On the Development of NOAA's Rapid Refresh Forecast System

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1. The Rapid Refresh Forecast System (RRFS)

This report describes the ongoing development of the RRFS, which is an hourly-updated, ensemble data assimilation and prediction system run at 3 km grid spacing covering North America. The RRFS is based on the Unified Forecast System (UFS) and is part of a larger effort to unify several operational National Weather Service regional, high-resolution modeling systems around a single UFS-based system.

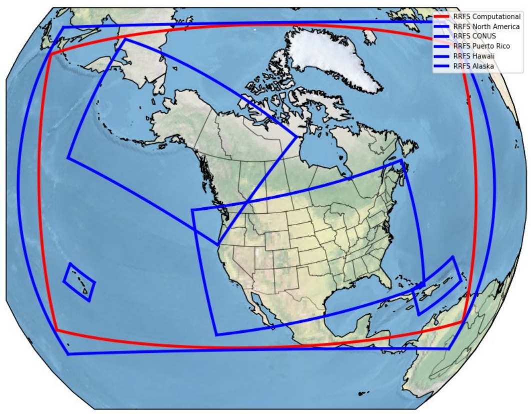

Fig. 1: Depiction of the prototype RRFS integration domain (in red) and output regions for gridded output (in blue)

2. Dynamics and Physics

The RRFS is based upon the fully compressible, nonhydrostatic Finite Volume Cubed-Sphere (FV3) dynamical core (Lin 2004; Harris et al. 2021) and uses the limited area model capability (Black et al. 2021). The gnomonic grid used for global applications has been replaced with an Extended Schmidt Gnomonic grid (Purser et al. 2020), which provides much more uniform grid spacing over a large regional domain than a purely gnomonic grid. The RRFS features 65 vertical layers with a 2 hPa model top. The vertical layers and model top were chosen based on a balance of forecast performance, computational expense, and a desire to improve the assimilation of satellite radiance observations with high peaking channels. The RRFS physical package is based upon the operational High Resolution Rapid Refresh (HRRR; Dowell et al. 2022) - which is planned to be subsumed upon the operational implementation of RRFS.

3. Data Assimilation

The RRFS data assimilation system (RDAS) is based upon a hybrid 3DEnVar-EnKF system. The EnKF, which features ~30 members, serves two purposes: (1) providing flow-dependent forecast error covariances in the hybrid 3DEnVar and (2) it provides the source for initial conditions for the ensemble free forecasts. The RDAS leverages a partial-cycling approach for the deterministic hybrid 3DEnVar analysis by way of a twice-a-day spin-up cycle that runs in parallel to the on-time analysis. At these times the atmospheric state in the RRFS is fully replaced with the atmospheric state from the corresponding best available forecast from the global model. At the same time, the 3 km land states are still preserved in the RDAS. This mitigates growing bias over a long period of cycling owing to a regional model's fundamental inability to resolve long wavelengths due to domain size. The RDAS assimilates a wide array of observations, which includes but is not limited to radar reflectivity and velocity, GOES ABI radiances, aircraft, rawinsonde, and surface observations. Land and soil states are updated via a simple covariance model with a one-coupling between the near-surface analysis increment and the underlying land state. The RDAS is designed such that analysis states are available at approximately t+40mins, where t is the cycle time (e.g., 1200 UTC).

4. Deterministic and Ensemble Forecasts

Forecasts from RRFS will include both a deterministic control running at an hourly cadence, and an ensemble system that produces forecasts every six hours. Both the deterministic and ensemble components will generate forecasts to 60 h for the 00/06/12/18 UTC synoptic cycles, and the deterministic alone will run to 18 h for the other cycles. The forecast ensemble will consist of five members; these will be combined with ensemble forecasts from the previous cycle and the two most recent deterministic runs to generate ensemble products from a total of ~12 members. The exact usage of time-lagged members, and whether it will be a single physics configuration matching the deterministic control, or a multi-physics configuration, remains to be decided. In either physics configuration, the forecast ensemble is planned to utilize stochastic physics perturbations to enhance forecast spread.

5. Preliminary Results and Concluding Remarks

Forecast verification statistics will be generated and compared against operational deterministic and ensemble baseline systems. Currently, most direct comparisons have been done with the operational HRRR system where the RRFS is proving to be competitive (Fig. 2).

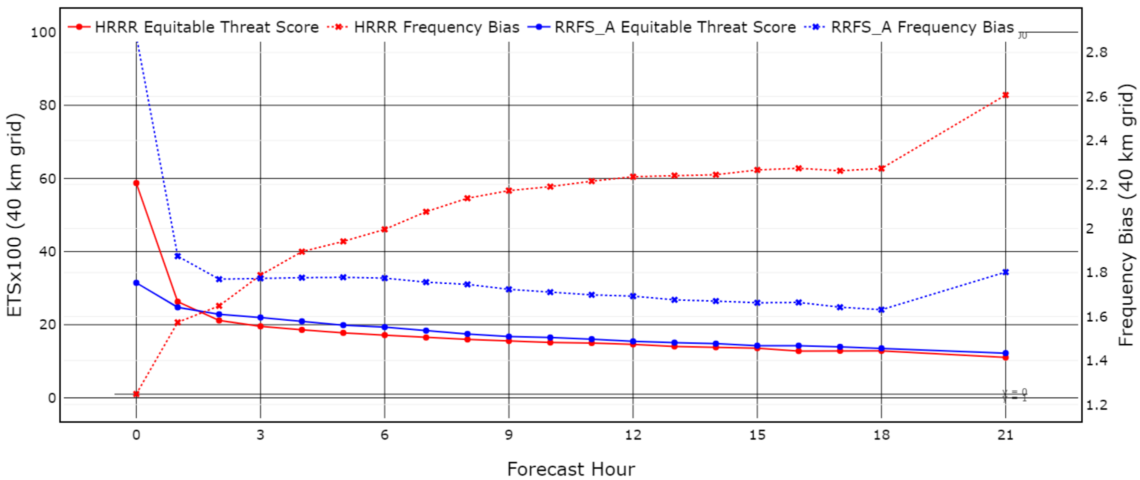

Fig. 2: Equitable Threat Score (solid) and Frequency Bias (dotted) for simulated composite reflectivity at the 30 dBZ threshold between March 20 and April 19, 2023, with forecast hour increasing along the abscissa, for the operational HRRR (red) and an RRFS prototype (blue). Verification scores were conducted on a common, upscaled 40-km grid.

The first version of the RRFS is expected to be finalized around Fall 2024. Remaining scientific priorities focus on addressing early feedback received from forecaster evaluations of prototype configurations, optimizing codes for speed and efficiency, finalizing the forecast ensemble, and tuning the data assimilation system.

References

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