Surface currents and the motion of marine debris

Nikolai Maximenko

International Pacific Research Center, School of Ocean and Earth Science and Technology, University of Hawaii, Honolulu, U.S.A.

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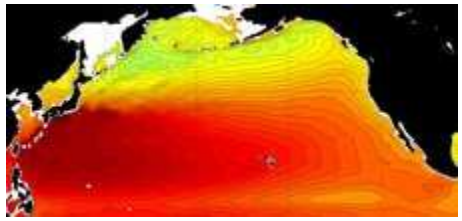
- JMA/MRI: *Masafumi Kamachi*
- many contributors to the JTMD dataset.

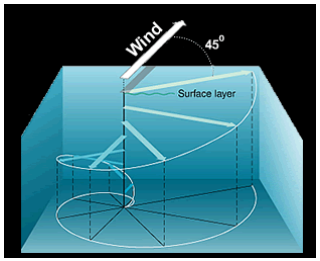
Modeling drift of marine debris

Velocity of drifter = Velocity of the ocean surface current + Velocity relative to water parcel

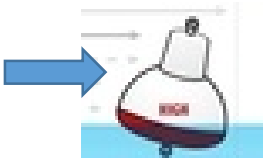
Currents due to non-local dynamics



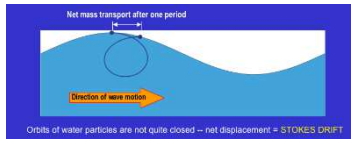
Wind-controlled currents



Direct wind force



Interaction with wind waves (Stokes drift in a linear case)



Today surface currents are not well measured and not well simulated.

Combination of wind force and wind waves amplifies wind drift

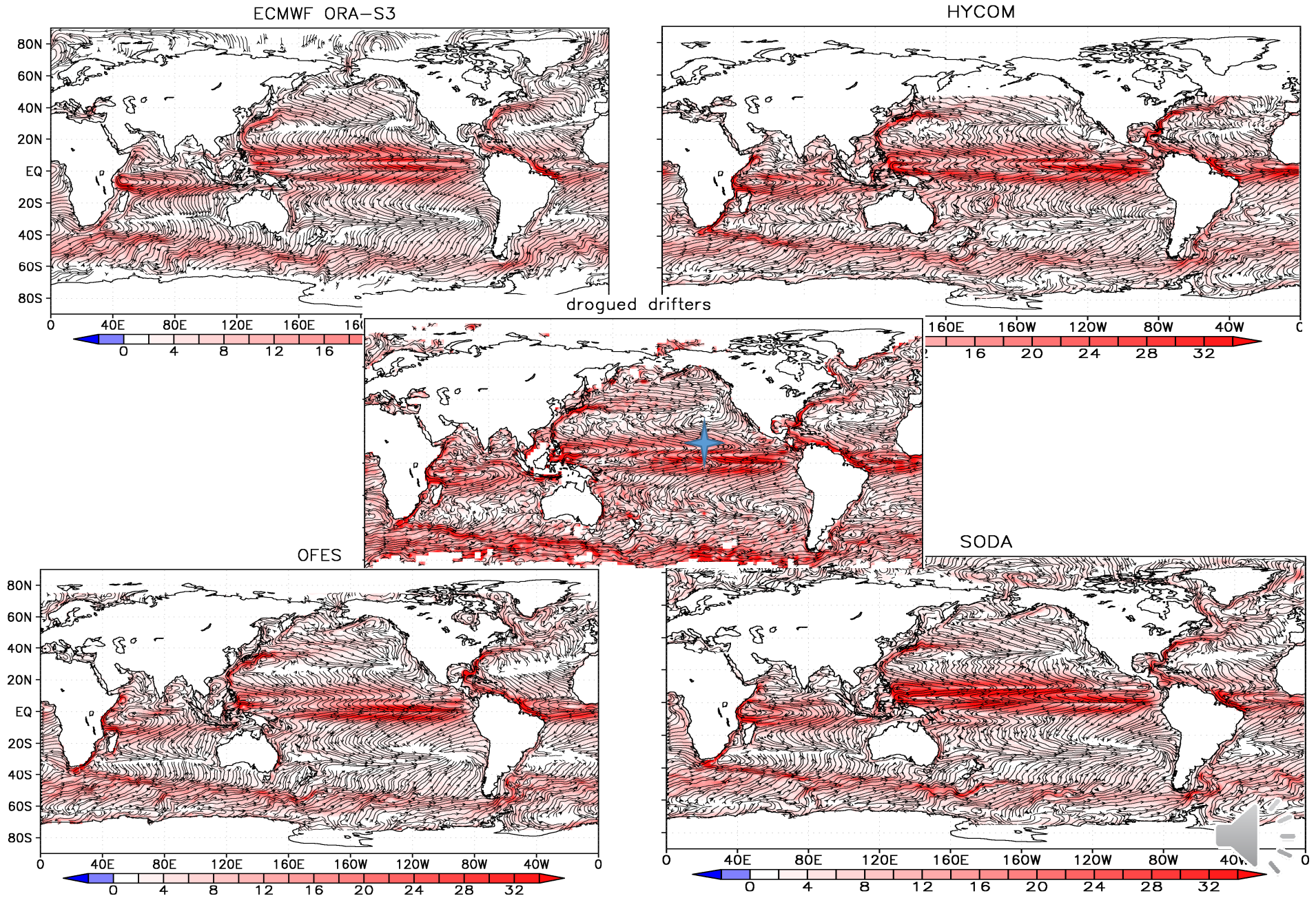
Practical formula:

Drift = Current + A(windage)*Wind

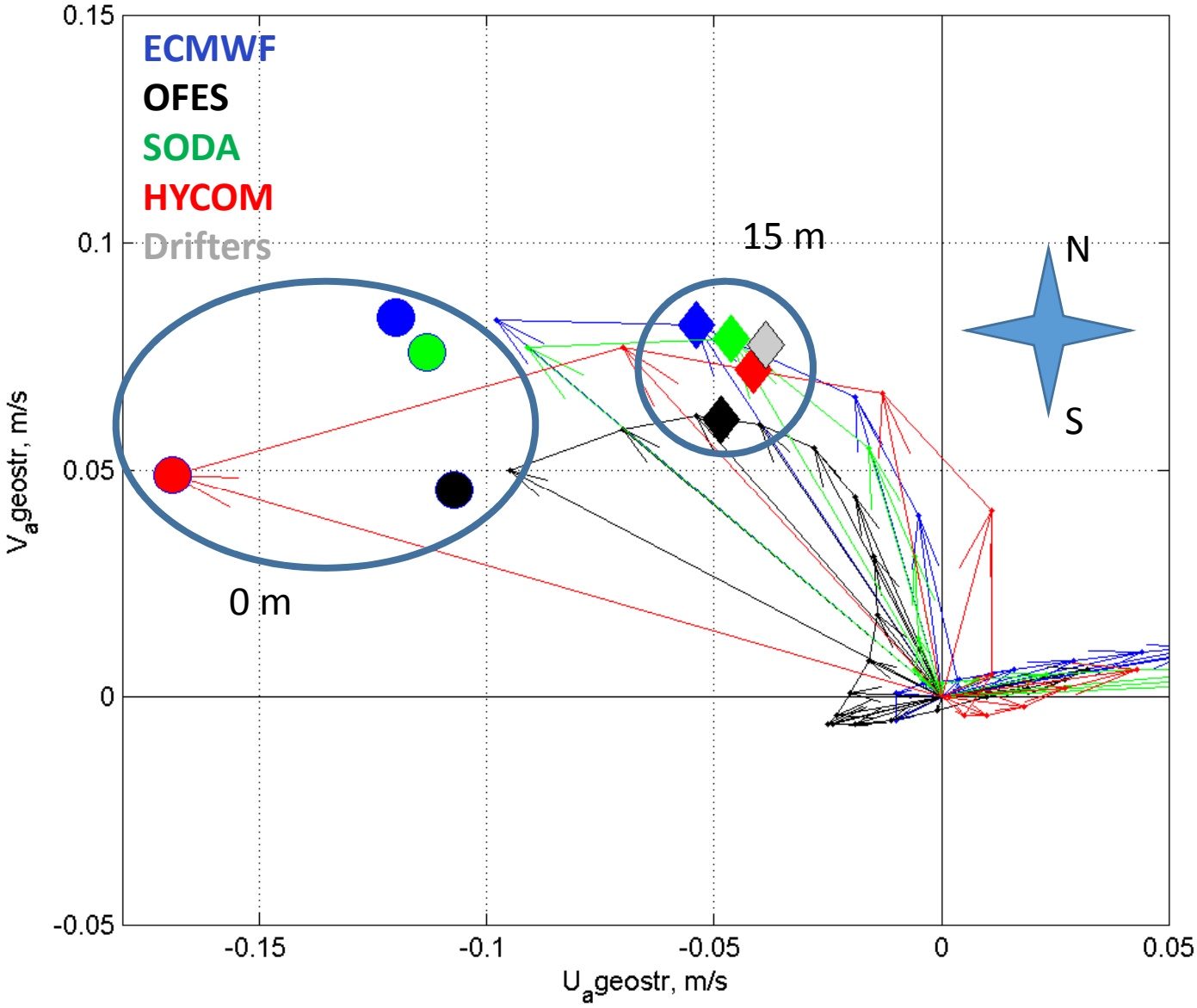
(from models) (from satellites or models)

Same object may dynamically correspond to **different windages** in different models

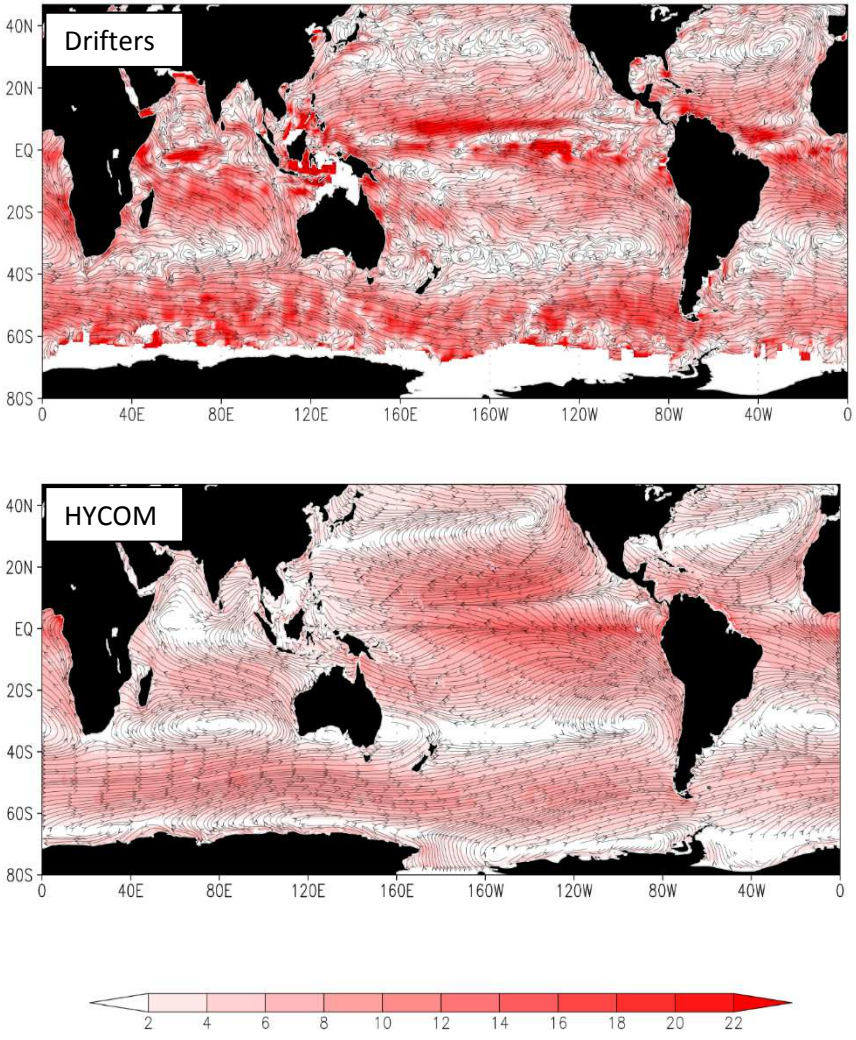
Time-mean currents at 15 meters level in different models

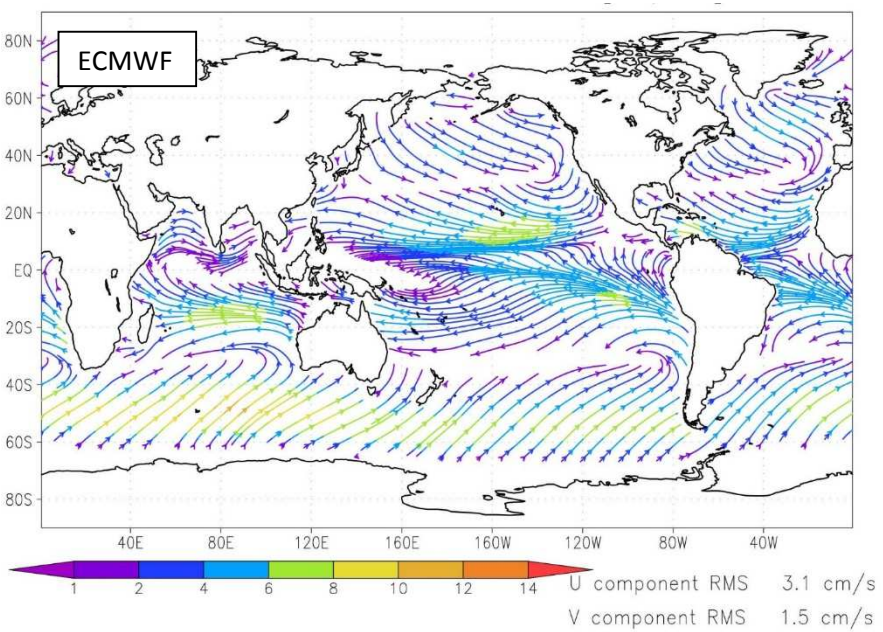


Mean Ekman spirals in the Tropical North Pacific (15N, 140W)



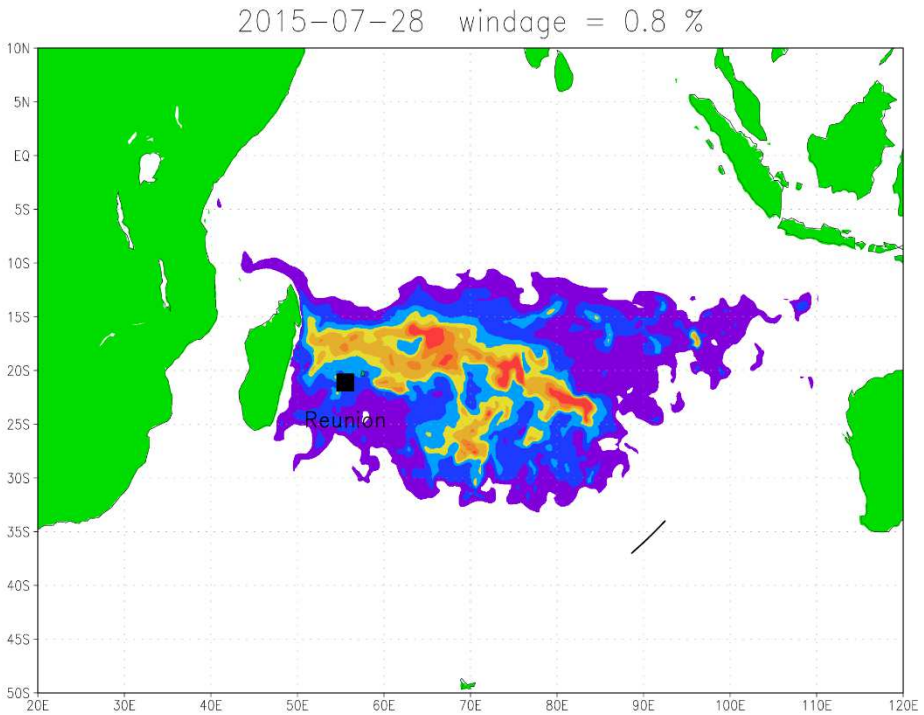
Mean velocity shear between 0 and 15 m depth



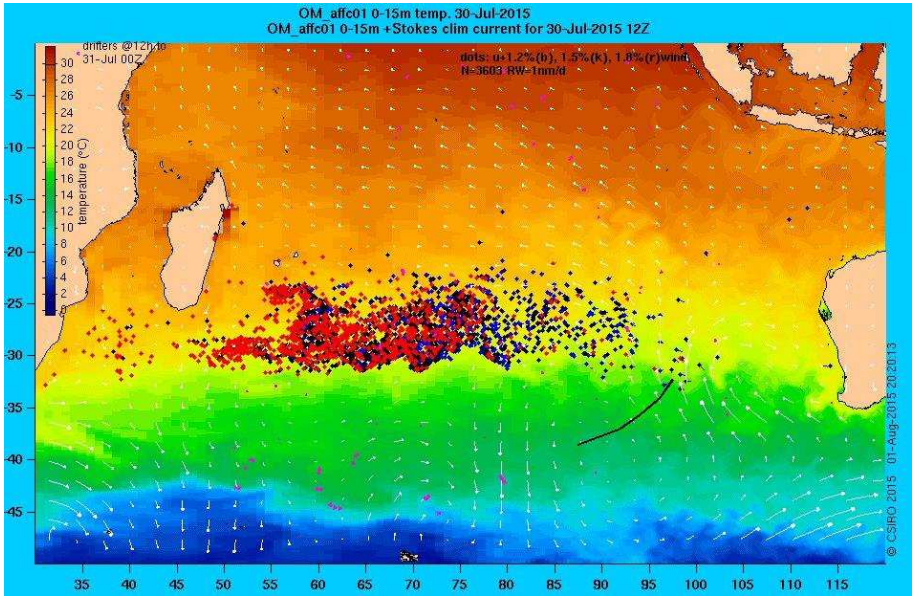


Flaperon found on July 29, 2015 on Reunion Island

Image source: Andrew Heneen on Wikipedia



Joint Agency Coordination Center (JACC, Australia) – search update of Aug 5, 2015



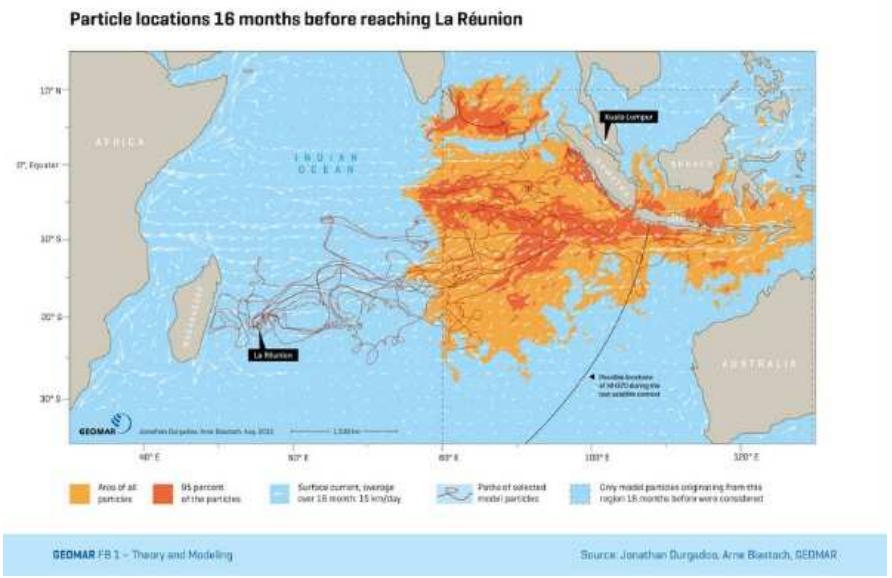
Drift modelling by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) shows that material from the current search area could have been carried to La Réunion, as well as other locations, as part of a progressive dispersal of floating debris through the action of ocean currents and wind.

Figure shows the indicative drift of debris from the search area as at 30 July.

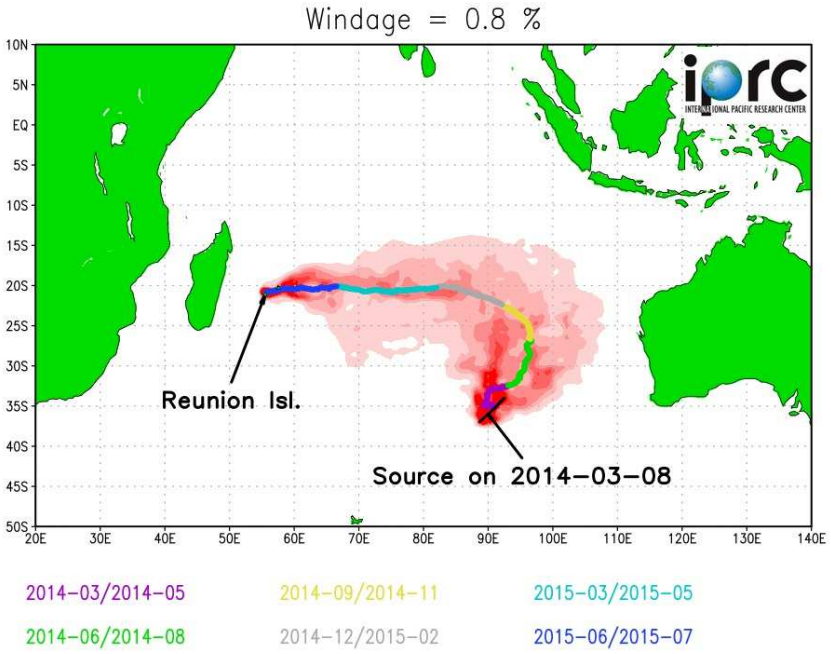
Blue, black and red dots simulate items with leeway factors (applied to the 10m wind velocity) of 1.2, 1.5 and 1.8%. The items originated along the black arc (7th arc) on 8 March 2014. White arrows are the winds for the day shown.

Magenta symbols are positions of real drifting buoys (with sea-anchors at 12m) on the day. Their movement has bee used to estimate the errors of the ocean current component of the total drift velocity.

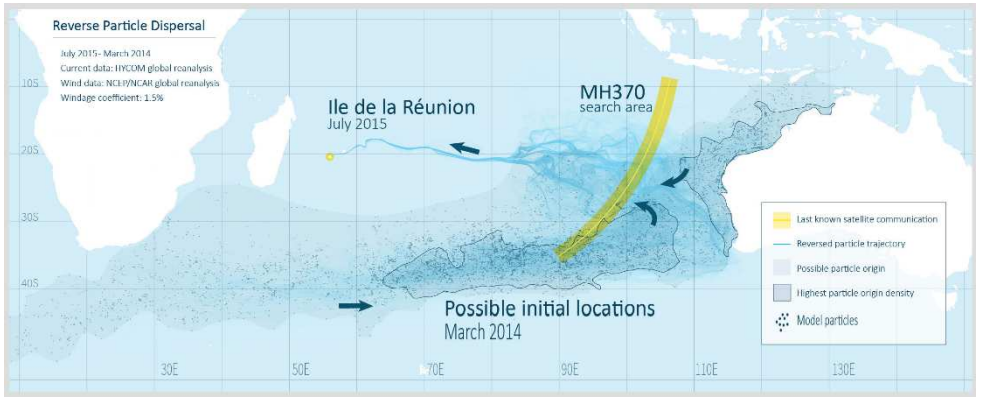
Flaperon backtracking by Geomar (Germany) group



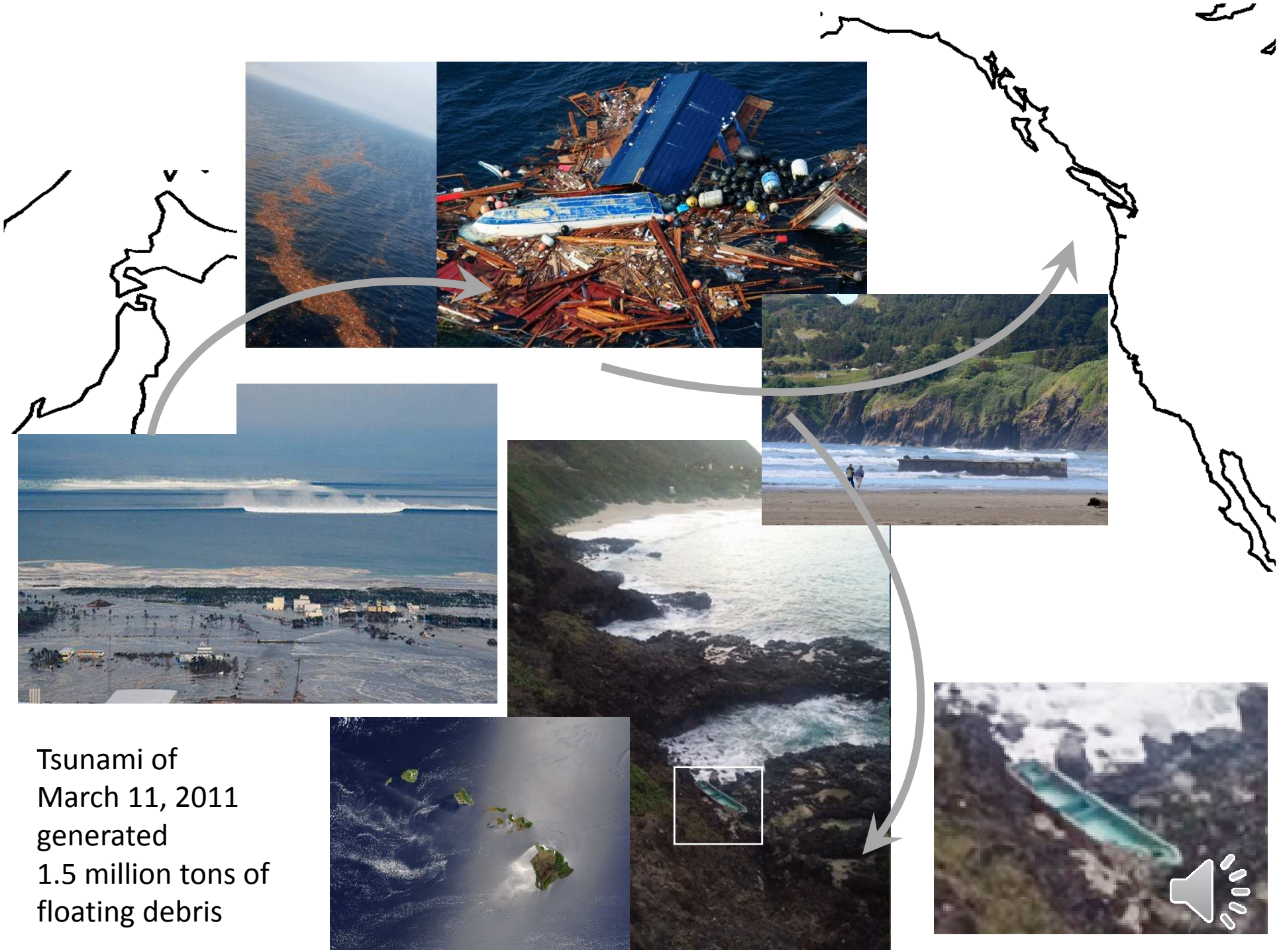
Probable trajectory of flaperon in the IPRC model



Flaperon backtracking by Laurent Lebreton (Dumpark, New Zealand)



Based on HYCOM + Stokes drift + 1.5% windag

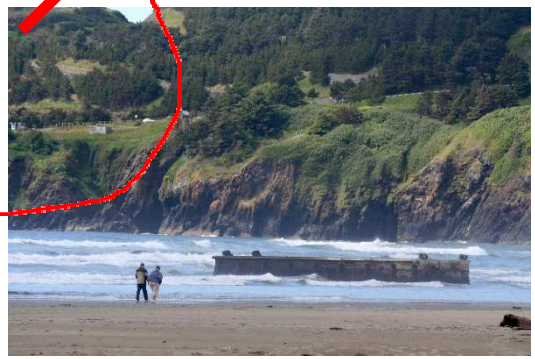


Tsunami of
March 11, 2011
generated
1.5 million tons of
floating debris

Examples of potential tsunami marine debris from or near Hawaii

Four 66-feet Misawa docks,
washed off shore Mar 11, 2011

Apr 5, 2013:
Olympic Coast



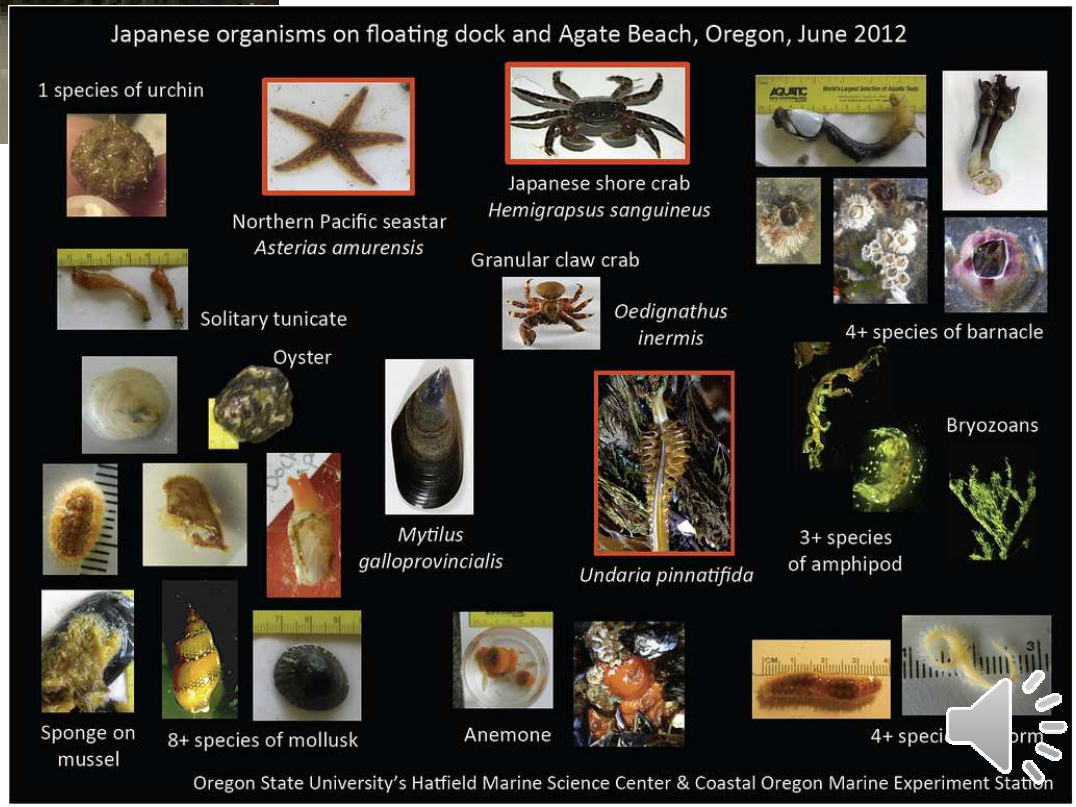
Jun 5, 2012:
Agate Beach, OR

Sep 17-19, 2012:
repeatedly reported by fishermen
north of Molokai.
Not found by the USCG.

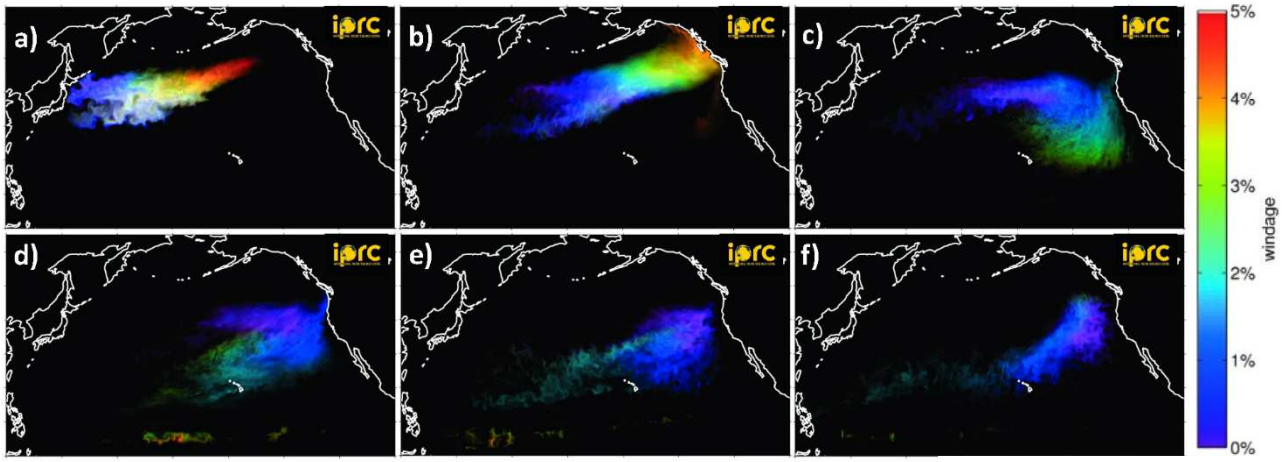
Dock #4 was never reported

Dozens of Asian species were found on all kinds of debris arriving in the North America and Hawaii, some have a potential of becoming invasive species.

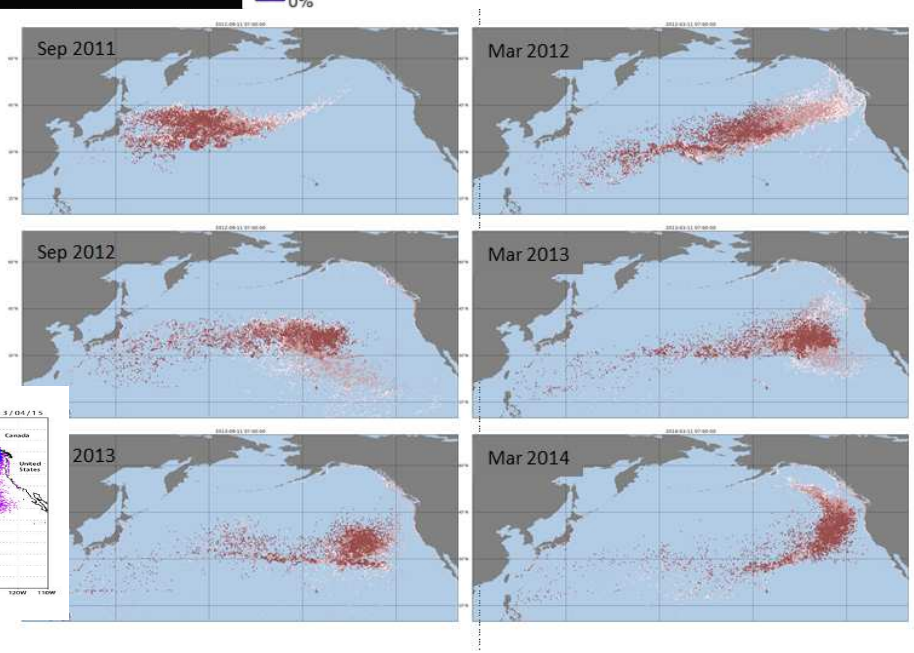
Japan Ministry of Environment sponsors a project, assessing risks to the US/Canada ecosystems from species, colonizing tsunami marine debris. The ADRIFT project is managed by PICES (North Pacific Marine Science Organization) and is now in year 2.
Modeling team includes UH, NOAA, and MRI.



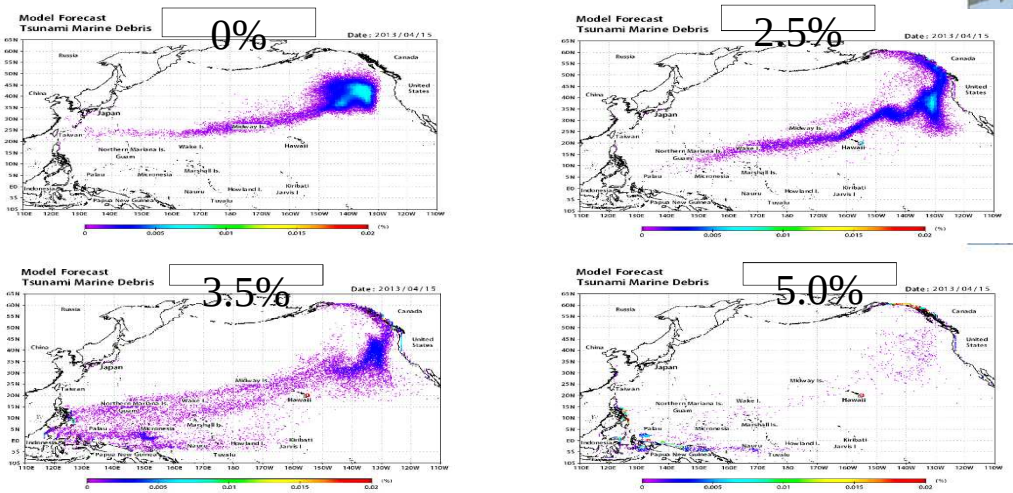
Model simulations used in the ADRIFT project



Motion of JTMD in SCUD model simulations. Colors indicate windage of the debris. Shown are maps for (a) September 1, 2011, (b) March 1, 2012, (c) September 1, 2012, (d) March 1, 2013, (e) September 1, 2013, and (f) March 1, 2014.

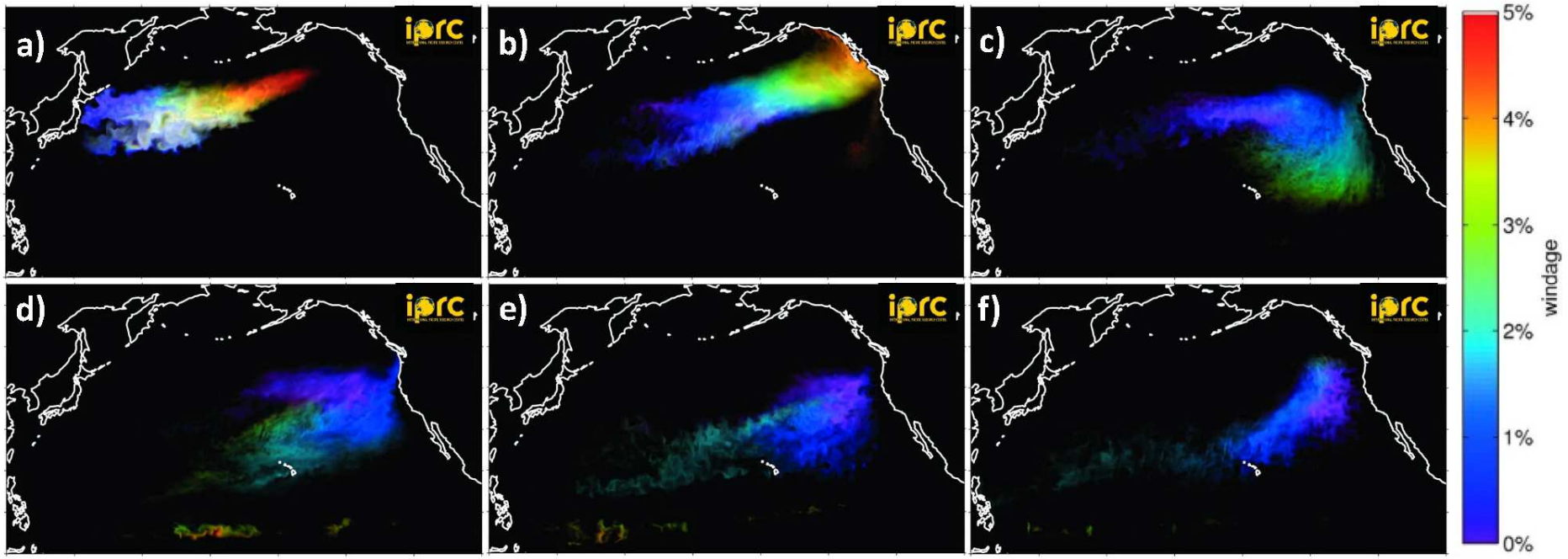


April 15, 2013 distributions of SEA-GEARN/MOVE-K7 model particles for four values of windage: 0, 2.5, 3.5, and 5%. Colors indicate concentration of particles on a computational grid.

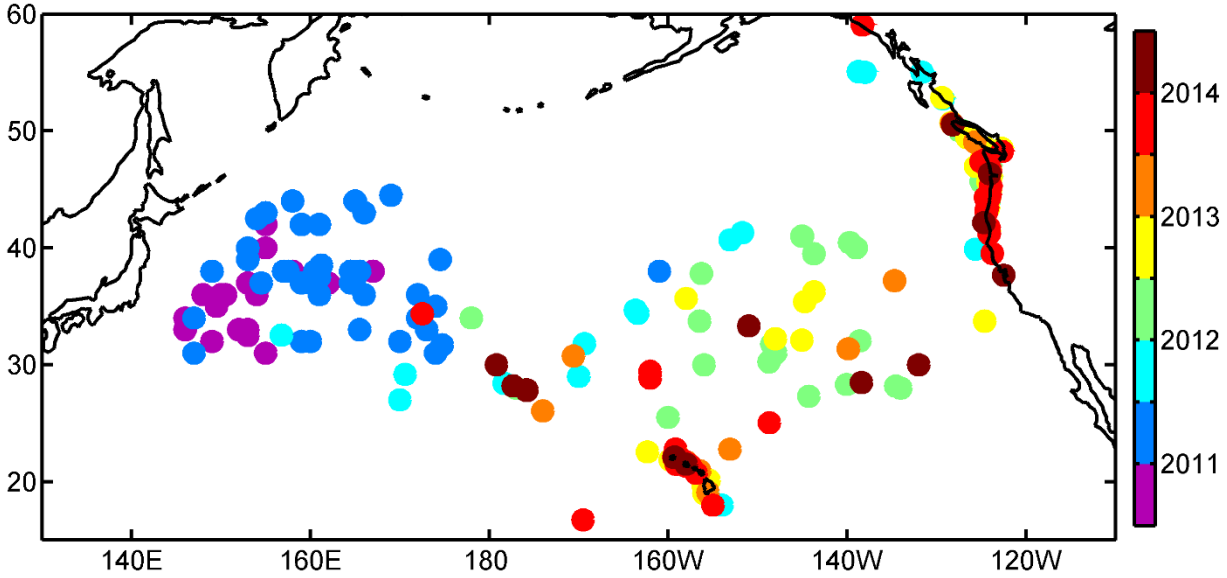


GNOME modeled particles simulate the movement of tsunami debris of varying types – from high windage objects like styrofoam (white) to low-windage objects like wood (red). These six panels show the distribution of the model particles every 6 months from September 2011 (6 m post-tsunami; top left) to March 2014 (3 years post-tsunami; bottom right).

Debris with different windages do not only move at different speeds –
– they have different destinations

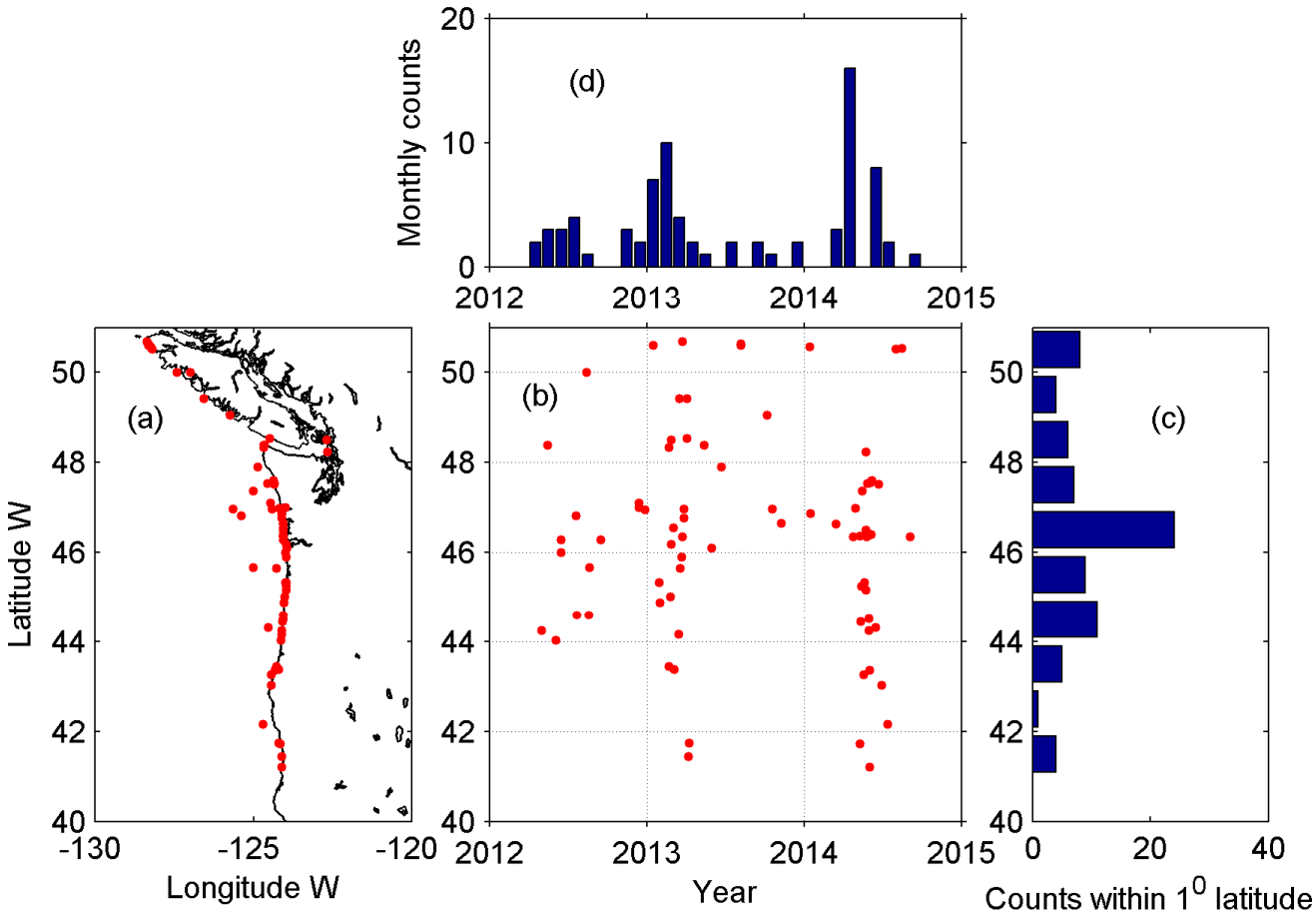


Motion of JTMD in SCUD model simulations. Colors indicate windage of the debris. Shown are maps for (a) September 1, 2011, (b) March 1, 2012, (c) September 1, 2012, (d) March 1, 2013, (e) September 1, 2013, and (f) March 1, 2014.

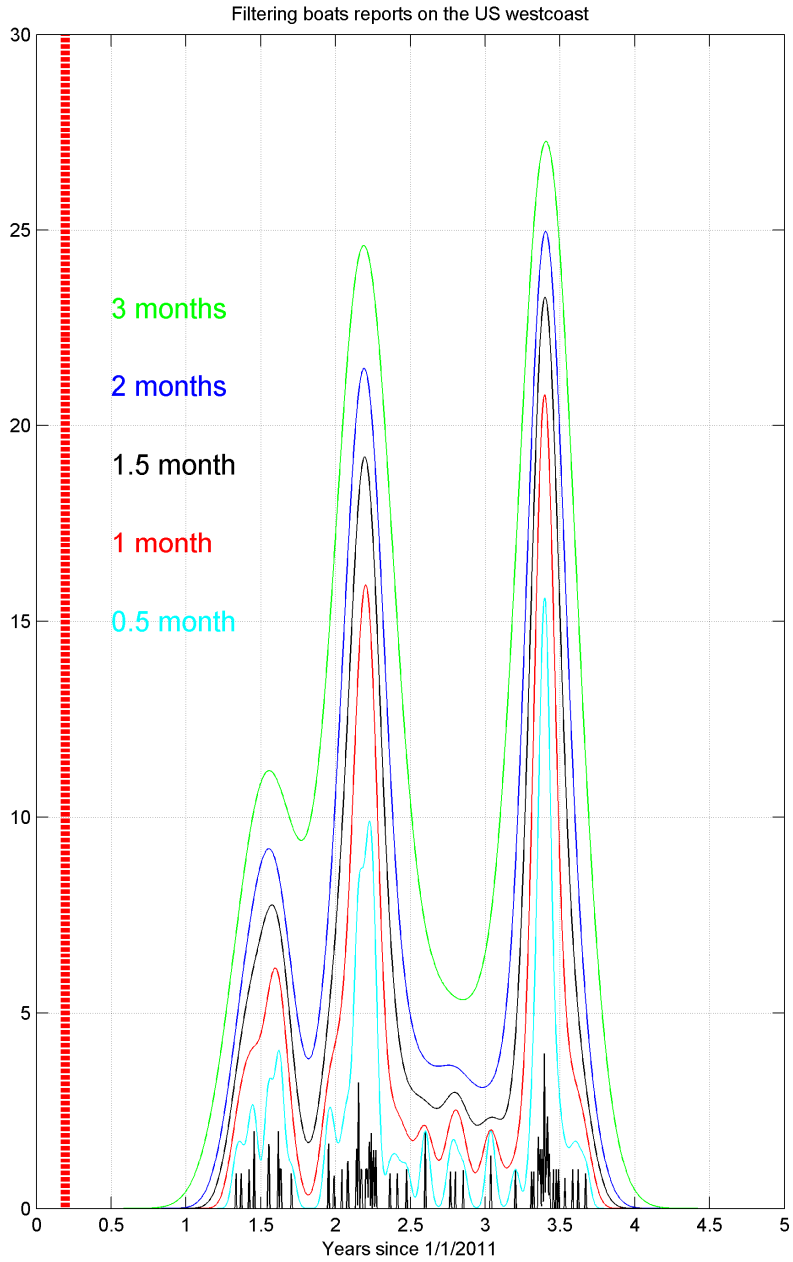


277 reported locations of boats/skiffs/ships and (colors) times of the reports. Color bar spans January 2011–December 2014 and labeled ticks mark central moments of the years.

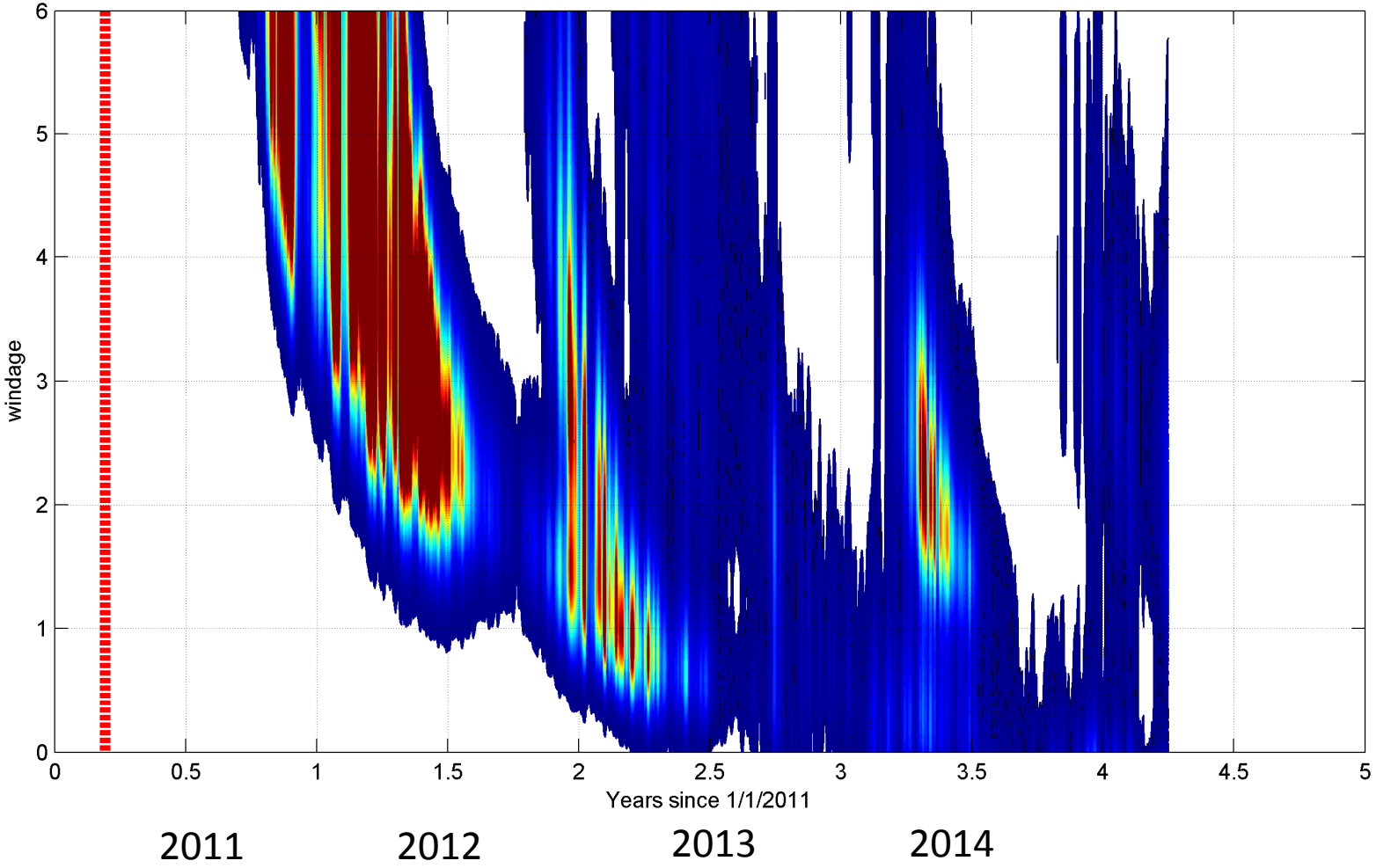
Problem is that “clean” regions are never reported.



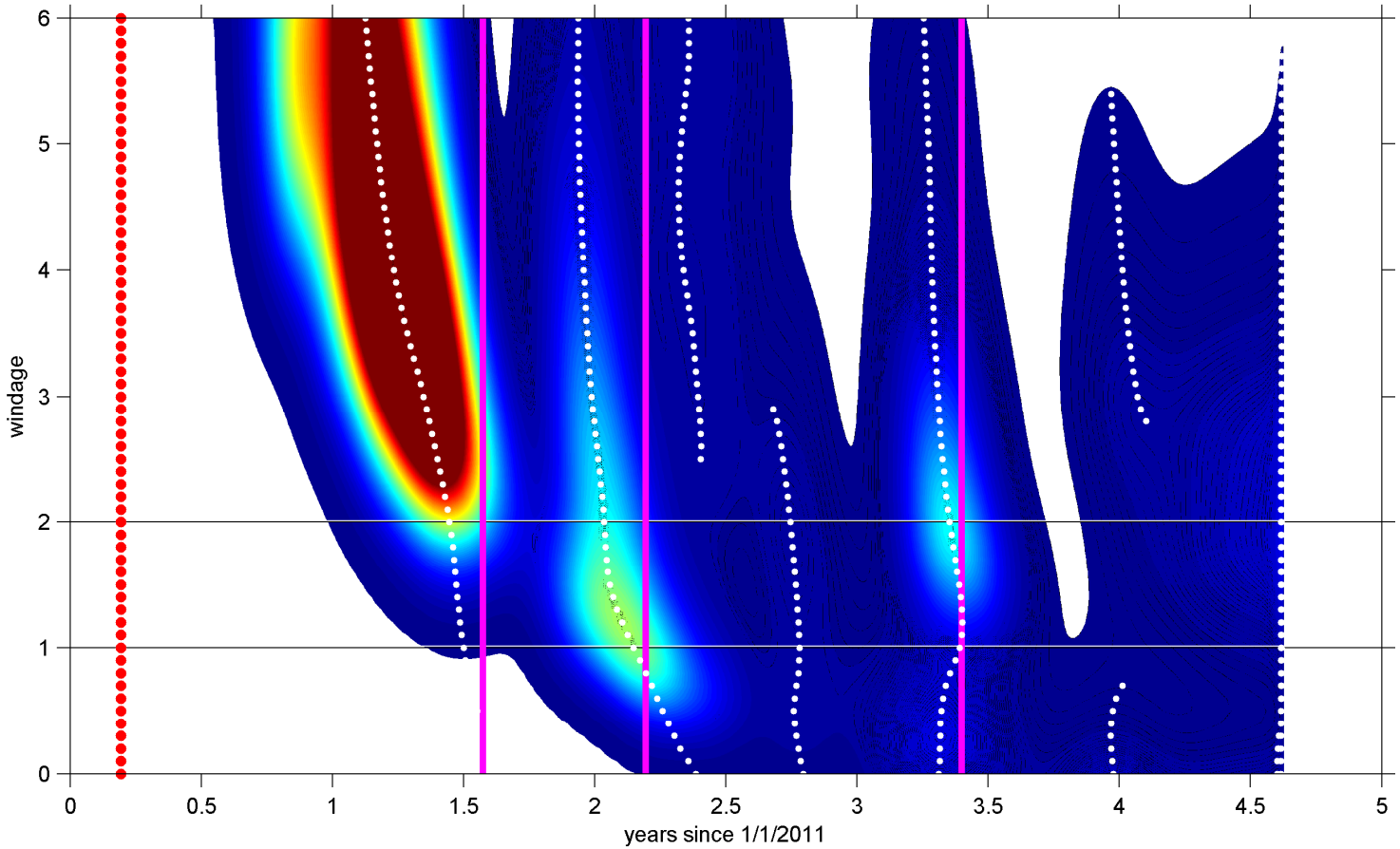
Latitude-time distribution of 79 boat reports on the US/Canada west coast



Monthly boat reports from the US/Canada west coast and smoothed indices.



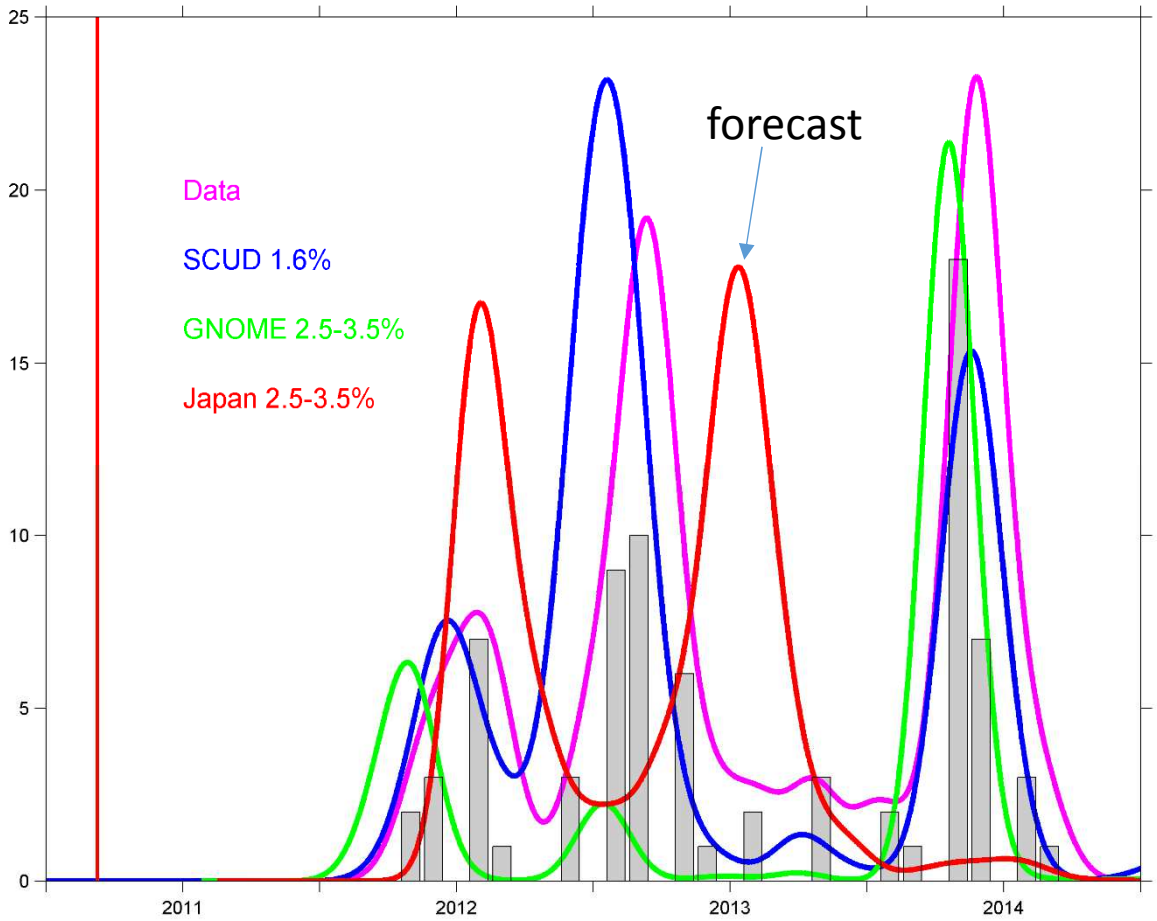
Timelines of SCUD model fluxes on the US/Canada west coast for a range of windages.



2011 2012 2013 2014

Timelines of SCUD model fluxes on the US/Canada west coast for a range of windages.

Low-pass filtered in time.



Monthly counts of boats on the U.S./Canada west coast (gray bars) and low-pass filtered timelines of boat fluxes in observations (magenta) and model experiments with different windages: 1.6% for SCUD (blue) and 2.5–3.5% averages for GNOME (green) and SEA-GEARN/MOVE-K7 (red). Vertical red line marks March 11, 2011. Units on y-axis are boat counts for monthly reports and conventional for other timelines.

Conclusions based on model-data comparison

1. All three models capture peaks in JTMD flux on the US/Canada west coast but not all reproduce successfully magnitudes of the peaks.

2. IPRC model, providing best correspondence, suggests that:

- About 1000 boats were originally released by the 2011 tsunami.

Consistent with this estimate, on November 16, 2011, the Japan Coast Guard detected 506 skiffs/vessels, drifting off the devastated shoreline.

- Approximately 700 boats are still floating in the “garbage patch”

and will continue washing ashore in the next several years.

Summary (1)

- Our study demonstrates that present marine debris observing system is not capable of monitoring the driftage even if the latter comes in millions of tons.
- At the same time, our study provides cautious optimism on feasibility of a simple observing system in some regions and for some types of marine debris.
- Japanese boat reports from the US/Canada west coast provide a unique opportunity for the model calibration/validation even though their windage is not constant.

Boats drifting at different windages

Examples of JTMD boat orientation in water (from left to right): normal, upright but filled with water, upside down, and vertical. (Photographs courtesy of the Japan Coast Guard: [http://www.kaiho.mlit.go.jp/info/kouhou/jisin/20110311miyagi/hyouryuu.htm)](http://www.kaiho.mlit.go.jp/info/kouhou/jisin/20110311miyagi/hyouryuu.htm)

Summary (2)

Main problems of the modeling of the drift of marine debris are associated with:

- the lack of observations of surface currents
- incomplete or incorrect description of the wind-driven mixed layer currents by models and theories
- vague understanding of the hydrodynamics or the object on the ocean surface, interacting with wind and waves
- rudimentary state of the marine debris observing system