The Weather Research and Forecasting Model: 2017 Annual Update

Jimy Dudhia

NCAR/MMM

Tests and Graphics: Ming Chen

22 June 2017

18th Annual WRF Users' Workshop

WRF Community Model

- Version 1.0 WRF was released December 2000
- Version 2.0: May 2004
- Version 3.0: April 2008 (add global ARW version)
- … (major releases in April, minor releases in summer)
- Version 3.8: April 2016
  - Version 3.8.1: August 2016
- Version 3.9: April 2017

New in V3.8 (April 2016)

- Kain-Fritsch cumulus potential scheme (KFCuP) – *cu_physics=10* (Berg and Stull, 2005)
- A new climatological aerosol option linked to Thompson microphysics – *aer_opt=3*
- Flux-adjusting surface data assimilation system (FASDAS) – *grid_sfdda = 2*
- New 30” global topography (GMTED) replaces GTOPO

Updates in V3.8.1 (August 2016)

- Radiation
  - RRTMG redefine top to 0 hPa for LW diagnostics
  - Goddard improve shortwave clear-sky water vapor treatment
  - *icloud=3* improved based on WRF-Solar testing
- Microphysics
  - Thompson updates
  - HUJI Spectral Bin option fix error coupling to LSM
  - Minor changes to WSM, WDM and Morrison schemes

Updates in V3.8.1 (August 2016)

- Cumulus
  - Zhang-McFarlane fix bug for *cudt=0* case
  - Minor changes to new Tiedtke scheme
- PBL
  - MYNN fixes and improvements including bug-fix for icloud_bl=1
- LSM
  - NoahMP and RUC updates and improvements

Updates in V3.8.1 (August 2016)

- Diffusion
  - Fix for *diff_opt=2* vertical diffusion to allow conservation of scalars

New in V3.9 (April 2017)

- Highlights
  - Introduction of physics suites
  - Hybrid vertical coordinate option
  - Predicted Particle Property (P3) microphysics
  - Stochastic physics options
  - NoahMP urban and crop capabilities
  - New 30” global soil dataset

Physics Suites

- 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 (talk 3.1)
  - Tropical (WSM6 mp, new Tiedtke cu, RRTMG, YSU PBL, MM5 surface layer, Noah LSM)
    - Based on physics used in MPAS for global TC forecasts (talk 9.4)

Physics Suites

- Namelist selectable and modifiable

  physics_suite = 'tropical'

  This replaces *mp_physics, cu_physics, sf_sfclay_physics, sf_surface_physics, bl_pbl_physics, ra_lw_physics, ra_sw_physics*

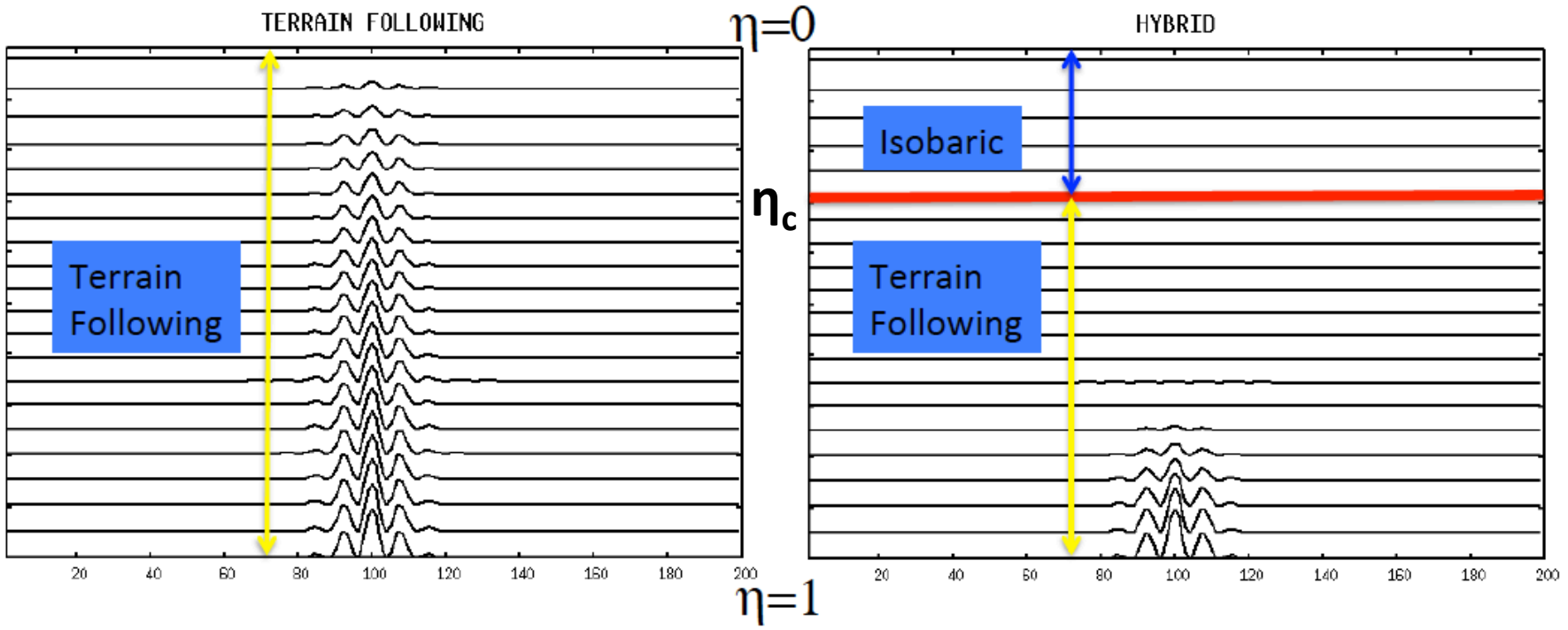
  To change defaults can add line such as

  cu_physics = -1, -1, 0

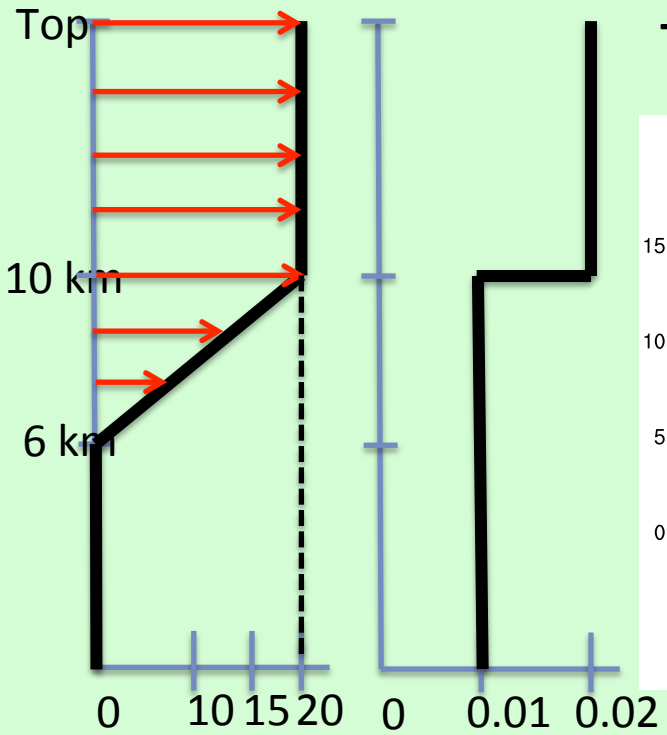
  – Keeps suite *cu_physics* in outer two domains, and turns it off in 3rd domain
  – Allows switching from suite option to another one
- Why suites?
  – Need well-verified combinations to provide a common basis for
    - New users to start with
    - Community to evaluate, test and feed back improvements
- Discussion topic 4:30 this afternoon

Hybrid Vertical Coordinate

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



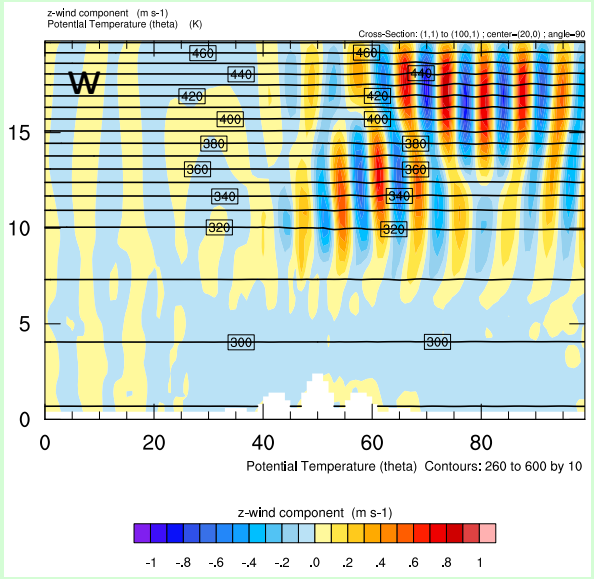
Hybrid Vertical Coordinate



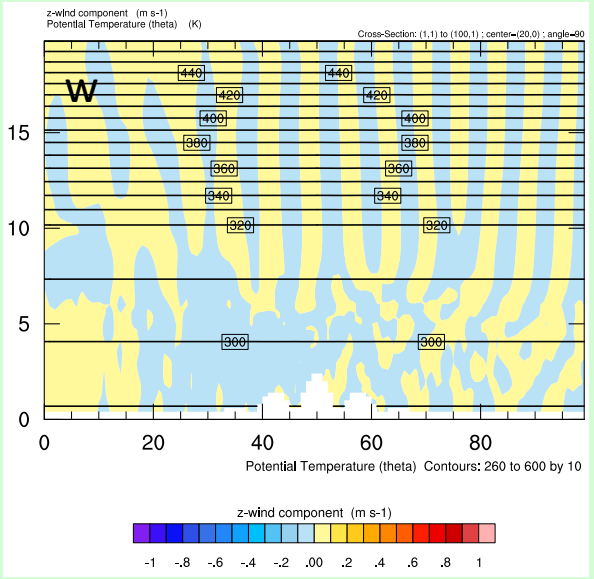
U (m/s) N (s^{-1})

dx=1 km, dz=500 m
ht=2000 m, top= 20 km
η_c=0.3, 5 hrs

Terrain Following



Hybrid Coordinate



- In this 2d test, all the flow is above the terrain.
- Terrain following coordinate shows response to coordinate in vertical motion (max < 1 m/s).
- Hybrid coordinate correctly shows no significant response.

Hybrid Vertical Coordinate

- V3.9 implementation
  - Compile-time choice to add hybrid option *(./configure –hyb)*
    - Uses C Pre-Processor (CPP) to mostly modify μ instances from 2d [$\mu(i,j)$] to 3d [$\mu(i,j)C_1(k)+C_2(k)$] form
    - Initial and boundary files from *real.exe* run with hybrid coordinate on *(hybrid_opt=2)*
    - Code compiled with hybrid option can also be run non-hybrid coordinate *(hybrid_opt=0)* – same results as original code
    - Only parameter to select is η_c level at which pure isobaric coordinate starts (*etac=0.2* is default)
  - Below this level the coordinate is a weighted function of terrain-following and isobaric
  - See README.hybrid_vert_coord in WRFV3 directory
  - Works for real cases, hill2d_x and LES idealized cases only
  - Works for nesting, restarts, WRFDA, WRF-Chem
  - Works for WRF NCL, RIP, UPP

Predicted Particle Property Microphysics

- Reference: Morrison and Milbrandt (2015, JAS)
- New microphysics options
  - *mp_physics*=50 has single-moment cloud water fixed *Nc*
  - *mp_physics*=51 has double-moment cloud water with prognostic *Nc* to allow activation of given aerosols
- Single ice category advected (*qi*) plus rimed ice mass, rimed ice volume and ice number concentration properties to predict density, fallspeed, etc.
- Cloud and rain advected (*qc* and *qr*) with rain number concentration and (for option 51) cloud number concentration

Stochastic Physics Options

- Stochastically perturbed physics tendencies (*sppt=1*)
  - Random pattern to perturb accumulated physics tendencies (radiation, cumulus, PBL) of potential temperature, wind and humidity (Berner et al., 2015 MWR)
- Stochastic perturbed parameter scheme (*spp=1*)
  - Random pattern to perturb parameters in specific physics schemes, currently GF convection, MYNN PBL, and RUC LSM (Jankov et al. 2016 MWR)
  - Poster P11

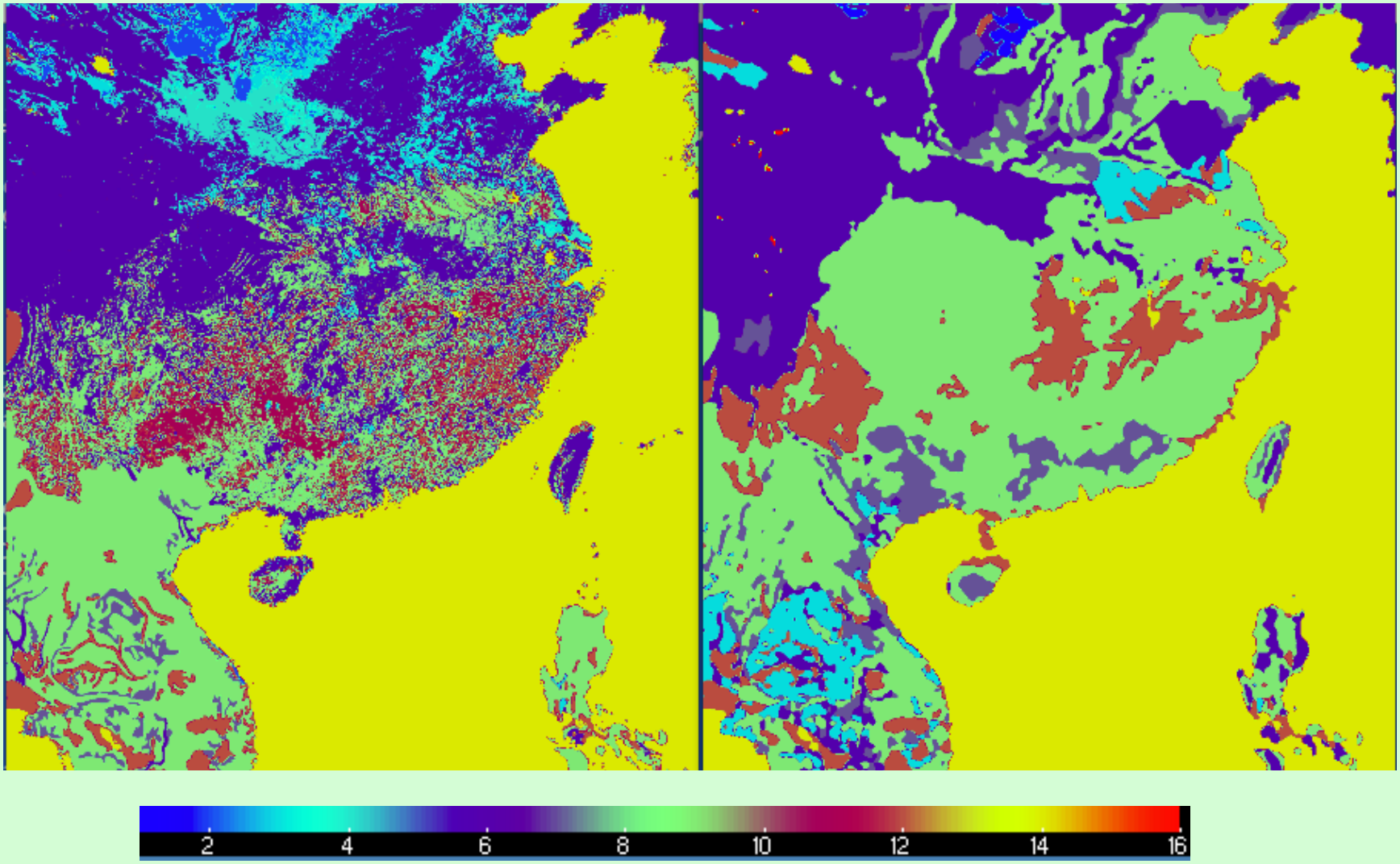
Other New Features

- Trajectory code has been updated by NCAR/ ACOM to interpolate diagnostic quantities to trajectories
- RASM (U Colorado) diagnostics for climate applications – includes diurnal and monthly averaging of surface and radiation budget terms
- Physics tendencies (RTHRATEN, RQVCUTEN, etc.) are now output uncoupled to mu
- HAILCAST diagnostic updated (*hailcast_opt=1*)

NoahMP Update

- See talk 4.6 by Mike Barlage
- NoahMP now has the urban options that were in Noah
- Better capabilities with crops and groundwater
- New option for hi-res global soil dataset for LSMs (default is not changed)
  - 30” (~1 km) global
    - Old dataset only 30” US, effectively 5’ outside US

New Hi-Res Global Soil Data



Other Updates

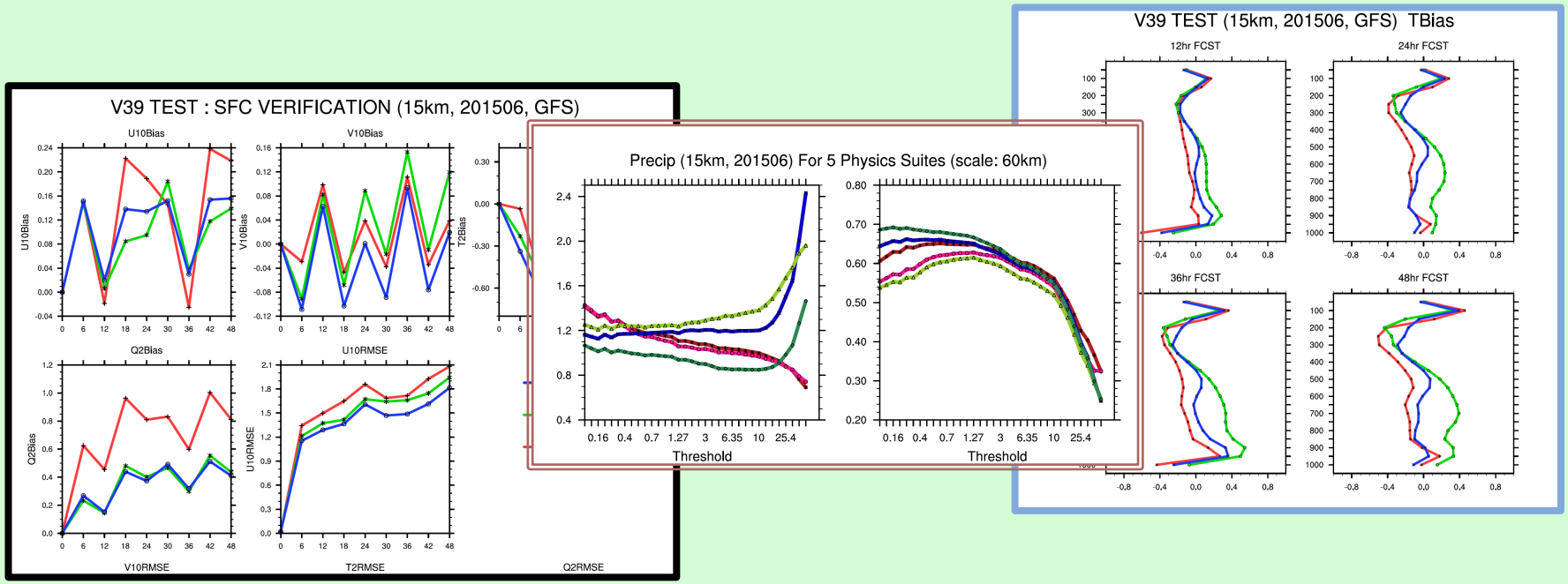
- *topo_wind =1* has been modified to allow for the diurnal cycle variation of sub-grid effect, where in daytime the effect is reduced
- Several important updates to RAP/HRRR physics (MYNN PBL, RUC LSM, GF cumulus)
- *icloud=3* has been improved slightly for surface solar flux
- Noah LSM fix to allow very small fractions of snow cover to melt away faster

Bug Fixes

- Bug since V3.7 *tmn_update=1* regional climate option on restarts would lead to gradual cooling of deep soil layers – fixed in V3.9
- Bug since V3.8: WSM3 and Kessler microphysics options would not provide cloud fractions to radiation – fixed in V3.9
- Bug, combination of Hi-res Ferrier microphysics with CAM radiation misses ice/snow contribution – fixed in V3.9
- Other bug-fixes were minor and listed on WRF V3.9 Updates page

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)
- 3 km – May/June 2016 – 18 cases – CONUS suite

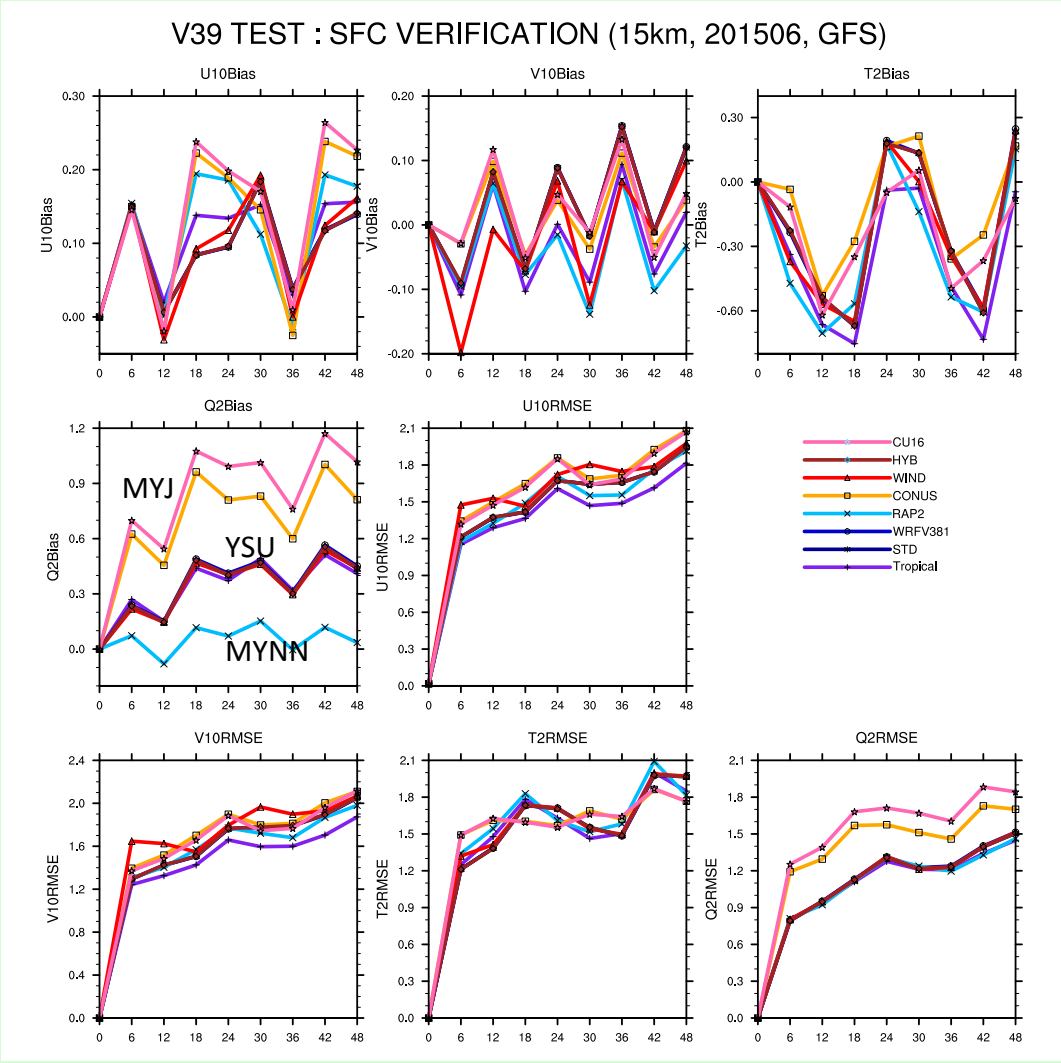


Test Suites

	Microphysics	Cumulus	Radiation	PBL	LSM
STD	WSM5	KF	RRTMG	YSU	Noah
Tropical	WSM6	New TDK	RRTMG	YSU	Noah
CONUS	Thompson	TDK	RRTMG	MYJ	Noah
CU16 (CONUS)	Thompson	New TDK	RRTMG	MYJ	Noah
RAP2 (RAP/ Noah)	Thompson-aero	GF	RRTMG	MYNN	Noah
RAP*	Thompson-aero	GF	RRTMG	MYNN	RUC
3 km (CONUS)	Thompson	none	RRTMG	MYJ	Noah

* We mostly show RAP2 because LSM initialization is with GFS soil

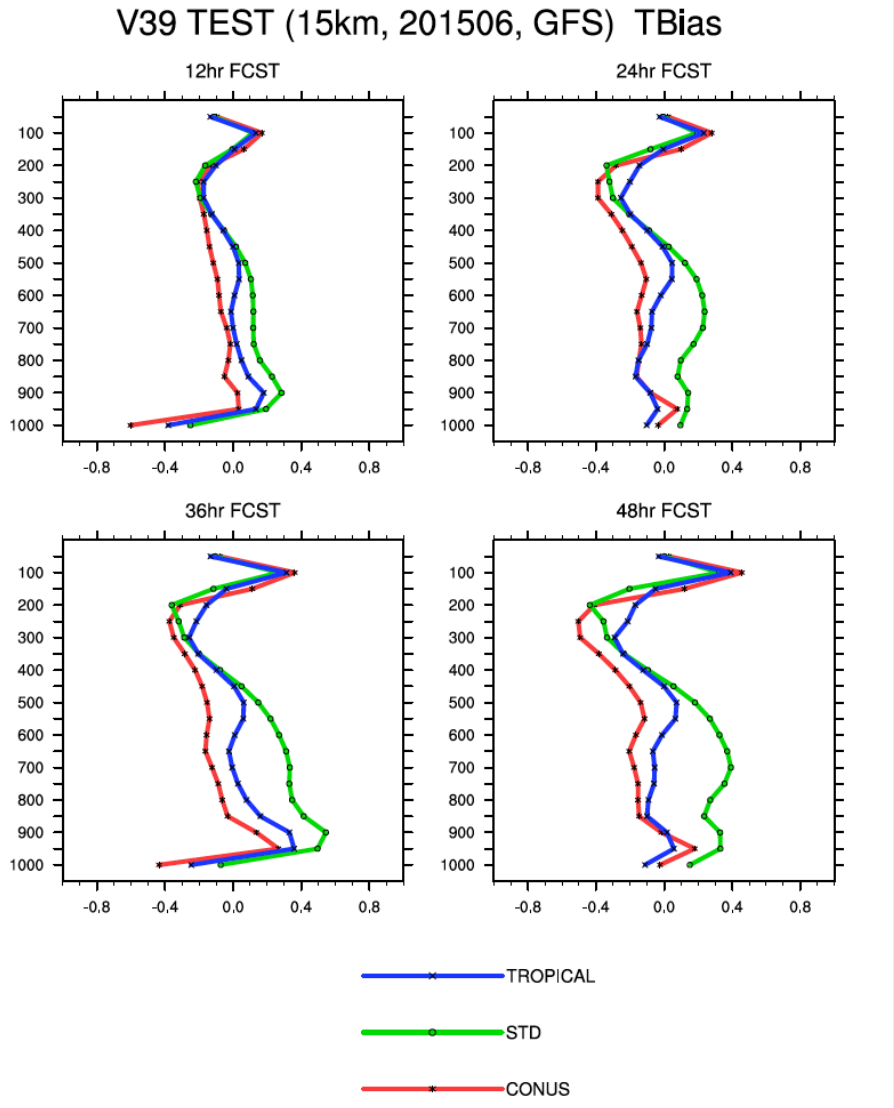
Surface Verification

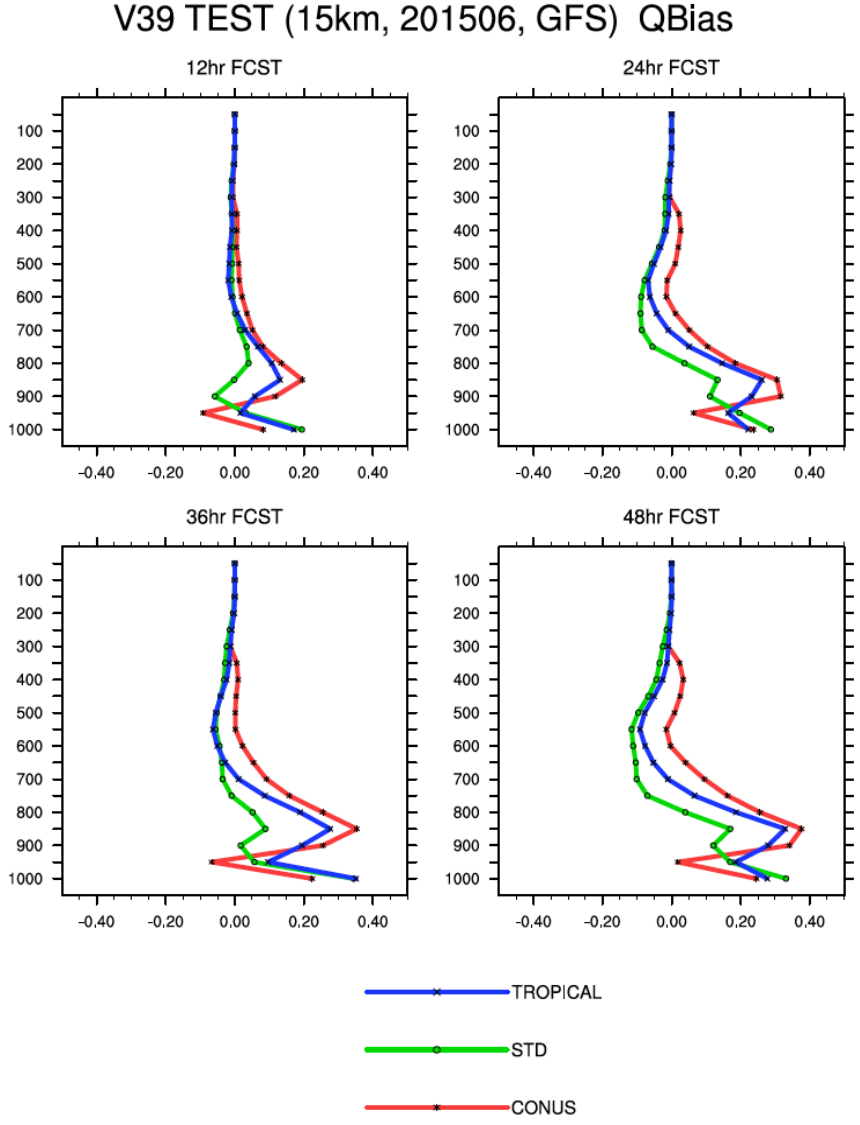


Summer versus GFS analysis

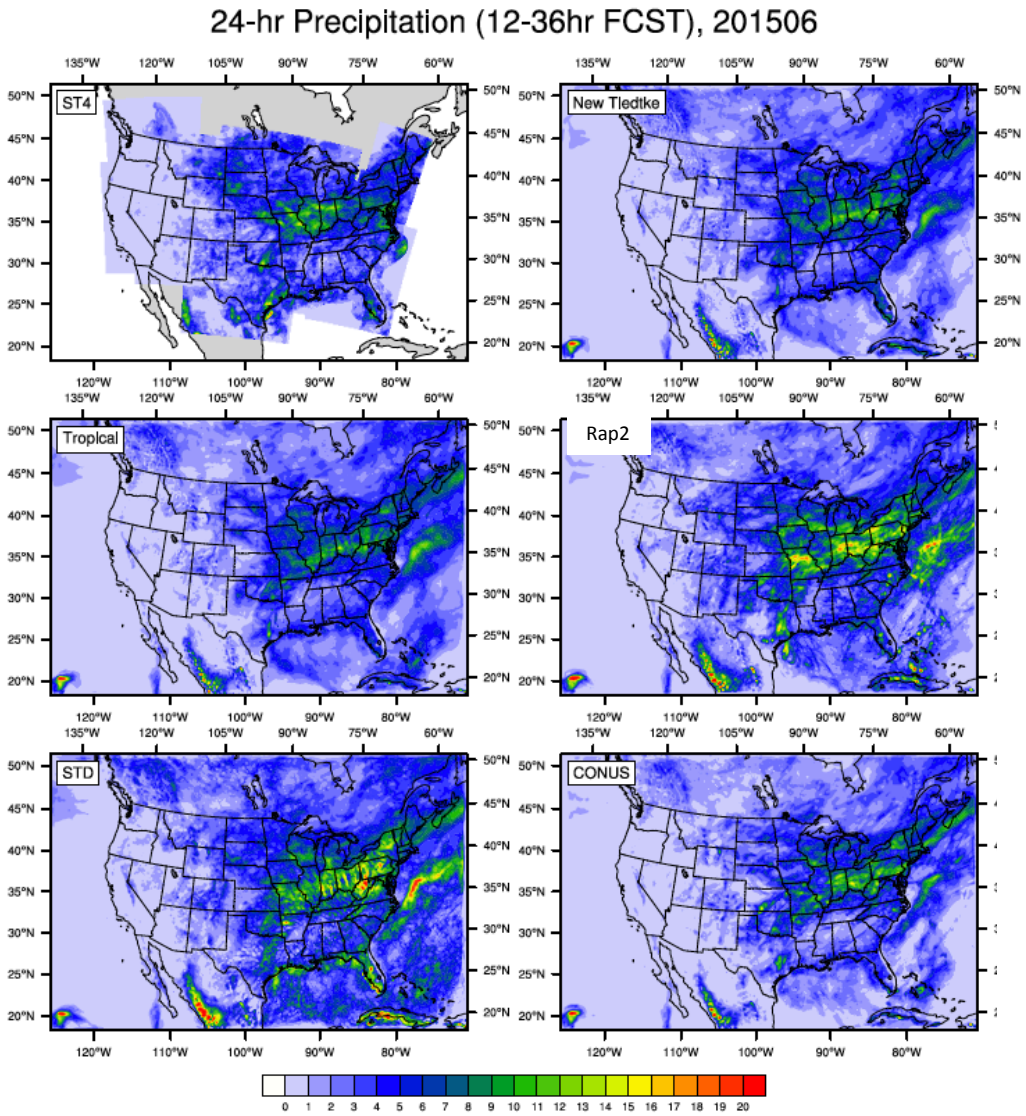
- CU16 and CONUS have higher 2m moisture bias (both MYJ suites) – also show in 2m T at 18Z
- MYNN has low 2m Qv bias
- For 2m T all other runs comparable including V3.8.1 versus V3.9 STD suite
- Hybrid coordinate test also shows no difference from STD

Profile Verification: Suites

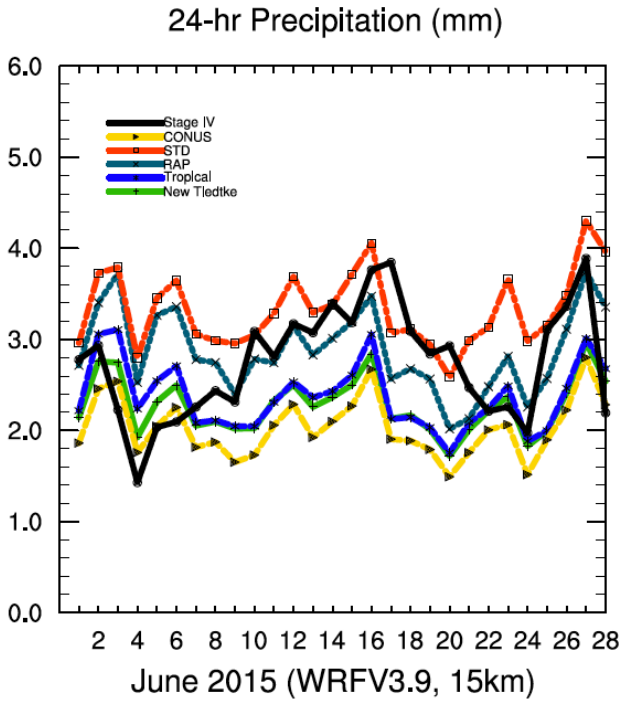




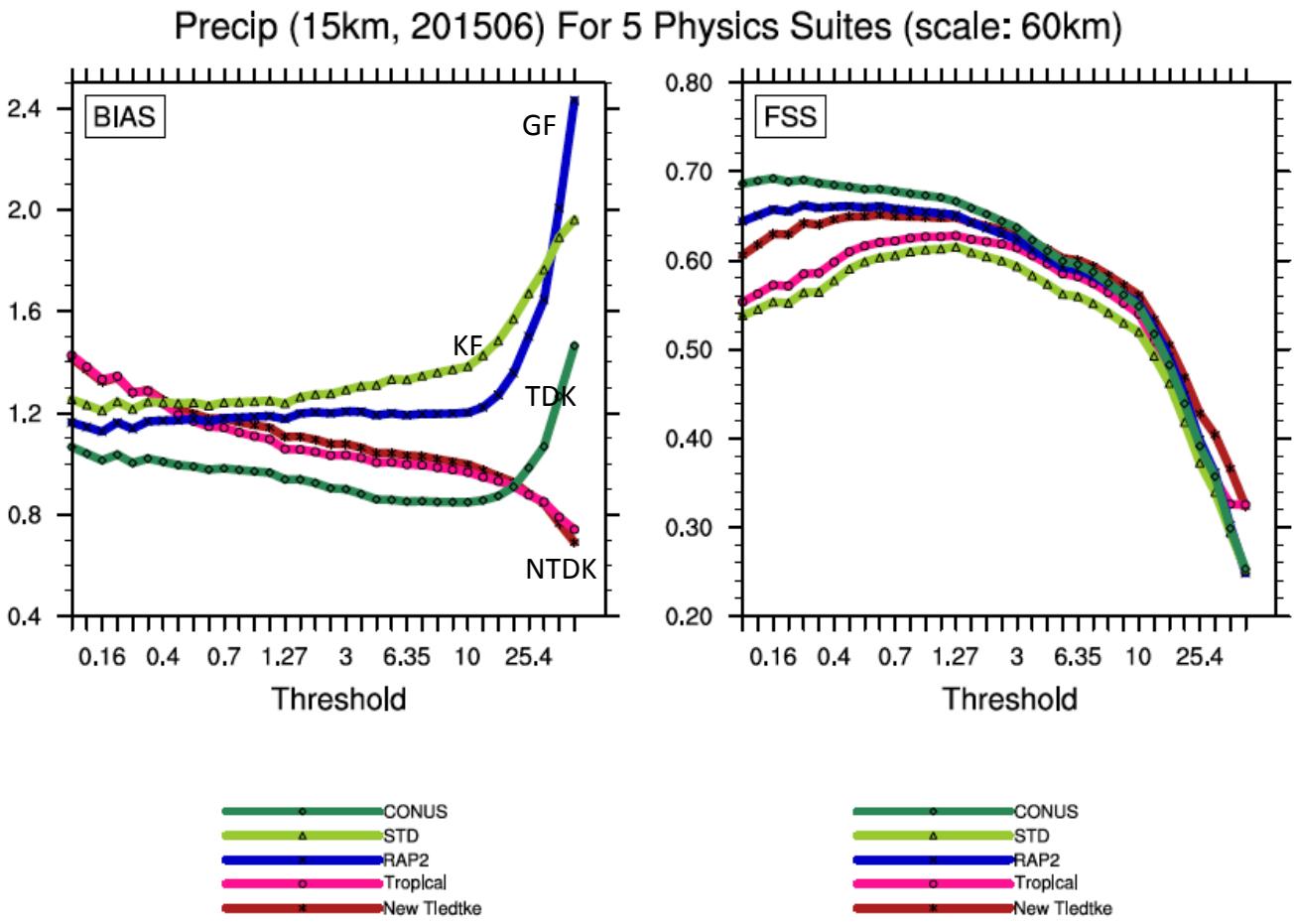
Precipitation Verification: 15 km Suites



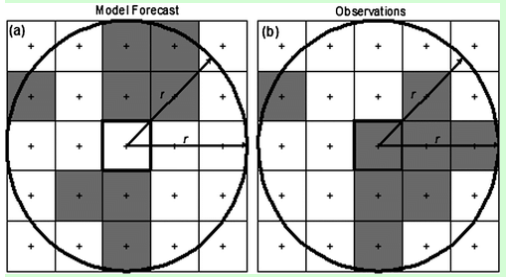
June 2015 daily-averaged precipitation (observation is ST4): STD and RAP2 have higher peak values



Precipitation Verification: 15 km Suites

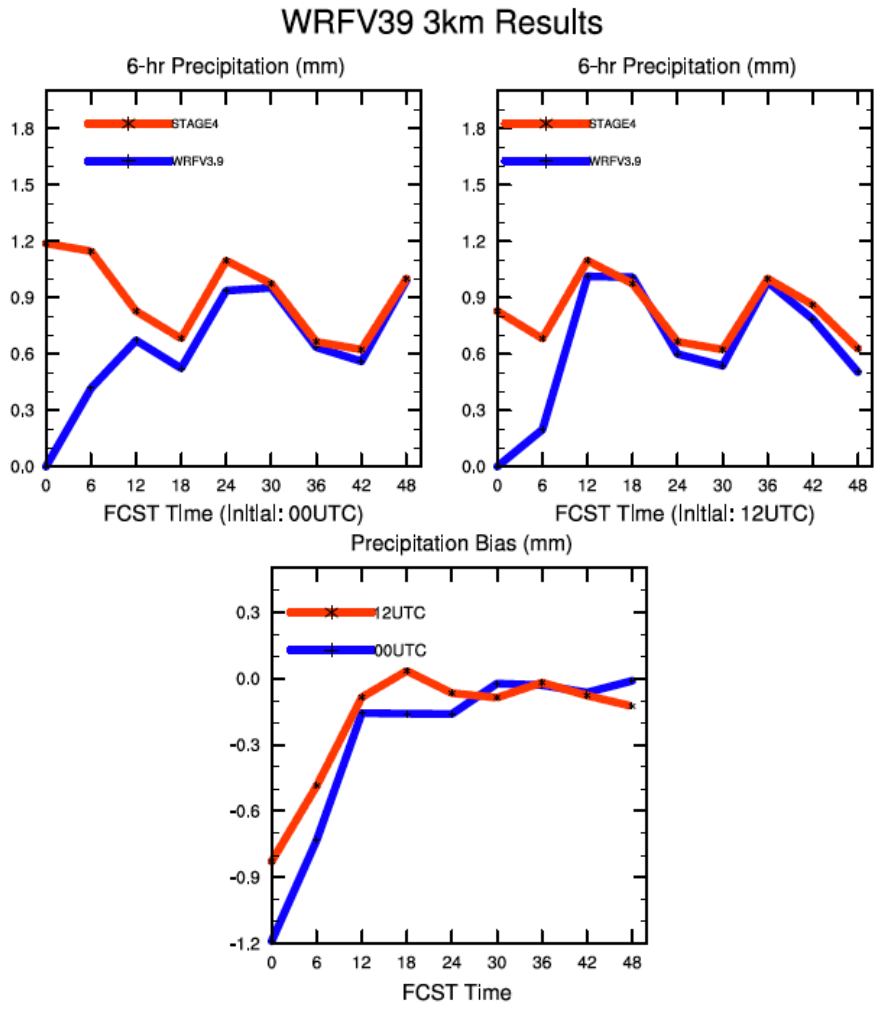


FSS = fractional skill score – verifies probability within radius (accumulated monthly stats)



Note: Biases same in Tropical and "New Tiedtke" which both contain same cumulus scheme but different other physics

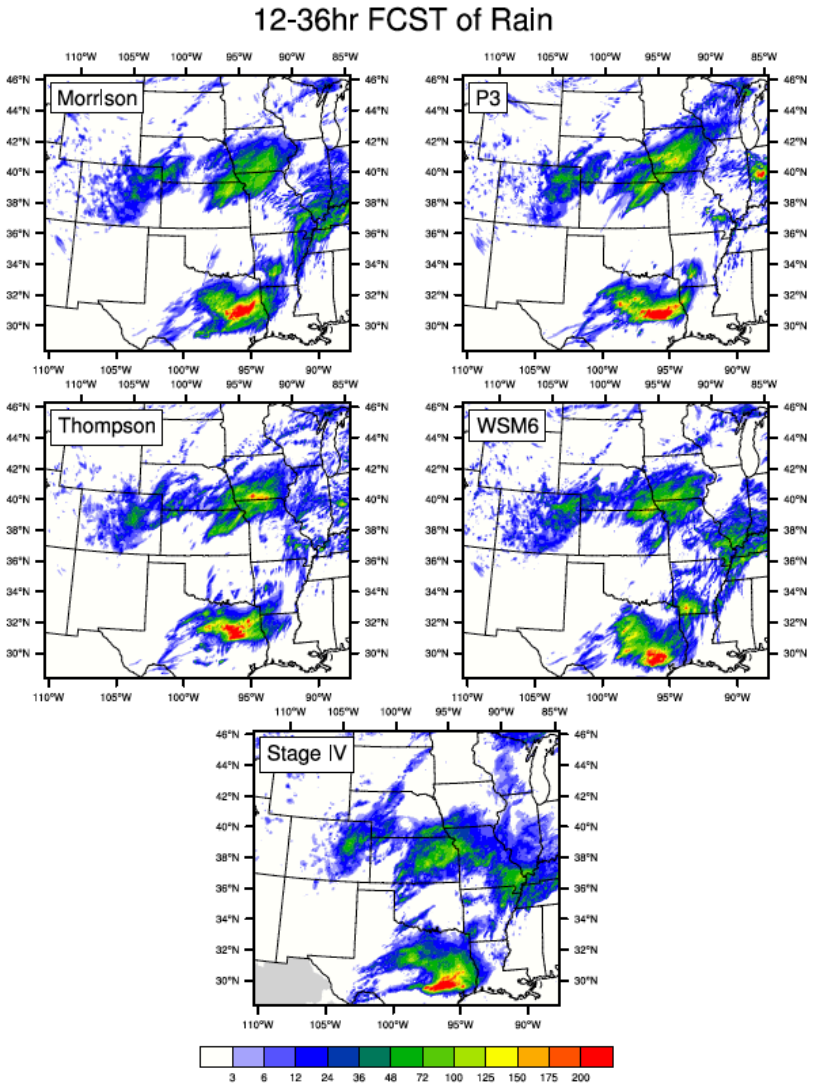
Precipitation Verification: 3 km CONUS



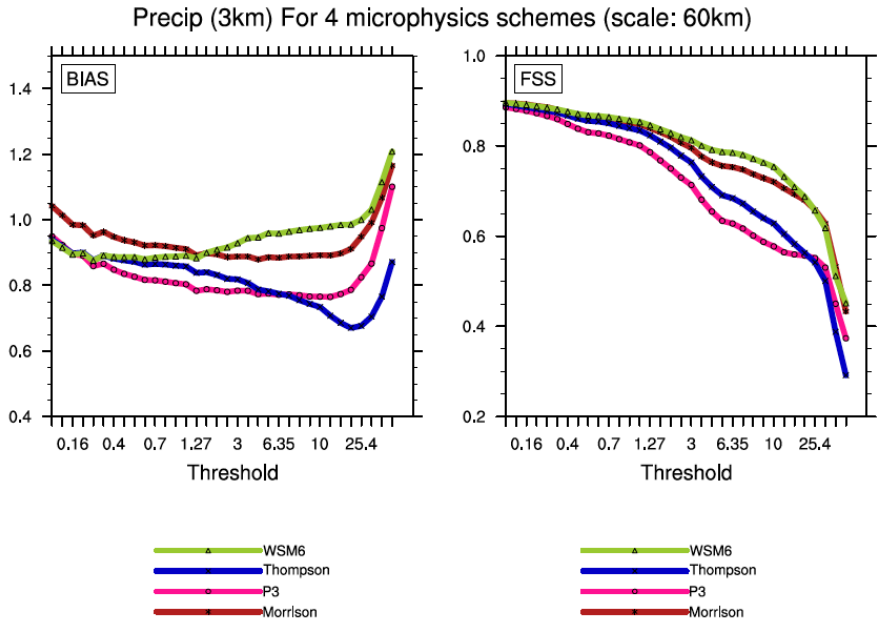
May/June 2016 average diurnal cycle of 6-hour precipitation (observation is STAGE4)

- 00Z init shows spin-up
- Biases small after spin-up period of ~6 hrs

Microphysics Comparison: 3 km Case



Testing P3 against Morrison, Thompson and WSM6 in *single case*



Version 4.0

- Planned for next major release in April 2018
- Hybrid Coordinate built in (no special pre-processing of code)
- Thermodynamic variable changes from θ to θ_m

  $\theta_m = \theta\,(1+(R_v/R_d)*q_v) \approx \theta\,(1+1.61*q_v)$

  - Note difference from $\theta_v \approx \theta\,(1+0.61*q_v)$

  – θ_m is used in MPAS and was used in old height coordinate version of WRF (see Klemp et al., 2007, MWR)
  – This variable is more closely related to pressure in moist conditions which has subtle dynamical benefits
  – In V3.9 use_theta_m does this transformation
  – When built into code and boundary files, code is simplified
- Lateral boundary file becomes uncoupled

WRF/MPAS User Support

- Considering forum-based approach
  - Pros
    - User can search for previous answers to their questions
    - Answers can be seen by all and may be useful for general awareness of issues
    - Other users can answer questions in addition to official NCAR support that will be maintained
    - Forum can be organized by topics such as compiling, preprocessing, runtime problems, regional climate, etc.
  - Cons
    - Some problems require iterations of tests and data transfers so this seems to need an offline capability to be maintained
    - Not clear how to present resolution of these problems back to forum
    - Moderation needed as well as vetting answers

Thanks