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# Developing data-driven ocean models for the Norwegian coast and fjords

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# Operational oceanography @ MET Norway

- ➔ Ocean & ice forecasting
  - Multiple domains
  - High-resolution
  - Ensembles
  - …
- ➔ Observational networks
  - Data assimilation
- ➔ Downstream models & use cases

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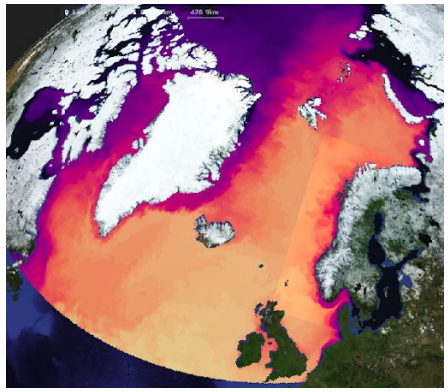
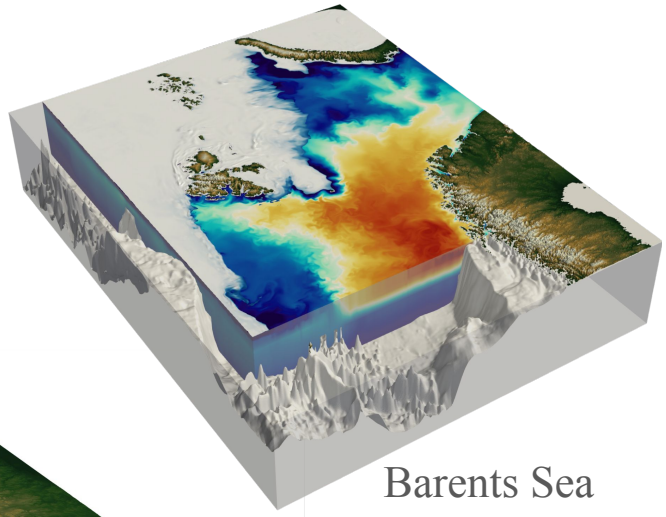
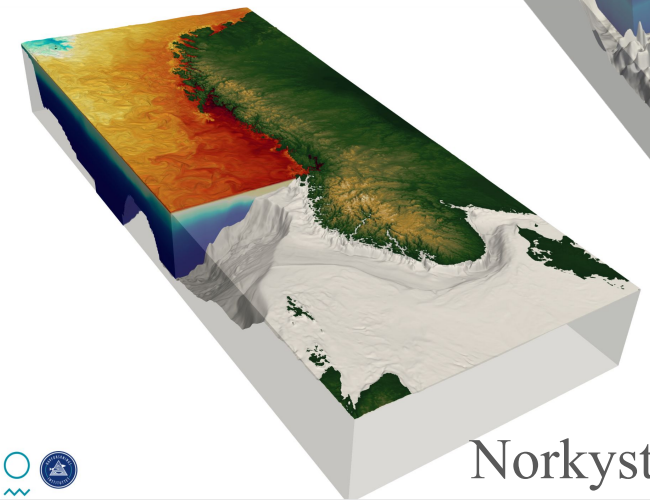


Pan-Arctic,
Topaz



Barents Sea
(ensembles)



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# Operational oceanography

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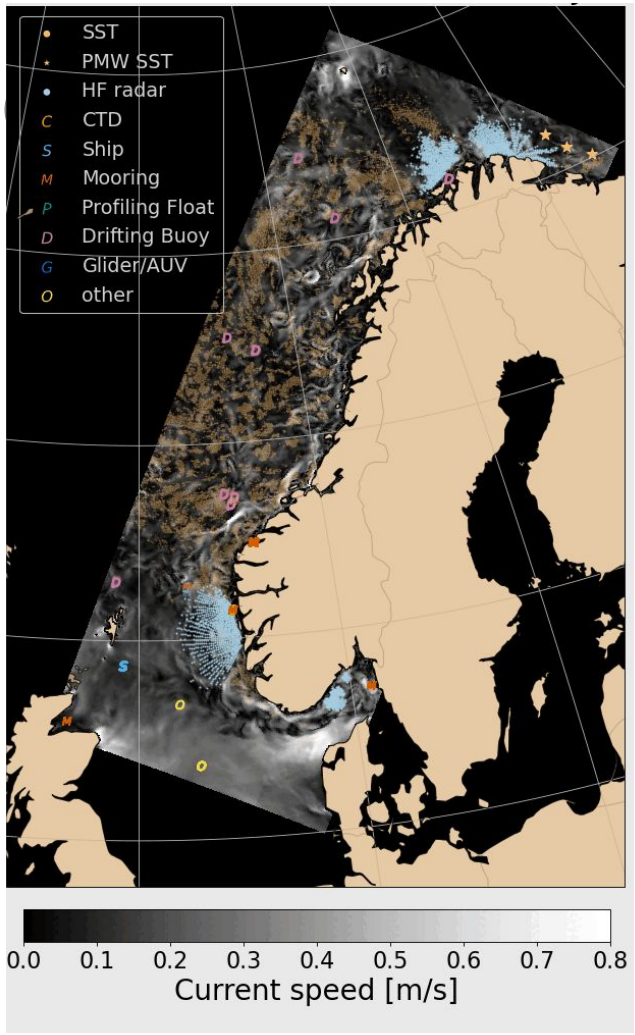
  - Data assimilation
- ➔ Downstream models: object drift
  - Search & Rescue
  - Oil spill preparedness
  - Biological material



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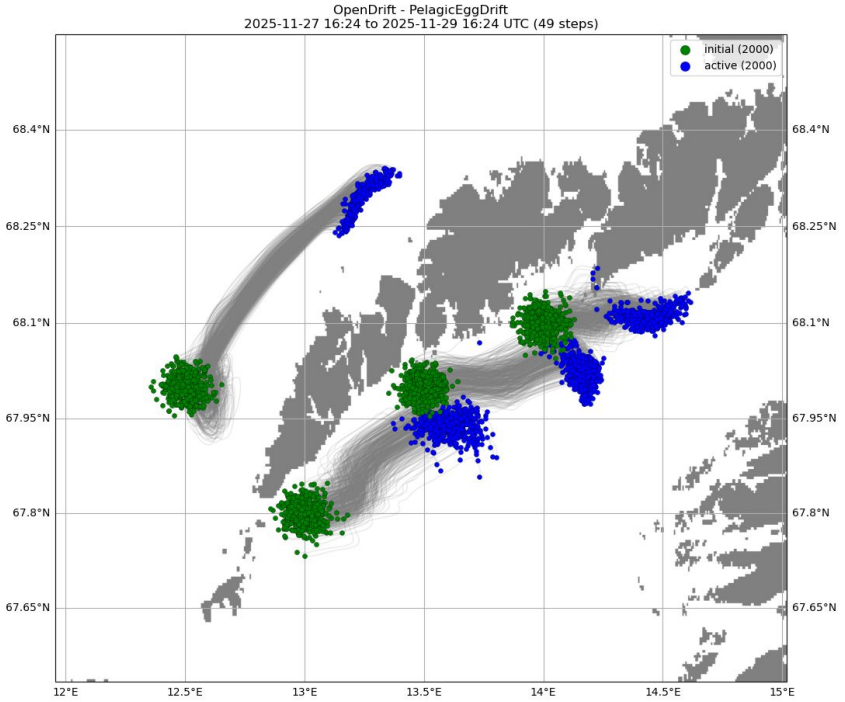


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Motivation:

# How can we provide better and cheaper ocean forecasts along the Norwegian coast and fjords?

# Norway has a complex & long coastline

Which models do we already have?
Which resolution?

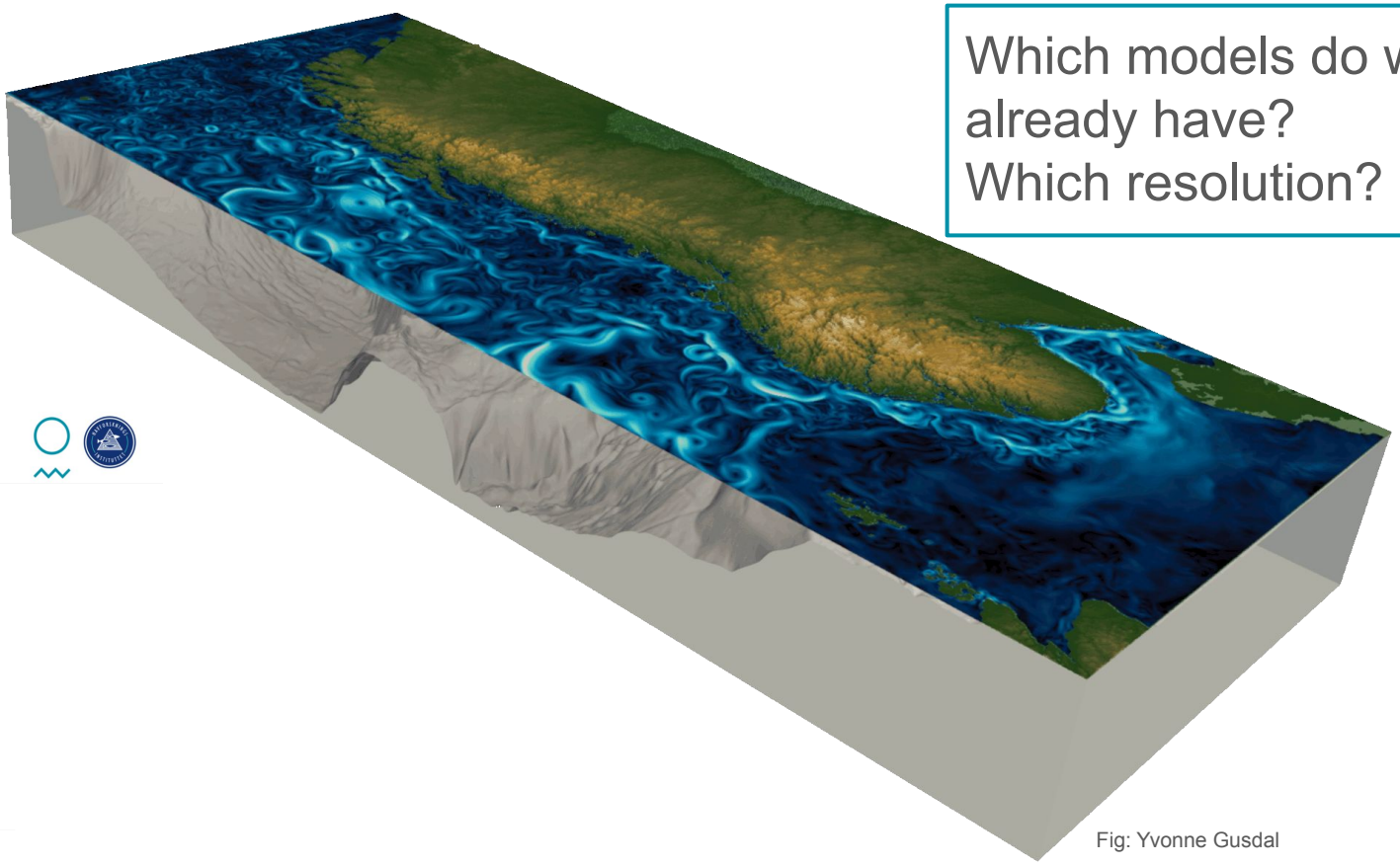

Fig: Yvonne Gusdal

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# Norway has a complex & long coastline

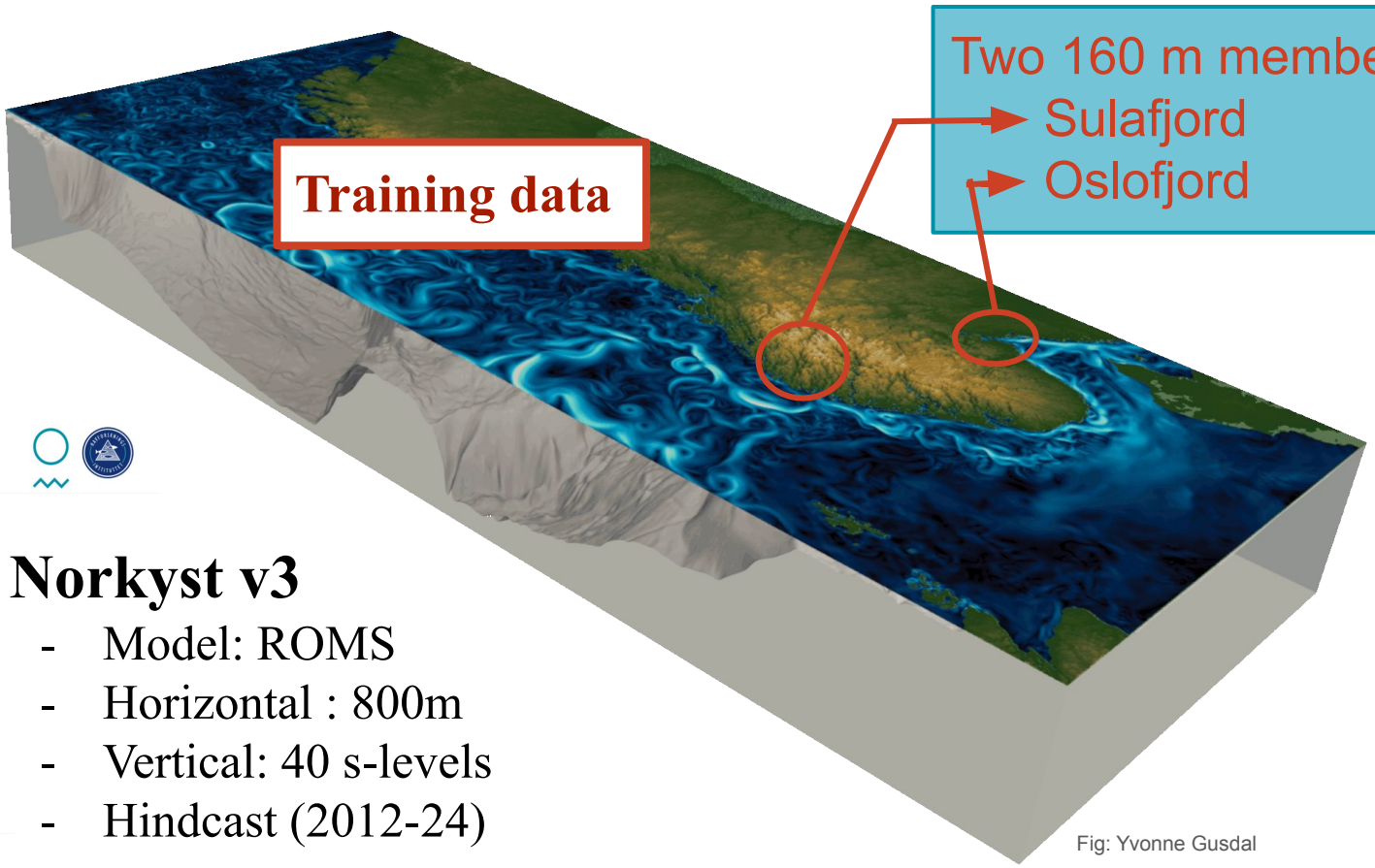


Fig: Yvonne Gusdal

## Norkyst v3

- Model: ROMS
- Horizontal : 800m
- Vertical: 40 s-levels
- Hindcast (2012-24)

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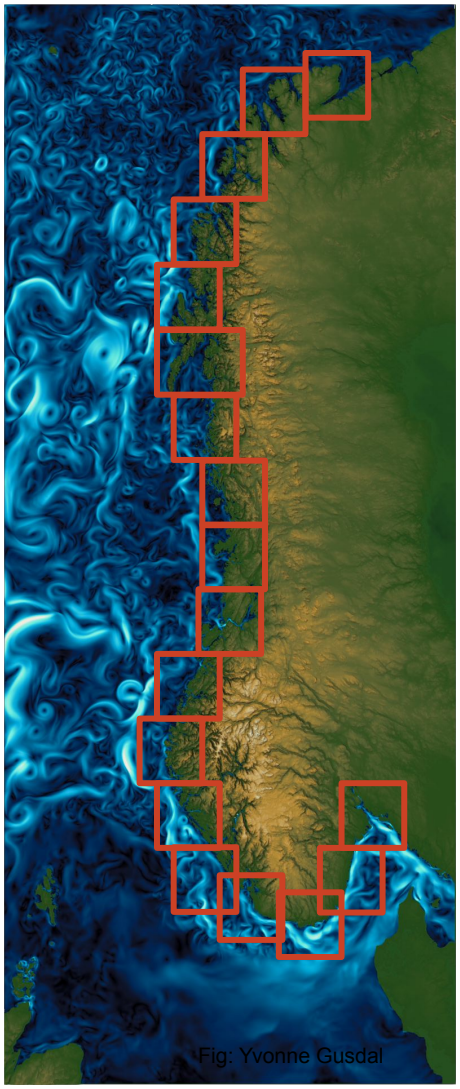
# Main Goal:

## Havbris:
## ML model with 160m resolution for the entire Norwegian coast

Data-driven models



# Training Data

**Phase 1.** Norkyst 800m hindcast ~12 years → Havbris 800m

**Phase 2.** Norkyst 160m operational ~2 year → Havbris 160m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# Havbris 160m

Assumption:

- Coastline and bathymetry is a strong constraint to circulation at 160 m scale. The ML model will learn this constraint from examples in the training data, and be able to produce high-quality forecast for geographical regions never seen in training (at 160 m scale).

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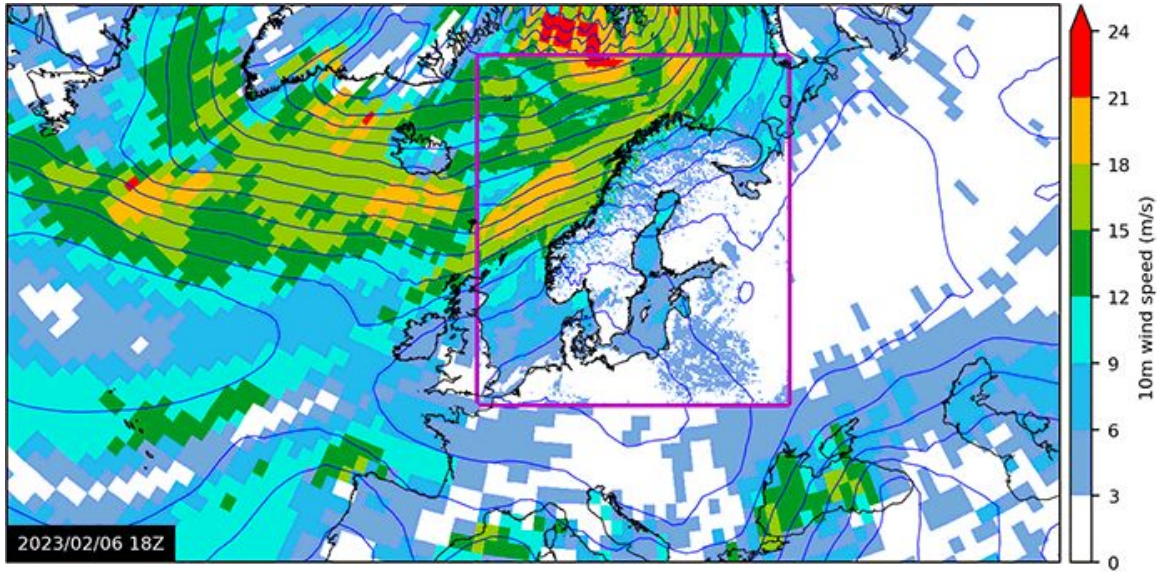
# How?

## Use the same setup as newest ML weather models!

anemoi

The ML framework developed by ECMWF and others.
Used to create the AIFS and




MET Norway's "Bris" weather model

Nipen et al. 2024 arXiv:2409.02891v1

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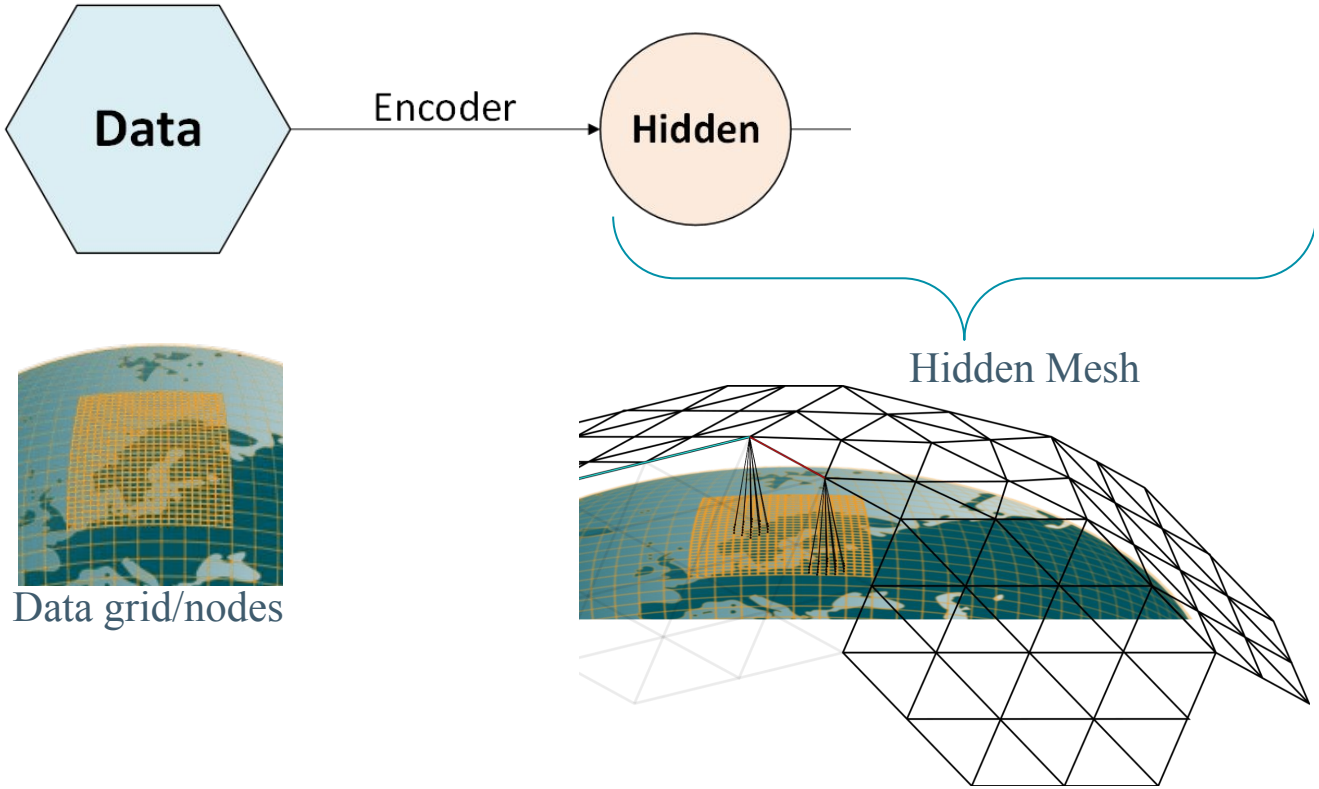
**Note:** Bris uses "stretched grid" while we use LAM

# Graph Neural Network

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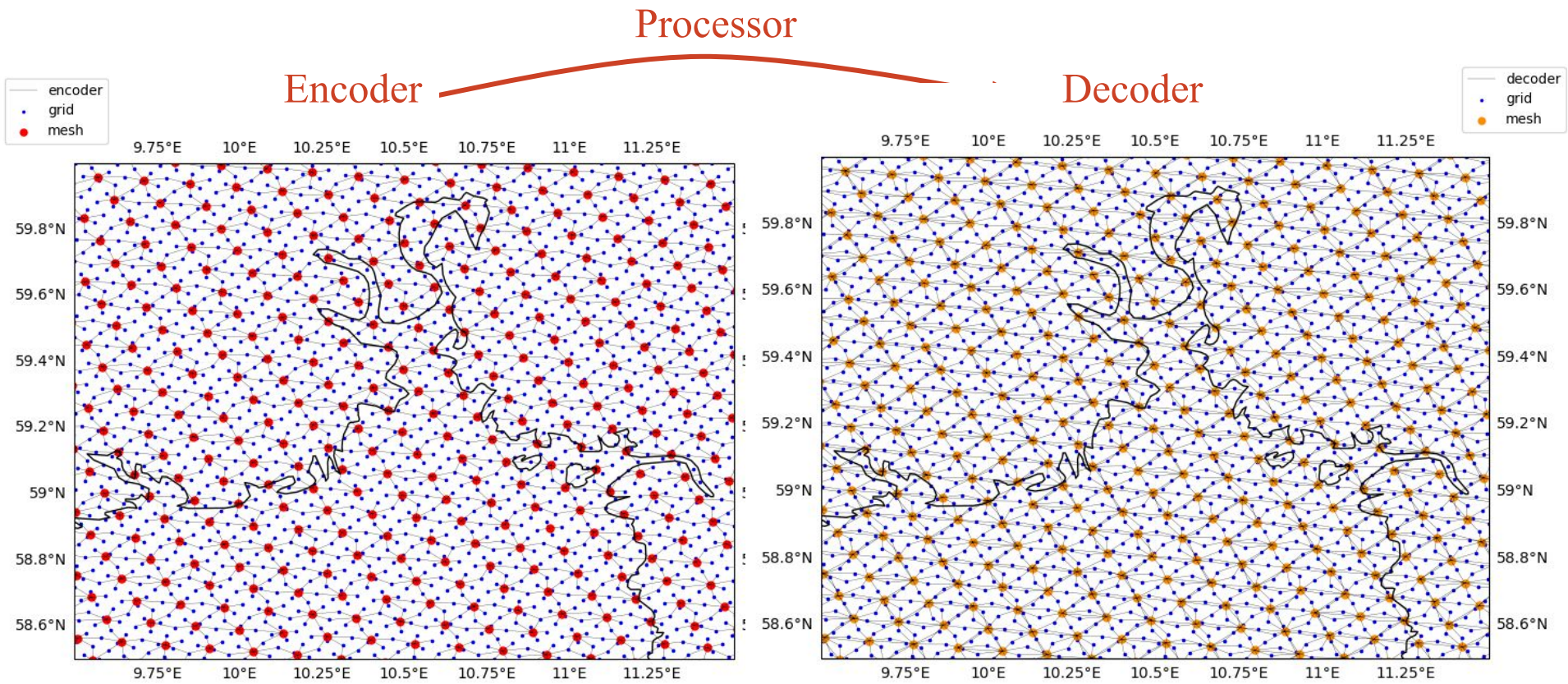
# Graph node positions (Oslo region)



# Forcing variables

| **Available Forcings** |
| --- |
| Atm. forcing |
| Topography |
| Boundary (next slide) |

| Wind (u,v) |
| --- |
| Atm. temp |
| Solar rad. |
| Rel. humidity |
| (Cloud cover) |
| Precipitation |
| Air pressure |

TODO: River inflow



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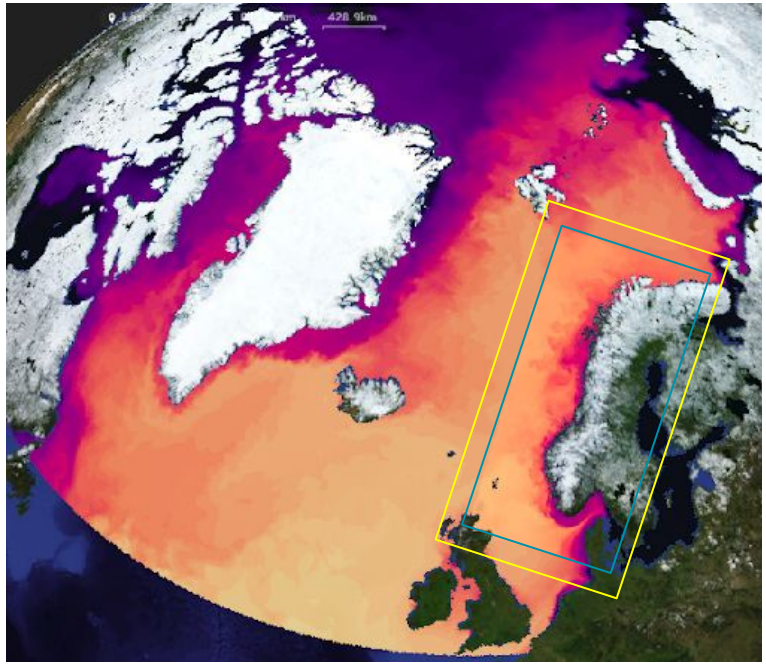
# Boundary conditions

1. <u>First setup:</u>
   Shrink Norkyst domain and use the outermost grid cells as boundary conditions for the ML model.
2. <u>Operational:</u>
   Take values from Topaz (6km) and add them around the Norkyst (800m) domain.

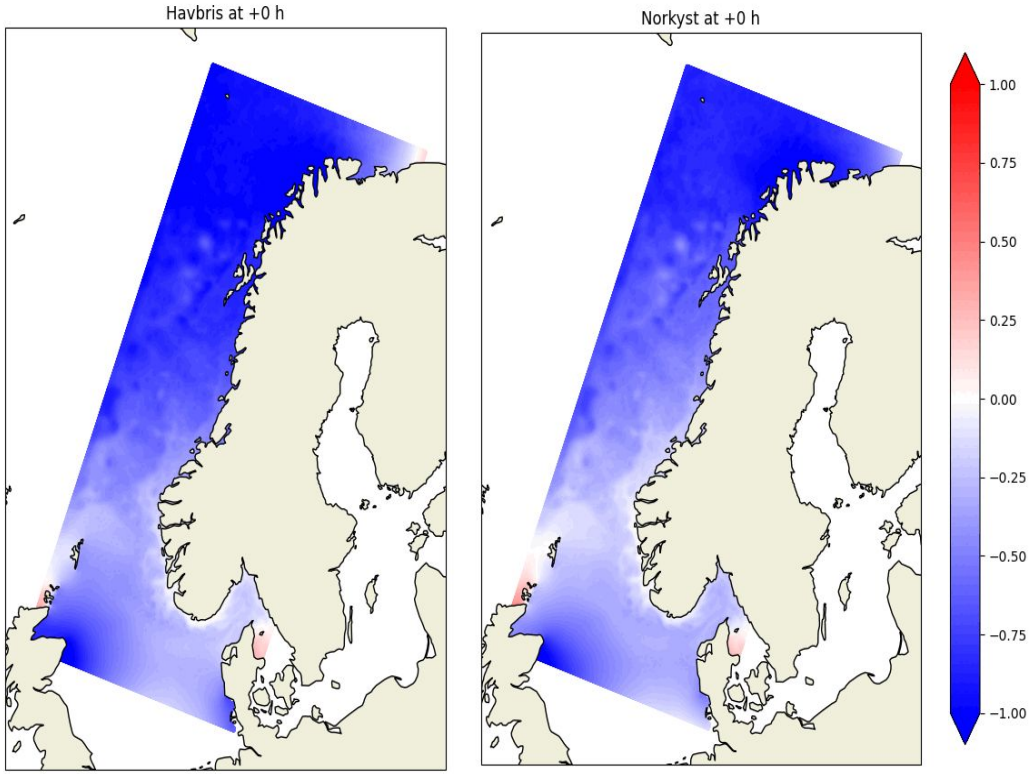
How many km around model domain?

→To be tested further…



# Preliminary Havbris results

Sea surface height




Simplifications (for now)

a. only surface layer
b. predict 5 variables: u,v, temp, salt, (ssh)
c. 3h time steps

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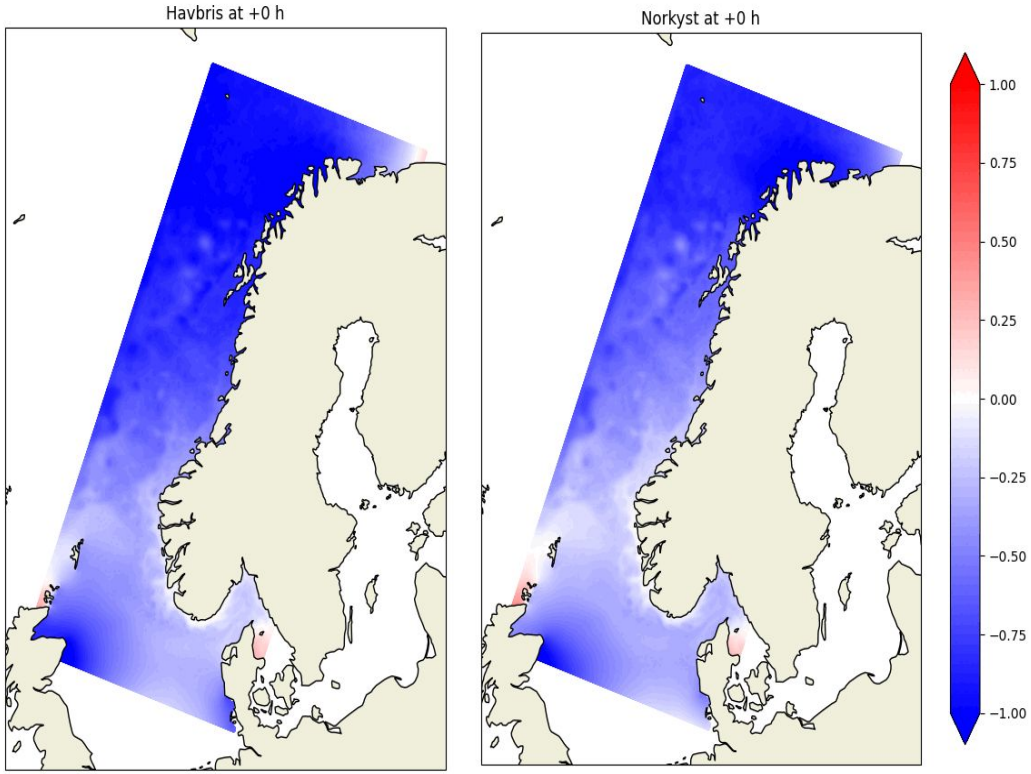
# Preliminary Havbris results

Sea surface height




Challenging time scales:

slow v.s. fast processes

→ large gap between advection processes and tidal and atmospheric forcings

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# TODO's & Future plans

- Hyperparameter tuning
- Try 6h time steps
- Try loss function scaling of SSH
- Size of boundary forcing domain
- Adding depth layers
- Fine-tune on 160m domains & test performance
- …
- Multi-encoder setup for including satellite observations (project funded)

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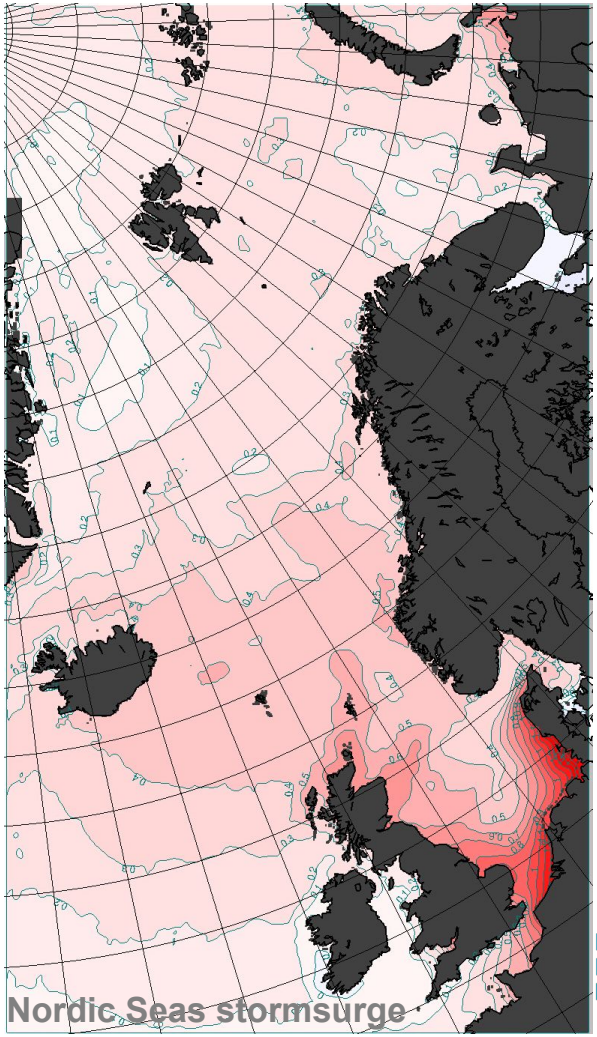
Another model:

# Storm Surge

- Storm surge + tides = main contribution total water level

- Dependence on atmospheric conditions (forcings)
- Only one prognostic variable (SSH)

→ Train on 1 GPU for 7 days

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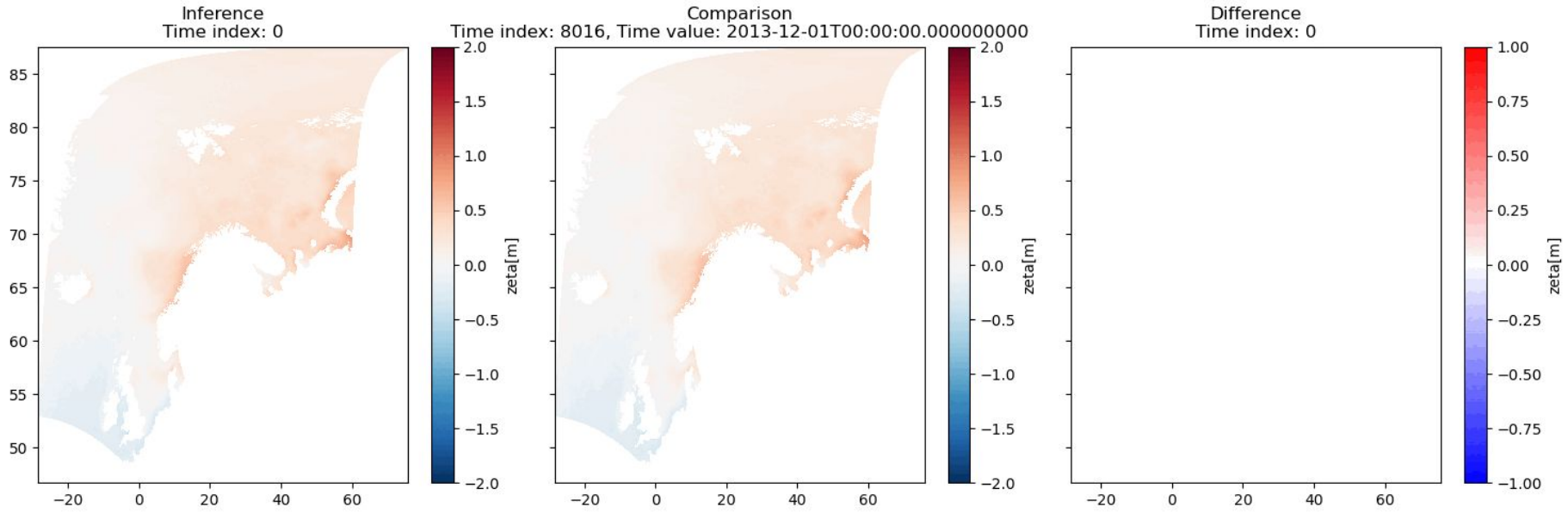
# Preliminary Storm Surge results




Storm Xaver, December 2013. Among the top 5 highest recordings of storm surge in the German Bight last 100 years.

# Collaborators & Acknowledgements

Thanks to the **Bris-team** for helpful discussions, brainstorming and tips, and all **colleagues at Department of Ocean and Ice @ MET Norway** who continue to contribute their time and help, and the extended **Anemoi community**, in particularly at **ECMWF**.

Thank you for your time!

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