MYNN PBL for WRF-ARW: Modifications & Impacts

Joseph Olson

Cloud Fraction Modification (Bug Fix)

Original Code

- Stratus and convective cloud mixing ratios were ***thought*** to be output as in-cloud mixing ratios
  - However, Nakanishi contacted me to discuss this. Stratus component is actually a ***grid mean*** mixing ratio, which the mass-flux clouds were ***in-cloud***.
- The main impact: the **stratus mixing ratios are underestimated - reduced cloud-radiative impact**!

Modified Code

- Both stratus and mass-flux components are now output as ***grid means*** (like all other variables in CCPP or WRF)
- The mixing ratios are converted to in-cloud in the pre-radiation modules when the namelist variable ***lcnorm*** = .true. (now a must!)
- Note that this is the only physically justifiable configuration. The radiation scheme expects in-cloud mixing ratios.

For reference: $qc_{in\text{-}cloud} = qc_{mean}/CF$; $qc_{mean} = qc_{in\text{-}cloud}*CF$, where CF is the cloud fraction.

Mass-Flux Modification (Code Optimization)

Original Code

- A **variable number of plumes** (*nup*), (with max = 10), with fixed increment of 100 m (100, 200, 300, …, 1000 m).
  - The maximum plume size is determined by environment properties (PBLH, cloud base, and surface fluxes) and grid spacing (Δx).
  - The actual **number of plumes (nup) used was allowed to vary**.
- Because nup varied, all do-loops over the plumes would not vectorize
- There is some debate on whether the smallest plumes were needed.

Modified Code

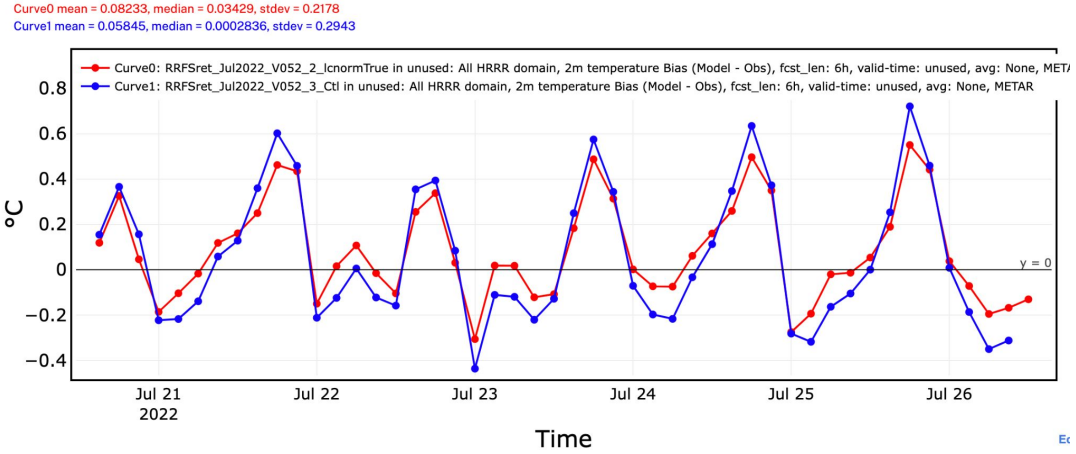
- A constant number of *nup* = **8 plumes** are now used (20% reduction).
  - The minimum size = 300 m.
  - The maximum size can be 1000 m, determined the same way as before.
  - The plume size increment now varies
- With *nup* fixed, more loops can be vectorized (**10-15 % speed up**)
- **Small change in behavior is expected/intended/seen**
  - Removing the smallest plumes allows the updraft areal fraction to be dominated by larger plumes, so slightly more nonlocal mixing

RRFS 2-m Temperature at Fh 6

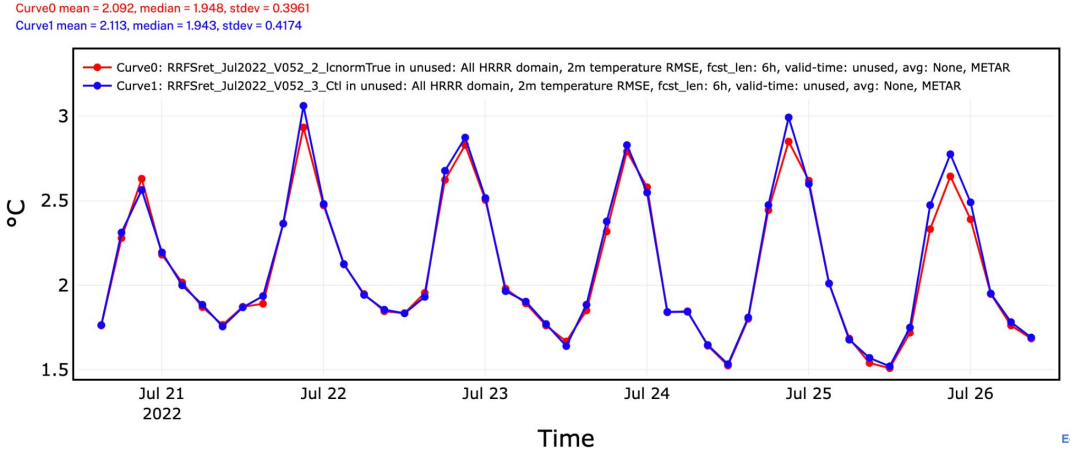
Bias

Control

Updated



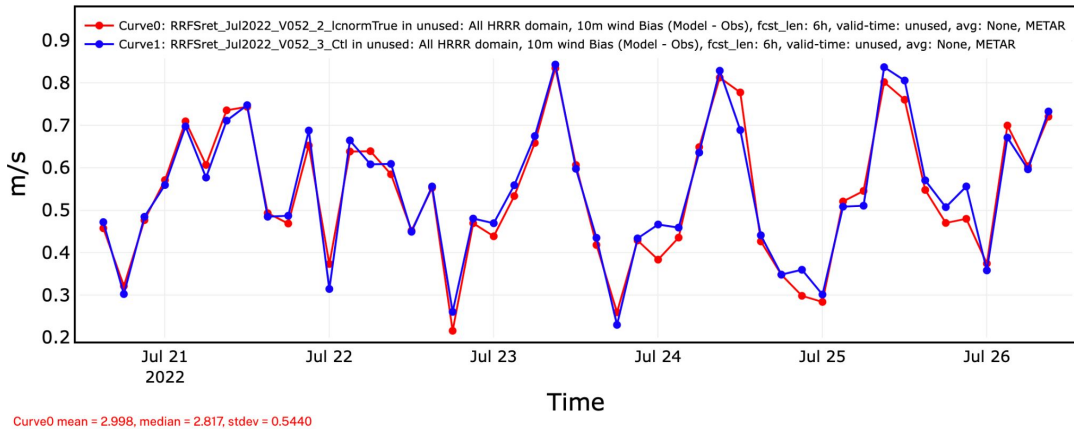
RMSE



RRFS 10-m Wind Speed at Fh 6

Bias

Curve0 mean = 0.5377, median = 0.5333, stdev = 0.1564
Curve1 mean = 0.5441, median = 0.5559, stdev = 0.1537

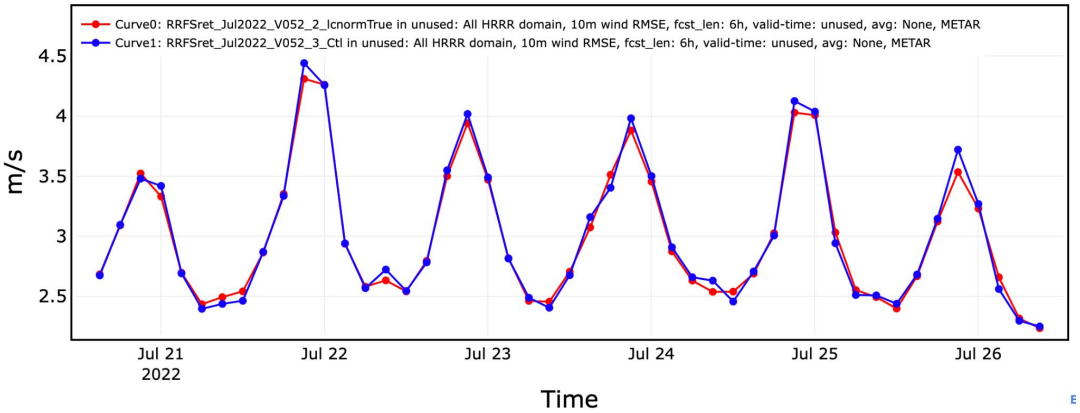


Control

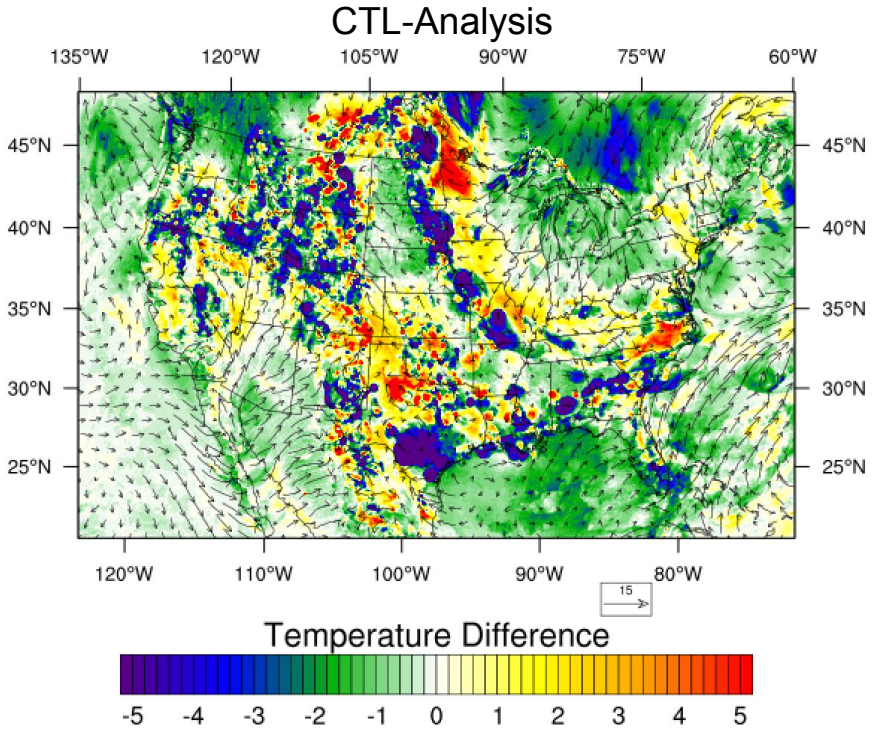
Updated

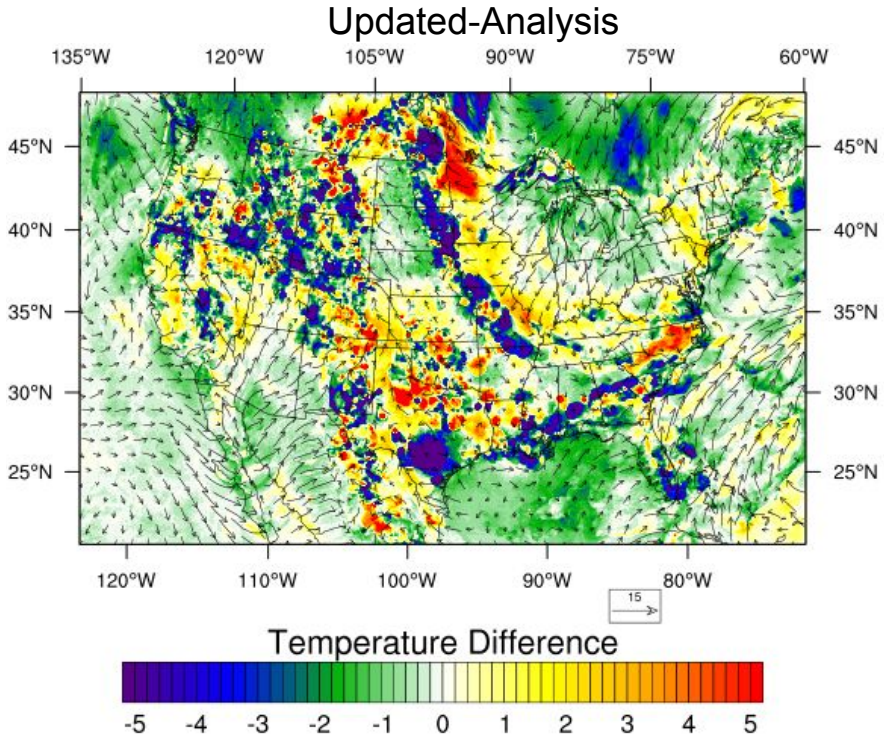
RMSE

Curve0 mean = 2.998, median = 2.817, stdev = 0.5440
Curve1 mean = 3.010, median = 2.814, stdev = 0.5720



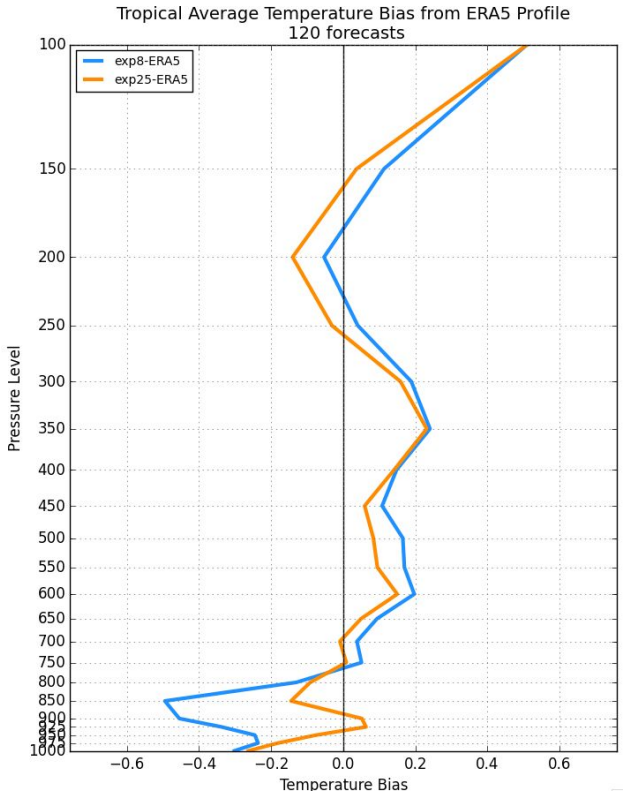
Example of Improvements in 2-m Temperature Bias
12 hr forecast - valid at 00 UTC 08 June 2023

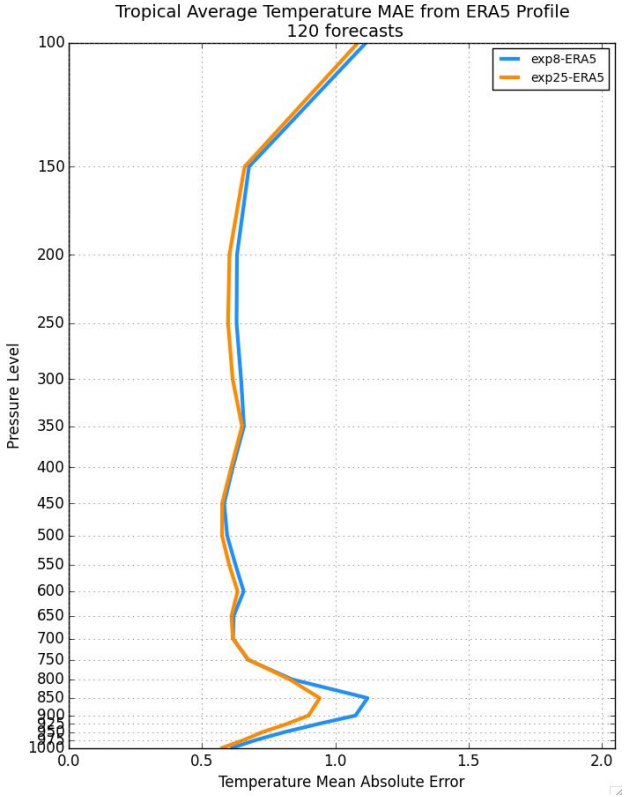




Temperature Verification in the Tropics

Updated MYNN with modified Thompson-Eidhammer AA scheme
Original MYNN with modified Thompson-Eidhammer AA scheme



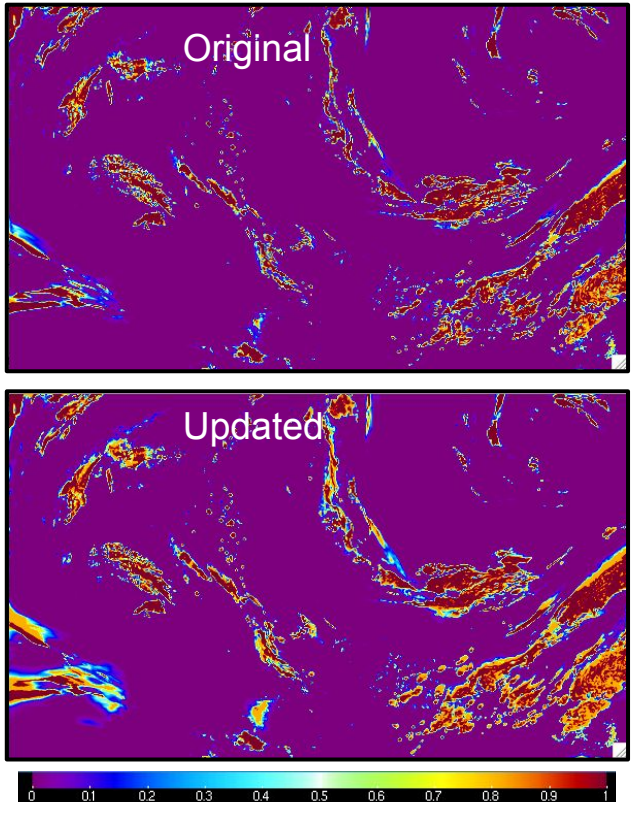


- The marine clouds became too bright, requiring some additional in-cloud turbulence to mix away some clouds.
- More MYNN-EDMF tuning is required, but the current updated version is much more compatible with the updated AA Thompson scheme compared to the original version.

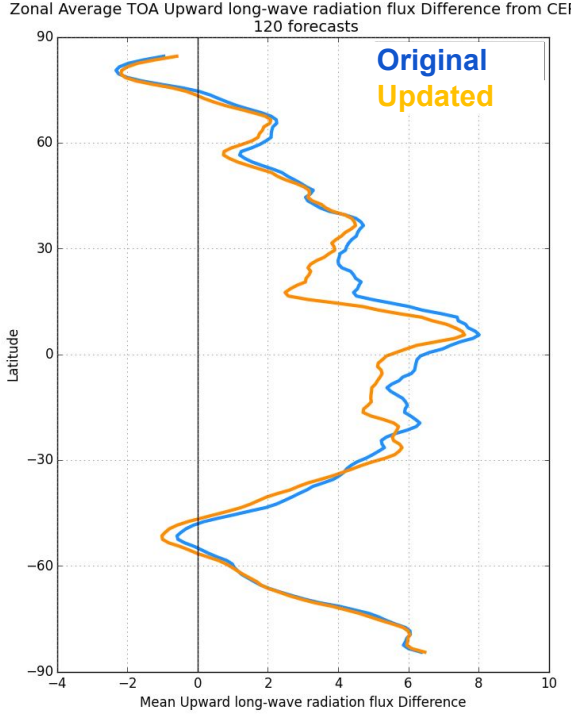
Improved Upper-Level Cloud Fractions for Snow/Ice Clouds

RRFS Cloud Fractions at 300 mb

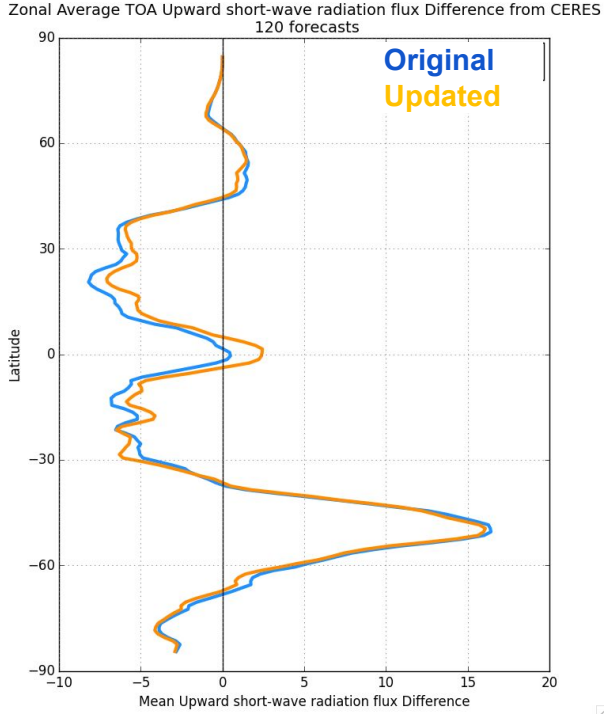
6 hr fcst valid at 18 UTC on 07 June 2023



GFS-MYNN OLR Bias



GFS-MYNN SW-up at TOA Bias



Summary

- Optimization work: fixed 8-plume model instead of variable number plume. maintains performance, allows more vectorization, and removed some logic outside of loops. This required a change in the output variables (nupdrafts is no longer useful, replaced by maxwidth and ztop_plume).
- Bug fix to correct grid mean vs in-cloud mixing ratios. Now all subgrid clouds (mass-flux and stratus) are output as grid means and the addition of subgrid clouds to the resolved cloud in the radiation driver was corrected.
- Adjustments to cloud pdf and diffusion to better fit modifications to the Thompson-Eidhammer aerosol-aware scheme over the marine boundary layer. This will require updates to the Thompson-Eidhammer scheme to be optimal. We consider this work in progress, but the results are still positive overall, especially in the tropics.
- Added a patch to ensure robust cloud fractions were diagnosed for radiatively significant water, ice, & snow mixing ratios.