Drifter-Based Predictions of the Spread of Surface Contamination Using Iterative Statistics: A Local Example with Global Applications

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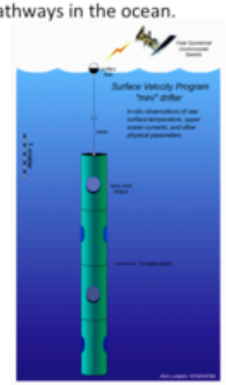
Introduction

In the aftermath of the 2011 Fukushima nuclear power plant accident, it became critical to determine how radioactive particles, both from atmospheric deposition and direct ocean discharge, were spreading in the ocean (Buesseler et al., 2011). One successful method used drifter observations to predict the timing of the spread of surface contamination. Here, the spread of surface contamination from a similar, but hypothetical, accident in the Atlantic Ocean illustrates the power of the historical drifter dataset as a prediction tool. Our hypothetical source is the Pilgrim Nuclear Power station on the east coast of Massachusetts.

Methods

We use a combined dataset of drifter tracks from the Global Drifter Program and the NOAA Northeast Fisheries Science Center. By expanding the iterative technique introduced by Rypina et al., 2014, we are able to make best use of the available data; stitching together drifter trajectories to explore different potential pathways in the ocean.



Direct Probability

The direct probability is calculated using the trajectories of the drifters that have left the source domain at Pilgrim, P, and successfully entered a given bin, Z.

$$p^{direct}_{P\to Z} = \frac{\#\text{ successful direct trajectories}}{\#\text{ direct trajectories leaving P}}$$

Successive Iterations

The successive probabilities are calculated similarly.

$$p^{1stop}_{P\to Y\to Z} = \frac{\#\text{ successful one stop trajectories}}{\#\text{ one stop trajectories leaving P}}$$

$$p^{total1} = p^{direct} + p^{1stop}(1 - p^{direct})$$

$$p^{2stop}_{P\to X\to Y\to Z} = \frac{\#\text{ successful two stop trajectories}}{\#\text{ two stop trajectories leaving P}}$$

$$p^{total2} = p^{total1} + p^{2stop}(1 - p^{total1})$$

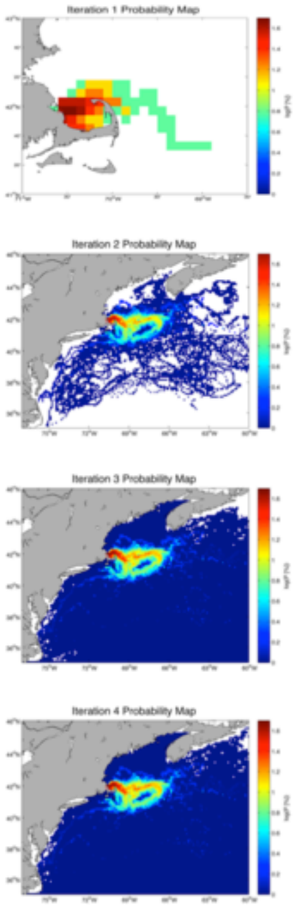
$$\vdots$$

Local Leakage

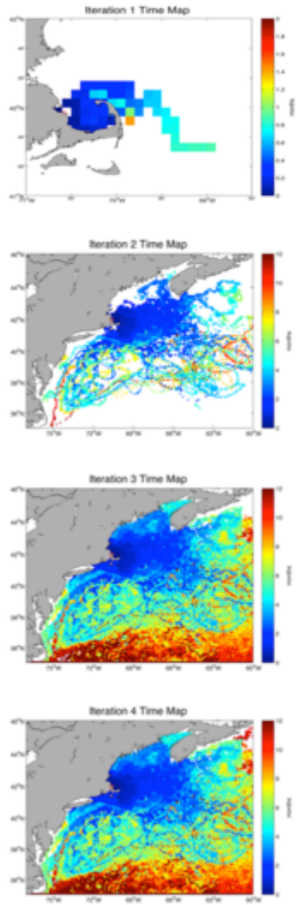
The local direct leakage scenario that could result from point source contamination is used to study the spread of contamination within and beyond Cape Cod Bay.

Studied using:
- 0.1° x 0.1° source domain
- 0.1° x 0.1° grid

Probability Maps



Time Maps

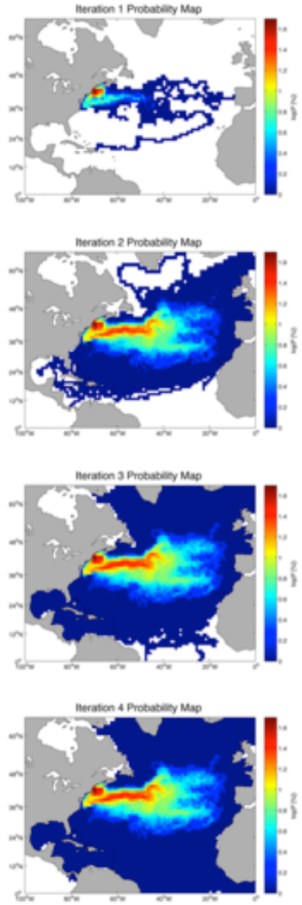


Atmospheric Deposition

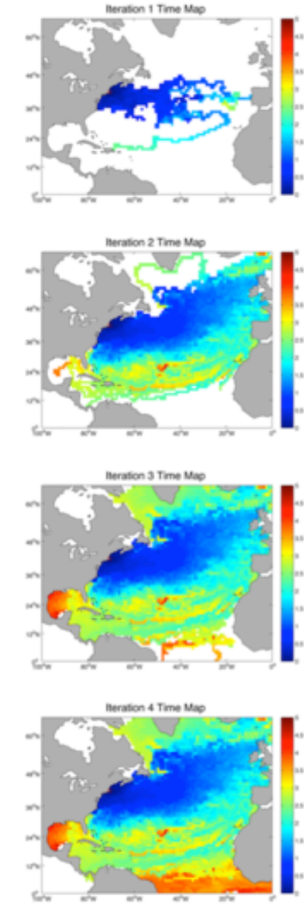
The broader atmospheric deposition scenario that could result from an explosion is used to study the large-scale spread of contamination throughout the North Atlantic.

Studied using:
- 2° x 3° source domain
- 1° x 1° grid

Probability Maps

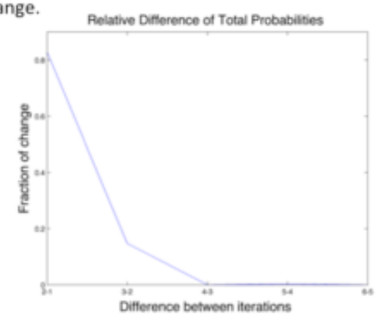


Time Maps



Conclusions

In both scenarios, new information was provided with successive iterations, and the iterative method was stopped after four iterations as the relative change in probabilities did not change.



Expanding the method beyond two iterations allows for the best use of the available drifter observations and provides reasonable timing of the spread of surface contamination. As shown with the two scenarios, this drifter-based analysis of the spread of surface contamination can be used to study varying spatial and time scales. The visible effects of circulation features on the probability and timing of contamination spread as illustrated here, were also seen in the earlier studies of the spread of radionuclides from Fukushima. This technique, which allows for direct observationally-based predictions, can be applied anywhere that drifter data are available to calculate estimates of the likelihood and general timing of the spread of surface contamination in the ocean.

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References

1. Buesseler, K., M. Aoyama, M. Fukasawa. 2011. Environmental Science and Technology: 45, 9931-9935, doi: 10.1021/es202816c.
2. Global Drifter Program database. http: //www.aoml.noaa.gov/phod/dac/index.php
3. NOAA Northeast Fisheries Science Center (NEFSC) drifter database. http://www.nefsc.noaa.gov/drifter/
4. Rypina, I. I., S. R. Jayne, S. Yoshida, A. M. Macdonald, K. Buesseler. 2014. Journal of Geophysical Research Oceans: 119, 8177-8193, doi: 10.1002/2014JC010306.

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