# Transport of marine debris from the 2011 tsunami in Japan: model simulations and observational evidence

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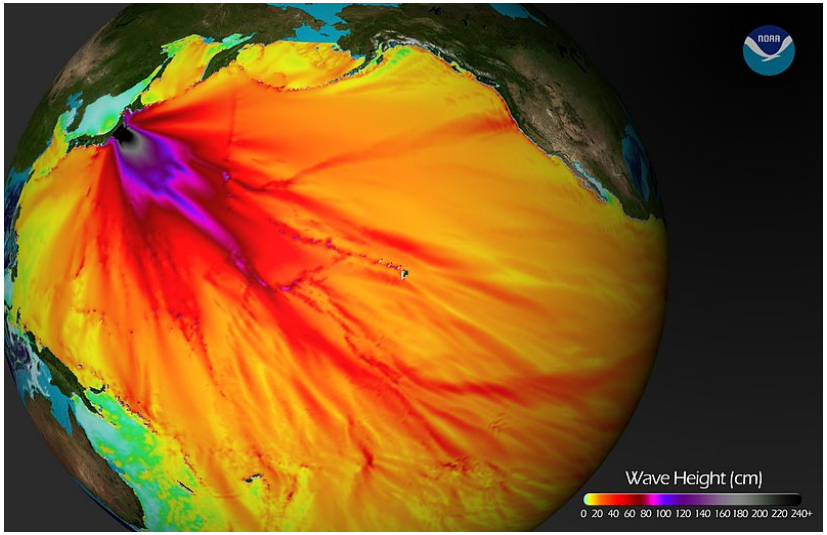
20-24 October 2014
PICES 2014 Annual Meeting
Yeosu, South Korea

# 11th MARCH 2011 Tsunami in Japan





Deposited on land

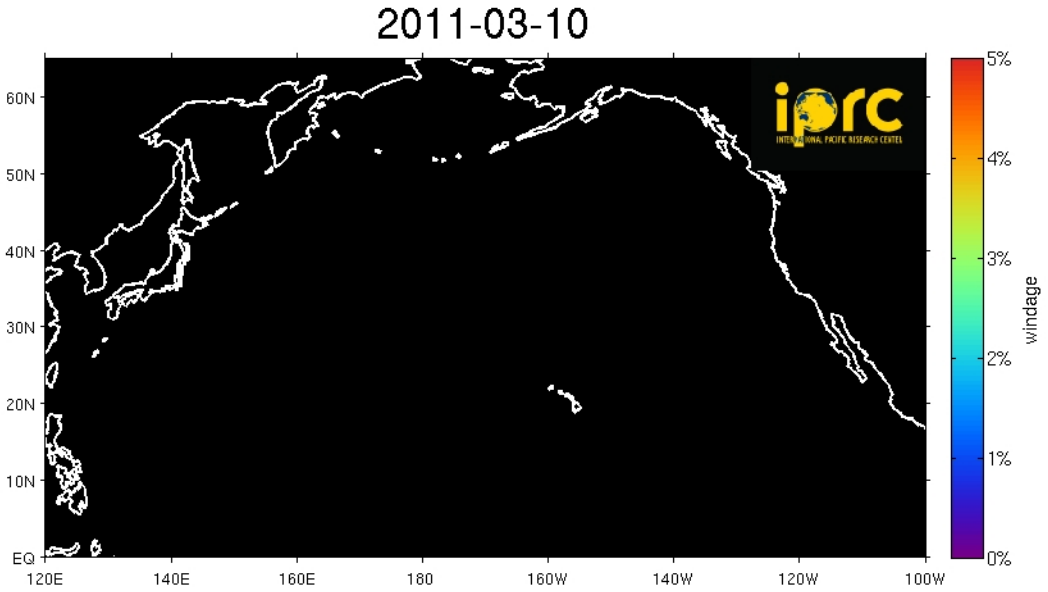
Sunk down  to the ocean bottom

Floating in the ocean


**Courtesy of US Navy**

# IPRC Drift Model tracking tsunami debris

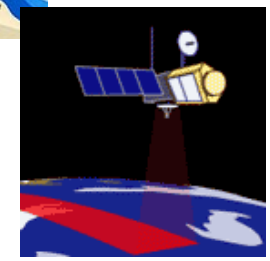
Apply our IPRC Drift Model which is based on our diagnostic model of ocean surface currents “SCUD “.
Debris is carried by surface ocean currents and moved by surface winds.
In computer model virtual tracer is placed along the coastline of east Japan and then advected by SCUD currents and QSCAT winds.



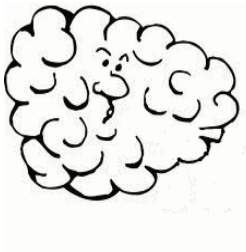

Source: Maximenko & Hafner, IPRC/SOEST, Univ. of Hawaii

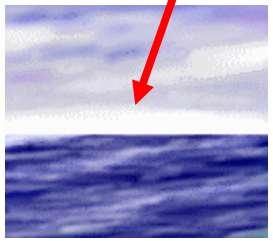
# SCUD - Surface CUrrents from Diagnostic model

**AVISO sea level**

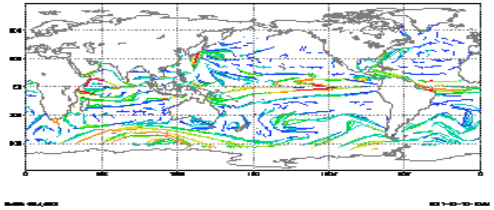
**QSCAT/ASCAT ocean surface wind**





**SCUD**

Ocean surface currents



Daily maps of ocean surface currents on ¼ deg. lon/lat grid

Starting 01 AUG 1999
ending 18 NOV 2009
extended into real time

# Formulation of the diagnostic model SCUD

$$U_{SCUD}(x,y,t) = U_0 + u_{hx} \cdot \nabla_x h(x,y,t) + u_{hy} \cdot \nabla_y h(x,y,t) + u_{wx} \cdot wx(x,y,t) + u_{wy} \cdot wy(x,y,t)$$

And similarly

$$V_{SCUD}(x,y,t) = V_0 + v_{hx} \cdot \nabla_x h(x,y,t) + v_{hy} \cdot \nabla_y h(x,y,t) + v_{wx} \cdot wx(x,y,t) + v_{wy} \cdot wy(x,y,t)$$

Where: $U_{SCUD}$ , $V_{SCUD}$ - modeled ocean current components

$U_0$ , $V_0$ - constant coefficient (mean)

h - sea level anomaly

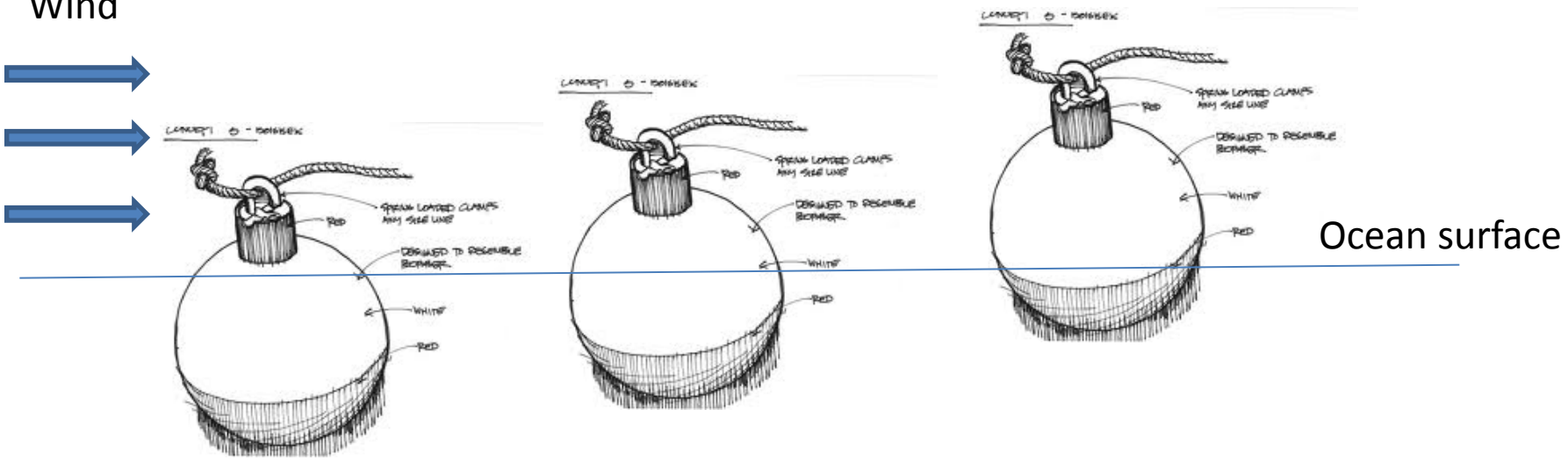
wx, wy U and V component of surface wind (QSCAT)

$u_{hx}$, $u_{hy}$, $u_{wx}$, $u_{wy}$ - U component coefficients corresponding to sea level gradient and surface wind (function of x and y only)

$v_{hx}$, $v_{hy}$, $v_{wx}$, $v_{wy}$ - similarly corresponding V component coefficients

# Windage

Wind




**Low windage,**
**object sitting deep in water**

Photo: Charles Moore

**Medium windage,**
**object sitting half in water**

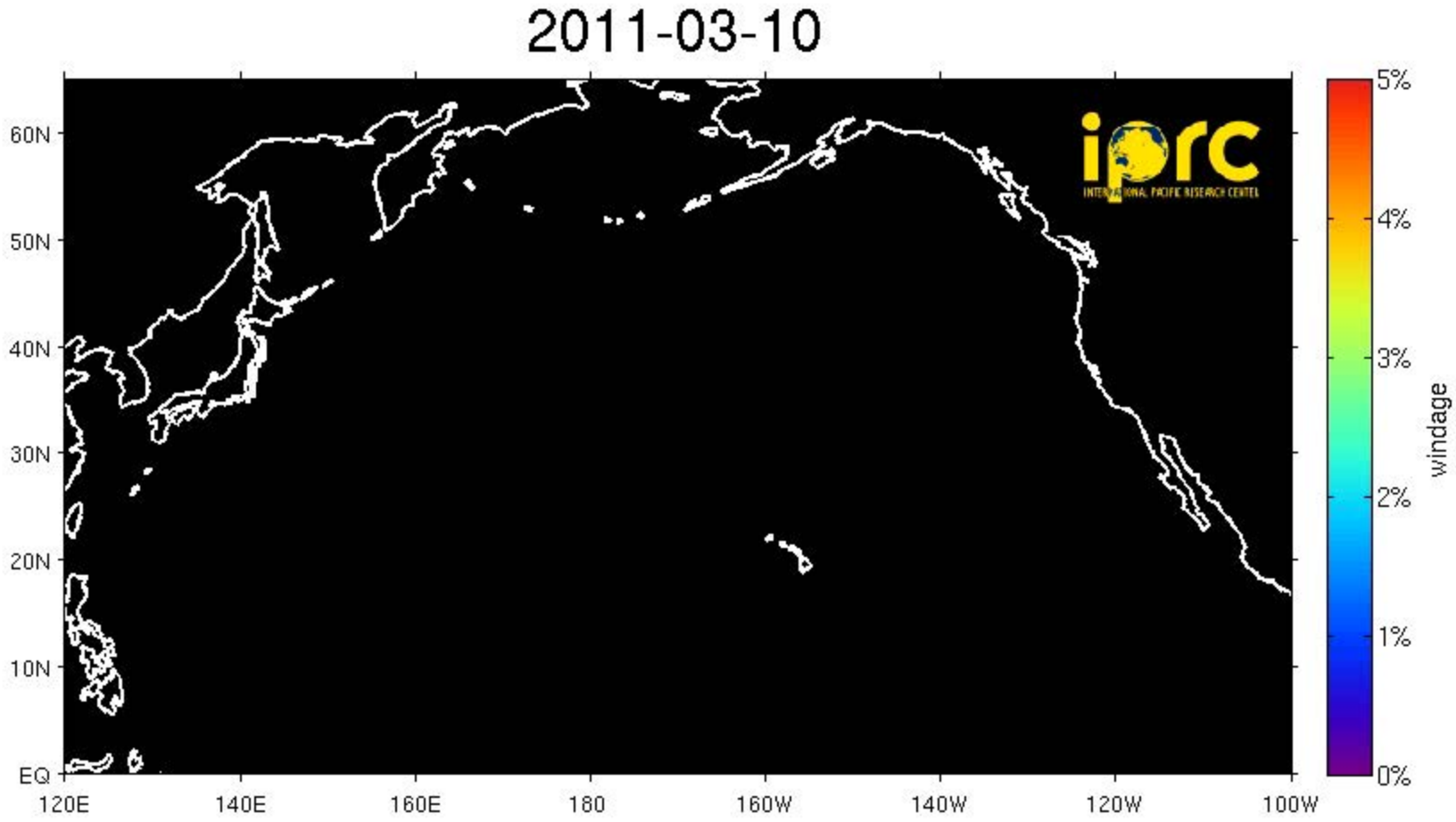
Photo: Randal Reeves

**High windage,**
**object sitting high on water**

Photo: S/V "Tregoning"

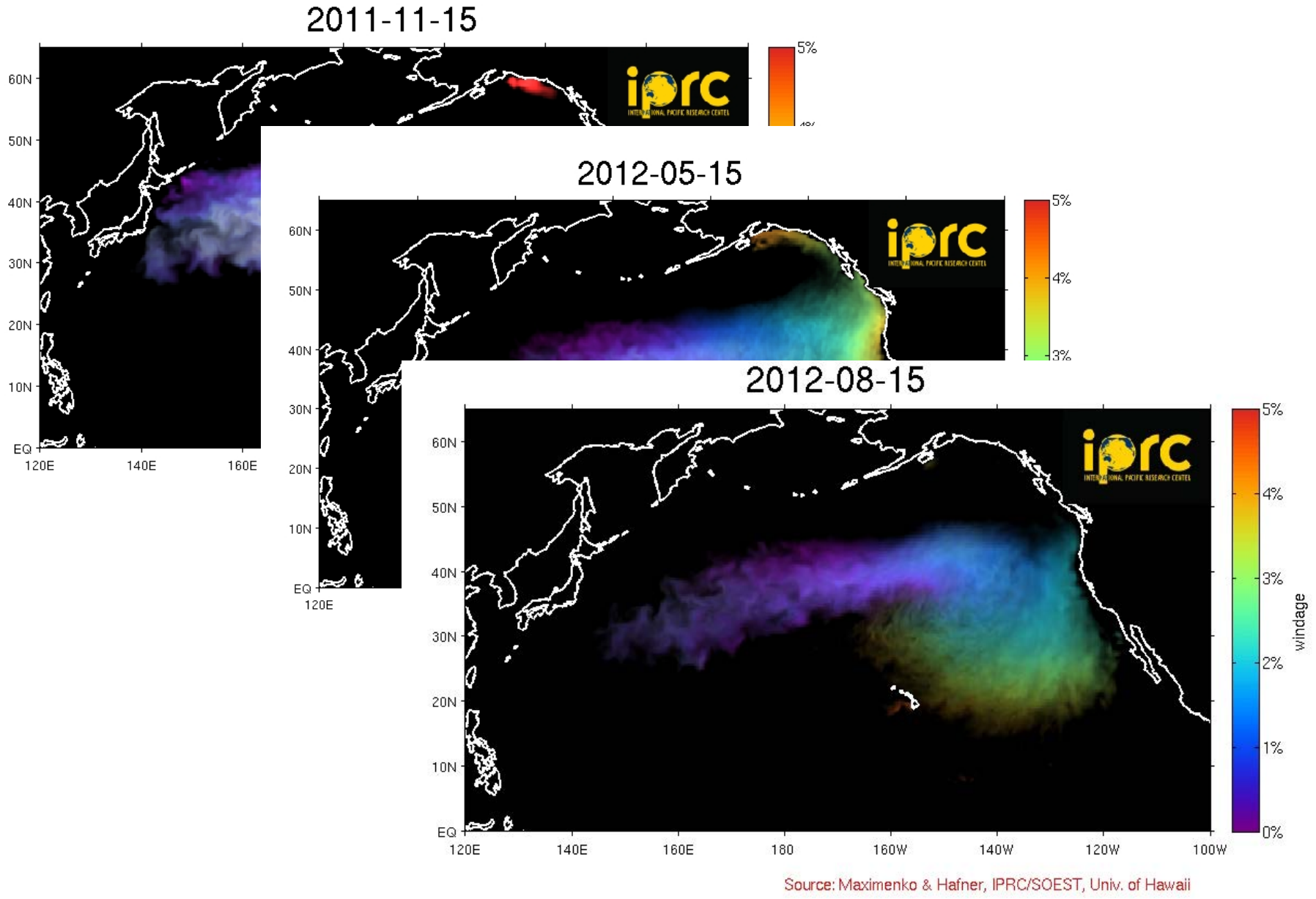
**For example 5% windage means an object is moving with the current + 5% wind speed**

# IPRC Drift Model:




Source: Maximenko & Hafner, IPRC/SOEST, Univ. of Hawaii

# Modeling the dispersion of tsunami debris

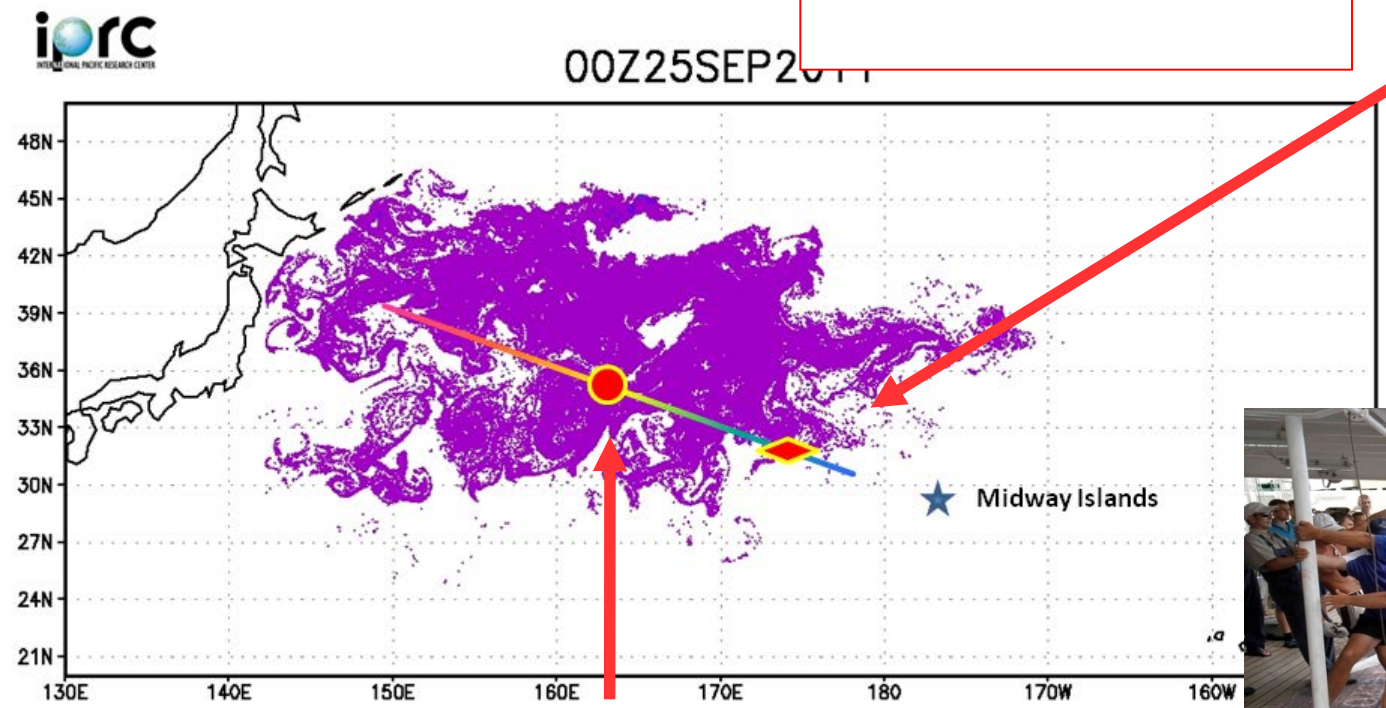



Source: Maximenko & Hafner, IPRC/SOEST, Univ. of Hawaii

# Actual Observations !

**“Pallada” found tsunami debris where SCUD predicted**

Small fishing boat, registered in Fukushima Prefecture




Observed maximum density of debris

# Actual Observations
## West Coast of N. America

20 Dec 2011 Whale Island AK


Early December 2011 Vancouver Island WA


Mid December 2011 Olympic Peninsula WA

Photo courtesy of Curtis Ebbesmeyer

# Actual Observations
## West Coast of N. America

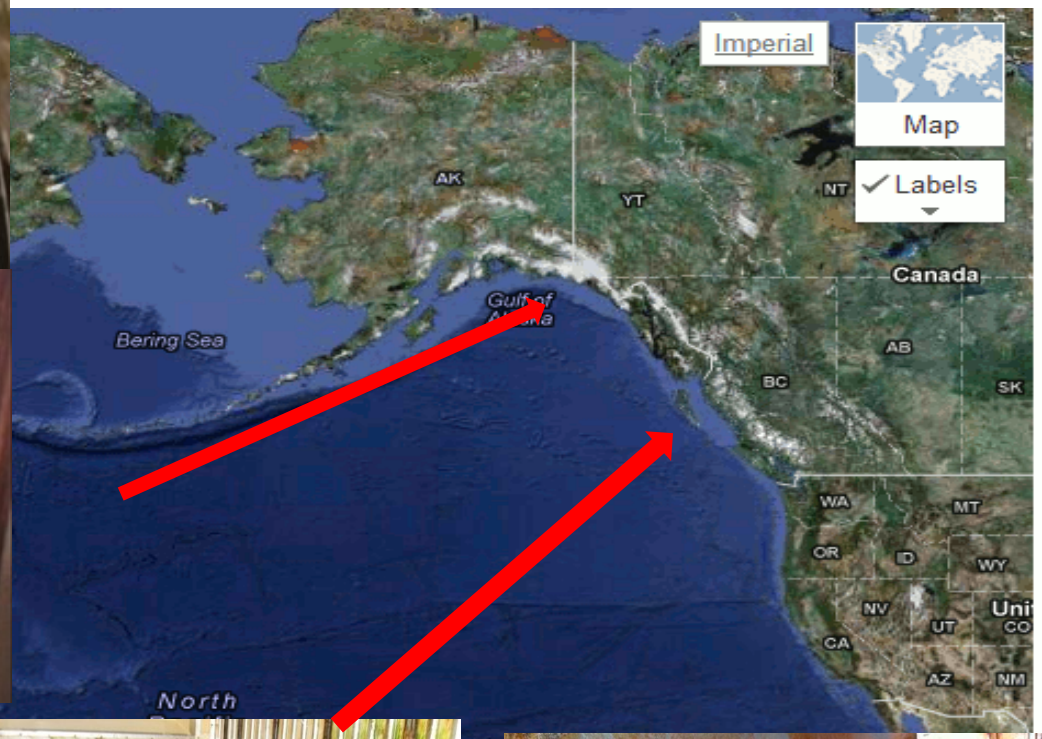
Photo: Department of National Defense

20 March 2012 150 nm south off Queen Charlotte Islands BC

# Actual Observations
## North Pacific Ocean



Middleton Island April 2011





Graham Island April 2011

# Actual Observations
## North Pacific Ocean

Randall Reeves

# Actual Observations
## North Pacific Ocean

# Actual Observations

## **Hawaii** shores

Hilo, Big Island of Hawaii , June 2012

June 2012 –report of s/v "Tregoning" north of Oahu

Kamilo, Big Island of Hawaii
Reported by Megan Lamson
July 14, 2012

**August 19, 2012 –oyster buoy reported by Carl Berg off Kilauea Point, Kauai**

**September 3, 2012 –oyster buoy reported by Cynthia Vanderlipin Turtle Bay, Oahu**

Kure Atoll Northwest Hawaiian Islands Reported by Scott Godwin
August 2012

# Actual Observations

## Hawaii shores


18 Sept. 2012 ,Y.K Suisan Co., Ltd

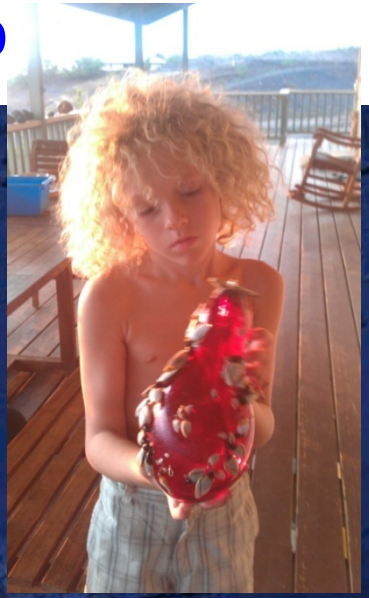
# Actual Observations
## Hawaii shores

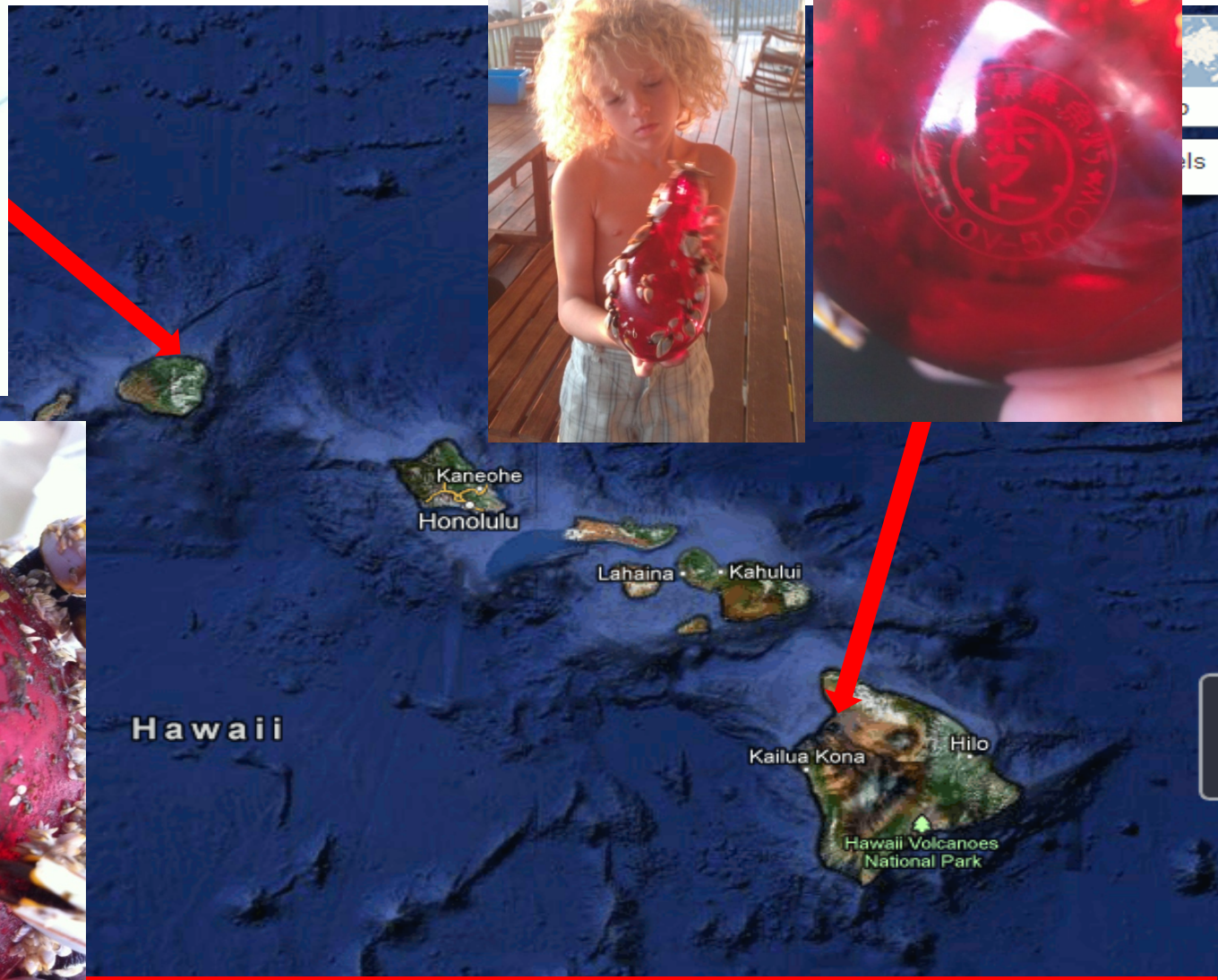


24-28 Sept. 2012 gasoline tanks Molokai

# Actual Observations

## Hawaii sho




24-26 Sept. 2012 Japanese light bulbs Hanalei, Kawaihae Harbor

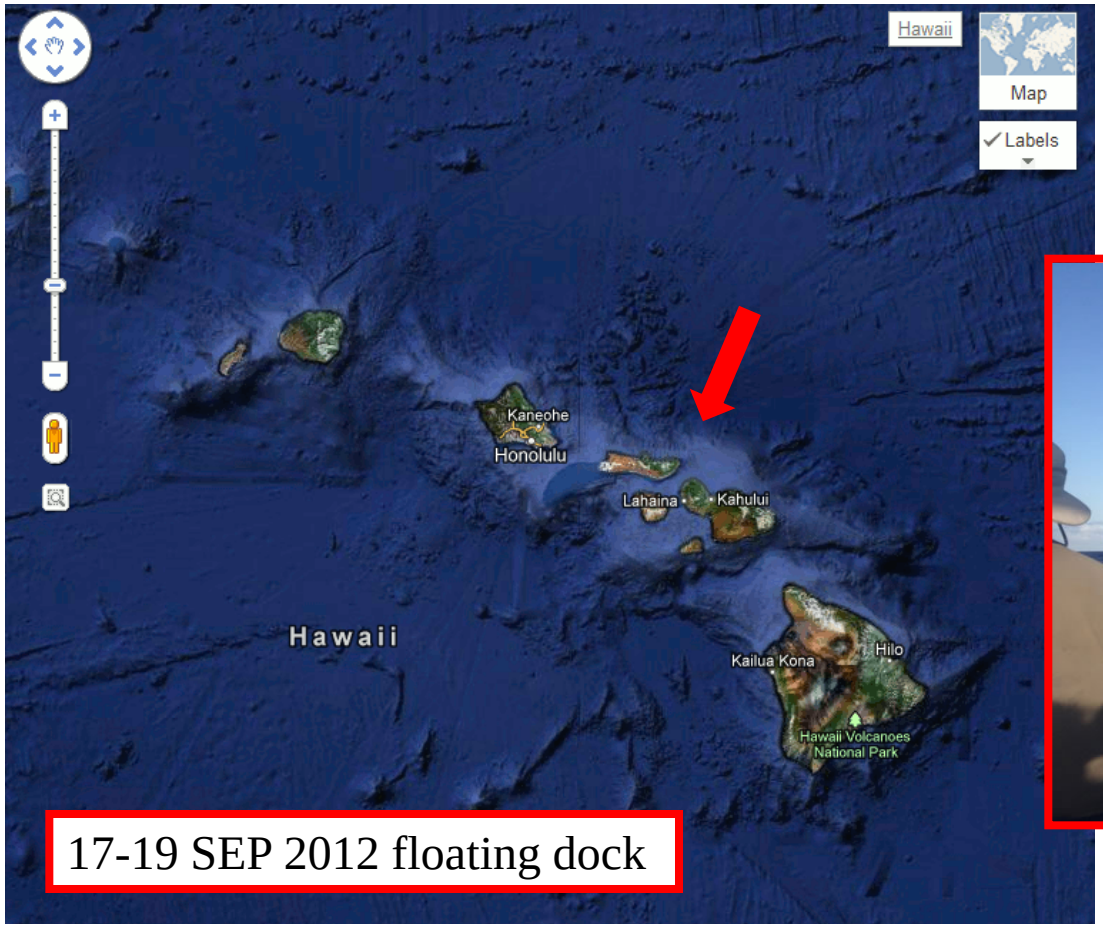
# Actual Observations

## Hawaii shores




03 Oct. 2012 yellow tank East of Big Island

# Actual Observations
## **Hawaii** shores




17-19 SEP 2012 floating dock

http://www.hawaiinewsnow.com/story/19601421/fisherman-spot-huge-japanese-dock-floating-near-molokai

# Actual Observations **Hawaii** shores

Nov. 2012 Kahuku Golf Club coast, Oahu

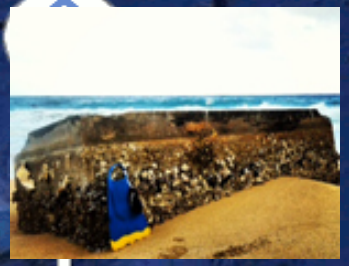
Jan 2013 Hanauma Bay, Oahu

Nov. 2012 Kahana Bay, Oahu

Dec. 2012 Punaluu, Oahu

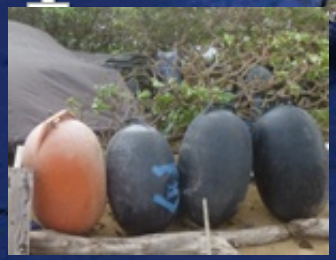
Jan 2013Waialua, North Shore, Oahu

# Actual Observations **Hawaii** shores



Feb. 2013 Makapuu, Oahu

Jul 2013 Malaekahana,Oahu



Feb. 2013 Kahuku, Oahu

Aug 2013 Turtle Bay, Oahu

Mar. 2013 Kahuku, Oahu

Sep 2013 Lanikai, Oahu

# Actual Observations **Hawaii** shores


Dec. 2012 Waipake Beach, Kauai

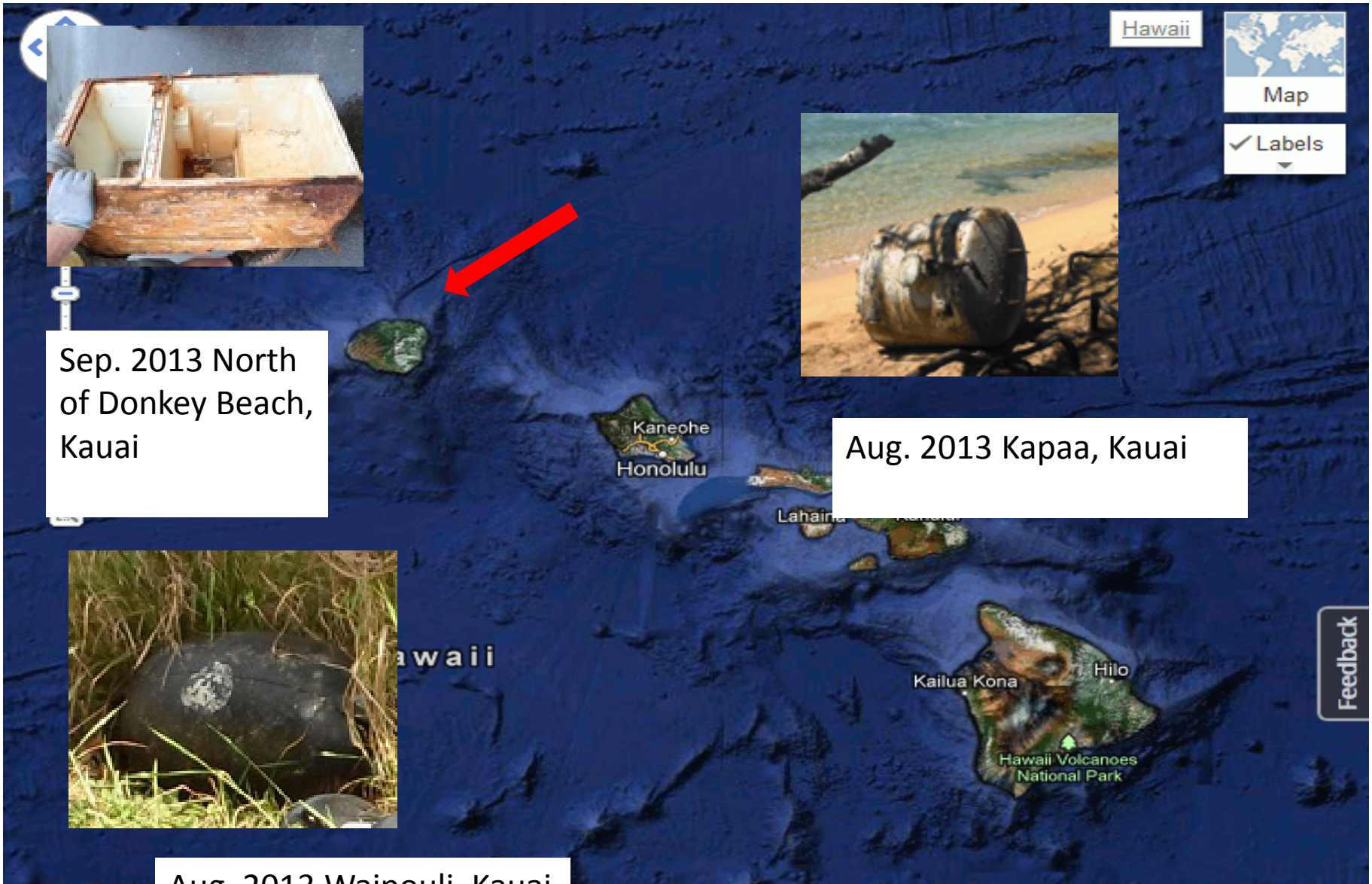
Mar. 2013 Waipake Beach, Kauai

Feb. 2013 Kapaa, Kauai

Jul. 2013 Kealia Beach, Kauai

Feb. 2013 Waipake Beach, Kauai

# Actual Observations **Hawaii** shores

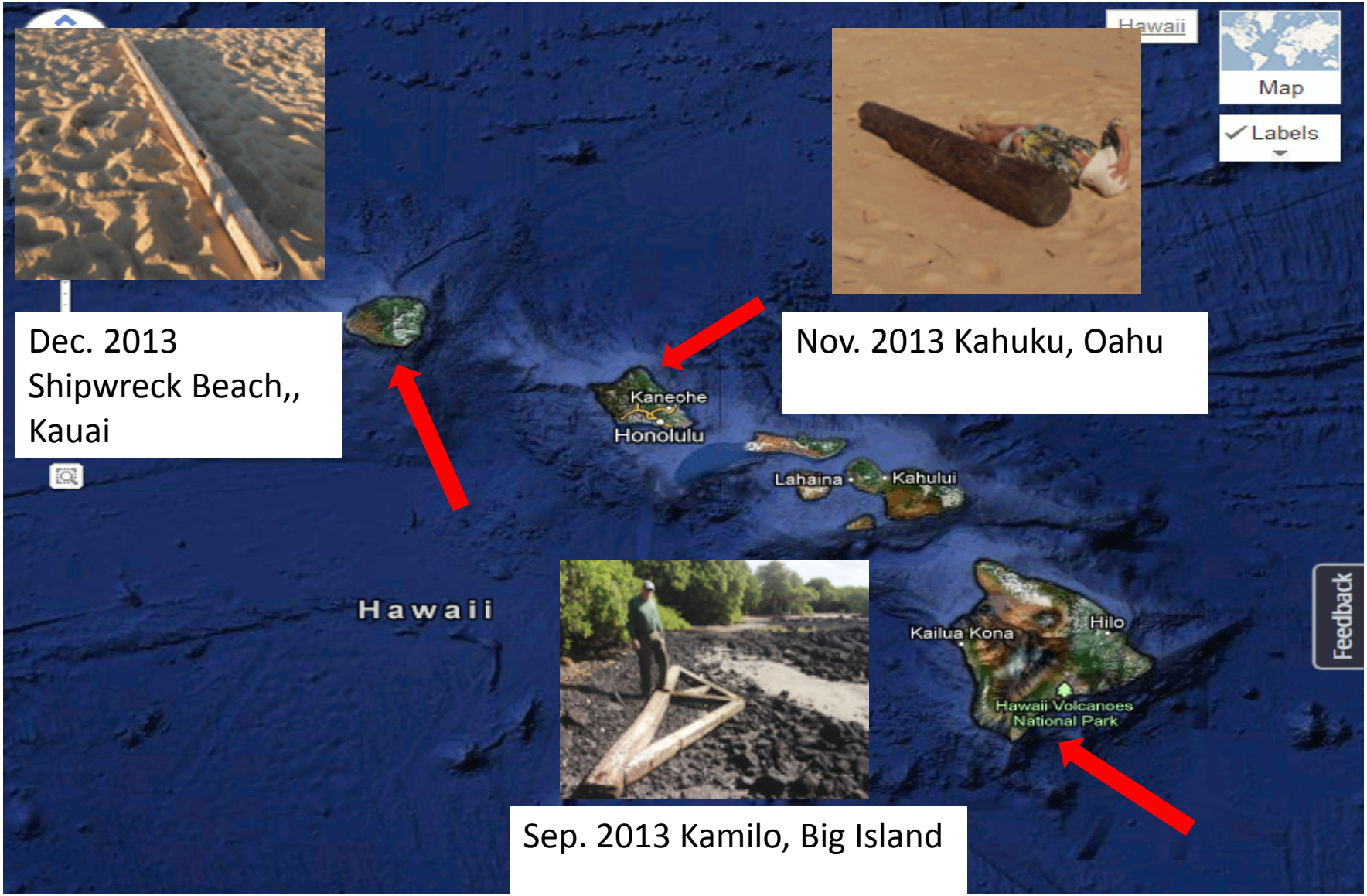



Sep. 2013 North of Donkey Beach, Kauai

Aug. 2013 Kapaa, Kauai

Aug. 2012 Waipouli, Kauai

# Actual Observations **Hawaii** shores wood

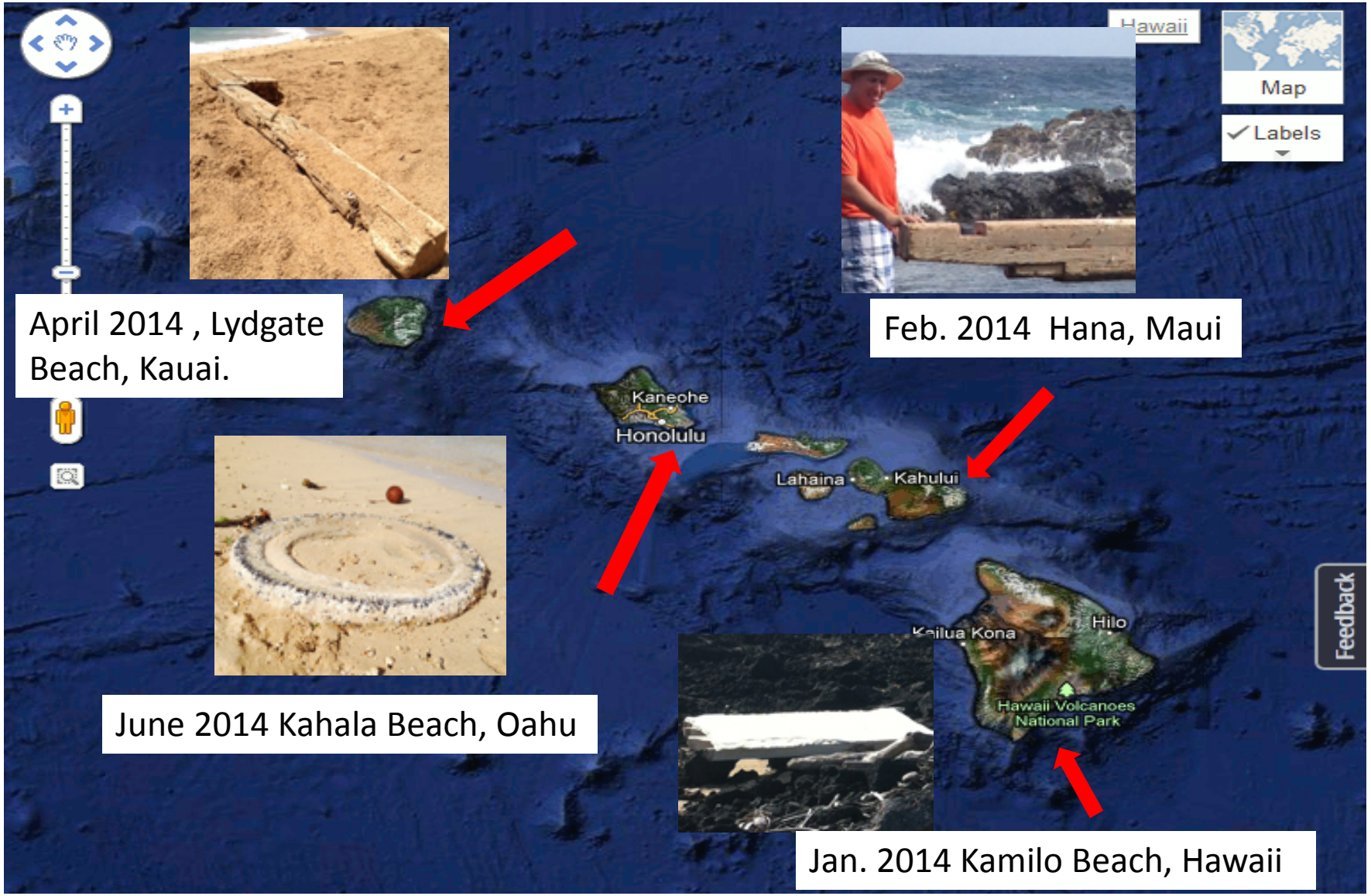



Dec. 2013
Shipwreck Beach,,
Kauai

Nov. 2013 Kahuku, Oahu

Sep. 2013 Kamilo, Big Island

# Actual Observations **Hawaii** shores wood




April 2014 , Lydgate Beach, Kauai.

Feb. 2014 Hana, Maui

June 2014 Kahala Beach, Oahu

Jan. 2014 Kamilo Beach, Hawaii

# Actual Observations **Hawaii** shores wood

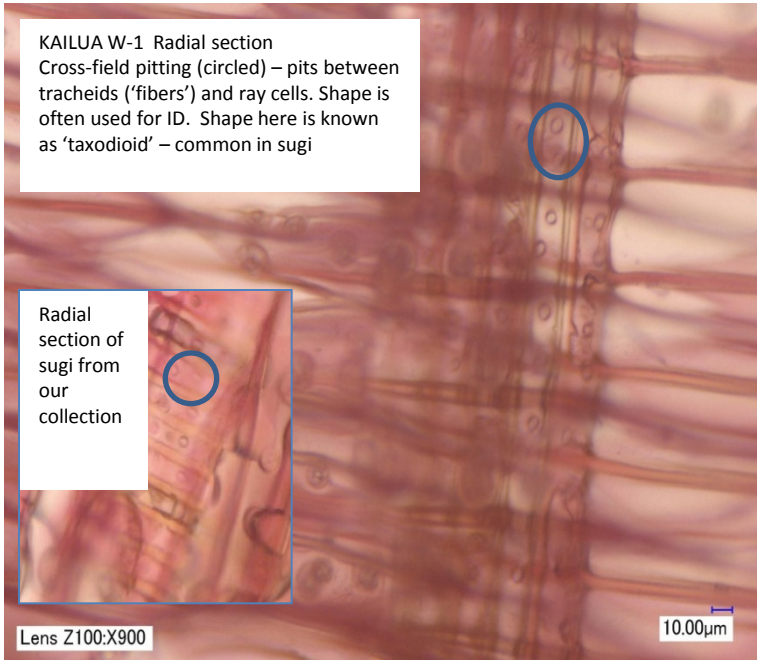
**Origin: most likely Japan**

tenon and mortise construction

many pieces of timber of Japanese cedar “sugi”

Also timing and large number of driftwood indicate origin from 2011 tsunami in Japan.

DNA analysis is pending


Scott Leavengood (Oregon State Univ.)

David Stallcop (Vanport International Inc.)

# The Story: Changing composition in time

## Observations

### AUG-SEP 2012





Buoys, bulbs, canisters, container

### MAR-APR 2013





Buoys, pallet, fridge, boat

### OCT-DEC 2013/2014



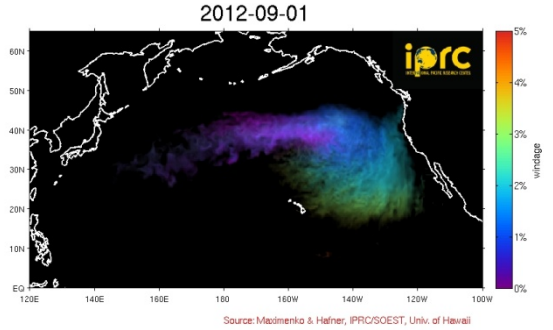


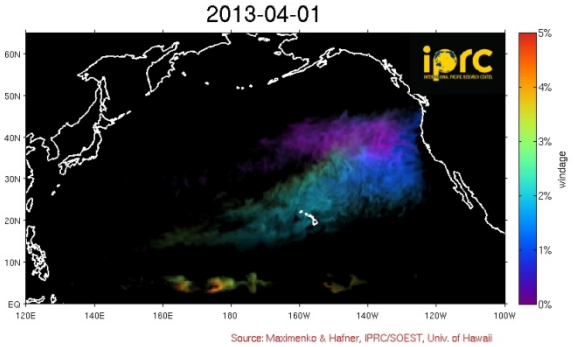


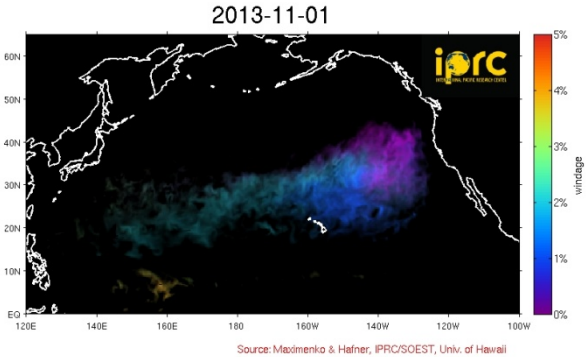
Buoy, gas cylinder,
Timber beams,
Processed wood,
Wood poles
Tree trunks
Total number 52

time

## Model



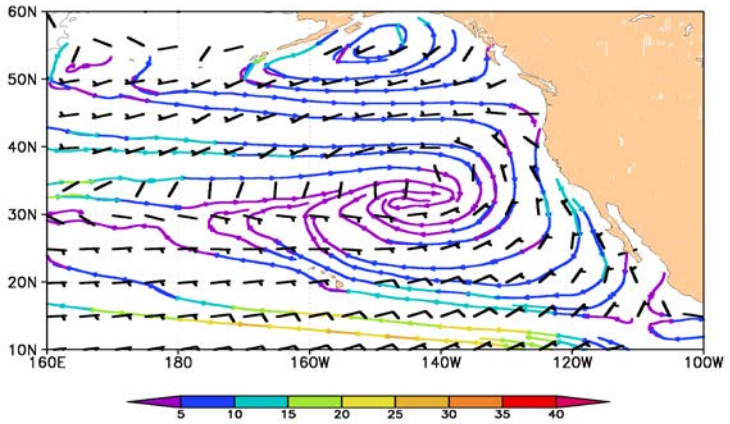
# The story, what we learned

OBS: Tsunami debris stayed afloat for over 3 years
especially wood

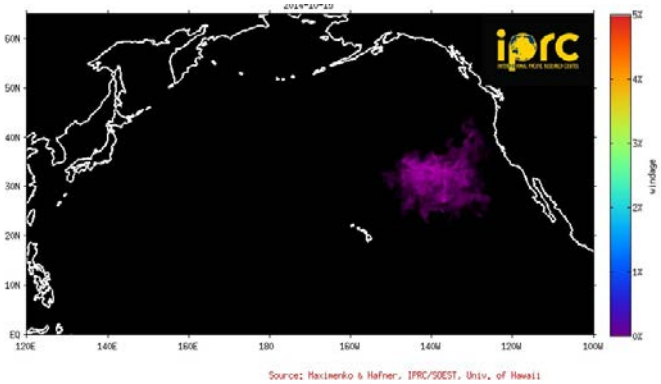
OBS+MODEL: effect of wind on timing of debris arrival
**high windage:** type reaching coastline first
the west coast of N. America
**low windage :** lagging behind the high
windage type

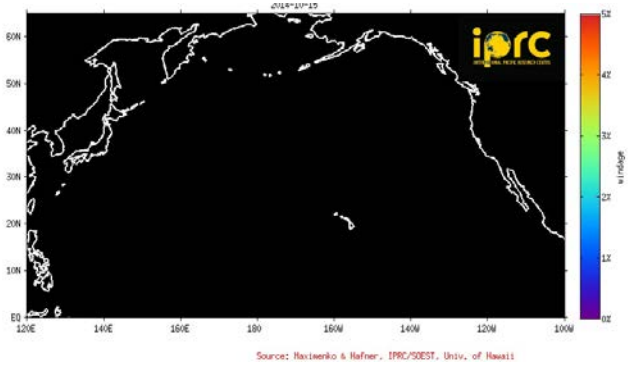
MODEL: effect of the wind on final destination
**high windage:** almost all deposited on shore
**low windage:** slow moving accumulation in
subtropical convergence zone or North Pacific Garbage Patch

Mean SCUD current (cm/sec streamlines)
and QSCAT wind barbs



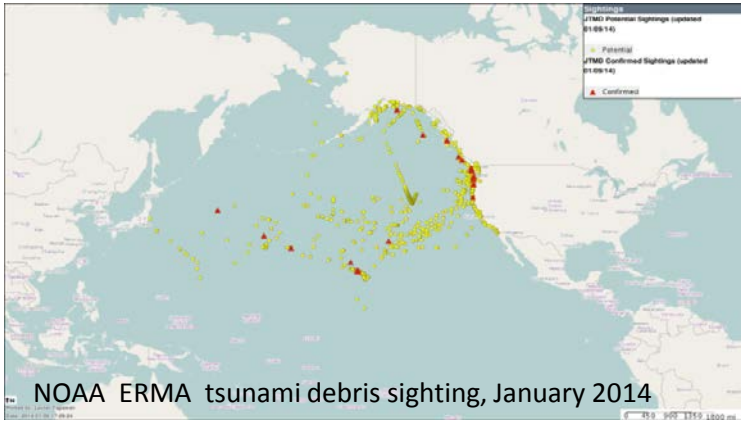

2014-10-15



# The summary, lessons learned

- Modeling approach applicable on marine debris transport
- Observations are critical, but sparse
- **Sea :** only in situ as remote sensing not applicable yet
  reliance on volunteers and ships of opportunity
  only few dedicated expeditions
- **Shoreline:** volunteers, beach clean-up activity


NOAA ERMA tsunami debris sighting, January 2014

- Lack of systematic approach, systematic documentation, accidental reports
- Needed: Marine Debris Observing System

Thank you !

- Updates: IPRC Marine Debris Webpage
  http://iprc.soest.hawaii.edu/news/marine_and_tsunami_debris/debris_news.php