Developing and Supporting NOAA's Buoy Observing Systems: PICO, OceanSITES and the Tropical Moored Buoy Array

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Table of Contents

Table of Contents 1
1. Project Summary 1
2. Scientific and Observing System Accomplishments 2
2.1. Outreach and Education 7
3. Publications and Reports 8
3.1. Publications by Principal Investigators 8
3.2. Other Relevant Publications 8

1. Project Summary

The Platform and Instrumentation for Continuous Observations (PICO) and associated Flexible and Low-cost Electronics/sensors (FLEX) advances NOAA's open ocean observation systems with the development of an easy to deploy and low cost mooring system using novel technology and commercially available sensors and instrumentation. The PICO project addresses critical issues regarding moored, deep-ocean observations: 1) reducing the total costs of high quality ocean observations, including realtime meteorological and sub-surface profiled measurements (~500m); 2) improving data return rates thru vandalism mitigation, sensor hardening and software maintenance; 3) providing more flexible sampling through controlled profiling rather than fixed-depth measurements. FLEX development is an effort to address legacy ATLAS system obsolescence and expand its capability. Both of these efforts are motivated by the need to enhance and replace the legacy ATLAS moorings used in the Tropical Moored Buoy Array and PMEL Ocean Sites.

Users of this technology are climate researchers, Met Services, warning and forecast managers and industry. Within NOAA, the electronics, sensors, software and mooring technology have been integrated into pCO2, RAMA, PIRATA, KEO, PAPA and ARC observatories that were facing component obsolescence. These FLEX and T-FLEX systems have now been ocean tested and verified against legacy ATLAS systems with very good results. We have transferred portions of the PICO technology to industry (SAIC), which is now selling complete mooring systems configured with meteorological and tsunami sensors to international customers.

Without support, the care and feeding for these critical observatories would cease and eventually software or component obsolescence problems would make them useless.

Updated web site containing videos and animations on the overall concept, basis of the cost savings and results from system deployments can be found at: http://www.pmel.noaa.gov/pico/

or short videos on PMEL's Ocean Buoys YouTube Channel:
http://www.youtube.com/playlist?list=PLE575643A95F6CED2&feature=plcp

2. Scientific and Observing System Accomplishments

Project deliverables from the FY'11 Work Plan include three main components:

a) Prawler CTD mooring crawler engineering/deployments
b) PICO mooring line/system development
c) Upgraded electronics/sensors to replace the legacy ATLAS system.

The accomplishments are critical for the advancement and maintaining of PMEL observing systems such as PAPA, KEO, ARC, Carbon and the Tropical Moored Buoy Array. Deliverables include relevance in 4 of 6 NOAA Climate Program Office deliverables:

1. Sea Surface Temperature and Surface Currents, to identify significant patterns of climate variability and change

2. Ocean Heat Content and Transport, to better understand the extent to which the ocean sequesters heat; to identify where heat enters the ocean and where it emerges to interact with the atmosphere; and to identify changes in thermohaline circulation and monitor for indications of possible abrupt climate change

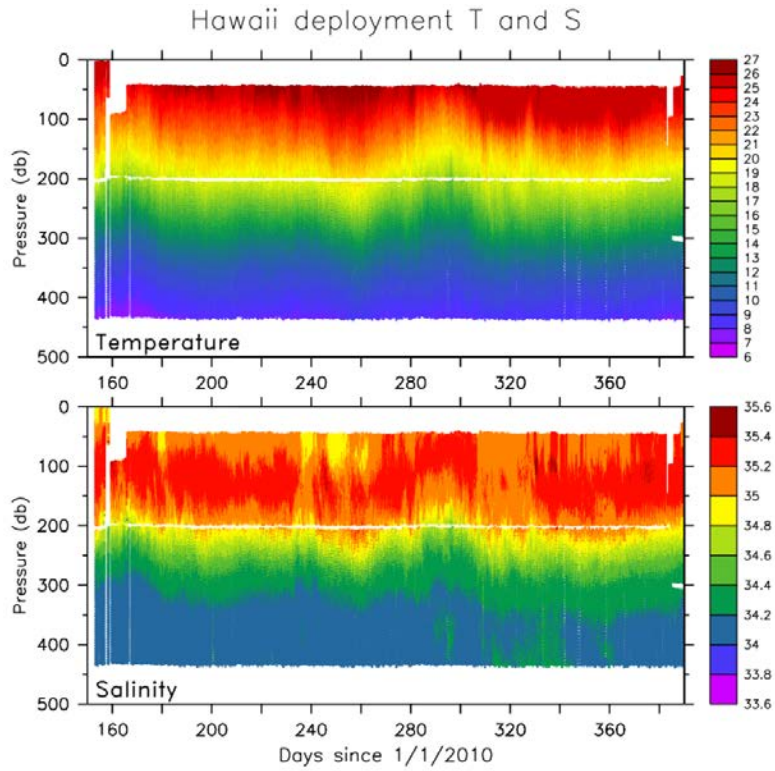
3. Air-Sea Exchanges of Heat, Momentum, and Fresh Water, to identify changes in forcing functions driving ocean conditions and atmospheric conditions; and to elucidate oceanic influences on the global water cycle

4. Adaptations of the technology that we've developed have been used for observing systems for NOAA's Carbon program, to better understand the extent to which the ocean sequesters CO2.

<u>a) Prawler CTD</u>

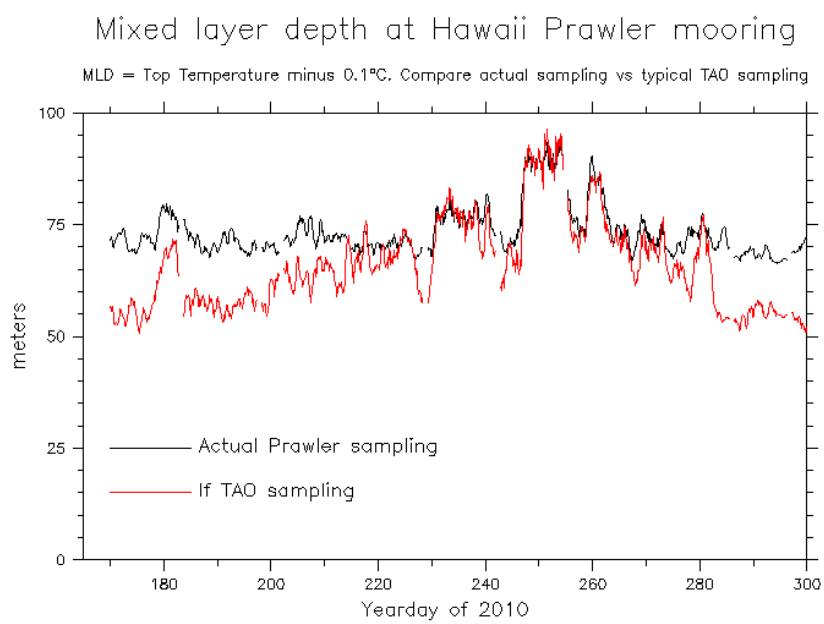
A line crawling profiler (Prawler) that uses wave energy for locomotion and a newly commercialized Seabird Prawler CTD has been successfully recovered and re-deployed in FY'11 with a new software and packaging. The moorings and Prawlers were recovered in early 2011 and inspected for sensor accuracy and mechanical wear of the system. Plots of a >7month deployment and significance of our new technology are included in Figs 1&2. The sensor accuracy, system endurance and vehicle control and communication are meeting GCOS goals and can dramatically reduce the cost of moored observations from traditional mooring technology. The closely-spaced data of a profile provides a more accurate measurement of the mixed layer-depth (MLD) than discreet sensors. Figure 1 show the complete TS data series collected in FY'10&11 from the Prawler CTD. Figure 2 shows a comparison of Prawler data MLD from 50nm SW of Honolulu, compared to what would be found by sampling at typical TAO depths (20,40,60,80,100,120m) . The TAO-like sampling often misses the inflection, substituting a straight line between points so the calculated MLD is generally shallower, often by

a substantial amount (10-20m). Since the MLD is a key climate variable - we typically assume that heat and momentum exchange with the atmosphere occurs within the ML - getting this wrong will make estimates of ocean-atmosphere exchange wrong.



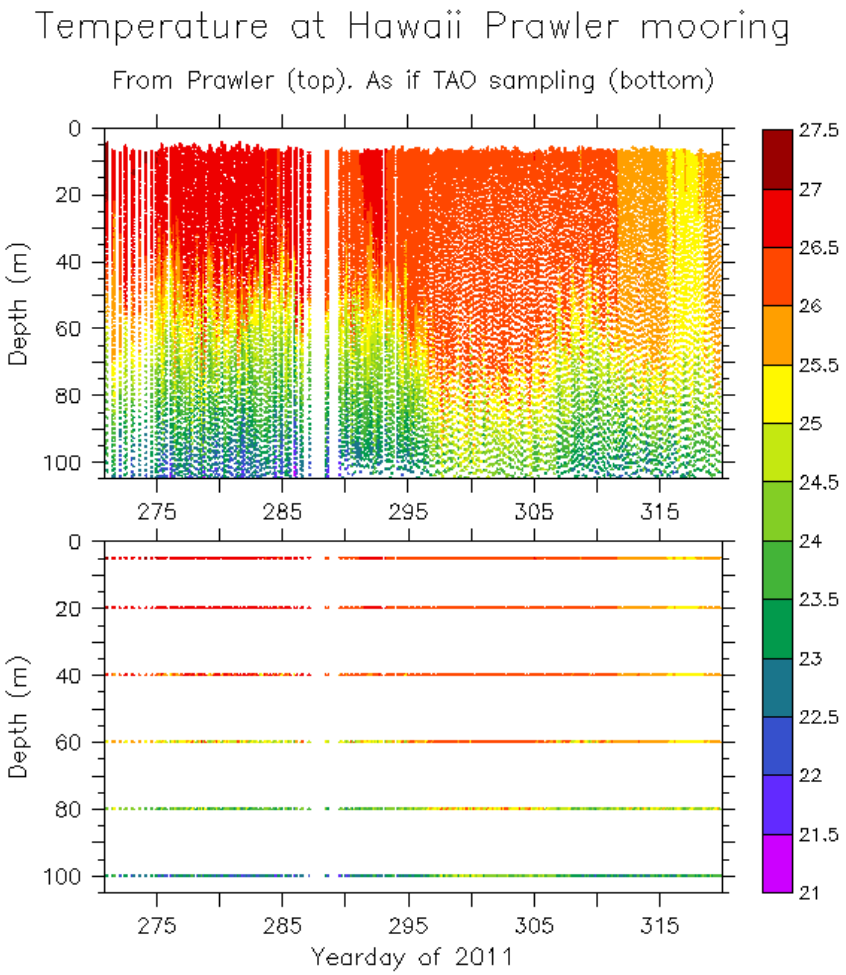
~7 month prototype Prawler Mooring CTD data set, 50nm SW of Honolulu

Figure 1



MLD determination using Prawler vs. ATLAS spacing

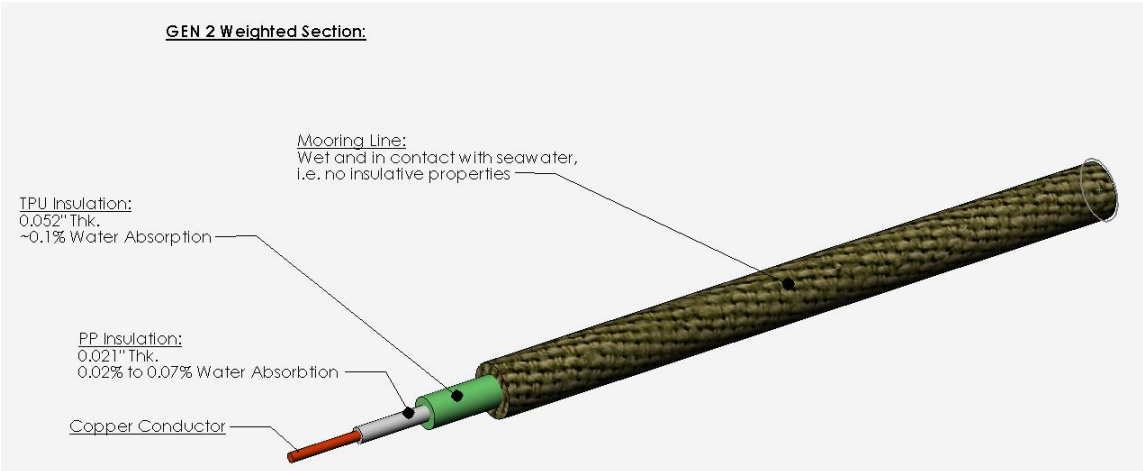
Figure 2



Sample CTD data return: Prawler (top) vs ATLAS spacing
Figure 3

This production design developed/tested in FY'11 is anticipated to be deployed in October 2012 as part of the NASA Salinity Processes in the Upper Ocean Regional Study (SPURS) program in the subtropical Atlantic. We envision 2012 as the transition from engineering to science evaluation.

b) PICO mooring line/system development
An engineering effort in FY'11 has lead to breakthroughs in electro-mechanical mooring fatigue limits with endurance approaching 1.x million cycles on our dynamic line testing machine, which is the equivalent of 8 months in the ocean. The design success in specific formulation and manufacture of the mooring line has resulted in the filing of a joint patent application w/NOAA-PMEL and Cortland Cable.



2nd Generation PICO Inductive Mooring line
Figure 4

c) Upgraded electronics/sensors to replace the obsolete ATLAS system.

The legacy ATLAS system is obsolete and electronic components can no longer be purchased. An interdisciplinary science and engineering effort is underway to maintain and enhance the PMEL OceanSites moorings (PAPA, KEO, ARC) and Tropical Moored Buoy Array (PIRATA, RAMA) with modernized electronics, software and sensors. This effort is envisioned as a medium term (<5 year) solution until next generation PICO systems are proven and transferred to operations. PMEL's upgraded electronics and sensors (FLEX and T-FLEX) have been developed over the past 2 years and have recently been deployed in side-by-side ocean testing with very encouraging results.

The upgraded KEO FLEX system recently survived a strike by Typhoon Choi-Wan, while a legacy ATLAS system on the same buoy failed completely. The KEO Choi-Wan unique dataset resulted in Bond et al. 2011 finding that the upwelling extended deeper than 400m after the typhoon for 6-7 days. (Figure 5). In addition to the robust packaging of the FLEX system, the high resolution data is now reported hourly over Iridium for inclusion in a wide array of research and operational products.

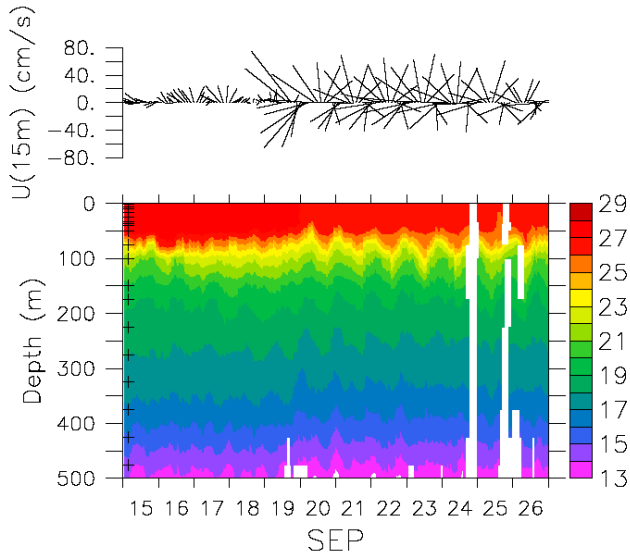


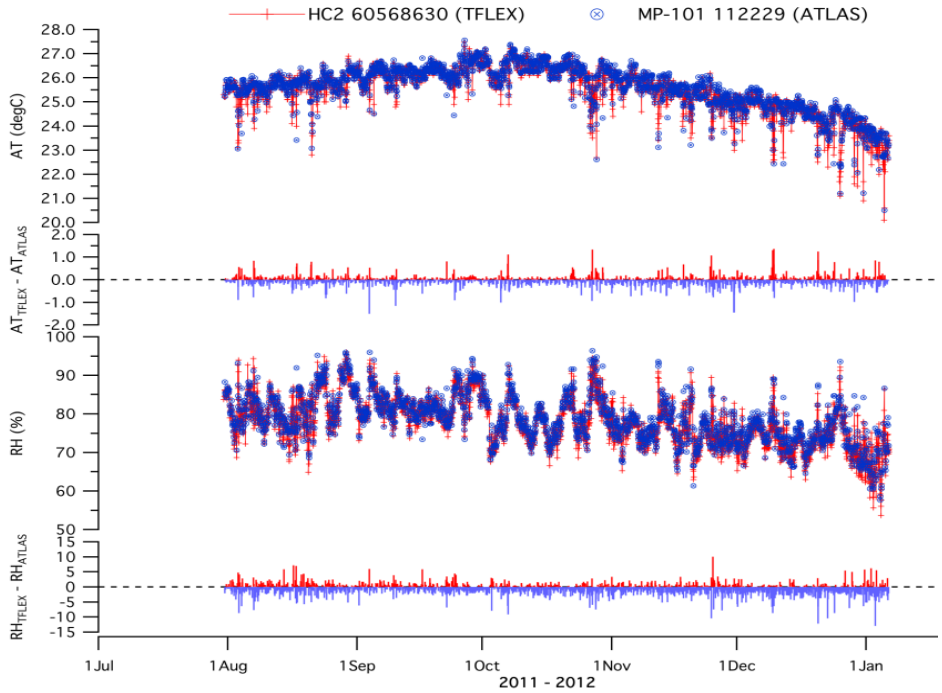
Figure 5. Time depth section of temperature (C) from KEO (color scale at right; contour interval 0.5 C). The nominal depths of the sensors are shown as plus marks near the start of the time series.

During this reporting period an ATLAS and T-FLEX system were deployed ~3nm apart in the RAMA and PIRATA arrays to qualify them per OCO observing principles. Prior to the deployment ~ 6 months of rigorous lab testing was done to validate the software, sensors and engineering parameters to make sure the baseline

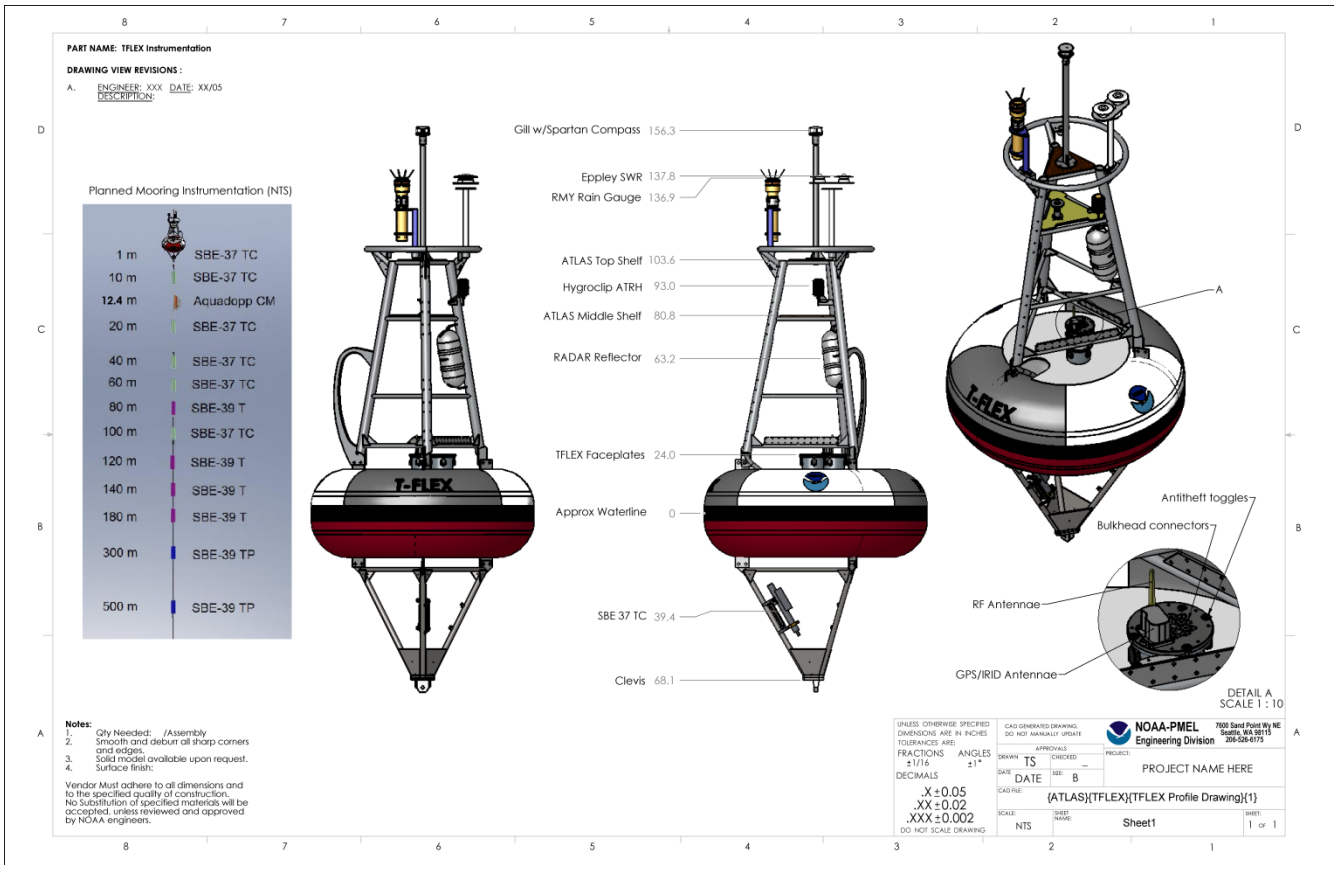
scientific specification of the system are met. Cost-engineering is incorporated to take advantage of economies of scales and to make systems backward compatible with lab testing equipment and user interfaces.

Lab Testing and Ocean Deployment of T-FLEX systems in 2011
Figure 6

Once the systems are deployed, PMEL scientists and engineers evaluate the data quality and engineering parameters per rigorous standards and results are documented (Figure 7,8). In the short-term the health of these arrays are jeopardized without continued modest support to fund the engineering that is required for the 'care and feeding' of these observing systems.



Sample dataset: PIRATA AirT/RH
Comparison of T-FLEX and legacy ATLAS
Figure 7



T-FLEX upgrade to legacy ATLAS
Figure 8

2.1. Outreach and Education

Education and outreach was primarily accomplished thru an updated website www.pmel.noaa.gov/pico and on the PMEL Buoy YouTube channel: http://www.youtube.com/playlist?list=PLE575643A95F6CED2&feature=plcp

International collaborations included outreach and training to Indonesian and Indian engineers and scientists. Also, during FY'11~50 middle school students at NOAA Summer program were given tours of the technology and the importance of climate observations. Additionally ~12 tours were given to students and academics highlighting NOAA developed technology.

Additionally, talks have been on-going with the San Francisco Exploratorium, http://www.exploratorium.edu/ that is very interested in featuring realtime climate observations in the museum with exhibits of PMEL technology.

3. Publications and Reports

3.1. Publications by Principal Investigators

None.

3.2. Other Relevant Publications

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. (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.

McPhaden, M.J., K. Ando, B. Bourlès, H.P. Freitag, R. Lumpkin, Y. Masumoto, V.S.N. Murty, P. Nobre, M. Ravichandran, J. Vialard, D. Vousden, and W. Yu (2010): The global tropical moored buoy array. 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.61.

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. [PDF Version]

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. [PDF Version]