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THE WEATHER RESEARCH AND FORECASTING MODEL: 2008 ANNUAL UPDATE

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1. INTRODUCTION

WRF Version 3.0 was released in April 2008, and includes many new features and options, some of which are significant additions to the code, leading to the transition to Version 3.

The biggest enhancement was the introduction of a global domain capability for the ARW dynamical core. Here we outline this and other major new features of the WRF model. Changes to the pre- and post-processing, including WPS and graphics tools, will be described in a separate workshop paper (Duda et al, 2008).

2. VERSION 3.0

2.1 Global ARW

This new feature is described in more detail by Skamarock (2008 workshop paper). The global capability comes from the planetary WRF model developed at Cal Tech (Richardson et al., 2007 workshop). It uses a latitude-longitude grid that can be rotated to put the "poles" at other locations, and has polar filtering to keep the model stable with small grid sizes near the poles. This required a generalization of the map factors that impacts the dynamical core code. The global version requires no boundary file, being periodic in one direction, and having new polar conditions in the other. The WPS has been also modified to add the new projections. A new idealized case has been added to run the standard Held-Suarez test (*test/em_heldsuarez*) with the global model.

2.2 Digital Filter Initialization (DFI)

This new feature in ARW is described in more detail by Peckham et al. (2008 workshop). This capability is a merged version of separate efforts at NCAR and NOAA/ESRL. The digital filter is a time filter to remove noise from the initial conditions, and is of value in short-range forecasting or forecast cycling applications. Several filters and filtering window methods are available as options.

2.3 Dynamics additions

The dynamical part of the ARW code has two new upper boundary condition options. One is a rigid-lid option (*top_lid*) for idealized cases, which would replace the normal constant-pressure condition. The other (*damp_opt=3*) is an implicit implementation of Rayleigh damping on the vertical motion field, that has been found to be effective and simple to apply in real-data simulations (Klemp et al. 2008 workshop paper).

The ARW diffusion scheme has been modified to account for isotropic and anisotropic mixing (*mix_isotropic*). Isotropic mixing should be chosen in large-eddy type applications where the horizontal and vertical grids sizes are similar. The idealized test cases now include a Large Eddy Simulation (LES) (*test/em_les*) set-up as an example of using WRF with a 100-meter grid driven by specified surface heat fluxes. A further enhancement has been to allow the vertical diffusion scheme to directly receive surface fluxes from the physics schemes in WRF. This allows the replacement of the PBL schemes with explicit vertical diffusion, as would be desired for very fine grids (<~100 m) when the major eddies are resolved. This is the so-called LES PBL approach that can be activated by using surface-layer and surface physics, but turning off the PBL, and using 3D diffusion (*diff_opt=2*) with either the TKE or 3D Smagorinsky (*km_opt=2* or *3*) approach.

The ARW dynamical core has also had a variable time step approach added as described by Hutchinson (2007, workshop paper). This is a scheme that attempts to maximize the model time-step while it is running, which can lead to a reduction in a forecast's wall-clock time, and can be activated with the switch *use_adaptive_time_step*, together with other parameters to control the time-step behavior.

2.4 Physics additions

Version 3.0 includes a variety of new physics packages contributed by WRF community users or developed at NCAR.

The Goddard microphysics package, basically similar to the option in MM5 for many years, is now available in WRF as *mp_physics=7*. The scheme, provided by We-Kuo Tao and his team at NASA Goddard, has options to choose graupel or hail or simplified 2-class ice microphysics.

The new Morrison double-moment microphysics option (*mp_physics=10*), includes number concentrations for ice, rain, snow and graupel/hail, making a total of ten microphysical arrays.

Georg Grell of NOAA/ESRL has developed the Grell-3 cumulus parameterization for this release (*cu_physics=5*). This scheme shares the ensemble features of Grell-Devenyi, but also spreads subsidence to neighboring grid columns, making the scheme suitable for grid sizes in the 5-10 km range, where other schemes have scale separation issues (Grell, 2008 workshop).

Jon Pleim and the EPA group have added the ACM2 PBL (Gilliam et al., 2007 workshop) and the Pleim-Xiu 2-layer land-surface model (e.g. Pleim and Gilliam, 2008 workshop). These can be selected with *sf_sfclay_physics=7, sf_surface_physics=7,* and *bl_pbl_physics=7.*

For regional climate applications, the capability of specifying sea-ice changes and time-varying albedo are now added to the previously existing SST and vegetation fraction in the *wrflowinp* file. Also, for such applications it is often recommended to use a broader boundary zone with an exponential, rather than linear, relaxation function, so an optional exponential multiplier is now added and can be controlled by setting *spec_exp*.

For hurricane applications, an ocean mixed-layer parameterization was added (*olmcall*) to simulate the feedback of high winds on SST. Also, a new switch *isftcflx=1* can be used to change the formulation for wave drag to a Donelan-type fit to observations for high winds. This reduces frictional stress and is more appropriate for hurricane winds. In Version 3.0, this switch does not yet affect the heat and moisture flux formulations, but this may be changed in the next minor release, as there are formulations for the enthalpy flux over water that may also improve hurricane simulations. A minor related change was made to the convective velocity calculation for water points that would help fluxes to develop even in zero-wind situations.

A new idealized case (*em_seabreeze2d_x*) was added with the help of Joe Galewsky (UNM). This case has several physics options activated, namely the land surface, PBL, and radiation, to give an example of an idealized case that can run with more realistic physics than the other idealized options.

Time series outputting is now available at stations chosen via a *tslist* file, as described in *run/README.tslist*, and prints of model noise and other diagnostics (*diag_print*) are now also possible with code respectively from Mike Duda and Wei Wang.

2.5 Physics improvements

Changes have also been made to existing schemes. One that is an important enhancement is to the Dudhia shortwave scheme (*ra_sw_physics=1*), where Guenther Zaengl has added a topographic slope (*slope_rad*) effect to the surface shortwave flux, which accounts for the slope of the topography in direct solar heating. This is useful for fine-grid runs (probably less than 5 km). For even finer grids, there is a further shadowing effect on neighboring grid points (*topo_shading*).

The YSU PBL scheme has been modified by Songyou Hong (Hong et al., 2008 workshop) to improve its behavior under stable surface conditions. The modified scheme allows enhanced vertical mixing when sufficient wind is present, giving a more realistic mixing profile that may be important for the representation of night-time boundary layer profiles. This PBL option is also added to those available to the NMM dynamical core in this release.

The Noah land-surface scheme is now unified between the NCAR and NCEP versions. It also includes an improved treatment of snow emissivity that is now consistent with the radiation schemes, leading to better energy conservation in the surface longwave flux treatment over snow.

The Urban Canopy Model has had an anthropogenic heat source capability added in Version 3.

The WSM6 microphysics scheme now has a new way of treating snow and graupel fall speeds (Dudhia et al., 2008, workshop poster), using a combined weighted fall speed, to simulate the gradual transition of properties between snow and graupel rather than the discontinuous particle separation used in most existing bulk schemes.

The CAM radiation shortwave and longwave schemes are now separated and can be called in combination with other radiation schemes.

In the NCEP suite of physics, available to both dynamical cores, the Ferrier microphysics, and BMJ cumulus schemes have been upgraded to reflect changes in the operational code. For the Ferrier scheme, the main changes are designed to improve supercooled water amounts. The BMJ cumulus scheme had a variety of changes detailed on the WRF Version 3 Updates Page.

3. PLANNED ADDITIONS

As can be seen in this workshop, there is much ongoing development work that could potentially be released in future versions of WRF. The next major release will be Version 3.1, planned for March 2009. Before that there will be one or more minor bug-fix releases, including 3.0.1, planned for the near future to address many mostly minor issues fixed since the Version 3.0 release.

New features will not be publicly available until the Version 3.1 code is released.

The QNSE PBL scheme (Galperin et al., 2007, Sukoriansky et al., 2008 workshop papers) is aimed at improving the stable-regime behavior of TKE-based schemes, and this work is nearing completion of a first version. Other schemes are being developed by Angevine and Mauritsen (2008 workshop paper), and Pagowski of NOAA/ESRL.

There is an increasing use of WRF for finer scales. Mirocha et al. (2008 workshop) will present a new large-eddy scheme, and there is also ongoing work at Penn State on a higher-order turbulence scheme by Ramachandran and Wyngaard, and testing and improving large-eddy capabilities at Texas Tech (Basu).

Microphysics developments, particularly of double-moment schemes, continue on several fronts including Hong (YSU), Thompson (NCAR), and Fowler (CSU). In this workshop, another bulk scheme by Lin and Colle (2008), and a bin scheme by Xue et al. (2008) will be presented.

Plans also exist to port more of the CCSM climate-model physics into WRF as part of the ongoing research that drives WRF with CCSM output for future climate downscaling. The physics being considered include the CLM land model (which is partially completed), the new Neale-Richter cumulus scheme, and the microphysics scheme developed by Hugh Morrison for CAM that considers sub-grid variability effects. Consideration should also be given to the UW (Bretherton et al.) PBL scheme which is being developed for CAM.

With the increasing use of WRF ARW as a global model, gravity-wave drag, due to sub-grid orographic effects, has become a need, and work is already progressing with the help of Song-You Hong of adding such a scheme as an option in WRF.

A monotonic advection scheme is also being considered. This has the benefits of positive definite schemes, but also prevents overshooting in maxima and minima, which is useful for scalars, and may be important in WRF-Chem applications.

In the area of FDDA, the Penn State/NCAR collaborative effort is currently developing surface analysis nudging to go with the nudging techniques that became available in Version 2.2.

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