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1. OPENING AND WELCOMING

The third session of the GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC) was held at Mas du Calme, Grasse, France, 6-8 April 1998. The meeting was hosted by Francois Barlier of CERGA D'Etudes et Recherches en Geodynamique et Astronomie). CERGA is part of the Nice Observatory.

Neville Smith, OOPC Chair, opened the meeting and welcomed the Panel Members and invited guests. He noted apologies from Panel Members Gwyn Griffiths, Walter Zenk and Peter Haugan due to overlapping cruise schedules. He thanked Michel Lefebvre and Anne Julian and Veronique Georgel (Agence DAG) for arrangements for the meeting, and Francois Barlier and colleagues from CERGA for acting as local hosts. The full list of participants is in Annex II.

Barlier, on behalf of CERGA, welcomed the OOPC to Grasse and wished members and guests a successful meeting. He invited the participants to visit the CERGA laser satellite-tracking facility on Tuesday evening (7 April).

2. REVIEW AND ADOPTION OF THE AGENDA

The Chair tabled the Annotated Agenda and invited comment. Tom Spence, Director of GCOS, noted that a document has been prepared as a background to a proposed 1997/98 ENSO Retrospective and he asked that it be tabled under Item 9.1 for the information of the Panel. Masaki Kawabe wished to present material related to climate variability in the North Pacific; the Chair suggested that this material be more conveniently under 9.4.1. Peter Taylor suggested that flux sites (formerly included with Agenda Item 4) should be considered under Item 8.1. The Agenda was adopted with these changes (Annex I).

3. REVIEW OF INTERSESSIONAL ACTIVITIES

3.1 OOPC

The Chair reviewed the principle intersessional activities that have involved the OOPC in a significant way, including :

(i) The Time-Series Workshop (Baltimore, 15-17 March 1998; Haugan Chair; Alexiou, Weller, Field, Smith, Zenk participants);

(ii) The Sea Level Workshop (U. Hawaii, 10-11 June 1998; Smith Chair; Le Provost, Kawabe participants);

(iii) GODAE (1st Workshop on GODAE, Martinique, July 24-29 1998, Smith Chair, plus Le Provost, Harrison; the 1st GODAE Scientific Steering Team, Melbourne, Smith Chair, Le Provost; 1st GODAE Patrons Group, also Melbourne, Jan 98 ; creation of GODAE Office in Melbourne headed by N. Smith);

(iv) The Sydney Implementation Workshop (4-7 March 1998, Sydney; Needler, Weller, Smith, Reynolds participants);

(v) Reports to JGOOS, JSTC & JSC; Represented at CEOS AG, GOSSP (Lefebvre), AOPC (Harrison), TAO IP (Weller), GLOSS GE (Le Provost, Smith).

The Chair referred members to the Report written for JSC XIX (Annex III) for further details.

3.2 GCOS

Tom Spence discussed several issues related to the GCOS. He himself plans to step down as Director and to leave the Office in July; OOPC help in identifying a replacement would be welcomed. The present chair of JSTC is also stepping down. The sponsors are considering candidates for his replacement. Spence noted that the AOPC & JDIMP were meeting the last week of April (Ed Harrison attending for OOPC). He asked OOPC to consider the future roles of GOSSP and JDIMP (see Sections 4.1, 8.1and 8.3).

Spence informed the Panel that IACCA is responding to a request from SBSTA for a Report on the Adequacy of the Global Observing System. GCOS has the lead for preparing the initial draft. He underscored the importance of this process and that it made important political links. He asked the OOPC to participate in the preparation of an authoritative document, over the next 2-3 months, in preparation for COP 4 of the UNFCCC. An outline of the present draft was circulated, with the intention of seeking 2 or 3 people from OOPC to actively participate in the process (Needler, Smith). The final draft is due 30 September.

Spence also brought the Panel's attention to an exercise underway to produce a retrospective of the current El Nino. The scientific and technical retrospective is discussed under item 9.1.

3.3 G3OS

In a subsequent discussion regarding joint G3OS activities, the OOPC agreed that the GOSSP can be an important conduit for providing an integrated response to CEOS from the G3OS and was under-utilized for this purpose at present. GOSSP can be effectively used to represent views of OOPC and other groups at various satellite planning meetings. OOPC also concluded that JDIMP should place greater emphasis on pilot projects (the bottom-up approach) in order to take experimental systems into an operational model. JDIMP also needs to address generic management issues.

3.4 IOC

Art Alexiou noted the recent appointment of a new IOC Executive Secretary of the IOC, Patricio Bernal (Chile). Alexiou also noted the appointment of Colin Summerhayes as Director of the GOOS Project Office in late 1997. The Chair noted that the former J-GOOS has been restructured as a GOOS Steering Committee (GSC), with Worth Nowlin as Chair, and includes responsibility for the implementation activities of the former GOOS Strategy Sub-Committee. The GSC is to meet April 20-23 and wishes to review a report from OOPC III.

4. TIME SERIES WORKSHOP

The Chair introduced a report of the OOPC Time Series Workshop which was held in Baltimore, March 18-20 1997, and co-sponsored by GOOS, GCOS, SCOR/JGOFS and the WCRP. The full report can be found at the following web site.
http://www.bom.gov.au/bmrc/mrlr/nrs/oopc/tswsrpt.htm

The purpose of the Workshop was to:

Review the contribution from ocean time series (stations);
Discuss the viability and feasibility of existing stations;
Discuss the possibility of reoccupying old sites; and
Identify possible new sites.

In doing so the Workshop intended to:

Formulate objective assessment criteria
Identify key relevant scientific objectives in operational and research programmes;
Identify advantages offered by new technology; and
For OOPC (GOOS, GCOS) identify time series that satisfy the "operational" criteria.

The Workshop considered and agreed on an appropriate definition for time-series data: *"A time-series data set, or a time-series station, is one in which temporal sampling is the dominant attribute of the gathered information."* Four categories were considered:

(i) Exploratory (pilot)sites -- where the main aim was "tasting" the variability (e.g., KERFIX at Kerguelen).

(ii) Laboratory sites -- where understanding basic processes associated with the variability is the primary objective. HOTS (Hawaii), BATS (Bermuda) and TAO are examples.

(iii) Phenomenological or process "sensor" sites -- are located in places believed to be representative of climate variability over broader regions. Bravo, Papa and Mike provide examples.

(iv) Possible "climate reference sites" -- stations maintained as reference standards for climate, were also considered. Sea level records might provide an example.

The most important attributes of time series were found to be:

Record length;
Temporal sampling and continuity;
Data quality and metadata;
"Breadth" of the data set;
Data availability;
Relevance;
Logistical considerations;
Cost;
Availability of proxies;
Exploitation; and
Opportunism (e.g., political considerations).

The following conclusions were reached regarding categories of sites;

(i) The exploratory sites could not be reviewed individually, so no recommendation was made in terms of continued support.

(ii) The value of laboratory sites was acknowledged and it was reasoned such sites should be continued so long as their scientific productivity was satisfactory (i.e., it is the call of research programmes and agencies). The question of whether the same sites should be occupied was left open.

(iii) "Bravo" would seem to justify long-term support as a "sensor" or indicator of climate variability. It is consistent with the aims of GCOS/GOOS. Panulirus/Station "S" is another likely candidate.

(iv) No sites clearly fell in the "climate reference station category".

The value of time-series data for models was acknowledged, and more use of OSEs was encouraged. It was recommended that an assessment of the latest technologies suitable for time series observations be conducted (see section 4.2). The diversity of purposes, opportunities, etc., made prioritisation across all time series stations impossible. However, the Workshop established sound guidelines for the assessment of stations and provided both the OOPC and programmes like CLIVAR a firmer foundation for implementation.

The Panel thanked The Organising Committee for the Workshop (Chaired by P. Haugan) for their work. The Panel noted that, in some respects, the Workshop recommendations needed to be clarified and priorities for future work emphasized. (This was done in part in the summary above.)

4.1 OOPC CONCLUSIONS ON TIME SERIES WORKSHOP

The Panel wished to make the Workshop conclusions with respect to the Ocean Climate Observing System explicit. Both Bravo and "S" rated highly with respect to the assessment of attributes mentioned previously, though the former does not include a continuous record and has only a limited number of occupations in some years. Starting in 1990 as a contribution to WOCE, the Bedford Institute of Oceanography (BIO) has, at least once a year, and usually in late spring, carried out a hydrographic section crossing the Labrador Sea from the coast of Labrador to Greenland and passing close to the position previously occupied by OWS Bravo. A major purpose of these sections has been to observe the nature and quantity of the Labrador Sea water formed in the previous winter by deep convection. During the same period and in the same region, a number of moorings measuring the vertical structure and currents have been in place at various times for extended periods. Such programmes are expected to continue in the foreseeable future as part of CLIVAR.

The Panel concluded that **the time-series stations Bravo and Panulirus ("S") were of sufficient value and importance to the Ocean Climate Observing System that they should be maintained under long-term (operational) support.**

The Panel also noted that Papa had a long, comprehensive record, but agreed with the Workshop conclusions that, at this time, the scientific rationale for maintaining Papa as an operational site was not as strong as for Bravo or "S". PMEL has deployed a mooring at Papa (and another NW of Hawaii) with a view to moving them to operational status if the technology and outcomes are seen as successful..

Le Provost and others noted that sea level was not considered explicitly by the Workshop (the GLOSS Group of Experts (GE) meeting was held in the same week). The Panel noted the conclusions of the Sea Level Workshop (Item 5), where **the value of long sea level time series for interannual variability and climate change studies was emphasised**. The Panel was also alerted to the fact that the time-series attributes of various satellite data sets were not explicitly mentioned by the Workshop report (the Chair noted that these issues had been considered by the *In Situ* Observations Workshop and the Long-Term Change (Asheville) Workshop). Continuity of satellite data sets, and cross-calibration through instrument change-overs were extremely important issues for future applications to climate problems. The Panel noted that these issues were generic to the GCOS components and that they should also be considered by the Space Panel (and perhaps the CEOS Cal/Val groups).

Keeley suggested that consideration be given to charging JDIMP with the task of ensuring that time series stations and repeat sections are identified in the data directory project they were undertaking. The Panel agreed this suggestion should be posed to JDIMP.

Several Panel members also drew attention to the importance of repeat sections and like strategies for long-term climate monitoring. Smith noted that this issue had also been raised after the JSC presentation. Further discussion of this issue was deferred to Items 8.2 (Subsurface Subprogramme) and 9.5 (Carbon Cycle).

John Field and others noted that time series data, whenever and wherever they have been created, have almost always proved extremely valuable. The biological community was extremely keen to see stations like BATS and HOTS continued (both have now been funded for several more years). There was also a high level of interest in the preliminary data from KERFIX. It was noted that the value of satellite ocean colour data were greatly enhanced in the presence of high-quality *in situ* data. The Panel agreed to revisit this issue under Item 9.5.

Recommendations for flux reference sites were developed under Item 8.1.2.

4.2 POTENTIAL TIME-SERIES STATION TECHNOLOGY.

The Panel also noted the discussion of new technology in the Workshop report and the recommendation that OOPC examine opportunities for exploiting new, more cost-effective technologies in the occupation of time series stations. Such a discussion was scheduled for OOPC III but was postponed due to the absence of Griffiths. Weller and Harrison emphasised that there was enthusiasm in some parts of the community for examining this issue. New instruments make it possible to collect long time series of surface meteorology and of temperature, salinity, and velocity in the water column. Sites formerly occupied by Ocean Weather Station (OWS) ships can now, for example, be re-occupied at much reduced cost. Illustrative of these are instruments that move along sub-surface moorings. These have been developed at Bedford Institute of Oceanography (BIO), Woods Hole Oceanographic Institution (WHOI) and by a consortium including LODYC, GRGS/LEGOS, SOC UK and other European agencies.

The BIO instrument uses heave in the mooring (due to surface wave motion) and a ratchet mechanism to move a sensor package up (or down) the mooring, and negative buoyancy (or positive) to return the package to its resting position near the bottom (or the top) of the mooring cable. The cost of the profiling mechanism, including data logging is of order US $20,000. Standard mooring and instrument packages depend on the application and are extra. Present cost for a deep water CTD is $12-15,000; an acoustic link to the surface and a satellite transmitter is $7-8000. Twice daily profiles over a period of a year (servicing at 6-month intervals) are presently targeted in the Labrador Sea moorings.

The WHOI profiler is trimmed to near neutral buoyancy and uses an electric motor and traction drive system to crawl along a conventional plastic-jacketed mooring wire. These profilers are capable of moving between near the bottom up to their subsurface float, which may, with care, be set within 50 feet of the surface. Depth range is set by the mooring; instrument housings are capable of full-ocean-depth. To date, the profiler has been fitted with a CTD and a 3-axis current meter (ACM) to measure the vertical structure of ocean currents. Integration of biogeochemical sensors to the moored profiler is anticipated. Data are recorded internally, with the option of real-time satellite telemetry via a slack-tethered surface buoy attached to the top of the subsurface mooring. (Both inductive and acoustic links between the profiler and the surface buoy are feasible.) Periodic release of data capsules from the subsurface mooring is also possible. To date, deployments of these instruments have been made offshore from Bermuda, in the Labrador Sea, and on the U.S. continental slope. Profiling endurance exceeds 200 full-depth profiles per deployment. The instrument's sampling schedule is flexible; full-depth profiles may be interspersed with repeated profiles of the upper ocean if desired. Deployment durations of one month to one year or longer are expected, depending on the processes being studied.

The WHOI Moored Profiler technology has been licensed to McLane Research Laboratories, Inc. of Falmouth, MA. Current price of the instrument fitted with a CTD and ACM is $72,000. The capitalization cost of reusable mooring elements (flotation, release, surface buoy) is probably comparable. Representative maintenance costs, expendable components (anchor, mooring wire, batteries) and servicing activities (including technician costs, shipping and travel but exclusive of ship time) are expected to be around $50,00 per deployment.

Surface mooring technology has evolved to make it possible to maintain surface buoys in most ice-free locations. Meteorological sensors have been deployed on such moorings with good success, replacing sensors every 6-9 months to ensure they remain in calibration. Wind speed and direction, air temperature, sea temperature, incoming shortwave radiation, incoming longwave radiation, relative humidity, barometric pressure, and precipitation are being measured routinely. Freezing spray remains a challenge as the buoys lack the power to use electric heaters for de-icing.

In the open ocean, autonomous vehicles provide an alternative approach for collection of temperature and salinity profiles. One type is a Lagrangian freely drifting float that changes its buoyancy to regularly move up and down the water column and record temperature and salinity vs depth. Typically, such profiles are obtained in the upper 1000 to 1500 m, as too much energy would be required to dive to greater depth. These profilers are expected to cost ~ $ 8-10,000 when "mass" produced. They can make 50-60 profiles during their 2-3 year lifetime.

Such floats would be carried away from a fixed site, so a second type of float, which has station-keeping abilities, is being developed. This float is equipped with GPS and "wings" and can steer as it glides up and down while recording T-S profiles. It is better suited for station-keeping in order to occupy a fixed site.

5. SEA LEVEL WORKSHOP

The Chair opened discussion of the report of the OOPC (/CLIVAR/NOAA) Sea Level Workshop, held in Hawaii, June 1997. The executive summary from the meeting is in Annex IV. The full report and its recommendations can be found at the following web site.

http://www.bom.gov.au/bmrc/mrlr/nrs/oopc/slwsrpt.htm

The Workshop was chaired by Smith, and Panel Members Christian Le Provost and Masaki Kawabe participated. The Workshop built upon the excellent ground work of the GLOSS GE and their Implementation Plan.

In reference to the recommendations in the OOSDP Report, the Chair drew the Panel's attention to Recommendation (iii) which now constituted the preferred approach for estimating long-term trends in sea level (see Annex XIII). The Sea Level Workshop placed great emphasis on altimetry for future measurement of sea level, complemented by appropriate *in situ* measurements, consistent with the view expressed in the GLOSS IP. The Chair also noted the detailed analysis provided by Vivien Gornitz as background to the Workshop. A prioritized approach for geodetic positioning was recommended. The Workshop also identified several coastal/western boundary sites and tropical Pacific sites which are now considered to be of scientific importance.

5.1 OOPC RESPONSE TO SEA LEVEL WORKSHOP RECOMMENDATION

The Chair raised several points for consideration by the Panel. Regarding the recommendation related to the establishment of a Working Group (WG) for Sea Level (rec. (I); a letter has been drafted by N. Smith and Phil Woodworth (Chair GLOSS GE) for the consideration of the Secretary of the IOC (see Annex V). The Chair noted that the establishment of this WG was consistent with new implementation structure (see Section 7). He also noted that it was important that the new WG did not place extra financial burdens on the IOC and GOOS which, in his opinion, it would not. It was also expected that some of the scientific functions of the present IAPSO Committee for Mean Sea Level (chaired by Le Provost) would also be included in the terms of reference of the Working Group. The Panel agreed that the establishment of the WG was an appropriate response to the progress made at the Workshop and requested the Chair to support this recommendation at the upcoming GSC.

Recommendation (viii) called for the transition of the WOCE Fast Delivery Center into an operational Center for climate sea level observations. That is, it called for long-term support for the functions of the centre, and for a formal broadening of its remit to include all data relevant to climate applications (as identified in the Sea Level Workshop report). The Panel supported this recommendation.

The Workshop recommended enhancements and strengthening of the network in support of tropical Pacific and western boundary studies and in support of high latitude monitoring. The Panel noted that these recommendations were consistent with the overall plan for the observing system. The Panel noted that bottom pressure records were of particular value in some high latitude locations in particular, for monitoring the transport of the Antarctic Circumpolar Current (ACC) and the Antarctic Circumpolar Wave, and in high northern latitudes such as Bering Straight. Roger Colony asked the Panel to note the existence of Bering Straight data. [Le Provost would take this point to GLOSS.]

Le Provost made the point that, for tidal studies, the existence of good current data sets were now becoming increasingly important. No account of such applications had appeared in previous discussions of the OOPC or OOSDP. The Panel noted this point and requested it be brought to the attention of the Coastal Panel (Needler, for action).

The Panel discussed the background report planned for sea level change. Le Provost noted that much of the material destined for that report had now been included in the GLOSS IP and Sea Level Workshop Report. Le Provost suggested that it may be timely to draft a paper on the updated sea level network, based on the combined conclusions of the GLOSS IP and Sea Level Workshop Report. The Panel agreed that this would be a more useful approach at this time and requested Le Provost to look into this possibility.

The Chair noted that the Workshop also raised the issue of the next IPCC Climate Assessment and the possible role of the Working Group in that assessment. It was noted that authors were already being sought for the next assessment and that the opportunity to influence this process has already passed.

6. GODAE

Chairman Neville Smith informed the panel of progress with GODAE since the proposal was introduced at OOPC II. Much of the background material can be viewed at the following web sites.
http://www.bom.gov.au/bmrc/mrlr/nrs/oopc/godae/homepage.html
http://www.bom.gov.au/bmrc/mrlr/nrs/oopc/godae/docs.htm

The concept had been presented at a number of fora and was greeted with enthusiasm. A decision was made early on to develop GODAE somewhat independently of existing programmes as a way of generating a broad base of new support. An International GODAE Steering Team -- NASA, NOAA, ESA, JAMSTEC, NASDA, and the Bureau of Meteorology --representing the so-called Partners in GODAE, and a Patrons Group have been established. The Patrons Group is the source of support and, for the first International GODAE Steering Team meeting, included representatives of CNES (through CERFAX), EUMETSAT, NASA, NOAA, NASDA/STA and the Bureau of Meteorology. NSF, together with NOAA, NASA and several French agencies provided support for the initial Workshop (held in Martinique, July 1997). The report is on the following web site.
http://www.bom.gov.au/bmrc/mrlr/nrs/oopc/godae/1stwsrpt.htm

The UKMO and NRL have also been involved. The Partners consist of entities with a vested interest in the science and applications related to GODAE activities, e.g., participants in MERCATOR, etc. A schematic outlining the structure of GODAE is included as Annex VI.

Smith briefly reviewed material presented at the recent JCS-XIX and, last year, at the Biarritz Ocean Monitoring Symposium. More detail is available at the following web sites:
http://www.bom.gov.au/bmrc/mrlr/nrs/oopc/godae/jsc_xix_report/
http://www.bom.gov.au/bmrc/mrlr/nrs/oopc/godae/biarritz_ppt

The symposium addressed a number of issues that had already been identified, some of which were already receiving attention. For example, regarding the ARGO proposal to seed the global ocean

with several thousand floats, there is a need to explore the technological challenges and possible tradeoffs. For more on ARGO, see the following web site.
http://www.bom.gov.au/bmrc/mrlr/nrs/oopc/godae/argo.htm

As to the actual number of floats required (the first suggestion being order 3000), focussed studies are required to determine the most effective sampling; complementarity with altimetric data is a key factor, as is the ability of models to utilise float data. Smith suggested GODAE may be fatally flawed with less than the equivalent of 1000 profiles every ten days. Another question concerns the balance between subsurface sampling, be it from floats or other platforms, and other data (e.g., surface measurements).

Model sensitivity experiments are needed to support decisions. Some objection was raised during discussion regarding the reference to ARGO as "the core" of the ocean observing system (OOS) as is argued in the draft proposal. From the panel's point, a major float deployment needs to be viewed as complementing the other elements of the OOS, including satellite observations. Smith noted that the ARGO proposal was a draft and that major revisions are likely as the various scientific and technical challenges are identified. Annex VII contains a draft strategy developed at the first International GODAE Steering Team meeting (Melbourne, Jan 20-22 1998). It is provided here for information. Smith noted that the concept has yet to be considered in detail by CLIVAR, but that would happen at the next Upper Ocean Panel meeting (last week in April, Toulouse).

Smith informed the Panel of a Modelling Workshop on Global Scale Ocean State Estimates organized by Deflef Stammer and held at Johns Hopkins University in Baltimore in March. It emphasized practical experience in assimilation. A report from this workshop was planned to be added to the GODAE Web site shortly.

The next meeting of the GODAE SST is planned for Tokyo, the first week of July 1998. Smith also reported that a GODAE Office is being established in Melbourne via support from the Patrons. It is likely that this Office may also provide some level of support for OOPC-related activities. While GODAE was receiving a great deal of attention, both scientifically and for its likely impact on GOOS, Smith emphasized that the OOPC still had a vital role in ensuring that the ocean observing system for climate was implemented consistently with the scientific plan developed in the OOSDP Report. GODAE was not a substitute for this process. OOPC would need to take the lead for the basic observing network and for ensuring the GODAE contribution complemented the other elements of the network.

Smith also noted that the OOSDP report regarding the modelling role in the OOS needed updating and needed to address the issues of carbon modelling and CFC's tracers. He listed the modelling groups that could be a starting place to redo the OOSDP survey. Ed Harrison agreed to consider this issue and will report at the next OOPC meeting.

7. IMPLEMENTATION WORKSHOP FOR GCOS-GOOS OBSERVING SYSTEM

The Workshop held in Sydney, March 4-7, 1998 included participation from all of the important implementation and oversight groups, including CMM, IGOSS, DBCP, TAO, SOOP, GLOSS, IODE and OOPC. The Panel was represented by Smith, Needler and Weller; frequent Panel participant Reynolds also attended). The contribution from OOPC to that Workshop had been reviewed by Panel members and by several CLIVAR scientists. That contribution and the initial draft of the implementation plan are available on the Web at the following web site.
http://bom.gov.au/bmrc/mrlr/nrs/oopc/reqments.htm

The final report from that meeting was not yet available, but Smith referred to several critical decisions taken at the workshop. Smith noted that both OOSDP and OOPC sought new implementation paths for ocean climate observations. This workshop on global observing systems for GCOS/GOOS was an appropriate and timely response. In order to have an updated set of requirements for the Workshop (the OOSDP report was taken as the basis), the OOPC was asked to consolidate and update the requirements in a form that was suitable for the implementing bodies. The above-mentioned document did this, and included a Table summarising the most important characteristics of the sampling (see Annex VIII).

The Workshop, on behalf of the groups represented, agreed to a unified and integrated implementation mechanism under a Joint WMO-IOC Commission for Ocean Oceanography and Marine Meteorology (JCOMM) that would merge the existing implementation mechanisms: CMM (Commission on Marine Meteorology), IGOSS (Integrated Ocean Services System) and GLOSS (also see Annex VIII). Three Measurement Sub-Programmes under JCOMM were included in this structure: (I) Sea Level, (ii) Surface and Marine, and (iii) Subsurface. Other structures had been considered but this structure appeared to balance idealism with realism. Within each of these programmes it is hoped that detailed implementation plans will be drafted.

For the Sea Level Sub-Programme this is effectively done with the publication of the GLOSS Implementation Plan, supported by the Sea Level Workshop report.

Section 8 effectively addresses the start of this process for the other Sub-Programmes (Smith noted that some elements had existing plans, though none at the level desired). It was noted that the input to the Workshop from the OOPC made use of the concept of "benchmark standard" for sampling to avoid unduly complicated, platform-dependent prescriptions.

The Workshop drafted terms of reference for an interim group that would act in place of the Joint Committee (JCOMM) until such time as the parent bodies (IOC and WMO) agreed to the structure and terms of reference and responsibilities. The Panel was asked to, and agreed to support this overall structure. It is likely OOPC will be asked to participate in the interim structure for JCOMM. The Chair also noted that, while the OOPC and its predecessor, the OOSDP, might take a degree of satisfaction from the outcome of the Workshop, it also posed several challenges, not the least being the updated revision of the requirements. The OOPC would also be expected to provide leadership in the drafting of the implementation plan and, in particular, providing input on the scientific rationale for the specified sampling.

In terms of the tasks facing the Sub-Programmes, the Chair noted that the Workshop had addressed for each a range of common issues (see Item 8.1 for example). The issues ranged from scientific rationale and participation, through data and information management issues, to organisational structures, resources and capacity building. Some issues were identified as generic; it was suggested these might be handled best by cross-cutting groups. Yet others would require substantial work, either by individuals or groups. It was expected that final ratification of the implementation plans would be through Sub-Programme workshops.

The OOPC was asked to assign high priority to the drafting of the plans. This was agreed to (the invited participation at the Workshop provided the first installment on this commitment). In closing this item the Chair noted that several major obstacles remain, with perhaps the most important being the ratification of the Workshop recommendations by WMO and IOC. He also noted that it was unclear at this point how groups such as the TAO Implementation Panel would be included in this structure; there is a strong case for leaving effective groups alone as far as is practical.

8. TOWARDS AN OOPC IMPLEMENTATION PLAN

8.1. SURFACE AND MARINE DATA SUBPROGRAMME

The Chair noted that the writing of a plan arose as a direct result of the Sydney Implementation Meeting. The OOPC needed to review the requirements provided by the OOSDP as these were to be the "drivers" for the implementation plan. In the first instance, for the Surface and Marine Data Subprogramme, the OOPC was going to consider SST, heat flux, surface winds and, perhaps, SSS. The treatment of surface waves, sea ice and pCO_2 remains an issue.

Peter Taylor opened the discussion by referring to the work of the WCRP/SCOR Working Group on Air-Sea fluxes (WGASF). See the following web site.
http://www.pcmdi.llnl.gov/airseawg/1stmtgrep/index.html

Taylor discussed the work at SOC and elsewhere in deriving appropriate climatologies. In the case of the SOC, ship metadata were exploited to provide corrections to measurements. This allowed 1-degree square monthly mean estimates with accuracies better than 10 W/m^2 in densely sampled areas. He noted that correlations between model products (e.g., NCEP) and the COADS climatology were high only in regions of high data density. Data from flux moorings have been used to provide an independent assessment of some products. For the Arabian Sea it was shown that the SOC approach was more reliable than estimates from a climate model. This work (and independent work by Weller) demonstrated the strength and utility of high quality marine data.

Taylor noted that the issue of whether the WGASF could act as the scientific advisor to the Subprogramme on Surface and Marine Data was raised at the JCS. A statement was agreed to at the JCS (Annex IX). In brief, it concluded that it would be unwise to modify the Terms of Reference of the WGASF at this time. WGASF has a limited life (till 2000) at which time the issue would be revisited. In the interim it was suggested that a more informal arrangement be developed whereby some members of the WGASF provide advice as needed in the drafting of the implementation plan. The OOPC endorsed this strategy.

Taylor also drew the Panel's attention to several other points beginning with conclusions 4 and 5 from the WGASF meeting:

> "4. Recognizing that the efforts of the COADS project have been vital for surface flux research, and noting that the collection of further historical data and the development of new algorithms for correcting COADS variables will be valuable both for the coming COADS release 2 and for future releases of COADS, the WGASF recommends to JCS/SCOR that these activities, together with the expeditious production of COADS release 2, be encouraged."

> "5. Recognizing that high quality *in situ* data from buoys, research-quality ships, ocean radiation sites, and similar installations, form an important resource for surface flux evaluation, the WGASF recommends that further such activities should be supported."

The OOPC supported both recommendations. With respect to the uses for surface data, Taylor noted three main applications:
Model initialisation;
Verification of models, satellite algorithms and flux estimates; and
Climate monitoring.

For the latter application, an ability to return to the raw data was critical. He drew the Panel's attention to the lack of emphasis on these aspects in the present SBSTA draft (see Item 3.2).

Taylor provided a specific example of the application of surface data for model validation. It is recognized that there will be regional biases in surface data whether they be, for example, from satellite SST estimates, model derived surface products, or surface flux fields calculated from ship data. While the reference sites will provide a primary accuracy standard, these will be limited in number and cover a restricted range of locations. It is therefore necessary to define a set of data products which are "secondary standards" in the calibration sense, that is they have been directly compared and are traceable to the primary standard provided by the reference sites. Data sets which are potentially valuable for this purpose include :

- VOS observations from ships with improved instrumentation and/or for which improved quality control has been applied;

- Satellite measured fields which have been verified against reference sites and/or improved VOS. These may include SST, surface radiation, and surface wind velocity.

An example of the use of VOS data for this purpose is shown in Figures 8.1-1 and 8.1-2.(Figures are at the end of the report text). Comparison with accurate buoy data (Figure 8.1-1) is used to define the characteristics of ship derived data, in this case latent heat flux estimates in the SOC climatology. The SOC values have been calculated after applying bias corrections to the raw ship observations on a ship-by-ship basis. Following verification against the buoy data, the SOC values may be used to detect a bias in model derived values (Figure 8.1-.2) for regions other than those where the reference data is available.

The issue of metadata for ships and buoys was raised. Taylor noted that the document known as WMO-47 addressed this issue, though not across all platforms concerned with marine and surface data.

Harrison noted that a reference site ideally should include upper ocean temperature, salinity and current observations as well as observations for air-sea fluxes. This consideration will be taken up at a future time when the technology for unattended profilers has been fully field tested.

8.1.1 Outcome from the Sydney Meeting

Bob Weller briefed the Panel on the outcomes of the Sydney meeting with respect to surface and marine data. He summarized the Workshop response to thirteen key issues (see Table 8-1 on next page)

The Sydney Workshop concluded that a Pilot Project might be effective in dealing with items (3) through (7) in the table. Weller noted that in respect of regulation, the setting of appropriate benchmarks will be important. Taylor noted that there are several activities which could be used as the basis for a Pilot Project. Coordinating and resourcing such a project looms as an issue.

8.1.2 Recommendation for Surface Reference Sites

The OOPC noted the considerable progress in estimating surface fluxes from *in situ* data and from purpose-built surface moorings. The accuracy of the surface moorings provided a high-quality benchmark for climate products. The OOPC concluded that operational centres should now be encouraged to include surface flux reference sites in their operational model skill measures.

Well instrumented surface moorings are recommended at select sites. Significant improvements made over the last 15 years have led to buoys capable of measuring monthly mean net heat flux to better than 10 W/m^{-2} (Figure 8.1-3) and of estimating the freshwater flux as well as the heat flux and wind stress. These buoys measure wind speed and direction, incoming short wave radiation, incoming long wave radiation, relative humidity, air temperature, sea temperature, barometric pressure, and precipitation. The sensors perform reliably for 6-9 months, and their data is both telemetered and recorded on board.

The select sites occupied by the surface moorings will provide high quality, accurate reference sites to be used to check, verify, and/or calibrate surface meteorological and air-sea flux fields from models, remote sensing, and other in-situ measurements. Recent deployments of such buoys, even in severe environments such as the Arabian Sea, have demonstrated their ability to perform well and of the utility of their data to identify problems in model fields (Figure 8.1-4; see also Figures 8.1-1 and 8.1-2.).

TABLE 8-1

1. SCIENCE *Action by OOPC, JSC*	*SCOR/WCRP* *- Air-Sea Flux Working Group ; review charge, add expertise, refine ownership;* *- resources,* *- ice, waves, currents*
2. OBSERVING NETWORK *- identify integrating strategy* *- establish steering group* *- develop strategic plan*	Develop strategy to pull together parts (only parts of mechanisms and structures relevant to GOOS) of existing structures - VOS, DBCP, SOOP, TIP, CMM, NDBC, satellite (operational + future) ; benchmarks
3. INFORMATION FLOW *-Pilot project for surface*	Problems in distribution, acquisition ; need to integrate data flows - flux quantities a good example - require several basic obs, should be able to recompute ; cost ; bandwidth of satellite link
4. ARCHIVES, STDS *Part of pilot project (review existing archives stds)*	Problems - for some, like waves, no general archive ; QC, keep meta data in archives ; for some - multiple archives - standardized formats ?
5. QA *-GOOS handbook science group review feed back /involvement by science group ;* *-pilot project brings in existing expertise*	QC by people close to data streams ; keep information about quality decisions ; develop scientific level quality control - capture + blend in expertise from DACS
6. RESOURCES *-Dialog between science + operations* *- what is feasible* *- what is optimal*	Focus + coordinate ; prioritize ; new resources + attention for archiving
7. REGULATORY *-Look toward pilot proj.* *-review existing reg's ;* *-establish GOOS benchmarks*	Who sets standards ? No one regulatory body
8. TECH SUPPORT *- build on existing base* *- invest. possibility to streamline*	Coordinate existing tech efforts; get people in operational agencies involved
9. ADMINISTRATION *- Note concern*	Nightmare
10 CAPACITY BUILDING *- Use of satellite + other integrated fields* *- waves*	Build on existing infrastructure for in-situ ; develop awareness of use of data to determine fluxes ; learning curve on variables like waves
11. AFFILIATED DRIVERS *- Ensure effective comm. with CEOS*	*(CLIVAR) WMO ; research ; IPCC, safety of life at sea; space agencies (CEOS), governments*
12. ISSUES *- OOPC includes agenda item to assess ice obs. system ; secretariat accumulates info* *- status report on radars* *- note, sea ice volume + velocity in research mode + will watch*	- Which variables (sea ice, *extent*, waves, ...) - new methods - radar - priorities change with focus, user (coastal vs open ocean ; location) - how to communicate with and influence existing impl. structure - funding for observing system research - Space / time variability is large how to determine sampling - some quantities are derived from several basic observables - sampling bias - don't go where weather is bad - funding / coordination of technology development
13. PRODUCTS	*For some variables* *Not working, people not getting what they want*

The following sites are candidates for reference sites (Figure 8.1-5). The specific regional issues that guided the selection of these sites are noted. Unless other factors dominate, for exact positioning in a region, consideration should be given to positions that are triple crossover points of satellites

Site 1 **North Atlantic, east of the Gulf Stream.** There is strong variability in the western regions of the Atlantic and Pacific basins associated with westerly flow off the continents. However, VOS data fail to show humidities as low as are anticipated, and, as a result the VOS-based latent-heat fluxes in these regions may be too low. This site (and site 2 in the Pacific) will serve to better quantify the variability.

Site 2 **North Pacific, east of the Kuroshio.** See rationale for site 1 .

Site 3 **Tropical western Pacific warm pool.** Regions of very warm SST (> 28°C) provide a challenge for models, and this site in the western Pacific warm pool is recommended to provide a means to evaluate model performance.

Site 4 **South Atlantic southwest of Cape Town.** The Southern Ocean is data sparse. This site should be located near ship tracks to Antarctic bases in order to provide a badly needed, high-quality Southern Ocean site.

Site 5 **Gulf of Lyons, Mediterranean Sea.** The Mediterranean Sea has been studied as a volume whose inflow and outflow of heat and freshwater can be estimated and for which a heat and freshwater budget might be used to assess the accuracy of surface flux fields. Site 5 is recommended in conjunction with such work.

Site 6 **Arabian Sea.** This site in the monsoon region, and sites 7, 8, and 9 are chosen as representative of important regimes of the ocean-atmosphere system.

Site 7 **Center of Azores.** Mid-latitude high (Bermuda) regime. See site 6.

Site 8 **West of Peru.** Peruvian stratus deck regime. See site 6.

Site 9 **N. Atlantic (20°N, 30°W).** Northeast tradewinds regime. See site 6.

Site 10 **N. Pacific, OWS Papa.** This site and site 11 are chosen as characteristic of sites with strong winter storms and to provide links to past OWS time series.

Site 11 **N. Atlantic, OWS Juliet or Lima.** See site 10.

8.1.3 Surface and Marine Data Plan Outline

The OOPC agreed on the following outline for the Surface and Marine Data section of an implementation plan.:

(i) The role of surface data and fluxes in climate applications
(ii) Scientific rationale
(iii) Requirements
(iv) The instrumental basis
(v) Data and information management issues
 Information flow
 Archives
 Formats & standards
 QC (scientific involvement)
 ... (see table 8-1)
(vi) Resources

The OOPC concluded that the drafting of the Implementation Plan could begin now as many parts are already described in detail in, e.g., the OOSDP report. A target of end of 1998 was set for the 1st draft. A Pilot Project on the D&IM issues could be started during 1998.

8.2 SUBSURFACE SUBPROGRAMME

The Chair informed the Panel that Rick Bailey had provided an outline of an implementation plan for this Subprogramme using the Sydney Workshop outcome as the basis. The elements of this draft, which is included as Annex X, are the same as chosen for the surface and marine data programme. For this meeting, it was not possible to get the individuals who would most likely be responsible for the scientific development of the plan. However, at the upcoming CLIVAR UOP meeting, several key people would be involved and the Chair expressed the hope that some time might be devoted to this issue at that time.

8.3 DATA MANAGEMENT ISSUES

Bob Keeley provided some perspectives on the data managements issues. He identified a number of elements for a data and information management system that should be considered to determine their importance to an implementation plan. Broadly speaking these include:

- Clear statements of the problems to be addressed and required output products.
- Scientific guidance on the variables to be measured and at what space and time scales.
- Translation of the scientific requirements to an operational data collection system.
- Selection of a data transfer system considering issues such as fault tolerance and timeliness.
- The demands on the data processing facilities with respect to such things as quality control, duplicates management, etc.
- A reliable and secure archive facility that provides appropriate access to data and metadata.
- Facilities to generate and distribute the requested products.

Between these elements there needs to be feedback, for example, to data collectors concerning systematic problems, monitoring and correcting transmission faults, provision for issues and comments on product suitability, and provisions for adjustments to accommodate new or additional instrumentation for data collection. The data system elements and the information feedback paths between them are illustrated in Figure 8.3-1.

There already exist a number of programmes that represent elements of a complete subsurface operational system. The main challenge is to coordinate these activities to provide a level of integration of their data streams and to identify gaps. In examining this coordination issue the implementation plan must address the need for good documentation of the resulting system. This must include statements of the responsibilities of participants to the system, clear descriptions of data quality assessments and at which points in the system, agreement on data formats, data access and exchange mechanisms, etc. Among other reasons, clear documentation is crucial to establish trust of the users in delivered products.

Any implementation plan needs to be mindful that adjustments will be needed so that a robust operation is guaranteed. The WOCE experience says that close cooperation between data centres and science centres provides a good model. In terms of data quality assessment, the value added by the work carried out at a data centre and that done at science centres needs a quantitative assessment. It is expected that the added value will be product dependent. Finally, although there are many variables and measurement techniques that may be desirable for a subsurface operational system, it is prudent to begin with those currently managed and to expand the system as experience is gained.

8.4 IMPLEMENTATION PLANNING CONCLUSIONS

The subsequent discussion regarding the surface and subsurface subprogrammes and the data management issues produced the following outcomes:

(i) The scientific design of the subsurface OS is in need of revision. The present plan is based on TOGA/WOCE and does not reflect the history of occupation nor the impact of recent alternate observing strategies. The OOPC adopted a policy to seek leadership from the research community in the revision, though the OOPC itself is committed to participating and meeting the deadlines of an IP for subsurface ocean data.

(ii) The OOPC welcomed the draft outline of the IP provided by Bailey. The OOPC noted and welcomed the common approach across the surface and subsurface programmes.

(iii) The OOPC noted the variety of potential data inputs, not all of which would be classed as routine, systematic or long-term. It was recommended that the IP concentrate initially on existing data collection systems such as TAO and SOOP. In drafting the implementation plan, these other potential inputs should be considered so that if and when they become routine, they can be readily integrated into the subsurface observing system.

(iv) Several of the issues discussed with respect to the subsurface programme are common with the surface programme. The OOPC therefore encouraged action on these generic issues (many were identified at the Sydney meeting) and will ask GSC to follow this up.

(v) The GTSPP and TAO IP, plus the expertise existing in, e.g., the WOCE DACS/UOT, provide a strong foundation for an operational upper ocean thermal data management system. The key aspects are:
- integration and coordination and consolidation of existing activities and expertise,
- documentation of standards, formats, etc.,
- examination of the value-adding obtained by various processes particularly QC.

(vi) The OOPC endorsed the draft schedule (the draft considered at OOPC III and the draft considered at UOP III), namely to:

- convene an ad hoc group of scientists (to include someone with data management sensitivities to develop the scientific design, in collaboration with SOOP; initial draft, etc., around Sep 98;
- conduct simultaneous work on the key D&IM issues during April-September;
- produce a first draft/outline by September;
- discuss by SOOP IP (TAO IP) ~ October;
- further development Oct-Feb 99;
- convene a Workshop ~ March 99.

(vii) Needler stressed that the larger problem was that monitoring the full depth ocean circulation requires more than those elements addressing the surface and the main pycnocline, and should include repeat sections. In addition, float data to various depths, cable technologies, deep boundary current. arrays, new profiling technologies, upward looking sounders, deep basin to basin measurements, etc., etc., all provide important alternate sources of information. These are not being addressed in the present tasks associated with the Subsurface Programme Implementation Plan.

A range of alternate observation strategies were not addressed in any detail by the OOSDP and some were left for further evaluation (after WOCE). One might ask whether the spectacular success of TOPEX/POSEIDON and the possibility of a much improved geoid, especially at shorter space scales, could change the strategy for observing the full-depth circulation. It is not clear that the OOPC can rely on CLIVAR for advice on such matters as the OOSDP to some extent relied on advice from TOGA and WOCE.

The OOPC noted that repeat sections and hydrography were not the focus of the Implementation Plan and, furthermore, in view of the recent conclusions of the WOCE and JGOFS observational phases, it was timely to revisit the OOSDP recommendations and provide improved guidance with specific regard to repeat sections activity, G. Needler noted the following:

Repeat Hydrography. Trans-ocean sections were included in the OOSDP initial observing system but, recognising the existing WOCE field programme which was yet to be analysed, the OOSDP did not specify a network of sections or a time scale for repeats. CLIVAR includes specified sections, except in the N. Pacific, and suggests a 3-5 yr repeat time but provides little justification. Variability has been demonstrated wherever sections have been repeated with sufficient resolution and accuracy, e.g., 24° N, the "Koltermann" Section. Without hydrographic sections, deep variability will not be well characterised. Repeat sections thus appear to have a unique value but the appropriate network remains to be determined as does the frequency of repeats required to meet specified objectives.

Carbon Inventory. During WOCE a global carbon inventory was obtained using WOCE ships and observations and analyses carried out by JGOFS. There is no provision for CO_2 observations to be obtained by CLIVAR or any other existing global programme. Questions remaining to be answered include determining the relative value of oceanic carbon inventories versus estimating carbon budgets using surface fluxes. The OOPC needs to determine if the conclusions of the Wallace report still stand. Given that an inventory needs to be directly determined, the design of the network and frequency of sections need to be determined. In addition, some level of adequacy of inter-calibrations as a function of the expected signal needs to be decided.

Geochemical Tracers. Several tracers were measured during the WOCE one-time survey at reduced station resolution. The data obtained remain to be fully analysed. Tracers were not considered as a priority by the OOSDP. Tracers are given a role in many of the CLIVAR upper ocean mixing process studies in many of the principal research areas. It would seem natural for CLIVAR to develop and consolidate these activities across CLIVAR. It remains to be determined which tracers, if any, could provide unique information and provide a changing opportunity for observing changes in water mass origins, mixing, etc. The question as to whether the expected coverage of repeat hydrography could give adequate coverage (probably not) and the location of critical areas needs to be addressed.

(viii) In view of the importance of deep measurements for monitoring long-term and slow change, the OOPC recommended that a task group or Workshop be convened to: (1) re-examine the conclusions of OOSDP in the light of subsequent research results; (2) assess the readiness of measurement methods for operational implementation; and (3) draft revised recommendations. The outcome is important in the light of the emphasis on gaps in the SBSTA review. A Workshop would be a "natural follow-on" from the Time Series Workshop and was the preferred strategy of OOPC.

9. OOPC SCIENTIFIC ISSUES

9.1 THE 1997-1998 ENSO

Ed Harrison reviewed the anomalies, difficulties, failures and successes that characterized the forecasts of the 1997-98 El Nino. He cautioned that both the UN and NOAA are conducting "ENSO 97-98 Retrospective" efforts, so his comments, which were his personal impressions, would be superseded by the full "Retrospective" results that would become available by the end of 1998.

Harrison began by mentioning the operational funding by the US of parts of the ENSO Observing System, including TAO and Ship of Opportunity lines. This is a major step forward toward realizing the recommendations of the OOSDP Report.

Though a "Forecast Review" was underway at the time of OOPC-III, Harrison believed it was certainly fair to summarize the overall forecast skill for this event as being "mixed". An example of a successful forecast was NCEP which, at the end of 1996, predicted equatorial warm sea-surface temperature anomalies (SSTA) would be about 1.5sigma in mid-1997. An example of an unsuccessful forecast was that of the LDEO dynamical model (Cane-Zebiak) which, at the end of 1996, predicted cooler than normal conditions through 1997. None of the published forecasts, at the end of 1996, predicted the observed amplitude of the event (close to 4 sigma). Widespread announcement of the ENSO event in the US took place in April, 1997 when equatorial SSTAs were already observed to be about 1 sigma, and the public announcement that it would be a major event took place in June, 1997 when SSTAs were about 2 sigma according to observations.

Overall, the ENSO observing system performed well. SST, surface winds and subsurface thermal data from the TAO array were available in real time via the GTS and the World Wide Web. Sea level data were reported from the island stations, and were complemented by satellite altimetric data that were available in delayed mode. Equatorial current data only become available after the moorings are reset, but preliminary results from the first part of 1997 were available. No substantial difficulties in user access to data have been reported. The operational ocean surface products available from different centers include SST and surface wind fields. In the tropical Pacific, where the ENSO observing system (OS) is in place, SST analyses typically agree to about 0.5° C on monthly average time periods. However the operational surface wind fields continue to differ from each other and from the TAO values more than is desirable; ocean model hindcasts using different wind products continue to show substantial differences from each other.

Unlike previous events this one generated huge public interest. Many issues have arisen from our experiences during the event, particularly in dealing with the press and the public. These could be classified under three general headings: Descriptive, Related Weather Impacts and Communications.

Descriptive Issues. Under this heading, the following questions arose:

(i) What exactly is meant by El Niño?
(ii) When has one begun?
(iii) How to compare different events?
(iv) Which aspects of this El Niño were "typical" and which were idiosyncratic?

Having an operating ENSO OS means more info is available than in the past. This raises the matter of how to normalize in order to adjust for the increased amount of information in previously poorly observed areas.

Historical weather associations to El Niño are weak in the US., and, depending on how one is defined, the years for assembling the composite average can be different and the correlations drawn with them to US weather can be very different. For this event, the winds were very anomalous. The SSTs off the US were also very anomalous.

In view of these difficulties, Harrison suggested a standard El Niño Index was needed. He addressed considerations that needed to be taken into account in establishing such an index. Trenberth recently proposed one for the onset using SSTA over "NINO 3.4" > 0.4° C, but this index does not accord with the historical definition of several events since WWII. Harrison and Larkin (Reviews of Geophysics, 1998), based on a composite analysis of the events since WWII have proposed a multivariate index, using sea level pressure (SLP), and zonal and meridional wind anomalies, that is consistent with the common historical identification of El Niño periods. Their "Bjerknes ENSO Index" (see section 9.1.1) disagrees in many ways with the NINO 3.4 index for conditions since 1985. In particular, it indicates that the periods of warm Dateline SSTAs in 1993 and 1994 should not be considered to be El Niño events.

Related Weather Impacts. Under this topic, the following questions surfaced:

(i) What are the statistically significant historical weather anomalies associated with El Nino periods?
(ii) How probable is the occurrence of extreme weather anomalies in general?
(iii) How much added value came from the available seasonal forecasts?

The International Research Institute (IRI) for Climate Change made efforts to address (i) and (ii) above over much of the globe. Within the US, many different groups prepared different impact assessments.

Communications. Under this general topic, the number of different voices and graphics that were presenting information was notable. It was not simple for the non-specialist to evaluate the information that was available.

9.1.1 Assessments of Recorded Observations.

A new publication attempts to address the matter of which anomalies at the air-sea interface are typical of El Niño periods, by constructing the statistically significant average anomalies over the ten El Niño periods since WWII (Harrison and Larkin, 1998, Reviews of Geophysics; see: http://tmap.pmel.noaa.gov/~larkin/RoG). Based on identifying the composite anomaly patterns that are typical of almost all of these El Niño periods, they propose a new quantitative index for the identification of El Niño periods, the Bjerknes ENSO Index (BEI). The BEI is also suitable for quantifying the peak intensity and the overall power of El Niño periods; El Niño periods with intensity greater than 2.5, 5, and 7.5 are classified as "moderate", "strong" and "severe" El Niño periods, respectively. Only the 1982-83 and 1997-98 El Niño periods are severe according to this classification.

According to the NCEP SST analysis and comparison with the Harrison and Larkin Composite, the 97 El Niño tropical Pacific anomalies followed the space and time evolution of the composite to a considerable degree, but they were roughly 3 times larger in amplitude. Cold anomalies in the mid-latitude North Pacific during summer-fall 1997 were also typical of the composite, as were warm anomalies in the tropical Indian ocean in boreal Autumn-Winter 1997-98. The absence of strong anomalies in the tropical Atlantic is typical of previous El Niño periods. The very warm waters off the west coast of North America that existed from March 1997 into early 1998 are not typical of previous El Niño periods.

There were very strong, short-duration, westerly, surface-wind anomalies in the equatorial Pacific, according to the TAO surface winds and the operational wind analyses. From late 1996 into summer 1997, these wind events typically forced substantial thermocline depth changes, and SSTA became increasingly positive. SSTA were negative in 1996 and until April 1997. These observations tend to support the idea that this El Nino began as a response to wind forcing; there were no conspicuous antecedent thermocline anomalies as would be expected according to the delayed-oscillator model for El Nino. Through the end of 1997 surface westerly-wind events occurred sporadically and became common in the central Pacific; the eastern Pacific developed systematic, westerly wind anomalies by autumn 1997 and these continued into early 1998. The central Pacific equatorial westerly anomalies ceased abruptly late in 1997. Warm surface waters continued in the central and eastern equatorial Pacific until May 1998, even though the surface zonal winds returned to near normal in March, and the thermocline anomaly was negative. Detailed analysis of the SST and thermocline-anomaly change mechanisms using ocean general circulation models is underway.

Harrison closed by stressing there is much we don't understand. He noted that he would attend AOPC and provide a similar briefing.

The Panel concluded that the great scientific and political interest in this event provides an opportunity to enhance the global observing system. For the retrospective, GCOS/GOOS (OOPC) has the lead for monitoring aspects. OOPC's emphasis is the role of subsurface data for initialisation; and data for validation of coupled models. "Impacts" are also an issue for observations, as are non-Pacific signals and observations. Harrison and Smith were designated to be contacts for the retrospective exercise.

9.2 THE ICE COVERED OCEAN, FOCUSSING ON THE ARCTIC

Roger Colony informed the Panel on Arctic programmes (ACSYS, SHEBA and IABP) and observing activities. He addressed questions like: What do we know? Can we design an observing programme for climate purposes? Is suitable technology available? His answer was definitely yes. He identified the science issues

Commenting on the North Atlantic Oscillation (NAO) Colony noted the results of a study to look at the NAO and relationships to observations north of 70° N. Strong effects were found. Colony further noted some investigators believed that the real forcing is the variation in the circumpolar vortex and that the NAO is an adjustment to it. For this reason it has been suggested the NAO should really be called the "AO", for the Arctic Oscillation.

Colony summarized the bounds of what we know about Arctic sea ice. Sea ice over the seasonal cycle has been reasonably well observed over the last 50 years, and modern, physically based, mathematical models yield simulations in reasonable agreement with the observations. Sea ice is an agent for partitioning salt in the ocean and, as sea ice is highly mobile, the net changes in ocean salinity by sea ice show distinct geographical patterns. Enough data exist to characterize the surface and subsurface fields and their interannual variability. In winter it covers 10% of the Northern hemisphere. The surface air temperature response to an ice covered ocean is in sharp contrast to the that of an ice free ocean. In summer a larger fraction (up to 70%) of the incoming solar radiation is reflected by the ice, compared to 10% for an ice-free ocean. The net energy flux going into the ocean in summer goes to melting ice - not to raising sea surface temperature. As fall approaches, surface temperatures drop below 0°C in September and the winter ice cover leads to surface temperatures on average of -30° C during the months December through March. Melting starts only in mid-June.

Sea ice can be thought of as a thin thermal sponge isolating the upper ocean from the large seasonal changes of surface energy budget. In the past, the temperature mixed layer has been deeper than the halocline under the ice. The halocline has not changed but the depth of the isothermal layer has shallowed.

Ice Thickness. Typically 20-50 cm of ice is melted June through August, at the upper surface of perennial ice. In the seasonally ice-covered seas, sea ice up to several meters thick is completely melted during the summer. After 2-3 years of melting and freezing, the perennial ice pack of the central basin is characterized by 3 m thick ice, often referred to as the equilibrium thickness. The sea ice community has developed a thickness distribution function to characterize pack ice. Knowledge of the distribution is important because the relative abundance of different ice thicknesses may control different processes. For example, turbulent motion in the upper ocean may be controlled by the motion of deep keels.

Ice thickness is best measured by sub-surface sonar. Such information from US and UK submarine cruises has been available for many years. A typical submarine track may extend over 1000 km and record ice draft every 1.5 m. An alternative approach is an upward looking sonar (ULS). In this mode, ice cover drifts over the stationary sonar and draft is measured every few minutes. Long-term time series of ice draft are now available from the Arctic Ice Thickness Monitoring Project. See the following web-site.

http://www.lby.npolar.no/ADACIT

Sea Ice Extent. Records of high latitude sea ice extent date back 400 years and modern ice charts have been maintained since the 1930s. Beginning in the 1970s satellite sensors have monitored sea ice extent.

The mean maximum is about 15 million square km in March. By late summer that area is reduced to about 8 million square km, slightly more than half of the winter coverage.

Ice Concentration. There are stark differences between the summer and winter ice packs. Winter ice contains crack patterns that may extend hundreds of km. Another feature of the winter ice pack is the lee polynya, formed by off shore winds driving the ice pack away from the coast and exposing the coastal ocean to intense convective cooling and the rapid production of new ice. In summer the ice pack is characterized by a multitude of individual floes, typically 1 km across. The floes are often in contact but are always identified by some amount of nearby water. Almost all radiometric data yield some measure of ice concentration. Typically ice concentration for the perennial ice pack ranges from 99.5% in winter to 85% in summer

Ice Types. The relative amount of radiative energy measured in different frequency bands can be used to classify sea ice into up to three categories. Standard types are: ice formed since the last melt (first-year ice), and ice surviving at least one melt season (multi-year ice).

Ice Motion. Ice motion has been observed from a number of manned ice stations and automatic weather stations. Observation of ice motion is further supplemented by analyses of successive satellite images to estimate the motion of identifiable ice features. On time scales of a few hours to several months, ice motion is controlled by local wind; typical daily motions are 6-8 km. Decadal variability is also proportional to the decadal variation in atmospheric circulation.

Ice Export. Movement of ice from the Arctic Ocean to the World ocean happens almost exclusively through the Fram Strait, the passage between Greenland and Svalbard. The flux from the Arctic Basin to the Nordic Seas is aided by the East Greenland Current, having a speed of 0.12 - 0.15 m/sec. Annual export estimates are for 900,000 km^2 of ice area and 2,850 km^3 of ice volume. The fresh water flux associated with this export is comparable to the Amazon River, 4,700 km^3, or to 20 Congo rivers. To first order, ice export volume can be measured by an area measurement. Good measure of the export volume is important to quantifying the freshwater budget and the thermohaline circulation.

ACSYS (Arctic Climate System Study) is a WCRP sponsored ten-year project launched in 1994. The scientific questions that ACSYS is confronting are:

- What are the transient and equilibrium response of sea ice to an increased greenhouse effect?
- Are there multiple equilibria for sea ice cover?
- What is the role of sea ice in the decadal-scale natural variability of Northern Hemisphere atmospheric circulation?
- Is sea ice responsible for the "high latitude amplification", i.e., the strong wintertime warming of the Arctic, which is simulated to be several times the mean global change?
- On what time scales does the ice pack respond to anomalies of summer ice conditions?

In addition, ACSYS also has a mandate to establish and maintain sea ice monitoring programmes.

SHEBA (Surface Heat Budget of the Arctic Ocean) is a major initiative to further understand the role of sea ice in the global climate. During the 12 month period beginning September 1997, all the energy fluxes will be measured from a drifting ice station in the Beaufort Sea. These data will support our understanding of the vertical energy and moisture fluxes in the context of a single column of a GCM model.

IABP (International Arctic Buoy Programme) is an Action Group of the WMO-IOC DataBouy Cooperation Panel (DBCP). It is operated and funded through IABP participants (Canada, US, Germany, Finland, Russia, Norway, China, Japan and France [ARGOS]). Typical operation is 25 buoys of different types per year, with a nominal separation of 500 km. Buoy operating life averages 2 ½ years. The Polar Ocean Profiling Buoy requires drilling a hole in the ice to place the buoy. It supports a 300 m cable with CTD sensors at 6 depth levels (10, 40, 70, 120, 200 and 300 m) and depth sensors at 40, 120 and 300 m.

In the past 20 years the IABP has operated some 500 buoys of various kinds. The IABP website: http://iabp.apl.washington.edu/ provides additional details on the buoy types and their distribution.

9.2.1 Conclusions on Ice Covered Regions

The OOPC agreed with Roger Colony's suggestion that the OOPC/OOSDP plan should focus on the "ice covered regions of the ocean" rather than sea ice. The plan needs to be revisited with this change in perspective.

The OOPC, as requested by the GSC (J-GOOS) and JSTC, will assume responsibility for scientific oversight and implementation of operational observing system for the ice-covered regions of the ocean. This remit would include short-range forecasting (sea-ice warning systems).

The OOPC noted the methods for the Antarctic ice-covered regions were in general not as mature as those developed for the Arctic, except for remote sensing of ice extent/coverage. The revised plan will reflect this.

Specific modifications to the existing plan for ice-covered regions (formerly sea ice) are

- Remote sensing is the sole approach for ice extent;

- There is no longer any real role for *in situ* data for observing ice extent. The remote sensing methods for ice extent are mature, but there is a lack of coordination of methods and data handling. The OOPC recommended some action to provide better documentation of methods, of information distribution and of verification, as well as greater attention to assembly and archiving.

- Because sea level pressure observations are very closely correlated to geostrophic winds, which in the Arctic essentially are the winds, sea level pressure measurements are of enhanced importance in the Arctic.

- At the two metre height level, air temperature is the same as ice temperature.

- RADARSAT and the buoy programme are candidates for the operational observing system. However, it must borne in mind that any operational use of RADARSAT imagery must take into account the commercial aspects of getting data from the satellite.

- The emphasis for subsurface measurements must be on both temperature and salinity. One without the other is of little value. Development of cost-effective autonomous or unmanned methods is essential ("Operational" ice-breakers for measurement are not practical).

9.3 GRAVITY MISSIONS AND OCEAN CIRCULATION

Johnny Johannessen described three gravity missions now being considered: the ESA Gravity Field and Steady State Ocean Circulation Explorer (GOCE), launch date of beyond 2003; the German-led mission CHAllenging Minisatellite Payload (CHAMP) for geophysical research and application, scheduled for launch in 1999; and NASA's Gravity Recovery and Climate Experiment (GRACE) including German participation with tentative launch date in 2001. In his presentation (see Annex XI) Johannessen highlighted the importance of the GOCE mission for oceanography. During the Phase A study, which runs for one year (from July 1997),the goal is to investigate and demonstrate the preliminary quantitative impact of the GOCE mission on ocean circulation studies. He was concerned that the ocean community may not be able to answer the question of whether the ESA GOCE is needed if the US GRACE flies. A meeting is needed between the GOCE and GRACE scientists to identify and discuss mission objectives, instrument specs, performance assumptions, observation requirements, degrees of complementarity, and optimum solutions. Johannessen summarized the importance of the gravity missions for the OOPC agenda and, in particular, for the better determination of ocean circulation.

He stated that the objective of gravity missions was a more accurate determination of the marine geoid and noted the beneficial consequences for mean sea surface topography, dynamic topography, ocean circulation, heat transport, etc. Comparisons of how the three missions enhance the determination of these features are shown in Figure 9.3-1.

The following requirements for GOCE have been specified for ocean circulation:

	Geoid Accuracy	Spatial Resolution (half wavelength)
Mesoscale	2 cm	60 - 250 km
Basin Scale	< 1 cm	1000 km

The GOCE mission would open a completely new range of spatial scales (100 km) of the Earth's gravitational field spectrum to research..

In combination with altimetry the absolute dynamic topography is recovered. If it is assumed to be invariant with time (a good approximation for the open ocean) it can be applied not only for present studies but also for the reanalysis of past data (e.g., SeaSat). Johannessen summarized the attributes of the 3 missions:

CHAMP:	± 1.0 cm,	5000 km	Launch: 1999
GRACE:	± 1.0 cm,	500 km,	Launch: 2001
	± 0.1 mm,	1000 km	
GOCE:	± 2.0 cm,	100 km	Launch: >2003
	<1.0 cm,	1000 km	

GRACE can also capture temporal variations. Gravity changes directly reflect changes in the masses of the ocean, (thus allowing the separation of steric and non-steric contributions to sea- level rise), the polar ice sheets, and the liquid water stored in the continents. From a GRACE type mission an increasing mass of water in the ocean equivalent to 0.1mm/yr of sea-level rise can be measured. Changes in the masses of the Antarctic and Greenland ice sheets are the major unknown contributors to sea-level change. Even the sign of ice sheet mass change is in dispute. Gravity measurements over ice sheets, particularly in combination with a laser altimeter mission would lead to those contributions with an accuracy of a few tenths of a millimeter per year.

It was noted by Johannessen and Michel Lefebvre that temporal variations arise principally from seasonal and other variations in the terrestrial water reservoirs. The implication is that it may be a factor in coastal regions but probably not for the open ocean. There was also discussion about the impact of ridges and mountains (short space scales) on the impact on error estimates. Requirements of resolution and accuracy of the gravity field and geoid for geodynamics and geodesy are included in Annex XI.

Johannessen stated that several meetings were scheduled for the next 12 months to consider these scientific issues. In addition, the possibility of arranging a joint GOCE-GRACE scientific and technical meeting is under consideration for the first part of 1999.

9.3.1 Conclusions on Gravity Missions

The OOPC thanked Johannessen for his presentation and welcomed in particular the clarification of the objectives of the missions and the clear articulation of the complementarity between GOCE and GRACE. The OOPC agreed that these missions were truly complementary, not competitive. The OOPC concluded that the gravity missions would be valuable contributions to oceanography and, in particular, to the exploitation of the altimetric component of the observing system.

M. Lefebvre brought the comments of Roemmich (concerning the impact of floats on the estimation of the marine geoid) to the attention of the OOPC, pointing out the difficulties and ambiguity in the estimation of mean sea level from samples of drift. Even if one assumes as is proposed in the ARGO float proposal, that ARGO is capable of producing a marine geoid of equal or better accuracy than the gravity satellites, an estimate that combines the two data sets is likely to be better than either one separately because scale-dependence of random errors will be quite different for the two systems and systematic errors will be completely independent. For example, it is plausible that a long term ARGO data set would fill in small spatial scale information missing from the gravity satellite, but the latter might be better on the basin scale.

The OOPC concluded that the existence, or not, of a float programme did not lessen the interest in the gravity missions.

The OOPC noted that an experiment in the determination of gravity was both timely and relevant. It offered the potential for enhanced exploitation of contemporary and past data, and offered the potential for increased flexibility in a float programme (less need for the subsurface drift, opening up the possibility of station-keeping floats).

9.4 THE OPEN OCEAN-COASTAL INTERFACE

9.4.1 Coastal Panel

Needler reported on the recent Coastal Panel meeting; he noted that the length of the meeting did not permit members to develop issues in detail but that the Panel made substantial progress in addressing general issues and the scope of its future work. The meeting did consider the recommendations from the earlier ad hoc Miami coastal meeting. A further meeting is planned within the year to take advantage of this initial progress.

Needler had informed the Coastal Panel of the desire of the OOPC to examine whether or not the initial observing system as specified by the OOSDP provides the required off-shore boundary conditions for modelling and describing the continental shelf and coastal circulation. The Coastal Panel recognised the importance of this question and decided in the inter-sessional period to form a small informal working group (including Needler) to initially address the issue from the coastal perspective. Needler also noted that little progress had been made on the OOPC proposed background paper for this issue. The joint effort with the Coastal Panel might be one way to address this. The Chair noted that this remains high on the agenda for GODAE and for the closure of the ocean climate plans. The Chair would discuss these issues in further detail at the GSC.

9.4.2 The Kuroshio and the North Pacific

Masaki Kawabe briefed the Panel on some N. Pacific climate studies. He touched on several of the issues related to the coastal region interface. His talk addressed decadal variations in the Pacific. He stressed the importance of monitoring the ocean circulation, specifically the transport by the Kuroshio, for understanding global climate. Surface heat fluxes calculated from merchant ship and weather ship data in the Kuroshio extension region (about 30° N, 165° E) showed significant interannual variability. These variations may be correlated with the presence or absence of the "large meander" in the Kuroshio south of Japan. Periods when the large meander exists correlate with large mean volume transport in the Kuroshio which can be linked to periods in which the Aleutian low is particularly strong. Numerical modelling shows that the variations of heat flux in the Kuroshio region have more effect on the atmosphere than do variations in sea surface temperature. These heat flux anomalies also correlate well with sea level pressure and geopotential height in the Kuroshio. To satisfy an obvious need for monitoring the course of the Kuroshio, Japan will soon have in place a system for monitoring volume transport using a number of submarine cables, and determining the variations of the path of the Kuroshio using sea level data.

In the discussion, the use of Topex/Poseidon data was recommended; some research is already underway. It was also suggested that the large meander may be an ocean response to the ocean circulation anomaly induced by the enhanced Aleutian low. It was recommended that more emphasis be placed on obtaining sea level data for monitoring western boundary currents. The Panel concluded that more recognition was needed for the role of various methods for monitoring transport, and in particular the role of submarine cables. More detailed information on Kawabe's talk is in Annex XII.

Kawabe made an offer to develop a background paper around these issues. The OOPC were asked to consider this off-line.

9.5 THE CARBON CYCLE

Michael Fasham discussed the issues that needed to be considered in an ocean carbon measurement programme. He had recently reviewed the OOSDP Background Paper on the subject by Douglas Wallace and judged it to be a good starting place for an update. It was clear that the technology for measuring the ocean carbon inventory and air-sea carbon fluxes using remote buoys was developing strongly but was probably still just short of being fully operational. However, he stressed estimates of these quantities were a high priority. He stated that the importance of measuring dissolved organic carbon (DOC) content was still an open question and, although there was now a consensus about how to measure it from bottle samples, remote measurements from buoys was some way off. Some models are now available to look at the question of whether we need this measurement.

He noted that the best estimate of flux from pCO_2 is 1.0 -1.5 gtC, a lot less than the 1.8 to 2.0 gtC estimated from ocean carbon models. However, if account is taken of the flux of DOC from rivers, then these two estimates agree more closely. The air-sea carbon flux is an important number to get right with known error bars. Establishing the variability over the global ocean is likewise important and he wondered about the robustness of the algorithms for determining fluxes from satellite ocean color sensors and how to detect changes in the biological pump that might be a consequence of climate change.

Regarding nutrients, Fasham discussed recent technology development for in-situ nitrate measurement (essentially a spectrophotometer in the water -- UV absorption is related to nitrate concentration). The instrument can be attached to a CTD to obtain nitrate profiles .

Fasham mentioned that funding was assured by NSF for the HOTS and BATS JGOFS time-series stations until 2001. The ESTOC station was also funded to 2001.

Regarding 3-D carbon models, he noted there were large differences in their results. The Hadley model was the closest to reality because it had an explicit mixed-layer model incorporated, something that the Hamburg and Princeton models did not. He informed the panel that a new test of 7-8 such models was being planned as part of a project developed within the IGBP-GAIM Programme and funded by the European Union and NSF.

9.5.1 Conclusions Regarding Carbon Observations

The discussion following Fasham's presentation produced the following conclusions:

(i) An observing system for carbon is urgently required, because of its central importance in climate change, and because a carbon inventory is required by IPCC.

(ii) The technology for routine unmanned pCO_2 measurement has now been developed and is now being field tested for operational use on unmanned buoys and VOS.

(iii) It is likely that global air-sea CO_2 fluxes can be estimated from a combination of satellite-measured SST, ocean colour and wind fields, plus buoy and VOS pCO_2 measurements. OOPC requests that JGOFS develop the models to achieve this. The deployment of buoys, their numbers and locations needs further modelling and statistical research.

(iv) As part of the carbon inventory, it is desirable to be able to model export carbon flux from the upper ocean, using remotely sensed ocean colour, SST, plus *in situ* time-series measurements of

pCO_2, nitrate, fluorescence and physical variables at key sites. OOPC requests that JGOFS undertake the necessary modelling and research.

(v) In order to test the methods of (iii) and (iv) above during the operational life of SeaWiFS, OOPC recommends that pCO_2, fluorescence and nitrate sensors be deployed at the JGOFS time series and other key sites to better characterize the seasonal cycle of pCO_2, phytoplankton and nitrate.

(vi) Repeat hydrographic sections are needed with tracers such as carbon isotope ratios, CFC's and carbon tetrachloride at 5-year intervals at locations to be decided. These sections are needed for slower deep inventory and for carbon cycle models. There is a need to calculate anthropogenic CO_2 uptake (see Wallace document).

(vii) Long-term time series stations are needed at key locations to be determined. These are essential for calibration and validation of ocean carbon-cycle models. The length of the observational period is important (hence discontinuation of a station is a serious decision) and breadth of the range of measurements adds additional value. Key locations may include: BATS, HOTS, KERFIX, ESTOC, as well as sites in the North Atlantic, North Pacific and Southern Oceans. Additional biogeochemical measurements to be considered are sediment traps, dissolved organic matter, and zooplankton.

(viii) JGOFS should recommend on the measurements to be made and the calibration standards to be applied.

(ix) JGOFS should recommend on what future observation system(s) are needed for monitoring climate, and the carbon system in particular.

9.6 SEA SURFACE TEMPERATURE AND SALINITY

Dick Reynolds gave some background on the need for sea surface salinity (SSS) observations. Variation in the upper ocean salinity field affects ENSO forecasts. Trying to finesse the absence of data with models using climatology and winds does not work. Reynolds brought the Panel's attention to a workshop on salinity remote sensing that took place 7-8 February 1998 in La Jolla, CA. See the following web site.

http://www.esr.org/lagerloef/ssiwg/ssiwgrep1.v2.html

He stated that with altimeter data, SSS, temperature profiles and historical T-S relationships a useful estimate can be obtained of the salinity profile with EOF dynamic height correction. Aircraft tests have demonstrated the plausibility of obtaining SSS with remote sensors operating at low microwave frequencies (1-3 Ghz) and using 30-day averaging. But there are cloud/rain problems and cold sea water problems that make it problematical at present. Under optimum conditions, i.e., in the tropics under a clear sky, a precision of 0.2 psu (practical salinity units) is achievable.

Reynolds then turned to SST issues. He noted that NCEP and UKMO SST values at high latitudes in blended products drift apart. This is probably due to differences in blending methodologies. There is some debate about what value of SST to use near sea ice. NCEP SST optimum interpretation analysis (OI) has had some promising fitting when utilizing -1.8 C for an *in situ* temperature value in areas of greater than 50% sea ice concentration. He stressed the importance of *in situ* observations for producing the blended product and noted that the southern hemisphere does not have enough buoys to make corrections to the remotely sensed data. He raised several questions that OOPC should address regarding SST products:

What accuracy is required?
Which SST is best (skin, ship, buoy)?
What are the desired time and space scales for analysis?
What is the optimum spatial scale for *in situ* sampling?
What is the appropriate trade-offs between satellite bias and analysis resolution?

How many satellites are needed -- 1 or 2? Polar and/or geostationary?.
How should SST be treated near sea ice?
Is GOES SST data an important input? If so, OOPC must make specific recommendations so that 12-bit resolution replaces 10 bit and at least the 11 and 12 micron IR channels are used/available.

To provide a basis for answers to these and other questions concerned with SST observations, it was proposed that an SST observing system experiment be designed and conducted that would include the following:

A 1-yr run of SST fields on an ocean model high-resolution output.
A subsampling of these fields with realistic errors (bias + random).
A comparison of the two.

A proposal needs to be written and several groups are needed to participate in the experiment. The following were suggested:

An OOPC group (Reynolds and Harrison),
ENSO OS Council,
Climate Panel (Tom Karl, Trenberth),
UKMO (Parker).

The OOPC concluded there was a clear need to look again at the OOSDP recommendations for SST sampling.

Note: The OOPC and the Atmospheric Observations Panel for Climate (AOPC) are planning to convene a workshop (November 1998) to examine SST analyses for climate and the needed data.

9.7 SATELLITE OBSERVATIONS - ALTIMETRY AND SCATTEROMETRY

Michel Lefebvre preceded his discussion on altimetry and scatterometry by voicing some general concerns. He believes that, considering the number of groups involved, CEOS, GOSSP, OOPC, CLIVAR, GODAE, etc., the responsibility is not explicitly focussed for updating space ocean observation requirements and following the action after requirements are specified. It is not enough for various groups to meet once a year and draft recommendations, etc. He proposed that OOPC consider the preparation of a comprehensive document to be used as a baseline for a range of space observations similar to the so-called "Purple Book"*. He envisioned this document would provide the synthesis that is lacking at present that addresses requirements of users in a more meaningful way than single numbers can of accuracy and resolution of a specific variable. It would reflect the current realities of what is possible with proven sensor systems, orbiting on single platforms or in tandem with others, and what combination of satellite and *in situ* systems would meet the long-term requirements for data for the full range of time and space scales. Such a document would also address the ancillary data issues and the archiving of data whose future value can only be guessed. Certainly, there is ample experience that tells us we should have done a better job of archiving old data that would be invaluable today if we had done so. The concept is to have this document always at the ready for referral by all groups as the situations change with time.

Lefebvre also recommended that some other group (GOSSP or CEOS?) be charged with the follow-on task to be aware of situation changes and to generate appropriate responsive actions on a timely basis when necessary. This is not a problem when a funded project is generating a need for a particular launch and there is a motivated principle investigator with a personal vested interest in what's happening. But it is that kind of motivated week-by-week oversight that is not charged explicitly to any single group that Lefebvre believes is necessary to prevent things from falling through the cracks. The most effective impact would probably come from organizing such a legacy for projects like GODAE.

*The Future of Space-Borne Altimetry - Ocean and Climate Change: A Long-Term Strategy. C. Koplinsky, P.Gaspar and G. Lagerloef. March 1992.

Michel Lefebvre then opened the discussion on altimetry and scatterometry His aim was to raise some issues emerging from experience and new expertise developed with ongoing projects, to refine the currently specified requirements and to think about ways to impact commitments.

9.7.1 Altimetry

Theoretical sensitivity studies have been performed for optimizing the number of satellites needed for different applications. In the meantime, several laboratories and organizations have been running in quasi-operational mode and real-time programmes to forecast the ocean at a typical weekly interval. Both the operational experience with TOPEX/ POSEIDON (T/P) and other altimeter systems and the theoretical studies show that for the mesoscale, it is a prerequisite to have two satellites, one of which must be of the T/P class, in orbit at the same time with different repeat cycles. The experience with T/P and ERS-2 demonstrated that clearly. Dramatic detail became available from the combination that was not retrievable from either satellite alone.

It is important to understand that the T/P class system can provide data for tracking mesoscale features but its high accuracy and demonstrated reliable continuity is essential for observing large-scale, long-term variability over periods of years with no data gaps. Results from more than five years of T/P analyses have highlighted the capability of such an accurate system to observe features at wide scales of variability on a continuing basis. It can resolve, for example, the seasonal variations as well as year-to-year variations. Without reliable continuity, important transients in the record can go undetected and advancement in our understanding of large-scale processes will be impeded. This is well illustrated by the T/P observations of the 1997-98 El Nino. A series of images prepared by JPL show the evolution of the El Nino -- its occurrence, development, relaxation and then transition to La Nina 1998. This remarkable series can be seen on the following JPL web site.
http://www.jpl.nasa.gov/elnino/

Lefebvre noted that a third altimeter in orbit at the same time provides some additional gain but not as much as gained with the combination of two (an ERS class and a T/P class). However, a third satellite in reserve will be useful as a replacement in the event of an unscheduled breakdown. Ready replacements are the norm for operational systems. He cautioned that as a replacement, it must be of the T/P (or JASON) class to assure continuity at the high accuracy. He added that another concern that should be continually expressed is the overlapping required for cross-calibration between series of TOPEX/POSEIDON class altimeter systems -- as a first example, replacing T/P with JASON-1. Otherwise, the overlapping requirement may fall through the cracks.

Lefebvre emphasized that a single number for specifying altimeter accuracy is insufficient - it must be defined in terms of height error with a specific time and space scale e.g., ± 1.0 cm, over one month, over 4000 km. He also expressed concern, that at meetings he has attended, terms like sea level, sea height and dynamical topography are often misused leading to confusion about the capabilities of different altimeter systems operating alone or in combination, and thus mudding the waters about the class of altimeters needed for different purposes. Individuals whose interest is in sea level changes due to warming may not appreciate that dynamical topography is an integral measurement that provides information on the overall ocean circulation.

Altimetry systems will be the core of integrated programmes. That means that simultaneity of deployment and maintenance is required of *in situ* networks of observing instruments with satellites. It also implies that there is an impact on the selection of the type of *in situ* observations. The real complementarity with altimeter data is one issue. The second issue is to favor systems providing data in quasi-real time in order to match in time with the altimetry in the operational programmes. The ARGO system under study now seems to be an example of an optimized integration. It would be good if ARGO is deployed commensurate with JASON-1 and ENVISAT, thus allowing integrated systems starting in 2002-2003 like GODAE to be fully operational.

Lefebvre provided the following updated list of projects.

	Mesoscale	Accurate Large scale	Back-up
Until 2000	ERS-2; T/P	T/P	GFO****
2000-2003	ENVISAT; JASON-1	JASON-1	GFO
2004-beyond	NPOESS*; JASON-2**	JASON-2**	(OCEANSAT)***

* National Polar-orbiting Operational Environmental Satellite System (US)
** Not yet approved
*** Indian Satellite
****GEOSAT Follow On

The situation appears safe until 2005-6 but there is no assured altimeter combination thereafter. Although CEOS, is aware of this condition, it does not make multi-year commitments.

Lefebvre summarized by stating that a firm recommendation can be made and justified for a continuous operational system with:

- 2 satellites with different repeat cycles for mesoscale
- 1 satellite continuous (no data gaps) having the T/P class system. Obviously the T/P class can be used for mesoscale features as well.

9.7.2 Scatterometry

Lefebvre reported some good news and bad news on scatterometer status. The good news was there was an overlap between the ERS-2 instrument and NSCATT on ADEOS and that the data from NSCATT are within the specifications or better. The bad news was that NSCATT on ADEOS is no longer functioning. More good follow-up news is that Windscat/ADEOS has an approved launching in 2000-2001. Also METOP/EPS from EUMETSAT has been approved as an operational system starting 2003.

Lefebvre considered ways to optimize the future. The use of scatterometer is twofold: (a) for improving sea state forecasting and (b) to calculate the wind forcing fields for input for ocean circulation models. He hoped the case made for (a) is obvious and will be convincing enough to have several satellites in orbit -- the overriding justification being the sea state forecasting. Indeed, at ECMWF the ERS-2 data are collected in real time and assimilated operationally. As for (b) the wind-forcing for ocean models, the expertise is still not at the level to justify optimized solutions but is enough to already deduct some bias in the wind forcing computed without the scatterometer and to justify the zero order request to have two double-swath scatterometers flying at the same time. Lefebvre noted that OOPC has already decided that we definitely need one double-swath scatterometer and he believes a good case can be made for two in orbit at the same time. Lefebvre summarized his view of the scatterometer future:

- Initial tests have already resulted in an appeal by the modelling community for 2 double-swath scatterometers operating simultaneously.
- Further studies are needed with existing data from scatterometers and microwave radiometers to clarify the pros and cons before a firm recommendation can be made for a system that will meet wind forcing requirements.

9.8 INVITED SCIENTIFIC TALKS

In keeping with a tradition of OOPC meetings to include invited scientific talks from the host organization, our host Francois Barlier arranged two presentations from scientists in his laboratory. Barlier himself has been a P.I. on altimetric satellite experiments from the beginning of the science of satellite altimetry. He is an internationally known expert in nongravitational forces acting on satellites and his air-drag model is widely used in all the centers computing precise orbits. He informed the Panel of the work of the tracking center and arranged a tour of the laser moon tracking facility at the mountain nearby. In addition to the moon, the center also tracks ERS-2, TOPEX/POSEIDON, and more recently, GFO on an operational basis.

Pierre Exertier, a CNRS expert in satellite geodesy, spoke on their work in analysing long time series to calculate the temporal variation of the geoid. From this type of analysis they are able to recover new values of nutation and other parameters that affect the variation of the geoid. This work is important for precise measurement of sea level from altimetry. At long range, the reference is the orbit and the limitation at the present time results from the inability to accurately compute continuous orbits (due to drag, ocean tides, etc.). The analysis made by Exertier and others is an attempt to decorrelate and account for the various known signals that contribute to the variation of the geoid and to estimate the remaining effects.

Pascal Bonnefond, another expert in satellite geodesy, but fromAstronomie, provided the second lecture. Bonnefond described a calibration campaign using a laser tracking station in Corsica, with colocation from a CERGA laser and DORIS with GPS coordination to improve satellite orbit determination. He explained the methods he is utilizing in order to use these orbits for on-site calibration.

10. PENDING ISSUES

10.1 END-TO-END BROCHURES

The Chair noted that these had been on the work programme of the OOPC since OOPC I but, as yet, apart from a few outlines, no progress had been made. All concerned groups had agreed that such material was needed to explain the case and approach for the observing elements of the ocean climate observing system.

The Panel re-considered the proposed brochures (from the standpoint of whether they are still needed or not) and responsibilities.

Sea level. Yes. Le Provost in collaboration with GLOSS (Le Provost to work with Smith - an outline by April, May.

Subsurface data for ENSO prediction. Yes. Smith and Bailey (SOOP), possibly with input from Linda Mangum (TAO). Draft by end of June.

Sea surface temperature, highlighting range of applications from NWP, through ENSO, to climate change. Yes, noting outline previously developed by Weller; Reynolds and ?

Surface fluxes. Yes, built around the reference sites as developed at OOPC III - Weller and Taylor, outline by end of June.

Carbon. Yes, redo this around the time series stations as validation sites. Field + ?

Satellite technology. Yes, consider ALT, SCAT + SST in an integrated system. Lefebvre

Deep ocean - no specifics; Time series report ideas?

Ice-covered ocean - Colony.

10.2 THE AGREEMENTS MEETING

Alexiou informed the Panel that planning for the original idea to feature the "GOOS 98" publication at an agreements meeting in Lisbon in September 1998 as part of the Year of the Ocean was not progressing and that at best a postponement to later in the year and change of venue to Paris might result. Subsequent to this OOPC meeting, the matter was taken up by the GSC. It was decided there that planning had not proceeded sufficiently to conduct a successful meeting and recommended that the effort cease.

11. ORGANISATIONAL ISSUES

Expanding Workload. The chair noted the considerable work-load now being undertaken by the OOPC, its members and friends. Its remit is broadening (sea ice, open-coastal issues). No specific suggestions were tabled to curtail this expansion though it was noted that the establishment of the GOOS Coastal Panel might ease some pressures. The Chair emphasised once again the many tasks the panel was taking on, and that no one should be under the illusion that these were not real and important tasks. The SBSTA document and the ENSO Retrospective offered unique opportunities for the OOPC to leverage political interest and investment in the ocean observing system. GODAE was providing a similar opportunity within the ocean science and applications community. Success would depend on a range of activities from the mundane (e.g., brochures) to leading-edge research (e.g., GODAE, surface reference sites). The Panel was suitably sobered by this prospect.

Membership. There was little opportunity to discuss this in detail. The Chair resolved to interact with members and determine specific membership life-times.

11.1 SUMMARY OF TARGETED ACTIVITIES

The chair recapitulated the OOPC needs/actions that were identified during the course of the meeting. They are summarized as follows:

(i) Organize a workshop to examine the status of Repeat Hydrographic and Geochemical Sections, and future needs.

(ii) Conduct a review of the ocean carbon observing plan from the OOSDP, and modify in recognition of present status of technology.

(iii) Revise implementation plans from Sydney GOOS Implementation Meeting.

(iv) Proceed with Ocean Observing System Impact brochures (end-to-end).

(v) Schedule briefing on status of Antarctic Observing System and strategy for the future.

(vi) Consider approaches to address open ocean/coastal interface issues.

(vii) Continue liaison with CLIVAR, ACC, PBECS, PACS research efforts

12. NEXT MEETING

Weller offered WHOI as the site for the next meeting. Norway and Australia were alternate offers from Peter Haugan and Neville Smith. In order to capture an advantageous time it was proposed that the next meeting be in May 1999, noting that the activities of the OOPC will inevitably bring several members together intersessionally.

The Chair brought the meeting to a close at 1800 Wednesday 8 April, thanking Agence DAG for their help, and Michel Lefebvre and Francois Barlier for logistical support.

FIGURES

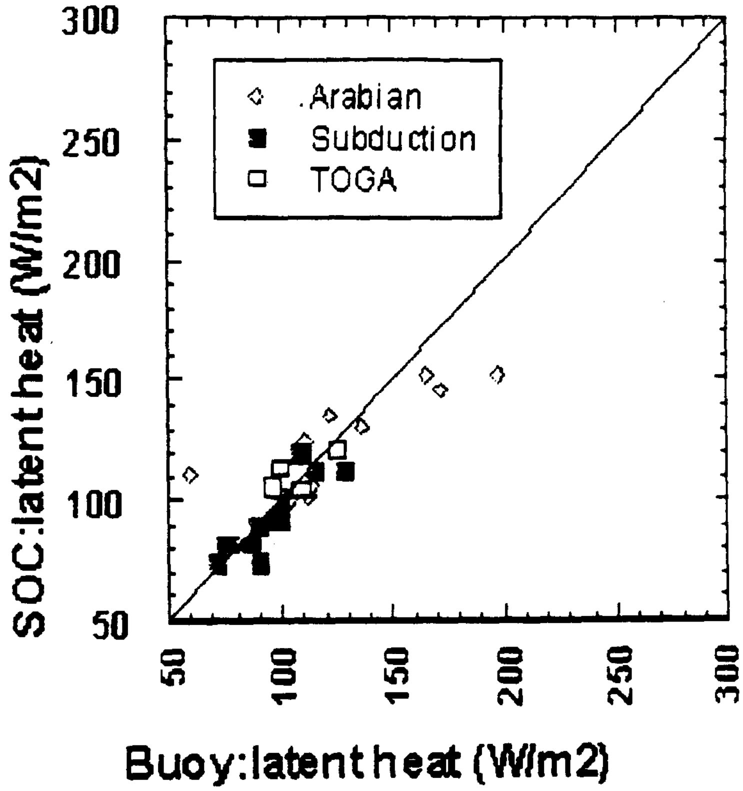

Figure 8.1-1 Comparison of latent SOC heat flux values calculated from VOS vs flux values calculated from accurate buoy data.

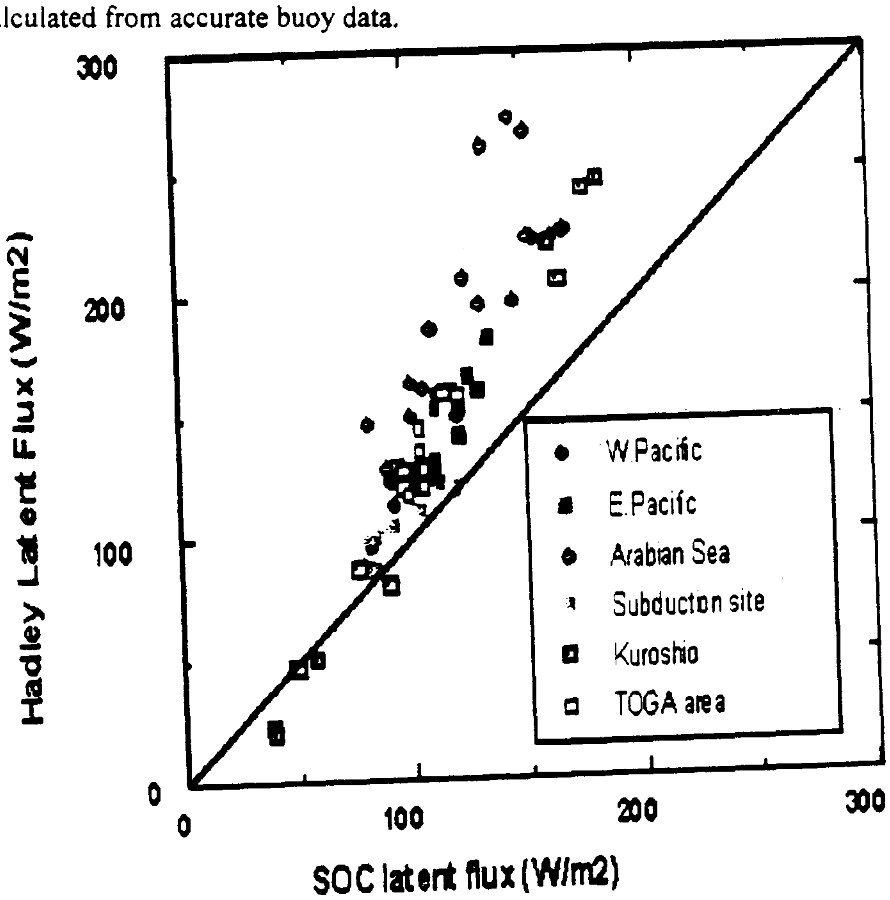

Figure 8.1-2 Comparison of SOC latent heat flux values computed with corrected VOS data vs. flux values produced by the Hadley model showing model bias.

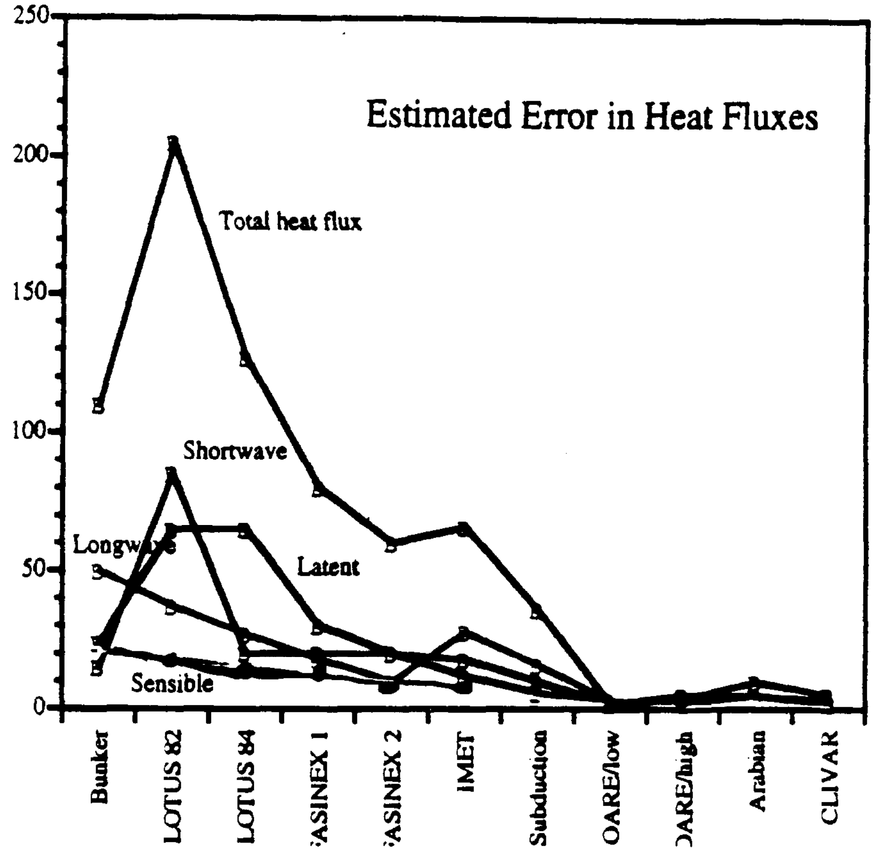

Figure 8.1-3 Reduction in the measurement error (in Wm^{-2}) in the four components of heat flux (sensible, latent, shortwave, and longwave) and in the total net heat flux achieved by improvements to the sensors since the early 1980s. In the early 1980s, when attempts were made to measure air-sea fluxes from surface moorings, the errors were large, larger than the stated error estimates in Bunker's atlas, which are shown as the first set of points to the left.

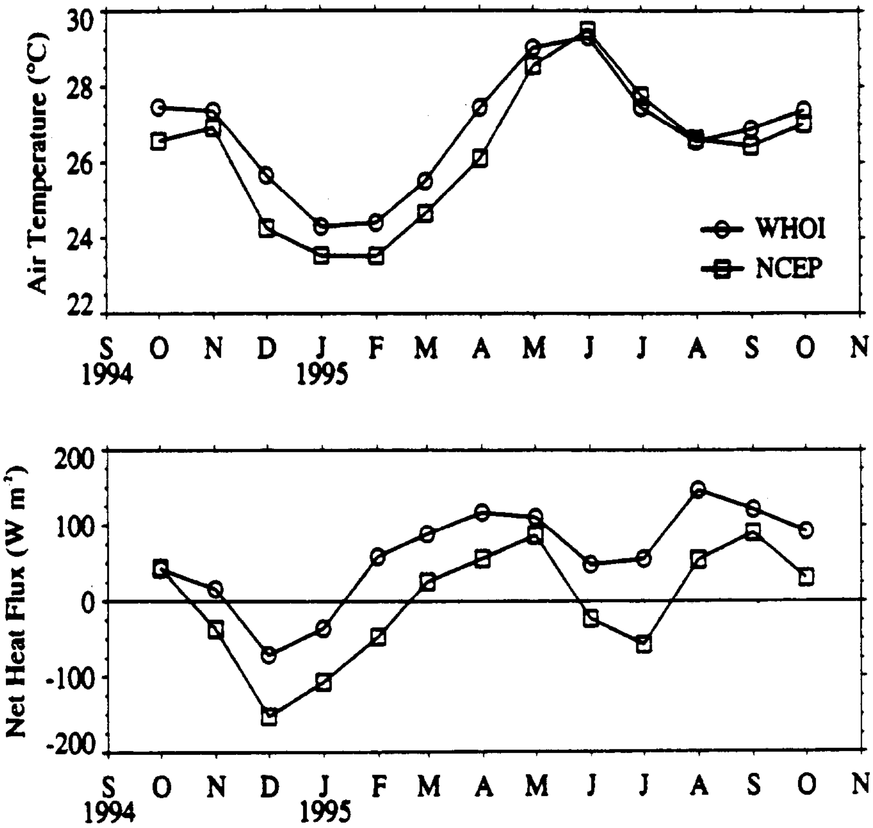

Figure 8.1-4 Comparison of National Centre for Environment Prediction (NCEP) numerical weather prediction model surface air temperature (upper) and net heat flux (lower) with those quantitites based on measurements from WHOI surface mooring deployed in the Arabian Sea

Oceanographic Observatories for Global Climate Observations

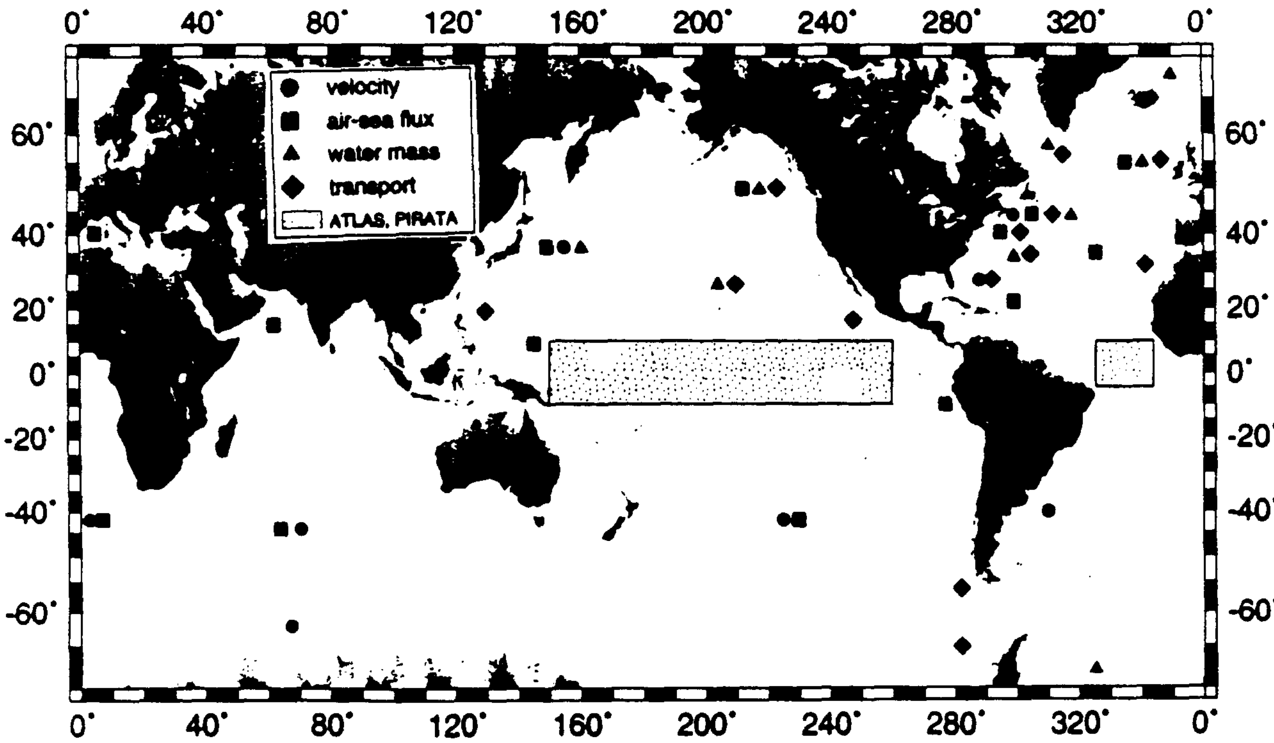

Figure 8.1-5 World's oceans, summarizing the sites recommended for ocean observatories

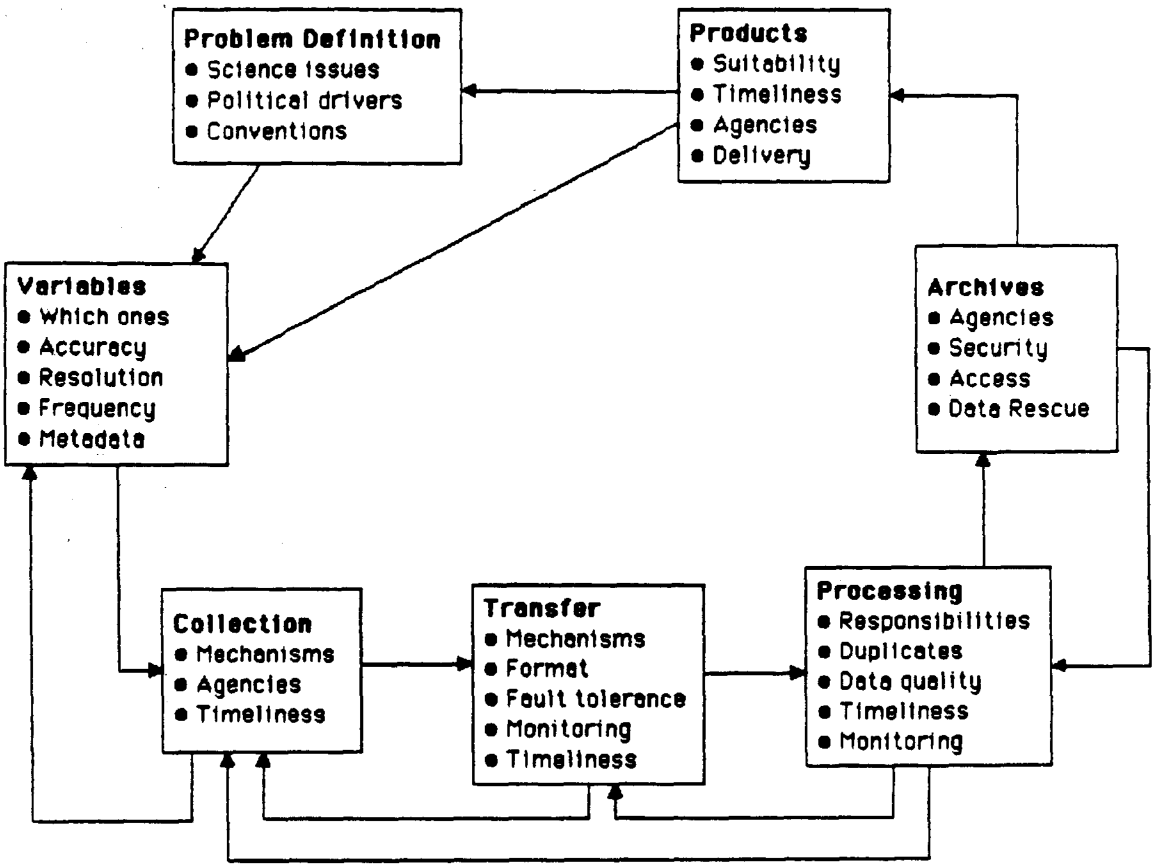

Figure 8.3-1. Data system elements and information feedback paths for a data and information management system to be considered for an Implementation Plan.

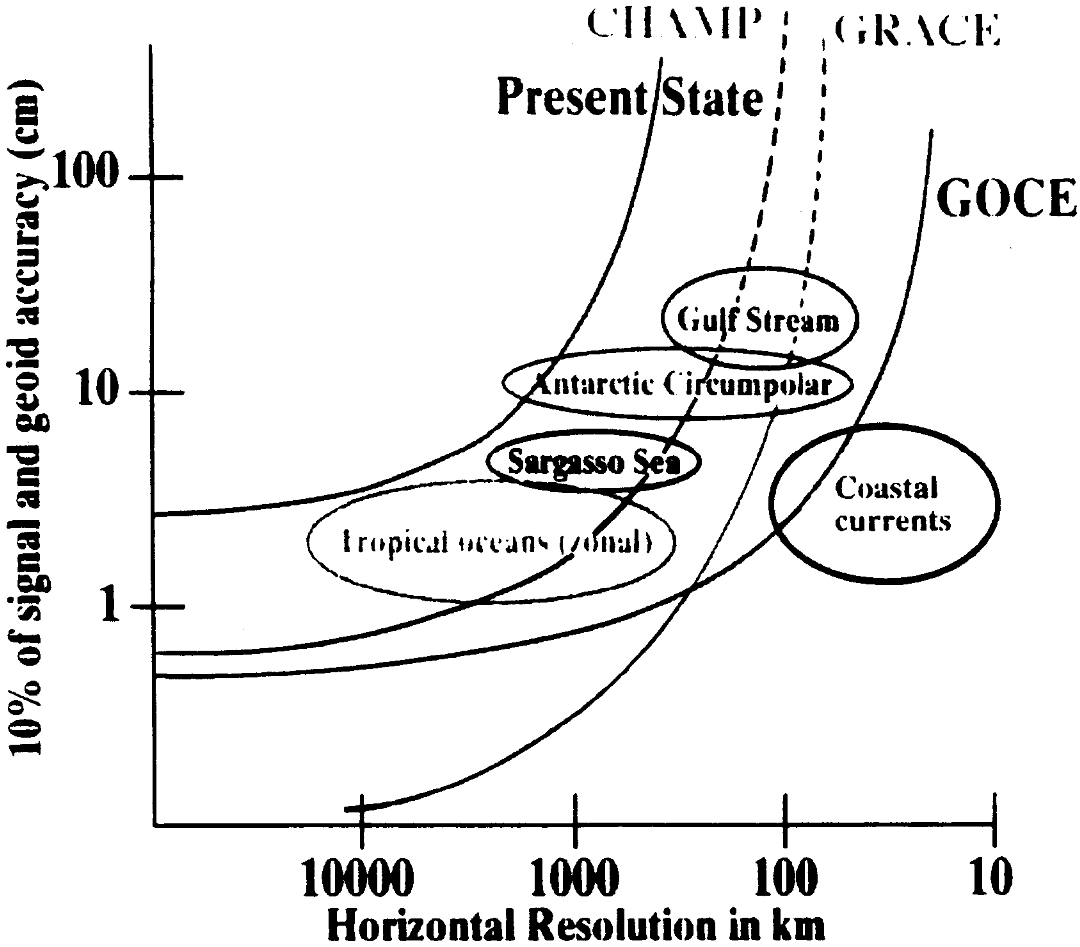

Figure 9.3-1 Horizontal Resolution vs. geoid accuracy anticipated from CHAMP, GRACE and GOCE as applied to the scales of ocean features of interest.

ANNEX I

AGENDA

1. **OPENING AND WELCOMING**

2. **REVIEW AND ADOPTION OF THE AGENDA**

3. **REVIEW OF INTERSESSIONAL ACTIVITIES**

   3.1 OOPC
   3.2 GCOS
   3.3 G3OS
   3.4 IOC

4. **TIME SERIES WORKSHOP**

   4.1 OPPC CONCLUSIONS ON TIME SERIES WORKSHOP
   4.2 POTENTIAL TIME-SERIES STATION TECHNOLOGY

5. **SEA LEVEL WORKSHOP**

   5.1 OOPC RESPONSE TO SEA LEVEL WORKSHOP RECOMMENDATION

6. **GODAE**

7. **IMPLEMENTATION WORKSHOP FOR GCOS-GOOS OBSERVING SYSTEM**

8. **TOWARDS AN OOPC IMPLEMENTATION PLAN**

   8.1. SURFACE AND MARINE DATA SUBPROGRAM

      8.1.1 Outcome from the Sydney Meeting
      8.1.2 Recommendation for Surface Reference Sites

   8.2 SUBSURFACE SUBPROGRAM
   8.3 DATA MANAGEMENT ISSUES
   8.4 IMPLEMENTATION PLANNING CONCLUSIONS

9. **OOPC SCIENTIFIC ISSUES**

   9.1 THE 1997-1998 ENSO

      9.1.1 Assessments of Recorded Observations

   9.2 THE ICE COVERED OCEAN, FOCUSSING ON THE ARCTIC

      9.2.1 Conclusions on Ice Covered Regions

   9.3 GRAVITY MISSIONS AND OCEAN CIRCULATION

      9.3.1 Conclusions on Gravity Missions

9.4 THE OPEN OCEAN-COASTAL INTERFACE

9.4.1 Coastal Panel
9.4.2 The Kuroshio and the North Pacific

9.5 THE CARBON CYCLE

9.5.1 Conclusions Regarding Carbon Observations

9.6 SEA SURFACE TEMPERATURE AND SALINITY
9.7 SATELLITE DISCUSSION - SCATTEROMETERS AND ALTIMETERS

9.7.1 Altimetry
9.7.2 Scatterometry

9.8 INVITED SCIENTIFIC TALKS

10. PENDING ISSUES

10.1 END-TO-END BROCHURES
10.2 THE AGREEMENTS MEETING

11. ORGANISATIONAL ISSUES

11.1 SUMMARY OF TARGETED ACTIVITIES.

12. NEXT MEETING

ANNEX II

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ANNEX III

OOPC REPORT for JSC XIX
THE OCEAN OBSERVATIONS PANEL FOR CLIMATE
Report to JSC XIX, Item 3
March 16-21, 1998

(Submitted by the Chairman of the GCOS/GOOS/WCRP Ocean Observations Panel for Climate)

1. BACKGROUND

The Ocean Observations Panel for Climate (OOPC) was established in 1995 under the joint sponsorship GCOS, GOOS and the WCRP. Its establishment followed the successful completion of the Report by the Ocean Observing System Development Panel on an Ocean Observing System for Climate (OOSC) and recognized the need for continuing scientific and technical advice and guidance for operational climate observing systems. The abbreviated terms of reference require the Panel

(a) To evaluate, modify and update, as necessary, the design of the GOOS/GCOS ocean observing system for climate,
  - to monitor, describe and understand the physical and biogeochemical processes that determine ocean circulation and its influence on the carbon cycle as well as the effects of the ocean on seasonal to multi-decadal climate change, and
  - to provide the information needed for climate prediction;

(b) To provide a procedural plan and prioritization for an integrated set of requirements consistent with the observing system design criteria and in a form that enables timely and effective implementation;

(c) To liaise and provide advice, assessment and feedback to other panels and task groups of GCOS, GOOS and WCRP, as requested;

(d) To establish the necessary links with scientific and technical groups; and

(e) To carry out agreed assignments from, and report regularly to, the JSTC, J-GOOS and the JSC for the WCRP.

This paper constitutes the first formal report from the OOPC to the JSC for the WCRP. It will detail the work program of the Panel since its first meeting in 1996 and provide a summary of planned activities, including activities associated with the Global Ocean Data Assimilation Experiment (GODAE).

2. GENERAL

The OOPC views the implementation of the OOSC as its central mission (ToR b). An effort is required to make the recommendations accessible and doable by those responsible for implementation. Possible strategies include:

- The development of End-to-End illustrations of the role played by certain data streams in existing and potential products and services;
- Inviting participation in Panel activities from the implementation community in order to improve dialogue between the scientists and agencies charged with implementation;
- Working with existing bodies in order to develop a more focussed and relevant implementation pathway;

- Establishing strong dialogue with relevant research groups and panels to ensure a coordinated articulation of the requirements;
- Hosting workshops and participating in meetings which enhanced the understanding of the requirements and improved the Panel's appreciation of implementation issues; and
- Initiating (pilot) projects to entrain scientific and technological (and intellectual) investment in the development of the observing system, to develop the capacity of the community to support the OOSC, and to demonstrate the value and potential of a global ocean observing system.

3. CO-OPERATION WITH RESEARCH

The OOPC has placed emphasis on, and greatly values, its liaison with research programs, particularly CLIVAR and its Upper Ocean Panel. The Upper Ocean Panel continues to provide excellent leadership for the sustained (long-term experimental) component and the OOPC has enjoyed fruitful cooperation.

At its most recent meeting, the GCOS JSTC composed a statement indicating where it believed the boundaries of responsibility for the ocean observing system lie, for scientific oversight, implementation and data and information management. The GCOS/GOOS Plan is based on the definition and implementation of an initial observing system (IOS). Key attributes of the IOS are that it is long-term and systematic, has well defined scientific rationales, well-define applications, and can be operated routinely. The first levels of enhancement to the IOS depend upon further research and/or technical development, and on satisfactory demonstrations of the need for that information. It is assumed that the programs of the WCRP will play a critical role in this evolution.

The JSTC noted that its scientific panels must assume lead responsibility for scientific oversight of the various components of the IOS, in cooperation with implementation agencies and science programs. However GCOS seeks continued involvement of the science programs and scientists in the evaluation and evolution of the IOS.

Conversely, GCOS expects research programs such as CLIVAR to provide significant leadership in the research and development, and implementation, of enhancements that are driven by the specific scientific goals of research. Since in several cases the implementation of the IOS and sustained research components will be through the same mechanisms, it is important that high levels of cooperation are maintained. The foundations of the sustained component lie in the IOS (basic component), while the future of the IOS lies in the research and development of the sustained and intensive components.

4. WORKSHOP

A Time Series workshop was convened in March 97, cosponsored by GOOS, GCOS, WCRP and JGOFS, and hosted by SCOR. The workshop developed a framework for assessing different stations as well as developing recommendations on the future role of time series data sets, for example as biological "laboratories", in model validation and improvement, and for long-term climate change applications. "Bravo" and Station "S" emerged as candidates for long-term GOOS/GCOS support.

Improved ties with GLOSS have been a high priority. OOPC helped convene a Sea Level Workshop (Hawaii, June 97), jointly with CLIVAR and NOAA, in order to explicitly link the science and operational "drivers" to the GLOSS network. The workshop provided a detailed account of the design basis for the sea level network, and in turn explicitly linked (and prioritized) each of the stations with respect to applications and/or scientific objectives. There was a resolve for GLOSS and the OOPC to work more closely together, and a recommendation for the support of a "Fast Delivery Center" in support of climate sea level observations.

5. IMPLEMENTATION

Both the OOPC and OOSDP emphasized the need for a more streamlined and focussed pathway toward implementation. TOGA and WOCE were able to exploit (and develop) existing mechanisms through the agency of research funding. An operational ocean observing system requires long-term, dedicated support and, to be effective, an efficient and rational method of implementation. The present system can be characterized as *ad hoc*, though well intentioned, and lacks a focus with respect to climate observations. The OOPC believe this should be addressed as a matter of urgency.

To this end, the relevant international programs jointly convened a Workshop to consider the implementation of the GOOS/GCOS "blue water" observing networks (Sydney, March 98). OOPC provided an updated set of requirements (see attached Table), taking account wherever possible of expected research needs. At this meeting the various groups, including GLOSS, the DBCP, IGOSS, IODE, TAO, GOOS and CMM jointly resolved to pursue implementation within a unified, cooperative framework. Three observational sub-programs were identified: (1) Sea Level, (2) Surface and Marine, and (3) Subsurface. An implementation plan already exists for Sea Level, courtesy of GLOSS and the OOPC Sea Level workshop. It was resolved that high priority should be given to the development of integrated implementation plans for the surface and subsurface sub-programs, building as far is practical on the extant plans.

For the ocean surface sub-program the key groups will be TAO, the DBCP and CMM VOS program. It was suggested that the JSC/SCOR WG on Air-Sea Fluxes could be used as the primary source of technical advice. This would require the agreement of the JSC and, perhaps, slight modification of its terms of reference.

Initially these three programs will be coordinated through an interim (*ad hoc*) group for Ocean Measurements. In the longer term the workshop supported a proposed Joint (Technical) Commission for Ocean Measurements, in place of the present multi-body structure. A proposal is presently before IOC and WMO.

The outcome of this Workshop is likely to be a watershed in the implementation of GOOS. Not only does it provide a unified and integrated approach to ocean measurement, it also provides a real indication of the commitment to implementing the ocean climate observing system recommended by the OOSDP, appropriately modified and updated by the OOPC in preparation for the meeting.

6. REMOTE SENSING AND THE (CEOS) INTEGRATED GLOBAL OBSERVING STRATEGY

Through the actions of its parent groups, and through direct interaction between OOPC and satellite agencies, OOPC has sought to play a stronger role in the definition of future remote sensing requirements. One manifestation of this role was the meeting on "In Situ Observations for the Global Observing Systems" (Sep 96) at which the OOPC and others provided input on the role of *in situ* observations for GOOS. The meeting was held against the background of the proposed CEOS "Integrated Global Observing Strategy" which sought to provide, among other things, greater integration across the global observing systems. In this respect the meeting fell short of its ideal, but it did provide greater appreciation of common issues among the observing systems (e.g., the tasks involved with of prioritization) and provided a useful link into the remote sensing communities. The OOPC has worked with CEOS and its Analysis Group (as well as with the GCOS/GOOS Space Panel) to articulate its remote sensing requirements, taking account as far as possible perceived research requirements.

7. THE GLOBAL OCEAN DATA ASSIMILATION EXPERIMENT

The general objective and sub-objectives (see Table) of GODAE are:

To provide a practical demonstration of real-time global ocean data assimilation in order to provide regular, complete depictions of the ocean circulation, at high temporal and spatial resolution, and consistent with a suite of space and direct measurements and appropriate dynamical and physical constraints.

[The GODAE sub-objectives table omitted here; it can be seen on the OOPC/godae web page.]

GODAE is a practical test and demonstration of our ability to deliver timely, useful products, derived from a global ocean data set, and assimilated into skilful models in order to extract greater benefit from the information. GODAE is founded on the belief that such a demonstration is vital if we are to realise a permanent, global ocean observing network and prediction system, with all components functional and operating on a global domain, providing operational services and routine data for research, and delivering useful products in a timely manner. The transition of research systems into operational mode also demands such demonstrations.

GODAE embodies a range of processes and applications, drawing power from the fact that they all require ocean data and models, and that there are important commonalties in all components that can be exploited for cost-effectiveness. The GODAE schedule includes feasibility studies and scoping during 1998-1999, a pre-operational phase 2000-2002, and the intensive "experimental" phase during 2003-2005.

At the first joint meeting of the GODAE Scientific Steering Team (GSST) and GODAE Patrons Group (Melbourne, Jan 98) it was resolved that the modelling, assimilation and observing (remote and direct) components should be pursued with equal vigour. That is, GODAE demands a complementary and integrated effort for its inputs, processing and applications.

At the first GODAE Workshop (Martinique, July 97) and at the Melbourne meeting considerable progress was made in defining the strategy of GODAE and its goals. The scientific and technical strategy will be built around several projects, including real-time North Atlantic Ocean forecasting, North Pacific operational systems, and prototype global eddy-resolving assimilation systems. These projects will provide short-term products as well as the foundations for GODAE, the experiment.

It has been argued that the existing satellite schedules provide for an adequate remote sensing input stream (though there is important work to be done with respect to future missions and with respect to the transition of systems like Topex/Poseidon - Jason toward operational status). However there are no such riches on the horizon for direct measurements. The GSST unanimously concluded that a major effort was required. Because of logistical constraints, the candidates for such a global system at the requisite resolution are few. Following a presentation on a planned global deployment of floats (the so-called ARGO proposal) the GSST agreed that such a strategy provided the only viable route for GODAE. It therefore agreed to pursue, with as much vigour as it can muster, and wherever possible in co-operation with research programs, a systematic deployment of subsurface profiling floats, at a nominal resolution of 250-300 km (order 3000), targeting the GODAE period 2003-2005 for the realisation of this array.

While there are many scientific, technical and resource questions remaining, the significance of this decision cannot be over-emphasised. In effect, it is saying that GODAE cannot be realised, or successful, unless such an array is in place. GODAE argues that both remote sensing and modelling efforts will be severely compromised without such input data.

An assimilation workshop was held in Baltimore 10-12 March (jointly with WOCE) to assess the capabilities of available modelling and assimilation methods and to consider issues arising from the need to implement methods in an operational, near-real-time environment.

A great deal has already been achieved in the definition of GODAE and in enlisting the encouragement and support of the community. Perhaps more than the OOPC imagined. However this enthusiasm must now be translated into real development of the observing network, and practical and tangible interim products, taking advantage of interest in the Year of the Oceans, and various Year 2000 initiatives.

The next GSST meeting is scheduled for Tokyo 4-8 July 98 at which time a draft Strategic Plan will be available for consideration. The lead-time for GODAE is short but it is an effort that is mandatory if oceanography is to progress from a curiosity-driven discipline to one with a mature observing capability upon which both research and operational oceanography can thrive.

ANNEX IV

EXECUTIVE SUMMARY FROM THE SEA LEVEL WORKSHOP

The GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC) and the CLIVAR Upper Ocean Panel, through their respective Chairs, convened a Workshop on the international *in situ* sea level network for climate applications and research, with the sponsorship and support of the US National Oceanic and Atmospheric Administration (NOAA). The aim of the workshop was to more explicitly link the scientific requirements of the Ocean Climate Observing System plan of GCOS/GOOS, and the scientific research areas of the CLIVAR Science Plan, to the implementation of the *in situ* sea level network, as represented by GLOSS and its Implementation Plan.

Preparation for the Workshop, NOAA engaged a consultant, Dr V. Gornitz, to draft a report on the design for a global sea level network for monitoring climate variability on seasonal to centennial time scales. This report provided a substantial basis for the Workshop discussions and is presented here as a foundation for the future scientific development of the observing system, in conjunction with GLOSS and its Implementation Plan.

The Workshop framed several statements and conclusions for consideration by its principal sponsors (the GCOS/GOOS/WCRP OOPC and CLIVAR UOP), NOAA, and the organisations with prime oversight responsibility (IOC/GOOS and CLIVAR).

(i) Scientific and technical oversight The Workshop recommends that a scientific Working Group for climate aspects of sea level be established. This group would provide scientific advice on climate related aspects of sea level to the GLOSS GE and to the research and operational programs via the UOP and the OOPC. A proposal has been forwarded to IOC.

(ii) *In situ* network and altimetry The workshop emphasized that in situ and high-accuracy altimetric measurements provide powerful complementary information on the climate scale variations of sea level. Altimetry is very important due to its open ocean spatial coverage, but it is not yet an "operational" system, and it cannot be considered a replacement for in situ sea level observations for scientific and technical reasons. It is critical that altimetric data are made more readily available.

(iii) Estimation of Long-term Trends in Sea Level The Workshop endorsed a dual strategy. The *preferred observing system* comprises:
- altimetry for global sampling, at approximately 10 day intervals;
- approximately 30 *in situ* gauges for removing temporal drift;
- additional gauges at the margins of the altimeter (e.g., continental coasts and high latitudes);
- a program of geodetic positioning; and
- a program of data archaeology and development.

An *alternative observing system*, proposed due to the lack of guaranteed availability of altimetric data and due to the lack of experience and confidence in the application of altimetry to measuring long-term trends, would comprise:
- a globally distributed network of *in situ* measurements, similar in effect to the GLOSS-LTT set;
- a program of geodetic positioning; and
- a program of data archaeology and development.

(iv) Report on the Sea Level Network The Workshop commended Dr Gornitz on the draft report "Design of a Global Sea Level Network for Monitoring Climate Variability on Seasonal to

Centennial Time Scales", but requested some modifications as a result of the Workshop discussions.

(v) Priority for Geodetic Positioning The Workshop recommended the following priorities for geodetic positioning:
- sites used for referencing altimetric measurement;
- sites used for long-term trend estimation; and
- sites used for ocean circulation studies.

(vi) Data Archaeology The Workshop wished to explicitly acknowledge the valuable contributions to the sea level data base from data rescue and data rehabilitation efforts and recommended further effort be devoted to this area.

(vii) Sea Level for ENSO Prediction The Workshop concluded that sea level data were important for studies of predictability and for experimental and practical prediction. This conclusion reversed a tendency to downgrade sea level data relative to other data. The Workshop also noted that western Pacific sites were relatively more influential in validation and prediction problems.

(viii) The WOCE Fast-Delivery Center The Workshop recommended that the WOCE Fast-delivery Center be continued but with a broader mandate, effectively servicing all the climate sea level near-real-time delivery requirements.

(ix) Development of the in situ sea level network In consideration of the Gornitz report, the Workshop recommended
- enhancement of the network in the tropical western Pacific and in the region of the Indonesian Throughflow;
- support for those Southern Ocean stations and for stations implemented or planned in the vicinity of the Antarctic continent, and adjacent to Drake Passage; and
- encouragement for improved accessibility to data from Brazil (e.g., Recife) and other stations presently not included in the Fast-Delivery service.

(x) MSLP data and other ancillary data The Workshop recommended that atmospheric pressure be designated a required variable for all non-tropical sites, particularly at high latitudes, and a desirable variable at tropical sites.

ANNEX V

A SEA LEVEL WORKING GROUP

Options for the future oversight of the sea level network and sea level science

We propose to form a Scientific Working Group for Sea Level, with GLOSS/IOC as its lead sponsor, and OOPC (GOOS/GCOS) and UOP (CLIVAR) as secondary sponsors. In addition we would like to embrace many of the scientific interests of the IAPSO Commission on Mean Sea Level and Tides, which might imply further co-sponsorship by IAPSO. This SWG would be the prime group for providing scientific advice on global (*) sea level measurement (direct and remote) and on tides (**). It would have around 10 members. Its terms of reference would include an advisory role to GLOSS, GCOS/GOOS, CLIVAR and IAPSO, and responsibility for considering specific issues as requested.

One implication is that there would be a restatement of the role of GLOSS and its Group of Experts. The scientific responsibilities of the GE would pass to the SWG, so the key roles of the GE would now be primarily in coordination, technical development and oversight of implementation. The SWG would likely meet annually and would comprise active scientists, some of whom would be involved with the implementation of the sea level network within the GE. The GE would meet less often, but at least as often as every 2 years at present enhanced by regional gatherings in between, and would function as now as the intergovernmental mechanism for GLOSS. The GE participants would mostly be the operators and managers of the network, though some would also be scientists, and would discuss technical, intergovernmental and bi/multi-lateral support mechanisms for the network.

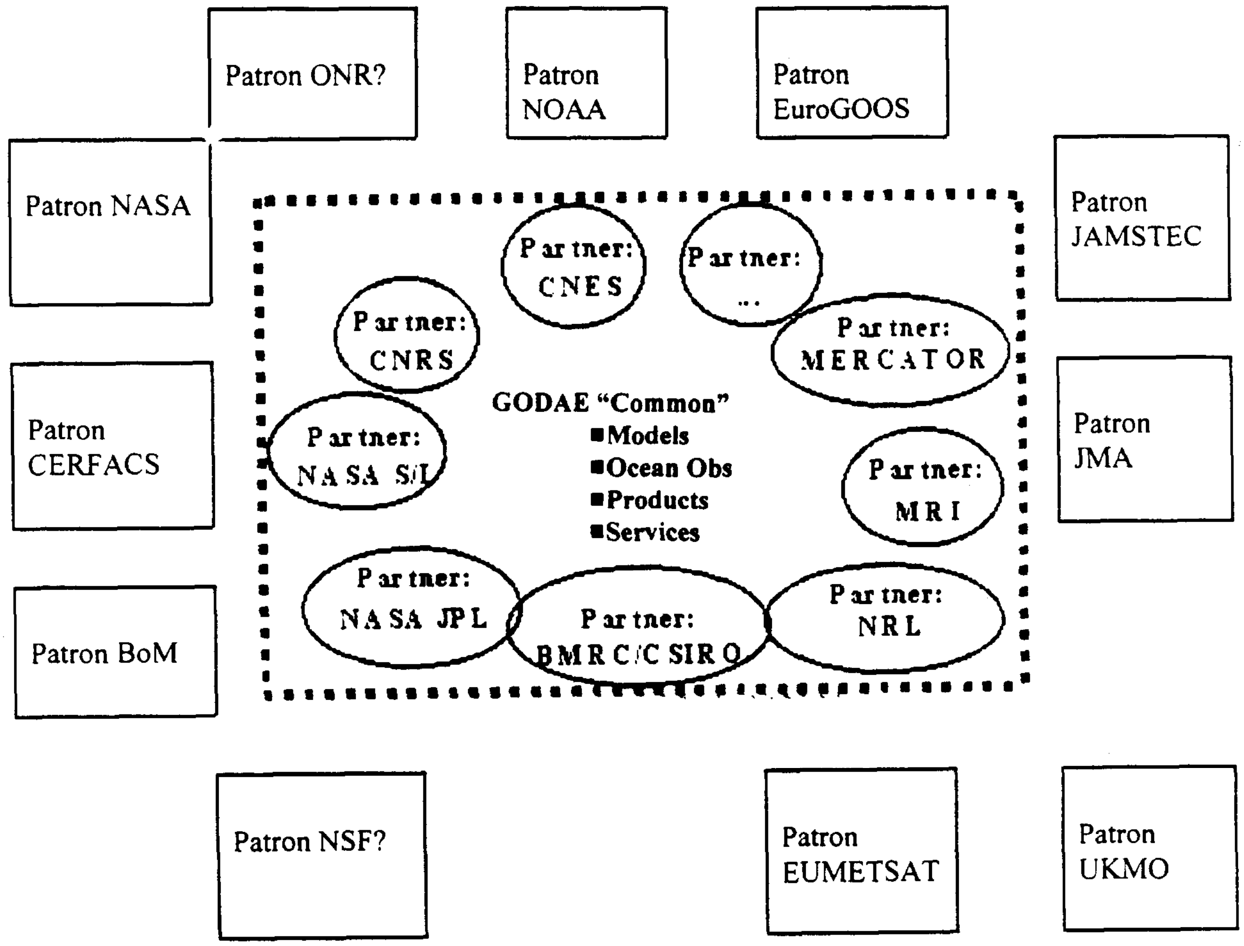
The SWG would be responsible for the scientific aspects of the Implementation Plan, while the GLOSS GE would advise on technical and operational aspects. The two committees would include both chairmen and maybe other joint representatives.

In time the recently adopted ToR for the GLOSS GE would need to be changed to reflect the new arrangements but it is probably not crucial that this be done immediately since the SWG would be sponsored by the GLOSS GE and could be regarded as fulfilling the ongoing scientific charge of the GE. There is also the consideration of changes in the overall implementation mechanisms for oceanographic data, beginning with the Implementation Workshop to be held in Sydney in the first week of March 1998, so it would probably be wise to await the outcomes of that meeting before requesting any change.

(*) We assume here that GLOSS/GOOS coastal aspects are best handled regionally.

ANNEX VI

GODAE STRUCTURE



ANNEX VII

Draft *In Situ* Strategy for GODAE, including an "ARGO" core

The following document was drafted at the 1st GODAE SST and Patrons meeting, Jan 19-22 1998, Melbourne, Australia. The material is based in part on a prospectus for a global float network ("ARGO") developed by D. Roemmich and colleagues, and tabled at the GODAE SST meeting.

The GODAE SST endorsed the broad thrust of this strategy that follows.

DEVELOPING A STRATEGY FOR THE GODAE DIRECT OBSERVING NETWORK

1. THE APPROACH

- Determine minimal and maximal direct measurement requirements of GODAE, taking into account the needs of satellite calibration, complementarity between the remote and direct data sets, and the need for information on fields that cannot be easily and/or reliably inferred from other information sources. [Minimal = bare minimum upon which GODAE could function; Maximal = ideal. This view looks backward from the processors.]
- Determine the information content of all the existing and planned networks and ascertain the potential of these, or perhaps emerging techniques, to satisfy the requirements of GODAE. This looks forward from the obs. Network.
- Seek synergism and complementarity with observing plans of research programs, e.g. CLIVAR, ACCE, etc.
- Seek and initiate dialogue with existing groups and agencies who support, or might support direct observations, with the aim of encouraging support for a practical and affordable plan for direct observations that is compatible with the objectives of GODAE and achieves a high degree of integration and efficiency over the total observing network.
- Identify needed network studies and/or observing system experiments.
- Draft an observing system design and set out a strategy for implementation.

2. CANDIDATE MEASUREMENTS AND PLATFORMS

Routine data stream

- Sea surface temperature (salinity)
    - surface drifters (e.g., SVP)
    - VOS
    - surface moorings
- Temperature (salinity) profiles
    - moorings (e.g., TAO)
    - Ship-of-Opportunity Program (broadcast XBT)
    - Profiling floats (e.g., (S)PALACE, MARVOR)
    - Acoustic thermometry (e.g., ATOC)
- Surface, subsurface velocity
    - moorings (e.g., TAO)
    - floats (RAFOS, ALACE, ...)
    - ADCP on VOS
- Sea level
    - tide gauges
    - DORIS, GPS

- Surface marine data
    - VOS (winds, Ta, etc.)
    - Surface moorings (e.g., TAO)
    - Over-the-Horizon radar (?)
    - Rain gauge network (?)

Ancilliary

The following data streams may be needed for validation or for special needs.

- In situ sea ice data
- Surface flux sites
- Hydrographic sections
- Time-series stations
- Climatological data (constraining mean)
- High-density XBT
- Regional tomography, acoustic doppler
- Tracer data
- Biological data
- Profiling moorings

Considerations

GODAE must be discriminating when selecting candidate instruments and platforms; only those that contribute meaningfully to the objectives should be selected.
Choose data to complement the satellite and processing capabilities.
Do not rely on research to fill gaps and requirements. GODAE is laying the foundations for permanent systems so, if a data set is needed, state it explicitly.
Do rely on other operational data streams when appropriate. E.g., data from coastal systems, data in the operational meteorological streams, data used for operational climate forecasting.
Identify requirements for telemetry to meet near-real-time needs.
Identify novel and useful strategies for autonomous instrument deployment (e.g., float farms, EMMA).
Identify data management requirements (e.g., QC, continuity, reliability, etc.).
Boundary currents and fronts may require particular attention.
Identify needed research, e.g. on sampling, network design, sampling errors, data errors, etc.
Emphasis should be on integrated, multi-variate data streams and not on individual data types or platforms.
Do not be grandiose or unrealistic in planning. Have vision, but be realistic and remember that in the end the data are candidates for long-term support and so must be amenable to "operational" implementation.
What is the implication of eddy-resolving versus coarse?
The data stream has utility beyond GODAE, particularly for climate studies.
The direct data stream will depend upon multinational cooperation and support. The advantages of an integrated data set need to be made explicit and tangible, so those nations appreciate that the return from a contribution IS greater than the investment.
Identify the critical interfaces into other programs.
Consider Lagrangian versus Eulerian approaches.
Special attention needs to be paid to remote areas. What are the ramifications of inadequate sampling in these regions? Do they threaten the viability of GODAE? Where will the impact of these inadequacies be greatest?

3. THE PREFERRED STRATEGY

The GODAE SST recommended the following strategy.

Surface observations.

Support the basic network, as recommended by OOSDP (1995) and contained in the Implementation Plan of the Ocean Observing System for Climate (Sydney, March 1998). GODAE has not identified any additional surface wind or surface temperature requirements. However enhanced surface salinity sampling (consistent with preliminary CLIVAR recommendations), and improved validation data for short-wave radiation and precipitation are seen has high priority issues. In cases where intermediate analysis steps are used (e.g., SST, wind stress), it is critical that estimates of the bias and error are developed.

The subsurface network.

The float ARray for GODAE Observations (ARGO!! Otherwise known as the Array for Real-time Geostrophic Oceanography) is recommended as the centerpiece of the GODAE network.

At this time, GODAE believes the provisional ARGO plan is a realistic and reasonable option. In brief, it requires

- Around 3000 profiling floats at full configuration;
- All floats measure both T and S;
- A re-seeding rate of 750 per year under the assumption of a 4-year lifetime;
- A near-homogeneous global spread (about one float per 3° square); and
- Preferred cycle depth 1500 m (samples important upper ocean structure) and drifts at a depth where the signal-to-noise ratio is "favourable".

The highest priority drivers for ARGO were seen to be:

- It provides key information for the real-time estimation of the ocean state;
- It provides information that is complementary to the key remote sensing streams (ALT and SCAT), and is thus consistent with the integrated global observing strategy (it enhances coherency and allows greater exploitation and cost-effectiveness of an "existing" information stream).
- It provides a true global sampling strategy for climate variability in the thermal field, and an essentially new data set for studying the hydrological cycle.

The cost/profile is estimated to be US$100 for temperature alone, though communicationss and processing are not included. This compares favourably with the present cost of an XBT, but in addition provides deeper sampling and subsurface drift. An additional cost for salinity depends on salinity sensor stability.

The annual cost of ARGO is expected to be around US$10M.

There are implications for other elements of the subsurface observing program.

- The broad-scale sampling strategy with SOOP XBT would appear to be redundant with a fully-staged ARGO. However, in order to ensure that changing technology does not harm the existing climate record, an overlap of 3-5 years is recommended in order to ensure that the climatological value of the XBT as a time series is not lost.
- In regions of high gradients (WBCs, fronts) the denser sampling of the XBT lines would be preferred.
- The frequently-repeated lines of SOOP (O(18) repeats along the same line per year, with O(100 km) sampling) were seen as a cost-effective, complementary strategy.

The provisional priorities for implementation were seen to be:

- Ensuring the ACCE (and other international) float network is maintained.
- Cooperation with CLIVAR Pacific BECS for a North Pacific deployment (shared resourcing and additional scientific leverage and usage).
- Seeking an international/multi-national framework for cooperative resourcing and deployment of network.

GODAE also recommended

- Studies to explore the complementarity of the altimetry and proposed float network; in particularl, providing additional guidance on the optimal sampling pattern and rate.
- Studies to explore the best cycle depth, and to ascertain whether occasional deep-cycling floats would be effective.
- Further studies to determine the sampling characteristics (errors) of a float data stream (T, S and U).

GODAE noted that ramping-up of ARGO would not be trivial, and that there were several technical issues that needed to be addressed immediately. In particular, the sensor characteristics (e.g., salinity drift), telecommunication implications (Is bandwidth limiting access to important information?), tradeoffs between longetivity, sampling depth, and sampling, etc.
GODAE supports convening a Workshop (including possible international partners to aid cross-calibration).

Notes on Cost

Present hardware cost: US$8000/float, temperature only; $12,000 for T & S
Assuming a lifetime of 4 years, 750/year would be required for a 3000 global program, implying a net cost for T+S of around US$9m/year. However the salinity sensor is likely only useful for about 1 (so the effect S sampling would be 750 globally). For a program with these numbers we might expect some extra saving in cost.

ANNEX VIII
OUTCOMES FROM THE SYDNEY IMPLEMENTATION WORKSHOP
PROPOSED SCIENTIFIC SAMPLING REQUIREMENTS AND JCOMM STRUCTURE

BACKGROUND ON SAMPLING REQUIREMENTS

In the late 1980's, as activity in TOGA was reaching its peak and the observational program of WOCE was beginning, the then prime scientific bodies for ocean andclimate research, the Committee on Climate Changes and the Ocean (CCCO) and the Joint Scientific Committee (JSC) of the World Climate Research Program joined forces to create the Ocean Observing System Development Panel (OOSDP). The OOSDP was given the task of formulating a "Conceptual design of a long-term, systematic observing system to monitor, describe, and understand the physical and biogeochemical processes that determine ocean circulation and the effects of the ocean on seasonal to decadal climate changes and to provide the observations needed for climate predictions."

The physics and dynamics of ocean circulation are the dominant theme, but there is also scope to consider processes associated with the carbon cycle and climate. In addition to climate observations, this plan includes some consideration of other physical and dynamical observations where the requirement is obvious and relevant to the implementation mechanisms.

The OOSDP plan that emerged in 1995 (OOSDP 1995) contained a comprehensive review of the scientific issues and a set of specific recommendations for implementation of the observing system. Smith et al (1995) and Nowlin et al. (1996) contain shorter synopses.

The plan contained four primary goals. The first focussed on exchanges with other components of the climate system, and in particular on the surface fields and surface fluxes which help determine the variability of the coupled ocean-atmosphere system. The 5 sub-goals were estimation of (i) sea surface temperature (SST) and sea surface salinity (SSS), (ii) surface wind stress, (iii) surface fluxes of heat and water, (iv) surface sources and sinks of carbon, and (v) the extent, concentration, volume and motion of sea ice.

The second goal focussed on seasonal-to-interannual variability and, in particular on the upper ocean (that part which varied on these time scales). This goal was in turn broken into three sub-goals; (i) monitoring and analysis of monthly upper ocean temperature and salinity changes; (ii) the provision of data for the initialization of models and prediction of the El Niño-Southern Oscillation; and (iii) the provision of data outside the Pacific for monitoring and initialization of models of seasonal to interannual climate variations.

The third goal concentrated on longer time scales (e.g., climate change) and, inevitably, involved observations of the deep ocean. The 3 goals were (i) inventories heat, fresh water, and carbon on large space- and time-scales; (ii) description of the ocean circulation and transport of these quantities; and (iii) measurement of long-term sea level changes.

The final goal concerned the processing and management of these data streams, including (i) climatologies (means and variances), (ii) information management, and (iii) modeling and assimilation systems.

APPLICATIONS

While the scientific rationale is organized behind the goals listed above, it is the recognized applications that ultimately drive the 'shape' of the requirements for the ocean observing system for climate (OOSC). While there is some degree of arbitrariness about the way the goals are selected and arranged, the applications are directly linked to recognized societal needs. The applications are:

(i) Atmospheric Prediction. The OOSC is a provider of information to, and a customer for, numerical weather prediction products.

(ii) Ocean and Climate Prediction. Seasonal-to-interannual climate forecast systems, principally for the ENSO phenomenon, exist in both experimental and operational forms. Ocean analysis and coastal ocean forecast systems are also major applications under this theme.

(iii) Climate Assessment. The large heat capacity and slow but relentless circulation of the ocean means that the, sometimes confounding, high-frequency noise attached to climate signals of the atmosphere is filtered to some extent by the ocean thus making the signals somewhat easier to detect.

(iv) Model Validation. It is important that models faithfully represent, as far as is practical, the actual physical, dynamical and geochemical processes of the ocean. Ocean data are used to check that that is the case.

The priorities that are attached to the different requirements are determined in part by a judgement of how relevant that data are for the above applications, and in part by their perceived contribution toward the scientific goals. For each requirement, there may be one or more candidate measurement methods, and the ranking attached to alternative approaches will be determined by how well they address the requirement (some approaches may address several requirements) and by the cost, feasibility and effectiveness of the method.

The above addresses a very important point. In plans such as this, it is necessary to reduce a complicated and inter-related set of requirements to a more "accessible" form. In this process the nuances and scientific rationale can sometimes be lost or obscured. There is no easy remedy other than to provide joint oversight between the scientists and implementers so that the observing system is kept as true as possible to the design and purpose of the plan, thus maintaining scientific credence.

SAMPLING SPECIFICATIONS

It is important that we understand the connection between the scientific drivers on the one hand, and the desirable characteristics of the data network on the other. The priorities among the different applications, and among the different scientific goals, do evolve, as does the technology used to collect the observations. In some cases, sampling requirements for a particular field may be extremely sensitive to such evolution, in other cases, not.

At this point it is also useful to clarify some of the terminology and how it relates to the scientific goals and applications. When we discuss applications we usually also refer to products and outputs. These may be fields in some cases, but often are in a tailored form that is more useful to those exploiting the product. For the scientific goals we are almost always referring to fields (e.g., a SST analysis, or an estimate of global sea level rise); these in fact represent the signals that we want our observing network to yield. In most cases, there are likely to several useful signals associated with a particular field (e.g., tides, equatorial Pacific dynamic height and climate change sea level rise are all important signals from sea level), each with its own characteristic variability.

The real ocean not only contains these signals but also many other variations, sometimes with small amplitude, but not always. We refer to these as noise, though it should be remembered that the division between signal and noise is just an artifact of our particular interests and characterisation. Our ideal observing network aims to minimise the errors in our estimate of the real signal, or minimise the influence of the noise. The normal strategy is to exceed the sampling rate suggested by the characteristic space and time scales of the signal, and use our knowledge of the noise to assist the signal processing. Since ocean models and assimilation are usually our preferred signal processing technique, it should also be noted here that the grid resolution of the model is not directly involved in the sampling rate decisions. There may be some indirect influence since, for example, the capabilities of particular models may restrict the signals that can be processed. The more relevant parameters are those used to characterise the statistics and coherences in the assimilation method. Ocean model assimilation systems are, in general, relatively simple compared with our meteorological equivalents. SST analyses, for example, are mostly performed without the aid of any dynamical or physical models. This can be compared with re-analysis estimates of surface wind stress and heat flux where very complex estimation systems are used.

It is also important to appreciate that the sampling requirements are usually met through a mix of data from different platforms (e.g., AVHRR, VOS and TAO for SST), and sometimes also from indirect methods. For example, previous analyses may be used to forecast the present state, or other fields may be used (with models) to infer the field of interest (e.g., altimetry for u). Usually, no one method will provide the desired accuracy for the product. To avoid a method-by-method account of useful accuracies, we introduce the concept of a "benchmark accuracy" (see next section on requirements).

While the sampling rate is an effective strategy for reducing the (geophysical) noise, the sampling strategy must also address bias and other sources of noise. Data quality is a prime consideration for reducing measurement bias (quality in turn will depend on the instrument characteristics and any algorithms used to convert the instrument measurement into a geophysical parameter. In some cases instrumental bias may be removed after the fact, so long as the bias has scales that are resolved by an independent data source (e.g., AVHRR corrected by buoys+VOS; ALT sea level trends corrected by in situ gauges). This is sometimes referred to as calibration, but to oceanographers (and meteorologists) calibration usually means checking the signal from an instrument against a "standard" (e.g., a CTD and standard seawater for salinity; or a radiometer against a blackbody with known properties). The assumption is then made that this calibration will hold true for the deployment period of the instrument and/or is reliable for other locations.

Bias can also be introduced through aliasing; that is, the sampling rate permits signals of one frequency/wave number to manifest as another signal. Aliasing can distort the amplitude and shape of the signal spectrum, including a shift in the mean.

All these issues make the specification of a sampling requirement difficult, rendered even more so by the fact that our knowledge of the real ocean (which we use to characterise signals and noise) is extremely limited. In the present case a balance must be drawn between the need to stay faithful to the science and what we really understand, and the need to specify requirements which are feasible and meaningful from the point of view of those charged with implementation. OOSDP (1995) focussed on requirements for each sub-goal (the so-called Feasibility-Impact diagrams) and attempted to present a rationale for prioritising different candidate elements of the observing system.

For this Plan it seems more sensible to focus on requirements for particular fields since, to a large extent, the available implementation mechanisms are arranged that way (TAO for ENSO is probably an exception). It should be noted that OOSDP preferred to leave sampling requirements open-ended if it believed insufficient knowledge existed to make such a recommendation. In some cases that remains so, particularly with respect to global inventories and the deep ocean circulation. In the following we give guides where we think it is reasonable to do so.

REQUIREMENTS

These are derived for the most part from the OOSDP (1995) report and several subsequent publications (Smith et al. 1995; Nowlin et al. 1996), but consideration has also been given to re-evaluations by the Ocean Observations Panel for Climate meeting reports (OOPC, 1996, 1998) and various activities it has been associated with.

As noted above, we will present the requirements by field, first noting the desired characteristics of the processed signal (output) for different applications. The sampling is presented in terms of a strategy and a set of "benchmark" accuracies (P. Taylor, pers. comm.). The benchmark accuracy is a standard against which measurement accuracies can be compared. Measurements which fall well below the benchmark may not be useful at all, or may require improved technique and/or quality management. On the other hand, measurements with accuracy far greater than the benchmark may have reduced cost-effectiveness. Where appropriate we note specific implications of remote sensing. We also comment on alternative sources of information and perceived trends in the requirements.

The sampling requirements are summarised below. The sampling requirements are summarised in Table 1. Table 2 shows space-based requirements alone, with particular reference to the Global Ocean DataAssimilation Experiment (GODAE is lilely, in general, to be more demanding in terms of spatial and temporal resolution, but with decreased emphasis on the deep ocean and perhaps slightly weaker accuracy requirements).

Sea Surface Temperature

Characteristics of the processed signal

a) NWP (stress, heat flux estimates): 0.2-0.5C on 100 km square x 3 days resolution N.B. Regional systems and severe weather prediction seek 10-20 km resolution, daily; these are becoming increasingly important for coastal applications (e.g., hurricane forecasts) and some climate applications. *[The fields were typically weekly averages. Since the Sydney meeting there has been a move toward daily estimates and perhaps even toward the diurnal cycle.]*

b) ENSO: 0.2-0.3C on 200 x 30-100 km x 5 days in the tropics. The bias requirement is more severe in the convective regions, less severe in the central eastern Pacific. Meridional resolution has a high premium attached to it.

c) Climate change: 0.1C, 200-500 km square x monthly

d) Mesoscale and coastal oceanography/GODAE: 0.2C (relative), 20 km square, 1 day. Quality and bias is less of an issue, but gradients and features are more important.

The diurnal cycle is a potential source of error for most of these signals.

Sampling strategy and benchmark accuracies

Use geostationary and polar orbitting satellite data for spatial resolution and to reduce geophysical noise in climate signals.

Use *in situ* data for calibration and to produce blended products with optimised bias reduction. The requirement for remotely sensed SST is 10 km resolution and 3-6 hr sampling, the latter to reduce aliasing error, with 0.1-0.3C relative error. The temporal sampling implies increased utilisation of geostationary platforms. The NWP and mesoscale applications are the dominant determinants of resolution;

The sampling for in situ is controlled by the need to remove bias from the satellite product, mainly for climate change applications, but also in the event of unexpected aerosol interference. The best estimate remains at 0.1C on 500 km square by weekly time scales (25) samples with accuracy ~ 0.5C. ENSO requires an adjustment in the tropics as suggested by the scales mentioned above.

Indirect sources of information

Virtually none. None of the operational analysis systems use model predictions or assimilation to great effect. It remains a field that is far easier to observe than model.

New directions. CLIVAR and GEWEX may require resolution of the diurnal cycle and improved accuracy of products in the tropics (0.1C). There remain some issues concerning the use of bulk, near-surface and skin temperatures in climate applications. This is likely best addressed through greater use of mixed layer models. High-latitude SSTs might also become more important; satellite sampling is poor in some regions and so in situ programs become more important.

Surface salinity

Characteristics desired of the processed signal

While surface salinity products remain largely in the research community, the OOSDP expressed a strong desire for improved monitoring of SSS. At high-latitudes, surface salinity is known to be critical for decadal and longer time-scale variations associated with deep over-turning and the hydrological cycle (S_{annual} ~0.2; $S_{interannual}$ ~0.5). These are relatively large-scale signals. In the tropics, and in particular in the western Pacific and Indonesian Seas, and in upwelling zones salinity is also believed to be important (S ~0.3). A product with 250 km square x monthly resolution x 0.2 PSU accuracy would be satisfactory for most applications.

Sampling strategy and benchmark accuracies

One sample per 200 km square x 10 d x 0.1 PSU accuracy is the benchmark [the signal to noise ratio is typically not favorable]. The tropical western Pacific and Indian Oceans, and high latitudes are the highest priorities.

Indirect sources of information

Precipitation estimates provide some useful indirect estimates of SSS. In theory, a combination of altimetry and ocean temperature should also be useful for inferring SSS, but this has yet to be demonstrated in practice.

Trends

There does remain some possibility of remotely-sensed SSS, at the threshold level listed in Table 2. The need for improved salinity networks has been a theme in CLIVAR and in the OOPC, principally because of the significant interest in the tropics and the interest in decadal-to-centennial variations.

Surface wind velocity

Characteristics desired of the processed signal

Estimates come from both NWP and from direct analyses of wind data (e.g., the FSU product). Re-analysis products are also popular in the research community.

For ENSO applications 2 lat x 5 long x 1 month x 5% direction; 0.5 m/s speed estimates are required. For longer periods the accuracy requirements are slightly weaker, but a global resolution of 2 x 2 degrees (or 100 x 100 km) is desirable.

Sampling strategy and benchmark accuracies

The OOSDP did not give a specific sampling rate, citing the many different applications as one of the mitigating circumstances. The following is a guide:

2 x 2 degrees x 1-2 days x 0.5-1.0 m/s in the components is the benchmark accuracy for climate applications;

50 x 50 km x 1 day x 1-2 m/s for mesoscale and coastal applications.

Indirect sources of information

Clearly NWP and forecasts based upon previous data are an important source of indirect information, as are the other contemporary atmospheric and ocean surface data (e.g., cloud drift winds; MSLP). Atmospheric assimilation systems continue to have problems ingesting surface wind data, so direct estimates are essential, particularly in the tropics (e.g., TAO).

Trends

NSCAT showed that estimates of around 2 m/s accuracy every 2 days could be obtained, at resolution of around 50 km. If such an instrument is flying operationally, then the role of in situ data would be more like that of in situ SST data for SST estimates. That is, providing ground truth for bias correction.

The reanalysis projects have yielded improved products, which are popular, but which have short-comings with respect to quality and resolution. The demand for higher resolution, particular for cyclones and hurricanes, is growing. Together these suggest a pair of double-sided operational scatterometers may be needed.

Surface flux of heat, water

Characteristics desired of the processed signal

Heat flux: 10 W/m2 accuracy over 2 latitude by 5 longitude by monthly bins.

Precipitation: 5 cm/month over 2 latitude by 5 longitude by monthly bins.

Sampling strategy and benchmark accuracies

Use flux estimates from NWP/re-analysis projects use the sampling requirements of WWW.

Direct calculations based on surface marine data, both satellite- and ocean-based (e.g., FSU, SOC); 50 observations of the main parameters (wind, air temperature, humidity, MSLP, SST) per bin. Specific high priority actions include:

- Improved SST, air temperature, humidity, MSLP, precipitation and absolute wind velocity on selected VOS;
- Shortwave and longwave radiometers on selected VOS;
- Satellite-based estimates of radiation and precipitation; and
- A number of flux buoys to provide high-quality verification.

Indirect sources of information

There are no direct methods for measuring the net heat and water surface fluxes, though there are methods for measuring some components. NWP takes advantage of many indirect (non-ocean) sources of information. Ocean budget techniques (e.g. TOGA COARE) have proved quite effective for estimating net heat flux; a similar technique can be employed for net water flux based on salinity (water) budgets. Ocean models with assimilated ocean temperature data can also be used to infer surface fluxes.

Trends

As noted above, there is increasing emphasis on the oceanic water budget, so at-sea measurements of precipitation (e.g., from TAO, VOS) are becoming increasingly important. Several methods are available based on satellite data and high-quality in situ data are needed for algorithm development and calibration. NWP prediction estimates are still plagued by large uncertainties and systematic bias, particularly in those components influenced by cloud cover. Ocean models are extremely sensitive to bias errors, so the sampling strategy must endeavour to provide as much ground truth as possible. This strategy then places a high premium on data quality, and hence on improving the qaulity of VOS data streams.

Sea Level

The OOSDP report discussed long-term trends and ocean variability needs, but was not specific with respect to the in situ gauges or altimetry. The OOPC and CLIVAR, and NOAA, convened a Workshop to refine these requirements, in conjunction with the GLOSS Plan.

Characteristics desired of the processed signal

Estimates of annual global sea-level change on large space scales (~ 500 km square), with accuracy of around 1-2 mm/yr.

Estimates of sea surface topography anomalies (for ENSO and ocean variability studies), for 10-30 day periods, with accuracy of 2-5 cm:

500 km zonal x 100 km meridional in the tropics;

Estimates of mesoscale variability 25 x 25 km to 100 x 100 km, x ~ 5 days x 2-10 cm accuracy (see also Table 2).

Ocean circulation (estimates of absolute sea level) with 200 km square and 2-5cm accuracy.

Sampling strategy and benchmark accuracies

Long-term trends require a dual strategy. The preferred observing strategy comprises:

- altimetry for global sampling, at approximately 10 day intervals;
- approximately 30 in situ gauges for removing temporal drift;
- additional gauges at the margins of the altimeter (e.g., continental coasts and high latitudes); and
- a program of geodetic positioning.

An alternative observing system, proposed due to the lack of guaranteed availability of altimetric data and due to the lack of experience and confidence in the application of altimetry to measuring long-term trends, would comprise:

- a globally distributed network of in situ measurements, with similar effect to the GLOSS-LTT set; and
- a program of geodetic positioning.

For large-scale variability, sites for in situ measurements are limited. The TOGA network should be maintained (at higher priority than assigned in OOSDP, 1995), with increased focus on the tropical western Pacific and Indonesian Throughflow, and in the western boundary current regions. The GLOSS Implementation Plan and OOPC/CLIVAR Sea Level Workshop detail priority stations for monitoring large-scale variability. Topex/Poseidon-class altimetry with 100-200 km resolution and ~2 cm accuracy is also highly recommended. Altimetry, in general, is now rated far more highly than it was at the time of OOSDP (1995).

Mesoscale variability is only accessible with multiple altimeters, at least one, but preferably two, being T/P class. The optimal sampling is ~ 25 km square x 2 days x 2-4 cm.

Indirect sources of information

For long-term trends there are no viable alternatives, though acoustic thermometry may offer some sort of alternative measure. For ENSO monitoring and prediction, there is redundancy between wind, SST, sea level and subsurface temperature; sea level has the advantage of a history stretching back into the 1970's, and the fact that it measures the joint effect of thermal and haline variations. For large-scale variability in general, thermal data offer similar types of information. However, their complementarity would seem a more powerful attribute, with sea level measuring the vertically integrated variability, and temperature profiles measuring vertical structure. There is no alternative for mesoscale variability.

Trends

For ENSO prediction, sea level is enjoying a revival, courtesy of Topex/Poseidon and improved methods for assimilating sea level information. There is more confidence on altimetry for long-terms trends (c.f. OOSDP 1995). For the mesoscale, the number and type of altimeters required still remains open (see notes in Table 2). The gravity mission GRACE will provide an opportunity to exploit absolute measures of sea level.

Sea Ice

Sea ice extent. Daily 10-30 km resolution using passive microwave and, where feasible SAR (for finer accuracy). In situ techniques largely insignificant.

Sea ice concentration. 2-5% in concentration, measured daily.

Sea ice drift. Measurement of drift as opportunities arise, using buoys and pattern-tracking from remote sensors (SAR, AVHRR).

Sea ice thickness. 2-500 km square mapping of ice thickness on monthly time scale, with accuracy 0.2 m, using upward-looking sonars and other devices.

Other comments. Operational systems are more advanced in the Northern Hemisphere than in the Antarctic. Work in the Antarctic is largely driven by climate concerns. In the Arctic operational real-time prediction of sea ice is also a major issue. For decadal-to-centennial variability, sea ice extent, concentration and volume is a key issue. Surface salinity and sea-ice export estimates are complementary. For models to be useful for sea ice prediction (on short time scales), good wind data are essential.

Surface carbon flux

For the most part, these measurements remain within the research community. But the technology exists to use VOS and drifters to collect pCO2 in situ measurements, and satellite ocean colour provides effective proxy data for pCO2.

Sampling strategy and benchmark accuracies

- Seek pCO2 and total CO2 measurements with accuracy ±2-3 μatm and ±2 μmol respectively.
- *In situ* sampling is not expected to reach threshold rates, so simply aim for enhanced VOS, mooring and drifter measurements, piggy-backing wherever possible on existing operational systems. Ancilliary SST and atmospheric data are important.

- Aim for continuing global satellite ocean colour measurements, at 25-100 km square daily coverage, with 2-10% accuracy.
- Development and validation of satisfactory remote sensing algorithms is important.
- Time-series stations are playing a key role in research and the OOPC-sponsored Time Series Workshop saw an important role in the future.

Comments. Some non-biological applications (e.g., tropical ocean modelling) are using ocean colour to estimate opacity.

Upper ocean temperature

In the past, upper ocean thermal networks have largely been the province of research. Making significant parts of these networks operational is one of the key themes of OOSDP, and remains a high-priority issue. The key methods are XBTs from VOS and mooring networks such as TAO and TRITON.

Characteristics desired of the processed signal

- 200 x 200 - 500 x 500 km x bimonthly global maps of the heat content and the first few vertical modes of variability; monthly climatologies on 1 resolution. Accuracy is useful at ~ 0.5C.

- 1 latitude x 5 longitude x 10 day with the first 5 modes in the upper 500 m well resolved (MLD + ~ 5 vertical modes) fields for ENSO forecasts. Accuracy: 0.2 - 0 .5C.

- Mesoscale applications require 25 x 25 - 50 x 50 km x 2 day x 500 m with an accuracy of around 0.5C.

Other sources of information.

Clearly altimetry offers complementary data. For the tropics, it is feasible a good model plus SST and wind-forcing may be able to forecast subsurface temperature structure with useful skill. However, at the present time, there is no reason to lessen the requirements outlined above. Acoustic thermometry has good potential, particularly for long-term change and in regional modelling. It seems highly unlikely that an in situ solution will be found for the mesoscale applications. Rather, it is likely a mix of moorings, XBTs and profiling floats may be used to pin-down the global, large-scale thermal structure, and a mix of altimetry, SST and colour used to specify the horizontal structure of the mesoscale field.

Trends

Profiling floats are arousing a great deal of interest and seem to offer the one real chance for global temperature sampling (VOS are limited in terms of geographic coverage, and moorings are better suited to tropical and boundary regions). A program called PIRATA is testing TAO-like moorings in the tropical Atlantic, and the Japanese TRITON program is testing moorings for mid-latitude climate studies, and for Indian Ocean studies.

Upper ocean salinity

Upper ocean salinity remains an experimental field. XCTDs on selected VOS lines, and salinity sensors on some TAO moorings, were recommended by OOSDP. Again, the profiling float would seem to offer the best opportunity for increased global coverage, though there remains some question about the stability of the salinity sensor. Studies using a combination of altimetry, sea surface salinity and ocean temperature have shown promise for estimating salinity (Reynolds, pers. comm.). CLIVAR is intent on pursuing a better description of the hydrological cycle which implies greater emphasis on subsurface salinity.

Ocean currents

The OOSDP (1995) report was vague with respect to the need for velocity measurements, principally because there were few, if any, operational applications. They recommended a minimal array from moorings and VOS ADCPs for validation of models. Accuracies of the order 5 cm/s for monthly averages would be the benchmark for the tropics.

A global surface drifter program can yield very good surface currents estimates. The benchmark is global coverage of one drifter measurement per 600 km square per month, with current-following accuracy of around 2 cm/s, would give estimates of the mean velocity good to 10% of the eddy variability.

Complementary data sets.

There are several measurement strategies which do not neatly fit into the above field-by-field description.

Time series stations provide long records with temporal resolution short compared with the characteristic scale of the dominant variability, as well as co-located measurements of several different variables, sometimes including chemical and biological parameters. These attributes make such data sets powerful and complementary to the data mentioned previously, particularly for physical and phenomenological studies. The Ocean Time Series Workshop (Baltimore, March 1997, in print, from IOC) presented a strong case for continuing the long time series at Bravo and station "S". The TAO array also contains several important long records (e.g. at 110W) which should be maintained. Station "Papa" is to be the subject of sustained study within CLIVAR and may be another potential site for consideration.

Management and oversight

The OOSDP (1995) stressed the importance of scientific involvement in all parts of the data flow, from measurement through to end product. The OOSDP recommended the establishment of an evalution process, perhaps built around a distributed network of contact points in operational centres, whose prime objective was to ensure that the data gathering, processing and dissemination was consistent with observing system plan. It was important that this evaluation process provided feedback to the sources of the data in regard to quality, timeliness, percentage consumption (that amount of data that were actually ingested), and so on.

The OOSDP all set out several principles for data management:

- the information management system will be built as far as is possible and appropriate on existing systems;
- the information management system should be "operational" (c.f. experimental) in the sense as that for the observational network;
- the information management system should be consistent with the objectives, needs and priorities of the scientific design;
- data should be transmitted from instrument platforms to appropriate data centers and made available for further processing as soon after measurement as is feasible and practical;
- quality assurance of data and products should receive high priority to maximize the benefit drawn from the often difficult and expensive ocean measurements;
- the information management system should be user-oriented to ensure that the needs of users, the ultimate sponsors of the observing system, are served well;
- full and open sharing of data and information among the participants and users of the observing

system is essential to its successful implementation and operation;
- observing system participants should contribute data voluntarily and with minimal delay to data archival centers which in turn should be able to provide information to users effectively free of charge;
- the observing system will be most effective if practical international standards are developed for all phases of information management;
- information management will be most effective if it is part of the overall monitoring and evaluation process of the system;

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Smith, N.R., G.T. Needler and the Ocean Observing System Development Panel, 1995. An ocean observing system for climate: The conceptual design. Climatic Change, 31: 475-494.

Table 1. A summary of the sampling requirements for the global ocean, based largely on OOSD (1995), but with revisions as appropriate. These are a statement of the required *measurement network* characteristics, not the characteristics of the derived field. The field estimates must factor in geophysical noise and unsampled signal. Some projections (largely unverified) have been included for GODAE.

2.

Sampling Requirements for the Global Ocean							
Code	**Application**	**Variable**	**Hor. Res.**	**Vert. Res.**	**Time Res.**	**#samples**	**Accuracy**
A	NWP, climate, mesoscale ocean	Remote SST	10 x10 km	-	6 h	1	0.1-0.3°K
B	Bias correction, trends	*In situ* SST	500 x 500 km	-	1 week	25	0.5°C
C	Climate variability	Sea surface salinity	200 x 200 km	-	10 day	1	0.1 PSU
D	Climate prediction and variability	Surface wind	2° x 2°	-	1-2 day	1-4	Direction 20% 2 m/s
E	Mesoscale, coastal	Surface wind	50 x50 km	-	1 day	1	1-2 m/s
F	Climate	Heat flux	2°lat x 5°long	-	month	50	Net: 10 W/m^2
G	Climate	Precip.	2°lat x 5°long	-	daily	several	5 cm/month
H	Climate change trends	Sea level	50-1000 km	-	monthly means	30-50	1 mm/yr
I	Climate variability	Sea level anomalies	100-200 km	-	month	~ 10	2 cm
J	Mesoscale variability	Sea level anomalies	25-50 km	-	2 days	1	2-4 cm
K	Climate, short-range prediction	sea ice extent, concen.	~ 30 km	-	1 day	1	10-30 km 2-5%
L	Climate, short-range prediction	sea ice velocity	200 km?	-	Daily	1	cm/s?
M	Climate	sea ice volume	500 km	-	monthly	1	~ 30 cm
N	Climate	surface pCO_2	25-100 km	-	daily	1	0.2-0.3 μatm
O	ENSO prediction	T(z)	2°lat x 15°lon	15 m over 500 m	5 days	4	0.2°C
P	Climate variability	T(z)	1.5° x 5°	~ 5 vert. Modes	1 month	1	0.2°C
Q	Mesoscale ocean	T(z) for large-scale	500 km	~ 5 modes	10 days	1	0.2°C
R	Climate	S(z)	large-scale	~ 30 m	monthly	1	0.1 PSU
S	Climate, short-range prediction	U(surface)	600 km	-	month	1	2 cm/s
T	Climate model valid.	U(z)	a few places	30 m?	Mon. means	30	2 cm/s

Table 2. Requirements (threshold and optimal) for global ocean circulation studies, with particular reference to the Global Ocean Data Assimilation Experiment (GODAE) and the space-based observation program. The specifications are based on the OOSDP Report (Compilation by Michel Lefebvre and colleagues.).

Global Observations of Ocean Circulation - Space-based data Requirements										
Details			Optimized requirements				Threshold requirements			
Code	Application	Variable	HR(km)	Cycle	Time	Accuracy	HR(km)	Cycle	Time	Accuracy
ALTIMETRY										
A	Mesoscale variability	sea surface topography	25	7 d	2 d	2 cm	100	30 d	15 d	10 cm
B	Large scale variability	sea surface topography	100	10 d	2 d	2 cm	300	10 d	10 d	2 cm
C	Mean SL variations	sea surface topography	200	> 10 yr	10 d	1 mm/yr	1000	> 10 yr	10 d	5 mm/yr
D	Circulation, heat transport	sea surface topography	100	NA	NA	1 cm	500	NA	NA	5-10 cm
REMOTE SALINITY										
E	Circulation water transport	surface salinity	200	10 d	10 d	0.1 PSU	500	10 d	10 d	1 PSU
SCATTEROMETRY										
F	Wind-forced Circulation	surface wind field	25	1 d	1 d	1-2 m/s 20°	100	7 d	7 d	2 m/s 30°
SEA SURFACE TEMPERATURE										
G	NWP; climate, mesoscale models	Sea surface temperature	10	6 h	6 h	0.1°K (relative)	300	30 d	30 d	1°K
SEA ICE										
H	Ocean-ice coupling warnings	sea ice extent, concentration	10	1 d	3 h	2%	100	1 d	10 d	10%
OCEAN COLOR										
I	Biogeochemistry, transparency	ocean color signal	25	1 d	1 d	2%	100	1 d	1 d	10%

Footnotes:

A requires wave height + wind (EM bias correction) measured from altimeter, water vapor content measured from on board radiometer, and ionospheric content / measured from 2 frequency altimeter.

B requires precise positioning system with an accuracy of 1-2 cm for a spatial resolution of 100 km.

C requires precise monitoring of transit time in the radar altimeter.

A, B and C require repeat track at ± 1 km to filter out unknowns on geoid.

A requires adequate sampling which implies at least 2, and preferably 3, satellites simultaneously.

A, B and C require long lifetime, continuity, cross calibration.

D requires absolute calibration.

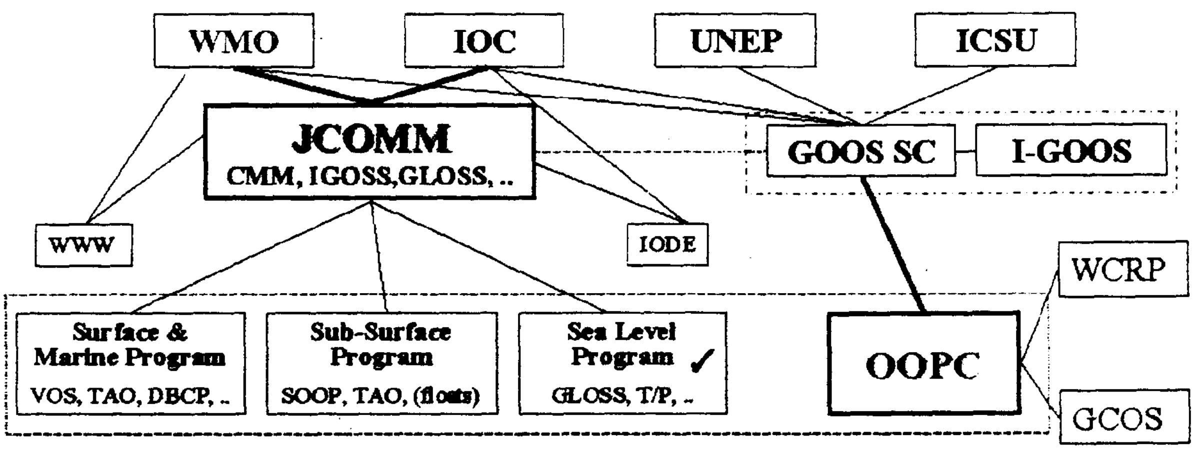
F: The requirements on the wind field for sea state determination normally exceed sampling requirements for wind forcing

G: High resolution SST from new geostationnary satellite + combination with low satellite

**PROPOSED STRUCTURE FOR
A JOINT COMMISSION (JCOMM)
FOR OCEANOGRAPHY AND MARINE METEOROLOGY**

A Unified Structure

- Create a new unified, ocean focussed implementation mechanism: a Joint "Commission" for Oceanography and Marine Meteorology (**JCOMM**)



ANNEX IX

THE WGASF STATEMENT

The following statement was endorsed by the JSC at its 19th session.

"The JSC noted the request of the OOPC Chair for the WGASF to act in an advisory capacity for the implementation of the Surface and Marine Sub-Program of GCOS/GOOS. In particular the OOPC sought advice on:

- instrumentation, particularly new technologies
- sampling strategies
- the relationship between remote and *in situ* data streams
- direct feedback and evaluation of the effectiveness of the OS; and
- quality control issues, in particular getting scientific input at the data source.

The Chair of the WGASF noted that the WGASF term of existance was to year 2000. He also noted the intention of CLIVAR to create a coupled boundary layer group, and the emergence of SOLAS. He noted the present WG has specific tasks which already place a considerable burden on the members.

The JSC resolved that it was not an appropriate time to modify the ToR of the WGASF.`However it did agree that it was appropriate to encourage the participation of some members of the WG in the immediate issues brought to the attention of the JSC by the OOPC (see above). It asked the Chairs of the WGASF and OOPC to facilitate close cooperation, noting that the Chair of the WGASF was to attend OOPC III. The JSC requested the Chairs, through the OOPC, to develop a formal mechanism for providing advice to the Sub-Program on implementation issues."

ANNEX X

DRAFT OUTLINE OF THE IMPLEMENTATION PLAN FOR THE SUBSURFACE PROGRAMME

Prepared by: Rick Bailey[1,3] and Neville Smith[2,3]

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1. INTRODUCTION

The ocean plays an important role in the Climate System over a broad range of space and time scales. It is therefore important that we further our understanding of the processes in the ocean and develop systems to monitor its properties. With the emergence of the observational requirements of the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS), it is time to re-evaluate existing observational systems and begin implementation of optimally integrated operational programs. The resulting observational networks should not only support the needs of operational programs such as GOOS and GCOS, but should also support the ongoing needs for science, including research and development of observing systems.

Extensive ocean subsurface monitoring programs have already be established under research programs such as the Tropical Ocean Global Atmosphere (TOGA) project and the World Ocean Circulation Experiment (WOCE) of the World Climate Research Program (WCRP). Now the field activities of these programs have drawn to a close, it is time to re-evaluate these observational systems in light of the new scientific knowledge gained and the ongoing requirements of operational systems, particularly climate prediction and monitoring applications.

2 SCIENTIFIC DESIGN AND REQUIREMENTS

2.1 PRIMARY SCIENTIFIC DESIGN

Through TOGA and WOCE, extensive ocean observing networks and sampling programs were established to monitor the upper ocean and deep ocean thermal, and to some extent, salinity fields. These observing programs were developed on *a priori* knowledge of the observed fields, which were scientifically reviewed and modified as the research progressed. This was achieved via such groups as the TOGA WOCE XBT XCTD Program Planning Committee (TWXXPPC). The legacy of these two major international research programs has been the initial development of an extensive global ocean observing network.

With the conclusion of TOGA and with the full implementation of WOCE, the Committee on Climate Changes and the Ocean (CCCO) and the Joint Scientific Committee (JSC) of the WCRP created the Ocean Observing System Development Panel (OOSDP). The OOSDP was tasked with:

> *Conceptual design of a long-term, systematic observing system to monitor, describe, and understand the physical and biochemical processes that determine ocean circulation and the effects of the ocean on seasonal to decadal climate changes and to provide the observations needed for climate predictions.*

The OOSDP devised a plan (OOSDP, 1995) which contained a comprehensive review of the scientific issues and a set of specific recommendations for implementation of an observing system. The plan focused on four primary goals, the last three of which are directly relevant to a subsurface ocean observations program:

- Goal 1 focused on exchanges with other components of the climate system, and in particular on the surface fields and surface fluxes which help determine the variability of the coupled ocean-atmosphere system.
- Goal 2 focused on seasonal-to-interannual variability and, in particular on the upper ocean (that part which varied on the same time scales). This goal was broken into three sub-goals: i) monitoring and analysis of monthly upper ocean temperatures and salinity changes; ii) the provision of data for the initialisation of models and prediction of the El Nino-Southern Oscillation; and iii) the provision of data outside the Pacific for monitoring and initialisation of models of seasonal-to-interannual climate variations.
- Goal 3 focused on longer time scales (eg., climate change) and, inevitably, involved observations of the deep ocean. Its three subgoals included: i) inventories of heat, freshwater, and carbon on large space-and time-scales; ii) description of the ocean circulation and transport of these quantities; and iii) measurement of long-term sea level changes.
- Goal 4 focused on the processing and management of these data streams, including: i) climatologies (means and variances); (ii) information management; and iii) modelling and assimilation systems.

Although the upper ocean salinity field was still considered as experimental, the OOSDP plan gave the characteristics desired of the processed signal for upper ocean temperature as:

(I) 2-500 km^2 x bimonthly global maps of the heat content and the first few vertical modes of variability; monthly climatologies on 1° resolution. Useful accuracy ~ 0.5°C.

(ii) 1° latitude x 5 longitude x 10 day x 500m (MLD + ~ 5 vertical modes) fields for ENSO forecasts. Accuracy ~ 0.2 - 0.5°C. (NB 500m is debatable in western boundary currents where $750\text{-}1000^{+}$m may be more applicable).

(iii) Mesoscale applications require 25-50 km^2 x 2 day x 500m (again, 500m is debatable in western boundary currents where $750\text{-}1000^{+}$m may be more applicable) with an accuracy of around 0.5 C.

(iv) For climate trends, need better than 0.1°C/year accuracy.

2.2 ONGOING RESEARCH AND DEVELOPMENT

The CLIVAR Upper Ocean Panel (UOP) and the GOOS/GCOS/WCRP Ocean Observations Panel for Climate (successor to the OOSDP) are the principal scientific groups responsible for the specification of ongoing research and operational upper ocean thermal data requirements, respectively. The UOP will provide leadership in the design of the observing system in support of CLIVAR research and will promote and oversee research into the sensitivity of the observing system (supporting research and operational activities) to particular elements.

The OOPC, upon continuing the work of the OOSDP, has made the following recommendations for upper ocean thermal sampling in lieu of revised sampling design studies:

1. Maintain the TOGA/WOCE broad-scale VOS sampling (1 XBT x 1 month x 1.5° latitude x 5° longitude). Priority to lines with established records, of good quality, and in regions of scientific significance (eg., tropics, particularly outside the domain of TAO, and the TRANSPAC region).
2. Maintain TOGA Pacific network, in particular TAO (OOSDP did not specify part or all of the present array, but did suggest "close to" 1994 levels). Around 4 samples every 5 days per 2° x 15°bin, with 10 - 15m vertical resolution is deemed satisfactory.
3. Enhanced coverage in the equatorial regions and in the vicinity of sharp gradients (eg. Kuroshio): O(18) sections per year, with 50-100 km resolution. (NB: Results from the WOCE High Density XBT Program indicate closer sampling in regions such as western boundary currents may be more appropriate).
4. Boost routine sampling of the polar regions (at broadcast mode levels)
5. Use profiling floats (this is a technology that is developing rapidly and real-time data are now available; sampling strategies have yet to be defined for "operational" use but a float profile per 2-300 km square every 10 days might be a feasible target.

It was also recognised that other sources, such as altimetry, may offer complimentary data. Pseudo observations such as "synthetic" subsurface temperature profiles derived from a combination of altimetric and AVHRR data may be required in addition to the above *in situ* observations to enhance temporal and spatial coverage. For the tropics, it is feasible that a good model plus SST and wind-forcing may be able to forecast subsurface temperature structure with useful skill. Not withstanding this, there is no reason at present to lessen the requirements as outlined above.

Acoustic thermometry has good potential, particularly for long-term change and in regional modelling. Similarly, a continuing program of repeat hydrography and time series stations may be required for observing longer-term signals. It seems highly unlikely that an *in situ* solution will be found for the mesoscale applications. Rather a mix of moorings, XBTs and profiling floats may be used to pin-down the global, large-scale thermal structure, and a mix of altimetry, SST and colour used to specify the horizontal structure of the mesoscale field. Other technologies such as inverted echosounders and cables should also be investigated.

2.3 PROPOSED OCEAN SUBSURFACE WORKSHOP

At the Workshop on the Implementation of Global Ocean Observations for GOOS/GCOS held at Sydney in March 1998, it was decided the time is right to review the requirements for subsurface ocean observations and to develop an implementation plan. The emphasis would be on the upper ocean and deep ocean thermal field. A workshop was therefore proposed for early 1999 based on the same lines as the successful International Sea Level Workshop held at the University of Hawaii in June 1997.

3. OBSERVATIONS NETWORK

The following are platforms and techniques involved with providing ocean subsurface data (details of each requiring inclusion):

- SOOP
- TAO
- Profiling floats
- Time series stations
- Repeat hydrography
- ATOC
- Cables
- Inverted echosounders
- Synthetic Obs (eg synthetic XBT from altimeter)
- Model observations
- Remotely sensed observations (eg dynamic height/heat content from altimeter)

4. INFORMATION AND DATA FLOW

Mechanisms exist for SOOP (GTSPP/IGOSS) and TAO to ensure the transmission and availability of data in real-time for operational applications. Similarly, generated data products are available from a number of sources in a number of ways (bulletins, web sites, etc).

It is now time to evaluate each existing mechanism with the view to establishing a dynamic system utilising the best of each system integrated. The integration of various data streams from different platforms needs to be considered. Such integration should have scientific oversight at designated centres. With today's technologies which facilitate information exchange, it may also be time to investigate and trial alternative data transmission systems to the GTS (eg. data exchange on the internet, etc).

5. DATA ARCHIVAL AND STANDARDS

Existing activities like the Global Temperature Salinity Profile Project (GTSPP), World Data Centres and WOCE Data Assembly Centres should be utilised and further developed wherever possible. Any newly developed data archival systems should interface with and utilise the IODE system. Designated data centres within the program and their Terms of Reference should be constantly evaluated and reviewed. Such centres should not be able to exist ad infinitum once established, as under the IODE system.

"Standards" are at present generally only recommendations and not regulated, which makes consistency sometimes hard to achieve. Standards should be developed in consultation with users and reviewed regularly. Data and products should be easily and freely available.

6. QUALITY ASSURANCE

The Science Centre concept of WOCE UOT/GTSPP has proven to be very effective. The data has been value added by having scientists who use and have an intimate knowledge of the data involved in the scientific quality control of the data. Expertise is also transferred in this process to the data management community. Studies need to be undertaken, however, to determine what level of QC is required to truly value add, bearing in mind the full range of uses/applications of the data (operational=>research, Climatology development, etc).

GTSPP, SOOPIP and TAOIMP monitoring of data quality from reporting platforms, for example, has been effective in ensuring high quality data is constantly available. Such monitoring ensures problem platforms are corrected sooner rather than later. These or similar processes should be implemented for all types of contributing platforms.

Instrument/technique evaluation/calibration studies (eg such as performed by the SOOP Task Team for Instrumentation and Quality Control STT/IQC - formerly TT/QCAS) should be regularly maintained and supported by both operational and research organisations to ensure quality and required accuracy of the observations. At present too many of these studies are mainly supported by research efforts, with insufficient priority attached.

Throughout any devised Ocean Subsurface Program there needs to be strong feedback and links between users, collectors, data managers, etc, to ensure the appropriate quality is maintained throughout the "production line. The quality standards should be set by the users in consultation with the data collectors and data processing and archival centres.

7. RESOURCES

Estimates of current and required resources should provided by the platform implementation panels for the GOOS Commitments Meeting later in 1998. The required resources should then be reviewed after review of the scientific design at the proposed Workshop. Resources should be optimised wherever possible through design/integration of the different measuring systems/platforms.

At present many of the networks are maintained by research organisations/bodies without long-term commitments and/or funding to support them. An increase is required in designated operational funding to alleviate research resources from monitoring, whilst ensuring observation stability/security. Sponsors need to be identified to provide ongoing funding support, and groups like the SOOP Management Committee (SMC) should perhaps be formed for other platforms.

8 REGULATION

Regulation is needed to ensure consistency throughout the program (data collection, data management, etc). At present good will scenario's can be easily overridden by resource issues. There is a need for regulations to ensure data is collected and exchanged to required standards, etc.

9. TECHNICAL SUPPORT AND COORDINATION

More formal support is required to ensure basic and ongoing evaluation/calibration work is continued to ensure data integrity (presently voluntary and low priority within contributing predominantly research organisations). With various measuring systems providing data streams, and given the need to integrated these data streams, strong coordination is required. Adequate support should be provided at an international level for technical coordination of the Program. Coordinators would best be located at participating agencies as opposed to within intergovernmental offices, and have an intimate knowledge of the systems. Appointments should be ongoing as opposed to term to ensure continuity and effectiveness of coordination.

10. ADMINISTRATIVE STRUCTURE

The Workshop on the Implementation of Global Ocean Observations for GOOS/GCOS called for the establishment of a Joint Commission for Oceanography and Marine Observations responsible to IOC and WMO to rationalise the intergovernmental coordination mechanisms. This basically proposes a merger of WMO's Commission on Marine Meteorology and the Joint IOC/WMO Integrated Global Ocean Services System (IGOSS). Scientific oversight and guidance would be provided by groups such as the OOPC, CLIVAR UPO and GOOS Steering Committee (GSC). The Commission would have regulatory powers.

It was further proposed that the Commission oversee three programs: Surface Marine, Ocean Subsurface and Sea Level. These programs would be supported by the present implementation groups (SOOP, VOS, TAO, GLOSS, etc). These implementation groups have structures already established to provide technical implementation and scientific oversight, and which will need to be incorporated and reviewed as necessary. Profiling floats, as they become more widely deployed, were identified as requiring an implementation and coordination mechanism, as for the other panels.

11. CAPACITY BUILDING

Wider country/organisation involvement should be enlisted through well coordinated communication plans, and through effective provision of access to generated products and data streams. Training activities such as TEMA of the Joint IOC/WMO IGOSS should be re-evaluated and utilised to ensure and enhance data collection and data management compliance by member countries. The end-to-end brochures planned by the OOPC will also be of great value in marketing the system.

12. AFFILIATED DRIVERS

Apart from the operational requirements for GOOS, there are many different affiliated drivers for data collected and utilised by the observational program. These alternative drivers must be taken into consideration and taken advantage of on an opportunistic basis wherever possible. These include research, fisheries, navies, individual national/ organisational requirements, etc.

13. PRODUCTS

Numerous products exist (Climate Centre products, regional analyses, etc) who's delivery needs to be coordinated along the lines of the IGOSS Products Bulletin. Appropriate products directly related to the GOOS/GCOS requirements need to be identified, vetted and developed by groups such as the GSC and OOPC in conjunction with the originators. They should then be provided under a GOOS/GCOS banner to provide a presence of GOOS/GCOS in the international community.

14. ISSUES

There are several issues which need to be considered in the implementation of a Subsurface Ocean Observations Program. The following list is by no means exhaustive and not ranked by priority:

- Maintain existing "individual" networks until integrated systems are proven and operational.
- Decisions need to be made on whether sampling by new instrumentation (eg profilers) is still to be considered research or operational.
- Logistical constraints of observation platforms such as SOOP and floats versus theoretical requirements need to be taken into consideration (eg desired sampling programs must be logistically feasible).
- Strong links must be maintained between data collectors, managers, and users.
- Requirement for ongoing scientific oversight of any observational program.
- Plans and resources must be outlined for the transition of research systems to operational systems.
- Resource support must be considered in light of requirements versus optimisation of available resources through scientific design and integration of related networks/data streams.
- Biochemical sampling requirements must be taken into consideration, at least in early planning stages, in light of future developments and expansions in this area.

15. REFERENCES

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ANNEX XI

INPUT TO THE SATELLITE SCHEDULES FOR GRAVITY MISSIONS

(Provided by J Johannesson at OOPC-III)

The Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) is a mission with possible launch around 2003. It is proposed as a candidate mission under ESA's Earth Explorer Programme and is currently selected for Phase A to begin in June.

The mission which is based on satellite gradiometry technique is aimed to measure the relative acceleration of two test masses at different locations inside the satellite. Each test mass is enclosed in a housing and kept levitated (floating, without ever touching the walls) by a capacitive or inductive feedback mechanism. The difference in feedback signals between two test masses is proportional to their relative acceleration and exerted purely by the differential gravitational field. Non-gravitational acceleration of the spacecraft affects all accelerometers inside the satellite in the same manner and so ideally drops out during differencing. The rotational motion of the satellite affects the measured differences. However, the rotational signal (angular velocities and accelerations) can be separated from the gravitational signal, if acceleration differences are taken in all possible (spatial) combinations (= full tensor gradiometer).

The main scientific objective of GOCE is to provide, at high spatial resolution, a better gravity field model and estimate of the reference equipotential surface (geoid) for use in a wide range of research and application areas, including global ocean circulation and climate change studies, physics of the interior of the Earth and datum connection. In particular, it would for the first time provide a precise reference surface at a wavelength of about 100 - 200 km for:

- unification of height systems;
- levelling of GPS;
- the study of the continental lithosphere;
- the determination of the absolute ocean topography and hence absolute ocean circulation and transport of heat and freshwater (from data delivered by satellite altimetry).

The observation requirements specified for the Gravity Field and Steady-State Ocean Circulation Explorer Mission (GOCE, 1996) are the following:

	Geoid Accuracy	Spatial Resolution (half wavelength)
Mesoscale	2 cm	60 - 250 km
Basin Scale	< 1 cm	1000 km

Altimetry combined with a precise geoid yields dynamic ocean topography: - it removes assumption of level of no (or known) motion; - it reduces uncertainty of deep circulation, heat and mass transport; and it yields global initial (or control) condition of global circulation models.

Associated with this we find key applications within areas such as: - world-wide height system; - levelling by GPS; - inertial navigation; - separation of steric from non-steric fluctuations of sea level; and ice-mass balance.

Requirements for the resolution and accuracy of the gravity field and geoid for geodynamics and geodesy are shown in the following table.

	Accuracy Geoid	Accuracy Gravity	Spatial Resolution (half wavelength)
Geodynamics			
- Continental Lithosphere (thermal structure, post-glacial rebound)		1 - 2 mgals	50 - 400 km
- Mantle composition, rheology		1 - 2 mgals	100 - 5000 km
- Ocean lithosphere and ineraction with asthenosphere (subduction processes		5 - 10 mgals	100 - 200 km
Geodesy			
- Ice and land vertical movmennts	2 cm		100 - 200 km
- Rock basement under polar ice sheets		1 - 5 mgals	50 - 100 km
- Worldwide height system	< 5 cm		50 - 100 km

The members of the GOCE Mission Advisory Group are: Dr. G. Balmino (CNES-GRGS), Professor R. Rummel (TUM-IAPG), Professor H. Sünkel (TU-ITG), Dr. P. Woodworth (PSMSL), Dr. C. Le Provost (CNES-GRGS), Professor C. Tscherning (Univ. of Copenhagen), Dr. P. Visser (TUDelft) and Professor K. Wakker (TUDelft).

ANNEX XII

HOW IMPORTANT IS THE MONITORING OF DECADAL VARIATIONS OF THE KUROSHIO FOR THE OCEAN AND ATMOSPHERE CLIMATE?

by Masaki Kawabe

Decadal variations with about 20-year periods are significant in the Kuroshio and the climate in the North Pacific. The probable relation between them is summarized in Fig. 1.

The Kuroshio has a significant decadal variability, in particular characterized by the current path variation between the two typical paths with and without a large meander. According to a monitoring since 1897, the large meander is a decadal phenomenon with the most dominant period of 21 years (Kawabe 1987; Fig. 2). The 1957-92 observation data show that the large meander does not occur during small volume transport and velocity of the Kuroshio and can occur only during large transport and velocity; the Kuroshio volume transport is related to the large meander in terms of the decadal time scales (Kawabe 1995; Fig. 3). It is well known that the latent and sensible heat fluxes are large in the region around the Kuroshio south of Japan and the Kuroshio Extension east of Japan, and the net heat release from the ocean in this region is largest in the world ocean. This heat flux supplies a major energy to the atmosphere over the North Pacific (Wyrtki 1965; Hsiung 1985; Fig. 4).

The surface heat flux in the Kuroshio region changes in decadal time scales. Figure 5 shows the variations of heat flux in a small grid around 35° N, 165° E in the Kuroshio Extension (the cross in Fig. 4) from 1961 through 1980. Large heat release from the ocean occurs during 1961-63 and 1975-80, during which the Kuroshio has a large meander and large volume transport.

Thus the Kuroshio large meander, the Kuroshio volume transport, and the heat release from the ocean around the Kuroshio are correlated to each other in terms of decadal time scales of about 20 years, according to the data analyzed so far. Large volume transport causes large heat transport, large heat convergence, and eventually large heat content around the Kuroshio, and the heat in the Kuroshio may be largely released to the atmosphere (Fig. 1).

Strong decadal signals in the atmosphere over the North Pacific have been found in strength of the Aleutian Low and the PNA(Pacific North America)-like pattern. They are monitored by the North Pacific Index (NPI) defined as a difference in sea level pressure between 40° N, 120° W and 50°N, 170°W (Hamilton and Emery 1985) or an average of sea level pressure in the subarctic region of 160° E-140°W, 30-65° N, (Trenberth and Hurrell 1994). Figure 6 shows the NPI of Trenberth and Hurrell. A negative value means strong Aleutian Low and stong Westerlies. The NPI changes in decadal time scales of about 20 years with low values during the large meander of the Kuroshio. Accordingly, the Aleutian Low and the Westerlies are strong during the large meander and large volume transport of the Kuroshio and during large heat release from the Kuroshio to the atmosphere.

The difference in sea level pressure of 1977-86 (a period of strong Aleutian Low) minus 1967-76 (weak Aleutian Low) is large negative in the subarctic North Pacific and positive over North America, like the PNA pattern, although it is not significant in the subtropics, unlike the PNA pattern (Nitta and Yamada 1989). Since the PNA pattern in association with most (not all) of the El Niño events is formed by the influence of the equatorial sea surface temperature (SST), climate scientists think that the PNA-like pattern in decadal time scales is also due to the equatorial SST. However, the high correlation of the NPI with the heat release from the Kuroshio suggests that the variations of NPI with periods of about 20 years and the PNA-like pattern are due to latent and sensible heat fluxes in the Kuroshio region.

In fact, Weaver 1987) concluded that the wintertime heat flux in the Kuroshio region is highly correlated with sea level pressure, and showed that the correlation is in the PNA-like pattern having negative high correlation with the subarctic sea level pressure.

The effect of heat flux in the Kuroshio region on the atmosphere should be further examined by data analysis and numerical experiments. This is a scientific subject. Meanwhile, an effort should be started to construct a Kuroshio monitoring system for volume and heat transports and current path of the Kuroshio. In a Japanese program, we are beginning to try to make such a system using submarine cables and tide gauges.

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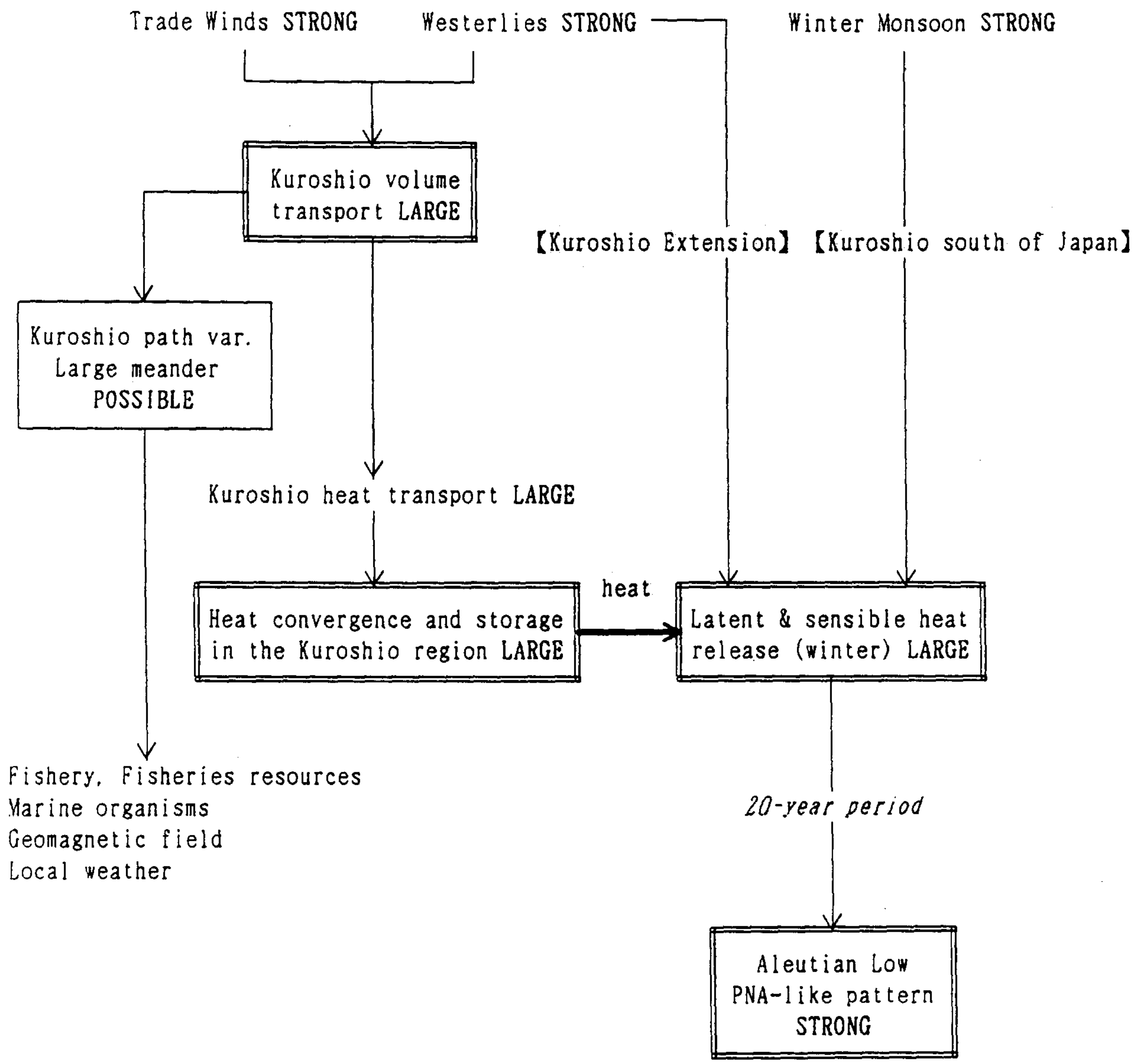

Figure 1. Relation of decadal variations of the Kuroshio and the ocean/atmosphere climate in the North Pacific.

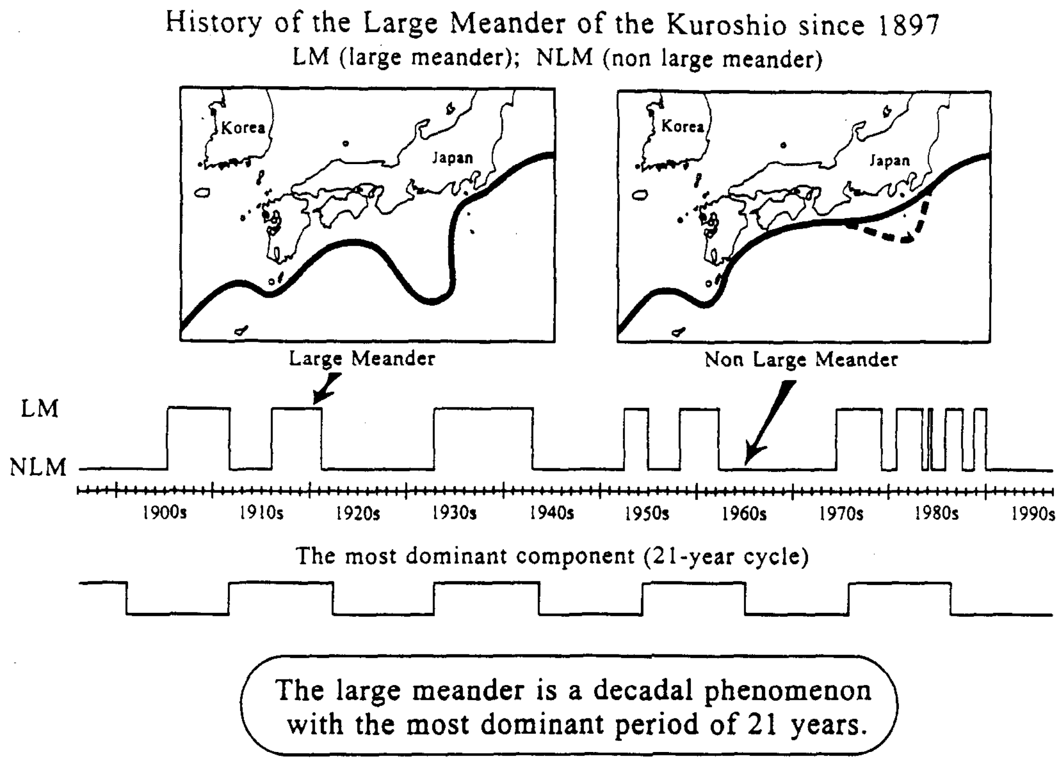

Figure 2. History of the large meander of the Kuroshio during one century since 1897 and its dominant cycle.

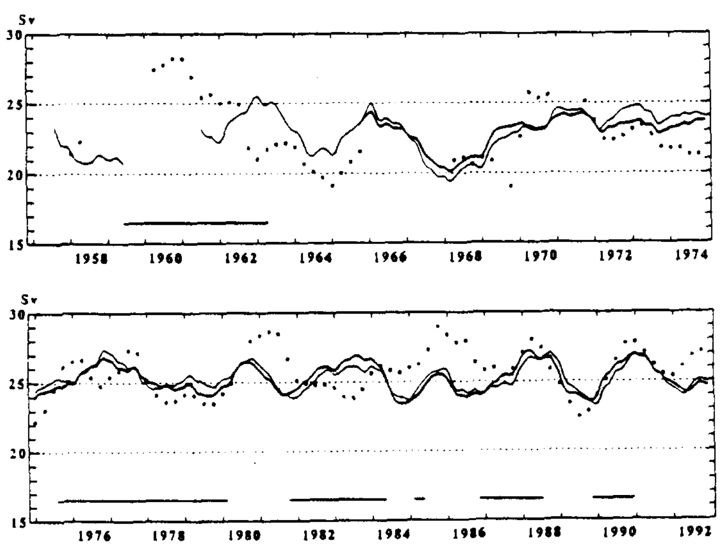

Figure 3. Interannual variations of volume transport of the Kuroshio in the East China Sea, by geostrophic calculation (dots) and estimated from tide gauge data fitted to the geostrophic transports (lines). The horizontal lines show the large meander periods. (from Kawabe 1995)

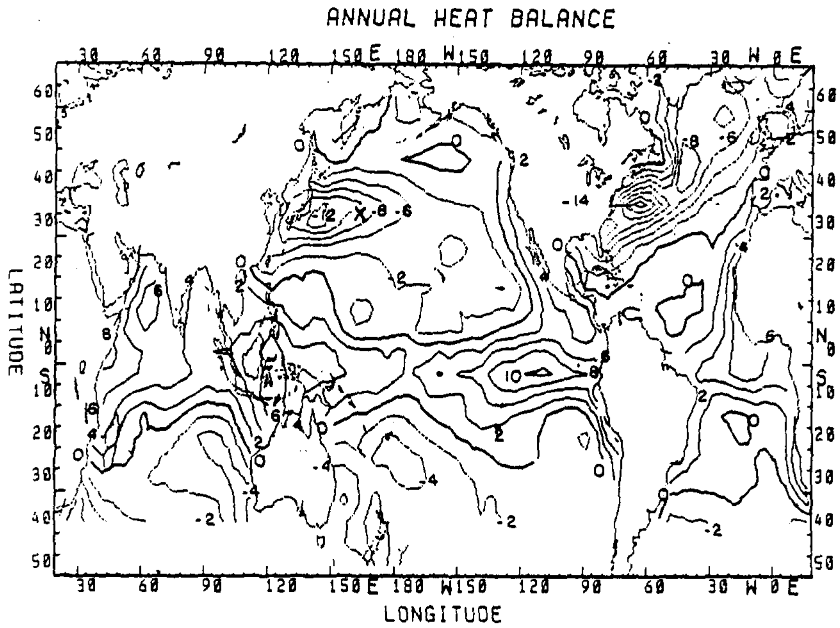

Figure 4. Annual mean net heat balance at the surface. The units are in W m^{-2} when multiplied by 10. (from Hsiung 1985) The cross at 35°N, 165°E shows the position of heat estimate in Fig. 5.

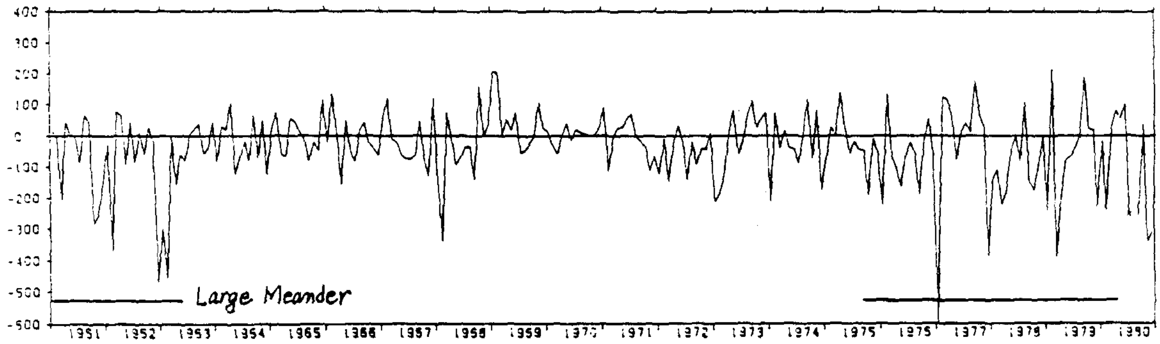

Figure 5. Anomalies (ly day^{-1}) of surface heat gain of the ocean around 35°N, 165°E (X in Fig. 4) from the mean seasonal cycle during 1961-80. Large negative values mean large heat loss of the ocean. This figure was drawn by Dr. Atsushi Nishikawa.

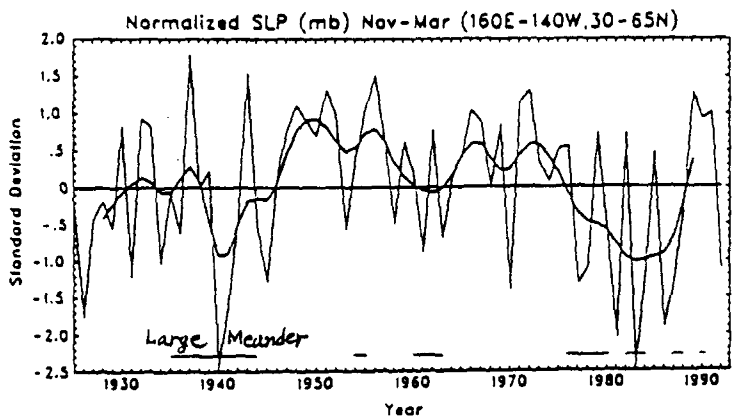

Figure 6. Time series of mean north Pacific sea level pressures for November through March. (from Trenberth and Hurrell 1994)

ANNEX- XIII

Recommendation (iii) From the International Sea Level Workshop 10-11 June 1997 Honolulu (Supersedes OOSDP Report Recommendation for Sea Level Observations)

Estimation of Long-Term Trends in Sea Level

The Workshop acknowledged the continuing high level of interest in the estimation of sea level trends and possible accelerations in the rate of sea level change. Accordingly, it endorsed a dual strategy.

The preferred observing system comprises:

- altimetry for global sampling, at approximately 10 day intervals, for spatial patterns and estimation of spatial and temporal variability;
- approximately 30 in situ gauges for removing temporal drift in the altimetric measurements;
- those gauges of the GLOSS set for Long Term Trends (LTT) which sample the margins of the altimeter, for example, coastal regions and high latitudes;
- a program of geodetic positioning (see below); and
- a program of data archaeology and development, targeting the sampling gaps and areas where referencing of the altimetric measurements is weak.

In view of the lack of guarantee attached to altimetric measurements, and the lack of experience and confidence in the application of altimetry to measuring long-term trends, the Workshop further recommended the maintenance of an alternative observing system comprising

- a globally distributed network of in situ measurements (in effect, similar to the GLOSS-LTT set, and listed under long-term trends in the network report);
- a program of geodetic positioning (see below); and
- a program of data archaeology and development, targeting the sampling gaps and areas where referencing of the altimetric measurements is weak.

For regions where there exists several alternative, but potentially equally effective in situ sites, the strategy requests regional groups to designate the preferred site and a backup, and to implement geodetic positioning accordingly. The Workshop endorsed the strategies of GLOSS for its GLOSS-LTT and GLOSS-ALT networks and noted that the strategy recommended above is broadly consistent with the GLOSS Implementation Plan.

ANNEX XIV

LIST OF ACRONYMS

ACC	Antarctic Circumpolar Current
ACM	Axis Current-Meter
ACSYS	Arctic Climate System Study
ADEOS	Advanced Earth Observing Satellite, (Japan)
AO	Announcement of Opportunity (e.g., NASA)
AOPC	Atmospheric Observation Panel for Climate (GCOS)
ARGO	Array for Real-time Geostrophic Oceanography (CLIVAR-GODAE)
ARGOS	[(System) not an acronym] CNES-NASA-NOAA Satellite-based System for Data Collection and Platform Location
BATS	Bermuda Atlantic Time-Series Station
BEI	Bjerknes ENSO Index
BIO	Bedford Institute of Oceanography (Canada)
CEOS	Committee on Earth Observing Satellites
CERGA	Centre d'Etudes et Recherches en Géodynamique et Astronomie
CFC	Chlorofluorocarbon
CLIVAR	Climate Variability and Predictability
CMM	Commission for Marine Meteorology
CNES	Centre National d'Etudes Spatiales (France)
CNRS	Centre National de la Recherche Scientifique
COADS	Comprehensive Ocean-Atmosphere Data Set
COARE	Comprehensive Ocean-Atmosphere Response Experiment
CTD	Conductivity-Temperature-Depth Probe
DACS	Data Assembly Centres
DBCP	Data Buoy Co-operation Panel
ECMWF	European Centre for Medium-Range Weather Forecasting
ENSO	El Niño and the Southern Oscillation
ENVISAT	Environmental Satellitte (ESA)
EOF	Empirical Orthogonal Function
EPS	European Polar System
ERS	Earth Resources Satellite
ESA	European Space Agency
ESTOC	Estación de Series Temporales Oceánicas de Canarias
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
GAIM	Global Analysis, Interpretation and Modelling
GCM	General Circulation Model
GCOS	Global Climate Observing System
GE	Group of Experts
GEOSAT	Geodetic Satellite (USA)
GFO	Geosat Follow-On
GLOSS	Global Sea-Level Observing System
GOCE	Gravity Field and SteadyState Ocean Circulation Explorer
GODAE	Global Ocean Data Assimilation Experiment of the OOPC
GOOS	Global Ocean Observing System
GOSSP	Global Observing System, Space Panel
GPS	Global Positioning System
GRGS	Groupe de Recherches de Géodésie Spatiale
GSC	GOOS Steering Committee

GTS	Global Telecommunications System
GTSPP	Global Temperature -Salinity Profile Programme
G3OS	Global Observing Systems (GOOS, GCOS & GTOS)
HOTS	Hawaii Ocean Time-Series Station
IABP	International Arctic Buoy Programme
IACCA	Inter-Agency Committee on the Climate Agenda (FAO-ICSU-UNEP-UNESCO/IOC-WHO-WMO)
IAPSO	International Association for the Physical Sciences of the Ocean
IGBP	International Geosphere-Biosphere Programme - A Study of Global Change
IGOSS	Integrated Ocean Services System
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data and Information Exchange
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate
JAMSTEC	Japan Marine Science and Technology Centre
JASIN	Joint Air-Sea Interaction Experiment
JASON	Altimeter Satellite (TOPEX Follow-on)
JCOMM	Joint Commission for Oceanography and Marine Meteorology (WMO-IOC)
JDIMP	Joint Data and Information Management Panel
JGOFS	Joint Global Ocean Flux Study
JGOOS	Joint GOOS Scientific and Technical Committee (replaced by GSC)
JPL	Jet Propulsion Laboratory (USA)
JSC	Joint Scientific Committee for the WCRP
JSTC	Joint Scientific and Technical Committee for GCOS
KERFIX	Kerguelan Islands Time-Series Measurement Programme
LDEO	Lahmont Doherty Earth Observatory
LODYC	Laboratoire d'océanographie dynamique et de climatologie (France)
METOP	Meteorological Operational Satellite (EUMETSAT)
NAO	North Atlantic Oscillation
NASDA	National Space Development Agency (Japan)
NCEP	National Centre for Environmental Prediction
NDBC	National Data Buoy Centre
NOAA	National Oceanic and Atmospheric Administration (USA)
NPOESS	National Polar Orbiting Environmental Satellite System (USA)
NRL	Naval Research Laboratory
NSCAT	NASA Advanced Scatterometer (USA)
NWP	Numerical Weather Prediction
OCEANSAT	Ocean Satellite (India)
OOPC	Ocean Observations Panel for Climate
OOS	Ocean Observing System
OOSDP	Ocean Observing System Development Panel
OSE	Observing System Experiment
OWS	Ocean Weather Station
PBECS	Pacific Basin-Wide Extended Climate Study
PMEL	Pacific Marine Environmental Laboratory (NOAA)
POSEIDON	*See*:TOPEX-POSEIDON
QA	Quality Assurance
QC	Quality Control (of data)
RADARSAT	Radar Satellite (Canada)
SBSTA	Subsidiary Body for Scientific and Technological Advice (UN/FCCC)
SCAT	Scatterometer
SCOR	Scientific Committee on Oceanic Research
SEASAT	Earth Satellite Dedicated to Oceanographic Applications
SEAWIFS	Sea-Viewing , Wide-Field-of-View Sensor

SHEBA	Surface Heat Budget of the Arctic Ocean
SLP	Sea Level Pressure
SOC	Specialized Oceanographic Centre
SOC	Southampton Oceanography Centre
SOOP	Ship of Opportunity Programme
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
SSTA	Sea-Surface Temperature Anomaly
STA	Science and Technology Agency (Japan)
TAO	Tropical Atmosphere Ocean Array
TOPEX-POSEIDON	Ocean Topography Experiment/Poseidon (NASA-CNES Altimetric Mission)
UKMO	United Kingdom Meteorological Office
ULS	Upward Looking Sonar
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UOP	Upper Ocean Panel (of CLIVAR)
UOT	Upper-Ocean Thermal Project
VOS	Voluntary Observing Ship
WCRP	World Climate Research Programme
WGASF	Working Group on Air-Sea fluxes
WHOI	Wood Hole Oceanographic Institute (USA)
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WWII	World War II