Reducing systematic errors in GFS sensible weather forecasts

T. Dorian[1,2], M. Ek[1], C. Guastini[1,2], J. Han[1,3], G. Manikin[1], J. Meng[1,2], V. Tallapragada[1], H. Wei[1,2], G. White[1,2], Y. Wu[1,2], W. Zheng[1,2], I. Jirak[4], A. Dean[4], S. Weiss[4]

[1] EMC/NCEP/NWS/NOAA/DOC
[2]IMSG at NOAA/NCEP/EMC
[3]SRG at NOAA/NCEP/
[4]SPC/NCEP/NWS/NOAA/DOC

Glenn.White@noaa.gov

--Not just 500 hPa height anymore

--GFS sensible weather forecasts used and scrutinized ("They complain, but they use it".)

--EMC developers respond to forecaster complaints, modifying GFS physics

--Model Evaluation Group found many problems and heard about many others

--New implementation procedure increased forecaster-developer interaction http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb/

Includes link to precipitation verification

http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb/g2o/g2o_00Z/

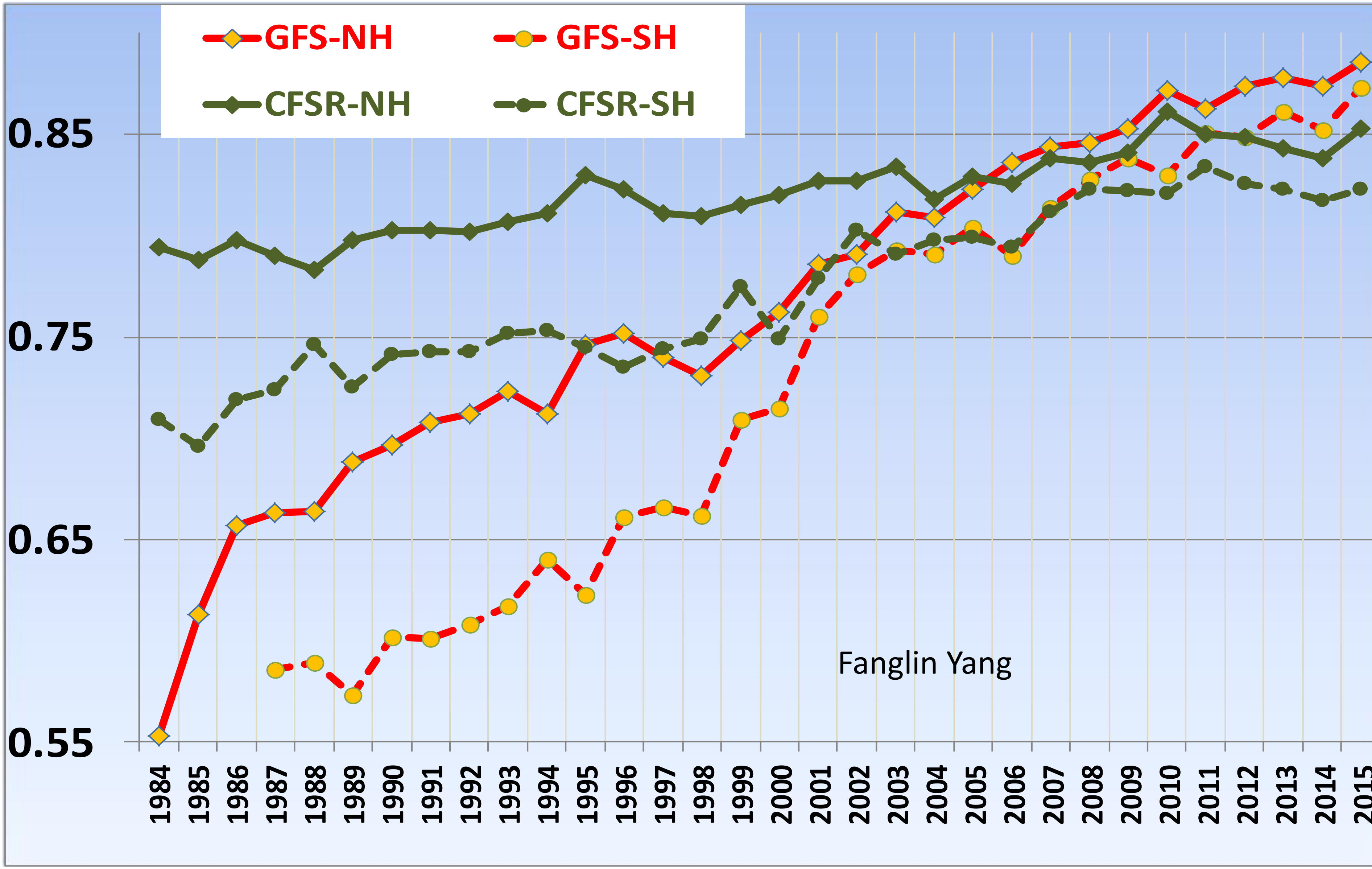
Verification of near surface fields over continental US.

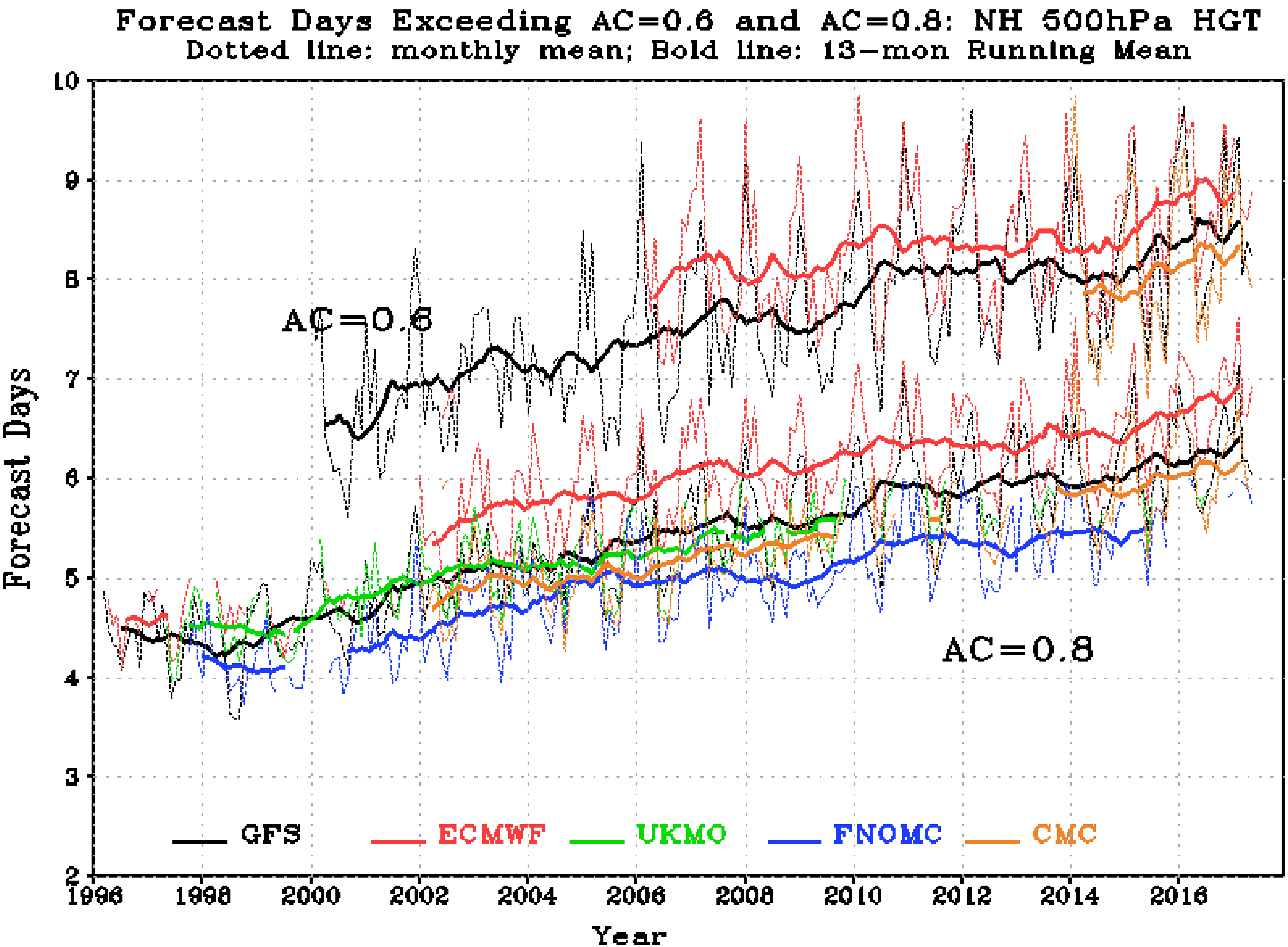
Posters:

Yihua Wu—land surface parameterization
Tracey Dorian-GFS mode verification
Glenn White-systematic errors

Annual Mean 500-hPa HGT Day-5 Anomaly Correlation

http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb/longterm/





Forecast Days Exceeding AC=0.6 and AC=0.8: NH 500hPa HGT
Dotted line: monthly mean; Bold line: 13-mon Running Mean
Forecast Days
Year
AC=0.6
AC=0.8
GFS
ECMWF
UKMO
FNOMC
CMC
10
9
8
7
6
5
4
3
2
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

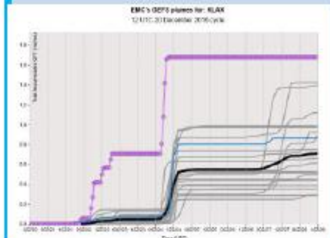
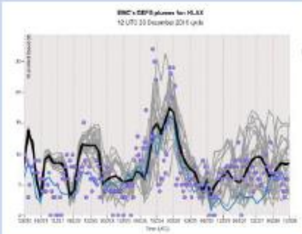
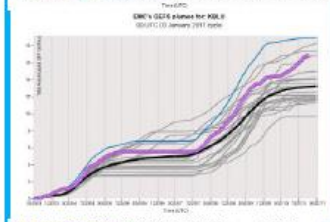
588. EMC's Model Evaluation Group

Geoffrey Manikin[1], Glenn White[1], Tracey Dorian[1,2], Corey Guastini[1,2]
[1]EMC/NCEP/NWS/NOAA/DOC [2]IMSG

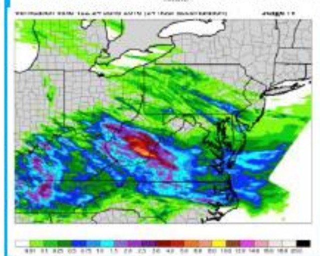
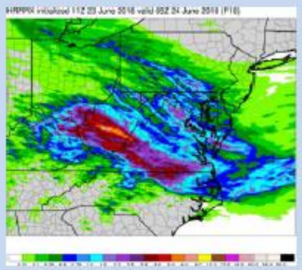
MEG presents weekly synoptic model evaluations to

1) **Improve NOAA forecast systems**
2) **Improve communications between model developers and model users.**

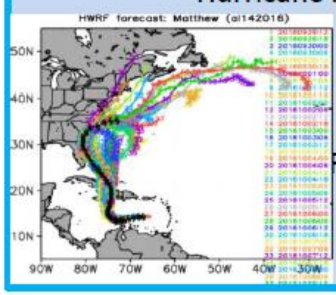
Recent West Coast Storms

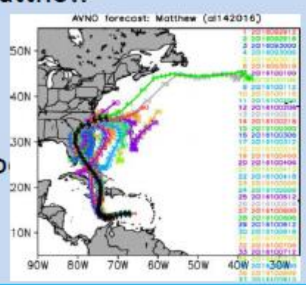
GEFS plume plots for Los Angeles (top) and Emigrant Gap, Blue Canyon Nyack Airport, CA (right)
Grey GEFS ensemble members
Black GEFS ensemble mean
Blue GFS
Purple dots observed

Hurricane Matthew



Flo



MEG's Role in New Implementation Process

Work with forecasters to find model problems, present to developers
Developers address problems,
MEG examines tests of model fixes
Initial briefings from developers on upgrades
Alert field on what to look for before evaluation begins
Longer scientific evaluation before, separate from 30 day IT test
Greater forecaster involvement
Set up and maintain web pages for each implementation
Review cases and stats
Must find effective way to get parallel data to the field
Bring in visitors to evaluate tests with developers
New process improved GFS 2016 implementation

Greater involvement with NWS regions, forecast offices

MEG involved in Science Technology Integration teams with NWS SOOs

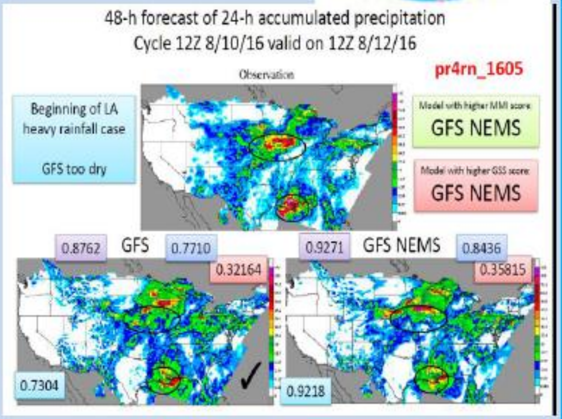
Global: Involved in GFSX evaluation effort, providing recommendations on global model development
Hi-Res Ensemble: Evaluating hi-res guidance to provide recommendations on construction of future convection-permitting ensemble
Communication/Dissemination: Working on better ways to get model data to forecast offices

MEG Visiting scientist program

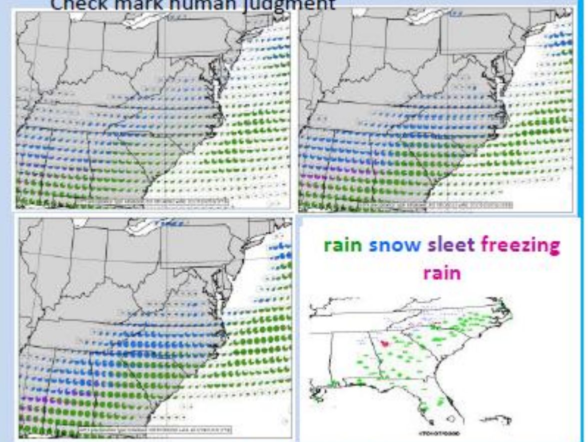
MEG personnel visited 5 WFOs last fall
Plans for WFO forecasters to visit EMC

Questions

geoffrey.manikin@noaa.gov
glenn.white@noaa.gov tracey.dorian@noaa.gov
corey.guastini@noaa.gov



Mode verification given by numbers
Check mark human judgment



Winter storm Jan. 7, 8, 2017 Individual pies show how many GEFS ensemble members forecast that category

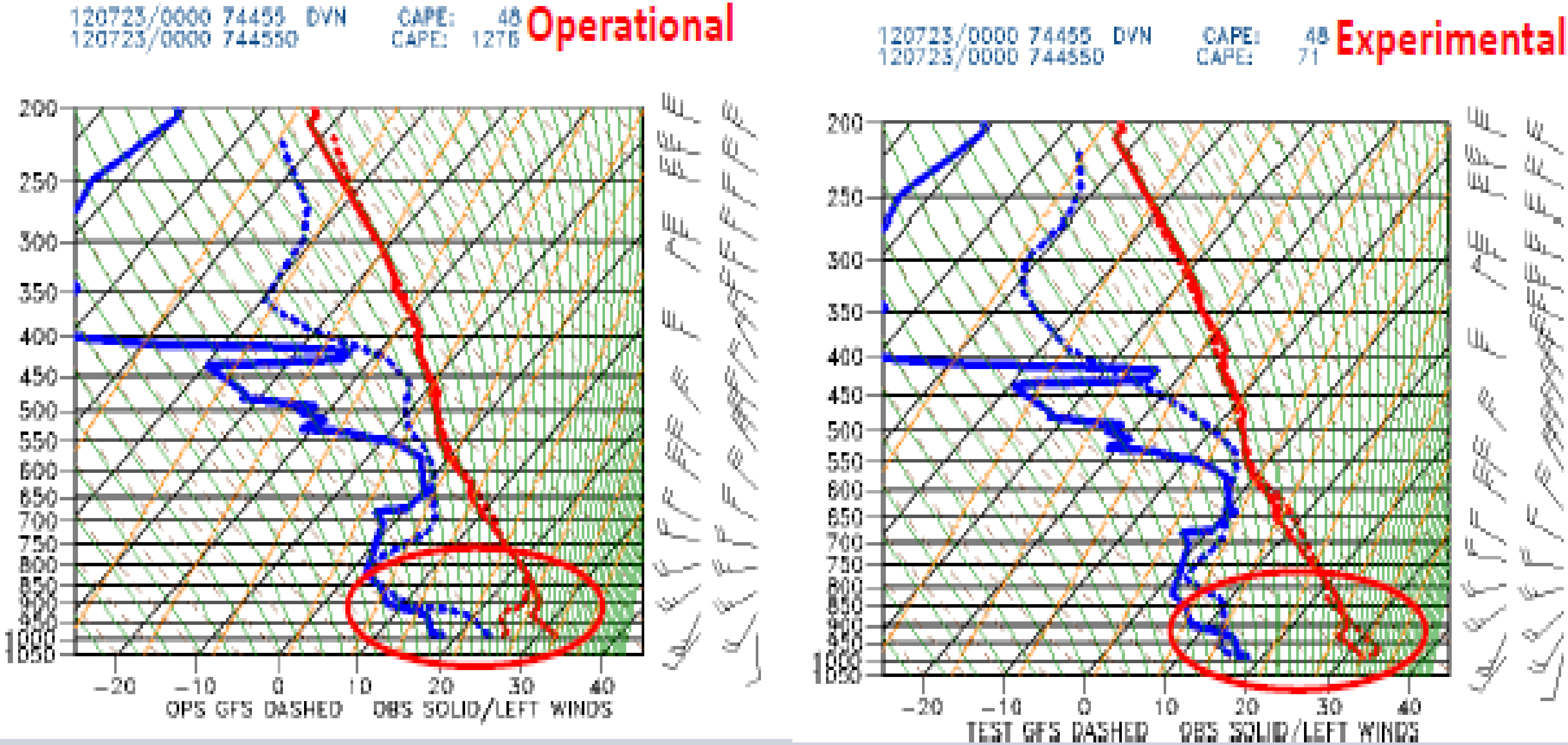
The MEG meets each Thursday 11:30 AM EST NCWCP

ALL ARE WELCOME TO ATTEND

Webinar access available, presentations recorded

Contact mary.hart@noaa.gov for MEG announcements/agendas

evaluations are held. The group noted a late afternoon moist bias in the GFS (especially over the mid west US); an associated cold bias became evident as summer arrived since the problem was most evident in hot air masses. EMC was aware of issue by the time forecasters noticed it and were able to implement a correction in early September.



GFS soundings for Davenport, Iowa 0Z July 23, 2012 G. Manikin

09/05/2012 12Z: GFS Minor Change. A look-up table used in the land surface scheme to control Minimum Canopy Resistance and Root Depth Number was updated to reduce excessive evaporation to mitigate GFS cold and moist biases in late afternoon over the central US when drought conditions existed in summer of 2012.

Physics "Whack-a-mole" or "wheel of pain"

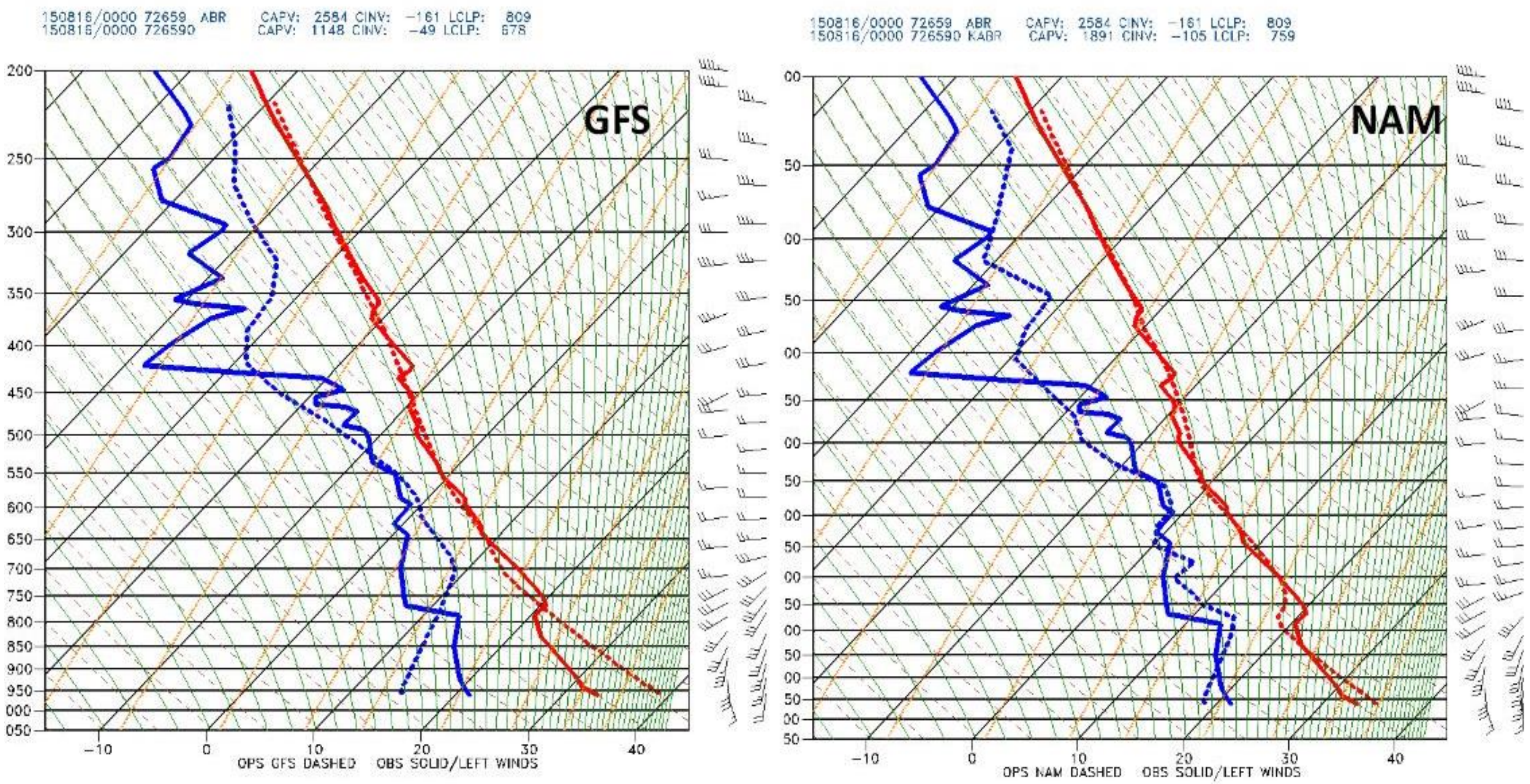
GFS 2016 implementation

http://www.emc.ncep.noaa.gov/gmb/noor/4dGFS/synergy%20announcementjan08.htm

Complaints

- **We received many complaints about the GFS being too warm and too dry from the field offices particularly over the Great Plains in the summer of 2015.**

12h FCSTS vs OBS for Aberdeen, SD



Solutions

Evaporation is too low and sensible heat flux is too high after the new soil moisture climatology (GLDAS/CFS) is used in the operational GFS since January 2015.

Factors include:
•Thermal roughness and momentum roughness
•Canopy resistance
•Soil moisture

We proposed the following parameter refinements in pr4devb:

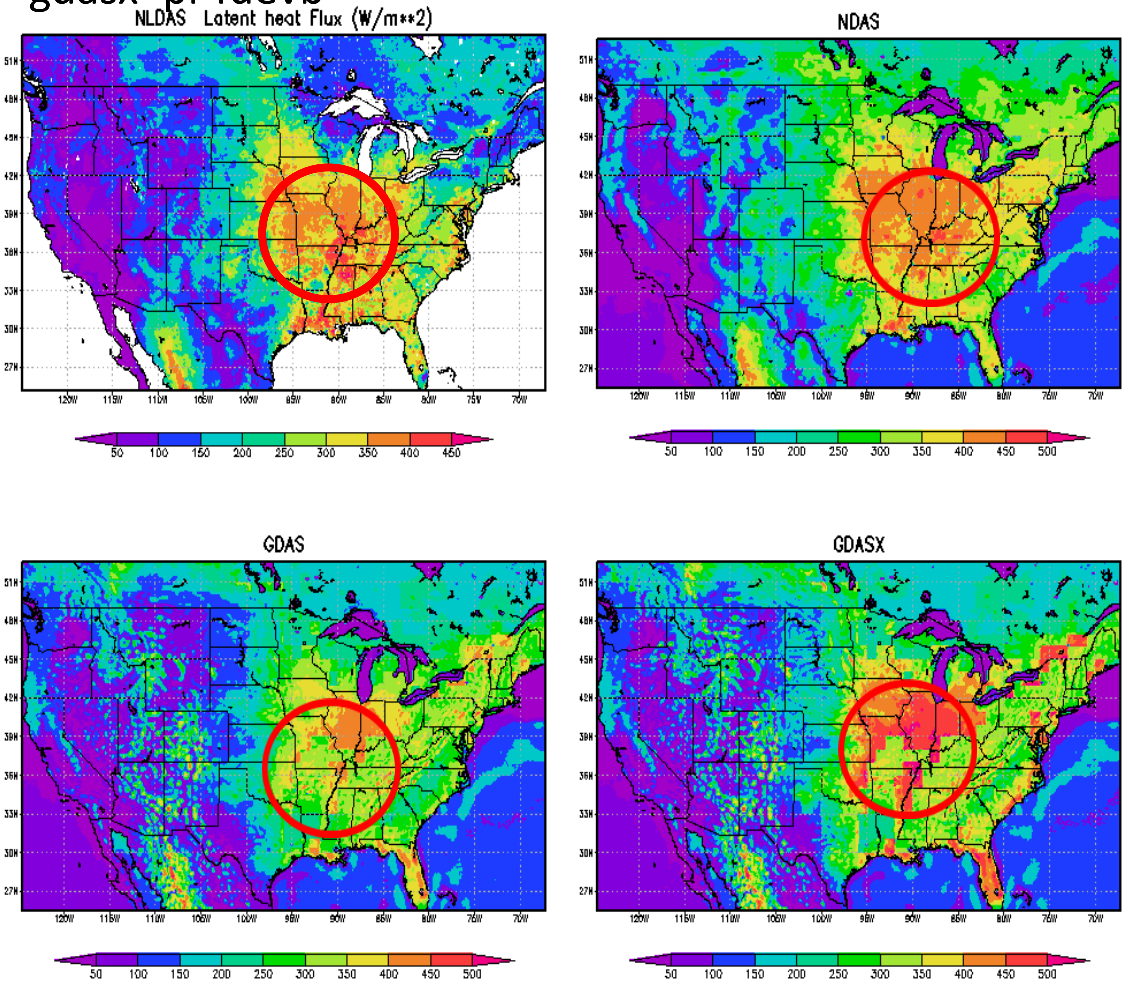
- **rsmin (veg resistance coefficient) for grassland from 45 to 20**
- **rsmin for cropland from 45 to 20**
- **roughness length for cropland from 3.5cm to 12.5cm (used to address too strong surface winds)**

Improvements

focus on the summer period of pr4devb (from July 8 to August 31, 2015)

18z latent heat flux averaged over 20150708-20150831

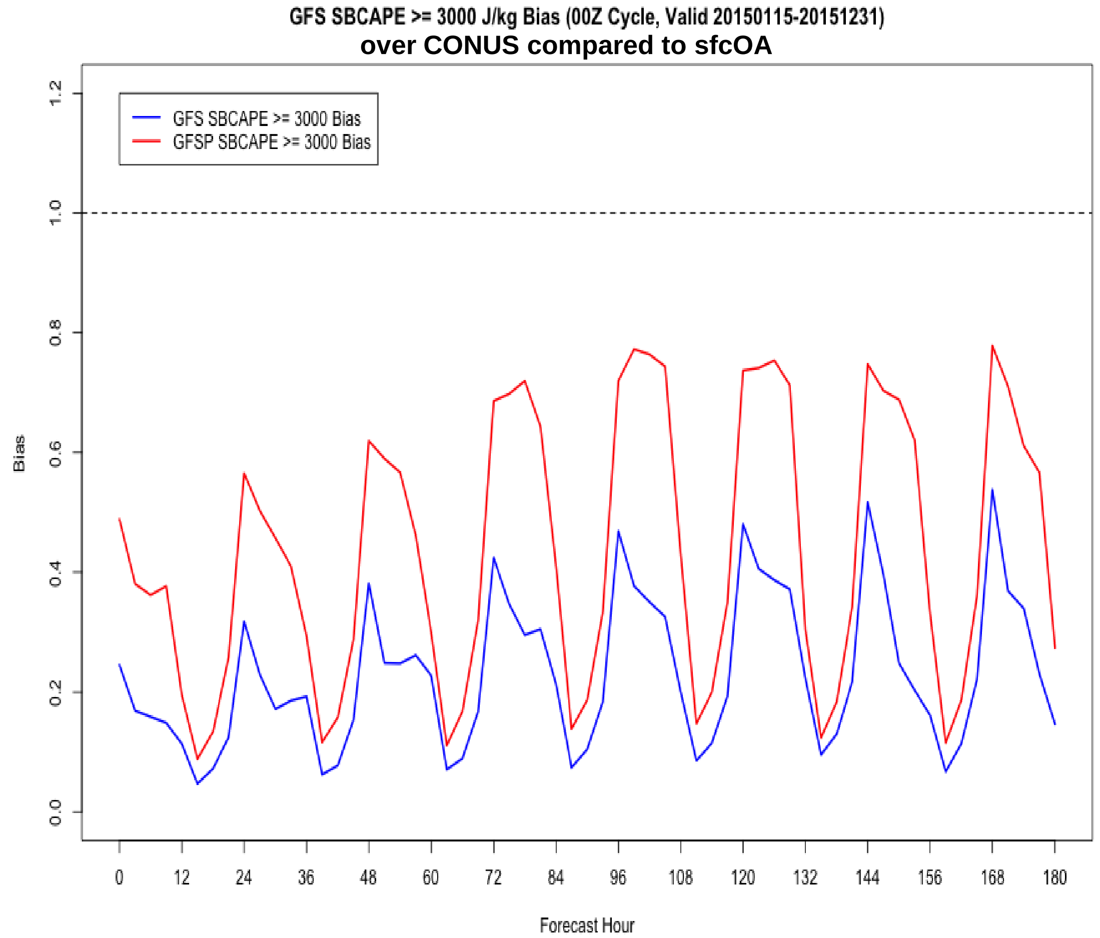
gdasx=pr4devb



Compared to NLDAS (quasi observation) and NDAS, the operational GFS produces too little evaporation. The parallel GFS has increased the evaporation.

SPC GFS Evaluation

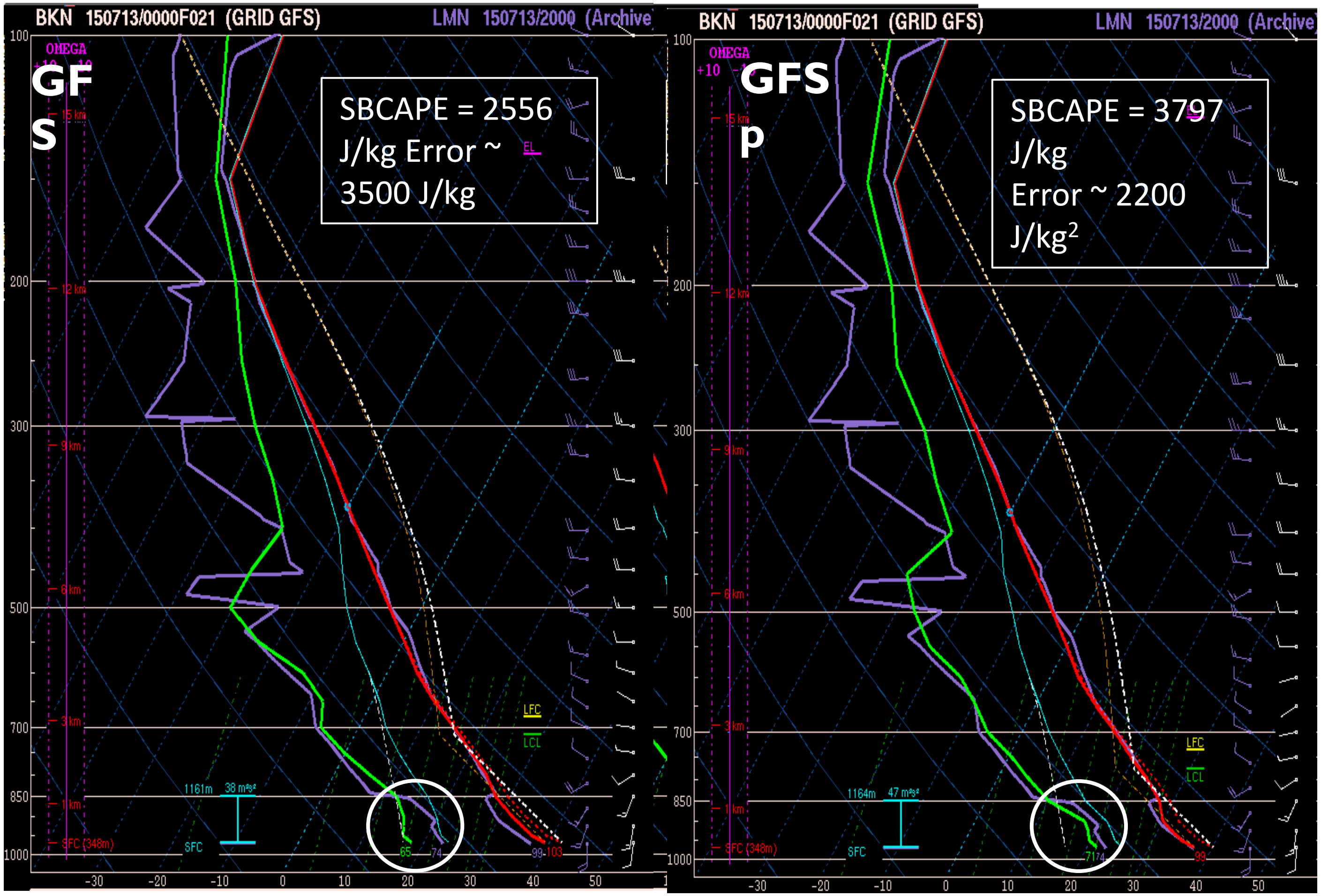
SBCAPE Bias: Jan-Dec 2015



- For 2015, the low frequency bias of SBCAPE is improved at all instability thresholds in the GFSp, but still very low compared to observations.

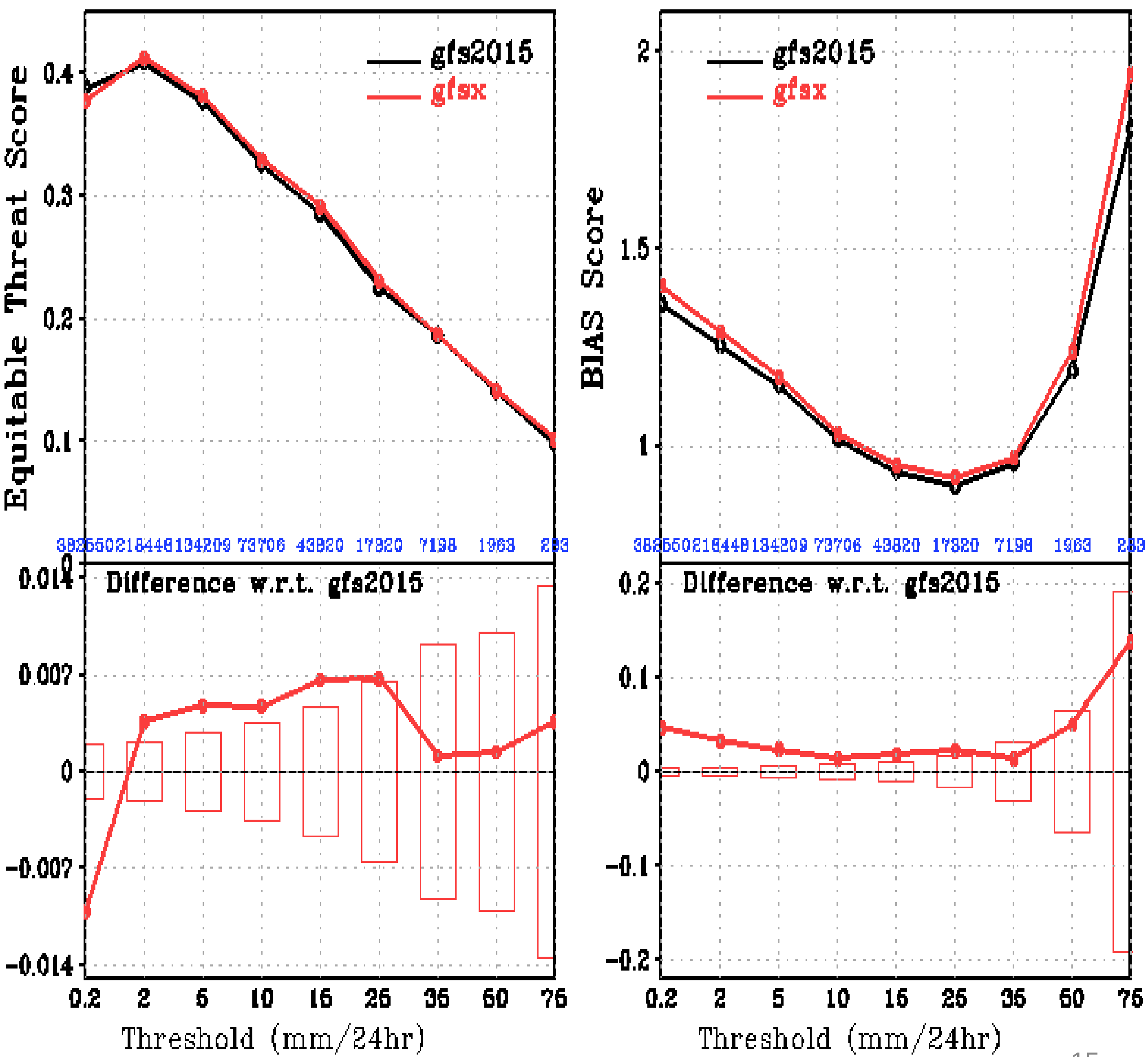
3 Jul 2015 Moderate Risk

LMN Obs/Forecast Sounding: 13/20 & 12/00F021 Valid 21Z 13 Jul – D1



- The GFS is too hot and much too dry near the surface, while the GFSp is an improvement. However, it is still too low by ~2200 J/kg compared to observed sounding.

CONUS Precip Skill Scores, f36-f60, 01may2013-28feb2016 00Z Cycle



Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

GFS17 implementation

http://www.emc.ncep.noaa.gov/gmb/noor/GFS2017/GFS2017.htm

Major science issues addressed in Q3FY17 GFS Upgrades

Surface Parameters (Land Surface Upgrades):

- Cold temperature bias over snow
  - » Alaska, NW, NE
- Stable boundary
- Land-Atmosphere Decoupling
- Snow albedo too large

- IGBP 20-type land classifications and STASGO 19 type soil classifications
- New MODIS-based snow free and max snow albedo
- Diurnal albedo treatment
- Unify snow cover and albedo between radiation driver and Noah LSM
- Fix excessive cooling of T2m during sunset
- Increase ground heat flux under the deep snow

Precipitation (Convection Scheme Upgrades):

- “socialist” rain (too much drizzle)
- “popcorn” precip in western US
- convective fraction consistent w/resolution

- Scale/aerosol-aware, parameterization
- Decreased rain conversion rate above freezing level.
- Update convective adjustment time in deep convection
- Update cloud base mass flux in shallow convection scheme
- Additional trigger based on CIN
- Enhanced convective cloudiness

SST (Replace RTGSST with new NSST):

- Oceanic vertical temperature structure near surface due to the diurnal warming and sub-layer cooling physics processes

Improving the Stable Surface Layer in GFS

Introduction of a stability parameter constraint that prevents the land-atmosphere system from fully decoupling:

$$z/L < z/L|_M = \ln(z/z_0)/[2*\alpha*(1-z_0/z)]$$

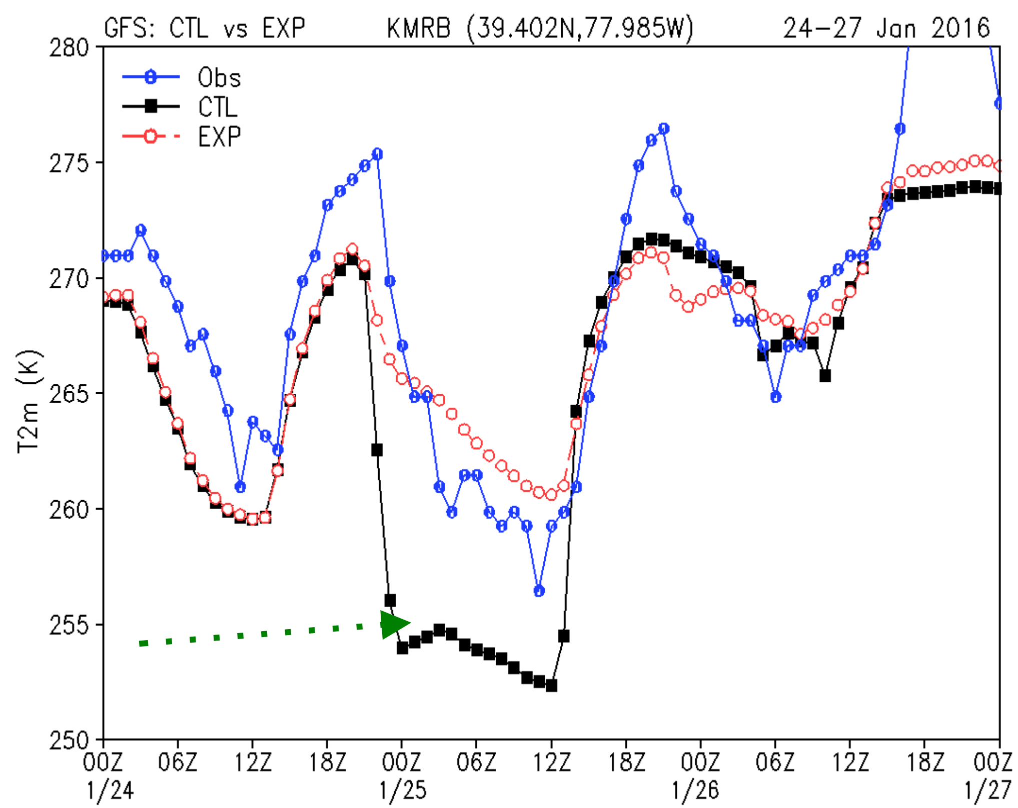
Here *z* is the height, *L* is the Obukhov length, *z0* is the momentum roughness length, and *α*=5.

GFS Test: 00Z, 2016-01-24 Cycle

T2m @ MRB Martinsburg RGNL, WV

CTL: Rapidly cooling more than 15 °C during 3hr;

EXP: Substantially improved



Change in rms fit to station observations May 1, 2015-Dec. 28, 2016
96 hr forecasts

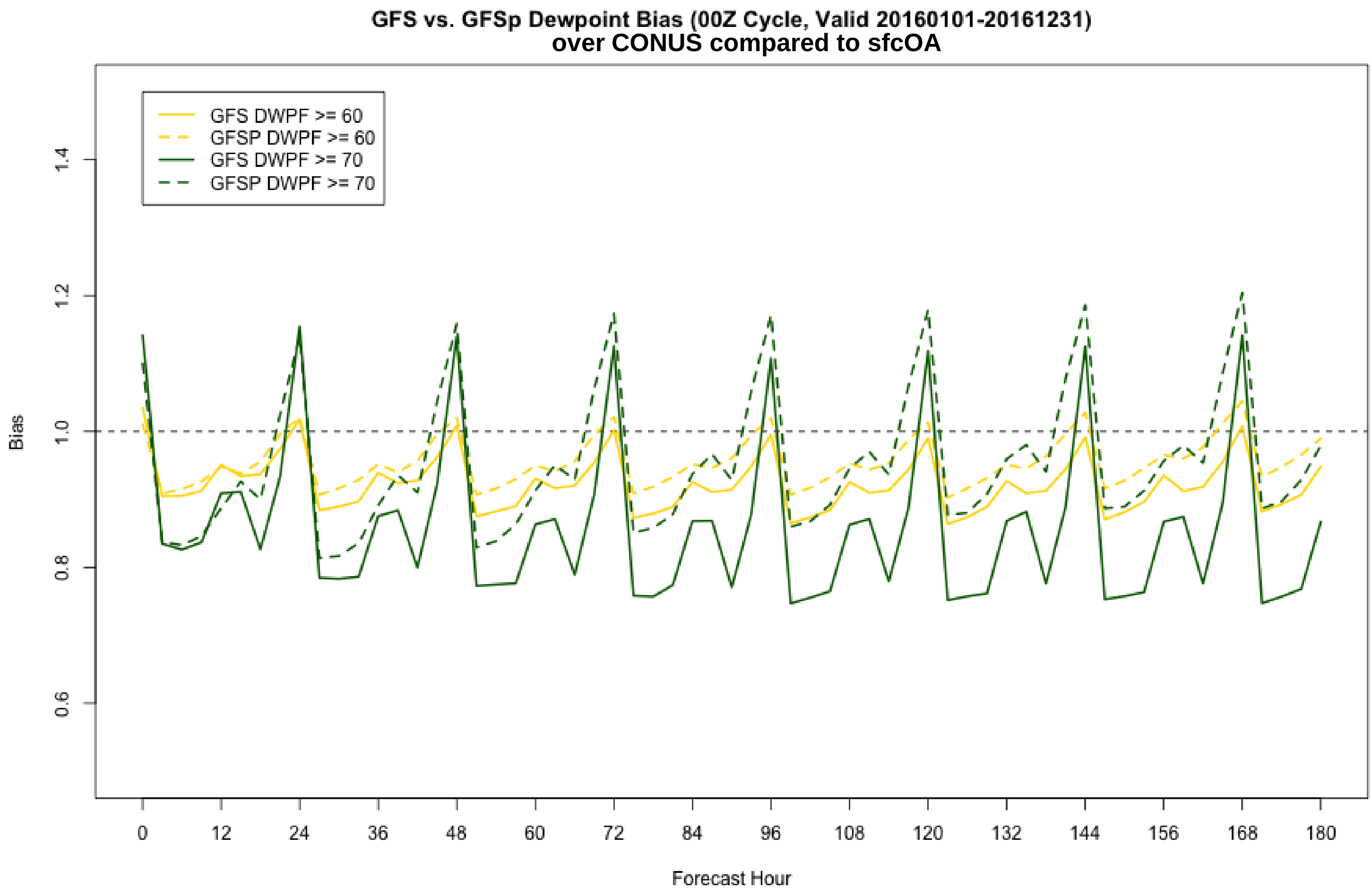
	0000GMT	0600GMT	1200GMT	1800GMT	AVERAGE
T 2m					
west	-6.9%	-3.6%	+1.1%	-1.8%	-2.8%
east	-8.6%	-1.6%	+2.3%	-1.2%	-2.2%
T_d 2m					
west	-4.3%	-4.4%	-3.8%	-5.2%	-4.4%
east	-2.1%	-3.4%	-1.3%	-2.4%	-2.0%
Winds 10m					
west	+0.1%	+0.8%	+0.1%	+0.1%	+0.3%
east	-1.2%	-1.8%	-1.5%	-1.1%	-1.4%

RMS fit to obs decreased in GFS2017

RMS fit to obs increased in GFS2017

SPC GFS Evaluation

2-m Dewpoint Bias: Jan-Dec 2016



- For 2016, the low frequency bias of 2-m dewpoint is generally improved in the GFSp. The high bias at ≥70°F for forecasts valid at 00Z increases slightly with forecast length.

CONUS Precipitation

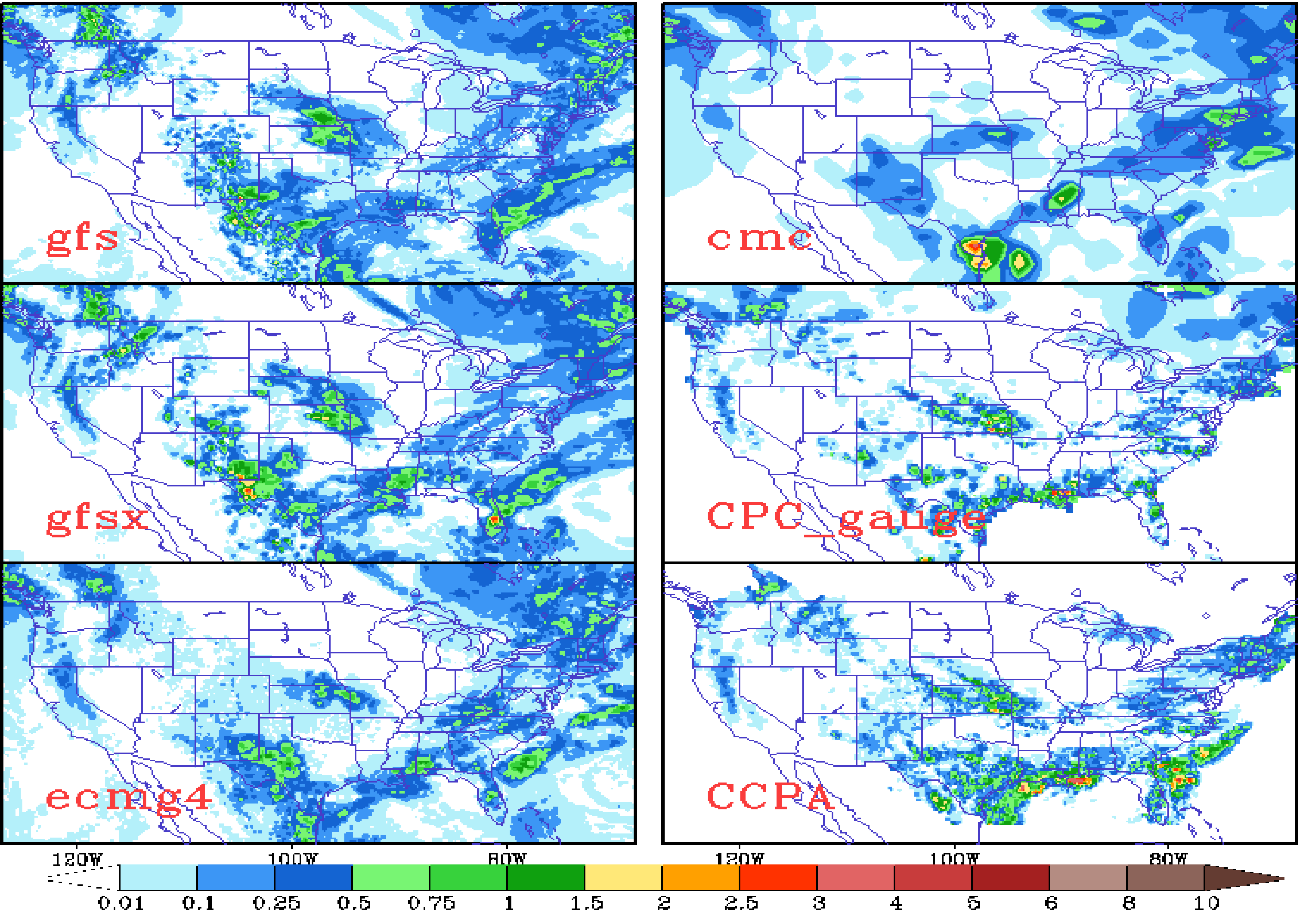
Reduced drizzle

Increased bias light to medium amounts

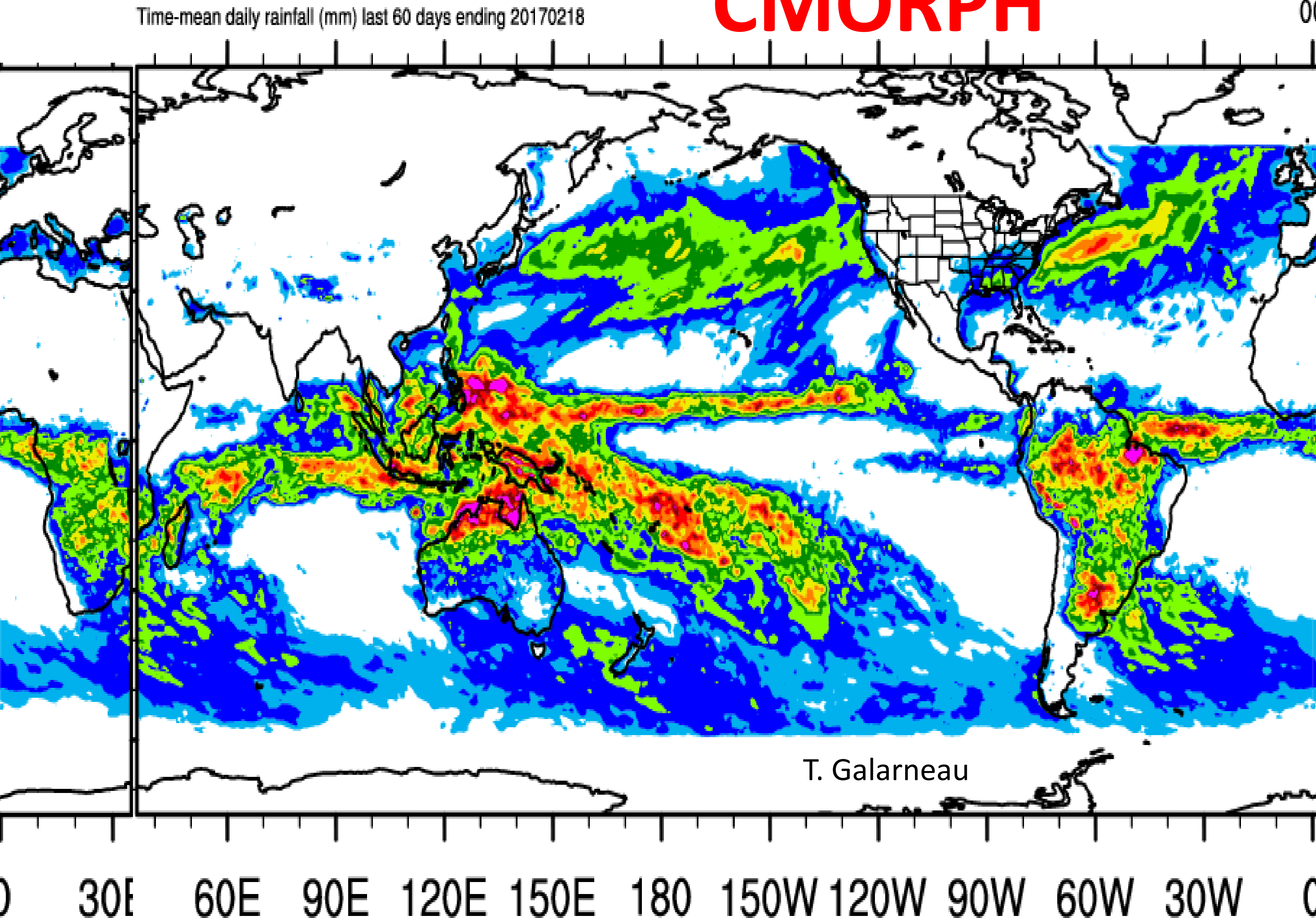
Significant improvements in skill
for thresholds of 0.2 to 15 mm/day
forecast lengths 0-24 to 72-96 hrs

AWC, WPC improvements in tropical convection

24-Hr Accumulated Precip (inch) Valid: 2017053112 – 2017060112
36hr to 60hr Forecast from Cycle 2017053000

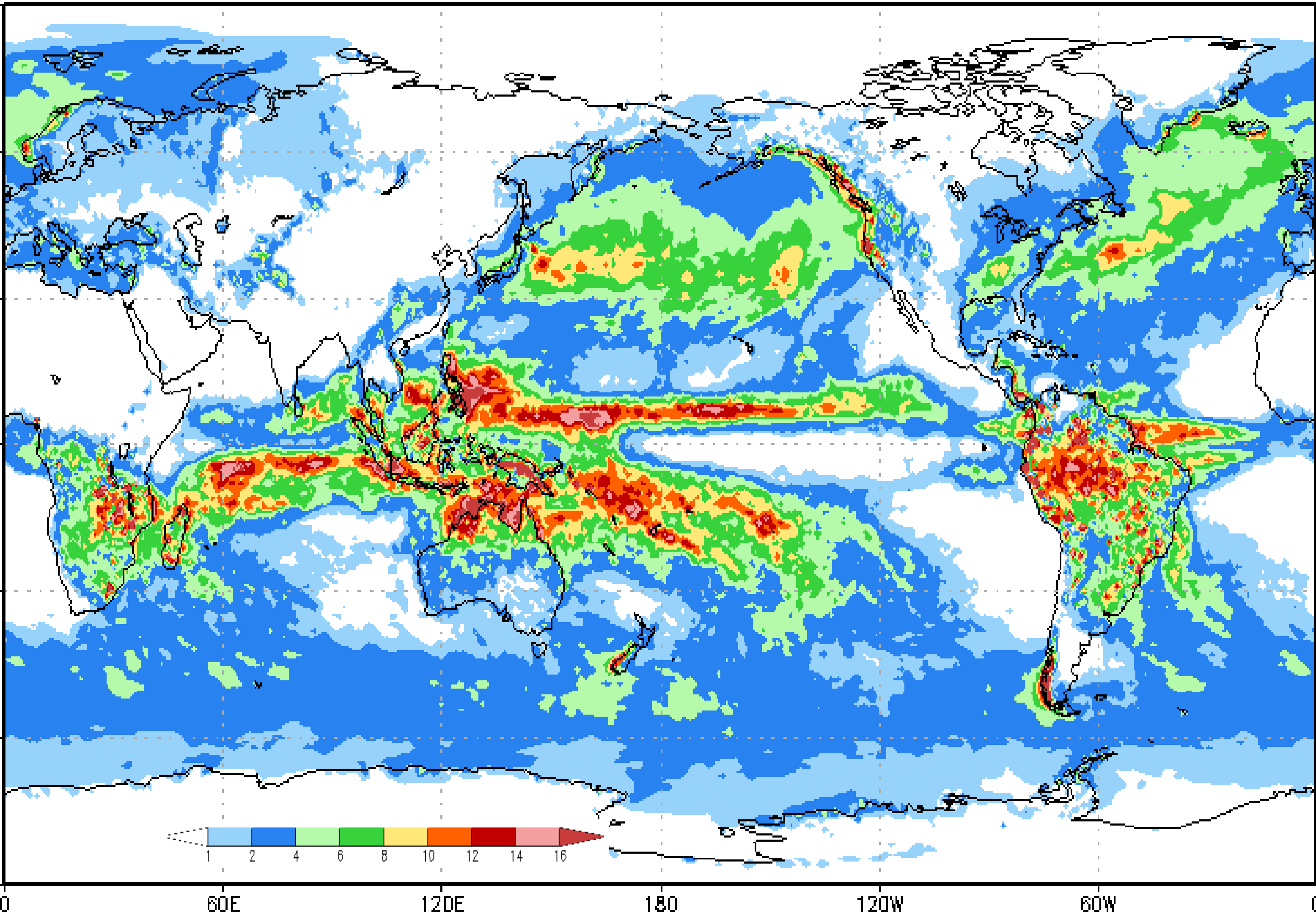


CMORPH

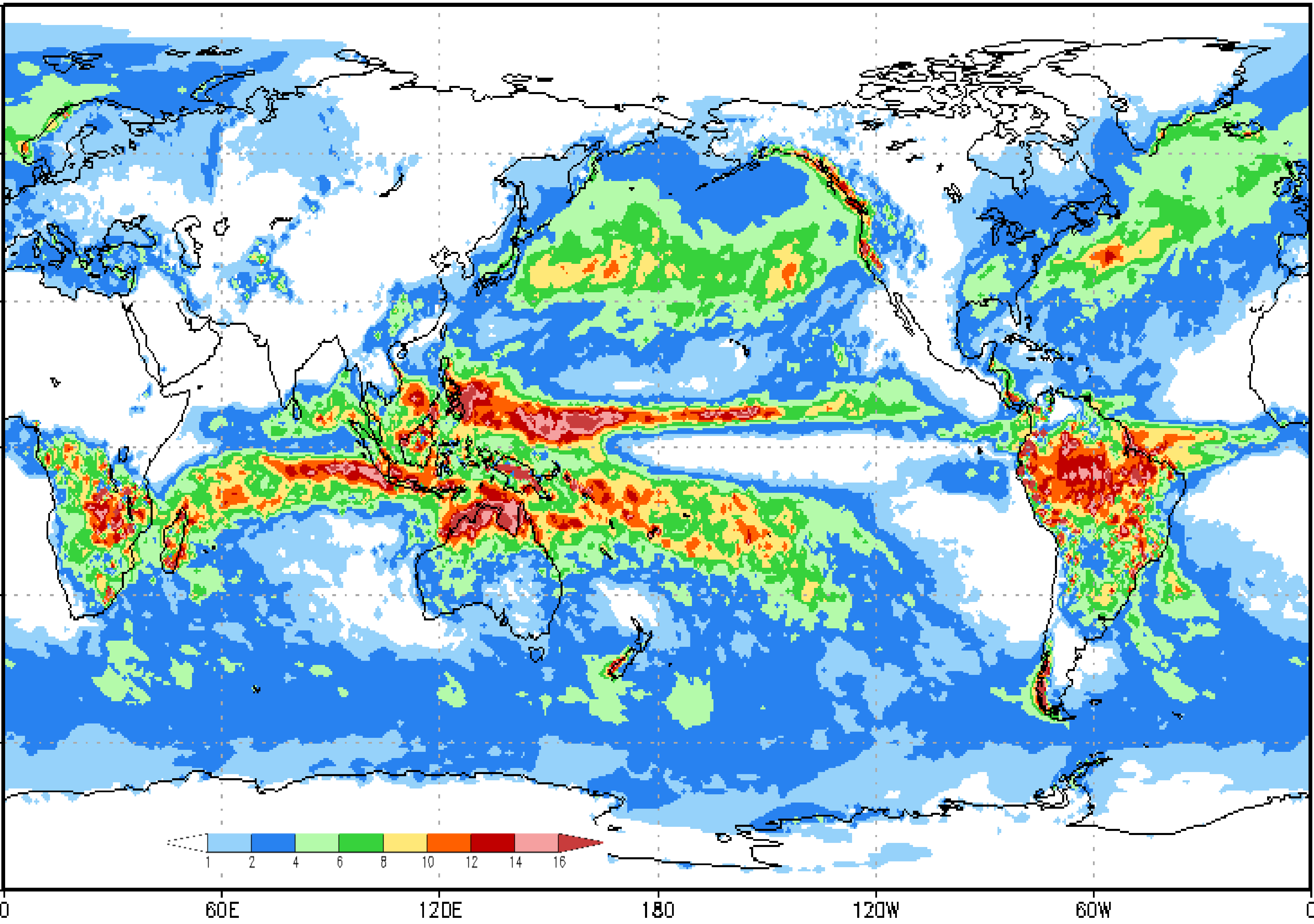


Time-mean daily rainfall (mm) last 60 days ending 20170218
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
T. Galarneau

precip f168 Dec21Feb182017 gfs



precip f168 Dec21Feb182017 gfsx



Links to Case studies and evaluation/analysis by MEG/EMC

Tracey Dorian, Geoffrey Manikin, Corey Guastini

Case Studies	Case Studies
Louisiana flooding case study	Christmas Day 2016 Northern Plains Blizzard
January 23, 2016 East Coast Blizzard	January 22-23, 2017 California precipitation event
Hurricane Matthew	Portland heavy snow Jan. 10-11, 2017
Hurricane Joaquin	Long-range predictability of high-impact west coast atmospheric river
February 7-8, 2016 explosive cyclone	West Virginia flooding case
MODE Jet Verification	MODE Precipitation Verification
Minnesota Blizzard November 18-19, 2016	MODE CAPE Verification
Weather Prediction Center case studies	Hurricanes Joaquin and Matthew
Central Region case studies	Systematic Biases Summer2016
Hurricane Joaquin precipitation	
California precipitation January 9-10, 2017	

Most requested by other NCEP centers, regional headquarters, forecast offices

Endorsements from Stakeholders

Region/Center	Recommendation	Remarks
Western Region	Implement	GFSX precip lighter in valleys GFSX more jumps 120-180 h fcsts in December
Central Region	Implement	No significant improvements nor detriments
Southern Region	Implement	GFSX slightly better Matthew, worse on Louisiana flooding
Eastern Region	Implement	Some beneficial improvements and upgrades
Pacific Region	No evaluation	
Alaska Region	Implement	Forecast improvements largely neutral
WPC	Implement	Slight improvement, Better tropical convection So. America
NHC genesis	Oppose	9-10% less skill in track forecast at 48-72h in Atlantic Forecasts of tropical storm genesis improved

Endorsements from Stakeholders

Region/Center	Recommendation	Remarks
AWC	Implement	Significant improvements to tropical convection and ceiling and visibility over CONUS
CPC long range stratosphere	Implement	Stratospheric fields improved, slight improvement D+8, week 2
OPC	Implement	Small scale features improved; large scale features similar
SWPC	No evaluation	
MDL	Implement	see little to suggest any dramatic MOS impacts from implementing new GFS
OWP	Implement	Mixed results, extremely limited testing
SPC report	Implement	Slightly improved 2-m dew point and instability bias

--Interaction with operational forecasters increased

--MEG invaluable for finding and highlighting model problems

--model developers responded quickly, effectively to problems

--development and implementation of new dynamic core FV3 underway, new physics under development

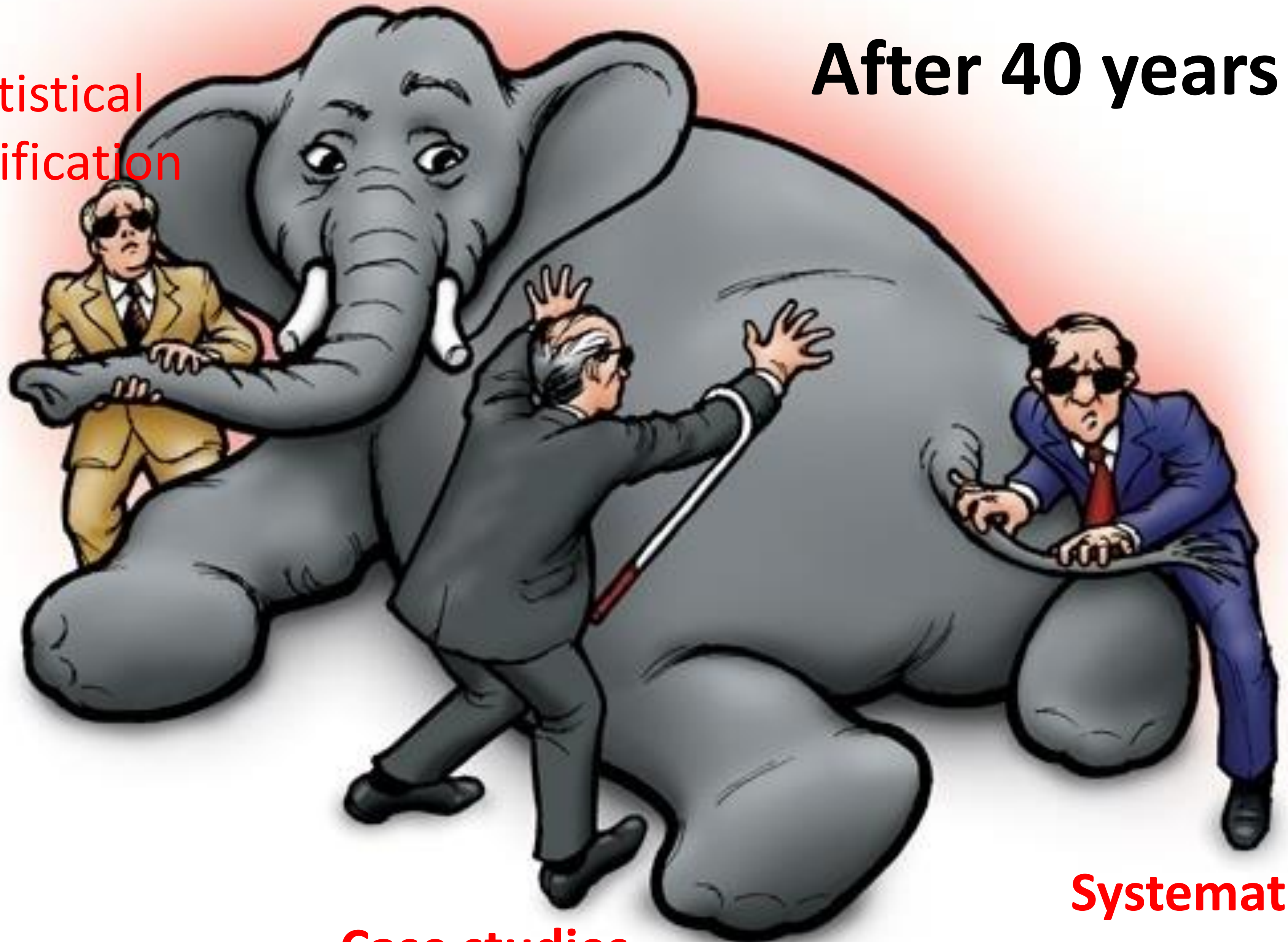
--many areas need more examination

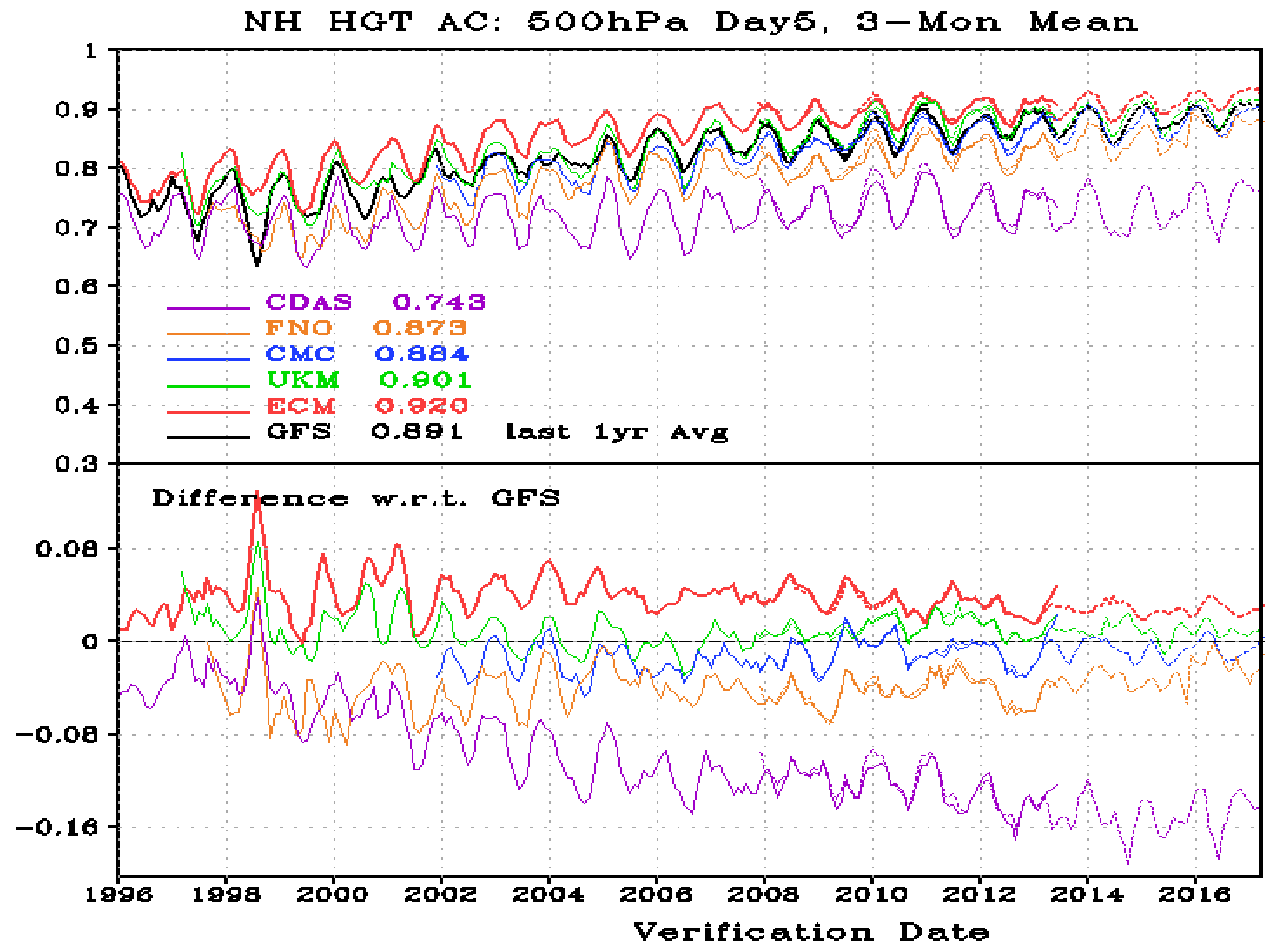
--Alaska

--tropics

Extra slides

How I view model evaluation After 40 years




NH HGT AC: 500hPa Day5, 3-Mon Mean
CDAS 0.743
FNO 0.873
CMC 0.884
UKM 0.901
ECM 0.920
GFS 0.891 last 1yr Avg
Difference w.r.t. GFS
Verification Date
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.08
0
−0.08
−0.16
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

Major implementation July 27, 2010

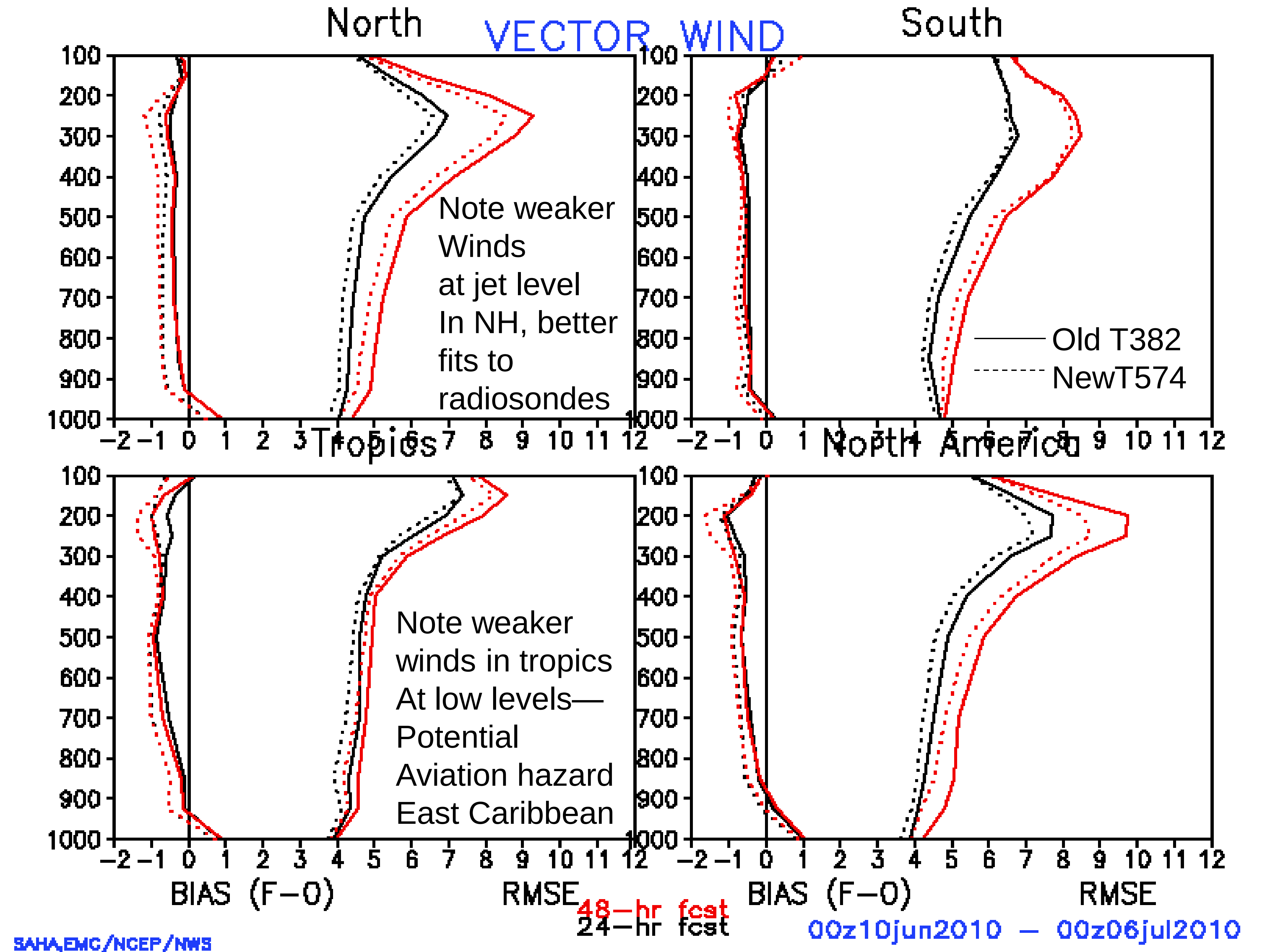
Resolution increase: T382 (35 km) -> T574 (27 km) to 192 hrs
T190 192-384 hrs

Tuning--Gravity wave drag one half as strong
Mountain blocking four times stronger (Alpert and Yang)

New mass flux shallow convection (Han and Pan 2010)
New planetary boundary layer
Updated deep convection

Background diffusivity for momentum substantially increased
To 3.0 $m^2 s^{-1}$ everywhere to reduce wind forecast errors

Caribbean forecasters complained changes weakened previously realistic
trade wind bursts in eastern Caribbean

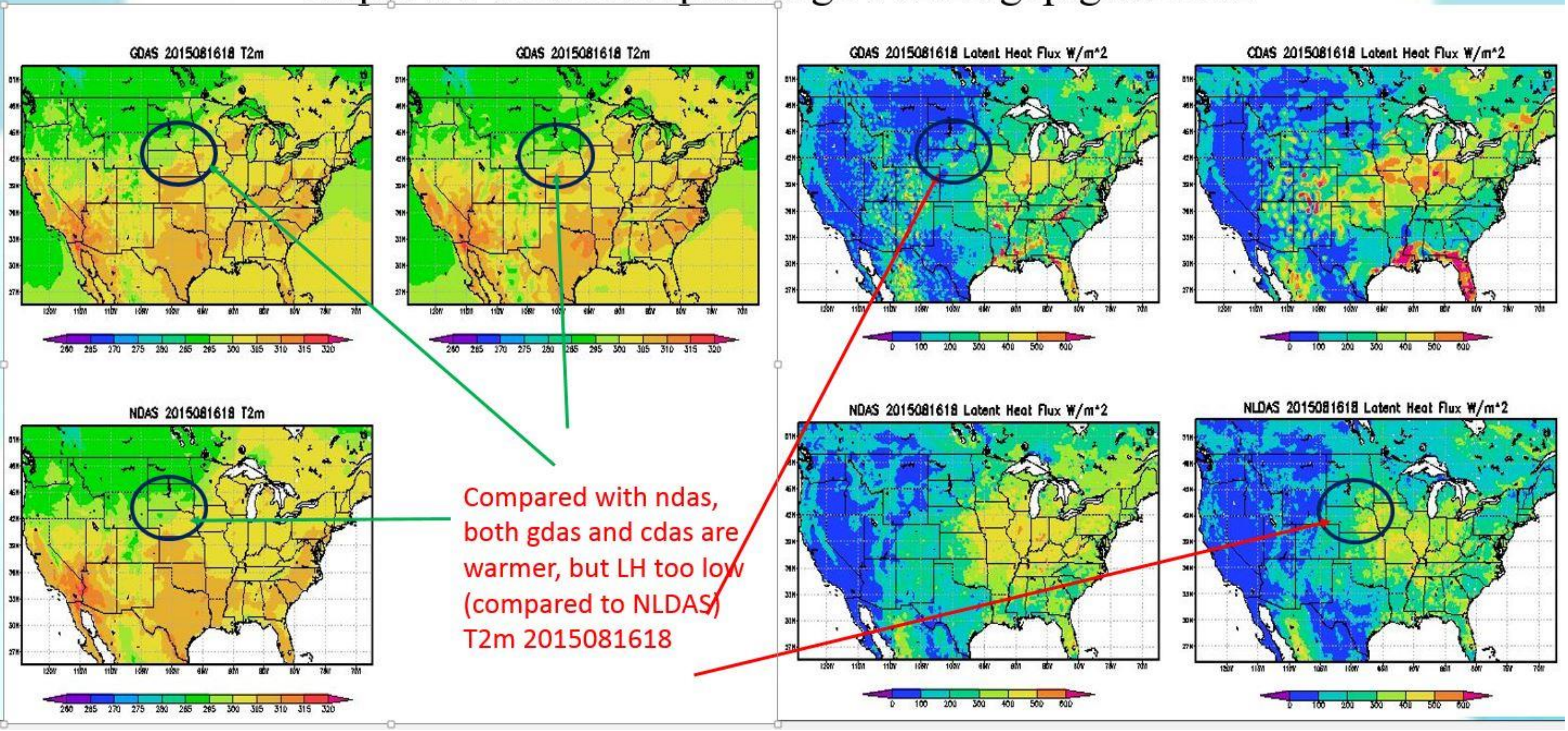

VECTOR WIND
North
South
Tropics
North America
Note weaker Winds at jet level In NH, better fits to radiosondes
Note weaker winds in tropics At low levels— Potential Aviation hazard East Caribbean
Old T382
NewT574
BIAS (F−O)
RMSE
48−hr fcst
24−hr fcst
00z10jun2010 − 00z06jul2010
SAHA,EMC/NCEP/NWS

Causes

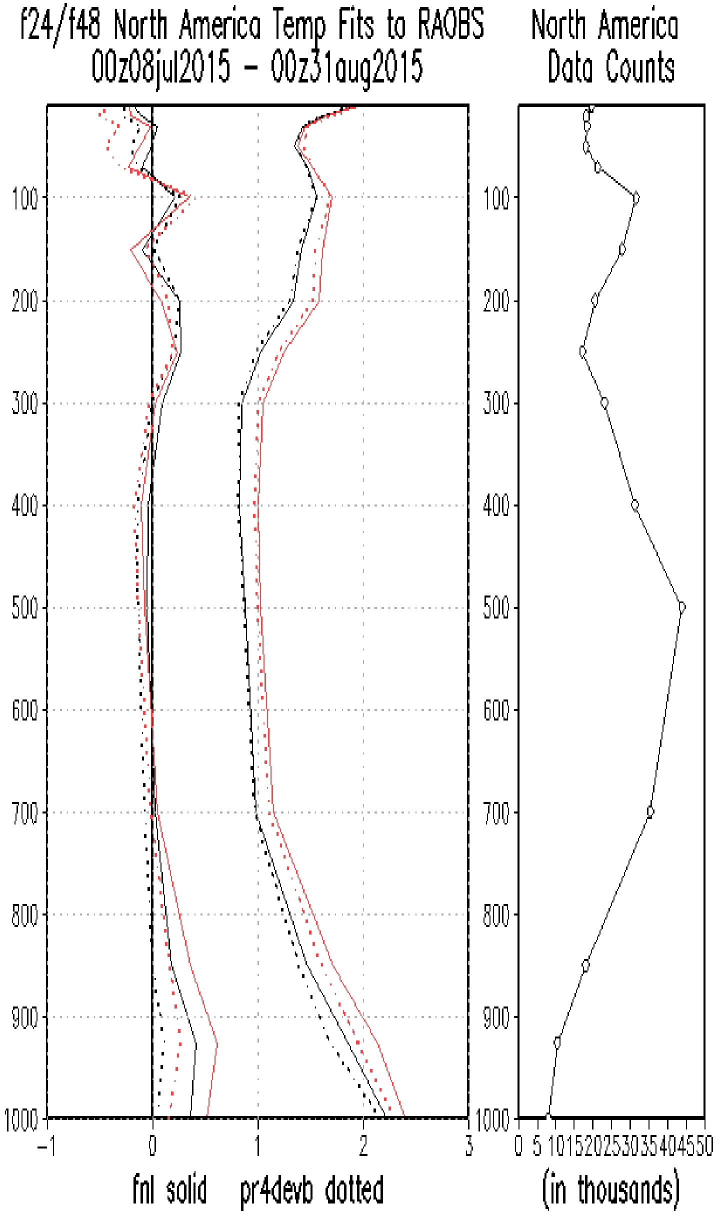
- The evaporation is too low and the sensible heat flux is too high after the new soil moisture climatology (GLDAS/CFS) is used in the operational GFS since January 2015.

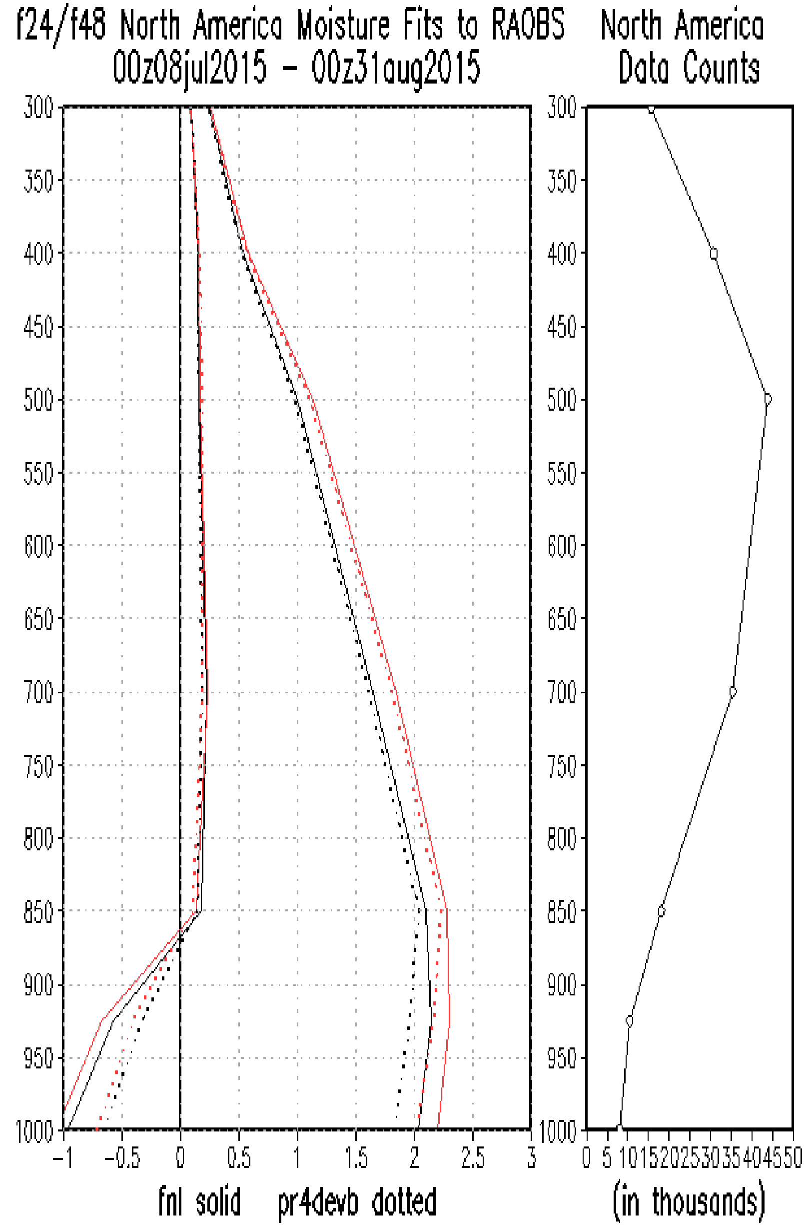
From daily land surface monitoring page

http://www.emc.ncep.noaa.gov/mmb/gcp/gfs/soilm

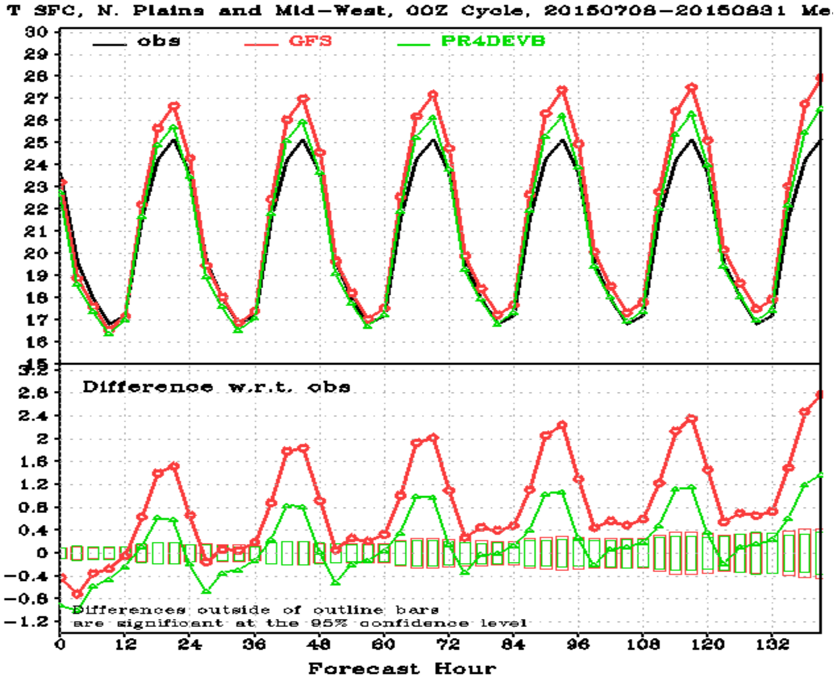


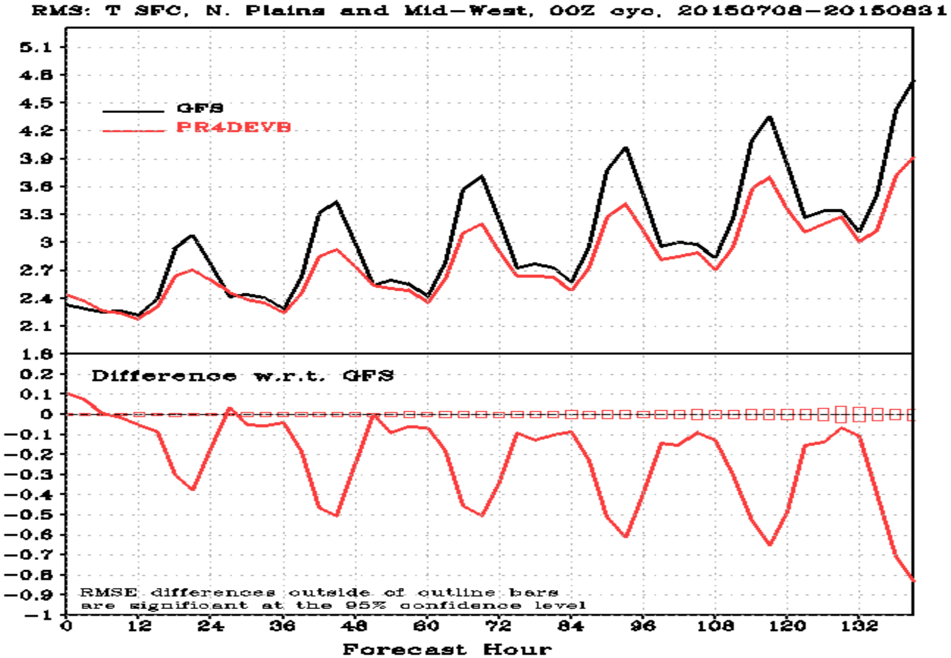
The warm/dry biases was significantly reduced in the lower troposphere(24/48h fcst over NA)



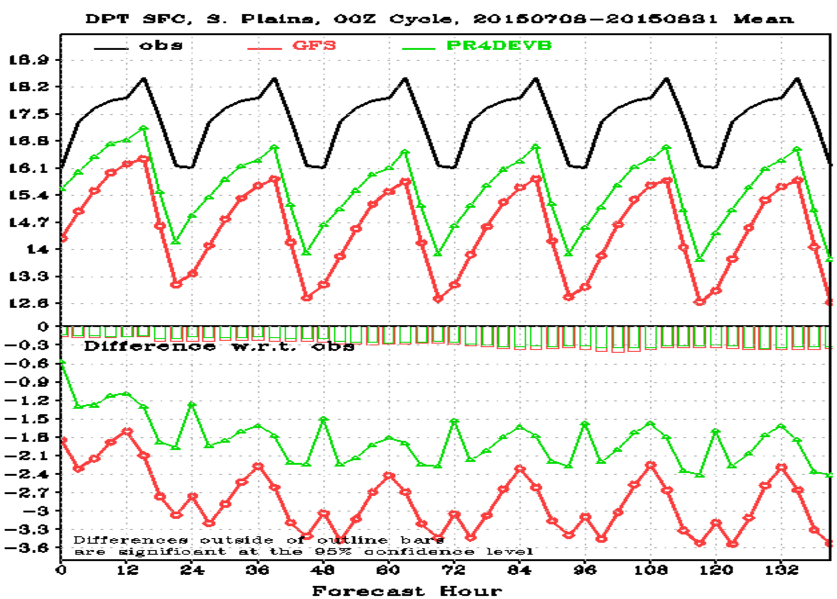


2m T over North Plains

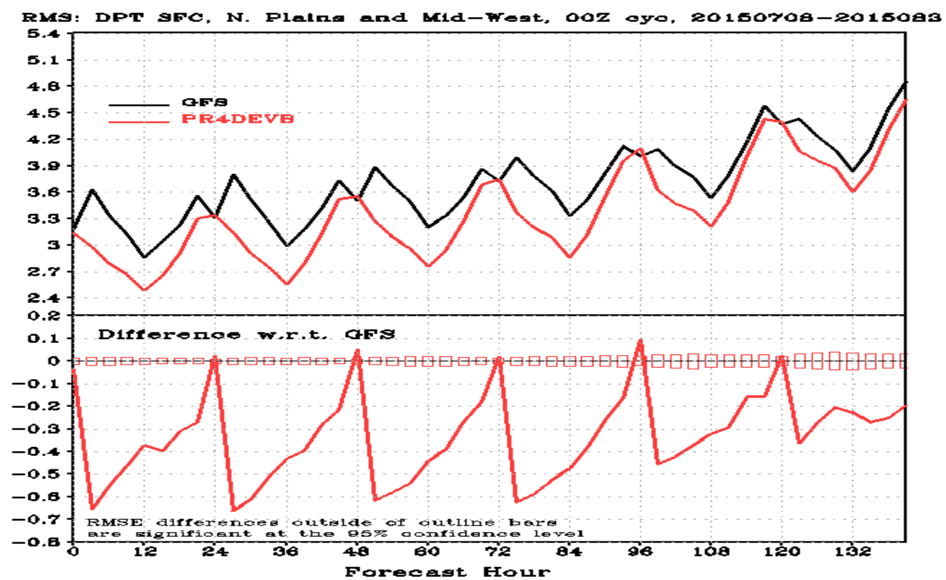


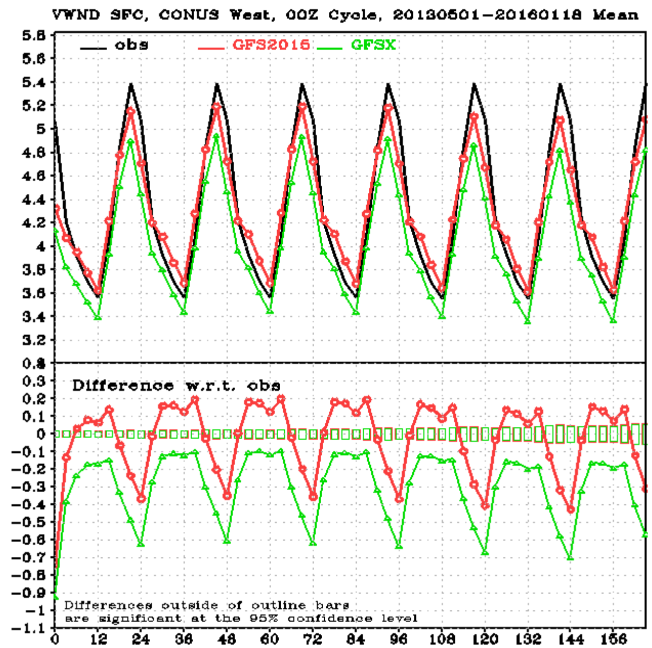


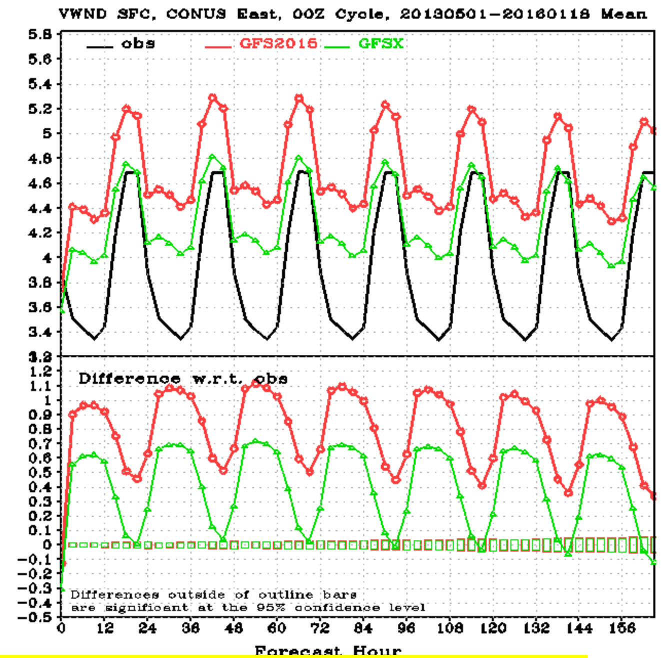
2m T_d over South Plains



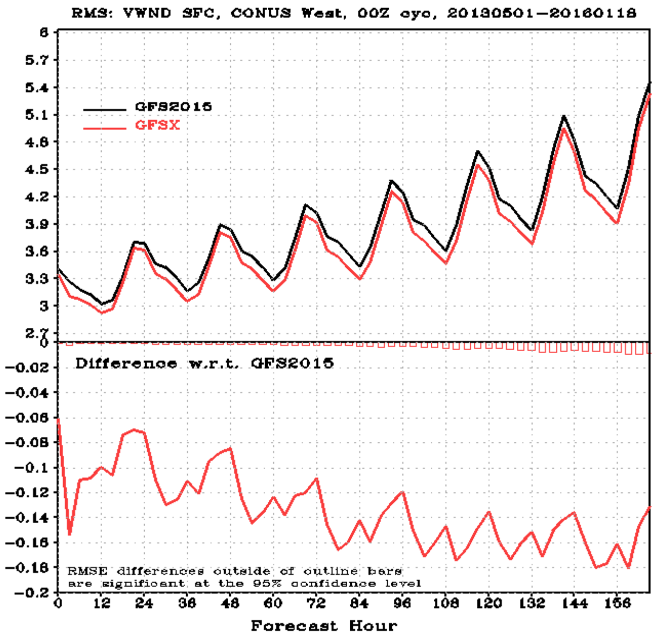
2m T_d over North Plains

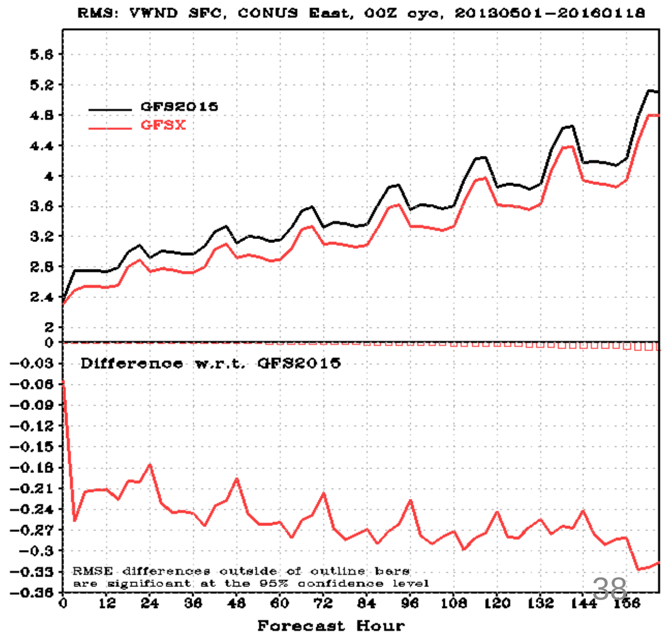






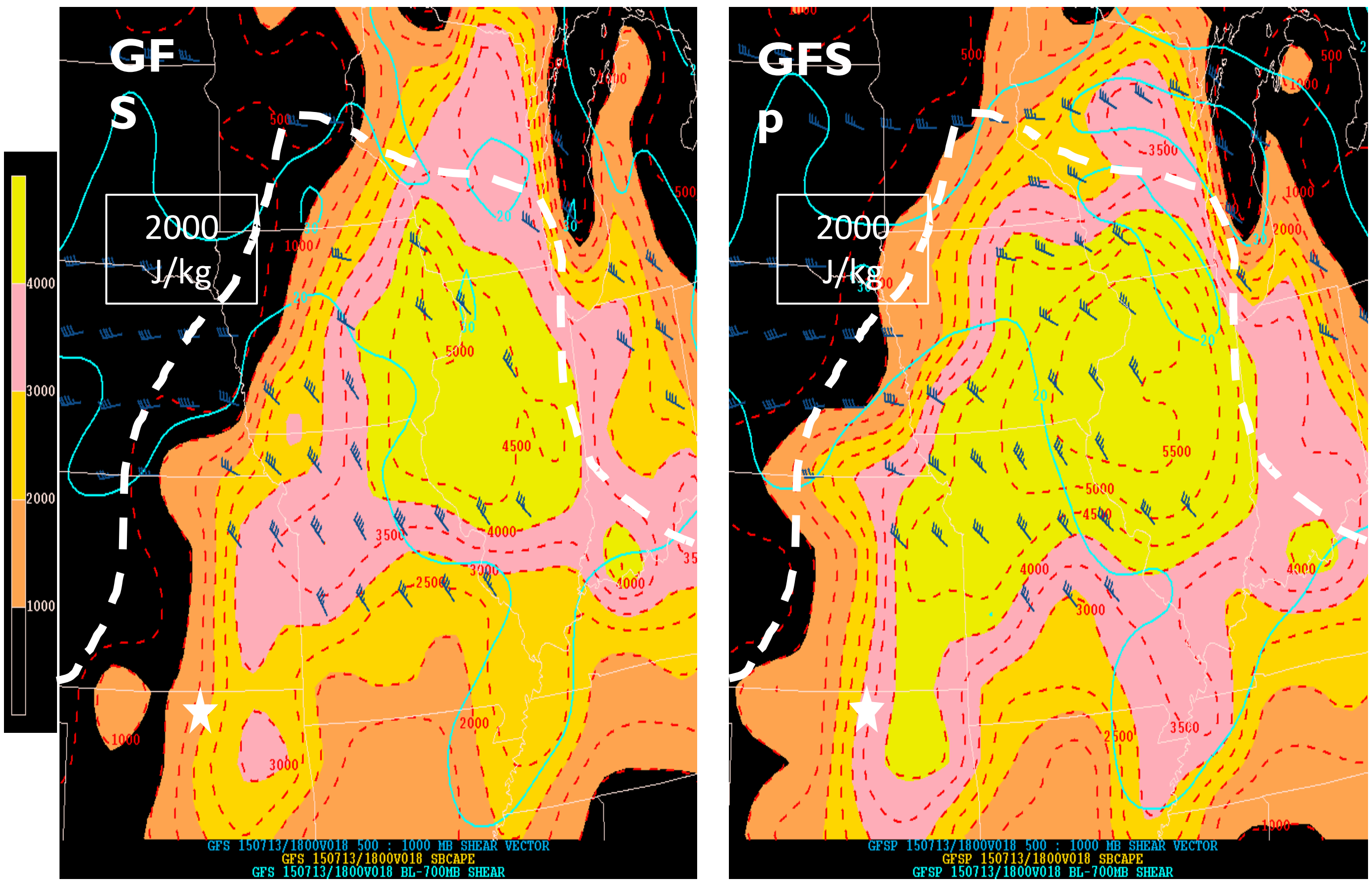
Surface wind, CONUS West and East, 00Z





3 Jul 2015 Moderate Risk

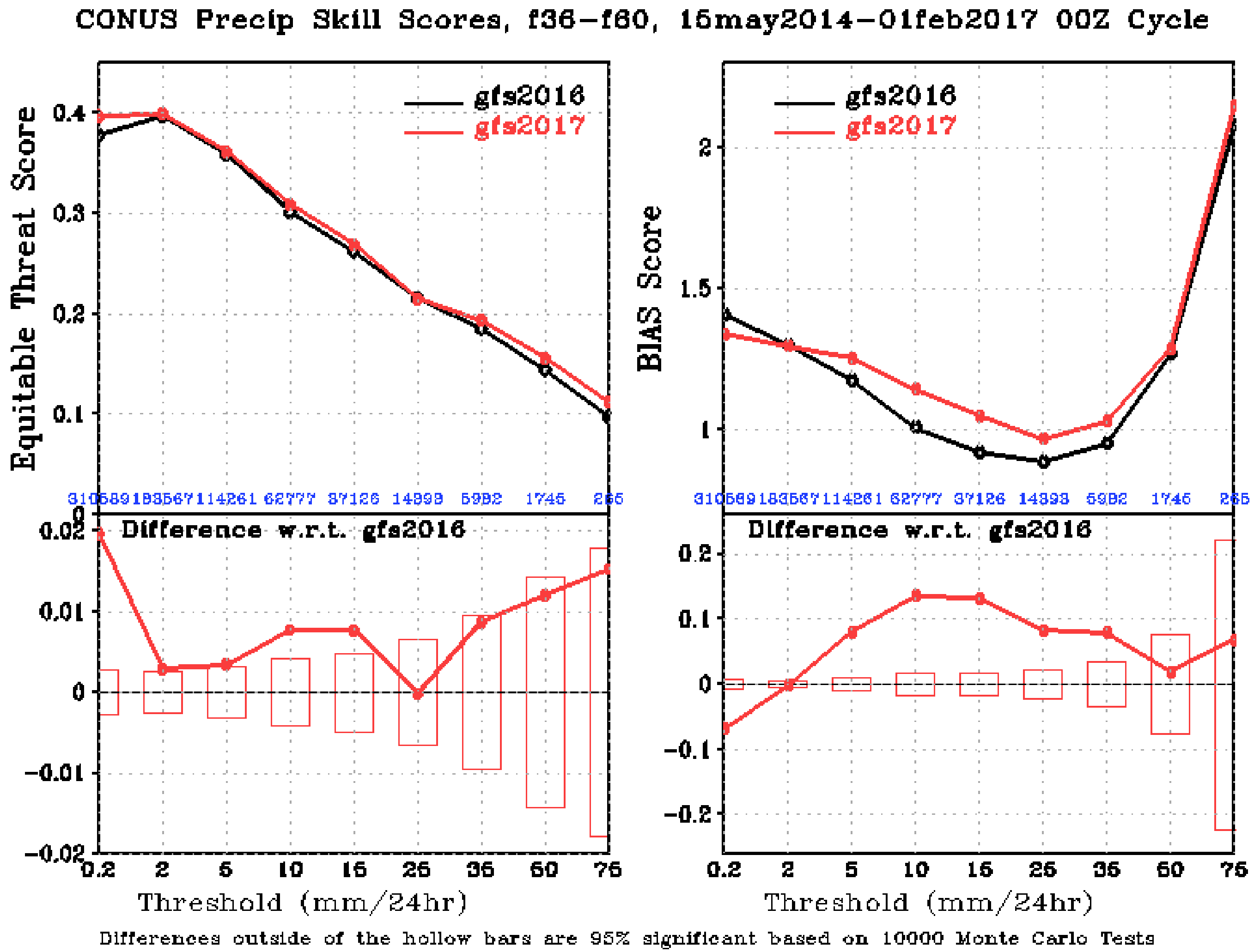
SBCAPE, Shear: 13/00F018 Valid 18Z 13 Jul – D1



Dashed white line is the approximate contour of SBCAPE = 2000 J/kg as estimated from SPC mesoanalysis (RAP-based)

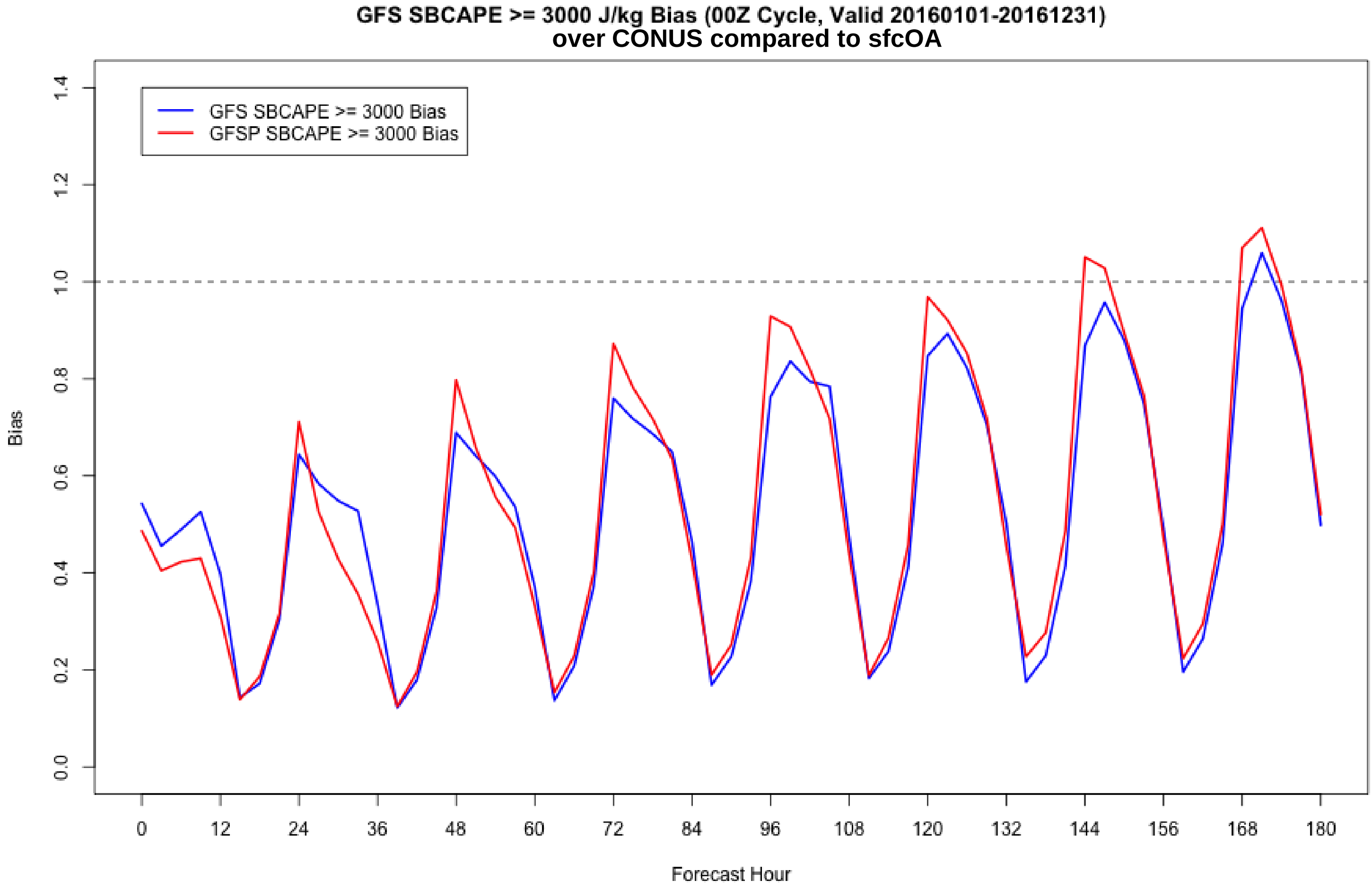
- The instability gradient location is shifted westward in the GFSp. There remains an eastward bias of the unstable warm sector, which still indicates overmixing in the plains.

CONUS Precip Skill Scores



SPC GFS Evaluation

SBCAPE Bias (3000 J/kg): Jan-Dec 2016



- The frequency bias is lowest at the highest SBCAPE threshold (≥3000 J/kg). Only the forecasts valid at 00Z and 03Z are improved in the GFSp.

Aleksandr Korolokov, Meteorological Center, FOBOS, Moscow—GFS main source for forecasts

extreme short cold waves in GFS forecasts—GFSX better

Year earlier, complaint from Argentina that GFS too hot, dry over pampas

GFS2016 contained partial fix