Confronting the low summer CAPE behavior in GFSv16

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Motivation

- The Convective Available Potential Energy (CAPE) low bias issue is listed as one focus area in the Final List from 2020-21 OSTI Forecasters Workshop.
- CAPE magnitudes are reduced in Global Forecast System (GFS) v16 compared with GFS v15 (Yang et al. 2020)

UFS Case Studies Platform

- We investigate the 2020 low summertime CAPE case included in the case catalog of Unified Forecast System (UFS) Case Studies Platform.
- The UFS Case Studies Platform provides resources for representative cases that reveal GFS forecast challenges and includes model setup for multiple UFS applications, IC/BC datasets hosted on cloud storage, results, and example visualization scripts.

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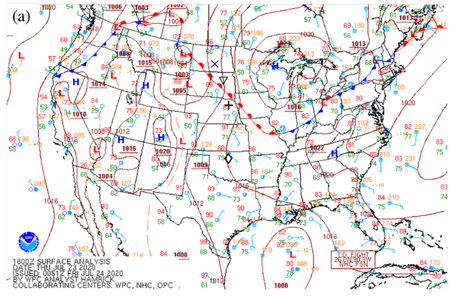
2020 July CAPE Case

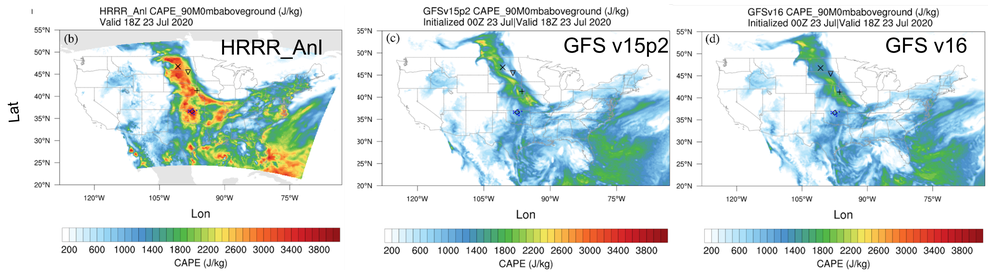
- **Model:** GFS v16 and GFS v15p2
- **Initialization:** 00z Jul 23, 2020
- **Initial conditions**: GFS operational dataset in NEMSIO format
- **Resolution:** 128 vertical levels and C768 spatial resolution (~13km)



Weather Prediction Center (WPC) surface analysis at 07/23/2020 at 18 UTC

- Warm front passage over Northern Great Plains
- No significant synoptic pattern impacting the Southern Great Plains (SGP)

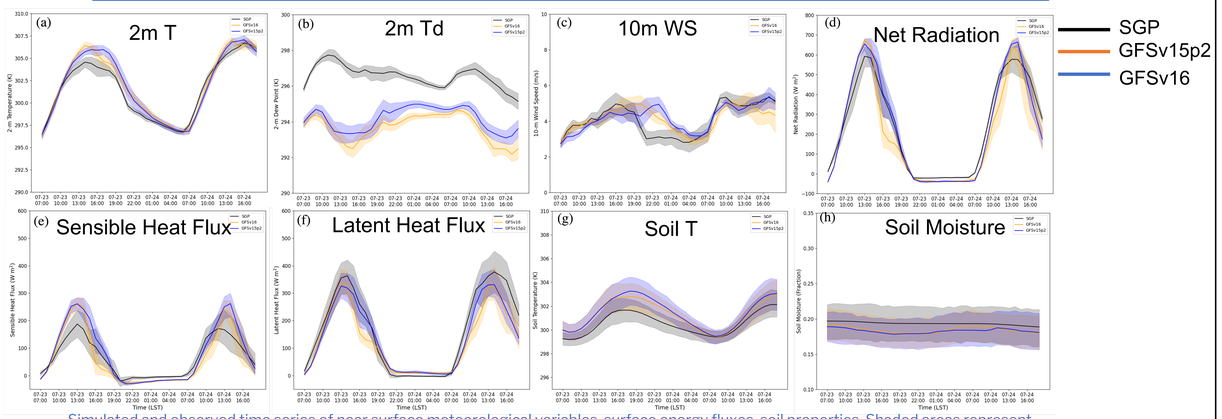
Spatial Distribution of CAPE (18Z 07/23)



Mixed-layer based CAPE (MLCAPE) from HRRR analysis and GFS forecasts valid at 18UTC Jul 23, 2020.

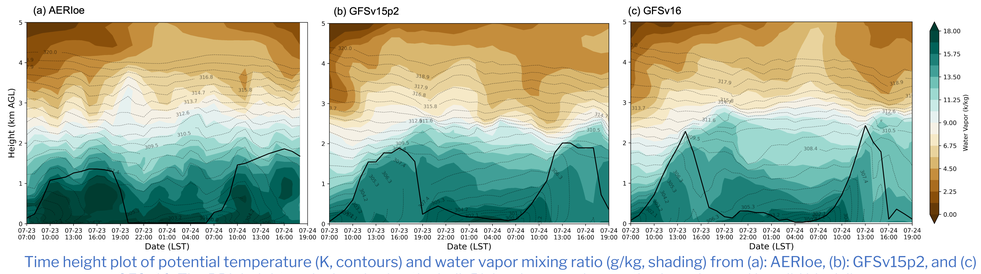
- Large CAPE reservoir exist over both Northern Great Plain and Southern Great Plain (SGP)
- The low summertime CAPE is present in GFS models (here: 18-h forecast)
- CAPE in GFS v16 even lower than GFS v15p2

Surface Met, Soil Properties, and Boundary Layer Structure (07/23-07/24)



Simulated and observed time series of near surface meteorological variables, surface energy fluxes, soil properties. Shaded areas represent data range with 95% confidence.

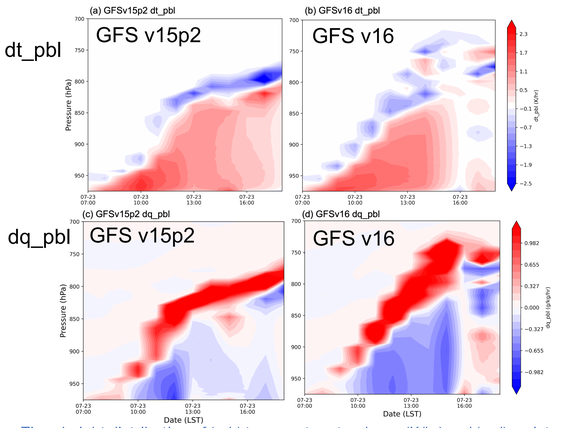
- GFS has lower magnitudes of latent heat flux (LHF) than observed
- The daytime Bowen ratio derived from measurement was 0.42. More energy was partitioned into sensible heat fluxes in GFS with a Bowen ratio of 0.67 and 0.60 for v15p2 and v16



Time height plot of potential temperature (K, contours) and water vapor mixing ratio (g/kg, shading) from (a): AERIoe, (b): GFSv15p2, and (c) GFSv16. The PBL heights calculated using the bulk Richardson number method are denoted in solid black lines.

- AERIoe water vapor at low levels above 18 g/kg
- Overall drier in GFS in the lowest 1.5 km AGL
- The larger computed planetary boundary layer height (Bulk Richardson number method) from GFS v16 suggests more entrainment of drier and warmer air from above

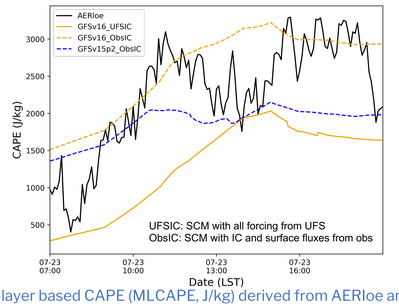
Temperature and Moisture Tendencies (07/23)



Time-height distribution of (a, b) temperature tendency (K/hr) and (c, d) moisture tendency (g/kg/hr) from PBL schemes in GFSv15p2 and GFSv16 from 07:00 to 19:00 local time on July 23, 2020 .

- The PBL scheme warms and dries the atmosphere within the boundary layer
- Near the top of the PBL, the detrainment process cools and moistens the free atmosphere

Single Column Model (SCM) Experiments (07/23)



Mixed-layer based CAPE (MLCAPE, J/kg) derived from AERIoe and SCM runs

- The lower-than-observed CAPE in global runs is well mimicked in CCPP SCM (GFSv16_UFSIC)
- With observed initial conditions, the SCM MLCAPE (GFSv16_ObsIC) is consistently about 1000 J/kg larger than with the GFS v16 initial conditions (GFSv16_UFSIC)

Summary

- The larger-than-observed Bowen ratio in GFS suggests an incorrect surface energy partitioning associated with soil moisture and soil temperature.
- The drier air simulated in GFS v16 compared with GFS v15p2 and observations is mostly related to local physics in this case.
- With realistic IC of vertical profiles and surface fluxes, the GFS v16 physics suite is able to produce the large CAPE.

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