CONCEPT PLAN:

Developing an ICOADS Value-Added Database (IVAD) to Support Climate Research

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Executive summary

The international community has had organized discussions about a program that would create an "advanced" version of the International Comprehensive Ocean–Atmosphere Data Set (ICOADS). Community experts have done significant work on specific variables and temporal periods to enhance homogeneity across observing systems, to estimate the uncertainty of observations, and to apply advanced quality control techniques (e.g., track checking). These activities typically result in analyzed (gridded) datasets or manuscripts describing the characteristics of uncertainties arising from various aspects of the observations in ICOADS. The proposed idea is to make the underlying observations used in these improved datasets readily available to all ICOADS users. As a result of ongoing international discussions, the authors envision a group of active researchers with experience using ICOADS assuming responsibility for making data adjustments, metadata, and other derived information available alongside the original data fields, which would remain unaltered. Proposed contributions would be vetted by a coordination group, and a unified interface would inform the users about the latest updates and provide flexible data access. The proposed system would be dynamic and would evolve as recommended adjustments are evaluated, reviewed, and refined. The result would be an ICOADS value-added database (IVAD) that would support a new broad set of statistical or analyzed summary products. At present, many details need to be clarified and only partial funding for the IVAD has been secured (via NOAA). Establishing a JCOMM[1] pilot project has been proposed by the JCOMM Expert Team on Marine Climatology (ETMC) to foster establishing the IVAD.

[1] Joint World Meteorological Organization and International Oceanographic Commission Technical Committee on Oceanography and Marine Meteorology

1. Introduction

The International Comprehensive Ocean–Atmosphere Data Set (ICOADS) is a sustained element of the global ocean observing system (Worley et al. 2010). ICOADS is notably inhomogeneous because the measured and estimated data in ICOADS are derived from changing measurement technology and multiple archive sources and are subject to significant historical events throughout the (more than) three-century record (Figure 1). Community experts have done significant work on specific variables and time periods to enhance homogeneity across observing systems, to estimate the uncertainty of observations, and to improve QC (e.g., track checking); however, the resulting "adjustments" to the ICOADS are not presently available to the wider community alongside the original ICOADS records. The proposed concept is to make the underlying observations used in these improved datasets readily available to all ICOADS users. The plan would take advantage of methods and best practices provided by marine climatologists with extensive experience working with ICOADS.

The overall goal of this proposed new program is to develop a value-added set of marine reports (i.e., individual observations) from ICOADS that are quality controlled (QC) and adjusted for observing system inhomogeneities in a manner that represents the current state-of-the-art. The adjustments could include (but would not be limited to) the following:

- Ship (buoy, etc.) heating
- Beaufort wind adjustments
- Height adjustments (e.g., anemometer)
- Platform mixture issues (ship, buoy, profile, etc.)
- Adjustments for known instrument variations (e.g., bucket vs. intake vs. drifting buoy SST)
- Improved QC procedures (e.g., adaptive QC, track checking, platform-type checks)

As an integral part of the plan, adjustments should have associated uncertainty estimates. As possible, the adjustments should be applied to the entire ICOADS formal release period at any given time (presently Release 2.5 covering 1662–2007; Woodruff et al. 2011). We anticipate that adjustment algorithms would account for temporal variations in relative biases (e.g., ship heating would be different for metal vs. wooden ships). Adjustments would be stored in a database that would retain the "original" ICOADS data and provide for selective adjustments based on user requirements. The resulting ICOADS value-added database (IVAD) would then be used to develop new monthly climatologies (e.g., updating da Silva et al. 1994), new ICOADS monthly summary products, and marine climate indices. This master set would pull together the combined knowledge and efforts of the marine data community to create a global resource that would be available for future generations of scientists. The authors anticipate that the proposed program would provide guidance and collaborative activities facilitating a wide range of climate and other research activities based on ICOADS. The IVAD would be the marine equivalent of efforts by the land surface temperature community to create datasets that account for station moves and instrumentation changes, e.g., the US Historical Climatology Network (HCN).

As a critical component, the IVAD project would also initiate development of an extensible data management framework to allow additional and improved adjustments to be included as continuing research activities expand our knowledge of parameter-specific adjustments. The

project would manage extensions and improvements in the underlying unadjusted ICOADS original data through historical data rescue activities (e.g., Wilkinson et al. 2011) and other advances in contemporary or historical marine data management.

To help initiate the IVAD, a limited duration (e.g., 3-year) pilot project is proposed to explore the value and practicality of the overall concept and to allow for a demonstration of downstream science results (e.g., improved climatologies). For details, see the Annex.

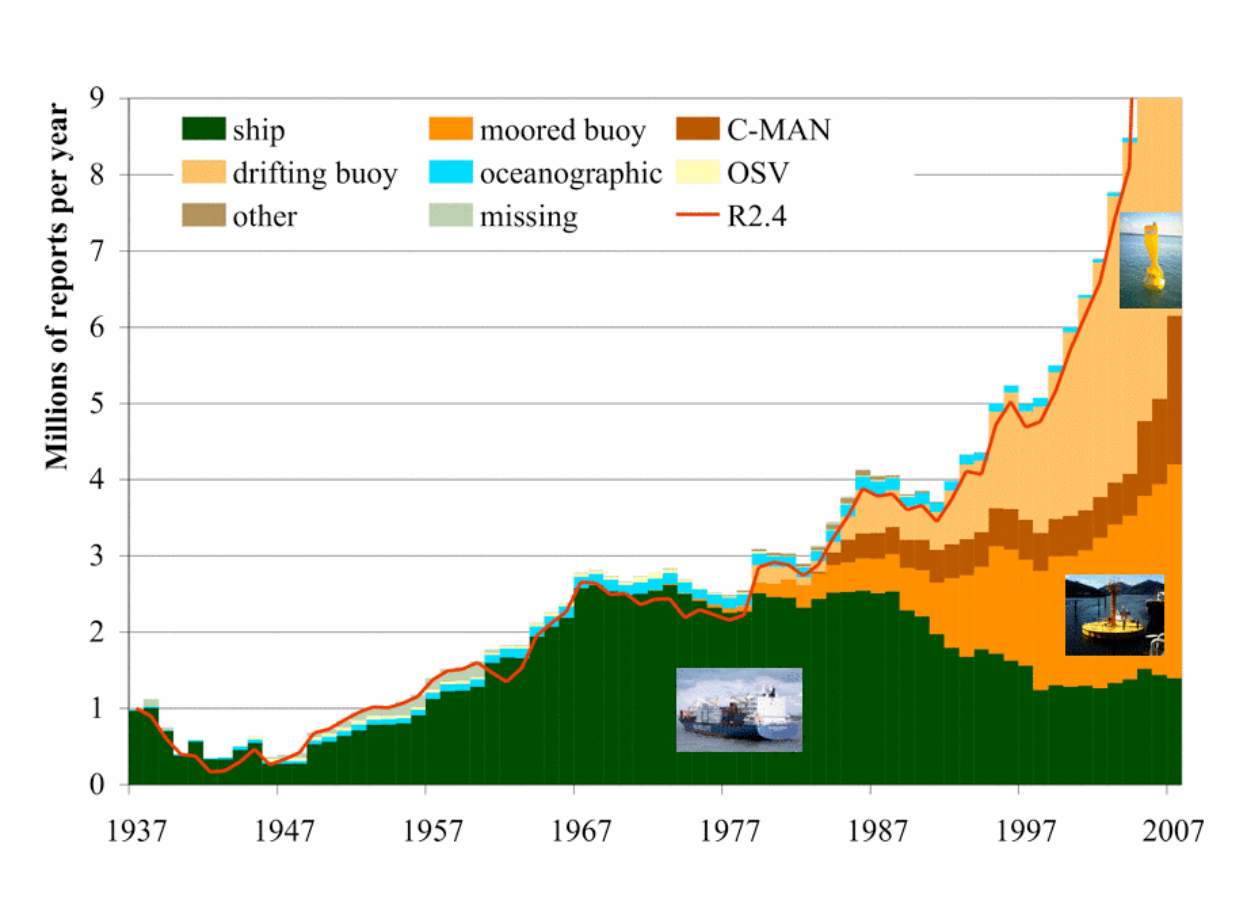

Figure 1. Annual distribution (1937–2007) of major platform types in Release 2.5 shown as millions of reports per year. For clarity the vertical scale is truncated at 9M; years 2005–07 have 13M, 15M, and 16M total reports respectively (not visible) in Release 2.5. The red line curve shows the Release 2.4 annual counts. Ships (mainly VOS plus some R/Vs), buoys, and oceanographic are self-explanatory; Ocean (permanent) Station Vessel = OSV; Coastal-Marine Automated Network = C-MAN; ocean drilling rigs/platforms and other small entities = other; and unidentified platform types = missing. (Ship photo courtesy of www.ShipPhotos.co.uk.) Figure adapted from Woodruff et al. (2008).

2. Structure

The proposed structure for the program would support international contributions from multiple agencies and institutions.

The preliminary program concept includes the following:

1. *Central data management:* This activity would focus on technical aspects of data and metadata formats and database development, storing the adjustments, providing user access to database content, distribution, archival, etc. The current US ICOADS partners at NCAR and NOAA (ESRL and NCDC) would lead this effort.
2. *Defining adjustments:* Groups with expertise in various parameters within ICOADS (e.g., sea surface temperature, air temperature, winds, waves, clouds) would be targeted to create and recommend adjustments.
3. *Metadata augmentation:* Metadata (e.g., instrument types, observations heights, platform type) would be enhanced to support the development of adjustments to ICOADS.
4. *Quality control:* Groups specializing in marine data quality would develop and implement improved methods (e.g., adaptive QC, track checking, multivariate checks) that expand or augment the current ICOADS quality evaluation.
5. *Product development:* Using IVAD content, products will be created that include, but not limited to, new climatologies, indices, and summary statistics.
6. *Steering panel:* A panel of experts would be selected for the primary purpose of approving adjustments prior to their linkage with ICOADS. This panel would also provide overall guidance to the advanced ICOADS program. User-friendly documentation is a key goal of this panel. The steering panel would have to define mechanisms for approving adjustments (options to consider include having adjustments undergo peer review or providing a vetting level tag [with peer review being preferred]). Also, the steering panel would have to establish a de-certification policy for retiring adjustments.

3. What Parameters?

A wide range of oceanic and atmospheric parameters is included in the standard marine reports within ICOADS. On the basis of the current state of the art for bias adjustments and the desires of the user community, a subset of these adjustments would be included in IVAD during the pilot project. Additional parameters can and would be added after the pilot project and the initial parameters were completed.

The decision of which parameters to include (both in the pilot project [Annex] and subsequent work) would likely be tempered by our current state of the art for bias adjustments. Table 1 lists parameters and characteristics that one or more authors thought could be addressed by this effort. The authors considered not only existing adjustments, but also parameters for which adjustments might be developed in the next 3–5 years. At the Third JCOMM Workshop on Advances in Marine Climatology (CLIMAR-III; Gdynia, Poland, 2008), attendees suggested that some JCOMM task teams also could contribute to adjustment factors.

Table 1: Parameter or characteristic within ICOADS for which IVAD adjustments exist or may be developed.
Wind direction and speed
Air temperature
Sea surface temperature
Atmospheric pressure
Moisture (humidity)
Clouds (cover, type, height)
Waves and swell
Ice cover (specific ice parameters TBD)

There is a wide range of additional issues to be addressed within the ICOADS. Early data (e.g., pre–WWII or pre-instrumental data prior to ~1854) have a number of unique challenges that have partly been addressed either by the earlier CLIWOC project (García-Herrera et al. 2005) or through ongoing activities at the Met Office Hadley Centre. The IVAD project would continue to encourage research into historical marine observations and how to best blend these data with modern era observations. The diurnal variability within marine observations is also a topic of great interest for the climate and satellite communities.

4. Data Stewardship

Objectives of the long-term data stewardship and management plan include the following:

- Providing developers of adjustments a method to link them with ICOADS
- Providing mechanisms to include new metadata and quality control in ICOADS
- Tracking adjustment versions and methods
- Maintenance, archival, and distribution of
    - original data
    - adjusted data (with currently approved adjustments applied)
- Provision of data in multiple scientific formats (e.g., IMMA, NetCDF, etc.)
- Potentially allowing for a series of adjustments to be applied in a reasonable sequence and for providing users with a sequence of individual adjustment factors

The proposed activity would take advantage of the latest version of ICOADS (presently Release 2.5). The data management aspect of the project is planned to include a combination of database technology and the established International Maritime Meteorological Archive (IMMA) format. The entire ICOADS observational data collection (presently 261 million marine reports or 297.4 million reports in the "intermediate" product containing flagged duplicates) would be imported into a database to offer fast access in the spatial, temporal, and parameter domains. Use of database technology could ease the task of populating metadata and provide a structure for tracking adjusted and original data (providing necessary version control of adjustments), together with uncertainty estimates. The database could also create a range of output formats including the IMMA format, simple ASCII (spreadsheet interface) formats, and potentially, NetCDF.

As a parallel component of the data storage plan, the IMMA format would be expanded with new attachments to carry along the original and adjusted data elements. This aspect is also crucial because the IMMA format is suitable for permanent retention by archive centers (e.g., NCDC). Linking the IMMA format with the database would require assignment of a unique identification number (UID) to tag all marine reports in ICOADS. The UID would provide a number of attractive benefits, including facilitating reintegration of the ICOADS records once adjustments are determined by multiple international partners.

Enhancing and improving metadata in ICOADS is an essential component of the proposed program, and the use of database technology linked with the IMMA format would help support new metadata activities. This could include back-filling records where gaps exist for individual ships in the WMO Pub. 47 (Kent et al. 2007) ship metadata and blending metadata from other available sources (e.g., buoy metadata; also, CLIWOC project participants expressed interest at CLIMAR-III in providing metadata for early ship data). The proposed project would capitalize on the efforts already made by the National Oceanography Center – Southampton (NOCS) and others working on ICOADS metadata issues (e.g., efforts at the Florida State University [FSU] to evaluate platform identifiers and type mismatches). It might be possible to include supplementary information about data quality by platform or ship identifier or deck number. This might include some form of "black list" for poor performing platforms or decks (with specific date ranges when suspect), which could potentially connect as well with planned access to data quality feedbacks from numerical weather prediction and reanalyses.

Another data activity would center on improving or enhancing the current ICOADS quality evaluation procedures. The longstanding need for general QC improvements for ICOADS (DMPA 2008), potentially coupled with improved standardization in conjunction with JCOMM data management changes (Woodruff et al. 2010), remains an important and under-resourced problem, since the results of QC can have broad impacts on the data and products provided for research. As discussed in Woodruff et al. (2011), globally complete climatological trimming fields could be highly beneficial, facilitating the blending and prompt use of newly recovered data from remote regions. New procedures might include platform tracking, multivariate checks for physical plausibility, checks based on platform type, etc.

Applying adjustments to individual observations might not be optimal for all climate applications, but the authors agree that adjustments should be applied and made available via IVAD only when sufficient information is available for a given marine record. The distribution system must allow for provision of the original (unadjusted) observations, a "best estimate" adjusted value, and potentially a series of individual adjustment values for each observation (for advanced users). In some cases, these individual adjustment algorithms might be applied in a specific sequence (which would be transparent to those looking for the "best estimate" but would be documented for all users).

The proposed database storage of multiple corrections would allow tracking of each correction and the methods by which multiple corrections are applied to a single original ICOADS value. Such a system would allow for future modifications to the correction factors and for the steering panel to propose "best estimate" corrections for different applications (e.g., some applications might need temperature adjusted for ship heating, but not height adjusted to a reference height).

The potential would exist for the user interface (web, etc.) to allow selection of desired corrections and then the user would receive an "adjusted" dataset. The adjusted dataset would include detailed documentation describing which adjustments were applied to ensure traceability and reproducibility. The general user would be able to simply access the original and "best" estimate for each parameter, while advanced users would have the opportunity to download the original data and a series of adjusted values that have been created from several well-documented methods.

Although the primary thrust of this proposed program is on corrections/adjustments that are designed for individual observations, CLIMAR-III participants raised the issue of adjustments designed for grid cells (e.g., monthly 2° × 2° latitude–longitude boxes). Grid-cell adjustments could potentially be applied to all the observations within such a time-space box, but would probably be applied more often to creating fields or climate summary products. A class of general users typically will not know what corrections they want, so a method must exist to provide what the steering panel agrees is the "best" adjusted value for each parameter.

5. Potential Users and Science Goals

A wide range of potential applications exists for the IVAD. Examining long-term atmospheric variability on multiple temporal scales over the oceans, ideally with some of the artificial trends removed from the data, is one area of interest.

Other uses/users might include (but would not be limited to) the following:

- Atmospheric reanalysis efforts – important for ensuring that these groups are using "best" bias-adjusted marine observations (not simply raw GTS observations)
- Ocean analysis and reanalysis efforts – e.g., http://www.clivar.org/data/synthesis/directory.php
- Air-sea flux developers – improving and enhancing SST and flux products
- Radiation budget estimates – assessing cloud observations and their biases within ICOADS
- Satellite data validation – aiding the development of new products and retrieval algorithms
- Climate change assessment (global and regional) – seeking trends with instrument and vessel biases removed
- Climate monitoring – creating climate indices or other indicators on a routine basis (only possible if bias-adjusted ICOADS can be updated in a timely manner)
- Hurricane activity patterns – patterns can be assessed using enhanced air temperature and humidity climatologies

6. Deliverables

The overall goal of the IVAD project would be delivering products to the community. Potential products include the following:

- The IVAD dataset, including height adjustments, bias corrections, and enhanced metadata, via web services and expanded IMMA records
- Advanced ICOADS statistics (e.g., monthly summaries)
- Improved climatologies based on advanced ICOADS data
- New flux products from NOCS and FSU using advanced ICOADS data
- Characterization of climate change using advanced ICOADS data
    - Hurricane trends
    - 5-year averages to assess long term trends
- Enhanced or reproduced climate indices

In terms of the development of new monthly climatologies, the authors note several items to consider. It is clear that the spatial data coverage and known changes in the climate of the globe would not allow the use of all observations from the present full period 1662–2007. This is one reason why, during early discussions, the authors supported making corrections on the individual marine reports. A new climatology can be created using the modern (e.g., Figure 1) era, if desired, but other users could create climatologies using their desired period from the individual marine reports.

One potential climatology centers on the idea of forming a "weighted" average within 1° × 1° or 2° × 2° grid cells. The weighting could take into account different platform types (ships, drifters, buoys, floats, etc.) and the relative quality of the observations on the basis of known vs. unknown metadata. This type of climatology would not be a full spatial objective analysis (e.g., no gap filling where there are no data), although such an endeavor also has merit. In addition, the climatology values at each grid cell should include some measures of the uncertainty.

Another aspect of climatology development is the desire within the climate/ocean community to have new marine climate indices and summary statistics. JCOMM task teams (section 7) among others are working on this topic (Woodruff et al. 2010). The creation of these indices would be aided by the existence of the IVAD.

To characterize long-term trends in climate, 5-year mean fields could be created. This approach would recognize that we are in a period of ongoing climate change and should help inform users of the changes within longer term climatologies. These 5-year means could also be tied to the World Ocean Atlas (Boyer et al. 2006) time scale and open up possibilities for linking changes in the ocean interior to surface forcing.

A current limitation of in-situ based monthly flux products (e.g., NOCS, Berry and Kent 2009; FSU; Bourassa et al. 2005) is that they were created from different versions of ICOADS. One deliverable would result from reconstructing the NOCS and FSU flux climatologies using the common "best" adjusted ICOADS for a common time period. This would allow for a direct comparison of the two flux methods.

7. Support Statements

The authors have begun approaching several international programs and panels to assess their willingness to endorse the proposed IVAD plan. In addition to endorsements, we seek input from the panels in regards to their needs for a bias-adjusted surface marine dataset, and how this proposed advanced ICOADS would support each panel's short- and long-term goals. The authors also plan to engage the numerical weather prediction, ocean modeling, and satellite communities.

Potential panels and programs to approach include the following:

- The Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM)
    - JCOMM Expert Team on Marine Climatology (ETMC) and its Task Teams on Marine-meteorological and Oceanographic Climatological Summaries (TT-MOCS) and Delayed-Mode VOS data (TT-DMVOS)
    - JCOMM Expert Team on Wind Waves and Storm Surges (ETWS)
- WCRP Observational and Assimilation Panel (WOAP) and its Working Group on Observational Data Sets for Reanalysis
- GCOS Atmospheric Observation Panel for Climate (AOPC) and Ocean Observations Panel for Climate (OOPC), and the AOPC/OOPC Working Groups on Surface Pressure (WG-SLP) and Sea-Surface Temperature and Sea-Ice (WG-SST/SI).
- CLIVAR Global Synthesis and Observation Panel (GSOP)

8. Resources

Resources will be needed to support a central data management center and several institutions with expertise in developing corrections and quality evaluation methods for the marine observations within ICOADS. The authors anticipate that multiple proposals will be submitted through international agencies to support national contributions to the program. These proposals would be linked through a common set of objectives to create and make available the IVAD for climate research and application.

Resources for the central data management are critical for the success of this program. The resource level must ensure that data management activities are properly budgeted and scaled by desired parameters (with thought to future expansion). Initially, adjustments and uncertainties for a limited number of parameters would be considered as part of the pilot project. After proof of concept, additional or updated adjustments/uncertainties could be added as funding allows. Most important is that the data management system must be designed initially to be expandable to allow for new adjustments and improvements that are approved by the steering panel. Data management resources must be scaled to match the anticipated increase in demand for bias-adjusted ICOADS observations.

9. Way Forward

A team led by the ICOADS project at NOAA ESRL was awarded three years of funding by NOAA's Climate Observation and Monitoring Division to design, test, and implement the data management structure for archiving and distributing the IVAD. Via this funding, the ICOADS team anticipates implementing corrections for a limited number of parameters. The number of parameters will be set by the resources allocated to the US effort and the contributions made by our international partners. Contribution from the international committee were solicited during a plenary discussion *Challenges and solutions to enhance ICOADS* during the Third International Workshop on Advances in the Use of Historical Marine Climate Data (MARCDAT-III; 2-6 May 2011, Frascati, Italy). Once the data management structure is in place, we anticipate that additional corrections and uncertainties will be developed and made available over an additional 3 to 5 years. To date, no resources have been secured to support activities 3–6 of the concept plan (see section 2). To further the IVAD effort, the JCOMM Expert Team for Marine Climatology (ETMC) recommended development of a proposal to make the IVAD a JCOMM pilot project (Annex).

10. Participants and Partners

Table 2. Authors of concept plan with their relevant international panel memberships and roles in the IVAD project.

Name	Email	Organization; relevant international roles	Primary role in IVAD
Shawn Smith	smith@coaps.fsu.edu	COAPS/FSU; TT-DMVOS	Data management, quality control, climatologies
Mark Bourassa	bourassa@coaps.fsu.edu	COAPS/FSU; Ocean Vector Winds Steering Panel	Bias correction and uncertainty for many variables, climatologies
Scott Woodruff	Scott.D.Woodruff@noaa.gov	NOAA/ESRL; JCOMM ETMC	ICOADS management and development, monthly summaries
Steve Worley	Worley@ucar.edu	NCAR; WOAP	ICOADS archival and database development
Elizabeth Kent	eck@noc.soton.ac.uk	NOC, Southampton; WOAP, ETMC, TT-MOCS	Metadata, adjustments for several parameters
Simon Josey	Simon.A.Josey@noc.soton.ac.uk	NOC, Southampton; GSOP	Air-sea fluxes, climate change
Nick Rayner	nick.rayner@metoffice.gov.uk	UK Met Office; GCOS WG-SST/SI	SST adjustments and uncertainty, ice cover, historical data, diurnal variability
Eric Freeman	Eric.Freeman@noaa.gov	NOAA/NCDC; TT-DMVOS	ICOADS data management, IMMA development
Dick Reynolds	Richard.W.Reynolds@noaa.gov	NOAA/NCDC; OOPC	ICOADS, SST adjustments

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Annex: Proposed JCOMM Pilot Project

As an outcome of the Third ETMC Session in February 2010 (JCOMM 2010), a limited duration (e.g., 3-year) JCOMM pilot project is proposed to explore the value and practicality of the overall concept and to allow for a demonstration of downstream science results (e.g., improved climatologies). The pilot project would be limited in scope, possibly considering a subset of the full ICOADS version 2.5 (limiting the number of years or parameters). The outcome of the pilot project would be an initial advanced observational data set—to be made available to the international user community by the US ICOADS partners—including bias adjustments and uncertainty measures. The ETMC endorsed the following approach:

1. Hold a session focusing on advanced ICOADS data at the Third International Workshop on Advances in the Use of Historical Marine Climate Data (MARCDAT-III) in May 2011.
    a. Engage the satellite community, showing the strength of an advanced ICOADS database as a quick-query mechanism to create satellite match-up datasets.
    b. This session would allow participants to present available corrections and adjustments and could contribute to the pilot project (see below).
2. Combining feedback from MARCDAT-III with current concept plan, develop a final white paper proposal to establish a JCOMM pilot project. Components of the white paper would include the following:
    a. Establishing a steering panel
    b. Drafting terms of reference for the steering panel
    c. Identifying goals and a time table for the pilot project
    d. Selecting a subset of corrections/adjustments that are ready now to test concept and develop technical solutions

    NOTE: The pilot would be designed to be short term and have deliverables and test cases for some corrections.
3. Develop and submit proposals to support national contributions.
4. ETMC also agreed that planned merger of the Extended Edited Synoptic Cloud Reports Archive (EECRA) cloud information into ICOADS could possibly form a useful test-bed for developing some of the related data management techniques.