



Coastal dynamics & coastal evolution

Why does Sylt exist?

Climate Change II excursion at AWI Sylt

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Beach

Sediment gain or loss? By which processes?

- Weststrand: 1 mio m³/yr sand loss

-> transported away by:

- waves, storm surges
- tidal currents
- winds
- longshore sediment transport

! under natural conditions



Beach

How do storm events change the beach profile?

- High energy waves take away sediment from upper beach and dunes
- > beach flattens and narrows
- Entire shape constantly changes
- > important for survival

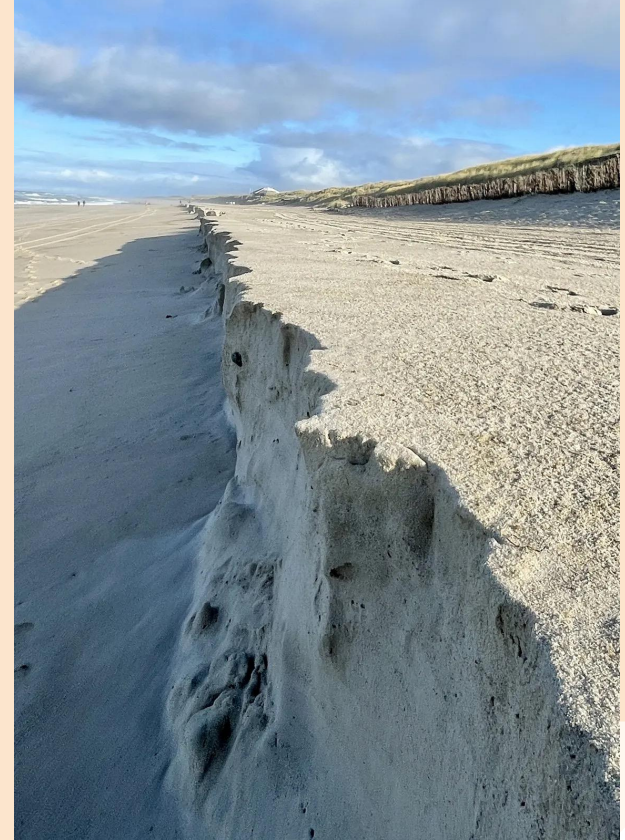


https://hamburg.t-online.de/region/hamburg/id_101308922/sylt-verschwindet-in-der-nordsee-hamburger-forscher-erklaert-die-gefahr.html

Beach

Evidence of recent erosion or deposition

- Dune cliff formation (Abbruchkante)
 - Narrow beach sections
 - Coastal protection measures
-
- + Growing dunes
 - + Expanding tidal flats



Dunes

Why are dunes important for coastal protection?

- natural barriers between sea and inland
- reduce wave and storm surge energy
- reduce coastal erosion
- provide habitats for plants and animals



<https://stroenhof.com/de/lage>

Dunes

How are dunes formed?

- dry beach sand transported inland by **wind**
- **accumulation** behind shells, driftwood etc.
- accumulations grow over time
- **vegetation** stabilized dune with roots

-> availability of these factors controls dune growth

- storm frequency
- sea-level rise
- human influence



<https://www.instagram.com/p/DWiAFztjd5t/>

Dunes

What happens when dunes are damaged during storms?

- during storms wave erode seaward dune side or even entire dune section can collapse
- > reduces coastal protection
- > increased inland flood risk

Can dunes recover naturally after extrem events?

- depends (sediment availability, storm frequency, damage impact, vegetation amount)



https://www.baltrum-online.de/news_artikel.php?id=7563

Coastal protection

Idea

Coastal protection responds to:

- Erosion
- Flooding
- Dune damage
- Risk to settlements or tourist infrastructure

But not the cause!



Main types of protection

Hard protection:

- groynes, seawalls, revetments, dikes
 - Protect locally but can reflect wave energy or shift erosion to nearby areas

Soft protection:

- beach nourishment, dune reinforcement, vegetation planting, sand flooding
- Work more with natural sediment movement, but are temporary and need repeated maintenance



Sand volume budget Sylt:

Mass loss:

$\sim 1.0 - 1.2\text{m}^3$

Accumulation:

$\sim 1.0 - 1.3\text{m}^3$



Trade offs

- Protecting one place can disturb the wider coastal system
 - Complex interactions
- Coasts are connected through waves, tides, and sediment transport -
 - Protection is always a compromise ➡ erosion moves elsewhere
- With warming, sea-level rise increases the baseline for storm surges
- The same storm can cause more erosion or flooding than before



Can a coastline be permanently stabilized?

- Sylt cannot be permanently fixed in place
- Coastal protection can buy time, but society needs to choose what to:
 - Defend
 - Adapt
 - Give up



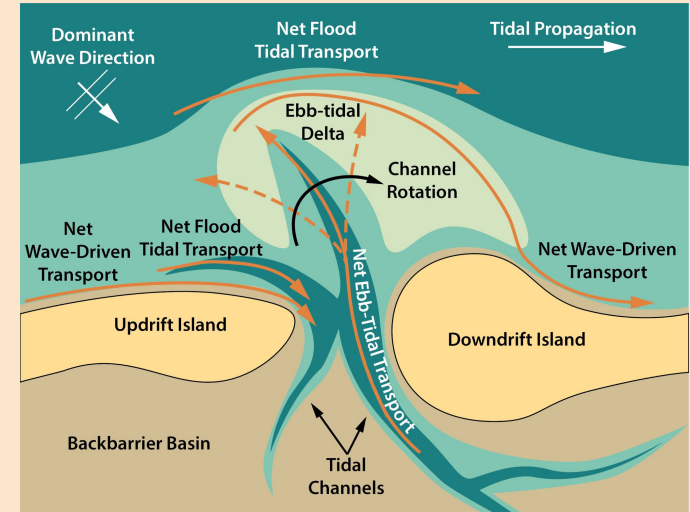
Tidal Flats in the Wadden Sea

- Where do sediments originate?
 - Rivers
 - North Sea
 - Coastal erosion
 - Redistribution & Reworking
- Why do tidal channels form?
 - Concentrated water flow erodes pathways through the sediment
 - channels drain tidal-flats or local areas
 - adapt frequently to changes in currents & sediment distribution



Tidal Flats in the Wadden Sea

- How do tides influence sediment transport?
 - tides transport marine sediment landward/seaward
 - strong tidal currents erode, transport and deposit sediments
 - Balance determines loss or gain



Sediment Pathways on Ebb-Tidal Deltas –
Coastally Curious

Stable and dynamic areas

stable:



Salt marshes



High tidal flats

**Discussion: Why is the
Wadden Sea often
described as a
self-organizing system?**

Dynamic:



sandbanks



Tidal channels

Processes and Timescales

- | | |
|-----------------------------------|-------------------|
| - Waves | hours/days |
| - Storm surges | hours/days |
| - Dune migration | years |
| - Sea-level rise | decades |
| - Ice-sheet response | centuries |
| - Tides | hours |
| - Sediment Accumulation & Erosion | hours/days |

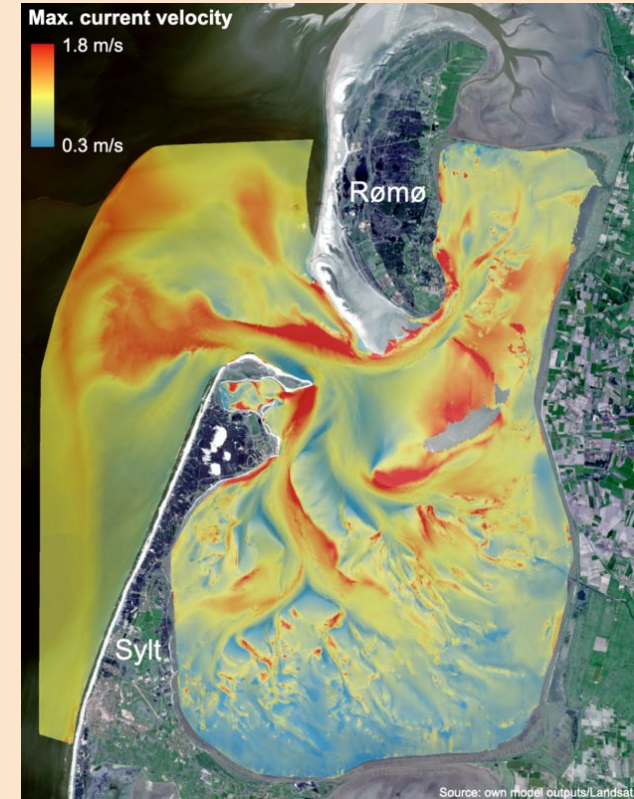
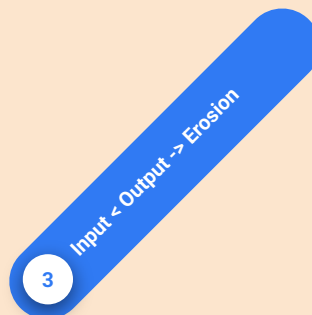
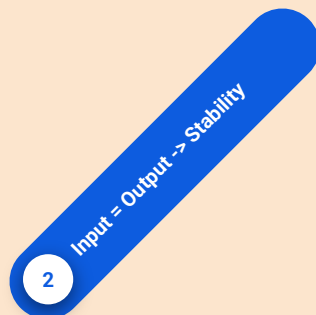
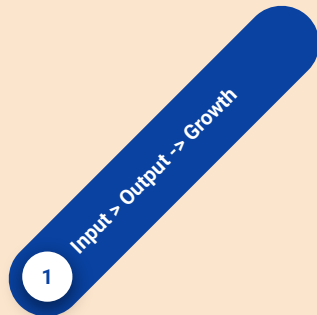
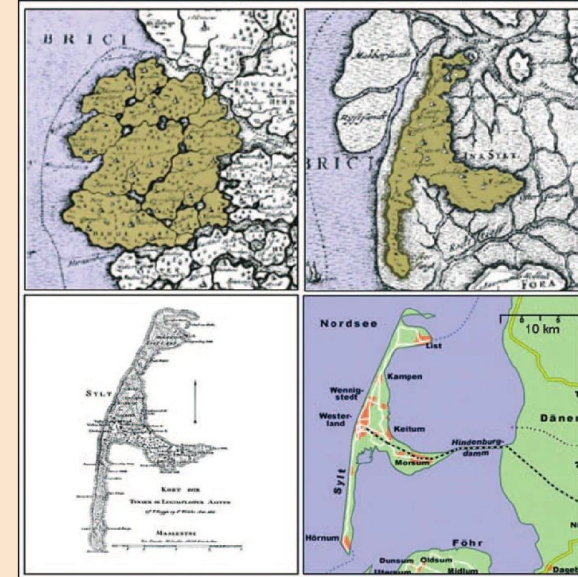


Fig 1: Alfred Wegner Institut

Processes and Timescales

- Storm surges **1362 and 1634 formed the island**
- Dune migration **annual dune migration rate 3.75m**

Fig 1: top left: Sylt before storm surge of 1362, top right: before storm surge in 1634, bottom left: Sylt in 1793



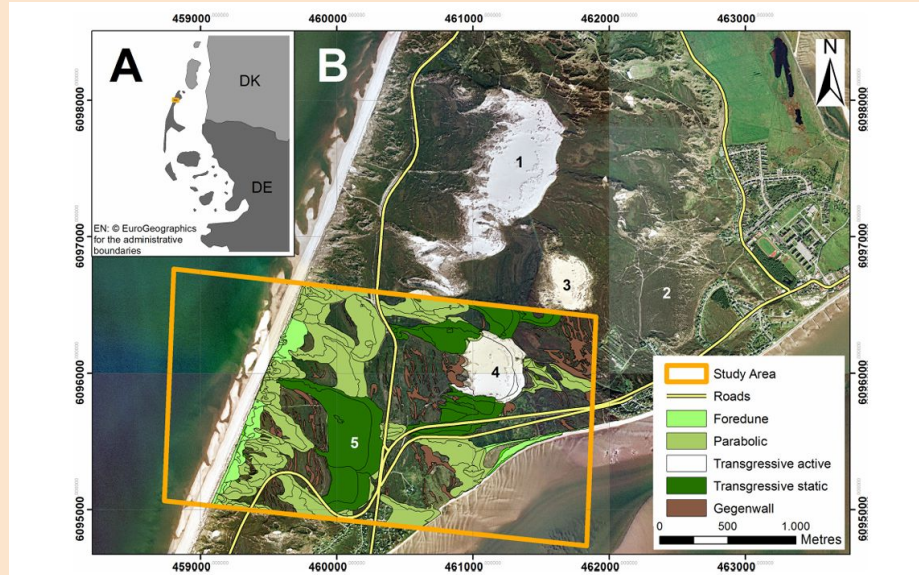
[Development of the island of Sylt; top left: Sylt before the severe... | Download Scientific Diagram](#)

Processes and Timescales

- Storm surges
- Dune migration

1362 and 1634 formed the island
annual dune migration rate 3.75m

Paper:
“Remobilizing
stabilized island
dunes for
keeping up with
sea level rise?”
by Osswald, F.,
Dolch, T.& Reise,
K.



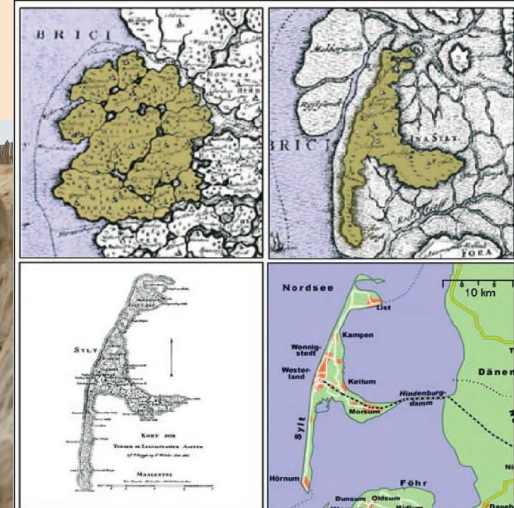
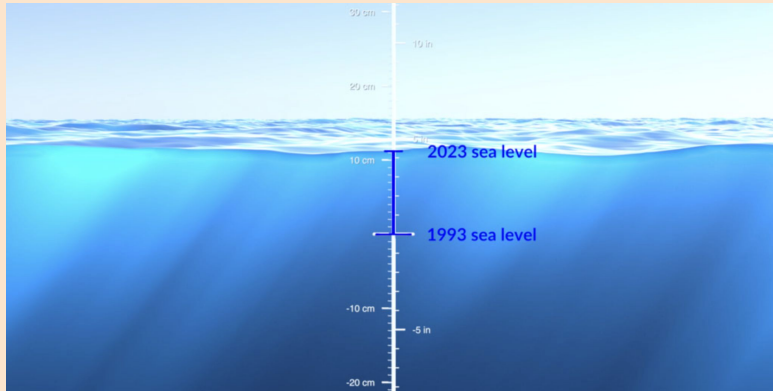
https://media.springernature.com/lw685/springer-static/image/art%3A10.1007%2Fs11852-019-00697-9/MediaObjects/11852_2019_697_Fig2_HTML.png?as=webp

Fig: migration rates calculated by comparing positions of steep white slip sides of migrant dunes meeting dark deflection plain vegetation

Discussion

What changes will you expect in a 2°C warming scenario?

- More erosion, especially on the westcoast between Westerland and List, dunes
- Increased storm surges
- Shift of ecosystems



Exam questions

- Why are tidal channels usually more dynamic than salt marshes?
- What are the main soft & hard coastal protection measures and their trade-offs?
- How can coastal protection conflict with natural coastal dynamics?
- Why is coastal protection a societal choice, not only a technical problem?
- What are the limits of engineering in a dynamic coastal system
- How can barrier islands survive?

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