The Weather Research and Forecasting Model: 2019 Annual Update

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WRF Community Model Releases

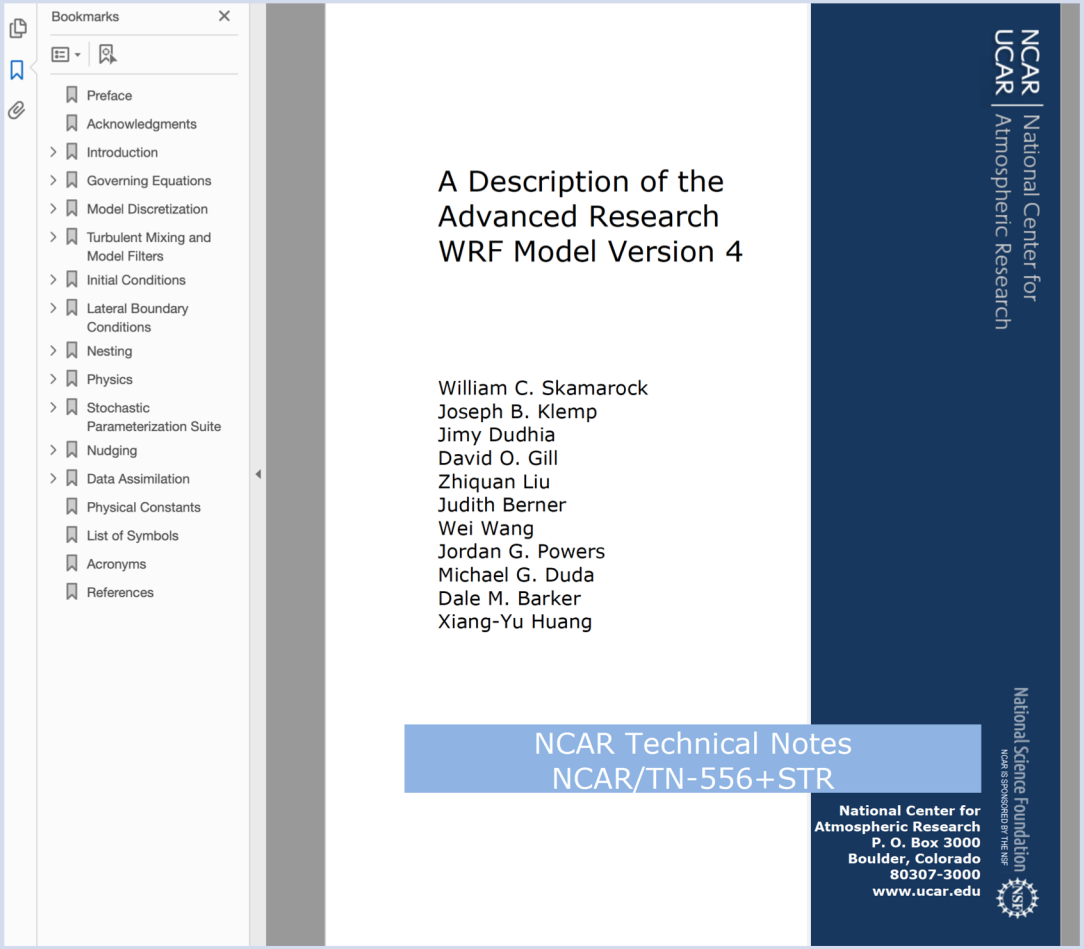
- Version 1.0: WRF was first released December 2000
- Version 2.0: May 2004
- Version 3.0: April 2008
- Version 4.0: June 2018 (add hybrid vertical coordinate)
  - Version 4.0.1: October 2018
  - Version 4.0.2: November 2018
  - Version 4.0.3: December 2018
- Version 4.1: April 2019
  - Version 4.1.1: June 2019

Outline

- Recap of new features in V4.0
- Bug-fix releases since V4.0
- New in V4.1

Updated Tech Note for V4

- Published March 2019
- 11 Chapters
- 145 pages
- online active pdf
- Doc/Pub tab on ARW Users Page

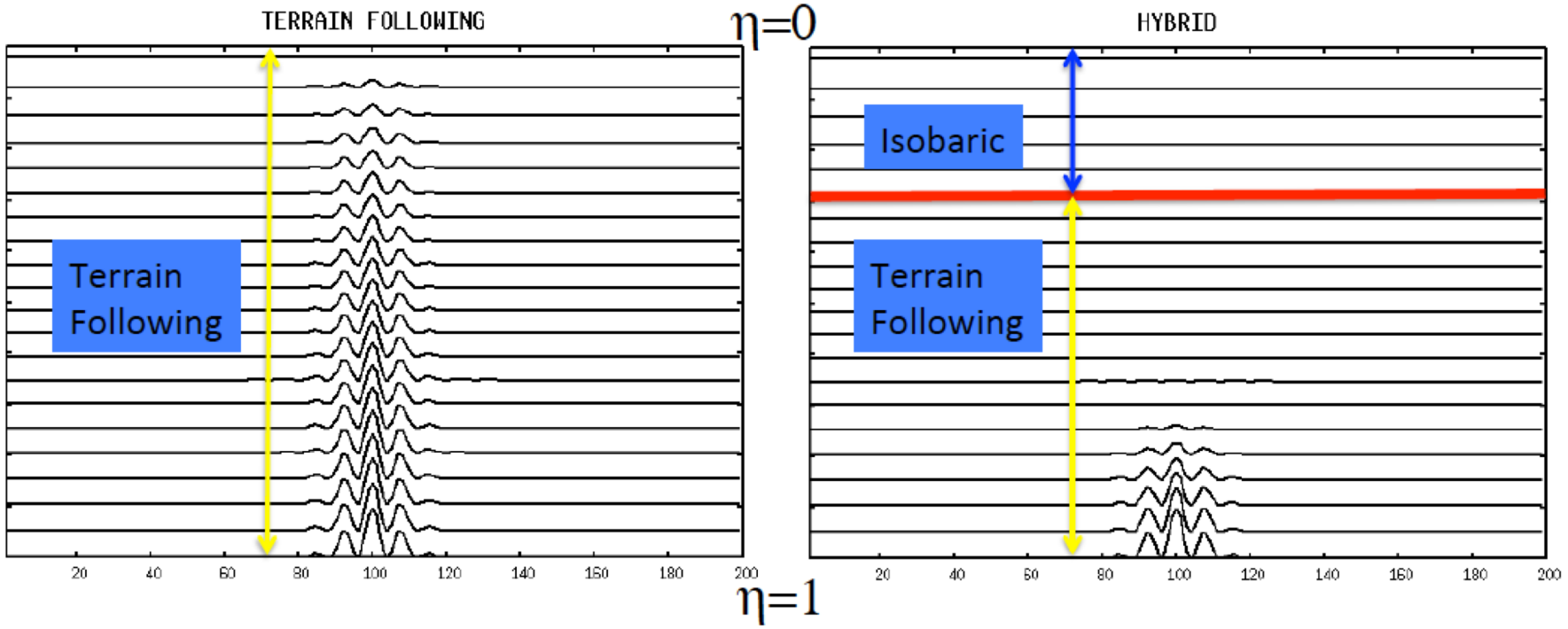


Recap of New Items in V4.0

- Hybrid coordinate integrated into code
  - Became default
  - Old coordinate is an option
- θ_m (moist theta) replaced θ as prognostic variable
  - outputs retain *T* as theta-300 for backward compatibility
- New method of automatically setting vertical levels in *real.exe* via stretching factors
- Idealized cases mostly combined into a single *module_initialize_ideal.F*

Hybrid Vertical Coordinate

- New hybrid vertical coordinate option in V3.9
- Isobaric at top means less noise in upper-air output over mountains



Recap of Updated Physics in V4.0

- Predicted Particle Property (P3) microphysics
  - Introduce a 2nd free category option (*mp_physics=52*)
- Thompson-Eidhammer Aerosol Aware microphysics
  - Dust emission added (*dust_emis=1*)
  - Surface aerosol emission modified
- Multi-Scale Kain-Fritsch cumulus scheme (from NCSU/EPA)
  - Prescribed climatological aerosol capability added along with a specialized aerosol version of Morrison microphysics (*mp_physics=40*)
- Gravity Wave Drag generalized for rotated projections

Recap of New Physics in V4.0

KIAPS (Korea) contributions

- RRTMG-K: a version of RRTMG that combines MCICA calculations in longwave and shortwave and reduces computational cost (*ra_lw_physics=14, ra_sw_physics=14*)
- KSAS: a scale-aware version of NSAS (replacement for *cu_physics=14*)
  - Note this needs *shcu_physics=4* to activate NSAS shallow convection because it is a deep-only scheme
- WDM6 (*mp_physics=16*) now distinguishes autoconversion rates over land and water

Physics Suites Introduced in V4

- Suite is defined by microphysics, cumulus, radiation, land-surface, surface-layer and PBL schemes
- Two initial suites available
  - *CONUS* (Thompson mp, Tiedtke cu , RRTMG, MYJ PBL and surface layer, Noah LSM)
    - Based on physics used in NCAR ensemble forecasts
  - *Tropical* (WSM6 mp, new Tiedtke cu, RRTMG, YSU PBL, MM5 surface layer, Noah LSM)
    - Based on physics used in MPAS for global TC forecasts where it is known as the '*mesoscale-reference*' suite
    - Now officially released with V4.1

Bug-fix Release 4.0.1

- October 2018
- Fixes to problems introduced in V4.0
  - minor issue with vertical staggering in small steps
  - initial pressure computation double-counted moist theta effect – problem dies out quickly after initialization
- Bug-fixes in physics
  - Thompson microphysics, NoahMP LSM
- Also DA and WRF-Chem fixes

More details on gitHub releases page

Bug-fix Release 4.0.2

- November 2018
- Fixes to problems introduced in V4.0
  - Initial output T field on nests was zero (only affects outputs not results)
- Bug-fixes in physics
  - Morrison 2-moment microphysics, Grell 3d cumulus, RUC and Noah LSMs
- Also DA and WRF-Chem

More details on gitHub releases page

Bug-fix Release 4.0.3

- December 2018
- Fixes to problems introduced in V4.0
  - Important fix for LES application with theta_m related to surface moisture flux
- Bug-fixes in physics
  - Morrison 2-moment microphysics, Grell 3d cumulus, RUC and Noah LSMs
- Also DA and ndown and FDDA obs-nudging

More details on gitHub releases page

New in Version 4.1

- April 2019
- Microphysics
  - ISHMAEL (Anders Jensen, NCAR) – ice particle shape prediction scheme (*mp_physics=55*)
  - WSM7 and WDM7 (KIAPS, Korea) – adds hail category to WSM6 and WDM6 (*mp_physics=24, 26*)
  - Goddard 4-ice (Tao et al., NASA Goddard) – separate hail category, replaces 3-ice scheme (*mp_physics=7*)
- Shallow Convection
  - Deng shallow scheme (AJ Deng, IBM, formerly Penn State) – part of WRF-Solar, mass-flux scheme, cloud fraction and liquid content, deep scheme included but not very active so recommend use with deep scheme at lower resolutions (*shcu_physics=5*) – more on this at releases page

More details on gitHub releases page

New in Version 4.1

- Radiation
  - Goddard radiation (shortwave and longwave) updated (Matsui et al. NASA Goddard) – interacts with particle sizes from microphysics, clear-sky radiation improvement, efficiency improvement (*ra_sw_physics=5, ra_lw_physics=5*)

More details on gitHub releases page

Jensen et al. ISHMAEL Microphysics

- Jensen, Harrington, Morrison and Milbrandt (2017, JAS)
- Ice-Spheroids Habit Model with Aspect-Ratio Evolution (ISHMAEL) using Active-Habit (AHAB) approach

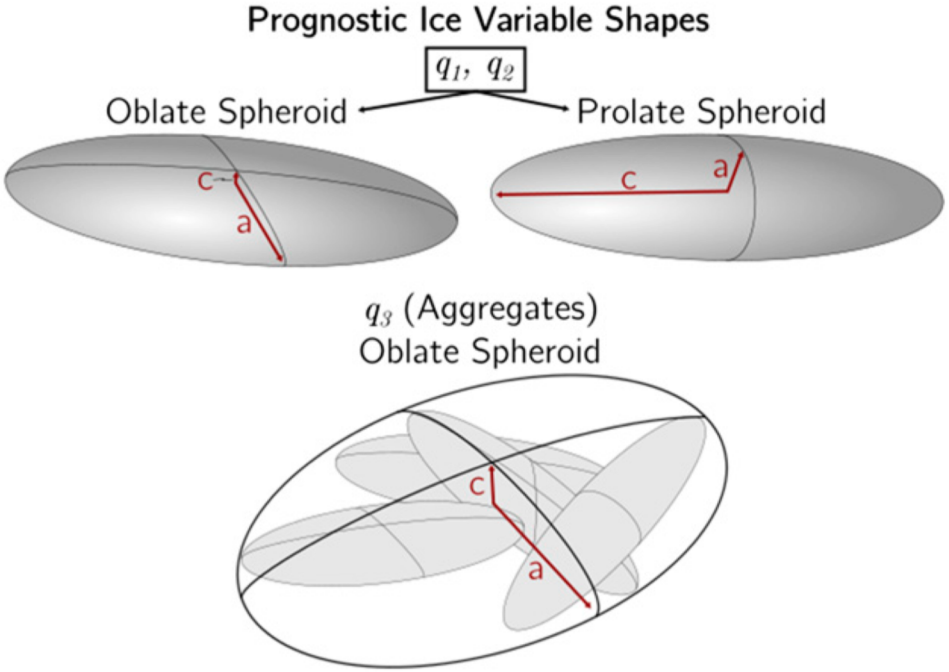
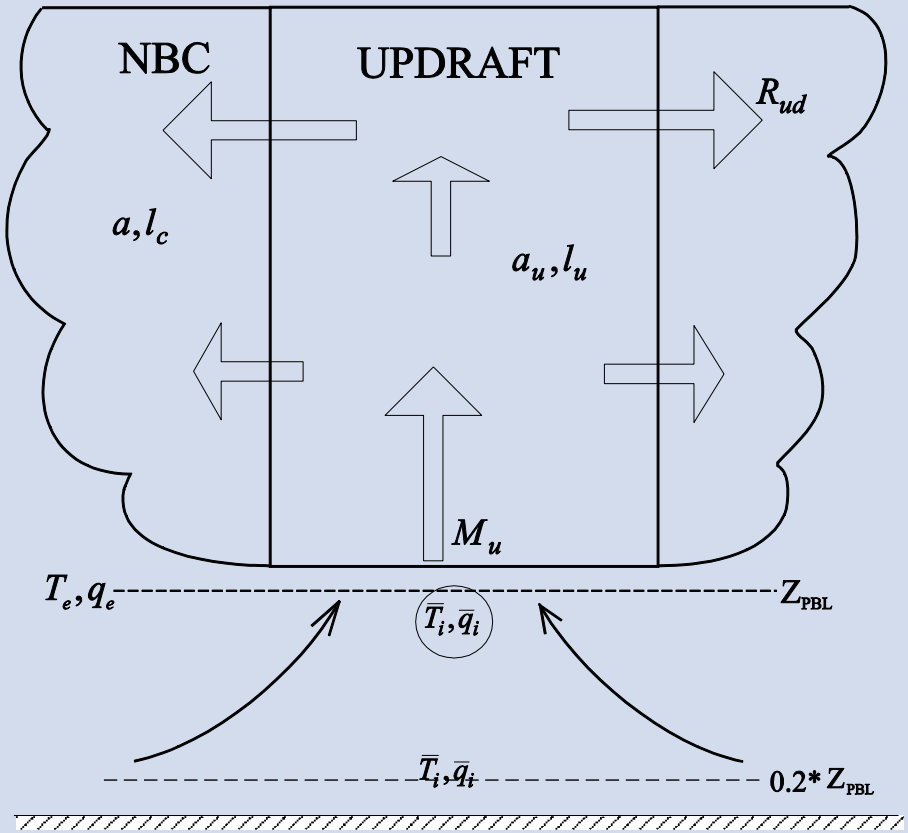


FIG. 1. A schematic of the ice species used in ISHMAEL. When $\delta_{dep} \leq 1 (\delta_{dep} > 1)$ ice nucleates as q_1 (q_2). These two species can evolve to be oblate or prolate spheroids. Note that aggregates are assumed to be oblate spheroids.

PSU-Deng SCP Schematic

Combined Shallow and Deep Convection Parameterization

(Deng et al. 2003a, 2003b, JAS; Deng et al. 2013, 2014)



- **Triggering Function**:
  - Parcel T´, Q´
  - Cloud initiation includes resolved scale lifting and TKE representing sub-grid scale
- **Cloud Model**: Kain-Fritsch (KF) entraining/detraining cloud model to define updraft
- **Closure Assumption**: Amount of total cloud-base mass flux is determined with a hybrid of TKE and CAPE, depending on the cloud depth.
- **Prognostic Cloud Scheme** for cloud fraction (**a**) and subgrid cloud water ($\mathbf{l_c}$) for neutrally-buoyant clouds (NBC)

a: neutrally-buoyant cloud (NBC) fraction,
$\mathbf{l_u}$: cloud water content in the updraft and,
$\mathbf{R_{ud}}$: updraft detrainment rate

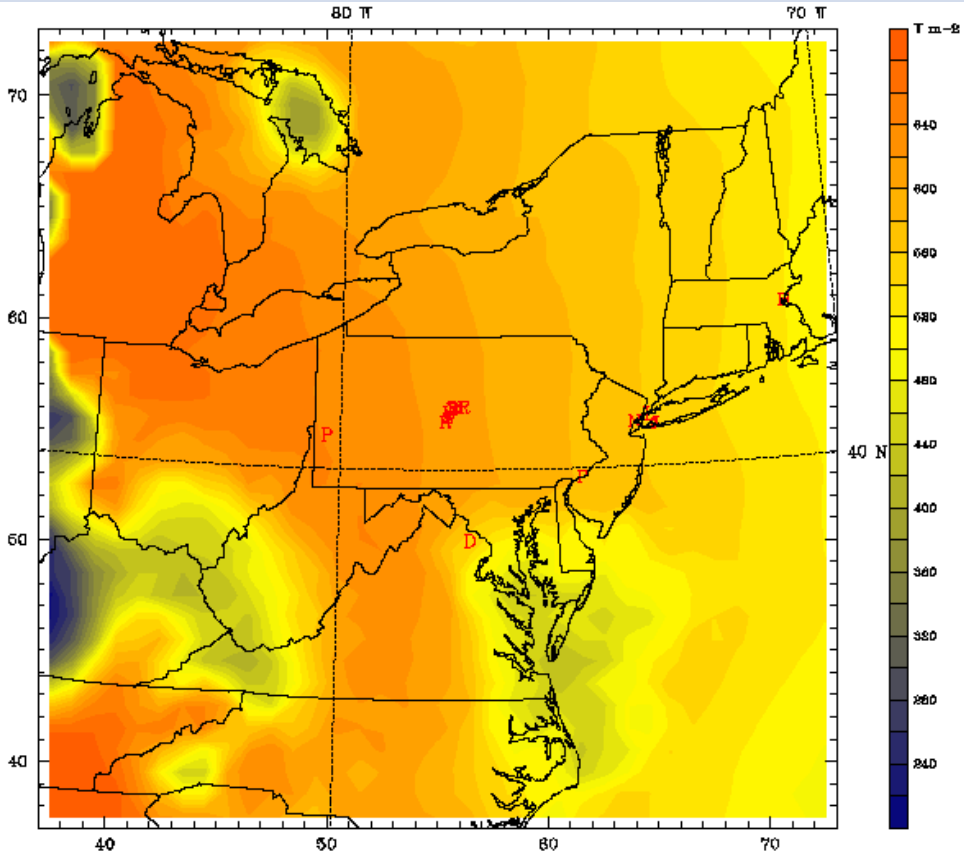
$\mathbf{l_c}$: NBC cloud water content,
$\mathbf{a_u}$: updraft fraction
$\mathbf{Z_{PBL}}$: depth of the PBL.

SW Flux Reaching the Ground

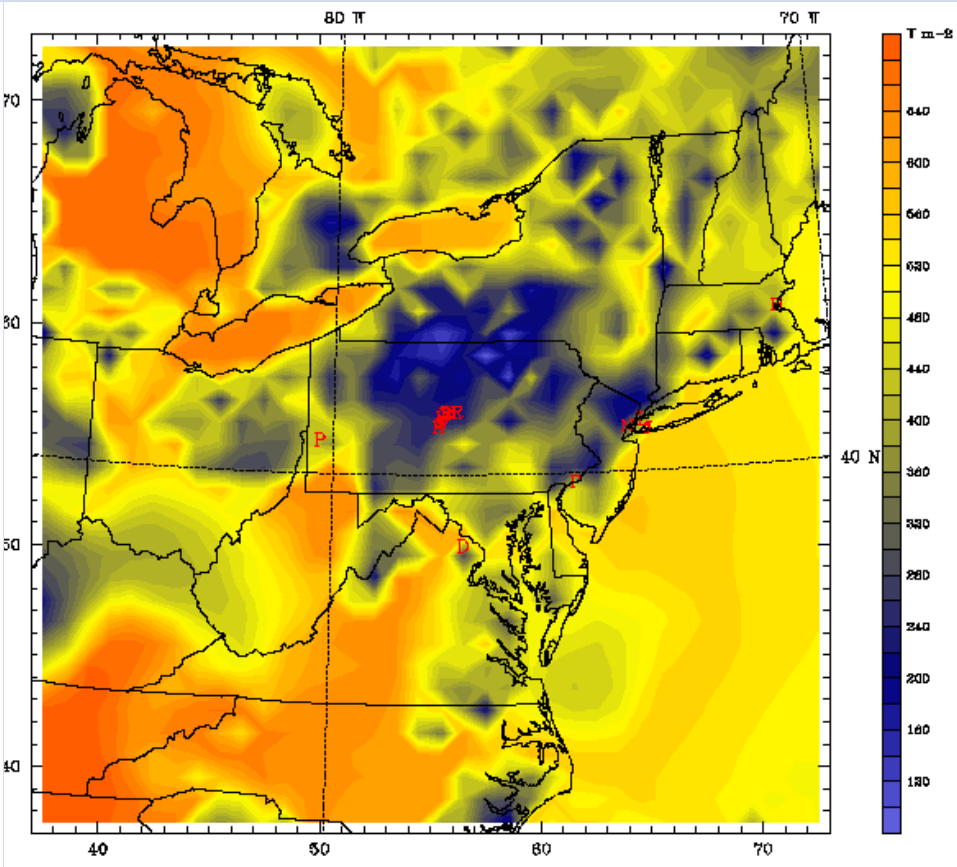
AJ Deng 2014 WRF-Solar Workshop

at 9 h (21 UTC, 30 July 2013)

NoShCu



ShCu



Improvements in Version 4.1

- Urban Models in Noah and NoahMP LSMs
  - significant memory usage efficiency improvement (Barlage, NCAR)
  - added capabilities in BEM urban model
- Pleim-Xiu LSM
  - allows time-varying vegetation fraction for seasonal runs (*px_modis_veg=1*)
- MYNN PBL
  - multiple improvements (see releases page for details) including internal mixing option for scalars
- Thompson microphysics
  - add number concentration initialization if microphysical species in analysis
- Cloud fraction
  - *icloud=3* option further modified to improve surface solar flux

More details on gitHub releases page

Improvements in Version 4.1

- Traditional Fields Output
  - capability expanded to include new diagnostics like RH, PW, precip totals with *diag_nwp2=1* switch
  - Note that Traditional Fields is a capability to output full fields instead of perturbations and base values separately in auxhist stream 1 (*h1*)
- Time Series
  - allow location to be specified by *i,j* instead of lat/long
  - vertical velocity and pressure now in profile outputs

More details on gitHub releases page

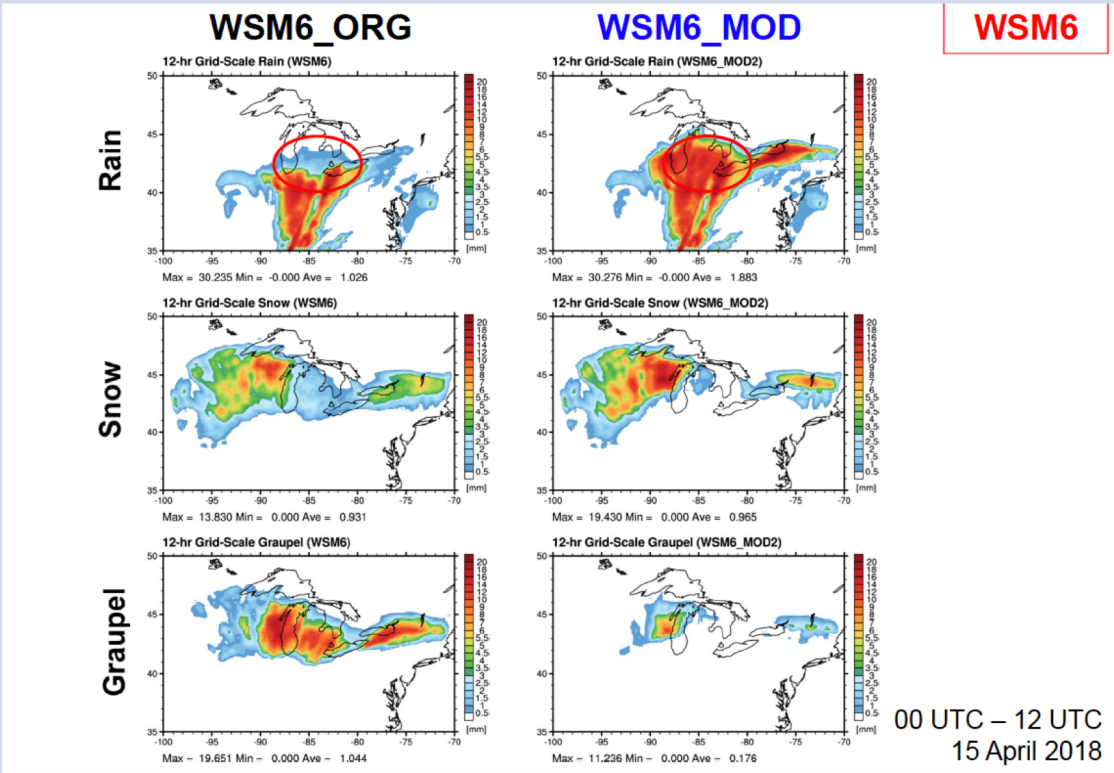
Bug-fixes in Version 4.1

- Ozone
  - Monthly ozone climatology for *o3input=2* (current default) in RRTMG shortwave was off by a month with too low values for Dec-Jan – affects stratosphere in long runs with high tops
- Microphysics
  - WSM5, WSM6, WDM6 fixed to allow more freezing rain (IBM report)
  - P3 add snow to RAINNC and RAINNCV (used also for LSM)
- Diagnostics
  - since V4.0 some diagnostics were not adjusted to keep using dry theta instead of new default theta_m – this is now fixed (details on releases page)
- Real-data initialization
  - if microphysics species are provided, vertical interpolation is now linear to maintain positive values

More details on gitHub releases page

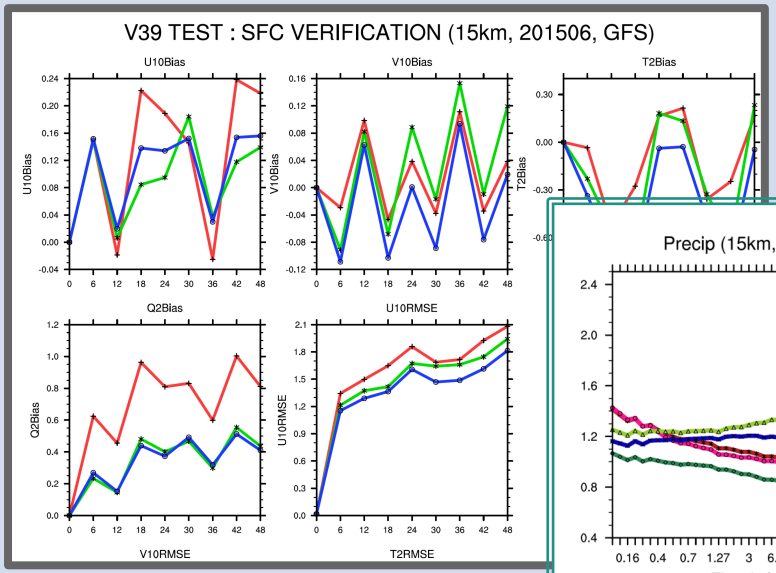
WSM6/WDM6 Freezing Rain Issue

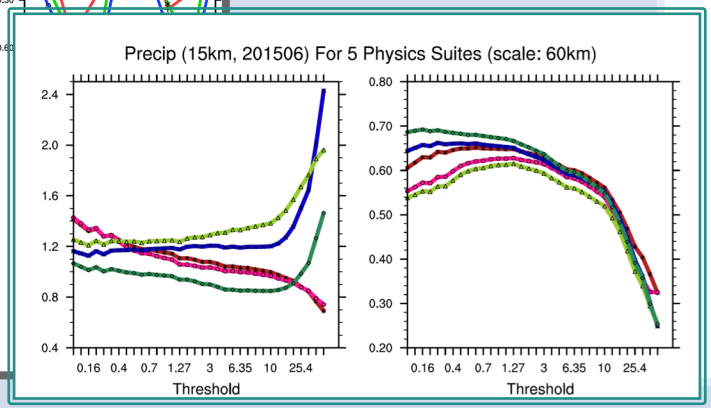
- Brett Wilt (IBM) reported lack of freezing rain in WSM6 and WDM6 versus obs
- Rain freezes too easily in presence of ice
- Fix is to limit freezing efficiency by ratio of ice to liquid

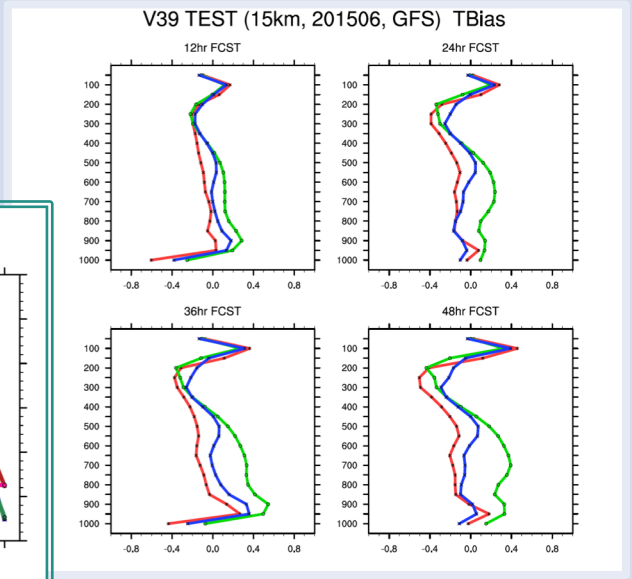


Release Testing

- 15 km – June 2015 and January 2016 – 28 cases each, test new suites, new and changed options and “standard configuration” new version against previous version (YSU, RRTMG, WSM5, Noah, KF) – 00Z initializations
- 3 km – Tests not done yet this year





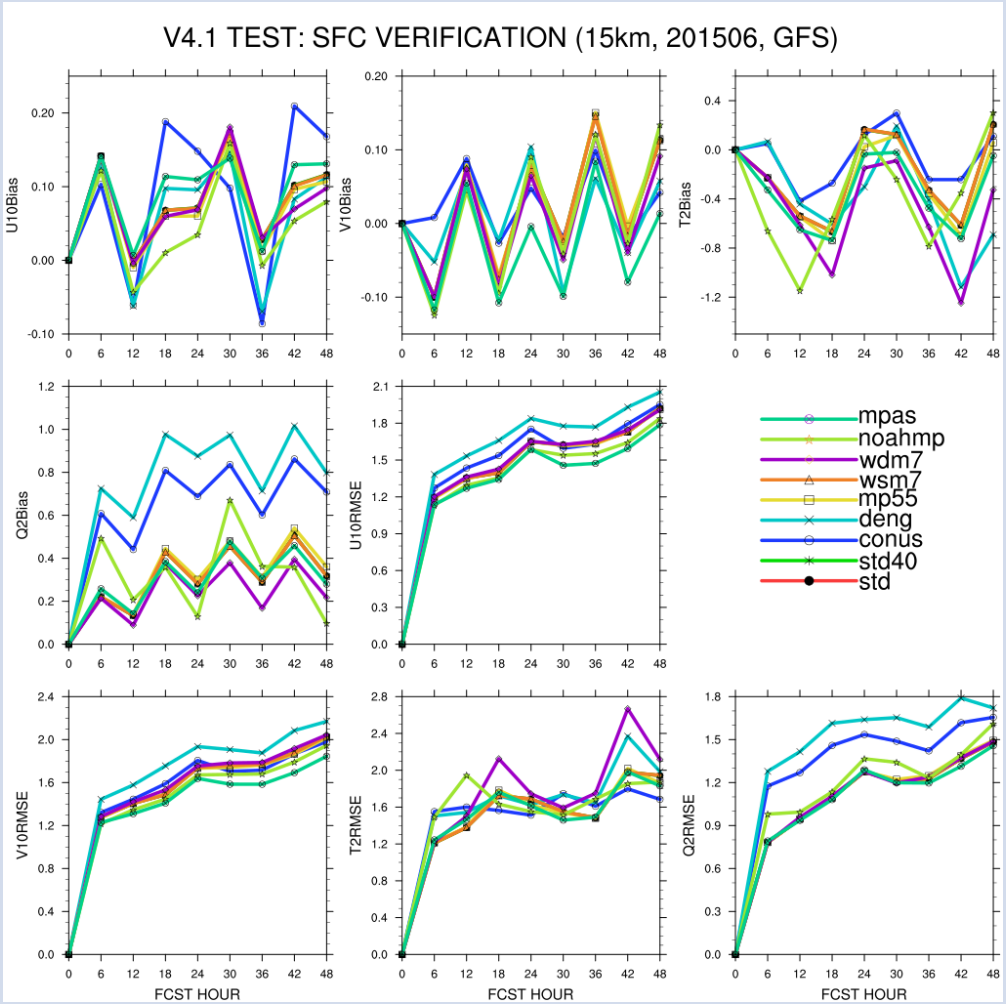


Test Suites for V4.1

Suite	Microphysics	Cumulus	Radiation	PBL	LSM
STD 4.1	WSM5	KF	RRTMG	YSU	Noah
mpas (tropical)	WSM6	New TDK	RRTMG	YSU	Noah
CONUS	Thompson	TDK	RRTMG	MYJ	Noah
STD 4.0.1	WSM5	KF	RRTMG	YSU	Noah
WSM7	WSM7	KF	RRTMG	YSU	Noah
WDM7	WDM7	KF	RRTMG	YSU	Noah
NoahMP	WSM5	KF	RRTMG	YSU	NoahMP
NASA	Goddard	KF	Goddard	YSU	Noah
mp55	ISHMAEL	KF	RRTMG	YSU	Noah
Deng	WSM5	only Deng shcu	RRTMG	MYJ	Noah

red = difference from standard

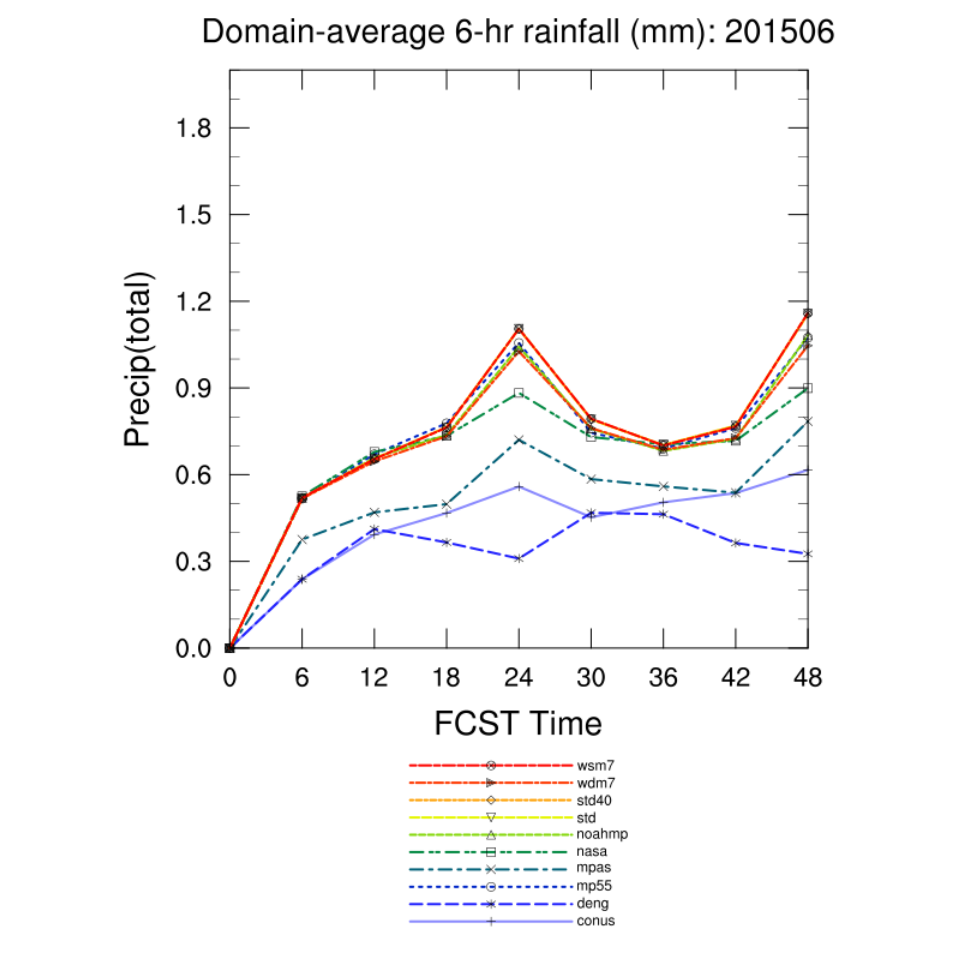
Surface Verification (Summer)



Summer surface versus GFS analysis

- NoahMP cooler at first 12Z
- mpas/tropical and conus suites more moisture than others (possibly Tiedtke new and old versus KF)
- conus slightly more u-wind in daytime (maybe MYJ)

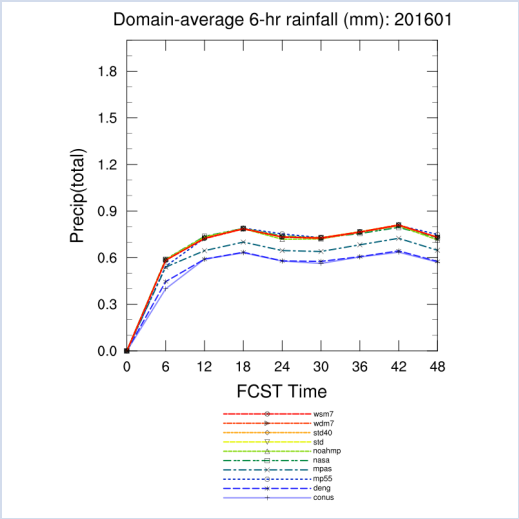
Precipitation Mean Diurnal Cycle (Summer)



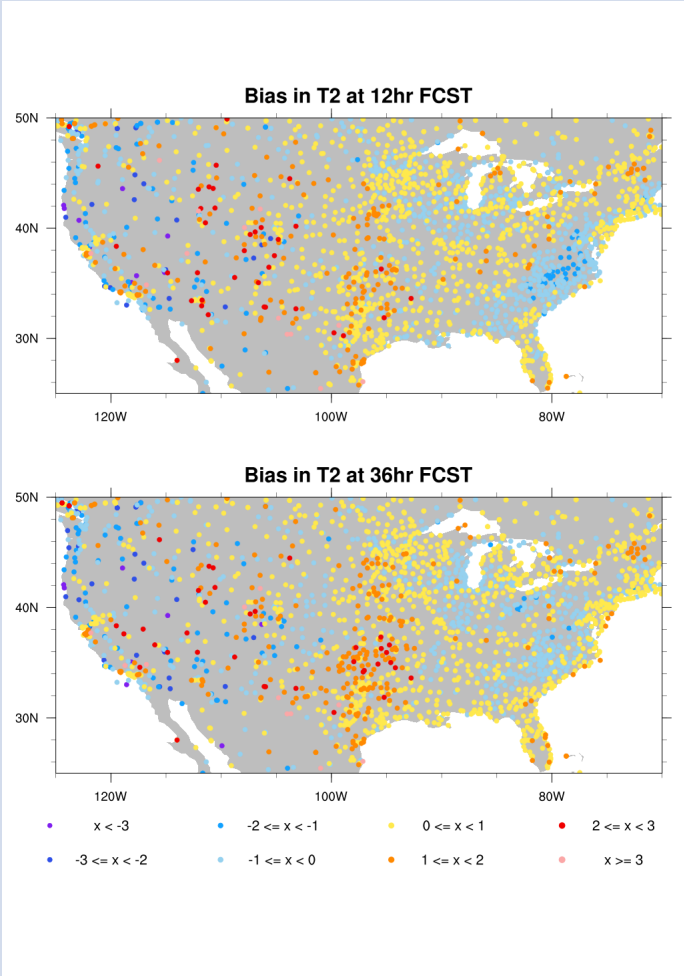
Summer precipitation differences (left)

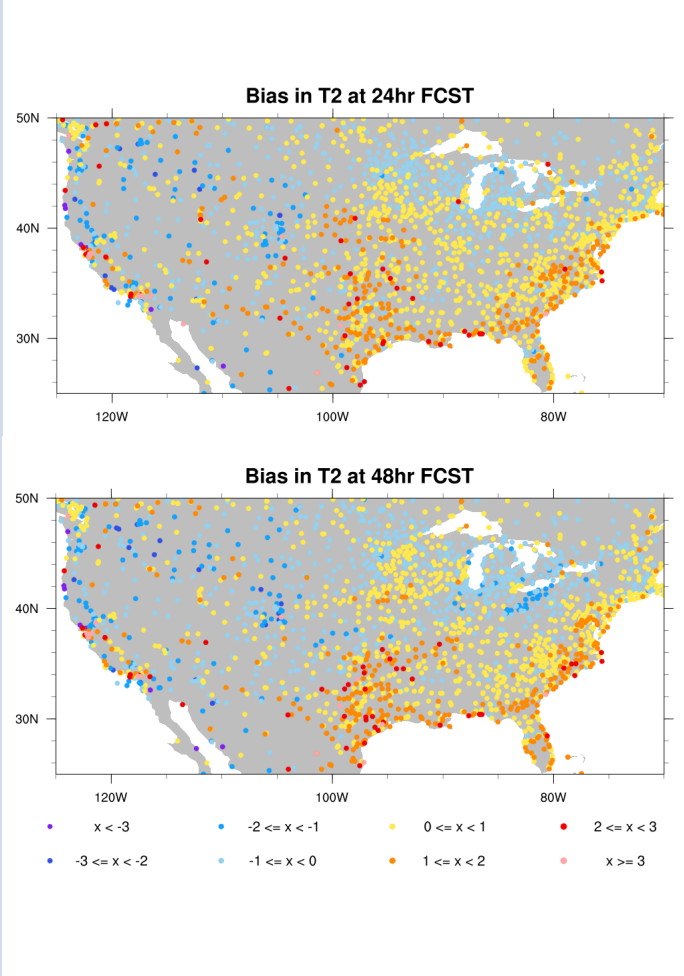
- lowest values are Deng and CONUS (both use MYJ, CONUS uses old Tiedtke)
- mpas/tropical also lower (new Tiedtke)
- New microphysics options do not stand out WSM7, WDM7, mp55(ISHMAEL)

Winter (below) similar tendencies



Verification against observations with MET





Version 4.2

- Planning for next major release in April 2020
- Upgraded fast spectral bin model from HUJI (Shpund, Lynn and Khain)
- New 3d hybrid TKE/PBL scheme (Xu Zhang talk 8.5)

Credits

Ming Chen for verification