

Estimating the travel time and most likely path from the Global Drifter Program

Michael O'Malley

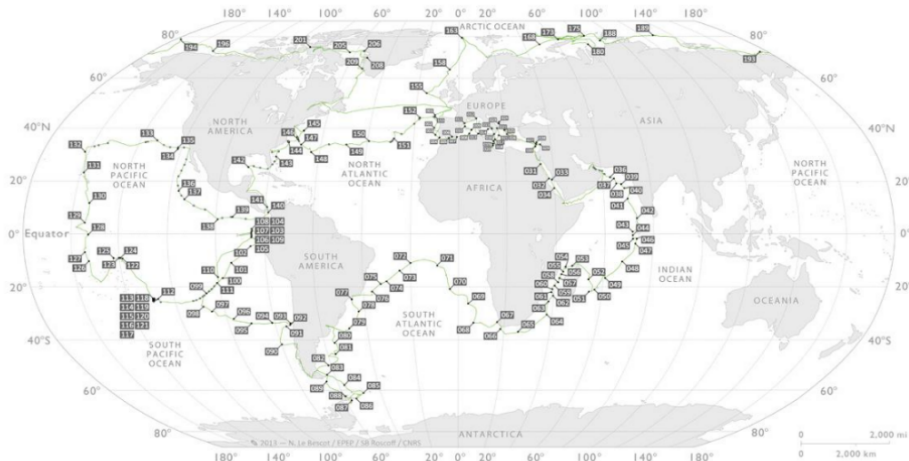
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Lancaster University

April 30, 2021



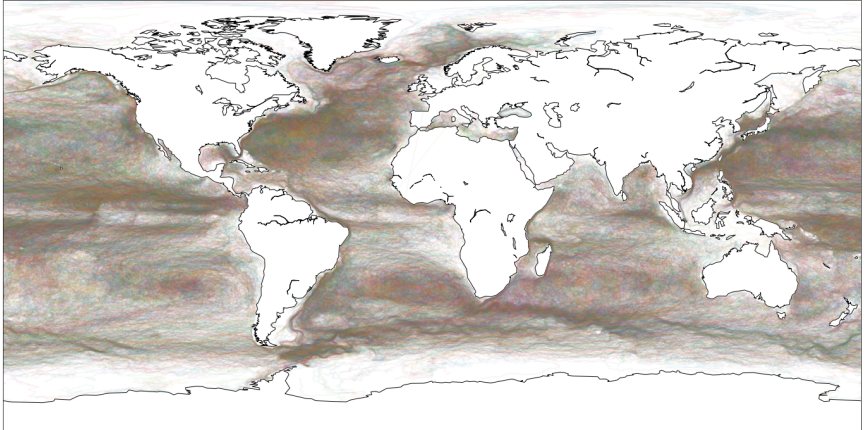
Goal:



Species Difference $\sim$ Spatial Distance + Environmental Variables

Drifter Data

'Spagetti' plot of all drifters



Goal: Estimate a dissimilarity derived from Trajectories.

- Estimate the travel times directly.

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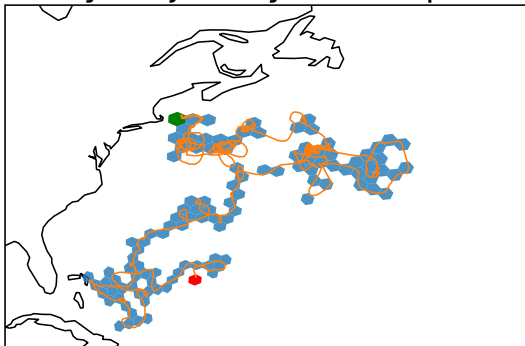
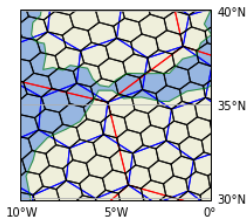
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- Complete the travel times using matrix completion algorithms.

Goal: Estimate a dissimilarity derived from Trajectories.

- Estimate the travel times directly.
- Complete the travel times using matrix completion algorithms.
- Reduce the data to a Markov Chain representing probabilities of changing location.

Extracting Travel Times - UBER's H3 Index

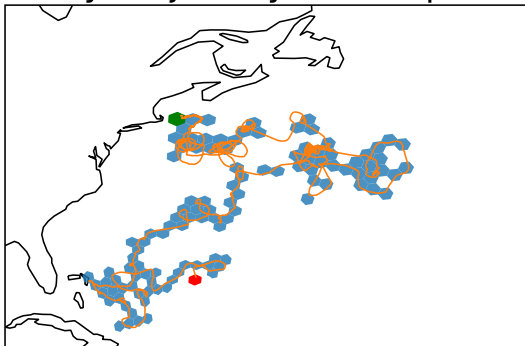
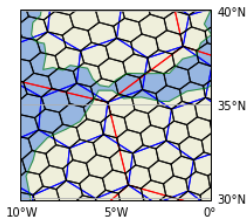
Daily Trajectory -> H3 spatial



- Better area distribution than a Lon-Lat grid.
- Equivalent neighbors.

Extracting Travel Times - UBER's H3 Index

Daily Trajectory -> H3 spatial



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- Equivalent neighbors.
- Estimate a transition matrix from these, as the probability of going from state i to state j after 5 days.

Using the Markov Chain

- We find the most likely path from the Markov chain which goes from the origin o to the destination d .

$$\arg \max_{n, p_1, p_2, \dots} \prod_{i=1}^n T_{p_i, p_{i+1}} \quad (1)$$

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- Simplified down to a shortest path problem

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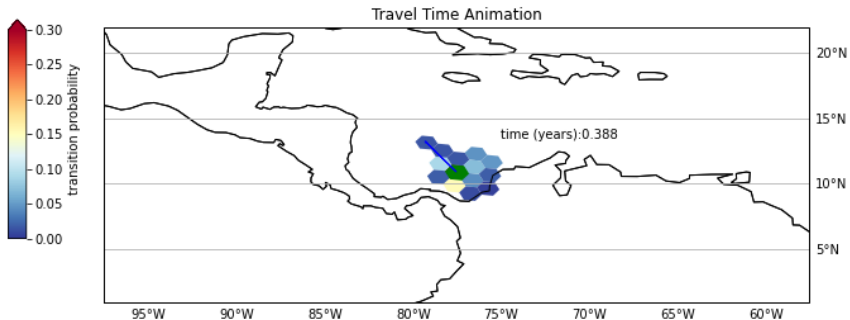
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$$k_i \sim NB(1, a) \quad a = \frac{T_{p_i, p_i}}{T_{p_i, p_i} + T_{p_i, p_{i+1}}}$$

- The quantity we're using as our distance is:

$$\sum_{i=0}^{n-1} E[k_i]$$

Animation

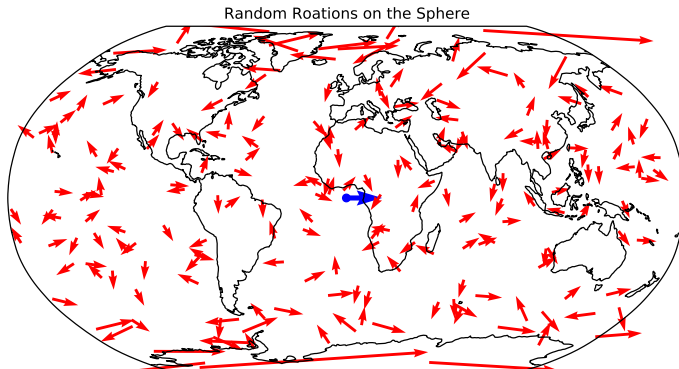


Animation

drifter mp4 animation

Discretise trajectories > Estimate Transition matrix
> Dynamic Program > Distribution.

Extracting Travel Times - Randomness



Only compute $\hat{k}_i = \mathbb{E}[k_i]$. Run the algorithm n_{rot} times. Treat these as samples.

Brief Results

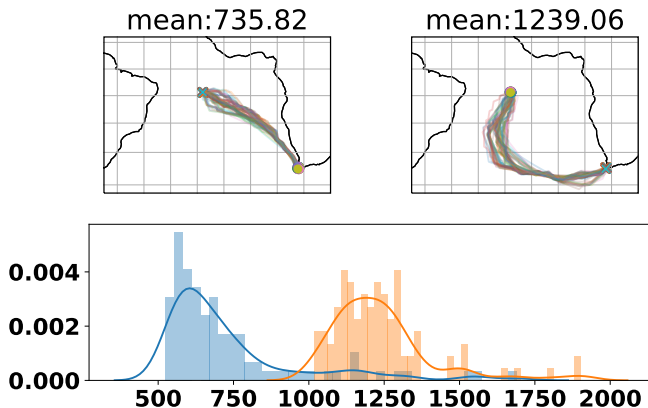


Figure 1: Travel time for drogued drifters using just rotations. The circle is the start, x the end. The lines connect the centroids of hexagons.

Brief Results

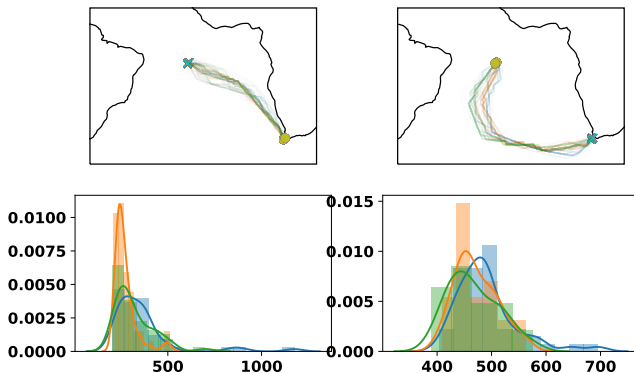
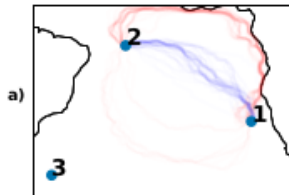


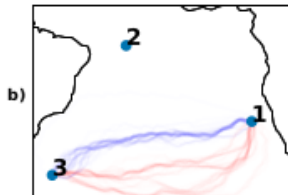
Figure 2: Travel time for drogued and undrogued drifters. Different colors represent different rotations. 50 bootstrap samples plotted for each rotation.

Sample Results

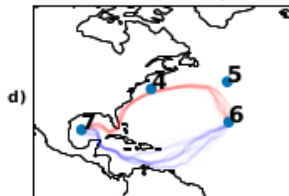
1 -> 2: 2.4(sd 0.5) Years
2 -> 1: 3.7(sd 0.9) Years



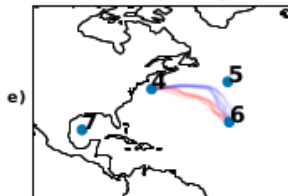
1 -> 3: 4.0(sd 0.6) Years
3 -> 1: 2.4(sd 0.6) Years



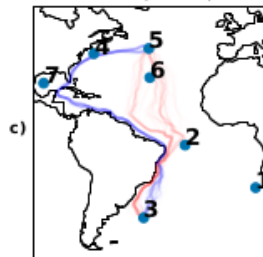
6 -> 7: 2.7(sd 0.4) Years
7 -> 6: 2.9(sd 0.8) Years



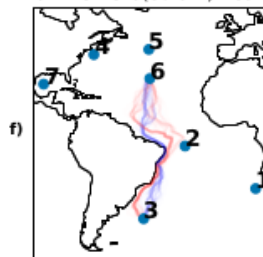
4 -> 6: 5.0(sd 2.7) Years
6 -> 4: 4.4(sd 1.9) Years



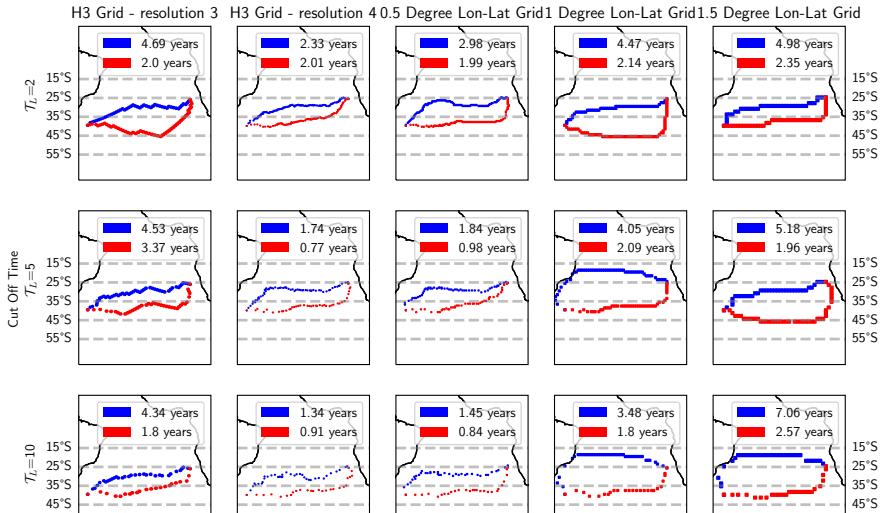
3 -> 5: 6.5(sd 2.1) Years
5 -> 3: 7.8(sd 1.8) Years



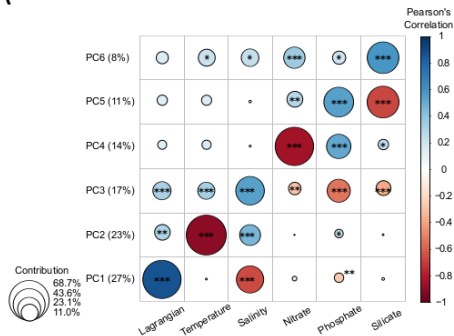
3 -> 6: 7.1(sd 1.8) Years
6 -> 3: 5.6(sd 0.7) Years



Longitude-Latitude vs H3



A



B

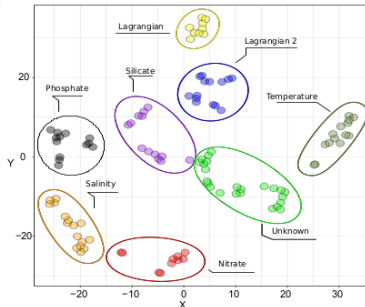


Figure 3: Identified species whose genetic differentiation are increased by oceanic currents

Conclusion

- It is straightforward, quick and deployable. The matrix T can be provided in 10MB.
- Python Package in development “DriftMLP”.
- (Almost) Published in Journal of Atmospheric and Oceanic Technology.
- Interactive demonstration on NOAA website.

- O'Malley, M., Sykulski, A. M., Laso-Jadart, R., and Madoui, A. (2020). Estimating the travel time and the most likely path from lagrangian drifters. *arXiv preprint arXiv:2002.07774*.

Thanks for Listening!

- Shortest path algorithms with uncertain inputs.
- Continuous Time Markov chain
- Include Covariates: Drifters measure SST for example. Estimate $T_{i,j}$ as a model.
- Top k paths rather than a single shortest path.