

Gefördert durch:

Bundesministerium
für Digitales
und Verkehr

aufgrund eines Beschlusses
des Deutschen Bundestages

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Toward a digital twin of the coastal sea

Progress in the Wadden Sea

Data Science Symposium 2025

September 04. 2025

Funding No.: 01F2206-A

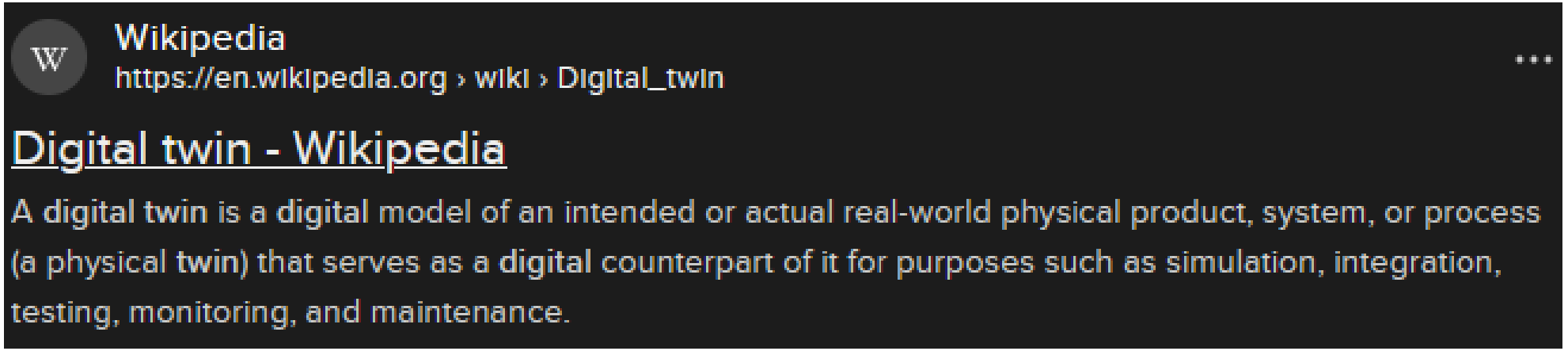
BAW
Federal Waterways Engineering
and Research Institute

mFUND

TrilaWatt

Outer Weser estuary (Bremerhaven) Source: BAW

Let’s start with some definitions



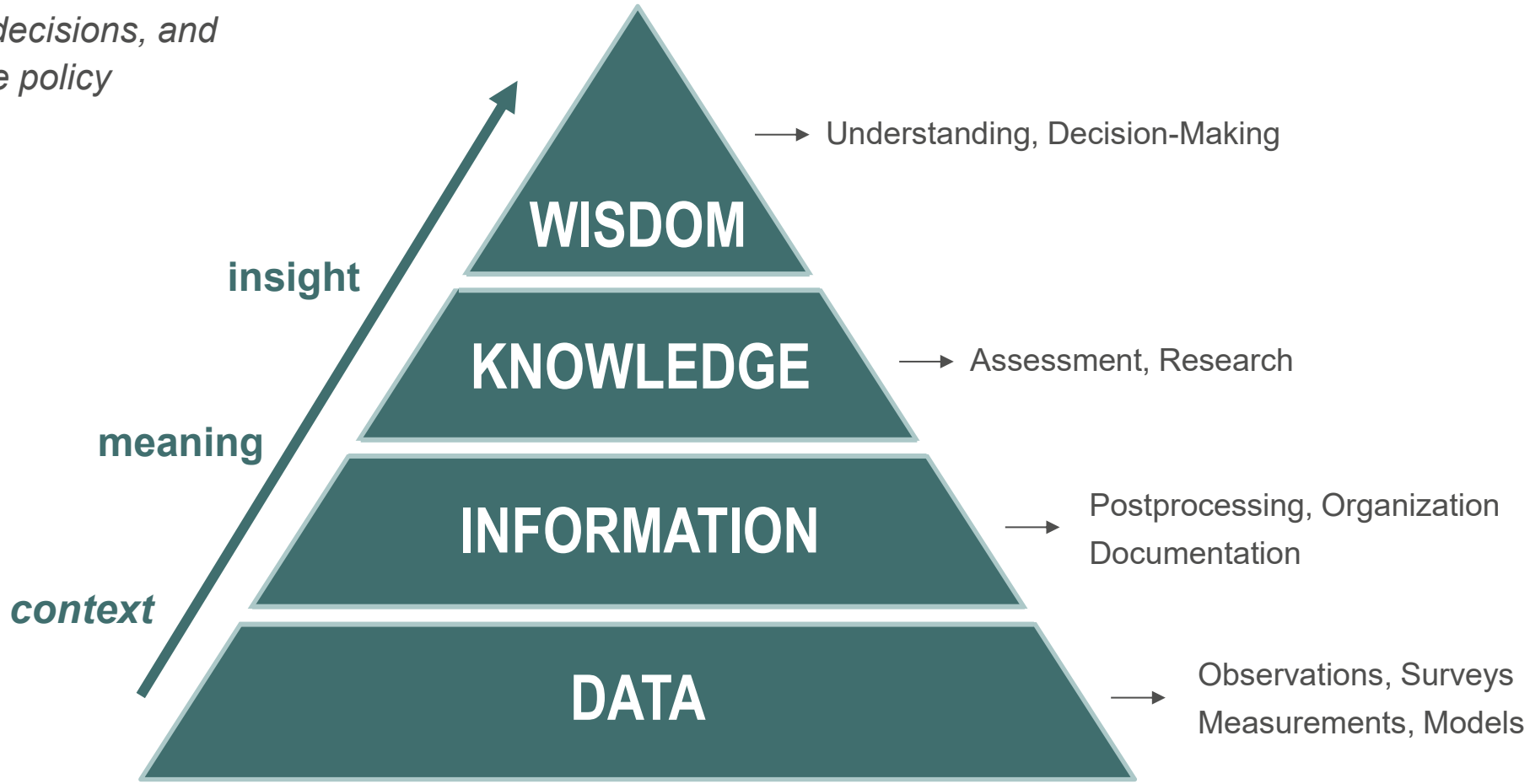
- **The scientific version:**
  - The concept of a digital twin of Earth envisages the convergence of Big Earth Data with physics-based models in an interactive computational framework that enables monitoring and prediction of environmental and social perturbations for use in sustainable governance. (Li et al., 2023)
  - The term 'digital twin‘ […] specifically refers to the comprehensive utilization of physical models, sensors, historical operational data, and additional relevant information to simulate multidisciplinary and multiscale processes. The goal is to create a virtual representation that can mirror the entire lifecycle of its corresponding physical entity. (Glaessgen and Stargel, 2012)

Glaessgel and Stargel (2012), Li et al. (2023)

Why do we need digital twins?



Data is the foundation for research, decisions, and sustainable policy



The data-information-knowledge-wisdom (DIKW) concept to collect, organize, interpret data to achieve wisdom for sustainable decisions

Criteria for a digital twin in the Earth Sciences following Li et al. (2023)

I

Real-time connection

e.g., long-term data, operational modeling or short-term prediction

II

Bi-directionality

e.g., data-exploration, analysis toolkits

III

Interactivity

e.g., interaction with users, interactive data-exploration

Bauer et al. (2021), Li et al. (2023)

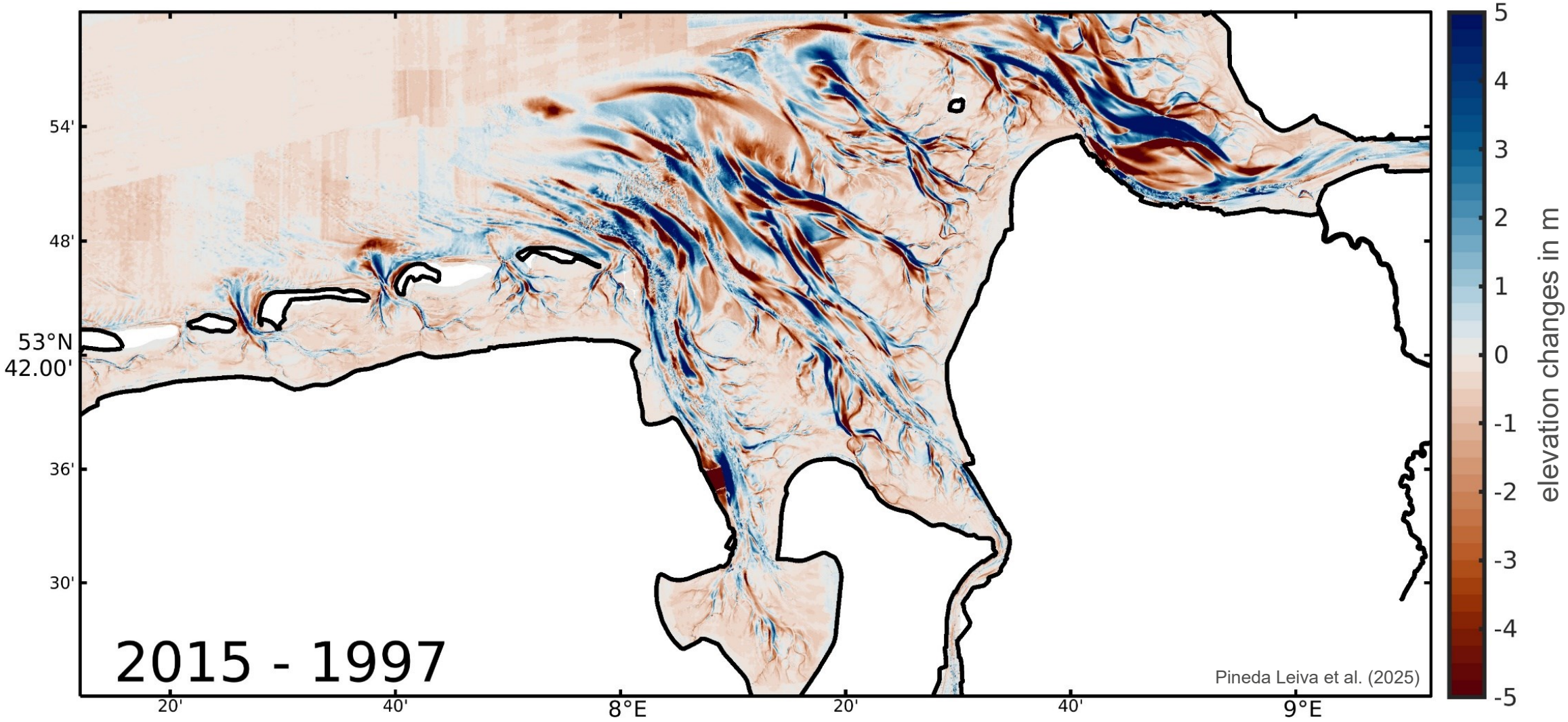
Short version



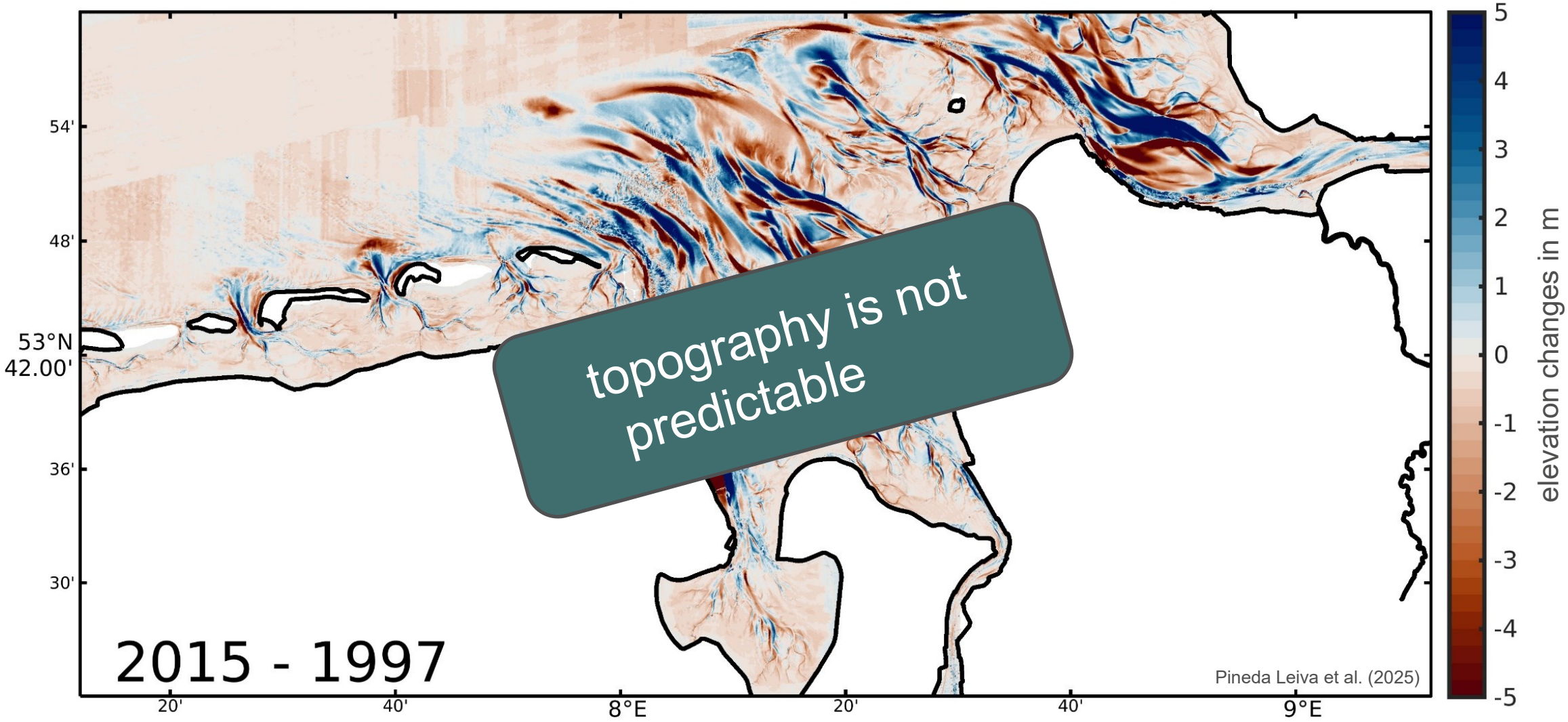
Short version



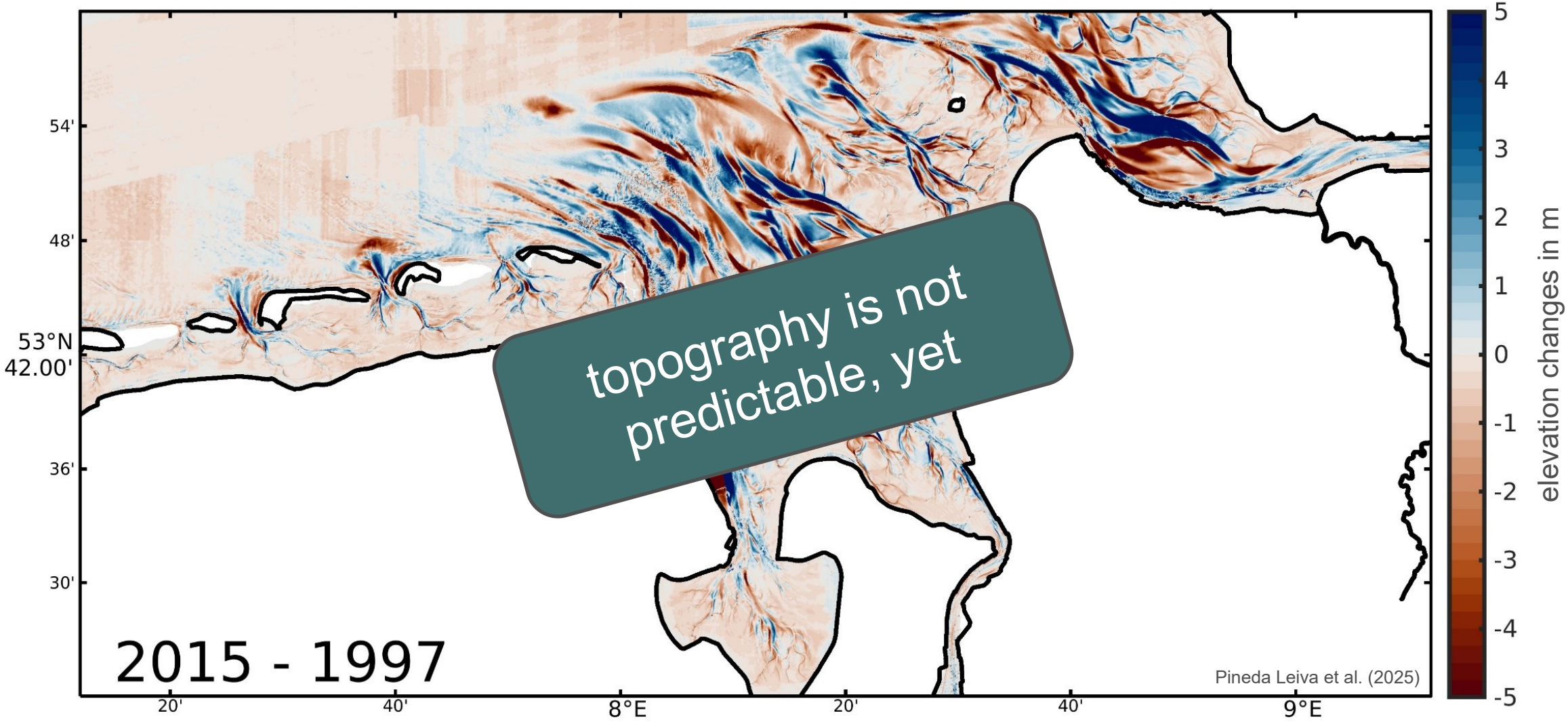
Ocean vs. Coastal ocean: The dealbreaker



Ocean vs. Coastal ocean: The dealbreaker



Ocean vs. Coastal ocean: The dealbreaker



Criteria for a digital twin in the Earth Sciences following Li et al. (2023)

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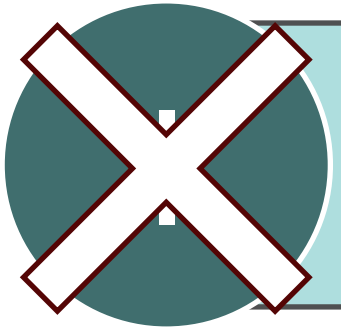

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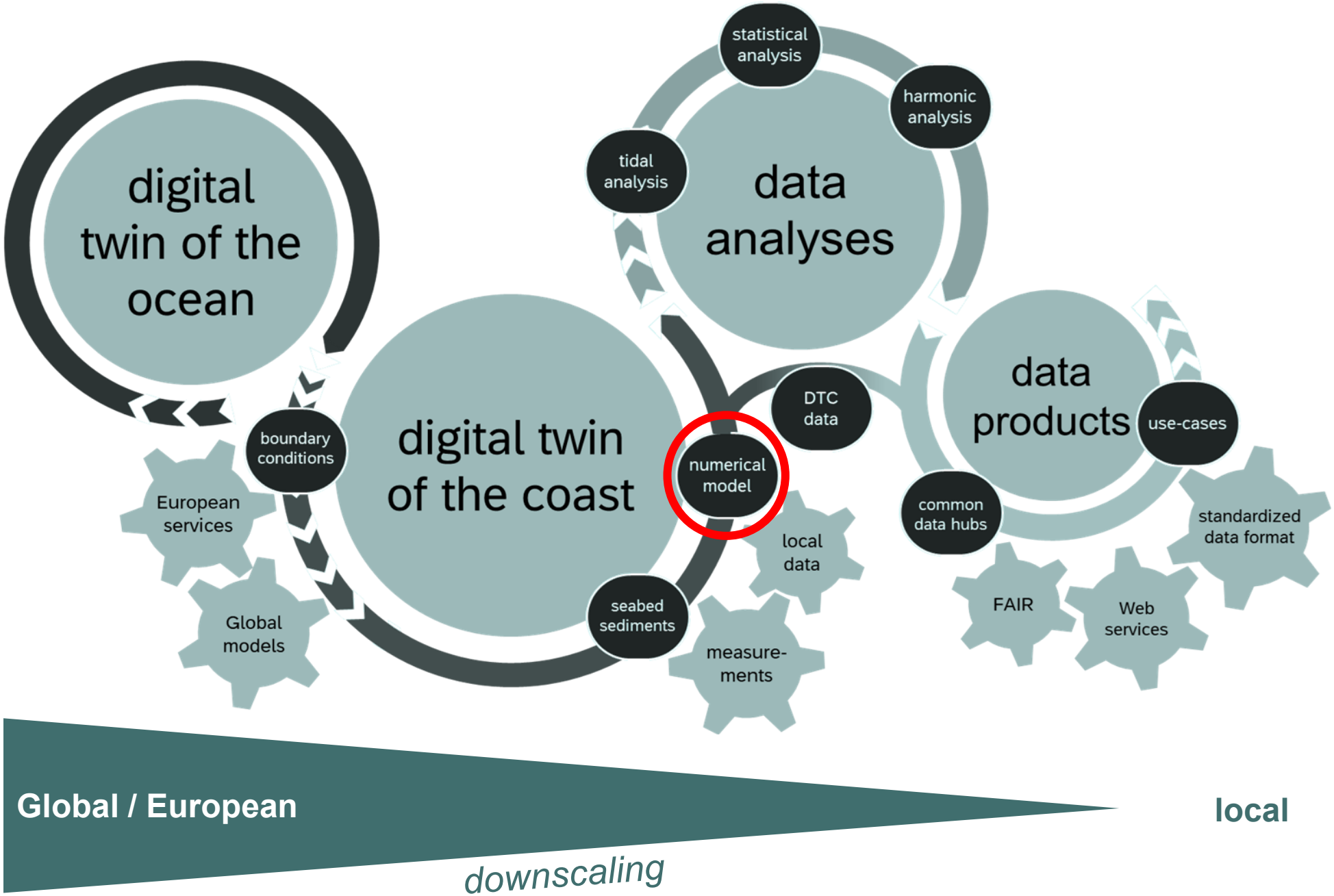


DTC: digital twin of the coast

The digital twin of the Wadden Sea

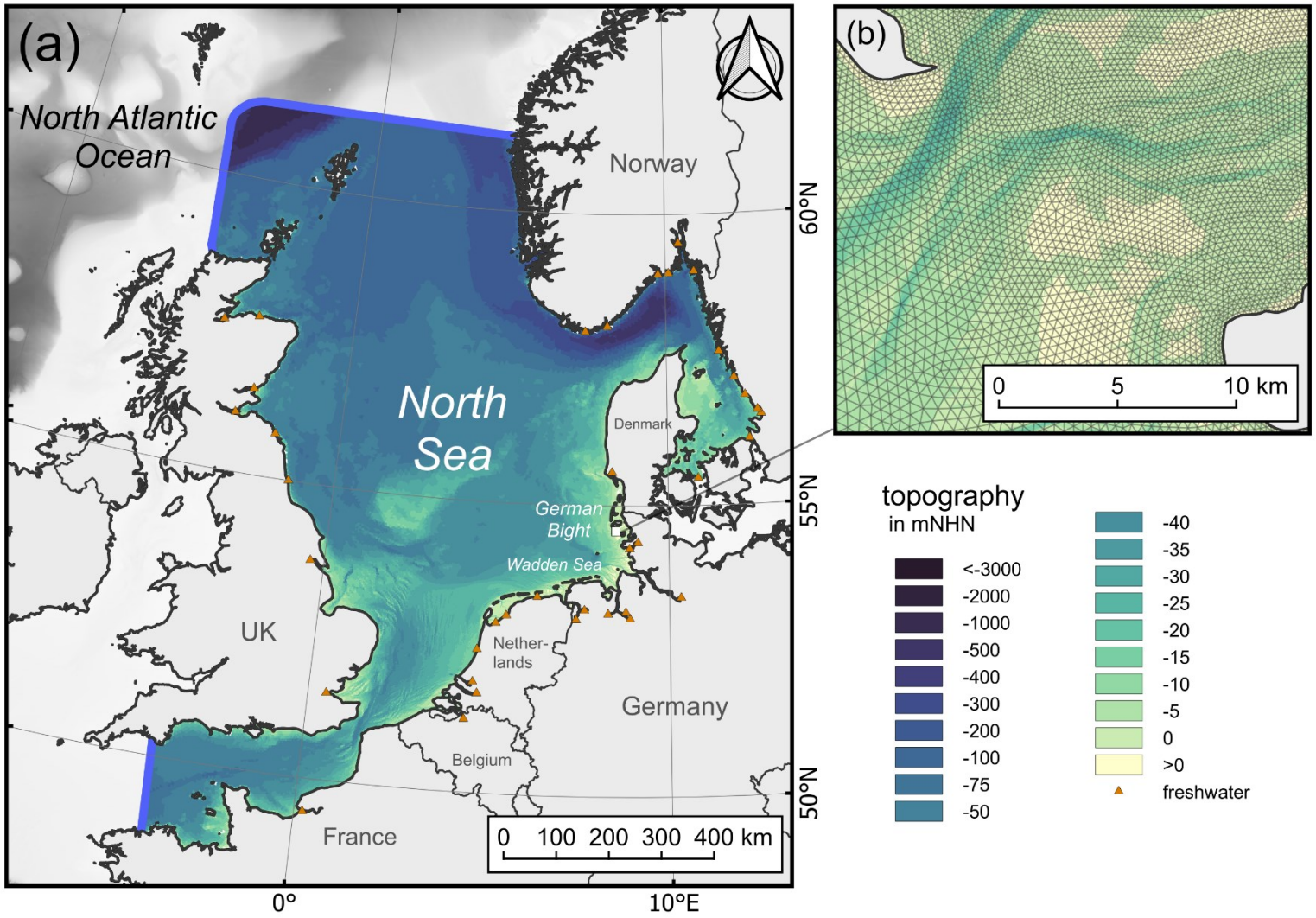


Illustration of the digital twin of the Wadden Sea, Lepper et al (2025, in review)

- **External interface**
  - Global tide model
  - Copernicus Marine Service
  - ICON-EU (Meteorology)
  - Observations (e.g., discharge)
  - Annual topography updates in the Wadden Sea + EMODnet

- **Processes**
  - Tidal dynamics
  - Salinity and sea water temperature
  - Sediment transport
  - Waves
  - Groins, barrages, and training walls
  - Sediment sources to the Wadden Sea

Outcome of our current implementation

- Topography (2015 – 2022) with additional data covering 1996 – 2014
- Intertidal topography (2015 – 2021)
- Surface sediments (2015 – 2022)
- Hydrodynamic analyses (2015 – 2022)
- Tidal dynamics, transport and waves in 20-minute intervals (2015 – 2022)

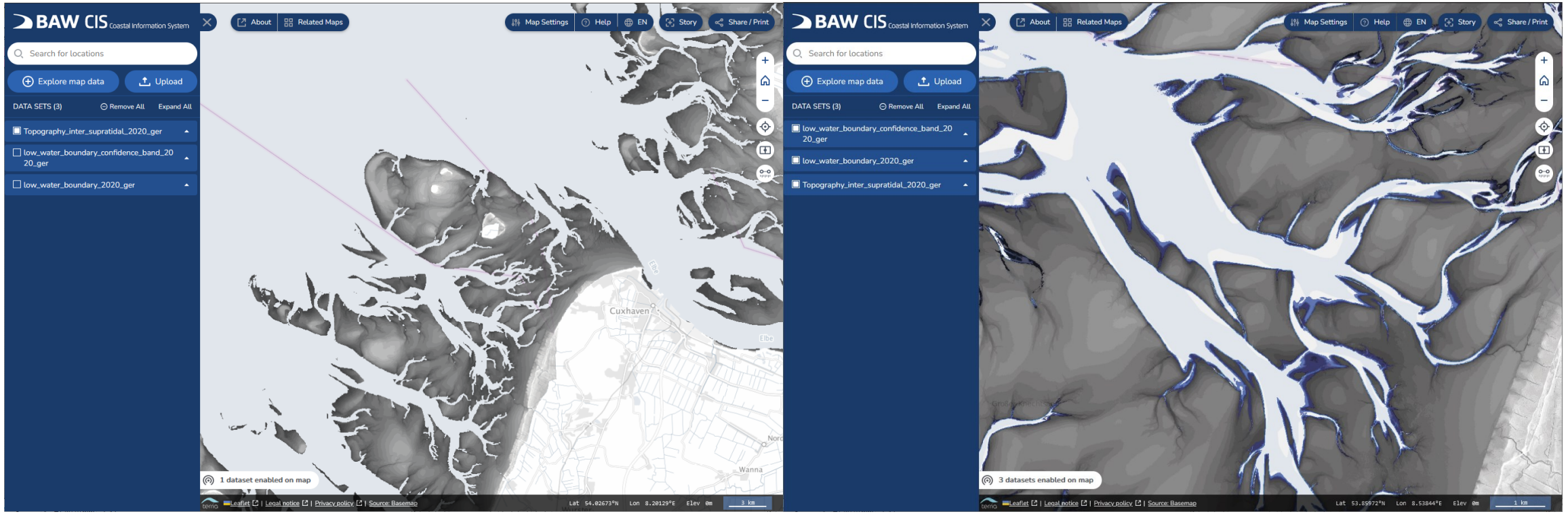
- **In summary:**
  - 8 Year coverage
  - Full Wadden Sea coverage
  - More than 2,000 files
  - Roughly 3 TB in total data size

Data publication overview

- Topography (2015 – 2022) with additional data covering 1996 – 2014
- **Intertidal topography (2015 – 2021)**
- Surface sediments (2015 – 2022)
- Hydrodynamic analyses (2015 – 2022)
- **Tidal dynamics, transport and waves in 20-minute intervals (2015 – 2022)**

TrilaWatt: Intertidal topography (2015 – 2021)

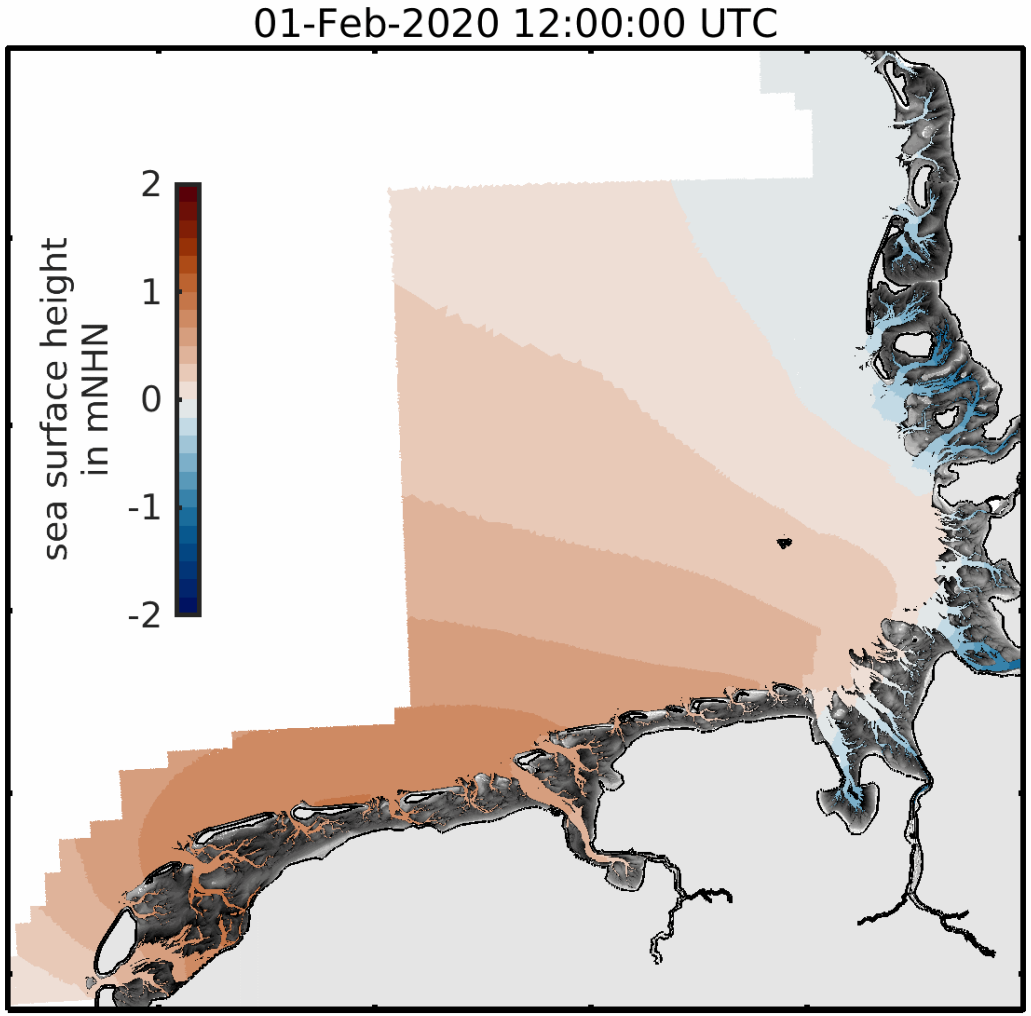
- **Data products (2015 – 2021 for Germany and the Netherlands)**
  - Topography of (only) the intertidal zone
  - Tidal high water and tidal low water lines + their area of confidence
  - https://doi.org/10.48437/5a882d-b3a571 (Lepper et al., 2025)



TrilaWatt: Tidal dynamics, transport and waves (2015 – 2022)

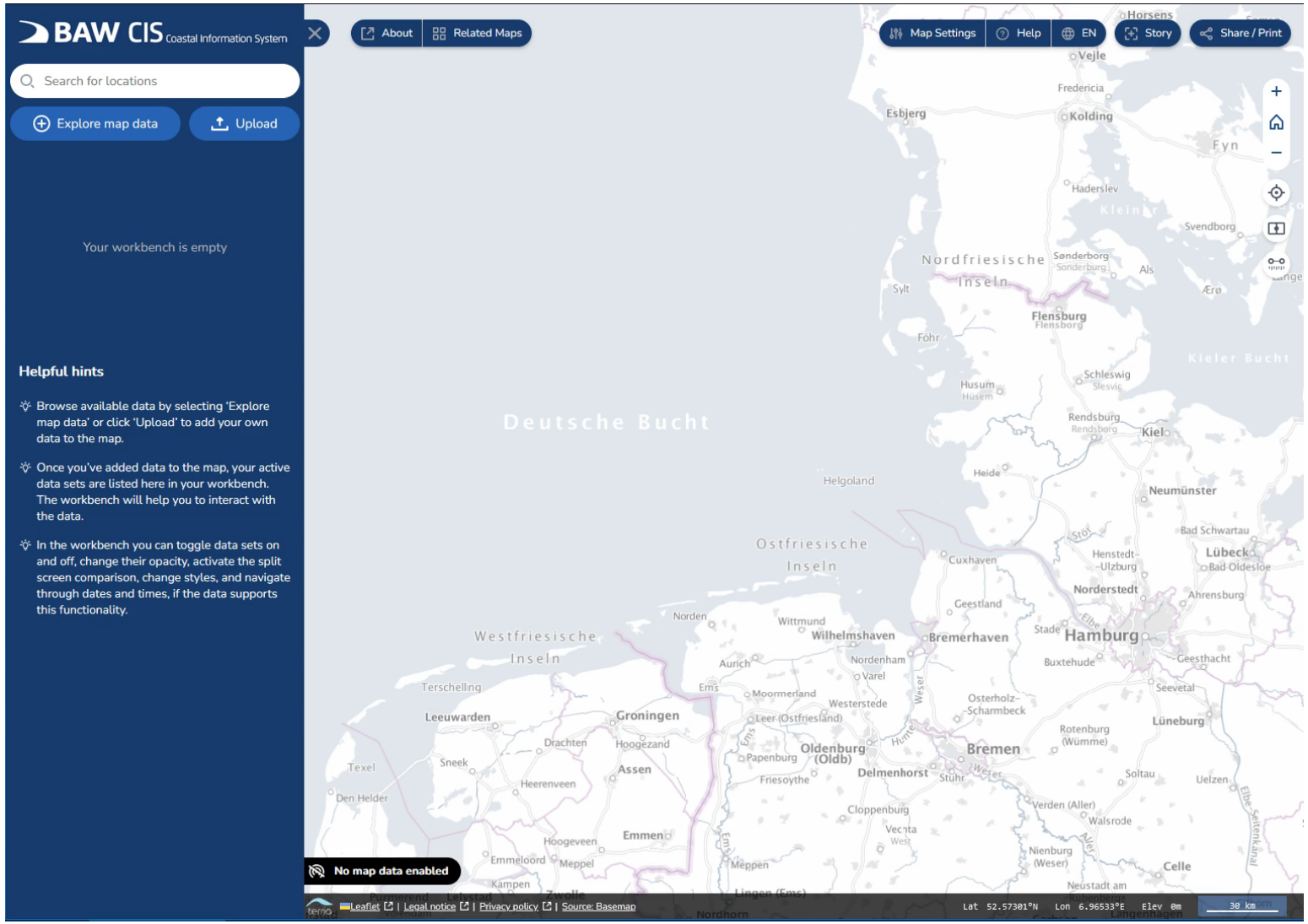
- Hydrographic parameters at all times
  - Sea surface elevations
  - Current velocity
  - Sea water salinity
  - Sea water temperature
  - Suspended sediment transport
  - Bed shear stress
  - Waves

- 20 minute intervals on 500 m grids → 2.3 TB
- https://doi.org/10.48437/7ca5ef-2e1287



Sea surface elevation from TrilaWatt data in the year 2020 (Lepper et al., 2025)

Interactive data viewer and download



- BAW Coastal information system
  - *german: Küstenportal*
- BAW data repository
  - *german: Datenrepository*

← *Interactive data viewer*

Summary and outlook

- **Take-Home Messages**

  (1) Major steps to a digital twin of the Wadden Sea were taken

  → A full digital twin of the Wadden Sea is achievable and could be operational in a few years.

  (2) We published a full hydrographic survey of the Wadden Sea from 2015 to 2022

  → First shared data-base for all Wadden Sea stakeholders

  (3) All data are open-access and can be cited

  → No restrictions for applications

- **Outlook**

  - TrilaWatt officially ended on 30th April 2025 → for now, we are working on new funding
  - TrilaWatt architecture has moved to a permanent location at BAW → Research and staff as the critical path to more data
  - The need for a digital twin of the Wadden Sea remains in the Wadden Sea community

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TrilaWatt

Funded by:
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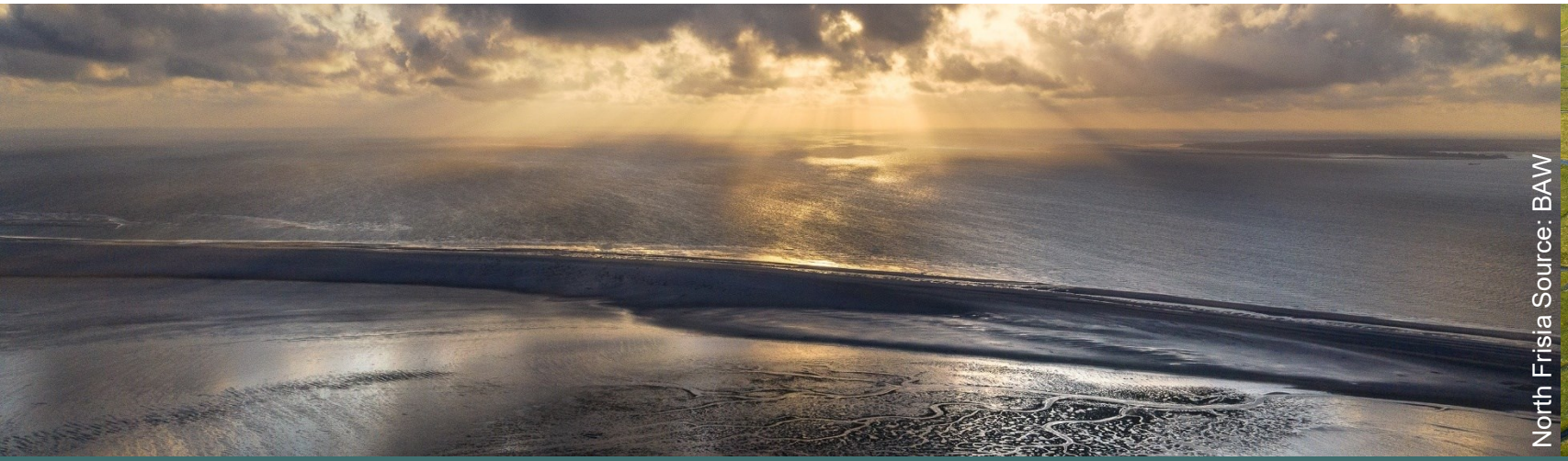


North Frisia Source: BAW



Hallig Langeness Source: BAW

Visit the coastal information system

Or write a mail to daten-k@baw.de

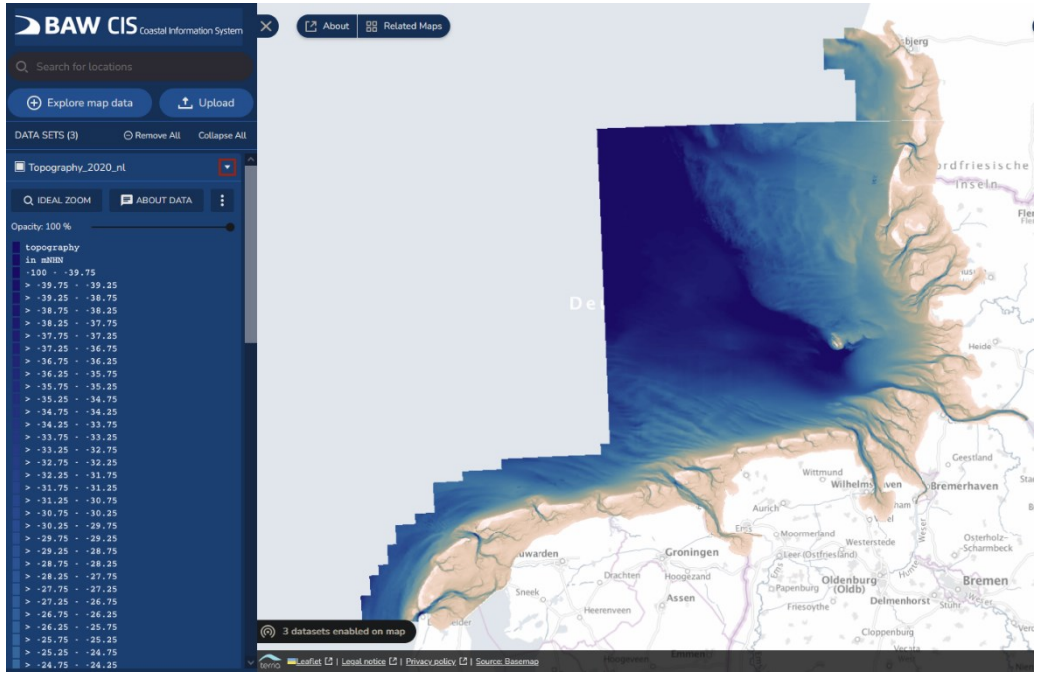
mFUND

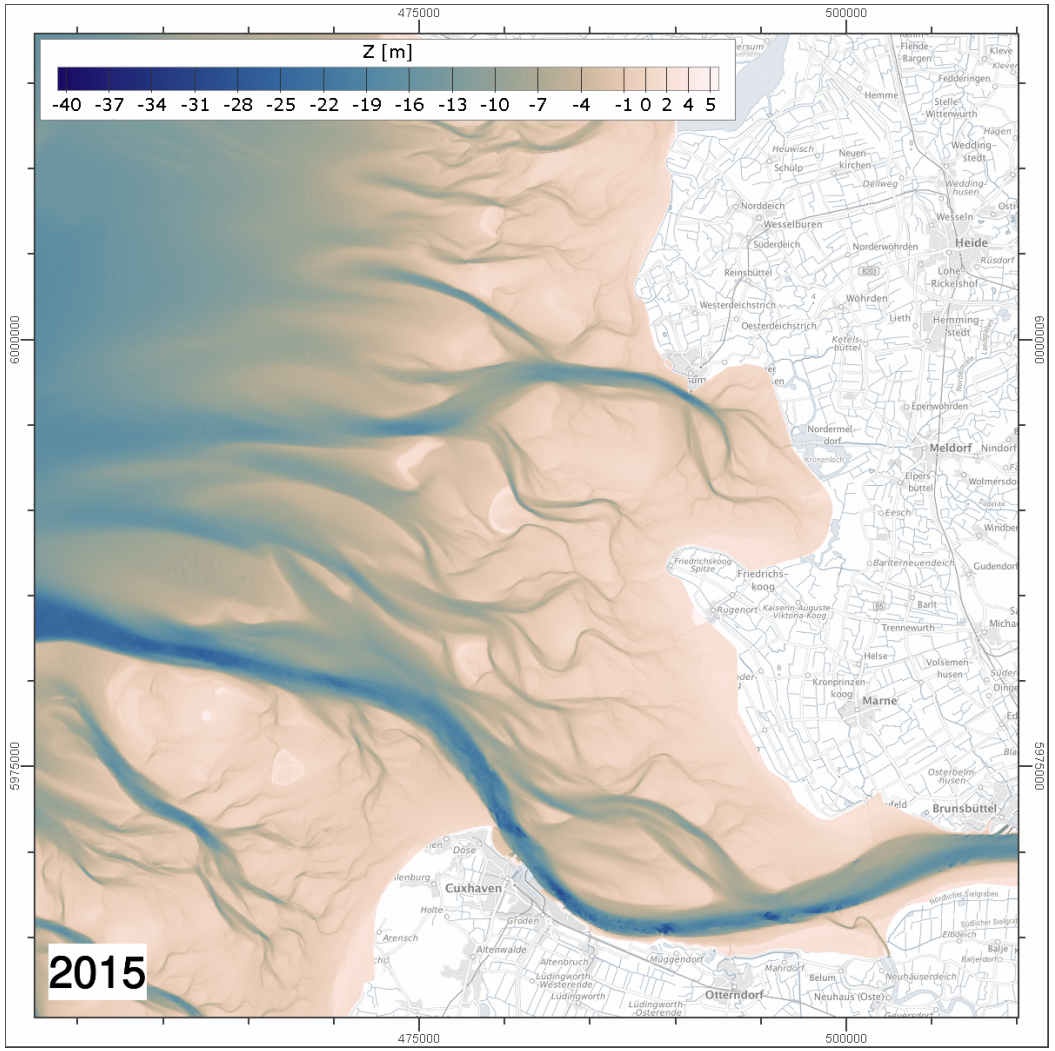
BAW
Federal Waterways Engineering and Research Institute

https://baw.de

TrilaWatt: Topographie (2015 – 2022)

- **Data product: Topography**
  - Full coverage for Germany and the Netherlands
  - One year for Denmark
  - 10m resolution
  - https://doi.org/10.48437/366eab-3640c8





Animation of the topography based on TrilaWatt Topographies (Milbradt & Pineda, 2025)