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

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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

Courtesy of Robin Bond
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

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

Ocean surface currents

Starting 01 AUG 1999 ending 18 NOV 2009 extended into real time
Formulation of the diagnostic model

SCUD

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

And similarly

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

Where: \( U_{SCUD}, V_{SCUD} \) - modeled ocean current components
\( U_0, V_0 \) - constant coefficient (mean)
\( h \) - sea level anomaly
\( w_x, w_y \) 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

Ocean surface

Low windage, object sitting deep in water

Medium windage, object sitting half in water

High windage, object sitting high on water

For example 5% windage means an object is moving with the current + 5% wind speed
IPRC Drift Model:

2011-03-10

Source: Maximenko & Hafner, IPRC/SOEST, Univ. of Hawaii
Modeling the dispersion of tsunami debris
“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
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

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

June 2012 – report of s/v “Tregoning” north of Oahu

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

[Map of Hawaii with locations marked]

18 Sept. 2012, Y.K Suisan Co., Ltd
Actual Observations
Hawaii shores

24-28 Sept. 2012 gasoline tanks Molokai
Actual Observations
Hawaii sho

Actual Observations
Hawaii shores

03 Oct. 2012 yellow tank East of Big Island
Actual Observations
Hawaii shores

17-19 SEP 2012 floating dock

Actual Observations Hawaii shores

- Nov. 2012 Kahuku Golf Club coast, Oahu
- Nov. 2012 Kahana Bay, Oahu
- Dec. 2012 Punaluu, Oahu
- Jan 2013 Hanauma Bay, Oahu
- Jan 2013 Waialua, North Shore, Oahu
Actual Observations Hawaii shores

Feb. 2013 Makapuu, Oahu
Feb. 2013 Kahuku, Oahu
Mar. 2013 Kahuku, Oahu
Feb. 2013 Makapuu, Oahu
Jul 2013 Malaekahana, Oahu
Aug 2013 Turtle Bay, 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. 2013 Wainouli, Kauai
Actual Observations Hawaii shores wood

- Nov. 2013 Kahuku, Oahu
- Sep. 2013 Kamilo, Big Island
- Dec. 2013 Shipwreck Beach, Kauai
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

**Model**

*Images of buoy, gas cylinder, timber beams, etc.*
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
- Lack of systematic approach, systematic documentation, accidental reports
- Needed: Marine Debris Observing System

- Updates: IPRC Marine Debris Webpage

Thank you!