Marine Debris

by

Nikolai Maximenko and Jan Hafner

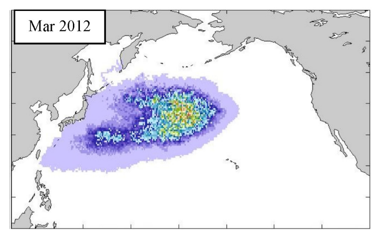
at the International Pacific Research Center

Asking Ships to Report Any Sightings of Tsunami Debris

September 16, 2011

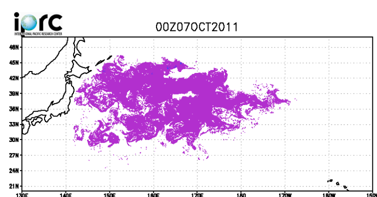
In the wake of Nikolai Maximenko's and Jan Hafner's meeting with Captain Sviridenko of the Russian Tall Ship STS Pallada to be on the look-out for any debris from Japan's tsunami, Hafner was interviewed by KITV4 about any knowldedge of the whereabouts of the debris. To help in efforts to track the debris, the scientists need to validate their models' projections of the debris field and are asking ships in the North Pacific to report to them on what they see, and if possible take samples. Click here to listen to interview.

Websites to see projected tsunami debris paths



For the original animation from the statistical model, please visit:

http://iprc.soest.hawaii.edu/users/nikolai/2011/Pacific_Islands/Simulation_of_Debris_from_March_11_2011_Japan_tsunami.gif



The SCUD model driven with daily wind conditions and sea level height is at:

http://iprc.soest.hawaii.edu/users/hafner/PUBLIC/TSUNAMI_DEBRIS/tsunami_tracers_no_vector_large.html

INTERNATIONAL PACIFIC RESEARCH CENTER

IN THE SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY AT THE UNIVERSITY OF HAWAI'I AT MĀNOA

Press Release **Tuesday, September 13, 2011**

Russian Tall Ship to Search for Missing Tsunami Debris

Shortly after the devastating tsunami in Japan on March 11, 2011, aerial photographs and satellite images captured massive islands of lumber and other debris floating in the sea. Less than a month later the debris had mysteriously disappeared from view and virtually nothing has been heard of it since. Is it still swimming dispersed in the ocean the way the now famous animation has the debris travelling across the North Pacific, some washing first up on the shores of the Hawaiian Islands, then on the shores of the west coast of Canada and the US?

From left: Jan Hafner, Captain Vasily Sviridenko, and Nikolai Maximenko on board the *STS Pallada.* Photo courtesy Beatrix Hu.

Released by the International Pacific Research Center at the University of Hawaii at Manoa on April 5, that animation, broadcast on such stations as CNN and CBS, caught the attention of the media worldwide. Senior Researcher Dr. Nikolai Maximenko and Scientific Computer Programmer Dr. Jan Hafner, the developers of the animation, have been inundated with questions about where the debris is now in real time. Although based on present-day scientific knowledge, the model animation is a best guess. Eager to validate their projections, the two scientists have tried to get the assistance of the relevant federal agencies, but none is ready to deal with such an unknown threat or danger.

Some of the young cadets who will be on the look-out for the debris. Photo courtesy *Pallada.*

Now help is on the way in the form of the Russian three-master sailing ship, the *STS Pallada*, which docked at the Aloha Market Place pier in Honolulu on September 11. The *Pallada* with 102 cadets on board is on a 3 1/2 month training voyage that has taken its young crew from their homeport in Vladivostok to Kodiak, Vancouver, San Francisco, Los Angeles, and now Honolulu. On its homeward journey, perhaps via Tokyo, the ship is likely to pass through some of the now widely scattered debris.

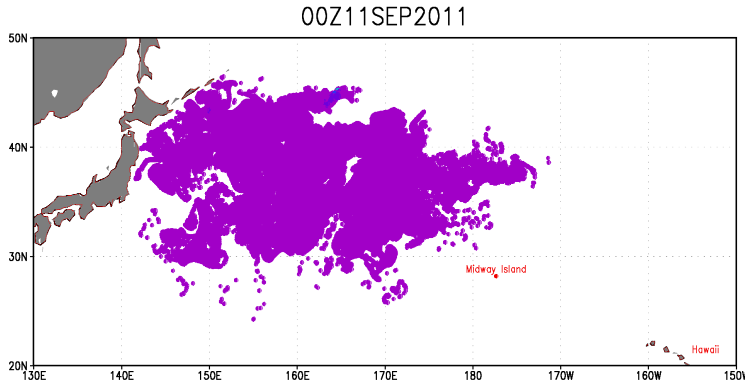
On the ship's arrival, Maximenko and Hafner met with Captain Vasily Sviridenko and Natalia V. Borodina, information and education mate. Maximenko, a native of Russia, described in fluent Russian where the debris might be found, pointing to the September 11 map of the estimated locations.

The captain is seriously concerned about the debris, according to translation by Borodina. “The reason the huge commercial vessels travelling the North Pacific have not reported anything,” the captain said, “is because they cut through such stuff like through butter.” For the *Pallada*, however, although it is one of the largest tall ships plying the sea, the debris is very dangerous. With its 300-foot length, it is a small ship by today’s standards. “It is especially vulnerable as its hull is thin,” the captain explained.
When asked whether he will help, he replied, “Sure! I will have our eager young cadets be on the look-out for debris 24 hours a day.” The safety of his crew is of primary concern.

“What we need are verbal descriptions of what you see floating in the ocean,” said Maximenko. “Take photos, and if possible, even take samples. Objects might be hard to see as they might be camouflaged, covered with algae and other marine life. Negative data, that is regions free of debris,” he said, “is also useful information and helps to determine the edge of the field.”

The ship has Geiger counters to measure radio activity. Although Maximenko thinks the debris will likely not be radioactive as it washed into the ocean nearly two weeks before the leakage of water from the Fukushima nuclear plant, no theorizing can substitute for direct measurements.

The *Pallada* will be back in its homeport in mid-October. What will she find? Will the tsunami debris be detected and its existence be realized?



Map of the debris scatter as of September 11. The model which generated this image is updated with the daily winds and sea level height since March 11, the day of the tsunami.

Click her for original statistical model animation.

Click here for maps of the model that is updated every day with current winds and sea level.

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The International Pacific Research Center (IPRC) of the School of Ocean and Earth Science and Technology (SOEST) at the University of Hawai`i at Mānoa, is a climate research center founded to gain greater understanding of the climate system and the nature and causes of climate variation in the Asia-Pacific region and how global climate changes may affect the region. Established under the “U.S.-Japan Common Agenda for Cooperation in Global Perspective” in October 1997, the IPRC is a collaborative effort between agencies in Japan and the United States.

Press Release **Tuesday, April 5, 2011**

Where Will the Debris from Japan's Tsunami Drift in the Ocean?

The powerful tsunami triggered by the 9.0 Tohoku Earthquake destroyed coastal towns near Sendai in Japan, washing such things as houses and cars into the ocean. Projections of where this debris might head have been made by Nikolai Maximenko and Jan Hafner at the International Pacific Research Center, University of Hawaii at Manoa. Maximenko has developed a model based on the behavior of drifting buoys deployed over years in the ocean for scientific purposes. What this model predicts about the tsunami debris can be seen in Figure 1. The debris first spreads out eastward from the Japan Coast in the North Pacific Subtropical Gyre. In a year, the Northwestern Hawaiian Islands Marine National Monument will see pieces washing up on its shores; in two years, the remaining Hawaiian islands will see some effects; in three years, the plume will reach the US West Coast, dumping debris on Californian beaches and the beaches of British Columbia, Alaska, and Baja California. The debris will then drift into the famous North Pacific Garbage Patch, where it will wander around and break into smaller and smaller pieces. In five years, Hawaii shores can expect to see another barrage of debris that is stronger and longer-lasting than the first one. Much of the debris leaving the North Pacific Garbage Patch ends up on Hawaii's reefs and beaches.

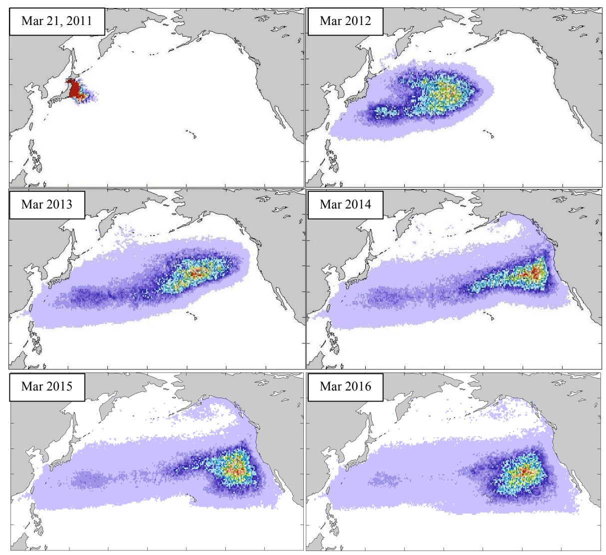

Figure 1. The probable pathways of the debris that entered the ocean on March 11, 2011, as estimated from historical trajectories of drifting buoys. Click for animation of model.

These model projections will help to guide clean-up and tracking operations. Tracking will be important in determining what happens to different materials in the tsunami debris, for example, how the composition of the debris plume changes with time, and how the winds and currents separate objects drifting at different speeds.

Even before the tsunami, the World Ocean was a dump for rubbish flowing in from rivers, washed off beaches, and jettisoned from oil and gas platforms and from fishing, tourist, and merchant vessels.

The picture shows the density and size of some of the debris. The black items in the pictures are tires. Photo courtesy of US Navy.

The mass of debris stretches for miles off the Honshu Coast. Photo courtesy of US Navy.

Marine debris has become a serious problem for marine ecosystems, fisheries, and shipping. The presentations given at the recent week-long 5th International Marine Debris Conference in Hawaii, at which Maximenko had organized a day-long workshop, are a testimony to the magnitude of the ocean debris problem. The massive, concentrated debris launched by the devastating tsunami is now magnifying the hazards.

Maximenko's long-standing work on ocean currents and transports predicted that there are five major regions in the World Ocean where debris collects if it is not washed up on shores or sinks to the ocean bottom, deteriorates, or is ingested by marine organisms. These regions turn out to be "garbage patches." The North Pacific Garbage Patch has become famous, the North Atlantic Patch was fixed some years ago, and the South Atlantic, South Indian Ocean, and South Pacific patches have just been found, guided by the map of his model that shows where floating marine debris should collect.

This research was supported by grants from the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), NASA, and NOAA.

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The International Pacific Research Center (IPRC) of the School of Ocean and Earth Science and Technology (SOEST) at the University of Hawaii at Manoa, is a climate research center founded to gain greater understanding of the climate system and the nature and causes of climate variation in the Asia-Pacific region and how global climate changes may affect the region. Established under the "U.S.-Japan Common Agenda for Cooperation in Global Perspective" in October 1997, the IPRC is a collaborative effort between agencies in Japan and the United States.

Expedition to Kamilo Beach, the "Dirtiest Beach on Earth"

Five large garbage patches in the world ocean are predicted by **Nikolai Maximenko's** surface current model (*IPRC Climate*, vol. 8, no. 2). The North Atlantic and North Pacific patches have already been found and are making news.

The debris from the North Pacific Patch occasionally escapes and the model shows it floats towards the Hawaiian Islands, making windward shores of the islands trashcans for marine debris. Kamilo Beach near South Point on the Big Island is arguably the most famous beach for the enormous amount of marine debris sweeping up on it. A BBC video labeled it as "The Dirtiest Beach in the World." The beach is unusual, however, in that it lies not on the windward side of the island, but at its southern tip.

Curious about why this beach is so favored by marine garbage and what currents take it to this unusual location, Maximenko put together a team to investigate: Assistant Visiting Researcher **Oleg Melnichenko** took the lead in deploying current meters in the surf to determine the impact of currents, Scientific Computer Progammer **Jan Hafner** took charge of documenting the garbage and collecting samples, and undergraduate marine biology student **Jeremy Soares** was the "above-and-below-water" movie camera man.

The expedition took place in early June 2010. "We had prepared well, but everything turned out differently from what we had pictured in the IPRC conference room," recollects Melnichenko. Already finding the way to Kamilo Beach was an adventure with so many unmarked rough little dirt roads.

"Without **Bill Gilmartin** as our guide, we might still be wandering around the lava," says Maximenko.

Gilmartin, Director of Research from the Hawai'i Wildlife Fund, has been leading clean ups of the beach since 2003, and over 100 tons of marine debris have been removed. Hafner was surprised by how clean the beach looked: "I was maybe a little disappointed, as our mission was to explore the garbage on Kamilo, though of course it is better this way."

The largest piece of debris they saw was a 4-foot long tree trunk. Objects that typically litter the windward Hawai'i beaches were there: Hagfish trap cones from the Pacific Northwest and oyster spacer tubes from East Asia. "The typical size of the debris, however, was 1 inch or smaller," said Hafner.

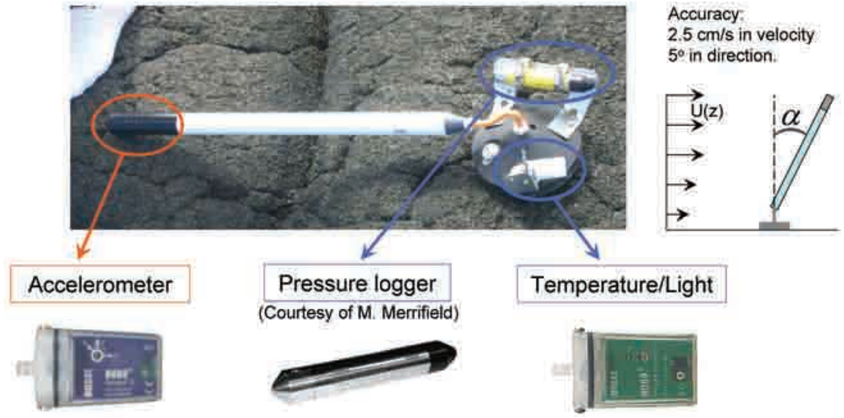
Setting the current meters was a challenge. The surf breaks far out, rolling in over a long rocky distance to shore. So the meters had to be put in place during fairly strong waves. "The meters were too heavy for us to swim with them; so we crawled, pushing them forward and coming up for deep breaths," said Melnichenko.

Kamilo Beach as it was several years ago, before the regular clean-up efforts. Image courtesy Mrs. Soares. Red dot in satellite-picture inset shows location of Kamilo Beach.

The pilot deployment showed the meters were feasible. Although "the environment is hostile" for the meters with waves pounding them ceaselessly, they held. Melnichenko: "Their design is simple and they are inexpensive. We were surprised how well they worked. With an accelerometer and with pressure, temperature and light sensors, they are flexible and can be deployed over uncharted ocean topography. You can move them readily if you want to redesign your experiment, for instance place, them in a line straight out from the beach, or along the beach. No drilling is needed so there is no harm to the environment. And they give instant data. The two days the meters stayed, we collected data that showed the daily cycle, the impact of waves and tides, and lower frequency variations of the currents."

"We are still unclear about the current pattern that brings marine trash to this unusual southwest location. the picture is very complex; the meters are responding to many different things," explained Melnichenko.

"Our exploration brought us no answers but inspired more questions and speculations," said Maximenko. "We confirmed that some debris on Kamilo Beach has travelled in the Pacific subtropical gyre from far away East Asia and from the North American West Coast. The current meters tell us that the waves and the tides provide the energy, pushing the debris to shore like a broom. The rather long shore break may contribute to debris accumulation. But, we still need to understand the interaction between large-scale currents collecting debris from the entire North Pacific and the coastal dynamics that move the debris over the reef."

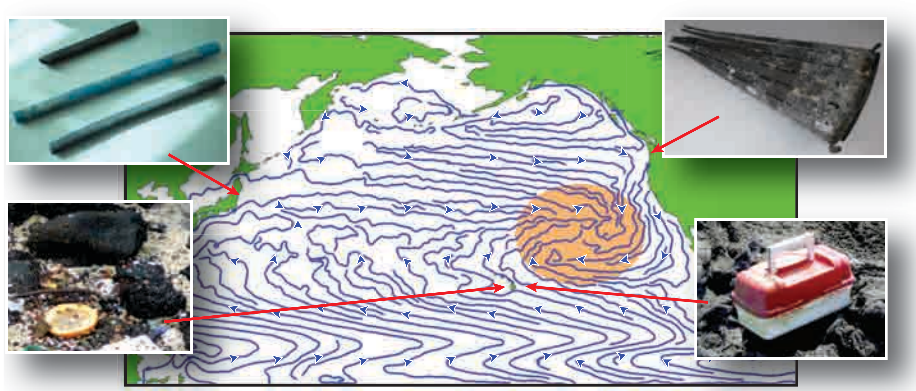


SeaHorse tilt current meter developed by Vitalii Sheremet from the University of Rhode Island. While in the water, a buoyant plastic pipe containing an accelerometer is anchored vertically to the sea floor. Currents cause the pipe to tilt. The angle of the tilt, measured by the accelerometer, is converted into velocity of the current. Additionally, temperature and pressure sensors are attached to the current meter's anchor.

"I'm particularly curious about what happens over time to the plastic, how the small pieces form. The fragments have no sharp edges. Does the plastic dissolve? This could account for the puzzling results of our recent *Science* study with **Kara Lavender Law** on the North Atlantic Patch, which found no increase in plastic density over the decades, even though plastic production increased a lot during that time. If plastic dissolves, does it release CO_2 and contribute to ocean acidity?"

"We need chemists and we need unified global observations to tackle this marine debris problem," Maximenko thinks. "Much is being done, but efforts are so varied that scientifically usable data has not yet been collected."

In conjunction with the "5th International Marine Debris Conference" to be held in Honolulu in March 2011, Maximenko is organizing the "Hydrodynamics of Marine Debris Workshop" to try to generate a more unified and scientific approach to this huge problem facing our oceans and the life in it.



Map showing the actual "mean trajectories of surface drifters" (blue lines with arrows) and the convergence associated with the garbage patch (in orange). The origins of objects found on Kamilo Beach are also shown: oyster spacer tubes from Asia, Hagfish trap cones from the US West Coast, and items from waters around the Big Island.

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

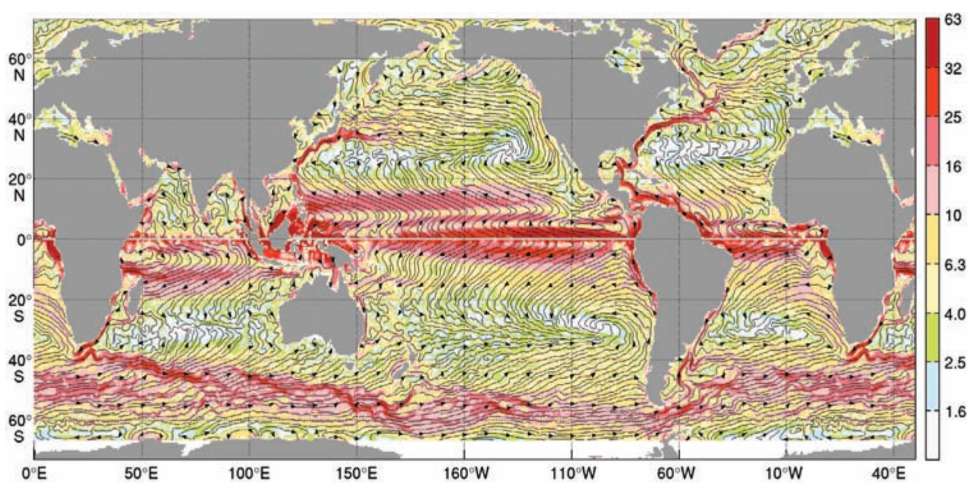


Figure 1. Mean near-surface current streamlines and mean zonal velocity (colors; unit cm/s) calculated at 1-m depth. Currents are calculated as a combination of geostrophic and Ekman currents.

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-

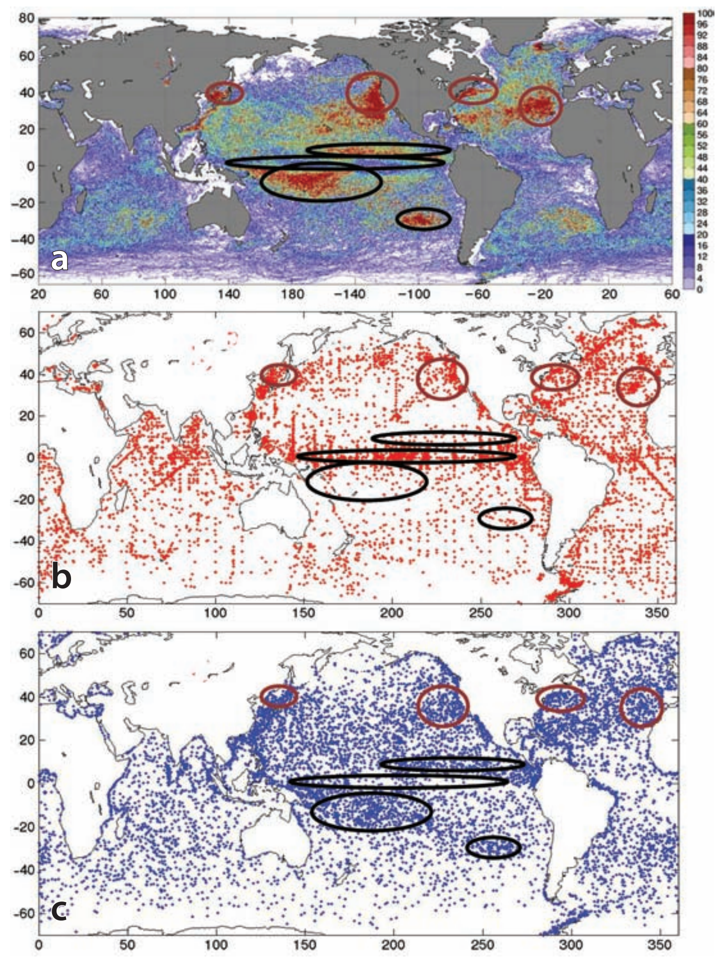


Figure 2. (a) Number of 6-hourly drifter fixes in 1/4-degree boxes, (b) locations of the drifter releases, and (c) last reported coordinates. Brown ellipses indicate regions where higher density of drifter data is consistent with the drifter deployments. Black ellipses indicate regions of highest and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

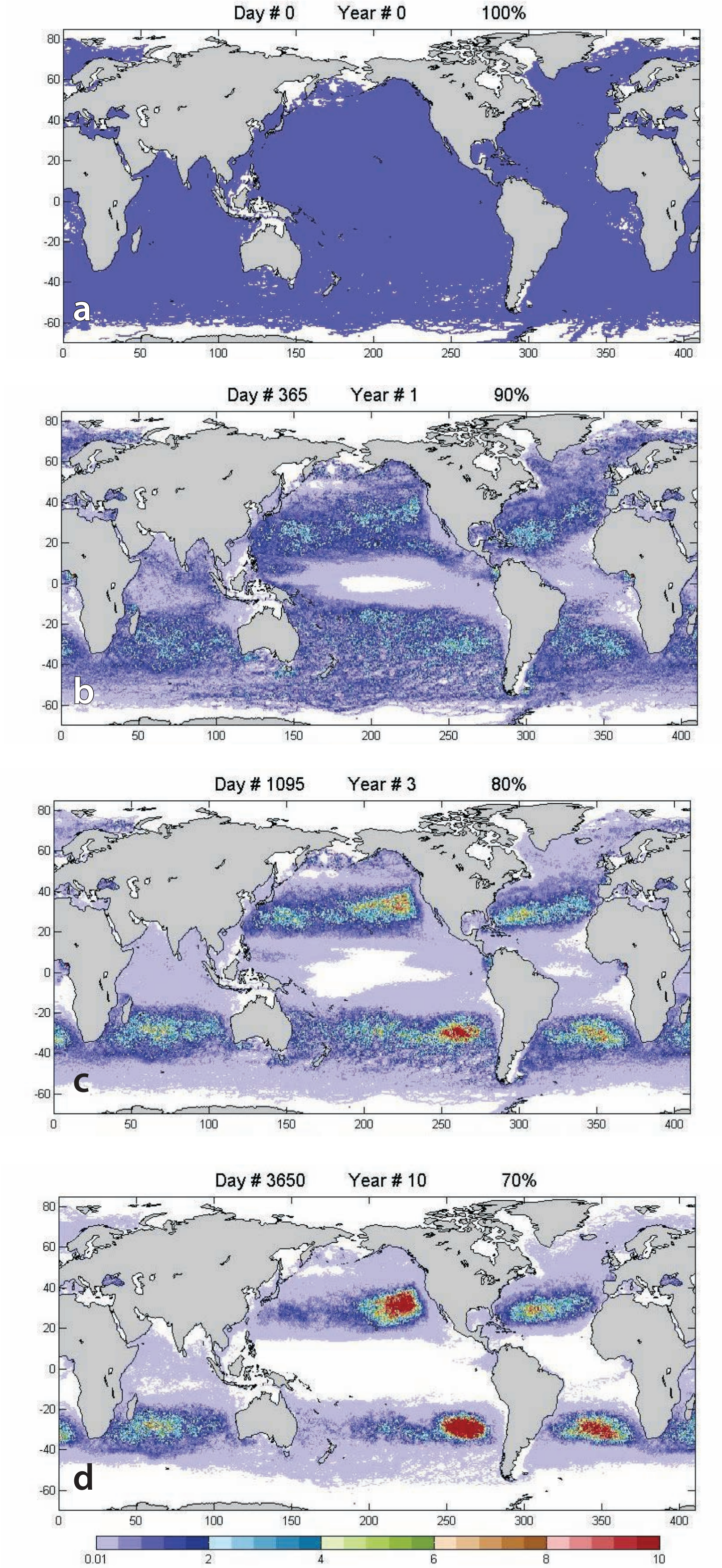


Figure 3. Simulation of evolution of drifter density (or marine debris): (a) from an initially homogeneous state, (b) after one year, (c) after 3 years, (4) after 10 years of advection by currents, as determined from real drifter movements. Units represent relative change in drifter concentration.

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.

Reference

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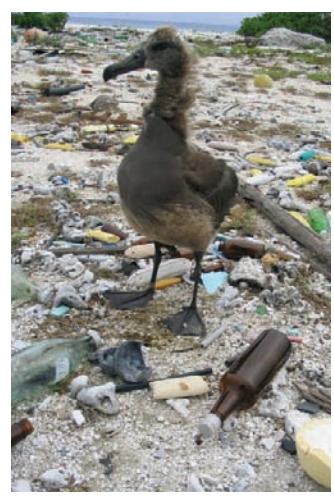

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IPRC Teams with Adventure Sailor

There is a long tradition in oceanography and meteorology of employing "ships of opportunity" whose crew take measurements incidentally as they pursue their course through the ocean. IPRC has now engaged its own very unusual ship of opportunity, one that will take novel measurements of solid pollution in the ocean. The adventure sailor **Jim Mackey** is attempting a solo circumnavigation of the globe and has volunteered to take samples of floating debris as he makes his way from his starting point in the North Atlantic through the South Atlantic, Indian, and South Pacific Oceans, back into the Atlantic. To collect the samples, he will use a trawl designed and built by **Markus Eriksen** (Algalita Marine Research Foundation) especially for use on his small sailboat. By trawling for debris samples in seldom visited regions, his voyage will contribute to several scientific programs.

IPRC's **Nikolai Maximenko** and **Jan Hafner** have supplied Jim with equipment and key navigational data so that he can measure the levels of partially defragmented plastics in the eastern part of the South Pacific, where Maximenko's model predicts is the world's ocean strongest convergence of flows and where floating matter collects from the Southern Hemisphere (see story in *IPRC Climate*, Vol. 8, No. 2). Guided by the model results, Jim will also be looking for plastic fragments in the subtropical convergences of the South Atlantic and South Pacific and along the Antarctic Circumpolar Current.

A Rival 34, the type of sailboat on which Jim is sailing. Photo source http://www.yachtsnet.co.uk/index.htm

Trawl built by Markus Eriksen for measuring marine debris from Jim's boat.

Projected route of Jim Mackey's solo circumnavigation.