2.4 THE NOPP YEAR OF THE OCEAN DRIFTER PROGRAM

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1. INTRODUCTION

Beginning in March of 1998, over 150 WOCE type drifting buoys, drogued at 15 meters depth, were launched in the Gulf of Mexico and the Caribbean Sea and their approaches, providing in excess of 30,000 drifter days of data to date. Buoys were provided by the U.S. National Ocean Partnership Program; launch co-ordination was provided by NOAA and academic research scientists interested in regional ocean circulation studies; and logistical and data processing support was provided by the NOAA/AOML Global Drifter and Data Assembly Centers. Buoys were launched with the cooperation of commercial ships, the Colombian Navy, the U.S. Coast Guard, and research vessels working in the region. Drifter track figures and data have been made available in real time via the WWW at www.IASlinks.org and www.drifters.doe.gov. In addition to the web-based educational resources, articles appeared in *Scientific American* and NMEA's *Current* magazine. The result was a program that generated an important oceanographic research data set and also numerous opportunities for interactive educational involvement.

2. SCIENCE: TRANSPORT PATHWAYS THROUGH THE CARIBBEAN

The Gulf Stream is one of the most well known, closely studied, and significant features of the ocean. For centuries those traveling the seas have used or avoided the Gulf Stream and other strong currents. Palm trees in the British Isles at the latitude of Moscow stand as a tribute to the Gulf Stream's ability to transport its warm water over long distances and impact coastal climates. This powerful North Atlantic ocean current has a relatively humble beginning in the Caribbean Sea. The large-scale wind field over the North Atlantic Ocean, with westerlies at mid-latitudes and easterlies at lower latitudes, drives a warm surface westward ocean flow in the tropics that finally reaches the islands of the Lesser Antilles. Most of these currents flow through the passes between the islands of the Caribbean, where they eventually converge in the western Caribbean as the Caribbean Current. However, these "fragments" of a highly variable current with many eddies do not organize themselves until they approach the Yucatan Channel, where they form into a coherent northward flow known as the Yucatan Current. Once through the Yucatan Channel, the flow becomes the Loop Current in the Gulf of Mexico and then the Florida Current east of the southeastern U.S. coast. The manner in which these warm western Atlantic and Caribbean currents organize into the powerful Florida Current / Gulf Stream system is not well understood.

The Caribbean Sea is also the location of some of the richest coastal and reef habitats in the tropical oceans. As the Caribbean Current flows westward on its way to the Yucatan Peninsula, it passes through very productive zones of coastal upwelling (produced by the easterly winds) north of Venezuela and Colombia, fertile coastal "nurseries" and estuaries such as the Cienaga Grande de Santa Marta in Colombia, the continental shelves east of Nicaragua and south of western Cuba, and a large number of reef regions along the coasts of Panama, Costa Rica, Jamaica, Cuba and other sites (reference: The Sea of Streams, Nature Conservancy, May/June 1999). The Caribbean Current is then clearly also a possible "highway" along which drifting objects such as fish or crustacean (e.g. lobster) larvae can be carried downstream. It is strongly suspected by marine biologists that larvae traveling along this current could replenish populations farther downstream, such as on the Campeche Bank north of the Yucatan Peninsula, or even more importantly for the U.S., in the shallows of Florida Bay and the Florida Keys. Of course, if larvae can be transported over these long distances through the Caribbean and ultimately to the U.S. mainland, then it is equally true that pollutants introduced by man farther "upstream" in the Caribbean could also be transported to the U.S. coast by the identical mechanism.

Figure 1. WOCE SVP drifter deployed

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One way to study the motion and trajectories of surface water parcels, larvae, or pollutants, is to introduce surface drifters into the flow. We hope to use these buoys to study the how the Caribbean Current forms, to better understand current patterns, and to determine how and where nutrients or larvae are distributed. These drifters can make measurements of quantities such as surface water temperature as they move along with the flow, and can automatically report their positions to satellites at predetermined intervals. Drifters are commonly "drogued" with a parachute or similar high-drag element so that the influence of surface winds on the drifter is reduced and so that the drifter follows approximately the flow at the depth of the drogue. Clearly, drifters can only be rough representation of the manner in which larvae are carried along by the currents. For example, larvae do not all drift at the same depth, nor do they even stay at the same depth over periods as short as a day.

Until recently, the number of surface drifters deployed in the Caribbean Sea could almost have been counted on one hand. Therefore, many of the basic features of the Caribbean flow field remained only poorly defined. However, beginning in 1998 a major deployment of drifters took place as part of the so-called "Year of the Ocean" ("YOTO") experiment (Fig. 2). The drifter tracks shown in this figure are all based on the "WOCE" (World Ocean Circulation Experiment) drifter design, and all are drogued at a depth of 15 meters (information is available from the NOAA/AOML GDC web site www.aoml.noaa.gov/phod/dac/gdc.html). Since the beginning of the YOTO experiment over 150 surface drifters have been launched. Due to the high expense of launching drifters from oceanographic research vessels, most of the drifters shown in Fig. 2 were launched from so-called "ships of opportunity", such as commercial freighters, U.S. Coast Guard vessels in the eastern Caribbean, or vessels of the Colombian Navy in the southwestern Caribbean. Typically, groups of drifters were introduced into the flow every few months, and lifetimes of individual drifters were usually at least six months.

Several features stand out in Fig. 2. First, there is an immense range of distances over which drifters can travel. While there is no preferred path for drifters through the eastern and central Caribbean, an organized westward-flowing Caribbean Current begins to form at around 80^{o} W. Most drifters entering this region enter the Gulf of Mexico, where the "looped" pattern of the Loop Current is clearly seen, most of those are advected far north into the Atlantic by the Gulf Stream. Second, some drifters can be "trapped" within the Caribbean Sea for extended periods. In fact, one region of the Caribbean that appears to be effective in trapping

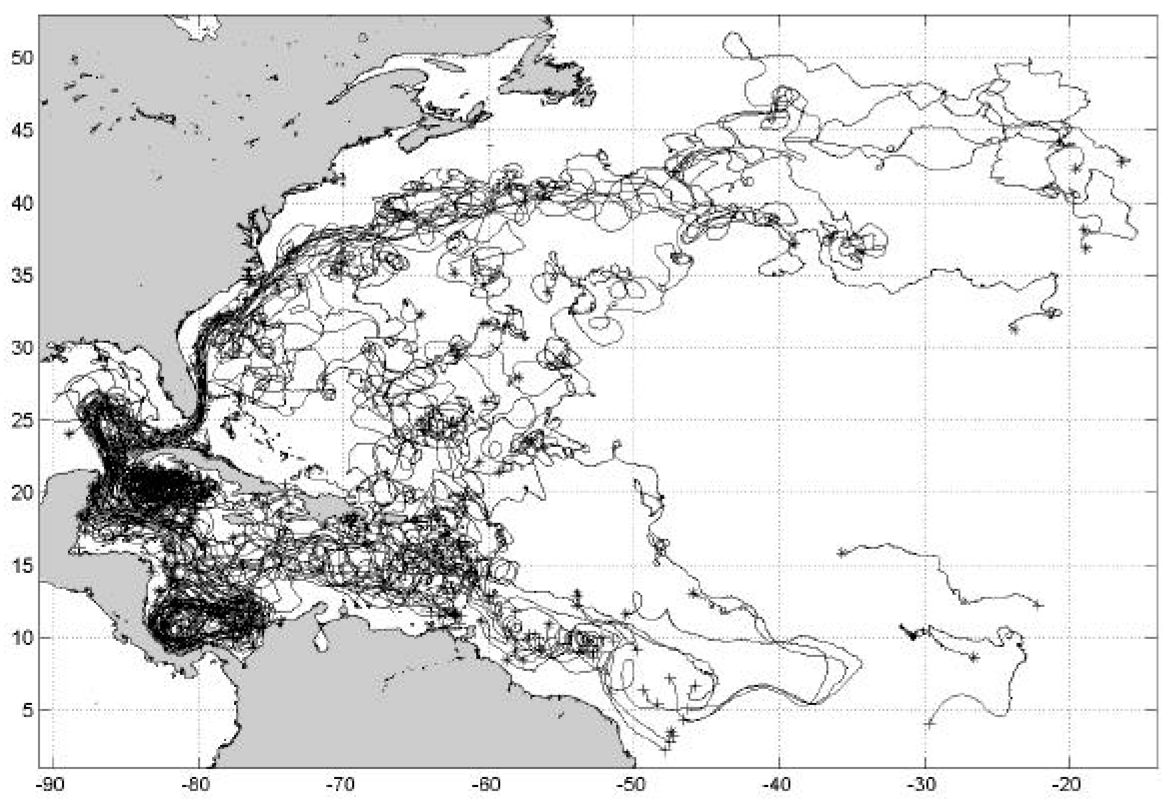

Figure 2. Tracklines of all NOPP Year of the Ocean drifting buoys, March 1998 – October 1991.

drifters was only suspected before these drifters were deployed; this region is formed by a typically closed pattern of cyclonic (counterclockwise in the Northern Hemisphere) flow north of Panama called the "Panama-Colombia Gyre". Another region where drifters seem often to become trapped is south of the western part of Cuba. Finally, although some overall patterns of flow can be discerned in Fig. 2, there is also clearly a very high level of variability in the flow.

To try to make some order from the apparent chaos shown in Fig. 2, we can create an average picture of the currents using all the drifter data (Fig. 3). Here, we have gathered together all the velocities inferred from any drifter paths that passed through geographic boxes of approximately 50 km by 50 km on a side and averaged them together to obtain a field of the mean velocities. Velocities along each drifter track were simply determined by differencing sequential drifter positions and dividing the resulting differences by the time intervals between each sequential pair of positions. From Fig. 3 we can more clearly see the broad, westward drift of the Caribbean Current in the central Caribbean Sea, the "organizing" of the currents in the approaches to the Yucatan Channel, and the cyclonic Panama-Colombia Gyre north of Panama.

One conclusion from all this is that the variability of the currents is as important as, if not more important than, the mean flows. This explains the necessity to repeat drifter launches into the same region so that a large number of "realizations" of the flows can be observed; only then can we form some statistically accurate picture of the flow field as a whole. This becomes even more important when biology is introduced into the problem, since many marine organisms have seasonal reproductive cycles that may or may not coincide with favorable physical conditions. Information from the NOPP YOTO drifters, in conjunction with numerical model outputs, is already being used to study regional larval drift patterns and determine appropriate locations for Marine Protected Areas.

3. EDUCATION: REAL-LIFE, REAL-TIME SCIENCE, MATH, AND GEOGRAPTHY

Drifting buoys make an excellent educational tool because of their dynamic nature and direct links to mathematic, physics, geography, and technology as well as oceanography and meteorology. The selection of the Caribbean Sea and Gulf of Mexico as a location was also a good choice, due to its proximity and impact on the United States as well as its scientific significance. During the experiment, the AOML Global Drifter Center, in conjunction with oceanographers, balanced the needs of continuous drifter distribution with the limited resources available for deployment. They were able to deploy

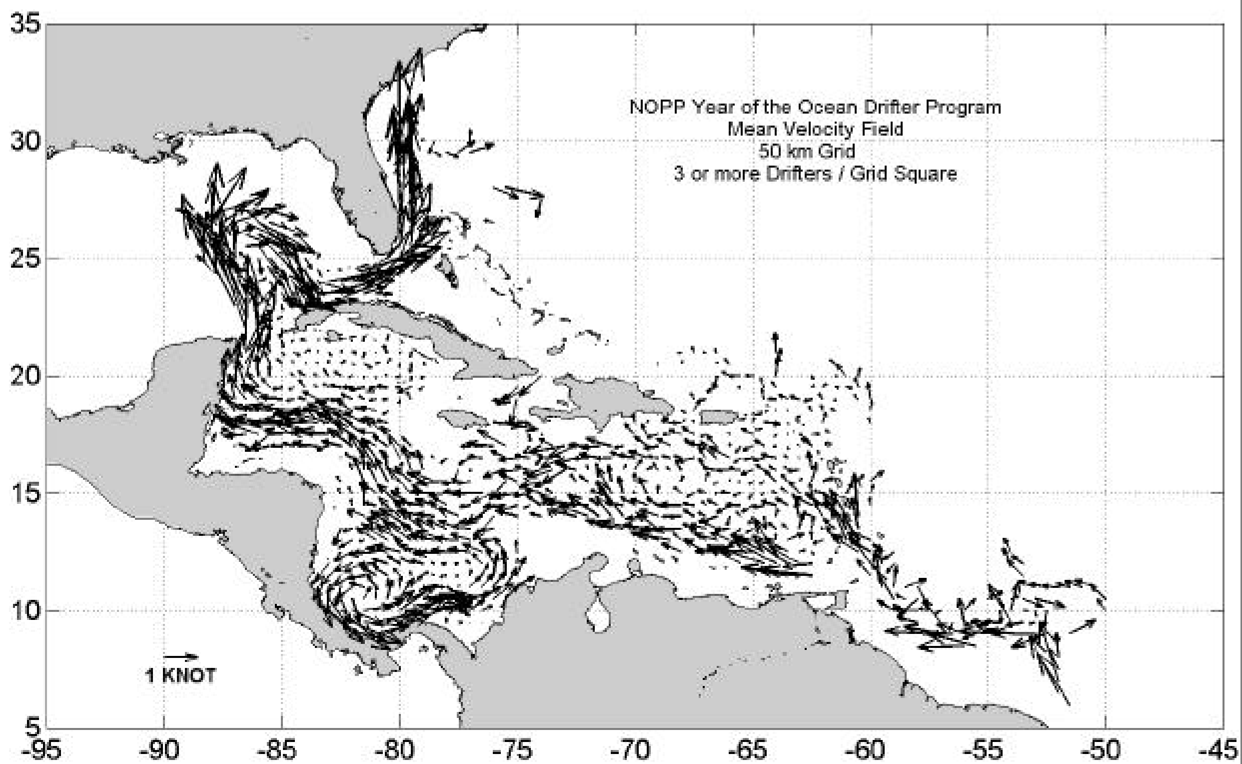

Figure 3. Mean currents estimated from NOPP Year of the Ocean drifting buoy tracks. Velocities were averaged within 50 km squares; only squares with 3 or more drifters are shown.

over 150 drifters in the course of two years, most during the actual 1998 Year of the Ocean.

During the experiment, scientists and data analysts at AOML made the data available to web sites on a daily basis. The primary web site was maintained at the Department of Energy's Oak Ridge Laboratory, based on data display software developed for the GLOBE (Global Learning and Observations to Benefit the Environment, www.globe.gov) program. At the site www.drifters.doe.gov students could view news and information on the program, see the deployment schedule and status of drifters, view drifter track lines, download position and ocean temperature data in near real time, and submit questions about oceanography and the program to be answered by oceanographers and posted online. Links ere also provided to other relevant web sites. The AOML web site for Caribbean and Gulf of Mexico physical oceanography, www.IASLinks.org, featured daily updated drifter tracks organized by deployments and regions.

In addition, downloadable educational activity modules were developed on tracking drifters, building drifters, and ocean currents. Drifting buoys were featured in the Scientific American Amateur Scientist section in November 1998. Now that the data are edited, archived, and available, there is a need for development of programs further utilizing the resource; new drifting buoy data are continuously available.

4. ACKNOWLEDGEMENTS

The large majority of the drifter launches were coordinated by Doug Wilson of the NOAA Atlantic Oceanographic and Meteorological Laboratory, Kevin Leaman of the University of Miami Rosenstiel School, and Peter Niiler of the Scripps Institute of Oceanography. Logistics were carried out by the NOAA AOML Global Drifter center, primarily by Mark Bushnell and Warren Krug. Buoy data processing was done by the NOAA/AOML Drifter Data Assembly Center, led by Mayra Pazos. Ellen Prager followed by Sarah Schoedinger of CORE made the program possible. Sharon Walker of Mississippi State University and the National marine Educator's Association directed the educational program; WWW display was done by the Department of Energy's Oak Ridge Laboratory. Drifters were launched on a volunteer basis by ships from NOAA, the U.S Coast Guard, the Navies of the United States and Colombia, the Cuban Instituto de Oceanologia, the Sea Education Association, Texas A&M, Harbor Branch Oceanographic Institution, and Crowley Shipping Line.

5. REFERENCES AND RESOURCES

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