Workshop on Mission Concepts for Marine Debris Sensing
Honolulu, Hawaii, January 19-21, 2016

Using disaster debris data to train dynamical models

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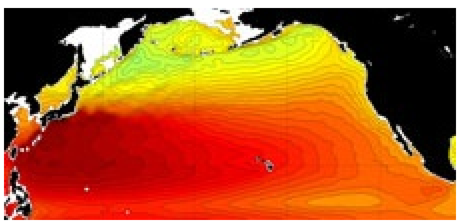
- University of Hawaii: *Gisela Speidel, Kin Lik Wang, Christina Curto*
- NOAA: *Nir Barnea, Peter Murphy, and Lexter Tapawan*
- many contributors to the dataset.

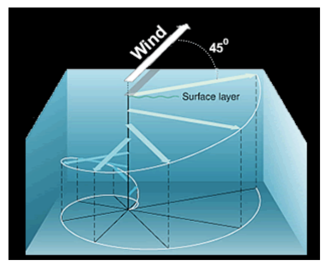
Drift Models of marine debris

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

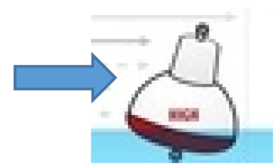
Geostrophic currents (non-local dynamics)



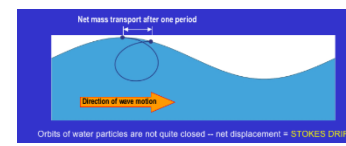
Wind-controlled currents



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 (from models) + A(windage)*Wind (from satellites or models)

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

Both are not well known

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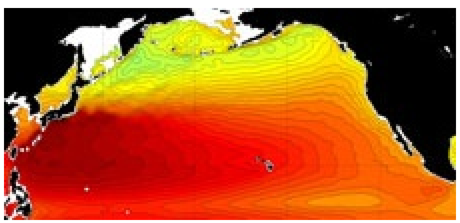

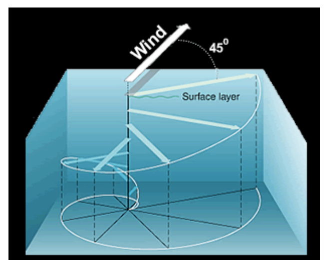

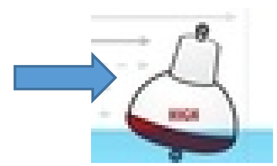

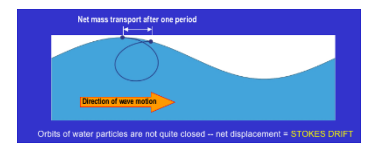

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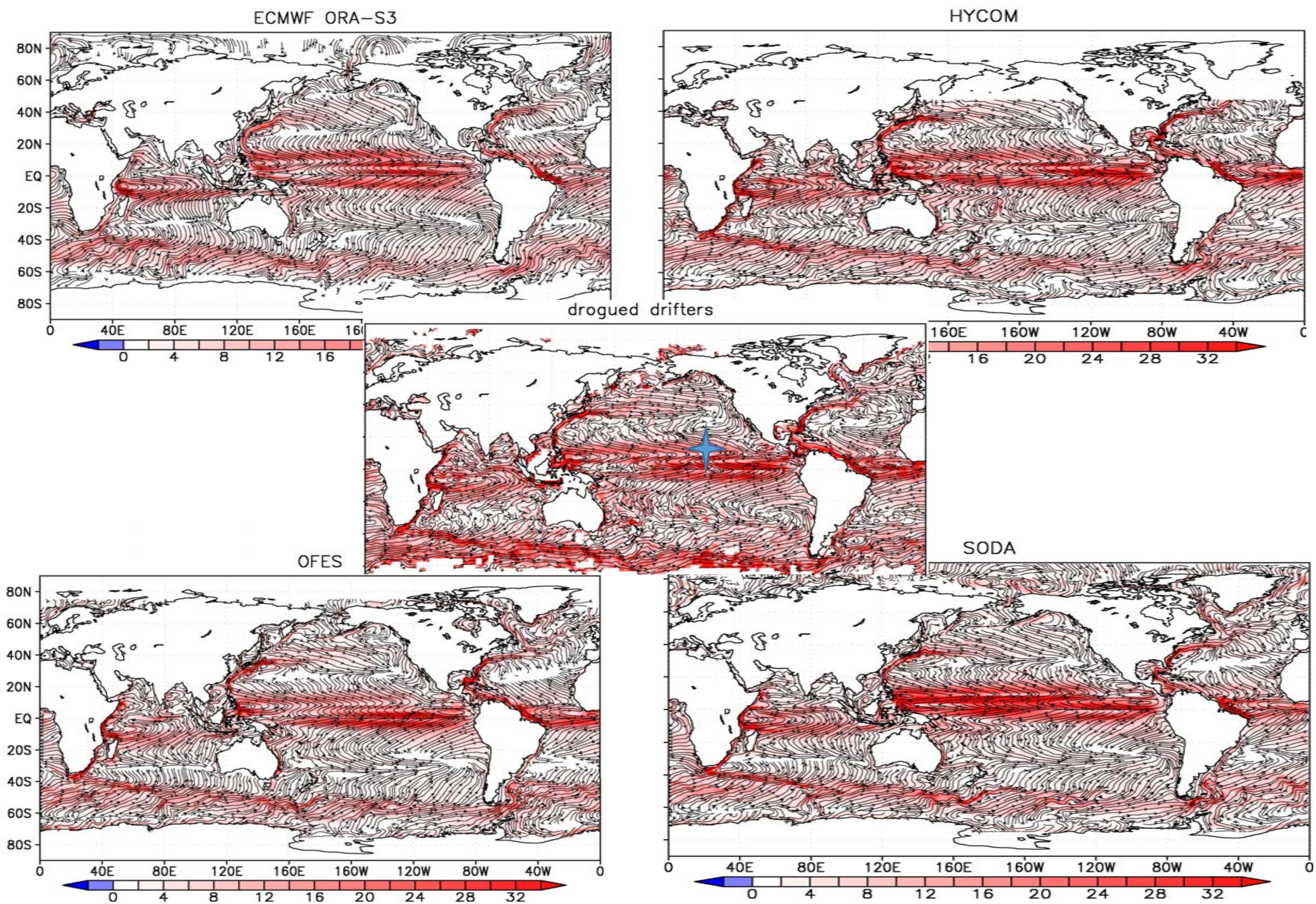
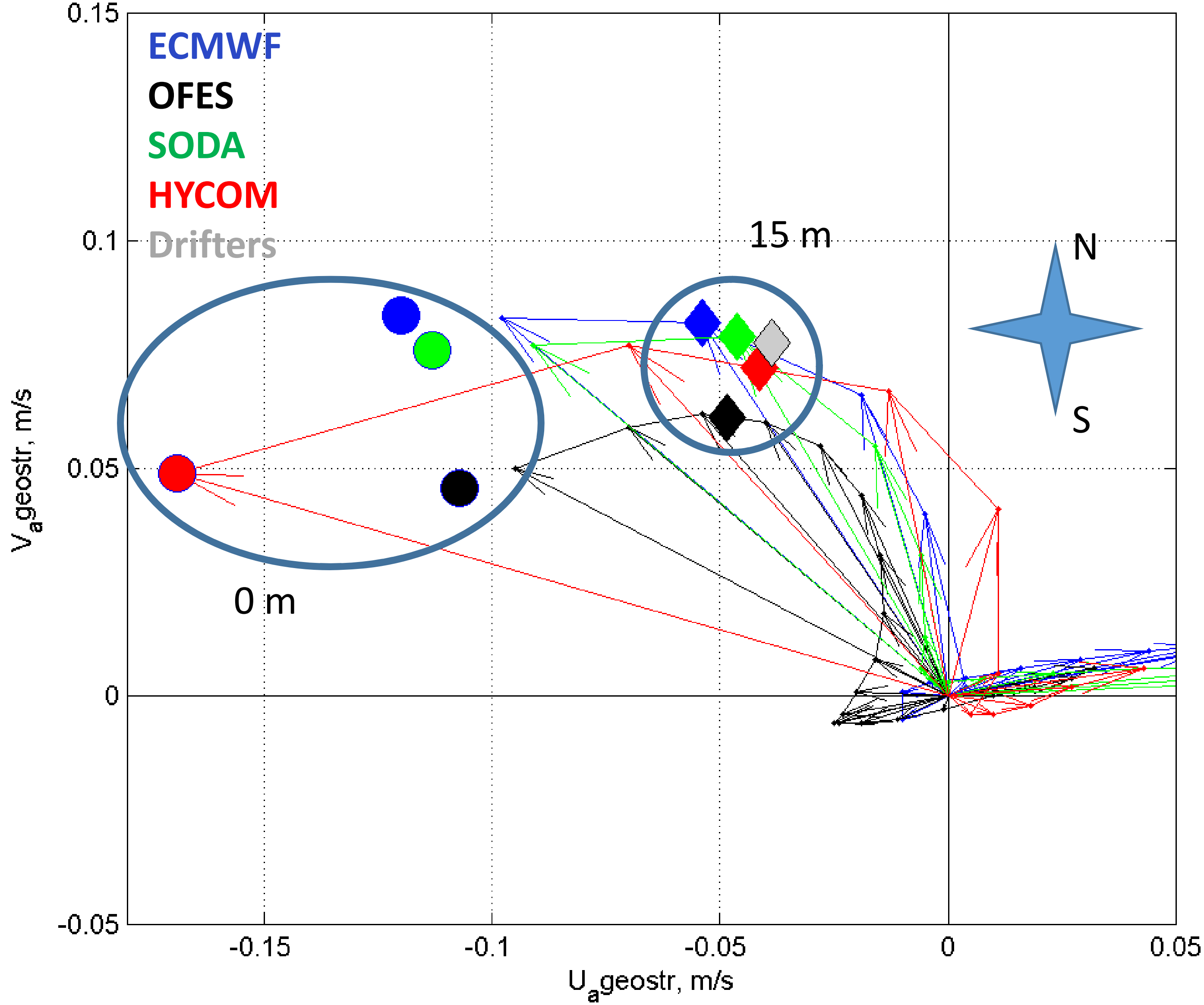
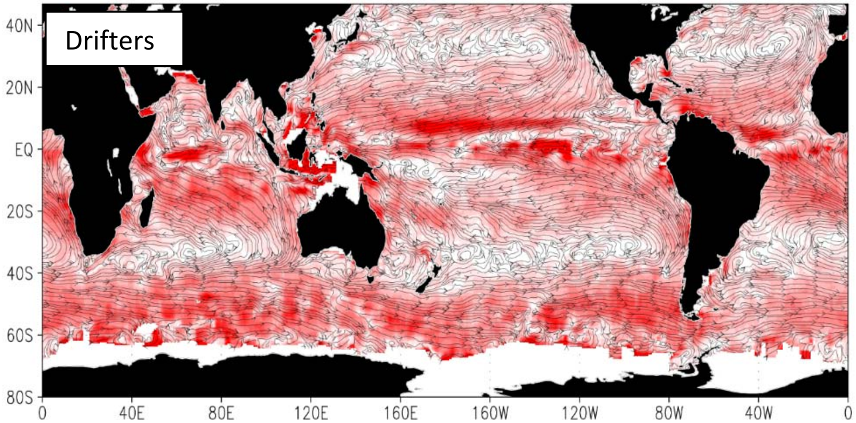
Time-mean currents at 15 meters level in different models

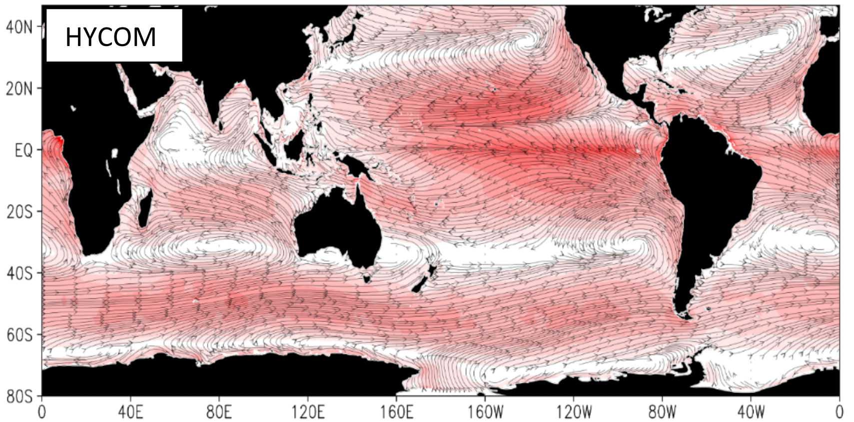


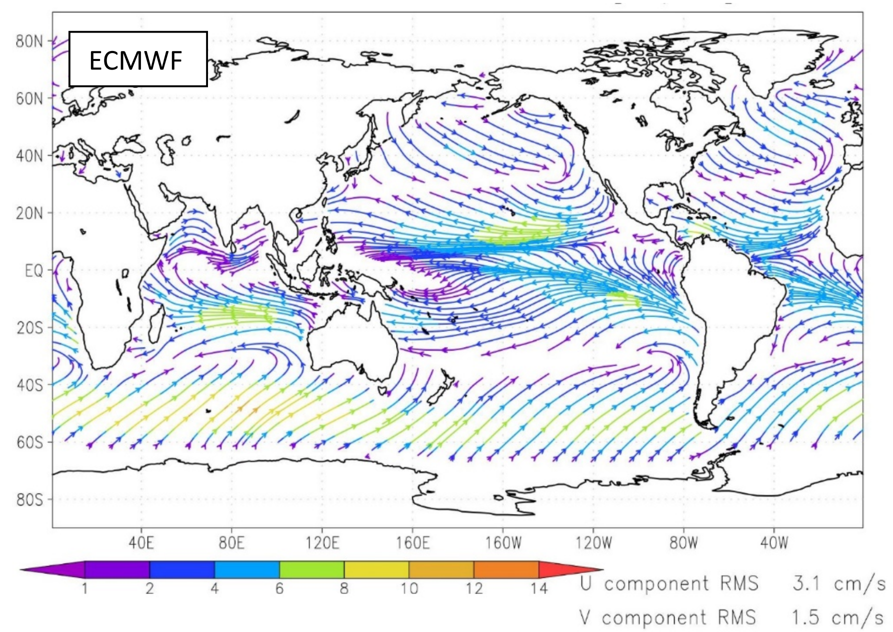
Mean Ekman spirals in the Tropical North Pacific (15N, 140W)



Mean velocity shear between 0 and 15 m depth







Unknown or misrepresented physics of wind driven currents produces systematic biases.

In addition, mixing, unresolved processes and stochastic processes produce uncertainties.

Malaysian Airlines Flight MH370 estimated path on March 8, 2014

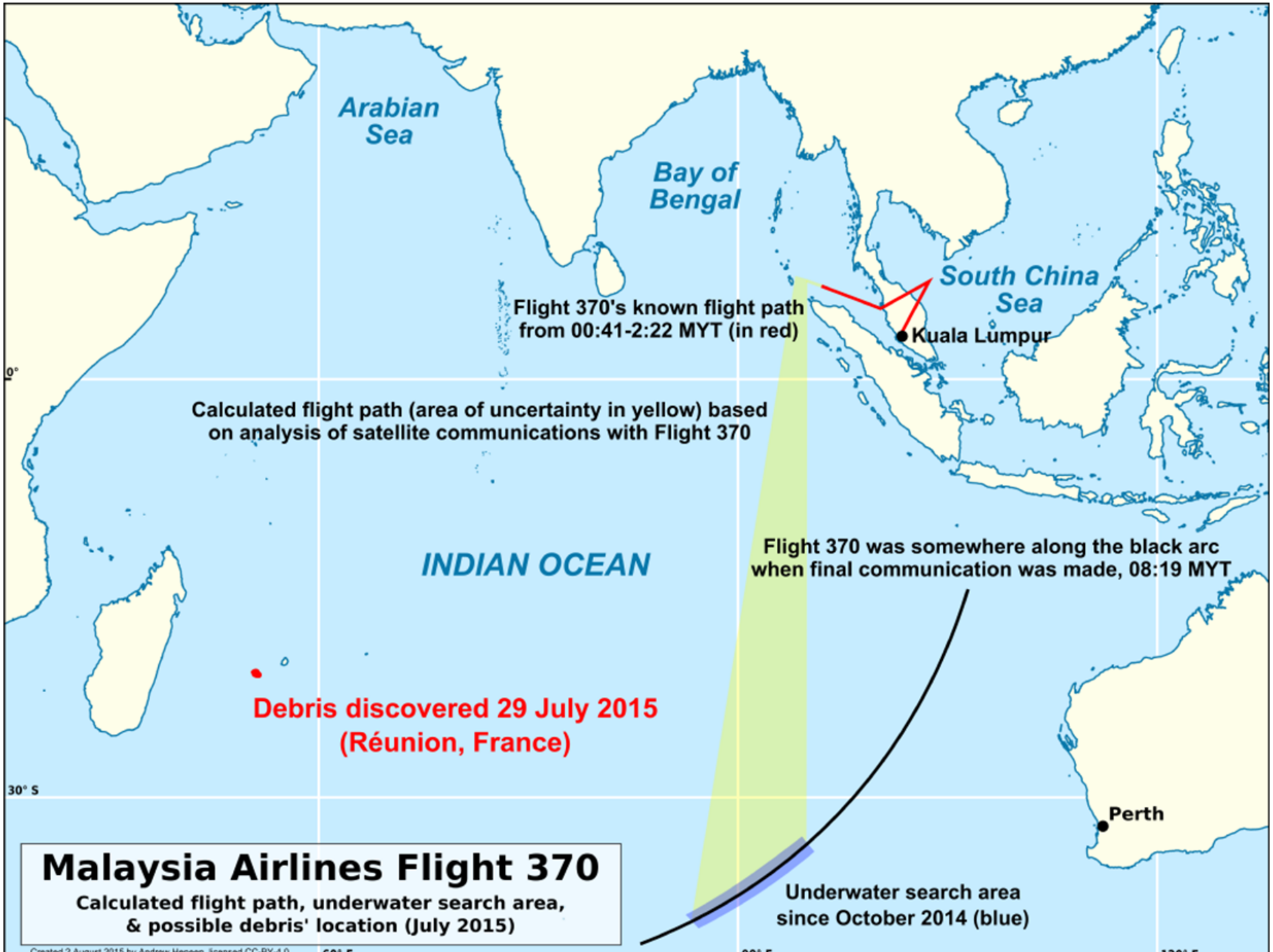
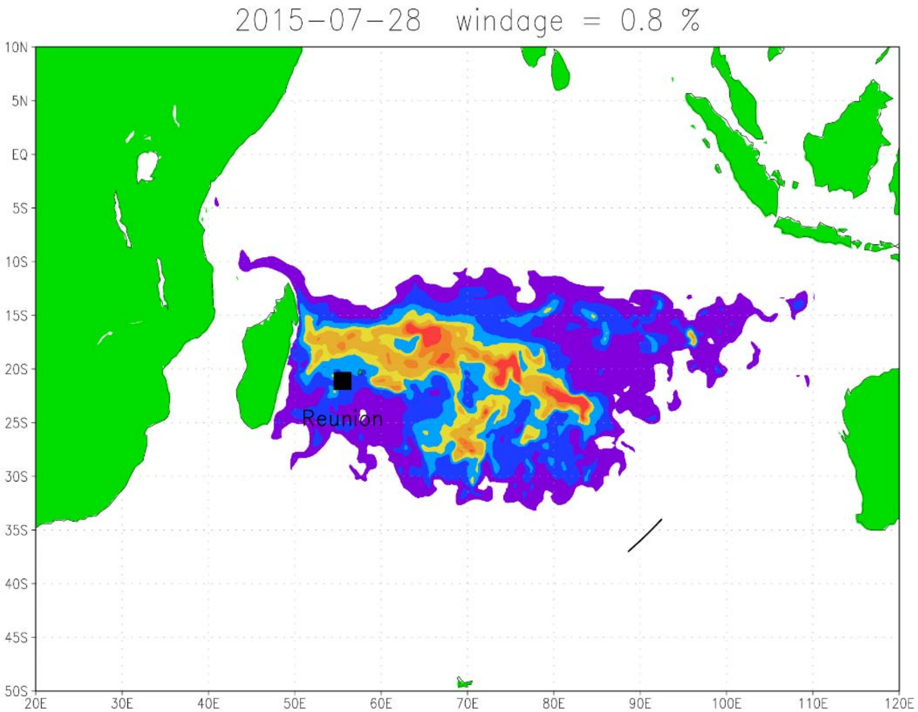


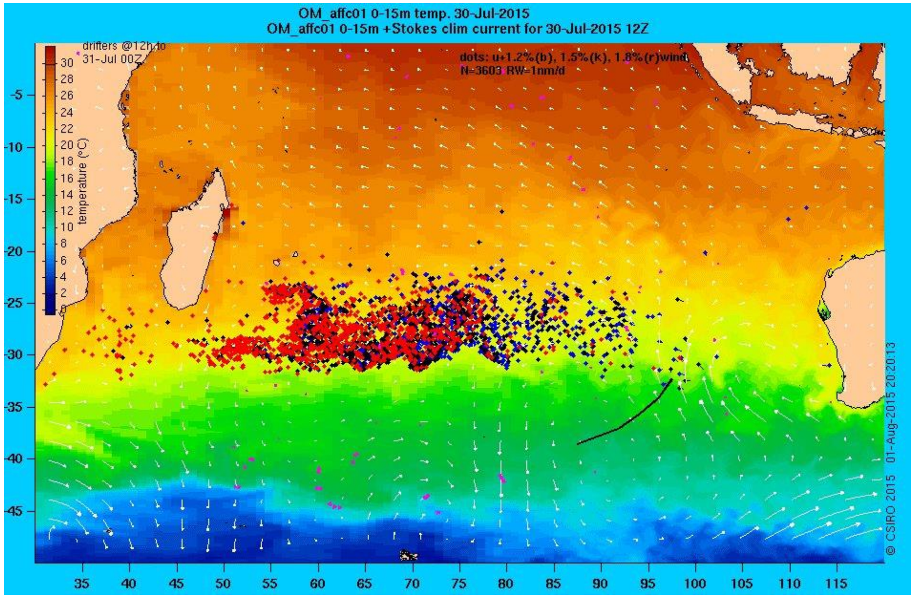
Image source: Andrew Heneen on Wikipedia

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.

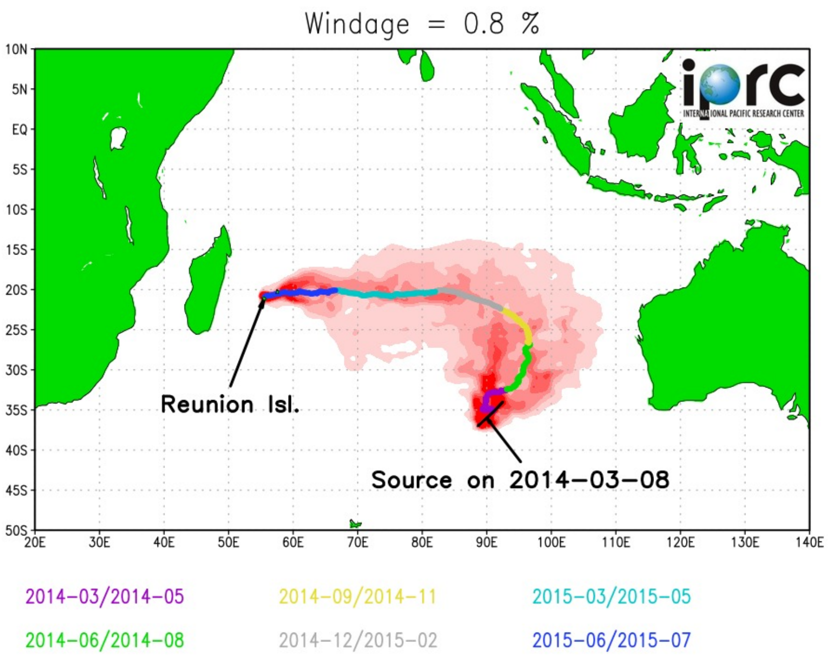
Figure shows the indicative drift of debris from the search area as at 30 July.

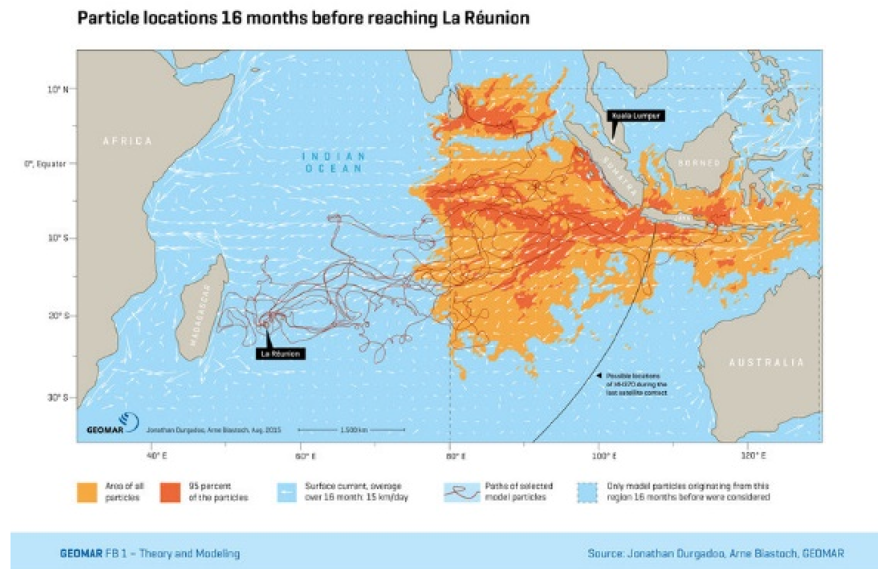
Blue, black and red dots simulate items with leeway factors (applied to the 10m wind velocity) of 1.2, 1.5 and 1.8%. The items originated along the black arc (7th arc) on 8 March 2014. White arrows are the winds for the day shown.

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.

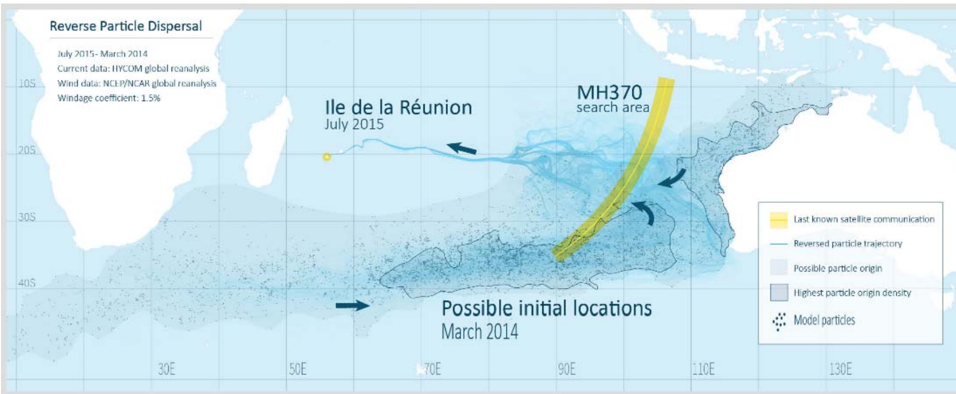
Flaperon backtracking by Geomar (Germany) group

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

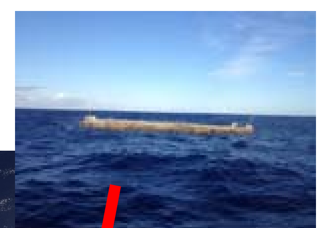
Examples of potential tsunami marine debris from or near Hawaii

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

Apr 5, 2013:
Olympic Coast

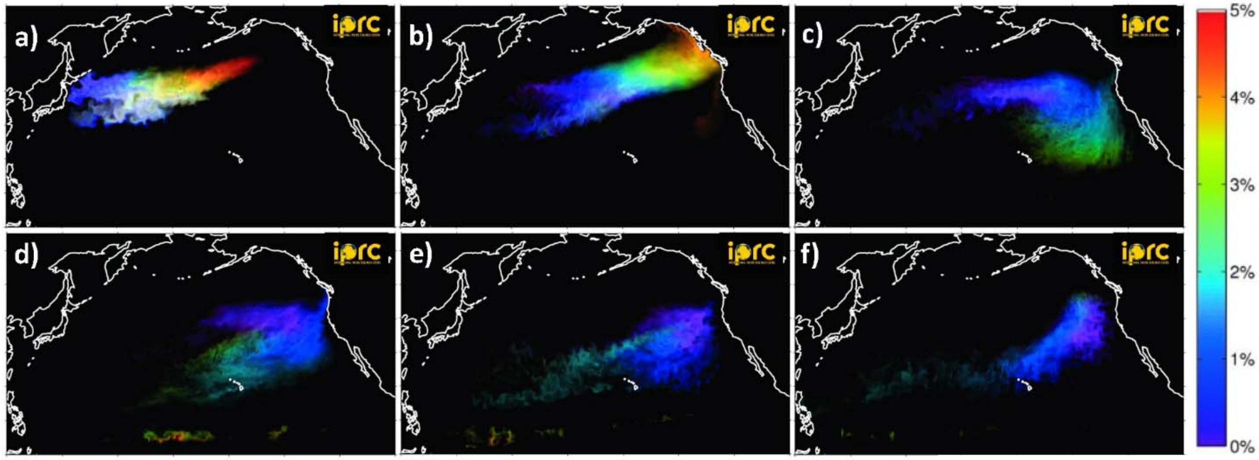
Jun 5, 2012:
Agate Beach, OR

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

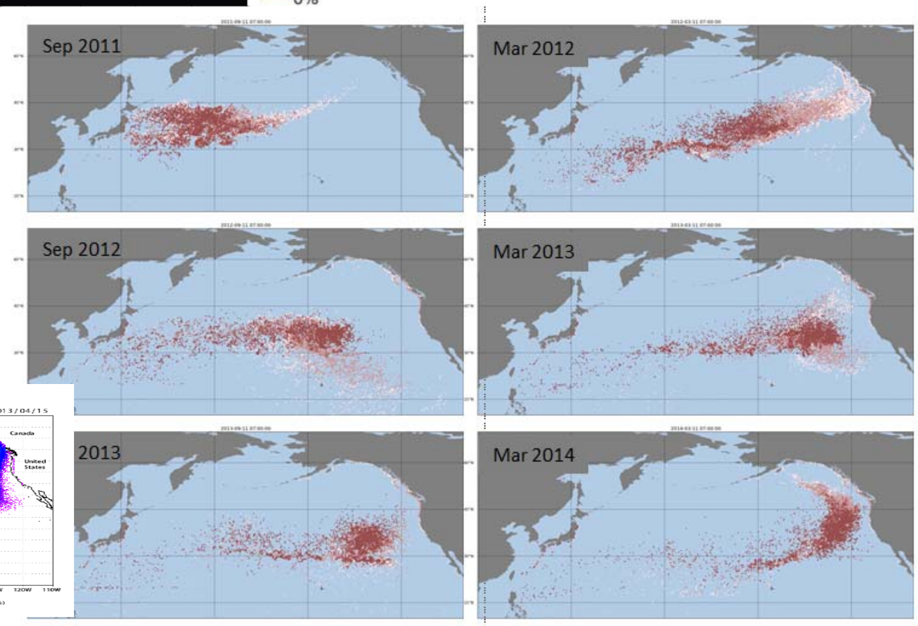


Dock #4 was never reported

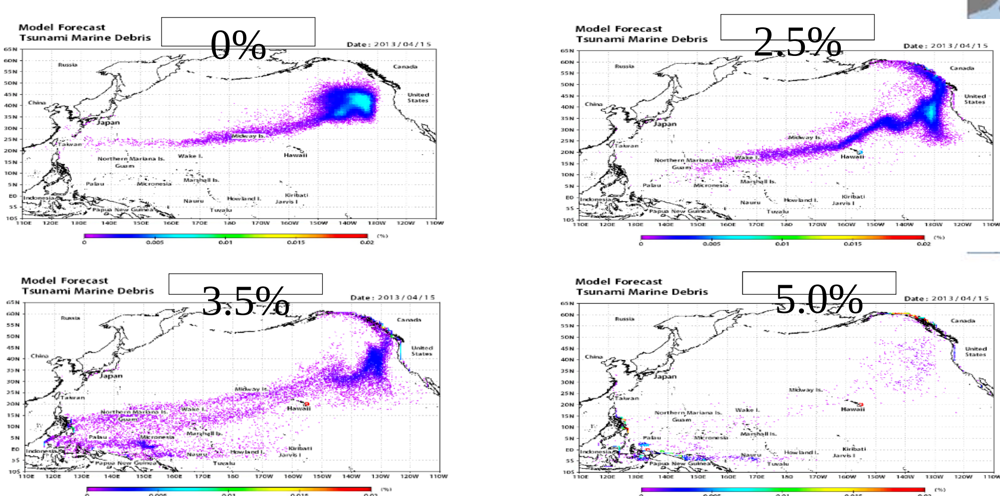
Model simulations used in the ADRIFT project



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.

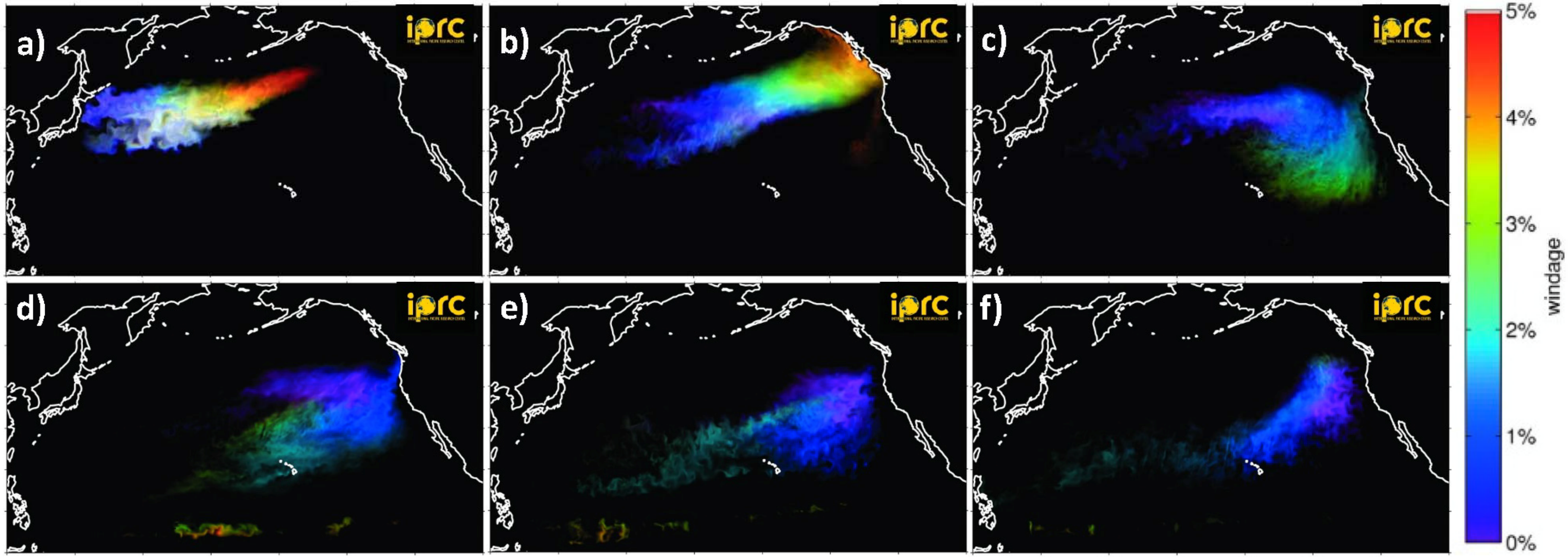


April 15, 2013 distributions of SEA-GEARN/MOVE-K7 model particles for four values of windage: 0, 2.5, 3.5, and 5%. Colors indicate concentration of particles on a computational grid.



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 months 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



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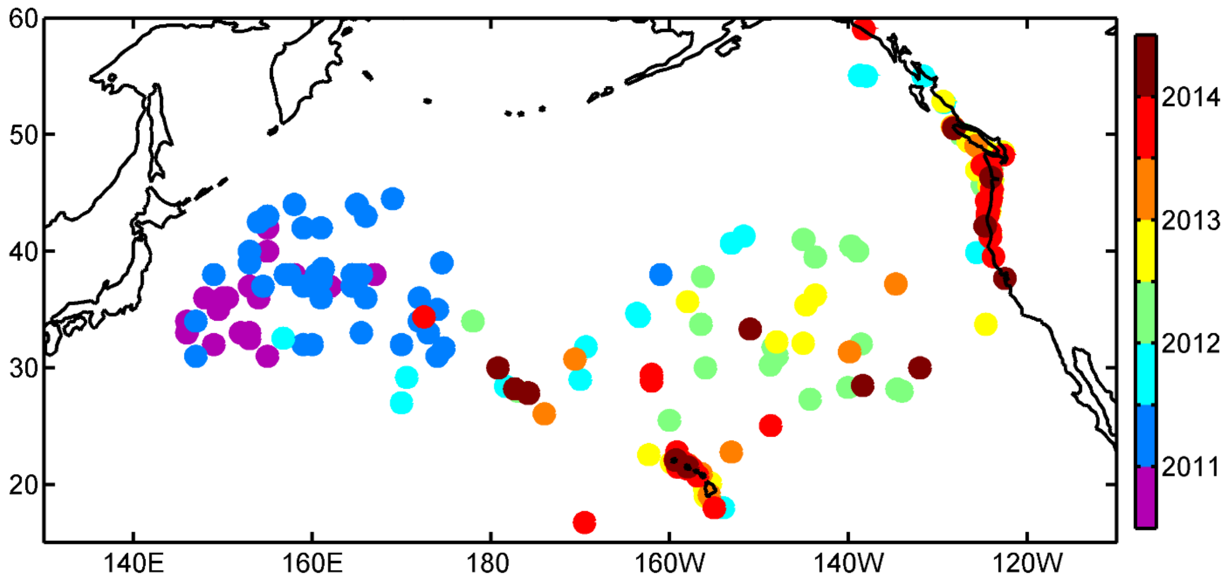
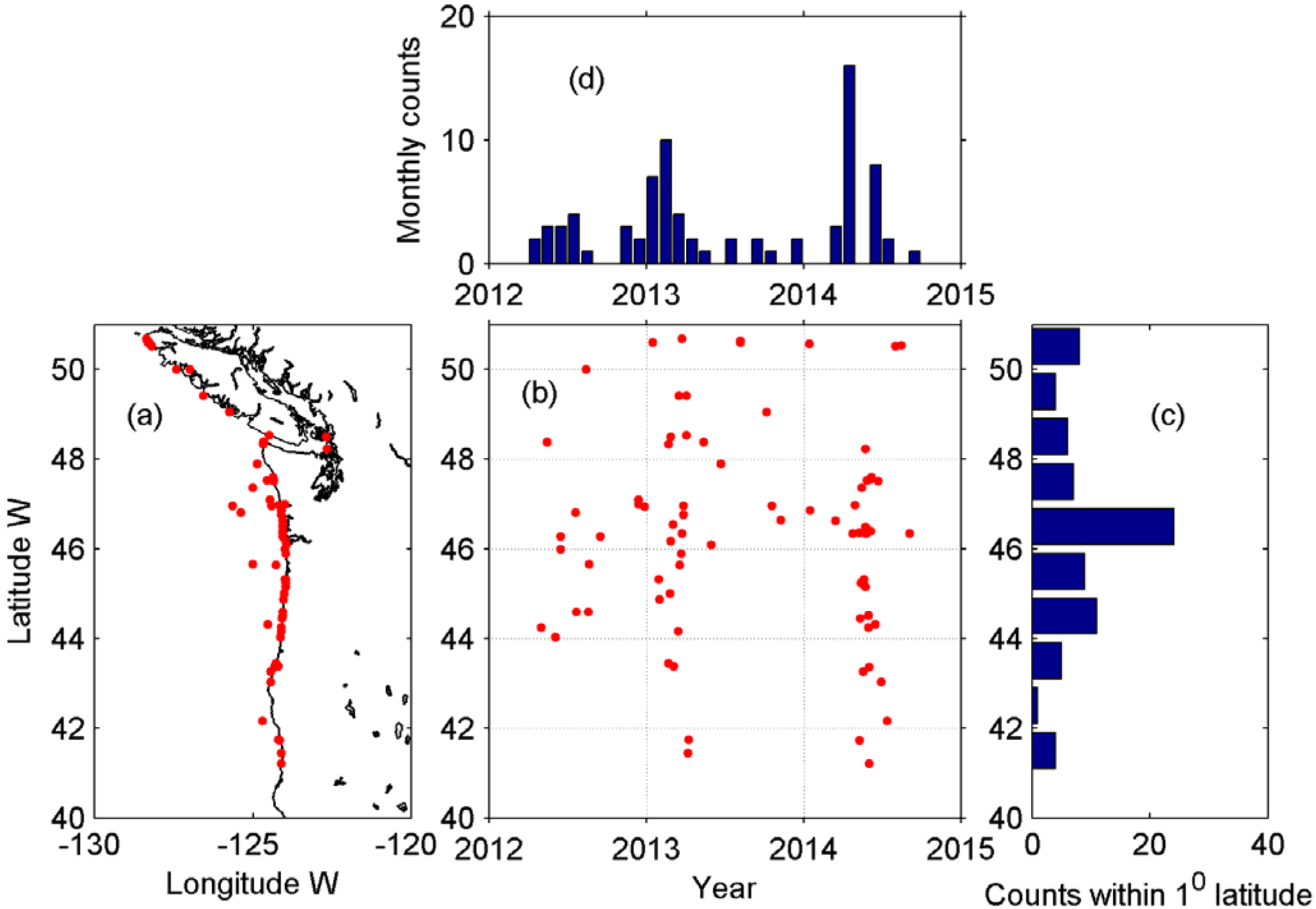
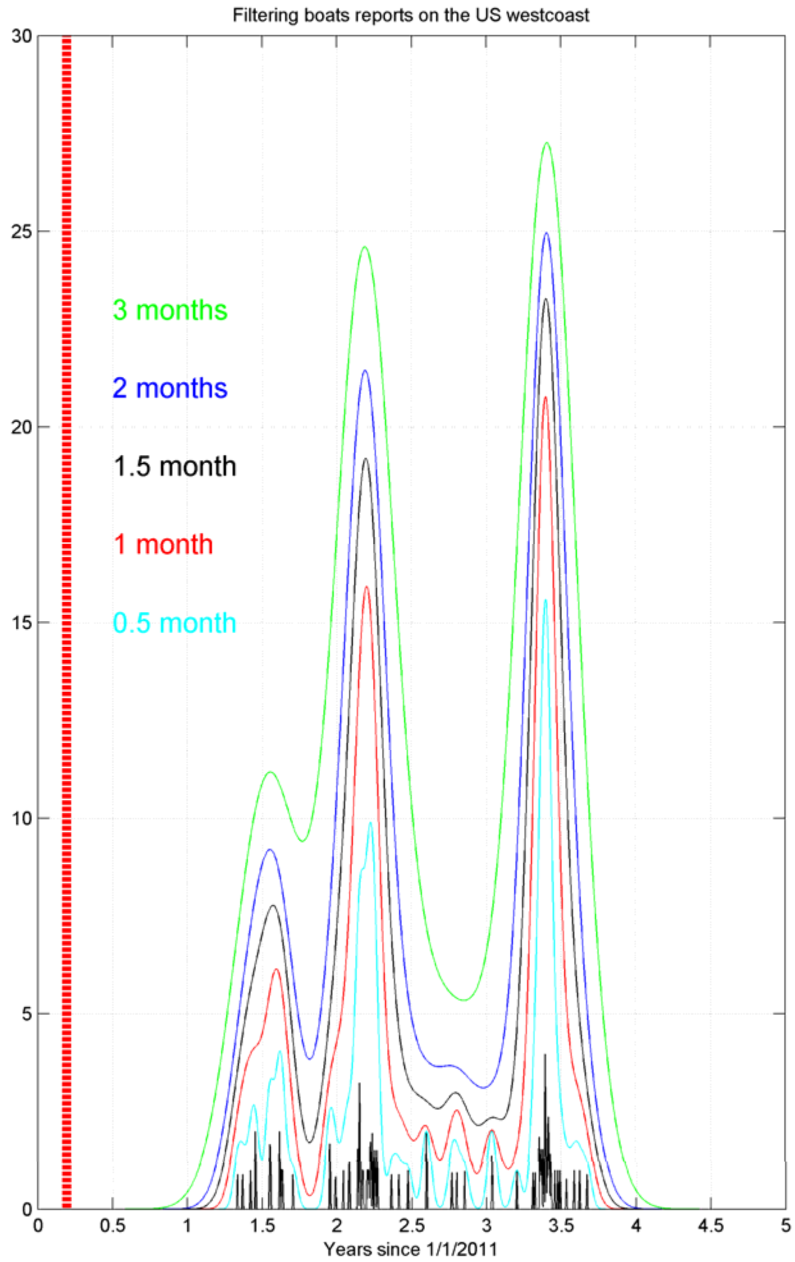


277 reported locations of boats/skiffs/ships and (colors) times of the reports. Color bar spans January 2011–December 2014 and labeled ticks mark central moments of the years.

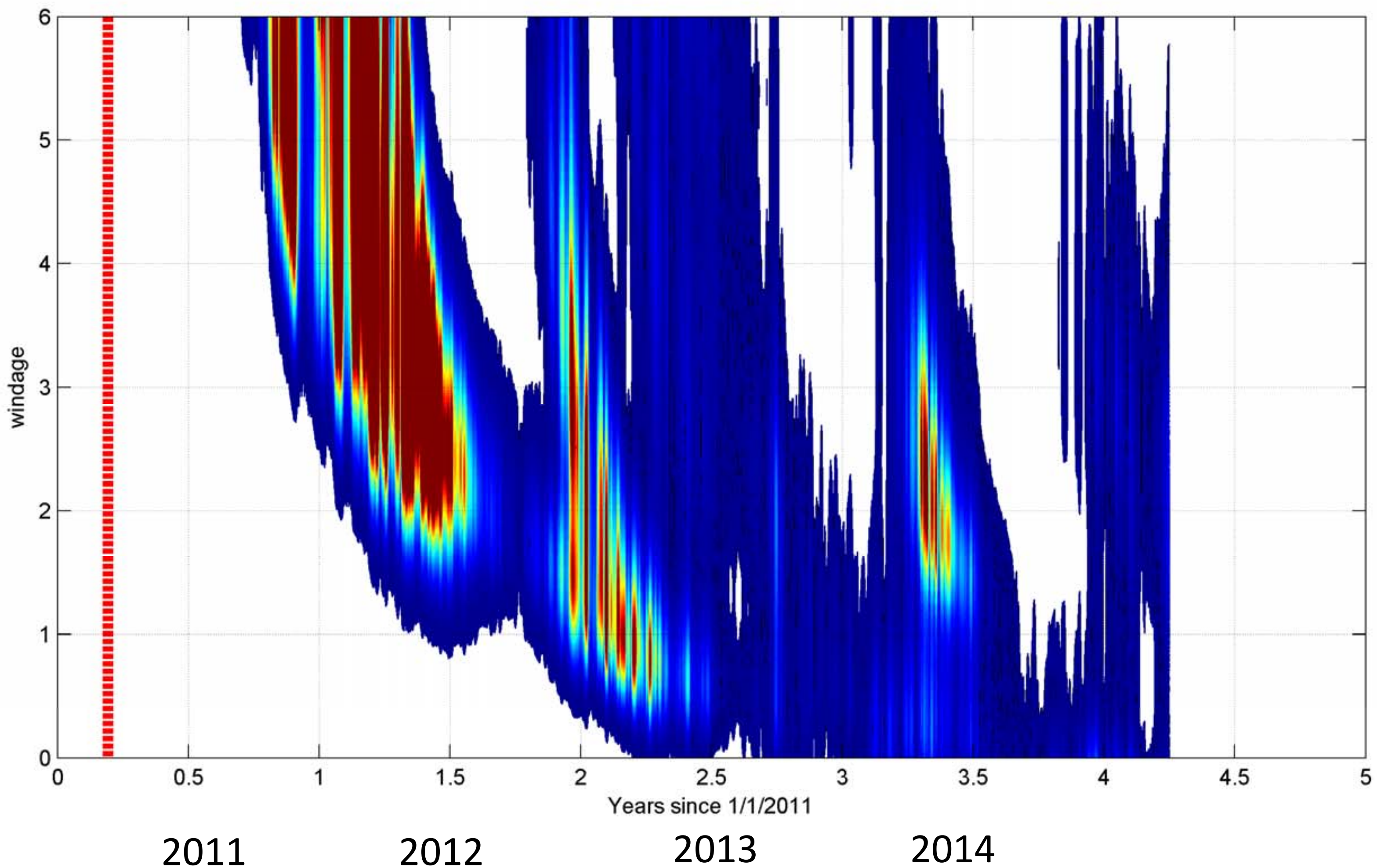
Problem is that “clean” regions are never reported.



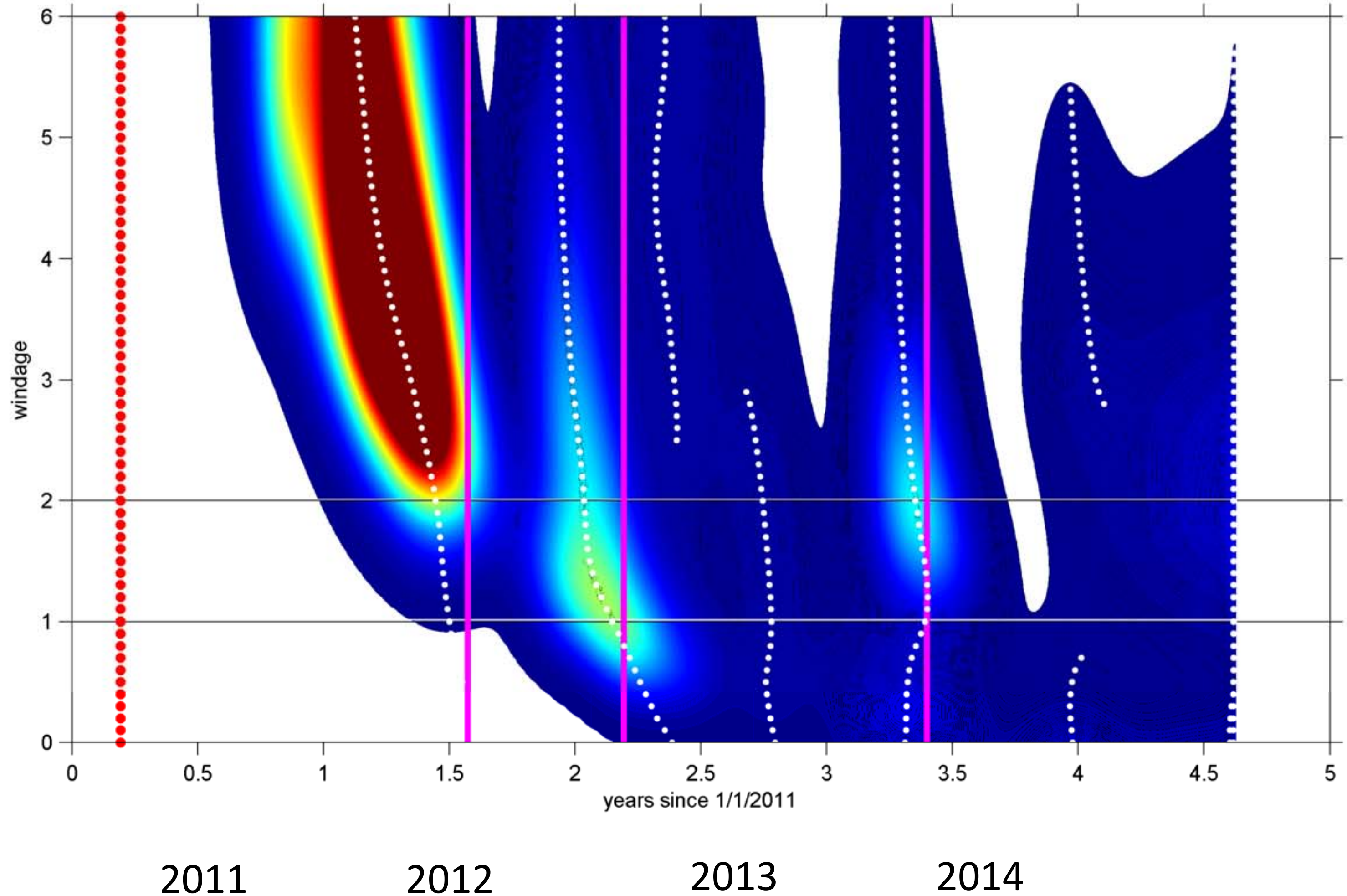
Latitude-time distribution of 79 boat reports on the US/Canada west coast



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.



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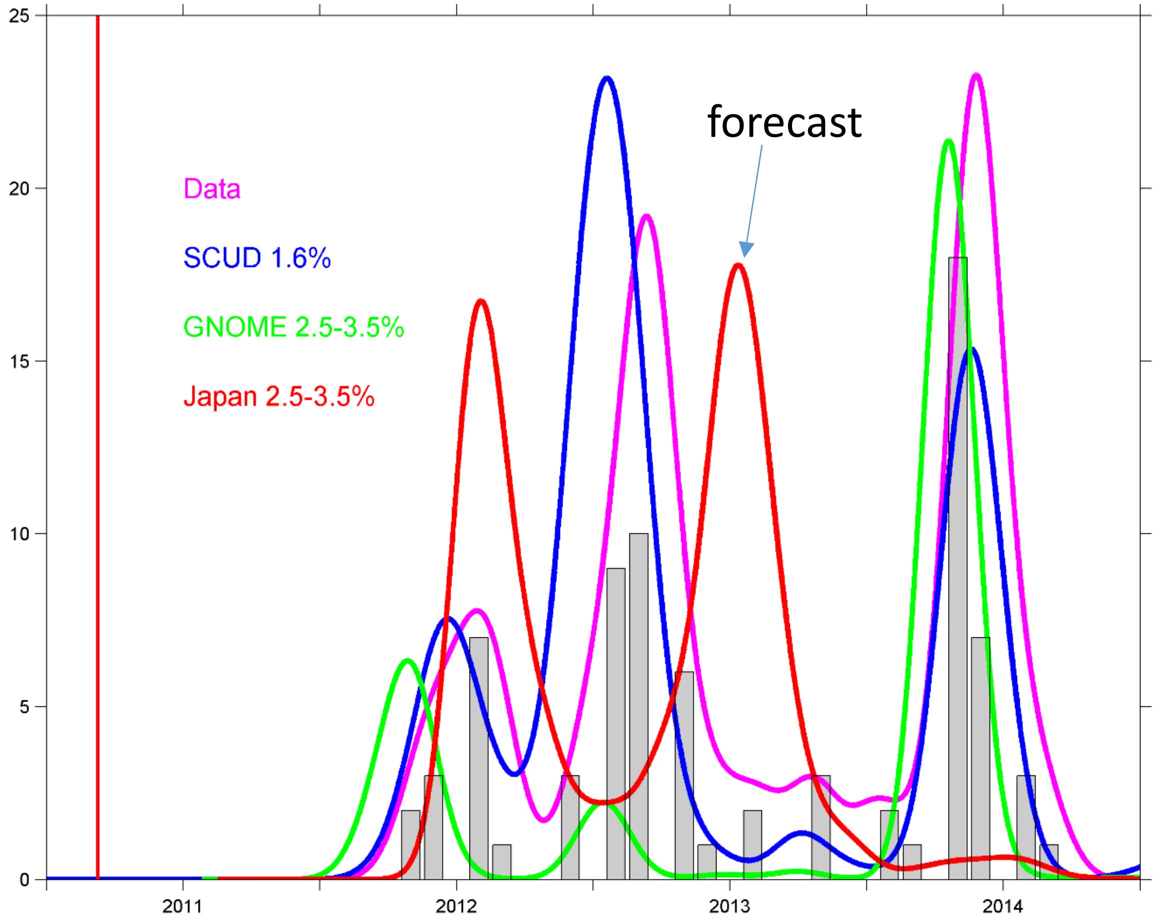
Low-pass filtered in time.



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.

This quantitative estimate was obtained due to sufficient number of boat data and their correlation over large distances.

Generalization worked well even though windage of individual boat was varying largely depending on the boat orientation in water.




But how useful are data and models in case of a single item?

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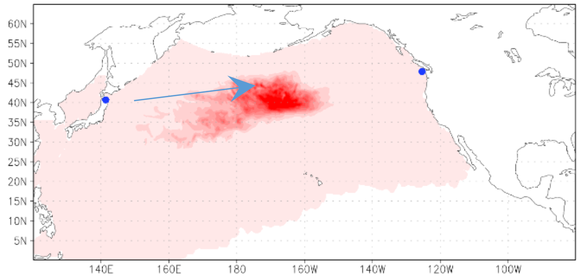
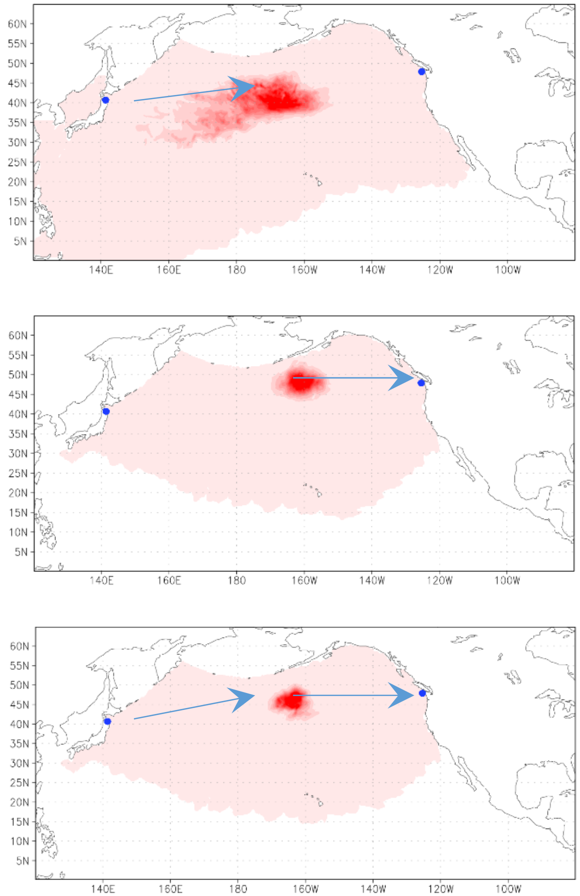
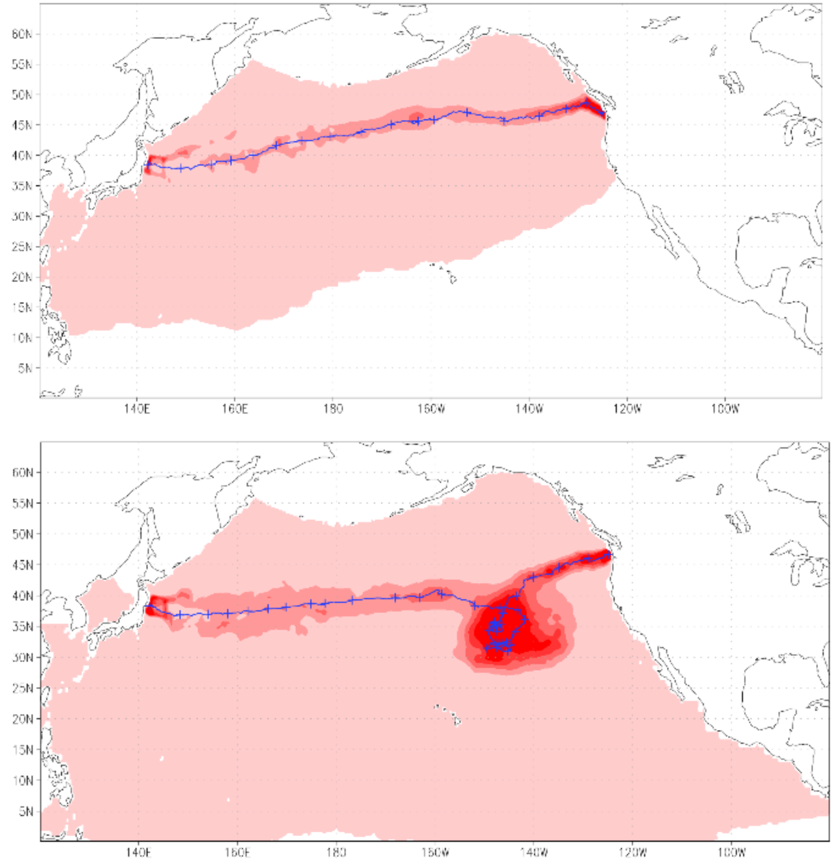


IPRC study of the drift of potential debris from MH370 is based on a new technique developed to estimate most probable pathways of floating object between known origin and destination

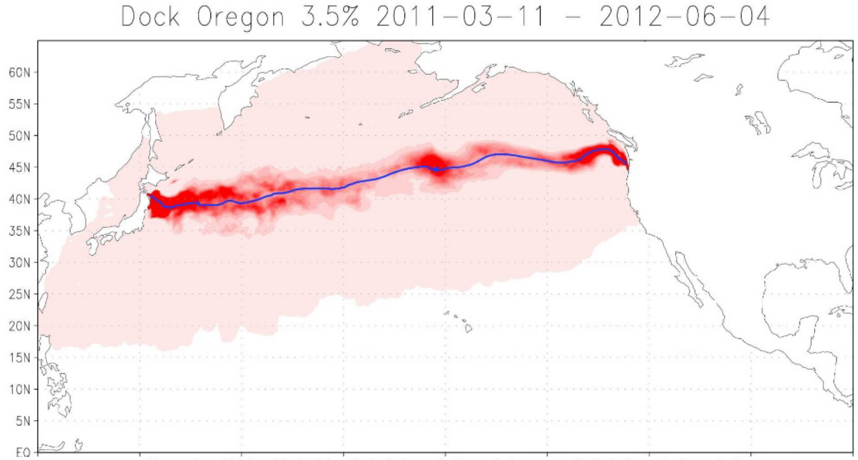


PDF's of particle locations on January 1, 2012 for the particles that: (left) started from Japan on Mar 11, 2011, (left bottom) ended in Washington state on Aug 15, 2012, and (below) started from Japan on Mar 11, 2011 and ended in Washington state on Aug 15, 2012. Note how fixing start and end points (blue dots on the maps) and times reduced uncertainty at intermediate times).

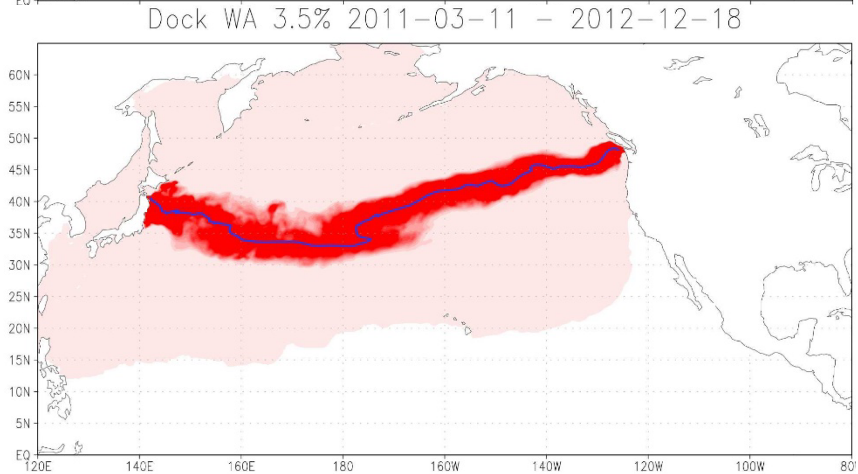


Probable pathways of two particle with the same start points and start time (Japan, March 11, 2011) but arriving on the Washington coastline nearly two years apart (August 15, 2012 and May 15, 2014). Saturated red colors show locations visited by the particles at higher probability. Blue lines connect most probable locations on monthly maps. Note that slower particle takes more southern route and spends significant time in the "garbage patch" area.

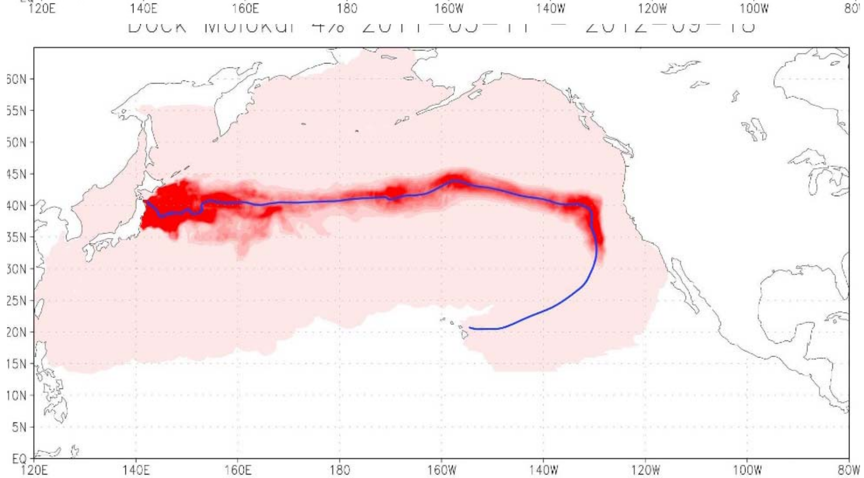
Misawa docks found:



In Oregon



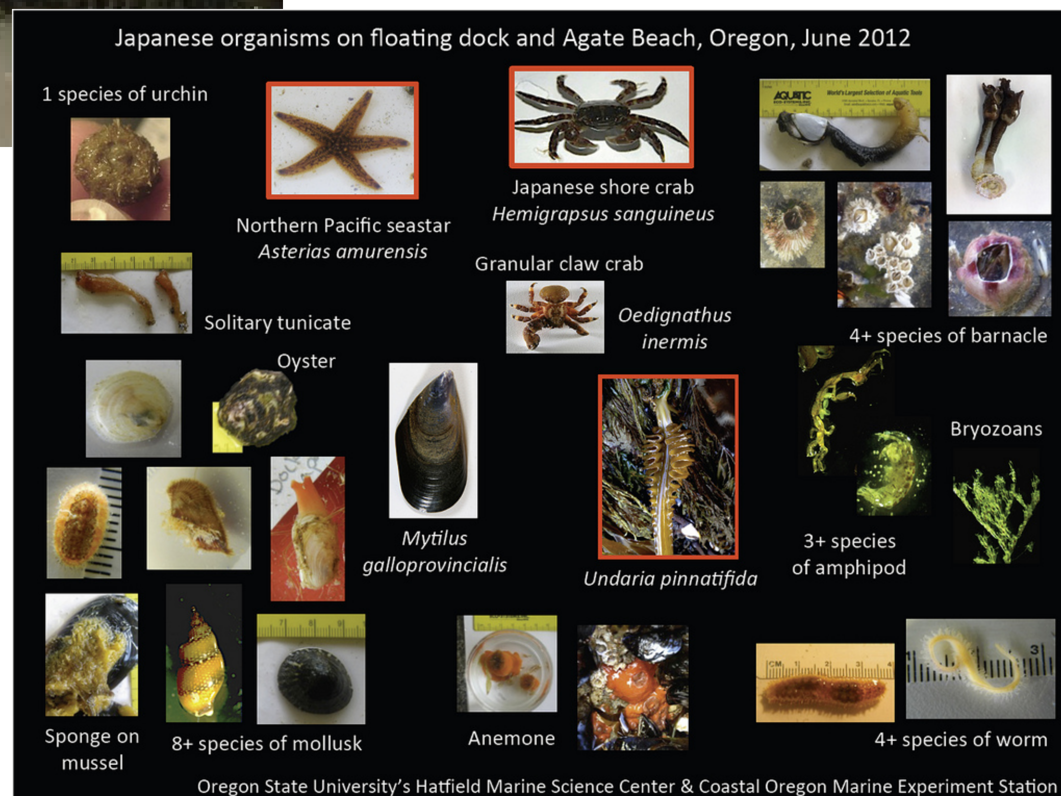
In Washington



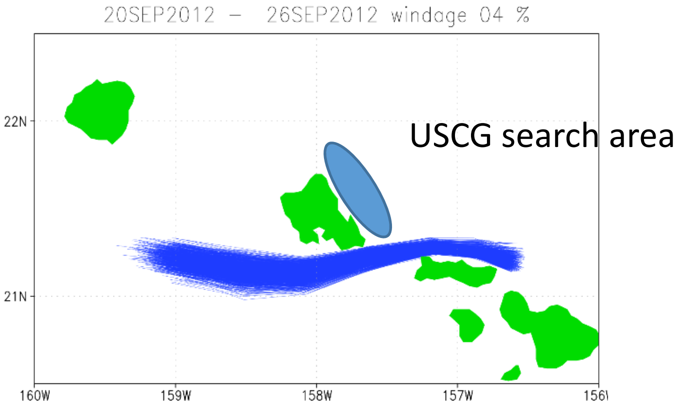
North of Molokai

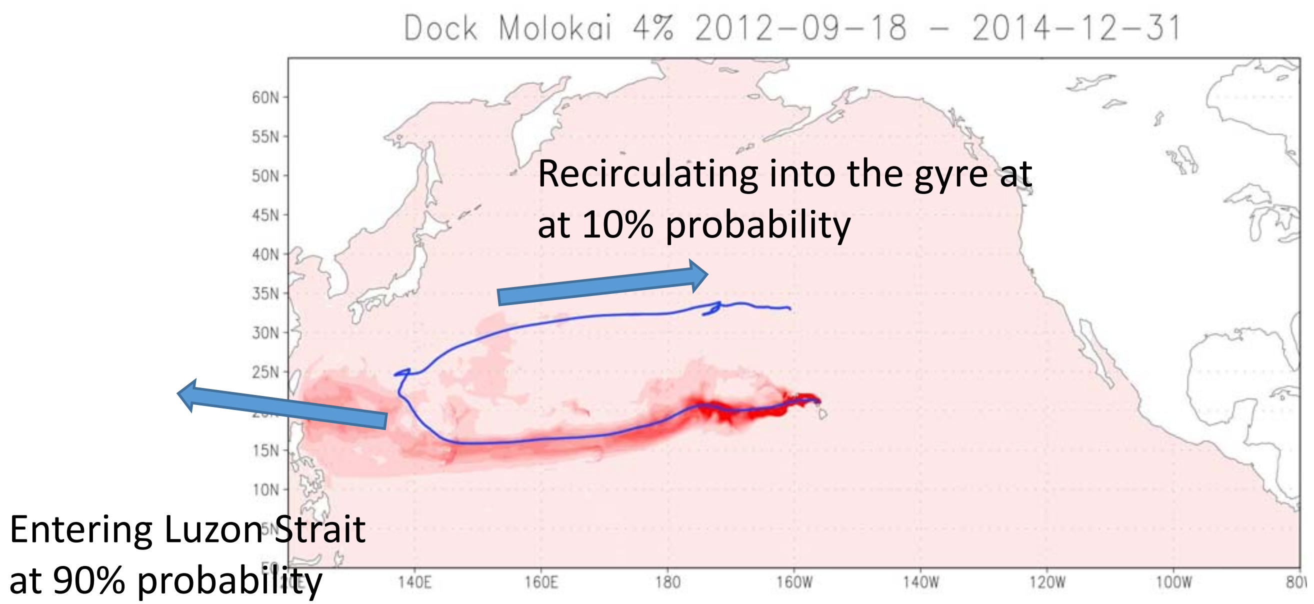
Dozens of Asian species were found on all kinds of debris arriving in the North America and Hawaii, some have a potential of becoming invasive species.

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.

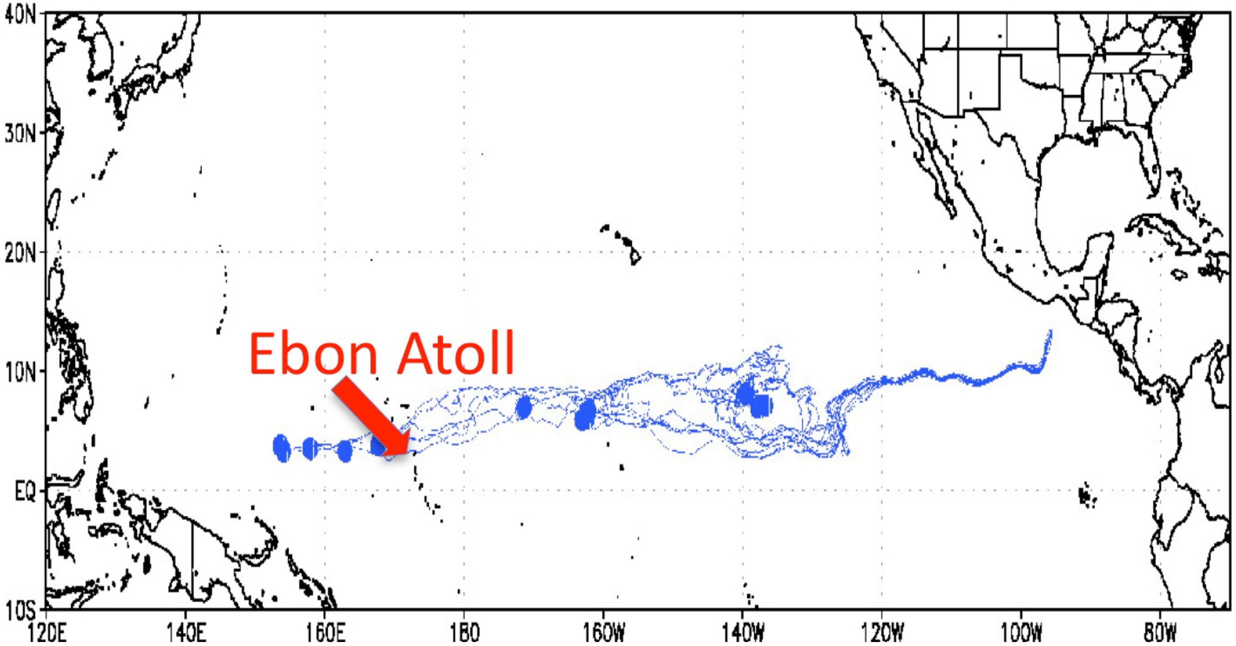


Fate of Molokai dock





Applications of the IPRC Drift Model



The 438-day journey of the castaway fisherman Alvaregna across the Pacific verified by IPRC drift model.

It is likely that the path was determined by wind convergence in the ITCZ, which also provided sufficient amounts of fresh water (rain) and food (fish, sea birds and turtles).

Conclusions

What do we need to improve dynamical modeling of drift?

- Improved description (therefore, understanding) of mixed layer physics
- Improved description (therefore, understanding) of air-sea coupling
- Improved description of floating object (with different values of buoyancy/windage) interaction with wind, waves and turbulence.

Because theoretical or numerical descriptions are difficult, massive drift observations are needed to calibrate/validate models.