Extended Abstract, 25th Conference on Severe Local Storms
Amer. Meteorol. Soc., Denver, CO, Oct. 2010

LOW-LEVEL REALTIME WIND ANALYSIS OF CASA AND WSR-88D RADAR DATA USING ARPS 3DVAR

Jidong Gao[1,3], Keith Brewster[1], Ming Xue[1,2], Jerry. A. Brotzge[1], Kelvin W. Thomas[1], and Yunheng Wang[1]

[1]*Center for Analysis and Prediction of Storms, and* [2]*School of Meteorology, University of Oklahoma*
[3]*NOAA/National Severe Storm Laboratory, Norman, Oklahoma, 73072*

1. Introduction

The advantages of using Doppler weather radar to track and forecast mesoscale severe weather events are widely recognized. With the use of the Next Generation Radar (NEXRAD) Doppler network, meteorologists can provide better information to the public, ultimately saving lives and property, by remotely observing the internal structure of thunderstorms at high resolution. Despite the tremendous capabilities of NEXRAD, it is unable to view much of the lower atmosphere (< 3 km AGL) because of the Earth's curvature and the distance between radars. To completely understand and analyze the atmosphere, especially convective thunderstorms, the boundary-layer wind field is critical. To address this problem and provide improved surveillance of severe weather, a National Science Foundation Engineering Research Center, the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA), was established in 2003 to develop low-cost, high spatial density and dynamically adaptive networks of Doppler radars for sensing the lower atmosphere (McLaughlin et al. 2005; Brotzge et al. 2007). This project is a joint effort between the University of Massachusetts-Amherst, the University of Oklahoma, Colorado State University, and the University of Puerto Rico at Mayaguez. The first CASA test bed was deployed in Oklahoma and consists of four scanning polarimetric Doppler radars located on average 27 km apart with a radar range of 40 km. The network was designed to maximize dual-Doppler wind coverage and within certain parts of the network, triple Doppler wind coverage is also available (Fig 1).

Data from four CASA radars and two WSR-88D radars were collected in real-time during the spring of last several years. Using radial wind and reflectivity data from these CASA radars, along with NEXRAD, Oklahoma Mesonet, satellite and conventional data, some real-time data assimilation and forecast experiments were performed at 400m and 1-km grid resolution using the Advanced Regional Prediction System (ARPS; Xue et al. 2000, 2001) and ARPS Data Analysis System (ADAS; Brewster, 2003a, b) in 2007 and ARPS 3DVAR data assimilation system since 2008 (Gao et al. 1999, 2004, 2005; Hu et al. 2006; Ge and Gao 2007; Brewster et al. 2010; Schenkman et al. 2010). These were run in near-real time using a local cluster of Pentium4 Linux computers. Gao et al. (2008) demonstrated a potentially significant benefit of CASA radar to provide real-time low-level wind analysis, in addition to the WSR-88Ds. However, due to constraints associated with real-time analysis, problems remain associated with the quality control during the analysis. These problems have been addressed recently (Gao et al. 2009).

In this paper, we will discuss several cases in low-level wind analysis experiments during 2009. Our purpose is to continuously demonstrate the importance and usefulness of low-level wind analysis for CASA radar network. Our major effort for the next several years will be to provide reliable, real-time low-level wind analysis product to end-users for improving severe weather detection and prediction using data from the CASA network together with other data sources. Section 2 provides a brief description of experiments and future work is discussed in Section 3.

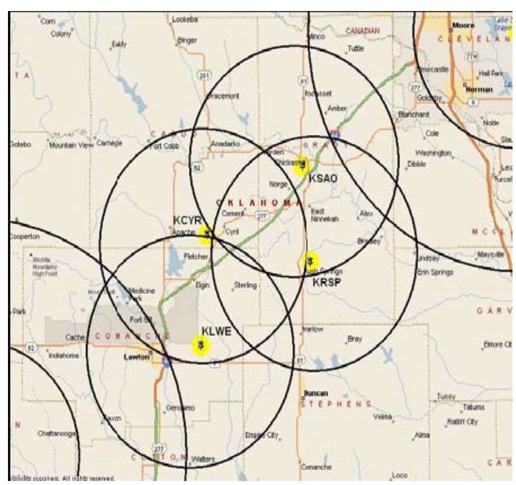

Fig. 1. The 4-node CASA test bed in Oklahoma –CASA radar network and analysis domain. (The analysis domain is about 140X140 km).

Corresponding author new address: Dr. Jidong Gao, NOAA/National Severe Storm Laboratory, NWC, 120 David. L. Boren Blvd., Norman, OK 73072. Jidong.gao@noaa.gov.

2. Experiments

To provide the CASA end users, especially the NWS forecasters, more useful wind products that can help improve decision making, we performed real time 400m resolution low-level wind analyses in the spring of 2009. These analyses integrated radial velocity data from CASA and NEXRAD radars as well as other sources of wind information. Based on the ARPS 3DVAR system, the analysis was able to take advantage of dual or even triple Doppler velocity coverage in the IP1 domain (Fig. 1). Compared to raw radial velocity data, these analyses are much easier to use and interpret by the end users, and are spatially and temporally much more continuous.

This major effort provided much improved wind products during spring 2009 because ARPS 3DVAR analysis system allows for the combination of CASA data with all available data sources, including WSR-88D and mesonet data. A significant upgrade in CASA radar data quality control also made to improve the quality of analyses (Gao et al. 2009). The wind analyses have been found very valuable by the forecasters at the Hazard Weather Testbed (HWT) and the products directly influenced the issuance of tornado warnings in at least one instance. HWT forecasters repeatedly pointed out that gridded wind analysis was much more intuitive to use.

As in 2008, the ARPS 3DVAR was run on a 160x160 km grid at 400 m grid spacing that encompasses the IP1 network and the surrounding counties. In the spring of 2009, the analysis grid in the vertical was upgraded to 10 physical model layers, representing a physical extent to 10 km AGL. Multiple processors on the OU OSCER supercomputer were used. The wind analyses were performed every 5 minutes and they included CASA, WSR-88D radar data, Oklahoma Mesonet and all other available observations, together with the operational NAM model analysis/forecast background. Compared to conventional dual-Doppler wind synthesis method, a variational system is able to produce a useful analysis, using all data available, even in regions where radial velocity data are not available.

The high spatial and temporal resolutions of the CASA radar data and the much improved low-level data coverage provide an unprecedented opportunity for producing detailed low-level wind analyses for real-time warning and prediction applications in spring of 2009. The following two examples especially received very favorable reviews from the end users. The first case occurred on 10 February 2009 when convective cells at the tail end of a squall line moved across the southern half of the CASA network (Figure 2). The formation of a small vortex can be identified easily in real-time analyses. This small vortex propagated along the squall line, and eventually produced a tornado near Edmond/Ok area. The squall line was passing the IP1 domain, and associated updrafts embedded along the line were very evident from our low-level analyses (not shown).

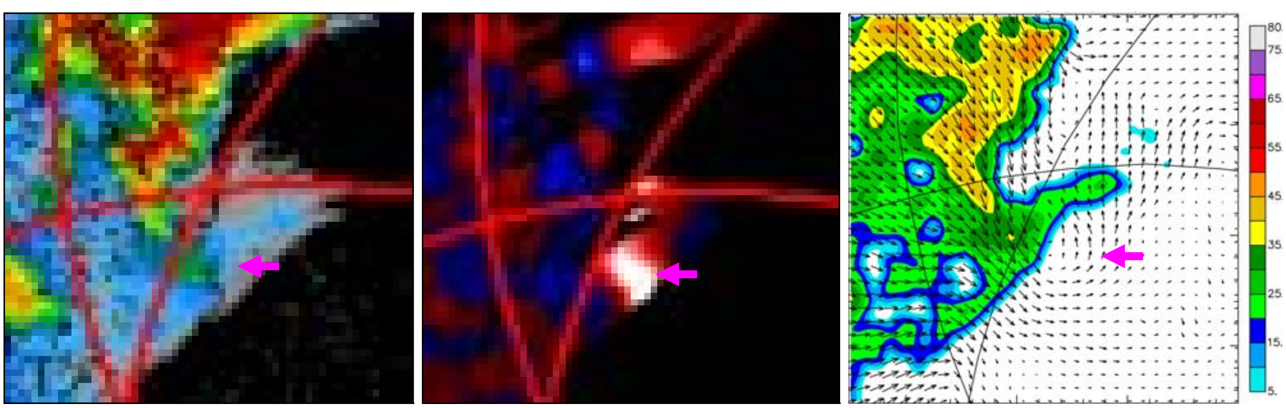

Figure 2. (left panel) Reflectivity observed by the CASA radars at 4:10 pm local daylight time, February 10, 2009, showing a thin 'finger' of radar echo having a weak 'hook' at its tip (pointed to by the arrow), (middle panel) velocity shear calculated from the radial velocity data from one of the CASA radars showing a heightened shear region (bright color shading), and (right panel) the low-level 3DVAR wind analysis at 200-m resolution showing a well-defined smaller-scale circulation centered on the strong-shear region. The reflectivity field is overlaid with the winds.

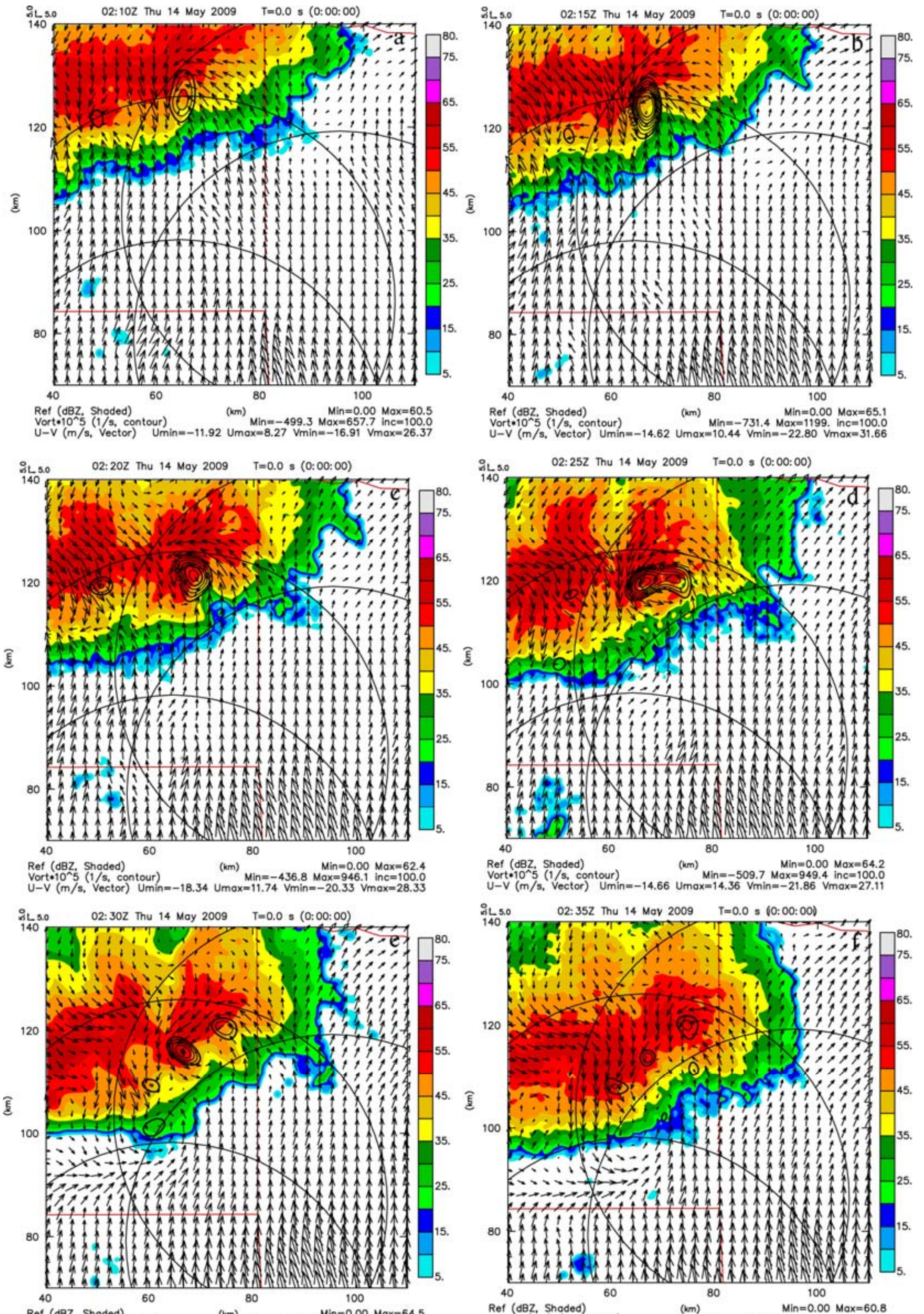

Figure 3. The total u-v wind vector, vertical vorticity (contours) and reflectivity (colored) at z=500m AGL from 0210 UTC -0235 UTC 14, May, 2009 for the Anadarko, Oklahoma tornadic thunderstorm case.

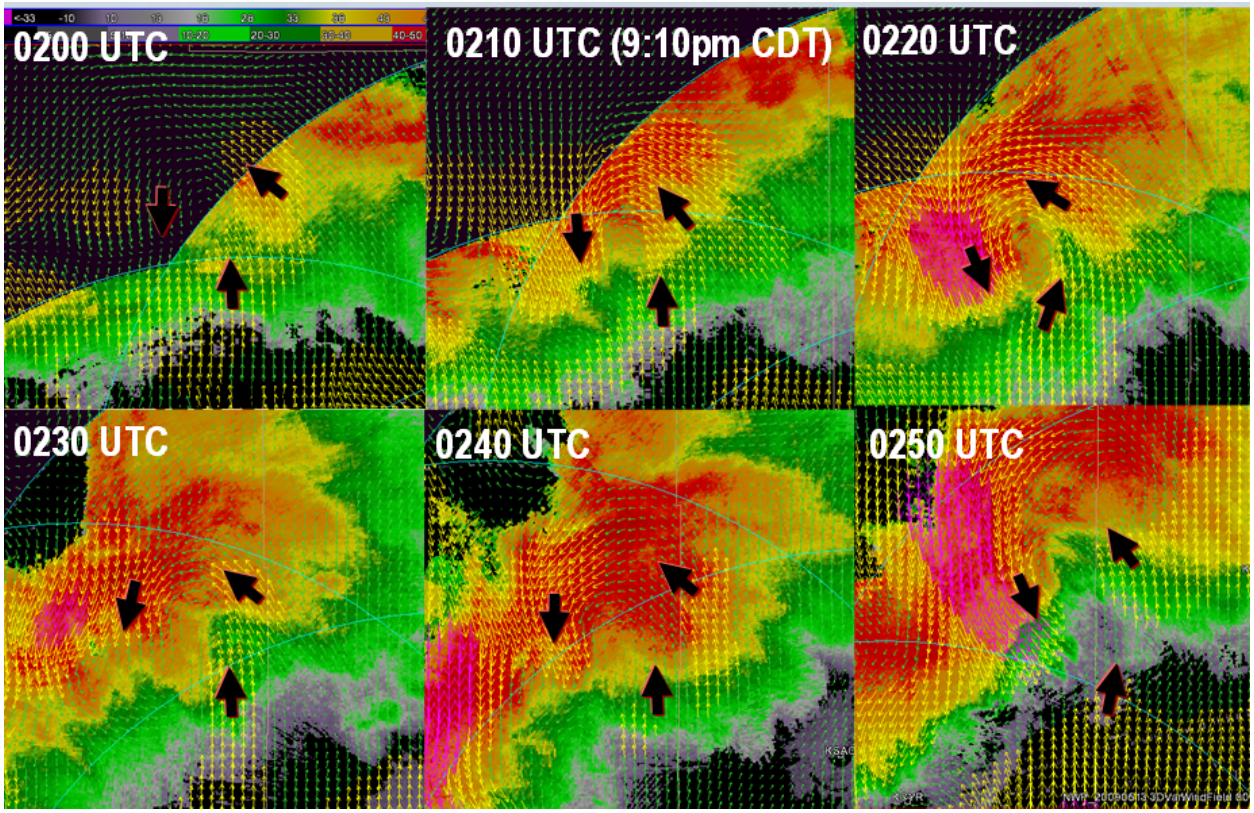

Figure 4. Real time display of low-level wind analyses for the Anadarko tornado case using WDSS-II.

On 14 May 2009, an EF-2 tornado hit Anadarko, OK. The strong damaging winds produced several million dollars worth of damage, and two-thirds of the town was without power for at least one day. Figure 3 shows the 25-minute evolution of low level wind fields during the time period of tornado touchdown. At 0210 UTC (*Figure 3a*), a weak vortex was observed and this alerted the forecasters that a possible strong vortex could develop.

Five minutes later, the vortex became much stronger (*Figure 3*b). This graphical information was posted to the CAPS realtime analysis/forecasting website, and was openly available to anyone, including the county emergency managers, and CASA students and scientists. At the HWT in Norman where the analysis products were evaluated by the end-user group together with the NWS forecasters, displays of the wind analysis within the WDSS-II system developed by National Severe Storms Laboratory were also available (*Figure 4*). The NWS forecasters issued a tornado warning immediately based on this and other information. Even after the circulation in the storm was weakened, very strong destructive winds were still observed in the area which produced major damage to this area (*Figure 4*, lower panels at 0240 and 0250 UTC). This case shows the value of the CASA radar network and its low level wind analysis products.

3. Summary and future work

In this paper, we report the progress of a real-time, low-level wind analysis enabled by CASA technology and several case studies. Our major effort in the next few years will be to provide a reliable and robust real-time low-level wind analysis product to end-users for improving the severe weather detection and prediction using data from the CASA network together with other data sources including the WSR-88D radar network.

In a related study, the analyzed winds from CASA radar network were fed into a storm-scale numerical weather prediction (NWP) model, through intermittent assimilation cycles, at frequencies comparable to that of volume scans. The impact of the wind observations on the subsequent forecast of convective storms has been tested (Brewster et al. 2010).

Our future work includes improving the timeliness, quality and vertical extent of the wind analyses. We will especially focus on further improving the efficiency of the 3DVAR program, and make the overall analysis program, including QC, more robust.

Acknowledgments. This work was supported by NSF grants EEC-0313747, ATM-0738370, ATM-0331756, ATM-0129892. The OSCER/University of Oklahoma was acknowledged for providing computational facility.

REFERENCES

Brewster, K. A., 2003a: Phase-correcting data assimilation and application to storm-scale numerical weather prediction. Part I: Method description and simulation testing. *Mon. Wea. Rev.*, **131**, 480-492.

Brewster, K. A., 2003b: Phase-correcting data assimilation and application to storm scale numerical weather prediction. Part II: Application to a Severe Storm Outbreak. *Mon. Wea. Rev.,* **131**, 493-507.

Brewster, K. A., K. W. Thomas, J. Brotzge, Y. Wang, D. Weber, and M. Xue, 2007: High resolution assimilation of CASA X-band and NEXRAD radar data for thunderstorm forecasting. 22 Conf. on weather analysis and forecasting and 18th conf. on numerical weather prediction, Park City, Utah, Amer. Meteor. Soc., CDROM.

Brewster, K. A., K. W. Thomas, J. Gao, J. Brotzge, M. Xue, and Y. Wang, 2010: A Nowcasting System Using Full Physics Numerical Weather Prediction Initialized with CASA and NEXRAD Radar Data. 25th Conference on Severe Local Storms, Denver, Amer. Meteor. Soc., Online publication.

Brotzge J., and K. Brewster, V. Chandrasekar, B. Philips, S. Hill, K. Hondl, B. Johnson, E. Lyons, D. McLaughlin, and D. Westbrook, 2007: CASA IP1: Network Operations and Initial Data. 23rd Conference on IIPS, San Antonio, Texas. Amer. Meteor. Soc., 8A.6.

McLaughlin, D.J., et al. 2005: Distributed Collaborative Adaptive Sensing (DCAS) for Improved Detection, Understanding, and Prediction of Atmospheric Hazards. Preprints, 9th Symp. Integrated Obs. Assim. Systems - Atmos. Oceans, Land Surface, Amer. Meteor. Soc., San Diego, CA. 12th Conference on IOAS-AOLS New Orleans, LA, Jan, 2008

Gao, J., M. Xue, A. Shapiro, and K. K. Droegemeier, 1999: A variational method for the analysis of three-dimensional wind fields from two Doppl radars. *Mon. Wea. Rev.*, 127, 2128-2142.

Gao, J., M. Xue, K. Brewster, and K. K. Droegemeier 2004: A three-dimensional variational data assimilation method with recursive filter for single-Doppler radar, *J. Atmos. Oceanic. Technol.* **21**, 457-469.

Gao, J., C. Nuttall, C. Gilreath, M. Xue, K. Brewster, and K. Droegemeier, 2005: Multiple Doppler wind analysis and assimilation via 3DVAR using simulated observations of the planned CASA network and WSR-88D radars, 11th conf. on mesoscale processes and 32nd Conference on Radar Meteorology, CDROM J1J.4.

Gao, J., K. Brewster, Y. Wang, K. W. Thomas, J. Brotzge, and M. Xue, 2008: High-resolution three-dimensional wind analysis of CASA IP-1 and WSR-88D radar data using the ARPS 3DVAR, *12th Conference on IOAS-AOLS*, AMS, New Orleans, LA (online).

Gao, J., J. A. Brotzge, Y. Wang, K. W. Thomas, K. Brewster, M. Xue, V. Chandrasekar, Y. Wang, B. D. Phillips, and M. Zink, 2009: High Temporal and Spatial Resolution 2D Wind Analysis of CASA and WSR-88D Radar Data using the ARPS 3DVAR. Preprint, 13th Conf. IOAS-AOLS, Phoenix, AZ., Amer. Meteor. Soc., Paper 6.4.

Ge, G., and J. Gao, 2007: Latest development of 3DVAR system for ARPS and its application to a tornadic supercell storm, 22nd Conference on Weather Analysis and Forecasting/18th Conference on Numerical Weather Prediction, on-line publication, 2B.6.

Hu, M., M. Xue, J. Gao, and K. Brewster, 2006: 3DVAR and cloud analysis with WSR-88D level-II data for the prediction of Fort Worth tornadic thunderstorms. Part II: Impact of radial velocity analysis via 3DVAR. *Mon. Wea. Rev*., **134**, 699–721.

Schenkman, A., M. Xue, A. Shapiro, K. Brewster, and **J. Gao**, 2010: Impact of radar data assimilation on the analysis and prediction of the 8-9 May 2007 Oklahoma tornadic mesoscale convective system - Mesoscale features on a 2 km grid. *Mon. Wea. Rev*. (accepted).

Stumpf, G., T. Smith, K. Manross, and D. Andra, Jr., 2008: The Experimental Warning Program 2008 Spring Experiment at the NOAA Hazardous Weather Testbed. 24th Conf. Severe Local Storms, 27-31 October., Savannah, GA.

Xue, M., K. K. Droegemeier, and V. Wong, 2000: The Advanced Regional Prediction System (ARPS) - A multiscale nonhydrostatic atmospheric simulation and prediction tool. Part I: Model dynamics and verification. *Meteor. Atmos. Physics,* **75**, 161-193.

Xue, M., K. K. Droegemeier, V. Wong, A. Shapiro, K. Brewster, F. Carr, D. Weber, Y. Liu, and D. Wang, 2001: The Advanced Regional Prediction System (ARPS) - A multiscale nonhydrostatic atmospheric simulation and prediction tool. Part II: Model physics and applications. *Meteor. Atmos. Phy.*, **76**, 143-165.