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Exploring Land-Atmosphere Interactions in the Unified Forecast System using the Common Community Physics Package Single Column Model (CCPP SCM)

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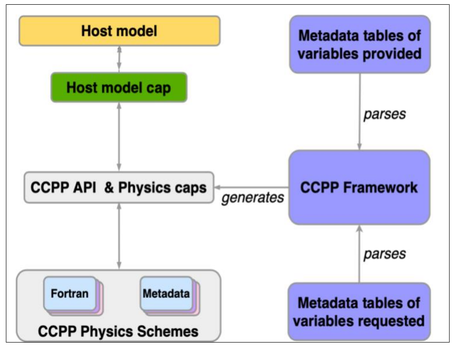
Motivation

- Processes that transport energy and moisture within the land-atmosphere (L-A) system contribute to the structure and diurnal evolution of the planetary boundary layer (PBL)
- Biases in L-A model parameterizations can negatively impact weather forecast skill by influencing the state of the PBL (e.g., differences in surface properties altering PBL temperature and moisture, impacting cloudiness and precipitation)

In this study we assess the representation of processes within the L-A system in NOAA's Unified Forecast System (UFS) over the Continental United States.

Common Community Physics Package Single Column Model (CCPP SCM)

The CCPP SCM is a simple host model that utilizes the Common Community Physics Package, a library of physical parametrizations used by multiple host models, including the UFS and NOAA's operational Hurricane Analysis and Forecast System (HAFS). Large scale forcing is prescribed in the SCM, so there is no feedback to the dynamical core. This simplifies the interpretation of modifications to physics parameterizations and makes SCMs a useful tool for examining the L-A system.



Architecture of the CCPP and its connection to a host model. The CCPP Framework auto-generates the CCPP API and physics caps that connect the schemes in CCPP Physics with the host model (Bernardet et al. 2024; Heinzeller et. al 2023).

New for CCPP SCM Version 7: UFS Case Generation (casegen)

Typically, prescribed forcings used to drive the SCM come from observations or field campaigns. UFS casegen gives the ability to generate SCM cases from UFS simulations by either deriving the forcings needed by the SCM or using tendencies from the dynamical core ("native" forcing).

- Derived forcing: horizontal advection is computed using a stencil of surrounding UFS grid points, can also "nudge" the SCM state back to the UFS state
- Native forcing: use the tendencies from from the dynamical core to drive the physics, requires rerunning the UFS to produce additional diagnostics (more computationally expensive)

Model Setup

Source model for initial conditions and forcing: UFS C96 atmosphere-only simulations from NOAA Seasonal Forecast System (SFS) using prototype HR4 physics
CCPP SCM configuration:

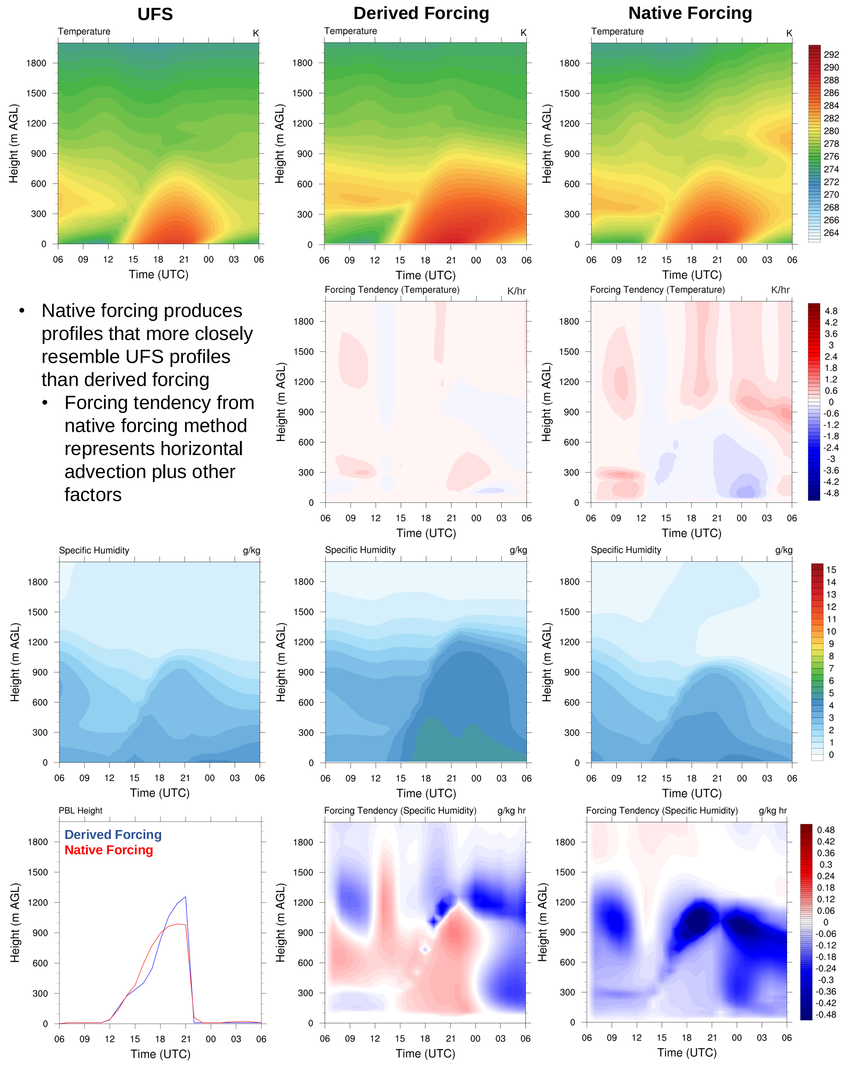
- Column location: central Massachusetts (42.53, -72.17)
- Physics: GFS v17 p8 ugwpv1 with NoahMP land surface model
- SCM simulations run using either derived forcing or native forcing
- Simulation period: 06 UTC 22 March 2021 to 06 UTC 23 March 2021
- Column size: equivalent to SFS C96

Check these out to learn more about model testing and development using CCPP SCM:

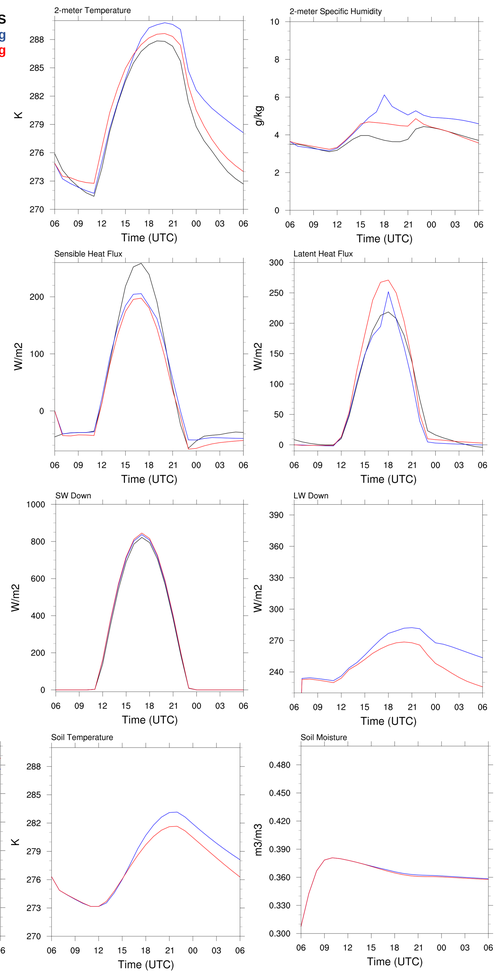
15R20: Zhang et al. Bridging Community Physics Innovations and NWP Models: UFS Physics Testing by the Developmental Testbed Center, Jan 16 at 2 pm in Room 213

Poster #993: Hertneky et al. Investigating Microphysics Timestep and Multi-Microphysics Intercomparisons in Arctic Stratiform Mixed-Phase Clouds during MOSAiC, Jan 16 at 3 pm in Hall C

Case Study: 22 March 2021



- Native forcing produces profiles that more closely resemble UFS profiles than derived forcing
  - Forcing tendency from native forcing method represents horizontal advection plus other factors



- Near-surface variables in both SCM simulations tend to be similar in magnitude to UFS before sunrise (10:48 UTC), differences arise after 15 UTC
  - SCM divergence from UFS state is greatest during midday for sensible, latent, and ground fluxes as well as downwelling shortwave
  - Temperature and humidity at 2 meters from derived forcing run continue to deviate from the UFS through the afternoon and evening hours

Summary and Future Work

- Differences in state variable profiles between the SCM runs attributed to forcing method, response of near-surface conditions to atmospheric forcing differs temporally
- Utilizing both forcing methods can provide insight into L-A interactions within the SCM
- Future work will apply the SCM to diagnose sources of near-surface variable biases in the UFS, as well as to test and evaluate modifications to physics parameterizations
- The SCM can also be used to diagnose bias origin (i.e., model dynamical core versus physics parameterizations)

Acknowledgements:
DTC Physics TnE team: Weiwei Li, Evelyn Grell, Tracy Hertnecky, and Jimy Dudhia.
This study was supported by NOAA cooperative agreements NA17OAR4320101 and NA22OAR4320151, NOAA Seasonal Forecast System Development Plan subproject: Physics and Dynamics Improvements. The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

References

Bernardet, L., and Coauthors, 2024: Common Community Physics Package: Fostering Collaborative Development in Physical Parameterizations and Suites. Bull. Amer. Meteor. Soc., 105, E1490–E1505, https://doi.org/10.1175/BAMS-D-23-0227.1.
Heinzeller, D., Bernardet, L., Firl, G., Zhang, M., Sun, X., and Ek, M., 2023: The Common Community Physics Package (CCPP) Framework v6, Geosci. Model Devel., 16, 2235–2259, https://doi.org/10.5194/gmd-16-2235-2023.