Prediction of the Distribution of Tritium Over the Pacific Ocean from Fukushima Wastewater Until 2090

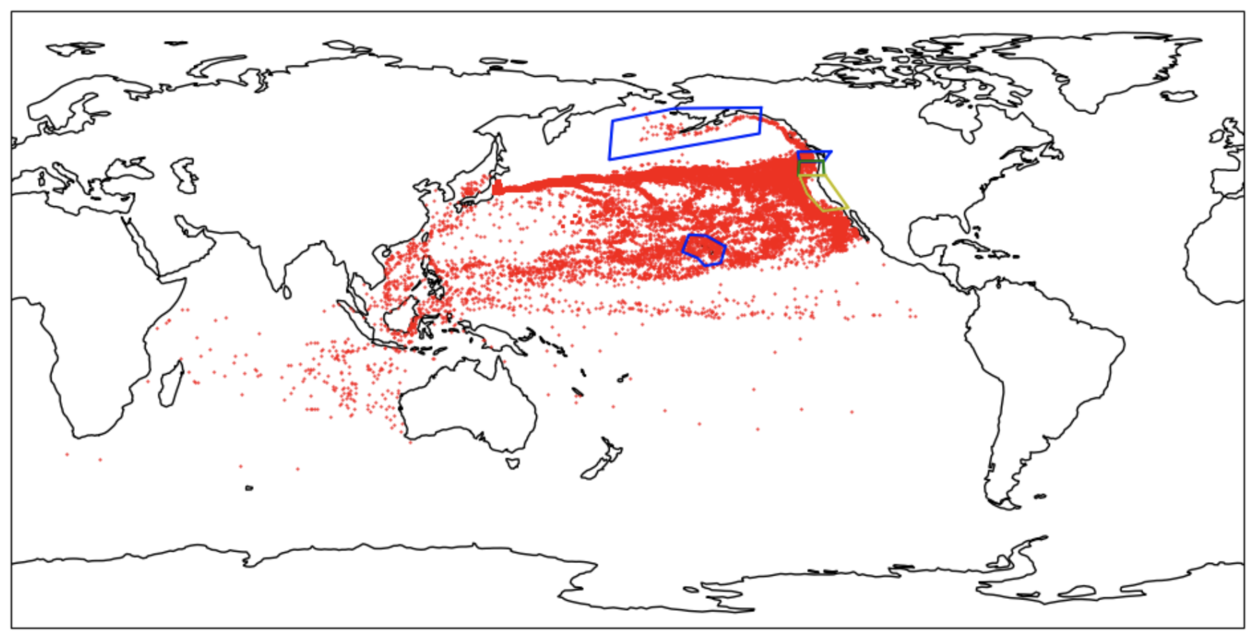
Author: Jie Ma Supervisor: Thomas Haine

Johns Hopkins University

JOHNS HOPKINS WHITING SCHOOL *of* ENGINEERING

Abstract

The Fukushima nuclear wastewater release into the Pacific Ocean, starting August 25th, 2023, has prompted global concerns. This project, the first of its kind, investigates the distribution of tritium radioactive particles and assesses their impact on the U.S. west coast.



Utilizing IAEA monitor, ECCO currents, and AOML drifter data, the model simulates tritium movement, revealing its arrivals at the U.S. coast. Potential adjustments to U.S. power plant emissions are considered, with the first wave reaching Hawaii in the 5th year and U.S. coastal regions experiencing subsequent waves post-2033. Adjustments aim to mitigate potential west coast Pacific overload.

Intro to The Problem

The Fukushima nuclear wastewater release into the Pacific Ocean commenced on August 25th, 2023, and is anticipated to occur gradually over decades. Rigorous monitoring and safeguards have been implemented to mitigate environmental and health risks. Despite undergoing treatment, the wastewater still contains tritium, a radioactive element resistant to current removal techniques. This has ignited both domestic and international debates regarding its potential repercussions on marine ecosystems and public health.

In response to these concerns, this project aims to construct a predictive model utilizing historical and real-time data on wastewater and ocean currents. The goal is to forecast the distribution of tritium in the Pacific Ocean 50 years after the commencement of wastewater release. The simulation will consider the emission and distribution of tritium particles across various sea areas over time, focusing on a 66-year period due to the 12.33-year half-life of tritium.

Data for Use

The dataset employed for this project comprises IAEA monitor data on real-time wastewater release, ECCO currents data, and AOML global drifter data.

- IAEA (International Atomic Energy Agency) monitor data
  Real-time monitoring of radioactive particles at Fukushima by the International Atomic Energy Agency, utilized to initiate tritium particle positions and amounts in the model.
- ECCO (Estimating the Circulation and Climate of the Ocean) currents data
  Incorporating both *in situ* observations and calculated data points from the MITgcm model, this dataset includes variables such as currents, eddies, temperature, and salinity. The project primarily utilizes the 3-dimensional velocity field for predicting particle distribution and movement.
- NOAA (National Oceanic & Atmospheric Administration) global drifter data
  Derived from buoys in the global drifter program, this dataset provides real-time movement information across the Pacific Ocean. It serves as evaluation data for the prediction model.

Methods: Model of Particle Drift and Decay

The project's objective is to simulate the movement of tritium particles released into the ocean and analyze their distribution along the U.S. coast, assessing potential effects on ecosystem safety. The simulation model is a critical component, encompassing three main aspects:

1. When and how tritium release
   Utilizing IAEA monitor data, the model determines the location and depth where wastewater pipes end. With the fact that 7,800 tons of wastewater have been released in the first 17 days, and the plan that **1,340,000** tons of wastewater with **140,000 Bq/L** tritium was aimed to be released in the next **43** years. This model utilizes a release strategy involves **uniformly releasing wastewater over 43 years, with 31,200 tons annually**
2. How tritium particles drift and distribute
   Leveraging ECCO data, the model approximates future current fields, **computing Lagrangian trajectories of particles based on the velocity field at specific timestamps with the Seaduck package**.
3. How tritium particles die out
   Employing a decay formula, the model calculates tritium concentration within the wastewater after release, considering an annual update of released wastewater.

$$N = N_0 e^{-\lambda t} \qquad ; \qquad \lambda = 5.63 * 10^{-2}$$

Model Statistics and Results

The visualization of this simulation model is shown in the animation.

The simulation model produces **79376 * 1518 * 3** matrix indicating **79,376 data points' position in 3-dimension within next 66 years**.

79376 representatives of particles in total
1518 stored trajectory updates (23 each year)
3 dimensions of position: latitude, longitude, and depth into the ocean

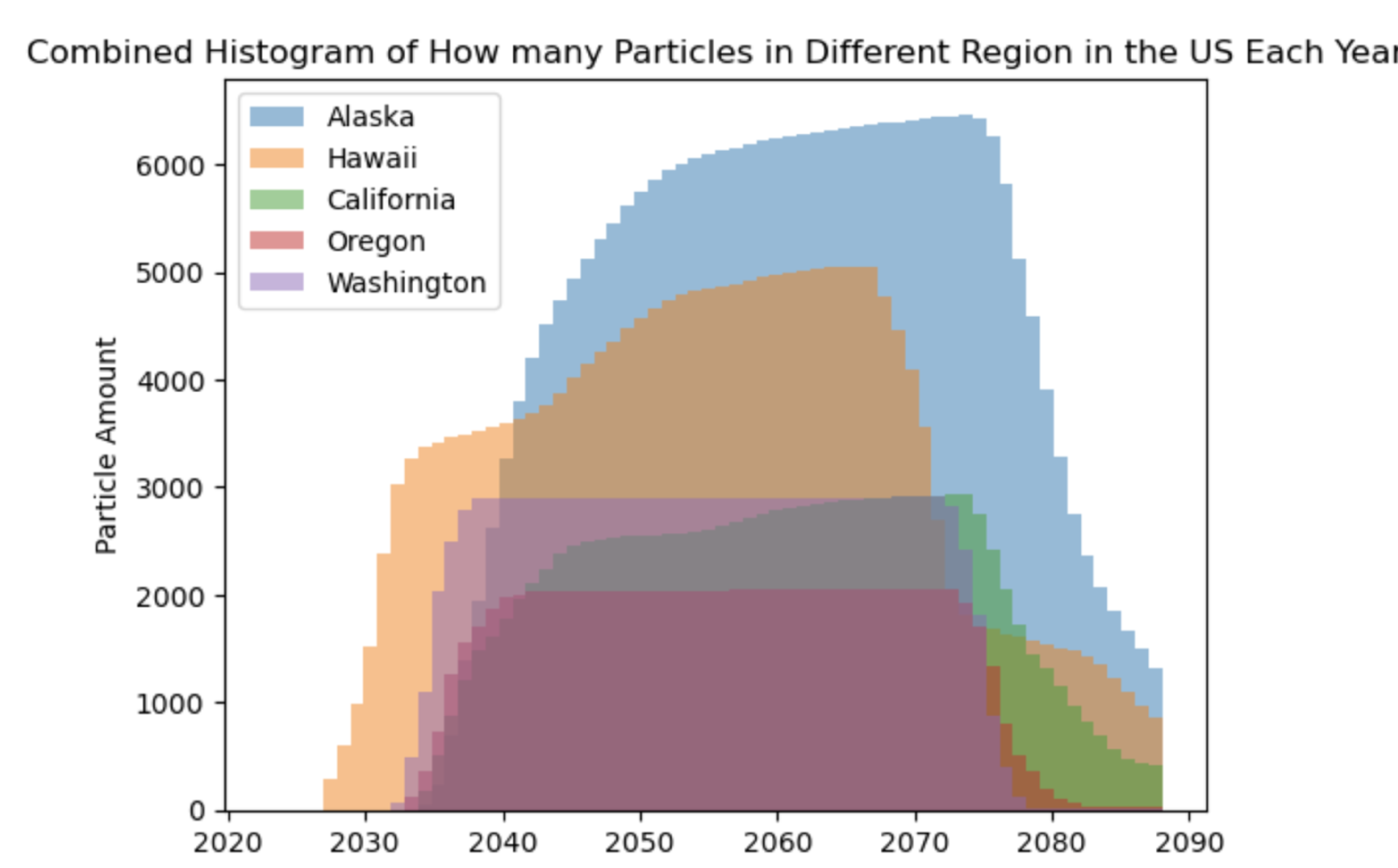


Figure 1. Here Particle Amount means number of particle representatives while taking decay into consideration; 1 particle amount = 0.002184 ±0.000122 TBq tritium

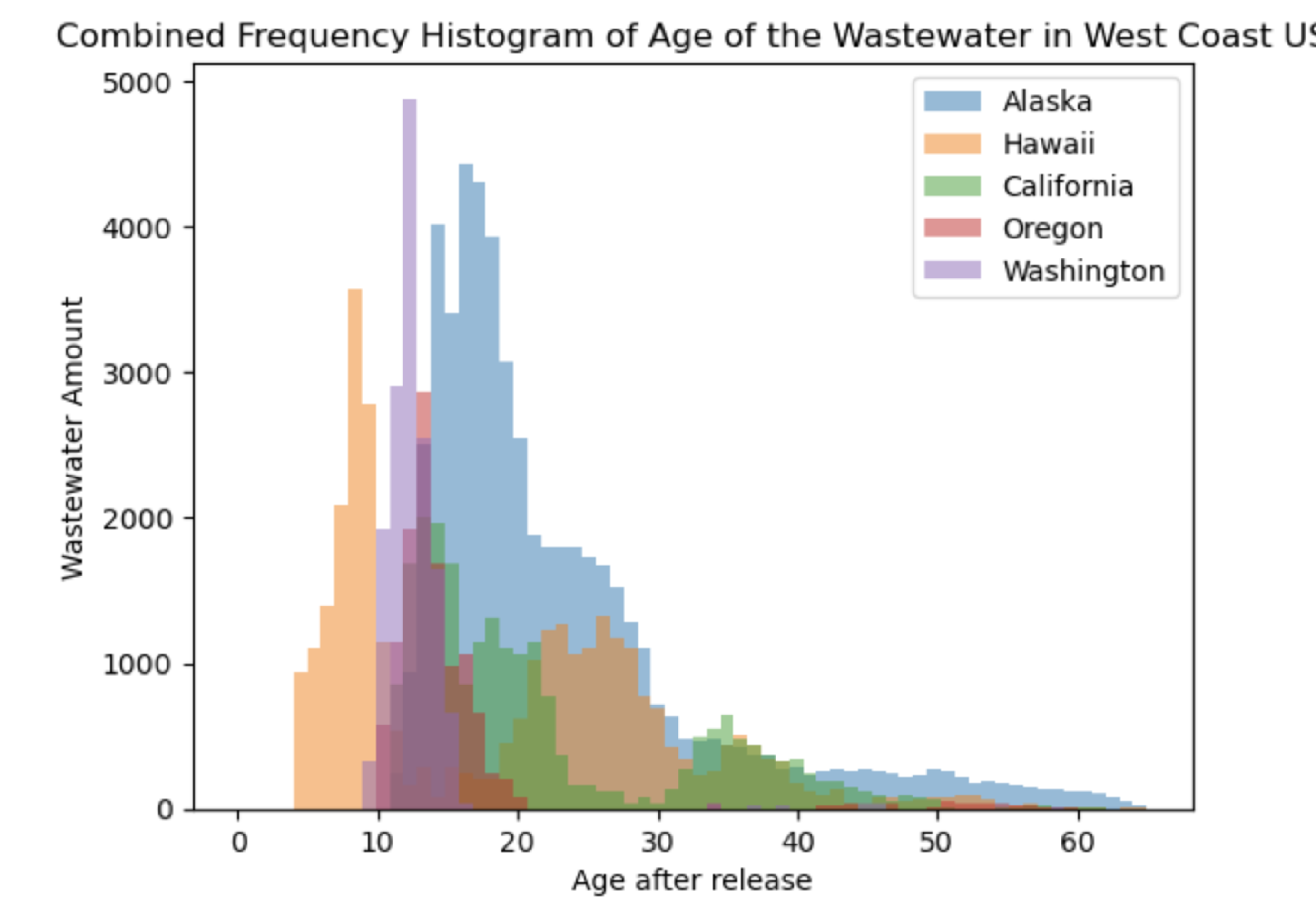


Figure 2. Here Wastewater Amount means the quantity of wastewater, notice that 1 unit of wastewater could contain different amounts of tritium when at different ages; 1 wastewater amount = 15.6 tons of wastewater

Comparing Tritium Amount Arrived the US Coast Each Year From Fukushima with Tritium Release From Diablo Canyon Power Plant

Tritium Type	Yearly Amount (TBq)	Upper Bound	Lower Bound
Fukushima Mean	25.85	27.29	24.41
Fukushima Max	42.07	44.41	39.72
Diablo Canyon (2019-2022)	80.00	102.93	39.96

Conclusion

The first wave of Fukushima wastewater will reach Hawaii in the 5th year post-release, with most U.S. coastal regions experiencing their first wave after 2033, when the tritium particles is almost passing their first half-life.

Every wave of wastewater waves will arrive twice over 66 years, initially 5-10 years post-release and subsequently 20-40 years later. However,tritium particles will consistently drift around Alaska during their 10-30 year lifespan.

The Fukushima wastewater brings a significant amount of tritium to the U.S. West Coast, rivaling the tritium released by U.S. power plants during peak years–in 2070, tritium brought to West Coast by Fukushima wastewater will be over half the amount of tritium released by U.S. west coast power plant Diablo Canyon.

References

[1] Pacific Gas and Electric Company (PGE).
Diablo canyon power plant 2022 annual radioactive effluent release report.
https://www.nrc.gov/docs/ML2312/ML23121A323.pdf.

[2] J. Marshall, A. Adcroft, C. Hill, L. Perelman, and C. Heisey.
A finite-volume, incompressible Navier-Stokes model for studies of the ocean on parallel computers.
Journal of Geophysical Research, 102:5753–5766, 1997.

[3] C. Wunsch and P. Heimbach.
Practical global oceanic state estimation.
Physica D, 230:197–208, 2007.

[4] C. Wunsch, P. Heimbach, R. Ponte, and I. Fukumori.
The global general circulation of the ocean estimated by the ECCO-consortium.
Oceanography, 22:88–103, 2009.

 jma84@jh.edu