MYNN PBL/Sfc & Thompson Mods: Modifications & Impacts

Joseph Olson and Anders Jensen

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

Surface Layer Scheme Modification

Original Code

- Czil = 0.085

Modified Code

- Czil = 0.1
- This basically increases the thermal resistance, which reduces the land-atmospheric coupling.

For *iz0tlnd* = 0 (default), the form of Zilitinkevich (1995) is used:

$$z_t = z_0 exp\left[-kC_{Zil}\left(\frac{u_* z_0}{\nu}\right)^{1/2}\right], \qquad (2)$$

where k is the von Karman constant (= 0.4), C_{Zil} is a free parameter set to 0.085, u_* is the friction velocity (defined below), and ν is the kinematic viscosity, which varies with temperature according to Andreas (1989). For this form, $z_q = z_t$.

Taken from the MYNN Sfc Lay Tech Note

RRFS 2-m Temperature at Fh 6

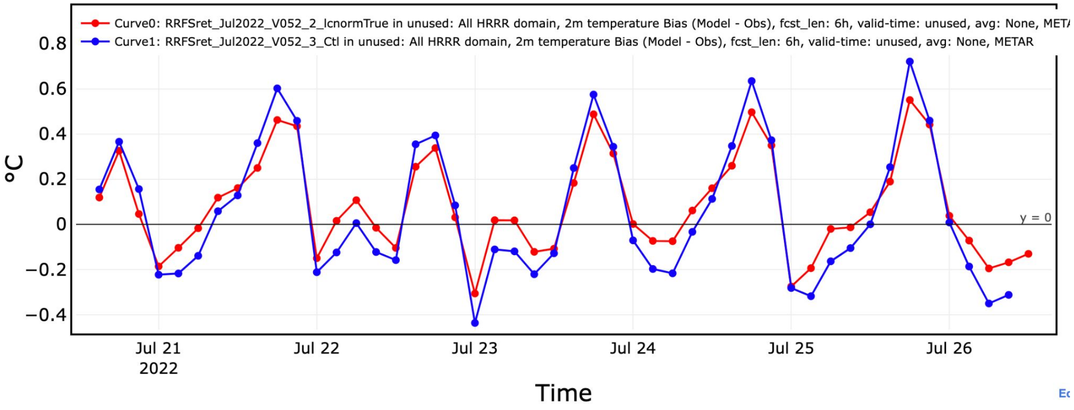
Bias

Control

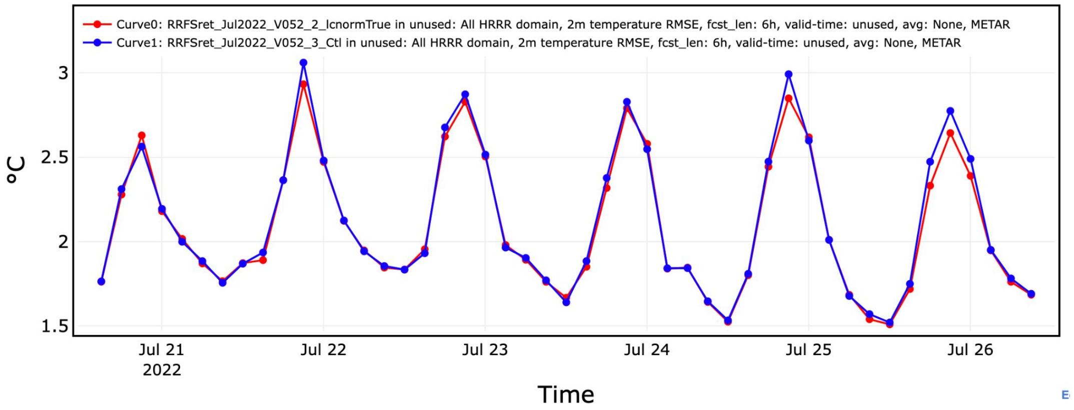
Updated

RMSE

Curve0 mean = 0.08233, median = 0.03429, stdev = 0.2178
Curve1 mean = 0.05845, median = 0.0002836, stdev = 0.2943



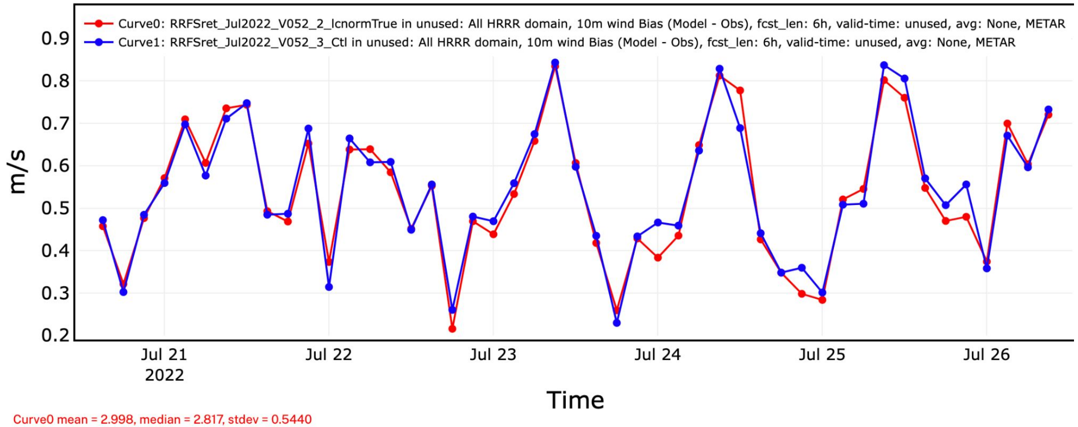
Curve0 mean = 2.092, median = 1.948, stdev = 0.3961
Curve1 mean = 2.113, median = 1.943, stdev = 0.4174



RRFS 10-m Wind Speed at Fh 6

Bias

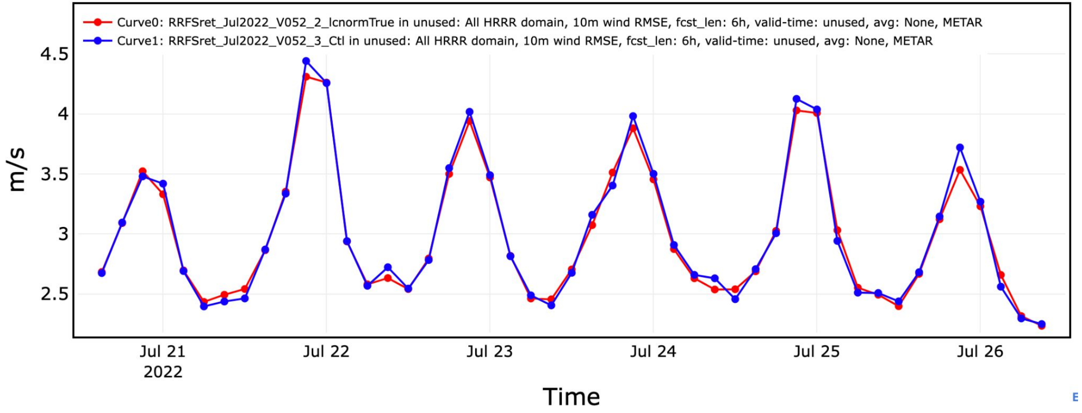
Curve0 mean = 0.5377, median = 0.5333, stdev = 0.1564
Curve1 mean = 0.5441, median = 0.5559, stdev = 0.1537



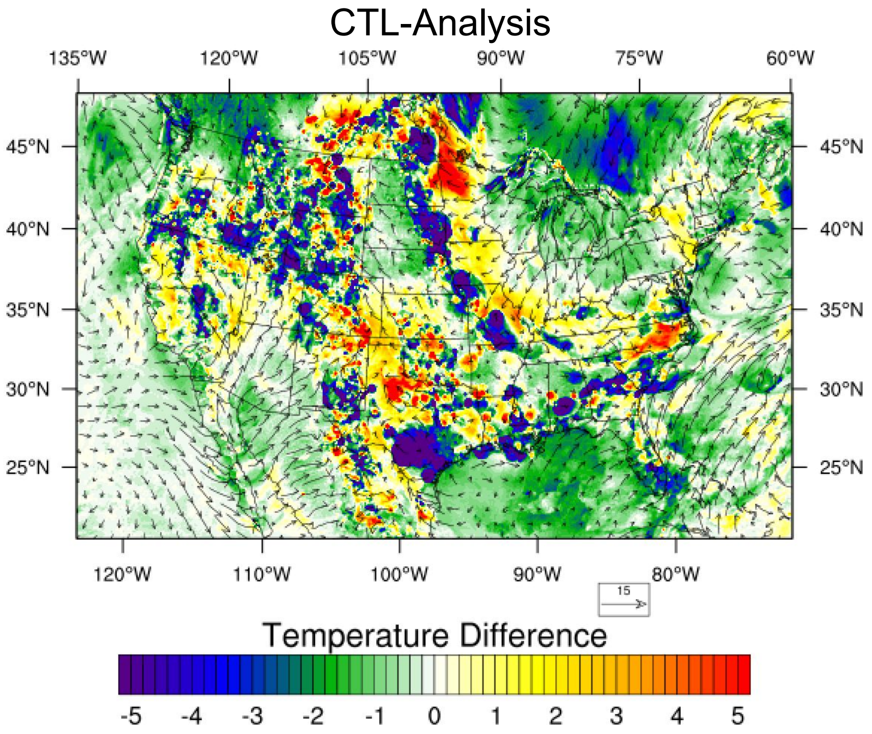
Control
Updated

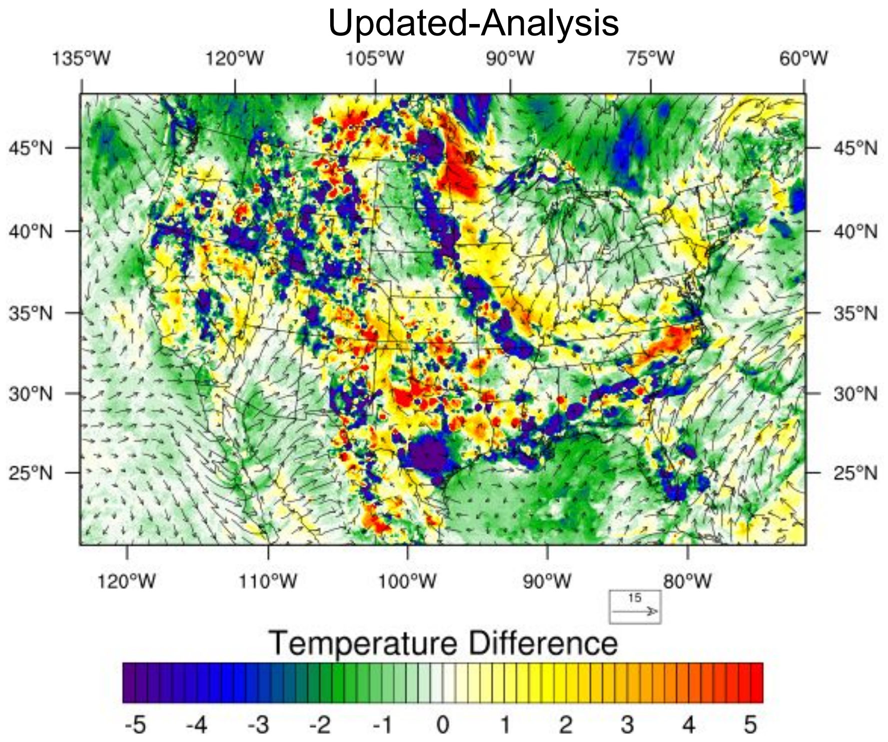
Curve0 mean = 2.998, median = 2.817, stdev = 0.5440
Curve1 mean = 3.010, median = 2.814, stdev = 0.5720

RMSE



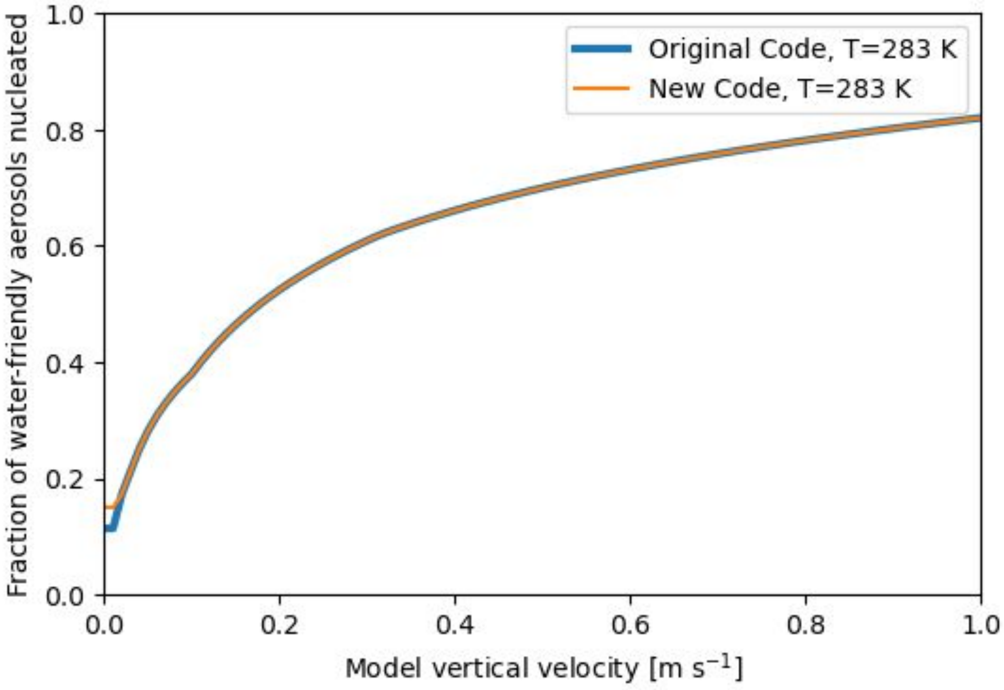
Example of Improvements in 2-m Temperature Bias
12 hr forecast - valid at 00 UTC 08 June 2023





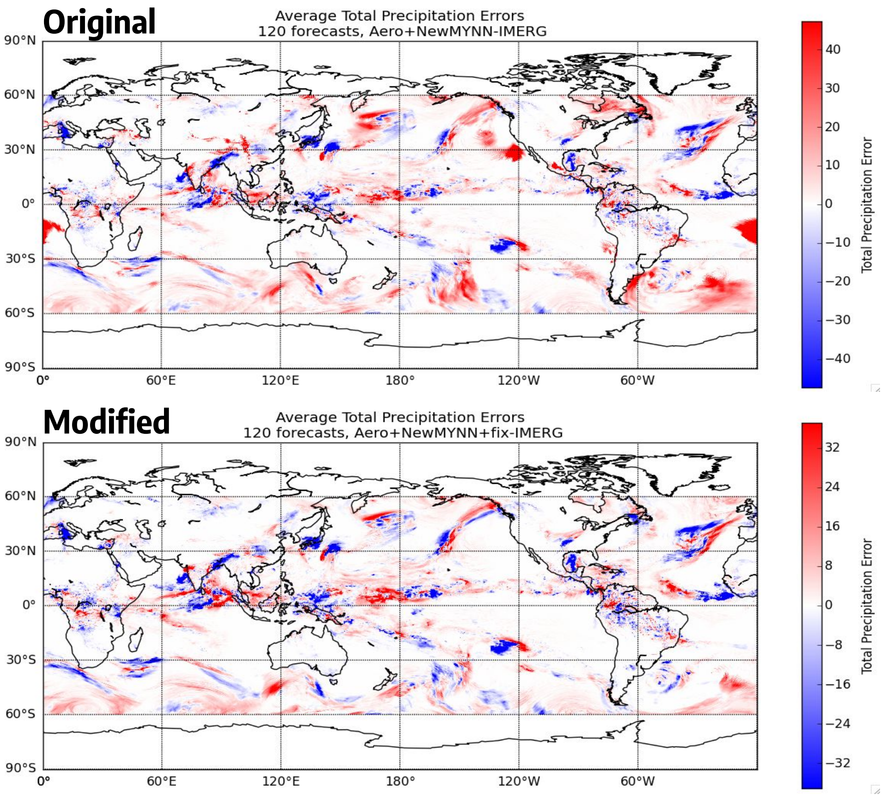
Modifications to Thompson

- Code modifications over water and ice (NOT over land)
- Increased both the assumed size and hygroscopicity of water-friendly aerosols over water (both are currently tuning knobs)
- This minor change is based on the assumption that aerosols (salt) are larger over water than land
- This change result in an increase in the fraction of water-friendly aerosols that are nucleated over water and ice (orange curves, right)
- Higher nucleation rates result in more cloud droplets that are smaller, reducing warm-rain production over water
- Note that nucleation also depends on temperature and vertical velocity



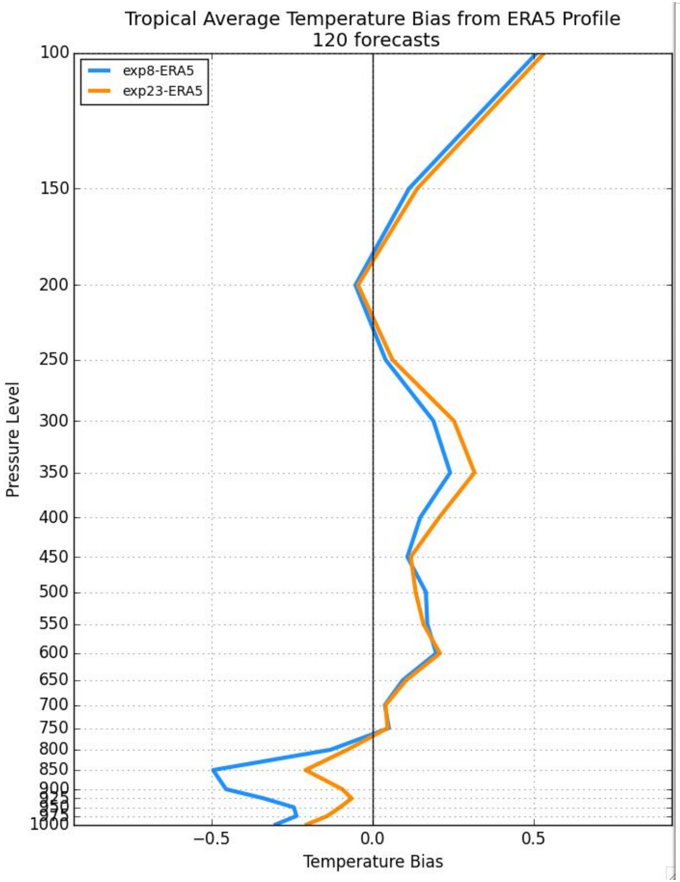
Impacts on global precipitation

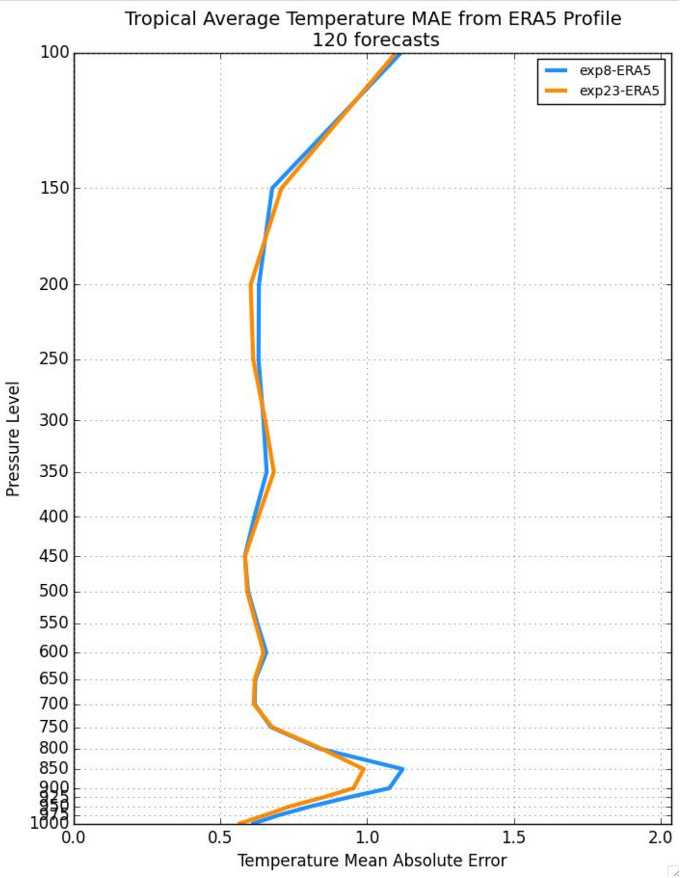
- As noted on the previous slide, higher nucleation rates result in more cloud droplets that are smaller, reducing warm-rain production over water
- This greatly improves the precipitation problem but makes marine clouds much brighter, required subsequent tuning of the MYNN-EDMF before a general forecast improvement is achieved…



Example from a single forecast using the original (top) and fixed version (bottom).

Orange line - Tuned MYNN with modified AA Thompson
Blue line - Original MYNN with modified AA Thompson





- 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.