Using Hydrostatic & Non-Hydrostatic Dynamics for Regional Downscaling as Multi-Model Ensembles

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NCEP/EMC,CPC 1985-2001

Scripps 2001-2011

Introduction

- Regional climate/seasonal forecasts using RSM has been presented in past CDPWs due to the NOAA projects in CPC and EMC with outside collaborations, such as Scripps.
- Several major collaborations have been conducted, such as NAME and recent project with MRED for winter case.
- Present NCEP RSM and MSM results through the MRED project.

MRED-winter

- MRED- joined by NCEP/EMC, Scripps, Iowa State University, ERSL/GSD, PNNL, UCLA, etc
- Study winter cases (1983 - 2009)
- 15-member ensemble, 5 month more integrations from Nov.
- NCEP RSM/MSM, ECPC RSM, ISU MM5, GSD WRF-ARW, UCLA MM5 etc, 25km resolution.
- Using CFS v1 T62L64 as initial and boundary conditions.
- Verification by NARR (North America Regional Reanalysis, about 25km)
- For NCEP, we provide rerun of CFS to save every 6 hour data, a data server for other institutes, and contribute RCMs.
- Web page http://cppa.ncep.noaa.gov with links to CFS data for regional model, MRED data, and MRED home page.

RSM and MSM

- NCEP RSM has two dynamic options:
  - hydrostatic dynamics : used to call it RSM
  - Non hydrostatic dynamics: we call it MSM
- One model with two dynamics.
- Same model physics
- Same numerical computation method
- The only difference
  - MSM has prognostic vertical velocity
  - RSM has diagnostic vertical velocity
- Question is “can we use single model with multi dynamics as MME?”

RSM/MSM spectral computation

$$\frac{\partial A_R}{\partial t} = f(A_R) = f(A_G + A')$$

$$\frac{\partial A'}{\partial t} = \left(\frac{\partial A_R}{\partial t} - \frac{\partial A_G}{\partial t} \right)$$

Spectral transformation is applied to $\frac{\partial A'}{\partial t}$

then update regional perturbation in spectral space

$$A'(n+1) = A'(n-1) + \frac{\partial A'}{\partial t}(n) 2\Delta t$$

Global or base field is updated by nesting period

$$A_G(n+1) = A_G(n-1) + \frac{A_G(t+6hr) - A_G(t)}{6hr * 3600} 2\Delta t$$

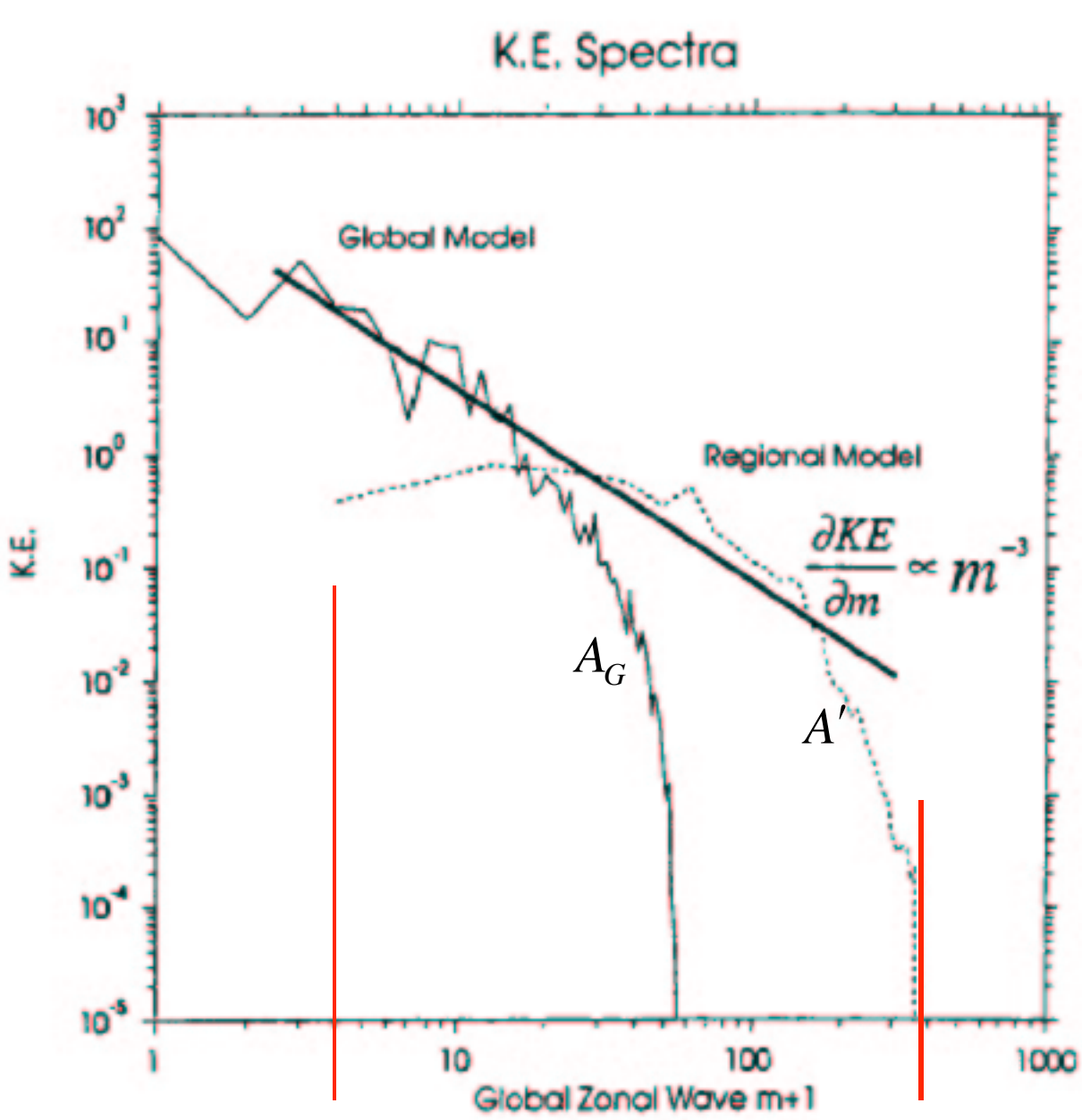


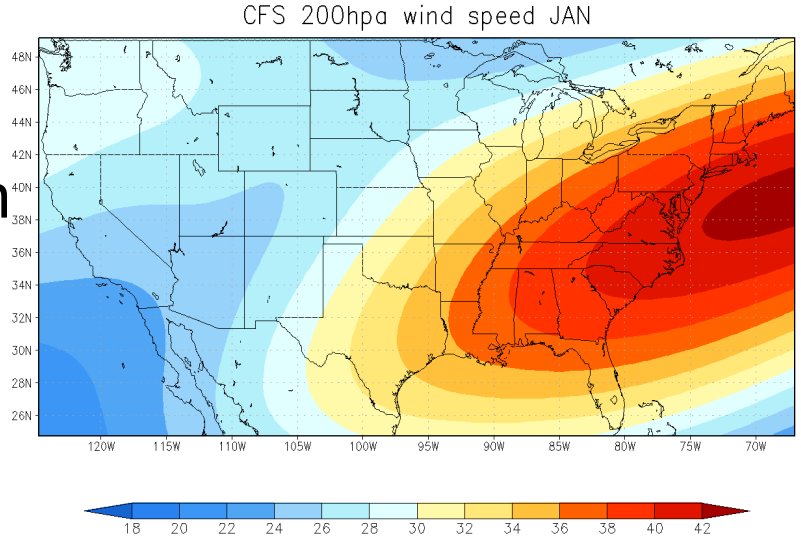
FIG. 2. Regional (dotted line) and global (thin solid line) model kinetic energy spectra. Courtesy of Chen et al. (1999).

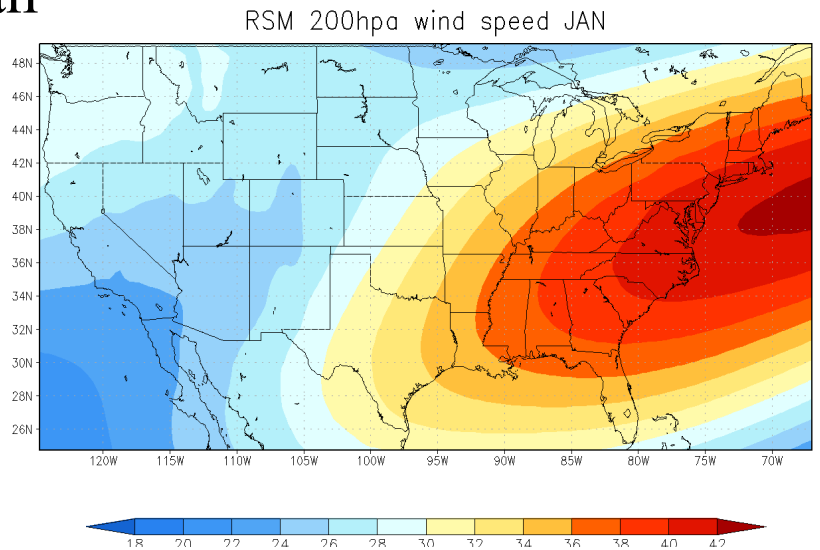
Verification of RSM/MSM

- The first order verification presents here
  - Any large scale ‘drift’ for nesting ?
  - Any mesoscale feature generated ?
- Verification Statistics:
  - mean, bias, anomaly correlation, rmse
- We have plots for wind, T, Z for 200, 500, 850 mb, SLP, rain, 2m T, q, 10m wind etc.
- Using NARR as observations

Mean

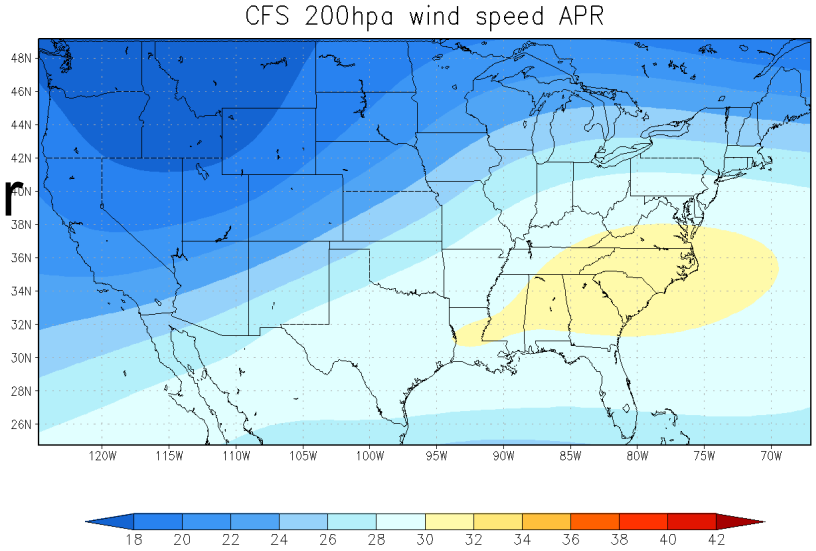
Jan

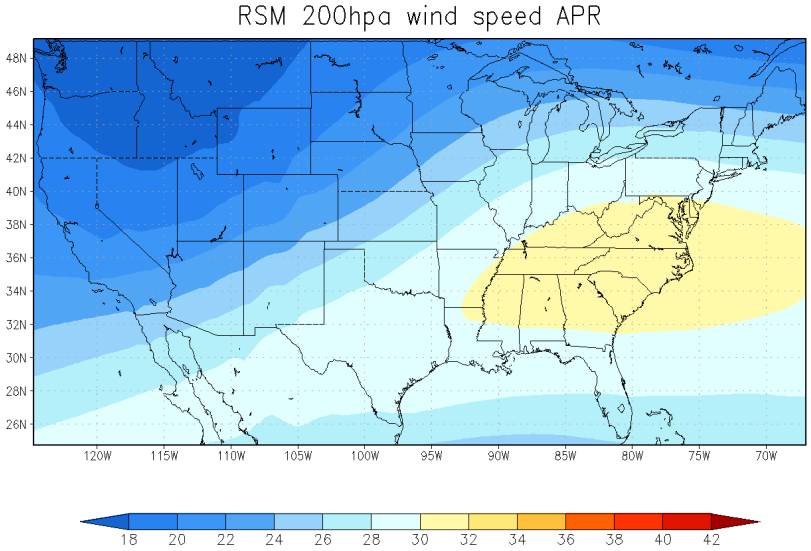




Wind200

Apr





Mean

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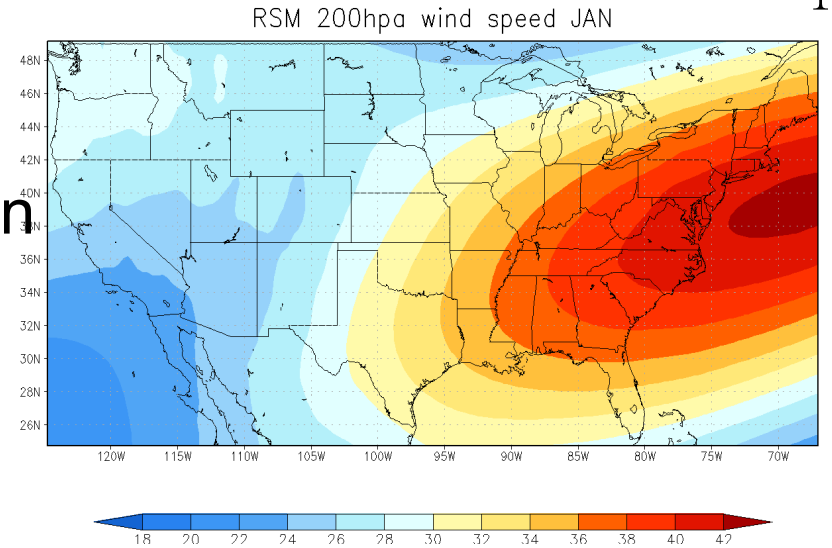

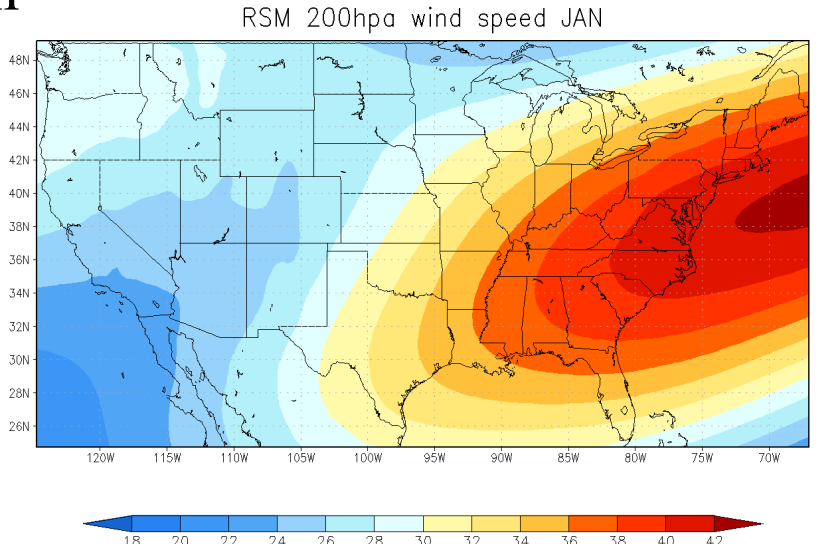

Wind200

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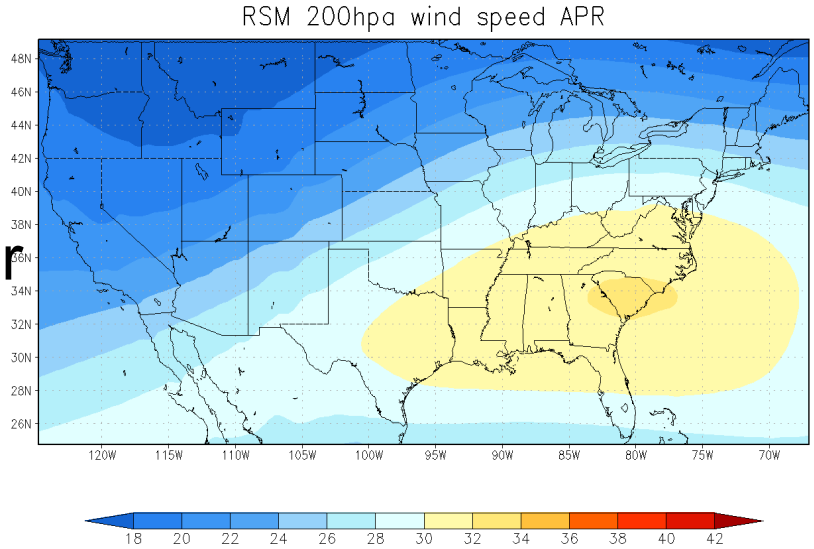

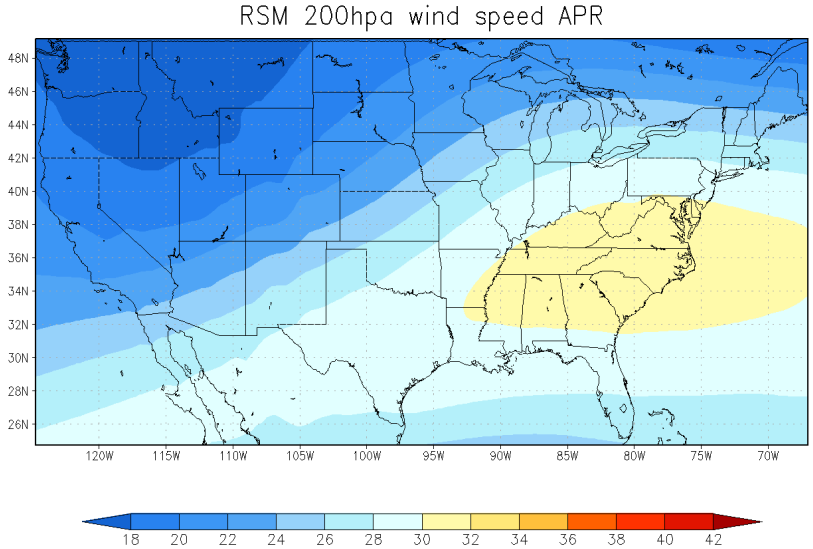

Mean

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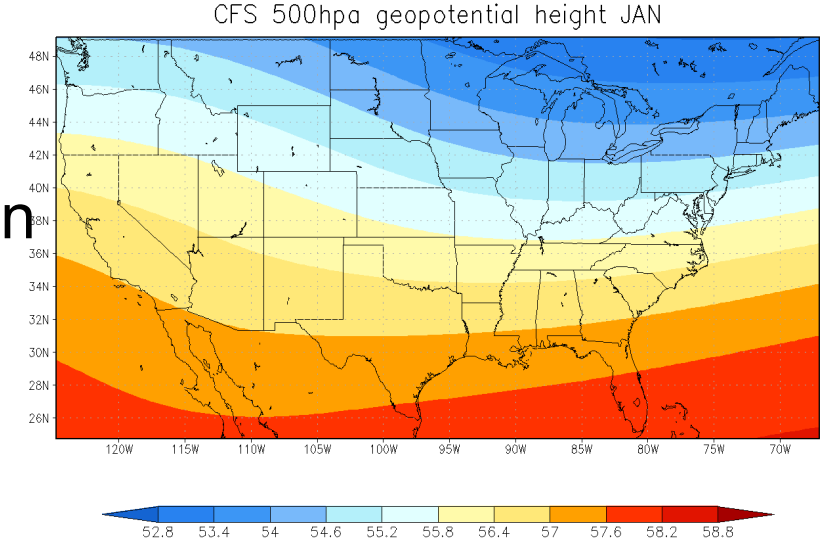
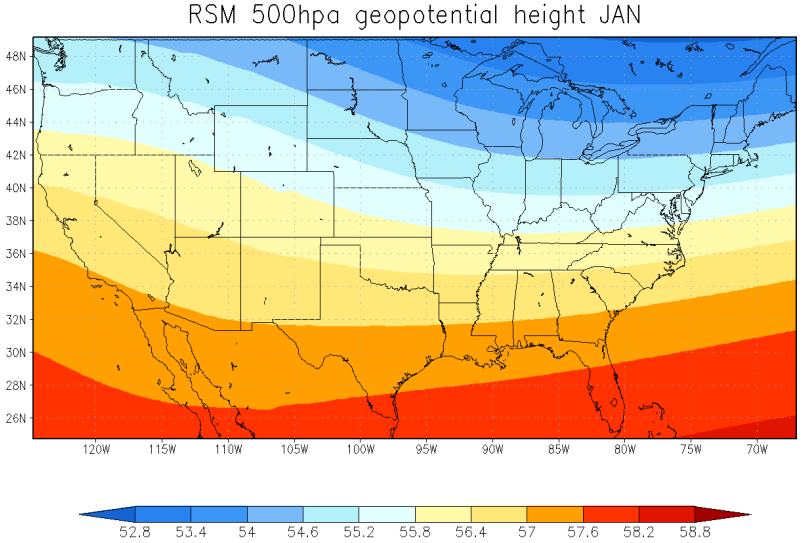
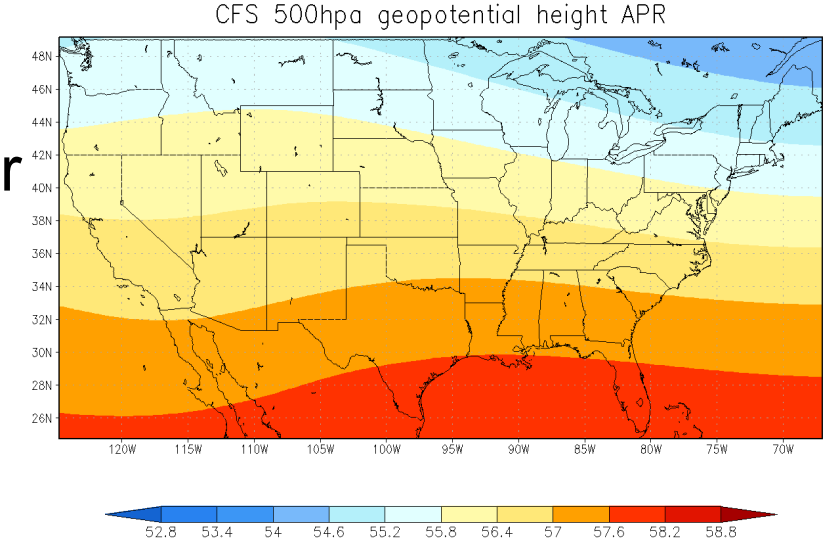


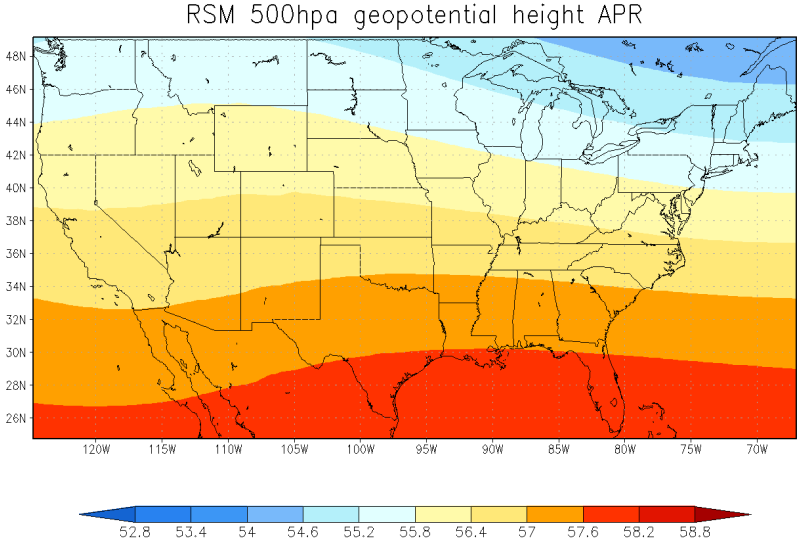


Z500

Apr



CFS



RSM

Mean

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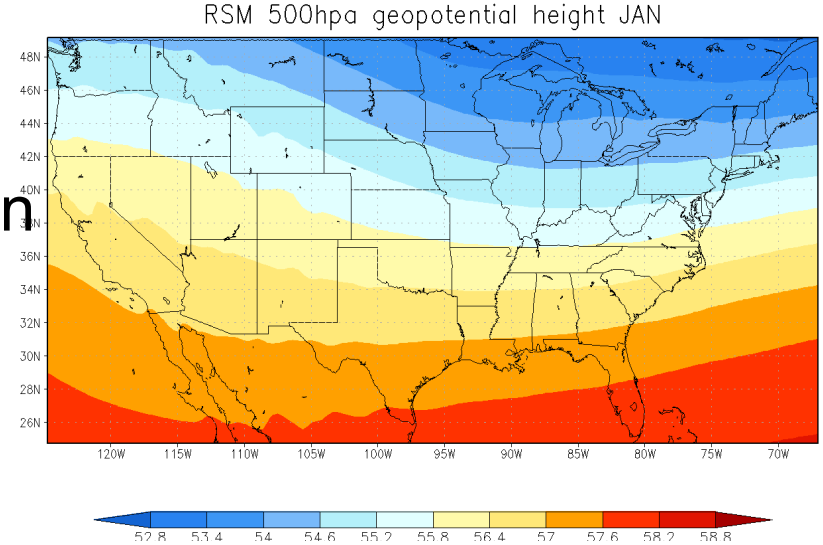

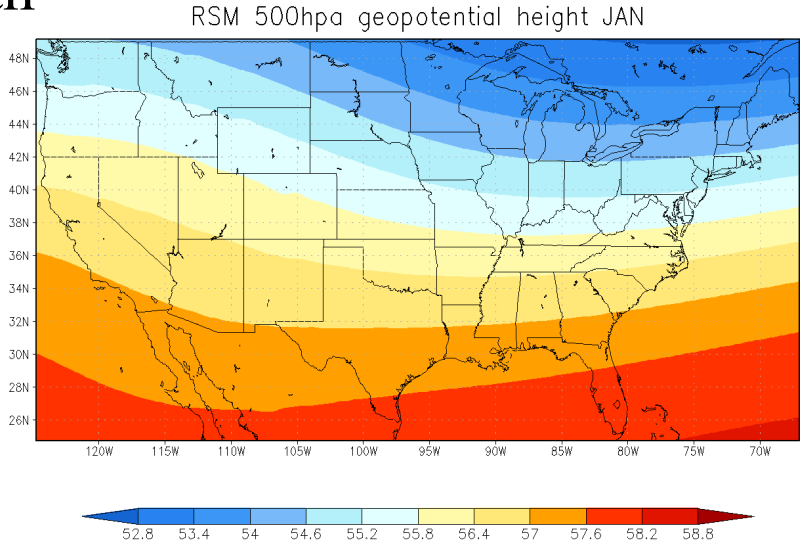

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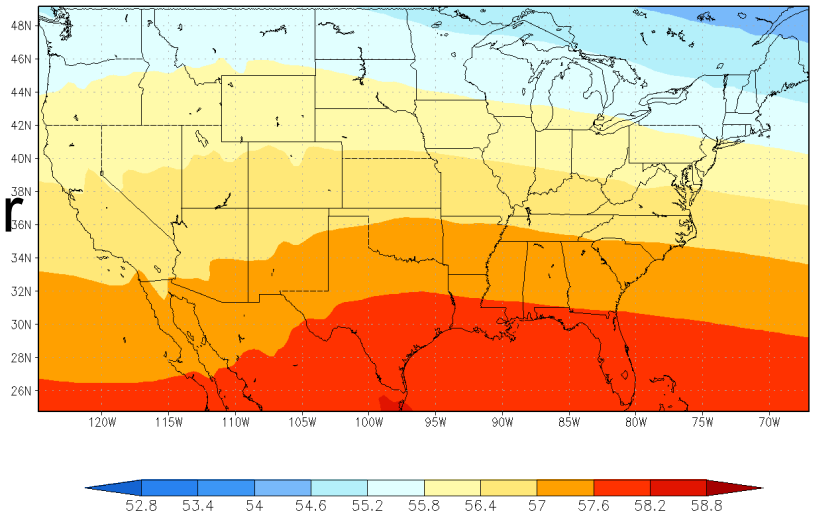
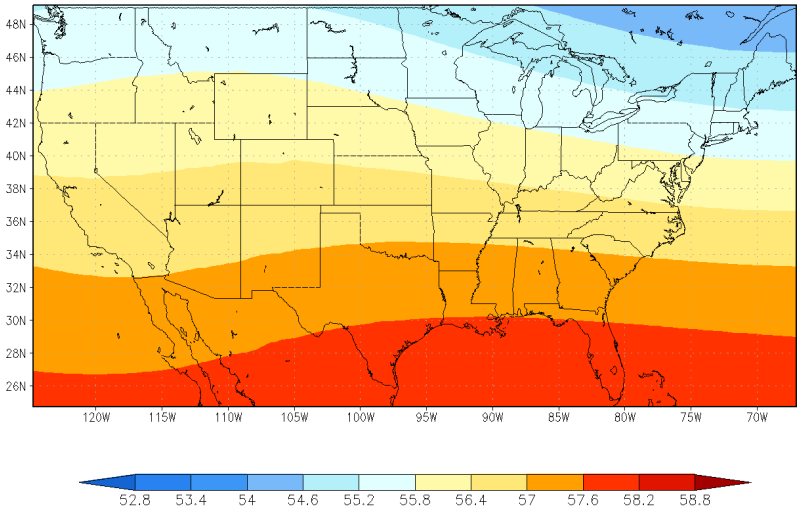
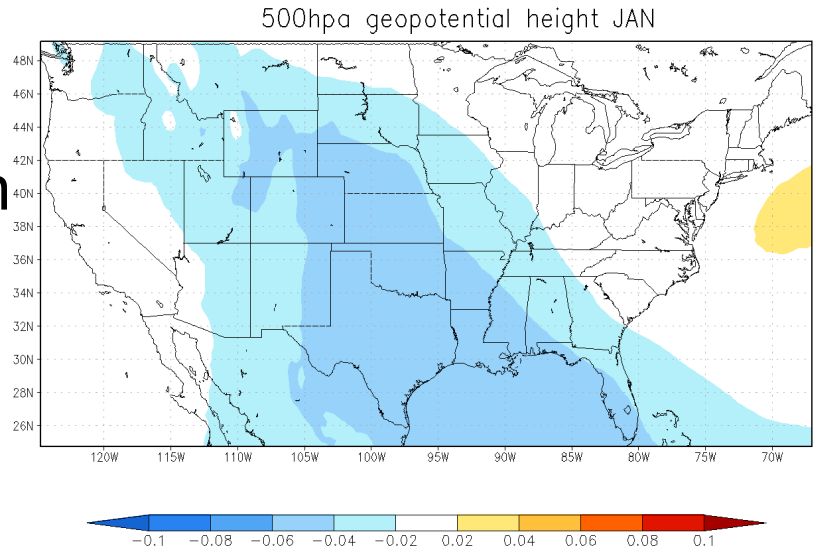
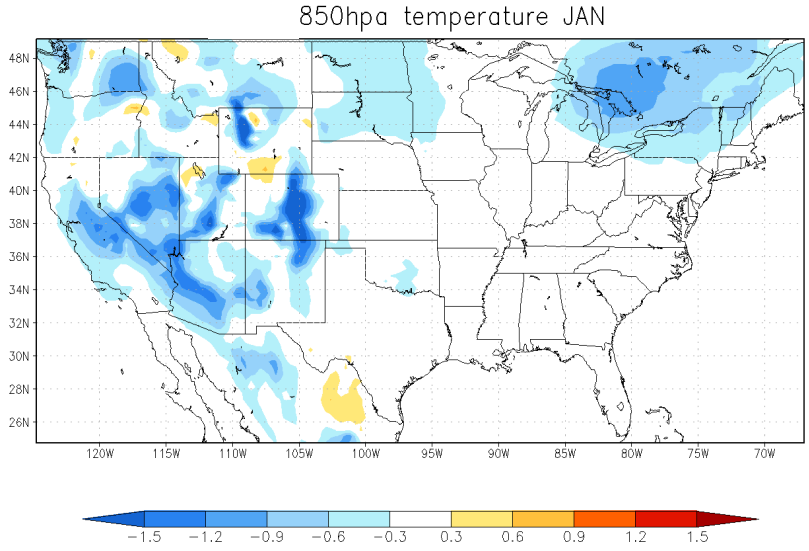




RMSE diff (RSM-CFS)

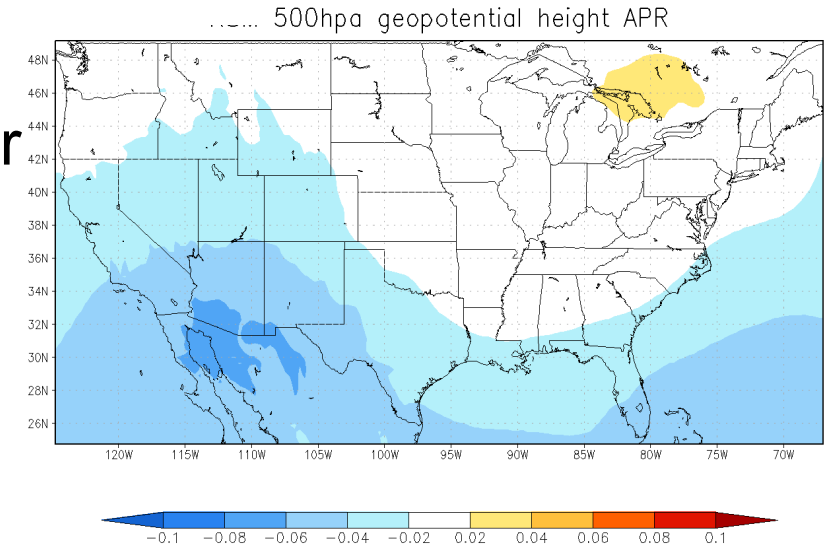
Jan

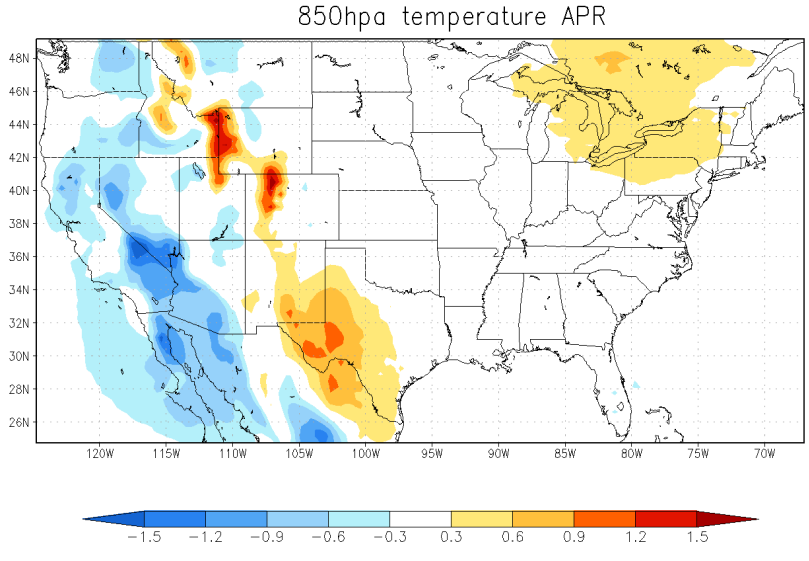




Z500 RSM T850

Apr





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RMSE diff (MSM-CFS)

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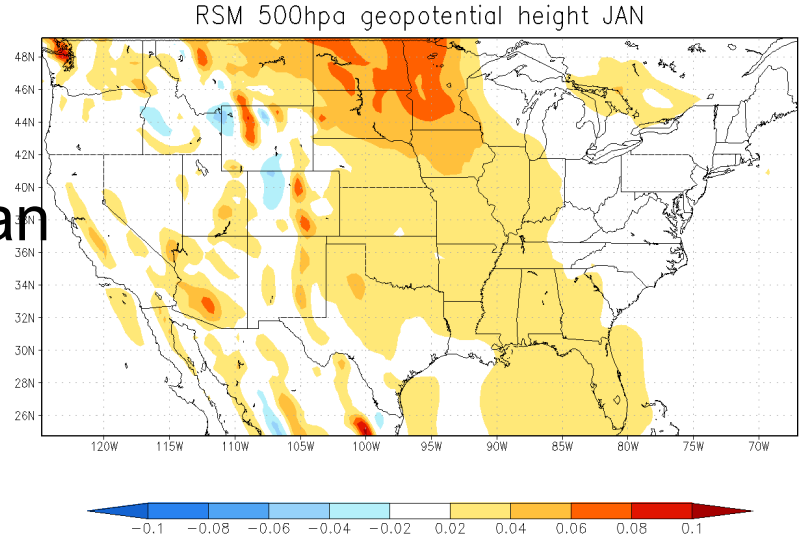
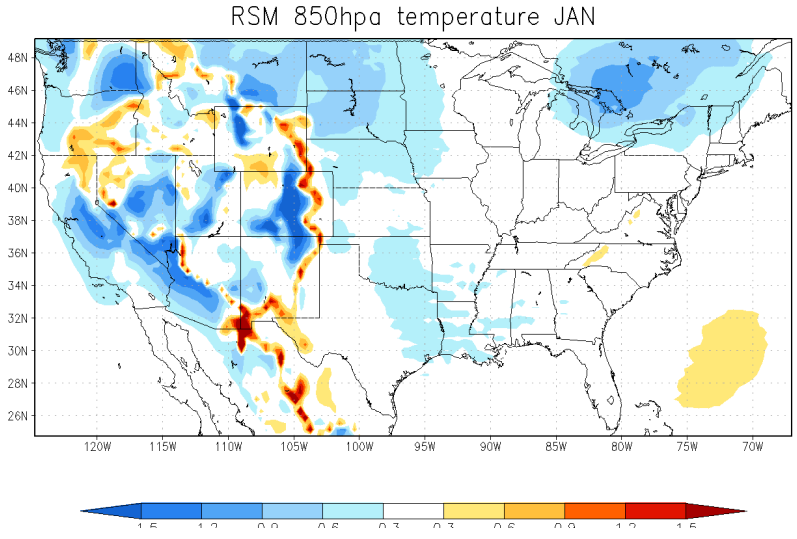


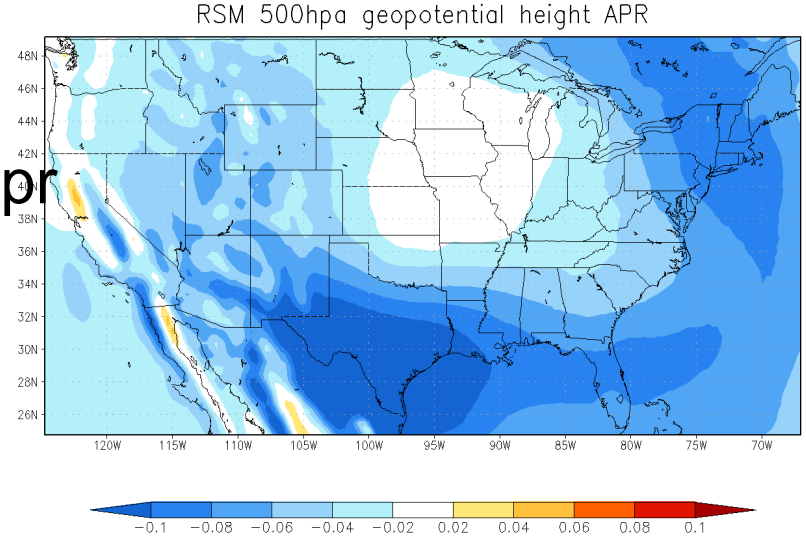


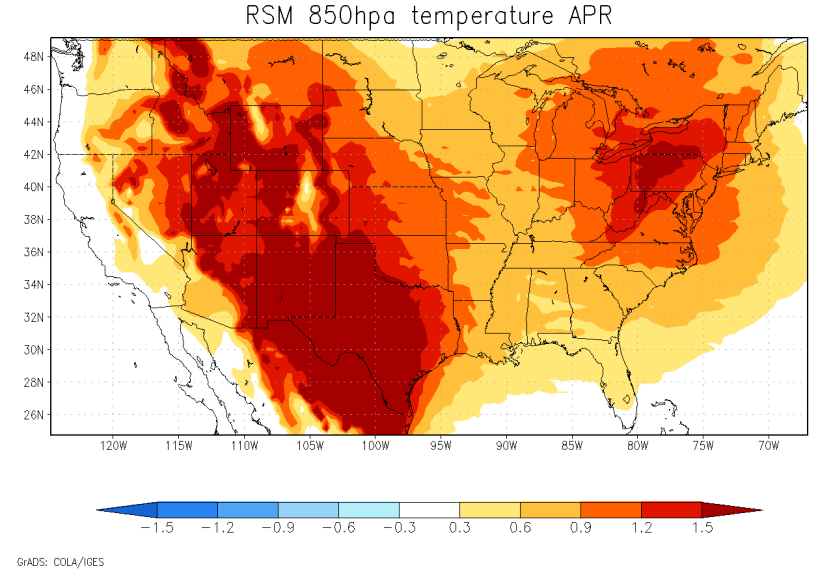
Z500

MSM

T850

Apr





RMSE diff (RSM-CFS)

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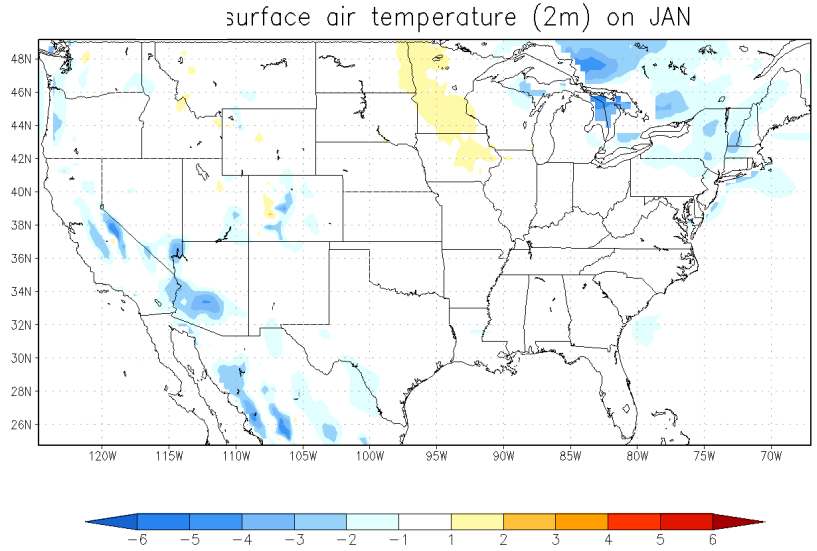

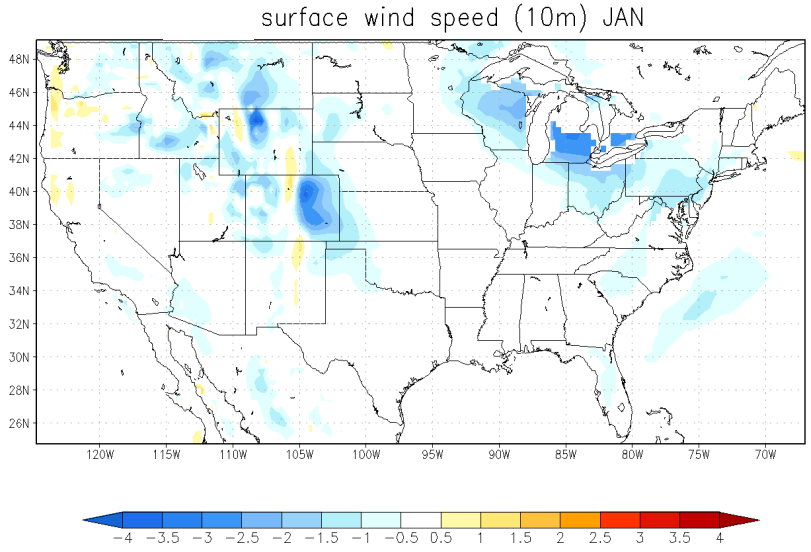

T2m

10m wind

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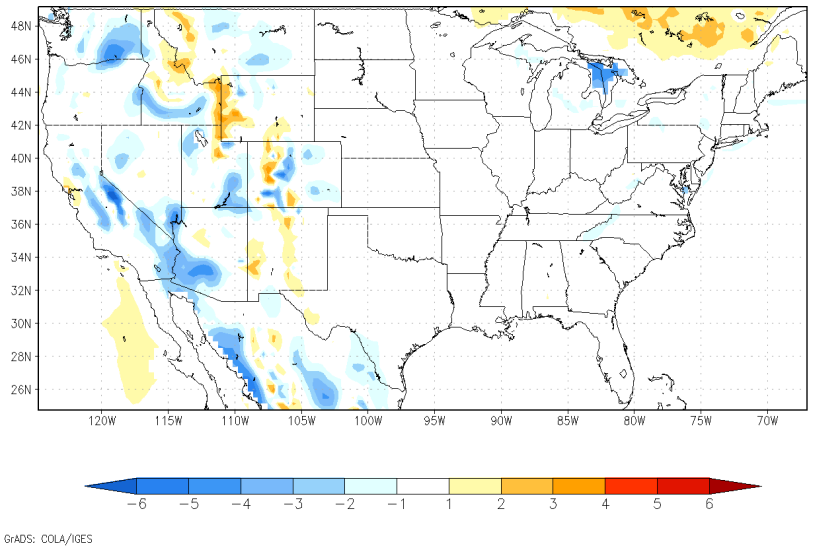

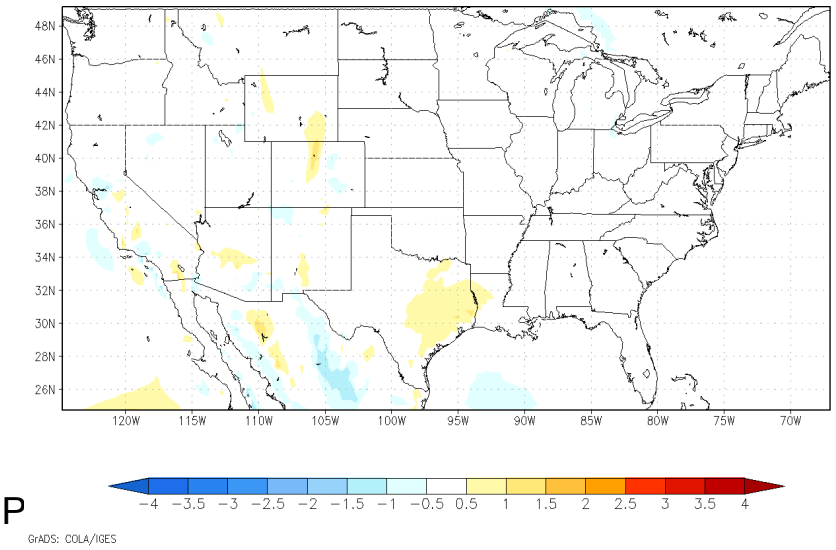

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RMSE diff (MSM-CFS)

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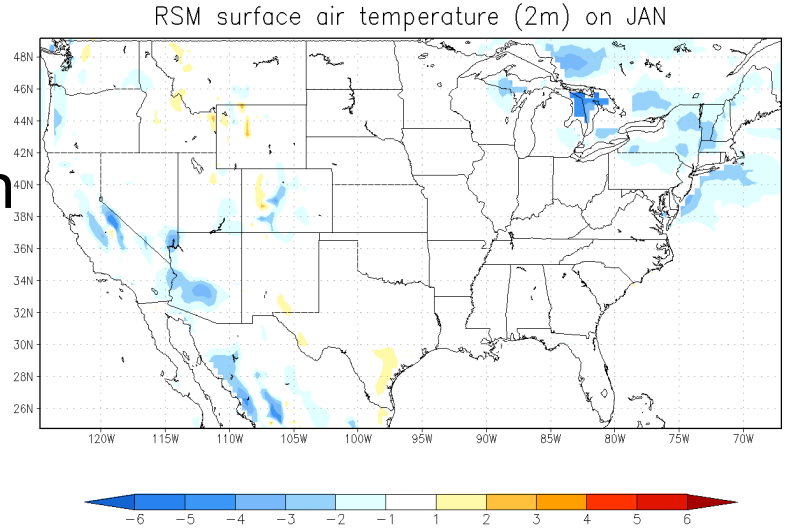
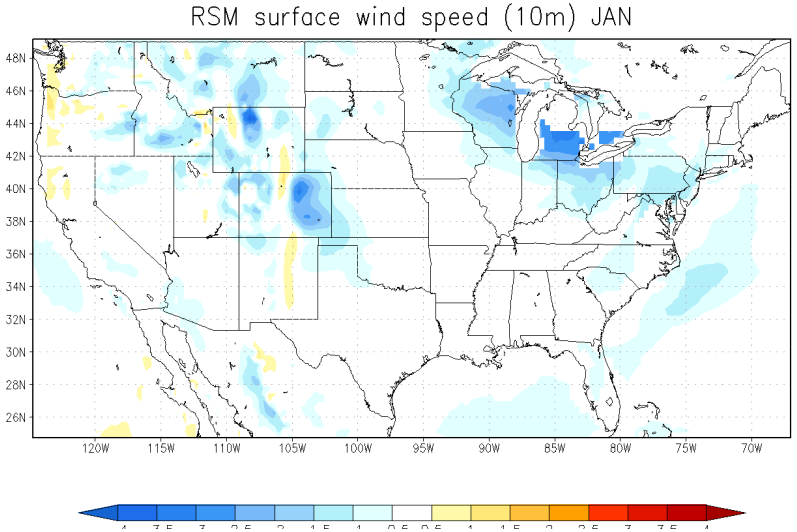
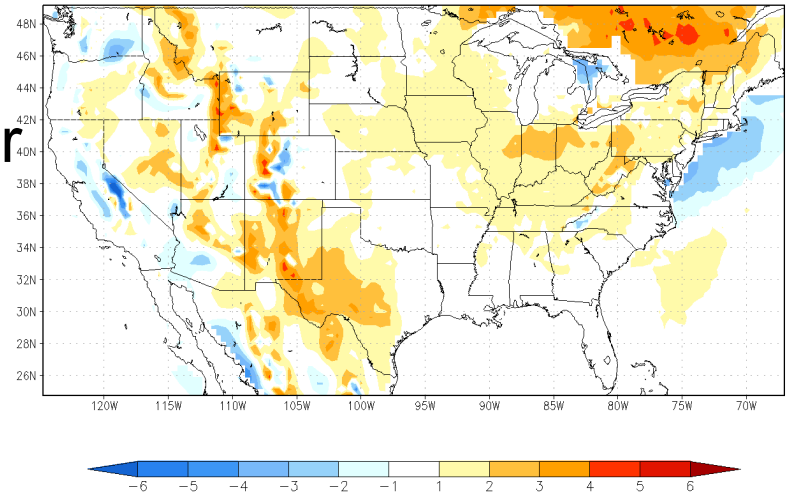
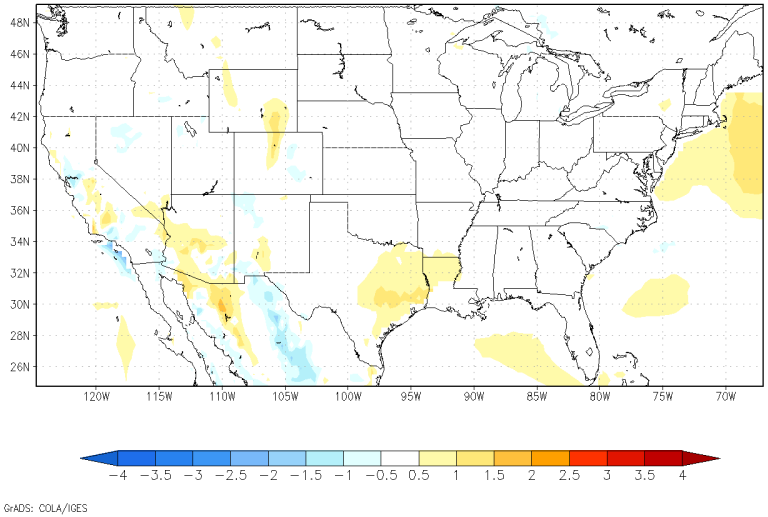




T 2m MSM 10m wind

Apr



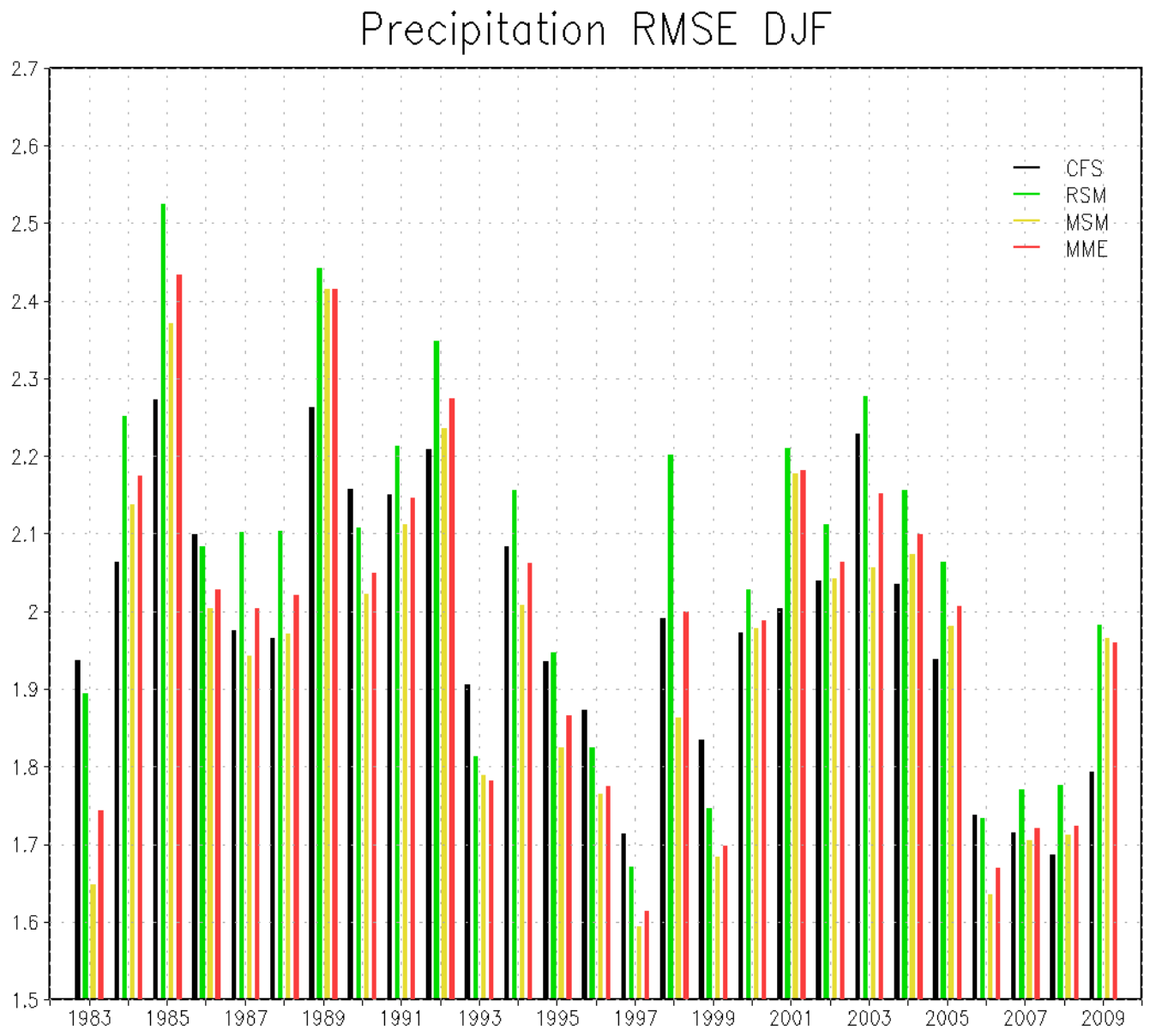


Multi-dynamics Ensemble by RSM/MSM

RSM and MSM together can be a good example to do Multi regional model ensemble due to difference in dynamics, though they have the same physics

Compare RSM 15 members
MSM 15 members
and combine RSM+MSM 15 members.

Since the optimal ensemble size for RSM is about 10 members, 15 members are very well represented. Though the mixed RSM+MSM have not examined the performance of ensemble size, we simply get existed RSM and MSM to construct the multi model ensemble alike by 27-yrs hindcasts.



best
CFS 11
RSM 0
MSM 15
MME 1

Better
RSM 0
MSM 27
MME 27

GrADS: COLA/IGES

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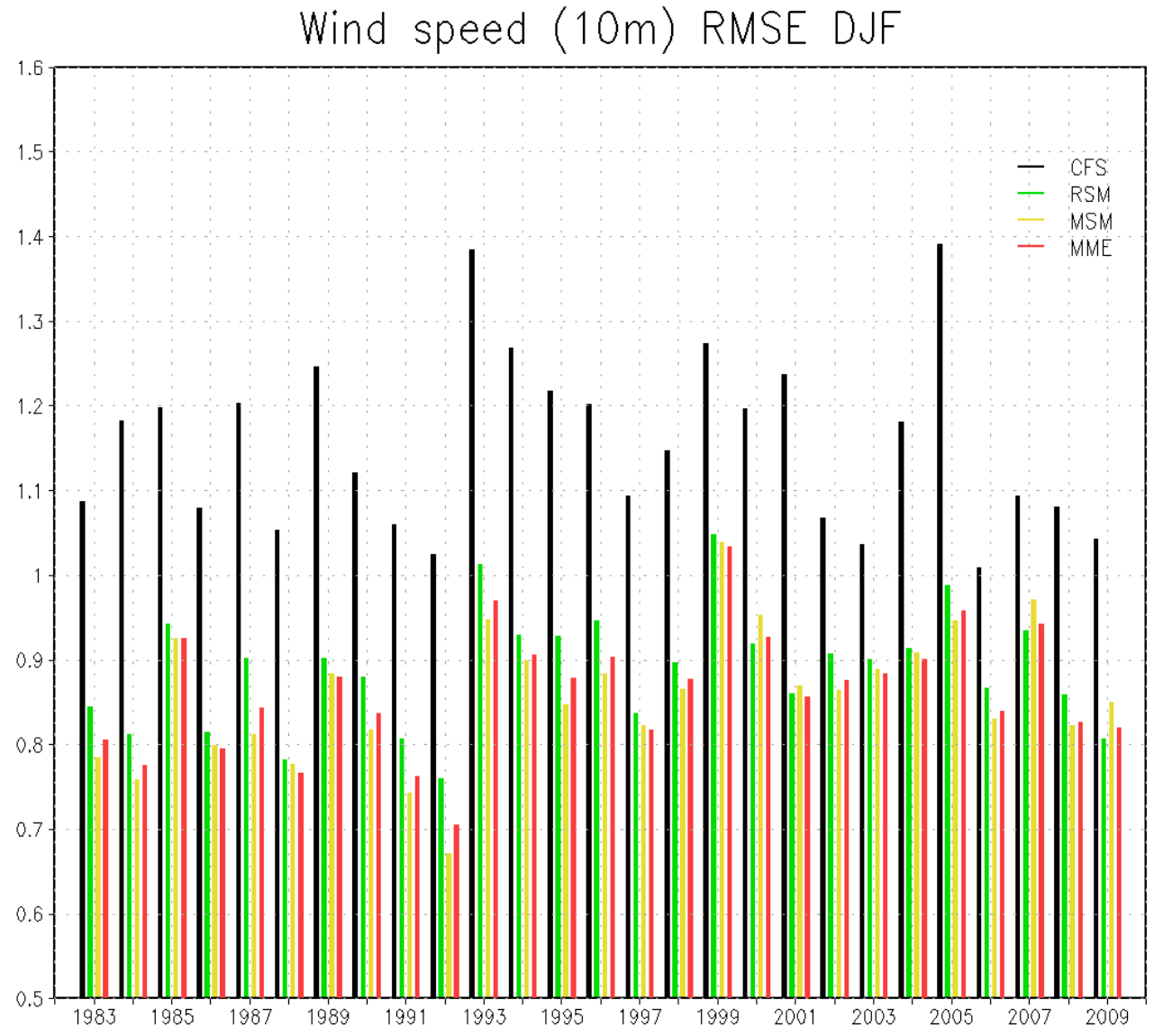
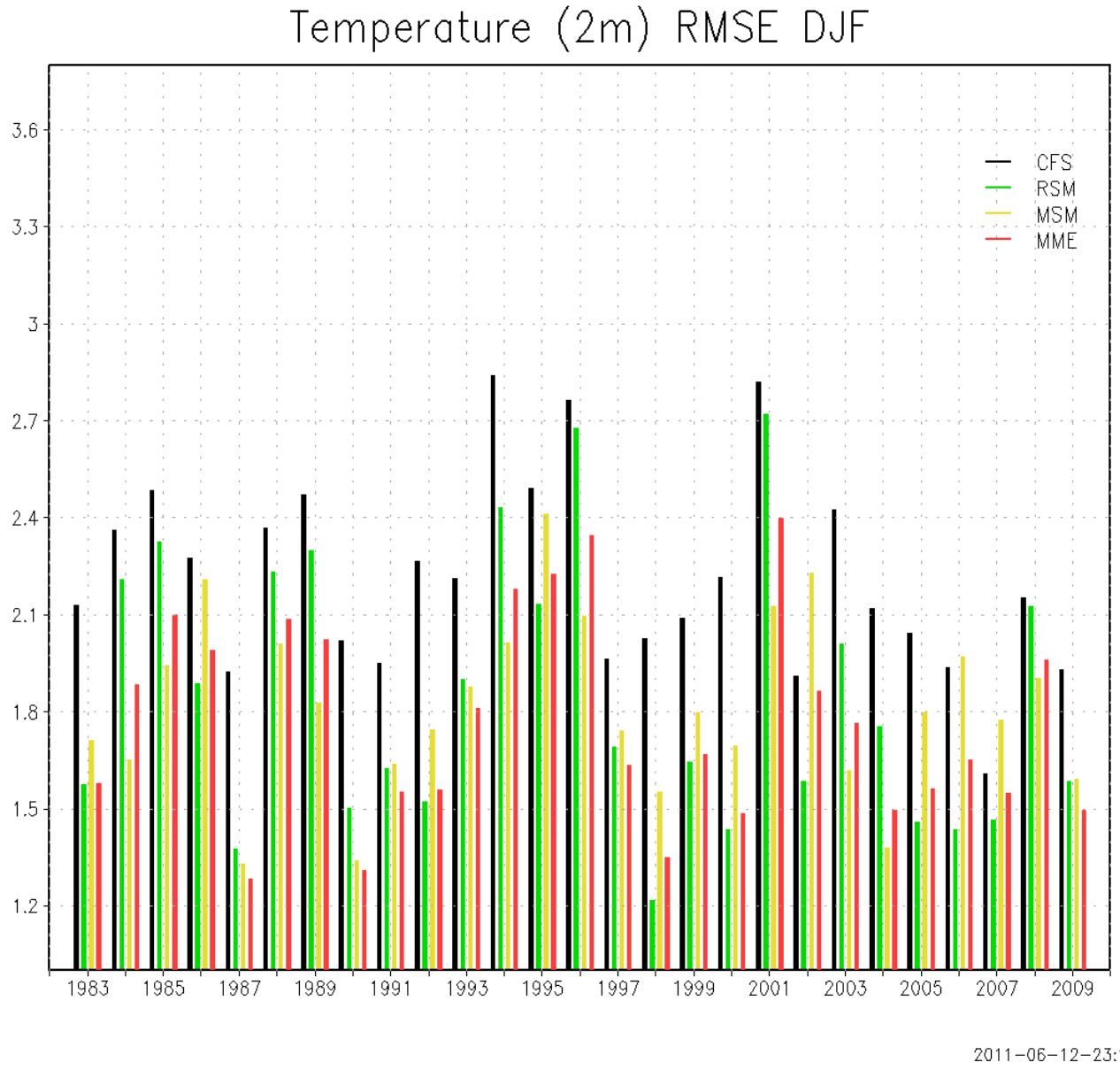


best

CFS	0
RSM	3
MSM	16
MME	8

Better

RSM	4
MSM	22
MME	27



best
CFS 0
RSM 11
MSM 10
MME 6

better
RSM 13
MSM 13
MME 27

MRED RSM/MSM Summary

- Based on the spectral computational method in RSM/MSM, the integrated regional values are through a band passed filter without planetary- and large-scale waves=> thus it keeps large scales unchanged.
- From the upper layer results, RSM/MSM not only preserves large scale but also improves large- and synoptic scales.
- In term of spatial/temporal scores, Regional model has add-in values to mesoscale as 2mT and 10m wind.

MRED RSM/MSM Summary

- Examine 27-year hindcasts on the RMSE of 2m T and 10m wind, we found, RSM, MSM and MME have much better score than CFS.
- In term of 10m wind, MSM has better score than RSM, and very close to MME. Number of the best, RSM has 3, MSM 16, MME 8, out of 27 years.
- In term of 2m T, RSM and MSM has equal score and better than MME. Number of the best, RSM has 11, MSM 10, MME 6 out of 27.
- It indicates MSM, nonhydrostatic can be better than hydrostatic, may be due to correct vertical velocity.
- MME using RSM/MSM provides over-all most reliable forecast as compared to either RSM or MSM.

The Further Concerns

- To get multi-model ensemble may not be difficult, but may be too cost to maintain multi models in operational mode
- While multi-dynamic options exists in a single model, doing dynamics options can be an MME-alike system
  - Obtain more ensemble members due to dynamic options
  - Maintain one model, but ensembled as multi models.
- Adopt from current GFS/CFS dynamics
  - They may have equal options between model physics and model dynamics
  - Dynamics:
    - Generalized vertical coordinates: sigma, sigma-p, sigma-theta
    - Different thermodynamic: virtual temperature, enthalpy
    - Different advection: Eulerian and semi-Lagrangian