# Tracking Ocean Debris

Mankind generates large amounts of debris that end up in the ocean: plastics thrown carelessly overboard, torn fishing nets, cargo ship losses, and all the junk carried by rivers into the ocean. Such debris is a hazard to shipping and to marine life. As more and more of the stuff accumulates, tracking and even removing it becomes necessary. But the oceans are vast and the debris is hard to track over the huge distances. Coastline surveys and air-borne monitoring systems are costly efforts. IPRC's **Nikolai Maximenko** has been heading a team that has developed a computer model to chart the likely paths of floating marine debris and where it may end up in the World oceans.

Maximenko's work on the debris problem started with basic research. In collaboration with **Peter Niiler** at Scripps Institution of Oceanography, he wanted to improve maps of ocean currents. Surface currents are mainly a combination of Ekman currents driven by local wind and geostrophic currents maintained by the balance between pressure gradients and the Coriolis force. These surface currents are detectable from the paths taken by drifters released into the ocean. Almost 12,000 freely drifting buoys of a unified design have been deployed in the Global Drifter Program during and after such experiments as WOCE and CLIVAR. Maximenko thus determined the recent paths of the drifters tracked by satellites and combined the information with satellite altimetry, wind and gravity measurements. In this way, he was able to create a high-resolution map of the mean dynamic ocean topography and derive the mean geostrophic and Ekman circulation in the upper ocean (Figure 1, Maximenko et al., *submitted*).

The distilled data reveal, among other things, the existence of narrow east-west jet-like streams that give the ocean-current map a striped look (Maximenko et al., 2008). Oceanographers had begun to detect such flows

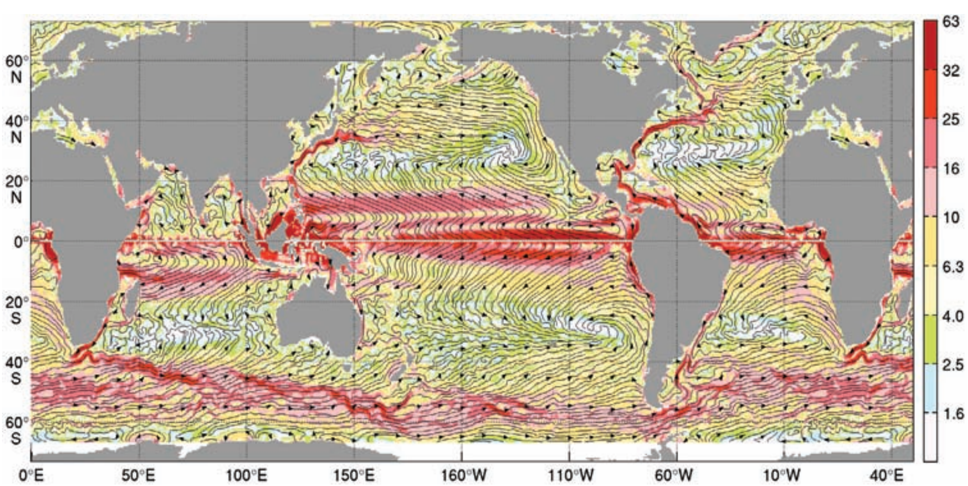


Figure 1. Mean near-surface current streamlines and mean zonal velocity (colors; unit cm/s) calculated at 1-m depth. Currents are calculated as a combination of geostrophic and Ekman currents.

at depth in high-resolution ocean general circulation model results, but were uncertain whether they were real or just a model artifact (*IPRC Climate*, vol. 5, no.1). Maximenko's observational data showed the "jets" are a real phenomenon and even more pronounced at the surface than indicated by the general circulation model simulations. The origin of the jets is still a mystery.

The freely drifting surface buoys also happen to provide a unique opportunity for tracking ocean debris. Carried along by ocean currents, the trajectories of these buoys yield estimates not only of ocean current velocities, but also, where the flows separate or diverge and where they come together or converge. Where flows diverge and water wells up from the deep, the ocean is often rich in nutrients for marine life. Where flows converge, debris can be expected to collect.

One approach to using drifters for determining flow divergence and convergence is to analyze the density of drifters. As a Lagrangian "particle," a drifter will stay longer in regions of surface convergence. Unfortunately, drifter density is affected by not only ocean currents but also the deployment scheme. The drifters have been deployed over many years and often in small areas for special regional experiments. Figure 2 illustrates how deployment and currents interact. Hundreds of drifters were let loose close to the equator but they were soon pushed to higher latitudes by the divergence associated with the equatorial upwelling forming the famous "cold tongue" along the equator. Other massive drifter launches occurred off the California and the US East Coast, as well as in the Japan Sea. These drifters have not been dispersed much by ocean currents. In contrast, although deployments in the mid-latitude South Pacific are scarce, the density of drifters, the blue dots in Figure 2c, is high and must therefore be ascribed to the ocean currents.

To skirt this problem of non-uniform drifter-distribution due to deployment, Maximenko developed a computer model that can use even short drifter trajectories to chart the probable paths of drifters over long time periods. The movement of each drifter in the model is based on the actual paths that the nearly 12,000 drifters took over five days from their various locations in the ocean. Maximenko first divided the globe surface into thousands of two-dimensional bins of a half degree in size; for each drifter, he used all its positions as given by the satellite determinations. From these displacements, he calculated the probability of a statistical drifter to move in 5 days into, or over, bins surrounding its original location. This calculation yields estimates of both mean distance and dispersion of the drifters. The process can then be repeated in the model every five days for as long as is needed to determine the final maximum drifter density.

Once he had computed the behaviors of real drifters, Maximenko initiated his ocean model with uniformly distributed drifters (Figure 3a) and tracked the evolution in drifter density for as long as 1000 years, the assumption being that statistics of the winds and currents remain steady over this long period.

In the model, the drifters are lost only when they enter, but never leave, a bin. This typically occurs in shoreline bins where drifters are washed on shore. The model shows that such drifter losses are surprisingly scarce, implying that debris tends to stay in the ocean for a very long time. Wind-

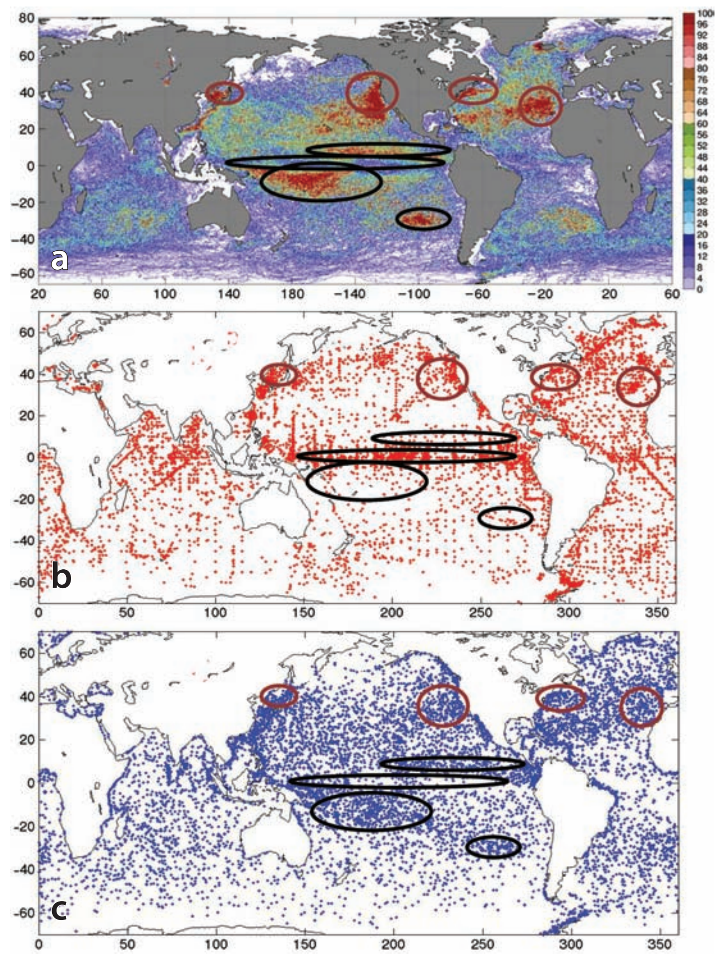


Figure 2. (a) Number of 6-hourly drifter fixes in 1/4-degree boxes, (b) locations of the drifter releases, and (c) last reported coordinates. Brown ellipses indicate regions where higher density of drifter data is consistent with the drifter deployments. Black ellipses indicate regions of highest and lowest drifter density that results from ocean currents.

driven ocean currents are organized in such a way that most of the drifters are pushed offshore and kept in regions of convergences, which are far from the coast. After ten years of integration, only 30% of the model drifters had been lost.

Calculations show that the drifters tend to collect in five regions (Figure 3). These regions correspond to the centers of the five subtropical gyres.

The model shows that, before the drifters start to dissipate, their density increases to as much as 15 times their original density in the North Atlantic and South Indian Ocean, 30 times in the South Atlantic, 45 times in the North Pacific, and 150 times in the South Pacific.

The two regions where most drifters collect or converge are in the eastern North and South Pacific. In the North Pacific this place lies between Hawai‘i and California and has been recently identified as the location of the Great Floating Garbage Patch, a huge cluster of partly defragmented plastic and ghost nets and other flotsam endangering marine life. The South Pacific patch has an even higher drifter-density in the model. Despite its predicted location being so close to Easter Island, this patch has not yet been detected in the real world. Perhaps this is because much less long-living debris is produced in the Southern Hemisphere than in the Northern Hemisphere.

In support of the NOAA Marine Debris Program, Maximenko is now developing further this diagnostic technique for identifying places in the ocean where debris is likely to collect and be retrieved.

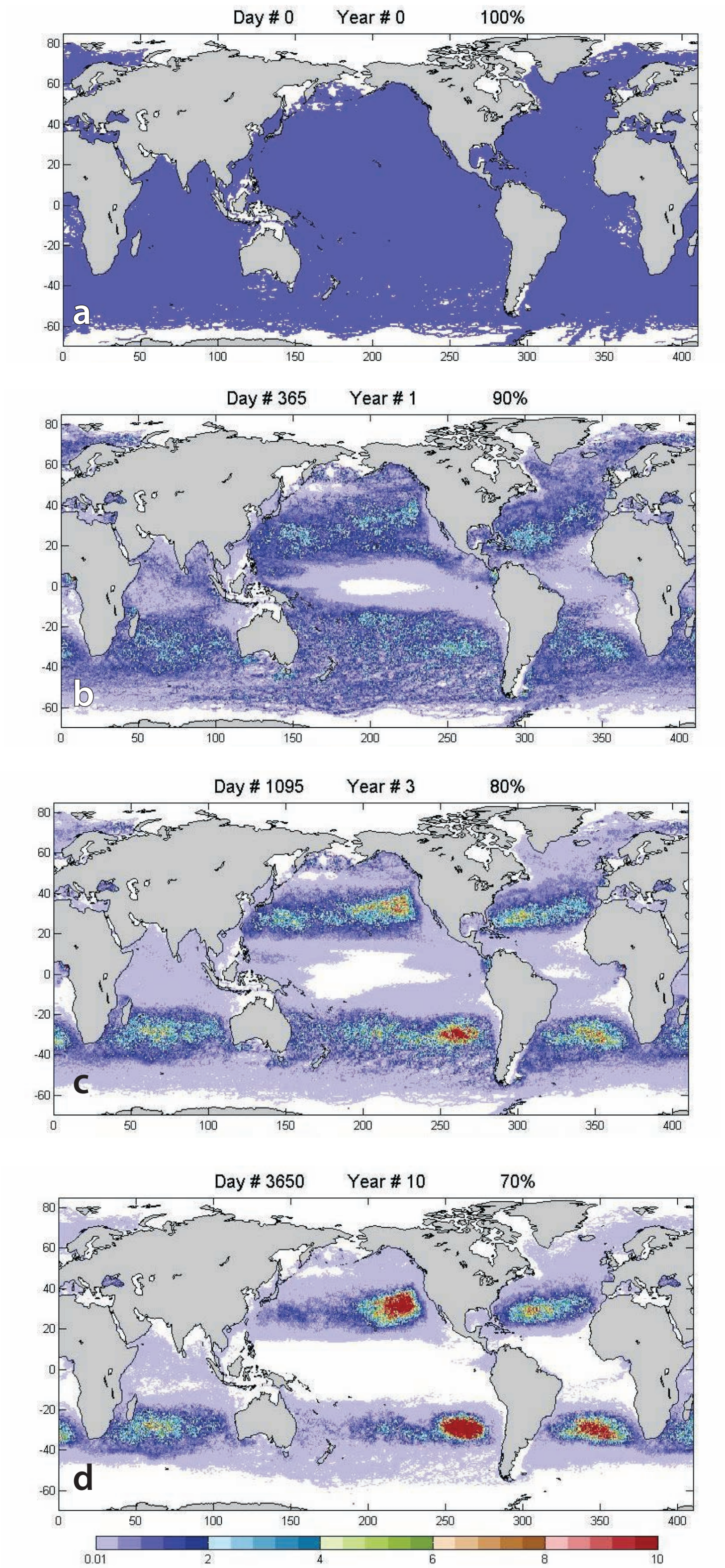


Figure 3. Simulation of evolution of drifter density (or marine debris): (a) from an initially homogeneous state, (b) after one year, (c) after 3 years, (4) after 10 years of advection by currents, as determined from real drifter movements. Units represent relative change in drifter concentration.

## Reference

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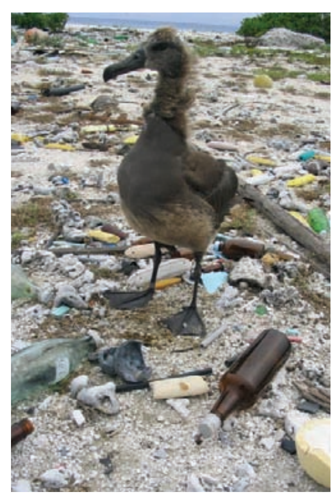

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