

# STOCHASTIC DOWNSCALING OF THE 2M TEMPERATURE WITH A GENERATIVE ADVERSARIAL NETWORK (GAN)

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# MOTIVATION

## Why do we focus on downscaling of 2m temperature?

- Global reanalysis data coarse-grained, e.g. ERA5 ($\Delta x \sim 30$ km)
- High spatial variability of meteorological fields,
  but increasing resolution is challenging (*Gross et al., 2018*)
- Data driven alternative: Statistical downscaling
- Recent advances in downscaling with deep neural networks
  (e.g. *Harris et al., 2022*, *Price and Rasp, 2022*)
- Here: **2m temperature [T(2m)] downscaling**
- Adverse effects of T(2m) variability (e.g. *Sheridan, 2019)*
  - Local nightly frost
  - Local heat stress

Protection measurement against nighty freeze in Neuwied. Photo: Rhein-Zeitung.

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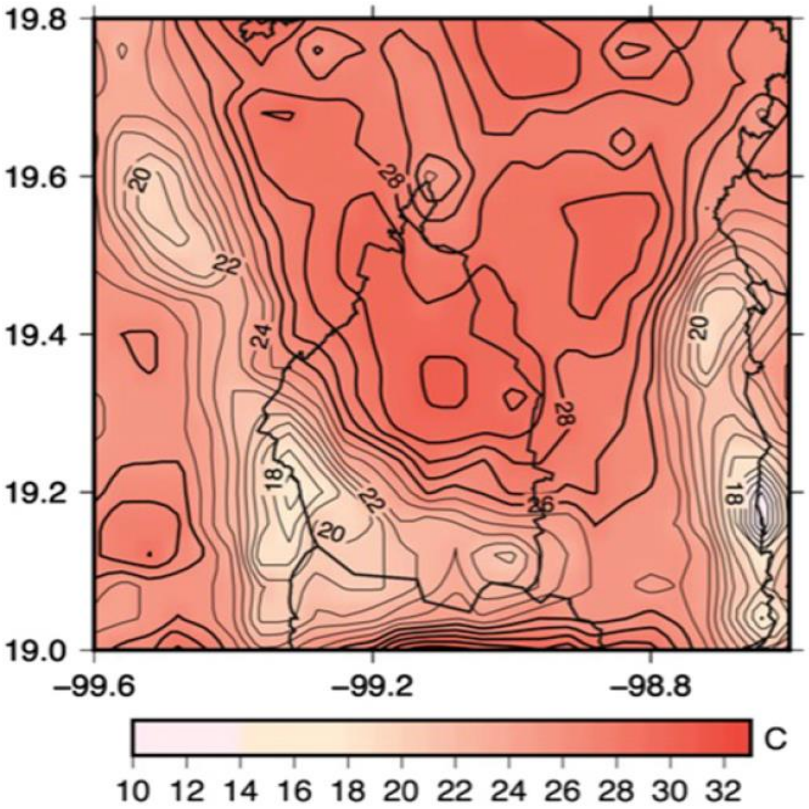


Spatial variability of 90th percentile of daily Tmax in Mexico City (from *Vargas and Magana, 2020*).



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# PRIOR WORK

## Development steps in the scope of the MAELSTROM project

Visit the **MAELSTROM** webpage

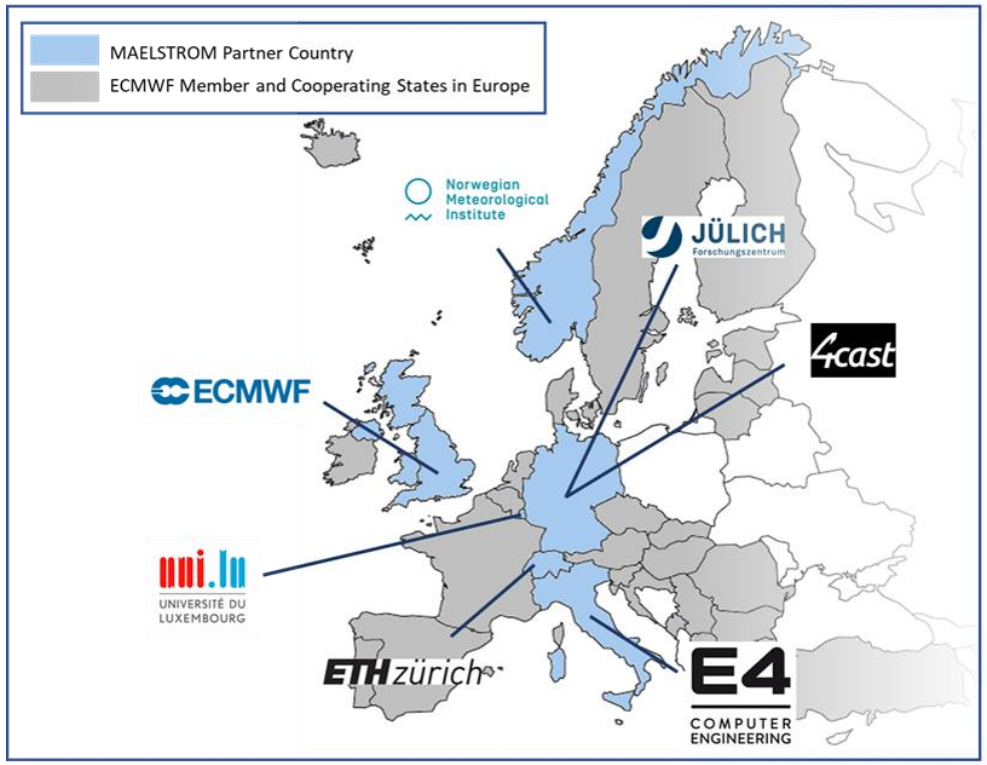
- Work as part of AP5 in the MAELSTROM project
- First approach: Pure downscaling of coarsened IFS data with a Unet following *Sha et al., 2020*
- Evaluation & benchmarking in MAELSTROM deliverables

✓ Promising results despite small dataset (4 years)

x ‘Synthetic’ downscaling task

x No model bias correction involved

x Limited model capacity: only T(2m) and surface elevation as predictors → bound to specific daytimes and season



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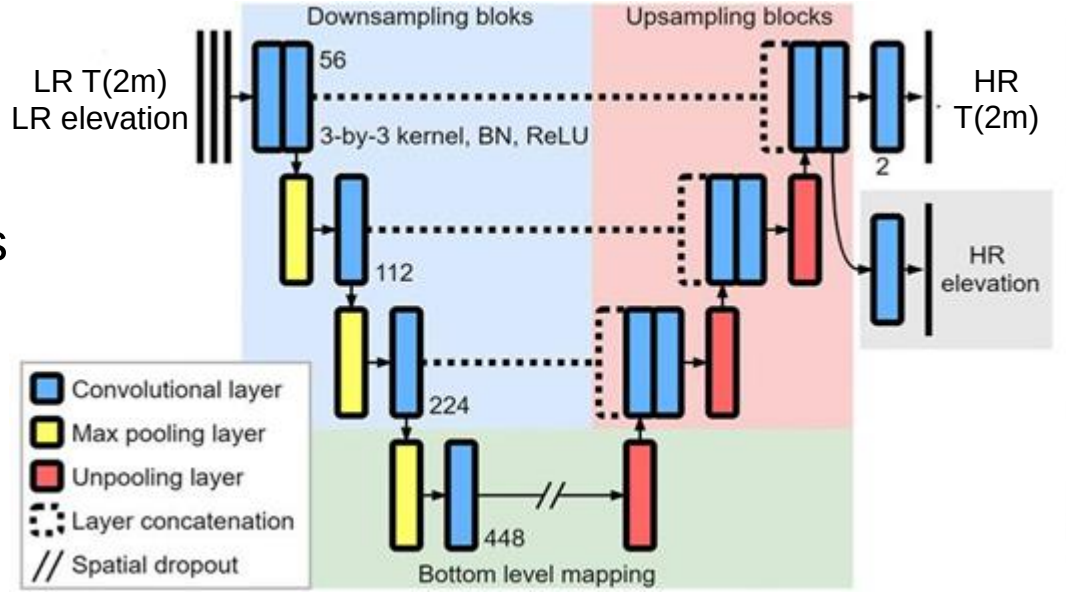


U-shaped encoder-decoder network (Unet) used for downscaling of T(2m). Adapted from Sha et al., 2020.

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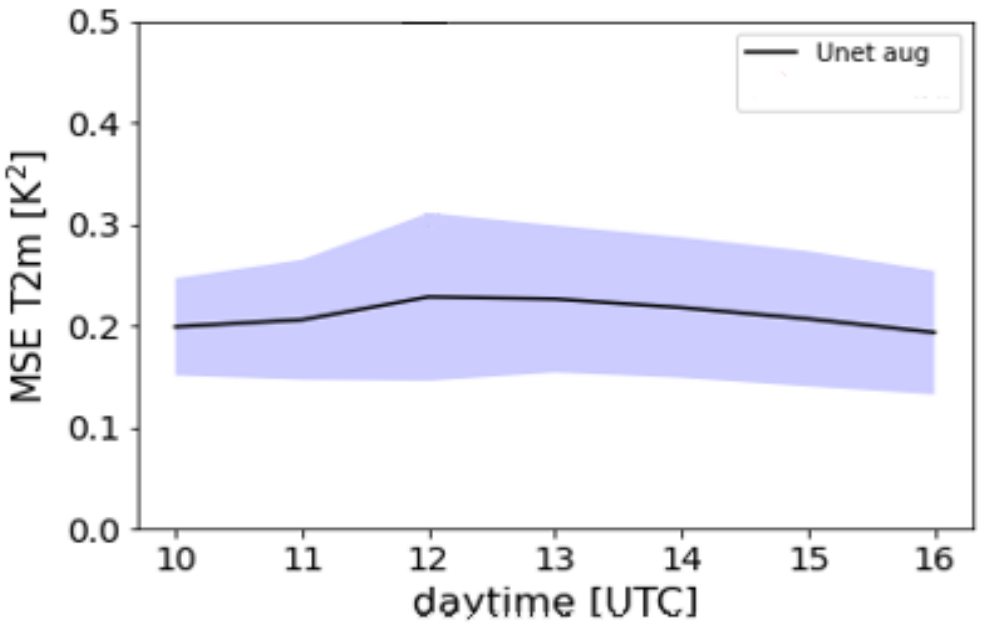


Mean-squared error (MSE) of T(2m) for Unet trained on 4 years of IFS data (Apr-Sep of years 2016-2019). Test data from 2020.



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# CURRENT APPROACH

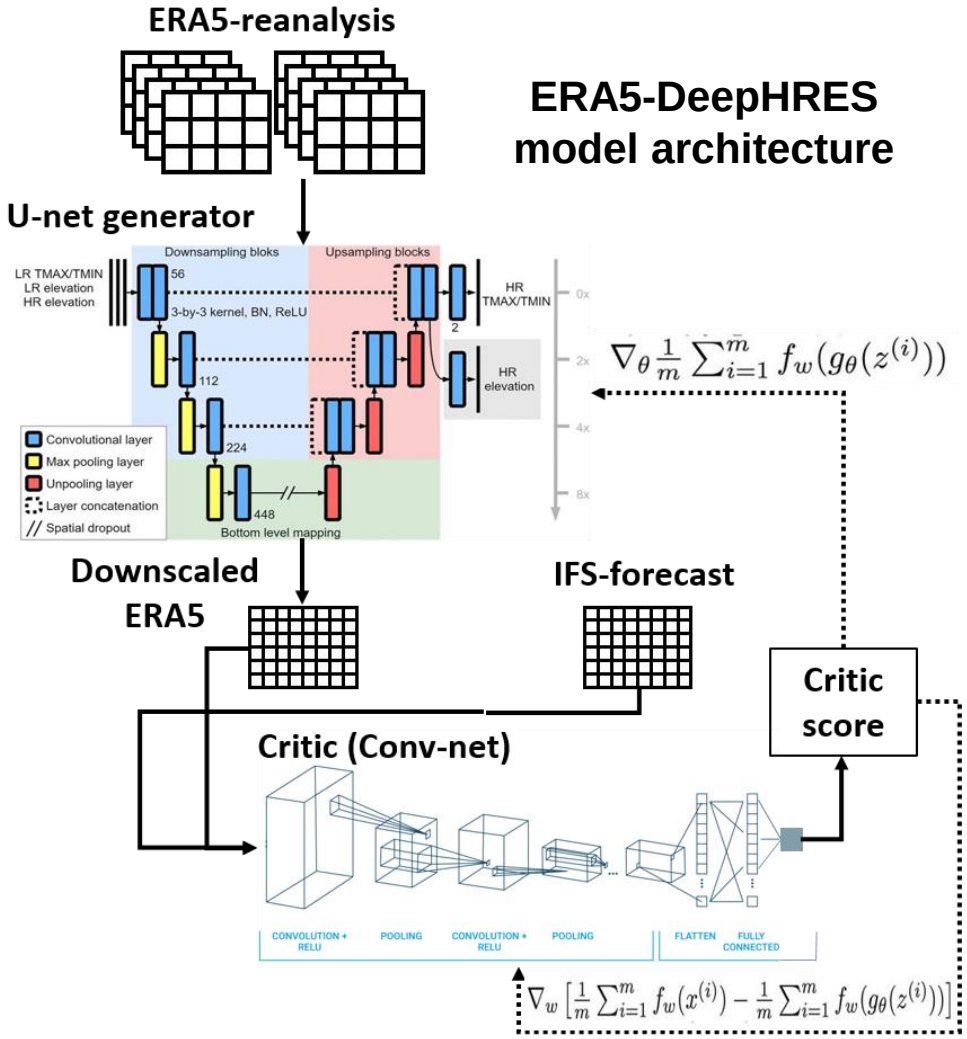
## Towards a real downscaling task

### Target

- Learn mapping from coarsened ERA5 (0.8°) to IFS (0.1°) data → shared model, but different spatial resolution
- Generalize downscaling model for arbitrary daytimes and season

### Experimental approach

- Several predictor variables to encode atmospheric state: T(2m), T(850hPa), T(925hPa), $\mathbf{v}_h$(10m), PBL height, surface fluxes (+ surface elevation)
- Integrate Unet into a Wasserstein Generative adversarial network (WGAN) → **ERA5-DeepHRES** model



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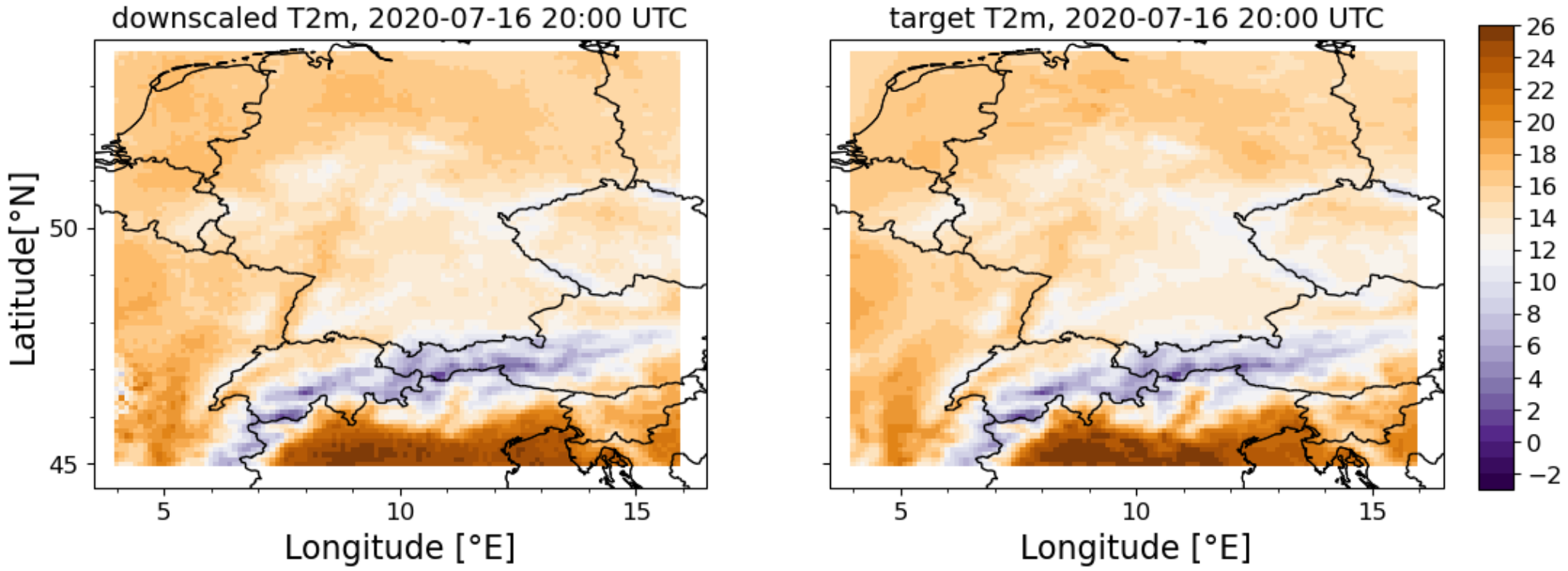
# PRELIMINARY RESULTS

## How does ERA5-DeepHRES perform? A snapshot

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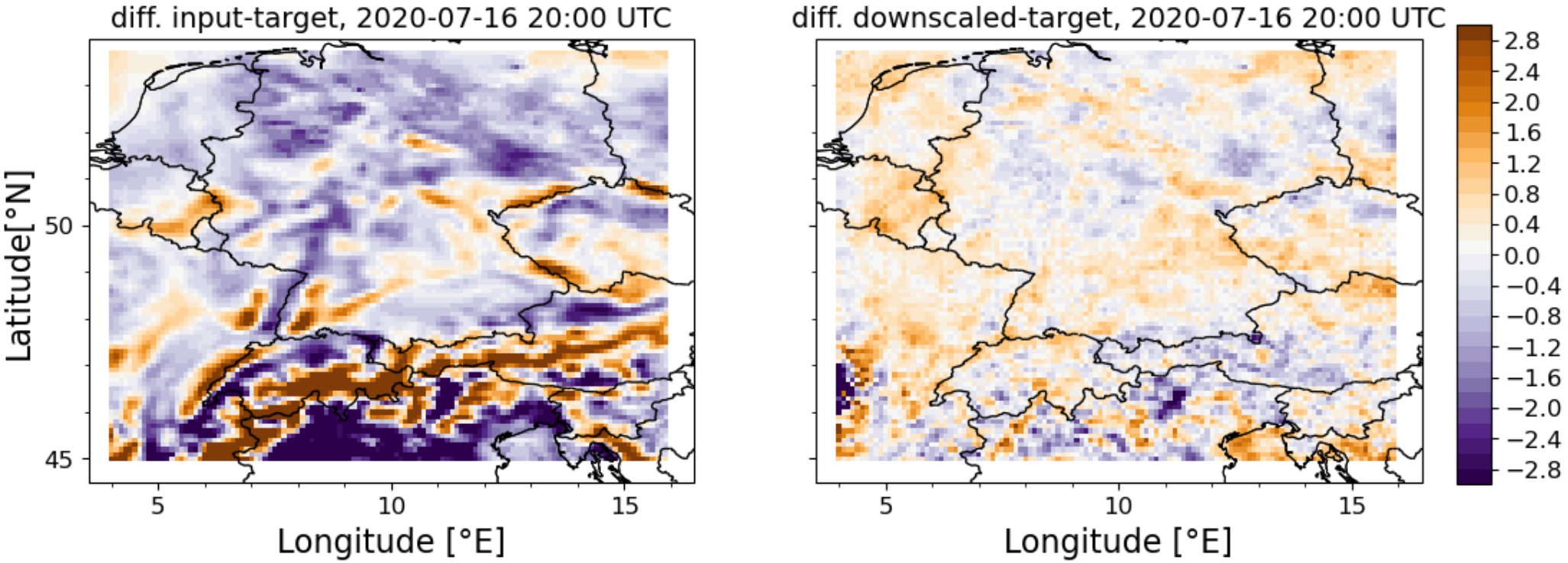


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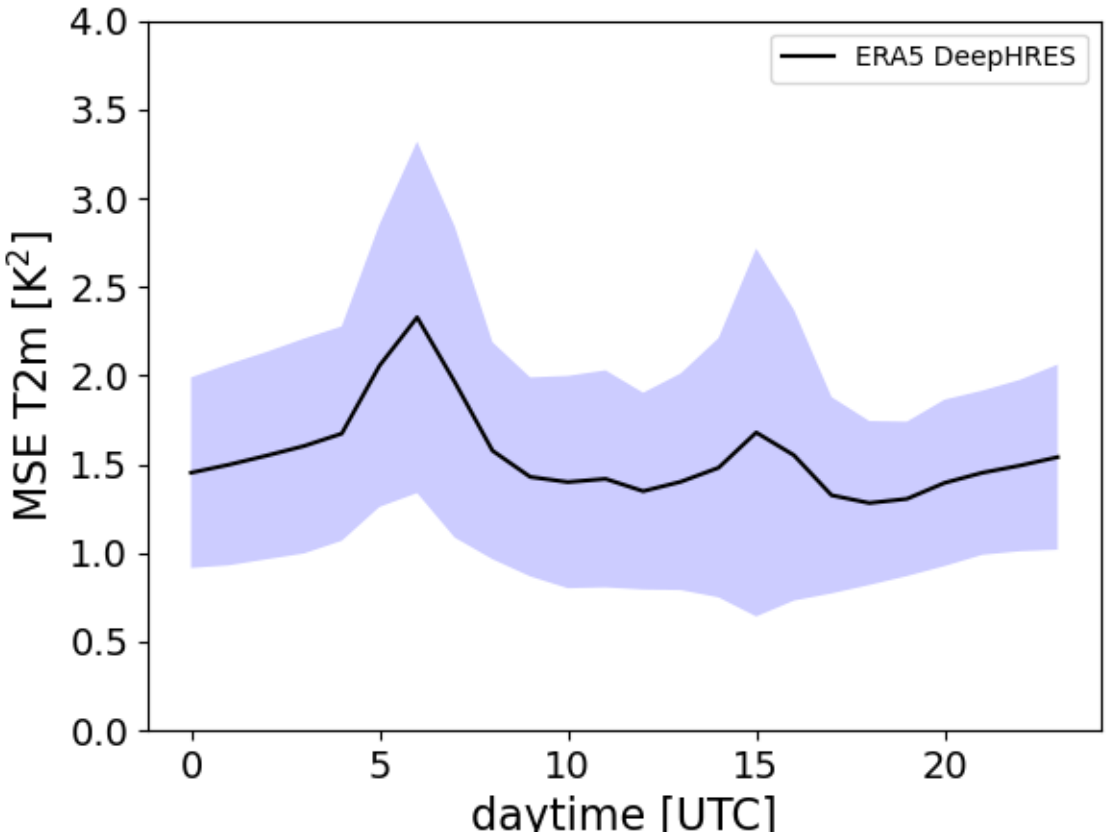


- x Overall MSE tracks high
- x Major problems in the morning hours



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# OUTLOOK

## What comes next in MAELSTROM?

- Elaborate on **ERA5-DeepHRES** model
  - Fine-tune hyperparameters and include embeddings for daytime and month
  - Improve model architecture (optionally)
  - Comprehensive evaluation
- Develop approach for downscaling on kilometre-scale
  - Mapping from ICON to COSMO-D2
  - Include observations
  - Transformer-based architecture, e.g. Swin Transformer (see *Liu et al., 2021*)

# REFERENCES


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# Thanks for your attention!


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