PMEL Ocean Climate Stations

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Table of Contents

1. Project Summary 1
2. Scientific and Observing System Accomplishments 2
   2.1. Education and Outreach 11
3. Publications and Reports 11
   3.1. Publications by Principal Investigators 11

1. Project Summary

The NOAA Climate Observation Division provides global climate analysis products which include air-sea exchanges of heat, momentum, and freshwater; carbon dioxide uptake and outgassing by ocean; ocean temperature and salinity, and surface currents. High quality, *in situ* time series reference data are necessary to assess and reduce the errors and uncertainties in these products and the models that generate these and other products. The Ocean Sustained Interdisciplinary Time series Environmental Observatory (OceanSITES) is a global network of reference station moorings that provide long, high-resolution time series for this purpose. The reference station moorings maintained by the Ocean Climate Stations (OCS) program contribute to this global OceanSITES network of reference stations.

OCS currently maintains two reference station moorings (Figure 1): The Kuroshio Extension Observatory (KEO) at 32.3°N, 144.5°E, and Station Papa at 50°N, 145°W. The KEO surface mooring is located in the Kuroshio Extension recirculation gyre, which has some of the largest air-sea heat, moisture and carbon dioxide fluxes found in the entire Pacific basin. The Station Papa mooring is located in the Gulf of Alaska, at the site where a weather ship was stationed from 1949-1981, and where the impacts of ocean acidification resulting from increasing levels of atmospheric carbon dioxide, will likely be felt first.

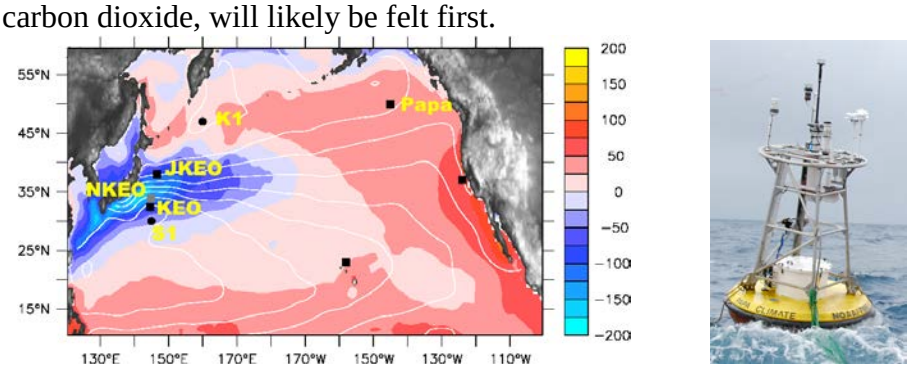

Figure 1: (a) The network of OceanSITES flux (black squares) and subsurface biogeochemical (black circles) reference stations in the North Pacific shown on a map of the mean net air-sea heat flux in Watts per square meter. Mean sea level height contours are shown in white and can be interpreted as streamlines of the surface geostrophic flow. The new Hot-Spot KEO (NKEO) flux mooring is also shown (grey square). (b) The Papa mooring shortly before recovery.

All OCS moorings carry a suite of sensors to monitor air-sea heat, moisture, momentum, and CO_2 fluxes, as well as the upper ocean temperature, salinity, and near-surface currents. Surface and subsurface data are telemetered to shore in near real-time and a subset of the surface meteorological data are also made publicly available in near real-time through the Global Telecommunications System (GTS), used by operational data centers. The Carbon components of the OCS moorings are described separately in the progress report for Sutton's "High-Resolution Ocean and Atmosphere pCO_2 Time Series Measurements" project. OCS data are made available through the project website: www.pmel.noaa.gov/OCS/ in a variety of formats, including ASCII and netCDF. In FY12, there were 180 download requests from the OCS data display and delivery page alone. The OCS data are also served through the PMEL OceanSITES Data Assembly Center (DAC). With the FY12 Add-task, the OCS group is working to make the data available through the OceanSITES Global DAC (GDAC) in the standard OceanSITES format, i.e. as deployment files with all sensor data (primary, secondary and full meta data) included. Voluntary usage descriptions included model, sensor and satellite data validation, assessment studies, mooring design, forecast verification, research (air-sea interactions, mixing processes, nutrient transport, mixed layer saturation), and student projects. The data serve a broad community of researchers and operational centers in the US and internationally.

The OCS group values international partnerships. All stations were initiated during large collaborative process studies, and have strong international partners. KEO was first deployed in June 2004 as part of the National Science Foundation (NSF) funded Kuroshio Extension System Study (KESS). At the conclusion of KESS, a partnership with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) was formed. The mooring deployment and recovery operations have been performed on charter and partner cruises, including a KEO turnaround cruise in November 2011 aboard the Military Sealift Command (MSC) USNS SAFEGUARD and a turnaround in July 2012 aboard JAMSTEC's R/V MIRAI. Station Papa was initially funded in 2007 through an NSF grant to Dr. Steve Emerson (University of Washington) to study the North Pacific Carbon Cycle. At the conclusion of the NSF process study, NOAA Office of Climate Observations took over support of this site. The Canadian Fisheries and Oceans Canada, Pacific Region, Line-P program, has provided ship time on the JOHN P TULLY for the Station Papa mooring maintenance. More recently, NSF has funded a wave measuring mooring to be deployed next to the NOAA Station P mooring from June 2010 – June 2014. NSF Ocean Observatory Initiative (OOI) will deploy a cluster of subsurface profiler moorings near the NOAA Station P mooring beginning summer 2013. Likewise, KEO has been a central mooring of the 1-billion yen Japanese process study "Hot-Spot". In July 2012, JAMSTEC deployed a new KEO mooring in the center of the Kuroshio Extension jet, north of the NOAA KEO site. It is an exciting time in the NOAA OCS program.

2. Scientific and Observing Systems Accomplishments

All OCS systems carry sensors to monitor wind speed and direction, air temperature, relative humidity, incoming solar and long wave radiation, barometric pressure, rain rate, sea surface temperature and salinity, near-surface currents, and (except for the ARC mooring) subsurface temperature and salinity through the mixed layer to the top of the main thermocline (Figures 2-3). From this suite of meteorological and surface sensors, the air-sea fluxes of heat, moisture, and

momentum can be computed. OCS moorings also carry a suite of carbon and biogeochemical sensors that are described under Adrienne Sutton's pCO_2 and Ocean Acidification projects.

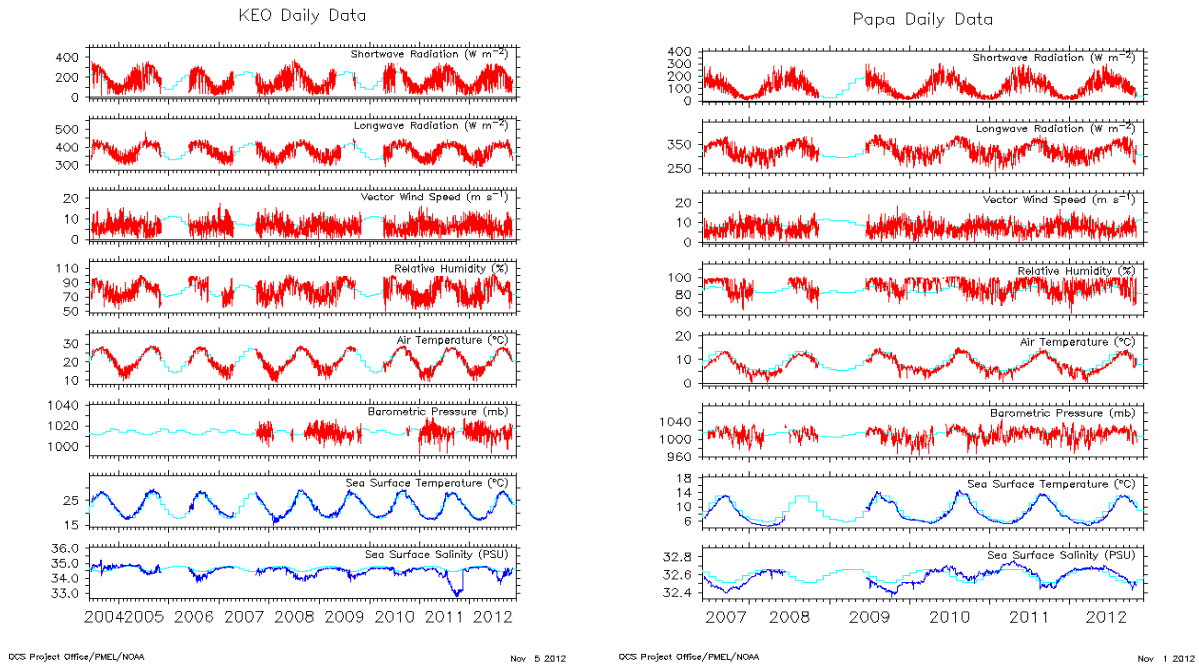

Figure 2: Data plots by the OCS disdel web page http://www.pmel.noaa.gov/ocs/disdel/disdel.html**. The left panel shows daily meteorological observations from the KEO mooring, 2004 to present. The right panel shows daily meteorological observations for the Papa mooring, 2007 to present.**

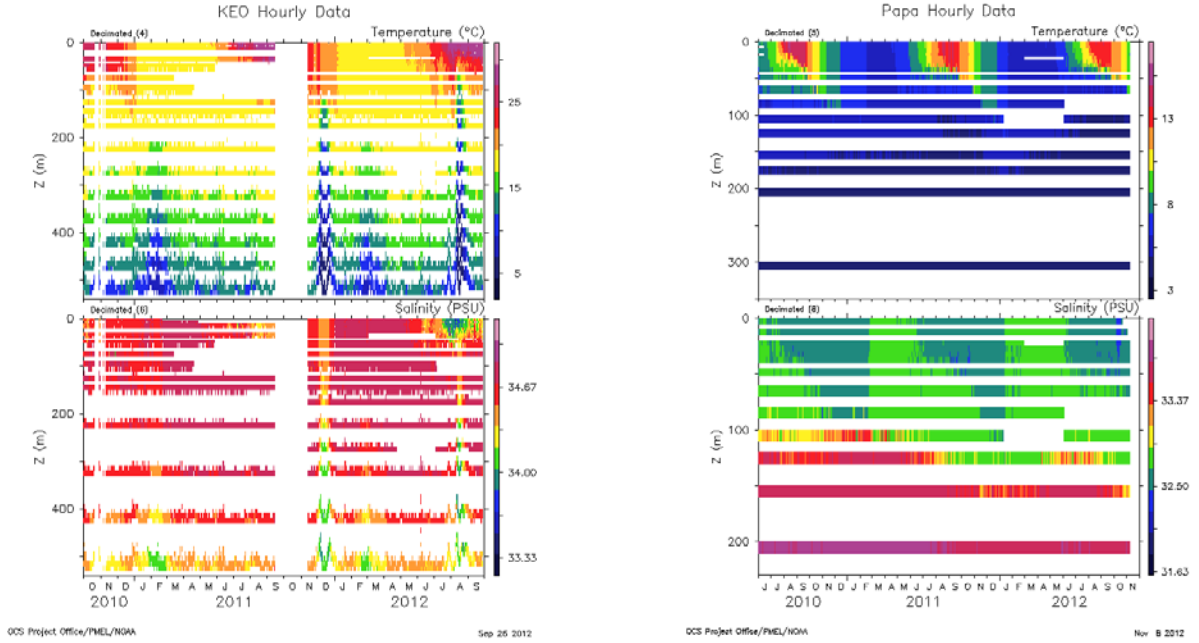

Figure 3: Data plots by the OCS disdel web page http://www.pmel.noaa.gov/ocs/disdel/disdel.html**. The left panel shows telemetered hourly subsurface temperature and salinity observations from the KEO mooring, October 2010 to present. The Sept-Nov 2011 gap in KEO hourly data will be filled by delay mode observations currently in processing. The right panel shows the same for the Papa mooring, June 2010 to present.**

Deliverable 1: Return calibrated surface meteorological measurements, and subsurface temperature, salinity and current data from reference station moorings.
OCS mooring systems are refreshed at least once a year. The deployed system is recovered, and a new mooring, with fresh sensors and data acquisition electronics, is deployed in its place. In order to preserve data return within the harsh environment of the North Pacific, OCS moorings carry redundant meteorological sensors, and two independent data logger and telemetry systems. The ATLAS system, a legacy of the TAO program, transmits daily average and intermittent spot meteorological measurements to shore through Service Argos. The newer FLEX system transmits via Iridium hourly averaged data from the secondary meteorological suite of sensors, as well as hourly data from the subsurface measurements. The ATLAS system is near obsolescence and needs to be replaced on OCS moorings by a second FLEX system. The use of both systems on OCS buoys thus provides important field-testing for when the FLEX system will be the sole data logger and telemetry system.

This field-testing revealed a problem in FY12 when a new type of compass (Sparton), that offered improved performance, was used inside the FLEX Gill wind sensor. After deployment on both KEO-2011 and Papa-2011, the data comparison with ATLAS showed a discrepancy, and an error was found in the FLEX box firmware which limited the precision of the wind direction observations to ±25° rather than the ±3° expected. This bug has been fixed and a corrected version was deployed on the KEO-2012 and Papa-2012 systems.

Higher resolution meteorological data are logged internally in both systems, and retrieved after recovery of the mooring. ATLAS data are generally considered primary. Due to insufficient programmer support, the FLEX redundant "secondary" data are processed only on an ad hoc basis. Our goal though is to provide a merged "best available" data set that uses the secondary data when the primary data are not available. During the time period when Flex systems with the firmware bug were deployed, the ATLAS data loggers functioned well, and the secondary FLEX winds data will not be used in our merged "best available" data set.

Pre- and post-deployment calibrations are performed on all sensors to verify measurement reliability. Real-time data are processed and the primary measurements are made available in near real-time through the OCS website (e.g. Figures 2-3). After recovery, delayed-mode high-resolution data are processed and the primary measurements are made available on the OCS website within six months for surface data and within 12-18 months for subsurface data. The actual date of release of delay-mode subsurface salinity data is dependent upon release of CTD data from international partners.

Although not needed for the 2011 wind measurements, the redundant data from moorings has repeatedly proven to be valuable and necessary. These redundant meteorological data from the FLEX system, however, require significant extra time both to evaluate and to process. OCS plans to eventually provide all primary and secondary data (ATLAS and FLEX) in deployment files, properly annotated with meta data and flagged for quality and source, using the standard OceanSITES format v1.2. The FY12 Add-task provided additional programmer support to develop tools to make these files.

We note that the field-testing of the FLEX system, and the data processing methods being developed for the FLEX system by OCS, is quite useful to the TAO group as they also plan to phase out the ATLAS system in the future, and are deploying test moorings with the equivalent TFLEX system.

KEO: There were two KEO mooring recovery and deployments in FY12. Our Japanese partner was unable to provide the use of a JAMSTEC ship during the summer 2011 season, but we were able to secure the use, at no charge to NOAA, of the US Navy's Military Sealift Command ship USNS SAFEGUARD, a 255 ft salvage vessel stationed in Japan. Through this new partnership, the KEO-2010 mooring was recovered early in FY12, on November 14, 2011 after a longer than planned 13.5-month deployment. The KEO-2011 mooring was deployed on the same date.

We accepted a JAMSTEC offer of free ship time on the R/V MIRAI for a June/July 2012 recovery/deployment of the KEO-2011 mooring. The KEO mooring was thus recovered after 7.5 months on July 5, 2012. During the KEO-2010 deployment, 10 Seabird temperature and conductivity sensors, which are normally very reliable, stopped updating measurements before the time of recovery due to early depletion of the lithium batteries. OCS and PMEL engineers worked closely with SeaBird, and eventually a solution was found that would enable the instruments to last a full 1-year deployment. The KEO-2012 mooring, with freshly calibrated instruments using revised battery packs, was deployed on 4 July 2012. At present, the Seabird sensors on KEO-2012 are updating properly, however we will not know for certain if the problem is solved until late in the deployment (mid 2013). The battery issues are detailed in an OCS Technical Note (Keene, 2012a).

Unfortunately, the recovery teams for both the KEO-2010 and KEO-2011 moorings were unable to induce the acoustic release to operate, and both moorings had to be recovered while still anchored. Since the KEO mooring is a “slack-line” design, in which the length of the mooring exceeds the depth by 40%, we were able to recover both buoys, all instruments and the internally recorded data. The acoustic release, 18 glass ball floats, 2400 m of polyolefin line, and more than 2000m of nylon was lost from each mooring, and remain on the bottom, making these sites unusable for future deployments. In response to these failures, we will be using a dual release frame on future OCS moorings so that the firing of either acoustic release will cause the mooring to detach from the anchor. We are also lengthening the line between the releases and the anchor from 20 to 50 m, (to decrease the chance of any possible entanglement of the release with the anchor and collision of glass balls with ocean bottom), expanding the spacing between the glass floatation balls, and using glass floatation balls with a greater depth rating. Operational details can be found in the Cruise Reports for the respective cruises (Ronnholm and Zimmerman, 2012; Keene et al, 2011).

A detailed bathymetry survey of the KEO area was obtained from the SEAbeam system on the R/V MIRAI. Prior detailed bathymetry was a limited swath. The new bathymetry will be a great help in choosing future mooring locations.

Station Papa: Papa-2011 was recovered on June 3, 2012 during a 17 day cruise onboard the Canadian Coast Guard ship TULLY. The ATLAS and FLEX data systems performed well

during the entire deployment. On June 2, 2012, the Papa-2012 mooring was deployed. Details of operations at Papa may be found in the cruise report, available up on request.

Currently, all systems are functioning properly and real-time data are being telemetered from the buoy by both the ATLAS and FLEX systems (Figures 2-3). Data returns for Station Papa are shown in Table 1.

Data Return: As shown in Table 1, FY12 data returns from both KEO and Papa moorings are high for surface variables: nearly 100% for Papa and above 95% for KEO; but slightly lower for subsurface variables in part due to the Seabird battery failures (Keene, 2012a) and in part due to the poor performance of current meters.

On September 1, 2011, the KEO-2010 FLEX data logger, which had performed well up until this point, experienced multiple system resets and data transmissions stopped completely on September 14, 2011. A newer version of the firmware, deployed in Nov 2011, appears to have solved this problem.

	KEO FY12 1 Oct 11 – 1 Oct 12		**Papa FY12** 1 Oct 11 – 1 Oct 12	
	Realtime	All Available	Realtime	All Available
ATLAS				
MET	91.5	95.1	99.7	99.7
SSTC/SSC	98.6	98.6	99.7	99.7
FLEX (secondary)				
MET	87.9	87.7	97.2	97.0
SST/SSC	87.1	93.9	99.9	99.9
SubSfc TCP	84.0	91.0	87.6	88.9
SubSfc V	52.6	94.0	72.1	72.5

Table 1: Data return for Kuroshio Extension Observatory and Station Papa moorings, in percent.
The decreased data return numbers for the KEO subsurface instruments are due to sensor battery failures, and a current meter which would not communicate inductively in real-time but whose data was recorded internally. At Papa, the subsurface data return was reduced by several instruments sliding down the wire in Dec 2011, with no evidence of fishing or debris as a cause.

The most recent delay mode data from Papa publically available is June 8, 2010. The Papa-2010 (recovered June 2011) primary data logger (the ATLAS tube) failed after 5 months, and the preparation of a merged FLEX-ATLAS data set is proceeding slowly. The Papa-2011 delay mode data was recovered 5 months ago, and will be processed and released in FY12. The KEO-2010 (recovered Nov 2011) ATLAS datalogger performed well for the entire KEO-2010 deployment, but a data corruption issue is complicating the processing of the KEO-2010 delay mode met data and this data is not yet released. We expect the KEO-2010 met and subsurface delay mode data to be available by Dec 31, 2012. A portion of the delay mode met data from KEO-2011 (recovered July 2012) (winds, AT, RH) has been released, and the remaining met parameters, and the subsurface observations are awaiting processing for release in FY13. Data

processing is subcontracted to the TAO group at PMEL. While this made sense when the OCS data system was a TAO clone, this is no longer the case. The necessity for OCS to process and merge data from two different data systems is time consuming, and OCS urgently needs additional programmer resources that would be solely dedicated to the OCS program.

In addition, in FY12, ARC mooring data processing was completed and the delay-mode data was released via the OCS DisDel web page. These data, collected in FY10, had 100% data return.

Mooring Enhancements: In Nov 2011, KEO was enhanced with additional biogeochemical measurements to make it an ocean acidification mooring, similar to Papa. In particular, a SAMI pH sensor and a CTD with a chlorophyll fluorescence sensor were provided through the PMEL Carbon group and ocean acidification programs, and a gas tension device/dissolved O_2 package was provided by Dr. S. Emerson (UW). For more information, see the progress report from the PMEL Carbon Group.

Evaluation of New Sensors: Evaluation of new sensors has been ongoing in FY12. As technology improves, new instruments become available that might allow greater simplicity, lower cost, or improved measurements. Sensors tested in FY12 include the Rotronics HygroClip HC2-S3 for monitoring air temperature and relative humidity with improved accuracy, the Vaisala WXT520 combined weather instrument, and the RDI Sentinel ADCP.

The Rotronics HygroClip HC2-S3 is being considered as a possible replacement to the older Rotronics MP101 air temperature and relative humidity sensor on OCS moorings. The goal is to find a sensor with low cost, and better stability of the relative humidity sensor, while maintaining or improving on the accuracy specifications of the older instrument. In an internal lab study, the data from the HygroClip compared well to the MP101, however longer term testing is needed to determine if the HygroClip has improved accuracy over the MP101 (Keene, 2012b).

One instrument that has been tested by OCS over the past few years is the Vaisala WXT520 combination weather instrument. This instrument combines sensors for wind speed and direction, air temperature, relative humidity, barometric pressure, and rainfall in one small package. OCS has concluded that the expense and time necessary for maintenance and calibration is not justified by the data returned, and that this all-in-one sensor cannot be used to replace individual sensors for the OCS reference station moorings. The wind speed measurements can be erratic at high speeds, vibrations can cause the unit to register rainfall, and the sensor ATRH section cannot be calibrated using our standard calibration methods (Keene, 2012c). We have found the BP to be reliable and we plan on continuing to deploy the WXT520 sensors for use as a secondary BP sensor until our inventory is depleted by loss or failure.

The RDI Sentinel ADCP has been deployed on the bridle of several OCS moorings as an ADCP can provide significantly more data than the discrete current meters. Data were analyzed for fish bias and mooring line reflections at KEO and it was determined that noise from fish presence at KEO made the data unusable, so the Sentinel was not deployed at KEO-2011. Due to a shortage of data processing personnel, the Station Papa data set has not yet been analyzed. A Sentinel was recovered from the Papa-2011 mooring and a fresh instrument as deployed at Papa-2012.

Project Compliance with US Statutes
The OCS project has not undertaken a formal review process of our data collection efforts and at this time, we do not know if we are compliant with US statutes such as 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). However, individually, and as a group, we do strive to conduct our buoy maintenance and data collection efforts in an environmentally conscious manner to protect the oceanic ecosystem, and to reuse or recycle materials to the best of our abilities.

Deliverable 2: Provide access to reference station data and metadata in a standardized format, and through linked web pages to encourage broad use of data.
The OCS data display and delivery (disdel) page provides access to the "best available" data from all OCS moorings (KEO, Station Papa, Agulhas Return Current (ARC)). For most recent data, these are telemetered data. For older data, these are the delayed-mode "primary" data as described earlier. Figures 2-3 were generated from the disdel page. The user can choose variables to display, time frame of interest, and resolution. Data can be provided as plots, ASCII, or netCDF format. Updates are being made to the rest of the OCS web pages to more clearly direct users to the data and metadata for each mooring.

In previous years, the primary surface (ATLAS) and subsurface data from the OCS moorings were made available in the OceanSITES netCDF format as one big concatenated time series file. These site files do not include deployment meta data as attributes, as is expected of OceanSITES data. Likewise, these files do not include redundant data. Thus, in FY12, an Add-Task was funded to develop tools at PMEL to archive high-resolution delay-mode data and meta data from OCS moorings into OceanSITES deployment files. The efforts begun in the FY12 Add-Task will enable OCS to release and archive data obtained by both the primary ATLAS data logger as well as the secondary data collected by the FLEX data logger and its independent sensors. Work is underway on developing an effective tracking database for all FLEX meta data, developing quality control and processing tools that currently do not exist for FLEX data, and developing automated tools for converting ATLAS and FLEX data and meta data into OceanSITES format. Under this 1-year Add-Task, only 2 of the 15 OCS deployments were reformatted in the OceanSITES 1.2 format: KEO-2004 and Papa-2009. Additional funding is needed to complete all historical and current deployments.

OCS works with several other partner groups, both within NOAA and internationally. Some of these partners' websites include links to the OCS pages, such as:

OceanSITES: http://www.oceansites.org/data/index.html
KESS: http://uskess.org/data_public.html#buoy
JKEO/JAMSTEC: http://www.jamstec.go.jp/iorgc/ocorp/ktsfg/data/jkeo/
Fisheries & Oceans Canada, Line P:
http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/line-p/index-eng.htm
PMEL CO2: http://www.pmel.noaa.gov/co2/story/KEO and
http://www.pmel.noaa.gov/co2/story/Papa
UW/APL Wave Measurements at Station Papa:
http://www.apl.washington.edu/projects/station_papa/summary.html

UW/Joint Institute for the Study of the Atmosphere and Ocean (JISAO):
http://jisao.washington.edu/research/oceanography-info
Surface Fluxes Analysis (SURFA) project: http://www.ncdc.noaa.gov/thredds/surfa.html

OCS web site pages were viewed over 17,800 times in FY12 and over 79 GB of text and data was downloaded by visitors. In addition, the OCS Data Display and Delivery page had 180 download requests, yielding 385 ascii files and 281 cdf files. Over the last 2 years, data was requested by users in government agencies (NOAA, CPC, NCEP, NASA, DFO Canada, JAMSTEC, UK Met Office) and universities (UW, UW/APL, JHU/APL, Scripps, MBARI, Univ of Cape Town, Univ of Tokyo, Tohoku Univ, Korea Institute of Ocean Science and Technology, Imperial College London, Univ of Redding UK) and by many anonymous users. Usage descriptions included model, sensor and satellite data validation, assessment studies, mooring design, prediction, forecast verification, research (air-sea interactions, mixing processes, nutrient transport, mixed layer saturation), and student projects. It should be noted that we still also make KEO and Papa data available through project pages that do not have a user register and therefore the above data download statistics are an underestimate. During FY13, OCS expects to complete a major redesign of the OCS web site that should make it easier to obtain data, and information about sensors and data collection parameters.

A subset of the surface meteorological data from the ATLAS system are also made publicly available in near real-time through Service Argos to the Global Telecommunications System (GTS) for use by the operational data centers. Efforts, in conjunction with NDBC, to develop a means of getting Iridium transmitted data (e.g. barometric pressure data) to the GTS were unsuccessful. As OCS moves forward to the use of redundant FLEX data loggers (Iridium), and the retirement of the ATLAS system (ARGOS), the transmission of PMEL & OCS data to the GTS is a problem that will need to be addressed.

During FY12, a data management plan was prepared and is in review. During FY13, this plan will be made available on the OCS web site. All data from sensors and instruments on OCS moorings is stored on multiple internal PMEL servers and backed up daily throughout the stages of collection, processing, and public distribution.

Deliverable 3: Scientific analyses utilizing reference station data

Several experiments and funded research projects involve OCS data and PIs. In particular, Co-PI Dr. Bond was supported for one month in FY12 through the final year of an NSF-funded KESS project titled "Kuroshio Extension System Study (KESS) – Upper and deep ocean response to atmospheric forcing in the Kuroshio Extension". Dr. Cronin was a formal collaborator on this project. Bond and Cronin presented three talks at the Ocean Sciences meeting in Salt Lake City in Feb 2012. Topics included the use of KEO data to determine which type of storms are most effective at exciting oceanic near-inertial waves (Bond et al., In Prep), the influence of these near-inertial waves on ocean mixing and the formation and erosion of the seasonal thermocline at KEO (Cronin et al. 2012a), and a vision of ocean observations in 2030. Cronin was a session convener for the "Air-sea interaction in western boundary currents and marginal seas" session and organized a Kuroshio Extension group dinner with more than 90 US and Japanese scientists (including Cronin and Bond). In addition, our JAMSTEC partner gave a presentation of the

atmospheric response to sea surface temperature variations as observed by the KEO buoy (Kawai et al., In Revision).

A new 1-billion yen Japanese climate experiment named "Hot-Spot", begun in FY11, is in full swing. Hot-Spot's goal is to investigate air-sea interactions and the impacts of the large ocean heat release in the Kuroshio Extension region. As part of this experiment, a new JAMSTEC surface mooring (NKEO) was deployed in June 2012 at the center of the KE jet. Together with KEO and JKEO, the three surface moorings will provide data for investigating the atmospheric response to variations in the ocean SST front. Cronin was an invited speaker at the Japanese Geoscience Union meeting in Chiba, Japan in May 2012, and also spoke at a side meeting for Hot-Spot PIs and collaborators held at JAMSTEC in Tokyo.

Cronin presented results of the "Ongoing time series at Station P" at the WCRP meeting in Denver in Oct 2011. The presentation showed all the collaborative projects that have resulted from the OCS mooring deployment at Station P, including enhancements of the OCS mooring with various biogeochemical sensors to monitor the carbon cycle and ocean acidification (PIs: S. Emerson, C. Sabine), butterfly surveys around the OCS mooring by a UW underwater glider (PI: C. Eriksen) that will be used to analyze the carbon export from the upper ocean (Pelland PhD dissertation in prep.), deployment of a nearby ADCP mooring (PIs: Alford, Cronin, Klymak) to analyze deep penetration of near-inertial waves at Station P (Alford et al. 2011), deployment of a nearby surface waverider mooring, a Lagrangian mixed layer float in January 2011, and Swift buoys (Surface Wave Instrument Floats with Tracking) in Oct 2012, (PIs: E. D'Asaro, J. Thomson, R. Harcourt) to analyze the impact of waves on the evolution of the ocean mixed layer. Meteorological data for these projects is provided by the NOAA Station P mooring. Cronin also organized a Station P Science Workshop held at NOAA PMEL on April 3, 2012. There were 20 participants from UW, UW APL, PMEL, and DFO. 11 presentations were given, including 3 from UW PhD candidates who will use Papa data for their dissertations.

Dr Cronin was a member of the program Committee for Chapman Conference "The Agulhas System and its Role in Changing Ocean Circulation, Climate, and Marine Ecosystems", held in Stellenbosch, South Africa, 8-12 Oct 2012: http://chapman.agu.org/agulhas/. Nearly 120 scientists from around the world participated in this extremely successful conference. As co-chair for session 2 ("Effects of Agulhas system variability on regional weather, climate, bio-physical interactions, marine ecosystems and fisheries"), she presented an Introduction that included a review of the Agulhas sustained observing system. She also gave an oral presentation of "the prevalence of strong bottom currents in the Greater Agulhas system". The study was motivated by the need to find a location that a surface mooring could survive, but is relevant to issues ranging from the global energy balance, carbon export into the abyss, and interpretation of sedimentary records in terms of paleo currents. This study will be submitted to Nature. Cronin also had a poster presentation on the ARC mooring results, and one on results from the NOAA Adopt A Drifter experiment in which pairs of drifters were seeded in the Agulhas Current. This workshop had considerable outreach as discussed below in Section 2.1.

2.1 Outreach and Education

In FY12, Dr. Cronin participated in NOAA's Adopt a Drifter program, by arranging for 2 NOAA drifters to be deployed in Agulhas Current on 2 August 2012. A total of 5 schools are participating: Roosevelt High School in Seattle WA, and 4 high schools in Cape Town, South Africa. See: http://www.adp.noaa.gov/schools/101634_109207.html. Dr Cronin visited one of these black township schools in October 2012, which had been participating in the South African Environmental Observation Network (SAEON) Learner program. The schools in Africa were invited to join the program, with coordination provided by SAEON, ASCLME, GLOBE-Africa (Global Learning and Observations to Benefit the Environment), South Africa Weather Service.

Dr. Cronin served as a committee member for 3 M.S. University of Washington candidates. Two of these defended their M.S. during FY12 and are now continuing as PhD students. In FY12 Dr. Cronin also became a mentor leader for the Mentoring Physical Oceanography Women to Increase Retention (MPOWIR) group.

3. Publications and Reports

3.1. Publications by Principal Investigator

Published - Peer-Reviewed

Alford, M.H., M.F. Cronin, and J. Klymak, 2012: Annual cycle and depth penetration of wind-generated near-inertial internal waves at Ocean Station Papa in the northeast Pacific. *J. Phys. Oceanogr.*, **42**(6), doi: 10.1175/JPO-D-11-092.1, 889–909.

Cronin, M.F., R.A. Weller, R.S. Lampitt, and U. Send, 2012: Ocean reference stations. In *Earth Observation*, R.B. Rustamov and S.E. Salahova (eds.), InTech, ISBN: 978-953-307-973-8. Available from:http://www.intechopen.com/articles/show/title/ocean-reference-stations.

Praveen Kumar, B., J. Vialard, M. Lengaigne, V.S.N. Murty, M.J. McPhaden, M.F. Cronin, F. Pinsard, and K. Gopala Reddy, 2012: TropFlux wind stresses over the tropical oceans: Evaluation and comparison with other products. *Climate Dynam.*, doi: 10.1007/s00382-012-1455-4.

In Press – peer-reviewed

Bourassa, M., S. Gille, C. Bitz, D. Carlson, I. Cerovecki, M.F. Cronin, W. Drennan, C. Fairall, R. Hoffman, G. Magnusdottir, P. Pinker, I. Renfrew, M. Serreze, K. Speer, L. Talley, and G. Wick, 2012: High latitude ocean and sea ice surface fluxes: Requirements and challenges for climate research. *Bull. Amer. Meteor. Soc.*

Cronin, M.F., N. Bond, T. Farrar, H. Ichikawa, S. Jayne, Y. Kawai, M. Konda, B. Qiu, L. Rainville, and H. Tomita, 2012: Formation and erosion of the seasonal thermocline in the Kuroshio Extension Recirculation Gyre. *Deep-Sea Res. II*, doi: 10.1016/j.dsr2.2012.07.018.

In Revision – peer reviewed

Kawai, Y., H. Tomita, M.F. Cronin, and N.A. Bond, 2012: Low-level atmospheric response to mesoscale sea surface temperature variations in the Kuroshio Extension region. *J. Geophys. Res*.

Submitted – peer reviewed

Wada, A., M.F. Cronin, A.J. Sutton, Y. Kawai, and M. Ishii, 2012: Numerical simulations of interactions between Typhoon Choi-wan (0914) and the ocean. *J. Geophys. Res*.

Newsletters

Kumar, B.P., J. Vialard, M. Lengaigne, V.S.N. Murty, M.J. McPhaden, M.F. Cronin, and K.G. Reddy, 2012: Evaluation of air-sea heat and momentum fluxes for the tropical oceans and introduction of TropFlux. CLIVAR Exchanges, No. 58, 17(1), 21-24.

Proceedings from Conferences

Fairall, C.W., M.A. Bourassa, M.F. Cronin, S.R. Smith, R.A. Weller, G. Wick, S. Woodruff, L. Yu, and H.-M. Zhang, 2012: Observations to quantify air-sea fluxes and their role in global variability and predictability. In *Proceedings of the IOOS Summit, Interagency Ocean Observation Committee (IOOC)*, Herndon, Virginia, 13-16 November 2012.

Lumpkin, R., K. Dohan, M. Baringer, L. Centurioni, M. Cronin, G. Goni, G. Lagerloef, D. Lee, and N. Maximenko, 2012: Observing the global ocean surface circulation. In *Proceedings of the IOOS Summit, Interagency Ocean Observation Committee (IOOC)*, Herndon, Virginia, 13-16 November 2012.

Technical Reports

Keene, J.A., 2012: Ocean Climate Stations High-Latitude Buoy Setup and Deployment Manual v2.0, *PMEL OCS Tech. Note 1.*

Keene, J.A., 2012: Data Drift in Load Cells form Load Cell Central, *PMEL OCS Tech. Note 2.*

Keene, J.A., 2012b: Investigation of Rotronic HygroClip, *PMEL OCS Tech. Note 3.*

Keene, J.A., 2012a: Capacity Issue with AA Li Batteries in SBE37's, *PMEL OCS Tech. Note 4.*

Keene, J.A., 2012c: Wind Speed Variability of Vaisala WXT520, *PMEL OCS Tech. Note 5.*

Cruise Reports:

Keene, J.A., J.M. Strick, S. Bushinsky (2011): Cruise Report KE1-11-SG: Recovery/Deployment of KEO Mooring at 32°N, 144.5°E, November 12 – November 17, 2011, 15 pp.

Keene, J.A. and M. Craig (2012): Cruise Report PA1-12-TU: Deployment/Recovery of Papa Mooring at 50°N, 145°W, May 23 – June 8, 2012, 9 pp.

Ronnholm, K. and D. Zimmerman (2012): Cruise Report KE1-12-MI: Deployment and Recovery of the KEO Mooring at 32°N 145°E, June 24 – July 12, 2012, 22 pp.