Continuous, real-time LES over the Bankhead National Forest

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Continuous Large Eddy Simulations – With Integrated Land-Surface Modelling

Motivation

- Bankhead national forest environment provides a unique landscape with localized forced convection initiations, leading to formation of shallow cumulus clouds which in some cases transition to deep convection over the region.
- A land-surface model coupled LES maybe required to fully understand the effects of local forcing.

Goal

- Implement a simple land-surface coupled LES model with a homogeneous land condition and interactive radiation that runs continuously through the ARM-AMF3 deployment period.
- Make this continuous LES output available along with quality values for these simulations based on how well individual properties compare with AMF3 observations.

LES-LSM Model Setup

LES Model

- MicroHH LES code with interactive radiation scheme (RRTMGP).
- Initial condition and Large Scale Forcing – ECMWF-ERA5 (114km Forcing Scale).

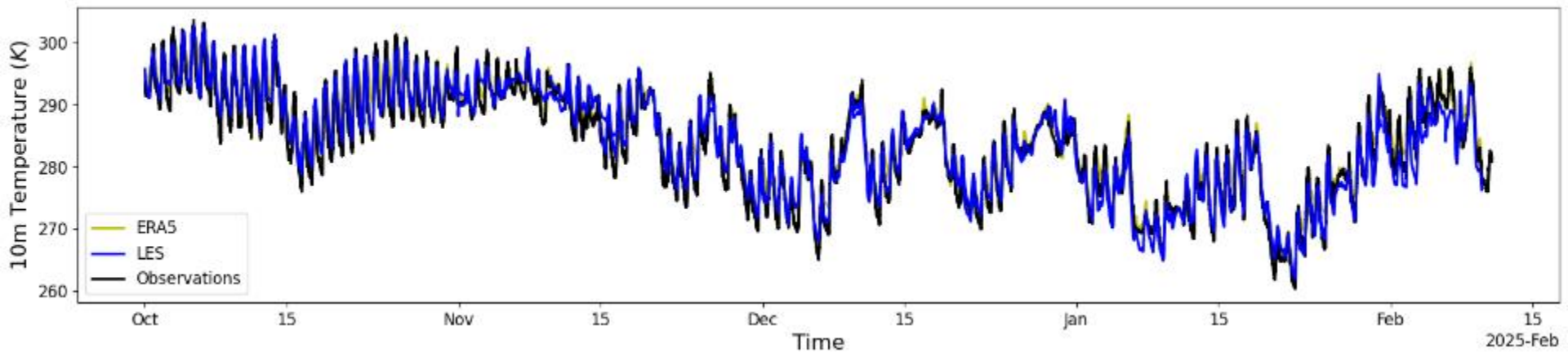
Soil Model

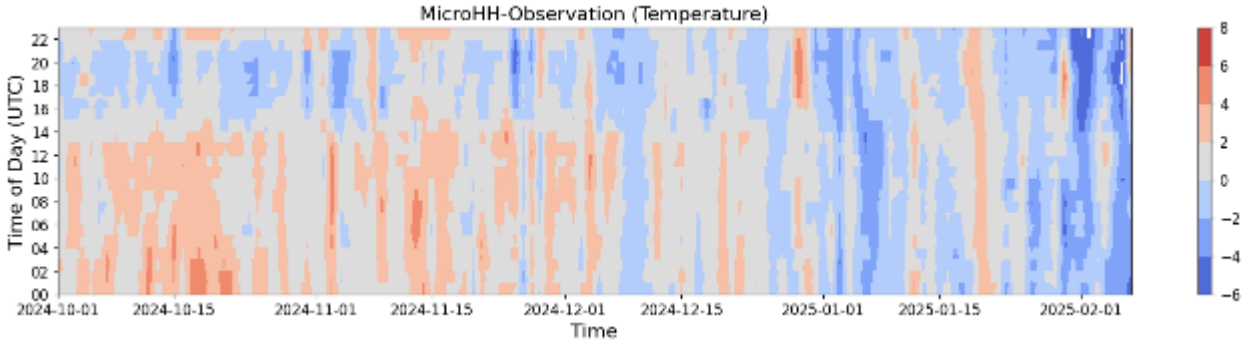
- Land Surface Model derived from HTESSEL scheme by ECMWF.
- Homogeneous over model domain.
- Initial Soil Water Vapor, Soil Temperature profiles and Leaf Area Index from ERA5.
- Vegetation Parameters (Minimum vegetation resistance, Thermal conductivity etc.) based on type of vegetation over the domain.

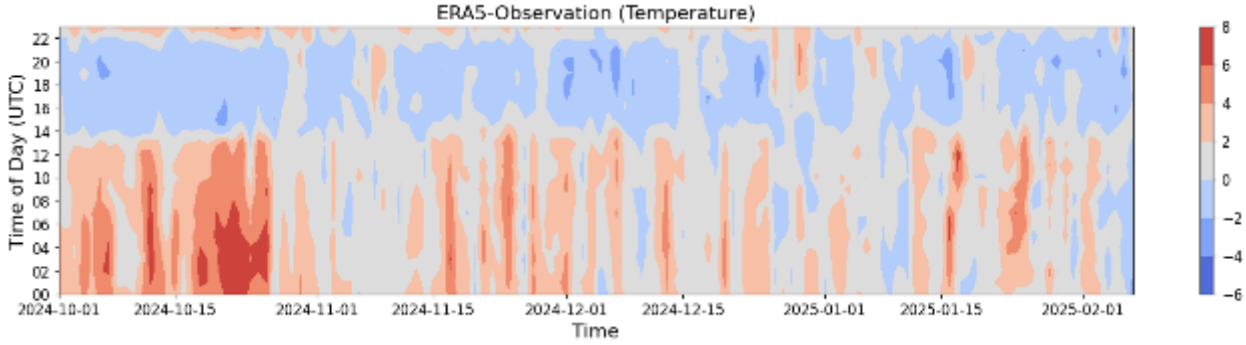
BNF Simulations

- Output domain size – 12.8 km, Resolution – 100 m (Δx, Δy) and 20-40m (Δz), Spin-up Time ~ 1-day, Nudging above 5 km with a 3-hr timescale
- Continuous 7-day simulations starting every 5 days after 1st May 2024 and 1st September 2024.
- Performed on GPUs, a 7-day simulation takes ~7 hours to complete at the above-mentioned resolution.
- ERA5 data are usually available within 5 days of the actual date.

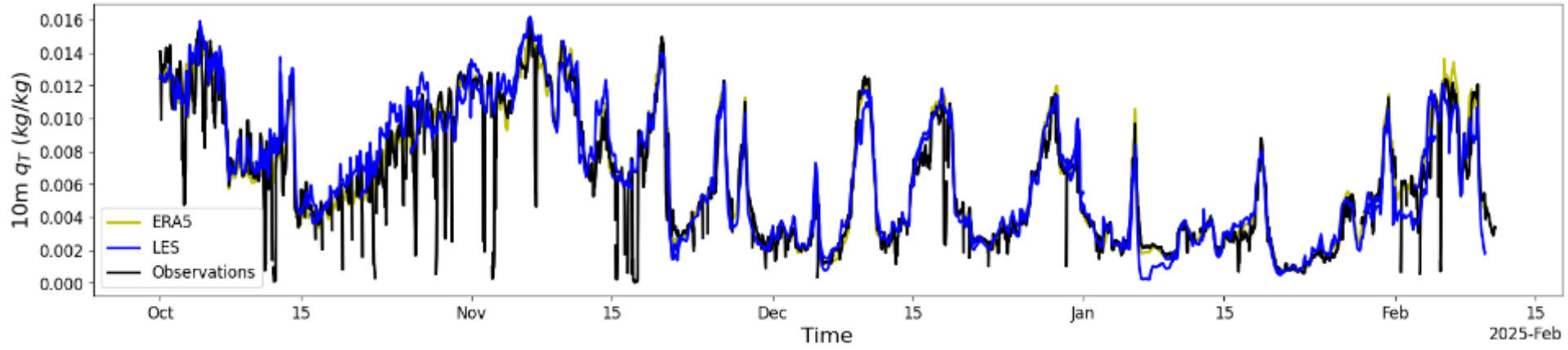
Overview of Simulations - Surface Temperature

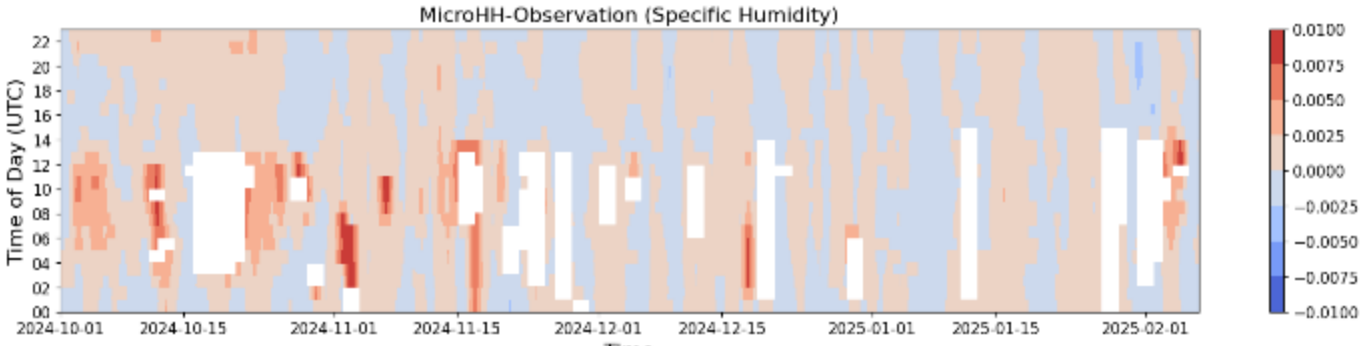


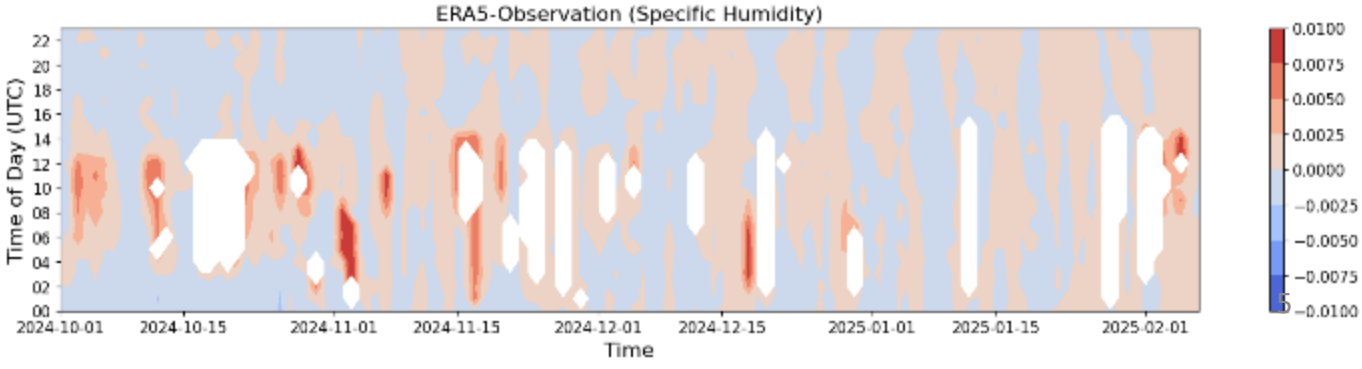




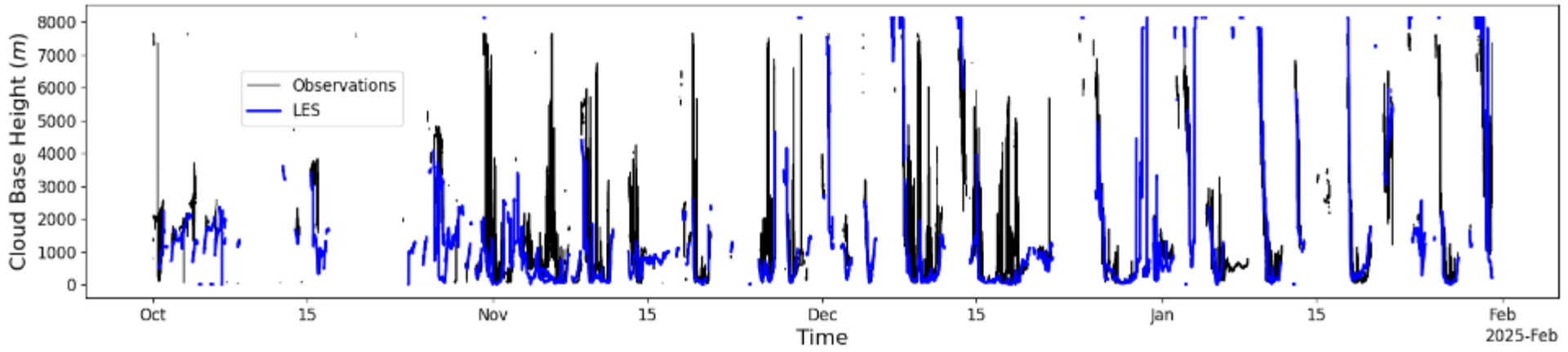
Overview of Simulations - Surface Humidity

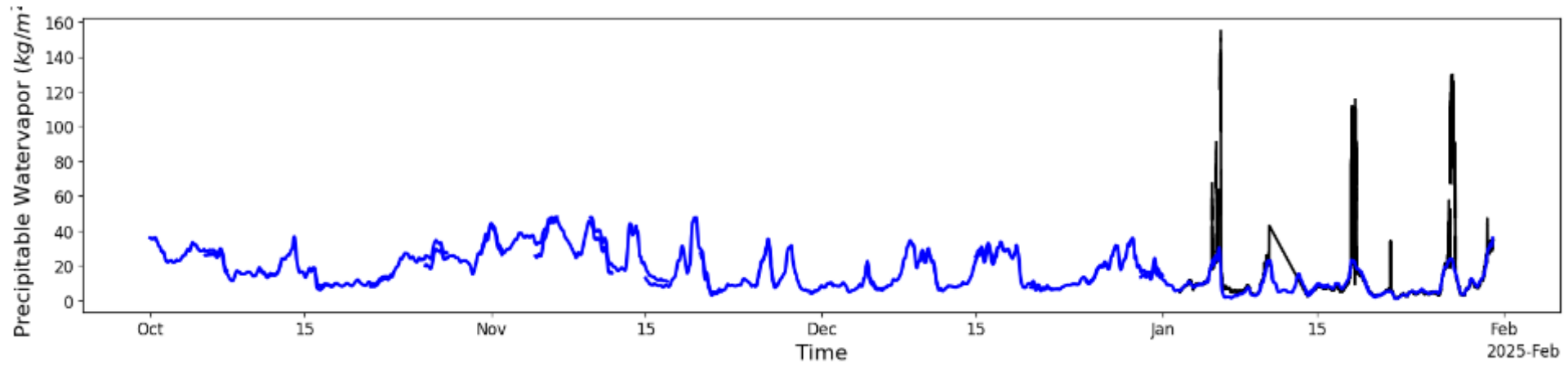




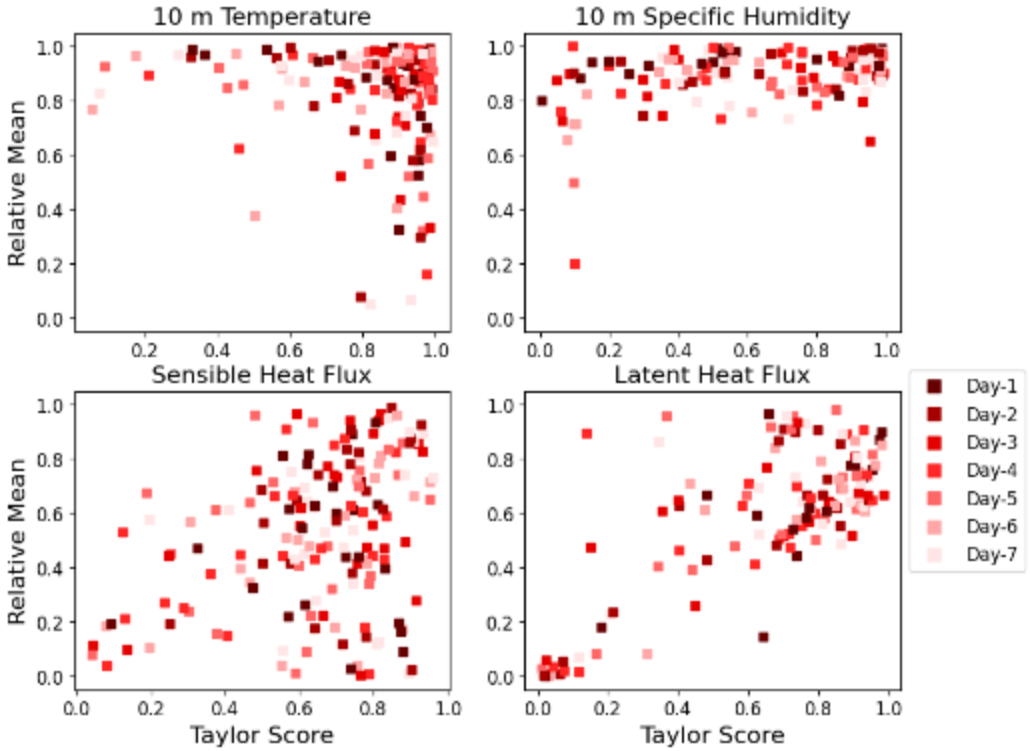


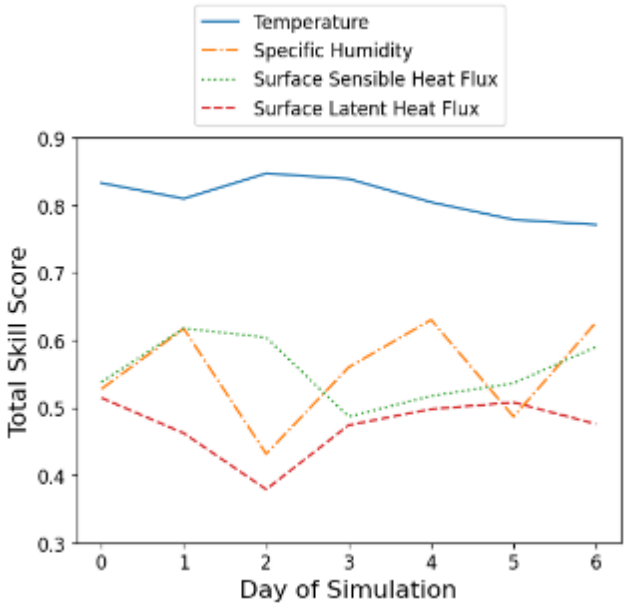
Overview of Simulations – Cloud Properties





Skill Scores - 7-day skill scores





Taylor Skill Scores

- Based on shape/variation of time-series plots between model and observation

$$S_T(Var) = \frac{4(1+R)}{\left(\sigma_r + \frac{1}{\sigma_r}\right)^2 (1+R_0)}$$

Where R is correlation coefficient, σ_r is normalized standard deviation and R_0 is maximum correlation coefficient (Set to 1)

Relative Mean Skill Scores

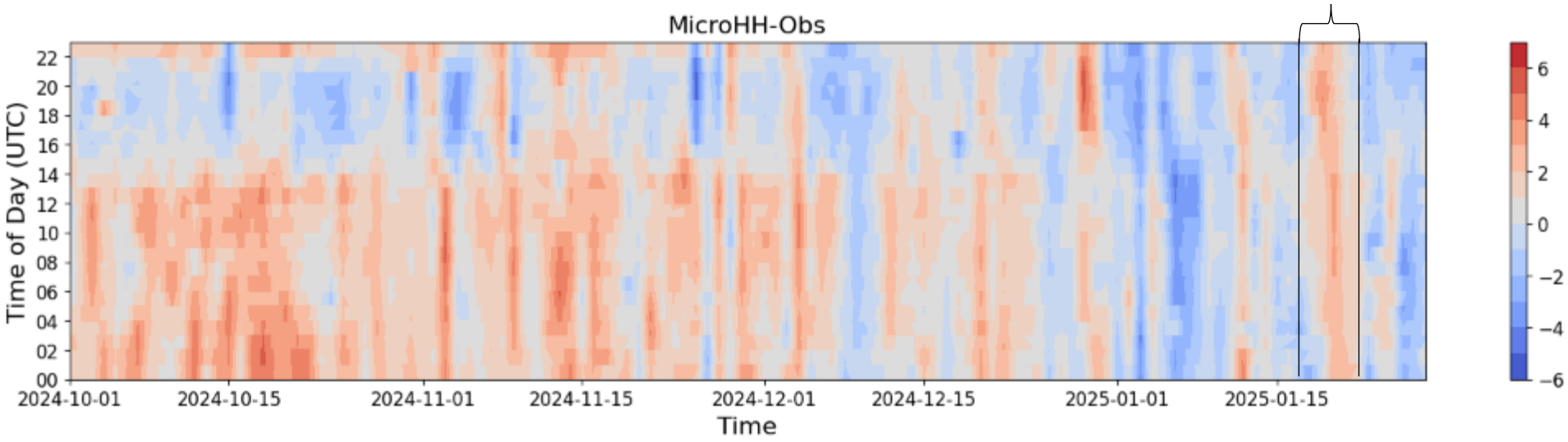
- Based on the mean of time-series plots

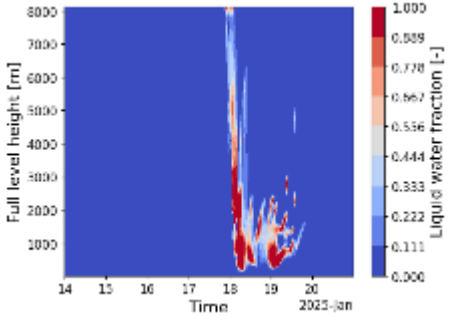
$$S_{RM}(Var) = \begin{cases} x, & x \le 1 \\ 1/x, & x > 1 \end{cases}$$

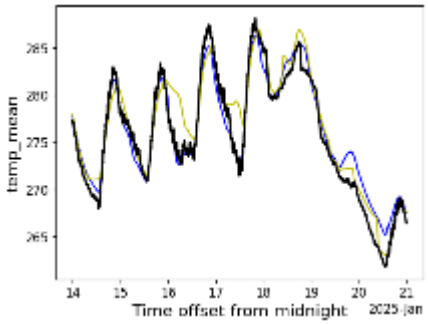
Where x is the ratio of model mean to observed mean

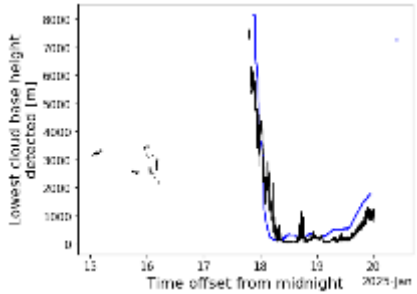
Total Skill Score → $\sqrt{S_T S_{RM}}$

Reduced Skill Scores - Incoming Front









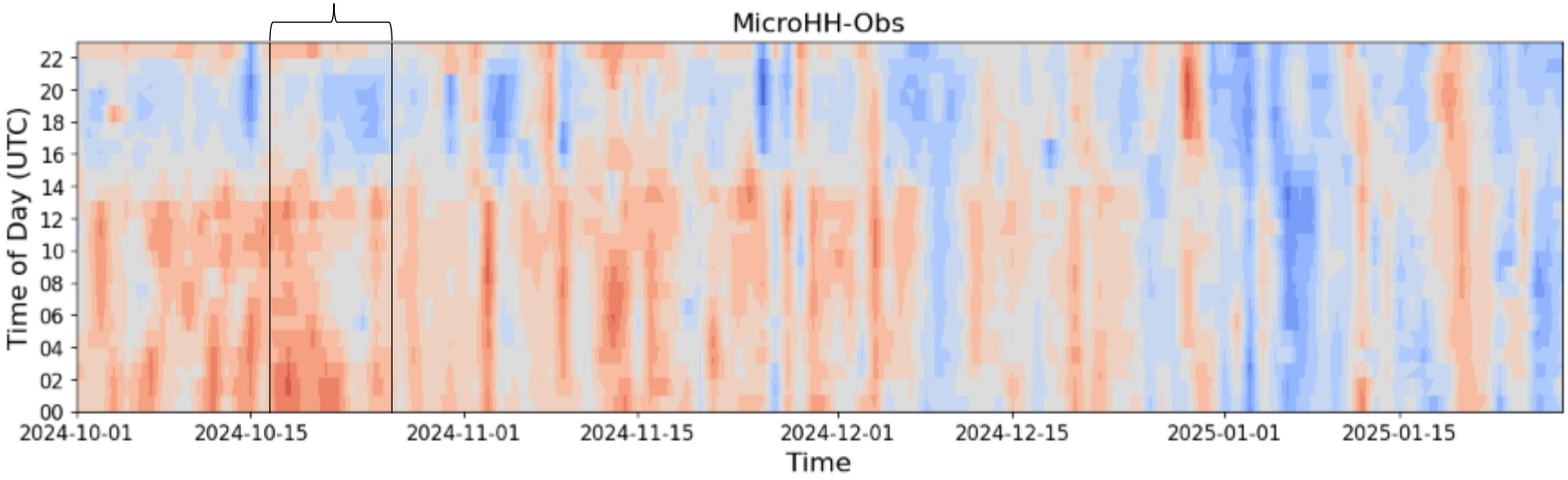
17th January

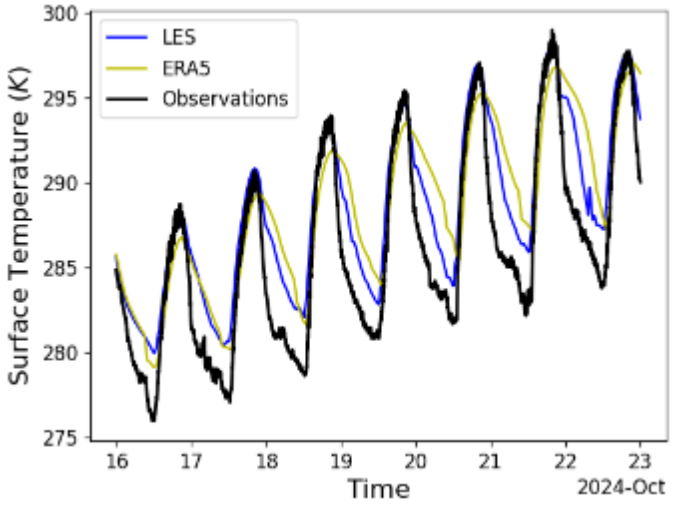
18th January

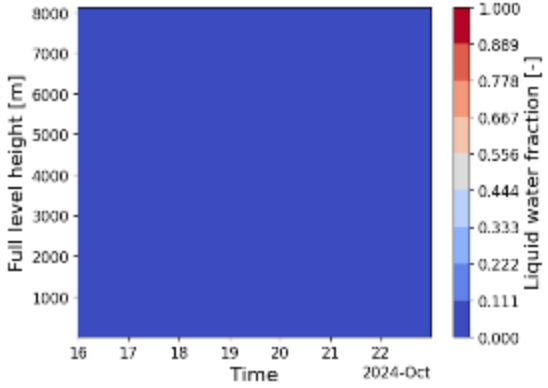
19th January

20th January

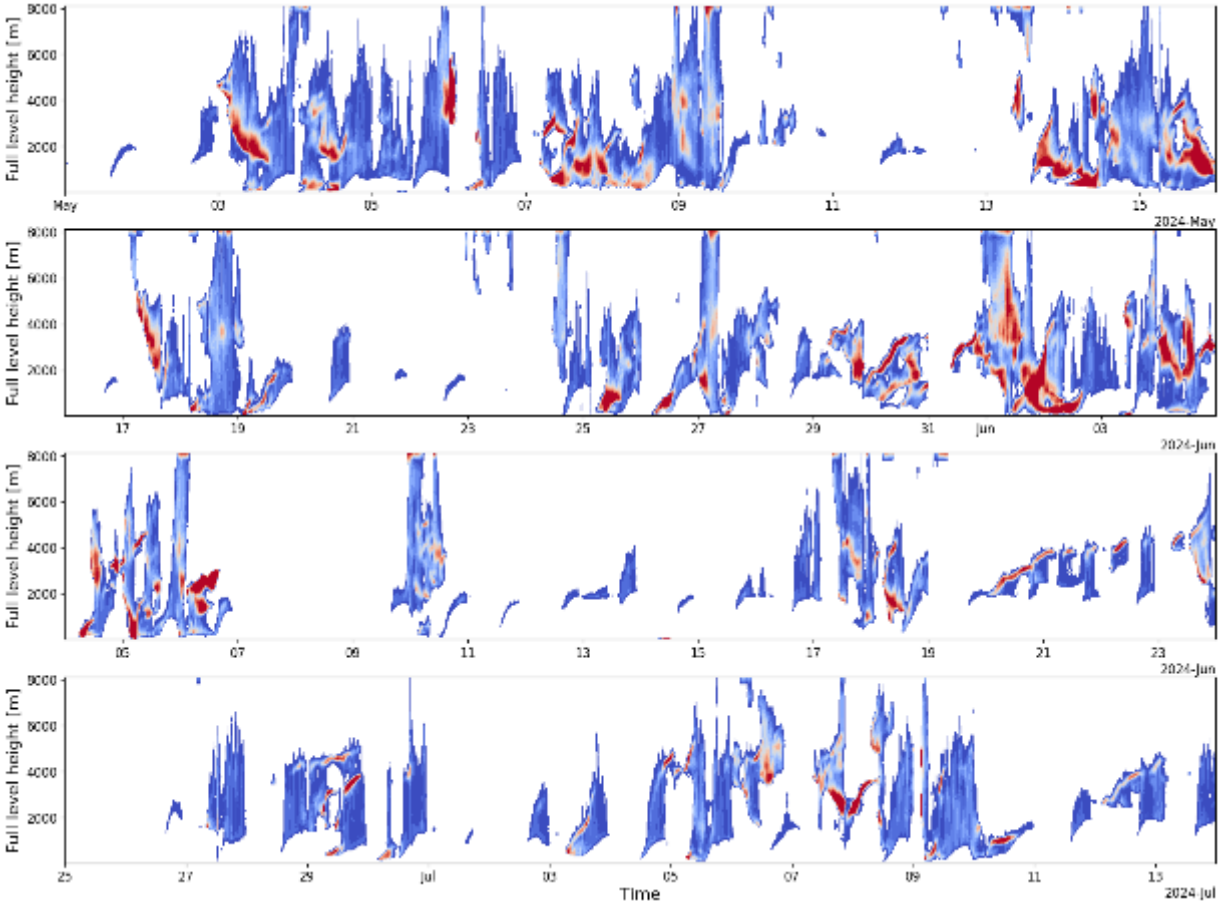
Reduced Skill Scores - Nighttime Warm Bias

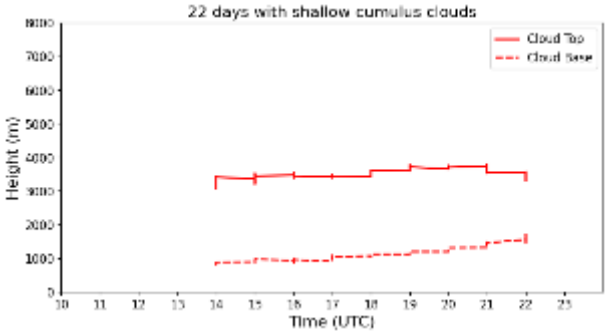


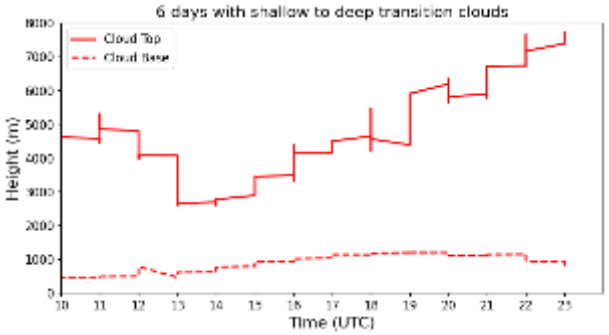




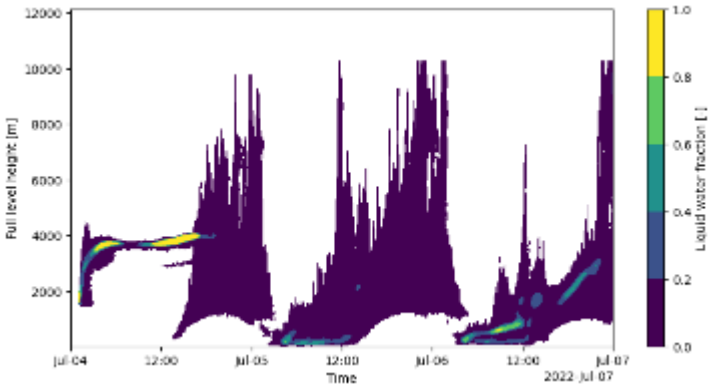
Continuous LES – Summer of 24’





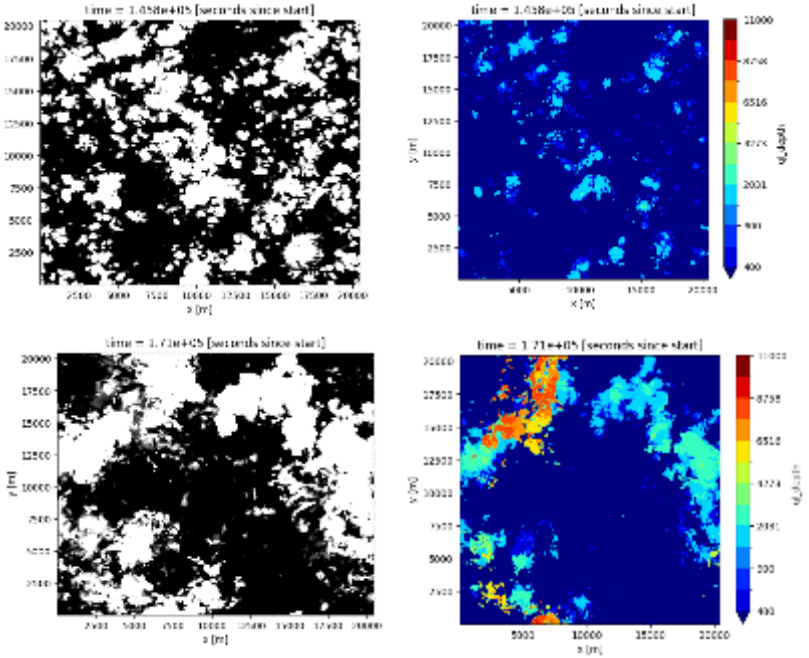


What can LES provide? – Shallow to Deep transition



Cloud liquid water fraction during summer 2022, with shallow to deep transition over the BNF site.

- High-resolution LES (Δx, Δy ~ 45m, Δz ~20-40m, 25.6 km domain)
- Impact of cloud organization, cold pools, land surface heterogeneity, moisture convergence on localized deepening convection.



2D Liquid Water Path (>0.01 kg/m^2) and Cloud Depth (Cloud Top – Cloud Base height) at 16 and 23 UTC on July 5th 2022.

Limitations

- Homogeneous land-surface considering one particular land-type (Evergreen forest with seasonality controlled by ERA5 imported LAI)
- Fixed Cloud Droplet Number concentration ignoring the effect of terrestrial aerosol emissions.
- Night-time warm bias during days dominated by surface forcings.
- Doubly periodic boundary condition with ERA5 initial conditions.

LASSO Scenario Implementations suggestions

- Implementation of Land-Surface coupled LES integrating atmosphere-soil-canopy interactions, including small-scale heterogeneity effects if feasible.
- Identifying and simulating days with localized convection onset, potentially evolving into deeper clouds.
- Integrating local aerosol observations into LES simulations to capture the impact of terrestrial emissions.

Summary

- LES model with coupled land surface model capable of producing continuous fast paced output is established over the BNF site.
- The skill scores calculated for LES output variables in comparison with observation.
- Scenarios involving a passing front or deep convective cells result in higher-than-observed surface temperatures, a trend also noticeable on certain surface forcing dominated cloud-free nights.
- This framework is to be used to identify days of interest during which more sophisticated, high-resolution LES runs can be performed if required.