津波で流されたものは太平洋上をどうさまよったか？

Model Simulation of Japan Tsunami Marine Debris (JTMD)

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Plan of the presentation　話の内容

The largest "island" of debris stretches 60 nautical miles (69 miles) in length and covers an expanse of more than 2.2 million square feet, according to the US Navy's 7th Fleet, which is closely monitoring the floating rubbish

Picture: REUTERS

1.Introduction　はじめに

2. Data Assimilation System: MOVE and K7

海洋のモデル、データ同化システム

3. Modelling of Drifting JTMD and Examples of the Model Solution

漂流予測の方法と結果

4. Summary　まとめ

I. INTRODUCTION

Tragic event of the March 11, 2011 tsunami in Japan has generated estimated 1.5 million tons of debris floating off the eastern Honshu (Japan Ministry of Environment, 2014). 150万トン流出

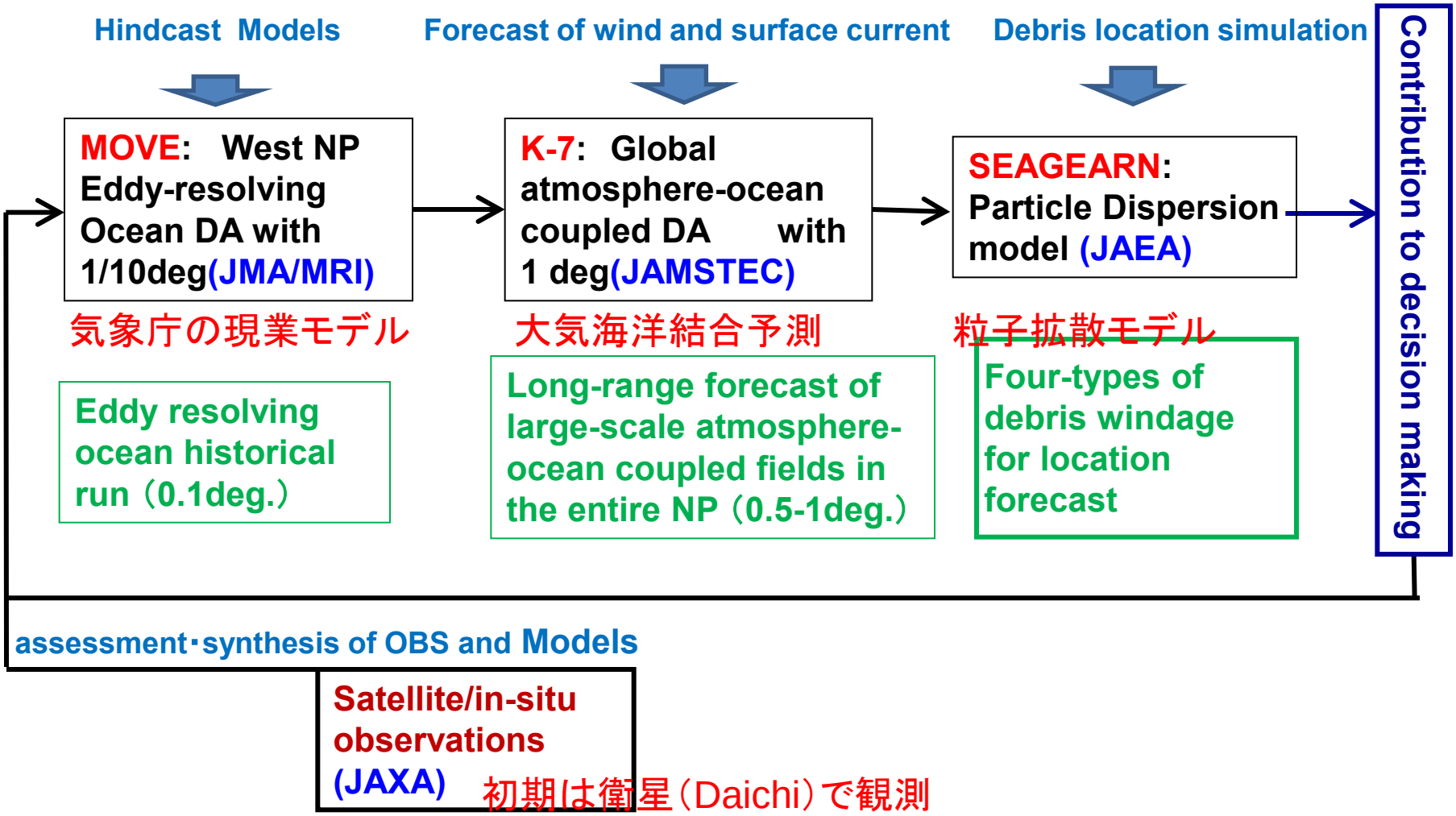
This is an amount comparable to the annual budget of plastic marine debris of the entire North Pacific (Jambeck et al., 2015). 通常漂流（漂着）物の1年分くらいに相当

This Japan Tsunami Marine Debris (JTMD) was seen on photographs in the coastal areas. 漂流物は沿岸では下の写真のように観測できる

Several weeks later, after JTMD drifted off shore and dispersed, its monitoring became very difficult. 数週間後には外洋に出て観測は困難

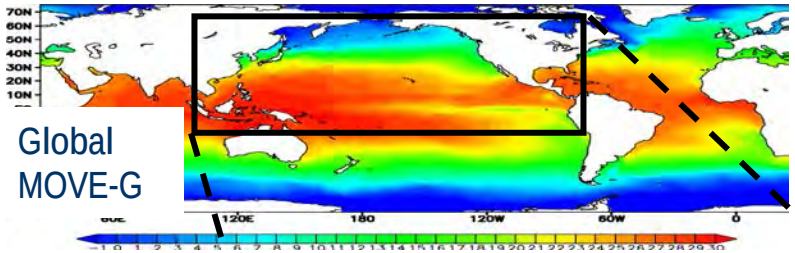
Sparse reports from the sea were not able to provide a coherent description of the pattern and drift motion of JTMD and this task was adopted by numerical models. 外洋での分布や動きは粗い報告のみー＞数値モデルに頼るほかない

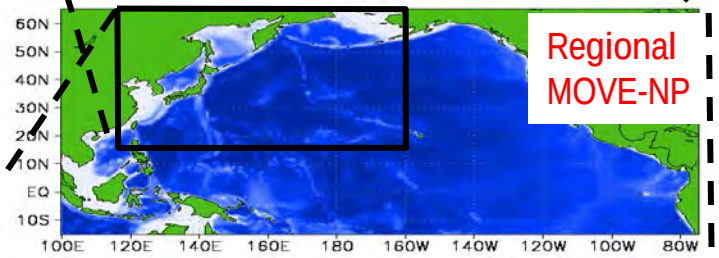
Tsunami Debris Nowcast and Forecast procedure in Japan Team



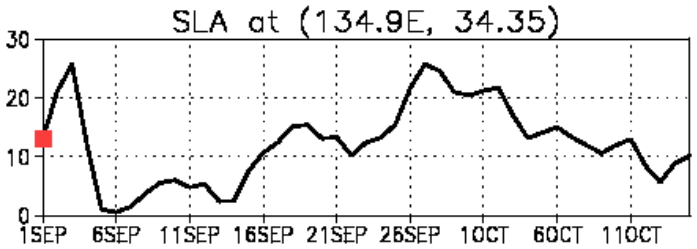
気象庁の海洋に関する予報モデルシステム
JMA/MRI systems

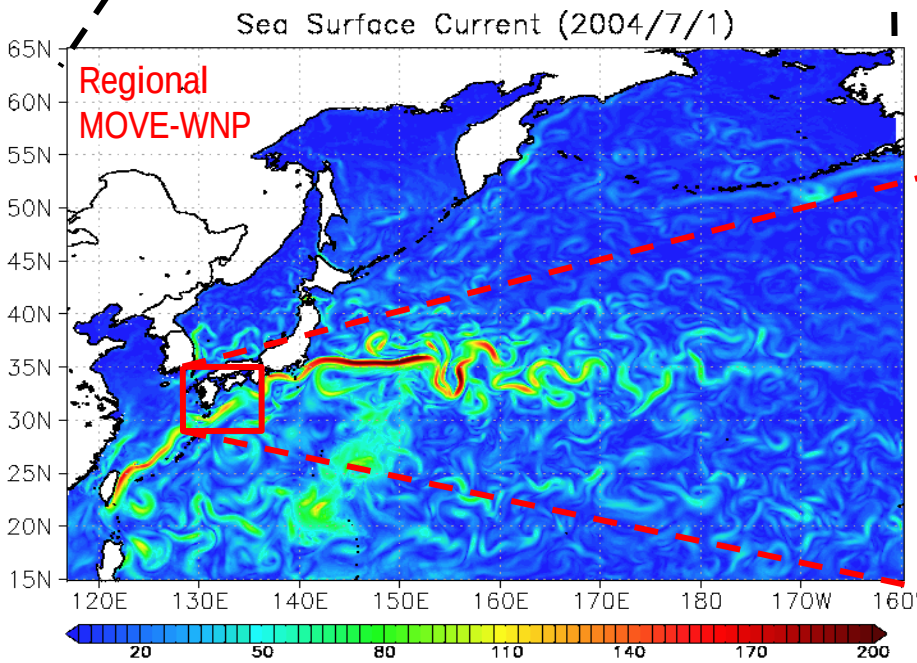
GlobalWarming, Seasonal-ElNino (Global, 1°)
Ocean Weather (N. Pac, 1/2°~1/10°)
Ocean Weather (W.N. Pac, 0.1°~)
Coastal mdl (Seto, Jpn, Tohoku-SICAT02:2km)

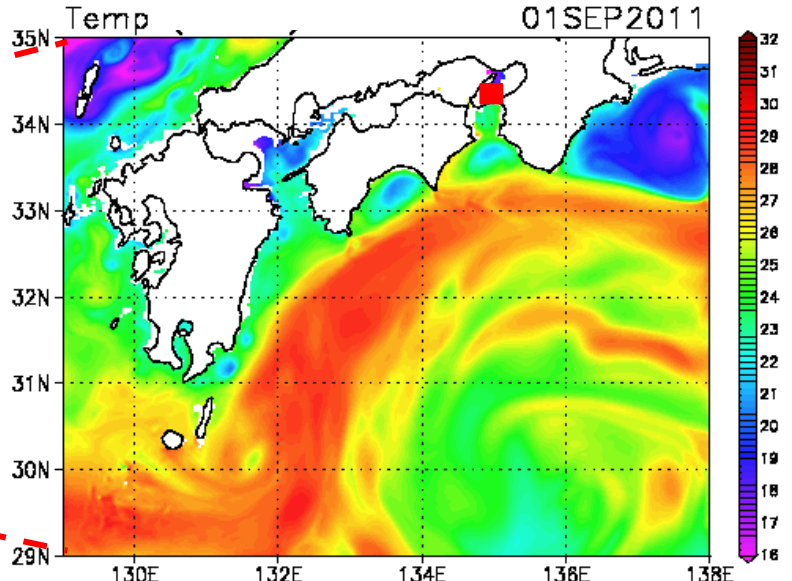




Coastal Application:
Abnormal High Tide





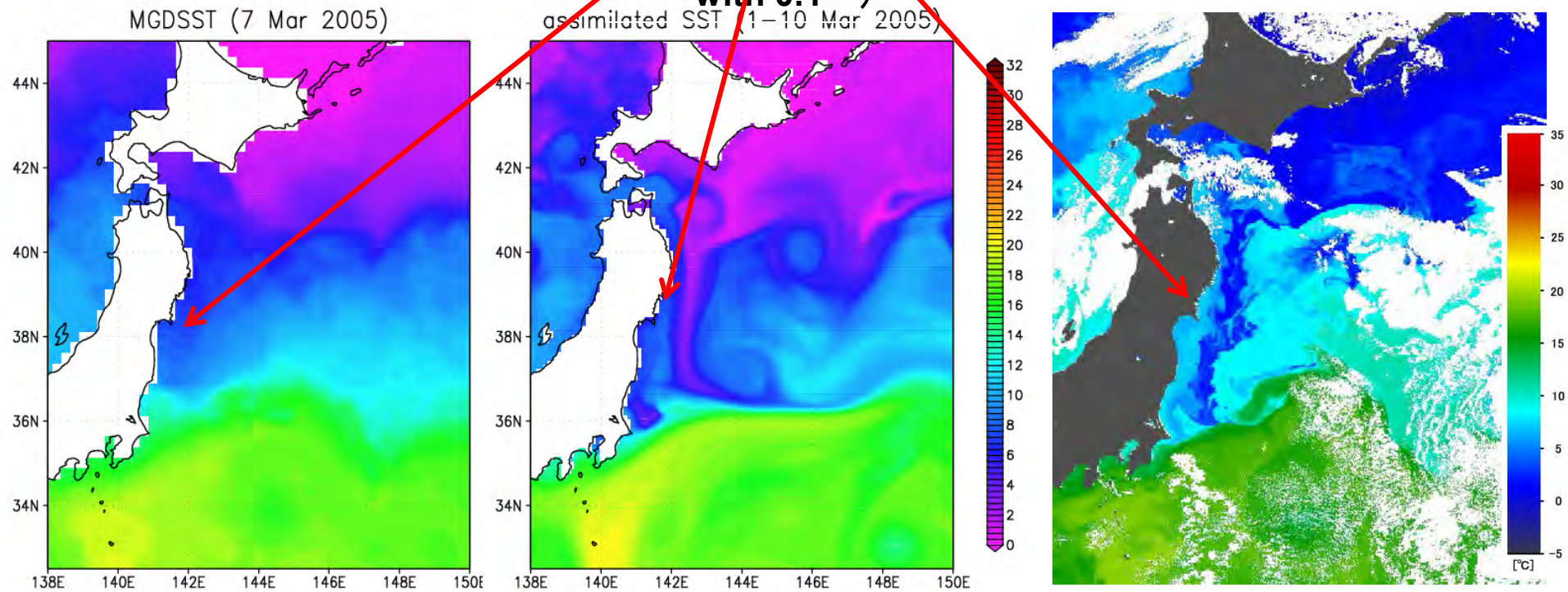


Snapshot of SST（March 7, 2005）offshore of Target areas (Tohoku)

MGDSST
（statistical 1/4°）

MOVE / MRI.COM
（data assimilation with 0.1°）

Terra/Aqua MODIS
（satellite OBS）



Dynamic framework of Particle tracking粒子を流す方式

$$x_{t+\Delta t} = x_t + u_m \Delta t + \delta x$$

(時間発展) (移流) (乱流拡散)

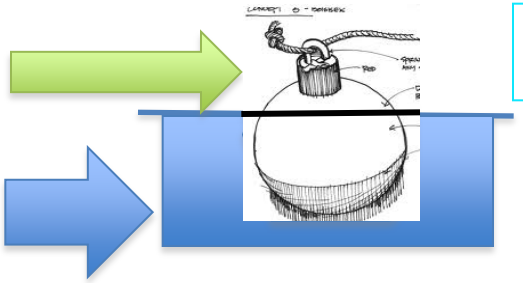
u_m **Particle Movement by** = **Ocean current** + **Wind – force velocity**

(移流のもと) (海流) (風による直接効果)

粒子運動の風で駆動される効果
Wind-driven effect for particle movement

wind

Ocean current



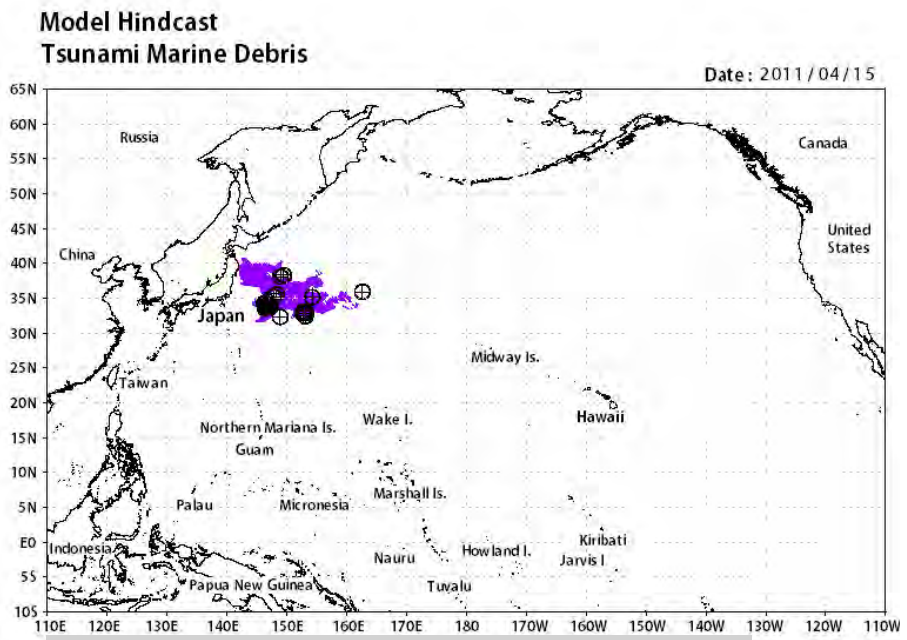
Square measure of cross-section above sea surface: A

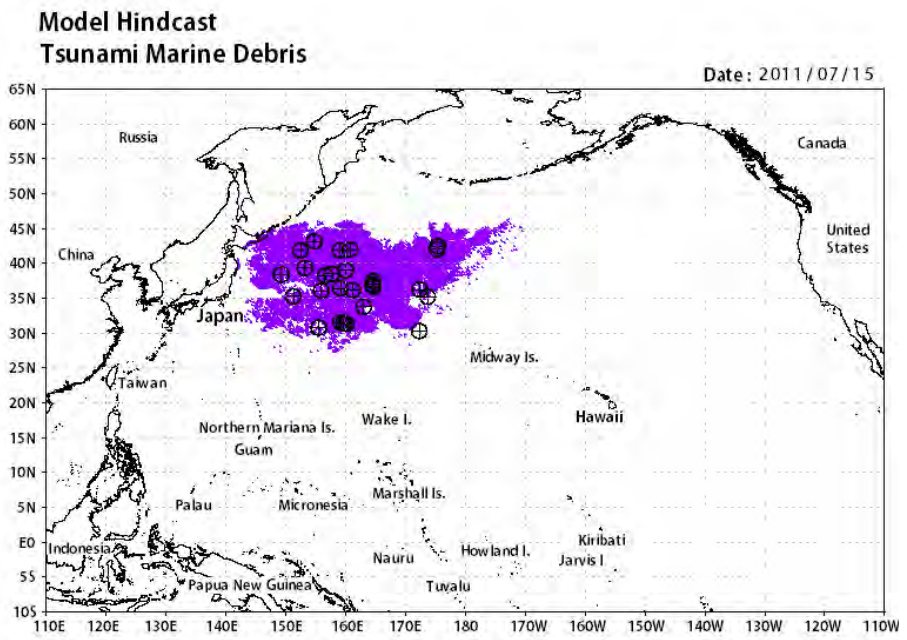
Square measure of cross-section beneath sea surface: B

Wind force velocity = $k\sqrt{\frac{A}{B}} \times W_{10}$

windage × sea surface wind velocity

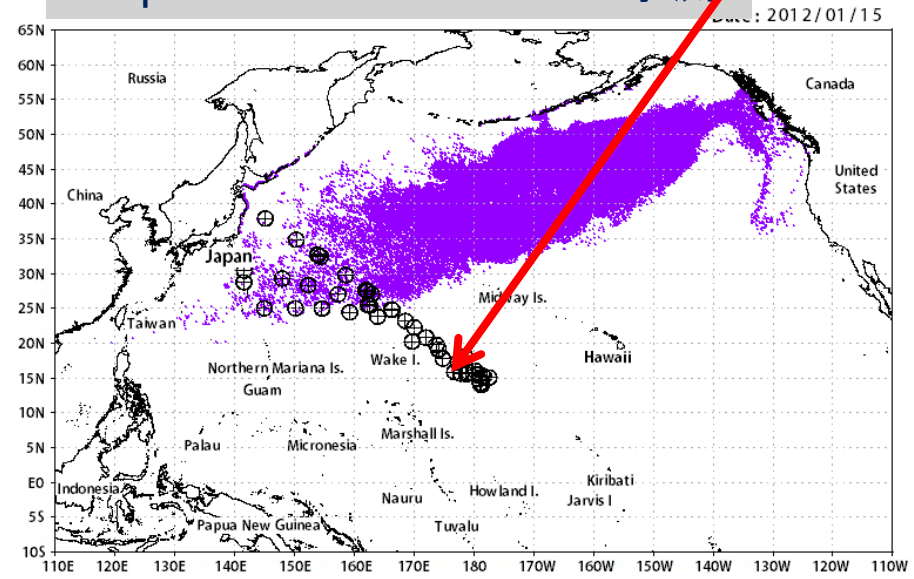
Forecast runs for 4 windage cases
k=0.025
A:B=windage%
0:1=0% Low windage
1:1=2.5%
2:1=3.5%
4:1=5.0% High windage

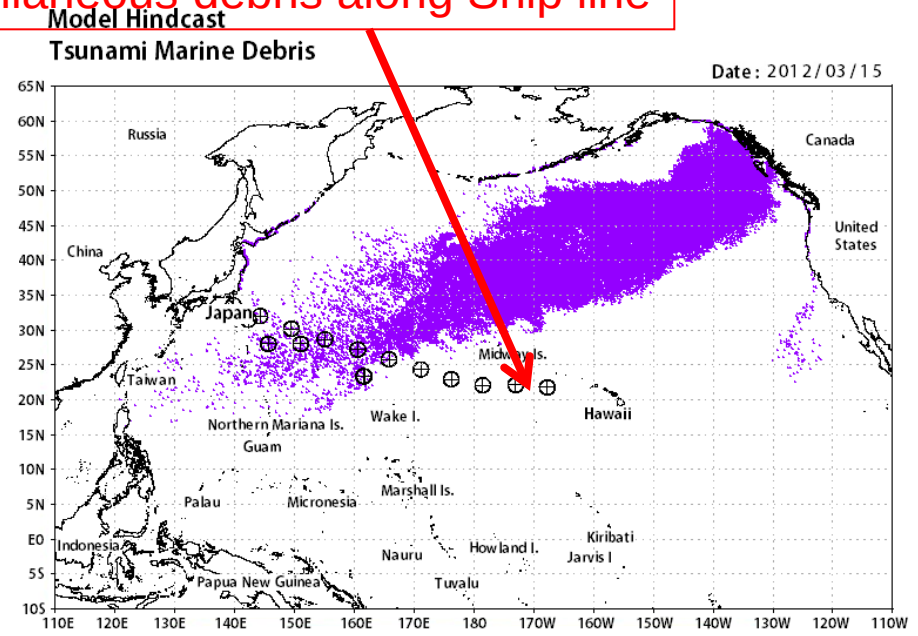




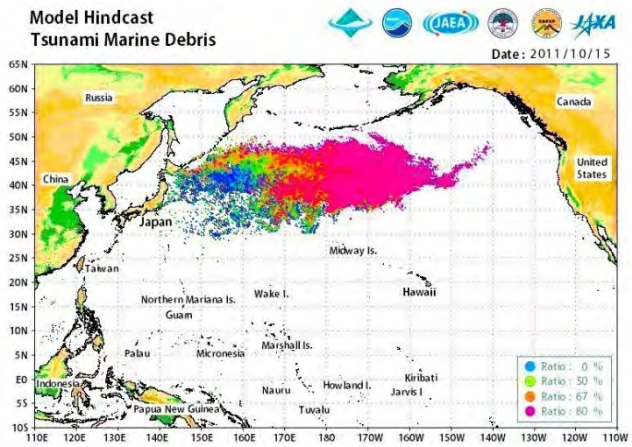
●:sighting location 目観測
Purple : forecasted cloud 予測

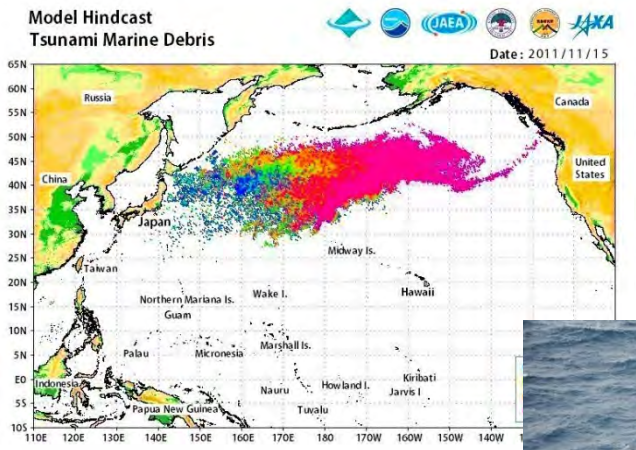
miscellaneous debris along Ship line

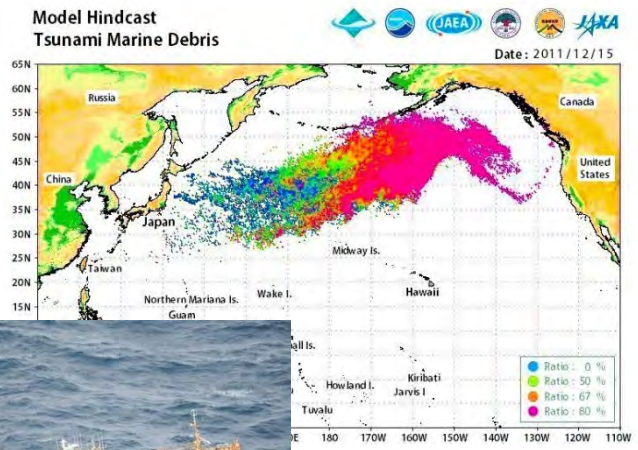




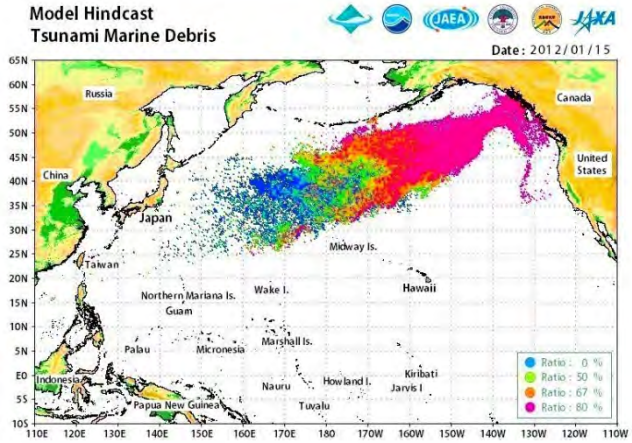
forecast (Oct. 2011 ～ March 2012) : time-series of all forecast cases: overlapped

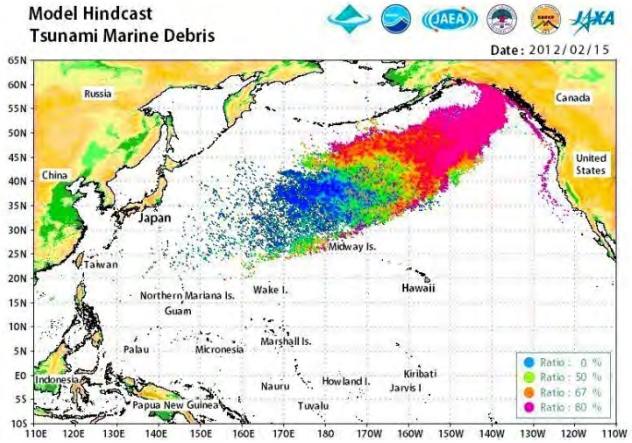


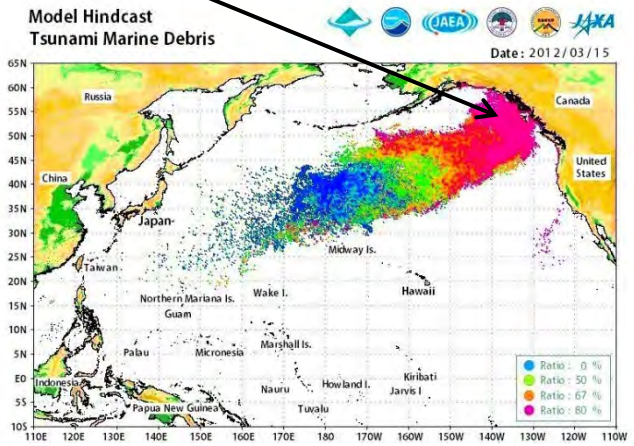




robust agreement

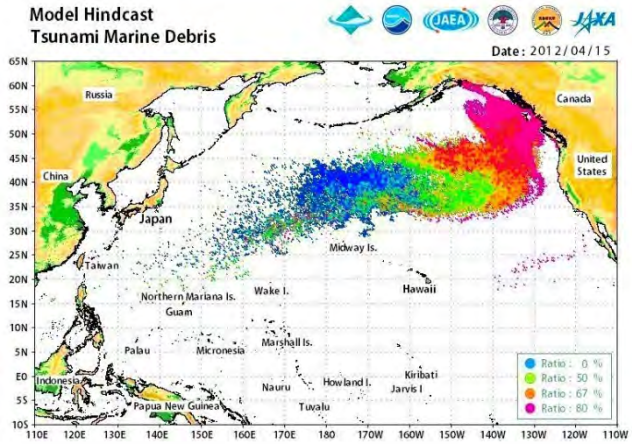


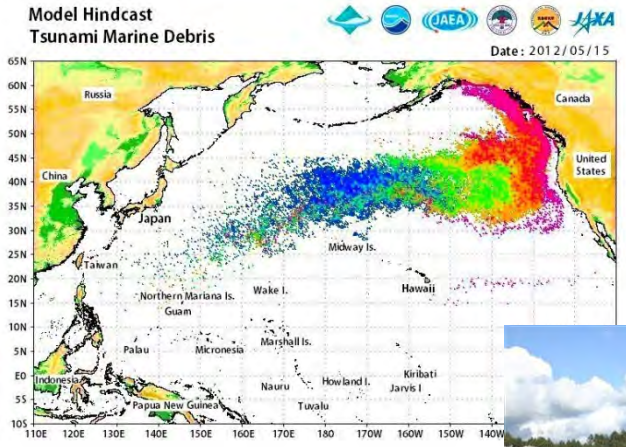


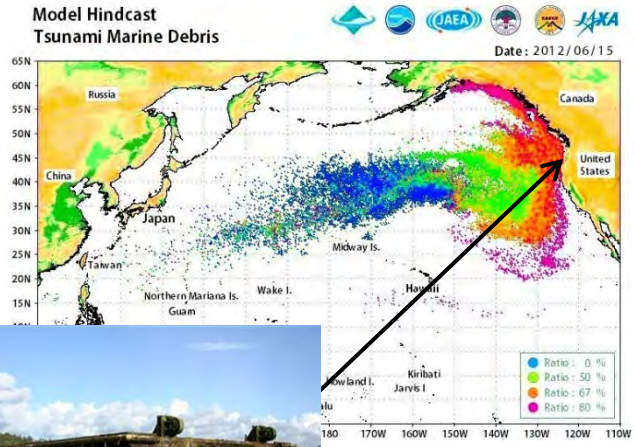


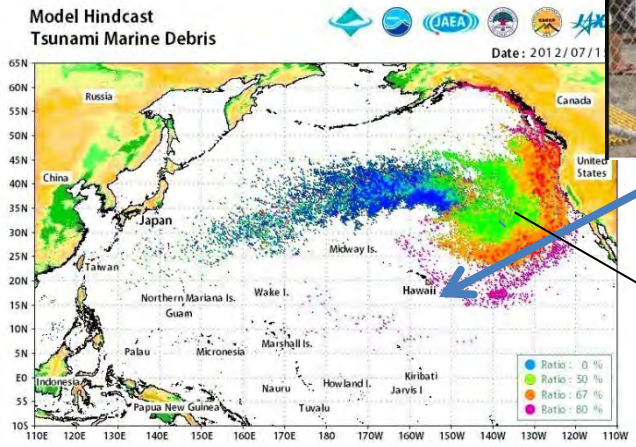
Ratio		beneath : above (the sea surface)		windage
Ratio : 0%	->	1 : 0	->	0.0 %
Ratio : 50%	->	1 : 1	->	2.5
Ratio : 67%	->	1 : 2	->	3.5
Ratio : 80%	->	1 : 4	->	5.0

forecast（Apr. 2012 ～ July 2012）: time-series of all forecast cases: overlapped



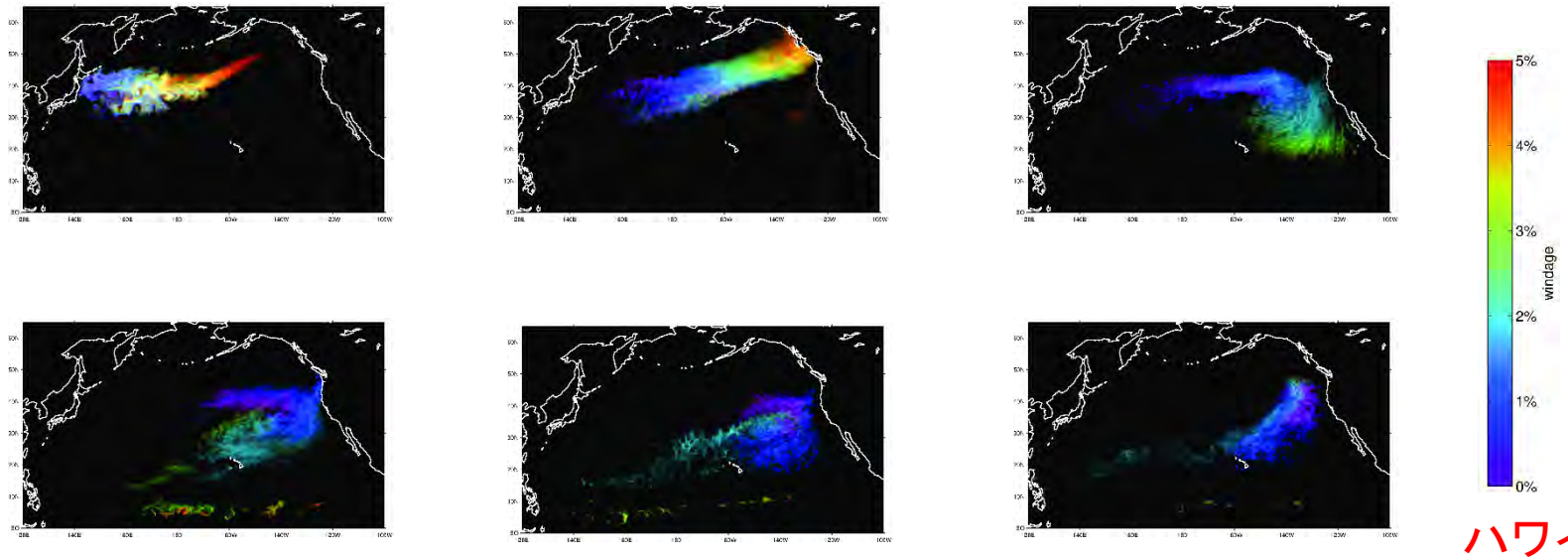






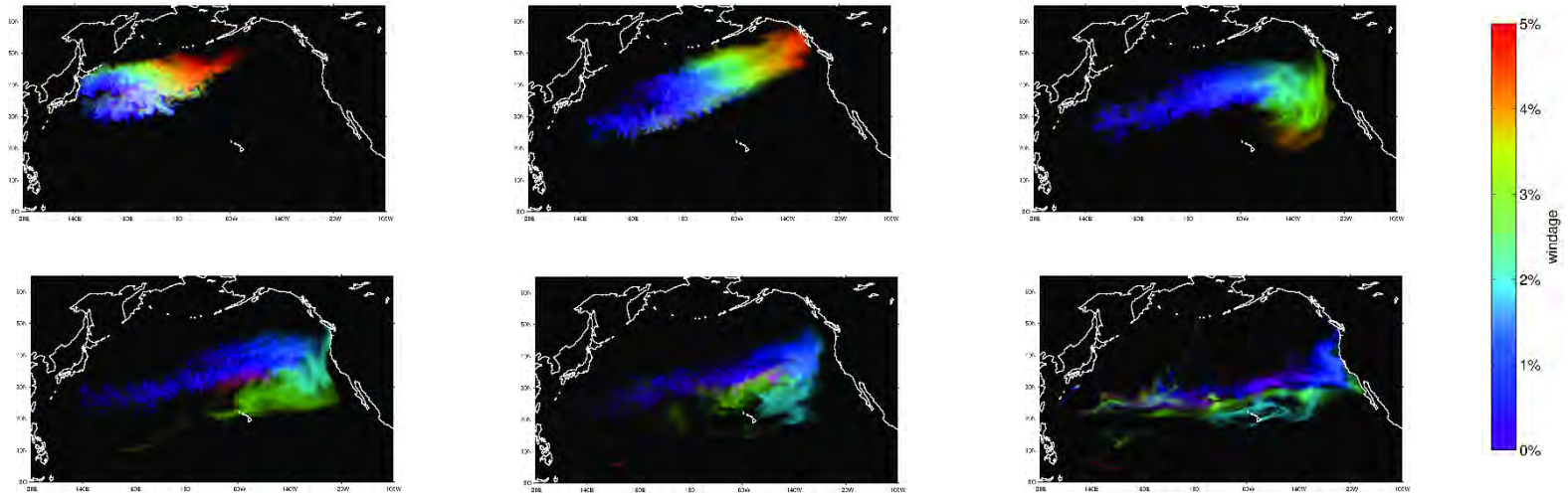
Convergence area
“Garbage Patch”

Ratio		beneath : above （the sea surface）		windage
Ratio : 0%	->	1 : 0	->	0.0 %
Ratio : 50%	->	1 : 1	->	2.5
Ratio : 67%	->	1 : 2	->	3.5
Ratio : 80%	->	1 : 4	->	5.0



ハワイ大学

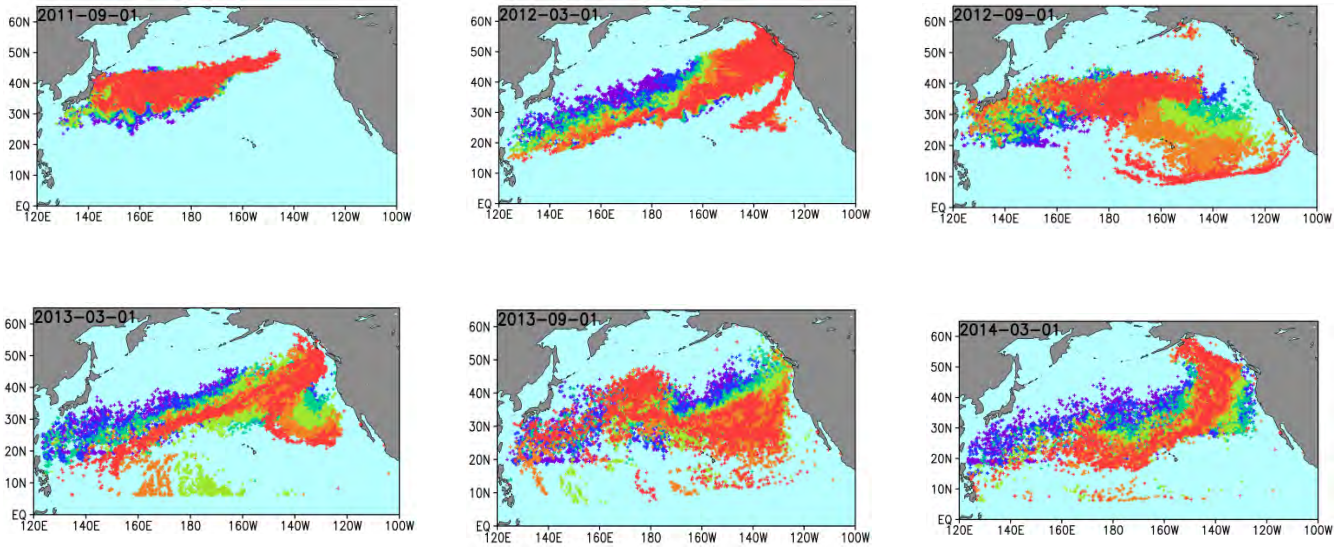
Figure 5. Evolution of JTMD tracer in the SCUD model simulations. Colors indicate windage of the debris. Shown are maps, corresponding to September 1, 2011, March 1, 2012, September 1, 2012, March 1, 2013, September 1, 2013, and March 1, 2014.



日本チーム

Figure 6. Same as in Figure 5 but for but for MOVE/K-7/SEA-GEARN model simulations.

米国海洋大気庁(NOAA)のシミュレーションシステム(GNOME)による結果

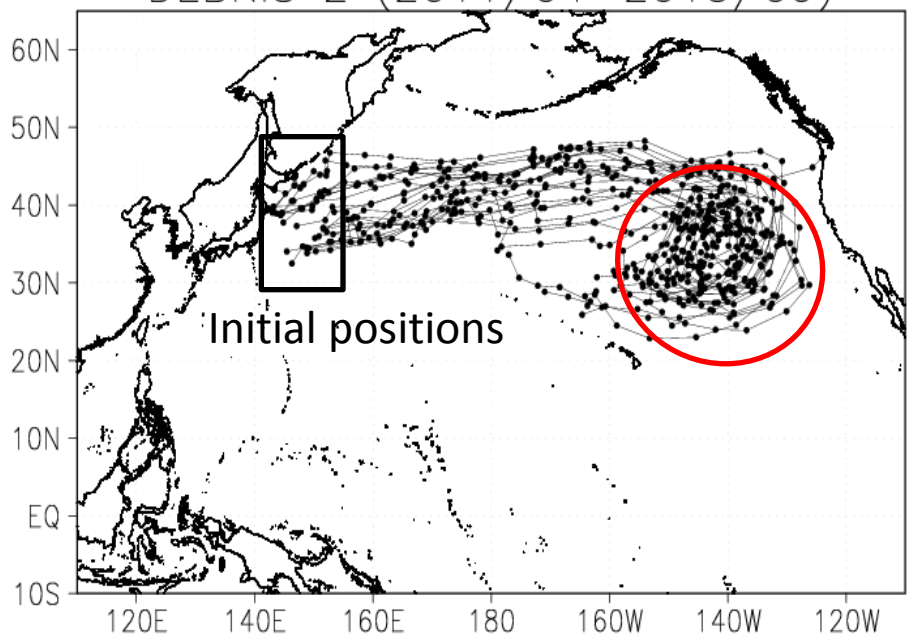


米国現業モデル

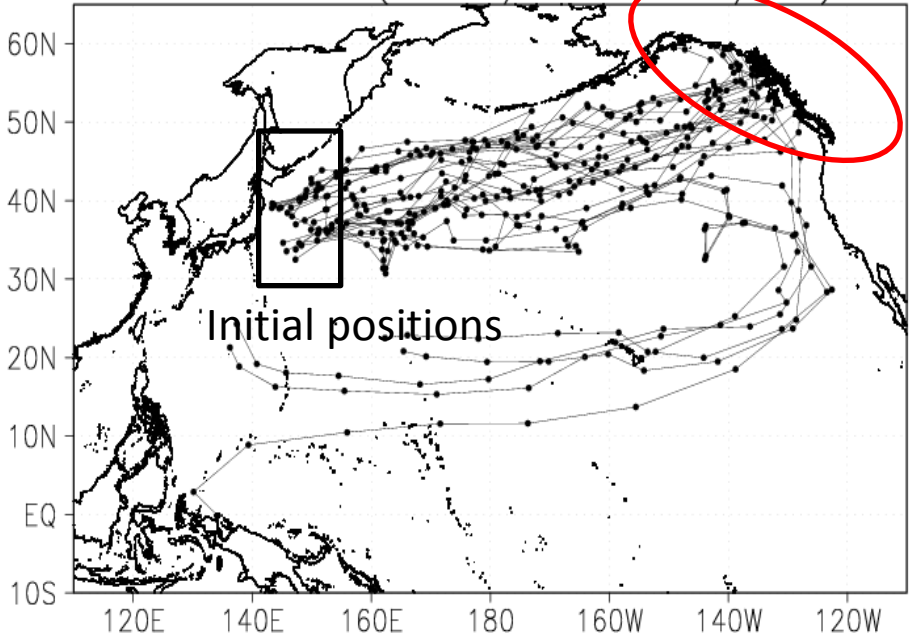
Figure 7. Same as in Figures 5 and 6 but for particle locations in the GNOME model simulations. Colors indicate particle windages according to the color scales of Figs. 5 and 6. High windages are plotted on a top of lower windages.

Typical debris trajectories with windages (a) 2.5% and (b) 5.0% from April 2011 to September, 2013.

(a) Lower windage 水没

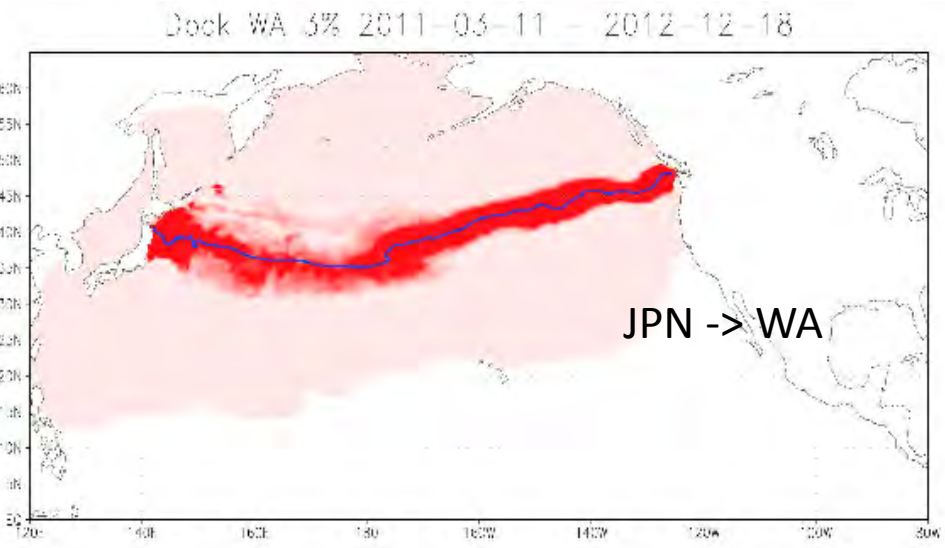


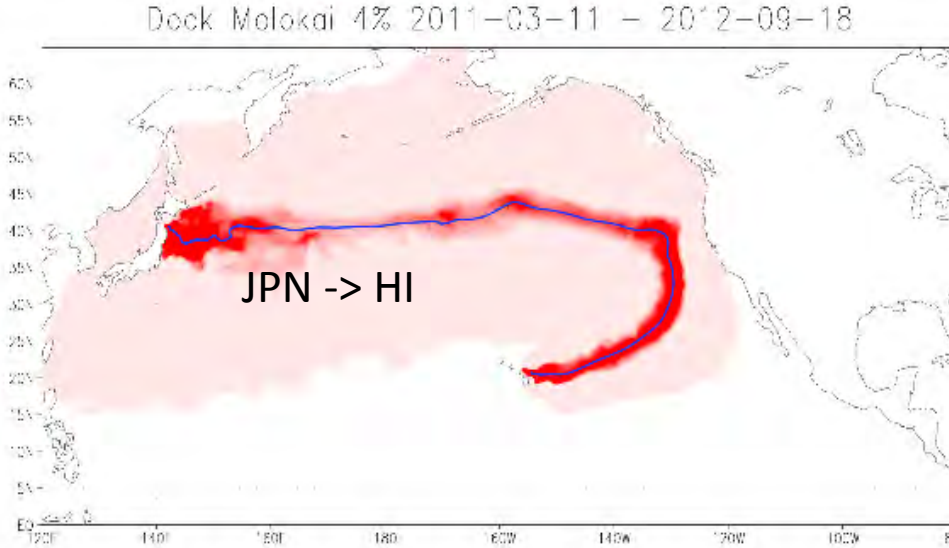
(b) Higher windage 海上8割

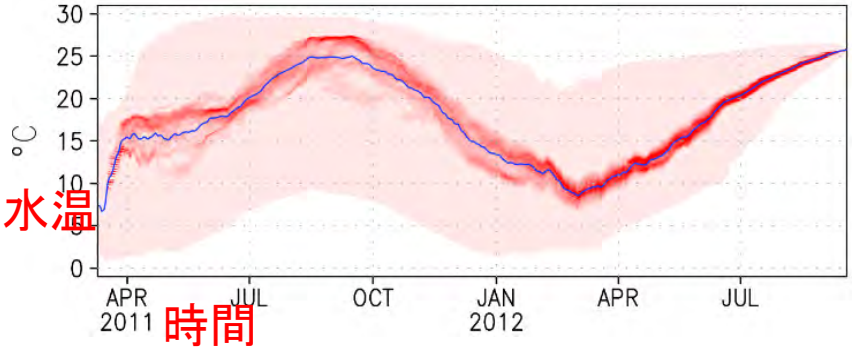


Deterministic Trajectory

Probabilistic Trajectory 確率的な経路分布







Probability density function of near-seasurface temperature, measured by the Argo network, along the probable path of Molokai dock

As shown in the figure (Maximenko et al., 2015b, and also Maximenko and Hafner, 2010), such approach gives not only the uncertainty of the trajectoriy of debris but also probabilistic information of the sea environment (e.g., temperature) along the trajectory and time. This information is critical for detecting probable path of invasive species colonizing debris items.

Example (Request)

宮城県気仙沼水産試験場

Research Vessel (Kaisyou, 1.1ton) of Kesennuma Local Fisheries Laboratory (Miyagi prefectural Government) was found at about 6km offshore area from Miyako-city, Okinawa prefecture in May 12, 2016.

The prefectural government group would like to know the route.

Before 2011

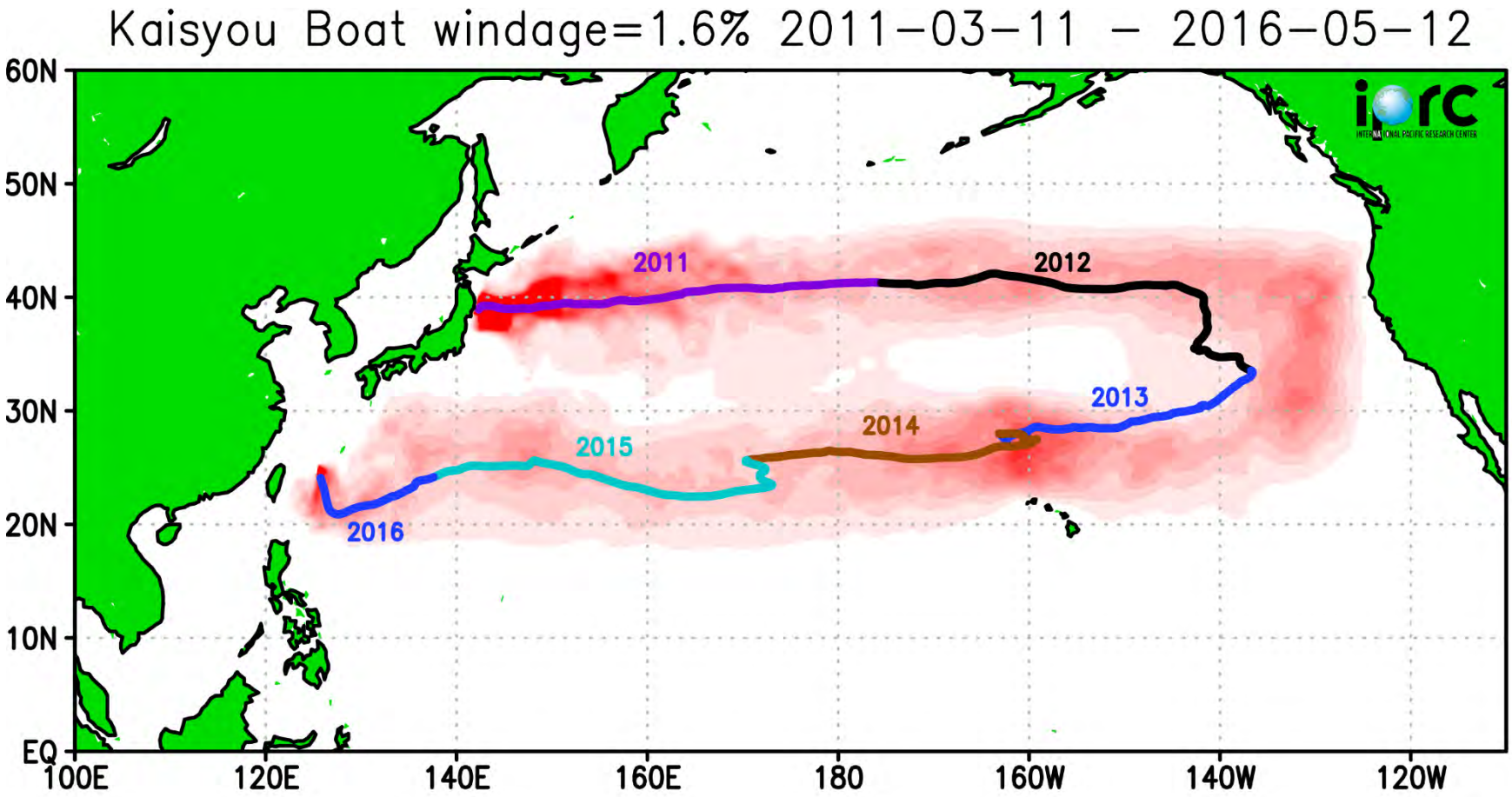
(Lat=38.8, Lon=141.6

(Lat=24.7, Lon=125.3)

After found in 2016/5/12

?

Example (Answer)
Probabilistic route



Summary (some figures are not shown)

1.High computing simulation and data assimilation are useful for the calculation of marine debris distribution. The model solution depends on the windage. 海上と海中の割合が重要

2.On-shore observation and model solution estimated seasonal change: e.g., summer 2012, winter-spring 2013, spring-summer 2014, due to seasonal wind and ocean current fields. 季節的な変動

3.Model solution estimates that less than 10% of the tracer washes ashore annually and suggests that more than 50% of JTMD with boat type windage was still floating in the end of 2016. This means that boats from the 2011 tsunami, built to withstand rough ocean conditions, will likely continue coming to the US/Canada coastline in several future years. At the same time, JTMD wandering in the gyre gradually mixes with marine debris from other sources and loses its identity. まだ半分程度は漂っていそう

4.Future progress in marine debris modeling requires radically improved at-sea and on-shore observing systems as well as better model descriptions of coastal process and processes on the sea surface (such as Stokes drift by wind waves) and their effects on floating objects. より細かい沿岸モデルが必要

Thank you for your attention