# The Current State of NOAA's Rapid Refresh Forecast System

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*on behalf of the wider RRFS team*

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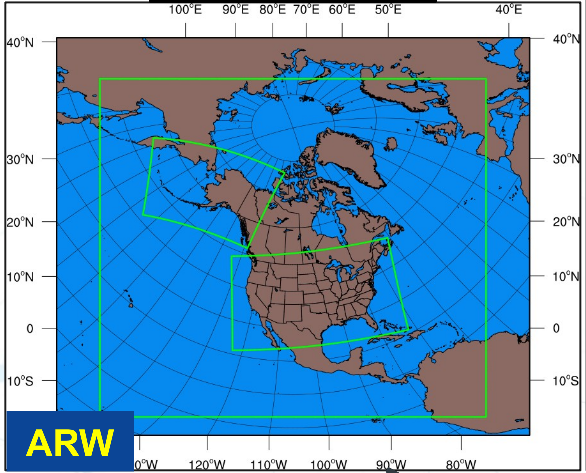
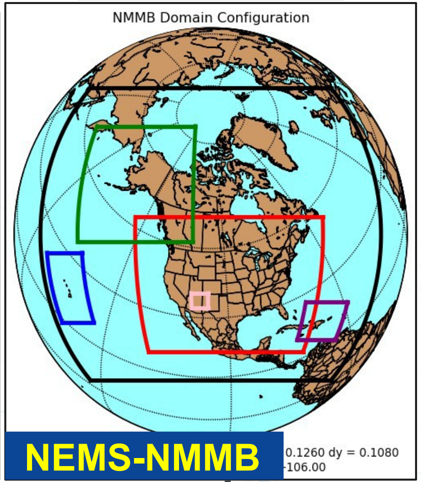
# Planned NWS regional CAM unification

Current operational CAMs

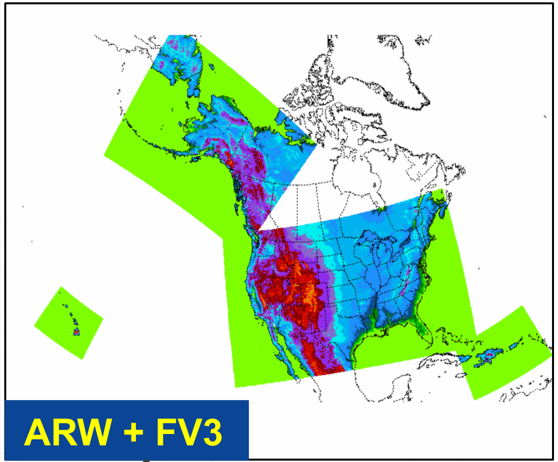
RAP/**HRRR**



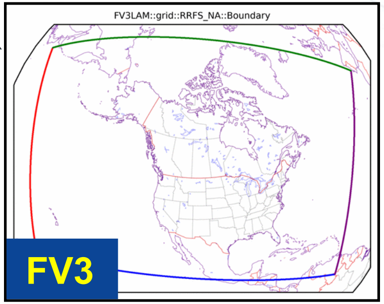

NAM+**Nests**




**HiResW/HREF**




Single UFS-based system for future operations (RRFS)

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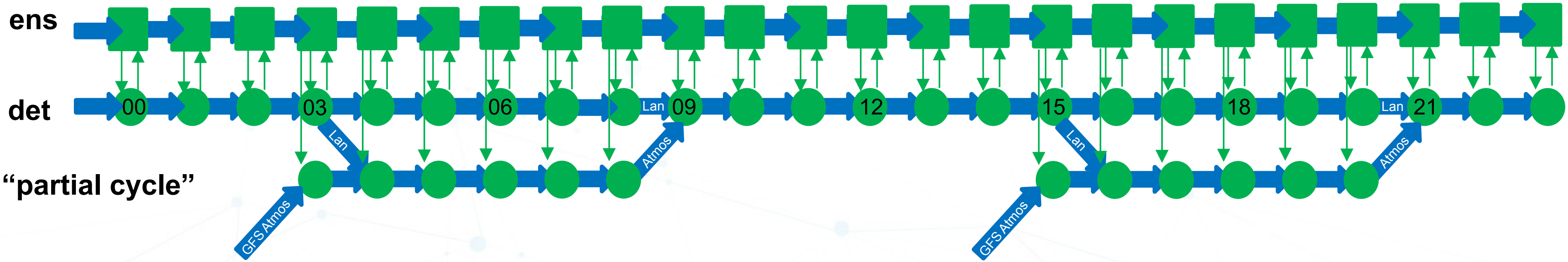
# A move toward UFS: RRFS

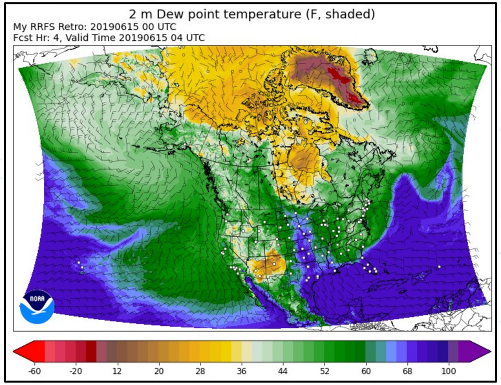
A bold plan to replace all CAM guidance with a *single North American domain* forecast ensemble running at 3 km grid spacing

- Hourly DA cycle, w/ a 3 km, ~30 mem ensemble for hybrid 3DEnVar
- Forecasts to 60 h every 6 h (deterministic + forecast ensemble), with deterministic-only forecasts to 18 h for other cycles
- Physics in deterministic RRFS broadly similar to those of the HRRR
- 65 vertical levels; 2 hPa model top
- Subsumes all products and functionality from HRRR, NAM nest, HiresW, and HREF

# RRFSv1 Data Assimilation Cycling




- Two-way interaction between 30 member 3-km DA ensemble ( ) and 3-km deterministic RRFS hybrid 3DEnVar analysis( )
- Partial cycle spin-up of atmosphere from GFS twice per day (RAP like), land states fully cyc’d
- All ensemble members (in square) and deterministic/control (circle) on 3-km NA grid



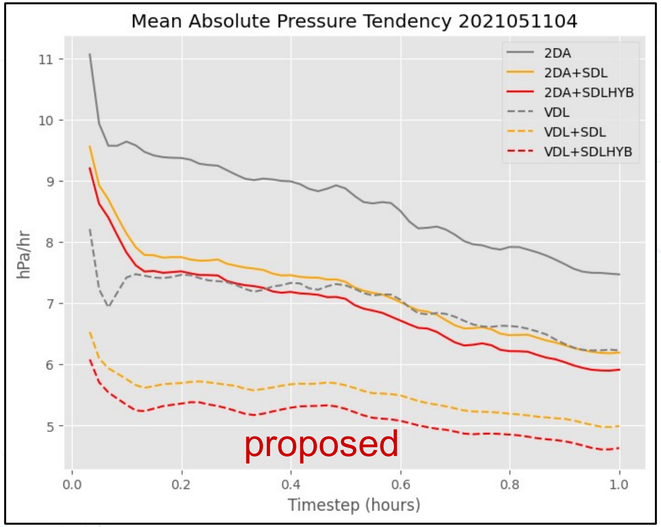
# Planned additions to RRFSv1

- Multiscale DA
- Inclusion of modeling small lakes (w/ CLM Lake Model) - matching the functionality contained in HRRR, but for larger RRFS domain.
- 32-bit physics (maybe) - efficiency gained from this change would ease the computational burden of running RRFS.

# Multiscale DA Algorithm

- Scale and variable dependent localization (SDL/VDL) employed in the EnVar DA algorithm
  - Ensemble covariances undergo scale-selective filtering (short & long waves)
  - Localization radii appropriate for each scale and variable group are used
- Allows for *all* observations to be assimilated simultaneously
  - Eliminates 2 step implementations with ad-hoc separation of observations (sondes vs radar)

*Acknowledge JMA visiting scientist Sho Yokota (currently @ EMC), OU/MAP group, and Ting Lei (EMC)*




**Imbalance (as measured by mean absolute pressure tendency) is ~40% lower over 1 h DA cycle forecast with proposed multiscale approach than with two step approach**

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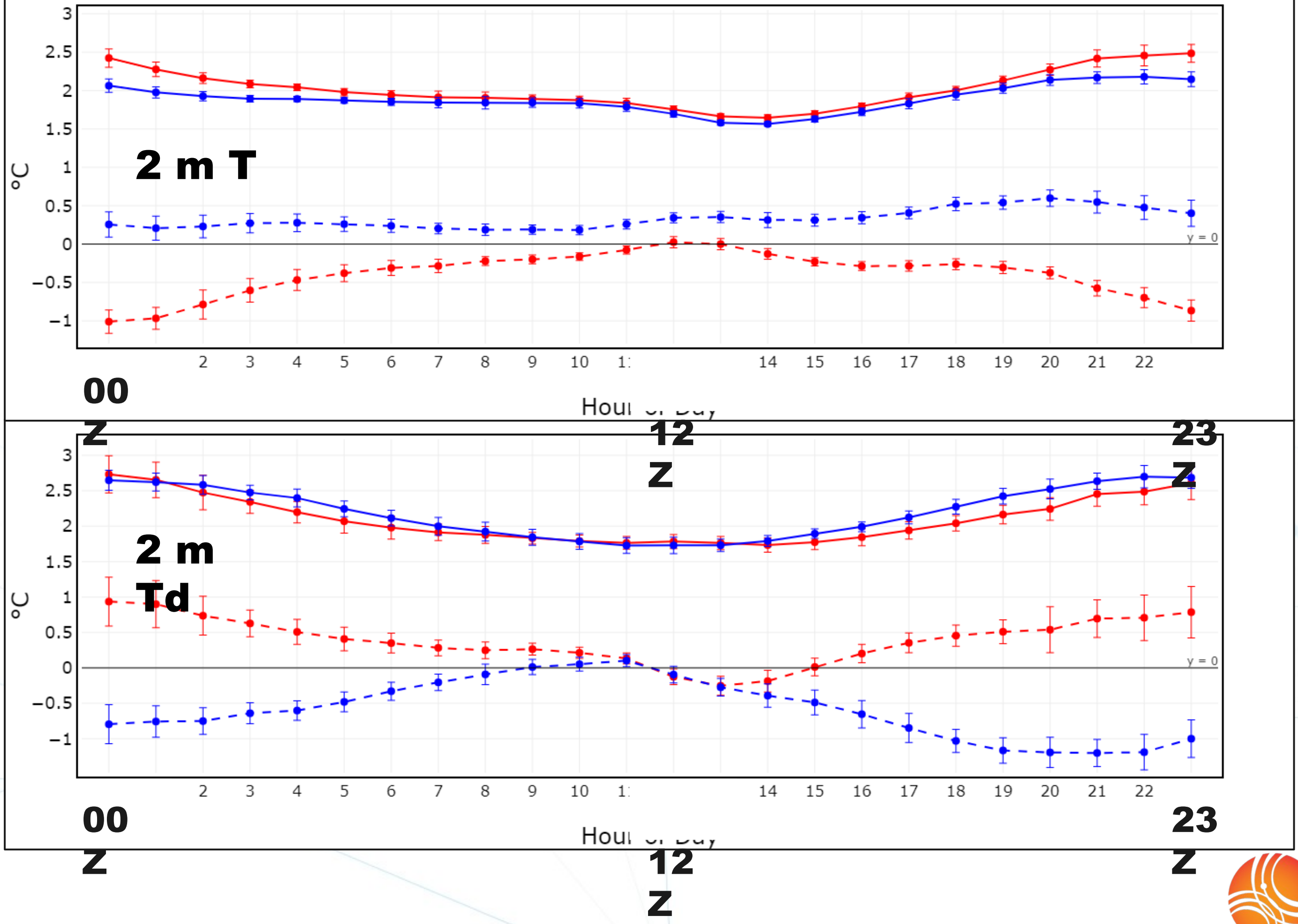


Deterministic 12 h forecasts

Diurnal 2 m T/Td

May-June 2023


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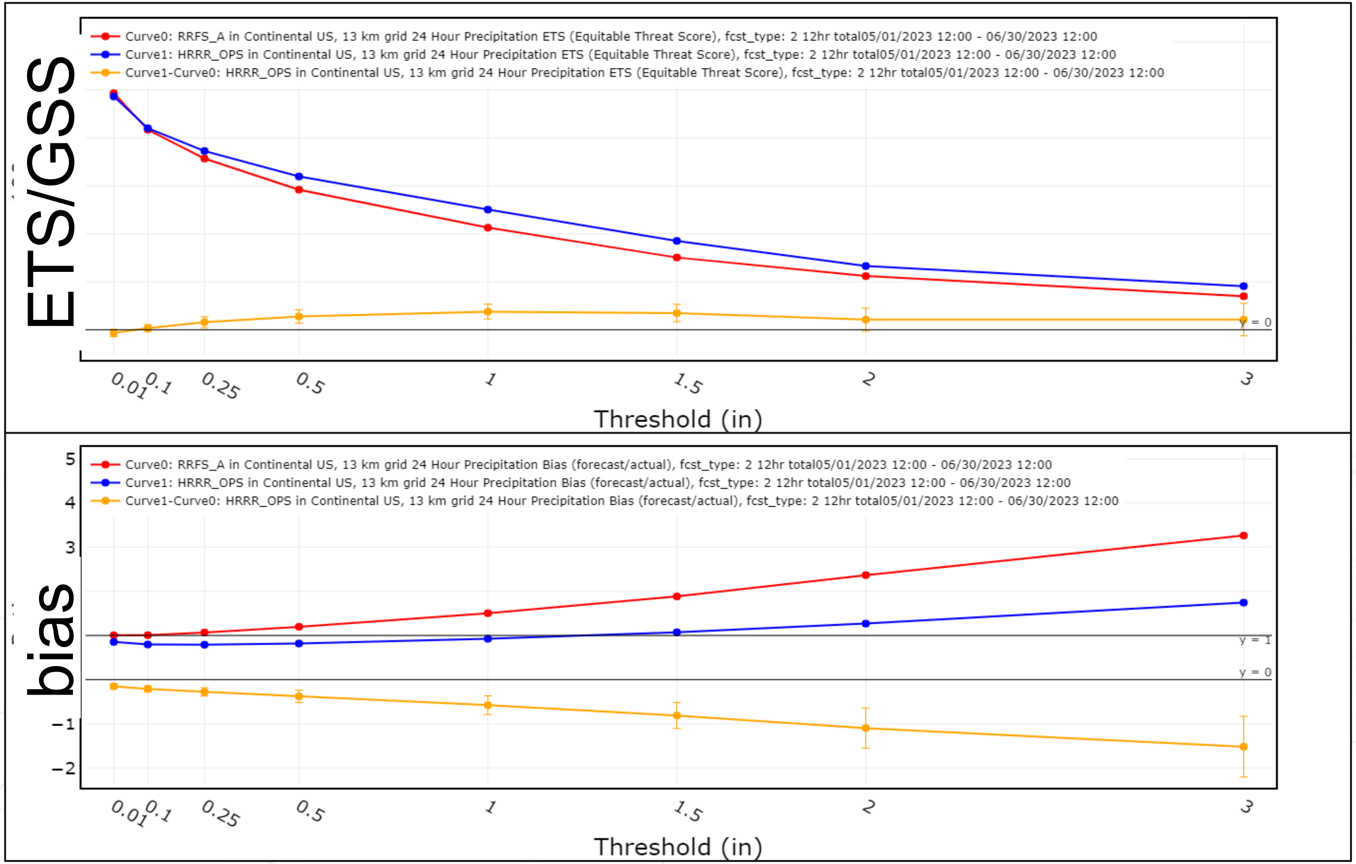


24 h QPF

May-June 2023

RRFS

HRRR

*verif on 13 km grid*

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# Heavy precipitation issue

- A high bias in heavy precipitation is a long-standing RRFS/FV3 issue, particularly in the warm season. Also manifests as a high bias at higher reflectivity thresholds.
- A more focused effort to solve it has been ongoing over the last year (including a coordinated effort between GFDL, GSL, and EMC), leading to exploration of a variety of approaches:

<u>Less scientific (damping) approaches</u>

- Damping of condensational heating
- Capping of MP heating tendency

<u>Scientifically-based approaches</u>

- Revisions to physics-dynamics coupling
- Inclusion of Grell-Freitas deep convection

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# Parameterized Deep Convection w/ Grell-Freitas

[Not yet in official RRFS Prototype System]

**No GF scheme** | **MRMS - observations** | **With GF scheme**

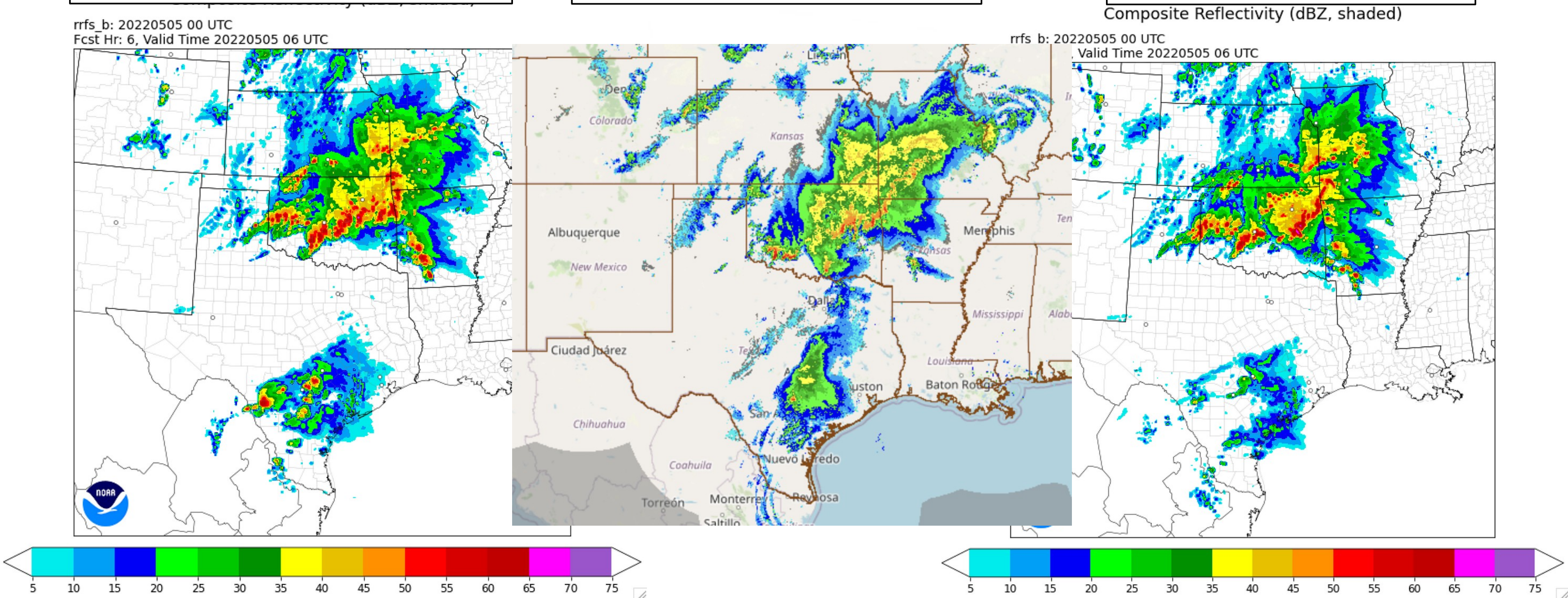


*figure courtesy of GSL*

# Forecast ensemble considerations

- Computational constraints will limit RRFSv1 to generating 6 members (5 ens members + deterministic run) per cycle, so it will utilize members from previous cycle to generate a 12 member, time-lagged ensemble.

- Single-physics or multi-physics configuration?
    - RRFS long term plan is to get to a single physics configuration, but possibly use multi physics for RRFSv1 to enhance ensemble spread.
    - Both options were run for evaluation during the 2023 HWT/SFE period.
    - Decision still to be made for RRFSv1 - options show differences in skill/spread/reliability space (and neither unambiguously better).

# RRFS single/multi-physics ensemble comparison (12 member TL) - sensible weather

May 10 - June 29
(133 cycles)

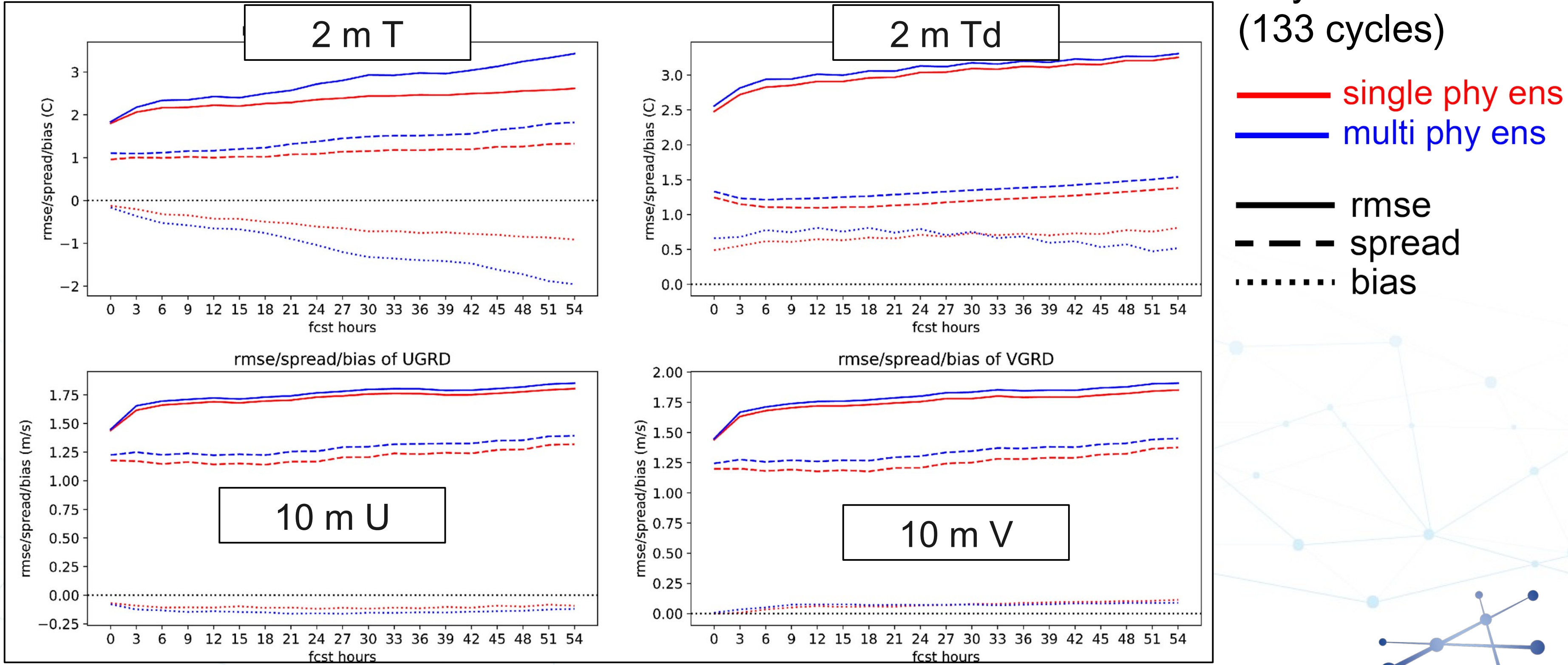


*Figure courtesy Jili Dong*

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# RRFS single/multi-physics ensemble comparison (12 member TL) - simulated reflectivity reliability

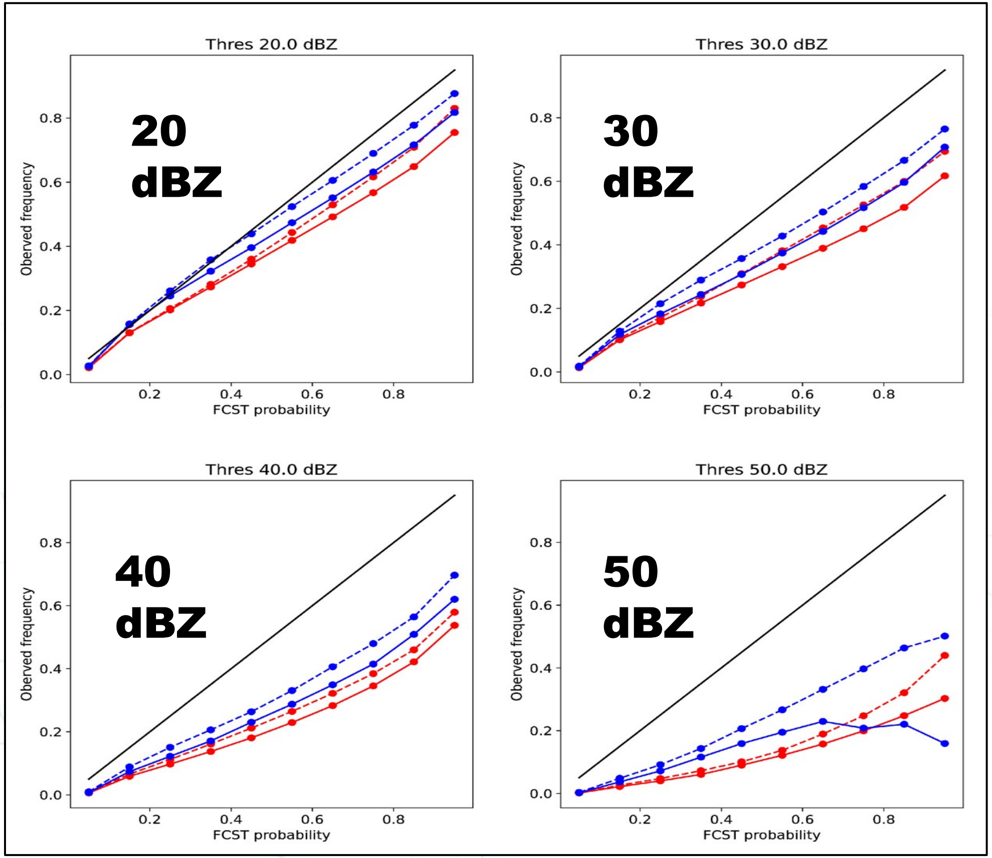



*Figure courtesy Jili Dong*

May 10 - June 29 (133 cycles)

single phy ens
multi phy ens

nbr=45 km
nbr=85 km

# Summary

- Tremendous progress has been made on the RRFS system, but work remains to get it to a place where stakeholders will be comfortable with it replacing HRRR and HREF (among other models) in NWS operations.

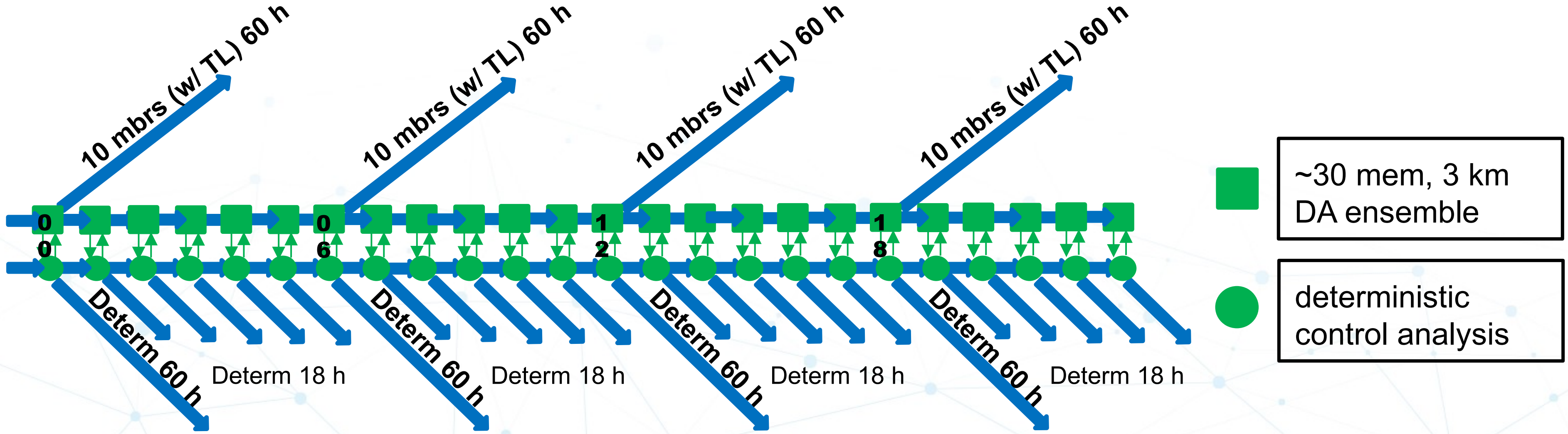
- The high precipitation bias and deficient RRFS ensemble performance on day two (noted in HWT/SFE results) are two critical items that must be improved.

- Have been targeting a late 2024 implementation for RRFSv1, but addressing the issues listed above is likely to push the implementation date back into 2025.

***QUESTIONS??***

# Supplemental slides

# Anticipated RRFSv1 Forecast Design

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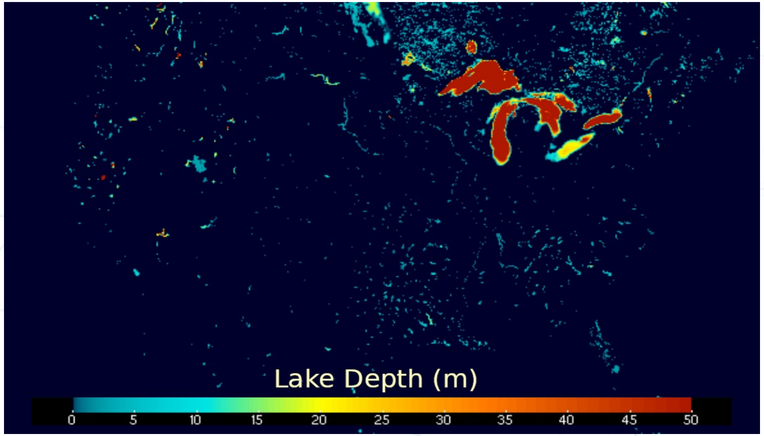
# CLM Lake Model for the RRFS

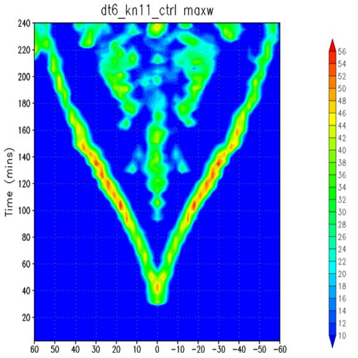
- The CLM code is committed to the UFS Repository, includes all modifications done for HRRR
- The RRFS lake depth uses GLOBv3 data
- Cycling of lake variables has to be enabled and tested in RRFS configuration.



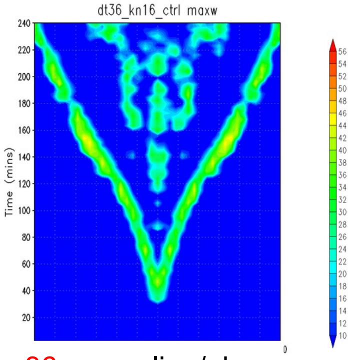

**To do: mask out the Great Lakes from the GLOBv3 lake mask (GLs are being handled by FVCOM in RRFS)**

***CLM Lake information courtesy of Tanya Smirnova***

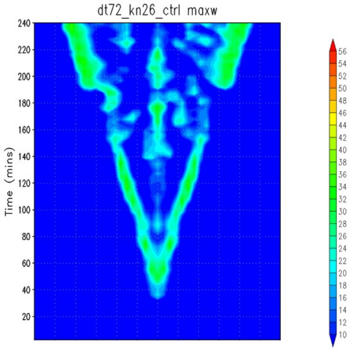
# Updated Physics-Dynamics Coupling




6 s coupling/phys frequency



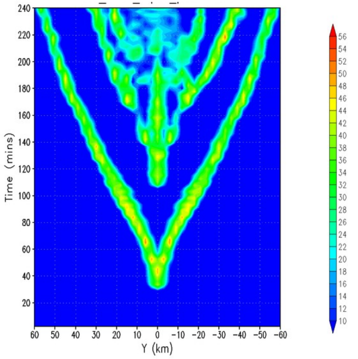

36 s coupling/phys frequency



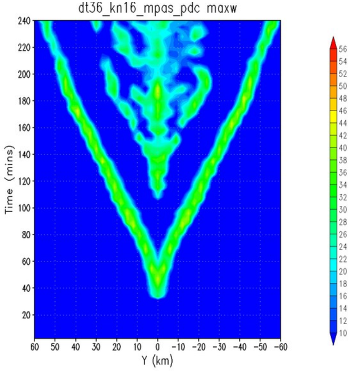

72 s coupling/phys frequency

Hovmoeller of maximum vertical velocity over the convective region for idealized splitting supercell

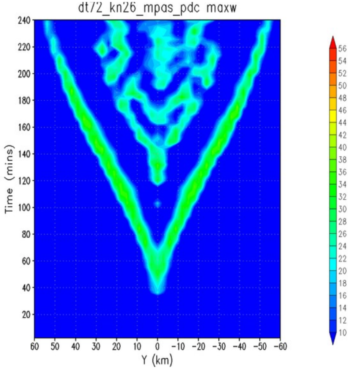
Current FV3 coupling leads to significant sensitivity of solution to choice of physics time-step




6 s coupling frequency,
6 s phys frequency




6 s coupling frequency,
36 s phys frequency




6 s coupling frequency,
72 s phys frequency

Modified FV3 coupling greatly reduces sensitivity of solution to physics time-step

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*Acknowledge Kevin Viner (EMC) for this work*

# Possible introduction of Subgrid Vertical Transport Scheme

- JMA and other centers have noticed challenges with excessive grid point storms in their modeling systems
- To address this, they have introduced a scheme to account for unresolved vertical transport of heat and moisture in deep convection
    - Known as The Leonard Term
- EMC is exploring the feasibility of including this term into the UFS

$$L_{\phi w} = \frac{K_L}{12}\left(\Delta_x^2 \frac{\partial \bar{\phi}}{\partial x}\frac{\partial \bar{w}}{\partial x} + \Delta_y^2 \frac{\partial \bar{\phi}}{\partial y}\frac{\partial \bar{w}}{\partial y}\right)$$

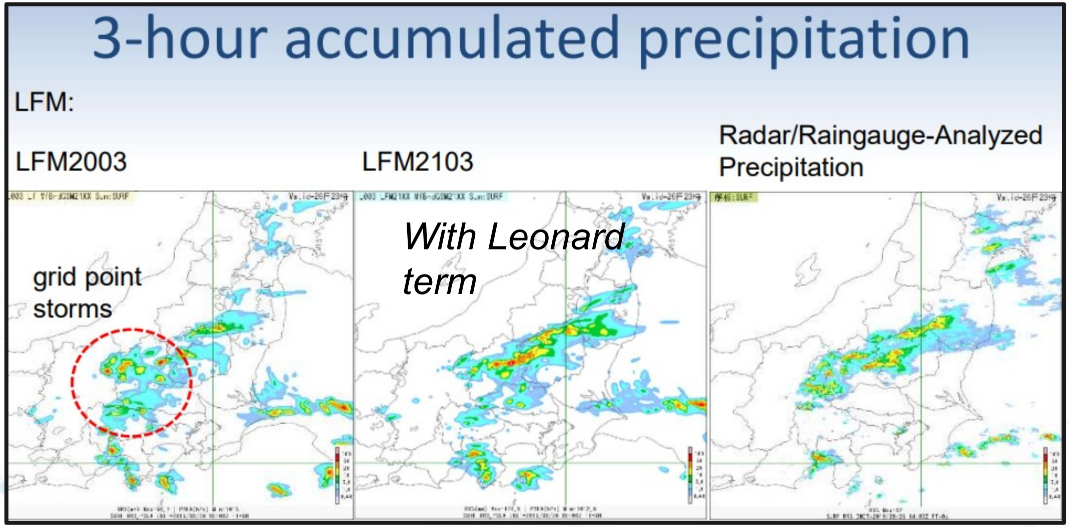


Figure obtained from presentation by Hiroshi Kusabiraki et al. (2021) demonstrating impact at JMA

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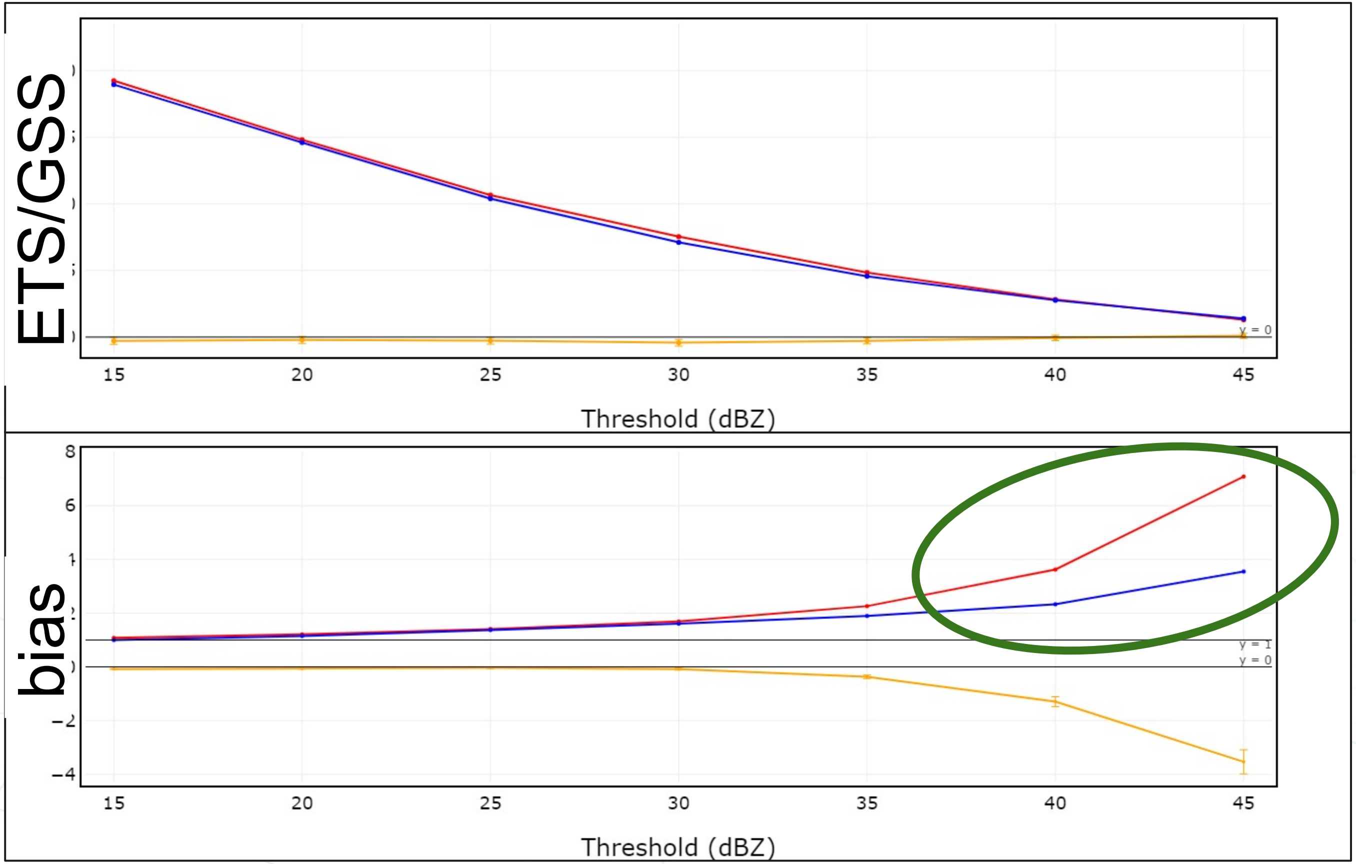
*Acknowledge JMA visiting scientist Sho Yokota and his JMA colleagues*




REFC 18 h fcst

18Z-00Z VTs

May-June 2023

RRFS

HRRR

*verif on 20 km grid*

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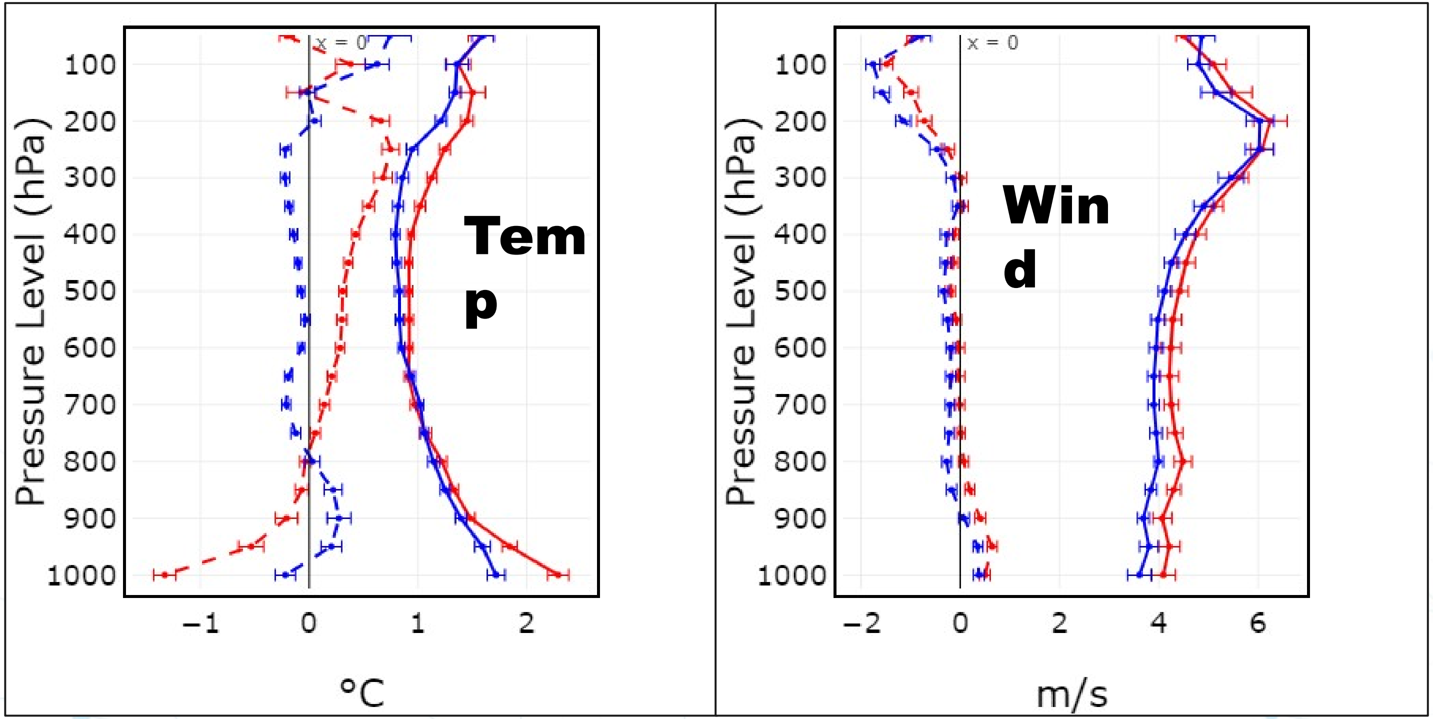


24 h forecasts

00Z valid

May-June 2023

RRFS

HRRR

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# RRFS time-lagged, multi-physics membership during HWT period

| | MP | PBL | sfc | lsm | Cu | IC/LBC |
|---|---|---|---|---|---|---|
| m1 (ctrl) | Thompson | MYNN | MYNN | RUC | N/A | RRFS hybrid/GFS |
| m2 | Thompson* | H-EDMF | GFS | RUC* | saSAS Shal | RRFS enkf1/GEFSm1 |
| m3 | Thompson* | TKE-EDMF | GFS | RUC* | saSAS Shal | RRFS enkf2/GEFSm2 |
| m4 | NSSL** | MYNN* | MYNN* | RUC* | N/A | RRFS enkf5/GEFSm5 |
| m5 | NSSL** | H-EDMF | GFS | RUC* | saSAS Shal | RRFS enkf6/GEFSm6 |
| m6 | NSSL** | TKE-EDMF | GFS | RUC* | saSAS Shal | RRFS enkf7/GEFSm7 |

*: Stochastic physics parameterization (SPP)

**: parameter perturbation using Latin hypercube sampling with multidimensional uniformity (lhs-mdu)

SPP also applied to GWD, radiation

sppt and skeb are applied to all perturbed members