

Diffusion-LAM: Probabilistic Limited Area Weather Forecasting with Diffusion

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Machine Learning for Weather Forecasting

Machine learning methods have been shown to be an effective approach for weather forecasting based on the speed and accuracy compared to traditional numerical models. While early efforts primarily concentrated on deterministic predictions, the field has increasingly shifted toward probabilistic forecasting to better capture the forecast uncertainty.

Main Contributions

- We propose a new framework for encoding boundary information in the limited area modeling (LAM) setting, allowing conditioning on boundary conditions from a global forecast also at future time steps. This results in better alignment with the boundary compared to previous methods.
- We develop a conditional diffusion model tailored to LAM weather forecasting making use of the boundary encoding framework.
- We show in experiments on the MEPS LAM dataset that the model achieves accurate ensemble forecasts with highly detailed and physically realistic fields.

Diffusion-LAM [1]

This work introduces Diffusion-LAM, a probabilistic limited area weather model leveraging conditional diffusion. We introduce a new framework for boundary encoding in the LAM setting where we also include the boundary of the previous time step.

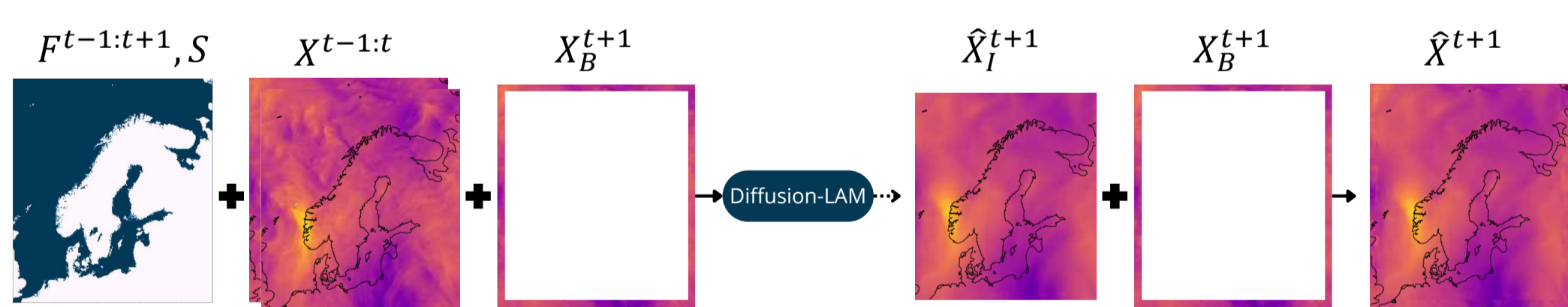


Figure 1: An overview of the prediction process showing the inputs and outputs of the model.

By conditioning on boundary data from surrounding regions, our approach generates forecasts within a limited area.

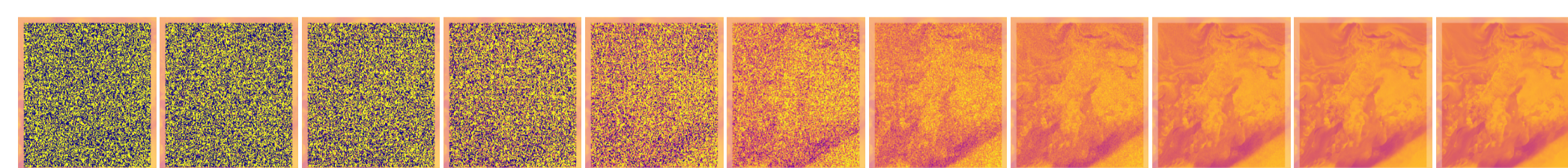


Figure 2: The noise process for r_2 (relative humidity).

We sample 57 h (3 h time steps) forecasts with 25-ensemble members using batched sampling in 8 min (20 s per ensemble member) on a single 80 GB A100 GPU.

Results

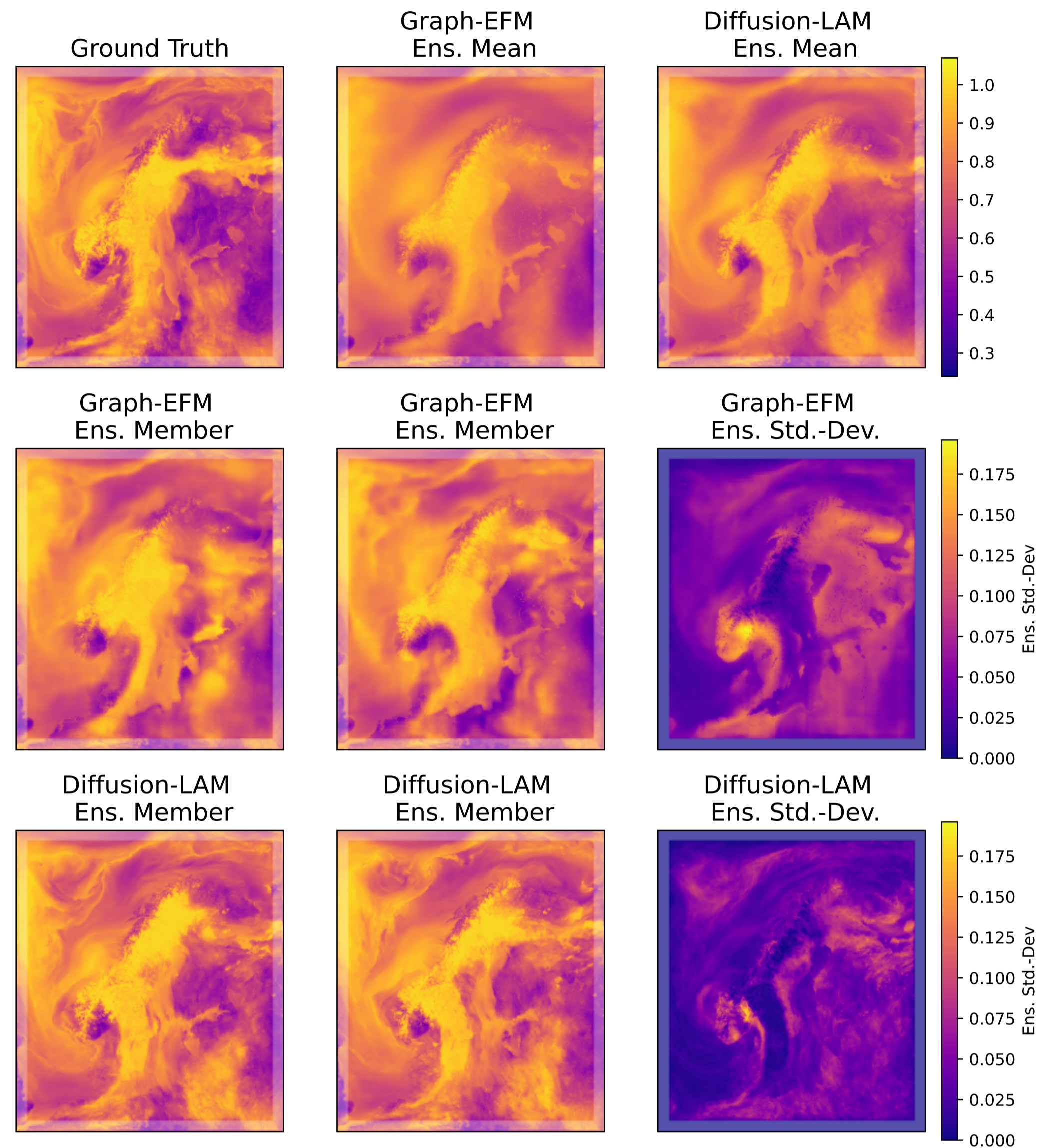


Figure 3: Forecasts at 57 h lead time for r_2 . The faded area constitutes the boundary region. Note the difference in fine-scale details and the consistency with the boundary in the ensemble members.

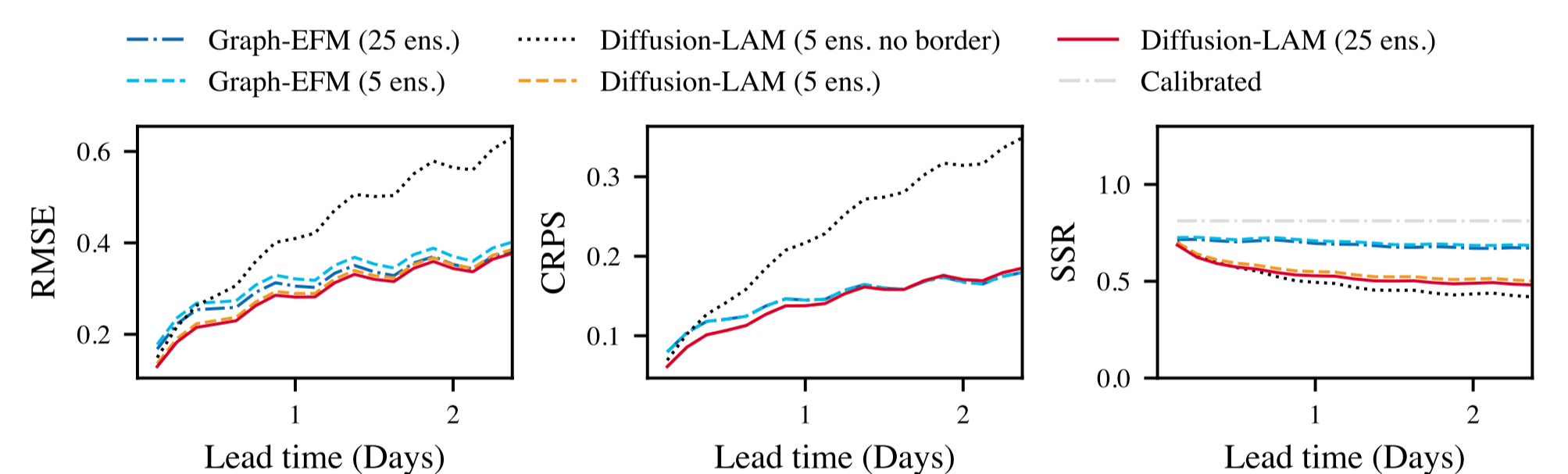


Figure 4: The mean of the normalized RMSE, CRPS, and SSR for all variables.

Conclusion

Diffusion-LAM delivers accurate ensemble forecasts with much more detailed and physically realistic fields compared to previous work.

References



Paper



Code



LinkedIn

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- [1] Erik Larsson, Joel Oskarsson, Tomas Landelius, and Fredrik Lindsten. Diffusion-lam: Probabilistic limited area weather forecasting with diffusion. In *ICLR 2025 Workshop: Tackling Climate Change with Machine Learning*, 2025.