

Continuous Large Eddy Simulation of the onset of convection over BNF and SGP

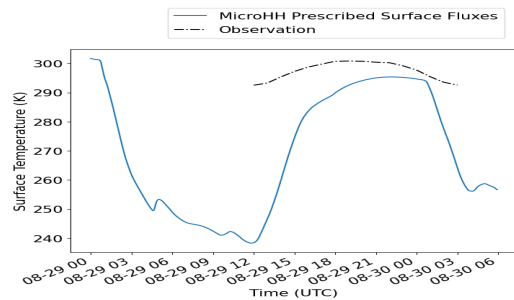
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Large Eddy Simulations – With Integrated Land-Surface Modelling

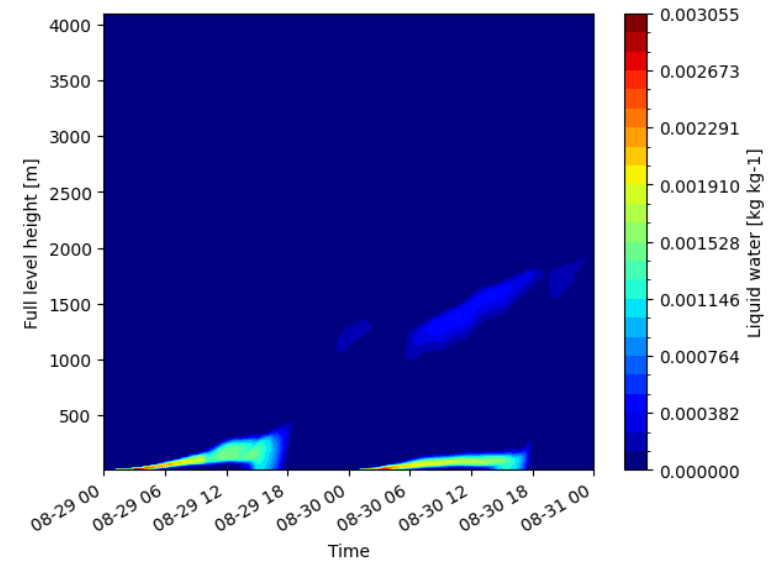
Motivation

- Automated LES model running continuous simulations with a start date over land-domain (SGP and BNF)
- Model with prescribed surface fluxes produces a dense nighttime fog layer resulting in surface decoupling.

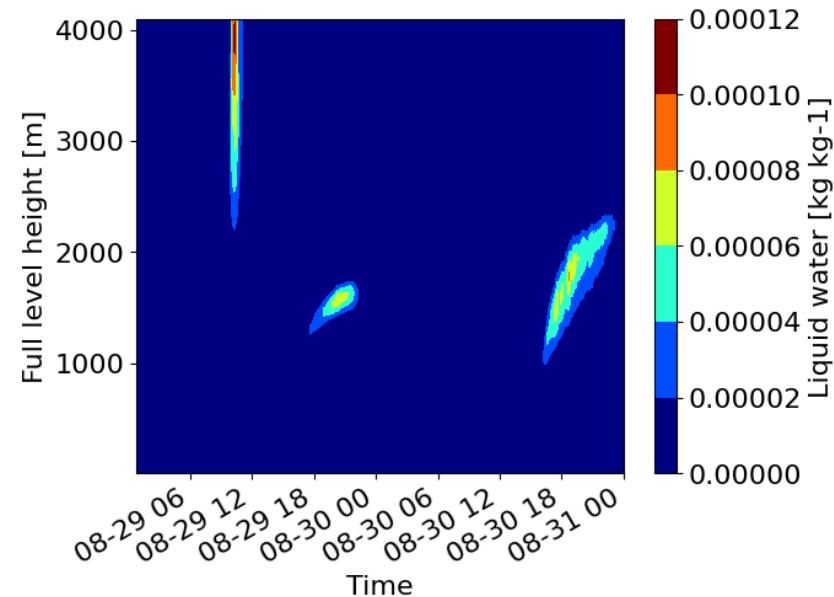


Goal

- Setup a generic LSM-coupled LES model that allows for a continuous run.
- Evaluate model performance with observations over ARM-SGP site and LASSO LES simulations.



29th August 2015
With prescribed Surface Flux



With Coupled LSM

LES-LSM Model Setup

LES Model

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

Soil Model

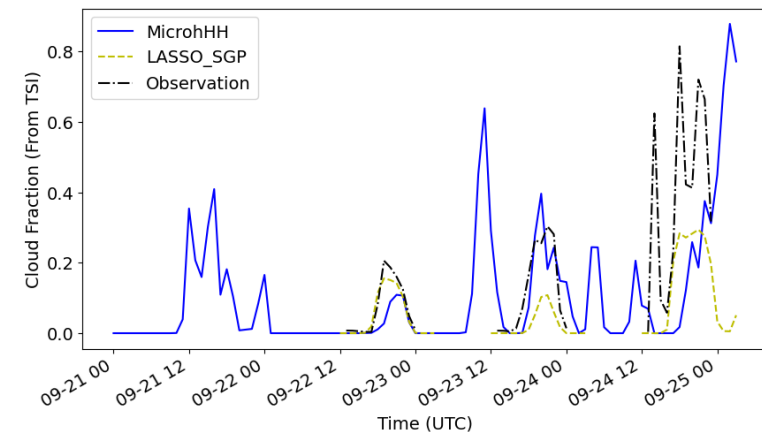
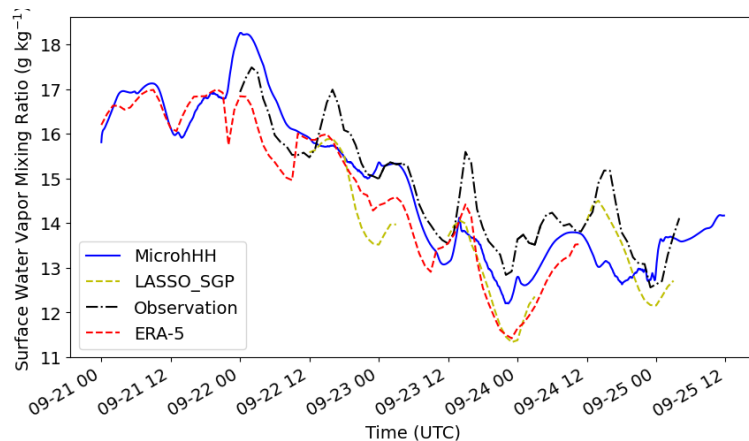
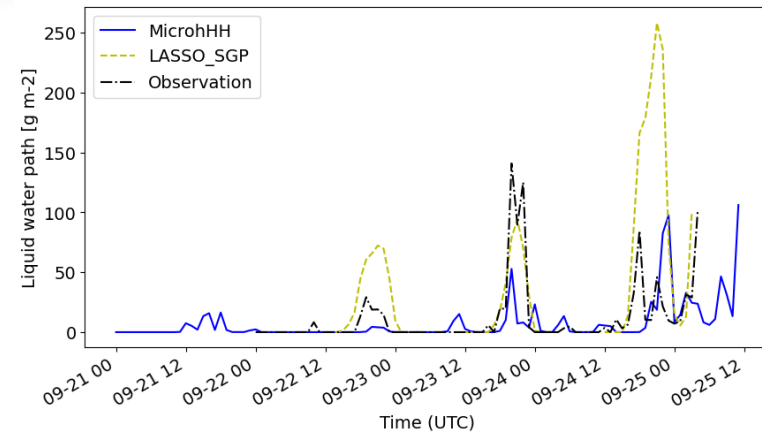
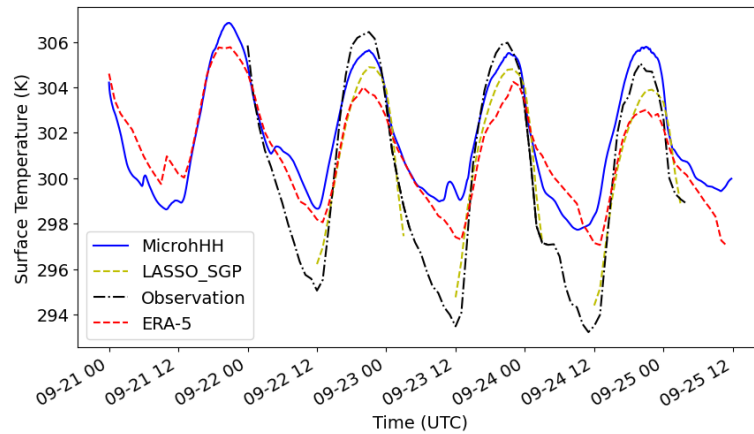
- Land Surface Model derived from HTESSEL scheme by ECMWF
- Homogeneous over model domain
- Initial Soil Water Vapor, Soil Temperature profiles from ERA5
- Vegetation Parameters (LAI, Minimum Vegetation Resistance, Roughness Length etc.) based on type of vegetation over the domain

SGP/BNF Simulations

- Output domain size – 25.6 km, Resolution – 100 m (Δx , Δy) and 10-20m (Δz), Spin-up Time \sim 1-day, No Nudging
- Comparison with LASSO-SGP (simulation-2: 25.0 km, 100m, VARANAL Surface Treatment and Large Scale Forcing with 300 km forcing scale)

SGP Comparison Plots – Surface and Liquid Water Path Plots

Initialized: September 21st, 2017; Run-time: ~4.5 days



Taylor and Relative Mean 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)

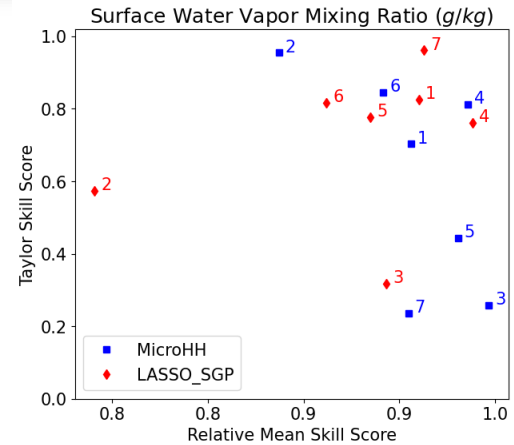
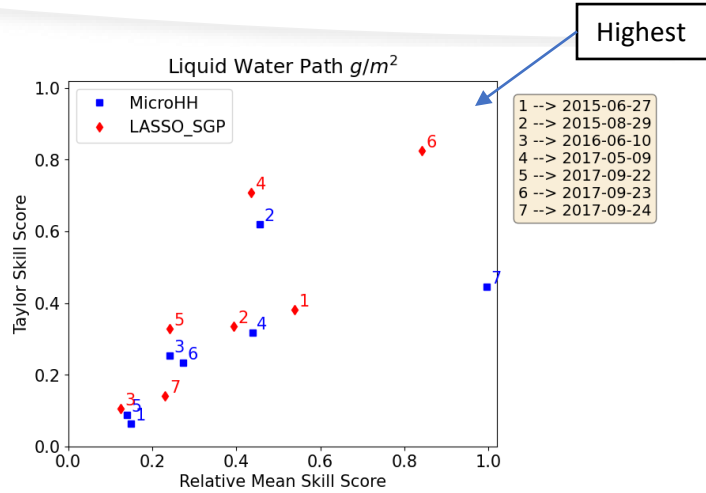
Relative Mean Skill Scores

- Based on the mean of time-series plots

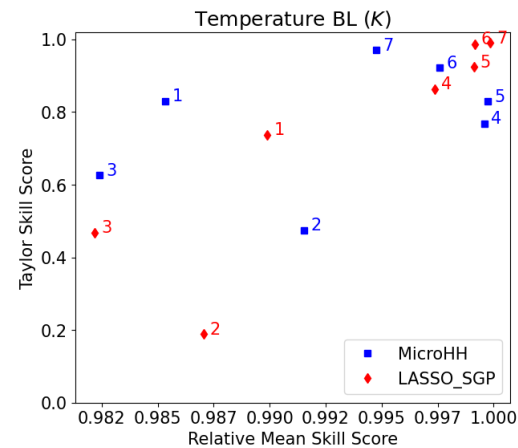
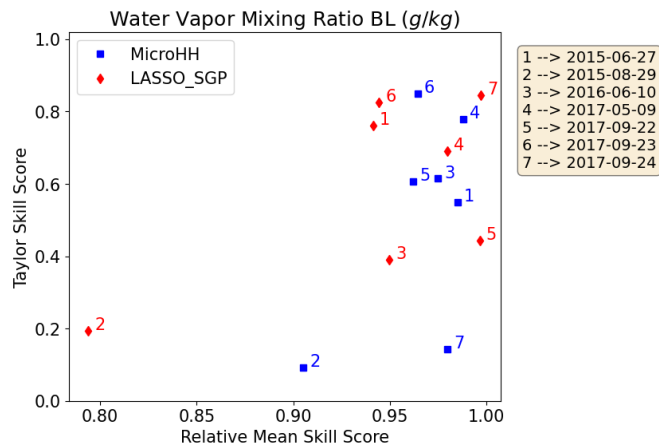
$$S_{RM}(Var) = \begin{cases} x, & x \leq 1 \\ 1/x, & x > 1 \end{cases}$$

Where x is the ratio of model mean to observed mean

Comparison with LASSO – Skill Scores



Red → LASSO
 Blue → LES-LSM



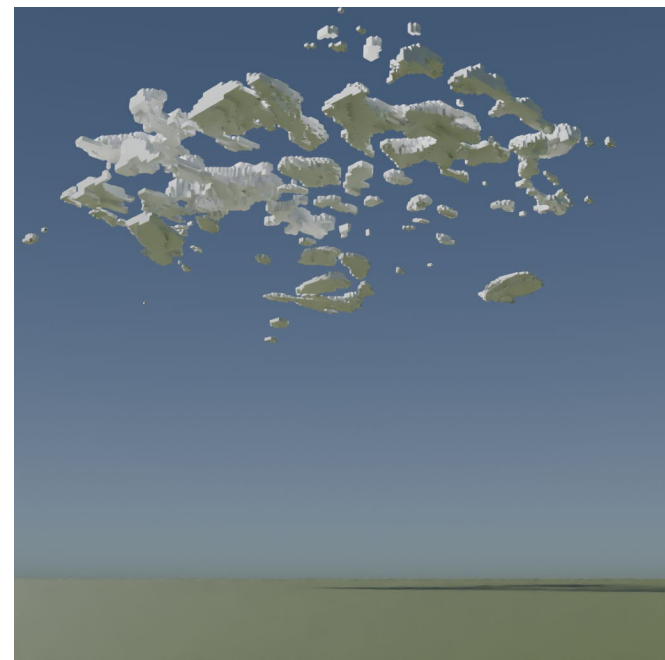
Boundary Layer --> 500m to 700m AGL

Comparison against Stereo Camera Data

Visualization Technique

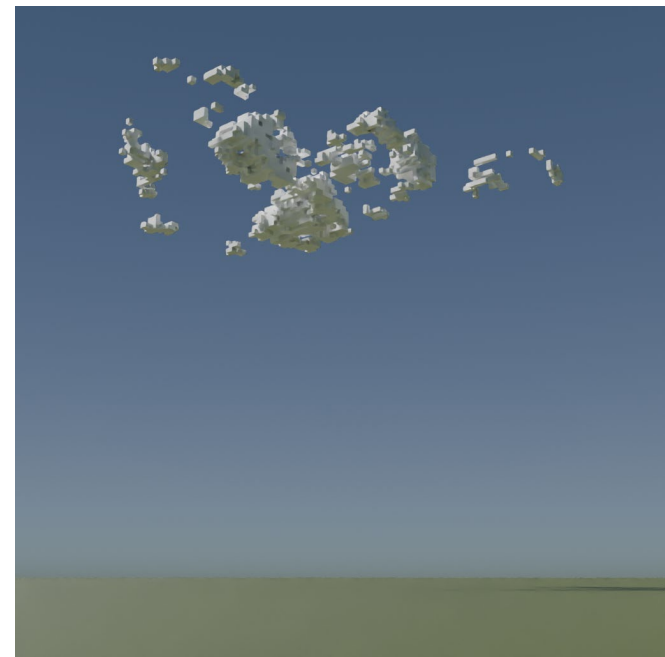
- Cloud visualization method employing blender (Burchart et al. 2023*)
- To enable a comparison between LES-LSM and COGS, the clouds were visualized by uniform white boxes, regardless of their amount of contained liquid water.
- The material characteristics of these cloud boxes are simulated using a principled Bidirectional Scattering Distribution Function (BDSF).

*Burchart et al. *A Stereo Camera Simulator for Large-Eddy Simulations of Continental Shallow Cumulus clouds based on three-dimensional Path-Tracing*. ESS Open Archive . June 23, 2023.



LES-LSM
Model

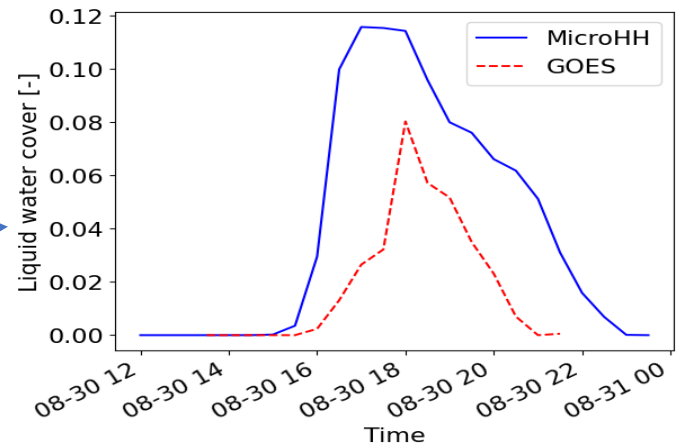
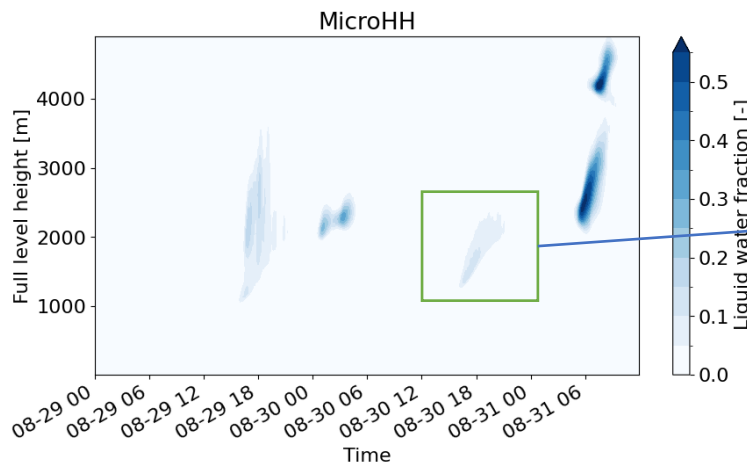
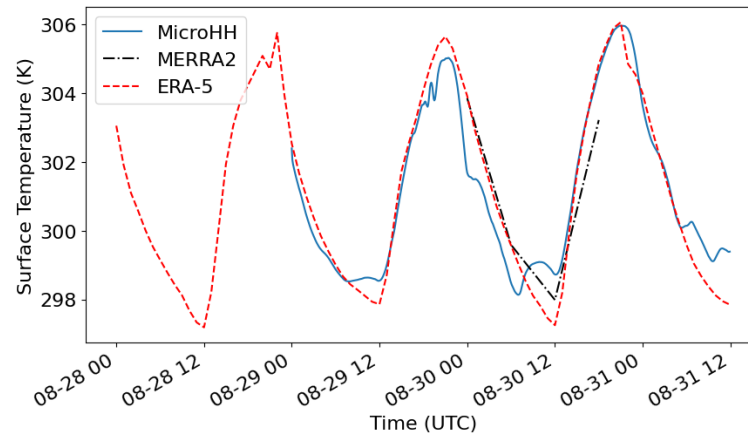
14th May 2019,
11:30 am CT



COGS
Stereo
Camera
Data

Simulations over Bankhead National Forest

August 30th, 2016



GOES Satellite data to calculate Cumulus Cloud Fraction by Dr. John Mecikalski (University of Alabama)

Summary

- User friendly Automated LES-LSM Model to perform Land-based LES simulation with specified time, duration and location.
- Run continuously over shallow cumulus days without runaway.
- GPU based model runs a lot faster (256*256 grid simulation – 3 days ~ 6 hours)
- Model performs well during SGP days in comparison to ground observations.
- Model cloud field visualization using Blender shows good agreement with on field COGS Stereo Camera observation.
- Results from simulations over BNF compare well with ERA-5
- To be installed on the ARM-Cumulus supercomputer to perform high-resolution simulations over Bankhead National Forest.

References

1. Atmospheric Radiation Measurement (ARM) user facility. 2017. Clouds Optically Gridded by Stereo (COGS) product (COGS). Southern Great Plains (SGP) Southern Great Plains Network (N1). Compiled by R. Oktem. ARM Data Center. <http://dx.doi.org/10.5439/1877293>
2. **Burchart et al. A Stereo Camera Simulator for Large-Eddy Simulations of Continental Shallow Cumulus clouds based on three-dimensional Path-Tracing.** ESS Open Archive . June 23, 2023.