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1. OPENING

The Chairman opened the meeting at 8:30 and welcomed the participants to Miami. He noted that there were two new panel members, Ken Denman and Julie Hall. The participants introduced themselves and their affiliations. Several of the GOOS sponsors were represented: ICSU represented by Sophie Boyer King and Elisabeth Merle; IOC by Arthur Alexiou and Colin Summerhayes, the new Director of GOOS; UNEP by Isabelle Vanderbeck; and GTOS by Michael Glantz. Tom Spence, Director of GCOS, was present and he also represented WMO on behalf of Peter Dexter, who could not attend. WMO expressed pleasure that GOOS was making good progress and that it was involved in this process. The full list of participants is given in Annex II.

2. ADOPTION OF THE AGENDA

After some minor changes were agreed, the agenda in Annex I was adopted.

3. BRIEF ON STATUS OF J-GOOS

Chairman Otis Brown briefly described the activities which had taken place between sessions. He noted the active planning effort that had taken place since J-GOOS III with the goal of bridging current planning activities toward implementation, and that this was making good progress. Nic Flemming had recently chaired a Coastal Module workshop which provided a perspective on how to go about planning in this module. The Health of the Oceans plan had been published. FAO had agreed to work with other sponsors on the Living Resources Module. Brown indicated that later scheduled discussions would cover other significant actions: a proposal for a Global Module, and, from the Ocean Observations Panel for Climate, a proposal for a Global Ocean Data Assimilation Experiment (GODAE) and results of its workshop on Time Series Observations.

3.1. DEVELOPMENTS ON GOOS STRUCTURE

Colin Summerhayes informed the panel about a restructuring proposal that had been recommended by the I-GOOS Strategy Sub-Committee (SSC) which involved merging the SSC with J-GOOS to create a GOOS Steering Committee (GSC). This GSC would have more executive function than the present J-GOOS. The membership of the present Committee would not change immediately, but, recognizing that GOOS is moving from phase 1 (planning) to phase 2 (implementation), over time the balance would be modified to include more participants from the operational organizations. There will be up to 12 Ordinary Members selected on the basis of their personal expertise, about half from the operational agencies. Additionally, one representative would be appointed from each sponsor. Adding the I-GOOS chair would bring the total to 17. As a practical matter, the Terms of Reference for this GSC would not differ substantially from the existing ones for J-GOOS. The Strategy Sub-Committee of I-GOOS would be discontinued.

Summerhayes noted that in part the structural changes are being made to align GOOS with the structure of the other two observing systems (GCOS and GCOS). Needed clarification regarding the relationship of the new GOOS Steering Committee (GCS) to I-GOOS led to changes in the Terms of Reference. After some discussion, the Committee endorsed the proposal for a restructured GOOS (See 9.11).

4. GOOS PROJECT OFFICE (GPO) BRIEF

Colin Summerhayes updated the participants on the activities of the GPO. He reported that his appointment as Director of the GOOS Project Office was now confirmed, and his first priority was to make contact with all the various communities which contribute to the development of GOOS. He had recently visited several national organizations in different countries, including the NSF and NOAA in March, and the GCOS office. He told participants of a US forum on approaches to GOOS which was being held in May, and preceded by a NOAA meeting at the end of April (see 8.5 HOTO). He emphasized his conviction that building the "GOOS Constituency" is an important part of the GOOS Director's activities.

Other contacts were being built with GLOSS and EuroGOOS, including EuroGOOS -NEARGOOS linkages. For example, Nic Flemming from the EuroGOOS office was invited to attend a NEARGOOS meeting in Bangkok.

Members noted that the name of the GOOS Office has been changed from "GOOS Support Office" to "GOOS Project Office" (GPO) in order to stress the need for pro-active implementation of GOOS policies and decisions.

The staff at IOC dedicated to the GPO is very limited. If the GPO is to carry out all the recommendations of I-GOOS and J-GOOS, then more staff is needed. The options are:

(i) IOC to allocate more of existing staff to GOOS
(ii) Member states to fund more secondments to IOC
(iii) National agencies or consortia to fund projects

The meeting discussed connections within IOC between GOOS, OSLR, GIPME, GLOSS and other programmes. UNESCO's budget is reducing, with consequent effects on IOC and hence on the GPO. But the GPO has to support extra workshops and panels because of the growing activities in LMR, the Coastal Panel and the new involvement of IOC/GOOS in CEOS and the G3OS space and data information panels.

It was suggested that although GOOS could be developed strongly through the IOC regions, this has not happened as quickly as might have been hoped. Nevertheless, NEARGOOS has developed successfully in the WESTPAC region and EuroGOOS has developed in Europe. As a future policy it might be advantageous to have member states or regions appoint local staff to act as GOOS representatives. These individuals could provide links to the GPO, help to develop the structure of GOOS in the region, identify local and regional requirements, and carry out projects.

The Sponsor bodies responsible for GOOS have met three times during the last year, and have been very supportive. The steady interest of the Sponsors is important to GOOS and has helped to provide much needed direction. It has been very much appreciated.

4.1 J-GOOS BUDGET

Arthur Alexiou went through the draft of proposed expenditures and budget for 1998-1999. It was noted that the shortfall for 1998 would be between $50K and $80K, depending on whether or not all the proposed activities were carried out.

Participants agreed that it was important to clarify to I-GOOS that the funds for J-GOOS activities came from several sources in addition to those from the Sponsors, for example, JGOFS, WCRP, and some directly from EuroGOOS and the US. The budget is contained in Annex III.

5. TOWARDS THE REALIZATION OF GOOS

John Woods introduced the J-GOOS *ad hoc* planning group and its activities. The goal of this group is to establish and publish a planning framework for GOOS in a single comprehensive document. *"GOOS 1998"* is the title settled on by the planning group. Peter Ryder has been hired to write this document, the funding for which is being sought from Europe, the USA and Japan. The planning group has met twice, and will meet again twice more before the report is complete. Publication of *GOOS 1998* is expected in June 1998, the *Year of the Ocean*.

Peter Ryder introduced himself and explained his background from the services and operational sector. The concept underlying the preparation of the plan is that the document will persuade people that GOOS is a safe and real investment, and ready. He went through each of the seven chapters pointing out where he needed advice.

Discussion followed, mainly around the last chapter, which Ryder made clear was in the least developed state. Allyn Clarke suggested that Tsunami warning services and storm surge predictions should be highlighted. Several participants cautioned that the document could convey the unintended negative message that although all countries would have an input, the benefits of such an operational GOOS would only go to some. Johannes Guddal proposed more examples of services be added to satisfy requirements of oil and other marine industries, ports, *etc.* Julie Hall observed that there might be a special chapter devoted to this material. Michel Lefebvre believed that the report concluded in themes which were too general, and that it should contain more specific goals and timetables, something to persuade sponsoring agencies that GOOS is a good investment of scientists efforts and financial resources. Eric Lindstrom thought it important to get the balance of the document right in terms of planned systems and expected benefits. Neville Smith added that it was not clear that climate change ranked among the high priority issues based on the proposed observations. Tom Spence thought that it was important to involve the signatories of existing documents such as the Framework Convention on Climate Change in the review process. He saw the priorities for action having two themes: the first involving climate, end-to-end prediction (ENSO), coastal integration, LMR and HOTO; and the second, providing functional services. He believed a concerted statement on what needs to be done to create end-to-end services and products is necessary concerning climate change.

Spence's suggestion of themes triggered a further discussion on themes. During the early planning phases, the designation of the GOOS Modules was employed to get planning underway. This Module compartmentation of GOOS was an unhappy one because the science questions refused to be compartmentalized. Nevertheless, it was appreciated that, if it was not the optimum approach, it was a workable approach up to this point. As the activity begins moving toward the implementation phase it is becoming increasingly clear that the Module structure will diminish in utility, and implementation issues are developing conceptually along two fronts, namely global and regional. J-GOOS believes that these two themes will ultimately dominate implementation planning and priority setting. Clearly every participating nation has local concerns and priorities that translate into observational needs which hopefully will be satisfied by GOOS. These local requirements will have to be amalgamated and set in a global context. Thus while the services will involve the distribution of local/regional products to local/regional managers, there will be a necessary global dimension backing up them. J-GOOS thinking in the future regarding implementation will increasingly be divided and paced along the global and coastal themes. J-GOOS instructed that this new approach be introduced in *GOOS 1998*.

J-GOOS agreed that the *GOOS 1998* document should be published in the spring of 1998 as a J-GOOS (or GSC) document, after consultation with the community (See 9.1). This document must be consistent with the Strategy and Principle documents. Timing is a factor. There is much to be done in serial fashion that needs to be carefully scheduled. Issues which need clarification, or which are potentially contentious, must be brought to the attention of J-GOOS in time to be resolved before J-GOOS V. It will be too late at that time to be taking them up and then do any serious rewriting. Accordingly, text on such issues will be sent to J-GOOS members by Peter Ryder between sessions for comment and approval.

6. I-GOOS ACTIVITIES

Michel Glass opened the discussion by emphasizing that it is important for GOOS to develop a structure that is coherent with the structure and activities of the other G3OSs. This view was contained in the report of the G3OS Sponsors group, held in Geneva on 13-15 January 1997. Coherence enables the combining of certain working groups and panels (such as is occurring with GOSSP and DIMP) but it is also necessary for the funding of GOOS itself. GOOS cannot appear to have inefficient overlapping panels.

He reported that two important outcomes of the third meeting of the I-GOOS Strategy Subcommittee in January were: (1) the drafting of a set of 'principles' governing the design of GOOS and the rules of participation in GOOS; and (2) progress in the drafting of a strategic plan. He noted that a third essential element, a comprehensive GOOS plan, was still missing, although by now several documents existed. Without this, it is not clear what support GOOS is asking for from sponsors, governments and agencies; how GOOS might be funded; and what would make GOOS attractive to stockholders. He believed the *GOOS 1998* document would help to meet this need.

I-GOOS is one vehicle for gaining governmental commitment to GOOS, but it is equally important to engage the interests of national institutions and agencies. Therefore, as a first step in the process, a "First GOOS Forum" is planned on 25 June, to be held in conjunction with I-GOOS III. Representatives of interested agencies will be invited, to this "Forum", which is intended to set the stage for a planned high-level governmental "Head of Agencies Meeting" during the Year of the Ocean. Ryder's document would be introduced in outline or synopsis form. Steps to obtain resources for the special effort required to properly plan and carry out the 1998 meeting needed to begin now, and each Committee member was expected to contribute by "greasing the wheels" in his/her own country to help make this meeting a success.

The January meeting of the Sponsors was reviewed briefly. The Committee noted that the Sponsors were invited to a meeting by CEOS and IGFA. Integration of effort between the observing systems was an important focus of the meeting, and discussion had included 'crosstalk' between the systems and the need for a single, coordinated outreach to governments of which I-GOOS is presently the only example. Neville Smith was encouraged by the report of this meeting, however, he believed that the systems should not lose sight of the atmospheric component in this integration. The Committee was briefed on the initiative taken by CEOS to implement a set of six pilot projects on Global Observation. An Analysis Group was charged with examining in detail the Space Observation Requirements for these projects.

A Sponsors meeting is to be held in September, with one day scheduled for the Directors of each observing system to meet.

The Committee heard that a G3OS Brochure defining the three systems and targeted at decision-makers and funding organizations was being prepared. The draft of the brochure was presented to GOOS for comments. Amongst other things, it was suggested that the brochure should be more focused on user-groups and customers, and should emphasize capacity building.

Nic Flemming updated participants on the latest developments of EuroGOOS. A brochure and shortened version of the plan have now been produced. J-GOOS was informed of the Dutch intention to put EuroGOOS before the Council of EU ministers (The Netherlands presently hold the EU presidency). Su Jilan mentioned that NEARGOOS decided that data accession and exchange is a high priority. It was unclear whether NEARGOOS would be compliant with Global GOOS, particularly in relation to data policy. A coordinating committee is being set up by Dr. Hasigawa to look at these issues. It was agreed that there should be one point of contact for each regional GOOS for more effective communication. Nic Flemming is to attend the next NEARGOOS meeting in Bangkok.

6.1 GOOS PRINCIPLES

Angus McEwan tabled the latest version of the GOOS 'Design principles' and 'Principles of Involvement', initially drafted by George Needler, and outlined the rationale for each of them. These received general endorsement from the Committee. The possibility of a further 'principle' covering the support for the costs of GOOS implementation was discussed. It was again stressed that there needed to be complete consistency between versions of the principles, for instance, as they appear in other documents, *e.g.*, *GOOS 1998*.

6.2 GOOS STRATEGIC PLAN

McEwan went on to outline progress in the drafting of a Strategic Plan for GOOS. This had begun during the second meeting of the SSC in March 1996, and although all sections had been drafted by participants at that meeting, there remained the task of bringing the draft texts into alignment. It was seen as important that this Plan too be entirely consistent with other GOOS documents, in particular the *GOOS 1998* document being prepared by Peter Ryder. Considerable progress had been made in achieving this alignment during the planning meeting held immediately prior to J-GOOS IV. McEwan and Summerhayes agreed to work collaboratively to complete the Plan in time for the "Forum" in June.

During discussion it was noted that the Plan should include 'vision' and 'mission' statements as well as the 'Principles' and 'Objectives' already incorporated.

6.3 PLANS FOR OBTAINING COMMITMENTS BY NATIONS

The Committee reviewed a draft timetable for the First GOOS Forum. It noted that concrete proposals for pilot or demonstration GOOS projects would need to be presented. The *GOOS 1998* document would not be completed in time for this Forum, but efforts were being made to prepare a synopsis. A substantial block of time should be committed to its presentation and discussion. It was noted that there were still inconsistencies between the items on the draft timetable and the content of the *GOOS 1998* document, and that it was important for the Principles and the Strategic Plan to be correctly reconciled with that document in advance of the Forum.

Tom Spence noted parallel preparation for a National Participants Meeting for GCOS and/or Climate Observations in 1998 as a follow-on from the WCRP meeting. He reported consideration of a similar meeting for CLIVAR. IACCA and WMO support would also be needed. In terms of his planning, the success of the Forum would be reviewed with interest. He also invited GOOS to become involved in these plans through OOPC, which was endorsed by the meeting (See 9.2).

7. UPDATE ON PROGRESS OF GOOS COLLABORATORS

7.1 GCOS

Angus McEwan informed the Committee on developments of JSTC-VI of interest to J-GOOS. Some accomplishments mentioned at that meeting were: the establishment of the GCOS Upper Air network (GUAN), progress on the GCOS Surface Network (GSN), enhancements (Southern Hemisphere) of the Data

Buoy Cooperation Panel (DBCP), and the number of GCOS publications has reached 34.

J-GOOS noted the focus of GCOS on implementation and to the Climate Agenda. The joint panels between GOOS and GCOS had been reviewed, including a possible study of socio-economic benefits of the observing systems. The *ad hoc* Sessional Working Groups of JSTC-VI had gone over the IGOS concept, and it was pointed out that, in principle, this had been approved by the JSTC, but that it should only be applied when necessary and appropriate. Mechanisms for GCOS implementation which had been proposed were that the science panels define "user-driven" requirements, existing networks should be assessed, and that participation of existing groups should be sought or new ones established when required. On the issue of getting national involvement, the need for a 'participants' meeting and the formation of an organizing committee had been discussed.

7.1.1 *In-Situ* Observations

Erlich Desa reported on the meeting on *In-Situ* Observations for Global Observing Systems which took place in Geneva on 10-13 September 1996. Inadequacies of present *in-situ* observations were addressed, such as incompatibility of observations, and the fact that there is no global strategy for long term observations. He emphasized the need for the G3OS to prioritize; and added that demonstrations of end-to-end products and services are difficult. They involve combining *in situ* and remote observations with modeling, something we have little experience in doing. The solutions to these problems lie in explaining to governments the importance of IGOS, and the benefits and advantages of international cooperation. Demonstrations are necessary to show improvements, impact, feasibility and cost effectiveness. He encouraged participants to carry the message home with them that everyone benefits if everyone contributes.

Desa noted the need to identify users for the data products, and that the whole scientific community should be involved in these decisions. He added that, in many respects, GCOS was well advanced in this area, and emphasized that GOOS must get its priorities right, so as not to get left behind.

During the discussion, Michel Lefebvre pointed out that *in situ* observations are not only used for cross-calibration. He stressed that there are observations which cannot be measured by remote sensing, and these must be highlighted. It was noted that important observations which were difficult or not yet feasible to make should be targeted and techniques developed for them. Mickey Glantz suggested that potential funders should be persuaded to get involved not only through demonstrations, but also through studies which show the costs of not undertaking certain actions.

7.2 GTOS

Mickey Glantz reported on the formation of the GTOS Committee. It has eighteen members, with wide discipline and geographical coverage. At present, there is only one person, an acting director, for the GTOS secretariat at FAO. The position is funded for one year. It was noted that although GTOS had ambitious plans, there were very few resources. A brochure being produced about GTOS is now on hold. In 1993, a GTOS plan, written by D. Norse was accepted in theory by the co-sponsors. It's principle criticism was that it should have focused more on a few core things that were reasonably achievable given the existing circumstances. Glantz added that much could be learned from GOOS and GCOS, particularly about prioritizing. He believed it was critical to be able to demonstrate some achievements soon or support will tend to evaporate.

In May, a small sub-set of the Steering Committee will meet, so that GTOS activity can focus on an implementation plan. This plan will concentrate on five issues:

1. Land use
2. Water resources
3. Pollution
4. Loss of biodiversity
5. Climate Change

Glantz mentioned the GTOS joint panels with the other observing systems, and explained that GTOS would like to be involved in Coastal Zone issues. One goal of GTOS is to build on existing systems, such as the Terrestrial Ecosystem Monitoring Sites (TEMS) Database which is an international directory of meta-data on monitoring stations throughout 20 countries. It was noted that proposals for funds have gone to the Netherlands and Norway for support of the Secretariat. During the ensuing discussion, Neil Andersen mentioned that HOTO was keen to get involved with GTOS to ensure overlap. GTOS data are needed in the coastal zone for a variety of reasons. He also supported the idea of showing potential funders what is lost if certain actions are not taken.

8. MODULE ACTIVITIES

8.1 GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC)

8.1.1 OOPC Interactions with Other Panels

Neville Smith, chair of the OOPC, provided a detailed review of the recent progress of the Panel, including OOPC-II. He noted that the Panel had focused on operational issues, and has developed working relationships with SOOP, DBCP,and GLOSS. He expressed his concern with the number and diversity of the groups and projects the OOPC must advise and encouraged the Committee to continue to examine ways to reduce the burgeoning G3OS structure. In this regard, he further encouraged support of a GCOS recommendation calling for restructuring the WMO Commission for Marine Meteorology to allow it to assume greater responsibility for climate observations, and consideration of a technical commission, jointly sponsored by IOC and WMO, with ocean climate as one of its principle missions.

In his review, he highlighted several tasks the OOPC is currently addressing. Examples include a suite of brochures illustrating the end-to-end approach to justify observations in terms of the products which users require. These are to be used at the GCOS 'Participants Meeting'. The Panel is continuing its liaison with CLIVAR's Upper Ocean Panel (UOP); OOPC is responsible for the Upper Ocean Panel (UOP) baseline observing system. Smith brought the Committee's attention to the intensive observational effort scheduled for the North Atlantic by several groups with apparently little overall coordination. Walter Zenk surveyed the commitments/plans and sent the information to the WOCE IPO.

Smith noted that membership of the OOPC should be reviewed to ensure an appropriate balance is retained and that a rotation procedure be instituted. He stated that space observations expertise was needed and representation from JMA and the UK Met Office would be helpful. J-GOOS agreed to consider the issue of rotation of membership and that it would be decided by J-GOOS, along with GCOS and WCRP (See 9.3).

Members discussed the work of the panel and the methods whereby the OOPC determines priority for attention and balances alternative mechanisms, in particular, how the Panel would consider optimizing observing methodology (*e.g.* SOOP, DBCP). In this regard, Clarke cautioned that XBTs may no longer be the best way to get upper ocean heat content. Smith agreed and in any case some XBT tracks specified in 1985 were dispensable now. It was noted that the Panel will encourage Observation System Experiments (OSEs) to optimize observational strategies. Members inquired about plans for carbon observations. Smith replied that future meetings would address carbon. JGOOS agreed that the efforts should continue to engage the CMM on the issue of climate observations.

8.1.2 Time Series Workshop

Neville Smith reported on the Time Series Ocean Observations Workshop, the idea for which originated at OOPC-I. The Workshop addressed the various types of time-series observations including "laboratory" sites, repeat observations, and sections. The value of laboratory sites was acknowledged and it was reasoned that such sites should be continued so long as their scientific productivity was satisfactory (*i.e.*, it is the call of the research agencies). Using criteria developed for the GOOS/GCOS monitoring programmes, Smith concluded that few of the present sites would be merit consideration as climate reference stations. He noted that Station BRAVO justifies long-term support as an indicator of climate variability.

J-GOOS expressed its thanks to the organizers of the workshop.

In subsequent discussion, it was suggested that similar studies should take place on coastal time-series, considering that most existing sites are open ocean. The areas where time-series are ready for further evaluation were discussed and included sea-level, probably the parameter of choice for observing ENSO variability. Clarke suggested that further study should focus on how many Time series stations are needed or how to design one. Lefebvre believed the site design should involve linkage to space observations. How to make headway in the continuing struggle to secure funding for time-series stations was debated. Members noted the need for clear user-driven requirements. For climate change, in particular, the link to users should be strengthened in order to obtain enhanced funding. GEF funding was proposed as a possibility. Formulating the correct strategy to obtain GEF funds, whilst not easy, is possible, and needs to be addressed.

8.1.3 Global Ocean Data Assimilation Experiment (GODAE)

Neville Smith described a proposal for a Global Ocean Data Assimilation Experiment. The motivation for this proposal arises both from the growing need for products which depend on global information, and the merging capabilities for global modelling and global observations (both remote and direct). He noted that if the present circumstances persist, models will remain under-developed because of lack of suitable data; direct observations will be limited because of lack of investment; and the future of remote observations will remain uncertain due to lack of commitment and utility to global problems. Computational resources are also limited because of the lack of impetus in the solution of global ocean data assimilation problems. He also noted that the future of GOOS and its global measurement program depends critically on an adequate and convincing demontration of practicality and utility.

Smith explained that a major effort in data assimilation is being proposed now for a number of compelling reasons. There is a maturing suite of space and direct observing systems. There is a momentum building for integrating these systems. Global ocean models are nearing the point where real time operation is practical, and advances in computing technology make assimilation increasingly feasible. It is timely also to capitalize on WOCE, on satellite data, and on the transition of observing systems from research to operational. Implementation of GOOS and GCOS demands a demonstration of feasibility.

GODAE will give a practical demonstration of real time global ocean data assimilation to provide a complete depiction of ocean circulation. A realistic portrayal of the state of the ocean on a global scale will help extend predictability on a regional scale. A range of models and assimilation strategies will be employed. Development will be in phases. In 1997, the experiment design will be undertaken; during 1998-

99, feasibility and scoping studies will take place. Testing will occur in 1999-2000, with realization of the experiment planned for 2003-2005.

GODAE has been accepted as a project of the CEOS Strategy Implementation Team. Members noted that dialogue has begun with the CEOS Analysis Group, and responses from the consultation have been very positive. Project teams will be created for scoping different work packages.

The EuroGOOS community is keen to see GODAE move ahead, as is the NEARGOOS community (*e.g.*, for a NW Pacific project). GLOBEC is also interested, for instance in embedding biological models in such a system.

During the discussion, John Woods pointed to the enormous computing requirement for such a project, namely teraflop machines, but reminded members that GARP started when the computers it would require were not yet available. The level of computing power is needed to run the models which GODAE requires to succeed. The fact that it is not readily available should not stop the plan from being developed. Allyn Clarke regarded the lack of infrastructure as a prime limitation and suggested that one approach that could work would be to find an institute that has or could get the computer and would be willing to propose to take the lead. Woods added that moves were already afoot in Europe to develop an appropriate modeling centre and that the Los Alamos laboratory in the US had the potential to run the appropriate models. Eric Lindstrom welcomed the proposal as a means of focusing NASA's attention on extending application of its computing investment.

J-GOOS recommended that OOPC continue to advance plans for GODAE, and asked to be fully informed of the process (See 9.4). The Chairman expressed his satisfaction with the good progress of the OOPC. Spence added his complimentary comments and passed on those expressed to him by Peter Dexter as well.

8.2 GLOBAL MODULE

John Woods introduced participants to the concept of a Global Module, and the need for J-GOOS to have an identified global planning activity. He stated that coastal models that now exist will need to be embedded in global models to improve their performance. As the number of local services increase, he believed there will be more demand for a global model. Therefore, he reasoned the major customers for the global model will be the local managers producing the local services. A way needs to be found to determine what products managers want, and they must find a way to determine their own requirements. So far this hasn't happened. Woods suggested that the Module Panels ask these managers what their needs are. He was confident that funding the local operational services would not prove to be difficult but he was concerned about finding the funding for the global aspects of GOOS. He believed it was important enough to have a J-GOOS group to work on this. Woods strongly supported GODAE, and stressed that it too would be judged on how well it is able to produce deliverables and foster linkages to coastal customers.

In the ensuing discussion, Jilan Su raised the question of whether the global module could actually produce the boundary conditions on the time scale needed by regional models, *e.g.*, say the South China sea, on a weekly or monthly basis, the time scale for which services have been designed to deliver products. The debate suggested that both short and long term thinking were necessary. Erlich Desa described his lack of success in convincing modeling groups operating local models to think global. He found that such groups have not been enthusiastic about exploring the advantages of larger scale models because, so far, they have not been persuaded that any potential improvements would be worth the effort. Nevertheless GOOS must be in charge of pushing the concept of a global module.

Allyn Clarke saw a close link between the Smith and Woods proposals but believed they involved different groups of people. They are parallel to each other, and the same committee would not be able to implement and plan both. Michel Lefebvre described a French experiment which looked at whether a global model could improve a regional model. Users from many unexpected places became interested when they realized that services could be improved.

The Committee agreed that the proposal did not fit as another GOOS Module, but as a cross-cutting theme to pull the modules together. In discussing the kind of structure needed to pursue this approach, it was suggested that Module Chairs could be asked to communicate and report on the global perspective, and the link to the user community could be made from each module. This would avoid the establishment of additional structures. J-GOOS endorsed the proposal for such a GOOS Core System, emphasizing the links with GODAE and other processes, and determining user needs (See 9.5).

8.3 COASTAL MODULE

Nic Flemming briefed J-GOOS on the results of the Coastal Workshop held in February in Miami. A report of the workshop was tabled and Flemming requested the Committee to endorse it and distribute it in the usual way. The purpose of the workshop was to make recommendations to J-GOOS for the way ahead to develop the Coastal Module. Selection of workshop participants was critical to a successful workshop. There were around 20 people from different disciplines, organizations and countries. There is considerable activity in the coastal zone, time and space scales range from hours to decades. Thus it was important to limit planned actions to what realistically can be done. The workshop noted the global commonality of many issues in the Coastal Zone. Many problems encountered are ubiquitous. This observation led participants to conclude that observations of certain core variables can be identified that relate to the coastal zone globally.

It was noted that although no GTOS representative was able to attend the meeting due to unavoidable circumstances, enthusiasm for participation in the future was conveyed.

The ensuing discussion brought up issues about the Terms of Reference and work plan, particularly with respect to the lack of a clearly identified LOICZ link for the recommended Coastal Panel. Ken Denman and Julie concurred that a formal linkage to LOICZ was needed, and they believed LOICZ would welcome it. It was agreed that the Coastal Panel and LOICZ should work closely together. Denman cautioned that the coastal area was a popular GOOS area for developing countries to become involved. With so many interests, some of them conflicting, Denman cautioned that J-GOOS should be prepared for a major, potentially messy effort and should take great care in setting its objectives in this area. Michael Glantz was suggested that emphasizing seasonality issues in the coastal area might help focus the big demand for diverse services.

Neil Andersen commended Flemming for organizing and running an excellent workshop on a subject with such wide scope. He looked forward to quick action being taken with the workshop's recommendations adding, that on the basis of his recent experience on a fact-finding trip to the Far-East, he believed that action could be expedited by the development of a generic plan which could be used by regions to develop their own regional plans.

J-GOOS endorsed the establishment of a Coastal GOOS Panel. Reformulated Terms of Reference were prepared and accepted (See 9.6).

8.4 HEALTH OF THE OCEANS MODULE (HOTO)

Neil Andersen reviewed progress on HOTO and reported that a new panel had been formed. No new session had been convened, with the intention of first obtaining outputs from the Coastal Zone and LMR. The fourth panel meeting will probably take place in August, either in Argentina or Singapore. Andersen reported that on a recent fact-finding tour in the WESTPAC region - Thailand, Singapore, China, Korea and Japan - it was revealed that some people in these countries know very little of the documents produced by GIPME and HOTO. Using IOC action addressees as a communication mode does not appear to be effective. It was noted that China, Korea, Russia and Japan are organizing a cooperative monitoring project in about one and a half years time, using HOTO documents and US coastal planning reports. The fourth HOTO Panel meeting will look at joint activities in particular areas, and will rethink HOTO parameters in the light of the Coastal Module report.

Anderson informed the Committee that the US was in the process of reconsidering the GOOS question, and a US NOAA meeting was to take place the following week to discuss GOOS, followed by a US-wide meeting later on in May. These meetings will have a climate and coastal focus. Anderson shared with the Committee a set of questions that the US will be addressing in these exercises and asked members to provide their reactions in time for these meetings .

8.5 LIVING MARINE RESOURCES MODULE

Chairman Otis Brown observed that there had been internal discussion within communities as to the direction of GOOS concerning LMR. GLOBEC and FAO have different views that needed to be considered. Eric Lindstrom reported that there is much interest in going forward in LMR, but there is some tension about the way to proceed. He believed the module should address the major issue of LMR, which is "health of the resource".

LMR GOOS is particularly relevant to developing countries, therefore monitoring should be cost-effective so that all countries can participate. FAO is the lead UN agency for sustainable use of fishery resources. It is critical that they take an active role. They are now prepared to jointly sponsor LMR planning with IOC. It was recognized that stock assessment, process studies and critical habitat must be appropriately balanced elements of GOOS, it was this balance that the discussion tried to sort out. Other points important to the thrust of the LMR model were: consistency with user needs, and a design more likely to be made operational in developed and developing countries, while still including an observation component intended to detect and improve understanding of emerging issues. Strategies for funding are important, and it was noted that the GEF is supporting the development and implementation of several Large Marine Ecosystem programmes. There is the opportunity for GOOS to influence the design of these projects, and thereby enhance chances for significant funding. Lindstrom recommended that LMR panel work begin immediately under IOC and FAO. Panel membership should include scientists with practical experience in providing scientific information to non-scientist users and the need for an operational system to serve these users should be emphasized.

It was agreed that the LMR Panel should be user-driven, but there was some concern that LMR could not encompass all fish stock assessment, particularly without the cooperation of the fishing industries and managers. The matters of identifying user groups and the applicability of stock assessment were discussed at length. The latter and its relative importance in the LMR sphere from the GOOS view was debated. Allyn Clarke stated that setting the harvesting percentage of a fishery depends on the health of the stock, and stock assessment by itself does not give this information. Among other things, one needs to know what there is available for the stock to eat. Ken Denman believed that managers put too much faith in the simplistic curves that are used to predict next year's stock on the basis of this year's assessment and projected recruitment. Julie Hall wondered how far down the trophic level LMR could be expected to go with such issues, some of which involved EEZ political matters, the health of the regional environment, etc.

Chairman Otis Brown considered the question by reflecting on the aims of the other GOOS modules. Observations from those modules ultimately are for the purpose of improving prediction. Stock assessment from the GOOS view is not being done, *i.e.*, we can't use stock assessment as it is being done for prediction. He concluded that stock assessment was not in itself essential, but that links to it were necessary. He suggested that the GOOS contribution to stock assessment was the ability to nowcast and forecast using the best scientific tools available. The Chairman asked Denman and Hall to review the efforts of the two previous workshops and the existing proposed terms of reference over the next couple of months and report to him their recommendations for moving forward. He also asked their advice on candidates to chair an LMR Panel. (See 9.7).

8.6 SERVICES MODULE

J-GOOS-III had tasked members Gerbrand Komen, Nic Flemming and Neville Smith to identify areas where J-GOOS guidance would be helpful in the Services Module (SM). Komen and Smith co-authored a paper in this regard titled "Scientific Priorities for the GOOS Ocean and Marine Meteorological Services Module: Wave and Sea Level Monitoring and Prediction", is included as Annex IV. A second companion report was also generated for discussion by Howard Cattle and Ian Allison. That report, titled "Sea Ice Processes, Sustained Measurements and Oceanographic Services", is included as Annex V.

Smith reviewed the material covered in the report on the scientific priorities for the Services Module. He went over the scientific and technical guidance required and the state of present capability for sea wave forecasts, sea level predictions, tsunami warnings, storm surge forecasts and sea ice forecasting. He observed, that in several of these applications, model derived winds are used to develop forecasts and, in the case of sea wave forecasts, they are the dominant sources of error. The basic data therefore needs to be improved and error estimates put on the data. Michel Lefebvre noted that assimilation of wind data helps wave forecasts but so far not much in very rough seas when concern is most important. He wondered whether this was a lack of good wind observations or an inadequacy of the physics of the forecast model. Smith alluded to an OOSDP study that urged the installation of hull-mounted contact temperature sensors to improve the accuracy of the sea surface temperature field used in models. J-GOOS was reminded that accurate bathymetry is critical for most modeling, including tsunami warnings.

Smith pointed out that many science issues related to GOOS services have commonalities with issues being considered elsewhere in GOOS. The principle ones are surface winds, sea level, sea ice, bathymetry, coupling to coastal models, telemetry and computational resources. Many of these problems are being worked by other bodies including CMM and its working groups. Smith believed that J-GOOS has to decide whether it should default scientific oversight of GOOS services to existing bodies or to explicitly take it on, either through existing panels or through new structures. One approach might be to explore a partnership with existing bodies. He concluded with the following recommendations:

(i) that the services of GOOS be the responsibility of the J-DIMP, and that it in turn look to existing bodies to meet its needs.

(ii) that GOOS seek consolidation of existing bodies responsible for implementation and delivering services with a view to having a single entity, whose mission aligns with GOOS needs with respect to marine forecasts, climate and the physical aspects of the coastal module.

(iii) that the GOOS Director open a dialogue with those responsible for coordinating existing scientific working groups, mostly within the WMO structure, in order to establish what long-term responsibilities should reside with J-GOOS.

Johannes Guddal had also done a study at the request of I-GOOS on Services and the status, deficiencies and trends regarding existing GOOS Services. He alluded to the "Production Line" concept, which is another way of expressing the concept of an end-to-end system. A questionnaire on the "Production Line" concept was send out to several agencies, and a compilation of responses from China, Japan, Malaysia, Germany, Russia and Norway was provided. Guddal pointed to a potential conflict between the strategy of 'careful, long-term planning' and that of the more opportunistic, market-driven services establishment. The latter is in growth and should not be overlooked because these already appear as "GOOS" products to industry and governments.

Guddal addressed IOC-WMO-CMM interaction. There are some overlaps now in services for the Climate, Coastal and HOTO modules. Planning is going on to address these overlaps by drafting a coordinated action plan. Some members wondered how CMM reached some conclusions that it did in the past without meaningful interaction with J-GOOS. The Committee looked forward to improvement in the future noting that Guddal had recently been elected as President of CMM.

Colin Summerhayes raised the point that joint sponsorship by IOC and WMO of CMM activities was suggested, and he hoped to see a more conclusive decision as an implementation body is needed. The Chairman expressed his concern about product generation and users. He made the point that on a national level, products are distributed from many agencies. But the meteorological community has weather forecasting as a driving force and thus concentrates products in one agency. GOOS is different. GOOS has to develop an interface with the marine meteorological community to have CMM service GOOS service needs. This problem is not with observations it is with the products and delivery system. Managers must be included when designing the system.

J-GOOS agreed on steps for ways to go forward in services beyond what has been done to date (Action Item 8).

8.7 SPACE OBSERVATIONS

Michel Lefebvre gave an overview of ongoing, approved and planned satellite missions for sea surface temperature, sea state, ocean topography, sea level, ocean circulation and ocean color measurements up to 2005 (See Annex VI). ARGOS is set to continue as well. As an aside he noted that development of a remote system for measuring salinity is showing some promise. His point here was that we now have assured on the near horizon a full suite of space based instrument systems for ocean observations and GOOS's job is to make them operational. This involves having available routine, reliable and tested intercalibration techniques. A facility to validate data should be included in project teams so that this function is considered in every step of planning, development and operation of satellite sensors. It is happening now with altimeter and wind observations, but not color. Methods for assimilating different data types are beginning to be developed and employed. This will bring to the fore questions concerning cal-val issues of data sets from different agencies and from different countries. Operational systems will have to consider intercalibration between satellites and coherence (measuring the same thing differently) between sensors.

In the following two to three years the next priorities will be decided. Lefebvre emphasized that there is no chance to have any influence on satellite missions once they are approved. So the oceanographic community needs to act now, with one voice, to assure ocean satellite systems are scheduled beyond 2005. Stronger arguments and stronger operational motivations will be needed for missions after 2005. Eumetsat's transition to operational use will happen in 2-3 years.

It was noted that an important but often overlooked point in planning satellite requirements is that mesoscale coverage requires two satellites, *e.g.*, for observing features in the Mediterranean.

8.8. GLOBAL OBSERVING SYSTEMS SPACE PANEL (GOSSP)

Tom Spence noted that involvement of all three observing systems was reflected in the GOSSP-II report. J-GOOS help is needed as to whether GOOS and GTOS requirements should be looked at, although these are not well articulated. The next GOSSP meeting is taking place in Paris at the end of May. Members were informed that the CEOS plenary in Australia set up a panel which is looking at six selected topics. An analysis group and a team of representatives of user and operational agencies were also set up. At the Paris meeting GOSSP will discuss those of the six topical areas which fall in the purview of the Space Panel.

Tom Spence put two issues to J-GOOS:

(i) How does it want GCOS to work on behalf of the panel?
(ii) J-GOOS representatives for GOSSP should be experts who understand what is needed and who can interact with panel chairs.

Members agreed that a joint GCOS Space Panel should be composed of a few members who understood the requirements. Suggestions for representatives were encouraged from around the table. The Committee endorsed fully GOOS participation in a joint GOSSP, and accepted the redrafted Terms of Reference which now incorporate specific oceanographic requirements (See 9.9).

8.9 JOINT DATA AND INFORMATION MANAGEMENT PANEL

Tom Spence noted that the panel was institution-oriented and informed participants that Thomas Karl was the new chairman. He pointed out that at present DIMP is an I-GOOS link, and brought up the issue of the relationship between DIMP and J-GOOS and how this could be formalized. Membership of the panel must also be considered.

Colin Summerhayes suggested that the GOOS Project Office could take responsibility for J-DIMP. It was agreed that the limited resources at the GPO should be recognized, but that it could assist in liaising between GOOS and DIMP. The Chairman added that under the chairmanship of T. Karl, J-DIMP would become more strategic and would eventually focus on climate change detection issues. It was further suggested that I-GOOS continue to play a role in terms of its Member States. The Committee endorsed the above suggestions, and the recommendation that it should participate in a Joint Data and Information Management Panel with GTOS and GCOS (See 9.10).

9. SUMMARY OF ACTION ITEMS

9.1 GOOS 1998 DOCUMENT

J-GOOS will publish *GOOS 1998* as a J-GOOS document which will be consistent with the Strategy and the Principles documents. The J-GOOS Planning Committee (J. Woods, P. Ryder, A. McEwan, O. Brown. E. Lindstrom, and N. Smith) has been constituted to take responsibility for the development of this document. Representatives of the GPO and ICSU are encouraged to participate in meetings of the group to maintain continuity.

J-GOOS recognizes that in writing *GOOS 1998*, Ryder and/or members of the Planning Committee may identify important issues where J-GOOS has not established a clear policy. The Planning Committee should develop policy options to deal with such issues and circulate these to J-GOOS members via electronic mail for comment and approval so that neither the writing of the document nor its final approval in April 1998 should be unduly delayed.

J-GOOS requested that *GOOS 1998* introduce the two themes of global and coastal along which implementation planning is expected to proceed.

An annotated outline of *GOOS 1998* will be available for presentation at the First Forum, 25 June 1997.

A complete draft of *GOOS 1998* should be sent to all J-GOOS members for review in sufficient time that a revised document can be presented to J-GOOS V for final approval and subsequent publication.

9.2 GCOS PARTICIPANTS MEETING

J-GOOS is to give assistance to the GCOS "Participants" meeting through the OOPC.

9.3 OOPC

Membership and rotation of membership of OOPC is to be decided by J-GOOS, along with GCOS and WCRP. The J-GOOS Secretariat should coordinate a recommendation to Chairman Otis Brown by August.

9.4 GODAE

Recognizing that GOOS is in transition from the planning phase to the implementation phase, and that assimilation of data into numerical models is essential to the success of any integrated global observing strategy, J-GOOS endorsed the GODAE proposal. J-GOOS commended the OOPC on their initiative in identifying an appropriate global ocean data assimilation project and noted the strong support, in principle, from many sections of the oceanographic community.

J-GOOS noted that while the foundations of the project are mainly within the domain of the OOPC, the deliverables and the user communities involve GOOS as a whole, making the project in part a demonstration of the GOOS concept. That being the case, J-GOOS directs that the OOPC stay in close contact with the other GOOS planning activities during the development and implementation of GODAE to ensure that a broad spectrum of GOOS interests are considered and met.

J-GOOS noted and endorsed the strong emphasis on integration of direct and remote observing systems, consistent with the principles of GOOS, and endorsed and encouraged the close interaction with groups like CEOS and its working groups. J-GOOS also noted the emerging links with GCOS and its offer of support, and the obvious links with the WOCE Analysis, Interpretation, Modeling and Synthesis (AIMS) phase, CLIVAR, and other programmes of the WCRP, SCOR and IGBP.

J-GOOS instructed the OOPC to continue to advance the plans for GODAE, in consultation with the GPO, and asked that J-GOOS be kept fully informed of progress. J-GOOS further instructed the OOPC to develop a draft plan for GODAE, including support for appropriate infrastructure to enable implementation, for presentation at the next meeting of J-GOOS or its successor.

9.5 GLOBAL PERSPECTIVE

GOOS is evolving beyond the framework of panels and modules to the practical organization of projects and tasks that lead to operational products.

J-GOOS IV received two proposals relating to the next stages of design and implementation:

(i) to establish a GOOS Module Panel
(ii) to endorse and support a Global Ocean Data Assimilation Experiment

The proposed Global Module Panel would design a global modeling system which will provide the definition of global ocean fields to be used as inputs by the managers of coastal and regional operational products. In view of the evolution of GOOS the terms "Module" and "Panel" are not be used in this resolution, and the GOOS Core System (GCS) will be used instead to refer to the global oversight system.

The Global Ocean Data Assimilation Experiment (GODAE) is a proof of concept demonstration that collection and assimilation of real time data into global models is technically feasible. GODAE would have a 3-year field phase from 2003-2006.

The GOOS Core System (GCS) will be an integration of observing systems, both remote sensing and in-situ/direct, with global numerical models, to deliver a detailed field description of the global ocean on a real time (operational) basis. The global products will be used for the specification of boundary conditions for coastal and regional model forecasts, and to extend their predictability. Open ocean fields are essential for coupled ocean atmosphere climate modeling. These fields will also be used to improve information supplied to service organizations in the business of ship routing, fisheries management, and deep water offshore gas and oil production. The GOOS Coastal Workshop confirmed the need for open ocean fields to maximize benefits in the coastal zone. GCS will be a major component of GOOS.

The Global Ocean Data Assimilation Experiment (GODAE) is an essential step in the realization of the GOOS Core System. GODAE is not a permanent service, but a technical task to test the feasibility of integrating the techniques, sub-systems, and procedures required in the GCS. Additional work will be needed to analyze and define the processes linking open ocean fields to shelf sea processes, and the precise requirements of coastal and regional models and their end users. The economic and social benefits of GODAE and GCS need to be assessed. J-GOOS IV decided that:

(i) The Planning Committee responsible for supervising the drafting of *"GOOS 1998"* should assure the inclusion of an appropriate section on GODAE and GCS, and stress the central importance of this component of GOOS.

(ii) A task team or study group should be considered during the next session of J-GOOS to study the integration of GODAE and GCS into the planning framework of GOOS, with particular attention to the design of products needed by coastal modeling managers and end users.

9.6 GOOS COASTAL PANEL

J-GOOS accepted the GOOS Coastal Module Planning Workshop Report and instructed that it be circulated widely. The Chairman will establish a GOOS Coastal Panel to oversee and review coastal activities without causing delays in urgently required actions. In particular the Panel must take into account the vigorous level of national and commercial activity that will take place in the coastal zone regardless of

GOOS and try to integrate these activities in the most efficient way possible. The Terms of Reference for the Panel are given in Annex VIII.

J-GOOS noted that while waiting for a Coastal Panel to form, and while a plan for the Coastal Module is being developed, many of the recommendations proposed by the workshop could be progressed by the GOOS Project Office, for example, working with the regions.

9.7 LIVING MARINE RESOURCES

Ken Denman and Julie Hall were charged with the following:

(i) to review the results of the two previous LMR workshops,

(ii) to review the existing Terms of Reference in light of discussions at this meeting,

(iii) within 90 days to propose any changes deemed advisable in the TOR and to propose candidates for a chair for this Panel as well as candidates for membership.

J-GOOS recognized that action on the establishment of this Panel is urgent and should be accomplished as soon as possible after the Denman-Hall report is received.

9.8 SERVICES MODULE

J-GOOS acted on the two main services issues that were brought to the fore: (1)the services associated with, and the coordination of, the GOOS product stream; and (2) the scientific and technical oversight for various marine activities not covered by other modules. J-GOOS also noted that services develop and get implemented on two levels: agencies to end-users, and infrastructure to agencies.

Regarding action on the GOOS product stream, J-GOOS bore in mind the following factors:

(i) the expertise and linkages of CMM into the services and user community of GOOS as well as similar expertise, sometimes overlapping, in other groups, including local and regional commercial services;

(ii) the capability that such groups have to encourage and excite participation in, and exploitation and marketing of, GOOS product lines;

(iii) the need for effective coordination of the various actions required for implementation of an effective GOOS product stream;

(iv) that development of the GOOS product stream requires significant collaboration with and knowledge of other operations.

Accordingly, J-GOOS took the following action. J-GOOS:

(i) directed that the GPO Director, in collaboration with the chairs of CMM, and the WMO coordinator for marine services, prepare a position paper on GOOS products and service requirements;

(ii) recommended that the sponsors of GOOS and of the existing mechanisms for marine services and product management consider consolidation of existing mechanisms so that a more efficient structure is established for GOOS.

Regarding the scientific oversight issue, J-GOOS noted the significant scientific and technical issues associated with marine and surge forecasts and sea ice forecasts. It was also noted that some of these same issues were of significant interest to several other groups, particularly those of CMM. Bearing this in mind, J-GOOS instructed the GPO Director to:

(i) prepare an assessment of the existing lines of scientific stewardship, particularly within WMO. A position paper should be prepared and circulated prior to and for consideration at J-GOOS V, taking into account the Coastal Panel, the OOPC and other groups as well as the long term plans of the WCRP.

(ii) work closely with the sponsors and the appropriate operational organizations such as IGOSS and CMM with the object of designing an improved means of delivering operational services so as to enable efficient and effective implementation of GOOS products and services.

Finally, J-GOOS concluded that the J-DIMP should take on the responsibility for operational services.

9.9 GOSSP

The Committee was pleased to approve its participation in the reformulated GOSSP. Since the TOR of this Panel were formulated, there have been several developments that warrant their examination in the context of specific oceanographic requirements. These include:

(i) the formulation by the OOPC of the GODAE project, a "proof of concept" experiment to test the feasibility of near real time assimilation of space and *in situ* data into global ocean numerical models;

(ii) the adoption of GODAE by CEOS as an oceanographic prototype project;

(iii) the adoption by CEOS of a second, less specifically defined prototype project on long term ocean biology measurements;

(iv) the development of the IGOS concept and possible inclusion of oceanographic experiments in the context of these.

Since none of these is likely to be specifically oriented to end-users and will involve significant *in situ* components, J-GOOS considered the following minor change to the TOR might be warranted:

> TOR 1: add "for both long-term and near-real-time observations, and their requirements for specific pilot experiments that combine space and *in situ* data"

J-GOOS encouraged GOSSP to keep in mind certain special requirements for Ocean observations for GOOS which are:

(i) the need for some types of intercalibrated, consistent observations to be sustained continuously for a long time in order to capture the longest scales of variability;

(ii) the fact that GOOS is evolutionary and will be implemented gradually and in discrete phases.

9.10 DATA AND INFORMATION MANAGEMENT

J-GOOS recognized that the design of an appropriate data and information management system is an essential part of the overall scientific and technical design of GOOS. Accordingly, J-GOOS agreed to have its representatives participate with GCOS and GTOS in a proposed Joint Data and Information Management Panel (J-DIMP) – the successor to the GCOS-DIMP – to develop a strategic view of the management of data and information within the three global observing systems.

At the same time J-GOOS recognized that there are "nuts and bolts" issues to address in data and information management, and that these are more properly addressed in the planning process at the module level. J-GOOS also noted that such issues are being addressed by IGOSS and IODE, and decided that the IGOSS/IODE proposal for a data management strategy in support of GOOS be discussed at the next J-GOOS meeting.

In view of the existence of these various ongoing approaches to data and information management, J-GOOS instructed the GPO to liaise between them to ensure that there is an appropriate level of coordination and cross-communication and to ensure that the results are complementary. The end product should be a comprehensive data and information strategy and plan for GOOS.

J-GOOS recognized that I-GOOS will play a complementary role in assessing the implications of the proposed data and information management designs in terms of the national and regional structures of Member States.

9.11 GOOS RESTRUCTURING

Bearing in mind the SSC-III proposal that the functions of the SSC be combined with J-GOOS to form a new GOOS Steering Committee (GSC) with an executive function;

Noting that this will align the GOOS structure more closely with those of GCOS and GTOS, and that the change is endorsed by the sponsors of GOOS; and

Recognizing that as GOOS is moving from the planning to the implementation phase a change in the membership to include significant participation from operational agencies will be useful to assist in the application of the end-to-end principle;

J-GOOS accepted the recommendation of the SSC, but requested certain changes to the draft terms of reference of the GSC as follows:

(i) change TOR 2 so that it begins "Coordinate and take responsibility for..."

(ii) change TOR 4 so that it reads "Submit reports to the sponsoring organizations and I-GOOS at appropriate times."

Regarding the GOOS Office, J-GOOS agrees with the proposal made to the sponsors that the primary functions of the Office will be:

"to assist in the promotion, planning, coordination and implementation of GOOS, to provide staff support to GOOS committees and officers, consistent with resources, and to facilitate coordination between the GSC and I-GOOS, and with the secretariats of GCOS and GTOS."

J-GOOS further accepted that the TOR of the Office should be, as proposed to the sponsors:

to assist the GOOS committees in:

(i) the promotion, coordination, implementation and management of GOOS;

(ii) identifying the resources needed for GOOS and the means for obtaining them;

(iii) developing and updating plans for initiating implementation stages and monitoring the progress of GOOS;

(iv) liaising with related research projects and other observing system bodies as appropriate;

(v) conducting public and information activities to promote GOOS.

Consistent with the proactive role expected of the GOOS Office, J-GOOS accepted the proposal made to sponsors that it should continue to carry its new name of GOOS Project Office, while recognizing that this designation may change as GOOS evolves.

10. MESSAGE TO I-GOOS FROM J-GOOS

At I-GOOS III in June, the Chairman of J-GOOS plans to review the J-GOOS news and to report on the proposed GOOS restructuring. He will also cover J-GOOS action taken on GOSSP, J-DIMP and the Coastal Module. He will also update the meeting on the developments of the *GOOS 1998* document.

11. SCHEDULE OF FORTHCOMING EVENTS

Members amended the existing schedule of events (Annex VII)

12. DATE AND PLACE OF THE NEXT J-GOOS MEETING

Jilan Su and Erlich Desa both tabled offers to host J-GOOS-V in their respective countries of China and India. The exact dates of J-GOOS V were not set, but it was decided to seek a date in the period mid to late April 1998. The pros and cons for China *vs*. India would be considered by the J-GOOS secretariat before the Chairman decided on the place.

The Chairman thanked participants for the effort and the time. they put into J-GOOS. He observed that the meeting had been productive, and that much had changed in J-GOOS over the last few years. He thanked Su Jilan and Erlich Desa for their kind invitations. The meeting closed at 3pm on Friday 25 April.

ANNEX I

AGENDA

1. **OPENING**

2. **ADOPTION OF THE AGENDA**

3. **BRIEF ON STATUS OF J-GOOS**

   3.1. DEVELOPMENTS ON GOOS STRUCTURE

4. **GOOS PROJECT OFFICE (GPO) BRIEF**

   4.1 J-GOOS BUDGET

5. **TOWARDS THE REALIZATION OF GOOS**

6. **I-GOOS ACTIVITIES**

   6.1 GOOS PRINCIPLES
   6.2 GOOS STRATEGIC PLAN
   6.3 PLANS FOR OBTAINING COMMITMENTS BY NATIONS

7. **UPDATE ON PROGRESS OF GOOS COLLABORATORS**

   7.1 GCOS

      7.1.1 *In-Situ* Observations

   7.2 GTOS

8. **MODULE ACTIVITIES**

   8.1 GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC)

      8.1.1 OOPC Interactions with Other Panels
      8.1.2 Time Series Workshop
      8.1.3 Global Ocean Data Assimilation Experiment (GODAE)

   8.2 GLOBAL MODULE
   8.3 COASTAL MODULE
   8.4 HEALTH OF THE OCEANS MODULE (HOTO)
   8.5 LIVING MARINE RESOURCES MODULE
   8.6 SERVICES MODULE
   8.7 SPACE OBSERVATIONS
   8.8. GLOBAL OBSERVING SYSTEMS SPACE PANEL (GOSSP)
   8.9 JOINT DATA AND INFORMATION MANAGEMENT PANEL

9. SUMMARY OF ACTION ITEMS

- 9.1 GOOS 1998 DOCUMENT
- 9.2 GCOS PARTICIPANTS MEETING
- 9.3 OOPC
- 9.4 GODAE
- 9.5 GLOBAL PERSPECTIVE
- 9.6 GOOS COASTAL PANEL
- 9.7 LIVING MARINE RESOURCES
- 9.8 SERVICES MODULE
- 9.9 GOSSP
- 9.11 GOOS RESTRUCTURING

10. MESSAGE TO I-GOOS FROM J-GOOS

11. SCHEDULE OF FORTHCOMING EVENTS

12. DATE AND PLACE OF THE NEXT J-GOOS MEETING

ANNEX II

LIST OF PARTICIPANTS

I. MEMBERS OF J-GOOS

Neil **Andersen**
University of Maryland
Horn Point Environment Laboratory
Box 775, Cambridge, MD 21613
USA
Tel: (1410) 228 8200
(private 1410 221 8479)
Home: (1410) 745 3316
Fax: (1410) 476 5490
E-mail: andersen@hpel.cees.edu

Otis B. **Brown (Chairman)**
Dean, Rosenstiel School of
Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149-1098, USA
Tel.: (1 305) 361 40 18
Fax: (1 305) 361 46 96
E-mail: obrown@rsmas.miami.edu

R. Allyn **Clarke**
Bedford Institute of Oceanography
Ocean Circulation Division
1 Challenger Drive, P.O. Box 1006
Dartmouth, Nova Scotia B2Y 4A2
CANADA
Tel.: (1 902) 426 25 02
Fax: (1 902) 426 78 27 or 426 22 56
E-mail: a_clarke@bionet.bio.dfo.ca

Ken **Denman**
Institute of Ocean Sciences
P. O. Box 6000
9860 W.Saanich Road
Sidney, B.C. V8L 4B2, CANADA
Tel.: (1 250) 363 6346
Fax: (1 250) 363 6746
E-mail: denman@ios.bc.ca

Ehrlich **Desa**
Director, National Institute
of Oceanography
(Council of Scientific & Industrial
Research, Govt. of India)
Dona Paula, Goa 403004, INDIA
Tel.: (91 832) 22 13 52
Fax: (91 832) 22 13 60 or 22 33 40
E-mail: ehrlich@bcgoa.ernet.in

Nic C. **Flemming**
Room 346/18
Southampton Oceanography Centre
Empress Dock, European Way
Southampton, SO14 3ZH, U.K.
Tel.: (44 1703) 596242 or 596262
Fax: (44 1703) 596399
E-mail: n.flemming@soc.soton.ac.uk

Michel **Glass**
IFREMER/PGB
155, rue Jean-Jacques Rousseau
92138 Issy-les-Moulineaux Cedex
FRANCE
Tel.: (33 1) 46 48 22 22
Fax: (33 1) 46 48 22 24
E-mail: michel.glass@ifremer.fr

Johannes **Guddal**
Norwegian Programme for Ocean Monitoring
&Forecasting
Allegt. 70
N-5007 Bergen
NORWAY
Tel: (47 5) 23 66 00
Fax: (47 5) 23 66 61
E-mail: j.guddal@dnmi.no

Julie **Hall**
NIWA
Gate 10 (University of Waikato)
Silverdale Road
P.O. Box 11-115
Hamilton, NEW ZEALAND
Tel: (64 7) 856 7026
Fax: (64 7) 856 0151
E-mail: j.hall@niwa.cri.nz

Dr. Gerbrand J. **Komen**
Royal Netherlands Meteorological Institute
Wilhelminalaan 10
Postbus 201
3730 AE de Bilt, THE NETHERLANDS
Tel: (31 30) 20 66 76
Fax: (31 30) 22 02 570
E-mail: komen@knmi.nl

Michel **Lefebvre**
8, avenue de Cugnaux
31270 Villeneuve Tolosane, FRANCE
Tel. & Fax: (33) 61 92 94 69
E-mail: milef@calvanet.calvacom.fr

Angus **McEwan**
Senior Science Adviser (Oceanography)
Bureau of Meteorology
5th Floor, 111 Macquarie Street
GPO Box 727G
Hobart, Tasmania 7001, AUSTRALIA
Tel.: (61 3) 6221 2090
Fax: (61 3) 6221 2089
E-mail: a.mcewan@bom.gov.au

Neville **Smith**
Bureau of Meteorology Research Centre
150 Lonsdale Street
Box 1289K
Melbourne, VIC 3001, AUSTRALIA
Tel.: (61 3) 9669 44 34
Fax: (61 3) 9669 46 60
E-mail: nrs@bom.gov.au

SU Jilan
Second Institute of Oceanography
State Oceanic Administration
P.O. Box 1207
Hangzhou, Zhejiang 310012, CHINA
Tel.: (86 571) 807 69 24
Fax: (86 571) 807 15 39
E-mail: sujil@ns2.zgb.co.cn

John **Woods**
Dean, Graduate School of the Environment (GSE)
Professor of Oceanography, Dept. of Earth
Resources Engineering (ERE)
Imperial College
Rm B348, Bessemer Bldg, RSM, Prince Consort
Road
London SW7 2BP, U.K.
Tel.: (44 171) 59 47460 (GSE)
Fax: (44 171) 59 47462(GSE)
Tel.: (44 171) 59 47414 (ERE)
Fax: (44 171) 59 47444 (ERE)
E-mail: J.Woods@ic.ac.uk

(MEMBERS NOT ATTENDING)

Ichio **Asanuma**
Assistant Senior Scientist
Ocean Research Department
Japan Marine Science and
Technology Center (JAMSTEC)
2-15, Natsushima, Yokosuka 237
JAPAN
Tel.: (81) 468 66 38 11
Fax: (81) 468 65 32 02
E-mail: asanumai@mstkid.jamstec.go.jp

Mike **Bewers**
Head, Chemical Oceanography
Bedford Institute of Oceanography
1 Challenger Drive, P.O. Box 1006
Dartmouth, Nova Scotia B2Y 4A2
CANADA
Tel.: (1 902) 426 23 71
Fax: (1 902) 426 66 95
E-mail: m_bewers@bionet.bio.dfo.ca

II. OTHER INVITED PARTICIPANTS

Michael H. **Glantz**
Chairman GTOS Steering Committee
UCAR
Box 3000
Boulder, Colorado 80307
Tel.: 1 303 497 8119
Fax: 1 303 497 8125
E-mail: glantz@ucar.edu

Eric J. **Lindstrom**
Physical Oceanography Program Manager
NASA Headquarters, Code YS
300 E Street SW
Washington, DC 20546
Tel.:1 202 358 4540
Fax: 1 202 358 2770
E-mail alias: e.lindstrom@omnet.com

Peter **Ryder**
8, Sherring Close
Bracknell, Berks
RG 42 2LD, UK
Tel. & Fax: 44 1344 423 380
E-mail: peteryder@msn.com

Thomas W. **Spence**
Director, Joint Planning Office GCOS
c/o W.M.O., 41, Giuseppe-Motta
P.O.B. No. 2300
1211 Geneva 2, SWITZERLAND
Tel.: (41 22) 730 8401
Fax: (41 22) 740 1439
E-mail: jpo@gcos.wmo.ch

III. J GOOS SPONSOR REPRESENTATIVES

Arthur **Alexiou**
Senior Assistant Secretary IOC
IOC - UNESCO
1, rue Miollis
75732 Paris Cedex 15, FRANCE
Tel.: (33 1) 45 68 40 40
Fax: (33 1) 45 68 58 12
E-mail: a.alexiou@unesco.org

Sophie **Boyer King**
ICSU Environment Officer
51, Bld de Montmorency
75016 Paris, FRANCE
Tel.: (33 1) 45 25 03 29
Fax: (33 1) 42 88 94 31
E-mail: sophie.king@icsu.lmcp.fr

Elisabeth **Merle**
Administrative Assistant ICSU
51, Bld de Montmorency
75016 Paris, FRANCE
Tel.: (33 1) 45 25 03 29
Fax: (33 1) 42 88 94 31
E-mail: elisabeth.icsu@lmcp.jussieu.fr

Colin **Summerhayes**
Director GOOS Project Office
IOC-UNESCO
1, rue Miollis
75732 Paris Cedex 15, FRANCE
Tel.: (33 1) 45 68 40 40
Fax: (33 1) 45 68 58 12
E-mail: c.summerhayes@unesco.org

ANNEX III

J-GOOS DRAFT PROPOSED EXPENDITURES FOR 1997-1998

	1997	1998	1999
J-GOOS:			
Annual mtg	32000	35000	30000
Chair Misc travel	5000	6000	6000
J-GOOS Plan	30000*	20000*	
Subtotal	**67000***	**61000***	**36000**
J-GOOS Panels:			
OOPC	25000*	30000*	30000
HOTO	25000	28000	28000
LMR	25000	28000	28000
Coastal	25000	28000	32000
Space	25000*	25000*	25000*
Data Mgmt	25000*	25000*	25000*
OOPC GODAE	0	0	30000
Subtotal	**150000***	**164000***	**198000***
J-GOOS Workshops:			
OOPC-Time series	16000*	0	0
Coastal	30000	0	0
OOPC GODAE	0	30000	0
Technology Workshop	0	0	30000
Subtotal	**46000***	**30000**	**30000**
J-GOOS Contracts:			
J-GOOS Plan	100000*	85000*	0
Modelling Paper	7500	0	0
To be named	7500	0	0
To be named	0	8000	0
To be named	0	0	10000
Subtotal	**115000***	**93000***	**10000**
Contingencies:			
J-GOOS Plan	8000	7000	10000
Miscellaneous	5000	6000	6000
Subtotal	**13000**	**13000**	**16000**
Totals	**391000***	**361000***	**290000***
J-GOOS Travel:			
IOC staff (AA)	9500	11000	13000
WMO staff	3000	3000	3000
ICSU staff	5000	3000	3000
SCOR	3000	3000	3000
Experts	10000	10000	10000
Resources			
Carryover	33000	?	
IOC	100000	?	
ICSU	20000	?	
WMO	10000	15000	
Other	205000*	?	
Grand total	**368000***	?	

* Denotes funds in the figure include monies supplied from sources outside the J-GOOS operating budget composed of J-GOOS earmarked contributions from IOC, WMO and ICSU.

Staff support:	
IOC	5 man/mo
WMO	1
ICSU	2
SCOR	2
Other	?

ANNEX IV

Scientific Priorities for the GOOS Ocean and Marine Meteorology Service Module:

Wave and Sea Level Monitoring and Prediction

Gerbrand Komen and Neville Smith

1. Introduction

The development of a Global Ocean Observing System (GOOS) was endorsed by the second World Climate Conference and the United Nations Conference on Environment and Development. Subsequently, IOC, ICSU, UNEP and WMO have jointly undertaken to support and to facilitate the development of GOOS. To this end an intergovernmental Committee for GOOS (I-GOOS) was established in 1992. A joint GOOS Scientific and Technical Committee (J-GOOS) was set up in 1994.

As a basis for organisation GOOS has been defined in terms of five "modules" ordered according to categories of perceived user interest. These are the following:

- climate monitoring, assessment and prediction;
- monitoring and assessment of marine living resources;
- monitoring of the coastal environment and its changes;
- assessment and prediction of the health of the ocean;
- Marine Meteorological and Oceanographic Operational Services.

For all of the GOOS-modules scientific plans and implementation plans are being developed.

In 1995 both I-GOOS and J-GOOS established ad hoc working groups on Marine Meteorological and Oceanographic Services. The I-GOOS group, chaired by J. Guddal, and the J-GOOS group, consisting of G. Komen and N. Flemming, worked closely together.

At its third meeting, in the Spring of 1996, J-GOOS decided to make a distinction between two activities that had previously been incorporated into the Services Module.

A. Services for GOOS Modules

Each of the modules is concerned with data and information management issues and services. These include telemetry, communications, quality assurance, data assembly, data bases, archives, dissemination, etc. A central idea is that the other modules should build on the experience of the Marine Meteorological and Oceanographic Services. The GOOS Director has been asked to draft a position paper setting out the issues which are critical for GOOS.

B. Marine Prediction proper

J-GOOS decided that it should provide scientific guidance on the development of observing and modelling involved in marine prediction. They have asked an ad hoc group (Komen, Flemming and Smith) to formulate ideas for discussion. The present document is the result of the activities of this group. It identifies scientific issues that need to be addressed for the further development of the Ocean and Marine Meteorology Service Module.

This document consists of two parts: 1. sea wave prediction; and 2. sea level prediction (storm surges and tsunamis). Another important aspect of the Service Module, sea ice prediction, is treated in a separate paper (Cattle and Allison, 1997). Conclusions are summarised at the end.

2. Ocean Wave Forecasting

Forecasts of wave conditions at sea are important for many applications. The modern approach uses numerical models which are being run operationally in Meteorological Centres, for both global and regional applications. Sea state observations are used for model validation and initialisation (data assimilation). We will begin this section with the observations; then follows a discussion of the modelling approach; and we will end with a few remarks about data assimilation. We have not attempted to be exhaustive in the bibliography. Additional references can be found in Komen et al (1996).

2.1 Observations

Visual observations of wind speed and direction, significant wave height, wave period, and wave direction (wind sea and swell) have always been of great importance, and will continue to be important. In addition, *instrumental* observations from *buoys and platforms* of the (two-dimensional) spectrum have grown in importance. Certain areas, such as the North Sea, are covered reasonably well. Instrumental observations in other areas, notably in the southern hemisphere are extremely scarce. Fortunately, a wealth of ocean wave observation has become available from *satellites* such as Geosat, Topex-Poseidon and ERS-1 and ERS-2. The radar altimeter has proven quite reliable for the measurement of the significant wave height. However, global models are also performing well. At present, instrument accuracy is the same order of magnitude as global wave model errors in wave height. For future instruments to be of use operationally, the accuracy must be higher. Both UKMO and ECMWF global wave models showed an improvement in bias of significant wave height in the analysis (verified against buoys) simply by switching from assimilating ERS 1 data to ERS 2 data in April 1996 (Martin Holt, private communication).

Altimeters do not provide directional or spectral information. This type of information can be obtained from the synthetic aperture radar (SAR). Short waves can not be detected by this instrument and first-guess model information is normally used for conversion of the SAR-image spectrum into a wave spectrum.

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Quasi-real time dissemination of wave observations is of crucial importance. The GTS continues to play an important role for this. In case of satellite observations specialised data links are gaining importance.

Atmospheric observations in general, and observation of the surface winds over sea in particular, are also important, because the quality of wave prediction depends on the quality of the weather forecast.

2.2 Wave modelling
Over the last fifty years, considerable progress was made in the field of ocean wave forecasting (WMO, 1988; Komen et al, 1994). A major intercomparison study in the 1980s (SWAMP, 1985) indicated that all existing wave models suffered from a number of shortcomings. Therefore, an effort was made to develop so-called third generation wave models, in which the basic equation describing wave generation, propagation and decay is integrated. As a results of this activity the so-called WAM model (WAMDI, 1988) has been developed, which has now been implemented in global and regional modes for operational forecasting. Examples of model results are given in figure 1 (global analysis) and figure 2 (North Sea analysis). More recently, several alternative third-generation wave models have been developed (Tolman, 1992; Vledder, 1994).

The WAM model is based on an explicit formulation of the physics of generation of waves by wind, nonlinear wave-wave interactions and dissipation due to whitecapping and bottom processes, rather than on the approach of ad hoc modelling which was commonplace with second generation models. The latter approach was shown to be inadequate under extreme circumstances such as hurricanes (SWAMP, 1985), while the WAM model gives very satisfactory results in situations with rapidly changing winds. Nevertheless, under 'normal' circumstances both approaches give similar results for the wave height. The reason for this is that although second generation models have inadequate physics they have been tuned to a considerable extent. Thus, the benefits of a third generation model are mainly related to a better representation of the spectrum itself and to a more explicit formulation of the underlying physics of wave evolution.

This became clear in recent intercomparison between the UKMO second generation model and the third generation WAM model. After SWAMP the UKMO model was modified by introduction of a suitable parametrisation for directional relaxation under turning winds. As a results UKMO now also gives very satisfactory results in situations with rapidly varying winds. The main difference between UKMO 2G and WAM 3G lies in the better representation of spectral detail by WAM. In case studies it was found that the difference between models and observation were greatest due to errors in the wind fields, rather than due to differences in model formulation. (Martin Holt, private communication.)

We still are not able to make wave predictions that always fall within the error bands of the observations. In view of the progress that has been made by going from second to third generation models, one should not be too optimistic about the effect of further refinements, possibly with one exception, namely the further improvement of the quality of the driving winds including the effect of gusts. With this in mind we will now discuss the three main sources of error: inadequate input winds, inadequate wave model physics and inadequate numerics and resolution.

2.2.1 The winds

From the application point of view there is a strong need for improvement of the quality of forecast winds over sea in the medium-range, i.e. up until five to ten days. But also nowcasts and short-term forecasts are important.

Most studies use winds obtained from the large numerical models that are used for weather prediction. These models assimilate observations. Occasionally a subjective analysis of the observations is still made, but even then the first guess model fields are an important tool. In general, one may expect better winds from more observations, better assimilation techniques and better (atmospheric) models. Specific ocean satellites have considerably increased the number of observations. It will be a challenge to the atmospheric modelling community to make full use of these extra observations and it is important to realise that wave models can be of help here. If this is successful, one may expect that the present experimental satellites will be replaced by operational ones. At the same time everything possible should be done to continue conventional observations from ships and buoys and - if possible - to increase their quality and reliability.

For weather (and wind) prediction model initialisation is essential. Therefore, once the observations are there, it is important that they are used in the best possible way. To this end data assimilation techniques should be further improved. There is hope here because the new generation of computers may allow the running of four-dimensional data-assimilation schemes.

A widely accepted strategy for improving atmospheric models is to improve the resolution, its numerics and its physical parametrizations. Although all parametrizations (clouds, for example) are relevant, wave modelling has a particular interest in the parametrization of the turbulent atmospheric boundary layer. In the past, curious inconsistencies have occurred. For instance, the friction that the atmospheric model used to compute the surface winds might be different from the drag computed from these winds, which in turn might be inconsistent with the momentum flux into the waves. This is clearly unacceptable if the differences become too large. In such cases it is essential to introduce a two-way coupling between the atmosphere and the waves. This should take into account also the effects of density stratification caused by air/sea temperature difference. It appears that these stability effects also determine the level of gustiness of the winds, which has an effect on the wave growth. The prediction of gustiness - not done at present - would be highly welcome.

2.2.2 Model physics

The wind input term of the WAM model is based on the quasi-linear theory, which extends Miles' description of shear flow instability. It is in fair agreement with observations both in the laboratory and in the field, although there is considerable scatter in these observations. It should be realised that the quasi-linear theory is a semi-analytic approximation to the problem of turbulent air-flow over a given wave profile. The problem of turbulent flow in the coupled air/sea system is only partially understood. One would need a full model of this flow to describe realistically such phenomena as air flow separation and the shear in the top layer of the ocean. It is important to compare the present theories in detail with measurements in the boundary layer over growing waves, to see how accurate they are. At the same time one should try to extend the theory. A few items deserve special attention. What is the correct scaling velocity: is it u*, U10 or something else? How do stability and density stratification affect wave growth? How should gustiness be described and parametrized? How should the roughness of the very short waves be treated? What is the best turbulence closure in an oscillating boundary layer? What happens in the case of adverse wind? What is the effect of swell on wave growth?

For the wave-wave interaction the so-called discrete interaction approximation is made. Wave growth comes out well, but it cannot be denied that the approximation gives transfer rates that differ from the exact ones. It would be useful therefore to search for other economic approximations to the Boltzmann integral.

With respect to deep water dissipation much work remains to be done. The WAM model has a wave dissipation source term which is quasi-linear in the spectrum, i.e. linear but with proportionality constants depending on integral spectral properties. Such a source term can be justified under quite general conditions. However, the challenge remains to work out the statistics and hydrodynamics of different whitecapping dissipation theories and to find experimental ways of distinguishing between them. In the end it should be possible to determine the constants from first principles. The same applies *mutatis mutandis* to dissipation at the bottom.

These `microscale' approaches to the determination of the source functions are traditionally complemented by comparing model predictions with observations. The usual approach was to compare model behaviour in idealised fetch-limited growth with observed growth curves. It appears that this approach should be abandoned, because we have come to realise hat the idealised fetch-limited conditions never occur in the field. Therefore, we should replace the traditional approach by an inverse modelling approach.

2.2.3 Numerics and resolution

For propagation several higher order schemes have been considered, but they never seemed to lead to better predictions. One of the reasons is perhaps the fact that source regions of waves (the storms) normally extend over many grid points so that wave modelling is somewhat remote from the usual numerical tests in which one follows the evolution of an initially localised signal. Another reason is perhaps the approximate agreement between the numerical dispersion and the physical dispersion, required by the finite frequency and directional resolution of the spectrum. Yet cases are known in which the propagation accuracy seems to be a limitation, so that one might want to consider higher order or Lagrangian schemes.

An unsolved problem is the parametrization of sub-resolution scale variations of bathymetry for refraction calculations. Further study is also required concerning the interaction of waves and currents. In coastal waters, resolution of the coastline can determine the effective fetch in the wave model. The ability to resolve mesoscale features in the modelled wind field is also important.

In general, the resolution limits the quality of the predictions. This explains the natural tendency to strive for higher resolution. The resolution that can be obtained is usually limited for economic reasons by the computer capacity. Grid nesting may sometimes help, but here also more research is needed. The ability to make high resolution models operational will depend to a large extent on the availability and architecture of large computers.

2.3 Data-assimilation

Traditionally, data-assimilation of wave observations in wave models received little attention. However, recently considerable progress was made. The presently operational, simple wave data-assimilation schemes based on optimum interpolation (Lionello, 1992; see also Foreman et al, 1994) are being extended to include more wave parameters. Recent progress was made by Young and Glowacki (1996) and by Voorrips et al (1996) who extended the O/I approach and successfully assimilated two-dimensional spectra, obtained from directional buoys and the SAR (figures 3 and 4). In addition, so-called four-dimensional methods should be further developed. A promising method is based on use of the adjoint of the WAM model (de las Heras and Janssen, 1992; Hersbach, 1997). Kalman filtering approaches should also be considered, however. It is important that corrections made to wave estimates are consistently introduced in the forcing wind fields. Therefore, future models should attempt have two-way coupling between atmosphere and waves. As long as this is not achieved one may expect the greatest impact of wave data-assimilation to occur for swell. Once the coupling has been realised, one may also expect a beneficial impact on wind sea forecasting.

3. Sea level prediction.

This section is concerned only with sea level changes caused by unusual events such as tropical cyclones, storms or submarine disturbances (e.g., earthquakes, landslides, etc.). Sea level changes associated with coastal waves, coastal circulation and climate variability and change are covered in other modules of GOOS.

In many cases there already exist international and intergovernmental mechanisms for the coordination of scientific experimentation and planning and implementation of observing and warning systems, mostly separate from GOOS. For example, significant research is being undertaken on surges by national agencies with partial oversight by WMO, and tsunami warning falls under the auspices of the International Coordination group for the Tsunami Warning System in the Pacific (ICG/ITSU) [IOC, 1995]. Storm surges are important across a range of disciplines, including engineering, coastal management and physical oceanography, and this tends to mean less focused coordination. The present discussion focuses on scientific issues that are relevant to GOOS and the Service Module.

3.1 Tsunami warning

3.1.1 Introduction.

Tsunamis (sometimes referred to as tidal or seismic sea waves) are ocean gravity waves generated by some rapid large-scale distortion of the ocean volume, such as an impulsive vertical displacement of the water column. A tsunami can be generated by deformations of the sea floor (e.g., volcanic eruptions or earthquakes), by submarine "landslides" (large-scale disturbances in sediments), by coastal landslides, even by cosmic events such as the impact of a meteor. Earthquakes are by far the most frequent cause and are the predominant source of tsunamis capable of basin-scale propagation.

Tsunamis are shallow-water waves, that is their wave lengths are many times greater than the depth of the medium (wave lengths usually exceed 100 km whereas 4000m is the characteristic depth of ocean basins) and the periods are relatively long (order of an hour). As such, they travel extremely fast (order 200 m/s) but have relatively weak dissipation meaning they can cross ocean basins with limited loss of energy.

The uplift or subsidence of the sea floor, such as might occur along fault lines, disturb the normal equilibrium of the ocean column, displacing large volumes of water. The ocean reacts to this large-scale, rapid disruption of equilibrium by propagating waves away from the disturbance, the amplitude, period and extent of the waves depending upon the nature of the disruption; the larger scale of earthquakes means the associated waves are less likely to dissipate energy as they travel large distances.

The waves generally propagate orthogonal to the submarine disturbance. As the depth shallows, the speed of the wave diminishes and its height increases (the energy is basically conserved), some times to several tens of meters, unleashing potentially destructive energy at the shoreline. The runup and inundation of land can have catastrophic consequences.

3.1.2 Present understanding.

The physics and dynamics of the tsunami wave are relatively well understood. However there are several factors which make the simulation of tsunamis and the prediction of sea level changes and land inundation and potential environmental damage very difficult. With modern seismological monitoring facilities the detection of significant submarine disturbances is now relatively straightforward. However, as suggested in the previous subsection, the generation of the tsunami is very sensitive to the details of the submarine disturbance. The amplitude and period of the tsunami are directly related to the amplitude and duration of the disturbance, while the details of the submarine disruption (location, depth and pattern of the disturbance) determine much of the character of the tsunami wave pattern. In effect, if we wish to adequately initialise a tsunami model, we need detailed knowledge of the seismic disturbance which generated the waves. The propagation of the wave depends on changes in depth and interactions with submarine mounts and islands. In order to model the changing nature of the waves as they reach coastal, shallower waters we need detailed knowledge of bathymetry and, to model inundation and the effects over land, detailed knowledge of orography, land and land-sea boundary structures, and the general nature of the terrain. In many cases this information is either unavailable or inadequate.

In the past knowledge of tsunamis has mostly depended on observations of changes in coastal sea level, anecdotal evidence of inundation and the indirect evidence emanating from observations of associated damage and erosion. In more recent times seismologists have been able to give more reliable depictions of the generation mechanism; open ocean, bottom mounted sea level (height) gauges have improved in precision and accuracy to the point where the relatively small displacements associated with tsunami waves can be detected (with a triangular array, the amplitude, direction and phase of the waves may be measured); the coastal sea level measuring network and communications are now more reliable in the event of extreme conditions; and post-tsunami surveys are carried out to more accurately determine the extent of inundation and damage (with accurate data it is possible to determine the nature of the impacting wave and hence, through inversion, shed light on the nature of the generating disturbance).

3.1.3 Ocean observations.

The study of tsunamis requires an interdisciplinary approach (seismologists, geophysicists, oceanographers, terrestrial specialists, sociologists, etc.) and international cooperation (Lander and Yeh, 1995). While the impact is sometimes local (for example, the effect of major landslides in semi-enclosed bays), the generation and impact are more often on the scale of basins and thus require observations and cooperation among several nations. The ICG/ITSU was created to facilitate such cooperation among nations affected by Pacific tsunamis.

The most important physical ocean observations are of changes in sea height, preferably from open ocean sites. Sea level gauges are often located in harbours or in enclosed bays, which is fine for measuring tides and other low-frequency phenomena (e.g., climate change sea level rise), but are less suitable for measuring rapid, large changes caused by tsunamis, often under altered, hostile conditions. They are also susceptible to local effects which may mask the significant tsunami signal. New instruments, such as ocean reverse bathymetry and bottom pressure gauges, have the advantage of recording the tsunami in the open ocean undistorted by shoaling and refraction effects. The major challenge is to provide accompanying telemetry that would enable timely access to such data. For GOOS, the aspects of international cooperation and the prospect of multiple uses for pelagic gauges makes such observation very relevant. If tsunami warning systems are to be effective, which means adequate initialisation/constraints on tsunami models, such data, available in real-time (several minutes delay, not several hours) are essential.

Measurements of currents and sediment shifts in the coastal zone are also important for tsunami work. Some of these measurements may be available through other activities in GOOS (e.g., the coastal module and coastal forecasts). Telecommunications and telemetry facilities may also be available through cooperation. Good bathymetric data, at fine resolution, is a recurring theme through most activities of GOOS and is a pressing requirement for tsunami studies. Many of the data collected for GOOS could be useful as opportunistic data for validating tsunami models.

3.1.4. Tsunami warnings.

There has been an extensive international effort to create a coordinated and timely tsunami warning and response system. The tsunami warning system in the Pacific (figure 5; still to be added) comprises 26 participating Member States who together monitor seismological and tidal stations throughout the Pacific Basin to evaluate potentially serious tsunami-generating earthquakes and to distribute assessments and warnings. The seismic stations detect and estimate the location and magnitude of seismic activity in the Pacific Basin and, if the amplitude and location indicate the possible generation of a significant tsunami, warnings are disseminated with estimates of the arrival time at certain locations about the basin. As noted above, due to uncertainties in the interpretation of the seismic activity, there is a tendency for caution and over-prediction. Supporting open-ocean measurements of any waves can greatly narrow this uncertainty.

The Pacific tsunami warning system has been relatively successful, though it could be improved with better in situ sampling of generated tsunami waves and better methods for real-time communication (for data, warnings and assessment). There are moves to create a similar system in the Indian Ocean, initially focused on seismic activity in the eastern Indian Ocean and their impact on the north-western Australian coastline.

3.2 Storm surge forecasts

3.2.1 Introduction.

Like tsunamis, storm surges involve abnormal and sustained elevations of coastal sea level, often endangering life and property, and usually involving some non-trivial impact on the coastal environment. Again, they involve the excitation and propagation of long waves, but in this case through sustained, anomalous meteorological forcing. The meteorological forcing is predominantly through the action of wind stresses at the surface of the ocean but anomalous (reduced) atmospheric pressure can also be a significant factor in many cases. Knowledge of the past, current and future intensity and pattern of the meteorological forcing is the key to successful simulation and prediction of storm surges.

There are, however several other factors that influence the evolution and build-up toward potentially critical surge-induced sea levels. The character of the continental shelf (bathymetry, roughness, etc.) and the geometry of the coastal region (bays, headlands, reefs, etc.) can have a profound effect on the evolution and amplitude of the surge. There is also the potential for interaction and superposition of the surge effect on other coastal changes. Clearly the phasing of the astronomical tide relative to the storm surge is critical. A peak surge coincident with low tide may be of no practical consequence, whereas even a modest surge occurring at high tide can have significant consequences. Surface waves and other coastal circulation changes can moderate or amplify the impact of a surge in the coastal region. While the astronomical tide is relatively well understood and predictable, our knowledge of the role played by many of the other factors is imperfect, a fact that can confound our ability to predict.

The storm surge phenomenon is usually divided into two categories, those associated with tropical cyclones and those associated with mid-latitude storms. The development of understanding and predictive capabilities has differed for these two types of storm surge forcing. One of the factors leading to this differential development has been the relatively poor skill of numerical weather prediction systems in low latitudes compared with that at midlatitudes. Another is that of pure circumstance: one of the areas that is impacted by mid-latitude storm surges is the North Sea. The coastal regions of the various countries bordering the North Sea, like Britain and The Netherlands, are mostly very sensitive to water level changes because of the degree of commercial and industrial development and the tendency for denser population of the coastal regions. This in turn has fostered considerable research and development in the area of storm surge monitoring, modelling and prediction, far greater than in any other region of world.

3.2.2 Theoretical understanding.

Storm surges are meteorologically forced long waves. The anomalous forcing is generally sustained for several days with the largest disturbances arising from storm tracks which interest the continental shelf (compared with the short-lived, remote excitation of tsunamis). It follows then that knowledge of the meteorological forcing (its history, pattern and amplitude, and its future development or decay), and the physics of energy transfer from the atmosphere to the ocean, is crucial for understanding and modelling surges. All models of surges rely on sound information on the surface forcing. However the method of representing the coastal ocean, the interaction of the circulation with bathymetry, the influence of external ocean regions (the open boundaries), and the several possible internal and/or external dynamical interactions (e.g., with surface waves, or bottom friction) vary considerably. Much of the early work focused on two-dimensional shallow water models where the vertical structure of the currents was ignored and only the vertically-averaged currents were retained as prognostic variables (baroclinic effects are usually insignificant). Surface elevation provided the other prognostic variable, and forcing was provided by horizontal stresses (parametrised in terms of the near-surface winds) and mean sea level pressure. The equations of motion usually included Coriolis effects and some form of bottom friction, normally parametrised in terms of the depth-averaged velocities. For many situations these models have proved very robust and reliable, their simplicity offering considerable computational advantages. They remain the principal "work-horse" for many European operational storm surge warning systems and have proved relatively successful for several tropical cyclone studies.

Three-dimensional models are now becoming the norm, partly because integrations are no longer limited by available computing resources, and partly because three dimensional models give a more accurate and richer description of the circulation associated with surges. The parametrisation of bottom friction is more realistic if the near bottom velocity is used rather than the depth mean, and it is possible (though not always with significant impact) to capture nonlinear surge-astronomical tide and surge-surface wave interactions. The three-dimensional representation can be decomposed into an equation for the depth-averaged velocity (essentially the same as that used for 2D models) and equations for the shear. The coupling between these "external" and "internal" modes is via the bottom and surface stresses. The ocean depth is a critical parameter for these models. Most 3D models use a bottom-following coordinate system to provide for better interpretation of topographic effects. Even so, limitations in our knowledge of bathymetry and practical limitations on our ability to represent the subtleties of changes in depth (some of which are extremely important) are a significant source of error for all surge models. There is also considerable uncertainty in the parametrisation of bottom drag, which also may depend on the bottom shape and roughness. In some cases, because the drag depends on the total flow field, it is necessary to take account of flow arising from other effects, such as tides or coastal currents.

In most cases the domain of interest is not bounded so it is necessary to find suitable representations for the open boundaries. The boundary conditions should allow energy to propagate out of the domain "freely" and not excite free modes of oscillation related to the location of the boundaries. Ideally, of course, we would also like to propagate energy into the domain from the far field when appropriate. The specification of such conditions remain a significant problem, the rule of thumb being make the boundaries as far away from the region of interest as possible.

3.2.3 The role for observations.

The discussion above highlights several key areas:

(1) Meteorological observations are critical for determination of the past forcing and for initialising atmospheric model predictions, be they from a complex numerical weather prediction system or, as is most often the case for the tropics, from a simple representation of the storm/cyclone (for cyclones it is usual to represent the atmosphere in terms of just a few parameters for the intensity, maximum winds, radius and path);

(2) It is important to have accurate, high-resolution bathymetric data; and

(3) It is useful to have sea level measurement sites located near or at the open boundaries to help determine appropriate boundary conditions, and at locations within the domain to tune and validate the model.

The surface forcing is always imperfectly known due to lack of direct observations, inadequate numerical weather analysis and prediction systems, and lack of understanding of the momentum transfer process. The availability of satellites capable of inferring surface stress (e.g., scatterometry) is bound to improve capabilities in this area, as might over-the-horizon radars in certain locations. Further research is still required on the boundary layer, in particular the way energy and momentum is partitioned between the wave and velocity fields.

Sea level observations have potential beyond description of the open boundary and validation. Modern data assimilation techniques, such as the Kalman filter and adjoint methods, offer the potential for amending the solution so that it has a pattern and evolution that is consistent with measured sea level. The corrections may be accomplished by adjusting the forcing, adjusting the open boundary conditions, or perhaps by adjusting the bathymetry. Data assimilation techniques such as these have now been adopted for several systems with varying degrees of success.

3.2.4. Surge prediction systems.

The North Sea/western Europe area continues to provide the leading edge in storm surge prediction systems. The first operational system began in the early 1980's in the UK and has since evolved into coupled tide-surge-wave model, capable of resolutions of a few kilometres and data assimilation. Figure 6 (to be taken from the POL annual report) shows the currents simulated by the UK Waters Operational Model (UKOPMOD) for a test case in January 1993. For some models data assimilation clearly has a positive impact at shorter periods (it is better initialised) but the forecasts at longer periods can be worse. Figure 7 (still to be added) shows an example from the Dutch Continental Shelf Model.

As noted above, systems for mid-latitude storms, such as those developed for western Europe, are now quite mature. In the tropics severe problems remain, partly because of the shorter history of research and development, and partly because prediction of tropical storms/cyclones is significantly more difficult, thus making useful prediction of surface forcing more problematic. The lead times for which useful wind predictions can be made are often too short to be of practical benefit. Nevertheless several countries are now moving toward operational systems, most often with simple limited-parameter cyclone models and two-dimensional surge models (on balance it would seem that unless detailed knowledge of the currents is required, as might be for engineering applications, a 2D model is adequate for simulation and prediction of the sea level changes. Figure 8 (to be added) shows an example for a cyclone in the Australian region.

3.2.5 Summary.

In so far as GOOS is concerned, there are several areas where useful synergy is available between operational surge warning activities and those planned under the GOOS module umbrella. The most obvious is the need for accurate representation of the surface wind stress. This is a requirement for other parts of this module (e.g., surface waves), for the coastal module, and for climate prediction and climate change simulations. The need for cooperation with the numerical weather prediction community is acute since storm surge forecasts often depend on good initialisation of the forecast model (the fact that many surge predictions systems are implemented at meteorological agencies assists in this area). High-quality bathymetry is also a recurring theme. Sea level data has many applications but for storm surge systems it is usually the most important form of validation and is an increasingly important source of information for model initialisation. Finally, many of the storm surge models are now being coupled to wave models and/or being embedded in coastal forecast systems, and have many commonalities with the models used for coastal prediction and tsunami warnings.

4. Conclusions and recommendations

Wave and sea level prediction form the heart of the Service Module of GOOS. Both observations, - conventional as well as satellite - and models are important. Much research has been done already, leading to predictions of relatively high quality. There is no doubt however that the increasing importance of these predictions justifies further research and development. One point that requires particular attention is the quality of forecast sea level winds in the medium-range.

Because of the considerable experience with ocean wave, storm surge and tsunami modelling it is relatively well understood where advances can be expected. These points have been summarised in the main body of the text. Research should focus on these points.

5. Acknowledgements

We would like to thank Vince Cardone, Martin Holt, Peter Janssen and Aart Voorrips for useful suggestions.

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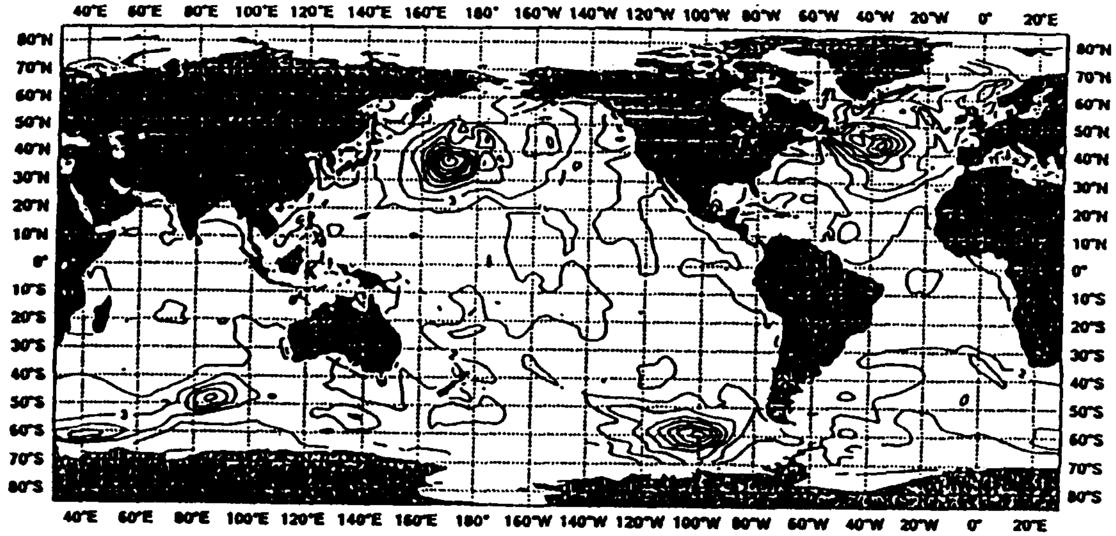


Figure 1 Example of a significant wave height field as produced by the analysis of the ECMWF's global wave forecasting system. Contour spacing is 1 m (After Bidlot et al., 1997).

Figure 2 Example of a significant wave height field as produced by the analysis of the KNMI's North Sea wav e forecasting system. Contour spacing is 1 m. The arrows indicate the mean wave direction.

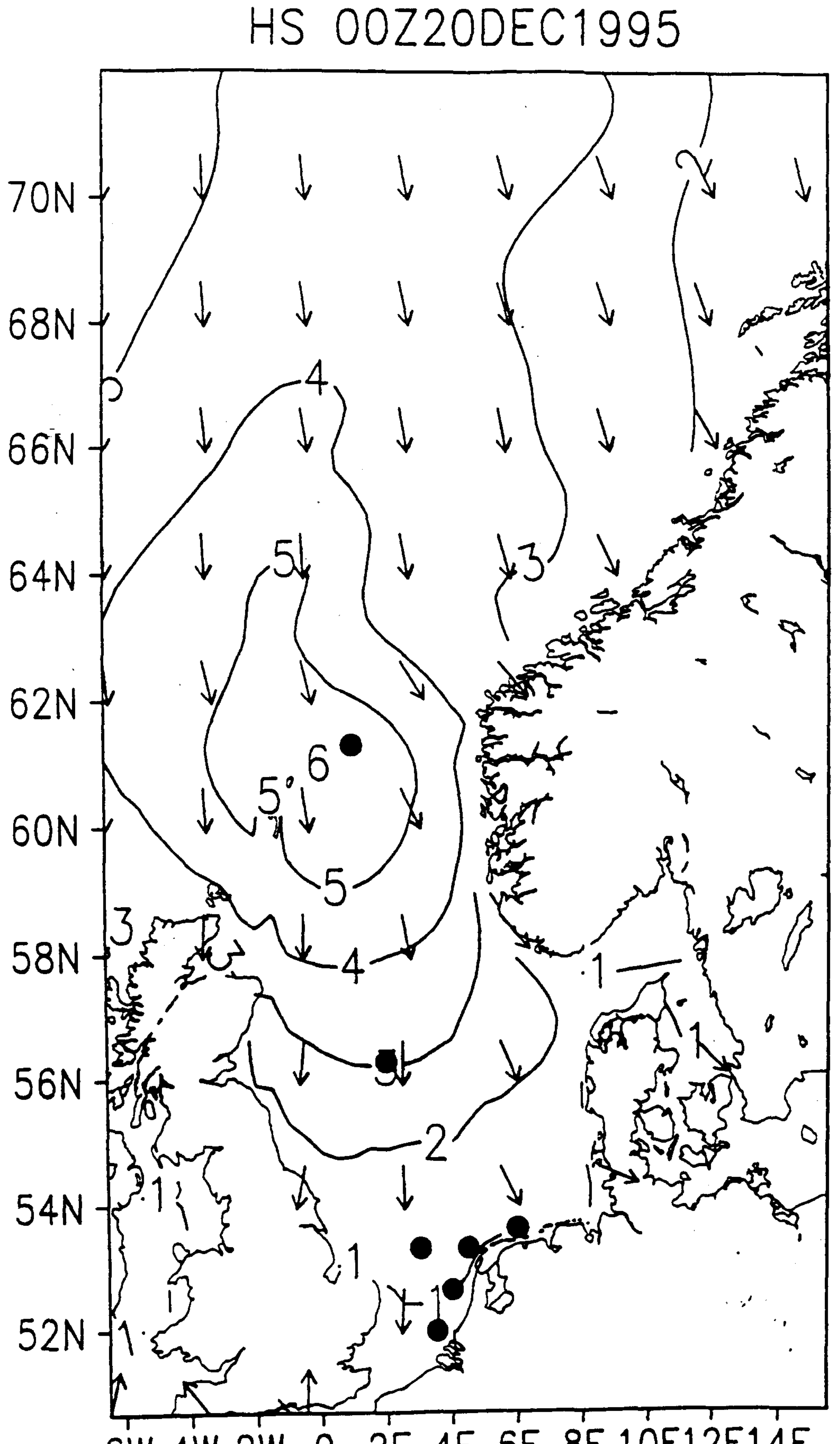


Figure 3 The same analysis is given in figure 2, however, information from directional buoys has been ignored (Voorrips, private communication).

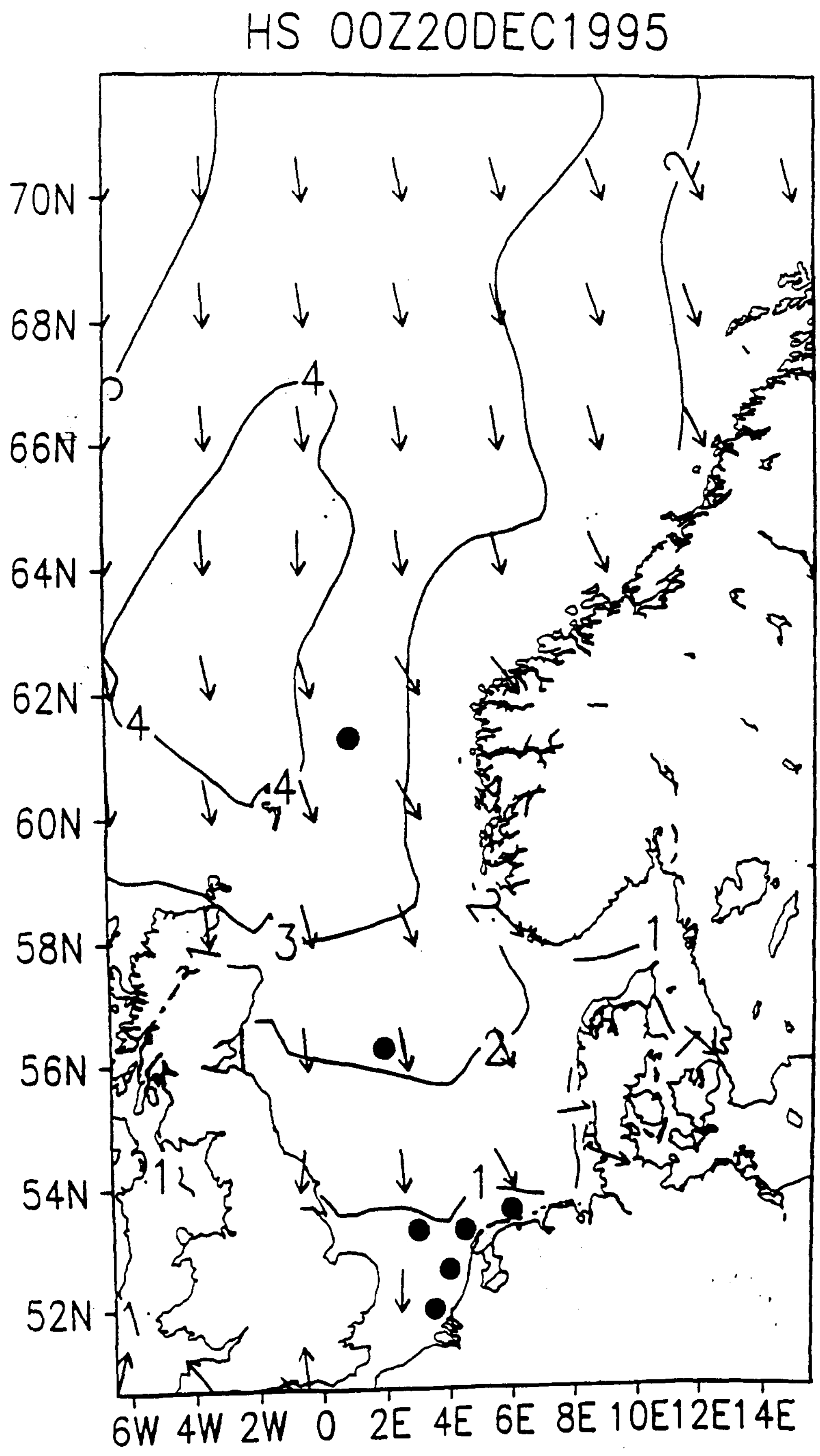
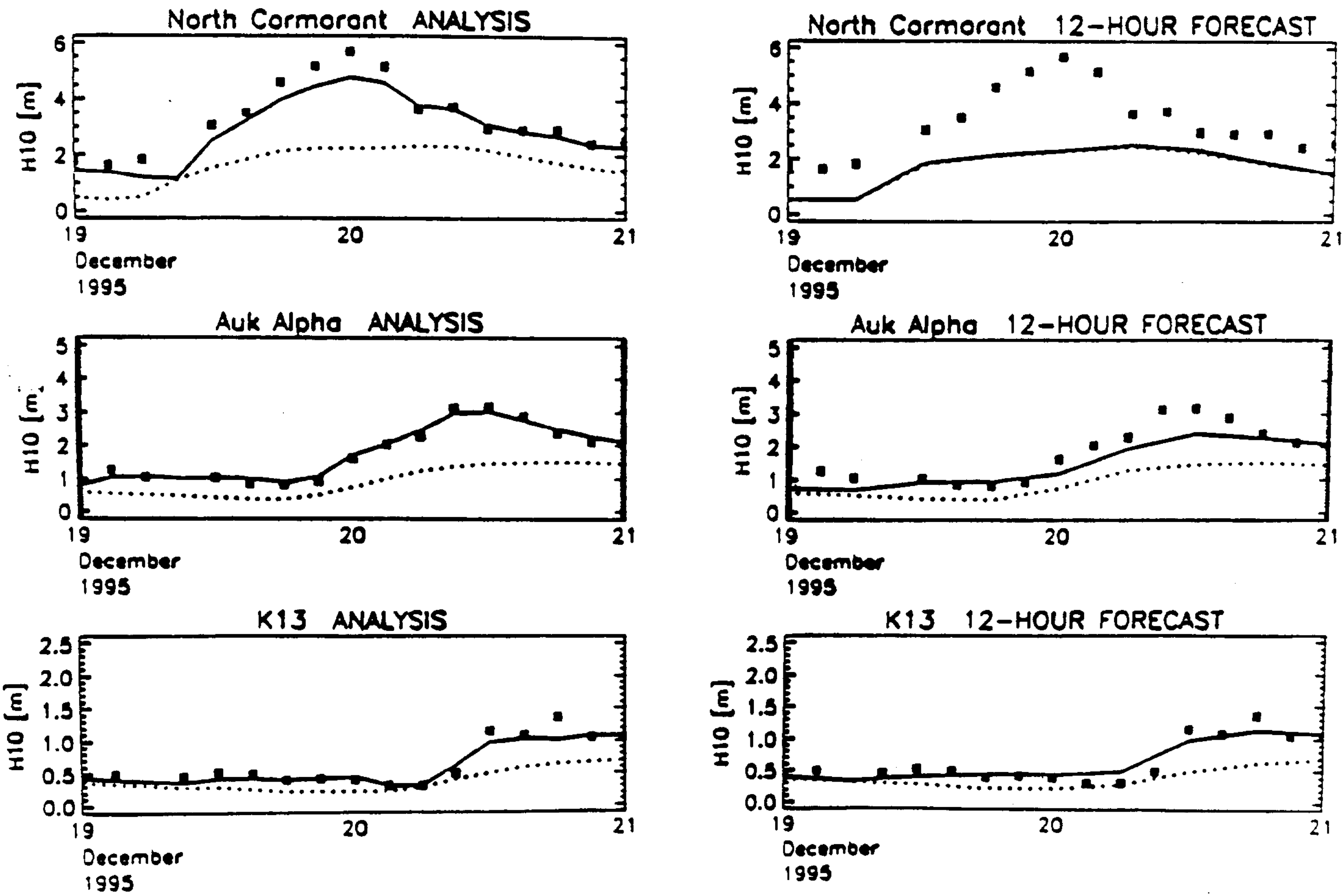


Figure 4 Model analysis (left) and predictions (right) of H10 (low frequency wave height) for three different stations in the North Sea. Dotted = No Assimilation; Solid = With Assimilation; Squares = Observations. (Voorrips, private communication).



Pacific Tsunami Warning System

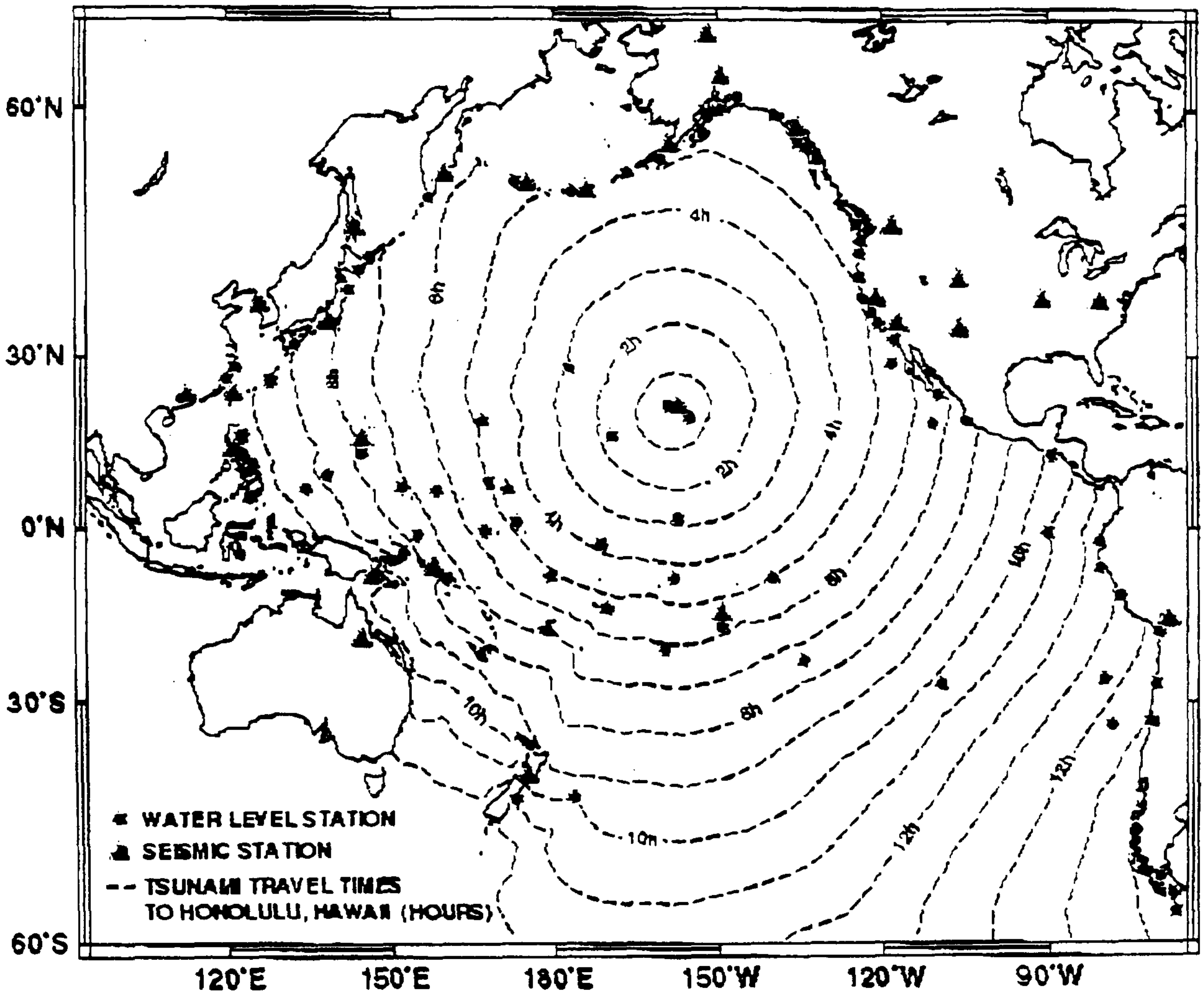


Figure 5 Seismic and sea level stations of the Pacific Tsunami Warning System.

COASTAL AND SHELF SEA INTERACTIONS

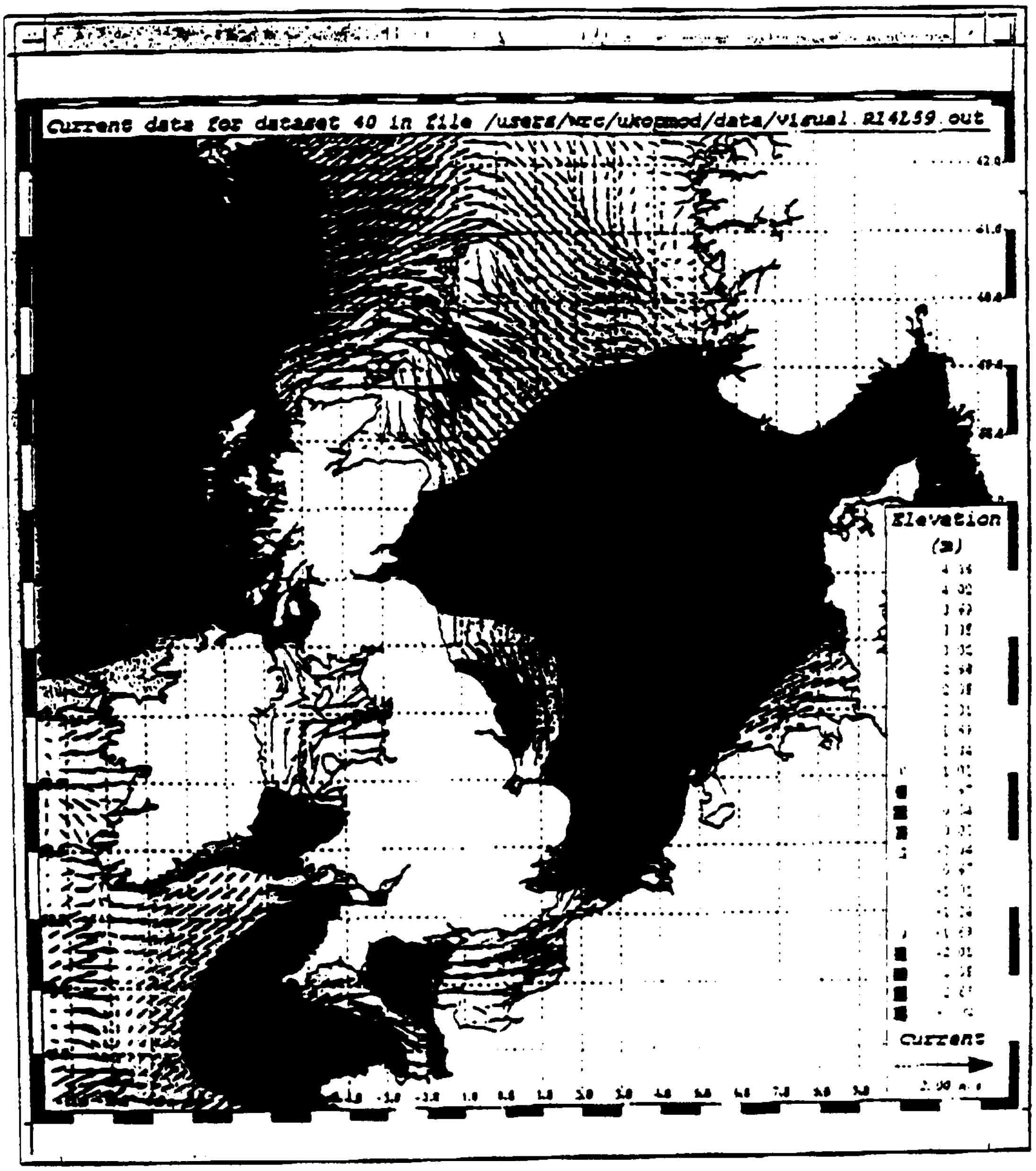


Figure 6 An example of surface currents and surface elevation as simulated by the UK Waters Operational Model (from the Proudman Oceanographic Laboratory Annual Report, 1995-96, 38 pp. Publ. NERC, UK).

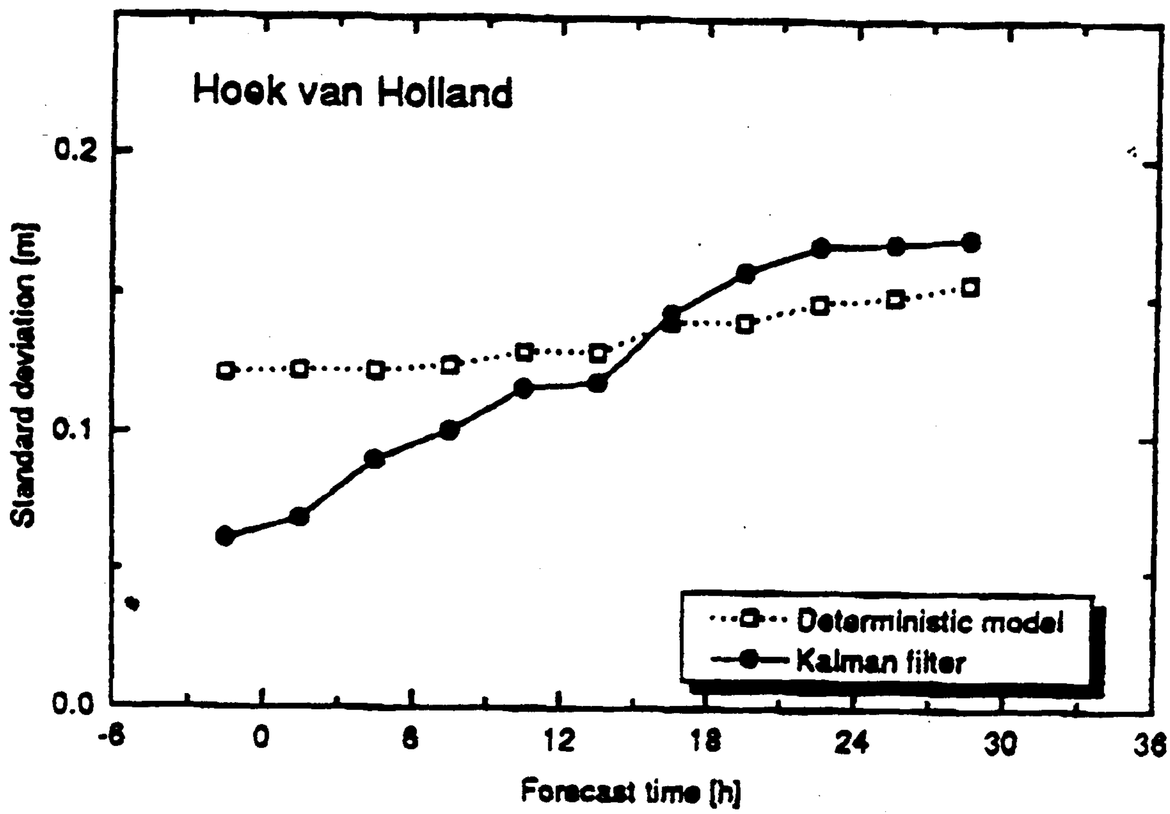


Figure 7 An example from the Dutch Continental Shelf Model of the impact assimilating observed sea water levels in a prediction of sea level. The open boxes show the model forced by winds alone and the black circle the model with data assimilation. Over the first 12 hours data assimilation has a positive impact but errors can be larger at longer lead times. (From H. De Vries, The Dutch Continental Shelf Model, in Lynch and Davies 1994).

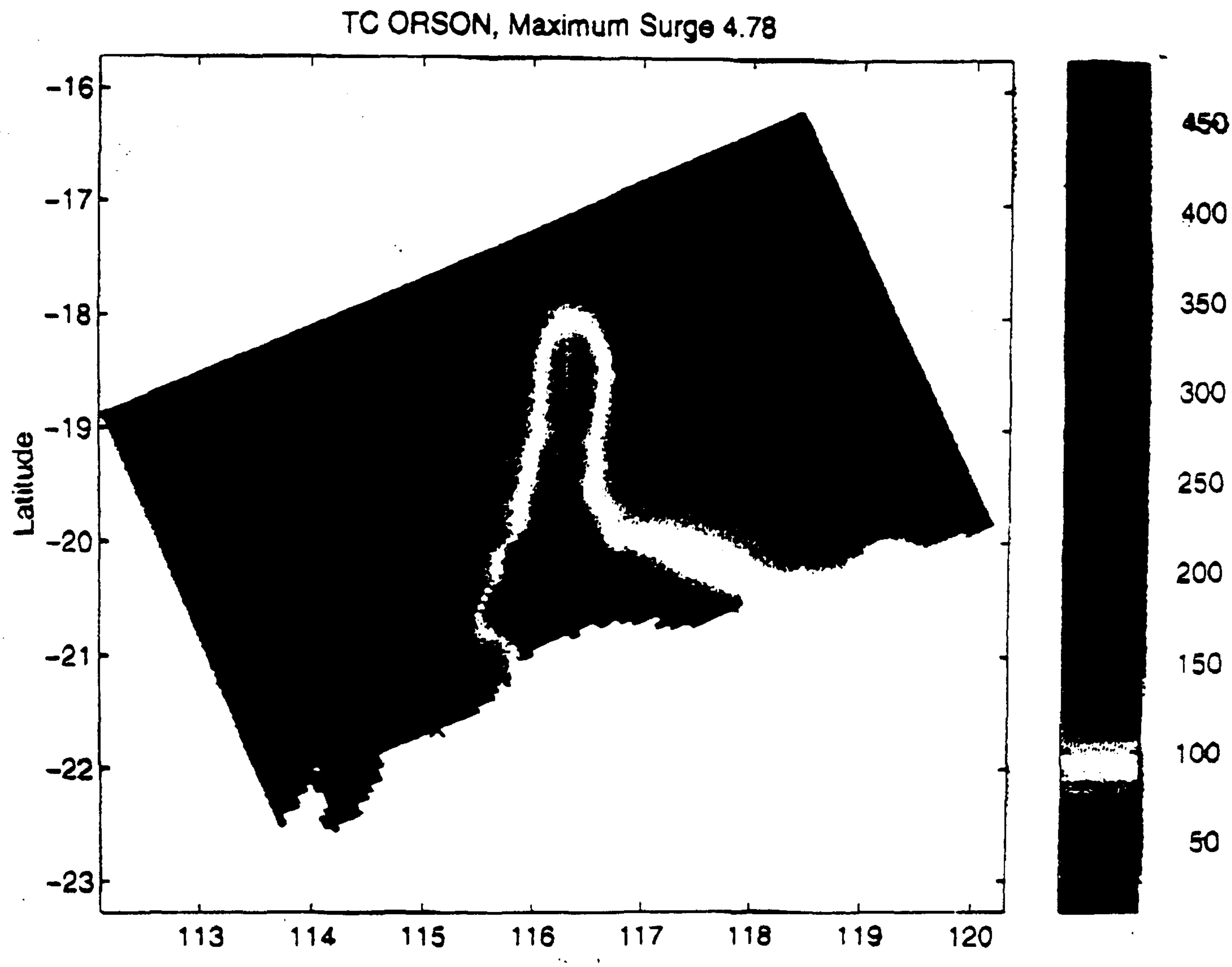


Figure 8 A simulation of a tropical cyclone storm surge (Tropical Cyclone Orson) off the Australian Northwest Shelf (B. Sanderson, private communication).

ANNEX V

SEA ICE PROCESSES, SUSTAINED MEASUREMENTS AND MODELLING

H Cattle(1) and I Allison(2)

(1) Ocean Applications, Meteorological Office, London Road, Bracknell, Berkshire, RG12 2SZ, United Kingdom.

(2) Antarctic Cooperative Research Centre, University of Tasmania, Hobart 7001, Tasmania, Australia

1. SCOPE

This paper addresses issues of sea ice processes, modelling and observation as a contribution to J-GOOS discussions. It does so from a global perspective, and so has particular relevance to the GOOS modules on 'Climate Monitoring and Prediction' and 'Marine Meteorological and Oceanographic Services'. It does not attempt to consider issues of sea ice ecology or the coastal zone (except through a brief discussion of fast ice) and so is less relevant to the needs of the GOOS modules on 'Monitoring and Assessment of Marine Living Resouces' , 'Assessment and Prediction of the Health of the Oceans' and 'Monitoring of the Coastal Environment and its Changes'. Sea Ice issues in relation to these modules therefore remain to be addressed. The paper draws heavily on, and expands, a similar document by the same authors written as a contribution to the drafting of the World Climate Research Programme Climate Variability (WCRP CLIVAR) DecCen Implementation Plan.

2. SEA ICE PROCESSES

An overall effect of sea ice is to decouple the ocean from the atmosphere, substantially modifying the surface albedo and providing a barrier to the direct exchange of momentum, heat and freshwater across the air-sea interface in regions where it is present. As a result, the impact of surface stress in driving ocean currents, and its role for mixing, is reduced over ice covered surfaces. On the other hand, keel stirring is likely to increase the total contribution to mixing of the upper ocean. When it forms, ice rejects the brine from the sea water as it freezes increasing the convective stirring of the upper layers. Ice melt, which may occur in regions far removed from the original location of formation, deposits fresh water on the ocean surface, stabilising the upper ocean layers. Further the density structure of much of the Central Arctic is salinity stabilised due to both summer ice melt and the input of freshwater from rivers flowing off the continental areas surrounding the Arctic Basin. The continental shelf areas, particularly along the Siberian coast show a marked seasonality in their density structure as a result of the intensive ice formation and reduced river flow in winter and ice melt and markedly increased river input in summer. In the North Atlantic, the ice edge is often a favoured location for oceanographic eddies and a marked region of upwelling.

In the Antarctic, the near coastal region is a key area of winter ice formation. Ice dynamics is of particular importance to the southern hemisphere ice pack, which, except in limited regions, is divergent in nature, so that ice formed in the near coastal regions is carried out into the southern hemisphere ocean in winter resulting in greater ice coverage and seasonality than would otherwise be the case. In the northern hemisphere, the ice dynamics, driven by the combined influence of the atmsopheric and oceanic flow, modifies the geographical ice thickness distribution, resulting in high (5 m or more) ice thicknesses north of Greenland and the Canadian Archipelago.

3. SEA ICE AND CLIMATE.

Sea ice is important for climate both as a potentially sensitive indicator of high latitude atmospheric and oceanic change, and because changes in sea ice distribution feedback to the climate system through the ocean-atmosphere heat budget and the vertical salt flux to the ocean. Interactive sea ice models, albeit often highly simplified ones are an essential component of coupled general circulation climate models. Model predictions demonstrate a marked reduction in both Arctic and Antarctic sea ice extent with global warming (IPCC, 1990, 1995). Given their predicted high sensitivity, monitoring of sea ice extents, thickness and concentration is seen as an important activity for searching for indicators of the inset of climate change.

In the northern hemisphere, analysis of satellite passive microwave data by Johannessen et al. (1995) have indicated a significant decrease of sea ice extent (-4.6%, within the 99% confidence level) and area (-5.8%, within the 99% confidence level) over the past 16 years, though it is not clear as yet whether this is part of a long term trend, or a manifestation of longer timescale climate variability. As yet though, no statistically significant changes in southern hemispheric ice extent have been observed in more than 20 years (since satellite passive microwave monitoring of sea ice extent commenced). There is, however, evidence for a systematic spatial variability of ice extent in the form of eastward propagating anomalies in Southern Ocean sea ice extent, sea surface temperature, sea level pressure and meridional wind stress, which are possibly linked to low latitude processes (White and Peterson, 1996). Also, regional decreases of ice extent by as much as 20% over 20 years have occurred in the Amundsen and Bellingshausen Seas (Jacobs and Comiso, in press), and some proxy records of sea ice also hint at a significant decrease in hemispheric extent since the first half of the century.

Presently available data are only adequate to examine variability in the areal extent of the ice - and not the change in total ice mass or its distribution. Systematic, spatially distributed data on both the Arctic and Antarctic ice thickness distribution, and its seasonal development, are required for both the detection of variability and change and for model validation. For this reason, the WCRP, for the Arctic, has initiated the Arctic Climate System Study, ACSYS, and SCAR, through it's Global Change Programme, has recently initiated a ASPECT, a programme to investigate Antarctic Sea-ice Processes and Climate.

ACSYS aims to promote the observational systems needed to fill the observational gaps in Arctic sea ice data acquisition for large-scale climate studies, to assemble a climatological archive to document the ice pack and to support studies of the interactions of sea ice with other parts of the climate system. Particular aspects of the ACSYS sea ice programme include the development of a basin-wide sea ice climatology database, monitoring of ice export from the Arctic Ocean, integrated studies of ice-atmosphere-ocean interactions and sea ice process studies. Aspects of the ACSYS atmospheric programme concentrate on determination of the surface forcing of sea ice. Further details can be found in the ACSYS Initial Implementation Plan (WCRP-85)

The broad objectives for ASPECT are to establish the distribution of the basic sea ice properties important to air-sea interaction and biogeochemical processes within the Antarctic sea-ice zone (ice and snow cover thickness distributions; structural, chemical and thermal properties of the snow and ice; upper ocean hydrography; floe size and lead distribution). It aims to derive forcing and validation fields for models, to understand key sea-ice zone processes for model development and to improve parameterisation of these processes in coupled models. The programme includes systematic sea ice observations from "ships of opportunity" that will help to define the broad climatology of sea ice and snow cover thickness distribution in the Antarctic, and their seasonal variability. This is unlikely however to provide the accuracy required to monitor interseasonal variability.

Both of the programmes are aniticipate to be of limited duration (ACSYS has a current end-date of December 2003). In terms of climate monitoring, there is therefore a need to examine the need and mechanisms for a longer-term sustained network of observations of sea ice, which is also an issue for the WCRP CLIVAR Programme.

4. SEA ICE AND OPERATIONAL FORECASTING

A number of centres produce detailed operational analyses of sea ice characteristics, either regionally for globally for one or both hemispheres which meet a variety of operational needs, but principally for shipping. In the context of operational forecasting, Numerical Weather Prediction (NWP) models also require information on global sea ice extents as a component of the fields of analysed sea surface temperature which provide the bottom boundary condition for these models. For example the UK Met Office utiises NOAA/NESDIS Joint Ice Centre charts to determine the NWP ice edge, which is updated in the model on a weekly basis. Satellite data provide an essential input to the derivation of these analyses. Sea ice information is also required as a component of operational ocean modelling systems. For example, the U.S Fleet Oceanography Center suite of oceanographic models and products (Clancy and Sadler, 1992) includes PIPS, the Polar Ice Prediction System (Preller, 1985, Preller and Posey,1989) which enables numerical analysis and forecasts of ice extents, both hemispherically and for detailed regional areas (e.g. Preller et al., 1989) to be carried out in an oceanographic context. In the UK, the Met Office is developing FOAM, the Forecast Ocean-Atmosphere Model System (Foreman et al., 1994) which will provide operational analyses and forecasts out to five days of the global ocean. The FOAM system includes a sea ice component coupled to a global ocean model. Production of sea ice analyses within both of these systems requires not only sea ice data (FOAM will access Canadian sea ice concentration analyses for this purpose), but also techniques to update the model analysis fields via appropriate methods of data assimilation. Sea ice also affects the surface wave field, so that operational wave prediction models also need to take its presence on the ocean surface into account.

5. SUSTAINED OBSERVATIONS OF SEA ICE

As GOOS-related oceanography develops, there is likely to be increased demand for improved and sustained observations of sea ice in support of operations and climate. We therefore give below an outline of the character of the observations required for an effective contribution to these areas.

5.1 Ice extent and ice concentration:

5.1.1 Background
Fo purposes of observation and monitoring, it is important to distinguish ice-covered from ice-free ocean. At the largest scales, this distinction defines the ice edge: the location where the open ocean gives way to the pack ice. Ice extent may be defined as the area of ocean surface enclosed by the ice edge.

Ice cover on the ocean is usually expressed as a fraction of the ocean covered by ice (C, tenths of concentration) but it is the fraction of surface area covered by leads or other open water features, (1-C), that is the more important parameter within the ice-covered oceans. During winter, the average surface heat budget and ice mass balance are highly sensitive to this fraction, as most heat loss from the ocean surface occurs through areas of open water or very thin ice. But the total heat loss is not a linear function of open water fraction: the largest changes with ice concentration occur in the concentration range 0.8 - 1.0, while there is little change in total heat loss with further decrease in concentration below about 0.5. Thus in winter, ice concentration affects the temperature of the atmospheric boundary layer and the depth of the oceanic mixed layer. During summer the ice concentration has a significant effect on area average surface albedo and on the melting rate of floes due to solar radiation absorbed in the open water.

5.1.2 Measurement
Existing satellite passive microwave systems such as the SSM/I on DMSP satellites provide routine global radiance measurements that enable determination of sea ice extent and concentration irrespective of darkness or cloud. These have been available since 1973. The DMSP 5D2 and 5D3 satellite series will ensure continuity into the next decade. The total ice concentration and area fraction of different ice types within the relatively large footprint of the sensors (20 - 40 km) can be estimated using multi-spectral methods. The ice edge can usually be located with an accuracy of about 30 km. Valuable additional information is provided by the complementary weekly microwave images produced by data from the ERS-1 scatterometer over its mission lifetime from December 1991-June 1996. Additional improvements are expected with images at approximately 6-12 km generated from ERS-2 and NSCAT scatterometers. The passive microwave data enable the ice extent to be determined with some 25 km resolution in both hemispheres. In general the ice extent estimates are adequate for many large-scale applications. However ice concentration estimates (accuracy 6-10%), and the areal fraction of various ice types such as "first year ice" and "multi-year ice", from the SSM/I observations are subject to large error because the brightness temperatures are affected by properties of the ice and snow, which are significantly different in the Antarctic and Arctic, and of the intervening atmosphere. The present systems do provide consistent and routine monitoring data, but further improvement and validation of the algorithms used to interpret the data is required.

A particular effort to determine ice edge variability in the Greenland sea over the century timescale is being undertaken jointly between the Norwegian Polar Institute and Norwegian Meteorological Institute (Vinje, Nyborg and Kjaernli, unpublished). These ACSYS-related data sets will be of direct relevance to CLIVAR Dec-Cen and to the climate modeule of GOOS.

5.2 Ice and Snow Thickness

5.2.1 Background
The ice thickness distribution is determined by a combination of thermodynamic processes (melt/freezing) and dynamic processes (advection, divergence, rafting, ridging) and may be further modified by snow accumulation. These dynamic and thermodynamic processes are generally dependent on the ice thickness itself. To determine the thickness distribution it is necessary to measure both the thickness at a point sufficiently accurately, and to measure at enough points. Ice thickness is know to be geographically non-uniform over the Arctic, with the greatest thicknesses of 5m or more being found to the North of Greenland and the Canadian Archipelago and a typical mean thickness of some 3 m. Ridging is an important process for Arctic sea ice. In the Arctic, the ice has a mean ridge height of around 1m, with a maximum ridge height for drifting ice of 3 m and for grounded (fast) ice of 10 m. Mean keel depths are of order 10 m, with a maximum depth of 30 m. Study of the four-year (1990-94)

monthly mean Upward Looking Sonar (ULS) ice draft series from the Fram Strait shows a non-systematic seasonal cycle with an average minimum (1.77 m) in September, and maximum (2.75 m) in July, with an average month to month variation of 0.7 m. There are very few measurements of ice thickness in the Antarctic. The limited data indicate an ice thickness distribution completely different from the Arctic: the ice has a modal ice thickness of only about 0.5 - 0.7 m and few ridges-keel thicknesses greater than than 10 m.

Snow cover on sea ice increases the albedo and effective insulation; particularly in the Antarctic it may be infiltrated by seawater to form new ice. Present knowledge of the snow cover thickness on sea ice is minimal and its observation is as difficult as that of ice thickness. The broad scale pattern and seasonal variation of snow cover needs to be determined as for ice thickness.

5.2.2 Measurement
Sea ice thickness is not presently amenable to direct measurement by satellite remote sensing. and satellite-borne sensors capable of accurately estimating sea ice thickness remain 5 or more years in the future. Satellite microwave radar polarimetry has demonstrated some capability to measure ice in the 0-50 cm thickness range. Other than on the space shuttle, this technology is not expected to be available on a space platform until the European Space Agency's ENVISAT mission.

In the Arctic, measurements of ice thickness have been made from submarines equipped with ULS, on an opportunistic basis. The WCRP ACSYS Arctic Ice Thickness Project , based on moored ULS, was launched in 1988 and underwent rapid progress with significant increase in ULS deployments in 1991 and a further increase in 1992. Altogether 19 ULS moorings were deployed by 1993 and some 15 are currently operational, though the distribution is very much confined to the peripheries of the Arctic basin and the region and the Fram Strait and the East Greenland Coast.

Some Antarctic data are becoming available from measurements of ice draft, made with moored ULS as part of the WCRP Antarctic Ice Thickness Research Progamme. The spatial coverage of such moorings is poor and the data are not available until the mooring is recovered. However a number of quasi-permanent ULS moorings at key locations (e.g. 3 moorings along each of 0 degrees E [Weddell Sea], 80 degrees E [Prydz Bay] and 150 degrees W [Ross Sea] longitudes are required as part of Dec-Cen sustained measurements. The SCAR ASPECT programme aims to define the broad climatology of sea ice and snow cover thickness distribution in the Antarctic, and their seasonal variability.

5.3 Pack Ice Velocity

5.3.1 Background
Ice motion in response to wind and currents plays a major role in determining the ice thickness distribution and ice edge location. Ice thickness and motion combined determine the transport of ice mass, and therefore of latent heat, salt, and fresh water. Ice velocity data are also necessary to verify sea ice models and, since ice motion provides the mechanical forcing for the ice-covered ocean, can be used to drive ocean models.

5.3.2 Measurement:
The large scale motion of sea ice can be observed using data buoys deployed on ice floes and tracked using the ARGOS location and data relay system on NOAA series satellites. Most of the data buoys also report sea level air pressure and some, temperature. In the Arctic, this is carried out through the International Arctic Buoy programme, which has good coverage over

the central pack. Data from these buoys are transmitted in real time over the GTS. Buoy deployments in the Antarctic have been far fewer than in the Arctic, and often in support of specific research projects rather than contributing to an optimum hemispheric network. The WCRP International Programme for Antarctic Buoys was established in 1994 to promote and coordinate buoy deployments in the Antarctic seasonal sea ice zone. There is a need for greater density and launch frequency of buoys in the Antarctic sea ice zone, and optimally 50 or more buoys a year are required to support Dec-Cen. However the largely divergent ice drift around the Antarctic makes it difficult to maintain buoys within much of the Antarctic pack for more than a few months; it will therefore be difficult to achieve the desired coverage with buoys alone.

High spatial resolution fields of ice motion can be obtained by tracking identifiable floes in successive images from aircraft or space-borne SAR. Satellite systems with regular repeat cycles, such as Radarsat, now provide data from which synoptic ice velocity fields can be derived. A dedicated Antarctic geophysical processing centre, and some improvement of automatic recognition and tracking routines, are required for this to become operational there. Although motion is sometimes difficult to determine from SAR data in areas of high deformation or new ice, current capabilities appear quite robust, particularly if buoy data are blended with the satellite observations.

Synoptic ice motion fields also provide a capability to monitor ice divergence and thus open water formation, and the age history of individually tracked floes. Both of these provide some proxy data on the ice thickness.

5.4 Land-fast ice thickness

The thickness of fast ice is determined by the energy balance between heat conduction away from the lower boundary, and turbulent heat transfer from the underlying ocean. In the Antarctic this oceanic heat flux can be significant (typically 15 Wm-2) and will vary with changes in large scale ocean circulation and water mass properties. It is a recommendation of ASPECT that simple measurements of the annual growth of the fast ice, and the snow cover, should be regularly made at near coastal Antarctic stations where water depth is greater than 100 m. Thermodynamic modelling of the ice growth, driven by observed meteorological data (e.g. Heil et al., 1996), will give an accurate estimate of the oceanic heat flux, and a proxy record of larger scale ocean changes.

6. SEA ICE MODELS

As already noted, sea ice models, in one form or another, already form an essential component of climate and forecasting models, including NWP models. We give below a brief and by no means comprehensive summary of the current status of ice models, including their application to climate and operational forecasting, including consideration, in section 7, of the surface forcing required to drive them. Overall, such models are designed to give representation of the two important components of sea ice formation, maintenance and decay: ice thermodynamics and ice dynamics.

6.1 Sea ice thermodynamics

The basic thermodynamics of sea ice and the combined ice/snow layer is often treated in a fairly simple way in sea ice models, in many cases following the formulation of Semtner (1976) utilising either his zero, or multi layered model. Semner's formulation was designed as a simplification for use in climate models of the more detailed treatment of Maykut and

Untersteiner,(1971) which included many layers and more detailed representation, in particular, of the role of brine pockets for heat storage. Other more sophisticated treatments are also available, particularly in relation to treatment of the ice surface, including interactive ice surface albedo and the effects of Arctic summertime melt ponds (e.g Ebert and Curry, 1993) which reduce the large-albedo of the ice field from values of 0.8 and more to 0.5 or less in that season.

Fractional ice concentration adds further complications to the treatment of ice thermodynamics, as the exchange of heat, freshwater and momentum into or out of the leads and their effects on upper ocean mixing and sea ice formation and melt need to be taken into account. Particularly in the southern hemisphere, it is also necessary to treat the effects of on the ice of sea water swamping the ice/snow layer. These effects are taken into account, though in a very simple way, in the sea ice model used at the UK Met Office, for example (Cattle and Crossley, 1995). Treatment of lead processes by sea ice models of varying degrees of sophistication are available (e.g Parkinson and Washington, 1979; Hibler, 1979) but global models generally employ fairly simple parametrisations (see e.g Cattle and Crossley, 1995).

6.2 Sea ice dynamics

A number of models of sea ice dynamics exist. Some are highly simplifed such as that utilised by Bryan et al.(1975), in which the ice is assumed to be advected with the upper ocean velocity (derived directly from the effects of wind stress in their coupled model), with motion stopping if the ice thickness exceeds 4m metres (providing a highly simplified representation of sea ice rheology). Parkinson and Washington (1979) used a rather more sophisticated but still simplfied approach in their ice dynamics formulation. Others, e.g Hibler, 1979; Coon, 1980; Hibler and Walsh, 1982, Hunke and Dukowicz, 1996) are based on the fuller equations of ice motion with complex ice rheologies. Important factors to be represented are the effects of the wind and ocean currents, together with the slope of the sea surface, in providing the driving of the ice, coupled with Coriolis effects and the ice rheology. Choice of appropriate ice rheology, which allows the important effects of internal stresses and strains within the ice pack itself to be described, is a key issue for detailed modelling of sea ice dynamics. Some of these (e.g Hibler, 1979) are appropriate for the more continuous central pack ice regions of the Arctic basin, whilst others (e.g Bratchie, 1984) attempt to represent processes appropriate to the marginal ice zone, and include treating the ice as a series of colliding floes which can also ridge and raft. A more recent model with simplified rheology is the cavitiating fluid model of Flato and Hibler (1992). Hibler (1980) introduced the concept of an ice thickness distribution, which impacts both the dynamic and thermodynamic responses of the model. Alternatives to the Hibler approach to modelling ice rheology have been sought, for example by Gray and Moreland (1994).

6.3 Sea ice models in climate and operational models

Despite the role of sea ice for high latitude climate sensitivity, many climate models have, in the past, used a thermodynamics-only approach to sea ice modelling. However, running interactive thermodynamics-only models is now well know to provide an inadequate representation of the seasonal variability of sea ice and geographical distribution of ice thickness (especially in the southern hemisphere, where the seasonal cycle and the ice fields themselves all but diappear, despite use of flux correction). These inadequacies can be overcome by the introduction of even a highly simplified representation of ice dynamics such as the one devised by Bryan et al. (1975). The trend, however, is to use of models based on either the Hibler (1979) or the Flato and Hibler (1992) cavitating fluid model approaches for climate studies. The ACSYS Sea Ice-Ocean Modelling Panel has set itself the task of deriving a recommended optimum sea ice model for climate studies. As already noted, the Hibler model has also been used as the basis of the PIPS system used by the US FNOC. (Preller, 1985, Preller and Posey, 1989).

As described, NWP models, run at operational forcasting centres such as ECMWF, the UK Met Office, Meteo-France and the US National Centres for Environmental prediction, are only concerned with sea ice as a lower boundary condition. Ice edge information (based on an ad hoc limiting ice concentration assumption) is used to set the ice boundary in these models which assume ice covered grid squares to have 100% concentration. Ice thermodynamics is treated in a simplied way in these models, assuming constant ice thickness over the whole ice field. These factors have serious repercussions for determination of surface fluxes over ice covered oceans, especially since there is no representation of open water (leads) within the pack. At present, therefore, NWP models provide an inadequate description of the thermodynamic forcing of sea ice and the underlying ocean, though the dynamical forcing, is better determined, in the Arctic thanks, in particular, to the contribution of the Arctic Ocean Buoy Programme.

6.4 Further consideration of forcing fields

6.4.1 Background

A goal of ACSYS is the derivation of improved data sets of daily values of all components of the surface forcing of ice and ocean in the Arctic region. In the past, surface conditions have been obtained from available climatological data or in situ measurements of relevant atmospheric parameters. In addition, use has been made of surface forcing data derived from operational NWP models, adjusted by reference to in-situ measurements. As discussed above, at present the reliability of dynamical forcing deduced from NWP analyses (the surface wind field) is considerably better than that of the thermal forcing. The largest uncertainties are associated with errors in the NWP computations of surface radiation and absence of allowance for leads in the pack. Because of this, the approach advocated by ACSYS is based on use of model data, with particular reference to use of re-analysis datasets (from ECMWF, NCEP and the Goddard Space Flight Centre Data Assimilation Office), coupled with use of surface radiation budget data based on retrievals from satellite data and of in-situ data. Aside from issues of inadequacy of cloud and radiation and other physical parametrisation schemes in the models employed absence of representation of exchanges through leads mean that reanalysis data alone are certainly insufficient to determine the surface fluxes adequately for climate purposes. Surface pressure, wind, and air temperature fields derived from NWP analyses for the Southern Ocean are generally referenced to far fewer data than the Arctic analyses, although Turner et al (1996) suggest that the synoptic-scale circulation over the ocean areas is reasonably represented by the models.

Finally, determination of the forcing on sea ice by the ocean surface tilt is problematic in both hemispheres. A particular ACSYS effort relevant in particular to CLIVAR Dec Cen is calculation and reconstruction of the dynamic heights and depth of the upper boundary layer from 1949 onwards, based on existing Russian datasets (Timokhov, unpublished).

6.4.2 Measurements

As noted, the International Arctic Buoy Programme and the International Programme for Antarctic Buoys provide direct measurements of surface pressure over the Arctic Ocean and the Southern Ocean seasonal sea ice zone respectively. It is essential that these networks be maintained, and in the Antarctic enhanced, together with ongoing data transmission through the GTS. Sea ice buoys should also include instrumentation for measuring these and oceanic variables.

7. CONCLUDING REMARKS

This paper attempts to summarise the current situation with regard to sea ice observations and modelling for climate and large scale operational forecasting. A number of aspects of sea ice modelling and observational studies are being addressed by the WCRP ACSYS programme for the Arctic and are planned to be addressed by SCAR ASPECT for the Antarctic, but in a research context. Key issues are (i) the need for greater sophistication in the sea ice models used for both climate and operations, including the specification of surface forcing, particularly from NWP models which currently do not include representation of open water (leads) in the ice, and (ii) the need to maintain and develop the current network for sustained observations, and particularly to develop the buoy network in the Antarctic sea ice zone. Satelllite data are of high relevance to monitoring of high latitudes and some algorithm improvment is required in particular for ice concentration and ice type is required Measurment of global fields of ice/snow thickness remains problematical, A important advance would be the capability to remotely-sense sea ice/snow thickness from space.

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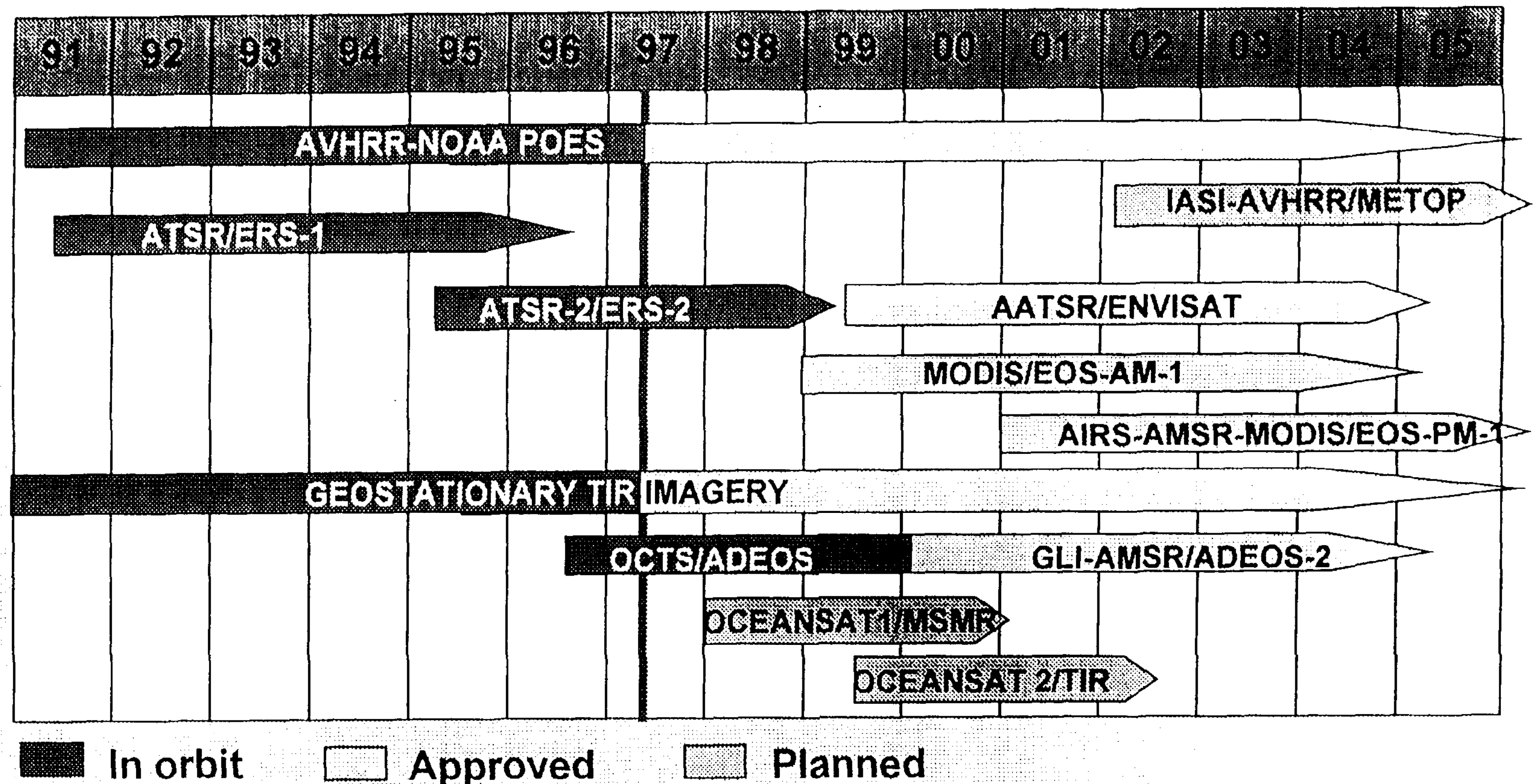
ANNEX VI

SATELLITE MISSIONS

ML-04/97

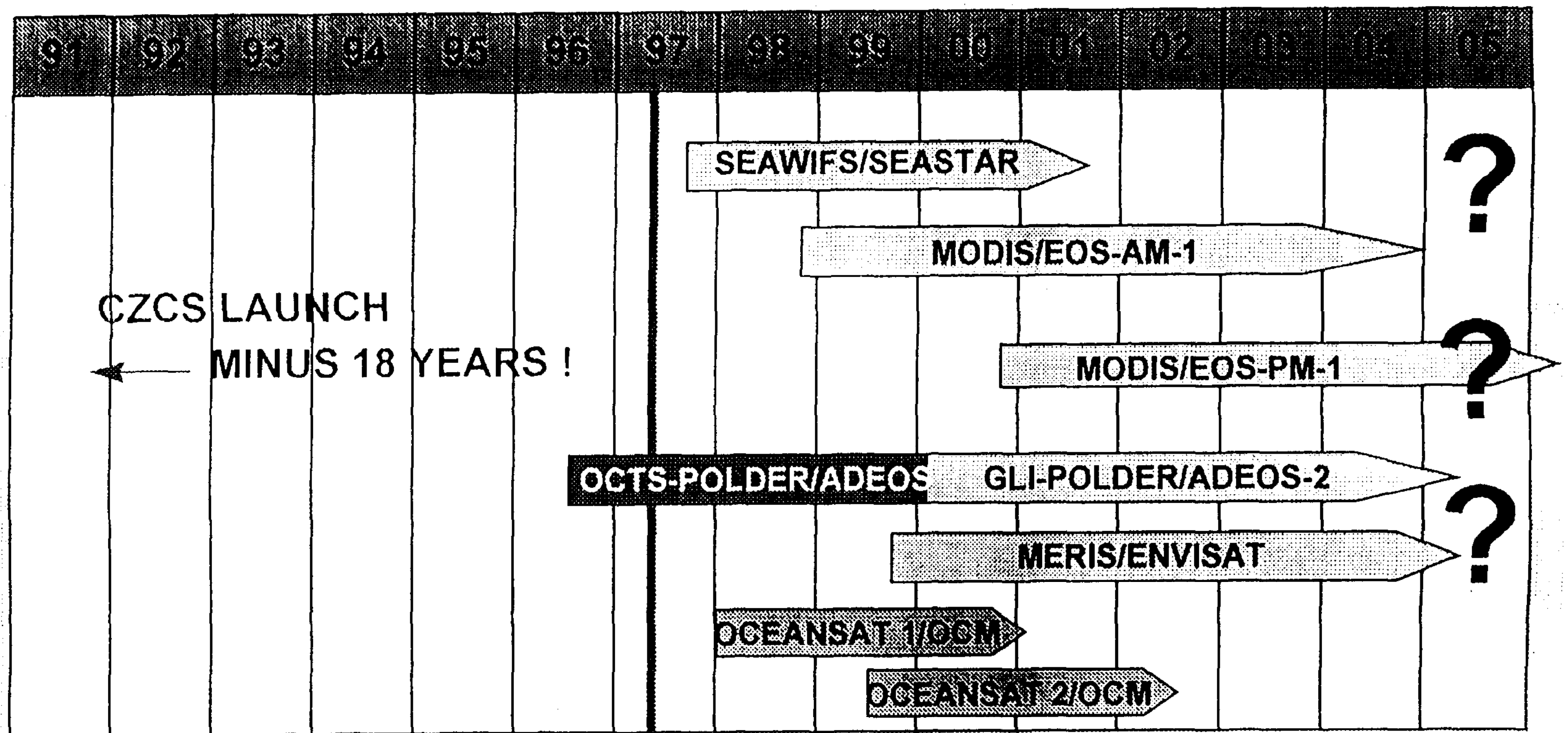
SEA SURFACE TEMPERATURE MEASUREMENTS



*all sensors with 1 km resolution at nadir or less, except GEO systems (a few km) and IASI, AIRS, MIMR, AMSR (some 10 km)
* SST primary objective of (A)ATSR(2); other sensors multipurpose; absolute accuracy of GEO systems and microwave radiometers lower, to be documented
* all sensors wide-swath (eg 2000 km) except (A)ATSR (2)(450 km)
*impact of US convergence TBD

ML-04/97

OCEAN COLOUR

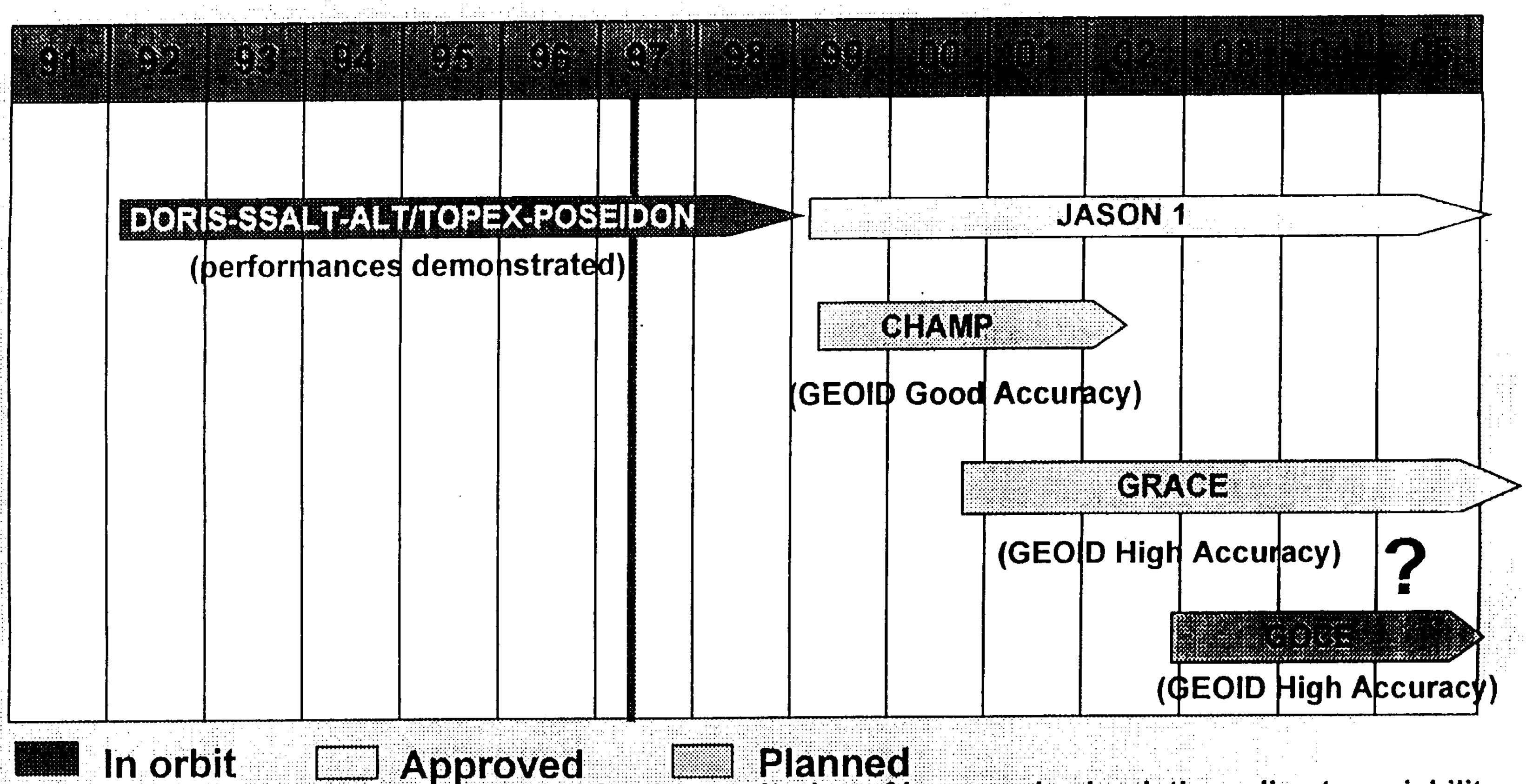


In orbit   Approved   Planned

* All sensors represented are dedicated to or optimized for ocean colour
* Other missions approved/considered by INDIA,TAIWAN, KOREA, etc...not represented

ML-04/97

OCEAN TOPOGRAPHY, SEA LEVEL, OCEAN CIRCULATION : <5 cm acc. class



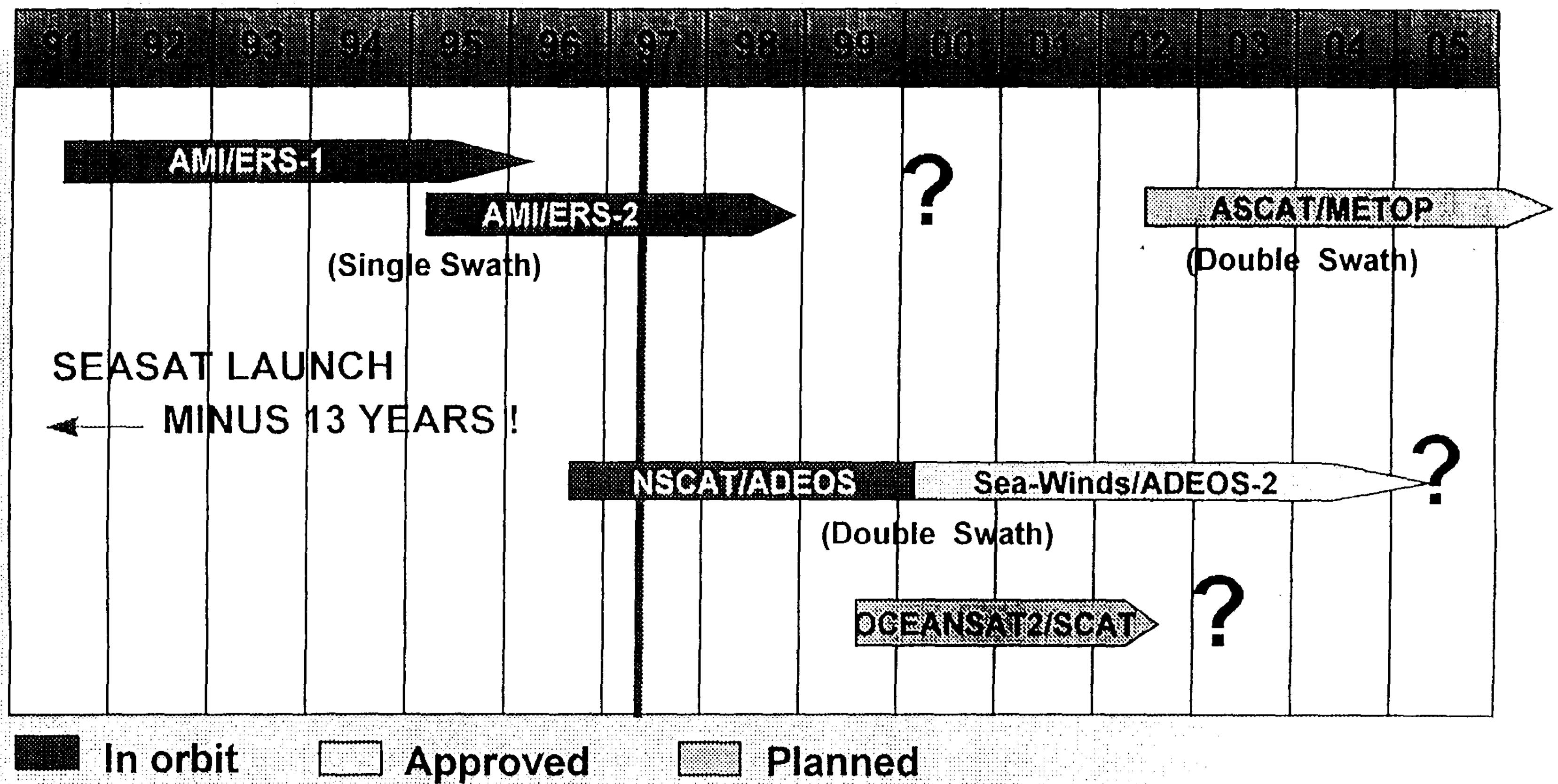
*TOPEX/POSEIDON class missions optimized for the monitoring of large scale circulation, climate variability (interannual ..) and global mean sea level,

* an ocean ciculation observing system requires two to three altimeter missions simultaneously in orbit for proper sampling of all significant time-space scales, with at least a TOPEX class mission.

*single shot gravity mission desirable to access permanent circulation at all climate-significant scales

ML-04/97

MEASUREMENTS OF WIND VECTORS AT THE OCEAN SURFACE

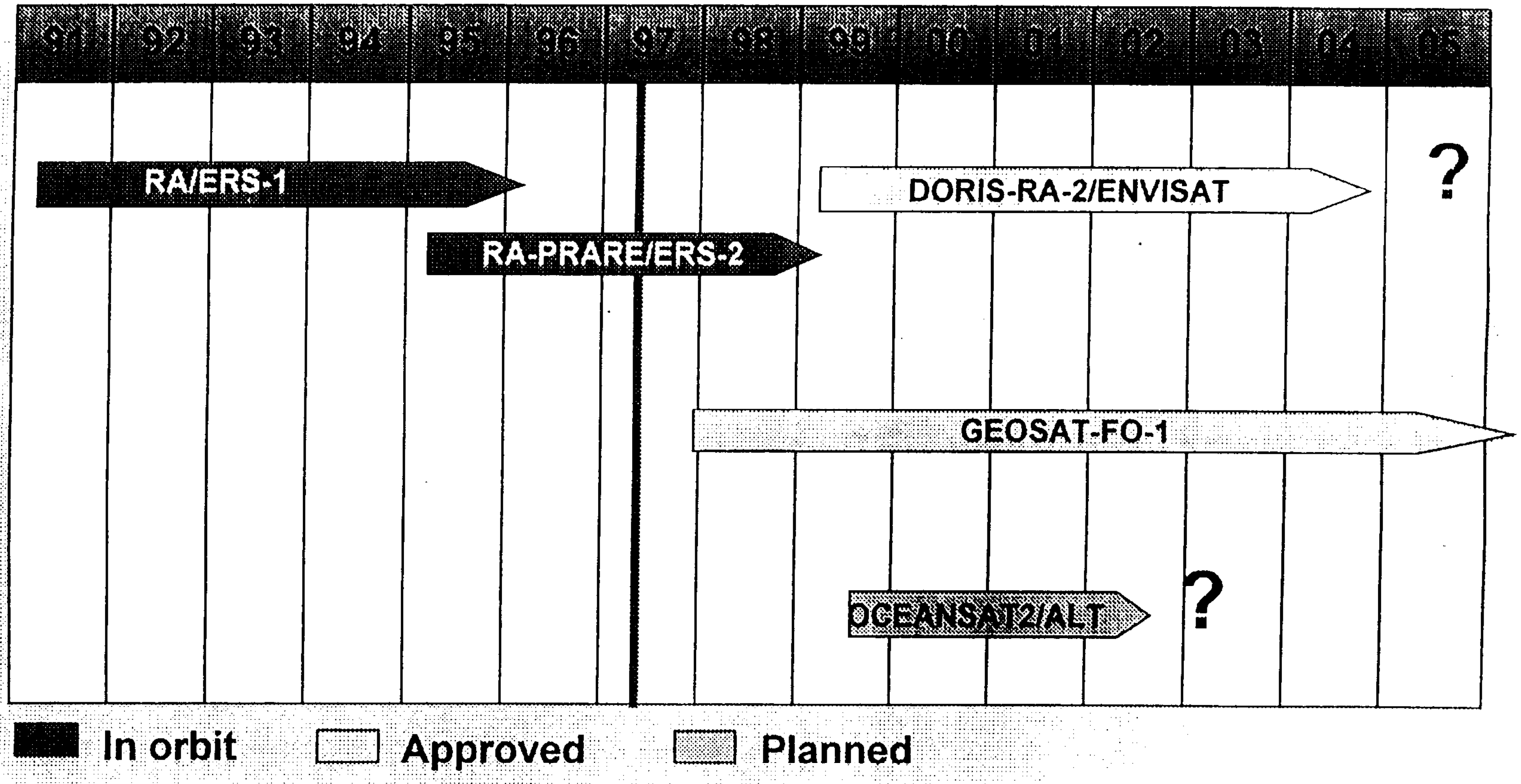


*AMI single - swath (500 km), ASCAT, NSCAT dual swath, (2 x 500 km), Sea-Winds dual conical swath (1000 km swath, number of independent viewing angles varies throughout swath) ,

*AMI and ASCAT operating at C band, NSCAT and Sea-Winds operating at KU band; performances in C and KU bands to be compared with ERS-2 and ADEOS simultaneously in orbit

ML-04/97

OCEAN TOPOGRAPHY, SEA LEVEL, OCEAN CIRCULATION : 15-20 cm acc. class



*all missions optimized/adequate for mesoscale observations
* all civil , fully accessible missions except GEOSAT-FO, US Navy missions (only level 2 data available off line),

ANNEX VII

TERMS OF REFERENCE FOR GOOS COASTAL PANEL

1. The panel should be initially appointed for two years by J-GOOS with the chair of the panel reporting to the chair of J-GOOS.

2 .Membership of the Panel shall be based on informal suggestions from the J-GOOS Coastal Module Workshop held in February 1997, combined with recommendations from the existing members of J-GOOS and enquiries by the chairman of J-GOOS. The membership shall represent an appropriate range of professional skills, experience of coastal monitoring and forecasting, and representatives of organisations and agencies who are users of operational marine data, or providers of operational marine environmental services. The Panel shall also include representatives from HOTO and LMR.

3. Jointly with the Director of the GOOS Project Office, the Panel will set priorities for the project officer assigned to Coastal GOOS. This will include:

   (i) action on the recommendations in the GOOS Coastal Module Planning Workshop;

   (ii) promotion of Coastal GOOS.

4. Develop a scientifically based generic plan for Coastal GOOS integrating the coastal elements of HOTO, LMR and the physical observational and modelling activities. (A draft to be presented to J-GOOS V and the Services Module).

5. Provide guidance and advice to J-GOOS on planning and implementation of Coastal GOOS.

6. Communicate with GTOS, GCOS, LOICZ, and other agencies, committees and programmes, on behalf of J-GOOS where there are requirements for common data procedures for the coastal zone.

ANNEX VIII

Schedule of Forthcoming Events

1997

Meeting of the CIESM/IOC GE on MedGLOSS [AT]	Jan 20-21	Paris
3rd Session of the SSC for I-GOOS [JPR/YT]	Jan 27-30	Geneva
OOPC-II [AA]	Feb 11-13	Capetown,
Coastal Module Workshop [AA]	Feb 24-28	Miami
Gulf of Thailand Science Planning Mtg [JW]	Feb 25-28	Bangkok
APEC Seminar Earth Obs. for Users [JW]	Mar 3-5	Tokyo
CMM-XII [YT]	Mar 10-20	LaHabana
IGS/GLOSS/PSMSL Workshop on Geodetic Fixing	Mar 17-18	Pasadena
IOCCG (2nd Session) [JW]	Mar 17-18	Tokyo
JSC-XVIII [AA]	Mar 17-22	Toronto
Time Series Workshop [AA]	Mar 18-20	Baltimore
IOCCG (Int. Ocean Color Coord. Group) Executive [JW]	Mar 19	Tokyo
5th Session of IOC Group of Experts on GLOSS [CS]	Mar 19-21	Pasadena
CEOS WGISS Sub-groups Mtg. [JW]	Apr 13-18	Toulouse
Sponsors Meeting [CS]	Mar 24pm-25	Paris
1st SOOP Implementation Panel TT/QCAS [BH]	Apr 14-18	Capetown
Planning Group for Realization of GOOS [CS]	Apr 21-22	Miami
J-GOOS-IV [CS/AA]	Apr 23-25	Miami
CLIVAR SSG-VI [AA]	Apr 28-2 May	Washington
CEOS WGISS [JW]	May	Ottawa
GTOS [CS]	May 12-13	Rome
Near-GOOS Co-ordinating Committee [CS?/NI?]	May 14-16	Bangkok
G3OS Space Panel [CS/JW]	May 27-30	Paris
IOC-JGOFS Ocean CO_2 Advisory Panel [AA]	Jun 2-6	Warnemünde
2nd SOOP Management Committee [BH]	Jun 4-6	Hamburg
WOCE South Atlantic Workshop [AA]	Jun 16-20	Brest
Training Seminar/Workshop on Sea-Level Obs.& Analysis [AT]	Jun 16-27	Bidston
Sponsors Meeting [CS]	Jun 24	Paris
IOC-WMO-UNEP Committee for GOOS (I-GOOS-III) [CS]	Jun 25-27	Paris
IOC-EC/XXX [CS and all GOOS staff]	Jul 1st	Paris
XIXth IOC Assembly [CS and all GOOS staff]	Jul 2-18	Paris
WOCE Southern Ocean Workshop [AA]	Jul 7-11	Hobart
CEOS Analysis Group [JW]	Jul	Japan
G3OS Data and Information Panel [JW]	Jul 21-25	Tokyo
WCRP Scientific Conference [AA]	Aug 26-28	Geneva
G3OS Sponsors meeting [CS]	Sep 15-17	Geneva
GCOS JSTC [CS/JW?]	Sep 22-27	Holland
WOCE SSG 14 [AA]	Sep 22-26	Boulder
Ocean PC Training Course [JW]	Sep/Oct	Bangkok
Near-GOOS Training Course [NI]	Oct (tent.)	Tokyo
IODE Ocean Data Symposium [JW]	Oct 15-18	Dublin
DBCP Workshop [YT]	Oct 13-14	LaRéunion
J-GOOS Planning Group	Oct.	London

DBCP-XIII [YT]	Oct 14-17	La Réunion
Int'l Symposium on Monitoring Oceans [AA]	Oct 15-17	Biarritz
Symposium on Management & Exchange of Info. for Scientific Use [JW]	Oct 15-18	Dublin
ARGOS JTA-XVII [YT]	Oct 20-22	La Réunion
IGOSS/IODE Senior Officers Meeting [CS]	Oct/Nov	Goa
Planning Group for Realization of GOOS [CS]	Nov	London
CEOS Plenary [CS]	Nov 19-21	Toulouse

1998

J-GOOS Planning Group	January	N/D
CLIVAR Int'l Implementation Conf. [AA]	20-24 April	Paris
OOPC [AA]	6-8 Apr	Sarlat
J-GOOS (GSC) V	April 98	N/D
Ocean Expo [AA]	22 May-30 Sep	Lisbon
WOCE Conference	24-29 May	Halifax
COST-WMO-IOC Conf. on "Needs & Applications of Wave Spectral Data in Marine Engineering & Operation" [YT]	Sep 21-25	Paris
DBCP Workshop-II [YT]	Oct (2nd half)	N/D
DBCP-XIV [YT]	Oct " "	N/D
ARGOS JTA-XVIII [YT]	Oct " "	N/D
IOC-EC/XXXI [CS and all GOOS staff]	N/D	Paris

ANNEX IX

LIST OF ACRONYMS

CEOS	Committee on Earth Observation Satellite
CLIVAR	Climate Variability and Predictability Programme
CMM	Commission for Marine Meteorology
DBCP	Data Buoy Co-operation Panel
DIMP	Data and Information Management Panel
EEZ	Exclusive Economic Zone
ENSO	El Nino Southern Oscillation
EuroGOOS	European GOOS
G3OS	The 3 Observing Systems (GOOS, GCOS, GTOS)
GARP	First GARP Global Experiment
GCOS	Global Climate Observing System
GEF	Global Environment Facility
GIPME	Global Investigation of Pollution in the Marine Environment
GLOBEC	Global Ocean Ecosystems Dynamics
GODAE	Global Ocean Data Assimilation Experiment
GOOS	Global Ozone Observing System
GOSSP	Global Observing Systems Space Panel
GSN	GCOS Surface Network
GTOS	Global Terrestrial Observing System
HOTO	Health of the Ocean (Module of GOOS)
IACCA	Inter-Agency Committee on the Climate Agenda
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
IGFA	International Group of Funding Agencies
IGOS	Integrated Global Observing Strategy
IGOSS	Integrated Global Ocean Services System
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data and Information Exchange
IOP	Intensive Observation Period
JGOFS	Joint Global Ocean Fluxes Study
JGOOS	Joint GOOS Scientific and Technical Committee
JMA	Japan Meteorological Agency
JSTC	Joint Scientic and Technical Committee for GCOS
LMR	Living Marine Resources
LOICZ	Land-Ocean Interaction in the Coastal Zone
NEARGOOS	Northeast Asia Regional GOOS
NOAA	National Oceanic and Atmospheric Administration (USA)
OOPC	Ocean Observations Panel for Climate
OOSDP	Ocean Observing System Development Panel
OSE	Observing System Experiment
OSLR	Intergovernmental ommittee for Ocean Science and Living Resources
SCOR	Scientific Committee on Ocean Research
SOOP	Ship of Opportunity
SSC	Strategy Sub-Committee (of I-GOOS)
TEMS	Terrestrial Ecosystem Monitoring Sites
UNEP	United Nations Environmental Programme
UOP	Upper Ocean Panel (of CLIVAR)
WCRP	World Climate Research Programme
WESTPAC	IOC Sub-Committee for the Western Pacific
WMO	World Meteorological Organization
WOCE	World Weather Watch (of WMO)
XBT	Expendable BT