

9. Tyler, J.E., ed. Data Report of the SCOR DISCOVERER Expedition
SIO Ref. Rep. 73-t16, 1000 pp. (June 1973).
10. Tyler, J.E. Radiance Distribution as a Function of Depth in an Underwater Environment. University of California, Bulletin of the Scripps Institution of Oceanography, Vo. 7, #5, pp. 363-412 (1960).
11. Jerlov, N.G. and Fukuda, M. Radiance Distribution in the Upper Layers of the Sea. Tellus, vol. 12, pp. 348-355 (1960).
12. Sasaki, T. On the Instruments for Measuring Angular Distributions of Underwater Daylight Intensity. In Physical Aspects of Light in the Sea, J.E. Tyler, ed. Univ. of Hawaii Press, pp. 19-24 (1964).
13. Tyler, J.E. (Chairman). Report of the first meeting of the joint group of experts on photosynthetic radiant energy. UNESCO technical papers in marine science, # (1965).
14. Tyler, J.E. (Chairman). Report of the second meeting of the joint group of experts on photosynthetic radiant energy. UNESCO technical papers in marine science, #5 (1966).
15. Tyler, J.E. (Chief Scientist). Technical report of sea trials conducted by the Working Group on Photosynthetic Radiant Energy. UNESCO technical papers in marine science, #13 (Aug. 1969).

ANNEX V

SCOR WORKING GROUP 27 (WITH ICES AND UNESCO) TIDES OF THE OPEN SEA

Report on 4th Meeting, Wormley, UK, 10 November 1973

Members present: Cartwright, Dohler, Hyacinthe, Radok, Schott, Voit and Zetler. Munk and Teramoto sent their apologies for their inability to attend. M. Demerliac of SHOM, Brest, attended as an observer. Zetler acted as Secretary for the meeting.

Dr David Cartwright, Chairman, reviewed the following changes in membership: Schott for Germany; Eyries replaced by Hyacinthe, with Eyries listed as his alternate; and Zetler as alternate for Munk.

The Chairman read the SCOR terms of reference for the Working Group. There were no comments. The agenda for the meeting was then distributed.

1. Intercalibration Exercise

- (a) The Chairman reported on the mooring cruise (30 October to 7 November 1973) in which eight gauges were deployed on a line west from Brest as follows:

Depth 2200 M

No. 1-FSMW	No. 4-IOS-B	No. 7-SHOM
No. 2-COB	No. 5-IOS-W	No. 8-Canada 2
No. 3-NOAA	No. 6-Canada 1	

FSMW (= F. Snodgrass, M. Wimbush) records absolute pressure using Hewlett-Packard crystals.

COB (CNEXO) records differential pressure using a vibrating wire.

NOAA (Filloux gauge) records differential pressure using a Bourdon tube and optical lever.

IOS (Bidston) includes 2 Hewlett-Packard crystals, 1 vibroton and 1 strain gauge.

IOS (Wormley) uses a capacitance plate and a strain gauge sensor.

Canada measures differential pressure using a bellows transducer.

SHOM (French) records absolute pressure using a vibrating wire.

A deep-sea gauge developed by IOS-Wormley had not yet been retrieved from its previous mooring in the OVERFLOW experiment. It was recovered in mid-November and will be placed in the test area next February. M. Hyacinthe with withdrawn his shallow water gauge from the experiment because it is soon to be put on a six month test alongside the tide gauge in Brest Harbour.

All eight gauges were launched successfully but the FSMW had to be recovered, a leaking o-ring corrected, and relaunched. There were also some difficulties in launching the very bulky NOAA capsule. Ten days in December are allocated for recovery.

- (b) Proposed analysis of data. All participants are to edit and remove drift from their own data and then furnish hourly series (exact GMT hours) on punched cards to all participants. Time and units (cm or mbar) to nearest unit are to be specified. The format of data on cards is to be as follows:

Column 1	- blank
2	- station number as per previous list
3	- blank unless more than one sensor on gauge, then 1, 2, etc. as appropriate
4-6	- day number of year
7-8	- 73 (for 1973)
9-80	- 24 data (3/data), 0 ^h - 23 ^h

The Chairman will furnish lists of addresses to all participants. Brest harmonic constants from 1972 data and observed hourly heights spanning the intercalibration exercise period will also be furnished.

All participants may analyse all data if they wish but the following commitments were made:

Cartwright will do a response analysis of all data.

Demerliac will do a harmonic analysis of all data.

Zetler will prepare a combined plot of all data.

Hyacinthe will prepare a final report on all instruments and mooring techniques including any available information on cost of parts and their source.

Note: Although the Group agreed at the meeting that only one pressure series from each capsule should be analysed for the intercomparison, it was later agreed between the Chairman and other members present on the recovery cruise that where more than one sensor is attached to a capsule they should all be included in the intercomparison (unless obviously deficient in some way) and copies of the data sent to Cartwright, Demerliac and Zetler as above. The data should be sent to all participants by 1 April 1974. A three day meeting in Brest in September 1974 is proposed to complete the Working Group's report on the entire exercise.

- (c) The analysis exercise is to be extended as indicated in the workshop report. Cartwright will distribute two series of hourly heights, 31 days each, edited and drift removed, by 1 January 1974. Participants will analyse series X (a 29 day series and the first 15 day series) to predict for series Y, get residual variance and, if possible, residual variances in the tidal bands, $1 \text{ cpd} \pm 4\frac{1}{2} \text{ cpm}$ and $2 \text{ cpd} \pm 4\frac{1}{2} \text{ cpm}$. Similarly, series Y will be analysed to predict series X and residuals calculated. The 1-year IHB harmonic constants for Lerwick were distributed at the meeting.

The results of these analyses will be sent to Radok by 1 April 1974. He will distribute a summary well before the September meeting.

2. National reports on progress and plans for future.

Zetler reported on the one-year capsule being developed by Snodgrass and indicated that no decision has been reached on a deployment site. It was suggested that an anti-amphidrome (as described at the Venice meeting) might be considered. Munk, Hendershott and Zetler have proposed a satellite global tide programme to NASA in conjunction with GEOS-C (Dohler commented that his group is negotiating with NASA on a related programme using his gauges for ground-truth and for reference purposes). Zetler briefly summarized CICAR developments by AOML, NOAA, including a six-month series of pressure measurements near an amphidrome in the Caribbean and a three-month series in the Gulf of Mexico that resolved a problem on continuity calculations for the K_1 tide.

Dohler reported that five gauges have been deployed successfully on both Atlantic and Pacific coasts. The shelf observations were obtained in conjunction with land-based gauges and have been analysed. A gauge was laid on the Denmark Strait but malfunctioned. The gauges will be used for the GEOS-C satellite experiment for one year at a depth less than 200 m and less than 100 miles from the coast. Mean sea level will be used for geoid determination and ERTS will be used for data transmission. Dohler reported that Aanderaa is building a deep-sea tide gauge costing less than \$10 000 (US).

Radok reported that his capsules have not been used.

Schott's report had three main points. (1) Existing gauges (type Graafen) are being used in shallow waters in combination with current meter moorings. A German company making tests with new sensors has resigned and no replacement has been selected. (2) Cross-spectral analysis of current data with other parameters such as temperature is being done to separate barotropic and baroclinic tidal currents. He described areas of moorings in the OVERFLOW region and at the NW-African shelf. (3) Schott reported on plans for ITEX (internal tide experiment) west of Portugal. A PRE-ITEX is scheduled in the Iberian Basin for January 1974.

Teramoto wrote that the future plans of the Ocean Research Institute includes work on deep-sea tides.

Voit reported that theoretical investigations are continuing. These include a Poincaré solution of tidal equations assuming constant f , a stratified ocean and a turbulent bottom layer. A list of papers had been distributed to the Working Group in 1972. The USSR is starting development of a deep-sea gauge at the Institute of Oceanology, Moscow. Voit will arrange for the test tide analysis to be done at the Hydromet Office. He plans to work with Radok in the Lake Baikal experiment.

Cartwright reported that tidal work previously done at Bidston and Wormley will be combined at Bidston with Cartwright as head. There is a commitment to work on tides in the ocean as well as on the shelf; most of their present gauges (about 12) are shallow-water but a deep instrument has recently been designed. Plans include measurements out to and along the mid-Atlantic ridge. He has completed his programme of pressure and current measurements round the northern shelf edge from Ireland to Norway, including a special survey of the Shetland area. He hopes to continue the chain from southern Ireland to Brittany in the near future. Some year-long tidal recordings are now being made at strategic coastal sites west of Ireland. Observations near a supposed amphidrome in the Faroes showed a larger M_2 tide than might have been expected.

Hyacinthe presented his report on "Budgeting aspects of a possible global tide survey". The programme suggests 250 tide stations of one year duration, tied in with altimetry, using 25 deep-sea gauges (with mooring) over a ten year period. At \$20 000 each, the equipment cost would be \$500 000. A boat for deployment and recovery of the gauges is proposed. It would be about 25 m long and carry a crew of 3 or 4 (scientist, captain and technician). Equipped with both sail and motor, it would cost about \$500 000. The scientific equipment, computer, etc. would also cost about \$500 000. The cost of salaries, maintenance, fuel, etc. for ten years would cost about \$1 500 000. Therefore, about 250 stations would be obtained for a total cost of \$3 000 000, or about \$10 000 per station. Advice would be needed from theoreticians on deployment sites. There was considerable discussion concerning the ability of a small crew to operate effectively and with respect to the proposed one-year at each site. It was suggested that it might be necessary to demonstrate other geophysical benefits to obtain this level of support. There may be problems in getting permission to fund one ship under international auspices. It would be useful to tie-in such a programme as complementary to the space altimetry programme. The Chairman thought it was important to consider realistically how much the real objectives of the Working Party would cost on the smallest possible budget, as Hyacinthe has

done. He also thought that half the battle for funds would be won if a team of keen scientists actually undertook to carry out the proposed programme if funded.

3. Reports on tidal work associated with MODE, OVERFLOW and GATE.

Zetler reported on MODE. Five UCSD records were obtained from three gauges for periods ranging from a half-month to two months. Data have been analysed referred to Bermuda complex predictions but it may be well to consider fewer time lags in the analysis, particularly for the shorter series. The experiment provides unique possibilities to examine instrument response (two sensors together) and to relate nearby tide observations in the deep sea.

Cartwright reported that the OVERFLOW exercise included some tidal measurements between the British shelf and Greenland. He has undertaken to collate all of these tidal data.

In GATE (international experiment in the Atlantic between 0° and 17° N), some tidal measurements may be made by Bidston (Cartwright) and NOAA (Mofjeld).

FGGE (First GARP Global Experiment) is in the planning stages for 1976.

4. Possibilities of Data Bank or Inventory for New Data and for Harmonic Constants.

The future role of IHB is not clear and some consideration is being given to IHB seeking another agency, possibly Bidston, to perform the data bank service. No deep-sea tidal constants have yet been sent to IHB but Cartwright will send his collected results from IOS shelf sites soon. Note - Some additional comments and suggestions on this subject appear to be unnecessary based on a very recent communication from the Chairman indicating preliminary negotiations have been initiated for IHB to transfer responsibility for storing tidal harmonic constants to Bidston.

5. Future Activities of Working Group No. 27.

In addition to preparing a report on the intercalibration exercise and the extended analysis workshop at the proposed meeting in Brest in September 1974, consideration will be given to studies involving the dissipation of tidal energy through internal waves at tidal frequencies.

It was suggested that it was desirable that a Working Group No. 27 meeting be included in the IAPSO 1975 meeting in Grenoble, as well as the meeting in Brest in September 1974, mentioned on page 44.