LOST: Lagrangian Ocean Search Targets

A Particle Trajectory Model for Search and Rescue in the Greater Agulhas System

Michael G. Hart-Davis [1,a,b,c], Björn C. Backeberg [b,d,e], Juliet Hermes [a,c] and Mostafa Bakhoday-Paskyabi [d]

[a] Institute for Coastal and Marine Research, Nelson Mandela University, Port Elizabeth, South Africa, [b] Nansen-Tutu Centre for Marine Environmental Research, University of Cape Town, Cape Town, South Africa,
[c] Egagasini Node, South African Environmental Observation Network, Cape Town, South Africa, [d] Nansen Environmental and Remote Sensing Center, Bergen, Norway, [e] EGI Foundation, Amsterdam, Netherlands, [1] Corresponding author, email - s218197187@mandela.ac.za

1 Introduction

Particle Tracking

Particle tracking is the observation of motion of virtual particles advected by the flow information provided by numerical ocean models. Particle tracking has been developed for a variety of applications including larval dispersion, oil spills, oceanographic connectivity and search and rescue.

The Capsized Vessel

On the 18th of January 2016, the upturned hull of a catamaran was spotted approximately 113 nautical miles off Cape Recife, near Port Elizabeth (South Africa). 5 days after being spotted off Cape Recife, on the 22nd of January 2016, the National Sea Rescue Institute (NSRI) found the capsized catamaran south of Cape Agulhas. The approximate locations, the last known position and the recovery site of the capsized vessel provides valuable information that are used to assess the ability of the LOST particle trajectory model. Further information about the capsized vessel can be found in Hart-Davis et al. (2018)

2 Data and Methodology

Copernicus

The operational Mercator global ocean analysis and forecast system provides 10-day, 3D global ocean current forecasts on a daily basis (available at http://marine.copernicus.eu). Output files are available at an hourly or daily temporal resolution and a 1/12° spatial resolution and includes daily data of temperature, salinity, currents, sea level, mixed layer depth and ice parameters throughout the full depth of the global ocean. The current data provided from this ocean model is used in the particle trajectory model to represent the ocean surface currents.

ECMWF

Winds from the ECMWF (European Centre for Medium-Range Weather Forecasts), were used to account for the wind drift of the virtual particles. The wind data is at 10 m above sea surface and has a 3-hourly temporal resolution and 1/10° spatial resolution.

Parcels

The particle trajectory model is based on the developments of a Lagrangian particle tracking tool known as Parcels (Probably a Really Computationally Efficient Lagrangian Simulator, Lange and van Sebille 2017). The Parcels tool was used due to its computational efficiency and scalability which allows for the customisation of virtual particles to represent certain different objects.

3 Particle Trajectory Model Parameter Testing

Currents and Winds

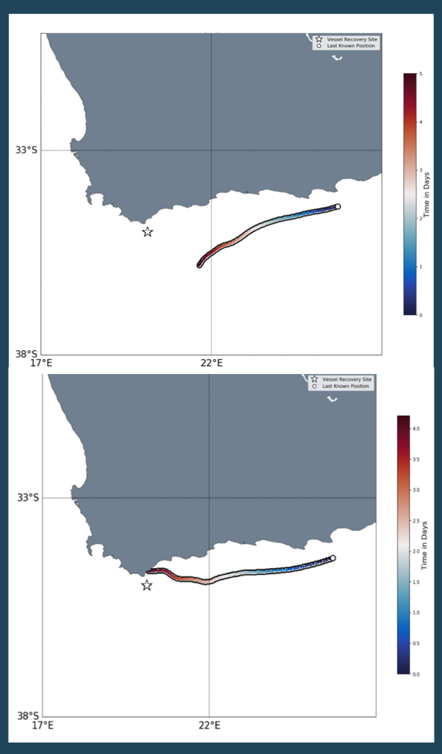

Fig. 1. A simulation of 1,000 virtual particles deployed at the location where the capsized vessel was last seen (white circle) forced with (top) current only and (bottom) wind and current only. The colorbar represents the time in days since deployment, reaching a maximum of five days.

In order to assess the importance of including windage when conducting simulations on capsized vessels in the ocean, experiments were designed to assess the contribution of wind (Fig. 1). The virtual particles in simulations forced with only surface currents (Fig. 1 top) suggest that using only ocean surface currents to force the virtual particles is inadequate in terms of simulating the pathway of the capsized vessel. Although combining wind and surface currents (Fig. 1 below) improved the result drastically, the results remained insufficient in estimating the path of the capsized vessel. To learn more about these results, refer to Hart-Davis et al. (2018).

Currents, Winds and Stochastic Motion

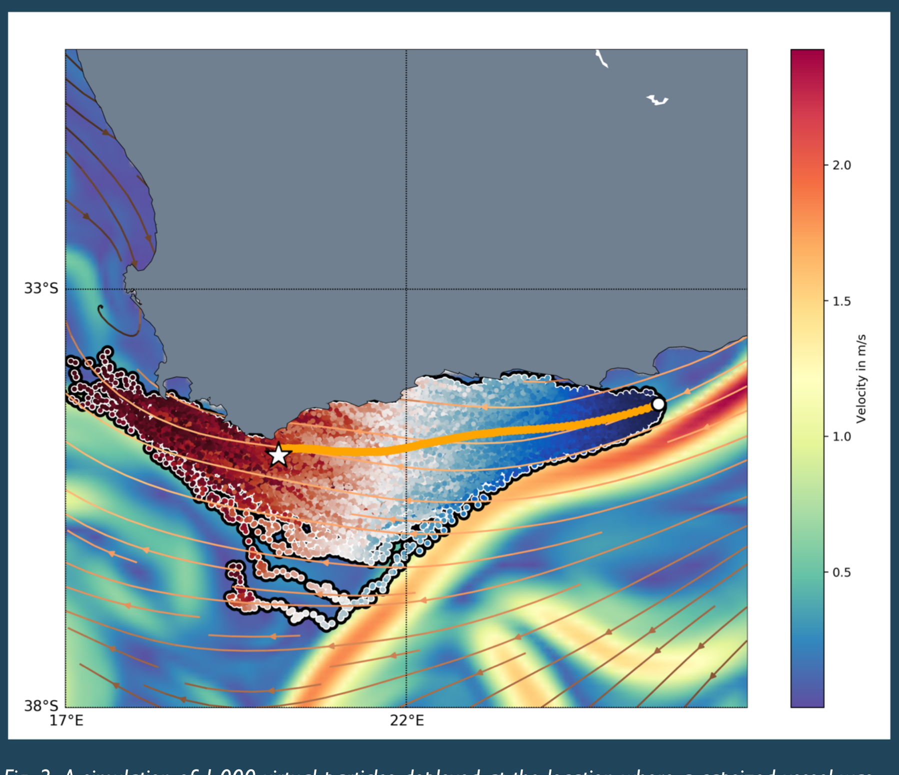

Fig. 2. A simulation of 1,000 virtual particles deployed at the location where a capsized vessel was last seen (white circle). The trajectory of the particles are overlaid over a map of the ocean surface currents. The orange line represents the mean trajectory of virtual particles over the 5-day experiment. The wind fields are represented by the orange streamplots. The white star represents the site where the vessel was recovered by the NSRI.

The results shown in Fig. 1, could be due to the spatial resolutions of the surface current velocity data (1/12°) and the wind data (1/10°) which are not able to represent the correct effects of sub-grid scale processes of the region. In an attempt to resolve the sub-grid scale processes in the particle trajectory model, Brownian motion (Hida 1980) was applied to account for the turbulent features not resolved in the velocity field (Fig. 2). The results show a strong number of virtual particles that pass through the point where the capsized vessel was recovered. It can be implied that the particle trajectory model performs best when the wind, surface currents and stochastic motion are incorporated as the mean estimates the final location of the capsized vessel relatively well.

4 Real-Life Applications

Capsized Catamaran Probability Density Analysis

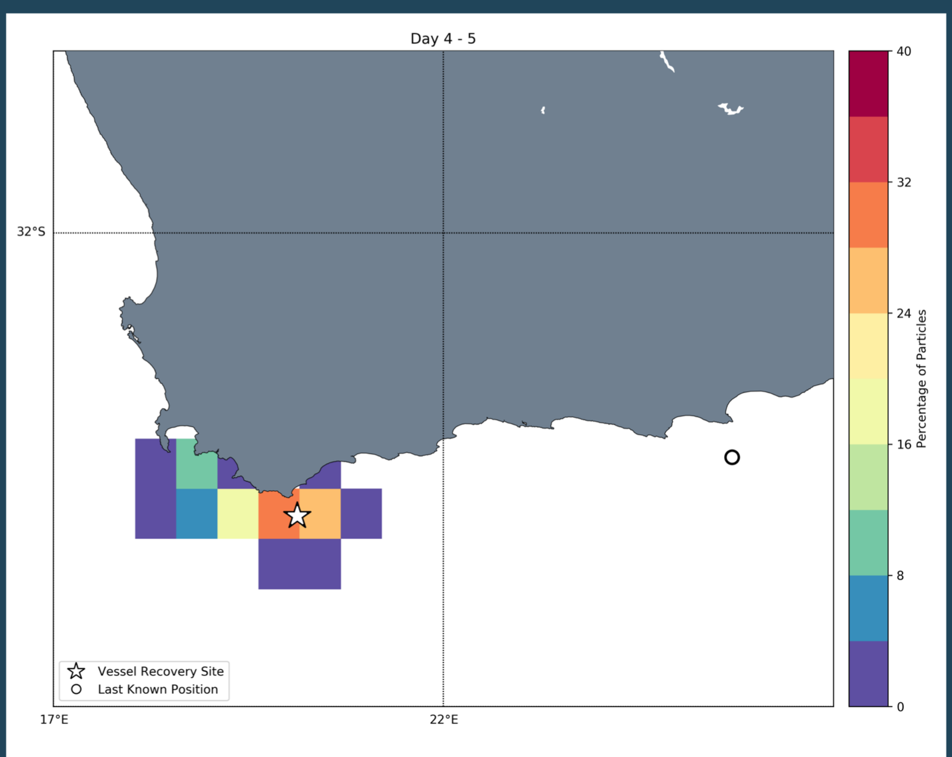

Fig. 3. The percentage of virtual particles per 0.5° x 0.5° grid of the domain for the final day of the simulation. The white circle represents the last known position of the capsized vessel and the white star represents the position where the vessel was recovered.

Based on the previous experiment, Fig. 3 shows the percentage of total virtual particles in the ocean per 0.5° x 0.5° grid at the end of the 5th day of the experiment. This figure shows the maximum likelihood for an object to be found in a 0.5° x 0.5° geographical grid, and could be used to assist in the search and recovery of objects lost at sea. Encouragingly, the predicted maximum likelihood for the location of the capsized catamaran on day 5 agrees well with the location where NSRI found the vessel. This indicates that the methodology and input data used to predict the trajectories of the capsized catamaran are of sufficient accuracy to be quantitatively useful in large scale ocean search and rescue applications.

Surfboard Lost at Sea

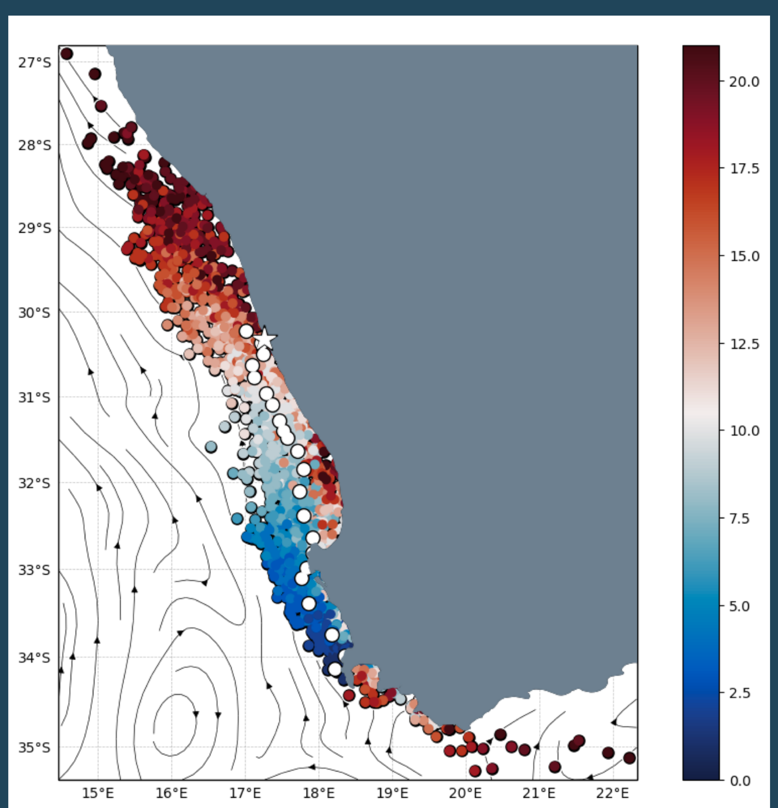

Fig. 4. A simulation of 1,000 virtual particles deployed at the site where a surfboard was lost. The white dots represent the average trajectory, while the white star represents the site where the board was found. The colorbar represents the time in days from deployment. The streamplots represent the mean surface currents.

A surfboard was lost near Kommetjie, Cape Town during a surfing incident and found two weeks later near Hondeklipbaai. The data from where the board was lost and recovered was used as a test case for the LOST model. It was found that the average trajectory of virtual particles, which were designed to account for the characteristics of a surfboard, was found to very closely estimate the final location of the board (Fig. 4). It was highlighted that there is a need to be accurate in providing data about the location and time were the object is lost.

5 Conclusion

A particle trajectory model combining ocean surface currents, winds and stochastic motions is assessed for potential application in a search and rescue scenario for a capsized catamaran. It is shown that, by incorporating stochastic motion, windage and surface current data into the particle trajectory model, the model more accurately predicts the drift of the capsized vessel over a five day period. It is anticipated that, with some refinement, the particle trajectory model will assist in optimizing search and rescue operations improving chances of finding objects lost at sea, thereby potentially saving lives.

- Hart-Davis, M.G., Backeberg, B.C. and Bakhoday-Paskyabi, M. 2018. An assessment of the importance of combining wind, ocean currents and stochastic motions in a particle trajectory model for search and rescue applications. *SASAS: Interactions between the atmosphere and ocean*. Page: 157 – 160.
- Hida, T. 1980. Brownian Motion. In Brownian Motion, edited by T. Hida, 44–113. New York, NY: Springer US.
- Lange, M. and van Sebille, E. 2017. Parcels v0.9: prototyping a Lagrangian ocean analysis framework for the petascale age. Geoscientific Model Development, 10(11), pp.4175–4186.

6 Acknowledgements

Mr Michael G. Hart-Davis acknowledges financial support from the Nansen-Tutu Centre for Marine Environmental Research and the South African Environmental Observation Network Egagasini Node. The Lagrangian particle tracker, Parcels is licensed under an open source MIT license and can be downloaded from https:/oceanparcels.org.

NELSON MANDELA UNIVERSITY
Change the World
Nansen-Tutu Centre for Marine Environmental Research
NRF National Research Foundation
SAEON South African Environmental Observation Network