DATA BUOY COOPERATION PANEL
DATA USERS AND TECHNOLOGY WORKSHOP

Reading, United Kingdom, 27-28 March 2006

FINAL REPORT

JCOMM Meeting Report No. 40

INTERGOVERNMENTAL OCEANOGRAPHIC
COMMISSION (OF UNESCO

WORLD METEOROLOGICAL ORGANIZATION

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1. Opening

1.1 The DBCP Data Users and Technology Workshop was opened at 9 am in the Council Room of the European Centre for Medium-Range Weather Forecasts on Monday, 27 March 2006.

1.2 The DBCP chairperson, Mr David Meldrum, reminded the meeting that this was an informal working session, and that participants should lay aside any national or organizational preconceptions in the days that lay ahead. The meeting agreed that Ms Elizabeth Horton would chair this workshop.

1.3 On behalf of the Executive Secretary IOC, Dr Patricio Bernal, and the Secretary-General of WMO, Mr Michel Jarraud, the Secretariat representative thanked ECMWF Director, Dominique Marbouty, for hosting the workshop, welcomed the participants, and wished for a successful meeting.

1.4. The list of participants in the workshop is given in Annex I.

2. Agenda approval

2.1 The meeting reviewed the provisional agenda, made slight amendments and adopted it. The agenda is given in Annex II.

3. Introduction and goals for the workshop

3.1 The chairperson, Ms Elizabeth Horton, and Mr David Meldrum elaborated on the goals for the workshop. The DBCP has long recognized the need to engage closely with the users of buoy data to identify current and upcoming issues. Currently, the most important requirements were to re-examine the basic principles behind data buoy observations, to think laterally, and to explore new avenues that might be important for the next decade.

3.2 One aim is to optimize buoy design, deployment strategies and data management to maximize the usefulness of buoy data, both in terms of their impact on model forecasts and their value for money. Alongside this aim is the need to develop and validate new generations of sensors and observing platforms to address future requirements in terms of spatial and temporal measurement densities, improving the impact of buoy data, smart in situ data selection, communications options, data processing and overall value for money. The meeting agreed that this process, in which the DBCP has an established track record, can take many years.

4. Data buoy networks and the DBCP – the status quo

4.1 Mr David Meldrum presented a brief overview of the DBCP and data buoy networks. In particular he drew attention to the evolution of the DBCP since its inception, and its success in addressing its initial aims in data quality, quantity and timeliness. Drifter numbers on the GTS had risen from a hundred or so in the early years of the panel to more than 1300 at the present day. However, relatively few drifters reported sea level pressure, and this continued to be an area of concern for the panel. The panel was also mindful of its obligation to identify and respond to new challenges: amongst these were:

- Maximizing the impact of data buoy observations
- Engaging in dialogue with data users, sponsors and manufacturers
- Demonstrating the value for money of data buoy observations

- Development of optimal deployment strategies: identification of critical areas
- Identification of key new variables
- Evaluation and validation of new sensors: chemical and biological
- Investigation of new communication techniques and energy sources
- Development of smart platforms to maximize the usefulness of the data flow
- Promoting increased visibility of DBCP amongst decision makers
- Involvement of new observation groups
- Counter-measures against vandalism

4.2 It was hoped that the workshop could make some progress in addressing these issues.

5. User Requirements

The meeting reviewed user requirements for Numerical Weather Prediction (NWP), climate variability and predictability, as well as ocean modelling and climate forecast. After an in-depth discussion, the meeting finally agreed to build a requirements matrix, as given in Annex III.

5.1 NWP

5.1.1 Mr Pierre Blouch presented results from the EUMETNET Surface Marine Programme (E-SURFMAR) design study which was performed from 2003 to 2004, addressing mainly NWP requirements, and which were aimed at designing in situ surface marine networks as a complement to satellite data. He explained that E-SURFMAR started in 2003 as an optional element of the EUCOS programme and concerned data buoys and the VOS. It has now been adopted by the DBCP as one of its regional action groups. The design study, which was adopted by the EUMETNET Council in 2004, is aimed at designing in situ surface marine networks and identifying required parameters. It indicated that the recommendations were to be implemented as of 2005, with a review/revision in 2008.

5.1.2 The study concluded that, despite the fact that wind could in principle be measured by remote sensing, the Mean Sea Level Pressure (MSLP) was the main parameter required by NWP which cannot be filled up by the satellite component at the sea surface. For example, it was noted that surface winds assimilated in isolation can have a detrimental impact on NWP and that MSLP observations are actually essential to anchor the surface pressure field.

5.1.3 The threshold where MSLP begin impacting the model is estimated at a spatial resolution of about 250 km x 250 km. Climatology of sensitive areas had been computed and specific deployment areas proposed in the North Atlantic and Mediterranean Sea. It was found that due to the moving of low pressure areas, good temporal resolution could compensate low spatial resolution. Hourly MSLP data are now required. On the other hand, according to OSE studies, accuracy of the data is more important than network density.

5.1.4 While recognizing that there was a lower requirement for MSLP in tropical regions, the meeting agreed that all drifters should eventually be reporting MSLP while stressing on deployments in extra-tropical regions first (**recommendation**). Some drifters equipped with barometers can move between tropical and extra-tropical regions and MSLP remained a required variable in other applications, especially hurricane prediction and tracking, as well as climate applications (e.g. relationship between MSLP and sea level). To refine the requirement for barometer drifters in tropical regions, the meeting agreed that a study showing balance of drifters moving to and from tropical regions should eventually be performed (**recommendation**).

5.1.5 Air temperature data and air relative humidity cannot be correctly measured by satellite remote sensing either, but can be predicted through satellite SST and wind. While the satellites may provide these parameters, validation and calibrations are required. Due to the atmospheric attenuation, more in situ SST observations (drifters) are required than wind observations (moored buoys).

5.1.6 Both requirements for satellite and in situ observations need to be considered, in view of the relationship and complementarity between these two components. In situ data are needed for satellite data calibration and validation.

5.1.7 NWP experts agreed that acceptable delays for data transmission depended on the model-run schedule. Ideally all data should be received within 3 hours and near as possible for the main synoptic hours. The meeting noted that for national operations, operational forecasters might have more stringent requirements.

5.1.8 The meeting recommended instructing the Technical Coordinator (TC) of the DBCP to investigate the different data assimilation schemes used by Member countries and to report on recommended acceptable delays to the Panel **(action)**.

5.1.9 Jon Turton suggested that spatial density could be increased in certain data sparse areas thanks to new deployment strategies. Thanks to ocean current estimates, AOML offered to provide tools to address this issue and provide statistics regarding probability of floats and drifters remaining in certain regions (see also 5.2.4). The development of optimal deployment and reseeding strategies was also a research interest at the Scottish Association for Marine Science (SAMS). AOML and SAMS were therefore urged to collaborate in developing this important capability for the Panel **(action)**.

5.1.10 In considering the transmission bandwidth limitation of some satellite communication systems, the meeting discussed to what extent the precision of reported observation time could be reduced in order to increase the reported precision of other variables. NWP experts suggested that such precision should be better than model step, i.e. better than 12 minutes for the ECMWF models.

5.1.11 The meeting noted that advances in buoy computing power enabled certain variables to be derived on board the buoys from sensor data. Such data (for example, standard deviation of wind speed, near-surface turbulence) could be useful for NWP research purposes and for NWP model improvement. It was recommended that NWP users investigate such needs in more details **(action)**.

5.1.12 Similarly, advances in sensor technology meant that new observables, such as pCO_2, might in due course be routinely made available to NWP. While no immediate requirement for new observables was expressed by the NWP experts present, the NWP community was asked to reflect on what might be desirable in due course, so that buoy manufacturers and operators might develop and validate the required technology in a timely manner **(action).**

5.1.13 It was noted that data quality requirements could be implemented at different levels, depending on the spatial density requirement. For example, regions requiring only a coarse observational density might be satisfactorily observed at a lower quality standard.

5.1.14 It was explained that when quality information was not available and there was limited confidence in the data, observations were assimilated anyway although with a lower weight. The meeting therefore recommended evaluating, for example, the quality of wind data in order to build confidence in such data. In general, the meeting agreed that there was a strong need for metadata (e.g. information on data quality) and that these should eventually be made available to the end users either in real-time (e.g. instrument height in the event that the measurement is not made at standard height) or delayed mode, as appropriate **(recommendation)**.

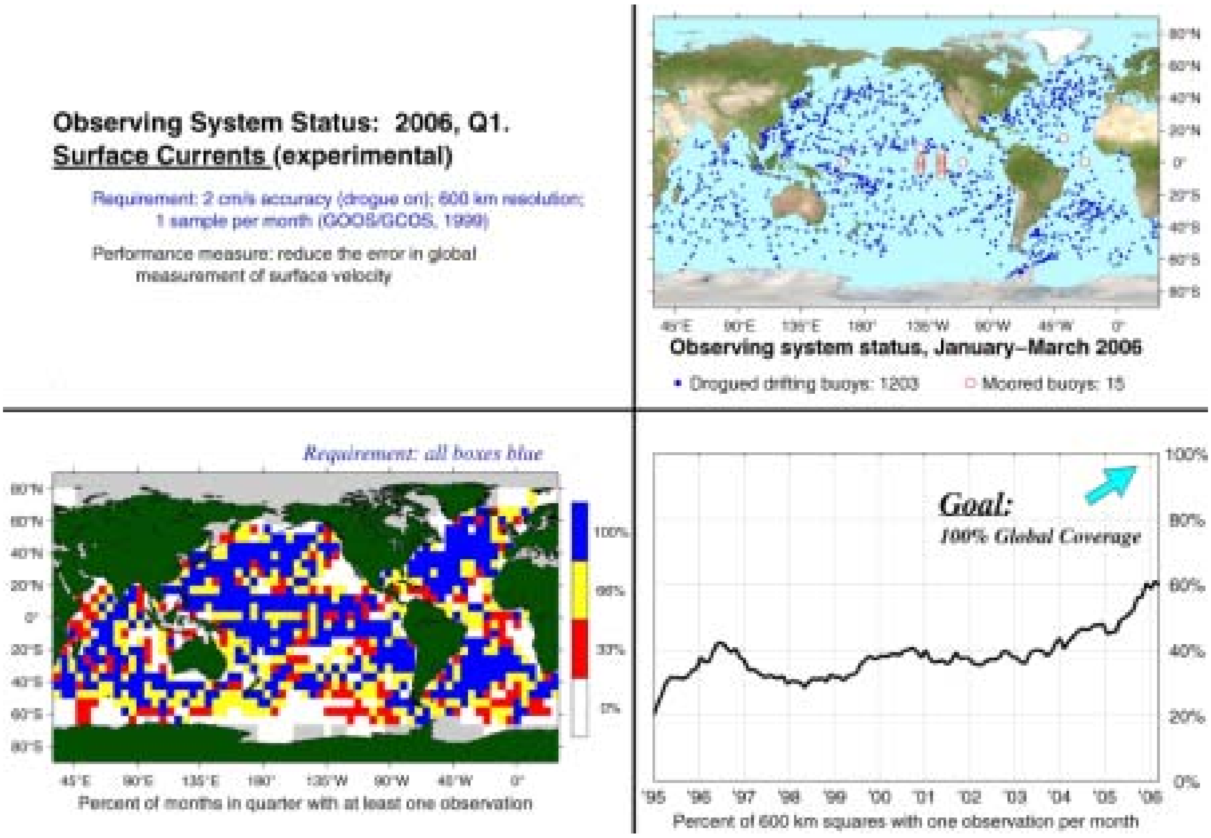
5.1.15 Dr Antonio Garcia Mendez reported on quality monitoring activities performed at ECMWF regarding drifting buoy data. At the outset, the meeting noted with concern the large day-to-day variability in the number of drifter reports received by ECMWF: this unexplained variability might be a topic to be investigated by the new TC **(action).** Dr Mendez explained the data assimilation scheme, the thinning of the data to avoid over-sampling, and the black list process to reject stations systematically reporting erroneous data. Quality flags were computed and stored for further assessment. Some of this monitoring information is available via the ECMWF web site (http://www.ecmwf.int/products/forecasts/monitoring/mmr). He explained the automatic pressure bias correction applied to surface marine data, where Optimal Interpolation (OI) and Kalman filter schemes were run in parallel. OI was generally used for the corrections, although Kalman filtering could be switched on if required. For example, on 3 March 2006, for 5340 MSLP buoy observations assimilated, 192 had automatic bias corrections applied. He explained that a substantial amount of surface data showing consistent pressure biases but only small RMS errors were showing up in the monthly statistics. These results pointed to a station height catalogue which was not correct. A correct and unified station height catalogue was therefore needed. MSLP and wind data were the basic variables from buoys assimilated by ECMWF: air temperature was not used. The need for MSLP from tropical regions was also stated: this ran contrary to some accepted views, but such observations had proved extremely useful in predicting hurricane/typhoon tracks.

5.1.16 Dr Mendez then presented a case extracted from one of the daily reports written by the Met Analyst on duty 15 February 2006 where a drifting buoy in the North Pacific data had demonstrated positive impact on the quality of the model. He explained that there were indeed many areas where drifter data have a positive impact on the quality of the model, a particular example being the tracking of winter storms.

5.1.17 Finally the workshop noted that NWP research was also essential and that provision of accurate metadata was important for improving the models.

5.2 Climate variability and predictability

5.2.1 Dr Rick Lumpkin presented requirements for climate research, climate signal detection and mean heat advection. He explained that the GOOS/GCOS requirement for surface current observations was of one observation per month, per 600x600km box, at an accuracy of 2 cm/s. For surface drifters, this requirement demands the presence of a drogue. NOAA/AOML evaluates how well the GOOS is satisfying this requirement, by both moored and drifting buoys, for each quarter. The report for the first three months of 2006 is shown below. By the end of March 2006, the goal was satisfied for slightly more than 60% of the world’s oceans.



Observing System Status: 2006, Q1.
Surface Currents (experimental)

Requirement: 2 cm/s accuracy (drogue on); 600 km resolution; 1 sample per month (GOOS/GCOS, 1999)

Performance measure: reduce the error in global measurement of surface velocity

5.2.2 Surface current observations are sufficient at this point to map time-mean currents at 1º resolution for 75% of the ocean. Combined with temperature (SST), estimates can be made of the heat advection convergence/divergence.

5.2.3 Eddy variability can be monitored in some regions, e.g., in the tropical Pacific (both drifter and TAO arrays). Elsewhere, drifter observations are generally too sparse to continuously monitor eddy variations, requiring their synthesis with satellite measurements of wind and sea level height variations.

5.2.4 With regard to historical data, Dr Lumpkin noted that there was a gap in some regions and particularly in the North Pacific, the Gulf of Guinea, and the Northwest Indian Ocean. To move towards 5º x 5º resolution, both the logistical demands of deployments on the major shipping routes and the ability to predict future coverage must be addressed. To do the latter, the Probability Distribution Function (PDF) can be calculated for each 5º x 5º box – i.e., if a drifter is in a box, the odds of it remaining in that box or moving to adjacent boxes for a given lag. These PDFs can be accumulated over all drifters in the present configuration of the drifter array, to make a prediction for a given time later. NOAA/AOML is now offering 90-day predictions on the Global Drifter Program web page, http://www.aoml.noaa.gov/phod/dac/gdp.html (information, latest maps).

5.2.5 It was noted that drifters are also useful for calibration and validation of wind and SST fields from satellites. For example, in situ drifter data can be used to reduce global bias in satellite Sea Surface Velocity. Routine combined satellite/in situ products are already in place.

5.2.6 While the upper ocean thermocline could be better characterized by higher resolution Argo float measurements, such data would still be unlikely to resolve the top 5 metres with sufficient accuracy, and would be incapable of observing diurnal signals. The meeting suggested that drifters equipped with thermistor strings would be much better suited to the measurement of near-surface temperature profiles in the mixed layer and for thermocline depth estimates (**recommendation**). Recent technology, including inductive and acoustic data transmission, can now be used to increase reliability of the thermistor string cables. A possible scenario might be to make measurements at a 1 metre vertical resolution near the surface (to 5 metre depth, say), then at 5 metre intervals thereafter down to 200 metres.

5.2.7 Mr Mike Johnson presented sampling requirements for the global ocean, based largely on an OOSDP report (Needler). More recent requirements for SST analysis (Reynolds) suggest that requirements for in situ SST measurements are of 25 samples per week in every 10° x 10° box. Although the drifter array is now completed with more than 1250 drifters operational at any time, gaps remain in the Indian Ocean, North Pacific, and the Southern Ocean.

5.2.8 The meeting agreed that the unpublished “Needler” requirements, with some slight modifications taking latest expressed requirements into account, were a good basis for drifter array implementation. These are given in the matrix in Annex III. The meeting suggested that the DBCP consider them as its implementation requirement within the DBCP implementation strategy (**recommendation**). It was also noted that requirements expressed by the international meteorological and oceanographic communities are being documented in the Committee on Earth Observation Satellites (CEOS) database and updated annually. CEOS data provides for two levels of requirements, ideal and threshold. GOOS, GCOS, and WMO requirements as expressed in CEOS are given in Annex IV. The meeting noted that many of the observables called for in the database are not currently available operationally, and that a considerable amount of development and evaluation effort would be required to bring such sensor data online in an operational sense.

5.2.9 The workshop noted that both NWP and ocean/climate modelling applications now relied very much on SST analysis products (e.g. Reynolds). SST analysis can therefore be considered as a new and separate requirement.

5.2.10 Dr Ed Harrison explained that the SST diurnal cycle was of great scientific and practical interest at present. The GODAE High Resolution SST Pilot Project (GHRSST) was working to produce SST globally at the highest feasible space and time resolution. However, present satellites cannot observe the diurnal cycle of SST to the required level of accuracy. Provision of hourly in situ SST data from drifters could make it possible to document the diurnal cycle globally, and would be particularly useful in understanding and prediicting extreme events. The workshop agreed that surface drifter technology could address such requirements relatively easily and at practically no additional cost. The workshop therefore urged the DBCP to take necessary steps to permit collection and transmission of hourly SST data from all drifters (**action**). Meanwhile, OOPC was asked to provide a detailed rationale and documentation for this requirement (**action**).

5.2.11 Mr Ali Mafimbo explained that Western Indian Ocean studies were under way (e.g. Indian Ocean dipole) and that they relied very much on the availability of real-time data. However, it was noted that not all of the drifter data eventually reached end users in Africa. The workshop therefore recommended investigating and fixing possible GTS routing problems between Argos data processing centres and Region I users (**action**).

6. Drifter network system components

6.1 Manufacturers

6.1.1 Process for technological developments and design improvements

6.1.1.1 Buoy manufacturers explained that they were not developing sensors but adapting existing sensor technology to observing platforms. This was a relatively simple task which did not require many additional resources.

6.1.1.2 The workshop discussed how new technology or design changes could be proposed in cooperation with the manufacturers. Experience has shown (e.g. development of the SVP and the SVPB under WOCE) that research projects can be efficient tools to conduct technological developments or design changes and to put them in the production line in cooperation with the manufacturers. For example, SAMS is presently developing ice drifters for ice motion, ice stress, and ice thickness purposes that can survive in the open ocean and can continue to provide valuable data. Also, US based manufacturers are encouraged to use Small Business Innovation Research Program (SBIR) in cooperation with the buoy operators and the DBCP. There are similar mechanisms in other countries or regions (e.g. EU) that can be used.

6.1.1.3 Manufacturers stressed that design improvements can be made easier when operational drifters are recovered at sea and sent back to them for investigation (e.g. when the barometer is still working but providing noisy series of data). While the workshop agreed that recovering drifters at sea was an expensive and time consuming exercise, it nevertheless recommended that buoy operators do their best to recover a small number of units whenever possible. As far as transmitting drifters that went ashore are concerned, as these were easier to recover, unless they continue to provide value data from data sparse areas, the workshop recommended to recover as much of them as possible and to send them back to the manufacturers (**recommendation**).

6.1.2 Production cost reduction

6.1.2.1 Manufacturers agreed that 10% to 15% cost reduction was possible in case the number of units produced by a manufacturer increased substantially.

6.1.3 Batteries

6.1.3.1 It was noted that new regulations with regard to lithium battery transportation had been implemented which permitted increased use of such batteries in the community provided that proper documentation is provided. For example, lithium batteries, which are also lighter, permit to approximately double available electric energy while only increasing the cost by about 30%. The meeting agreed that extended lifetime of up to three years was useful in large ocean areas were the buoys were unlikely to go ashore and to be picked up by fishing vessels before the batteries cease functioning, typically the Southern Ocean (**recommendation**). In other regions, the use of alkaline batteries is recommended.

6.1.3.2 Mr Tony Chedrawy agreed to provide the panel with a comparison of alkaline battery performance, cost and features compared to lithium batteries in an SVPB buoy and an SVPBW buoy (**action**).

6.1.4 Drogue

6.1.4.1 The workshop agreed that an efficient drogue was an essential component of the drifter which permits to provide for more accurate surface velocity estimates and for keeping drifters longer in a given area. The workshop noted however that a relatively large number of drifters may be losing their drogues early. The workshop agreed that drogue construction and attachment needed to be improved in order to have drifters with drogues that last longer (**recommendation**). Recovery of buoys that have lost their drogues can facilitate understanding of drogue failure problems and suggest appropriate design changes. Buoy operators are encouraged to recover such buoys and to return them to the manufacturers for investigation.

6.1.5 Submergence and drogue detection

6.1.5.1 The workshop agreed that the DBCP should work towards standardization of drogue detection. Technologies other than submergence sensors can be used for drogue detection. Tether strain between the surface float and drogue is an option and the workshop recommended that the feasibility for eventually adopting it as a standard be investigated (**recommendation**).

6.1.5.2 The workshop agreed that the usefulness of drifter data for other operational applications should be investigated. For example, more accurate and reliable submergence, defined as a percentage of time the drifter spends under the surface in a 30 minute period, could have some merit not only for drogue detection but also for cost-effective sea state or wave estimate purposes. The workshop agreed that cheap optical liquid level sensors, or hydrostatic pressure could be used for submergence/drogue detection and/or wave measurement purposes and recommended that such techniques be further investigated (**recommendation**).

6.1.6 Lifetime

6.1.6.1 Sergey Motyzhev presented recent developments by Marlin-Yug. He explained that increasing SVPB drifter lifetime can be realized (i) by using new electronic components with lower power consumption, and (ii) by adapting data transmission modes according to ocean/weather conditions. For example, Marlin-Yug developed in 2006 a new Argos PTT which permits to increase buoy lifetime by about 20% compared to the one that was used before. Also, experiments can be proposed to test new technology as well as new generations of buoys.

6.1.7 Cheaper sensors

6.1.7.1 The workshop agreed that cheaper sensors can be tested and used provided that they eventually provide for the required accuracies, and long-term drift (e.g. air pressure, temperature profiles). Manufacturers are invited to be pro-active in building cost-effective drifters.

6.1.8 Derived variables

6.1.8.1 Substantial computing power is now available on-board buoys. Certain variables can be deduced from the buoy suite of sensors. While the individual sensor data used to compute such variables couldn’t be transmitted because of the limited bandwidth, it is now possible to compute the required deduced variables on-board and to transmit them. Such derived variables (e.g. fluxes) can be useful to understand complex events such as cyclogenesis.

6.1.9 Thermistor strings

6.1.9.1 Bill Scuba noted the excellent performance of thermistor chain drifters deployed in 2005, in the path of hurricane Rita. However, the workshop recognized the poor performance of thermistor strings in general in terms of reliability. Sergey Motyzhev argued that cost effective acoustic data transmission (within rope) between sub-surface electronics and surface data logger could be used in the future to increase reliability of thermistor strings and facilitate packaging and deployment. This could indeed alleviate a number of so-called “weak places” in the thermistor string. Thermistor strings should eventually last for at least

6 months (**recommendation**). Any additional cost should be balanced by increased reliability.

6.1.9.2 The meeting also agreed that drifters equipped with thermistor strings could not be used for sea surface velocity purposes as part of the standard fleet of GDP drifters, in view of the presence of elements with high drag coefficient below the standard 15m drogue. While questioning the usefulness of the drogue on such drifters, the meeting considered that it was still useful in order (i) to provide stability for the thermistor string, and (ii) to reduce drifter speed and keep it in the deployment area as long as possible (**recommendation**).

6.1.9.3 The workshop recommended the use of cheap pressure sensors on thermistor strings to estimate the depth of probes accurately (**recommendation**).

6.1.10 Salinity Measurement

6.1.10.1 Past experiments have shown that salinity can be measured from drifters with the required accuracy of 0.1 psu. The workshop suggested that installing conductivity cells deep enough could reduce bio-fouling. However, tests should be conducted. Also the quality of salinity is related to the difference between the depth of the temperature probe and the depth of the conductivity cell, particularly in certain ocean conditions. This needs further investigation (**recommendation**).

6.1.11 Air pressure tendency

6.1.11.1 The meeting discussed the possibility of using cheaper pressure sensors to measure air pressure tendency. Long term drift for pressure tendency sensors does not have to be as low as for absolute pressure sensors. They must however continue to provide accurate differential pressure values. It was noted that the cost of a standard drifter was about $1900. Adding an absolute pressure barometer and port requires adding about $1200 to that cost. It was estimated that savings on the pressure sensor itself would be in the order of about $100 to $500. The workshop agreed that the savings might not be high enough to justify using them unless additional savings could be made with the barometer port.

6.1.12. Smart buoys

6.1.12.1 Mr David Meldrum gave a brief presentation on some early work with smart thermistor string drifters that had used an onboard processor and rule-set to select only data likely to be of interest to the end user. Results were shown that indicated how upper ocean thermal structure could be much better described by such a drifter. The drifter used less energy than a conventional drifter by only transmitting the useful data, and by using onboard orbital parameters to predict Argos satellite overpasses. The workshop agreed that such techniques could be of considerable value in maximizing the value for money and impact of buoy data, and urged the DBCP to pursue this line of technology development **(action).**

6.2 Satellite data telecommunication

6.2.1 Mr David Meldrum gave a presentation on existing satellite data telecommunication system capabilities (Table 1). He listed the main criteria to consider when selecting a system, i.e. bandwidth, timeliness, availability, global coverage, normal temperature conditions in which transmitter/receiver can work, energy budget, cost, physical size, reliability, and foreseen future of the system (e.g. future launches, etc.).

Satcomm system	Type	Orbit	Data rate
Inmarsat D+	Pager	Geostationary	< 1 kbyte/day
GOES, Meteosat	Messaging	Geostationary	< 5 kbyte/day
Argos	Messaging	Low Earth Orbit	< 5 kbyte/day
Inmarsat C	Messaging	Geostationary	< 10 kbyte/day
Orbcomm	Messaging	Low Earth Orbit	< 50 kbyte/day
Iridium	Voice	Big Low Earth Orbit	1 Mbyte/hr
Inmarsat BGAN	Internet	Geostationary	50 Mbyte/hr

Table 1: Satellite data telecommunication systems, type, orbit, and data transmission rates.

6.2.2 Regarding applications in polar regions, It was noted that (i) Geostationary satellites do not provide adequate coverage in these regions, and that (ii) available Iridium transceivers were not certified for extreme low temperatures (<-30°C), although successful operation down to -45°C had been noted.

6.2.3 In Low Earth Orbit (LEO) constellations, large numbers of satellites are required to assure good availability of communications opportunities (and data timeliness) for platforms.

6.2.4 Stored-and-forward capability (also known as 'global', 'delayed mode') provides for global coverage as all data received are recorded by on board storage and can be replayed when in view of system ground station. Direct readout capability (also known as 'bent-pipe', ‘regional', 'real-time mode') provides for immediate rebroadcast of received data by the satellite to any suitable receiving station in view of the satellite. In such cases the satellite must see both the transmitting observing platform and the local receiving station at the same time in order for the data to go through.

Iridium

6.2.5 David Meldrum provided information regarding the Iridium system which is a true two-way global phone system with a 66-satellite constellation. Iridium provides for direct Internet access, dial-up, and Short Burst Data (SBD) modes. SBD can be cost-effective for short messages only (1$/kByte). Dial-up is recommended for larger files ($0.1/kByte, and 20J/kByte for files exceeding 10 kBytes). As a guide to energy consumption, 1 alkaline D-cell contains about 50kJ of electrical energy, equivalent to the transmission of 2.5 Mbytes of data. Iridium operates at L band (i.e. about 1.5 GHz), which is a relatively clean part of the spectrum, and a relatively compact antenna can be used. Iridium appears to be useful for the interactive control of mobiles. Mobiles can initiate the call (e.g. when a profiling float reaches the surface). There are plans to replenish the Iridium constellation of satellites to extend operations beyond the current estimates of 2014.

Orbcomm

6.2.6 Orbcomm operates as a basic email service in bent-pipe mode with store-and-forward add-on. Energy cost is of about 200J/kByte. It was noted that Orbcomm used a relatively noisy part of the frequency spectrum (138-148 MHz) that was not licensed worldwide. A relatively large antenna is required. Orbcomm provides for good real-time coverage provided that the observing platform is close to a direct readout station. It currently has little capability in polar regions.

Argos

6.2.7 Christian Ortega described oncoming Argos enhancements, real time station network implementation, Argos-3 capabilities (two-way, 4.8 kbps high data rate channel, data processing enhancements) and how they relate to the issues of interest to drifter operators and users, i.e. timeliness, data bandwidth, lifetime, flexibility and data processing. He suggested the following drifter design enhancements:

- Timeliness: Timeliness for Argos system is related to the number of satellites and the network of real time receiving stations. But it can also be improved by working on transmission strategies and formats, for example:
  - Tune sampling according to specific timeliness required for each data type (take more MSLP updates (before each transmission or satellite pass), less SST, typically 1 every 3 hours)
  - Transmit blocks including real time data (e.g. MSLP updates) more frequently

- Resolution / Data bandwidth: data resolution either in time or accuracy relates to the amount of data to be relayed by the satellite data telecommunication system. With the current satellite configuration, more data can be relayed by using shorter repetition periods and the transmission of more data blocks. Drifters with thermistor strings and GPS fixes every 5 minutes have been successfully deployed in the China Sea with a 40 second repetition rate. With Argos-3, the interactive data mode (data Ack) will enable the transmission of more blocks in a shorter time (timeliness issue) whereas the high data rate channel could take on large data sets containing less urgent or historical data. One satellite with Argos-3 will already provide 3 to 12 passes per day to collect such data sets.

- Increasing drifter lifetime
  - Substantial battery power savings can be achieved by tuning the transmitter ON only when there is a satellite above. This will be enabled by the Argos Downlink which will provide the orbital parameters of all satellites of Argos constellation.
  - The Downlink will enable to switch off some of the buoys appearing in a cluster and that provide redundant data.
  - In order to provide for simulation of possible scenarios and assess lifetime gains, it was recommended to design an SVP drifter power budget spreadsheet that would include information on sampling, data processing and transmission consumption (**action**).

6.2.8 In order to facilitate GTS distribution of the data, the workshop recommended using standard DBCP Argos message formats (e.g. DBCP-M2) as much as practicable, even for prototypes. In case new Argos transmission strategies and formats have to be defined because of specific requirements that cannot be met by existing recommended formats, the workshop urged buoy manufacturers, Service Argos, buoy operators, and the Technical Coordinator of the DBCP to coordinate their efforts as much as possible (**recommendation**). For example, manufacturers are invited to inform the DBCP TC and Service Argos of proposed new formats discussed with customers as early as possible in the development process. DBCP TC and Service Argos would study compatibility of proposed formats with existing processing tools and possibly provide recommendations. Once defined, processing templates can be defined, validated, and be ready for operational use.

6.2.9 CLS agreed to provide updated information via the web on system performance and/or guidelines for transmitter parameter setting according to geographical area.

6.2.10 The workshop recommended that Service Argos, buoy manufacturers and transmitter manufacturers work together to promote wider use of the available Argos frequency spectrum (**recommendation**). The workshop noted that present technology permits the use of programmable frequency transmitters. These are only about $100 more expensive than regular transmitters. CLS agreed to provide guidelines for frequency allocation via the web. Monthly maps showing recommended frequencies in specific regions could be routinely produced by Service Argos (**action**).

Two-way Communication

6.2.11 The workshop agreed that in order to save battery power it would be useful to adjust transmission cycles, using two-way communications, according to seasonal or specific weather conditions such as hurricanes (**action**). The workshop recommended that the DBCP TC investigate this with NWP experts. It was also suggested that communication between satellite transmitter manufacturers, buoy manufacturers, and Service Argos was required (**recommendation**). CLS informed the workshop that 80 Argos two-way and high data rate Platform Messaging Terminals (PMT) will be provided for free for pilot operations. Interested buoy operators and manufacturers are invited to contact CLS directly (**recommendation**).

Sampling

6.2.12 As far as reporting of SST data, the workshop recommended that measurements be made on the hour, every hour (**recommendation**).

6.2.13 The workshop recommended that a feasibility study (i.e. impact on electric power consumption) be made regarding sampling sea level pressure data more frequently (5 min., 10 min.) in order to provide the latest measurement in Argos messages and therefore to improve overall data timeliness for data buoys using Argos (**action**).

6.3 Buoy operators (e.g. operations and logistics)

6.3.1 he workshop agreed to continue efforts in producing cost-effective drifters.

6.3.2 Shipping/deployment packaging

6.3.2.1 Buoy operators stressed that buoy deployments had increased substantially in the last few years and that in order to sustain the drifter array at its present level, standardized and cost effective deployment packages had to be proposed (e.g. smaller packages, easier to carry and deploy for one person and easier to store) (**recommendation**). Deployment packages should be designed in such a way to ensure for safe deployments from 20 metres above the sea level height from ships moving up to 25 knots. Graeme Ball reported on successful deployments in such conditions.

6.3.2.2 Dr Rick Lumpkin informed the workshop that Craig Engler was working on standardizing packaging for deployments from ships. The workshop asked GDC to report at the next panel session (**recommendation**). Packaging for air deployment is being designed separately.

6.3.3 Buoy activation upon deployment

6.3.3.1 Presently, the synchronization of the buoys (i.e. to have the parameters measured on the hour) is done, depending on the manufacturer, by either removing a magnet on the hour or 45 minutes past the hour. The meeting agreed that the buoy activation system had to be designed in such a way that it shouldn’t necessarily require an operator to act on the buoy on the ship before deployment. However, manual activation of the buoy (e.g. magnet) should remain an option for test purposes. For example, the drifter real-time clock needs to be stable enough to provide for observation time accuracy better than 10 minutes during the whole operational lifetime of the drifter (i.e. 10 minutes maximum drift over 5 years). The workshop agreed that since electric power consumption was negligible, the real-time clock could be activated well before deployment by the manufacturer (**recommendation**). Manufacturers indicated that (i) some crystals are accurate enough in the kind of temperature range where the drifters are operating, and that (ii) cost impact of such changes should not be significant. Such features would make the programme more operational.

6.3.3.2 Buoy operators reminded manufacturers that in order to avoid having a large number of buoys transmitting at the same time, the Argos transmission cycle should be randomly activated and repetition periods did not have to be exactly of 90 seconds (**recommendation**).

Label/markings

6.3.4 Jon Turton suggested to add markings on the drifters to facilitate recovery and identification of ownership. This could for example be useful for permitting shipping of recovered drifters back to the manufacturers for investigation purposes. Simple markings in several languages as is done for Argo could be used. Markings could for example include words like “don’t open”, “contact local authorities”, “contact JCOMMOPS”, and include Argos or WMO identification number. After discussion, the workshop agreed that such markings could be recommended only for drifters powered by lithium batteries. The workshop recommended that the DBCP consider this issue for discussion at its next Panel session (**recommendation**).

6.4 Users and operational centres (e.g. data assimilation)

6.4.1 The workshop agreed that it was essential to demonstrate the relevance of surface drifter data to decision makers. It recommended that modellers should consider conducting additional impact studies or that existing ones should be better advertized (e.g. impact of surface pressure on NWP). DBCP Action Groups are invited to conduct similar design studies as the one that was made by E-SURFMAR (**recommendation**). It was noted, however, that the DBCP web site contains a web page describing past impact studies and their results.

7. General discussion and brainstorming

7.1 The workshop agreed that global uniform coverage was critical and was recognized to present deployment challenges. The workshop agreed that a feasibility analysis was needed that would consider all observing platforms (satellite, in situ) and would seek (i) to estimate global coverage, (ii) to identify regions that are unlikely to be appropriately sampled without further deployment assets, and (iii) estimate what specific deployment assets/efforts are likely to be needed every year (**recommendation**).

7.2 The workshop agreed that the DBCP should work with the United Nations Framework Convention on Climate Change (UNFCCC) to seek ways to facilitate programme implementation in data sparse areas (**recommendation**).

7.3 The workshop recognized that efforts should be made to fill the gap among regions in technological development, including drifting buoy construction, satellite data telecommunication, data processing and its applications. As a starting point, the workshop recommended to organize a training course for African and Western Indian Ocean region, in close cooperation with ODINAfrica, on application and management of the data from in situ oceanographic and marine meteorological observations (**recommendation**).

7.4 It was noted that climate studies addressed means, anomalies and variances. Particularly, extreme events are one measure of variance of considerable interest at present. For example, are storms getting stronger or more frequent? How best to evaluate this? How to address requirements for applications related to rapidly deepening phenomenon? The workshop agreed that providing observation data at a higher temporal resolution could help to address these issues.

7.5 The meeting agreed that there was a need for sea surface salinity measurements in coastal regions for ship routing applications (e.g. estimating draught of ship) as well as for estimating freshwater influxes.

List of questions asked and answers

7.6 The meeting reviewed the questions that had been prepared in advance of the workshops. Answers were proposed based on earlier discussion and brainstorming. Proposed answers are given in Annex VI. Additional recommendations were also made during this exercise (see Annex VI).

7.7 The workshop agreed that such workshops would be a good opportunity not only for information exchange among buoy operators, data users, and manufacturers; but also for education/capacity building purposes. It was recommended to continue these efforts as best as possible (**recommendation**).

8. Workshop’s recommendations

8.1 The list of Workshop recommendations and actions are given in Annex V.

9. Closing

9.1 The DBCP Data Users and Technology Workshop closed at 12:00 hours on Tuesday, 28 March 2006.

Annex I

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Annex II

AGENDA

1. Welcome, call to order, meeting information

2. Agenda approval

3. Introduction and goal for the workshop

4. Brief description of drifting buoy networks

5. User requirements

    5.1 NWP
    5.2 Climate variability
    5.3 Ocean modelling and climate forecast

6. Potential impact of any proposed modifications for

    6.1 Manufacturers (e.g. developments, production lines, unit cost)

    6.2 Satellite data telecommunication (e.g. GTS encoding)

    6.3 Buoy operators (e.g. operations and logistics)

    6.4 Users and operational centres (e.g. data assimilation)

    6.5 General Discussion and conclusions from each agenda item

7. Brainstorming

    7.1 List of questions asked
    7.2 Identification of new questions to be asked
    7.3 Questions/answers session

8. Workshop’s recommendations

9. Disbanding

Annex III

REQUIREMENTS MATRIX

Matrix basically suggests what is the workshop’s interpretation of the requirements in order to tentatively and realistically achieve drifter array implementation that would meet most of them.

	NWP	**Climate variability, predictability, ocean modeling, climate forecast**
Space resolution	250x250km threshold for MSLP; all drifters with barometers; study needed on drifters escaping into tropical regions; MSLP needed in tropical regions for hurricane prediction and tracking; impact of wind (TAO) in tropical regions demonstrated	SST: 5 degrees SSS: 200km Wind: 2 degrees T profiles: 1m to 5m, then 5m down to 200m Surface velocity: 600km Sea ice velocity: 200 km
Time resolution	MSLP: Hourly SST: High resolution hourly data required for diurnal cycle resolution	SST: 25 samples per week SSS: 1 sample per 10 days Wind: 1 to 4 samples per 1 to 2 days T profiles: Surface velocity: 1 sample per month Sea ice velocity: 1 sample per day
Timeliness	<3H at main synoptic hours (global models); forecasters need timely data. NWP requirements will be sufficient for all other applications.	
Quality	Time of observation: 10 minutes MSLP: 0.6 hPa SST: 0.5C Wind: 5m/s for tropics; Quickscat needs in situ wind in rain conditions; wind 10 min. averages; turbulence: desirable e.g. gustiness W Pacific (research)	SST: 0.2C SSS: 0.1 psu Wind: 0.1 to 1 m/s T profiles: Surface velocity: 2cm/s Sea ice velocity: 1cm/s

	NWP	**Climate variability, predictability, ocean modeling, climate forecast**
Adapting to specific ocean/weather conditions		
Metadata	Real time: Anemometer height; instrument height; measurement technique (acoustic, WOTAN, cup ...)	

Annex IV

REQUIREMENTS FROM CEOS DATABASE

The Committee on Earth Observation Satellites (CEOS) Data base Expressed requirements for GOOS, GCOS, and WMO

CEOS/WMO database, release February 2003, Version 2.5
(http://alto-stratus.wmo.ch/sat/stations/SatSystem.html)

Global Ocean Observing System (GOOS) requirements

Requirement	Hor Res	Vert Res	Obs Cycle	Accuracy	Delay	Confidence	Use
Aerosol (total column) size	1 km / 10 km	/	24 h / 48 h	0.1 µm / 1 µm	3 h / 7 h	Firm	Marine biology (coastal water)
Aerosol (total column) size	4 km / 50 km	/	24 h / 48 h	0.1 µm / 1 µm	3 h / 7 h	Firm	Marine biology (open ocean)
Air pressure over sea surface	50 km / 100 km	/	24 h / 48 h	10 hPa / 15 hPa	3 h / 7 h	Firm	Marine biology (open ocean)
Dominant wave direction	10 km / 30 km	/	1 h / 6 h	10 degrees / 20 degrees	2 h / 4 h	Firm	GOOS Surface
Dominant wave period	10 km / 30 km	/	1 h / 6 h	0.5 s / 1 s	2 h / 4 h	Firm	GOOS Surface
Geoid	250 km / 500 km	/	240 mo / 360 mo	2 cm / 5 cm	12 y / 24 y	Firm	JGOOS-III
Ocean chlorophyll	1 km / 5 km	/	1 d / 3 d	5 % (Max) / 20 % (Max)	3 d / 7 d	Firm	Marine biology (coastal water)
Ocean chlorophyll	10 km / 50 km	/	1 d / 3 d	0.1 % (Max) / 0.5 % (Max)	3 d / 7 d	Firm	Marine biology (open ocean)
Ocean chlorophyll	25 km / 100 km	/	1 d / 3 d	0.1 % (Max) / 0.5 % (Max)	1 d / 3 d	Firm	GOOS Climate - large scale
Ocean dynamic topography	25 km / 100 km	/	7 d / 30 d	2 cm / 10 cm	2 d / 15 d	Firm	GOOS Climate - mesoscale
Ocean dynamic topography	100 km / 300 km	/	10 d / 30 d	2 cm / 5 cm	10 d / 30 d	Firm	GOOS Climate - large scale
Ocean salinity	200 km / 500 km	/	10 d / 30 d	0.1 psu / 1 psu	10 d / 30 d	Firm	GOOS Climate - large scale
Ocean yellow substance absorbance	1 km / 5 km	/	1 d / 2 d	5 % (Max) / 20 % (Max)	3 d / 7 d	Firm	Marine biology (open ocean)
Ozone profile - Total column	50 km / 200 km	/	24 h / 48 h	10 DU / 20 DU	3 h / 7 h	Firm	Marine biology (open ocean)
Photosynthetically Active Radiation (PAR)	1 km / 5 km	/	0.04 d / 1 d	5 % (Max) / 20 % (Max)	3 d / 7 d	Firm	Marine biology (coastal water)
Photosynthetically Active Radiation (PAR)	10 km / 50 km	/	0.04 d / 1 d	5 % (Max) / 20 % (Max)	3 d / 7 d	Firm	Marine biology (open ocean)
Sea surface bulk temperature	1 km / 5 km	/	24 h / 48 h	0.1 K / 0.5 K	3 h / 7 h	Firm	Marine biology (coastal water)
Sea surface bulk temperature	10 km / 50 km	/	24 h / 48 h	0.1 K / 0.5 K	3 h / 7 h	Firm	Marine biology (open ocean)
Sea surface bulk temperature	10 km / 300 km	/	6 h / 720 h	0.1 K / 1 K	6 h / 720 h	Firm	GOOS Climate - large scale
Sea surface bulk temperature	1 km / 10 km	/	6 h / 12 h	0.1 K / 2 K	2 h / 4 h	Firm	GOOS Surface
Sea-ice cover	10 km / 100 km	/	1 d / 6 d	2 % (Max) / 10 % (Max)	0.125 d / 1 d	Firm	GOOS Climate - large scale
Sea-ice thickness	25 km / 100 km	/	1 d / 6 d	50 cm / 100 cm	1 d / 6 d	Firm	GOOS Surface
Specific humidity profile - Total column	Missing / Missing	/	24 h / Missing	Missing / Missing	3 h / 7 h	Firm	Marine biology (open ocean)
Wind speed over sea surface (horizontal)	25 km / 100 km	/	24 h / 168 h	1 m/s / 2 m/s	24 h / 168 h	Firm	GOOS Climate - large scale
Wind vector over sea surface (horizontal)	25 km / 100 km	/	24 h / 168 h	1 m/s / 2 m/s	24 h / 168 h	Firm	GOOS Climate - large scale
Wind vector over sea surface (horizontal)	4 km / 50 km	/	24 h / 48 h	2 m/s / 5 m/s	3 h / 7 h	Firm	Marine biology (open ocean)

Global Climate Observing System (GCOS) requirements

Requirement	Hor Res	Vert Res	Obs Cycle	Accuracy	Delay	Confidence	Use
Aerosol profile - Total column	1 km / 4 km	/	24 h / 48 h	Missing / Missing	24 h / 120 h	Speculative	Terrestrial Climate
Air specific humidity (at surface)	25 km / 100 km	/	3 h / 6 h	1 % / 2 %	24 h / 72 h	Speculative	Terrestrial Climate
Air temperature (at surface)	25 km / 100 km	/	3 h / 12 h	0.2 K / 0.5 K	24 h / 48 h	Speculative	Terrestrial Climate
Atmospheric temperature profile - Higher stratosphere & mesosphere (HS & M)	100 km / 500 km	2 km / 3 km	3 h / 6 h	1 K / 3 K	3 h / 12 h	Firm	AOPC
Atmospheric temperature profile - Higher troposphere (HT)	100 km / 500 km	0.1 km / 0.5 km	3 h / 6 h	0.5 K / 2 K	3 h / 12 h	Firm	AOPC
Atmospheric temperature profile - Lower stratosphere (LS)	100 km / 500 km	0.1 km / 0.5 km	3 h / 6 h	0.5 K / 2 K	3 h / 12 h	Firm	AOPC
Atmospheric temperature profile - Lower troposphere (LT)	100 km / 500 km	0.1 km / 2 km	3 h / 6 h	0.5 K / 2 K	3 h / 12 h	Firm	AOPC
Cloud cover	100 km / 500 km	/	3 h / 6 h	10 % (Max) / 20 % (Max)	3 h / 12 h	Firm	AOPC
Cloud ice profile - Total column	100 km / 500 km	/	3 h / 6 h	Missing / Missing	3 h / 12 h	Firm	AOPC
Cloud imagery	1 km / 10 km	/	3 h / 12 h	/	12 h / 24 h	Speculative	Terrestrial Climate
Cloud top height	100 km / 500 km	/	3 h / 6 h	0.5 km / 2 km	3 h / 12 h	Firm	AOPC
Cloud top temperature	100 km / 500 km	/	3 h / 6 h	0.3 K / 0.6 K	3 h / 12 h	Firm	AOPC
Cloud water profile (< 100 µm) - Total column	100 km / 500 km	/	3 h / 6 h	Missing / Missing	3 h / 12 h	Firm	AOPC
Cloud water profile (> 100 µm) - Total column	100 km / 500 km	/	3 h / 6 h	Missing / Missing	3 h / 12 h	Firm	AOPC
Downwelling long-wave radiation at the Earth surface	25 km / 100 km	/	3 h / 6 h	5 W/m2 / 10 W/m2	24 h / 120 h	Speculative	Terrestrial Climate
Downwelling short-wave radiation at the Earth surface	25 km / 100 km	/	24 h / 120 h	5 W/m2 / 10 W/m2	24 h / 720 h	Speculative	Terrestrial Climate
Downwelling solar radiation at TOA	/	/	0.125 d / 7 d	1 W/m2 / 2 W/m2	0.125 d / 1 d	Firm	AOPC
Fire area	0.1 km / 1 km	/	10 d / 365 d	5 % (Max) / 20 % (Max)	30 d / 90 d	Tentative	Terrestrial Climate
Fire temperature	0.1 km / 1 km	/	10 d / 365 d	50 K / 200 K	30 d / 90 d	Tentative	Terrestrial Climate
Fractional Photosynthetically Active Radiation (FPAR)	0.1 km / 2 km	/	10 d / 30 d	5 % (Max) / 10 % (Max)	10 d / 30 d	Tentative	Terrestrial Climate
Glacier cover	10 m / 100 m	/	30 y / 50 y	10 % (Max) / 20 % (Max)	720 d / 1500 d	Speculative	Terrestrial Climate
Ice-sheet topography	0.01 km / 0.05 km	/	5 y / 10 y	50 cm (vert.) / 100 cm (vert.)	365 d / 720 d	Speculative	Terrestrial Climate
Land cover	100 m / 1000 m	/	1 y / 10 y	50 classes / 20 classes	90 d / 365 d	Tentative	Terrestrial Climate
Land surface imagery	1 m / 10 m	/	1500 d / 3000 d	/	1500 d / 3000 d	Speculative	Terrestrial Climate
Land surface temperature	100 km / 500 km	/	3 h / 6 h	1 K / 3 K	3 h / 6 h	Firm	AOPC
Land surface topography	10 m / 1000 m	/	10 y / 30 y	30 m (vert.) / 100 m (vert.)	720 d / 1500 d	Firm	Terrestrial Climate
Leaf Area Index (LAI)	0.1 km / 1 km	/	10 d / 30 d	20 % (Max) / 100 % (Max)	10 d / 30 d	Tentative	Terrestrial Climate
Normalized Differential Vegetation Index (NDVI)	100 km / 500 km	/	168 d / 720 d	10 % (Max) / 20 % (Max)	10 d / 30 d	Firm	AOPC
Ocean dynamic topography	100 km / 250 km	/	10 d / 30 d	5 cm / 10 cm	0.125 d / 1 d	Firm	OOPC
Outgoing long-wave Earth surface	25 km / 100 km	/	3 h / 6 h	5 W/m2 / 10 W/m2	24 h / 120 h	Speculative	Terrestrial Climate
Outgoing long-wave radiation at TOA	50 km / 100 km	/	480 h / 1440 h	5 W/m2 / 10 W/m2	816 h / 2448 h	Speculative	Terrestrial Climate
Outgoing long-wave radiation at TOA	200 km / 500 km	/	3 h / 6 h	5 W/m2 / 10 W/m2	3 h / 24 h	Firm	AOPC
Outgoing short-wave radiation at TOA	200 km / 500	/	3 h / 6 h	5 W/m2 / 10	3 h / 24 h	Firm	AOPC

Requirement	Hor Res	Vert Res	Obs Cycle	Accuracy	Delay	Confidence	Use
	km			W/m2			
Ozone profile - Total column	1 km / 8 km	/	24 h / 48 h	Missing / Missing	240 h / 720 h	Speculative	Terrestrial Climate
Permafrost	0.01 km / 1 km	/	10 d / 365 d	Missing / Missing	90 d / 365 d	Speculative	Terrestrial Climate
Precipitation rate (liquid) at the surface	100 km / 500 km	/	3 h / 6 h	0.6 mm/h / 2 mm/h	3 h / 12 h	Firm	AOPC
Precipitation rate (liquid) at the surface	1 km / 10 km	/	3 h / 6 h	0.05 mm/h / 0.1 mm/h	24 h / 120 h	Tentative	Terrestrial Climate
Precipitation rate (solid) at the surface	1 km / 10 km	/	3 h / 6 h	0.05 mm/h / 0.1 mm/h	24 h / 120 h	Tentative	Terrestrial Climate
Precipitation rate (solid) at the surface	100 km / 500 km	/	3 h / 6 h	0.6 mm/h / 2 mm/h	3 h / 12 h	Firm	AOPC
Sea surface bulk temperature	100 km / 500 km	/	24 h / 72 h	0.3 K / 1 K	3 h / 12 h	Firm	AOPC
Sea surface bulk temperature	200 km / 500 km	/	24 h / 72 h	0.5 K / 2 K	3 h / 12 h	Firm	OOPC
Sea-ice cover	30 km / 100 km	/	1 d / 7 d	2 % (Max) / 5 % (Max)	0.125 d / 1 d	Firm	OOPC
Sea-ice cover	100 km / 500 km	/	1 d / 7 d	10 % (Max) / 20 % (Max)	0.125 d / 1 d	Firm	AOPC
Significant wave height	100 km / 250 km	/	3 h / 6 h	0.5 m / 2 m	3 h / 12 h	Firm	AOPC
Snow cover	1 km / 5 km	/	24 h / 72 h	5 % (Max) / 10 % (Max)	48 h / 72 h	Tentative	Terrestrial Climate
Snow cover	100 km / 500 km	/	24 h / 168 h	10 % (Max) / 20 % (Max)	6 h / 24 h	Firm	AOPC
Snow melting conditions	10 km / 25 km	/	24 h / 72 h	6 classes / 2 classes	48 h / 72 h	Tentative	Terrestrial Climate
Snow water equivalent	100 km / 500 km	/	24 h / 168 h	5 mm / 10 mm	6 h / 24 h	Firm	AOPC
Snow water equivalent	10 km / 25 km	/	24 h / 72 h	5 mm / 10 mm	48 h / 72 h	Speculative	Terrestrial Climate
Soil moisture	25 km / 100 km	/	1 d / 5 d	Missing / Missing	3 d / 5 d	Speculative	Terrestrial Climate
Specific humidity profile - Higher stratosphere & mesosphere (HS & M)	100 km / 500 km	1 km / 3 km	3 h / 6 h	5 % / 10 %	3 h / 12 h	Firm	AOPC
Specific humidity profile - Higher troposphere (HT)	100 km / 500 km	0.5 km / 1 km	3 h / 6 h	5 % / 10 %	3 h / 12 h	Firm	AOPC
Specific humidity profile - Lower stratosphere (LS)	100 km / 500 km	0.5 km / 1 km	3 h / 6 h	5 % / 10 %	3 h / 12 h	Firm	AOPC
Specific humidity profile - Lower troposphere (LT)	100 km / 500 km	0.1 km / 2 km	3 h / 6 h	5 % / 10 %	3 h / 12 h	Firm	AOPC
Specific humidity profile - Total column	100 km / 500 km	/	3 h / 6 h	1000 kg/m2 / 2500 kg/m2	3 h / 12 h	Firm	AOPC
Wind profile (horizontal component) - Higher stratosphere & mesosphere (HS & M)	100 km / 500 km	2 km / 3 km	3 h / 6 h	3 m/s / 7 m/s	3 h / 12 h	Firm	AOPC
Wind profile (horizontal component) - Higher troposphere (HT)	100 km / 500 km	0.5 km / 1 km	3 h / 6 h	2 m/s / 5 m/s	3 h / 12 h	Firm	AOPC
Wind profile (horizontal component) - Lower stratosphere (LS)	100 km / 500 km	0.5 km / 1 km	3 h / 6 h	2 m/s / 5 m/s	3 h / 12 h	Firm	AOPC
Wind profile (horizontal component) - Lower troposphere (LT)	100 km / 500 km	0.1 km / 2 km	3 h / 6 h	2 m/s / 5 m/s	3 h / 12 h	Firm	AOPC
Wind vector over land surface (horizontal)	25 km / 100 km	/	24 h / 120 h	2 m/s / 5 m/s	24 h / 240 h	Speculative	Terrestrial Climate
Wind vector over sea surface (horizontal)	100 km / 500 km	/	3 h / 6 h	2 m/s / 5 m/s	3 h / 12 h	Firm	AOPC
Wind vector over sea surface (horizontal)	100 km / 500 km	/	12 h / 24 h	2 m/s / 5 m/s	3 h / 12 h	Firm	OOPC

World Meteorological Organization (WMO) requirements

(excerpt for ocean related variables)

Requirement	Hor Res	Vert Res	Obs Cycle	Accuracy	Delay	Confidence	Use
Air pressure over sea surface	50 km / 250 km	/	1 h / 12 h	0.5 hPa / 2 hPa	1 h / 4 h	Firm	Global NWP
Air pressure over sea surface	10 km / 250 km	/	0.5 h / 12 h	0.5 hPa / 1 hPa	0.5 h / 2 h	Firm	Regional NWP
Air specific humidity (at surface)	50 km / 250 km	/	1 h / 12 h	5 % / 15 %	1 h / 4 h	Reasonable	Global NWP
Air specific humidity (at surface)	10 km / 250 km	/	0.5 h / 12 h	5 % / 15 %	0.5 h / 2 h	Reasonable	Regional NWP
Air temperature (at surface)	10 km / 100 km	/	1 h / 12 h	0.5 K / 2 K	1 h / 4 h	Firm	Synoptic Meteorology
Air temperature (at surface)	50 km / 250 km	/	1 h / 12 h	0.5 K / 2 K	1 h / 4 h	Reasonable	Global NWP
Air temperature (at surface)	10 km / 250 km	/	0.5 h / 12 h	0.5 K / 2 K	0.5 h / 2 h	Reasonable	Regional NWP
Air temperature (at surface)	5 km / 20 km	/	0.25 h / 1 h	0.5 K / 1 K	0.25 h / 0.5 h	Reasonable	Nowcasting
Atmospheric stability index	5 km / 50 km	/	0.08 h / 0.5 h	Missing / Missing	0.25 h / 1 h	Firm	Nowcasting
Atmospheric stability index	20 km / 200 km	/	1 h / 6 h	Missing / Missing	1 h / 3 h	Firm	Synoptic Meteorology
Dominant wave direction	50 km / 200 km	/	3 h / 12 h	20 degrees / 30 degrees	1 h / 3 h	Firm	Synoptic Meteorology
Dominant wave direction	10 km / 50 km	/	1 h / 12 h	10 degrees / 20 degrees	0.5 h / 2 h	Firm	Regional NWP
Dominant wave direction	50 km / 250 km	/	1 h / 12 h	10 degrees / 20 degrees	1 h / 4 h	Firm	Global NWP
Dominant wave period	10 km / 50 km	/	1 h / 12 h	0.5 s / 1 s	0.5 h / 2 h	Firm	Regional NWP
Dominant wave period	50 km / 250 km	/	1 h / 12 h	0.5 s / 1 s	1 h / 4 h	Firm	Global NWP
Dominant wave period	50 km / 200 km	/	3 h / 12 h	0.5 s / 1 s	1 h / 3 h	Firm	Synoptic Meteorology
Iceberg fractional cover	1 km / 50 km	/	1 d / 12 d	10 % (Max) / 20 % (Max)	1 d / 4 d	Firm	Hydrology
Iceberg height	1 km / 50 km	/	1 d / 12 d	1 m / 2 m	1 d / 4 d	Firm	Hydrology
Land surface temperature	0.1 km / 10 km	/	1 h / 72 h	0.3 K / 2 K	3 h / 24 h	Reasonable	Agricultural Meteorology
Land surface temperature	0.01 km / 250 km	/	1 h / 168 h	0.3 K / 3 K	24 h / 168 h	Reasonable	Hydrology
Land surface temperature	10 km / 250 km	/	0.5 h / 12 h	0.5 K / 4 K	0.5 h / 2 h	Firm	Regional NWP
Land surface temperature	50 km / 250 km	/	1 h / 12 h	0.5 K / 4 K	1 h / 4 h	Firm	Global NWP
Land surface temperature	1 km / 50 km	/	0.25 h / 1 h	0.5 K / 3 K	0.08 h / 0.5 h	Firm	Nowcasting
Land surface topography	100 m / 1000 m	/	10 y / 50 y	1 m (vert.) / 5 m (vert.)	30 d / 600 d	Reasonable	Hydrology
Long-wave Earth surface emissivity	5 km / 250 km	/	24 h / 720 h	1 % (Max) / 5 % (Max)	24 h / 720 h	Tentative	Regional NWP
Long-wave Earth surface emissivity	15 km / 250 km	/	24 h / 720 h	1 % (Max) / 5 % (Max)	24 h / 720 h	Tentative	Global NWP
Long-wave Earth surface emissivity	0.01 km / 250 km	/	24 h / 288 h	5 % (Max) / 20 % (Max)	24 h / 288 h	Reasonable	Hydrology
Ocean chlorophyll	25 km / 100 km	/	1 d / 3 d	5 % (Max) / 20 % (Max)	1 d / 3 d	Firm	S & I A
Ocean currents (vector)	10 km / 50 km	/	0.25 d / 6 d	0.5 cm/s / 1 cm/s	0.25 d / 4 d	Firm	Nowcasting
Ocean dynamic topography	25 km / 100 km	/	7 d / 30 d	1 cm / 4 cm	2 d / 15 d	Firm	S & I A
Ocean salinity	100 km / 250 km	/	30 d / 60 d	0.1 psu / 0.3 psu	9 d / 120 d	Reasonable	S & I A
Ocean suspended sediment concentration	100 km / 500	/	1 d / 6 d	5 % (Max) / 20	30 d / 90 d	Speculative	S & I A

Requirement	Hor Res	Vert Res	Obs Cycle	Accuracy	Delay	Confidence	Use
	km			% (Max)			
Ocean yellow substance absorbance	100 km / 500 km	/	1 d / 6 d	5 % (Max) / 20 % (Max)	30 d / 90 d	Speculative	S & I A
Outgoing long-wave radiation at TOA	10 km / 250 km	/	0.5 h / 1 h	5 W/m2 / 10 W/m2	240 h / 720 h	Firm	Regional NWP
Outgoing long-wave radiation at TOA	10 km / 100 km	/	1 h / 12 h	5 W/m2 / 20 W/m2	24 h / 168 h	Reasonable	Hydrology
Outgoing long-wave radiation at TOA	50 km / 250 km	/	1 h / 1 h	5 W/m2 / 10 W/m2	240 h / 720 h	Firm	Global NWP
Outgoing short-wave radiation at TOA	50 km / 250 km	/	1 h / 6 h	5 W/m2 / 10 W/m2	240 h / 360 h	Firm	Global NWP
Outgoing short-wave radiation at TOA	0.1 km / 200 km	/	1 h / 6 h	5 W/m2 / 20 W/m2	24 h / 168 h	Reasonable	Hydrology
Outgoing short-wave radiation at TOA	10 km / 250 km	/	0.5 h / 1 h	5 W/m2 / 10 W/m2	240 h / 360 h	Firm	Regional NWP
Precipitation index (daily cumulative)	50 km / 250 km	/	1 h / 12 h	0.5 mm/d / 5 mm/d	24 h / 720 h	Reasonable	Global NWP
Precipitation index (daily cumulative)	10 km / 250 km	/	0.5 h / 12 h	0.5 mm/d / 5 mm/d	24 h / 720 h	Reasonable	Regional NWP
Precipitation index (daily cumulative)	10 km / 50 km	/	24 h / 72 h	2 mm/d / 10 mm/d	24 h / 48 h	Reasonable	Agricultural Meteorology
Precipitation rate (liquid) at the surface	20 km / 100 km	/	1 h / 6 h	0.1 mm/h / 1 mm/h	0.25 h / 6 h	Firm	Synoptic Meteorology
Precipitation rate (liquid) at the surface	50 km / 100 km	/	1 h / 12 h	0.1 mm/h / 1 mm/h	1 h / 4 h	Tentative	Global NWP
Precipitation rate (liquid) at the surface	5 km / 50 km	/	0.08 h / 1 h	0.1 mm/h / 1 mm/h	0.08 h / 0.5 h	Firm	Nowcasting
Precipitation rate (liquid) at the surface	10 km / 50 km	/	0.5 h / 6 h	0.1 mm/h / 1 mm/h	0.5 h / 2 h	Tentative	Regional NWP
Precipitation rate (solid) at the surface	5 km / 50 km	/	0.25 h / 1 h	0.1 mm/h / 1 mm/h	0.5 h / 0.5 h	Firm	Nowcasting
Precipitation rate (solid) at the surface	10 km / 100 km	/	0.5 h / 12 h	0.1 mm/h / 1 mm/h	0.5 h / 2 h	Tentative	Regional NWP
Precipitation rate (solid) at the surface	50 km / 100 km	/	1 h / 12 h	0.1 mm/h / 1 mm/h	1 h / 4 h	Tentative	Global NWP
Precipitation rate (solid) at the surface	20 km / 100 km	/	3 h / 6 h	0.1 mm/h / 1 mm/h	0.25 h / 6 h	Firm	Synoptic Meteorology
Sea level	0.1 km / 10 km	/	1 d / 7 d	2 cm / 10 cm	1 d / 7 d	Reasonable	Hydrology
Sea surface bulk temperature	5 km / 50 km	/	1 h / 6 h	0.5 K / 2 K	1 h / 2 h	Firm	Nowcasting
Sea surface bulk temperature	5 km / 50 km	/	3 h / 24 h	0.5 K / 2 K	1 h / 24 h	Firm	Synoptic Meteorology
Sea surface bulk temperature	50 km / 250 km	/	3 h / 12 h	0.1 K / 0.5 K	3 h / 24 h	Firm	S & I A
Sea surface bulk temperature	50 km / 250 km	/	3 h / 360 h	0.5 K / 2 K	3 h / 180 h	Firm	Global NWP
Sea surface bulk temperature	25 km / 50 km	/	1 h / 12 h	0.5 K / 1 K	1 h / 24 h	Firm	Regional NWP
Sea-ice cover	15 km / 250 km	/	1 d / 15 d	5 % (Max) / 50 % (Max)	1 d / 7 d	Firm	Global NWP
Sea-ice cover	25 km / 50 km	/	0.5 d / 7 d	5 % (Max) / 50 % (Max)	0.3 d / 3 d	Firm	Regional NWP
Sea-ice cover	5 km / 50 km	/	1 d / 24 d	10 % (Max) / 20 % (Max)	1 d / 6 d	Firm	Nowcasting
Sea-ice surface temperature	15 km / 200 km	/	1 h / 12 h	0.5 K / 4 K	1 h / 4 h	Reasonable	Global NWP
Sea-ice surface temperature	5 km / 100 km	/	0.5 h / 12 h	0.5 K / 4 K	0.5 h / 2 h	Firm	Regional NWP
Sea-ice thickness	15 km / 250 km	/	1 d / 7 d	50 cm / 100 cm	1 d / 7 d	Speculative	Global NWP
Sea-ice thickness	5 km / 250 km	/	1 d / 7 d	50 cm / 100 cm	1 d / 7 d	Speculative	Regional NWP
Significant wave height	100 km / 250 km	/	1 h / 12 h	0.5 m / 1 m	1 h / 4 h	Firm	Global NWP
Significant wave height	10 km / 50 km	/	1 h / 12 h	0.1 m / 0.2 m	1 h / 2 h	Firm	Regional NWP
Snow cover	5 km / 250 km	/	12 h / 168 h	10 % (Max) / 50 % (Max)	6 h / 24 h	Reasonable	Regional NWP

Requirement	Hor Res	Vert Res	Obs Cycle	Accuracy	Delay	Confidence	Use
Snow cover	0.1 km / 100 km	/	24 h / 168 h	5 % (Max) / 20 % (Max)	24 h / 144 h	Reasonable	Hydrology
Snow cover	15 km / 250 km	/	12 h / 168 h	10 % (Max) / 50 % (Max)	12 h / 24 h	Reasonable	Global NWP
Snow cover	1 km / 10 km	/	120 h / 168 h	2 % (Max) / 10 % (Max)	24 h / 144 h	Reasonable	Agricultural Meteorology
Snow cover	5 km / 50 km	/	1 h / 144 h	10 % (Max) / 20 % (Max)	1 h / 6 h	Firm	Nowcasting
Snow melting conditions	0.1 km / 10 km	/	0.5 h / 288 h	5 classes / 2 classes	1 h / 144 h	Reasonable	Hydrology
Snow water equivalent	50 km / 500 km	/	24 h / 168 h	5 mm / 20 mm	24 h / 168 h	Tentative	S & I A
Snow water equivalent	1 km / 10 km	/	168 h / 720 h	5 mm / 500 mm	24 h / 168 h	Reasonable	Agricultural Meteorology
Snow water equivalent	0.1 km / 10 km	/	24 h / 168 h	5 mm / 20 mm	24 h / 144 h	Reasonable	Hydrology
Snow water equivalent	5 km / 250 km	/	6 h / 288 h	5 mm / 20 mm	6 h / 24 h	Tentative	Regional NWP
Snow water equivalent	15 km / 250 km	/	12 h / 168 h	5 mm / 20 mm	6 h / 24 h	Tentative	Global NWP
Wind speed over sea surface (horizontal)	10 km / 100 km	/	0.5 h / 12 h	0.5 m/s / 3 m/s	0.5 h / 2 h	Firm	Regional NWP
Wind speed over sea surface (horizontal)	50 km / 250 km	/	1 h / 12 h	0.5 m/s / 3 m/s	1 h / 4 h	Firm	Global NWP
Wind speed over sea surface (horizontal)	20 km / 200 km	/	1 h / 12 h	2 m/s / 5 m/s	1 h / 3 h	Firm	Synoptic Meteorology
Wind speed over sea surface (horizontal)	5 km / 50 km	/	0.25 h / 3 h	1 m/s / 5 m/s	0.25 h / 1 h	Firm	Nowcasting
Wind vector over sea surface (horizontal)	10 km / 100 km	/	0.5 h / 12 h	0.5 m/s / 5 m/s	0.5 h / 2 h	Firm	Regional NWP
Wind vector over sea surface (horizontal)	50 km / 250 km	/	1 h / 12 h	0.5 m/s / 5 m/s	1 h / 4 h	Firm	Global NWP
Wind vector over sea surface (horizontal)	20 km / 200 km	/	1 h / 12 h	2 m/s / 5 m/s	1 h / 3 h	Firm	Synoptic Meteorology
Wind vector over sea surface (horizontal)	5 km / 50 km	/	0.25 h / 3 h	1 m/s / 5 m/s	0.25 h / 1 h	Firm	Nowcasting

Annex V

RECOMMENDATIONS AND ACTIONS

1. Recommendations:

Para	Item	By whom	Target date
5.1.4	to include in DBCP implementation strategy that all drifters should eventually report MSLP while stressing on deployments in extra-tropical regions first.	DBCP-22	Oct. 2006
5.1.4	to address performing a study showing balance of drifters moving to and from tropical regions	DBCP-22	Oct. 2006
5.1.14	to collect/archive metadata to evaluate wind data quality (e.g. instrument height in case measurement is not made at standard height, information on data quality)	DBCP Evaluation Group	ASAP
5.2.8	to adopt/improve sampling requirements for the global ocean in terms of realistic implementation by the Panel (e.g. Annex II) based on "Needler OOSDP table", and on WMO CEOS database. To include matrix of User Requirements in DBCP implementation strategy.	DBCP-22	Oct. 2006
6.1.10.1	to test salinity at depth under certain ocean conditions	DBCP EG	Oct. 2006
5.2.6	to investigate methods to derive sea state and waves from submergence and near-sub-surface water pressure	Sergey Motyzhev	Oct. 2007
6.2.10	to spread Argos transmission frequencies across available spectrum (e.g. by using programmable frequency transmitters).	Buoy and transmitter manufacturers	Ongoing
6.2.8 6.2.9	to design new Argos transmission strategies and formats in close coordination between buoy manufacturers, Service Argos, buoy operators and the Technical Coordinator of the DBCP	Buoy operators, Argos, manufacturers, DBCP TC	Ongoing
6.3.3.2 7.6	to rationalize data transmission cycle, i.e. randomly activated, allowing for variability of 90 seconds repetition period, consideration of seasonal aspects (e.g. higher repetition rates during hurricane season for transmitting high resolution temperature profile data).	Buoy and transmitter manufacturers	Ongoing
6.2.11 7.6	to investigate the usefulness of Argos two-way communication for adjusting data-processing parameters and transfer more data (e.g. according to season, likelihood of hurricanes, wind drifter evaluation purposes, turning beached drifters off).	DBCP EG	Oct. 2007
6.2.12	to reinforce the importance of global uniform coverage for SST measurement, as well as high temporal resolution (i.e. hourly, and on the hour), to meet climate and GHRSST requirements	DBCP	ASAP
6.3.3.1	to design and standardize drifters activation and real-time clock	Manufacturers	Oct. 2006
6.1.4	to design and test drogues and attachments that last longer	Manufacturers	Oct. 2007
6.1.9.1	to consider making near-surface temperature measurements using new technology for thermistor strings (e.g. inductive or sonic data transmission)	DBCP	Oct. 2006
6.1.3.1	to use lithium batteries in Southern Ocean for planned operational life-time of up to 3 years.	Buoy operators	Ongoing
6.3.2.1 6.3.2.2	to design and test new standardized and cost effective deployment packages (ship, air) and report at DBCP-22	Craig Engler	Oct 2006
6.3.4	to consider appropriate labelling, based on current situation/recommendation of ODAS, Argo, etc.	DBCP-22	Oct. 2006
6.1.9.1 6.1.9.2 6.1.9.3	to increase reliability and cost-effectiveness of thermistor string drifters by testing use of acoustic data transmission (target at least 6 months). To use cheap and accurate water pressure	Sergey Motyzhev, buoy manufacturers	Oct. 2007

Para	Item	By whom	Target date
	sensors on thermistor strings. To keep drogue on thermistor string drifters.	and buoy operators	
6.1.5.1 6.1.5.2	to investigate cost-effectiveness and reliability of tether strain sensor for drogue detection. To investigate using cheap optical sensor for submergence	SIO, DBCP Evaluation Group	ASAP
7.6	To consider developing new sensor technology, including pCO_2, precipitation, sea ice extend, forming ice, and to improve acoustic wind sensor knowledge	DBCP	Oct. 2007
6.1.1.3 6.1.4.1	to recover small number of operational drifters at sea, including ones that lost their drogues or report noisy MSLP, for investigation purposes, and to send them back to the manufacturers. To recover non-essential transmitting drifters that went ashore and to send them back to the manufacturers	Buoy operators	Ongoing
6.2.11	to test Argos two-way and high data rate PMTs (80 free units)	Buoy operators	Mid-2006
6.4.1	to conduct similar design studies similar to what E-SURFMAR had done and advertize results via DBCP web site	DBCP Action Groups	Ongoing
7.1	to conduct feasibility analysis that considers all observing platforms (satellite, in situ) and is seeking (ii) to estimate global coverage, (ii) to identify regions that are unlikely to be appropriately sampled without further deployment assets, and (ii) estimate what specific deployment assets/efforts are likely to be needed every year.	DBCP in coop. With OOPC	ASAP
7.2	to work with UNFCCC to seek ways to facilitate programme implementation in data sparse areas.	DBCP	ASAP
7.7	Organize similar workshops in the future and involve developing countries (Capacity Building)	JCOMM	Ongoing
7.3	to plan a training course for buoy data use and buoy operation, targeting African and Western Indian Ocean region, in cooperation with IODE/ODINAfrica.	IOC, ODINAFRICA	2007

2. Actions:

Para	Item	By whom	Target date
5.1.8	to investigate on the different data assimilation schemes used by Member Countries and to report on recommended acceptable delays to the Panel.	DBCP TC	Oct. 2007
5.1.9	to provide tools to address spatial density issue and provide statistics regarding probability of drifters remaining in certain regions. AOML and SAMS to collaborate	AOML & SAMS	Oct. 2006
5.1.11	to investigate the needs for variables derived from sensor data on-board the buoys.	NWP users	Ongoing
5.1.12	to reflect on what new observables might be desired	NWP	Oct. 2007
5.1.15	To investigate day to day variability in number of drifter data received by ECMWF	DBCP TC	Oct. 2006
5.2.10	to provide detailed rationale for the collection and transmission of hourly SST data (diurnal cycle resolution).	OOPC	Oct. 2006
5.2.10	to record and transmit hourly SST data on newly deployed drifters.	Buoy operators	ASAP
5.2.11	to investigate the Western Indian Ocean GTS transmission problem.	DBCP TC, Ali Mafimbo and Mohamudally Beebeejaun	ASAP
6.1.3.2	to provide a comparison of alkaline battery performance, cost and features compared to Lithium batteries in an SVP/BP buoy and an SVP/WSD buoy.	Tony Chedrawy	ASAP
6.2.13	to conduct electric power consumption impact study on sampling sea level pressure data more frequently (5 mn, 10 mn…).	Andy Sybrandy	Oct. 2006
6.1.5.1 6.1.5.2	to study standardization of drogue detector (e.g. tether strain).	Peter Niiler, Bill Scuba	Oct. 2006
6.1.12.1	To pursue development of new data transmission strategies maximizing value for money and impact of buoy data	DBCP	Ongoing
6.2.11 7.6	to conduct survey on the impact of drifter observations as a function of season and geographical locations.	DBCP TC, NWP	Oct. 2007
6.3.2.1 6.3.2.2	to draft recommendation on the packaging recommendations for ship operators.	Craig Engler	Oct. 2006
6.2.7	to design an SVP drifter power budget spreadsheet that would include information on sampling, data processing and transmission consumption.	Service Argos, manufacturers	Oct. 2006
7.6	to coordinate with GOOS on the agenda of GOOS Regional Alliance Forum (November 2006, Cape Town), in particular for cooperation in Capacity Building.	Secretariat, DBCP chairperson	Nov. 2006
6.2.10	to routinely produce maps showing recommended Argos frequencies	Argos	ASAP

Annex VI

QUESTIONS/ANSWERS

These result from the workshop's discussions.

a) Do drifters carry the right sensors for the end-users?

For NWP purposes, MSLP and wind are the most important variables. Air temperature at 2 metres is usually not assimilated by NWP. MSLP, including in tropical regions is important for climate related applications.

Following sensor technology can be developed:

- Precipitation (rain/no rain sensor)
- Tether strain (drogue detector)
- Salinity at depth (coastal applications)
- Near surface T profile in mixed layer down to 200m
- pCO_2
- Sea ice extend (GPS)
- Forming ice (GPS, vertical accelerometers)
- Improve acoustic wind sensor knowledge

b) Are data quality, quantity and timeliness adequate for current and future needs?

Timeliness is driven by NWP requirements. For global models, MSLP and wind data should be assimilated at least within 3 hours. Operational forecasters need shorter delays, e.g. 90 minutes. Timeliness for SST data, which are used primarily for SST analysis and climate related applications, can be relaxed somehow.

The following can be implemented:

- Improve data timeliness thanks to (i) better Argos network of local receiving stations, (ii) use of Argos multi-satellite service, and (iii) use of other satellite data telecommunications systems (e.g. Iridium)
- Increase SST resolution (provide for hourly data, at the hour)
- Improve quality of sensor data through existing quality information monitoring activities and feed back mechanisms (e.g. buoy QC guidelines)
- Advertize known quality of buoy data in order to build confidence
- Increase deployments or deployment strategies in certain regions. This involves Capacity Building. GOOS can be used as a mechanism. Coordinate with GOOS on the agenda of GOOS Regional Alliance Forum (November 2006, Cape Town), in particular for cooperation in Capacity Building (**recommendation**).

c) Are there advantages in using cheaper sensors to permit more drifters?

Users rely on high quality data. Cheap sensors can be used provided that the quality meets required standards in terms of reliability, accuracy, precision, and long term drift.

Cheap sensors could be used for:

- Sea state and wave estimates (using submergence, near surface water pressure sensor)

- Air pressure tendency and variation for hurricane tracking (slow drift sensors). Long term drift sensors are more expensive. New air pressure sensors need to be investigated.

d) Are there useful derived variables computed on-board by the buoy from available sampled data that could be transmitted (e.g. pressure variation, statistical or cumulative variables)

- Pressure tendency and/or variation to complement existing MSLP data but not replacing them
- Standard Deviation of wind speed (using other wind sensors than WOTAN)
- Near surface turbulence

e) Smart buoy concept:

Concept must be developed with caution. For example, Weather forecasters require continuous, real-time buoy data through good and bad weather conditions in the mid and high latitude regions. Buoy data is often the only source of data in remote ocean areas and is required all the time to drive the models. Even during intense anticyclonic situations, buoy pressure data is required to verify the high pressure centre.

General ideas for developing the smart buoy concept:

- Discard raw measurement data of little value to save energy and bandwidth; Derived variables might be more useful;
- Maximizes usefulness of the data.
- Temperature profiles: transmit higher density data when interesting ocean conditions exist. This save energy and adds value to the data. Two-way telecommunication is useful to inform the buoy that interesting ocean conditions are occurring. Pre-defined rules can be used if two-way communication is not available.
- Work with NWP experts (e.g. ECMWF) to study requirements
- Operational forecasters requirements need to be considered

f) Are there ocean or weather conditions where the time resolution of timely data could be reduced bearing in mind that higher resolution data could be delayed somehow?

- Only two-way communication can realistically be used to manually reduce resolutions and play on data timeliness.
- Work with NWP experts to define rules and conditions

g) Network management (i.e. data sampling and transmission strategy controlled from the land): provided communication can be established with the buoy from the ground, is it potentially useful to try to extend the buoy life-times and therefore to increase the number of buoy locations by temporarily shutting down buoy transmissions of certain units, and under what conditions?

- Adjust transmission cycles with season
- Map of frequency use
- Turn off some of the redundant buoys that appear in clusters

h) Where do drifter data have the most impact?

Weather forecasters and modellers from New Zealand (NZ) agreed that buoy data from the southern Tasman Sea and the Southern Ocean to the southwest of NZ had the most impact on NZ forecasting operations. Both these ocean areas are data sparse, with huge variations in pressure and buoy data is vital in providing feedback on the rapidly developing and moving weather systems. Buoy data from the tropical area, north of NZ is also considered very useful in the Tropical Cyclone season.

- Tracks of storms in winter
- Regions affected by hurricanes during hurricane season
- Weather services and NWP need to provide feedback on impact studies
- See E-SURFMAR design study
- Action Groups encouraged to conduct similar design studies as E-SURFMAR

i) Where are the critical areas for deployments to be made?

- See above
- E-SURFMAR design study. Other studies to be conducted in other regions
- Climate applications require global coverage

j) Is there any seasonality in the impact which might affect deployment strategy and buoy design

- Cyclone season
- Winter storms
- Monsoon break forecasting
- Deployments in sea-ice zones, survivability of drifters
- Most deployment opportunities in the Southern Ocean occur during the summer months (October to March) when research vessels, eco-tourist ships and re-supply ships voyage to Antarctica and the sub-Antarctic islands.

k) What mechanisms could be put in place so that end users could routinely provide input to those who define deployment strategy and manage the networks.

- JCOMMOPS can be used as a focal point and provide web pages
- JCOMMOPS provides information on deployment opportunities as well as past deployment areas
- Deployment centres should be recruited by Member states and information on recognized deployment centres made available via JCOMMOPS.
- Research cruise database being developed under POGO.
- JCOMMOPS and GDC provides information on deployment techniques
- GDC designed tools on network array prediction

l) How does drifter value for money compare with other observing systems?

- Any study should consider all in situ marine observations: moored buoys, islands, drifters, VOS.
- Drifters are recognized by NMHS as cost effective instruments compared to other ones. NMHS who have made such comparisons should share their information.

- The value of buoy data is accentuated by the sparsity of data in ocean regions, and thus has a much greater impact per $ spent than surface land observations.

Annex VII

LIST OF ACRONYMS

AOML	Atlantic Oceanographic and Meteorological Laboratory (NOAA)
ARGO	Array for Real-time Geostrophic Oceanography programme
CEOS	Committee on Earth Observation Satellites
CLS	Collecte Localisation Satellites
DBCP	Data Buoy Cooperation Panel (WMO-IOC)
DBCP-M2	DBCP recommended Argos message format number 2 for meteorological applications
DBCP EG	DBCP Evaluation Group
DBCP TC	DBCP Technical Coordinator
ECMWF	European Centre for Medium-Range Weather Forecasting
E-SURFMAR	EUMETNET Surface Marine Programme
EUCOS	European Composite Observing System
EUMETNET	The Network of European Meteorological Services
EU	European Union
GCOS	Global Climate Observing System
GDC	Global Drifter Center
GDP	Global Drifter Programme
GHRSST	GODAE High Resolution SST Pilot Project
GODAE	Global Ocean Data Assimilation Experiment
GOOS	Global Ocean Observing System
GPS	Globap Positionning System
GTS	Global Telecommunication System (WMO)
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
JCOMM	Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology
JCOMMOPS	JCOMM *in situ* Observing Platform Support Centre
LEO	Low Earth Orbit
MSLP	Mean Sea Level Pressure
NOAA	National Oceanographic and Atmospheric Administration (USA)
NWP	Numerical Weather Prediction
OCG	JCOMM Observations Programme Area Coordination Group
ODINAFRICA	Ocean Data and Information Network for Africa
OOPC	Ocean Observation Panel for Climate (of GOOS, GCOS, WCRP)
PDF	Probability Distribution Function
PMT	Platform Messaging Transceiver
PTT	Platform Terminal Transmitter
QC	Quality Control
RMS	Root Mean Square
SAMS	Scottish Association for Marine Science
SBIR	Small Business Innovation Program (USA)
SST	Sea Surface Temperature
SSS	Sea Surface Salinity
SVP	Surface Velocity Programme Drifter
SVPB	Surface Velocity Programme Barometer Drifter
SVPBW	Surface Velocity Programme Barometer Drifter with Wind measuring capability
TAO	Tropical Atmosphere Ocean Array
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
URL	Universal Resource Locator
US	United States
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment (WCRP)