Evaluating the Ocean Observing System: Surface Currents

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1. Abstract

The goal of this add-task project is to evaluate on a quarterly basis how well the Global Ocean Observing System is satisfying the requirement to sample surface currents, and to quantify the potential bias in satellite-based surface currents as a function of the observing system configuration. In FY09, we produced and distributed the reports on a quarterly basis, and made progress towards quantifying satellite bias. Rapid progress in quantifying this bias has been impeded by a specific problem identified in this study: the wind (or wave) driven motion appears to significantly exceed the published parameterization of this motion in regions such as the Southern Ocean and the North Pacific. We are addressing this in an informal collaboration with Nikolai Maximenko (Univ. Hawaii), and anticipate an improved parameterization of this motion will be an outcome of this study.

2. Project Summary

The Integrated Ocean Observing System (IOOS) includes an array of moored and drifting buoys that measure SST and near-surface currents throughout the world's oceans. The success of the IOOS in resolving SST variations and reducing satellite SST bias is quantified in a quarterly report (Zhang et al., 2004). However, until this project was initiated, no comparable evaluation was performed for surface currents even though surface currents carry massive amounts of heat from the tropics to subpolar latitudes, leading (and potentially improving prediction of) SST anomalies. Current anomalies can also be an early indicator of phase shifts in the ENSO, NAO, and possibly other climate cycles. The GOOS/GCOS (1999) report specified that the IOOS should resolve surface currents at 2 cm/s accuracy, with one observation per month at a spatial resolution of 600 km. There is currently no requirement for potential satellite bias in surface currents.

The goal of this project is to maintain a quarterly "Observing System Status Report for Surface Currents", which evaluates how well the IOOS satisfied the GOOS/GCOS requirements, and evaluate the evolution of the globally averaged potential satellite bias. This product is being used as a guide for future drifter deployments in conjunction with NOAA/AOML's Drifter Operations Center, a branch of the Global Drifter Program, and may demonstrate where future moored observations are necessary in order to meet these requirements.

Many researchers routinely calculate surface currents from satellite observations of wind and altimetry. As an example, geostrophic currents derived from blended satellite altimetry fields are estimated at AOML and posted daily in near-real time[1]. However, careful, quantified comparison with the in-situ observations has only been published for a few regions such as the Kuroshio Extension (Niiler et al., 2003). Prior to this project, no one had performed this comparison globally using non-interpolated altimetry, and the observing system had not been evaluated in this context.

3. Accomplishments

Near-real time drifter data is obtained at weekly resolution from the Global Drifter Program's drifter Data Assembly Center (DAC). The DAC identifies drifters which have run aground or been picked up, and removes these from the data stream. The DAC separate maintains a metadata file documenting the drogue-off date (date when each drifter lost its sea anchor). When a drifter has lost its drogue, it is significantly affected by direct wind forcing and no longer satisfies the GOOS/GCOS quality requirement for surface current measurement accuracy. We thus eliminate drogue-off drifters from our analysis.

Moored current measurements are collected by near-surface point acoustic meters on the Tropical Atmosphere-Ocean (TAO) array in the Pacific, the Prediction and Research moored Array in the Tropical Atlantic (PIRATA), the sustained array of ATLAS moorings in the tropical Indian Ocean (RAMA), the Kuroshio Extension Observatory (KEO) mooring at 32.3ºN, 144.5ºE and the PAPA mooring at 50°N, 145°W. Currents at daily resolution are downloaded from the TAO Project Office at PMEL each quarter to quantify the number of observations at each site, and the TAO office separately provides a record of days of observations per site, per quarter. Each quarter, these independent measures are compared to ensure accuracy.

The primary deliverable for this project is the Surface Current quarterly report. In FY09 we produced and distributed these reports within two weeks of the end of each quarter. Each report is e-mailed directly to CPO (contact D. Snowden) and also published on AOML's "State of the Ocean" web page at http://www.aoml.noaa.gov/phod/soto/gsc/index.php. The most recent FY09 quarterly report (Fig. 1) presents the overall spatial coverage of surface curent measurements for that quarter (top right), the spatial distribution of success at meeting GOOS/GCOS requirements (bottom left, requirements stated in top left panel), and a time series showing the month-by-month fraction of the world's oceans that were measured at the resolution and accuracy stated by these requirements (bottom right).

[1] http://www.aoml.noaa.gov/phod/altimetry/

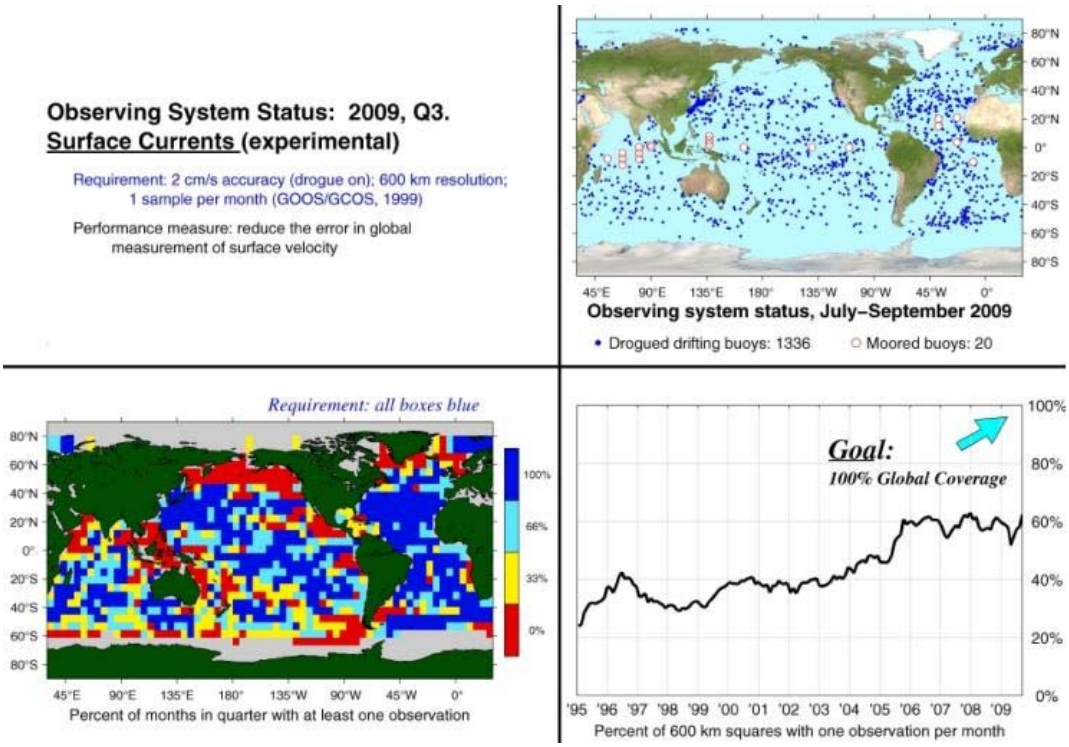

Fig. 1: FY09 Q4 (calendar Q3) report evaluating the IOOS's performance for near surface current measurements.

The percent of 5° squares with at least one observation per month has effectively reached a plateau since early 2008, at slightly over 60%. Much of the shallow (too shallow for 15m drogued drifters) Indonesian Seas region remains unsampled, along with coastal divergent regions where drifters move rapidly away from the coast (e.g., the west coasts of Africa and South America, where drifters move into the convergent centers of the southern subtropical gyres which are heavily oversampled by the array). Regions along the ice edge of the southern ocean, and in marginal seas such as the Caribbean and Bering, are also persistent gaps in the array.

Evaluating potential satellite bias

Potential satellite bias error can be calculated for surface current measurements in analogy to the process for SST measurements. Satellite measurements are collected of intensity at various light frequencies, in particular infrared and microwave. A model is used to convert these measurements to surface temperatures in degrees C. Due to various biases that exist in the model, for example the influence of atmospheric dust, the resulting SST field can be significantly offset from actual SST. In-situ observations can be used to reduce this maximum bias, which varies spatially, and the resulting globally-averaged potential satellite bias error is a function of the number and distribution of the observing network.

For surface currents, models to convert satellite measurements to surface current estimates are less mature than with SST. The most developed example is NOAA's OSCAR, which includes both geostrophic and wind-driven components. However, it is not immediately clear how to compare drifter measurements to OSCAR measurements, as differences may not necessarily be

due to biases in the OSCAR model. In fact, analysis funded by this project points to biases in the in-situ drifter measurements at high wind speeds.

As reported in last year's progress report, our work has highlighted that the Ralph and Niiler (1999) parameterization (herafter RN99) of wind-driven motion was insufficient to parameterize the downwind motion in regions of strong wind and wave action. In those regions, the downwind motion (derived using the method described above) significantly exceeded RN99. Assessing what this motion is, and properly parameterizing it, will greatly increase the value of the drifter velocity data in data assimilation efforts and allow for a proper quantification of potential satellite bias; ignoring these discrepancies will improperly project these errors onto the satellite bias, when in fact the error is due to the parameterization (this would be analogous to having an error in a parameterization scheme that extracts SST from microwave backscatter, and allowing this error to magnify the potential satellite bias in SST; the problem cannot be corrected by a reconfiguration of the observing system, as the bias calculation would imply, but rather a fixed parameterization). To this end, in FY09 we have initiated collaboration with Nikolai Maximenko (Univ. Hawaii) who has derived an improvement upon RN99 with latitude-dependent gain coefficients and offwind angles (related to the structure of the Ekman spiral) that reduce drifter-derived residuals in a least-squares sense (Fig. 2). He has shared these coefficients with us, and we will be repeating our drifter/satellite comparisons employing this parameterization in FY10.

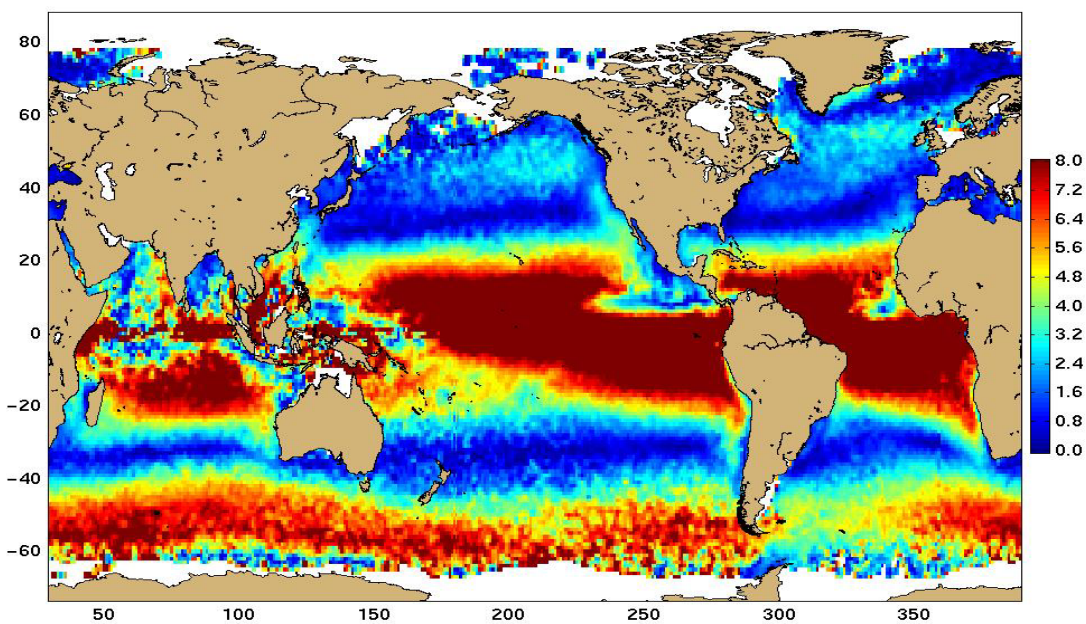

Fig. 2: time-mean magnitude of directly wind-driven currents ("Ekman" currents, cm/s) derived using spatially varying coefficients from Nikolai Maximenko, applied to six-hourly wind observations in NCEP/NCAR reanalaysis v.1 and averaged over the period 2000—2008. Values exceed the color scale in the tropics, and exceed estimate from the RN99 parameterization in the Southern Ocean and North Pacific.

The PIs of this project, Lumpkin and Goni, also contribute the "Surface Currents" section for the State of the Ocean report using results generated in this study (Lumpkin et al, 2009). This year,

we invited Kathleen Dohan (Earth and Space Research, Seattle WA) in order to more strongly entrain NOAA's OSCAR effort in this report.

4. Education and Outreach

R. Lumpkin represented the Global Drifter Program for visiting members of NOAA's Buoy Recapitalization Plan on 10 March 2009, in which he emphasized the importance of the program remaining in a research laboratory due to issues such as properly understanding the water-following characteristics of drifters and the relationship between in-situ and satellite-derived surface current products (the subject of this add-task).

5. Publications and Reports

5.1. Publications by Principal Investigators

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