Predictability Considerations of the 10 August 2020 Midwest Derecho

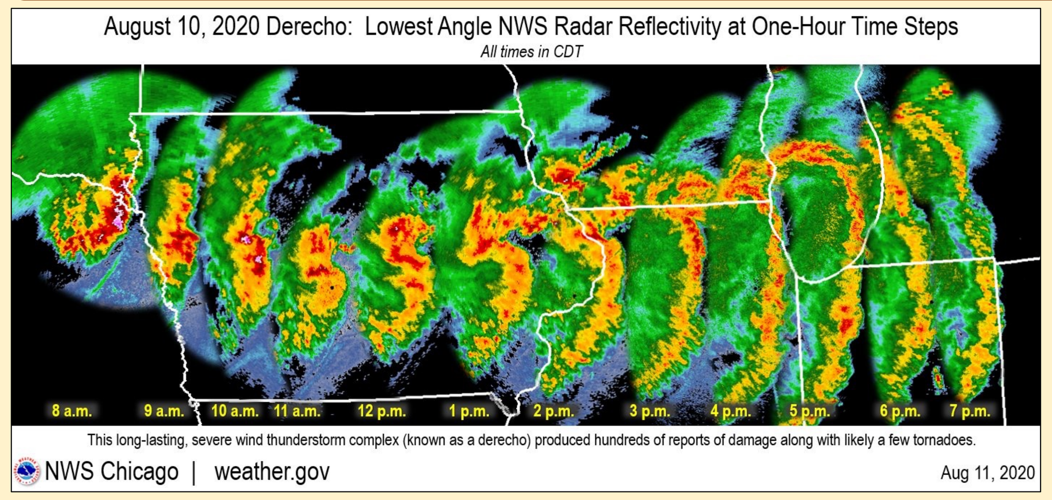
Jeffrey D. Duda – CIRES/WCD, NOAA/Global Systems Laboratory

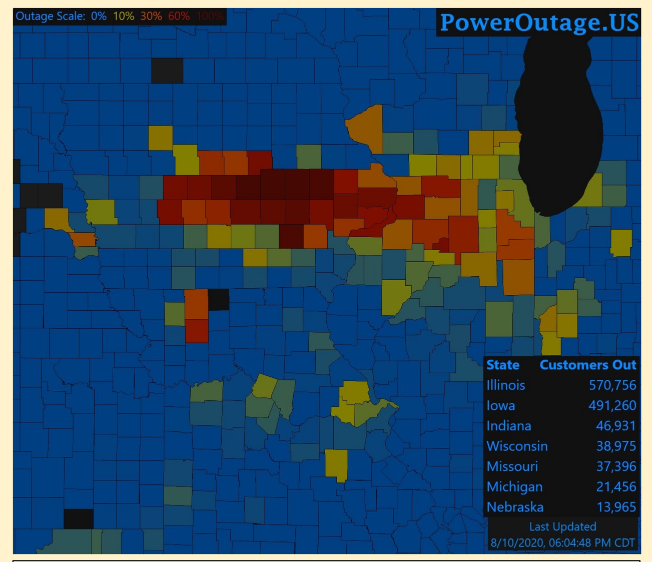
Abbreviations/definitions

- **MCS** – mesoscale convective system
- **NWP** – numerical weather prediction (model)
- **WRF** – weather research and forecasting (model)
- **CAM** – convection-allowing NWP model
- **HRRR** - High-Resolution Rapid Refresh version 3 or 4 (v3/v4)
- "cycle" – the entire NWP forecast initialized at a single time

Event Overview

Through the late morning and afternoon of 10 August 2020 a derecho (thunderstorm-induced wind storm) struck the Midwest, hitting parts of Iowa and Illinois the hardest. This derecho produced more extreme weather events than most derechos, including maximum measured 10-m wind gusts exceeding 120 mi hr^{-1} and maximum estimated wind gusts (based on damage) of 140 mi hr^{-1}. In addition, an instrumented tower in Ames, IA sampled several instances of winds exceeding 120 mi hr^{-1} at heights as low as 80 m above ground level and sustained winds at lower levels above 100 mi hr^{-1} over a 7-min period. The AWOS site at the Clinton, IA airport sampled 60+ mi hr^{-1} winds continuously for nearly one hour! At the peak, an estimated 1.9 million customers were without power, and some customers in Iowa were without power for nearly two weeks afterward. Damage was extensive, with a total estimated cost of $11 billion, making this the second-most expensive weather event to impact the U.S. in 2020, and the costliest thunderstorm event in the history of the United States. Four fatalities occurred along with dozens of injuries and significant tree and crop damage.





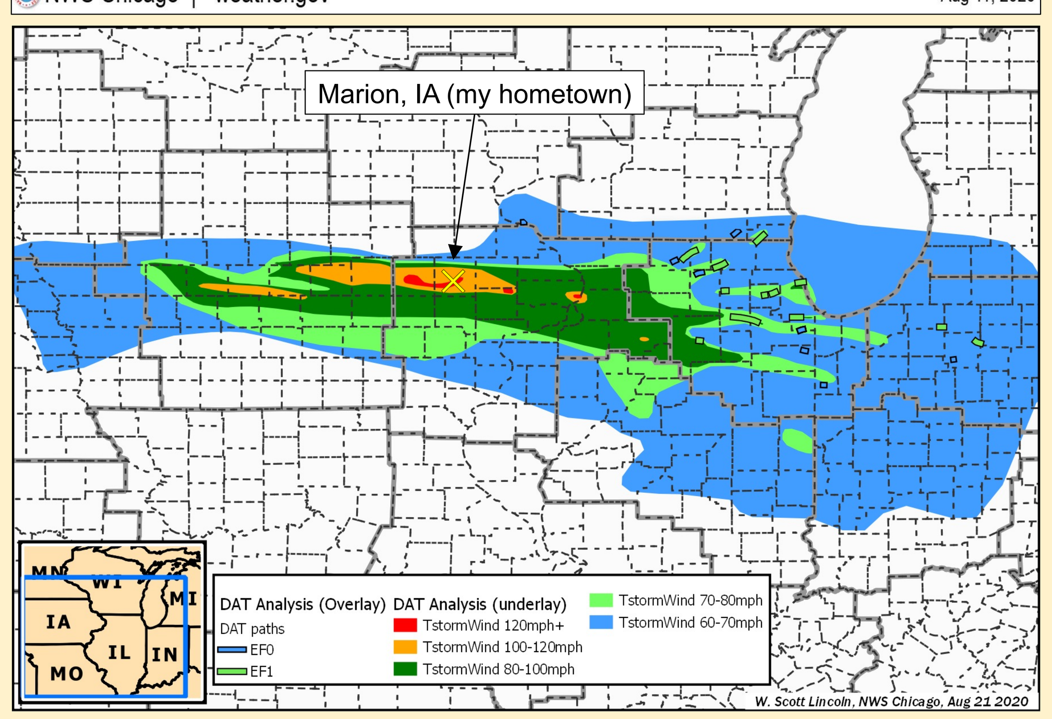
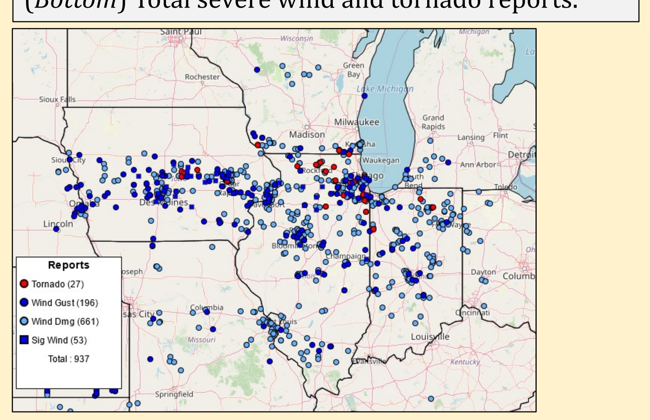
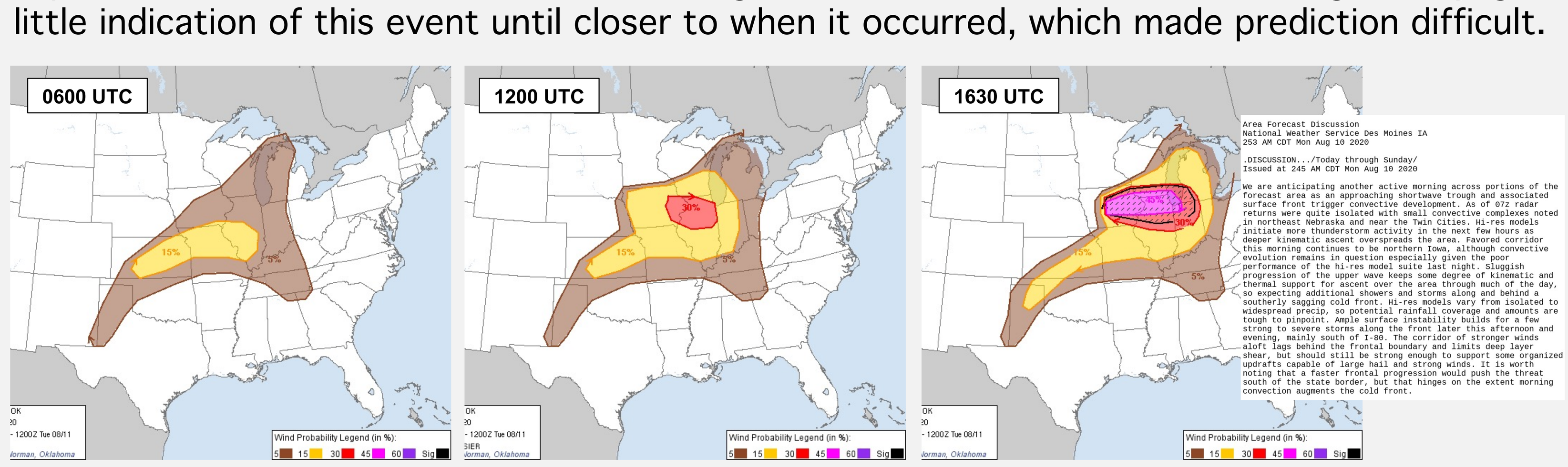


Figure legend
(*Top left*) Radar depiction of the derecho – hourly radar reflectivity throughout the event.
(*Left*) Analyzed wind swath from the derecho, including tornado tracks.
(*Above*) Power outages near the peak of the event.
(*Bottom*) Total severe wind and tornado reports.

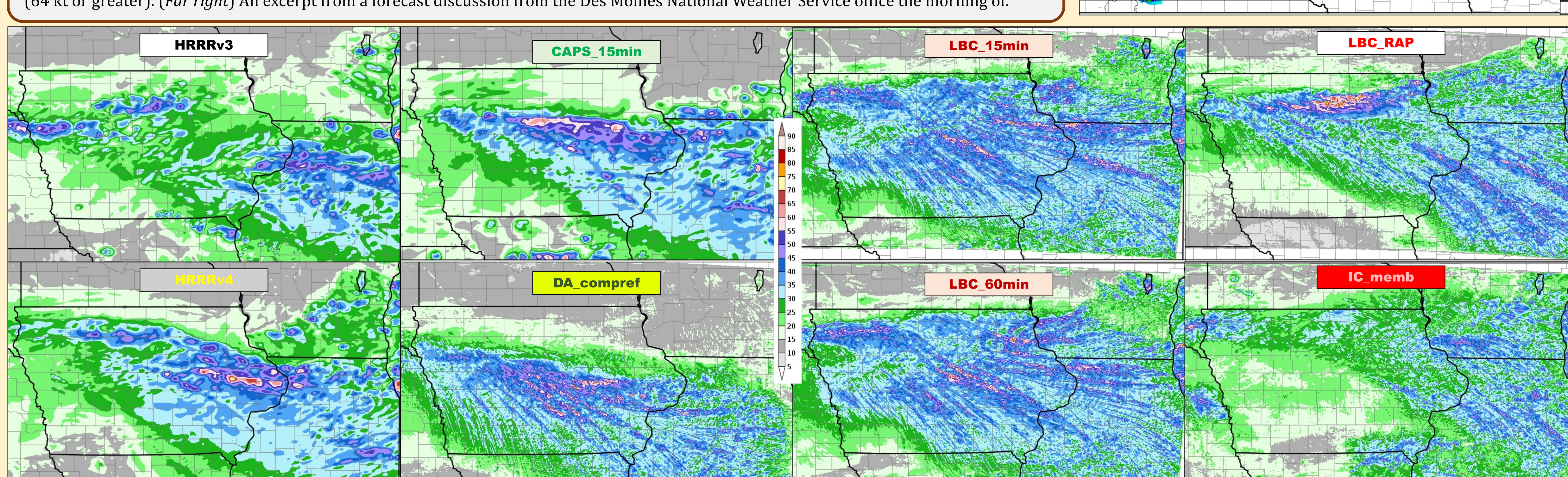


Operational Forecast Overview

Many operational forecast agencies did not suggest the potential for a derecho-producing MCS in discussions the night before and the early morning of until the convection began organizing into the mature MCS after 1200 UTC. In defense of the miss from the human aspect of the forecast of this event, the guidance from CAM forecasts also generally gave little indication of this event until closer to when it occurred, which made prediction difficult.



Above: Outlooks of probability of severe wind gusts (50 kt or greater) from the Storm Prediction Center. Forecasts were issued at (*left*) 0600, (*middle*) 1200, and (*right*) 1630 UTC 10 August 2020. The black hatching delineates a 10% probability of "significant" severe wind gusts (64 kt or greater). (*Far right*) An excerpt from a forecast discussion from the Des Moines National Weather Service office the morning of.



Above: Wind swaths (forecast-maximum 10-m grid-resolved wind speed; kts) from all 0600 UTC cycles. The purple shade denotes the minimum threshold for severe wind speeds.
Maximum 10-m winds within each simulation [kt]: HRRRv3 – 70.7; HRRRv4 – 74.5; CAPS_15min – 65.8; DA_compref – 87.5; LBC_15min – 87.3; LBC_60min – 79.3; LBC_RAP – 88.6; IC_memb – 69.7

What's the point of this poster?

I grew up in Marion, IA – a location near the epicenter of the worst of this event. Inspired by the hometown destruction, I sought to analyze the aspects of the NWP forecasts that led to the miss of this event. Along the way, I decided to attempt to create better NWP forecasts of this event. This poster discusses my findings of both the predictability analysis and the forecast performance.

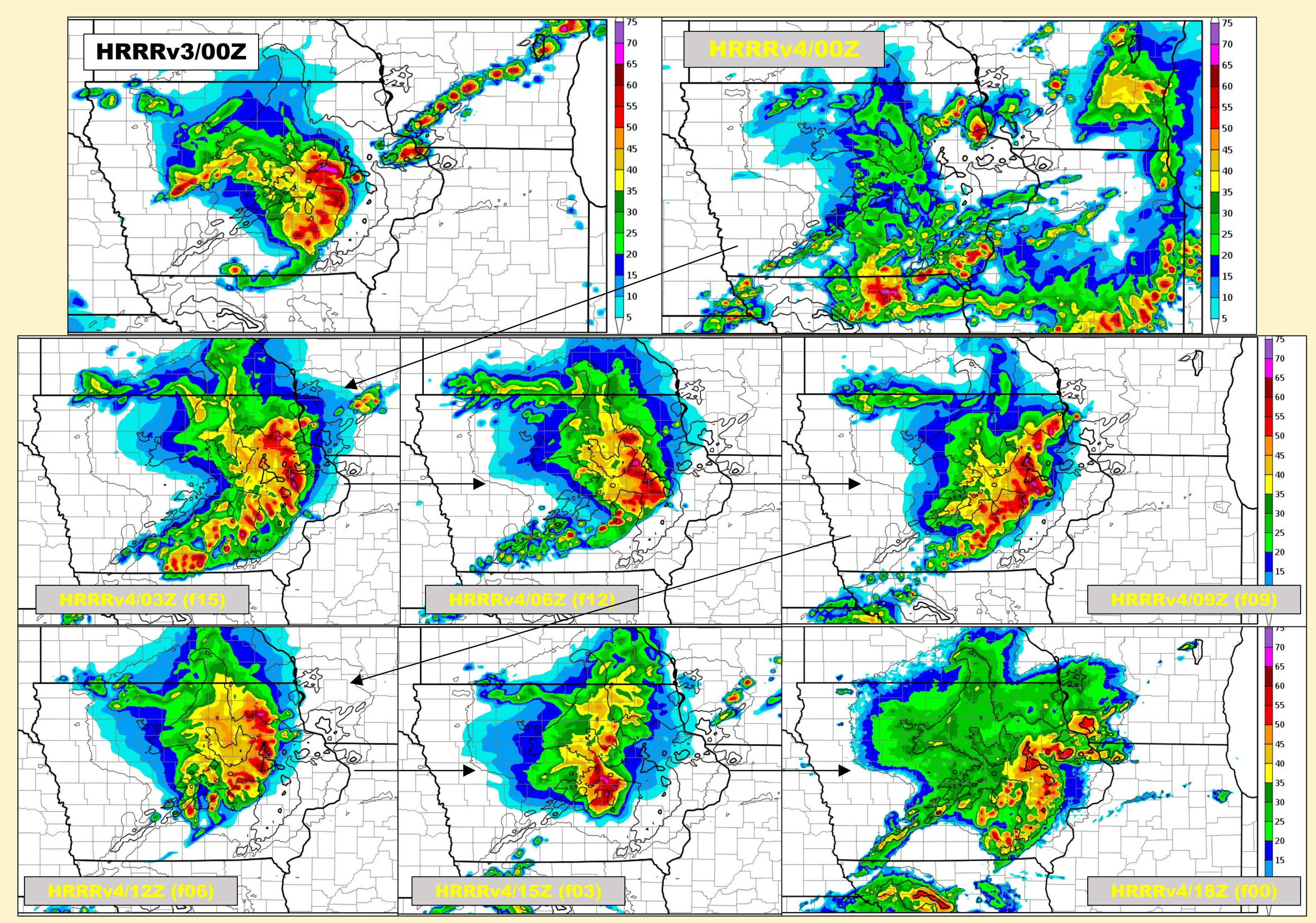
Which NWP models were used?

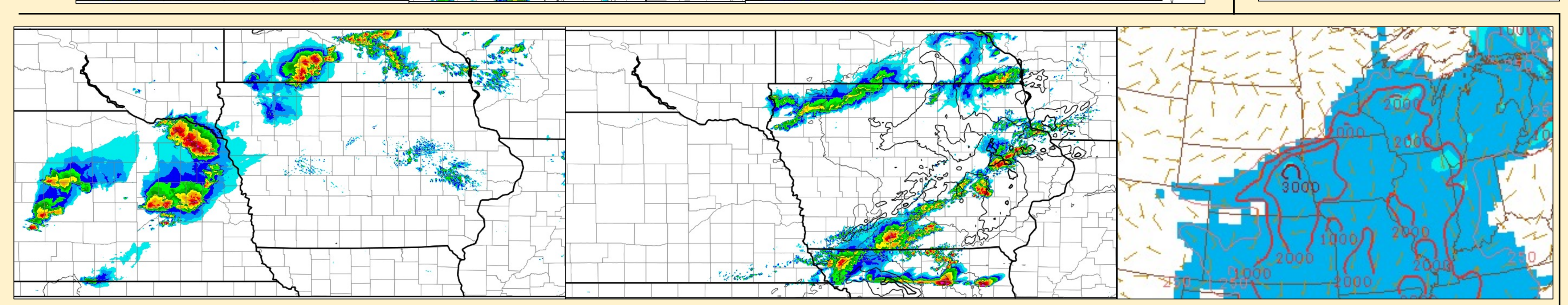
Short answer: HRRR-like 3-km and 500-m grid spacing NWP models. Any given model configuration was initialized either every hour or every three hours, starting approx. at 00Z 10 August until approx. 15Z 10 August. Investigation of predictability of this event relies on the change of forecast trajectory with successive forecast initializations.

Long answer: The WRF model served as the dynamical core of the operational HRRR model, with 3-km grid spacing. HRRRv3 was operational at the time, but the next version, HRRRv4, was running in parallel in a pre-operational mode at the time as well. Some additional HRRR-like forecasts were also used, with other configuration settings.

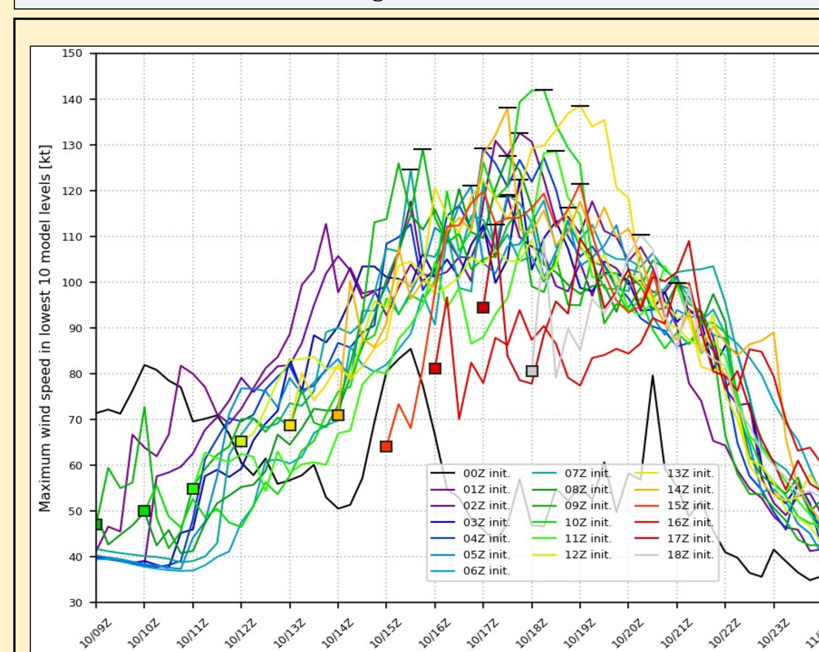
The 500-m horizontal grid spacing NWP forecasts are a primary feature of this research. Such grid spacings enable effectively full resolution of the scale of air flows involved in this event. The 3-km forecasts cannot do this. Secondarily, 500-m horizontal grid spacing should allow for increased wind speeds to be depicted, thus indicating if the model is capable of producing the wind speeds in the derecho.

Below: (*top row*) 18-h forecast valid 1800 UTC 10 August 2020 from the HRRRv3 and HRRRv4 models. A HRRRv4 forecast trajectory bifurcation is evident from the difference between the 18-h and 15-h forecasts initialized at 00Z and 03Z 10 August, respectively.
(*remainder*) Evolution of MCS forecast with successive HRRRv4 model cycles. All images valid at 1800 UTC 10 August 2020. Forecast hour decreases rightward across columns and downward across rows, as indicated by the arrows.





Above: What happened in IC_memb? Answer: spurious convection developed in E NE/W IA, ahead of the cold front, and disturbed the convective environment, making it less supportive of a derecho-producing MCS (observed SBCAPE at 0900 UTC 10 August; *right*). (*Left*) 4-h forecast valid 1000 UTC 10 August; (*center*) 10-h forecast valid 1600 UTC 10 August.

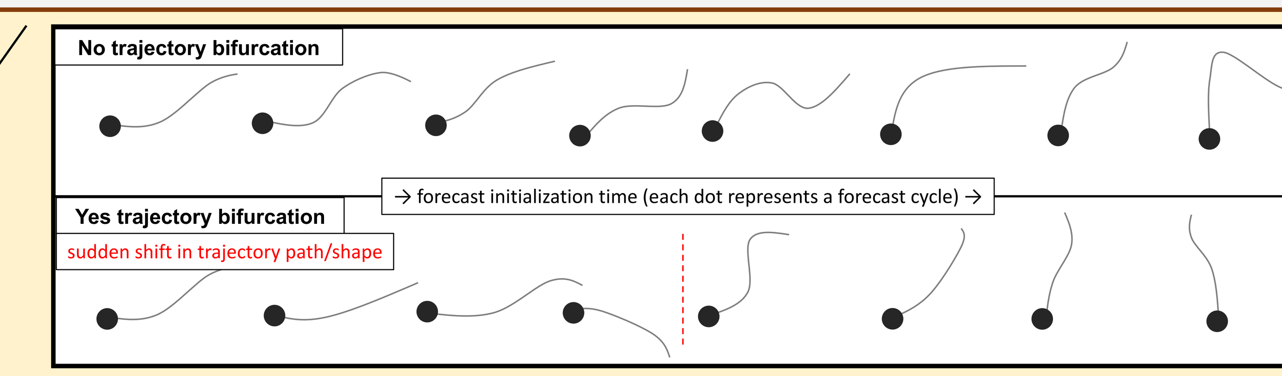


Left: Time series of maximum wind speed in the lowest few km above ground from DA_compref model configuration forecasts initialized at the indicated times. Colored squares represent model initialization, whereas the black bars denote the time and magnitude of the maximum wind speed.

How did the models perform?

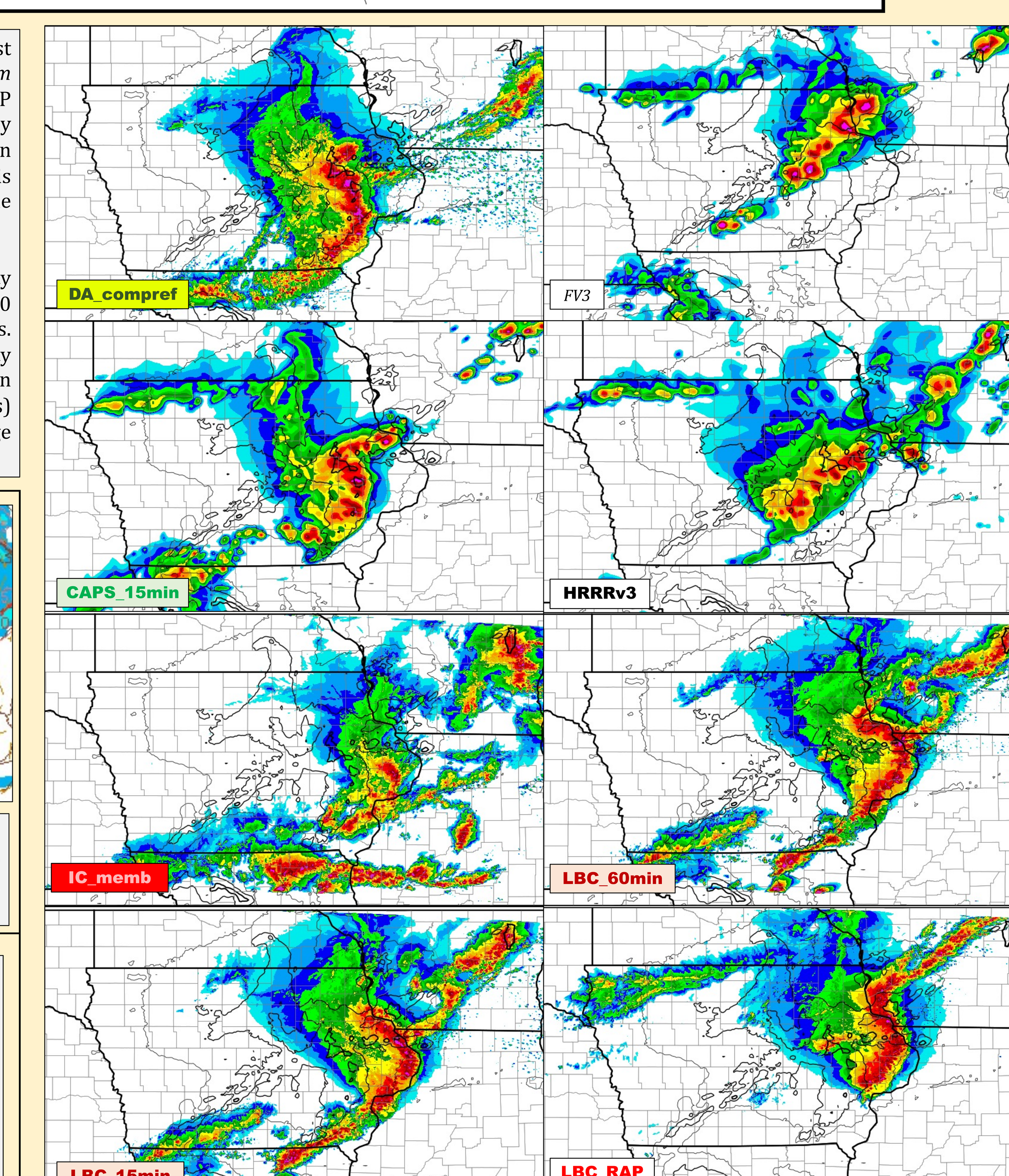
- HRRRv3 and v4 forecasts initialized before 00Z 10 August performed quite poorly; they did not depict anything resembling the actual event. (no other models were run before 00Z).
  - A *forecast trajectory bifurcation* occurs in many models at around 00Z 10 August, especially in the HRRRs. Model cycles starting at 00Z and for several hours later depicted an impressive forecast of the event, capturing not only a bowing MCS* moving across Iowa and into Illinois during the late morning through afternoon, but also indicated widespread surface winds, some being extreme. Many of these forecasts' MCSs were within about 1 hour of the longitude of the actual event, although many forecasts placed the MCS track 50-150 km to the north of where it actually occurred. A *second forecast trajectory bifurcation* occurs roughly between 09Z and 15Z (varying by model, and more gradual) after which the forecasts actually become less accurate.

  *The vertical structure was canonical/nearly textbook in appearance.
- HRRRv4 outperformed HRRRv3, with the 00Z cycle being the lone exception.
- Models using direct reflectivity assimilation tended to perform better than all other models.
- 500-m Δx models produced an MCS that had more a expansive and "meatier" leading convective line and also higher wind speeds.
- All models had trouble keeping the MCS moving at the speed of the actual event; that is, they had a slow bias in the forward move speed.
- No model was able to produce 10-m wind speeds as high as the maximum measured values, but some got near or above 100 mi hr^{-1}. However, one of the 500-m grid spacing forecasts produced winds in the lowest few km above ground as high as 160 mi hr^{-1}!
- Ultimately, a given forecast's performance was correlated to how open it kept the warm sector ahead of the cold front, thus leaving the inflow environment to the MCS undisturbed, and thus was a primary factor determining the predictability of the event.



Above: Schematic of a forecast trajectory bifurcation (*bottom panel*). Ordinarily, a given NWP model will shift more gradually with successive initialization times as new information is obtained and assimilated into the model grid, as in the *top panel*.

Right: Composite reflectivity valid 1800 UTC 10 August 2020 from the indicated models. Observed composite reflectivity contours (10, 30, 50 dBZ in increasingly thick black contours) are shown for reference to gauge accuracy.



Take home message(s)

The 500-m grid spacing forecasts did a remarkably good job replicating the three-dimensional structure of the MCS-producing derecho, nearly matching the wind speeds, and tracking in the same direction and over a similar path as the observed event. The 3-km forecasts were more variable. Keeping an undisturbed inflow environment was critical for accurately forecasting this event.