PROJECT TITLE: An International Comprehensive Ocean-Atmosphere Data Set (ICOADS) Value-Added Database (IVAD) to Support Climate Research

Final Report

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NOAA GRANT NUMBER: NA11OAR4310169

TIME PERIOD ADDRESSED BY REPORT: 09/01/2011 – 08/31/2015

1. Project Summary

The International Comprehensive Ocean-Atmosphere Data Set (ICOADS) is the largest collection of surface marine *in situ* observations, spanning 1662 to present. The primary aim of the ICOADS Value-Added Database (IVAD) project is to develop a system whereby dataset developers and other ICOADS expert users can contribute to ICOADS by providing detailed information on the quality of individual ICOADS observations. IVAD is designed to allow the user community to provide adjustments (e.g. bias corrections, height adjustments, enhanced quality control) and uncertainty estimates for parameters within the individual ICOADS reports that can be distributed as an attachment alongside the main ICOADS data. Using the IVAD concept, researchers will have ready access to expert-derived adjustments and corrections to the ICOADS marine reports, which will facilitate the development of new products to support decision making in the areas of climate change, extreme events, and marine hazards and safety; improve numerical weather prediction, particularly reanalysis products; and facilitate a wide range of marine climatological research topics. The IVAD project was a collaborative research initiative between NOAA (Earth Systems Research Laboratory, Cooperative Institute for Research in Environmental Sciences, and National Centers for Environmental Information [NCEI]), the National Center for Atmospheric Research (NCAR), and the Center for Ocean-Atmospheric Prediction Studies (COAPS) at the Florida State University (FSU).

The FSU component of the project involved international coordination of the IVAD project, contributing to the IVAD design, developing a prototype adjustment for estimated (Beaufort) winds from ships, and engaging students in topics of marine data stewardship. FSU completed prototype IVAD records for estimated winds and showed the feasibility of using linked ICOADS and IVAD records to resolve a simple research question. The outcome of NOAA's investment in IVAD is a working prototype that is ready for future scientists to create new adjustments and deliver them to the wider research community.

2. Objectives and Scientific Accomplishments

The FSU component of the IVAD project completed the following deliverables (revised through the project from the original proposal as a result of funding instability for the core ICOADS project):

Year 1

1. Coordinate selection of initial parameter value adjustments to be included in IVAD,
2. Validate the IVAD design and initial scope with the international community at the MARCDAT-III workshop, refine approach as necessary, and seek additional contributors,

3. Collect and organize IVAD documentation associated with each parameter value adjustment method.

Year 2

4. Liaise with IVAD team members during the final design and implementation of prototype IVAD.

Years 3 and 4

5. Derive prototype adjusted values for estimated (Beaufort) winds for a limited subset of the IVAD marine reports.
6. Format the wind records into IVAD International Marine Meteorological Archive (IMMA) attachments and submit to NCAR for inclusion in the database.
7. Liaise with IVAD team members and other developers of prototype parameter adjustments.
8. For variables with prototype value-added data, conduct analyses to compare IVAD original and adjusted data.

All Years

9. Report on IVAD status and comparison studies at relevant meetings or symposia

The core activity at FSU in year 1 focused on working with our project partners (the IVAD team) at NOAA/ESRL/CIRES, NOAA/NCEI, and NCAR to design the IVAD and the IVAD attachment for distributing value-added adjustments using the IMMA format. A preliminary design for IVAD was vetted by the international marine climate community at the Third International Workshop on Advances in the Use of Historical Marine Climate Data (MARCDAT-III; Frascati, Italy, 2-5 May 2011) and recommendations from this meeting were discussed and implemented through subsequent teleconferences with project partners [Deliverable 2]. Following MARCDAT-III, the PI (Smith) coordinated four teleconferences and one face-to-face meeting (31 October 2011, hosted by NCAR in Boulder) where the project partners discussed all aspects of IVAD design. The design included plans for adding a unique record identifier (UID) to the individual marine reports in the intermediate ICOADS release 2.5 (R2.5i) dataset and placing the R2.5i data in a structured query language database at NCAR.

During the year 1 project team meetings and teleconferences, the team identified two parameter adjustments for inclusion in the prototype IVAD [Deliverable 1]. The FSU team created value-added adjustments to visual wind estimates using an approach based on Lindau (1995). Adjusted air temperature and associated uncertainty estimates were developed and provided by our colleagues at the National Oceanography Center – Southampton (NOCS). The NOCS adjustments will account for ship heating effects on air temperature and will be based on Berry et al. (2004). The FSU team collected the publications related to the visual wind estimates and ship heating affects on air temperature [Deliverable 3] for use during the IVAD prototype development.

Late in 2011, NOAA/ESRL decided to terminate internal support for the ICOADS project. As a result, Scott Woodruff and the ESRL ICOADS staff had to shift their focus from IVAD to develop a plan to transition ICOADS activities to NCEI-Asheville and other project partners. The PI contributed to several transition teleconferences and, with approval of NOAA/CPO, agreed to modify the FSU IVAD budgets for years 2 and 3 to provide additional FY12 support to the core ICOADS project. This limited FSU work in year 2 and shifted the bulk of our deliverables to years 3 and 4.

The sole activity at FSU in year 2 focused on collaboration with our project partners (the IVAD team) at NOAA/ESRL, NOAA/NCEI, and NCAR to complete the design for the IVAD and the new International Marine Meteorological Archive version 1 (IMMA1) IVAD attachment [Deliverable 4]. FSU arranged three teleconferences for the IVAD team on the following dates: 20 June 2012, 1 March 2013, and 9 May 2013. Through this series of teleconferences, the IVAD team continued to modify the IMMA1 IVAD attachment structure and moved toward having a final version available to the IVAD attachment prototype teams by June 2013. The team finalized the prototype for the unique record identifier (UID) in the database and how it would be stored in the IMMA1 records. A prototype for the Author Reference Code (ARC), which allows developers of IVAD attachments to provide documentation of their processes and procedures, was also completed. The team also continued to make changes to other IMMA1 attachments (e.g., ocean data, quality control, etc.) that are not directly related to the IVAD. Another result from the May 2013 teleconference was a plan for archiving the IVAD attachments received from IVAD developers. The plan ensures that multiple copies of each IVAD attachment are stored at NCAR, the attachments are imported into the database management system, and they are periodically exported in IMMA1 format as updates are received for the latest release of the ICOADS.

In addition, Mr. Smith participated in the EarthTemp Network SST-ICOADS Exchange of Visiting Scientists meetings via videoconference and WebEx from 4-10 April 2013. These meetings were hosted by NOC-Southampton and the UK Met Office. The IVAD project was a prominent topic throughout the meeting and several sessions specifically focused on IVAD development and the implications for the international marine climate community. The following recommendations were made by the international participants to the U.S. IVAD team for improving the IVAD attachment: (1) including three user-defined uncertainty fields with indicators of the uncertainty type, (2) providing a precision indicator to the value-added value and uncertainty fields, (3) identifying a more flexible quality control scheme, and (4) outlining a procedure for developers to select an ARC. Design changes to the IVAD and IMMA1 format were iterated among team members throughout the funding period and have been finalized for use in creating release 3.0 of ICOADS (R3.0) scheduled for beta release in early 2016.

Years 3 and 4 included the development of a prototype value-added record for estimated (Beaufort) winds [Deliverable 5]. A graduate student, Mr. Keqiao Li, analyzed the estimated winds found in ICOADS release 2.5.1 reports for the period 1970-2007 and noted a wide range of variability in the wind speeds associated with “estimated” wind reports. By extracting all records from ships that have a wind indicator (WI) that defined the wind speed as “estimated” and created histograms of the observations (Figure 1), the analysis revealed that only WI=5, indicating a wind value that was known to be converted from the Beaufort 0-12 estimated wind scale, had wind speed values that fell into the 13 discrete bins anticipated for a Beaufort wind. The others had much larger spread because of varying national practices for converting an estimated wind to a wind speed value (in many cases this was up to the subjectivity of the observer on the ship). After consultation with members of the ICOADS and marine climate community, it was decided that we should only create IVAD records for those ICOADS reports with WI=5. This turned out to include a select set of reports digitized by NOAA’s Climate Data Modernization Program from a Japanese Whaling Ships for the period 1946-1984. For these select ICOADS reports, the originally reported wind speed has be replaced (with the original value retained for the user as well) with the wind speed estimate provided by Lindau (1995).

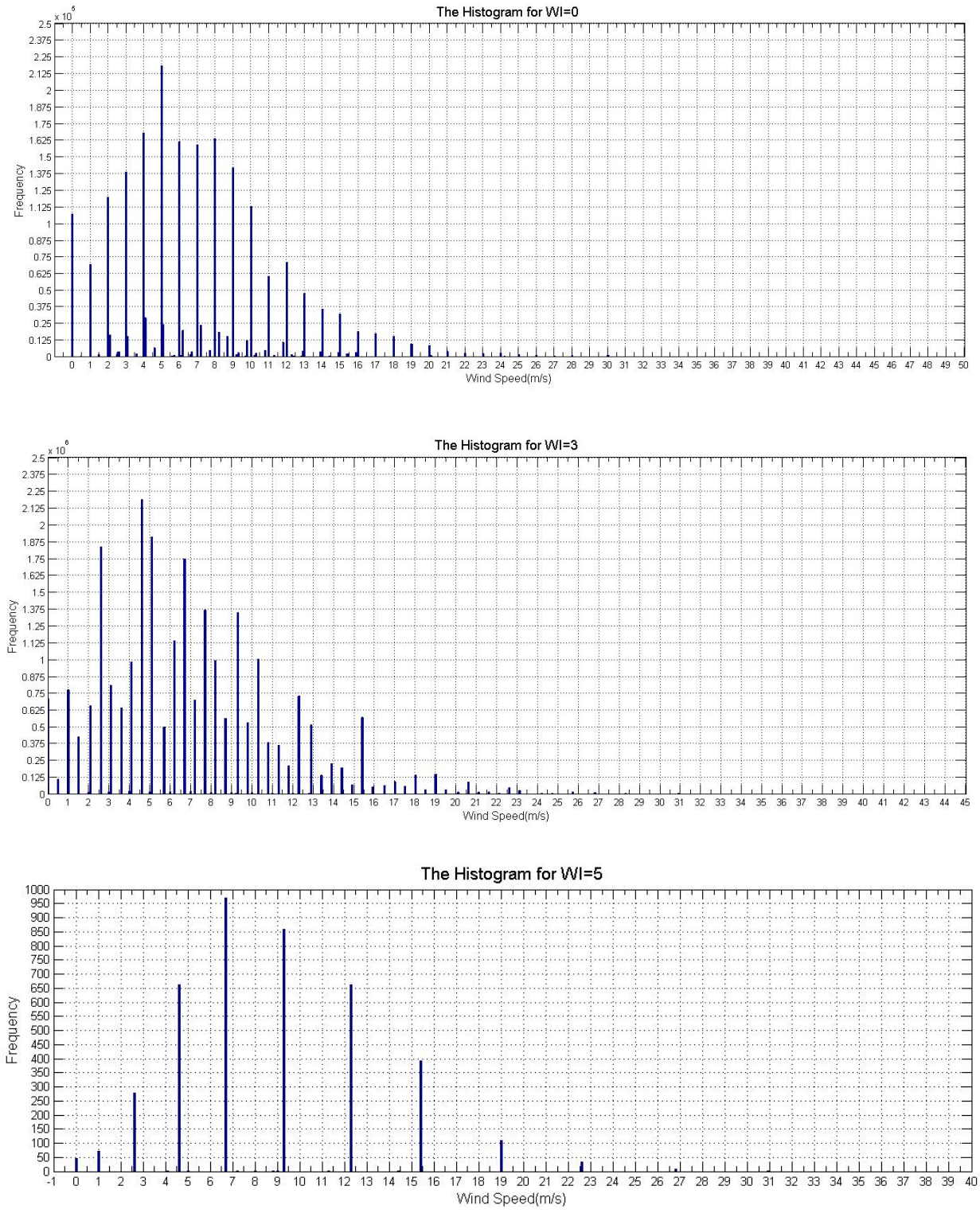

Figure 1: Histograms of estimated wind speeds from ICOADS release 2.5 categorized by wind indicator. (a) Meter per second, estimated (WI=0), (b) knot, estimated (WI=3), and (c) Beaufort force based on documentation (WI=5). All wind speeds are plotted in meters per second as read from the ICOADS data files.

The value-added data records applying the Lindau (1995) correction for the Japanese Whaling Data records have been created and were submitted to NCAR (the host of the IVAD database management system) on 12 August 2015. The data used the new *ivad* data attachment for the IMMA1 format [Deliverable 6]. A sample of these records is shown in Table 1. Final documentation of the procedure (Smith et al. 2015), the author reference document, was created and submitted along with the data.

Table 1: Sample of *ivad* attachments containing Beaufort wind adjustments using the Lindau (1995) approach for April 1983. The format of the data includes the unique record identifier attachment (*uid*) followed by the *ivad* attachment. Details of the attachment format is available from http://icoads.noaa.gov/ivad/IMMA-Rev.pdf.

981528S9NS251219653	0201	27	FS01201412160
981528SG8Y251219653	0201	12	FS01201412160
981528SMX6251219653	0201	97	FS01201412160
981528STW2251219653	0201	0	FS01201412160
981528T0L7251219653	0201	97	FS01201412160
981528T7C7251219653	0201	27	FS01201412160

The FSU team continued collaboration with our project partners at NOAA/CIRES, NOAA/NCEI, and NCAR and other international collaborators [Deliverable 7]. The primary focus was finalizing the changes to the IMMA format to include the *ivad*, *uid*, and other attachments in preparation for R3.0 of ICOADS. In addition, ICOADS formally created an international steering committee (ISC) in June 2014 and a Mr. Smith is chairing a sub-group of the ISC that is focused on the future development of the IVAD component of ICOADS.

In 2014, Ms. Kristen Briggs from FSU evaluated the air temperature IVAD developed by NOC-Southampton [Deliverable 8]. Her testing included exercising a prototype version of the ICOADS IMMA1 records that contained the air temperature IVAD attachments. This was the first use of the new multi-record IMMA1 format and the related read software developed by our partners at NOAA and NCAR. Ms. Briggs reported that the new read code ran smoothly and that extracting both the adjusted (from the IVAD attachment) and unadjusted (from the ICOADS core record) air temperature data was straightforward. She was able to quickly identify the reports with air temperature adjustments in the period 1970-2006 and used these reports to calculate pseudo-sensible heat flux (SHF) values (Figure 2). The SHF was calculated using both the adjusted and unadjusted air temperatures. The comparison shows a scatter falling to the left of the (y=x) line, which is expected since the air temperature correction applied by NOC is intended to remove ship heating from air temperature (i.e., smaller air temperature means larger gradient between ocean and air and bigger SHF out of ocean). This quick test revealed that (1) new IVAD attachments can be created by an expert researcher and ingested into the central ICOADS database at NCAR, (2) these records can be exported from the database in IMMA1 format for research use, and (3) a researcher can easily extract and apply the IVAD adjusted values to their research task using the NOAA developed read software. Additional tests are not deemed necessary at this time as the concept has been proved and the structure of the IMMA1 records (and the associated *{rwimma.f}* software) have been shown to work.

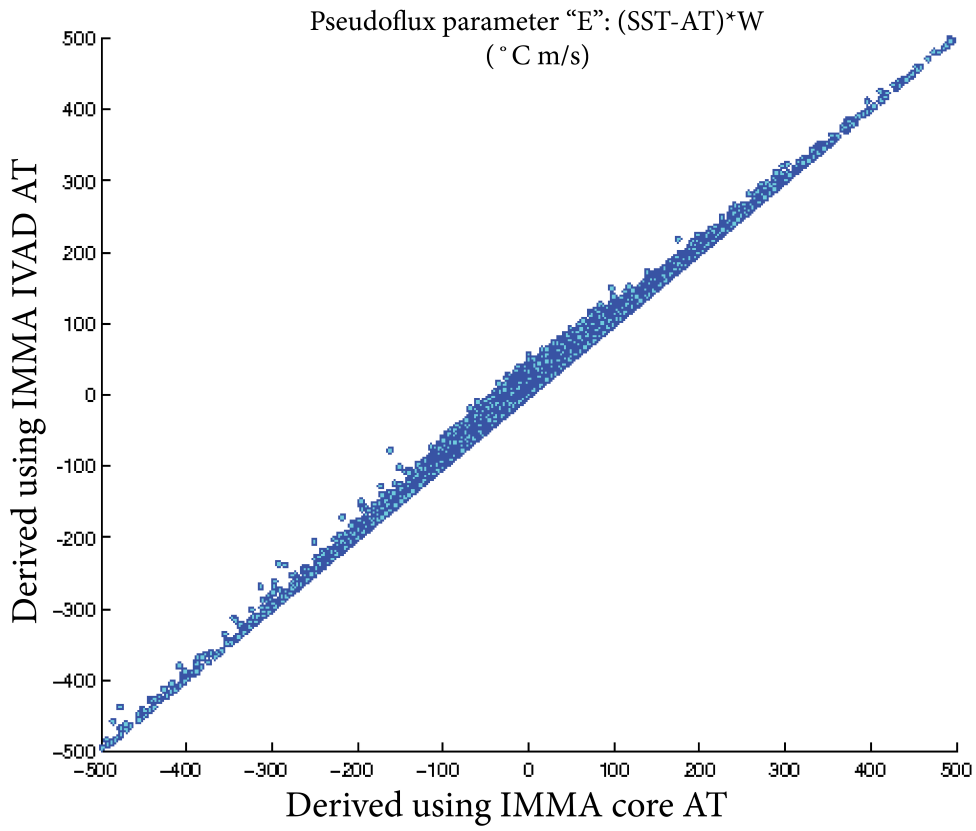

Figure 2. Comparison of pseudo-sensible heat flux calculated using original air temperature (core AT) and bias-adjusted air temperature (IVAD AT) for ship reports extracted from ICOADS for the year 2000.

In the final activity for the project, Mr. Smith attended a face-to-face meeting of the ICOADS and IVAD team members on 28-30 July 2015 in Boulder, CO. At the meeting the team reviewed the Beaufort wind IVAD package and documentation submitted by FSU to NCAR. The team decided that blending the two IVAD prototypes (Beaufort wind from FSU and marine air temperature from NOC-Southampton) would not occur until after R3.0 is completed. This effort will have to leverage core ICOADS funding if no other options can be found. With no immediate future funding for IVAD, the team noted that future progress on the IVAD concept will be slow. The team discussed the need to seek out additional funding for NCAR/FSU/NCEI to redesign the web service interface for ICOADS to support user access to community-developed data adjustments supported by IVAD.

3. Outreach and Education

The development of the prototype IVAD for estimated winds was conducted by Mr. Keqiao Li, an M.S. candidate in the Earth, Ocean, and Atmospheric Science department at FSU. Through this project Mr. Li has become familiar with ICOADS, IVAD, and aspects of international marine data management. His work will partially complete his requirements for an M.S. in meteorology. Mr. Li has expanded his research into bias-correcting estimated winds using satellite wind observations (separately funded by NASA).

Throughout the project, the PI and collaborators provided updates on the progress of IVAD development to the marine climate community [Deliverable 9]. Outcomes of the IVAD project were disseminated to the international research community by the PI at the JCOMM Fourth Workshop on Advances in Marine Climatology (CLIMAR-IV; 9-12 June 2014 in Asheville, NC), for which the PI served on the international organizing committee. In addition, the PI chaired the first IVAD workshop in conjunction with CLIMAR-IV on 13 June 2014. The IVAD workshop provided an open forum where ~30 data and research scientists were updated on the IVAD project and were provided an opportunity to contribute to the ongoing development and future directions for the project. Following the meeting, Mr. Smith collaborated on reporting outcomes of CLIMAR-IV and IVAD1 in the JCOMM workshop report (JCOMM 2015) and an article in Flux News (Berry and Smith 2015).

IVAD presentations during this project include the following (bold indicates FSU team members):

Kent, E. C., E. Charpentier, C. Donlon, S. Iona, N. Rayner, **S. R. Smith**, V. Swail, and S. D. Woodruff, 2011: The CLIMAR Community Initiative: A 10-year vision. Poster, *WCRP Open Science Conference*, Denver, CO, 24-28 October 2011.

Smith, S. R., S. D. Woodruff, S. Worley, and E. Freeman, 2012: IVAD – Enhancing marine climate data records. Poster, *2012 Ocean Sciences Meeting*, Salt Lake City UT, 20-24 February 2012.

Smith, S. R., S. D. Woodruff, S. Worley, E. Freeman, and E. C. Kent, 2014: ICOADS Release 3.0. Presentation, *2014 Ocean Sciences Meeting*, Honolulu, HI, 24-28 February 2014.

Smith, S. R., D. I Berry, **M. A Bourassa**, J. E. Freeman, E. C. Kent, S. D. Woodruff and S. J. Worley, 2014: ICOADS Value-Added Database (IVAD). Presentation, *Fourth JCOMM Workshop on Advances in Marine Climatology (CLIMAR-IV)*, Asheville, NC, 9-12 June 2014.

Li, K., M. A. Bourassa, and **S. R. Smith**, 2015: Adjustment of visually observed ship winds (Beaufort winds) in ICOADS. Poster, *2015 International Ocean Vector Winds Steering Team meeting*, Portland, OR, 19-21 May 2015.

4. Research Publications and Products

4.1 Publications

Smith, S. R., 2011: Ten-year vision for marine climate research. *EOS, Trans Amer. Geophys. Union*, **92**(43), 376.

4.2 Reports

Smith, S. R., K. Briggs, and **K. Li**, 2015: Beaufort Wind Corrected Records for Deck 761 within the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) Value-Added Database (IVAD). COAPS, Tallahassee, FL, USA, 5 pp. Available from Center for Ocean-Atmospheric Prediction Studies, Florida State University, Tallahassee, Florida, 32306-2840, USA.

JCOMM, 2015: Proceedings of the Fourth JCOMM Workshop on Advances of Marine Climatology. JCOMM TR-079. Available from: http://www.jcomm.info/index.php?option=com_oe&task=viewDocumentRecord&docID=15293

Berry, D., and **S. Smith**, 2015: The 4th JCOMM Workshop on Advances in Marine Climatology and the 1st ICOADS Value-added Database Workshop, Asheville, 9-13 June 2014. *FLUX NEWS*, 7, Feb. 2015, pp. 16-17. Available from: http://www.clivar.org/sites/default/files/documents/FluxNews_7.pdf

4.3 Data Sets

One outcome of this project was the development of a prototype IVAD dataset for Beaufort winds (Table 1). This dataset, described in Smith et al. (2015) has been submitted to NCAR for inclusion into ICOADS R3.0 following the release of that product in 2016. The prototype IVAD records were submitted in IMMA1 format, have been archived with redundant copies at NCAR, and will be made available as part of the IVAD management system later in 2016. These data are a prototype and are only available on request from NCAR or COAPS (contact smith@coaps.fsu.edu for details). There are no plans to update this dataset at this time. Archival and maintenance of the submitted data set are the responsibility of the ICOADS project and will be conducted by NCAR's Research Data Archive as resources allow.

5. Summary

Through this CPO funding, the FSU team has contributed to the development of the IVAD concept, which will support future inclusion of expert-derived adjustments or corrections to individual ICOADS marine reports. We successfully completed a prototype IVAD for estimated winds and verified that once adjustments are included in ICOADS in the IMMA1 format, they can be easily retrieved and applied to scientific analyses. FSU's contribution to the IVAD project was also key in our contributions to the future development of the core ICOADS project. ICOADS is internationally recognized as the most complete and extensive surface marine climate data set and plays a critical role in numerical weather prediction reanalysis exercises, air-sea interaction studies, satellite algorithm development, and a host of individual process and research studies. CPO's investment in IVAD helped lay the foundation for NCEI-Asheville taking the lead on developing ICOADS R3.0, a foundational NOAA marine data product, and put in place the core infrastructure and procedures for IVAD to succeed in the future.

6. References

Berry, D. I., E. C. Kent, and P. K. Taylor, 2004: An analytical model of heating errors in marine air temperatures from ships. *J. Atmos. Ocean Technol.*, 21, 1198-1215.

Lindau R., 1995: A new Beaufort equivalent scale. *International COADS Winds Workshop*, Institut fur Meereskunde, Kiel, and National Oceanic and Atmospheric Administration: Kiel, Germany; 232–252.