Continuous, real-time LES over the Bankhead National Forest

Girish Nigamanth Raghunathan[1], Thijs Heus[1], John M Peters[2]. | 1. Cleveland State University, 2. Pennsylvania State University

ASR Atmospheric System Research

Land-Atmosphere coupled LES simulations

MOTIVATION

The Bankhead National Forest provides a distinctive setting where localized forced convection initiates, leading to the formation of shallow cumulus clouds, and in some instances, transitioning into deep convection as they evolve over the region. The objective of this study is to generate continuous LES output as an initial step during the ARM site measurement period, which can later be used to identify key days for analyzing localized transitions from shallow to deep convection.

LES SETUP

- MicroHH LES code with interactive radiation scheme (RRTMGP)
- Initial conditions and large-scale forcings – ERA5 (114 km forcing scale)
- Land surface model derived from HTESSEL scheme by ECMWF
- 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.
- 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 October 2024.

Simulation Skill Scores

OBSERVATIONS USED

Surface meteorology data at the main site was for evaluating Surface Temperature. Eddy correlation flux measurement system data at the double spring (S40) supplemental site is used for Surface Fluxes and specific humidity measurements

TAYOR AND RELATIVE MEAN SCORES

Taylor Skill scores quantify agreement in shape/variation while Relative Mean Skill scores quantify correspondence in terms of the mean. Total skill score = $\sqrt{TSS * RMS}$

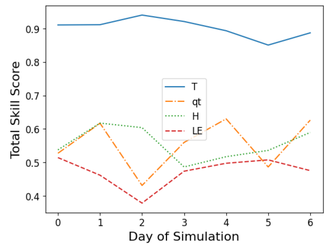

Fig 3: Average total skill score based on number of days since start of simulation

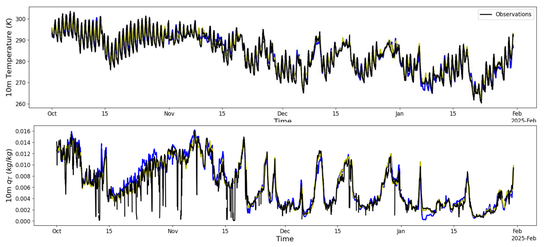

Fig 1: Comparison of LES output (blue) of Surface temperature and humidity vs ERA5 (yellow) and observations (black)

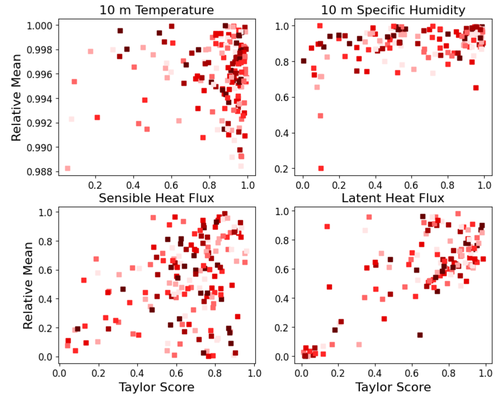

Fig 2: Skill scores of 10m Temperature, specific humidity, Sensible and Latent heat fluxes at the surface evaluating LES against observations.

Reduced skill scenarios

The LES simulation showed poor performance compared to observations when an incoming front passed over the BNF site, consistently overestimating surface temperature.

Similarly, the simulations exhibited a nighttime warm bias, with higher temperatures than observed; however, they still aligned more closely with observations than ERA5 on those days.

NIGHT-TIME TEMPERATURE BIAS

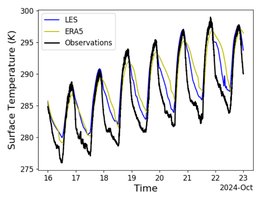

Fig 5: Comparison between LES, ERA5 and Observed surface temperatures.

PASSING FRONT

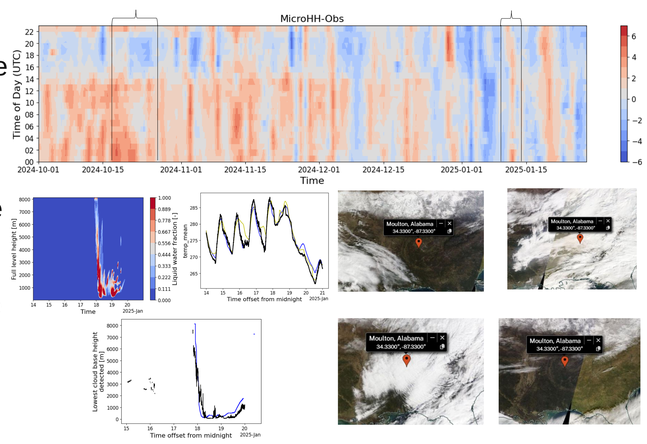

Fig 4: Difference between LES and observed surface temperature (top) Cloud fraction from LES, Surface Temperature and Cloud base comparison with observations (bottom left) and satellite images on January 17th,18th, 19th,and 20th (bottom right).

Shallow-to-Deep transition

Multiple days with localized shallow to deep convection transitions from identified in summer. One such case in 2022 is shown.

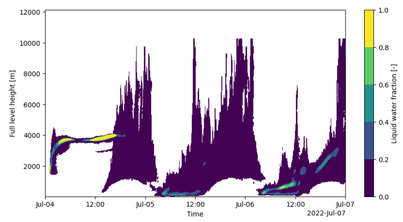

Fig 6: Cloud liquid water fraction during summer 2022, with shallow to deep transition over the BNF site.

Summary

- LES model with coupled land surface model capable of producing continuous fast paced output is established over the BNF site.
- The results so far show good agreement with field observations, as reflected in the skill scores of their comparison.
- Scenarios involving a passing front or deep convective systems result in higher-than-observed temperatures, a trend also noticeable on certain 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.

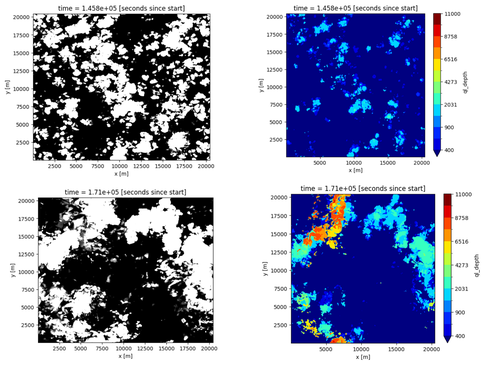

Fig 7:2D Liquid Water Path (>0.01 kg/m²) and Cloud Depth (Cloud Top – Cloud Base height) at 16 and 23 UTC on July 5th 2022..

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Contact Information:
- Girish N. Raghunathan, g.raghunathan@csuohio.edu

Cleveland State University 1964 | PennState | U.S. Department of ENERGY