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THE WEATHER RESEARCH AND FORECASTING MODEL: 2014 ANNUAL UPDATE

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1. INTRODUCTION

WRF Version 3.6 was released in April 2014, and includes several new features and options that have been added since the 3.5 release a year earlier. Additional changes related to bug-fixes and improvements for the existing schemes are listed fully on the Version 3.6 Updates page. Separate papers will describe updates to WRF-Chem and WRFDA.

2. VERSION 3.6

2.1 New options in V3.5.1

Version 3.5.1 was released in September 2013.

The Thompson microphysics particle sizes were coupled to the RRTMG radiation option as a new default mode of running these together (as done by Thompson and Eidhammer 2014 for their aerosol study). This entailed passing 3d effective radii for ice, snow and cloud droplets to the radiation scheme and using these instead of the previous internal assumptions about particle sizes in the radiation scheme. It is hoped that this capability can be extended to other microphysics schemes in the future by their filling in the new 3d effective radii arrays that are now ingested by the RRTMG radiation options.

Several improvements were made for solar radiation. The *swint_opt=1* option was added to allow surface downward solar radiation flux to vary smoothly, instead of stepwise, between radiation calls. This is achieved by using the new and previous step calculation with interpolation and extrapolation based on the valid cosine zenith angle for the current time-step. Smoothly varying fluxes also lead to smoothly varying skin temperature and land-surface fluxes. In addition the so-called “equation of time” correction has been applied to solar zenith angle calculations for RRTMG, new Goddard and Dudhia shortwave options. This is a simple correction for the seasonal variation of solar hour angle due to earth’s orbital eccentricity, and may affect sunrise/sunset times by 15-20 minutes in parts of the year.

Surface diffuse and direct downward solar components were added as diagnostics for all shortwave schemes (e.g., see Ruiz-Arias et al. 2013). RRTMG and new Goddard were modified to output these, while for other schemes an external approximation is made based on clearness index, the ratio of surface to top-of-atmosphere downward solar flux. The diffuse component (DIF) is the diffuse flux on a horizontal surface. The direct component outputs are direct normal irradiance (DNI) and direct horizontal irradiance (DIR), which are the components normal to the solar angle, and normal to a horizontal surface.

Another new option was a fog-settling scheme (*grav_settling*=2) for all PBL schemes. This allows fog deposition based on vegetation type (named as the FogDES scheme, Katata et al. 2011) in addition to gravitational settling of cloud droplets. Option 1 for settling alone was also extracted from MYNN and made general.

2.2 New options in V3.6

a) *HUJI Spectral Bin microphysics (mp_physics = 30,32)*

WRF's first spectral bin microphysics options (fast option and full option, Khain et al., 2010 and references therein). These have 33 mass bins for each particle category, each bin is double the mass of the previous, and therefore resolve the size distribution. The fast scheme has 4x33 bins for cloud/rain, ice/snow, graupel and aerosols, and the full scheme has 8x33 bins for the above but dividing ice into columns, plates and dendrites and adding hail. Note that the large number of extra advected arrays increases the cost and memory a lot over bulk microphysics schemes.

b) *Thompson microphysics coupled to climatological aerosols (mp_physics = 28)*

An enhancement to the Thompson microphysics option with global low-resolution monthly climatologies of water-friendly and ice-friendly aerosols and their emissions (Thompson and Eidhammer 2014). This allows the microphysics to be sensitive to typical local aerosol conditions such as pollutants, natural organic aerosols, dust and sea-salt. The scheme initializes with a climatological distribution, but also advects the aerosols and has surface sources.

c) *Kain-Fritsch cumulus parameterization coupled to radiation (cu_rad_feedback = 1)*

Previously this switch only applied to the Grell cumulus schemes, but now KF convective clouds are also seen by the radiation schemes through a representation in the cloud fraction (Alapaty et al. 2012). This helps to reduce solar biases in general.

d) *Cloud Fraction Method option (icloud = 1,2)*

Previously the Xu-Randall and simple cloud fraction options were tied to the selected radiation options. Now through extending the *icloud* switch functionality, this can be chosen. This also forces consistent cloud fractions between longwave and shortwave radiation. Option 1 is Xu-Randall, and option 2 is the simple 1/0 option. Option 0 still deactivates cloud-radiation interaction.

e) *Aerosol input option (aer_opt = 2)*

Option 1 was available before to use the Tegen global low-resolution monthly aerosol climatology dataset for RRTMG shortwave radiation. The new option 2 allows input of a 2d aerosol optical depth (AOD) and/or other properties from another source, such as analysis, or specification of aerosol properties via additional namelist parameters (Ruiz-Arias et al. 2014). This works for both the RRTMG and new Goddard shortwave schemes.

f) *CLM Lake model (sf_lake_physics = 1).*

A 10-layer 1-dimensional lake model (Subin et al. 2012) that includes freezing and can take lake bathymetry (from the FLake 30" global lake dataset) now available in WPS, or can use a fixed-depth option. Initialization can use diurnal-averaged skin temperatures and the WPS inland lake category to initialize lake-surface temperatures, and this changes to a fixed 277 K at deeper levels. This lake model can be used with any LSM option.

g) *Noah LSM sub-tiling (sf_surface_mosaic=1)*

Within a model grid square, this option can sub-divide the surface into several dominant land-uses (e.g. *mosaic_cat=3*). The sub-tiling loop in the Noah driver calls the Noah LSM for each tile and returns the weighted average fluxes and quantities to the driver.

h) Scalar and tracer mixing with PBL K coefficients (scalar_pblmix=1, tracer_pblmix=1)

Previously vertical mixing of scalars and tracers was only done when vertical diffusion was called (i.e. no PBL scheme chosen), and only selected scalars like cloud water and cloud ice and sometimes TKE were mixed in the PBL scheme. This was a limitation for tracers that would not be mixed with a PBL scheme, so this option now allows the K coefficient extracted from the PBL schemes (*exch_h*) to be used in the pbl_driver by a standalone vertical mixing subroutine (*diff4d*). The option is on by default for tracers, but off for scalars. For scalars, there are special fields that are not mixed with this option, such as precipitating microphysics species, and TKE.

2.3 Other new capabilities in V3.6

Moving nests can now use high-resolution elevation and land-use in the nest instead of just interpolated values.

A new 15” 20-category MODIS monthly vegetation fraction dataset is available.

Monthly leaf-area-index climatology is available at global 30” resolution (*rdlai2d=.true.).* This would replace the vegetation-fraction dependent seasonal LAI variation when selected.

Some additional AFWA diagnostics were made available as WRF outputs (more in V3.6.1).

2.4 Improvements and bug-fixes in versions 3.5.1 and 3.6

See the V3.5.1 and V3.6 Updates Web pages for a complete list.

Between V3.5 and V3.6, there were no major changes to the popular options, and WRF results are substantially the same.

In V3.6, the MM5 surface-layer scheme (*sf_sfclay_physics=1*) was replaces with the Jimenez et al. (2012) revisions to this scheme that only affect the results slightly, which was previously option 11. The old scheme has been moved to option 91, and will be phased out later.

The NSAS cumulus scheme had a grid-size dependent option added to improve scale-awareness (*nsas_dx_factor=1*)

Fractional sea ice was extended to work with the QNSE-EDMF PBL option.

NoahMP had numerous changes to improve its options that may affect its results between V3.5 and V3.6.

WRF-Hydro Version2.0 supports both Noah and NoahMP.

The purely horizontal diffusion (*diff_opt=2*) was made more stable for complex terrain when using *km_opt=4* making it a potential choice for real-data cases. Further enhances were prepared for V3.6.1 to improve the stability even more. This is expected to help in calm conditions in valleys, for example by preventing diffusion up slopes.

3. PLANNED ADDITIONS

Development is ongoing for version 3.6.1 due out later in 2014, and next year’s major release in 2015. Several things are being worked on that may make it into this or future releases.

The Deng (Penn State) shallow convection scheme is being added and designed to interact with radiation. Some work on MYNN in conjunction with GF shallow convection is also aimed at improving shallow-cloud radiative interactions.

Work continues on scale-aware convective parameterizations, including Grell-Freitas, Kain-Fritsch.

We hope to further improve the interactions between radiation and convective parameterizations and/or microphysics options.

Vertical grid refinement in nested domains is another new capability being developed.

Methods for coupling WRF to ocean models via a standard interface are being added as hooks in the model.

4. ACKNOWLEDGMENTS

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