the Workshop (Supplement to this document), a summary of each, in order of presentation, is given below:

(i) **New Zealand (Dr. J. Hannah)**

New Zealand has, at infrequent intervals, collected sea-level data in the Ross Sea region since 1957. The best continuous data sets are 1958/59 (14 months at Scott Base), 1970/71 (2 months at McMurdo), 1988/89 (2 months at Cape Roberts) and 1988/90 (15 months at Scott Base).

Analyses show the diurnal O1 and K1 tidal constituents to be both dominant and almost of identical magnitude.

The Scott Base gauge (of an absolute pressure transducer type) was lost in a storm in February 1990. This gauge is to be re-established as a permanent site later in 1990 with a second gauge to be established as a permanent site at Cape Roberts in 1991.

Dr. Hannah reported on the specific problems encountered in establishing permanent gauges in the Antarctic region.

(ii) **Chile (LCDR. A. Cabezas)**

Chile began Antarctic tidal observations as early as 1947 although these were limited to short periods of time during summer seasons. In 1971 Chile began planning a co-ordinated Programme between the Hydrographic Institute of the Chilean Navy and the Chilean Antarctic Institute, the latter depending on the Foreign Affairs Ministry, with the aim of establishing long-term tide stations, of five years of continuous data collection in the permanent manned bases at the Antarctica, and short-term stations of one month duration with specially detached personnel, during summer seasons.

Long-term tide stations were established in Puerto Covadonga (Base O' Higgins station) from 1974 to 1979, giving reliable results at intermittent intervals only, in King George Island (Base Marsh station) from 1979 to 1983 and in Greenwich Island (Base Prat station) from 1983, where it now runs as a permanent station.

The specific problems of installing permanent structures in ice covered regions and the experiences leading to bubbler type gauges were highlighted.

(iii) **Japan (Dr. M. Odamaki)**

Dr. Odamaki gave a summary both of the recent work done in collecting tidal observations at Syowa Station and of the analysis of the tides and tidal currents at the same station.

A mechanical pressure type gauge was used from 1965-1974, followed by two strain type gauges, one from 1975-1985 and the other from 1980 to present. In addition, a quartz oscillator gauge was installed in 1987.

The installation is fully protected, well calibrated and uploads data into a communications satellite. Initial results indicate that annual mean sea levels from 1981-1988, are falling at a rate of 5-6 cm/year.

Other results presented included tidal current observations from

the Kita-no-Seto Strait and the harmonic constituents of both the tide and tidal currents.

(iv) **United Kingdom (Dr. I. Vassie)**

Dr. Vassie spoke specifically to the commitment which Bidston observatory has made to the World Ocean Circulation Experiment (WOCE) and how the installations undertaken as part of this experiment could contribute to GLOSS. He noted the desire of Bidston investigators to determine the sealevel differences across the Southern Ocean current and showed both the island and deep ocean sites presently occupied by UK gauges.

He presented an analysis of data collected at Tristan da Cunha from both onshore and offshore gauges.

It is intended that data collection continue throughout the WOCE time frame.

(v) **Norway (Dr. S. Osterhus)**

Dr. Osterhus noted that Norway, at this time, had no shore located, Antarctic tide gauge data. Norway has deployed bottom pressure recorders off the Bouvet Island and would like to place a permanent gauge on Peter 1 Island.

A bottom pressure recorder has been run since 1979 on the shelf break to the Weddell Sea.

Technology has been developed to transfer data from ocean floor instrumentation, via coaxial cable, through shelf ice to recorders on the ice surface. Dr. Osterhus raised the question as to the possibility of using this type of technology for a gauge on the thin ice patches on the Fimbul Ice Shelf.

(vi) **Federal Republic of Germany (Dr. G. Krause)**

As part of the WOCE Programme an offshore pressure gauge has been established at Vestkapp to monitor both tidal constituents and Antarctic current fluctuations. Current measurement devices are attached to the same mooring as the pressure gauge. Dr. Krause presented a comparison of the tidal constituents derived from gauge data against those implied by the Swiderski tidal model.

It is intended that data collection continue throughout the WOCE Programme.

(vii) **France (Dr. C. Le Provost)**

As part of WOCE, France has placed two offshore tide gauges in the Southern Ocean, one at Kerguelen Island and the other at Amsterdam Island. In the near term, a third is planned at Crozet together with a further gauge on a nearby shallow water ridge. France plans to place conventional onshore gauges on the Kerguelen and Amsterdam Islands which will be fully automated with remote data collection through the ARGOS system.

(viii) **USA (Dr. T. Delaca)**

Dr. Delaca noted that the US Antarctic Programme had indications that tidal records had been collected spasmodically since 1940, one of the longest being from a bubbler type gauge at Palmer Station from 1971-73. The data however, is at best of questionable accuracy.

He commented upon present trends in the US Programme, the most obvious being the emergence of co-ordinated, multidisciplinary groups interested in studying the dynamics and mass balance of ice stream movement.

He noted, in particular, the ongoing studies which sought to determine the changes which had occurred in Antarctic sea levels during the past 5000-7000 years.

(ix) **USSR (Dr. V. Kaliazin)**

Since 1956, sea levels have been measured at five coastal stations on the Antarctic Continent by Soviet Antarctic expeditions. The vast majority of these data were collected between 1962 and 1972. Because all gauges were installed on the ice, they monitored the sum of two variables (i.e. water oscillation and ice thickness). The data are not of high reliability. Some analysis of the harmonic constituents has been performed.

At present, there are no permanent Soviet tide gauges installed. Before such installations can proceed, it will be necessary to resolve such issues as the number of stations needed, their locations, the logistics of servicing, and information exchanges.

(x) **USA (Dr. D. Beaumariage)**

Dr. Beaumariage described NOAA's current initiatives with their Next Generation Water Level Measurement Systems. He described its genesis, its current status and gave a description of the units used for both measurement and data transmission. The presentation was illustrated through the use of slides of typical installations.

At present, NOAA has no plans for NGWLMS installation in the Antarctic regions.

(xi) **Australia (Prof. G. Lennon)**

Australia initiatives have, to the present day, focussed upon obtaining data from bottom mounted pressure gauges near the Heard and Macquarie Islands in support of studies of the Southern ocean current.

It was reported that success in data collection, thus far, had been limited. Theoretical studies are, however, underway into the physics of the Southern Ocean current.

Australia now plans to install permanent shore based tide gauges at both the Heard and Macquarie Islands. In addition an array of NGWLMS gauges will be deployed around Australia.

(xii) **United Kingdom (Dr. D. Pugh)**

Dr. Pugh's presentation focussed upon efforts being made in the U.K. to develop a fine resolution numerical model (FRAM) for the Southern Ocean current. He discussed some aspects of the model and presented some initial results from it. He suggested that such a model may well provide a theoretical foundation for the location of sea-level measurements sites in the Southern Ocean.

1. GLOSS NETWORK IN THE SOUTHERN OCEAN

Dr. D. Pugh presented a summary of available information about the various tide-gauge installations maintained in the Southern Ocean. A map of the Antarctic continent was drawn and the relative locations of both the operational and planned gauges, displayed. Participants were encouraged strongly to work within the framework of their various national organizations to ensure both that there was on-going maintenance of the existing gauges and that the gauges proposed came to fruition.

5. PROBLEMS ASSOCIATED WITH SEA-LEVEL MEASUREMENTS IN HOSTILE CONDITIONS

The specific problems faced in installing reliable tide gauges in the Antarctic were discussed, i.e.:

- (i) ice scouring on the near shore sea bed;
- (ii) the destruction of support structures by sea ice;
- (iii) the logistics of gauge maintenance;
- (iv) the lack of ice free locations and/or the unknown spurious effects encountered when using a gauge with a heated stilling well; and
- (v) the power requirements necessitated by any mechanism including automated data uplink to a satellite.

A review of the gauges currently in operation revealed that one was a conventional float gauge (using a heated stilling well), one was a bubbler gauge and four were absolute pressure gauges.

After some discussion amongst participants, a consensus began to emerge that the most appropriate type of gauge for Antarctic condition was a bottom mounted absolute pressure gauge both recessed in to the sea floor and with cabling either recessing into the local rock or well protected, by some other means, from ice action.

The technique of avoiding cables by using low frequency sound waves to transmit data was raised.

It was agreed that gauges must be calibrated on an annual basis at ice free periods.

6. DATA RECORDING AND TRANSMISSION

This subject was introduced by Dr. D. Beaumariage, who described the automated data collection and transmission techniques being used by NOAA with the NGWLMS. While primary transmission of data is via the GOES satellites, all stations have back-up telephone lines. The primary advantage of near-real time data transmission is the capability to monitor the systems performance, and for certain navigation or warning applications. However for Antarctica applications, only the first is of special advantage.

7. GEODETIC CONTROL FOR ANTARCTIC TIDE GAUGES

Dr. W. Carter presented to the Meeting a summary of the most precise geodetic positioning techniques currently available. He spoke mainly about:

- (i) Absolute gravity for vertical control. Accuracies are now down to 2-4 ugal and likely to reach 1 ugal (Note: 1 ugal = 3 mm in the vertical);
- (ii) VLBI (Intercontinental baseline accuracies now down to the 1 cm level); and
- (iii) GPS (1000 km baselines accuracies now at the 1-2 cm in the horizontal components but 3-5 cm in the vertical).

In planning for connections between tide gauges and geodetic control, he drew attention to conclusions contained in the earlier report 'Geodetic Fixing of Tide Gauges Bench Marks' by W.E. Carter et al, (1989) CRC89-5, Coastal Research Center, Woods Hole Oceanographic Institution.

8. IGOSS SEA-LEVEL PILOT PROJECT FOR THE SOUTHERN OCEAN

The Working Group comprised of Dr. G. Lennon (Australia), Dr. C. Le Provost (France), Dr. J. Hannah (New Zealand), Dr. V. Kaliazin (USSR), Dr. G. Krause (FRG), Dr. I. Vassie (UK), Dr. E. Delaca (USA), Dr. M. Odamaki (Japan) and Dr. A. Cabezas (Chile) was formed and asked to report back to the Workshop with appropriate recommendations related to development of GLOSS in this region.

The results of the discussion were presented by Prof. G. Lennon (Chairman of the Working Group) as follows:

The Working Group expressed the unanimous agreement on the strategic significance of the sea-level signal from the Southern Ocean in relation to WOCE, WCRP, Interannual climate variability, ENSO mechanisms and implications for greenhouse effects on sea-level trends. In the latter connection note was taken of the great uncertainty which currently exists concerning the role of the Antarctica and the adjacent ocean. Against this background and recognizing the need for international collaboration and cooperation, there was strong support for the concept of a SLPP for the Southern Ocean.

There was general agreement that sea-level data acquired for the Southern Ocean should be made generally available to the Scientific Community through a Central Service such as may be provided by a SLPP. Some sensitivity about data access was expressed by the experts from New Zealand, Japan and USSR, but mainly in a desire to use the system effectively and naturally to promote high latitude research. No serious problem emerged.

The area of interest was defined as "South of Latitude 30° S" so as to establish continuity of activities with the TOGA Sea-Level Centre.

Recommended tasks for the Centre for the Southern Ocean was as follows:

- (i) Communication forum for those agencies active in the region;
- (ii) To access sea-level data and to establish an efficient data bank;
- (iii) To provide an index of available sea-level data for the Southern Ocean and to publicize this to contributors and relevant research workers through a regular newsletter;

- (iv) To aim to databank hourly averages of sea-level and associated barometric pressure, but to be aware of the changes of some recording routines; -

- (v) Data banked to be labelled comprehensively with all relevant qualifying information, e.g.:
 - (a) sampling and integration routine;
 - (b) type of sensor with special reference to venting capability in the case of pressure sensors;
 - (c) procedure and information in repeated datum check;
 - (d) associated bench mark information;
 - (e) contract person for further queries.

During the discussion on dissemination of data from the Centre, the participants confirmed the necessity to aim towards free exchange but noting that some restriction or moratorium may be inevitable in certain circumstances. Note was taken of the fact that New Zealand would prefer to have responsibilities to release within the donor country to be vested in the country's representative. In this way national political support for activity in this area may be promoted.

The Centre is to strive towards publicity possibly through IOC and IUGG Programmes but also through WOCE, WCRP, etc.

During the discussion on establishment of such a Centre, some participants of the Workshop informed on relevant developments in their countries (New Zealand, Chile, Australia), which the Group recommended to take into account in future consideration of this matter.

The participants of the Working Group discussed the idea of transects across the Circumpolar Current concluding that they had strategic importance. They considered some possible sites for sea-level measurements in Antarctica, but the Group also recognized difficulties in establishing sealevel stations at the proposed locations. The Group also recommended including data from moorings where no bench mark ties were available.

9. GENERAL CONCLUSIONS AND RECOMMENDATIONS

(i) Not all GLOSS stations located in the Antarctic area are suitable for long-term installations, but all manned Antarctic stations should try to measure mean sea level for at least a year relative to permanent shore bench marks.

(ii) SCAR is invited to complete the questionnaire returns to get the full picture of sea-level sites in the Antarctic area.

(iii) Sea-level measurements conducted by all the countries in the Antarctic area and, in particular, the New Zealand and Italian sea-level measurements in Mc Murdo Sound are welcomed and should be continued because of their importance for GLOSS.

(iv) Numerical modelling of the Southern Ocean should be applied to define the priority for selection of the most sensitive sea-level sites in the Antarctica. IOC would be requested to provide necessary means by which a meeting of GLOSS experts could be arranged to discuss this problem, preferably not later than in 1991.

(v) The great importance of further development of Absolute Geodetic Fixing of Tide Gauge Bench Marks was unanimously confirmed, There would be considerable advantage in locating a VLBI at McMurdo to connect to the New Zealand sea-level measurements. It would also compliment the existing VLBI station at Syowa and that proposed for O' Higgins. Wherever possible absolute fixing of benchmarks should be undertaken, using GPS, DORIS, USSR system, etc.

(vi) Because of the hazardous conditions in Antarctica it appears that bottom pressure measurements linked a shore station are the most practical way of obtaining good quality data. There are difficulties bringing the signal ashore; the work underway at the Bedford Institute on EM transmission through the rocks will be followed with interest. Improved measurements of air pressure are needed,. Automatic equipment for making annual or more frequent levelling checks would be valuable. Transmission of data to national centres in "real time" would be a valuable addition.

(vii) Bearing in mind the severe Antarctic environment, it is desirable to recalibrate all the recording devices at sea-level stations as frequently as possible, but at least annually. Redundancy of sea-level stations is also necessary because of the hostile conditions.

(viii) There is a need to hold, in the near future, a workshop/training course on sea-level measurement in ice for specialists working at the Antarctic stations.

(ix) The Australian offer to establish a Sea-Level Pilot Project for the Southern Ocean is strongly endorsed. The pilot period should extend through WOCE and data collected should include bottom pressure and inverted echo sounder measurements, where available.

(x) The conclusions and recommendations of the Workshop could be generally applied to the Arctic ocean sea-level Programme.

10. CLOSURE

Dr. J. Vassie concluded the Workshop thanking all the experts involved in the meeting for their contribution to the solution of complicated problems related to sea-level measurements in Antarctica.

Dr. J. Vassie closed the Workshop, expressing, on behalf of all the participants, his sincere gratitude to the IOC Secretariat and the Hosts of the Workshop, who did an excellent job in ensuring the success of the meeting.

ANNEX I

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 - 3.3 Japan (Dr. M. Odamaki)
 - 3.4 United Kingdom (Dr. J. Vassie)
 - 3.5 Norway (Mr. S. Osterhus)
 - 3.6 Federal Republic of Germany (Dr. G. Krause)
 - 3.7 France (Dr. C. Le Provost)
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ANNEX II

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