Simulating the transport of floating marine litter across scales

Erik van Sebille
and the topios.org and oceanparcels.org teams
Simulating surface transport on a global scale with GlobCurrent

Separating the effects of Ekman and geostrophy

The effect of Stokes drift in transporting floating items southward

The effects of waves via Stokes drift

Wave-driven Stokes drift (WaveWatchIII 1/2°)

The depth distribution of plastic

Transition matrices from drogued vs undrogued drifters

The effect of large-scale vertical shear

So how important are the initial conditions?
Quantifying mixing entropy

\[ S_k(t) = -\sum_i p_{i|k}(t) \ln p_{i|k}(t), \quad p_{i|k}(t) = \frac{\rho_{i,k}(t)}{\sum_i \rho_{i,k}(t)} \]
Toward the Integrated Marine Debris Observing System

Mapping of plastic with Earth Observation?

<table>
<thead>
<tr>
<th>Marine process</th>
<th>Spatial</th>
<th>Temporal</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Extent (max)</td>
<td>Resolution of observations</td>
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<tr>
<td>River discharge</td>
<td>100 Km</td>
<td>30 m (G) 500 m (T)</td>
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<tr>
<td>Spill</td>
<td>100 Km</td>
<td>1 m (G) 50 m (T)</td>
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<tr>
<td>Shoreline accumulation</td>
<td>1000 km</td>
<td>1 m (G) 5 m (T)</td>
</tr>
<tr>
<td>Submesoscale convergence filaments</td>
<td>10 km</td>
<td>30 m (G) 100 m (T)</td>
</tr>
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Table 1 summarises the link between questions, processes, their spatial and temporal scales and required observation requirements.

The greatest difference in sampling requirements is on the observation frequency. To resolve spatial and temporal scales of processes, observations must be made within the lifetime of processes. For example, to detect changes in accumulation areas driven by highly dynamic processes (river discharge, spills), lower observation frequency (up to 5 day revisit) should be sufficient to monitor shoreline accumulation processes beyond the supratidal zone. Riverine debris is more readily detectable at spatial extents of 10 km or less and at resolutions of 30 m (Goal) and 500 m (Threshold) if observed weekly or monthly. The current review focuses on Q1, Q2 and Q3, which are potentially tractable using satellite remote sensing. We further limit the scope of this review to marine realms due to the urgent socio-economic implications of plastic pollution. The dynamics of marine plastic debris in the upper ocean (Q2 and Q3) are typically studied at the global to mesoscale, with riverine debris requiring more frequent, higher-resolution observations. The extent and lifetime of processes are reported alongside corresponding spatial and temporal observation requirements. Observation requirements are reported in terms of Goal (G) and Threshold (T) levels, see text for definition. The greatest challenge to scaling up observations to the global scale using models that describe the movement of small positively buoyant plastic particles (see Godijn-Murphy, Lebreton, Leslie, Lindeque, Maximenko, Martin-Lauzer, Moller, Murphy, Palombi, Raimondi, Reisser, Romero, Simis, Sterckx, Thompson, Topouzelis, Van Sebille, Veiga & Vethaak (2019) Remote Sensing) is a lack of observations even in the gyres. At smaller spatial scales than ocean gyres down to mesoscale eddies. At present, such models show disagreement up to a factor of 10 in their estimates of plastic abundance in the most frequently sampled areas with high concentrations of plastics, such as the Northern Pacific and Atlantic Gyres. Most of the disagreement among models has been attributed to the lack of observations, even in the gyres. At smaller spatial scales than ocean gyres down to mesoscale eddies. At present, such models show disagreement up to a factor of 10 in their estimates of plastic abundance in the most frequently sampled areas with high concentrations of plastics, such as the Northern Pacific and Atlantic Gyres.
Tracking pumice to validate surface flow

El Niño – Southern Oscillation (ENSO) was relatively neutral during the time of raft dispersal (see https://www.esrl.noaa.gov/psd/enso/mei/). We therefore expect the dispersal pathways to be similar to e.g. 2003-2006. For the model hindcast, we consider the cumulative coverage over 14 years (2000-2013) to be representative of much of the variability in ocean currents.

Figure 4 Oceanographic simulations of raft dispersal. a) and b) One-month simulation with Parcels (un-rimmed circles) compared with satellite imagery (black-rimmed circles). c) and d) 2-year simulation with Parcels for releases on each 7 August of the years 2000-2013, with 1\% windage and including Stokes drift. c) Cumulative distributions of particle concentration as grid-cell fraction. d) Cumulative distributions of minimum days adrift. Red triangle for source volcano.

4. DISCUSSION AND CONCLUSION

The application of the Parcels short-term simulation to the well-constrained trajectories of the pumice raft is a rare opportunity to explore windage and Stokes drift parametrizations. The windage for pumice is likely typical for semi-submerged objects, such as pelagic Sargassum for which 1\% windage has also been estimated [Putman et al., 2018]. A refined understanding of windage would thus be of broad utility in tracking...
Conclusions

Geostrophy, Stokes and Ekman are all important for the transport of floating material.

Events like the Tonga eruption provide unique opportunity to validate transport models.

However, not on timescales of much more than a few years.
The physical oceanography of the transport of floating marine debris