An estimate of the tsunami-debris quantity washed ashore on the US and Canadian beaches, based on a webcam monitoring and a particle tracking model experiment

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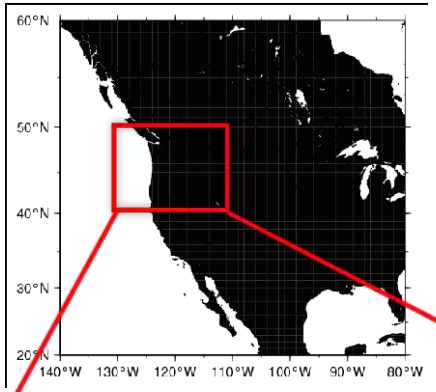
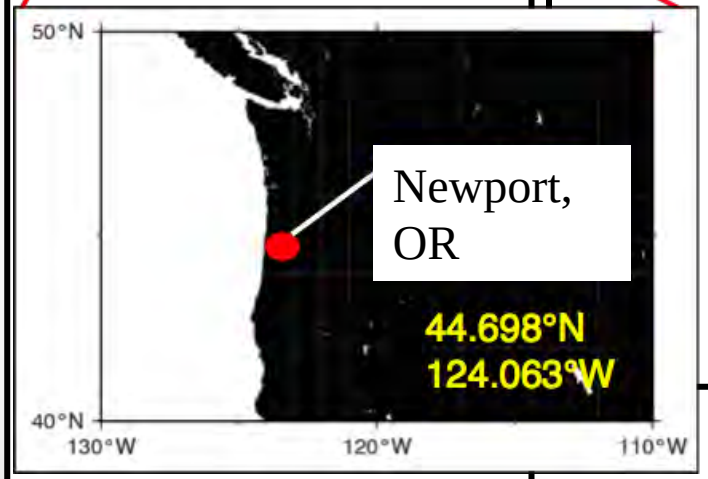
Webcam monitoring

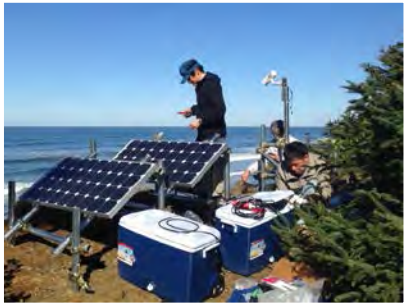
Kako et al. (in revision)

location





specifications

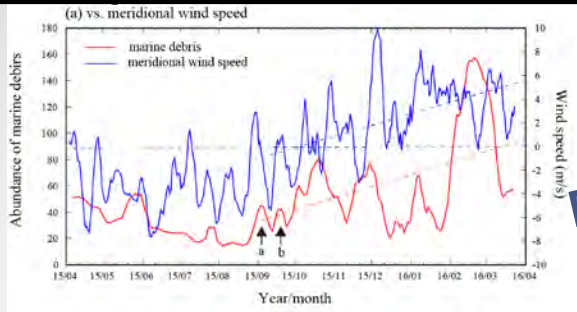


interval:
9:00~18:00 once at each hour

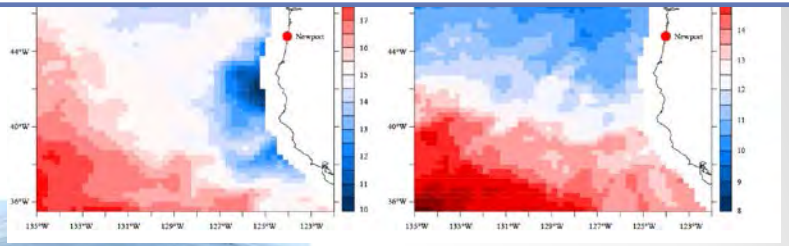
resolution:
1920 × 1080 pixels

period:
2015/Apr～on-going

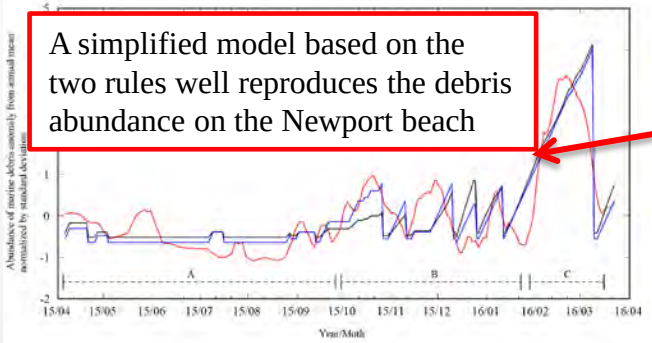
Summary of webcam monitoring



(**Rule.1**) Seasonal increase from summer to winter owing to the coastal downwelling



A simplified model based on the two rules well reproduces the debris abundance on the Newport beach



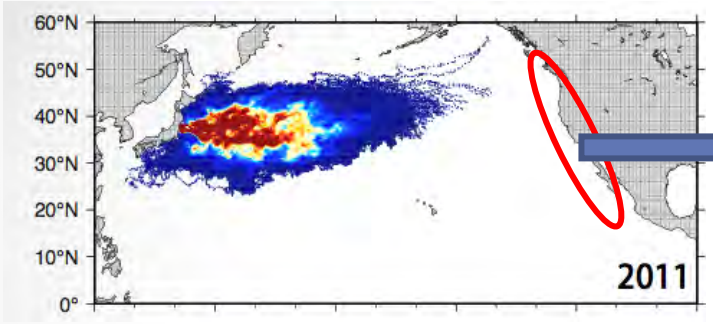
(**Rule.2**) Rapid decrease owing to the wind setup (at spring tides) during the westerly (onshore-ward) winds

Kako et al. (in revision)

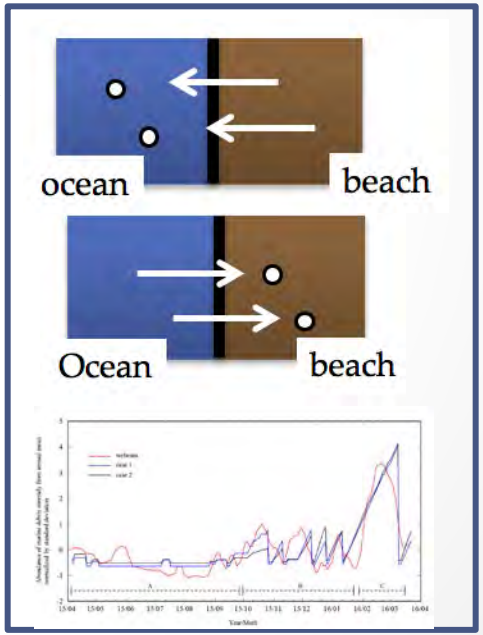
Model setup by a combination of a particle-tracking model and sub-model

Particle-tracking model using an ocean re-analysis data and satellite wind to reproduce the debris motion in the ocean

Sub-model based on the two rules associated with satellite winds at the nearest grid cell to reproduce the debris washing ashore and re-drifting (nearshore processes).



+



Objective of the present study

>>To estimate the abundance of tsunami debris washed ashore on the western coasts of US and Canada?

>>To find the beaches on which the massive amount of tsunami debris has been washed ashore (→ "hazard map" of invasive species)

Particle tracking model

$$X^{t+\Delta t} = X^{t} + \mathbf{U}\Delta t + \frac{1}{2}\left(\mathbf{U}\cdot\nabla_{H}\mathbf{U} + \frac{\partial \mathbf{U}}{\partial t}\right)\Delta t^{2} + R\sqrt{2K_{h}\Delta t}\,(i,j)$$

Particle position at the time t+Δt

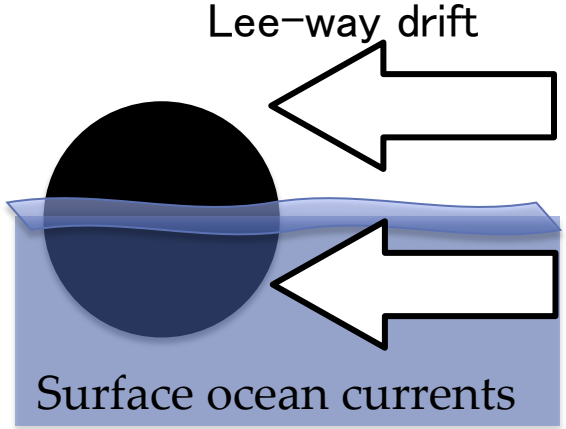
Time increment (360s)

Random number (average=0, SDV=1)

Horizontal diffusivity

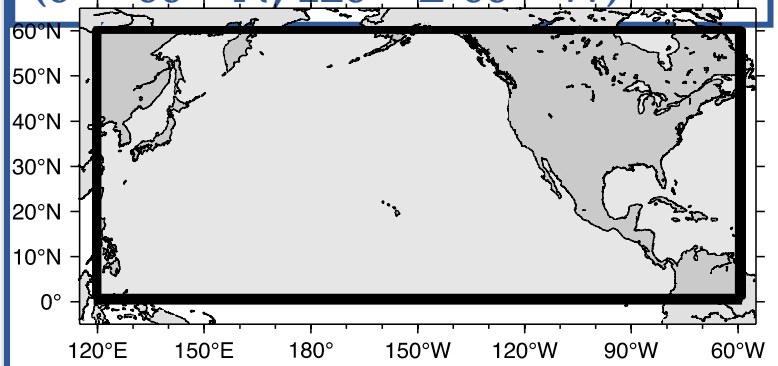
Surface velocities

Ocean Currents + Winds (lee-way drift)



Model domain

(0° -60° N, 120° E-60° W)

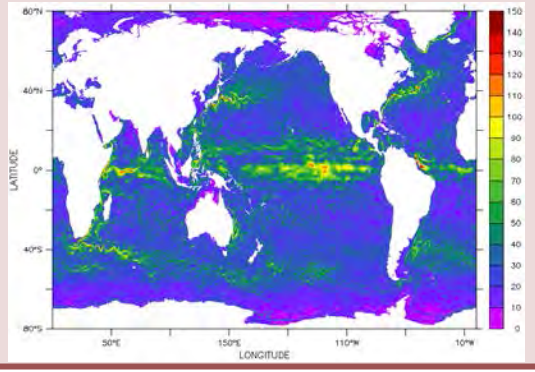


Ocean surface currents

HYCOM
(Chassignet et al., 2007)

Spatial resolution: 0.08°× 0.08°
Temporal resolution: daily

https://hycom.org/



Monthly averaged current speed in Dec., 2012

Satellite-derived winds

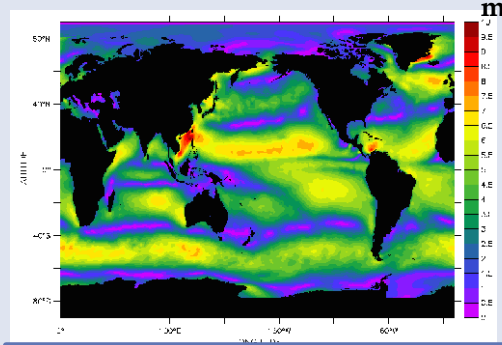
ASCAT (Kako et al., 2011)

Spatial resolution: 0.25°× 0.25°
Temporal resolution: daily

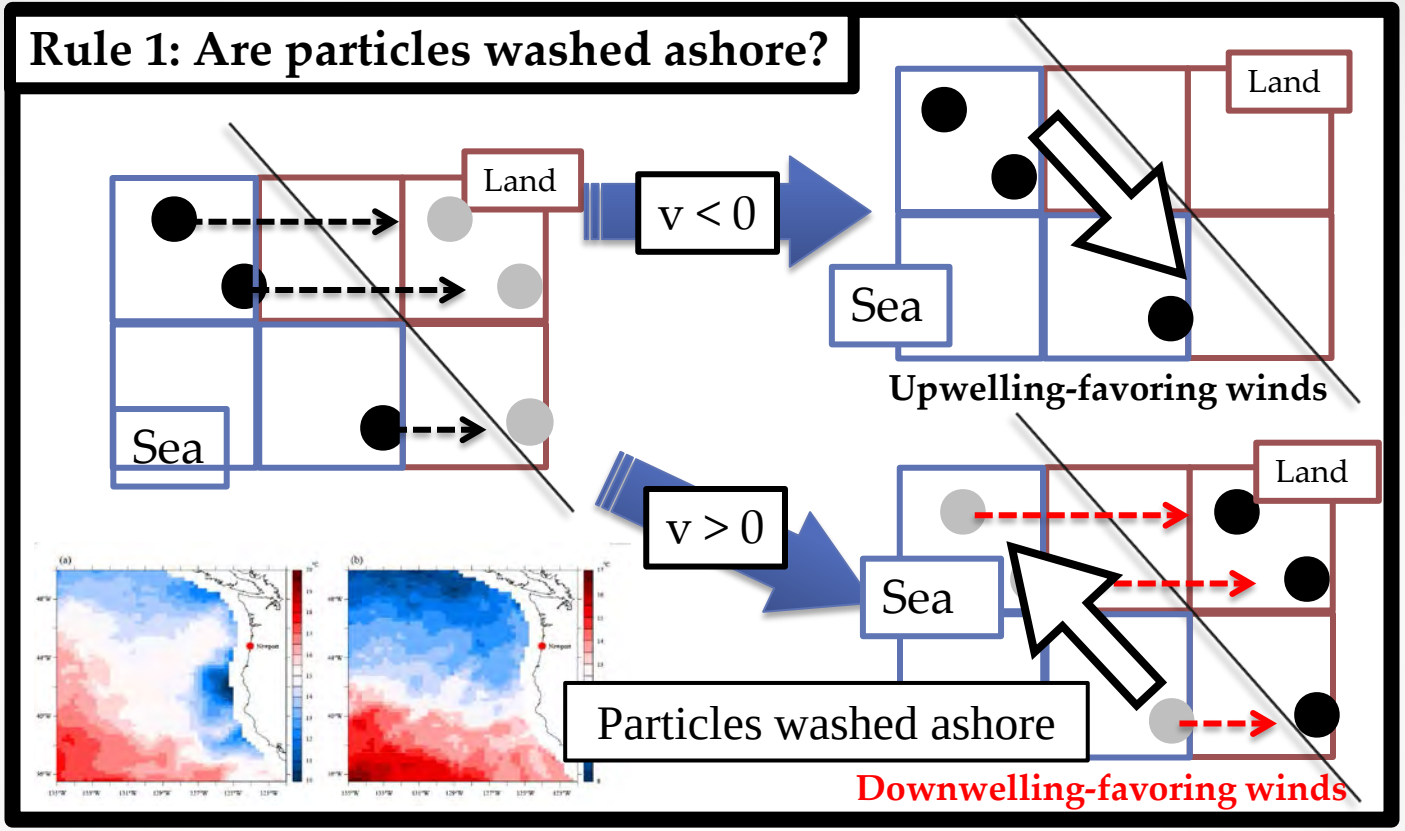
Lee-way drift (Richardson, 1977)

$$V = \sqrt{\frac{\rho_a}{\rho_w}\frac{Cd_a}{Cd_w}\frac{A_a}{A_w}}W$$

Ratios of
Density= 1.15×10^{-3}
Drag coefficients=1.00,
Projected areas=1~1/300 (given by random numbers)



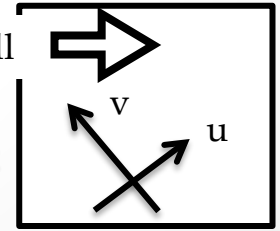
12 月の月平均値(2009-2015)



Sub-model

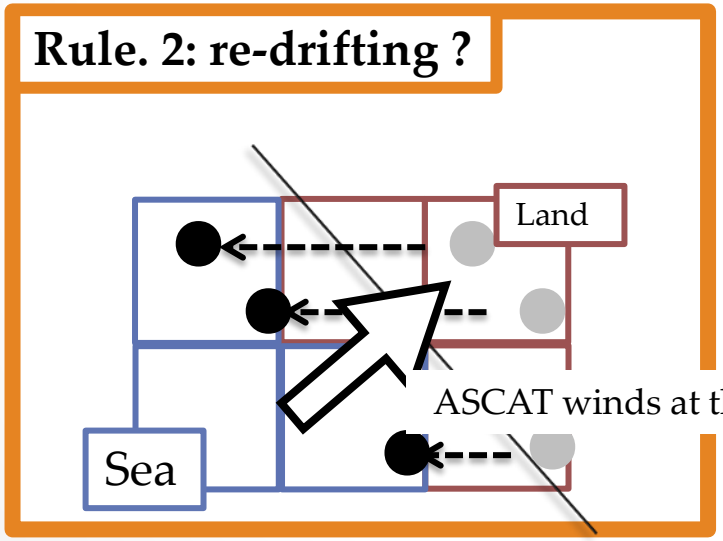
working at grid cells neighboring beaches

ASCAT winds at the nearest grid cell



Sub-model
working at grid cells neighboring beaches

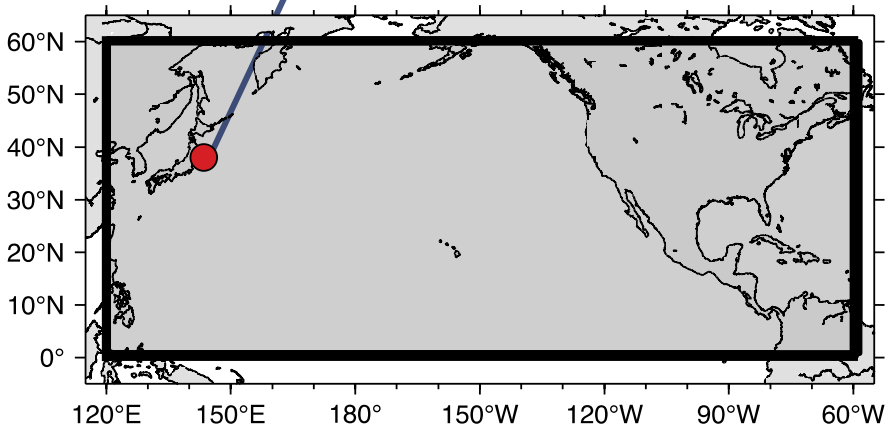
When intense **onshore-ward winds** (> average + SDV) occurred at **spring tides** (i.e., the occurrence of the **wind setup**), all debris “littered” on land cells returns to the oceanic cells.



Experimental design

50,000 particles were released at the area off the Sanriku coast (38.1N, 143.5E) on Mar. 11, 2011

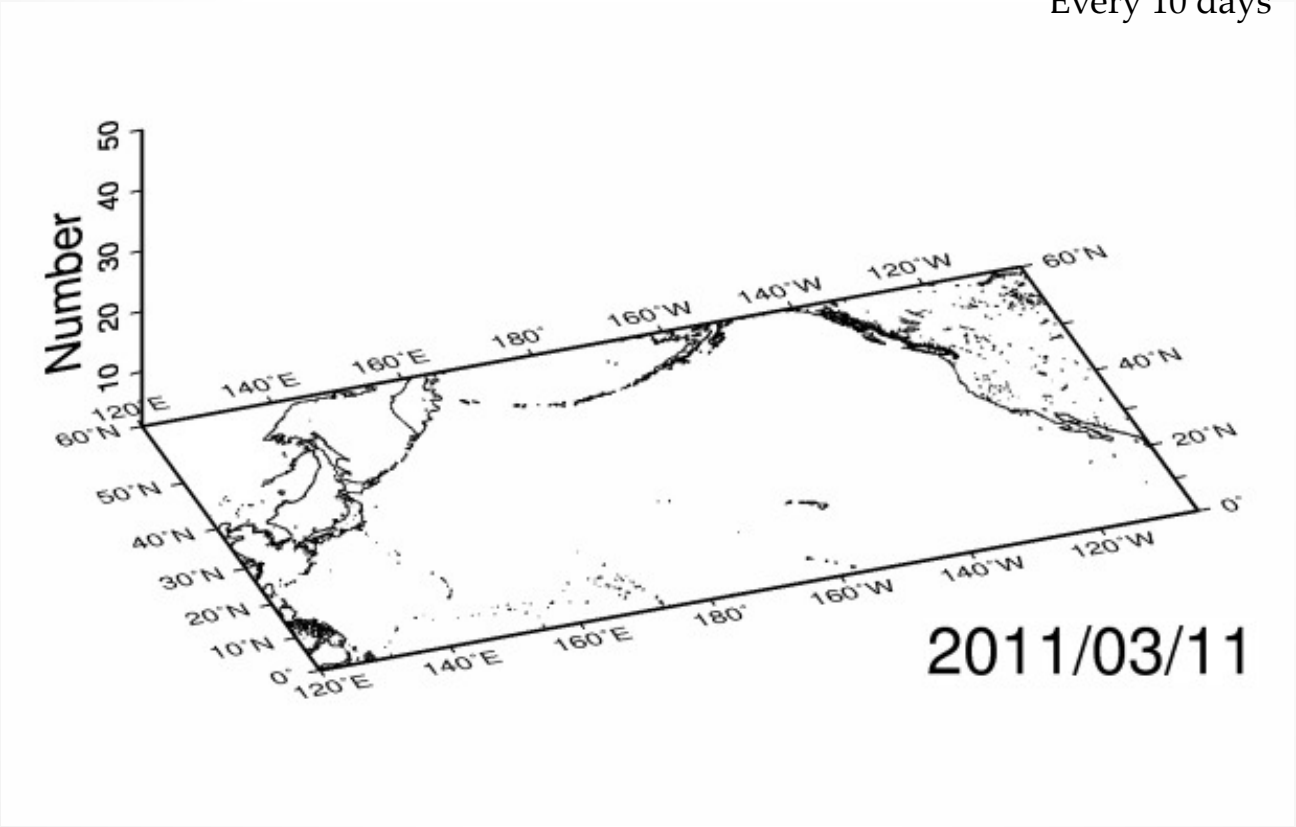
Model domain (0°-60°N, 120°E-60°W)



Computation period: 2011/03/11-2016/06/30

Movie in the period 2011/03/11 through 2016/06/30

Every 10 days

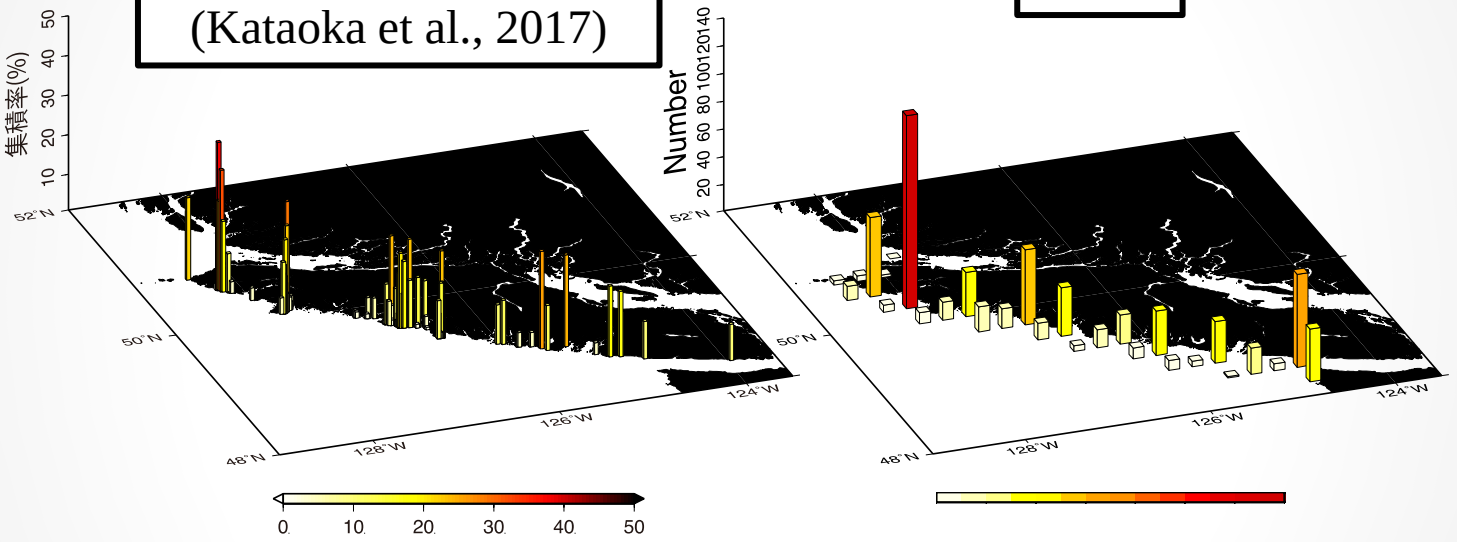


Validation

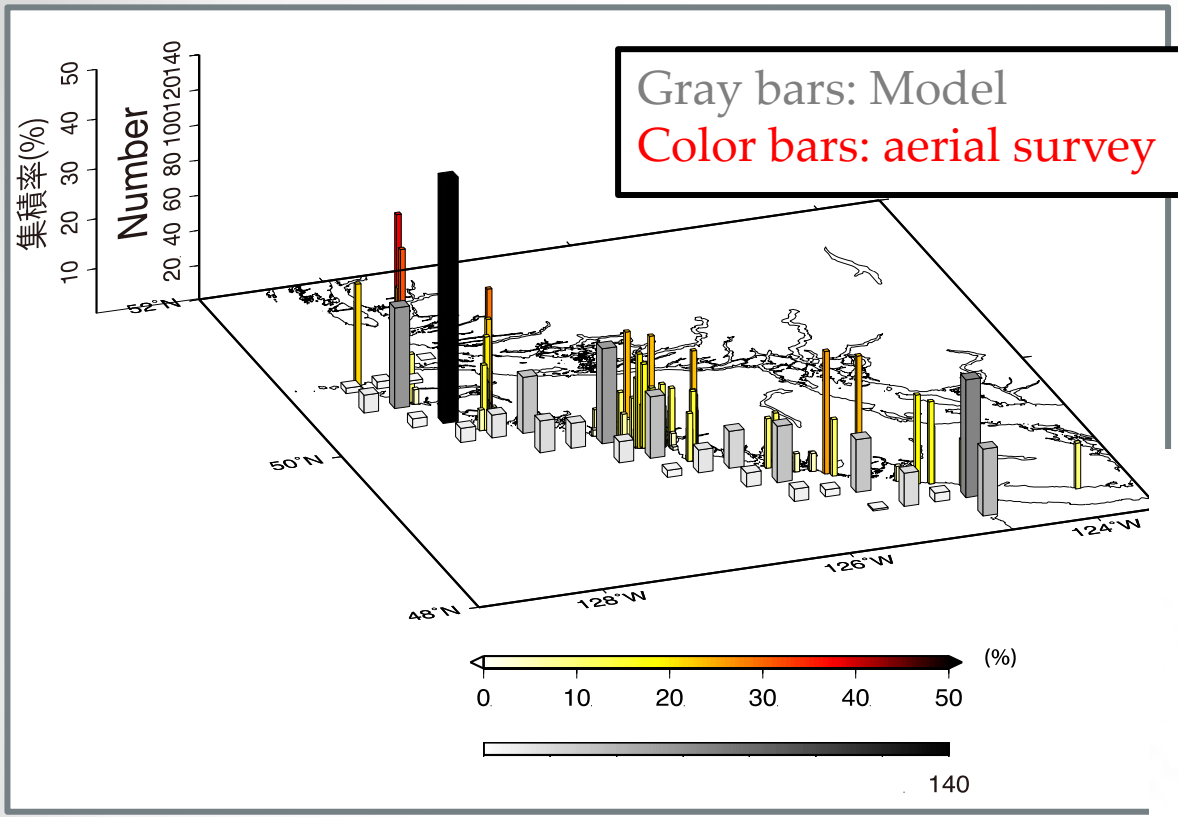
2014/10/7, 2014/12/3

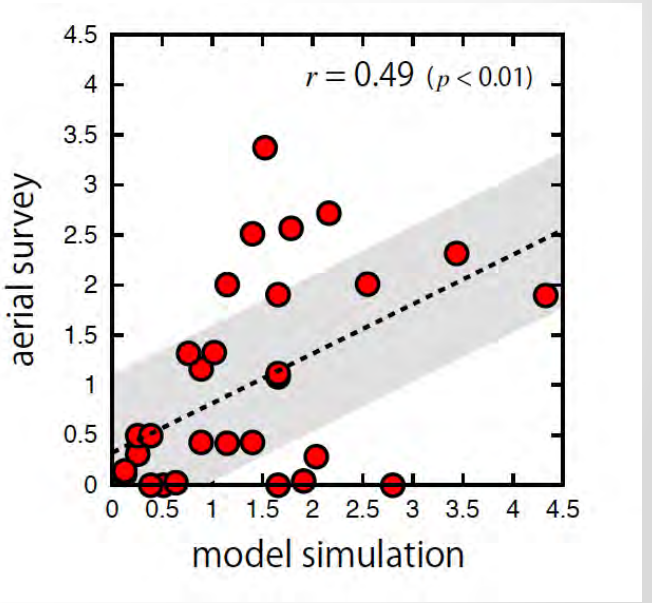
Aerial surveys
(Kataoka et al., 2017)

Model

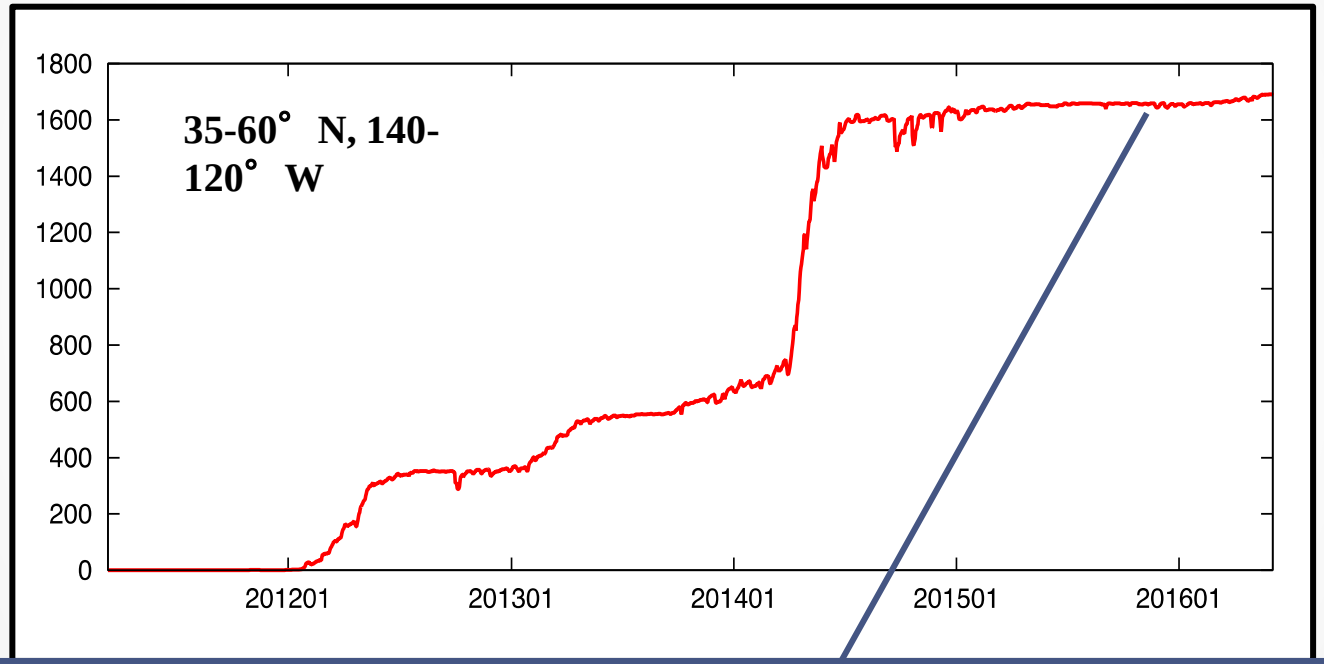


Percent Cover
(Ratio of the area occupied by beach litter to that of the beaches)


Gray bars: Model
Color bars: aerial survey
集積率(%)
Number
10 20 30 40 50
20 40 60 80 100120140
52° N
50° N
48° N
128° W
126° W
124° W
(%)
0 10 20 30 40 50
140

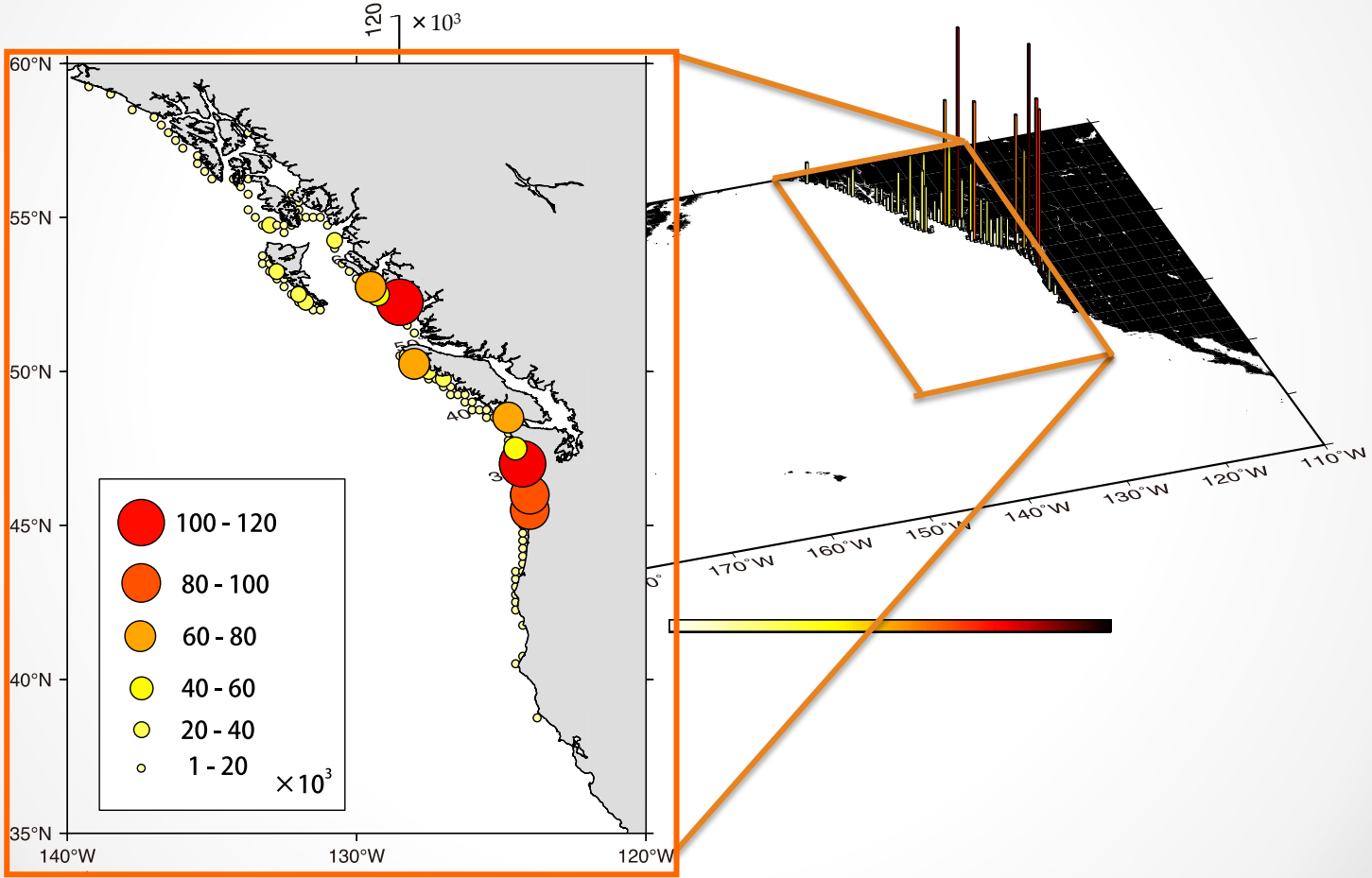

r = 0.49 (p < 0.01)
aerial survey
model simulation
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5

Abundance of particles washed ashore on the US and Canadian coasts (2011/03/11-2016/06/30)



1600 particles were 3% of all particles (50,000) released at the Sanriku coast. Approximately estimated was 5,000,000 tons × (100- 70)%× 3% = 45,000 tons of tsunami debris washed ashore on the US and Canadian beaches.

Map of cumulative number of particles washed ashore on the beaches (2011/03/11-2016/06/30)

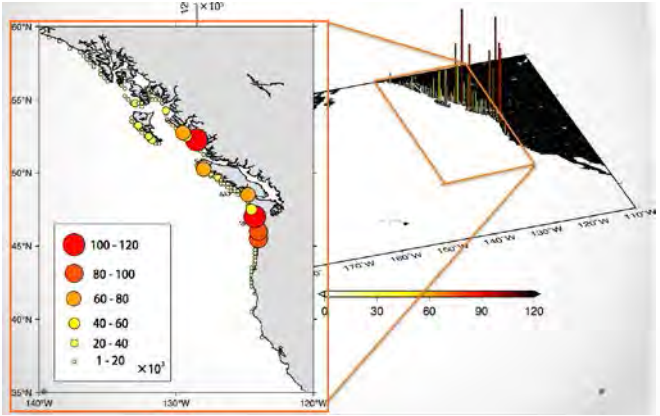


Conclusions

- A webcam-based sub-model was combined with a particle tracking model to estimate the abundance of 3.11 tsunami debris washed ashore on the US and Canadian beaches.

- In total, 45,000 tons of debris potentially exist on the beaches at the present time.

- The model result states that the invasive spices carried by tsunami debris were unlikely to wash ashore widely on the entire US and Canadian beaches. They have been washed ashore on the relatively narrow area (<1000 km) around the south of BC and the north of WA, which might act as a “gate” of the invasive spices carried by the tsunami debris.



Abundance in each year