PROCEEDINGS OF THE THIRD INTERNATIONAL WORKSHOP ON ADVANCES IN THE USE OF HISTORICAL MARINE CLIMATE DATA

Frascati, Italy
2-6 May 2011

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JCOMM Technical Report No. 59

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WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (OF UNESCO)

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NOTES

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EXECUTIVE SUMMARY[1]

Marine surface observations—which represent a vital component of the Global Climate Observing System (GCOS)—are key to understanding global climate, including its variability on time scales ranging from sub-daily to weekly to centuries. Prior to 1970, ships were almost the only source of observations. In the modern era, sensors deployed on ships, moored and drifting buoys, aircraft, and Earth Observation (EO) satellites all provide surface measurements of many different variables. The *Third International Workshop on Advances in the Use of Historical Marine Climate Data* (MARCDAT-III) was hosted by the European Space Agency (ESA) in Frascati, Italy, from 2 to 6 May 2011, and brought together 52 members of the *in situ* and satellite communities to address the collection, collation, evaluation, distribution, and application of surface marine observations.

The International Comprehensive Ocean-Atmosphere Data Set (ICOADS) provides *in situ* marine surface data spanning the past four centuries (currently 1662–2011). Meeting participants considered how to (1) enhance and improve ICOADS; (2) better integrate *in situ* and satellite marine observations, particularly in the context of the ESA Climate Change Initiative (CCI); (3) link marine and land surface data; (4) develop multi-decadal, homogeneous gridded datasets for climate applications; and (5) characterize data and product uncertainty and bias.

One meeting outcome was a 10-year vision for the marine climate community, including the following three components: (1) an international data flow and marine observing system that meets the needs of both the operational and research climate communities, (2) an observing system that is assessed by establishing requirements to ensure system-wide adequacy for a range of users, and (3) the capability to underpin climate services and a range of scientific applications. The vision further requires marine data to be accessible, integrated, and discoverable—linking different platform types and scientific communities—and includes adding value to the climate record through data rescue and partnerships between international marine programs, governmental agencies, universities, and the private sector. Capacity building and cooperation in the international community are essential to the "I" in ICOADS.

Advances in marine climatology require the rescue of historical data available only in deteriorating paper documents or outdated digital media. The meeting recognized the past[2] contributions of the National Oceanic and Atmospheric Administration's Climate Database Modernization Program (CDMP) and strongly recommended continuing US and international support for data rescue to provide ongoing resources to image, digitize, preserve, and use historical climate data.

The participants recommended developing a value-added version of ICOADS that capitalizes on the marine climate community's decades of work on bias adjustments, data quality control (QC), and metadata enhancements. Discussions on meeting future requirements considered the need for developing ICOADS wave summary products and setting priorities for adding additional parameters to ICOADS (salinity, radiation, radiometric sea surface temperature, etc.).

Persistent challenges within the marine climate community include determining the need for and methods of selecting reference standards for marine climate variables. Assessing system requirements for satellite calibration and algorithm development along with validating global analysis/reanalysis products will establish priorities for obtaining future marine climate observations and rescuing historical observations. Leveraging ongoing data homogenization activities from the land surface community and developing software to streamline satellite-to-*in situ* and model-to-*in situ* data comparisons will aid product development.

Note: Considerable editing was applied to some sections during the last steps to finalize this publication, with the aim to define all acronyms, and balance the length of similar sections.

1: Adapted from a report in *Eos*, vol. 92, no. 43, p. 376, 25 October 2011 (doi:10.1029/2011EO430005).

2: Under budgetary constraints and owing to governmental decisions external to NOAA, the US terminated—it appears permanently—all of CDMP's external grant funding, starting in fiscal year 2011.

PROCEEDINGS OF THE *THIRD INTERNATIONAL WORKSHOP ON ADVANCES IN THE USE OF HISTORICAL MARINE CLIMATE DATA* (MARCDAT-III)

(1) Introduction

1.1 The *Third International Workshop on Advances in the Use of Historical Marine Climate Data* (MARCDAT-III) was held at the European Space Agency (ESA) Centre for Earth Observation (ESRIN), in Frascati, Italy, 2–6 May 2011. This workshop follows international marine workshops in Canada (1999), USA (2002), Belgium (2003), UK (2005) and Poland (2008) where MARCDAT alternates with more formal JCOMM *Workshops on Advances in Marine Climatology* (CLIMAR). These workshops have brought together a wide spectrum of marine data users, and managers of marine data and products, and have included an underlying focus on the continuing evaluation, utilization, and improvement of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS).

1.2 The workshop showcased and built on recent advances in marine climatology, including (i) evaluation, utilization and improvement of the over 300-year record of ICOADS (e.g. using satellite data); (ii) development of multi-decadal, homogeneous gridded datasets for climate applications; and (iii) characterization of uncertainty and bias in marine observations and products.

1.3 The overall objective of the workshop was to recommend a 10-year action plan for improved integration and accessibility of climatological observations (see section 4 below).

1.4 Within this general context three themes were identified for this particular meeting, and papers dealing with research related to these were given particular consideration:

1) Improving integration and promoting joint analysis of remotely sensed and *in situ* data, in the context of the IOC-WMO-UNEP-ICSU[3] Global Climate Observing System (GCOS) and Committee on Earth Observation Satellites (CEOS) Essential Climate Variable (ECV) framework, and ESA Climate Change Initiative (CCI);
2) Improving the data management, accessibility, traceability, homogenization, and analysis of marine surface variables as part of the development of long-term global surface datasets—with reference to cross-cutting issues in land-based research;
3) Initiatives seeking to capitalize on available advances in resolving data homogeneities and uncertainties, and in quality control (QC)—by making bias-adjusted and better characterized data and metadata available directly to researchers.

1.5 Other research and operational aspects of marine data processing and usage were also discussed, including wave summaries, historical data rescue priorities, climate observing system adequacy assessments, dataset comparisons, and the construction of marine climate indices.

1.6. The programme consisted of invited and contributed oral presentations organized into eight sessions (see section 2), punctuated by five plenary discussions (section 3). In addition, 16 posters (see Annex I) were presented, organized according to the three workshop themes. The workshop also facilitated two closely related side meetings, the first for the GCOS Sea Surface Temperature (SST) and Sea Ice Working Group (SST-SI-WG), and the second for JCOMM Expert Team on Marine Climatology (ETMC) Task Teams.

1.7 Further information on the workshop, including copies of oral and poster presentations, and their abstracts is also available from the CD-ROM accompanying this JCOMM Technical Report, as well as on-line[4].

3: All acronyms are defined at the end of this publication.
4: This *Proceedings* is available on-line from: ftp://ftp.wmo.int/Documents/PublicWeb/amp/mmop/documents/JCOMM-TR/J-TR-59-MARCDAT-III/index.html and from http://icoads.noaa.gov/marcdat3/

(2) Session reports

2.1 SESSION A: ESA activities in support of marine climate data

Chair: Dr Craig Donlon (ESA)
Rapporteur: Dr Andrew Bingham (National Aeronautics and Space Administration (NASA), USA)

2.1.1 Opening: ESA activities in support of marine climate data – Dr Mark Doherty (Head of the ESA CCI Programme)

Dr Doherty provided a summary overview of ESA Earth Observation Programmes and Climate Data stressing the continuity of EO missions at ESA since 1991. An expanding portfolio of successful missions addressing ocean, atmosphere, land, ice and solid earth applications were reviewed. ESA now has in place a data policy of free and open access to on-line datasets, for all uses. Moreover, ESA is fostering scientific cooperation by building long-term cooperation to ensure sustained and active ESA data contribution to major international scientific efforts, promotion of ESA missions within new and wider earth science communities and, continued coordination of ESA activities with international scientific priorities.

The ESA CCI has a focus on GCOS requirements for ECVs with a goal of allowing ESA, together with its Member states, to realize the full potential of the long-term (now 30-year) global EO archives as a significant and timely contribution to the ECV databases required by the United Nations Framework Convention on Climate Change (UNFCCC). The ESA CCI has started with 10 ECV projects: SST, sea level (SL), ocean colour, greenhouse gasses, aerosol properties, fire disturbance, land cover, glaciers, atmospheric ozone and cloud properties. Three new projects are expected to start in late 2011 and include soil moisture, sea ice and ice sheets. Each CCI project is tasked to collect user requirements, test and select the best algorithms to apply to EO data, develop product specifications and a define a system for future CCI reprocessing activities. Key issues for the programme include the development of uncertainty characterisation and uncertainty estimates for all EO data, conducting all work in an open, transparent and repeatable manner, adherence to international data standards and fostering excellent international cooperation. A climate modelling user group (CMUG) provides guidance and review of each project to ensure that all outputs can be accommodated by the climate modelling community. This is essential if EO measurements are to be fully exploited by the climate community to enable climate services. CCI is a €75M activity funded for a period of five years.

Dr Doherty stressed that both EO and *in situ* measurements are fundamental to CCI activities and the challenge is to learn how both communities in the marine environment can work effectively together. This was the driving reason for ESA hosting the MARCDAT meeting at ESRIN and he encouraged all present to address the need for providing homogenous climate data records (CDR) that seamlessly include the long-term historical *in situ* records and the modern era satellite records that are expected to continue into the future through missions such as the European Union (EU) Global Monitoring for Environment and Security (GMES) Sentinel series of satellites.

2.1.2 WMO activities in support of marine climate data – Mr Etienne Charpentier (WMO Secretariat)

Mr Charpentier presented an overview of WMO activities in support of marine climate data focusing on the strategic objectives and priorities approved[5] by the WMO sixteenth Congress (Geneva, 16 May–3 June 2011) for the next financial period (2012–2015), many directly relevant to MARCDAT. For example, ocean data, and historical marine climate data in particular are expected to play a crucial role in the Global Framework for Climate Services (GFCS) now under development. WMO will also start implementation of the WMO Integrated Global Observing System (WIGOS) during this period, an activity aiming to produce observational data that are more

5: As anticipated, the presented strategic objectives and priorities of the WMO, were approved by the WMO sixteenth Congress shortly after the workshop.

traceable, more coherent, documented with appropriate metadata, and of known quality. Information on requirements for marine data, including marine climatological data for a number of WMO applications addressed in the WMO Rolling Review of Requirements (RRR) was presented, as well as the roles of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM), and other Technical Commissions such as the Commission for Basic Systems (CBS), and the Commission for Climatology (WMO-CCl).

2.1.3 IOC/IODE perspectives on long-term ocean climatic datasets – Mrs Sissy Iona (JCOMM Data Management Programme Area Coordinator, IODE Co-Chair, Hellenic Centre for Marine Research (HMCR), Greece)

The International Oceanographic Data and Information Exchange (IODE) Programme of the Intergovernmental Oceanographic Commission (IOC) was presented by Mrs Iona. The role of IODE is to enhance marine research, exploitation and development by adopting standards and formats, recovering historical and recent datasets and providing easy discovery and access to the data and their information. Specific activities that contribute to the rescuing, management, long-term archival and provision of global datasets available to the research scientific community for climatic studies were highlighted, such as Global Oceanographic Data Archaeology and Rescue (GODAR) and the World Ocean Database (WOD) Project. Participants were also informed about progress on the development of interoperability through the Ocean Data Standards (ODS) Pilot Project and the ambition of the oceanographic community was stressed to build an integrated global easy access system for non-homogenous and geographically distributed marine data and information systems through the Ocean Data Portal (ODP).

2.1.4 The JCOMM *in situ* Observations Programme Support Centre (JCOMMOPS) – Mr Mathieu Belbéoch (JCOMMOPS), presented by Mr Etienne Charpentier (WMO Secretariat)

Mr Charpentier also reported on the activities of the JCOMM *in situ* Observations Programme Support Centre (JCOMMOPS) and its role with regard to the implementation of ocean observing systems as well as its usefulness to the MARCDAT community. JCOMMOPS provides day-to-day technical support at the international level to the national programme managers of *in situ* marine observing systems (i.e. drifting buoys, moored buoys in the open ocean, ships, and profiling floats) participating in the IOC-WMO-UNEP-ICSU Global Ocean Observing System (GOOS). While JCOMMOPS is already assisting with real-time distribution of these data to international users, and collection of instrument/platform metadata and submission to archive centres, the workshop recommended that JCOMMOPS play an increasing and pro-active role in the management of such metadata from Rigs and Platforms. In addition, JCOMMOPS is producing monitoring products, and performance metrics, of utility to the marine climatological community. With the view of enhancing links with satellites agencies, the workshop further recommended that JCOMMOPS could play a useful role in this regard—for example by enabling the relay of data-quality information between the *in situ* and satellite communities, by promoting the use of appropriate *in situ* instrumentation to address the requirements for satellite validation, and providing information about such requirements.

2.1.5 Global ocean fundamental climate data records – Dr David Halpern (Senior Advisor, Earth Science Research, NASA, USA)

Dr Halpern explained that a CDR often requires combining measurements from different instruments, each with different performance characteristics, which makes the creation of a harmonious data record, with high accuracy and stability, challenging. The process is dependent on continuous calibration and transparency, must be reproducible, and the results accessible. Reprocessing data is also essential to incorporate new knowledge on sensor performance and algorithms relating raw measurements to geophysical variables. Dr Halpern illustrated these issues through observations of global mean sea level trend where continuous monitoring, *in situ* validation, satellite cross-calibration and inter-agency cooperation was required to provide an accurate record of sea level rise. Two additional CDRs were discussed: sea ice and SST. In addition, Dr Halpern pointed out the usefulness of the uniform characteristics of satellite data to calibrate *in situ* data, and showed how satellite data contributed to the identification of errors in *in situ* measurements of surface wind speed, sea level, and ocean heat content. He concluded with a list of critical attributes for CDRs: characterization of multiple instruments; calibration; data processing and product generation; interaction with the scientific community; continuous vigilance; expert scientific staff; open and transparent data processing information; and, international collaborative effort.

2.2 SESSION B: The ESA Climate Change Initiative (CCI) and other satellite data

Chair: Dr Craig Donlon (ESA)
Rapporteur: Dr Andrew Bingham (NASA, USA)

2.2.1 The European Space Agency's Climate Change Initiative project for sea surface temperature (SST CCI) – Dr Chris Merchant (University of Edinburgh, UK)

Dr Merchant began with an overview of the process used for SST retrieval using thermal infrared satellite measurements. Many teams with some success have used a traditional regression to *in situ* data to determine SST retrieval algorithm coefficients. An alternative approach relies on radiative transfer forward modeling (RTM) to determine the retrieval coefficients, which allows *in situ* data to remain largely independent and available for validation. In both approaches the issue of identifying and flagging cloudy data in thermal infrared satellite data is not yet completely solved. Another challenge is to adequately account for thermal stratification of the upper water layers that may lead to a decoupling of the warmer diurnal layer from SST at several meters depth. Modeling tools have been developed to address this situation but a lack of high temporal resolution data hinders the application of diurnal variability models.

Dr Merchant explained that the Advanced Along Track Scanning Radiometer (AATSR) flying on the ESA Envisat (Environmental Satellite) platform was specifically designed for climate research. Considering the requirements for climate quality, the motivation behind the SST CCI project is to demonstrate of the potential for a stable, accurate and independent (i.e. with respect to *in situ* data sources) SST dataset using a variety of satellite sensors. The project will develop consistent records with uncertainties attached—which is a strong user requirement. The approach will be to look at the components of the error (including calibration/forward model uncertainty, radiometric uncertainty, algorithm retrieval uncertainty, contamination i.e. clouds/ice uncertainty) for specific time and space scales (e.g., several days at 1000km). This has not been thoroughly tackled to date. It is also a challenge to communicate uncertainties compared to traditional bias and standard deviation approaches taken by other projects.

Additionally Dr Merchant explained that in the project *in situ* SST data would be kept as independent as possible from the retrieval (a small number of *in situ* data are necessary to constrain the radiative transfer model). *In situ* data can then be used to assess the new EO dataset. This means that *in situ* data must be stable and accurate over time: this is a problematic due to the changing nature of the *in situ* observing platforms in time and the limited number of measurements early in the satellite record (1980s to early 1990s). Maps were presented showing that for the AATSR, climate quality is possible over large areas of the global ocean when comparing to QC'd drifting buoy measurements. However, in order to perform this comparison measurements must be adjusted to account for SST_{skin}[6] (satellite) and SST_{depth}[7] (*in situ*) differences, diurnal variability signals and differences between successive satellite sensors. The project will also use AATSR as a reference for other satellites, maintaining the *in situ* independent for validation. For example the long-term (1981-) Advanced Very High Resolution Radiometer (AVHRR) satellite data will also be processed using RTM for the first time.

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[6] SST_{skin}: Sea Surface Skin Temperature – https://www.ghrsst.org/ghrsst-science/sst-definitions/

[7] SST_{depth}: Sea Water Temperature at depth z, e.g. SST_{2m} – https://www.ghrsst.org/ghrsst-science/sst-definitions/

Dr Merchant concluded by noting that developing uncertainty estimates is just as much work as generating the SST retrieval algorithm—especially if *in situ* data are reserved for verification and validation work. However, with the right satellite and *in situ* sensors, measurements and approach the SST CCI team is confident of delivering a stable and accurate SST climate record from space. More information on the project can be found on the web[8].

2.2.2 Accurately measuring sea level (SL) change from space: an ESA Climate Change Initiative (Sea Level CCI) – Dr Gilles Larnicol (Collecte Localisation Satellites, (CLS), France), presented by Dr Michael Ablain (CLS, France)

Dr Ablain explained how sea level serves as a sensitive index of climate change and variability—in effect integrating changes and interactions of all components of the climate system (ocean, atmosphere, cryosphere, hydrosphere). Moreover SL varies globally and regionally in response to internal climate variability and external—including anthropogenic—forcing, with its rise among the most negative consequences of global warming. For about two decades, SL has been routinely measured from a number of satellite instruments using altimetry. After removing annual and semi-annual signals from the altimetry record, the global mean SL (GMSL) trend is 3.25mm/yr (with glacial-isostatic adjustment) from 1993–2011. The regional MSL trends are estimated using all available altimetry missions. Regional variability in MSL trends at ±10mm/yr is much larger than the GMSL trend. The confidence on the GMSL trend is good (±0.6mm/yr) but falls short of the GCOS requirement for GMSL stability of 0.3mm/yr. However, to fully address important scientific questions, space-based SL measurements need to be as accurate as possible. These questions include: How much is SL/GSML rising, how unusual is its rise, and what are its causes? What are the factors causing non-uniform SL change and how do corresponding spatial trend patterns evolve through time? Are climate models able to reproduce present and past SL changes? What are the coastal impacts of SL rise? A greater understanding and reduction of all sources of error affecting altimetry-based SL products therefore is required. This is the main goal of the ESA CCI Sea Level project (composed of nine European partners plus selected international experts).

Using multi-mission satellite altimetry data, the project proposes a new ECV processing system for the generation of high-accuracy SL products for the last two decades. The project incorporates calibration/validation (Cal/Val) phases (including tide gauge comparisons and an SL budget approach), and comparisons with climate models and ocean reanalyses. In order to measure the drift of each altimetric MSL time series, *in situ* measurements are used including global tide gauge networks and temperature/salinity ocean profiles from the Argo float program. Both data types are complementary since tide gauges provide very good temporal sampling (hourly) but poor spatial sampling with data only close to the coasts, whereas Argo provides global open ocean coverage but with reduced 10-day sampling. Furthermore, Argo data are only available from 2004 with ~3K floats covering ~80% of the ocean surface. Dr Ablain noted that using these *in situ* data sources, improvements to the SL calculation for all the altimetry missions especially in terms of long-term stability are possible. For example, altimetry and *in situ* comparisons can also be useful to demonstrate which satellite mission is correct when discrepancies are detected.

The project is currently comparing altimetry algorithms, developing new algorithms and has initiated an algorithm validation using *in situ* data. Three types of global diagnostics will be used including internal analyses, multi-mission comparisons and altimeter comparisons to *in situ* data. The high-accuracy space-based SL time series will complement historical tide gauge-based SL, ensuring a high-quality climate record. The project will produce global and regional SL anomalies, error indicators, trends and phase of key signals, etc. More information on the project can be found on the web[9].

2.2.3 ESA Ocean Colour CCI – Dr Laurent Bertino (NERSC, Norway)

8: http://www.esa-sst-cci.org/
9 : http://www.esa-sealevel-cci.org/

Dr Bertino explained that understanding the structure and function of marine ecosystems requires frequent and global observational coverage, which is only possible from space. Ocean colour from satellite measurements provides information on the distribution of marine phytoplankton at synoptic scales. Phytoplankton are known to influence both the carbon cycle and heat budget. Dr Bertino noted that ocean colour observations are needed for the evaluation, initialisation and constraint of models of the marine ecosystem, biogeochemistry and fisheries.

The major scientific problems tackled by the ESA CCI Ocean Colour project include: satellite calibration (with particular focus on the MEdium Resolution Imaging Spectrometer (MERIS)), pixel classification and masking (to avoid cloud or glint affected pixels, for example), atmospheric correction, product algorithms, data merging (including merging MERIS with MODerate resolution Imaging Spectroradiometer (MODIS) and Sea-viewing Wide Field-of-view Sensor (SeaWiFS)) and evaluation of the NASA Coastal Zone Color Scanner (CZCS) mission to extend the ocean colour record back to three decades.

A critical component of the project is to quantify, and where possible reduce errors. This requires meticulous analyses of the various sources of error in ocean colour products including instrument specifications, instrument calibration procedures, atmospheric correction and in-water algorithms. Several approaches to error characterization will be used such as neural networks, formal error analysis and fuzzy logic. The scope of this first stage of the work includes analysis of requirements, algorithm specification, algorithm development, product prototyping and validation. A significant challenge is to work with an under-sampled ocean: despite efforts of the ocean community over many years, the *in situ* databases for ocean colour matchups are limited in number, and also in geographical distribution. This presents a major challenge to the stabilization and development of a satellite ocean colour time-series, and consequently also to demonstrate how the project data products will meet GCOS requirements for the quality and long-term stability of ocean-colour data.

The expected outcomes include quantification of uncertainties with: details of the processing chain for different sensors; improved calibration of sensors; atmospheric correction and cloud detection; retrieval of Inherent Optical Properties (IOP) and concentrations of water constituents; and the vertical distribution of constituents. For all of these a quantification of uncertainties for different regions / provinces will be derived. Furthermore, the relationship between uncertainties and changes in water properties/ trends for different provinces will be developed. More information can be found on the web[10].

2.2.4 **ESA Cloud CCI** – Dr Juergen Fischer (Free University of Berlin, Germany)

Dr Fischer explained that the ultimate objective of the CCI Cloud project is to provide long-term coherent cloud property datasets exploiting the synergic capabilities of different EO missions relevant to cloud properties. Large differences exist between different cloud datasets, which need to be properly characterized and understood. This is a difficult task due to the many and varied sensors and channels, algorithms and corrections applied to datasets. The project will improve product accuracies and enhance temporal and spatial sampling compared to single source data sets. The output will be an intercalibrated radiance dataset combining ESA and non-ESA missions. Uncertainty estimates will be derived through international collaboration building on Global Space-based Inter-Calibration System (GSICS) results. Complementary methodologies will be developed where necessary enhancing the GSICS capabilities to address the project requirements.

The project will also develop a coherent physical retrieval framework for the GCOS cloud property ECV (i.e. cloud cover, cloud top height and temperature, liquid and ice water path) as an open community retrieval framework to be publicly available and usable by all scientists. Two multi-annual global datasets including uncertainty estimates will be generated based on carefully calibrated and intercalibrated radiances. The baseline specification outputs will be monthly means for each dataset (e.g. AVHRR, Along Track Scanning Radiometer (ATSR), MERIS, MODIS), for sensor group and merged datasets. This will be a unique multi-sensor CDR of cloud properties

10: http://www.esa-oceancolour-cci.org/

based on a coherent physical retrieval framework, with improved quality, pixel scale error characterisation and multi-layer cloud estimates.

Validation of cloud property products will be performed against ground based and other satellite based measurements taking into account the individual error structures of each measurement as much as possible. A common database will be established within the framework of the Global Energy and Water Cycle Experiment (GEWEX) for the assessment of cloud datasets. More information can be found on the web[11].

2.2.5 Climate relevant aerosol retrieval over ocean from the ESA Aerosol CCI project – Dr Gerrit De Leeuw (Finish Meteorological Institute, Finland)

Dr De Leeuw presented the ESA Aerosol CCI project and described how aerosols exert a perturbing influence on the observations of ocean parameters with electro-optical instruments such as those used from space to detect ocean colour, chlorophyll or SST. The retrieval of such parameters requires the application of an atmospheric correction that accounts for aerosol effects. One of the goals of the project is to provide the best possible global multi-year aerosol dataset using data from several European satellite sensors. This will be achieved through the preparation of consistent prototype aerosol retrieval algorithms. An analysis and comparison of the retrieval results for a selected dataset and specific case studies has begun in order to understand the strengths and weaknesses of each algorithm and the differences between the products. Information on best practices is exchanged and implemented to improve existing algorithms. Through comparison and validation against other satellite and ground-based reference datasets, the reasons for differences between the algorithms are explored in detail. At the same time, elements of community algorithms and harmonized retrieval are being developed. This analysis covers the different assumptions and algorithms on optical aerosol properties, surface reflectance, the treatment of bi-directionality and cloud masking as well as auxiliary datasets used in the retrieval algorithms.

The key scientific issues addressed by the project include a joint definition of micro-physical / optical aerosol types using consistent comparisons between different algorithms for all prototype aerosol ECVs. Cloud masking is a significant challenge to be tackled through a comparison and optimization of algorithms. By comparing different approaches to address the treatment of reflectance properties, solutions will be identified for the ATSR, MERIS and POLarization and Directionality of the Earth’s Reflectances (POLDER) instruments. In addition the auxiliary data (e.g. elevation, land cover, ocean reflectance, humidity) used by the different retrievals will be harmonized. The *in situ* AErosol RObotic NETwork (aeronet) atmospheric aerosol properties datasets will provide an important tool for the project and aeronet data will be used extensively throughout the analyses. As for all other CCI projects, a comprehensive uncertainty estimate will be provided with all data. More information can be found on the web[12].

2.2.6 Critical issues for the specification of unbiased and homogeneous marine surface wind reanalyses – Dr Vince Cardone (Oceanweather Inc., USA)

Dr Cardone began with a series of questions related to the development and application of marine surface wind reanalyses: What drives our interest in marine wind climatology? How have we, and do we, satisfy our needs? What has been the impact of remote sensing of marine surface winds vs. traditional Voluntary Observing Ship (VOS) sources? What has been the impact of global atmospheric reanalyses? What are the critical issues? A key user is the met-ocean design community that uses hindcasting tools to understand extreme conditions through analysis. Winds drive ocean response models in this approach. Today, the community is concerned with the 10K-yr return period criteria for extreme events, an extremely challenging target. At 10K years the Weibull distribution extrapolates to a significant wave height (H_s) of ~26m, which implies a maximum wave height (H_{max}) of ~46m. Limiting his analysis to post-1950 storms increased extremes by about 10%

11: http://www.esa-cloud-cci.org/
12: http://www.esa-aerosol-cci.org/

to Hs ~28m and H_{max} ~50m for a "normal" maximum wave! Dr Cardone questioned if a tropical cyclone on this planet could generate such a sea state noting that this is an issue of physics vs. statistics.

There is a clear need to homogenize ship wind reports to equivalent neutral winds. These data are used to validate satellite wind speeds together with winds derived from ocean weather buoys. There seems to be a systematic lack of high wind speed data from buoy installations possibly related to the fact that buoys are often located near to continental areas where winds are not the strongest. This poses a challenge to validate winds derived from satellite measurements above 20m/s and there is a clear need for better *in situ* wind speeds in these conditions. Large oil and gas platforms can be used with fixed reference frames but measurements are often taken at much higher elevations (>40m) and they are few in number and data are not always available due to commercial sensitivities.

Dr Cardone described a number of data assimilation experiments to understand the impact of satellite winds on reanalysis and hindcast operations. QuikSCAT (Quick Scatterometer) and other such wide-swath satellite instruments provided excellent monitoring of the time and space evolution of the surface wind field. Dr Cardone noted that the "recent" multi-decadal climate of the "normal" surface marine wind and waves over the open global oceans is fairly well known through recent reanalysis projects, the availability of scatterometry and progress in wave modeling. However the climate of extremes over the global oceans associated with "winter hurricanes" and tropical cyclones remains less well known. The structural evolution of the wind field is just as important as minimum central pressure or absolute peak wind speed. Such a climatology is critically needed for both engineering design purposes and to establish the climate extremes of the present climate to serve as a baseline for climate change studies.

Following the lead of the ESA Data User Element (DUE) GlobWave project that conducted extensive altimeter data homogenization and QC, a similar effort should be directed toward passive and active microwave remotely sensed wind datasets. There is a clear need to extend the buoy arrays into remote and harsh ocean environments, to serve as a reference for remote sensing systems. Large hulled buoys are better for winds, small hulled buoys are better for waves and these conflicts need to be resolved. Dr Cardone explained that there is a need to develop a sound physical basis for the evident wide dynamic range of Ku-band scatterometry and new conceptual models of kinematic properties of wind fields in "winter hurricanes". Although fully assimilative reanalysis approaches leave no surface marine wind data to independently assess skill, forcing of wave models and their output validation against *in situ* and altimeter wave measurements appears to provide a good substitute metric. Finally, there is a need to prepare for the next generation of super-giant container vessels that raise new challenges to continuation of VOS density of observations and their accuracy. Wind and other meteorological data from these ships will need to be understood and properly characterized.

2.2.7 Pathfinder, GHRSST, and the SST Essential Climate Variable framework – Dr Ken Casey (NOAA/NODC, USA)

Dr. Casey explained that in the last view years, the SST community has coalesced its thinking on an ECV framework through the efforts of the Group for High Resolution SST (GHRSST) and the GCOS SST-SI-WG. The resulting framework consists of a three-dimensional cube-array of related and coordinated products, each with different space-time, processing level, and SST-type characteristics. Considering related SST datasets together in a cube framework facilitates joint analysis and visualization, and can help optimize the distributed efforts of the international community—thus e.g. the ESA CCI projects all use the same "cube" approach.

The challenge now is to connect the satellite data of the last 30 years to the long-term SST climate record derived from *in situ* measurements from ships and buoys. SST-SI-WG has initiated an experiment together with GHRSST to study differences between 10 historical SST analyses and satellite data (see web[13]). The goal is to understand the differences arising from the analysis systems themselves. Contributing to this framework is the latest version of the AVHRR SST CDR, known as Pathfinder Version 6, which has been significantly improved and is compliant with agreed GHRSST data formats. Pathfinder 6 includes: latitudinal-banded coefficients for the retrieval algorithm; a new land mask; corrections for rounding errors; use of the Reynolds daily Optimal Interpolation (OI)[14] as a background field and other improvements. The resulting dataset compares well to *in situ* drifting buoys with a standard deviation of 0.37K. The need for accurate SST measurements from ships and drifting buoys was stressed. Dr Casey also noted the need for each new SST measurement to be reported with a depth of observation.

Dr Casey then described the GHRSST Reanalysis Technical Advisory Group (RAN-TAG) that helps to coordinate international SST reanalyses activities together with the SST-SI-WG. A summary (see web[15]) of current and planned SST satellite reanalysis activities from around the world presents 21 projects with some gaps identified, in an easy to understand and consistent format. Dr Casey concluded that SST is an active area of climate data production with strong international collaboration (e.g. ESA CCI SST project, GHRSST, CEOS SST Virtual Constellation and SST-SI-WG) that demonstrates the continuing coordination and maturity in the SST world. Further collaboration with the *in situ* community in both forward-looking (Argo and improved drifting buoy capability) and historical (improved *in situ* uncertainty estimates) contexts is a key focus for the satellite community

2.3 **SESSION C:** Satellite and *in situ* datasets, reanalyses, and analyses

Chair: Dr Ken Casey (NOAA/ National Oceanographic Data Centre (NODC), USA)
Rapporteur: Mr Martin Rutherford (Royal Australian Navy, (RAN), Australia)

2.3.1 **A co-location service for *in situ* and remotely sensed measurements** – Mr Steve Worley (National Oceanographic Data Centre (NCAR), USA)

In this invited talk, Mr Worley proposed an on-line web based capability to extract and deliver matchup data in three modes: find satellite data by spatio-temporal and parameter search to match *in situ* observations; find *in situ* observations to match satellite data or find both matching satellite and *in situ* data that meet spatio-temporal and parameter search criteria.

Discussion: It was suggested that the system should be user friendly, web based and use open standards for future interoperability with the WMO Information System (WIS) and Ocean Data Portal. There appeared to be sufficient interest to support further development based on likely use and willingness to provide feedback during the development phase. The authors were also encouraged to compare their proposal with a similar but much larger activity underway at ESA to develop a Generic Environment for Cal/Val Analysis (GECA). A concern was expressed that the proposed solution might not be scalable to large satellite datasets such as MODIS or across multiple datasets.

2.3.2 **Satellite data for marine climate monitoring purposes** – Mrs Gudrun Rosenhagen (Deutscher Wetterdienst (DWD), Germany)

Mrs Rosenhagen described two existing systems, the Satellite Application Facility on Climate Monitoring (CM SAF), which concentrates on atmospheric water and energy from operational weather satellites, and the Hamburg Ocean Atmosphere Parameter and Fluxes from Satellites (HOAPS), which provides orbit, daily and climatological precipitation, evaporation and freshwater cycle flux variables from microwave instruments.

13: http://ghrsst.nodc.noaa.gov
14: Reynolds, R.W., N.A. Rayner, T.M. Smith, D.C. Stokes, and W. Wang, 2002: An improved in situ and satellite SST analysis for climate. *J. Climate*, **15**, 1609-1625.
15: http://ghrsst.nodc.noaa.gov

2.3.3 Creating a consistent time series of global SST from *in situ* and satellite data sources – Dr John Kennedy (Met Office, UK)

Dr Kennedy outlined a method for generating a homogeneous long-term data record covering *in situ* and satellite SST, including uncertainties. He identified significant biases to be addressed. For satellite data corrections for aerosols and drift in the equatorial crossing time for AVHRR were required as was removal of known biases in ATSR1. *In situ* data need adjusting for the evolution of instrument types. The bias reduced data would then be blended, and a Monte Carlo approach used to determine uncertainties.

Discussion: A request was made to feedback all QC information on *in situ* data to ICOADS.

2.3.4 Use of satellite data for gridded SST analysis of the pre-satellite period – Dr Alexey Kaplan (Columbia University, USA)

The complex technique presented by Dr Kaplan used satellite data to estimate covariances, which can then be applied to the older data sparse historical datasets, because the uncertainties are stationary in time.

2.3.5 Improved historical reconstructions of SST and marine precipitation variations – Dr Tom Smith (University of Maryland, USA)

Dr Smith described an iterative technique using rotated Empirical Orthogonal Functions (EOFs), which iteratively adds data to reconstruct a pre-satellite era analysis from satellite observations. He also illustrated another application of this technique with precipitation data, where post-1979 satellite precipitation statistics were applied to historical rain gauge measurements.

2.3.6 The ERA-Clim Project – Dr Hans Hersbach (European Centre for Medium-Range Weather Forecasts, (ECMWF))

Dr Hersbach provided a detailed overview of activities in preparation for the next major ECMWF reanalysis (ERA), planned for 2014. These included increased recovery of upper-air data and of other data for sparse areas, preparation of relevant satellite datasets for input into the analysis and the construction of a pilot reanalysis. The advantages of reanalyses were outlined, emphasizing the benefits of combining models and observations in a way consistent with assimilation and forecasting systems. Any data recovered will be made available to the entire community.

2.3.7 OSTIA Reanalysis – A high resolution SST and sea ice reanalysis – Dr Jonah Roberts-Jones (Met Office, UK)

Dr Roberts-Jones detailed the numerical methods used to construct the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) SST and sea-ice analysis based on single sensor bias corrected ATSR1, ATSR2, AATSR, AVHRR and Ocean and Sea Ice Satellite Application Facility (OSI-SAF) inputs. Comparisons with Argo and the Hadley Centre SST Data Set (HadSST) elicited questions on the comparison depth used for Argo matchups (near surface value at nighttime). The observed cold bias in OSTIA against Argo could not be explained.

2.3.8 Satellite and *in situ* SST comparison and merging in the Mediterranean Sea – Dr Aida Alvera-Azcarate (University of Liège, Belgium)

Dr Alvera-Azcarate described a regional SST analysis research project for the Mediterranean. The coverage, resolution and precision of satellite only and *in situ* only observations do not meet numerical weather prediction (NWP), ocean forecasting and climate research requirements. This is addressed through merging of the two datasets.

Discussion: In response to a question, Dr Alvera-Azcarate stated that variations in the depth of ship-based SST observations are not accounted for in the analysis; also she was encouraged to make her analysis available to GHRSST.

2.3.9 Session concluding summary/discussion

Researchers are currently using satellite and *in situ* data together to perform analyses, either through using satellite data to calculate statistics and applying them to sparse historical *in situ* data in climate studies, or though blended operational analyses. The requirement for easy access to both satellite and *in situ* observations appears strong, noting existing use and the positive response to the proposal by Steve Worley (section 2.3.1) to build an online interactive web based data matchup extraction tool. This requirement is further evidenced through the existence of online satellite datasets such as GECA and those presented by Gudrun Rosenhagen (section 2.3.2).

While a number of clear requirements for the combined analysis of satellite and *in situ* measurements were outlined in this session the communities are yet to establish interoperable data access systems.

2.4 SESSION D: *In situ* datasets, reanalyses, and analyses

Chair: Dr Thomas Smith (University of Maryland, USA)
Rapporteur: Dr Alexey Kaplan (University of Columbia, USA)

These six talks—one invited from Dr Kennedy, and five contributed by Drs Hirahara, Berry, Sansó, Gouretski, and Fukuda—focused on the issues relevant to the workshop goals: resolving data inhomogeneities by identifying and correcting biases (Kennedy, Hirahara, Gouretski, and Fukuda), countering the effects of spatial sampling inhomogeneities by producing gap-free gridded analyses of available observations (Hirahara, Berry, Sansó, and Fukuda), and estimating and representing the uncertainty of bias-corrected observations (Kennedy) and of interpolated fields (Berry and Sansó).

2.4.1 All historical SST analyses are wrong*, probably even this one – Dr John Kennedy (Met Office, UK)

Dr Kennedy presented a comprehensive investigation of platform-specific biases and their proposed correction for the ICOADS *in situ* SST data in the traditional pre-1941 correction period as well as in the post-1941 period, for which until now observations have mainly remained uncorrected. The post-1941 biases may be changing due to a change from ship intake temperatures, which dominated the record before the 1980s, to buoy observations, which have become dominant in recent years. Dr Kennedy emphasized structural uncertainty and advocated multiple independent approaches to bias corrections and other data analysis issues; he recommended using as a measure of structural uncertainty a spread of an ensemble of multiple dataset versions that correspond to various “reasonable” choices and approaches used in data processing. These structural uncertainties are critical for determining multi-decadal variations. Multiple independent attempts at covering the spread of plausible biases can be used to determine the uncertainty in multi-decadal variations, but these do not yet exist so uncertainty remains only partly quantified.

2.4.2 Systematic errors in the hydrographic data and their effect on global heat content calculations – Dr Viktor Gouretski (University of Hamburg, Germany)

Dr Gouretski presented a detailed analysis and described recent advances in bias identification and sophisticated correction approaches in the ocean temperature data obtained from Expendable BathyThermograph (XBT) and Mechanical BathyThermograph (MBT). Biases in recorded XBT profiles were traced to fall-rate and possibly independent temperature sensor biases, which differ from one manufacturer to another and might depend on ocean state, ship characteristics, and observational details.

2.4.3 Ocean heat content variations and its trends estimated from historical oceanographic observations – Dr Yoshikazu Fukuda (Japan Meteorological Agency (JMA), Japan)

Since subsurface temperature biases can create noticeable errors in analyses if not accounted for, Dr Fukuda described the JMA approach to implementing such bias corrections and their analysis of 0-700m ocean heat content. With and without adjustments the multi-decadal subsurface temperature indicates warming, but variations are significantly changed when the adjustment is used. Some adjustments remain unresolved due to data from unknown types of instruments.

2.4.4 A new historical SST analysis: COBE2-SST – Dr Shoji Hirahara (JMA, Japan)

Dr Hirahara described a new version of the historical SST analysis from JMA (COBE2-SST) that was produced using EOF-based OI analysis methods. The analysis first computed a background field representing the time-changing climatology, then uses EOF modes to analyze monthly deviations from that background state, and then uses an OI to analyze the remaining daily increments from the combined background and EOF monthly analysis.

2.4.5 Assessment and validation of the NOCS2.0 dataset – Dr David Berry (National Oceanography Centre (NOC), UK)

Because of data changes over time, there may be unevenness in analysis variance, especially for daily data. Dr Berry described an existing analysis of surface fluxes from the NOC, performed by a more traditional OI implementation, as well as their plans for a newer version. Good agreement of theoretical and actual analysis error was demonstrated by comparison to moorings. Sampling biases and the influence of noise were also evaluated using statistical tests.

2.4.6 A hierarchical Bayesian model for ocean properties reconstructions – Dr Bruno Sansó (University of California Santa Cruz (UCSC), USA)

Dr Sansó presented a reconstruction of monthly SST fields from the World Ocean Atlas (WOA), 2005 edition, using a hierarchical Bayesian modeling approach. The advantages of this method include a possibility to account systematically for many types of uncertainties that are not easy to account for in more traditional methods and to represent the uncertainty of results via their posterior distribution, conditional on all the available data. Results indicate spatial structures that more faithfully reflect known oceanic physical variations, compared to the gridded fields available from WOA that are produced using a simple statistical interpolation scheme. Analyses are planned for subsurface temperature and salinity.

2.5 SESSION E: *In situ* data rescue

Chair: Mr Frits Koek (Koninklijk Nederlands Meteorologisch Instituut (KNMI), the Netherlands)
Rapporteur: Mr Wolfgang Gloeden (DWD, Germany)

Several different projects were described in the four oral presentations composing this session—together with four posters related to this topic listed in Annex I—operating both nationally internationally, to rescue historical *in situ* data. Speakers highlighted sparser amounts of data available for years before the First World War (WWI), and thus the importance to sustain and strengthen as feasible the work of data rescue for that period.

2.5.1 ACRE, citizen science and Old Weather – Dr Rob Allan (Met Office, UK)

In this invited presentation, Dr Allan discussed the Atmospheric Circulation Reconstructions over the Earth (ACRE[16]) initiative. ACRE both undertakes and facilitates the recovery of historical instrumental surface terrestrial and marine global weather observations to underpin 3D reanalyses spanning the last 200-250 years for climate applications and impacts needs worldwide. Dr Allan highlighted, for example, a "citizen science" project to digitize UK Royal Navy ships' logs for an extended period (1914 –1923) around WWI (see web[17]).

2.5.2 English East India Company logbooks – significant contributions to history and science – Mr Eric Freeman (NOAA National Climatic Data Center (NCDC), USA)

Mr Freeman described in detail a cooperative project among the British Library, UK Met Office, and NOAA Climate Database Modernization Program (CDMP) to catalog, image and digitize English East India Company about 1000 logs containing very early daily instrumental surface weather observations (mainly air temperature and pressure) covering ~1789–1834.

2.5.3 International marine data rescue: The RECovery of Logbooks And International Marine Data (RECLAIM) Project – Dr Clive Wilkinson (University of East Anglia)

Dr Wilkinson reviewed the current status of the RECLAIM—a cooperative international project to help locate and image historical ship logbooks and related marine data and metadata from archives across the globe, and facilitate digitization of the observations for merger into ICOADS. Several best practices for marine and terrestrial data rescue were proposed (e.g. to ensure that the output from data rescue activities, including from preparatory archive investigations, are preserved in formats that will be accessible to future generations).

2.5.4 Rescue of historical records of the US Fish Commission and the US Navy – Dr Catherine Marzin (NOAA/ National Marine Sanctuaries Program (NMSP), USA), presented by Mr Scott Woodruff (NOAA/ Earth System Research Laboratory (ESRL), USA)

A project led by the NMSP is rescuing historical data from these two archives. The interdisciplinary (i.e. biological, oceanographic, and meteorological) Fish Commission records are being mined (as resources permit) for their full environmental potential (i.e. not just weather data), thus helping support historical marine ecology together with other research. The largely untapped potential for rescue of additional early ship logbook data from private collections and museums (e.g. Mystic Seaport Museum, Connecticut, USA) was also noted.

2.5.5 Session concluding summary/discussion

Activities to examine and rescue historical logbooks should ensure that not only the data, but also relevant metadata, are digitized; and also that there is some mechanism such as an index linking back to the original records. While large resources have already been expended to make additional historical data available, the job remains extremely cost intensive—thus new approaches and funding sources are needed. For digitization (keying), "crowd sourcing" shows great promise, e.g. for UK Navy WWI ships' logs (section 2.5.2), provided the data are of sufficient interest to the volunteer "citizen scientists." On the other hand digitization of strictly numerical land station data seems unlikely to be as successful. It was suggested that these projects consider expanded outreach, seeking to demonstrate the critical value of data rescue, by contributing to exhibitions in museums or climate change discussions.

It was suggested that all these data rescue activities should be coordinated, leading to permanent archival of the data and information in appropriate global repositories and databanks, including:

- Documenting the known content of archives, but also whether there might be other material and sources not yet documented
- The digitization (and imaging) status of the data

16: http://www.met-acre.org/
17: http://www.oldweather.org/

- Descriptions of the quality of the original data
- What portions of data have already been digitized
- Where the digitized data are archived
- How to obtain both the digitized data and original records

Such information is mandatory to avoid unnecessary duplicative work, make the best use of sparse funds and help move further towards the generation of user-friendly datasets.

2.6 SESSION F: Land-marine: cross-cutting data and analyses

Chair: Dr Albert Klein-Tank (KNMI, Netherlands)
Rapporteur: Mrs Gudrun Rosenhagen (DWD, Germany)

Dr Klein Tank stressed in his introductory remarks to this session, consisting of the following four talks, the mutual profit gained through the co-operation between land and ocean climatologists within the WMO-CCI/CLIVAR[18]/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI). He appreciated the initiative of MARCDAT-III in taking this into account through a plenary discussion session as part of the workshop.

2.6.1 Land surface temperature records - are we keeping our side of the bargain? – Dr Peter Thorne (NOAA NCDC, USA)

In this invited talk, Dr Thorne stressed that a global dataset comparable to ICOADS does not exist for land surface observations. One major reason for this is national proprietary issues. Building on the ICOADS experience, an international databank for *in situ* land meteorological observations has been proposed, under the new International Surface Temperature Initiative (ISTI[19]). More broadly the initiative aims to create a new suite of estimates of land surface air temperature (LSAT) changes from global to regional and at a range of timescales, to benchmark these in a consistent manner and provide data products and information to end-users. As many users want to consider the entire globe rather than the land or marine components in isolation, a continuing close connection to marine data is envisaged.

2.6.2 Is it good enough? Benchmarking homogenisation algorithms and cross-cutting with efforts for land observations – Dr Katharine Willett (Met Office, UK)

With regard to the need for long-term, widespread observational datasets that are robust to varying non-climatic influences over time on systematic biases and random errors, Dr Willett proposes the benchmarking of homogenisation algorithms against known synthetic reference datasets to improve the understanding and quantification of uncertainties. Efforts towards this are underway in the land community but much can be learned from and shared with those working on marine data.

2.6.3 Changes in cloud cover and cloud types over the ocean from surface observations, 1954-2008 – Mr Ryan Eastman (University of Washington, USA)

Mr Eastman presented a climatology of cloud cover and types over the world ocean from surface observations for 1954–2008. Synoptic ship weather observations have been analyzed in 10° grid boxes for interannual variations and trends. Long-term variations were found likely to be spurious when compared with coincident island data. The global average time series of total cloud cover over the oceans showed low-amplitude, long-term variations. Among the cloud types, the most widespread and consistent relationship was found for marine stratus and stratocumulus clouds over the eastern parts of the subtropical oceans, both in their correlations with SST and their trend with global temperature changes. Little long-term agreement was found with land data covering 1971-96, while the agreement was higher at shorter time scales.

18: CLIVAR: Climate Variability and Predictability (WCRP)
19: http://www.surfacetemperatures.org

2.6.4 Estimating long-term trends of ENSO variability – Dr Andrew Chiodi (University of Washington, USA)

Dr Chiodi showed results of investigations of a high quality, 135-year record of sea level pressure at Darwin, Australia. The data are of special interest as a good proxy for the state of El Niño-Southern Oscillation. Examinations of the trend with various methods for long (>90 years) and shorter multi-decadal segments found that the distribution of multi-decadal trends includes nearly equal numbers of positive and negative trends. Over the full record, multi decadal variations but no statistically significant trend were found.

2.7 SESSION G: *In situ* and satellite wave data and analysis

Chair: Dr Elizabeth Kent (NOC, UK)
Rapporteur: Mr Etienne Charpentier (WMO Secretariat)

2.7.1 Wave measurement Evaluation and Testing – Mr Val Swail (Environment Canada (EC))

In this invited talk, Mr Swail reviewed the joint Data Buoy Cooperation Panel-JCOMM Expert Team on Wind Waves and Storm Surges (DBCP-ETWS) Pilot Project on Wave measurement Evaluation and Testing (PP-WET), which is developing a basis for continuous testing and evaluation of existing/planned wave buoy measurements, to bolster user community confidence in the validity of wave measurements from moored buoy systems. This project was established in view of wide variations internationally in buoy platforms/systems (e.g. 10% differences in significant wave height found between US and Canadian buoys). Reliable wave observations are required for a variety of applications: e.g. assimilation into offshore wave forecasting models/model validation; Cal/Val of satellite sensors; analysis of ocean wave climate/variability; roles of waves in coupling; and coastal zone modeling, e.g. erosion, sediment transport and inundation. Improved guidelines and best practices for buoy wave measurements are therefore important for making buoy measurements more consistent across networks and instruments.

An intercomparison methodology for co-located observations has been developed by PP-WET called the "First Five," based on a Fast Fourier Transform (FFT) wave spectrum analysis where that "first five" refers to the total wave energy, as well as to four directional parameters that define the low-order directional moments of underlying directional distribution of wave energy, at each wave frequency. Metadata are being collected and a catalogue being developed of quality assurance procedures used for making wave observations in different countries. Other JCOMM wave related activities and requirements for wave observations were also presented.

Discussion: In addition to supporting specific PP-WET recommendations (i.e. development of bias-adjustments methods; understanding differences between buoy systems; and the need to investigate new wave observing technologies including OceanSITES), the workshop noted that the use of wave observations from ships for inter-comparison purposes is problematic due to the lack of spectral data and because ships are mobile platforms. The workshop also stressed the importance of making the ICOADS wave observational record as correct and unbiased as possible.

2.7.2 Project GlobWave – Dr Geoff Busswell (Logica, UK)

Dr Busswell described an international project providing access to wave observations from multiple satellite platforms including altimeters and Synthetic Aperture Radar (SAR), with 25 years of consistently calibrated multi-mission satellite data currently available—utilizing a common project format for wave data and metadata:

- Physical parameters: backscatter coefficient (sigma0), altimeter/SAR wind speed, and quality/rejection flags;
- SAR: H_s, dominant wavelength, mean direction, standard errors;

- Altimeter: H_s, H_s standard error (work is also in progress on a merged altimeter product as a result of user requests.

Near real time data are available within 1-4hr of the remotely sensed observation. Additional results and products were described, including an on-line tool for querying satellite vs. *in situ* buoy data matchups, and an Error Characterization Analysis (accuracy of satellite data and buoy networks) from which discovered errors are fed back in the database as metadata fields.

Discussion: GlobWave represents a major improvement in providing consistent and convenient access to satellite-derived wave observations, which the workshop felt should prove very useful. The workshop noted that interactions with PP-WET (section 2.7.1) are highly desirable, also that a Pilot Spatial Extension to the Wave Forecast Verification Project also described in this presentation was analogous to assessments being made for buoy wave data under PP-WET. The workshop further noted that swell from SAR is complex to retrieve but GlobWave believes that it has succeeded in developing appropriate algorithms.

2.7.3 Global ocean wind waves from ICOADS during the last 130 years: reliability, extremes and climate variability – Dr Vika Grigorieva (P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences (IORAS), Russia)

ICOADS visual wind wave estimates from VOS reports were analysed for 1880 onwards. Along with model wave hindcasts and satellite data, visual waves from VOS represent an important source of global wave information, which allows for the centennial analysis of waves. The pre-processing methodology was presented along with assessments of uncertainties. A global wind wave dataset covering 1880–2008 is available, derived from bias adjusted data. Two streams cover the period prior to 1960 (when only the highest of sea and swell were reported) and from 1960 (when all wave parameters, including separate estimates of heights, periods and directions of wind sea and swell were available). The results of directional and extreme analyses were also presented. There is some evidence that extreme waves have tended to increase in height during the last decades and also became steeper.

Discussion: While visual wave observations provide a useful long-term record for mean wave parameters, estimating extreme waves from VOS observations is challenging and a range of methods has been used. Extreme wave heights computed using the Peaks-Over-Threshold (POT) method are generally higher compared to those from the Initial Value Distributions (IVD) method. POT-based estimates from VOS are closer to estimates obtained from model hindcasts. Interdecadal variability in extreme waves (1900–2007) showed weak positive changes from decade to decade, especially in well-sampled regions. ICOADS Release 2.5 was used for the presented analysis, but available preliminary monthly updates (after 2007) were not used.

2.7.4 Comparing significant wave height statistics from ICOADS and satellite altimeter data – Mr Martin Rutherford (RAN, Australia)

Mr Rutherford presented a preliminary comparison between wave statistics derived from ICOADS marine observations, and H_s data from altimeters. The rationale and results were presented, including data sources, QC and processing techniques. GlobWave provided near global coverage with about 741M altimeter observations since 1985, with further QC needed to identify a small number of unflagged invalid observations and the release of all ancillary data (note: according to GlobWave V1.3 documentation, the H_s calibrates well against *in situ* moored buoy data). In terms of *in situ* wave observations, ICOADS provided patchy coverage, particularly poor in Southern Oceans. Minimal QC was applied to ICOADS Release 2.5 wave data. This initial analysis showed climatological wave distributions from GlobWave and ICOADS have similar shapes and features but different values which were not uniform in space or time. The ICOADS statistics were found to be sensitive to whether Sea and/or Swell were included in the H_s calculations.

Discussion: The workshop encouraged GlobWave to reassess the availability of data in view of the helpful feedback provided in this presentation. Also these possible future work directions were suggested: (i) seek higher level QC information available with some ICOADS data (i.e. International Maritime Meteorological Tape format (IMMT)), (ii) consider using more complex statistical methods for gridding observations (e.g. OI), (iii) compare results with individual altimeter climatologies and ERA-40 reanalysis; (iv) decide whether to replace or augment individual altimeters with GlobWave; and (v) maintain a suite of separate satellite, *in situ* and reanalysis climatologies.

2.7.5 The effects of changes in observational practices for moored buoys on long term wave trend – Ms Bridget Thomas (EC), presented by Mr Val Swail (EC)

The primary motivation of this work was the need for homogeneous long-term marine data for validation of reanalyses/satellite data, design, and trend analysis. Also there has been high media interest in recent studies of moored buoy data but these studies did not assess or account for changes in observing methods, which affect the trends.

In terms of methodology, changes in weather buoy wave measurement methods were examined using homogeneity testing software and metadata for individual NOAA National Data Buoy Center (NDBC) and EC buoy stations, and trends based on data adjusted for these changes then calculated. The results showed that long-term moored buoy wave records contain inhomogeneities due to (i) changes in payload processing methods to determine spectral data; (ii) changes in hull type; (iii) changes in wave sensor; and (iv) other unexplained reasons. Before adjustment for non-climatic step changes, trends in monthly mean significant wave height (Hs) in the Northeast Pacific for NDBC and EC buoys were inconsistent. After adjustment, trends for NDBC and EC buoys were more consistent (for example in their variation from south to north), markedly reduced, and somewhat statistically significant. It was also noted that buoy wave data served via ICOADS are from inhomogeneous sources.

Discussion: Related to moored buoy observing system changes, the workshop emphasized the critical importance of platform/instrumental metadata, and that buoy time-series should be adjusted for such changes prior to trend analysis. A constant offset adjustment for monthly mean values may not apply to extremes or to the hourly reports (a percentage based correction factor may be better). Side-by-side installations/deployments of new and older observing systems/platforms are useful, to determine relationships that could be used to adjust the entire distribution to a common reference level. Findings from researchers regarding such inhomogeneous data need to feed back to ICOADS and buoy operators, and the workshop agreed JCOMMOPS could play a role in this regard.

2.7.6 Session concluding summary/discussion

The workshop agreed that it is important to understand the differences between buoy systems and supports the activities of PP-WET. Such activity must be ongoing and e.g. might eventually become operational under DBCP. From that perspective, it is important that instrument/platform metadata be collected and provided to ICOADS, to keep track of observing changes that might introduce artificial trends into the record. Side-by-side installations/deployments of new and older observing systems/platforms are useful, to determine statistical adjustments that could be used to create a consistent record.

Bias adjustment methods for wave observations need to be developed especially for ICOADS. The importance of adjusting long-term buoy time series for observing changes prior to trend analysis was reiterated. A constant offset adjustment for monthly mean values may not apply to extremes or to the hourly reports (a percentage based correction factor may be better). Findings from researchers regarding inhomogeneous data need to feed back to ICOADS. The workshop agreed that JCOMMOPS could play a role in this regard.

The workshop invited OceanSITES to continue working with ETWS and PP-WET investigating the development of new wave observing technologies. It also agreed that GlobWave provided a major improvement in providing consistent and convenient access to satellite-derived wave observations and urged users to use it. Noting that some GlobWave data records do not contain all the ancillary parameters, the workshop urged GlobWave to remediate them where possible. The workshop agreed that studies by Australia for comparing H_s statistics from ICOADS and Satellite Altimeter Data have been useful and should continue, since such comparisons complement the work being done to develop long-term homogeneous wave datasets from ICOADS.

2.8 SESSION H: *In situ* marine data management initiatives

Chair: Dr David Berry (NOC, UK)
Rapporteur: Mrs Sissy Iona (JCOMM/DMPA Coordinator, IODE Co-Chair, HCMR, Greece)

The three talks presented in session H examined current and new data management initiatives for *in situ* marine data. The three initiatives, as summarized below, are interlinked with the potential to impact each other. For example, delayed mode VOS data feed through to ICOADS, which in turn will form the basis for the ICOADS Value-added Database (IVAD) initiative. IVAD also has the potential to improve ICOADS. Through linkages within JCOMM, ICOADS in turn can influence the way the delayed mode VOS data are processed.

A number of themes were common across the initiatives. In each case, additional resources and more certainty about future funding would aid the initiatives. The reading of different formats and conversion to the International Maritime Meteorological Archive (IMMA) or Tape (IMMT) formats either used or had the potential to use a large amount of the resources currently available. Quality control, both minimum quality standards and more advanced QC techniques, were common to all three talks. A summary of the discussions after the talks is given below.

2.8.1 Status and plans for ICOADS – Mr Scott Woodruff (NOAA/ESRL, USA)

In this presentation Mr Woodruff reviewed the background and objectives of the ICOADS project, and the current status, with the most recent update Release 2.5 spanning 1662–2007, together with "preliminary" real-time updates extending the observation record and products forward in time monthly. Plans were discussed including completion of Release 2.6—the next major delayed-mode update by approximately 2012. Emerging linkages with satellite data (see section 2.3.1) and with the new land surface data management initiatives (section 2.6.1) were also discussed, together with resource constraints and possibilities for further internationalization of the work.

Discussion: Software to translate observations into the IMMA format is available from ICOADS. As described in the presentation, the preservability of the original observations in the context of the migration to BUFR[20] needs to be addressed. BUFR is not a format suitable for archiving because it is only machine-readable and dependent on software to read and convert the data. Different versions of the software cannot necessarily read the same data and give the same results. Additionally, there can be a loss of precision and rounding errors that are not recoverable due to conversion between units and formats. An example is observations made in °C, converted to Kelvin as part of the translation to BUFR and back to °C when translated to IMMA.

2.8.2 Developing an ICOADS Value-added Database to support climate research – Mr Shawn Smith (Florida State University (FSU), USA)

In his invited talk Mr Smith reviewed the proposed IVAD project, which would include the US ICOADS group and interested international partners to develop a "climate-quality" surface marine dataset, and create products based on this new resource. The effort seeks to preserve the legacy of hard work done by the marine climate community, i.e. in ensuring that (i) corrections and adjustments developed over the years will exist not only in the literature; (ii) easy access to adjustments for marine data; and (iii) expandable design for inclusion of new or better adjustments.

20: FM 94 BUFR GTS format: Binary Universal Form for Representation of meteorological data

Discussion: The workshop agreed that the IVAD should also be developed as part of a JCOMM Pilot Project, and related developments included in the future JCOMM Marine Climate Data System, including the concept of WMO-IOC Centres for Marine-meteorological and Oceanographic Climate Data (CMOCs), and establishment of a steering panel to approve adjustment factors prior to their inclusion in IVAD. Currently, the requirements of future users of IVAD are unclear and the workshop agreed that a survey of the potential users is needed to identify these requirements.

2.8.3 **Improving VOS data management: an update on progress from JCOMM Task Team on Delayed Mode VOS data** – Ms Nicola Scott (Met Office, UK)

Ms Scott presented the vision for a future WIS and WIGOS compliant JCOMM Marine Climate Data System (MCDS), including for the collection of delayed mode data (e.g. VOS, drifters), data providers, receiving and collecting centres, data store (i.e. CMOCs) and quality control centres. The development status of a Higher Quality Control System (HQCS) was also presented.

Discussion: The workshop emphasized that the HQCS under development needs to be aligned, as appropriate, with existing international procedures (formats, flagging, etc.). A linkage with IVAD may also prove to be useful (e.g. QC centres feeding into IVAD), thus synergies should be explored. Updates were proposed to the land mask to enable the recovery of observations made over inland lakes/seas and rivers. These are currently flagged as over land by the currently operational Minimum Quality Control Standard (MQCS) and may be excluded from analyses and the proposed changes would improve this. Concern was raised that the observations need to be flagged differently for open ocean observations compared to observations made over rivers/lakes.

There are delays in the submission of delayed mode data to the JCOMM Global Collecting Centres (GCCs) by Contributing Members (CMs). The GCCs are helping to reduce these by proactively retrieving the data from some of the CMs and applying the MQCS where the CMs do not have the resources to do so themselves. This has had a large impact on the amount of delayed mode VOS data available and was welcomed by the workshop.

(3) Plenary discussions

3.1 PLENARY DISCUSSION 1

REANALYSES, AND ANALYSES USING SATELLITE AND *IN SITU* DATASETS IN SYNERGY

<u>Co-Chair</u>: Drs David Halpern (NASA, USA) and Chris Merchant (University of Edinburgh, UK)
<u>Rapporteur</u>: Dr Vincent Cardone (Oceanweather, Inc., USA)

Opening remarks by the co-chairs clarified that the discussion session was not limited to SST, although the opening remarks attempted to stimulate discussion first on SST, since the immediately preceding technical sessions had thoroughly addressed this variable.

The co-chairs suggested the discussion begin with the addressing of issues of uncertainty in the components of any reanalyses and in the final product, and whether any single data type or its basis in an *in situ* or satellite-borne sensor, could be considered to provide an absolute standard of accuracy (the "gold standard ideal"). The considerable discussion of this issue trended toward a consensus that since SST as a variable does not enjoy a simple universally accepted definition—since ships systems, buoys and remote sensors measure different things (e.g. skin temperature versus temperature say at 3m depth)—any attempt to identify a "gold standard" is not particularly appropriate or useful (e.g. for some applications such as short-range NWP, SST accuracy requirements are not as demanding as for climate assessment applications). Still it was suggested that to check satellite systems it would be useful to install high quality calibrated radiometric SST sensors on at least Research Vessels (RVs) if not on buoys, though apparently no single such benchmark instrument has been identified nor was a global sampling strategy identified for such benchmark instrument. In analogy to the ~160 site reference land station surface climate monitoring network[21], it was suggested that perhaps the deep ocean remote area OceanSITES program might play a similar role over the global oceans, particularly since the experience of the reanalysis community appears to indicate that the arrays of operational met-ocean buoys installed mainly for weather monitoring and forecasting purposes have historically not provided unbiased SST measurements of the desired accuracy for climate monitoring purposes.

With regard to SST, these other issues were discussed:

(a) Statistical analysis methods (OI, EOF, etc.) dominate the generation of a time (i.e. monthly mean) and space continuous analysis of historical global SST from component datasets. The consensus opinion was that dynamical methods, such as those employed in atmospheric reanalysis projects, could, in principle, be implemented, and would be beneficial through coupled reanalysis, which provides continuous information exchange between ocean and atmosphere. Progress in this area is expected to be slow because of the slow time scale of the temporal evolution of SST, the paucity of temperature profile data relative to SST data, and insufficient computing capacity and capability.

(b) There is a need for continued unbiased third-party inter-comparison tests and evaluation of the many different reanalyzed datasets, but there was no discussion as to how an independent comparison effort might be implemented.

(c) There is often a distinction between the steps taken in ”reanalyses” by scientists in their attempts to homogenize different biases in different datasets, and the steps taken in the “reprocessing” of individual datasets by, say, buoy and remote sensing data processing centers. It is very important that the scientists feedback their findings to first-line data processing centers so that biases may be minimized as far up the processing chain as possible and that a metadata trail document each data manipulation process in a way that such a trail is automatically communicated to reanalysis users.

When the discussion turned to atmospheric reanalyses, it was generally agreed that notwithstanding the success of recent atmospheric reanalyses projects, with the exception of the recent GlobWave homogenization of satellite altimeter wind and wave estimates, the identification of biases over time in many marine wind and wave historical *in situ* and remote sensing datasets were not nearly as far along as for SST. The most critical need identified was for an effort comparable to GlobWave to homogenize the surface marine wind speed and direction datasets from all of the passive and active microwave satellite missions within the past three decades and that such an effort should include the currently active datasets being acquired by satellite-borne scatterometers—e.g. WindSat, Advanced Scatterometer (ASCAT) and Oceansat-2. Such an effort may also include identification of biases in winds measured by buoys of various hull size and payloads and other offshore platforms.

3.2 PLENARY DISCUSSION 2

PROSPECTS FOR WAVE SUMMARIES IN ICOADS

Chair: Mr Val Swail (EC, Canada)
Rapporteur: Mr Scott Woodruff (NOAA, USA)

3.2.1 Background

Since COADS (now ICOADS) Release 1 was completed in 1985, there have been limited changes in the simple gridded monthly summary products for 2° latitude x 2° longitude boxes (now

21: Reference type measurement work in the surface land community includes the GCOS Reference Upper-Air Network (GRAUN; http://www.gruan.org) and the US Climate Reference Network (USCRN; http://www.ncdc.noaa.gov/crn/).

computed back to 1800). Initially only 19 observed and derived variables were included, but in 1999 (as part of Release 2.0) the product suite was extended to 22 variables. Also at that time, 1°x1° summaries were added, but extended back only to 1960 (in view of sparser prior data coverage). Ten statistics (e.g. the mean, median, and number of observations) are now calculated for each year-month-box for each variable, and for two different product types: (i) “standard” (ship-only, more restrictive QC limits) and (ii) “enhanced” (ships and other platform types; broader QC limits).

Wind (sea) wave and swell parameters have not yet been among the variables summarized in ICOADS. The original selection of variables was guided by the views (back in 1981) of the Equatorial Pacific Ocean Climate Studies (EPOCS) Program as to which elements would be most useful for analyses in that narrower research context. Some of the scientific and practical considerations regarding the calculation of wave summaries for ICOADS have been discussed (Gulev, S. et al., 2011: Prospects for ICOADS Wind Wave and Swell Summaries, report in preparation). That report primarily discusses wave observations from VOS, but it should be borne in mind that ICOADS also includes some wave measurements from moored buoys.

3.2.2 Discussion

Introducing the discussion, the Chair, Val Swail, suggested a somewhat broader remit beyond “wave summaries” might prove useful. For many purposes, wave summaries might realistically only start around 1970, but we could explore possibilities for going back earlier. The main discussion questions raised by the Chair were: (i) whether we should calculate waves (and possibly swell) summaries, (ii) if so, of which specific elements, (iii) whether it would be advisable to mix buoy and ship wave data, and (iv) what QC/“trimming” should be applied? The discussion raised the following points:

- It would be important to identify users and their requirements.
- Monthly wave summaries were expected to be useful to a wide range of users although the existence of alternative satellites or hindcasting wave products was noted.
- It was noted that the existing ICOADS summaries are based on unadjusted data and that QC based on the IORAS research could be implemented. In addition checks on the consistency between different elements of the report could be developed. Known problems with the wave data should be documented and that information on data quality provided along with any summary products.
- Although IORAS do currently provide monthly wave statistics they were in favour of ICOADS proceeding with the calculation of summary wave statistics.
- The proposed IVAD project would be a suitable mechanism to capitalize on the IORAS, wave QC and analysis work and any future developments.
- It was further suggested that summaries could usefully be extended to include other variables not yet included (e.g. present weather) and calculated separately by platform types.

3.2.3 Conclusion

The consensus was that wave and swell summaries would be worth producing, if ICOADS project resources could be located to add them to the regular product mixture. No specific agreement was reached on the specific variables that should be summarized (again as practical), but extending the scope of these very basic, but important, benchmark products was thought to be important.

3.3 PLENARY DISCUSSION 3

CHALLENGES AND SOLUTIONS TO ENHANCE ICOADS

Co-Chair: Mr Shawn Smith (FSU, USA) and Mr Steve Worley (NCAR, USA)
Rapporteur: Mr Eric Freeman (NOAA/NCDC, USA)

Many topics regarding enhancing ICOADS were discussed in this plenary session, including the proposed ICOADS Value-Added Database (IVAD).

3.3.1 Enhancing data and metadata in ICOADS

3.3.1.1 New/additional digital observations available:

Digitization of new sources is resource intensive and a proposal was made to the participants to investigate if individual countries can review a list of candidate datasets and determine if they are willing to adopt a digitized collection and translate it from source formats to the IMMA format. These data could then be readily added to ICOADS as an auxiliary dataset and easily ingested in the next Release processing.

Many potential data sources were noted and include the following:

- HISTOR at DWD: still being developed. ICOADS recommended sending samples of the data as they were completed in a sort of pipelining strategy to convert the data as it becomes available rather than waiting for the full project to be completed, potentially taking many years.
- The Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP) or CLIVAR data, including sources from the Rolling Deck to Repository group (R2R).
- Eurofleets[22]: European Research Vessel (RV) alliance.
- Various baseline surface radiation and ocean colour collections.
- The International Ocean Colour Coordinating Group (IOCCG) and the Sir Alister Hardy Foundation for Ocean Sciences (SAHFOS), both for ocean colour.

A statement was also made to stress that approaching non-scientific organizations (humanities groups, museums, and archives) could be beneficial to ICOADS by enhancing input of original sources to include fully understanding the data and methods used in recording the observations.

3.3.1.2 Additional parameters that could be added to ICOADS

Many new parameters were suggested to be included in future updates of the IMMA format and additionally IVAD. These include:

- Salinity from the Global Ocean Surface Underway Data (GOSUD), WOD, and RVs – these are useful for ocean flux studies, new satellite data validation, and hydrological system research.
- Short/long wave radiation – the Shipboard Automated Meteorological and Oceanographic System (SAMOS), Russian RVs, baseline surface radiation.
- Ocean colour – historic Secchi disk observations are likely available from:
  - World Ocean Database at US NODC *[Post-meeting note: The WOD has two 2nd Header fields that could be useful, ocean colour and Secchi disk. Steve Worley and Zaihua (Hua) Ji (NCAR) will evaluate how often these data are reported.]*
  - SAHFOS
  - US and International fisheries groups (e.g. NOAA/National Marine Fisheries Service (NMFS))
- High-resolution radiometric SST skin temperatures from RVs.
- Ocean currents.
- Precipitation – historically from moored lightships and ocean weather ships, but modern observations likely found on board vessels with radiometers (e.g. on RVs) and rarely on moored buoys.

22: Eurofleets: Towards an Alliance of European Research Fleets - http://www.eurofleets.eu

The various requests for additional parameters need some further study to assess the availability (including temporal and spatial coverage), complexity of including them in the IMMA format, effort required to add them and resources that are available. The best first step is to create a draft priority list for action and then seek community review.

3.3.1.3 Existing analyses that can be leveraged

New reanalysis products can show where new data is needed in ICOADS and where biases and uncertainties can be reduced by filling spatial and temporal gaps, as identified by the reanalysis output.

Leveraging past and ongoing efforts to develop *in situ*-based climatologies provides the basis for defining corrections and adjustments for IVAD. Development of new climatologies is critical, but they are difficult, and full-scale projects would require proposals and many new resources. This would need to be a separately funded task.

3.3.1.4 Digitization best practices

For record provenance and validation, it was requested to investigate the potential of adding a new attachment to the IMMA record that points back to the original image. It was recognized in implementing this that a permanent archive would need to be maintained for the images.

3.3.1.5 Metadata enhancements

The workshop noted that better buoy metadata is critical for ICOADS and that the addition of a buoy metadata attachment would need to be designed and implemented for IMMA. The Ocean Data Acquisition System (ODAS) database in China is difficult to access and not complete enough to fulfil this requirement at this time.

3.3.2 Enhancing Access to ICOADS

It was strongly noted that IVAD will promote access to ICOADS and the value-added database is a much-needed product. It was suggested that IVAD is actually the next generation of ICOADS. Also noted was the desire to enrich the user's interface to show users more information about the data they are selecting as they are making their choices, possibly through graphics and additional documentation.

It is desirable to distribute the archive internationally by leveraging cooperation through the proposed network of WMO-IOC CMOCs. It was recognized that the first crucial step to enabling the distributed development model for ICOADS is the need for a unique identification on each ICOADS record. This will permit synchronization of ICOADS over time.

Users would like to see ICOADS linked on the IODE ODP.

3.3.3 IVAD

3.3.3.1 Information and initial steps

To make a successful and useful value-added ICOADS, user needs must first be assessed. These needs will need to be discussed at an IVAD-focused workshop where a structure and implementation plan will need to be drafted. From this information, a Terms of Reference can also be drafted including input from representatives from the land and satellite communities to work towards making marine, land and satellite data more interoperable. To keep interested parties informed on the progress of IVAD, it is essential to start an information-based website to promote, inform and coordinate efforts. *[Post-meeting note: see web[23].]*

23: http://icoads.noaa.gov/ivad/

3.3.3.2 Adjustments

There is a clear need for a bias adjustment attachment that includes the value and the estimate of error of that value and other source tracking information. IVAD will need to plan for multiple adjustments for the same field and avoid using a "best" value label on any particular one.

Groups have often done adjustments by gridded strategies and ship identification, but IVAD will need to coordinate with these groups to place adjustments on individual records. For traceability, a unique identification number (UID) for each record will be crucial and is considered top priority. The IMMA structure will need to be adapted to use the UID, although this is no trivial task. UID schemes such as used for CMIP5[24] and the Universally Unique Identifier (UUID) should be investigated as potential models. Some research is still needed in this area. Community schemes for tagging datasets should be distinguished from those for tagging individual records. First and foremost the UID is a pure identifier. Secondary purposes, e.g. sorting or time reference coding should be considered with the understanding that successive Releases will impact the collection.

3.3.3.3 Matchups

Users often prefer ways to subset from certain time and space domains. In this regard, a matchup scheme is recommended. One possibility is a matchup scheme with supporting software that the user can have on their own machine to access the data for their own needs. Quick lookups with graphics could assist users downloading and discovering data using these matchup schemes.

Matchups are fundamental in the satellite community, and many products and analyses can be built after a matchup is performed. For this scheme, a standards-based approach should be used. The NOAA/National Environmental Satellite, Data, and Information Service (NESDIS) Products Validation System (NPROVS) should be investigated for ideas as well as the GECA for functionality.

Data across multiple agencies will be a challenge and many standalone systems should be avoided if possible.

3.3.4 Software

As with any processing system it is crucial that all software being used is properly documented in order to promote full transparency and avoid accusations of improperly processed data or introducing artificial conditions. It is recommended that software packages for ICOADS and IVAD be available and portable to the extent possible.

3.3.5 Actions:

a) Circulate to all workshop participants information about newly available data sources, including what additional processing is needed to prepare data for blending into ICOADS, e.g. digitized but need translation to IMMA (ref. on the web[25]). Request assistance from participants in translating observations into IMMA format. (Action: ICOADS group)
b) Create a draft priority list of additional parameters for inclusion into ICOADS and then seek community review. (Action: ICOADS group)
c) Start an information-based website on IVAD (suggested to be hosted under the ICOADS portal) to promote, inform, and coordinate efforts. (Action: ICOADS group and ad hoc IVAD working group)
d) Investigate options for UID and determine which approaches best satisfy the needs for unique labelling of individual records (as opposed to whole datasets). (Action: ICOADS group).

24: CMIP5: Coupled Model Intercomparison Project, Phase 5
25: http://icoads.noaa.gov/reclaim/pdf/marine-data-rescue.pdf

3.3.6 Recommendations

i. Begin a historical buoy metadata recovery initiative and investigate the current state of ODAS and collect the existing metadata from that database.
ii. Complete thorough assessment of users' needs as relevant to IVAD. Once this is done, a workshop will need to be organized to draft structure and implementation plans.
iii. Draft a Terms of Reference and include representatives from the land and satellite communities to work towards better interoperability between the groups.
iv. Encourage all countries to provide resources for historical data rescue, including imaging and digitization—to ensure observations critical to climate research and services are not lost.

3.4 PLENARY DISCUSSION 4

ANALYSIS AND UNCERTAINTY ISSUES COMMON TO *IN SITU* LAND AND MARINE DATA

Chair: Drs Albert Klein Tank (KNMI, the Netherlands) and Elizabeth Kent (NOC, UK)
Rapporteur: Dr Katharine Willett (Met Office, UK)

3.4.1 Introduction

The land and marine communities share many of the same problems when trying to create climate quality data-products from historical observations. Traditionally, these fields have worked in relative isolation. Recently, there have been concerted efforts to bring the two communities together—much can be learned from both communities. Here we discuss key areas for crossover between these communities.

3.4.2 Discussion areas

3.4.2.1. Common approaches to solving data problems

Errors in marine and land data may differ in type but ultimately need addressing in common terms of quality control, bias correction and uncertainty quantification. Common to both are three types of errors, which can be broadly categorised as red (systematic, correlated), pink (partially correlated, e.g. synoptic, country or platform dependent) and white (random, uncorrelated) noise. Regardless of the many differences, an approach that works from the base observation upwards is preferable—together with methods that can be used on both land and marine data. Approaches should be modular and flexible, allowing breakdown of uncertainties into specific entities later on, for example on different time and space scales. A Monte Carlo style approach is also recommended to fully explore all plausible estimates of reality and hence the median/best estimate. Encouraging multiple independent efforts to characterise bias, uncertainty and estimates of multiple variables is essential to building confidence in both communities. Widening our spread of expertise is also desirable—software engineers, statisticians and metrologists can be very useful additions to project teams. Importantly, we need to be using the same language and communicating/serving uncertainties in similar ways in order to help get this complicated information to the user and make it accessible with clear downstream consequences of uncertainties.

There does need to be more communication between groups developing methods for quantifying and applying uncertainties. This can be done through maintaining close contact with colleagues in the other community. A list populated with who is working on what and a list of guidance material/good practices and user requirements should be created and hosted on respective land and marine web interfaces (ICOADS and the International Surface Temperature Initiative (ISTI)). We should also foster a practice of exchanging ideas, findings, new papers with peers in the other community, perhaps having somewhere to record all discovered biases for each community (e.g. IVAD for marine data). Having representation from the other community on key committees and working groups is also desirable. Funding could be sought e.g. from European Cooperation in Science and Technology (COST) for meetings and workshops on collaborative projects.

3.4.2.2. Benchmarking of methods to quantify structural uncertainty (cross-over with the Land Surface Temperature Initiative)

There has been little similar benchmarking work undertaken in the marine community to date although ideas have been discussed. The GCOS SST-SI-WG and the palaeoclimate communities are however using pseudo-proxy experiments. It remains to be seen whether such techniques can be applied usefully to the marine data beyond fixed platforms and moored buoy networks that are similar to the land set up. In order to investigate this further it is desirable for a marine community representative to sit on the Benchmark and Assessment Working Group both to follow progress there and feed into possible utilisation within the marine data domain. *[Post-meeting note: Dr David Berry (NOC) has joined the ISTI Benchmarking and Assessment Working Group]*

3.4.2.3. Reference networks

Much effort and much value has been placed on climate quality reference networks for the land data to ensure a legacy of monitoring data for the future, where multiple instruments record simultaneously, and are maintained and regularly calibrated to a known high standard. Historically, the marine community have not used such a systematic approach to ensuring data accuracy as the land community. The Argo float network has the potential to be a high quality reference data source and OceanSITES now replaces the Ocean Weather Ship network. However, it is not clear that effective coordination exists between the multiple data sources in the marine climate observing system or how these will function into the future and this should be investigated. The WMO Commission for Instruments and Methods of Observation (CIMO) might provide a relevant framework, but marine observations are often affected by the measurement platform and infrastructure so the link to reference standards is perhaps even more challenging than over land.

RVs have the potential to be sources of high quality data, but do not always deliver high quality data. Initiatives like SAMOS are doing much to improve the quality and integration of data delivery from RVs. There are also voyages specifically staffed with someone responsible for RV observations (Ship of Opportunity Programme – SOOP – ship riders) but this has not always been the case. Another improvement is that German RVs are now required to have duplication of instruments. The Working Group on Surface Fluxes developed a handbook, published by NOAA describing how to take high quality observations (see web[26]).

Does the marine community require reference sites? More investigation is needed to establish what is useful. It was noted that references sites have acted to raise awareness of climate monitoring over the land, the same could be true for ocean reference sites. These can be useful for tying together *in situ* and satellite data that in turn can be useful to back out some issues with the historical *in situ* network. A compilation of user requirements of marine data and recommendations of preferred instrument selection and practices could be made as has been done for some variables in the land community. Importantly, reference sites across land and ocean should tie to the same known standard. Setting up a reference network would involve challenges of funding and management but this has been achieved with success for Argo and drifting buoys.

3.4.2.4. Data exchange

There are far more data that could be associated with both the marine and land databanks. Establishing a list of areas/types of data that should be focussed on will help to optimise use of sparse resources. There are raw data known to both communities that may be of interest to the other. For example, inland seas, lakes, river data and other fixed platform data reported within the

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26: http://samos.coaps.fsu.edu/html/docs/NOAA-TM_OAR_PSD-311.pdf land framework should be associated with ICOADS. ICOADS island, coastal data and data from ships in port may be of interest to the land community. All of these present valuable opportunities to cross-validate between land and marine data. Similarly, metadata can apply to both communities and should be shared where relevant. NDBC has many data over coastlines and piers. Many German coastal stations observe waves and so would be relevant to ICOADS. Flagging of coast/lake/river/port data would help identify potentially useful data subsets for different communities.

The land community uses standard sets of indices to describe the climate, especially concerning extremes (e.g. Hadley Centre global climate extremes indices (HadEX[27])). While these mostly concern extremes of temperature, which are more relevant to human impacts such as heat stress and food production, quantifying these over the ocean too has significant scientific value. There may be indices more relevant to marine extremes—storms, sea level pressure (SLP), winds—that should be developed jointly between communities. Both land and marine communities provide averaged summaries for users (ICOADS Summaries and CLIMAT Normals/NCDC's New Normals). There is significant value to continuing these values across both land and ocean in a consistent manner.

3.4.2.5 Recommendations

- Multiple independent efforts to characterise bias, uncertainty and estimates of multiple variables is essential to building confidence in both communities
- Widening our spread of expertise is also desirable – software engineers, statisticians and metrologists can be very useful additions to project teams.
- Mechanisms to share expertise and information between those working in the land and ocean domains should be developed. Information could include key personnel and publications, guidance material and user requirements.
- The practice of exchanging ideas and new papers between land and ocean communities should be fostered.
- It is desirable to include representation from the other community on key committees and working groups. A first step should be a marine community representative on the Benchmark and Assessment Working Group.
- Effective coordination across the marine climate observing system should be developed.
- The need for formal GCOS marine climate reference sites should be investigated.
- A compilation of user requirements of marine data and recommendations of preferred instrument selection and practices has been found valuable by the land community and should be considered by the marine community.
- Coastal data are of interest to both communities, and not always managed the same way in different countries. An example is that many German coastal stations observe waves and so would be relevant to ICOADS.
- The value of providing climate summaries and indices in a consistent way across land and ocean should be investigated.

3.5 PLENARY DISCUSSION 5

ISSUES AND OPPORTUNITIES WHEN EXTENDING THE LONG TERM-RECORD USING SATELLITE DATA

Chair: Dr Mark Doherty (ESA)
Rapporteur: Dr Craig Donlon (ESA)

3.5.1 Background

27: http://www.metoffice.gov.uk/hadobs/hadex/

This session began with a short presentation highlighting the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) sea level curve from 1840 to ~2005, derived from combined analyses of tide gauge data and EO altimeter measurements. The importance of combining data from different sources to construct a long time-series of data appropriate for climate applications was noted. The satellite and *in situ* measurement communities must work together to ensure that the data needed to underpin climate services is developed.

3.5.2 Discussion

- The importance of ECVs for enabling climate services and delivering the GFCS was noted. There is a requirement for high quality and QC'd data to establish a baseline of normal conditions against which to evaluate changes in climate, such as the recent heat waves in Europe. The GMES and ESA CCI programmes are intended to help provide the information that the GFCS requires.
- There were thought to be many benefits to establishing and maintaining links between the land and the marine communities
- The urgent need for exchange of expert opinion and advice between EO and in situ communities was expressed. Each community perceives barriers to working together and wishes to access high quality advice. It was recognised that these problems were not likely to be easily solved but that bringing the communities together was an important start.
- The importance of *in situ* experts being involved at an early stage in the planning of EO missions was discussed. It was clear that *in situ* scientists felt that they were being asked to provide input to programs such as the ESA CCI at a late stage when it was difficult to have influence and obtain funding for participation. There was thought to be a perception at funding agencies that space agencies were taking care of ECVs and that it would be helpful for the space agencies to communicate the needs for additional work not covered by EO programs. Examples of good practice in involving the *in situ* community in EO mission design were noted, but not thought to be universal. It was also recognised that it has proved easier to make the case for satellite missions rather than the *in situ* network, which is delivered by a wide range of different operational and research organisations. The need for a focal point for in situ surface marine *in situ* data was discussed.
- The role of initiatives such as GHRSST in exploring differences between EO and *in situ* observations (for example in spelling out the physical connection between SST_{skin} and SST_{depth}) was noted as being important. In GHRSST discussions with critical scientists led to a physics-based understanding of the fundamental measurements made by both *in situ* and satellite data. A critical mass of people is needed to look at the issues in variables other than SST.
- There was a call for interoperable datasets and the barrier that inadequate documentation and version control forms to the combined use of satellite and *in situ* data was recognised. It was noted that JCOMMOPS could provide operational support for EO data as it does for *in situ* marine data, but that additional resources would be required.
- Practical ideas to promote joint projects included PhD funding with both *in situ* and EO supervisors, which would provide training and sustain the research community.
- The lack of observational requirements for surface marine climate data was discussed. Although the WMO RRR is intended to cover a wide range of applications, including climate, many meeting participants felt it was not meeting the needs of the climate community. It was noted that WMO CBS, which is managing the RRR is doing its best to keep the balance between all application areas[28]. However, RV operators were not able to find information about the details of observations that would contribute to the GCOS or provide validation for satellite observations. The need for continuity and overlap of observations is not addressed as the RRR is non-specific about implementation and technology. There is a need to translate the

28: The WMO RRR (http://www.wmo.int/egos) is multi-disciplinary exercise addressing 12 application areas, plus the Global Cryosphere Watch (GCW) and GFCS, three of them being climate related: Seasonal and Inter-Annual Forecasting (SIAF), GCOS, and climate applications. RRR is also fully recognizing the GCOS Implementation Plan as a Statement of Guidance feeding into the Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP). Participants are invited to review the draft EGOS-IP (available from the WMO ftp site at: ftp://ftp.wmo.int/Documents/PublicWeb/www/gos/egos-ip/), and submit their comments to the chair of the ET-EGOS, Dr John Eyre (UK Met Office).

requirements into ship measurement specifications and to co-ordinate validation datasets. It was thought that Observing System Simulation Experiments (OSSE) would help indicate requirements for satellite validation work. The disparate nature of the *in situ* observing system was recognised as forming a barrier to the development of robust user requirements for climate observations and to the securing of funding for the *in situ* marine component of GCOS. It was noted that the satellite community utilizes extensive and comprehensive mission Cal/Val planning which should involve the *in situ* community and the information made available to researchers. It was suggested that the RRR Gap analysis could be used to look at validation issues and that the JCOMM Observations Programme Area (OPA) could also consider this issue and requirements for satellite validation could be documented through the JCOMM Observations Coordination Group (OCG). It was noted however that difficulties arose through the division of responsibility for satellite observations within the WMO Space Program and JCOMM.

- Issues related to the reliance on observations collected for operational applications such as NWP or ocean analysis for climate applications were discussed. Space agencies are realising the importance of climate applications as the satellite record becomes longer, but the required Cal/Val measurements are not yet in place. It was suggested that some of these issues should be addressed by GMES and that a proposal from the surface marine *in situ* community be prepared for the GMES Climate meeting in June 2011 *[Post-meeting note: A Background paper on the Marine Surface Global Climate Observing System (MS-GCOS) was formulated and submitted to that meeting, available on the web[29]].*
- It was suggested that because the observing system is largely managed by the operational community, data quality does not meet the quality standards required for climate applications. An example is the lack of critical platform/instrumental metadata for the operational buoys which is required to ensure that the collected data meet climate accuracy requirements. Whilst relatively cheap this still hasn't been implemented. Similarly (thus far anyway) the WMO RRR appears to have been primarily controlled by NWP, as opposed to climate, requirements. The way forward is to get the climate community to monitor the data and provide an end-to-end system. This can then be translated into a historical context; GFCS should give us clarity on this issue. The aim should be for a managed sub-set of climate infrastructure, analogous to the U.S. Climate Reference Network (USCRN) or the GCOS Reference Upper-Air Network (GRUAN).
- Despite the various difficulties identified with coordination it was noted that the marine community is relatively mature and other communities such as those for clouds and aerosol are much more diverse.
- Various mechanisms for providing feedback on data quality were discussed. The importance of providing feedback from reanalysis activities alongside the original observations was stressed. It was thought that MARCDAT should maintain strong connections to analysis and reanalysis efforts. Data problems should be communicated to users when they are discovered and blogs were noted as being a solution that had been used successfully.

3.5.3 Recommendations

- There is a need for interoperable data access to relive the burden of format support (e.g. netCDF[30]) and all datasets should be well documented to ensure that researchers from different communities are able to use data of all types appropriately.
- The EO community should involve *in situ* data experts at an early stage of mission design and communicate requirements for *in situ* calibration and validation measurements to the *in situ* community and to funding agencies.
- Substantial effort is required to define and articulate observational requirements for *in situ* observing systems, particularly because many observations important for climate monitoring and research are made by operational agencies. The combined EO and *in situ* climate community should assess the adequacy of observations used for climate applications and

29: http://www.marineclimatology.net/web/
30: netCDF: Network Common Data Format

work to ensure that resources are made available to meet the appropriate requirements, including for quality, traceability, metadata and sampling.

- The concept of GHRSST should be extended to variables other than SST.

(4) Additional workshop recommendations

4.1 Unique Identifiers (UID)

UID development was suggested as critical (e.g. for further internationalizing ICOADS, and in the context of the IVAD project). Basically the idea as proposed for ICOADS/IVAD will be to affix a permanent number to each individual ICOADS marine report. This UID will then be provided to users together with the observed data records, thus facilitating precise feedbacks on the data from analysis and reanalysis projects, as well as other users. Possible utilization of existing technologies for UUID was suggested for purposes of assigning the identifier[31].

4.2 Resources issues

The issue of very limited (and in some cases deteriorating) funding for *in situ* data management work was a persistent issue underpinning several workshop presentations and discussions; e.g. as an continuing challenge for the core ICOADS project, likely for the proposed new IVAD work, and generally applicable to the very costly tasks typically involved in historical marine/oceanographic data rescue. As stated in the Executive Summary, the workshop strongly recommended continuing US and international support for data rescue to provide ongoing resources to image, digitize, preserve, and use historical climate data.

Unfortunately, the cessation in fiscal year 2011 of NOAA Climate Database Modernization Program (CDMP) funding, has ended—probably permanently in view of current budgetary constraints and governmental decisions external to NOAA—what was felt by the workshop to be an enormously valuable program, and this adverse action has wide downstream impacts on individual projects that had been funded by CDMP. Further in this regard the workshop recommended in the future seeking to avoid such “vendor lock-in,” with a truly international and sustained data rescue effort that was better coordinated, to prioritize and avoid duplication and not overly reliant on any single program. A potential strengthened role for WMO, potentially in the context of GFCS, also was suggested.

4.3 Decline in the VOS

The continuing decline in the VOS network was also a concern underlying several workshop presentations and discussions. Figure 1 for example illustrates a substantial degradation in marine climate data network since about 1980, as stratified by major marine variables (except SST coverage has remained fairly stable, e.g. due to good drifting buoy coverage). These patterns arise partly from the loss of many shipboard visual observations, e.g. cloudiness (see also: Kent, E.C., D.I. Berry, S.D. Woodruff, and P.K. Taylor, 2006: Voluntary Observing Ships: A vital observing system in decline. *CLIVAR Exchanges*, No. 38 (Vol. 11, No. 3, July 2006), 15 & 20-21).

While the workshop agreed that this was a very important issue, and not widely enough recognized—with significant negative impacts possible on global climate assessments reanalyses, and other research—affordable and practical solutions to the problem are not at all evident. The

31: According to http://en.wikipedia.org/wiki/Universally_unique_identifier, UUID is defined as: “A universally unique identifier (UUID) is an identifier standard used in software construction, standardized by the Open Software Foundation (OSF; http://www.opensoftwarefoundry.org/) as part of the Distributed Computing Environment (DCE; http://www.opengroup.org/dce/). In this context the word unique should be taken to mean "practically unique" rather than "guaranteed unique". Since the identifiers have a finite size it is possible for two differing items to share the same identifier. The identifier size and generation process need to be selected so as make this practically impossible.”

only specific recommendation from the workshop was to seek to increase visibility of this deterioration in the observing system, and its importance.

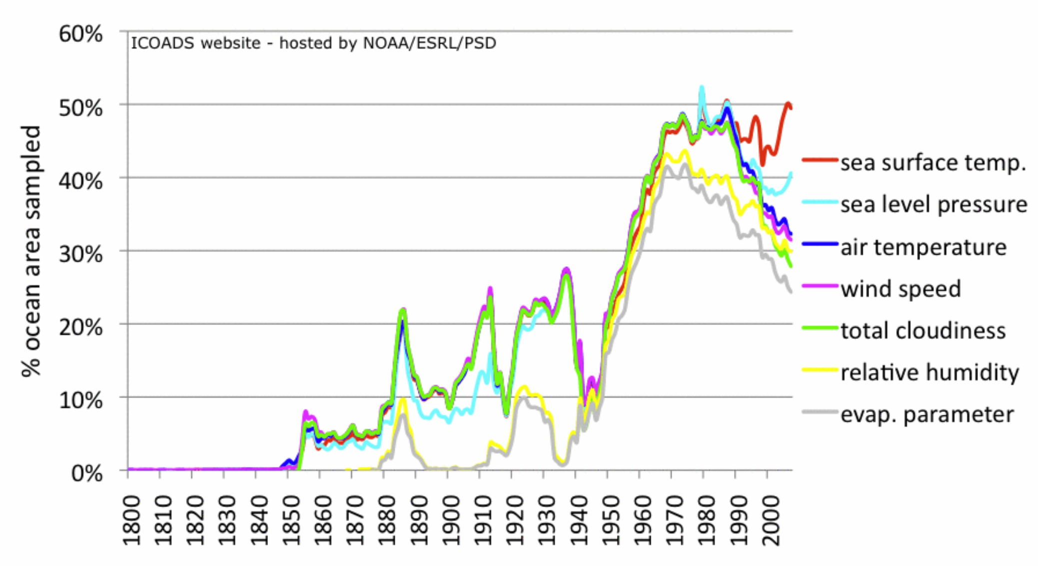

Figure 1 (from web[32]). Percentage global ocean and coastal area (1800-2007) sampled in Release 2.5 based on area-weighted 2° boxes (smoothed) for SST (*S*), requiring at least five observations per month in each box, and determined from the "enhanced" (4.5σ trimming) product that includes ship and buoy records. Other curves compare the *S* coverage, at five observations per month, with that for sea level pressure (*P*), air temperature (*A*), wind speed (*W*), total cloudiness (*C*), and relative humidity (*R*). Also plotted is the evaporation parameter (*G*), which is computed from *S*, *P*, *A*, *W*, and *R*, and thus illustrates the extent to which surface fluxes can be computed from the individual observations.

32: http://icoads.noaa.gov/

ANNEX I

THIRD INTERNATIONAL WORKSHOP ON ADVANCES IN THE USE OF HISTORICAL MARINE CLIMATE DATA

(MARCDAT-III, 2-6 May 2011, Frascati, Italy)

PROGRAMME OF THE WORKSHOP

Timetable of introductory (in green; generally 20 min.), contributed (25 min.), and invited (in blue; 30 min.) oral presentations (all presentation times including ~5 min. for questions).

Note: In a few cases titles of actual presentations differed from the presentation titles listed below.

Monday 2 May		
Session/ Timeslot	*Title*	*Chair/ Rapporteur/ Lead author*
Session A: Introductory		
9:00-9:10	Welcome and Logistics	Craig Donlon
9:10-9:30	Opening: ESA Activities in support of marine climate data	Mark Doherty (Head of the ESA CCI Programme)
9:30-9:50	WMO activities in support of marine climate data	Etienne Charpentier
9:50-10:10	IOC/IODE perspectives on long term ocean climatic datasets	Sissy Iona
10:10-10:30	The JCOMM *in situ* Observing Programme Support Centre (JCOMMOPS)	Mathieu Belbeoch (presented by Etienne Charpentier)
10:30-11:00	Global ocean fundamental climate data records	David Halpern
11:00-11:30	Coffee/tea	
Session B: The ESA CCI and other satellite data		Chair: Craig Donlon; Rapporteur: Andrew Bingham
11:30-11:45	Introduction to Session B; and seeking a 10-year MARCDAT Vision	Craig Donlon
11:45-12:15	The European Space Agency's Climate Change Initiative Project for sea surface temperature (SST CCI)	Chris Merchant
12:15-12:45	Accurately measuring sea level change from space: an ESA Climate Change Initiative (Sea Level CCI)	Gilles Larnicol
12:45-13:15	ESA Ocean Colour CCI	Laurant Bertino
13:15-13:45	ESA Clouds CCI	Juergen Fischer
13:45-15:15	Lunch	
15:15-15:45	Climate relevant aerosol retrieval over ocean from the ESA aerosol_CCI project	Gerrit De Leeuw
15:45-16:15	Critical Issues for the specification of unbiased and homogeneous marine surface wind reanalyses	VinceCardone
16:15-16:45	Coffee/tea	
16:45-17:15	Pathfinder, GHRSST, and the SST Essential Climate Variable Framework	Ken Casey
17:15-19:00	Welcome icebreaker hosted by ESA/ESRIN	
Tuesday 3 May		

Session C: Satellite and in situ datasets, reanalyses, and analyses		Chair: Ken Casey; Rapporteur: Martin Rutherford
9:00-9:05	Introduction to Session C	Ken Casey
9:05-9:35	A collocation service for *in situ* and remotely sensed measurements	Steve Worley
9:35-10:00	Satellite data for marine climate monitoring purposes	Gudrun Rosenhagen (for Jörg Trentmann)
10:00-10:25	Creating a consistent time series of global sea-surface temperature using *in situ* and satellite data sources	John Kennedy
10:25-10:50	Uses of satellite data for gridded sea surface temperature analyses of pre-satellite period	Alexey Kaplan
10:50-11:50	Coffee/tea & First Poster Viewing (Big Hall)	
11:50-12:15	Improved historical reconstructions of SST and marine precipitation variations	Tom Smith
12:15-12:40	The ERA-CLIM Project	Hans Hersbach
12:40-13:05	OSTIA Reanalysis: A high resolution SST and sea-Ice reanalysis	Jonah Roberts-Jones
13:05-13:30	Satellite and *in situ* sea surface temperature comparison and merging in the Mediterranean Sea	Aida Alvera-Azcarate
13:30-13:45	Buffer time	
13:45-15:15	Lunch	
14:10- 15:00 (Big Hall)	Side meeting: GCOS SST Working Group	Chair: Tom Smith
Session D: In situ datasets, reanalyses, and analyses		Chair: Tom Smith; Rapporteur: Alexey Kaplan
15:15-15:20	Introduction to Session D	Tom Smith
15:20-15:50	All historical SST analyses are wrong*, probably even this one	John Kennedy
15:50-16:15	A new Historical SST Analysis: COBE2-SST	Shoji Hirahara
16:15-16:45	Coffee/tea	
Cross-cutting plenary discussion		
16:45-18:00	Plenary Discussion 1 (75 min.): Reanalyses, and analyses using satellite and *in situ* datasets in synergy	Co-Chairs: David Halpern and Chris Merchant; Rapporteur: Vince Cardone
18:00-20:00 (Big Hall)	Side meeting: JCOMM Expert Team on Marine Climatology (ETMC) Task Teams	Chairs: Nicola Scott and Gudrun Rosenhagen
Wed. 4 May		
Session D: In situ datasets, reanalyses, and analyses		

(continued)		
9:00-9:25	Assessment and validation of the NOCS2.0 dataset	David Berry
9:25-9:50	A hierarchical Bayesian model for ocean properties reconstructions	Bruno Sanso
9:50-10:15	Systematic errors in the hydrographic data and their effect on global heat content calculations	Viktor Gouretski
10:15-10:40	Ocean heat content variations and its trends estimated from historical oceanographic observations	Yoshikazu Fukuda
10:40-11:40	Coffee/tea & Second Poster Viewing (Big Hall)	
Session E: In situ data rescue		Chair: Frits Koek; Rapporteur: Wolfgang Gloeden
11:40-11:45	Introduction to Session E	Frits Koek
11:45-12:15	ACRE, Citizen Science and OldWeather	Rob Allan
12:15-12:40	English East India Company logbooks – significant contributions to history and science	Eric Freeman
12:40-13:05	International Marine Data Rescue: The RECovery of Logbooks And International Marine Data (RECLAIM) Project	Clive Wilkinson
13:05-13:30	Rescue of historical records of the US Fish Commission and the US Navy	Catherine Marzin (presented by Scott Woodruff)
13:30-13:45	Buffer time	
13:45-15:15	Lunch	
Session F: Land-marine: cross-cutting data and analyses		Chair: Albert Klein Tank; Rapporteur: Gudrun Rosenhagen
15:15-15:20	Introduction to Session F	Albert Klein Tank
15:20-15:50	Land surface temperature records - are we keeping our side of the bargain?	Peter Thorne
15:50-16:15	Is it good enough? benchmarking homogenisation algorithms and cross-cutting with efforts for land observations	Kate Willett
16:15-16:45	Coffee/tea	
16:45-17:10	Changes in cloud cover and cloud types over the ocean from surface observations, 1954-2008	Ryan Eastman
17:10-17:35	Estimating long term trends of ENSO variability	Andy Chiodi
19:30	Self-funded dinner at Restaurant *Il Cortiletto*	Via S.L. Filippini–Frascati 069419920
Thursday 5 May		
Session G: In situ and satellite wave data and analyses		Chair: Elizabeth Kent; Rapporteur: Etienne Charpentier
9:00-9:05	Introduction to Session G	Elizabeth Kent
9:05-9:35	Wave measurement Evaluation and Testing	Val Swail
9:35-10:00	Project GlobWave	Geoff Busswell
10:00-10:25	Global ocean wind waves from ICOADS during the last 130 years: reliability, extremes and climate variability	Vika Grigorieva
10:25-10:50	Comparing significant wave height statistics from ICOADS	Martin Rutherford

	and satellite altimeter data	
10:50-11:15	The effects of changes in observational practices for moored buoys on long term wave trend	Bridget Thomas (presented by Val Swail)
11:15-11:45	Coffee/tea	
Session H: In situ marine data manage-ment initiatives		Chair: David Berry; Rapporteur: Sissy Iona
11:45-11:50	Introduction to Session H	David Berry
11:50-12:15	Status and Plans for the International Comprehensive Ocean-Atmosphere Data Set (ICOADS)	Scott Woodruff
12:15-12:45	Developing an ICOADS Value-added Database to support climate research	Shawn Smith
12:45-13:10	Improving VOS data management: an update on progress from JCOMM Task Team on Delayed Mode VOS data	Nicola Scott
Cross-cutting plenary discussion		
13:10-13:45	Plenary Discussion 2 (35 min.): Prospects for wave summaries in ICOADS	Chair: Val Swail; Rapporteur: Scott Woodruff
13:45-15:15	Lunch	
Cross-cutting plenary discussion		
15:15-16:30	Plenary Discussion 3 (75 min.): Challenges and solutions to enhance ICOADS	Co-Chairs: Shawn Smith and Steve Worley; Rapporteur: Eric Freeman
16:30-17:00	Coffee/tea	
17:00-18:00	Plenary Discussion 4 (60 min.): Analysis and uncertainty issues common to *in situ* land and marine data	Co-Chairs: Albert Klein Tank and Elizabeth Kent; Rapporteur: Kate Willett
Friday 6 May		
Cross-cutting plenary discussion		
9:00-10:00	Plenary Discussion 5 (60 min.): Issues and opportunities when extending the long term-record using satellite data	Co-Chairs: Mark Doherty and Craig Donlon; Rapporteur: TBD
10:00-10:15	Summary of major issues arising at the meeting so far and introducing remaining discussion sessions	Scott Woodruff
10:15-10:45	Coffee/tea	
10:45-11:45	Priorities and next steps	
11:45-12:30	Conclusions	
12:30	Workshop close	
13:45-15:15	Lunch	
	Develop workshop report and action plans	

Posters		
Theme 1		
1	A comparison of surface wind speed datasets	Elizabeth Kent
2	(A)ATSR Re-Analysis for Climate (ARC): stability of ATSR data versus *in situ* observations	David Berry
3	Quantifying variance due to temporal and spatial difference between ship and satellite winds	Mark Bourassa (presented by Shawn Smith)
4	Remotely sensed surface turbulent fluxes and validation with *in situ* observations	Mark Bourassa (presented by Shawn Smith)
5	Application of remote sensing in decadal marine climate prediction: challenges and opportunities in Nigeria	A.O. Ediang
6	Importance of the deep ocean for estimating decadal changes in Earth's radiation balance	Matt Palmer (presented by John Kennedy)
Theme 2		
7	Long term variability of the Mediterranean sea surface temperature using international databases including the ICOADS	Sissy Iona
8	Creating a marine humidity monitoring product	Kate Willett
9	Research Vessel observations: a modern data record for marine climatology	Shawn Smith
10	Advancing the use of historical environmental data through the Climate Database Modernization Program	Eric Freeman
11	Keying Dutch 19th Century ships' logbooks in CDMP	Frits Koek
12	Digitization of met. journals from ships	Wolfgang Gloeden
13	Digitization of data from overseas	Gudrun Rosenhagen and Birger Tinz
Theme 3		
14	The NOCSv2.0 Surface Flux Dataset	Elizabeth Kent
15	Estimating and presenting uncertainties in an historical sea-surface temperature analysis	John Kennedy
16	Improved estimates of uncertainty in gridded sea-surface temperature data sets	John Kennedy

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ANNEX II

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ADVANCES IN THE USE OF HISTORICAL MARINE CLIMATE DATA
(MARCDAT-III, Frascati, Italy, 2-6 May 2011)

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LIST OF ACRONYMS AND ABBREVIATIONS

ACRE	Atmospheric Circulation Reconstructions over the Earth
aeronet	AErosol RObotic NETwork (NASA)
Argo	International profiling float programme
AATSR	Advanced Along Track Scanning Radiometer
AR4	IPCC Fourth Assessment Report
ASCAT	Advanced Scatterometer
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
BUFR	FM 94 BUFR GTS format: Binary Universal Form for Representation of meteorological data
Cal/Val	Calibration and Validation
CBS	Commission for Basic Systems (WMO)
CCI	Climate Change Initiative (ESA)
CD-ROM	Compact Disc, Read-Only-Memory
CDMP	NOAA Climate Database Modernization Program
CDR	Climate Data Record
CEOS	Committee on Earth Observation Satellites
CIMO	Commission for Instruments and Methods of Observation (WMO)
CLIMAR	Workshops on Advances in Marine Climatology (JCOMM)
CLIMAT	Code for reporting monthly climatological data assembled at land-based meteorological surface observation sites to data centres (WMO)
CLIVAR	Climate Variability and Predictability (WCRP)
CLS	Collecte Localisation Satellites
CM	Contributing Member (JCOMM)
CMOC	WMO-IOC Centre for Marine-meteorological and Oceanographic Climate Data
CM SAF	Satellite Application Facility on Climate Monitoring
CMUG	Climate Modelling User Group
CNES	Centre National D’Etudes Spatiales (France)
COADS	Comprehensive Ocean-Atmosphere Data Set (now ICOADS, USA)
COBE2-SST	SST analysis from JMA
COST	European Cooperation in Science and Technology
CZCS	Coastal Zone Color Scanner (NASA)
DBCP	Data Buoy Co-operation Panel (WMO-IOC)
DUE	Data User Element (ESA)
DWD	Deutscher WetterDienst (Germany)
EC	Environment Canada
ECV	Essential Climate Variable
ECMWF	European Centre for Medium-Range Weather Forecasts
Envisat	Environmental Satellite (ESA)
EO	Earth Observation
EOF	Empirical Orthogonal Function
EPOCS	Equatorial Pacific Ocean Climate Studies
ERA	ECMWF Reanalysis
ESA	European Space Agency
ESRL	NOAA Earth System Research Laboratory (USA)
ESRIN	ESA Centre for Earth Observation (ESRIN)
ETCCDI	Joint CLIVAR / CCI / JCOMM Expert Team on Climate Detection and Indices
ETMC	Expert Team on Marine Climatology (JCOMM)
ETWS	Expert Team on Wind Waves and Storm Surges (JCOMM)
EU	European Union
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
Eurofleets	Towards an Alliance of European Research Fleets
FFT	Fast Fourier Transform
FSU	Florida State University (USA)
GCC	JCOMM Global Collecting Centers

GCOS	Global Climate Observing System (IOC, WMO, UNEP, ICSU)
GCW	Global Cryosphere Watch (GCW)
GECA	Generic Environment for Calibration/validation Analysis
GEWEX	Global Energy and Water Cycle Experiment
GFCS	Global Framework for Climate Services
GHRSST	Group for High Resolution SST
GlobWave	ESA Global Wave DUE Initiative
GMES	Global Monitoring for Environment and Security (European Union)
GMSL	Global Mean Sea Level
GODAR	Global Oceanographic Data Archaeology and Rescue
GOOS	Global Ocean Observing System (IOC, WMO, UNEP, ICSU)
GO-SHIP	Global Ocean Ship-based Hydrographic Investigations Program
GOSUD	Global Ocean Surface Underway Data
GRAUN	GCOS Reference Upper-Air Network
GSICS	Global Space-based Inter-Calibration System (WMO and Coordination Group for Meteorological Satellites)
HadEX	Hadley Centre global climate extremes indices
HadSST	Hadley Centre SST Data Set
HCMR	Hellenic Centre for Marine Research (Greece)
HISTOR	Data digitisation project based at DWD
H_{max}	Maximum Wave Height
HOAPS	Hamburg Ocean Atmosphere Parameter and Fluxes from Satellites
HQCS	Higher Quality Control System
H_s	Significant Wave Height
ICOADS	International Comprehensive Ocean-Atmosphere Data Set (USA)
ICSU	International Council for Science
IMMA	International Maritime Meteorological Archive format
IMMT	International Maritime Meteorological Tape format
IMOS	Integrated Marine Observing System (Australia)
IOC	Intergovernmental Oceanographic Commission of UNESCO
IOCCG	International Ocean Colour Coordinating Group
IODE	International Oceanographic Data and Information Exchange (IOC)
IOP	Inherent Optical Properties
IORAS	P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences
IPCC	Intergovernmental Panel on Climate Change
ISTI	International Surface Temperature Initiative
IVAD	ICOADS Value-Added Database
IVD	Initial Value Distributions
JCOMM	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
JCOMMOPS	JCOMM *in situ* Observations Programme Support Centre
JMA	Japan Meteorological Agency
KNMI	Koninklijk Nederlands Meteorologisch Instituut
LSAT	Land Surface Air Temperature
MARCDAT	International Workshops on Advances in the Use of Historical Marine Climate Data
MBT	Mechanical BathyThermograph
MCDS	Marine Climate Data System
MERIS	MEdium Resolution Imaging Spectrometer
MODIS	MODerate resolution Imaging Spectroradiometer
MSL	Mean Sea Level
MQCS	Minimum Quality Control Standard
NASA	National Aeronautics and Space Administration (USA)
NDBC	NOAA National Data Buoy Center (USA)
NCAR	National Center for Atmospheric Research (USA)
NCDC	NOAA National Climatic Data Center (USA)
NESDIS	NOAA National Environmental Satellite, Data, and Information Service (USA)

NetCDF	Network Common Data Format
NMFS	NOAA National Marine Fisheries Service (USA)
NMSP	NOAA National Marine Sanctuaries Program (USA)
NOAA	National Oceanic and Atmospheric Administration (USA)
NOC	National Oceanography Centre, Southampton (UK)
NODC	National Oceanographic Data Centre (IODE)
NPROVS	NOAA/ NESDIS Products Validation System
NWP	Numerical Weather Prediction
Oceansat-2	Ocean remote sensing satellite (India)
OceanSITES	Ocean time-series stations
OCG	Observations Coordination Group (JCOMM)
ODAS	Ocean Data Acquisition System
ODP	Ocean Data Portal (IODE of IOC)
ODS	Ocean Data Standards process (IODE, JCOMM)
OI	Optimal Interpolation
OPA	Observations Programme Area (JCOMM)
OSI-SAF	Ocean and Sea Ice Satellite Application Facility
OSSE	Observing System Simulation Experiment
OSTIA	Operational Sea Surface Temperature and Sea Ice Analysis
OSTM	Ocean Surface Topography Mission
Pathfinder	NODC AVHRR Pathfinder SST analysis
POLDER	POLarization and Directionality of the Earth's Reflectances
POT	Peaks-Over-Threshold
PP-WET	DBCP/ETWS Pilot Project on Wave Measurement Evaluation and Testing
QC	Quality Control
QuikSCAT	Quick Scatterometer (NASA)
R2R	Rolling Deck to Repository
RAN	Royal Australian Navy
RAN-TAG	GHRSST Reanalysis Technical Advisory Group
RECLAIM	RECovery of Logbooks And International Marine Data
RRR	Rolling Review of Requirements (WMO)
RTM	Radiative Transfer forward Modeling
RV	Research Vessel
SAHFOS	Sir Alister Hardy Foundation for Ocean Science
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SIAF	Seasonal and Inter-Annual Forecasting (WMO)
SAMOS	Shipboard Automated Meteorological and Oceanographic System
SL	Sea Level
SLP	Sea Level Pressure
SMOS	Soil Moisture and Ocean Salinity (ESA)
SOOP	Ship of Opportunity Programme (JCOMM)
SST	Sea Surface Temperature
SST_{depth}	SST measured at a specified depth, e.g. SST2m
SST_{skin}	Skin SST, as measured by radiometrically
SST-SI-WG	GCOS SST and Sea Ice Working Group
SAR	Synthetic Aperture Radar
T/P	Topex/Poseidon satellite altimeter (USA, France)
UID	Unique Identifier
UUID	Universally Unique Identifier
UNEP	United Nations Environment Programme
UNESCO	United National Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USCRN	US Climate Reference Network (USA)
VOS	Voluntary Observing Ship (WMO)
WCRP	World Climate Research Programme
WIGOS	WMO Integrated Global Observing System

WindSat	Satellite Based Wind Speed and Direction System (USA)
WIS	WMO Information System
WMO	World Meteorological Organization (UN)
WMO-CCI	WMO Commission for Climatology (CCI)
WOA	World Ocean Atlas
WOD	World Ocean Database (USA)
WWI	First World War
XBT	Expendable BathyThermograph