The High Resolution Ensemble Forecast (HREF) system: Applications and Performance for Forecasting Convective Storms

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Abstract

In November 2017, the High Resolution Ensemble Forecast version 2 (HREFv2) system was implemented by the U.S. National Oceanic and Atmospheric Administration (NOAA). The HREFv2 is NCEP's first operational convection-allowing model (CAM) ensemble and runs twice daily at ˜3-km horizontal grid spacing. Coinciding with the operationalization of the HREFv2, the NOAA National Weather Service's Storm Prediction Center (SPC) launched its HREF Ensemble Viewer (https://www.spc.noaa.gov/exper/href), a public web display for real-time HREF data. In addition to products traditionally used in operational forecasting, the HREF Ensemble Viewer also employs post-processing and visualization techniques which leverage the convective structures explicitly modeled in CAM ensembles. This presentation describes and illustrates products from the SPC viewer unique to CAM ensembles which are targeted at forecasting convective storm coverage, intensity, and evolution. A key aspect of HREF's ensemble design is membership diversity with respect to model cores and parameterization schemes, in conjunction with a time-lagging approach. Verification is performed on ensemble fields related to explicitly modeled convection for various modified configurations of the HREF membership, illustrating how each dimension of membership diversity contributes to the system's skill in forecasting convective evolution. These results help to illuminate potential tradeoffs entailed in configuring future HREF iterations beyond version 2 as CAMs using new dynamical cores and parameterization schemes become available.

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What is the HREF?

The HREF is an "ensemble of opportunity," meaning that several independently-designed, deterministic convection-allowing models (CAMs) are collected and post-processed as an ensemble. An analogy to global NWP would be processing models like NCEP's GFS and ECMWF's global model together as an ensemble. At the Storm Prediction Center (SPC), we currently process HREFv2.1, which contains 10 members. The members are diverse with respect to dynamical core, physics parameterizations, and initial/boundary conditions; time-lagging is also utilized. The figure and table below illustrate HREFv2.1's membership design.

Member	Dyn. Core	ICs	LBCs	Microphysics	PBL	Time-lagging
HRRR	WRF-ARW	RAP -1h	RAP -1h	Thompson	MYNN	none
HRRR -6h	WRF-ARW	RAP -1h	RAP -1h	Thompson	MYNN	6 hrs
HRW ARW	WRF-ARW	RAP	GFS -6h	WSM6	YSU	none
HRW ARW -12h	WRF-ARW	RAP	GFS -6h	WSM6	YSU	12 hrs
HRW NMMB	NMMB	RAP	GFS -6h	Ferrier	MYJ	none
HRW NMMB -12h	NMMB	RAP	GFS -6h	Ferrier	MYJ	12 hrs
HRW NSSL	WRF-ARW	NAM	NAM -6h	WSM6	MYJ	none
HRW NSSL -12h	WRF-ARW	NAM	NAM -6h	WSM6	MYJ	12 hrs
NAM CONUS Nest	NMMB	NAM	NAM	Ferrier-Aligo	MYJ	none
NAM CONUS Nest -12h	NMMB	NAM	NAM	Ferrier-Aligo	MYJ	12 hrs

Table 1. Model configurations for HREFv2.1 members. ICs and LBCs refer to the parent model providing initial and lateral boundary conditions, respectively. PBL is the planetary boundary layer scheme.

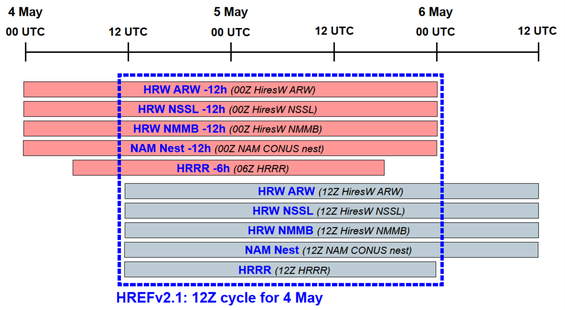


Fig. 1. Diagram of time-lagging approach for HREFv2.1 for a hypothetical run initialized at 1200 UTC on May 4. Red-shaded members are time-lagged, while blue members are not lagged. Blue labels are HREF member names, while italicized black labels are corresponding deterministic CAM names.

HREF Performance: Forecasting Convective Storms

Each spring, the NOAA Hazardous Weather Testbed in Norman, OK, hosts the Spring Forecasting Experiment (SFE), where state-of-the-art CAM ensembles are used and evaluated in real-time for forecasting severe convective storms. Whereas the HREF is an ensemble of opportunity, other experimental CAM ensembles evaluated in the SFE are typically formal ensembles with unified model configurations. Ensemble spread in the formal CAM ensembles is achieved primarily through perturbations to ICs and LBCs. In the HREF, spread also results from the members' diverse dynamical cores, physics, and time-lagging.

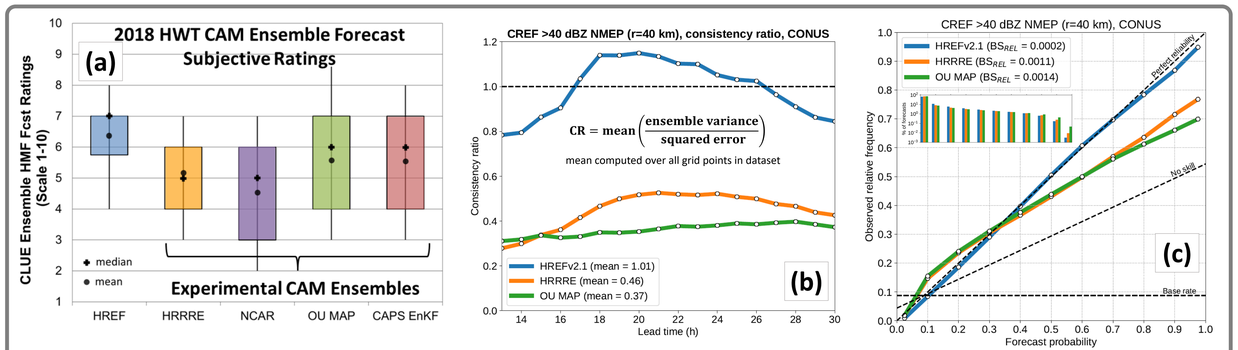


Fig. 2. (a) Box plots of subjective SFE participant ratings (N=~168 ratings per ensemble) for CAM ensembles during SFE 2018 (sample of 24 days between 30 April-1 June). (b) For neighborhood (r=40 km) maximum ensemble probability forecasts of CREF >40 dBZ (bias-corrected by member) over the CONUS, the consistency ratio as a function of forecast lead time. (c) Attributes diagram for the same set of neighborhood probability forecasts as in (b). Objective statistics in (b) and (c) use a 21-day subset of SFE 2018 operation days due to data availability.

Daily during the 5-week SFE, participants rate each ensemble on a 1-10 scale based on its performance the previous day in forecasting storm coverage, placement, and severity. Composite reflectivity (CREF) and updraft helicity forecasts are the focus. In SFE 2018 (30 April-1 June), we compared the 0000 UTC HREF against several formal ensembles, including GSD's HRRRE and the OU-MAP ensemble. Objective verification above is for neighborhood (r=40 km) probability forecasts for CREF >40 dBZ.

- **(a)** Subjective participant ratings favored HREF (*mean=6.3*) over OU-MAP (*mean=5.6*) and HRRRE (*mean=5.1*).
- **(b)** HREF had much better statistical consistency in its probabilistic forecasts of CREF >40 dBZ, with HRRRE and OU-MAP exhibiting too little ensemble spread relative to their forecast error.
- **(c)** HREF showed excellent reliability in its probabilistic CREF forecasts, whereas HRRRE and OU-MAP were less reliable.
- HREF's overall performance advantage in convective forecasts appears strongly tied to *better representing model error* through its diverse membership. Some formal CAM ensembles are now beginning to explore using stochastically perturbed parameterizations (SPPs) in an attempt to represent this type of error more methodically within unified model configurations.

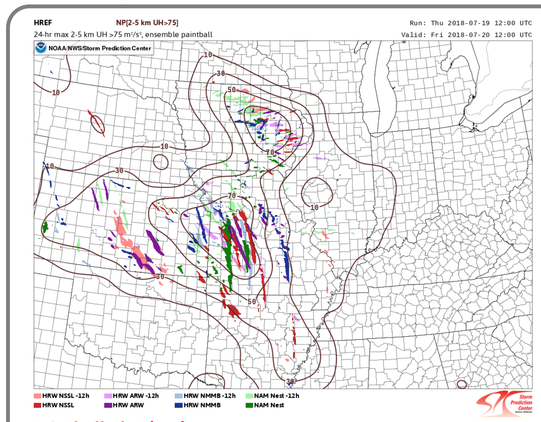
SPC HREF Ensemble Viewer / CAM Ensemble Visualizations

The HREFv2 became **NOAA's first operational CAM ensemble** in November 2017. Coinciding with this implementation, the SPC launched the web-based SPC HREF Ensemble Viewer. As the HREF runs twice daily at 0000 UTC and 1200 UTC, the SPC viewer post-processes and plots model output in real-time (48-h forecast available within 4 h of initialization) at this URL:

spc.noaa.gov/exper/href

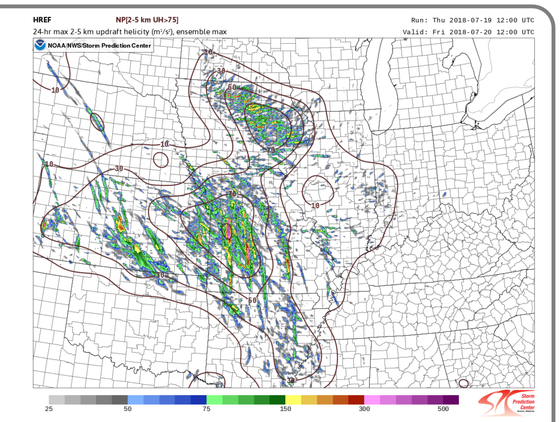
The SPC web viewer offers over 50 forecast products serving various National Weather Service operational needs. Because the SPC is a national center tasked with forecasting severe and fire weather, products supporting those requirements are the focus.

For assessing CAM forecasts of severe convective storms, forecasters often look at simulated reflectivity and storm attribute fields like updraft helicity (UH), which highlights simulated storms with rotating updrafts. In the panels below, we show four unique ensemble visualization methods for the same HREF forecast of convective storms in the central U.S. on July 19, 2018. Each of these four products is available on the web viewer, both in real-time and archived (daily back to November 2017).



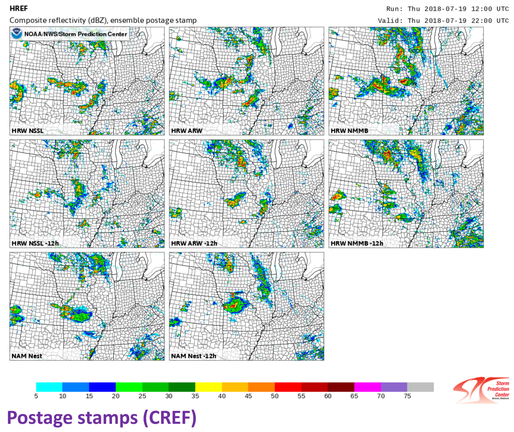
Paintball plot (UH)

UH exceeding a threshold is plotted color-coded by ensemble member, highlighting *member-to-member placement* differences. Overlaid NH probabilities (contours) help emphasize areas of good agreement.



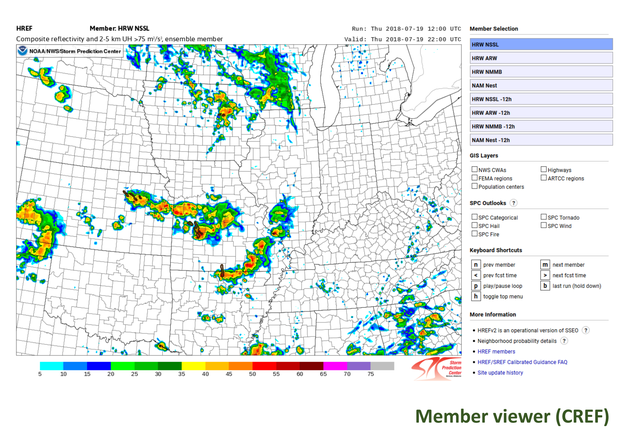
Ensemble-max plot (UH)

The ensemble-max UH is plotted at every grid point, highlighting the ensemble distribution of UH *magnitude*. NH probabilities are overlaid to retain some information about member agreement.



Postage stamps (CREF)

The full CREF field from each ensemble member is plotted in a separate panel. Requires more time to interrogate, but allows forecasters to view all ensemble data unabridged.



Member viewer (CREF)

The full CREF field from each ensemble member is plotted; in this tool, a mouse-over menu on the web UI is used to toggle through members. Allows for larger plots than postage stamps.

Acknowledgements

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