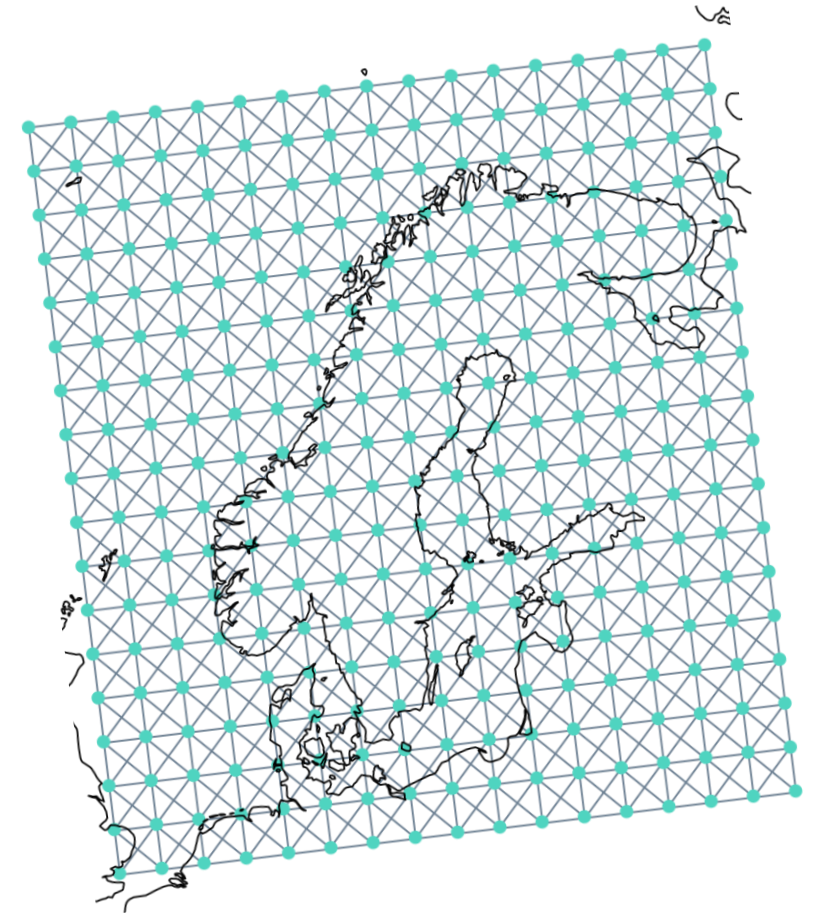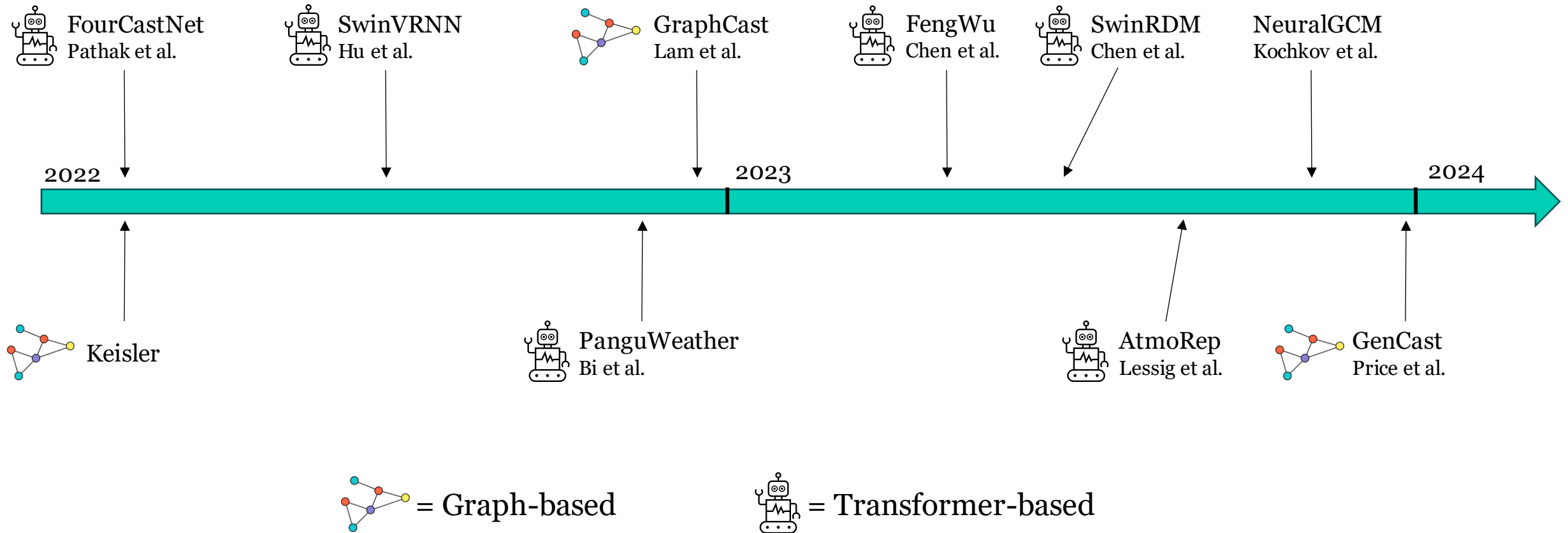# Neural Weather Prediction for Limited Area Modeling

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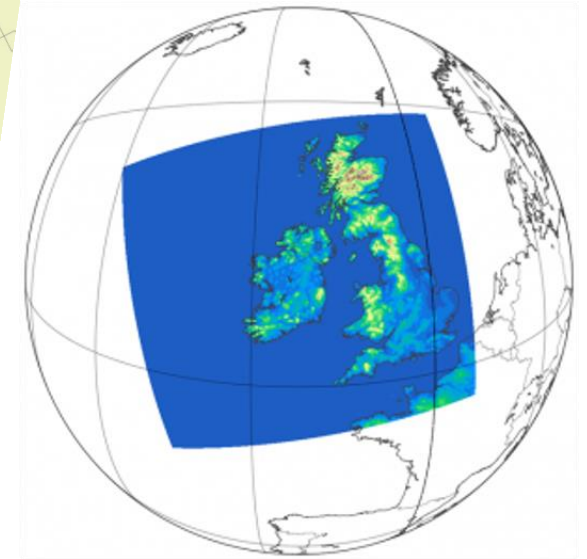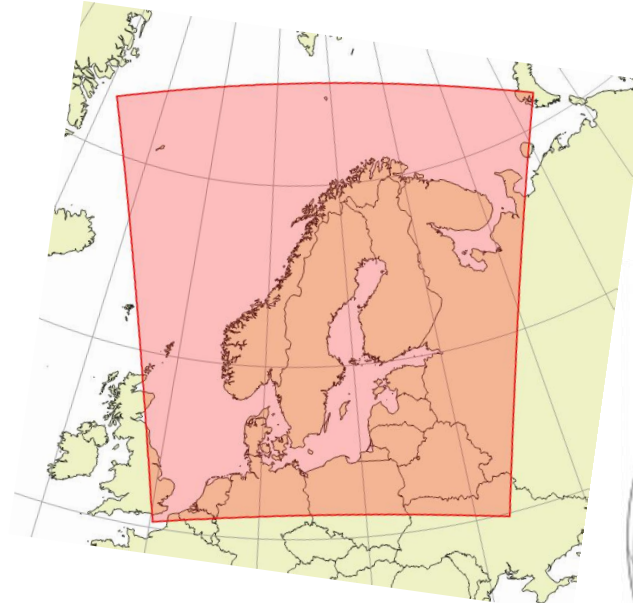Joint work with: Tomas Landelius (SMHI), Fredrik Lindsten (LiU)

LI.U LINKÖPING UNIVERSITY

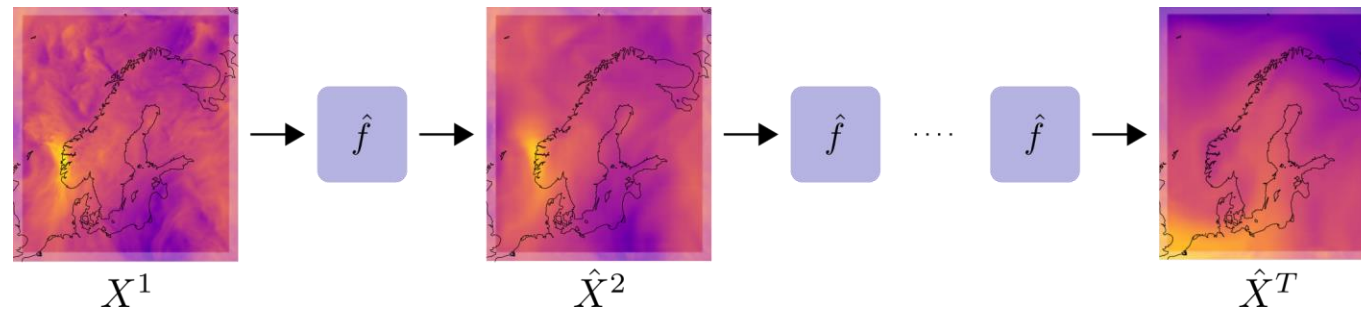# A timeline of global model

Neural Limited Area Models (LAM)

- Smaller scale models
  - o Computationally cheaper
  - o Large ensemble forecasts

- Finer resolution

- Utilize LAM datasets
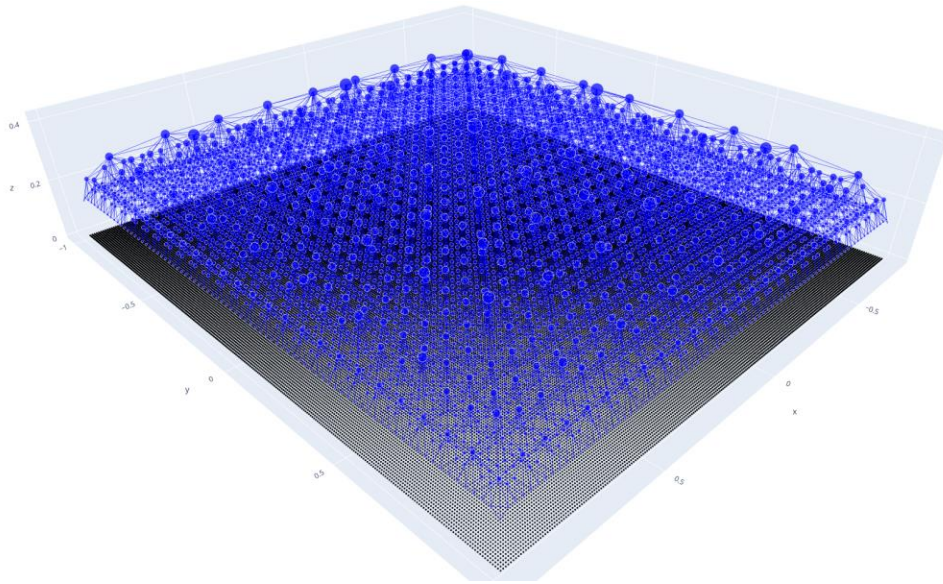
Machine learning for NWP

- Weather state X^t

- Dynamics model $X^t = f(X^{t-1}, \ldots, X^{t-p})$

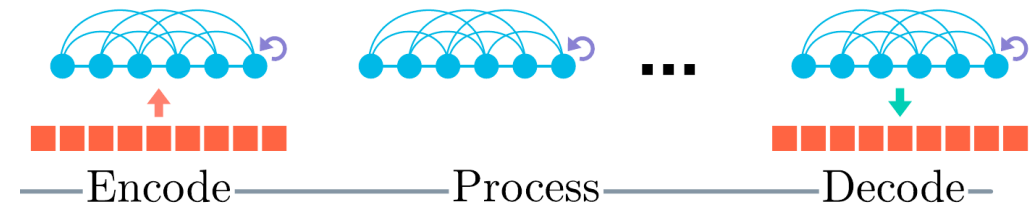- Approximate with machine learning model $\hat{f} \approx f$

- Train on dataset of trajectories $X^1, X^2, \ldots, X^T$.
    - Forecast data: Fast surrogate model
    - Reanalysis data: Surpass existing NWP

Graph-based Neural Weather Prediction[1]

- Construct mesh graph covering forecast area

- The encode-process-decode framework

Encode ——— Process ——————— Decode

- Graph Neural Networks (GNNs)

[1] Keisler, R. (2022). Forecasting global weather with graph neural networks. *arXiv preprint*.
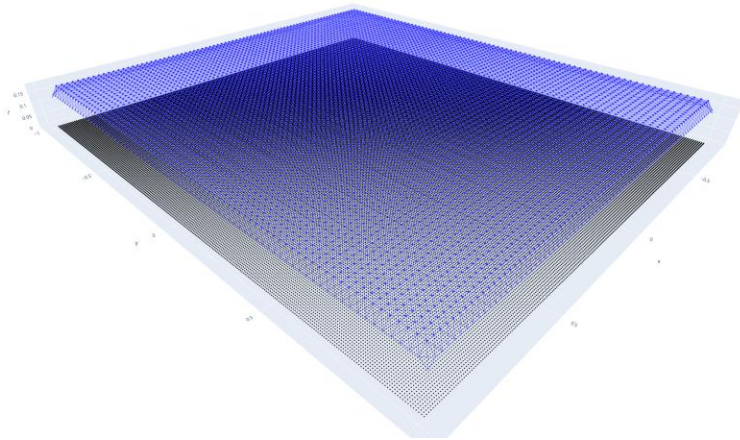
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Dataset from MetCoOp Ensemble Prediction System (MEPS)

- Limited area NWP system
  - 10 km resolution, 238 × 268 grid
  - Idea: Emulate with fast deep learning model[1]
- Dataset:
  - 6000 forecasts
  - 57h forecasting time
  - 3h time steps
- Variables:
  - Wind, temperature, water vapor, solar radiation, pressure, geopotential, humidity
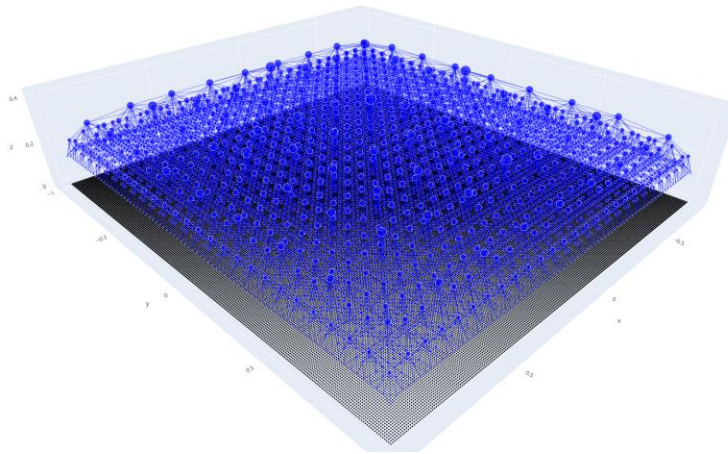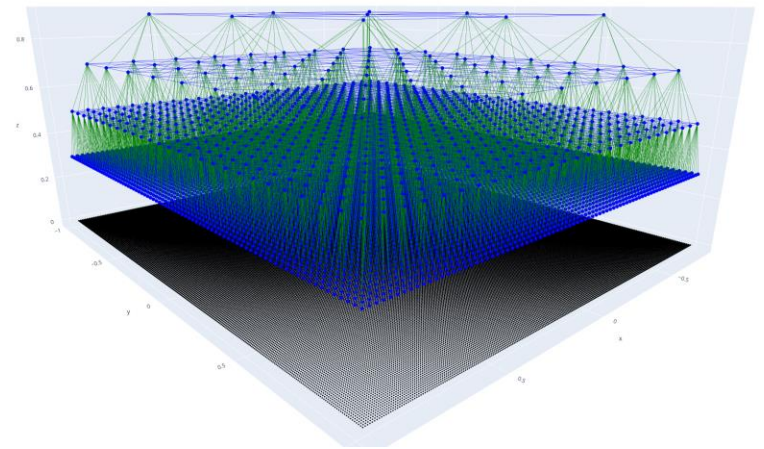- Forcing inputs:
  - e.g. land/water mask

[1] Oskarsson, J., Landelius, T., & Lindsten, F. (2023). Graph-based Neural Weather Prediction for Limited Area Modeling. *Tackling Climate Change with Machine Learning workshop @ NeurIPS 2023.*

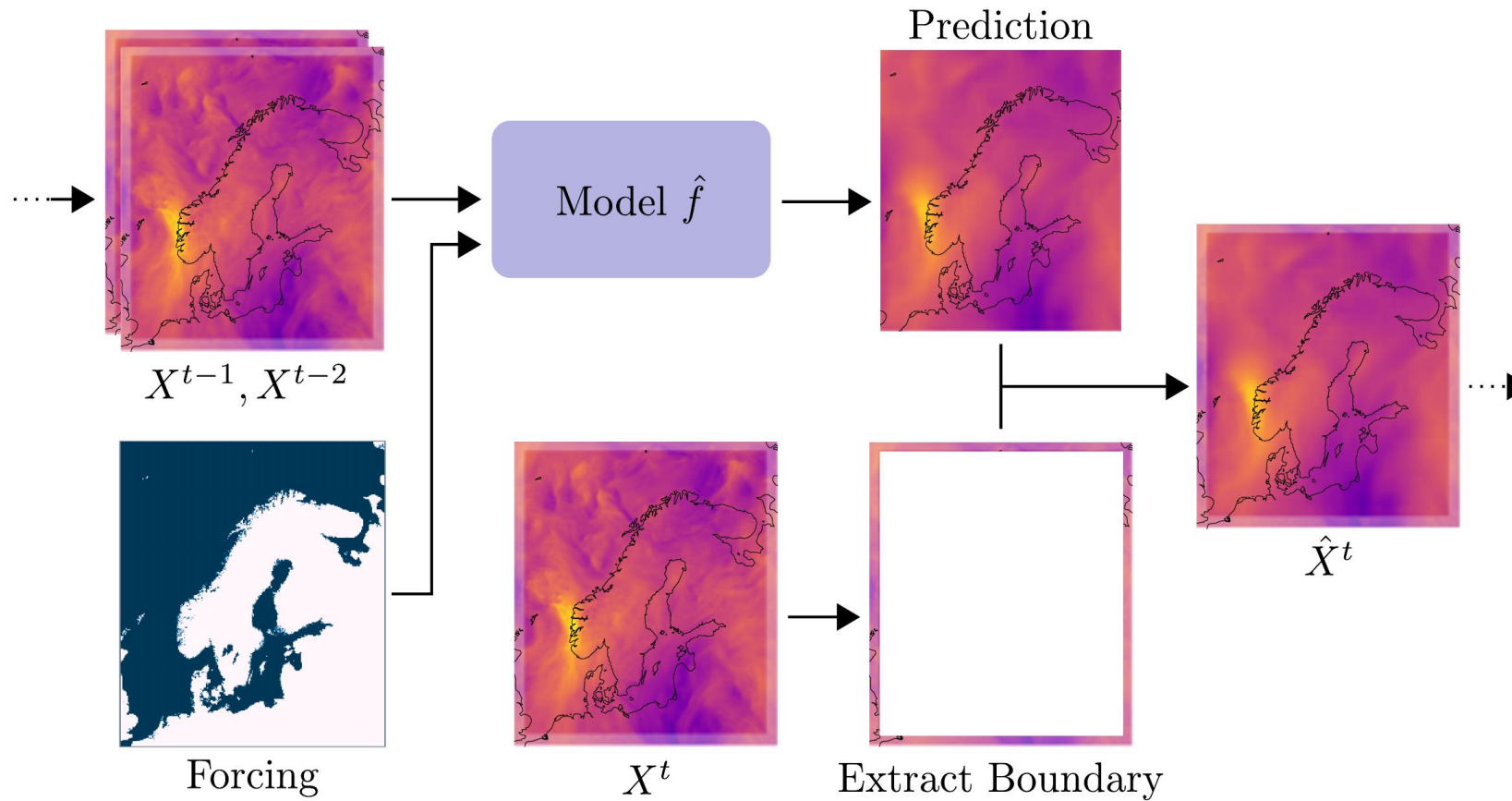# Mesh graph for LAM

Single resolution mesh[1]: 1L-LAM   Multi-scale mesh[2]: GC-LAM   Hierarchical mesh: Hi-LAM

[1] Similar to model from: Keisler, R. (2022). Forecasting global weather with graph neural networks. *arXiv preprint*.
[2] Similar to GraphCast: Lam, R., et al. (2023). Learning skillful medium-range global weather forecasting. *Science*.
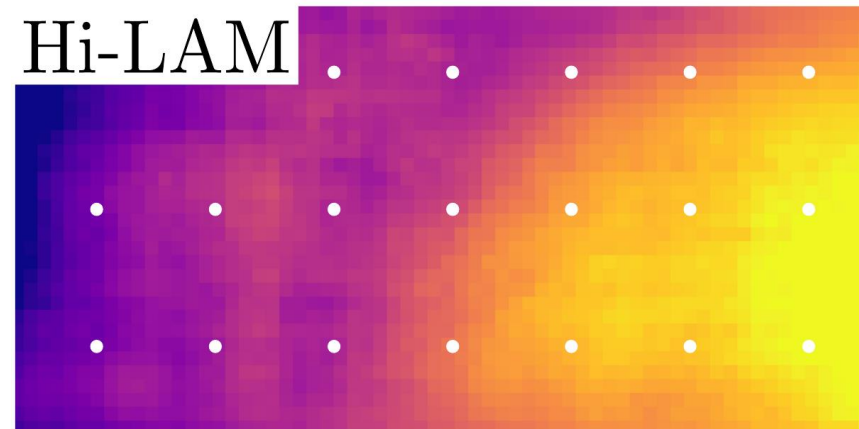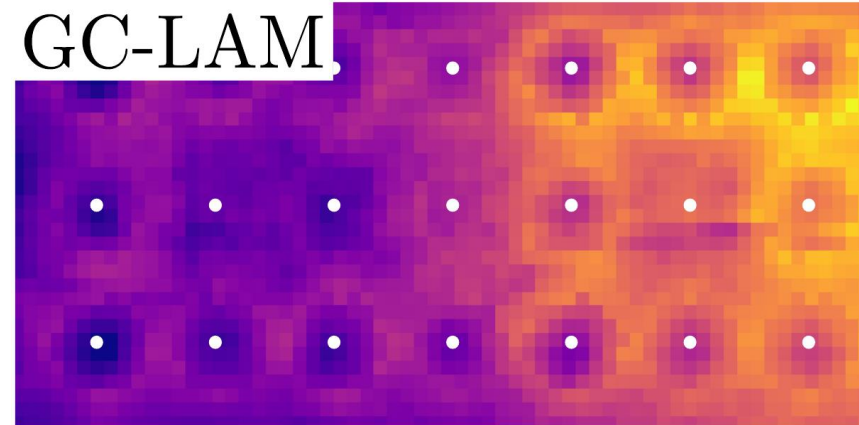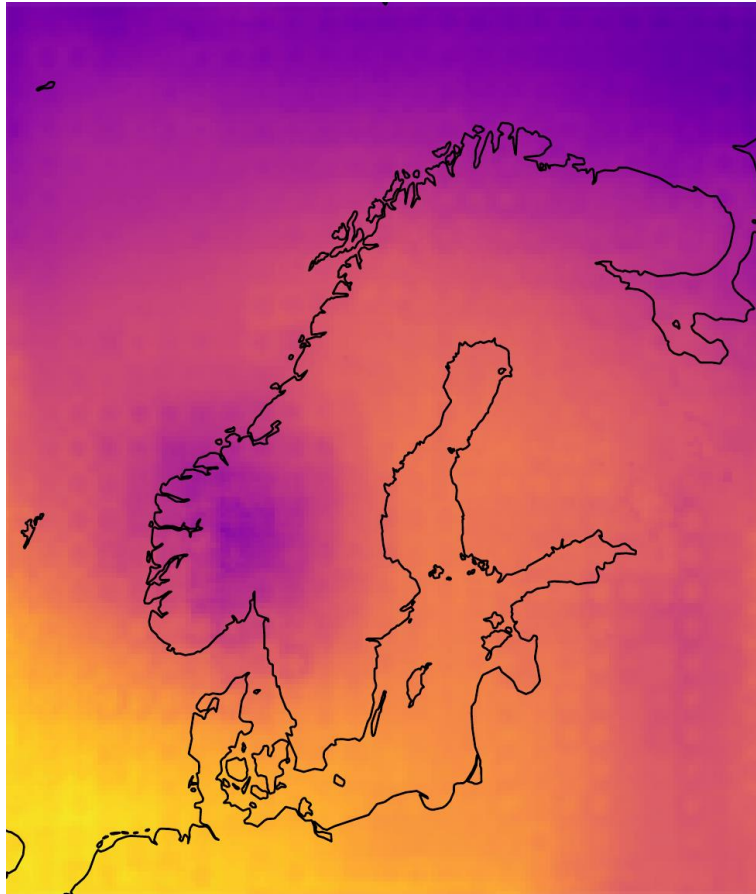
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Boundary forcing

Results: Example forecasts

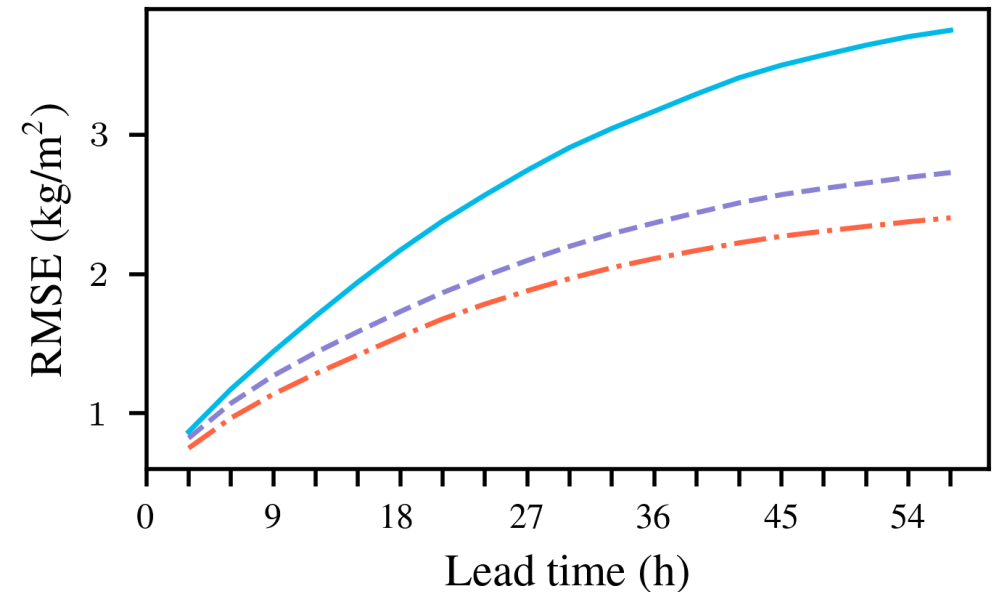

Net longwave radiation
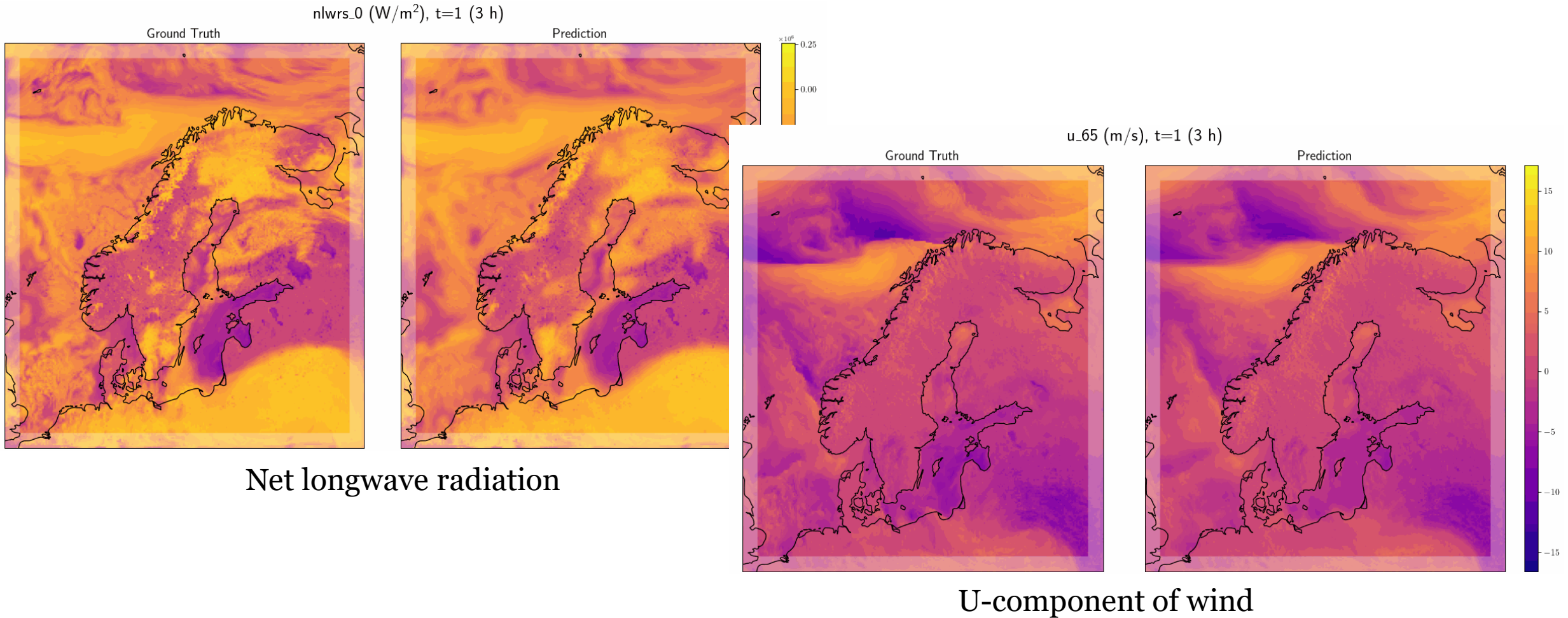
U-component of wind

Results: Artefacts

Results: Errors over time
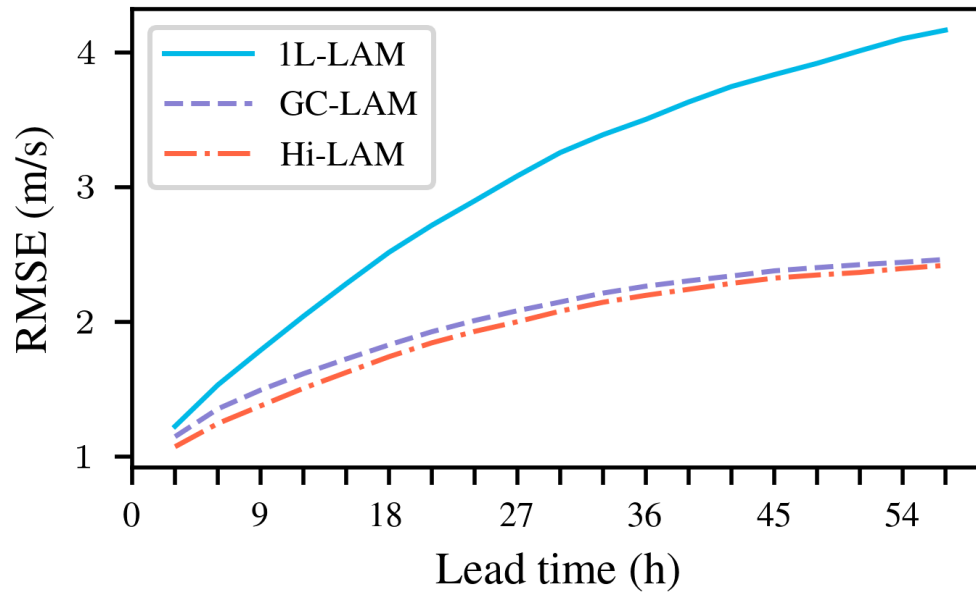
V-component of wind

Total water vapor column
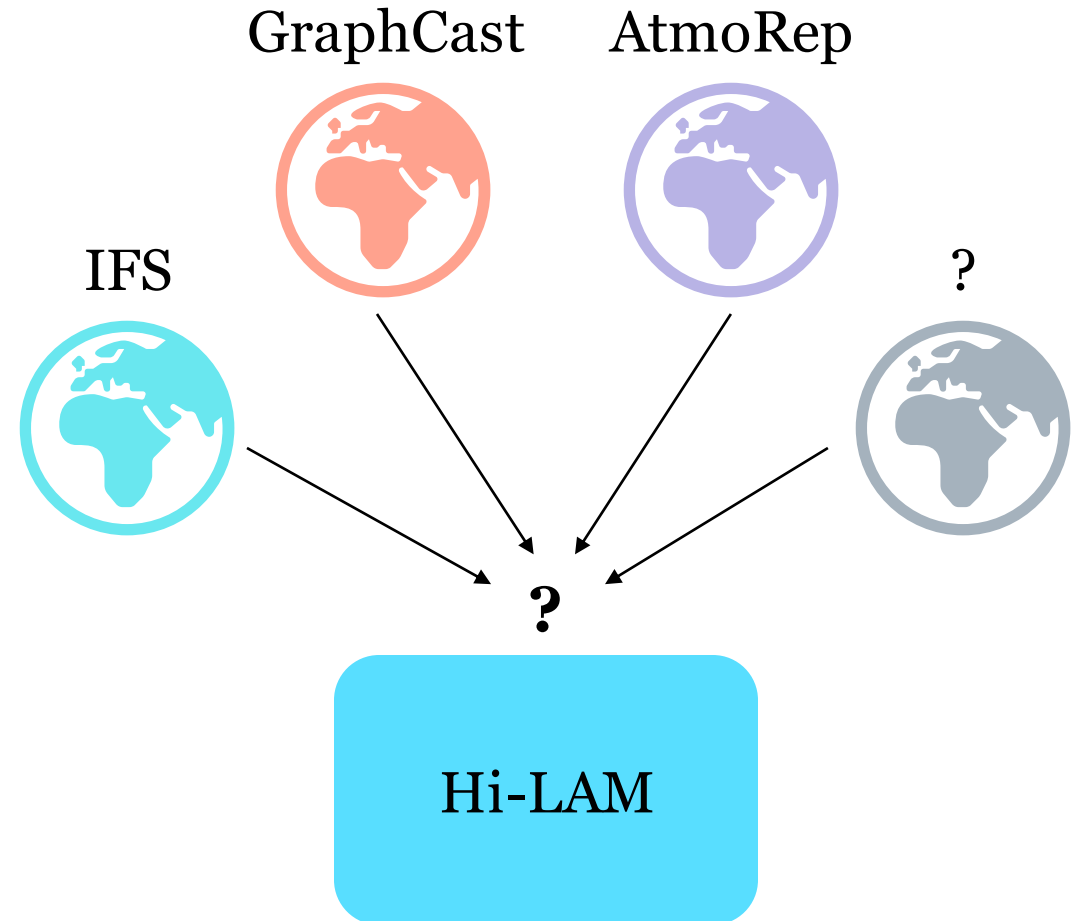
Our implementation: Neural-LAM

- github.com/joeloskarsson/neural-lam

- PyTorch implementation

- Maintained and collaborative
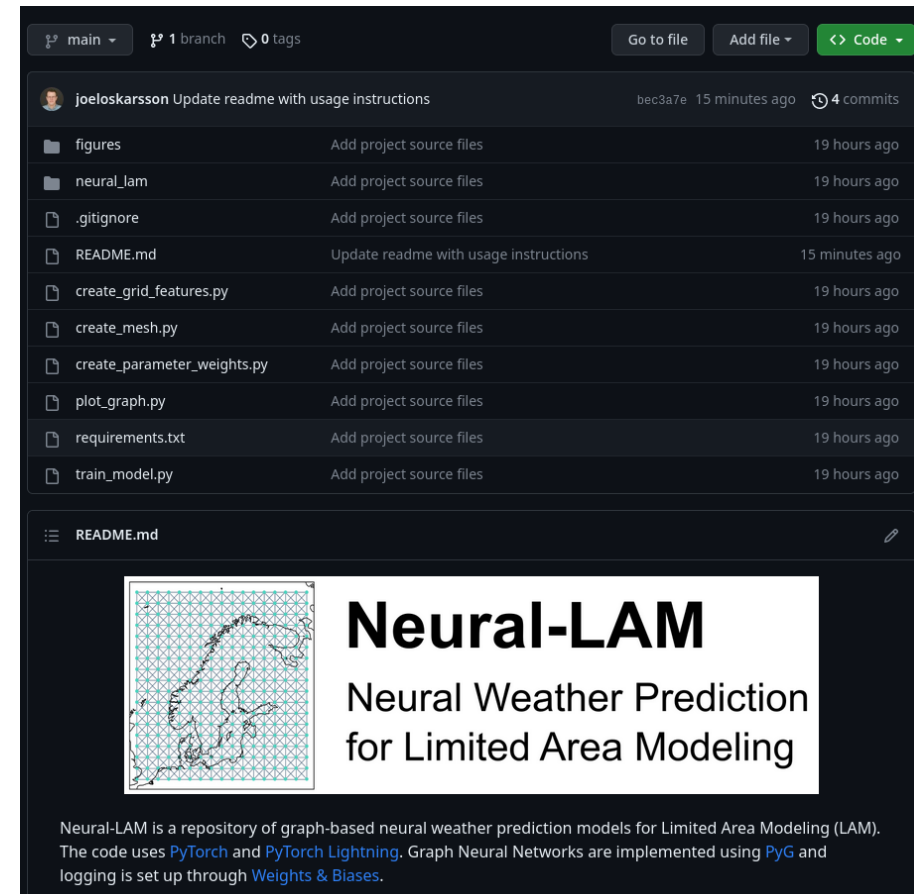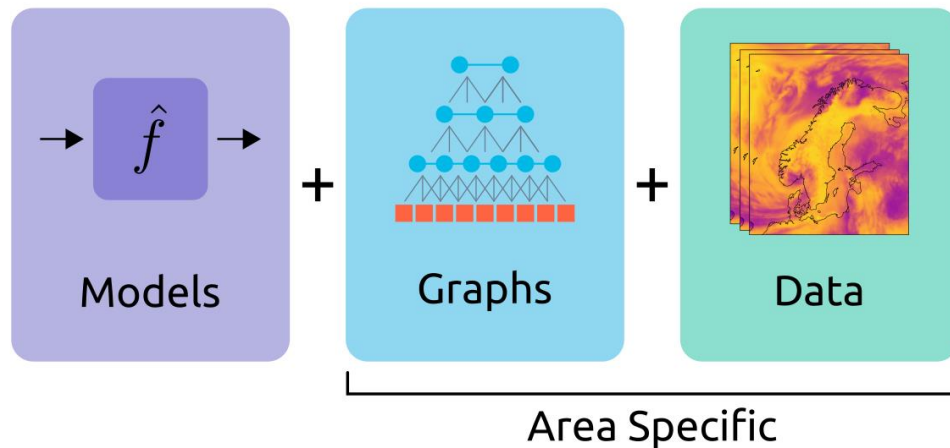
Outlook: Neural LAM

- Connecting global and LAM models
  - Couple with coarse global model?
  - Forcing from global forecast?

- Probabilistic modeling
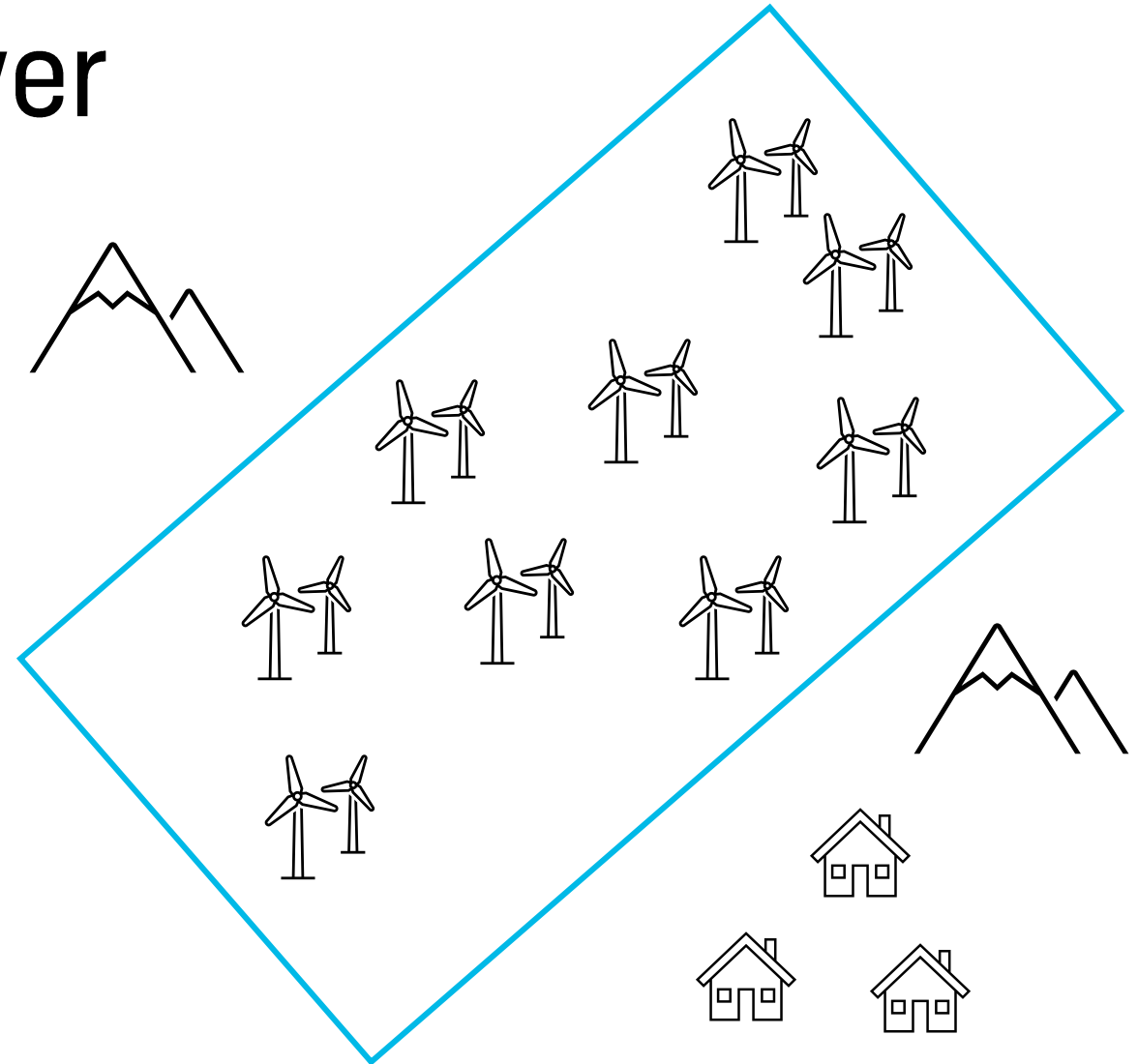 - Ensemble forecasting

GraphCast   AtmoRep

IFS

?

?

Hi-LAM

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Speculation: Wind power

- LAM models for wind power sites

- Modeling uncertainty

$$P\left(\text{wind speed} > x \mid X^0\right)$$

- Data
  - Training data challenge
  - Combining weather and generation data

Neural Weather Prediction for Limited Area Modeling

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`joeloskarsson.github.io`

Paper: arxiv.org/abs/2309.17370

Code: github.com/joeloskarsson/neural-lam

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