Ocean Surface Topography Science Team Meeting (OSTST)
October 20-23, 2015

Predictability of marine debris motion, simulated with numerical models and diagnosed using oceanographic satellite data

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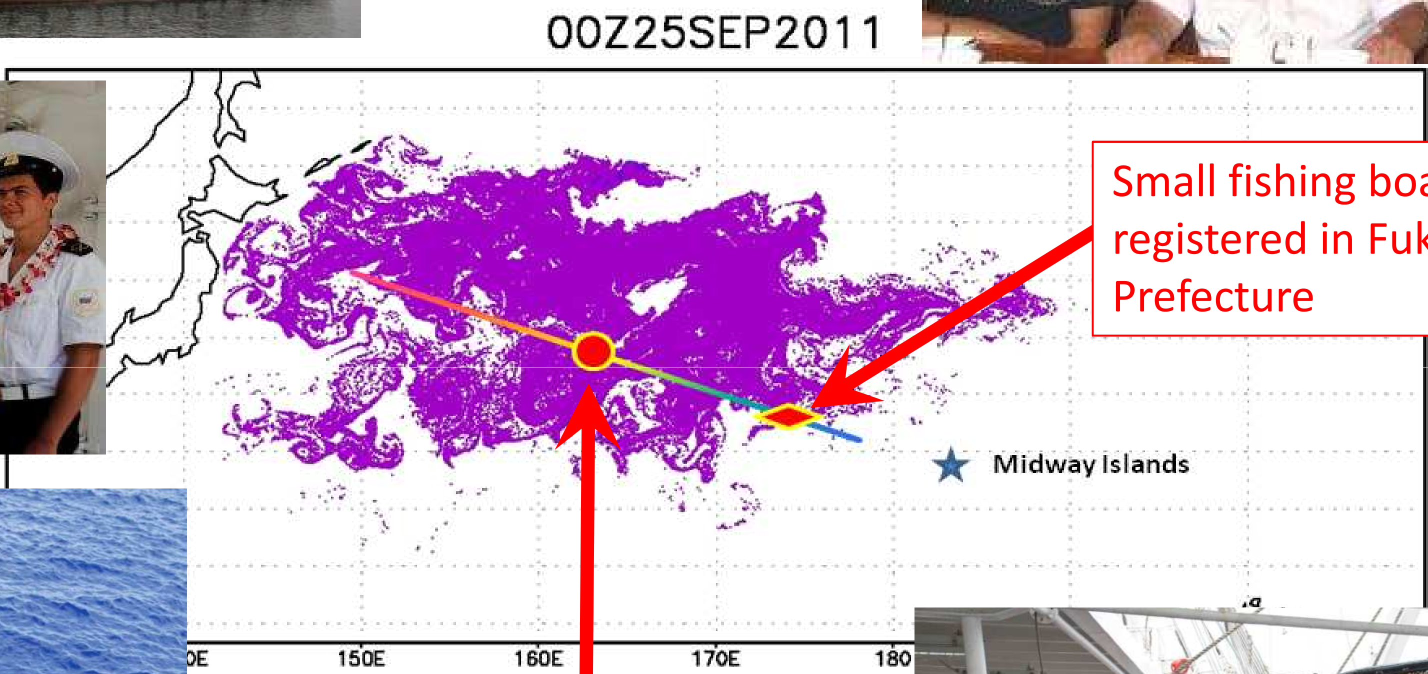
- NOAA: *Nir Barnea, Peter Murphy, and Lexter Tapawan*
- many contributors to the dataset.

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

Examples of potential tsunami marine debris from or near Hawaii


Apr 5, 2013:
Olympic Coast
Four 66-feet Misawa dock,
washed off shore Mar 11, 2011
Sep 17-19, 2012:
repeatedly reported by fishermen
north of Molokai.
Not found by the USCG.
Jun 5, 2012:
Agate Beach, OR
Dock #4 was never reported

“Pallada” found tsunami debris where SCUD predicted



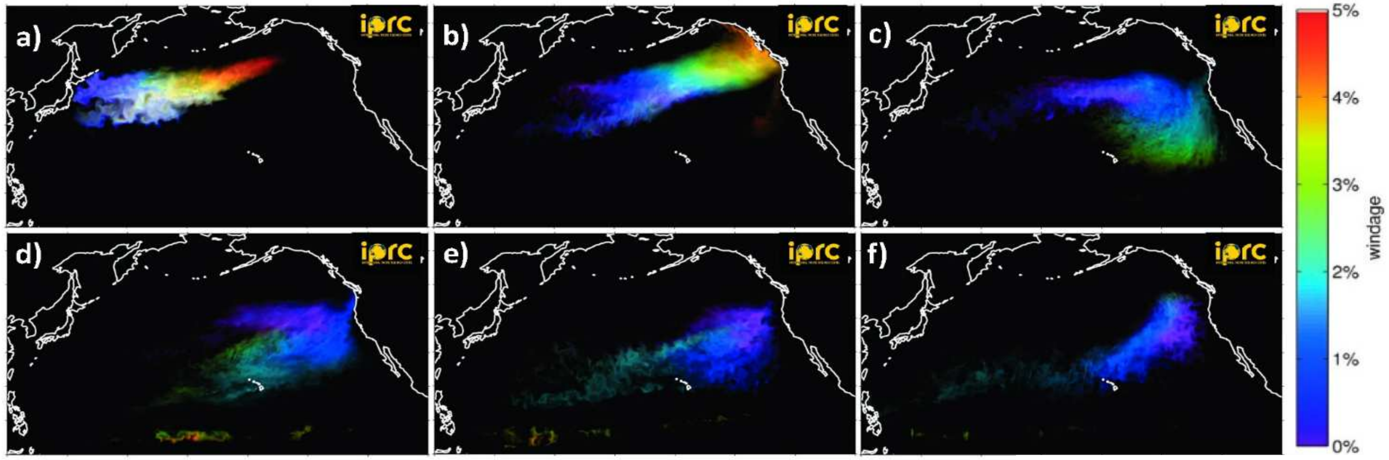
Small fishing boat, registered in Fukushima Prefecture

Observed maximum density of debris:
fridge, TV set, other home appliances, various debris

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.

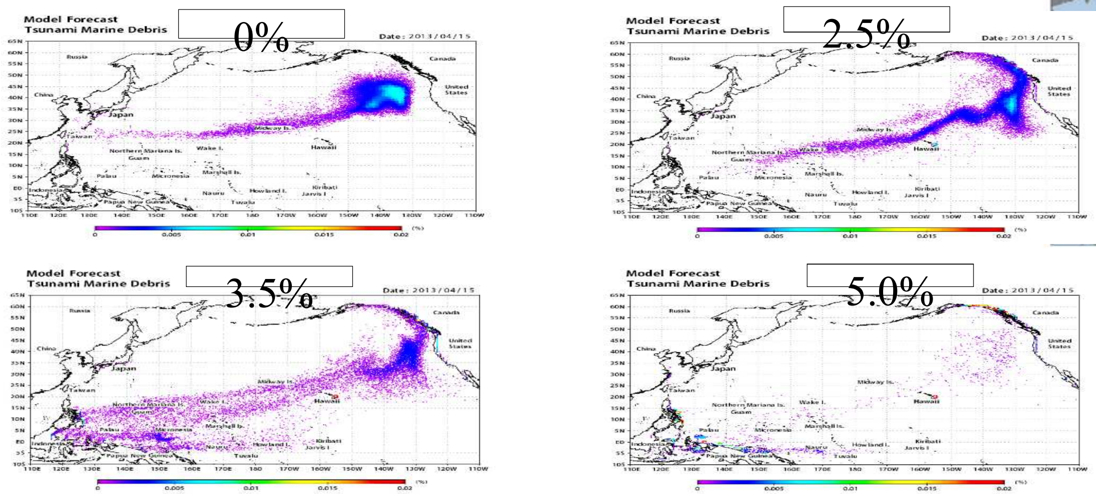
Japan Ministry of Environment sponsors a project, assessing risks to the US/Canada ecosystems from species, colonizing tsunami marine debris. The ADRIFT project is managed by PICES (North Pacific Marine Science Organization) and is now in year 2. Modeling team includes UH, NOAA, and MRI.

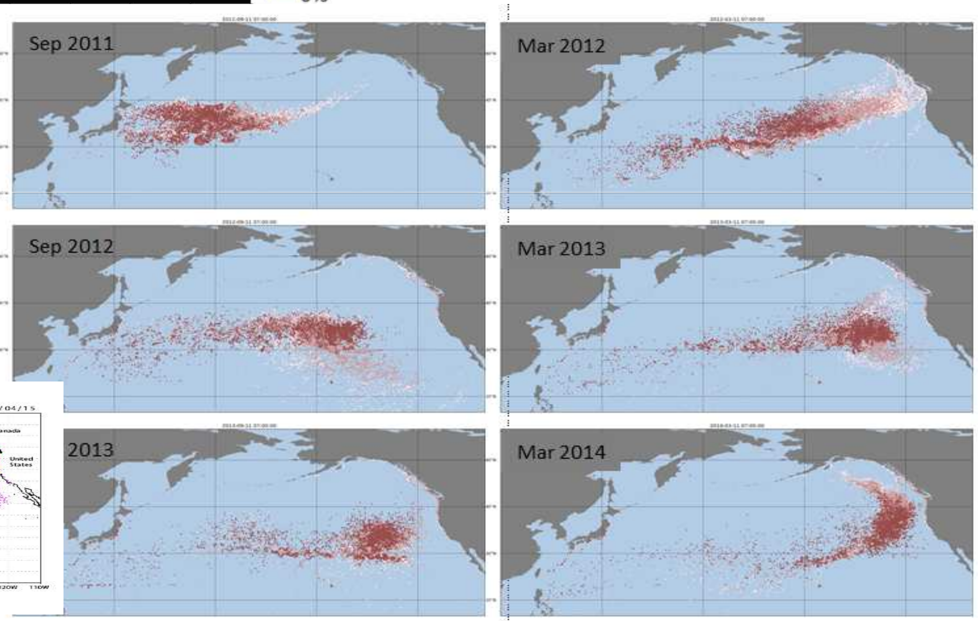
Model simulations used in the ADRIFT project



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.

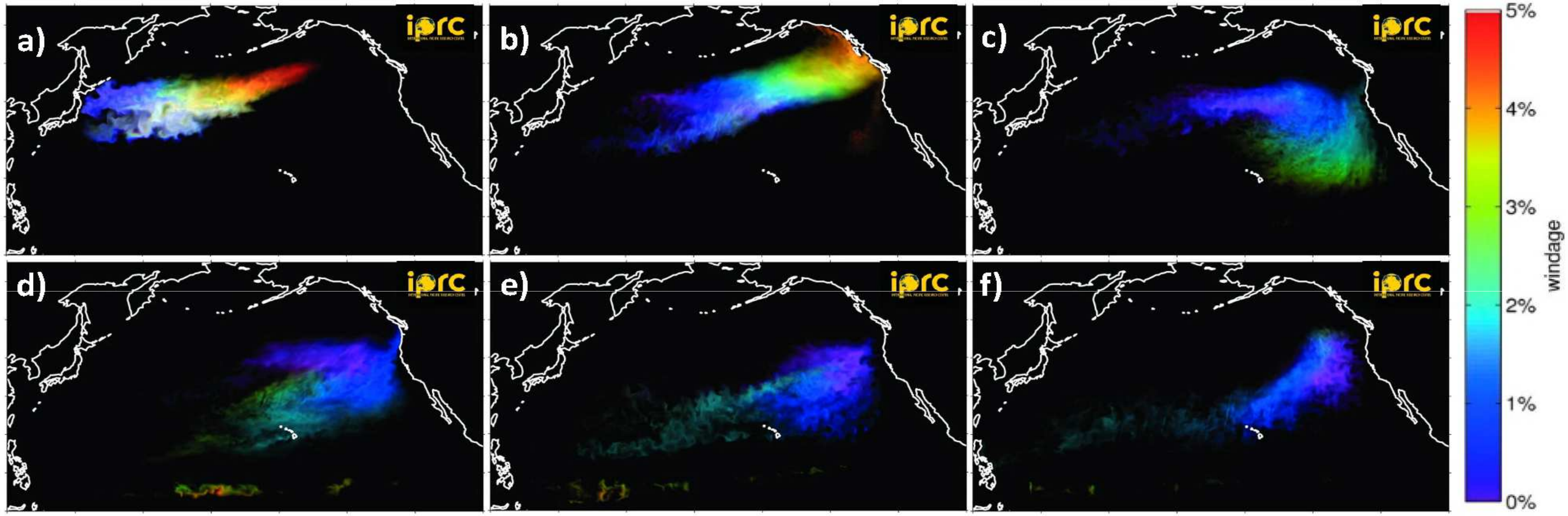
April 15, 2013 distributions of SEA-GEARN/MOVE-K7 model particles for four values of windage: 0, 2.5, 3.5, and 5%. Colors indicate concentration of particles on a computational grid.





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 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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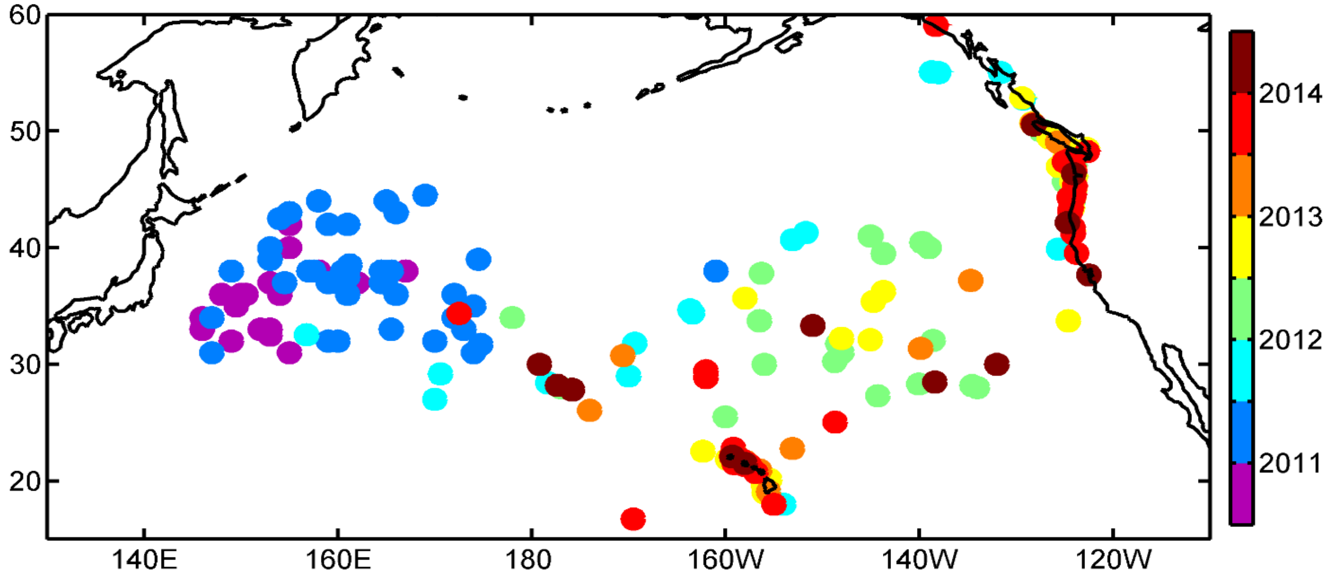
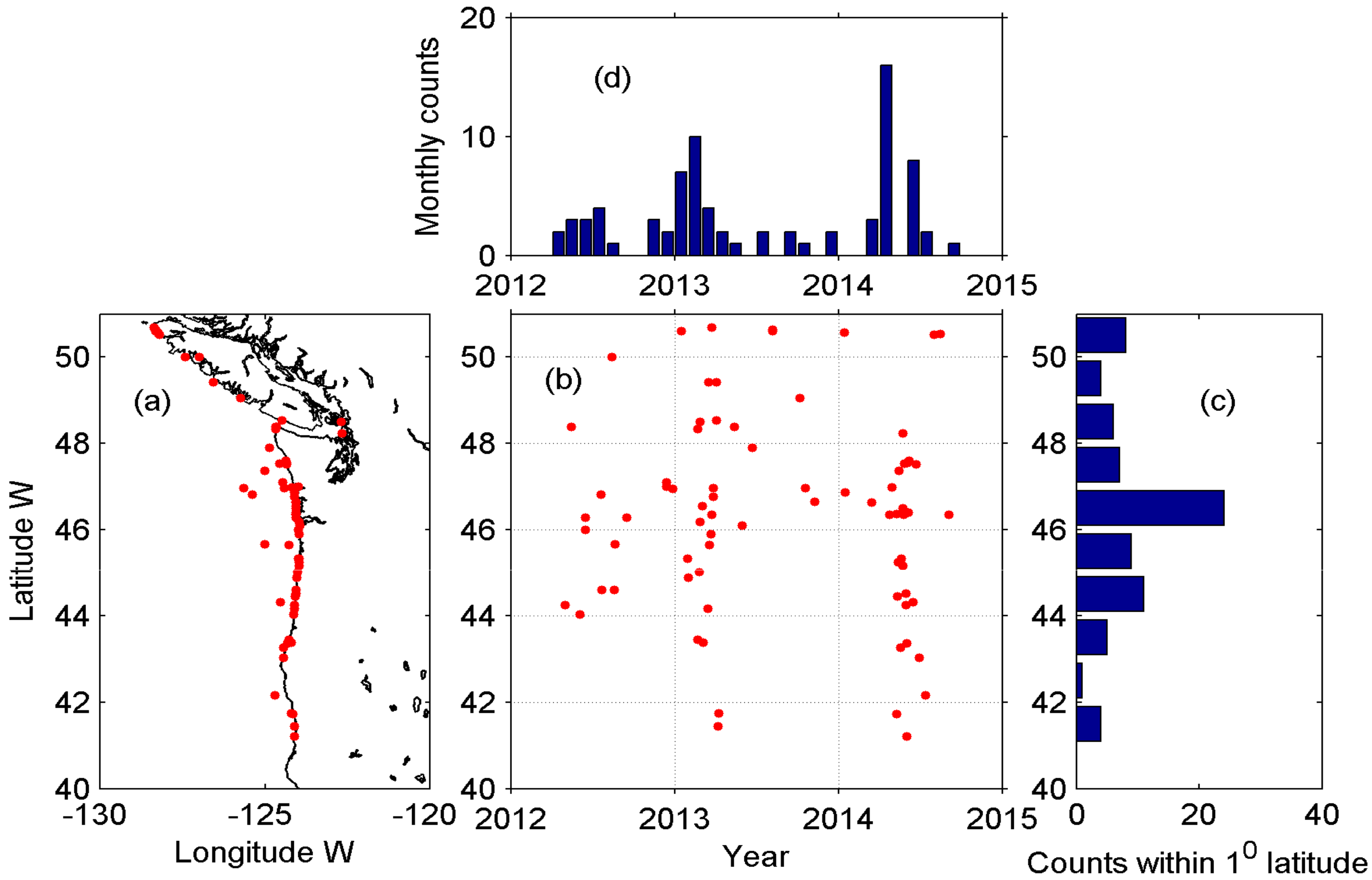
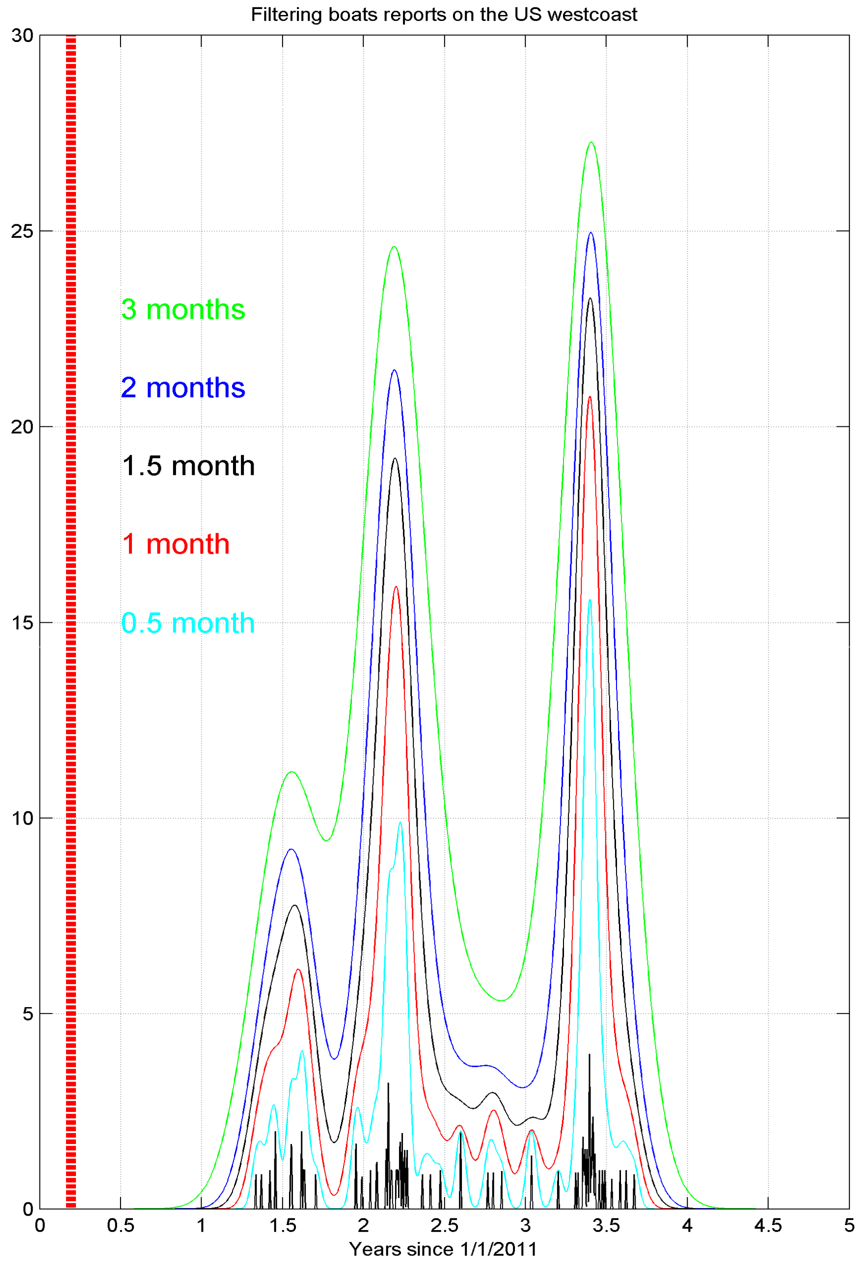


277 reported locations of boats/skiffs/ships and (colors) times of the reports. Color bar spans January 2011–December 2014 and labeled ticks mark central moments of the years.

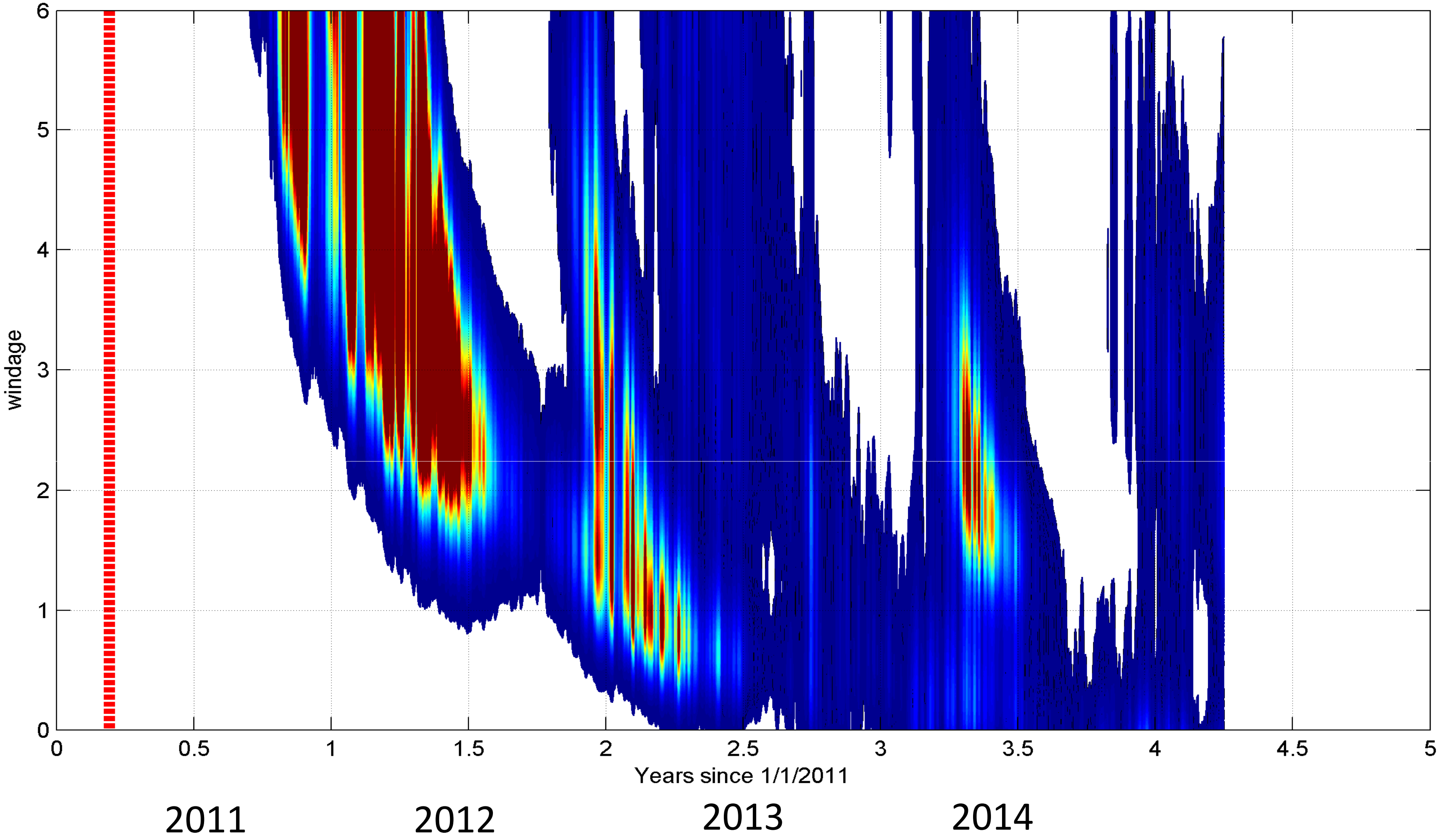
Problem is that “clean” regions are never reported.



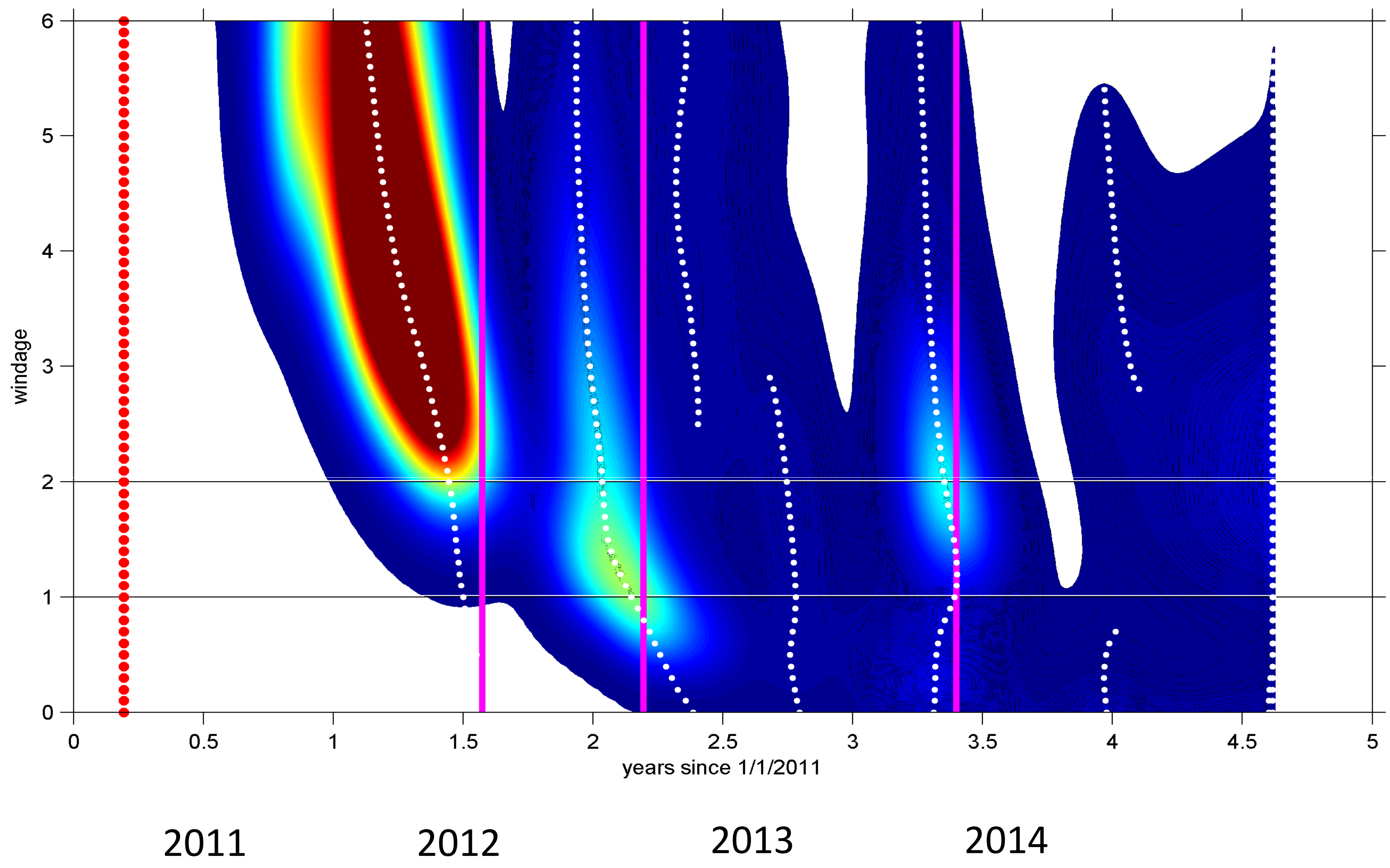
Latitude-time distribution of 79 boat reports on the US/Canada west coast



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

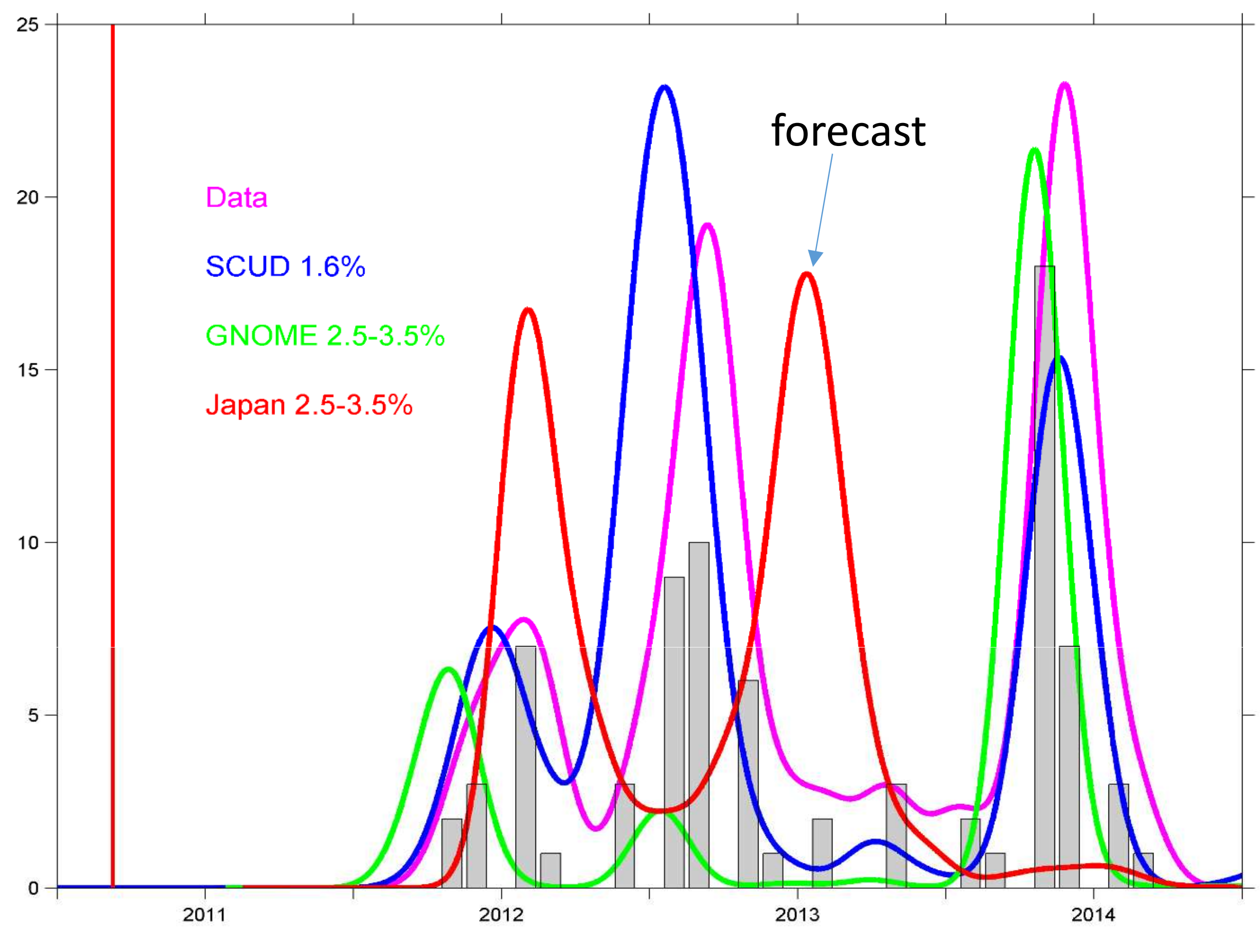


Timelines of SCUD model fluxes on the US/Canada west coast for a range of windages.



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.

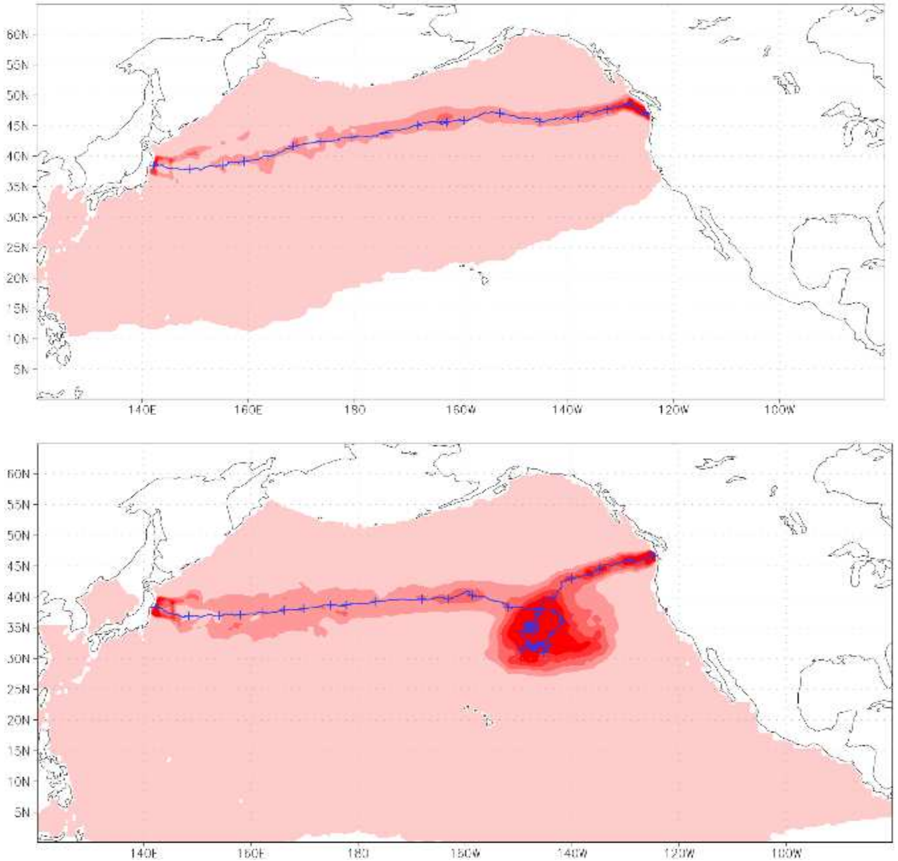
2. IPRC model, providing best correspondence, suggests that:

- 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.

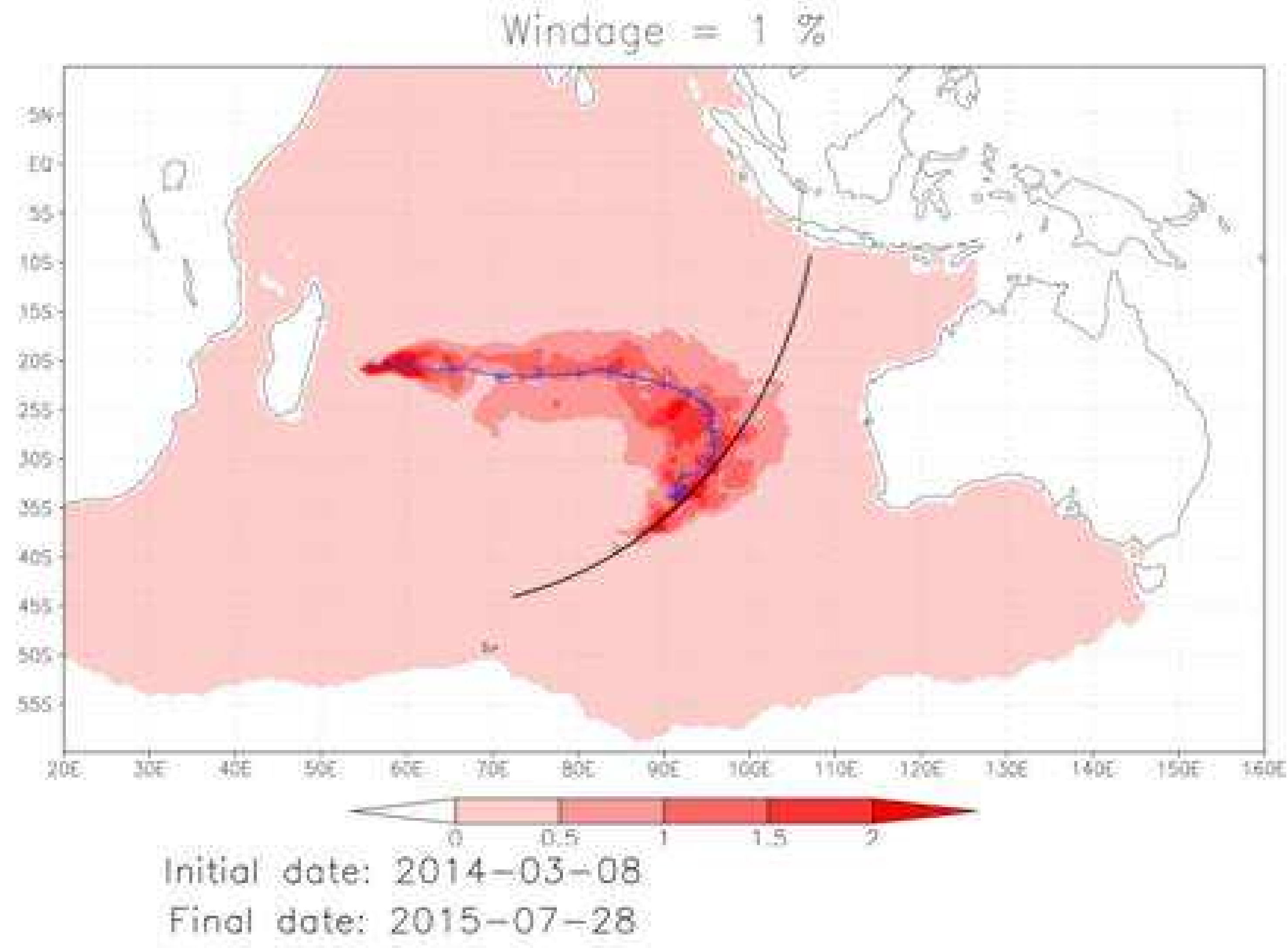
- Approximately 700 boats are still floating in the “garbage patch”
and will continue washing ashore in the next several years.

Predictability of particle trajectory is significantly increased if start and end points and times are known



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.

Probable path of debris from the 7th arc to La Reunion



Modeling drift of marine debris

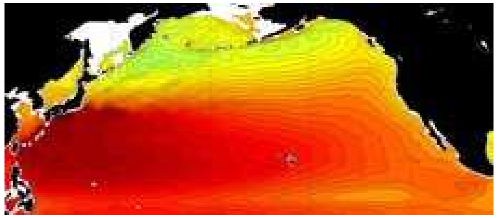
Velocity of drifter = Velocity of the ocean surface current + Velocity relative to water parcel

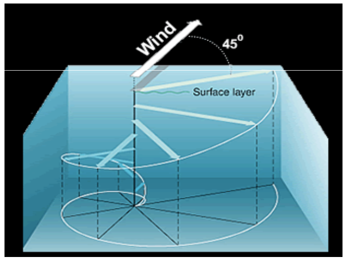
Currents due to non-local dynamics

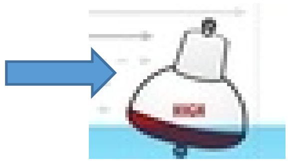
Wind-controlled currents

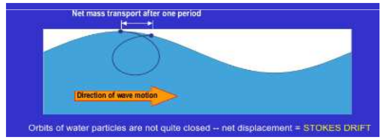
Direct wind force

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

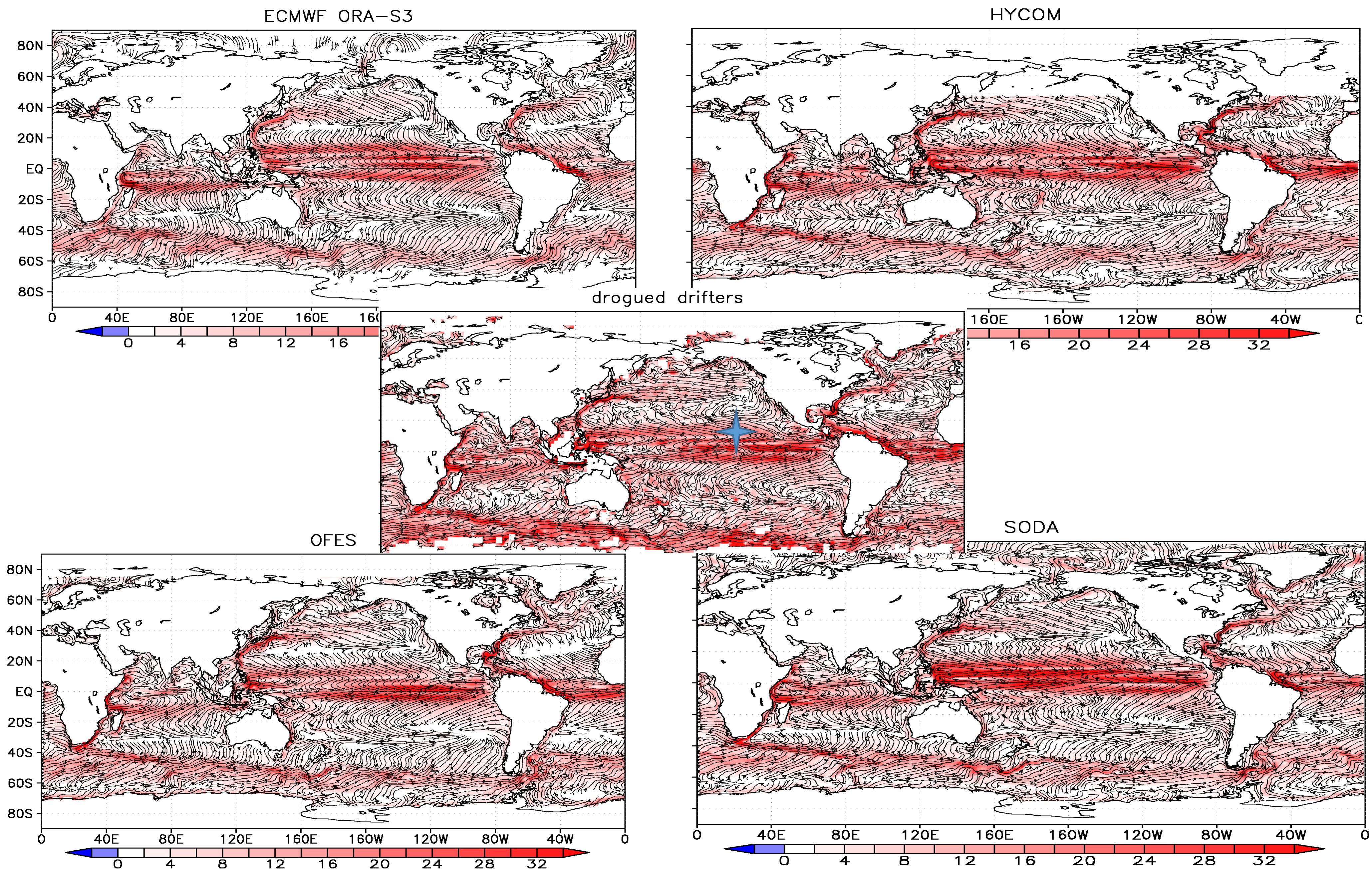
Practical formula:

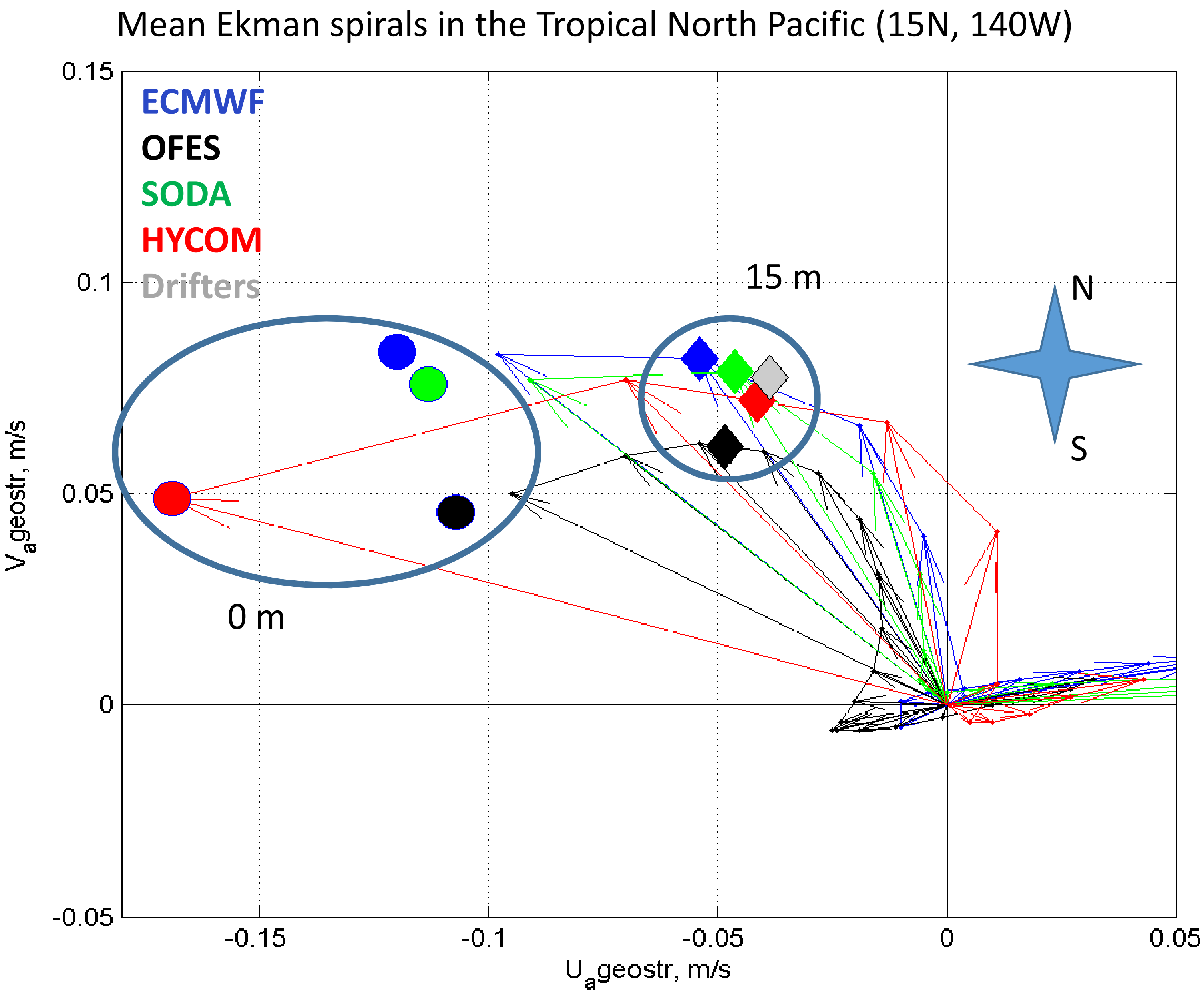
Drift = Current + A(windage)*Wind

(from models) (from satellites or models)

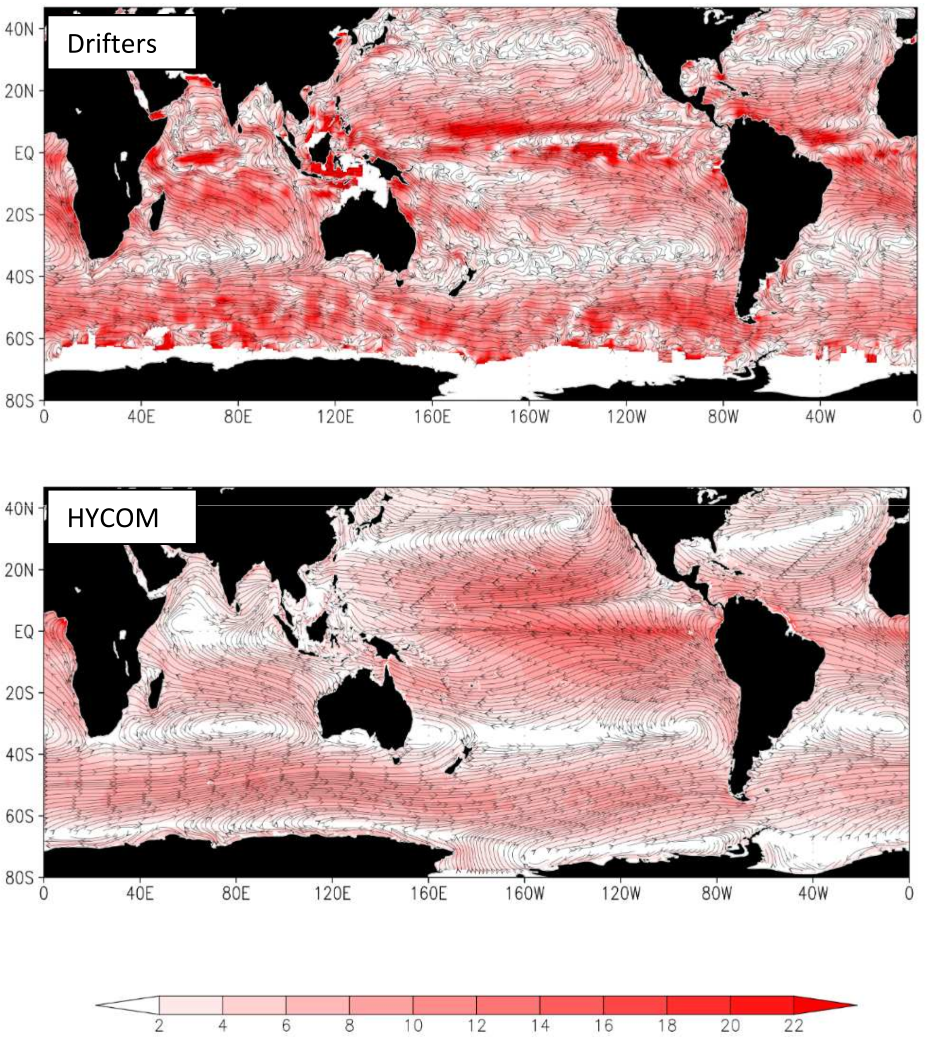
Same object may dynamically correspond to **different windages** in different models

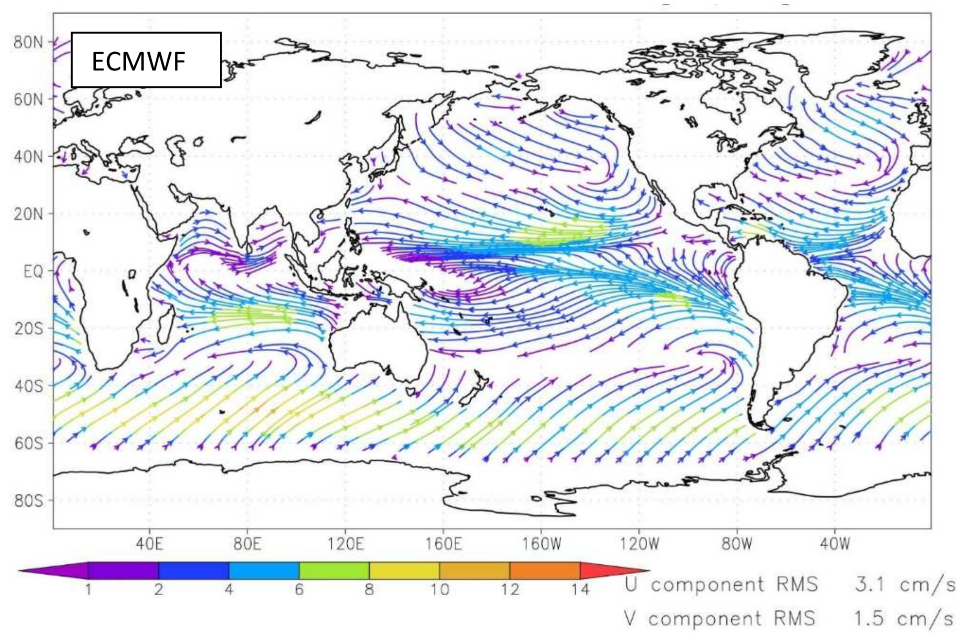
Time-mean currents at 15 meters level in different models




Mean Ekman spirals in the Tropical North Pacific (15N, 140W)
ECMWF
OFES
SODA
HYCOM
Drifters
15 m
0 m
N
S
0.15
0.1
0.05
0
-0.05
-0.15
-0.1
-0.05
0
0.05
$V_a$geostr, m/s
$U_a$geostr, m/s

Mean velocity shear between 0 and 15 m depth





Summary

While the ocean mixing leads to the loss of predictability:

- In some cases its role may be overestimated
- Artificial “mixing” may result from errors, lack of data, and limitations of methods
- In some cases mixing can be efficiently neutralized by wind-driven convergence
- Right choice of the formalism (particle vs tracer concentration, trajectory vs probability density) may help to enhance results of the study.
- Start/end (or along-trajectory) data dramatically increase predictability of the path

Main problems with simulating the drift are

- 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