WRF Version 3.1: New Features and Updates

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WRF releases

- Version 1.0 WRF was released December 2000
- Version 2.0 May 2004 (NMM added, EM nesting released)
- Version 2.1 August 2005 (EM becomes ARW)
- Version 2.2 December 2006 (WPS released)
- Version 3.0 released in April 2008 (global version)
- Version 3.1 released April 9th 2009
New Physics Options

• Boundary Layer
  – QNSE PBL (Quasi-Normal Scale Elimination, Galperin and Sukoriansky, $bl_{physics}=4$)
  – MYNN PBL (Level 2.5 and Level 3, Nakanishi and Niino, $bl_{physics}=5,6$)
  – BouLac PBL (Bougeault and Lacarrère, $bl_{physics}=8$)
QNSE PBL

- From Galperin and Sukoriansky
- Based on MYJ PBL code
- Designed for improvement in stably stratified conditions
- New theoretically based dependence of mixing on Richardson number in stable to neutral conditions
- Unstable regime more similar to MYJ
Nakanishi-Niino PBL

- Added by M. Pagowski (NOAA/ESRL)
- Two Mellor-Yamada type schemes
  - Level 2.5 predicts TKE
  - Level 3 predicts TKE, $\theta'_l^2, q'_w^2, \theta'_l q'_w$
BouLac PBL

- Bougeault and Lacarrère scheme
- Added by A. Martilli (CIEMAT, Spain)
- Designed for use with multi-layer urban model (BEP, see later)
- TKE prediction scheme (Level 2.5)
- Length-scale computations differ from other schemes
Physics

• Surface
  – MODIS landuse map option
  – Snow albedo improvement in Noah
  – Multi-layer Urban model (BEP) option (sf_urban_physics=2)
  – Monthly-veg-frac dependent z0, albedo, emissivity replaces summer/winter switch
  – LAI also made variable with land-use and time
  – See talk 1.7 by Tewari

• Sea-ice fraction (fractional_seaice=1)
MODIS Land-Use

- Newer than USGS 24-category (~2001 versus ~1993)
- 20 categories
- 30” global gridded data
- Percentage data at lower resolution
Building Environment Parameterization (BEP)

- New urban option from A. Martilli (Spain), S. Grossman-Clarke (Arizona State U)
- Multi-layer building fraction represented
- Can be used with BouLac PBL and MYJ PBL
- Handles heat fluxes at multiple levels
- Wall, roof, road energy budgets
Noah LSM Snow Albedo

- Livneh scheme from F. Chen (NCAR)
- Snow albedo varies with age (darker with time)
- New formulation agrees with observed snow albedo variation
Noah LSM Seasonal Variation

- Old method used summer/winter values of albedo, emissivity and roughness length from LANDUSE.TBL switching quickly in April and October.
- New method uses monthly vegetation fraction to scale these properties gradually with day of year and defines the max/min in VEGPARM.TBL.
- Additionally leaf-area index (LAI) is made dependent on land-use and veg frac.
Sea-Ice Fraction

- From Kevin Manning (NCAR) and Ohio State U (Polar Physics developers)
- Sub-grid water and ice surfaces accounted for for SFCLAY and MYJSFC surface-layer options
- Ice fraction of surface uses standard LSM treatment
- Water fraction uses standard surface layer treatment
- So far tested for Noah LSM, but may be used with other LSMs
New Physics Options

• Radiation
  – RRTMG longwave and shortwave (from AER, Inc., 
    ra_lw_physics=4, ra_sw_physics=4)

• Microphysics
  – New Thompson (double-moment rain added, 
    mp_physics=8) - old scheme becomes 98
  – WDM5 and WDM6 (double-moment rain and cloud 
    and CCN added to WSM5 and WSM6, 
    mp_physics=14,16)
RRTMG Radiation Schemes

• Rapid Radiative Transfer Model for GCMs (RRTMG) from M. Iacono (AER, Inc.)
• Efficient new version of RRTM
• Shortwave scheme also available
• Deals with sub-grid clouds using Monte Carlo Independent Column Column Approximation (McICA)
• Will be used by ECMWF and CCSM models in the future
New Thompson Microphysics

- From G. Thompson (NCAR)
- Adds double-moment rain to double-moment ice in older version
- Updates several processes especially drizzle
- Older scheme still available as Thompson07 option
WDM5 and WDM6

• Added by K.-S. Lim and S.-Y. Hong (YSU)
• Double-moment warm-rain processes added to WSM5 and WSM6
• Predicts CCN, cloud-droplet concentration, and rain-drop concentration
• Talk 5B.6 by K.-S. Lim
Regional Climate Options

- Water skin-temperature diurnal cycle prediction (Zeng and Beljaars, \textit{sst\_skin}=1)
- Deep-soil temperature update option (\textit{tmn\_update}=1)
- CO2 variation with year in CAM radiation
- No-leap-year option (for CCSM coupling \textit{-DNO\_LEAP\_CALENDAR})
- Bucket rainfall and flux accumulations for accuracy over long simulations (\textit{bucket\_mm, bucket\_J})
Other new options

- Monotonic advection (e.g. moist_adv_opt=2)
- Spectral grid-nudging (Miguez Macho, grid_fdda=2)
- Surface analysis nudging (Penn State, grid_sfdda=1)
- Gravity-wave drag (NMM and ARW, gwd_opt=1,2)
- Base-state improvement (iso_temp)
Monotonic Advection

- Talk 1.2 by Bill Skamarock
- Option to improve hydrometeor, chemical, and scalar advection properties
- moist/chem/scalar_adv_opt=0,1,2 replaces pd_moist/chem/scalar in namelist
Spectral Grid-Nudging

- Added by G. Miguez-Macho (Spain)
- Allows grid-nudging of only wavenumbers smaller than selected values in x and y grid directions (only larger scales are nudged)
- Uses same FFT capabilities as polar filter
- Nudges u, v, theta and height fields
- Preserves fine-scale model details
- Makes model less sensitive to position of lateral boundaries than un-nudged runs
Spectral nudging

- Model variables
- Observations (reanalysis)
- Davies nudging

\[
\frac{dQ}{dt} = L(Q) - K(x, y) \cdot (Q - Q_o)
\]

Davies nudging

Model variables
- Model operator
- Relaxation coefficient

\[
\sum_{|n| \leq N} \sum_{|m| \leq M} \frac{dQ_{mn}}{dt} \cdot e^{ik_{m,x}} \cdot e^{ik_{n,y}} = L(Q) - \sum_{|n| \leq N} \sum_{|m| \leq M} K_{mn} \cdot (Q_{mn} - Q_{o_mn}) \cdot e^{ik_{m,x}} \cdot e^{ik_{n,y}}
\]

Spectral nudging

- \(K_{mn}\) (spectral nudging coefficient) may depend on height
- To nudge longwaves, make it nonzero ONLY for small \(m\) and \(n\)

From G. Miguez Macho
50 km grid

500 mb Kinetic energy spectra

Control (no nudging)

Spectral nudging

Conventional nudging

Due to higher resolution, the model generates small scales not present at t=0

The model generates small scale structure as in the control

No more structure than in driving fields (reanalysis)

From G. Miguez Macho
More energy in wave # > 7 (λ < 1000 km)

Same energy in waves 0-7 (λ > 1000 km)

Spectral nudging keeps the small scale structure

Nudging scales > 2000 km only
No nudging near surface

From G. Miguez Macho
Surface Analysis Nudging

• Added by A.-J. Deng, D. Stauffer (Penn State U)
• Can use high-resolution (in space and time) surface analyses to nudge boundary-layer fields
• Can be used with existing grid-nudging for upper-air analyses
• See talk 1.9 by A.-J. Deng
Gravity Wave Drag

• From S.-Y. Hong and H.-Y. Shin (YSU)
• Useful for low-resolution and global simulations
• To represent sub-grid orographic effects on vertical momentum flux
• Improves jet-stream winds and general circulation
• Recommended for medium-range, seasonal, and regional climate runs with \( dx > 10 \text{ km} \) and high mountains in domain
• Poster P2B.1 by H.-Y. Shin
An overview of the GWDO scheme

\[
\frac{\partial u}{\partial t} = -\frac{1}{\rho} \frac{\partial \tau_x}{\partial z}
\]

< Kim and Arakawa 1995>
The zonal mean zonal wind tendency due to the GWDO \((10^{-6} \text{ m s}^{-2})\)

- A very large mid-latitude lower stratospheric drag (Alpert et al., 1988)
- A substantial amount of wave breaking in the lower troposphere

From Hailey Shin
The DJF zonal wind speed
Base-State Improvement

- Real-data simulations use a base state with $T_0$ linearly decreasing with log pressure.
- The default lapse rate cannot be used when model top is above about 5 hPa where $T_0$ goes to 0 Kelvin.
- Version 3.1 adds an option for a minimum ($T_{iso}$ isothermal layer).
Single-Column WRF

• From J. Hacker (NCAR)
• Can use single column with specified advective forcing
• Idealized example in test/em_scm_xy directory
• See talk 5B.3
Pre- and Post-Processing

- Geogrid adapted for new gravity-wave-drag and MODIS inputs
- Tropical-cyclone bogussing program (vortex replacement method)
- Obsgrid can write observation-nudging and surface analysis nudging files for WRF
- New versions of NCL, VAPOR and IDV graphics and MET verification software (see Friday instructional sessions)
Conclusion

- Version 3.1 available for download
- Many new options including 4 PBL schemes and 3 microphysics schemes
- Many regional climate and large-scale physics enhancements
- Small-scale application also has new urban option
- See abstract for further details and plans