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THE WEATHER RESEARCH AND FORECASTING MODEL: 2007 ANNUAL UPDATE

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1. INTRODUCTION

WRF Version 2.0 was released in May 2004, followed by Version 2.1 in August 2005, and Version 2.2 in December 2006. Along with Version 2.2 of the model, a new pre-processing system (WPS) was released at the same time.

Here we outline the current status of the WRF model. We also present the timeline for Version 3.0, which is planned to be the next major release.

2. VERSION 2.2

Several new features became available in Version 2.2. Here we will just outline the major ones.

Four-dimensional data assimilation by grid-nudging was added by Penn State (Stauffer et al., 2005 workshop). This provides a capability for keeping the model domain constrained by analyses over a period, and is activated with *grid_fdda* and other switches in the *fdda* section of the namelist.

Observational-nudging was added by NCAR/RAL (Liu et al. 2006 workshop), providing a capability of ingesting individual observations as the model runs, and is activated by *obs_nudge_opt* and other switches in the *fdda* namelist.

An urban canopy model was added as an option in the Noah LSM. Tewari et al. (2006) described this in the last workshop. The urban canopy model, designed for use with high-resolution grids, has a sophisticated treatment of sub-grid roads, walls, and roofs in the surface radiation and fluxes, and is activated by the *ucmcall* flag when the Noah LSM is selected.

The CAM3 radiation package from the NCAR CCSM climate model has been added. This includes accurate, and sophisticated shortwave and longwave schemes that also can handle a variety of aerosols for atmospheric chemistry applications, although the aerosol link has not been completed yet, and it just uses specified constant aerosol amounts.

A fully revised and rewritten microphysics package was introduced by Thompson et al. 2006 (workshop paper).

The NCEP physics was updated to the pre-operational suite for NAM, but the current operational suite is not yet in the released code. Among these changes, the Betts-Miller-Janjic cumulus scheme was made more active again, more similar to the 2.0 version. The Ferrier microphysics was adapted to work better with radiation for ARW, which previously did not distinguish the cloud and precipitation species from the Ferrier total condensate. This will mostly reduce the shortwave blocking effect of clouds with that scheme.

The Dudhia shortwave scheme has a new parameter (*swrad_scat*) to allow tuning of the clear-sky scattering effect that can account for aerosols to some extent.

A sixth-order filter (Knievel and Bryan, NCAR) was added as an option to selectively remove grid-scale noise. This is a numerical filter and can be used in conjunction with the physical

diffusion options already available. This is activated with *diff_6th_opt = 1*, and *diff_6th_factor* for its strength.

Positive-definite advection was added as an option for all WRF scalars (Skamarock, NCAR). This scheme is activated by the *pd_moist, pd_scalar, pd_chem,* and *pd_tke* logical switches. This scheme prevents the generation of negative values by the advection process, and is therefore beneficial for conservation because it means that the non-conservative *mp_zero_out* option is no longer required.

The upper absorbing layer was modified so that it could be used with real-data cases.

Several more minor changes were made to the model physics, and are outlined in the WRF Version 2 Updates Web page.

3. RECENT CHANGES IN 2.2

Since the release, several bug-fixes have been posted on the Known Problems Page, or will be posted soon. WRF Version 2.2 has presented problems in compilation on several platforms due to some code features in the new model. The pages outline some techniques to help compilation.

The observational nudging had several problems with reading data and map projections that have now been fixed. For grid-nudging, the FDDA could not be turned off without ramping.

The Thompson microphysics has had several changes to prevent occasional blow-ups.

Those described below are not yet posted. One is an improvement to the Noah LSM for evaporation over melting snow which was overestimated using the existing Penman technique (see also workshop poster paper by Dudhia et al. 2007).

The CAM radiation has a correction related to its use with the simple-ice WSM3 microphysics scheme.

We are also working on an improvement to one-way nesting when using *ndown* in complex terrain, where boundary terrain needs to be consistent with the parent domain. The *real* program's vertical interpolation is also being generalized and improved.

4. PRE- AND POST-PROCESSING

The WRF Preprocessing System (WPS) was released with Version 2.2. This was designed to take over the functionality of the Standard Initialization (which is also still supported), and has been developed with generality in mind, also building on the idea of modularity in the pre-processing stages. The WPS components and functions are

- GEOGRID: Sets up domain location information and interpolates geographic (static) data onto the model grid.
- UNGRIB: Converts Grib data to a simple *intermediate* format.
- METGRID: Interpolates intermediate data to the model grid, and combines it with geogrid output.

The new version of the *real.exe* program now does the vertical interpolation step when WPS (metgrid) data is input, but can also handle SI data that is already interpolated.

Since 2.2, WPS has been extended to work with the NMM dynamical core, and this is already available in a pre-release version available from the DTC.

For graphics capabilities, ARWpost was released with Version 2.2, replacing wrf2grads and wrf2vis5d. This converts from WRF and WPS output files

(Netcdf) to GrADS and Vis5D formats. RIP was also adapted to work with WPS outputs, and with idealized WRF output.

5. VERSION 3.0 PLANS

A timeline has been developed that will lead to a Version 3.0 release in March 2008. The primary new feature in that version is expected to be an initial global capability for ARW built on the Planetary WRF (PWRF) developed by Richardson, Toigo, et al. (2007, see workshop paper) at Cal Tech.

In addition to this, Version 3.0 will have extensive software framework changes (Michalakes et al. 2007 workshop paper), and an updated and extended WRF-Var system (Barker et al. 2007 workshop paper).

Physics development continues in several directions. For global WRF and regional climate applications, large-grid physics schemes from the CCSM physics suite are being ported to WRF. CAM radiation was the first example, and the next targets are the Morrison microphysics package and the Neale and Richter cumulus scheme that are currently being added to the CCSM. The CLM land model also is already partially coupled to WRF, and may be ready after the 3.0 release.

At the fine-grid end, the 3d TKE sub-grid scheme in WRF is being coupled to the fluxes produced by the surface physics with the aim of using a 3d LES-type closure instead of a one-dimensional PBL scheme when grid sizes approach the 100-meter range of scales. Early results with this scheme are already showing promise.

NCEP and NCAR are now finalizing a unified version of the Noah land-surface model. NCEP's current NAM operational physics is also going to be in the next release.

Other features to be available in Version 3.0 include a sea-ice update capability, similar to the SST update, an outgoing longwave radiation output, and accumulated surface and radiative fluxes for more accurate budgets, which will all be useful for regional climate studies. Also, an upper boundary condition will be available that applies Rayleigh damping on the vertical motion only. Testing has shown this to be a viable alternative to the upper absorbing layer for use in real-data deep-atmosphere cases. A capability for a variable timestep is also being introduced (e.g. Hutchinson 2007 workshop paper).

A digital filter initialization (DFI) is being developed to remove initial high-frequency noise for applications to short-range forecasting and data assimilation.

In the area of pre- and post-processing, Version 3.0 will include a version of RIP that can plot NMM outputs. NCL is being upgraded to directly support WRF outputs in the NCL download, instead of needing to also install a WRF_NCL add-on as is currently done.

Other physics development is continuing, and some may be ready for Version 3.0.

There is active research on new PBL schemes being presented at this workshop (Galperin et al. 2007, Gilliam et al. 2007), while Songyou Hong is modifying the YSU scheme's stable BL treatment, and is planning to provide a gravity-wave drag scheme for large-grid applications of WRF.

In the area of land-surface schemes, Y. Xue and R. Vasic (UCLA) are developing Simple SiB for WRF.

Work in the area of microphysics continues at several centers including CSU, Goddard, and NCAR. Future

schemes being considered include double-moment schemes and spectral-bin microphysics.

Work on Polar WRF includes improvements in the treatments of snow and sea ice being developed in a collaborative effort between NCAR and Ohio State.

6. ACKNOWLEDGMENTS

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