Surface Drifter Program

AOML's component of NOAA's Global 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 META 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 website at http://www.aoml.noaa.gov/phod/dac; 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. This number has since been approximately maintained on average. During FY11, the drifter array averaged 1172 drifters (compared to 1319 in FY10), with a standard deviation of 87. Although the number of drifters deployed in FY11 was close to the mean value since FY06, the size of the array generally decreased through the fiscal year, from a maximum of 1332 drifters on 4 October 2010 to a minimum of 1013 drifters on 19 September 2011. Causes of this decrease are discussed below; in summary, drifters from two manufacturers, Technocean and Clearwater, exhibited abnormally short lifetimes. The impact was particularly severe for Technocean drifters, which had represented the single largest contributor to the global array. These problems were still being addressed as of the end of FY11, and due to the lag between manufacturing and deploying, the size of the array continued to drop through early 2012. As production is ramped up by other manufacturers, the size of the array will be rebuilt through FY12.

2.1 Deliverables

The FY11 work plan outlined the following deliverables:

1. *META 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 FY11, 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 September 2011 and can be accessed at http://www.aoml.noaa.gov/envids/gld/. Data through 30 June 2011 have been downloaded by PI R. Lumpkin to insure their format and quality. CIMEC-SIO maintains surface currents files in which a wind slip correction has been applied, which are distributed upon request. 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.

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

During the fiscal year, the Surface Drifter Program coordinated worldwide deployments of 1300 drifters, 1175 funded by NOAA/CPO. AOML managed observations from 2346 unique drifters during FY10 (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	**FY11**	**FY10**	**FY09**	**FY08**	**FY07**
Technocean	419	306	266	243	311
Clearwater	360	453	427	458	570
Metocean	234	231	137	179	101
Pacific Gyre	268	219	208	193	97

Table 1: deployments per fiscal year by manufacturer

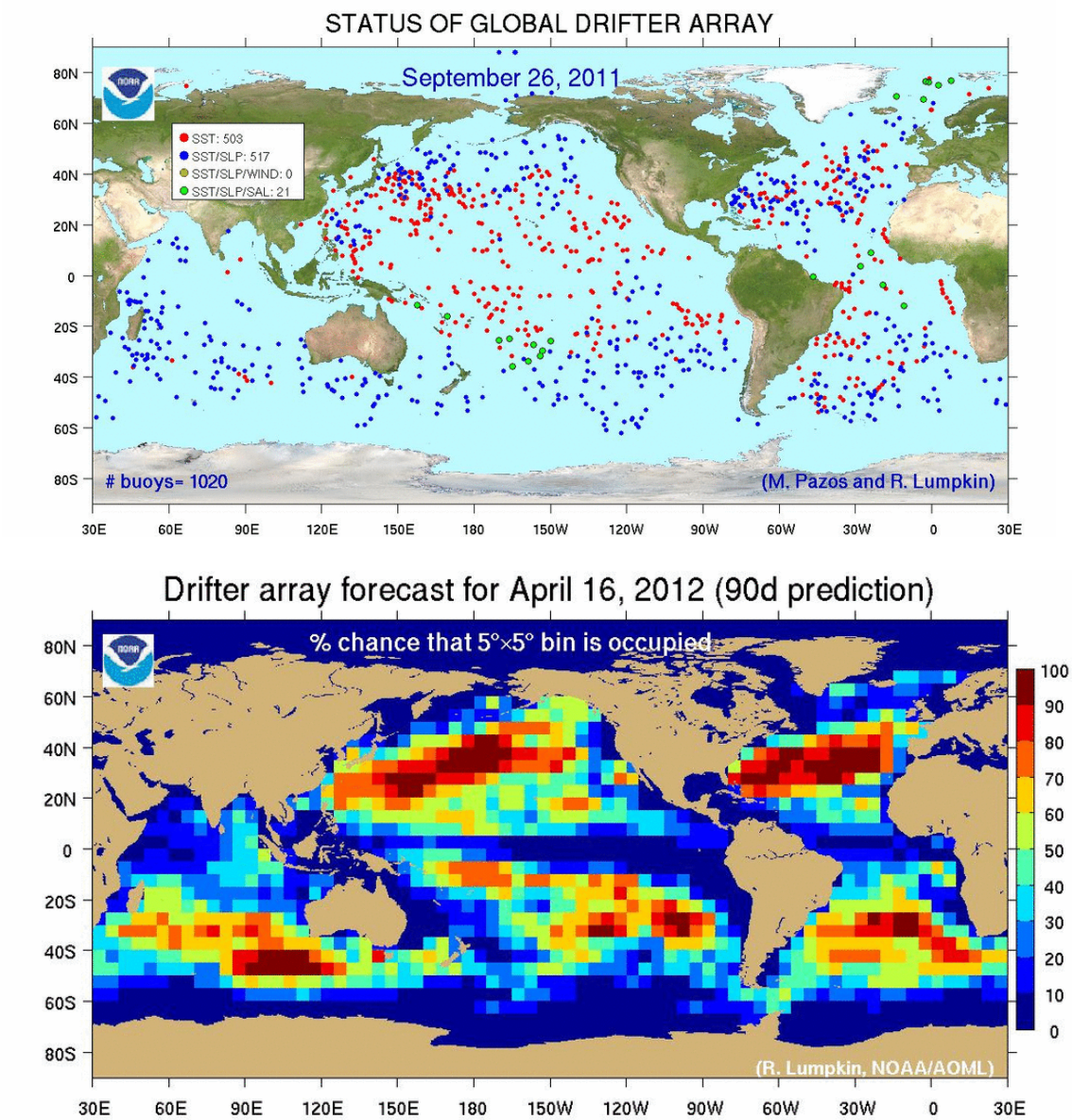

Fig. 1: **Top**: Global population of drifters near the end of FY11. **Bottom**: 90 day prediction of coverage as of 16 January 2012 (% chance that a 5ºx5º bin will have a drifter if no additional drifters are deployed in the interim).

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 (Fig. 3) 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 (identified in FY10 and addressed during this FY). These problems were communicated to the manufacturers and to our colleagues at Scripps as they were identified, and the number of deployments was increased.

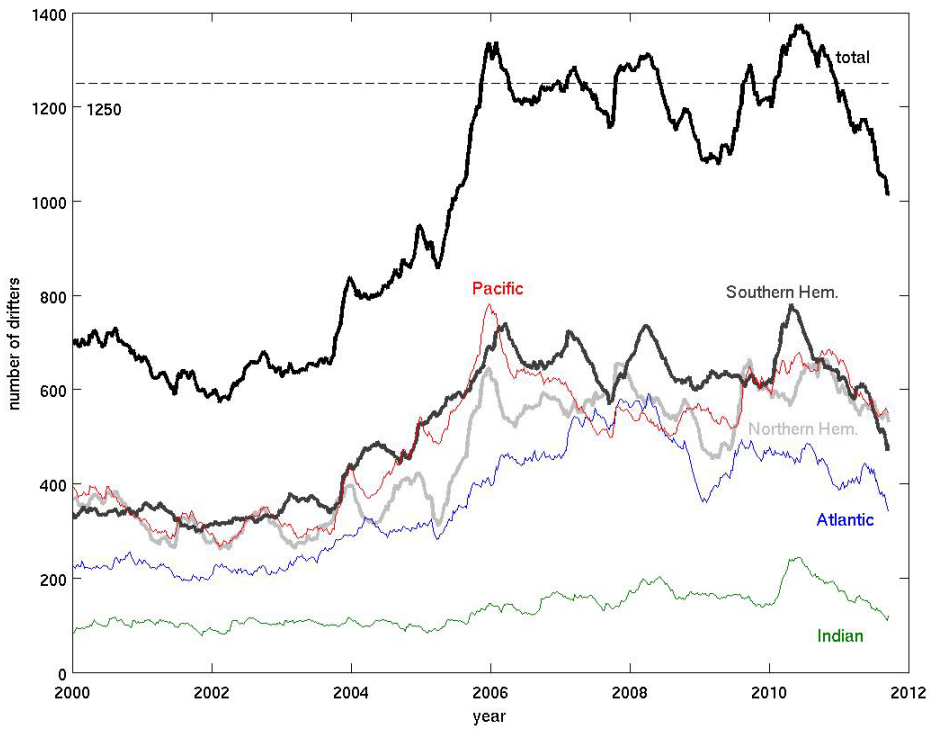

Fig. 2: Size of global drifter array in regions. Atlantic/Indian divided at 25°E in the Southern Ocean, Atlantic/Pacific at 70°W in the Southern Ocean, Indian/Pacific at 125°E south of Timor.

The number of drifter deaths per month, per 1250 drifters, is shown in Fig. 3. This is the number of drifters that must be deployed each month in order to maintain the array at 1250. The death rate increased from ~71 in September 2005 to ~100 in late 2008, which we attributed to the average age of the array increasing during this time period. The death rate decreased through early 2009 to a minimum of ~80 in mid-summer. In last year's report, we anticipated that, should the death rate stay at this level, we would need to increase the number of deployments to ~1150 per year (up from 1000 per year) to maintain an array of 1250 drifters. Instead, the death rate steadily increased until averaging around 150 by the end of FY11. At this unacceptable rate, the GDP would have to deploy a total of 1800 drifters per year to maintain an array of 1250

drifters. The mean age of a drifter in the array has slightly decreased over the last few years, from ~450 days in August 2008 to a current value of around 400 days (Fig. 3, bottom).

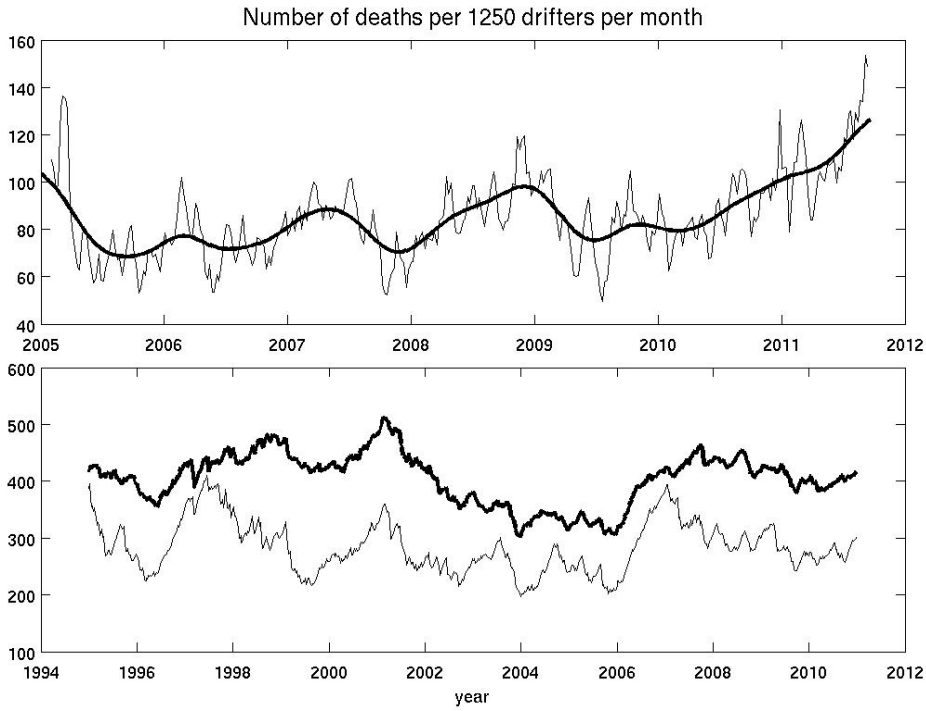

Fig. 3: (Top) Number of drifter deaths per 1250 drifters per month. (Bottom) The mean (thick) and median (thin) age of a drifter in the global array.

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). 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), the resulting anomalous "quit" deaths are shown in Table 2 by manufacturer.

Manufacturer	**FY11**	**FY10**	**FY09**	**FY08**	**FY07**
Technocean	269	143	121	120	108
Clearwater	248	316	262	273	304
Metocean	133	132	81	114	59
Pacific Gyre	170	126	111	104	56

Table 2: anomalous "quit" deaths by manufacturer.

These numbers can be crudely compared to the numbers deployed (Table 1) to evaluate their relative significance, as manufactures with more drifters deployed can be expected to have more quit (ideally after the design lifetime goal of 450 days). Table 2 shows that there was an extremely dramatic increase in Technocean drifters quitting in FY11 compared to previous years, while the other manufacturers had "quit" rates closer to earlier years. Table 3 lists the median age at death of these "quit" drifters: values >450 days indicate that the drifters met or exceeded

the design goal. The decrease in median age for Technocean is particularly dramatic compared to the large lifetimes of earlier years.

Manufacturer	**FY11**	**FY10**	**FY09**	**FY08**	**FY07**
Technocean	269	498	829	699	401
Clearwater	217	135	264	345	233
Metocean	279	428	349	386	315
Pacific Gyre	385	287	126	174	415

Table 3: median age at death by manufacturer.

Table 4 shows the percent of drifters that died <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 fiscal year (Table 1). 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 FY08-09 include hurricane and typhoon drifters air-deployed in the paths of major storms.

Manufacturer	**FY11**	**FY10**	**FY09**	**FY08**	**FY07**
Technocean	17%	9%	4%	10%	10%
Clearwater	17%	26%	9%	8%	9%
Metocean	9%	3%	10%	6%	10%
Pacific Gyre	4%	9%	21%	20%	9%

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

The alarming increase in rapid failures of Technocean drifters became apparent from a number of deployments during the fiscal year. For example, 19 Technocean drifters were deployed during the summer 2011 PIRATA Northeast Extension cruise (R. Lumpkin, chief scientist). Of these, one failed on deployment, four transmitted for <10 days, and 8 more had lifetimes between 15—38 days; the half-life of these 19 drifters was 23.5 days. Similar experiences were shared by southern hemisphere meteorological partners who deployed Technocean barometer drifters for numerical weather forecasting efforts. When these results were communicated to Technocean, they replied that they had identified a major problem with the Rayovac batteries used in the battery packs, which caused them to corrupt. In many cases, the batteries were corrupt before deployment; unfortunately, this did not affect the battery pack voltage until after deployment. In late FY11, the remaining undeployed drifters were returned to Technocean for refurbishing at their expense. As of now Technocean has still not resolved this problem, based on the performance of recently deployed "refurbished" drifters, and the situation is still being investigated by the GDP. A similar problem had affected a large number of Clearwater drifters in the previous fiscal year. As a consequence of this experience, the GDP is now requiring that manufacturers use only industrial grade Duracell batteries for battery pack construction (see Scripps' component of the FY11 Global Drifter Program report for additional details).

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. 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 has been maintained on average through FY11 (Fig. 4), although it slightly exceeded the goal at the end of the fiscal year for some months.

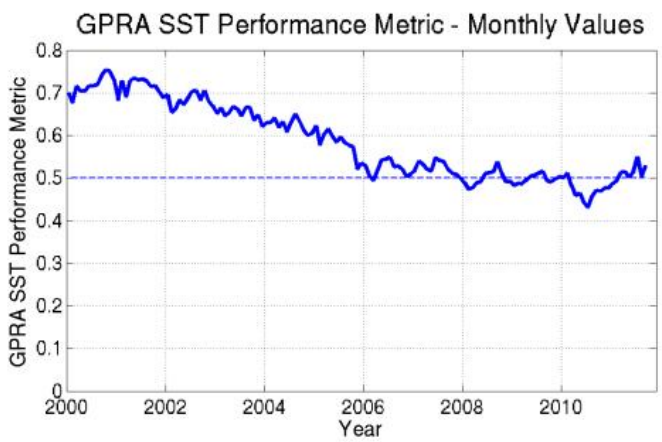

Fig.4: GOOS performance for SST measurements, quantified as maximum potential bias in satellite SST. Goal of 0.5°C indicated by dashed line. Figure courtesy Huai-min Zhang, NOAA/NCDC.

2.4 Drogue detection

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 suggested 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 is 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).

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 is shown in Fig. 5.

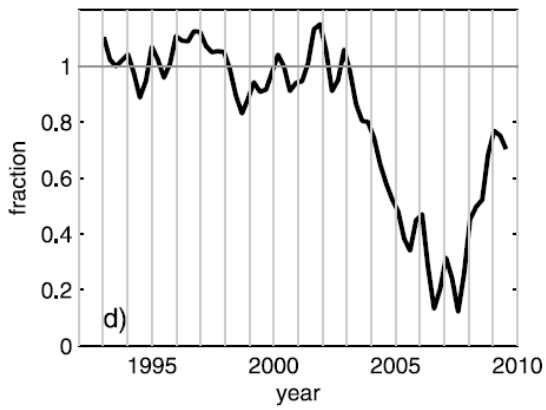

Fig. 5: Fraction of drifters assessed as “drogue on” which actually have drogues attached. Fig. 3d of Grodsky, Lumpkin and Carton (2011).

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 some improvements, has been implemented at AOML and is in the process of being evaluated and improved before the GDP applies it to the historical dataset (Lumpkin, Centurioni, Grodsky and Rio, manuscript in preparation). This reevaluation will be a major focus of activity in FY12.

2.5 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.

In anticipation of the deployment of salinity drifters, 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.

2.6 Scientific advances

Lumpkin and Garzoli (2010) described interannual to decadal variability in the position of the Brazil-Malvinas confluence front of the southwest Atlantic Ocean using a synthesis of drifter-

derived currents, altimetry, and wind products. They showed that the annual mean position of the front shifted significantly southward by over 100km during 1993—2000, corresponding to a shift in the wind stress curl over the South Atlantic basin. At longer time scales, NCEP data was used to infer the position of the confluence front based on these results, and deduce that the southward shift was part of a multi-decadal oscillation related to SST anomalies advected from the Indian Ocean along the Agulhas-Benguela pathway of the southeastern Atlantic.

Lumpkin and Elipot (2010) examined the spreading of surface drifter pairs and trios deployed as part of the CLIMODE experiment in the Gulf Stream region. At scales from 1–3 km to 300–500 km, drifter pair spreading indicated stirring by eddies comparable in scale to the pair separation distance, inconsistent with quasigeostrophic turbulence theory (which predicts stirring at the Rossby deformation radius at scales smaller than that scale) but qualitatively consistent with energetic submesoscale vortices observed in some drifter trajectories. At larger scales, the spreading became a random walk described by a constant diffusivity. These results indicate that significant energy at the submesoscale in the Gulf Stream region flattens the wave number spectrum and dominates surface stirring at this scale range.

Grodsky, Lumpkin and Carton (2011) examined climate-scale fluctuations in surface currents derived from surface drifters and concluded that large variations in the early to mid-2000s were likely due to misdiagnosed drogue presence, rather than a true climate signal. They derived the fraction of the array identified as “drogue on” which was truly drogue on (see Fig. 5 of this report). Results from this paper are now being used to reassess drogue presence in the historical data set.

Lumpkin, Goni and Dohan (2011) examined surface current variations in 2010 as part of the BAMS “State of the Ocean in 2010” article. They performed this evaluation using currents from surface drifters, altimetry, winds, SST and moored instruments in the tropical moored array. In 2010, the La Nina surface current signal in the Tropical Pacific Ocean exceeded those of 2000 and 2008, and thus became the strongest such event observed this decade by this metric.

Brassington, Summons and Lumpkin (2010) used eddy-resolving numerical simulations and drifter observations to provide new insights into Lagrangian eddy dynamical processes in the East Australian Current (EAC) and Tasman Sea regions. They showed that the EAC can exhibit transient separation via interaction with a vortex dipole, and that eddies in general affect the formation and propagation of the EAC separation point from the coast.

Dong et al. (2011) derived an empirical scheme to identify eddies in the trajectories of surface drifters, and applied the methodology to drifters in the Kuroshio Extension region. This methodology could potentially be applied to the global data set to derive a global census of the characteristics (such as size and orbital period) of eddies.

2.7 FY11 Meetings

R. Lumpkin organized and served as chief scientist of the July 21—August 21 2011 PIRATA Northeast Extension cruise aboard the NOAA ship *Roland H. Brown*. Lumpkin also attended the following meetings:

> *NOAA Ocean Climate Observation Annual System Review* (Silver Spring, MD, Oct 27—29, 2010) where he gave a presentation on NOAA's Global Drifter Program and participated as a panel member for a discussion in the session "Requirements, Status and Issues".
>
> *The Southeast and Caribbean Regional Team (SECART) winter meeting* (Savannah, GA, Jan 12—14, 2011) where Lumpkin represented AOML and OAR on this NOAA regional team.
>
> *The Inertial Oscillations PI meeting* (Seattle, WA, Feb 22—24, 2011), a PI workshop to kick-start the NSF-funded effort "Global Impact of Eddies on Inertial Oscillations of the Mixed Layer." At this meeting Lumpkin gave a presentation about drifter data and how the Global Drifter Program could profit from the NSF study.
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> *Physical Oceanography Division Science Retreat* (Miami, FL, Feb 15—16, 2011); Lumpkin gave presentation on using Lagrangian observations to simulate marine debris and led session on "General Oceanography".
>
> *PIRATA/TACE/TAV annual meeting* (Fernando de Noronha, Brazil, March 14—18, 2011); Lumpkin presented PIRATA Northeast Extension report and US plans for 2011 and served on the PIRATA Science Steering Group.
>
> *Ronald H. Brown Users' Meeting* (Charleston, SC, June 21—22, 2011); Lumpkin represented AOML in conversations and presented AOML plans for the ship in FY11 and beyond, including the PNE, CLIVAR and Western Boundary Time Series cruises.
>
> *Fritz Schott Memorial Lectureship* (Kiel, Germany, July 8—14, 2011); Lumpkin wasw invited to give this annual lecture in honor of Fritz Schott, and also held a "meet the scientist" lecture for students and led a discussion forum on Atlantic Ocean circulation.

R. Lumpkin and S. Dolk attended the *4th International Port Meteorological Officers Workshop* (Orlando, FL, December 8—10, 2010), where Lumpkin presented "Deployment of Drifting Buoys from Ships" describing NOAA's needs for ship deployments to maintain the global drifter array and Dolk liased with the officers. Lumpkin and Dolk also performed a site visit of the drifter manufacturer Technocean in Cape Coral, FL on November 15—16, 2010.

R. Lumpkin, M. Pazos, S. Dolk and E. Valdes attended the *Data Buoy Cooperation Panel (DBCP)* meeting in Oban, Scotland (Sept. 27—30, 2010). R. Lumpkin, M. Pazos and S. Dolk attended the DBCP meeting in Geneva, Switzerland (September 26—30, 2011).

2.8. Education and Outreach

R. Lumpkin gave lectures to several groups of South African students aboard the Ronald H. Brown at the conclusion of the 2011 PNE cruise. These lectures focused on the need for ocean observations to better understand weather and climate fluctuations, on observing platforms such as drifters, floats, and moored buoys, and on the PIRATA project and tropical Atlantic climate variations.

Lumpkin was invited to give the annual lecture at the Fritz Schott Memorial Lectureship in Kiel, Germany, on July 8—14, 2011. While at IFM-GEOMAR in Kiel, he also held a "meet the scientist" lecture for students and led a discussion forum on Atlantic Ocean circulation attended by German graduate students.

Lumpkin gave a presentation about the Global Drifter Program at the 4th International Port Meteorological Officers Workshop in Orlando, FL on December 8—10, 2011, with the goal of expanding cooperation with these officers to identify worldwide drifter deployment opportunities.

3. Publications and Reports

3.1. Relevant Publications by PIs this Fiscal Year

Brassington, G. B., N. Summons and R. Lumpkin, 2010: Observed and simulated Lagrangian and eddy characteristics of the East Australian Sea and Tasman Sea. *Deep-Sea Res. II*, **58**, 559—573, doi:10.1016/j.dsr2.2010.10.001.

Dong, C., Y. Liu, R. Lumpkin, M. Lankhorst, D. Chen, J. McWilliams and Y. Guan, 2011: A Scheme to Identify Loops from Trajectories of Oceanic Surface Drifters: Application to the Kuroshio Extension Region. *J. Atmos. Ocean. Techn.*, **28**, 1167–1176, doi:10.1175/JTECH-D-10-05028.1.

Grodsky, S., R. Lumpkin and J. Carton, 2011: Spurious trends in global surface drifter currents. *Geophys. Res. Letters*, **38**, L10606, doi:10.1029/2011GL047393.

Lumpkin R., G. Goni and K. Dohan, 2011: State of the Ocean in 2010: Surface Currents. In "State of the Climate in 2010", J. Blunden, D. S. Arndt and M. O. Baringer (eds), *Bulletin of the American Meteorological Society*, **92**, S92-S95.

Lumpkin, R. and S. L. Garzoli, 2011: Interannual to Decadal Variability in the Southwestern Atlantic's Surface Circulation. *J. Geophys. Res.-Oceans*, **116**, C01014, doi:10.1029/2010JC006285.

Lumpkin, R. and S. Elipot, 2010: Surface Drifter Pair Spreading in the North Atlantic. *J. Geophys. Res.-Oceans*, **115**, C12017, doi:10.1029/2010JC006338.

Submitted/Accepted/In press

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