

Direct observation prediction of clouds capturing kilometer-scale processes



**Dhamma Kimpara,
Omid Bagheri, Chris Snyder**

NSF National Center for Atmospheric Research, Boulder, CO, USA

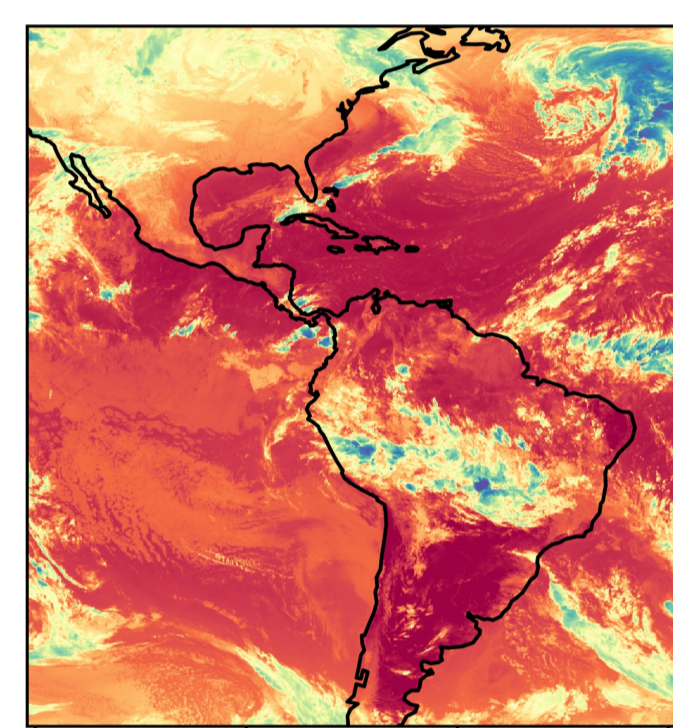


Research question and configuration

Can Machine Learning (ML) methods predict the evolution of clouds in geostationary satellite observations?

Data

- "Prognostic" variables: GOES-East ABI
- ~10 km latitude-longitude grid (coarse grained)
 - 10 minute temporal resolution
 - Years: 2018-2022
 - Subset <72 degree Local Zenith Angle
 - Channels: 4, 7, 8, 9, 10, 13



GOES-E Channel 13
"Clean" longwave window
Infrared Band
(2022-12-16 12Z)

- Dynamic "forcing": ERA5
- Analog of a NWP-type product
 - Bilinear Interpolation to ~10 km grid
 - 1 hour temporal resolution
 - Subset of 11 model levels up to ~200hPA
 - Surface Pressure, 2m temperature

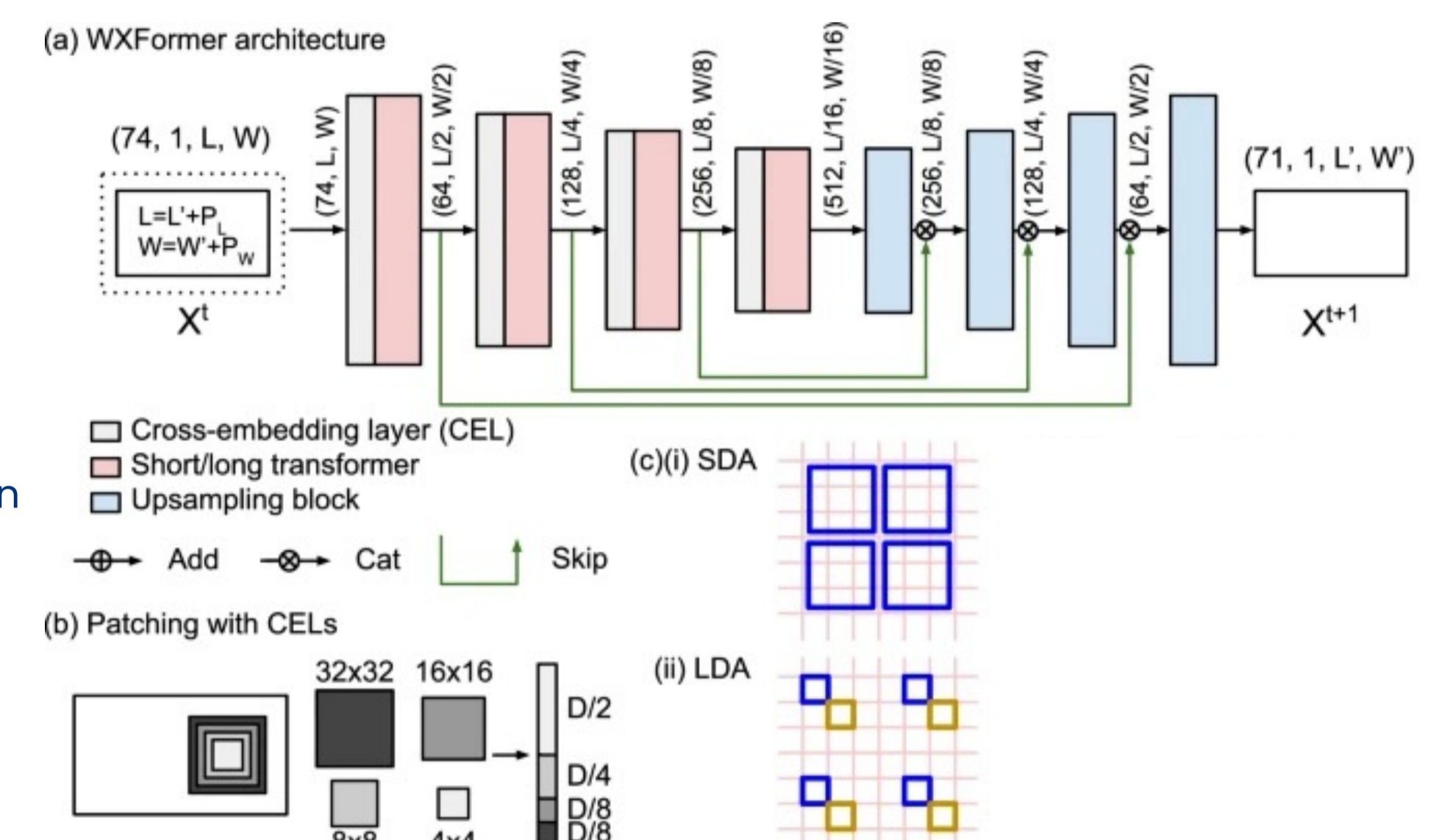
ML Model – WxFormer^(a)

Scale-aware vision transformer with cross-attention

- Autoregressive prediction
- 10/20/30-minute timestep
- Deterministic loss function: Mean Squared Error
- 24h forecast in seconds

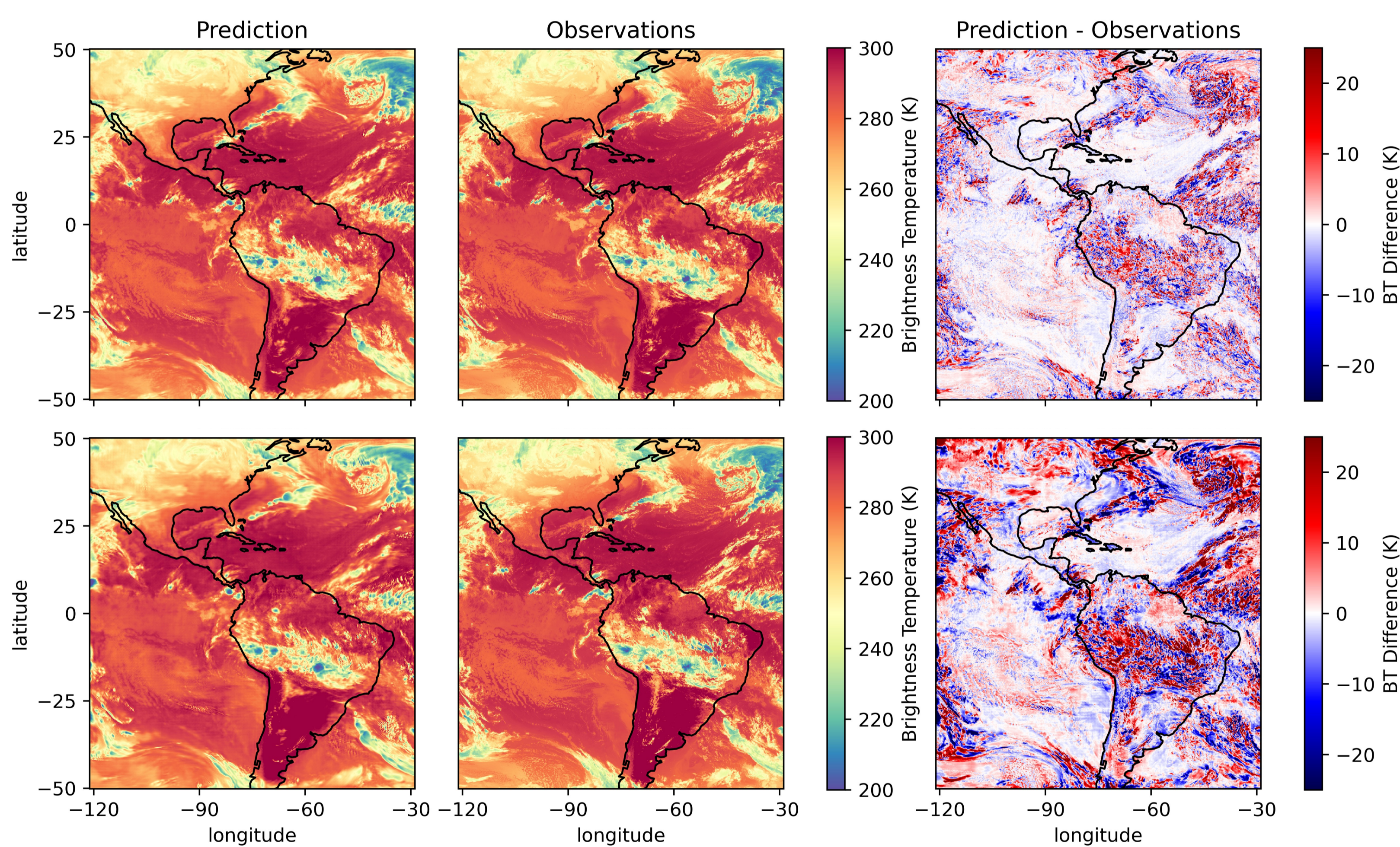
Modifications:

- Forcing input: nearest hourly ERA5 state
- Time conditioned with Feature-wise Linear Modulation (FiLM)
- Upsampling blocks: Pixel shuffle super-resolution technique



^(a)Schreck et al. (2025), npj Clim Atmos DOI:10.1038/s41612-025-01125-6

Case Studies



Verification period:

- July 1, 2022 – December 16, 2022
- Initialized every two weeks
- At 6Z and 18Z

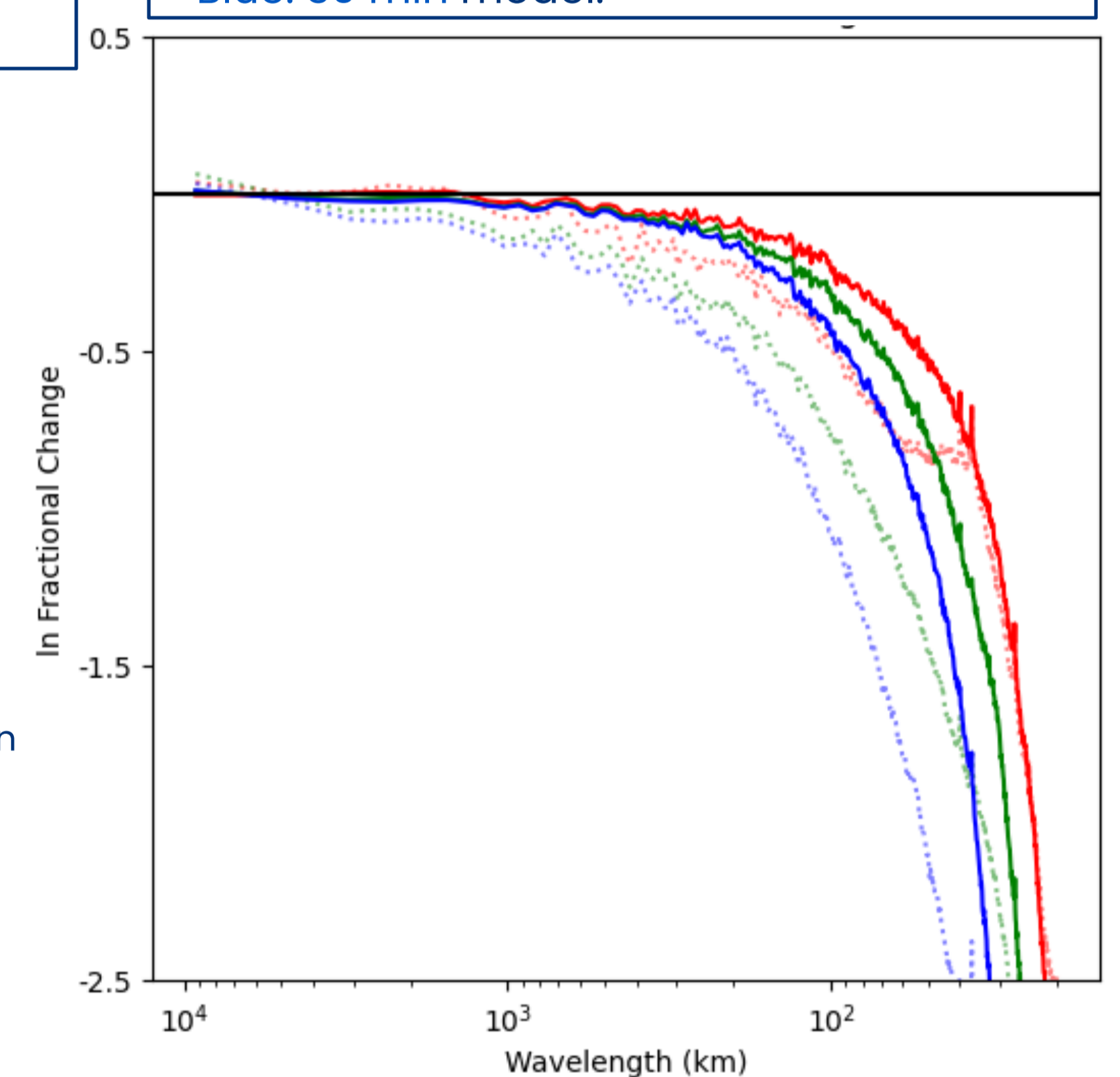
Model Color Legend

- Red: 10 minute timestep model.
- Green: 20 min model.
- Blue: 30 min model.

← Visualization of a South American convective case with a ML model with 10 minute timesteps.

- Top: 1h lead time
- Bottom: 3h lead time

Initialized 12Z December 16, 2022

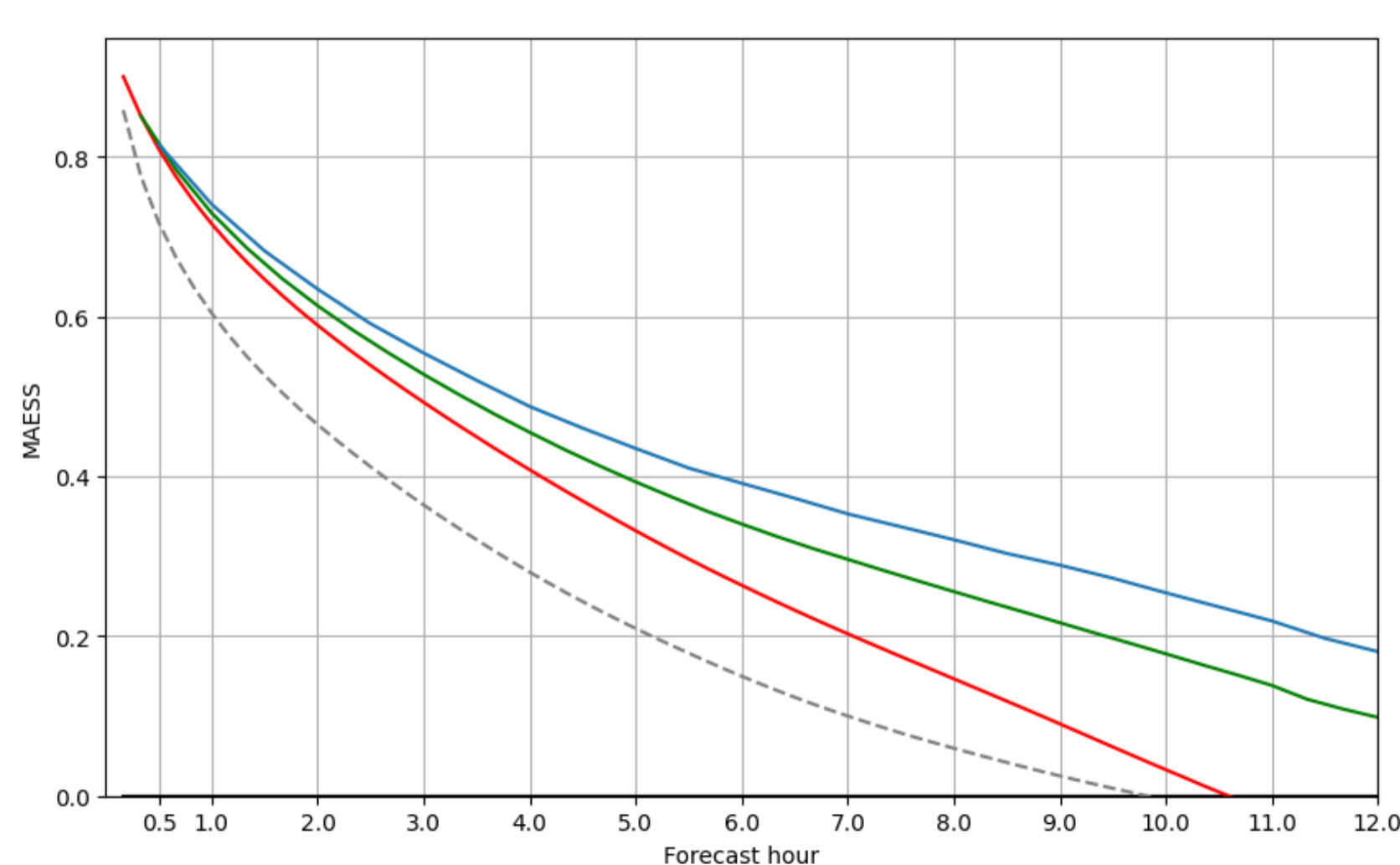


Fractional Change in Power Spectra for channel 13.

- Solid lines: 1 hour lead time.
- Dotted lines: 3 hour lead time.

Verification Metrics

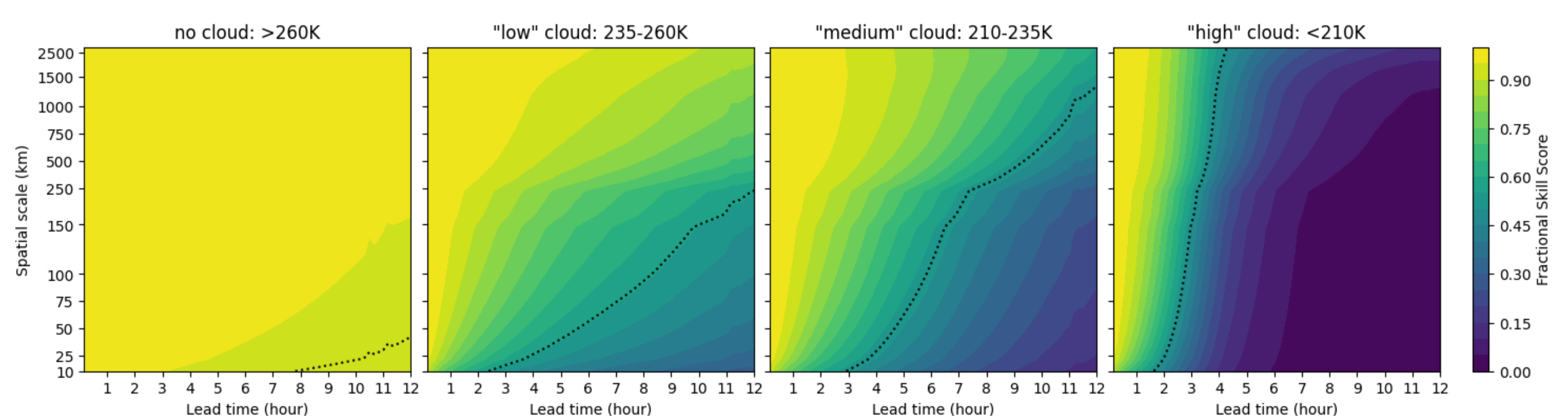
While difficult to resolve convection remains challenging even for our ML model, it demonstrates skill and fidelity at lead times of 3 hours.



Mean Absolute Error Skill Score as a function of lead time for a 12-h forecast.

- Dashed line: Persistence

All the ML models are skillful compared to climatology and a persistence forecast up to 10-h forecast lead time.



Fractional Skill Score of the 10 minute model over four brightness temperature categories.

- Dotted line: skillful ("uniform") forecast as defined by Roberts and Lean (2008)

As expected, higher clouds (<210K), commonly associated with more vigorous convection and overshooting tops, are the most difficult features to predict. Even so, at the smallest spatial scale (10km) our 10 minute ML model is skillful up to 1.5-3 hour lead time, depending on the cloud category.