Weather Modelling activities at DMI

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ACCORD — A Consortium for COnvection-scale modelling Research and Development

United Weather Centres

Introduction and operational framework

The **Danish Meteorological Institute (DMI)** was founded in **1872** and is responsible for **providing weather and climate forecasts for Denmark and Greenland**. The **Weather Models unit**, part of the **Weather Research department**, currently features 27 scientists working on a variety of core-funded and externally-funded numerical weather prediction (NWP) projects.

DMI issues **weather forecasts** with continuous cycling on the **DINI** (Northern Europe) and **IG** (Iceland-Greenland) **domains** at **2km** resolution through co-production with **UWC-W** partner institutes, as well as on three smaller domains **TAS**, **SGL**, and **NUUK** in Greenland at **750m** resolution.

In addition, forecasts are **triggered** on **three additional Greenland domains** when certain **thresholds** on average wind values corresponding to **storm conditions** are **exceeded** (Figure 1 and Table 1). Specifically, **observed values at stations** located inside the on-demand domains are checked as well as **model output** on the IG runs at 12UTC and 18UTC on the previous day.

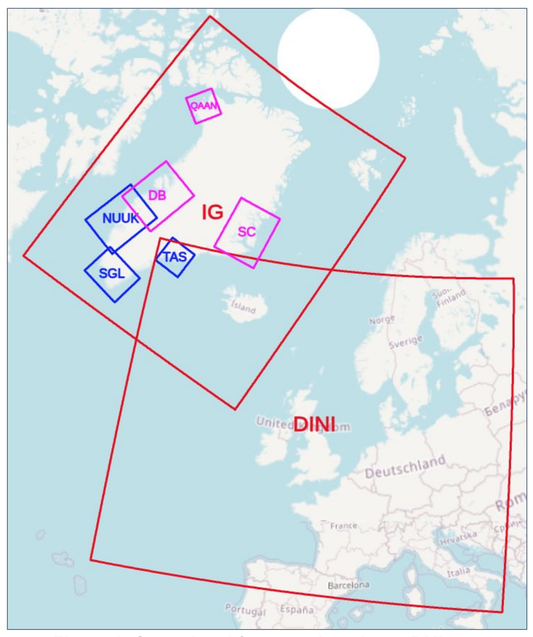

Figure 1: Operational forecast domains at **DMI**.

Suite name	Area coverage	Type of model	Mesh	Grid size (m)	Launch (Z)	Forecast Leadtime (h)	Time step (s)	OBS threshold (m/s)	MODEL threshold (m/s)
DINI-EPS	DINI20A, Northern Europe	Continuous cycling	1920x1620x90	2000	Hourly	60	50	-	-
IG	IG20A, Greenland/ Iceland	Continuous cycling	1350x1600x90	2000	00-21:03	72	60	-	-
TAS	TASIILAQ, Tasiilaq	Continuous cycling	400x400x90	750	00-18:06	60	15	-	-
SGL	SGL750, South Greenland	Continuous cycling	600x480x90	750	00-18:06	60	15	-	-
NUUK	NUUK750, Nuuk	Continuous cycling	600x800x90	750	00-18:06	60	15	-	-
DB	DB1000, Diskobugt	On-demand triggered	480x600x90	1000	00-18:06	60	25	15	20
SC	SC1000, Scores-bysund	On-demand triggered	480x600x90	1000	00-18:06	60	25	18	20
QAAN	QAAN, Qaanaaq	On-demand triggered	400x400x90	750	00-18:06	60	25	18	18

Table 1: Suites names and configuration features for **operational weather forecasts** at **DMI**.

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On-demand sub-km extreme weather modelling

DMI serves as the **technical coordinator** for the **Destination Earth On-Demand Extremes Digital Twin** project. It leads the DEODE operation and co-leads data-driven uncertainty quantification. As part of the EU's Destination Earth initiative, the project brings together a consortium of many NHMSs with primary objective to establish a technical framework for an integrated, on-demand workflow. This framework bridges hectometric-scale Numerical Weather Prediction (NWP) with impact sector applications, including flooding, storms, heatwaves, wildfires, storm surges, and renewable energy (solar/wind) applications.

The novel **DEODE Workflow** (Figure 2) features an **on-demand** high resolution NWP system, running the ACCORD forecast models **HARMONIE-AROME, AROME, and ALARO** at **sub-km scale** on domains suggested by the DEODE detection-triggering modules**.** The NWP simulations run on ECMWF ATOS or EuroHPC facilities and use Lateral Boundary Conditions from the ECMWF Global Digital Twin (4.4 km resolution) or operational models (9km resolution).

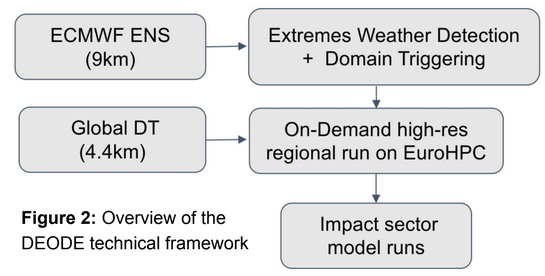

Figure 2: Overview of the DEODE technical framework

Simulation of the heaviest Danish rainfall events in 31 years

21-22 July 2025: The large-scale weather pattern was dominated by an undulating frontal zone, along which a surface low-pressure system developed. Precipitation was primarily concentrated in narrow, frontal rainbands, with periods of embedded convective cells intensifying rainfall in short, localized bursts. During the episode, four stations recorded precipitation exceeding 100 mm. The DEODE EPS-750 run successfully simulated a narrow band of high rainfall accumulation, closely aligning with observation.

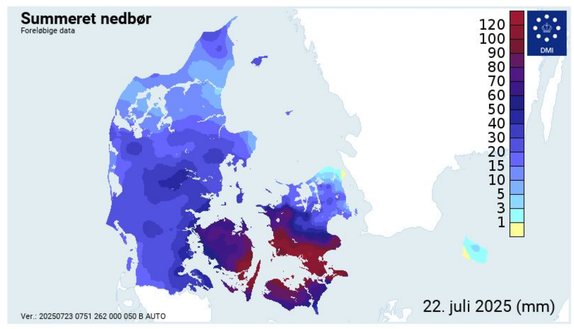

Figure 3: Total precipitation during 21-22 July 2025 as derived from Danish rain gauge network. This was the heaviest rainfall event in Denmark over the last 31 years. (Source: DMI)

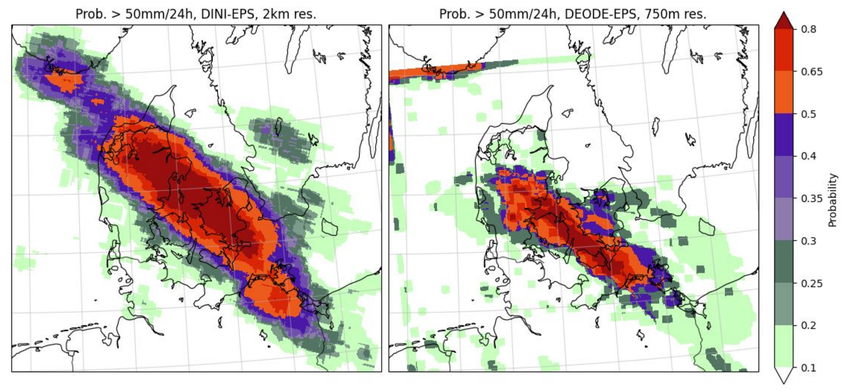

Figure 4: Upscaled 24-hour probabilities for precipitation exceeding 50 mm, as simulated by the operational DINI-EPS (2 km resolution, left) and the DEODE EPS Harmonie-Arome system (750 m resolution, right).

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Machine learning activities

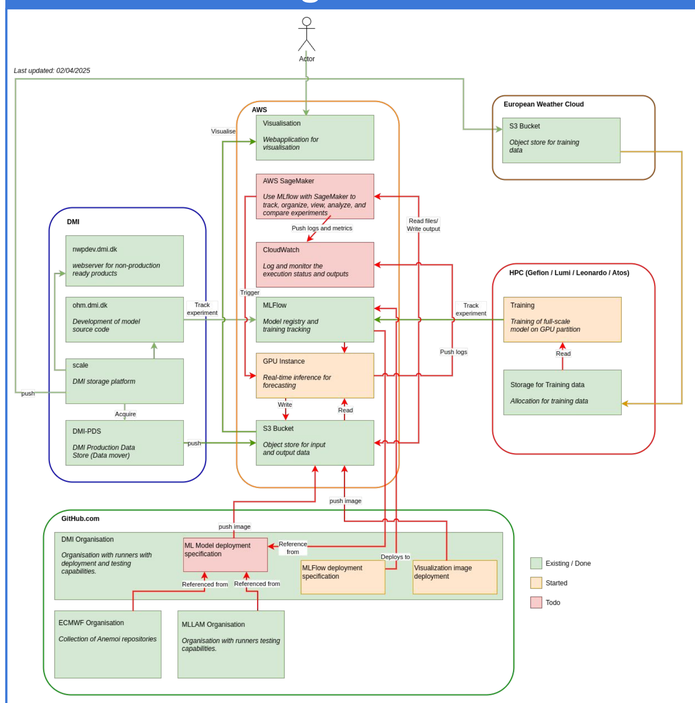
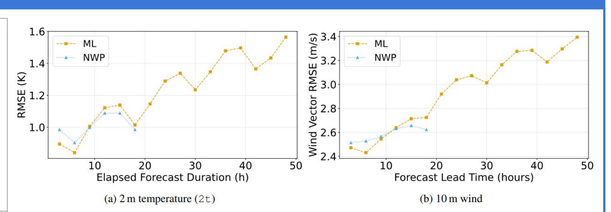


Figure 5: Overview of infrastructure plan and status of deployment of data-driven weather forecasting

Infrastructure & MLOps	• **ML pipeline**: complete workflow from data prep → training → evaluation with **DVC** for experiment tracking • **Data versioning:** zarr-based datasets • **Experiment tracking**: local **MLflow** on Gefion (air-gapped HPC) • **Deployment setup**: **GitHub runners** for automation, visualization partly integrated • First steps towards a reproducible and operational ML ecosystem at DMI
Supercomputer Training	**ANNA**: Graph neural network for km-scale forecasts (3-day window) trained in **NeuralLAM** framework. Orders of magnitude faster than NWP with comparable or lower error. Trained on **Gefion** HPC, requiring roughly **2,500 GPU hours** per run on **H100 80GB** cards, with a total effort on the order of 35K GPU hours across pre-training and fine-tuning cycles. Adamov, S. et al. Building machine learning limited area models: Kilometer-scale weather forecasting in realistic settings. arXiv preprint arXiv:2504.09340 (2025). **LDcast**: Latent diffusion model for precipitation nowcasting critical for flood response (Beredskabsstyrelsen). Multi-GPU scaling on LUMI & Leonardo Leinonen, J., Hamann, U., Nerini, D., Germann, U., & Franch, G. (2023). Latent diffusion models for generative precipitation nowcasting with accurate uncertainty quantification. arXiv preprint arXiv:2304.12891.
Vision	Our vision is to deliver AI-driven, faster, and more accurate weather forecasts by integrating machine learning models directly into DMI's operational systems, enabling timely and reliable predictions that serve both society and critical infrastructure.
Next Steps & Collaborations	• Contributing to ECMWF's **ANEMOI** framework for limited-area models • Train a stochastic ML LAM model, and add more variables, e.g. precipitation • Finish training ML nowcasting models of precipitation (e.g. LDcast) and solar radiation (see EnergyWeather below).



(a) 2 m temperature ($2t$) (b) 10 m wind

Figure 6: RMSE for the DANRA NWP and ANNA ML forecast models compared to station observations.

Steps Towards Operationalizing LeeWaveNet

LeeWaveNet is being adapted at DMI for the real-time detection of **trapped lee waves** in the **Iceland–Greenland** region. Current work focuses on ongoing **validation** over Norway and preparing integration into DMI's forecasting pipeline with automated data handling and scalable deployment. These steps mark the transition of LeeWaveNet from research towards **operational use,** supporting aviation safety and hazard awareness in the North Atlantic.

Coney, J., et al. (2023). Identifying and characterising trapped lee waves using deep learning techniques. Quarterly Journal of the Royal Meteorological Society, 150. 10.1002/qj.4592.

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Explore ML-LAM collaboration on GitHub

DANRA - Danish Reanalysis

DANRA is a 34-year, **2.5km** regional atmospheric reanalysis for Denmark and surrounding areas. Its high resolution representation of Danish coastline and **enhanced use of observations** in data assimilation helps to better capture climate and extremes (e.g. Aug 2007 cloudburst, see Fig. 7) than global reanalyses like ERA5.
DANRA is available as a **Zarr dataset** (doi.org/10.5281/zenodo.17294179).

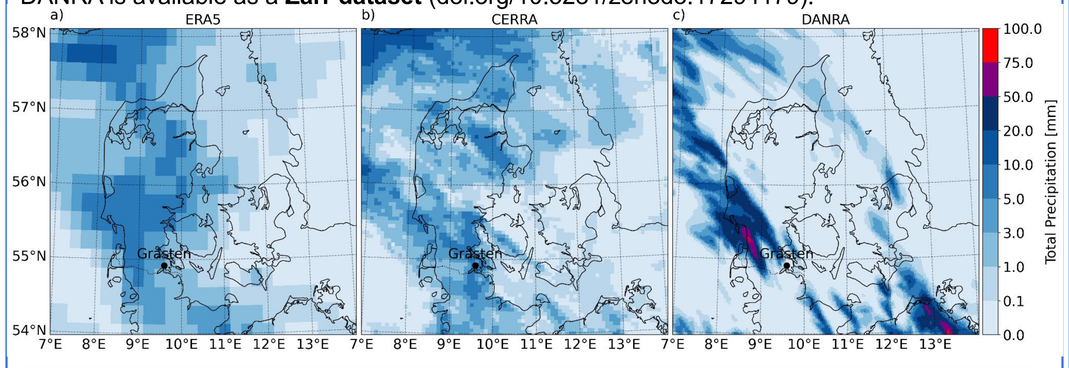

Figure 7: Accumulated Precipitation • August 20 2007, 15:00–21:00 UTC. Comparison of ERA5, CERRA, and DANRA reanalyses during the 20 August 2007 cloudburst, an extreme precipitation event recorded in Denmark, with more than 140 mm falling in 1.5 hours over Gråsten at the border of Denmark and Germany.

Yang et al: DANRA: The Kilometer-Scale Danish Regional Atmospheric Reanalysis, Earth Syst. Sci. Data, 18, 2251–2264, 2026 (https://essd.copernicus.org/articles/18/2251/2026/)

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EnergyWeather, IEA PVPS Task 16 and Weather2X

With increasing penetration of **wind and solar power**, **accurate forecasts** of potential **power production** are **key** to the **balancing** of the **electricity grid** and for t**hose producing, selling and buying power** in advance. In **Weather2X DMI**, in collaboration leading Danish institutions and power products aims to improve the forecasts of wind and solar radiation.

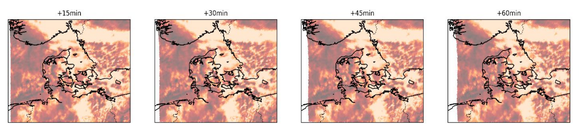
In **IEA PVPS Task 16**, international experts make recommendations for solar resource assessment and forecasting. **DMI** here works on benchmarking and quality assurance of NWP, reference year, and climate model datasets.

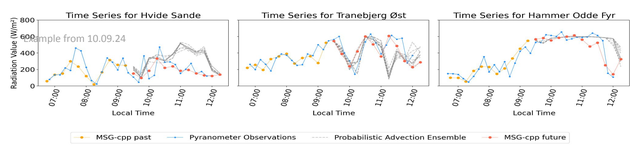
Solar radiation nowcasting
DMI is in charge of operationalizing satellite-based solar nowcasting for the National TSO, Energinet, using:

- **Optical flow** techniques, traditionally used for radar-based precipitation nowcasting, applied to satellite-derived surface solar radiation.
- Energy sector-driven **15 min-6h lead times with 15 min update frequency**
- Future work: **machine learning-based nowcasting model** trained on MSGcpp data, e.g. **SHADEcast**

Carpentieri, A., Folini, D., Leinonen, J., & Meyer, A. (2024). SHADECast: Enhancing solar energy integration through probabilistic regional forecasts (No. EGU24-5571). Copernicus Meetings.

Probabilistic Advection





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