Predictability of Severe Weather Environments in GEFSv12 Reforecasts

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Introduction

Prediction of severe convective storms (SCSs) and their hazards in the sub-seasonal to seasonal (S2S) timescale has become a growing topic in the atmospheric sciences. In this study over the United States, a forecast evaluation of variables relevant in the prediction of SCSs is conducted using Global Ensemble Forecast System Version 12 reforecasts at lead times up to four weeks.

Both deterministic and probabilistic measures of forecast skill are used in examining kinematic and thermodynamics fields. We also test weekly summations of convective parameters to minimize the role of temporal differences between ensemble members that may otherwise reduce skill over shorter time windows.

Data and Methodology

DATA:

- 11-member Global Ensemble Forecast System version 12 (GEFSv12) reforecast data across the CONUS during the period from 2000-2019
- Each reforecast runs for 35 days and is initialized weekly
- Daily GEFSv12 reanalysis as the reference from the same period to establish climatology and to calculate forecast skill

Practically Perfect Hindcast (PPH):

- PPH data derived from SPC severe reports using the method from Gensini et al. (2020)

Anomaly Correlation Coefficients (ACC) and Ranked Probability Skill Scores (RPSS):

- Rolling 3-day, 5-day, and 7-day means of ACC and RPSS (using three categories) for 12 selected variables are computed for each reforecast – for all valid dates – over the CONUS

Ensemble Consistency and Ranked Histograms:

- Compute ensemble consistency (ensemble variance versus mean-squared error) and rank histograms to assess dispersion and biases amongst the variables
- Mainly focused on week 2

Weekly Sums for Convective Parameters:

- Calculate the weekly summation for daily (12 UTC–12 UTC) maxima of four composite convective parameters
- Uses a threshold for convective precipitation to remove more environments where convection is unlikely (e.g. large inhibition)

Brier Skill Scores and Reliability Diagrams for Exceedance Thresholds:

- Thresholds based on the CONUS mean value associated with 15% or greater weekly PPH (at all grid-points) for tornadoes and hail
- Model climatology from a running-monthly window based on the third technique from Manrique-Sunen et al. (2020)

Spatial Correlations and Relation with Weekly PPH anomalies:

- Directly compare the weekly summations with weekly severe weather activity

Results

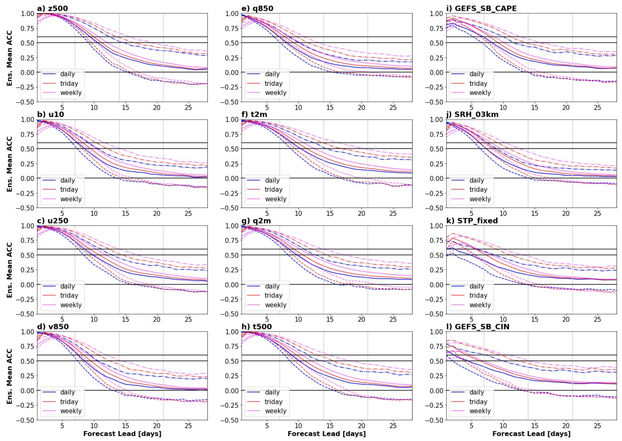

Figure 1: 20-year climatological ensemble mean ACC for a) z500; b) u10; c) u250; d) v850; e) q850; f) t2m; g) q2m; h) t500; i) GEFS-SBCAPE; j) SRH-03km; k) STP-fixed; and l) GEFS-SBCIN. Solid lines represent the mean. Dashed and dash-dotted lines represent the 25th and 75th percentile ACC. Blue, red, and magenta lines represent daily means, three-day centered rolling means, and weekly centered rolling means, respectively.

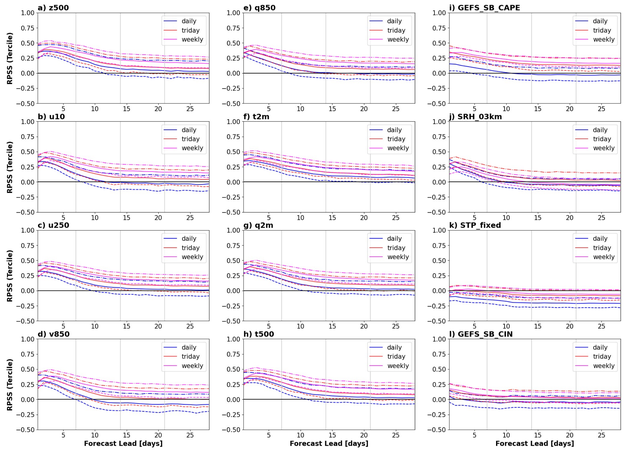

Figure 2: As in Fig. 1, but for RPSS for three categories.

Key Points (Figures 1, 2, and 3)

- **Skill measured by both deterministic and probabilistic metrics is higher for individual kinematic and thermodynamic fields**
- **Aggregating forecasts into periods longer than a day can extend skillful forecasts by several days in the best-case scenario**
- **Composite convective parameters fail to consistently yield skill based on ACC and RPSS into week 2**
- **Will likely change when calculated over a larger domain**

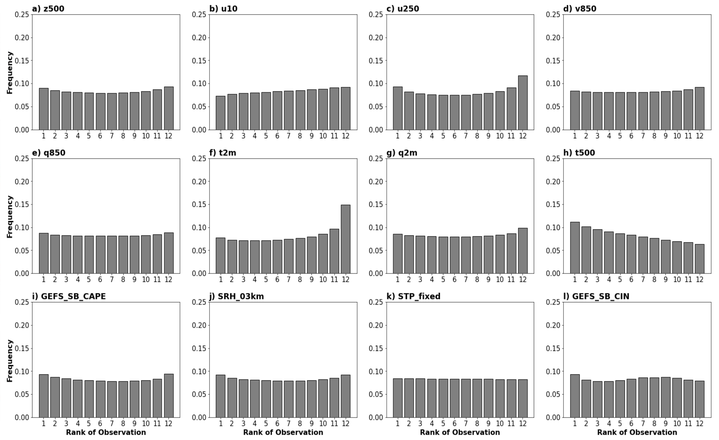

Figure 3: Rank histograms for daily means of the same variables from Figs. 1–2 for all seasons during forecast week 2.

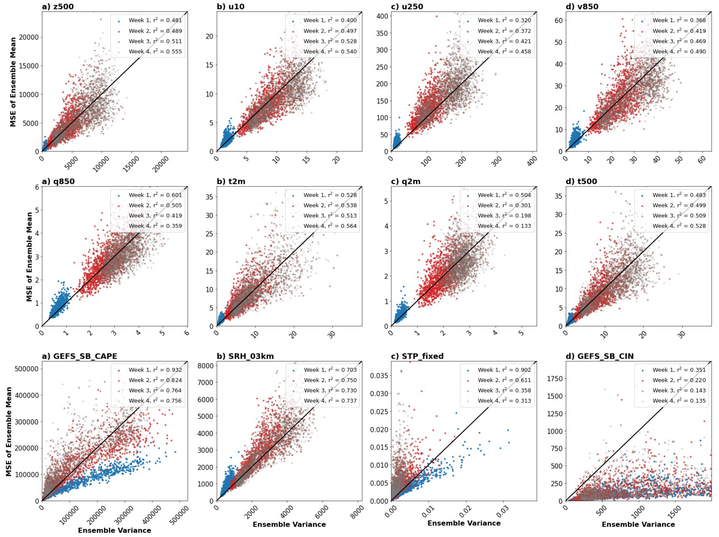

Figure 4: Ensemble consistency for daily means of the same variables from Figs. 1–3 for all seasons during forecast weeks 1–4.

Key Points (Figures 3 and 4)

- **Biases are more prevalent in thermodynamic fields, with cool biases in 2-meter temperature and warm biases mid tropospheric temperature than moisture**
- **Degree of spread-skill relationship changes as a function of lead time for moisture variables more than others**
- **Ensemble variance is a poor indicator of error for CIN in particular**

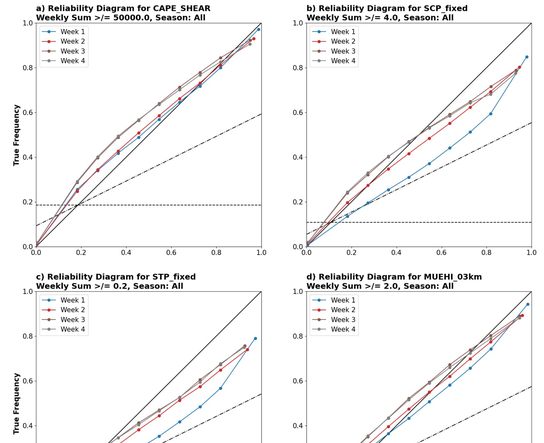

Figure 5: Reliability diagrams of threshold exceedance for weekly summations of a) CAPE-SHEAR; b) SCP-fixed; c) STP-fixed; and d) 0-3 km EHI. Different colors represent different forecast weeks, 10 probability bins are used. Dashed lines represent zero skill and climatology.

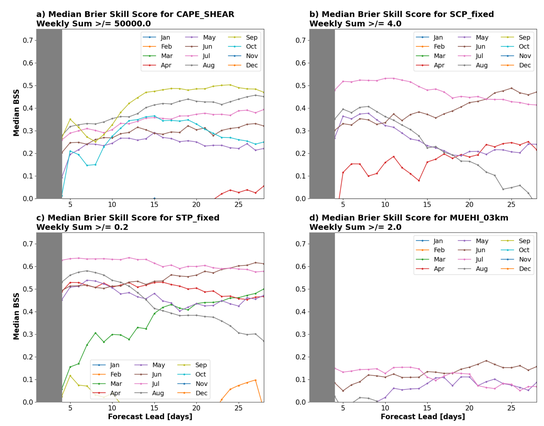

Figure 6: Monthly median threshold BSS for weekly summations of a) CAPE-SHEAR; b) SCP-fixed; c) STP-fixed; and d) 0-3 km EHI.

Key Points (Figures 5, 6, and 7)

- **Reliability and BSS metrics show promise of using weekly summations of convective parameters**
- **Favorable environment still does not necessarily suggest SCSs will occur**
- **Northern Plains and Gulf Coast see less correlation of environmental parameters and resulting severe weather**

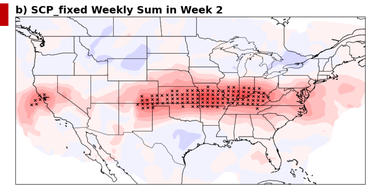

Figure 7: Spatial correlation during forecast week 2 of SCP-fixed with weekly PPH anomalies.

Summary/Future Study

- The relaxation of time-space constraints on forecast verification can yield greater skill in S2S timescales for severe convective storm environments, with composite convective parameters performing poorly via deterministic and probabilistic means
- Technique using weekly summations of convective parameters shows some promise, but calibration is necessary to relate these weekly sums with actual severe weather activity that occurs
- Individual kinematic and thermodynamic fields may be more useful as input into a machine learning model (e.g. Hill et al. 2023) for S2S severe forecasting

References

- Gensini, V. A., A. M. Haberlie, and P. T. Marsh, 2020: Practically perfect hindcasts of severe convective storms. Bull. Am. Meteorol. Soc., 101, https://doi.org/10.1175/BAMS-D-19-0321.1.
- Hill, A. J., R. S. Schumacher, and I. L. Jirak, 2023: A New Paradigm for Medium-Range Severe Weather Forecasts: Probabilistic Random Forest-Based Predictions. Weather Forecast., 38, https://doi.org/10.1175/WAF-D-22-0143.1.
- Manrique-Suñén, A., N. Gonzalez-Reviriego, V. Torralba, N. Cortesi, and F. J. Doblas-Reyes, 2020: Choices in the verification of s2s forecasts and their implications for climate services. Mon. Weather Rev., 148, 3995–4008, https://doi.org/10.1175/MWR-D-20-0067.1.

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