Thompson MP in the FV3GFS

Ruiyu Sun

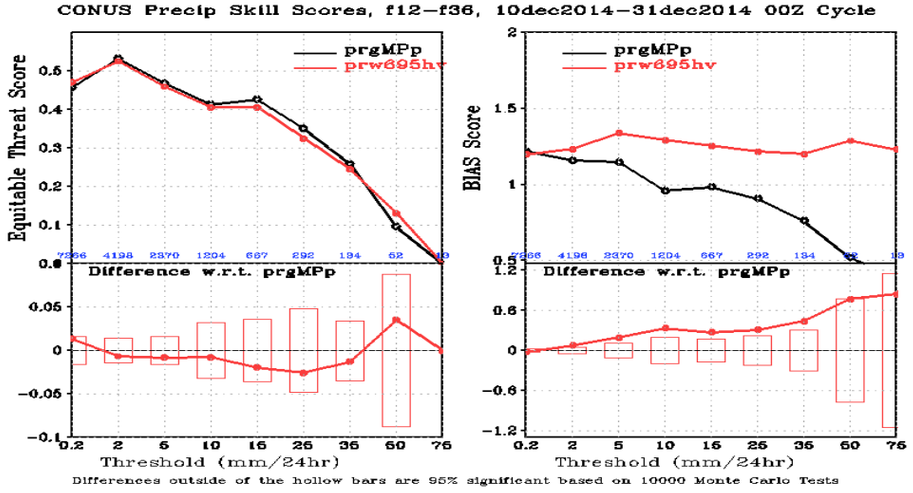
Fanglin, Jun, Rusty, Greg Thompson, Vijay, Moorthi, Yu-Tai, Anning, Huiya, Jongil, Brad Ferrier, and other colleagues

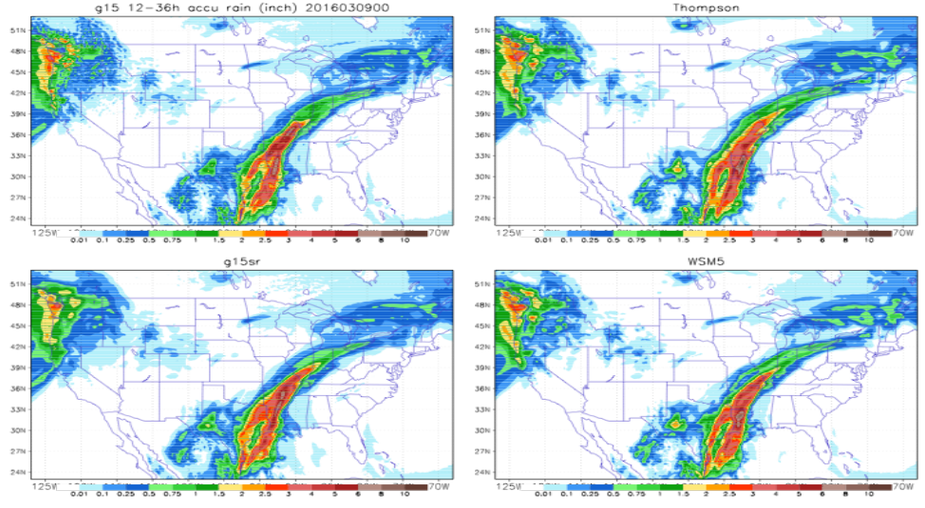
Available MP options in NGGPS

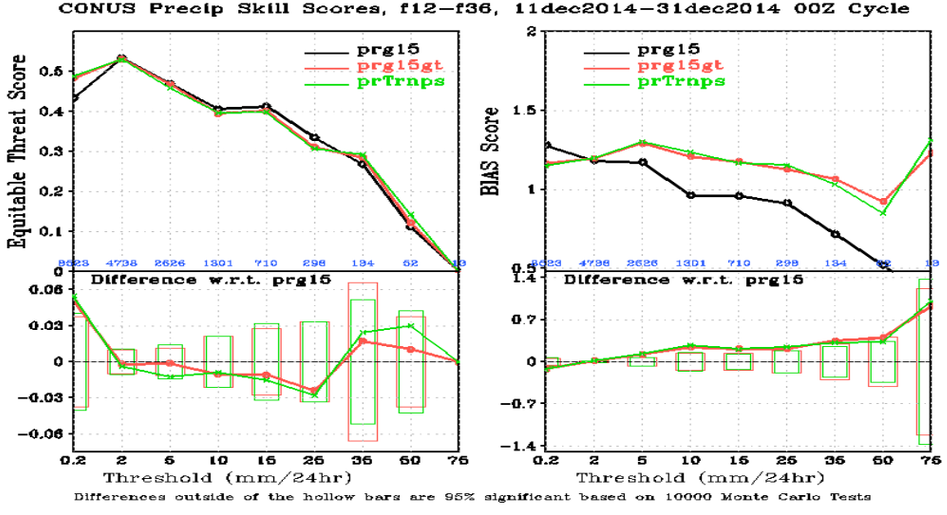
	Ferrier &Aligo	GFDL MP	WSM6	MG (double) (from GMAO)	Thompson (double) 2008/2014
prognositic variables	qv, qc, qr, qi+qs+qg, RF1/2	qv, ql, qi, qs, qr, qg	qv, ql, qi, qs, qr, qg	qv, ql, ,nl, qi, ni (qr, nr, qs, ns) Aerosol aware	qv, ql, qi, qs, qr, qg, ni, nr (2008) + nc, nwfa, nifa (2014 aerosol-aware)
condensation and evaporation	Asai (1965)	Asai (1965)	Yau and Austin (1997)	MG2008, MG2015, Barahona et al 2014 SHOC 2013	Yau and Austin (1997), Thompson and Eidhammer(2014)
mixed-phase clouds	yes	yes	yes	yes	yes
precipitation sedimentation	qi, qr, qs, qg sediment vertically	qi,qr,qs,gq sediment verically	qi, qr, qs,qg sediment vertically	qc and qi sediment vertically (testing prognostic qr and qs)	qi, qr, qs, qg sediment vertically

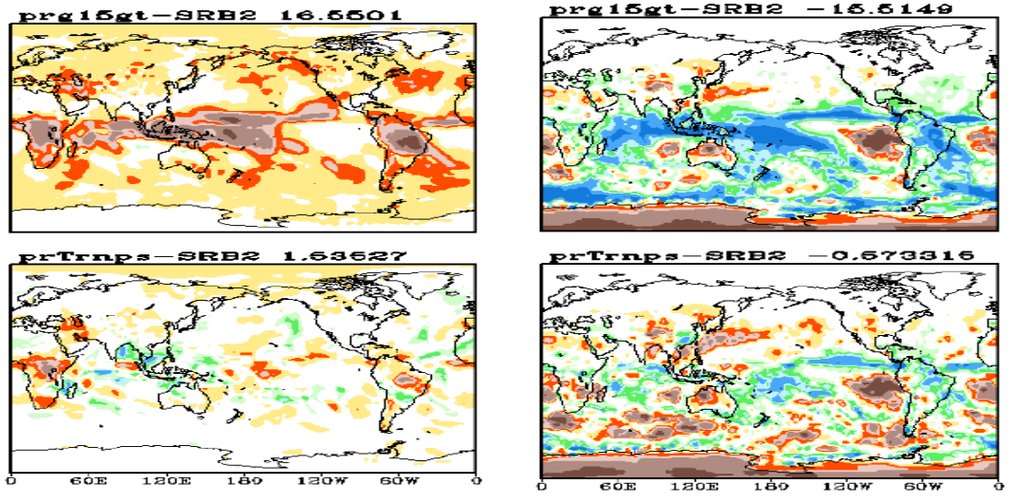
Thompson and WSM6 MPs in NEMS/GSM

Ruiyu Sun







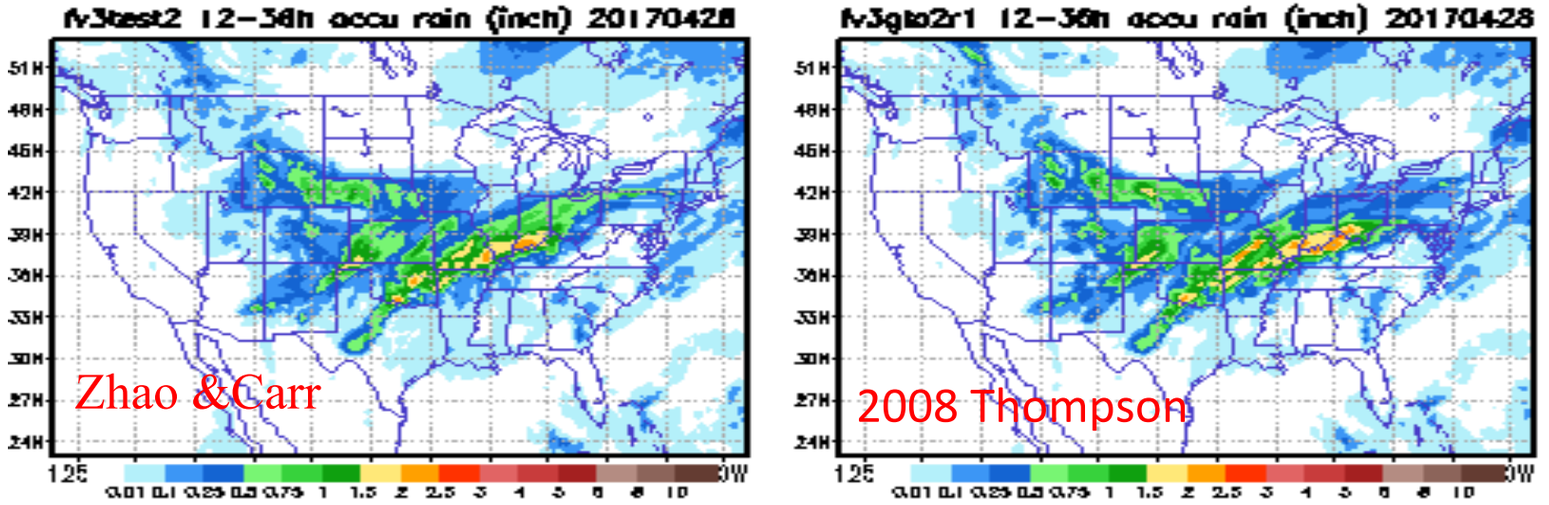


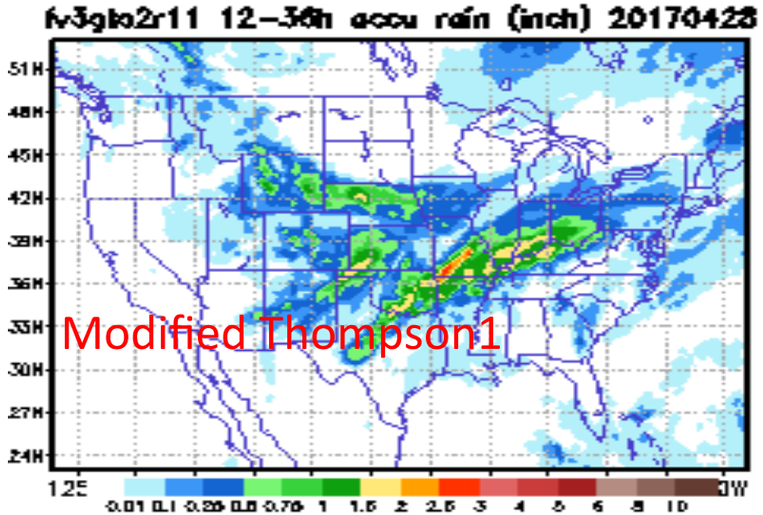
- Both schemes were Tested in the operational GFS
- Thompson MP significantly improved the cloud radiative effects
- Thomspon MP significantly improved the precipitation skill score in the light rain, but degraded in the moderate range
- Both scheme eliminated spotty precipitation seen in the GFS with Zhao and Carr (1997)
- Thompson MP is testing in FV3GFS

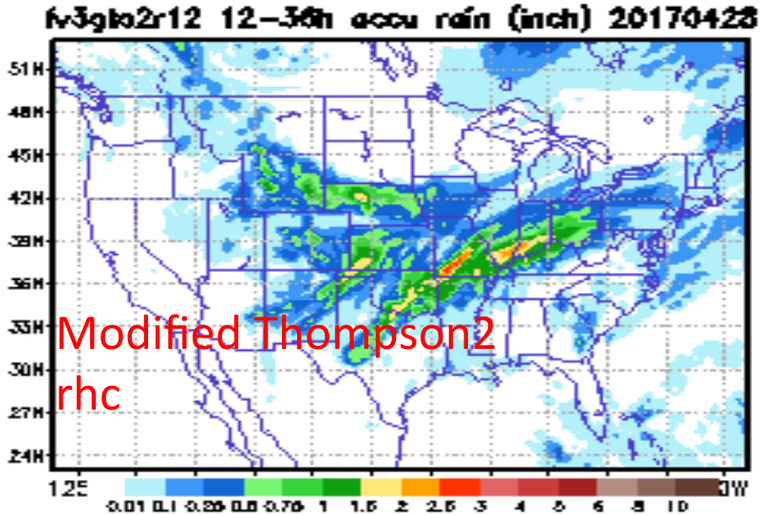
10 Day Forecast Experiments (ICs = 2017042800)

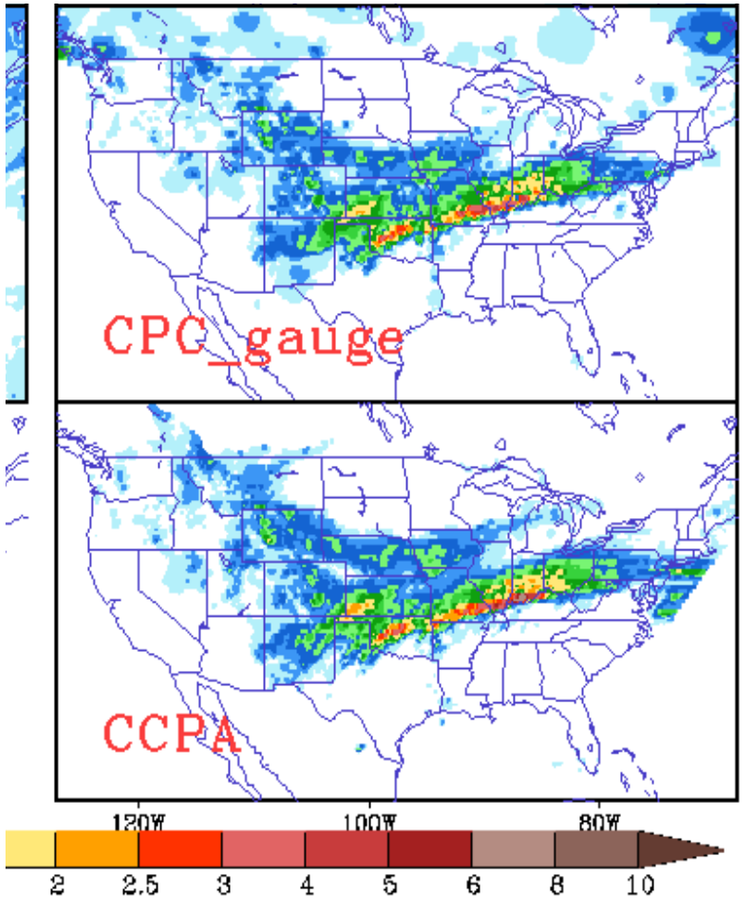
1. **fv3test2**: default physics with Zhao & Carr (Zhao&Carr)
2. **fv3gto2r1**: fv3test2 + original 2008 Thompson MP replaces Zhao_carr + close coupling with radiation + ice number for detrained cloud ice from deep and shallow convection + snow treated as ice in cloud cover calculation in radiation (2008 Thompson)
3. **fv3gto2r11f**: **fv3gto2r1** + modifications of cloud drop number and ice nucleation (Modified Thompson 1)
4. **fv3gto2r12f**: **fv3gto2r11f** + rhc partial cloudiness (Modified Thompson2:rhc)

12-36h CONUS Precipitation Map



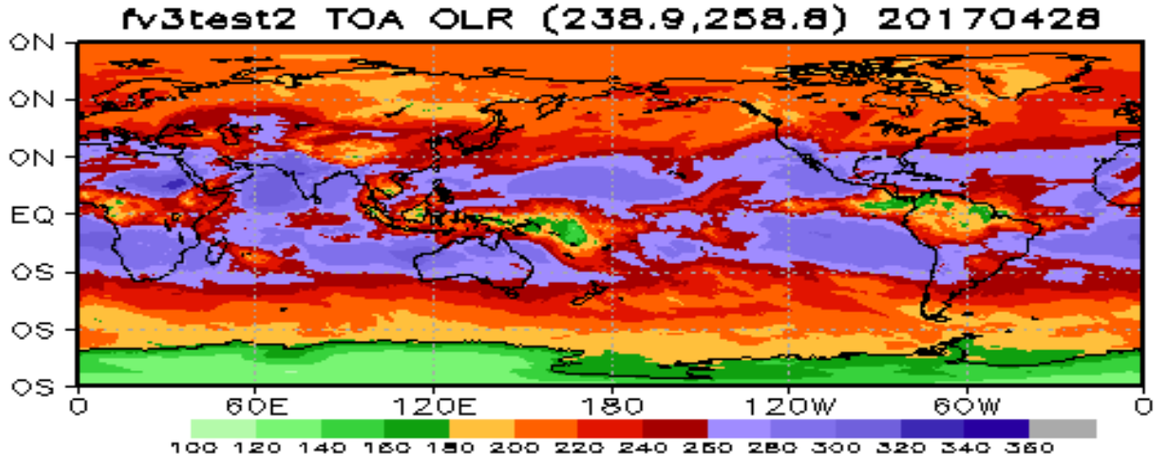




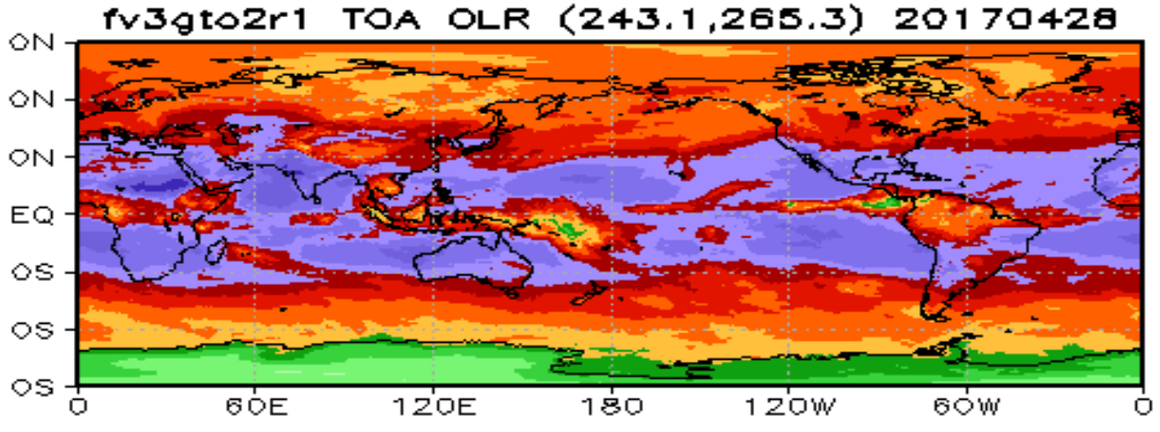


2-10day Mean Global OLR

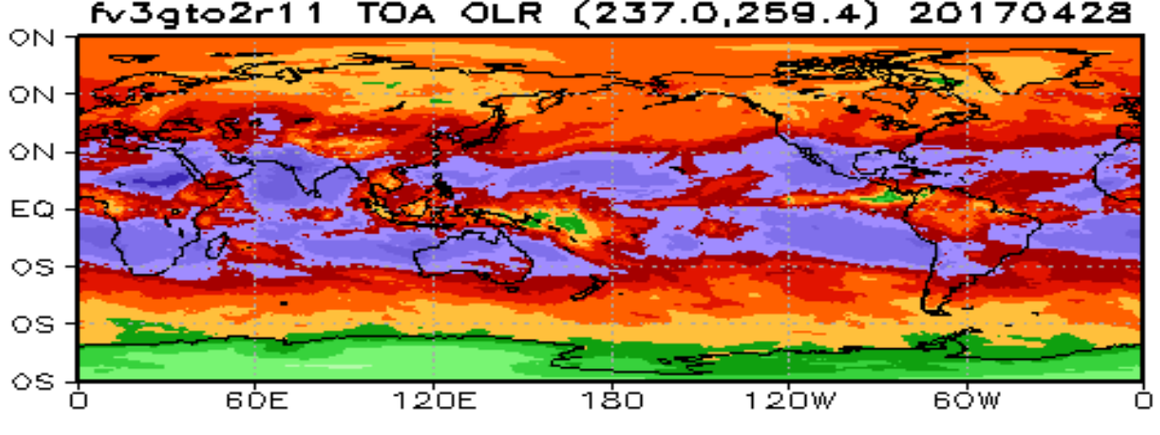
Zhao &Carr



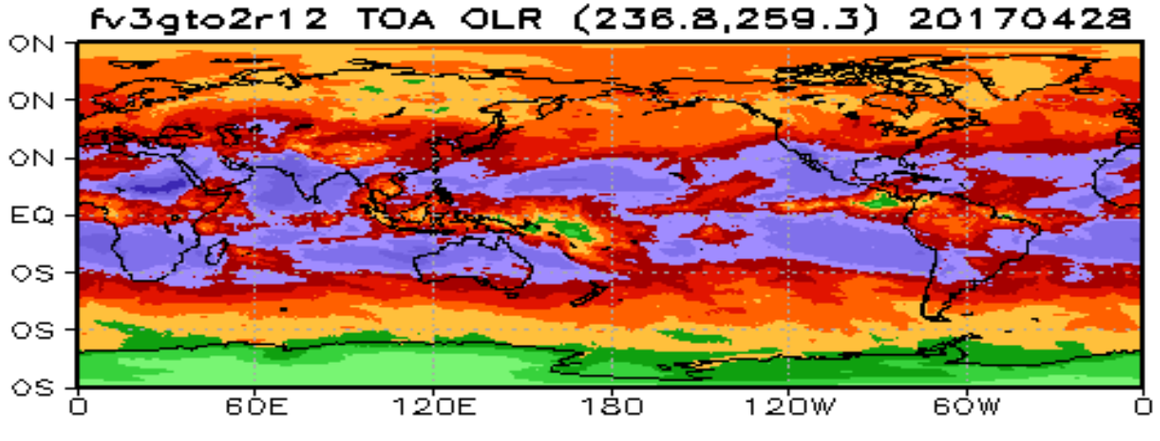
2008 Thompson



Modified Thompson1

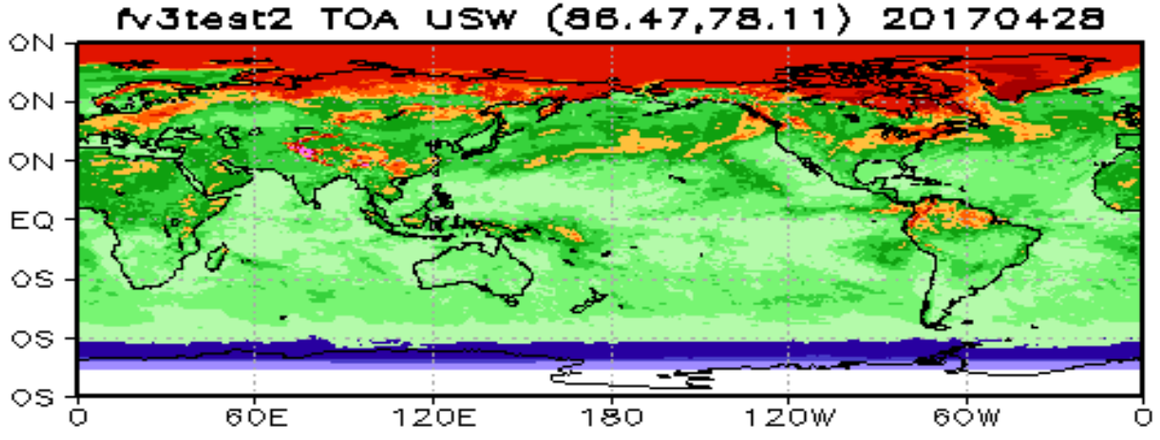


Modified Thompson2 rhc

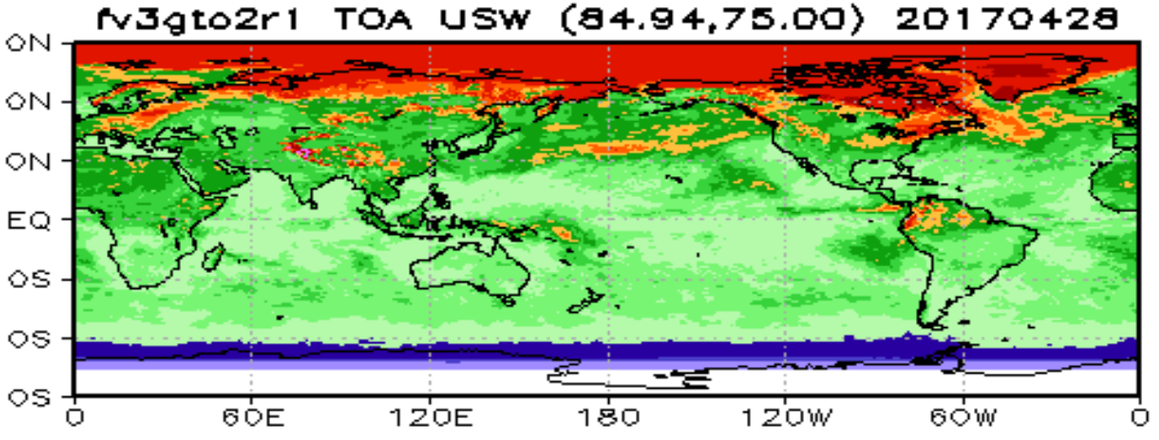


2-10day Mean Global USW at TOA

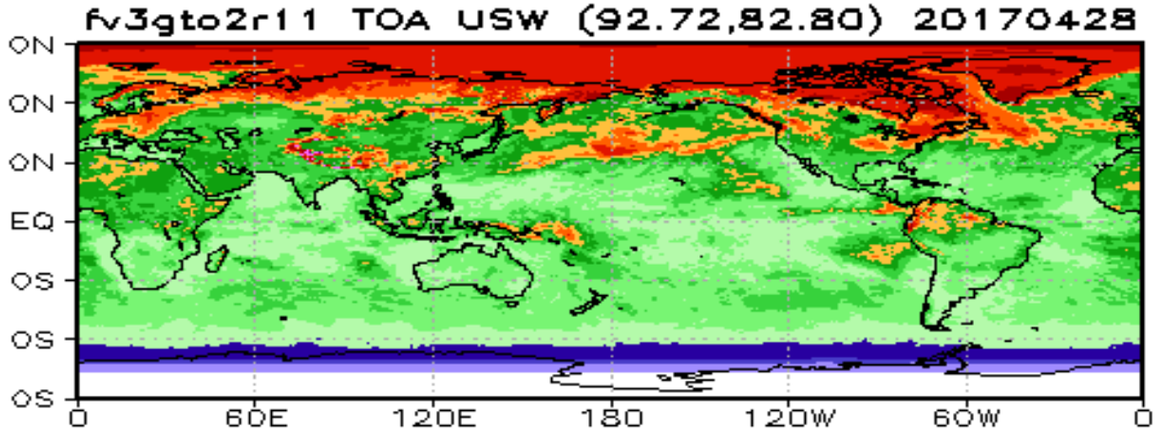
Zhao &Carr



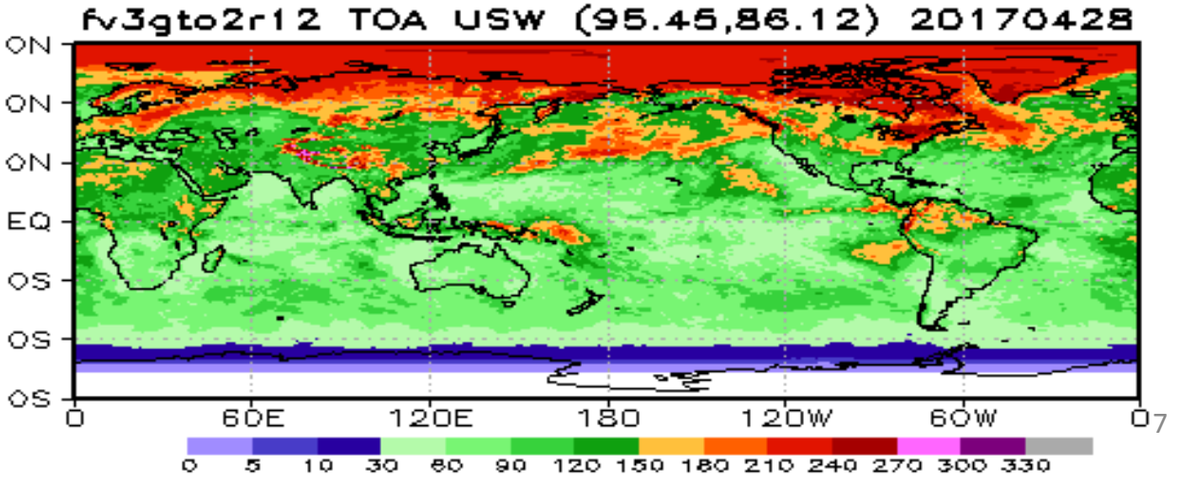
2008 Thompson



Modified Thompson1

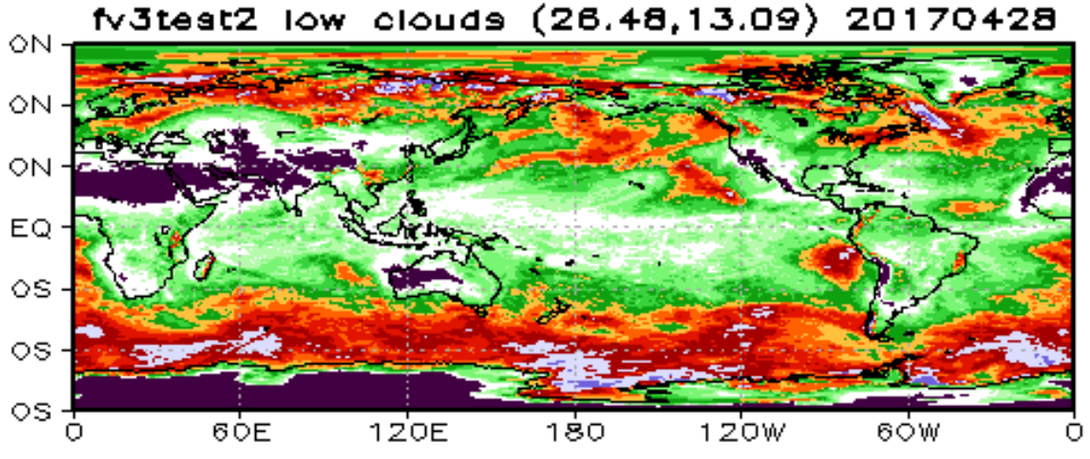


Modified Thompson2 rhc

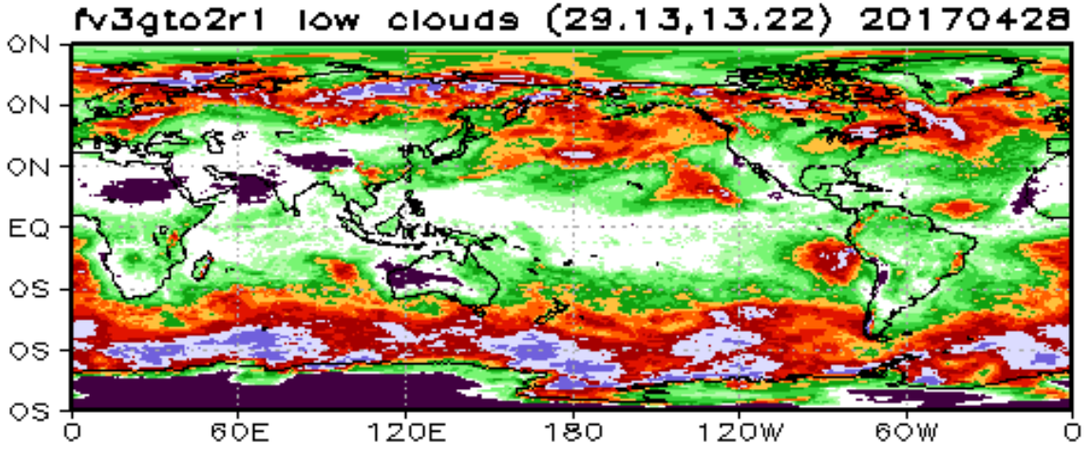


2-10day Mean Global Low Clouds

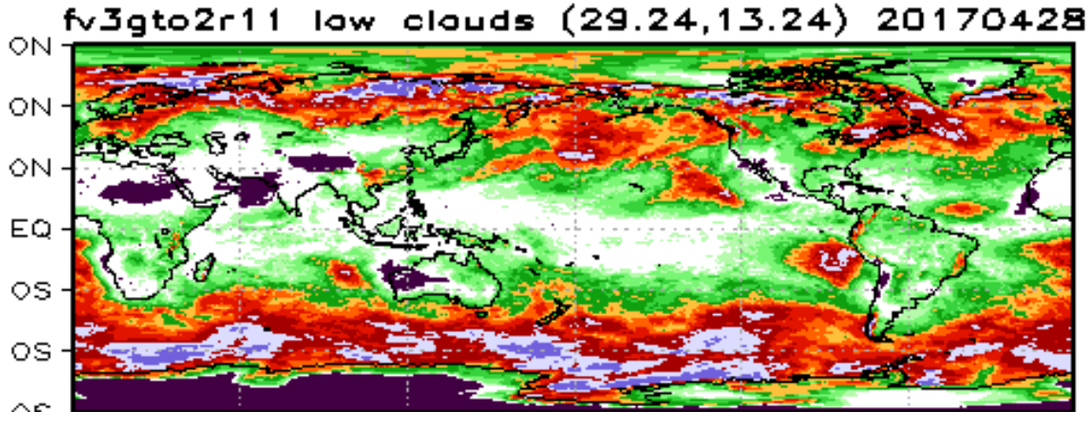
Zhao &Carr



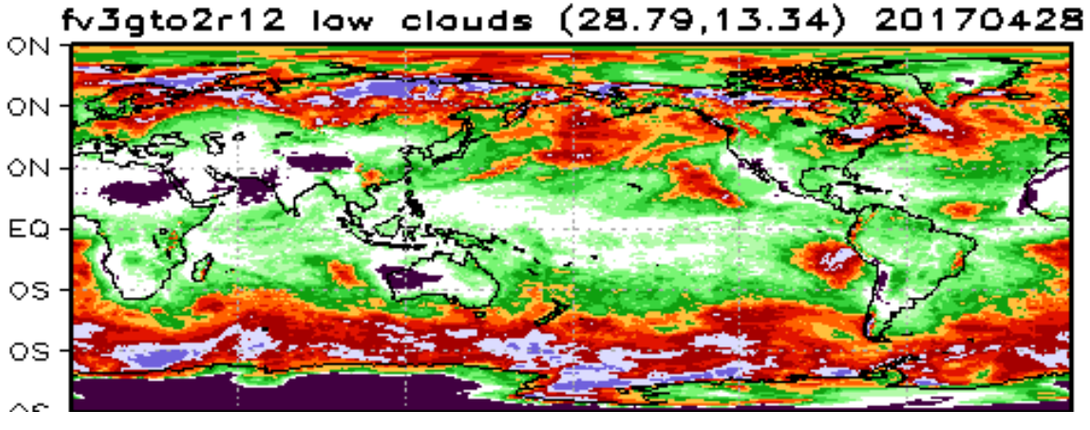
2008 Thompson



Modified Thompson1

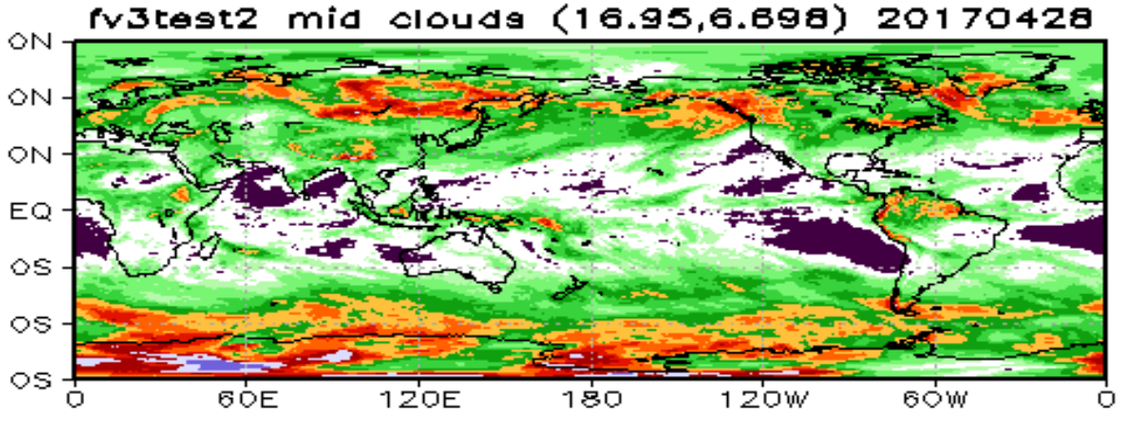


Modified Thompson2 rhc

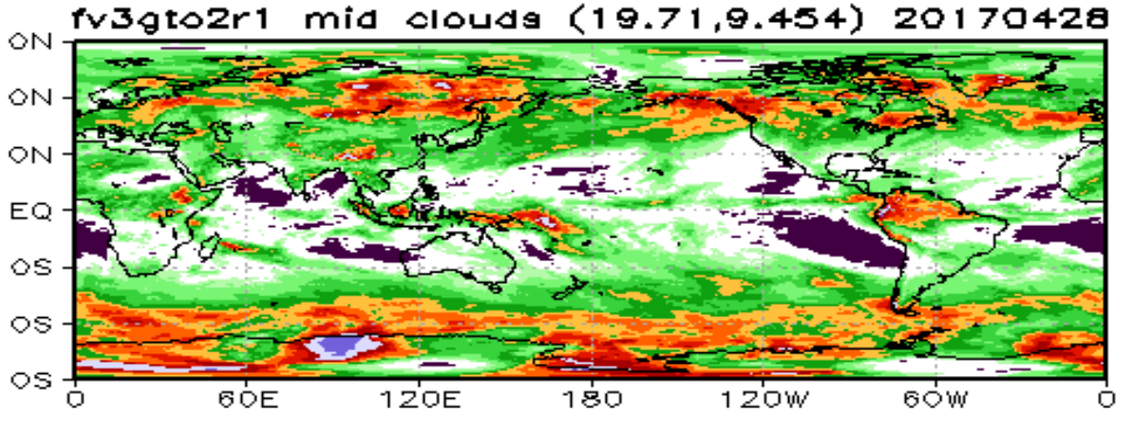


2-10day Mean Global Middle Clouds

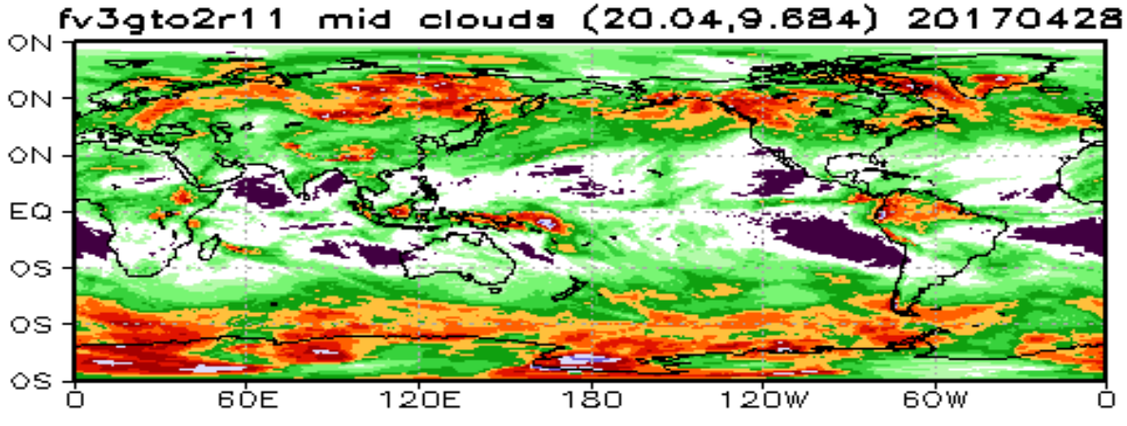
Zhao &Carr



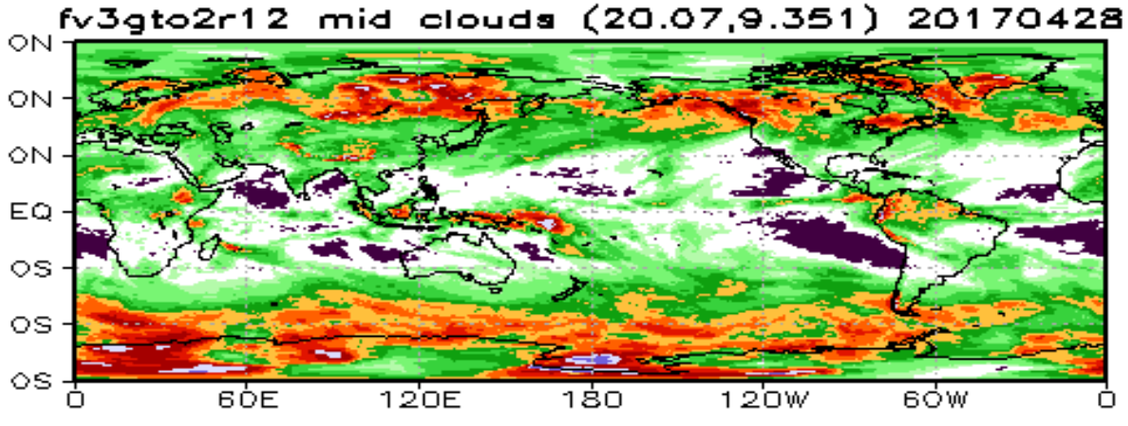
2008 Thompson



Modified Thompson1

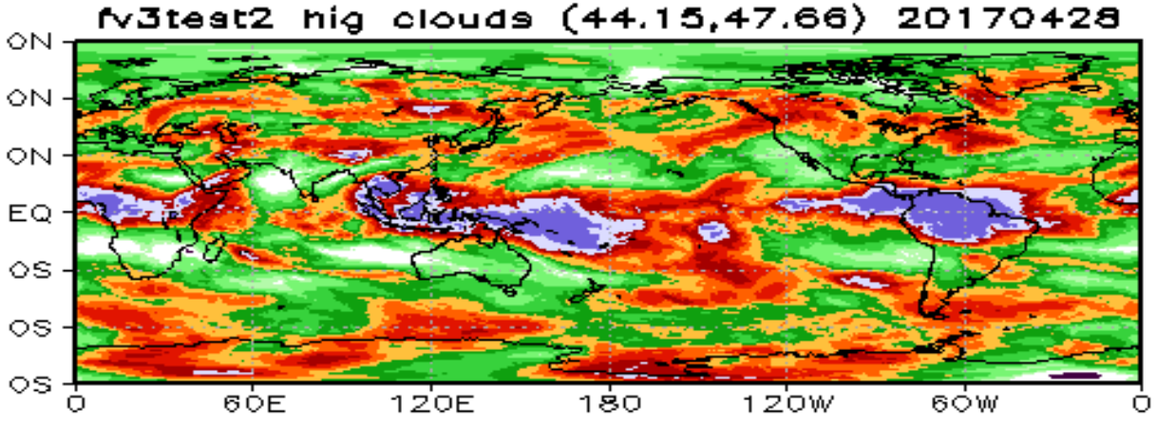


Modified Thompson2 rhc

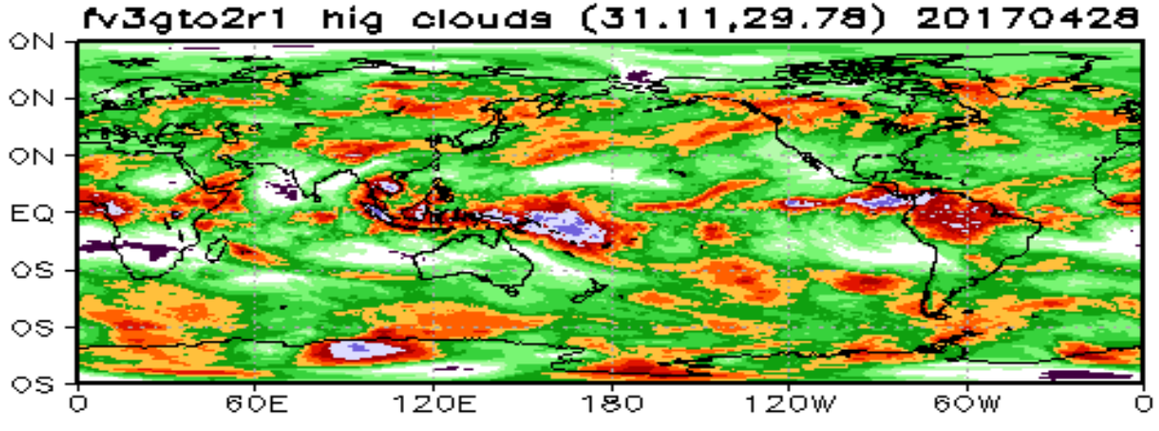


2-10day Mean Global High Clouds

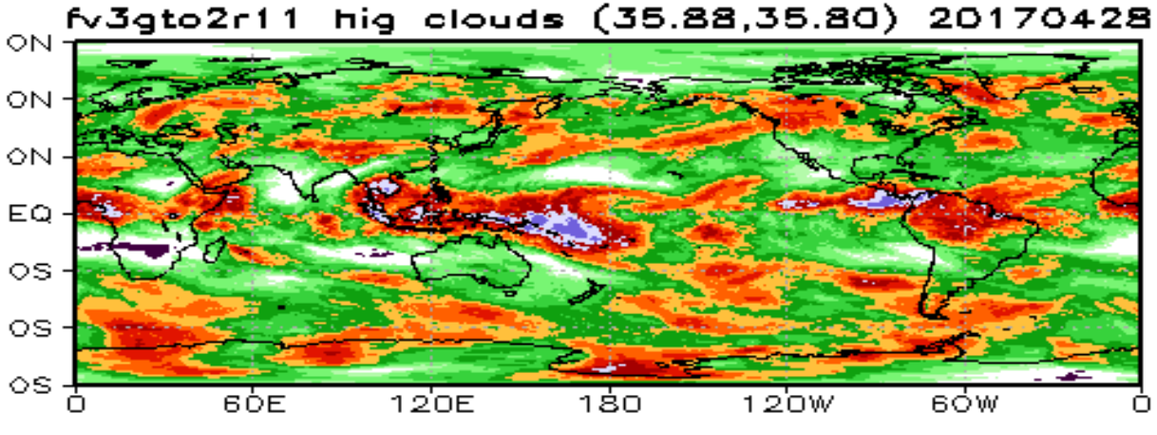
Zhao &Carr



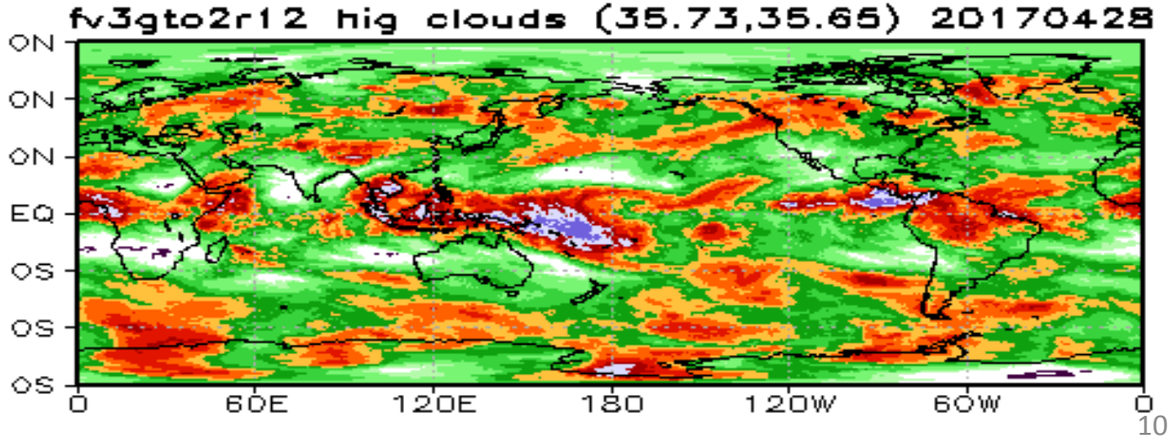
2008 Thompson



Modified Thompson1

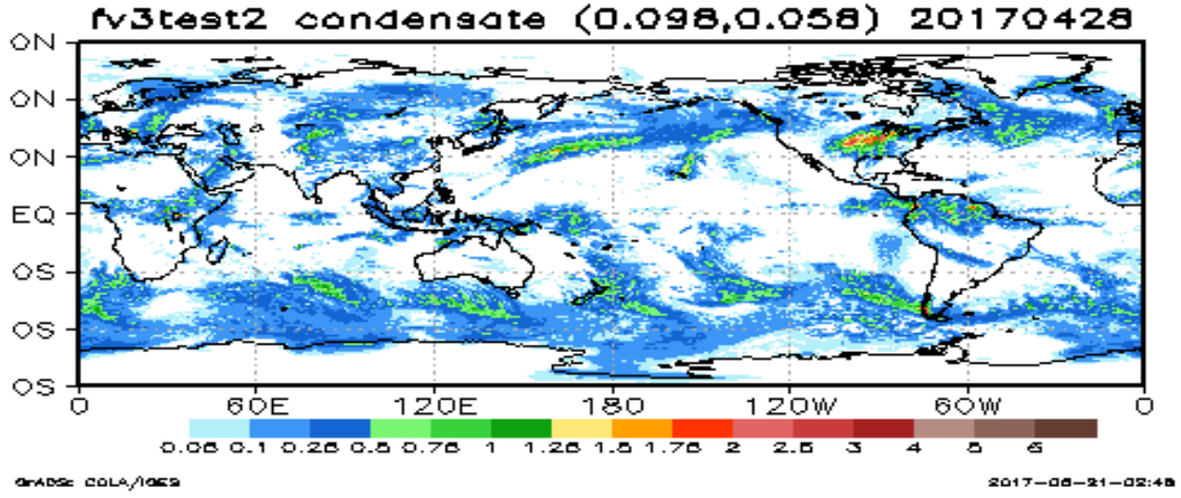


Modified Thompson2 rhc

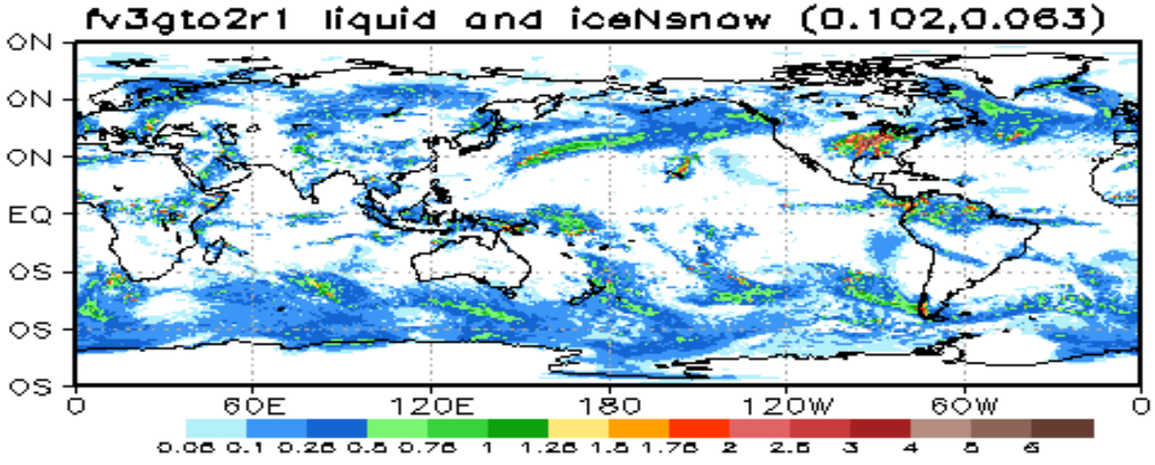


2-10day Global Condensate Path (ice + liquid + snow)

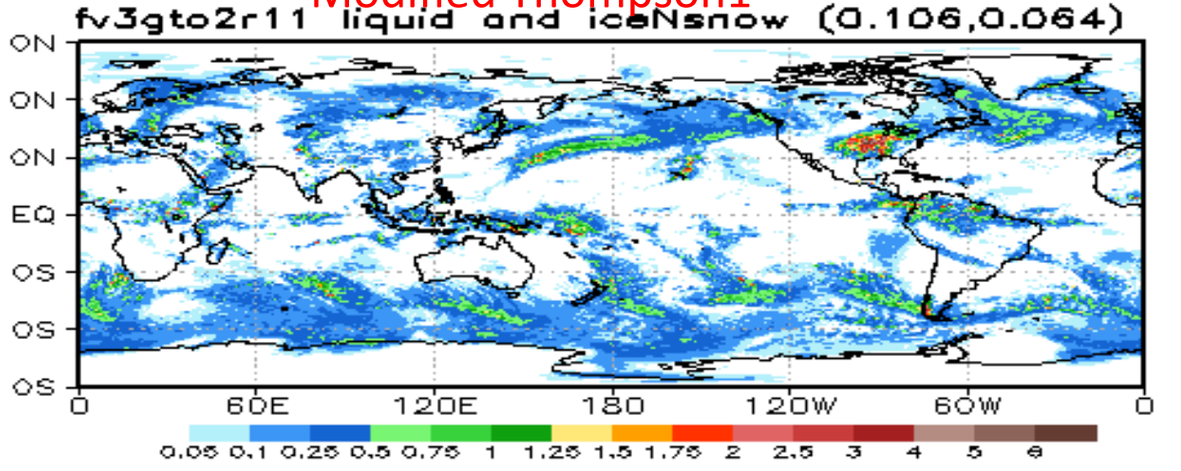
Zhao &Carr



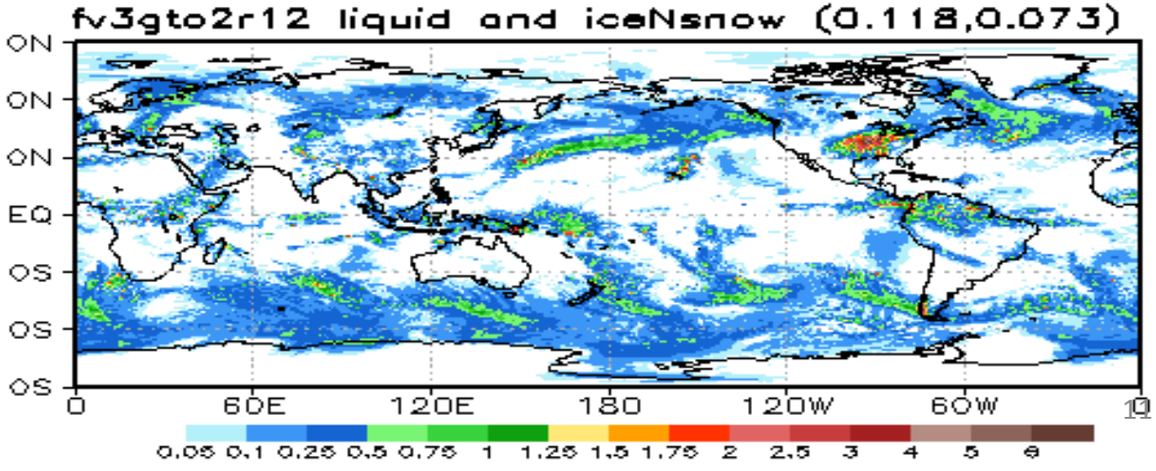
2008 Thompson



Modified Thompson1

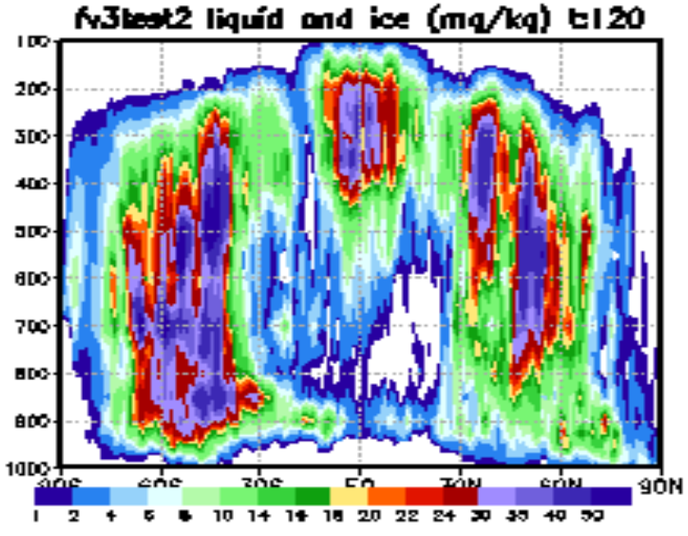


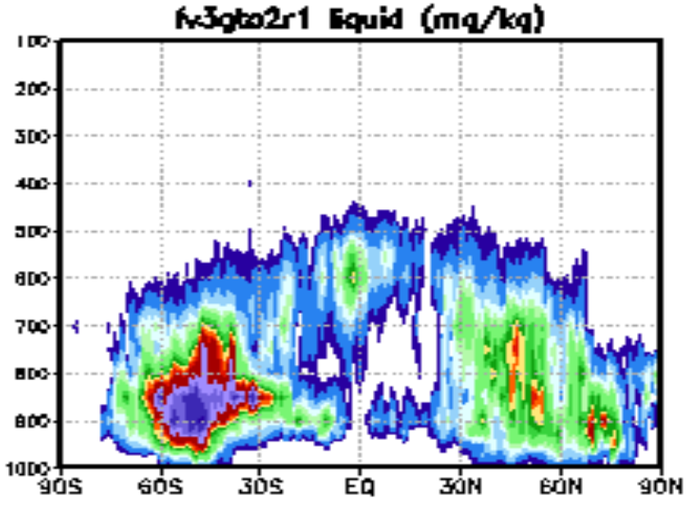
Modified Thompson2 rhc



Liquid Cross-section at 120h

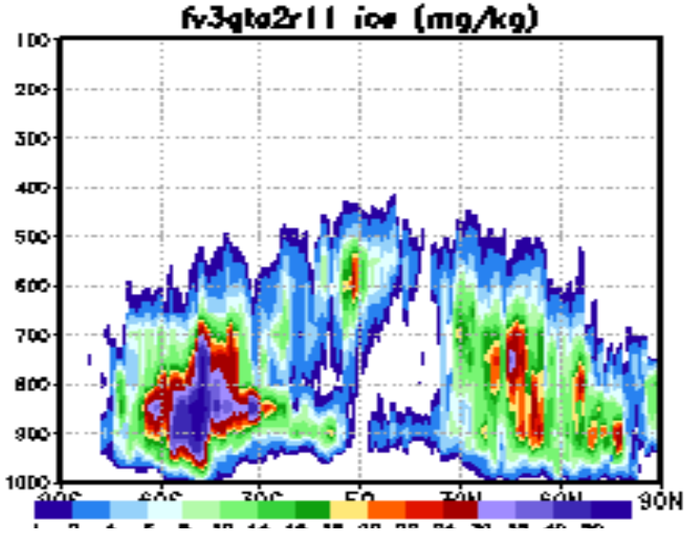
Zhao &Carr

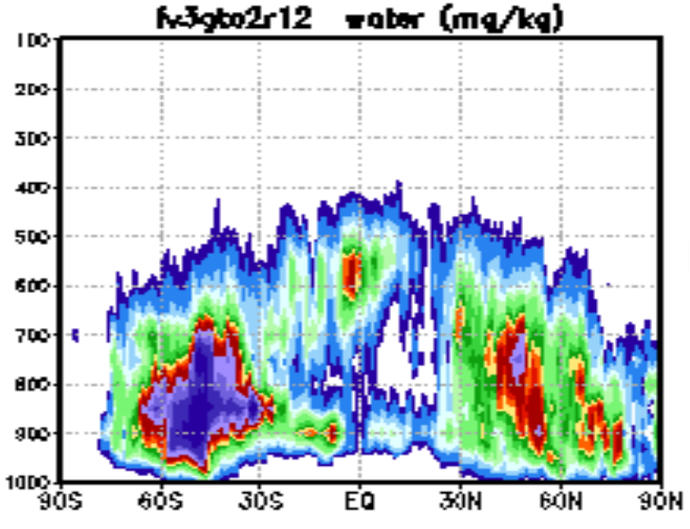




2008 Thompson

Modified Thompson1





Modified Thompson2 rhc

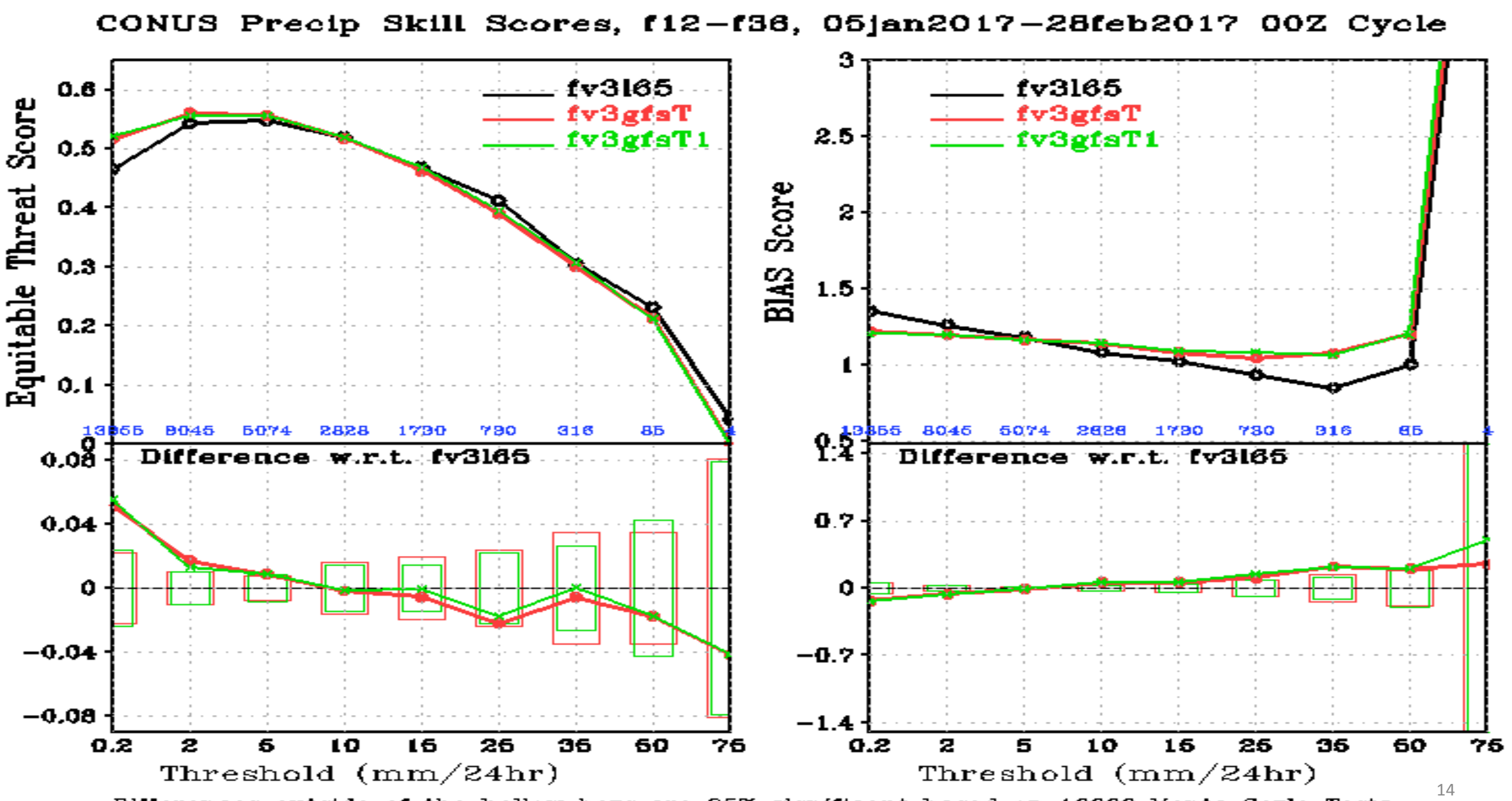
Winter Precipitation Statistics (I)

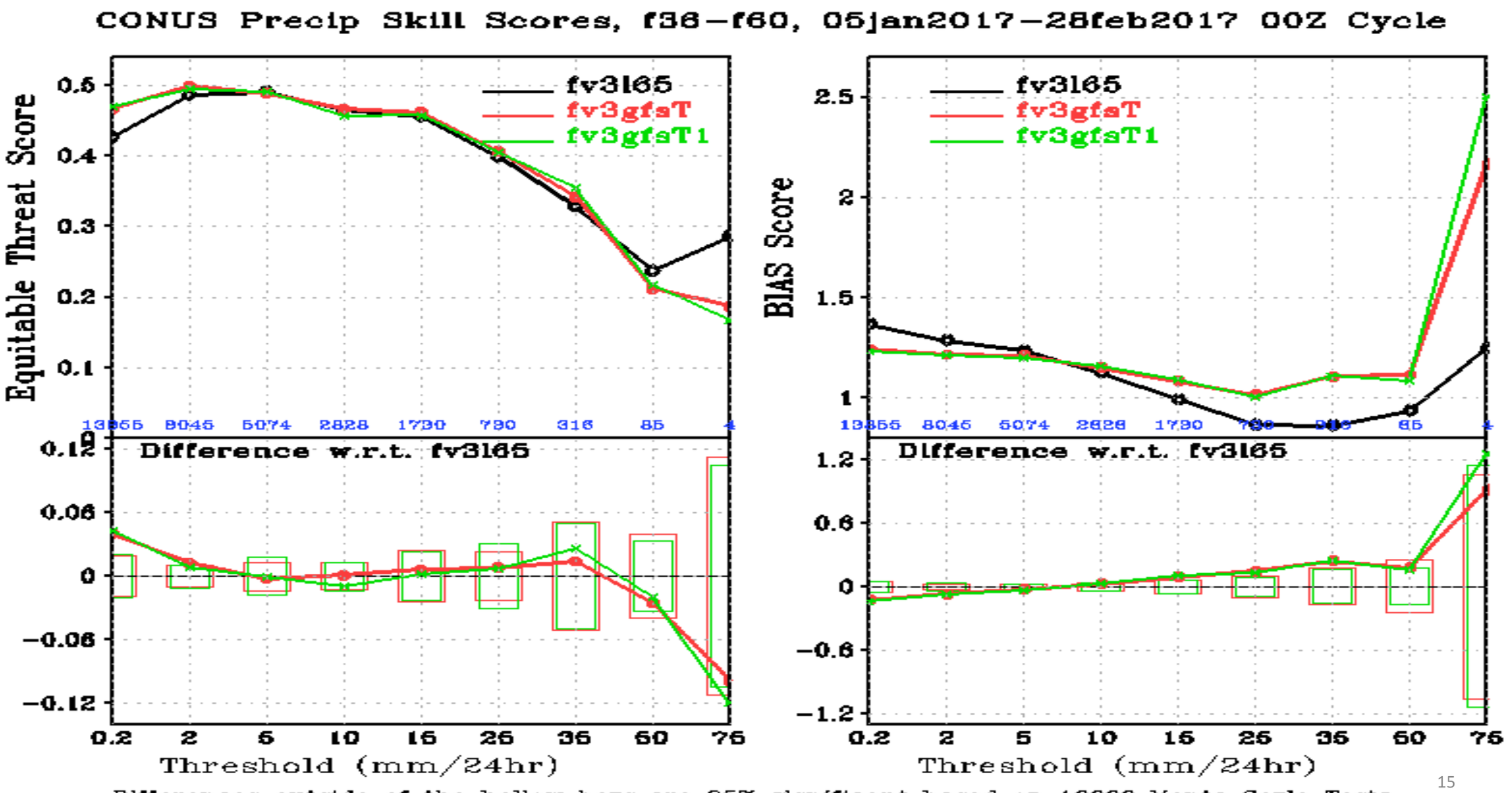
– 20170105-20170228 (need more)

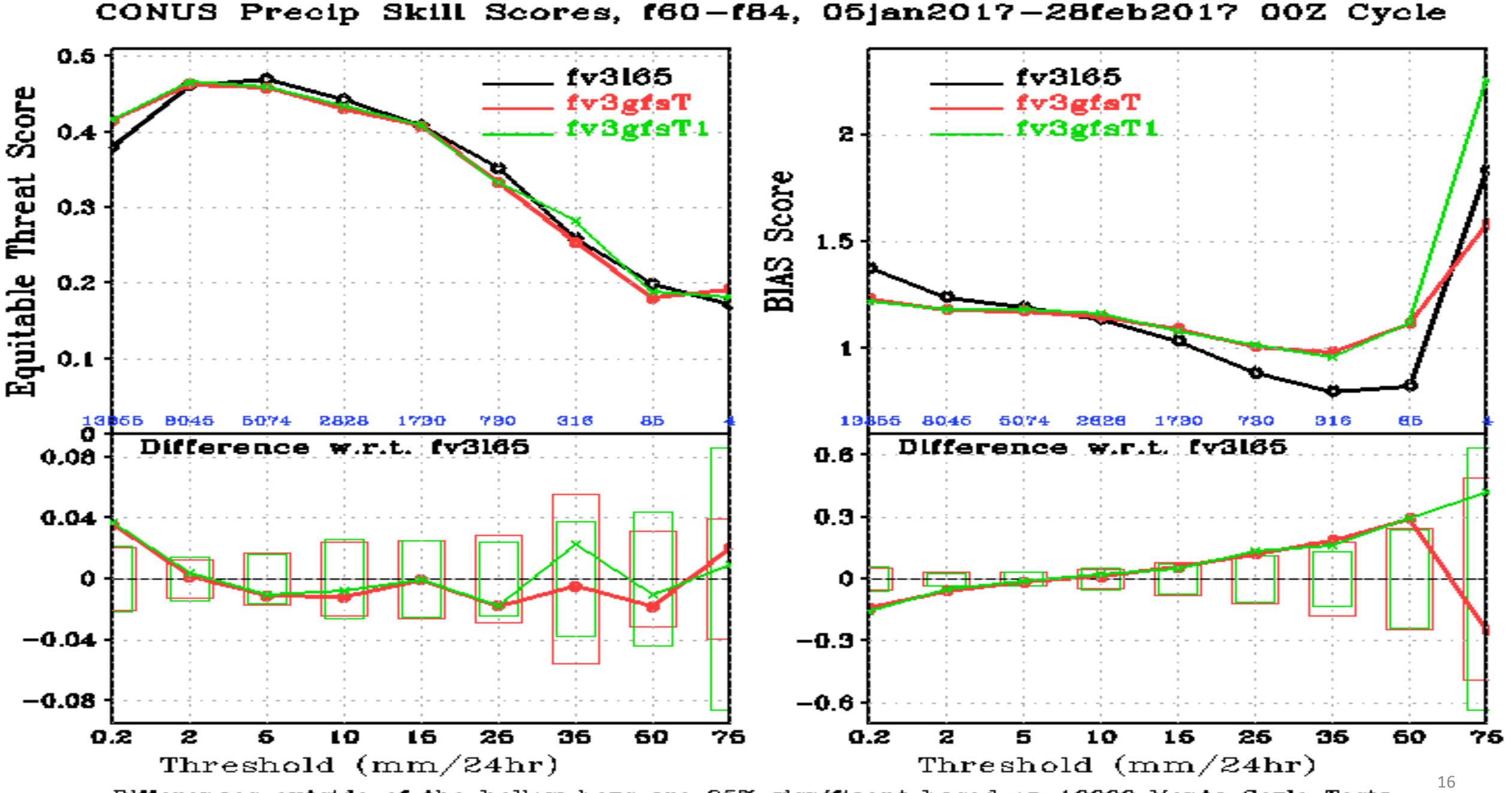
1. **fv3l65**: Fanglin's fcst only run (control=default physics with Zhao & Carr, previous **Zhao&Carr**)

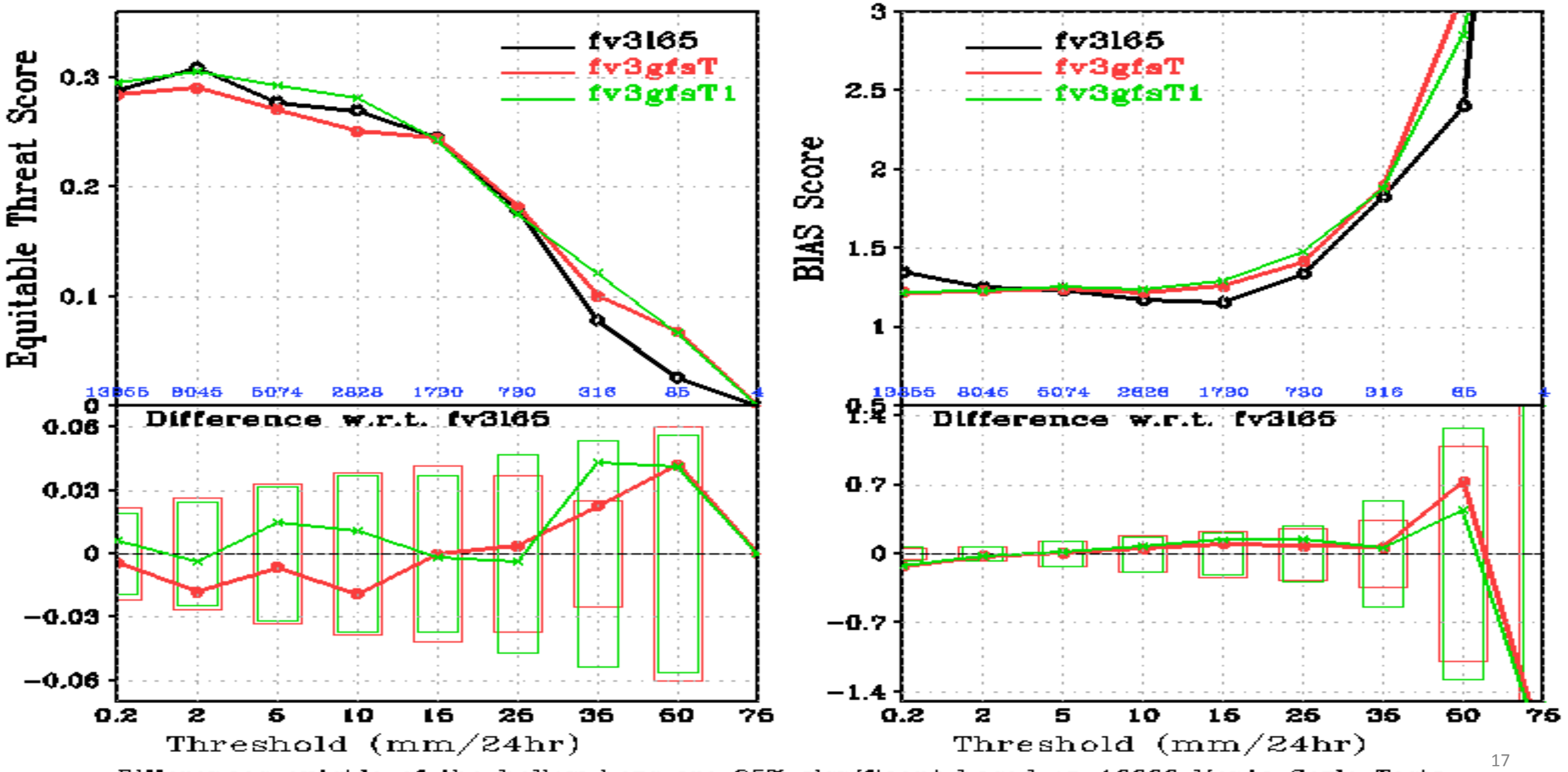
2. fv3gfsT: **fv3l65** + original 2008 Thompson MP replaces Zhao_carr + close coupling with radiation + ice number for detrained cloud ice from deep and shallow convection + snow treated as ice in cloud cover calculation in radiation + modifications of cloud drop number and ice nucleation (dt=225s) (Modified Thompson1)

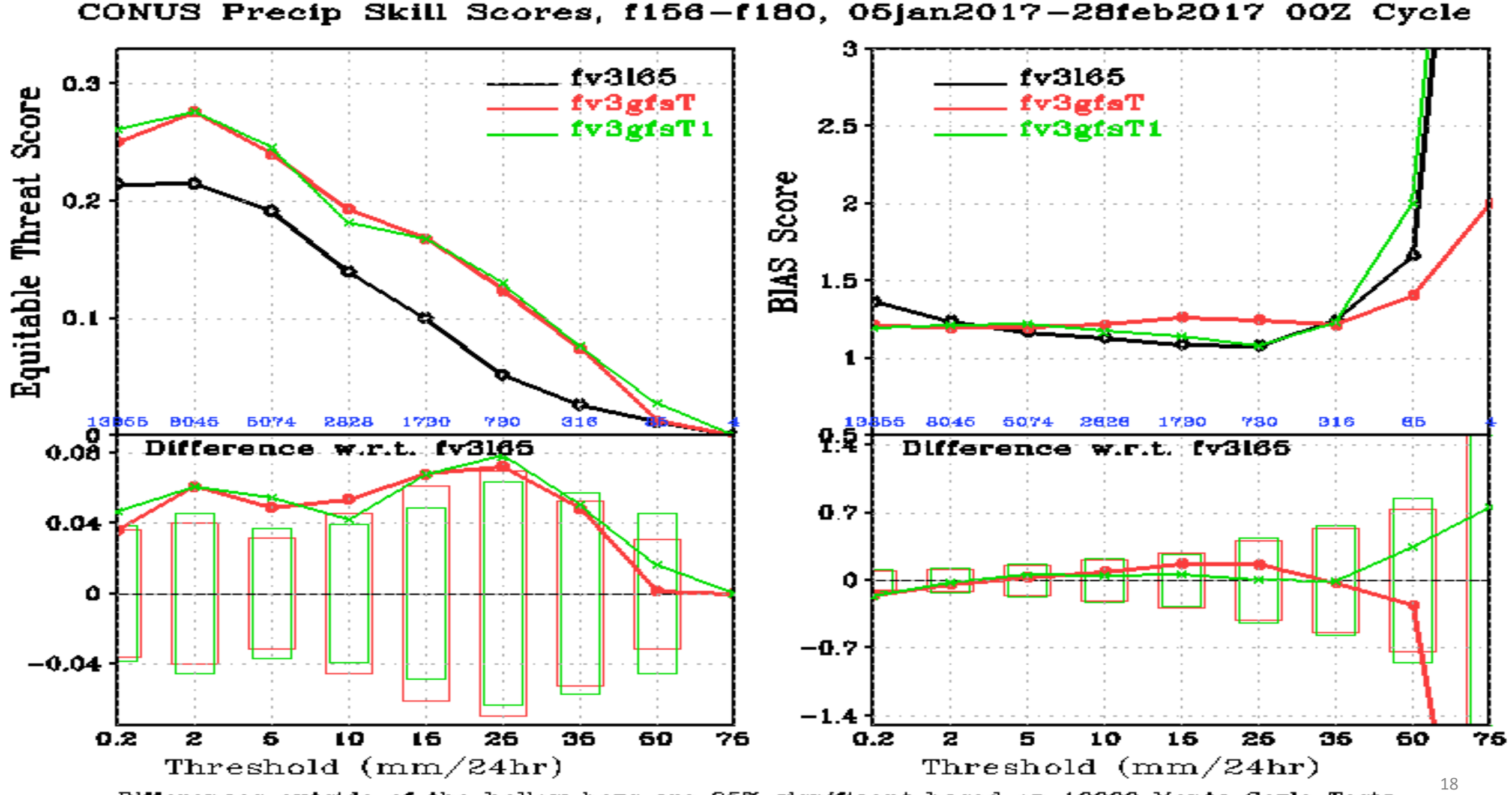
3. fv3gfsT1: fv3gfsT + rhc partial cloudiness (dt=225s) (Modified Thompson2:rhc)


CONUS Precip Skill Scores, f12-f36, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
BIAS Score
fv3l65
fv3gfsT
fv3gfsT1
13855 8045 5074 2828 1730 730 316 85 4
Difference w.r.t. fv3l65
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests


CONUS Precip Skill Scores, f36-f60, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
fv3l65
fv3gfsT
fv3gfsT1
0.5
0.4
0.3
0.2
0.1
13865 8045 5074 2828 1730 790 316 85 4
Difference w.r.t. fv3l65
0.12
0.06
0
-0.06
-0.12
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
BIAS Score
fv3l65
fv3gfsT
fv3gfsT1
2.5
2
1.5
1
13865 8045 5074 2828 1730 790 316 85 4
Difference w.r.t. fv3l65
1.2
0.6
0
-0.6
-1.2
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests


CONUS Precip Skill Scores, f60-f84, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
BIAS Score
fv3l65
fv3gfsT
fv3gfsT1
13855 8045 5074 2828 1730 790 316 85 4
Difference w.r.t. fv3l65
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

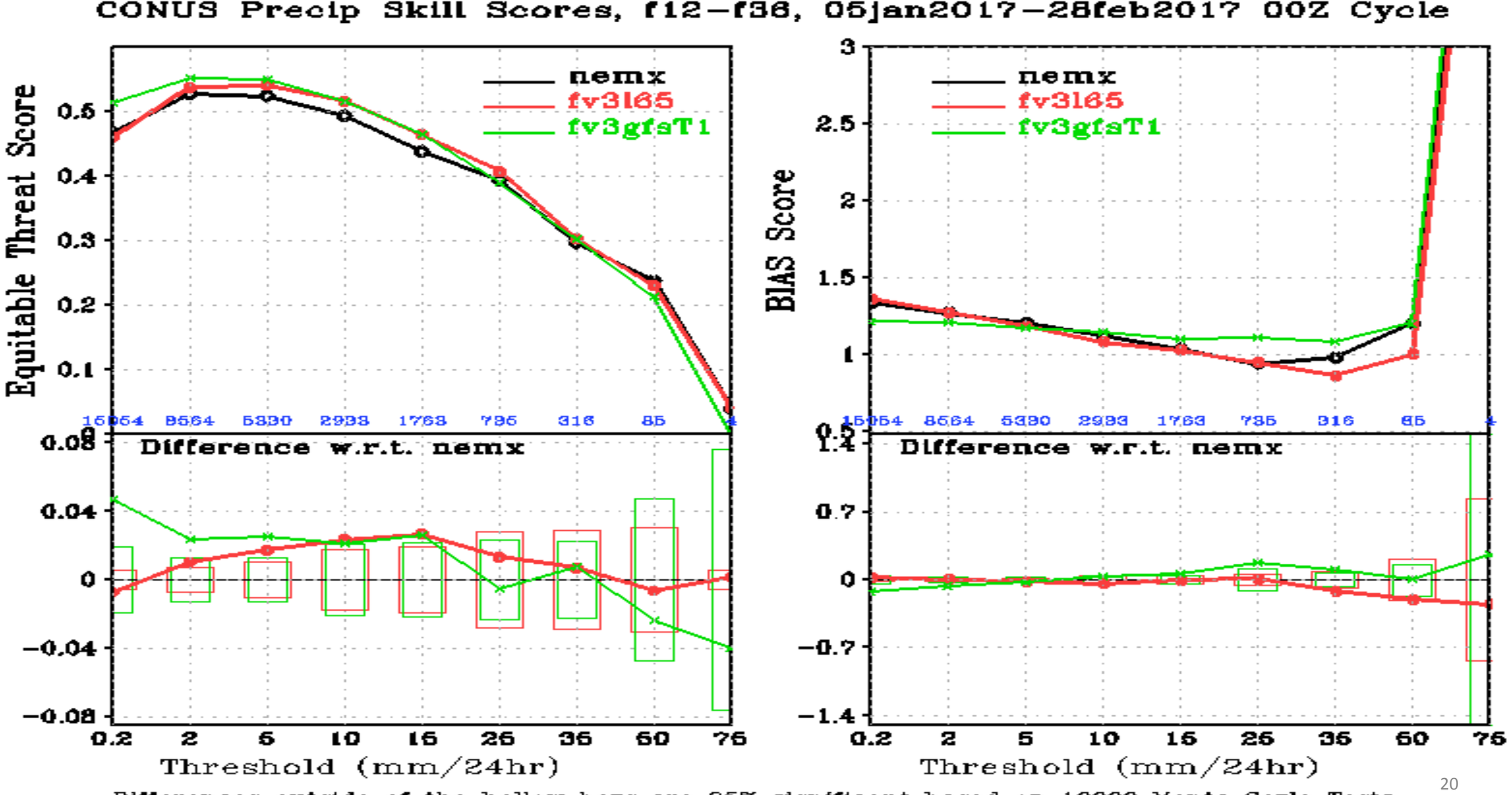

CONUS Precip Skill Scores, f132-f156, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
BIAS Score
fv3l65
fv3gfsT
fv3gfsT1
13865 8045 5074 2828 1730 730 316 85 4
Difference w.r.t. fv3l65
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

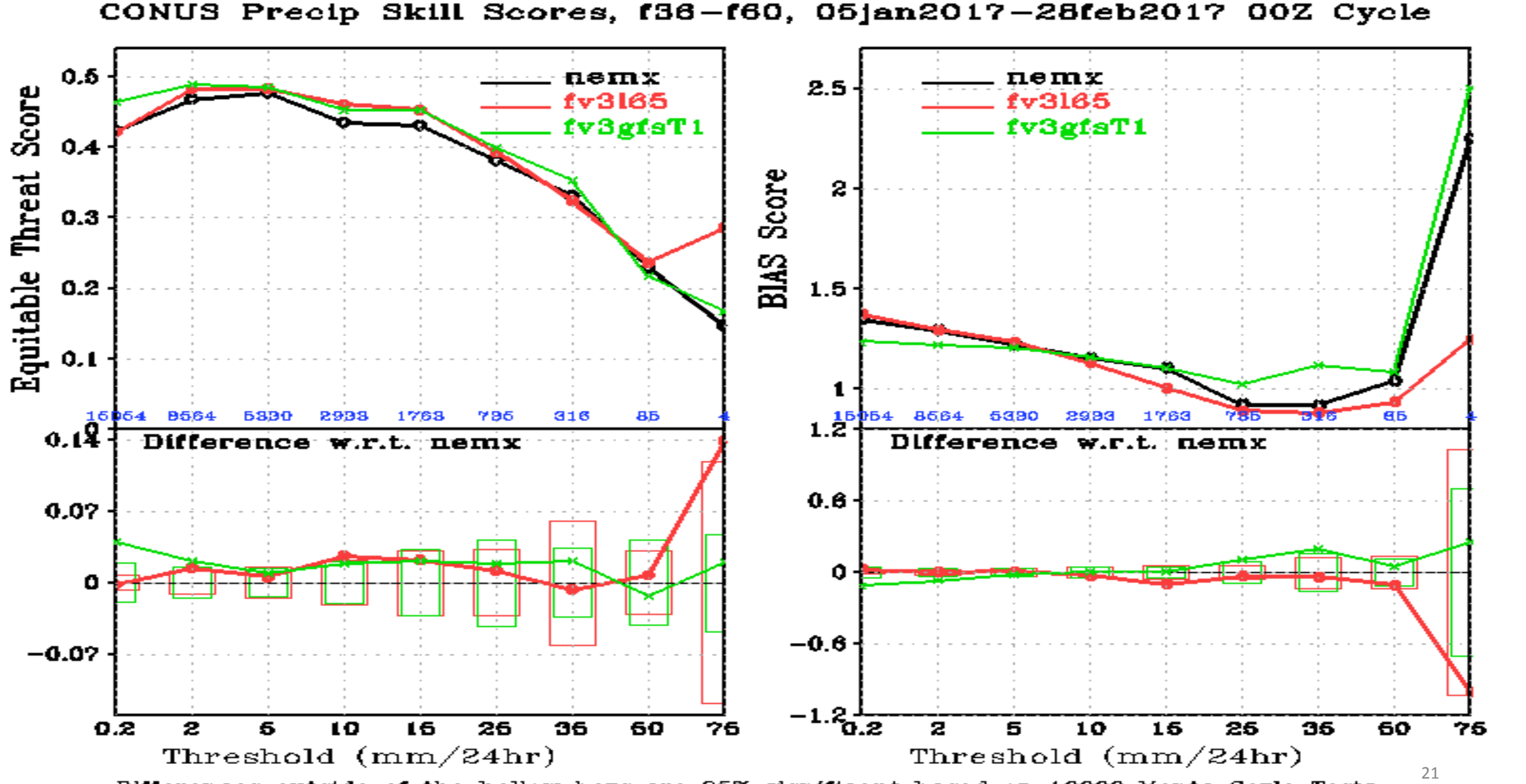

CONUS Precip Skill Scores, f156-f180, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
fv3l65
fv3gfsT
fv3gfsT1
0.3
0.2
0.1
0
13355 8045 5074 2828 1790 790 316 85 4
Difference w.r.t. fv3l65
0.08
0.04
0
-0.04
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
BIAS Score
3
2.5
2
1.5
1
0.5
1.4
0.7
0
-0.7
-1.4
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

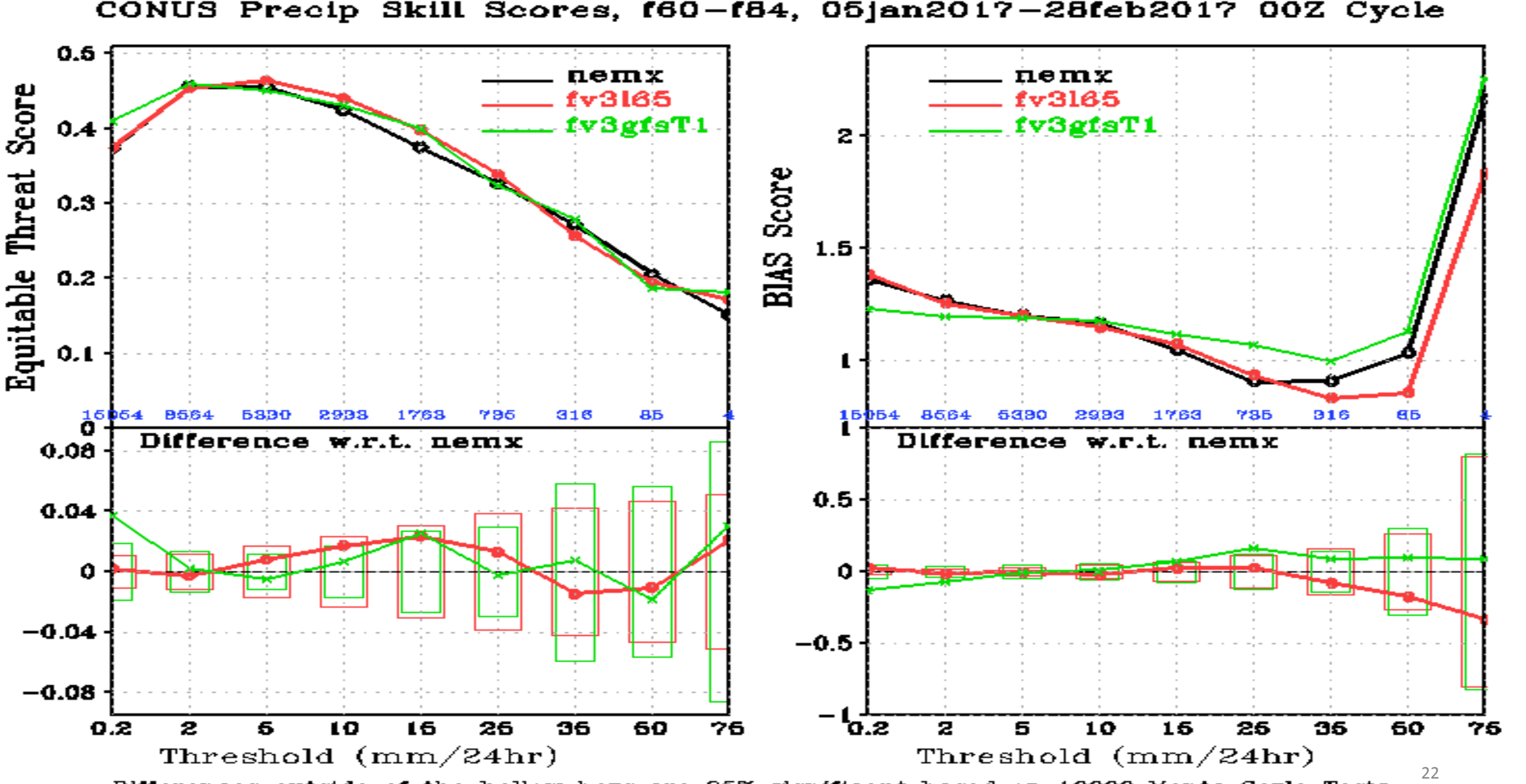
Winter Precipitation Statistics (II)

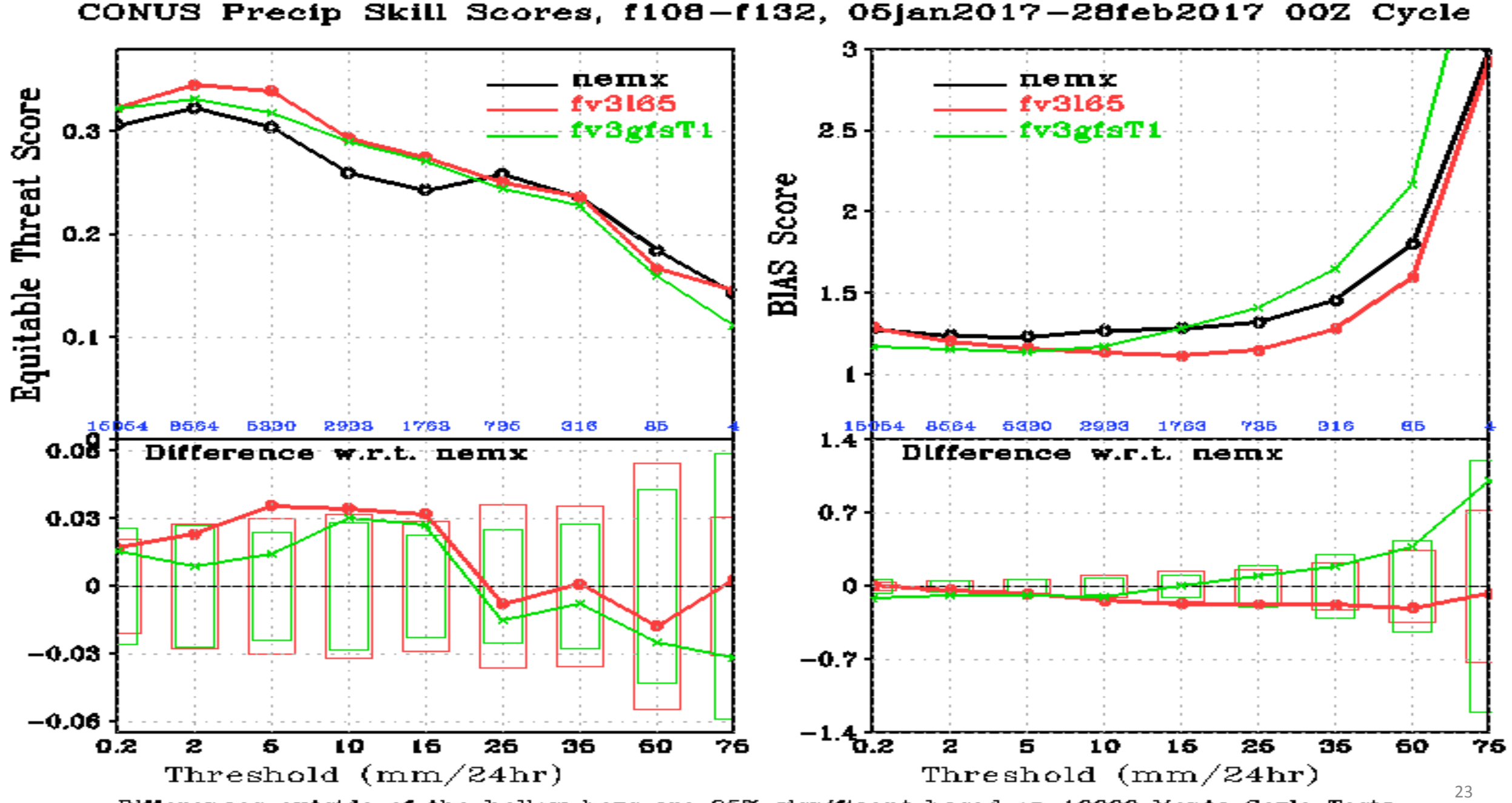
– **20170105-20170228 (need more)**

1. **nemsx:** NEMS parallel
2. fv3l65: Fanglin's fcst only run (control=default physics with Zhao & Carr, previous **Zhao&Carr**))
2. fv3gfsT1: **fv3l65** + original 2008 Thompson MP replaces Zhao_carr (dt=120s) + close coupling with radiation + ice number for detrained cloud ice from deep and shallow convection + snow treated as ice in cloud cover calculation in radiation + modifications of cloud drop number and ice nucleation + rhc partial cloudiness (dt=225s)

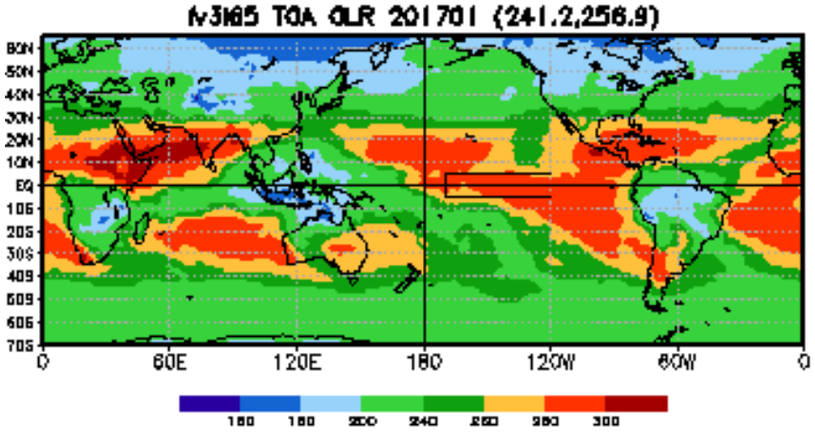

CONUS Precip Skill Scores, f12-f36, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
BIAS Score
nemx
fv3l65
fv3gfsT1
15064 8564 5330 2933 1763 795 316 85 4
Difference w.r.t. nemx
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

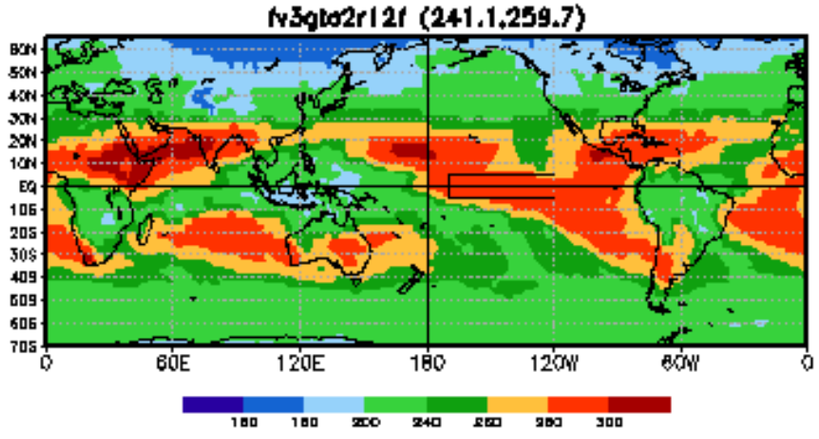

CONUS Precip Skill Scores, f36-f60, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
BIAS Score
nemx
fv3l65
fv3gfsT1
15064 8564 5330 2993 1763 795 316 85 4
Difference w.r.t. nemx
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests


CONUS Precip Skill Scores, f60-f84, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
BIAS Score
nemx
fv3l65
fv3gfsT1
Difference w.r.t. nemx
16064 8564 5390 2993 1763 795 316 85 4
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

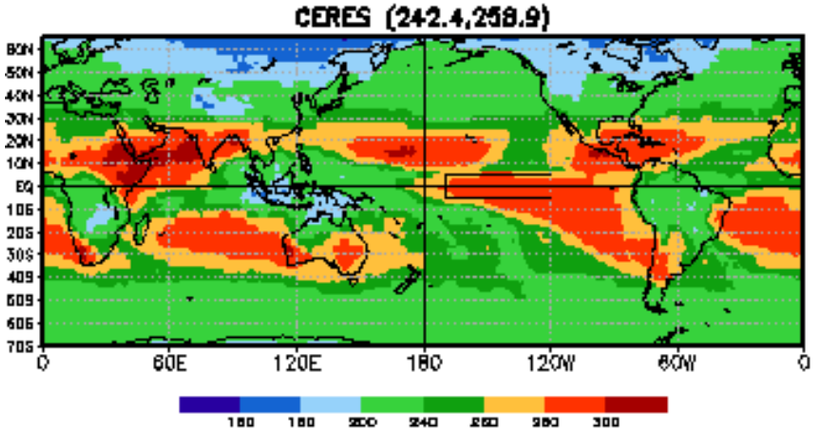

CONUS Precip Skill Scores, f108-f132, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
BIAS Score
nemx
fv3l65
fv3gfsT1
15054 8564 5330 2933 1763 795 316 85 4
Difference w.r.t. nemx
0.2 2 5 10 15 25 35 60 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

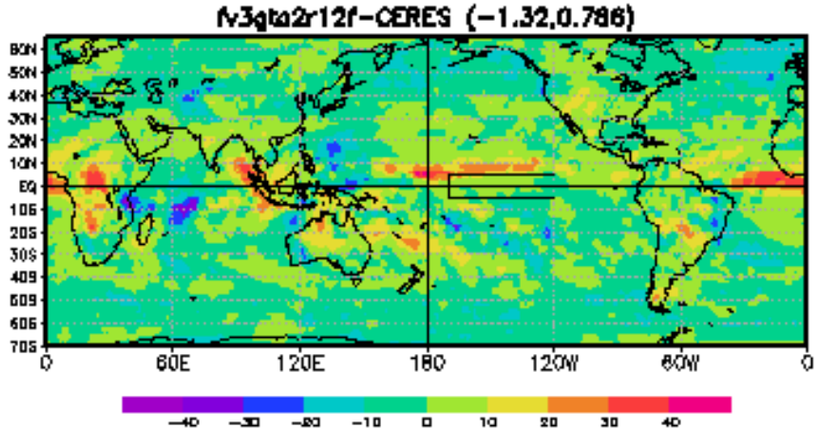
OLR (201701 monthly mean)





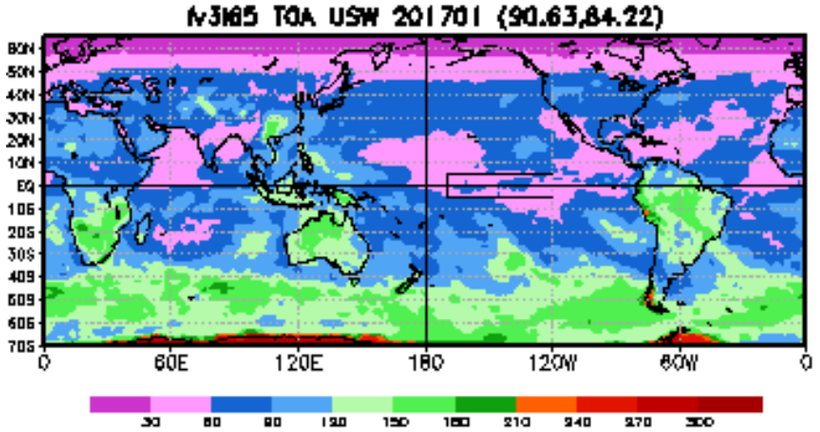
fv3gfsT1

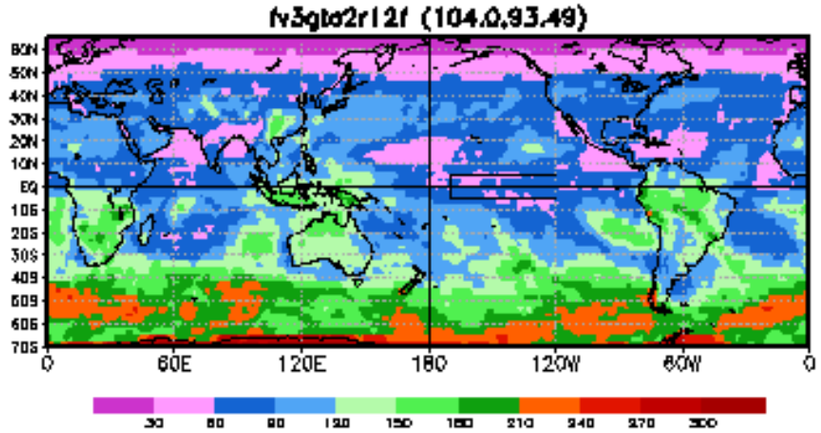




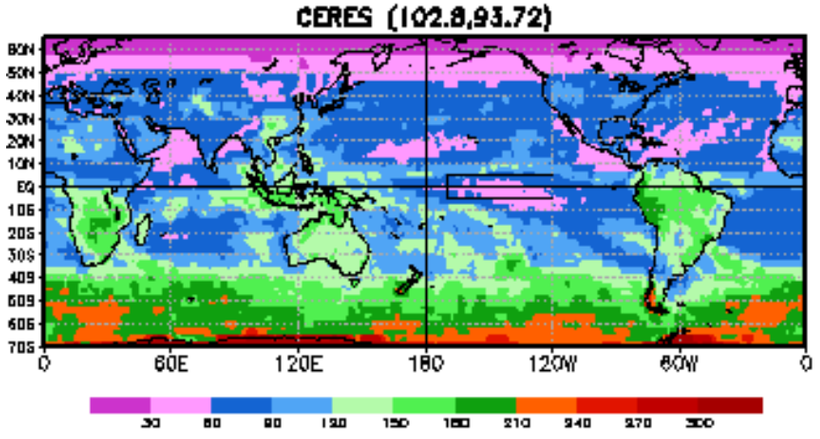
fv3gfsT1-CERES

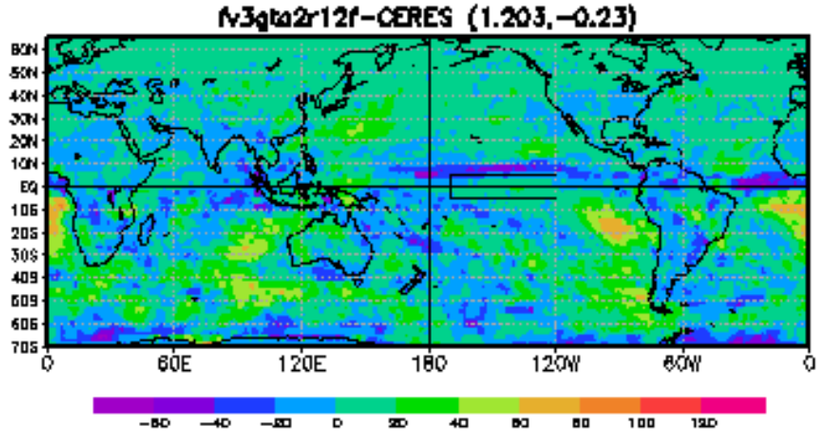
USW at TOA (201701 monthly mean)



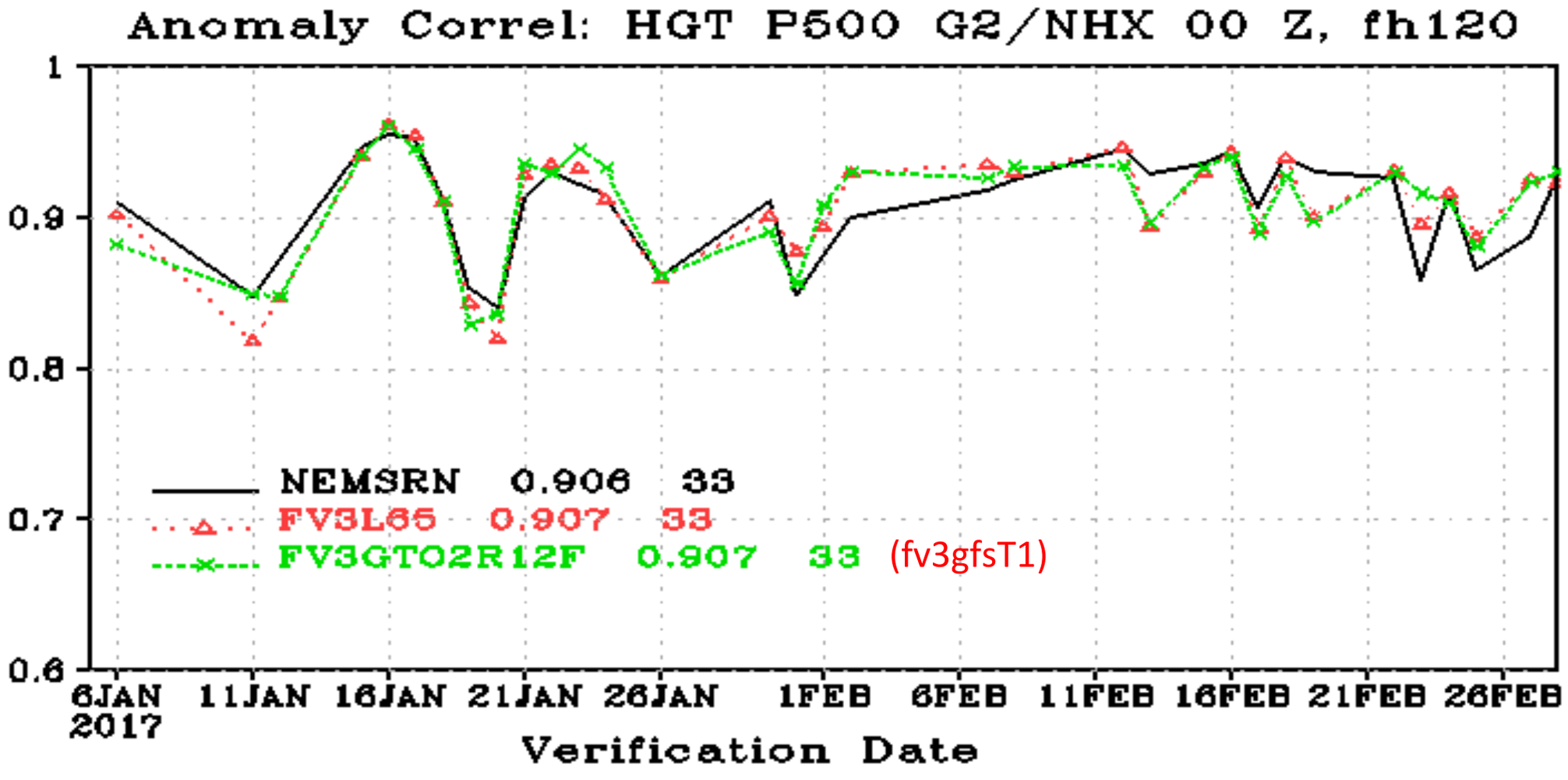


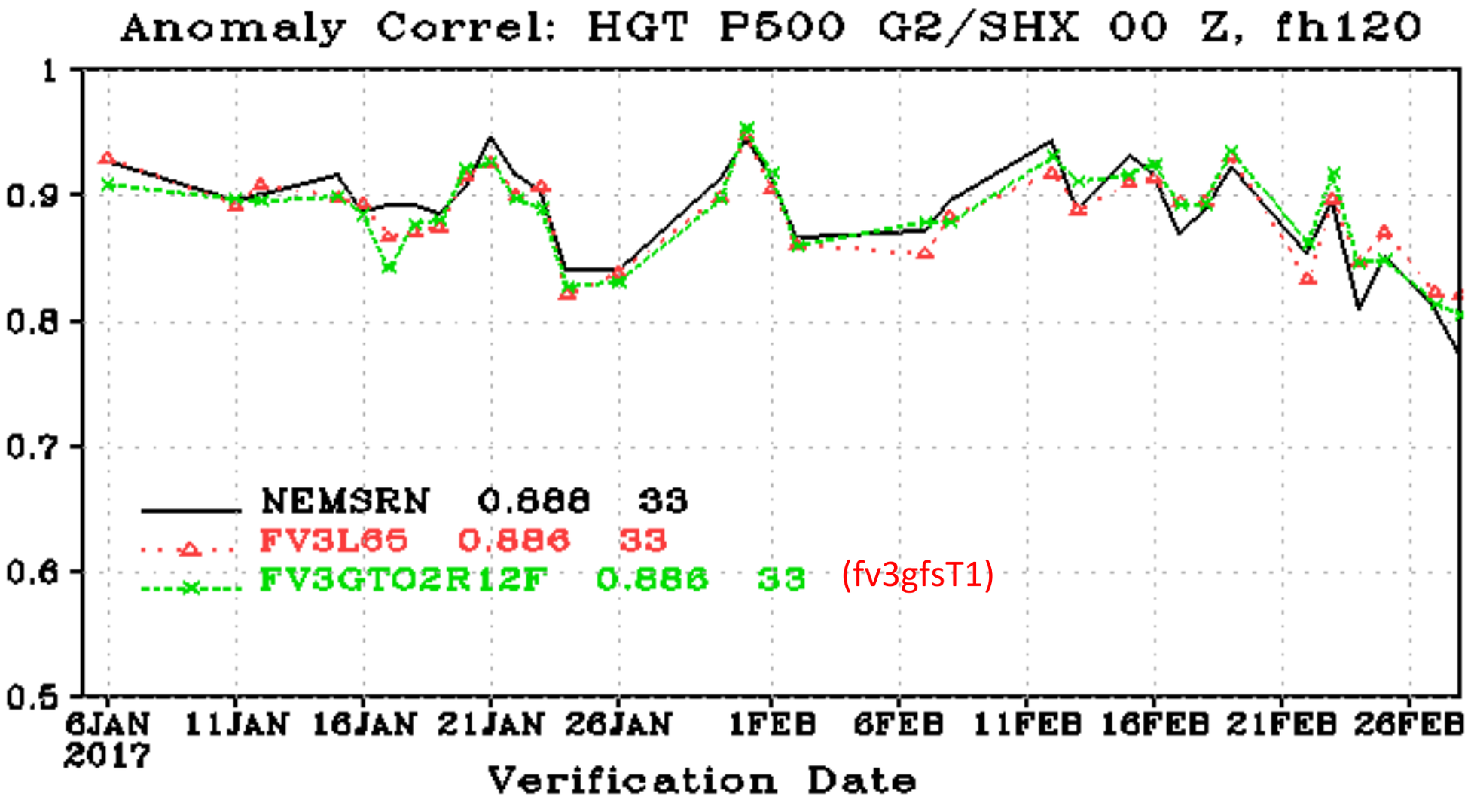
fv3gfsT1

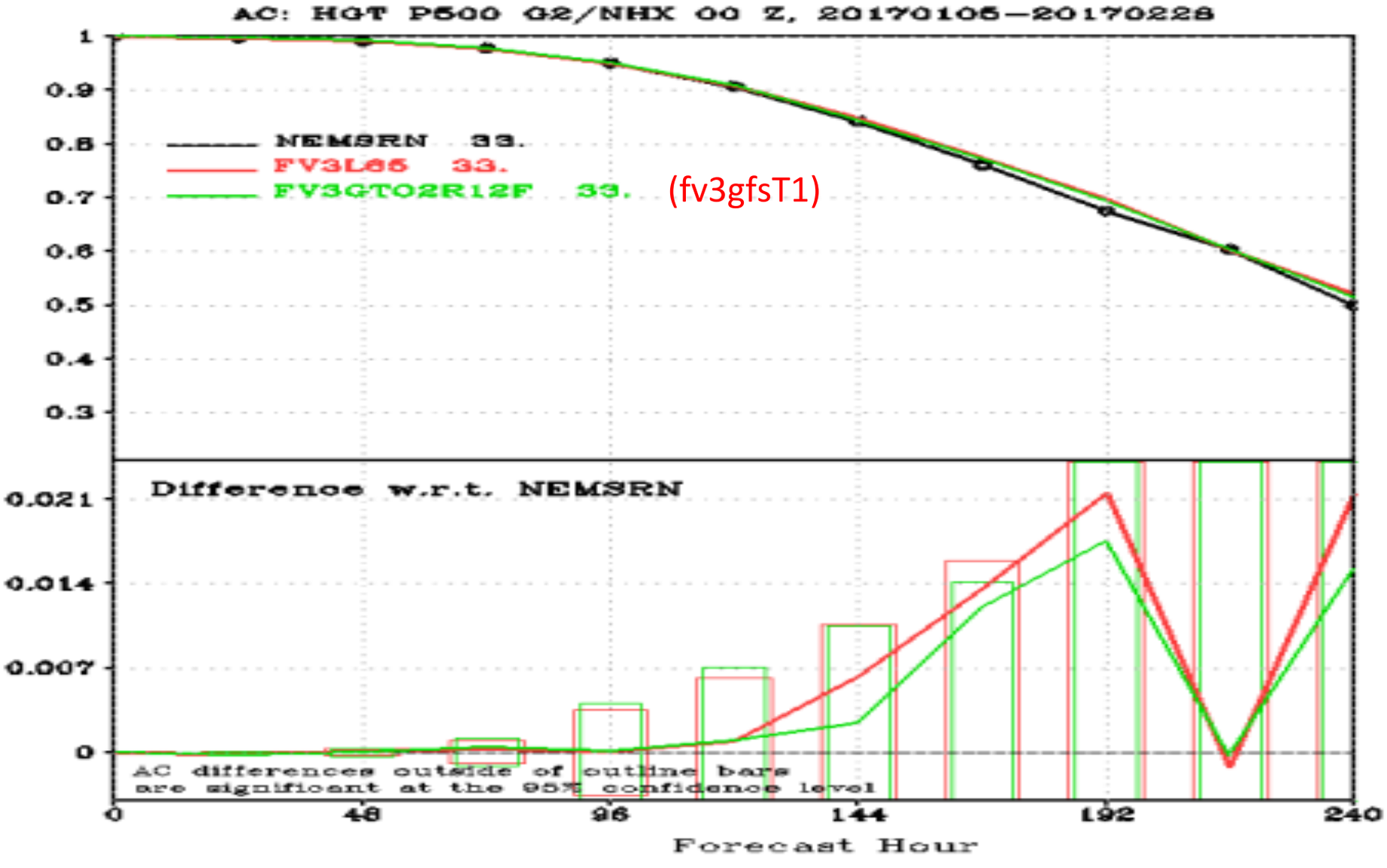


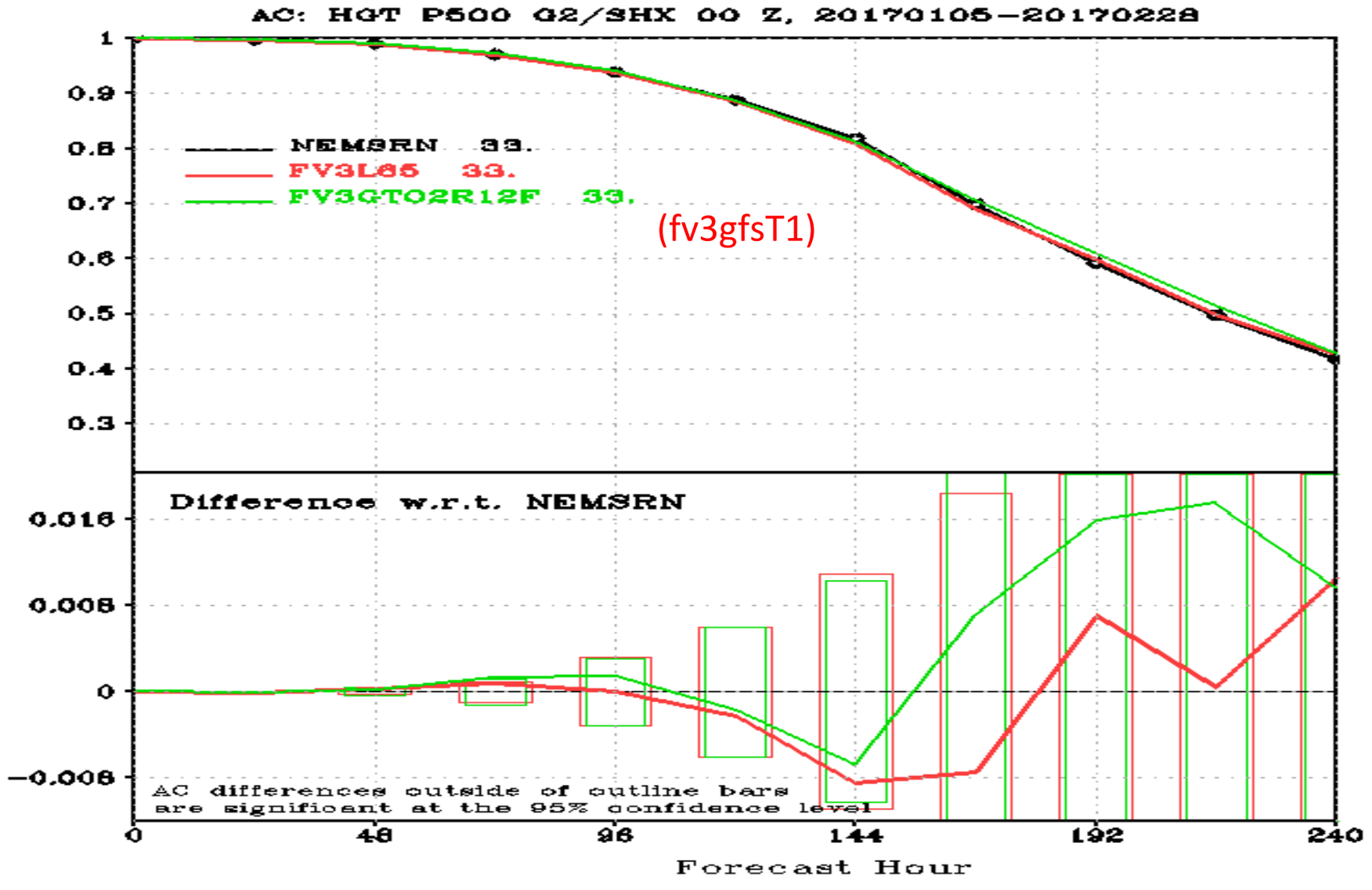


fv3gfsT1-CERES


Anomaly Correl: HGT P500 G2/NHX 00 Z, fh120
1
0.9
0.8
0.7
0.6
NEMSRN 0.906 33
FV3L65 0.907 33
FV3GTO2R12F 0.907 33 (fv3gfsT1)
6JAN 2017
11JAN
16JAN
21JAN
26JAN
1FEB
6FEB
11FEB
16FEB
21FEB
26FEB
Verification Date


Anomaly Correl: HGT P500 G2/SHX 00 Z, fh120
1
0.9
0.8
0.7
0.6
0.5
NEMSRN 0.888 33
FV3L65 0.886 33
FV3GTO2R12F 0.886 33
(fv3gfsT1)
6JAN 2017
11JAN
16JAN
21JAN
26JAN
1FEB
6FEB
11FEB
16FEB
21FEB
26FEB
Verification Date


AC: HGT P500 G2/NHX 00 Z, 20170106-20170228
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
NEMSRN 33.
FV3L65 33.
FV3GTO2R12F 33.
(fv3gfsT1)
Difference w.r.t. NEMSRN
0.021
0.014
0.007
0
AC differences outside of outline bars
are significant at the 95% confidence level
0
48
96
144
192
240
Forecast Hour

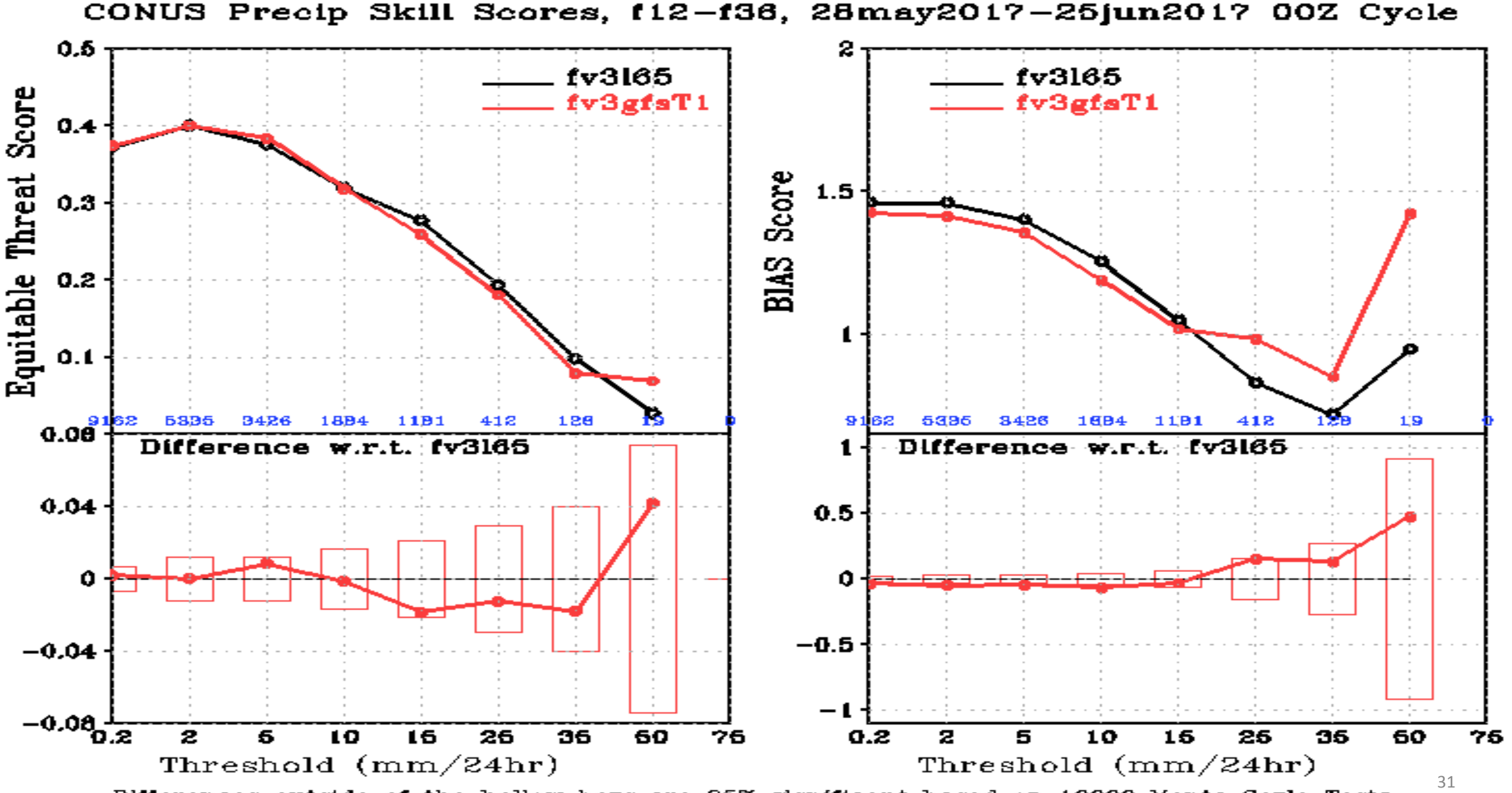

AC: HGT P500 G2/SHX 00 Z, 20170105-20170228
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
NEMSRN 33.
FV3L65 33.
FV3GTO2R12F 33.
(fv3gfsT1)
Difference w.r.t. NEMSRN
0.016
0.008
0
-0.008
AC differences outside of outline bars
are significant at the 95% confidence level
0
48
96
144
192
240
Forecast Hour

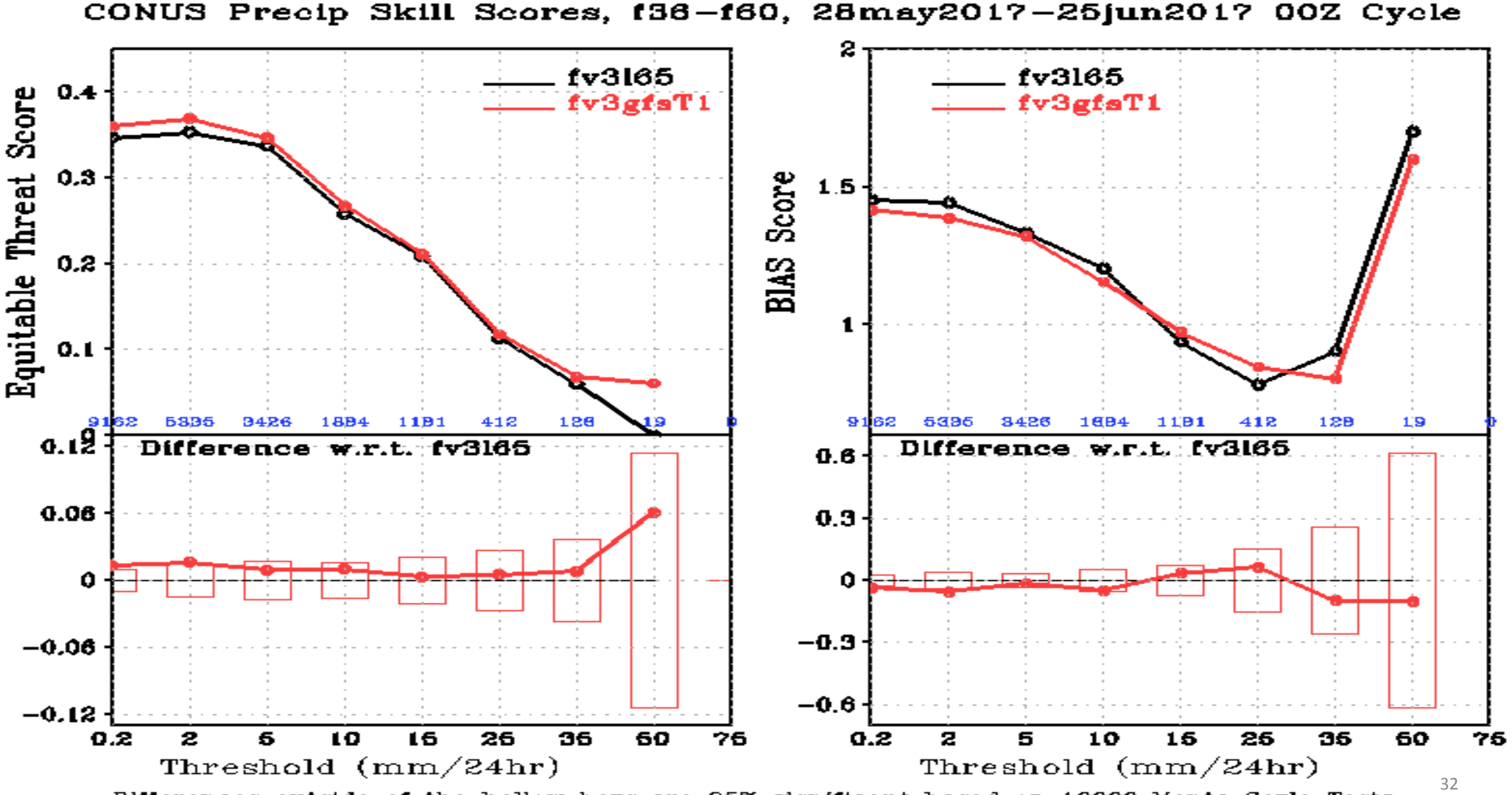
Summer Precipitation Statistics (III)

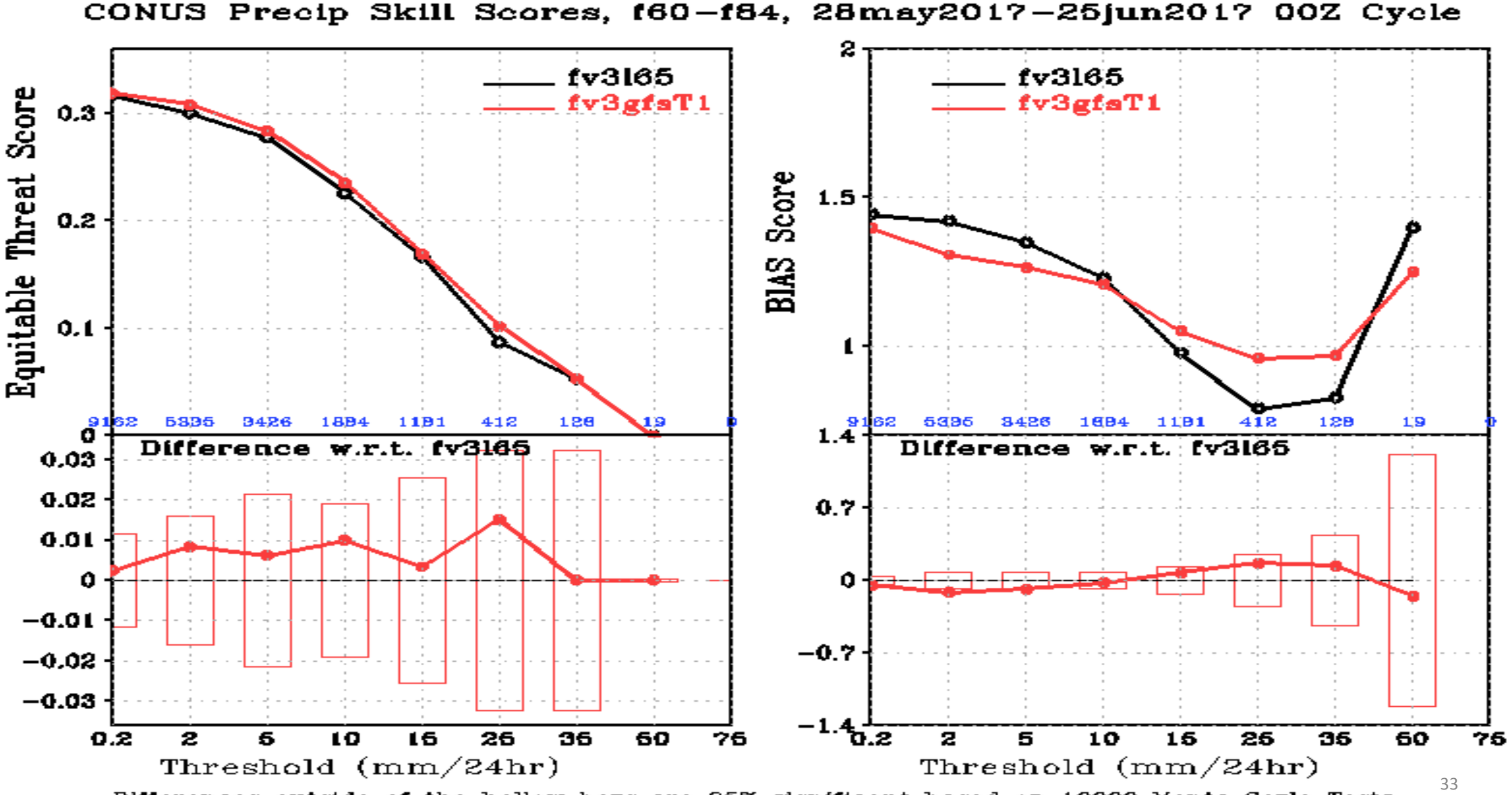
– **20170528-20170625 (need more)**

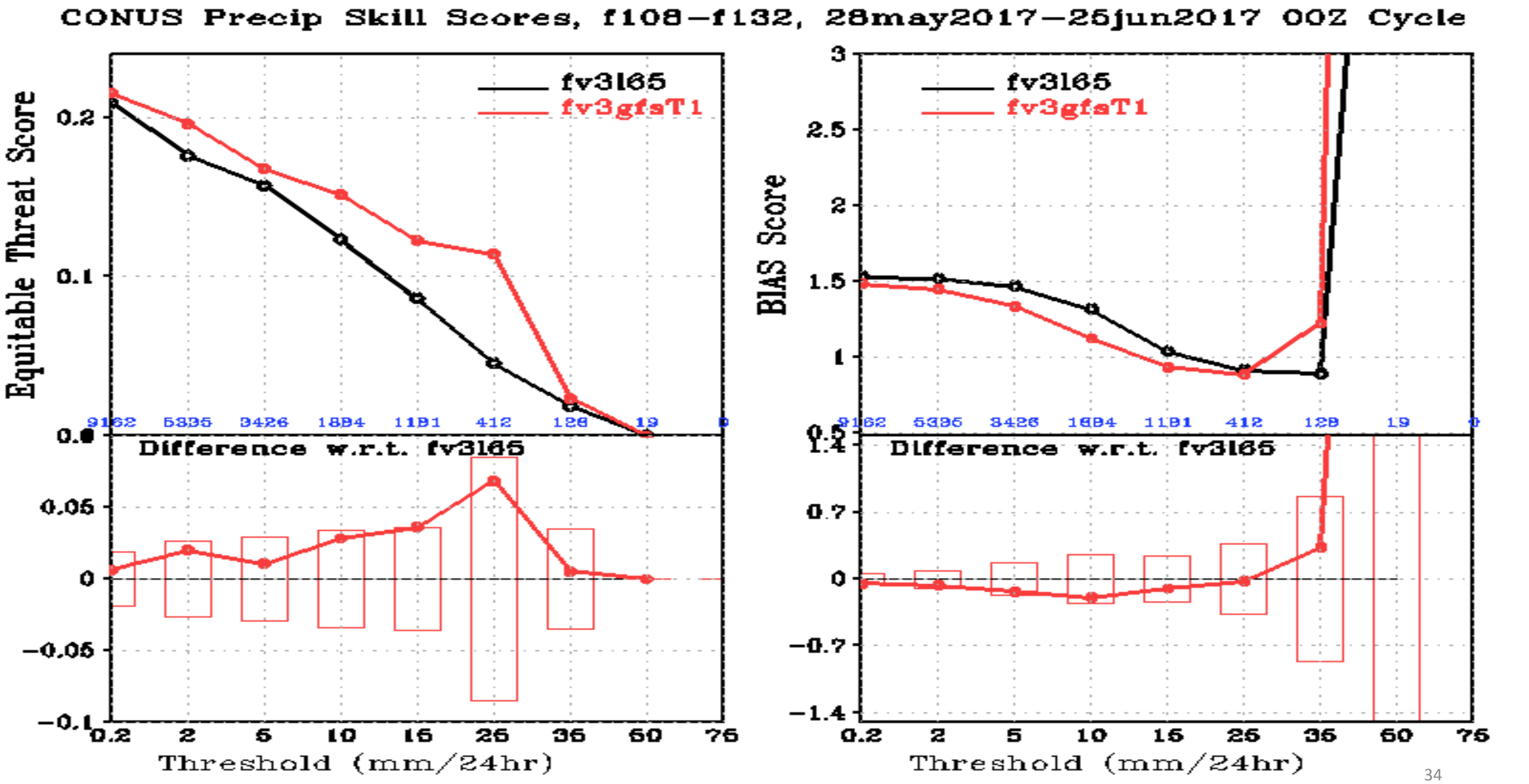
1. fv3l65: Fanglin's fcst only run (control=default physics with Zhao & Carr, previous **Zhao&Carr**))

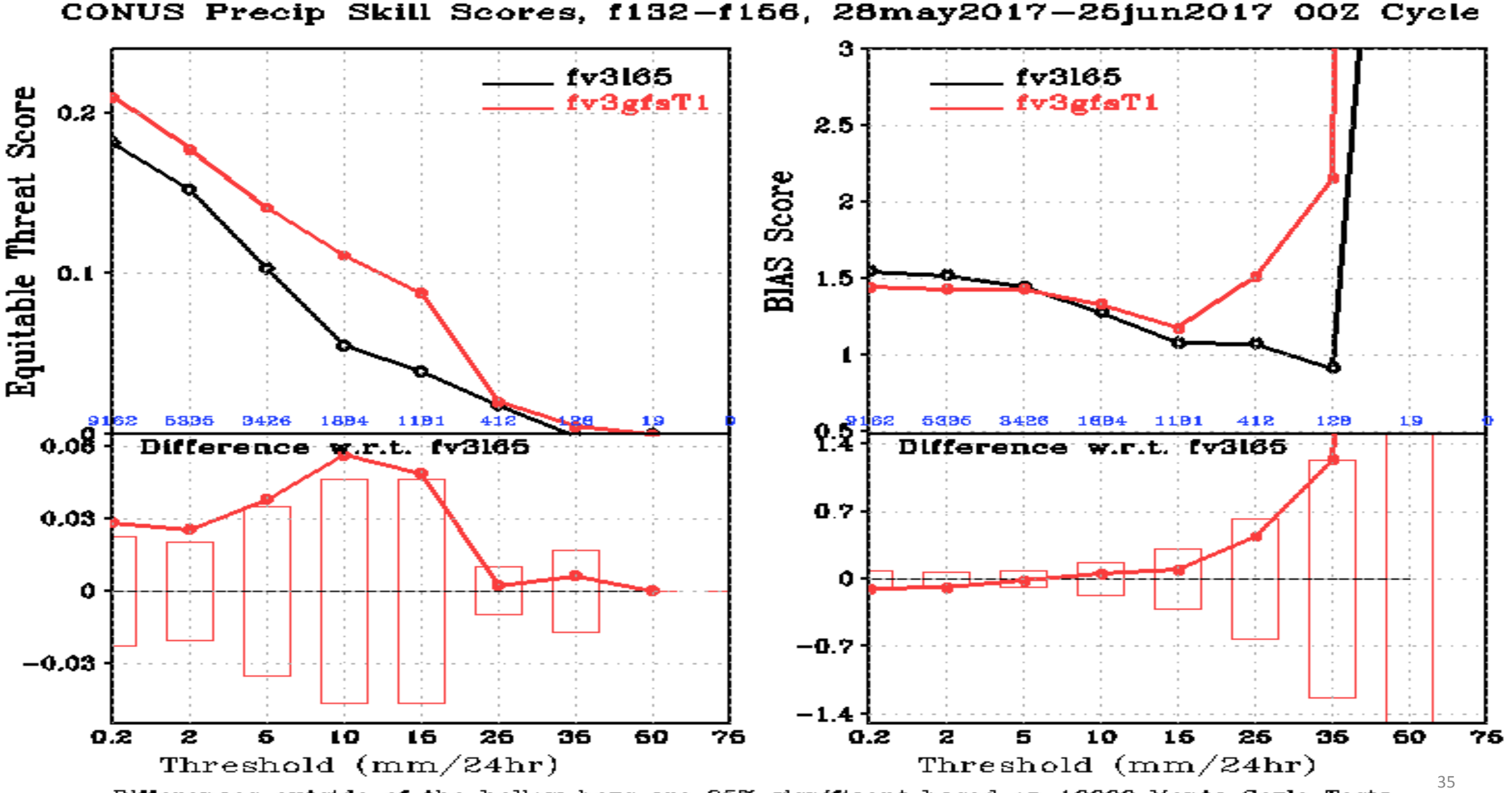
2. fv3gfsT1: **fv3l65** + original 2008 Thompson MP replaces Zhao_carr (dt=120s) + close coupling with radiation + ice number for detrained cloud ice from deep and shallow convection + snow treated as ice in cloud cover calculation in radiation + modifications of cloud drop number and ice nucleation + rhc partial cloudiness (dt=225s)

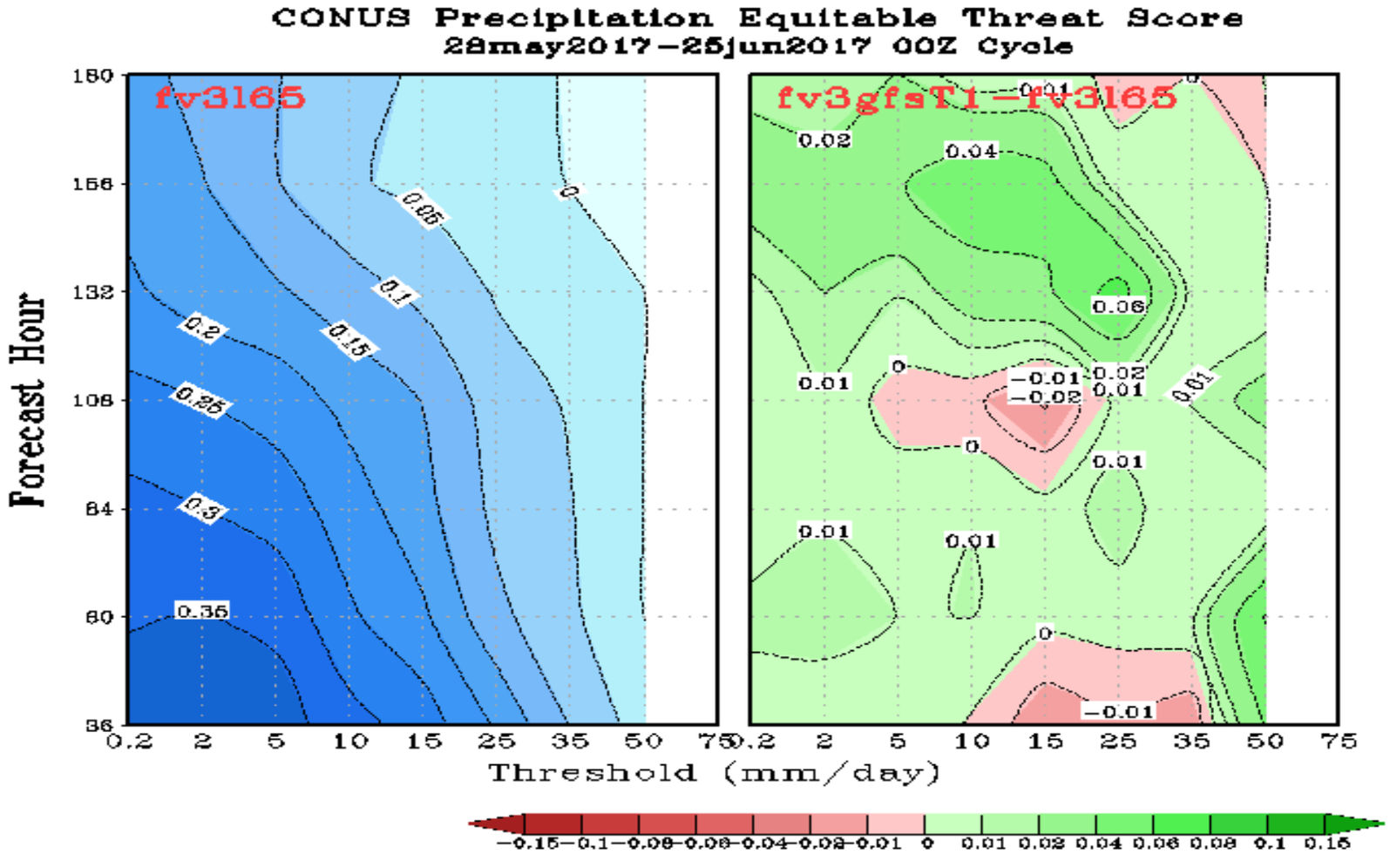

CONUS Precip Skill Scores, f12-f36, 28may2017-25jun2017 00Z Cycle
Equitable Threat Score
BIAS Score
fv3l65
fv3gfsT1
9162 5395 3426 1894 1191 412 128 19 0
Difference w.r.t. fv3l65
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests


CONUS Precip Skill Scores, f36-f60, 28may2017-25jun2017 00Z Cycle
Equitable Threat Score
fv3l65
fv3gfsT1
0.4
0.3
0.2
0.1
9162 5395 3426 1894 1191 412 128 19 0
Difference w.r.t. fv3l65
0.12
0.06
0
-0.06
-0.12
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
BIAS Score
fv3l65
fv3gfsT1
2
1.5
1
9162 5395 3426 1894 1191 412 128 19 0
Difference w.r.t. fv3l65
0.6
0.3
0
-0.3
-0.6
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests


CONUS Precip Skill Scores, f60-f84, 28may2017-25jun2017 00Z Cycle
Equitable Threat Score
fv3l65
fv3gfsT1
0.3
0.2
0.1
9162 5395 3426 1894 1191 412 128 19 0
Difference w.r.t. fv3l65
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
BIAS Score
fv3l65
fv3gfsT1
2
1.5
1
9162 5395 3426 1894 1191 412 128 19 0
Difference w.r.t. fv3l65
1.4
0.7
0
-0.7
-1.4
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests


CONUS Precip Skill Scores, f108-f132, 28may2017-25jun2017 00Z Cycle
fv3l65
fv3gfsT1
Equitable Threat Score
0.2
0.1
0.0
9162 5335 3426 1894 1191 412 128 19 0
Difference w.r.t. fv3l65
0.05
0
-0.05
-0.1
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
fv3l65
fv3gfsT1
BIAS Score
3
2.5
2
1.5
1
0.5
9162 5335 3426 1894 1191 412 128 19 0
Difference w.r.t. fv3l65
1.4
0.7
0
-0.7
-1.4
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests


CONUS Precip Skill Scores, f132-f156, 28may2017-25jun2017 00Z Cycle
fv3l65
fv3gfsT1
Equitable Threat Score
0.2
0.1
0
9162 5395 3426 1894 1191 412 128 19 0
Difference w.r.t. fv3l65
0.06
0.03
0
-0.03
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
BIAS Score
3
2.5
2
1.5
1
0.5
9162 5395 3426 1894 1191 412 128 19 0
Difference w.r.t. fv3l65
1.4
0.7
0
-0.7
-1.4
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests


CONUS Precipitation Equitable Threat Score
28may2017-25jun2017 00Z Cycle
fv3l65
fv3gfsT1-fv3l65
Forecast Hour
180
156
132
108
84
60
36
0.2
2
5
10
15
25
35
50
75
Threshold (mm/day)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.02
0.04
0.06
0.01
-0.01
-0.02
-0.15 -0.1 -0.08 -0.06 -0.04 -0.02 -0.01 0 0.01 0.02 0.04 0.06 0.08 0.1 0.15

Summary

1. The FV3gfs-Thompson MP generated more low and middle clouds, less high clouds, and less total clouds (Will be compared with satellite observation) than the FV3gfs-Zhao&carr
2. FV3gfs-Thompson MP generated a little less OLR and more and better USW at the TOA than theFV3gfs-Zhao&carr.
3. The FV3gfs-Thompson MP signficant better precipitation and bias scores in the light rain range and in the 156h-180h fcst period.
4. The FV3gfs-Thompson MP produced better precipitation scores than the NEMX in the winter period.

To Do:

1. More diagnoses of the results from the completed experiments
2. Experiments in Summers
3. Comparison with GFDL MP and MG, and others
    - Need GFDL MP code in FV3GFS

Thanks

BACKUP SLIDES

Moist workshop recommendations (01/2015)

- The most promising treatment of moist physics at or near the current state-of-the-art that roughly 100 US and international scientists agreed on:
  - "Two moment microphysics with multiple categories of ice habits. This implies that all particles are predicted (not diagnosed) and fall with finite velocity".
  - "Utilizing these approaches, especially the two-moment microphysics, places demands on other components of the model including dynamics (especially advection schemes) and aerosol representation"

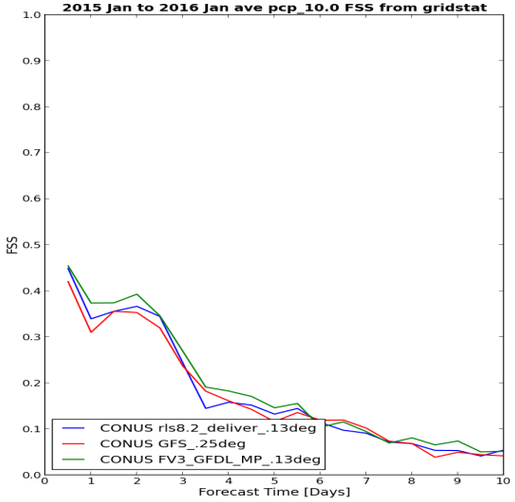
Current status —GFDL MP

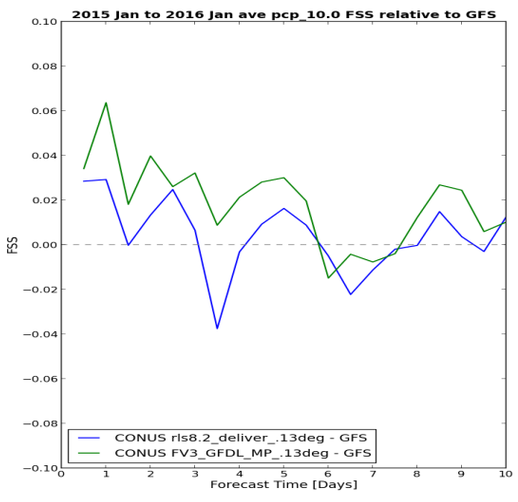
Fractions Skill Score over CONUS

(based on NGGPS 74 cases)

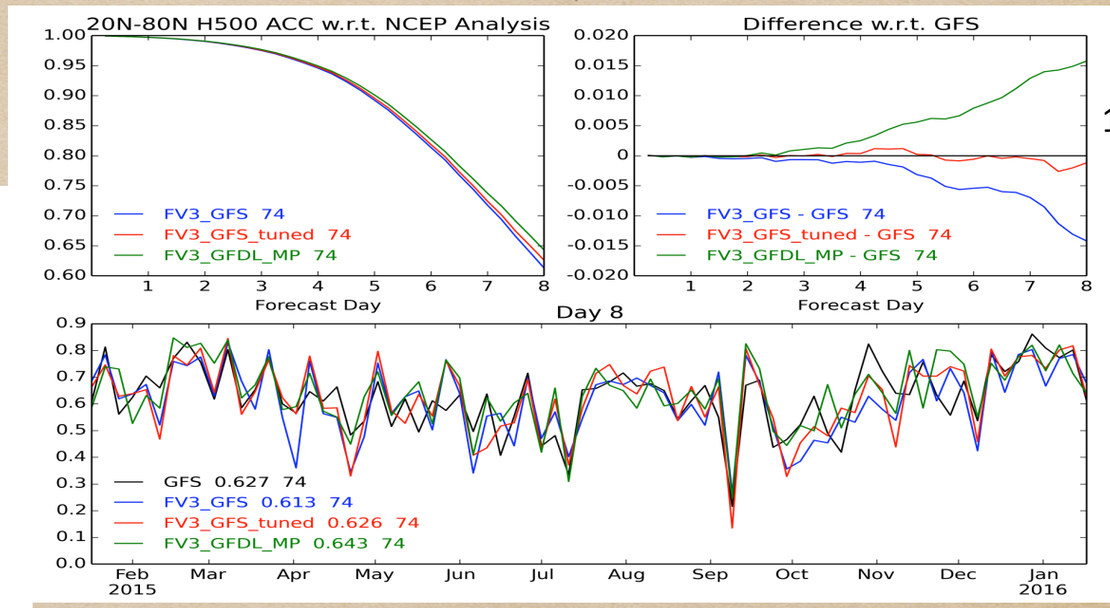
GFDL_MP made a significant improvement

Precipitation Events >= 10.0mm/6hr





Relative Skill to Operational GFS



13-km fvGFS with GFDL_MP

13-km fvGFS with tuned GFS

13-km fvGFS (no tuning)

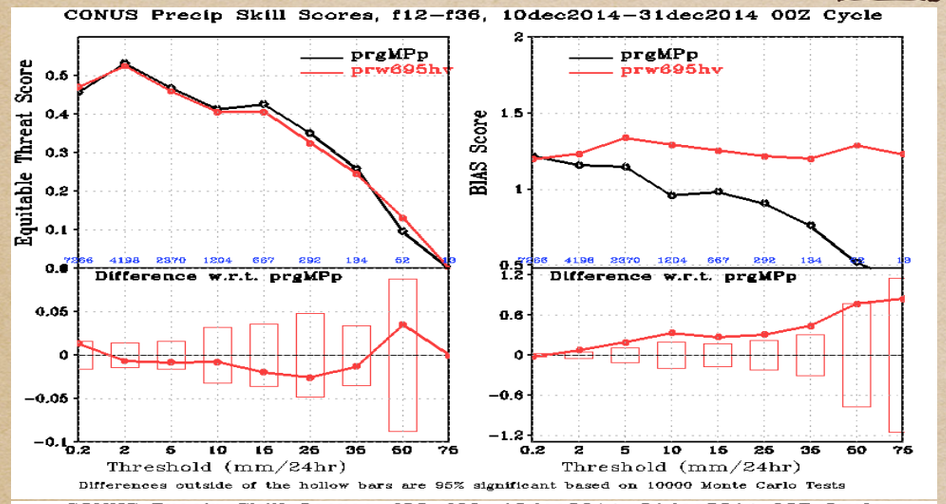
cloud fields from latest IFS, using Stage IV data

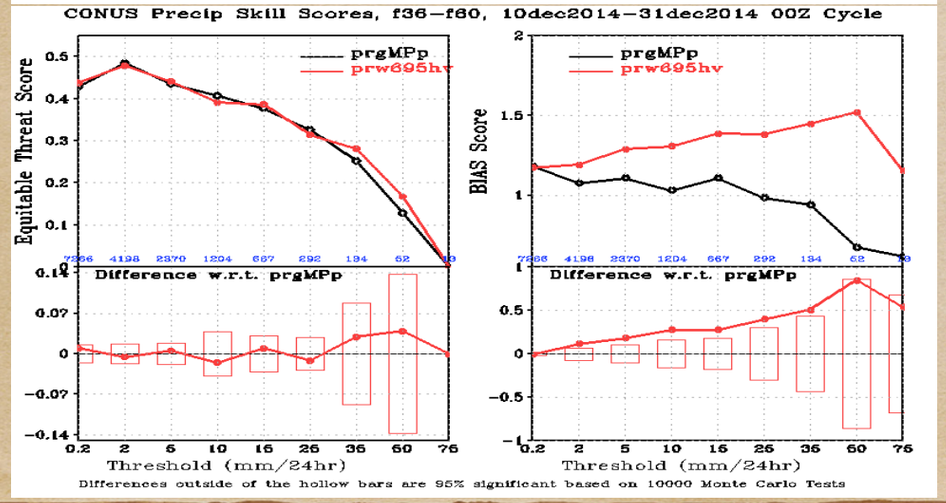
FSS by MET tool

The scheme is being tested with FV3 in NGGPS

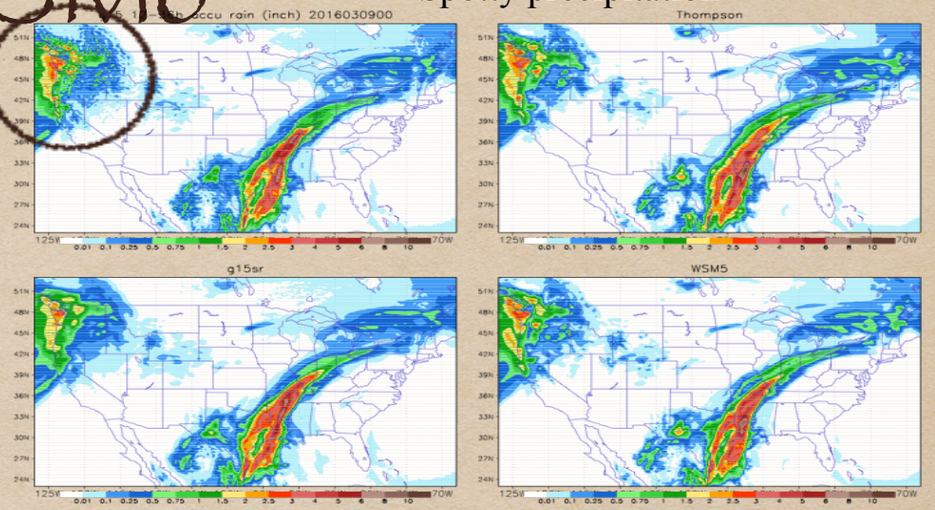
Courtesy of Dr S.J. Lin from FV3 workshop

Current status —WSM6



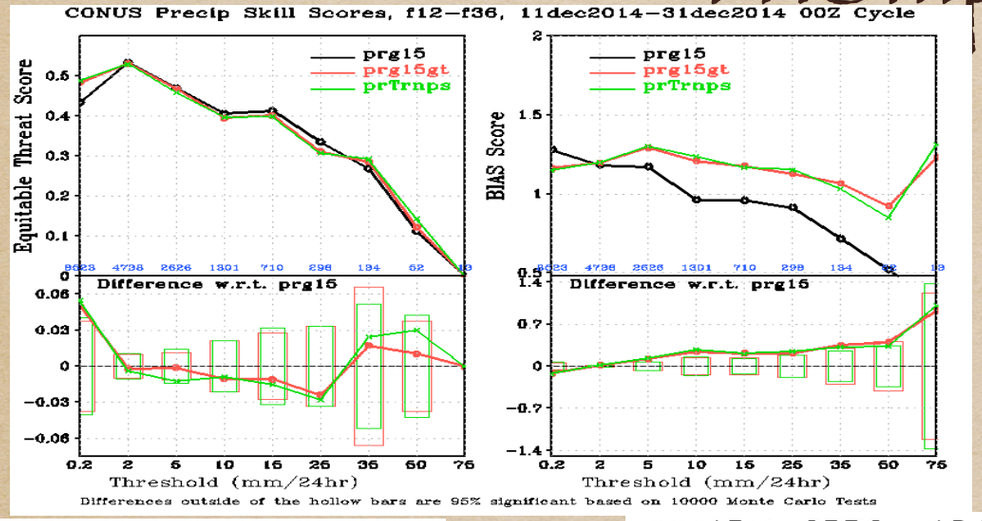


Spotty precipitation

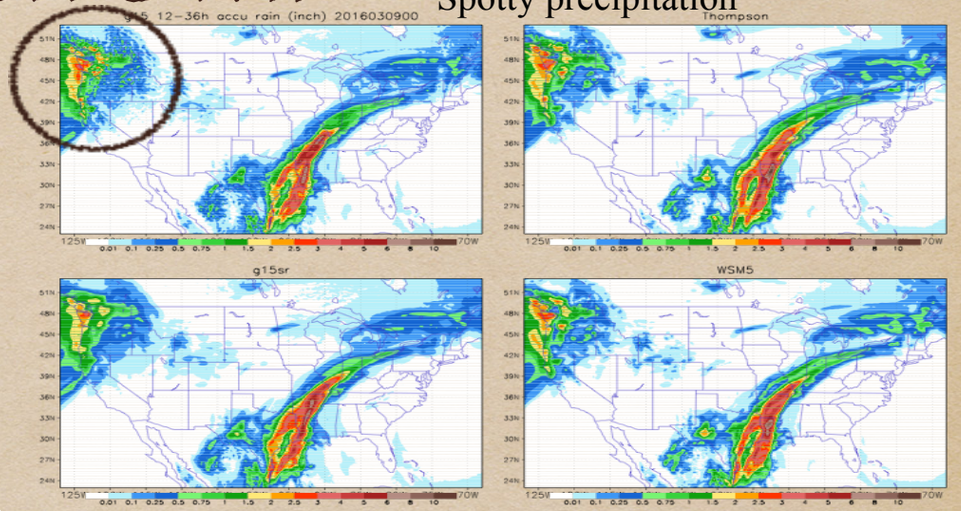


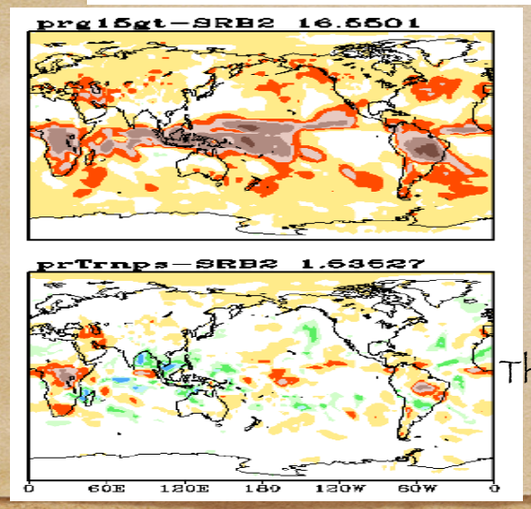
- Tested in the operational GFS
- Precipitation ETS score is close to GFS
- Cloud radiative effect is a little weaker than the GFS
- Eliminated spotty precipitation seen in the GFS with Zhao and Carr (1997)

Current status —Thompson's MP



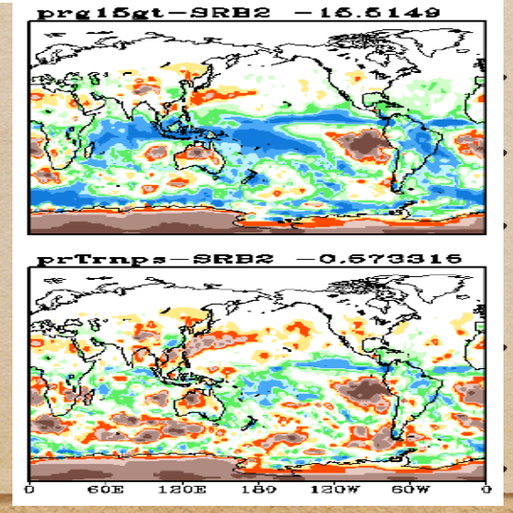
Spotty precipitation





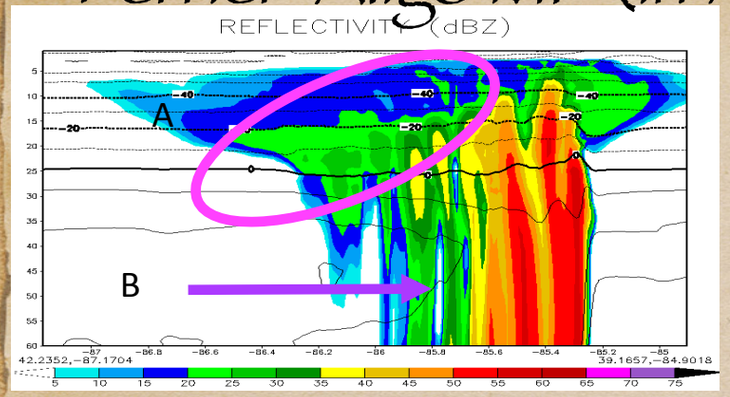
GFS

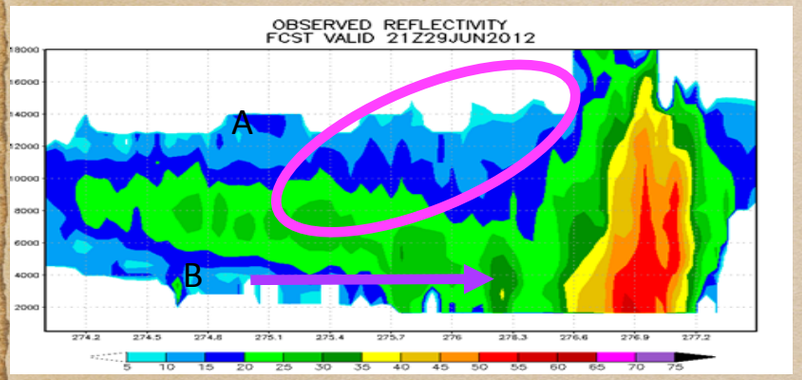
Thompson



- Tested in the operational GFS
- Significantly improved the cloud radiative effects
- Significantly improved the precipitation skill score in the light rain, but degraded in the moderate range
- Eliminated spotty precipitation seen in the GFS with Zhao and Carr (1997)
- In a version of NEMS now.

Ferrier-Aligo MP (in NAM)



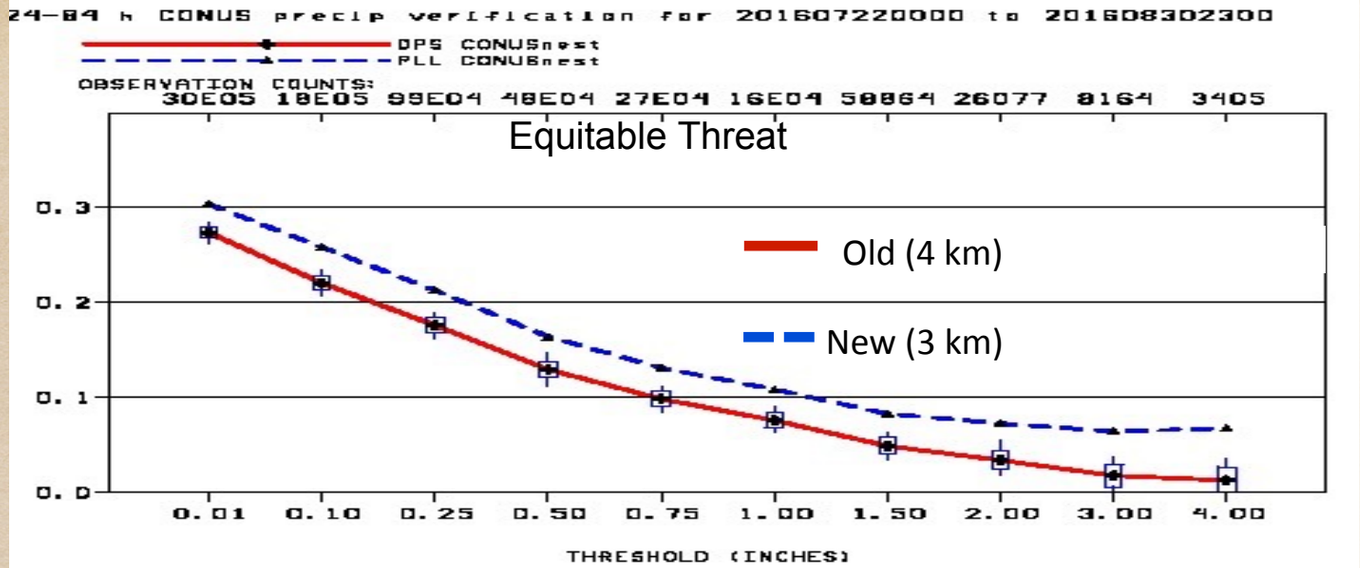


(Note different vertical coordinate)

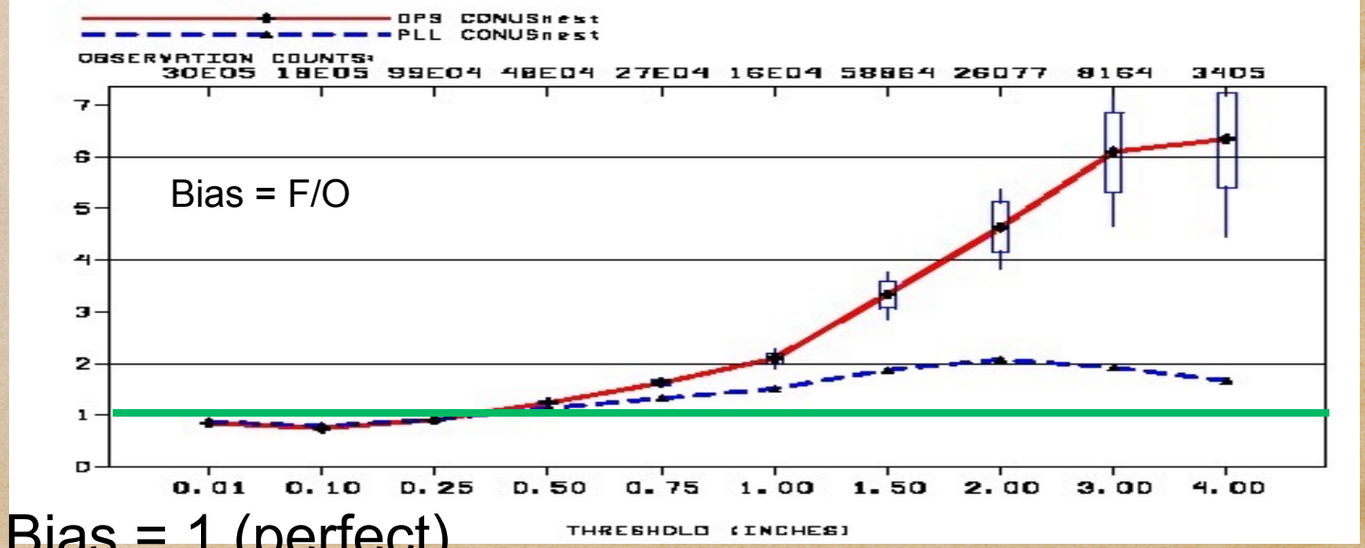
A - Reduced reflectivity in stratiform anvils
B - Increased reflectivity & rainfall below anvils
C - Improved dBZ (from objective verification)

Courtesy of Brad Ferrier and Eric Aligo

19 July – 29 August 2016 (0-24 h + 12-36 h + 24-48 h + 36-60 h)

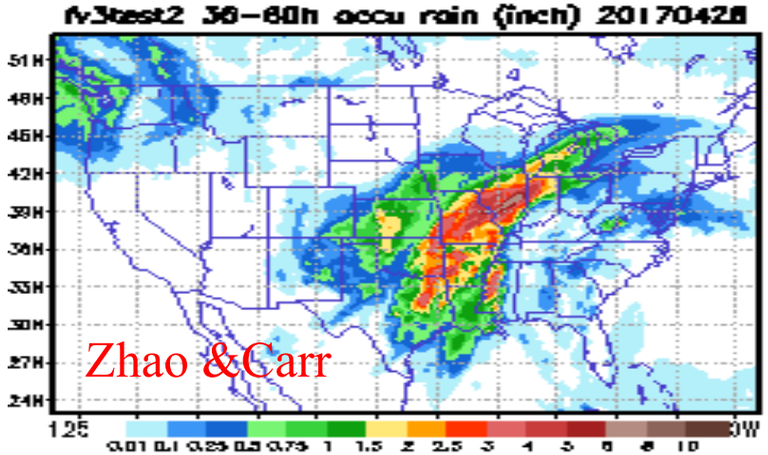


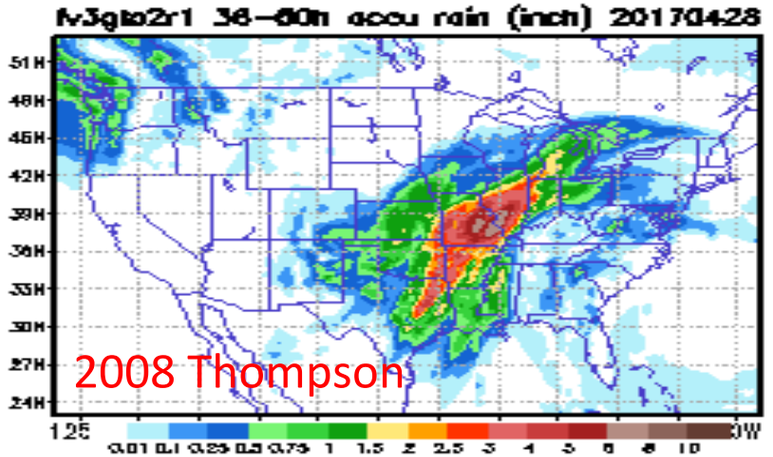
Precipitation Scores (CONUS Nests)

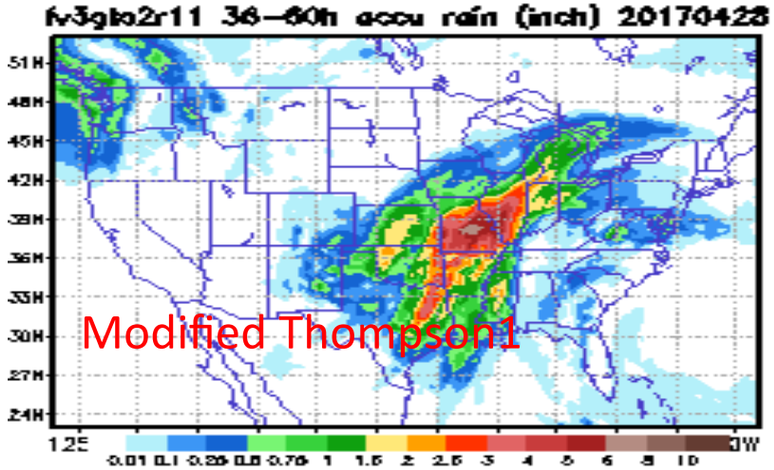


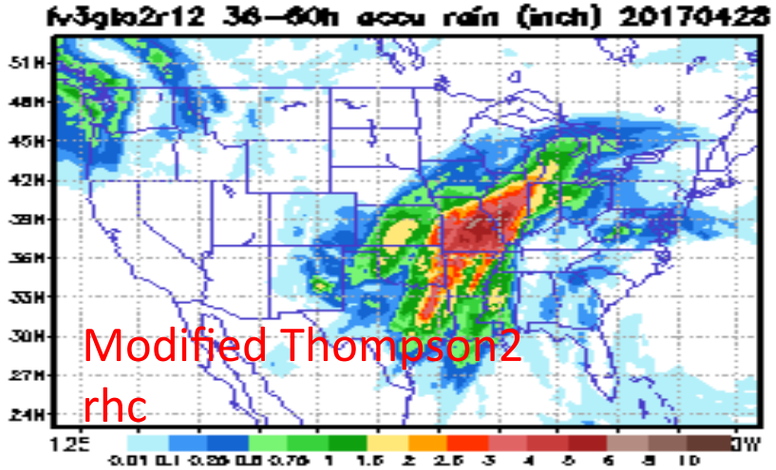
Bias = 1 (perfect)

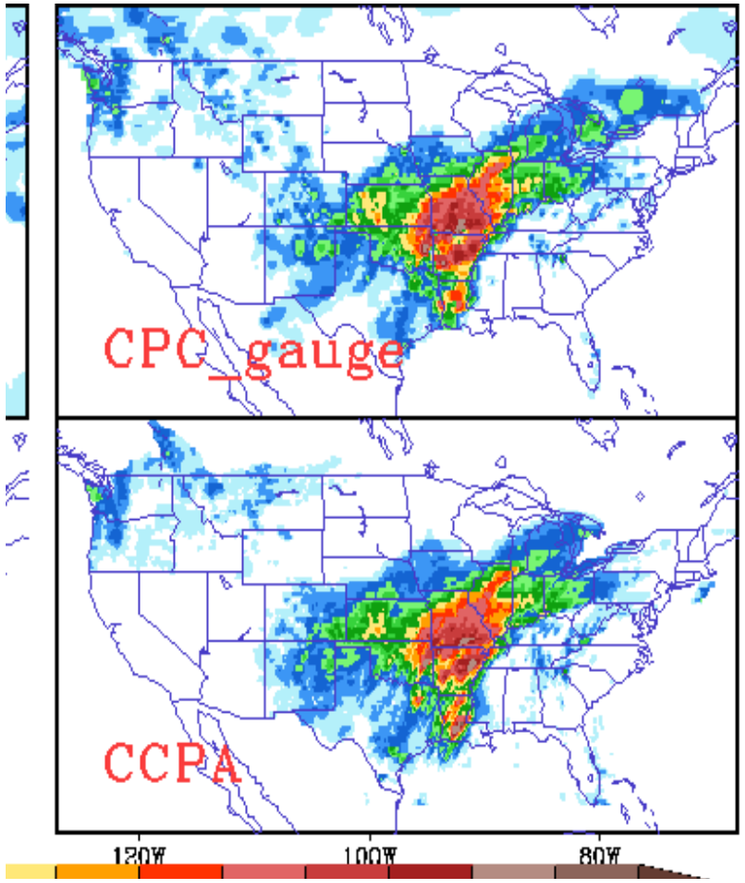
36-60h CONUS Precipitation Map

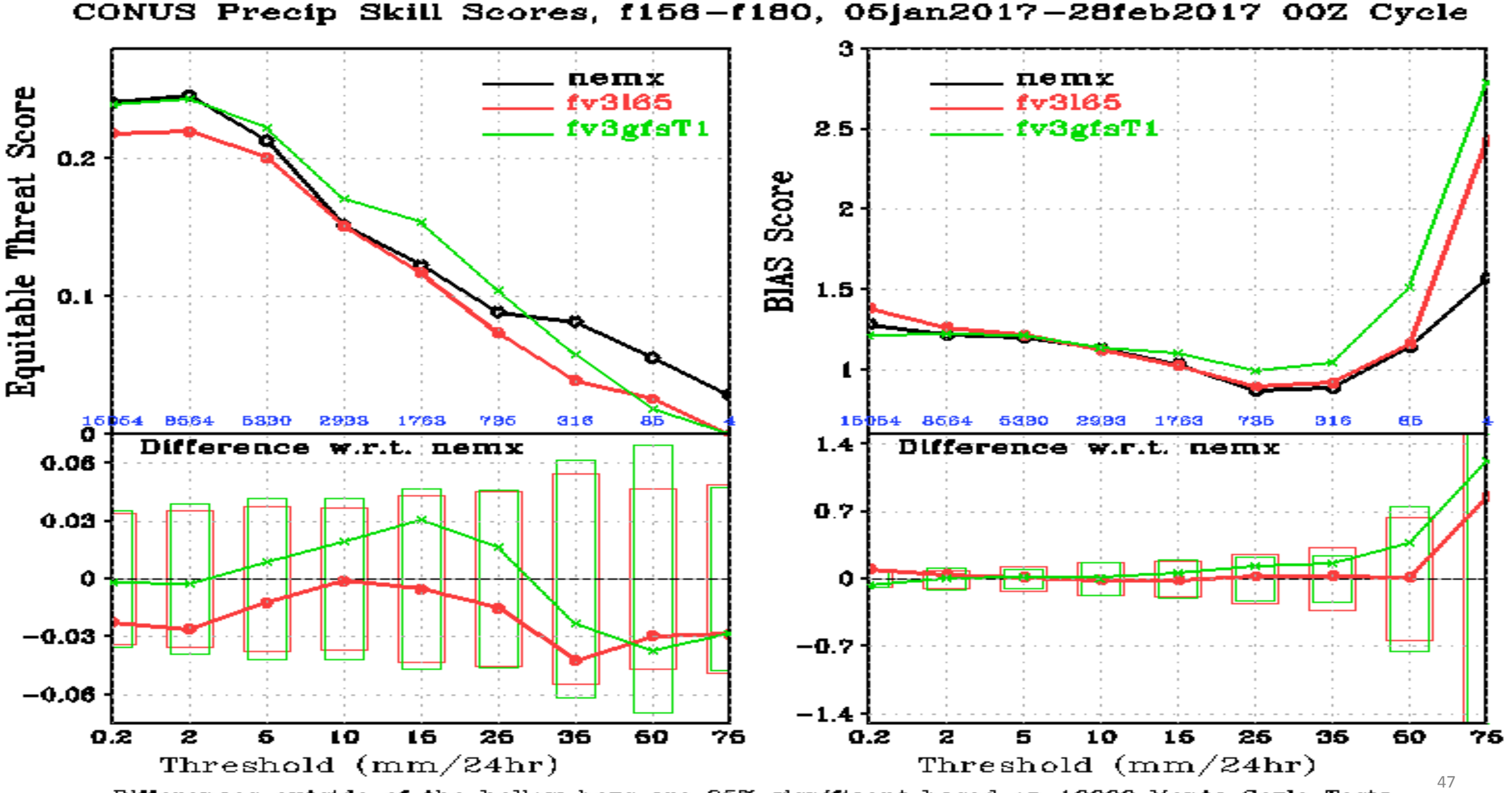






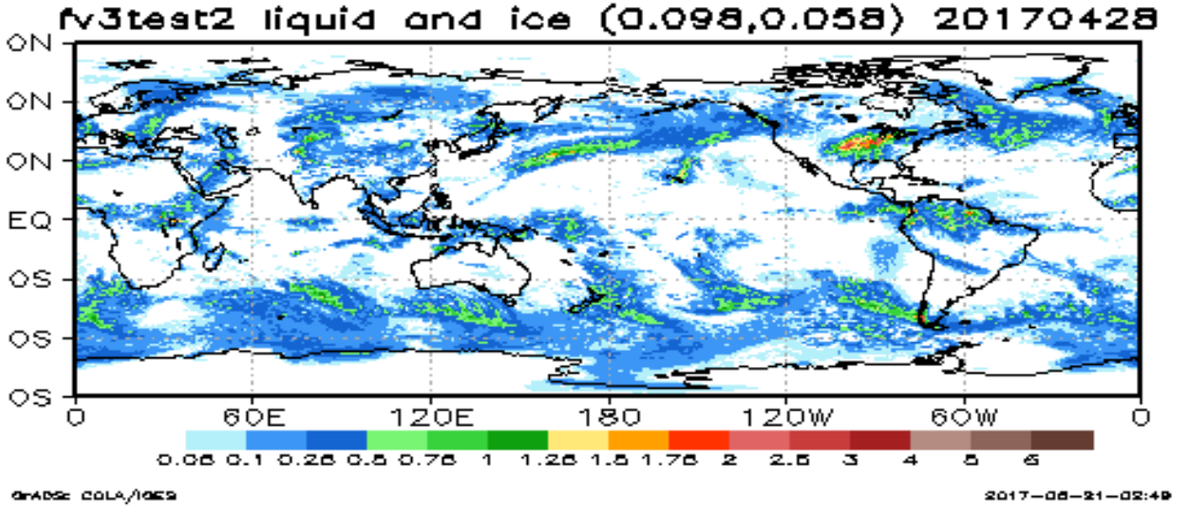




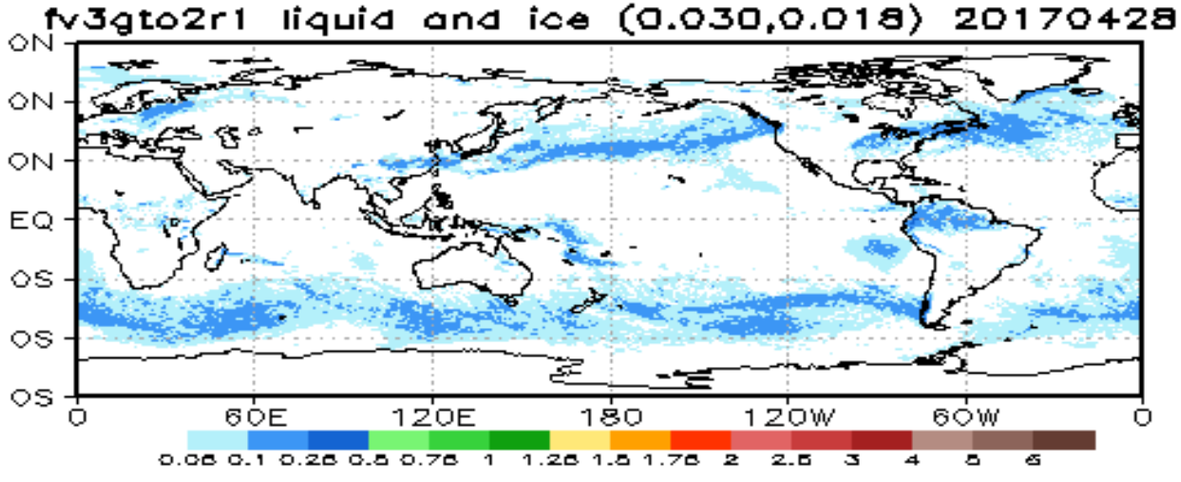

CONUS Precip Skill Scores, f156-f180, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
BIAS Score
nemx
fv3l65
fv3gfsT1
15054 8564 5330 2993 1763 795 316 85 4
Difference w.r.t. nemx
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

2-10day Global Condensate Path (ice + liquid water)

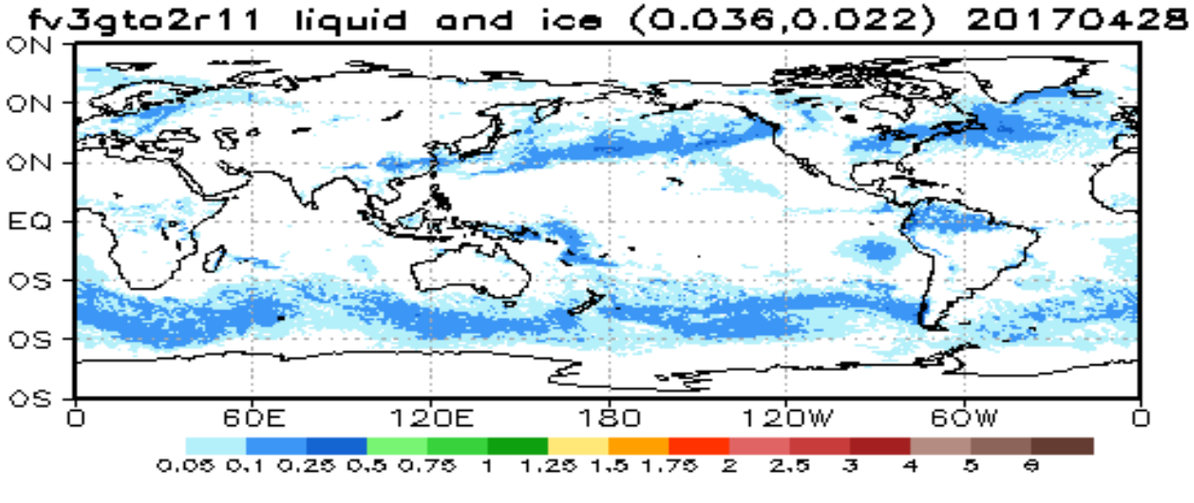
Zhao &Carr



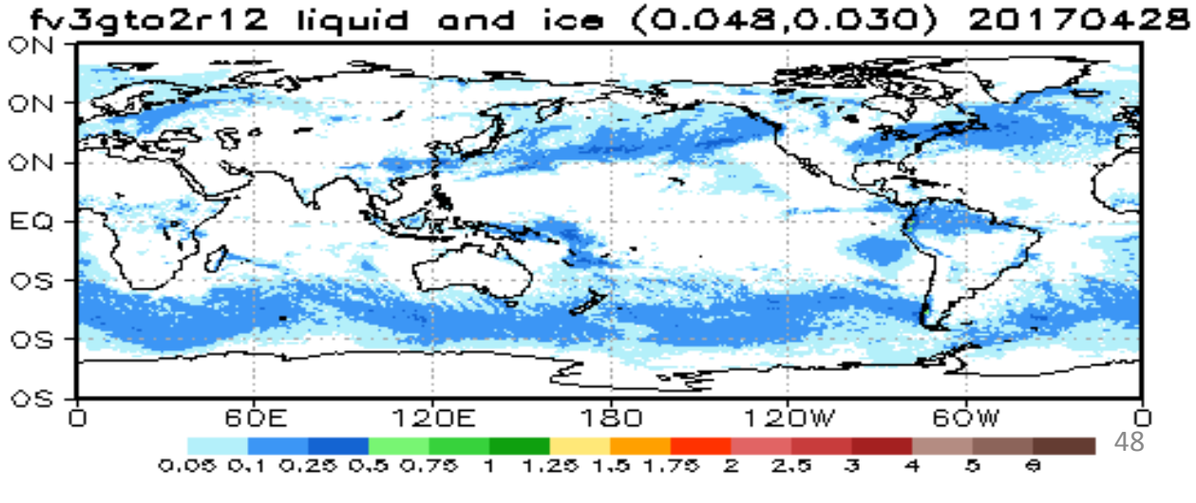
2008 Thompson

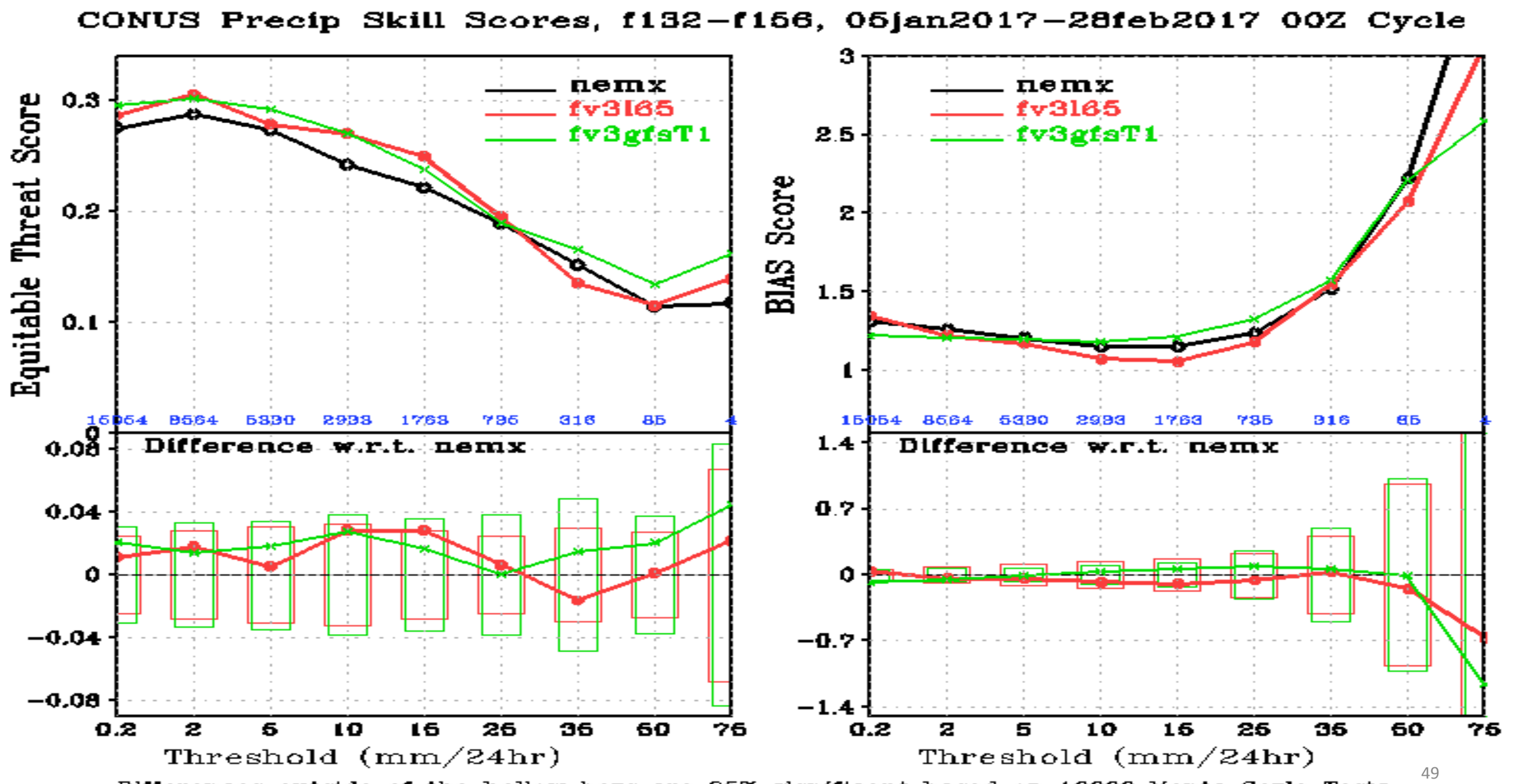


Modified Thompson1



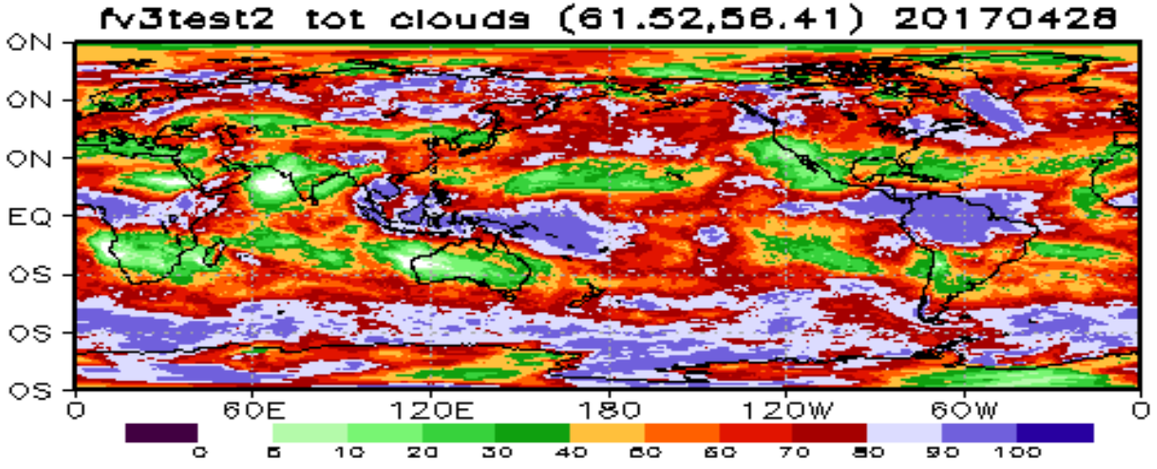
Modified Thompson2 rhc



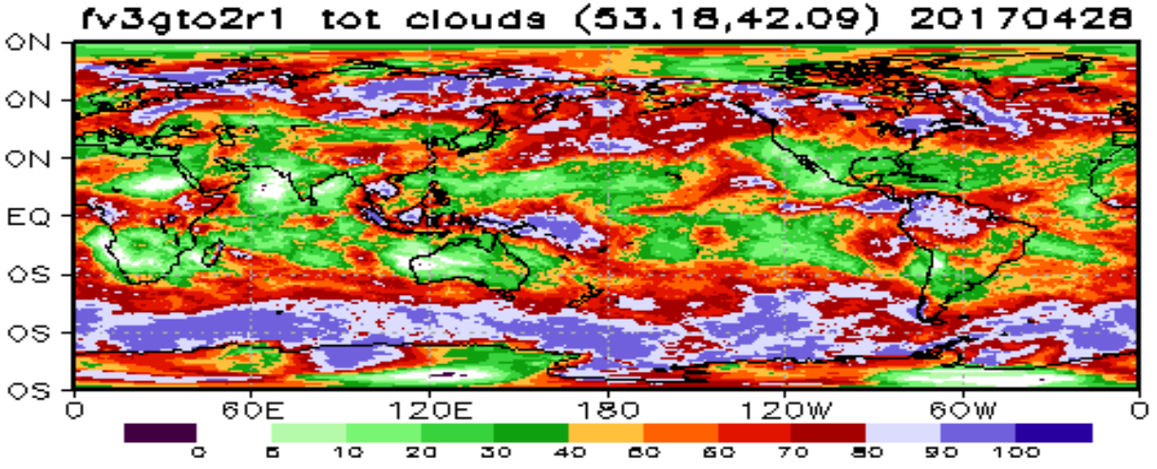

CONUS Precip Skill Scores, f132-f156, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
BIAS Score
nemx
fv3l65
fv3gfsT1
15064 8564 5390 2993 1763 785 316 85 4
Difference w.r.t. nemx
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

2-10day Mean Global Total Clouds

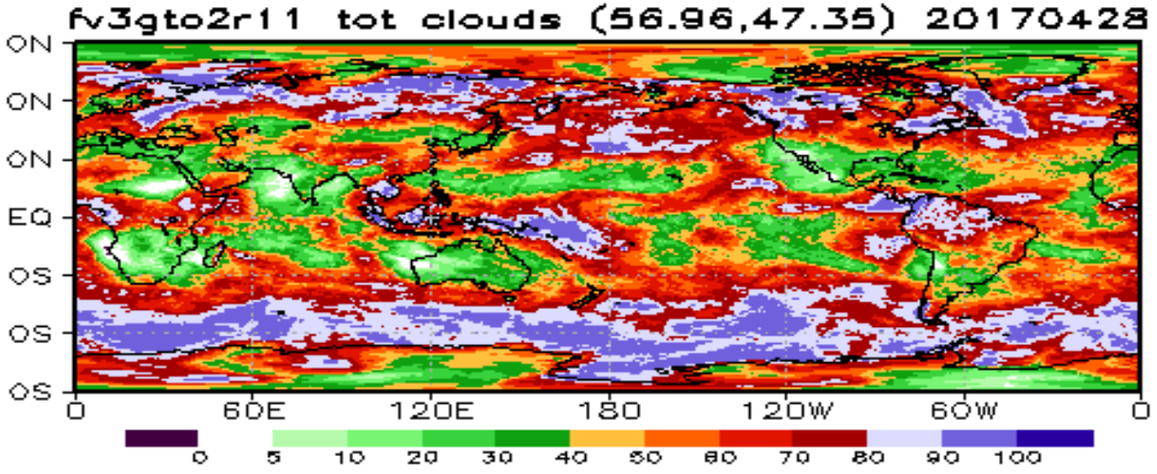
Zhao &Carr



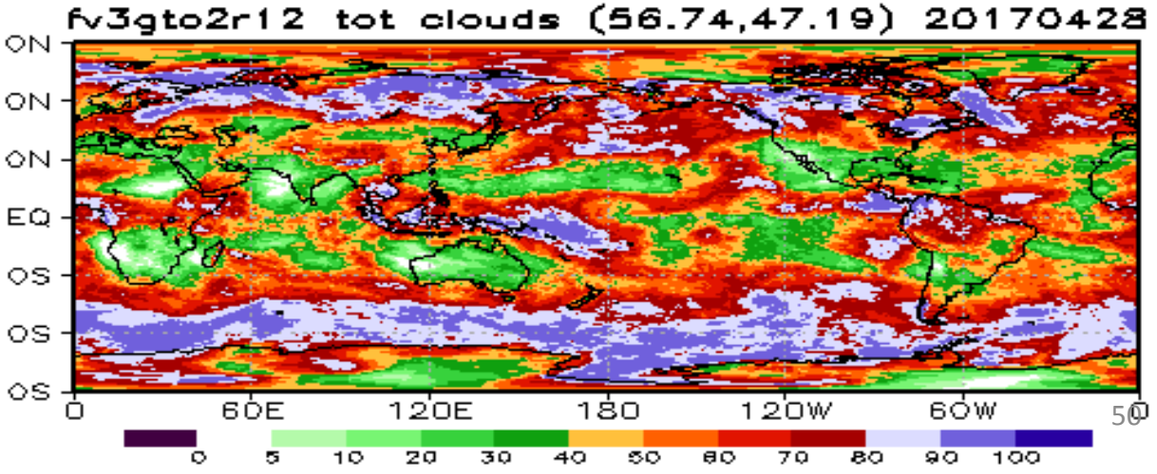
2008 Thompson

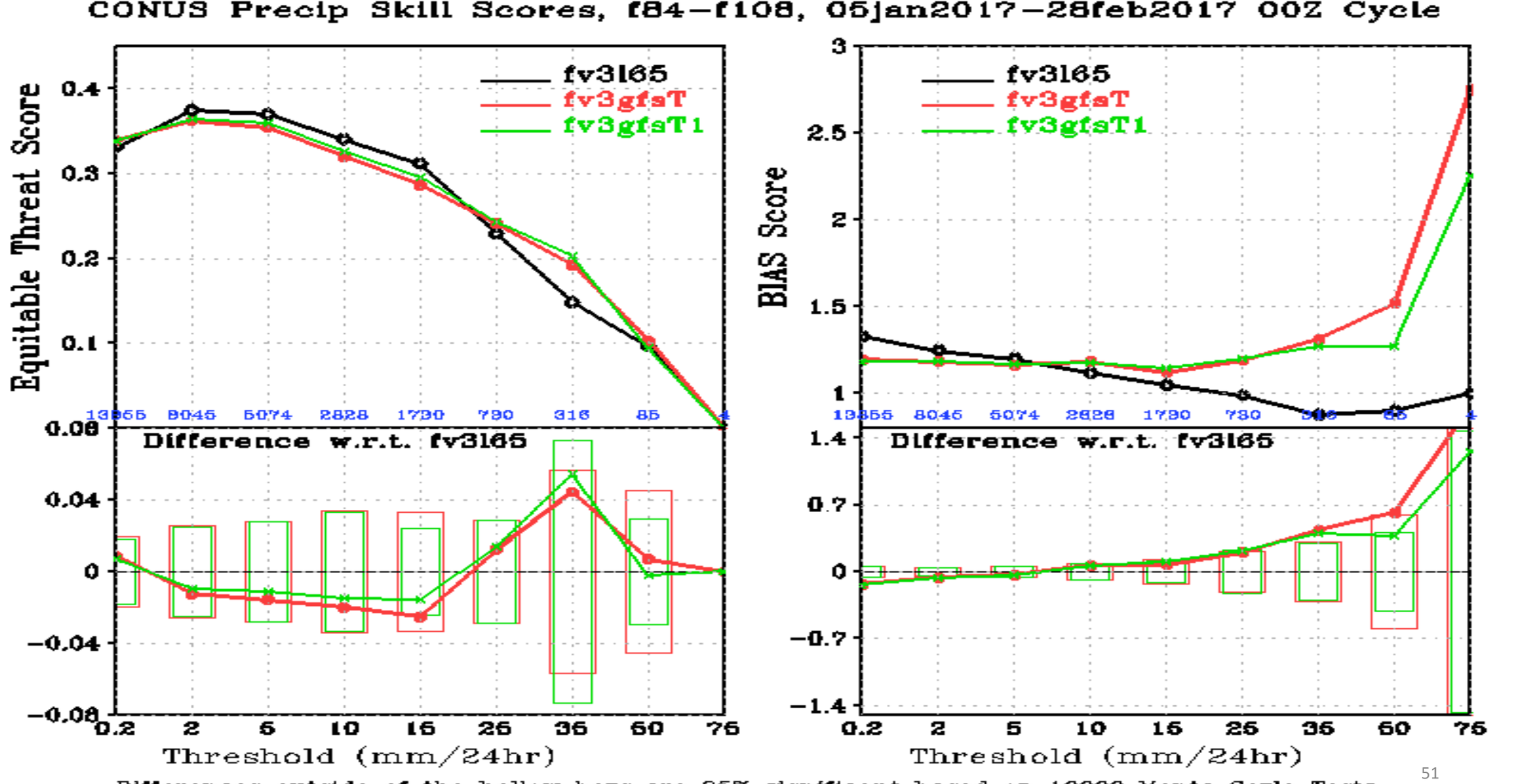


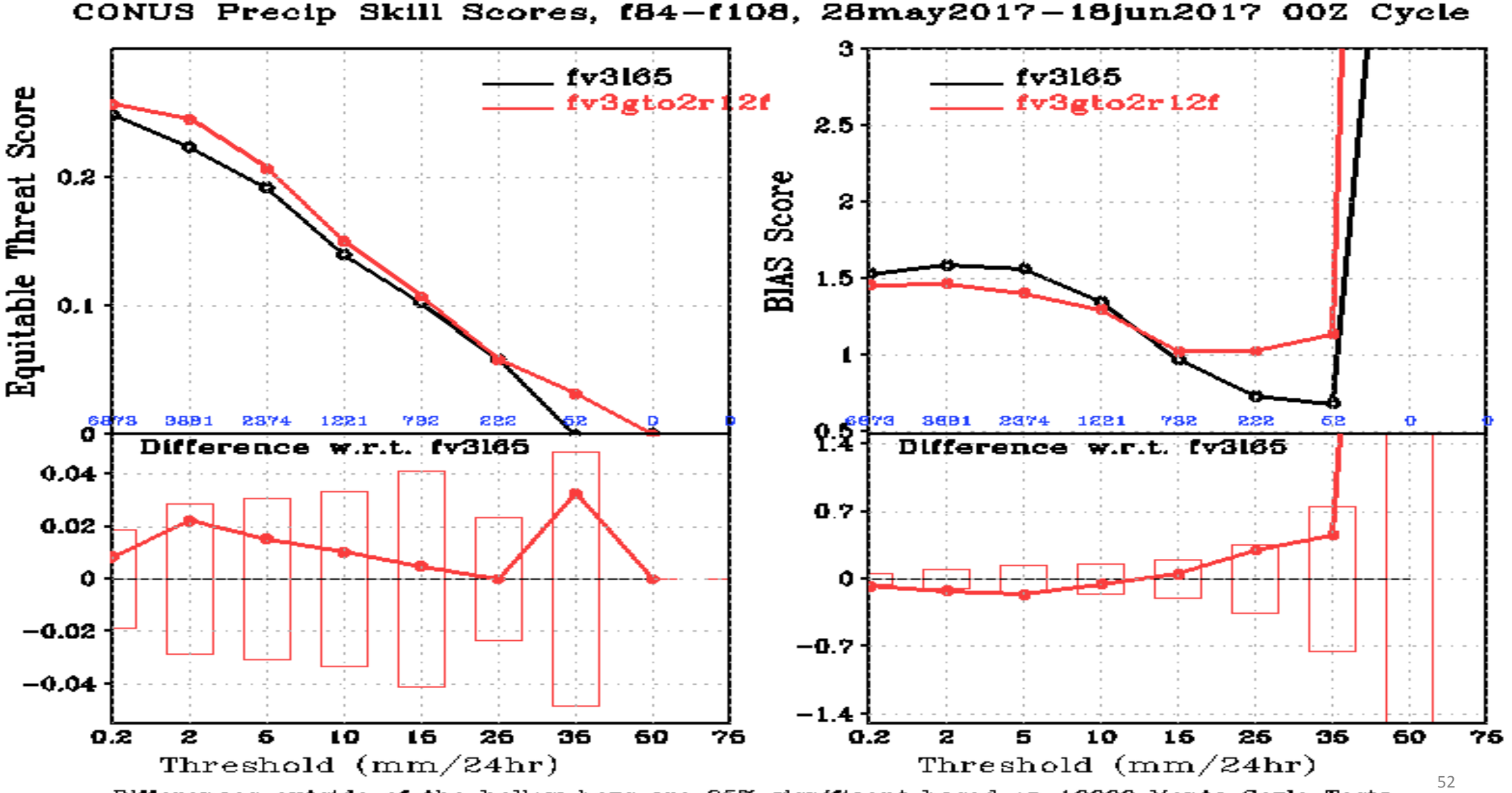
Modified Thompson1

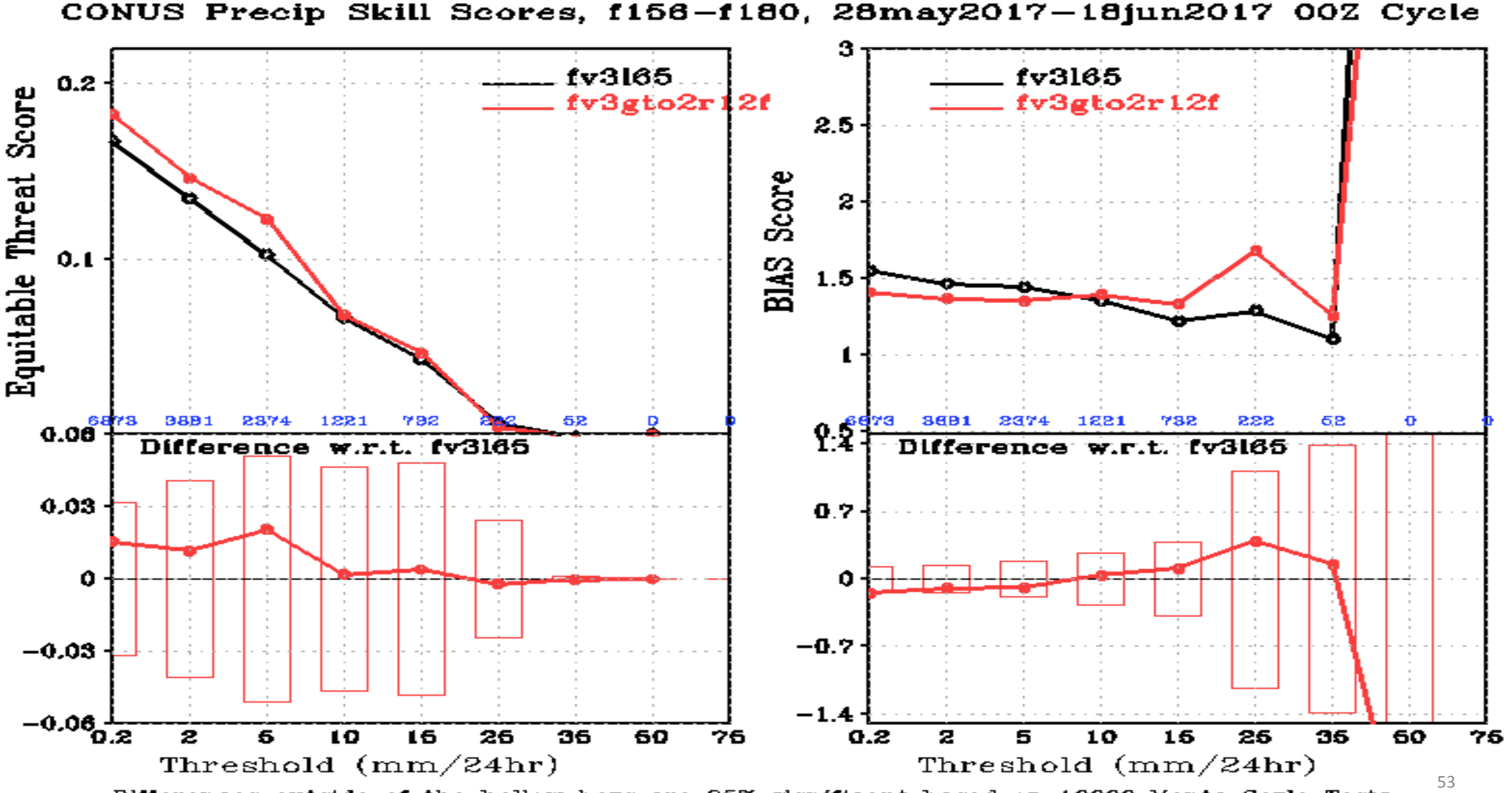


Modified Thompson2 rhc




CONUS Precip Skill Scores, f84-f108, 05jan2017-28feb2017 00Z Cycle
Equitable Threat Score
BIAS Score
fv3l65
fv3gfsT
fv3gfsT1
13355 8045 5074 2828 1730 730 316 85 4
Difference w.r.t. fv3l65
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests


CONUS Precip Skill Scores, f84-f108, 28may2017-18jun2017 00Z Cycle
Equitable Threat Score
BIAS Score
fv3l65
fv3gto2r12f
6873 3891 2374 1221 792 222 52 0
Difference w.r.t. fv3l65
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests


CONUS Precip Skill Scores, f156–f180, 28may2017–18jun2017 00Z Cycle
Equitable Threat Score
fv3l65
fv3gto2r12f
0.2
0.1
6873 3891 2374 1221 792 222 52 0 0
Difference w.r.t. fv3l65
0.06
0.03
0
−0.03
−0.06
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
BIAS Score
fv3l65
fv3gto2r12f
3
2.5
2
1.5
1
0.5
6873 3891 2374 1221 792 222 52 0 0
Difference w.r.t. fv3l65
1.4
0.7
0
−0.7
−1.4
0.2 2 5 10 15 25 35 50 75
Threshold (mm/24hr)
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests