Examining Boundary Layer Evolution during the Morning Transition Using Observations and the Common Community Physics Package Single Column Model (CCPP SCM)

Julia M. Simonson[1,2], David D. Turner[2], Timothy J. Wagner[3], Thijs Heus[4], Girish Raghunathan[4], Samuel Kimball[3]
1. CIRES, University of Colorado Boulder, 2. NOAA Global Systems Laboratory, 3. Space Science and Engineering Center, University of Wisconsin–Madison 4. Cleveland State University

ASR Atmospheric System Research

The Morning Transition

STARTING THE DAY OFF RIGHT

Transitions present differing challenges from the full stable (nighttime) and fully convective (daytime) states:

- Few forcings can be ignored
- Boundary layer conditions change rapidly over a short period of time
- Tight coupling between boundary layer evolution and land surface processes

Understanding the contribution of forcings to the growth of the convective boundary layer (CBL) during the morning transition is important for forecasting air quality, aerosol dispersion (i.e., smoke), daytime cloud cover and precipitation.

This work investigates the processes that lead to the growth of the CBL during the morning transition and assesses the representation of CBL evolution by model physics using a single–column model.

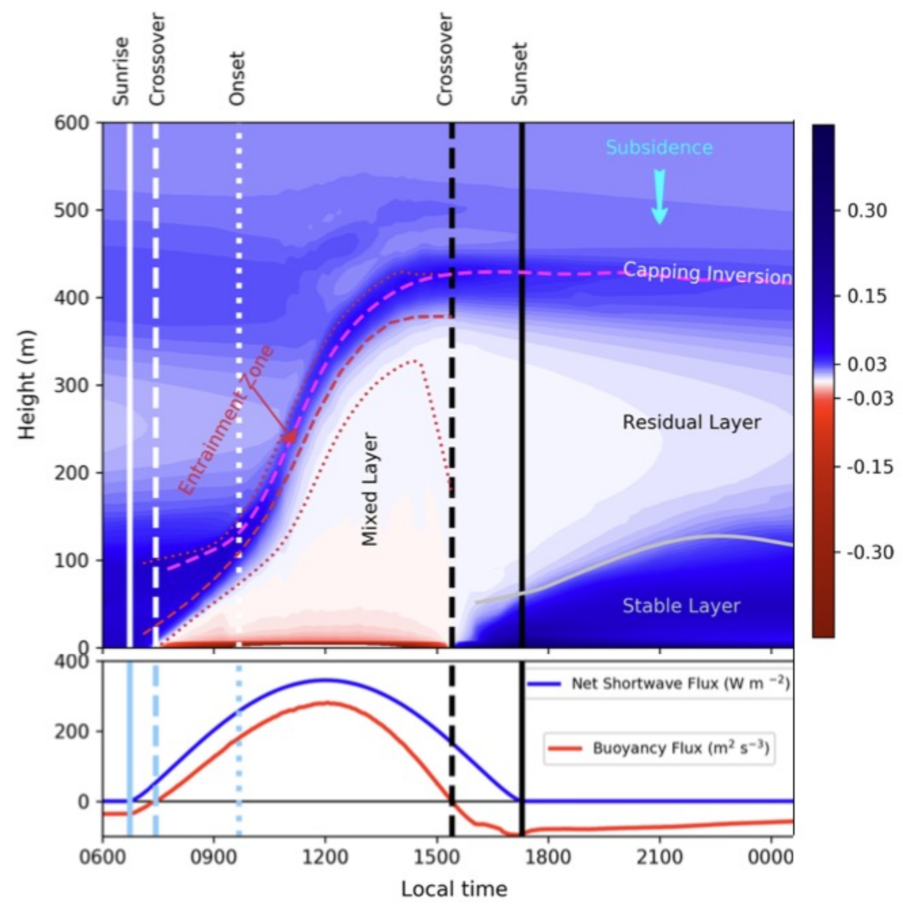

Fig 1: (Top) Schematic of an idealized LES simulation of the vertical gradient of potential temperature throughout the diurnal cycle.
(Bottom) Time series of the net shortwave flux (blue) and buoyancy flux (red) corresponding with the simulation in the top panel. From Angevine et al. 2020.

CBL Evolution and Contributing Forces

MIXING DIAGRAMS

The SCM represents the proportion of surface fluxes to entrainment despite differences in the transition timing and duration.

In the SCM, forcing magnitudes are larger when surface fluxes are from the RAP analysis or observations than when a land surface model is used, showing how decoupling the land surface from the atmosphere impacts CBL evolution.

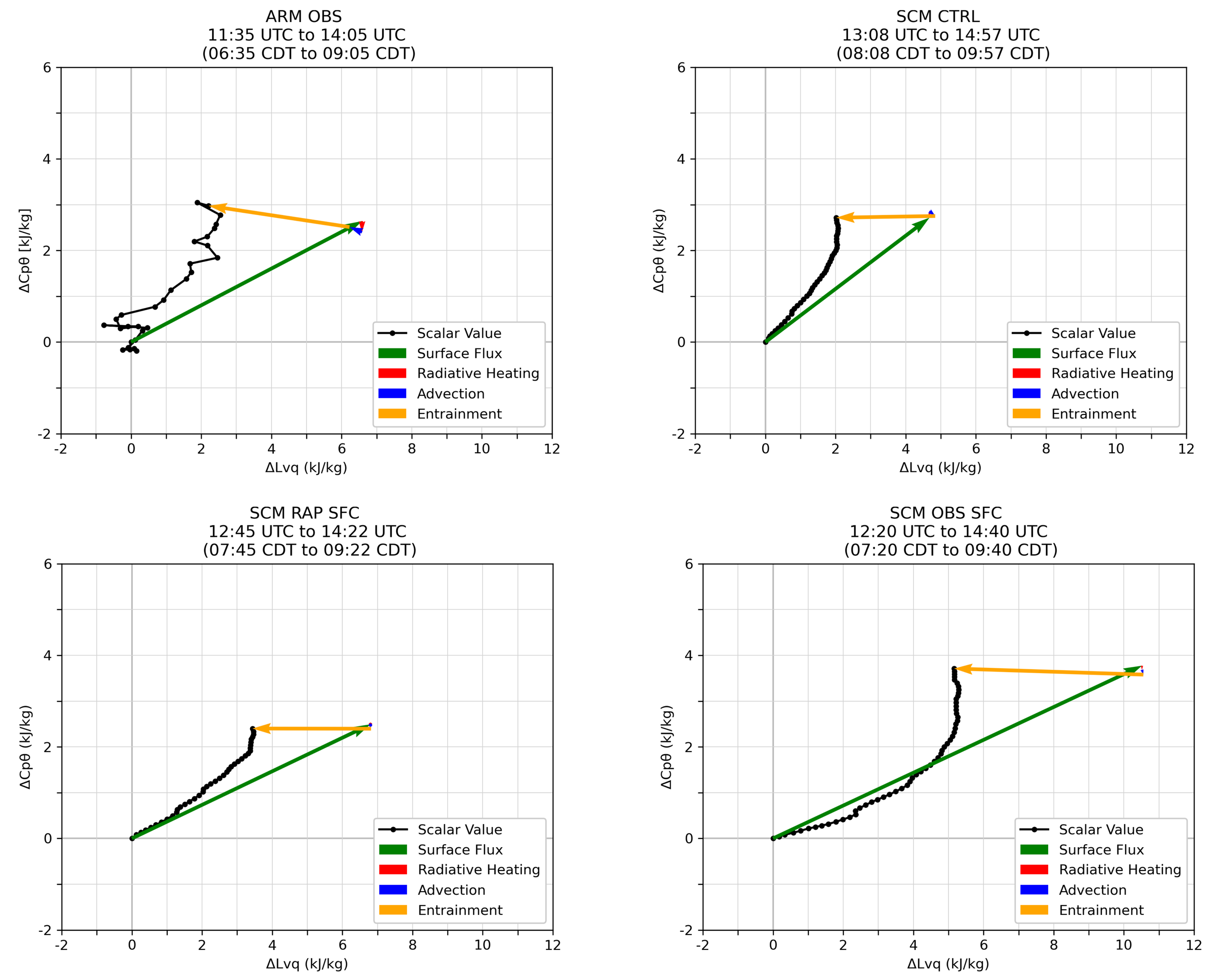

Fig 3: Mixing diagrams for observations and SCM simulations. The black curves represent the coevolution of CBL mean potential temperature and specific humidity in energy units (kJ kg^{-1}), and the vectors represent the forcing contributions. The mixing diagrams are normalized to start at the origin at the beginning of the analysis period.

State of the Atmosphere and CBL Growth

SGP OBSERVATIONS VS. SCM

Compared to observations, CBL growth starts later and the morning transition is shorter in the SCM regardless of surface forcing (land surface model or surface fluxes from ECOR observations or the NOAA Rapid Refresh analysis).

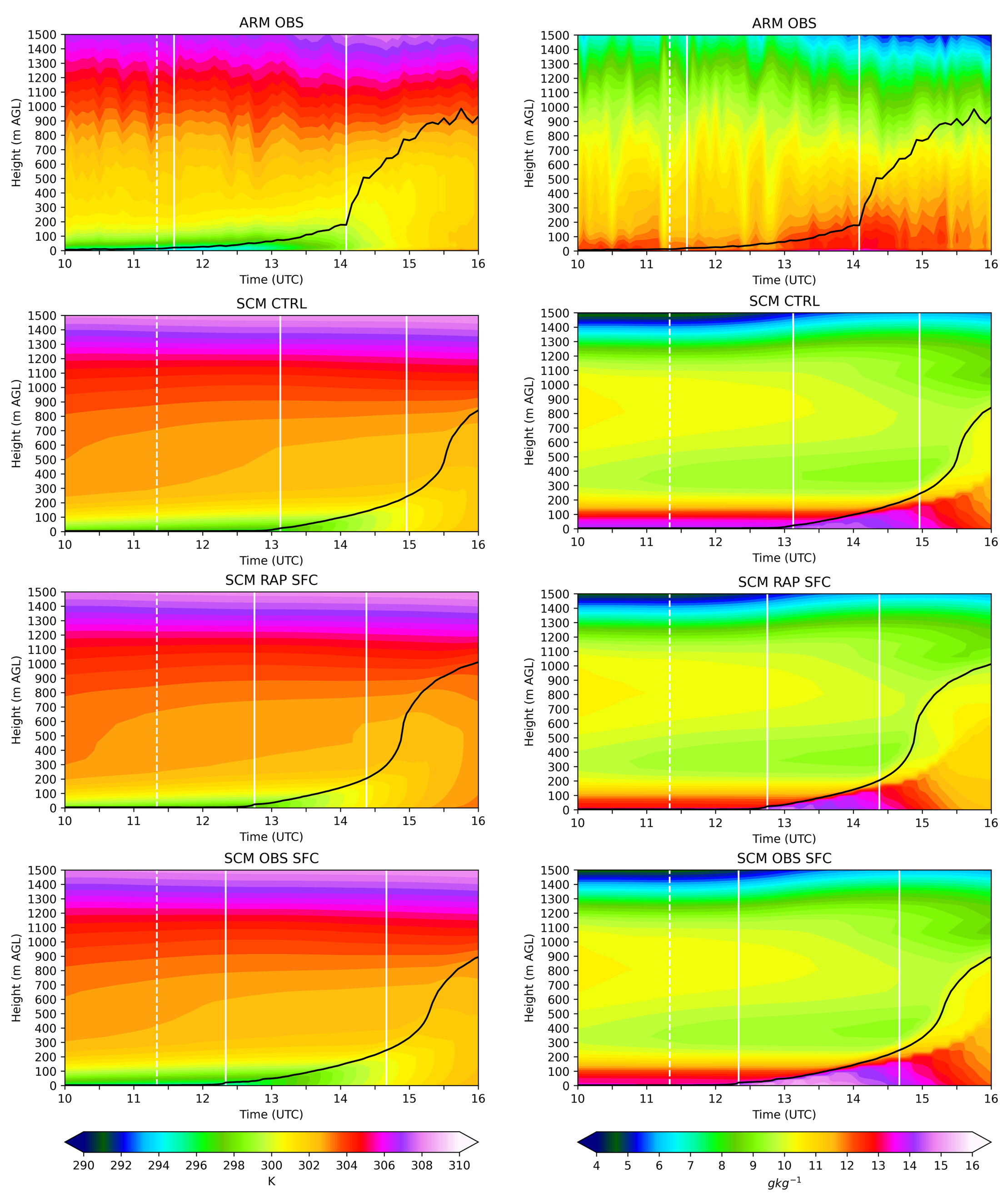

Fig 2: Time/height cross-sections of potential temperature (left, in K) and water vapor mixing ratio (right, in g kg^{-1}) from TROPoe retrievals and the SCM simulations. The black lines represent the CBL height, the vertical dashed white lines represent sunrise, and the vertical solid white lines represent the start and end of the morning transition.

Surface Energy Balance

TEMPERATURE RESPONSE TO SURFACE HEATING

The response of skin and near-surface air temperatures in the SCM to sunrise is more gradual compared to observations. This indicates that a greater build-up of heat in the ground is required before heating of the air above the surface can occur, resulting in a longer time period between sunrise and when sensible heat fluxes become positive in the SCM, delaying the initiation of CBL growth.

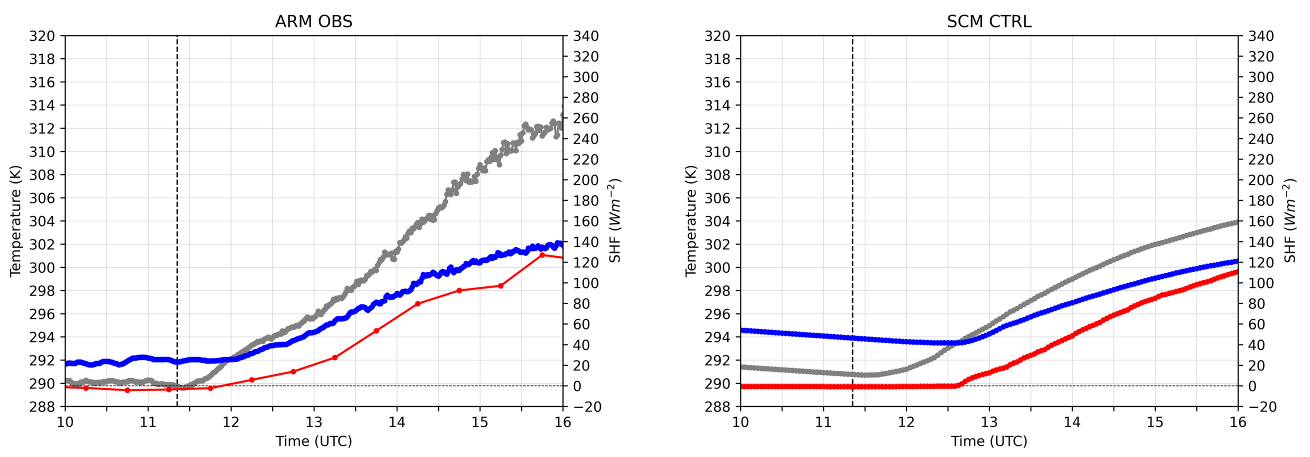

Fig 4: Timeseries of sensible heat flux (red, in W m^{-2}), skin temperature (gray, in K), and near-surface temperatures (blue, at 2-meters for observations and the first atmospheric model level for the SCM in K). The vertical dashed line indicates the time of sunrise.

Summary

MORNING TRANSITION IS SHORTER AND STARTS LATER IN SCM

The results indicate that the boundary layer physics scheme is compensating for biases originating in the land surface model, with the reduced rate of heat transfer from the ground to the atmosphere resulting in an increased rate of change in CBL heat and moisture.

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Contact Information: • Julia M. Simonson, julia.simonson@noaa.gov

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Angevine, W. M., J. M. Edwards, M. Lothon, M A. LeMone, and S. R. Osborne, 2020: Transition periods in the diurnally-varying atmospheric boundary layer over land. *Bound.-Layer Meteor.*, **177**, 205-223. https://doi.org/10.1007/s10546-020-00515-y.

NOAA CIRES CSU Cleveland State University WISCONSIN UNIVERSITY OF WISCONSIN–MADISON U.S. Department of ENERGY