Forecasting the Weather with Graph Neural Networks
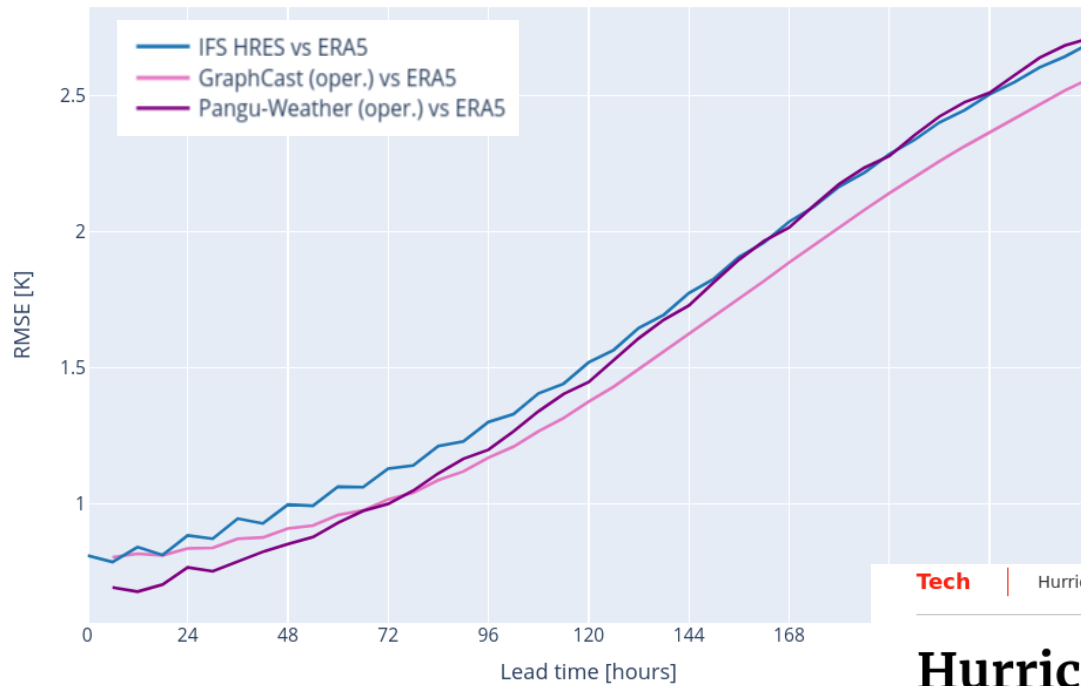
Learning on Graphs and Geometry Meetup 2025

Joel Oskarsson
Linköping University

LiU LINKÖPING UNIVERSITY

Machine Learning Weather Prediction (MLWP)

2 m temperature

The AI weather forecaster arrives

BY PAUL VOOSEN

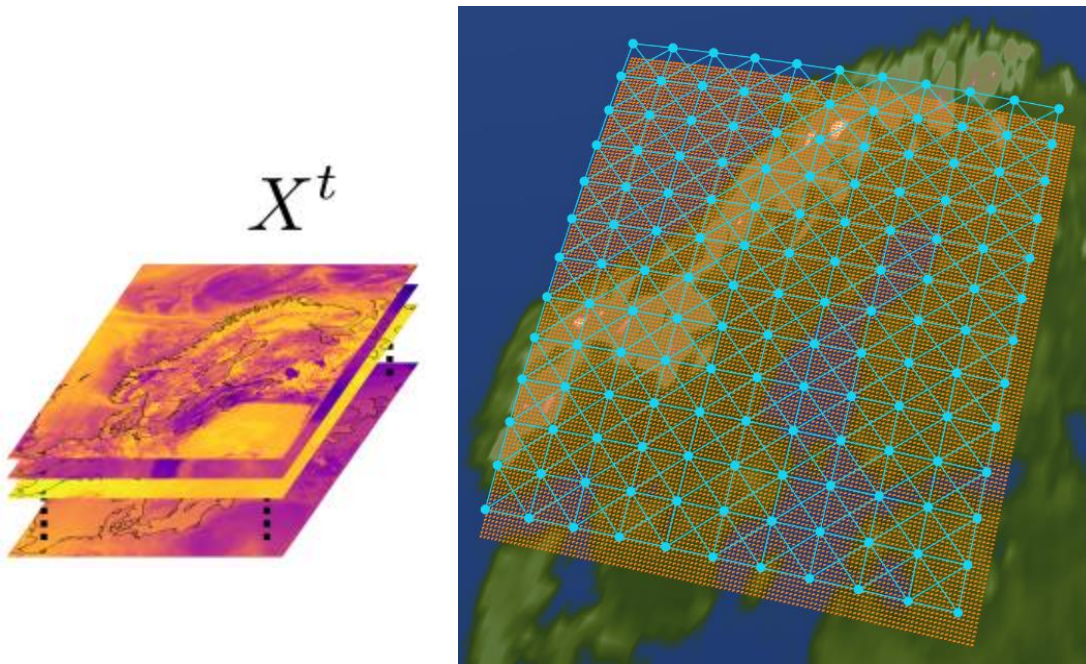Tech | Hurricanes   Artificial Intelligence   Machine Learning

Hurricane Milton's Path Predicted With 'Unbelievable Accuracy'—Here's Why

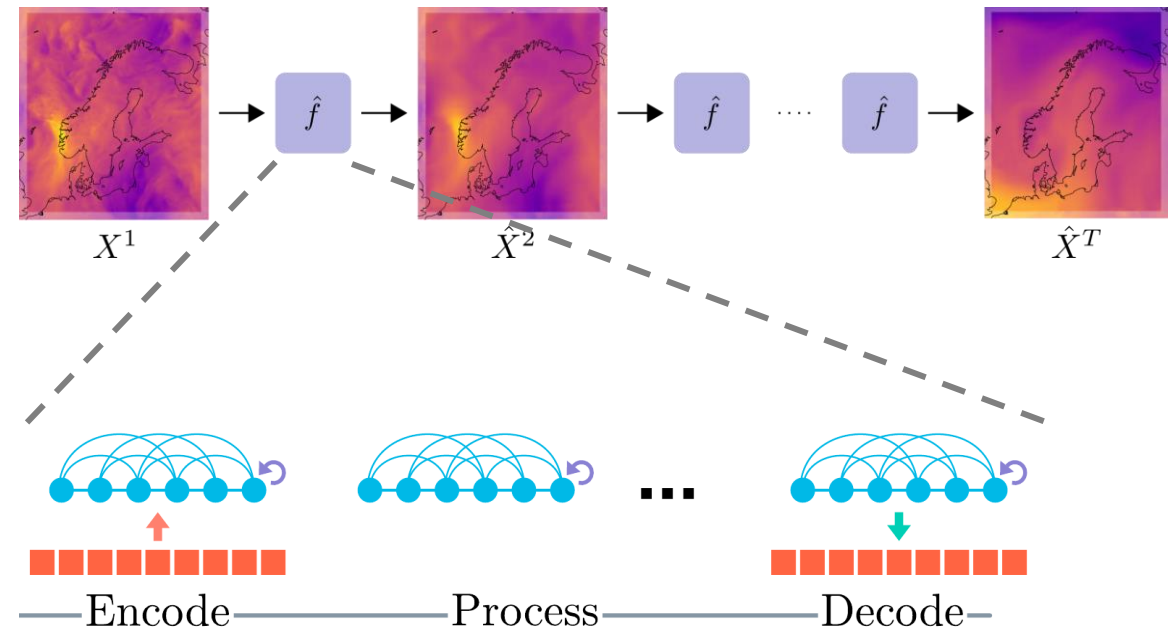Published Oct 14, 2024 at 7:08 AM EDT   Updated Oct 14, 2024 at 12:41 PM EDT

ADVERTISING

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Graph-based MLWP[1]

- Constructed mesh graph

X^t

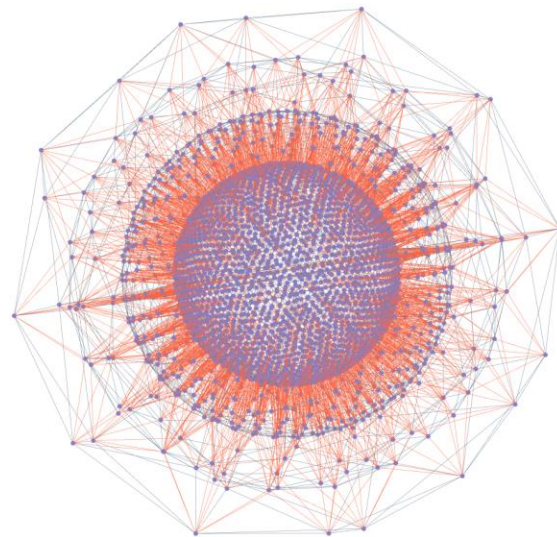- Encode-Process-Decode

X^1 $\hat{X}^2$ $\hat{X}^T$

—Encode——— Process———Decode—

- GNNs: Interaction nets[2], Sparse transformers

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[1] R. Keisler (2022). Forecasting global weather with graph neural networks. *Preprint.*

[2] P. Battaglia et al. (2016). Interaction Networks for Learning about Objects, Relations and Physics. *NIPS.*
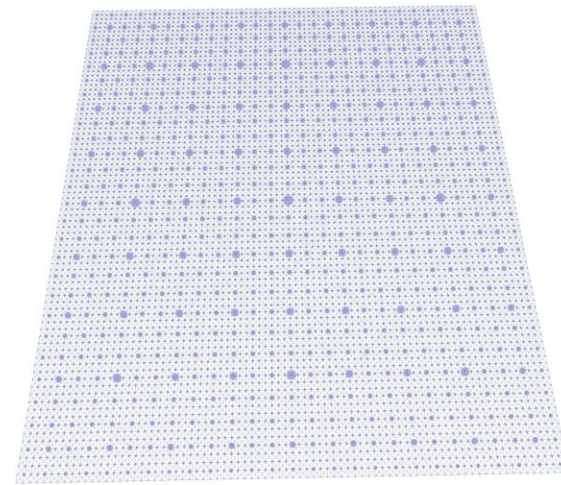
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Graph design

- Global models
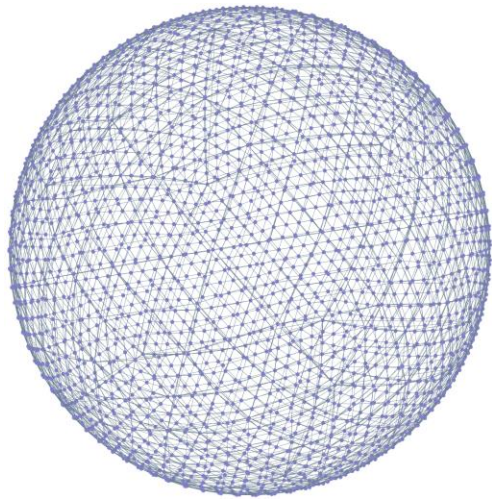
- Limited Area Models

Probabilistic weather forecasting

X^{t-1} → ? → X^t
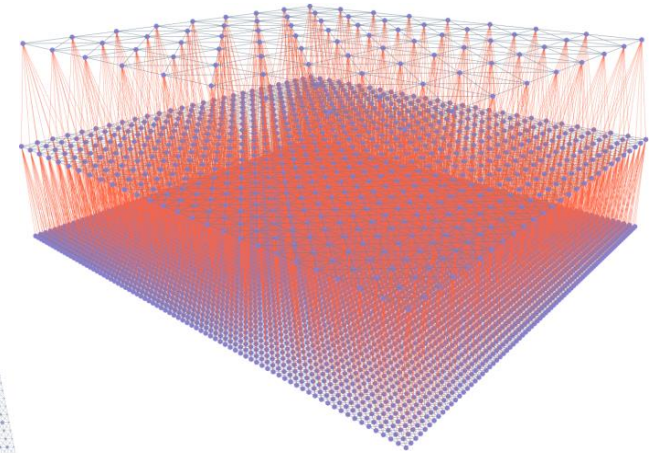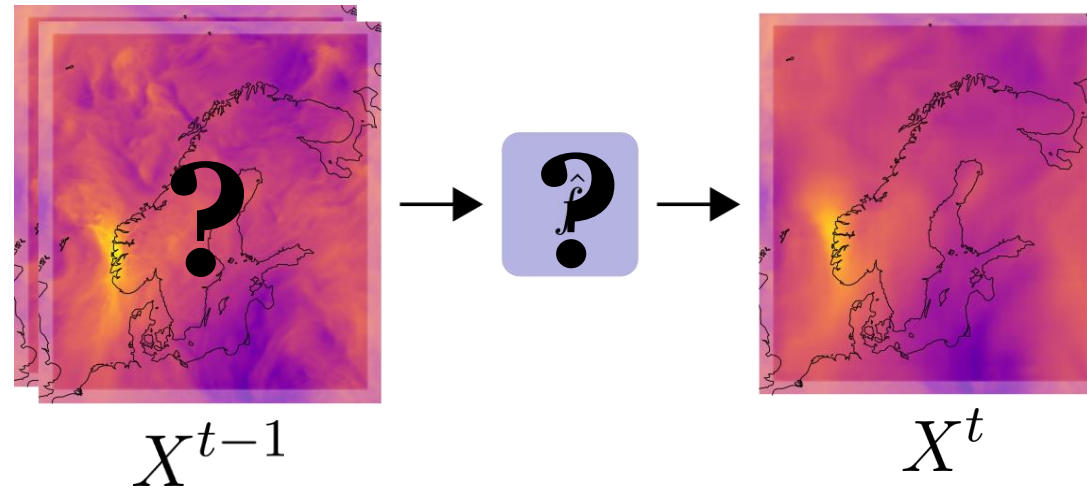
Quantifying forecast uncertainty:
- Capture full distribution

$$p\left(X^{1:T}\middle|X^0\right)$$

- Ensemble forecasting

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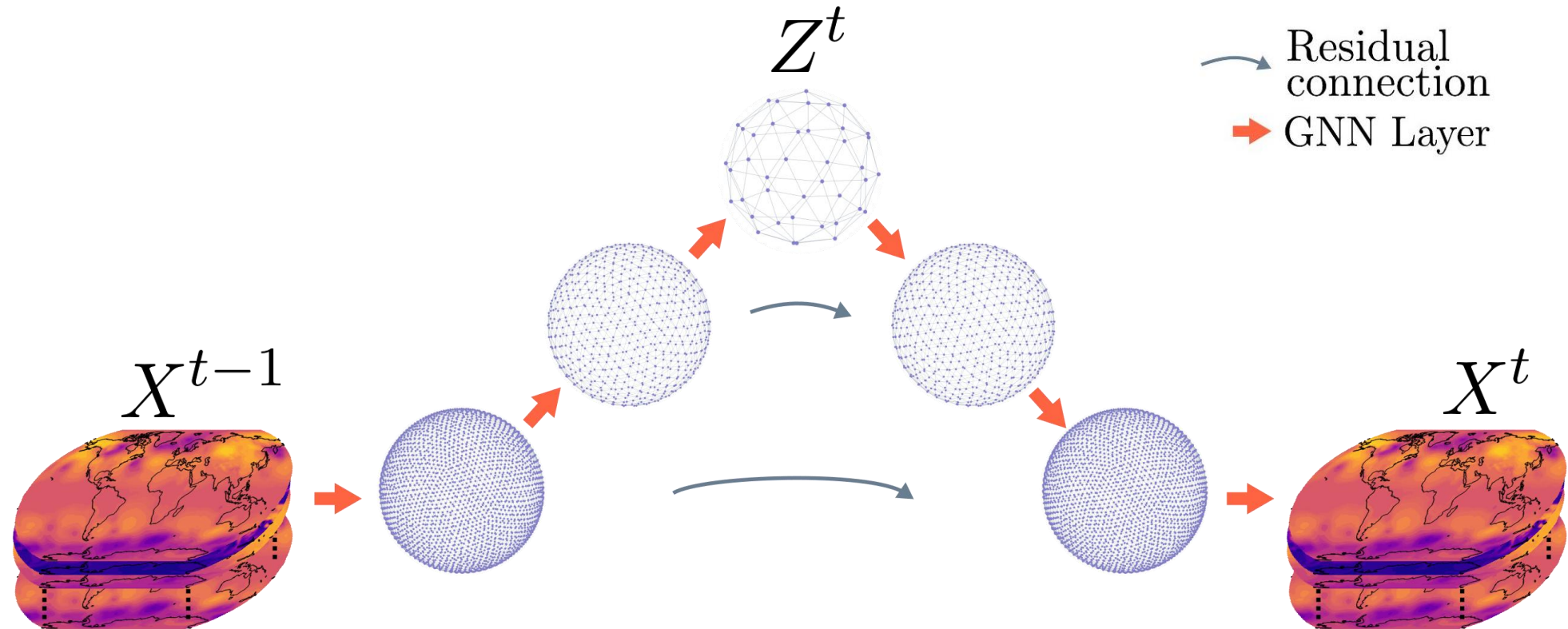UNIVERSITY

Graph-based latent variable model
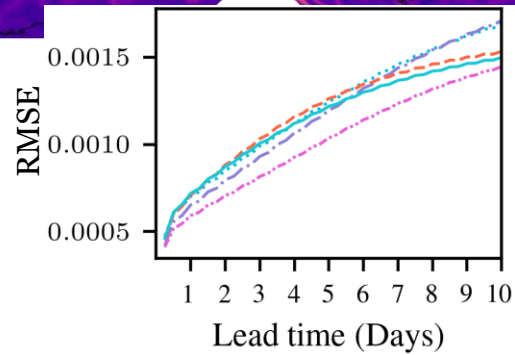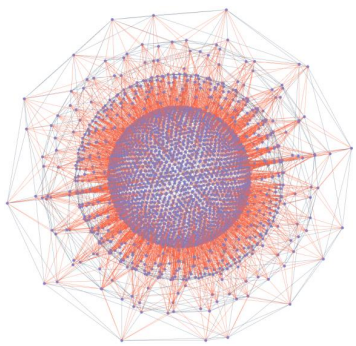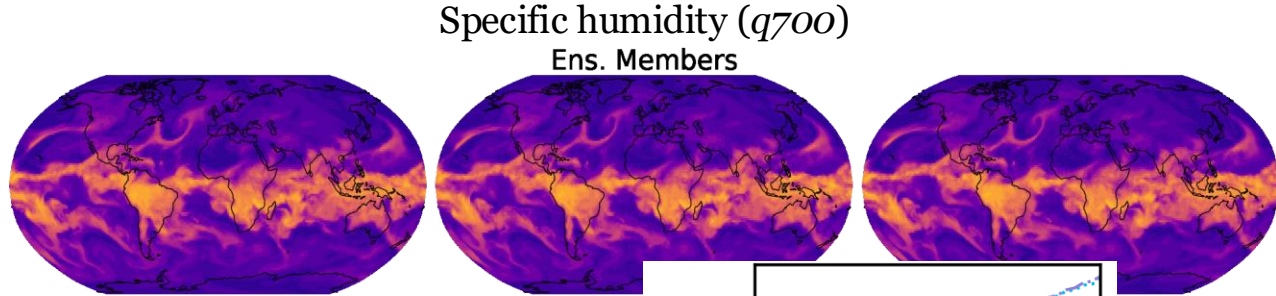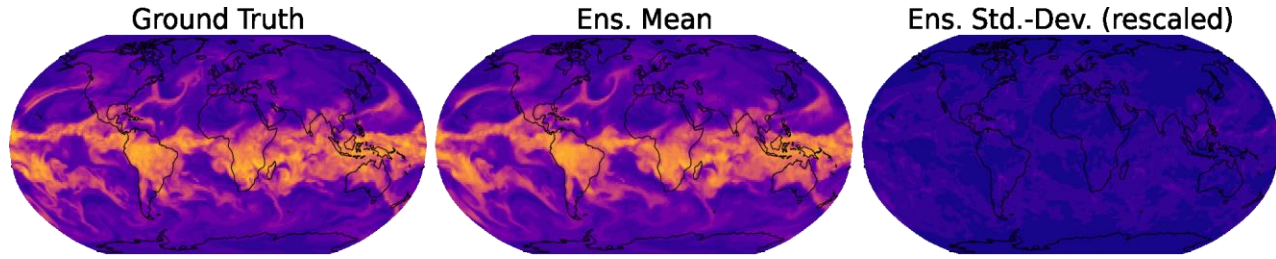
- Latent random variable Z^t

- + Hierarchical graphs
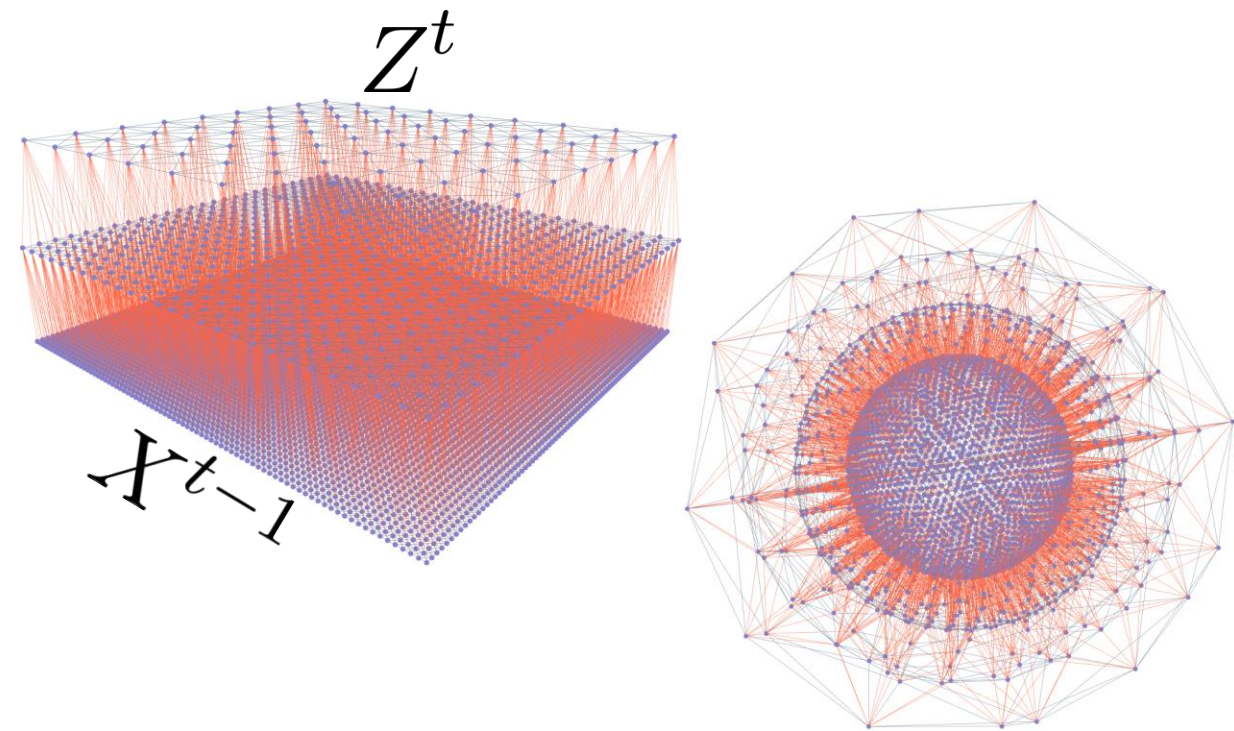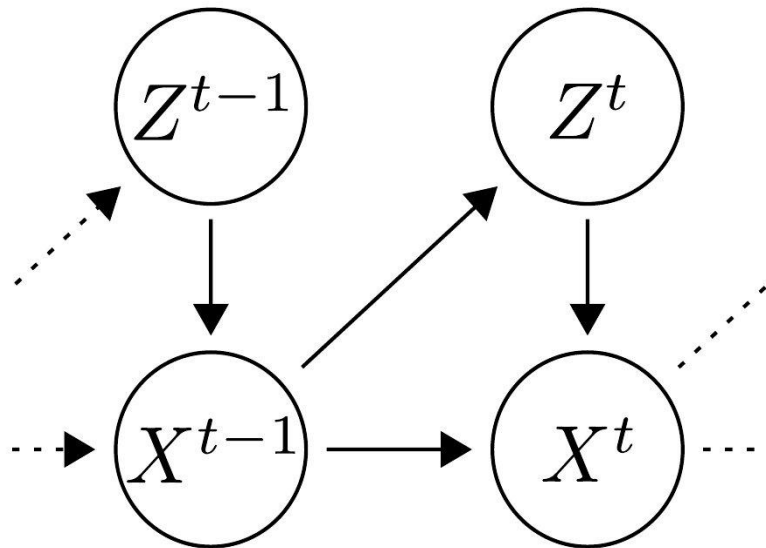
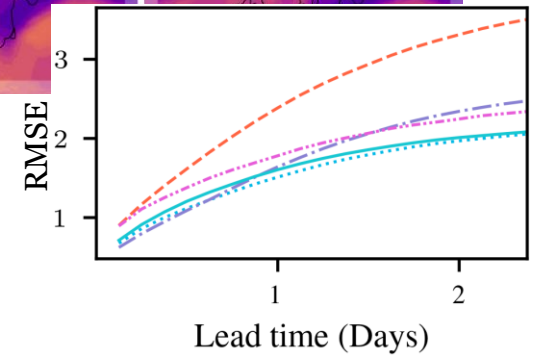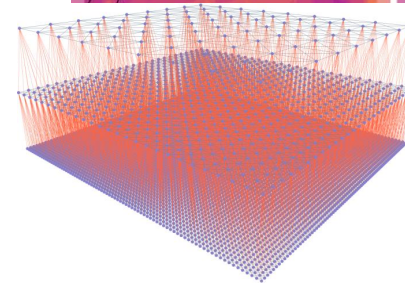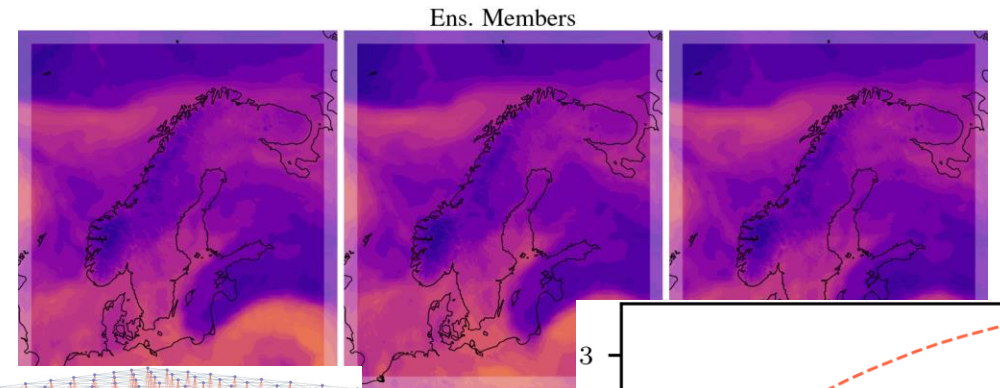# Graph-EFM: Graph-based Ensemble Forecasting Model[1]

[1] J. Oskarsson, et al. (2024). Probabilistic Weather Forecasting with Hierarchical Graph Neural Networks. *NeurIPS*.
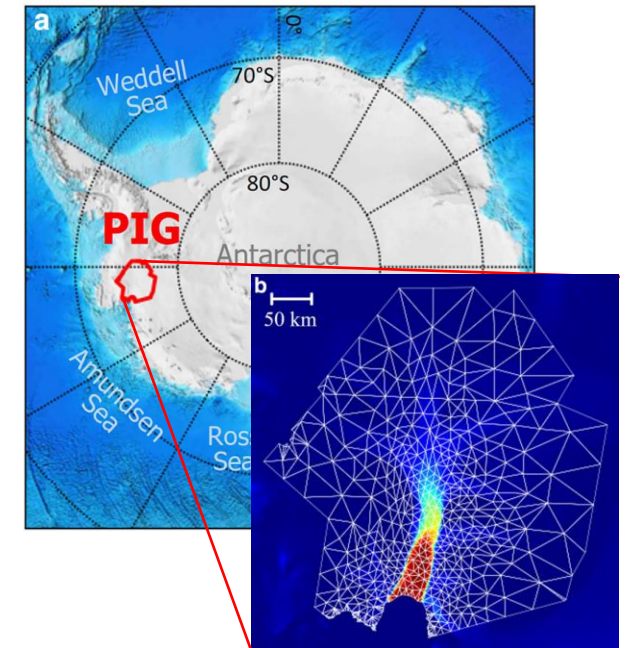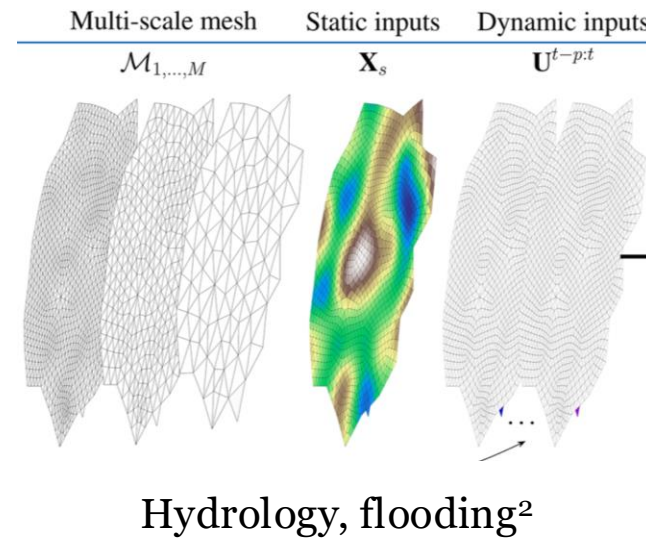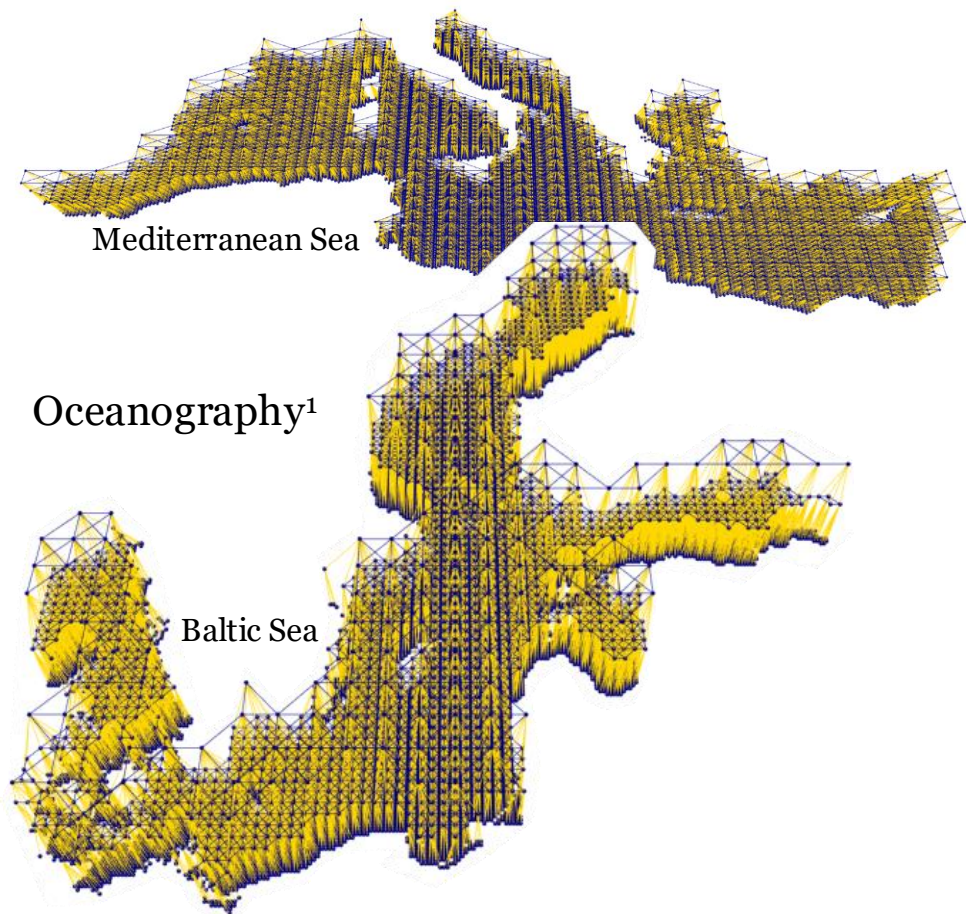
Forecasts

Specific humidity (*q700*)
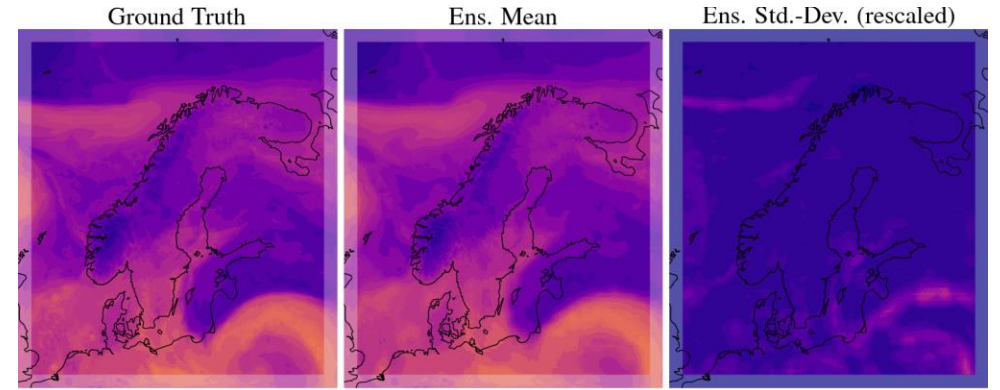
Water vapor (*wvint*)

GraphCast*   Graph-FM   Graph-EFM (ms)   Graph-EFM   GraphCast*+SWA

Outlook: Fun with graphs in earth science

Mediterranean Sea

Oceanography[1]

Baltic Sea

Multi-scale mesh $\mathcal{M}_{1,...,M}$
Static inputs $\mathbf{X}_s$
Dynamic inputs $\mathbf{U}^{t-p:t}$

Hydrology, flooding[2]

Glacier modeling[3]

[1] D. Holmberg et al. (2024). Regional Ocean Forecasting with Hierarchical Graph Neural Networks. *NeurIPS 2024 CCAI Workshop*.
[2] R. Bentivoglio et al. (2025). Multi-scale hydraulic graph neural networks for flood modelling. *Natural Hazards and Earth System Sciences*.
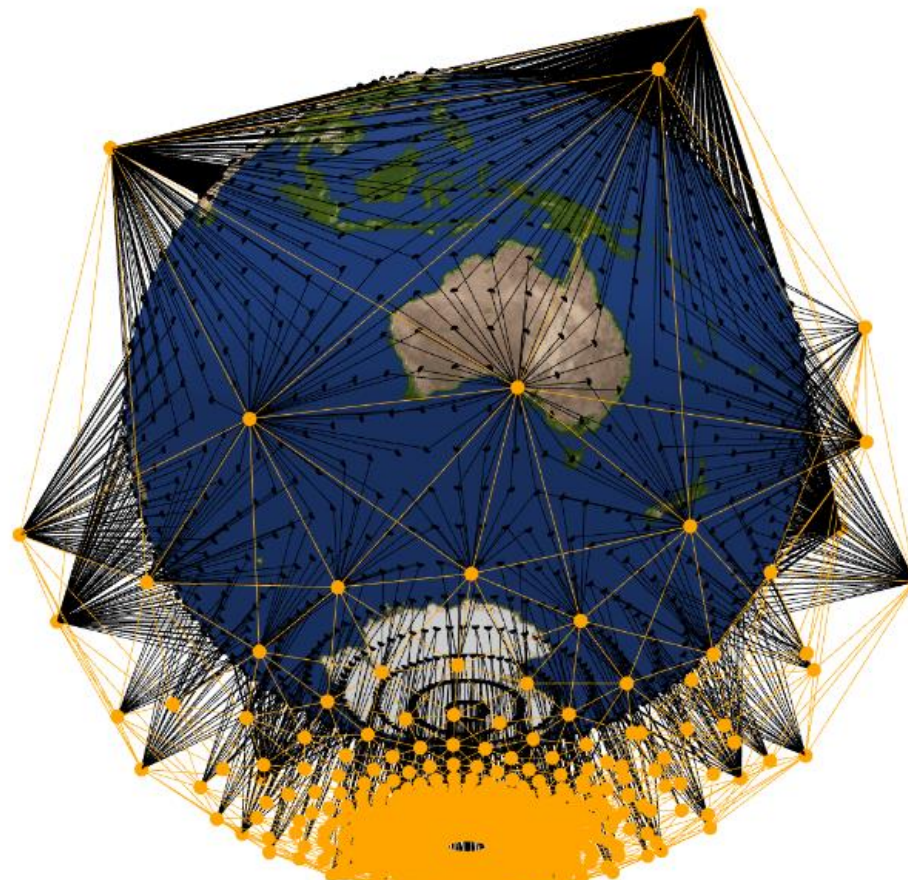[3] Y. Koo & M. Rahnemoonfar (2024). Graph convolutional network as a fast statistical emulator for numerical ice sheet modeling. *Journal of Glaciology*.

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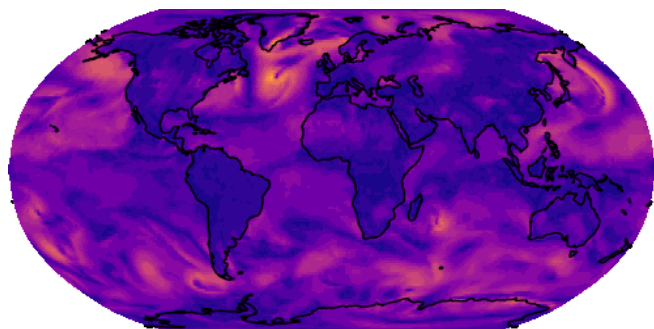
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J. Oskarsson, T. Landelius, M.P. Deisenroth, and F. Lindsten. Probabilistic Weather Forecasting with Hierarchical Graph Neural Networks. In *Advances in Neural Information Processing Systems,* 2024.

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