Comparing Storm Environments and Forecast Performance in the HRRR, RRFS, and the NSSL MPAS Models

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OVERVIEW

NSSL is performing daily deterministic runs of the Model for Prediction Across Scales (MPAS) over CONUS at 3-km grid spacing (Fig. 1). See Larissa Reames' talk at recent WRF-MPAS Workshop:

These NSSL MPAS runs were subjectively compared to NCEP High-Resolution Rapid Refresh (HRRR) and Rapid-Refresh Forecast System (RRFS) 12–36-h forecasts during the 2023 HWT Spring Forecasting Experiment (SFE). See Adam Clark's talks here (10.1) and at WRF-MPAS Workshop:

SFE participants rated HRRR, MPAS significantly higher than RRFS. Objective verification and model intercomparisons (some shown herein) support the subjective evaluations. See Larissa Reames' talk here (16.4) and Kent Knopfmeier's poster at WRF-MPAS Workshop:

NSSL is evaluating MPAS as a possible WRF-ARW replacement in the next-generation Warn-on-Forecast System (WoFS). The WoFS is a rapidly-updating 3-km ensemble targetting 0–6-h lead times. The current (ARW-based) WoFS is planned for operational transition after 2025.

METHODS

Models: All use MYNN PBL scheme, RUC land surface model, RRTMG radiation; differ in dycore, ICs/BCs, microphysics, cumulus scheme (Table 1)

Data: 0–48-h forecasts initialized 00 Z over May–June 2023 (59 cases)

Verification: NSSL Multi-Radar/Multi-Sensor (MRMS) comp reflectivity (CREF)

Storm objects: 99.8th %tile, min area = 108 km^2, merge objects within 9 km; classify mode using Potvin et al. (2022) technique

Near-storm environments (NSEs): 120-km storm-centered patches; only use cellular objects for which CREF < 10 dBZ over majority of patch. Compute kernel density estimates (KDEs) of NSE statistics and probability-matched composite means (PMMs) of NSE fields as in Potvin et al. (2019, 2020).

RESULTS

HRRR and (esp.) RRFS have large storm frequency biases (Fig. 2), due largely to lack of upscale growth (Fig. 3). RRFS IC also contains too many storms.

RRFS more poorly predicts storm locations during first ~15 hours (Fig. 4); MPAS-RT is best overall; similar results for larger scales (not shown)

RRFS has lower CAPE (Figs. 5,7), HRRR has warmer cold pools (Fig. 6)

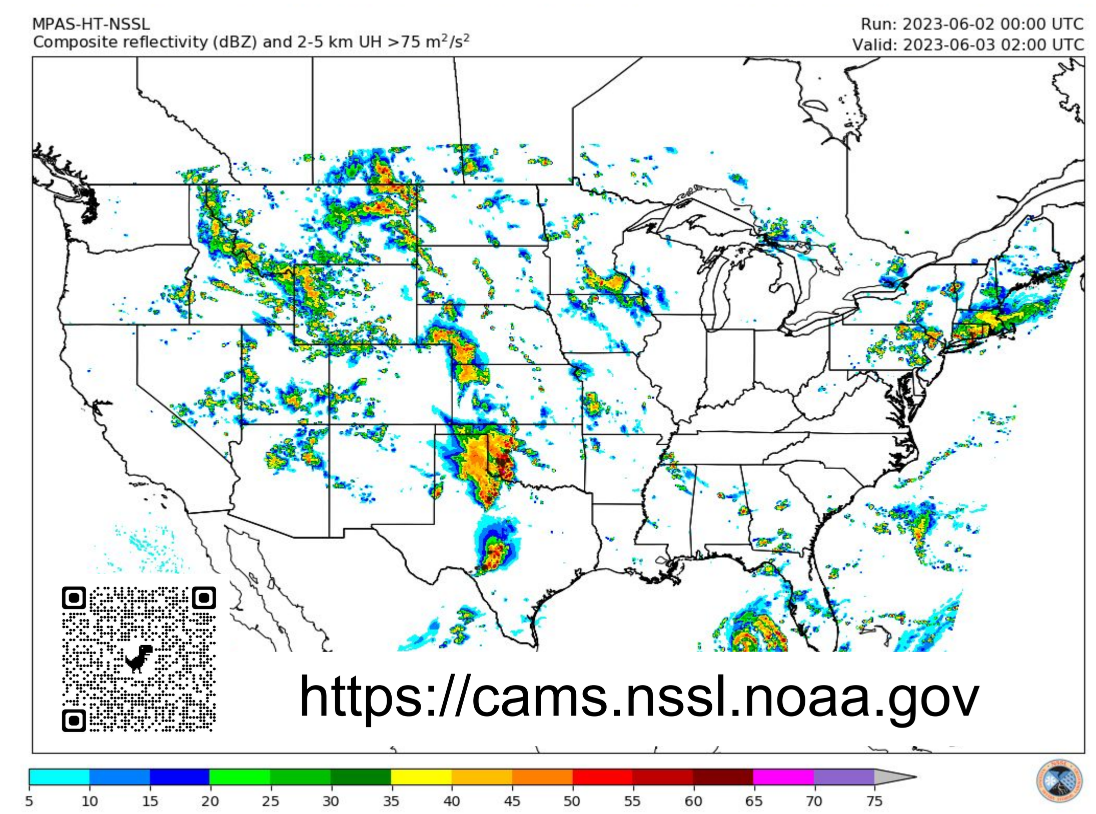


Fig. 1. Sample visualization from NSSL webpage for the daily 00 UTC RRFS, HRRR, and MPAS forecasts.

Model	Dycore	IC/BC	MP scheme	Cumulus scheme?
HRRR	ARW	HRRRDAS / RAP	Thompson	No
RRFS	FV3	RDAS / GFS	Thompson	No
MPAS-RT	MPAS	RRFS	Thompson	Grell-Freitas
MPAS-HT	MPAS	HRRR	Thompson	Grell-Freitas
MPAS-HN	MPAS	HRRR	NSSL 2-mom	Grell-Freitas

Table 1. Primary inter-model differences.

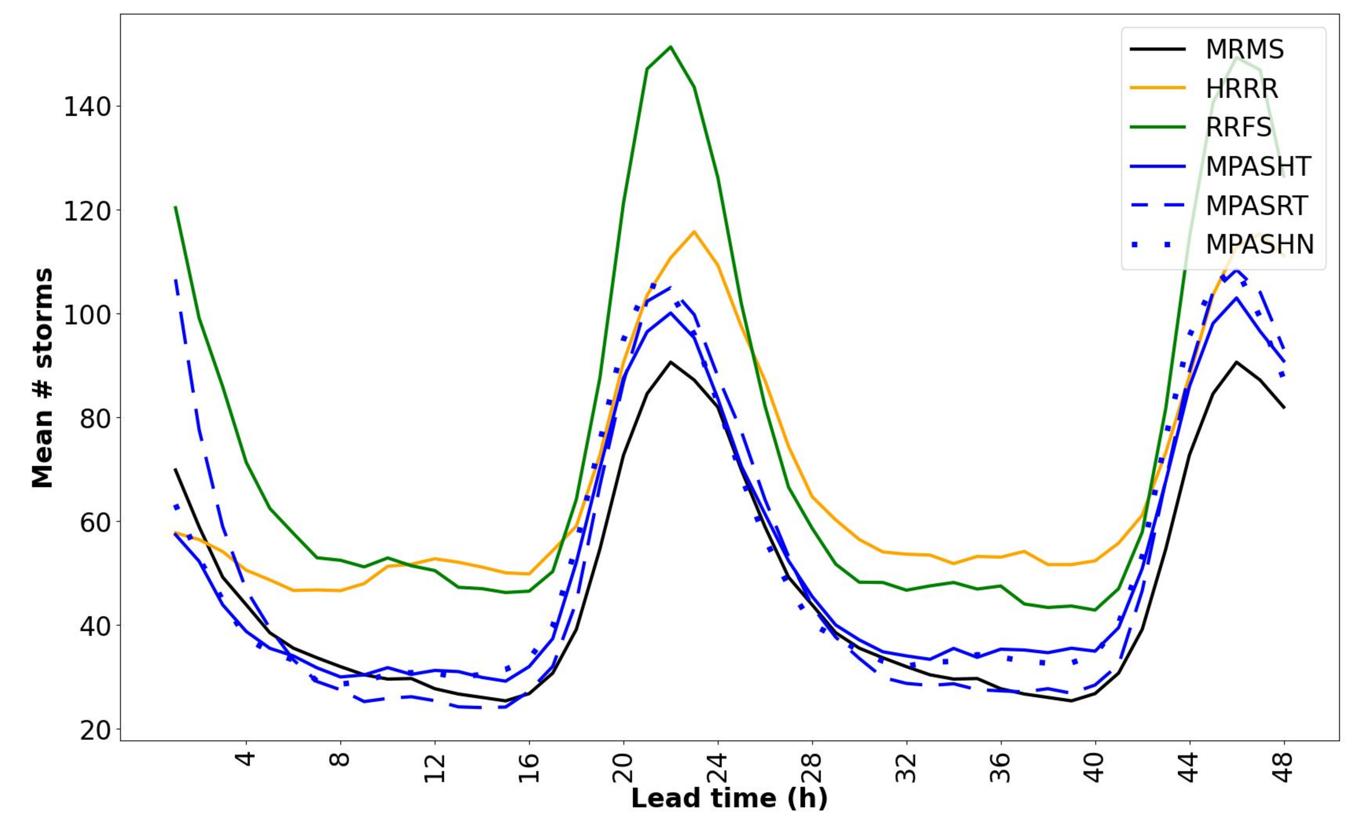


Fig. 2. Diurnal cycle of storm frequency.

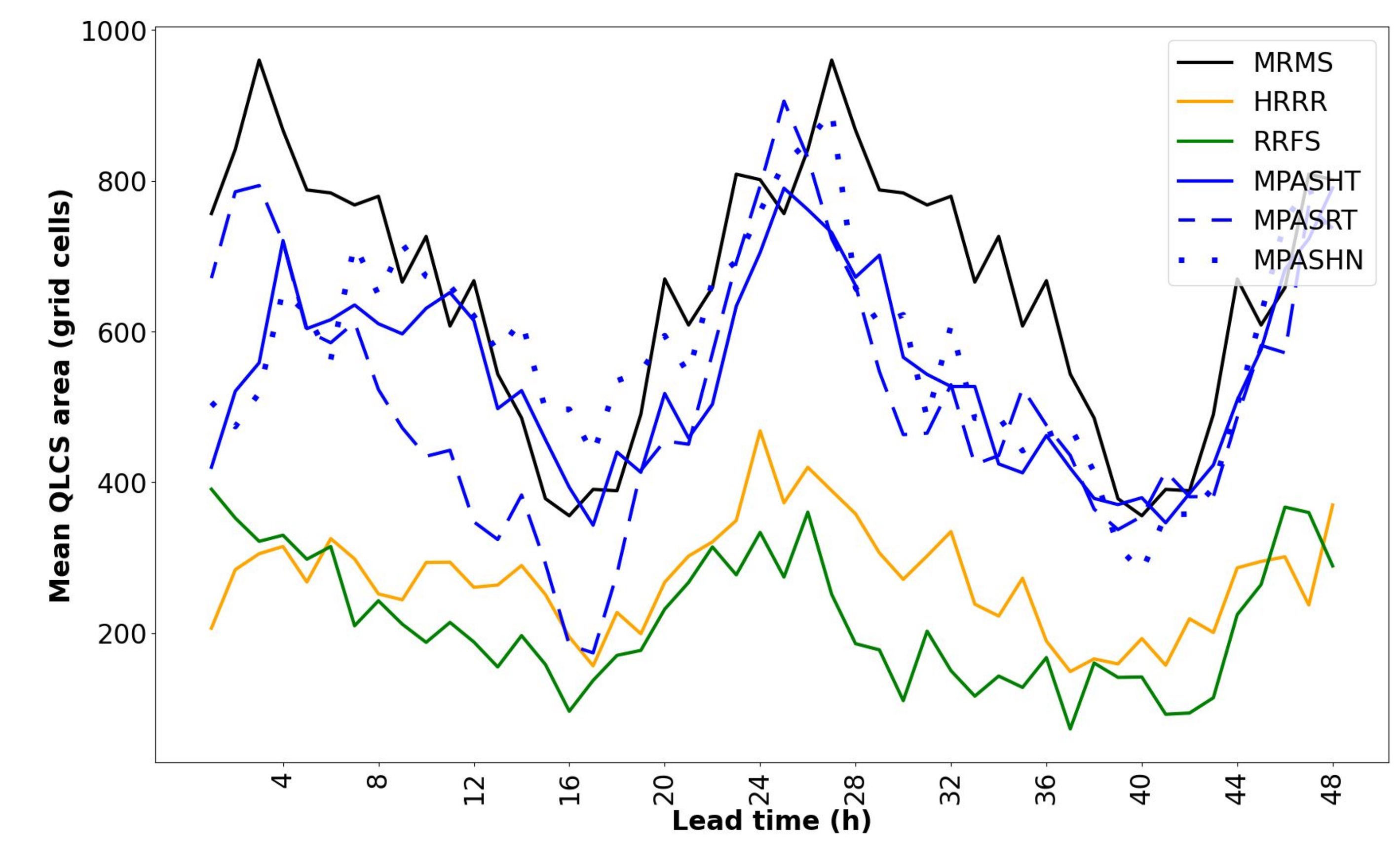


Fig. 3. Diurnal cycle of total QLCS area.

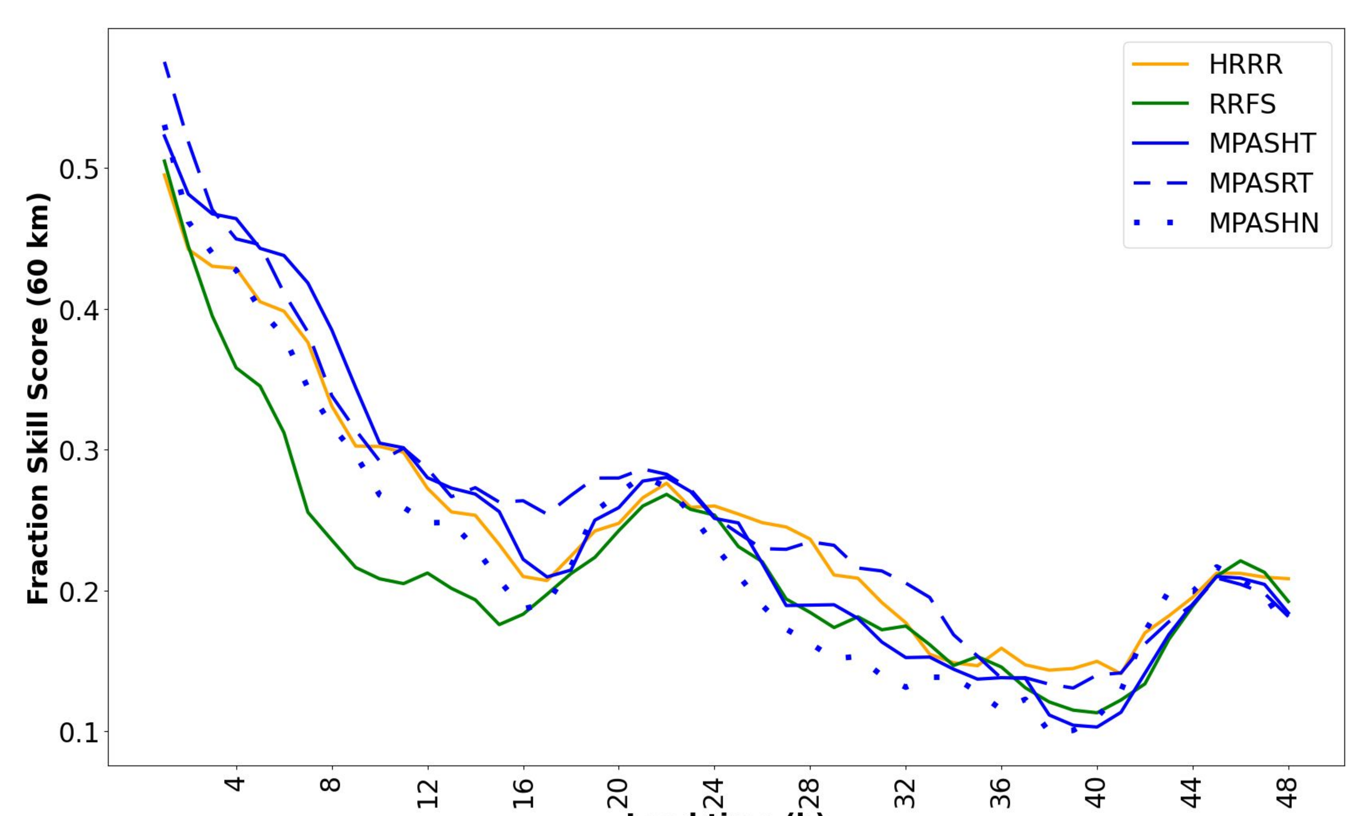
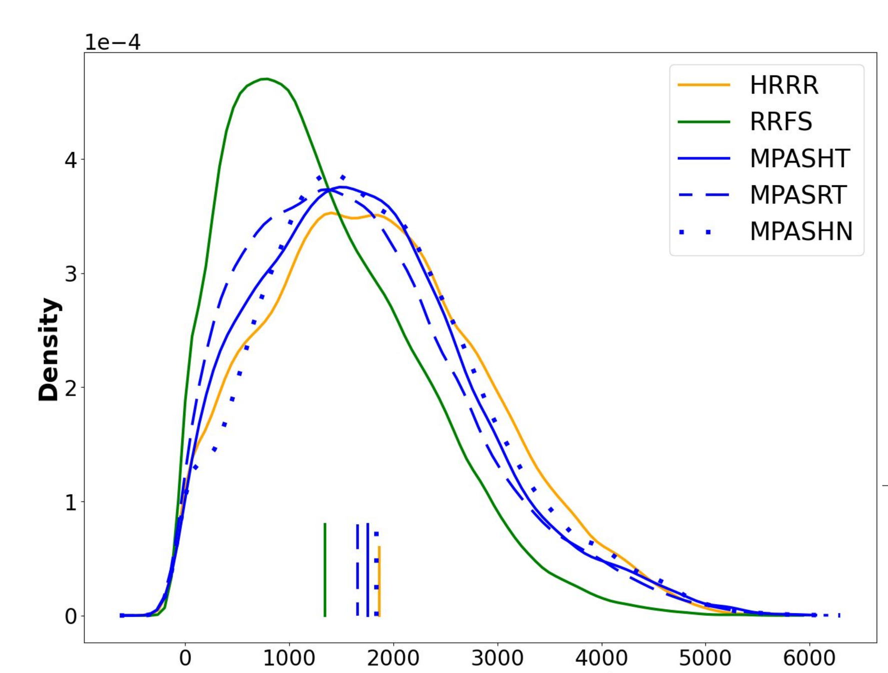


Fig. 4. Fractions Skill Scores using 60-km neighborhood, 99.8th %tile CREF.



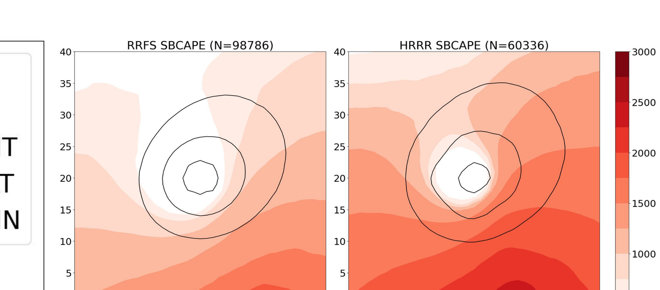


Fig. 7. PMM SBCAPE for RRFS (left), HRRR (right).

Fig. 5 (top). KDE of 90th %tile SBCAPE in NSE.

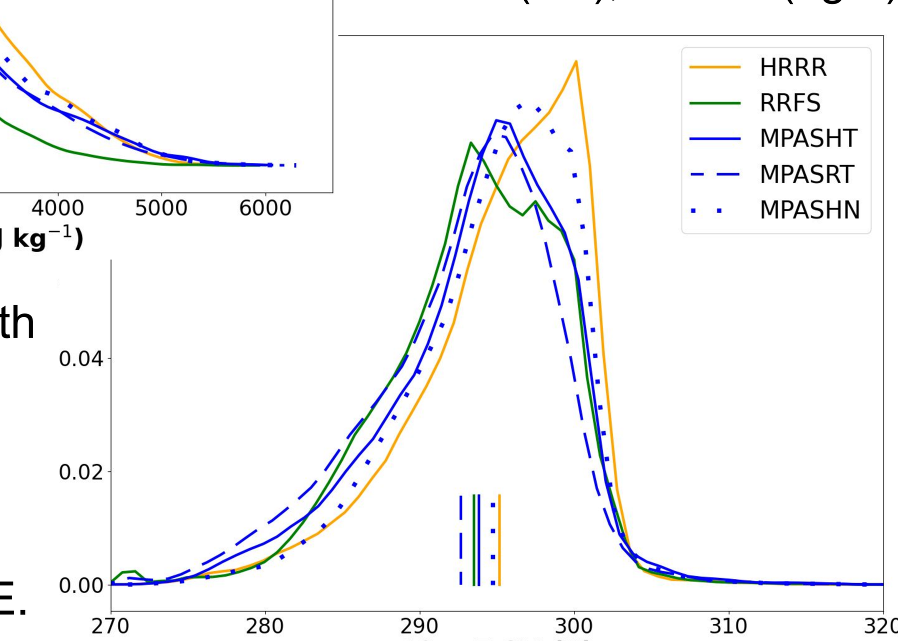


Fig. 6 (right). KDE of 10th %tile 2-m T in NSE.