Tracking the pumice rafts from the submarine volcano Fukutoku-Okanoba, Japan

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Iskandar, Park, Kim, Jin, Seo, Kim, 2023, Marine Pollution Bulletin

Submarine volcano
Fukutoku-Okanoba, Japan

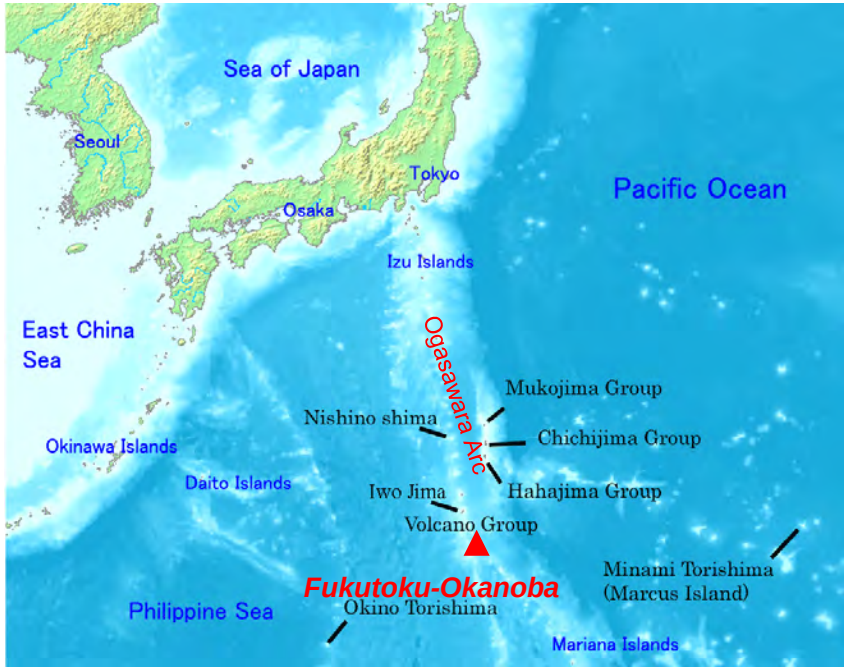


Figure source: www.wikipedia.com

Pumices position

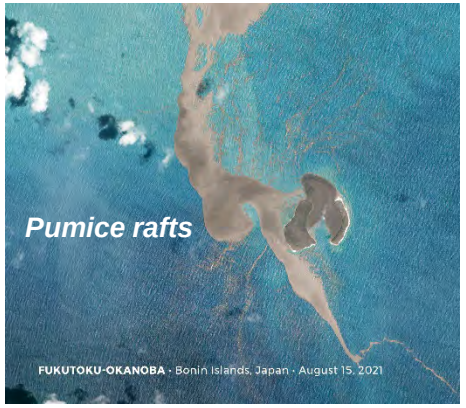


Figure source: www. volcanodiscovery.com

Erupted on 13th August 2021,
and pumice stones were produced.

Pumice 부석(浮石) 경석(輕石)

- A volcanic rock that consists of highly vesicular (void) rough-textured volcanic glass.
- It floats on water, possibly for years, until it eventually becomes waterlogged and sinks.

What is Pumice?

- Construction
- Personal Care
  - remove unwanted hair or skin.

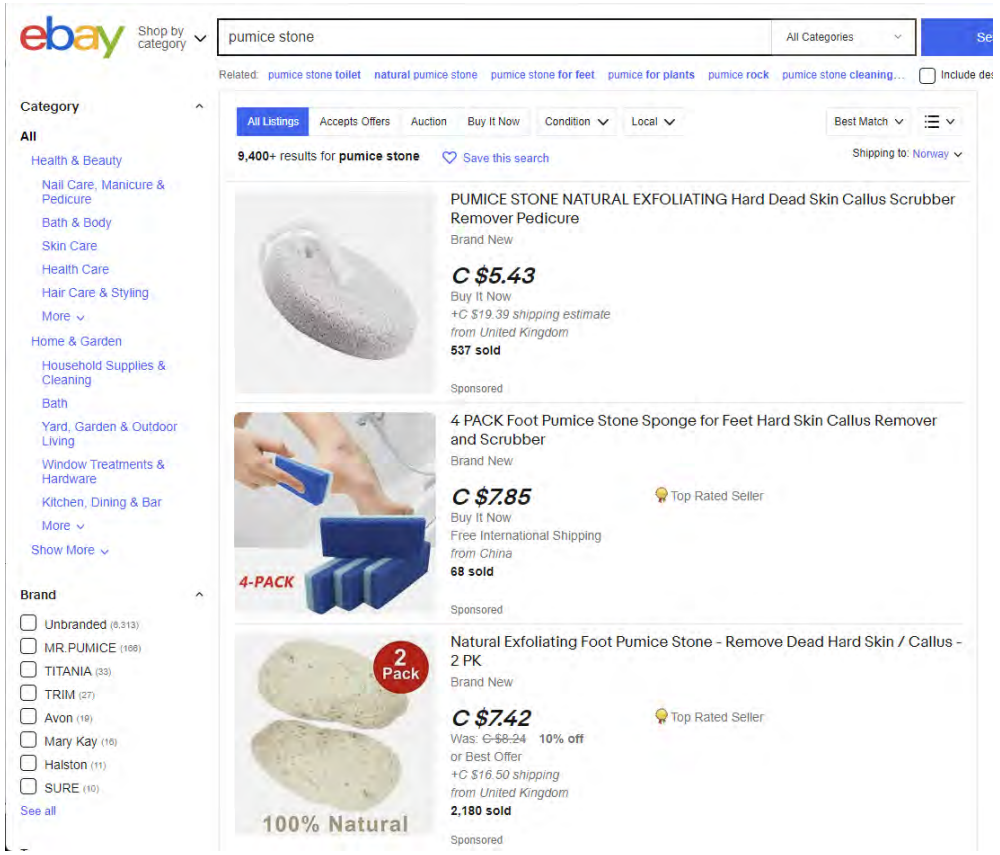


Figure source: NHK

marine traffic and damaging boat engines

Figure source: NHK

clog harbors and beaches

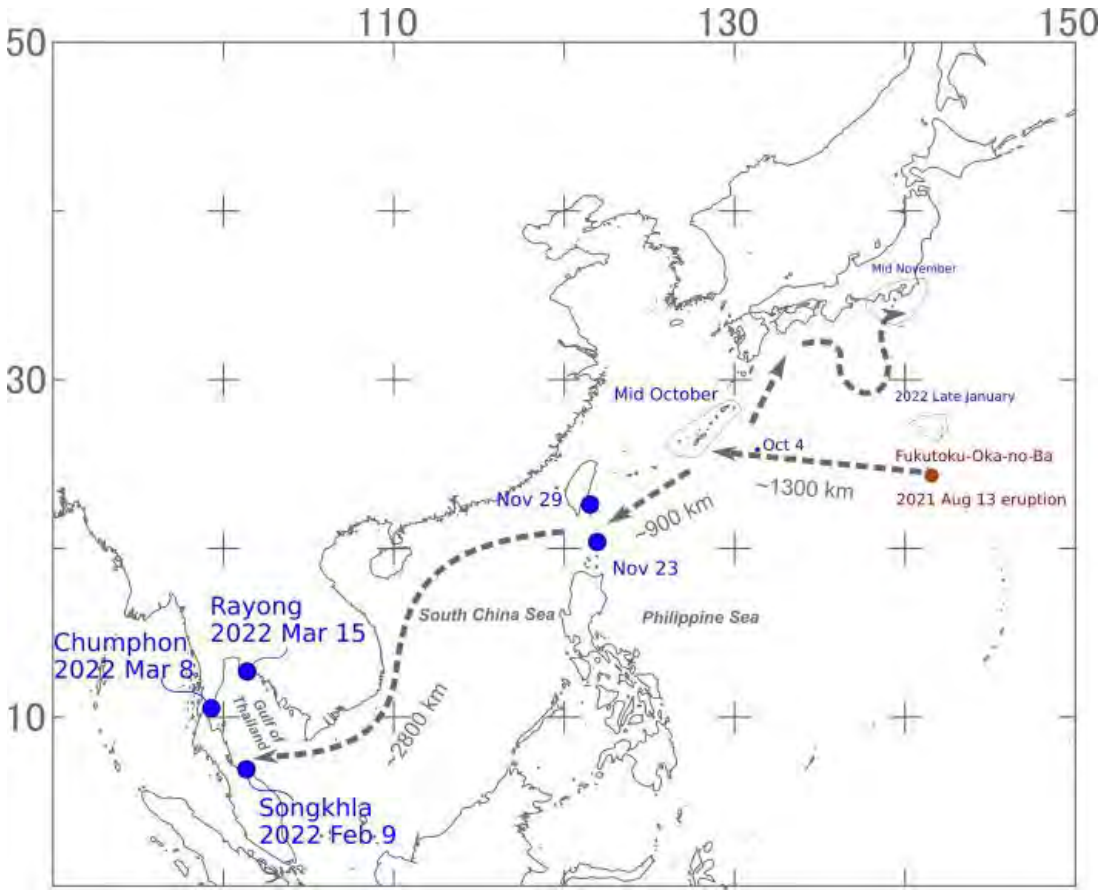
Figure source: NHK

disrupting the fishing industry

Figure source: NHK

threatening local tourism

Spreading of Pumice: Sighting



Yoshida et al., 2022

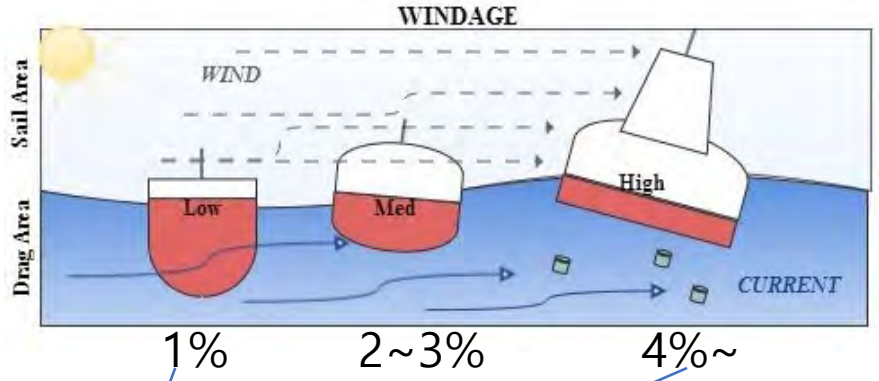
Can we predict/estimate the pathway?

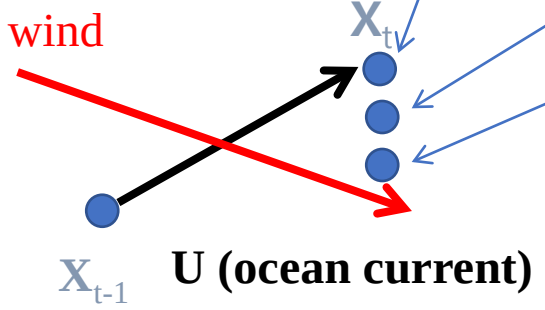
- Satellites
  - Near real time
  - No prediction
  - Cloud
- Lagrangian particle tracking
  - Ocean currents and wind
  - Correct?

Lagrangian Particle Tacking

$$\mathbf{X}_t = \mathbf{X}_{t-1} + \Delta T\mathbf{U} + \text{wind effect} + \text{diffusion}$$

$$\vec{x}_{t+\Delta t} = \vec{x}_t + \int_t^{t+\Delta t} \{\vec{u}_c(\vec{x}_t, t) + W_f \vec{w}_{10m}(\vec{x}_t, t)\}\Delta t + R\sqrt{2K_h \Delta t}$$





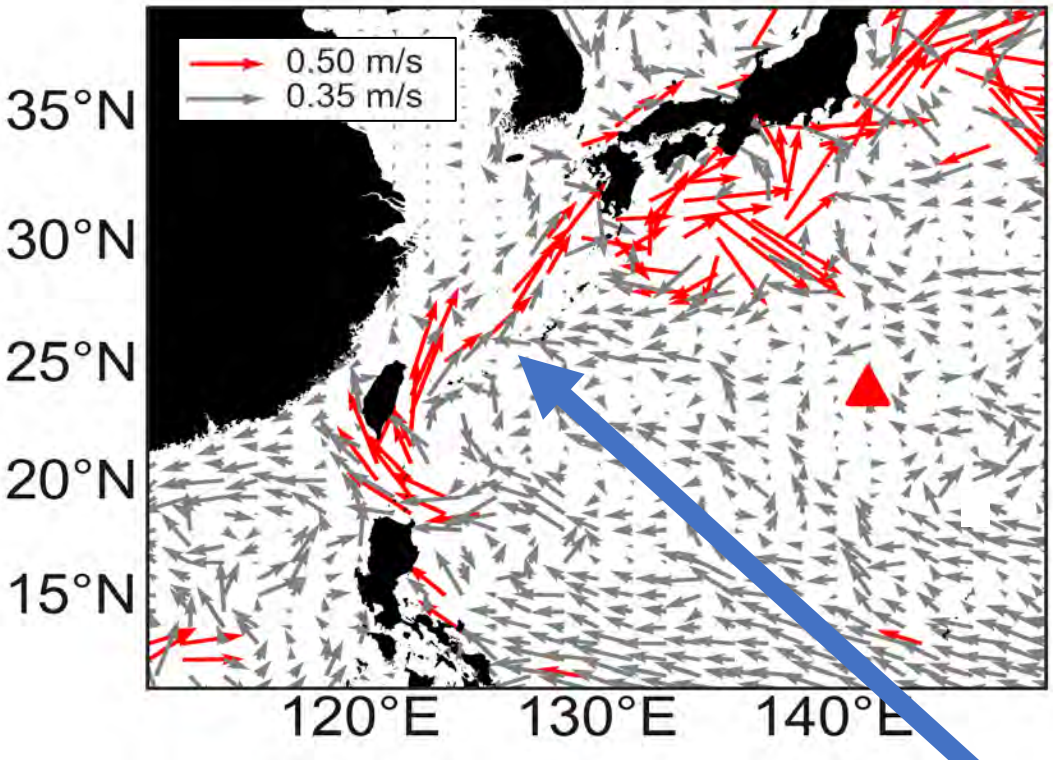
Typical debris (Duhec et al., 2015)

- 0~1%: Fishing nets, small plastic fragments, bottle caps
- 2~3%: Po… …y filled with sea …
- 4%: Emp… …s

For pumice?
Jutzeler et al., 2019

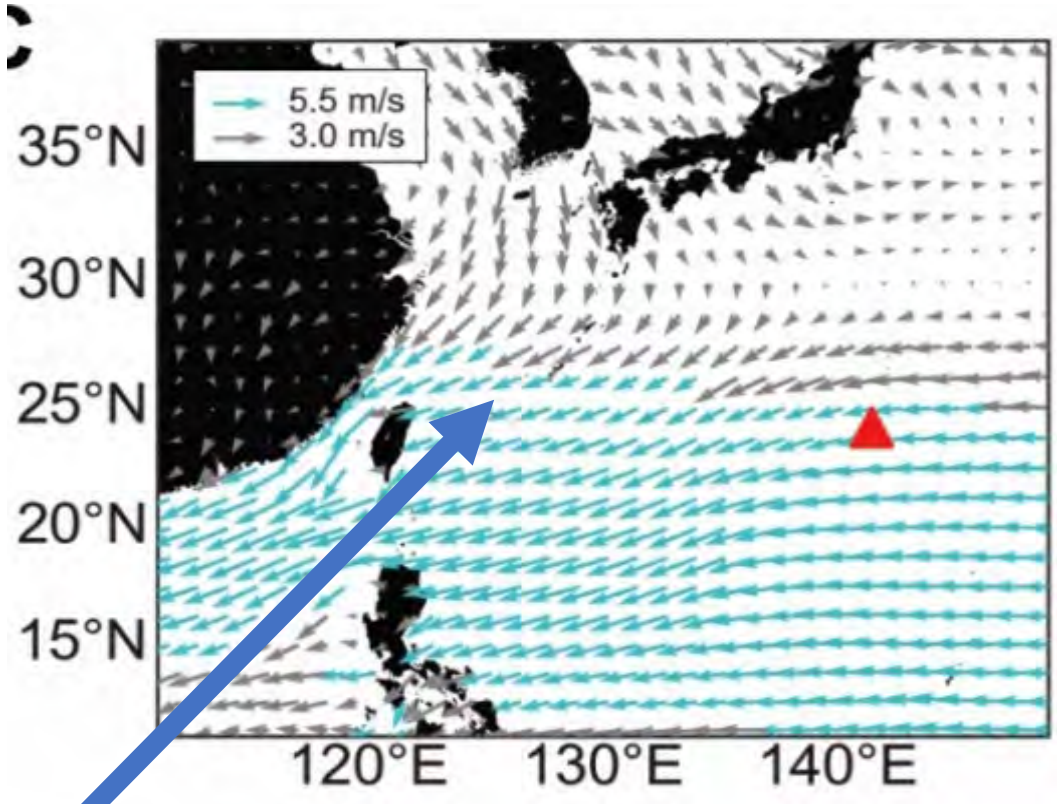
Aug-Dec 2021

$\vec{u}_c$



Ocean currents
HYCOM GOFS 3.1

$\vec{w}_{10m}$



Surface winds
ECMWF ERA5

Opposite!

Purpose

- Predict/estimate the pathway of the rafts using satellites and Lagrangian particle tracking
    - Optimal Windage factor
        - satellites images
        - Lagrangian particle tracking

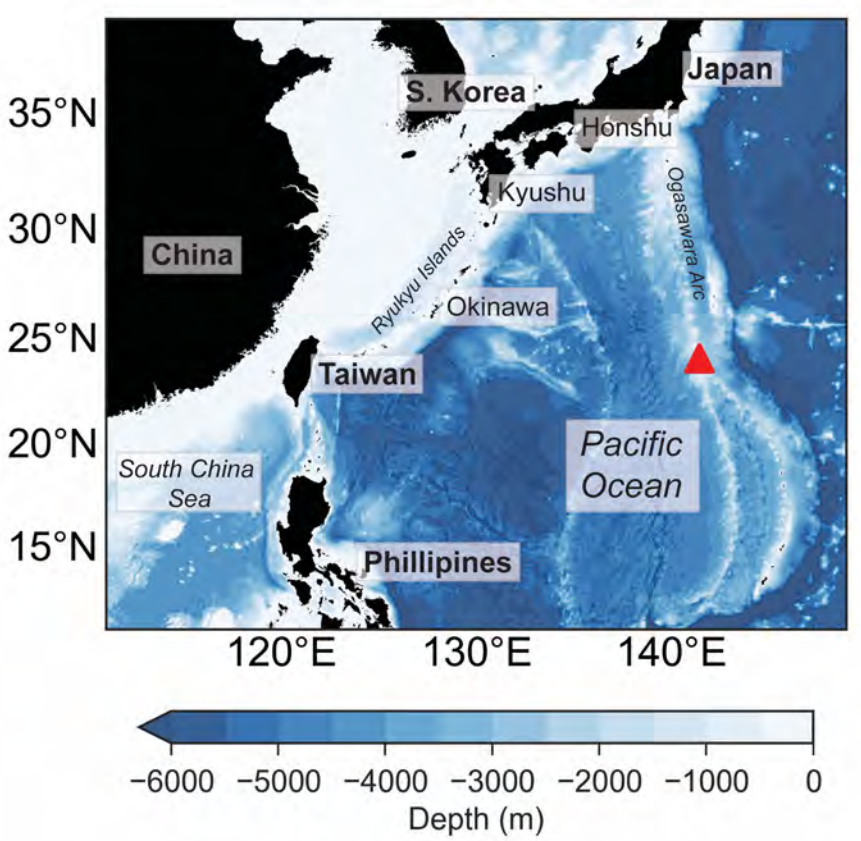
Data and Lagrangian experiments

- Reanalysis Data: HYCOM
- Ocean Parcels v2.0.0 (*Sebille et al., 2019*)

$$\vec{x}_{t+\Delta t} = \vec{x}_t + \int_t^{t+\Delta t} \{\vec{u}_c(\vec{x}_t, t) + W_f \vec{w}_{10m}(\vec{x}_t, t)\}\Delta t + R\sqrt{2K_h \Delta t}$$

(Seo et al., 2020; Seo and Park, 2020, 2021)

K_h → *Smagorinsky (1963)*



- Input data

Var	*Input*	*Source*	
$\vec{u}_c$	Ocean current	HYCOM GOFS 3.1	3hourly
$\vec{w}_{10m}$	10 m wind	ECMWF ERA5	

- ***Satelitte data***
Location validation

GOCI and Sentinel-2

24º14’ N and 141º 27’ E
~1000 particles

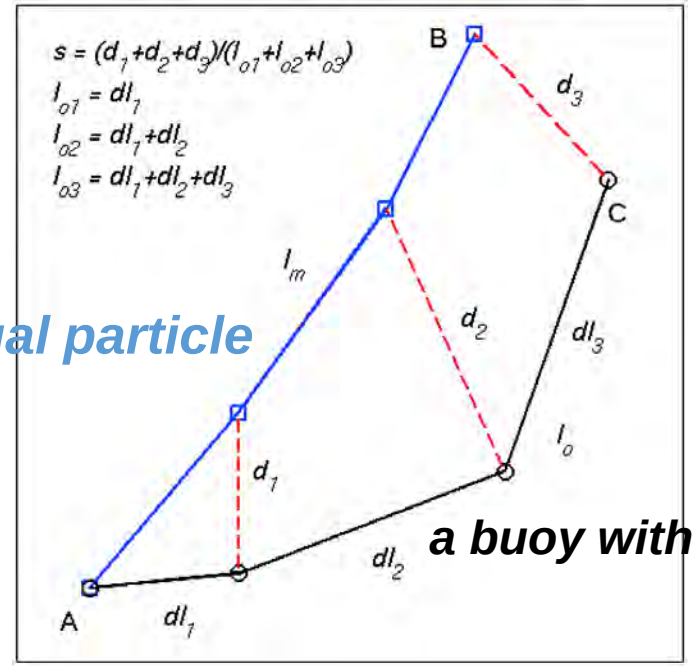
W_f = 0% - 4% ?

Satellite data

Product	Dates
GOCI-II	August 13/14/18/23/28 September 02/07/12/23 October 02/15/26/29 November 03/15
Sentinel-2A	November 02/05/12/15/22/25 December 02/05/12/15
Sentinel-2B	November 07/10/17/20/30 December 03/07/10/16

Best windage factor: skill score *ss*

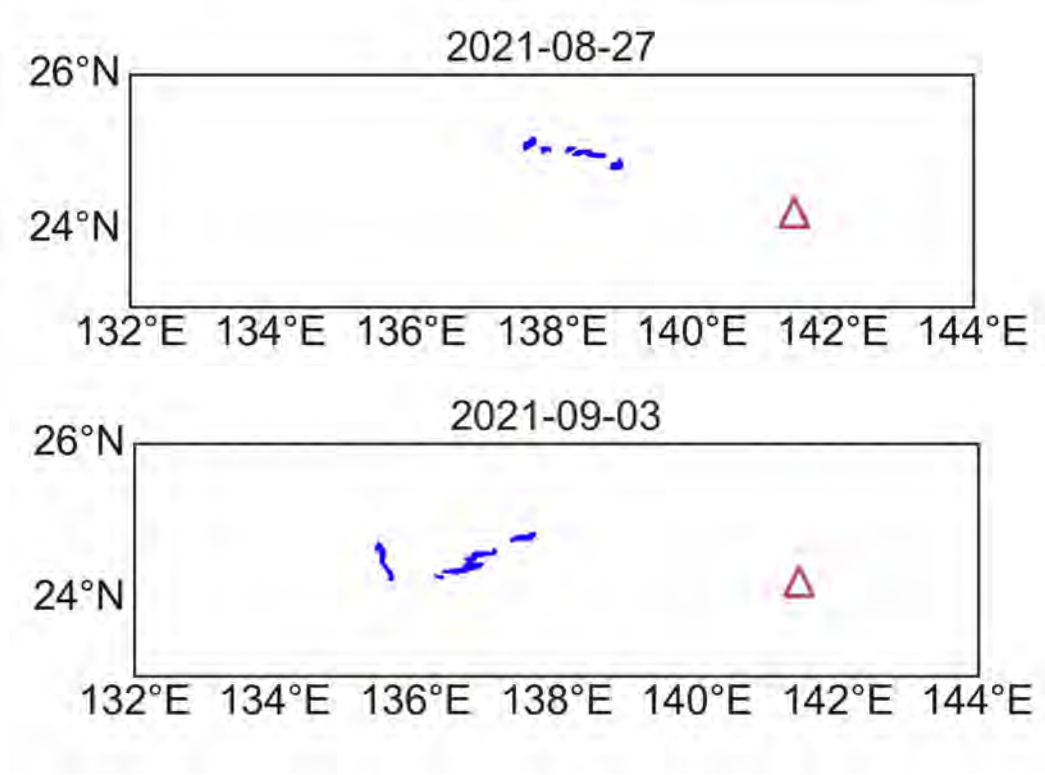
Liu and Weisberg (2011):
a trackable pair
Separation between a virtual particle and a buoy with GPS.



a virtual particle

a buoy with GPS

You cannot track individual pumice raft using satellite images! But there are many.



Best windage factor: skill score *ss*

A trackable pair ➔ Mean separation from clouds of partially trackable pairs

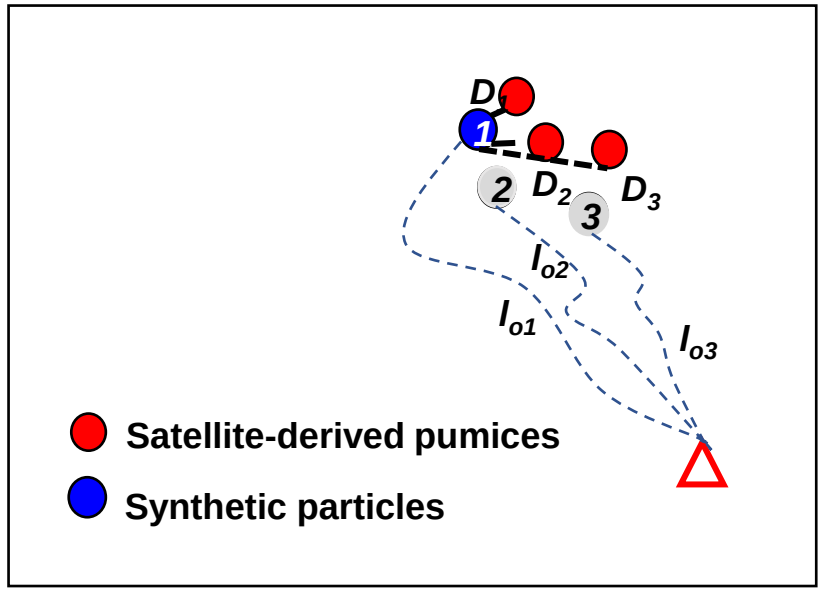
*** Skill score SS 1:perfect**

$$ss(t) = \begin{cases} 1 - MNLS, & (MNLS \leq 1) \\ 0, & (MNLS > 1) \end{cases}$$

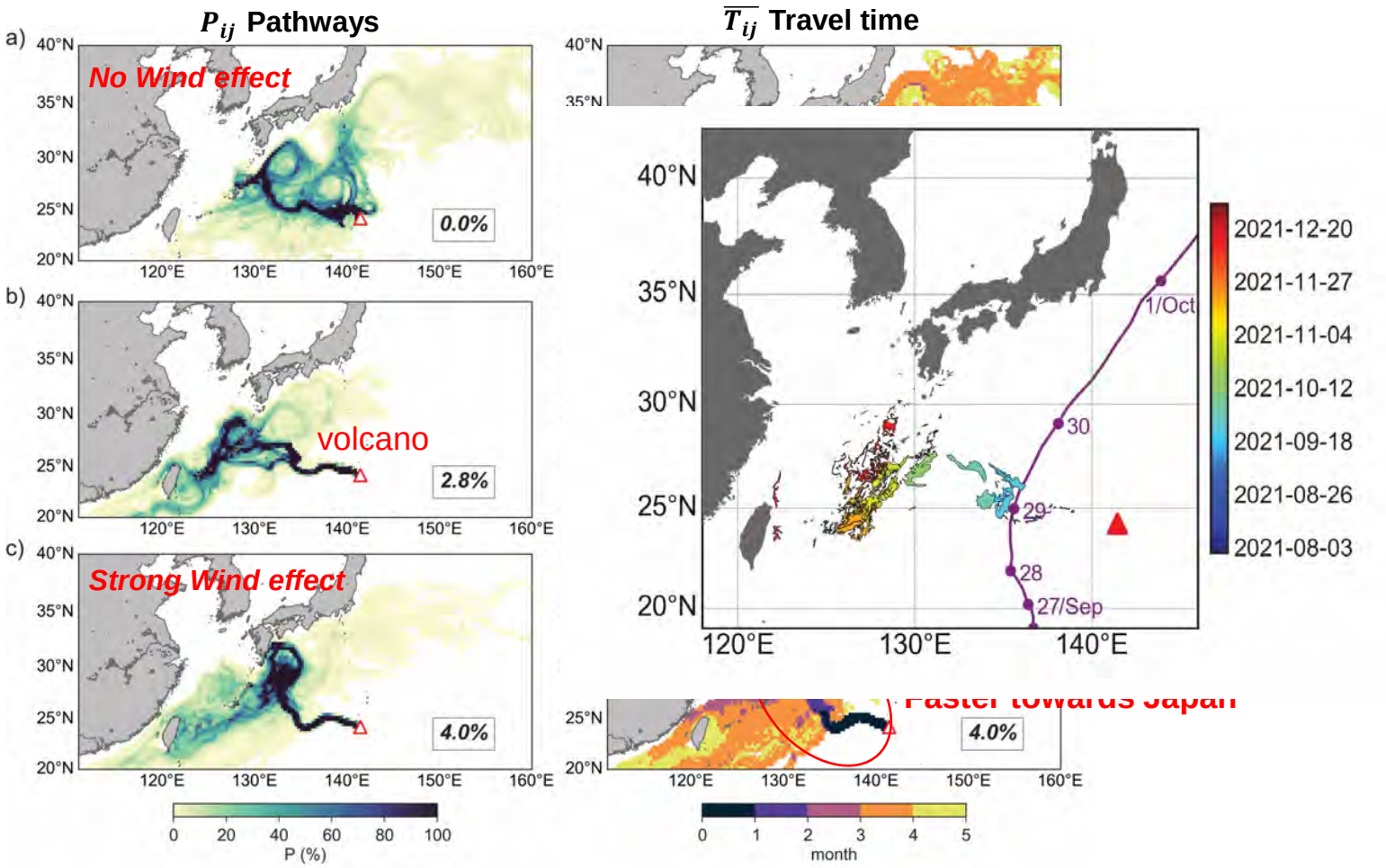
$$MNLS(t) = \frac{1}{M}\sum_{j=1}^{M}\left(\frac{1}{N}\sum_{i=1}^{N}\left(\frac{D(t_j)}{l_o(t_j)}\right)_i\right)$$

$MNLS\ mean\ normalized\ Lagrangian\ separation$

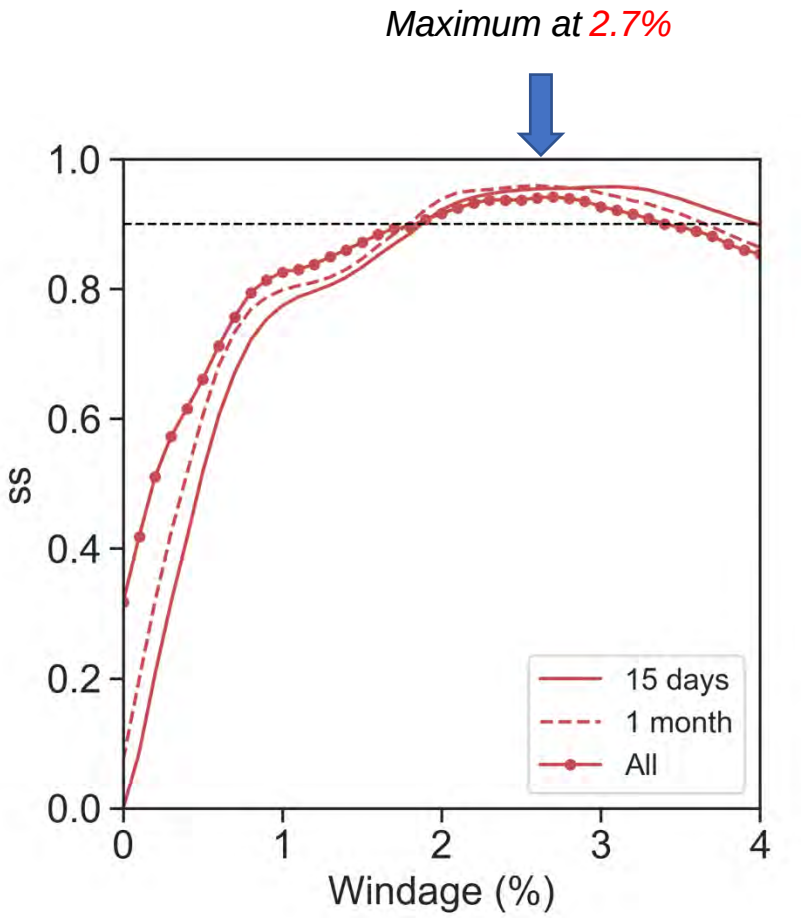
D_i: Distance of particle i to nearest pumice
N : Total number of particles
l_o: Length of particle trajectory from initial release
M*: numbers of satellite images available up to *t



Pathways and travel time from origins



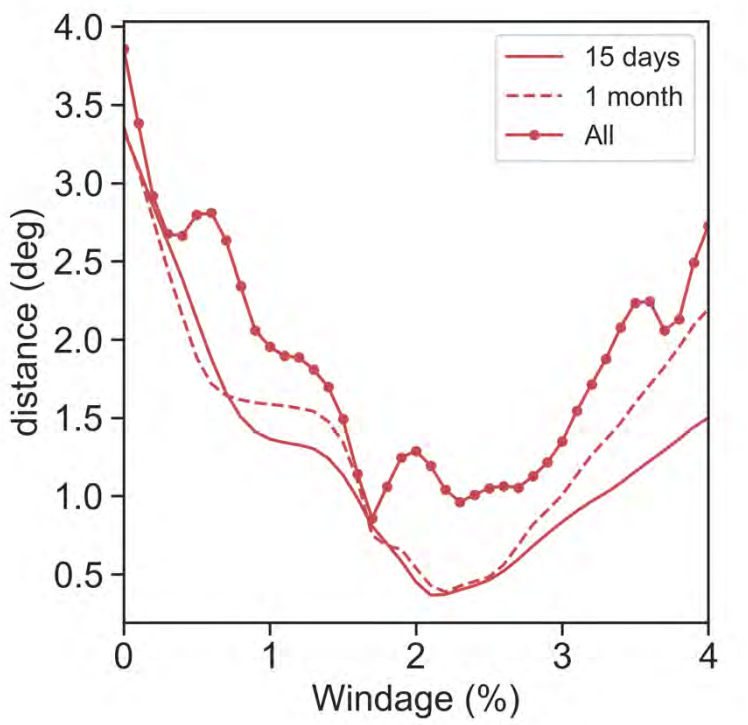
Sensitivity of SS to windage



- How many images do we need?
- Would change in shape (breaking) matter?

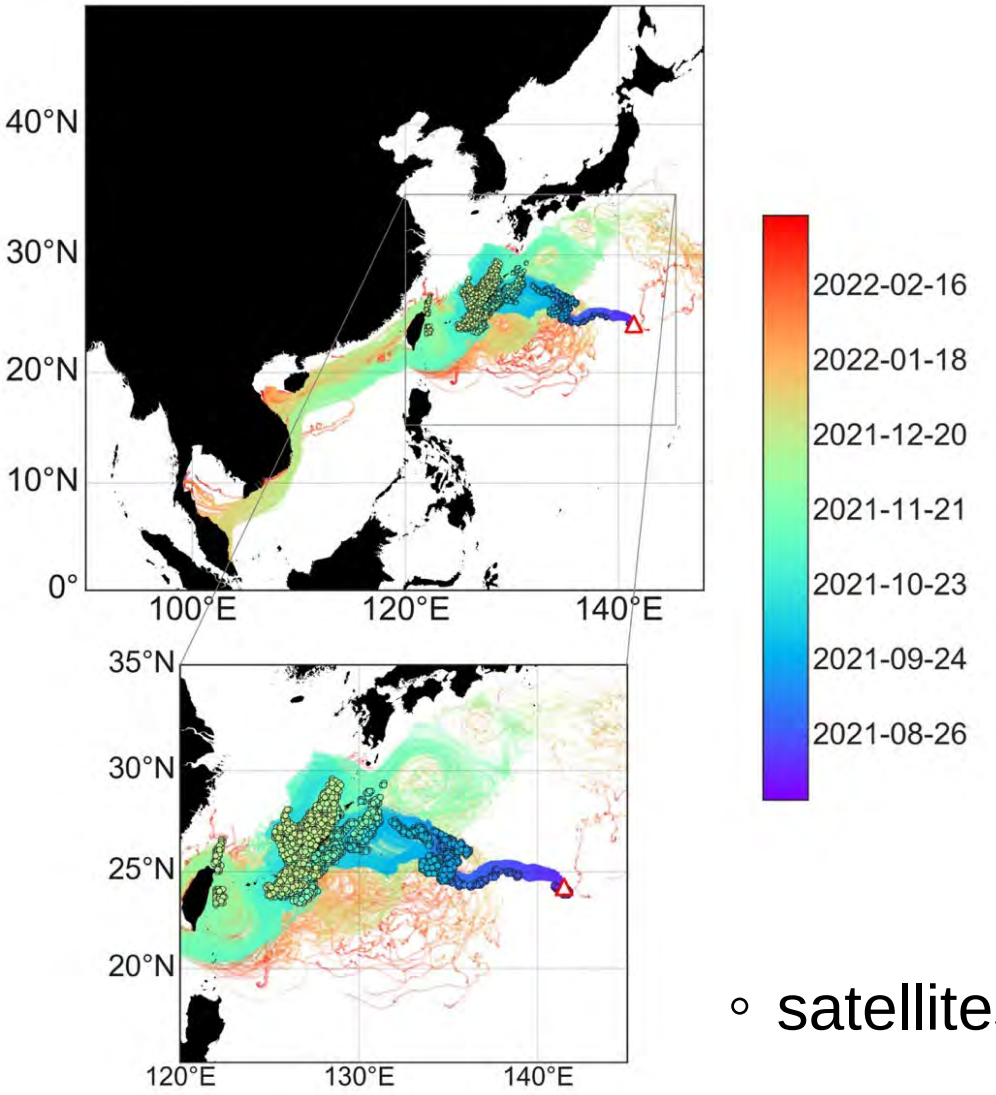
- Other ocean currents and wind data produced similar results.

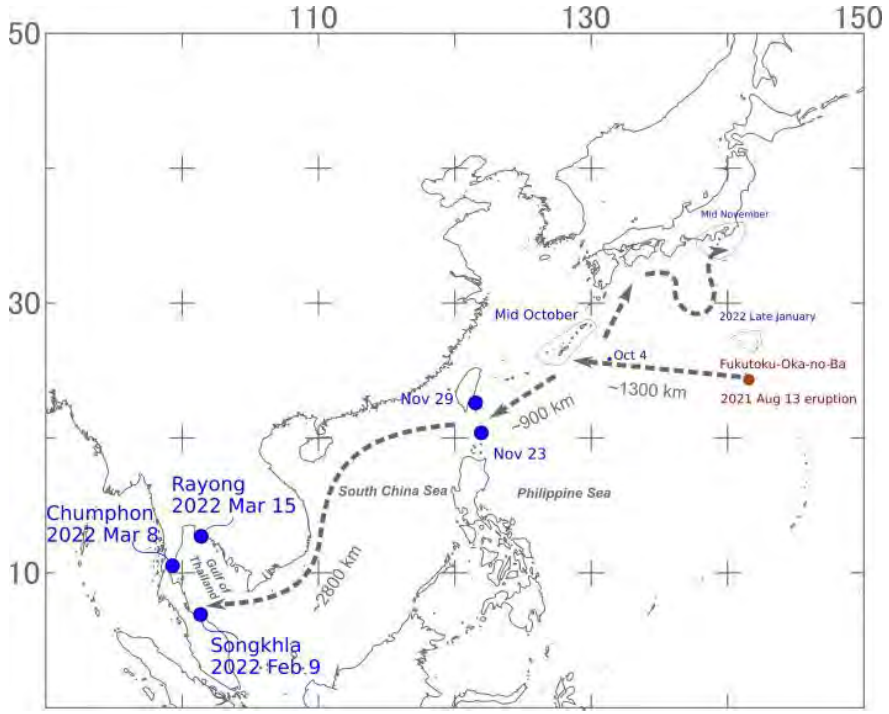
Comparison of Centroid



Cloud coverage?

Trajectories with the best windages factor 2.7%

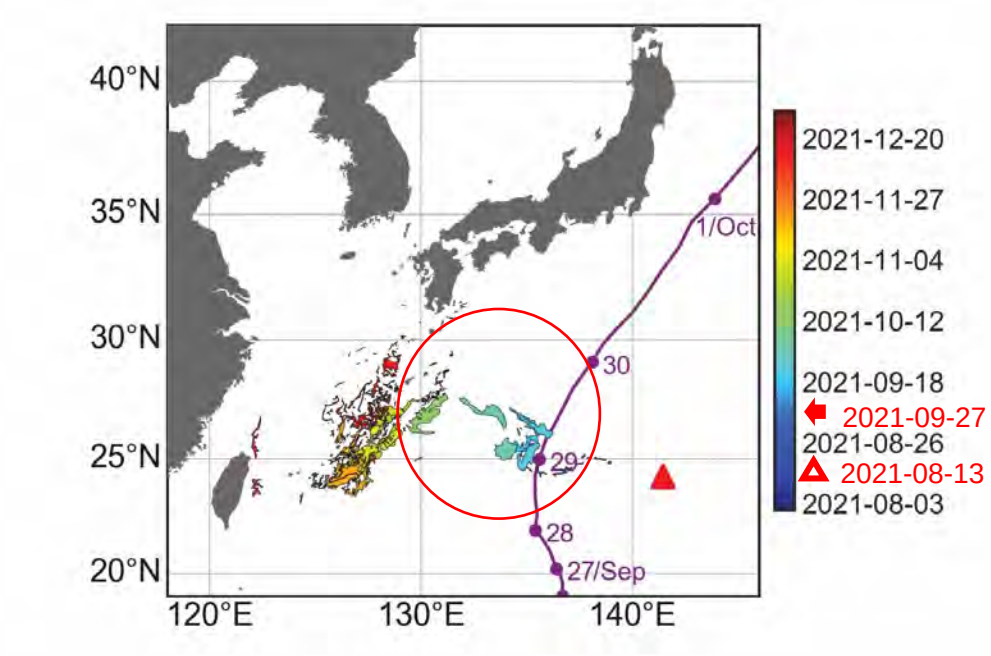




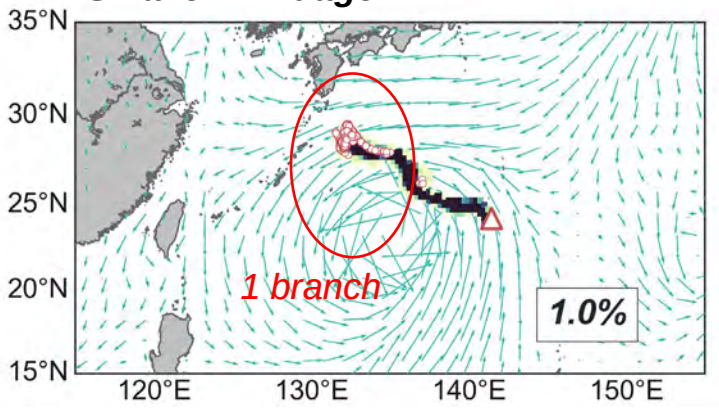
Yoshida et al., 2022

- satellites

Effects of a typhoon

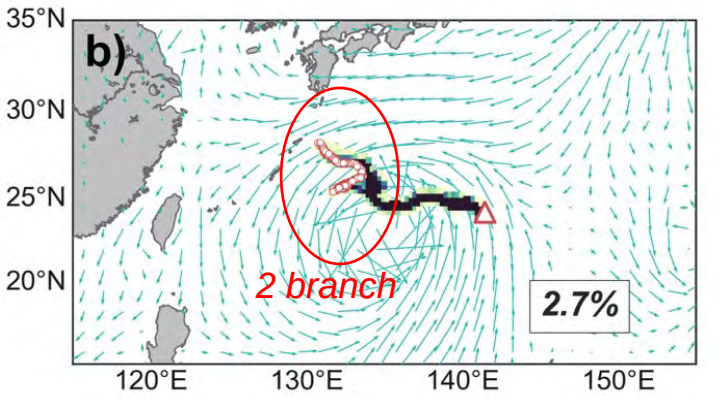


Smaller Windage



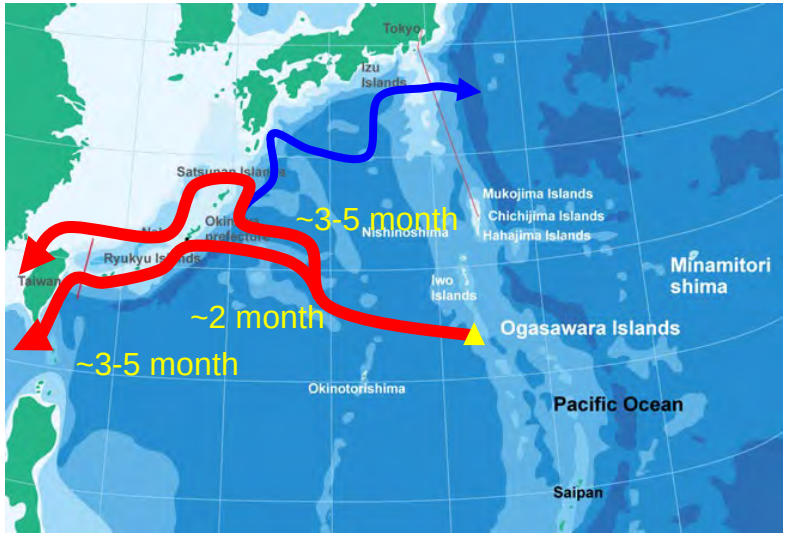
Particle position at 2021-09-27

Best windage factor

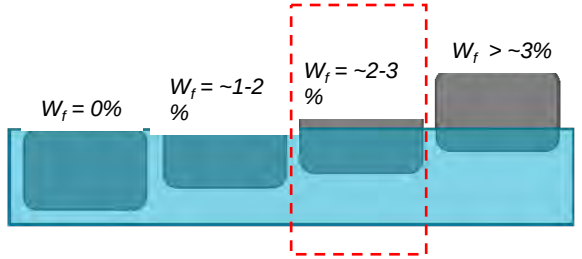


Summaries

- We could tune a model using satellite images.
- Optimal windage for pumice: 2~3%



Basemap source: https://en.vill.ogasawara.tokyo.jp/



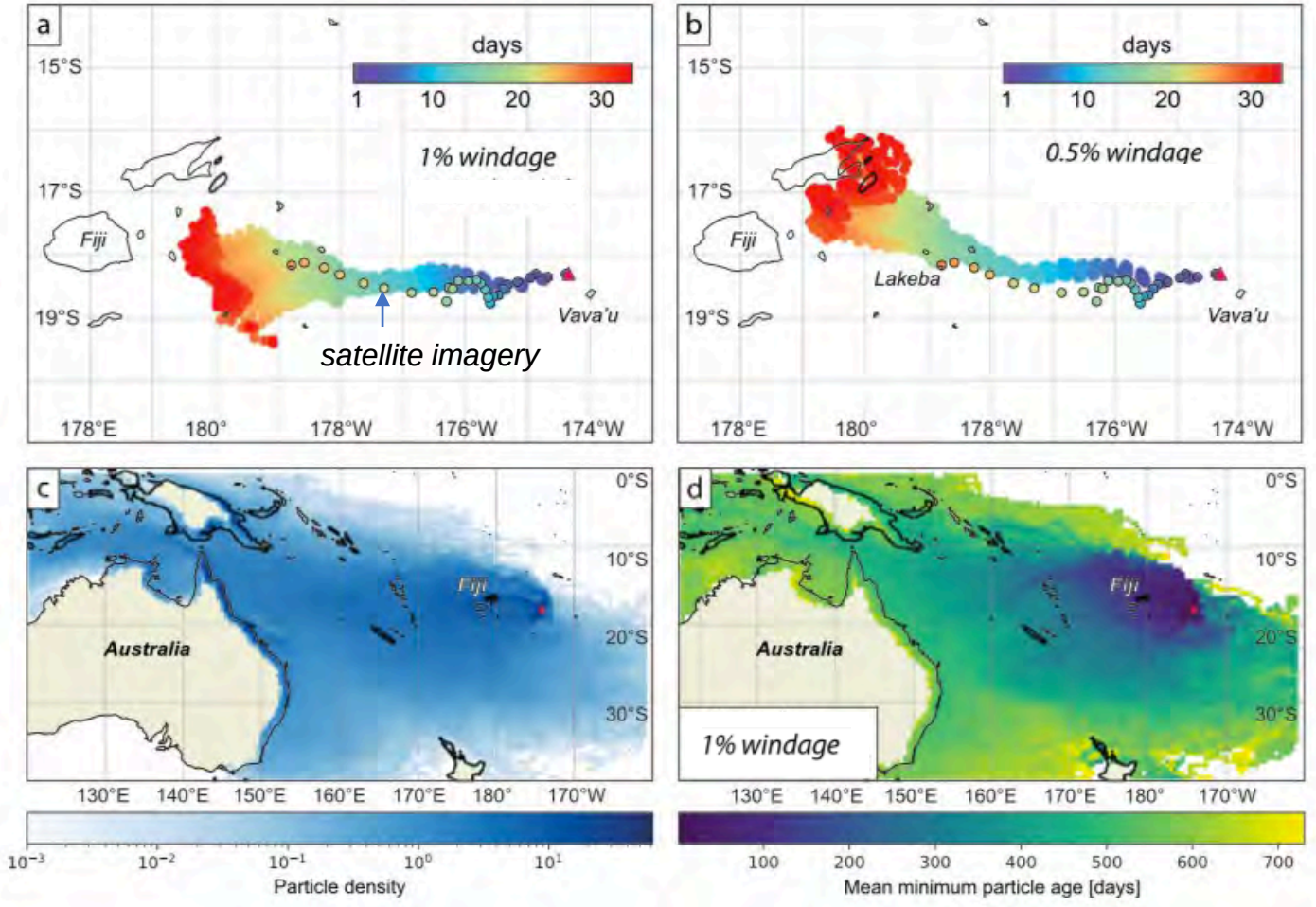
Optimum

Questions?

Previous Study (Jutzeler et al., 2019)

Ongoing Dispersal of the 7 August 2019 Pumice Raft From the Tonga Arc in the Southwestern Pacific Ocean

Raft dispersal one-month simulation



Best windage factor: skill score *ss*

Adapted from Liu and Weisberg (2011): a trackable pair
Separation between a virtual particle and a buoy with GPS.

You cannot track individual pumice raft using satellite images!
Many but partially trackable pairs

*** Skill score SS 1:perfect**

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$MNLS$ *mean normalized Lagrangian separation*

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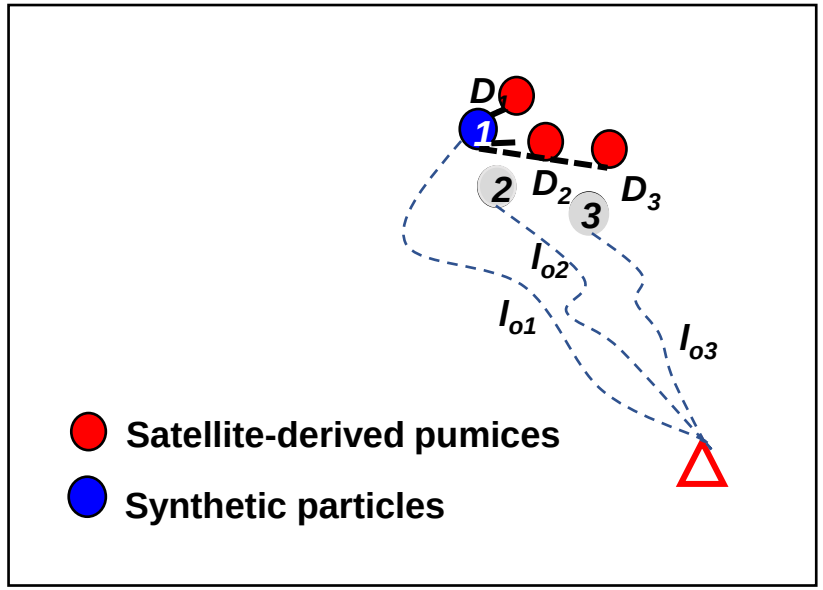
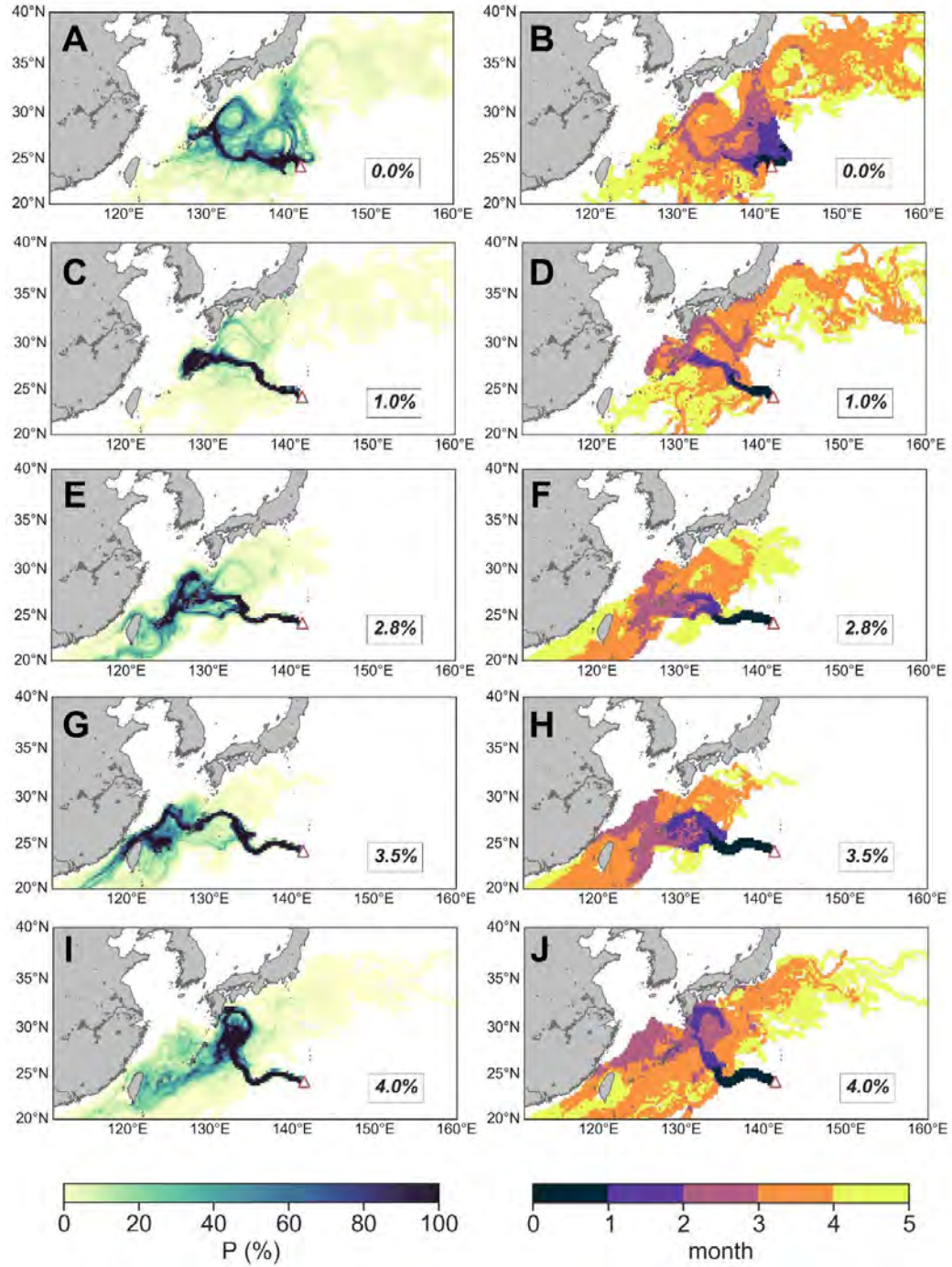
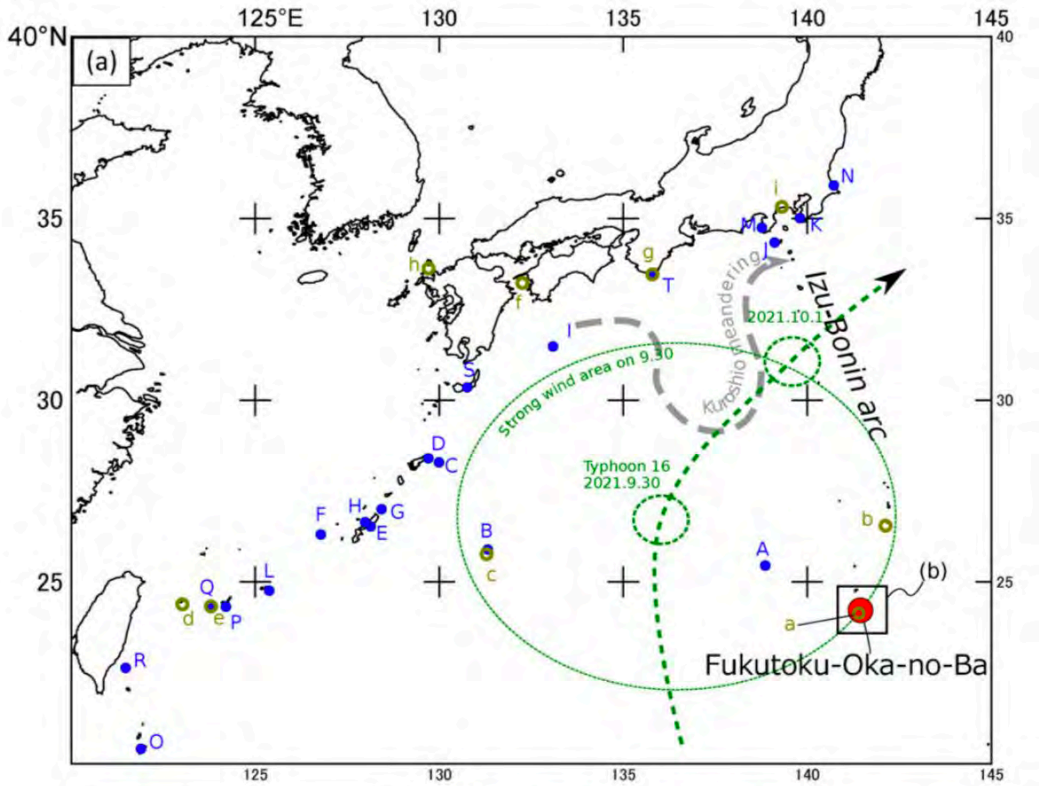



A
B
C
D
E
F
G
H
I
J
0.0%
0.0%
1.0%
1.0%
2.8%
2.8%
3.5%
3.5%
4.0%
4.0%
40°N
35°N
30°N
25°N
20°N
120°E
130°E
140°E
150°E
160°E
0
20
40
60
80
100
P (%)
0
1
2
3
4
5
month

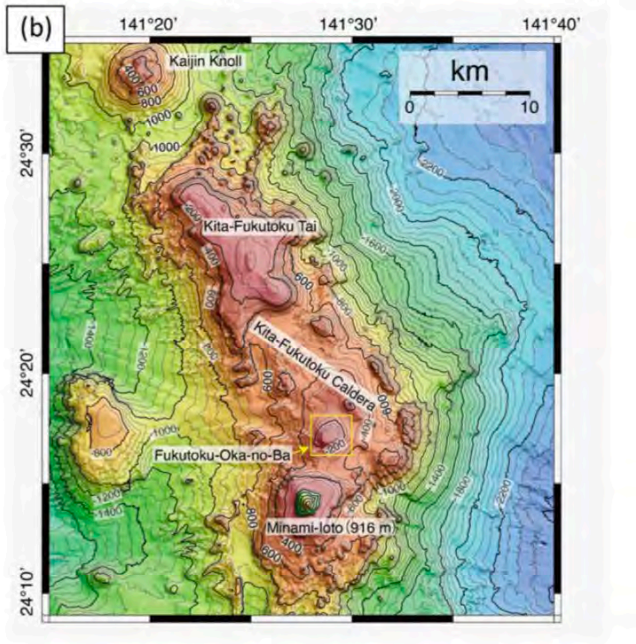
Sightings



Timeline

2021 Aug. 13 eruption
A: Aug 22 Sampling by RV *Keifu-Maru*
B: Oct. 5 Twitter report from Kita-daito Isl.
C: Oct. 10 Kikai Isl.
D: Oct. 12 Amami-oshima Isl.
E: Oct. 13 Okinawa Main Isl. East coast
F: Oct. 13 Kume Isl.
G: Oct. 14 Yoron Isl.
H: Oct. 18 Okinawa Main Isl. West coast
I:Oct. 30 Aircraft observation of the raft
J: Nov. 10 Shikine Isl.
K: Nov. 15 South Boso Peninsula
L: Nov. 19 Miyako Isl.
M: Nov. 23 South Izu Peninsula
N: Nov. 23 Kashima
O: Nov. 23 Ivana, Batanes Province (PH)
P: Nov. 26 Ishigaki Isl.
Q: Nov. 27 Iriomote Isl.
R: Nov. 29 Taiwan's Green Island
S: Dec. 5 Yakushima/Tanegashima Isl.
T: Dec. 13 Wakayama Pref. Kushimoto

1986 Jan. 18th eruption
a. Jan. 20 Sampling by RV *Takuyo*
b. Mar. 15 Hahajima Isl.
c. Late May Minami-daito Isl.
d. Late May Yonaguni Isl.
e. <June 15 Iriomote Isl.
f. June 26 Ehime Pref. Uwaumi
g. Aug. Wakayama Pref. Kushimoto
h. Oct. Genkai-nada
i. 1991. Sept. Sagami Bay



Yoshida et al., 2021