Poster: 50

# Examining Boundary Layer Evolution During the Morning Transition using Observations and a Single-Column Model


Julia M. Simonson[1,2,3], Wayne M. Angevine[1,4], David D. Turner[2], Timothy J. Wagner[5], Thijs Heus[6], Tessa E. Rosenberger[6], Girish Raghunathan[6], Siwei He[7]

[1] CIRES, University of Colorado Boulder, Boulder, CO; [2] NOAA Global Systems Laboratory, Boulder, CO; [3] Developmental Testbed Center, Boulder, CO; [4] NOAA Chemical Sciences Laboratory, Boulder, CO; [5] University of Wisconsin-Madison, Madison, WI; [6] Cleveland State University, Cleveland, OH; [7] Montana State University, Bozeman, MT

**Contact: julia.simonson@noaa.gov**

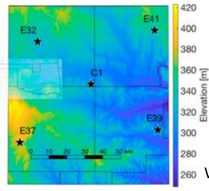

## Motivation

This study investigates the processes that lead to the growth of the convective boundary layer (CBL) during the morning transition.

- Transitions are more complicated and present differing challenges from the fully stable (nighttime) and fully convective (daytime) states
- Understanding the contribution of forcings and their relative importance to the heat and moisture budgets during the morning transition is important for forecasting air quality, aerosol dispersion (i.e., smoke), daytime cloud cover and precipitation

## Data and Methods

Data used in this study come from the DOE Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site (right).




Wagner et al. 2022

The following datasets were used:

- Potential temperature and specific humidity profiles: Atmospheric Emitted Radiance Interferometer (AERI), processed using the Tropospheric Remotely Observed Profiling via Optical Estimation (TROPoe) algorithm (Turner and Blumberg 2019)
- Sensible and latent heat fluxes: eddy correlation (ECOR) flux measurement system.
- Radiative heating rate: calculated from TROPoe profiles using the Rapid Radiative Transfer Model (RRTM)
- Advection: calculated using a Green's theorem-based approach (Wagner et al. 2022) with TROPoe and Doppler lidar data

*Common Community Physics Package Single Column Model (CCPP SCM)*
Simulations were conducted using CCPP SCM version 6.0.0 and the SCM_HRRR physics suite. The simulations were initialized at 0000 UTC 12 July 2019 with the NOAA Rapid Refresh (RAP) analysis providing the initial and forcing data. The configurations for the SCM simulations are listed in Table 1.

Table 1. SCM experiment configurations

| Experiment | Surface Forcing | Forcing Interval |
|---|---|---|
| CTRL | Rapid Update Cycle (RUC) Land Surface Model | Every time step (150 s) |
| RAP SFC | RAP Analysis | Every 60 minutes |
| OBS SFC | ARM Observations | Every 60 minutes |

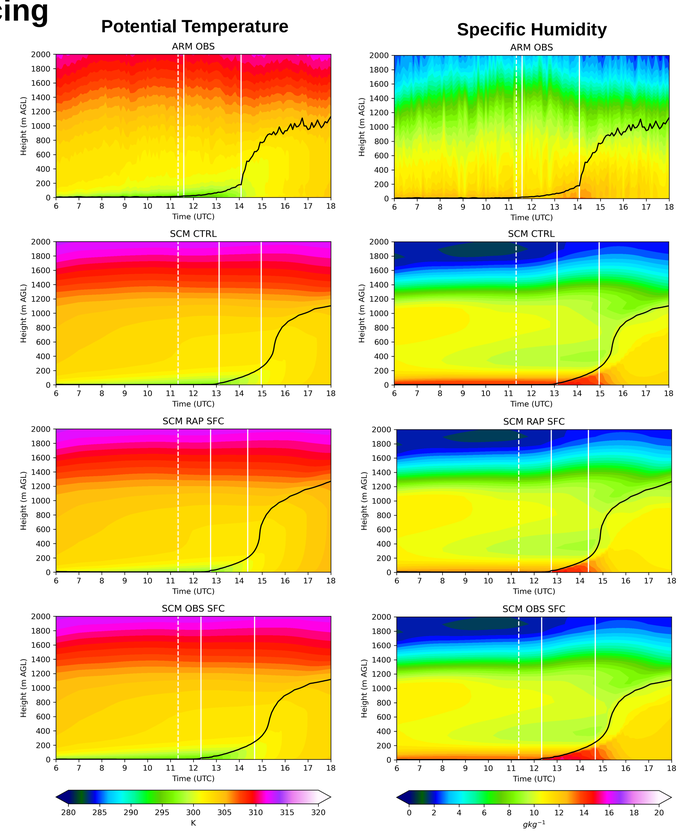
*Mixing Diagrams*
Mixing diagrams are a useful tool for quantifying the relative role of individual components of the heat and moisture budgets on CBL evolution (Santanello et al 2009). The heat and moisture budget equation (from Wakefield et al. 2023) is:

$$k\frac{\partial\langle\bar{\phi}\rangle}{\partial t} = k\langle -\boldsymbol{v}\cdot\nabla_h\phi\rangle + \frac{gF_s}{dp} + \frac{gF_i}{dp} + \frac{gk\bar{\rho}W_e(\overline{\phi_i} - \langle\bar{\phi}\rangle)}{dp} + k\langle\overline{Q_R}\rangle$$

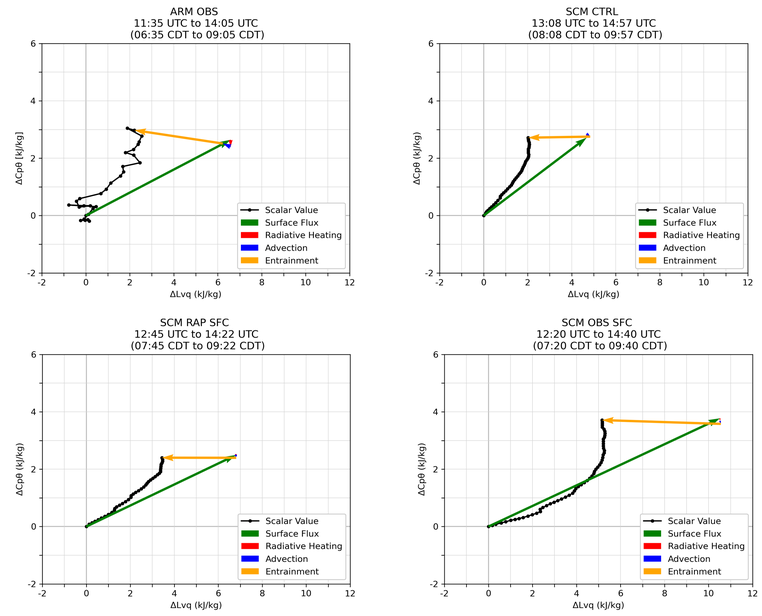
Time tendency of scalar | Advection | Surface Fluxes | Entrainment | Radiative Heating

where the time tendency, advection, surface flux, and radiative heating terms were calculated using ARM datasets and entrainment estimated as the residual of the other terms. The analysis period covers the interval where there is a measurable CBL height until the nocturnal temperature inversion has eroded.

## Result 1: CBL (black line) growth starts later and transition (solid white vertical lines) is shorter in the SCM compared to observations, regardless of surface forcing

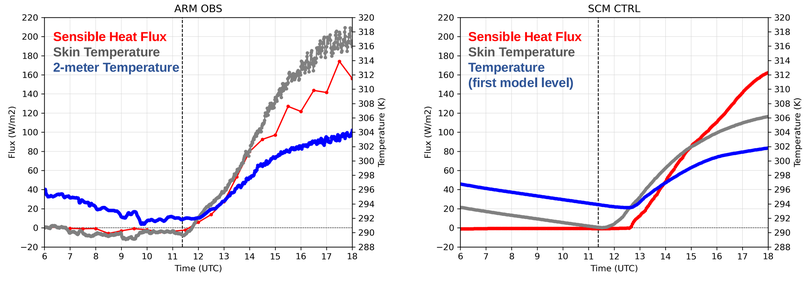



## Result 2: SCM represents the proportion of surface fluxes to entrainment during morning transition, magnitude of forcings differ between SCM simulations and observations




**Check out my poster at Wednesday's session!**
**Poster 582: Exploring Land-Atmosphere Interactions in the Unified Forecast System using the Common Community Physics Package Single Column Model (CCPP SCM)**

## Result 3: response of skin and near-surface air temperatures in SCM to sunrise (black vertical line) is more gradual compared to observations





**Acknowledgements**: This work was by the U.S. Department of Energy's Atmospheric System Research (ASR) program along with support from the NOAA Atmospheric Science for Renewable Energy (ASRE) Program. CIRES authors were supported under NOAA cooperative agreements NA17OAR4320101 and NA22OAR4320151.


**References**


Santanello, J.A., Jr., C. D. Peters-Lidard, S. V. Kumar, C. Alonge, and W.-K. Tao, 2009: A modeling and observational framework for diagnosing local land–atmosphere coupling on diurnal time scales. *J. Hydrometeor.,* **10**, 577–599, https://doi.org/10.1175/ 2009JHM1066.1.

Turner, D. D., and W. G. Blumberg, 2019: Improvements to the AERIoe thermodynamic profile retrieval algorithm. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, **12**, 1339–1354, https://doi.org/ 10.1109/JSTARS.2018.2874968.

Wagner, T. J., D. D. Turner, T. Heus, and W. G. Blumberg, 2022: Observing profiles of derived kinematic field quantities using a network of profiling sites. *J. Atmos. Oceanic Technol.*, **39**, 335–351, https:// doi.org/10.1175/JTECH-D-21-0061.1.

Wakefield, R. A., Turner, D. D., Rosenberger, T., Heus, T., Wagner, T. J., Santanello, J. A., Jr., and Bassara, J., 2023: A methodology for estimating the energy and moisture budget of the convective boundary layer using continuous ground-based infrared spectrometer observations. *J. Appl Meteorol Climatol.*, **62**, 901–914, https://doi.org/10.1175/JAMC-D-22-0163.1.