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IMPROVED SUPER-OB RADAR RADIAL WIND PRECISION FOR THE NCEP DATA ASSIMILATION AND FORECAST SYSTEM

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1. INTRODUCTION

The spatial and temporal densities of WSR-88D raw radar radial wind represent a rich source of high resolution observations. A characteristic of these observations is the presence of a significant degree of redundant information present in the radar returns. The quality control of the returns is improving, for example, with dealiasing techniques involving the use of the VAD wind as well as the filtering of anomalous propagation (Liu et al. 2003). Large variances in radar returns, from bean widening, are factors decreasing the information content in radar radial wind. Our goal is to improve high resolution numerical weather prediction models in NCEP operations by using suitable schemes to assimilate and analyze the radar radial winds with other conventional and non-conventional observations. The first task is obtaining quality returns from the radars to a central site for model ingest.

Improvements in quality control are dependent on application of level 2 radar data directly from the WSR88D radars to a central site for NWP model processing. Such data has high precision, <1 m/s, 16 antenna tilts, and 1/4 km resolution from each WSR88D radar. At present, the radar data received for operational model ingest is filtered in space, from 1/4 km to 1 km, truncated set of radar tilts, from 16 to 4, and for radar radial wind, 15 levels of precision or greater than 5 m/s for each return. This data, received at a central site, is known as level 3 radar data.

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Another difference between the level 2 and level 3 data is the large difference in the amount of level 2 data produced by the WSR88D over that delivered as level 3 returns. For some time it has posed a bandwidth problem to deliver the data to a central site although modern technology should solve this problem. In addition, the large amount of observations impose a burden on an operational assimilation system since each datum is processed with repetitive interpolations from the analysis grid to its location and back again. This effort is carried out for each datum regardless of the information that can be attributed to it in the overall assimilation. The time and storage expended on mutually redundant data could be better spent on improving other aspects of an assimilation (Purser, et. al., (2000). Therefore, it is desirable to effect whatever data compression the ensemble of fresh observations allow while minimizing any degradation of the information content. The term for a surrogate datum which replaces several partially redundant actual data is a "super observation" or "super-ob". When level 2 radar radial wind is present at a central site the method described in Purser et al., (2000) can be applied but a cost effective super-ob can be obtained at each WSR88D radar until the level 2 data are available for model ingest.

Super-obs have been applied to operational analysis at the National Center for Environmental Prediction (NCEP) Operational assimilation system for subsets of the WSR-88D radar radial wind observations in the form of the NEXRAD Information Dissemination Service (NIDS), which we call level 3. However, the precision and information content of the NIDS radial wind can be improved if data at each radar site is directly utilized at the unfiltered resolution and with improved precision of the WSR-88D radar radial wind, to construct a super-ob and then deliver the results as a product to a central site.

We reported the new product for the Open RPG software system called the Radar Super-ob in Alpert et al, (2003), which takes the result of radar scans and averages data points within a prescribed time and spatial 3-dimensional volume before transmitting reports to a central collection of base data. The new product will be super-obs of radar radial winds and known here in as level 2.5. These will be compared with the level 3.0 returns as well as a No-radar radial wind case in analysis and forecast experiments using the NCEP Eta Data Assimilation System (EDAS) 3-dimensional variational analysis and meso-Eta forecast model in its operational configuration with resolution of 12 km.

2. DESCRIPTION

The full-resolution WSR-88D base radial wind data provides sufficient data amounts for statistically significant averaging. The super-ob product is programmed using the Open Systems RPG (Radar Product Generator) to control all aspects of the calculation at WSR-88D radar sites. The Open RPG is the system which operates between the Open Radar Data Acquisition (RDA) system and more sophisticated display devices, such as the National Weather Service's Advanced Weather Interactive Processing System (AWIPS). The Open RDA collects data from the WSR-88D radar and forwards base data products to the Open RPG. These base data products consist of reflectivity, radial wind, and spectrum width. The Open RPG creates the special purpose products from the base data and forwards them to other systems for display or for further processing. Super-ob is one of the newly enabled, enhanced products under the Open RPG. Adaptable parameters for super-ob are the Time window, Cell Range Size, Cell Azimuth Size, Maximum Range and Minimum Number of Points. The values of these parameters, which define the super-ob averaging, are shown in Table 1 and in Alpert et al (2003). The default settings indicate that at each elevation angle, a wedge shape volume of 6 azimuth degrees by 5 km along a radius, averaged over a time of 60 minutes define each super-ob cell. Each of the super-obs contain no less than 50 points and no cell would extend past 100 km, as the radar beam width becomes too wide and returns become less certain at larger distances from the radar. These adaptable parameter values are programmed through the Open System RPG (ORPG). The range of possible values will allow for the super-ob product to adjust to different analysis resolution requirements as they occur. All the WSR-88D installations will contribute super-ob data by this process to initialize the cycling analysis system, with identical settings. The data transmission precision of the super-ob (mean) radial wind is better than ±0.05 m/s or 32767 possible levels. This is an improvement over the current transmission of 15 levels of data transmission precision for winds which can span ±70 m/s. The standard deviation of the mean radial wind super-ob is transmitted at 15 levels of precision.

Table 1. Adaptable parameters for the Super-ob product

Parameter	Default	Range
Time Window	60 minutes	[5-90 min]
Cell Range Size	5 km	[1-10 km]
Cell Azimuth Size	6 degrees	[2-12 deg]
Maximum Range	100 km	[60-230km
Minimum Number of points required	50 unitless	20-200]

3. RESULTS

To test the impact of the level 2.5 super-ob, three experiments were performed with the NCEP 12 km, meso-Eta regional model. Each experiment included a separate analysis of the EDAS cycling 3-dimensional variational analysis system starting 12 hours before the initial condition time of 28OCT12Z, 2003, assimilating all conventional and non-conventional observations. A 3-h window of radar radial wind observations, centered about 12Z was used. Case I is the level 2.5 super-ob radar radial wind, Case II was run with the level 3 super-ob and Case III had no radar radial wind data present.

The returns from radar radial wind vary with the amount of precipitation. The minimum number of returns required to make a super-ob, as shown in Table 1, is 50. Even when the air is clear, super-obs can be created as the WSR88D is quite sensitive. This number of super-obs is increased with increased precipitation. Of course, convective regions can distort the returns and we hope to filter these by observing the standard deviation of the returns which is transmitted with each super-ob. An example of how radar radial wind standard deviation change with height and wind value is shown in Alpert et al.(2003). The mean sea level pressure map in Fig 1 shows low pressure in the central US extending to northeastern US. The 12 hr forecast is shown so we may indicate the areas that had precipitation where more returns give greater numbers of super-obs. The differences between Case I and Case II, the level 3 and level 2.5 super-ob, respectively, are shown with difference plots of the EDAS analyzed winds. The difference plots are made by subtracting the vector wind and magnitudes from the No-radar experiment (Case III) from the level 2.5 (Case I) or level 3 (Case II) experiments. Comparison between total fields do not show changes because radar radial wind differences are of small scales. For example, the MSLP differences between the level 2.5 (Case 1) and level 3 (Case II) are as much as 1.5 mb at a few grid points but mostly less than 1 mb, the largest differences along the trough extending from north central to the northeastern US (not shown).

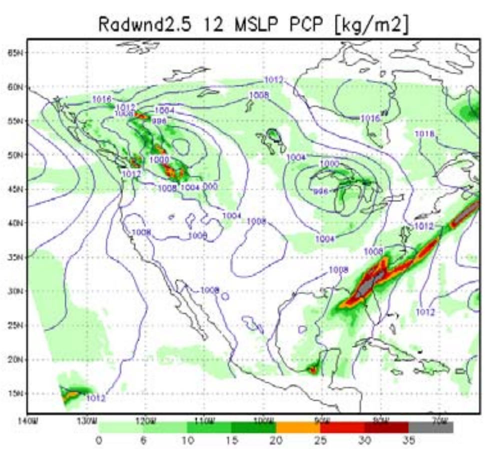

Fig 1. Eta 12-h forecast MSLP (hPa) and Accumulated precipitation rate verifying 29OCT 2003 00Z including level 2.5 super-ob (Case I).

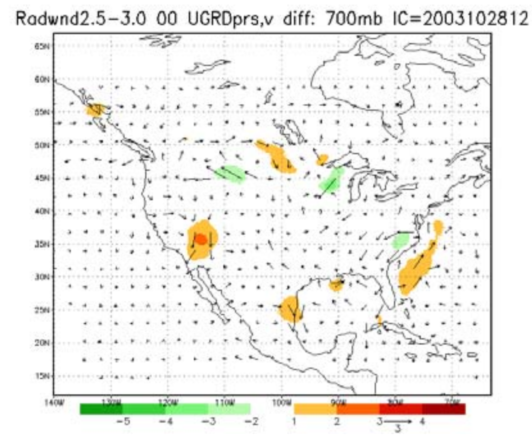

Fig 2. Difference in the analysis (00) of wind magnitude between the level 2.5 (Case I) and level 3 super-ob (Case 2) are shown in the color fill contours and the arrows show the vector difference of the wind fields at 700 hPa

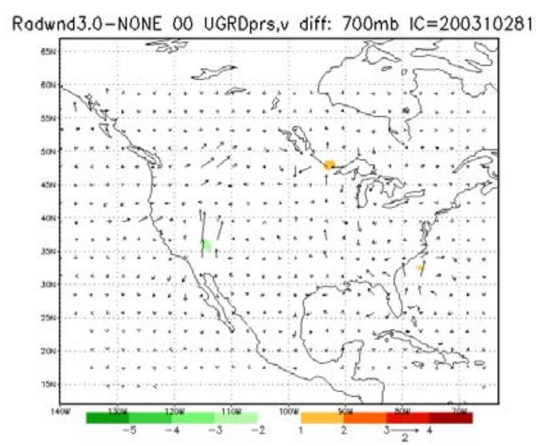

Fig 3. Difference in the analysis (00) of wind magnitude between the level 3 (Case 2) and No radial wind(Case 3) are shown in the color fill contours and the arrows show the vector difference of the wind fields at 700 hPa.

The 700 hPa wind differences between the level 2.5 (Case I) and the no-radial wind experiment (Case III) are shown for the EDAS analysis (00 forecast time) in Fig 2. The differences are of small scale, the larger differences, greater than 1 m/s, are located in areas along fronts (East Coast) or low pressure (along the Northern US). The wind vector differences are shown and are large in the same areas. There is not enough space to show the total wind fields which would indicate the direction of the total wind (See web page) but the difference vectors are sensitive to small differences between the wind field cases. The analysis wind difference between the level 3 super-ob (Case II) and No radial wind (Case III) is shown in Fig 3. In Fig. 3, the magnitude range is from -2.5 to 1.5 m/s compared to Fig 2 which shows a magnitude difference range of -4 to 1.5 m/s. Areas of larger magnitude and area extent are shown in Fig 2 while in Fig 3, smaller area and magnitude differences between the level 3 and no-radial winds. This indicates that the level 3 super-ob (Case II) were not "drawn" for as much in the analysis compared to the level 2.5 super-ob. This is confirmed in the difference plot of level 2.5 - no radial wind (not shown).

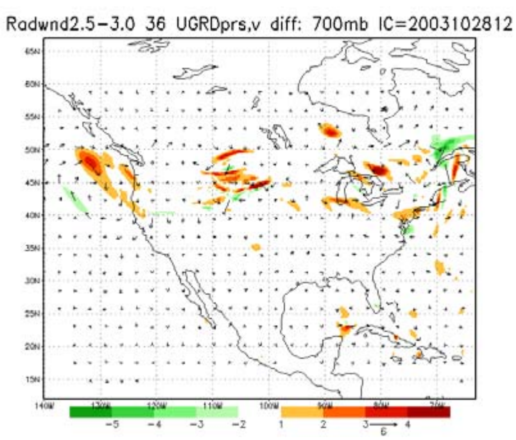

Fig 4. Difference in the Eta forecasts at 36-h of wind magnitude between the level 2.5 (Case I) and level 3 super-ob (Case 2) are shown in the color fill contours and the arrows show the vector difference of the wind fields at 700 hPa

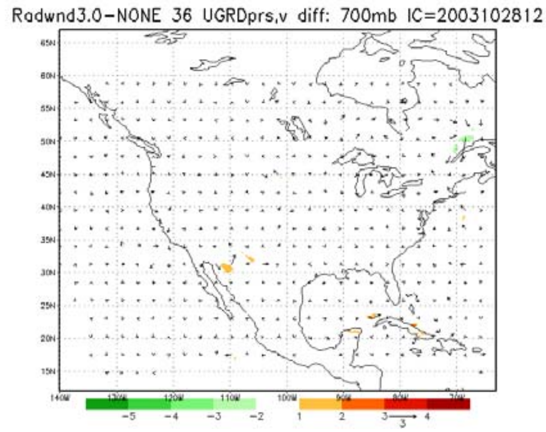

Fig 5. Difference in the Eta forecasts at 36-h of wind magnitude between the level 3 (Case 2) and No radial wind(Case 3) are shown in the color fill contours and the arrows show the vector difference of the wind fields at 700 hPa.

From each of the EDAS analysis, each experiments' initial condition was integrated with the meso-Eta model, at 12 km resolution, producing a 36-h forecast. Shown is the (36-h) forecasted wind differences between the level 2.5 super-ob and no-radar radial wind experiment (Case I - Case III) in Fig 4 and the (36-h) forecasted wind differences between the level 3 super-ob and no-radar radial wind (Case II - Case III) in Fig 5. We continue to use the 700 mb level as representative. The largest changes appear for the level 2.5 (Case 1 - Case 3) which had magnitude differences ranging from -7 to 5 m/s compared to the level 3 -(Case 2 - Case 3) ranging from -2.5 to 3.5. Thus, by 36-h forecast, the influence of the level 2.5 is double that of the level 3 super-ob. One also sees the differences appear as filament like regions in the level 2.5 super-ob while the level 3 differences appear more random. The main differences between the level 2.5 super-ob and the level 3 super-ob observations are the precision in the delivered radial wind values (0.05 m/s compared to 5 m/s, respectively) and the extra antenna tilt angles (16 compared to 4, respectively).

The EDAS analysis system, using

information about the error covariance and background error, creates statistics on how each set of observations have been used to create the analyzed variables. Statistics of how the radial wind super-ob observations project onto the analysis wind field are of interest even though this will vary from case to case.. The number of analysis wind increments that are smaller than the analyzed conventional wind from the level 2.5 super-ob is shown in Table 2. This can be thought of as the difference between the radial wind increment (observation minus guess) analyzed by the analysis system into vector winds compared to the conventional analyzed vector wind.

Table 2. For the Radar Radial Winds, the number of analysis wind increments (magnitude) greater than the conventional analyzed wind for all locations (3-hr):

Conventional Wind Magnitude	Number of Level 2.5 Super-ob
2 m/s	1055320
3 m/s	230193
4 m/s	158347
5 m/s	116907
6 m/s	81912
7 m/s	54285
8 m/s	33957
9 m/s	21209
10 m/s	13307
11 m/s	8724
12 m/s	5679
13 m/s	3864
14 m/s	3017
15 m/s	2816
16 m/s	2748
17 m/s	2546
18 m/s	2526
19 m/s	2137
20 m/s	1750
21 m/s	1394

Most of the level 2.5 super-ob are within 2 m/s of winds analyzed by the EDAS analysis (if there were not radial winds present). A 2 m/s wind difference over many observations can, of course, change vorticity and divergence significantly. There are a number of level 2.5 super-obs that have increment differences which are greater than 2 m/s but at some point these differences will be considered outside analysis error tolerances and the impact from such data will be reduced. If one compares this with the level 3 (Case 2) experiment (not shown) one finds that the number of winds with wind error peak at 3 m/s instead of the 2 m/s shown in Table 2.

The radar radial wind observations that are analyzed by the EDAS system, using past forecasts as a guess and knowledge of the Eta model forecast error, in terms of how wind vectors are made into radial winds, are found by the definition of radial wind (known as the forward model):

$$\mathbf{u}_{radial} = \mathbf{u} \sin\theta + \mathbf{v} \cos\theta$$

is a scaler, where θ is the angle between a line from the radar directed at 0 degrees azimuth (north) and the radial wind azimuth. There is only one direction where the regular wind will be identical to the radial wind and otherwise, can not uniquely compose radial winds into regular wind vectors. The EDAS analysis uses the information of how the regular winds are related to the radial winds to make an optimal decision of how the observed radial wind projects onto the regular winds. The difference between regular winds analyzed by the EDAS and the super-ob level 2.5 (Case 1) radial winds derived wind vector are measurements made by the analysis system. In this case the number of total radial wind observations for the level 2.5 (Case I) observations used in the analysis was 252,920 compared to level 3 (Case II) of 42,934.

4. SUMMARY AND FUTURE WORK

The level 2.5 radar radial wind super-ob product, composed at each WSR88D radar site, is received at NCEP and used in an EDAS analysis with the other remotely sensed and conventional observations, providing a high resolution wind component. In addition to experiments run with and without the presence of the radial winds from the full complement of WSR-88D radars, we compare with the level 3 radar feed and no radar data present for one initial condition period and for a 36-h meso-Eta forecast. The results show that the level 2.5 super-ob provides a larger number of suitable super-obs compared with the level 3. Even though this is for one case the large number of level 2.5 super-ob observation seems significant.

Refinements to the influence parameters in the EDAS analysis to better draw for the high resolution information content in the super-ob radar radial winds is under way. The experiments shown here in are meant to be a base line to gauge how the analysis system assimilates radar radial wind super-obs. Experiments to test for improved accuracy in high resolution forecasts are proceeding.

Figures shown and others that could not be shown in the paper are available at the web site:

http://wwwt.emc.ncep.noaa.gov/gmb/wd23ja/research/radar.

The pre-print figures shown in this report are located at:
http://wwwt.emc.ncep.noaa.gov/gmb/wd23ja/presentations.

4. REFERENCES

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