Real Time Ocean Observations from Surface Drifters

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Abstract

This note provides an overview of the methods used to make real-time observations of the physical properties of the upper ocean and of the atmospheric boundary layer from instruments drifting at the ocean surface. We begin with a description of the Global Drifter Program, which provides global coverage of 15 m depth currents and sea surface temperature observations. Atmospheric sea level pressure is also measured over a large portion of the aqueous globe. Several meteorological offices use the atmospheric sea level pressure data, which are available on the Global Telecommunication System, to improve their forecast. The Global Drifter Program data are freely accessible and are used by scientists around the world for scientific research. Recently, more specialized drifters have been developed to measure sea surface salinity, wind velocity and vertical profiles of temperature and currents and are used for specific, space-time confined, observational programs. The methods described are cost-effective since they involve minimal sea-going operations, mostly from ships of opportunity, and do not require specifically trained personnel.

1 Introduction

The purpose of this note is to provide an overview of established and emerging methodologies to make real-time observations of the upper ocean and in the atmospheric boundary layer from instruments drifting at the ocean surface. A global array of Lagrangian (water following) drifters has now been operational for several years, and yet more sophisticated drifting instruments are being developed as new technologies and faster telecommunication options become available. These instruments are long lived and rugged and, for example, they have been successfully deployed in front of hurricanes. Measurements of vertical profiles of three dimensional velocity are becoming a new powerful tool to study the physical processes of the open ocean and in coastal seas and estuaries. Examples of technical developments and applications will be given.

2 The Global Drifter Program (GDP)

The Global Drifter Program (GDP) is an important component of the Global Ocean Observing System of NOAA and a scientific activity of the Data Buoy Cooperation Panel (DBCP), a joint body of the World Meteorological Organization (WMO) and of the Intergovernmental Oceanographic Commission (IOC). It is the first oceanographic operational global array to have reached its full implementation on September 18, 2005. The GDP maintains an array 1250 Surface Velocity Program (SVP) drifters (Fig. 1) and involves international co-operation of more than 15 countries.
The goal of the GDP program is to provide accurate measurements of the 15 m depth horizontal ocean currents, Sea Surface Temperature (SST), atmospheric pressure, surface salinity and wind velocity and to facilitate the use of the data for operational and scientific purposes. The AOML (NOAA) maintains a public data archive.

All the SVP drifter data are transmitted through the Argos satellite system and posted free of charge on the Global Telecommunications System (GTS) to help the weather centers to produce improved forecast.
The SVP drifter is designed with a drag area ratio larger than 40. The drifters therefore behave like true water followers (Niiler et al. 1995) with a very contained slip due to the wind (Pazan; Niiler 2001). The SVP drifter development and several examples of scientific applications of drifter data are discussed by Niiler (2001). Fig. 2 shows the most recent status of the global drifter array. The distribution of the SST and velocity sensing drifters is rather uniform (red and blue dots), but that is not the case for Sea Level atmospheric Pressure (SLP) sensing devices (blue dots), since the barometer array is largely maintained by individual countries participating in the program.

Enhancing the SLP array in the tropical and Pacific and Atlantic Oceans would result in more accurate regional weather forecast products. The Global Drifter Program has a long-standing history of co-operation with national agencies to achieve global coverage.

The handling of drifter's data is relatively straightforward. The following is an example of how atmospheric pressure data are treated: 160 SLP samples (taking approximately 160s) are collected each hour and the following de-spiking algorithm is used to filter SLP data (Barometer Drifter Design Reference, available online at http:// www.jcommops.org/doc/DBCP/svpb_ design_manual. pdf):

• take the median of the lowest 10 points of 160;
• calculate the median of the points within the entire set of 160 points that are within 1 hPa of the 10 point median;
• store as 12 bit count: 0 => 800.0 hPa and 4095 =>

1209.5 hPa, with 0.1 hPa resolution;

• if 15 or more of the 160 samples include communication errors, the sampled set is deemed corrupt, and the transmitter count is set to zero.

Previously measured pressure data are stored in the drifter controller for 12 hours for redundancy in data transmission.

The GDP is one of the most successful oceanographic operational programs, and, to date, there are more than 300 scientific publications based on drifter data. Recent examples include a computation of the global Sea level (Niiler et al. 2003), a research paper on the Kuroshio intrusion in the South China Sea through the Luzon Strait during the winter monsoon (Centurioni et al. 2004) and an investigation of the dynamics of the California Current System (Centurioni et al. 2008).

3 The Autonomous Drifting Ocean Station (ADOS)

The ADOS is composed of a 0.46 m diameter surface buoy with a tether to which a drogue can be attached to make it a Lagrangian device. It can carry several sensors such as a radiometer, an hydrophone for measuring ambient noise, a SST sensor and a barometer. The version with the hydrophone, from which the wind speed can be inferred, wind vane and SLP sensor is also known as the Minimet (Fig. 3).

The ADOS can also be conFig.d without the drogue but with a 150 m long tether to which several low-cost, inductively coupled thermistors and pressure sensors are attached. In this case the ADOS is not a water following device. Both the Minimet the and the ADOS with thermistor chain have been successfully deployed from air (Fig. 4 and Fig. 5) to observe the thermal structure of the upper ocean (Fig. 6) and the wind field associated within hurricanes (Fig. 7).

The ADOS data are commonly transmitted through the Argos satellite system.

The most recent Minimet development is the upgrade of the wind speed sensor with an acoustic anemometer.

4 Open-ocean 3-D velocity observations from drifters: the ADOS-V

In recent years we have begun exploring the methodology to measure three-dimensional velocity profiles from drifting platforms. The ADOS fitted with the thermistor chain has been modified to accommodate a longer tether (200 m) and two or three Acoustic Current Profilers by Nortek. We refer to this instrument as to the ADOS-V (Fig. 8).

A GPS receiver has been added to compute absolute horizontal velocity profiles (i.e. referenced to Earth's co-ordinates). Twenty inductively coupled pressure and temperature sensors are attached to the 200 m long cable, with a spacing of approximately 9 m. Communications through the Iridium satellite system is being implemented for the transmission of all the data (position, temperature pressure and three-dimensional velocity). As of now, the ACP is the most expensive components of the system, and they limit the expendability of the ADOS-V. We anticipate that this will change once a market large enough to justify a significant ACP cost reduction will be established.

Arrays of ADOS-V can be quickly deployed from aircrafts and voluntary observing ships and should be used, for example, whenever spatial and temporal coherent oceanic processes need to be observed from closely spaced arrays.

As an example of applications of the ADOS-V technology, a study on the properties of Large amplitude Internal Waves (LIW) in the northern South China Sea (nSCS) was performed in April and May 2007 with an array of eight ADOS-V. Wave groups with two or three solitary-like waves are known to propagate throughout the deep waters of the nSCS during spring tides and are thought to be generated within the Luzon Strait by interaction of the tidal flow with the topography.

Accurate vertical profiles of temperature and velocity (Fig. 9) can be used for example to locate points of equal phase as the LIW groups propagate through the ADOS-V array and to compute the local phase speed of the waves, which, in this case, is of 2.8 m/s. Other properties of the waves, such as their nonlinearity and their spatial homogeneity and stability as they propagate through the array can be investigated with this methodology.

5 The restrained ADOS-V: a lightweight, self deploying coastal mooring.

The ADOS-V has recently been reconFig.d into a light weight coastal mooring. The layout of the sensors is similar to the one discussed in the previous section, the only differences being that a larger weight at the bottom and a larger surface floatation element are used, and an acoustic release is also included if the instruments needs to be recovered (Fig. 10).

The schematic shown here pertains to a 135 m long device that can be deployed in approximately 120 m of water. Alike the ADOS-V, the restrained version can be packed inside a deployment box and can be parachuted from aircrafts or can be deployed from ships of opportunity. We are in the process of implementing real-time data transmission of pressure, temperature and 3-D velocity profiles through the Iridium satellite system. Two units will be deployed for the first time in a pilot experiment in the southern East China Sea.

6 Shallow water observations from drifters: the River Drifter

Understanding the kinematics and the hydrodynamics of near-shore flows in very shallow water is essential to study and predict morphological changes of the coastline, sediments transport and their dispersal. A new instrument called the River Drifter (RD), was designed to bridge the gap between 2-D and 3-D data acquisition in shallow waters, such as lagoons, river estuaries and tidal flats, essentially by using a Lagrangian platform as a vehicle from which three-dimensional vertical profiles of velocity and local bottom depth measurements are made. The RD (Fig. 11) is based on the CODE design (Davis 1985) and measures GPS location, three-dimensional water velocity with a 1 or 2 MHz ACP (with a nominal range of 12-25 and 5-12 m, respectively), depth of the bottom, bottom characteristics and sea surface temperature.

The RD is lightweight (just over 4 Kg) and the data telemetry is through Iridium. Full functionality tests of the first unit (Fig. 12) have been successfully conducted and the instrument is ready for scientific research operations.

The RD can be packed compactly using water soluble paper tape and fits inside a deployment cardboard tube (Fig. 13).

7 Concluding remarks

The methodologies and the technical developments presented here are answering the need of modern oceanography for autonomous, low cost, self-deploying instruments which can both be used for operational purposes and yet provide data of enough good quality to support new scientific discoveries, The GDP being perhaps the best example. New venues to improve this technology are constantly explored and new sensors are being added. The addition of thermistor chains and profiling current meters is opening far reaching research and operational opportunities, ranging from the study of how the ocean and the atmosphere interacts to observations of surface gravity waves in the world oceans.

8. Concluding remarks

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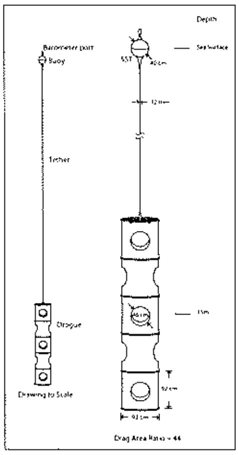

Fig. 1 Schematic of a SVP drifter with a barometer. The water depth at the center of the drogue is 15 m.

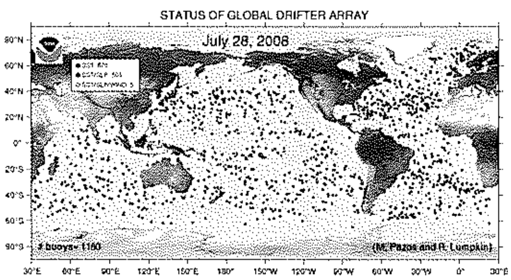

Fig. 2 Status of the Global Drifter Array as of July 28, 2008 (courtesy of M. Pazos and R. Lumpkin, available online at http:/www.aoml.noaa.gov/phod/ graphics/dacdata/ globpop.gif).

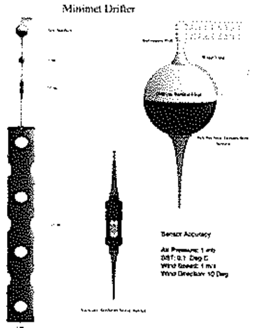

Fig. 3 Schematic of the Minimet drifter.

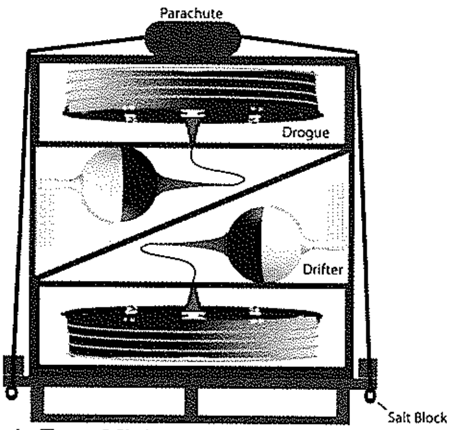

Fig. 4 Two Minimets are contained in the air deployment box, which is held together with straps and salt blocks. The package dissolves when is in the water thus freeing the instruments.

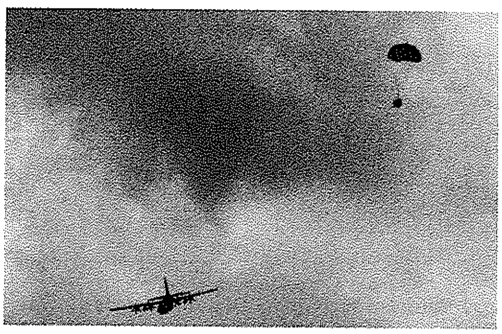

Fig. 5 The box with the Minimets is being deployed from a C-130.

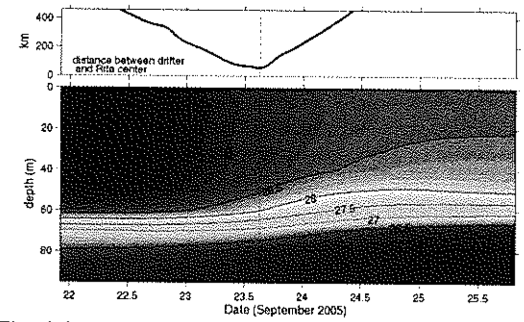

Fig. 6 Changes in the temperature field during the passage of hurricane Rita.

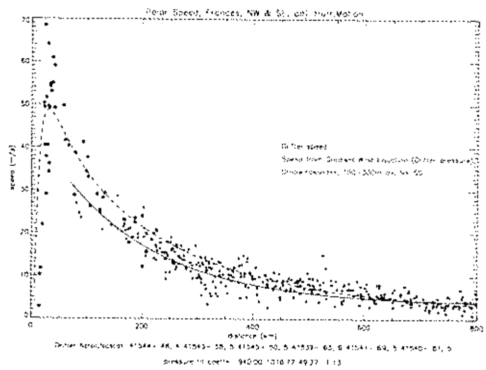

Fig. 7 Comparison of azimuthal wind speed measurements from the Minimet's hydrophone (black), SLP data (blue) and dropwindsondes (red). Hurricane Frances. The large speeds from dropwindsondes are due to localized swirls in front of the hurricane.

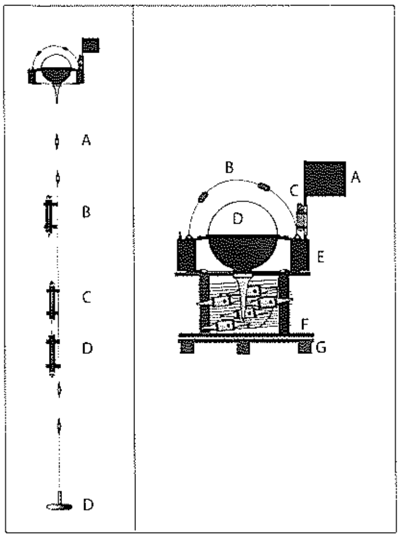

Fig. 8 ADOS-V schematic. Left: the surface element is connected to a tether on which the temperature and pressure sensors (A), one 1MHz Aquadopp at 25 m depth (B), two 400 KHz Aquadopps (C and D) at 110 m depth and a 20 Kg weight (D) are attached. The spacing between the temperature and pressure sensors is approximately 9 m. Right: the ADOS-V tether is wrapped around a wooden reel (F) which is mounted on a pallet through a spinning wheel. The spherical buoy (D) is mounted on a rectangular cross-section toroidal anodized aluminum buoy (E). A flag (A) and a strobe light (C) are attached to the aluminum buoy together with a bridle used for recovering the ADOS-V.

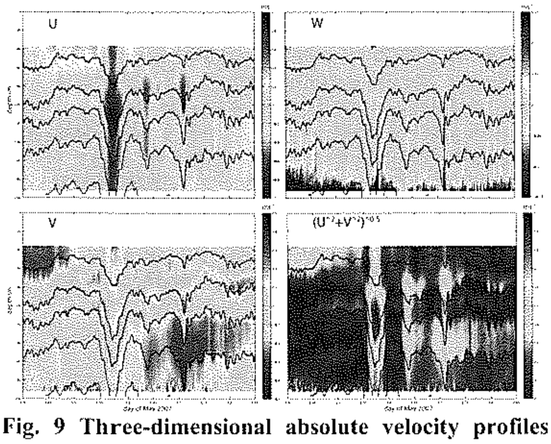

Fig. 9 Three-dimensional absolute velocity profiles and horizontal flow speed measured from the ADOS-V. The following isotherms are also shown: 25°C, 22.5° C, 20° C, 17.5° C and 15° C. U, V and W are the eastward, northward and vertical upward velocity respectively.

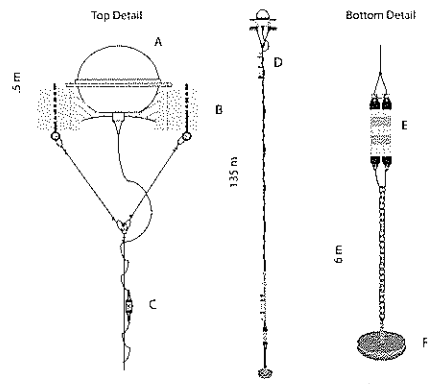

Fig. 10 Schematic of the restrained ADOS-V. A: ABS sphere with electronics and batteries. B: foam buoy. C: Inductive temperature and pressure sensor. D: acoustic current profiler. E: acoustic releases. F: weight.

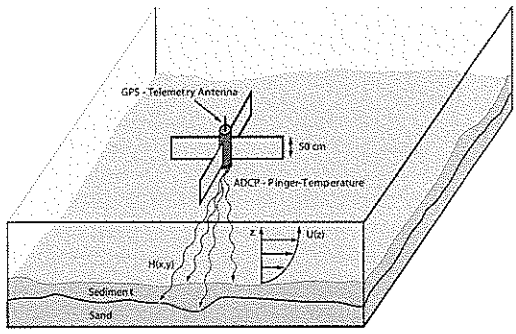

Fig. 11 Schematic of the river drifter (not to scale).

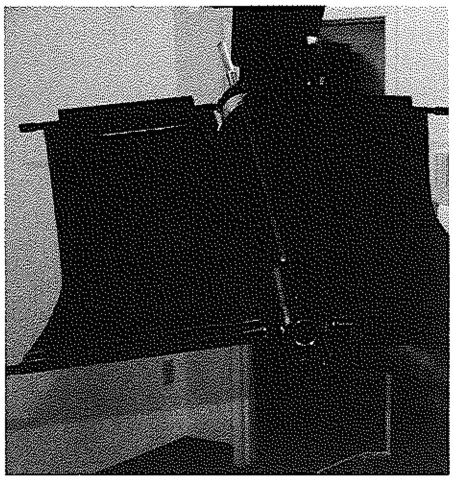

Fig. 12 River Drifter and detail of the acoustic head with the profiling current meter and the bottom pinger.

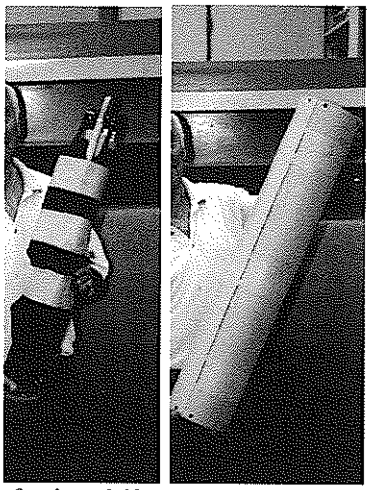

Fig. 13 Left: river drifter wrapped with water soluble paper tape. Right: river drifter inside the deployment cardboard tube.