Combining remote sensing and numerical modelling to reveal river delta sediment trapping processes

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Intro

Deltas form where the rivers discharge sediments into seas and oceans and host 400 million people and biodiverse ecosystems. Dams built by humans has reduced sediment supply, which is the lifeblood of deltas. Humans are also causing a new marine transgression which threatens to submerge deltas in the future.

Mission 1: Modelling realistic deltas with waves

Using the **ratio between river sediment discharge (Qs) and wave-driven longshore sediment transport (LST)** 'idealized' deltas are modelled utilizing the Delft3D-SWAN coupled modeling suite.

The model captures essential fluvial, wave and sedimentological processes, including critical hydro-morphodynamic interactions at river-delta interfaces that dictate long-term sediment bypass or retention mechanisms.

We calculate asymmetry in both natural and modelled deltas using an asymmetry index (Ai) (Korus and Fielding) which is the normalized difference ratio between the Updrift area and the Downdrift area.(N and S of river)

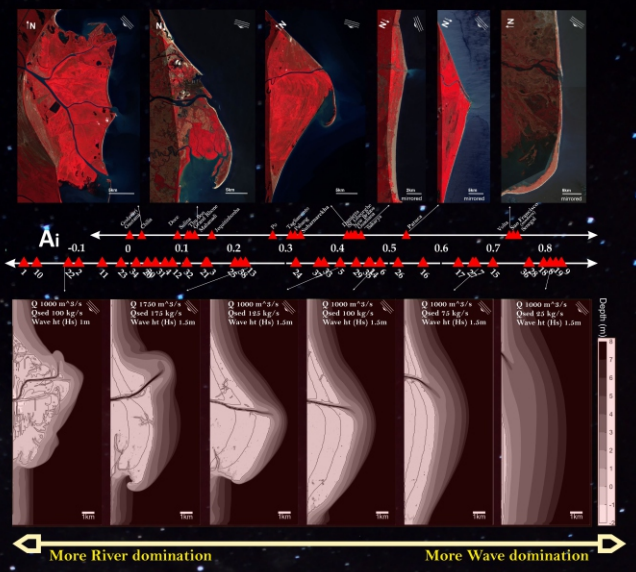


Fig. 1: Delta Asymmetry Comparison. Scaled Ai scores from real-world deltas (top) are contrasted with numerical model results (38 deltas, bottom). Higher Ai indicates more downdrift sediment redistribution, reduced lobe protrusion, and less sediment trapping near river mouths.

These morphologies can be viewed as equilibrium shapes.. If a delta experiences reduction in sediment supply, it will become more wave dominated in the future. For example, the Danube delta experienced a reduction of 66% in sediment supply and is transitioning towards more wave dominated regime, increased erosion and less accumulation.

Zainescu et al., submitted

Mission 2: Getting accurate delta elevation with ICESAT-2

iCESat-2 Data: Global LiDAR Elevations

Mission Objective: Satellite for measuring ICE elevation on Earth, repurposed for Assessing Delta Vulnerability

Workflow:

->Data Harvesting from Orbital Archives - ATL-08 Land product - 20m classified and fitted product. -> Using Python tools for obtaining and working with ICESat-2 data (icepyx)
->Subspace Filtering
->Geoid Calibration via EGM2008
->Synchronizing to Local Sea-Level (Mean Dynamic Topography)

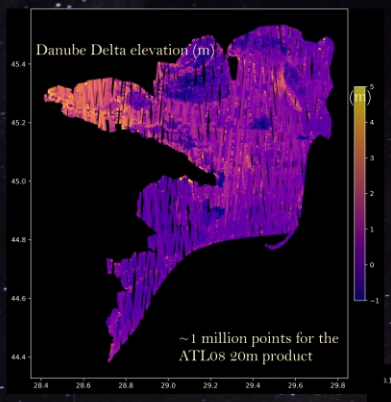


Fig. 2: ICESat-2 derived elevation for the Danube Delta. Lake surfaces are not filtered here.

Compared to classical global DEM's such as SRTM, Copernicus30 m or FABDEM, the ICESAT absolute elvation points predict much lower global elevations of deltas, particularly in tropical regions, which means a larger population vulnerable to sea level rise.

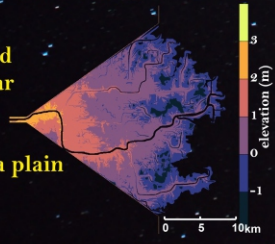
Elevation below 2m:

Published data Syvitski et al. (2009)	ICESat-2:
Amazon: 2.5%	-> 60%
Mekong: 50%	-> 85%
Niger: 1%	-> 60%
Yrrawaddy: 3%	-> 65%
Nile: 30%	-> 90%

Fig. 3: Elevation histogram for the Danube Delta and the cumulative surface frequency. 80% of the delta is below 1m!

Mission 3: Modeliing Delta response to Sea Level Rise

Calibrating the model to create a synthetic delta that mimicks the elevation distribution of a real world delta like Danube Delta.
Various parameters had to be tuned with accurate sediment concentration.



The model size surface in real term is still only 10% o the surface of the Danube Delta, but the balance in accommodation space with sea level rise is realistic.

Future work: expand to global deltas, marine influences (tidal, wave).
Include processes such as vegetation which restricts sediment dispersal on delta plain with

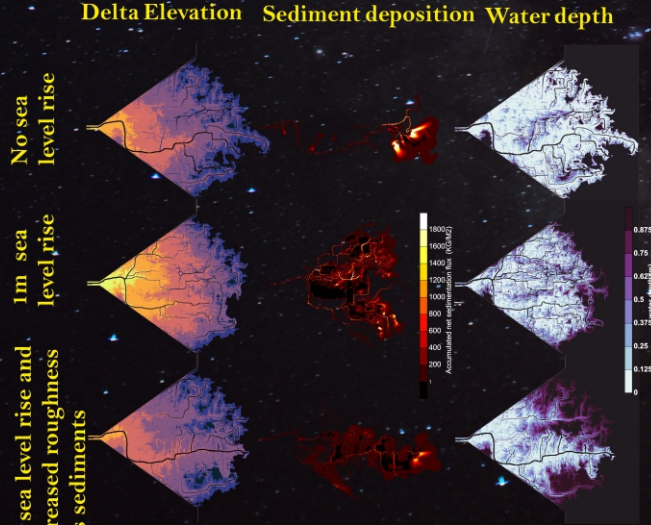


Fig. 4. 100 year evolution from the 1000 year delta plain with different scenarios

Balance of Accommodation Space and Sea level rise

Stationary Sea Level: Deltas prograde.

Sediemnt discharge balanced with accomodation space volume: Deltas aggrade with sea level rise, elevating delta plains, but still prone to localized flooding due to poor connectivity.

Insufficient Sediment and poor connectivity: Deltas slowly drown under vegetation constraints or low connectivity, maintaining offshore depocenters and increaseing delta plain sedimentation.

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