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PERFORMANCE OF RUC13 AND WRFRUC13 FORECASTS FOR THE AIRS-II 11 NOVEMBER 2003 ICING CASE

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1. INTRODUCTION AND MOTIVATION

Prediction of atmospheric conditions favorable for aircraft icing remains a formidable challenge for forecasters. Until recently, mainly semi-empirical methods have been employed, with the use of model guidance mainly restricted to examination of predicted relative humidity and temperature. Now, however, with increasing computer capacity available for operational numerical weather prediction, mixed-phase, bulk microphysics schemes are finding their way into operational forecast models. The Rapid Update Cycle (RUC) has been a pioneer in use of such a scheme by virtue of close working relationships between microphysics experts on the Winter Weather and Icing Product Development Teams (PDTs) and model developers on the Model Development and Enhancement PDT. These PDTs are part of the Aviation Weather Research Program, supported and administered by the Federal Aviation Administration. The RUC continues occupy the "situation awareness" niche amongst the suite of operational models at the National Centers for Environmental Prediction (NCEP), producing hourly analyses and hourly short-range (out to 9 or 12h) forecasts based on these analyses. The RUC is identified as the primary source of very short-range model forecast guidance for aviation over the conterminous US.

The RUC operational configuration at NCEP was upgraded on 28 June 2005. With this implementation, horizontal resolution is improved to 13km horizontal grid spacing (from 20km). There were also upgrades to all aspects of the RUC analysis, model and postprocessing. Because of the importance of RUC in providing guidance for aviation hazards, emphasis continues to be placed on improving the mixed-phase, bulk microphysics scheme that has been used in the model since 1998. The new RUC13 incorporates the Thompson *et al* (2004) scheme, which defines the zero-intercept for the inverse-exponential size distribution of snow particles as a function of temperature instead of mixing ratio. There is also a crude representation of drizzle by making the zero intercept for the inverse exponential size distribution of “rain drops” a function of rainwater mixing ratio, decreasing from 10^9 m^{-4} for rain mixing ratio ≤ 0.0001, to $2*10^7$ m^{-4} for rain mixing ratio ≥ 0.0003. [See Thompson *et al* (2004) for other features of this scheme.] The Thompson *et al* scheme tends to produce more supercooled liquid water, much less graupel, and somewhat more snow than earlier versions of bulk microphysics (based on Reisner *et al* 1998) used in the RUC.

Current plans call for the RUC to be replaced in late 2007 or 2008 by a new "Rapid Refresh" (henceforth, RR) system now under development at the Global Systems Division (GSD, formerly the Forecast Systems Laboratory, FSL) of the Earth System Research Laboratory (ESRL) of NOAA. The RR represents a notable departure from the present RUC, entailing 3 major changes. These are summarized below. A more complete discussion can be found in Benjamin *et al* (2006).

1) The present domain covering the coterminous US will be expanded to cover all

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of North America, including continental Alaska, as well as most of the Caribbean Sea.

2) The existing RUC 3dVAR will be replaced by the Gridpoint Statistical Interpolation (GSI) 3dVAR scheme under development by the NCEP (National Centers for Environmental Prediction of the National Weather Service) and the Joint Center for Satellite Data Assimilation. The GSD is modifying the GSI to better handle surface observations. Assimilation of hydrometeors derived from satellite, radar reflectivity (88D and perhaps TDWR) and METAR cloud and present weather observations, using procedures upgraded from the scheme currently used in the RUC13, will also be implemented.

3) The forecast model will be nonhydrostatic, either the WRF-NMM or WRF-ARW, in place of the current hydrostatic hybrid-vertical-coordinate RUC model. We are motivated to make this change because of the need to run a non-hydrostatic model at resolutions we expect to use on the RR domain by 2010. No non-hydrostatic model with a RUC-like hybrid isentropic vertical coordinate is sufficiently far along in development to likely be ready for operational application by that time. A strong further motivation toward WRF is to capitalize on the considerable community effort toward development and testing of the WRF model, including more advanced physics parameterizations.

Our present plan for physics in the RR WRF is to use an updated version of the NCAR Thompson microphysics, and, where possible, more advanced versions of other physics schemes now used in the current operational RUC13 (*e.g.*, the RUC land-surface scheme and the Grell-Devenyi ensemble convective scheme). A critical choice will be the parameterization of subgrid-scale vertical mixing (aka PBL and surface layer schemes). We do not plan to implement the present RUC version of the Burk-Thompson (1989) scheme in WRF. Extensive case-study, retrospective and real time testing will be required to arrive at the final physics configuration. Regardless of our other choices, we propose to use a subsequent version of the Thompson *et al* microphysics in the RR because of the RR's importance to aviation forecasting.

2. THE 11 NOVEMBER 2003 AIRS-II CASE

The 11 November 2003 AIRS-II icing case is one of the cases we will use for evaluation of WRF performance. The Second Alliance Icing Research Study (AIRS-II) was conducted in the Montreal-Ottawa area November 2003-February 2004, and featured aircraft and ground microphysical measurements.

The synoptic situation on 11 November featured a mid-level short-wave trough in the westerlies moving rapidly eastward across the Great Lakes and down the St. Lawrence Valley. In the strong southwest flow ahead of this feature there advanced an area of marked warm air advection (WAA) with abundant moisture. It appears that this WAA was associated with deep clouds exhibiting considerable ice and little supercooled liquid water (SLW) as it passed over the AIRS-II experimental area of southwestern QB. However, as the main thrust of the advection passed to the east above 700mb and clouds at upper levels diminished, the lower levels continued to experience weak WAA and ascent, and abundant SLW with supercooled large drops were observed near 2000 UTC in the vicinity of Mirabel QB.

We will subject both the present RUC13 (in its operational configuration) and the WRF-ARW to this case. Both models will run with identical versions of the Thompson microphysics. If we are able, we will also run a new version of the Thompson *et al* scheme that is more consistent with available data in assuming the mass of individual snow particles is proportional to the square of their diameter (Field and Heymsfield 2003) instead of the cube. We also may attempt to run the WRF-ARW with the Ferrier microphysics (Ferrier, 2005, personal communication) as well. Since the Ferrier microphysics is a simpler, more computationally efficient, but conceptually less complete, scheme than the NCAR microphysics, this is a potentially enlightening comparison.

All these runs will be initialized with initial conditions from a real-time 20km RUC forecast cycle archived at GSD (hence the term WRFRUC. Both 0000 and 1200 UTC 11 November 2003 initial times will be considered. The runs will use RUC boundary conditions from these same real-time runs. All runs will occur on the present RUC 13km grid over the RUC domain [shown in Fig. 1 inside the planned RR domain]. It will thus be necessary to interpolate the original 20km grids to 13km.

At the conference we will discuss these model forecasts. Emphasis of interpretation will be on the performance of the mixed-phase microphysics as it relates to supercooled liquid water production and icing. Comparisons will be made with observations where available, as well as between output from two sets of runs: the RUC and WRFRUC13 (ARW) using the Thompson *et al* microphysics, and, if possible, between the WRFRUC13 runs with the Ferrier and Thompson *et al* microphysics. For the first comparison, although the boundary layer and radiation physics differ between the RUC and WRFRUC, this does afford an opportunity to show how WRF-ARW and RUC compare at identical horizontal and similar vertical resolutions, and with identical initial and lateral boundary conditions. The second comparison will emphasize differences attributable to use of the Thompson *et al* versus the Ferrier microphysics schemes.

Of course, it is invalid to make generalized conclusions about model performance on the basis of one case. However, because microphysical observations for verifying model forecasts are difficult to obtain, we believe comparisons such as this are a necessary step in a thorough evaluation of performance.

We expect to eventually run this AIRS-II case using WRF-NMM as well. However, the Thompson *et al* microphysics is not yet adapted to run in the WRF-NMM, and it will likely not be possible to show any WRF-NMM results using the NCAR microphysics for this case at the conference.

3. ACKNOWLEDGEMENTS

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