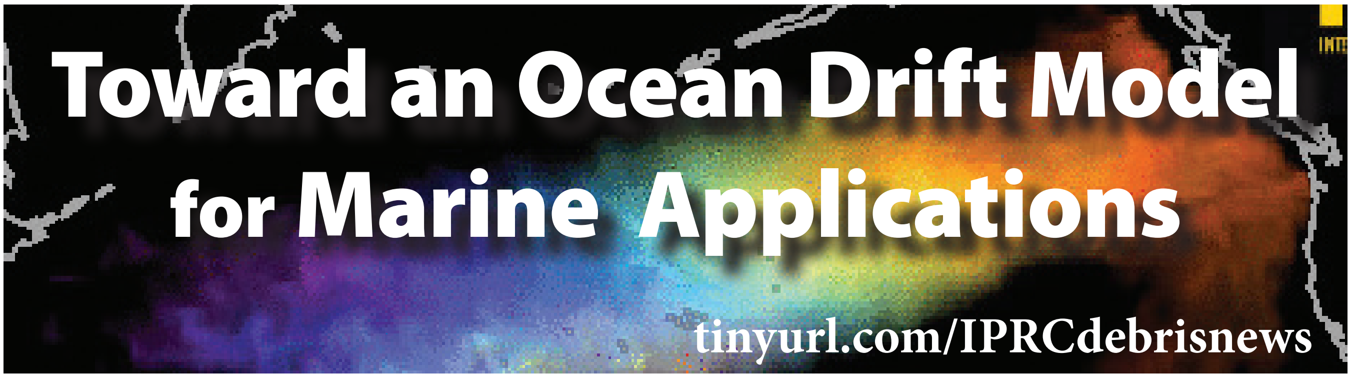
# Toward an Ocean Drift Model for Marine Applications




By **Gisela Speidel**

The more than 16,500 drifting buoys deployed in the Global Drifter Program provide a unique opportunity for tracking ocean debris, IPRC Senior Researcher **Nikolai Maximenko** realized. Carried along by ocean currents, the paths taken by these drifters yield information not only of ocean current velocities, but also about areas of accummulation. Where flows diverge, water wells up from the deep bringing rich nutrients to the surface; where flows converge, floating debris can be expected to collect.

An obstacle to developing a computer model from the drifter trajectories was the non-uniform drifter deployment in the World Ocean, each experiment having focused on a specific region. Maximenko dealt with the problem by compiling the actual 5-day movements of each drifter over its life-time into a probabilistic drift model. (For details see *IPRC Climate*, vol. 8, no. 2). As a next step, uniformly distributed tracers were placed into the model and the evolution of their dispersion tracked.

After 10 years, the virtual drifters had mostly collected in five regions in the World Ocean, namely in the centers of the five subtropical gyres (Figure 1). The areas with the strongest convergence and hence largest model drifter collections lie between Hawai‘i and California—the Great North Pacific Garbage Patch—and in the South Pacific. Despite its predicted location close to Easter Island, the latter patch was only verified in 2011 by **Jim Mackey**, who explored the area as a ship-of-opportunity following Maximenko's modeling results (See *IPRC Climate,* vol. 9, no. 2). **Marcus Eriksen** explored the area further during a dedicated expedition. Eriksen also collected evidence for the predicted patches in the Southern Indian and Southern Atlantic oceans.

When the tsunami tragedy happened in March 2011 in Japan and aerial images showed thick mats of debris floating in the ocean, Maximenko realized the importance of tracking the driftage. No drifting buoys were floating east of Japan at the time, but running his model with virtual drifters showed that the tsunami debris would drift toward the US - Canada west coast and to Hawai‘i. Maximenko presented these results at the 5$^{th}$ International Marine Debris Conference.

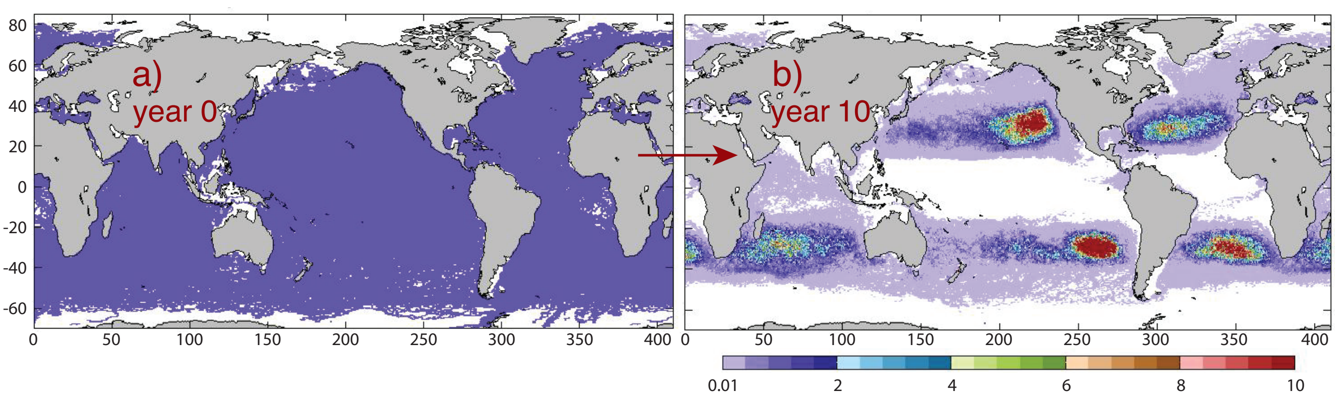



**Figure 1.** Evolution of density of drifters (or marine debris) from the initially homogeneous state (a) and after 10 years of advection by currents, measured by real drifters (b). Units indicate relative change of the concentration.

Tsunami debris off the Tohoku coast. Photo credit US Navy.

To make the simulations more practical, Maximenko had worked with IPRC Scientific Programmer **Jan Hafner** to develop a real-time drift model. Starting with conditions on the day of the tsunami, March 11, 2011, Hafner placed millions of virtual drifters into the this model off of the Tohoku Coast and ran the model with the daily updates, which were made publicly available. The model showed how the debris dispersed with time.

Maximenko had hoped to track the debris by satellite trackers placed on the floating debris and with airplane surveys. Over the next months he pleaded with NOAA, the Coast Guard, and other federal agencies, but to no avail. By summer 2011 the debris had scattered and vanished.

Public evidence of tsunami driftage resurfaced in fall. The Russian sail-training ship *Pallada* had stopped in Honolulu in September on its trip back to Vladivostok. Maximenko and Hafner took their maps of the tsunami debris field to the captain, who, warned of the danger to his ship, organized on his return trip round-the-clock watches by almost 200 cadets. Just northwest of Midway, consistent with the model's predictions, the sailors observed unusual debris and collected a fishing boat, the first confirmed tsunami driftage found thousands of miles from Japan (Figure 2).

In fall and winter 2011, fear loomed large that the debris would land on the beaches of the Papahānaumokuākea Marine National Monument and destroy habitats of endangered species. Together with **Doug Woodring** of the Ocean Recovery Alliance and **Luca Centurioni** of Scripps Institution of Oceanography Maximenko organized a small sailboat expedition with Jim Mackey (photo page 15) to survey the area northwest of Midway. Only old debris, however, was spotted: An anomalous current associated with a front kept tsunami debris away from the Northwestern Hawaiian Islands, and the model animation showed the core of the debris moving north of Hawai'i towards the North American West Coast.

A surprise came when large oyster buoys from aqua farms in Japan started to wash up on Washington coastlines in mid-December 2011, much sooner than the model had projected. The scientists realized that their model, which

Pallada cadets pick up fishing boat lost in tsunami.

simulated the paths of drifters with heavy drogues and intended for charting ocean currents, needed to be rebuilt to include the movements of very buoyant pieces, driven partly by winds like sailboats.

The scientists went back to the drawing board and added wind effects. Obtaining realistic values of windage levels to drive the model was challenging because observations with which to confirm these levels were, and remain, sparse. By August 2012, their expanded model was running with

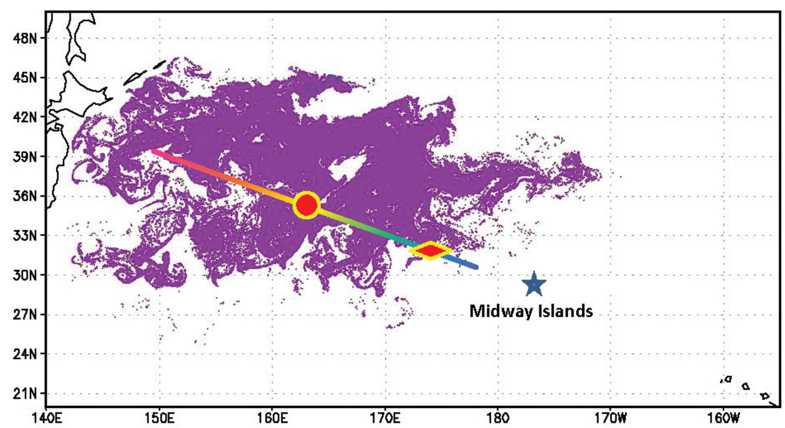



**Figure 2.** Rhombus shows where Pallada spotted Japanese boat, red circle where maximum debris density was seen, and purple the tsunami debris field in model on September 25, 20111.

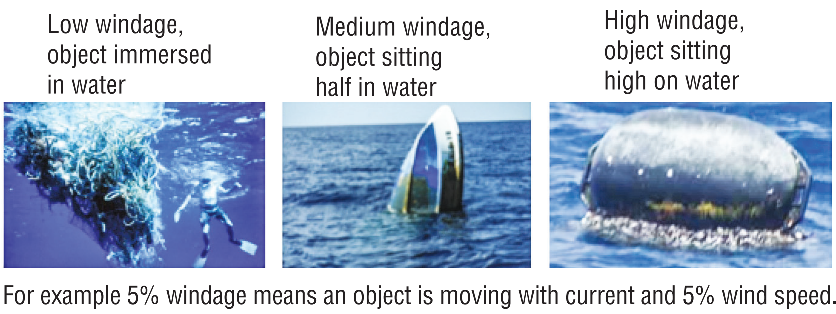



**Figure 3.** Illustration of different windages.

windage levels from 0 (original version) through 5% (Figure 3) and accommodated objects of different shapes, buoyancies, and amounts of surface exposed to the wind, resulting in different speeds and trajectories.

The updated model was completed just as it showed the front edge of tsunami driftage arriving in Hawai'i and as reports trickled in of unusual driftage washing up on Hawai'i windward-facing shores. In mid-August, **Carl Berg** of the Kaua'i Surfider Foundation sighted off of Kaua'i a black oyster buoy similar to those found on Washington beaches a half year earlier. Large 500-Watt light bulbs with Japanese manufacturer's names and gooseneck barnacles arrived. In mid-September, a blue bin bearing the name of a Japanese company destroyed during the tsunami floated in, followed shortly by an Asahi crate. The first of several fishing skiffs, similar to the one spotted by the *Pallada* sailors, was sighted 700 miles north of Moloka'i; the owner in Japan was found.

As the reports came in, the *Sightings* page listing arrivals of possible tsunami debris was added to the IPRC *Marine and Tsunami Debris News* website. Reports became more numerous. Until summer 2013 most of the driftage consisted of oyster buoys, parts of refrigerators, docks, and fishing skiffs. According to the model these pieces would have drifted with a 4%–5% windage.

In July 2013 the Transpacific Yacht Race, famous for fast downwind sailing with the trade winds, took place. During the 5-day journey from Point Fermin in Southern California to Honolulu, the racing boats reported numerous collisions with floating wood. The IPRC *Sightings* page has the following entries from the race: "Sighted 15′ chunk of floating telephone pole; sighted 35′ floating tree trunk; struck what may have been a 10′ section of telephone pole; large pieces of debris, a couple of pieces of lumber looked like parts of a house."

**John Sangmeister**, skipper of the winning boat *Lending Club*, reported on CNN: "mid-morning the second day, we were sailing at…about 28 miles an hour, when we encountered a patch of debris…. we hit that telephone pole and struck it mid-way in half like a Ginsu knife …..on days three and four we … encountered similar debris with dramatic consequences and damage to our boat."

Two months later, in September 2013, the large wooden debris started to arrive on Hawai'i shores. Through fall and winter 2013, and into spring 2014 reports came of poles, beams with finely executed mortise and tenon features and atypical US dimensions, and

Oyster buoy found by Carl Berg and Kaua'i Surfrider volunteers.

tree trunks. A gabled roof end of a small cabin with metal bracing holding all together was found end of September on Kamilo Point by **Megan Lamson**, **Bill Gilmartin**, and the volunteers of the Hawai'i Wild Life Fund. Carl Berg and his Kaua'i Surfrider Foundation volunteers reported they had never seen so many large wooden pieces washing up on Kaua'i beaches.

Although such pieces of wood do not often wash up on Hawai'i's beaches, are they from the tsunami devastation? To get some confirmation, Maximenko sent wood pictures and samples to **David Stallcop**, a wood export specialist with Vanport International, a lumber company based in Oregon and with worldwide ground support.


Cross-section of very "old" Sugi sample sent for analysis to experts.

James Mackey leaves Honolulu for Midway expedition.

Bill Gilmartin with gabled roof end at Kamilo Point.

Stallcop wrote: "It was easy for me to determine that the samples are definitely Japanese Cedar (Sugi) - *Cryptomeria japonica*. The fresh cross cuts definitely show that it is Sugi… grown in a higher elevation area than the other Sugi samples. The Sugi harvested today grows very quickly. This Sugi is from a very old timber. It could have been precut for a home or building construction 100+ years ago. Very cool." He added "The sizes of the Japanese Cedar samples are definitely indicative of Japanese Post and Beam construction." Morphological analysis of the same samples by **Scott Leavengood** from Oregon State University substantiated the conclusions of Stallcop.

Relevant to the accuracy of the model's simulation are the waves of debris type arriving in Hawai'i. From summer 2012 through spring 2013 oyster buoys and refrigerators were a common sighting, but are hardly seen anymore in spring 2014. Huge wooden beams up to 40-feet long only started to be sighted on their way towards Hawai'i in summer 2013, arriving in Hawai'i in early fall 2013 and becoming more numerous in winter 2013–2014. These waves of debris are broadly consistent with the model, the higher windage items arriving before low windage pieces.

The IPRC Ocean Drift Model is now poised for various applications. For example, the experience with Japanese fishing boats reaching Hawai'i 1½ to 2½ years after the tsunami guided the scientists in using realistic windage parameters to simulate the remarkable 13-month drift of **Jose Salvador Alvarenga**, the San Salvadoran fisherman, from Mexico to Ebon Atoll. The paths of the 16 tracers placed into the model 200 nautical miles southwest of the coastal fishing village Chiapas, Mexico, on December 20, 2012—the time that Alvarenga says he was blown off shore—are consistent with the fisherman's report (Figure 4). The particles are quickly driven offshore by very strong winds and by wind-induced currents. Over the 13 months, some move faster and overshoot Ebon Atoll where Alvarenga was found (red dot indicates approximate place), others have not yet reached the atoll. Given the variability of the daily winds and current that drove the model, the 16 tracers show a remarkably narrow path over this long period of time.

The IPRC scientists are now processing a wealth of further tsunami debris data to improve their ocean drift model. They plan to refine their model with the greatly enlarged drifting-buoy database now available and to broaden their model codes to study, for example, how winds, shapes of coastlines, and currents interact to make some beaches free of marine debris, and others collectors; or what causes the mystery of the vanishing marine debris: millions of tons of debris are washed into the ocean every year, much more than is estimated to be in the 5 "garbage patches."

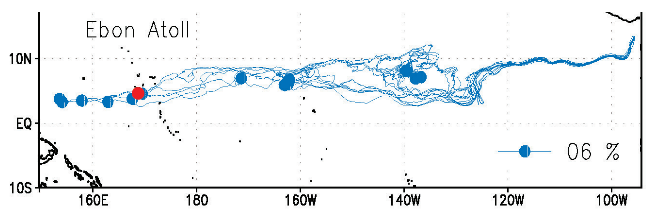



**Figure 4.** Path of the 16 tracers in the model from December 20, 2012, to February 1, 2014, driven with 06% wind force. Red circle shows Ebon Atoll where Alvarenga was found and blue circles mark positions of the tracers end of January 2014.