PMEL Ocean Climate Stations

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1. Project Summary

The NOAA Climate Programs Office provides global climate analysis products which include air-sea exchanges of heat, momentum, and freshwater; ocean carbon uptake; 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 quality time series for this purpose. The reference station moorings maintained by 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.

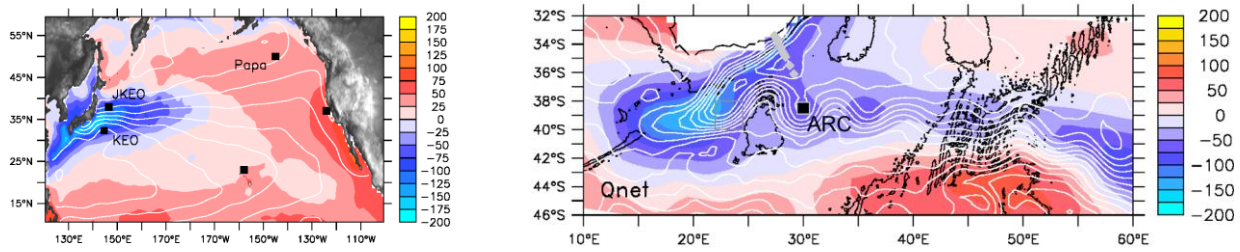

Figure 1: *The network of OceanSITES reference stations in the (a) North Pacific and (b) Agulhas region on maps of the mean net air-sea heat flux in Watts per square meter. Mean sea level height contours are shown in white and can be interpreted as streamlines of the surface geostrophic flow. The 3000 m isobath is shown in black for the Agulhas region (right).*

In FY10, with encouragement from the NOAA Climate Programs Office, the OCS group obtained a 1-year NSF RAPID grant to initiate a new site in the Agulhas Return Current (ARC), which is a region with some of the largest air-sea fluxes found in the entire Southern Hemisphere (Figure 1). The ARC mooring was deployed southeast of Africa at 38.5°S, 30°E on November 30, 2010. The add-task for FY11 NOAA funds was intended to support the ongoing maintenance of this important site, but instead a minimal one-time award was provided by NOAA to recover the ARC mooring after it went adrift in January 2011. The mooring drifted for 56 days before being recovered by the French research vessel *Marion Dufresne*. All sensors were recovered and the internally recorded data had 100% data return, providing an extremely useful and unique data set.

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 currents. Surface and subsurface data are telemetered to shore in near real-time. The Carbon components of the OCS moorings are described separately in the progress report for Sabine'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 FY11, there were 192 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) and the OCS group is working with National Data Buoy Center (NDBC) to make the data available also through the OceanSITES Global DAC (GDAC) in the standard OceanSITES format. 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 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 were performed on JAMSTEC cruises until September 2010. Station Papa was initially funded in 2004 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, provide ship time for the Station Papa mooring maintenance. In FY10, NSF awarded the OCS group a RAPID grant to expedite the ARC deployment so that it would be operational during the Agulhas Current Transport Experiment led by Dr. Lisa Beal (RSMAS). Ship time for ARC was provided by the Agulhas Somali Current Large Marine Ecosystems (ASCLME) project and shiptime for its recovery was provided by the Territory of the French Southern and Antarctic Lands (TAAF).

2. Scientific and Observing Systems Accomplishments

All OCS systems carry sensors to monitor wind speed and direction, air temperature, relative humidity, incoming solar and longwave 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 Chris Sabine's pCO_2 and Ocean Acidification projects.

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.

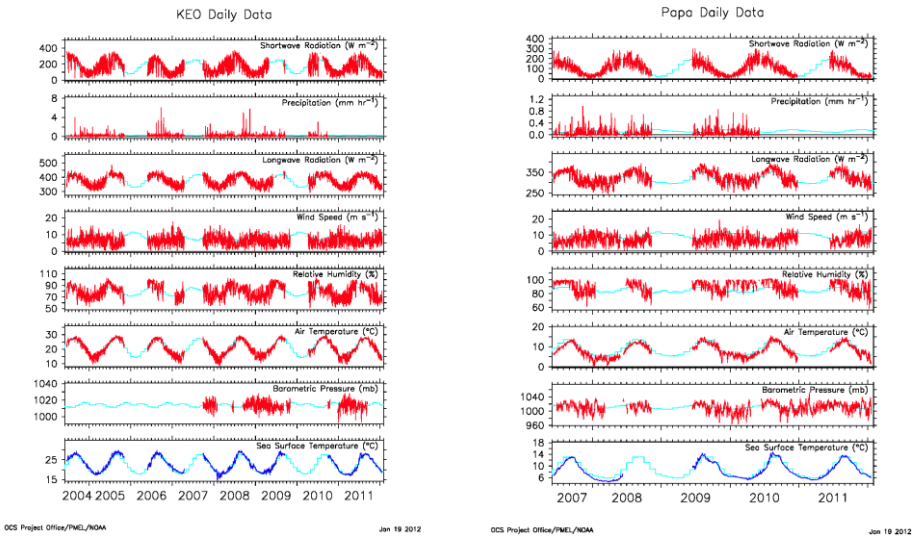

Figure 2*: Data plots by the OCS disdel web page http://www.pmel.noaa.gov/ocs/disdel/disdel.html. The left panel shows daily meteorological observations from the KEO mooring, 2004 to present. The right panel shows the same for the Papa mooring, 2007 to present.*

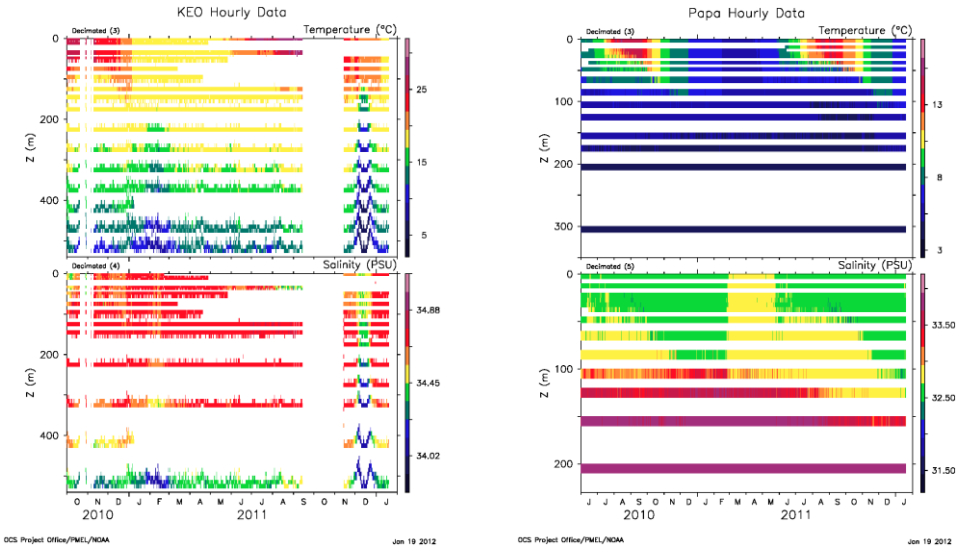

Figure 3: *Data plots by the OCS disdel web page http://www.pmel.noaa.gov/ocs/disdel/disdel.html. The left panel shows telemetered hourly subsurface temperature and salinity observations from the KEO mooring, October 2010 to present. The right panel shows the same for the Papa mooring, June 2010 to present.*

In order to preserve data return within the harsh environment of the North Pacific and Agulhas system, 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 in 2013 or 2014 will be replaced by the 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. We note that this field-testing 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.

Higher resolution meteorological data are logged internally in both systems, and retrieved after recovery of the mooring. ATLAS data are considered primary, unless unavailable, in which case the FLEX surface data become primary. The redundant data from these systems 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. At this point these secondary sensors are considered experimental. It is our goal to eventually provide a merged "best available" data set that uses the secondary data (properly annotated and flagged) when the primary data are not available. At present, these secondary data are flagged as lower quality data and are released as time allows.

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.

KEO: The KEO-2009 mooring was recovered at the end of FY10, on September 30, 2010. This mooring was damaged by typhoon Choi-Wan shortly after its deployment, causing decreased data return from both sets of meteorological sensors. The data that were acquired during the typhoon, however, were extremely valuable (Bond et al. 2011). Subsurface data return was nearly 100% (Table 1). Delayed mode surface data were processed in FY11 and the merged best available data set can be accessed through the OCS disdel page. Delay mode subsurface data from KEO-2009 are awaiting CTDs from JAMSTEC and will be available in FY12.

The KEO-2010 mooring was deployed at the end of FY10, on September 29, 2010. In February 2011, our JAMSTEC partners performed some repairs, replacing a malfunctioning rain gauge and the Vaisala WXT520 combination weather instrument that was damaged on deployment. Near the end of the year-long deployment, the FLEX software experienced multiple system resets and data transmissions stopped completely on September 14, 2011. This failure mode was also identified as a problem with similar systems recently deployed by the TAO group, and is currently being analyzed for a solution. Subsurface instruments log data internally, so delayed-mode subsurface data should not be affected by the loss of the FLEX system. However, several SeaBird temperature and conductivity sensors, which are normally very reliable, stopped updating measurements mid-deployment. Seabird, Inc. has issued a field service bulletin regarding premature battery failure. Further work is needed to determine if this is the cause and how to rectify this for future deployments. At present the Seabird sensors on KEO-2011 and Papa-2011 are updating properly, however this may change. Data return assessments for the delayed-mode data of the KEO-2010 mooring cannot yet be determined as the sensors have just returned to the lab. Real-time data return values for KEO-2010 are shown in Table 1.

	KEO-2010	**Papa-2010**		**Papa-2011**
	1 Oct 10 - 1 Oct 11	1 Oct 10 - 13 June 11		11 June 11 - 1 Oct 11
	Realtime	Realtime	Delayed	Realtime
ATLAS				
MET	96.2	15.4	33.5	100
SST/SSC	100	0	0	100
FLEX				
MET	85.8	99.5	99.5	100
SST/SSC	60.8	99.5	100	100
SBSFC TCP	70.8	99.5	100	99.9
SBSFC V	57.9	99.5	100	100

Table 1: Data return for Kuroshio Extension Observatory and Station Papa moorings, in percent.
The decreased data return numbers for KEO-2010 FLEX system are due to individual sensor failures, and a system malfunction late in the deployment. On Papa-2010, low ATLAS data return numbers are due to battery failure after five months and the ATLAS SST/SSC module returned bad data

Following the devastating tsunami and nuclear crises in Japan, there was quite a bit of interest in the KEO data (particularly the current meter data) and the mooring itself as a potential platform

for radiation detecting sensors. In the end, however, no radiation expert stepped forward with a clear plan and funding. The OCS group welcomes new partners who come with funding and expertise and who agree to the NOAA open data policy. New sensors from these partners will be considered for deployment if the measurement does not interfere with the primary measurements of the mooring. Thus, in 2011 KEO was enhanced with a gas tension device/CTD/O_2 package provided by Dr. S. Emerson (UW). These data will be made publicly available through the CO_2 data server and will be used to monitor the biological production of oxygen affecting the carbon cycle. Dr. Emerson has had a similar system deployed at Papa since 2007.

Station Papa: Papa-2010 was recovered on June 13, 2011. The ATLAS system on this buoy had stopped transmitting on November 15, 2010, after five months of operation. Upon recovery, it was found that the battery was completely dead, possibly due to a leak. There was some damage to the ATLAS electronics, and ATLAS data were not recorded internally for the final seven months of the deployment. The redundant data from the FLEX system will be substituted as primary during that time frame. The ATLAS SST/SSC module on the Papa-2010 mooring appeared to be out of calibration as the temperature and conductivity values did not compare well with the two other sensors on the bridle (FLEX SBE37 & UW SBE16). Consequently, the SST/SSC module data were discarded and not included in the data return calculations. On June 11, 2011, the Papa-2011 mooring was deployed. 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.

ARC: In order to expedite the launch of the ARC reference station and reduce risks, the mooring was to have two phases. During Phase 1, the ARC mooring would include a full suite of surface flux and engineering sensors, but minimal subsurface sensors. During Phase 2, the mooring would be enhanced with subsurface physical and biogeochemical sensors. This deployment was Phase 1, so the mooring had only a minimal suite of sensors.

The ARC mooring was deployed in the Agulhas Return Current south of Africa (Figure 1) on November 30, 2010, but unfortunately broke free from its anchor on January 16, 2011. The break was likely caused by higher than anticipated deep currents at the site. The break occurred below the subsurface instruments and all of the systems remained functional and telemetered data as the buoy drifted in the Agulhas Return Current. It was recovered on March 8, 2011 by the French research ship *Marion Dufresne* and brought to Mauritius. Dr. Cronin was planning to attend a workshop in Mauritius in May 2011 and was able to arrive several days early to disassemble the buoy and ship it back to Seattle. For the period that the buoy was in the water, the data return was nearly100% and represents a unique and extremely valuable data set.

The mooring line from ARC was recovered, and the point of failure is being analyzed. It is hoped that a similar type of flux mooring could be deployed in region to the north and east where air-sea fluxes are large, but currents appear to be much more benign. There is widespread enthusiasm for creating a permanent reference station in this region.

Evaluation of New Sensors: Evaluation of new sensors has been ongoing in FY11. As technology improves, new instruments become available that might allow greater simplicity, lower cost, or improved measurements. One instrument that has been tested by OCS 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. There have been some drawbacks that have delayed complete implementation of this instrument. The wind speed measurements can be erratic at high speeds, vibrations can cause the unit to register rainfall, and additional sealing is required in order to make the unit completely waterproof in an open ocean environment. OCS is working with the manufacturer to try to address some of these issues.

The RDI Sentinel ADCP has been deployed on the bridle of several OCS moorings. Data were analyzed for fish bias and mooring line reflections at both KEO and Station Papa. It was determined that noise from fish presence at KEO made the data unusable, so the Sentinel was not be deployed at KEO-2011. The Station Papa data set was usable and can provide significantly more data than the discrete current meters alone. A Sentinel was redeployed at Papa-2011.

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, 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, ATLAS data from the OCS moorings was made available in an OceanSITES netCDF format that is now obsolete. In FY11, OCS began working in partnership with NDBC to develop a method for getting OCS data into the standard OceanSITES format, starting with the high resolution delayed-mode data. Progress is slow, but being made. This effort highlights the need for a data manager within the OCS team. At present, OCS uses the TAO programmers to process OCS data. This arrangement made sense when OCS moorings and systems were clones of TAO. This is not the case now. The FLEX data stream, redundant data, and the OceanSITES data format all require new programming tools that are specific to OCS. OCS needs to have its own data manager/programmer to develop and use these tools and oversee the growing database of OCS data.

In addition to NDBC, 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

OCS web site pages were viewed over 14,000 times in FY11 and over 97 GB of text and data was downloaded by visitors. In addition, the OCS Data Display and Delivery page had 192 download requests, yielding 394 ascii files and 200 cdf files. Data was requested by users in government agencies (NOAA, NASA, DFO Canada, JAMSTEC, UK Met Office) and universities (UW, UW/APL, JHU/APL, Scripps, MBARI, Univ of Cape Town, Univ of Tokyo, Imperial College London) 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 project. 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.

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. OCS is currently working with NDBC to develop a means of getting Iridium transmitted data (e.g. barometric pressure data) to the GTS.

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 two months in FY11 through an NSF-funded KESS project titled "Kuroshio Extension System Study (KESS) – Upper and deep ocean response to atmospheric forcing in the Kuroshio Extension". This project, which had Dr. Cronin as a formal collaborator, combined KEO and KESS data sets to analyze the ocean response to typhoons and winter storms, including the forcing mechanisms for near-inertial waves (NIW), and the impacts of NIWs on mixing, SST, and mode water. A new Japanese-funded climate experiment named "Hot-Spot" began in FY11 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 will be deployed at the center of the KE jet for one year. Together with KEO and JKEO, the three surface moorings will provide data for investigating the atmospheric response to variations in the ocean SST front. At Papa, Drs. D'Asaro, Thomson, and Harcourt were funded by NSF to deploy a waverider mooring in June 2010 and a Lagrangian mixed layer float in January 2011 to study the effects of waves on the evolution of the mixed layer. Meteorological data for this project is provided by the NOAA Station P mooring. At both KEO and Papa, additional instrumentation was deployed on the OCS moorings through the acidification program and UW partners. In particular, as of 2011, both Papa and KEO carry sensors to monitor pH dissolved oxygen, gas tension, and chlorophyll fluorescence, in addition to the air-sea CO_2 flux. With these sensors, the moorings can monitor both physical and biological processes that affect ocean acidification.

All told in FY11, OCS PI Dr. Cronin was a co-author on 12 publications, 2 manuscripts that are *In Press*, and 2 manuscripts that are under review. Four of these were community or plenary white papers as part of the OceanObs09 conference, including Cronin et al. (2010) that made

recommendations for monitoring air-sea interactions in western boundary current extensions, regions of extremely large ocean heat release. The recommendation for a reference station in the Agulhas system led to Cronin being invited to be a member of the SCOR Working Group #136 on the climatic importance of the greater Agulhas system. As a member of this group, she was co-author on a Nature paper (Beal et al. 2011) describing the role of the Agulhas system in ocean circulation and climate. Cronin was also lead author on an book chapter on "Ocean Reference Stations" that will be published through InTech. As this is an open publisher, the book will be freely available on the web to the general public, without need for professional society membership. Cronin was also co-author on an article under review (Bourassa et al. 2012) that describes the requirements and challenges of making high latitude ocean and sea ice surface fluxes measurements for climate research.

OCS data were used in numerous studies, including one that assessed the radiative fluxes in MODIS satellite data (Niu et al. 2010). It is expected that the Bond et al. (2011) study, which shows the upper ocean response to Typhoon Choi-Wan as measured by the KEO mooring, will become a standard for assessing the ocean component of hurricane models. The data show that strong inertial oscillations can be generated even to the west of the eye, if the storm is transitioning to an extratropical storm. In these cases, the winds have an impulsive component as they rotate counter-clockwise. Cronin et al. (2012) show that energetic NIW generated by both winter storms and summer typhoons cause enhanced diffusivity at KEO, with values larger than 10^{-4} m^2/s at the base of the mixed layer. At Papa, Alford et al. (2012) show that NIWs are generated only during winter, but can propagate down to the deep ocean (below 800 m). Preliminary analysis show that diffusivity at the mixed layer base is enhanced during winter, but is at least an order of magnitude less than found at KEO. The CLIVAR ocean mixing climate process team is trying to develop a mixing parameterization based upon near-inertial waves that can be implemented in ocean general circulation models. They are very interested in these results and in the KEO and Papa data sets.

2.1 Outreach and Education

A NOAA press release and youtube video were prepared and released on Dec 14th, describing the NOAA ARC mooring and its importance for understanding how the ocean can affect global climate and weather (see http://www.pmel.noaa.gov/OCS/ARC). The youtube video has been viewed 3542 times thusfar.

In FY11, Dr. Cronin visited 4th and 5th grade classes at the Bryant Elementary School in Seattle, WA, on two separate occasions. She spoke about the Agulhas Return Current project and the classes participated in NOAA's Adopt-a-Drifter program, adopting two drifters deployed during the ARC cruise. Schools in Africa were also invited to join the program, with coordination provided by ASCLME, GLOBE-Africa (Global Learning and Observations to Benefit the Environment), South Africa Weather Service, and South African Environmental Observation Network (SAEON). Dr. Cronin shared her classroom presentations with Mark Brettenny from GLOBE-Africa, and James Stapley, outreach coordinator for ASCLME, to present in the South African schools.

Dr. Cronin also traveled to Mauritius for the SCOR Working Group workshop in May 2011 that was held in conjunction with the Data Buoy Cooperation Panel (DBCP) 2nd capacity building workshop. At this meeting, Dr. Cronin worked to solidify partnerships with ASCLME, the South African Weather Service, SAEON, and other outreach organizations, particularly GLOBE-Africa. She also formed collaborations with professors and students from the University of Cape Town, South Africa.

Students at the University of Washington also benefitted from Dr. Cronin's mentoring. She was the keynote speaker at the UW Oceanography Graduate Student "Toaster" retreat, and also served as committee member for two UW master's graduate students and one PhD graduate student.

K Ronnholm talked with the public and displayed a "Climate Buoy Deployment" video at the WeatherFest-2011 event in Seattle, a part of the AMS annual meeting in January. The event had over 4000 attendees.

3. Publications and Reports

3.1. Publications by Principal Investigators

Cronin, M.F. (2011): NOAA buoy deployed in the Agulhas Return Current. *South African Environmental Observation Network (SAEON) e-Newsletter*, http://www.saeon.ac.za/enewsletter/archives/2011/april2011/doc04.

Beal, L., W.P.M. de Ruijter, A. Biastoch, R. Zahn, M. Cronin, J. Hermes, J. Lutjeharms, G. Quartly, and T. Tozuka (2011): On the role of the Agulhas system in ocean circulation and climate. *Nature*, 472, doi: 10.1038/nature09983, 429–436.

Bond, N.A., M.F. Cronin, C. Sabine, Y. Kawai, H. Ichikawa, P. Freitag, and K. Ronnholm (2011): Upper-ocean response to Typhoon Choi-Wan as measured by the Kuroshio Extension Observatory (KEO) mooring. *J. Geophys. Res.*, 116, C02031, doi: 10.1029/2010JC006548, 8 pp.

Cronin, M.F., N. Bond, J. Booth, H. Ichikawa, T.M. Joyce, K. Kelly, M. Kubota, B. Qiu, C. Reason, M. Rouault, C. Sabine, T. Saino, J. Small, T. Suga, L.D. Talley, L. Thompson, and R.A. Weller (2010): Monitoring ocean-atmosphere interactions in western boundary current extensions. In *Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 2)*, Venice, Italy, 21–25 September 2009, Hall, J., D.E. Harrison, and D. Stammer, Eds., ESA Publication WPP-306, doi: 10.5270/OceanObs09.cwp.20.

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Kelly, K.A., R.J. Small, R.M. Samelson, B. Qiu, T.M. Joyce, Y.-O. Kwon, and M.F. Cronin (2010): Western boundary currents and frontal air-sea interaction: Gulf Stream and Kuroshio Extension. CLIVAR Western Boundary Current Special Issue, *J. Climate*, *23*(21), doi: 10.1175/2010JCLI3346.1, 5644–5667.

Konda, M., H. Ichikawa, H. Tomita, and M.F. Cronin (2010): Surface heat flux variations across the Kuroshio Extension as observed by surface flux buoys. *J. Climate, 23*, doi: 10.1175/2010JCLI3391.1, 5206-5221.

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Niu, X., R.T. Pinker, and M.F. Cronin (2010): Radiative fluxes at high latitudes. *Geophys. Res. Lett.*, *37*, L20811, doi: 10.1029/2010GL044606, 5 pp.

Tomita, H., S. Kako, M.F. Cronin, and M. Kubota (2010): Preconditioning of the wintertime mixed layer at the Kuroshio Extension Observatory. *J. Geophys. Res., 115*, C12053, doi: 10.1029/2010JC006373.

FY11 In Progress

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