Development of an Hourly-Updated NAM Forecast System and Application to the Damaging Summer 2012 Derecho Event

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B-P03

Abstract

The June 29th, 2012 derecho event began over northwest Illinois as a developing mesoscale convective system at approximately 1500 UTC. By 1900 UTC this system had evolved into a bow echo over central Indiana and produced surface wind gusts as high as 91 mph. The storm maintained its damaging characteristics as it later moved southeastward through Ohio, West Virginia, Virginia, Maryland, and the Washington, D.C. metropolitan area by approximately 0300 UTC on June 30th.

This damaging event was generally not well-forecast by the operational 4 km CONUS-nest North American Mesoscale model (NAM), a property that became more problematic as the event approached. Therefore, this event has since served as a benchmark case for the ongoing development of an hourly-updated version of the NAM forecast system. Unlike the operational system, which updates every three hours, this hourly-updated system also cycles and updates the 4 km CONUS-nest in addition to the 12 km parent domain. Furthermore, a cloud analysis system has been introduced along with a twice-diabatic digital filter step to improve the initialization of cloud thermodynamic and hydrometeor fields. The digital filter not only helps to reduce noise in the early part of the forecast, but also applies a radar-derived latent heating tendency based upon the earlier cloud analysis step to help initialize the cloud fields. Also included are updates to the microphysics parameterization to improve both the forecast and representation of convective storms, storm structure, and storm attributes (e.g. strong surface wind gusts). Results of these tests with a focus on the 4 km CONUS-nest forecast of the derecho event from the hourly-updated NAM forecast system will be presented.

For more information on the development of the hourly-updated NAM forecast system and applications to wind energy forecasting, please see **G-P05**.

NAM Rapid Refresh (NAMRR) Algorithm

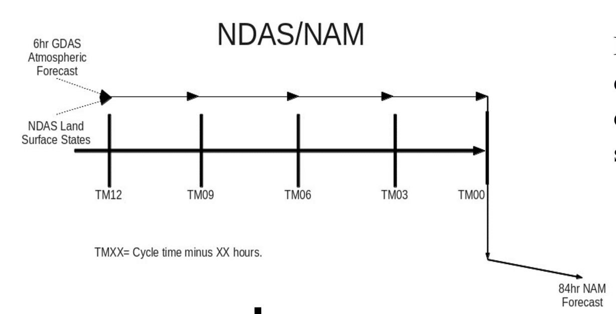

FIG 1. NAM/NDAS data assimilation cycling diagram for a single, arbitrary cycle.

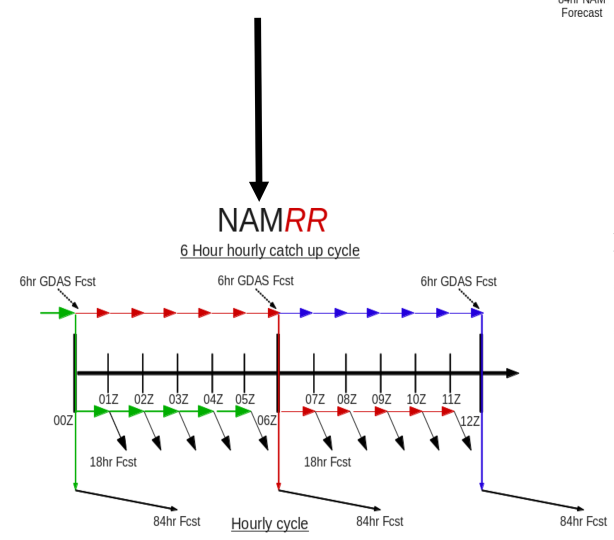

FIG 2. NAMRR data assimilation cycling diagram.

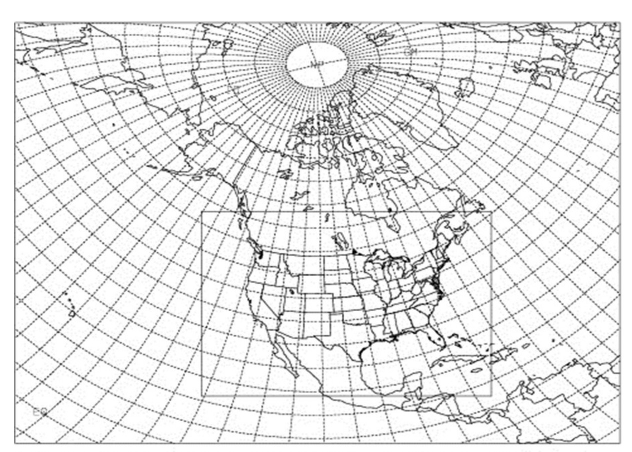

FIG 3. NAM Parent 12 km and 4 km CONUSNEST computational domains. The parent 12 km domain covers all areas depicted in the figure. The 4 km CONUSNEST domain covers only the area shown by the inner-rectangle.

Figure 1 shows a simplified configuration of the current, operational NAM Data Assimilation System (NDAS) cycling diagram. Each forecast cycle begins with a 12 hour analysis-forecast window during which analyses are conducted at three hour intervals (TM12, TM09, etc.). TM00 refers to the forecast initialization time (e.g. 00, 06, 12, or 18 UTC). At TM12 the first guess for the atmosphere is a 6 hour forecast from the GDAS. The land states are cycled from the previous NDAS cycle. Note that in this configuration no cycle is included for the 4 km CONUSNEST (Fig. 3). The CONUSNEST obtains its initial conditions via a downscaling of the 12 km parent fields.

Figure 2 shows the NAM Rapid Refresh (NAMRR) data assimilation cycling diagram. The NAMRR's configuration is broken up into two run-types, 'catchup' and 'hourly'. Catchup types occur at 00Z, 06Z, 12Z, and 18Z and are similar to the current NDAS configuration (Fig. 1). The 'catchup' step starts using a 6 hour forecast from the Global Data Assimilation System (GDAS) for the first guess atmospheric state for the analysis while still cycling the model land states from the previous 1 hr NAMRR forecast. However, unlike the NDAS system the NAMRR only goes back 6 hours, instead of 12, but does perform an analysis every hour (instead of every 3). Once the catchup's analysis/forecast cycling is finished (e.g. at 06Z) a 60 hour forecast with the 4 km nest and an 84 hour forecast with the 12 km parent domain is conducted. It should be noted that *both the parent and the CONUSNEST are cycled in this system* (Fig. 3).

For the 'hourly' runtype (occurring at all other hours, e.g. 13Z, 14Z, etc. - the bottom portion of Fig. 2) an analysis is performed based upon a 1 hour forecast from the previous cycle. Following the analysis an 18 hour forecast is conducted with both the parent and CONUSNEST domains.

Select References

GSI: Wu, W.-S., R. J. Purser, and D. F. Parrish, 2002: Three-dimensional variationalanalysis with spatially inhomogeneous covariances. *Mon. Wea. Rev.*, **130**, 2905–2916.
Hamill, T. M., 1999: Hypothesis tests for evaluating numerical precipitation forecasts. Wea. Forecasting, 14, 155–167.

Ops NAM vs. NAMRR Configuration

Model	Points	Grid spacing	Digital filter?	Radar Reflect. Initialization?	Vert. levels	Model top	Analysis/ Update frequency	Forecasts per day	Max forecast length
NAM	954x835	12 km	No	No	60	2 hPa	3 hourly	4	84 hours
NAM CONUSnest	1371x 1100	4 km	No	No	60	2 hPa	None	4	60 hours
NAMRR	954x835	12 km	Yes	Yes	60	2 hPa	Hourly	24	84 hours
NAMRR CONUSnest	1371x 1100	4 km (3 km testing)	Yes	Yes	60	2 hPa	Hourly	24	60 hours

Model	Param. Convection	Radiation (LW/SW)	Microphysics	PBL	LSM	Cycled analysis
NAM	BMJ	GFDL	Ferrier	MYJ	Noah	GSI-3DVar
NAM CONUSnest	BMJ "light"	GFDL	Ferrier	MYJ	Noah	None
NAMRR	BMJ (w/ updates)	RRTMG	Ferrier (w/ updates)	MYJ	Noah	GSI hybrid ens-3DVar (global EnkF)
NAMRR CONUSnest	None	RRTMG	Ferrier (w/ updates)	MYJ	Noah	GSI hybrid ens-3DVar (global EnkF)

Brief Derecho Event Overview, Motivation, and Results

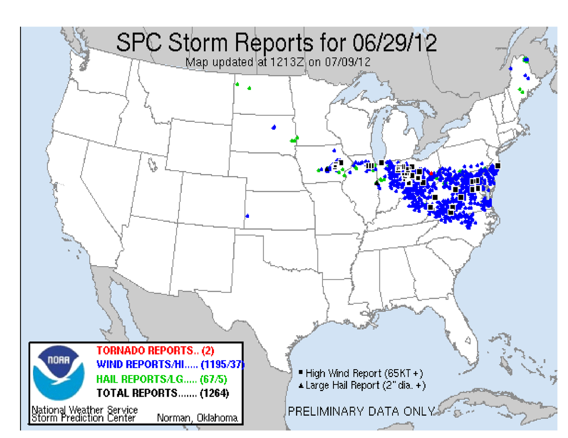

FIG 4. Preliminary storm reports from the Storm Prediction Center.

Fig. 4 shows preliminary reports of very widespread wind damage caused by the damaging derecho of summer 2012. During this time it was noted that a handful of forecasts from the operational NAM 4 km CONUSNEST domain failed to provide accurate forecasts of the derecho event, in some cases not even forecasting a derecho at all (e.g. Fig. 5, upper right). Therefore this case has served as a benchmark test case in the development of the NAMRR

Initial tests with the NAMRR at both 4 and 3km horizontal grid spacing show substantial improvement over the June 29th, 2012 18Z cycle of the operational CONUSNEST (Fig. 5).

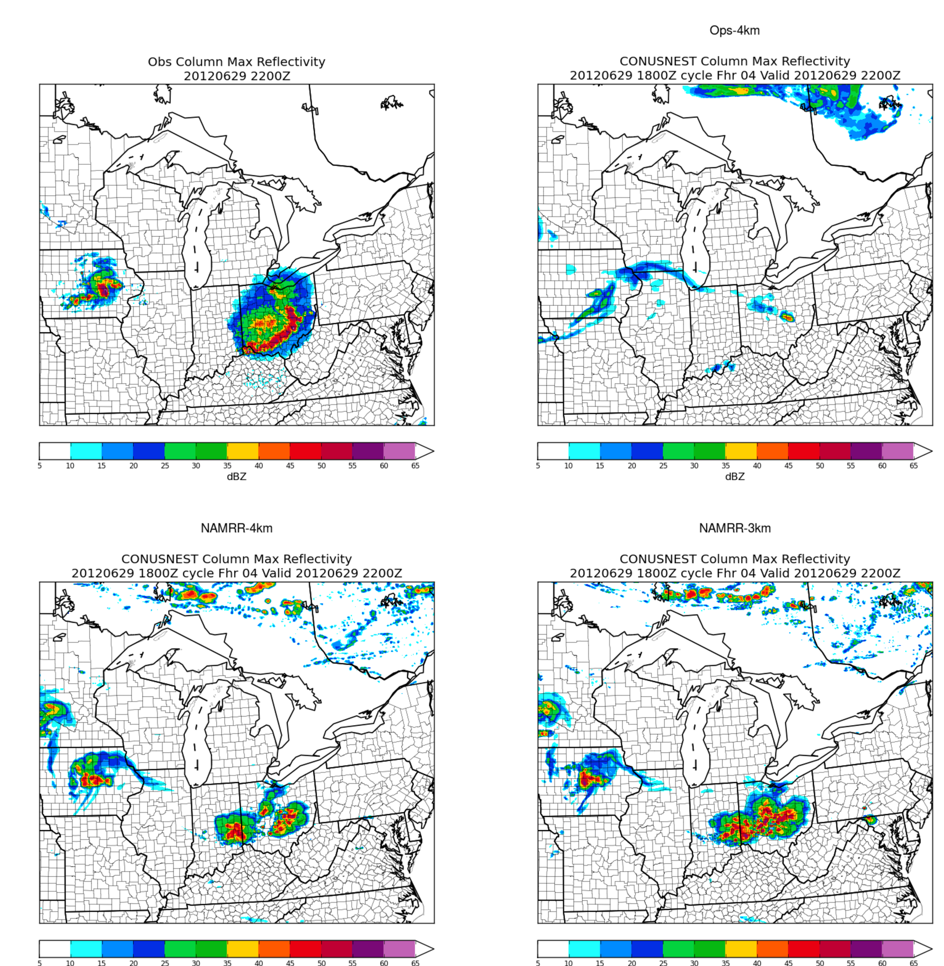

FIG 5. Observed composite, column maximum radar reflectivity (upper left) and 4 hour forecasts of column maximum radar reflectivity from the operational 4 km NAM CONUSNEST (upper right), 4 km NAMRR CONUSNEST (lower left), and 3 km NAMRR CONUSNEST (lower right) . All are valid June 29th, 2012 at 22 UTC.

Preliminary Results Continued

Long range forecasts:

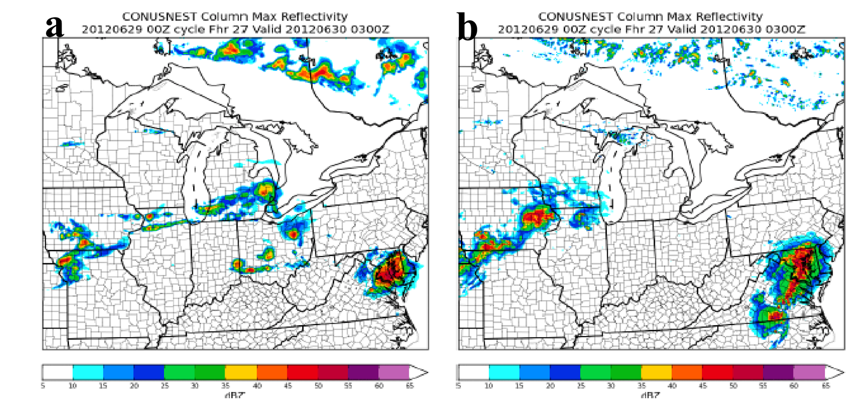

FIG 6. 27 hour forecasts of column maximum radar reflectivity from (a) the operational 4 km CONUSNEST and (b) the developmental 3 km NAMRR CONUSNEST. Observed composite column maximum radar reflectivity is shown in (c). All plots are valid 03 UTC on June 30th, 2012.

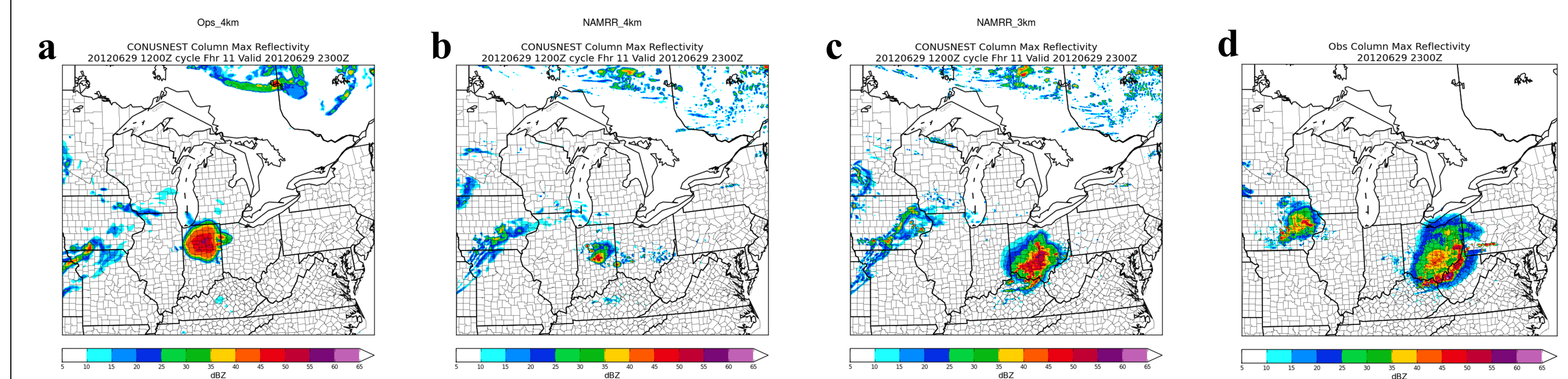

FIG 7. 11 hour forecasts of column maximum radar reflectivity from (a) the operational 4 km CONUSNEST , (b). the developmental 4 km NAMRR CONUSNEST, and (c) the developmental 3 km NAMRR CONUSNEST. Observed composite column maximum radar reflectivity is shown in (d). All plots are valid 23 UTC on June 29th, 2012.

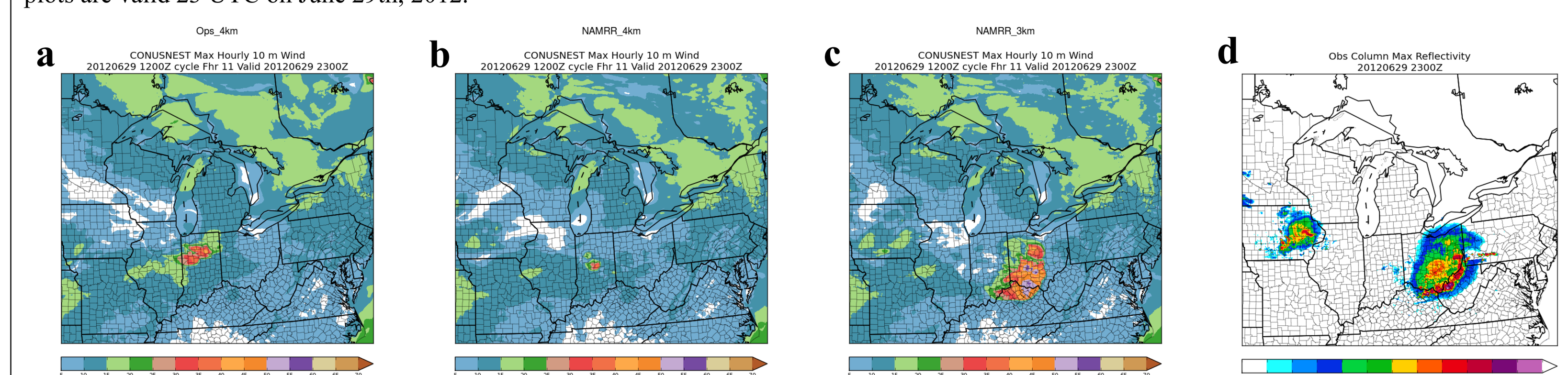

FIG 8. As in Fig. 7 except for forecasts of maximum hourly 10 m AGL wind speed in figures a-c. Observed composite column maximum radar reflectivity is shown in (d). All plots are valid 23 UTC on June 29th, 2012.

Verification - 4 km NAMRR

Lines falling outside the rectangles are significant at the p=0.05 level (Hamill, 1999)

Ops 4 km CONUSNEST vs. 4 km NAMRR CONUSNEST

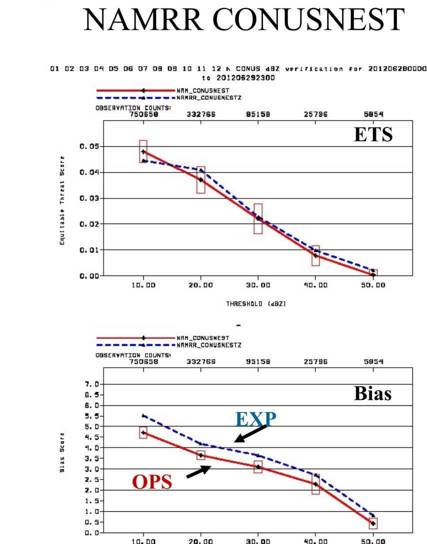

FIG. 9. Equitable threat score (top) and frequency bias (bottom) over CONUS vs. column maximum radar reflectivity throughout the 01-12 hr period covering June 28th at 12 UTC through June 29th at 00 UTC. *Note* since the Ops CONUSNEST is only run every 6 hours these results are from a limited number of samples.

4 km NAMRR CONUSNEST *without* Cloud Analysis vs. 4 km NAMRR CONUSNEST with Cloud Analysis

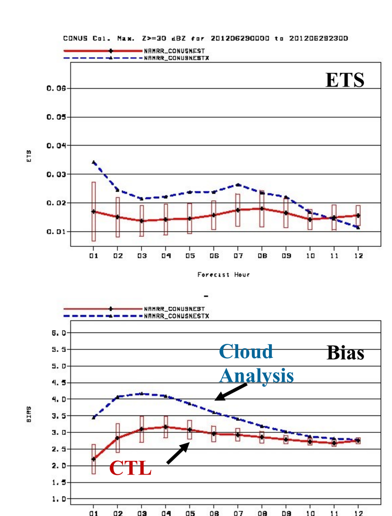

FIG. 10. Equitable threat score (top) and frequency bias (bottom) over CONUS based upon forecasts of column maximum radar reflectivity >= 30 dBZ vs. forecast hour. The period covers June 28th at 12 UTC through June 29th at 00 UTC.

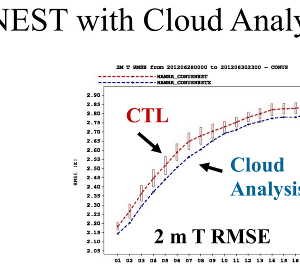

FIG. 11. 01-18 hr 2 m temperature RMSE.

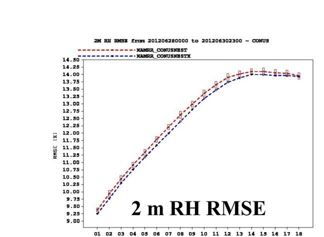

FIG. 12. 01-18 hr 2 m RH RMSE.

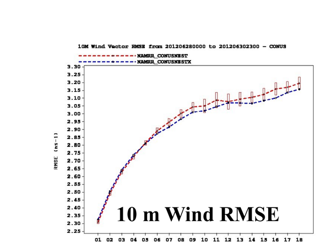

FIG. 13. 01-18 hr 10 m vector wind RMSE.

Discussion and Future Work

The NAMRR system provided significant forecast improvements over the operational CONUSNEST and, in general, the transition from 4 to 3 km horizontal grid spacing for the NAMRR CONUSNEST yielded marked improvements in the forecast of the derecho. Furthermore, tests without and with the cloud analysis procedure showed that, for this case, cloud analysis improves the NAMRR forecast. There is much future work still to be done, some of which includes testing updates to the model microphysics, running additional case studies, optimization, Ens4DVar assimilation, and real-time tests.

Acknowledgements

During a substantial portion of this work, J. Carley was affiliated with the UCAR Visiting Scientist Program. Initial development of the NAMRR system was supported by funding from the DOE for the Position of Offshore Wind Energy Resources project (see **G-P05**). Binbin Zhou is thanked for his help in setting up the grid2grid verification system.