SEDTRAILS: SIMULATING & VISUALIZING COASTAL SEDIMENT PATHWAYS

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INTRODUCTION

In the face of climate change, sea level rise, and increased human development on coasts and deltas, better quantification and understanding of coastal sediment transport is essential. Specifically, we need to know more about sediment pathways for system understanding and planning interventions (e.g., nourishments or beneficial reuse of dredged material).

Sediment transport models like Delft3D or XBeach adopt an Eulerian (fixed-grid) approach, which is useful for quantifying rates of sediment transport and morphodynamic change. However, tracking the fate of sediment from specific sources using these models is complex and computationally expensive. To better simulate the pathways that sediment takes, we can adopt a Lagrangian (particle-tracking) approach, as is common in oceanographic and water quality studies.

To fill these gaps, we present SedTRAILS (Sediment TRAnsport vIsualization & Lagrangian Simulator), a general-use process-based particle tracking model that is fast and easy to use for the coastal community. SedTRAILS provides a suite of analysis tools for better understanding and visualizing sediment pathways. what is special is also how we use it (e.g. querying particle fields to ask management questions, connectivity analysis),

METHOD

SedTRAILS is a MATLAB-based post-processing tool that is offline-coupled to hydrodynamic models like Delft3D or D-Flow FM. Building on earlier tools that focused on visualizing sediment transport fields (Pearson et al 2021a), we now directly simulate the trajectories of sand particles using adaptations of Storlazzi et al (2017) and the method of Soulsby (2011), including wave-driven transport as per Ruessink et al (2012).

We assume a fixed seabed (morphostatic conditions) and do not account for particle burial and trapping in the seabed (i.e., a “concrete bed”). In this way, we estimate maximum potential sediment pathways over relatively short (e.g. days to months) timescales and O(1-10 km) spatial scales.

RESULTS

Here we verify SedTRAILS against analytical test cases from Lange & van Sebille (2017), and then validate for real-world applications using a sediment tracer study at Ameland Inlet in the Netherlands (Pearson et al., 2021b).

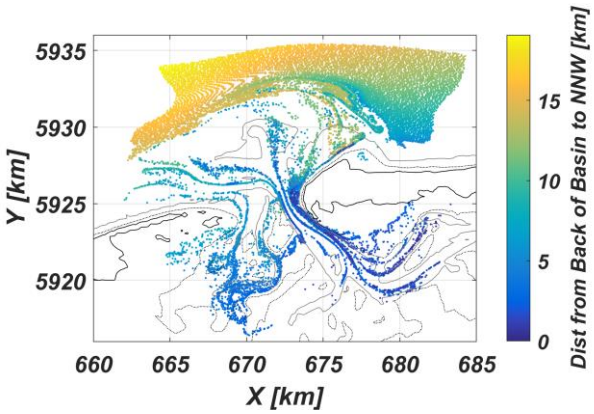

Figure 1 – Tracer particles at Ameland Inlet (the Netherlands) advected over a single tidal cycle, with colourmap indicating the distance of their original source from the back of the basin.

By selectively querying the database of sediment pathways produced by SedTRAILS and using techniques like connectivity analysis (Pearson et al, 2021a), we can answer coastal management questions such as:

- How is an ebb-tidal delta connected with the adjacent barrier islands and back-barrier basin?
- How likely is it that sediment from a coastal nourishment reaches a sensitive ecological habitat?
- How can we satisfy multiple objectives with respect to sand placement? e.g., Where can we place sediment to feed a nearby beach but not re-fill the navigation channel we dredged it from?

SedTRAILS is already used in research and consulting projects around the world, so we share examples of applications to sites in the Netherlands and abroad (e.g., Figure 1), and demonstrate the latest developments.

DISCUSSION

SedTRAILS is a practical tool for estimating and visualizing sand pathways in coastal systems. In this way we can both improve our understanding of complex coastal systems and answer practical coastal management questions about the placement of

sediment. It also provides a means of extracting added interpretive value from existing coastal area models, making it a useful tool for communicating complex coastal processes and model results with stakeholders, students, and non-experts.

This work sets the stage for future developments including improved simulation of burial and trapping processes in the seabed, sediment-structure interactions, and integration with aeolian transport models (e.g., Hoonhout & de Vries, 2017) to understand the full continuum of sediment pathways from lower shoreface to dune crest.

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