The Global Drifter Program

Drifter Measurements of Surface Velocity, SST, SSS, Winds and Atmospheric Pressure

Peter Niiler
The Scripps Institution of Oceanography
La Jolla, CA

1. Project Summary

1.1) *Rationale*:

The principal scientific questions of the role of the ocean in climate change are how well can we describe or model the ocean circulation today and how well can these descriptions or models predict the evolution of future climates. The principal climate index of oceans is sea surface temperature (SST) through which the atmosphere climate is forced to follow the oceans' change. A global array of drifters provide the operational instrumental data sets describing ocean surface circulation and SST evolution and these data are used for testing climate models and enhancing long-range weather prediction and interannual climate change. Sensors that measure sea surface salinity (SSS) can now be added to drifters and these SSS data are critical to determining the oceans' fresh water cycle and onset of deep-water renewals. Atmospheric pressure measured on drifters is assimilated into weather prediction models and is used by operational meteorological agencies to discern severe weather conditions over the oceans. Wind sensor and subsurface temperature chain data are used to improve prediction of tropical storm and hurricanes. Drifters have proven to be reliable, autonomous platforms for obtaining climate and operational weather data from the global oceans.

1.2) *Objectives of the Global Drifter Program*:

The "Global Drifter Program" (*GDP*) is the principal international component of the JCOMM *"Global Surface Drifting Buoy Array"*. It is a "Scientific Project" of the DBCP of WMO/IOC. It is a near-operational ocean-observing network that, through the ARGOS satellite system and the Global Telecommunication System (GTS), returns real time data on ocean near-surface currents, SST and atmospheric pressure (and winds, subsurface temperature, T(z), and SSS) and provides a data processing system for scientific utilization of these data. In addition to *GDP*, drifters are deployed by operational oceanographic and meteorological agencies and individual scientific research projects, whose data are utilized by *GDP*. In turn, *GDP* data are made available to operational users and scientists at large. Wind-sensors, salinity sensors and thermistor chains are added to SVP drifters, presently on a limited basis for specific operational and research requirements. The international protocols for these data exchanges and sensor additions are worked out each year by DBCP.

The scientific objectives of the *GDP*, and its operational and research partners, are:

1) Provide to GTS an near-operational, near-real time data stream of SST, sea level pressure and surface velocity.

2) Observe the mixed layer velocity on a global basis with 0.5° resolution and, jointly with satellite altimeter data, produce charts on the seasonal and interannual changing circulation of the world ocean at 0.5º resolution.

3) Develop and introduce into the drifter construction technological advances in sensors, electronics, power, methods of assembly and deployment packaging.

4) Provide enhanced research quality data sets of ocean circulation that include drifter data from individual research programs, historical data from instruments different from the Surface Velocity Program (SVP) Lagrangian Drifter and the corrected data sets for wind-produced slip of drifter velocity. To this end *GDP*:

• Provides to the coupled ocean-atmosphere climate modelers gridded, global data sets of SST, near surface circulation and dynamic topography for assimilation and the verification of the parametrized processes, such as wind-driven Ekman currents and spatial patterns of the seasonal circulation (Figure 1).
• Provides the Lagrangian data sets for the computation of single particle diffusivity, dispersal of ocean pollutants, the enhancement of models of fisheries recruitment and improvement of air-sea rescue.
• Obtains high-resolution coverage of ocean variability and time mean circulation in support of ENSO prediction model verification in the tropical Oceans and supports short-term research projects that require enhanced upper ocean velocity observations.

1.3 Required Drifter Observations and Status of Global Array

GDP began in 1988 as a World Climate Research observational program in the tropical Pacific. Between 1992 and 2003, an array of approximately 600 SVP drifters was maintained in the global ocean with contributions of resources from a variety of operational and individual research programs. Since October 2003 the array has increased from 800 to of over 1300 drifters in 2006. Thus, full implementation of the required global array for SST observations was completed in September 2005 with the deployment of the 1250th element of the global array (Figure 3).

The 'required' global drifter array size by JCOMM is based on the need to maintain 1250 platforms that return instrumental observations of daily average SST (+/- 0.1^{0}C) over the global ocean at a 5º resolution, or the spatial scale of the error covariance function of operational NOAA satellite infrared SST sensors. Surface pressure sensors are supported by regional meteorological agencies based on regional needs. The actual number of drifters in the array has been larger than 1250 because the required uniform spatial distribution is difficult to maintain in the complex ocean surface circulation and many drifters go ashore in remote locations and continue to transmit.

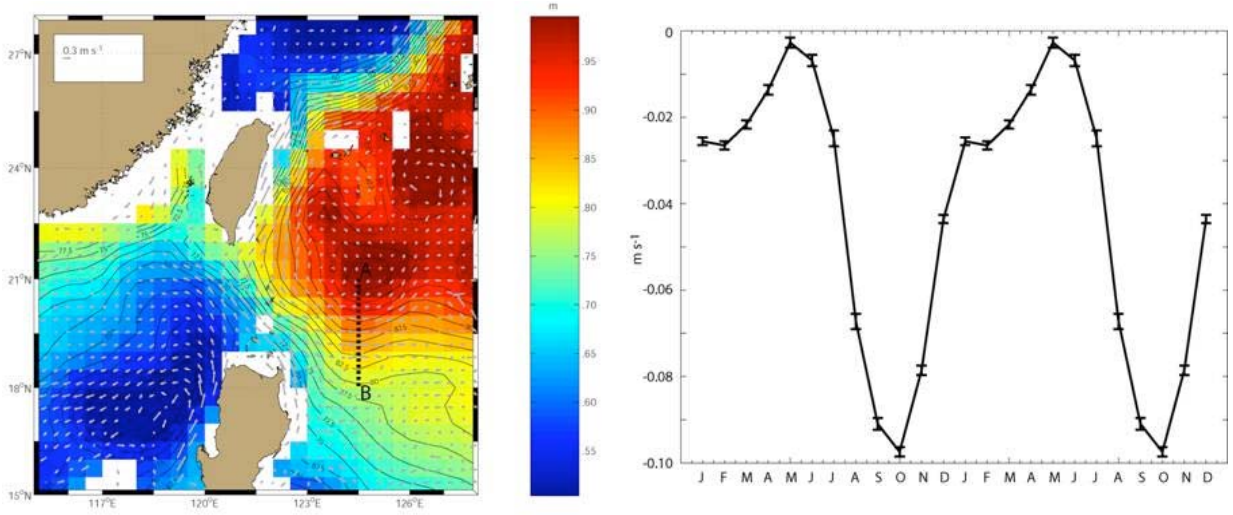

Figure 1. The mean geostrophic velocity of the Luzon Strait and Philippines Sea during northeast monsoon (Oct.-Jan.) overlain on the absolute dynamic topography (left panel). These data were produced with the combination of satellite altimeter, GRACE and drifter data and is available from GDP on a global basis. The A-B latitude average zonal velocity component from left panel. The strongest flow into the South China Sea across the Luzon Strait from the Philippines Sea occurs during the month of October.

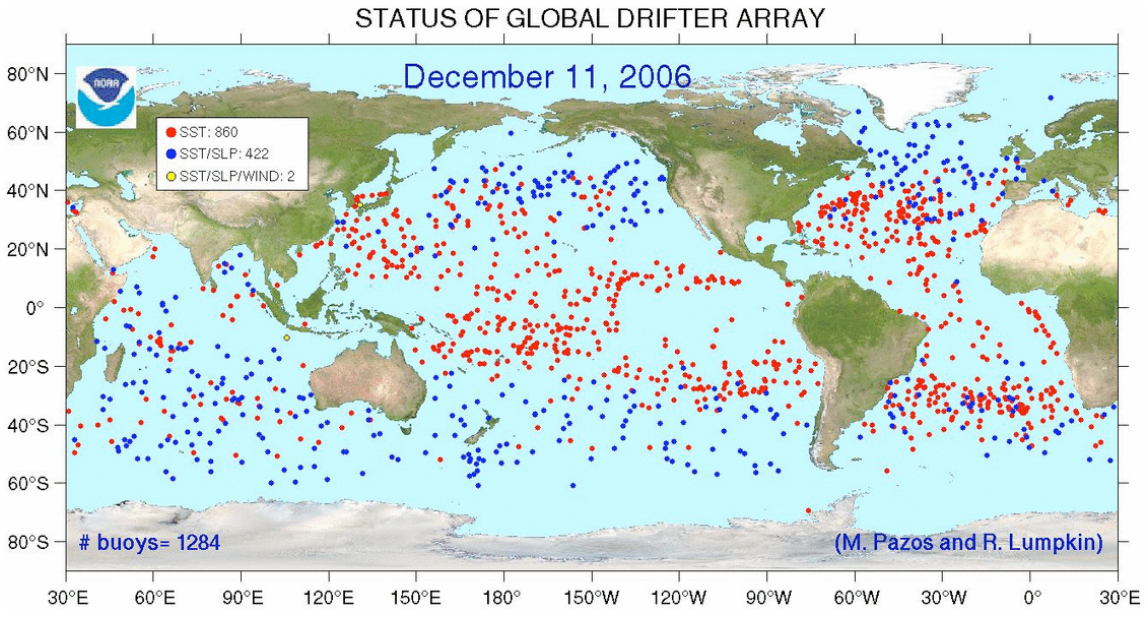

Figure 2. The *Global Drifting Buoy Array* on December 11, 2006.

Figure 3. Peter Niiler (left front) and Mike Johnson (right front) deploy SVP-B #1250 off the coast of Nova Scotia on September 18, 2005. The Global Drifter Array was the first international observing system of JCOMM to be completed and has been maintained at full 1250 drifter level since 9/18/05.

On December 11, 2006, 1296 of the 1250 'required' drifters are reporting to GTS and to the AOML *Drifter Data Center* (Figure 2). NOAA Climate Observations Program, funded to JIMO (920) and AOML (80) sufficient numbers of SVP drifters in FY'06, and with the contributions of drifters (200-300) from other national and international sources, the array was fully maintained from September 2005 to present date at the desired level. In 2007 the efforts will continue to adjust the array spatial density with the desired uniform coverage. Present distribution covers about 60%-70% of the surface of the ice-free ocean at 5^{o} resolutions.

The international science bodies, such as JCOMM, require that the drifter array is to provide instrumental observations of SST and the operational met agencies desire to provide atmospheric pressure observations from as many drifters as possible. To this latter end, the DBCP ('06) requested these met agencies now begin to provide funds in earnest to attach a barometer to every SVP drifter. Even though no internationally mandated operational requirement for surface velocity exists, nearly all research program contributions to the drifter array have been justified on the basis of upper ocean velocity

observations. In the research community 99% of reviewed scientific research papers make principal use of drifter velocity observations: (viz. list of peer-reviewed research publications at: http://www.aoml.noaa.gov/phod/dac/drifter_bibliography.html). We anticipate that a surface velocity observation requirement will also be instituted in the next overview of climate observations requirements.

1.4 Management:

GDP reports every year on its activities relative to advances in technology in the DBCP Technical Session and its deployment plans and management in the DBCP Plenary Session. *GDP* is largely a NOAA funded program and is managed according to the *"Ten Climate Monitoring Principles"* established by JCOMM. In these management tasks, the principal investigator, Peter Niiler, assumes the responsibility for the coordination between the following entities:

• US manufacturers in private industry (*Technocean, Inc*. of Cape Coral, FL*; Clearwater, Inc*. of Watertown, MA*; Pacific Gyre, Inc*. of Carlsbad, CA*)* who build the SVP drifters according to closely monitored specifications. Internationally, a total of 6 private firms and 3 research laboratories build SVP drifters. Periodically, drifter construction manuals are upgraded and are posted on the DBCP website (e.g. 2005 the SVP-B Mini Construction Manual).

• Atlantic Oceanographic and Marine Laboratory (AOML) who carries out the deployments at sea, processes the data and archives these at MEDS, Canada, maintains the META file on the description of each drifter deployed and the upgrades the *GDP* website.

• Technical staff of SIO, who assist in the supervision of aircraft deployments of drifters into hurricanes, place orders for the NOAA funded drifters, upgrade the technology, develop new sensors, enhance the data sets and maintain liaison with individual marine research programs that deploy SVP drifters.

This continuing proposal from JIMO addresses the progress of activities in FY'06 and proposes the activities for FY'07.

2. FY'06 Progress

In FY'06 NOAA Grants office funding of the *GDP* through JIMO occurred in the last week of September 2006. Additional funds were provided for a one-time acquisition 22 thermistor chain drifters for hurricane studies. This is a report of what was accomplished with both the FY'05 and FY'06 funding during the period of September 2005 - August 2006:

1. *Summary of Drifter Acquisitions and Technology: With the FY'05 funds 940 drifters with SST sensors were built and were delivered to AOML for deployment. With the FY'06 funds, 940 drifters were ordered in October 2006 and are now being*

delivered to AOML for deployment. In 2005, all 20 drifters deployed into Hurricane Rita worked well (12 were SVP-W wind drifters and 8 were SVP-T(z) thermistor chain drifters). Because of the operational success of the Rita deployments 22 SVP-T(z) thermistor chain drifters with air deployment capability, were built as an-add on project in with 2005 funds. All air deployable drifters were delivered to Keesler AFB for deployment for the 2006 hurricane season. Because no hurricane approached the US coast in 2006, there now are 30 SVP-T(z) and 12 Minimet drifters at Keesler AFB fully rigged for air-deployment in the 2007 hurricane season. With the FY'06 funds:

a) A total of 680 SVP-Mini drifters were ordered from Clearwater Instruments, Inc Pacific Gyre, Inc. and Technocean, Inc. These are now being delivered to AOML for deployment.
b) A total of 240 SVP-B drifters were ordered from Clearwater Instruments, Inc., Technocean, Inc. and Pacific Gyre, Inc. These are now being delivered to AOML for deployment.
c) A total of 12 SVP-W Minimet wind-drifters and 8 SVP-T(z) thermistor chain drifters, fully rigged for air deployment, were ordered from Pacific Gyre, Inc. This is the first time that an industrial firm will build, calibrate and rig for air-deployment a full suite of hurricane drifters. All 20 units will be delivered the 53rd Air Force Reserve "Hurricane Hunter Squadron" at Keesler AFB before June 1, 2007. Dr. Rick Lumpkin and Dr. Peter Black at AOML are jointly directing the deployment of what will now be 62 hurricane drifters in the 2007 hurricane season.
d) In April 2005 12 SVP drifters with salinity sensors were deployed in the Bay of Biscay by the French Met. Service. These were calibrated at various times against CTD measurements. Dr. Gilles Reverdin of the University of Paris directed this study and a multi-author paper was accepted in November 2006 for publication in the *Journal of Ocean and Atmospheric Technology* on the results (*Abstract* below).

In FY'06 JIMO has purchased 940 drifters and AOML purchased 60 drifters, for total NOAA contribution of 1000 drifters to the JCOMM *"Global Surface Drifting Buoy Array".*

2. Enhanced Data Sets and Publications: Between Octobe 2005 and December 2006, there were 18 requests for enhanced drifter velocity data sets. Dr. Yoo Yin Kim who works under the direction of P. Niiler as a Senior Statistician prepared and distributed these data. The drifter peer-reviewed publication list was upgraded in December 2006: (http://www.aoml.noaa.gov/phod/dac/drifter_bibliography.html).

3. Meetings and Lectures: The following JIMO personnel participated in the GDP presented lectures or attended the following organization meetings:

• DBCP-XXII, October 15-20, La Jolla, CA: "Permanent Meanders in the California Current System and Comparison of Near-Surface Observations with OGCM Solutions" (Luca Centurioni, Peter Niiler and Carter Ohlmann)

• DBCP-XXI, October 16-19, Buenos Aires, Argentina: " Hurricane Drifter Thermistor Chain Deployment Results" (Bill Scuba, Jan Mozel and Peter Niiler). Bill Scuba is the co-organizer of the DBCP Technical Session in 2005 and 2006.
• DBCP-XXII, October 15-20, La Jolla, CA: "Global Drifter Program" (Rick Lumpkin of AOML for Peter Niiler)
• Invited Lecture at the SIO Director's Council, SIO, March 3, 2006: "The Global Ocean Surface Circulation" (Peter Niiler)
• Ocean Climate Observations Workshop, May 10-12, 2006, Silver Spring, MD (Peter Niiler)
• Invited Lecture at the workshop on *Climate Effects on California Current Ecosystems,* November 15, 2006: "Unresolved Physics in the Circulation Models of the Coast" (Peter Niiler"

Appendix

"Surface salinity measurements – COSMOS 2005 experiment in the Bay of Biscay"

G. Reverdin[1], P. Blouch[2], J. Boutin[1], P. Niiler[3], J. Rolland[2], W. Scuba[3],

A. Lourenco[1], A. Rios[4]

[1] LOCEAN/IPSL, CNRS/UPMC, Paris, France
[2] CMM/CNRM, Brest, France
[3] Scripps Institution of Oceanography, La Jolla, CA, USA
[4] CSIC, Instituto de Investigacions Mariñas, Vigo, Spain

G. Reverdin, Laboratoire d'Océanographie et de climatologie par expérimentation et analyse numérique, Institut Pierre Simon Laplace, Université Pierre et Marie Curie, case 100, 4 pl. Jussieu, 75252 Paris Cedex 05, France (gilles.reverdin@lodyc.jussieu.fr ; tel : 33-1-44272342 fax : 33-1-44273805)

Abstract

Sea surface salinity (SSS) data were collected in the Bay of Biscay between April and November in the Bay of Biscay. The major source of data is from 15 surface drifters deployed during the COSMOS experiment in early April and early May 2005 (12 from SIO, and 3 from METOCEAN). This is complemented by thermosalinographe (TSG) data from four French research vessels, four merchant vessels, from salinity profiles collected by ARGO profiling floats and CTD casts, and from surface samples during two cruises. Time during two cruises was dedicated to provide direct inspection of the drifters, recover some, and provide validation data. This data set provides a unique opportunity to estimate the accuracy of the SSS data, and to evaluate the long term performance of the drifter salinities. Some of the TSG SSS data presented a large noise, presumably from bubbles. The TSG data from the research vessels needed to be corrected from biases, very commonly larger than 0.1 pss-78 (practical salinity scale), and which in some instances evolved quickly from day to day. These corrections are only available when samples were collected or ancillary data are available (for example from CTD profiles). The resulting accuracy of the corrected TSG data set is discussed, and varies strongly in time. The surface drifter SSS data presented anomalous day-time values during days with strong surface warming. These data had to be excluded from the data set. The drifter SSS presented initial biases in the range 0.009 to -0.026 pss-78. The (usually) negative bias increased by an average of -0.007 pss-78 during the average 65 days period before the COSMOS-2 cruise on June 22-27. High chlorophyll derived from satellite ocean colour and therefore high density of phyto-planktonic cells is observed in MERIS/MODIS composites during part of the period in particular in late April or early May. No correlation was found between the change in bias and the estimated surface chlorophyll. Evolution during the following summer months is harder to ascertain. For

three buoys, there is little change in bias, but for two others, there could have been an increase in bias by up to 0.03 or 0.04 pss-78 during July- August. Seven drifters were recovered in the autumn, which provide recovery or post-recovery estimates of the biases, suggesting in three cases (out of seven) a large (0.02 to 0.03 pss-78) increase in bias during the autumn months, but no significant increase for the other four drifters.