Development of a Unified Global Coupled System for sub seasonal to seasonal prediction

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We gratefully acknowledge ***Cecelia de Luca*** *and NESII (ESMF team at ESRL) for their significant contributions in setting up the coupled NEMS system.*

Models used:

All components of the UGCS are in NEMS:

A. GSM: Operational Spectral T574L64 semi-Lagrangian grid

B. MOM6: GFDL Ocean Model. Hybrid-coordinates, Tripolar grid 0.25^{o} global.

C. CICE5: Los Alamos SeaIce Model. Same grid as MOM6 ocean model.

Data used

- CFSR Initial Conditions for all experiments are from:
  Operational CFSv2 CDAS using:
  Spectral T574L64 Eulerian grid
  MOM4 GFDL Ocean Model, Z-coordinates, Tripolar grid, 0.25^o in the tropics and 0.5^o global.
  SIS1 GFDL SeaIce Model, same grid as MOM4 ocean model.

- April 2011 to March 2017 (6 years, 144 forecasts).

Data used (contd)

- UGCSmom6: 35-day coupled forecasts with MOM6 were made from the 1st and 15th of each month, a total of 144 forecasts.

- UGCSmom5: 35-day coupled forecasts with MOM5.1 were made from the 1st and 15th of each month, a total of 144 forecasts.

- UGCSuncpl_cfsbc: 35-day uncoupled forecasts, using bias corrected SSTs from the operational CFSv2 from the same set of 144 initial conditions.

- CFSv2ops: 35-day coupled forecasts from the operational CFSv2 from the same set of 144 initial conditions were used for comparison.

Calibration Climatologies

We need climatologies to form anomalies and, more importantly, for systematic error correction (SEC) which may be very large in some variables.

A climatology as an average over just 6 cases (years) would be much too noisy.

Here we produce a smoothly interpolated climatology by fitting the 6 year time series (144 elements, 2 weeks apart) to a sine wave of period 365.24 days plus three overtones. This way, leap days are handled correctly both on the input and output side. The climatology consists of an annual mean plus four harmonics.

This is done for each gridpoint and variable separately. Both for forecasts (as a function of lead, at 6 hour intervals) and verifying data (mainly CFSR).

All forecasts (coupled, uncoupled, control, experiment, etc) were bias corrected in exactly the same manner.

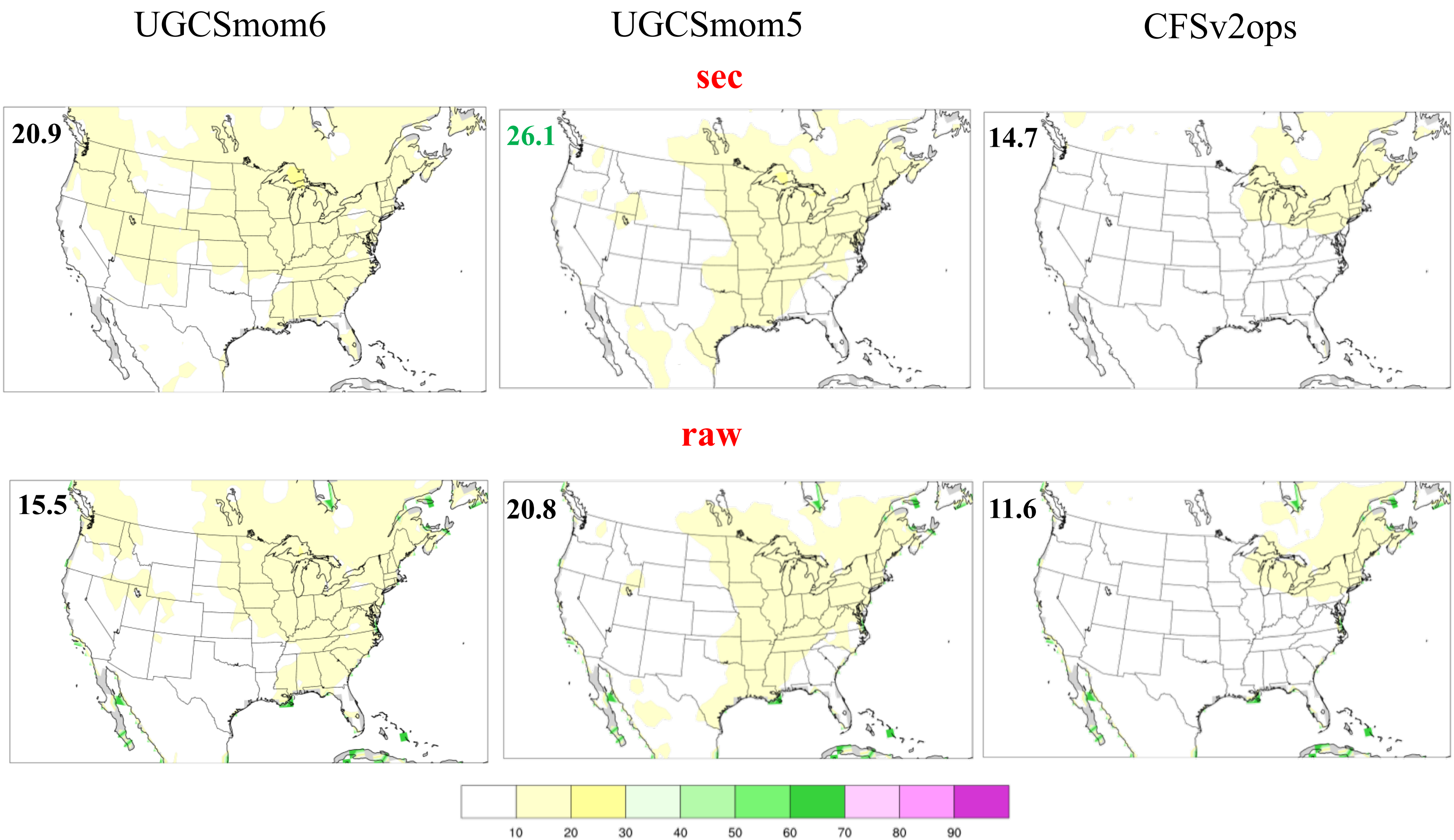
CONUS 2-meter temperature AC (CPC daily*)

	UGCSmom6	UGCSmom6	UGCSmom5	UGCSmom5	CFSv2ops	CFSv2ops
	raw	sec	Raw	Sec	Raw	Sec
week1	74.0	**87.3**	78.0	**87.5**	79.3	**85.9**
week2	38.3	**46.2**	40.1	**46.7**	41.7	**46.4**
week3	17.8	**22.3**	19.4	**23.3**	17.6	**19.9**
week4	9.9	**12.2**	11.0	**12.6**	0.3	**1.8**
week3&4	15.5	**20.9**	20.8	**26.1**	11.6	**14.7**

UGCSmom6 equal or better than the CFSv2ops for all lead times.
UGCSmom6 very slightly less than UGCSmom5 for T2m

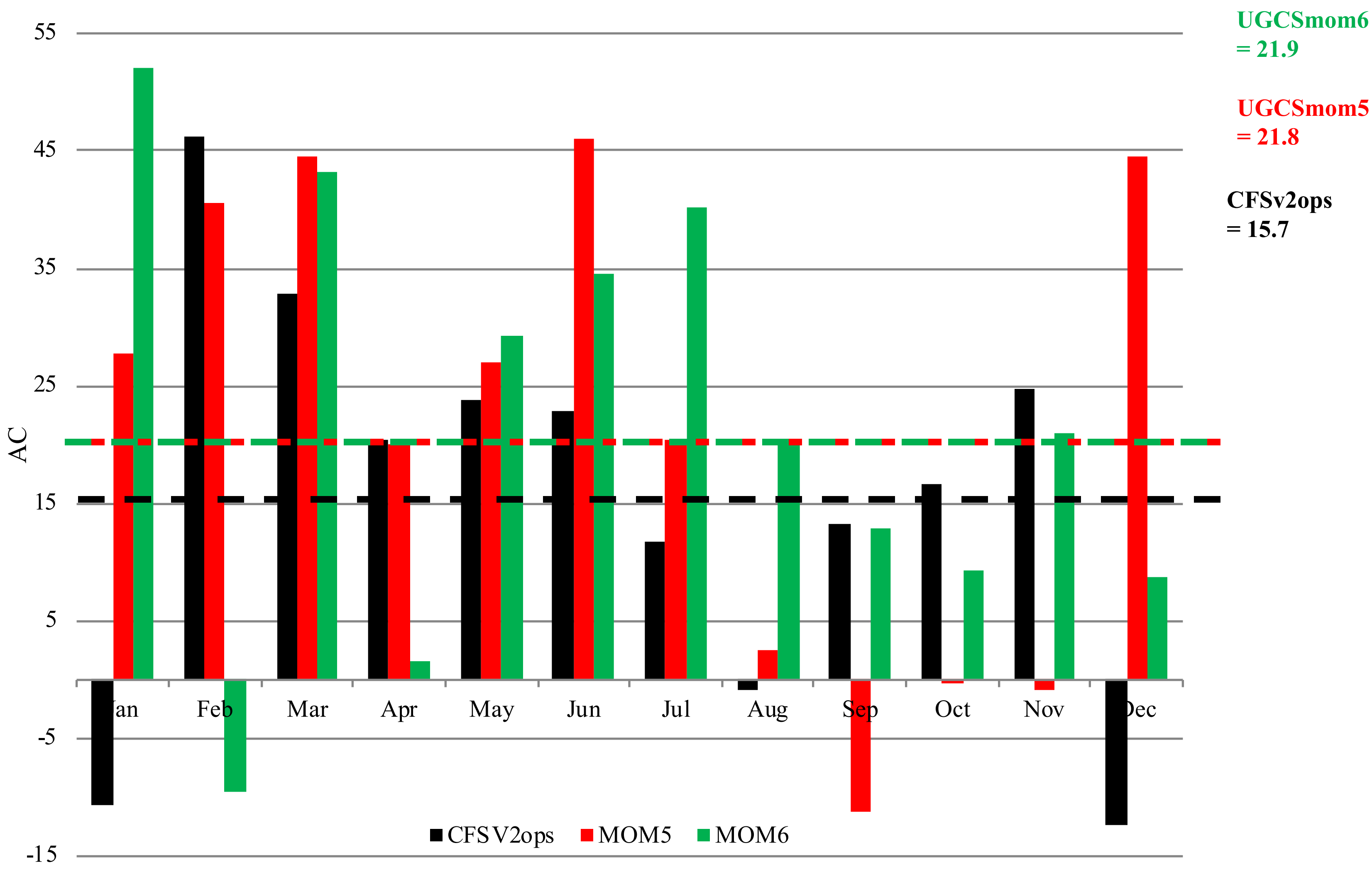
*CPC Global 0.5 degree Daily 2-m TMIN/TMAX from:
ftp://ftp.cpc.ncep.noaa.gov/precip/wd52ws/global_temp/
e.g., CPC_GLOBAL_T_V0.x_0.5deg.lnx.YYYY

Week 3 & 4
T2m AC



*CPC Global 0.5 degree Daily 2-m TMIN/TMAX from:
ftp://ftp.cpc.ncep.noaa.gov/precip/wd52ws/global_temp/
e.g., CPC_GLOBAL_T_V0.x_0.5deg.lnx.YYYY

CONUS average of week 3 & 4 SEC AC for T2m forecast
(Each bar based on 12 cases with IC in the month indicated)



CONUS Precipitation AC (CPC Unified Rain Gauge*)

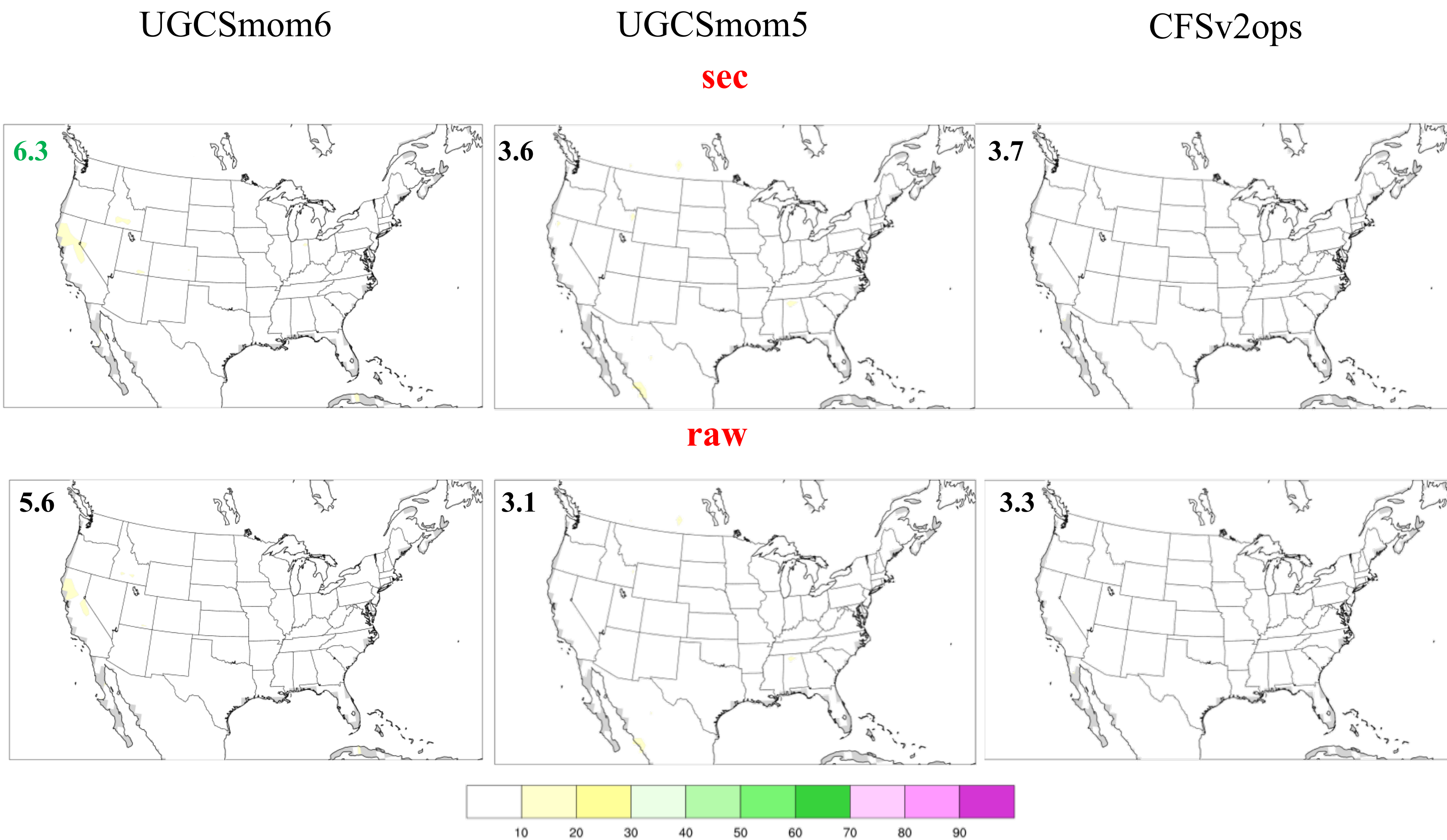
	UGCSmom6	UGCSmom6	UGCSmom5	UGCSmom5	CFSv2ops	CFSv2ops
	raw	**sec**	**Raw**	**Sec**	**Raw**	**Sec**
week1	52.5	**56.8**	51.7	56.0	48.6	53.0
week2	17.0	18/8	16.3	18.2	18.0	**19.9**
week3	4.6	4.9	4.9	**5.4**	3.2	3.5
week4	6.4	**7.1**	0.9	1.0	0.7	0.7
week3&4	5.6	**6.3**	3.1	3.6	3.3	3.7

UGCSmom6 generally performs as well or better than CFSv2ops for most lead times.

UGCSmom6 is at least as good as UGCSmom5 (in fact three winners)

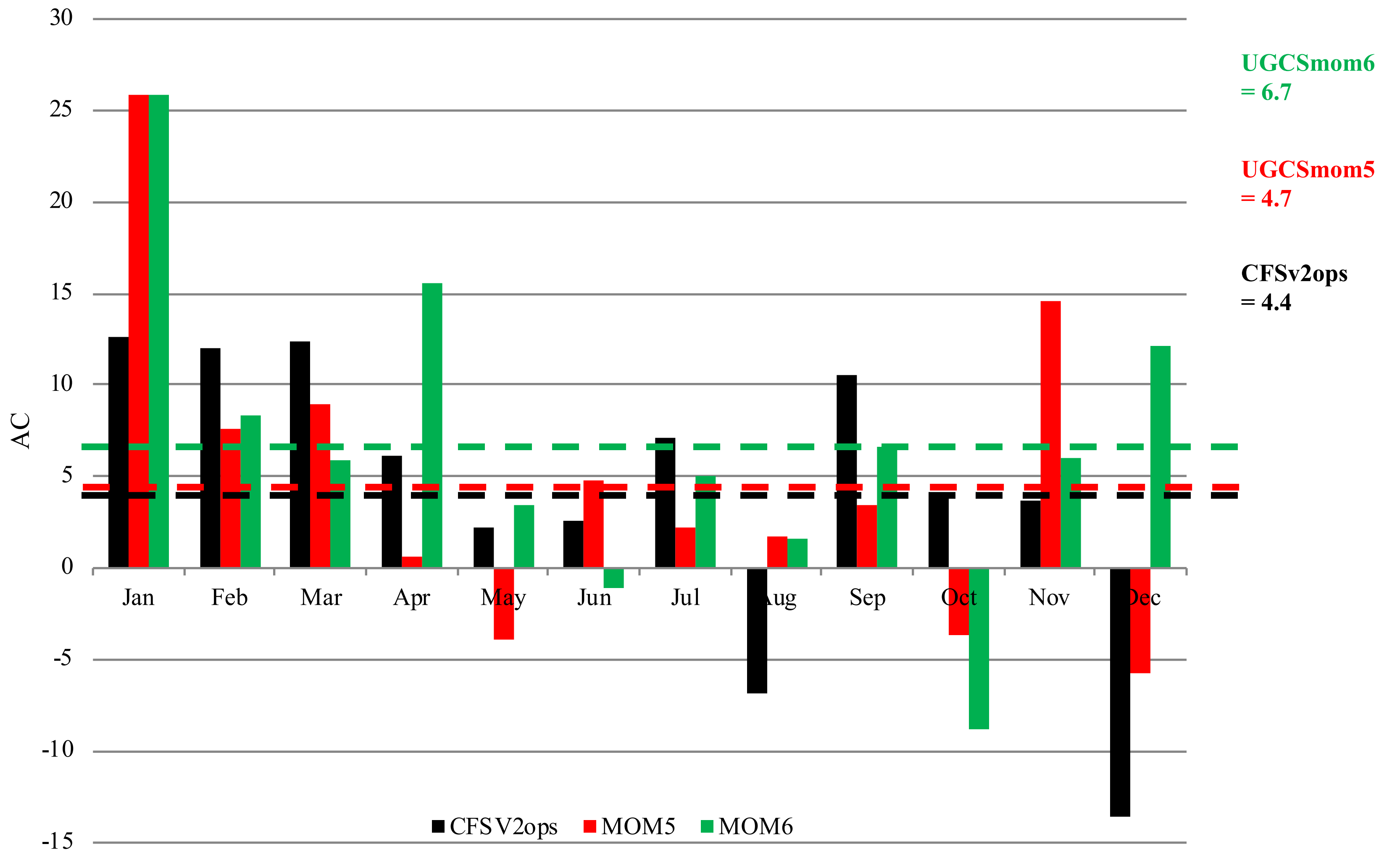
*CPC Global 0.5 degree Unified Rain Gauge data from:
ftp://ftp.cpc.ncep.noaa.gov/precip/CPC_UNI_PRCP/GAUGE_GLB/
e.g., PRCP_CU_GAUGE_V1.0GLB_0.50deg.lnx.YYYYMMDDRT

Week 3 & 4
PRATE AC



*CPC Global 0.5 degree Unified Rain Gauge data from:
ftp://ftp.cpc.ncep.noaa.gov/precip/CPC_UNI_PRCP/GAUGE_GLB/
e.g., PRCP_CU_GAUGE_V1.0GLB_0.50deg.lnx.YYYYMMDDRT

CONUS average of week 3 & 4 SEC AC for PRATE forecast
(Each bar based on 12 cases with IC in the month indicated)

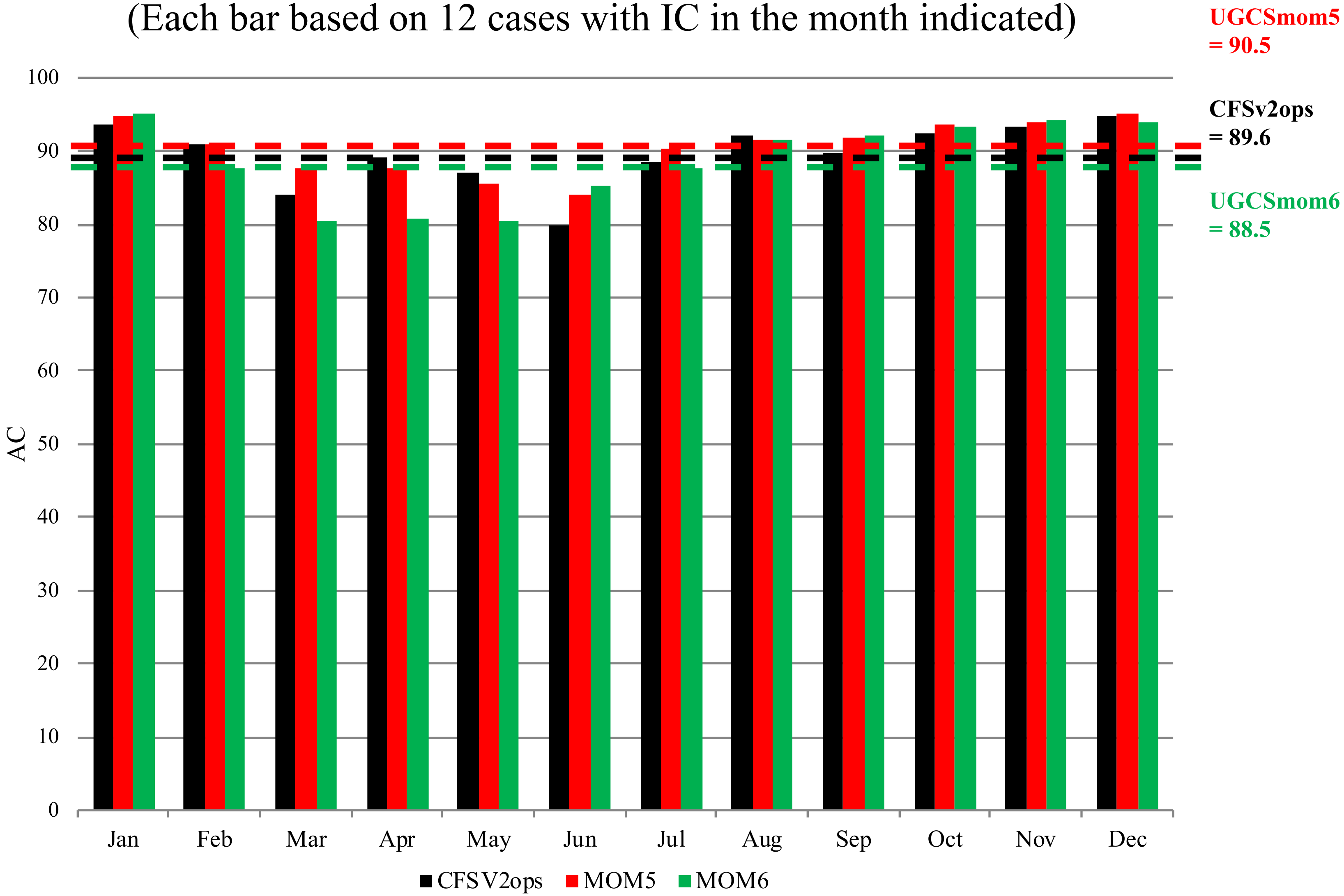


Nino34 SST AC (OISST)

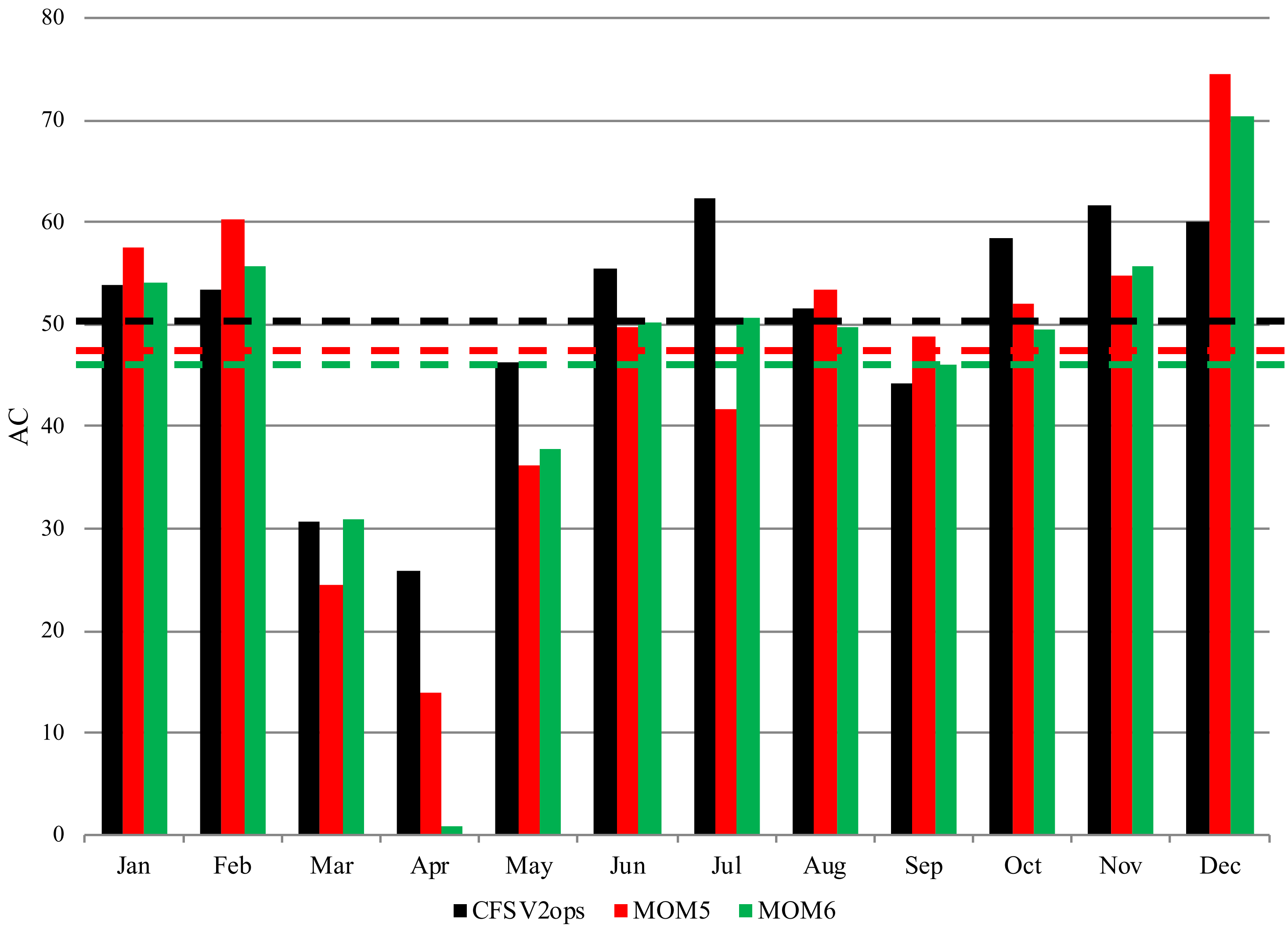
	UGCSmom6	UGCSmom6	UGCSmom5	UGCSmom5
	Raw	**Sec**	**Raw**	**Sec**
week1	95.5	96.3	96.7	**97.0**
week2	88.0	91.3	91.6	**92.6**
week3	81.3	88.2	87.9	**90.6**
week4	78.3	87.4	84.7	**89.3**
week3&4	81.8	90.0	88.2	**91.9**

UGCSmom6 slightly less than UGCSmom5 for all lead times
UGCSmom6 performs well for first 48 hours, but
then develops large, but mainly correctable errors.

Nino3.4 average of week 3 & 4 SEC AC for SST forecast
(Each bar based on 12 cases with IC in the month indicated)



Nino3.4 average of week 3 & 4 SEC AC for PRATE forecast
(Each bar based on 12 cases with IC in the month indicated)



CFSv2ops = 50.3

UGCSmom5 = 47.3

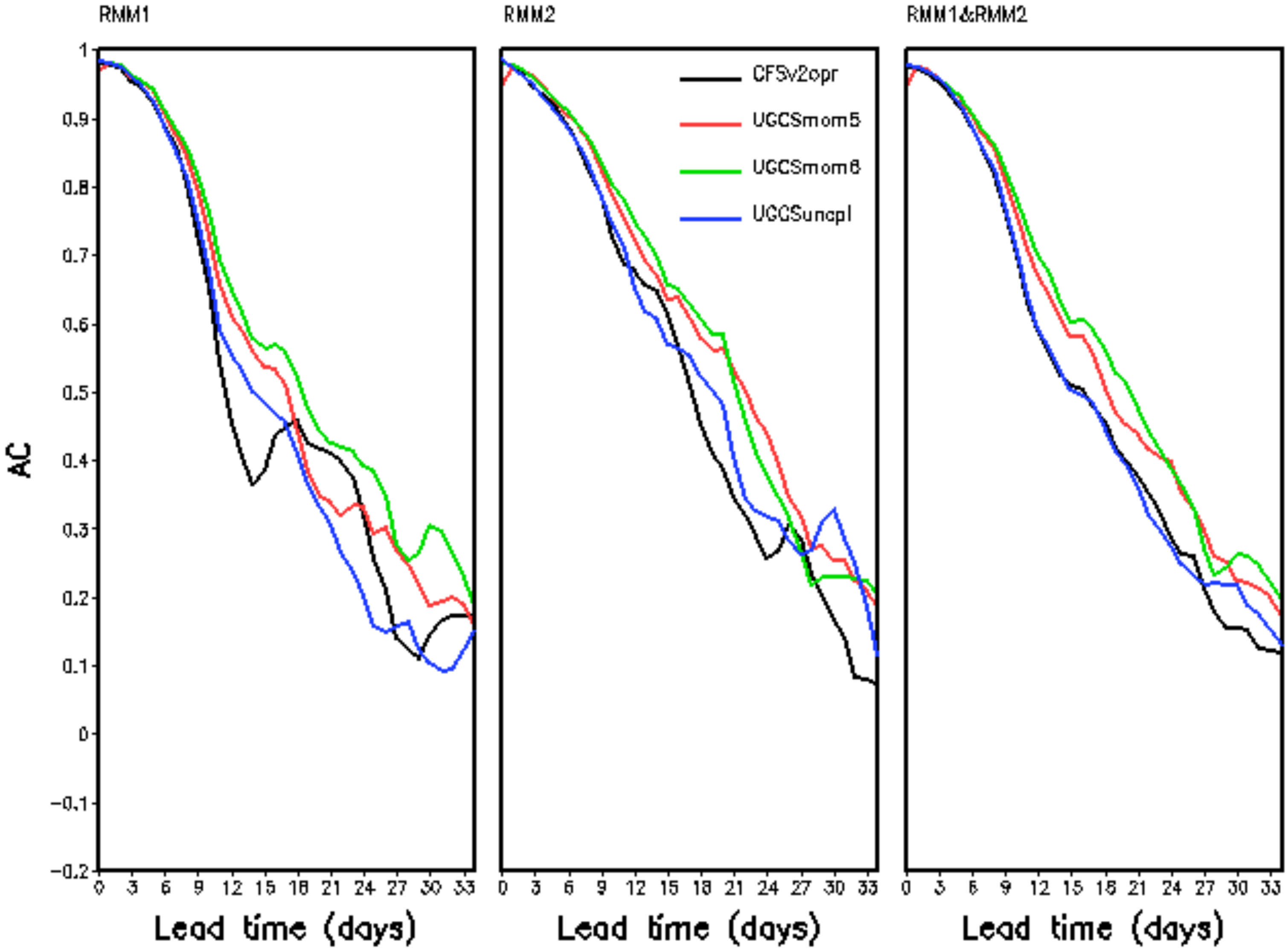
UGCSmom6 = 46

- All-seasons MJO’s two leading modes (RMM1 and RMM2) of the combined timeseries of OLR, U850 and U200 equatorial anomalies are shown.

- RMM1 series has the largest amplitude in the Maritime Continent and (negative) in the West. Hem. and Africa.

- RMM2 has largest amplitude in the Western Pacific and (negative) in the Indian Ocean.

Correlation Skill for MJO index RMM1 and RMM2 and Bivariate Correlation Skill for MJO index (RMM1 + RMM2)



500hPa Geopotential NH (20N-80N) AC

	mom6	mom6	mom5	mom5	uncpl	uncpl	CFSv2	CFSv2
	Raw	**Sec**	**Raw**	**Sec**	**Raw**	**Sec**	**Raw**	**Sec**
week1	96.1	**96.6**	96.1	96.6	96.1	**96.6**	95.0	95.9
week2	53.0	**55.4**	52.9	55.3	52.2	54.6	49.7	52.6
week3	17.6	18.8	18.8	20.2	19.3	**20.9**	17.0	18.7
week4	8.0	**8.7**	7.1	7.7	3.1	3.3	5.8	6.5
week3&4	14.4	15.8	15.9	**17.5**	12.9	14.2	13.9	15.6

Conclusions:
- UGCSmom5 does not hurt the uncoupled UGCSuncpl_cfsbc scores at week1.
- UGCSmom5 is generally better than the uncoupled UGCSuncpl_cfsbc scores after week1.
- UGCSmom6 looks fine for 500mb height scores, there are even some 'winners'.

CFSR used for verification

Bottom Line

The evaluation of the current UGCSmom6 configuration shows that the performance of this coupled system is comparable to the operational CFSv2

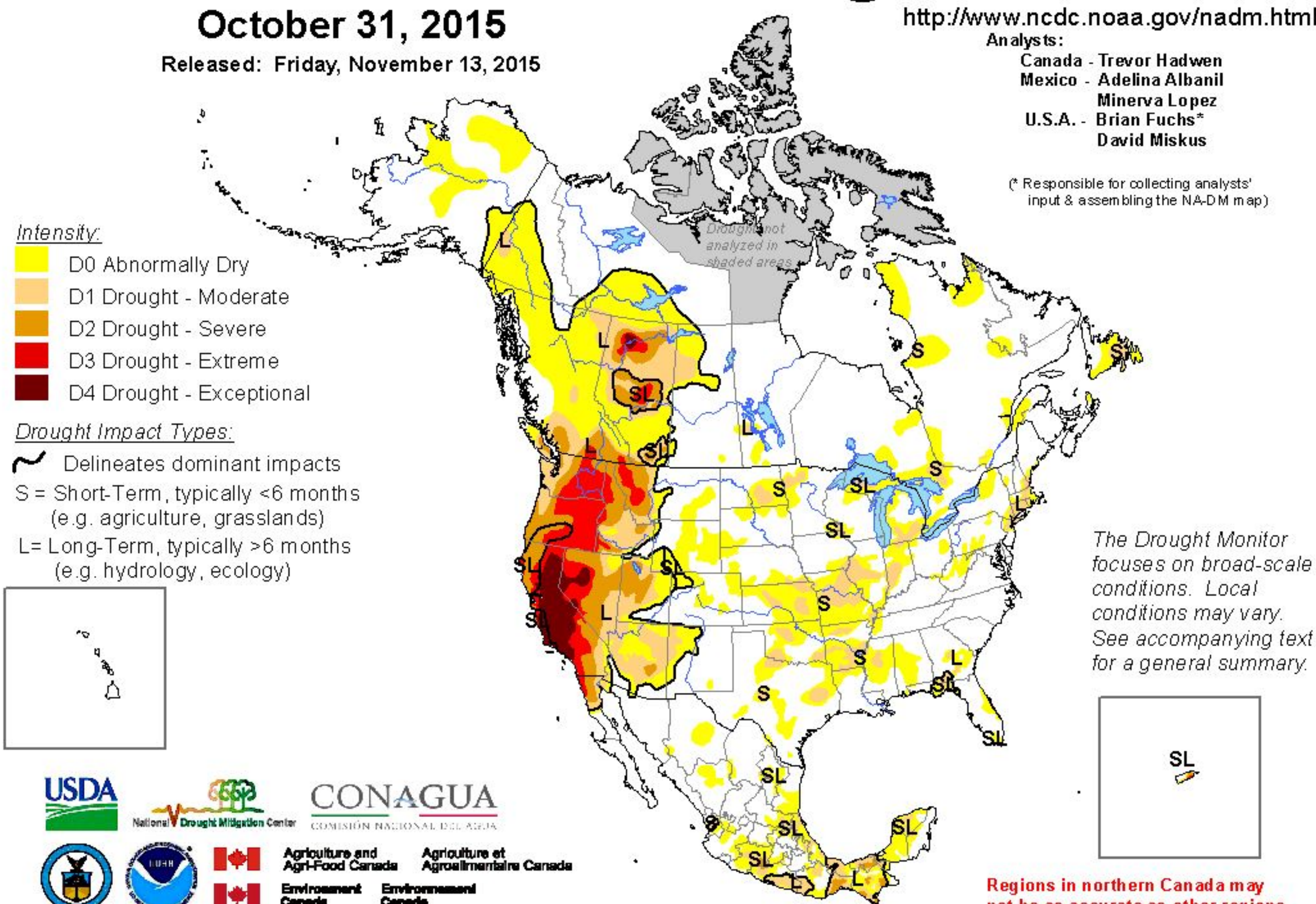
The following future enhancements will only serve to make it even more competitive:

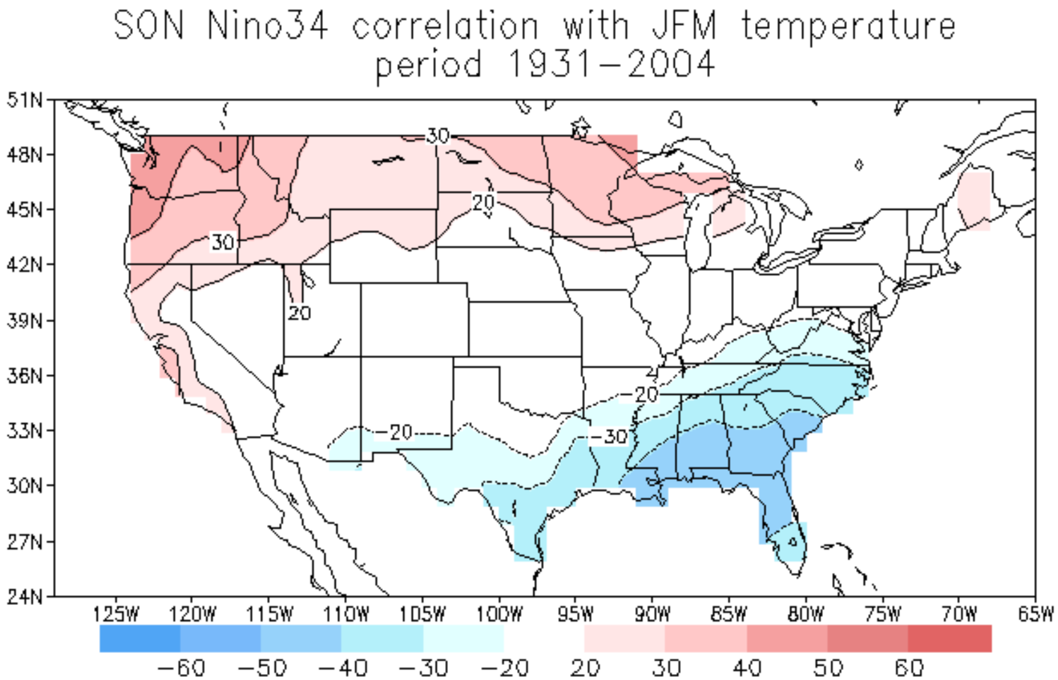
1. Replacing the spectral model with the GFDL FV3 dynamic core for the atmospheric model component (work underway)
2. Working towards improving the coupling physics with the new FV3 dynamic core (work underway)
3. Working towards an FV3 based weakly coupled data assimilation system, based on the hybrid EnKF approach to all component systems (work underway).
4. Working towards a full ensemble of coupled model members with consistent initial perturbations to all components.
5. Reanalysis and Retrospective forecasts for consistent and appropriate systematic error correction, as well as skill estimation.
6. Working towards a full end-to-end workflow infrastructure that includes full validation metrics (work underway).

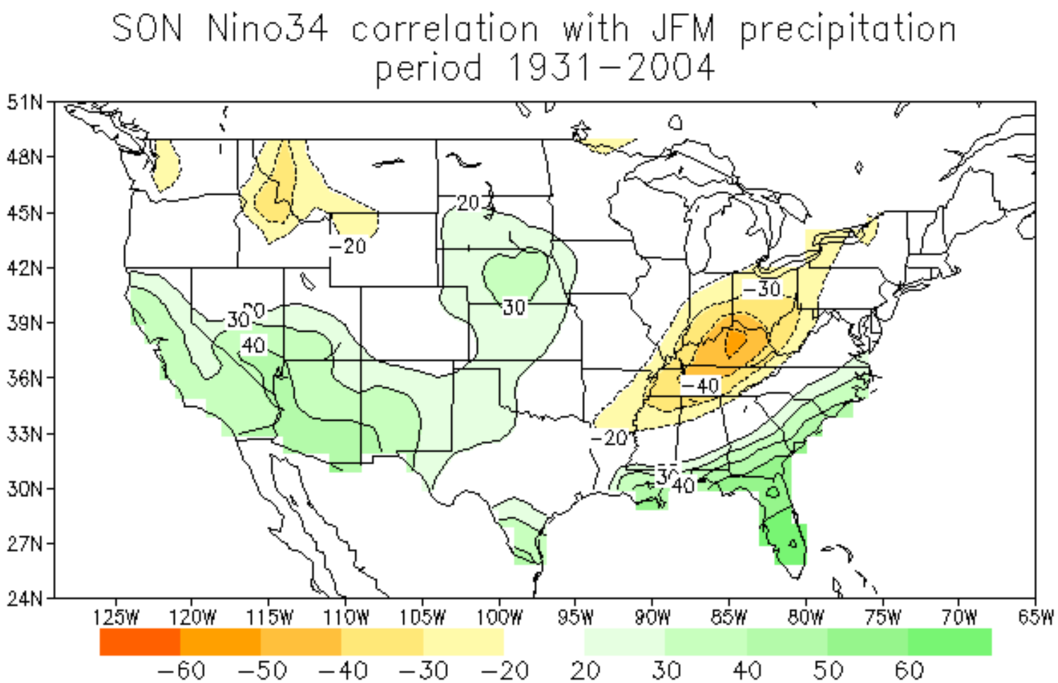
The problem of winter 15/16

- California (CA) had been in a multi-year drought through November 2015, so the good folks living there were ready for a high rainfall season.
- The occurrence of a very strong ENSO event during the winter of 2015/16 (one of three strongest ever) was an opportunity to predict bigly.
- Just before this epic warm event, most humans and seasonal prediction models were forecasting the classical ENSO composite, which called for wet conditions over CA, especially southern CA.
- And yet, nature had other ideas, and kept CA on the dry side, at odds with all the forecasts for a wet CA
- All models failed equally at this task, although Canada's CMC1 and the US CFSv2 were not as dreadful as the rest of the NMME models.

North American Drought Monitor



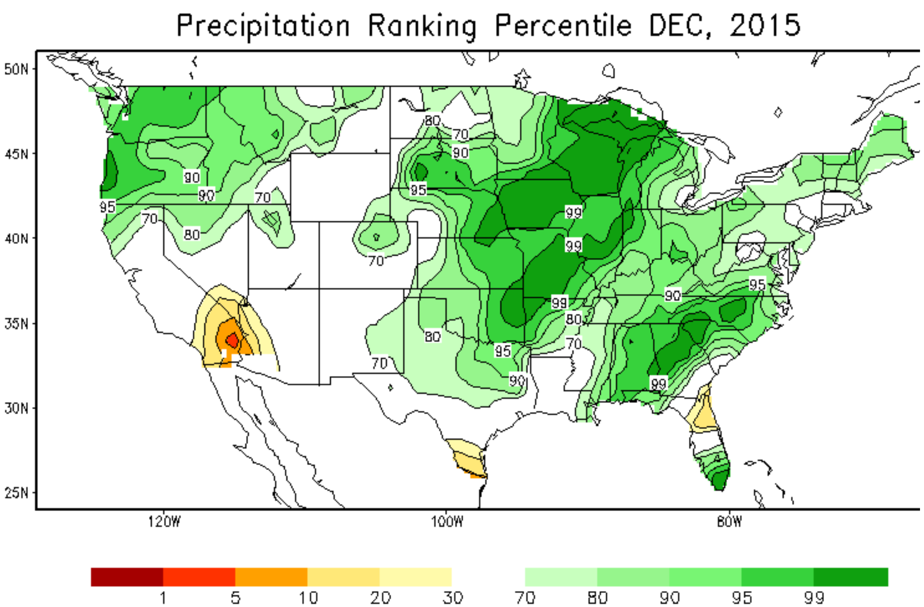


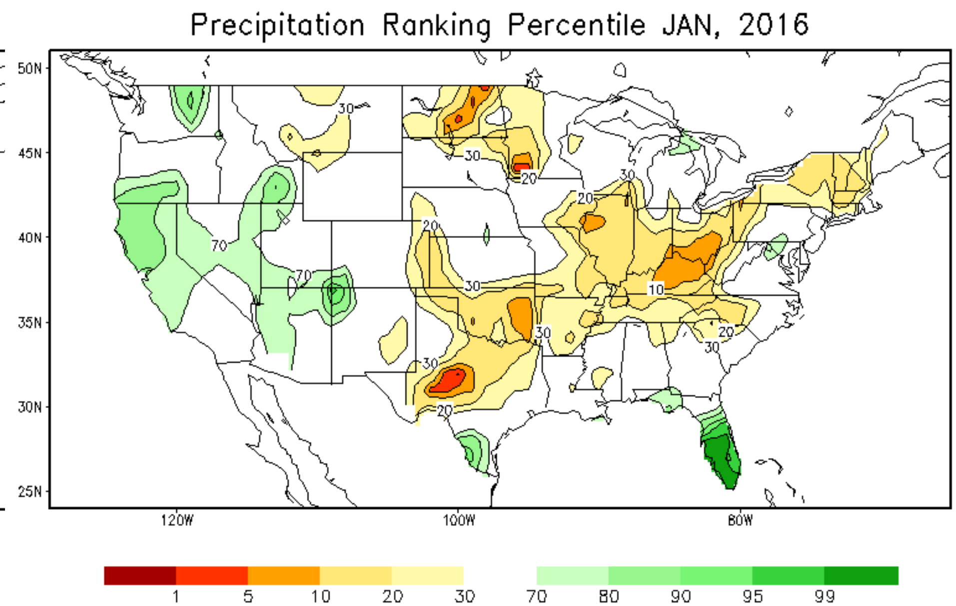


The correlation (*100.) between the Nino34 SST index in fall (SON) and the temperature (top) and precipitation (bottom) in the following JFM in the United States. Correlations in excess of 0.2 are shaded. Contours every 0.1 – no contours for -.1, 0 and +0.1 shown.

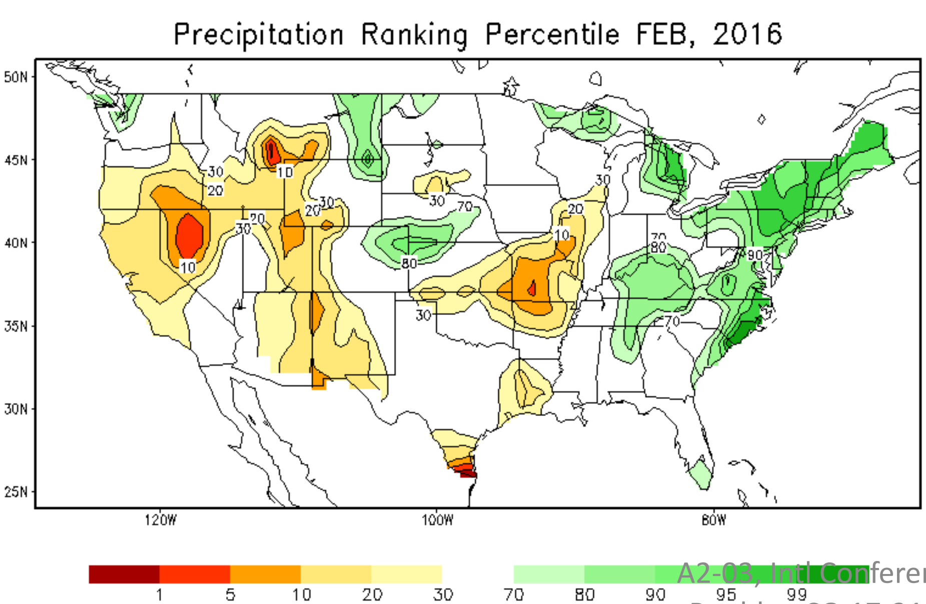
Reminder of how ENSO composites look like. Wet across the south, dry in OH valley

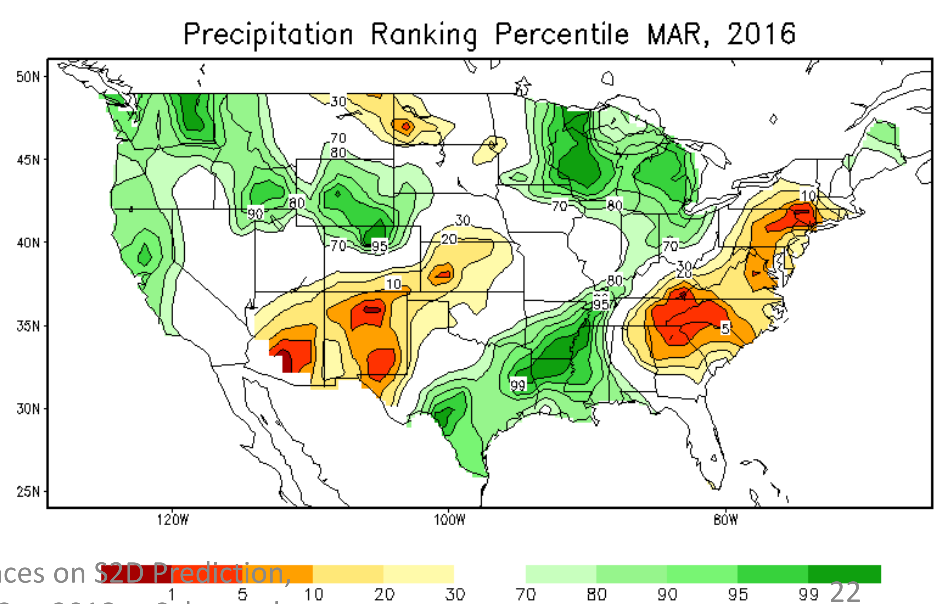
Courtesy: Huug van den Dool

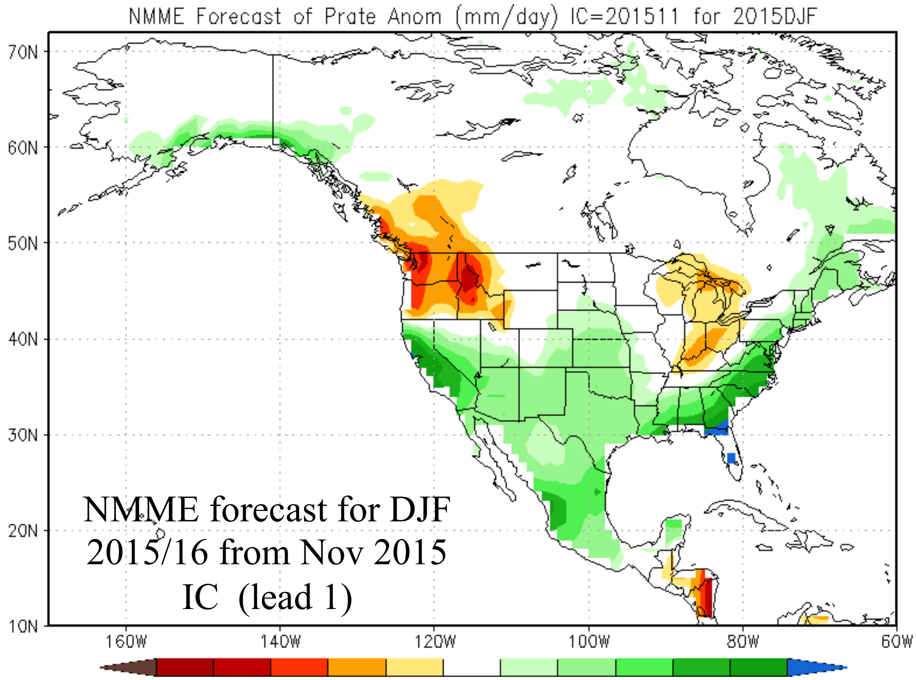


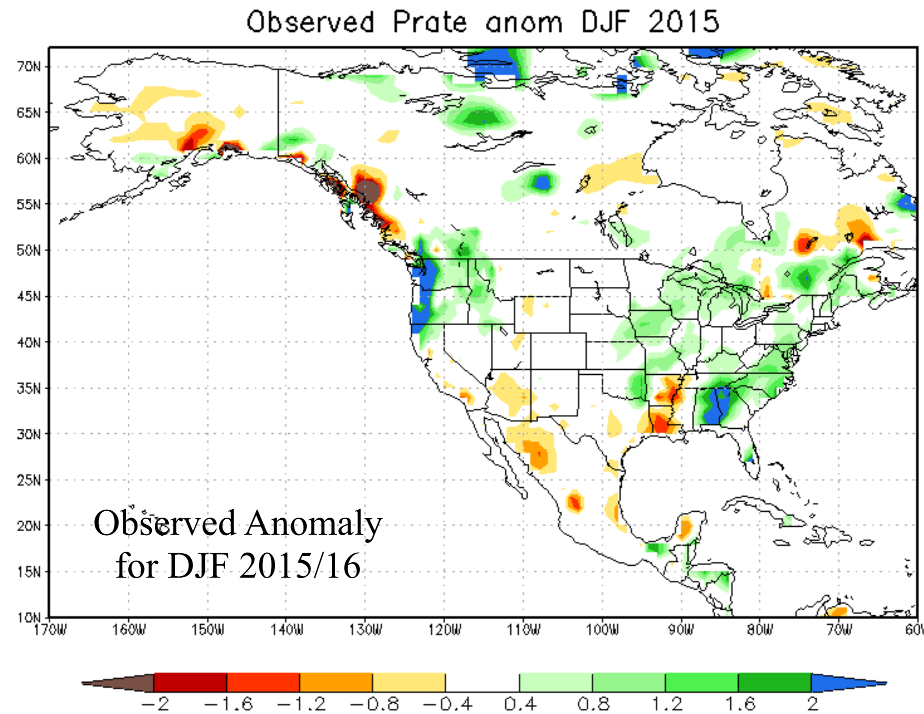


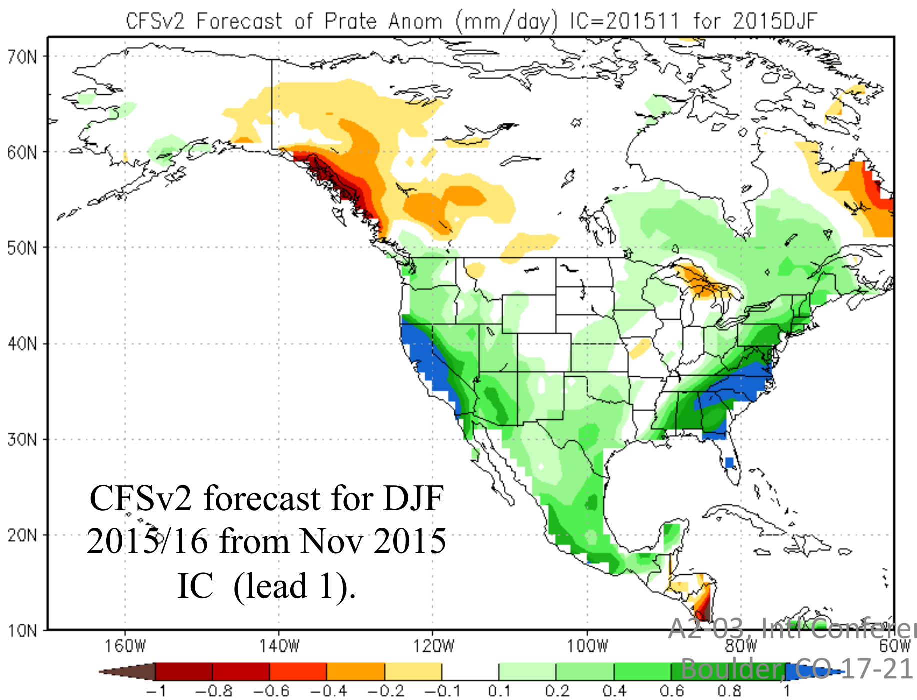
None of the months DJFM looked much like an ENSO composite

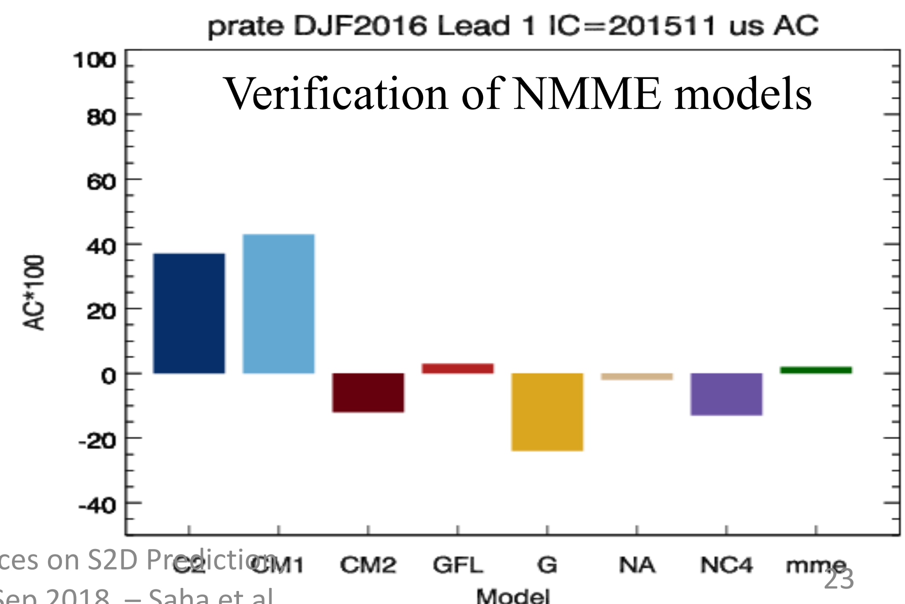


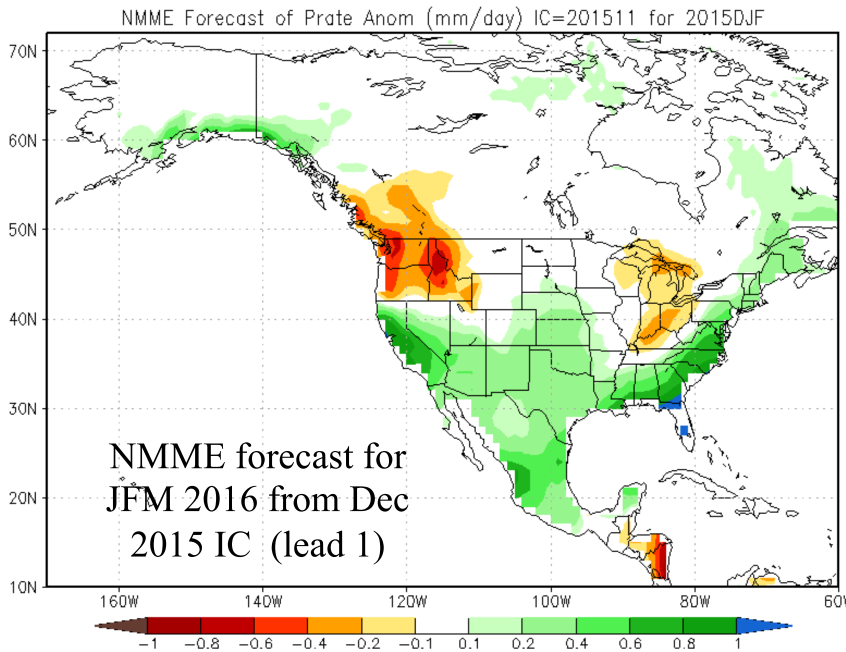


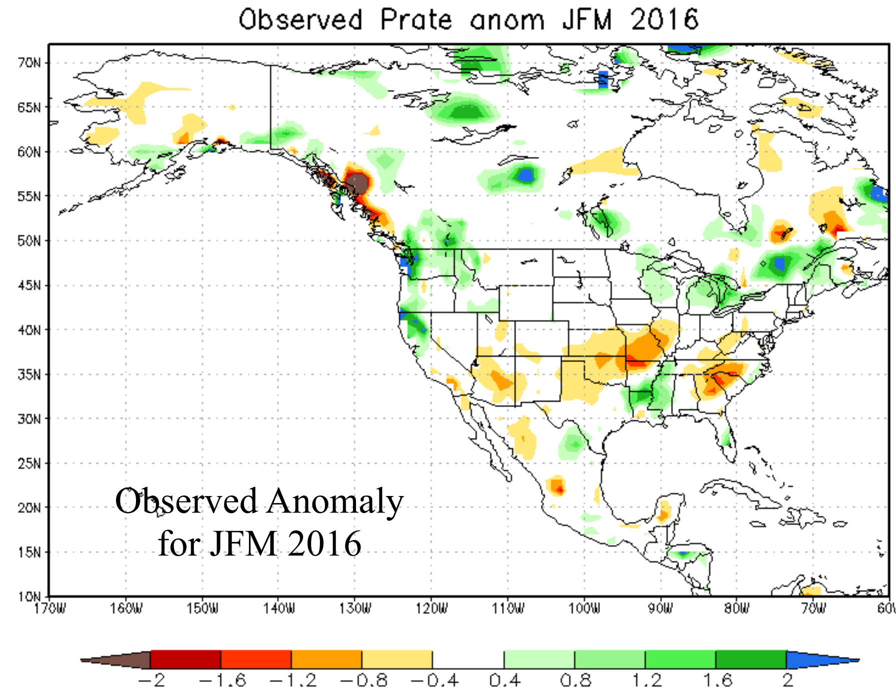

NMME Forecast of Prate Anom (mm/day) IC=201511 for 2015DJF
NMME forecast for DJF 2015/16 from Nov 2015 IC (lead 1)
70N
60N
50N
40N
30N
20N
10N
160W
140W
120W
100W
80W
60W


Observed Prate anom DJF 2015
Observed Anomaly for DJF 2015/16
70N
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
170W
160W
150W
140W
130W
120W
110W
100W
90W
80W
70W
60W
−2
−1.6
−1.2
−0.8
−0.4
0.4
0.8
1.2
1.6
2


CFSv2 Forecast of Prate Anom (mm/day) IC=201511 for 2015DJF
CFSv2 forecast for DJF 2015/16 from Nov 2015 IC (lead 1).
70N
60N
50N
40N
30N
20N
10N
160W
140W
120W
100W
80W
60W
−1
−0.8
−0.6
−0.4
−0.2
−0.1
0.1
0.2
0.4
0.6
0.8
1


prate DJF2016 Lead 1 IC=201511 us AC
Verification of NMME models
AC*100
100
80
60
40
20
0
-20
-40
C2
CM1
CM2
GFL
G
NA
NC4
mme
Model

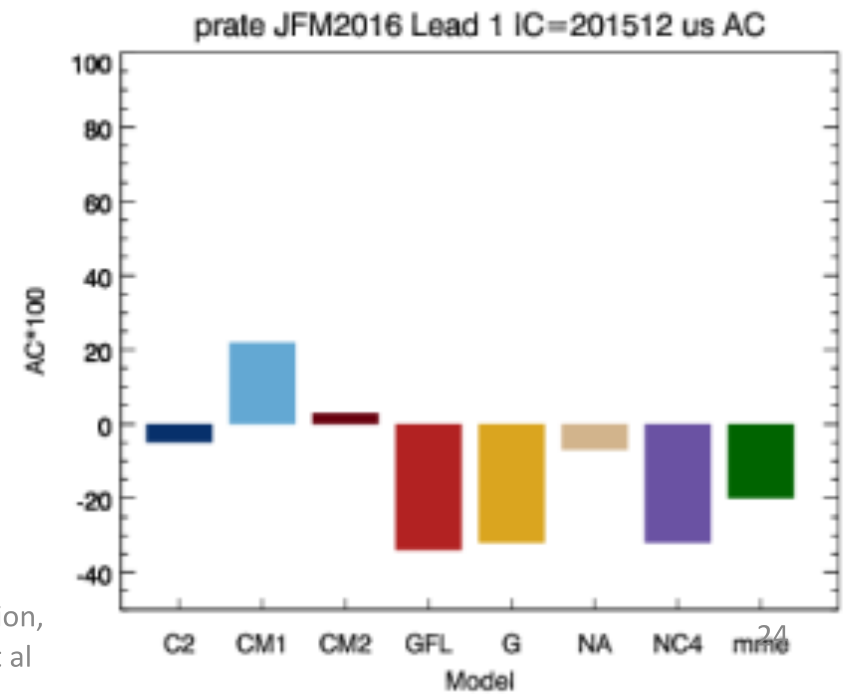


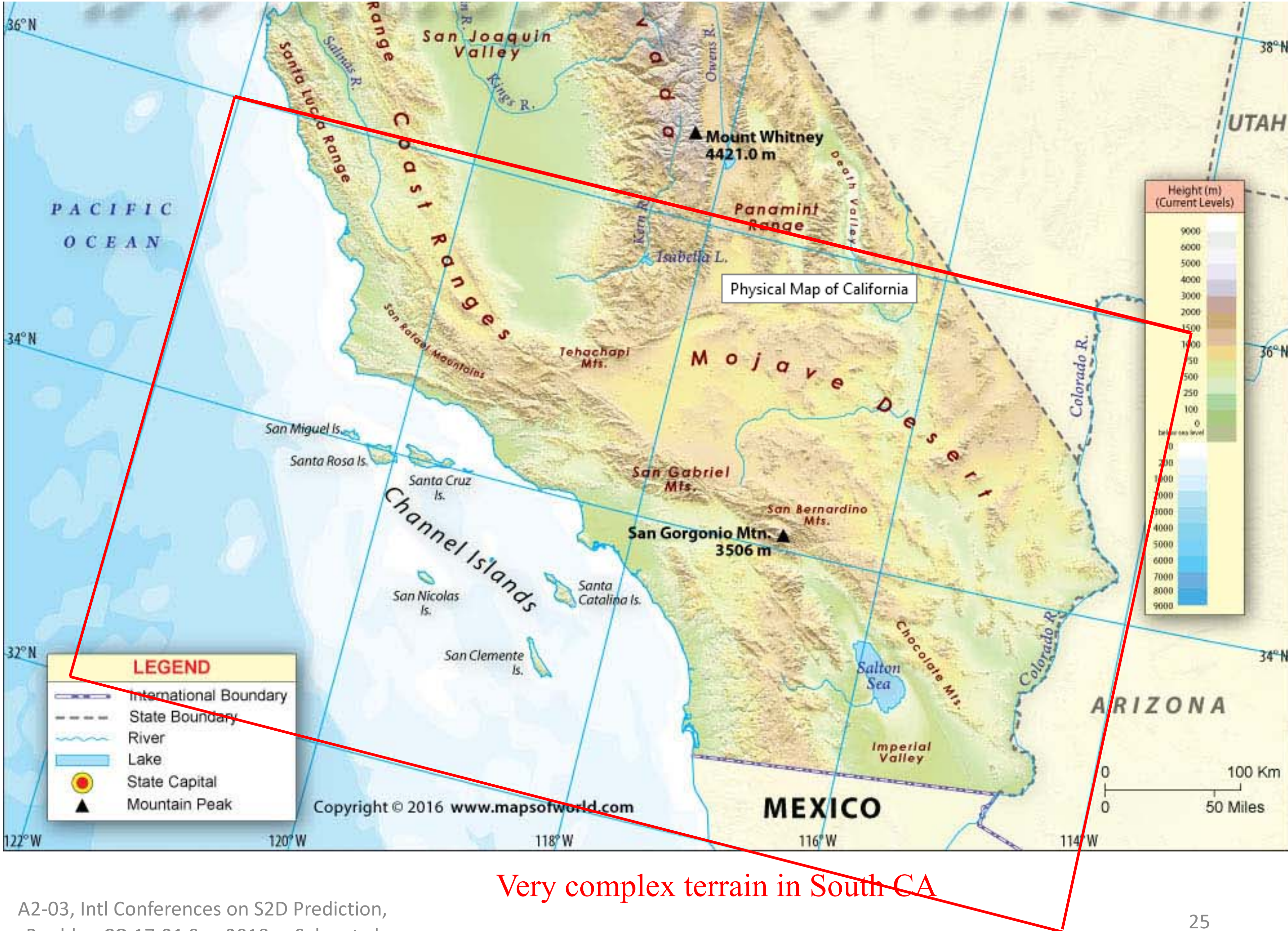


Again, for JFM 2016, the NMME models all made a perfect ENSO composite.

The observations show little rain over southern California.

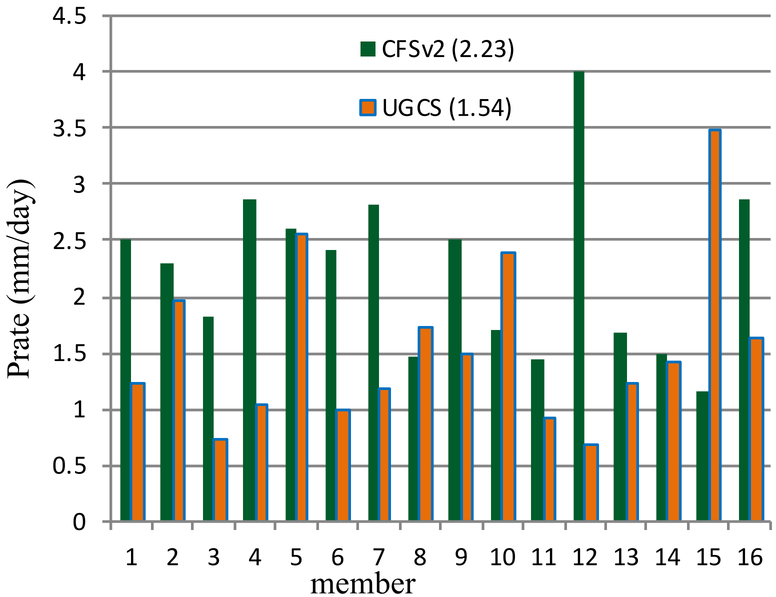
All NMME models faired poorly.

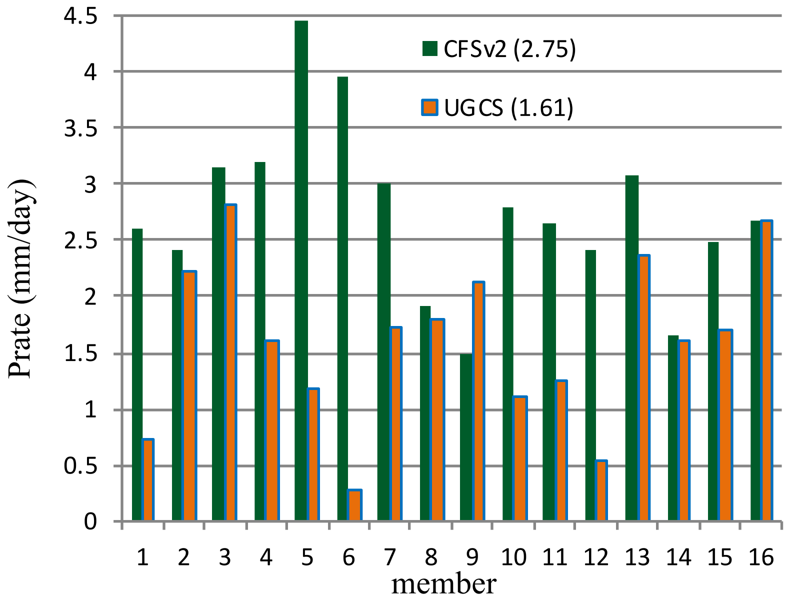




Very complex terrain in South CA

Prate (mm/day) for South CA box (land points between 32N and 36N, and 122W and 114W)

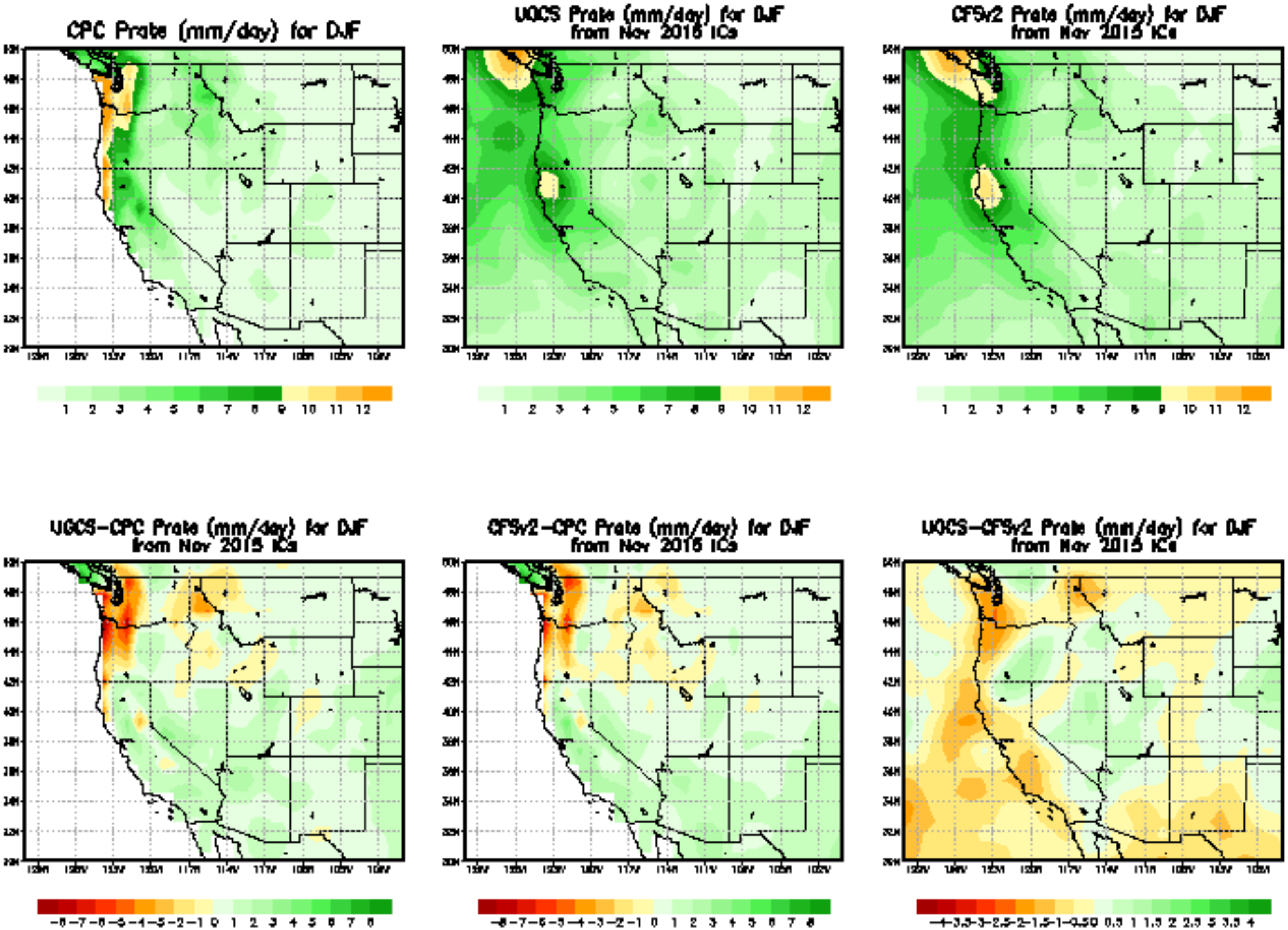




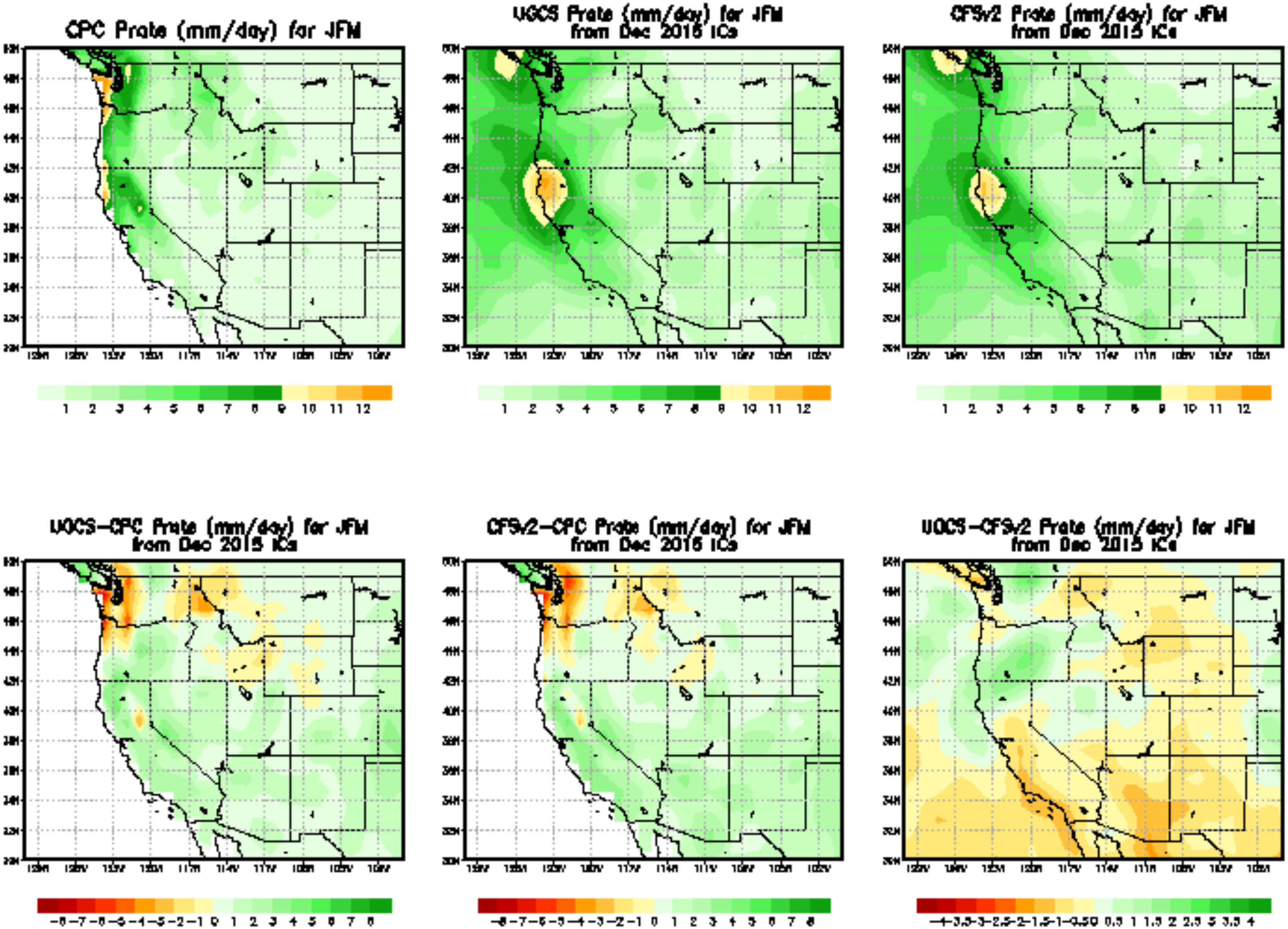
ICs: CFSR Nov 1, 0z to Nov 8, 12z, 2015
every 12 hours, 16 members in all
Target season is DJF 2015/16
UGCS 0.69 mm/day (31%) drier than CFSv2
13 out of 16 members are drier
As hoped, UGCS is significantly drier

ICs: CFSR Dec 1, 0z to Dec 8, 12z, 2015
every 12 hours, 16 members in all
Target season is JFM 2016
UGCS 1.14 mm/day (41%) drier than CFSv2
15 out of 16 members are drier
As hoped UGCS is significantly drier

Although UGCS is significantly drier than CFSv2 for both target seasons, the predicted UGCS rainfall is still quite a bit larger than CFSR (0.62 and 0.69 respectively) and CPC-daily analysis (0.62 and 0.72 respectively)



SURANJANA SAHA. EMC/NCEP/NWS/NOAA



SURANJANA SAHA. EMC/NCEP/NWS/NOAA

Summary

- Is the new model configuration discussed here perhaps drier than CFSv2 for the winter of 2015/16?
- Answer is YES.
- Drier may not be dry enough, but it is a big move in the right direction.
- Maybe dry in CA is, at seasonal leads, a 'signal' in certain ENSOs after all (the flavors of ENSO argument)