The Weather Research and Forecasting Model: 2020 Annual Update

Jimy Dudhia, Ming Chen and Wei Wang
NCAR/MMM

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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 4.1: April 2019
  - Version 4.1.1: June 2019
  - Version 4.1.2: July 2019
  - Version 4.1.3: November 2019
  - Version 4.1.4: February 2020
  - Version 4.1.5: March 2020
- Version 4.2: April 2020

Outline

- Recap of new features in V4.1
- Bug-fix releases since V4.1
- New in V4.2
- Some release verification tests for V4.2

Recap 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 details on gitHub releases page

Recap 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

Recap Improvements in Version 4.1

- Urban Models in Noah and NoahMP LSMs
- Pleim-Xiu LSM
- MYNN PBL
- Thompson microphysicsin analysis
- Cloud fraction
  - *icloud=3*
- Traditional Fields Output
- Time Series

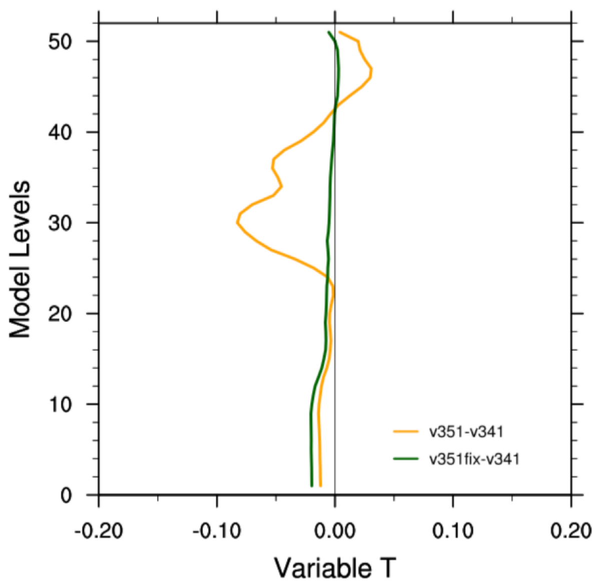
More details on gitHub releases page and in 2019 talk

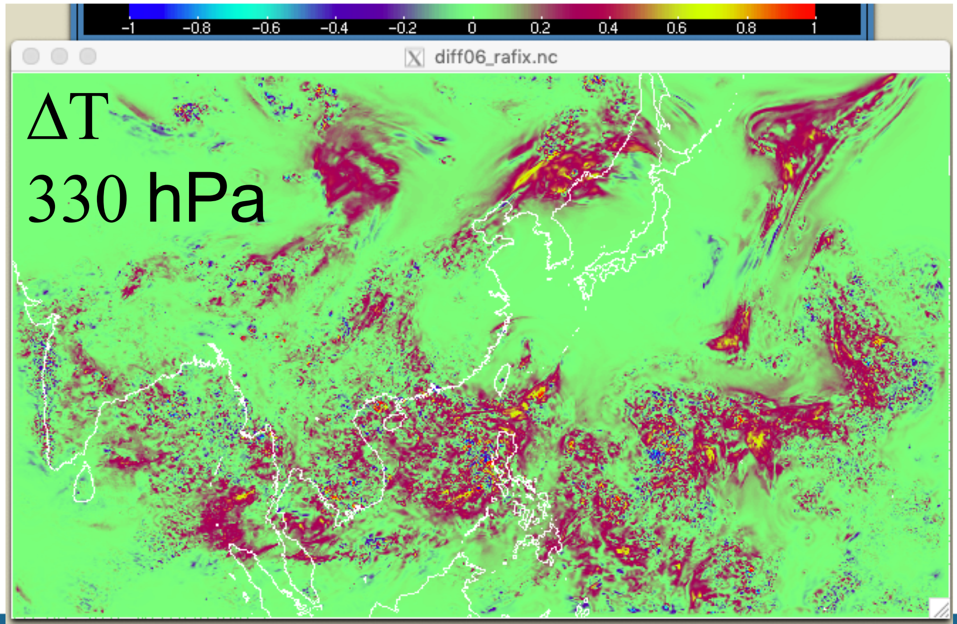
Bug-Fix Releases Since V4.1

- Details at https://github.com/wrfmodel/WRF/releases/tag/v4.1.1, etc.
- V4.1.1 June 2019
  - Vertical refinement option fixed for hybrid coordinate
  - Other minor fixes
- V4.1.2 July 2019
  - Bug-fixes for “traditional fields” special output (temperature and winds)
  - Fix bug in bucket_J radiation budget option since V3.9
  - Minor fixes in Jensen ISHMAEL microphysics
- V4.1.3 November 2019
  - Correction to a previous RRTMG shortwave fix in V3.5.1 (slightly changes in-cloud effect)
  - Minor fixes for Deng shallow cu, NSSL 2-moment mp, Thompson mp, MYNN pbl, WRF-Fire

RRTMG Shortwave fix

- Note this is a fix for WRF – standard RRTMG is OK
- Results changed unintentionally between V3.4.1 and V3.5.1 with a bug-fix – few tenths of degree cooler inside clouds with bug
- New fix in V4.1.3 restores correct behavior





Bug-Fix Releases Since V4.1

- V4.1.4 February 2020
  - WDM mp schemes updated to improve number concentrations
  - Minor fix for Deng shcu (combined with other sub-grid cloud schemes)
  - Minor fix for sfclayrev (rare divide by zero)
- V4.1.5 March 2020
  - NoahMP groundwater fix for divide by zero due to non-standard code (since V3.6) – only a problem with e.g. new gfortran versions

New in Version 4.2

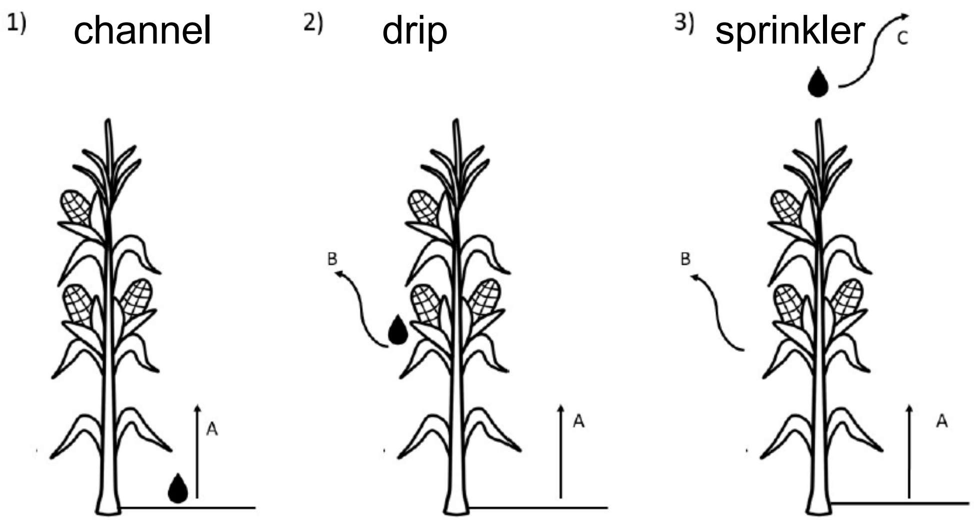
Version 4.2 April 2020

Details at https://github.com/wrf-model/WRF/releases/tag/v4.2

- 3d TKE PBL scheme (*km_opt=5*), X. Zhang et al., 2018, MWR.
  - See Bao's talk given Monday for details
- Irrigation options in Noah LSM (*sf_surf_irr_scheme = 1, 2, 3*), A. Valmassoi et al., 2020, GMD.
- FARMS surface solar radiation (*swint_op=2*), Y. Xie et al., 2016, Solar Energy, and Jimenez et al., 2016, BAMS (WRF-Solar).
- New WRF-Solar diagnostics package (*solar_diagnostics = 1*)
- Fast Spectral Bin Microphysics significantly upgraded (*mp_physics=30*), K. Shpund et al., 2019, JGR-Atmosphere.

New Irrigation Options in Noah LSM

- Arianna Valmassoi (UC Dublin, Ireland)
- 3 methods distinguished by water entry location (ground, canopy, air)



- Region fraction map

Controls for

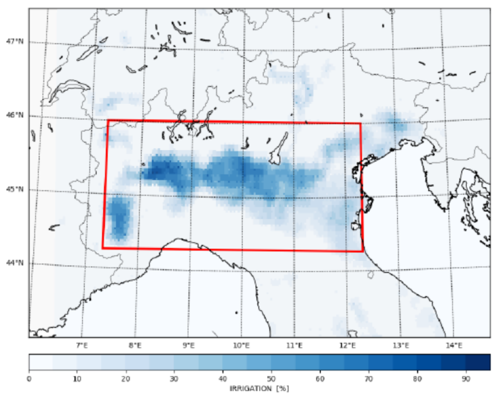
- Total water per day
- Timing start/end
- Daily or multi-day

Valmassoi et al., 2020, GMD)

Figure 1. Irrigation schemes (1-3) with increasing evaporative processes considered (A-C): A is the evaporation from the water at the soil level, B is the canopy interception and C is the drop evaporation and drift. This framework accounts only for surface water application, and not sub-surface.

Irrigation Results

Tmax verification



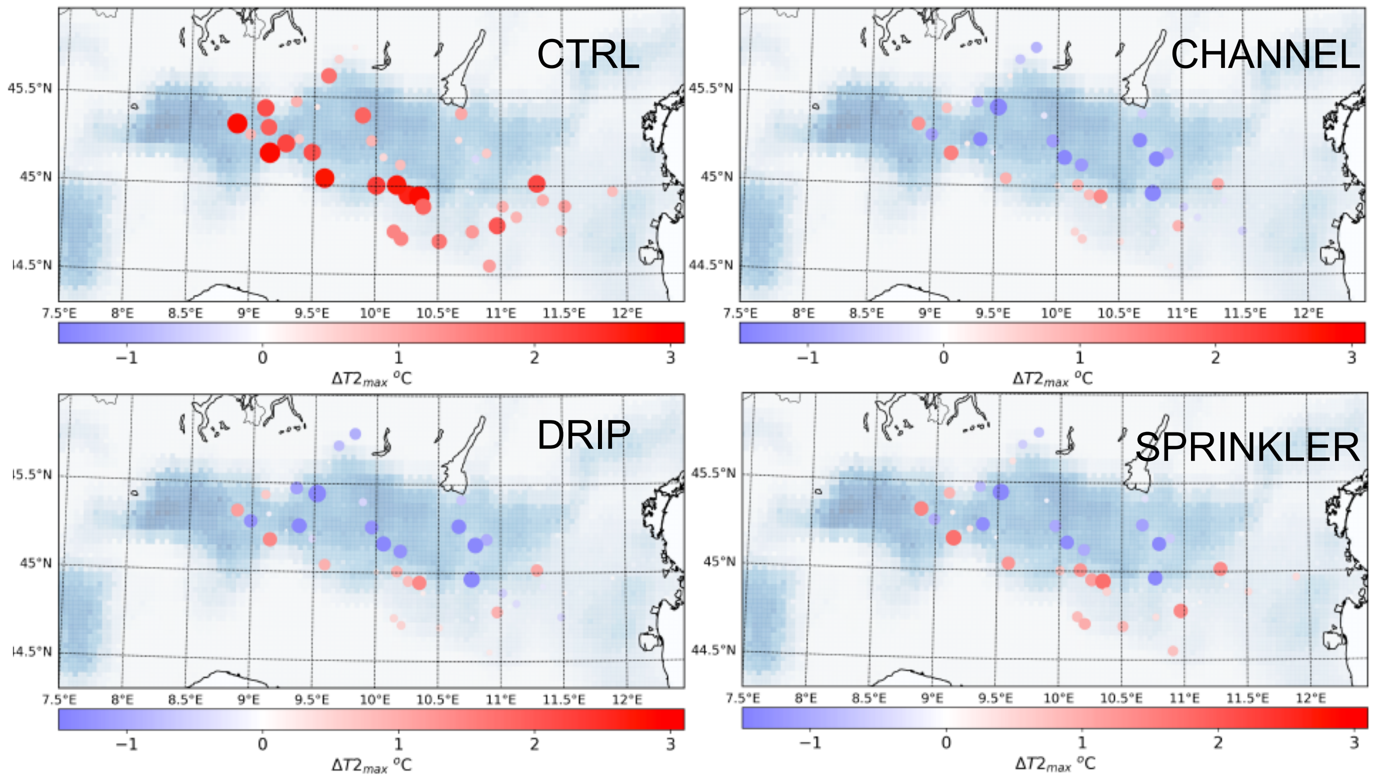


Figure 6. Monthly average for daily maximum 2-meter temperature difference between model run LR2 and the weather stations' location for the control run (top left), CHANNEL (Opt.1, top right), DRIP (Opt.2, bottom left) and SPRINKLER (Opt.3, bottom right)

Valmasssoi et al., 2020, GMD)

Based on slide from Jacob Shpund

New Fast Spectral Bin Microphysics

- The WRF sbm is based on 2D Hebrew University Cloud Model (HUCM) spectral bin microphysics [Khain and Sednev (1996), Khain et al. 2004)]
- (old) Prof. Alexander Khain & Dr. Barry Lynn
  – FULL sbm (8xPSD 43bins) / FAST sbm (4xPSD 33bins)
    - 8xPSD = Aerosol, droplets, 3 x Ice crystals, snow, graupel, hail
    - 4xPSD = Aerosol, droplets, snow, graupel/hail
- (new) Jacob Shpund, Prof. Alexander Khain & Dr. Barry Lynn
  – FULL sbm mod (12xPSD 43bins) / **FAST sbm mod (4xPSD 33bins)**
    - 12xPSD = 8xPSD + liquid mass in snow, liquid mass in graupel, liquid mass in hail, snow density (rimed mass)
  – FULL code included but not activated (see instructions in Release Notes)

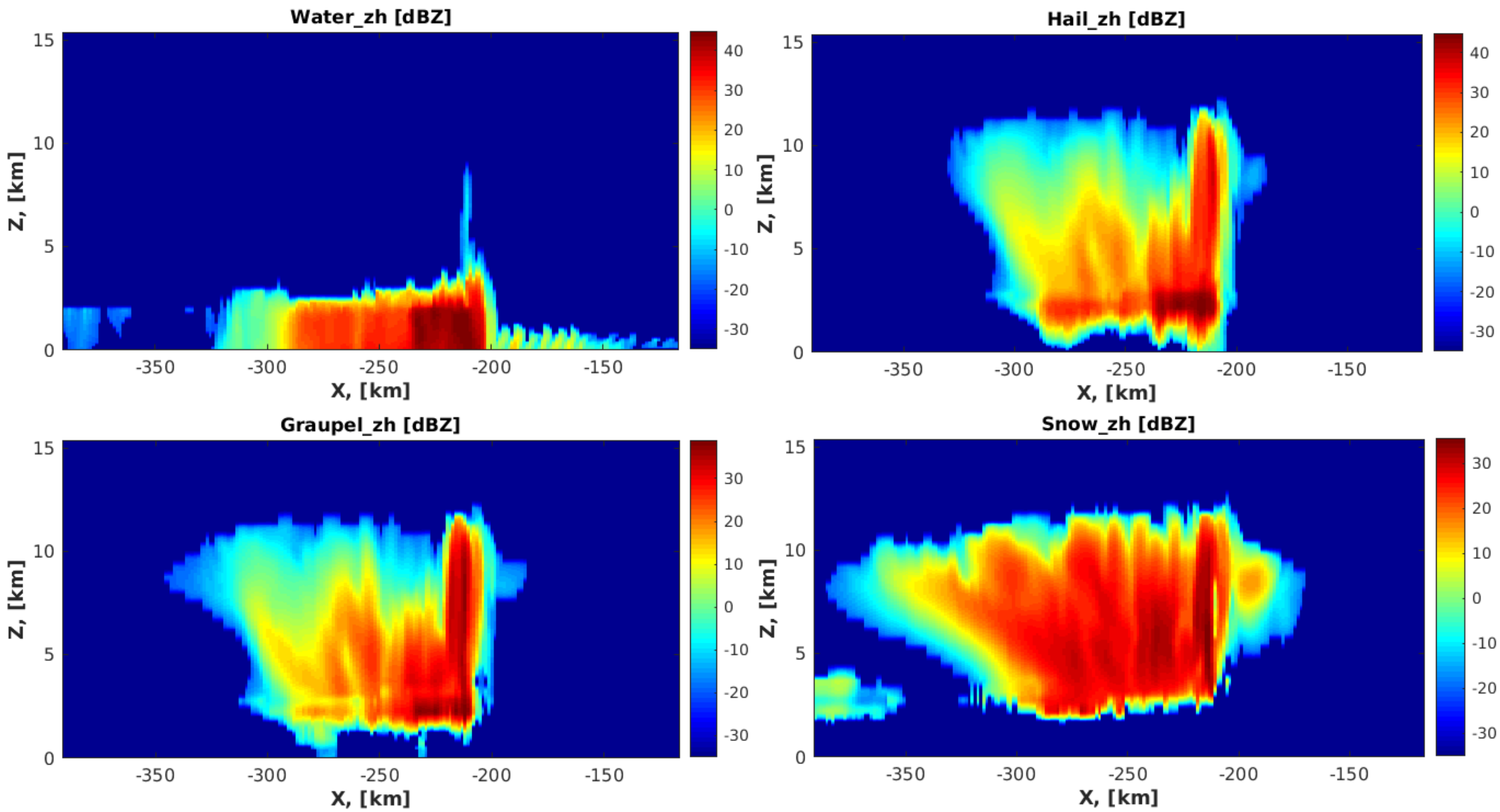
New Fast SBM

1. switch to use either graupel or hail, condensation/evaporation, nucleation (cloud base nucleation, log-normal user-defined aerosol distribution),
2. adaptive cond./evap. time-step,
3. updated collision-coalescence,
4. spontaneous rain breakup,
5. spontaneous snow breakup.

- A forward polarimetric radar operator is coupled to the FSBM scheme. The user can see the total reflectivity field, as well as the per hydrometeor total reflectivity (rain, snow, graupel/hail).

WRF-sbm Results – MCE3 (FULL-sbm-Mod)

- Radar reflectivity per hydrometeor species is a **standard output** of the SBM scheme



FARMS Surface Solar Radiation

- Fast All-sky Radiation Model for Solar applications
- Set *swint_opt=2*
- This only calculates surface solar radiation so it needs to run with a column radiation option such as RRTMG
- Has a coupled mode option so that surface physics uses FARMS shortwave instead of column radiation scheme
- Purpose: FARMS runs every model time step so its solar radiation is sensitive to all model cloud changes (not just radiation times)
  - Note that *swint_opt=1* only responds to solar angle changes between radiation steps, and cloud changes are interpolated

Diffuse transmittance

Colors: cos zenith angle

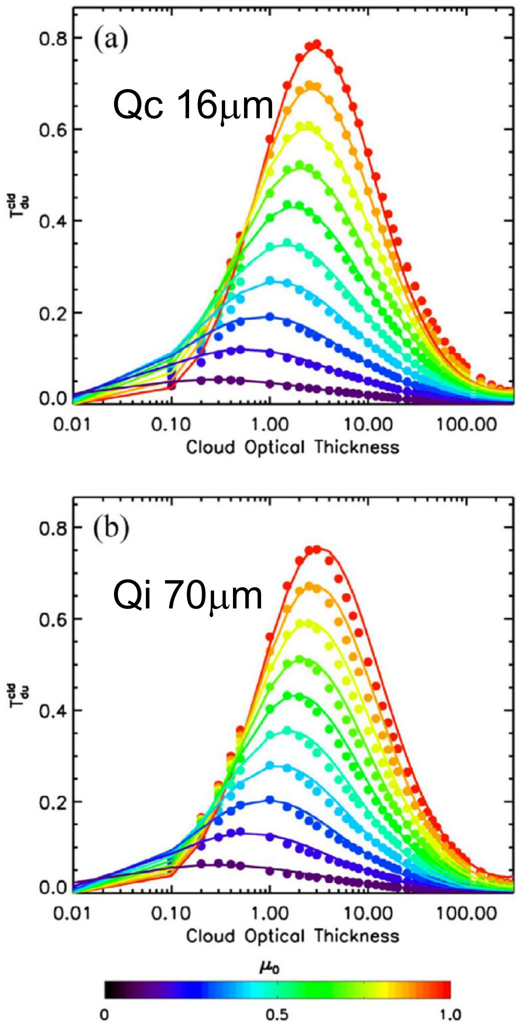


Fig. 2. Simulated T_{du}^{dd} (dots) for (a) water clouds with D_e = 16 µm and (b) ice clouds with D_e = 70 µm as functions of cloud optical thickness and solar zenith angle and their parameterization (solid lines).

FARMS

Y. Xie et al. / Solar Energy 135 (2016) 435–445

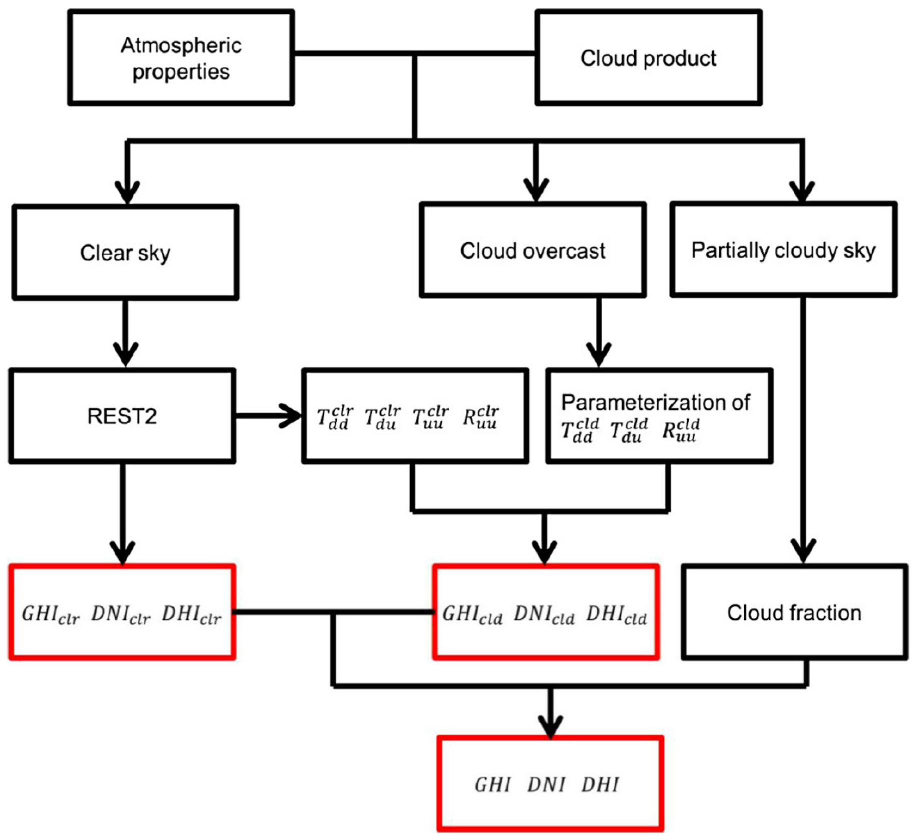


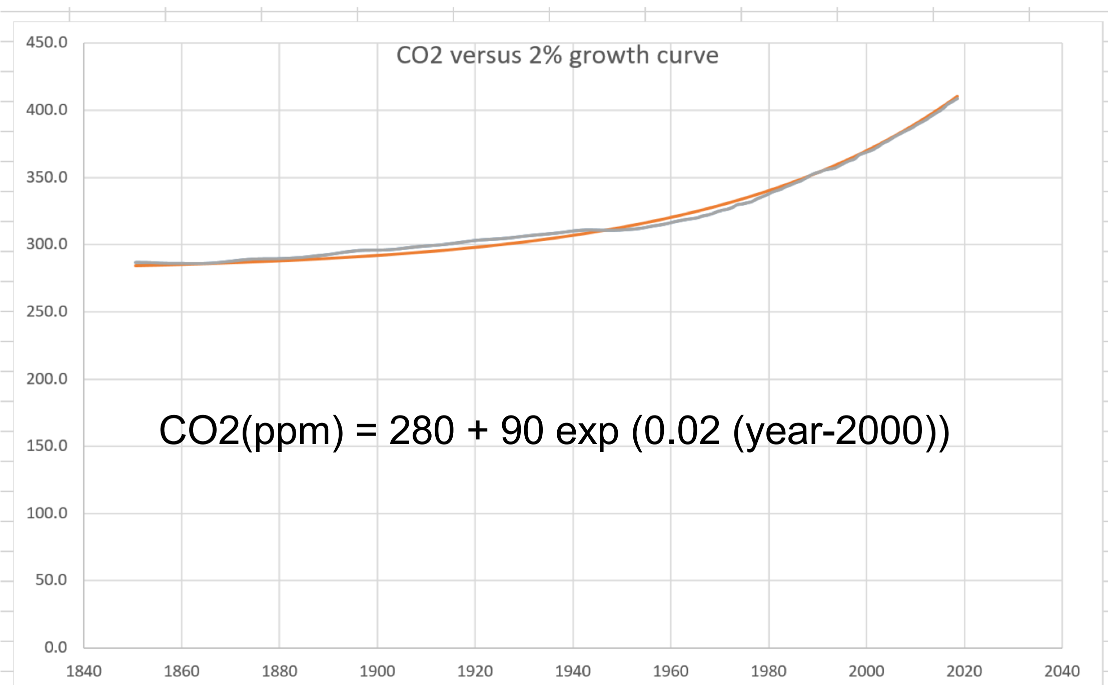
Fig. 1. Flowchart of the computation of GHI, DNI and DHI using FARMS.

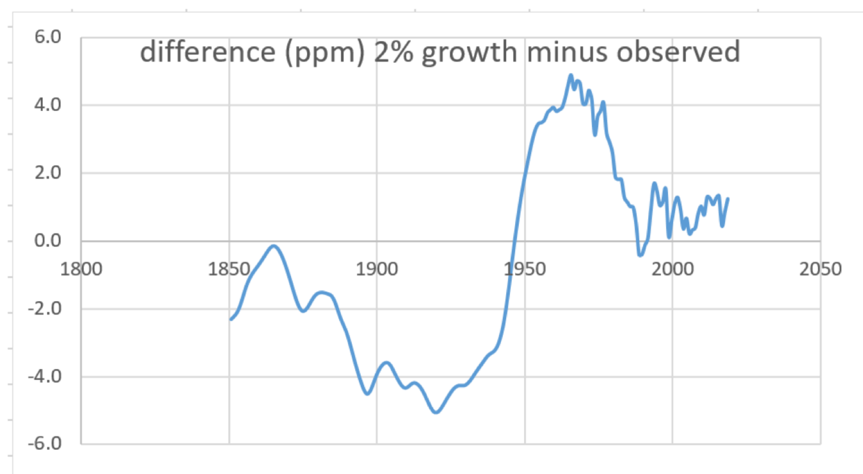
Updates and Changes in Version 4.2

- Dynamics
  - Horizontal diffusion of w modified for *km_opt=2,3* (J. Simon, LLNL)
  - Default upper damping is now *damp_opt=3* (J. Klemp et al., 2008)
- Radiation
  - RRTMG (sw and lw) CO2 changed from default fixed value (valid around 2005) to one calculated using function of year by default
- Cumulus
  - BMJ cloud-radiation scheme of Koh and Fonseca (2016, QJRMS) added, plus a bug-fix producing less surface rain
  - Multi-scale KF adds momentum transport of Zhang and McFarlane and also works with more PBL schemes (K. Alapaty)
- PBL
  - MYNN PBL updated (close to upcoming HRRRv4 operational version)
- Microphysics
  - Thompson upgrade to improve graupel versus reflectivity obs

CO2 Function for RRTMG

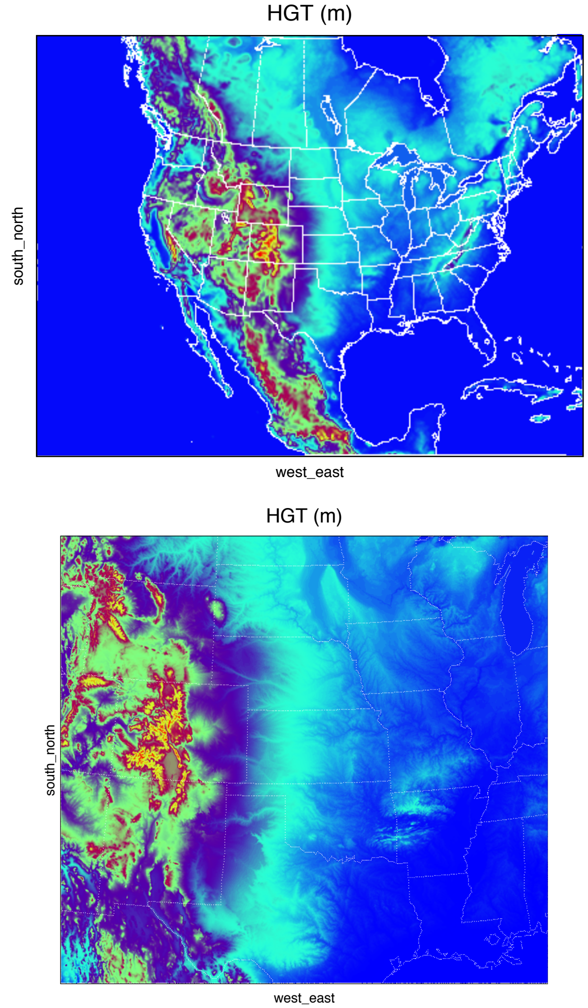
- Exponential growth rate replaces fixed constant
- Fits data well especially after 1980 (<0.5%)
- Specified GHG scenario option still exists





Verification of WRFV4.2

- The WRF ARW tests are conducted for the periods 1-31 May 2017 and 1-28 February 2017 over a single domain at the resolution of 15km
- Two extra suites of 3km resolution runs are conducted for the period 1-31 May 2017 to test spectral bin microphysics and predicted particle property (P3) bulk microphysics
- Results are verified against GFS analysis and GDAS in-situ observations



15km (upper) and 3km (bottom) domains

Experiments

Initial and boundary conditions are extracted from the NCEP GFS analysis product, which are in global 0.25 degree grids and at 6-hour intervals.

Each single case is initialized daily at 0000UTC and run for 48-hour forecast.

31 and 28 cases are conducted for the early summer and the winter 2017, respectively.

Various combinations of physics options are tested with the focus on new features of WRFV4.2.

Two baseline tests with the CONUS and TROPICAL suites are conducted using WRFV4.1.5 and WRFV4.2 for comparison.

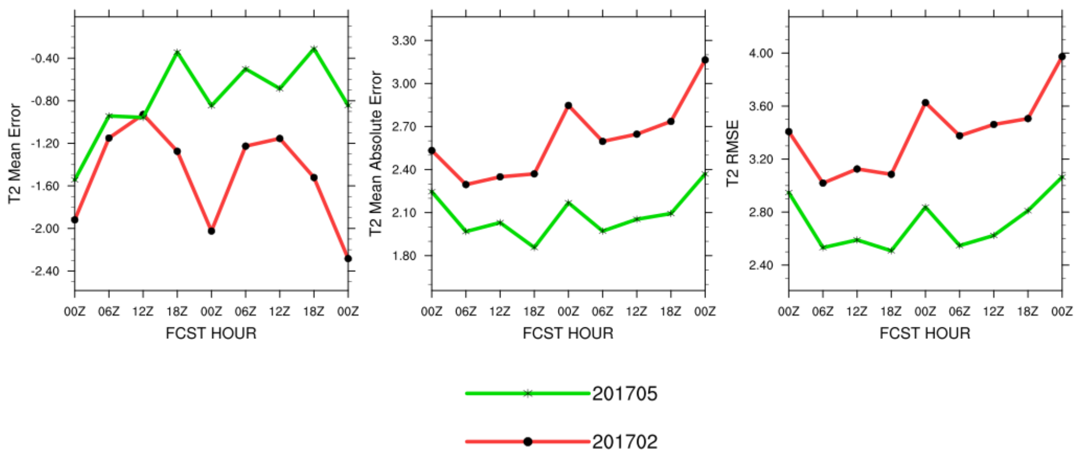
Table 1 Configurations for tests conducted (unless specified, all tests are based on WRFV4.2)

Name	Radiation	Cumulus	MP_PHYS	SFCLAY	LAND	PBL
Conus 4.1.5Conus 4.2	RRTMG	Modified Tiedtke	Thompson	Janjic	Noah	MYJ
Tropical 4.1.5 Tropical 4.2	RRTMG	New Tiedtke	WSM6	Old MM5	Noah	YSU
MSKF	RRTMG	MSKF	WSM5	Monin-Obukhov	Noah	YSU
BMJ	RRTMG	BMJ	WSM5	Monin-Obukhov	Noah	YSU
MYNN	RRTMG	MSKF	WSM5	MYNN	Noah	MYNN
IRR1-3	RRTMG	MSKF	WSM5	Monin-Obukhov	Noah	YSU
3DTKE	RRTMG	Modified Tiedtke	WSM5	Monin-Obukhov	Noah	OFF
FARMS	RRTMG	Modified Tiedtke	Thompson	Janjic	Noah	YSU
FSBM (3km)	RRTMG	OFF	FSBM	Monin-Obukhov	Noah	YSU
P3 (3km)	RRTMG	OFF	P3	Monin-Obukhov	Noah	YSU

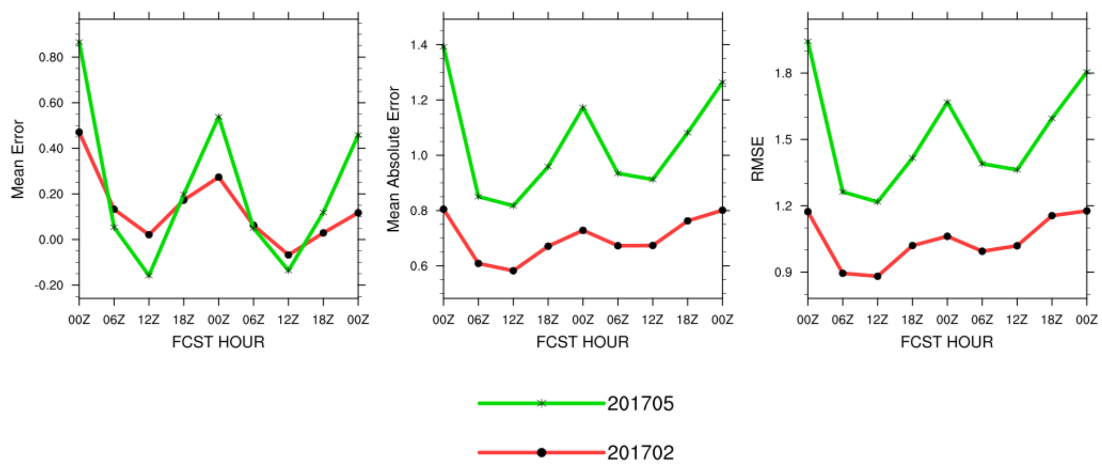
Verification against GDAS

CONUS suite
Surface and RAOBs

T2 Error averaged over full domain and for all cases (unit: K)



Q2 Error averaged over full domain and for all cases (unit: g/kg)



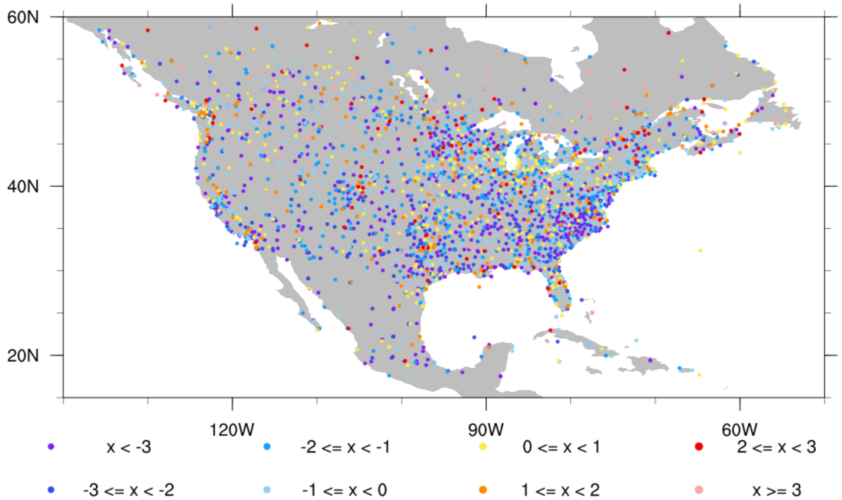
CONUS suite verified against GDAS observations.

- Large cold bias of T2 is found in the winter.
- Q2 is wetter in daytime and drier in the night.
- Model behavior is different in winter and in spring.

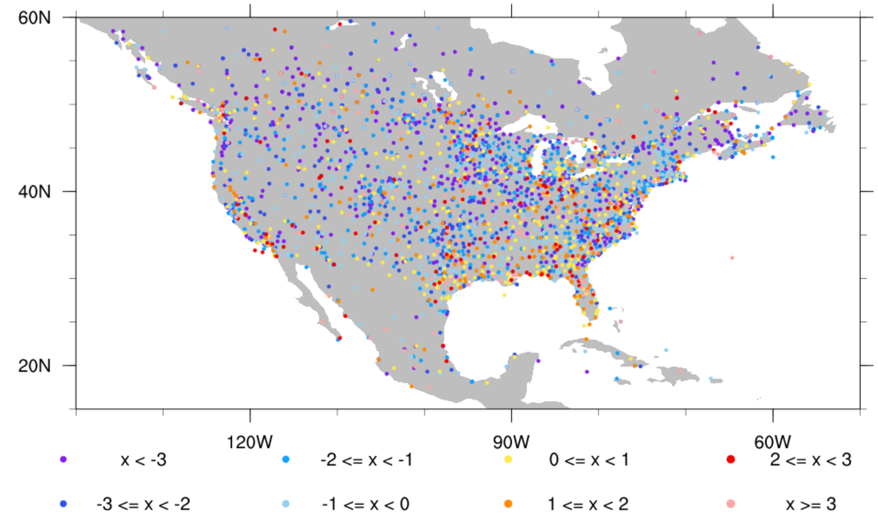
NCAR | UCAR

CONUS Suite GDAS verification: Winter

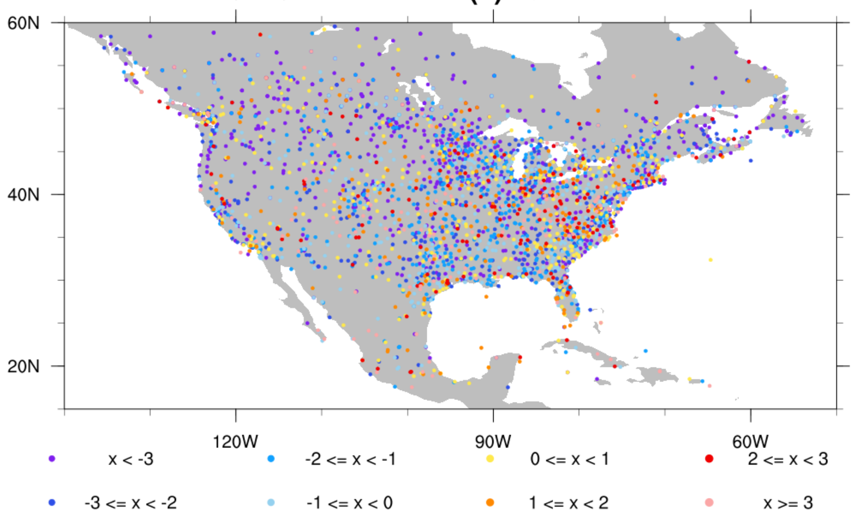
201702 Bias of T2 (k) at 00hr FCST



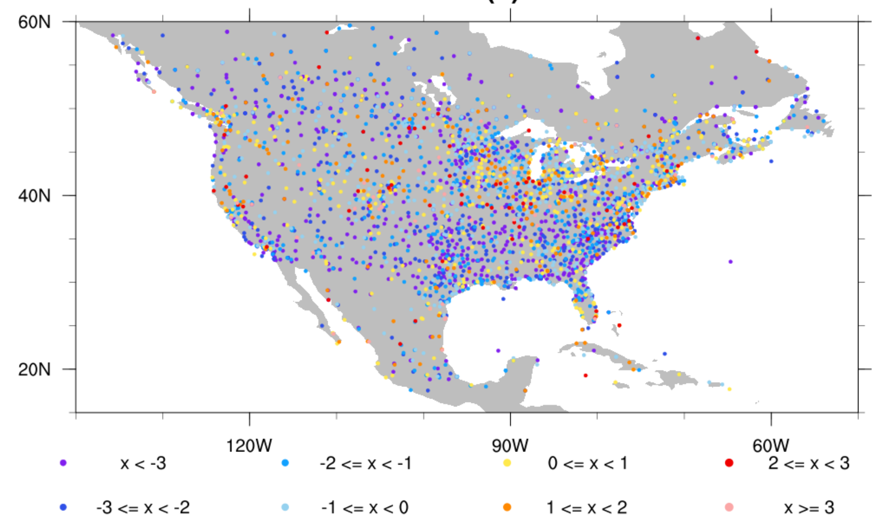
201702 Bias of T2 (k) at 06hr FCST

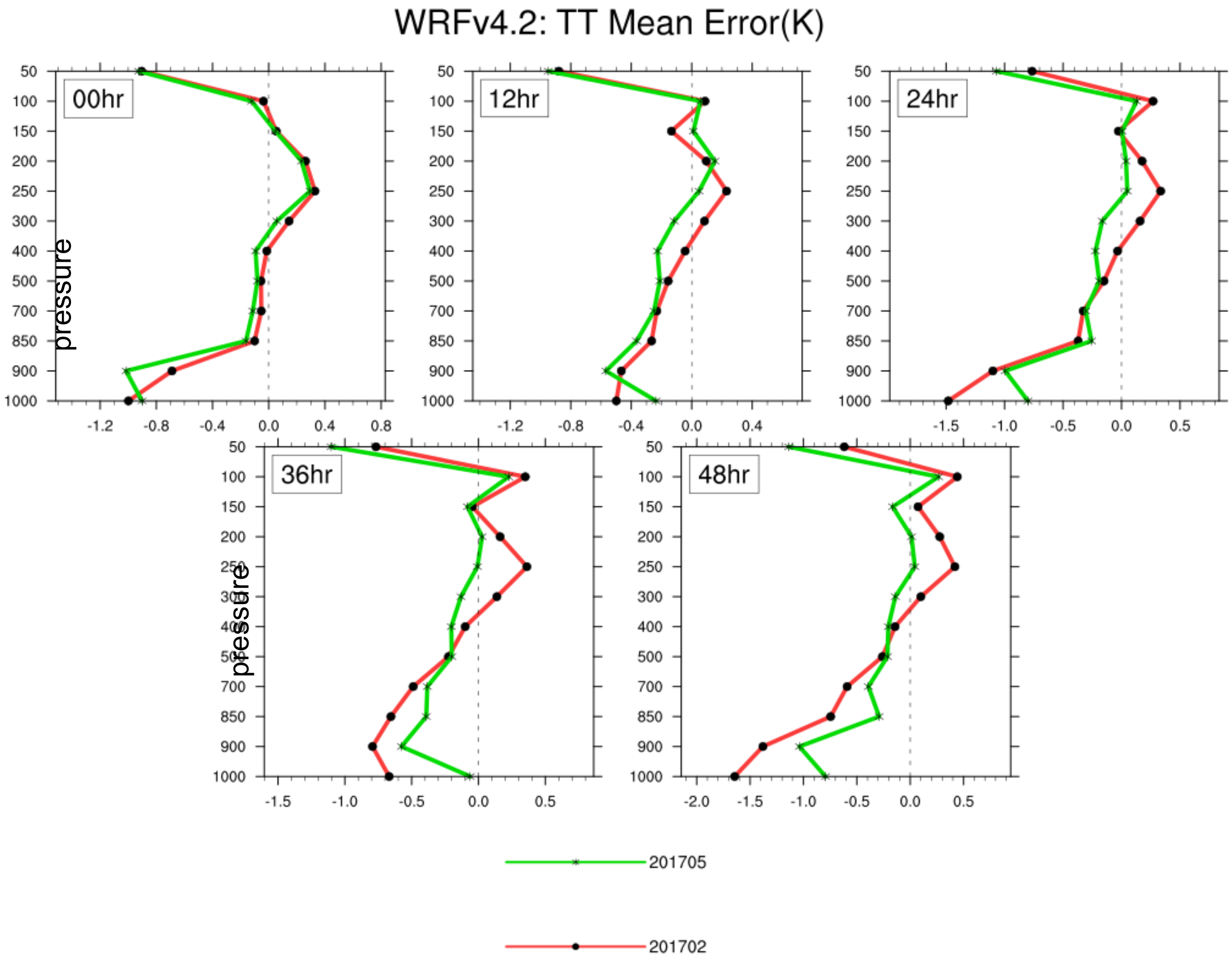


201702 Bias of T2 (k) at 12hr FCST



201702 Bias of T2 (k) at 18hr FCST



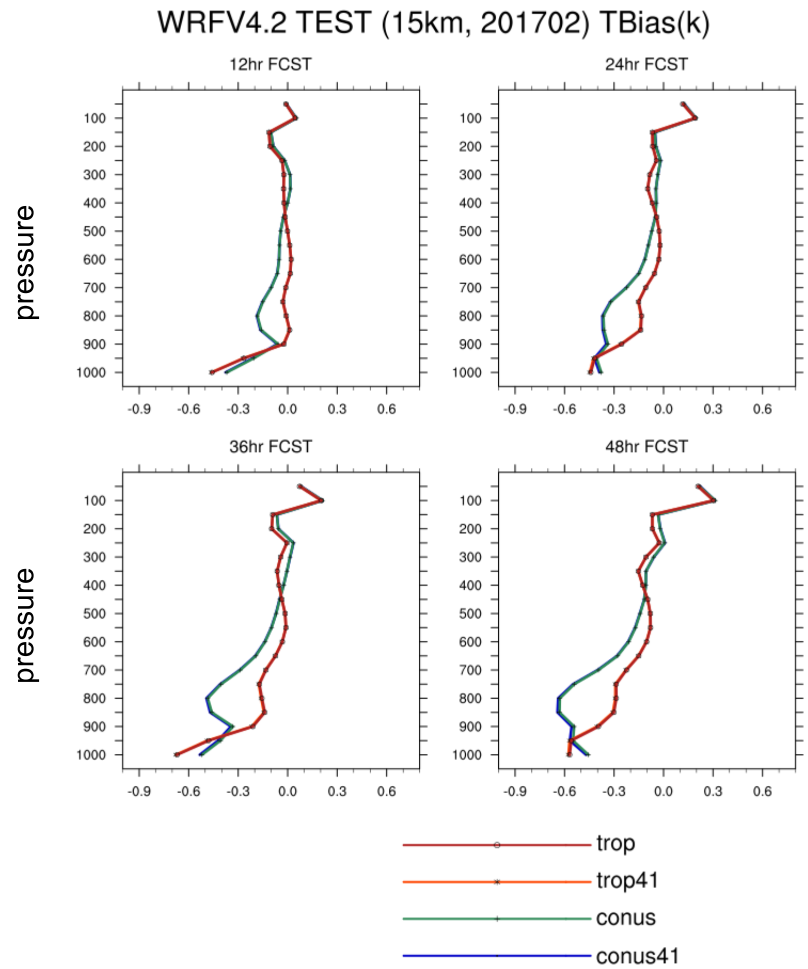


- Cold bias in lower levels below 700 hPa for both seasons
- warm bias in upper troposphere centered around 250 hPa in the winter
- Cold bias at 50 hpa for both seasons

Verification against GFS analysis

Comparison of V4.1 and V4.2 for CONUS and TROPICAL suites

T



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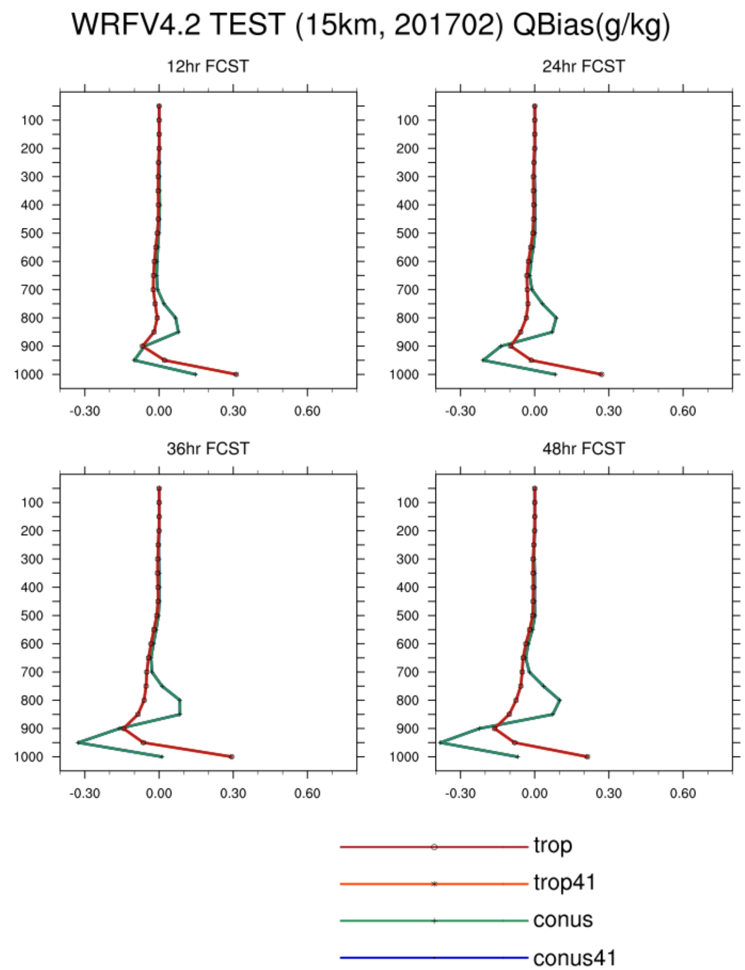
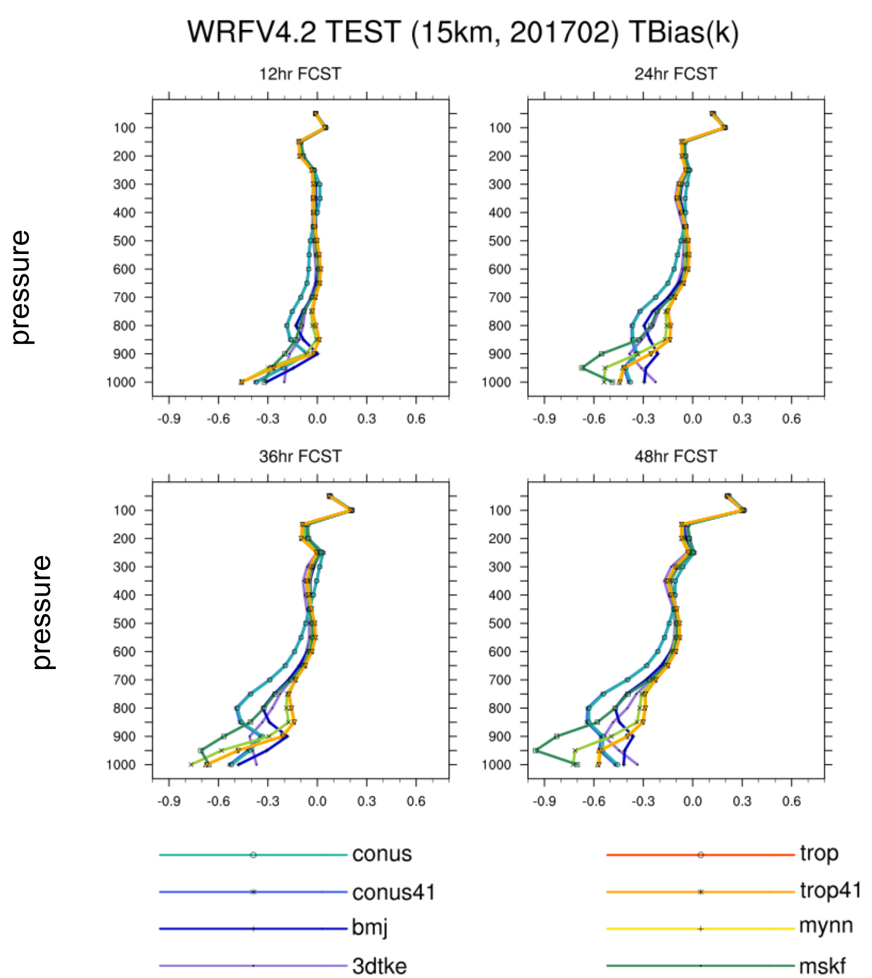


Neither suite has changed between V4.1 and V4.2

Verification of WRFV4.2 for eight suites of physics and dynamics options

T



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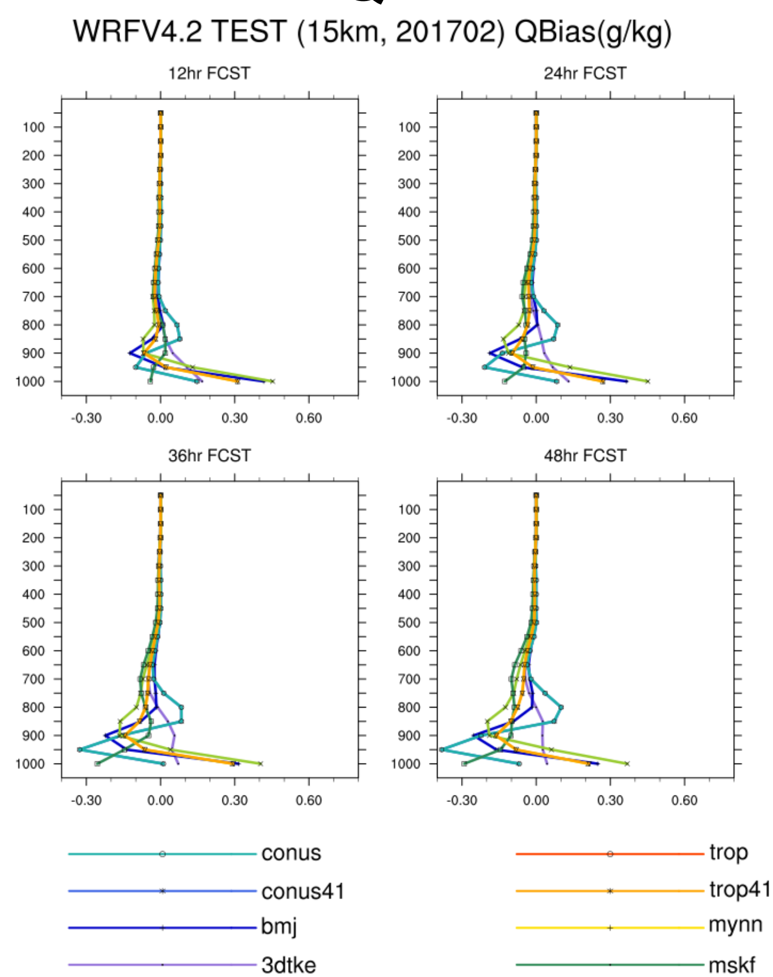
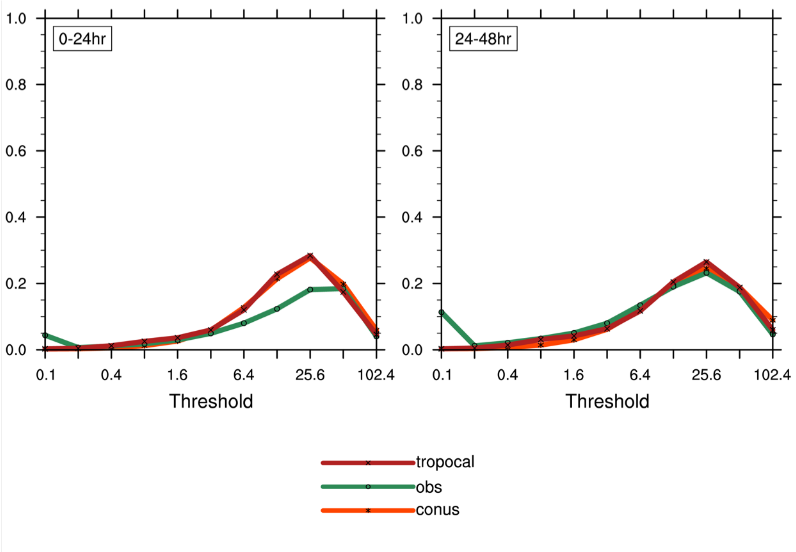
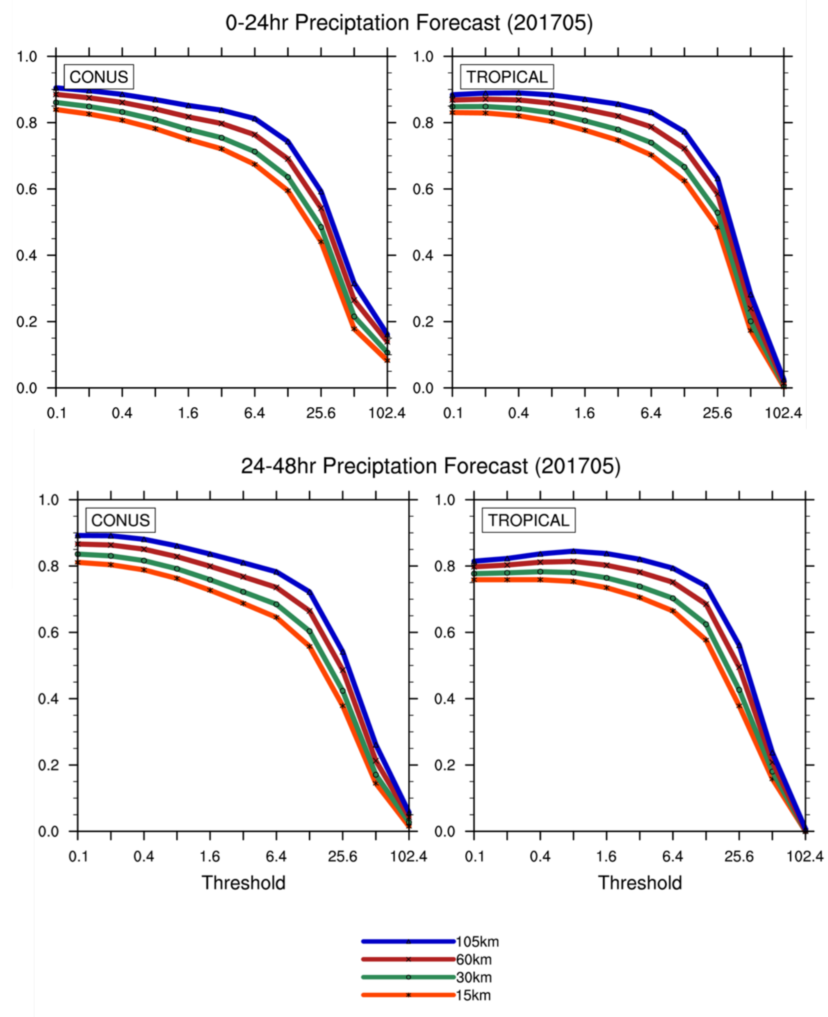


Precipitation simulation (15km runs, 201705)

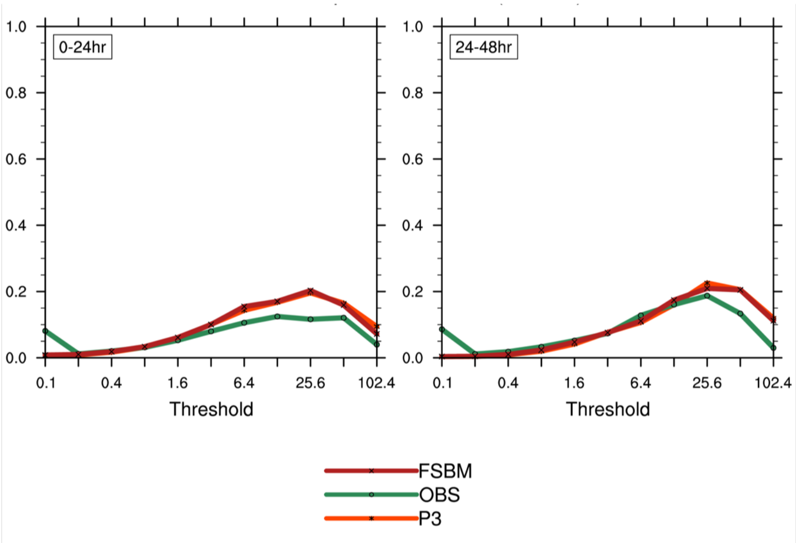


Percentage of total precipitation accounted for by precipitation in individual bins

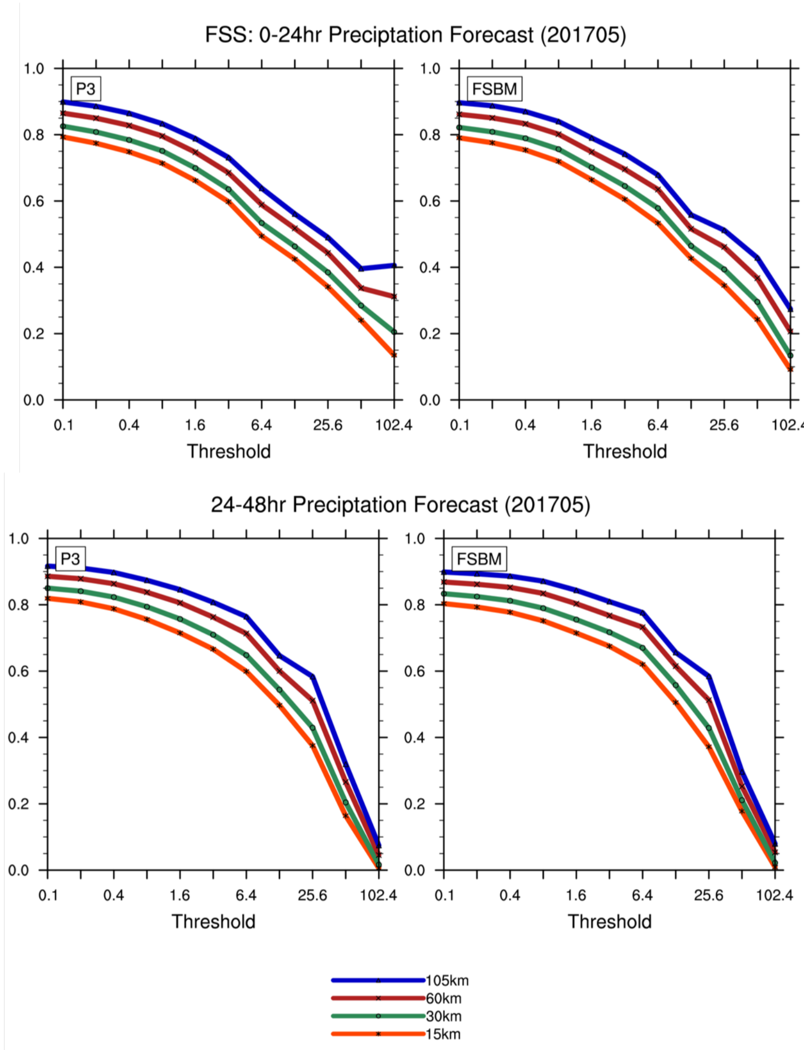
Fractional Skill Score (FSS)



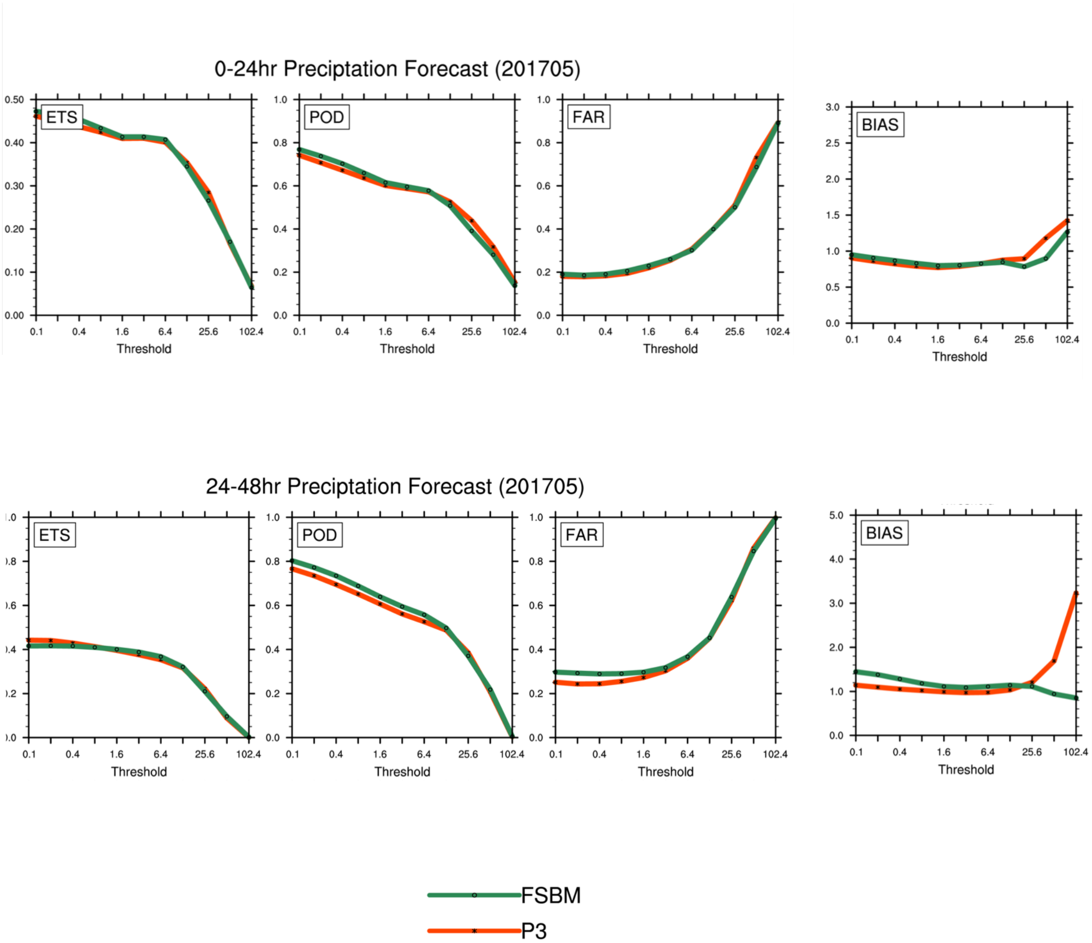
Precipitation simulation (3km runs, 201705) FSBM and P3



Percentage of total precipitation accounted for by precipitation in individual bins



Precipitation simulation (3km runs, 201705)



Credits

Ming Chen for verification