The Regional Climate Downscaling using RSM in MRED Project

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Introduction

- Project supported by NOAA OGP CPPA
- Using operational CFS (T62L64) re-run as boundary condition, check carefully to reproduce.
- Winter cases of 15 members from 1982 - 2008+ over CONUS.
- Present NCEP RSM results from these 15 members

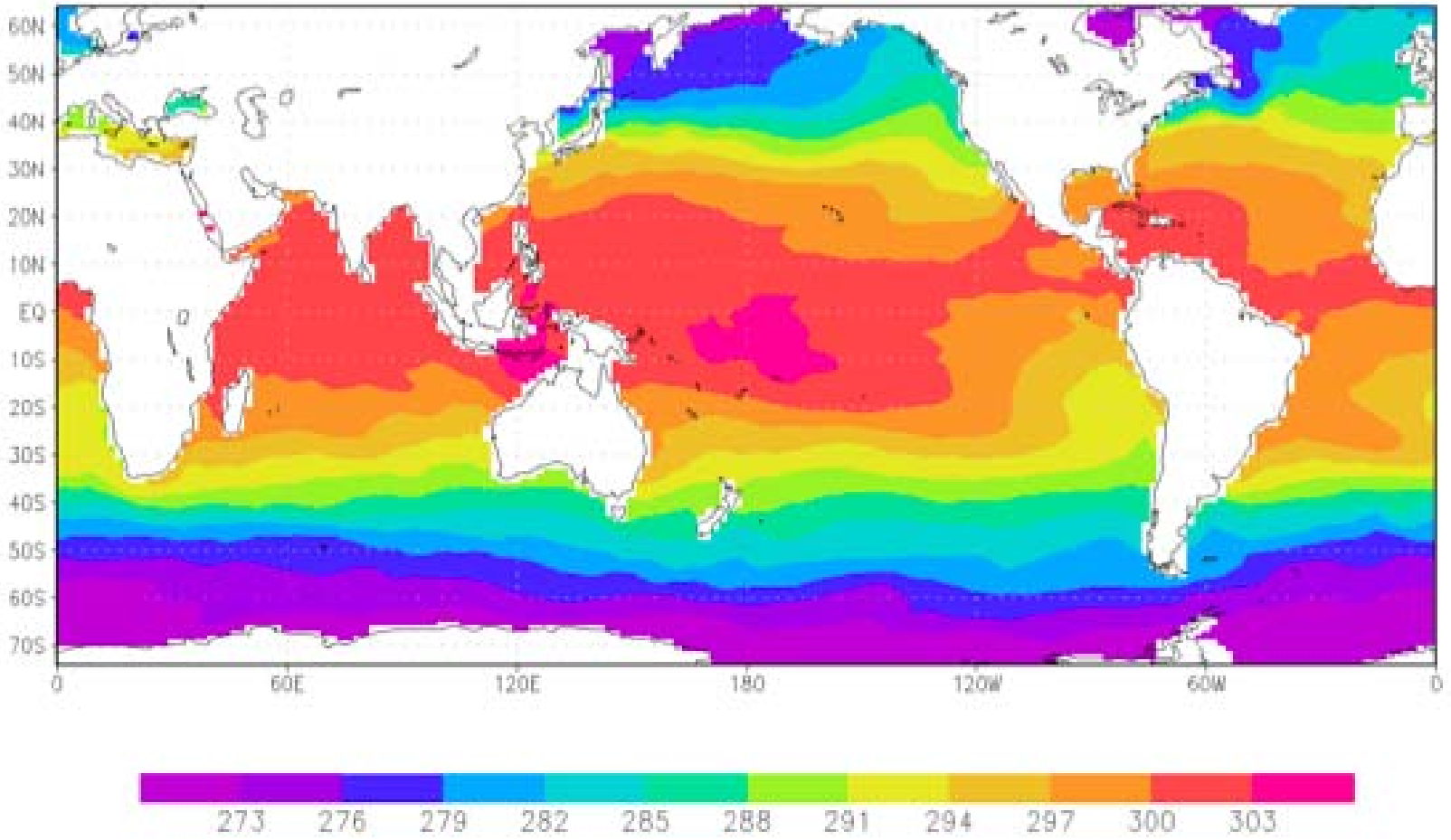
NCEP RSM Configuration

- NCEP Regional Spectral Model

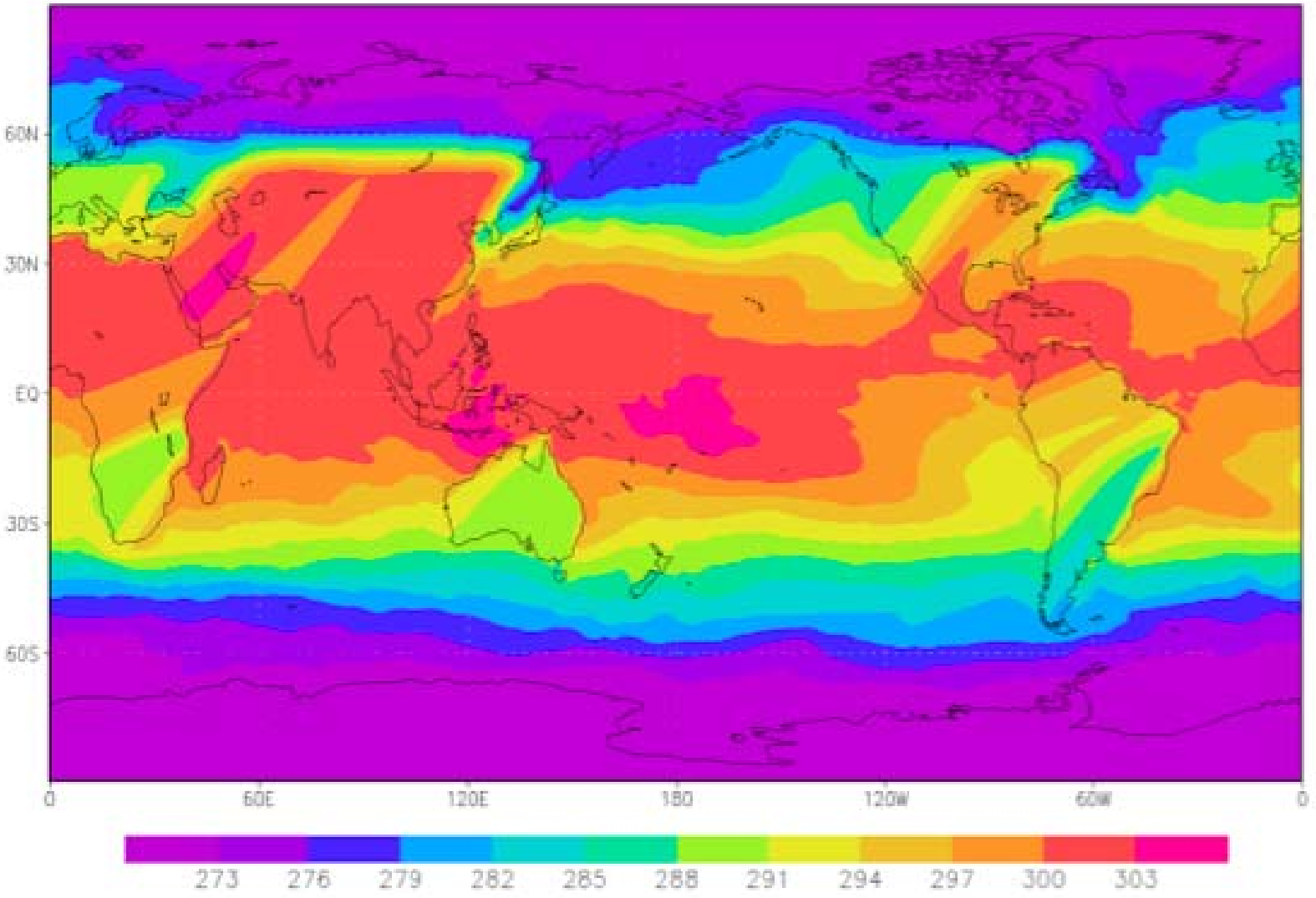
  RSM: 2004 version, 2D MPI, 32km, 64levels over US continental

- Surface condition
  - Terrain data from 4m data and CFS SST
  - Vegetation type (1°), vegetation fraction(0.144°), soil type (1°), albedo and surface roughness (1°)
  - Update every day
- Corrected Great Lake temperature
  - CFS data for SST over lakes has high temperature
  - Corrected by climatologic ocean data at the same latitudes
  - Example in http://cppa.ncep.noaa.gov/sst_correct.html

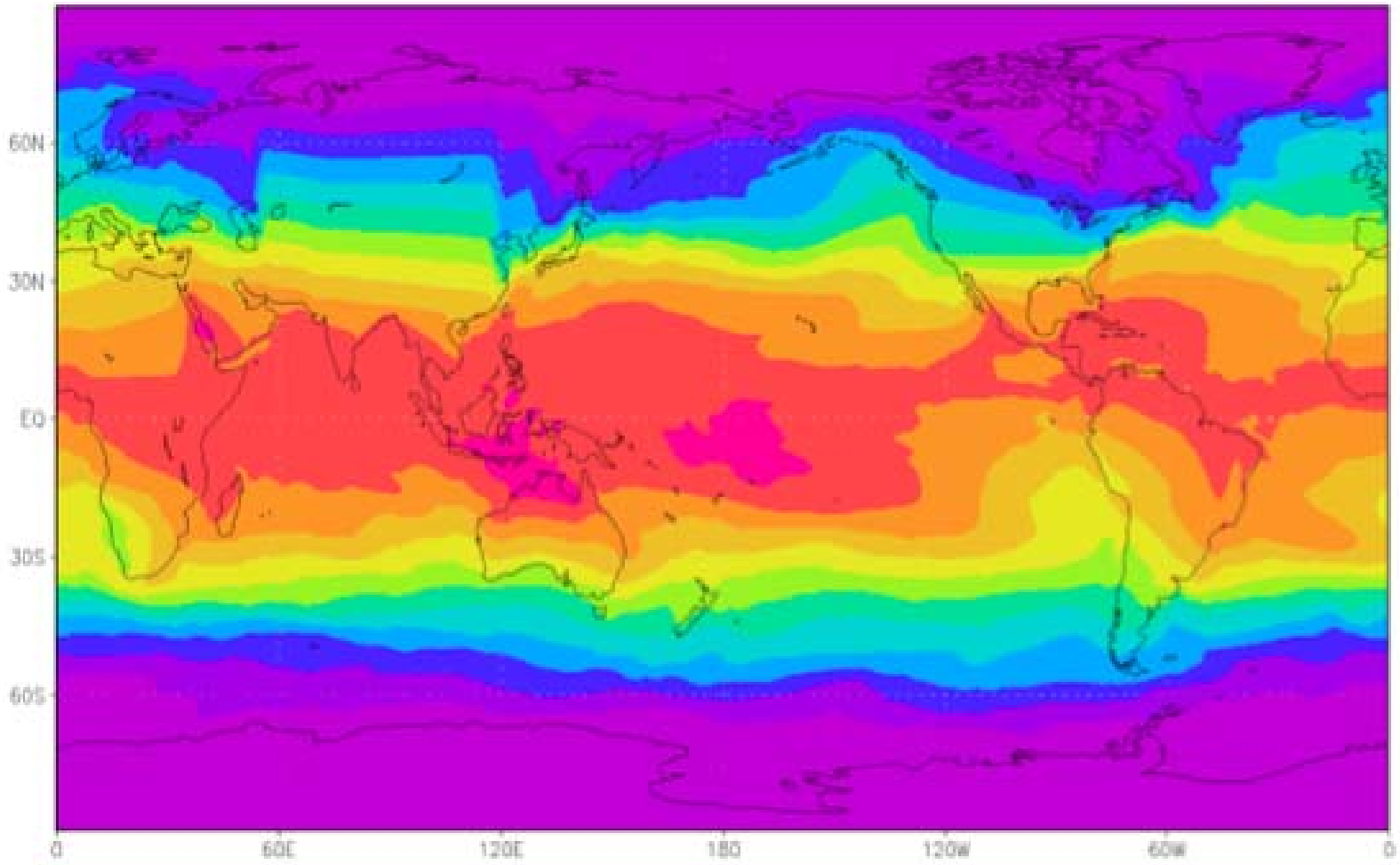
Ocean model SST

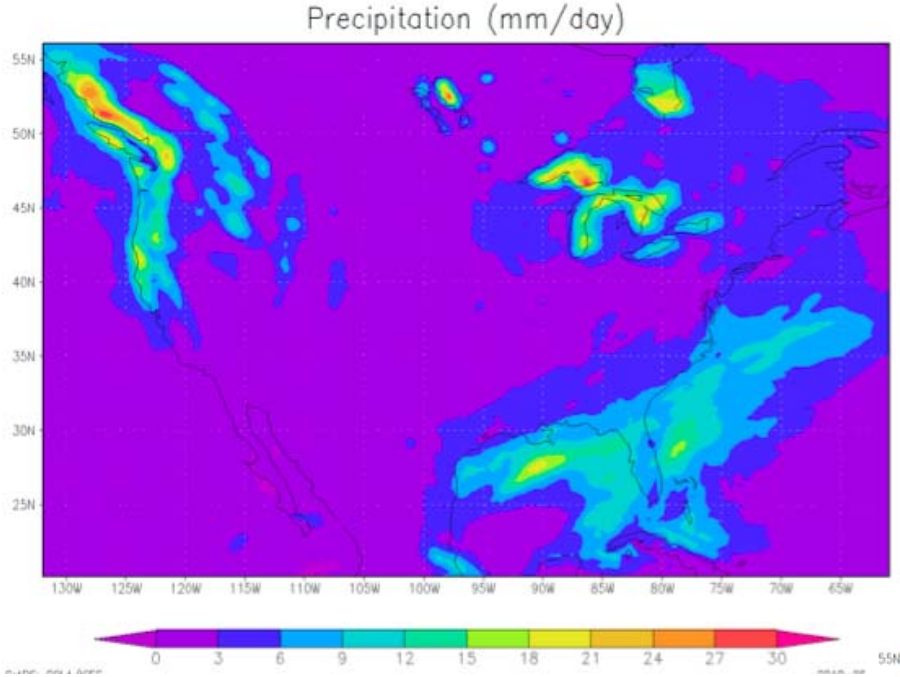


CFS SST for atmosphere model



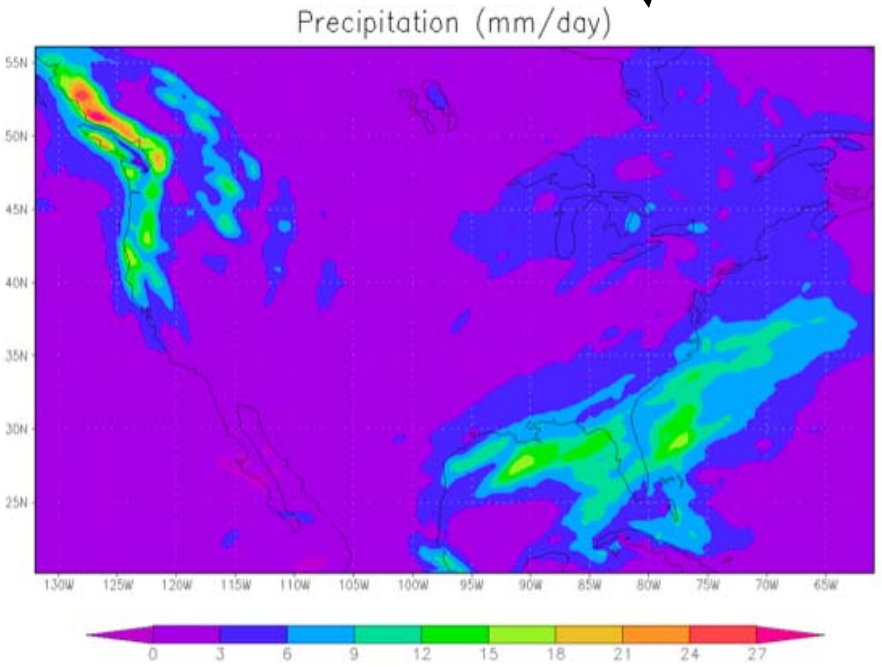
Correct CFS SST for MRED exp





without correct SST

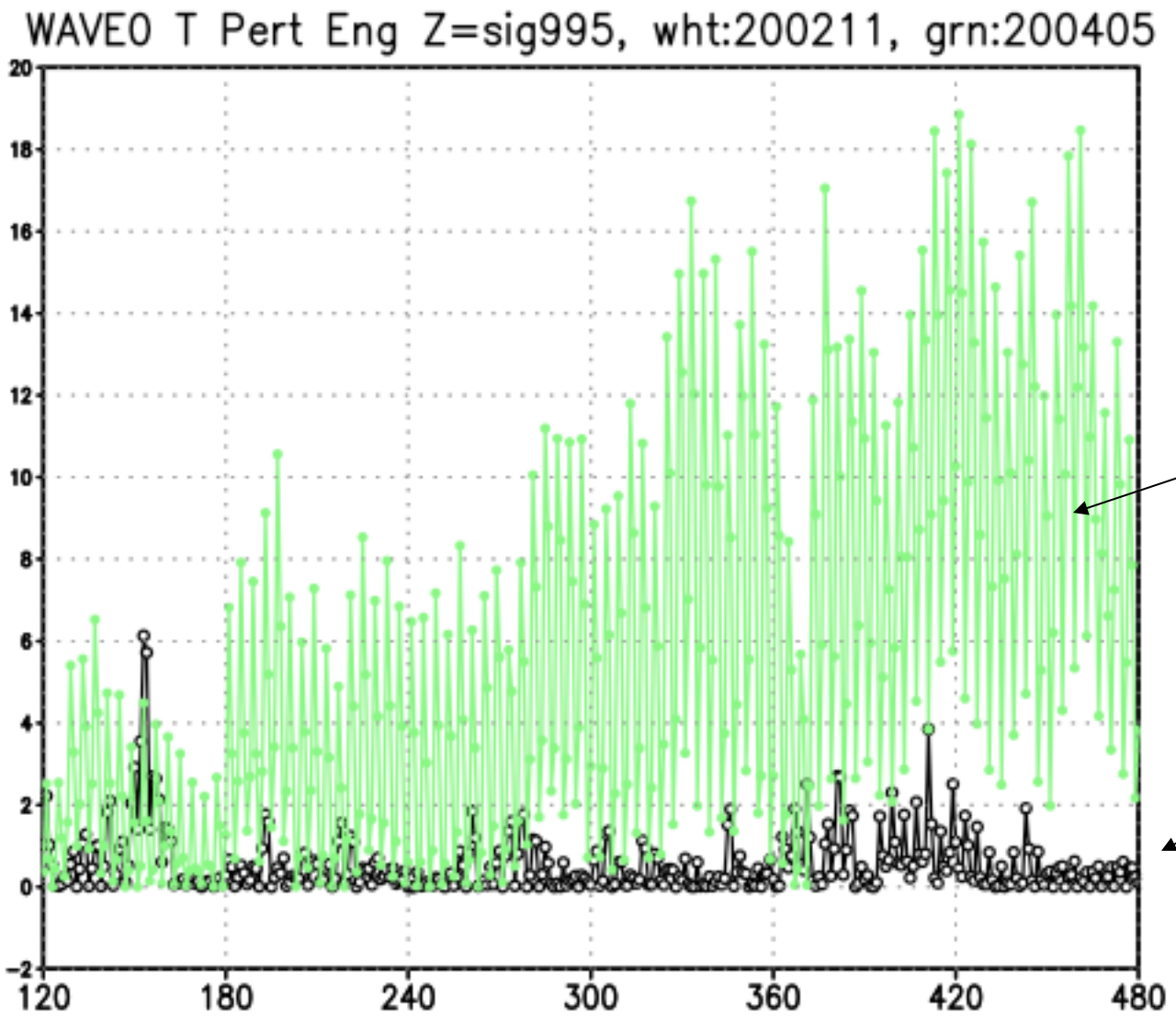
with corrected SST

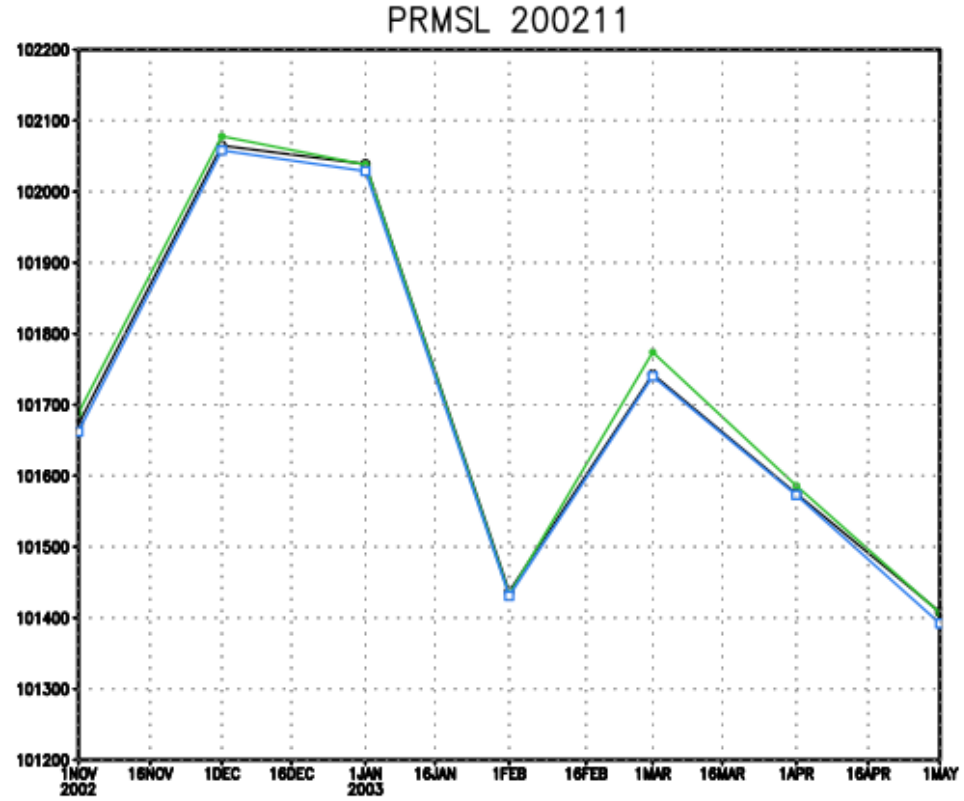


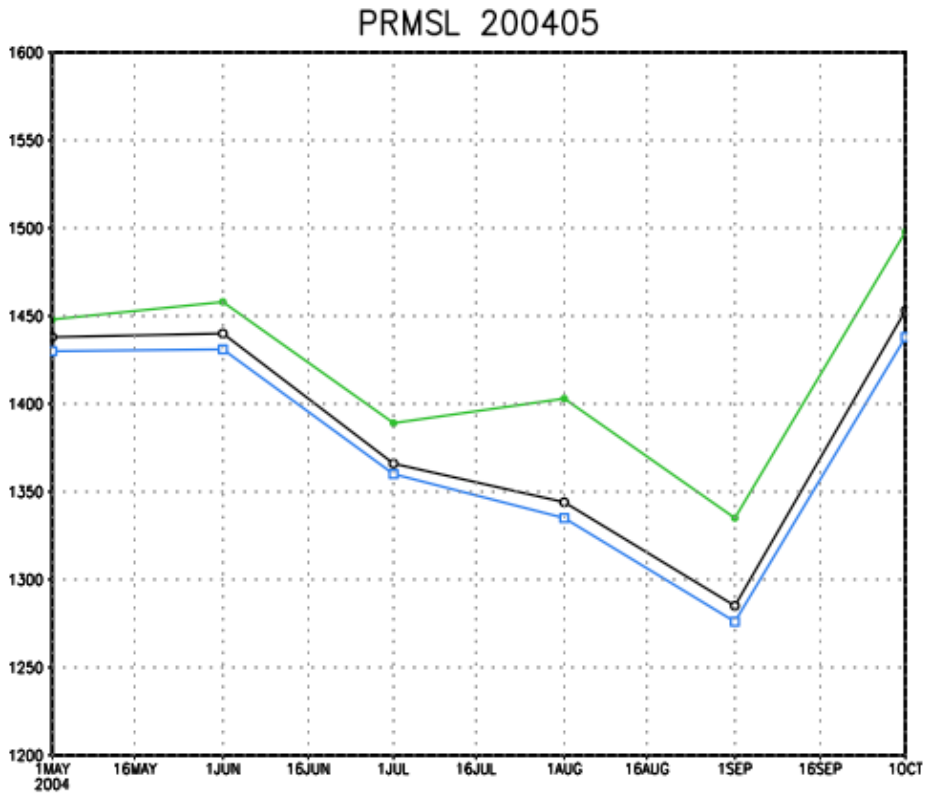
It is not easy to see from day by day forecast, but show out clearly from monthly mean daily precipitation.

Mean Bias Correction

- It is found that there are some systematic difference between RSM forecasted large scale fields and global background fields through regional domain mean value.
- The method was published in Shiao and Juang in 2006;
  - Larger domain of base field data with the same resolution as RSM and same terrain height.
  - Zero initial perturbation
  - Removal mean perturbation in spectral space at every time step.


WAVE0 T Pert Eng Z=sig995, wht:200211, grn:200405
20
18
16
14
12
10
8
6
4
2
0
-2
120
180
240
300
360
420
480
200405
summer
200211
winter





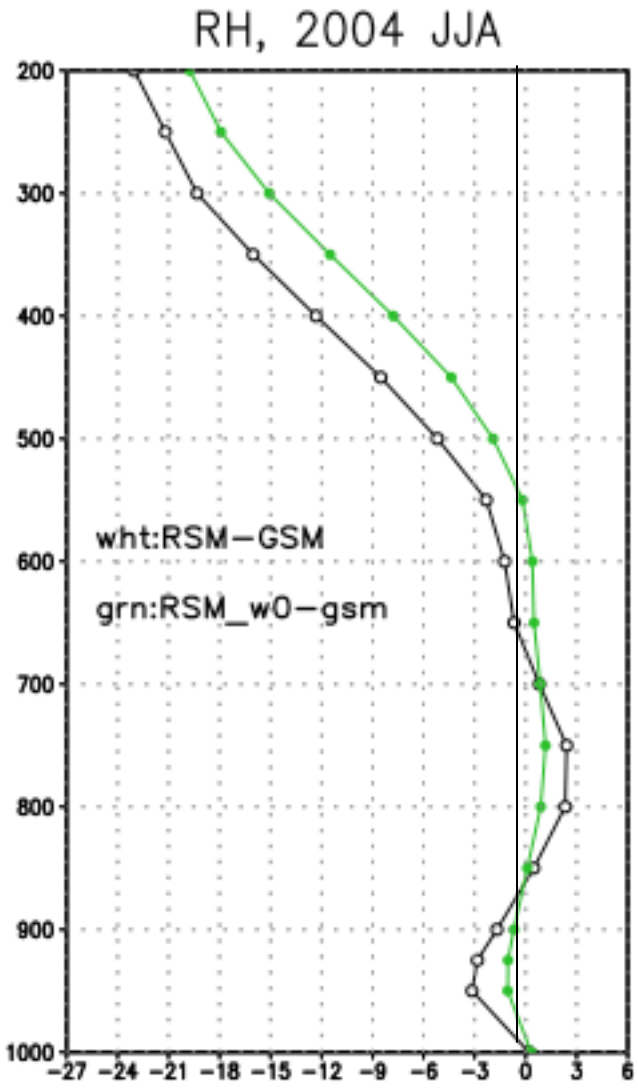
winter

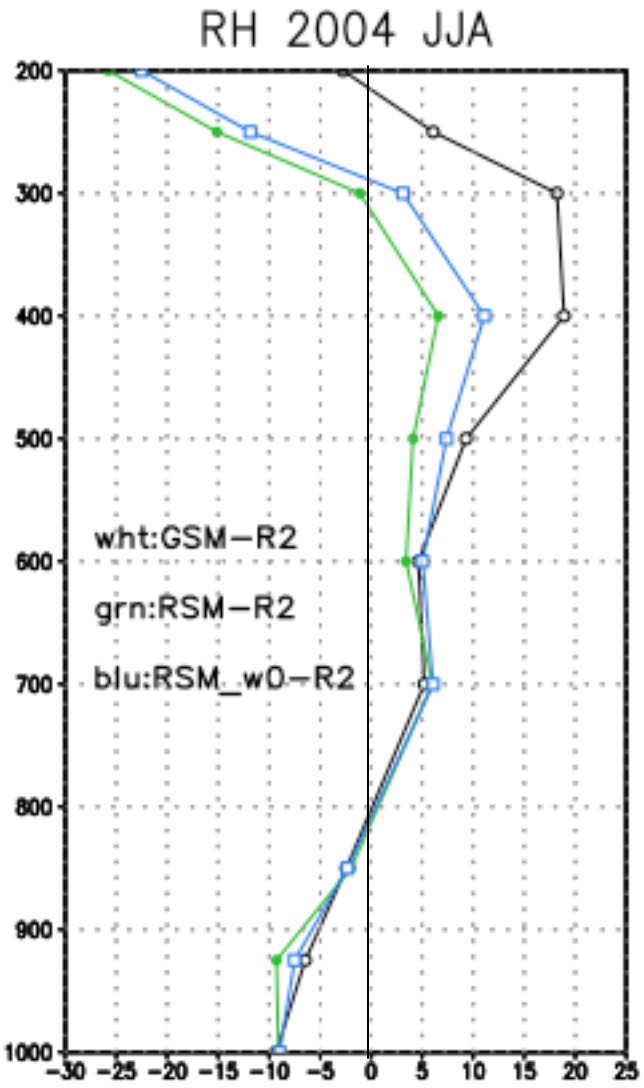
summer

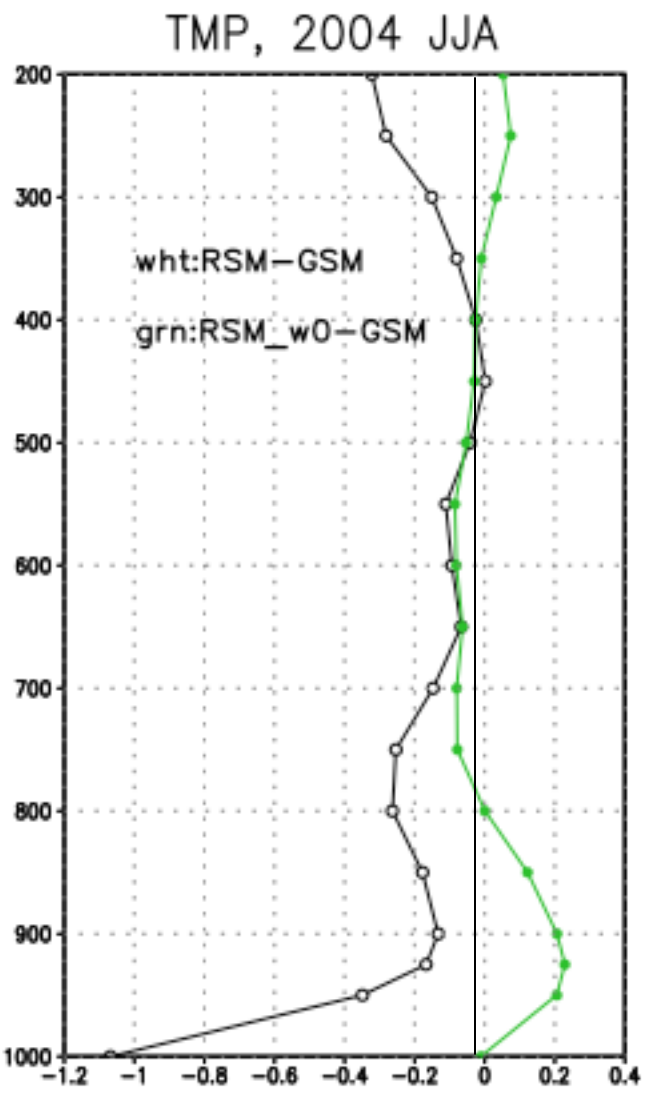
Black: GFS

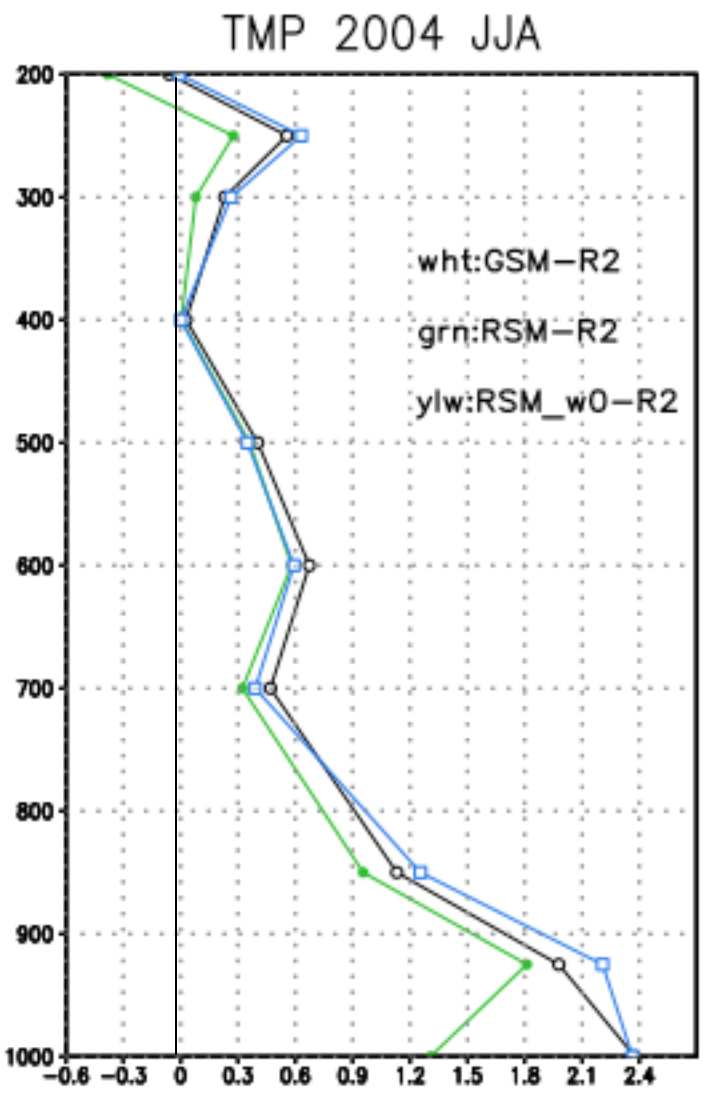
Green : RSM

Blue : RSM-w0


RH, 2004 JJA
wht:RSM−GSM
grn:RSM_w0−gsm
200
300
400
500
600
700
800
900
1000
−27 −24 −21 −18 −15 −12 −9 −6 −3 0 3 6


RH 2004 JJA
wht:GSM−R2
grn:RSM−R2
blu:RSM_w0−R2
200
300
400
500
600
700
800
900
1000
−30 −25 −20 −15 −10 −5 0 5 10 15 20 25


TMP, 2004 JJA
wht:RSM−GSM
grn:RSM_w0−GSM
200
300
400
500
600
700
800
900
1000
−1.2 −1 −0.8 −0.6 −0.4 −0.2 0 0.2 0.4


TMP 2004 JJA
wht:GSM−R2
grn:RSM−R2
ylw:RSM_w0−R2
200
300
400
500
600
700
800
900
1000
−0.6 −0.3 0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4

Note to bias correction

- Winter time has more large scale which is represented well through RSM nesting method, but summer has more smaller/local scale which is ill-represented through RSM nesting, so mean bias correction influence more in summer, winter has no need to correct, or the mean error is negligible.
- After correction, RSM atmospheric profile closes to global, may not be good as approach to reanalysis as the one without correction.
- We believe bias correction should be done, but what correction should we do?
  - Removal of nesting error, sound reasonable, but not enough.
  - Add back of observation/analysis bias?
  - Use analysis corrected GSM for RSM?

Verification of NCEP RSM

- The first order verification presents here
  - Any large scale ‘drift’ for nesting ?
  - Any mesoscale feature generated ?
- The verification suggested by WMO for long term and ensemble forecast are used
  - Including, mean, anomaly, anomaly correlation, rmse, spread, signal to noise ratio, mean square skill score
  - http://www.bom.gov.au/wmo/lrfvs/
- We have plots for wind, T, Z for 200, 500, 850 mb, SLP, rain, 2m T, q, 10m wind etc.
  - unfortunately, color scale between CFS and RSM are not matching for lots plots.

$$C_o = \frac{1}{N}\sum_{i=1}^{N} O_i \qquad C_f = \frac{1}{N}\sum_{i=1}^{N} F_i$$

$$Anom = \frac{1}{N}\sum_{i=1}^{N}(F_i - O_i) \qquad Rmse = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2}$$

$$AC = \frac{\sum_{i=1}^{xy}(F_i - C_f)(O_i - C_o)}{\sqrt{\sum_{i=1}^{xy}(F_i - C_f)^2 \sum_{i=1}^{xy}(O_i - C_o)^2}}$$

$$Corr = \frac{\sum_{i=1}^{T}(F_i - C_f)(O_i - C_o)}{\sqrt{\sum_{i=1}^{T}(F_i - C_f)^2 \sum_{i=1}^{xy}(O_i - C_o)^2}}$$

Mean square skill score (MSSS) is essentially the Mean Square Error (MSE) of the forecasts compared to the MSE of climatology for a station or grid point.

$$C_o = \frac{1}{N}\sum_{i=1}^{N} O_i$$

$$MSSf = \frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2$$

$$MSSo = \frac{1}{N}\sum_{i=1}^{N}(O_i - C_o)^2$$

$$MSSS = 1 - \frac{MSSf}{MSSo}$$

Decomposite MSSS to MSSS-1 for phase error,
MSSS-2 for amplitude error, and
MSSS-3 for overall bias error.

$$M_t = \overline{F}^E = \frac{1}{E}\sum_{e=1}^{E} F_e \qquad \overline{M} = \frac{1}{T}\sum_{t=1}^{T} M_t$$

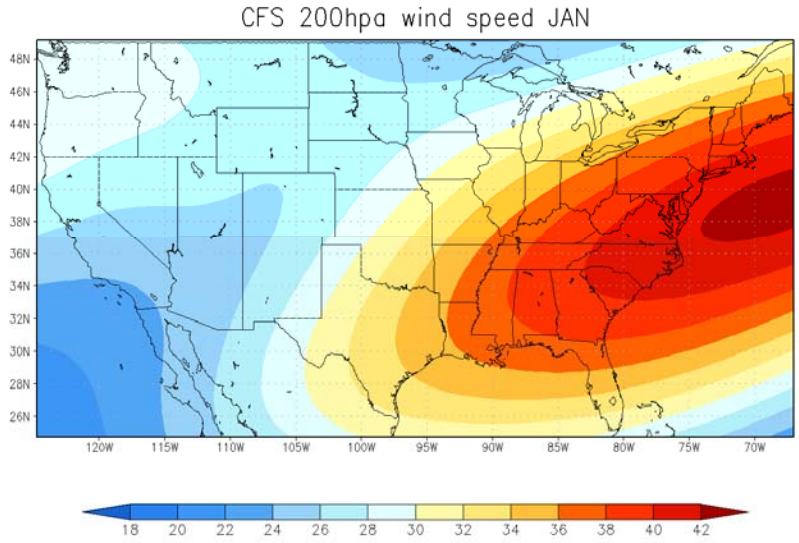
$$S_t = \sqrt{\frac{1}{E}\sum_{e=1}^{E}\left(F_e - \overline{F}^E\right)^2} \qquad \overline{S} = \frac{1}{T}\sum_{t=1}^{T} S_t$$

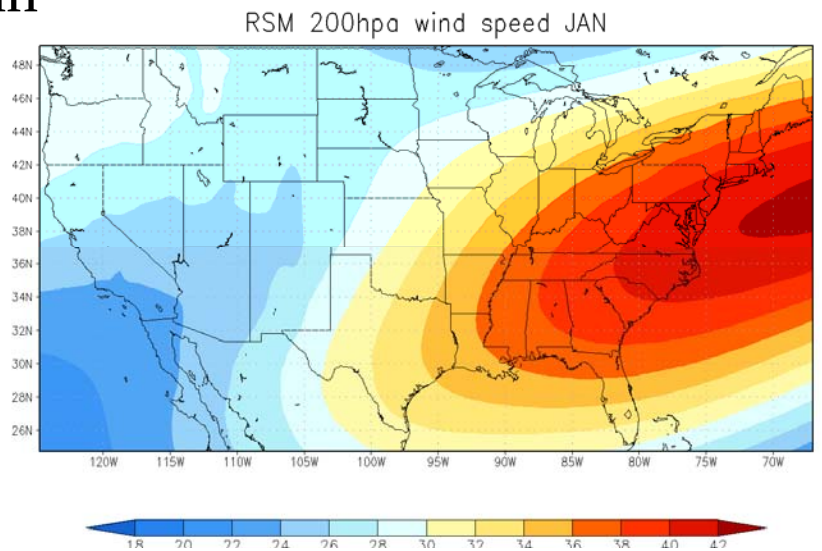
$$Spread = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(S_t - \overline{S}\right)^2}$$

$$SNR = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(M_t - \overline{M}\right)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(S_t - \overline{S}\right)^2}}$$

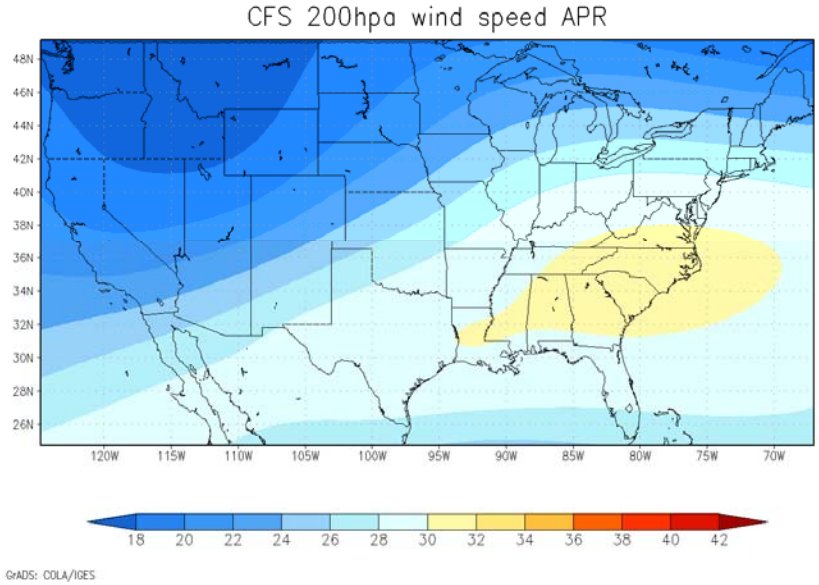
E is ensemble members, T is all years.

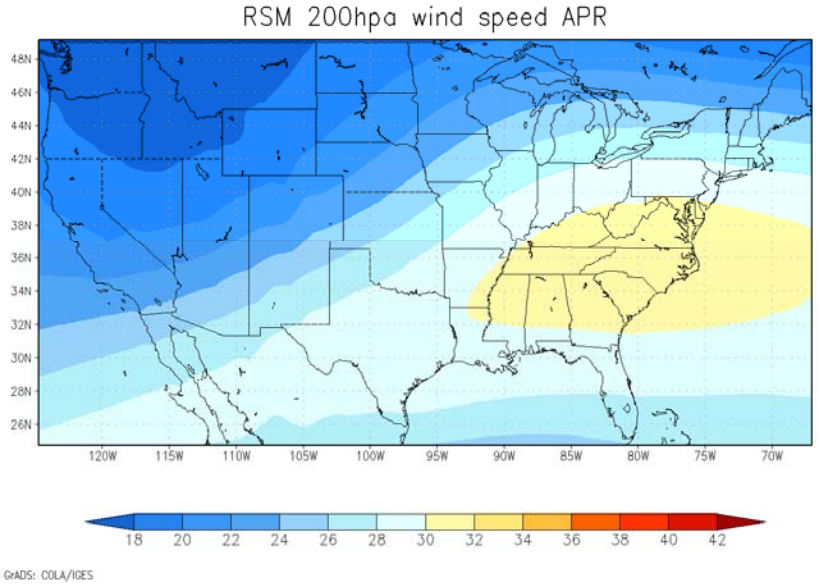
Mean



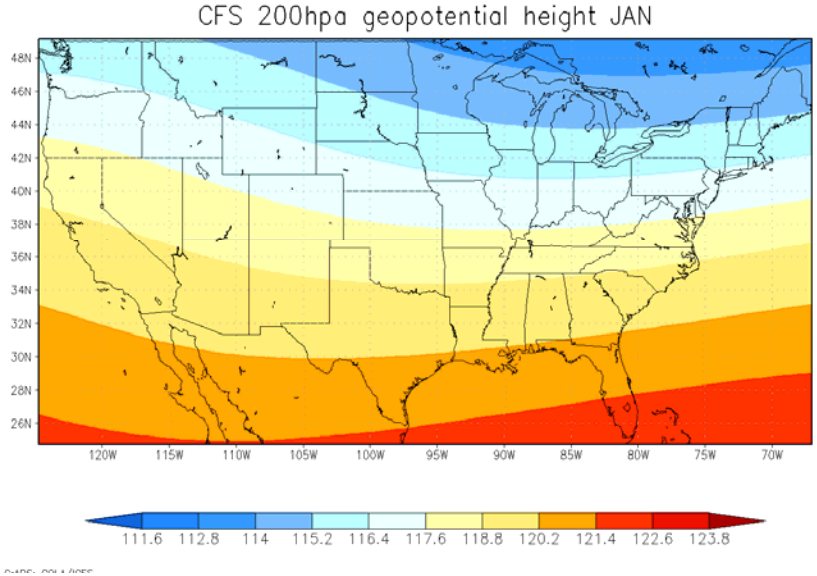


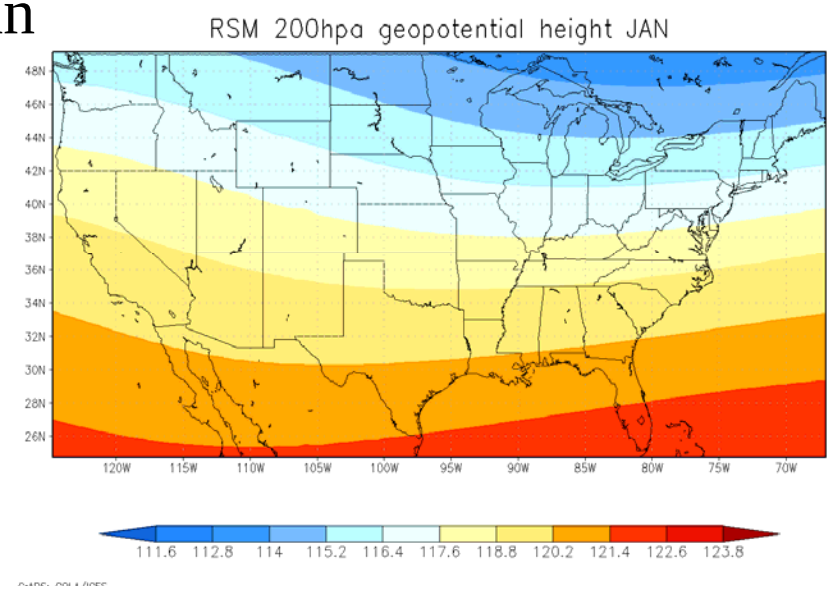
Wind200



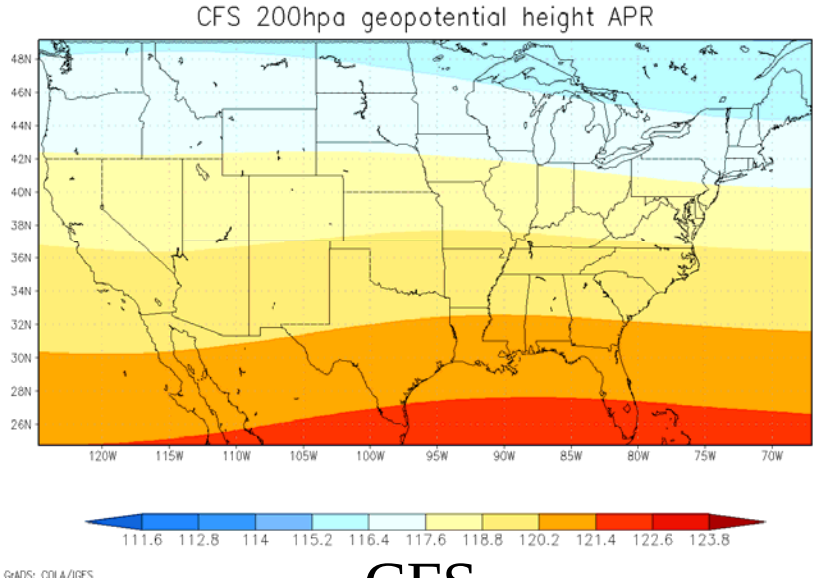


Mean


CFS 200hpa geopotential height JAN
48N
46N
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W
111.6 112.8 114 115.2 116.4 117.6 118.8 120.2 121.4 122.6 123.8
GrADS: COLA/IGES


RSM 200hpa geopotential height JAN
48N
46N
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W
111.6 112.8 114 115.2 116.4 117.6 118.8 120.2 121.4 122.6 123.8
GrADS: COLA/IGES

Z200


CFS 200hpa geopotential height APR
48N
46N
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W
111.6 112.8 114 115.2 116.4 117.6 118.8 120.2 121.4 122.6 123.8
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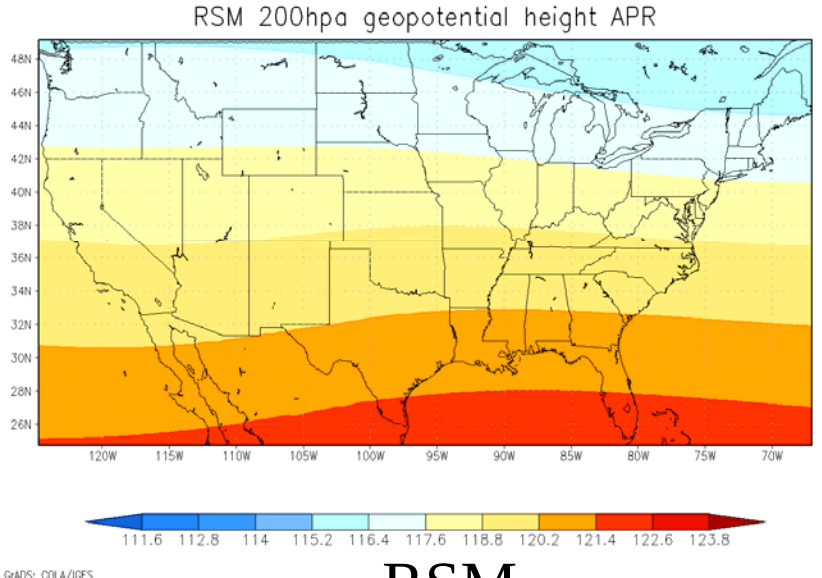
RSM 200hpa geopotential height APR
48N
46N
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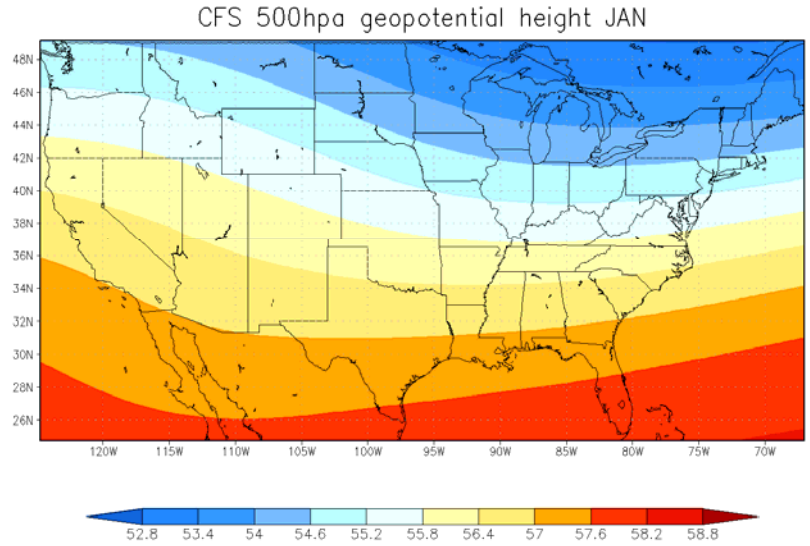
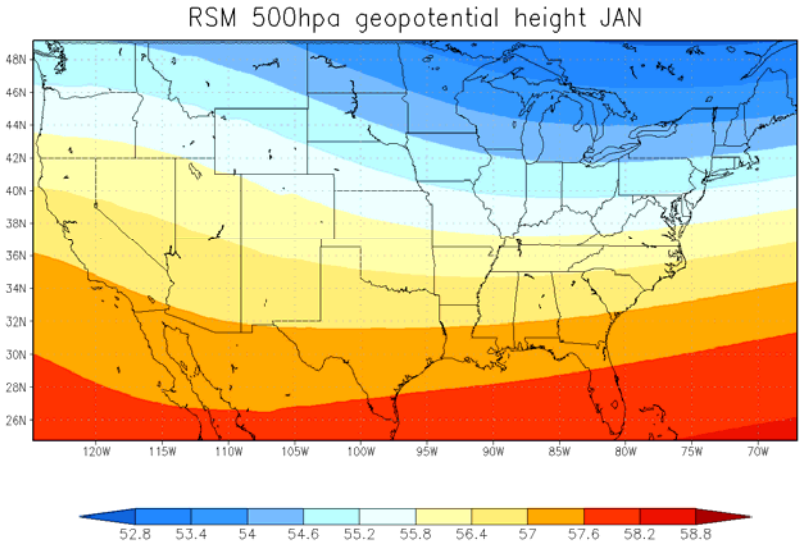
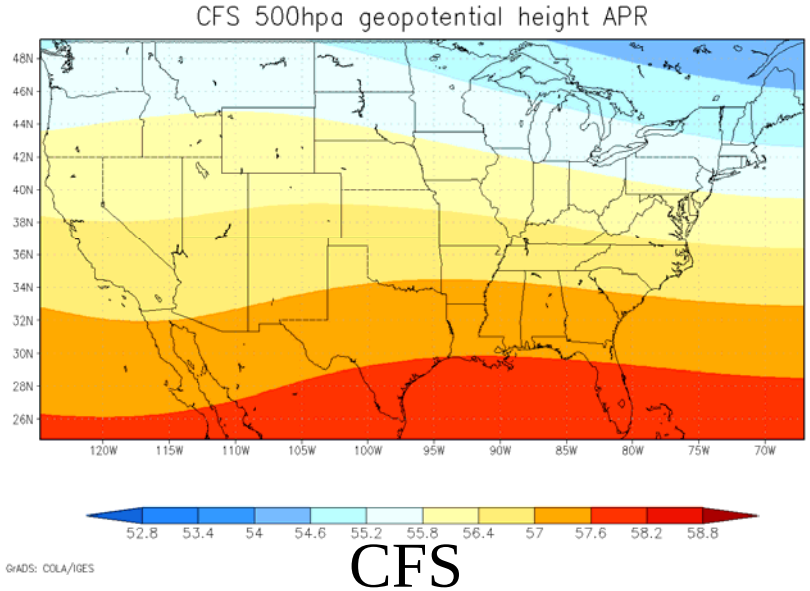
28N
26N
120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W
111.6 112.8 114 115.2 116.4 117.6 118.8 120.2 121.4 122.6 123.8
GrADS: COLA/IGES

Mean

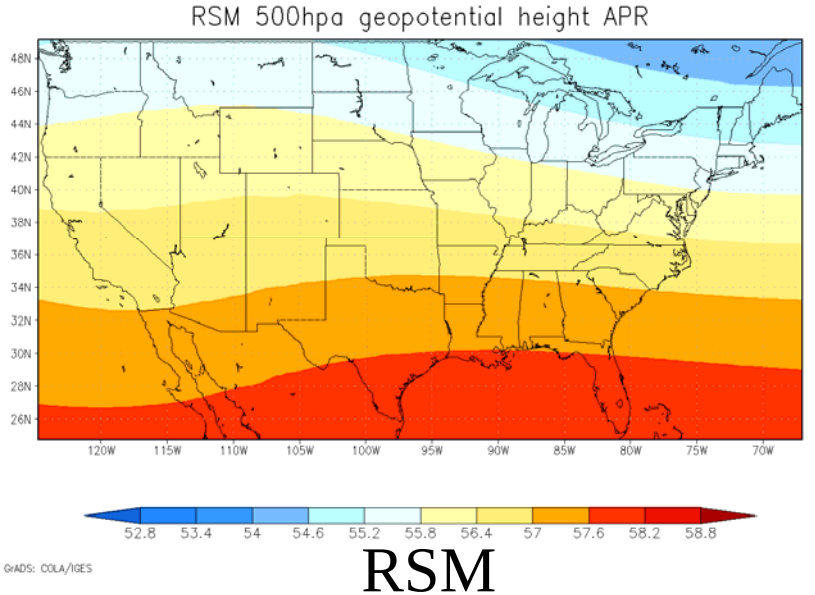




Z500

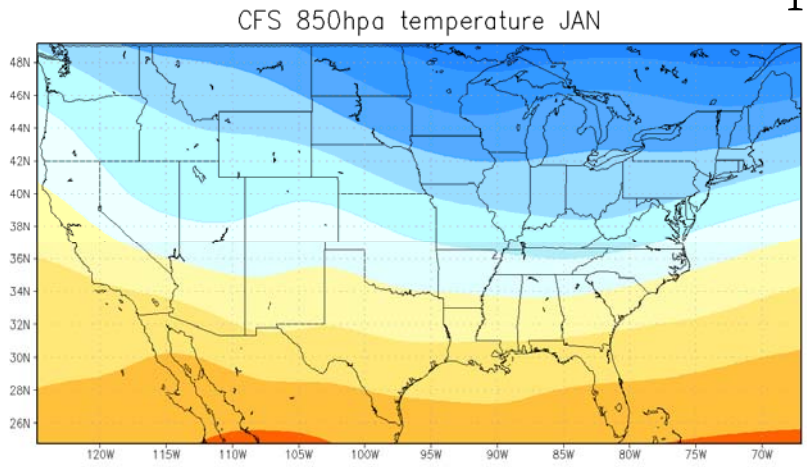


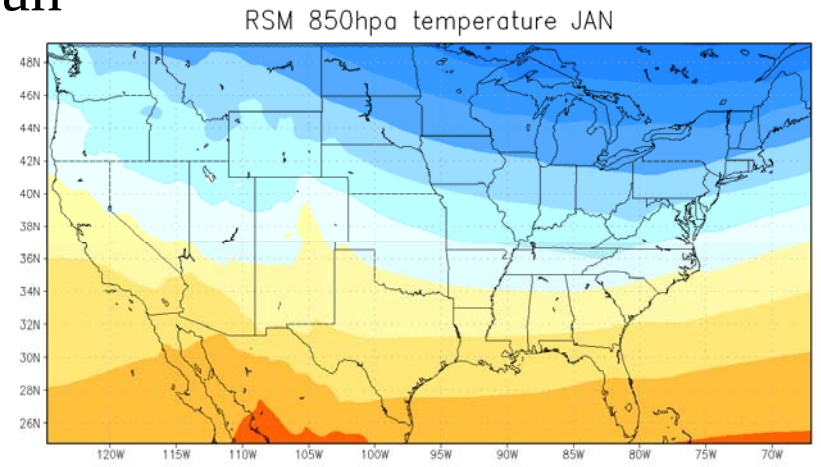
CFS



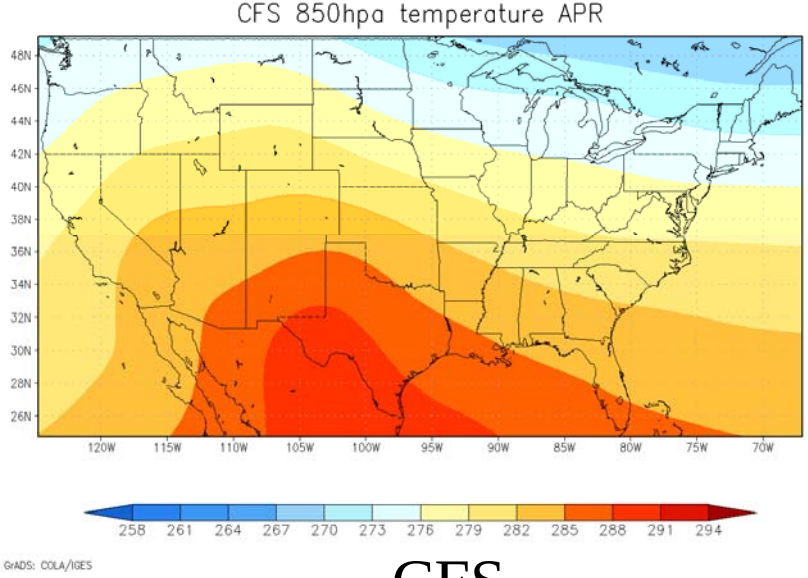
RSM

Mean

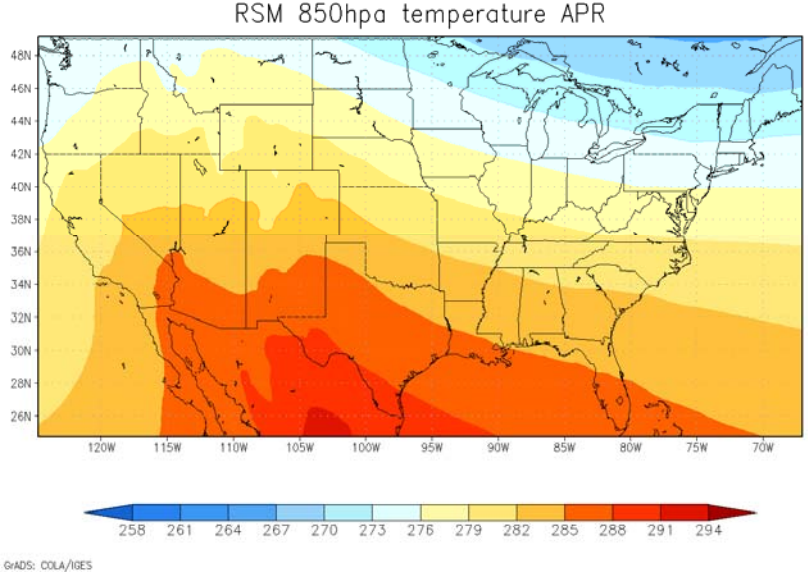




T850

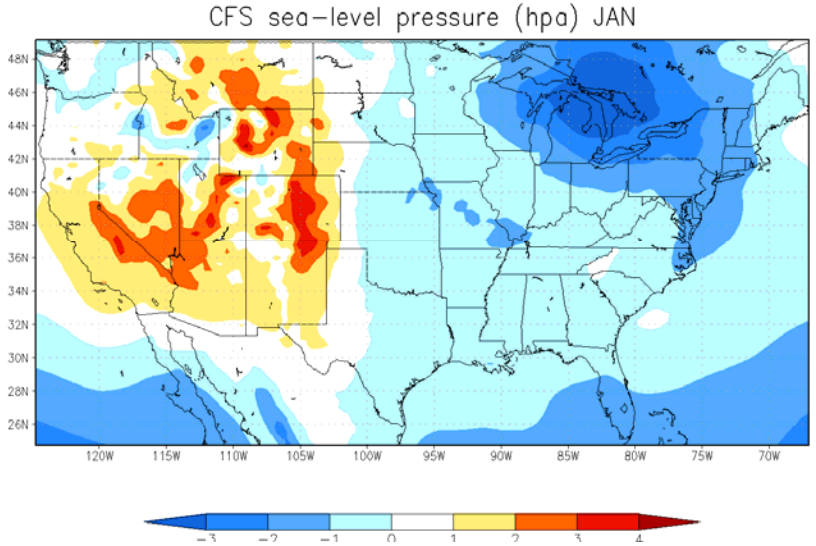


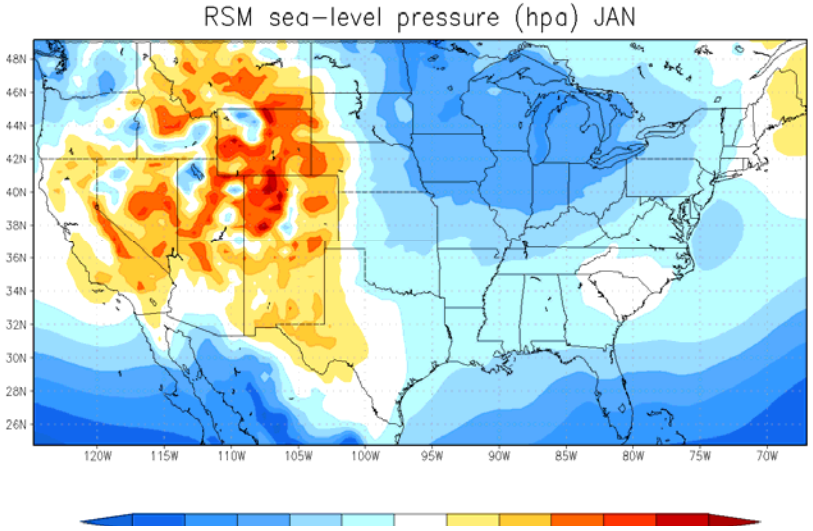
CFS



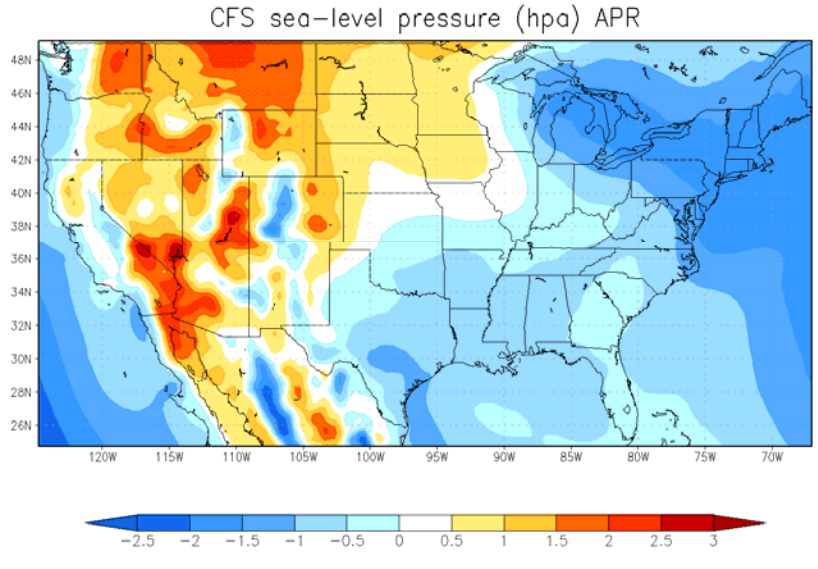
RSM

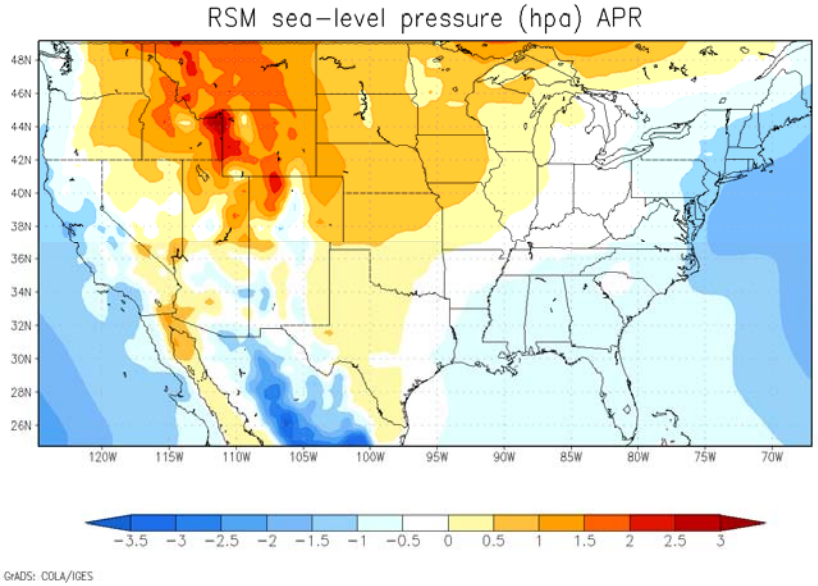
Anomaly wrt NARR





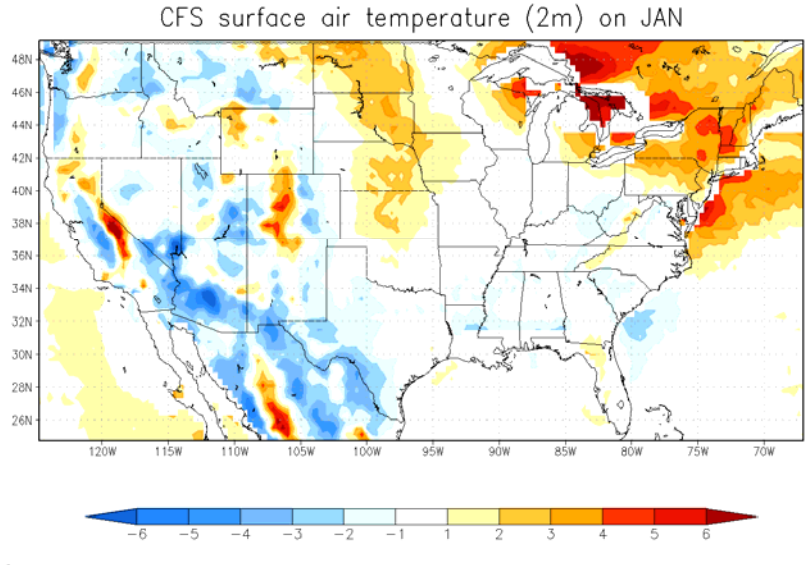
MSLP

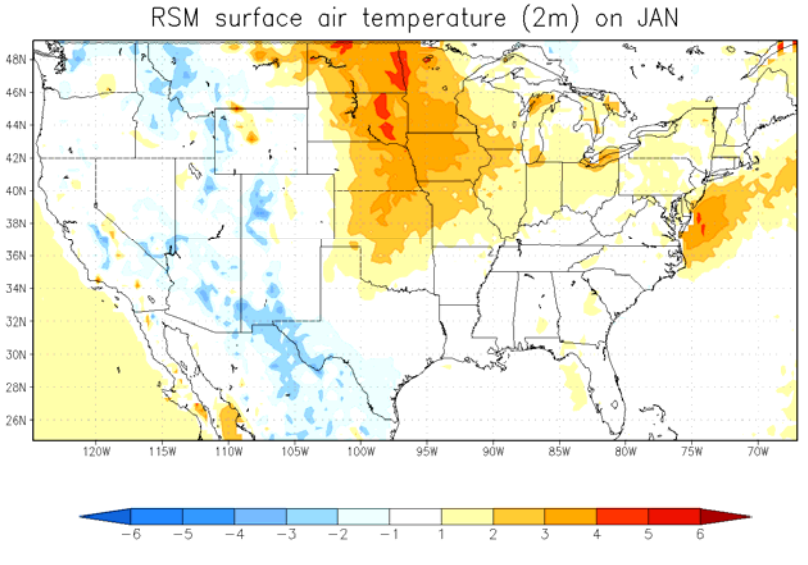




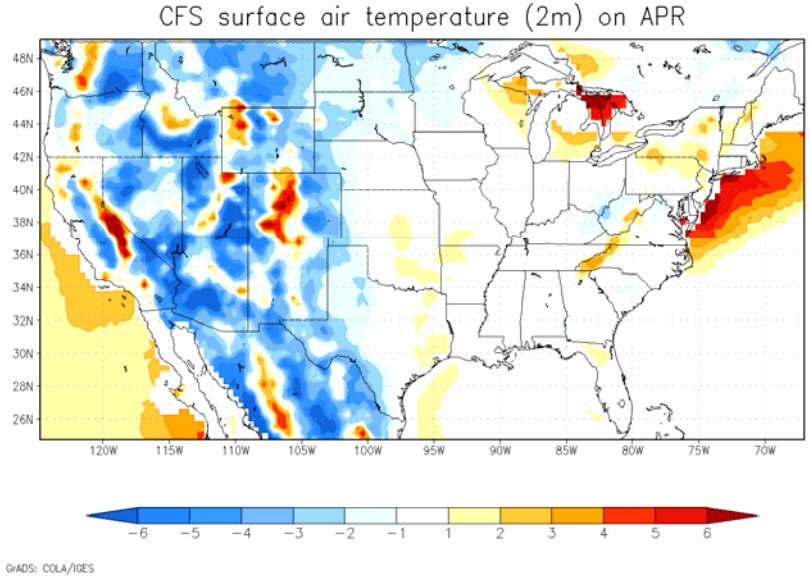
CFS RSM

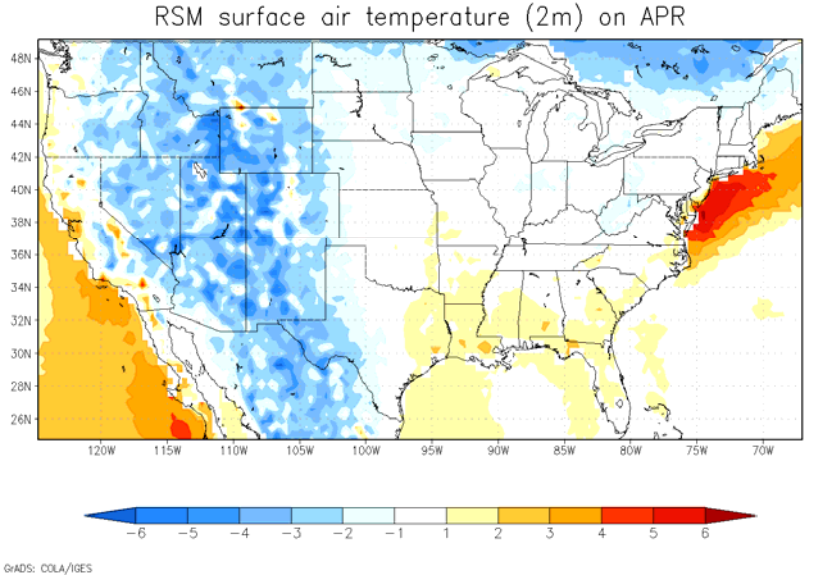
Anomaly wrt NARR



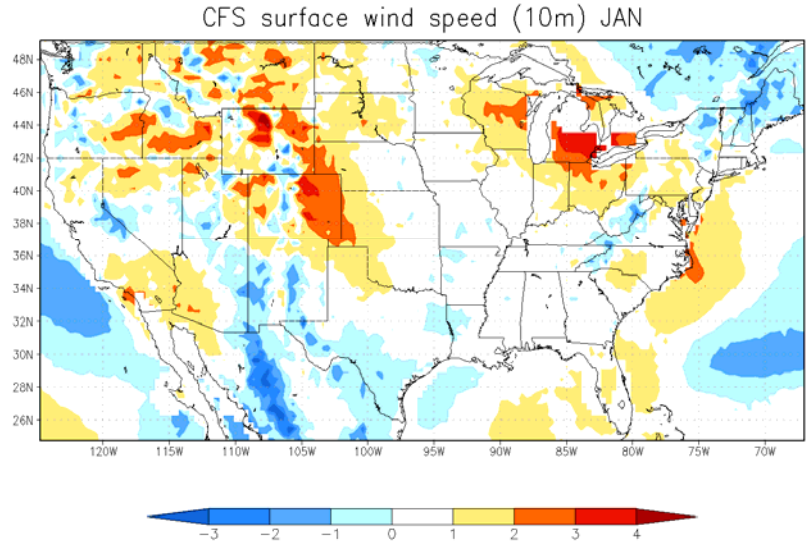


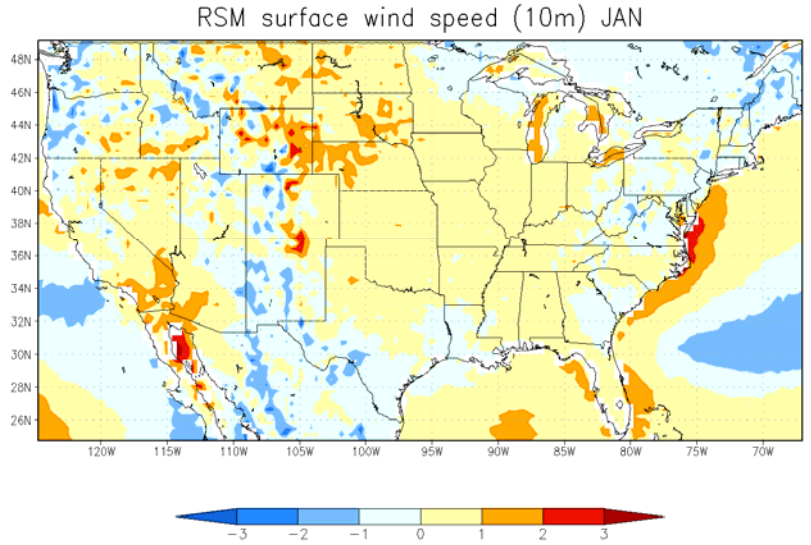
T2m



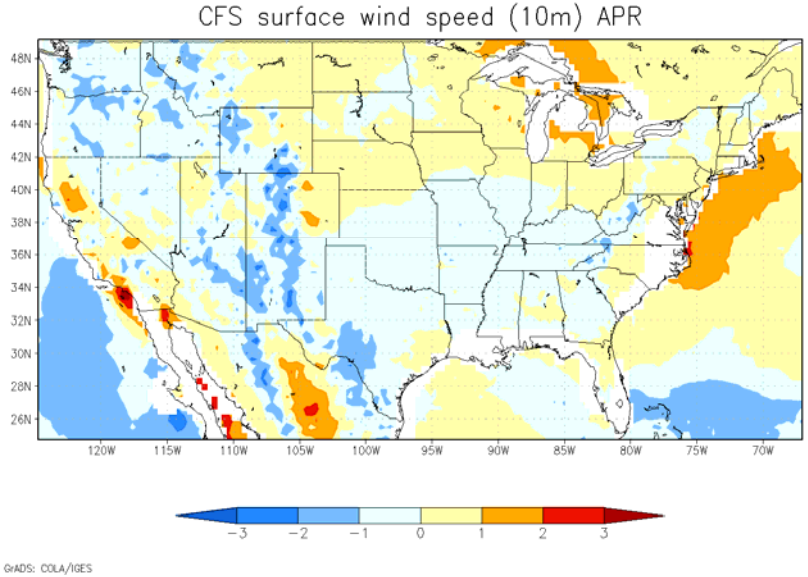


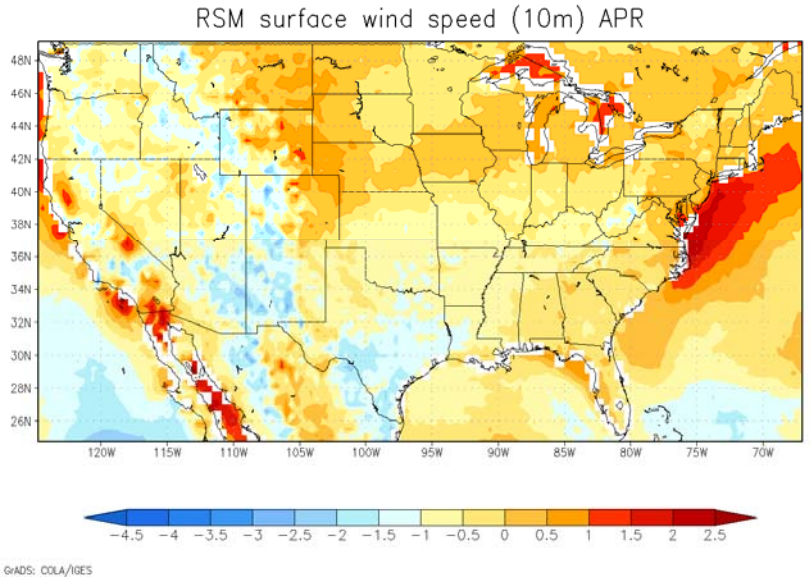
Anomaly wrt NARR



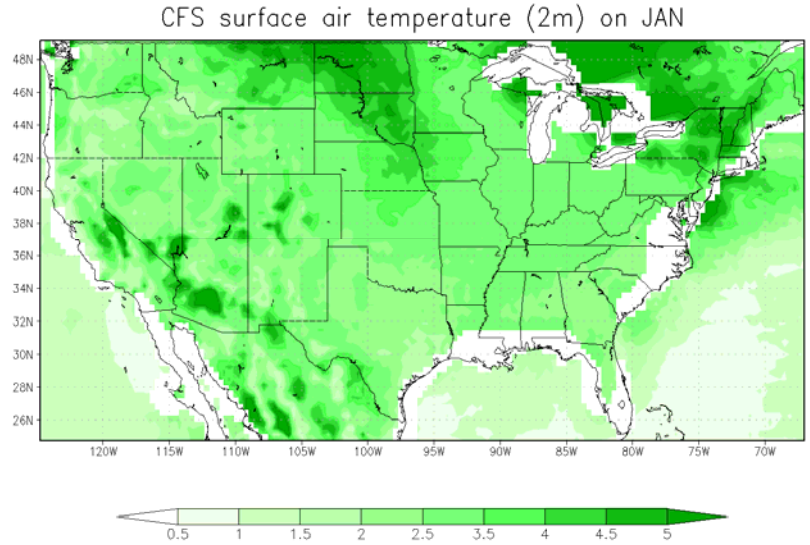


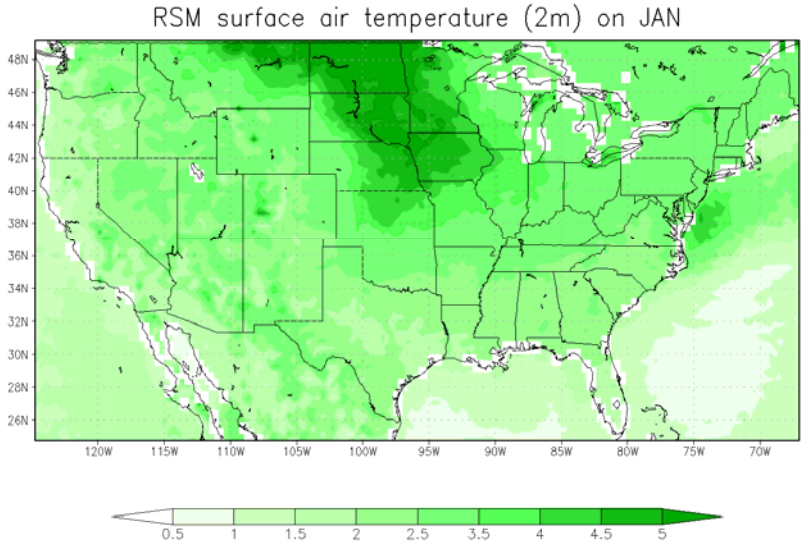
10m wind



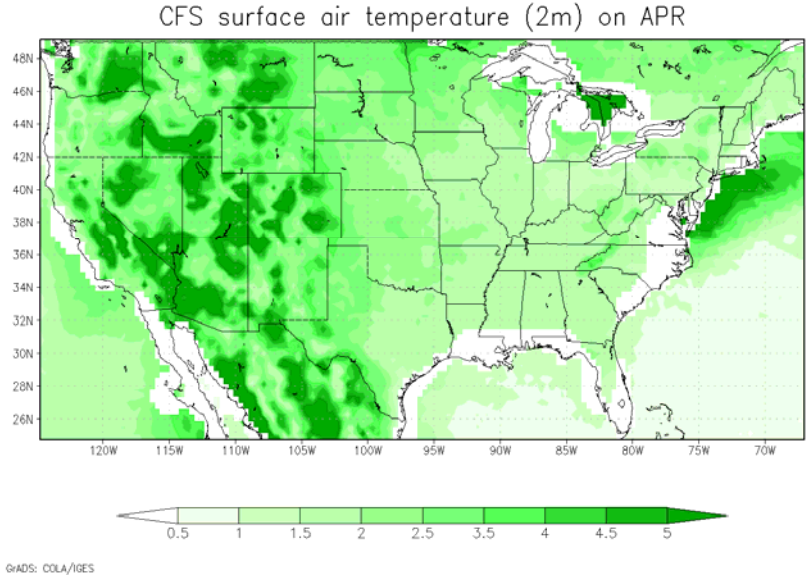


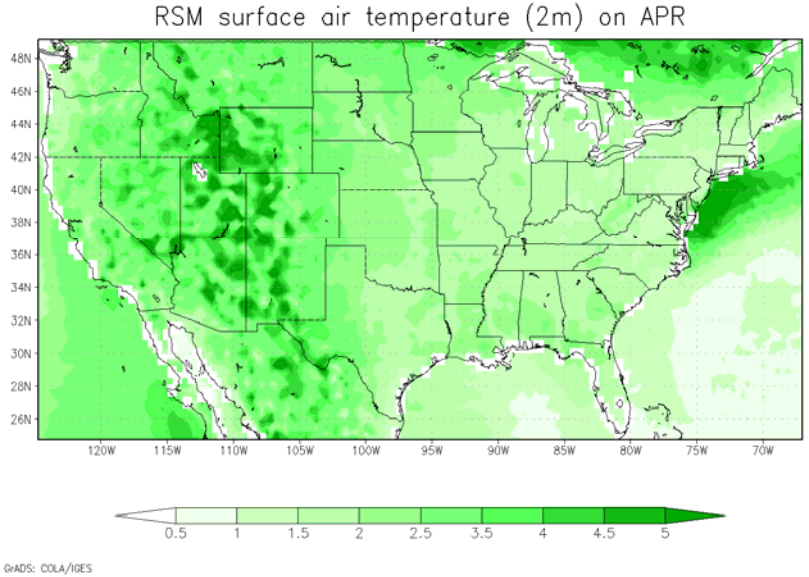
RMSE wrt NARR



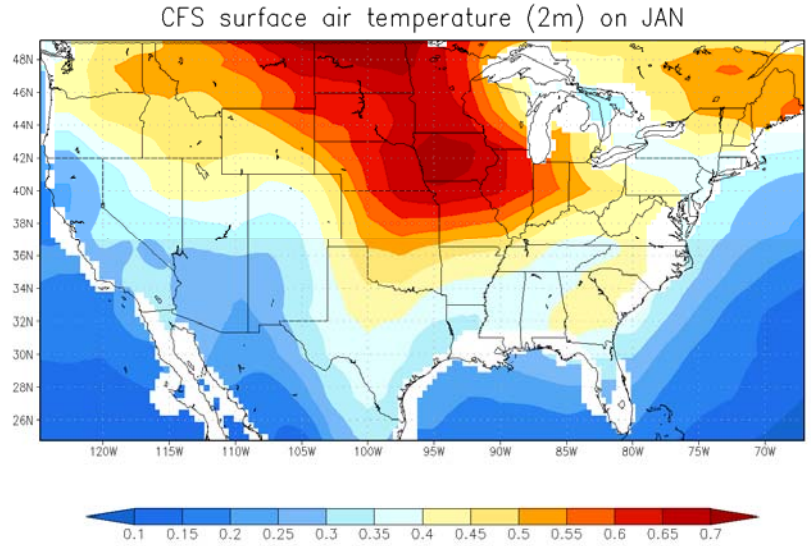


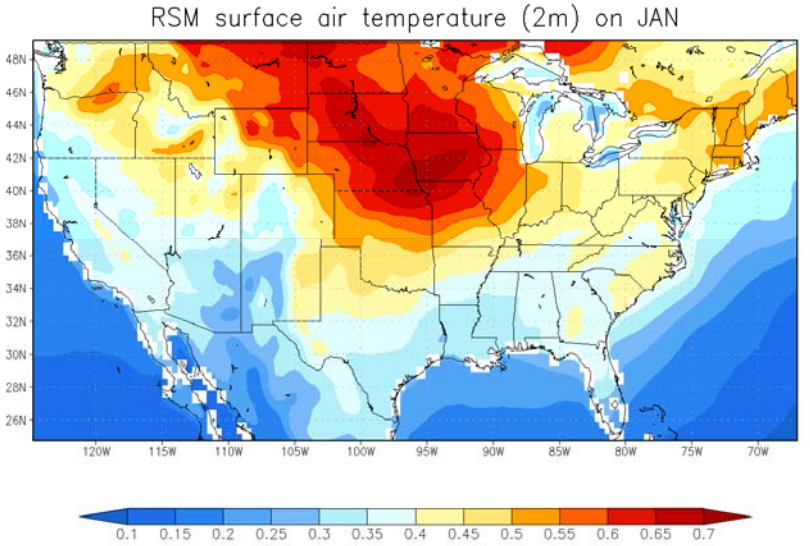
T2m





Spread within members





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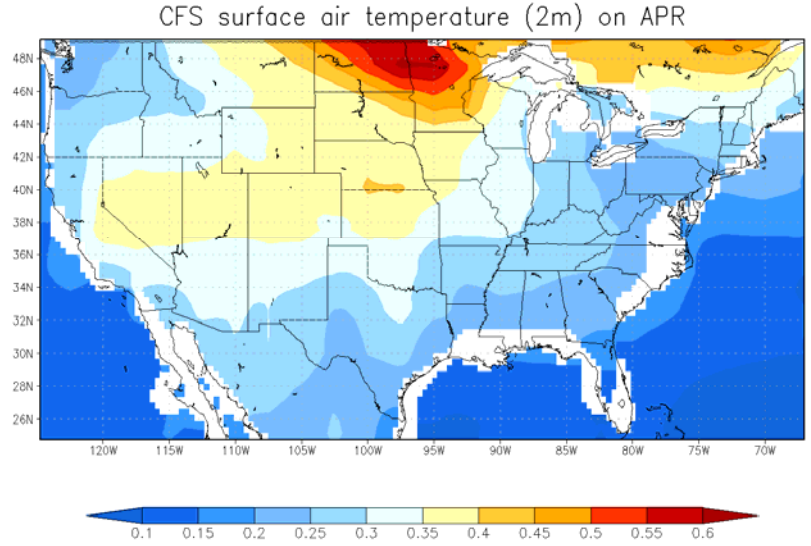
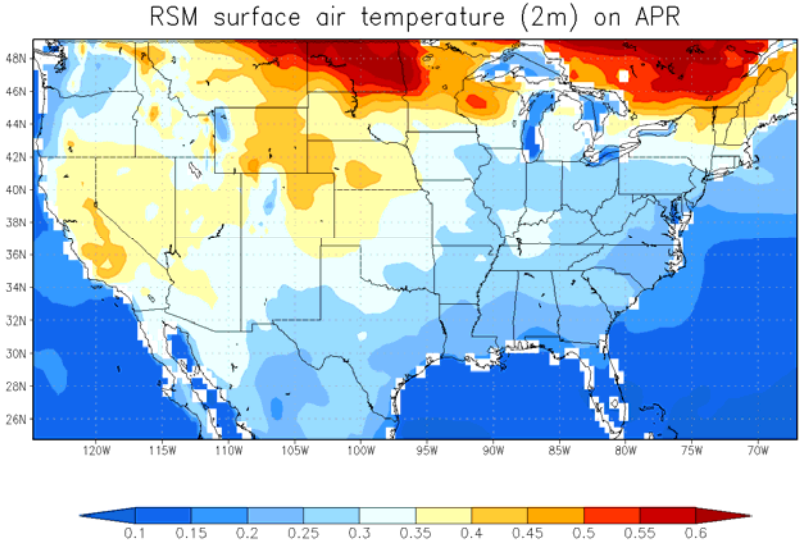
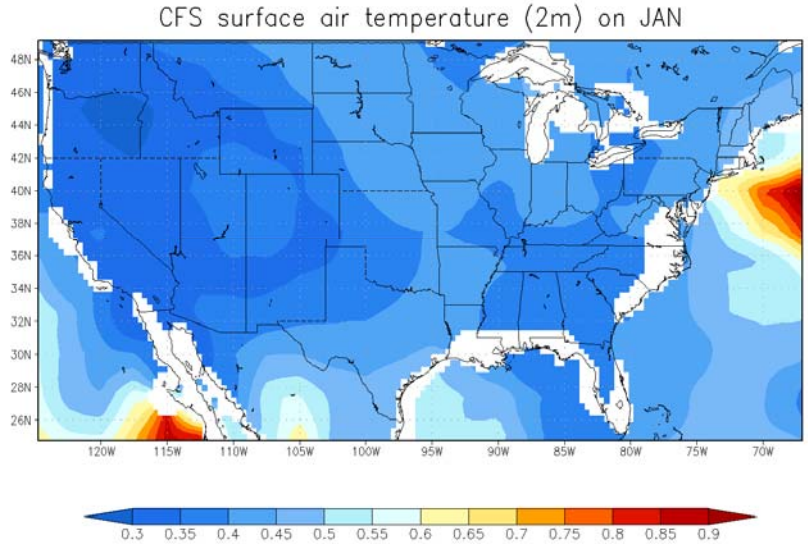
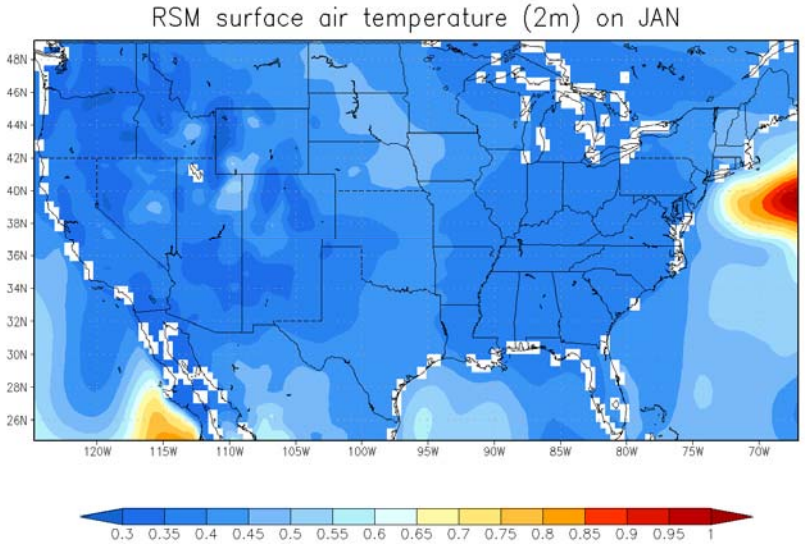




Signal to noise ratio





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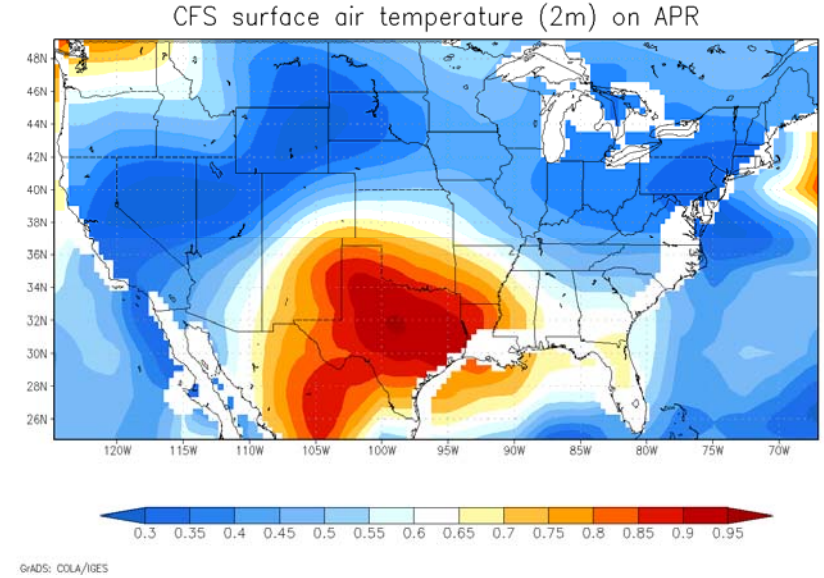

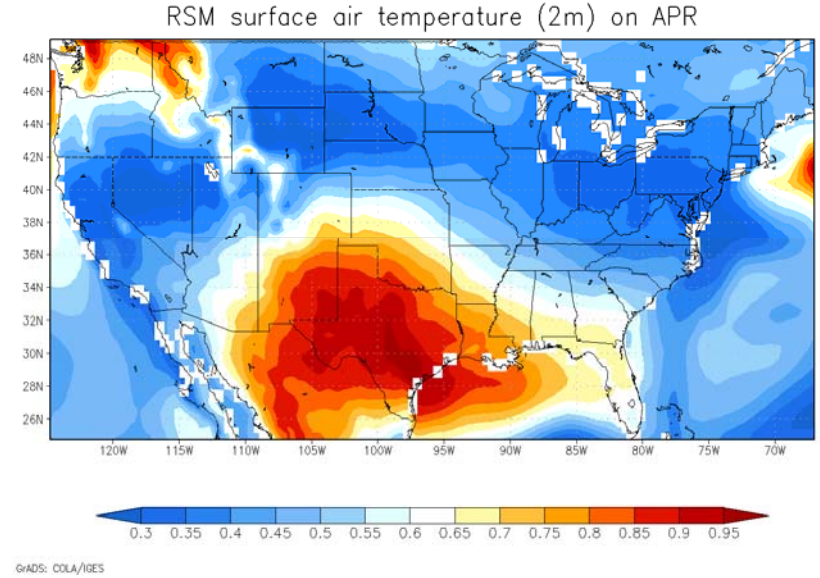

Summary

- RSM has capability to keep large scale feature for long term integration and resolve small scale ==> downscale
- Correct and high resolution of surface condition plays the important role in regional downscale.
- Surface results from RSM show better scores as compared to CFS, but not significant.
- Some color scales are not the same between CFS and RSM, which limits our figures and some further conclusions
- We will collaborate with MRED group for further verification and plan to show more in AMS annual meeting.

Future Concerns

- Improving performance
  - Implement multi-conserving scheme
  - Implement semi-Lagrangian finite volume advection
- Multi RCM ensemble downscaling
  - Supporting MRED CPPA project
  - Eulerian vs semi-Lagrangian
  - Different model physics
- Even high resolution?
  - Higher resolution surface data, higher resolution RSM or MSM?
- Coupling studies?
  - Couple with ocean