Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

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AI-emulators for extreme storm-surges

Operational forecasting, flood risk and climate change

RWS AI impulse programme

Martin Verlaan and Henk van den Brink

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Outline

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- Generate training data with DCSM
- GNN based models

KNMI

- SEAS5 for extreme storms
- Training for extreme storm-surges

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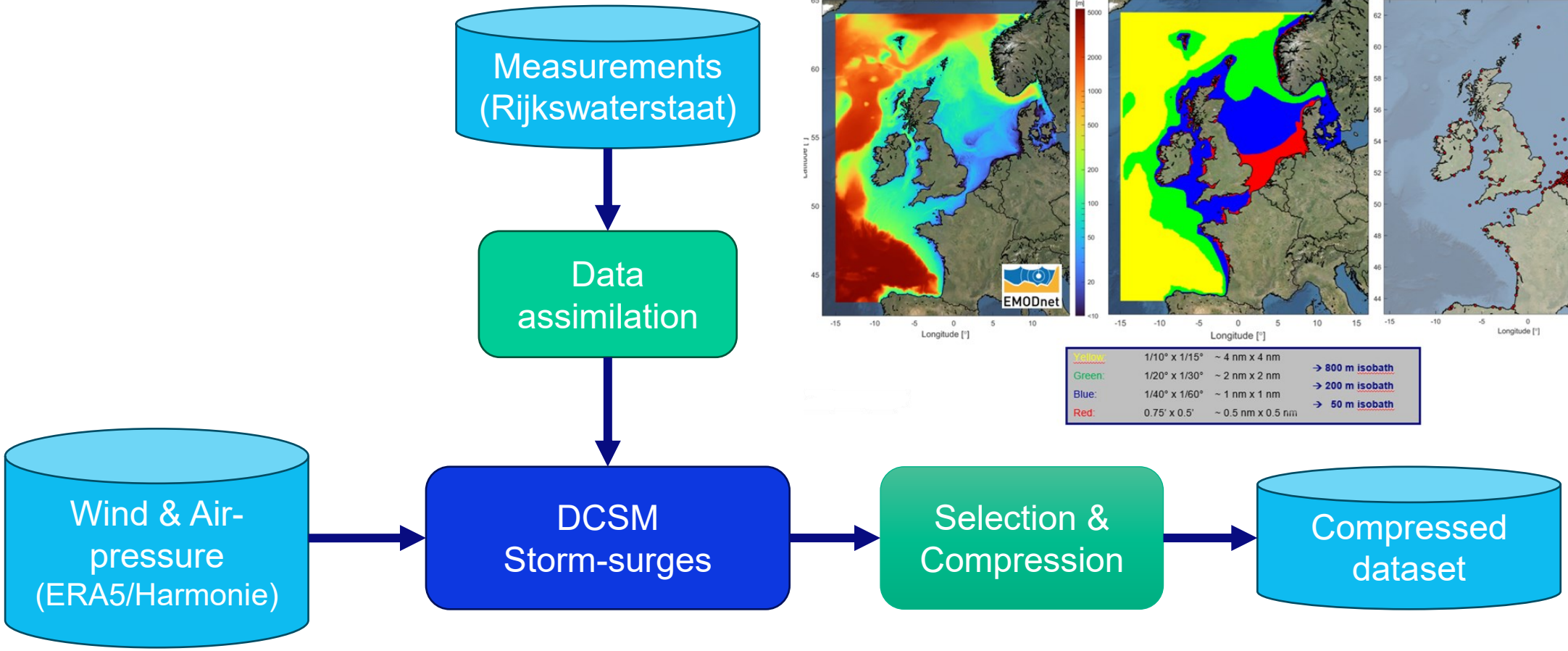
- Generate training data with DCSM
- GNN based models

Towards a reanalysis for waterlevel and currents in the North Sea



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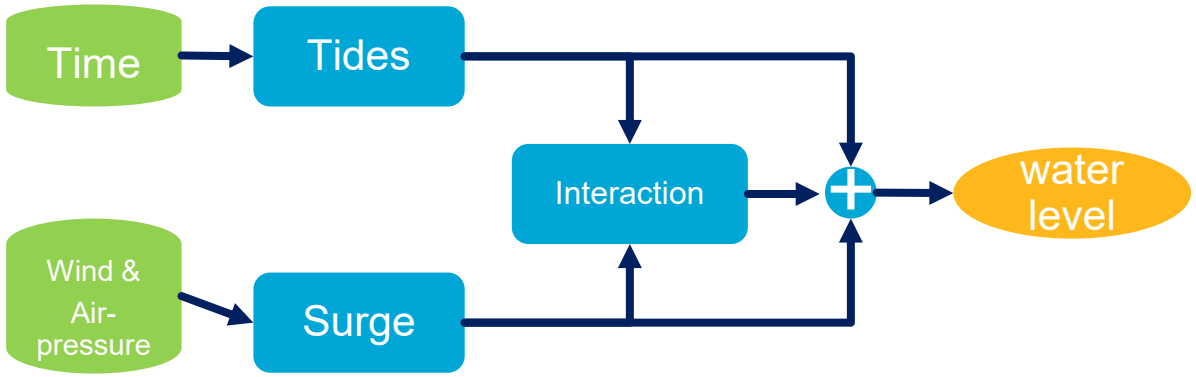
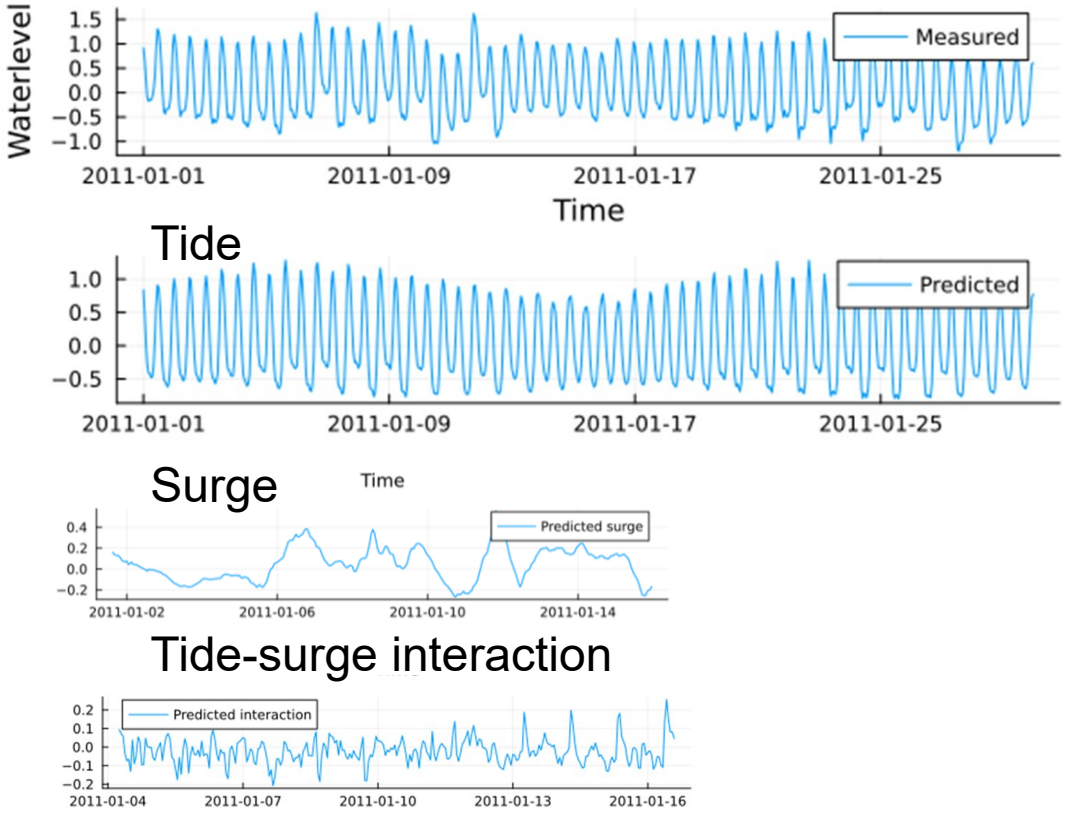
Pilot project North Sea



Station	Signal RMSE	>Tide	>Surge	>Interaction
Vlissingen	132.8	24.0	14.1	11.9
Hoek v Holland	67.4	23.4	11.9	9.8
Den Helder	55.6	24.9	10.4	8.7
Harlingen	70.7	31.6	13.5	10.2
Delfzijl	104.7	31.1	15.3	12.3

Location: Hoek van Holland



Dataset:
- 317 waterlevel time-series 1980-2013
- 2.8Gb compressed 0.9Gb
- Served on S3/Minio

- Training 2008, 2009 and 2010
- Test 2011

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AI for the North Sea modelling

- **Moonshot project:**
- Develop a Graph Neural Networks (**GNN**) based model for
- the storm surge forecasting.
- **AI technology:**
  - Use the MeshGraphNets framework (by Google DeepMind) via GNN.
  - Apply the Julia package “MeshGraphNets.jl” to train a GNN model.
  - Training data is obtained by numerical models.
  - Train on GPUs.

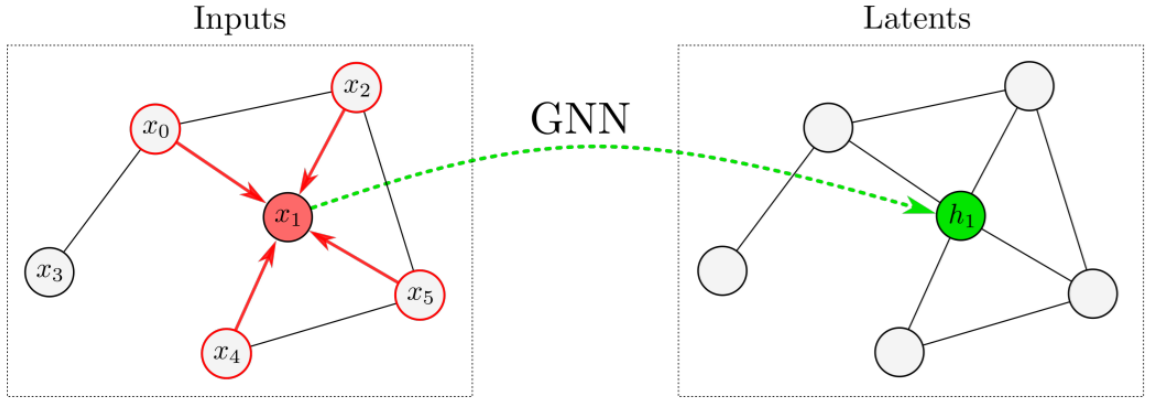
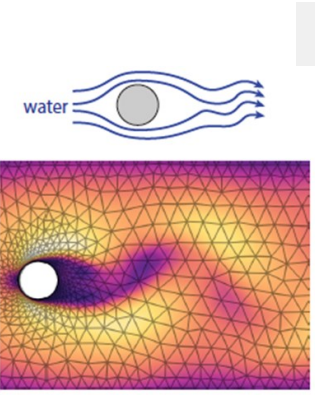


Figure: Key idea of GNN.

Proof of Concept (Finished)

Applied research (Ongoing)



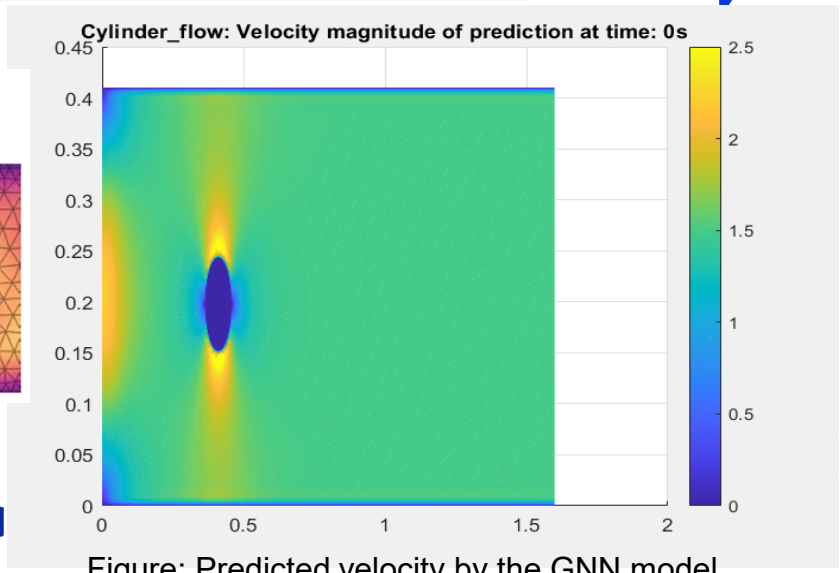


Figure: Predicted velocity by the GNN model

1. Small study case:
- Lake (Delft3D FM)
- To gain experience in, e.g the amount of training data, necessary features on nodes, etc.

2. North Sea (DCSM-FM)

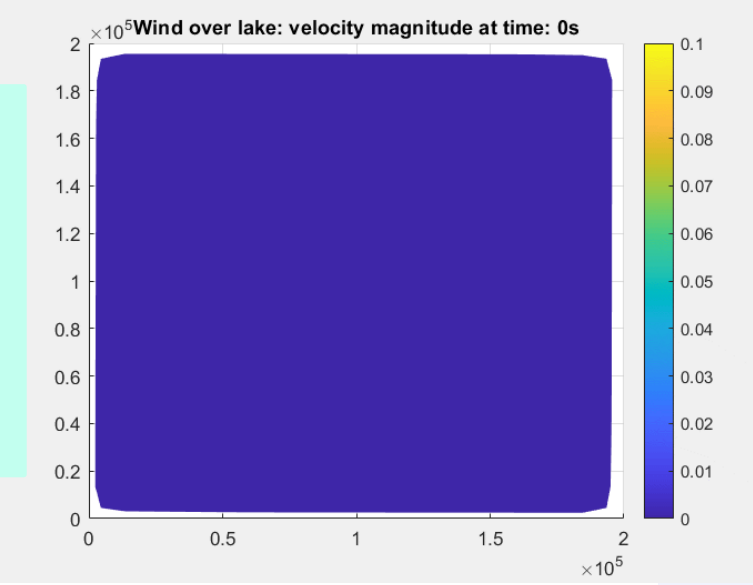
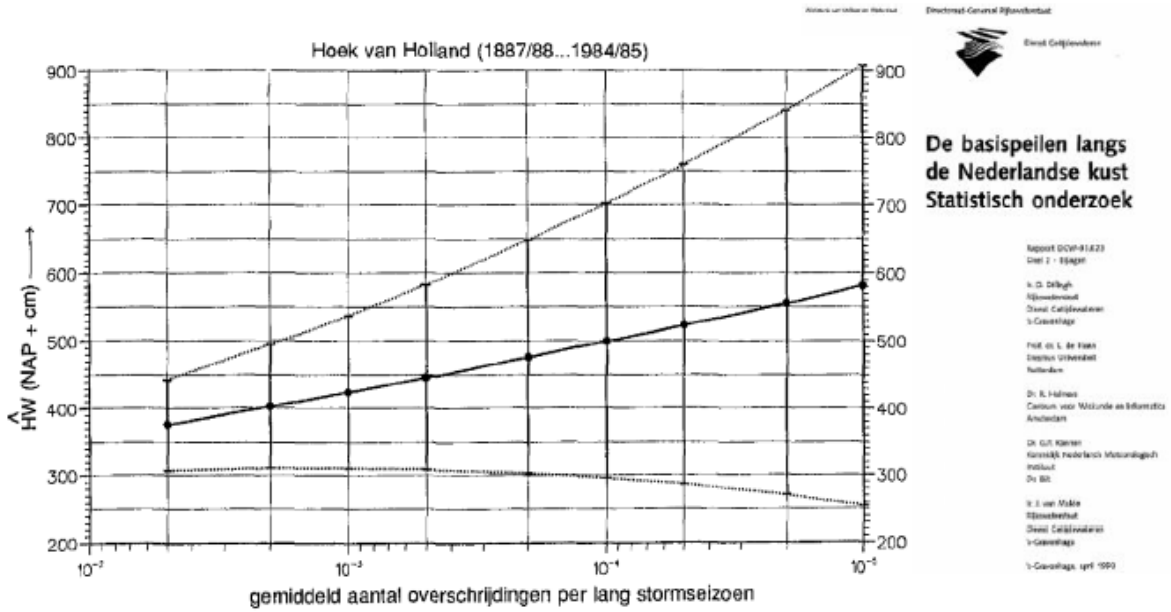


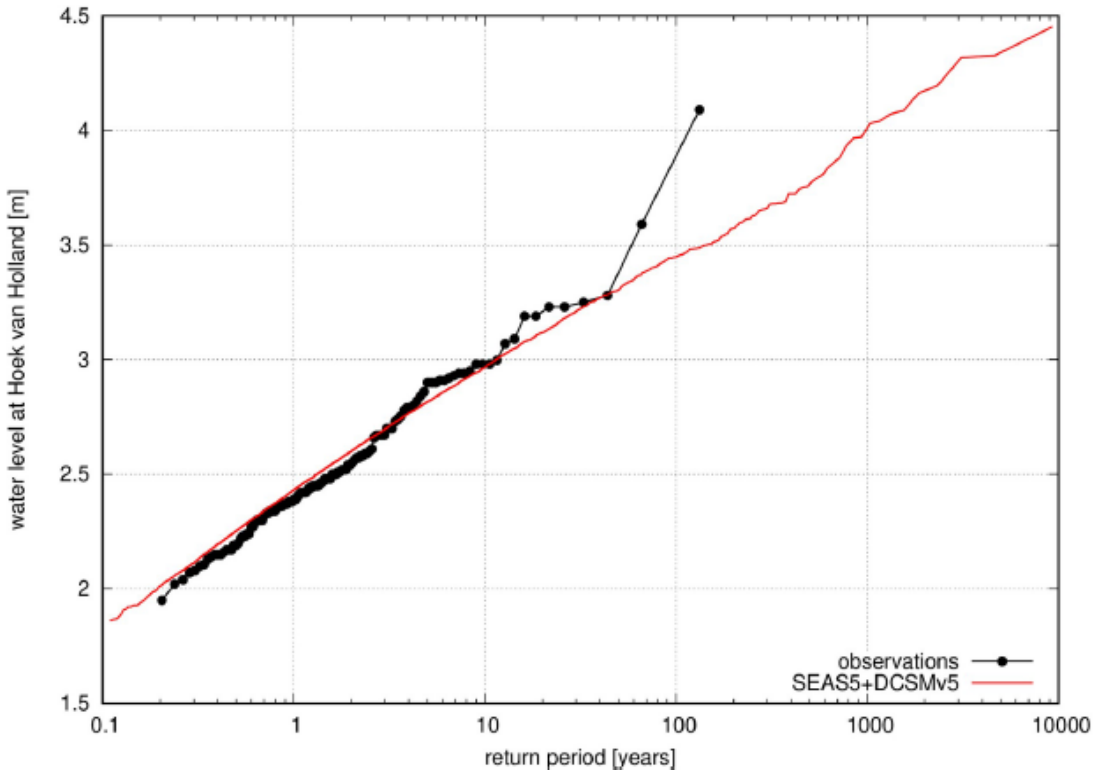
Figure: Target velocities to be predicted by the GNN model

KNMI
- SEAS5 for extreme storms
- Training for extreme storm-surges

"*What is the normative storm for dike design?*"

- Needed
  - once-in-10-million-years water level
- Historical approach
  - extrapolate from 150 years of observations
- Current approach
  - extrapolate from 8500 years of model data
  - Seasonal forecasts from **SEAS5** (ECMWF)
  - Water levels from **WAQUA**





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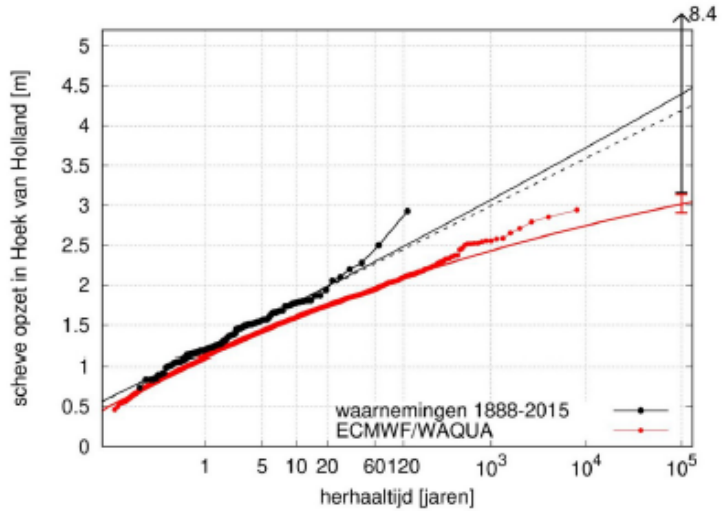
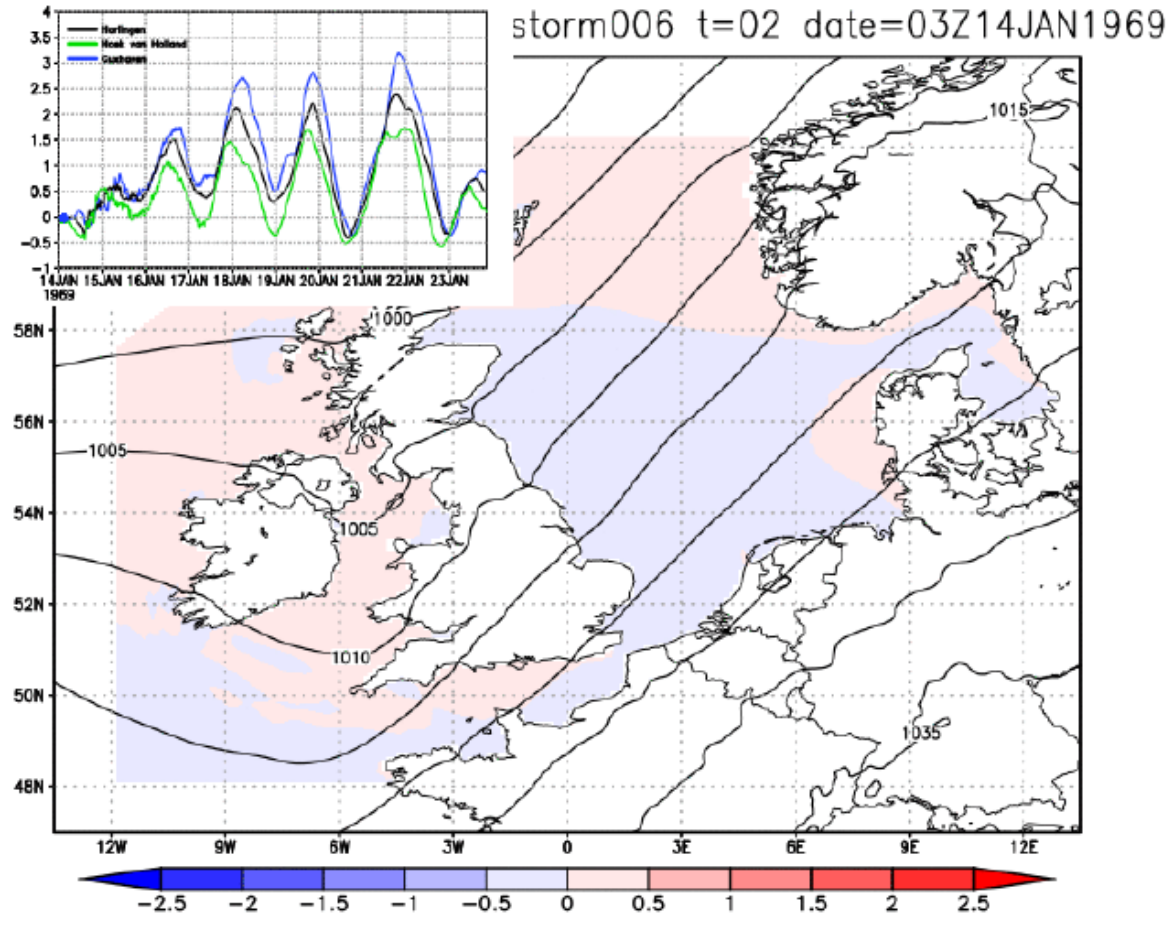
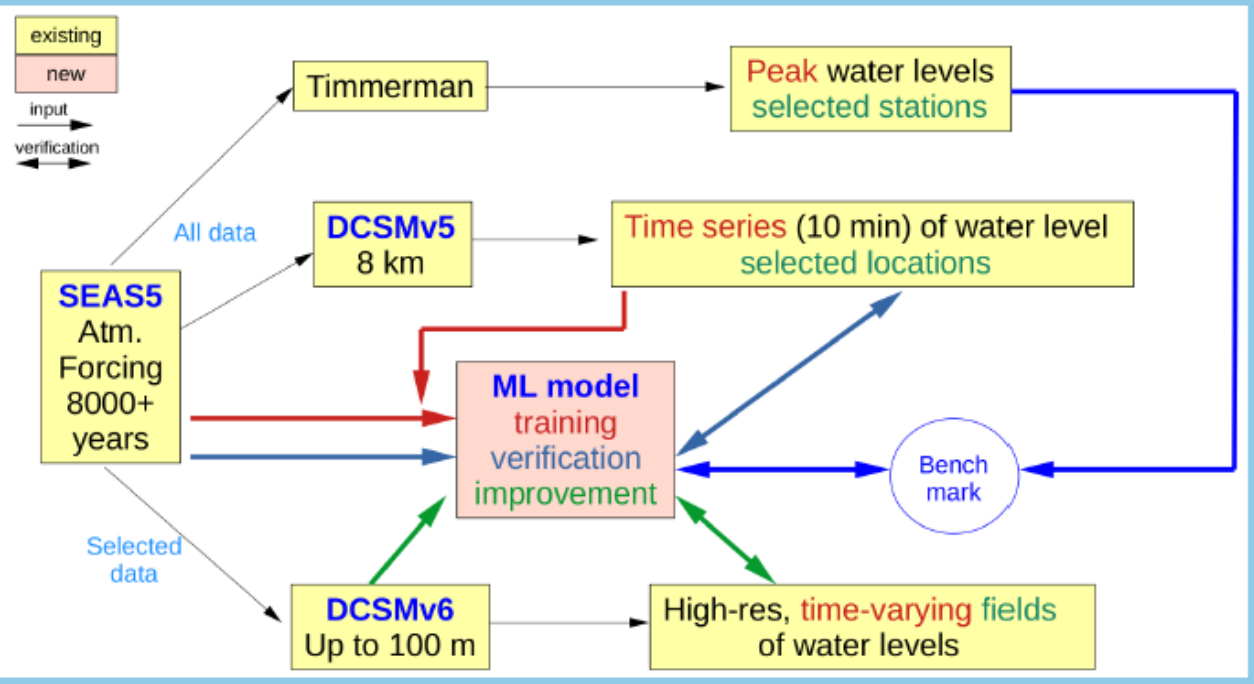
Next innovation

- Use *Machine Learning* to emulate the downscaling and storm surge generation model chain
- Start with reproducing the current WAQUA results using a *state-of-the-art vision transformer neural network*
- Refine model using transfer learning, based on a high-resolution dataset
- Special attention to extremes

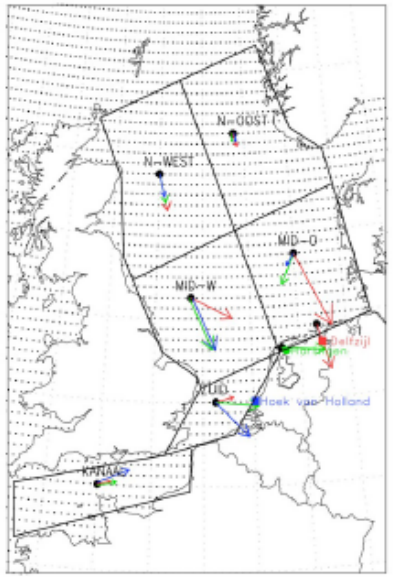


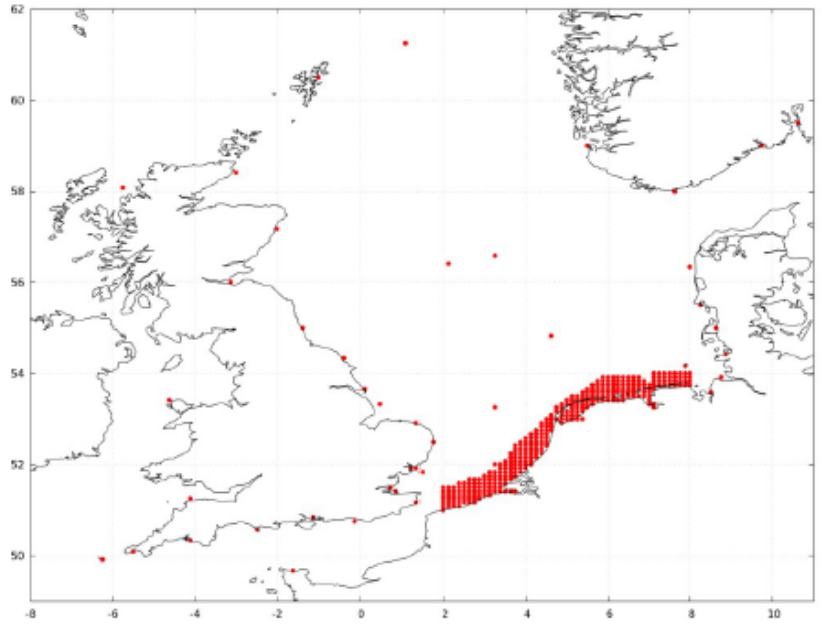


Approach

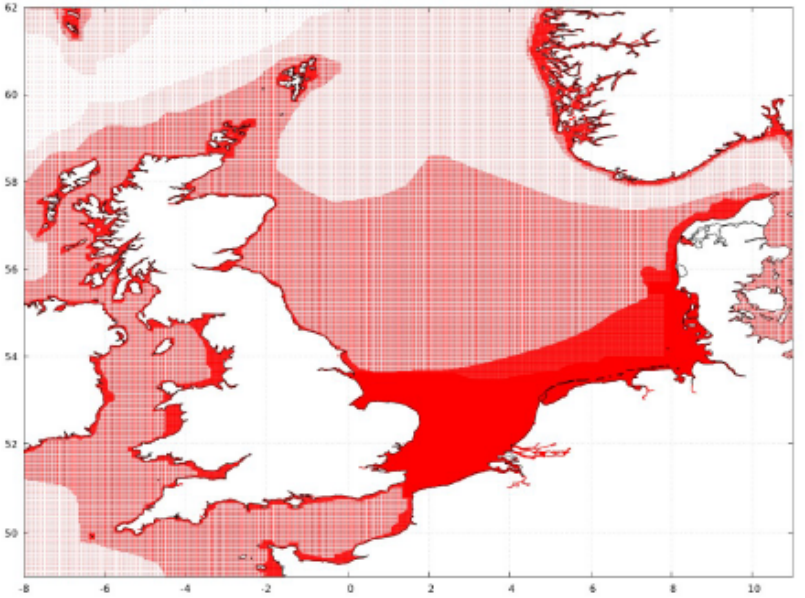


1. design and train a model to predict DCSMv5 water levels derived from the full 8000+ year of SEAS5 data
   - Use Timmerman model as benchmark for the peaks
2. Refine using *transfer learning* based on DCMSv6
   - Subset of 250 extreme surge events
3. Optimize between peak forecasts versus performance throughout the cycle





(a) DCSMv5



(b) DCSMv6

Anticipated outcomes:

- Improved prediction of extreme water levels along Dutch coast
  - very relevant for society
    - EWS
    - Dike design
- Increased knowlege about ML for *extremes*
- Applicable to *climate scenario's:*
  - downscaling from global climate models
- Applicable to other variables:
  - Waves
  - Temperature
- Strengthens cooperation (e.g. Rijkswaterstaat)

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Thanks for your attention.
Questions?

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