The Influence of Metocean Factors on the Long-Distance Dispersal of Pumice Rafts

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Introduction

- Western Boundary Currents (WBCs) are critical for the dispersal of pumice rafts forming from submarine volcanic eruptions in the Pacific Ocean.
- WBCs are likely to intensify, extend further, and warm faster than other ocean currents due to climate change, yet despite this, their impact on pumice raft drift is rarely addressed in academic literature.
- The Pacific Ocean hosts more than 350 active volcanoes across a 40000-kilometre-long stretch covering both the Asian and American sides of the ocean basin.
- Pumice rafts assist the migration of marine organisms, and the establishment and growth of coral reef systems. This material in large quantities has also caused extensive damage to coastal communities.
- This study attempts to simulate pumice raft dispersal from the Fukutoku-Okanoba volcano and the Hunga Tonga-Hunga Ha'apai volcano, which erupted in 2012, and 2021, respectively. These volcanoes are located in the WBCs of the Kuroshio Current (KC) and the East Australian Current (EAC), respectively.

Fig. 1 Major currents in the Pacific Ocean (Education Development Center, 2017).

Methods

- We sourced data from Copernicus at a daily frequency on ocean surface currents, drift, and wind as described below.

Product ID	Type	Date	Spatial resolution
GLOBAL_ANALYSIS_FORECAST_PHY_001_024	CUR	> 1 January 2020	0.083°
GLOBAL_MULTIYEAR_PHY_001_030	CUR	< 1 January 2020	0.083°
GLOBAL_ANALYSIS_FORECAST_WAV_001_027	WAV	> 1 January 2020	0.083°
GLOBAL_MULTIYEAR_WAV_001_032	WAV	< 1 January 2020	0.2°
WIND_GLO_PHY_L4_NRT_012_004	WIN	> 1 July 2020	0.125°
WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_006	WIN	< 1 July 2020	0.25°

- Data was input to the OceanParcels particle tracking model to simulate the trajectories of pumice rafts ejected from the Hunga Tonga-Hunga Ha'apai and Fukutoku-Okanoba volcanoes (Figure 2).
- Models used combinations of particle numbers ranging from 100 to 10000, for model durations ranging from 30 to 1461 days using different windage factors (0, 0.1%, 0.5%, and 1%), with and without Stokes drift.
- Models were run every 7 days between 1 July 2010 and 30 June 2017 to investigate variation in the particle trajectory profile at a more detailed timescale over several years from both volcanoes. Models were also run from the estimated start dates of the 2012, and 2021, eruption dates to simulate the actual trajectory of pumice rafts.
- Model outputs were compared with freely available satellite data from Sentinel-1 and Sentinel-2 (Figure 3) to identify rafts from the Hunga Tonga-Hunga Ha'apai eruption in 2021.

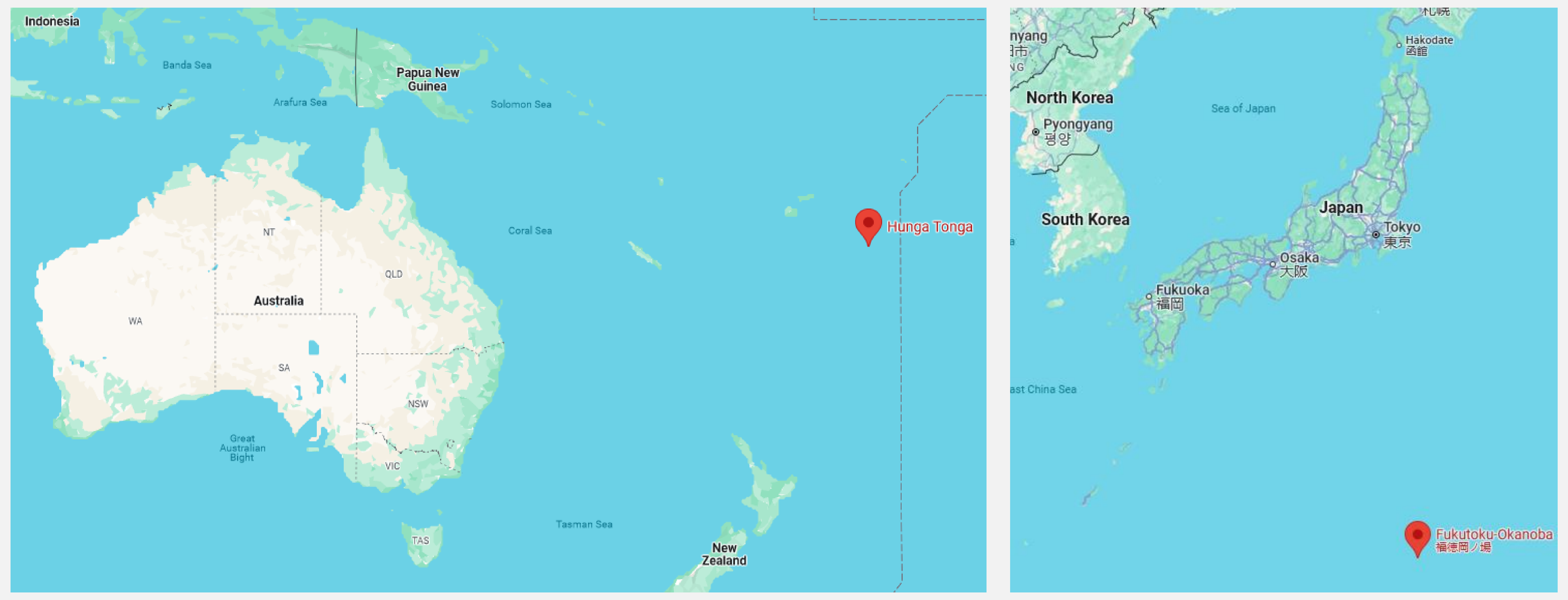

Fig. 2 Relative location of Hunga Tonga-Hunga Ha'apai (left) and Fukutoku-Okanoba (right).

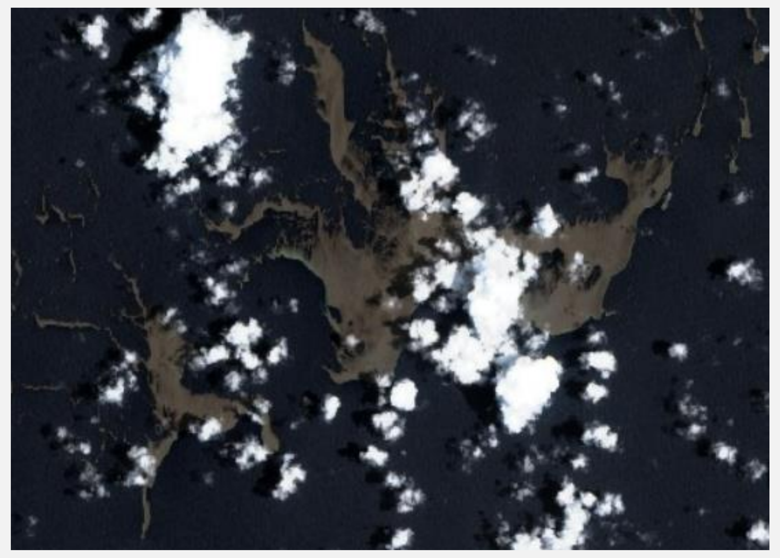

Fig. 3 Pumice raft near Hunga Tonga-Hunga Ha-apai on 28 December 2021.

Results

Hunga Tonga-Hunga Ha'apai:

- Results indicate particles from Hunga Tonga-Hunga Ha'apai move eastward into the South Pacific Gyre and west into the East Australian Current (Figure 4).
- Greater distances were travelled in higher surface current conditions which pushed particles further west and north.
- From 2010 to 2017 there was an annual increase in the distance travelled by particles from Hunga Tonga-Hunga Ha'apai of 49 kilometres per year when excluding windage.

Fukutoku-Okanoba:

- Particles from Fukutoku-Okanoba move largely northeast into the North Pacific Gyre, with a minority moving southwest.
- From 2010 to 2017 there was an annual decrease in the distance travelled by modelled particles of 34 kilometres per year.
- Comparison of model results with and without windage factors applied showed considerable difference in particle trajectories (Figure 4). Applying a windage factor during a La Nina period showed further south-westward movement of particles.

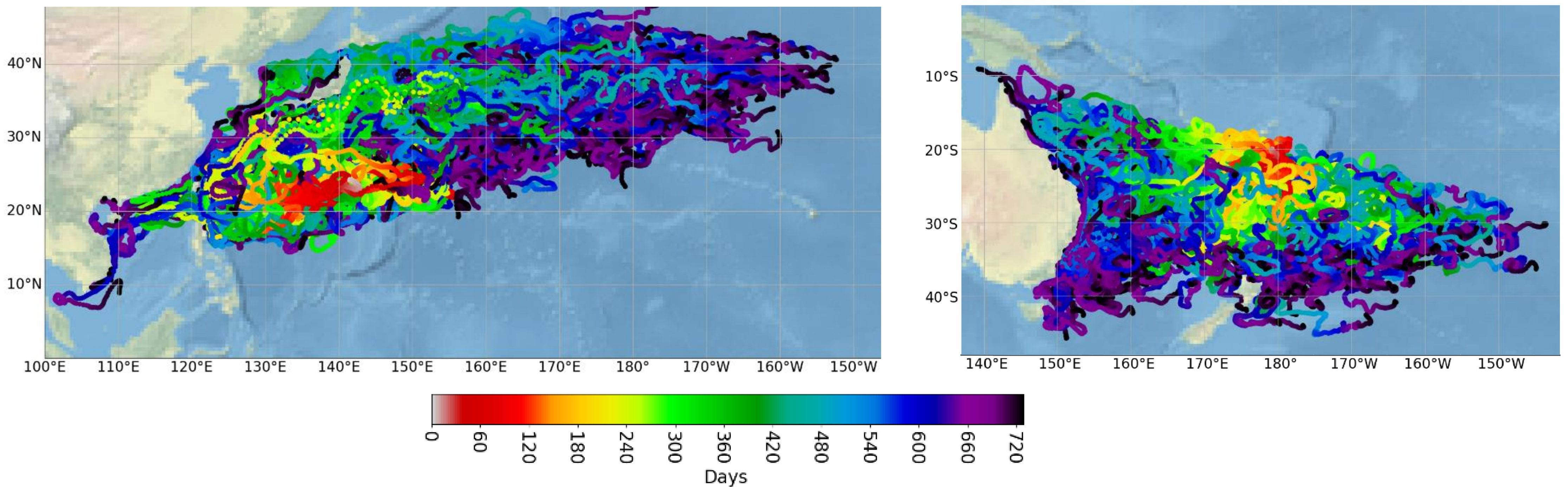

Fig. 4 Long-term particle model with no Stokes drift and 1% windage from Fukutoku-Okanoba (left) and with no Stokes drift and no windage Hunga Tonga-Hunga Ha'apai (right).

Discussion and Conclusion

- The distance travelled differed depending on the phase of the Southern Oscillation Index (SOI):
  - Modelled particles originating from Hunga Tonga-Hunga Ha'apai moved further during periods of negative SOI, and travelled less during periods of positive SOI.
  - Comparatively, particles originating from Fukutoku-Okanoba travelled further during positive SOI rather than negative SOI.
- Applying a windage factor of 1% during La Nina conditions pushed particles further west, from both volcanos.
- We were also able to track pumice rafts from Hunga Tonga-Hunga Ha'apai for several weeks using freely available satellite imagery, but not over longer timescales.
- Free satellite data is usually either low resolution, low frequency or obscured by cloud cover, making long-term tracking difficult.
- As the South Pacific is often poorly resourced, developing mature models of this nature requires significant financial assistance to secure high-resolution high frequency proprietary satellite data.
- Without access to high resolution high frequency proprietary satellite data, communities in the Global South will continue to be impacted by pumice rafts.
- Increasing access to observational satellite data for the purpose of tracking pumice rafts will be required to improve pumice raft models and determine appropriate windage and drift factors over long distances and long periods of time.