Sediment Connectivity and Exchange in Ameland Inlet

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Flood safety and vital habitat depend on the fate of the Wadden Sea & Islands

- Will tidal flats keep up with sea level rise?
- Is Wadden Sea sed. getting coarser?
- What effect do nourishments have?

Study Site: Ameland Inlet (Netherlands)

- Why are we studying this inlet?
  - Ameland Inlet is gateway to WS and understanding transport pathways through it will help us predict future response…

Motivation: how do nourishments on the adjacent coast affect the Wadden Sea?

Wadden Sea and SLR depends on sediment import

Need to test many future scenarios:
- Nourishments
- SLR
As well as existing:
- Historical bathy
- Different storm conditions
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Research Q: Is the WS getting coarser? Will it be able to keep up with SLR?
How will the inlet respond to future changes?

Fate depends on sediment transport pathways

Pathways in turn depend on grain size, hydrodynamic forcing, morphology, and timescale
How do we define connectivity?
- The degree to which sediment can travel from point A to B
- Well-established concept in ecology, geomorphology, neurology

Potential applications
- Improve native system understanding
- Predict future scenarios (i.e. the fate of nourishments or sea level rise)
- Connect to benthic ecology
Interpreting Connectivity Using Graph Theory

Adapted from Cowen and Sponaugle (2009)
Morphodynamic Model Setup

- Delft3D morphodynamic model
  - 2D, schematized tidal forcing only
  - 40x30 km domain, highest resolution ≈ 80 m
  - 4 sediment classes
    - 100, 200, 300, 400 μm
    - Distributed according to measured data
  - 1.5 year morphological time
Methodology [1/4]

Divide model domain into representative units

Label sediment differently each for source unit

- 4 background classes
- 4 tracer classes
Run Delft3D morphodynamic model

Track tracer sediment as it moves through domain
Tabulate the mass of each tracer sediment fraction in each unit at end of simulation.
Methodology [4/4]

- Include in adjacency matrix and network
- Repeat procedure for each source area

\[ \sum M_{sed} = 30 \times 10^9 \text{ kg} \]
Preliminary Results [1/3]

Connectivity is highest with neighbouring units

There are four key sediment-sharing “neighbourhoods”
Asymmetry implies one-way paths and net transport e.g. Basin Import ≈ 1.5x Basin Export
How does connectivity vary with grain size?

100 μm Sand
34.1% of Nodes Connected

200 μm Sand
21.4% of Nodes Connected

300 μm Sand
18.1% of Nodes Connected

400 μm Sand
13.6% of Nodes Connected

Preliminary Results [3/3]

Finer Sand

Coarser Sand

$\Sigma M_{sed} = 14 \times 10^9$ kg

$\Sigma M_{sed} = 7 \times 10^9$ kg

$\Sigma M_{sed} = 6 \times 10^9$ kg

$\Sigma M_{sed} = 2 \times 10^9$ kg
Sediment Sharing Communities & Grain Size

100 μm Sand
3 Sediment-Sharing Communities

200 μm Sand
5 Sediment-Sharing Communities

300 μm Sand
5 Sediment-Sharing Communities

400 μm Sand
4 Sediment-Sharing Communities

Finer Sand ——— Coarser Sand
With this framework, we can:

- **Quantify sediment transport pathways** across many different scenarios
- Better understand the **fate of nourishments** as a function of grain size
- **Anticipate future changes** in bed composition of the Wadden Sea
- Link sediment transport pathways to **benthic ecology**
What Next?

- Improvements to underlying model
  - Validation with field data
  - Include waves, wind-driven currents

- Analyze multiple scenarios:
  - Historical bathymetry/forcing
  - Nourishments & sea level rise

- Use particle tracking model
Asymmetries in connectivity (i.e. unidirectional transport) can be used to explain long-term erosional or depositional trends.

Connectivity is inversely proportional to grain size, but also depends on sediment supply.

Sediment connectivity provides a quantitative framework for assessing sediment transport pathways in coastal systems.
Thank you for your time!
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