Surface Drifter Program

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1. Project Summary

The Surface Drifter Program is the Atlantic Oceanographic and Meteorological Laboratory's (AOML) contribution to NOAA's Global Drifter Program (GDP), a branch of NOAA's Integrated Ocean Observing System, Global Ocean Observing System (IOOS/GOOS) and a scientific project of the Data Buoy Cooperation Panel (DBCP). The primary goals of this project are to maintain a global 5ºx5º array of satellite-tracked surface drifting buoys to meet the need for an accurate and globally dense set of in-situ observations transmitting in real time for weather forecasting, and to provide a data processing system for the scientific use of these data that support short-term (seasonal-to-interannual, "SI") climate predictions as well as climate research.

AOML's GDP responsibilities are to: (1) recruit ships and manage drifting buoy deployments around the world using research ships, Volunteer Observation Ships and aircraft; (2) insure the data is placed on the Global Telecommunications System (GTS) for real-time distribution to meteorological services everywhere; (3) maintain metadata files describing each drifter deployed, (4) quality control and interpolate the data (updated quarterly) and archive it at AOML and at Canada's Integrated Science Data Management (ISDM; formerly MEDS); (5) develop and distribute data-based products; (6) maintain the GDP; and (7) maintain liaisons with individual research programs that deploy drifters.

The drifters provide sea surface temperature (SST) and near surface currents. A subset of the drifters also measures air pressure, winds, subsurface temperatures and salinities. These observations are needed to calibrate SST and sea surface salinity observations from satellites, initialize global SI forecast models to improve prediction skill, and provide nowcasts of the structure of global surface currents. The surface drifter array provides the largest area coverage of all components of the global ocean observing system for surface temperature and currents, with observations provided by the drifters at approximately hourly resolution. Secondary objectives of this project are to use the resulting data to increase our understanding of the dynamics of SI variability and to perform model validation studies, in particular in the Atlantic Ocean. Thus, this project addresses both operational and scientific goals of NOAA's program for building a sustained ocean observing system for climate. The data are made available in near-

real time on the Global Telecommunications System for weather forecasting efforts, and in delayed mode (approximately three months, after quality control and interpolation) at the GDP web page and (with an additional six months' delay) at the data archive at ISDM.

2. Scientific and Observing System Accomplishments

The global drifter array became the first component of the IOOS that reached completion, with 1250 active drifters in September 2005. Until FY11, this number was maintained on average; in FY11, drifters from two manufacturers (Technocean and Clearwater) exhibited abnormally short lifetimes and by the end of FY11 the array size had rapidly dropped below the goal of 1250. During FY12, as the GDP interacted with these manufacturers to diagnose manufacturing problems and recall/repair/redeploy drifters, and drifters from two new manufacturers (DBi and SIO) were built and deployed. In FY12, the array size dropped from its starting value of 1049 (3-Oct-2011) to a minimum of 875 on 15-Apr-2012. At that point, deployments (which had been aggressively ramped up) began to outpace deaths and the array size began increasing at a mean rate of 35—40 each month, to reach 1069 on 24-Sep-2012. The array size has continued to grow into FY13 (1085 at the latest update, 22-Oct-2012).

2.1 Deliverables

The FY12 work plan outlined the following deliverables:

1. *medata files maintained that document information for each drifter deployed in the global array. Information includes manufacturer, deployment time, and deployment location, the "death" location and time, and the time of drogue loss.* **Status: Accomplished**.
2. *On a quarterly basis, the GDP's drifter Data Assembly Center (DAC) will produce a dataset of quality-controlled, evenly-interpolated drifter data of research quality. This data set will be archived at AOML and at Canada's Integrated Science Data Management (formerly MEDS) for public access.* **Status: Accomplished**.
2. *The DAC will continue to produce products derived from the drifter observations including time-mean and seasonal maps of currents, animations of currents in particular regions, and population reports. These products are publicly available at http://www.aoml.noaa.gov/phod/dac/dacdata.html.* **Status: Accomplished**.

In FY12, all data deliverables were achieved. The data were made available in near-real time via the Global Telecommunications System. Quality-controlled, evenly interpolated data were made available in delayed mode via the GDP web page approximately every three months, with a three- to four-month delay (http://www.aoml.noaa.gov/phod/dac) and at Canada's Integrated Science Data Management (ISDM). Data are sent to ISDM at approximately six-month intervals. The most recent quality-controlled data are available through 30 June 2012 and can be accessed at http://www.aoml.noaa.gov/envids/gld/. Every year, AOML files a "Global Drifter Program Report" on the statistics of survivability of power, drogues and sensors with the Data Buoy Cooperation Panel (DBCP), which is available on the DBCP web site. The drifter data

management plan is described in the OceanObs'09 Community White Paper "Data Management System for Drifting Buoys" by Keeley, Pazos and Bradshaw, available at http://www.oceanobs09.net/blog/?p=225.

2.2 Analysis of the global drifter array size: deployments and deaths

During the fiscal year, the Surface Drifter Program coordinated worldwide deployments of 1185 drifters, 909 funded by NOAA/CPO. AOML managed observations from 1825 unique drifters during FY12 (this is significantly greater than 1250, as some died while new ones were deployed during the fiscal year). Deployments for the four major manufacturers are shown in Table 1.

Manufacturer	***FY07***	***FY08***	***FY09***	***FY10***	***FY11***	***FY12***
Technocean	311	243	266	306	419	35
Clearwater	570	458	427	453	360	383
Metocean	101	179	137	231	234	288
Pacific Gyre	97	193	208	219	268	318
DBi	0	0	0	0	0	116
SOI	0	0	0	0	0	10
Other	4	16	26	19	6	8

Table 1: deployments per fiscal year by manufacturer

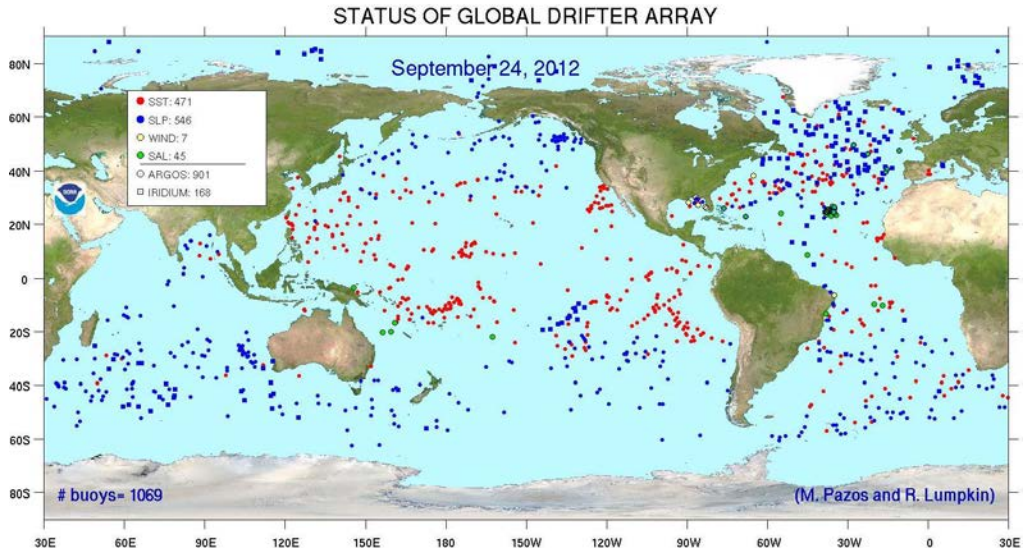

Fig. 1: Global population of drifters near the end of FY12.

A time series of the number of drifters in the global array is shown in Fig. 2. The GDP seeks to maintain an annually averaged array size of 1250 drifters – variations in the instantaneous array size through the year are normal. In 2005—2008 these variations were seasonal, with peaks in Boreal winter to spring and troughs in summer to fall. This reflects the variations in deployment

opportunities primarily due to dense Southern Ocean deployments during the research campaign season there. 2009 was an unorthodox year due to a lower number of deployments in Boreal winter (compared to the 2005—2009 average) and an increased death rate. We addressed the smaller array size with an aggressive increase in deployments throughout Boreal summer 2009, focused primarily in the Northern Hemisphere sectors of the Pacific and Atlantic Oceans. As a consequence the size of the array increased from nearly 1200 drifters in late 2009 to ~1400 drifters by late Boreal spring 2010. We subsequently reduced the number of deployments, allowing the array size to decrease below the 1250 level (to average 1250 for the year). As FY11 progressed, it became apparent that the drifter death rate was increasing dramatically, particularly for the manufacturer (Technocean) that contributed the largest fraction of the array. In addition, the second most significant manufacturer, Clearwater, also had drifters suffering from a high death rate (first identified in FY10). These problems were communicated to the manufacturers and to our colleagues at Scripps as they were identified, and the number of deployments was increased. As a consequence of these interactions, the GDP began purchasing drifters from Data Buoy instrumentation (DBi), began manufacturing drifters at Scripps (SIO), and ceased purchasing drifters from Technocean. The array reached a minimum of 875 in mid-April, after which deployments outnumbered deaths and the array size began increasing at a mean rate of 35—40 each month, to reach 1069 on 24-Sep-2012. The array size has continued to grow into FY13 (1085 at the latest update, 22-Oct-2012).

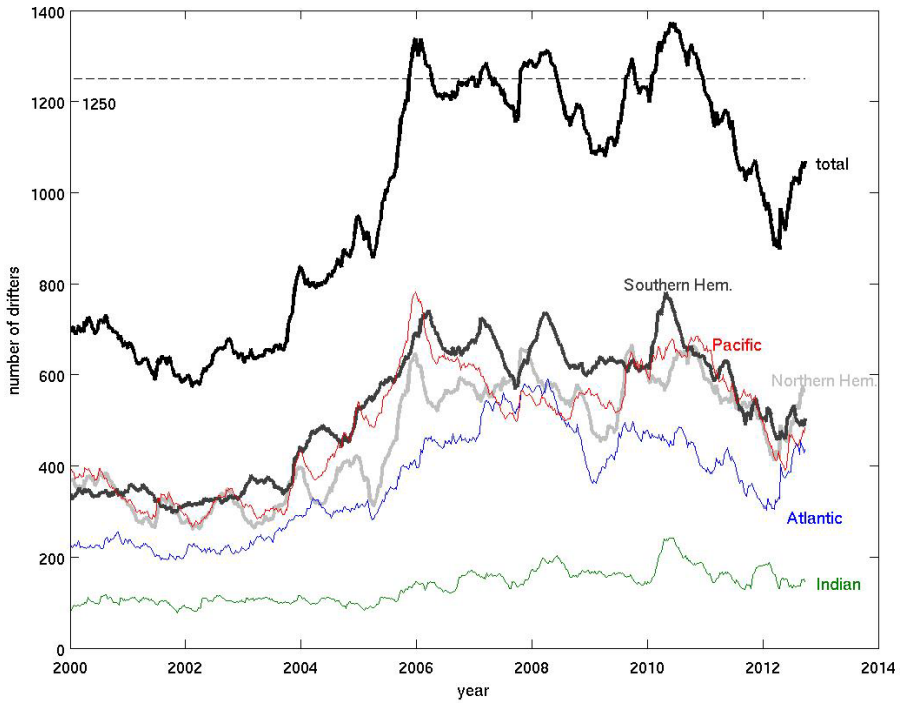

Fig. 2: Size of global drifter array in regions. Atlantic/Indian divided at 25°E in the Southern Ocean, Atlantic/Pacific at 70°W in the Southern Ocean, Indian/Pacific at 125°E south of Timor.

Drifter deaths are caused by "internal" reasons such as battery failures or hull leakage, and "external" reasons such as running aground or being picked up. The odds that each drifter died

due to an external reason can be assessed for each drifter (Lumpkin et al., 2012). Table 2 shows the number of "quit" drifters due to internal reasons for each major manufacturer, as a function of calendar year, after eliminating all drifters which had a >25% chance that its death was due to dying or running aground, and also deaths poleward of 55°N/S (as they could be due to ice interaction). 2012 is not shown as that date is not completed. Values are shown as a percentage of the number of drifters deployed that year.

Manufacturer	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***
Clearwater	29%	35%	63%	78%	67%	71%	95%
Marlin-Yug	N/A	0%	17%	13%	8%	36%	N/A
Metocean	53%	41%	28%	83%	38%	69%	69%
Pacific Gyre	24%	57%	53%	36%	45%	59%	51%
Technocean	24%	44%	39%	69%	43%	45%	115%

Table 2: anomalous "quit" deaths by manufacturer.

Table 2 shows that there was an extremely dramatic increase in Technocean drifters quitting in 2011 compared to previous years, while the other manufacturers had "quit" rates closer to earlier years. Table 3 lists the half-life of these "quit" drifters: values >450 days indicate that the drifters met or exceeded the design goal. The decrease in half-life for Technocean drifters is particularly dramatic compared to the large lifetimes of earlier years.

Manufacturer	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***
Clearwater	909	232	251	217	213	165	155
Marlin-Yug	N/A	849	635	>1229	634	>580	N/A
Metocean	395	384	436	452	431	271	>206
Pacific Gyre	244	173	192	424	346	335	>231
Technocean	535	563	691	1032	726	296	188

Table 3: drifter half-life by manufacturer.

Table 4 shows the percent of drifters that quit <90 days after being deployed. This was calculated by dividing the number that anomalously "quit" 0—90 days after deployment, divided by the number deployed in each year. These extremely short-lived drifters indicate recent major manufacturing problems or, in individual cases, problems such as improper deployment from a particular vessel. Pacific Gyre values in some years include hurricane and typhoon drifters air-deployed in the paths of major storms.

Manufacturer	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***
Clearwater	5%	8%	7%	11%	11%	26%	27%	12%
Marlin-Yug	N/A	0%	0%	0%	0%	18%	N/A	0%
Metocean	12%	6%	7%	5%	6%	5%	11%	27%
Pacific Gyre	15%	20%	13%	13%	17%	5%	5%	4%
Technocean	6%	13%	9%	8%	4%	11%	32%	75%

Table 4: percent dying <90 days after deployment, by manufacturer.

2.3 Evaluating the observing system for SST

The overall Global Ocean Observing System (GOOS) is evaluated for SST measurements by NOAA's National Climate Data Center (NCDC) and for near-surface current measurements by the Global Drifter Program (see section 2.4 of this report). SST measurements are quantified by Equivalent Buoy Density (EBD), which downweighs ship measurements compared to moored and drifting buoy measurements to reflect the relative accuracy levels. Most of the spatial coverage of the GOOS is due to drifters, which fill the vast gaps between the major shipping lines, although moored buoys are invaluable for maintaining instrumentation in regions of surface divergence (particularly on and near the equator). The target for the GOOS is to achieve a global maximum potential satellite bias of 0.5°C or less; this target was reached in 2006, and until this FY has been maintained on average (Fig. 3). In FY12, the maximum potential satellite bias averaged 0.56°C, with a maximum monthly value of 0.64°C in August 2012. The decrease in array size noted earlier in this report through 2011-2012 is primarily responsible for the increase in this metric, and recovery of the metric towards the 0.5°C goal has lagged recovery of the array size because of the sensitivity of the metric to Southern Ocean drifters. Most drifter deployments since mid-April 2012 (when the array reached its minimum size) through the end of the FY have been outside of the Southern Ocean, as winter deployment opportunities there are rare. As we enter their summer, deployments will be increasing in the Southern Ocean and the SST metric should demonstrate improvements.

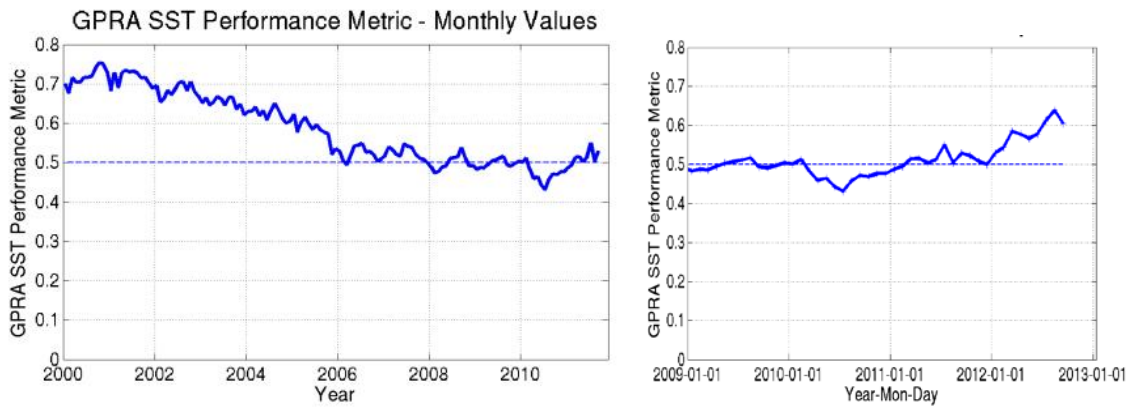

Fig. 3: GOOS performance for SST measurements, quantified as maximum potential bias in satellite SST. Goal of 0.5°C indicated by dashed line. Left panel: 2000—Jan 2012. Right panel: Jan 2009 through September 2012. Figures courtesy Huai-min Zhang, NOAA/NCDC.

2.4 Evaluating the observing system for Sea Surface Velocity (SSV)

The GOOS includes an array of moored and drifting buoys that measure SST and near-surface currents throughout the world's oceans. The success of the GOOS in resolving surface currents is evaluated by an add-task to AOML's Surface Drifter Program, $18,000 for FY12. This evaluation is motivated by the climate significance of surface currents, which 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 GOOS 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 the SSV add-task is to maintain a quarterly "Observing System Status Report for Surface Currents", which evaluates how well the GOOS satisfied the GOOS/GCOS requirements, and evaluate the evolution of the globally averaged potential satellite bias. 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. Because of the recent reevaluation of drogue presence (see section 2.5 of this report) which determined earlier drogue off dates for many drifters in the historical data set, the assessment of the GOOS's performance has become more pessimistic than prior to this reevaluation.

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.

The most recent SSV quarterly report (Fig. 4) 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). Since 1995, the success of the GOOS as hovered at 30—40% of complete global coverage. This curve has not increased with the increase in the global drifter array size in 2003—2006, primarily because the phase-in of the less expensive mini drifter design was associated with a sharp decrease in drogue lifetimes (Lumpkin et al., 2012). The Global Drifter Program is focusing attention on improving drogue lifetimes in FY13 (see next section).

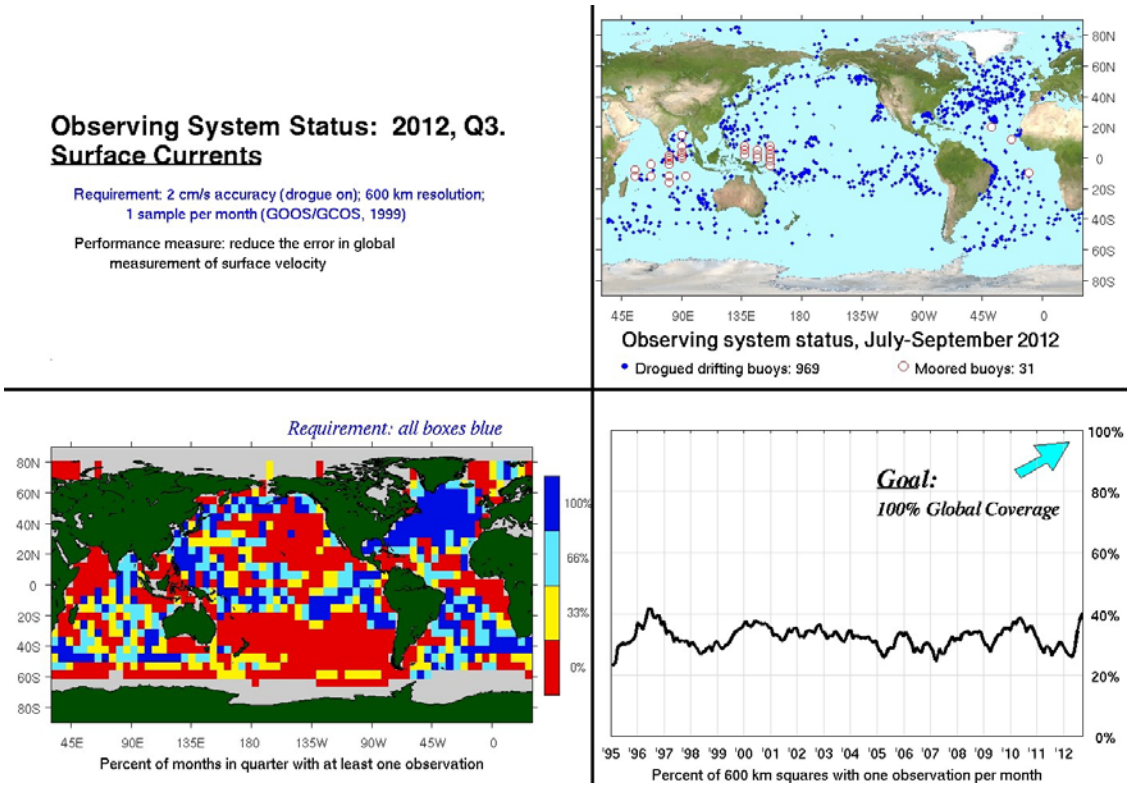

Fig. 4: GOOS performance for SSV measurements.

2.5 Drogue detection and lifetimes

While a drifter's drogue is attached, it slips downwind at <1 cm/s in 10 m/s wind. Once the drogue is lost, however, this increases by approximately a factor of 10 and wind forcing can significantly contaminate drifter-derived currents. Drogue presence is detected by either a submergence sensor, as the drogue frequently pulls the surface float underwater, or more directly by a tether strain sensor at the tether/surface float connection.

As reported in earlier years' reports, drogue detection was hampered for many years by extremely noisy submergence values, especially problematic for many Technocean drifters. Since the implementation of tether strain by all manufacturers, the GDP has been able to assess drogue presence more reliably. These improved drifters were deployed and represented a significant fraction of the global array by late 2008. During this same period of transition, the fraction of drifters identified as "drogue on" fell from around 70% to approximately 50% (see FY09 report). This indicated that a significant fraction of drifters in the pre-2008 period were misdiagnosed as "drogue on", when in fact they had lost their drogues. Because drifters without drogues are more strongly affected by direct wind forcing, misdiagnosis has the potential to bias ocean currents derived from drifters. This problem was the subject of a three-year NOAA Climate Change Data and Detection-funded project which started in 2010 (Principal Investigators Rick Lumpkin, NOAA/AOML, and Jim Carton and Semyon Grodsky, Univ. Maryland) and concluded in 2012.

The fraction of “drogue on” drifters (as evaluated by the GDP) that had actually lost their drogues was estimated in Grodsky, Lumpkin and Carton (2011). In this paper, we compared the downwind speed of “drogue on” drifters to (a) drifters which had lost their drogues, and (b) “drogue on” drifters <90 days old, which were likely to still have their drogues attached. The resulting ratio as a function of time dropped from ~100% in 1990—2004 to ~20% in 2006—2007, and then climbed to ~80% by 2010 with the phase-in of the tether strain drifters. At the 2011 Data Buoy Cooperation Panel meeting, Marie-Helene Rio (CLS) presented a methodology to evaluate when individual drifters lost their drogue, using results from Grodksy et al. (2011). This methodology, with improvements by R. Lumpkin, has been implemented at AOML and is now being used in a systematic manual reevaluation of all drogues in the post-altimeter time period. This reevaluation will be completed by the end of 2012. Results will be published in Lumpkin et al. (JAOT, in press) (Fig. 5).

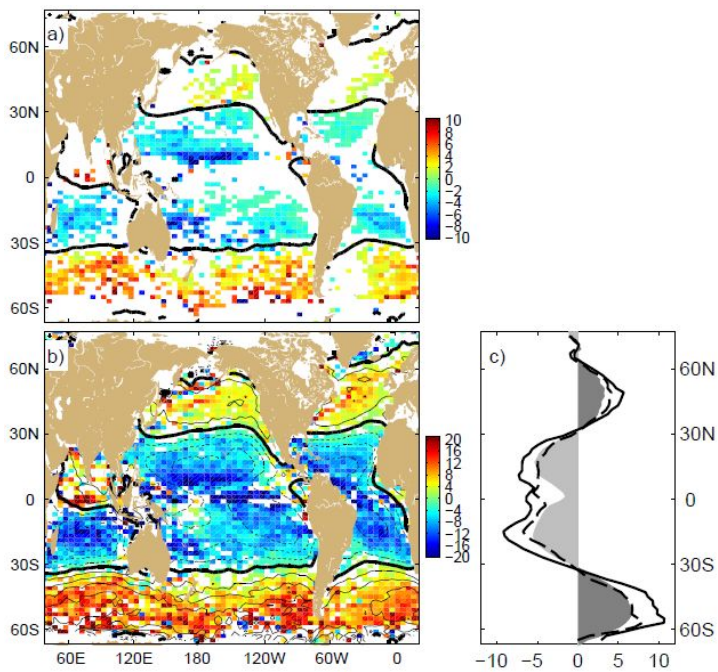

Fig. 5: a) Mean zonal current of “drogue on” drifters **before** minus **after** (cm/s), zero contour of time-mean zonal wind superimposed. b) Drogue off minus drogue on (**after**), time mean zonal wind superimposed (2 m/s contours). c) Time-longitude average of mean zonal wind interpolated to the drifters (shading, m/s) and drogue-off minus drogue-on zonal drifter speed (cm/s) **before** (dashed) and **after** (solid) automatic drogue reanalysis. From Lumpkin et al. (2012).

With the ability to reassess drogue loss in the historical data set, we have conducted an evaluation of drogue lifetime by manufacturer. As a function of calendar year, the half-lives of drogues from the various manufacturers, in days, is shown in Table 5.

Manufacturer	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***
Clearwater	89	63	72	106	106	96	88	>61
Marlin-Yug	N/A	197	152	72	57	167	N/A	16
Metocean	305	308	>407	280	225	85	90	>77
Pacific Gyre	>161	>321	>242	199	>263	>244	>164	>70
Technocean	13	45	47	33	65	77	154	>27

Table 5: drogue half-lives (days), by manufacturer.

The fraction of drogues that were lost in 90 days or less is shown in Table 6.

Manufacturer	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***
Clearwater	**46%**	**57%**	**54%**	**34%**	**28%**	**36%**	**39%**	22%
Marlin-Yug	*	0%	0%	**44%**	**46%**	**44%**	*	**100%**
Metocean	22%	14%	9%	15%	**25%**	**36%**	**46%**	**32%**
Pacific Gyre	**27%**	24%	16%	23%	12%	11%	14%	21%
Technocean	**69%**	**57%**	**62%**	**78%**	**52%**	**46%**	**26%**	**50%**

Table 6: fraction of drifters with drogues loss 90 days or less after deployment.

The GDP is examining these results in the context of design changes, particularly tether material and drogue attachment technique, so that recommendations to improve drogue lifetimes can be issued to the manufacturers.

2.6 Salinity drifters

With the November 2009 (SMOS) and June 2011 (Aquarius) launches of satellite missions for sea surface salinity, the demand for high spatial and temporal resolution sea surface salinity (SSS) observations will be considerable. In parallel with these efforts, and seeking to better understand the global hydrological cycle, the Salinity Processes in the Upper ocean Regional Study (SPURS) field campaign in Boreal Autumn 2012 through 2013 will focus on the processes governing SSS variations in the subtropical North Atlantic.

Drifters are the ideal platform to fill a critical need for calibrating and validating satellite salinity measurements. Because they follow water parcels in the mixed layer, their observations provide an estimate of d(SSS)/dt, a valuable term in the mixed layer SSS budget. While Argo floats will provide near-surface (5m deep) observations around the world, they do not stay at the surface long enough to resolve diurnal and high-frequency/wavenumber changes in SSS. In addition, significant salinity stratification in the upper ocean (e.g., regions of high rainfall and weak upper ocean mixing such as the ITCZs) may limit the value of Argo salinity observations compared to the ~20 cm depth measured by surface drifters in many regions.

Salinity drifters have been developed by several groups, including the Seacat-equipped salinity drifters developed at Pacific Gyre purchased by Scripps' component of the GDP. If

manufactured in quantities of 25-50 drifters, these instruments cost an additional $4.4k above the cost of a basic drifter. These drifters have been assessed in deployments in the South China Sea and in the Bay of Biscay, and upon recovery have demonstrated a sensor drift of no more than a few hundredths of a psu (practical salinity unit) over eight months, well within the anticipated accuracy of satellite SSS, O(0.5 psu instantaneous, 0.2 psu monthly mean). In a recent evaluation of the Bay of Biscay deployments, Gilles Reverdin estimates the accuracy is within 0.1 psu for up to a year (Reverdin, pers. comm.). The longer-term accuracy, and performance in tropical regions, remains uncertain and must be evaluated. 46 NOAA-CPO-funded SSS drifters will be deployed during the SPURS campaign.

AOML has begun serving salinity data files from the salinity drifters in delayed mode, with updates corresponding to updates of the quality controlled, interpolated data set. The raw sensor and position data files for all salinity-measuring drifters through 30 June 2012 are available at ftp://ftp.aoml.noaa.gov/phod/pub/buoydata/, in files p_salinity.dat and s_salinity.dat.

AOML has developed a quality control procedure based on Argo float observations of near-surface salinity. We are aware that in low wind conditions and/or high evaporation, the upper few meters of the ocean column may become strongly salt stratified, and the procedure described hereafter may flag drifter observations as anomalously saline in such regions. We collected all near-surface (10 dbar or less) quality controlled salinity measurements from Argo floats for the period May 1998 through June 2009 to build a climatology of near-surface salinity and its variations. The data were sorted in 5° (zonally) by 2° (meridionally) bins. In each bin, a mean plus annual and semiannual sinusoid were simultaneously fit to the data, to minimize bias from inhomogeneous seasonal sampling. Residuals with respect to this fit were also calculated. Results show the salinity maximum regions of the subtropical gyres and salinity minima of high precipitation, ice melt and river runoff regions. Residuals are largest in energetic western boundary regions and in the Intertropical Convergence Zone. By interpolating the time mean and seasonal variations (using their amplitudes and phases) onto SSS observations, residuals with respect to this climatology are calculated and compared to the quality-controlled Argo data set. Observations are automatically flagged which exceed two interquartile ranges from the mean+seasonal cycle. When applied to the existing set of salinity drifter observations, ~8% of the observations are flagged as questionable. Manual examination indicates that a significant fraction of these observations are acceptable, but that a larger interquartile range would result in some obviously biased observations not being identified. With experience we expect that we will be able to adjust this procedure to be more efficient in identifying bad salinity values. Other quality control flags, such as those described in the DBCP report “Sea Surface Salinity Quality Control processes for potential use on Data Buoy observations” will be implemented for application to salinity drifter data collected historically and as a part of SPURS.

2.7 Scientific advances

Hormann, Lumpkin and Foltz (JGR, 2012) examined interannual to decadal variations in the strength and position of the Atlantic’s North Equatorial Countercurrent (NECC) using a synthesis of drifters, satellite winds, and altimetry. This study showed that zonal propagation of NECC variations is consistent with long Rossby waves forced in the northeast tropical Atlantic,

that northward (southward) shifts of NECC core are correlated with positive (negative) meridional mode events, strenghtening (weakening) of NECC is correlated with negative (positive) zonal mode events, and that these interannual NECC changes are likely driven by changes in the wind stress curl field associated with the Tropical Atlantic climate modal events.

Lumpkin, Maximenko and Pazos (2012, JAOT) examined how exposed various coastlines are to the deposit of marine debris, using a statistical model derived from the trajectories and "ran aground" locations of all drifters in the GDP data base.

2.8. FY11 Meetings

PI R. Lumpkin attended the following meetings:

2012 Ocean Sciences, February 20—24, Salt Lake City, Utah; presented results from drogue detection study.

European Space Agency GlobCurrents, March 7—9, Brest, France; presented opening keynote lecture on ocean surface currents and in-situ measurements. Represented NOAA and PhOD activities in discussions on proposed GlobCurrents product.

2012 PhOD retreat, Miami FL, March 28—29; presented results from drogue detection study.

5th Workshop on the Impact of Observing Systems on Numerical Weather Forecasting, 21—25 June including one-day workshop on drifting buoys, 21 June, Sedona AZ; co-wrote report documenting value of drift sea level pressure measurements for improving numerical weather prediction.

NOAA Climate Observations Division Annual PI meeting, 25—27 June, Silver Spring MD; presented poster on results of drogue detection study.

US CLIVAR Summit, 17—20 July, Newport Beach CA; served as member of Phenomenon, Observation and Synthesis (POS) panel.

Tropical Atlantic Variability/PIRATA-17, 10—14 September; Kiel, Germany; co-chair of PIRATA Science Steering Group, session convener, two oral presentations and one poster.

2.9. Education and Outreach

R. Lumpkin gave a presentation on drifters and the Global Ocean Observing System for visiting students from Gulliver Schools, 9 November 2011, and for Miami-Dade Science Camp, 10 July 2012, and served as Technical Input Author for the National Climate Assessment Ocean and Marine Resources report, which will be published in Oceanography and Marine Biology: Annual Review in 2013.

3. Publications and Reports

3.1. Publications by Principal Investigators

The following FY12 peer-reviewed publications by the Surface Drifter Program principal investigators rely upon the drifter data supported by this project:

Submitted

Letscher, R. T., D. A. Hansell, C. A. Carlson and R. Lumpkin, 2012: Distribution and fate of dissolved organic nitrogen in the global surface ocean. *Global Biogeochem. Cycles*, submitted July 2012.

Lumpkin, R. and G. Johnson: Global Ocean Surface Velocities from Drifters: Mean, Variance, ENSO Response, and Seasonal Cycle. *J. Geophys. Res.-Oceans*, submitted September 2012.

In Revision

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