THE WEATHER RESEARCH AND FORECASTING MODEL: 2013 ANNUAL UPDATE

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1. INTRODUCTION

WRF Version 3.5 was released in April 2013, and includes several new features and options that have been added since the 3.4 release a year earlier. Additional changes related to bug-fixes and improvements for the existing schemes are listed fully on the Version 3.5 Updates page. Separate papers will describe updates to WRF-Chem and WRFDA.

2. VERSION 3.5

2.1 New options in V3.4.1

In Version 3.4.1, released in August 2012, an option was added for reflectivity outputs consistent with the microphysical schemes themselves, using their own size distributions to calculate the reflectivity. This option is activated by *do_radar_ref=1*. It works for many, but not all, of the microphysics schemes, Thompson, Morrison, Goddard, Lin, WSM5, WSM6, WDM5 and WDM6.

Pressure-level outputs were added as an option activated by *p_lev_diags=1* in the new *diags* section of the namelist where control is also given to which pressure levels to output. Standard met fields will be interpolated to these chosen pressure levels. These go into a separate output file. See examples.namelist for how to use this option.

2.2 New options in V3.5

a) CESM 1.0 microphysics (mp_physics = 11)

Microphysics from the CAM5 climate atmospheric model in CESM. This is based on Morrison and Gettelman (2008) and is located in *module_mp_cammgmp_driver.F.* This scheme produces its own cloud fraction for RRTMG radiation (a simplified macrophysics approach), and also can interact with the CAM MAM aerosol option in WRF-Chem.

b) CLM4 LSM (sf_surface_physics = 5)

The land component of CESM is the CLM4 land model (Lawrence et al., 2011), which is now added as a WRF option. Together with the above microphysics addition and previous additions of cumulus, shallow convection, and PBL schemes and RRTMG radiation, this completes the set of physics used in CESM atmosphere and land components as options in WRF.

c) Grell-Freitas cumulus parameterization (cu_physics = 3)

This is a new parameterization replacing the Grell-Devenyi scheme (now option 93) as option 3 (Grell and Freitas, 2013, to be published). The scheme is designed to become less active as the grid size reduces to cloud-resolving scales. Shallow convection can be used with this scheme by setting *ishallow=1.*

d) Grenier-Bretherton Mixing PBL scheme (bl_pbl_physics = 12)

A Mellor-Yamada TKE scheme designed for marine boundary layer applications, but also available for testing in other applications (Grenier and Bretherton, 2001).

e) GRIMS shallow convection (shcu_physics = 3)

This is part of the Yonsei University physics designed for addition to the YSU PBL. It uses an enhanced mixing approach modified from Tiedtke to represent shallow convection above the PBL (Hong et al., 2013, to be published).

f) PWP 3d simple ocean (sf_ocean_physics = 2).

Price et al. (1994) multi-layer 3d ocean model that handles ocean advection, but uses simple flat bathymetry. Can be run with 100 layers. Note that the old 1d ocean mixed layer is now option *sf_ocean_physics =1* instead of using *omlcall*.

g) UW topographic surface wind option (topo_wind = 2)

A second method from Mass and Ovens at University of Washington to improve surface wind biases using sub-grid variance to modify surface friction effect. Also works in YSU PBL only.

h) Climatological ozone for RRTMG radiation (o3input=2)

The global ozone climatology from CAM radiation as a function of month, pressure and latitude is added as an option for RRTMG. The default *o3input=0* is the old single-profile ozone. Option 1 is reserved for a future 3d prognostic or analysis ozone usage.

i) Aerosol climatology for RRTMG radiation (aer_opt = 1)

ECMWF (Tegen) aerosol climatology (month, lat, long, pressure) provided as input for RRTMG radiation (internal code already there). The old method *aer_opt=0* without aerosols is the default.

j) NSSL storm diagnostics output (nwp_diagnostics=1) and lightning diagnostic (lightning_option)

Additional output fields useful in severe-storm simulations. This gives maximum column or surface values of selected quantities between output times (column vertical velocity, helicity, reflectivity, surface wind, etc.).

A lightning diagnostic has been added that uses the microphysics reflectivity or deep-convection top for select cumulus parameterizations (GD, G3, GF). Several options exists and the output includes intra-cloud and cloud-ground strike counts.

2.3 Other new capabilities in V3.5

Greenhouse gas updating for climate runs is now made possible via a text file that gives annual values for CO_2, CH_4, N_2O for use in RRTMG, RRTM and CAM longwave radiation options. This is activated with compile option *#ifdef CLWRFGHG* otherwise the default constants are used for these gases. Text files provide several IPCC scenarios (A2, RCP6, etc.) and can be changed.

Trajectory parcel-following capability selected by *traj_opt=1*. This will track the positions of initialized parcels using the full model time-step resolution, making it more accurate than post-processed trajectories.

The time series option has been modified to also allow outputting of profiles at selected points.

Urban options (BEP, BEM) now have maps of 45 US cities with the new NUDAPT dataset, which allows their details to be better represented.

A new MODIS monthly vegetation fraction dataset is available with a 30” (~1 km) resolution.

EPA provided NLCD 2006 40-category data for the US that can work in slab, Noah and the PX LSMs.

Finally a major addition is the WRF-Hydro capability (see separate presentation by David Gochis). This is an interactive coupling to a hydrology model for streamflow computations using the land-surface run-off. The hydrology grid is typically 100 m and is sub-tiled in the WRF grid. There is a new top-level *hydro* directory in the WRF code.

2.4 Improvements and bug-fixes in versions 3.4.1 and 3.5

See the V3.4.1 and V3.5 Updates Web pages for a complete list.

In V3.4.1, the YSU PBL had a fix to the stable boundary layer that would reduce mixing in stable conditions. This is the only change that might have a noticeable impact in V3.4.1 versus V3.4.

In V3.5, the default base-state has been changed to include a 200 K stratosphere.

The old RRTM radiation CO_2 content was changed from 330 ppm to 379 ppm (consistent with RRTMG). CH_4 and N_2O were also given non-zero default values as in RRTMG.

For NSAS convection a significant bug-fix was made to allow shallow convection to activate.

The BouLac PBL scheme has had a countergradient option added. The MYNN PBL has had an option added to advect its TKE (QKE).

Morrison microphysics had a correction to reduce ice cloud in convective anvils.

For Noah, an alternative U. Arizona snow/vegetation treatment (*ua_phys*) was added. NoahMP has had several fixes since its first release in V3.4 that make the results better. Both Noah and NoahMP have had glacier physics separated from the land physics.

Polar physics changes from Ohio State included generalizations to allow initializing sea-ice depth and snow on sea ice.

3. PLANNED ADDITIONS

Development is ongoing for version 3.5.1 due out later in 2013, and next year's major release in 2014. Several things are being worked on that may make it into this or future releases.

For V3.5.1, the Thompson microphysics, and possibly some others will be passing their particle sizes for ice, snow and cloud to the RRTMG radiation scheme for more consistent coupling of the microphysics and radiation clouds. We are also working to add a connection between sub-grid convective cloud fractions and radiation, specifically between KF and RRTMG at first that may be extended to other cumulus schemes later (Alapaty et al., 2012).

In later development, MODIS Level 3 (1 degree) or ECMWF MACC AOD may be made available as options to initialize the model with an optical depth analysis for the RRTMG and Goddard shortwave radiation options.

A minor change will increase the accuracy of solar position using the 'equation of time' correction. This is an orbital effect that modifies sunrise/sunset time by up to 15 minutes through the year. Additionally we want to allow solar radiation to vary smoothly between radiation steps by accounting for the gradual zenith angle change, which would avoid the stepwise surface forcing currently seen in time series of surface fluxes.

The Deng (Penn State) shallow convection scheme is being added and designed to interact with radiation.

4. ACKNOWLEDGMENTS

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5. REFERENCES

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