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# Global Physical Ocean Observations for GOOS/GCOS: an Action Plan for Existing Bodies and Mechanisms

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# GLOBAL PHYSICAL OCEAN OBSERVATIONS FOR GOOS/GCOS

## An Action Plan for Existing Bodies and Mechanisms

(Version 4.3)

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**ANNEXES**

## 1. INTRODUCTION

*Background*

1.1 All the relevant planning bodies for the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS), i.e. the Intergovernmental Committee for GOOS (I-GOOS), the GOOS Steering Committee (GSC), the Joint Scientific and Technical Committee for GCOS (JSTC) and the GOOS/GCOS/WCRP Ocean Observations Panel for Climate (OOPC) have called for urgent actions to be taken to begin the implementation process for those parts of the systems where requirements are specified and largely agreed. This applies in particular to global physical and related chemical (e.g. $CO_2$) observations to support the common GOOS/GCOS module, ocean services and some other parts of GOOS, and is given added weight by the developing concepts of the Integrated Global Observing Strategy (IGOS) and the Global Ocean Data Assimilation Experiment (GODAE).

1.2 At the same time, all the planning documents (e.g. the **GOOS Strategic Plan**, doc. GOOS Report No. 41, IOC/INF-1091) recognize the need to build such implementation as much as possible on existing systems and mechanisms, without being explicit as to how this is to be done or on the overall co-ordination mechanism obviously required. In addition, I-GOOS-III stated: "*To make progress in implementing phase 3 of GOOS (integration with existing systems), the Committee considered that it was timely for the managers of GOOS, the Integrated Global Ocean Services System (IGOSS), the International Oceanographic data and Information Exchange (IODE), the Commission for Marine Meteorology (CMM) and other global data and information generating and management systems to come together to decide how to take this phase forward*" (summary report of the session, doc. IOC-WMO-UNEP/I-GOOS-III/3, para. 53).

1.3 The existing bodies themselves (in particular the Data Buoy Co-operation Panel (DBCP), the IGOSS Ship-of-Opportunity Programme Implementation Panel (SOOPIP), the CMM Voluntary Observing Ships (VOS) scheme sub-group, the Group of Experts for the Global Sea-level Observing System (GE-GLOSS), the Committee on International Oceanographic Data and information Exchange (IODE)) have in turn expressed a readiness to participate in this implementation, provided explicit requirements and instructions are issued as to what they are expected to do. These bodies are all in the process of developing their own implementation strategies, which are endeavouring to encompass, to the extent possible, the requirements of GOOS/GCOS, along with those of their constituent interest groups (operational meteorology, climate research, global and regional ocean research, etc.). In addition, it is increasingly the case that the bodies are representative of the full range of platform operators, and thus can effectively co-ordinate such operations in response to expressed requirements. However, in order to fully implement the operational and global GOOS/GCOS physical ocean observing system, these bodies in some cases will need to expand and/or modify their procedures and operations.

1.4 This **Action Plan** has been developed to bring all this together, and to provide at least an embryo mechanism also for co-ordinating the *in situ* operations with those involving satellites. The document is essentially a strategy defining the role and responsibilities of the existing implementation bodies and mechanisms, initially for global ocean physical and related chemical observations for GOOS/GCOS but which can be later progressively extended to other components and/or types of observations. The plan involves a list of actions that will be implemented by the existing systems, so that these systems make specific or improved contributions to GOOS. They will therefore contribute to the eventual implementation of GOOS, but in the first instance it will be the systems themselves which do the implementing, in the context of this plan and within their own areas of responsibility. The plan also involves actions and improved structures to assist in the transition of research systems into an operational mode, putting into place implementation mechanisms that can support research-driven and research-supported ocean climate observations. To this end, the plan:

- explicitly states implementation requirements

- recognizes the areas of competence, strengths and weaknesses of existing bodies and mechanisms
- assigns specific **actions** to be undertaken by each body/mechanism, on the basis of requirements
- analyses where there are implementation gaps and specifies how these are to be addressed
- specifies how future developments are to be addressed (new requirements, technologies, etc.)
- provides a workable operational co-ordination and integration mechanism, to include also satellite observations.

1.5 This action plan is the next step in the GOOS/GCOS planning and implementation process after the **GOOS Principles, GOOS Strategic Plan, GOOS 1998** and the **GCOS Plan**. It also draws on the results of the extensive report on **GOOS Services** compiled by a GOOS working group, on the **IGOSS/IODE Data Management Strategy for GOOS**, and on the **GCOS Data and Information Management Plan**. At the same time, it does not attempt to pre-empt the full implementation plans which are being developed by the different GOOS and GCOS panels. Rather, it provides a background and context of existing activities within which these plans can be further elaborated. In addition, the plan recognizes the present uncoordinated and sometimes divergent approach to ocean monitoring of the existing systems, and attempts to provide clearly demarcated lines of responsibility, eliminating areas of duplication and ineffective implementation. This implies in turn an acceptance by the main parties to the plan that they will co-operate in and accede to the actions specified, with the consequent implications for their own implementation plans, responsibilities and, eventually, terms of reference and reporting procedures.

1.6 Before entering into details of the action plan, it is important to stress that any operational ocean observing system must be designed and implemented with the primary objective of providing a set of products and services to support the requirements of identified end users. It is impossible, and not necessarily very useful at this stage, to try to specify the complete range of such users, and their requirements, to be addressed by the system which is the subject of this plan. Nevertheless, it is important at the outset to identify at least a representative subset of such users. It is also important to review in a general sense the process by which observations generated by the observing system are transformed into the products and services required by this user subset. To this end, Annex I contains, firstly, a set of eight potential user scenarios for applications of the data generated by the observing system. This is then followed by the presentation of the concept of a production line approach to the provision of products and services. Such an approach is in general use in the provision of most services required by society, including meteorological services. Finally, this concept is elaborated in the context of the eight user scenarios presented earlier, to illustrate the full development of the observing system in practice, as well as its interaction with the end users.

1.7 Eventually, of course, a wide range of chemical and biological measurements will be required to be delivered operationally or in near real-time for GOOS. What these measurements might comprise is under active consideration by the GOOS panels dealing with the Health of the Ocean, Living Marine Resources and Coastal Modules, and new or modified actions plans will be developed to address them in due course. For the time being, however, the present action plan is confined to physical and related chemical (primarily $CO_2$) observations, firstly because it is for these that the requirements are best known, especially for climate-related applications; and secondly because the existing mechanisms are largely concerned with collecting and managing such data.

## 2. REQUIREMENTS

### 2.1 Oceans and Climate

#### *2.1.1 Background*

2.1.1.1 In the late 1980's, as activity in the Tropical Ocean Global Atmosphere Programme (TOGA) was reaching its peak and the observational programme of the World Ocean Circulation Experiment

(WOCE) was beginning, the then prime scientific bodies for ocean and climate research, the Committee on Climate Changes and the Ocean (CCCO) and the Joint Scientific Committee (JSC) of the World Climate Research Programme joined forces to create the Ocean Observing System Development Panel (OOSDP). The OOSDP was given the task of formulating a:

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

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

2.1.1.2 More detailed requirements for physical observations in the coastal zone, and off-shore in support of coastal models, will be provided in the near future by C-GOOS and the Global Ocean Data Assimilation Experiment (GODAE).

2.1.1.3 The OOSDP plan that emerged in 1995 (OOSDP 1995) contained a comprehensive review of the scientific issues and a set of specific recommendations for implementation of the observing system. Smith et al (1995) and Nowlin et al. (1996) contain shorter synopses. The plan contained four primary goals. The first focussed on exchanges with other components of the climate system, and in particular on the surface fields and surface fluxes which help determine the variability of the coupled ocean-atmosphere system. The 5 subgoals were estimation of (a) sea surface temperature (SST) and sea surface salinity (SSS), (b) surface wind stress, (c) surface fluxes of heat and water, (d) surface sources and sinks of carbon, and (e) the extent, concentration, volume and motion of sea ice.

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

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

2.1.1.6 The final goal concerned the processing and management of these data streams, including (a) climatologies (means and variances), (b) information management, and (c) modelling and assimilation systems.

### *2.1.2 Applications*

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

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

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

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

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

2.1.2.2 In view of the broader approach being taken in this document, two further applications should be mentioned explicitly:

(v) **Short-range Ocean Prediction.** There are many applications related to the prediction of the open ocean, mainly currents and temperature in the upper ocean, on time scales from days to several weeks.

(vi) **Marine and Sea-state Prediction.** Ocean waves (mainly surface), sea-ice monitoring and prediction and high-seas marine forecasts are relatively mature activities in many agencies.

2.1.2.3 As noted previously, there are also many applications centered in the coastal regions, such as coastal forecast systems and storm surge, which have requirements for physical ocean measurements. Together with (v) and (vi), GOOS as originally conceived lumped these issues in the services module. Komen and Smith (1998) discusses some of these in more detail.

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

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

### *2.1.3 Sampling specifications*

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

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

2.1.3.3 The real ocean not only contains these *signals* but also many other variations, sometimes with small amplitude, but not always. We refer to these as *noise*, though it should be remembered that the division between *signal* and *noise* is just an artifact of our particular interests and characterization. Our ideal observing network aims to minimize the errors in our estimate of the *signal*, or minimize the influence of the *noise*. The normal strategy is to exceed the sampling rate suggested by the characteristic space and time scales of the *signal*, and use our knowledge of the *noise* to assist the signal processing.

2.1.3.4 Since ocean models and assimilation are usually our preferred signal processing technique, it should also be noted here that the grid resolution of the model is not directly involved in the sampling rate decisions. There may be some indirect influence since, for example, the capabilities of particular models may restrict the *signals* that can be processed. The more relevant parameters are those used to characterize the statistics and coherences in the assimilation method. Ocean model assimilation systems are, in general, relatively simple compared with our meteorological equivalents. SST analyses, for example, are mostly performed without the aid of any dynamical or physical models. This can be compared with re-analysis estimates of surface wind stress and heat flux where very complex estimation systems are used.

2.1.3.5 It is also important to appreciate that the sampling requirements are usually met through a mix of data from different platforms (e.g. Advanced Very High Resolution Radiometer (AVHRR), VOS and TAO for SST), and sometimes also from indirect methods. For example, previous analyses may be used to forecast the present state, or other fields may be used (with models) to infer the field of interest (e.g. altimetry for currents). Usually, no one method will provide the desired accuracy for the product. To avoid a method-by-method account of useful accuracies, we introduce the concept of a "benchmark accuracy" (see 2.1.4.2 below).

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

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

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

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

### *2.1.4 Requirements*

2.1.4.1 These are derived for the most part from the OOSDP (1995) report and several subsequent publications (Smith *et al.* 1995; Nowlin *et al.* 1996), but consideration has also been given to re-evaluations by the Ocean Observations Panel for Climate meeting reports (OOPC, 1996, 1997, 1998) and associated activities.

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

2.1.4.3 The sampling requirements are summarized in Table A, Annex II. Table B, Annex II shows space-based requirements alone, with particular reference to GODAE. GODAE is likely, in general, to be more demanding in terms of spatial and temporal resolution, but with decreased emphasis on the deep ocean and perhaps slightly weaker accuracy requirements.

**Sea Surface Temperature**

Characteristics of the processed signal

- For Numerical Weather Prediction (NWP) which supplies stress, heat flux estimates: 0.2-0.5°C on 100 km squares with 3-day resolution. (Note that regional systems and severe weather prediction seek 10-20 km resolution daily (Annex III), and that these are becoming increasingly important for coastal applications (e.g. hurricane forecasts) and some climate applications).
- For ENSO prediction and verification: 0.2-0.3°C at 200 km x 30-100 km scales every 5 days in the tropics. The bias requirement is more severe in the convective regions, less severe in the central to eastern Pacific. Meridional resolution has a high premium attached to it.
- For climate change detection: 0.1°C on 2-500 km squares monthly.
- Mesoscale and coastal oceanography/GODAE: 0.2°C (relative) 10 km scales daily. Quality and bias is less of an issue, but gradients and features are more important.

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

Sampling strategy and benchmark accuracies

- Use geostationary and polar orbiting satellite data for spatial resolution and to reduce geophysical noise in climate signals (Annex II, Table B).
- Use *in situ* data for calibration and to produce blended products with optimized bias reduction.
- The requirement for remotely sensed SST is 10 km resolution and 3-6 hour sampling, the latter to reduce aliasing error, with 0.1-0.3°C relative error. The temporal sampling implies increased utilization of geostationary platforms. The NWP and mesoscale applications are the dominant determinants of resolution; climate for the error.
- The sampling for *in situ* observations is controlled by the need to remove bias from the satellite product, mainly for climate change applications, but also in the event of unexpected aerosol interference. The best estimate remains at 0.1°C on 500 km squares on weekly time scales and O(25) samples with accuracy ~0.5°C. ENSO requires an adjustment in the tropics as suggested by the scales mentioned above.

Indirect sources of information

Virtually none. None of the operational analysis systems use model predictions or assimilation to great effect. It remains a field that is far easier to observe than model. It should be remembered that remotely measured SST is indirectly inferred from radiative measure. There is also no unique definition of SST.

Trends

CLIVAR and GEWEX may require resolution of the diurnal cycle and improved accuracy of products in the tropics (0.1°C). There remain some issues concerning the use of bulk, near-surface and skin temperatures in climate applications. This is likely best addressed through greater use of mixed layer models. Applications requiring accurate high-latitude SSTs might also become more important; satellite sampling is poor in some regions and so *in situ* programmes become more important. (See also the final report of the OOPC/AOPC Workshop on Global Sea Surface Temperature Data Sets, IRI, LDEO, Columbia University, USA, 2-4 November 1998.)

**Surface salinity**

Characteristics desired of the processed signal

While sea surface salinity (SSS) products remain largely in the research community, the OOSDP expressed a strong desire for improved monitoring of SSS.

- At high-latitudes, surface salinity is known to be critical for decadal and longer time-scale variations associated with deep over-turning and the hydrological cycle (the rms. annual variation is ~ 0.2; while interannual is typically ~ 0.2-0.5). These are relatively large-scale signals.
- In the tropics, and in particular in the western Pacific and Indonesian Seas, and in upwelling zones salinity is also believed to be important (rms variation ~ 0.3). A product on 250 km squares and monthly resolution with 0.1-0.2 accuracy would be satisfactory for most applications.

Sampling strategy and benchmark accuracies

One sample *per* 200 km square every 10 days with an accuracy of 0.1 is the benchmark [the *signal to noise* ratio is typically not favourable]. The tropical western Pacific and Indian Oceans, and high latitudes are the highest priorities.

Indirect sources of information

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

Trends

- Retrievals using passive microwave L-band with an accuracy of 0.1-0.2 over 200 km are sought. ESA's SMOS mission is aimed at such accuracy.
- There remains the possibility of remotely-sensed SSS, at the threshold level listed in Annex II, Table B. The need for improved salinity networks has been a theme in CLIVAR and in the OOPC, principally because of the significant interest in the tropics and the interest in decadal-to-centennial variations at high latitudes.

**Surface wind vectors**

Characteristics desired of the processed signal

Estimates come from NWP, from direct analyses of wind data (e.g. the Florida State University (FSU) product) and from products generated directly from remote sensing. Re-analysis products are also popular in the research community.

- For ENSO applications: 5% in direction and 0.5 m/s in speed estimates are required at 5° longitude and 2° latitude horizontal scales monthly. For longer periods the accuracy requirements are slightly weaker, but a global resolution of 2° x 2° is desirable (such products are not used directly for detecting climate change but for driving models studying climate change).
- Many mesoscale, coastal, and some climate applications seek much finer temporal and spatial resolution. Research applications also have demanding requirements.

<u>Sampling strategy and benchmark accuracies</u>

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

- 2° x 2° resolution at an accuracy of 0.5-1.0 m/s in the components every 1-2 days is the benchmark for climate applications;
- Daily 50 km resolution at an accuracy of 1-2 m/s daily is the benchmark for mesoscale/GODAE and coastal applications.

<u>Indirect sources of information</u>

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

<u>Trends</u>

- ADEOS/NSCAT showed that estimates of around 2 m/s accuracy every 2 days could be obtained, at resolution of around 50 km. If such an instrument is flying operationally, then the role of *in situ* data would be more like that of *in situ* SST data for SST estimates. That is, providing ground truth for bias correction.
- The reanalysis projects have yielded improved products, which are popular, but which have short-comings with respect to quality and resolution. The demand for higher resolution, particular for cyclones and hurricanes, is growing. There is consensus that at least one operational double swath scatterometer is justified, and an emerging case for two to eliminate aliasing of these high-frequency variations into climate signals.

**Surface flux of heat, water**

<u>Characteristics desired of the processed signal</u>

- For surface heat flux: 10 $W/m^2$ accuracy over 2° latitude by 5° longitude by monthly bins.
- For precipitation: 5 cm/month over 2° latitude by 5° longitude by monthly bins.

<u>Sampling strategy and benchmark accuracies</u>

- Use flux estimates from NWP/reanalysis projects and adopt the sampling requirements of WWW.
- Use direct calculations based on surface marine data, both satellite and ocean based (e.g. FSU, SOC) with O(50) observations of the main parameters (wind, air temperature, humidity, MSLP, SST) per bin. Specific high priority actions include:
  - ✓ Improved SST, air temperature, humidity, MSLP, precipitation and absolute wind velocity on selected VOS;

✓ Shortwave and longwave radiometers on selected VOS;
✓ Satellite-based estimates of radiation and precipitation; and
✓ A number of flux buoys to provide high-quality verification.

Indirect sources of information

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

Trends

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

**Sea Level**

The OOSDP report discussed long-term trends and ocean variability needs, but was not specific with respect to the *in situ* gauges or altimetry. The OOPC, CLIVAR and NOAA, convened a workshop to refine these requirements, in conjunction with GLOSS and its implementation plan (1997).

Characteristics desired of the processed signal

- For climate change: annual global sea-level change on large space scales (~ 500 km), with accuracy of around 1-2 mm a year.
- For estimates of sea surface topography anomalies (for ENSO and ocean variability studies): for 10-30 day periods an accuracy of 2-5 cm and a spatial resolution of:
  ✓ 500 km zonal x 100 km meridional in the tropics;
  ✓ 2° x 2° elsewhere.
- For estimates of mesoscale variability: on a 25-100 km square with an accuracy of 2-10 cm every 5 days (see also Table B, Annex II).
- For ocean circulation (estimates of absolute sea level): on a 200 km scale and 2-5 cm accuracy (dependent on a gravity mission).

Sampling strategy and benchmark accuracies

- Long-term trends require a dual strategy.
- The preferred observing strategy comprises:
  ✓ altimetry for global sampling, at approximately 10 day intervals;
  ✓ approximately 30 *in situ* gauges for removing temporal altimeter drift;
  ✓ additional gauges at the margins of the altimeter (e.g. continental coasts and high latitudes); and
  ✓ a programme of geodetic positioning.

- An alternative observing system, proposed due to the lack of guaranteed availability of altimetric data and due to the lack of experience and confidence in the application of altimetry to measuring long-term trends, would comprise:
  - ✓ a globally distributed network of *in situ* measurements, with similar effect to the GLOSS Long-Term Trends (LTT) set of tide gauges; and
  - ✓ a programme of geodetic positioning.
- For large-scale variability, sites for *in situ* measurements are limited. The TOGA network should be maintained (at higher priority than assigned in OOSDP, 1995), with increased focus on the tropical western Pacific and Indonesian Throughflow, and in the western boundary current regions. The GLOSS Implementation Plan and OOPC/CLIVAR Sea-level Workshop (GCOS,1998) detail priority stations for monitoring large-scale variability. TOPEX/Poseidon (T/P)-class altimetry with 100-200 km resolution and ~2 cm accuracy is also highly recommended. Altimetry, in general, is now rated far more highly than it was at the time of OOSDP (1995).
- Mesoscale variability is only accessible with multiple altimeters, at least one being T/P class. The optimal sampling is at a 25 km scale and an accuracy of 2-4 cm every 7 days.

Indirect sources of information

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

Trends

For ENSO prediction, sea level is enjoying a revival, courtesy of TOPEX/Poseidon and improved methods for assimilating sea-level information. There is more confidence in altimetry for long-term trends (c.f. OOSDP 1995). For the mesoscale, the number and type of altimeters required still remains open (see notes in Table B, Annex II). The gravity missions GRACE and GOCE (OOPC, 1998) will provide an opportunity to exploit absolute measures of sea level.

**Sea Ice**

Desired characteristics of processed signal and available techniques (for climate)

Although sea ice is a basic component of the climate system, systems to observe sea-ice properties are limited. The limited OOSDP recommendations reflect this situation.

- Sea-ice extent: daily 10-30 km resolution is attainable using passive microwave sensors and meets the requirement for large-scale observations at seasonal to interannual time scales but serious problems remain in their interpretation. Sea-ice regions vary greatly in character and there is difficulty in establishing algorithms to describe sea-ice extent and concentration in the presence of snow, melt water, thin ice, etc. Synthetic aperture radar (SAR) where feasible provides finer accuracy. *In situ* techniques are largely insignificant for large-scale monitoring.
- Sea-ice concentration: 2-5% in sea-ice concentration, measured daily, provides a target for microwave sensors at the same spatial scales as for sea-ice extent but the same interpretation problems exist.
- Sea-ice drift: Measurement of drift as opportunities arise, using buoys and pattern-tracking from remote sensors (SAR, AVHRR).

- Sea-ice thickness: 2-500 km scale mapping of ice thickness on monthly time scales with accuracy O(0.2m), using upward-looking sonars and other devices. Sea-ice thickness and volume are an important climate variable but are the most difficult to obtain on the large scale.

Other comments

- Operational sea-ice systems are more advanced in the Northern Hemisphere than in the Antarctic. Work in the Antarctic is largely driven by climate concerns. For decadal-to-centennial variability, sea-ice extent, concentration and volume are required. Surface salinity and sea-ice export estimates are complementary. For models to be useful for sea-ice prediction (on short time scales), good wind data are essential.
- There are extensive services for the provision of real-time sea-ice data in the vicinity of the Arctic. In some cases, observational programmes have been going for over 50 years.
- At this time, GOOS has not fully considered just how these activities should be dealt with. For JCOMM and the several activities that were being covered by CMM, it is clear sea-ice needs to be considered more fully in future versions of this action plan. In the meantime, the requirements set down by WMO will be used as a guide.

**Surface waves**

- Like real-time sea-ice monitoring and prediction, the requirements for surface wave/sea state analysis and forecasting have not been considered in detail by GOOS - Kamen and Smith (1998) examined some of the issues related to present forecasting systems but did not examine the requirements in detail. Within WMO, wind waves have been the province of CMM and there has been an active sub-group on wave modelling and forecasting. It is the published requirements of this programme that have been added to Table B of Annex I.
- A paper has been solicited for the OCEANOBS'99 conference to develop an agreed set of requirements for wind waves. In broad terms, we can expect wind wave requirements.
  - ✓ Significant wave height at 100-250 km and 6-12 hour with accuracy 0.5 m.
  - ✓ *In situ* (wave ride buoy) measurements at several locations, preferably in deep water, to verify remote measurements and operational models. These data should be circulated on R/T.
  - ✓ A wind-wave verification scheme whereby *in situ* data are assembled and made available to operation agencies.

**Surface carbon flux**

For the most part, these measurements remain within the research community. But the technology exists to use VOS and drifters to collect $pCO_2$ *in situ* measurements, and satellite ocean colour provides effective proxy data for $pCO_2$.

Sampling strategy and benchmark accuracies

- Seek $pCO_2$ and total $CO_2$ measurements with an accuracy of ±2-3 μatm and ±2 μmol respectively.
- *In situ* sampling is not expected to reach threshold rates, so simply aim for enhanced VOS, mooring and drifter measurements, piggy-backing wherever possible on existing operational systems. Ancillary SST and atmospheric data are important.
- Aim for continuing global satellite ocean colour measurements, at 25-100 km resolution and daily coverage, with 2-10% accuracy.
- Development and validation of satisfactory remote sensing algorithms is important.
- Time-series stations are playing a key role in research and the Ocean Climate Time-Series Workshop (Baltimore, MD, USA, March 1997) co-sponsored by GOOS, GCOS, WCRP and JGOFS (GOOS Report No. 33, GCOS Report No. 41) saw an important role in the future for such Time-Series.

Comments

Some non-biological applications (e.g. tropical ocean modelling) are using ocean colour to estimate opacity. Independently of any non-physical applications, this suggests that there is a good case for adding ocean colour to the list of needed remote sensing techniques.

**Upper ocean temperature**

In the past, upper ocean thermal networks have largely been the province of research. Making significant parts of these networks operational is one of the key themes of OOPC and remains a high-priority issue.

Characteristics desired of the processed signal

- General large scale requirement is for 2-500 km scale bimonthly global maps of the heat content and the first few vertical modes of variability; and monthly climatologies on 1° resolution. An accuracy of ~ 0.5°C is useful.
- For ENSO forecasts: 1° latitude and 5° longitude resolution every 10 days and over 500 m vertically (mixed layer depth (MLD) and ~5 vertical modes) to an accuracy 0.2-0.5°C.
- For mesoscale applications: 25-50 km resolution every 2 days over 500 m with an accuracy of around 0.5°C.
- For climate trend, better than 0.1°C/year accuracy.

Sampling strategy and benchmark accuracies

- Maintain TOGA/WOCE broad-scale VOS sampling (1 XBT *per* months with 1.5° latitude and 5° longitude resolution). Priority to lines with established records, of good quality, and in regions of scientific significance (e.g. tropics, particularly outside the domain of TAO, and the TRANSPAC region).
- Maintain TOGA Pacific network, in particular TAO (OOSDP did not specify part or all of the present array, but did suggest "close to" 1994 levels). Around 4 samples every 5 days per 2° x 15° bin, with 10-15 m vertical resolution is deemed satisfactory.
- Enhanced coverage in the equatorial regions in the vicinity of sharp gradients (e.g. Kuroshio): O(18) sections *per* year, with 50-100 km resolution.
- Boost routine sampling of the polar regions (at broadcast mode levels).
- Use of profiling floats to implement a truly global observing system. This is a technology that is developing rapidly and real-time data are now available; sampling strategies have yet to be defined for "operational" use but a float profile per 2-300 km square every 10 days might be a feasible target. Argo, developed under the auspices of GODAE, will become the mechanism for developing a strategy for deploying ~ 3000 floats globally for GODAE in the period 2003-5. As such it will serve as a pilot project for the longer term use of profiling floats in the GOOS/GCOS OOS.

Other sources of information

Clearly altimetry offers complementary data. For the tropics, it is feasible a good model plus SST and wind-forcing may be able to forecast subsurface temperature structure with useful skill. However, at the present time, there is no reason to lessen the requirements outlined above. Several groups are using empirical relationships plus assumptions about the T/S relationship to infer sub-surface structure from altimetry (variously known as synthetic or pseudo XBTs). Acoustic thermometry has good potential, particularly for long-term change and in regional modelling. It seems highly unlikely that an *in situ* solution will be found for the mesoscale applications. Rather, it is likely a mix of moorings, XBTs and profiling floats may be used to pin-down the global, large-scale thermal structure, and a mix of altimetry, SST and colour used to specify the horizontal structure of the mesoscale field.

Trends

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

**Heat and Water Transports and Budgets**

The OOSDP recognized that observing changes in the ocean circulation and its inventories of heat, fresh water and carbon would require the use of profiling floats, precision altimetry, knowledge of the surface forcing fields, etc. which are discussed elsewhere in this section. In addition, trans-ocean sections at key latitudes and in regions of watermass formation would be essential. The OOSDP report, which was published at the end of 1994, states that, although repeat hydrography and trans-ocean sections are essential, they lacked some urgency as part of the initial ocean observing system because of the global coverage being provided by WOCE and the expected repeat time of five to ten years. The OOPC has not yet reviewed the question of trans-ocean sections and repeat hydrography given the experience of WOCE.

Characteristics desired of the processed signal:

- For the estimates of the variability of meridional heat, fresh water and carbon fluxes, trans-ocean sections are required at key latitudes with station spacing that resolves mesoscale variability, 25-100 km, at specific latitudes and at a repeat time to be determined based on the experience of WOCE.
- For the determination of the changing inventories of heat, fresh water and carbon, additional sections with station spacing appropriate to the sales of variability may be required to supplement the trans-ocean sections for transport estimates.
- For the measurement of water mass formation, sections are at least annually to observed yearly watermass formation and at a station spacing adequate to sample region.

Sampling strategy and benchmark accuracies:

The sampling strategy, desirable accuracies and operational procedures for deep sea hydrographic observations are fully described in the documentation prepared for WOCE implementation and can be seen in WCRP (1988 a, b) and WOCE (1991), WOCE Hydrographic Programme Office (1994).

Trends

Hydrographic sections remain the fundamental tool for observing changes in watermasses and the climatically important meridional ocean transport of heat, fresh water and carbon. The availability of profiling floats measuring T and S, moored profiling instruments, and precision altimetry combined with the increasing power of ocean dynamical models and techniques for assimilating observations could lead to more comprehensive approaches in the future.

**Upper ocean salinity**

Upper ocean salinity remains primarily an experimental field in terms of applications. An exception for the OOSC are the upper ocean segments of the hydrographic data to be obtained from trans-ocean and repeat sections as well as time-series stations for which the techniques of obtaining accurate salinity data are well established. Expendable CTDs (XCTDs) on selected VOS lines and perhaps also high density lines, and salinity sensors on some TAO moorings, were recommended by OOSDP.

Characteristics desired of the processed signal

Monthly subsurface profiles with an accuracy of 0.1 on 3° squares would serve most large-scale purposes.

Sampling strategy and benchmark accuracies

Profiles per month *per* 3° square at better than 0.02 accuracy is a benchmark.

Trends

- There are suggestions that sub-surface salinity is important for ENSO forecasting and CLIVAR Upper Ocean Panel has given high priority to enhanced sampling.
- Again, the profiling floats of Argo would seem to offer the best opportunity for increased global coverage, though there remains some questions about the stability of the salinity sensor. Current plans suggest Argo will deliver in excess of 50,000 profiles of 5 to 2,000 m. Studies using a combination of altimetry, sea surface salinity and ocean temperature have shown promise for estimating salinity (Reynolds, pers. comm.). CLIVAR is intent on pursuing a better description of the hydrological cycle which implies greater emphasis on subsurface salinity.

**Ocean currents**

The OOSDP (1995) report was vague with respect to the need for velocity measurements, principally because there were few, if any, operational applications. They recommended a minimal array of current meter moorings and VOS acoustic doppler current profilers (ADCPs) for validation of models as well as gathering surface drift data from buoys.

Sampling strategy and benchmark accuracies

- At the surface: a global surface drifter programme can yield very good surface current estimates. The benchmark is global coverage of one drifter measurement per 600 km square *per* month, with current-following accuracy of around 2 cm/s which would give estimates of the mean velocity good to 10% of the eddy variability.
- For the subsurface: a minimal array for model verification. Accuracies of the order 5 cm/s for monthly averages would be the benchmark for the tropics.

Trends:

- Several groups are experimenting with surface current estimates derived from altimetry and from SST-pattern following techniques. GODAE will place greater premium on surface velocity data since its short-range forecasting goal include estimates of the surface currents.
- There is considerable interest in the prospects from the gravity missions GOCE and GRACE. GOCE to be launched in the period 2001-3 will provide geoid accuracy of ~1.0 cm on scales of 500km and ~0.1 cm on scales of 1000 km. GRACE to be launched after 2003 will provided geoid accuracy of 2.0 cm on 100 km scales and better than 1.0 cm on 1000 km scales. If successful, these missions would allow the calculation of absolute surface geostrophic currents on smaller scales (down to mesoscale at mid-latitudes) and greater accuracy than presently available, and enhance the already substantial impact of satellite altimetry.

**Time-Series Stations**

Time-series stations do not fit neatly into the above field-by-field description for the OOSC. They provide long records with temporal resolution that is short compared with the characteristic of the dominant variability, as well as co-located measurements of several different variables, sometimes including chemical and biological parameters. These attributes make such data sets powerful and complementary to the data mentioned previously, particularly for physical and phenomenological studies. The Ocean Time-series Workshop (IOC, 1997) discussed the merits of time series as a strategy for both GOOS/GCOS and CLIVAR. The CLIVAR Implementation Plan (WCRP-103, 1998) includes a summary of the attributes of 8 existing time-series and attempts to evaluate their relevance to meeting the goals of CLIVAR. The OOPC has yet to attempt this with regard to the OOS. However, it can be noted that the Time-series Workshop presented a strong case for continuing the long time series at Bravo and station "S". The TAO array also contains several important long records (e.g. at 110 W) which should be maintained. Station "Papa" is to be the subject of sustained study within CLIVAR and may be another potential site for consideration for the OOS. Others may be equally relevant.

**Ocean modelling**

- As noted at the beginning of this section and in OOSDP (1995), models are essential for the effective and efficient use of observations. Equally, data from the real ocean are essential if a model is to move beyond theory and concept.
- Ocean data assimilation, or ocean state estimation in the nomenclature of GODAE, is the preferred methodology for merging theoretical knowledge of the ocean (models) with data. Note the data may be ingested through both boundary conditions and adjustments to the sate variables.
- The development of models is not the purview of JCOMM. However, the end-to-end chain of observation-processing-service inevitably involves models of varying levels of sophistication and so JCOMM must take into consideration the implementation and routine use of models.

**Management and oversight**

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

The OOSDP all set out several principles for data management:

- *the information management system will be built as far as is possible and appropriate on existing systems;*
- *the information management system should be "operational" (c.f. experimental) in the sense as that for the observational network;*
- *the information management system should be consistent with the objectives, needs and priorities of the scientific design;*
- *data should be transmitted from instrument platforms to appropriate data centers and made available for further processing as soon after measurement as is feasible and practical;*
- *quality assurance of data and products should receive high priority to maximize the benefit drawn from the often difficult and expensive ocean measurements;*
- *the information management system should be user-oriented to ensure that the needs of users, the ultimate sponsors of the observing system, are served well;*
- *full and open sharing of data and information among the participants and users of the observing system is essential to its successful implementation and operation;*
- *observing system participants should contribute data voluntarily and with minimal delay to data archival centers which in turn should be able to provide information to users effectively free of charge;*
- *the observing system will be most effective if practical international standards are developed for all phases of information management;*
- *information management will be most effective if it is part of the overall monitoring and evaluation process of the system.*

*2.1.5 References*

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### 2.2 Operational Meteorology

2.2.1 The set of observational data requirements to support operational meteorology includes those for numerical weather prediction (NWP), nowcasting, regional numerical weather prediction and synoptic meteorology. They were first drafted as a part of the World Weather Watch Plan in the mid-1960s, and have been progressively updated since that time. They are kept under continuous review, and updated as necessary, by the WMO Commission for Basic Systems (CBS).

2.2.2 The comprehensive set of requirements for all surface and upper air variables, irrespective of source (satellite and *in situ*) is maintained by the WMO Secretariat on behalf of CBS in a data base which is accessible through the WMO homepage on the Web. The complete listing of requirements for surface variables, for all WWW applications, extracted from this data base, is given in Annex III. The composite ocean observing system which is the objective of this action plan must also address the parts of these WWW requirements which are on, under or above the ocean surface. A review of the current status of existing ocean observing system components, in the context of these WWW requirements, is given in section 5.4.2.

## 3. EXISTING OPERATIONAL IMPLEMENTATION MECHANISMS

### 3.1 Commission for Marine Meteorology (CMM)

*3.1.1 Status*

CMM is intergovernmental, and a Constituent Body of WMO with regulatory (what Members *shall* do) and guidance (what Members *should* do) responsibilities in marine meteorology. Established in 1907, it has around 200 members (marine experts) nominated by 120 Members of WMO.

*3.1.2 Responsibilities*

- **Services.** Marine meteorological, oceanographic, climatological, sea-ice. Services are both basic (safety of life at sea, environmental protection) and specialized (economic and commercial interests, such as offshore oil industry, ship routing, etc.).
- **Observations.** Primarily operation of the VOS, exchange and management of VOS data in both real time and delayed mode. Also co-ordination with other observing networks and with ocean satellite operations.
- **Capacity building.** Advisory missions to developing countries; preparation of development projects; specialized short-term training courses (around 1 per year); development of longer-term training; training manuals and other publications; seminars and workshops; preparation of specialized software packages; development of marine forecast techniques.

*3.1.3 Publications*

- **Manual** on Marine Meteorological Services (part of WMO Technical Regulations)
- **Guides**:
  - ✓ Marine Meteorological Services
  - ✓ Wave Analysis and Forecasting
  - ✓ Applications of Marine Climatology
- **Technical Reports**: in two main series, approximately 2-3 published each year
- **Handbooks** on marine meteorological services, offshore forecasting and sea-ice navigation services
- **Components** of other WMO publications, both operational and mandatory (e.g. WMO No. 9, Vol D; Manuals on Global Observing System, GTS, Codes, etc.).

*3.1.4 Structure*

The Commission has the following basic structure:

- **Commission** meets every 4 years in full session, 6-language interpretation, documents in 5 languages;
- Four main **working groups** (Advisory, Services, Observing Systems, Education and Training) which work mainly by correspondence (except advisory, which meets once in each intersessional period);
- Several specialized **Sub-groups** (Basic Services (GMDSS), Waves, Sea-Ice, Climatology, VOS, Ground-based Radar Ocean Sensing), which meet as often as necessary (1-4 times in each 4 years) and otherwise work by correspondence;
- **Rapporteurs** on specialized topics (e.g. ocean satellites, marine pollution).

*3.1.5 Operational Observing Network*

At the present time there are approximately 7,200 **Voluntary Observing Ships** (VOS), operated by 50 Members, reporting basic marine meteorological and surface oceanographic variables at six-hourly intervals (the basic synoptic hours). Observations are made normally by ships'officers, though there is increasing automation. The interface between meteorological services and the ships is through the international network of **Port Meteorological Officers** (PMOs), around 200 maintained by the operating Members. Global co-ordination of VOS operations is done through a CMM **Sub-group on the VOS**, as well as regional and global seminars and workshops for PMOs. In some countries, the PMOs are also actively involved in supporting the SOOP. PMOs maintain, calibrate and often supply/replace instrumentation. They also provide relevant literature, stationery and computer software and train ships' officers. The 7,200 VOS are divided into three classes, depending on main sailing areas and quality/extent of meteorological instrumentation.

*3.1.6 Data Collection, Exchange and Management*

- **Real time.** Observations are transmitted to shore in real time primarily *via* Inmarsat, in either SHIP or BUFR code, and routed directly to a small number of major meteorological services. Transmission costs are borne by these services. The observations are compiled into bulletins and distributed globally *via* the GTS. Real-time monitoring of the **quality** of VOS reports is undertaken by several major meteorological centres, primarily the U.K. Meteorological Office which has formal WMO responsibilities for marine surface data. Results of this monitoring are compiled and distributed at monthly and six-monthly intervals to PMOs, who are expected to take follow-up actions to correct deficiencies. This has resulted in substantial improvements in quality since the introduction of the scheme.
- **Delayed mode.** Observations are recorded on board in either hard copy or electronic **logbooks**, which are collected by PMOs of the recruiting countries at the end of each voyage. The reports are encoded in the international exchange format IMMT, **minimum quality control standards** applied by the recruiting services, and the data sent at 3-monthly intervals to two **Global Collecting Centres** (in Bracknell and Hamburg). These centres repeat and expand the quality control, compile global data sets, and forward these at regular intervals to data archival centres globally. The procedures for this data exchange and management, including the quality control standards, as well as regulations for the preparation of climatological summaries, form part of the WMO technical regulations (Manual on MMS) as the **Marine Climatological Summaries Scheme**. These procedures, *inter alia,* are maintained and updated by the CMM **Sub-group on Marine Climatology**.
- The WMO Secretariat maintains a complete **VOS Metadata Catalogue** (WMO-No. 47). This contains full details of ships, instrumentation and communications. It is maintained in data base format, updated continuously from quarterly submissions. Copies are provided on request in both hard copy and electronic format, and the catalogue will shortly be accessible *via* the WMO Web page.

*3.1.7 Analysis*

- **Strengths.** Responsibilities for regulation and guidance; long history and experience in management of an operational marine observing system and the collection, exchange and management of the data; global networks of experts; established management bodies; experience in and responsibilities for data applications and the provision of marine services, including direct interface with users; direct involvement of 120 national Meteorological Services worldwide.
- **Weaknesses.** Experience and existing expertise limited primarily to the management and applications of marine meteorological and some surface oceanographic data and services; some system inertia, with long lead-times required to get regulations developed, approved and implemented.

## 3.2 Data Buoy Co-operation Panel (DBCP)

*3.2.1 Status*

- The DBCP is a formal joint body of WMO and IOC, which was established in 1985 and reports directly to the Executive Councils of both organizations. It is self-supporting and employs a full time Technical Co-ordinator. It looks to other bodies and programmes of WMO/IOC for guidance on requirements.
- The Panel members are representatives of all Members of WMO or Member States of IOC which are interested in participating in its activities. Presently the following countries participate actively in the DBCP activities (attend meetings, contribute to trust fund, etc.): Australia, Canada, France, Greece, Iceland, Ireland, Netherlands, New Zealand, Norway, South Africa, United Kingdom, USA. Altogether, some 39 countries have nominated national focal points for the Panel.

*3.2.2 Responsibilities*

- **Services.** DBCP serves other programmes such as WWW, WCRP, GOOS, GCOS by trying to meet their requirements for oceanographic and atmospheric ocean surface *in situ* observations in real time or deferred time. Hence services are offered by those programmes, not by the DBCP directly.
- **Observations.** Drifting buoys and moored buoys deployed in the open ocean. Data are presently mostly being collected and processed through the Argos System (polar orbiting NOAA satellites). Data are disseminated in near-real-time onto the GTS. Data are also post-processed (e.g. surface velocity) and distributed in delayed mode for research purposes. Deployments in data sparse areas as a complement to other observing systems.
- **Technical development and information exchange.** It organizes workshops, and maintains a series of technical publications. DBCP maintains a Web Server (*http://dbcp.nos.noaa.gov/*). It encourages, supports, or initiates developments and testing of new observing techniques (e.g. barometer drifter, wind observation through ambient noise), implementation of quality control procedures (e.g. QC guidelines), implementation of new data processing systems (e.g. Argos GTS sub-system). It also encourages impact studies based on buoy data.

*3.2.3 Publications*

- **DBCP technical document series**: now 10 publications, approximately 3 per year.
- **DBCP annual reports**: one report per calendar year. DBCP annual report is now included in the DBCP document series.
- **DBCP session reports**: one report per year.
- **Components** in other WMO publications.

*3.2.4 Structure*

The Panel has the following overall structure:

- DBCP meets once a year, normally in October. The working language is English.
- One chairman, two vice-chairmen. Traditionally, one vice-chairman deals with American continent issues, the other vice-chairman deals with the rest of the world. One Technical Co-ordinator. Working Groups and Rapporteurs may be created based upon actual needs (e.g. working group on encoding buoy data in BUFR).
- DBCP relies upon Action Groups for regional or global (for specific purpose) implementation. Present DBCP Action Groups are:
  - ✓ The European Group on Ocean Stations (EGOS)
  - ✓ The International Arctic Buoy Programme (IABP)
  - ✓ The International Programme for Antarctic Buoys (IPAB)
  - ✓ The International South Atlantic Buoy Programme (ISABP)
  - ✓ The International Buoy Programme for the Indian Ocean (IBPIO)
  - ✓ The Global Drifter Programme (GDP)
  - ✓ The Tropical Atmosphere Ocean Array (TAO)

*3.2.5 Operational Observing Network*

- Approximately 1,200 drifting buoys worldwide, of which 700, operated by 20 countries, are reporting basic marine meteorological and surface oceanographic variables at random intervals (real time, about 7 times a day) and synoptic times for certain buoys (slightly deferred time) onto the GTS. Majority of the drifting buoys are oceanographic drifters, all equipped with SST sensors, some equipped with barometers. Other buoys are either meteorological TOGA type buoys (air temperature, air pressure, SST, wind), or ice floats.
- TAO array: Approximately 70 open-ocean moored buoys deployed in the equatorial Pacific Ocean by 4 countries, reporting basic marine meteorological, surface and sub-surface oceanographic variables at hourly and daily intervals (slightly deferred time) onto the GTS. Two

other PIRATA moored buoys presently deployed in the equatorial Atlantic Ocean for similar purpose with planned deployments of up to 12 buoys in 1999.

*3.2.6 Data Collection, Exchange and Management*

- **Real time.** Observations are transmitted to shore in real time primarily *via* Argos, in raw form. Data are processed and buoys located by the Argos system. Automatic quality control checks are operated at Argos centres and the data then encoded in BUOY code, and routed directly to the NOAA/NWS and Météo-France for insertion onto the GTS. Data collection/location costs are paid by the operators, and report transmission costs to the GTS nodes are borne by Service Argos. The observations are compiled into bulletins and distributed globally *via* the GTS.
- Real-time monitoring of the **quality** of buoy reports is undertaken by several major meteorological centres, primarily the U.K. Meteorological Office which has formal WMO responsibilities for marine surface data. **Quality Control Guidelines** have been implemented by the DBCP for buoy data on the GTS. The service is managed and co-ordinated by the Technical Co-ordinator and operates through a network of Principal Meteorological or Oceanographic Centres (PMOC). QC Guidelines have resulted in substantial improvements in quality since the introduction of the scheme, and now form a part of the WMO **Guide to the Global Observing System**.
- **Delayed mode.** Argos processed observations are collected by the buoy operators and Principal Investigators *via* the Argos system. Data can be obtained directly from them. For operators participating in DBCP Action Groups, data are post-processed, scientifically processed (e.g. computation of surface velocities based upon drogued drifter trajectories), quality controlled, and distributed usually within 6 months along with metadata information on buoys to the Responsible Oceanographic Data Centre for Drifting Buoys (RNODC/DB) operated by the Marine Environmental Data Service (MEDS) in Canada.
- The DBCP maintains a complete list of drifting and open ocean moored buoy programmes. WMO/Argos numbers cross reference list is published on a monthly basis *via* an Internet mailing list. DBCP Action Groups maintain their own archives and lists of buoys, including metadata information on buoys (e.g. type of buoy, of instrumentation ...).

*3.2.7 Analysis*

- **Strengths.** Responsibilities for guidance; long history and experience in management of an operational marine observing system and the collection, exchange and management of the data; global networks of experts (meteorological and oceanographic) directly involved in buoy operations; co-ordination involving all major buoy deployers; active in improving buoy technology and performance; established and proven data management system.
- **Weaknesses.** Experience and existing expertise limited primarily to the management and applications of buoy programmes; financial involvement of only a small number of countries; does not initiate requirements, only services others; lack of co-ordination with other network components.

## 3.3 Integrated Global Ocean Services System (IGOSS)

*3.3.1 Status*

An operational system for the real-time collection, exchange and processing of oceanographic data, co-ordinated by an intergovernmental committee, the Joint IOC/WMO Committee for IGOSS. The committee reports directly to the Executive Councils of IOC and WMO, and has, *inter alia*, guidance (what Members *should* do) responsibilities in its areas of competence. The system was established as a joint activity in 1976, and operates through National Representatives for IGOSS nominated by 68 Member States of IOC/WMO.

*3.3.2 Responsibilities*

- **Services.** The **IGOSS Data Processing and Services System** (IDPSS) exists to make available to users quality controlled and processed observational data, analyses and forecasts needed for marine activities. It operates through a network of 17 National Oceanographic Centres (NOCs), 11 Specialized Oceanographic Centres (SOCs), and two World Oceanographic Centres (WOCs). Lists of products available through these centres are published annually by the joint Secretariats in an **Information Service Bulletin**.
- **Observations.** The **IGOSS Observing System** comprises primarily the operation of the Ship-of-Opportunity Programme (SOOP), and the exchange and management of SOOP data in both real time and delayed mode. It includes also the operation of the IGOSS Sea-level Programme (ISLP), as well as co-ordination with other observing networks and with ocean satellite operations. The **IGOSS Telecommunications Arrangements** cover both facilities for the collection of oceanographic data from ships at sea (most normally now through Inmarsat), as well as the real-time exchange of these data, primarily over the GTS. To this end, IGOSS has developed and maintains a number of data exchange codes (BATHY, TESAC, TRACKOB), and contributes to the development and maintenance of others (BUFR, CREX).
- **Capacity building.** The VCPs of WMO and IOC are used, where possible, to develop and expand the capabilities of Member States to participate in and benefit from IGOSS. The system also incorporates the evaluation and development of new instrumentation and software; the development of capabilities for measuring new oceanographic variables; and the optimization and integration of sampling with similar measurements from other observing systems. IGOSS also maintains an extensive data flow monitoring service, with monitoring reports provided regularly to operators and IDPSS centres.

*3.3.3 Publications*

- **Manuals and Guides**: IOC Manuals and Guides series (in particular Nos 1,3,19,20);
- **Technical Reports**: UNESCO Technical Papers in Marine Science series; IOC Reports of Meetings of Experts and Equivalent Bodies;
- **IGOSS Regular Information Service Bulletins** on products and on non-drifting ODAS (annually);
- **IGOSS Monitoring Reports**, monthly, bi-annually and annually;
- Miscellaneous publications, such as **Plan and Implementation Programme, Composition of IGOSS**, etc.;
- **Electronic IGOSS Products Bulletin**, located at:
  *http://ingrid.ldeo.columbia.edu/sources/igoss/products_bulletin.html*
- **IGOSS Homepage**, located at: *http://www.unesco.org/ioc/igoss/igoshome.htm*
- Components of other IOC and WMO publications, both operational and mandatory (e.g. **WMO No. 9, Vol D; Manuals on Global Observing System, GTS, Codes, etc.).**

*3.3.4 Structure*

- The **Joint IOC/WMO Committee for IGOSS** is an intergovernmental body, which meets every four years, with interpretation and documentation in four languages. Around 50 participants from 20-25 countries attend sessions.
- The committee has three main subsidiary bodies:
  - ✓ **IGOSS Bureau**, to manage activities in the intersessional period;
  - ✓ **SOOP Implementation Panel** (SOOPIP) which is responsible for overseeing the implementation of the SOOP field programme and associated data flow and quality control; meets every 2 years in full session, with documents in English only (see section 3.4);
  - ✓ **Group of Experts on Communications and Products**, responsible, *inter alia*, for developing and maintaining IGOSS data collection and exchange procedures, formats and protocols.

- The committee also has a **Scientific Advisor**, and appoints **rapporteurs** for specific tasks as required.

*3.3.5 Operational Observing Network*

- The SOOP observing network is described in Section 3.4.5.
- The ISLP, managed in conjunction with GLOSS, maintains an operational programme of sea-level data exchange and processing from the GLOSS stations in the Pacific (ISLP-PAC). It also has developed through NOAA/USA a pilot sea-level analysis project using satellite altimetry.

*3.3.6 Data Collection, Exchange and Management*

- **Real time**. The SOOP real-time data flow is described in Section 3.4.6.
- **Delayed mode**. The SOOP delayed-mode data flow is described in Section 3.4.6. These delayed-mode data are managed under IODE (see Section 4.2), in particular through the GTSPP (see Section 4.3).
- IGOSS co-operates with IODE in the operation of the **Global Temperature Salinity Profile Programme (GTSPP)**, which provides an end-to-end data management mechanism for SOOP (see Section 4.3 for details).
- SOOP co-ordination and technical support is described in Section 3.4.6.

*3.3.7 Analysis*

- **Strengths.** Operational system, with established facilities, procedures, codes, formats and protocols for operational collection, exchange and processing of oceanographic data; responsibilities for guidance; history and experience in management of marine observing systems and the collection, exchange and management of the data; global networks of experts;
- **Weaknesses.** Experience and procedures to date limited primarily to sub-surface temperature and salinity data; until recently, lack of clearly defined requirements for data and services; limited involvement of Member States; no funding to maintain observation networks operationally; no regulatory responsibilities.

## 3.4 Ship-of-Opportunity Programme Implementation Panel (SOOPIP)

*3.4.1 Status*

SOOPIP is an intergovernmental subsidiary body under the Joint IOC/WMO Integrated Global Ocean Services System (IGOSS) with guidance (what Members *should* do) responsibilities in upper ocean thermal sampling observed from **Ships-of-Opportunity** (SOO); established 1996. Around 15 members (oceanographic experts) nominated by ten Member States of IOC and WMO.

*3.4.2 Responsibilities*

- **Services.** No specific services responsibilities. Service responsibilities are undertaken by national oceanographic and meteorological organizations and centres utilizing the data, and under the auspices of international programmes such as IGOSS, Global Temperature Salinity Profile Project (GTSPP), World Climate Research Programme (WCRP), etc.
- **Observations.** Primarily operation of the SOO, exchange and management of SOO data in both real time and delayed mode. Also co-ordination with other observing networks and with ocean satellite operations.
- **Capacity building.** Evaluation and development of new instrumentation and software; development of capabilities for measuring other oceanographic variables from SOO (e.g. surface and sub-surface salinity, plankton, etc.); optimization and integration of sampling with similar measurements from other observing systems.

*3.4.3 Publications*

- **Manuals and Guides**: IOC Manuals and Guides series; WOCE Data Handbook.
- **Newsletters**: e.g. International World Ocean Circulation Experiment (WOCE) Newsletter.
- **Technical Reports**: UNESCO Technical Papers in Marine Science series; IOC Reports of Meetings of Experts and Equivalent Bodies; technical report series of contributing organizations (e.g. CSIRO Marine Laboratories Report series, NOAA Technical Memorandums, etc.).
- **Scientific Papers**: e.g. **Journal of Deep Sea Research.**
- Components of other IOC and WMO publications, both operational and mandatory (e.g. **WMO No. 9, Vol D; Manuals on Global Observing System, GTS, Codes, etc.).**

*3.4.4 Structure*

- SOOPIP is responsible for overseeing the implementation of field programmes and associated data flow and quality control; meets every 2 years in full session, with documents in English only.
- There is one main working group (**SOOP Task Team for Instrumentation and Quality Control** (STT/IQC) - formerly Task Team on Quality Control and Automated Systems (TT/QCAS)) which works mainly by correspondence, and meets in conjunction with SOOPIP. *Ad hoc* groups are formed as required.
- Scientific guidance is received from the **Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate** (OOPC) and the **CLIVAR Upper Ocean Panel** (UOP).
- The **SOOP Management Committee** (SMC), co-sponsored by IGOSS, GOOS, GCOS and the WCRP, is charged with the responsibility of managing the resources made available by contributing nations to meet the scientific requirements provided to it from GOOS, GCOS and the WCRP.

*3.4.5 Operational Observing Network*

There are approximately 100 dedicated SOO, operated by 7 Members, which report upper ocean temperature along specified routes at sampling intervals developed under the Tropical Ocean and Global Atmosphere (TOGA) and WOCE programmes of WCRP. These sampling requirements have been designed for climate monitoring and prediction applications (the main support function for SOOP at present), and have since been endorsed by the WCRP Ocean Observing System Development Panel (OOSDP). Each vessel is equipped with a data acquisition system provided by the operating agency. These systems vary depending upon the agency, but generally meet agreed standards. Observations (such as the deployment of expendable bathythermographs - XBTs) are made normally by ships officers on a voluntary basis, though there is increasing automation in some underway systems such as used for measuring sea surface temperature (SST) and sea surface salinity (SSS). Observations are also utilized from other "opportunistic" vessels (navy, fishing, research, etc.) not formally participating in the programme. Interface between oceanographic agencies and met services and the ships is through designated **Ship Greeters** from the contributing national agencies and occasionally the international network of **Port Meteorological Officers**. Ship Greeters and PMOs maintain, calibrate and often supply/replace instrumentation. They also provide relevant literature, stationery and computer software, train ships' officers, and generally help to provide the feedback required to maintain the volunteer observer support and motivation.

*3.4.6 Data Collection, Exchange and Management*

- **Real time.** The low resolution (inflection point) realizations of the observations are transmitted to shore in real time primarily *via* satellite (e.g. GOES, METEOSAT, Argos, and Inmarsat systems), as either BATHY or TESAC messages, and routed directly to a small number of major oceanographic and meteorological services. Transmission costs are borne by these services. The observations are compiled into bulletins and distributed globally *via* the GTS under the Integrated Global Ocean Services System (IGOSS). Real-time monitoring of the quality and data flow of SOO reports is undertaken by the participating programme operators, WMO, and some of the major oceanographic centres, primarily the **Marine Environmental Data Service** (MEDS) in Canada which has formal GTSPP responsibilities for real-time upper ocean data quality control. The **IGOSS Operations Co-ordinator** undertakes and helps support these monitoring activities. Results of the monitoring are compiled and distributed at monthly intervals to the programme operators, GTS centres and SOOPIP, who are expected to take follow-up actions to correct deficiencies. This has resulted in substantial improvements in quality since the introduction of the scheme.

- **Delayed mode.** Full resolution realizations of the observations are recorded on diskette by the onboard data acquisition systems, and collected by the Ship Greeters and/or PMOs of the recruiting countries at the end of each voyage. The data are encoded in the international exchange format MEDSASCII, quality control standards applied by the operating agencies, and the data sent at 12-monthly intervals to the respective **Regional National Oceanographic Data Centre** (RNODC) for forwarding to the **World Data Centres** (WDCAs - USA, Russia). These centres repeat the quality control, compile global data sets, and forward these at regular intervals to Science Centres (Indian Ocean - CSIRO, Atlantic - AOML/NOAA, Pacific - SIO) for scientific quality control and analysis. The resultant value added, high quality data sets then replace the data in the global archives. The procedures for this data exchange and management, including the quality control standards, have been developed and maintained by WOCE and the GTSPP of IGOSS and IODE. SOOPIP, with the assistance of the IGOSS Operations Co-ordinator, undertakes six-monthly monitoring of the data coverage to ensure optimal deployment of available resources under the agreed sampling requirements and recognized priorities (in the first instance in support of seasonal-interannual climate forecasting).
- The IGOSS Operations Co-ordinator maintains information on SOOP, regularly up-dated lists of participating operators and vessels, ocean basin data coverage by line, and data flow statistics on a Web site under the **IGOSS Home Page**.

### *3.4.7 Analysis*

- **Strengths.** Responsibilities for guidance; long history and experience in management of research marine observing systems and the collection, exchange and management of the data; global networks of experts; utilization of existing operational mechanisms developed under IGOSS and IODE; utilization of existing operational infrastructures such as the GTS; strong links being established between present and past research organizations, which were involved in the development of SOOP under TOGA and WOCE, and present operational organizations wishing to, or currently operationally supporting SOOP; established management bodies; many of the present members of SOOPIP are active scientific experts in the field; strong links to scientific advisory bodies; scientifically designed network of observations; strong capabilities for instrumentation development and evaluation.
- **Weaknesses.** No regulatory responsibility (i.e. not formal WMO Commission or equivalent); limited funding support for members; no funding for permanent staff in support of SOOPIP activities and functions (e.g. presently no ongoing support for the IGOSS Operations Co-ordinator position); no funding support for ongoing operational quality monitoring activities or development projects (costs born by participating organizations - not always possible, and often low priority); some system inertia within intergovernmental bodies, with long lead-times required to get recommendations approved and implemented; direct links to and co-ordination with other upper ocean observing systems and implementation bodies weak; need for increased national, operational organization participation, with some research organizations still tentatively supporting the programme without ongoing permanent funding or mandate; insufficient resources to undertake complete sampling requirements; funding to Science Centres to ensure scientific integrity of the data (including historical data bases which contain corrupt data) not firm, with the Pacific Ocean Science Centre (JEDA) at SIO already closed.

## 3.5 Global Sea-level Observing System (GLOSS)

### *3.5.1 Status*

- GLOSS is an **operational system** under the auspices of IOC. GLOSS was established by the IOC in 1985 to provide a world-wide mechanism for monitoring global levels, and also to help to develop national capabilities to assess and anticipate changing risks. The basis of the first GLOSS Implementation Plan (1990) was the establishment of a network of approximately 300 tide gauge stations distributed along continental coastlines and throughout each of the world's island groups. Since 1990, several major technical developments have taken place, most notably in the ability of satellite radar altimetry to provide reliable and routine measurements of near-global sea-level changes. A new Implementation Plan (1997) provides a complete re-assessment of requirements for GLOSS, together with specifications for each component of the system.
- GLOSS is managed by means of a Technical Secretary at IOC, a set of National and Regional GLOSS Contacts and an international **GLOSS Group of Experts**.

*3.5.2 Responsibilities*

- Responsibilities consist of the provision of an ongoing overview of sea level recording worldwide. This includes: monitoring the status of gauges within the **'GLOSS Core Network'** and scientific and regional sub-networks (including the GLOSS-LTT network for long-term trends; GLOSS-ALT for altimeter calibration; and GLOSS-OC for ocean circulation monitoring); provision of advice and technical support to gauge operators where required; supply of training to sea-level scientists and technicians; continuous linkage with related technical areas such as altimetry, GPS and absolute gravity; and definition and implementation of data flow mechanisms.
- Responsibilities include ensuring that products are as relevant and as focussed as possible both for scientific research purposes (e.g. study of sea-level changes under climate change) and practical coastal studies. For the former, suggestions for formal mechanisms for ongoing scientific advice interchange have been made between GLOSS, OOPC and CLIVAR UOP. For the latter, the development of regional GLOSS activities (IOCARIBE is a good example) is a major means of addressing requirements.
- **Services** (see GLOSS Implementation Plan - 1997 (IOC Technical Series No. 50) for detailed information):
  - ✓ Data sets provision - Permanent Service for Mean Sea Level; University of Hawaii databank; Southern Ocean Sea-level Centre at Flinders University; 'Fast' and 'Delayed-mode' WOCE Sea-level Centres including ACCLAIM data bank at the BODC delayed-mode centre; IAPSO tidal constants at PSMSL; IGOSS sea-level anomaly maps in quasi-real-time (similar delayed maps from PSMSL).
  - ✓ Newsletters, etc. - **GLOSS Bulletin** (web) and **Afro-America GLOSS News** (paper and web). Compilation of GLOSS-related publications and keyword search service at PSMSL.
  - ✓ Capacity building - Since 1985, over 15 GLOSS training courses have been held in different parts of the world including UK, France, Brazil, China, India, Argentina. Plans are being made for two courses in different continents in 1998.

*3.5.3 Publications*

- **Manuals and Guides**: Two manuals on *'How to Operate Tide Gauges'*. A third is planned on *'How to Operate GPS at Gauges'* following the IGS/PSMSL GPS Workshop at JPL in March 1997;
- Three workshop reports on operating gauges in environmentally hostile areas, and in polar areas;
- Two workshop reports on new geodetic techniques (GPS, absolute gravity etc.);
- UNESCO Report for small island states;
- Regional IOC/GLOSS meeting reports;
- PSMSL, etc. data holdings reports;
- Tidal analysis software reports from UH, PSMSL and NTF;
- Training course reports following each course.

For a full list of GLOSS-specific publications, see the file **'gloss.pub'** on the PSMSL ftp disk. This excludes the wide range of scientific publications flowing from the GLOSS-related sea-level data sets. The scientific assessments of the Intergovernmental Panel on Climate Change represent an important use of GLOSS/PSMSL data sets.

*3.5.4 Structure*

- The GLOSS Group of Experts (GE) has hitherto met approximately every two years, usually alongside a workshop on a relevant technical or oceanographic subject. Future plans are for the complete group to continue to meet at a similar frequency but to take advantage of scientific conferences for at least a regional sub-group to meet every year. For example, the last full GE meeting was March 1997; a West Pacific meeting is planned for July 1998 in Taiwan alongside the WPGM.
- Subject to the approval of IOC for the suggested GLOSS/OOPC/CLIVAR scientific study group (which can be considered in a GLOSS context as a sub-group of the GE), meetings will be held of this group typically annually. Technical sub-committees of GLOSS (e.g. a GLOSS Data Co-ordination Panel, or a Technical Committee recommended by the IGS/PSMSL GPS Workshop) will be based first on e-mail exchange, then meet as opportune. Technical consultants for GLOSS have been proposed but have not been obtained so far due to limited funding.
- Day to day development of GLOSS is almost entirely undertaken at present by the Chairman GE, the present IOC Technical Secretary being a temporary appointment. A permanent position is required at IOC for this important activity. Languages used for GLOSS are primarily English; the AAGN has articles mostly in Spanish and Portuguese. Training courses have been held in the language appropriate for the host country and for attendees.

*3.5.5 Operational Observing Network and Data Exchange*

- The PSMSL data set contains data from over 1,750 stations of which approximately 1,000 are currently operational. The IOC/GLOSS system ensures the establishment of a high quality subset of these stations, flagged for global purposes, as far as possible with common operating and reporting standards, with guarantees of longevity.
- There are 287 stations in the present '**GLOSS Core Network**' of which 90 percent are operational. Most do not have real-time data reporting. Some are in hostile areas (e.g. Antarctica) with data loggers inspected only once a year. Only a handful have GPS at or near the gauge in order to monitor land movements and provide a calibration system for altimetry.
- Mechanisms for data exchange of monthly and annual mean values of sea level, stored at the PSMSL and the basis of most studies of long-term sea-level change for climate change or geological movements, are long established *via* FAGS/ICSU. The original requirement for data from GLOSS sites was also only the delivery of monthly and annual data to the PSMSL.
- In the new **GLOSS Implementation Plan**, we now expect contributing organizations to make original (typically hourly) data available. These higher frequency data sets are needed (a) because there is interesting oceanography at higher frequencies, (b) for altimeter calibration and (c) for better quality control. One or more Archiving Centres (e.g. PSMSL) will synthesize the data sets. This requires common standards for formatting and quality control, hence the need for a GLOSS Data Co-ordination Panel.
- Approximately 100 gauges are capable of quasi-real-time reporting, e.g. those providing data to the 'Fast' WOCE Centre. 'Real' real-time reporting, for example for storm surge or tsunami warning, is a feature of specialized, usually regional, activities which form important components of regional GLOSS activities. As modems, cellular systems etc. become cheaper and easier, real-time reporting will become more common, with benefits to data quality.
- Methods of quality control of tide gauge data are contained in two main sets of documents: (1) two manuals on operating tide gauges produced in the IOC Manuals and Guides series, and (2) the paper 'Developments in Sea-level Data Management and Exchange' by Lesley Rickards (BODC) and Bernard Kilonsky (UHSLC) which was presented at the Ocean Data Symposium, Dublin Ireland (October, 1997). The paper describes the methods followed for data banking of WOCE sea-level information, which are essentially those of GLOSS.

- Quality control is also addressed within the software packages for tidal analysis available from the University of Hawaii, the Australian National Tidal facility and from PSMSL. The methods used in all packages include tested methods for tidal analysis, inspection of residuals and 'buddy' checking between stations.
- The issue of quality control is the main reason why the GLOSS Implementation Plan now requires that original GLOSS sea-level data be sent to an International Centre as well as the monthly and annual means to the PSMSL. In addition, there is much interesting oceanography to be studied with high frequency data and all data should be preserved in several centres for security.

#### *3.5.6 Analysis*

- **Strengths.** In the US and Europe there are many experts in the use of sea-level data for scientific and coastal studies. The development of altimetry missions has stimulated use of gauge data for altimeter calibration and for analysis.
- **Weaknesses.** The GLOSS training courses have shown that, while some countries can be trained and are very proficient technically in the acquisition of sea-level data, there is often limited scientific experience to know how to make maximum use of them. A further concern is that much of the present good status of GLOSS has been achieved through research programmes such as TOGA and WOCE, and that funds may not continue to maintain that status in future. Significant investment is required at many sites to bring gauges to modern standards of **real-time** reporting and with, where desirable, GPS equipment (following recommendations of an IGS/PSMSL GPS workshop at JPL in March 1997).

### 3.6 Tropical Atmosphere-Ocean (TAO) Implementation Panel (TIP)

#### *3.6.1 Status*

- The TAO Implementation Panel (TIP) has been formed to define strategies that will ensure uninterrupted implementation and long-term maintenance of the TAO array. The TAO Panel was established in 1992 under auspices of the international Tropical Ocean Global Atmosphere (TOGA) programme. At the end of TOGA in 1994, sponsorship of the panel shifted jointly to the World Climate Research Programme's international Climate Variability and Predictability programme (CLIVAR), the IOC/WMO/UNEP/ICSU Global Ocean Observing System (GOOS) and Global Climate Observing System (GCOS) programmes.
- Most TIP members are representatives of Member States of IOC and WMO which are actively involved in TAO activities. Presently institutes and agencies from the United States, Japan, France and Brazil, and also Taiwan, participate in TAO by contributing critical resources (including ship time, specialized mooring hardware or instrumentation, or funding for operation), to the maintenance and/or expansion of the moored array.

#### *3.6.2 Responsibilities*

- **Services.** TIP co-ordinates technical and logistical support from institutions participating in the maintenance of the array. It also co-operates with organizations such as the WOCE/CLIVAR planning committees to ensure an integrated approach to tropical observational programmes. Reports are made regularly to the GCOS/GOOS Project Offices and the CLIVAR Scientific Steering Group on the status of the TAO array.
- **Observations.** TIP ensures the rapid dissemination of TAO data to serve both operational and research applications. Near real time surface meteorological and oceanographic data from the tropical Pacific and Atlantic Oceans are provided *via* Argos on the GTS network in BUOY format to operational weather centres (WWW). TAO works with Argos and DBCP to quality control and monitor GTS transmissions. Data are also provided in near-real time to the research community (GOOS/GCOS/CLIVAR) on anonymous ftp and on a Web server. High resolution data are distributed in delayed mode for research purposes.

- **Technical development and information exchange**. TIP promotes new technology and instrumentation for moored buoy applications, impact studies based on buoy data, exchanges of technical information and training between participating countries, and participates in data quality control procedures.

*3.6.3 Publications*

- **TAO Implementation Panel Reports** once *per* year
- Technical reports on instrumentation and calibrations (**NOAA Technical Reports**)
- Scientific publications (see *http://www.pmel.noaa.gov/pubs.html*)
- TAO Web Pages with detailed information on the project: *http://www.pmel.noaa.gov/toga-tao/*

*3.6.4 Structure*

- The TAO Implementation Panel meets yearly (September-November) and the working language is English.
- Membership of the TAO Implementation Panel will be by invitation of the Global Ocean Observing System Project Office, based on recommendations made by the TAO Panel or its sponsors (GOOS/GCOS/CLIVAR). Categories of membership are:
  - ✓ **Executive Committee**: One representative from each country actively supporting the TAO Array. The TAO Panel chairman and vice-chairman will serve as national representatives on the executive committee. Responsibilities of the executive committee include: co-ordinating intersessional activities, recommending membership changes, organizing panel meetings, reporting to parent bodies, etc.
  - ✓ **Members**: Individuals representing institutions (or agencies) that provide resources such as ships, mooring hardware and/or technician time to maintain the TAO array; or individuals having special expertise in analysis and/or interpretation of TAO and other ocean-climate data sets.
- The TAO project is managed by NOAA's Pacific Marine Environmental Laboratory in Seattle, Washington, USA.

*3.6.5 Operational Observing Network*

- The TAO array in the tropical Pacific consists of nearly 70 moored ATLAS and current meter buoys, which transmit *via* satellite basic marine meteorological, surface, and sub-surface data in near-real time. Moorings are typically deployed for a one-year period after which the instrumentation is recovered for calibration and refurbishment. The moorings are located between 8°N and 8°S from 95°W to 137°E and are maintained primarily through the efforts of the United States, Japan, and Taiwan. Approximately 350 days at sea are required to maintain the array.
- The PIRATA array in the tropical Atlantic consists of 5 ATLAS moorings at present with planned deployments of up to 12 buoys in 1999. These moorings are being supported by the United States, France, and Brazil.
- Standard sensors consists of surface winds, air temperature, relative humidity, sea surface temperature and ten sub-surface temperatures in the upper 500 meters. Ocean currents are also measured at five sites along the equator. Additional sensors including rainfall, radiation, and surface salinity can be added as required by collaborative programmes.
- Engineering developments continue to incorporate new technology in order to improve data quality and data return from the array.
- TAO is now officially supported in the United States by operational funds instead of research funds. This funding is expected to continue for the foreseeable future.

*3.6.6 Data Collection, Exchange and Management*

- **Real time.** Observations from the TAO moorings are transmitted to shore in real time through Argos. Data are processed and encoded into BUOY code by Service Argos, using calibrations and algorithms supplied by PMEL. Daily averaged sub-surface data and several hourly values of surface data are available in real time each day from the moorings. The TAO Project Office works with the Data Buoy Co-ordination Panel (DBCP) and Service Argos in quality controlling the real-time TAO data. In addition to the GTS data, TAO data are also processed and quality controlled by the TAO Project Office and made available to the community *via* the World Wide Web (*http://www.pmel.noaa.gov/toga-tao/* and *http://www.pmel.noaa.gov/pirata/*) and anonymous ftp. Quality control checks are performed daily to detect instrumentation failures or calibration problems.
- **Delayed mode.** On-line archives are maintained for all TAO sites. High-resolution data (e.g. hourly surface data files) are obtained after each buoy is recovered and the data read from onboard storage. These data are processed, quality controlled, and made available *via* the Web and anonymous ftp within two months after recovery. Current data from sub-surface ADCP moorings and traditional current meters are also processed and made available upon completion. Yearly submittals have been made of all TAO data to the USA National Oceanographic Data Centre (NODC).

*3.6.7 Analysis*

- **Strengths.** Long history and experience in data collection and dissemination from moored buoys in the tropical oceans; international oceanographers and meteorologists involved with strong links to the research community; active in improving buoy performance and technology.
- **Weaknesses.** Inability to control damage to the moored array caused by vandalism; limited participation of Member Countries due in part to specialized equipment and technology that is not easily transferable.

## 4. DATA MANAGEMENT AND EXCHANGE MECHANISMS

### 4.1 World Weather Watch (WWW)

*4.1.1 Introduction*

The objective of data management is to improve access to, and the usability of, data. One role of data management in the WWW environment is to solve the interface issues which arise as data originating from the GOS move *via* the GTS to data processing centres, and as information originating from the data processing centres moves *via* the GTS to users. Another role is to address the interface issues which arise when data and products are exchanged with groups outside of the WWW community. The terms of reference of the CBS **Working Group on Data Management** (WGDM) stress the integrative role of Data Management in reviewing the performance of the components of the WWW, its responsibilities for data representation and codes issues, its role in the quality control of data exchanged *via* the GTS, and its role in ensuring that the proper co-ordination occurs as interfaces are built between the various components of the WWW, and between elements of the basic system and those of other WMO programmes. It aims to improve the efficiency of data activities, thus enabling other WMO programmes to benefit from the WWW basic systems in support of their operational requirements.

*4.1.2 Data management co-ordination*

- Over the past few years there has been increased emphasis on service to and co-ordination with other WMO and related international programmes. Therefore, CBS expanded its terms of reference to ensure that the Basic Systems respond to the data management requirements of all

WMO and related international programmes. Twelfth WMO Congress requested CBS to co-ordinate the preparation of a WMO Plan for Data Management. WDM-sponsored inter-programme data management co-ordination meetings provide a forum to co-ordinate the data management activities of all WMO technical commissions and related international programmes and have led to significant progress and a methodology for developing an integrated WMO-wide data management plan.

- Among the tasks of the CBS Working Group on Data Management is the co-ordination of data management across all WMO programmes and leading the preparation of a WMO **Guide to Data Management**. A draft outline of the guide has been provided to the Presidents of the other technical commissions seeking comment and inviting them to nominate experts who could contribute to the guide.

*4.1.3 WMO distributed databases*

The development of distributed databases within the WMO systems is being undertaken to expand the ability of all Members to make *ad hoc* requests for data held in databases of Members who are willing to share specified data. In 1992, the tenth session of CBS renamed the WWW Distributed Databases concept WMO Distributed Databases (DDBs) to more accurately reflect its goals to meet the requirements to provide data and information needed by WMO, and related international, programmes but not routinely exchanged on the GTS. A trial of the DDBs concept began in October 1995 and as part of the trial the Secretariat has made the information contained in WMO Pub. 9, Vol. A and C and Publication 47 available *via* FTP. The trial will include reviews and adjustments to procedures every six months and will be expanded to the GTS once the Main Telecommunications Network (MTN) has been upgraded to support TCP/IP communications protocols.

*4.1.4 Software exchange*

WDM facilitates the exchange of software between Members through the CBS **Software Registry** which provides information on software available from and requested by Members. The latest version of the Registry was distributed and a digital version of the registry has been available *via* the World Wide Web since late 1995.

*4.1.5 Representation forms*

Agreed upon codes and data representation forms are one of the most fundamental requirements for efficient international exchange of meteorological data and products. The WGDM and its subgroup on data representation and codes is responsible for the development and maintenance of these code forms. Over the past 10 years the increasing automation of data exchange has led to development of binary table-driven data representation forms such as BUFR and GRIB. These data forms provide for much more flexible, efficient transfer and computer processing but are not directly readable by humans. Their enormous flexibility has proven to be so important, however, that a new character-based table driven code, CREX, has been developed and is now being used on a trial basis. The WWW supports and maintains a number of existing codes for oceanographic data exchange in character form (BUOY, BATHY, TESAC, TRACKOB, WAVEOB). A separate section has been included in BUFR exclusively for oceanographic data, maintained by IOC/IODE.

*4.1.6 Monitoring*

WDM is responsible for the monitoring of the operation of the WWW. It develops procedures for monitoring the quality and quantity of the data and products exchanged but these procedures are carried out by the other WWW components. The monitoring routinely includes oceanographic data exchange on the GTS in the existing oceanographic codes.

*4.1.7 Training and guidance material*

- The WGDM compiled the **Guide on WWW Data Management** with an additional WWW Technical Document: "**Guide to WMO Binary Code Forms**" which provides an in-depth tutorial of GRIB and BUFR. Following the request of CBS-X, the Working Group on Data Management has initiated actions to co-ordinate development of a WMO-wide guide on data management.
- Regional training seminars on WWW data management are held once every one or two years and provide up-to-date information on data management issues to WMO Members. These seminars cover all aspects of data management but often devote a considerable portion of their time to data representation and codes issues as these are often the most difficult to understand.

## 4.2 IOC Committee on International Oceanographic Data and Information Exchange

*4.2.1. Status*

The IOC's **Committee on International Oceanographic Data and Information Exchange** (IODE) was established in 1961 by the IOC as an intergovernmental mechanism to improve the management and exchange of marine data in delayed mode. Subsequently IGOSS was established for real-time collection, exchange and processing of oceanographic data (see Section 3.3). Today, IODE consists of over 65 member countries and with more than 40 **National Oceanographic Data Centres** and **Designated National Agencies** providing data management services to their countries and assisting the global exchange of data.

*4.2.2. Responsibilities*

IODE was established to *"enhance marine research, exploration, and development by facilitating the exchange of oceanographic data and information between participating Member States."* With the advance of oceanography from a science dealing mostly with local processes to one which is also studying ocean basin and global processes, researchers depend critically on the availability of an international exchange system to provide data and information from all available sources. Additionally, scientists studying local processes benefit substantially from access to data collected by other Member States in their area of interest. The success of the IODE programme depends on the support of participating Member States, and the involvement of many individual institutions and marine scientists, who contribute not only data, but also the necessary expertise to maintain and further develop the IODE system.

*4.2.3. Publications*

IODE produces a range of publications and other material in support of marine data management and data exchange processes. These range from **Manuals and Guides** on the creation of National Oceanographic Data Centres through to data quality control procedures and data exchange formats. There are other products such as the **OceanPC** suite of software for marine data management, analysis and display of oceanographic data as well as a 'shoe box' of data management software.

4.2.4. *Structure*

- The **IODE Committee** provides the direction and co-ordination for the operation of the IODE programme. The physical composition of IODE is a network of agencies, data centres, expert groups and specific projects that provides a framework for the management and exchange of data. This 'infrastructure' also undertakes the development of standards, introduces new technologies and undertakes a range of training and technology transfer activities.
- **Designated National Agencies (DNA).** Some Member States that have not established National Oceanographic Data Centres have instead officially assigned the responsibility of international

exchange of oceanographic data and information to some other agency within the Member State. These agencies are referred to as Designated National Agencies. DNAs are generally smaller agencies with few resources but with an interest in the co-ordination of marine data management.

- **National Oceanographic Data Centres (NODC).** National Oceanographic Data Centres are funded agencies with an endorsed government responsibility for the management, exchange and archiving of oceanographic data in the national interest. NODCs actively exchange data within their region and with other centres within the IODE programme such as the World Data Centres (WDCs). This facility acquires, processes, quality controls, inventories, archives and disseminates data in accordance with national responsibilities. In addition to disseminating data and data products nationally, NODCs are normally charged with the responsibility for conducting international exchange. Here, the most fundamental responsibility of the NODC within the IODE is to actively seek and acquire from national sources those data which are exchangeable internationally, and to process and quality control the data and submit them in a timely fashion to the appropriate WDC for Oceanography or RNODC. In return, the NODC can request and receive from the WDCs for Oceanography or RNODCs similar data or inventory information which they need for their own requirements.
- **Responsible National Oceanographic Data Centres (RNODC).** Some countries operate Responsible National Oceanographic Data Centres in association with the NODC's. RNODC's assist the World Data Centres in a specific area, such as a specific type of data or data exchange formats or they may cover a specific regions such as the RNODC Southern Ocean. Existing RNODCs include:
  - ✓ RNODC for the Southern Oceans
  - ✓ RNODC for Drifting Buoy Data
  - ✓ RNODC for IGOSS (BATHY and TESAC)
  - ✓ RNODCs for Marine Pollution Monitoring (MARPOLMON)
  - ✓ RNODC for Waves
  - ✓ RNODC for IOC Sub-Commission for the Western Pacific (WESTPAC)
  - ✓ RNODC for Indian Ocean
  - ✓ RNODC for JASIN
  - ✓ RNODC for Formats
  - ✓ RNODC for Acoustic Doppler Current Profiler (ADCP)
- **World Data Centres (WDC).** The top of the data exchange pyramid are the World Data Centres (WDC) for Oceanography, which form part of the network of data centres established by the International Council of Scientific Unions (ICSU). WDCs receive oceanographic data and inventories from NODCs, RNODCs, marine science organizations, and individual scientists. These data are collected and submitted voluntarily from national programmes, or arise from international co-operative ventures. On request, the WDCs provide copies of data, inventories and publications to NODCs/DNAs, to RNODCs and to international co-operative programmes, as appropriate, in exchange, or with a charge not to exceed the cost of providing the service. Another major responsibility of the WDCs for Oceanography is to monitor the performance of the international data exchange system and report their findings to the IOC Secretariat and the IODE Committee. The Committee can use this information to take appropriate action to correct deficiencies in the international exchange system. There are currently three World Data Centres (Oceanography):
  - ✓ WDC-A: United States (Silver Spring)
  - ✓ WDC-B1: Russian Federation (Obninsk)
  - ✓ WDC-D: China (Tianjin)

*4.2.5. Activities*

The IODE programme undertakes a wide range of activities. Some of the more significant ones include the:

- **Global Ocean Data Archaeology and Rescue (GODAR)** programme which has increased the global database with in excess of 1.5 million oceanographic observations.

- **Global Temperature and Salinity Profile Programme (GTSPP)** which is a joint programme with the IOC/WMO Integrated Global Ocean Services System (IGOSS) and provides a highly successful model of 'end-to-end' marine data management, merging both near real-time and delayed-mode data streams. The approach used in GTSPP, which integrates IGOSS, IODE and the scientific community in to an effective data management mechanism is considered a model for the GOOS requirements (for more on the GTSPP, see Section 4.3).
- **Marine Environmental Data Inventory (MEDI) Pilot Project** which is developing a global inventory of marine data sets (metadata) and is compatible with other global data inventory or data directory services such as those being developed by CEOS and NASA with the Global Master Change Data Directory. The MEDI Pilot Project is also compatible with the metadata pilot project being developed by the G3OS Joint Data and Information Management Panel (J-DIMP).
- **OceanPC** which is a suite of PC software for the management, analysis and display of oceanographic data in all parts of the world. The package is in use with over 400 marine scientists and data managers.

#### *4.2.6. Analysis*

- **Strengths.** These include: funding stability; redundancies in data archives ensuring no loss of data; demonstrated successful programmes including Global Ocean Data Archaeology and Rescue (GODAR) and the GTSPP; demonstrated capability to partner scientific organizations and programmes (e.g. WOCE DACs for UOT, Sea Level, ADCP, SVP); considerable experience in managing large amounts of a wide range of data types; ability to provide services and develop products such as CD-ROMs on GTSPP, World Ocean Atlas 94, World Ocean Database 98, GEBCO, etc.; existing infrastructure in place to manage global data.
- **Weaknesses.** These include: a large organization sometimes difficult to move; reliance on voluntary contributions of Member States; uneven levels of skills across the system.

### 4.3 Global Temperature and Salinity Profile Programme (GTSPP)

#### *4.3.1 Status*

- The GTSPP is a joint IOC/WMO project that knits together both real-time (typically IGOSS) and delayed-mode (typically IODE) data collections of global ocean temperature and salinity observations into a single programme. Participants are governmental and scientific organizations in various countries who support their contributions to GTSPP through their own budgets. It was initiated jointly by the Intergovernmental Committees for IGOSS and IODE in 1989 as a pilot project, and converted to a long-term programme in 1996.
- Tasks in the GTSPP are shared amongst the participants. Real-time data processing services are provided by the **Marine Environmental Data Service (MEDS)** of Canada. The **U.S. NODC** provides data processing services for delayed-mode data and maintenance of the **Continuously Managed Database, CMD**. AOML, CSIRO and Scripps provide scientific advice and assessment of the data handled by the project. Through co-operation with WOCE, the WOCE Sub-surface Data Centre in Brest (France) has also contributed data and expertise. Other data centres in IODE provide data to the project as they are processed. Co-operation with the GODAR Project also brings data into the GTSPP.

#### *4.3.2 Responsibilities*

- **Observations.** The GTSPP concerns itself with temperature and salinity profiles collected from the world's oceans. Other observations made in association with the T and S profiles, such as other profiles or surface marine observations, are also carried with the data.
- **Services.** One of the goals of the GTSPP is to provide data of the highest possible quality as quickly as possible to users. The foundation of this goal is the CMD. This database holds both real-time and delayed-mode data. Where both the real-time and delayed-mode data exist from a

particular location and time, the delayed mode is retained in the CMD because it represents the highest resolution and highest quality data. The contents of the CMD are available upon request from the U.S. NODC.

*4.3.3 Publications*

In co-operation with other partners this includes:

- **IOC Manuals and Guides #22**
- **CSIRO Quality Control 'Cookbook'**
- **AOML Quality control manual**
- All meeting reports
- GTSPP CD-ROM

*4.3.4 Structure*

- The **GTSPP Steering Committee** meets as required to continue the operation of the programme. Meetings have been jointly held with WOCE committee meetings to reduce costs. In the last few years of the programme, meetings have been roughly 18 months apart.
- The Chair of the GTSPP Steering committee was elected at the start of the Project and this post has been held by the same person since then.
- The GTSPP functions by actions undertaken by participants to achieve common goals agreed to at the meetings. Since it is a collection of volunteer organizations, adjustments are always needed to accommodate changes in levels of participation of members. These adjustments are made by current members taking on new roles or by recruiting new members.

*4.3.5 Observing Network*

- The GTSPP takes advantage of a number of services and infrastructures available at both the international and national levels. Internationally, the WMO provides the use of the GTS for the transmission of oceanographic messages through the IGOSS programme. GTSPP uses this service to acquire the data exchanged this way.
- Some nations have developed an extensive infrastructure to provide and service ships of opportunity in the collection of temperature (and some salinity) profiles around the world. These programmes have become a key component of the SOOP, and GTSPP provides the data management component.
- Many nations undertake both monitoring and research data collection programmes at sea. These may be through autonomous instruments, such as floats, or from ships. Data collected are provided to their National Oceanographic Data Centres or to RNODCs of the IODE system. From them, T and S data are provided to the GTSPP for inclusion in the programme.

*4.3.6 Data Exchange and Management*

- Real-time data are managed by MEDS. The data are received and processed through quality assessment and duplicates resolution software three times each week. At the same schedule, the data are transferred to the CMD held in the U.S. Users who require fast availability to these data can contact MEDS for this service. MEDS provides response to one time requests or routine downloads of the data received. At present there are both Canadian and international users of the service.
- Monitoring of the exchange of real-time data takes place primarily at MEDS. Each month MEDS reviews data from ships that show a more than 10% failure rate on profile data. Systematic problems are noted and ships operators are notified by e-mail. Those ships that have had problems consistently over time are specially noted in the report.
- GTSPP also monitors the data received by 4 different centres acquiring GTS data around the world. These include the Germans, Japanese and a U.S. site. Each month a report is prepared

comparing the data received from North American sites and then shortly afterwards from all of the sites. Discrepancies noted by these reports are used to track down problems with data getting to the GTS or getting sent around the world.

- GTSPP has also participated in special and routine monitoring projects of the GTS run by WMO.
- Delayed-mode data are managed by the U.S. NODC. They accept the real-time data from MEDS and update the CMD when data are received. Delayed-mode data are acquired either from other NODCs, or from co-operation with projects such as WOCE, GODAR and SOOP. Users are supported in a similar manner as at MEDS. Some of the data are also available through the Internet.
- Through comparisons with the holdings of the **WOCE Sub-surface Data Centre** in Brest and the U.S. NODC, discrepancies in content have been corrected. Scientific data quality assessment has been provided on yearly files by the scientific institutions noted above. Not only does this provide another level of assessment, but promotes the collaboration and exchange of expertise between scientific and data management personnel.

#### *4.3.7 Analysis*

- **Strengths:**
  - ✓ Co-ordination between real-time and delayed-mode data processing;
  - ✓ Data collectors provided with feedback;
  - ✓ Co-operation between researchers and data managers;
  - ✓ Expertise of the participants in data management;
  - ✓ Good technical and infrastructure support by participants;
  - ✓ Well connected to other complimentary programmes such as SOOP, GODAR and WOCE and services of WMO and IOC.
- **Weaknesses:**
  - ✓ Co-ordination between many organizations can be difficult;
  - ✓ Operational products not readily attributable to GTSPP;
  - ✓ Lack of independent funding requires voluntary participation.

### 4.4 Data management issues for GOOS/GCOS

#### *4.4.1 Introduction*

4.4.1.1 In the modern approach to data and information management, the delivery of oceanographic products is viewed as the result of a production-line process. This approach implicitly requires a number of functions to be recognized as important. These are specified below in the form of a checklist (4.4.2 to 4.4.6). In generating any one product, not all of the items on the checklist may apply, but all should be considered.

4.4.1.2 It is likely that steps in the production line will be carried out by more than one agency. In that case, the responsibilities of each agency must be clear, and national or international support must be provided on a sound basis. Co-ordination between agencies will be important and mechanisms to ensure this must be established.

4.4.1.3 The steps taken, agency responsibilities, and the other factors considered for each product must be well documented. The documentation must be accessible to existing and future clients and properly maintained.

#### *4.4.2 Parameter Measurements*

- **Variable Selection** Each product will require one or more variables to be measured. Combinations of variables from different environmental regimes (i.e. ocean, atmosphere, land) may need to be combined to form a single product. This demands recognition of the variables required and a scientific basis for their combination into the desired product.

- **Instrumentation** Each variable required for a particular product will have to be measured to a required level of accuracy and precision. Consideration must be given to the ability of the various instruments available for making the measurement to meet the accuracy and precision requirements.
- **Space and Time Scales** Each product will demand sampling at specified time and space scales determined by the scientific requirement to meet the product specifications. It must be clear what the scales are and what the consequences are for the product when the sampling requirement is not met.
- **Metadata Requirements** Each product will be associated with its own set of parameters which must be documented as part of the product generation process. These metadata must be preserved with the data to make the information available for generation of other products in the future.

### *4.4.3 Data Collection and Storage*

- **Timeliness of Collection.** For the generation of each product a schedule will be required for the delivery of data from the instrument to the processing centre. These demands will in turn create demands on the data assembly process. Failure to meet these demands may cause some degradation of the product and must be documented with the product.
- **Fault Tolerance.** The data collection system will not always perform at peak efficiency. It will usually be necessary to build in redundancies in the collection and transmission systems to provide an adequate degree of tolerance to faults in the system. Accommodating some degree of fault tolerance will help to offset degradation of the product.
- **Down-time Tolerance.** From time to time, the entire collection system may be shut down. Building a degree of redundancy into the system will enable it to perform robustly under adverse circumstances. Failure of a component of the collection system which shuts off provision of data to the processing system will also affect product generation, with a variety of possible consequences that need to be allowed for in designing product delivery.
- **Data Archives.** Data collected for a particular product may also serve other valuable ends. This is particularly true of long and continuous Time-Series measurements which are useful in climate change studies. Archiving may be required not only for original data and products but also for intermediate results used in product generation. Consideration must be given to how such archives will function.
- **Data and Information Transmission.** Details of data and information transmission must be decided, including such things as the appropriateness of existing transmission systems and data formats. Where needed, new forms of transmission and formats may be required. In such cases the impacts of changes on the complete production line must be considered.

### *4.4.4 Processing*

- **Timeliness.** In order for products to be useful they must usually be produced in a timely manner. The time constraints set limits on the speed at which data processing must be carried out. The production process, including data quality assessment, duplicates removal, computer model runs, etc., must be designed to be completed within the required time schedule.
- **Data Duplication.** Redundancies in a processing system, or other factors, cause data to be duplicated. The impact of duplicates on a product, and the necessity to control these duplications, must be assessed. Where duplications must be controlled, specific mechanisms for doing so must be identified and implemented.
- **Data Quality.** Each product will have a certain tolerance to data of poor quality affecting the result. It is important that this tolerance be considered. Mechanisms for managing data quality in order to screen out lower quality data must be put in place. The explicit rules of assessing quality must be well documented.
- **Feedback.** Each data collection system should include a mechanism for monitoring the characteristics of the data collection, including data quality, timeliness of transmission, adequacy of sampling strategy, etc. If there are problems with any of these factors, appropriate corrections must be made to prevent their recurrence.

- **Data Availability.** Once used for product generation, the data and information stored in archives should be available to others for other purposes.

*4.4.5 Product Dissemination*

Given products should be designed for a particular target audience, which should be consulted on the form and content of the product and the delivery mechanism for getting the product to the user. In some cases more than one delivery schedule and carrier may be used.

*4.4.6 Product Suitability*

Mechanisms must be devised for obtaining feedback from users on the adequacies of and desired changes in a product.

# 5. THE INITIAL OBSERVING SYSTEMS FOR PHYSICAL OCEAN OBSERVATIONS FOR GOOS/GCOS

Section 5 provides an overview of the need for ocean observations for climate as expressed by GCOS and the Subsidiary Body for Scientific and Technical Advice (SBSTA) of the Conference of the Parties (COP) to the Framework Convention on Climate Change (FCCC) as well as the recommendations of COP-4 in Buenos Aires in November, 1998. This is followed by a summary description and analysis of the capabilities and structure of the existing international observational and data management mechanisms that are described in detail in Sections 3 and 4 and which are available for the implementation of the GOOS/GCOS observing system (Section 5.2). The need for a modified and more unified structure are discussed. In Section 5.3, the main observation types, in particular, surface, sub-surface and sea-level, are examined in terms of their implementation requirements and factors that must be taken into account for GOOS/GCOS to facilitate implementation are suggested. In Section 5.4 the proposed OOS is examined in terms of the observing system applications and goals and how these relate to the implementation process. The status of specific surface networks is presented as are pilot projects and a number of emerging observation systems that might in the future become part of the IOS are also presented. Cross-cutting issues and a list of recommendations and actions are given in Sections 5.4 and 5.5.

## 5.1 The Statements and Recommendations of SBSTA and COP-4

5.1.1 In preparation for COP-4, SBSTA was requested to consider the adequacy of the relevant global observing systems. To meet this requirement, GCOS prepared a report for SBSTA (GCOS-48) which formed the basis of SBSTA's report to COP-4 at its meeting in Buenos Aires, 2 to 14 November, 1998. It includes the following general statement:

5.1.2 *"This report concludes that many of the observational requirements are generally known and documented and that many are in place, but need substantial augmentations and enhancements to fully serve climate purposes. Fortunately many of the techniques needed to obtain the measurements are currently available and cost effective, and an appropriate intentional infrastructure has been identified to facilitate the collection and distribution of climate-related observations.*

5.1.3 *What is urgently needed is commitment by nations to provide global coverage for the key variables, to reverse the degradation of existing observing systems, and to exchange information more effectively. It is recommended that each Party should undertake programmes of systematic observations in accordance with national plans, which they should develop in concert with the overall strategy for global climate observations. A positive response to this challenge would significantly advance the implementation of an effective observing system for climate and support the objectives of the FCCC."*

5.1.4 Regarding ocean observations SBSTA provided a general recommendation and several more explicit findings. They are, using the notation of GCOS-48:

- **Recommendation 4:** Countries should actively support stated national oceanic observing systems and particularly ensure that the elements of the GCOS and GOOS networks in support of ocean climate observations are implemented to the degree possible. Support should be provided to increase the number of surface observations, particularly in remote areas, and to establish and maintain reference stations and repeat sections. Current satellite missions to observe sea surface elevation, wind stress and temperatures should be continued.
- **Finding 11:** Support should be provided for the creation of a joint body for oceanography and marine meteorology, as proposed by the IOC and WMO, to implement and maintain the ocean observing system.
- **Finding 12:** Nations and responsible agencies should support a range of measures to improve the quality, continuity and long-term stability of the surface marine observation networks relevant to climate.
- **Finding 13:** Responsible national agencies should support the establishment of climate reference sites to obtain data for calibrating models and satellites.
- **Finding 14:** Noting the importance of measurements in ice-covered regions of the ocean and, consistent with the emphasis on global homogeneity, national agencies should maintain the Arctic programme and implement an enhanced programme for Antarctica. For ice extent it is recommended that better documentation of the data stream be provided.
- **Finding 15:** Increased participation is required to implement GLOSS plans for measuring sea level and to ensure long-term continuity of the surface network. In addition, satellite altimetry for climate change and programmes of geodetic positioning should be supported.
- **Finding 16:** Support is required for the programme to enhance the observing system for the global oceans, which emphasizes need for sampling to greater depth (1500-2000 meters) in data sparse regions. Both temperature and salinity profiles are needed.
- **Finding 17:** A programme of trans-ocean sections, at locations and frequencies to be determined, is needed to monitor heat, freshwater and carbon circulation in the ocean.
- **Finding 18:** The implementation and maintenance of time-series stations to provide high quality, climate records and to calibrate and validate ocean carbon-cycle models and satellite ocean colour instruments are required.
- **Finding 19:** Observations are required of the exchange of carbon across the air-sea interface. Available techniques include underway sampling and fixed buoys. Research is needed to better characterize the process of carbon uptake.

5.1.5 On receipt of the report from SBSTA, COP-4. at its meeting in November 1998, included in its Decisions two that have direct relevance to the implementation of the GOOS/GCOS OOS. Decision 2 focuses on the role that the Global Environment Facility (GEF) should play in providing funding to the developing country Parties to broadly develop their capability to participate in systematic observational networks to reduce scientific uncertainty relating to the causes, effects, magnitude and timing of climate change as well as to address general aspects of climate change and its impacts. Decision 14 more directly addresses GCOS and its partner programmes (GOOS and GTOS) and among other things "*urges Parties to actively support national oceanographic observing systems, in order to ensure that the elements of the Global Climate Observing System and Global Ocean Observing System networks support of ocean climate observations are implemented, to support, to the extent possible, an increase in the number of ocean observations, particularly in remote locations, and to establish and maintain reference stations.*"

5.1.6 The full text of COP-4 Decisions 2 and 14 are included in Annex IV.

## 5.2 System Analysis

5.2.1 The existing operational and data management mechanisms that can be used for the implementation of the GOOS/GCOS ocean observing system are those described in detail in Sections

3 and 4. A table summarizing the structure and capabilities of the former (CMM, IGOSS, SOOPIP, GLOSS, DBCP and TIP) is given in Annex V. For further details, refer to Section 3. It is clear that they have, in some cases widely, different reporting structures, responsibilities, level of quality control procedures, data transmission and archiving mechanisms, and approaches to capacity building. These differences do not reflect on their ability to carry out the tasks for which they were put in place, but rather that they have developed over time to meet a variety of research and operational requirements and have not been formed to address a single integrated observation system such as the GOOS/GCOS observing system. Indeed, most of these implementation mechanisms have some responsibility or co-ordination role for observations that may be of the same type, or from the same class of instrument, as the observations of the GOOS/GCOS OOS but which are collected for other reasons, for example research, and which may be of short duration or undergo quality control procedures inappropriate for GOOS/GCOS.

5.2.2 A similar table has not been prepared for the data management and exchange mechanisms given in Section 4 (the WWW, IODE and GTSPP) but it can be seen from Section 4 that the same diversity in structure and purpose exists. It is for this reason that a Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) has been proposed by the organizers of the GOOS/GCOS IOS and provisionally accepted by the IOC and WMO awaiting final formal approval. Its proposed form and function are described in Section 6. Its origin arises from the need to implement the GOOS/GCOS OOS in as rational and co-ordinated way as possible.

## 5.3. Observational Categories and Issues

For the purpose of the implementation of the ocean observing system for GOOS/GCOS, it is convenient to separate the elements as given in Section 2.1 into those that concern the surface, the upper ocean and the global sea level. This would be done within the structure of JCOMM. In this section, the characteristics of the observations and the implementation requirements for each of these categories is discussed. The same headings are used, where appropriate, as are used for the analysis in Section 5.2 and Annex V of implementation mechanisms. To some extent the analysis is redundant, especially for the surface and upper/sub-surface ocean, which is to be expected since many aspects and difficulties with the implementation of the components of the observing system are common.

### *5.3.1 Surface Observing System*

- **Status.** The elements of the surface observing system are specified in Section 2.1 based on the OOSDP report as modified and given increased detail by the OOPC.
- **Observation networks.** Required are satellite AVHRR and *in situ* observations for SST; satellite scatterometer and VOS and buoy observations for surface winds; the products of NWP models and regional *in situ* verification for the fluxes of heat and fresh water; *in situ* VOS and buoy observations of $pCO_2$; satellite and regional *in situ* observations for sea-ice extent concentration and thickness; and drifter surface velocity. For more detail of surface sampling requirements, see Section 2.1. These requirements can partly be met by some of the observations obtained through CMM, IGOSS, SOOP, DBCP and TIP as well as the availability of specific satellite data and the best NWP products. In addition, there is the need for additional observations where existing coverage is inadequate in space and/or time. There is a need to develop a strategy to pull together the relevant parts of the various systems and to influence them where necessary to meet GOOS/GCOS standards and continuity requirements. Only the CMM has regulatory powers.
- **Scientific support.** The principle support could be provided by the SCOR/WCRP Air-Sea Working Group if it is given the appropriate mandate and includes broad enough expertise. The OOPC also provides oversight scientific support.
- **Data management system.** As listed in Annex V and Sections 3 and 4, the international structure provides mechanisms for data flow, quality control and archiving for most of the required data. However, these are often not co-ordinated with each other and may not be close to either those that collect the data or those that will use it. Obtaining estimates of the surface fluxes, for example, requires several basic observations and an integrated data flow.

- **Quality Control.** Although the international implementation mechanisms all include some level of quality control, there is a need to ensure that there is quality control by those close to the data stream and that scientific level quality control is built into the system.
- **Data archiving.** Archives exist for most of the surface data, but for some, for example surface waves, no single archive exists. Metadata must be kept in archives. Standardized formats allowing easy use of data from different archives should be considered.
- **Resources (programme support).** The international agencies do provide some level of programme support that can be used for the implementation of the GOOS/GCOS observing system but as can be seen from Annex V present support is marginal and will need strengthening for the implementation of the full observing system.
- **Resources (operational network)**.. The resources to put the operational network in place can only come from nations. There is a need internationally to set priorities and to focus and co-ordinate national contributions in the most effective direction. The GOOS/GCOS surface observing system cannot be fully implemented without new resources.
- **Capacity building.** Capacity building can for the most part be carried out using the mechanisms available to the operational agencies and noted in Annex V. There is a need for more international and/bilateral resources for capacity building. as well as for a strong effort to make all nations aware of the benefits from participation in the GOOS/GCOS IOS.

### *5.3.2 Upper Ocean Observing System*

- **Status.** The elements of the upper ocean observing system are specified in Section 2.1 based on the OOSDP report as modified and given increased detail by the OOPC. This has been done in consultation with the CLIVAR UOP.
- **Observation networks.** Description of the upper ocean is dependant on the elements of the surface observing system given above. In addition, the requirement is for vertical profiles of T in the broadcast mode from SOO and Argo, as well as from TAO locations and in regions of special significance. Regarding SOOP lines, in general priority needs to be given to lines with established good-quality records. Vertical profiles of salinity are also a requirement, especially at high latitudes and parts of the tropics but are more difficult to obtain to the required accuracy operationally. Altimetry is also an element of the upper ocean observing system, as are repeat hydrography and Time-Series stations. For more detail of upper ocean sampling requirements, see Section 2.1. IGOSS, SOOP, DBCP and TIP all have a role in implementing the upper ocean observing system.
- **Scientific support.** The scientific support for the upper ocean observing system is provided by the OOPC and the CLIVAR UOP. The strategy for the implementation of Argo needs to be developed. In the future, the design of GODAE and its results can be expected to influence the upper ocean observing system. Argo has great potential for relatively inexpensive global upper ocean observations, especially if salinity accuracy can be established. The role of Argo *vis-à-vis* the traditional upper ocean hydrographic and XBT observations will need resolution in the future. GODAE itself will help determine the relative effectiveness of different observations in defining the (climate) state of the ocean.
- **Data management system.** As listed in Sections 3 and 4, the international structure provides mechanisms for the flow, quality control and archiving of upper ocean data. In implementing the upper ocean observing system, the experience gained from the GTSPP and TAO is important. As Argo is implemented special additional data management questions may arise.
- **Quality control.** In addition, to that provided by the international implementation mechanisms, there is the need to ensure that scientific level quality control is built into the system. The model used by WOCE and TOGA of an RNODC with a scientific institution for the quality control of a specific data type has merit (e.g. the co-operation between MEDS and AMOL regarding drifter data). Special quality control questions will arise from Argo.
- **Data archiving.** International archives exist for the upper ocean data within the framework of the IODE. Consideration needs to be given to maintaining the ability to obtain a special GOOS/GCOS quality controlled data set within the general IODE system.

- **Resources (programme support).** As for the surface observing system, full implementation of the upper ocean observing system will require additional support within the international operational mechanisms and for any special systems that need to be put in place for quality control or for Argo.
- **Resources (operational network).** National support is required beyond that presently being provided for operational systems (such as the ENSO array in the tropical Pacific) or for research programmes that presently obtain substantial upper ocean observations. To obtain this support from nations there is a need to prioritize the elements of the observing system and to make sure nations are aware of the rewards of participation.
- **Capacity building.** Much capacity building can be done within the existing international mechanisms. There is an overall need to attract users of the system by making the benefits of contributing clear.

*5.3.3 Global Sea Level*

- **Status.** The requirements for sea level as set out by the OOSDP and modified by the OOPC are given in Section 2.1. It addresses the different issues; namely, the determination of the change in ocean volume that can be the result of greenhouse gas warming, sea surface topography anomalies that arise from ocean variability on monthly to decadal time scales including that associated with ENSO and the NAO, and mesoscale variability.
- **Observation networks.** Required for the determination of the change in ocean volume are a precision altimeter and a limited set (of order 50-60) of geocentrically positioned tide gauges both on ocean islands for altimeter calibration/validation and at the continental margin to identify tectonic effects. Required for the determination of sea surface topographic anomalies and mesoscale variability are one or more altimeters, one of which should be of precision accuracy, and tide gauges on islands in the region of interest (for example the western tropical Pacific). In the event that a precision altimeter is not operationally available in the long term, the requirement for tide gauges increases. By making sea level a separate observing category for the purpose of this action plan, only one of the implementation mechanisms, GLOSS, is involved.
- **Scientific support.** The specific requirements have been established by the OOSDP and OOPC. The GLOSS Group of Experts has also provided both scientific and operational advice on the global tide gauge network and the TOPEX/POSEIDON community has mechanisms for providing advice on the scientific aspects of precision altimetry. For GOOS/GCOS it has been suggested that observing system design questions might be better addressed by a joint scientific panel of the OOPC and GLOSS. This proposition requires resolution. Since sea-level variability is of importance to C-GOOS on time scales of seiches to those of climate change, there is a need to for a co-operative approach to the design of the network of coastal tide gauges. In this context it is worth noting that accurately connecting coastal tide gauges to the open ocean sea-level variability as seen by precision altimeters requires continental shelf models that are not in general available.
- **Data management system.** A new requirement is that the original GLOSS sea-level data be sent to an International Centre as well as the monthly and annual means to PSMSL.
- **Quality control.** Checked by tidal analysis, inspection of residuals and checking with 'buddy' sites.
- **Data archiving.** Final archiving at PSMSL.
- **Resources (programme support).** About one-half the time of an IOC staff member is assigned to GLOSS. The GOOS/GCOS requirements for (precision) altimetry and a reliable geocentrically positioned set of tide gauges will require consistent and capable programme support.
- **Resources (operational network).** Tide gauges are supported by nations for a variety of mostly local reasons. A global network to meet GOOS/GCOS requirements requires tide gauges in locations where national interests may not choose to locate them, especially if the requirement includes the expense of continuous GPS location. Thus, mechanisms for supporting the global network are needed. In this respect the preferred location of the limited number of island and coastal tide gauges recommended by the OOSDP needs to be addressed by an expert group.
- **Capacity building.** GLOSS carries out training sessions on the operation of tide gauges and has produced a number of manuals on related topics. As for other aspects of the GOOS/GCOS

observing system, there is a need to increase local awareness of the importance and benefits of participating in GOOS.

### *5.3.4 Additional Elements of the Observing System*

- The analysis of the observing system in terms of its surface, upper ocean and sea-level parts has the potential for ignoring elements of the observing system as presently designed by the OOSDP or in the future as technologies and understanding of the observing networks change, perhaps as the result of the findings of pilot projects.
- Of immediate concern is that Section 2.1 includes hydrographic sections for the determination of changing ocean inventories and the transport of heat, fresh water and carbon, and of the production of watermasses in critical regions. It also includes reference to Time-Series stations, some of which will be occupied as part of GOOS/GCOS. These have not been included in the analysis of the mechanisms for implementing the GOOS/GCOS observing system given above. The OOSDP report states that " .. *the repeat hydrography and trans-ocean sections of T, S, carbon and selected tracers have been listed as category 3 (elements to be added later) even though they are essential to attaining sub-goals 3a and 3b. They lack some urgency because of the global coverage now being provided by WOCE and because their inclusion would require long term commitments (at least commitments with repeat terms of five to 10 years) that nations are unlikely to make to an operational observing system at this time.*" When, given the experience of WOCE, it is decided by the OOPC that it is time to initiate trans-ocean hydrographic sections, it may be necessary to include additional implementation mechanisms similar to those used by WOCE and being continued by CLIVAR. For observation of the changing ocean inventory of carbon, the only global ship programme that can presently be seen to meet the requirement for a platform for carbon observations is the hydrographic section programme of GOOS/GCOS.
- With the exceptions just noted, the division of the elements of the observing system into those concerning the surface, the upper ocean and global sea level would seem to facilitate oversight of its implementation in terms of common platforms, data streams, quality control issues, etc., as well as the interests of those scientists who must be involved in the process. Special characteristics and problems regarding for each type of observation will however remain and need to be accounted for in the implementation process.

## 5.4 Network Rationale, Status, Pilot Projects and Regional Programmes

### *5.4.1 Network Rationale*

5.4.1.1 This section partly serves as a reminder that the GOOS/GCOS OOS is not designed to meet the structure of the existing implementation mechanisms (Section 5.2) or the specific aspects of the surface, upper ocean and sea-level observing systems (section 5.3). It has instead been designed and justified because of the requirements for information regarding various aspects of the climate system such as the observation of the change in ocean volume from greenhouse gas warming or the need for observations to initialize models for ENSO prediction. The left hand columns of Tables A and B in Annex II serve to emphasize the purpose for which various observations are obtained.

5.4.1.2 It is difficult to separate one climate concern that places demands on the observing system from another. Various variables provide input to a number of fundamental climate signals. Some variables such as SST, which is important in its own right as an indication of global warming, is required in the tropics for the initialization and verification of ENSO predictions and globally for the estimates of the surface heat flux. Thus, the division of the requirements for the elements of the observing system into a number of non-redundant unique climate problems or signals is not possible. In designing the IOS, the OOSDP decided to divide the requirements for a climate observing system into three goals each with a number of sub-goals (OOSDP, 1995). The OOSDP based its priorities for elements of the observing system on the priorities given the sub-goals. First priority was given to those elements necessary for the measurement of SST, the measurement of surface wind and wind stress, the initialization and validation of models for ENSO prediction, and for the measurement of the long-term change in global sea level due to greenhouse gas warming.

5.4.1.3 In some ways the OOSDP's choice of its goals follows the division in Section 5.3 into the surface, upper ocean and global sea level that are to be used for implementation. This will aid implementation but differences still exist between the OOSDP goals and current implementation proposals.

5.4.1.4 The first OOSDP goal addresses the ocean's surface and the sub-goals concern the determination of a) SST, b) wind and wind stress, c) the surface fluxes of heat and fresh water, d) the surface flux of $CO^2$, and e) the extent, concentration, volume and motion of sea-ice. The observations to meet these goals have been included in the discussion of surface observations in Section 5.3 and most are included in the responsibilities of the implementation mechanisms in Section 5.2. In this sense the OOSDP surface sub-goals map easily onto the proposed implementation structure. However, the OOSDP also made use of feasibility-impact diagrams to describe the priority of various observed variables in meeting the sub-goal's objectives. In some cases the observations appropriate for various regions of the global ocean are different (e.g. SST from drifters where VOS are not present). These differences need to be addressed in the implementation mechanism.

5.4.1.5 The second OOSDP goal addresses the upper ocean with sub-goals addressing a) the global data required for monitoring, analyzing and understanding monthly to interannual temperature and salinity variations, b) the upper ocean tropical Pacific data necessary for the initialization and verification of models of models for ENSO prediction, and c) the upper ocean data outside the tropical Pacific for understanding and description of ocean variability and for the initialization and development of models aimed at climate prediction. For these sub-goals, the upper ocean observations required are included in the upper ocean observation category in Section 5.3 and are mostly included in the responsibilities of the implementation mechanisms of Section 5.2. The OOSDP analysis not only provides priorities among the upper ocean variables but also describes which of the surface variables are required to meet particular upper ocean sub-goals. These priorities and recommendations must be considered by the implementation mechanism.

5.4.1.6 The third OOSDP goal includes issues of the full-depth ocean and includes as sub-goals a) the determination of the oceanic inventories of heat, fresh water and carbon, b) the determination of the changes in the oceanic circulation and its transport of heat, fresh water and carbon on long time scales, and c) the determination of the long-term change in sea level due to climate change. In this case the mapping of the requirements onto the categories of Section 5.3 and the implementation mechanisms of Section 5.2 is far from perfect. The requirement for long-term global sea level falls into the global sea-level category and the responsibilities of GLOSS but GLOSS has broader sea-level responsibilities. The determination of the full-depth oceanic budgets, circulation and transports requires data from the surface layer and from the upper ocean but also includes full depth hydrographic observations that , as noted in Section 5.3, do not necessarily fit easily within the proposed and existing implementation systems.

5.4.1.7 The OOSDP also included a fourth goal focussing on the need to provide the infrastructure and techniques, which will ensure that the information obtained is used in an efficient way. A synthesis will be achieved in a variety of ways including routine monitoring and analysis, improved climatologies and through model data assimilation. Sub-goals addressed a) the need for improved climatologies, such as of temperature, salinity and carbon, especially for validating climate predictions and simulations at decadal and longer scales, b) the provision of data management and communication facilities for routine monitoring, analysis and prediction, and c) development of the facilities for processing assembled data sets and providing timely analyses, model interpretations and model forecasts. These integrated application and interpretation aspects of the observing system provide the mechanisms for ensuring that the benefits of the observations are realized to the greatest extent possible. They cannot be forgotten in the process of implementing the observing system.

5.4.1.8 The design of the observing system will evolve with time both because of changing understanding of the ocean climate system and changing technologies. Some changes from the OOSDP report are indicated elsewhere in this action plan. In addition, the priority placed on obtaining observations to meet certain goals may change as the result of evolving opportunities to provide needed products or changes in societal requirements. What is clear is that there must be an ongoing strong interaction between (1) the designers of the OOS and (2) those who apply its products with those concerned with its implementation described in this action plan.

*5.4.2 Network Status*

5.4.2.1 Although much of the GOOS/GCOS OOS will require additional resources for its implementation, some elements of the system already exist in some regions of the global ocean. Figure A of Annex VI shows the location of VOS reporting surface marine meteorological observations on the GTS during February 1999. These observations are a contribution towards meeting the WWW requirements as listed in Section 2.2. As is typical of VOS data, it is received primarily from ships in the main shipping lanes. Figure B shows the position of drifting and moored buoys that reported on the GTS during the same period. One can note that in the Southern Ocean, where VOS reports are in general sparse, drifting buoys are essential for meeting the WWW requirements. Even in the Atlantic, for example, drifting buoys can fill gaps in VOS coverage such as in the large triangular region north of the equator that can be seen in Figure A. The location of the TAO array in the topical Pacific is also evident in the report locations.

5.4.2.2 Tables C, D and E provide a more detailed analysis of the reports of surface pressure, surface wind and SST respectively. The numbers shown in each Marsden square show the percentage of the WWW requirement of 8 observations daily that was obtained as well as the percentage of the reports that were obtained from buoys. It is striking that it is only in very limited region of the global ocean that the WWW requirements are met. The importance of buoy data over a substantial part of the globe is also evident. That most buoys do not report winds is also clear from the analysis. Many of the buoys are supported by research rather than operational funding.

5.4.2.3 The distribution of VOS reporting Bathy messages (temperature profile data mostly from XBTs) is shown in Figure F and the Marsden square analysis of the number of records is given in Figure G. Most of the ships are part of the network set up by WOCE and TOGA and being continued under CLIVAR. Once again the location of the TAO array in the tropical Pacific is evident in Figure F, as is its influence on the number of reports from the region in Figure G.

5.4.2.4 The distribution of TESAC (including salinity profile data in addition to temperature) reports for February 1999 is shown in Figure H and the Marsden square analysis is given in Figure I. With the exception of data from some buoys of the TAO array in the eastern Pacific most of the reports are from the North Atlantic. These are almost entirely from profiling floats deployed in the area for research purposes. They show the potential for data return in the event of the implementation of Argo. The stated benchmark of Section 2.1 for vertical temperature profiles is for a profile every 10 days on a horizontal scale of 250-300 km, which is ~30-40 profiles per month per Marsden square at mid-latitudes. Although the analysis of Figure I says nothing about the sampling frequency or the depth reached by individual profiling floats, it can be seen that the present research activity was approaching the requirement for profiles in some areas of the North Atlantic in February 1999. Globally, ~110 profiling floats are reporting on the GTS at the present time compared to the 3,000 required for the operational Argo system.

5.4.2.5 The implementation of the complete GOOS/GCOS OOS will require similar analyses as given here for all the observational elements.

*5.4.3 Pilot Projects and New Technology*

5.4.3.1 During the development of the design of the GOOS/GCOS OOS, and its implementation, there are bound to be a sequence of systems that will be made operational for the first time, even though they may have been used extensively by large-scale research programmes. The Argo programme discussed below is one example of such a pilot project. Similarly, new instrumentation will replace existing instrumentation on various platforms that may themselves be improved. In this situation continuity of the observation and its calibration are important considerations. New observing system techniques will be developed that could be used to strengthen the OOS. The ATOC programme provides an example. However, it must be emphasized that, even if pilot projects are successful and new observational techniques are proven, there is no guarantee that they would be incorporated into the GOOS/GCOS OOS. The OOS must use the suite of instrumentation and analyses that provides the most cost effective end products given the overall goals and objectives for the OOS and their relative priorities.

**GODAE**

5.4.3.2 GODAE is a programme of the OOPC with the general objective "*to provide a practical demonstration of real-time global ocean data assimilation in order to provide regular, complete depictions of the ocean circulation, at high temporal and spatial resolution, consistent with a suite of space and direct measurements and appropriate dynamical and physical constraints*". It is not a research programme but a practical test of the ability to produce useful products derived from global ocean data assimilated into a skilful ocean model in order to derive greater benefit from the information.

5.4.3.3 GODAE is scheduled to be operational during the period 2003-2005, but its influence on observing system design are already taking place through the activities of its participants. Although an initiative of the OOPC, GODAE has a measure of independence from existing scientific and operational programmes in order to allow freedom of development and to build GODAE resources. As a demonstration of the capability to use ocean data operationally it is truly a pilot project. If successful, it will enhance the value of the OOS and hopefully bring resources for its full implementation. It needs to be emphasized however that that the justification of the OOS is much broader and stronger than providing input to GODAE.

**Argo**

5.4.3.4 The primary goal of the global array of profiling floats, known as Argo, is to provide sub-surface ocean information to complement and amplify the climate–relevant information of the remote sensing network, especially the Jason-1 altimeter and its successors. Although recently driven by the requirements of GODAE, the use of profiling floats as part of the GOOS/GCOS IOS was seen as essential in the OOSDP report and their role is discussed in Section 2.1. The design emphasizes the need to integrate Argo within the overall framework of the GOOS/GCOS OOS. The initial implementation will be based on a design with around 300 km resolution, global deployment, a cycle time of around 14 days and an assumed lifetime of around 100 cycles.

5.4.3.5 Although profiling floats have been used extensively for research over the past few years (see 5.4.2.4), Argo provides the first attempt at global systematic deployment and serves as a pilot project for the long-term use of profiling floats within the OOS.

**PIRATA**

5.4.3.6 The Pilot Research Moored Array in the Tropical Atlantic (PIRATA) is designed as a counterpart of the TAO array in the tropical Pacific. The field phase began with the deployment of 2 moorings in 1997 and up to 12 moorings are envisioned to be in place during 1999 as part of a multinational effort involving Brazil, France and the United States. The array will provide well-resolved Time-Series measurements of SST, salinity, surface heat and moisture fluxes, and sub-surface thermal and current structure up to depths of 500 m. PIRATA is being used to assess the feasibility and composition of a more permanent observational effort in the tropical Atlantic within the context of CLIVAR. Its potential for inclusion in the GOOS/GCOS can be similarly based on its results.

*5.4.4 Regional GOOS Programmes*

5.4.4.1 Some aspects of the physical observations of GOOS/GCOS are bound to be implemented regionally by groups of nations or agencies for practical reasons of sharing the task and obtaining the resources required. While this is more likely to be the case for physical ocean observations describing the continental shelves and regions such as the North Sea, it may also be the case for some of the global observations of the OOS. Three existing cases of such co-operation are briefly discussed here.

**NEAR-GOOS**

5.4.4.2 The North-East Asian Regional GOOS (NEAR-GOOS) programme is being implemented by China, Japan, the Republic of Korea and the Russian Federation as a WESTPAC project. It is intended to provide an operational demonstration of the usefulness of a regional ocean observing system in the achievement of its own specific goals and as a pilot project for other parts of the world. The region chosen is one of the most densely and frequently surveyed in the world and the programme is built upon the capabilities of the countries of the region to collect and exchange oceanographic data in near real-time. The oceanographic data for NEAR-GOOS include temperature, salinity, currents, waves, sea level, dissolved oxygen and nutrients.

5.4.4.3 Some of the more specific goals of NEAR-GOOS include improving regional ocean services, fishing vessel efficiency, pollution monitoring, the mitigation of natural disasters, and to provide the basic function of providing data sets required for data assimilation, modelling and ocean forecasting. An efficient data exchange service has been established and a real-time database contains data from the past 30 days with a delayed-mode database containing the complete data set.

**EuroGOOS**

5.4.4.4 The European Association for the Global Ocean Observing System (EuroGOOS) was established in December, 1994 to maximize the benefits to Europe from operational oceanography within the framework of GOOS. Members of GOOS are agencies who share a common set of goals and aims and are committed to work under the terms of a Memorandum of Understanding. The goals are (1) to gain benefits from the last 50 years of investment in marine science and technology in Europe, (2) to create new operational marine service businesses and jobs, whose goods and services will improve the efficiency of industries presently contributing 200bn ECU *per annum* to the European GNP and (3) to contribute to the effective management of the environment on the global scale, by predicting the behaviour of the ocean and coastal seas. A Strategy for EuroGOOS was published in 1996 and a EuroGOOS Plan in 1997. The Plan identifies regional programmes with distinctive objectives and a Task Team to carry out the agreed programme of work.

5.4.4.5 Existing regional Task Teams include one for the Arctic Ocean with the objective to develop an operational monitoring and forecasting system for the Arctic marine region, to detect trends in sea-ice parameters to help the prediction of climate change, to monitor sea-ice parameters and dynamics as an aid to fishing, shipping and offshore industries, and to monitor the spread of algal blooms and contamination. The objectives for an Atlantic Ocean Task Team are, by building upon current investments in observing systems, assimilation methods and models on the scale of the Atlantic, to build, test and develop a pre-operational eddy-resolving ocean modelling system that will be capable of supporting shelf and coastal modelling and providing open-ocean products. Other regions for which defined programmes exist include the Baltic Sea, the Mediterranean Sea, and the North West European Shelf.

**WIOMAP**

5.4.4.6 The Western Indian Ocean Marine Application Project (WIOMAP) is a developing regional project of the IOC and WMO to address the identified needs for improved and expanded marine meteorological and oceanographic services in support of living and non-living resource management, industrial development, marine pollution, disaster mitigation, climate monitoring, environmental protection and sea transport. The primary objective is the enhanced provision of operational meteorological and oceanographic data, products, services and advice through the development of operational marine services in the region based on applied research, the greater accessibility and exchange of marine data, enhanced marine modelling and forecast capabilities and enhanced personnel.

5.4.4.7 The project objectives are to be achieved on a co-operative regional basis among agencies and institutions in the countries concerned, which will allow economies of scale, improve overall regional co-operation and co-ordination, and eventually achieve a level of output and support to user communities beyond what could be realized working with individual countries individually.

### 5.5 Crosscutting and Generic Issues

5.5.1 In Sections 5.2, 5.3, and 5.4, the capabilities of the implementation mechanisms to co-ordinate and oversee the implementation of the physical ocean observations of GOOS/GCOS have been examined, as has been the potential grouping of activities in terms of surface, sub-surface and global sea-level categories. In addition, it has been reiterated that the design of the observing system has been on the basis of the observations required to meet specified goals and sub-goals addressing specified objectives such as initializing ENSO prediction models or observing changes in the ocean volume due to increasing greenhouse gasses. This section identifies a number of general issues that must be faced as the implementation mechanisms strive to meet the needs of GOOS/GCOS, initiate a new organizational structure and define their overall responsibilities. Particular initial actions to be taken are given in Section 5.6.

5.5.2 The first challenge to be faced is to balance the requirement for a co-operative unified approach to meet the pressing need to implement the physical ocean observations for GOOS/GCOS with the traditional, often platform-based, existing approach of the implementation mechanisms that in general have co-ordinated ocean observations obtained for a variety of reasons. In the case of climate, these have mostly been research and not operationally based.

5.5.3 The existing operational mechanisms have technical competencies and expertise, some of which is in particular special areas. This must not be lost in the larger structures, in particular JCOMM, needed to implement GOOS/GCOS.

5.5.4 There must be continual and clear advice on the requirements and priorities for the physical ocean observations of GOOS/GCOS provided to the operational mechanisms through JCOMM by the GSC and its scientific bodies. To the extent they are known the global ocean climate observations are specified in Section 2.1. Those required in the coastal zone will be provided in the future. The requirements will evolve with changing knowledge and technical capability but should only do so in a way that maintains the overall integrity of the observing system.

5.5.5 In many aspects, the requirement is for the transition from the co-ordination of primarily research based observations, often driven by the large research programmes such as WOCE, TOGA and CLIVAR, to a fully operational system of long-term systematic observations specified to meet GOOS/GCOS objectives. As noted in Section 5.3.5, some GOOS/GCOS observations are of the type that for the foreseeable future will require the direct participation of the scientific community acting within the framework of GOOS/GCOS and following the GOOS Principles. Some of these will require special structures for implementation, data quality control, and management such as the system of WOCE and TOGA DACs and SACS. Some of the latter may need to be folded into the JCOMM structure, other new structures will need to be put in place to manage, for example, the Argo pilot project of profiling floats which from its initiation will provide needed upper ocean data for GOOS/GCOS. JCOMM will need to co-operate with, but usually not oversee, such activities.

5.5.6 The transition to a fully operational system of physical ocean observations for GOOS/GCOS requires the implementation mechanisms to address questions associated with the routine acquisition of observations, real-time or near-real-time data streams, the systematic application of quality control procedures, data delivery to the users, and a myriad of details associated with the management and control of a truly operational ocean observing system. This means that the implementation mechanisms will need to change their procedures or structures to address this new, or extended, co-ordinated operational role. They may need substantial additional resources to meet their responsibilities regarding the implementation of GOOS/GCOS.

5.5.7 The physical observations of GOOS/GCOS must meet special quality control standards in accordance with the GOOS principles and the requirements set by the GSC. These must be an integral part of the new structures. It must be recognized that these standards may vary for the same variable to meet different GOOS/GCOS objectives. In addition, those implementing mechanisms that have a broader responsibility than GOOS/GCOS will in general have other standards and quality control procedures that apply to the broader role. It will be an ongoing challenge to keep all these responsibilities separate and clear.

5.5.8 While the implementation mechanisms will be required to direct a significant part of their effort to the implementation of the physical ocean observations of GOOS/GCOS, it must be clearly understood that they all play a role in the co-ordination and management of ocean observations that are not part of the GOOS/GCOS plan, do not meet the GOOS/GCOS standards, and/or are not collected in accordance of other aspects of the GOOS Principles. This broader role must not be lost in the push to implement GOOS/GCOS ocean observations and the transition from research based to operational systems.

5.5.9 The eventual status of the IODE *vis-à-vis* the new structure needs to be resolved. In the case of the IODE, given its broad responsibilities, there is a case to be made for a separate but strongly linked status. All data, as long as its quality is somewhat understood, must be kept within the international ocean data management system to the extent feasible.

5.5.10 There will always be a need for the structures implementing the ocean observations of GOOS/GCOS to be at the forefront of knowledge concerning existing and potential instrumentation availability, accuracies, etc. This may involve instrument testing, intercalibration and standardization. There is also the need to consider whether efficiencies can be obtained by maximizing the types of observations being obtained from various platforms. As an integrating mechanism, this should also be an ongoing consideration of JCOMM.

5.5.11 Ocean observations have and will be taken on scales varying from global to local, for reasons varying from pure research to commercial endeavours, and for periods varying from long-term (for the foreseeable future) to that appropriate for a specific short-term project. Structures appropriate for all these activities are in place and others will be formed in the future. Some are local or regional in nature, others are large scale and/or global. It is incumbent on JCOMM to use whatever means it can to implement the physical ocean observations for GOOS/GCOS. However, the boundary between what is an integral part of GOOS/GCOS and what is not needs to be defined to the extent feasible if control over the operational system is to be maintained. Guidance can be found in the GOOS Principles. For example, GOOS observations must satisfy the requirements stated in the GOOS/GCOS plan to meet certain specific needs. In addition, the data will be available as stated in a GOOS data management plan and they will be long-term, systematic and meet specified data quality standards.

5.5.12 The boundary between the observing system and the applications of its data also needs to be considered. The OOSDP report and GCOS have both considered this aspect of the observing system. A basic approach is that the observing system will provide products and assessments of the state of the ocean but not carry through applications. Thus, for ENSO predictions the observing system will provide descriptions of the SST, wind, etc. fields, but not undertake the prediction. An application of the global observing system is to provide boundary conditions for the coastal oceans. This is surely part of GOOS/GCOS. An application of the observations yet to be specified by C-GOOS will be to provide external conditions or a larger-scale context for applications in local regions, bays, etc. some of which will be short term and commercial in nature. These are not part of GOOS/GCOS since in general they will not satisfy the GOOS Principles. Another aspect of this boundary is that the observing system must include analyses which indicate the accuracy of the observations being obtained. Poor data from the WWW can often be identified by its assimilation in NWP models. These boundaries are the joint concern of JCOMM and the GSC, need not be rigid, and will not remain fixed in time.

5.5.13 Coercing and encouraging participation in the implementation of the physical ocean observations of GOOS/GCOS is a function of the JCOMM and the implementation mechanisms. Formally it is also a function of I-GOOS, which contains the mechanism for formal national commitments to GOOS. The actions of JCOMM, I-GOOS and the GSC need to be well co-ordinated.

5.5.14 The non-physical parts of GOOS, as defined by the HOTO, LMR and C-GOOS panels, will also need to be implemented. This could be through an expanded version of JCOMM or perhaps more appropriately through mechanisms more suited to their special needs. This will need to be resolved and the best mechanism may change with time. It can be noted that for the most part the non-physical aspects of GOOS will have a more coastal/regional character than the physical aspects presently defined.

### 5.6 Responsibilities and Actions

5.6.1 Based on the various analyses of Section 5, a number of specific and immediate actions for existing bodies and mechanisms can be identified. These are detailed in Annex VII and constitute the initial action list for the implementation of the GOOS/GCOS OOS by these bodies.

## 6. IMPLEMENTATION CO-ORDINATION AND MANAGEMENT

### 6.1 Overall co-ordination

6.1.1 Co-ordination and oversight of implementation of the action plan will be formally undertaken by the new Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM). This body has been established through the merger of CMM and IGOSS, and is the reporting and co-ordinating mechanism for all other existing bodies of WMO and IOC concerned with operational ocean observations and data management. It has the powers and status of a WMO Technical Commission, and serves a role for the oceans analogous to that of the WMO Commission for Basic Systems (CBS), which co-ordinates, regulates and manages the World Weather Watch. JCOMM will report primarily to the Executive Councils of WMO and IOC, but will also interact directly with GSC, the GCOS Steering Committee and I-GOOS. The position and responsibilities of JCOMM in the overall co-ordination and management of GOOS/GCOS are illustrated in Annex VIII, while its terms of reference are given in Annex IX.

6.1.2 JCOMM is an intergovernmental body, whose role is to review and take decisions on policy, regulatory, co-ordination and programmatic issues, on the basis of draft decisions which have been prepared in advance by its subsidiary groups and/or rapporteurs. Normally it meets every four years. At least initially, the subsidiary groups will include, *inter alia*, either formally or as reporting bodies, all existing implementation mechanisms. These groups will meet as often as necessary to support programme implementation and within the available budgetary resources. In addition, JCOMM will have a small executive group (a **Bureau** or **Advisory Working Group**), with responsibilities to oversee and manage the work of JCOMM on an ongoing basis, including in particular the implementation of this action plan. This group will include representatives of the groups specifically involved in implementation of the plan, together with one or more representatives of the scientific design and oversight bodies for GOOS/GCOS. It is expected that the advisory group will work primarily by correspondence, but in the initial stages of implementation it may need to meet reasonably frequently, perhaps as often as every six months. The group will report to GSC and the GCOS Steering Committee, as well as to JCOMM.

## 6.2 Scientific guidance

6.2.1 Initially, primary scientific guidance for the implementation of the action plan will be provided, through the GOOS Steering Committee and the GCOS Steering Committee, by the joint GOOS/GCOS/WCRP Ocean Observations Panel for Climate (OOPC). This guidance will be delivered through the JCOMM Advisory Working Group and by direct interaction with the different implementation mechanisms (DBCP, SOOPIP, etc.) as appropriate.

6.2.2 Scientific guidance and the specification of detailed additional requirements will also be provided in due course by other GOOS and/or GCOS panels as their scientific, management and implementation plans develop.

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# ANNEX I

## User Scenarios and Associated Services

*Scenarios*

GOOS and GCOS are operational systems designed to meet the needs of a wide range of users including government departments, industry, the scientific community and the general public. In order to define what data have to be collected, and in what manner, it is useful to start by imagining scenarios representing a range of user needs, and envisaging the services and products required to meet those needs. This then leads in turn to a statement of requirements in terms of the type and quality of data required as the basis for those services and products.

Scenarios have been used successfully in the GCOS Data and Information Management Plan (GCOS-13, April 1995) to illustrate what users are likely to require and expect from an information system in the early years of the next century. A number of scenarios can be envisaged, representing the interests of a range of end users. Different user groups are likely to be interested not only in different phenomena, but also in different time scales. For some users, interannual change is likely to be important; for others seasonal change may be the key interest; for yet others short-term change (e.g. storms) are likely to generate the most interest.

**Scenario 1.** To improve its local flood defences a coastal zone management group needs to know how water levels may vary along a particular stretch of coast, especially in storms, both seasonally and from year to year. Much the same information will be required by the local managers of ports and harbours, not only for flood defence but also for predicting and controlling access to loading and unloading. Water levels may vary because of tides, changes in sea level caused by climate change, surges caused by storms, or changes in wave height, for instance, all of which may be independent, but which may be combined, and all of which can be monitored, modelled and predicted.

**Scenario 2.** To plan national or regional energy supplies efficiently and effectively for the long term, major power suppliers and the energy companies or agencies who supply them need predictions of how long and cold winter conditions are likely to be year to year for a decade or more ahead. Much the same information, including the length and temperature of the growing season, is required by the agriculture sector. Monitoring and predicting ocean circulation and its control on the heat flux is central to obtaining the required forecasts. In the North Atlantic, for instance, this would require improved definition and prediction of the North Atlantic Oscillation.

**Scenario 3.** To plan the infrastructure for national or regional water supplies efficiently and effectively for the long term, major water suppliers need predictions of rainfall year by year for a decade or so ahead. Improved forecasts of rainfall, and hence water supply, based on ocean and atmospheric measurements and models, will benefit industry, help farmers determine what and when to plant, and enable public health problems to be anticipated.

**Scenario 4.** The growth in ocean trade, the increasing automation of ships, and the development of super-giant bulk and oil carriers demands much improved planning of ocean routes to take advantage of knowledge of the changing positions and strengths of ocean currents and the eddies and storm tracks with which they are associated. This requires greatly improved weather warnings and forecasts and ocean now-casts along with improved short-term ocean forecasts of ocean conditions and climate.

**Scenario 5.** Increasing development of oil and gas fields in deep water far offshore and in hostile Arctic conditions demands increasingly accurate forecasts of ocean and climate conditions so as to improve the efficiency and effectiveness of operations. Increasingly production will take place from well-heads at or under the seabed, but estimates of maximum wave height will still be required where production takes place from platforms, and ice forecasts for the longer term will be essential in polar regions. Needed measurements include, among others: wave height; ice dynamics; and current strength and direction.

**Scenario 6.** Farmers, fishermen and coastal zone managers need improved forecasts of the large interannual perturbations forced by the El Nino-Southern Oscillation (ENSO), which controls cyclical droughts, floods and ocean upwelling events around the Pacific basin and further afield. Continuation of ocean monitoring from the TAO array in the equatorial Pacific Ocean, backed by satellite observations of sea surface temperature and ocean modelling is regarded as essential if skill in ENSO forecasting is to be maintained and improved. Similar thermal oscillations in the tropical Atlantic but on longer time-scales appear to be related to the droughts which cause widespread devastation to the peoples of the Sahel in sub-Saharan Africa, calling for development of a similar monitoring and prediction system.

**Scenario 7.** Managers of many different kinds around the northern Indian Ocean require improved medium to long-range forecasts of the seasonal and interannual variability in the monsoon system, which can wreak havoc on coastal zones and agriculture alike, as well as being associated with massive flooding in places like Bangladesh. Measurements are needed to support an appropriate forecasting system.

**Scenario 8.** Port managers need information about circulation in support of safe navigation and environmental protection in harbours and their surrounding or approach areas. Coastal circulation is partly forced by the circulation in the outside open ocean basin, partly by tidal effects, local topography and hydrographic conditions. Pollution emergency response systems similarly depend on a good knowledge of local circulation, and their design should be based on climatological information on the variability of this circulation.

*Services and products*

This section deals with the professional conditions for implementation of operational systems for GOOS type services and products. The term *production line* is a standard phrase in most societal services, it is used not only in order to understand the functionality of the service, but also to facilitate quality assurance and control procedures. It also applies to GOOS type services and products. The general concept of a *production line* is discussed, as well as the characteristics of a GOOS/GCOS ocean climate service production line. Further, a set of specific production lines is described, corresponding to the user scenarios defined above. The coherence or connectivity of the production line is emphasized, as well as the windowing role of the end user services provider. Finally, the perception of the concept and the characteristics of the production line is seen to have some impact on the implementation of GOOS/GCOS type climate services.

## 1. General concept of a production line

The general definition of a production line is a string of consecutive actions or procedures to be taken, starting from the recognition of a product requirement from an end user, *via* provision of raw material such as *in situ* measured parameters, through pathways of different treatments onto a final, qualified product delivered to an end user. A pathway can be defined in terms of its key actions or junctions where for instance supplementary data enter the production line from other or external sources. The key functions of a general production line are:

- provision of field measurements of parameters relevant to the core content of the targeted end product, such as waves or currents;
- the collection, storage, quality assurance of these data;
- the blending of these data with data from other sources, the processing via numerical and statistical models, value adding, validation, etc.;
- product formatting and presentation/distribution to the end user.

Experience from operational services shows that this general concept applies to nearly every type of operational service provided, and the commonalities appear mostly within data management, quality assurance, and the relations with end users.

## 2. Production lines for ocean climate services and products

Requirements for ocean climate services may come from governmental authorities, industry, science, and the public. Services and products in response to such requirements may be implemented on a purely national basis, but most frequently there will be a need for a background or infrastructural system that can provide both data and expertise in support of the actual services. This is well known from services such as weather forecasting and climate services, where the World Weather Watch and its subsidiary programmes constitute the infrastructure. An intermediary regional function is often required, and consequently one might talk of three levels of production line, *the global, the regional, and the local or national.*

In a simplified description of a three-level production line it could be useful to use the following tabular template explaining typical key functions in each cell. If product requirements are known, the corresponding production line will be a combination or interplay of key actions at different levels.

| Level/Function | Parameter measurements | Data collection and storage | Processing | Product dissemination |
|---|---|---|---|---|
| **A. Global** | Long-term international campaigns | WODCs. | Global modelling<br>Capacity building | Summary schemes<br>Relations with end-user constituencies |
| **B. Regional** | Priorities for areas and parameters.<br>Initiatives for new missions.<br>Techno-logical advice | Regional data holding centres.<br>Capacity building<br>Development of tools. | Regional modelling centres.<br>Supplementary data provision as appropriate.<br>Development of model tools. | Large scale products for next level services.<br>Cost benefit studies and promotion for funding, etc. |
| **C. National or Local** | Local and dedicated networks | National centres | Regional and nested models.<br>Statistical models. Value adding, validation of products.<br>User tailoring. | Presentation to end user.<br>Windowing of GOOS climate products.<br>Live user contacts. |

Table 1. Template of a three-level production line for GOOS/GCOS ocean climate services and products.

The next section illustrates how production lines appear in response to the chosen scenarios. Should it appear that required products cannot be delivered, the use of this template will reflect the missing links or missing elements, such as inadequate measurement networks.

## 3. Production lines in response to scenarios

### Scenario 1: Local coastline water level variations, seasonally, annually, and in storms.

The product needs both hindcast data to provide a long-term time series for the actual site, and measured data to verify hindcast data, as well as variability studies based on measured data in order to compare the actual product with corresponding studies.

| Level/Function | Parameter measurements | Data collection and storage | Processing | Product dissemination |
|---|---|---|---|---|
| **A. Global** | GLOSS programme | WODCs. QC time series of water level | | |
| **B. Regional** | | | Possible provision of boundary value data and forcing data for local model | |
| **C. National or local** | Local and dedicated network if existent. | Local or adjoint site data base supplemented with data from level A. | Ocean model to provide hindcast time series if required. Validation of hindcast data by use of sensed data time-series analysis to produce variability | Expert presentation of study to the end-user audience, defending method, quality, validity of product, and to identify weaknesses |

**Scenario 2: Monitoring and predicting ocean circulation and its control of the heat flux, in order to find its correlation with the duration of long and cold winters.**

This service task requires the contributions both from global atmospheric climate analysis and prediction programmes, as well as regionally based ocean modelling organizations. If it should be done today, it would appear that there are few candidates for the modelling responsibility.

| Level/Function | Parameter measurements | Data collection and storage | Processing | Product dissemination |
|---|---|---|---|---|
| **A. Global** | GCOS time series IODE/IGOSS data | WODCs. | | |
| **B. Regional** | | Regional data holding centres. Provision of forcing data for ocean model | Regional modelling centres. Basin scales ocean model to produce time series of computed heat fluxes | |
| **C. National or local** | | | Correlation of ocean heat fluxes with GCOS time series for winter durations. | Publication and presentation to target end users |

**Scenario 3: Monitoring and predicting ocean circulation and its impact on rainfall variability on the climatological time scale. (El Nino effect)**

This requires large-scale network measurements for ocean surface temperature, ocean profile data, climatological rainfall time series, and an ocean model tool to assimilate data and compute predictions.

| Level/Function | Parameter measurements | Data collection and storage | Processing | Product dissemination |
|---|---|---|---|---|
| **A. Global** | GCOS rainfall time series. IGOSS/IODE data for SST and profiles | WODCs | | |
| **B. Regional** | | Driving data for ocean model | Ocean modelling to compute circulation. Assimilation of sensed data. Validation. Correlation of rainfall and SST | Publication and presentation to user audiences. |
| **C. National or local** | | | Value adding | Local awareness building. |

**Scenario 4: Introduction of ocean parameters to improve ship routing and efficiency of vessel operations.**

In principle this requires basin scale wave forecasting with emphasis not only on the general sea state, but also closer emphasis on wave spectral conditions (such as swell and composite sea states).

| Level/Function | Parameter measurements | Data collection and storage | Processing | Product dissemination |
|---|---|---|---|---|
| **A. Global** | Wave records by space-borne instr. | Via satellite agencies | | |
| **B. Regional** | | Driving data for Regional atmosphere, wave and circulation. | Atmospheric and wave global model, basin scale or global ocean circulation model | |
| **C. National or local** | | | Value adding and formatting. Use of long time series to extract favourable routes. | Climatological advice to shipowners. Along track operational conditions in graphical form, transmitted to bridge. |

**Scenario 5: Introduction of ocean parameters to improve operational performance of offshore operations (in particular in deep water and in Arctic waters).**

This requires both improved statistical information and improved monitoring technology. Since the end users are stationary, dedicated monitoring data are emphasised as compared to the previous example. Long time series (mostly by hindcast techniques) are required

| Level/Function | Parameter measurements | Data collection and storage | Processing | Product dissemination |
|---|---|---|---|---|
| A. Global | | WODCs | | |
| B. Regional | Collective long-term networks for prioritized area | | Medium range forecast models | |
| C. National or local | Dedicated stations | Combination of dedicated and global data sources | Statistical predict-ions for design and predicted performance. Local models for operations. | Design data to oil companies. Daily forecasts on required formats to operation managers. |

**Scenario 6: Improved ENSO forecasting around the Pacific basin and further afield.**

This requires a consolidation of the ongoing TAO array backed by satellite SST observations.

| Level/Function | Parameter measurements | Data collection and storage | Processing | Product dissemination |
|---|---|---|---|---|
| A. Global | TAO array<br>SST from space | WODCs | NODC | Publication and presentation to regions. |
| B. Regional | Regional initiatives according to given priorities | | | Follow-up actions on the regional scale. |
| C. National or local | | | | Awareness building |

**Scenario 7: Medium to long range forecast of the seasonal to interannual variability in the monsoon system.**

This appears as a major hindcast study in order to establish time series for a subsequent variability analysis. The science community may be a primary initial user; but agriculture and health sectors will find a use for the products.

| Level/Function | Parameter measurements | Data collection and storage | Processing | Product dissemination |
|---|---|---|---|---|
| **A. Global** | GCOS data<br>IGOSS/IODE | WODCs | TBD | |
| **B. Regional** | Indian Ocean<br>SST<br>time series. | | TBD | Presentation and awareness |
| **C. National or local** | | | TBD | Awareness |

**Scenario 8: Impact on coastal circulation systems from changes in the open ocean circulation.**

This is to provide a service to port managers in support of safe navigation and environmental protection in the harbour and its surrounding or approach area. Coastal circulation is partly forced by the circulation in the outside open ocean basin, partly by tidal effects, local topography and hydrographic conditions. Pollution emergency response systems depend on the good knowledge of local circulation, and its design should be based on the climatological information on the variability of this circulation.

| Level/Function | Parameter measurements | Data collection and storage | Processing | Product dissemination |
|---|---|---|---|---|
| **A. Global** | | | | |
| **B. Regional** | | Driving data for ocean model | Basin scale ocean model for long time range | |
| **C. National or local** | Local network for surface current.<br>Key stations for subsurface profiles. | Not in operation except for test sites. | Nested model for local area.<br>Assimilation of local data | For port authorities:<br>Statistical variability.<br>Nowcast.<br>Support to pollution drift model. |

**4. Coherence of a production line**

It has been demonstrated that most product lines visit different levels, although the end points most often are found at the national and local levels. The data flow will follow a data management system which transports data through the different junctions onto the final delivery point.

It is very important that responsible and qualified agencies and experts escort the product to the end user. It could be necessary that the product is defended or explained at this point.

The use of this template also shows that there is synergy to obtain in the sense that multiple products and services can be served by simple coordination of production lines.

## 5. The windowing function - role of the end-user service provider

The operational service agency, governmental or private, charged with the role of delivering the product to the end user, has experience of running operational services according to users demands. Very often, this is an underestimated quality in planning and implementation of new services. The operational person has a nose for quality assurance and user satisfaction that is indispensable for such services, and also, in the future, for the performance and success of GOOS services. The end users, governmental, industrial, scientific, and public, will build their confidence in GOOS/GCOS products and services according to the behaviour and performance of these people and institutions.

## 6. Impacts on implementation activities.

The discussion above, in particular the use of the template to visualise the internal life of an operational service, has pointed out some important issues of impact on the implementation of services:

- many services can be implemented from existing elements of measured ocean data or hindcast data;
- others will turn out to be unrealistic due to significant deficiencies, either with regard to data provision or to modelling capacities;
- most products require a powerful data management system that allows the production lines to visit both global, regional and national data sources and modelling centres;
- most services and products require the linkage to meteorological input data to models, including so-called driving or forcing data, such as wind fields to drive a wave model;
- most services require a skilled and representative end delivery point.

In some contexts, if it proves impossible to implement a required service based on existing data or networks, the solution may well be the establishment of new or enhanced field networks and data flows.

# ANNEX II

## Tabulated Observational Data Requirements for GOOS/GCOS

## Table A

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

| SAMPLING REQUIREMENTS FOR THE GLOBAL OCEAN | | | | | | | |
|---|---|---|---|---|---|---|---|
| Code | Application | Variable | Hor. Res. | Vert. Res. | Time Res. | No. of samples | Accuracy |
| A | NWP, climate, mesoscale ocean | Remote SST | 10 km | - | 6 hours | 1 | 0.1-0.3°C |
| B | Bias correction, trends | *In situ* SST | 500 km | - | 1 week | 25 | 0.2-0.5°C |
| C | Climate variability | Sea surface salinity | 200 km | - | 10 day | 1 | 0.1 |
| D | Climate prediction and variability | Surface wind | 2° | - | 1-2 day | 1-4 | 0.5-1.0 m/s in the components |
| E | Mesoscale, coastal | Surface wind | 50 km | - | 1 day | 1 | 1-2 m/s |
| F | Climate | Heat flux | 2° x 5° | - | month | 50 | Net: 10 $W/m^2$ |
| G | Climate | Precip. | 2° x 5° | - | daily | Several | 5 cm/month |
| H | Climate change trends | Sea level | 30-50 gauges + GPS with altimetry, or several 100 gauges +GPS | - | monthly means | | 1 cm, giving 0.1 mm/yr accuracy trends over 1-2 decades |
| I | Climate variability | Sea level anomalies | 100-200 km | - | 10-30 days | ~ 10 | 2 cm |
| J | Mesoscale variability | Sea level anomalies | 25-50 km | - | 2 days | 1 | 2-4 cm |
| K | Climate, short-range prediction | sea ice extent, concentration | ~ 30 km | - | 1 day | 1 | 10-30 km 2-5% |
| L | Climate, short-range prediction | sea ice velocity | ~ 200 km | - | Daily | 1 | ~ cm/s |
| M | Climate | sea ice volume, thickness | 500 km | - | monthly | 1 | ~ 30 cm |
| N | Climate | surface $pCO_2$ | 25-100 km | - | daily | 1 | 0.2-0.3 μatm |
| O | ENSO prediction | T(z) | 1.5° x 15° | 15 m over 500 m | 5 days | 4 | 0.2°C |
| P | Climate variability | T(z) | 1.5° x 5° | ~ 5 vertical modes | 1 month | 1 | 0.2°C |
| Q | Mesoscale ocean | T(z) | 50 km | ~ 5 modes | 10 days | 1 | 0.2°C |
| R | Climate | S(z) | large-scale | ~ 30 m | monthly | 1 | 0.01 |
| S | Climate, short-range prediction | U(surface) | 600 km | - | month | 1 | 2 cm/s |
| T | Climate model validation | U(z) | a few places | 30 m | monthly means | 30 | 2 cm/s |

## Table B

## Ocean Remote Sensing Requirements

| OBSERVATIONS | | | | OPTIMIZED REQUIREMENTS | | | | THRESHOLD REQUIREMENTS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Code** | **Application** | **Variable** | **Type** | **Horizontal scal e (km)** | **Cycle** | **Time** | **Accuracy** | **Horizontal scale (km)** | **Cycle** | **Time** | **Accuracy** |
| **ALTIMETRY** | | | | | | | | | | | |
| A | Mesoscale Variability | Sea Surface Topography | input | 25 | 7 days | 2 days | 2 cm | 100 | 30 days | 15 days | 10 cm |
| B | Large- scale Variability (seasonal, tides, gyres) | Sea Surface Topography | input | 100 | 10 days | 2 days | 1 cm | 300 | 10 days | 10 days | 2 cm |
| C | Mean Sea Level Variations | Sea Surface Topography | input | 200 | decades | 10 days | 1 mm/year | 1000 | decades | 10 days | 5 mm/year |
| D | Absolute Circulation Heat transport | Sea Surface Topography | input | 100 | N/A | N/A | 1 cm | 500 | N/A | N/A | 5 - 10 cm |
| E | Geoid Estimation | Geoid | Base | 100 | N/A | N/A | 2 cm | 500 | N/A | N/A | ~ 1 cm |
| **SURFACE WIND VECTORS** | | | | | | | | | | | |
| F | Wind-forced Circulation | Wind Field | input | 25 | 1 day | 1 day | 1-2 m/second 20° | 100 | 7 days | 7 days | 2 m/second 30° |

**Footnotes:**

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

B requires, in addition, precise positioning system: accuracy 1-2 cm for a spatial resolution of 100 km.; need to address aliasing from solar tides with non-sun- synchronous orbits.

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

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

A requires adequate sampling: at least 2, and better 3, satellites simultaneously.

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

D requires absolute calibration.

E requires *one-off* missions with both high- and broad-resolution determination.

F Wind field requirements for sea state determination normally exceed sampling requirements for wind forcing.

## Table B of Ocean Remote Sensing Requirements

*(continued)*

| OBSERVATIONS | | | | OPTIMIZED REQUIREMENTS | | | | THRESHOLD REQUIREMENTS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Code** | **Application** | **Variable** | **Type input** | **Horizontal (km)** | **Cycle** | **Time** | **Accuracy** | **horizontal (km)** | **Cycle** | **Time** | **Accuracy** |
| **SEA SURFACE RADIATIVE** | | | | | | | | | | | |
| G | Ocean/ Atmosphere coupling | Sea Surface Temperature (Radiometer) | input | 10 | 6 hours | 6 hours | 0.1 K (relative) | 300 | 30 days | 30 days | 1 K |
| H | Ocean Forcing | Short wave irradiance | input | 200 | 1 day | 1 day | 15 W/m$^2$ | 500 | 7 days | 7 days | 20-30 W/m$^2$ |
| **REMOTE SALINITY** | | | | | | | | | | | |
| I | Circulation and Water Transport | Salinity | input | 200 | 10 days | 10 days | 0.1 PSU | 500 | 10 days | 10 days | 1 PSU |
| **SEA ICE** | | | | | | | | | | | |
| J | Ice-Ocean Coupling | Sea Ice Cover | input | 10 | 1 day | 3 hours | 2 % | 100 | 7 days | 1 day | 10 % |
| **OCEAN COLOR** | | | | | | | | | | | |
| K | Upwelling to Recirculation | Ocean Color Signal | input | 25 | 1 day | 1 day | 2 % | 100 | 1 day | 1 day | 10 % |
| **SURFACE WAVES** | | | | | | | | | | | |
| L | Sea State Prediction | Significant wave height | input | 100 | 3 hours | 3 hours | 0.5 meters | 250 | 7 days | 12 hours | 1 meter |
| M | Sea State Prediction | Period and Direction | input | 10 | 1 hour | 2 hours | ½ second 10° | 30 | 6 hours | 4 hours | 1 second 20° |

**Footnotes**: G requires high resolution sea surface temperature: new geostationary satellite + combination with low satellite.

The requirements include consideration of climate applications as determined by the OOPC and ocean forecasting/estimation as determined by GODAE.

The requirements beyond the climate module have not been detailed here.

# Annex III

## World Weather Watch observational requirements for ocean parameters (1999)

*15-Jun-99*

| Requirement | Application: Hor Res | Min | Vert Res | Min | Obs Cycle | Min | Delay avail | Min | Accuracy | Min | Confidence | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Global NWP** | | | | | | | | | | | | |
| Air pressure over sea surface | 50 km | 250 km | | | 1 h | 12 h | 1 h | 4 h | 0.5 hPa | 2 hPa | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Air temperature (at surface) | 50 km | 250 km | | | 1 h | 12 h | 1 h | 4 h | 0.5 K | 2 K | Reasonable | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Higher stratosphere & mesosphere (HS & M) | 50 km | 500 km | 1 km | 3 km | 1 h | 12 h | 1 h | 4 h | 0.5 K | 5 K | Reasonable | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Higher troposphere (HT) | 50 km | 500 km | 1 km | 3 km | 1 h | 12 h | 1 h | 4 h | 0.5 K | 3 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Lower stratosphere (LS) | 50 km | 500 km | 1 km | 3 km | 1 h | 12 h | 1 h | 4 h | 0.5 K | 3 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Lower troposphere (LT) | 50 km | 500 km | 0.3 km | 3 km | 1 h | 12 h | 1 h | 4 h | 0.5 K | 3 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Cloud base height | 50 km | 250 km | | | 1 h | 12 h | 1 h | 4 h | 0.5 km | 1 km | Tentative | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Cloud cover | 50 km | 250 km | | | 1 h | 12 h | 1 h | 4 h | 5 % (Max) | 20 % (Max) | Reasonable | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Dominant wave direction | 50 km | 250 km | | | 1 h | 12 h | 1 h | 4 h | 10 degrees | 20 degrees | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Dominant wave period | 50 km | 250 km | | | 1 h | 12 h | 1 h | 4 h | 0.5 s | 1 s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Ice thickness | 15 km | 250 km | | | 1 d | 7 d | 1 d | 7 d | 0.5 m | 1 m | Speculative | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Precipitation index (daily cumulative) | 50 km | 250 km | | | 1 h | 12 h | 24 h | 720 h | 0.5 mm/d | 5 mm/d | Reasonable | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Sea surface temperature | 50 km | 250 km | | | 1 h | 12 h | 1 h | 24 h | 0.5 K | 1 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Sea-ice cover | 15 km | 250 km | | | 1 d | 15 d | 1 d | 7 d | 5 % (Max) | 50 % (Max) | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Sea-ice surface temperature | 15 km | 200 km | | | 1 h | 7 h | 1 h | 4 h | 0.5 K | 4 K | Reasonable | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Significant wave height | 100 km | 250 km | | | 1 h | 12 h | 1 h | 4 h | 0.5 m | 1 m | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Specific humidity profile - Higher troposphere (HT) | 50 km | 250 km | 1 km | 3 km | 1 h | 12 h | 1 h | 4 h | 5 % | 10 % | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Specific humidity profile - Lower troposphere (LT) | 50 km | 250 km | 0.4 km | 2 km | 1 h | 12 h | 1 h | 4 h | 5 % | 20 % | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Specific humidity profile - Total column | 50 km | 500 km | | | 1 h | 12 h | 1 h | 4 h | 1 kg/m2 | 5 kg/m2 | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Higher troposphere (HT) | 50 km | 500 km | 1 km | 10 km | 1 h | 12 h | 1 h | 4 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Lower stratosphere (LS) | 50 km | 500 km | 1 km | 10 km | 1 h | 12 h | 1 h | 4 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Lower troposphere (LT) | 50 km | 500 km | 0.4 km | 5 km | 1 h | 12 h | 1 h | 4 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (vertical component) - Higher troposphere (HT) | 50 km | 500 km | 0.5 km | 10 km | 1 h | 12 h | 1 h | 4 h | 1 cm/s | 5 cm/s | Speculative | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (vertical component) - Lower stratosphere (LS) | 50 km | 500 km | 0.5 km | 10 km | 1 h | 12 h | 1 h | 4 h | 1 cm/s | 5 cm/s | Speculative | 28-Sep-98, WMO TD No. 913, SAT-21 |

| Requirement | Hor Res | Min | Vert Res | Min | Obs Cycle | Min | Delay avail | Min | Accuracy | Min | Confidence | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Application** | | | | | | | | | | | | |
| Wind profile (vertical component) - Lower troposphere (LT) | 50 km | 500 km | 0.5 km | 5 km | 1 h | 12 h | 1 h | 4 h | 1 cm/s | 5 cm/s | Speculative | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind speed over sea surface (horizontal) | 50 km | 250 km | | | 1 h | 12 h | 1 h | 4 h | 0.5 m/s | 3 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind vector over sea surface (horizontal) | 50 km | 250 km | | | 1 h | 12 h | 1 h | 4 h | 0.5 m/s | 3 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| **Nowcasting** | | | | | | | | | | | | |
| Air temperature (at surface) | 5 km | 20 km | | | 0.25 h | 1 h | 0.25 h | 0.5 h | 0.5 K | 1 K | Reasonable | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Higher troposphere (HT) | 5 km | 200 km | 1 km | 3 km | 0.25 h | 1 h | 0.08 h | 0.5 h | 1 K | 2 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Lower troposphere (LT) | 5 km | 200 km | 0.5 km | 1 km | 0.25 h | 1 h | 0.08 h | 0.5 h | 0.5 K | 2 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Cloud cover | 1 km | 20 km | | | 0.0083 h | 1 h | 0.016 h | 0.5 h | 5 % (Max) | 20 % (Max) | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Cloud type | 1 km | 10 km | | | 0.01 h | 0.5 h | 0.02 h | 0.5 h | 10 classes | 5 classes | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Ocean currents (vector) | 10 km | 50 km | | | 0.25 d | 6 d | 0.25 d | 4 d | 0.5 cm/s | 1 cm/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Sea surface temperature | 5 km | 50 km | | | 1 h | 6 h | 1 h | 2 h | 0.5 K | 2 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Sea-ice cover | 5 km | 50 km | | | 1 d | 24 d | 1 d | 6 d | 10 % (Max) | 20 % (Max) | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Specific humidity profile - Higher troposphere (HT) | 5 km | 200 km | 1 km | 3 km | 0.25 h | 1 h | 0.08 h | 0.5 h | 10 % | 20 % | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Specific humidity profile - Lower troposphere (LT) | 5 km | 200 km | 0.5 km | 1 km | 0.25 h | 1 h | 0.08 h | 0.5 h | 5 % | 20 % | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Specific humidity profile - Total column | 5 km | 50 km | | | 0.25 h | 1 h | 0.08 h | 0.5 h | 1 kg/m2 | 5 kg/m2 | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Higher troposphere (HT) | 5 km | 200 km | 0.5 km | 1 km | 0.25 h | 4 h | 0.08 h | 0.5 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Lower stratosphere (LS) | 5 km | 200 km | 0.5 km | 1 km | 0.25 h | 6 h | 0.25 h | 2 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Lower troposphere (LT) | 5 km | 200 km | 0.5 km | 1 km | 0.25 h | 6 h | 0.25 h | 2 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (vertical component) - Lower troposphere (LT) | 5 km | 200 km | 0.5 km | 2 km | 0.25 h | 1 h | 0.08 h | 0.5 h | 1 cm/s | 5 cm/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind speed over sea surface (horizontal) | 5 km | 50 km | | | 0.25 h | 3 h | 0.25 h | 1 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind vector over sea surface (horizontal) | 5 km | 50 km | | | 0.25 h | 3 h | 0.25 h | 1 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| **Regional NWP** | | | | | | | | | | | | |
| Air pressure over sea surface | 10 km | 250 km | | | 0.5 h | 12 h | 0.5 h | 2 h | 0.5 hPa | 1 hPa | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Air temperature (at surface) | 10 km | 250 km | | | 0.5 h | 12 h | 0.5 h | 2 h | 0.5 K | 2 K | Reasonable | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Higher troposphere (HT) | 10 km | 500 km | 1 km | 3 km | 0.5 h | 12 h | 0.5 h | 2 h | 0.5 K | 3 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Lower stratosphere (LS) | 10 km | 500 km | 1 km | 3 km | 0.5 h | 12 h | 0.5 h | 2 h | 0.5 K | 3 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Lower troposphere (LT) | 10 km | 500 km | 0.3 km | 3 km | 0.5 h | 12 h | 0.5 h | 2 h | 0.5 K | 3 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Cloud base height | 10 km | 250 km | | | 0.5 h | 12 h | 0.5 h | 3 h | 0.5 km | 1 km | Tentative | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Cloud cover | 10 km | 250 km | | | 0.5 h | 12 h | 0.5 h | 2 h | 5 % (Max) | 20 % (Max) | Reasonable | 28-Sep-98, WMO TD No. 913, SAT-21 |

## Application

| Requirement | Hor Res | Min | Vert Res | Min | Obs Cycle | Min | Delay avail | Min | Accuracy | Min | Confidence | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dominant wave direction | 10 km | 50 km | | | 1 h | 12 h | 0.5 h | 2 h | 10 degrees | 20 degrees | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Dominant wave period | 10 km | 50 km | | | 1 h | 12 h | 0.5 h | 2 h | 0.5 s | 1 s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Ice thickness | 5 km | 250 km | | | 1 d | 7 d | 1 d | 7 d | 0.5 m | 1 m | Speculative | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Precipitation index (daily cumulative) | 10 km | 250 km | | | 0.5 h | 12 h | 24 h | 720 h | 0.5 mm/d | 5 mm/d | Reasonable | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Sea surface temperature | 25 km | 50 km | | | 1 h | 12 h | 1 h | 24 h | 0.5 K | 1 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Sea-ice cover | 25 km | 50 km | | | 0.5 d | 7 d | 0.3 d | 3 d | 5 % (Max) | 50 % (Max) | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Sea-ice surface temperature | 5 km | 100 km | | | 0.5 h | 12 h | 0.5 h | 2 h | 0.5 K | 4 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Significant wave height | 10 km | 50 km | | | 1 h | 12 h | 1 h | 2 h | 0.1 m | 0.2 m | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Specific humidity profile - Higher troposphere (HT) | 10 km | 100 km | 1 km | 3 km | 0.5 h | 12 h | 0.5 h | 2 h | 5 % | 10 % | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Specific humidity profile - Lower troposphere (LT) | 10 km | 100 km | 0.4 km | 2 km | 0.5 h | 12 h | 0.5 h | 2 h | 5 % | 20 % | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Specific humidity profile - Total column | 10 km | 250 km | | | 0.5 h | 12 h | 0.5 h | 2 h | 1 kg/m2 | 5 kg/m2 | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Higher troposphere (HT) | 10 km | 500 km | 1 km | 10 km | 0.5 h | 12 h | 0.5 h | 2 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Lower stratosphere (LS) | 10 km | 500 km | 1 km | 10 km | 0.5 h | 12 h | 0.5 h | 2 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Lower troposphere (LT) | 10 km | 500 km | 0.4 km | 5 km | 0.5 h | 12 h | 0.5 h | 2 h | 1 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (vertical component) - Higher troposphere (HT) | 10 km | 500 km | 0.5 km | 10 km | 0.5 h | 12 h | 0.5 h | 2 h | 1 cm/s | 5 cm/s | Speculative | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (vertical component) - Lower stratosphere (LS) | 10 km | 500 km | 0.5 km | 10 km | 0.5 h | 12 h | 0.5 h | 2 h | 1 cm/s | 5 cm/s | Speculative | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (vertical component) - Lower troposphere (LT) | 10 km | 500 km | 0.5 km | 5 km | 0.5 h | 12 h | 0.5 h | 2 h | 1 cm/s | 5 cm/s | Speculative | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind speed over sea surface (horizontal) | 10 km | 100 km | | | 0.5 h | 12 h | 0.5 h | 2 h | 0.5 m/s | 3 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind vector over sea surface (horizontal) | 10 km | 100 km | | | 0.5 h | 12 h | 0.5 h | 2 h | 0.5 m/s | 3 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |

## Synoptic Meteorology

| Requirement | Hor Res | Min | Vert Res | Min | Obs Cycle | Min | Delay avail | Min | Accuracy | Min | Confidence | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air temperature (at surface) | 10 km | 100 km | | | 1 h | 12 h | 1 h | 4 h | 0.5 K | 2 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Higher troposphere (HT) | 20 km | 200 km | 0.1 km | 2 km | 3 h | 12 h | 1 h | 3 h | 0.5 K | 3 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Lower stratosphere (LS) | 20 km | 200 km | 0.1 km | 2 km | 3 h | 12 h | 1 h | 3 h | 0.5 K | 3 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Atmospheric temperature profile - Lower troposphere (LT) | 20 km | 200 km | 0.1 km | 2 km | 3 h | 12 h | 1 h | 3 h | 0.5 K | 3 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Cloud type | 20 km | 200 km | | | 0.25 h | 6 h | 0.25 h | 6 h | 10 classes | 5 classes | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Dominant wave direction | 50 km | 200 km | | | 3 h | 12 h | 1 h | 3 h | 20 degrees | 30 degrees | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Dominant wave period | 50 km | 200 km | | | 3 h | 12 h | 1 h | 3 h | 0.5 s | 1 s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Sea surface temperature | 5 km | 50 km | | | 3 h | 24 h | 1 h | 24 h | 0.5 K | 2 K | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Specific humidity profile - Higher troposphere (HT) | 20 km | 200 km | 0.1 km | 2 km | 3 h | 12 h | 1 h | 3 h | 10 % | 20 % | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |

## Application

| Requirement | Hor Res | Min | Vert Res | Min | Obs Cycle | Min | Delay avail | Min | Accuracy | Min | Confidence | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Specific humidity profile - Lower troposphere (LT) | 20 km | 200 km | 0.1 km | 2 km | 3 h | 12 h | 1 h | 3 h | 10 % | 20 % | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Higher troposphere (HT) | 20 km | 200 km | 0.1 km | 2 km | 3 h | 12 h | 1 h | 3 h | 2 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Lower stratosphere (LS) | 20 km | 200 km | 0.1 km | 2 km | 3 h | 12 h | 1 h | 3 h | 2 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind profile (horizontal component) - Lower troposphere (LT) | 20 km | 200 km | 0.1 km | 2 km | 3 h | 12 h | 1 h | 3 h | 2 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind speed over sea surface (horizontal) | 20 km | 200 km | | | 1 h | 12 h | 1 h | 3 h | 2 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |
| Wind vector over sea surface (horizontal) | 20 km | 200 km | | | 1 h | 12 h | 1 h | 3 h | 2 m/s | 5 m/s | Firm | 28-Sep-98, WMO TD No. 913, SAT-21 |

# ANNEX IV

## Decision 14/CP.4

## Research and systematic observation

*The Conference of the Parties,*

*Recalling* Article 4. 1 (g)-(h) and Article 5 of the United Nations Framework Convention on Climate Change, and its decision 8/CP.3,

*Noting with appreciation* the comprehensive report on the adequacy of the global observing systems for climate,[1] prepared and coordinated by the Global Climate Observing System secretariat in the World Meteorological Organization on behalf of organizations participating in the Climate Agenda,

*Noting* the conclusions of the report that, *inter alia,* in many instances global and regional coverage is inadequate,

*Noting* the recommendations contained in the report to improve the global observing systems for climate,

*Noting* the ongoing work of the agencies participating in the Climate Agenda and others in support of global observing systems for climate, including their contributions to capacity-building,

*Recognizing* the significant national contributions made to the global observing systems for climate,

1. *Urges* Parties to undertake programmes of systematic observation, including the preparation of specific national plans, in response to requests from agencies participating in the Climate Agenda, based on the information developed by the Global Climate Observing System and its partner programmes;

2. *Urges* Parties to undertake free and unrestricted exchange of data to meet the needs of the Convention, recognizing the various policies on data exchange of relevant international and intergovernmental organizations;

3. *Urges* Parties to actively support capacity-building in developing countries to enable them to collect, exchange and utilize data to meet local, regional and international needs;

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[1] Contained in document FCCC/CP/1998/MISC.2 and summarized in document FCCC/CP/1998/7.

4. *Urges* Parties to strengthen international and intergovernmental programmes assisting countries to acquire and use climate information;

5. *Urges* Parties to actively support national meteorological and atmospheric observing. systems, including measurement of greenhouse gases, in order to ensure that the stations identified as elements of the Global Climate Observing System networks, based on the World Weather Watch and Global Atmosphere Watch and underpinning the needs of the Convention, are fully operational and use best practices;

6. *Urges* Parties to actively support national oceanographic observing systems, in order to ensure that the elements of the Global Climate Observing System and Global Ocean Observing System networks in support of ocean climate observations are implemented, to support, to the extent possible, an increase in the number of ocean observations, particularly in remote locations, and to establish and maintain reference stations;

7. *Urges* Parties to actively support national terrestrial networks including observational programmes to collect, exchange and preserve terrestrial data according to the Global Climate Observing System and the Global Terrestrial Observing System climate priorities, particularly hydrosphere, cryosphere and ecosystem observations;

8. *Requests* Parties to submit information on national plans and programmes in relation to their participation in global observing systems for climate, in the context of reporting on research and systematic observation, as an element of national communications from Parties included in Annex I to the Convention (Annex 1 Parties) and, as appropriate, from Parties not included in Annex I to the Convention (non-Annex 1 Parties);

9. *Requests* the Subsidiary Body for Scientific and Technological Advice, in consultation with the agencies participating in the Climate Agenda, drawing, *inter alia* on the information provided in the second national communications from Annex 1 Parties and, as appropriate, in the initial national communications from non-Annex 1 Parties, to inform the Conference of the Parties at its fifth session of developments regarding observational networks, difficulties encountered, *inter alia,* with respect to the needs of developing countries and options for financial support to reverse the decline in observational networks;

10. *Invites* the agencies participating in the Climate Agenda, through the Global Climate Observing System secretariat, to initiate an intergovernmental process for addressing the priorities for action to improve global observing systems for climate in relation to the needs of the Convention and, in consultation with the Convention secretariat and other relevant organizations, for identifying immediate, medium-term and long-term options for financial support; and *requests* the secretariat to report results to the Subsidiary Body for Scientific and Technological Advice at its tenth session.

*5th plenary meeting*
*11 November 1998*

## Decision 2/CP.4

### Additional guidance to the operating entity of the financial mechanism

*The Conference of the Parties,*

*Recalling* its decisions 11/CP.1, 1O/CP.2, 11/CP.2 and 12/CP.2,

*Recalling further* that the Global Environment Facility (GEF), as stated in its operational principles for the development and implementation of its work programme[1], will maintain sufficient flexibility to respond to changing circumstances, including evolving guidance of the Conference of the Parties and experience gained from monitoring and evaluation activities,

*Welcoming* the New Delhi Statement of the First GEF Assembly[2] and the Report on the Second Replenishment of the GEF Trust Fund, completed in March 1998[3],

*Noting* the continued concerns and difficulties encountered by developing country Parties with the availability and disbursement of financial resources, including for the transfer of technology, the problems arising from the GEF project cycle, the application of the concept of incremental costs, and the availability of resources through the GEF implementing/executing agencies,

*Noting also* the current and ongoing efforts of the GEF to address these concerns, *inter alia,* by streamlining its project cycle, increasing support for country-level coordination, strengthening its monitoring and evaluation programme, ensuring that its activities are country-driven and consistent with national priorities and objectives, further developing its resource allocation strategy to maximize the effectiveness of its climate change activities and making the process of determining incremental costs more transparent and pragmatic,

*Noting further* the need to examine and address climate change impacts and minimize the adverse impacts, in particular for the Parties identified in Article 4.8 of the United Nations Framework Convention on Climate Change,

1. Decides that, in accordance with Articles 4.3, 4.5 and 11.1 of the Convention, the GEF should provide funding to developing country Parties to:

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[1] Global Environment Facility, *Operational Strategy* (Washington, D.C., February 1996), p. 2.

[2] See document FCCC/CP/1998/12, annex B.

[3] Document GEF/C. 1 1/6 of 24 March 1998.

(a) Implement adaptation response measures under Article 4.1 of the Convention for adaptation activities envisaged in decision 11/CP.1, paragraph 1(d)(ii) (Stage II activities) in particularly vulnerable countries and regions identified in Stage I activities, and especially in countries vulnerable to climate-related natural disasters, taking into account their preparatory adaptation planning frameworks in priority sectors, the completion of Stage I activities, and in the context of their national communications;

(b) Enable them, in light of their social and economic conditions and taking into account state-of-the-art environmentally sound technologies, to identify and submit to the Conference of the Parties their prioritized technology needs, especially as concerns key technologies needed in particular sectors of their national economies conducive to addressing climate change and minimizing its adverse effects;

(c) Build capacity for participation in systematic observational networks to reduce scientific uncertainties relating to the causes, effects, magnitude and timing of climate change, in accordance with Article 5 of the Convention;

(d) Meet the agreed full costs of preparing initial and subsequent national communications, in accordance with Articles 4.3 and 12.5 of the Convention and decision 11/CP.2, paragraph 1(d), by maintaining and enhancing relevant national capacity, so as to prepare the initial and second national communications which will take into account experiences, including gaps and problems identified in previous national communications, and guidelines established by the Conference of the Parties. Guidance on subsequent national communications will be provided by the Conference of the Parties;

(e) Assist them with studies leading to the preparation of national programmes to address climate change, compatible with national plans for sustainable development, in accordance with Article 4.1 (b) of the Convention and paragraph 13 of the annex to decision 10/CP.2;

(f) Assist in developing, strengthening and/or improving national activities for public awareness and education on climate change and response measures, in full accordance with Article 6 of the Convention and decision 11/CP. 1, paragraph 1(b)(iii), and taking into account, where appropriate, relevant GEF operational programmes;

(g) Support capacity-building for:

*(i)* The assessment of technology needs to fulfil the commitments of developing countries under the Convention, the identification of sources and suppliers of these technologies, and the determination of modalities for the acquisition and absorption thereof;

*(ii)* Country-driven activities and projects to enable Parties not included in Annex I to the Convention (non-Annex I Parties) to design, evaluate and manage these projects;

*(iii)* Strengthening the capacity of non-Annex I Parties to host projects, including from project formulation and development to their implementation;

*(iv)* Facilitating national/regional access to the information provided by international centres and networks, and for working with those centres for the dissemination of information, information services, and transfer of environmentally sound technologies and know-how in support of the Convention;

2. *Requests* the GEF to continue to provide, and developing country Parties to avail themselves of, funding to translate, reproduce, disseminate and make available their initial national communications electronically;

3. *Encourages* the GEF to:

(a) Further streamline its project cycle with a view to making project preparation simpler, less prescriptive, more transparent and country-driven;

(b) Further simplify and expedite its procedures for the approval and implementation of GEF-funded projects, including disbursements for such projects;

(c) Make the process for the determination of incremental costs more transparent, and its application more pragmatic;

4. *Requests* the GEF to ensure that its implementing/executing agencies are made aware of Convention provisions and decisions adopted by the Conference of the Parties in the performance of their GEF obligations and are encouraged, as a first priority, whenever possible, to use national experts/consultants in all aspects of project development and implementation;

5. *Further requests* the GEF to include in its report to the Conference of the Parties the specific steps it has undertaken to implement the provisions of this decision.

*8th plenary meeting*
*14 November 1998*

# ANNEX V

## STRUCTURE AND CHARACTICS OF EXISTING OPERATIONAL MECHANISMS

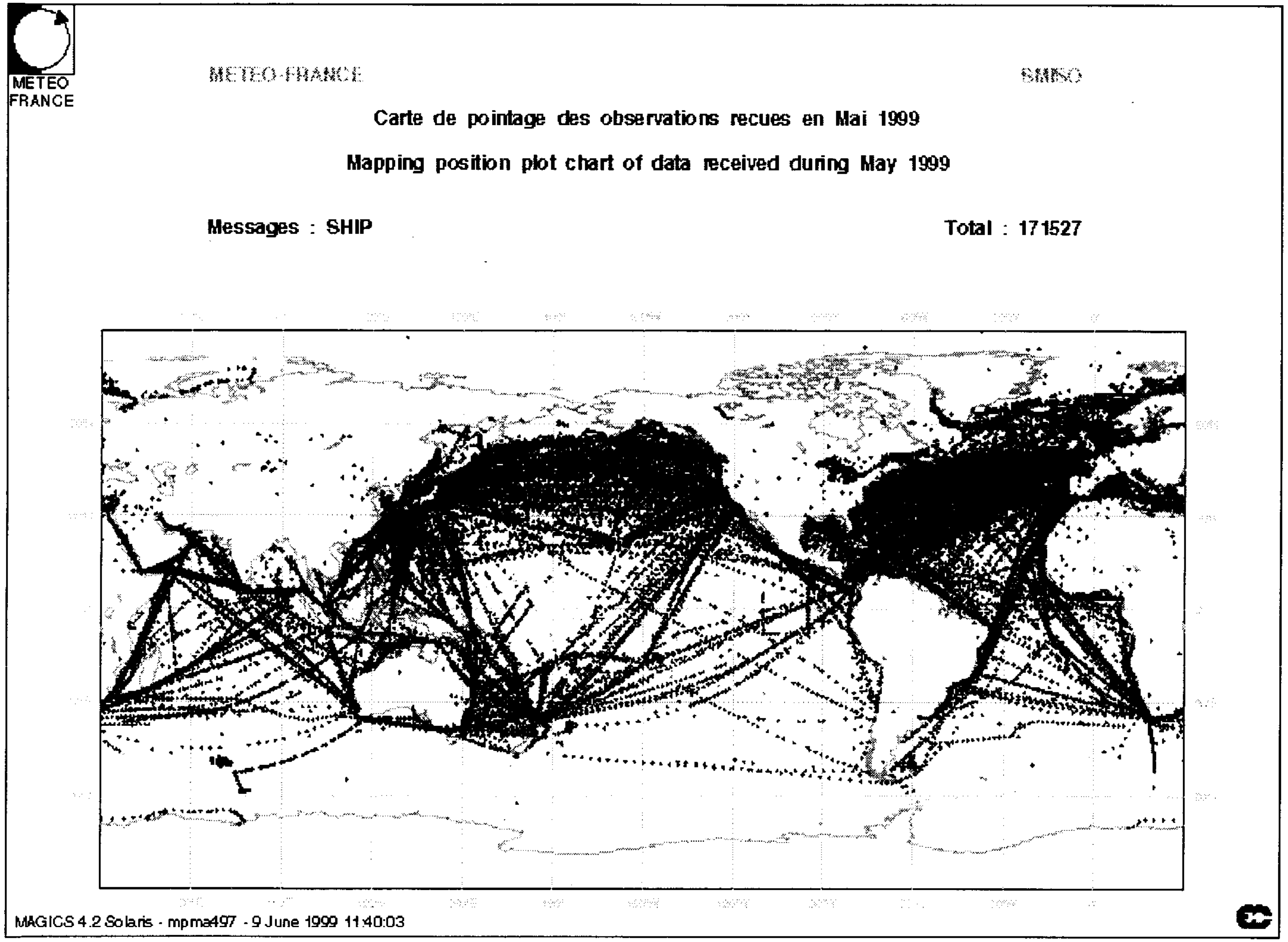
| Existing → Mechanisms / Implementation Topics ↓ | CMM | IGOSS | SOOPIP | GLOSS | DBCP | TIP |
|---|---|---|---|---|---|---|
| **Status** | Constituent intergovernmental body of WMO with regulatory and guidance responsibilities | Intergovernmental operational programme of the IOC and WMO with guidance responsibilities | Subsidiary IGOSS panel | Operational system of the IOC with guidance responsibilities | Formal joint body of WMO and IOC with guidance responsibilities | Subsidiary DBCP panel sponsored by CLIVAR, GOOS and GCOS |
| **Services** | Marine meteorological, oceanographic climatological and sea-ice products | Data processing and services system of observational data, analyses and forecasts | Co-ordination of the implementation of the SOOP | Establishment of a global network of tide gauges and provision of sea level data | Co-ordination of buoy surface observations for WWW, WCRP, GOOS, etc. | Technical and logistic support for contributing institutions |
| **Observations** | Operation of the VOS observing basic marine meteorological and oceanographic variables and co-ordination with ocean satellite operations | Operation of the SOOP, the IGOSS sea level programme and co-ordination with ocean satellite operations | Observations of surface and subsurface T, and S from the SOO | Observations of sea level, some from geocentrically positioned site, and co-ordination with satellite altimetry | Moored and drifting buoy measurements observing basic marine meteorological and oceanographic variables | Near real time surface and subsurface meteorological and oceanographic data from large moored buoys of the TAO array type |
| **Observation Network Status** | Approximately 7,200 VOS operated by 50 nations | As per SOOPIP | Approximately 100 dedicated SOO using XBTs | Core network of 287 stations ( about 90% operational and 100 reporting in near-real time) | Approximately 1200 drifting buoys, 70 moorings of the TAO array and 50 other moorings | 70 moored ATLAS-type buoys in the tropical Pacific and eastern Indian Ocean |
| **Scientific support** | Provided within the CMM by CBS and recently by OOPC | A science advisor and the input from the CLIVAR UOP and OOPC | From the CLIVAR UOP and OOPC | From GLOSS Group of Experts | Internal | From panel members |
| **Data Management System** | Real time transmission on GTS, delayed mode via log books | As for SOOPIP | Real time low resolution via satellite to operational meteorological and oceanographic services and onto GTS. Delayed mode full resolution at end of OOS trip. | Monthly and annual mean values submitted to PSML. Fast and delayed mode data of subset sent to WOCE Sea Level centres | Real time transmission primarily via Argos and transmitted to NOAA/NWS and Meteo-France and onto GTS. Processed Argos data collected by operators and PIs | Real time data via Argos and on to GTS. High resolution data (hourly) at buoy servicing and made available on World Wide Web |
| **Quality control** | Real time by meteorological centres including UKMO with WMO responsibilities for surface marine data. Expanded in delayed mode | As for SOOPIP | First by operational services and subsequently by GTSPP | By initial centres checking tidal analysis, residuals, and adjacent sites. | Real time on basis of formal quality control guidelines via internet. Delayed mode by PIs and MEDS as RNODC. | Both real time and delayed mode data quality controlled be TAO Project Office. |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Data Archiving** | Data available from global archival centres. VOS metadata catalogue at WMO | AS for SOOPIP | Data submitted yearly to responsible RNODC and forwarded to WDCs. | Monthly and annual means being archived at PSML. New requirement to archive 5 hourly data for better altimeter calibration and quality control | Drifter data archived at the RNODC for drifting buoy data at MEDSs | Yearly submissions of data to NODC |
| **Resources (Programme Support)** | 2 staff members between WMO and IOC | 1 staff member between WMO and IOC | ½ time of technical co-ordinator in IOC but partly funded by nations | ½ time of staff member in IOC | ½ time of technical co-ordinator in IOC but partly funded by nations | None |
| **Resources (Operational Network)** | The observational network, including personnel, instrumentation and supervision of the field programme, is supplied by the participating nations | | | | | |
| **Capacity building** | Varied, including advisory missions, training, training manuals and specialised soft ware packages. | As possible system is expanded and developed through the VCDs of WMO and IOC | None | Primarily via workshops | Primarily through the technical co-ordinator, various publications and manuals, and an annual technical workshop. | Only through exchange of technology. |

# ANNEX VI

## Status of some Existing Elements of GOOS/GCOS

### Figure A



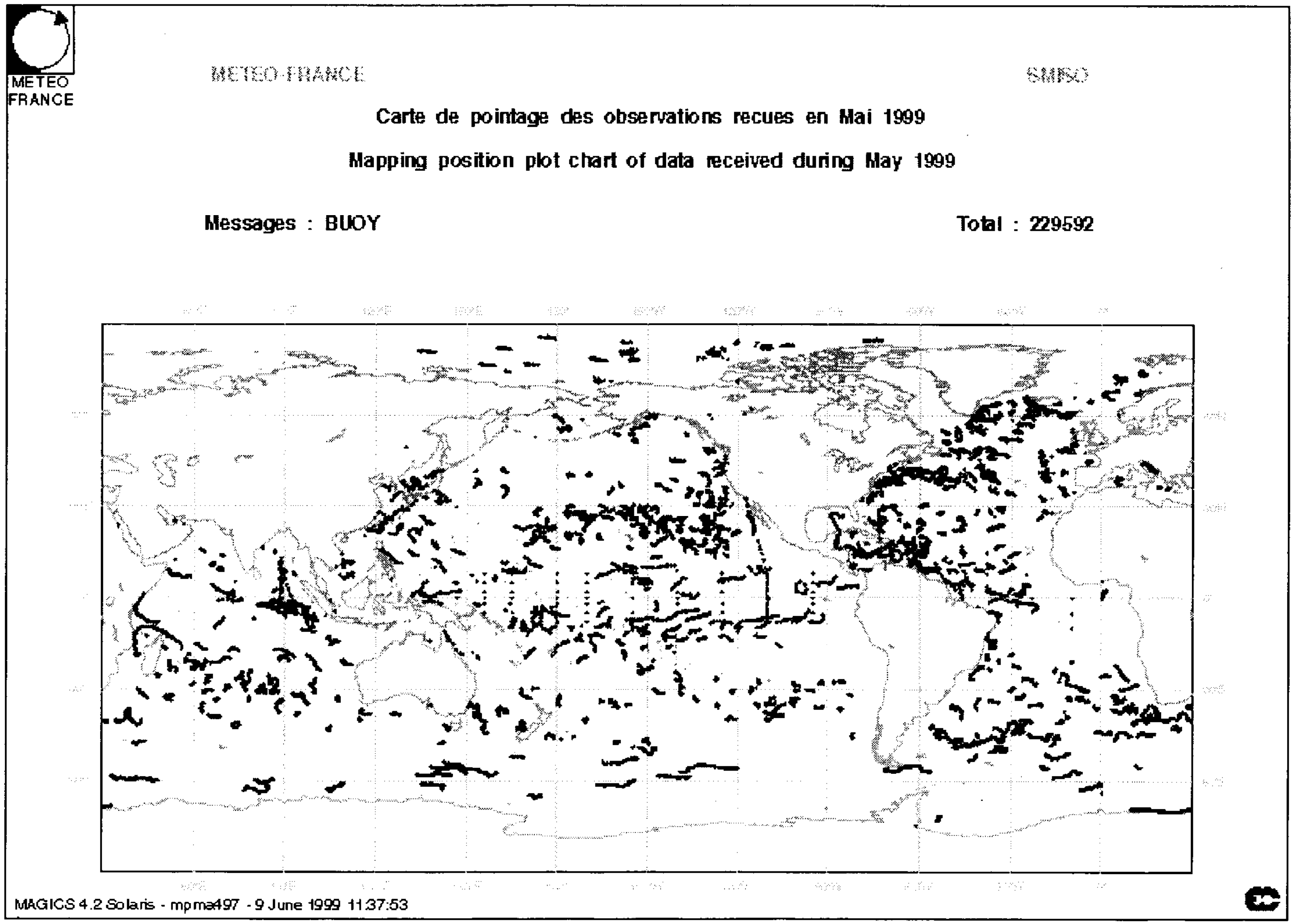
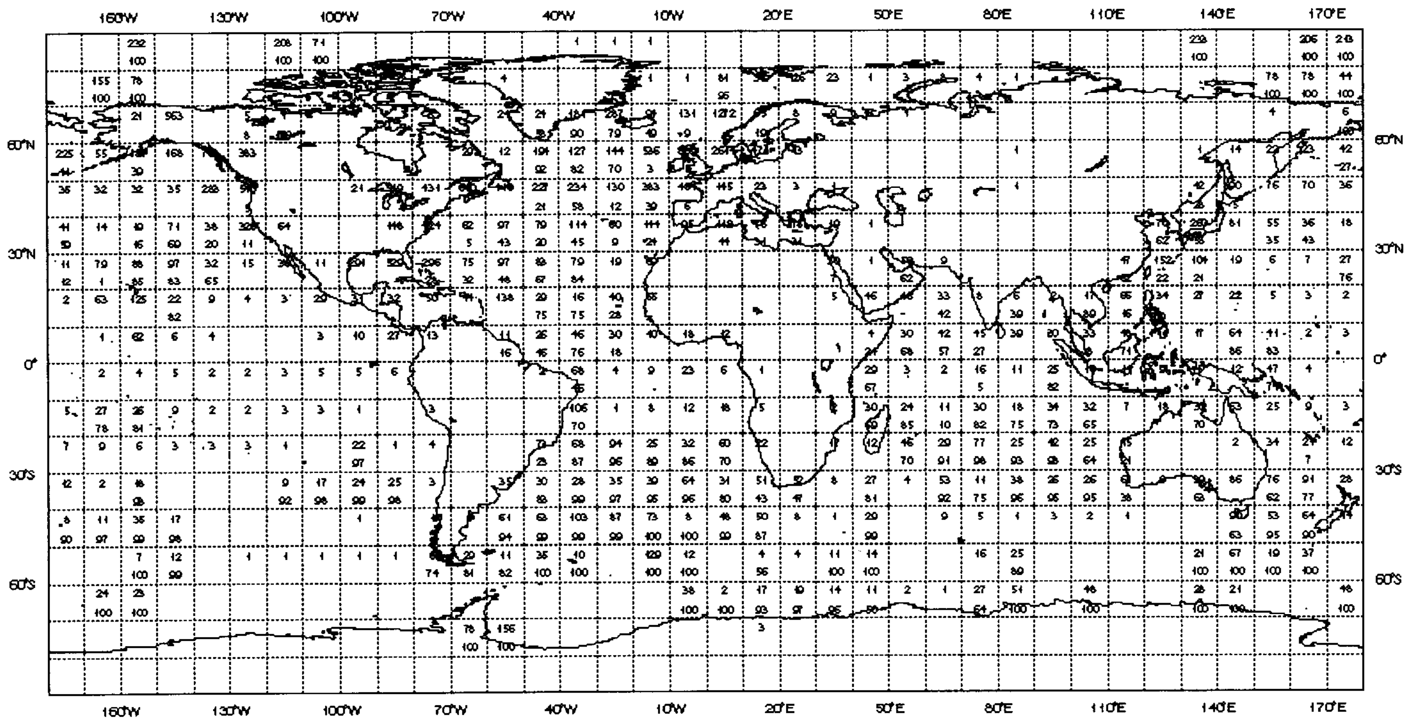

METEO
FRANCE
METEO-FRANCE
SMISO
Carte de pointage des observations recues en Mai 1999
Mapping position plot chart of data received during May 1999
Messages : BUOY
Total : 229592
MAGICS 4.2 Solaris - mpma497 - 9 June 1999 11:37:53

**Figure B**

METEO FRANCE

METEO-FRANCE PRESSURE MAY 1999

**Marsden square distribution chart of mean monthly data availability index (top)
(Index 100 = 8 obs. per day per 500kM * 500kM area of SHIP and BUOY reports)
and
Percentage of BUOY reports compared to SHIP+BUOY reports (bottom)**



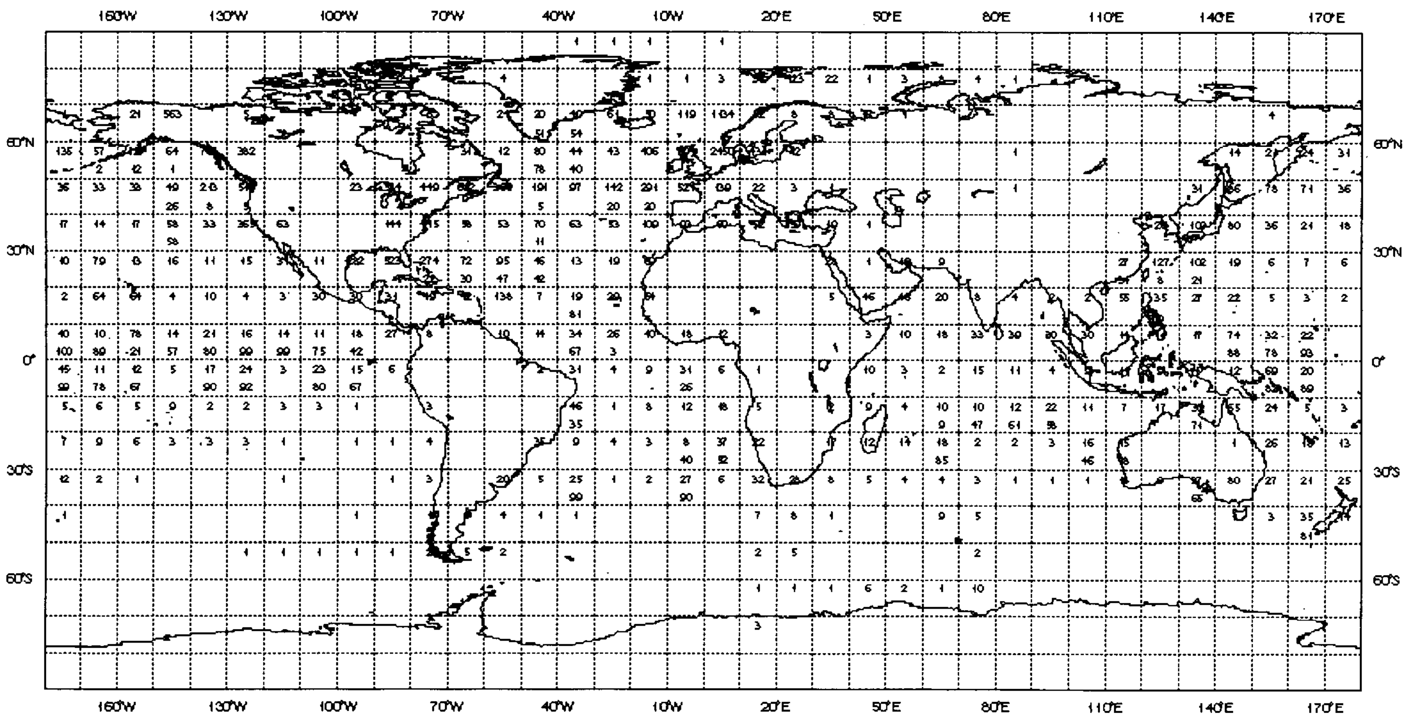

MAGICS 4.2 Solaris - mpma497 - 9 June 1999 14:47:39

Figure C

METEO FRANCE

**METEO-FRANCE** **WIND** **MAY 1999**

**Marsden square distribution chart of mean monthly data availability index (top)**
**(Index 100 = 8 obs. per day per 500kM * 500kM area of SHIP and BUOY reports)**
**and**
**Percentage of BUOY reports compared to SHIP+BUOY reports (bottom)**



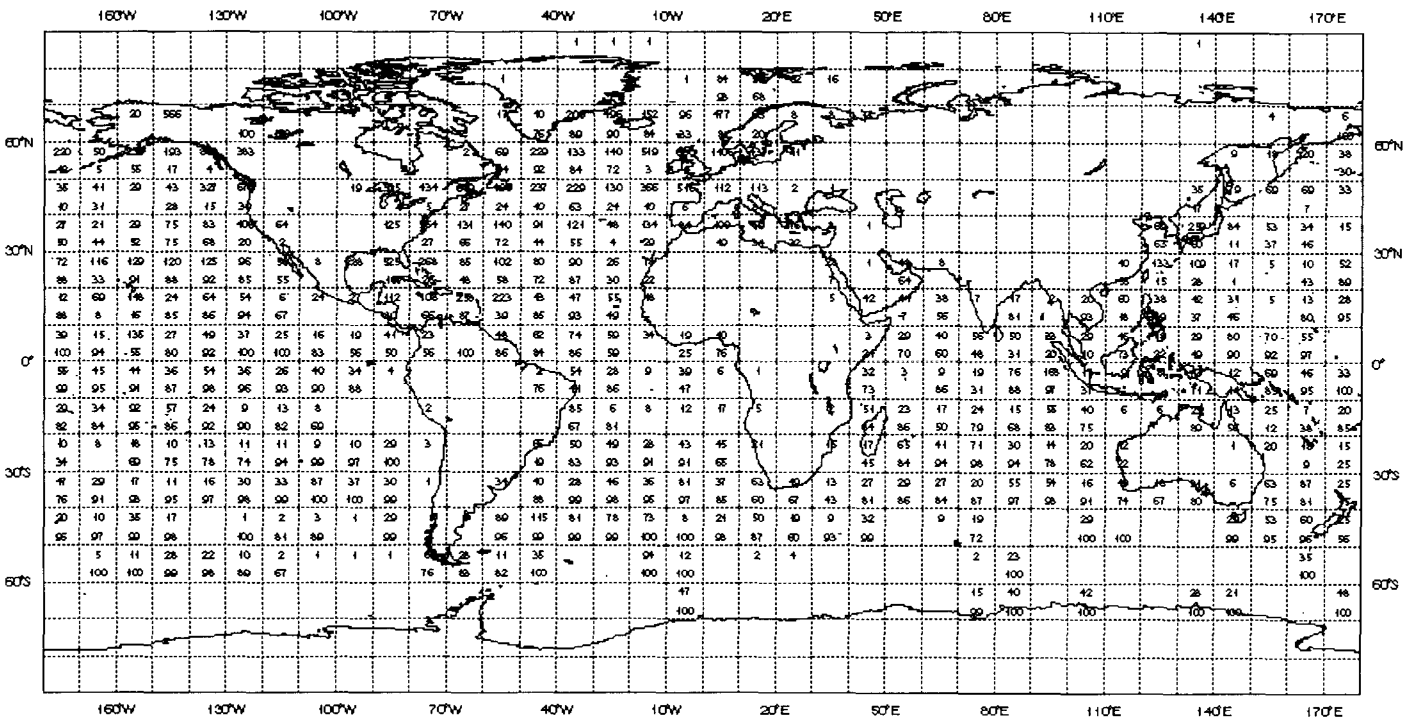

MAGICS 4.2 Solaris - mpma497 - 9 June 1999 14:47:48

Figure D

METEO FRANCE

METEO-FRANCE SEA SURFACE TEMPERATURE MAY 1999

Marsden square distribution chart of mean monthly data availability index (top)
(Index 100 = 8 obs. per day per 500kM * 500kM area of SHIP and BUOY reports)
and
Percentage of BUOY reports compared to SHIP+BUOY reports (bottom)




MAGICS 4.2 Solaris - mpma497 - 9 June 1999 14:47:44

Figure E

Figure F

METEO FRANCE

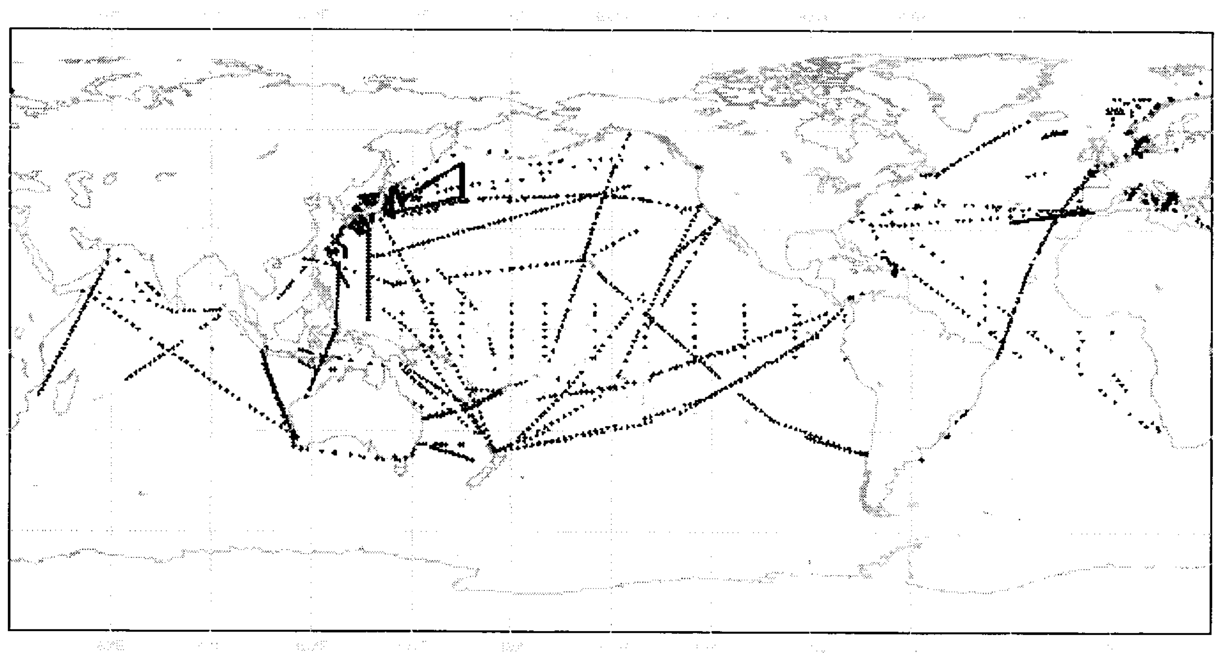
METEO-FRANCE SMISO

Carte de pointage des observations recues en Mai 1999

Mapping position plot chart of data received during May 1999

Messages : BATHY

Total : 4831



MAGICS 4.2 Solaris - mpma497 - 9 June 1999 11:35:30

Figure G

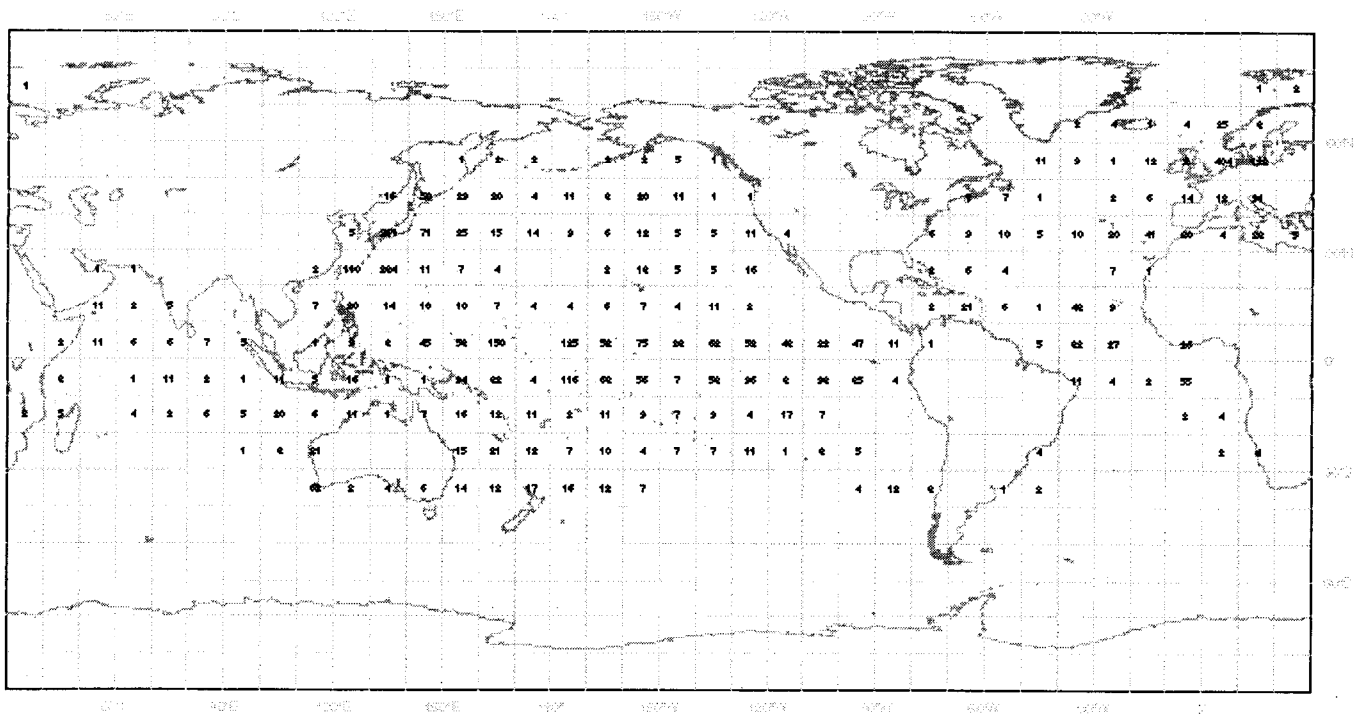
METEO FRANCE

METEO-FRANCE SMISO

**Repartition par carre Marsden des observations recues en Mai 1999**

**Marsden square distribution chart of data received during May 1999**

**Messages : BATHY** **Total : 4831**



MAGICS 4.2 Solaris - mpma497 - 9 June 1999 11:36:36

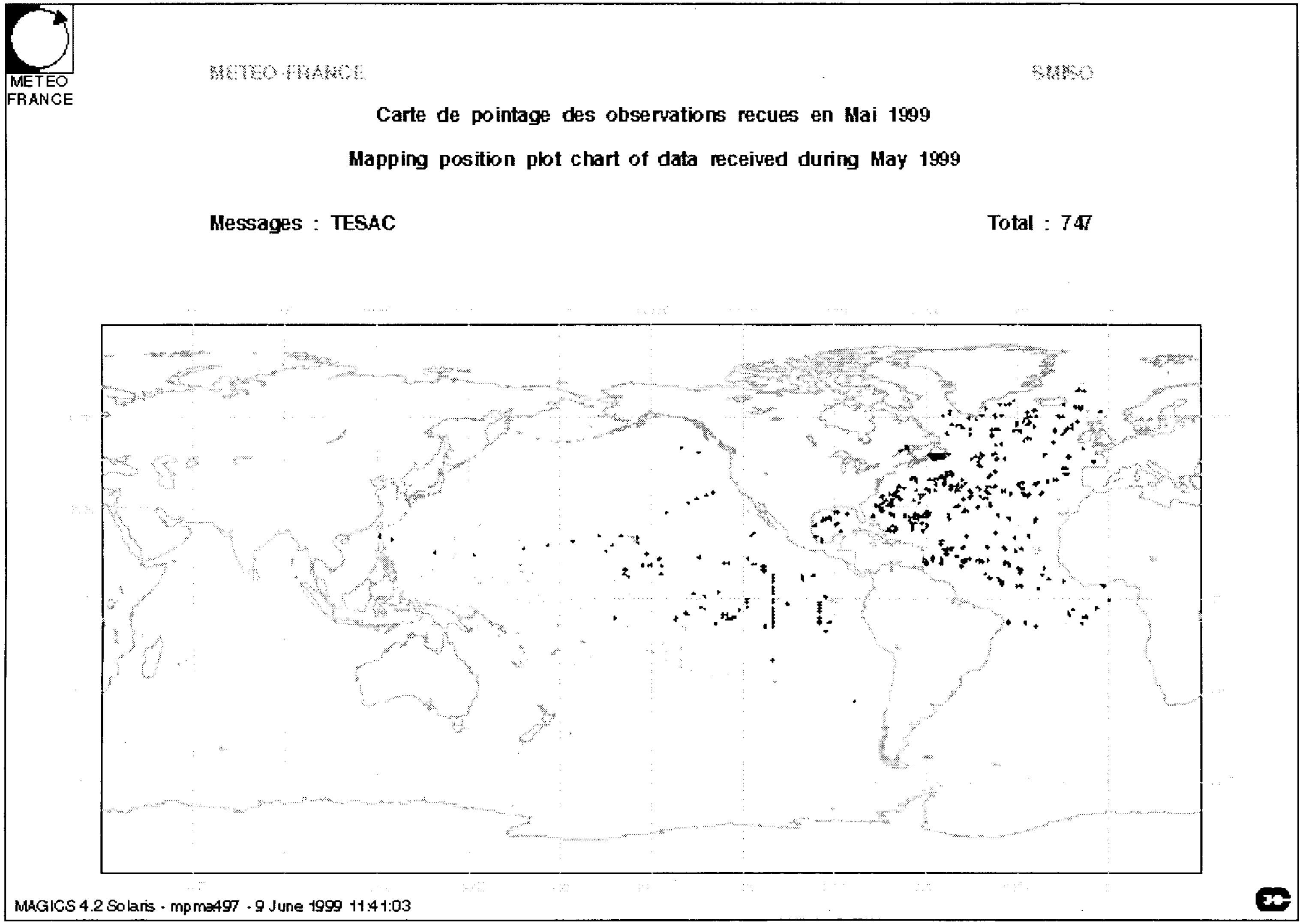

METEO
FRANCE
METEO-FRANCE
SMISO
Carte de pointage des observations recues en Mai 1999
Mapping position plot chart of data received during May 1999
Messages : TESAC
Total : 747
MAGICS 4.2 Solaris - mpma497 - 9 June 1999 11:41:03

Figure H

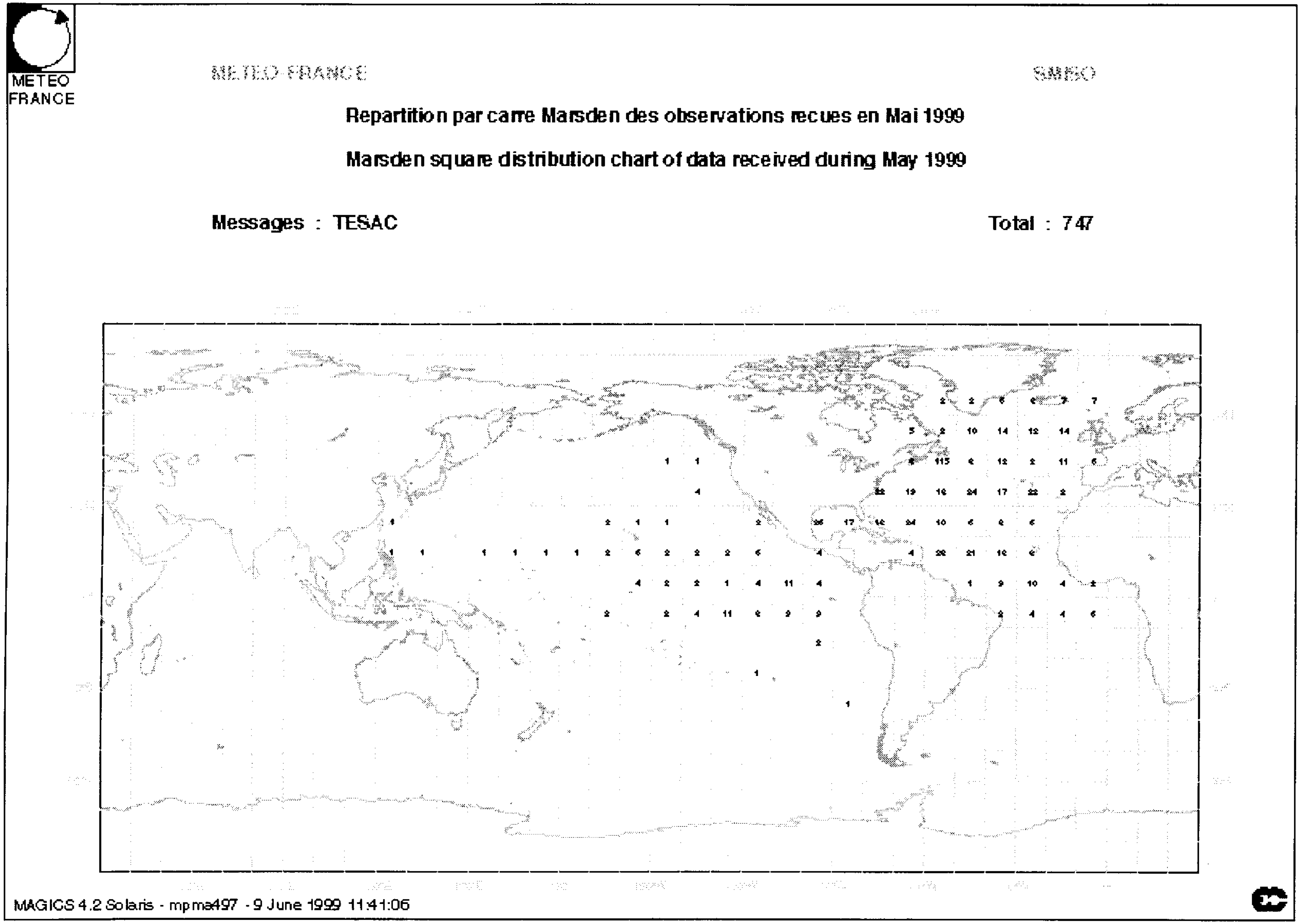

METEO FRANCE
METEO FRANCE
SMBO
Repartition par carre Marsden des observations recues en Mai 1999
Marsden square distribution chart of data received during May 1999
Messages : TESAC
Total : 747
MAGICS 4.2 Solaris - mpma497 - 9 June 1999 11:41:06

Figure I

# ANNEX VII

## Initial Implementation Action List for Existing Mechanisms

*Sea-Level Measurements*

1. Review requirements for and modalities of a science steering group for sea level. (**Action:** GLOSS, OOPC and IOC Secretariat)
2. Upgrade network according to design purpose. (**Action:** GLOSS and IOC Secretariat)

*Surface Measurements*

1. SCOR/WCRP Air-Sea Flux Working Group to be asked to broaden remit to become the *science steering group* for surface measurements. (**Action**: Chair/OOPC, P.Taylor and eventually Secretariats)
2. Develop an integrating strategic plan for surface measurements. (**Action**: science steering group, OOPC and implementers)
3. Develop and implement a *pilot project* (c.f. GTSPP) to integrate surface data management, quality assurance, archives, standards, regulations, and product preparation, involving ship and buoy operators, centres like COADS, WOCE DACs, plus analysis groups, etc. (**Action**: science steering group, OOPC, centres, implementers)
4. Study development of a high-quality subset of VOS for GOOS/GCOS purposes. (**Action**: P.Taylor, R.Weller, CMM/VOS group)
5. Enhance technical support for surface observation systems and rationalise administration. (**Action**: Secretariats, CMM, Member States)
6. Build on existing capacity building structure to include awareness of data applications to flux determination, integration of satellite and surface fields; develop an overall GOOS strategy for capacity building. (**Action**: Secretariats)
7. Dialogue with CEOS on the need for enhanced *in situ* observations. (**Action**: Secretariats, GSC)
8. Promote R&D for operational measurements of $CO_2$, precipitation, surface salinity from satellites. (**Action**: GSC)
9. Prepare a status report on HF radars for GSC. (**Action**: J.Guddal and G. Needler)
10. Assess existing sea-ice observing and data management system; prepare recommendations for enhancement to meet requirements. (**Action**: OOPC and Secretariats)

*Sub-surface Measurements*

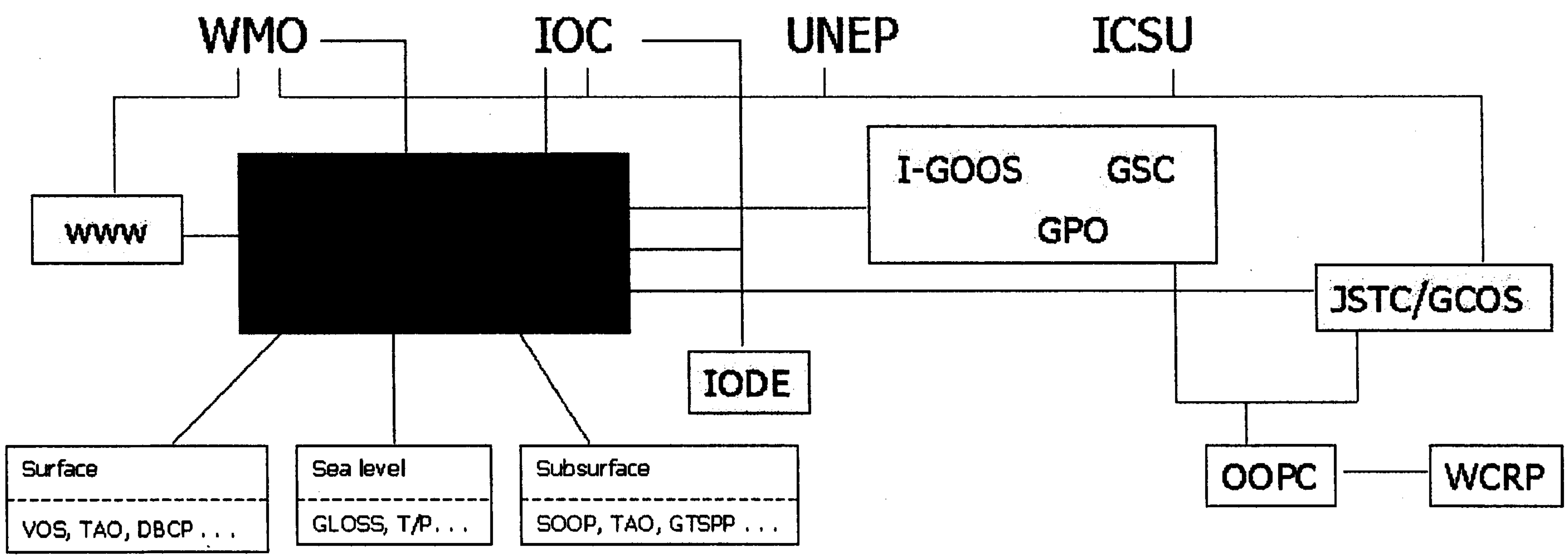
1. Prepare and hold a workshop to refine requirements for upper ocean thermal data, based on strategic assessment of these requirements from OOPC and in the light of likely available resources. (**Action**: OOPC, SOOPIP and Secretariats)
2. Assess need for possible second workshop on data management, quality assurance, "duplication" of GTSPP, etc. (**Action**: IGOSS, IODE, OOPC, Secretariats)
3. Evaluate mix of operational and research funding for SOOP, and work to decrease dependence on research programmes. (**Action**: Operations Coordinator, SOOPIP, Secretariats, Member States)
4. Improve coordination in implementation management among SOOP, TAO and DBCP; investigate incorporation of "operational" management of floats into existing structures; investigate also any requirement for technical coordination for float operations. (**Action**: SOOPIP, TIP, DBCP with Secretariats and float operators)
5. Propose products from the Electronic IGOSS Products Bulletin as a GOOS products bulletin. (**Action**: J. Guddal, D. Kohnke)

*General*

1. All implementation groups to adopt *General Principles of Long-Term Climate Monitoring*, as developed and agreed under GCOS. These principles first elaborated by T. Karl in *Long-Term Climate Monitoring by GCOS*, Special Issue of *Climatic Change*, 1995. (**Action**: Secretariats and implementation groups)
2. All implementation groups to adjust implementation plans to accommodate GOOS/GCOS requirements as specified in Annex I of Implementation Action Plan. (**Action**: DBCP, SOOPIP, GLOSS, VOS, TIP)

## ANNEX VIII

# GOOS/GCOS IMPLEMENTATION STRUCTURE



# ANNEX IX

## Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM)

The Technical Commission shall be responsible for matters relating to:

*Further development of the observing networks*

Under the guidance of the relevant scientific and operational programmes of IOC and WMO, development, maintenance, coordination and guidance of the operation of the global marine meteorological and oceanographic observing systems and supporting communications facilities of these organizations to meet the needs of the IOC and WMO Programmes and in particular of the Global Ocean Observing System (GOOS), the Global Climate Observing System (GCOS) and the World Weather Watch (WWW). Evaluation on a continuing basis of the efficiency of the overall observing system and suggesting and coordinating changes designed to improve it.

*Implementation of data management systems*

Development and implementation, in cooperation with the Commission for Basic Systems (CBS), the Committee for International Data and Information Exchange (IODE), the International Council of Scientific Unions (ICSU), and other appropriate data management bodies, end-to-end data management systems to meet the real-time operational needs of the present operational systems and the global observing systems; cooperation with these bodies in seeking commitments for operation of the necessary national compilation, quality control, and analysis centres to implement data flows necessary for users at time scales appropriate to their needs.

*Delivery of products and services*

Provision of guidance, assistance and encouragement for the national and international analysis centres, in cooperation with other appropriate bodies, to prepare and deliver the data products and services needed by the international science and operational programmes, Members of WMO, and Member States of IOC. Monitoring of the use of observations and derived products and suggesting changes to improve their quality. Coordination of the safety-related marine meteorological and associated oceanographic services as an integral part of the Global Maritime Distress and Safety System of the International Convention for the Safety of Life at Sea (SOLAS).

*Provision of capacity building to Member States*

Review and analysis of the needs of Member States of IOC and Members of WMO for education and training, and for technology transfer and implementation support in the areas of responsibility of the technical commission. Provision of the necessary technical publications, guidance material, and expert lecturers/trainers and operation of workshops as required to meet the needs. Development of projects to enhance Member States capacity to participate in and benefit from marine meteorological and oceanographic programmes of WMO and IOC.

*Assistance in the documentation and management of the data in international systems*

Development of cooperative arrangements with the data management bodies of IOC, ICSU, and WMO, such as IODE, the Commission for Climatology (CCl), and the ICSU World Data Centres to provide for comprehensive data sets (comprising both real-time and delayed mode data) with a high level of quality control, long-term documentation and archival of the data, as required to meet the needs of secondary users of the data for future long-term studies.

These responsibilities exclude those aspects specifically handled by other WMO constituent bodies or equivalent bodies of IOC.