Ocean Data Management at NCDC

From Ingest to Archive, Blended Products and Data Services

Huai-Min Zhang[1], Rich Baldwin[1], Eric Freeman[2], Ge Peng[3]
[1]NOAA National Climatic Data Center, Asheville, NC
[2]ERT, Inc, Contractor to National Climatic Data Center, Asheville, NC
[3]NOAA's Cooperative Institute for Climate and Satellites, NCSU, Asheville, NC

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1. Project Summary

<u>Summary in Brief:</u> This project is to ensure that the surface marine observations, of which most are invested and managed by NOAA, are officially archived at the NOAA archive and serviced to the public. This is to avoid any potential of permanent data and invest loss of NOAA/OCO investment (Figure 1). This project further carries through an End-to-End process (Figure 2), from data ingest of the observing systems, to data quality control, gridded and blended data production, and to direct data services to the user communities, including for scientific researches, marine ecosystems (e.g. NOAA's World Coral Reef Watch), renewable energy industries (offshore energy), marine transportation (e.g. ship routing services in near real time), outreach and education, among many others.

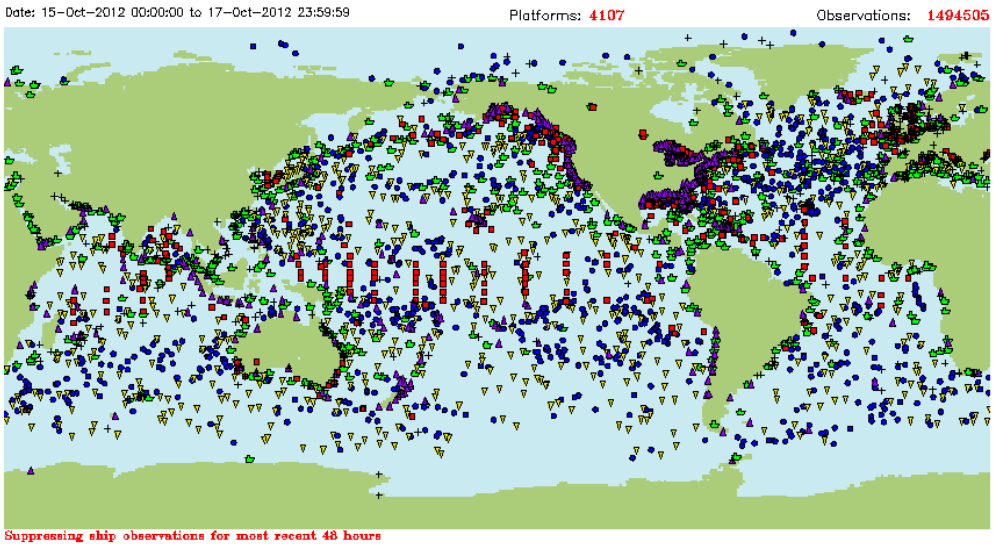

Figure 1: NCDC serves as NOAA's official archive of weather and climate data. This project is to ensure that the marine surface observations managed by NOAA OCO (this figure, from COD's Observing System

Monitoring Center: http://osmc.noaa.gov/Monitor/OSMC/OSMC.html), and others such as the international VOSClim (below for details), are in the NOAA Archive and serviced to the public online.

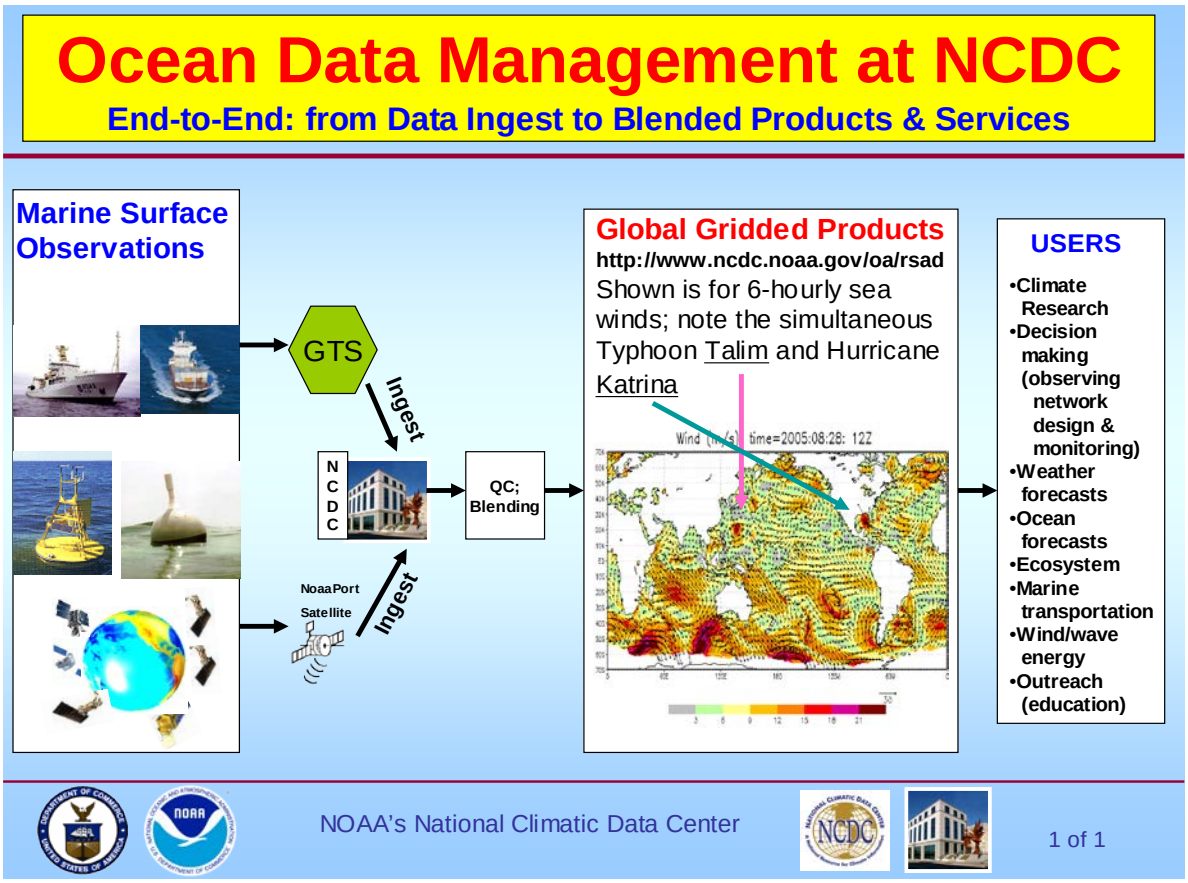

Figure 2: Conceptual diagram of the project's End-to-End data process, from ingest to archive, quality control and products development and services for societal benefits.

Project Scope:

The data of this project include those from ship and buoy observations invested by NOAA, data collected in ICOADS and VOSClim, as well as satellite observed sea surface winds. This project directly supports the NOAA's mission: "To understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs." It directly serves the COMD's Program Deliverables in: 1) To identify climate variability through surface marine observations including SST and sea surface winds; and 2) To identify changes in forcing functions through the air-sea exchange processes. This is accomplished by fulfilling NCDC's mission: "To provide stewardship and access to the Nation's resource of global climate and weather related data and information, and assess and monitor climate variation and change."

This project also supports NOAA's Congressional mandate to preserve the Nation's Weather and Climate Data as a National asset, and the National Climate Assessments required under U.S. Global Change Research Program (USGCRP), which began as a presidential initiative in 1989 and was mandated by Congress in the Global Change Research Act of 1990 (P.L. 101-606). This mandate provides essential support of the environmental data needs of the Nation's public, private, and academic

sectors. Partners and customers who will benefit from these services include federal, state and local agencies, scientists, researchers, resource managers, businesses, communities, and decision makers that can use the data and information for their strategic planning, actions, and decisions (e.g., coastal communities, building code, and planning of power plant, transportation infrastructure, to name just a few). A well-known example is the El Nino events that affect multiple billions of dollars worldwide. To map out the trends and to identify the frequencies of these extreme events require long term records of the climate (including the ocean) data. Long-term data records provide the foundation to advance the understanding and unlock the mysteries of the Earth's weather and climate system.

NOAA and NCDC play an active and important role in the national and international climate change monitoring and assessment programs (e.g., IPCC and USGCRP). Climate change monitoring and assessment require meteorological and marine data over both land and ocean. Changes of environmental variables at and near the marine surface are important since they occur over approximately 70% of the Earth's surface and contain important climate change signals. Due to the drastic property differences between water and air (e.g., density and heat capacity), huge amount of water, energy, momentum and gases (e.g., carbon dioxide) are constantly exchanged at the turbulent air-sea interface. These exchanges regulate the weather in the short term and the climate change in long term. Thus, NCDC has been actively archiving, serving and utilizing the world's surface marine data, and it will need to continue to do so.

Modern day Global Ocean Observing System (GOOS) consists of multiple platforms and instruments (both in-situ and remote sensing). Each of these observations contributes to the understanding and assessment of climate change signals. However, individual instrument observations have limitations in coverage (in both time and space) and limitations on accuracy (e.g. Zhang et al 2004). To maximize benefits and integrally use all the available observations, it is necessary to blend them together to produce higher resolution and higher accuracy products for the needs of both researches and societal applications (e.g. Zhang et al 2006; Reynolds et al 2007). For example, research on global water and energy budgets and numerical weather and ocean forecasts demand increasingly higher resolution forcing data (better than daily and 50 km; e.g., WMO/TD-No. 1036, 2000; Curry et al. 2004). The recent international Global Earth Observation System of Systems (GEOSS) and Global Climate Observing System (GCOS) also called for optimal combinations of the above platforms for integrated global observing system and service (reviewed in Zhang et al 2009). The high quality in-situ observations will be used to input directly into air-sea flux computations, as part of coupled atmosphere-ocean climate models, and to provide ground truth for calibrating satellite observations, evaluating and validating NWP model and reanalysis results.

The overall objectives of this project are: 1) to ingest the world's surface marine observational data into the NOAA archive; 2) to quality control the data for various applications; 3) to produce blended products for optimal use of all the observations; and 4) to improve services for a wide variety of user communities. A conceptual program summary and flowchart for this Ocean Data Management are shown in Figure 2.

2. Scientific and Observing System Accomplishments

Accomplishment Highlights: 1) Surface marine observations are ingested and archived in near-real-time via the GTS stream (including the observations supported by NOAA/OCO). 2) Data are serviced to the public online. 3) Blended products for research and societal benefits are generated and maintained. 4) Duties of ICOADS are being transitioned from NOAA/ESRL to NOAA/NCDC; 5) VOSClim webpages re-formatted and migrated to new NCDC web platform.

Our data and products are directly available online and in near real time (http://www.ncdc.noaa.gov/oa/rsad/air-sea/index.html and links therein for ICOADS and VOSClim). The user-friendly interfaces and formats have continued to extend the benefits to society, such as applications in marine ecosystems (e.g., the near-real-time use in NOAA's world Coral Reef Watch), marine transportation safety and efficiency (e.g. ship routing), and offshore renewable energy services, among others. These were evidenced during the 2014 Government Shutdown, with multiple near-real-time users' requests and statement of impact.

The Blended Seawinds are updated quasi-daily. ICOADS dataset is updated monthly. Our data management is done according to NOAA/NCDC archive requirements. Our data and products are not linked to the National Environmental Policy Act (NEPA) and other NOAA Environmental Statutes (e.g. Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), Essential Fish Habitat (EFH), and the National Marine Sanctuaries Act (NMSA).

Specific Deliverables:

- ***Surface Marine observational Data Archive and Service: ICOADS***

  Completed the transition from NCDC-variant IMMA format to the standard IMMA format for usability of data to wider communities. For FY13, servicing software was modified to account for both NCDC and IMMA formats. This provides a subset of the IMMA format online through the web. The full format is available through archive ordering. The amount of data that are available through online access applications has increased by 14%. Software to perform data sub-setting and bulk order processing is 70% complete. This functionality should be available in FY14.

Figure 3: Number of data orders as function of time.

- *Transition of duties from NOAA/ESRL to NOAA/NCDC:* Early in FY12, programmatic changes within NOAA resulted in NCDC taking responsibility and providing overall leadership for the ICOADS project in continuing close cooperation with ESRL, NCAR, and national and international partners. During FY13, ICOADS partners drafted transition plans that outlined steps and resources needed to fully transition operations from ESRL to NCDC. Preparations for the next major ICOADS release (e.g. R3.0) were outlined in a R3.0 work plan document. To assist with the R3.0 dataset development, international partners agreed to provide much-needed resources (limited to personnel) to ICOADS development and a Letter of Commitment (LoC) was drafted to formalize partnership duties. An improved Near-Real-Time (NRT) product was developed consisting of a blend of NCDC and NCEP GTS surface marine observations. The project remains underfunded, but assistance from new partners will alleviate some of the heavy workload required to further develop the dataset.

- *Data are available online (e.g. Figure 3 below):*
  http://www7.ncdc.noaa.gov/CDO/CDOMarineSelect.jsp
  http://has.ncdc.noaa.gov/pls/plhas/has.dsselect
  ftp://ftp.ncdc.noaa.gov/pub/data/icoads2.5/

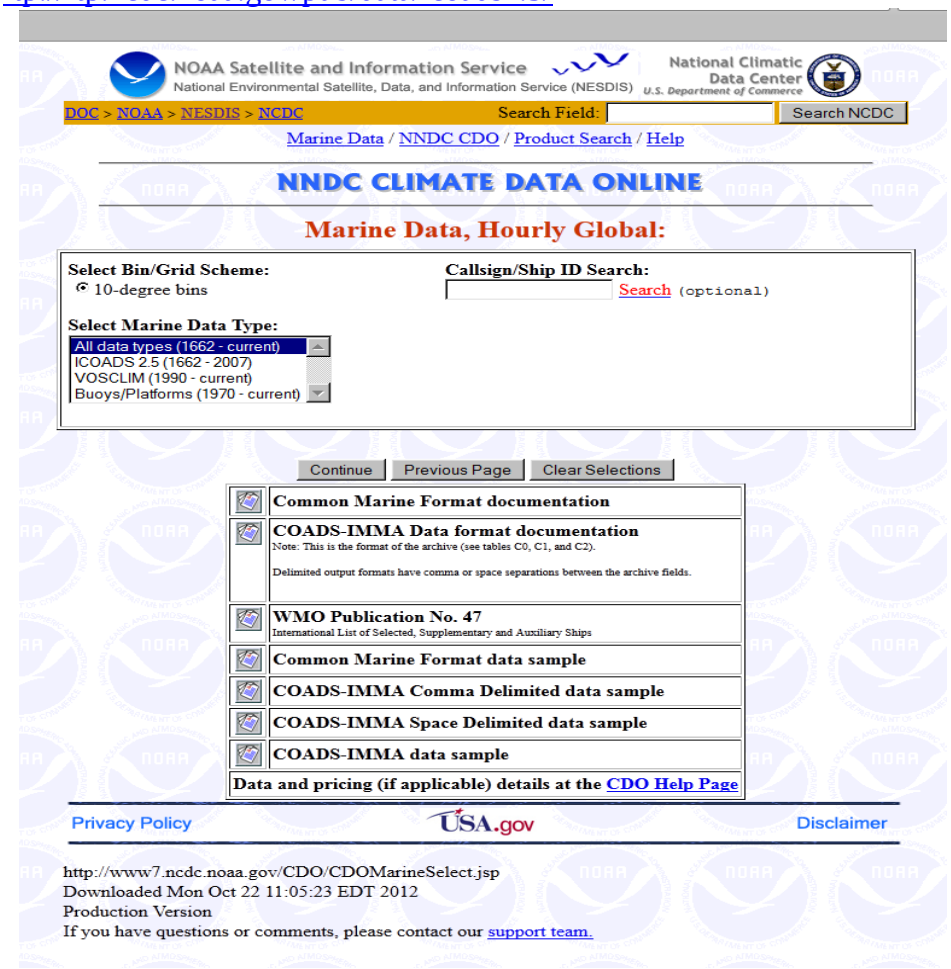

Figure 4: The Surface Marine Observations, including those funded by NOAA, are archived and serviced to the public online with web-based interactive tools.

- ***VOSClim - Increased data volume of archive and service; continued VOSClim webpage maintenance updating monthly statistics and data access, and service with the Global Collection Center (GCC); webpage update and migration to new NCDC web platform:***
  NCDC continues to serve as the Data Assembly Center (DAC) for this fleet. VOSClim ships aim to provide a high-quality subset of marine meteorological data, with extensive associated metadata, to be available in both real-time and delayed mode to support global climate studies.

  Program information and data are available online:
  http://www.ncdc.noaa.gov/oa/climate/vosclim/vosclim.html

  At the end of FY13, VOSClim webpages hosted at NCDC were migrated to the new NCDC web farm structure. This task included updating and streamlining content as well as moving from static html to a Drupal web content management platform. The web page has a new look and feel, but remains informative and user-friendly.

  The new URLs are listed below, while the previous URLs are still active and redirect users to the correct location. The old website is planned to be phased out in FY14 once the new sites are active for a while.
  http://www ncdc.noaa.gov/data-access/marineocean-data/vosclim
  http://www ncdc.noaa.gov/data-access/marineocean-data/vosclim/data-management-and-access
  http://www ncdc.noaa.gov/data-access/marineocean-data/vosclim/ship-metadata

- ***Operational production and service of the blended 0.25°, 6-hourly sea winds:***
  The importance for integrated use of the observing systems and production of air-sea interface products has been stipulated in the previous section (Project Summary). Our blended sea winds have been used by a wide variety of communities, including climate research, decision making & planning, wave hindcasting & forecasting, ecosystems, marine resource management, marine transportation (ship routing), wind/wave energy harvesting, and outreach & education. In FY13, we continued the production and service of the Blended Seawinds product.

- ***Integrated use of observations by in-situ and satellite platforms for model forecast evaluations and monitoring:***
  Recently, a WCRP Report, titled "Action Plan for WCRP Research Activities on Surface Flux" (WCRP Series Report No. 01/2012; http://www.wcrp-climate.org/documents/woap_fluxes_report_01_2012.pdf), strongly endorsed the Surface Flux Analysis (SURFA) project and approach. Project SURFA is an initiative of the World Climate Research Programme (WCRP), with the ultimate objective to institutionalize the evaluation of near real-time NWP fluxes and related fields with high quality reference data (over both land and ocean). The SURFA principle and infrastructure will also be utilized to evaluate climate models and satellite observations with the most accurate direct in-situ observations available. An example of the integrated

use of the CPO/COD/OCO-funded in-situ and satellite observations is show in the figure below.

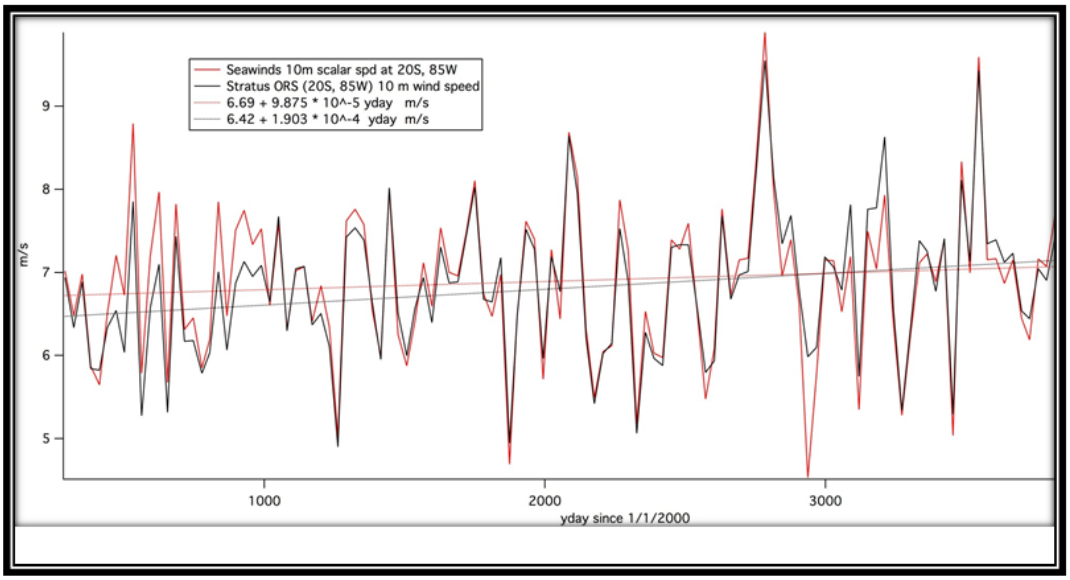

Figure 5: An example of cross-validation of sea surface winds observed by the Stratus Buoy and NCDC's Blended Sea Winds. (Courtesy: Dr. Robert Weller, Woods Hole Oceanographic Institution.)

Additionally, we continued the collaboration with the world Forecast Centers. We completed additional data analysis based on feedback from reviewers. A revised manuscript has been accepted and is in press by the Weather and Forecasting journal of the American Meteorological Society (Peng et al 2013; Figure 6 below). We will use these analysis results to improve our products.

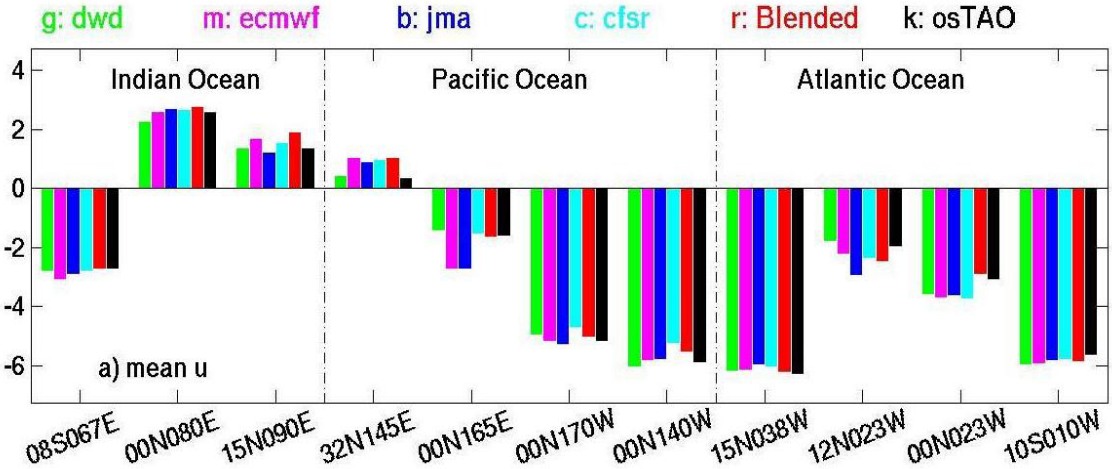

Figure 6: An example of the integrated use of observations from in-situ and satellite platforms for model forecast evaluations. Show are the mean zonal surface winds by OceanSITEs buoys, blended satellites, and forecasts from major international forecast centers: Green for German Weather Service DWD; Magenta for the European's ECMWF; blue for the Japanese Meteorological Agency (JMA); cyan for NOAA/NCEP's Climate Forecast System Reanalysis (CFSR); red for the NOAA/NCDC Blended Seawinds, and black for the OeanSITES buoys winds.

3. Outreach and Education

In 2013, our team has mentored a NOAA Undergraduate Scholar. The skills the student intern gained had helped him to find another opportunity under a NASA project.

Dr. Huai-Min Zhang took the lead publishing papers on the requirements for integrated in-situ and satellite observations. Dr. Zhang is serving in the AMS Scientific and Technical Action Commission's Committee on Air-Sea Interaction, as well as the WCRP working groups of SEAFLUX and SURFA. Eric Freeman serves in the JCOMM Expert Team on Marine Climatology (ETMC).

The societal applications of our products have been evidenced during the 2014 Government Shutdown, with multiple near-real-time users' inquiries. The International Ship Routing Service stated that "the interruption of Blended data has a considerable impact on our work", but "we do appreciate all of your efforts".

More than 90 new users have registered with us last year. We had also continued to engage private sectors, government agencies and policy makers to promote data use for societal benefits. The user-friendly web interfaces and data formats have continued to extend the products' benefit to the society, such as new applications in marine transportation safety and efficiency (e.g. near-real-time use in NOAA's world Coral Reef Watch, and Ship Routing services: Delta Western, Inc - Alaska's Petroleum Distributor; International Routing Services S.A.; Cornell Sailing Ltd; see the Outreach and Education section for more details). A partial list of our user communities includes not only climate research but also for direct societal benefits:

- For offshore renewable energy research & assessment: the Renewable Energy Systems Americas Inc, the UK Atmos Consulting Ltd, the Italy CESI RICERCA, the Univ of Maine, the UK Cranfield Univ, the Scotland Environmental Res. Inst, the Philippines Dept. Energy, the Demark DHI Port & Offshore Technologies, the UK 4C Offshore Limited, the Portugal wind projects evaluations, for domestic energy planning in Texas, MAETEC Renewable Energy (http://www.maetecengineering.com/), etc.
- Global Infrastructure Services Consultancy (http://www.cardno.com).
- Applications in ecosystem: the Inter-American Tropical Tuna Commission's research on spawning & recruitment by wind regimes, the South Africa Council for Scientific and Industrial Research's physical-biological processes study, and the near-real-time coral reef stress monitoring by the NOAA Coral Reef Watch (Figure 1), Examine sea wind data as a potential predictor of squid distributions (awinter@fisheries.gov.fk).
- Environmental applications: the oil/mineral slicks monitoring/modeling and the Environmental Resources Management Inc.
- Services to forecasting: marine weather forecasting by the Aerospace & Marine International.
- Construction engineering applications: the UK Scott Wilson Group plc and the McDonough Associates Inc (Chicago).
- Education: the Starpath School of Vavigation, the Univ Washington, among many other international schools for Maters and Ph.D researches.

4. Publications and Reports

4.1. Publications by Principal Investigators

- **In press/Early Online Release**

Huang, B., M. L'Heureux, J. Lawrimore, C. Liu, **H.-M. Zhang**, V. Banzon, Z.-Z. Hu, and A. Kumar, 2013: Why did large differences arise in the sea-surface temperature datasets across the tropical Pacific during 2012? *J. Atmos. Oceanic Tech*., (**in press**. doi:10.1175/JTECH-D-13-00034.)

Peng, G., H.-M. Zhang, H. P. Frank, J.-R. Bidlot, M. Higaki, S. Stevens, and W. R. Hankins, 2013: Evaluation of remotely-sensed and model surface wind forecast and reanalysis products with OceanSITES buoy measurements. *Weather and Forecasting*, (**in press**, doi: 0.1175/WAF-D-12-00086.1.)

- **Conference presentations**

Vasquez, L**., G. Peng**, M. Urzen, W.R. Hankins, and **H.-M. Zhang**, 2012: A Near Real-Time Monitoring System for NWP Forecast and Satellite-Based Products, Abstract IN31C-1504, *2012 AGU Fall Meeting*, San Francisco, CA, 3 – 7 December, 2012.

Zhang, H.-M., G. Peng, L. Vasquez, W. Hankins, C.W. Fairall, R. Weller, and A. Brown, 2013: The SURFA Project: Towards Near-Real-Time Quality Monitoring of NWP Forecasts and Historical Analysis. *4th WGNE Workshop on Systematic Error in Weather and Climate Models*. 15-19 April 2013, Exeter, UK.

4.2. Other Relevant Publications

The datasets have been used by many research projects including student theses. Over last year, known *added* users are over 60. Near-real-time applications include:

- NOAA Coral Reef Watch: http://coralreefwatch.noaa.gov/satellite/doldrums_v2/index.html
- International Routing Services, S.A.
- For more other applications, please see Section 2.1 under "Outreach and Education".

Banzon, Viva F., Richard W. Reynolds, 2013: Use of WindSat to Extend a Microwave-Based Daily Optimum Interpolation Sea Surface Temperature Time Series. *J. Climate*, **26**, 2557–2562.
doi: http://dx.doi.org/10.1175/JCLI-D-12-00628.1

Reynolds, R. W., D. B. Chelton, J. Roberts-Jones, M. J. Martin, D. Menemenlis, and C. J. Merchant, 2013: Objective determination of feature resolution in two sea surface temperature analyses. *J. Climate*, **26**. 2514-2533.

Banzon, V., R.W. Reynolds, and National Center for Atmospheric Research Staff (Eds), 2013: The Climate Data Guide: SST data: NOAA High-resolution (0.25x0.25) Blended Analysis of Daily SST and Ice, OISSTv2. (https://climatedataguide.ucar.edu/climate-data/sst-data-noaa-high-resolution-025x025-blended-analysis-daily-sst-and-ice-oisstv2)

Huang, B., J. Lawrimore, T. Smith, and National Center for Atmospheric Research Staff (Eds), 2013: The Climate Data Guide: SST data: NOAA Extended Reconstruction SSTs, version 3 (ERSSTv3 & 3b) (https://climatedataguide.ucar.edu/climate-data/sst-data-noaa-extended-reconstruction-ssts-version-3-ersstv3-3b)

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Curry, J.A., A. Bentamy, M. A. Bourassa, D. Bourras, E. F. Bradley, M. Brunke, S. Castro, S. H. Chou, C. A. Clayson, W. J. Emery, L. Eymard, C. W. Fairall, M. Kubota, B. Lin, W. Perrie, R. A. Reeder, I. A. Renfrew, W. B. Rossow, J. Schulz, S. R. Smith, P. J. Webster, G. A. Wick and X. Zeng, 2004: SEAFLUX, *Bull.Ameri. Meteorol. Soc.,* **85** (No. 3), 409–424.

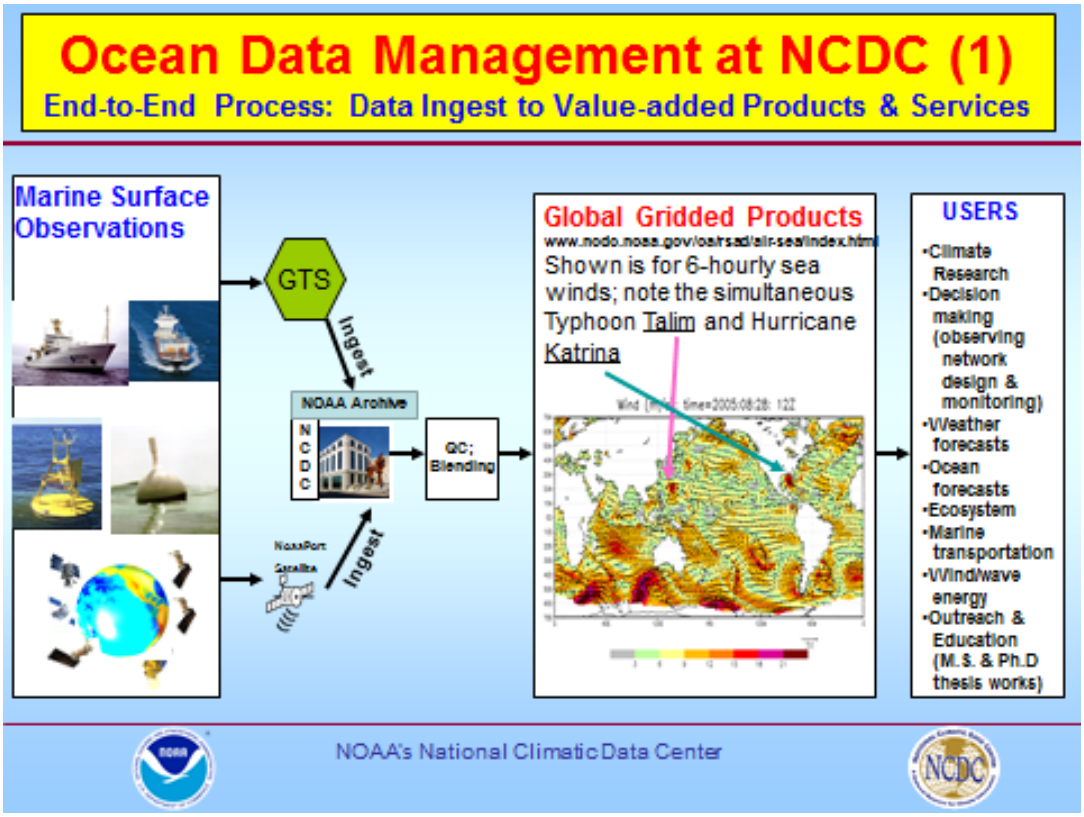
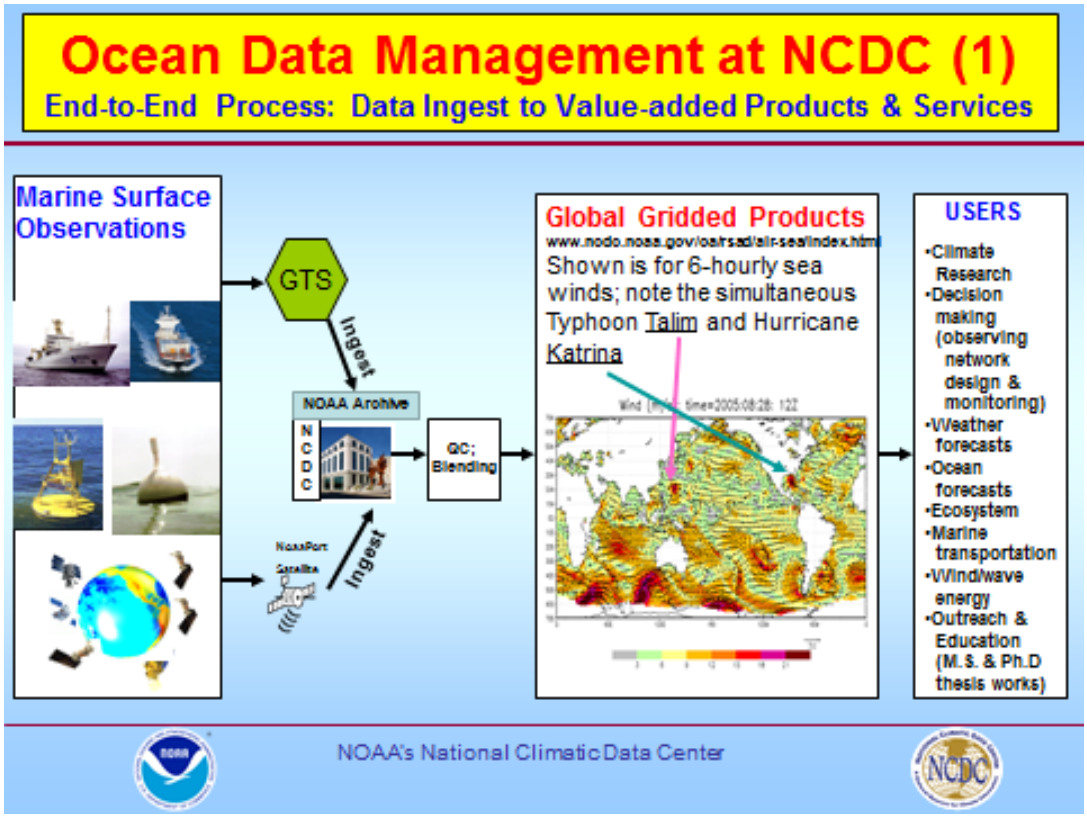
Reynolds, R. W., T. M. Smith, C. Liu, D. B. Chelton, K. S. Casey and M. G. Schlax, 2007: Daily High-Resolution-Blended Analyses for Sea Surface Temperature. *J. Climate*, **20**, 5473-5496, DOI: 10.1175/2007JCLI1824.1

WMO/TD-No. 1036/WCRP-112 (2000), Final Report of the Joint WCRP/SCOR Working Group on Air-Sea Fluxes (SCOR Working Group 110): Intercomparison and Validation of Ocean-Atmosphere Energy Flux Fields, 303pp+xvi.

Woodruff, S., 2010: Archival of data other than in IMMT format: The International Maritime Meteorological Archive (IMMA) Format. In Second Session of the JCOMM Expert Team on Marine Climatology (ETMC), Geneva, Switzerland, 26-27 March 2007, JCOMM Meeting Report No. 50, 68-101 [ref. JCOMM 2007]. Report updated in 2010 (http://icoads.noaa.gov/e-doc/imma/R2.5-imma_short.pdf).

Zhang, H.-M., R.W. Reynolds, T.M. Smith, 2004: Bias statistics of the AVHRR sea surface temperature. Geophys. Res. Letts., 31 (No. 1), L01307 10.1029/2003GL018804.

Zhang, H.-M., R.W. Reynolds, and T.M. Smith, 2006: Adequacy of the In Situ Observing System in the Satellite Era for Climate SST. J. Atmos. Oceanic Tech., 23 (1), 107-120.

Zhang, H.-M., R.W. Reynolds, R. Lumpkin, R. Molinari, K. Arzayus, M. Johnson, T.M. Smith, 2009: An Integrated Global Ocean Observing System for Sea Surface Temperature Using Satellites and In situ Data: Research-to-Operations, Bull.Ameri. Meteorol. Soc., 90 (No. 1), DOI:10.1175/2008BAMS2577.1

Appendix: Poster Slides