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OceanObs99 CONFERENCE STATEMENT

"Conference Statement" of the First International Conference on the Ocean Observing System for Climate (OceanObs99), St Raphaël, France, 18-22 October 1999.
The Statement for the OceanObs'99 Conference can also be found at:
http://www.bom.gov.au/OceanObs99/Papers/Statement.pdf

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1 - THE VISION

The 1st International Conference for the Ocean Observing System for Climate seeks a consensus within the oceanographic community on an appropriate blend of sustained observations to satisfy the collective needs of research and operational applications planned or underway under the Global Ocean Observing System (GOOS), Global Climate Observing System (GCOS), Climate Variability and Prediction Program (CLIVAR) and operational Programmes of the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC). The vision embraces an enhanced and deeper appreciation and understanding of the mutual benefits of each as contributions to the observing system.

In this vision, the Conference heralds the dawn of a new era for oceanography and ocean observations where the core needs of research and of operational applications for long-term observations are met by a realistic, integrated and sustained effort, an effort that meets the collective, highest priority need rather than the individual want.

At the heart of this vision is the belief that the strategy must be based on global, integrated networks, providing high quality data, but cost-effective, with timely and efficient distribution of data and products to all participants and other users. A global view is essential if the implementation is to effectively meet various operational and scientific uses, ranging from regional marine and ocean forecasts through to monitoring climate change trends. Integration delivers efficiency and effectiveness. We see at one end a broad class of users who wish to utilize data from many distinct parts of the network and to do this they need to be accessing a *system*, not a diverse array of parts. They would expect consistency between these parts; harmony and accord, not contrariety and discord (different formats, standards, etc.). The data gatherers, distributors and processors, at the other end of the system, gain efficiencies through multi-purpose platforms, use of common telemetry and data distribution networks, and implementation as a component of a larger system. Their reason for being is strengthened by the ability of users to exploit their data in conjunction with other information.

The vision includes an orderly progression toward this global system, a schedule of implementation that adopts proven methods and works to a time-line that maximizes long-term investment and balances it against both short and long-term returns. While the schedule must be realistic, it must also be developed with the conviction that the envisaged global system is realizable within the next decade.

The fact that CLIVAR and GOOS/GCOS have been able to work together for this Conference is also fundamental to this vision. While the former is about hypothesis and experimentation and the latter about routine applications, they share a common dependence on a sustained observing system. The strength of this commonality is such that there is no clear place where one ends and the other begins. The keywords are transition and evolution and this is effected through mutual understanding and cooperation between research and operational interests.

2 - THE FOUNDATIONS

The oceanographic community has a rich literature stretching back over a century detailing endeavors to observe and understand the ocean and its role in climate. From the very beginning there have also been attempts to apply this knowledge, for more efficient and safer ocean operations, for strategic national interests, and for the general betterment of humankind.

This Conference could only highlight some of the most prominent example uses of oceanographic data. Two research programs are prominent throughout the papers of the Conference and as such constitute the principal basis upon which this new era for ocean observations is to be built.

TOGA, the Tropical Oceans Global Atmosphere Experiment (1985-1994), was initiated at a time when the oceanographic community was just beginning to appreciate the unique and important role of the tropical oceans in the global climate system. The 1982/83 El Niño brought extreme and debilitating consequences to many communities around the Pacific Ocean and, in some cases, beyond. TOGA was built on the vision of implementing an observing system that would enhance understanding of the El Niño-Southern Oscillation (ENSO) phenomenon and enable the development of models to predict ENSO. The end of TOGA realized this vision.

The World Ocean Circulation Experiment (WOCE) was, and remains, a ground-breaking initiative to exploit the symbiosis between global ocean *in situ* and remote satellite observations, and eddy-resolving basin and global ocean models. WOCE promises to deliver an estimate of the current state-of-the-ocean and its fluxes of heat and fresh water, at least for one limited time period. This will provide a baseline against which future (and past) changes may be assessed. The new observational techniques developed by WOCE now promise to provide key elements of future ocean observing systems. WOCE leaves a legacy of a global data set of unprecedented comprehensiveness and quality, and models and data assimilation methods that can deliver useful, global products. The contribution from operational meteorology is also very significant. They have developed and sustained observing and modeling systems that now serve a wide array of users. Oceanography has drawn, and will continue to draw, many valuable lessons from meteorology. It is also likely that many of the sustained systems will be implemented and maintained in cooperation with operational meteorological agencies.

There are also several other factors that have contributed significantly to the foundation upon which we will build the global observing system.

Within the last decade satellite remote sensing has become a mature technology for collecting regular, global observations. Sea surface temperature, sea-ice conditions, near surface winds, surface waves and surface topography can all be measured reliably from space. For a global system such capacity is fundamental. In combination with direct measurements, models and data assimilation, remote sensing will make a lasting, long-term contribution to the global observing system.

There have been many other contributions and legacies both from individuals and coordinated research projects that have brought us to where we are today. Through these efforts it is fair to say we have matured from an era characterized by investigation and learning to one where we mostly know what we wish to do and how. Of course this progress has been gradual and there are many instances of extant, mature observational methods and applications. However it is also clear that the challenges associated with cementing our gains in place for a sustained observing system are greater now than they have been at any previous time.

It is for this reason that the Conference has been convened now and that, on the background of past endeavors, we are seeking to consolidate our gains and lay down a solid basis for sustained, future ocean observations. It is also timely because the global follow-on research program to TOGA and WOCE, namely CLIVAR, is completing its planning phase and beginning to embark on a phase of extended observations to determine ocean variability, on scales of seasonal and longer, and its predictability.

As outlined in the Preface, the Conference strategy has been to build toward consensus through

a) A series of solicited papers that discuss individual contributions, the scientific context and various applications;
b) Submitted papers that provide more detail on specific methods and applications;
c) Open discussion of papers prior to the Conference;
d) Plenary discussion of presentations; and
e) Round Table discussion on the appropriate blend of techniques.

The sections that follow attempt to capture the essence of the papers and discussions and detail those aspects for which an acceptable consensus emerged.

3 - WHY A SUSTAINED GLOBAL OCEAN OBSERVING SYSTEM?

As noted above, the words "global" and "system" emphasize the fact that we are seeking an integrated, efficient solution for a wide-ranging set of applications and scientific problems. The collection of solicited and submitted papers roam over many different problems. We will try to encapsulate these themes here but it should be recognized that emphases change and evolve, and that many relevant applications are beyond the scope of this Conference. Depending upon whether your primary attachment is to research or operational applications, you may choose to highlight these themes differently. A strong scientific rationale lies at the heart of the development of the sustained system and is intimately linked to the setting of priorities.

3.1 - Climatologies

Climatologies are fundamental for research and operational applications. The starting point for scientific inquiry is more often than not determination of the mean and the first moments of variability. Unfortunately, for many fields and much of the oceanic domain including the ocean surface, our information is grossly inadequate, despite the many fine endeavors of individuals and major projects. For some applications, such as engineering design, climatologies are in fact the required product.

3.2 - Climate change

Concern about possible climate change related to enhanced greenhouse gas concentrations has captured the attention of the community over the last decade. There are formal processes for assessing climate change and a UN Framework Convention specifically concerned with climate change. The emphasis on carbon accounting now places particular emphasis on the oceanic carbon cycle. For the purposes of this Conference, the concern is broadened somewhat to include environmental changes in general, be they related to human activity or natural change. Our basic premise is that slow climate change must involve the ocean and that, as a consequence, we have a responsibility to better observe the ocean and its coupling to the atmosphere. The scales of associated variability implicate the full depth of the ocean and all regions of the global ocean. Carbon and selected trace gas inventories and their change over time, water mass formation, and heat and water fluxes and storage are among the key issues.

3.3 - Slow climate variations

It is a moot point whether we should distinguish climate change from long period (order decade) changes. In this Conference many different modes of decadal and longer time scale variability were discussed, some with well understood impacts, others with yet to be determined impacts. One example is the decadal variation of the ENSO system. They often manifest as long-term changes in the weather carrying streams (e.g., the North Atlantic Oscillation). In most cases, the role of the ocean is not well understood, and in some cases the ocean may not have a first order effect; in other cases the ocean is the controlling factor. In all cases, the consensus is that high-quality ocean data and ocean state estimates are needed to understand the phenomena. In general, the modes involve global scale interactions and deep ocean circulation. Water mass formation, heat and water transports, heat content and the impact on the biogeochemical state of the ocean are key issues.

3.4 - Forecasts of ENSO and other interannual climate variations

As noted above, the propensity for extremes of ENSO to be associated with severe anomalies in rainfall (droughts, floods) and other climatically significant impacts (e.g., storms) has led to heightened public appreciation of the value of climate prediction. Several groups are now producing routine (operational and experimental) ENSO forecasts and there is wide consensus that oceanographic data contribute to increased forecast model skill and to the continual improvement of these models (validation). Predictable seasonal-to-interannual signals are now being sought in other regions and the influence of variability outside the tropical system (and on other time-scales) is being examined for its impact on forecast skill.

3.5 - Intraseasonal variability

Many regions, particularly in the tropics, experience large seasonal variations in precipitation associated with the monsoons. These phenomena are not well understood at this time and better quantification of levels of predictability is a central focus of CLIVAR. In addition to the monsoons, variations associated with, for example, the Atlantic Tropical Dipole and the Indian Equatorial Dipole are receiving considerable attention . Various process studies have been planned to advance scientific understanding. The role of the sustained observing system is to provide the basic observing network upon which such explorations can be developed. In some cases the ocean may play only a secondary role, while in others a more fundamental role has been hypothesized.

3.6 - Ocean prediction

Here the focus is the ocean and not the coupled system. Open ocean prediction encompasses a range of research and operational applications including strategic and tactical ocean forecasting related to national defense and civilian protection, shelf and coastal predictions and predictability, information for off-shore industries, safety and search and rescue, and information for a variety of other users. The time scales range from days to weeks and, in contrast to the above themes, air-sea coupling is not a dominant feature. Because of the link to coastal and ecosystem issues (the open ocean as a forcing term), there is increased focus on coupling with the biosphere and the land-coastal systems. Surface and near-surface currents tend to be the key variables and the role of mesoscale variability is an important factor. Since the problem involves a mix of deterministic forcing (wind forcing) and internal variability (eddies) the issues of predictability and model initialization are quite complex. The forecast systems are usually characterized by demand for high horizontal spatial resolution and the emphasis is often on the upper ocean and surface forcing.

3.7 - Surface marine products and forecasts

Sea state prediction is among the more mature application areas. This Conference has drawn particular attention to wave prediction and highlighted the role of surface waves in the estimation of other surface fields and the general importance of surface waves for climate problems. Knowledge of the surface wind field is central to these applications. Numerical weather prediction (and associated reanalysis projects) uses ocean and marine data and, in turn, provides products such as surface wind estimates that are useful for a range of other applications. There is also considerable interest in the dependency of storm intensity and tracks and their prediction on the underlying ocean conditions.

4 - THE SUSTAINED NETWORK

This section describes the highest priority contributions to the sustained network, as agreed at the Conference, and consistent with the rationale of the previous section. Initially, we specify the primary contributions to the network, contributions that are established now or that represent, in the view of the Conference, a high priority, practical option for transition to sustained support during the next five years. We then identify additional contributions and enhancements that were deemed to be of high priority in the future system. These contributions drew broad support and have clearly identified utility but require some level of development before being implemented as a long-term contribution to the sustained system. In some cases the development path may be short, in other cases it may be order ten years. The commonality is that the Conference was convinced a useful and practical contribution worthy of sustained support was being developed. Finally we describe contributions that are cross-cutting, providing the vital means for integration, assimilation and management of the system.

In all cases our judgement *must* take account of the feasibility and practicality of sustained support. As noted above and in several of the solicited papers, sustained support usually implies utilization much broader than a single application and/or scientific problem. In identifying *primary* contributions, this multi-purpose aspect is very important so that, almost without exception, all the elements contribute to several of the goals listed in Section 3. They are often contributions with global implementation, or regional implementations targeted at important phenomena.

The issue of prioritization is difficult. Ultimately it depends upon the level of priority that is attached to the various rationales listed in Section 3 and in the many papers of the Conference. For GOOS and GCOS it is also an issue of societal impact (what is valued and represents good investment), while for CLIVAR it depends upon the importance attached to various research areas. All of the contributions discussed in this section have been accorded high-priority in one or more of the application areas discussed in Section 3. Since our focus is the integrated global system, we do not attempt to single out any particular aspect for special attention but rather highlight the contributions to the whole. We do however choose to distinguish contributions in terms of their readiness for incorporation into the sustained system, as discussed above. We note that it may be counter-productive to promote developing networks prematurely since this limits the opportunity for experimentation and refinement.

This description could be approached in many different ways, including by field, by platform, by purpose, by instrument, or by some priority order. We choose an approach that focuses on the most conspicuous aspects of the network since this seems to most readily convey a description of the preferred, integrated network, free from encumbrances provided by detail. In same cases this means attention is on a particular field (eg, surface wind vectors), in others a phenomenon (eg ENSO) or a project/technique (eg *Argo*). A more complete description of the rationale and design details may be found in the relevant papers.

4.1 - Primary Contributions

The main global space-based networks were discussed at the conference. These measurements include sea surface temperature, height, winds, and salinity, as well as upper ocean color, sea ice properties, and the gravity field. Like all observational approaches, they are at varying levels of development. In all cases there is a clear need for complementary *in situ* data.

Networks of *in situ* (non-space based) observations have also been discussed at length. The fields measured include: sea surface temperature, winds, waves, salinity, sea level, and surface fluxes; upper ocean temperature and salinity; surface and subsurface currents; sea ice extent, coverage and thickness; whole-depth profiles of physical and chemical properties (including tracers); bottom pressure; and various integral measures. In many cases there is an implied dependence on complementary space-based data.

There are also various other contributions related to data and product distribution and infrastructure, some of which are discussed in the following sections.

4.1.1 - *Sea surface temperature*

Sea surface temperature is important to all user areas. The requirements are diverse, ranging from oceanographic applications and research at high resolution (better than 25 km and at least daily) to those of climate and climate change (coarse resolution but high in terms of accuracy).

The present operational sea surface temperature measurement network is sustained through complementary satellite and *in situ* measurement systems delivering products of modest accuracy (around 0.5°C) at intermediate resolution (order of 100 km at weekly time scales). **The Conference strongly endorsed a continuation and strengthening of this network with increased focus on the quality and accuracy of the long-term record and on improved integration of available remotely sensed data for high-resolution products.**

In situ observation coverage through VOS and drifting surface buoys remains poor in some locations and must be rectified. The uncertainty in the treatment of skin versus bulk measurements must also be addressed. For remote sensing, continuity of the higher accuracy ATSR-class measurements needs to be addressed and further research is needed on the assimilation and use of geostationary data for improved temporal resolution and microwave measurements for better spatial coverage.

4.1.2 - *Surface wind vectors*

Like sea surface temperature, the importance of good surface wind fields includes most user areas. Surface wind sampling capabilities have been vastly improved with the launch of various scatterometers this decade and the utilization of surface wind speeds provided by passive microwave measurements. The use of dedicated surface moorings (e.g. TAO) has also had a significant impact.

To support ongoing practical and scientific uses of wind data, the conference strongly endorsed provision of two scatterometers for sustained global daily coverage at around 25 km resolution, together with maintenance of support for *in situ* observations (particularly in the tropics). This strategy assumes continued support for analysis via NWP and re-analysis systems. The needed coverage is not assured for the coming ten years. The impact and utility of enhanced spatial and temporal resolution, including the diurnal cycle, should be carefully evaluated in the next decade using the projected multiple sensors that should be available and atmospheric data assimilation systems for global and regional numerical weather prediction.

4.1.3 - *The ENSO Observing System*

The El Niño/Southern Oscillation (ENSO) Observing System was set up to understand, monitor, and predict ENSO variations and consists of a network of voluntary observing ship lines (for both surface and subsurface parameters), drifting buoys, moored buoys (such as TAO and TRITON), and island and coastal sea level stations. SST, surface wind and surface topography measurements from satellites provide important complementary data sets. The utility of this network remains one of the most prominent and tangible examples of practical benefits accruing from the ocean observing system and real-time, free distribution of data. The pervasive influence of ENSO on time-scales ranging from the intra-seasonal to those of climate change mean the ENSO network also has utility far broader than ENSO prediction. **Maintenance of the ENSO observing network in the Pacific is accorded high priority by the Conference.** The Conference accepts that the detailed configuration will change as both knowledge and models improve. There is insufficient evidence at this time to recommend major changes though the demand for salinity and precipitation data, and the demand for expansion beyond the tropical Pacific are likely to influence future configurations.

4.1.4 - *Argo*

Recent advances in technology have made possible a major increment in *in situ* observing capabilities with the potential to close many of the wide gaps in our routine upper ocean measurement network. These data are important for seasonal-to-interannual climate applications as well as ocean prediction. Complementary ocean topography data are critical. **The Conference endorses *Argo*, an initiative to populate the global ocean with profiling floats, as an appropriate and effective strategy for large-scale sampling of temperature and salinity in the upper 2000 m of the ocean.** The expectation of the Conference is that *Argo* will become a fully sustained contribution over the next five years. The Conference agrees that the proposed sampling (order 300 km and every 10 days) is appropriate given the limited knowledge of global temperature and salinity variability.

4.1.5 - *Ocean surface topography*

The availability of precise measurements of ocean surface topography from space has had a dramatic effect on our understanding of ocean dynamics and contributed to an enhanced capacity to predict ocean and climate variations and monitor climate change. The remote sensing requirements can be met through a combination of continuing integrated missions of high-precision and low-precision/high-resolution altimetry. These data must be supplemented by a network of *in situ* measurements to calibrate the satellites and to produce accurate global determinations of sea level change (order 30 sites). **The Conference endorsed this strategy and emphasized the importance of identifying the mechanisms and funding for sustained operation at this level.** Critical complementary data include *Argo* (for baroclinic structure) and gravity missions for determination of the geoid (see Section 4.2).

Altimetric data also have utility for wave forecasting, surface wind estimation and other geophysical applications.

4.1.6 - *The surface marine network*

Surface marine data have important roles in addition to those covered above. These include the determination of global air-sea fluxes, inputs for weather prediction, the determination of surface salinity and surface current fields, and as inputs for ocean prediction. **The Conference endorsed a continued strong role for Volunteer Observing Ships (VOS) in the surface observation network, with emphasis on quality and a broader suite of measurements to better determine surface fluxes.**

The Conference made particular note of the increased emphasis given to salinity and of the intent to more closely coordinate VOS and SOOP operations. The present in situ network for salinity is most extensive in the western tropical Pacific. These observations have revealed a large influence of salinity on the dynamics and thermodynamics of the western Pacific warm pool region. The Conference **endorsed the continuation of the salinity network** (see also the ENSO Observing System). **The Conference also supported the continuation of a surface drifter program, particularly for remote locations and as a direct measure of surface currents.** Details of enhancements are covered in the next sub-section.

4.1.7 - *The Ship-of-Opportunity network*

The advent of Argo and precision altimetry has changed the environment within which the Ship of Opportunity Program (SOOP) operates. **The Conference endorsed the change in emphasis from broad-scale, areal sampling to line mode sampling (high-resolution or frequently repeated progressively over the next five years** and noted the synergy of this approach with *Argo*, altimetry and moored arrays. The Conference further noted the utility of such sampling in boundary regions and its unique role in heat and freshwater transport calculations.

4.1.8 - *Sea Ice Concentration, Extent and Motion*

Some sea ice measurements (concentration and extent) are sustained now through passive microwave observations and these will continue through the next decade. In addition buoys are used to monitor ice motion, notably as part of the International Arctic Buoy Programme. **The Conference recognizes the long-term need to monitor sea ice concentration, extent and motion and supports a sustained effort.** Enhancements for estimates related to surface fluxes and sea-ice thickness are also supported.

4.2 - Additional contributions and enhancements

In this sub-section we describe additional contributions and recommended enhancements that, for various reasons, should not yet be included in the primary network. These reasons include immaturity in, or lack of, clearly identified funding support mechanisms; the need for further planning and/or design studies; or immaturity of the knowledge and/or technical basis (that is, further experimentation is recommended).

As with the primary elements, we face a dilemma in terms of the order and mode of presentation. Each of the mentioned additions generated some level of interest and excitement. In some cases, it was the lure of a technological solution for a gap in the network. However, simply having promise is not enough -- there must be convincing evidence, either in terms of investment or in terms of initial results to warrant support here as a recommended enhancement/addition. In other cases it is regional and/or community commitment that is persuasive. A strong commitment to develop the investment and support is an essential step in the progress toward sustained operation. In yet other cases, the motivation is primarily scientific. That is, our scientific knowledge and our awareness of the societal factors that foster interest in environmental monitoring dictate that we must support a particular effort simply because it addresses issues that cannot be addressed in any other way.

We make no attempt to attach relative priority here other than to emphasize that all contributions have high priority for at least one of the rationales discussed in Section 3. The order of presentation is also not significant. We are fully aware of the tendency to attach greater priority to those aspects mentioned first, and reduced priority to those mentioned last. Other than generating a different order for every copy of these recommendations, we have no solution to this problem. In the end we opted to discuss global networks first, then remote sensing and finally regional and/or specific enhancements. We apologize if your particular preference does not fit well into this arrangement.

4.2.1 - *Global Enhancements*

In this sub-section we discuss those contributions that might be characterized as global network enhancements using direct measurement techniques. In other words, in relation to the scientific rationale, the enhancements a primarily aimed at problems that are global.

Hydrography and Carbon inventories

The topic of deep measurements drew considerable debate and discussion at the Conference. At one extreme, people worried that the field was not yet ready for any sustained measurements, while at the other there was an equally strong conviction that the approach to climate change and longer time scale problems would be fatally flawed in the absence of a systematic network. The latter view drew considerable strength from the resolutions associated with the Kyoto Protocol and the fact that monitoring and measuring the earth-system carbon cycle was now an issue of high political and societal interest. A special round-table session was convened specifically to examine the case for, and approach to deep measurements and, in particular, repeated hydrographic sections.

The relative importance of carbon inventories has been raised because climate change assessments require knowledge of the anthropogenic carbon (and related trace gas) inventories in the ocean and how they are changing. The inventories completed in 1997 as part of WOCE demonstrated flaws in our global carbon models. The models have been adjusted. However, neither the models or the global measurements of air-sea gas fluxes are yet reliable approaches to estimating future inventories and thus changes in storage. At least for the near-term, it will be necessary to make measurements of anthropogenic carbon and other tracers to provide new inventories. Such surveys will extend over the full depth but me more closely spaced in regions near carbon injection, and more widely spaced and limited in depth in areas where tracers have not yet penetrated into the deep waters. Moreover the frequency of such surveys will be less as one moves away from the injection region where changes are mostrapid.

The Conference concluded that the overall approach to deep measurements should change and that the over-riding consideration now should be the need to measure and monitor carbon inventories. An initial plan, consistent with this rationale, was drafted with the commitment to further develop this plan under the leadership of the CLIVAR research programme. The repeat hydrographic builds on this strategy as well as other regional commitments. Sampling from other network contributions such as *Argo* and SOOP are an important complement to this strategy.

Fixed-point time series

The above strategy might be termed a "deep line mode". **The Conference also recognized and endorsed the important complementary strategy of deep, point measurements and recommended the sustained support of a select number of fixed-point time series stations.** It was noted that fixed-point data do have wide applicability. Fixed location measurements are already established at various locations and enhancements for the North Atlantic are at an advanced stage of commitment. The multidisciplinary advantages of time-series stations are well accepted and they are a valued contribution for validating satellite ocean color measurements. The Conference encouraged the development of an implementation plan for the global network, based on the plan presented at the Conference, with the view toward a staged deployment over the next five years and demonstration of the capability to operate as a sustained, real-time network.

Surface reference data sets

In the climate community, the concept of reference sites and/or reference data sets is attracting considerable attention. This is principally because of the interest in climate change and a sustainable marine environment, but also draws on the idea of defining data sets that can be used to calibrate and tune models. High quality is the over-riding characteristic, with continuous records, preferably of some length, being important additional features. **The Conference accepted that high quality surface reference data sets were now in demand for testing weather prediction, re-analysis and coupled climate models and that sustained observing system should devote some resources to fulfilling this need. A network of selected surface reference flux sites and a selected network of climate quality Volunteer Observing Ship lines (VOSCLIM) were endorsed as an appropriate contribution.** The plan for the surface reference sites was incorpated in the fixed-point time series plan discussed above.

4.2.2 - *Remote sensing*

Remote sensing research is driven by both technological challenge and societal need. For the most part, experimental missions over the next 5-10 years have already been decided and many of the participants in this Conference have played significant roles in those decisions. In this sub-section we restrict the discussion to those developments that, in the view of the Conference, represent a high priority enhancement to the global networks described in Section 4.1. Six areas were considered to represent potentially significant contributions, with varying degrees of technical and scientific challenge.

Precision Gravity Field or Geoid

The Conference confirmed the value of improved estimates of the static (geoid) and time-dependent gravity field for oceanography and in particular for estimates of the ocean circulation (with altimetry). Several missions are planned, with varying degrees of accuracy and spatial resolution. In addition to altimetry, direct surface and subsurface measurements of ocean currents are considered an important, complementary data set.

Salinity

An inability to provide synoptic measurements of global salinity variations represents a significant gap in our primary capabilities. The Conference strongly supported the experimental development and demonstration of space technologies that can provide long term surface salinity data. The utility of such methods will need to be considered in conjunction with the enhanced capacity to measure salinity directly from *Argo* and other platforms (see below) and the availability of reliable surface precipitation estimates.

Sea-ice thickness

An inability to monitor the temporal and spatial variations in ice thickness for the ice-covered ocean constitutes a significant gap for several climate problems, particularly those requiring a determination of the heat and freshwater budget. The Conference welcomed exploratory remote sensing missions aimed at providing useful ice thickness measurements.

Sea Surface temperature

The major issue is to pursue the development of integrated products based on data from different platforms in order to realise sea surface temperature estimates to better than 0.4°C on fine (order 20 km) global grids.

Ocean Biology:

The Conference accepted the endorsement given by GOOS for sustained ocean color measurements and noted the utility of such data for climate and physical oceanography applications. There remain significant scientific challenges and long term continuity needs are yet to be defined.

Surface waves

The Conference noted the utility of SAR data for wave applications and ice studies. Enhanced availability is sought though the considerable cost will be a limiting factor.

4.2.3 - *Regional Networks and Other High Priority Enhancements*

It is beyond question that focussed regional initiatives offer a viable route for building and enhancing the global sustained observing system. **The Conference concluded that implementation should have both regional and global initiatives**, with the proviso that all initiatives and contributions should be consistent with the overall design and implementation principles. The Tropical Atlantic and Indian Ocean were the focus of considerable discussion at the Conference, principally because strategies were in place to develop a network for these two areas. It is equally important that strategies be developed for other regions, either through regional initiatives, or through special efforts within projects like *Argo*. We also include acoustic tomography here though we recognize that there is considerable potential in global acoustic thermometry methods. In the end it was the regional implementations that drew strong support from the Conference.

The Tropical Atlantic

The success of the ENSO observing system has led to the development of plans for the rest of the tropical oceans. For the tropical Atlantic the principal rationale is related to the search for predictable tropical modes on seasonal-to-interannual time scales. The Climate Observing System for the Tropical Atlantic initiative is attempting to piece together various contributions from the region into a coherent network, using the common link to regional climate to draw interest and involvement from many nations in this region. **The Conference endorsed this approach and made particular mention of the PIRATA array, a research Pilot Project to determine the effectiveness of tropical moorings in the Atlantic.** The view of the partners in this effort is that components of PIRATA and associated measurement systems should be ready for transition to sustained support within five years. Satellite observations, SOOP and *Argo* were seen as critical elements of this strategy.

An Indian Ocean Network

Despite the considerable interest in the Indian Ocean, on time scales from the intra-seasonal to those of climate change, a sustained network remains elusive. **The Conference endorsed a strategy to develop a coherent plan for the Indian Ocean, embracing all regional interests from ocean forecasting to climate change, and using existing and intended implementations as a basis for the development of a sustained network over a 5-10 year time frame.** Concerted studies of the value and design of an Indian Ocean network must be carried out over the next five years. Potential contributions include SOOP, *Argo*, moorings and a range of surface sampling. Satellite observations, particularly altimetry, are regarded as an essential contribution. Improved prediction of seasonal-to-interannual climate variations provide the immediate applied motive, while improved understanding of the Asian-Australian-African monsoon system and its related climate impacts provide a strong scientific motivation.

Acoustic tomography

The Conference was provided with a detailed account of the potential for acoustic tomography to make sustained contributions to the observing system. Till this point, it was a technique that had not figured prominently in the planning for either GOOS/GCOS or for CLIVAR. In terms of the scientific approach to sampling the full depth of the ocean, globally, acoustic tomography offers some attraction since it provides long-path, integral measurements of thermal variations to complement those from *Argo* and satellite altimetry.

The Conference concluded that acoustic tomography did represent a potentially valuable approach and that, initially, it should be implemented in the Arctic and at specific locations such as the Straits of Gibralter. The Conference also encouraged an exploratory implementation in the North Atlantic in the presence of substantial profiling floats to test the complementarity and/or redundancy between tomography and other measurements.

Boundary Current Networks

Measurements in the oceanic boundary currents are important for monitoring and studying integral quantities such as heat and freshwater fluxes and for short-range ocean forecasting systems. The strong gradients, rapid flow and long-stream meandering and eddies provide challenges that are shared among all the basins and make the design and implementation of an effective measurement network extremely difficult. The Conference discussed several different approaches including regular XBT/XCTD cross-sections, moored current meter arrays, ADCPs and remote sensing. While there are several examples of successful monitoring efforts, in general it seems the logistics of covering all the major boundary current regimes is beyond the capability of present technology.

In terms of specific need, the Conference noted that gliders (self-steered profiling floats) offered a potential effective solution for repeated sampling through narrow, swift boundary currents. Based on the cost of present prototypes, it seems that such devices may well provide the cost-efficiency that is presently missing.

4.2.4 - Other technological developments

The Conference included presentations on many novel and developing techniques, some of which offer immediate potential, others which will require significant research and development. Autonomous Underwater Vehicles (AUVs) offered the potential for specialist solutions in some areas. It was noted that the development cycle for new technology is typically 10 years, and that the transition from research demonstration to sustained operation may typically add another five years. **The Conference emphasized the important contribution being made in technological research and development, both for developing new methods and for providing more efficient solutions.**

The Conference noted that additional physical and chemical measurements may be possible from the new generation of platforms, including tropical moorings and profiling floats. There was a pressing need to develop more cost-effective methods for repeat hydrographic sampling, either through better automation or through more cost efficient research fleet options. In particular, improved automation and technology for carbon and tracer measurements was badly needed.

4.3 - What is Required for Integration and Management?

While the focus of the Conference was on sustained measurements and measurement networks, an implicit theme was that these efforts would only be fully effective if implemented in conjunction with model and data assimilation systems and with efficient and effective data and information management systems. The use of models and data assimilation are fundamental to the concepts of integration. Indeed, it is argued that the effective use of models and data assimilation is one measure of the maturity of the system.

The Conference discussed the broad application of models and data assimilation but did not have as an objective the assessment of such tools. However it is clear that the capacity of models to ingest and exploit observations has a direct bearing on the emphases given to different networks. The ability of ENSO models to develop predictions based on initialization with ocean data is a powerful argument for the sustaining of Pacific Ocean observations. In a truly integrated system, it is difficult to separate impact of data from the capacity of a model to exploit information, since the latter can both inhibit and enhance the former.

It is also clear that the ability to deliver data from the networks to the users, in a timely fashion, and to then organize the data so that it can be brought to maximum effect for both research and operations, is a critical aspect of the observing system. Examining the capacity to sustain these functions is as important as the need to sustain observing networks.

We briefly discuss both these aspects in this sub-section.

4.3.1 - *Modelling and data assimilation*

The role of ocean modeling and ocean state estimation (assimilation) is to bring the diverse ocean and climate observations of the various networks together to form a complete picture of the evolving ocean, thus making maximum use of the data.

The ocean state estimation activities need to serve a variety of community needs ranging from near-real-time operational ocean predictions (eg, GODAE) to high-level climate research in a re-analysis mode (CLIVAR). For these modes, there are different requirements in terms of data availability, data quality and quality and accuracy of the results.

For the purposes of this Conference, the climate mode of ocean state estimation has been given specific attention with applications ranging from those of ENSO prediction to those requiring a full-depth, dynamically consistent estimate of the evolving ocean state over a time in excess of 50 years. The latter applications reside primarily in the research community while the former are now being run both as experimental systems in the research community and as operational systems at various centers. While for ENSO prediction it is sufficient to focus on the tropical Pacific region, at least with the present class of models, for long-term ocean state estimates a more complete picture is required with circulation and surface flux fields that are consistent with the momentum, heat and freshwater balance of the evolving ocean.

Coupled models for seasonal-to-interannual prediction are the most prominent example of ocean data being exploited for climate forecasts. Much remains to be learned about predictability at longer time scales, knowledge that is vital if data are to be used for initialization. Extensive use is made of data, and ocean state estimates, to test and improve coupled models.

Short-range ocean prediction out to about a month provide special applications for the GODAE community, with the emphasis on timely, practical products. In this case the emphasis will be on the rapidly evolving part of the ocean state, including the mesoscale eddy field and frontal evolution, as well as full-depth boundary conditions for regional models (eg, coastal prediction systems).

The Conference emphasized the central role played by model and ocean state estimation and encouraged even greater efforts in this area. The Conference recognized the limitations imposed by computing resources and encouraged greater investment in Centers that facilitate high-end modelling and ocean data assimilation.

4.3.2 - *Data and information management*

Many papers at the Conference discussed the increasing importance accorded to efficient and effective management systems for oceanographic data and related information. TOGA, WOCE, and a range of individual and collective efforts have greatly enhanced our handling of data. Good data and information management systems (D&IMS) add considerable value to data sets through enhanced quality, enhanced good data return, synergistic assembly of related data, enhanced utilization and uptake of gathered information, and more rapid feedback from user to provider.

The Conference noted that **a sustained observing system requires a sustained data and information management system.** Many D&IMS are at present tied to projects with finite lifetimes, both at the platform level (eg, the system used by TOPEX/POSEIDON) and at the Programme level (eg, WOCE). Just as we are relying on Pilot Projects and other means of demonstrating robustness and effectiveness to justify networks being transitioned to sustained support, we must also develop strategies to achieve this effect for the D&IMS. The D&IMS must evolve with advances in technology, learn from mistakes of the past and be continually evaluated to determine effectiveness and the relevance to research and societal needs..

In line with the Vision for the Conference, **The Conference welcomed the introduction of a "new Paradigm" for oceanographic data systems, one where rapid dissemination and wide sharing of data is the norm**, not the exception. The Conference concluded that such a paradigm would stimulate wide and open participation in both data gathering and data usage, greatly expanding the community of ocean data users. In so doing, the community delivered benefits and added value to the resource providers and resource users. The implementation of a GODAE data server at Monterey is evidence of a broad commitment to this principle. The general acceptance of real-time data sharing for all networks of the sustained observing is perhaps the most striking indication of this change in approach.

The Conference endorsed the conceptual model of a dual data stream, one stream with focus on rapid, automated delivery of all data, and the other on delayed, higher-quality data. The rapid stream would use fast communications and existing and developing automated procedures to enable delivery within hours of a measurement being taken. The delayed-mode stream would have concentrate on scientific quality and would aim for turn around time commensurate with the technical and scientific issues and the usage of the higher-quality products. The norm would be a few months, not several years.

The Conference further noted the need to streamline procedures and the organizational support for D&IMS. In particular it noted the need for integration and coordination of information systems. **The Conference welcomed the creation of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) and encouraged all relevant groups within research and operations to seek efficient, well-coordinated solutions to the joint problem of ocean data and information management.**

The Initial D&IMS

The Conference agreed that past endeavors had established a sound basis upon which the new era could build. The Conference noted the several organizational groups charged with developing aspects of the D&IMS for oceanography and climate and recommended a high level of coordination and cooperation among these endeavors. The Conference emphasized the critical importance of a well-coordinated and efficient system and that there was an urgent need to assess the state of extant systems and take steps to transition needed components to a sustainable mode.

The basis for this transition will be derived from data systems, such as

(a) The extant marine meteorological data systems, now coordinated by JCOMM;
(b) The real-time sea-level data systems and the extant sustained efforts within GLOSS for *in situ* sea level;
(c) The several data delivery services associated with operational and exploratory satellites, such as U.S. Data Archive and Access Centers (DAAC) (check acronym) and the French AVISO system;
(d) The TAO (and TRITON) data systems;
(e) Telecommunication such as provided by the Global Telecommunications System and specialist services such as System Argos;
(f) The upper ocean thermal data assembly centres and associated projects (e.g., the GTSPP), now within the remit of JCOMM; and
(g) The WOCE Data Information Management System;

General issues

The Conference concluded that greater effort must be expended in assembling, and making available, integrated oceanographic data sets. The oceanographic community and users from outside this community are greatly empowered when impediments to data access are reduced. There are emerging techniques for enabling such capabilities and these should be encouraged.

The Conference noted that telemetry and communications continue to be a limiting factor in oceanography and that every encouragement should be given to easing or removing this restriction. While great strides have been made over the last several decades (a paradigm shift in itself), the move toward rapid dissemination and immediate telecommunication from platform to labs has greatly added to the communications burden. Improved satellite communications and the development of specialist data servers are important advances.

The Conference endorsed the strong emphasis given to data archaeology projects, such as the Global Ocean Data Archaeology and Rescue project (GODAR). These projects have greatly enhanced the amount of available information.

The Conference emphasized the importance of investment in data management at a level that ensures maximum benefit is drawn from the investment in associated observation networks.

5 - PLAN AND SCHEDULE FOR ACTION

Tables 5.1 and 5.2 provide a synopsis of how the networks described in the previous Section are to be created and provides a schematic outline of the schedule for implementation. The Tables are not comprehensive and do not include all the detail that was contained in the many Conference papers, nor are they intended to be definitive in terms of the schedule for implementation. We have tried to capture the important aspects both in terms of the identity/source of important contributions and in terms of the readiness. For the latter, we have adapted the color coding used by some mission-oriented agencies. White areas are used for periods dominated by planning and thinking. Red areas are used for periods where the scientific case is clear, the community consensus is clear, but the actual observations are missing. The failure of NSCAT produced a red patch (not shown). Blue areas are used for experimental systems or research program pilot experiments. PIRATA is a good example of such a system. Yellow areas are used to designate systems that are running in trial sustained (pre-sustained) mode but have no long-term commitment, for whatever reason. TOPEX/POSEIDON is a good example. Green areas are used for committed, long-term sustained systems (meteorologists might use the term "operational"). The ENSO network in the Pacific is an example. This does not of course imply "do not change or enhance", but simply that there is some long-term commitment to provide this component of the network.

No aspect of the global network is free from funding pressures and there are many decision points that will influence the path toward a fully sustained network. There should be no surprise in the fact that the Conference agreed the needed investment was warranted. However, the fact that the Conference worked extremely hard to avoid a "wish list", should be properly seen and acknowledged as a sign that the community realizes the observing system must be fully justified from a broad scientific and societal base and that only those elements that are valuable and worthy of being sustained should be sustained. This does not mean that short-term experimental systems and process studies are not highly valued, but rather that the community accepts that a sustained system must be selective and targeted, not eclectic and aimless over the longer term.

5.1 - Action list for the primary network contributions

The primary network (Table 5.1) reveals a sound foundation for most components and the short-term future seems reasonably secure. There are no dreams or starts from a zero base. There are however several critical points in the short- to medium-term, some having immediate importance, others holding implications for the long-term.

(a) There are no commitments for sustained altimetry beyond the present *Jason* and *ENVISAT* missions. A decision is required now.
(b) Full global implementation of *Argo* depends on favorable funding decisions and a willingness of participants to divert some resources away from the immediate national interest for the sake of the global integrity of the profiling float system.
(c) Potential gaps appear in the wind vector measurements from space that may compromise our ability to resolve surface winds, for both oceanography and meteorology, at the requisite time and space scales.
(d) Scientific study and decisions are required for analysis procedures for SST and winds in order to maximize the resolution and accuracy of such products, consistent with stated requirements.
(e) Commitment decisions are required if we are to avoid significant gaps in the surface marine data sets, including remotely sensed SST, and there needs to be greater commitment to quality observations.

(f) Salinity measurements are required for ENSO and global problems but our capacity to obtain such data depend on scientific, technical and resource decisions.
(g) There are a variety of decisions required for the transition of the existing SOOP from areal mode to line mode.

Assuming mostly favorable outcomes from these decisions, Table 5.1 suggests that by 2005 the community should have sustained investment in, and benefits from, operational satellites for SST, sea surface topography and surface wind vectors; complementary global upper ocean temperature and salinity profiles from a range of platforms; a tropical observing system capable of providing the data for ENSO forecasts and improved understanding; a high-quality surface observation network, including sea level, delivering high-quality products and appropriate calibration data for satellites.

5.2 - Action list for the selective enhancements

Measured against the requirements implied by the highest-priority scientific and applied objectives (Section 3) and the actions outlined above, the primary network will be deficient in several areas. It is for this reason that the Conference recommended a parallel stream of selective enhancements implemented over a somewhat longer time frame (2000-2010; see Table 5.2). The key issues are:

a) Selective expansion of the ENSO observing system to include salinity measurements, moorings and other instrumentation in the Indian Ocean, and, where appropriate, expansion into the subtropics.
b) A network of deep measurements to complement the upper ocean network and information drawn from satellites, including hydrography and carbon inventory measurements, fixed-point time series and an initial regional program of integral measurements from acoustic tomography. The detailed schedule is subject to further planning. For acoustic tomography, there is support for a pilot project in the N. Atlantic.
c) Dedicated projects (satellites and *in situ*) to address technical barriers for global surface salinity measurements and ice thickness measurements.
d) Continuous ocean color measurements.
e) Establishment of integrated networks in the tropical Atlantic (under COSTA) and in the Indian Ocean. For the latter, workshops are planned to initiate the process.
f) Targeted research to improve the methodology and techniques for monitoring in the western boundary current regions.

5.3 - Important areas of in-action

The conference heard of many other major issues, challenges and gaps in coverage that need to be addressed over the next decade. It was not clear how these issues were to be addressed, nor on what schedule we might expect solutions.

The action plans for the Southern Hemisphere contributions to the global ocean observing system lag in relation to the Northern Hemisphere. The remoteness of many of the Southern Hemisphere oceans from the interested nations inevitably leads to subdued scientific interest and muted commitment to deployment and maintenance of observation systems. This has been an issue for meteorology for many years and is looming as a severe issue for the ocean community, made more so by the prominence accorded to long-term climate variations and climate change. The Conference heard presentations on the Indian Ocean, Southern ocean and South Atlantic that testified to severity of such problems.

The Conference did not have a solution and was not inclined to use Recommendations/Resolutions as a substitute. The only effective way forward was to (i) provide articulate and feasible scientific plans, with a broad scientific and applied basis, and justified by societal interest; (ii) seek consensus among the community for an action plan to address these requirements with a clear plan for investment; and (iii) exploit international cooperation and synergy between the scientific and applied communities to implement and maintain these systems. Plans for Indian Ocean and Southern Ocean Workshops in 2000 were welcomed.

The Conference focussed on sustained observations but also discussed many examples of process experiments and other research observations. The Conference noted the fundamental importance of such research to the development of the observing system and drew attention to the fact that resources for such work were under strain. Syntheses and model data assimilation are only as strong as their weakest assumption or parameterization, and strengthening of such weaknesses inevitably involves access to high-quality data and knowledge from intensive process studies. These are not mentioned explicitly above since they are not a candidate for sustained support, yet they are a vital contribution to the action plan and to the health and evolution of the system.

6 - IMPLEMENTATION AND INFRASTRUCTURE

6.1 - Implementation strategy

6.1.1 - *Organizational mechanisms*

In 1999 a significant decision was taken jointly by the IOC and WMO to create a Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM). The JCOMM replaces the Commission for Marine Meteorology and the Integrated Global Ocean Services System. Until this point, the community had a rather disjointed implementation structure, in large part a reflection of the immaturity of oceanography as an applied discipline. The JCOMM provides a single focus for implementation for much of the networks discussed at this Conference and the Conference agreed that its creation was a significant moment for the development of a sustained observing system.

Table 6 attempts to indicate where the prime interest for each of the networks lies in terms of scientific design and assessment and technical issues and implementation. There is no need here to summarize the several organizations that are involved at the highest levels of scientific oversight. However, if implementation is to proceed in an orderly fashion, with adherence to agreed priorities and scheduling, it is important that the guardianship is clear for both science and implementation. Despite concerted attempts to rationalize these structures, Table 6 suggests there is still a way to go before the organizational structure is clear and efficient. In part this is due to the fact that several important activities are in experimental or pre-sustained (pilot project) phases. However, as progress is made with implementation (Tables 5.1 and 5.2) it is important that the organizational structure also evolves and matures.

Network Component	**Scientific Panels**	**Implementation Oversight**
Acoustic tomography	UOP/OOPC	?
Altimeters	Science Working Teams	Science Working Teams
Argo	GODAE/UOP *Argo* Science Team	*Argo* ST
Data management	DPC? JDIMP?	JCOMM, DPC
ENSO prediction assim.	CLIVAR WGSIP/OOPC	CLIVAR WGSIP/OOPC
Fixed-point time-series	OOPC/UOP	Pilot Project ST?

Network Component	Scientific Panels	Implementation Oversight
Global Tide Gauge	GLOSS/OOPC/UOP Sea Level Working Group	GLOSS
Gravity/GEOID	Science Working Team	Science Working Team
High Resolution SST Analysis	GODAE ST	Pilot Project?
Hydrography, carbon inv.	UOP/CO2 Panel	?
In situ SST	OOPC/AOPC SST WG	VOSCLIM of JCOMM
Ocean Carbon flux	IOC CO2 Panel	?
Ocean Color	IOCCG	IOCCG
Ocean forecasts, estim'n	GODAE/WOCE	GODAE
Satellite SST	OOPC, GODAE ST	?
Satellite wind vectors	Science Working Team	Science Working Teams
Sea-ice measurements	ACSYS/CLIC, OOPC	?
Ships-of-Opportunity	OOPC	SOOP IP
Surface data buoy	OOPC, UOP	DBCP of JCOMM
Surface salinity	UOP	?
Surface waves	OOPC/?	JCOMM
TAO / TRITON	WGSIP, UOP, OOPC	TAO IP of GOOS, GCOS, CLIVAR
VOS surface marine data	OOPC, JSC Air-Sea Flux WG	VOSCLIM of JCOMM

Table 6.1: Scientific and technical groups for network contributions

The OOPC and UOP, the joint conveners of this Conference, are the panels through which much of the scientific advice is filtered. They in turn have advice provided by several specialist groups, many of which are listed in Table 6. For space observations, the Global Observing Systems Space Panel is the prime scientific group. Implementation oversight for remote sensing comes in several forms. Recently the partners in the global observing systems cooperated in the formation of an Oceans Theme Team that has played a large part in the coordination and consolidation of implementation recommendations for remote sensing. The conclusions of the Conference match those of the Theme Team. It has also been recognized that some global observations are not well suited to the intergovernmental implementation mechanisms, principally because of the need for involvement of academic institutions. The Conference welcomed the formation of a Partnership for Observations of the Global Ocean to provide coordination between the ocean research institutions of the world.

The issue of transition of research systems to sustained support occupied significant time at the Conference. The developments discussed in the preceding paragraph are in essence an attempt to re-orient out structures so that such transitions are easier. It is also important that remote sensing and in situ issues are considered jointly. This is happening regionally, for example through coordination between EuroGOOS and EUMETSAT.

6.1.2 - *Regional and global*

In addition to the many talks on why the sustained observing system should be created, and what contributions are likely to be put in place, the Conference also heard presentations on how implementation might be approached. Some of these involved what we might term "global pilot projects" (demonstrations of effectiveness and utility), while others might be termed "regional initiatives". The Pacific Basin Extended Climate Study (PBECS) and the Atlantic Climate Variability Experiment (ACVE) are two such examples within the CLIVAR Programme.

Regional implementation is motivated by the fact that at least some of the important modes of climate variability can be regarded as regional, much as ENSO was regarded as a regional problem during TOGA. Following the TOGA example, regional partnerships are exploited to develop a coherent, integrated observing system with the over-riding scientific rationale being provided by regional climate modes. Such an approach has natural attractions for the partners since it more closely aligns the investment and return with issues that have regional prominence. They are not being asked to invest remotely on an assurance that they are impacted by remote forces, a concept that can be hard to sell politically.

The global approach takes a more pure line from the combined rationales presented in Section 3 and argues that a well-designed global system can meet all requirements effectively, and because it is a single system, can provide solutions that are far more cost-effective and stream-lined than a collection of regional systems for the same end purpose. Such an approach calls for wider international cooperation and thus has the potential to be both more unwieldy and harder to sell locally.

The Conference did not overwhelmingly favor one approach over the other, instead choosing to recognize the benefits of both approaches. However the Conference did conclude that, no matter which approach is being used, the ultimate goal must be to contribute to the establishment of an integrated and cost-efficient global system, and that the system must be managed in such a way as to maximize the cooperation and coordination while delivering maximum benefit to those who have invested in the system.

The prioritization of the different contributions will to some extent depend on the approach to implementation. For a regional approach, the contributions that have the most direct impact are likely to be weighted highest. Less weight will be given to global issues and little or no weight to applications from other regions. The Conference accepted this as the reality but pointed out that in both CLIVAR and GCOS/GOOS, significant weight has been given decadal and climate change issues, and that ultimately, the global observing system must be capable of addressing these issues, even if the benefit will not materialize for some time.

6.2 - Infrastructure

6.2.1 - *Networking the networks*

Quite clearly, with the range of networks and platforms involved, and with the wide variety of end users, there must be a robust system for communicating data from platform to shore-based laboratories and/or operational centers, and efficient and effective systems for ensuring data are assembled, quality controlled and distributed in a way that maintains, or adds to the value of the original data. The Conference did not discuss these issues in detail though, as noted in Section 4, the Conference agreed that there were major issues. The truism about strength and weakest links can be applied to networks also: an integrated observing system can only be as strong as the (weak) links between its component parts. The observing system needs increased attention to the networking of all the contributing parts, such as listed in Tables 5.1 and 5.2, in order to ensure that the concepts of integration, global cooperation wide data distribution can be made real.

6.2.2 - *Models and data assimilation*

Over the next five years there will be a dramatic increase in the utilization of measurements from the global ocean observing system by ocean model/data assimilation systems. The Global Ocean Data Assimilation Experiment (GODAE) is designed to accelerate this uptake and to broaden and strengthen the community of data users. GODAE exemplifies many of the ideals espoused by the Conference for global observations such as integration of data sets, exploitation in sophisticated models and ocean state estimation systems, and expanded exploitation of data by providing its benefits to a broader range of users. The degree to which GODAE is successful will in part be a reflection of the degree to which the ideals of integration and assimilation of data by models has been carried out.

There are of course many modeling and data assimilation activities that are beyond the domain of GODAE that are relevant to the development of the observing system. Indeed, for climate problems, there will continue to be a strong demand for data to develop climatologies and to test coupled climate models. The important theme from the Conference however was that, just as the barriers between the remote sensing community and ocean-going community have come down, so must the barriers between data gatherers and modelers. A partnership yields mutual benefits way beyond those possible if the communities work in isolation.

6.2.3 - *General needs*

Ocean observations and syntheses require a very unique infrastructure. The demands and requirements for this infrastructure are undergoing a rapid evolution with the advent of satellites, new in water measurement techniques, and improved model/assimilation systems mature. Some of the future issues for infrastructure were discussed at the conference and need immediate attention. These include: Ships, Computers, Modeling centers, Data assembly/Quality Control centers, communication systems/distributed networks and synthesis efforts, such as GODAE. Some progress on these issues can be expected from national agencies and forums, such as the European Union Fifth Framework program. The conference encourages international attention to these issues to facilitate the development of a truly global ocean observing system.

6.3 - Evaluation

Assessment of the effectiveness of the observing system provides its own set of challenges. At this time the Conference was only able to describe metrics in a very general sense. Moreover, because both the techniques for gathering data and the methods for applying data (the impact) change continuously, whatever system that is put in place must be able to cope with such change. The concept of "rolling requirements and review" based on assessments of impact and progress in methodology has been used elsewhere and was put forward as a sensible approach for the sustained ocean observing system.

Over the last decade infrastructure in the form of international and national committees have been put in place to oversee the development of the ocean observing system. As the systems mature, the process and responsibilities will change from that of design and implementation to implementation and assessment. For the case of the observations themselves, the data and product flow should be evaluated routinely.

The Tables presented in the previous section perhaps give the basis for measuring performance and impact. What is needed are equivalent tables listing the anticipated impact (utility) of the data. The Ocean Observing Panel for Climate (OOPC) and CLIVAR Upper Ocean Panel (UOP) should begin to develop such metrics. There was also general support for the idea of complete reviews of the system by the international community on an approximate 5 year cycles (eg, a Second International Conference on the Ocean Observing System for Climate) in order to lay out the system in its entirety for scrutiny and scientific assessment. Several space agencies are already committed to such a review process.

7 - CONCLUSIONS

The goal of this Conference was to provide a strategy that will lead to an integrated, coordinated and sustained global ocean observing system for climate and related physical oceanography issues. The Conference has provided a vision for the next decade and an initial schedule for the implementation of the system. The primary objectives can be met on a five year time scale. The long-term objectives by the end of this decade.

There are several mechanisms under development that will facilitate the integration of the observing system components that are described in the earlier sections. These include: plans for basin scale implementations of observing systems to meet the goals of the CLIVAR science plan; the GODAE that will implement ocean model/data assimilation systems to provide near real time estimates of the state of the global ocean; global coupled atmosphere ocean models for climate prediction that require an integrated set of ocean observations for initialization; and global syntheses of observations to assess decadal and climate change for research and assessment purposes. All of these systems are discussed in detail in the Conference papers.

The system will evolve. The science research program outlined by CLIVAR will add greatly to our understanding over the next 10 years. With an enlarged observation program, this research will provide new guidance for governance of the ocean observing system. New measurements may need to be added to the list of sustained observations, and we are likely to either cease or replace some methods. Technological advances help us improve cost-effectiveness, sampling, and distribution. For example, the expected maturity of autonomous underwater vehicles either through passive techniques, such as gliders, or active systems will change the abilities or plans for *Argo*. For space observations, there is promise of remote salinity measurements and remote sea-ice thickness estimates. Science must guide the development and implementation of the observing system and must guide us toward adoption of new technologies and approaches.

Investment will, of course, be addressed by national agencies. The Conference Prospectus emphasized the need to address needed investment and the real benefits. Papers delivered to the Conference stressed the importance of balancing short-term and long-term benefits in order to draw the needed investment into long-term climate problems. The same logic applies to regional implementation – see it as a stepping stone to attracting investment in the global system, not as a barrier to global implementation. Even if allowance is made for the optisism of the advocates, it does seem the sustained observing outlined by the Conference is sustainable and worthy of being sustained. The measures of benefit that have been studied suggest a manifold gearing of benefit versus investment, though the Conference accepted that it is extremely difficult to quantify "public benefit". Considerable information has now become available of the costs and benefits of global ocean observations and the Conference agreed that greater effort must be devoted to such studies and its sharing so that national patrons can have a mutual understanding of the financial impact of building a global system with international partners.

The full impact of this Conference will not be known for some years. Initial indications are that its impact will significant and that its conclusions will have a profound influence on the future of the ocean observing system. It is more difficult to assess the Conference against some of its other objectives, such as drawing the disparate communities closer together and generating a sense of common ownership in the development of the observing system. The enthusiasm at the Conference suggested success but the true test is whether this enthusiasm survives the pressures that are bound to arrive on the path toward implementation. For the sake of the observing system, we must ensure that it does.

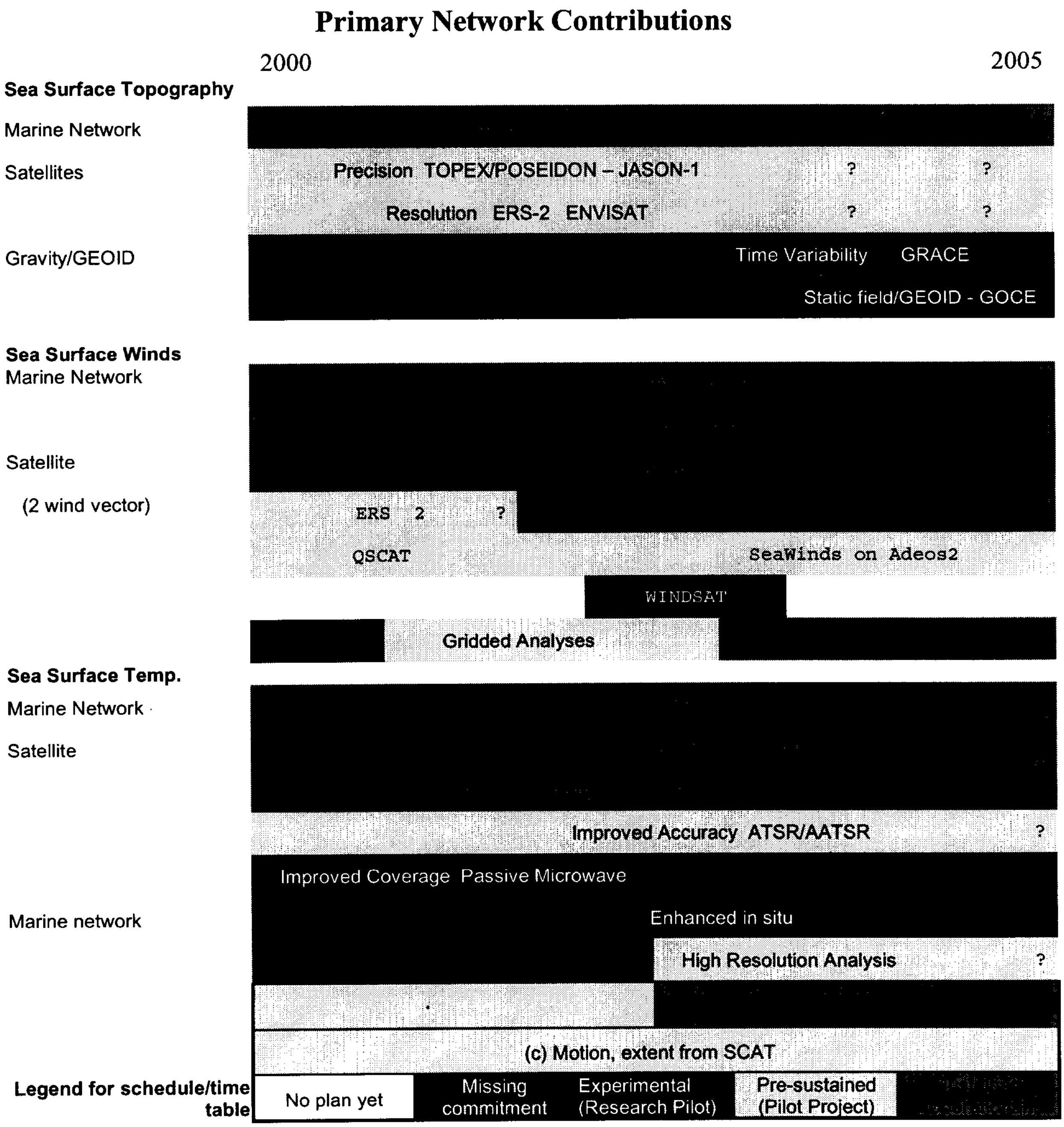

Table 5.1. Elements of the primary network plus the schedule for sustained implementation.

Primary Network Contributions (cont.)

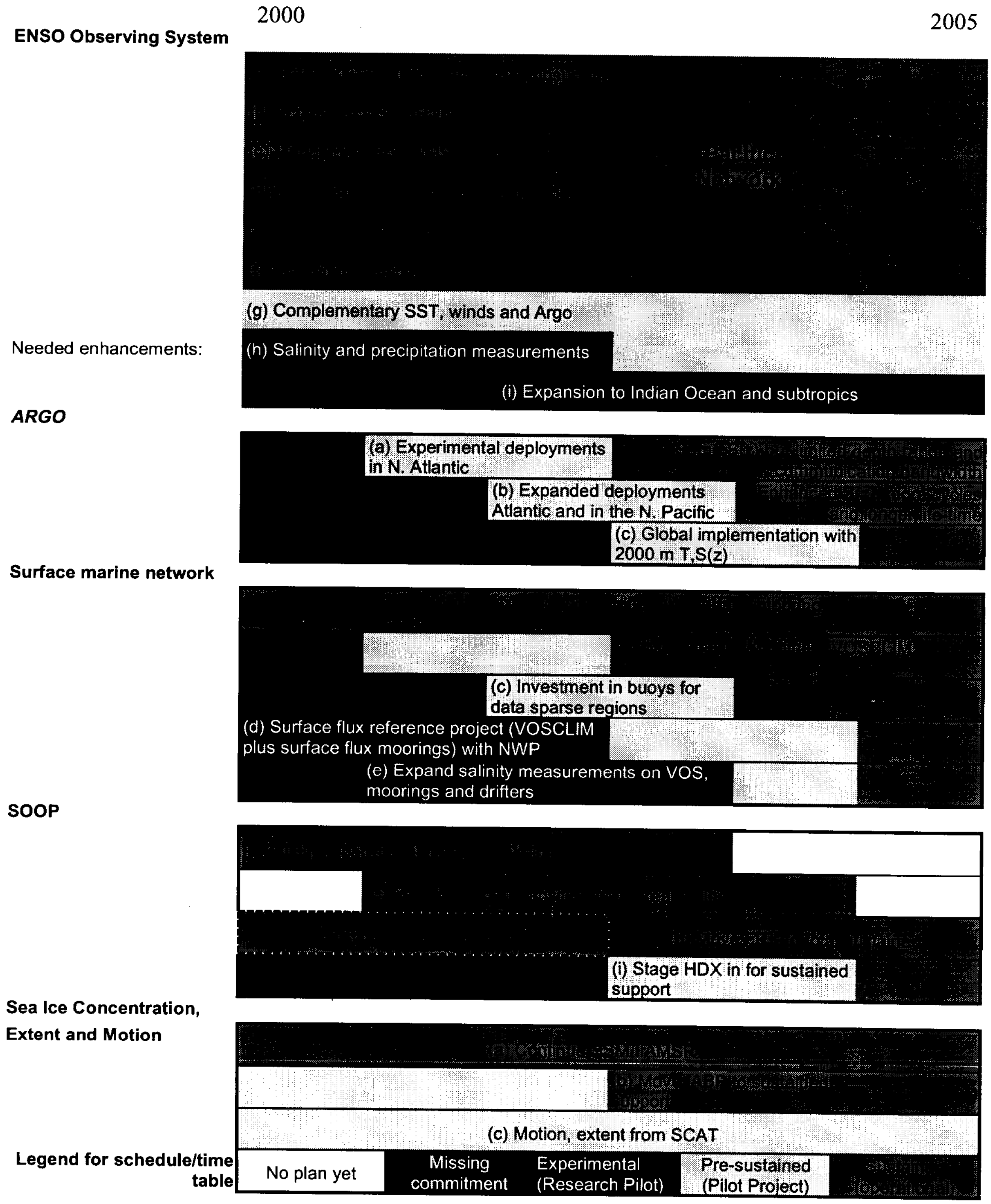

Table 5.1 (cont.)

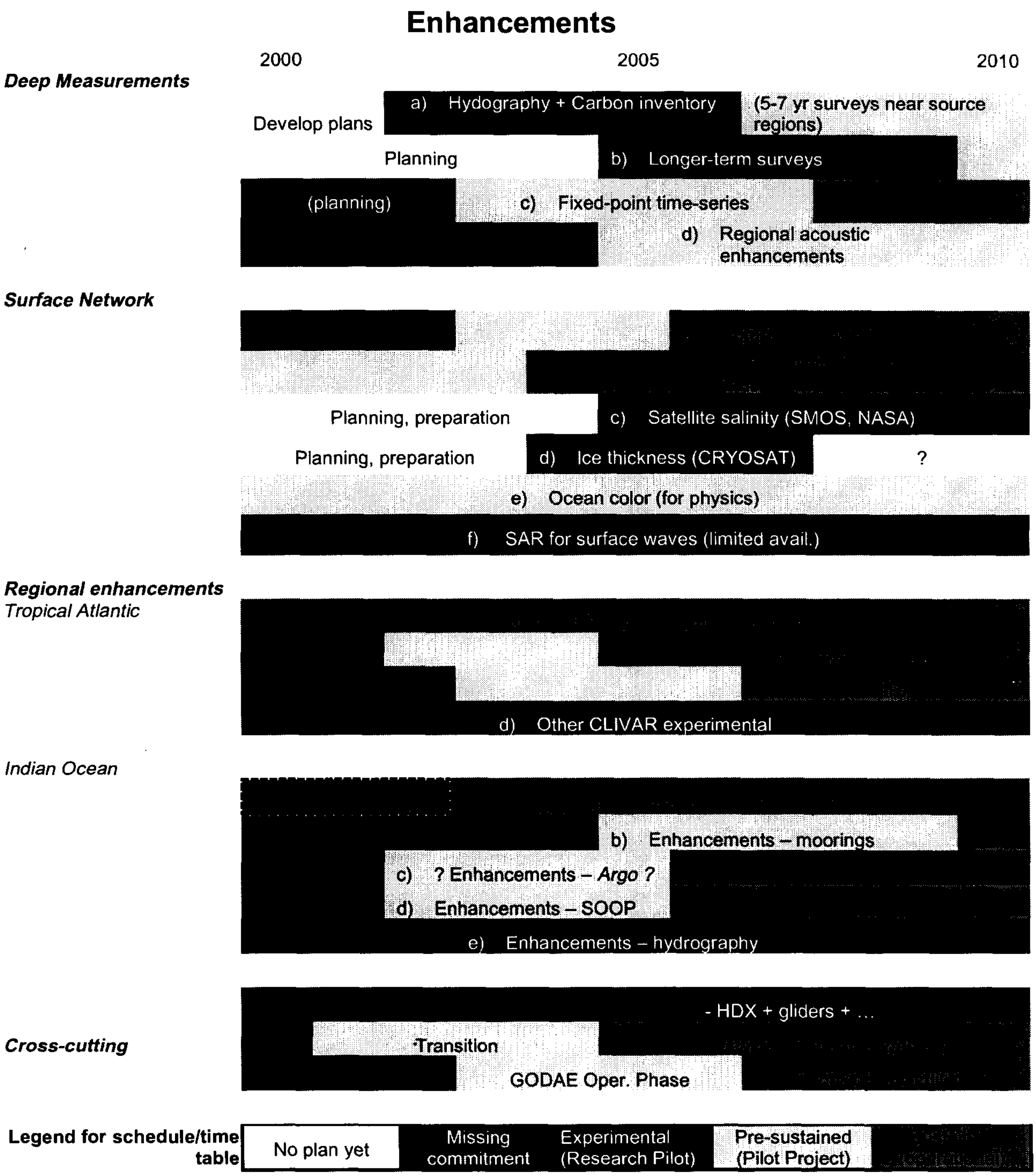

Table 5.2. Enhancements for the sustained network with schedule.