INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (OF UNESCO)

WORLD METEOROLOGICAL ORGANIZATION

DATA BUOY COOPERATION PANEL

GLOBAL DRIFTING BUOY OBSERVATIONS
A DBCP Implementation Strategy

Fifth Edition

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FOREWORD

The Drifting Buoy Co-operation Panel (DBCP) was established in 1985, jointly by the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO, as a means of enhancing cooperation, coordination and information exchange among the operators and users of drifting buoys, meteorological and oceanographic, research and operational, with a view to improving both the quantity and quality of buoy data available on the Global Telecommunications System of WMO in support of major programme requirements of the two Organizations. The panel appointed a full-time technical coordinator in 1987, using funds provided voluntarily by panel member countries, and in 1992 its terms of reference were widened and its name changed to Data Buoy Co-operation Panel to reflect its work in co-ordinating all forms of ocean buoy deployments.

During the 15 years of its existence, the panel has achieved great success in achieving its initial objectives. At the same time, this period has also seen remarkable advances in both buoy and communications technology, as well greatly enhanced and expanded requirements for buoy data, in particular in support of global climate studies. Major global experiments such as TOGA and WOCE have clearly demonstrated the value of buoy data for this purpose, and at the same time established and refined the buoy networks needed to fulfill the scientific requirements. One of the major challenges now facing the panel and buoy operators is to convert the buoy networks established for these experiments into long-term operational programmes.

In recognition of these new developments and expanded requirements, and in the context also of the implementation plans and requirements of the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS), the panel agreed in 1997 on the need for a DBCP Implementation Strategy, which would provide an overall framework for the panel's work, and at the same time enable it and its members to react appropriately to future developments. A draft strategy document was prepared for the panel by Mr David Meldrum, reviewed and revised at the panel session in 1998, and is now published in this DBCP Technical Document. The strategy document will also be made available through the DBCP web server.

PREFACE TO 2nd EDITION, October 2001

It was always intended that the Implementation Plan should be a dynamic document that reflected the evolution of the DBCP's aims and aspirations within the rapidly changing environment of oceanography and marine meteorology. This edition takes particular note of the consensus that is developing regarding the requirements for marine observations in support of climate modelling and operational marine forecasting, as stated at the 1st International Conference of the Ocean Observing System for Climate (OceanObs 99, St Raphaël, October 1999)[1], and at the first session of the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM-I, Akureyri, June 2001). [2]

CONTENTS

RECORD OF CHANGES

Version No	Date	Change
A	Oct 1997	First draft
1.0	Oct 1998	First release
2.0	Oct 2000	Revised and updated to take account of JCOMM and developments in satellite communications
2.1	Oct 2001	New references, graphics and textual changes
3.0	Oct 2002	New section 3.4, updated Annexes E and F
4.0	Oct 2003	Add para 8.13, update Annex F
5.0	Oct 2004	Updated paras 2.1, 3.5, 3.8, 4.1, 4.2 and 7

GLOBAL DRIFTING BUOY OBSERVATIONS - A DBCP IMPLEMENTATION STRATEGY

1. INTRODUCTION

Satellite-tracked drifting buoys have been used by oceanographers and meteorologists for two decades in support of both research and operational programmes. With the exception of the Global Weather Experiment FGGE, early deployments were largely uncoordinated at an international, or even national level. Co-operation between the meteorologists and the oceanographers was also practically non-existent, not only because of a lack of motivation stemming from different perceptions of the aims of drifter deployments, but also because no forum for dialogue existed. Some changes came about through the establishment of the Argos Joint Tariff Agreement (JTA), and its requirement for basic coordination of national plans, and through Argos User Conferences. However, it was not until the creation of the DBCP in response to WWW requirements for routine high quality observations from the world's oceans that positive steps were taken towards large-scale international cooperation in drifter deployment and data management.

Some time before the establishment of the DBCP, a European initiative (COST-43) was established involving the collaborative deployment of meteorological drifters in the north Atlantic, and this became in due course the first regional action group, EGOS, of the DBCP. The group retains complete autonomy in all its operational and administrative matters, but draws on the support of the DBCP through its technical coordinator, the WMO and IOC Secretariats, and its meetings. The freedom to determine its own affairs, yet benefit from association with an established and internationally recognized parent body, has been a keynote in the success and stability of EGOS, and it has become the model for subsequent drifter action groups such as IABP, IPAB, IBPIO, ISABP, TIP and the GDP.

All this has happened against a background of the fundamental global climate change that seems likely to result from increasing concentrations of greenhouse gases. Such is the universal appreciation of the consequences of climate change that climate issues have moved to the forefront of the international political agenda. GCOS and GOOS both owe their origins to this concern, and are responding directly to the needs, expressed in Agenda 21, by the IPCC, and in support of the FCCC, for ocean data to underpin the understanding and prediction of global climate and environmental change.

Much practical progress has been made in bringing together all sides of the oceanographic, meteorological and climate communities to define these observational requirements and the organisational structure that will assume responsibility for them, notably at the OceanObs 99[1] and JCOMM[2] planning meetings. This plan takes note of these requirements and defines the DBCP role in the new structure.

2. RATIONALE

Neither GCOS, GOOS, WWW, nor indeed the DBCP action groups, currently operate as funding bodies for observational networks. Therefore any DBCP implementation strategy must attempt to reconcile the needs and aspirations of the global programmes with those of the drifter programme operators and funders. Ultimately, it is an objective of the implementation strategy to assist in the unlocking of sustained national funding in support of the wider regional and global needs, at the same time recognizing that the aims of the programme operator remain paramount. In practice, with the advent of low-cost multi-function buoys (e.g. the WOCE/TOGA SVP-B barometer drifter, see Annex D), this is no longer the insurmountable problem that it once was.

2.1 The definition of requirements

The observational networks specified for the WWW[3] and the ocean observing system for climate (OOSC)[4] are detailed in Annex B. Taking SST as an example, the WWW seeks daily observations over a 100 km grid with 0.5 C rms error; OOSC's needs are an order of magnitude coarser in space and time, but at a level of accuracy an order of magnitude higher. In essence this means that the density of any network deployed and maintained in support of weather forecasting (WWW) will be more than adequate for the perceived needs of climate monitoring (OOSC), provided that the accuracy and stability of the sensors can be improved. It should also be noted that OOSC calls for new sensors (e.g. for conductivity) that are not yet operational. In this context, the OOSC suggest that any practical, achievable implementation plan be broken down into a number of elements running over differing time scales, viz:

- the identification of elements that are part of existing operational systems;
- the identification of elements to be added now to constitute the initial observing system (either enhancements to existing operational systems or parts of existing research observing systems ready for conversion to operational status);
- the identification and specification of observations not now readily obtainable that are urgently required and should be added as enhancements to the initial system at the earliest feasible time;
- the identification of future research and development likely to be needed for further development of the system.

This analysis is used as a basis for the plan that follows. Although this strategy is restricted to drifting buoy applications, the Panel recognizes that moored buoys, sub-surface floats and profilers will also play a part in any future ocean observation network.

These basic requirements have been endorsed and further developed by other agencies, notably by GCOS and the UNFCCC[5], and fall within the remit of the Group on Earth Observation (GEO), established by the Earth Observation Summit in 2003. While the exact composition of the desired network has yet to be defined, a figure of 1250 drifters is achieving wide acceptance, and has been set as a target within the US OCO implementation plan.

3. ANALYSIS OF EXISTING DRIFTING BUOY NETWORKS

3.1 Existing networks - current status

In general, most current operational drifter networks fall within the scope of one or other of the existing DBCP action groups. Figure 1 indicates the areas of responsibility of each action group. The deployments are increasingly of SVP-B drifters which combine quantifiable current-following characteristics with reliable measurements of atmospheric pressure and SST. At present, in excess of 1000 drifters report their data via the GTS (Figure 2 and 3); about 270 of these report atmospheric pressure. Regular re-seeding is needed to maintain observational density in dynamic areas such as the south Atlantic. The action groups are the key to implementing and maintaining deployments in all ocean basins. Annex C gives an example of the operating principles for an action group.

3.2 Existing networks - enhancements needed for the basic WWW/OOSC system

Although the statistics for data availability collected by the various operational and archiving centres do not always fully agree, it is clear that the existing networks do not even approach the required observational density in a number of areas, viz:

- the tropical Indian Ocean (wind)
- the Arctic (P)

- the North Pacific Ocean (SST, P)
- the North Indian Ocean (P)
- the Southern Ocean south of 40 S (SST, P)

Figures 4 to 7 illustrate the problem through data availability indices for specific variables as a function of expressed WWW requirements.

Deployment and re-seeding strategies will be developed which optimize the expenditure of available resources, and which allow accurate and credible prediction of future resource requirements, and their relation to declared objectives.

3.3 New observations urgently required

Equatorial areas, where the atmospheric pressure signal is typically weak, would benefit from a greatly increased density of wind observations. Whereas the equatorial Pacific is adequately sampled by the moored TAO and TRITON arrays, and the PIRATA programme is addressing the sparsity of observations in the tropical Atlantic, the Indian Ocean is currently almost devoid of accurate *in situ* wind measurements, although plans are being drawn up for the establishment of a moored buoy array in the area.

3.4 The observational challenge posed by 4D assimilation schemes

Recent studies using models that allow assimilation of non-synoptic-hour data have demonstrated the positive impact of such data. In particular, the inclusion of hourly extra-tropical buoy data was found to significantly improve forecast quality, particularly in the southern hemisphere. Non-synoptic-hour data is not routinely reported by all buoys, nor is its insertion on the GTS by CLS/Service Argos currently supported. In both cases, little change would be needed to current practice to allow these additional data to be made available to forecasters.

3.5 Future research and development

In addition to the development and proving of an accurate and reliable wind sensor, OOSDP have stated a requirement for ocean surface salinity and rainfall measurements. Very few drifters currently possess this capability, and it will become an area for further research and development. *In situ* salinity measurements will be of great value in developing the sensors and algorithms for salinity determination by satellite.

The Panel will also support other technology developments, e.g. the use of adaptive sampling to increase the impact and cost effectiveness of data buoy observations.

3.6 Regional and national issues

It should not be forgotten that drifter deployments continue to be made, in support of both operational and research programmes, which do not fall within the sphere of influence of any of the DBCP action groups. Efforts will continue by the DBCP and the action groups to involve these buoy operators in the work of the Panel, and to ensure, where appropriate, that their buoy data are made available to the wider community, in near real time if possible.

3.7 Deployment opportunities

The deployment and re-seeding of a large network of data buoys poses a huge logistical problem. To date, deployments have largely been accomplished opportunistically using volunteer ships and aircraft. This system is showing increasing signs of strain, and the DBCP will actively pursue additional strategies, recognizing that the issue of funding associated logistical effort will have to be tackled.

3.8 Coordination issues

Within the above context, the action groups are best placed to identify the precise needs in their particular areas of responsibility, and to obtain the resources required. The Panel recognizes the autonomy of these groups and does not seek to impose any additional level of management or control.

There are areas, however, where the Panel is best placed to advise on overall methodology and policy; such areas include:

a) Co-ordination of deployments in areas not covered by the Action Groups or which involve several Action Groups.

Such areas presently include:

- The Southern Ocean
- The North Pacific Ocean, and particularly the NE Pacific Ocean
- The Mediterranean Sea
- The Black Sea

Unless there is a need to specifically establish DBCP Action Groups for those areas, it is proposed to include one or more of such buoy programmes directly within the DBCP implementation strategy and to discuss important co-ordination and implementation issues at Panel sessions where all DBCP Action Groups are normally represented. During intersessional periods, co-ordination can take place through direct exchange between buoy operators (e.g. email, DBCP internet forum), and through the Technical Co-ordinator as focal point. Specific mailing lists can be established for this purpose. Initially, it is proposed to consider the following buoy programmes as part of the DBCP implementation strategy:

- The Southern Ocean Buoy Programme (SOBP), which would tentatively deploy about 80 barometer drifters South of 40S yearly, excluding the Antarctic sea-ice zone.
- The Black Sea Buoy programme (BSBP).

In the event that such programmes eventually reach a sufficiently high level of co-ordination, and if the need is expressed by the buoy operators, it could be proposed to eventually establish new DBCP Action Groups.

b) Real-time data quality control,

c) Data management,

d) Other co-ordination issues such as the negotiation of bulk purchase rates for drifter hardware and communications costs.

The role of the Panel and its technical co-ordinator within the proposed new JCOMM structure is discussed in section 7.

4. DATA COLLECTION AND EXCHANGE

4.1 The status quo

With very few exceptions, drifting buoys use the Argos satellite system for location and data collection. Telemetry datasets stored on board the NOAA satellites that carry Argos are processed by Argos centres in France and the USA. Data are quality controlled and inserted on to the GTS for use by weather forecasters and climate modellers, and for archival by the responsible data centres, if authorised by the buoy operator. Data timeliness, vital for weather forecasting, can be improved by using LUTs to access buoy data rebroadcast by the satellites in real time. The operators of the Argos system have been attentive to the need for faster data turnround times, and have taken steps to increase the amount of LUT data that are processed by the two main centres.

An agreed share of the operating costs of the two centres (approx USD 5 million in 2000) is recovered under the terms of the Argos JTA, under which all non-commercial usage of the system (of which drifting buoy operators account for roughly 50%) is charged out to designated national representatives (ROCs) at an agreed and supposedly equitable rate. ROCs then pass on costs to individual operators as they see fit. The Argos costs associated with a drifter programme are nowadays generally comparable with the actual buoy procurement costs, following the development of inexpensive buoy hardware. The DBCP will negotiate actively to achieve the best possible terms for data buoy users.

The charges associated with real-time data distribution via the GTS are currently borne by national weather services; individual buoy operators in general have to pay additional costs, over and above the processing costs described above, for access to their own data held at the Argos centres.

4.2 Future developments

Many new mobile satellite services are at the planning or pre-operational stage (see Annex F), and these are attractive to buoy operators, both from the cost perspective and from the increased operational flexibility (e.g. two-way communication) that they potentially offer. Systems which feature a continuous global coverage (e.g. those intended to supplement the existing terrestrial cellphone networks) would in addition allow a return to truly synoptic reporting of observations.

However, most of these new systems will never reach full operational capability, nor will buoy operators ever achieve more than minority status. Systems such as Iridium and Orbcomm, which have in fact launched services, encountered severe financial difficulties before emerging into commercial viability. Potential users of any new systems therefore need to exercise considerable caution in selecting a replacement for Argos. Argos for their own part have responded with a development programme which should greatly increase the usefulness of their system for data buoy operations. In particular, they have established a protocol for the assimilation of data from third party communications providers into their own GTS processing chain.

The Panel will, in this context, act as a focus for the exchange of practical information on the performance of the various systems, and will be active in sponsoring evaluation trials of new equipment and systems as they become available. As with Argos, the Panel will seek to negotiate the best possible terms for data buoy users of these systems.

5. DATA MANAGEMENT

5.1 Quality control

Quality control procedures, jointly developed and implemented by the DBCP and the operators of the Argos system, currently ensure that surface observations are validated in real time before insertion on to the GTS. Sub-surface (e.g. from the TAO array) data are further controlled by NOAA/NOS. Several other bodies (ECMWF, national weather and oceanographic agencies, GDC, MEDS, ...) contribute to an active off-line assessment of data quality. A well-defined feedback mechanism ensures that any interventions arising from this off-line quality control (e.g. modifications to individual sensor transfer functions) are implemented into the real-time data processing chain in a co-ordinated and auditable fashion. The Panel will encourage the users of other satellite communications channels and observing systems to benefit from its experience in this regard, with a view to avoiding the many quality pitfalls that beset the acceptance of early drifting buoy data by the operational community.

5.2 Data archiving

Drifter data inserted on the GTS are routinely archived by MEDS, the IOC RNODC for drifter data. The DAC archives all data from the GDP, and any other drifter data that are made available to it. The Panel and its action groups will actively encourage all buoy operators to forward their data to one or other of these responsible global archives.

5.3 Data access policy

At present, all of the archiving agencies and many of the operational and research bodies make provision for the release of drifter data to scientific and other customers. In particular, many data are available via the World-Wide Web (see Annex E), either in the form of trackplots or as datasets. In many cases, the policies relating to the release and use of these data are not immediately clear. The Panel is seeking clarification from these agencies, and from its action groups, with a view to developing a co-ordinated data access policy for drifter data within the letter and the spirit of the WMO data exchange policy defined in WMO Congress Resolution 40 (Cg-XII).

5.4 DBCP publicity

Many suggestions have been made over the years regarding ways of publicizing the DBCP and its activities. Most of these have in practice been superseded by the DBCP server on the World-Wide Web, and this web site is now the *de facto* entry point for current information about the DBCP and its action groups.

The Panel is taking steps to ensure that resources and information are available to allow this web site to be developed and updated as required.

6. RESOURCE REQUIREMENTS

6.1 Manpower

Most of the success of the Panel to date in implementing its objectives is entirely due to the efforts made on its behalf by its technical coordinator, and by the support afforded to him by the operators of the Argos system and other agencies. The Panel will build on this success by actively seeking adequate and secure resources to ensure the continued employment of its technical coordinator.

6.2 Hardware and telecommunications

A crude analysis of the current situation indicates that a minimum of 1600 SVP-B type drifters are currently needed in extra-tropical regions plus a minimum of 650 SVP type drifters (i.e. SST only) in tropical regions to bring existing networks up to the OOSDP requirements for SST and an acceptable fraction of WWW requirements for atmospheric pressure. This presently represents a hardware investment of USD 7.5 million.

Reseeding of networks to cover buoy mortality and dispersion will require a further annual hardware commitment of 2400 SVP-B and 1000 SVP drifters (USD 11 million at current cost levels), if present drifter lifetimes and trajectories are maintained.

The initial goal of the reseeding strategy is to tentatively maintain a homogeneous network of buoys with a 500*500 km resolution. Taking dispersion and reseeding into account, data from a fraction only of operating buoys would be required, i.e. about 2250 PTT-years. At present data telecommunication costs, this would represent USD 9 million. This is well above present usage of the Argos system for drifting and moored buoys. Present rules negotiated in the context of the Argos Joint Tariff Agreement (JTA) permit usage of extra Argos capacity. There is therefore a potential to substantially decrease telecommunication costs.

In recognition of the economies of scale that will flow from global annual procurements of this size, the Panel and its action groups will seek negotiations with the drifter manufacturers and the communications service providers to establish economical prices that will then be available to individual buoy operators.

7. THE DBCP ROLE WITHIN JCOMM

In deciding an organisational structure for JCOMM, the JCOMM planning meetings have noted the Panel's success in resolving many operational and co-ordination issues regarding buoy data quality, data flow, deployment scheduling and so on, and have adopted a similar 'Observations Co-ordination Group' for the management of the JCOMM observational programme (See Annex G). Membership of this group includes the Chair and Technical Co-ordinator of the DBCP. In practical terms, the DBCP technical co-ordinator works alongside the co-ordinators of other observing systems to implement a common approach to deployment strategy, data management and quality control, and to ensure the most efficient use of deployment opportunities. In this regard, the Panel will actively encourage the operators of other observing and satellite data collection systems to make full use of the Panel's experience and expertise in these areas.

8. SUMMARY OF AIMS AND OBJECTIVES

8.1 *Deployment and re-seeding strategies, and associated funding mechanisms, will be developed which optimize the expenditure of available resources, and which allow accurate and credible prediction of future resource requirements, and their relation to declared objectives.*

8.2 *In the particular case of equatorial areas, where the atmospheric pressure signal is typically weak, the Panel will strive to increase the density of wind observations, to be provided by drifter networks where there are no moored arrays.*

8.3 *Further research and development will be undertaken on new sensors to observe variables such as salinity, rainfall, wind, heat flux, ocean colour and* CO_2*.*

8.4 *Efforts will continue by the DBCP and the action groups to involve other buoy operators in the work of the Panel, and to ensure, where appropriate, that their buoy data are made available to the wider community, in near real time if possible.*

8.5 *The Panel recognizes the autonomy of its action groups and does not seek to impose any additional level of management or control.*

8.6 *The Panel acts as a focus for the exchange of practical information on the performance of the various satellite communication systems, and will be active in sponsoring evaluation trials of new equipment and systems as they become available.*

8.7 *The Panel and its action groups will actively encourage all buoy operators to forward their data to one or other of the responsible global archives.*

8.8 *The Panel will seek clarification of their data release policy from all agencies that distribute drifter data, and from its action groups, with a view to suggesting co-ordinated data access guidelines for drifter data, compatible with the WMO policy defined in Resolution 40 (Cg-XII).*

8.9 *In recognition of the economies of scale that will flow from global annual procurements of the size indicated by the WWW and OOSC observing network requirements, the Panel and its action groups will develop negotiations with the drifter manufacturers and the communications service providers to establish prices that will then be available to individual buoy operators.*

8.10 *The Panel will seek adequate and secure resources to ensure the continued employment of its Technical Co-ordinator.*

8.11 *Within the context of the proposed JCOMM operational structure, the Panel will encourage the users of other satellite communications channels and observing systems to benefit from its experience in data management and co-ordination, with a view to their avoiding the many pitfalls that beset the acceptance of early drifting buoy data by the operational community.*

8.12 *The Panel will note the deliberations of the UN Convention on the Law of the Sea (UNCLOS) and the provisions of the Antarctic Treaty, as amended by the Madrid Protocol (1991), with regard to data buoy operations.*

8.13 *The Panel will regularly review its mission in the light of changing research and operational imperatives, and will update this document and its terms of reference as appropriate.*

9. REFERENCES

1. Smith, N (ed), 2000. OceanObs 99 Conference Statement, 28 pp. WMO, Geneva.

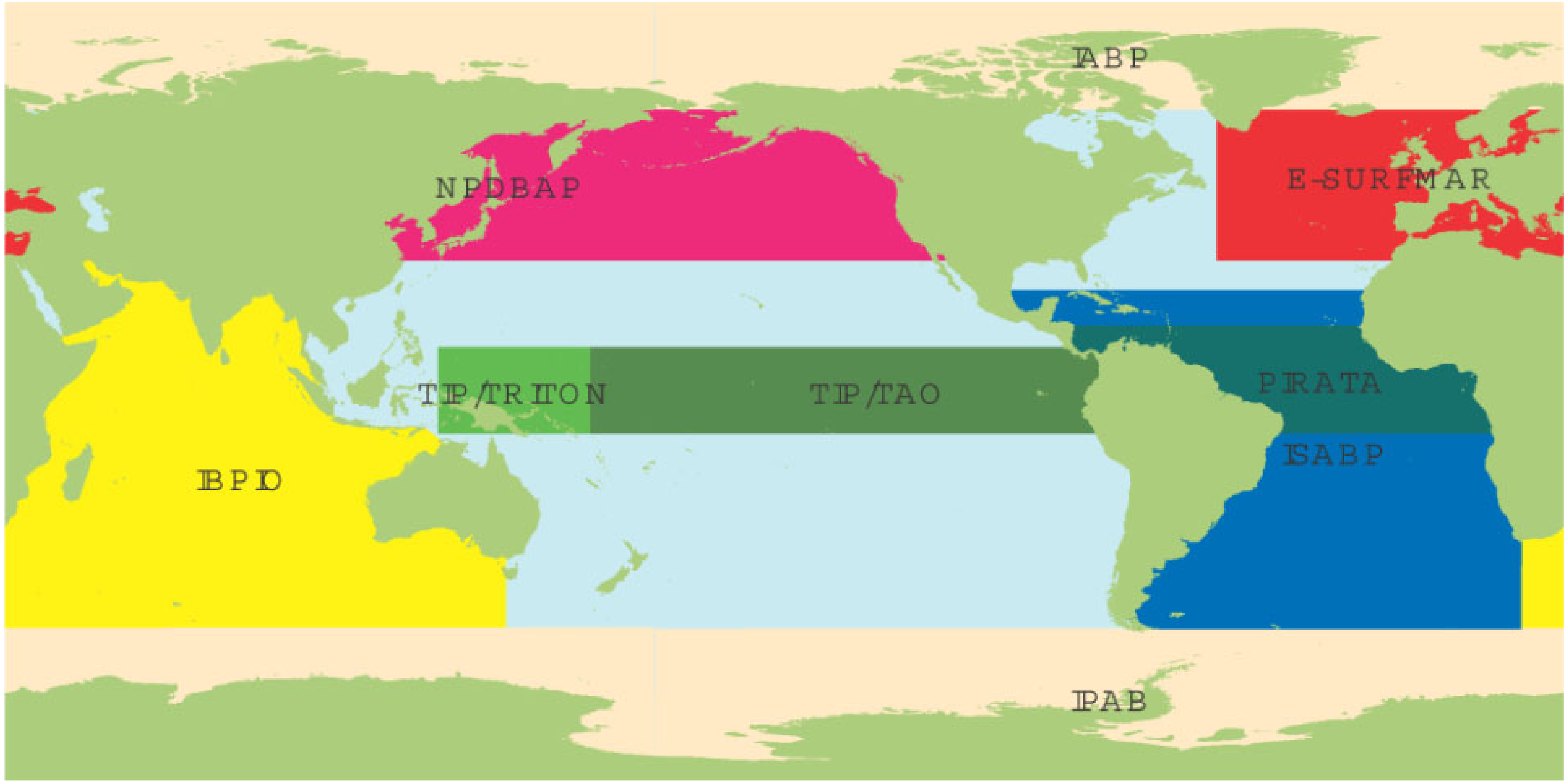
2. Guddal, J and Kohnke, D, 2001. Report by the Interim Co-presidents of the Commission, JCOMM-I, Doc 3, 14pp. WMO, Geneva.

3. World Weather Watch Fourth Long Term Plan, 1996-2005. WMO, Geneva.

4. Final Report of the OOSDP, 1995 - 'Scientific Design for the Common Module of the Global Ocean Observing System and the Global Climate Observing System: an Ocean Observing System for Climate'

5. The Second Report of the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC, 2003. GCOS-82, WMO/TD No 1143, WMO, Geneva.

FIGURES



E-SURFMAR: EUCOS Surface Marine Programme
GDP: Global Drifter Programme
IABP: International Arctic Buoy Programme
IBPIO: International Buoy Programme for the Indian Ocean
IPAB: WCRP-SCAR International Programme for Antarctic Buoys
ISABP: International South Atlantic Buoy Programme
NPDBAP: DBCP-PICES North Pacific Data Buoy Advisory Panel (North 30°N)
TIP: Tropical Moored Buoy Implementation Panel (includes PIRATA and TAO/TRITON Arrays)

Figure 1: DBCP Action Groups in 2005.

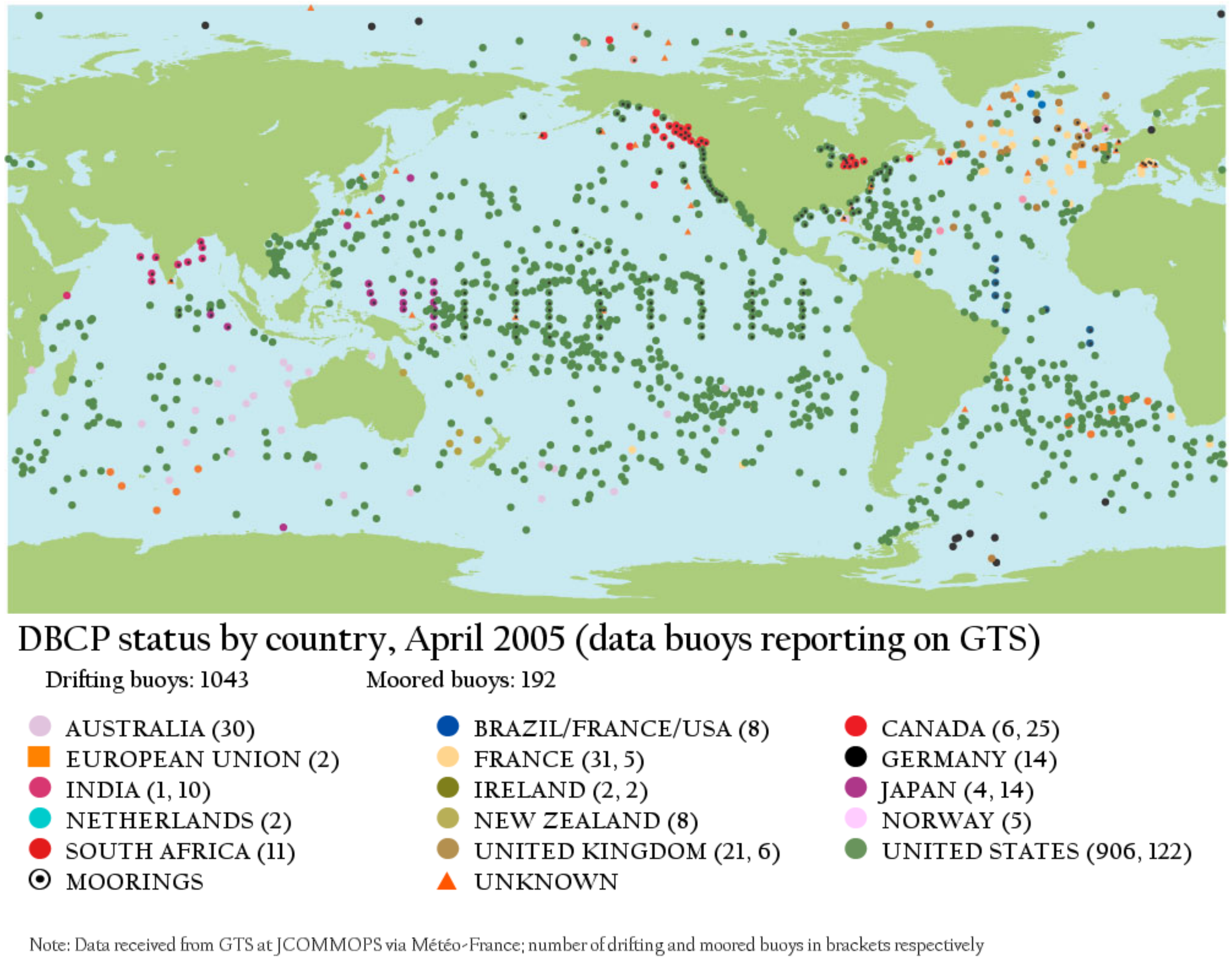


Figure 2. DBCP Status by country, April 2005.

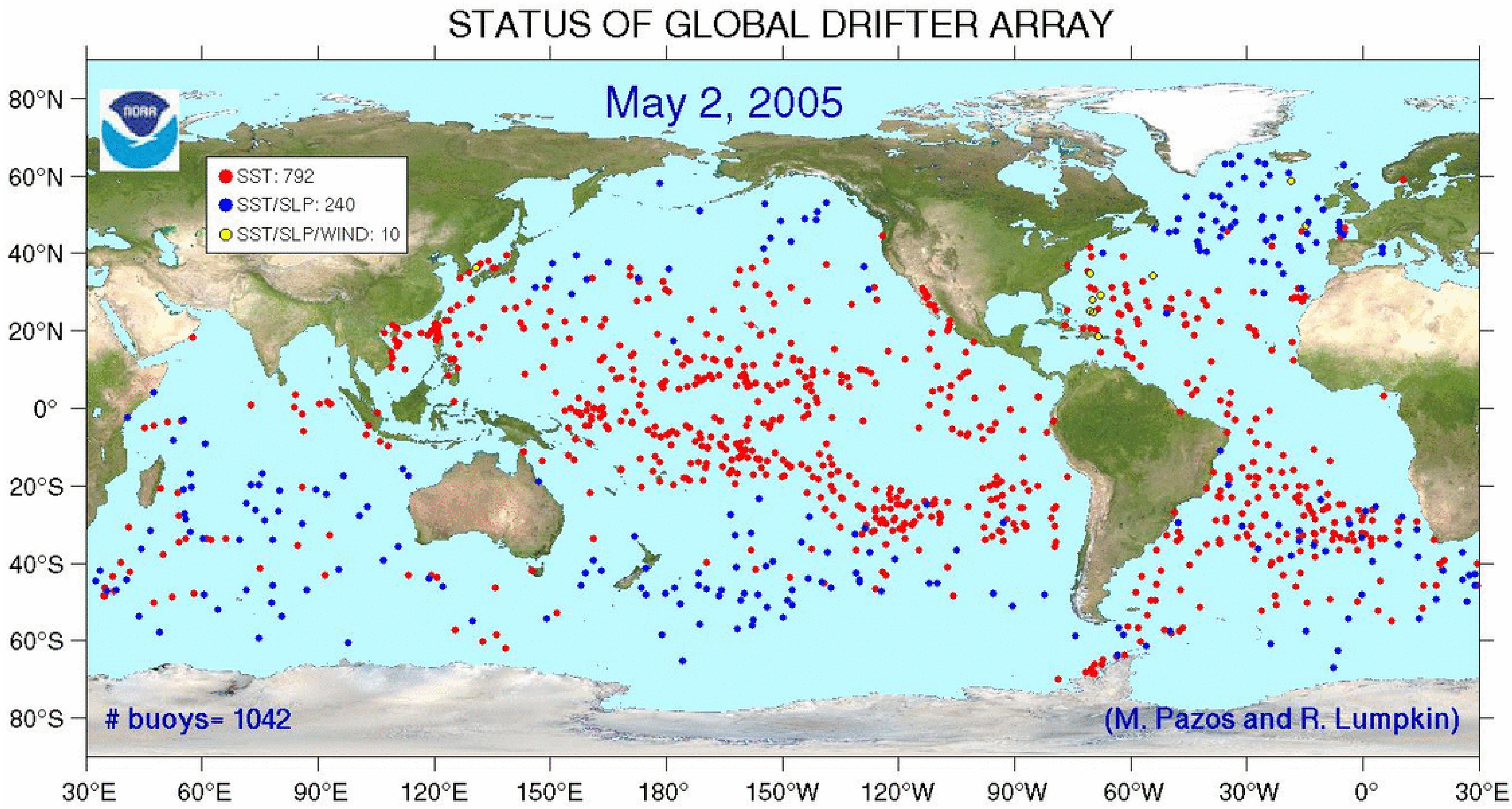


Figure 3. The Global GTS drifter array in April 2005, by courtesy of the Global Drifter Center, NOAA-AOML.

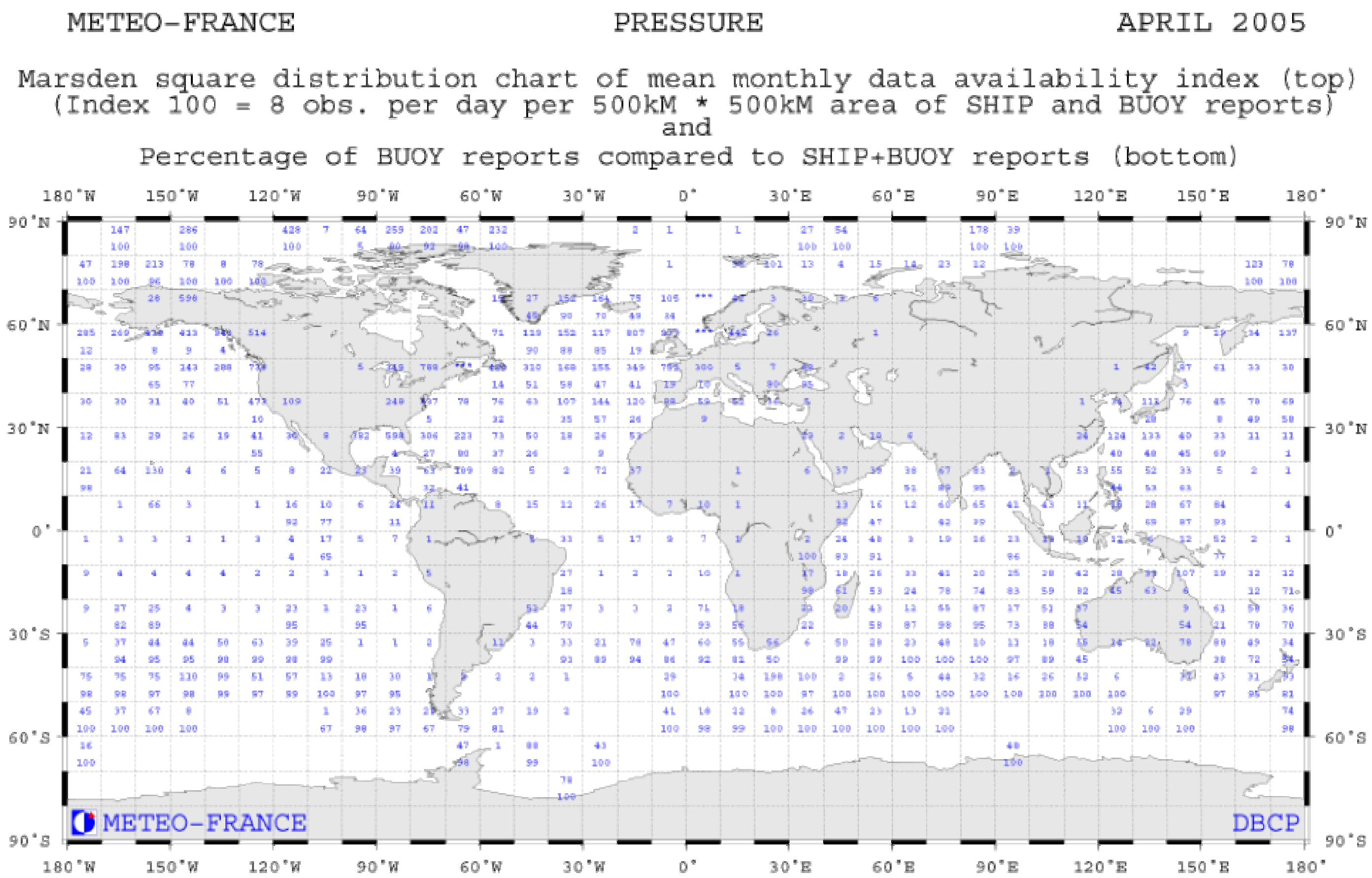


Figure 4. GTS data availability, April 2005 – Surface atmospheric pressure (by courtesy of Météo France).

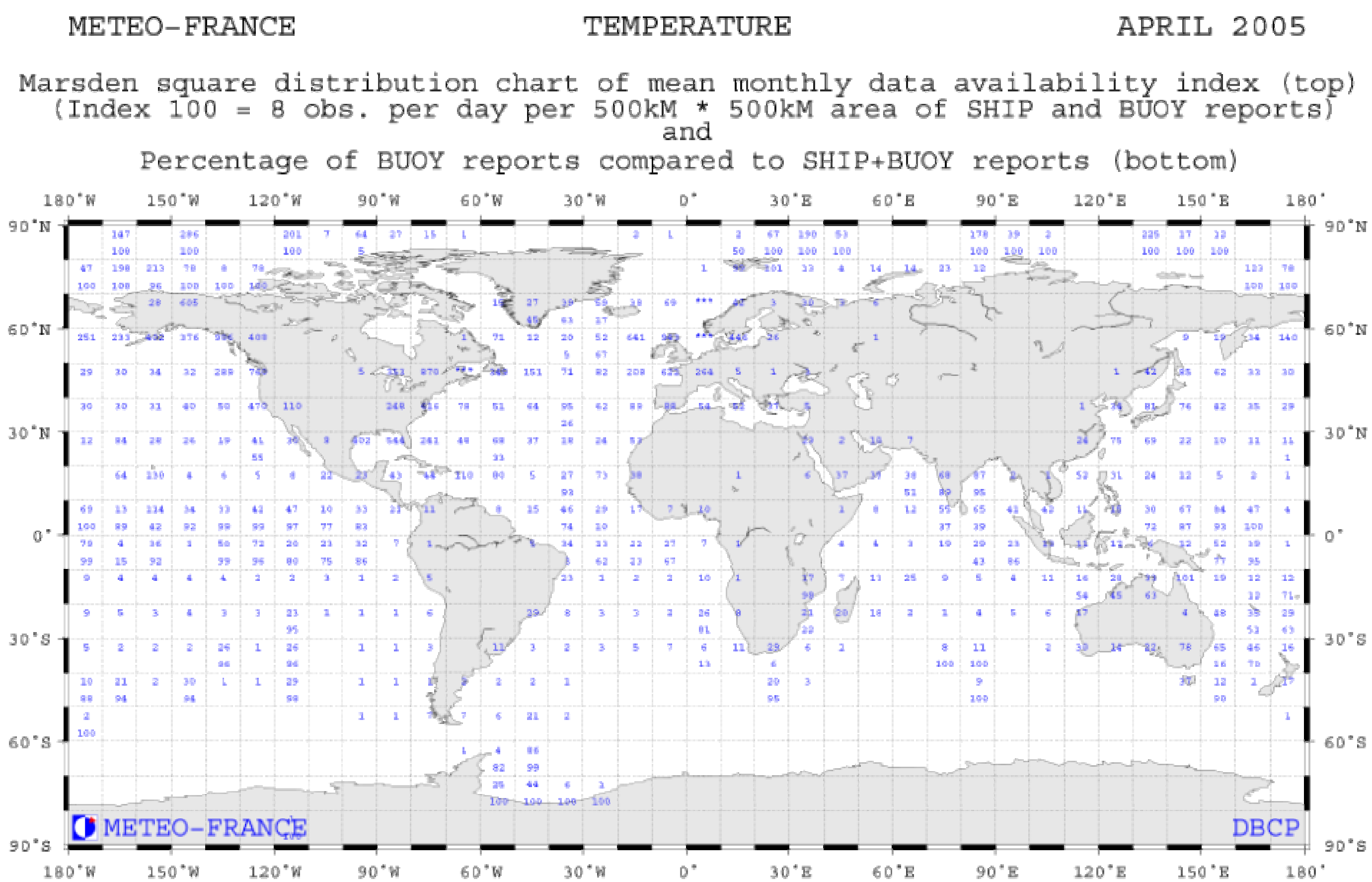


Figure 5. GTS data availability, April 2005 – Air temperature (by courtesy of Météo France).

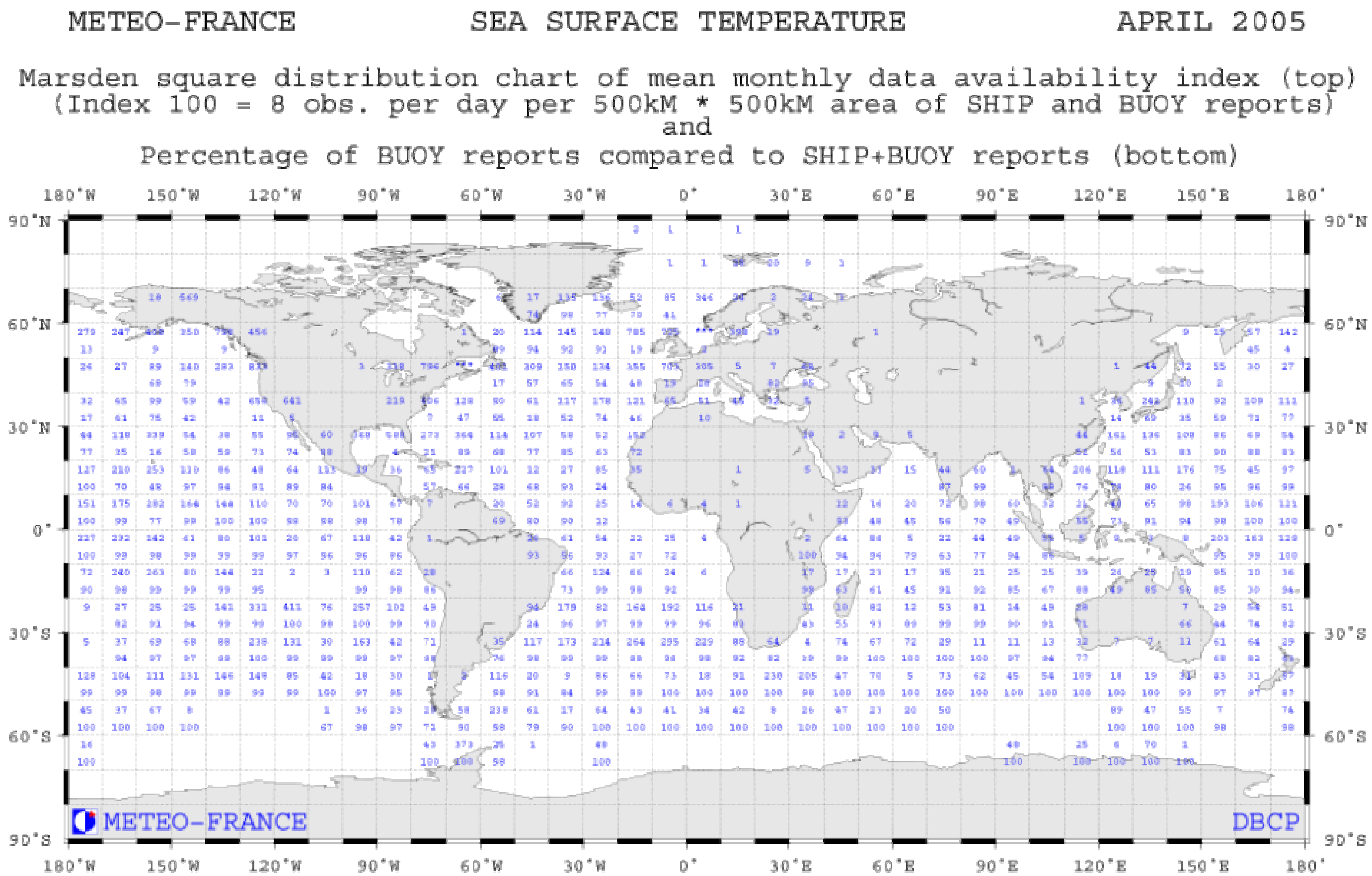


Figure 6. GTS data availability, April 2005 – Sea surface temperature (by courtesy of Météo France).

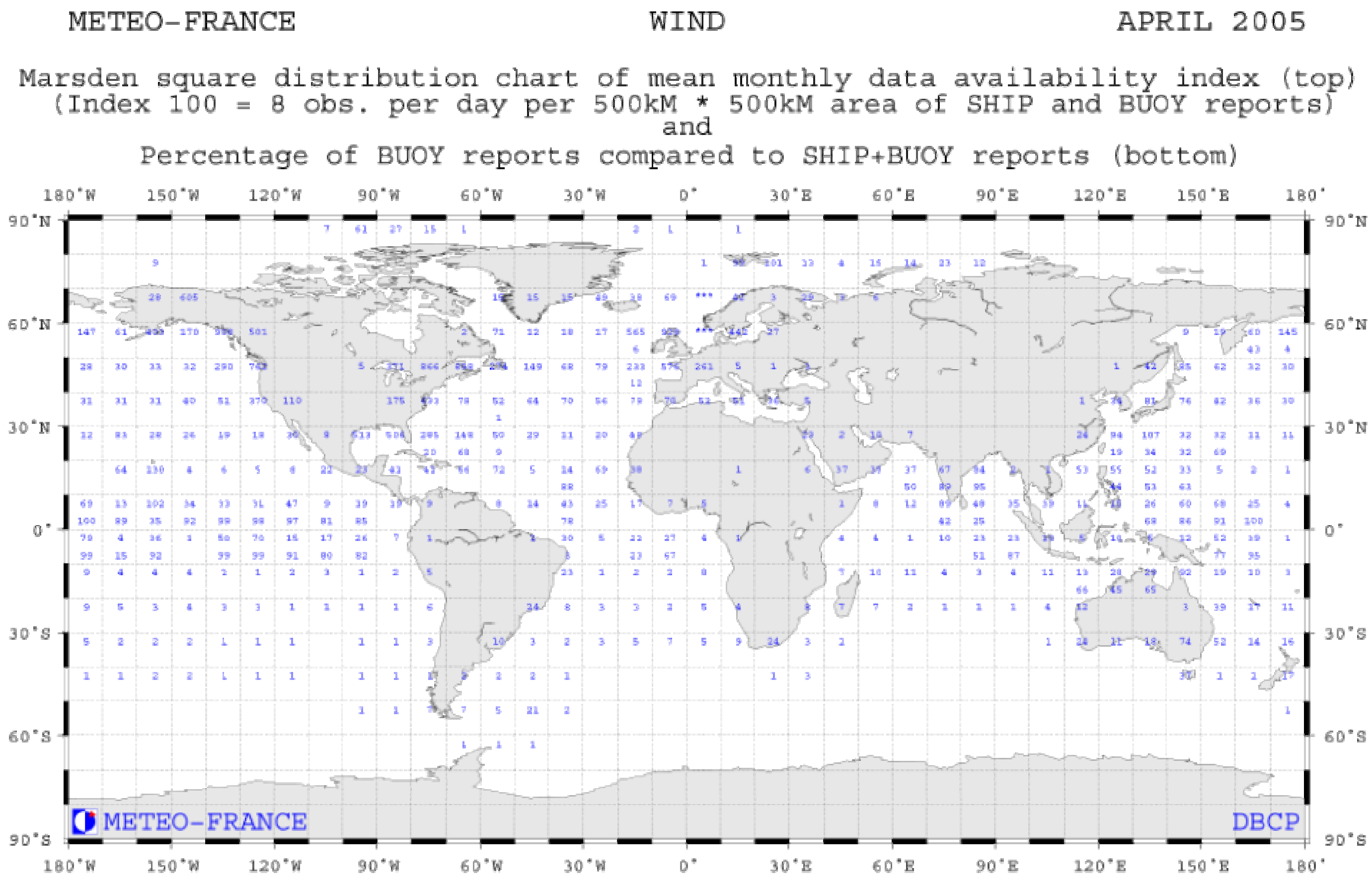


Figure 7. GTS data availability, April 2005 – surface wind (by courtesy of Météo France).

ANNEX A Acronyms

CLIVAR	Climate Variability and Predictability (WCRP)
CMM	Centre de Météorologie Marine (Météo France)
DAC	Data Assembly Center (of the WOCE Surface Velocity Programme)
DBCP	Data Buoy Co-operation Panel
ECMWF	European Centre for Medium-range Weather Forecasts
EGOS	European Group on Ocean Stations
FGGE	First Global GARP Experiment
FCCC	Framework Convention on Climate Change
GARP	Global Atmospheric Research Programme
GCOS	Global Climate Observing System
GDC	Global Drifter Center
GDP	Global Drifter Programme
GOOS	Global Ocean Observing System
GTS	Global Telecommunication System
IABP	International Arctic Buoy Programme
IBPIO	International Buoy Programme in the Indian Ocean
IOC	Intergovernmental Oceanographic Commission
IPAB	International Programme for Antarctic Buoys
IPCC	Intergovernmental Panel on Climate Change
ISABP	International South Atlantic Buoy Programme
JCOMM	Joint Commission for Oceanography and Marine Meteorology (WMO/IOC)
JCOMMOPS	JCOMM *in situ* Observing Platform Support centre
JTA	Joint Tariff Agreement
LUT	Local User Terminal
MEDS	Marine Environmental Data Service
NOAA	National Oceanographic and Atmospheric Administration
NOS	National Ocean Service
OOPC	Ocean Observation Panel for Climate
OOSC	Ocean Observing System for Climate
OOSDP	Ocean Observing System Development Panel
RNODC	Responsible National Oceanographic Data Center
ROC	Representative Organization of Country
SST	Sea Surface Temperature
SVP	Surface Velocity Programme
TAO	Tropical Atmosphere Ocean Array
TC	Technical Coordinator (of the DBCP)
TIP	Tropical moored buoy Implementation Panel
TOGA	Tropical Ocean Global Atmosphere
UNCLOS	United Nations Convention on the Law of the Sea
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WWW	World Weather Watch

ANNEX B Observational requirements

Observational requirements of WWW and GCOS/GOOS OOSC that could be addressed by drifting buoy networks

1. Ocean Observing System for Numerical Weather Prediction (World Weather Watch)

Variable	Spatial resolution	Temporal resolution	Accuracy
Atmospheric pressure	100 km	1 h	0.5 hPa
Wind	100 km	1 h	2 ms^{-1}
Air temperature	100 km	1 h	1 K
Integrated precipitation	100 km	3 h	0.1 mm
Sea surface temperature	100 km	1 day	0.5 K
Wave height	100 km	1 h	0.5 m

(from the WMO World Weather Watch Fourth Long Term Plan, 1996-2005)

2. Ocean Observing System for Climate (OOSC)

Variable	Spatial resolution	Temporal resolution	Accuracy
Sea surface temperature	500 km	1 week	0.1 K
Wind	250 km	1 month	0.5 ms^{-1}
Atmospheric pressure	250 km	1 day	1 hPa
Integrated precipitation	250 km	1 month	5 cm
Integrated heat flux	250 km	1 month	5 Wm^{-2}
Surface velocity	50 - 500 km	1 month	2 cms^{-1}
Sea ice velocity	250 km	1 month	2 cms^{-1}
CO_2, fluorescence	for ocean colour satellite calibration		

(adapted from the Final Report of the OOSDP, 1995 - 'Scientific Design for the Common Module of the Global Ocean Observing System and the Global Climate Observing System: an Ocean Observing System for Climate')

ANNEX C Example operating principles of a DBCP action group

OPERATING PRINCIPLES OF THE ISABP

The ISABP strives to:

- Maintain a data network over the South Atlantic Ocean using *in situ* ocean platforms such as island weather stations, moored buoys and in particular drifting buoys;
- Establish and maintain data collection and data communication facilities, and ensure that the necessary quality control is undertaken according to DBCP guidelines;
- Distribute basic meteorological and oceanographic data from the network at operationally useful time-scales over the Global Telecommunication System;
- Arrange for the archival of data from the network and for the provision of archived data sets to programme participants;
- Liaise on technical aspects of buoy development and operational matters;
- Continually review the effectiveness of the programme in satisfying data requirements of the users.

Operational area:

The operational area is the Tropical and South Atlantic Ocean.

Variables:

Atmospheric pressure, sea-surface temperature and buoy location are reported. Additional variables such as air temperature, atmospheric pressure tendency, wind speed and direction, and surface and sub-surface oceanographic variables, especially waves, are viewed as highly desirable.

Data archiving:

All basic meteorological and oceanographic data from drifting buoys in the programme are archived by the Marine Environmental Data Service (Canada), as the Intergovernmental Oceanographic Commission (IOC) responsible national oceanographic data centre for drifting buoys.

Other buoy data quality control and archival activities are relevant to the programme, in particular those of the Global Drifter Centre in Miami.

Basic network density:

To be consistent with the requirements stated by the World Weather Watch, we attempt to provide a network of the basic variables with data points spaced at approximately 250 km intervals over the operational area. As far as is practicable, sufficient platforms are deployed to achieve and maintain this density, taking into account other observing system components.

Buoy recovery and refurbishment:

Participants retain ownership of their buoys. While no specific plans for buoy recovery are made, agencies are encouraged to make arrangements, as appropriate, for the recovery, refurbishment and re-deployment of buoys which drift ashore or which, in other ways, no longer contribute to the goals of the programme.

Data acquisition and distribution:

All buoys in the basic network are equipped with transmitters to enable basic meteorological and oceanographic data to be transmitted in real-time (synoptic or asynoptic mode). As a preferred approach:

- Data are collected and located via the Argos systems;
- All basic meteorological and oceanographic data are coded in the approved WMO code form for buoys;
- Data collected through the Argos system are inserted by CLS/Service Argos into the Global Telecommunication System.
- Data collected by the participants through other means may also be inserted on the Global Telecommunications System;
- The programme seeks to establish and maintain, as necessary, Argos Local User Terminals (LUTs) covering the area.

Duration:

The programme will operate for an initial five-year period with formal review by the participants after three years leading to a decision on its continuation.

Funding arrangements:

The programme will be self-sustaining, supported by contributions in the form of equipment, services (such as communications, development, archiving or co-ordination) or monetary contribution. As necessary, suitable arrangements will be made for the administration of the monetary contribution by the participants.

Meetings:

An annual meeting of the participants will be held at a location to be determined by them. All the participants are eligible to attend at their own expense.

ANNEX D Specifications of the SVPB "barometer" drifter

1) <u>Introduction</u>

The SVPB drifter is basically a standard SVP drifter to which an air pressure port has been added (figure 1). Both standard SVP and SVPB drifters are proven and reliable designs and have been deployed at sea in large quantities for oceanographic research and operational meteorological programmes (e.g. WOCE, TOGA, WWW). SVPB is capable of accurately measuring sea surface currents (+/- 1 cm/s) in 10 M/S winds, sea surface temperature (+/- 0.1 C), and atmospheric pressure (+/- 1 hPa). Nominal lifetime is 18 month.

Design of the SVPB is regularly being upgraded to take advantage of new technologies and therefore to improve its overall reliability and lifetime. In latest design, the following changes have been proposed:

- Removal of sub-surface float.
- Reduction of drogue size (to keep a drag area ratio of 40).
- ABS plastic hull instead of fibreglass.
- Reduction of the tether diameter (to keep drag area ratio of 40).
- Three pressure sensors proposed instead of one: AIR (SB-2A), Vaisala (PTB 101C), Honeywell (still being designed, no ref. yet).
- Two designs proposed for the installation of the sea water switch.
- More latitude is left for the design of the barometer port provided that outside design is unchanged and certain requirements followed (e.g. submersible port, sufficient backing volume, water trap, desiccant …).
- New Argos message format.
- New instructions for installing the antenna.

A construction manual which does not mention above modifications has been produced and published by the DBCP (DBCP Technical document No. 4). Free copies can be obtained from the Technical Coordinator of the DBCP. A revised version of the manual is on the DBCP website.

2) <u>Surface current measurement</u>

For measuring surface velocity, standard SVP buoys have been designed to be good Lagrangian drifters (buoys which follow the water motion well) and very specific requirements of drogue and surface float design have been developed (large holey sock drogue, spherical floats and thin wire tethers...). Laboratory and at sea tests have been conducted to guarantee the reliability of SVP drifter measurements.

The slip (i.e. the motion of the centre of the drogue relative to the moving water parcel) has been minimized. Many phenomena can induce slip; the main ones are wind stress, surface gravity wave effects and vertical shear of currents. Therefore tests have been conducted on various shapes of floats and drogues (NOAA data report 1990). These tests show that the most efficient shapes are small, spherically-symmetric surface and subsurface floats, thin-wire tethers and a large semi-rigid drogue. The drogues which have high drag coefficient and stable water following characteristics are the TRISTAR (Niiler, *et al*., 1987) and the Holey Sock (Nath, *et al*., 1979). The drag area ratio is the drag coefficient of the drogue times the frontal area divided by the sum of the products of the drag coefficient and the largest projected frontal areas of floats and tethers. A drag area ratio for the drifter greater than 40 will give the instrument the capability to make current measurements accurate to within 2 cm/s. Using a correction formula, a wind correction will then improve this accuracy to 1 cm/s if the wind is known within 4 m/s.

3) <u>Drogue detector (Submersion switch)</u>

A drogue detector is necessary for ascertaining if the drogue is still attached. A drifter without a drogue is of little value for surface velocity measurements. Since the surface float goes under the water more often when the drogue is attached, one principle is to install a submersion detector (switch) on the surface float and to analyze the time series in order to deduce if the drogue is still attached.

4) <u>Sea Surface Temperature measurement</u>

The SVPB drifter is also equipped with a sea surface temperature sensor that is designed to make measurements accurate to 0.1 Celsius. Experience gained with the standard SVP drifter has been used. To obtain this accuracy, tests show that one must install the temperature sensor outside the hull of the drifter float. Also, calibrations of a number of thermistors while connected to the electronics circuitry in a test tank in various ranges of temperatures must be done. Only these kind of tests and calibrations can provide accurate coefficients to be used to convert raw data (resistance) into physical values (Celsius) within +/- 0.1 Celsius. The lifetime of the sensor will exceed that of the transmitter.

5) <u>Atmospheric Pressure Measurement</u>

The air pressure port has been designed to withstand frequent immersion with no loss of accuracy. The port is elevated to some height above the float itself to avoid Venturi effects caused by airflow over the curved float surface. The total surface of the mast is lower than 10% of the total frontal area so that wind stress does not induce a substantial slip effect compared to the one induced through the hull itself. The design is based on a port used on moored buoys by the United Kingdom Meteorological Office, which has had extensive field tests in the wind tunnel. Internal baffling is provided against submergence surges and sufficient back up volume of air assures that water does not enter the barometer duct.

The barometer port design is based on the following rationale:

(i) Field observations indicate that the surface float of the SVP Lagrangian drifter is pulled under the water to a depth of 1-2 m at the crests of wind waves, therefore an overpressure of 200 hPa can be expected on the barometer. Data from the submergence switch on drifters in WOCE Heavy Weather Drifter Test (Sybrandy and Niiler, 1991) indicate that they spend about 20-30% of the time under the water in winds in excess of 15 m/s. Upon resurfacing, the port has to clear from sea-water quickly and completely. Flaps and valves to close a port will fail or become encrusted. An inverted port, with sufficient backup volume of air which can be compressed upon submergence so the water is kept out of the barometer air duct was incorporated in the design.

(ii) A long air pressure duct to the barometer can collect condensation in the extreme changes of moisture and temperature which occur in synoptic weather systems. This problem was solved by placing the barometer very close to and above the air intake. Specially configured barometers were made for this application for GDC by several manufacturers.

(iii) In a wind stream, the surface float produces a lowering of air pressure due to the Bernouilli effect. In 10 m/s wind, this effect produces less than 0.1 hPa pressure lowering at a distance of one radius of a sphere. The barometer port air intake is placed on a mast 24 cm above the top of the sphere. A second Bernouilli effect is produced by the airflow around the mast. This problem has been studied extensively, and a tabular windshield, with air intake holes inside an inserted, second sleeve is adopted (Osmund and Painting, 1984).

(iv) The sampling and averaging scheme for the air pressure has to be sensitive to when the port is under the water. Tests have run at sea under 15 m/s wind conditions off San Diego, Ca. (WOCE/TOGA Lagrangian Drifter with barometer port, May 91, Sybrandy and Niiler) where pressure was sampled at 2Hz inside the surface float. A laboratory standard barometer of identical construction was used to obtain data at identical rates about 3 meters above sea level in a semi-enclosed laboratory on a ship. No significant wind effects, or delay times, were observed on the barometer port response on the surface float in the water.

The sensor itself is an AIR SB-1A model. It is a ceramic diaphragm capacitance sensor equipped with a built-in temperature compensating circuit. AIR sensors have been carefully tested for WOCE and finally proved reliable (Payne *et al,* IMET). Accuracy is +/- 1 hPa with a stability of +/- 1 hPa over a one-year period. Sensor output is digital in tenths of hPa.

Data are sampled at 1 Hz, and averaged over a 160 seconds period. A dedicated despiking algorithm was designed to remove from the average these air pressure measurements made while the barometer port is submerged.

The latest average of every hour is stored on-board. The last 12 hourly measurements are memorized on-board and transmitted through Argos using multiplexing techniques. It is expected that the full series of 24 hourly measurements will be recovered every day. Hence the latest available air pressure and tendency measurements (real time) as well as the synoptic air pressure measurements can be distributed on GTS (deferred-time).

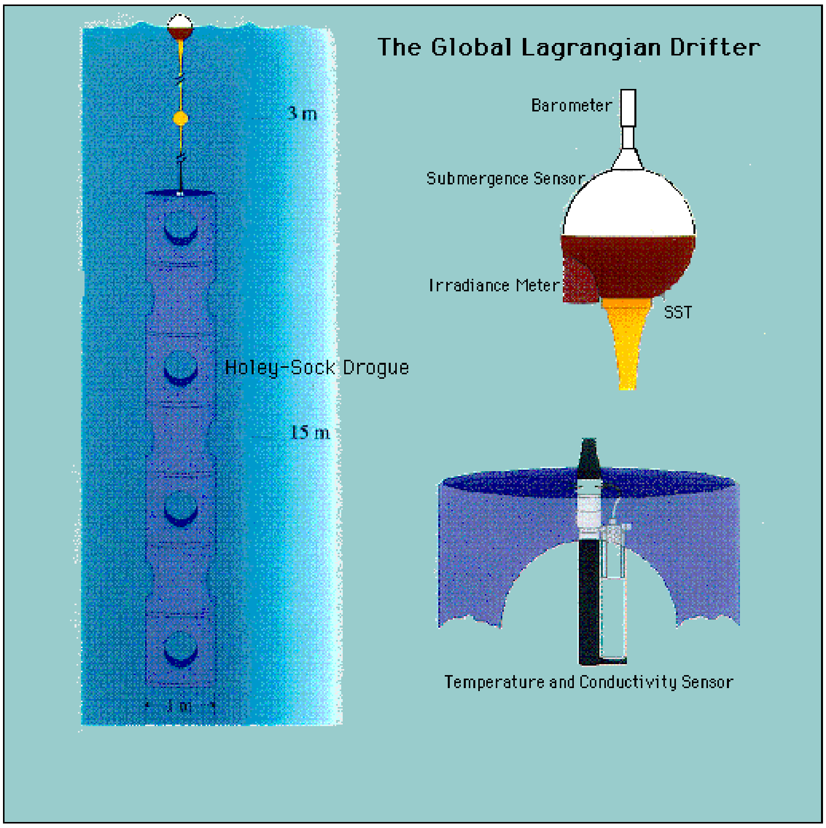


Diagram displaying the low-cost Global Lagrangian Drifter on the left hand side, and schematics of the sensor attachments (barometer, submergence, SST, irradiance and SEACAT), on the right hand side. Most drifters are also equipped with drogue sensors that indicate drogue loss. Buoys without drogues do not depict ocean currents accurately, because the drifter becomes susceptible to wave and wind action. Drifters transmit sensor data to satellites that determine the buoy's position and relay the data to Argos ground stations. Service Argos provides raw drifter data to the DAC where the data is processed and distributed.

Figure 1: The Minimet drifter. The SVPB drifter does not have the irradiance meter nor sub-surface temperature and conductivity sensor. The standard SVP drifter does not have the barometer as well. Latest designs omit the subsurface float.

ANNEX E Contact information and World-Wide Web addresses

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GCOS home page	http://www.wmo.ch/web/gcos/gcoshome.html
GOOS home page	http://ioc.unesco.org/goos/
OOSDP Final Report	http://ocean.tamu.edu/oosdp/FinalRept/
EGOS home page	http://www.meteo.shom.fr/egos/
IABP home page	http://iabp.apl.washington.edu/
IPAB home page	http://www.antcrc.utas.edu.au/antcrc/buoys/buoys.html
ISABP home page	http://www.dbcp.noaa.gov/dbcp/isabp/index.html
IBPIO home page	http://www.meteo.shom.fr/ibpio/
GDC home page	http://www.aoml.noaa.gov/phod/dac/gdc.html
MEDS home page	http://www.meds-sdmm.dfo-mpo.gc.ca/
NPDBAP home page	http://npdbap.noaa.gov/
TIP home page	

ANNEX F Developments in satellite communications

update October 2004

1. INTRODUCTION

Mobile satellite systems (MSS) may be classified according to orbit altitude as follows:

- GEO - geostationary earth orbit, approx altitude: 35 000 km
- MEO - mid-altitude earth orbit, approx altitude: 10 000 km
- LEO - low earth orbit, approx altitude: <1 000 km

LEOs can be further sub-divided into Big LEO and Little LEO categories. Big LEOs will offer voice, fax, telex, paging and data capability, whereas little LEOs will offer data capability only, either on a real-time direct readout ('bent pipe') basis, or as a store-and-forward service.

Since the satellite footprint decreases in size as the orbit gets lower, LEO and MEO systems require larger constellations than GEO satellites in order to achieve global coverage and avoid data delays. Less energy is, however, generally required for LEO and MEO satellite communication because of the shorter average distance between transmitter and satellite. Some systems implement several high-gain antennas to generate ‘spot beams’ and so reduce the requirement of the mobile to have a complex antenna and/or high output power. A key feature of several MSS currently under development will be their inter-operability with existing public switched telephone and cellular networks, using a dual-mode handset, for example.

Because of the commercial forces which are driving the implementation of the new systems, many will primarily focus on land masses and centres of population, and will not offer truly global or polar coverage. These systems will not in general be acceptable for global ocean monitoring. Furthermore, while the technical capabilities for the new MSS do currently exist, delays are inevitable due to problems with spectrum allocation, licensing (in each country where the service will be offered), company financing, and availability of launch vehicles and ground stations.

It is unlikely that all of the planned systems will overcome all of these hurdles. Indeed, major financial difficulties have hit a number of systems, with Starsys having been cancelled, Iridium having collapsed (and been relaunched), and Orbcomm, Globalstar and New ICO having been in and out of Chapter 11 bankruptcy protection in the US. Mergers are becoming increasingly common, as market reality forces system planners to cut their losses and pool resources: CCI, Teledesic, Ellipso and New ICO have all signed buy-out or collaboration agreements with cellphone entrepreneur Craig McCaw.

From a technical point of view, some systems do offer significantly enhanced capabilities compared to existing methods. Potential advantages include two-way communication, more timely observations, and greater data rates and volumes. Some systems may also prove to be considerably less expensive than existing channels, although this is as yet unclear. However, dangers will exist for data buoy users of most MSS, in that they will generally be small minority users of the system, with consequent lack of influence in regard to pricing. The arrangements

for data distribution are also unlikely to be tailored towards data buoy applications, in particular those that require data insertion on the GTS.

2. DESCRIPTION OF CANDIDATE SATELLITE SYSTEMS

The following paragraphs describe the salient features of those systems that might have a data buoy application. In many cases systems are at an early planning stage, and reliable technical information on which to base an evaluation is unavailable. This section is summarised in tabular form in the Annex of the document. Systems which are deemed to have failed have been removed from the main text, but remain in the summary table.

2.1 Little LEOs

2.1.1 Argos

Argos has been used by the oceanographic community for more than two decades, and is a dependable, true polar, operational data collection and platform location system. Traditionally, communication is one-way only, at 400 baud, with practicable data rates of the order of 1 kbyte per day. Transmissions by the mobile in this mode are unacknowledged by the system and therefore have to incorporate redundancy if data transfer is to be assured. The system enjoys a particularly clean part of the spectrum (401.65 MHz), with minimal interference from other users. Until now, Argos has flown as an attached payload on the NOAA 'TIROS' weather satellites, but the recent launch on board the Japanese ADEOS-II vehicle and projected launches on board the European METOP platforms mark an important diversification of service provision.

Enhancements to the Argos on board equipment ('Argos-2') include increased receiver bandwidth and sensitivity, with a highly significant move to two-way communication ('downlink messaging') which was piloted aboard the short-lived ADEOS-II, launched in December 2002. Next generation Argos equipment ('Argos 3') will fly from 2006 onwards on board METOP-1, and will offer order of magnitude increases in data rates, as well as two-way communications.

The system is one of the few that offers true global coverage, and currently has no commercial requirement to recover the cost of the launch or space segment equipment. The first of the Argos-2 satellites was launched in May 1998, and has been followed in September 2000 by NOAA-L (NOAA-16), and by NOAA-M (NOAA17) in June 2002. NOAA-N will follow in 2005. New direct readout stations continue to be commissioned bringing the current total to more than 40. Additions during the year have included stations in the Antarctic Peninsula (Chile, Meteo Chile), Athens (Greece, CLS), Fiji (Fiji, FMS), Punta Arenas (Chile), Ryad (Saudi Arabia, CACST), Söndre Stromfjord (Greenland, DMI) and Tromsö (Norway, NMI). This continues the programme of improving data timeliness by exploiting use of Argos in 'bent-pipe' mode.

2.1.2 Orbcomm

This company was awarded the first FCC Little-LEO licence in late 1994. Satellites consist of discs about one metre in diameter prior to deployment of solar panels and antenna. Two satellites were launched into polar orbit during 1995, using a Pegasus rocket piggy-backed on to a Lockheed L-1011 aircraft. After a prolonged period of launcher problems, 35 satellites are now in orbit, making up the complete constellation – although Orbcomm have been awarded a licence for an expansion to a 48 satellite constellation. Of these satellites, 30 are currently operational. The A, B, C and D planes are at 45° inclination and therefore have poor coverage at high latitudes: only two satellites, in the F and G planes (70°), offer a near-polar service, and these have proved to be unreliable. No further launches have been announced, although the satellites are starting to become quite elderly, and one would expect that replenishment will have to start soon

The system offers both bent-pipe and store-and-forward two-way messaging capabilities, operating in the VHF (138-148 MHz) band. User terminals are known as 'Subscriber Communicators' (SCs). Although there have been significant problems with interference close to urban areas, this is not expected to impact offshore operations, and trials of the system have been encouraging. Operational experience of the system is growing rapidly, although it remains difficult to obtain detailed technical information from Orbcomm.

The message structure currently consists of packets transmitted at 2400 bps (scheduled to rise to 4800 bps), and coverage is now global and near-continuous between the polar circles. Messages are acknowledged by the system when correctly received and delivered to a user-nominated mailbox. The platform position is determined, if required, using propagation delay data and doppler shift, or by an on-board GPS receiver. Position accuracy without GPS is similar to that offered by Argos, i.e. km-scale.

The limitations on the store-and-forward mode messages (known as globalgrams) have become apparent, with SC originated messages limited to 229 bytes and SC terminated messages limited to 182 bytes. Each SC can theoretically have a maximum of 16 globalgrams stored on each satellite. Currently, satellites will not accept or process globalgrams when in view of a ground ('gateway') station. As messages have to be designated as globalgrams or bent-pipe by the SC at the moment of origination, this presently limits the flexibility of the system to adapt to different coverage situations. Work-arounds do, however, exist, and it is expected that the next generation of SCs will be able to adapt more readily to changes in satellite communications mode.

Authorised transceiver manufacturers include Elisra (Stellar), Quake and MobiApps. All manufacturers offer units with integral GPS. Quake sell a fully integrated unit which features a built-in antenna as well as GPS. Prices of most units are falling, with models now available for around $500.

The ground segment has continued to expand, and there are now active stations in Italy, Morocco, Argentina, Brazil, Curacao, Japan, Malaysia and Korea in addition to the four in the US. However the Japanese station is not available for international registrations. Further potential sites have been identified in Russia, Ukraine, Philippines, Botswana, Australia and Oman, though these have yet to be implemented. 16 international service distribution partners have been licensed. Non-US customers have faced considerable difficulties because of the absence of ground stations, lack of spectrum licensing and the presence of other in-band users. However the situation is improving. Currently subscription costs within Europe are on a fixed cost per unit with two bands of usage (above and below 4kbytes per month with a typical monthly rate for the higher band being $70). A fully metered billing system based on users' actual data throughput was to be implemented in July 2000 but was postponed, officially due to technical problems. If this billing system is implemented with the planned charges ($6/kbyte) then it will result in a massive increase in airtime costs for any user with data rates over 0.5 kbytes/day. Metered billing is apparently implemented outside Europe.

Orbcomm has suffered financial difficulties, and filed for 'Chapter 11' bankruptcy protection in September 2000. The parent company, Orbital Sciences Corporation, has put together a new consortium to run Orbcomm. The outstanding debts are believed to stem largely from the system rollout phase, with net running costs being of much smaller concern. Industry confidence in Orbcomm continues to grow, largely because of the commitment of many third-party equipment and system manufacturers to the success of the system, and evidence of increasing service take-up by a diverse range of customers. Lately, the USCG have awarded Orbcomm a contract within their automatic ship identification (AIS) programme.

2.1.3 Vitasat/Gemnet

This was a 36 + 2 satellite constellation proposed by CTA Commercial systems. Their experimental satellite was the failed Vitasat launch in 1995. CTA is reported to have been taken over by Orbital Science Corporation, the parent organisation of Orbcomm, and the 36-satellite Gemnet component has been cancelled. However, the volunteer VITA organisation still exists and currently has one satellite in orbit, with plans to rent bandwidth on two other existing satellites, HealthSat-2 and UoSat-12. This proposal received FCC clearance in December 2000, and the company have now brought HealthSat-2 on line. The main mission is to offer low-cost messaging services to developing countries.

2.1.4 Faisat

The Final Analysis company have planned this 32 (+ 6 spare) satellite constellation to provide data messaging services, principally aimed at small messages (~ 100 bytes), but with support for larger messages as well. It will operate in both bent-pipe and store-and-forward modes. The first satellite launch, on the Russian Cosmos vehicle, was scheduled for early 2000, but nothing has been reported. Further launches were to have occurred roughly twice a year. The system received FCC authorisation in April 1998. A test satellite (also part of the Vitasat system) was launched in 1997. Despite the apparent lack of activity, the website continues to be updated.

2.1.5 Gonets

Two GONETS LEO messaging systems have been proposed by the former Soviet Union, using both UHF and L/S-band communications channels. Both will offer true global coverage from high inclination 1400 km orbits. One system, GONETS-D already has 8 satellites in orbit with a further 36 planned. No operational experience has been reported to date.

2.1.6 AprizeSat

Formerly known as LatinSat, this recent store-and-forward system uses low power ‘nanosatellites’ (20 cm cubes) in polar orbits to communicate with small user terminals. The satellites employ passive attitude stabilization and are said to be relatively inexpensive to construct and launch. Mobiles establish 2-way communication with the satellites at 402 MHz, message traffic currently being downloaded to a single ground station in Bermuda. The system currently has four satellites in orbit and is targeted at asset tracking. Plans include a 48-satellite constellation and a more extensive ground station network. Little further is known at present.

2.2 Big and Broadband LEOs

2.2.1 Iridium

Iridium filed for Chapter 11 bankruptcy protection in August 1999, and underwent financial restructuring. Financial difficulties continued and the system ceased operation in April 2000. At that time, Iridium had its complete constellation of 66 satellites plus spares in orbit, and offered a true global service through a network of ground stations backed up by inter-satellite links. The system has since been rescued from planned de-orbiting and resurrected by the US Department of Defense. A commercial service has also been relaunched. Most Iridium phones are data capable and will communicate with a standard modem. Throughput is about 2400bps. The component parts of some phones are now being repackaged as stand-alone modems. A short burst data (SBD) service (~1900 bytes max per message) was introduced in late 2002, as well as a dropout-tolerant direct Internet connection at up to 10kbps.

Of particular interest to data buoy operators in the early days of Iridium was the Motorola L-band transceiver module, which was designed to be easily integrated with sensor electronics via a standard serial interface. This product has now reappeared as the Motorola 9522 modem. Discussions are underway regarding the implementation of a 'soft-SIM' user identification facility as a way of minimizing the costs of system membership for occasional users such as Argo floats, which might only place a call once every 10 days.

The SBD service offers an easily implemented solution for the transfer of a few Kbytes of data per day, transactions taking place as conventional e-mails and attachments. The cost is currently ~$1/kbyte, plus a monthly fee. Dial-up remains the better option for larger volumes of data, with costs capable of falling below $0.1/kbyte. Energy costs are also low for both modes of access (~20J/kbyte), largely because of continuous satellite availability and the implementation of spotbeams to reduce the mobile transmitter power requirement.

Iridium continues to add to its constellation, with five new satellites launched in February 2002, and operational experience with the data service is starting to grow. However it is likely that its future survival will depend heavily on continuing support from defence interests.

2.2.2 Teledesic

This 'Internet in the Sky' system planned a 288 (originally 840) LEO constellation to carry global broadband services such as video conferencing, the Internet, etc. It recently merged with Celestri, another proposed broadband LEO system. Since then there has been some doubt over the actual makeup of the combined constellation. Teledesic has suffered because of the financial difficulties of Iridium, as Motorola, one of Teledesic's primary investors and head of the industrial partnership developing the system, transferred engineering effort and funding to prop up Iridium. Teledesic has received FCC licensing for operations in the USA, and recently joined forces with Craig McCaw's New ICO. The constellation plan has been further trimmed to 30 MEOs, and the company announced in October 2002 that it was suspending its satellite construction work.

2.2.3 Globalstar

Globalstar was Iridium's main competitor in the mobile satellite telephony market. After a bad start in September 1998 when 12 satellites were lost in a single launch failure, Globalstar now has its complete 48 satellite constellation in space, and commenced a limited commercial service in the US in October 1999. Service has since been expanding to other regions and was available in the UK in mid 2000. Globalstar differs significantly from Iridium in that for a call to be made the user must be in the same satellite footprint as a gateway station. There is no inter-satellite relay capability as in Iridium. This means that coverage will not be truly global, especially in the short term as far fewer gateways have been built than originally planned. Although Globalstar was currently in a much stronger financial position than any of its competitors, only 55,000 subscribers had been signed by late 2001 and the company laid off half of its work force in August 2001. Globalstar subsequently filed for Chapter 11 bankruptcy protection in February 2002. The company has now been taken over by Thermo Capital Partners LLC.

Data services at 9600 bps are now available, using a dedicated modem. Globalstar also has a second generation system planned, said to involve 64 LEO satellites and 4 GEO satellites. Little else is known about the planned enhancements of this system.

2.2.4 Other Systems

Other planned big LEOs still showing signs of life include Ellipso (a hybrid elliptical LEO/MEO system, now merged with Teledesic and New ICO), LEO SAT Courier (an ambitious German led system) and SkyBridge.

2.3 MEOs

2.3.1 New ICO

New ICO (formerly ICO Global Communications) was the third of the three main players in the global satellite telephony market. However it also has suffered severe financial difficulties and filed for Chapter 11 bankruptcy protection in August 1999, just two weeks after Iridium. The system, formerly known as Inmarsat-P but now fully autonomous, will use a constellation of 12 MEO satellites backed by a 12-station ground segment to provide a truly global voice, fax, data and messaging service. The aim is to complement and be inter-operable with existing digital cellular telephone networks. Prior to filing for bankruptcy protection, the first launch was planned for late 1999 with commercial service roll out scheduled for the third quarter of 2000. The company emerged from Chapter 11 protection in May 2000, and the first satellite was launched in June 2001, with service scheduled to start in 2003. However, ICO appear not to have launched any more satellites since 2001 and there is still no definite date for service rollout.

When the complete constellation is in service two satellites will always be visible from any point on the earth's surface. The space segment is being built by Boeing Satellite Systems. Data rate will be 9600 bps. Many large manufacturers are engaged in developing dual mode ICO/cellphone handsets. An ICO ‘engine’, is to be defined for the benefit of third-party equipment manufacturers (OEMs).

New ICO have joined forces with Teledesic (both owned by ICO-Teledesic Global), with major revisions to the scope of both systems. In particular New ICO is now putting a far greater emphasis on data services, rather than voice services which are now widely recognised as holding smaller potential. The company continues to face a number of regulatory difficulties, and is currently seeking the relicensing of its spectrum allocation.

2.4 GEOS

2.4.1 Inmarsat D+

This is an extension of the Inmarsat D service using the new (spot-beam) Inmarsat Phase 3 satellites and small, low-power user terminals. The system was initially designed as a global pager or data broadcast service, with the return path from the mobile used only as an acknowledgement. D+ permits greater flexibility, but the uplink packets are still limited to 128 bits. The first ground station has been implemented in the Netherlands by the existing Inmarsat service provider (Station 12), but useful technical information has been difficult to obtain. The only remaining manufacturer of D+ transceiver seems to be Skywave. The Skywave unit includes an integral antenna and is specifically designed for low power applications.

The service may prove particularly attractive to national meteorological services as protocols already exist with Inmarsat service providers for the free transmission of observational data to meteorological centres for quality control and insertion on to the GTS. Inmarsat, given its assured multinational backing and established infrastructure, is also extremely unlikely to disappear.

2.4.2 GOES, Meteosat, etc

These GEOs exist primarily to collect and disseminate weather imagery, but do also support low-rate data collection systems. Access to the satellites is controlled by pre-allocated time-slots, and the service is largely free. The requirement for significant transmitter powers and/or directional antennae has tended to restrict applications to larger data buoys, although some success has been reported with lower power installations.

2.4.3 Inmarsat Mini-M, Thuraya, ACes, AMSC, etc

These advanced GEOs offer voice-band communications using compact handsets or laptops by implementing high gain steerable spot beams to achieve sufficient link margin. Data services may available using a modem connection on the handset. Coverage is generally regional and not advertised for oceanic areas.

3. ACKNOWLEDGEMENTS

The assistance of Richard Winterburn of MES Communications Ltd in the preparation of this report is gratefully acknowledged.

4. REFERENCES

1. Hanlon, J (1996). Emerging LEOs telemetry options for use in scientific data buoys - a marine instrument manufacturer's perspective. In: *Proceedings of the DBCP Technical Workshop, Henley on Thames, October 1996*. DBCP Technical Document No 10, WMO, Geneva.

2. Hoang, N (1999). Data relay systems for drifting buoys utilizing low-earth orbit satellites. In: *Proceedings of the DBCP Technical Workshop,*

Hawk's Cay, October 1998. DBCP Technical Document No 14, WMO, Geneva.

5. USEFUL WEB SITES

5.1 General information

Little LEO status, launch dates	*http://centaur.sstl.co.uk/SSHP/const_list.html*
Constellation overview	*http://www.ee.surrey.ac.uk/Personal/L.Wood/constellations/*
The Satellite Encyclopaedia	*http://www.tbs-satellite.com/tse/online/*
General satellite news/gossip	*http://www.hearsat.org/*
Satellite news	*http://www.spacedaily.com/*
General space news	*http://www.space.com/spacenews/*

5.2 Specific operators

AprizeSat	*http://www.aprizesat.com*
Argos	*http://www.cls.fr/*
	http://www.argosinc.com/
Ellipso	*http://www.ellipso.com/*
Final Analysis	*http://www.finalanalysis.com/*
Globalstar	*http://www.globalstar.com/*
GOES	*http://www.goes.noaa.gov/*
Inmarsat	*http://www.inmarsat.org/*
Iridium	*http://www.iridium.com/*
LEO SAT Courier	*http://www.satcon-de.com/*
METEOSAT	*http://www.esoc.esa.de/external/mso/meteosat.html*
New ICO	*http://www.ico.com/*
Orbcomm	*http://www.orbcomm.com/*
Ocean DataLink (ODL)	*http://www.viasat.com/*
Skybridge	*http://www.skybridgesatellite.com*
Thuraya	*http://www.thuraya.com/*
VITA	*http://www.vita.org/*

Overview of mobile satellite systems with possible data buoy applications - update 2004

System	Status[*]	Date (if known)	Orbit type	Buoy position	Message type	Terminal size	Power (W)	Comments
APRIZESAT	Operational		Little LEO	GPS required	data: TBD	Handheld	7	4 nanosatellites in orbit, 2-way comms, directed at asset tracking
ARGOS	Operational		Little LEO	Doppler Shift	data: 32 bytes	Handheld	1	Various enhancements, incl 2-way messaging, are scheduled
ECCO (CCI Global)	On hold		LEO	GPS required	voice/data	Handheld	TBD	12 equatorial satellites planned by 2003. Status questionable – merged with ICO-Teledesic Global
ELLIPSO	Licensed On hold		Big LEO	GPS required	voice/data	Handheld	TBD	17 satellites in highly elliptical orbits, serving major land masses. Status questionable – merged with ICO-Teledesic Global
EYESAT	Experimental		Little LEO	GPS required	data: 60 bytes	Handheld	5	1 satellite 1995, principally for radio amateurs
E-SAT	Licensed On hold		Little LEO	GPS required	data: TBD	TBD		6 satellites for utility metering (aimed at Continental US only initially)
FAISAT	Licensed On hold	Service 2002+	Little LEO	GPS required	data: 128 bytes	Handheld	10	38 satellites 2000+ Test satellite launched 1997
GEMNET	Cancelled (pre-op)		Little LEO	GPS required	data: no maximum	Laptop	10	1st satellite 1995 - launch failure 36 satellites by ???
Globalstar	Operational	1999	Big LEO	GPS required	voice/data: no maximum	Handheld	1	48 satellites + spares (constellation complete) Limited coverage due to lack of ground stations. Financial difficulties.
GOES, Meteosat, GMS	Operational		GEO	GPS required	data: various options	Laptop	10	4 satellites; directional antenna desirable NOAA / ESA / Japanese met satellites.
GONETS-D	Pre-operational		Little LEO	GPS/ Glonass	Data	Handheld	TBD	8 satellites in orbit, 36 more planned

GONETS-R	Planned On hold?		Little LEO	GPS/ Glonass	Data	Handheld	TBD	48 satellites planned
INMARSAT-C	Operational		GEO	GPS required	data: no maximum	5.5 kg	15	Steered antenna not required
INMARSAT-D+	Operational		GEO	GPS required	data: 128bytes uplink, 8 bytes downlink	Handheld	1	Global pager using existing Inmarsat-3 satellites Note very oriented to downlink
INMARSAT-Mini-M	Operational		GEO	GPS required	voice/data: no maximum	Laptop	1	Mobile phone using regional spot-beams
ICO (New ICO)	Licensed On hold?	Service 2003	MEO	GPS required	voice/data: no maximum	Handheld	1	Global voice and packet data services. Recently merged with Teledesic to form ICO Teledesic Global. 12 satellites planned, only one launched so far.
Iridium	Revived	Service resumed 2001	Big LEO	GPS preferred	voice/data: no maximum	Handheld	1	72 satellites in orbit
IRIS/LLMS	Experimental On hold		Little LEO	Doppler + Ranging	data: up to few kbytes	Handheld	1	1 satellite in orbit. Belgian messaging system part of an ESA research prog.
LEO One	Licensed On hold	Service mid 2003	Little LEO	GPS required	data: uplink 9600bps, downlink 2400bps	Handheld	Max 7	48 satellite constellation, store and forward + 8 spares. No polar sats
LEO SAT Courier	Planned On hold?	Service 2003+	Big LEO	GPS required	Data / voice	Handheld	1-5	72 satellites
OCEAN-NET	Experimental		GEO	Moored	no maximum	Large		uses moored buoys + Intelsat
Ocean DataLink (ODL)	Experimental On hold?		GEO	GPS	no maximum	Handheld	TBD	uses Intelsat
Odyssey	Cancelled (pre-op)		MEO	GPS required	voice/data: no maximum	Handheld	1	12 satellites were planned

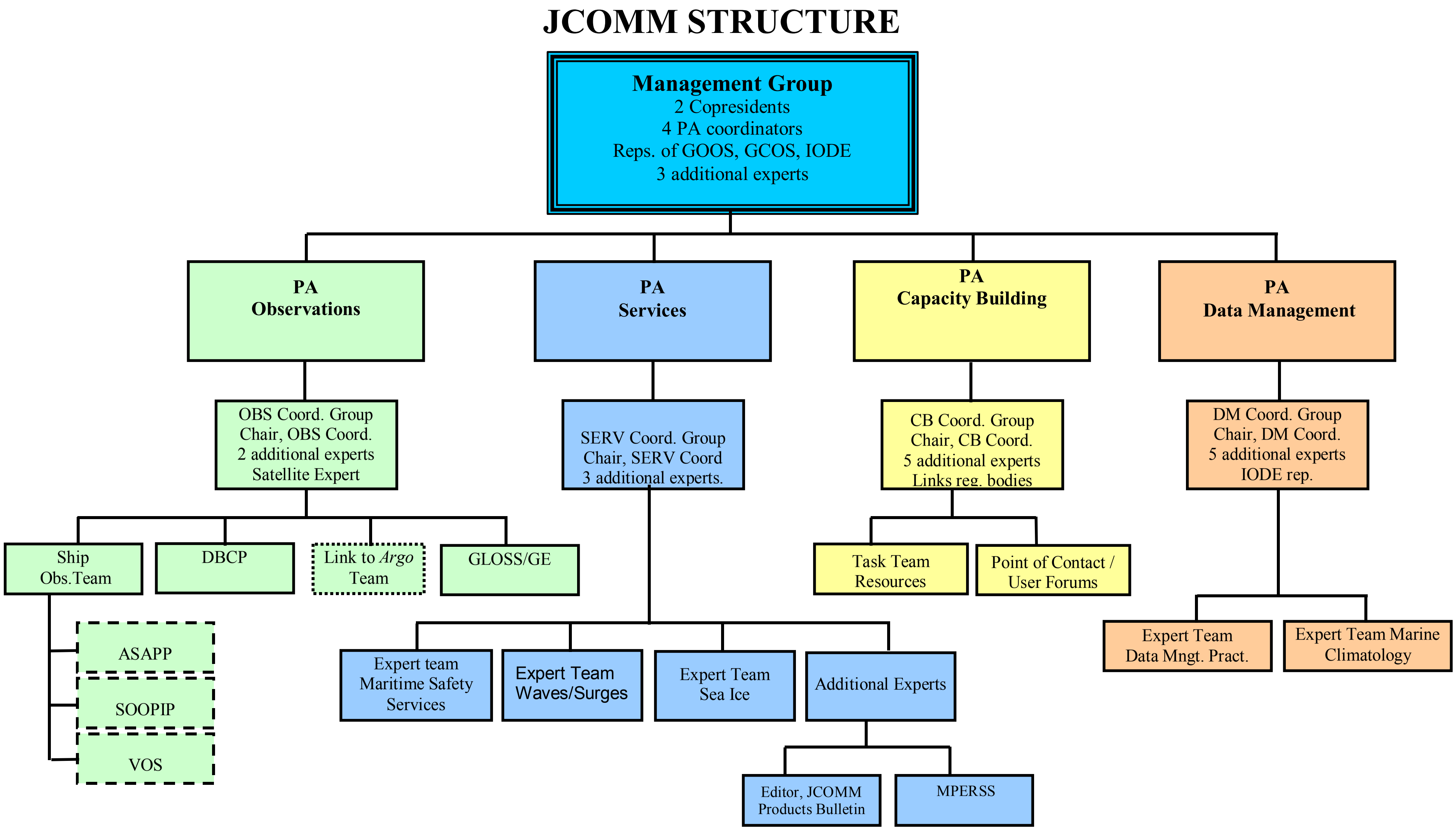
Orbcomm	Operational	1998	Little LEO	Doppler or GPS	data: no maximum	Handheld	5	35 satellites in orbit, 30 operational, expansion to 48 sats licensed
SAFIR	Pre-operational On hold		Little LEO	Doppler or GPS	data: no maximum	Laptop	5	2 satellites in orbit
Signal	Planned On hold?		Big LEO		voice/data			48 satellites planned
SkyBridge	Licensed On hold	Service 2002+	Big LEO	GPS required	Broadband	Larger than handheld		80 satellites planned, recycling GEO spectrum allocations
Starsys	Cancelled (pre-op)		Little LEO	Doppler + ranging	data: 27 bytes multiple msgs	Handheld	2	12 satellites 1998+ 24 satellites 2000+
Teledesic	Licensed On hold	Service Late 2004	Big LEO	GPS required	Broadband			288 LEOs planned, now reduced to 30 MEOs FCC licence granted, merged with new ICO
Temisat	Experimental		Little LEO		Data			7 satellites planned for environmental data relay. 1 satellite launched 1993.
Thuraya	Operational		GEO	Integral GPS	Voice/data	Handheld		1 multiple spot beam satellite in orbit (over Middle East), 1 planned
Vitasat	Pre-operational		Little LEO	GPS required	Data			2 satellites in orbit, 2 more planned
WEST	Planned On hold	Service 2003+	MEO	GPS required	Broadband			9 satellites planned

* Status of systems is categorized according to seven groups:

Planned: Little is known about the system except a name, notional type, and services to be offered. Mostly not licensed, although some may be.
Licensed: System has been licensed by a national or international regulatory agency (in most cases the FCC), but no satellites have been launched.
Experimental: System has one or more satellites in orbit for experimental purposes (not usually part of the final constellation). Includes new systems planning to use existing satellites.
Pre-operational: System is in process of launching, or has launched, its constellation but is not yet offering full services. Some limited evaluation service may be available.

Operational:	System has full or nearly full constellation in place and is offering readily available service to external users (not necessarily commercial).
Cancelled:	System has been cancelled, either before satellites launched (pre-op) or after (post-op).
On hold:	No progress reported or scheduled.

ANNEX G JCOMM Structure



TERMS OF REFERENCE AND GENERAL MEMBERSHIP OF THE OBSERVATIONS COORDINATION GROUP AND SHIP, DATA BUOY AND SEA LEVEL OBSERVATIONS TEAMS

1. Observations Coordination Group

Terms of Reference

1. Keep under review and advise on the effectiveness, coordination and operation of the observations work program, including performance measured against scientific requirements, delivery of raw data, measurement standards, logistics and resources.
2. Provide advice to JCOMM and to Observation Teams on possible solutions for newly identified requirements, consulting as appropriate with relevant scientific groups and CBS.
3. Taking into account the continuing development of satellite observations and their capabilities, review **in situ** data requirements and recommend changes as appropriate.
4. Coordinate the development of standardized, high quality observing practices and instrumentation and prepare recommendations for JCOMM.
5. Examine trade-offs and use of new and improved techniques/developments against requirements and available resources.
6. Liaise with and input to CBS activities regarding the consolidated requirements database and operational satellites.

General Membership

PA/Observations coordinator (chair)
Chairman Ship Observations Team
Chairman DBCP
Chairman GLOSS Group of Experts
Chairman Argo Science Team
Chairman TAO Implementation Panel
Technical coordinator DBCP/SOOP
Rapporteurs as required
Satellite expert
One other expert

2. Ship Observations Team

Terms of Reference

Generic

1. Review and analyse requirements for ship-based observational data expressed by the WWW, WCP, WCRP, GOOS, GCOS and in support of marine services, and coordinate actions to implement and maintain the networks to satisfy these requirements;
2. Review marine telecommunications facilities and procedures for observational data collection, as well as technology and techniques for data processing and transmission, and propose actions as necessary for improvements and enhanced application;
3. Coordinate PMO/ship greeting operations globally, propose actions to enhance PMO standards and operations, and contribute as required to PMO training;
4. Review, maintain and update as necessary technical guidance material relating to ship observations and PMOs;
5. Liaise and coordinate as necessary with other JCOMM Programme Areas and expert teams, in particular those relating to maritime safety services, marine climatology and ocean data management; in addition, liaise and coordinate with CBS, WCRP, GOOS

and GCOS regarding the contribution of ship based observations to their respective programmes;

6. Establish, as necessary, *ad hoc* task teams to address specific issues such as: accuracy of hardware and software used on board ship; data quality control procedures for shipboard instrumentation; specifications for modifications to data transmission codes and general data formats;
7. Participate in planning activities of appropriate observing system experiments and major international research programmes as the specialist group on ship based observations;

SOOP Implementation Panel

1. Review, recommend on and, as necessary, coordinate the implementation of specialized shipboard instrumentation and observing practices;
2. Coordinate the exchange of technical information on equipment and expendable development, functionality, reliability and accuracy;
3. Ensure the distribution of available programme resources to ships to meet the agreed sampling strategy in the most efficient way;
4. Ensure the transmission of low resolution data in real time from participating ships; ensure that delayed more high resolution data are checked and distributed in a timely manner to data processing centres;
5. Maintain, through the SOOP Coordinator, appropriate inventories, monitoring reports and analyses, and information exchange facilities;
6. Provide general guidance to the coordinator in his support for the SOOP;

ASAP Panel

1. Coordinate the overall implementation of the ASAP, including recommending routes and monitoring the overall performance of the programme, both operationally and in respect of the quality of the ASAP system data processing;
2. As may be required by some members, arrange for and use funds and contributions in kind needed for the procurement, implementation and operation of ASAP systems and for the promotion and expansion of the programme;
3. Carry out other activities as agreed upon by participating members to implement and operate ASAP and to promote and expand the programme internationally;
4. Prepare annually a report on the status of ASAP operations, data availability and data quality;

VOS panel

1. Review, recommend on and coordinate the implementation of new and improved specialized shipboard instrumentation, siting and observing practices;
2. Support the development and maintenance of the VOSClim Project;
3. Develop and implement activities to enhance ship recruitment, including promotional brochures, training videos, etc.

General Membership

Chairman selected by JCOMM
Operators of VOS, SOOP and ASAP
Representatives of monitoring centres, data management centres and bodies
Representatives of Inmarsat and other communications satellite systems
Representatives of manufacturers as appropriate
Representatives of science advisory bodies and users as appropriate

3. Data Buoy Observations Team

Terms of Reference

Existing Terms of Reference for DBCP, TIP and Action Groups

General Membership

Open, existing DBCP members, Action Groups, TIP

4. Sea Level Observations Team

GLOSS Group of Experts

Terms of Reference

Existing terms of reference as determined by the IOC Executive Council

General Membership

Existing GLOSS GE and GLOSS Scientific Subgroup

TECHNICAL DOCUMENTS ISSUED WITHIN THE DATA BUOY COOPERATION PANEL SERIES

No.	Title	Year of first issue	Last revision and year
1	DBCP Annual Report for 1994	1995	
2	Reference Guide to the GTS Sub-system of the Argos Processing System	1995	Rev. 1.4, 2004
3	Guide to Data collection and Location Services Using Service Argos	1995	
4	WOCE Surface Velocity Programme Barometer Drifter Construction Manual	1995	Rev. 2, 2005
5	Surface Velocity Programme Joint Workshop on SVPB drifter evaluation	1995	
6	DBCP Annual Report for 1995	1996	
7	Developments in buoy technology and enabling methods (DBCP workshop, Pretoria, Oct. 1996)	1996	
8	Guide to moored buoys and other ocean data acquisition systems	1997	
9	DBCP Annual report for 1996	1997	
10	Development in buoy and communications technologies (DBCP workshop, Henley on Thames, Oct. 1996)	1997	
11	DBCP Annual report for 1997	1998	
12	Developments in buoy technology and data applications (DBCP workshop, La Réunion, Oct. 97)	1998	
13	DBCP Annual report for 1998	1999	
14	Variety in buoy technology and data applications (DBCP workshop, Marathon, Florida, Oct. 98)	1999	
15	Global drifting buoy observations, A DBCP Implementation Strategy	1999	Rev. 4, May 2005
16	DBCP Annual Report for 1999	2000	
17	Developments in Moored and Drifting Buoy Design, Programmes, Sensors, and Communications (DBCP Workshop, Wellington, Oct. 1999	2000	
18	DBCP Annual report for 2000	2001	
19	Developments in buoy technology, communications, and data applications (DBCP Workshop, Victoria, Oct. 2000	2001	
20	DBCP Annual report for 2001	2002	
21	Dev. in buoy technology, communications, science and data applications(DBCP Workshop, Perth, Oct. 2001)	2002	
22	Research, applications and developments involving data buoys(DBCP Workshop, Martinique, Oct. 2002)	2003	
23	DBCP Annual report for 2002	2003	
24	Research, Applications and Developments involving data buoys (DBCP Workshop, Angra Dos Reis, Brazil, October 2003)	2004	
25	DBCP Annual report for 2003	2004	
26	DBCP Annual report for 2004	2005	

These publications can be ordered from: Etienne Charpentier, Technical Coordinator of the DBCP, JCOMMOPS, 8-10 rue Hermès, Parc Technologique du Canal, F-31526 Ramonville Saint-Agne, France – Internet mail: charpentier@jcommops.org – Telefax: +33 5 61 75 10 14 Telephone: +33 5 61 39 47 82