Exploring the Use of Ensembles for Real Time Diagnosis of the Severe Storm Environment

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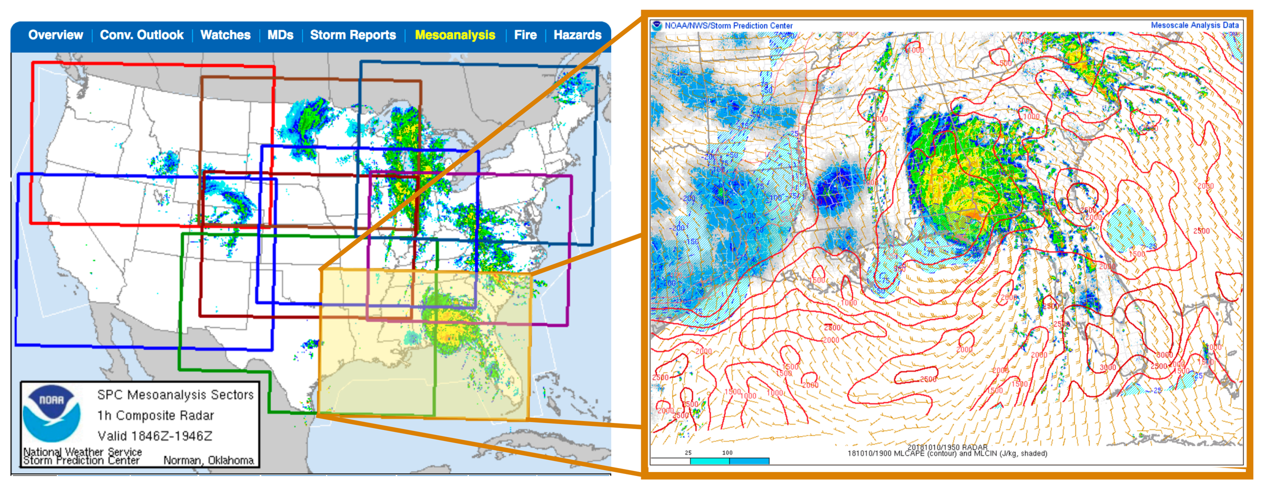
1. Background

The NOAA Storm Prediction Center (SPC) has long produced a real time mesoscale analysis to provide forecasters guidance in diagnosing the severe storm environment, termed here the SPC-MA (https://www.spc.noaa.gov/exper/mesoanalysis/):



The SPC-MA is produced by replacing surface conditions in Rapid Refresh (RAP) 1-h forecasts with a Barnes objective analysis of current surface observations to derive severe weather forecast fields (e.g. MLCAPE in above right) in a timely manner. ***SPC forecasters continue to rely heavily on this system for guidance on issuing short-term outlooks, mesoscale convective discussions, and convective watches.***

Current computing power and modern data assimilation/NWP models allow for real time systems that could significantly improve upon the deterministic SPC-MA. One potential system, run experimentally in spring 2018, is based on the High Resolution Rapid Refresh Ensemble (HRRRE) being developed and run at NOAA/ESRL:

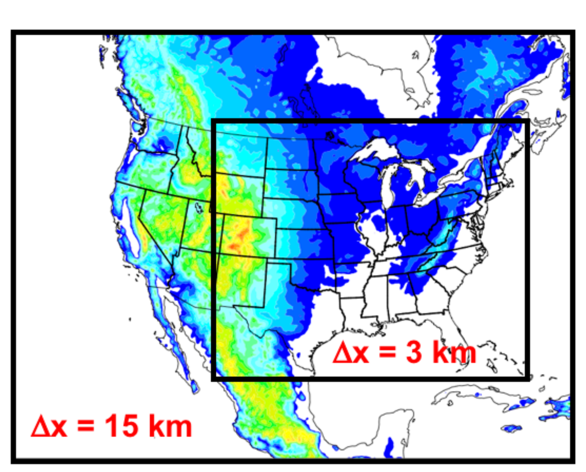
2018 HRRRE Analysis System

Nested 15-km and 3-km domains

HRRR v3 code

36 members initialized at 0300 UTC
- Initial mean from GFS (atmos.) and RAP-HRRR (soil)
- Atmospheric perturbations from GFS ensemble (GDAS)
- Random soil-moisture perturbations

Hourly cycling with EnKF DA
- Begins at 0300 UTC, ends at 0000 UTC the next day
- Conventional observations both domains
- Reflectivity observations 3-km domain only
- Analysis variables: U, V, PH, T, MU, QVAPOR, QCLOUD, QICE
- BC perturbations, posterior inflation



Courtesy David Dowell, NOAA/ESRL

2. Goals and Design

With the specific goal of improving real time mesoscale analyses used routinely by SPC forecasters (and the secondary goal of exploring the use of analysis uncertainty in diagnosis of the environment), this study compares SPC-MA severe weather forecasts fields to those produced by a HRRRE-based system termed the HRRRE-MA (HRRRE mesoscale analysis).

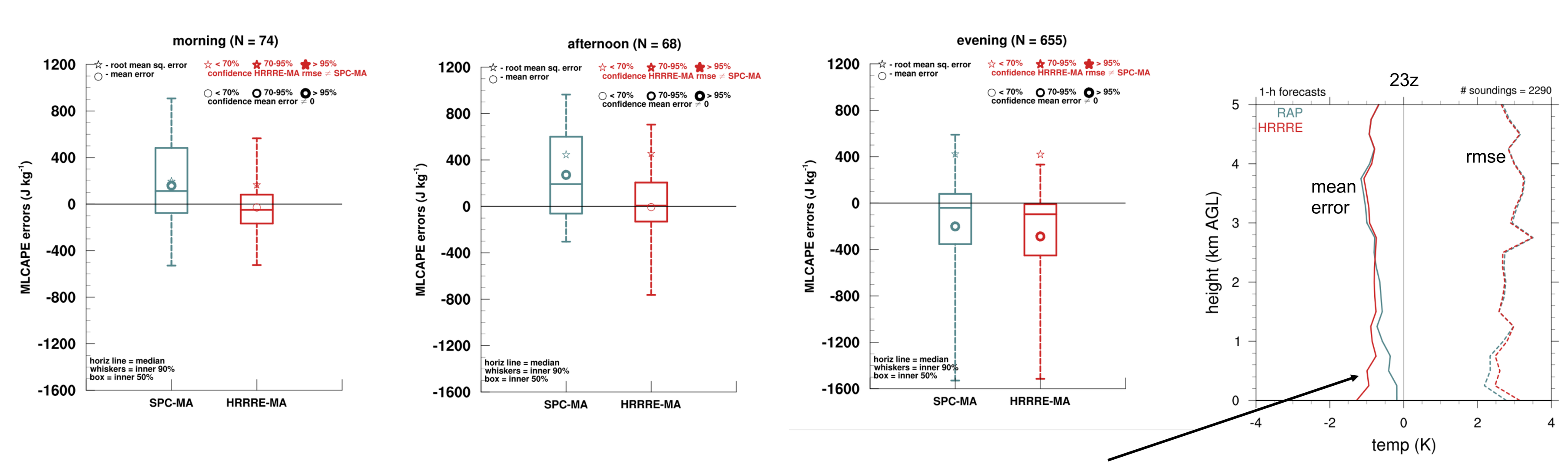
2. Goals and Design (continued from below)

SPC-MA	HRRRE-MA
20-km RAP 1-h forecasts	15-km HRRRE 1-h forecasts
Barnes OA of sfc. obs. replaces RAP sfc. conditions on 20-km grid	Ensemble Kalman Filter (EnKF) assimilation of sfc. obs. on 15-km grid
3D deterministic mesoscale (20-km) analysis	3D ensemble mesoscale (15-km) analysis (36 members)

Analyses made available 30-40 min before the full RAP and HRRRE analysis cycles are available[1]. For comparison purposes, analyses are produced here using an obs. cutoff time = valid time + 30 min and are filtered to a 25-km grid.

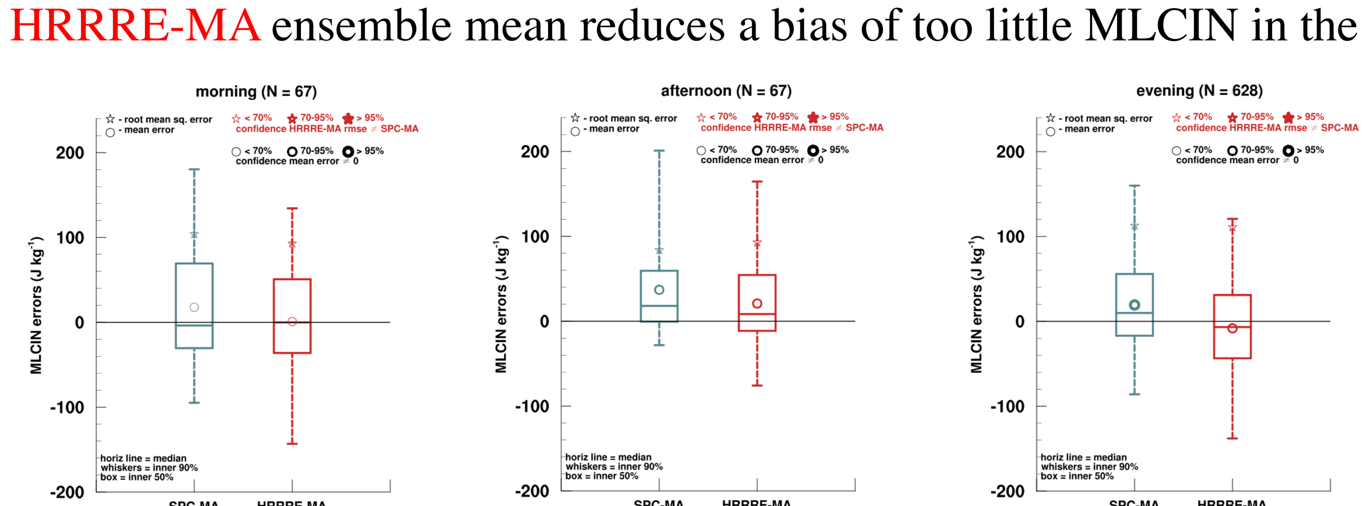
3. Findings

- Using NWS radiosondes over 44 days where MLCAPE > 0 for verification, the HRRRE-MA ensemble mean[2] removes a morning and early-mid afternoon high MLCAPE bias in the SPC-MA, and greatly reduces the spread of errors at these times, but makes an early-evening low MLCAPE bias in the SPC-MA slightly worse:



- The low MLCAPE bias at 23z is related to an evening cold bias in the HRRRE 1-h forecasts from too many clouds[3]. This cold bias produces larger errors in low-level lapse rates and SB/MUCAPE in the HRRRE-MA (not shown).

- The HRRRE-MA ensemble mean reduces a bias of too little MLCIN in the SPC-MA:

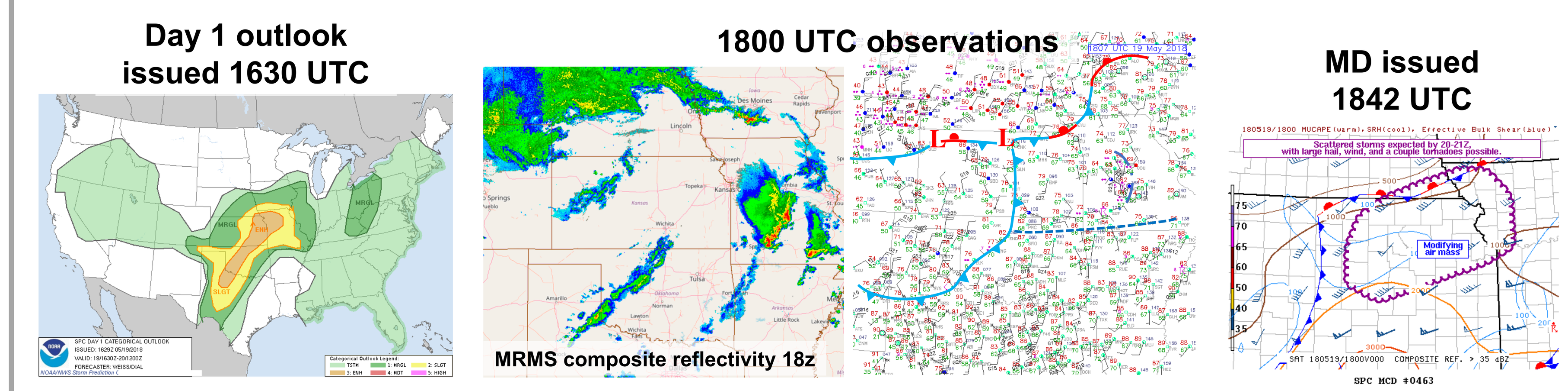


- Differences in shear between the HRRRE-MA and the SPC-MA are small (not shown).

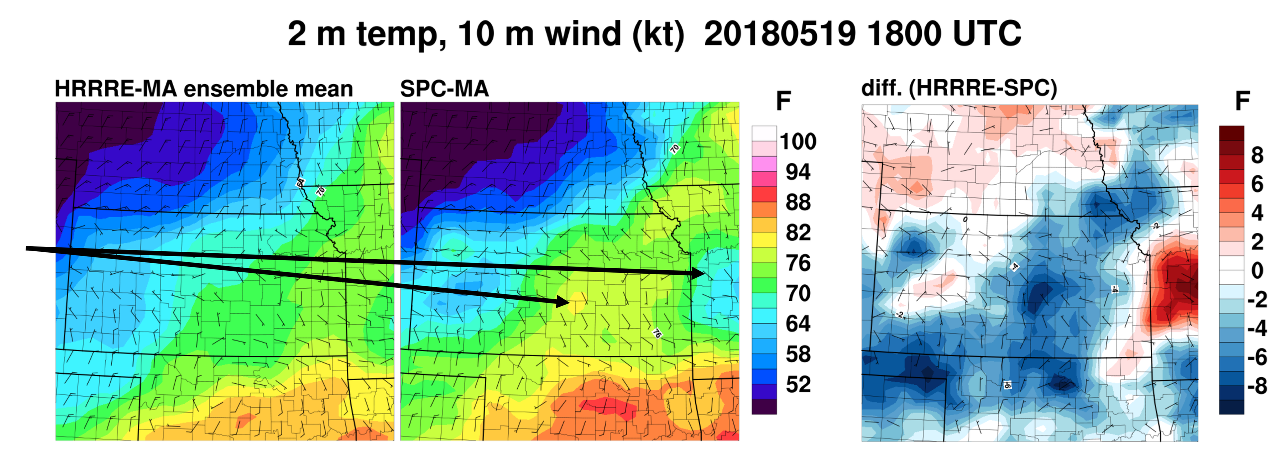
[1]Fields could be ready even earlier with more CPU, faster data transfer, and an earlier obs. cutoff time than that used in spring 2018.
[2]Severe weather fields are computed from individual members prior to averaging.
[3]This cold bias has since been mitigated with a satellite-based hourly cloud-clearing procedure (David Dowell, personal communication).

3. Findings (continued from below)

Example benefit of removing SPC-MA high MLCAPE biases: **19 May 2018**

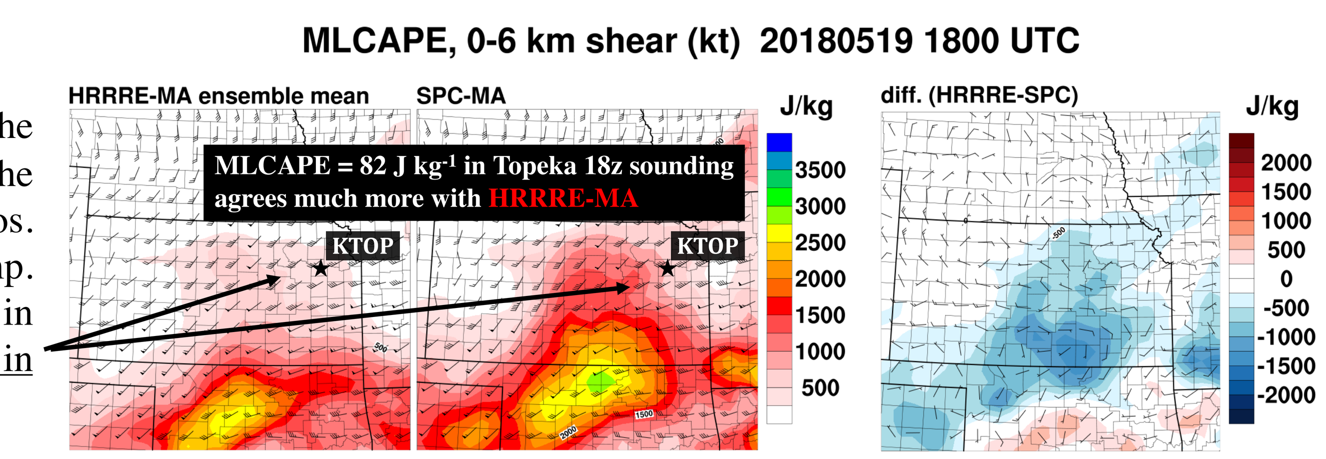


The Barnes analyses in the SPC-MA fits the surface obs. better behind the MCS that was over central Missouri at this time…

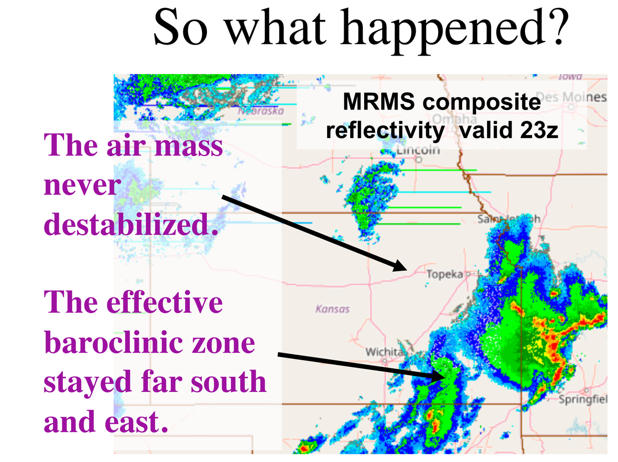


…BUT…

….the EnKF covariances in the HRRRE-MA spread info. in the surface obs. into the lower atmos. resulting in better low-level temp. /dewp. structures, which results in lower MLCAPE/MLCIN errors in the HRRRE-MA.

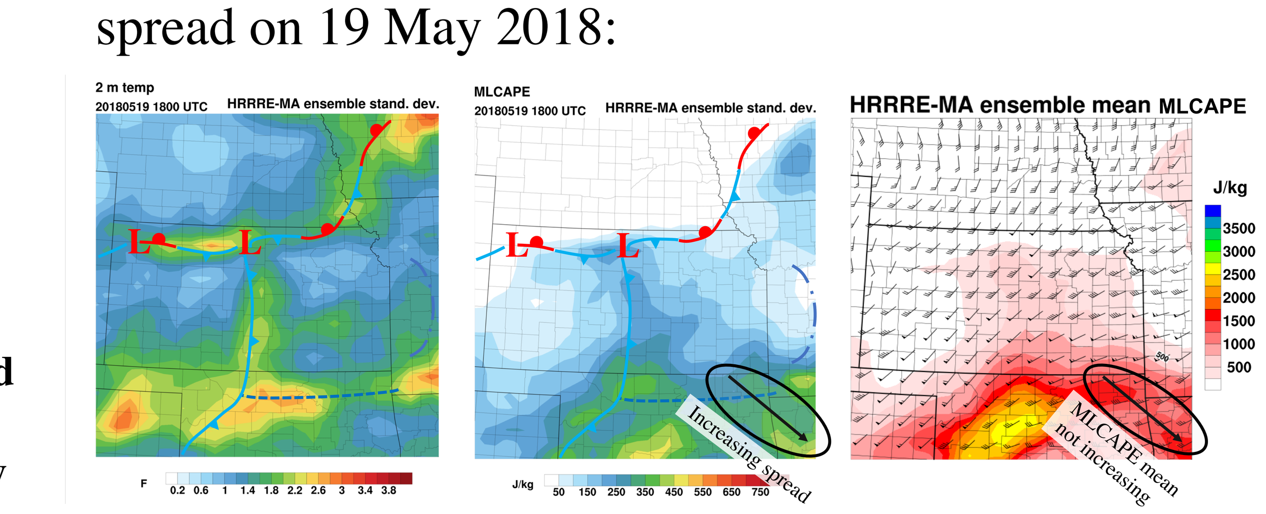


So what happened?



HRRRE-MA correctly indicated a smaller threat in KS than in the SPC-MA and anticipated by SPC forecasters.

Examples of ensemble analysis spread on 19 May 2018:



- Larger temperature spread focused near boundaries
- MLCAPE spread often scales with MLCAPE ens. mean, but not always (e.g. northeast OK to western AR)

4. Other analysis systems under development

3D-RTMA: Deterministic and **close fit to observations** for local WFO scale (valley flows, urban effects, etc.) – may not be optimal for a mesoscale analysis used to derive severe weather forecast fields on scales germane to SPC.

HRRRE data assimilation system (HRRRE-DAS): Will use GSI 3D hybrid EnVar data assimilation, **so opportunities to improve mesoanalyses for use in SPC operations using ensembles, as shown here, will continue.** Assimilation of radar fields and surface obs. on the 3-km grid should improve both analysis fit and modification of the environment by storms.