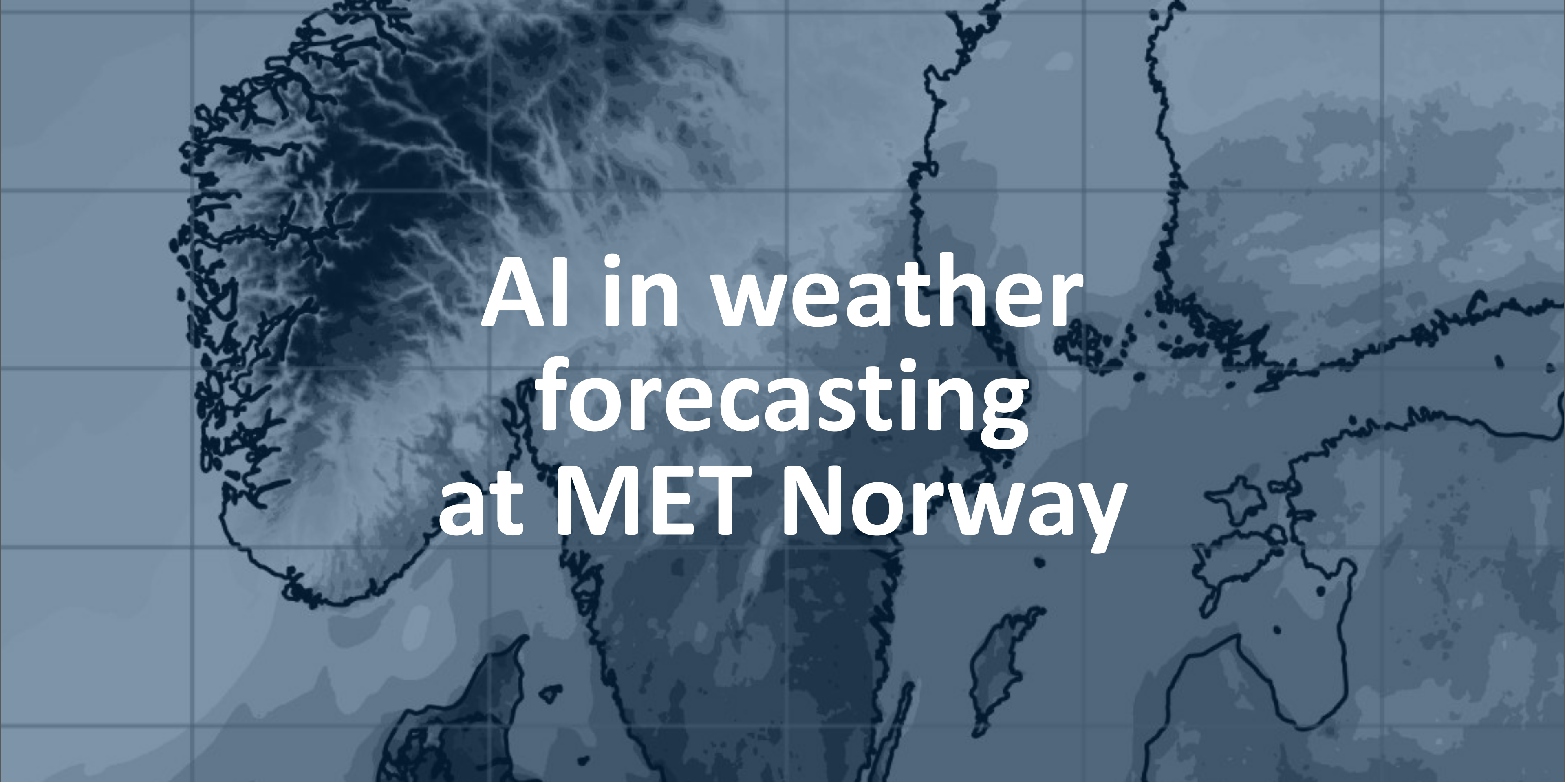


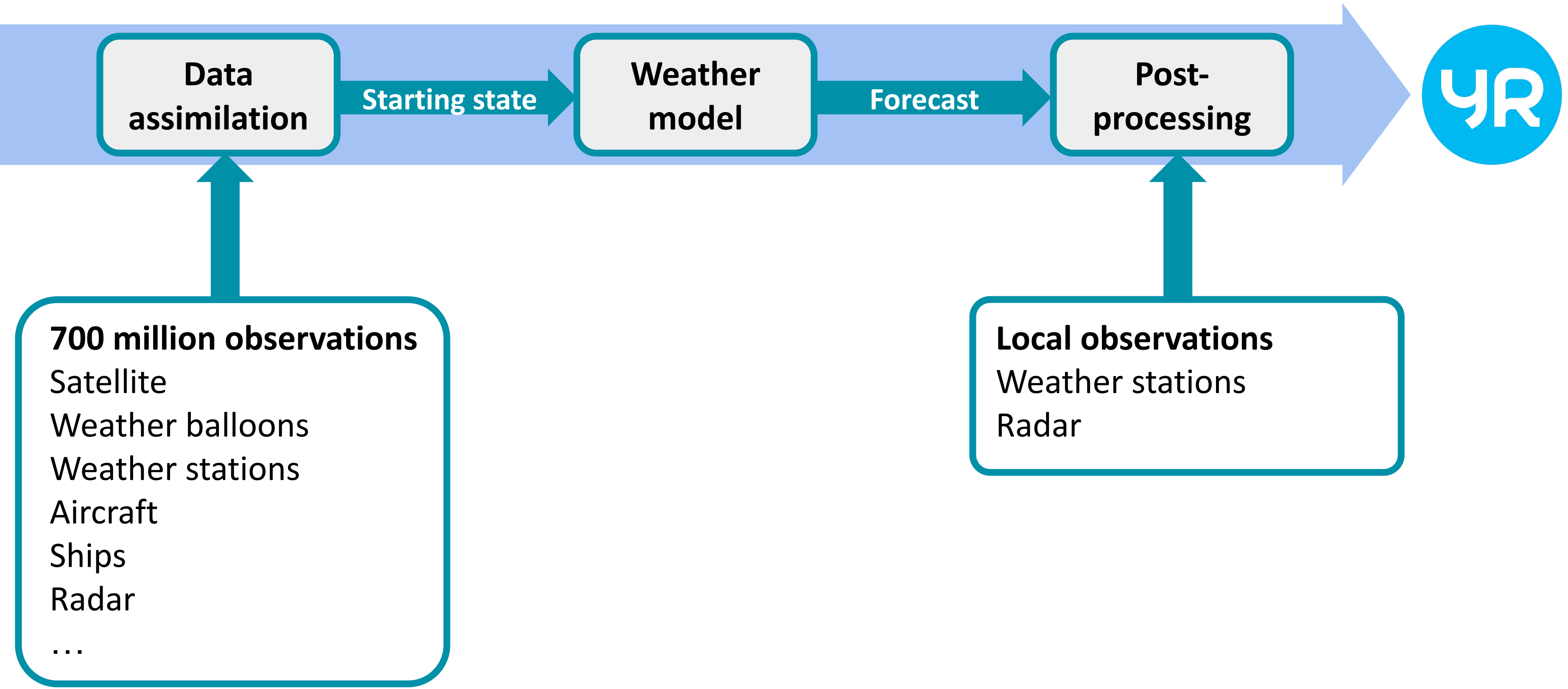
AI in weather forecasting at MET Norway

Norwegian Meteorological Institute

Thomas Nipen + many colleagues at MET Norway

YR

Fully automated production chain

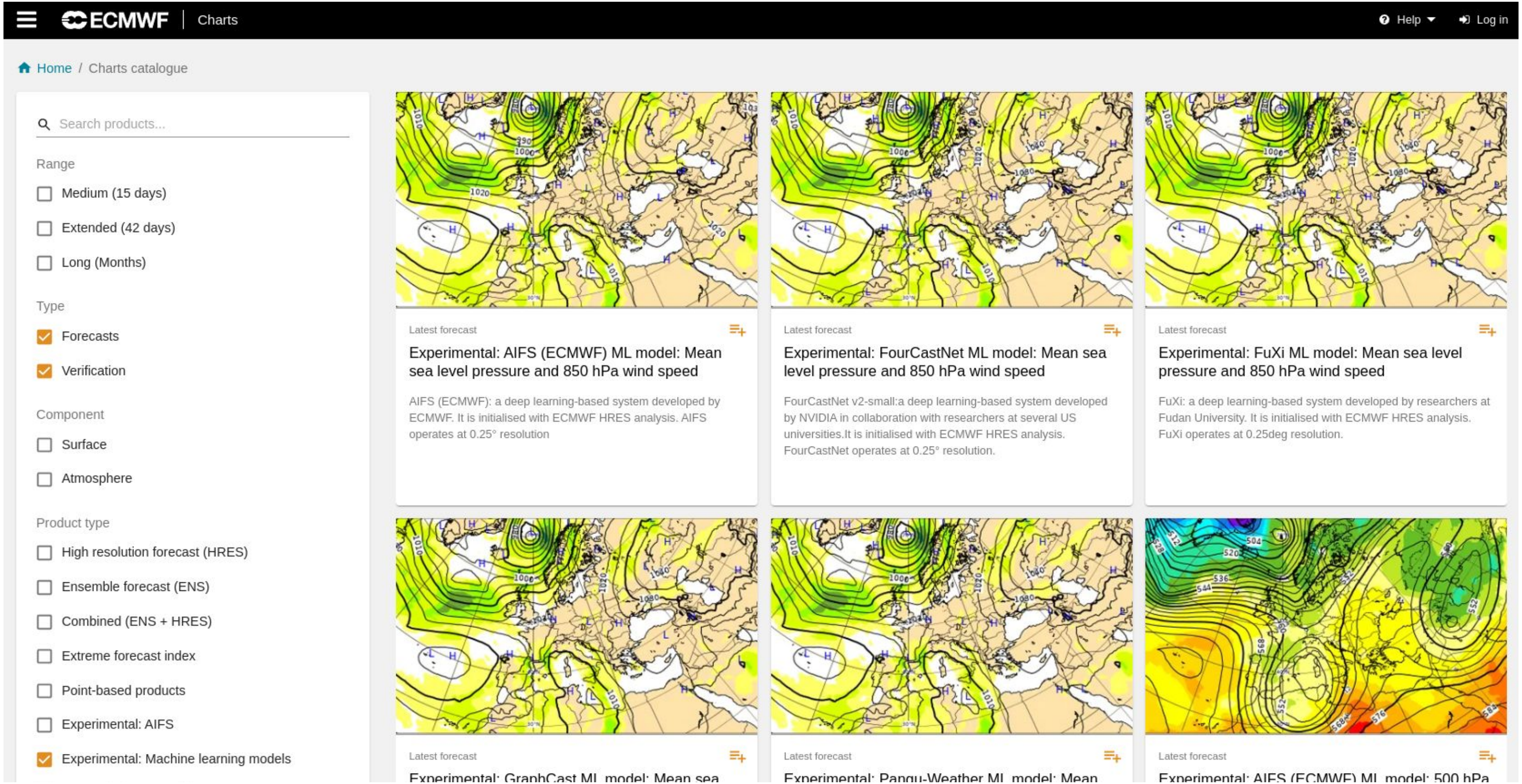


Data-driven models for NWP

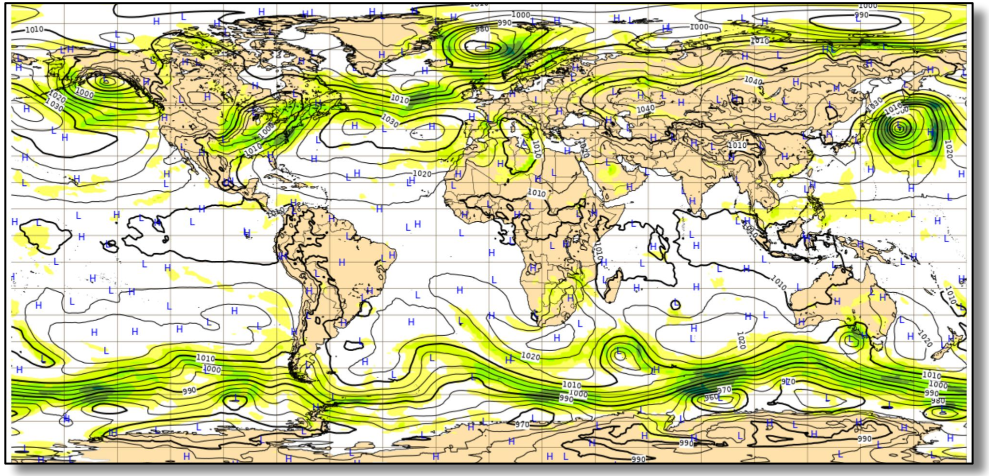
- Several very competitive models have emerged in the last 2 years
- Trained on 40+ years of global reanalysis data (ERA5 at ~31km resolution)
- Training is expensive (~10s of thousands of GPU hours)
- Inference is several orders of magnitude faster than physics-based models

Vision transformer	Fourier neural operator	Graph neural network
Pangu-weather Huawei	**FourCastNet** NVIDIA	**GraphCast** Google
FuXi Fudan University		**AIFS** ECMWF

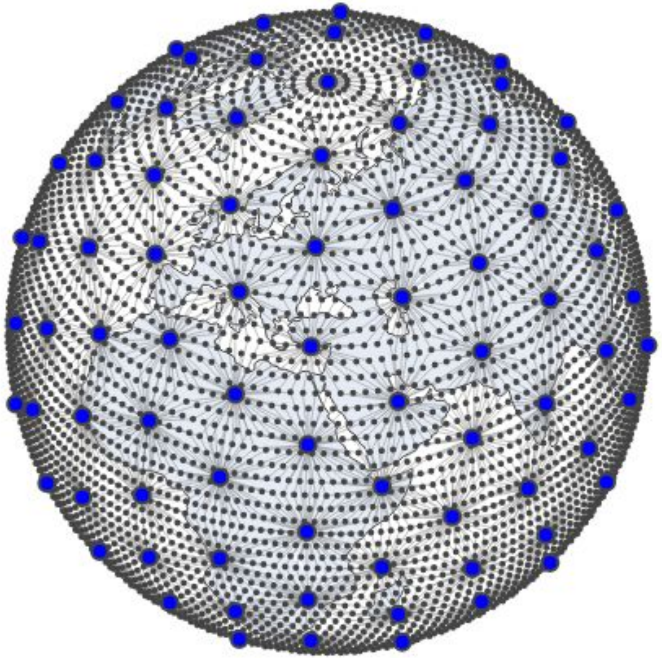
Data-driven models for NWP



Graph neural networks for NWP

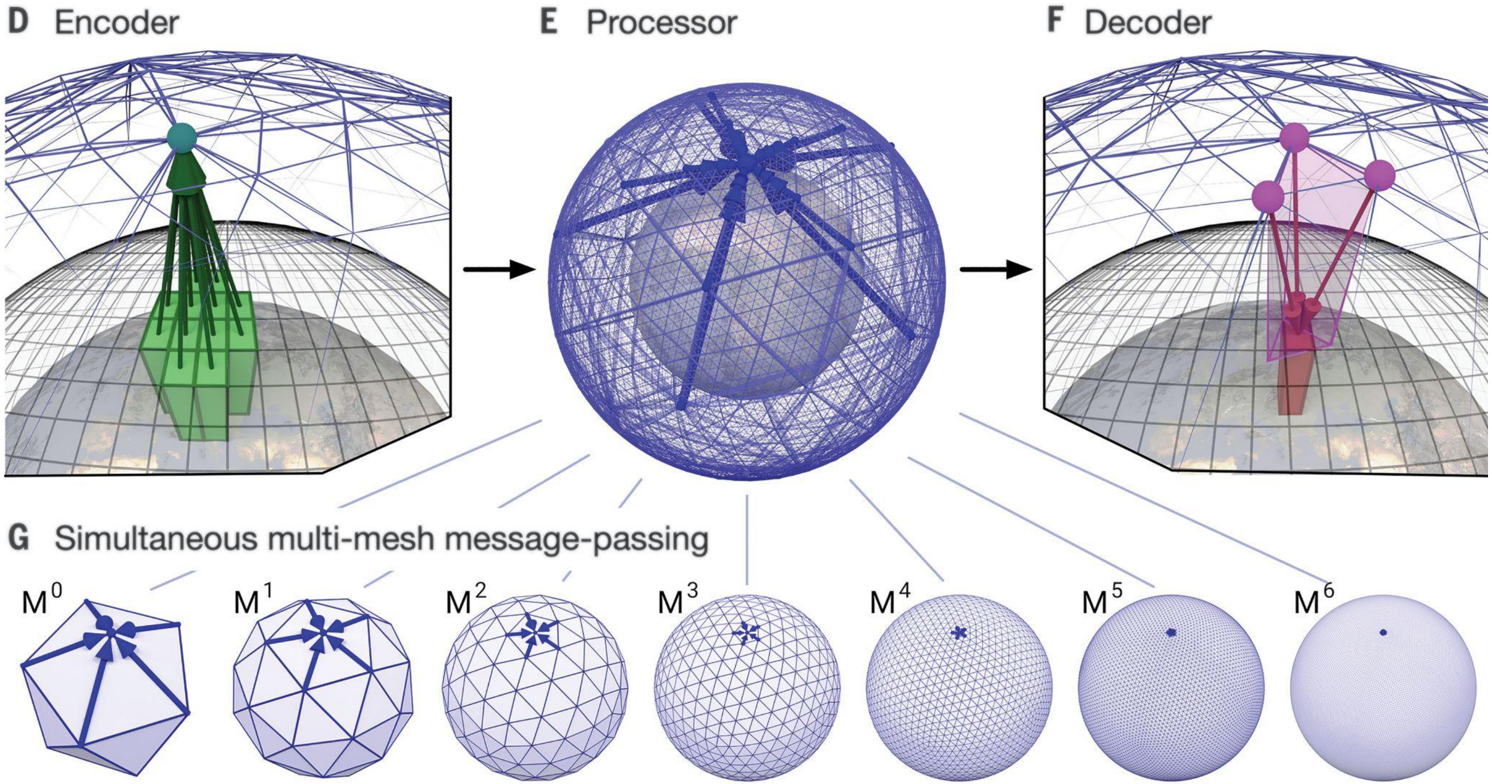


Vision transformer



Graph neural network

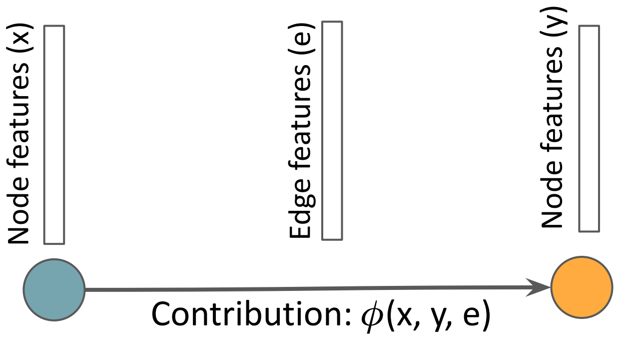
Graph neural networks for weather

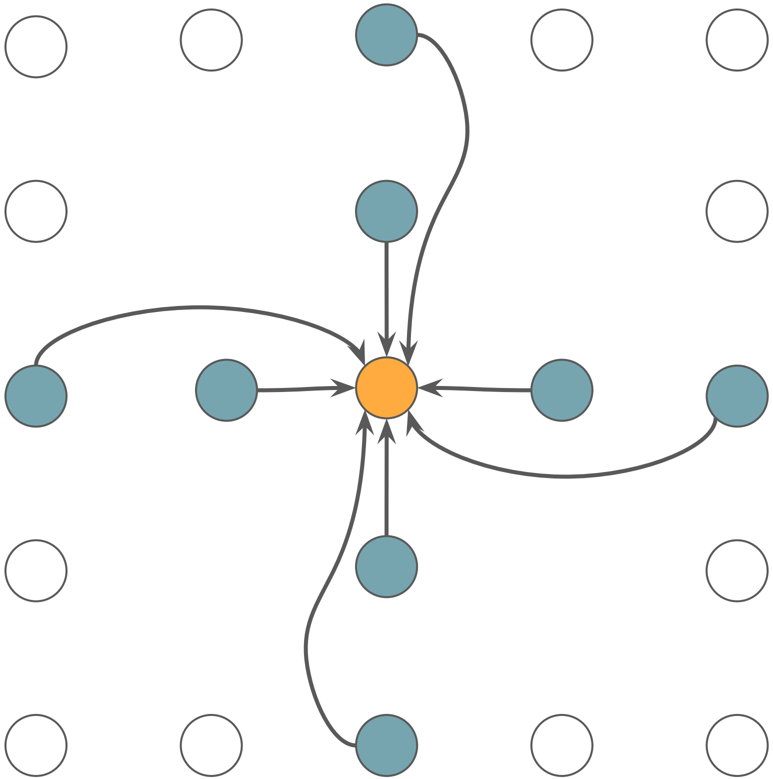


Learning skillful medium-range global weather forecasting
https://www.science.org/stoken/author-tokens/ST-1550/full

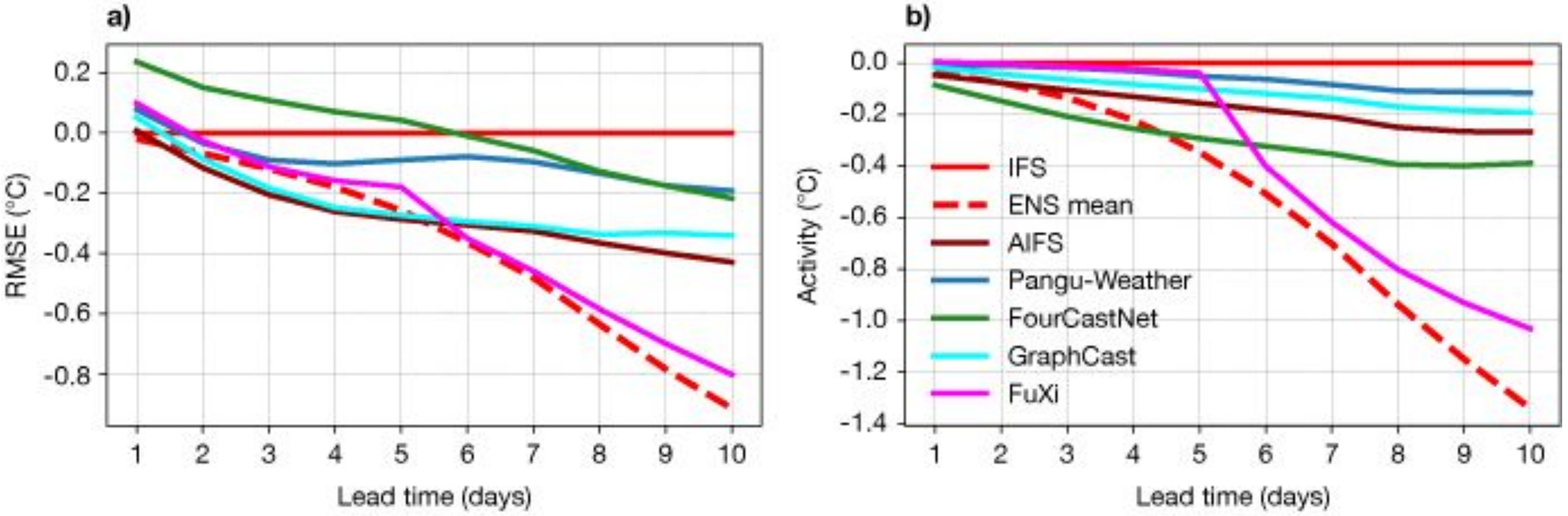
Graph neural networks for weather

- Each neighbour node provides a contribution
- Contributions are aggregated (e.g. summed)



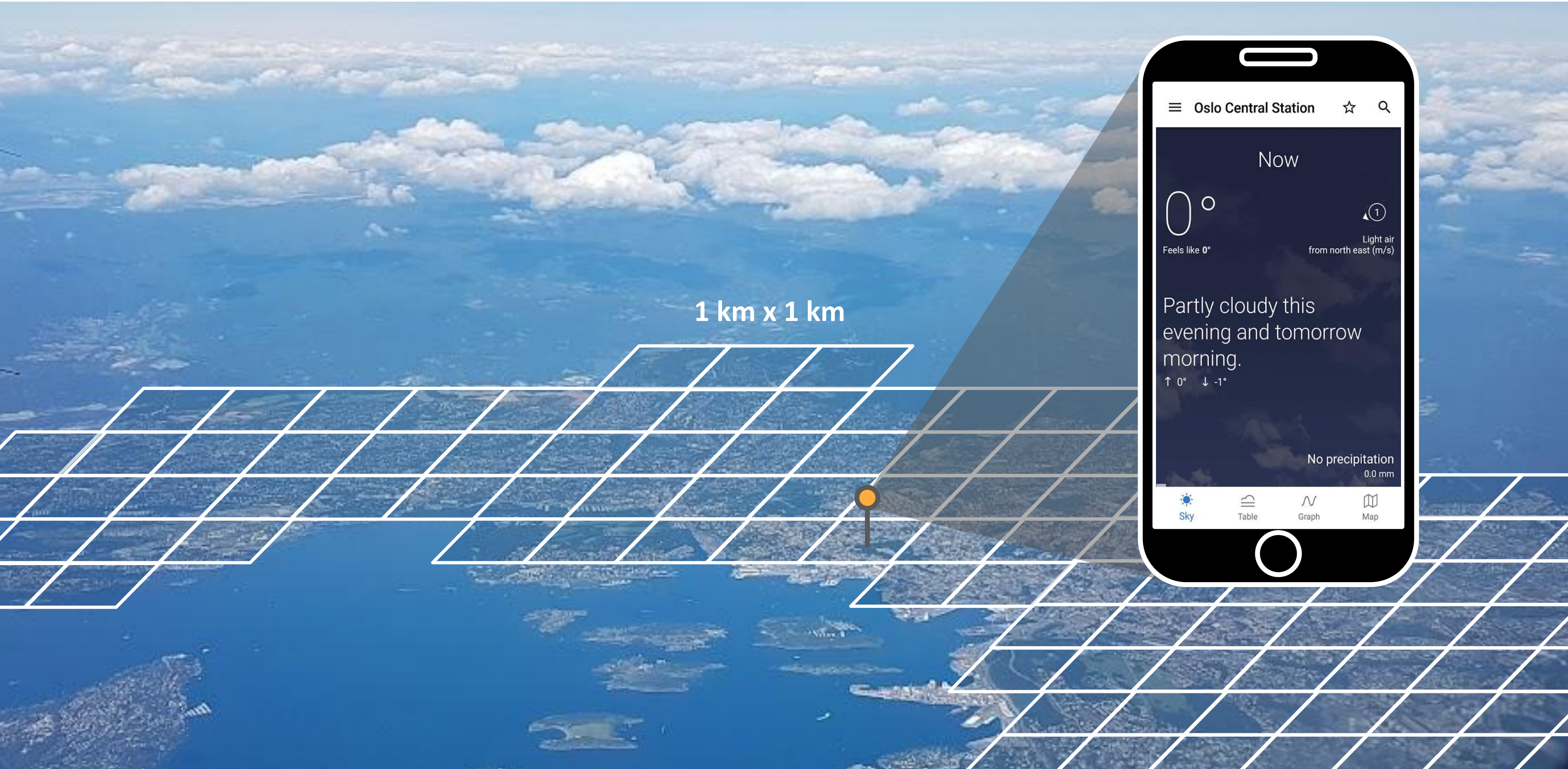


Results

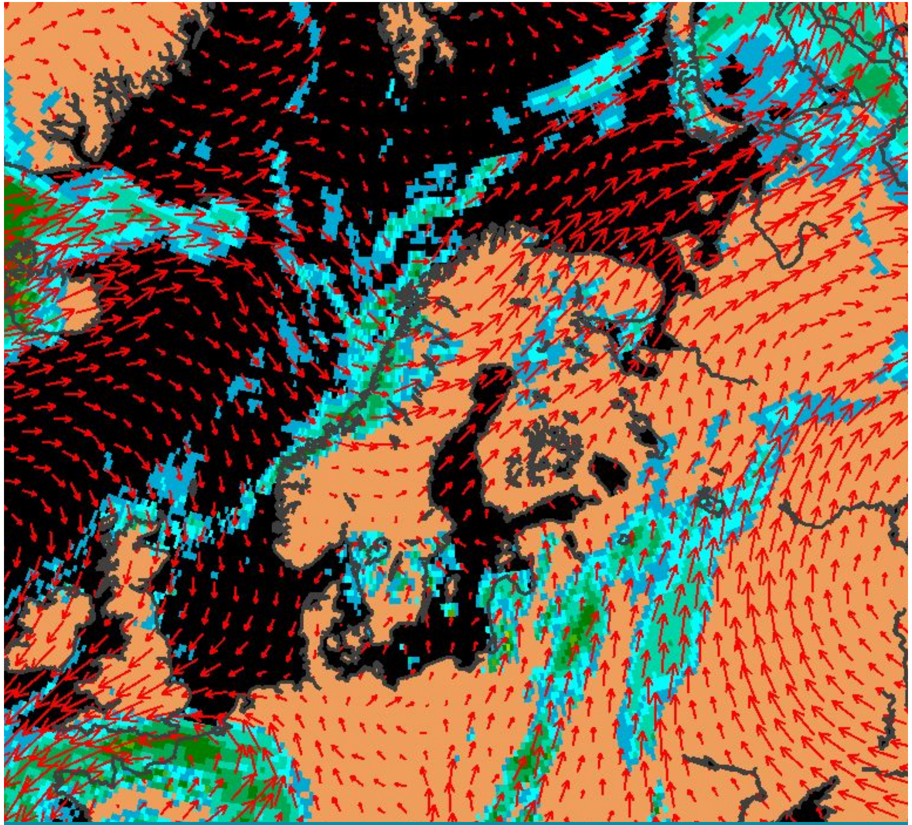


Physics-based reference forecast

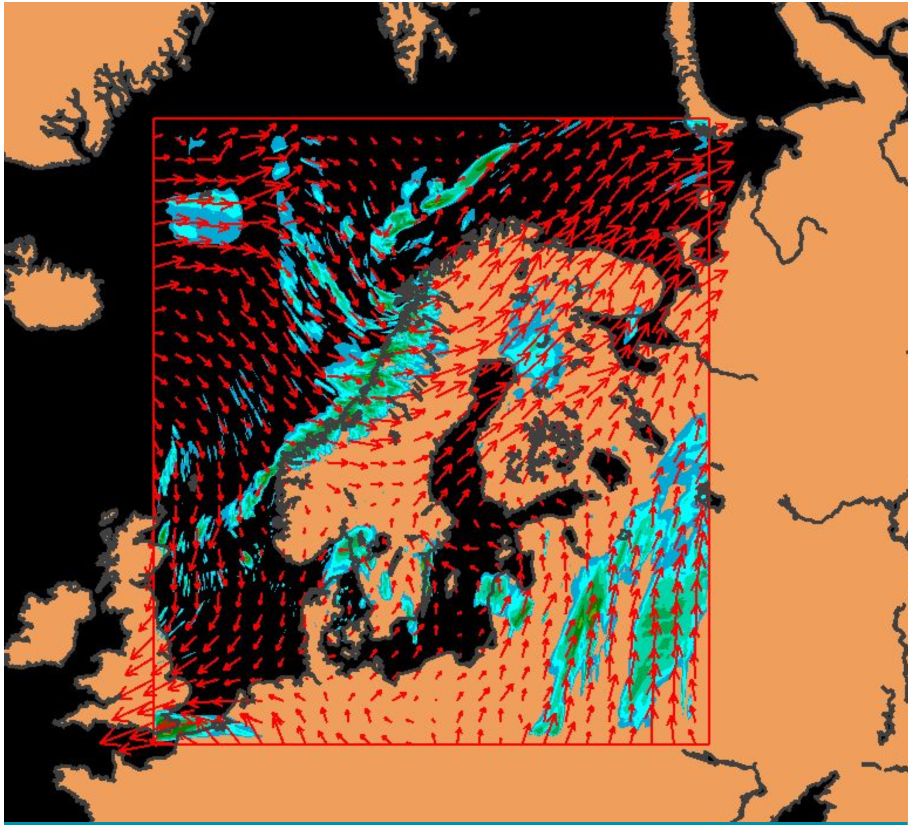
Users expect localized forecasts



Global vs regional models

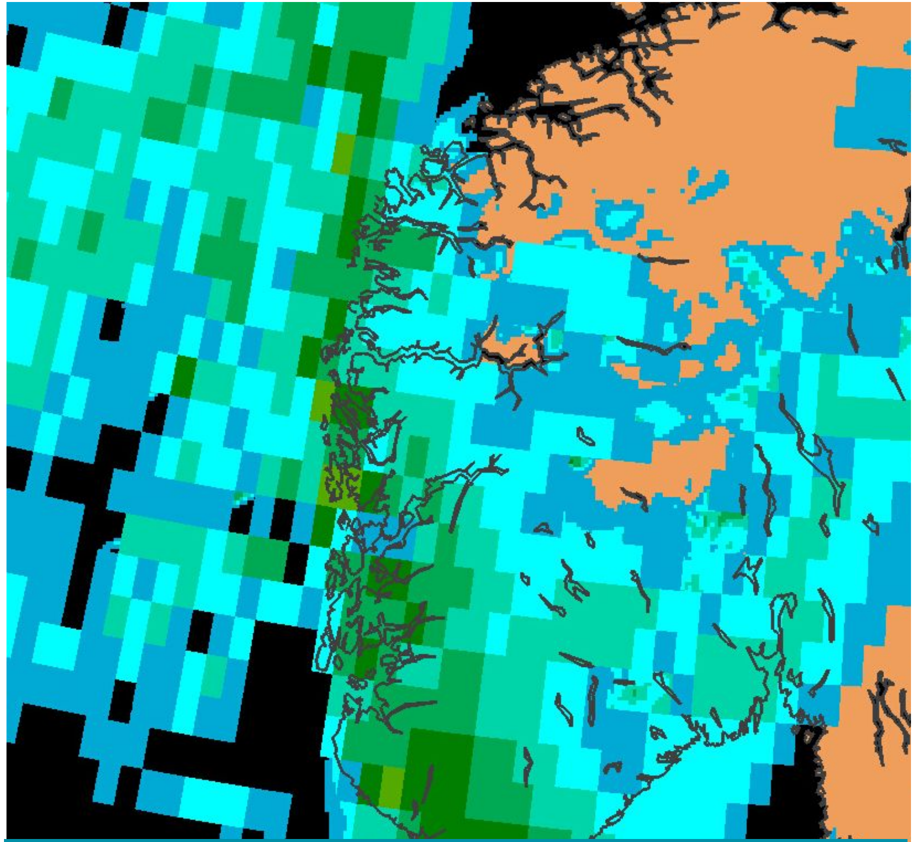


Global model (ECMWF IFS)

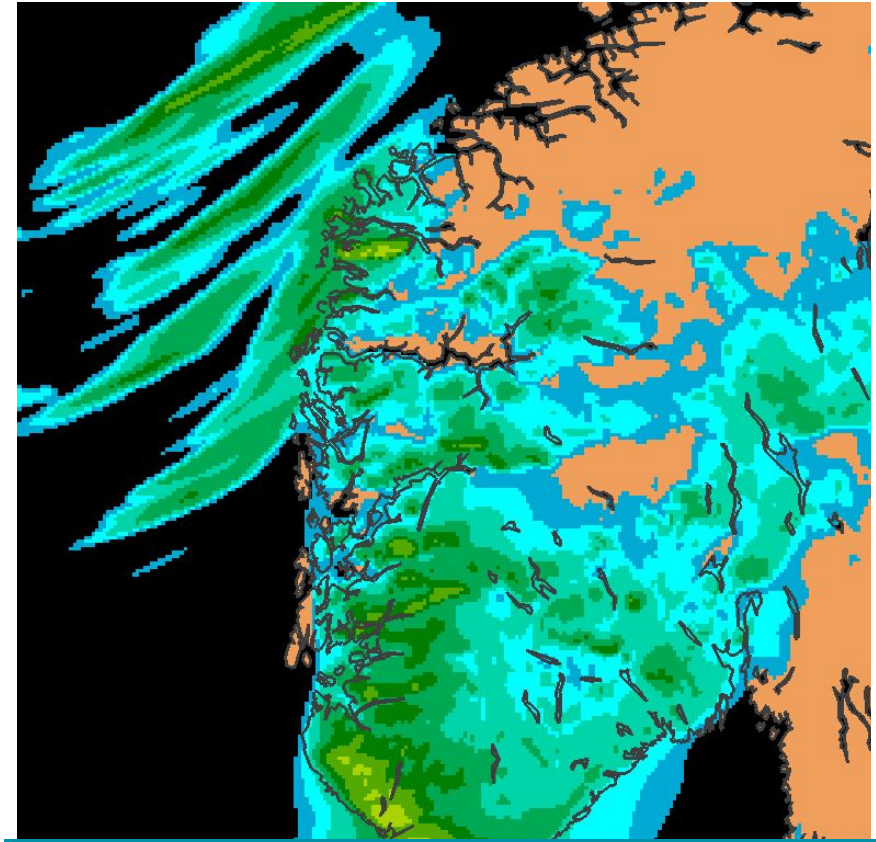


Regional model (MEPS)

Global vs regional models



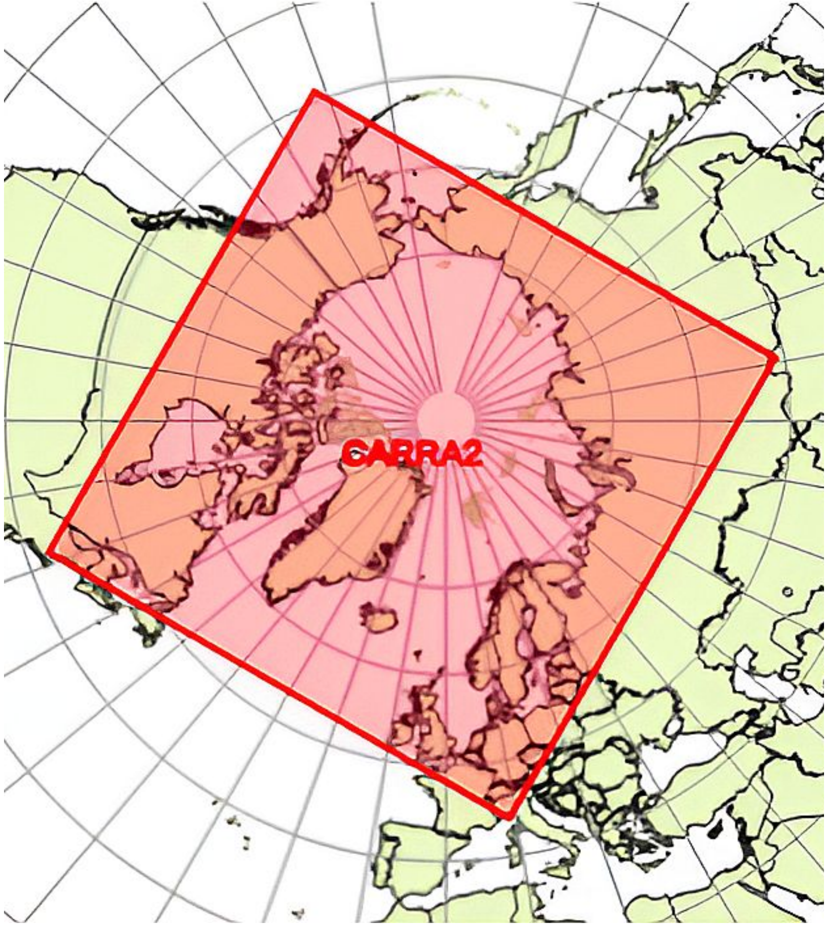
Global model (ECMWF IFS)



Regional model (MEPS)

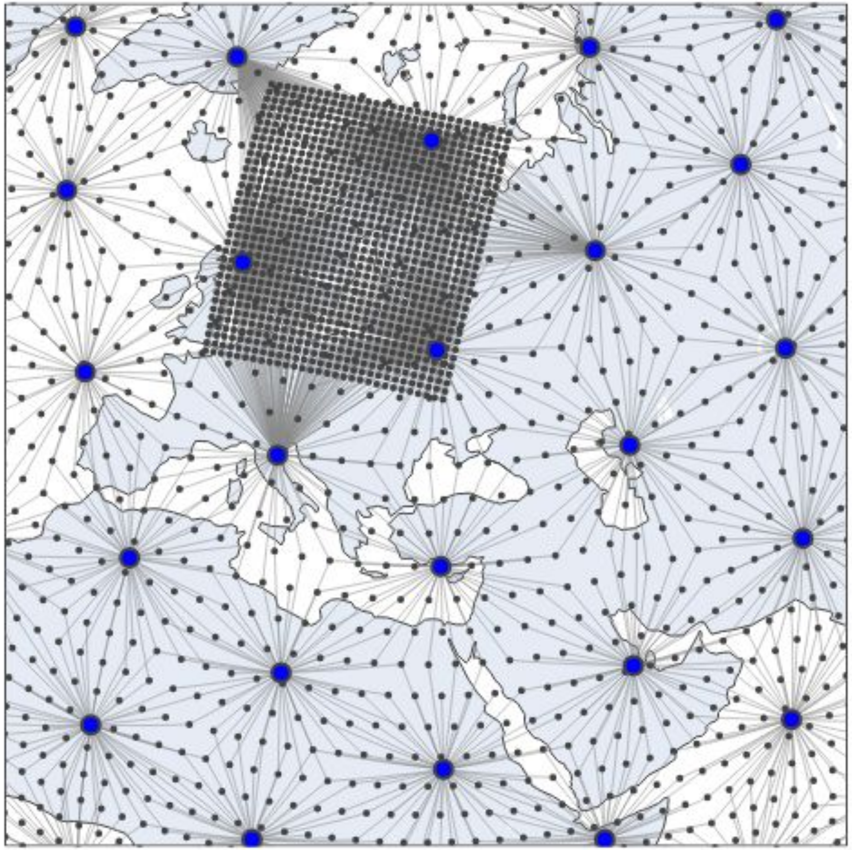
Regional reanalysis datasets

- CARRA2 reanalysis at 2.5 km resolution
- Time range: 1991-2025
- Expected completion: Q3 2026
- Allows us to train high-resolution models for Nordic conditions

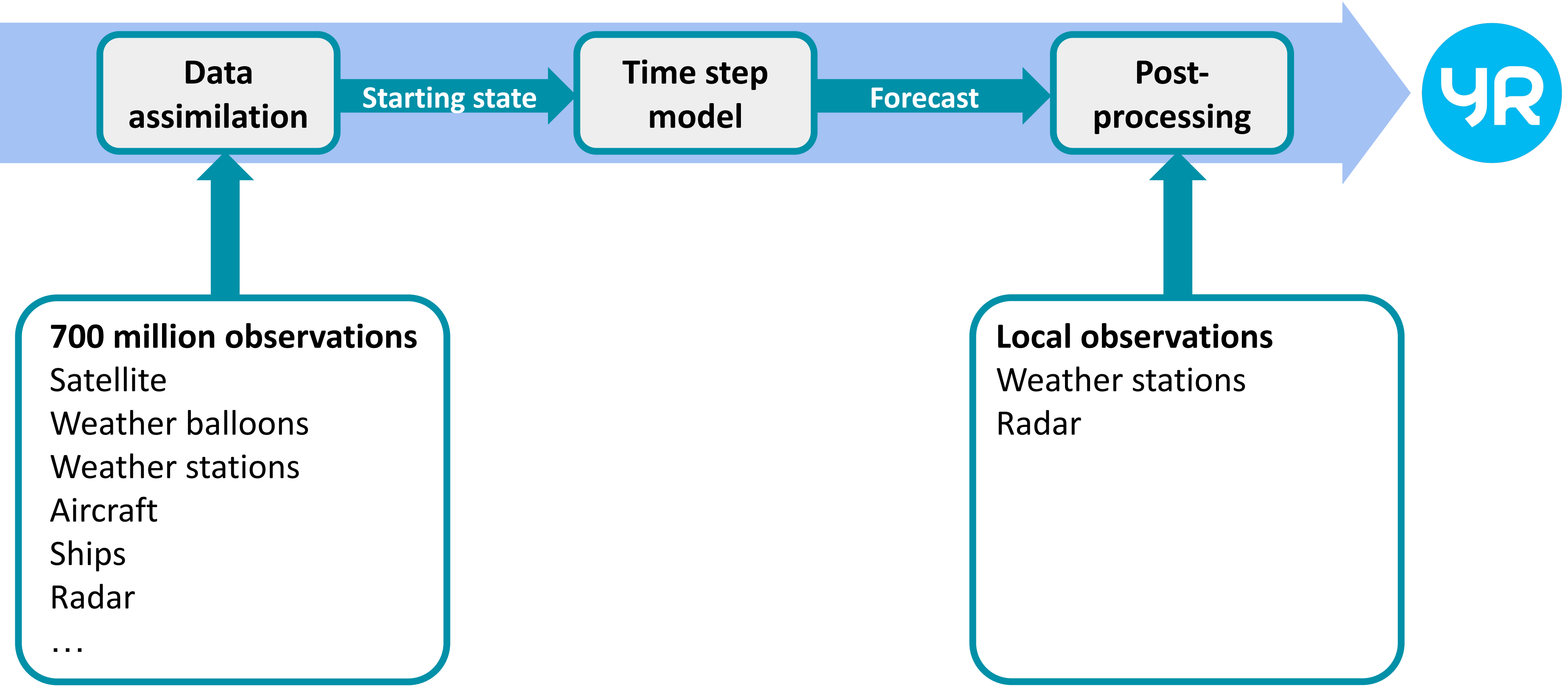


Stretched-grid AIFS

- GNNs allow for arbitrary grid topology
- The grid can be stretched to have higher resolution over the Nordics
- We can combine the initial state from ECMWF's 9 km global model with our own 2.5 km regional model.
- The goal is that a common model learns phenomena at the whole range of scales



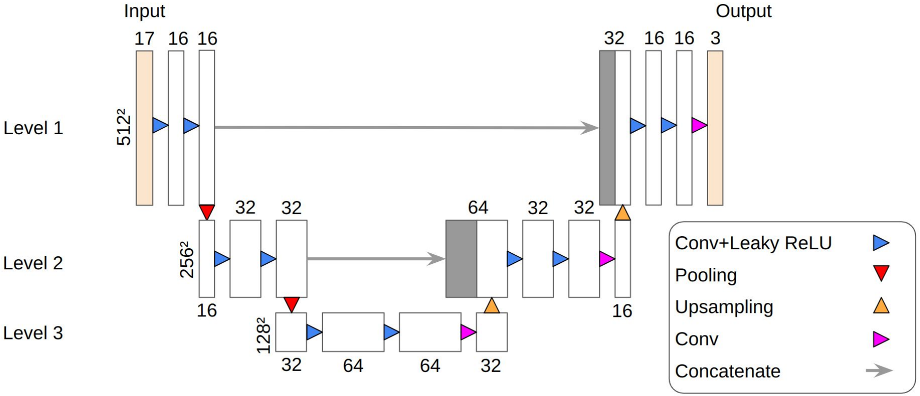
Fully automated production chain

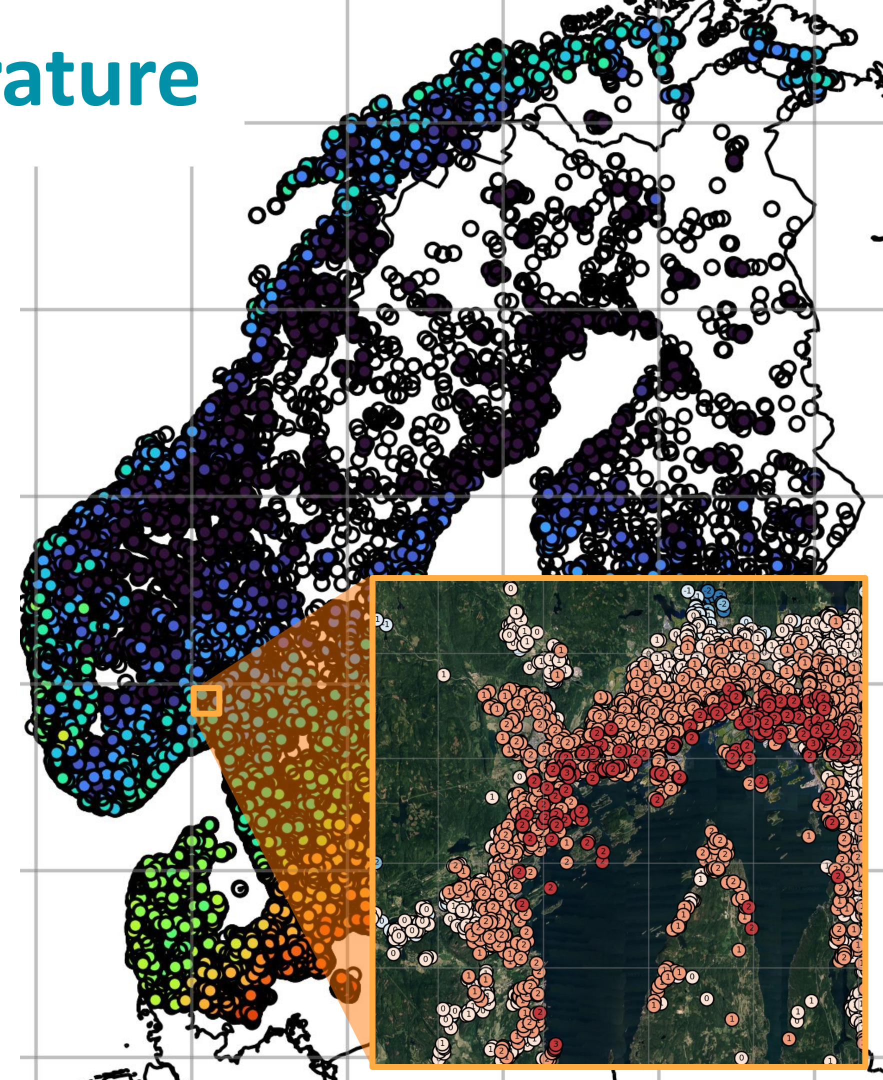


Post-processing of temperature

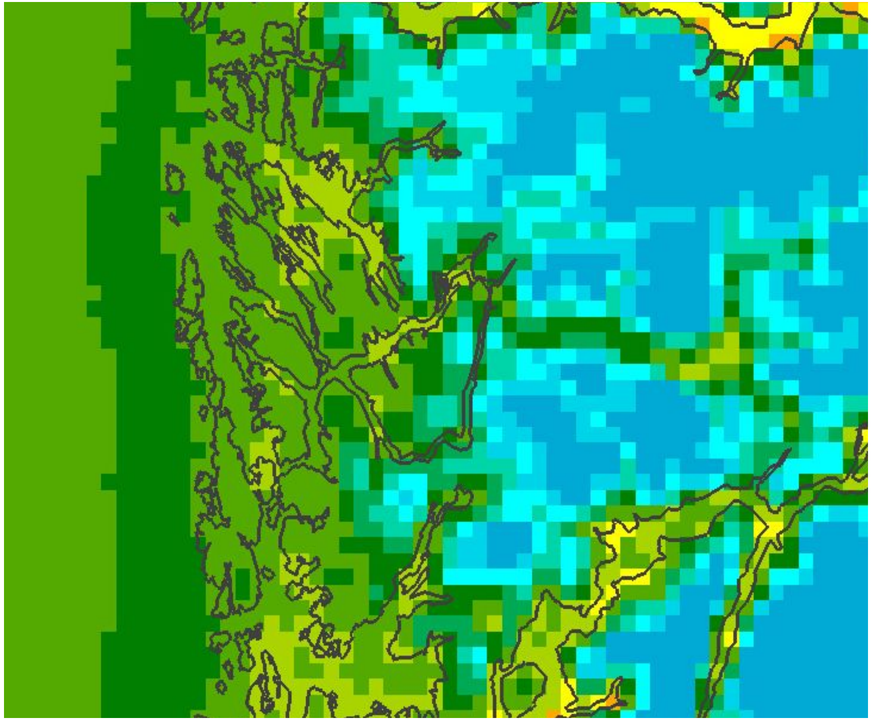
Bias-correction and downscaling of 2.5 km temperature to at 1x1 km resolution

Architecture: U-Net with 6 levels
Dataset size: 6TB
Targets: Citizen weather stations (Netatmo)
Parameters: 1,314,019
Training time: 12 hours on 4 NVIDIA A-100 GPUs

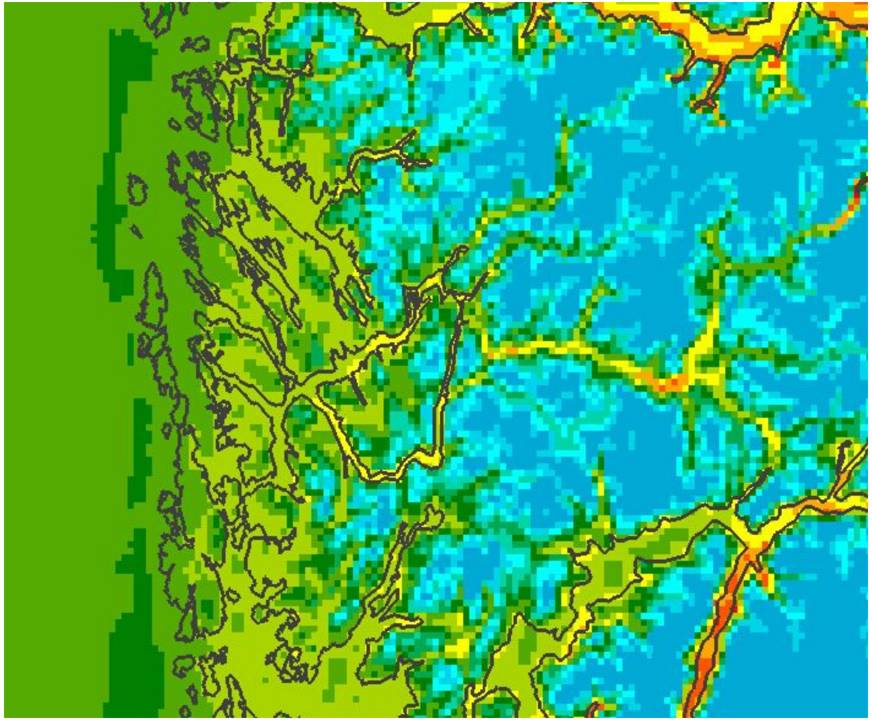




Post-processing of temperature



2.5 km (NWP model)



1.0 km (NWP+ML model)

Destination Earth projects

On-demand Extremes (DE_330)

- NWP modelling at hectometric resolutions
- Impact models
  - Hydrology, air pollution, renewable energy, …
- Machine learning components
  - Uncertainty quantification by probabilistic and generative modelling
  - Initial-state models

Machine Learning for Earth system Digital Twins (DE_371)

- Generative machine learning methods for
  - Space-time scenarios of multiple parameters given deterministic forecasts
  - Higher temporal resolution

Emulation of CFD model for turbulence forecasting

Aviation forecasting at 19 Norwegian airports

- Original system
  - MEPS control (2.5 km) → CFD model (100 - 250m)
  - **13 lead times, 2 times/day**
- New ML-based system
  - ML models trained separately for each airport
  - relevant variables from MEPS control at model levels (Lambert grid) as input
  - 3D wind and turbulence on 3D grids (rotated spherical) as targets
  - **18 lead times, 8 times/day**
  - computationally cheap
  - in operation from June 2023

Links

- Run data-driven models on your own: https://github.com/ecmwf-lab/ai-models
- ECMWF weather charts: https://charts.ecmwf.int/
- Open data from MET Norway: https://thredds.met.no/

EuroHPC Joint Undertaking

"The MAELSTROM project has received funding from the European High-Performance Computing Joint Undertaking (JU) under grant agreement No 955513. The JU receives support from the European Union's Horizon 2020 research and innovation programme and United Kingdom, Germany, Italy, Luxembourg, Switzerland, Norway".

Co-ordinated by ECMWF

Extra slides

Post-processing of temperature