Surface Drifter Program

AOML's component of NOAA's Global Drifter Program

Rick Lumpkin and Silvia Garzoli
NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami FL

Table of Contents

1. Abstract 1
2. Project Summary 1
3. Accomplishments 2
Evaluating the observing system for SST and ocean current measurements 5
4. Education and Outreach 11
5. Publications and Reports 11
5.1. Publications by Principal Investigators 11
5.2. Other Relevant Publications 12

1. Abstract

The Surface Drifter Program is AOML's contribution to NOAA's Global Drifter Program, consisting of the Drifter Operations Center and Data Assembly Center. The goal of this program is to maintain a global array of satellite-tracked drifting buoys for climate forecasting, climate research, and weather prediction, and to provide a research-quality data set of the drifter data. In 2009, the operations center maintained the array at an average size close to the goal of 1250 drifters. Analysis of the array indicates that the rate of drifter deaths stabilized in late 2008 through September 2009, along with the average age of a drifter in the array. If this death rate remains unchanged in the future, the annual deployment rate will have to be increased from the current goal of 1000 drifters/year to 1100 drifters/year. AOML continues to update the quality controlled data set on a quarterly bases, is an active participant in DBCP activities such as regional panels, data management panels, and the Argos 3 pilot project, and evaluates drifters from various manufacturers to identify problems and provide rapid feedback.

2. Project Summary

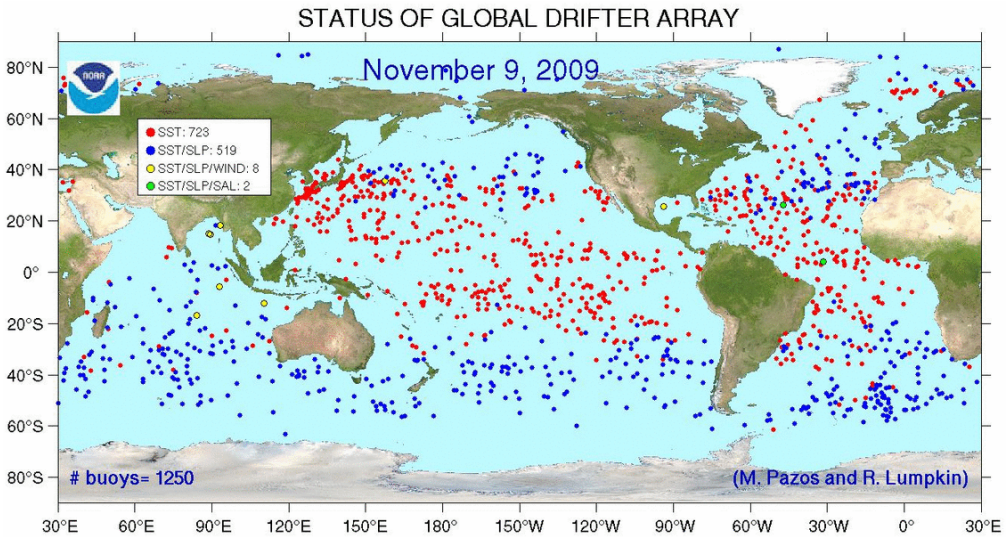
The Surface Drifter Program is the Atlantic Oceanographic and Meteorological Laboratory's (AOML) contribution to NOAA's Global Drifter Program (GDP), a branch of NOAA's Integrated Ocean Observing System, Global Ocean Observing System (IOOS/GOOS) and a scientific project of the Data Buoy Cooperation Panel (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 (formerly MEDS); (5) develop and distribute data-based products; (6) maintain the GDP website[1]; 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 (a) calibrate SST and sea surface salinity observations from satellites; (b) initialize global SI forecast models to improve prediction skill; and (c) provide nowcasts of the structure of global surface currents. 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.

3. 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 maintained. During FY08, the drifter array averaged 1232 drifters, with a standard deviation of 48. The maximum size was 1312 (7 April); the minimum was 1152 (11 August). During the fiscal year, the Surface Drifter Program coordinated worldwide deployments of 1090 drifters (1023 in FY07), 880 (FY07: 859) funded by NOAA/CPO; 227 drifters were deployed in the Atlantic between 30ºN and 40ºS (147 in FY08). AOML managed observations from 2113 unique drifters during FY08 (this is significantly greater than 1250, as some died while new ones were deployed to maintain ~1250).



[1] http://www.aoml.noaa.gov/phod/dac/gdp.html

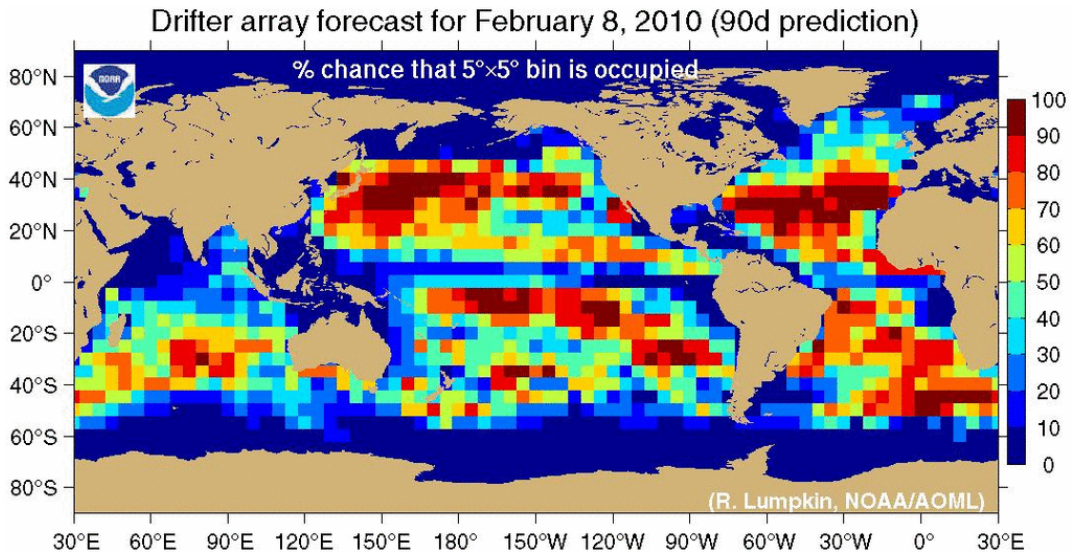


Fig. 1: Global population of drifters on 9 November 2009 (array size 1250 drifters), and 90 day prediction of coverage (% chance that a 5ºx5º bin will have a drifter if no additional drifters are deployed in the interim).

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, and anticipates that variations in this number through the year will be normal due to varying deployment opportunities. In most years these fluctuations reveal a seasonal pattern, with peaks in Boreal winter—spring and troughs in summer—fall. This seasonality reflects the variations in deployment opportunities, primarily due to dense Southern Ocean deployments during the research campaign season there. In this context, 2009 was an unorthodox year; for much of 2009, the total size of the array was smaller than 1250 drifters due to a lower number of deployments (compared to the 2005—2009 average) and an increased death rate. The higher Southern Ocean deployment rate in 2007—2008 was anomalous, and can be attributed to research cruises associated with the International Polar Year. The increased death rate is addressed later in this report. We addressed the shortcoming in array size evident by the end of Austral summer with an aggressive increase in deployments throughout Boreal summer, focused primarily in the Northern Hemisphere sectors of the Pacific and Atlantic Oceans.

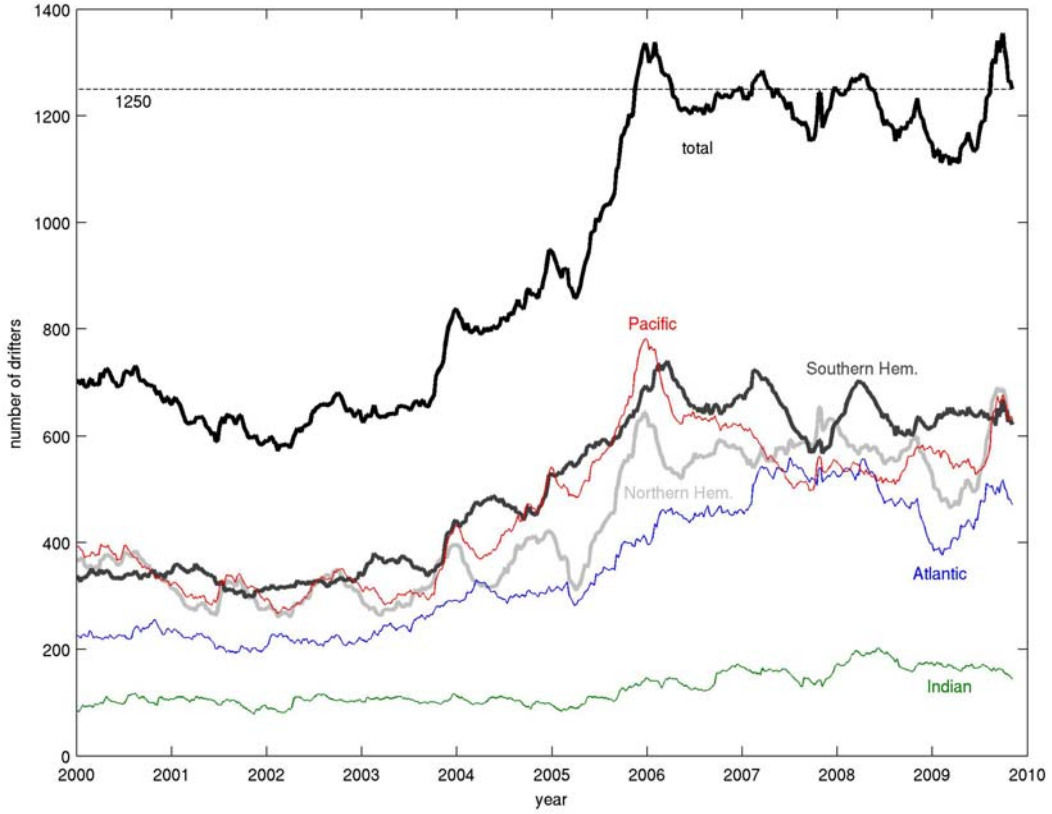


Fig. 2: Size of global drifter array in regions. Atlantic/Indian divided at 25°E in the Southern Ocean, Atlantic/Pacific at 70°W in the Southern Ocean, Indian/Pacific at 125°E south of Timor.

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. As noted in last year's report, the death rate had been increasing over the last several years, from ~71 in September 2005 to ~85 in September 2008. That report ascribed the average age of the array to this increase, and predicted that the death rate should cease increasing and become more constant in 2009 barring unexpected manufacturing problems. In fact, the death rate continued to increase through late 2008, reaching a maximum of ~100, then decreased through early 2009 to a minimum of ~80 in mid-summer. It then began increasing in July—September, with a pattern suggesting that the monthly values are fluctuating around the July 2008 through September 2009 average (see Fig. 3). That long-term average, a rate we anticipate is now the expected future death rate, is 92 deaths per 1250 drifters per month. This result suggests that a total of 1100 drifters will have to be deployed per year to maintain the array. This value is close to the 1080 drifters that were deployed in FY09, found in practice to be needed to maintain the array and exceeding the nominal goal of 1000 deployments. The mean age of a drifter in the array has slightly decreased over the last years, from ~450 days in August 2008 to a current value of around 420 days (Fig. 3, bottom).

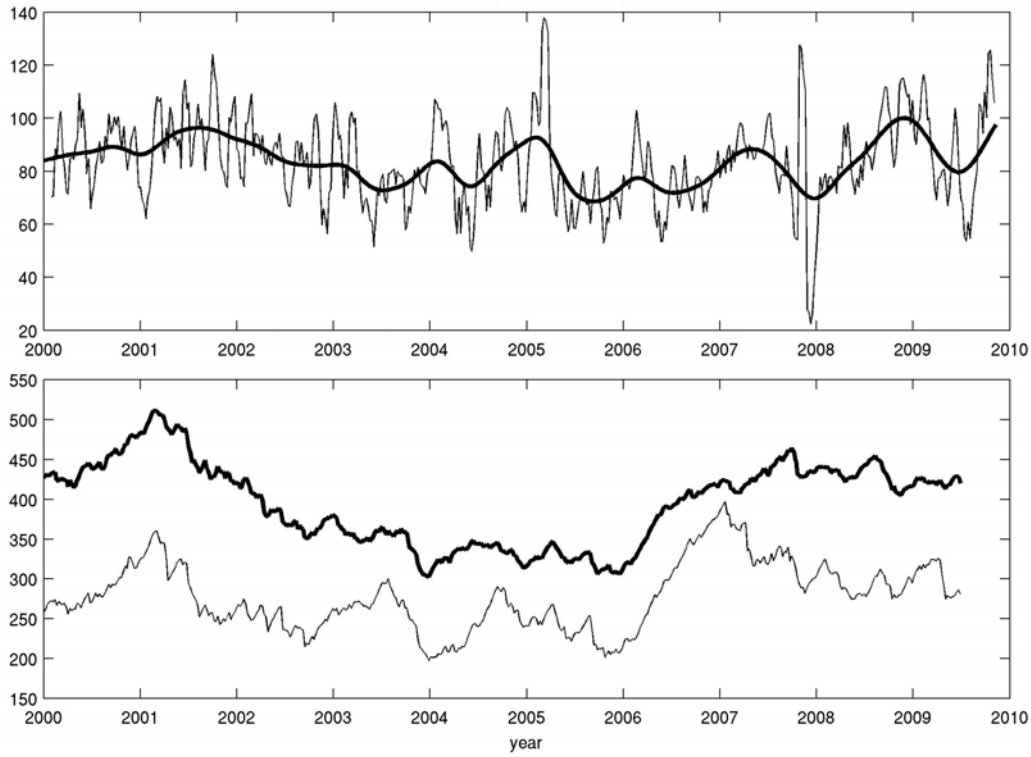


Fig. 3: (Top) Number of drifter deaths per 1250 drifters per month. (Bottom) The mean (thick) and median (thin) age of a drifter in the global array.

Evaluating the observing system for SST and ocean current measurements

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 (Fig. 4). 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 along the equator. Recent maps (see below) indicate that EBD is lowest in shallow, near-coastal and ice-covered regions. The target for the GOOS is to achieve a global potential satellite bias of 0.5°C or less; this target was reached in FY09 (Neil Christerson and Huai-min Zhang, pers. comm.).

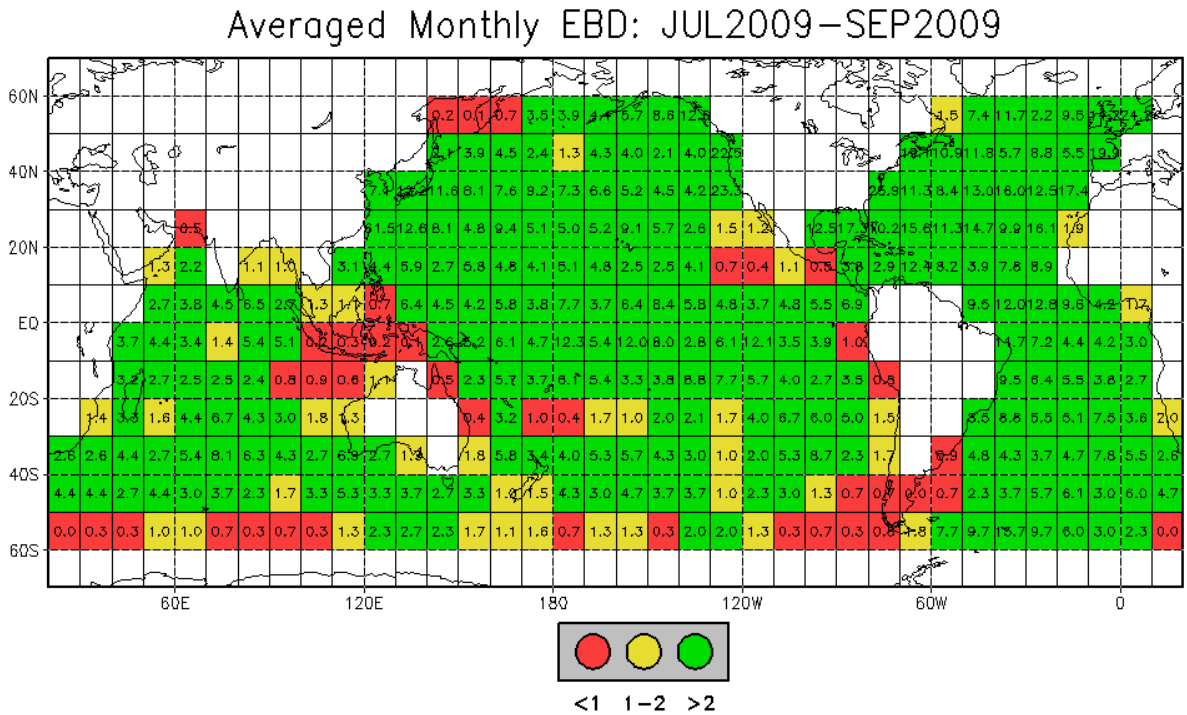


Fig.4: Equivalent buoy density (EBD) for July—September 2009. Figure courtesy Huai-min Zhang, NOAA/NCDC.

At the 2009 DBCP meeting, presentations by two attendees suggested that the errors in SST observations from drifters may exceed the manufacturer-specified 0.1°C thermistor sensor accuracy. Gilles Reverdin (LOCEAN, Univ. Paris) compared the surface thermistor to the subsurface thermistor of salinity drifters, and after accounting for upper ocean stratification deduced that trends and offsets exceeds the stated sensor accuracy in several cases. Chris Merchant (Univ. Edinburgh) presented comparisons between drifter SST (extracted from the GTS, i.e. not quality controlled), Advanced Along-Track Scanning Radiometer (AATSR) satellite SST, and Argo 5m temperatures, and deduced that the global error in drifter SST is ±0.20°C. If so, this represents a major limitation on further improving satellite-based SST. We are actively collaborating with Merchant so that he can repeat his analysis for subsets of the data, for example to include only drifters from particular manufacturers or for only the first three months of each drifter's life, in order to examine various hypotheses for his results.

The GOOS measures near-surface currents using moored current meters and drogued drifters, a subset of the overall drifter array (typically 2/3 to ½) due to drogue loss. The Surface Drifter Program evaluates how well the GOOS is achieving the OceanObs'99 goal for surface current measurements via support from Climate Program Office add-task funding. Over the most recent quarter, ~60% of all 5°x5° open-ocean squares were sampled at least once. Spatially (see Fig. 5), coverage is best in the Atlantic and subtropical North Pacific, with lowest coverage in the southeastern and subpolar north Pacific basin. The result of this analysis indicates that maintaining the array at an average instantaneous size of 1250 drifters, with 1/3 to ½ without drogues, results in this goal being sustained at 55—60% (Fig. 5, bottom right).

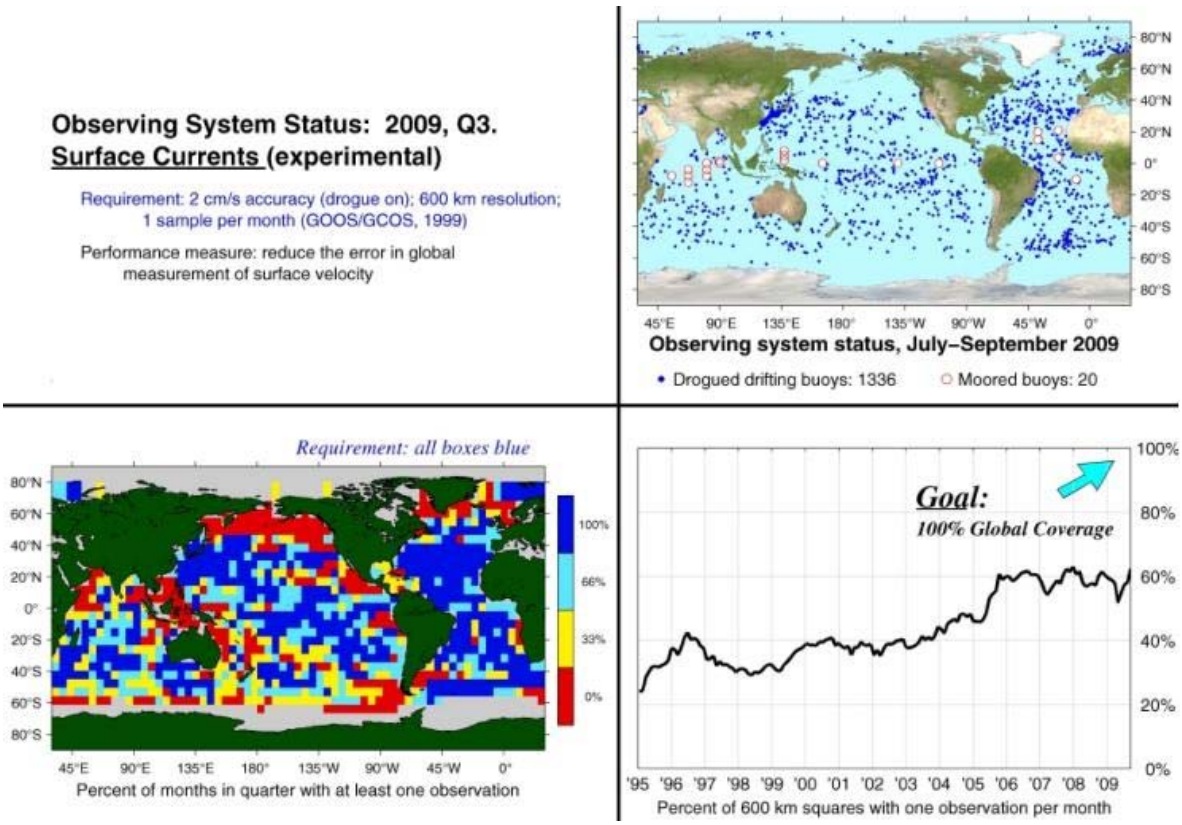


Fig. 5: GOOS measurements of near-surface currents for July-September 2009 (NOAA/GDP).

AOML Data Buoy (ADB) Comparison Study

This year, the AOML Data Buoy (ADB) comparison study results were updated for five drifter clusters deployed in 2008. In this study, drifters from four different buoy manufacturers (Clearwater Instruments Inc, Metocean Data Systems Ltd, Pacific Gyre Inc, and Technocean Inc.) are deployed in clusters in various regions throughout the world. The clusters of one drifter per manufacturer are at an initial separation of only a few meters, allowing us to cross-compare for SST quality and wind-driven slip. It is the goal of the GDP to evaluate the performance of each drifter, determine the strengths and weaknesses (if any) that exist, and communicate these results to the manufacturers. In particular, we examine the lifetime of drifter transmitters compared to the goal of 450 days (on average), and the lifetime of the drogues compared to the desired lifetime of 300 days.

The 2008 clusters were deployed on dates ranging from March 12 (cluster 1) to April 29 (cluster 5). As of the end of August 2009, the drifters had lived (i.e., transmitted data) for the number of days indicated in the following table:

Manufacturers	Clusters 1	2	3	4	5
Clearwater	212 (Quit)	301 (Quit)	125 (Quit)	*	359 (Quit)
Technocean	50 (Quit)	236 (Gr)	*	361 (Gr)	*
Metocean	34 (Quit)	*	*	*	64 (Quit)
Pacific Gyre	*	*	*	296 (Quit)	91 (Quit)
Max. Days Possible	506	485	469	467	457

Stars indicate drifters that were still alive as of the end of August 2009, and "Max. Days Possible" indicate the total number of days from deployment to end August. Drifter deaths are indicated as "Quit" or "Gr", the latter indicated that the drifter ran aground. Pacific Gyre and Metocean drifters exhibited the best lifetime performance, with three out of five from each still alive after >450 days. Clearwater drifters died more rapidly, with only one still alive after >450 days and the rest dying at 125—359 days after deployment. None of the drifters failed on deployment (this is typically observed at a 3—5% rate), although two from Metocean and one from Technocean ceased transmitting in less than three months. Technocean deaths were increased by two of the drifters running aground, a problem likely exacerbated by drogue loss.

Drogue lifetime is summarized in the following table:

Manufacturer	Clusters *1*	*2*	*3*	*4*	*5*
Clearwater	212* (Quit)	166	125* (Quit)	119	99
Technocean	50* (Quit)	101	100	75	200
Metocean	34* (Quit)	379	385	400	64* (Quit)
Pacific Gyre	*	354	250	296* (Quit)	12
Max. Days Possible	506	485	469	467	457

Stars indicate drogues still attached as of end of August 2009 (if not accompanied by a number) or when the drifter ceased transmitting (number, in days after deployment). The goal for drogue attachment is 300 days. This goal was not reached by the Clearwater and Technocean drifters,

although two of the Clearwater drifters still had their drogues attached when they died after 125 and 212 days. Four of the Technocean drifters lost their drogues before dying, with a mean drogue lifetime for these drifters of 120 days. Both Metocean and Pacific Gyre drifters had large average drogue lifetime, with Pacific Gyre claiming two extremes: the fastest drogue loss, at only 12 days after deployment, and the only drifter of the study to still have the drogue attached as of late August 2009.

SSTs from the drifters were accurate and tracked each other while the drifters were in close proximity, except for one Pacific Gyre drifter, which was too cold by a constant offset of 0.45°C. One Metocean thermistor failed five days after deployment.

The GDP will continue to conduct the ADB study in 2010, with more cluster deployments worldwide. Drifters purchased by the Data Buoy Cooperation Panel from a fifth manufacturer, Marlin-Yug (Ukraine), will also be included in the 2010 study.

Drogue detection

The GDP has been examining submergence and strain gauge for drogue detection. As noted in earlier DBCP sessions, submergence is not implemented uniformly across manufacturers. For example, Pacific Gyre submergence typically stays at a maximum value until drogue loss, while Metocean and Technocean values fluctuate while the drogue is attached. In all cases, the submergence should drop sharply at drogue loss, but many cases were identified where submergence became small but later increased, and drogue presence was unclear. In addition, in some cases submergence has been extremely sensitive and difficult to interpret. This was most evident in the past for Technocean drifters, which in some cases became dominated by noise and could not be used to determine drogue presence.

Clearwater has used strain gauge for many years, a technique which nearly always clearly shows when the drogue is lost. As a consequence, the GDP has recommended that all manufacturers implement tether strain in their drifters for drogue detection. This was tested this year in a pilot deployment of drifters from the three US manufacturers (Clearwater, Pacific Gyre, Technocean) all bearing tether strain, implemented as communicated by Clearwater to Pacific Gyre and Technocean. The Clearwater and Technocean tether strain sensors performed well, but the Pacific Gyre sensors did not (this has subsequently been addressed by Pacific Gyre).

Meanwhile, over the last two years Technocean submergence sensors have improved dramatically and now appear to clearly indicate drogue loss. Metocean submergence sensors have also continued to perform very well, clearly indicating drogue loss. If the Pacific Gyre submergence sensors are accurately reflecting drogue presence, then they have the longest drogue life of all manufacturers.

Hurricane drifter deployments

An array of hurricane drifters and subsurface floats (PI Eric D'Asaro) was planned for deployment in the path of Hurricane Bill on 21 August 2009, but was cancelled after the Air Force C-130J experience mechanical problems shortly after takeoff. The GDP issued a Buoy

Tasking Order (BTO) for deployment on August 28 in the path of Danny, but cancelled the plan when the storm began dissipating in the 48 hours leading up to deployment (BTOs must be issued at least 72 hours ahead of a flight). Subsequent storms in the 2009 hurricane season were too weak, too far east, or had widely varying forecast tracks – e.g., none were good candidates for hurricane drifter deployments. Consequently no hurricane drifters were deployed this year.

Deliverables

The FY09 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; updates include 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**.
3. *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**.
4. *The GDP is developing interactive global drifter array updates for Google Map and/or Google Earth, which include metadata for each drifter such as deployment information, drogue status, manufacturer, etc. A preliminary version can be seen at ftp://ftp.aoml.noaa.gov/phod/pub/lumpkin/googleearth/gdp-2008-Sep-22.kmz. Once ready for public distribution, this new product will be made available on the GDP web site.* **Status: Accomplished**.

FY09 Meetings

R. Lumpkin attended the OceanObs'09 meeting (21—25 September 2009, Venice, Itay), and contributed to a number of community white papers (those related to the drifter program are listed in "publications".

S. Dolk, M. Pazos, and R. Lumpkin attended the Second Panel Meeting of Coastal and Ocean Observations (22-24 April 2009, Miami, FL). The goal of this effort was to discuss collaborative efforts between NOAA and various Korean agencies.

S. Dolk, M. Pazos, E. Valdes and R. Lumpkin attended the Data Buoy Cooperation Panel (DBCP) meeting (28 September—1 October 2009, Paris, France). There, they presented the results of the 2008 drifter comparison study, the Global Drifter Program report, several subpanel reports, and attended numerous subpanel meetings such as regional planning panels.

M. Pazos attended the Argos Users Meeting (30 Sept—2 Oct 2008, Annapolis, MD) and is leading the data analysis effort required for the DBCP's Argos 3 pilot project.

4. Education and Outreach

R. Lumpkin gave lectures and taught data analysis lessons to Nigerian researchers in Lagos, Nigeria in the National Data Analysis Workshop, a part of the US Navy's Africa Partnership Station project (21—26 March 2009). He also represented the Global Drifter Program for visiting members of NOAA's Buoy Recapitalization Plan on 10 March 2009, and was interviewed as part of a National Geographic special on the Bermuda Triangle (interviewed 30 April 2009; program aired on the National Geographic Channel in November 2009). Lumpkin also contributed to the ocean display at the National Museum of Natural History, with input on displays about surface currents and the meridional overturning circulation.

5. Publications and Reports

5.1. Publications by Principal Investigators

Dohan, K., Lagerloef, G, Bonjean, F., Centurioni, L., Cronin, M., Lee, D., Lumpkin, R., Maximenko, N, and Uchida, H, 2009: Measuring the global ocean surface circulation with satellite and in situ observations. OceanObs'09 CWP-2B-06.

Goni, G., DeMaria, M., Knaff, J., Sampson, C., Price, J., Mehra, A., Ginis, I., Lin, I-I., Sandery, .Ramos-Buarque, S., Ali, M.M., Kang, K.R., Lumpkin, R., Halliwell, G., Lauer, C., Bringas, F., and Mavume, A., 2009: The ocean observing system for tropical cyclone intensification forecasts and studies. OceanObs'09 CWP-3C-01.

Lumpkin R., G. Goni, and K. Dohan, 2009: State of the Ocean in 2008: Surface Currents. In "State of the Climate in 2008", T. Peterson and M. Baringer (eds), *Bulletin of the American Meteorological Society*, 90:S12-S15.

Marshall, J., W. Dewar, J. Edson, R. Ferrari, D. Fratantoni, M. Gregg, T. Joyce, K. Kelly, R. Lumpkin, R. Samelson, E. Skyllingstad, F. Straneo, L. Talley, J. Toole and R. Weller, 2009: CLIMODE: a mode water dynamics experiment in support of CLIVAR. *Bulletin of the American Meteorological Society*, Sept 2009, doi:10.1175/2009BAMS2706.1

Sallée, J-B., K. Speer, R. Morrow and R. Lumpkin, 2008: An estimate of Lagrangian eddy statistics and diffusion in the mixed layer of the Southern Ocean. *J. Marine Res*., **66**(4), 441-463.

Zhang, H.-M., R.W. Reynolds, R. Lumpkin, R. Molinari, K. Arzayus, M. Johnson, and T.M. Smith, 2009 An Integrated Global Ocean Observing System for Sea Surface Temperature Using Satellites and In situ Data: Research-to-Operations. *Bulletin of the American Meteorological Society*, **90**(1), 31-38.

5.2. Other Relevant Publications

Elipot and Gille, 2009: Estimates of wind energy input to the Ekman layer in the Southern Ocean from surface drifter data. *J. Geophys. Res.* **114** C06003, doi:10.1029/2008JC005170.

Park, J. J., K. Kim and R. Schmitt, 2009: Global distribution of the decay timescale of mixed layer inertial motions observed by satellite-tracked drifters. *J. Geophys. Res.* **114** C11010, doi:10.1029/2008JC005216.