Progress on Coupling WRF within CCSM for Regional Climate Research

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1. **Motivation**
2. **Software Engineering**
3. **One-Way Results**
4. **Preliminary Results from Two-Way Coupling**
5. **Mapping between WRF and CAM**

As one of the methods for high-resolution climate model.

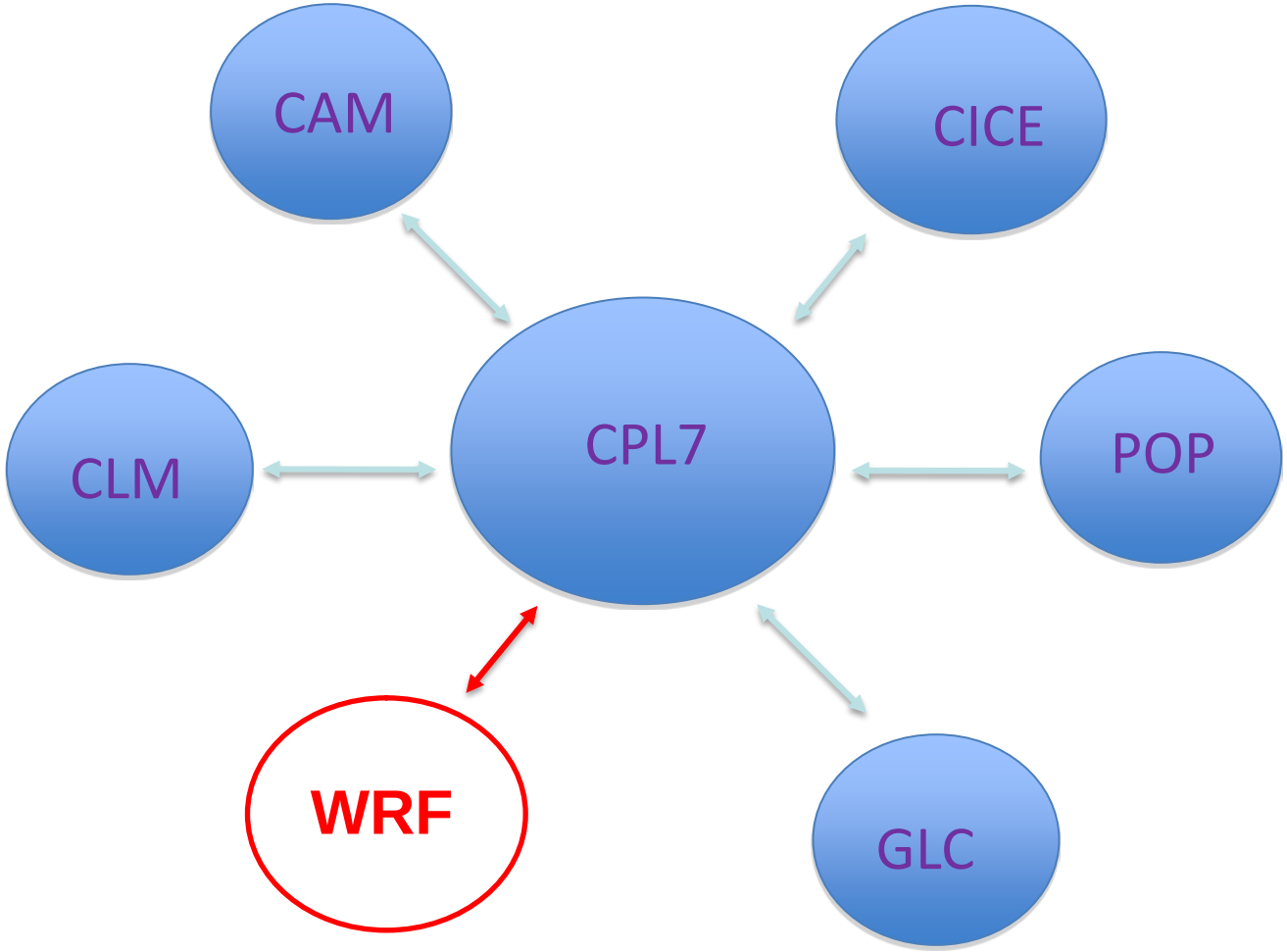
Pros:

The community has lot of experiences in using WRF. It works for weather events.

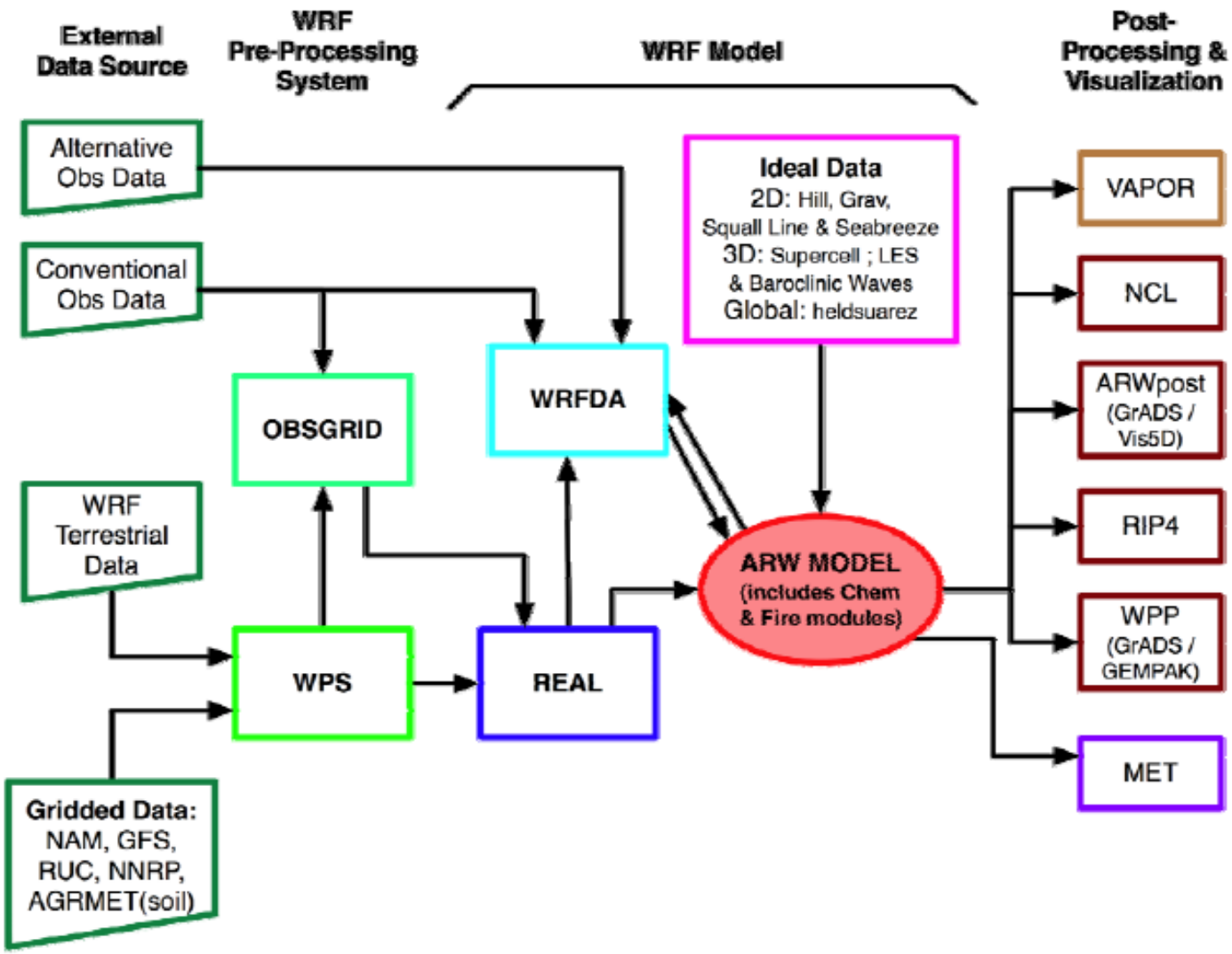
Cons:

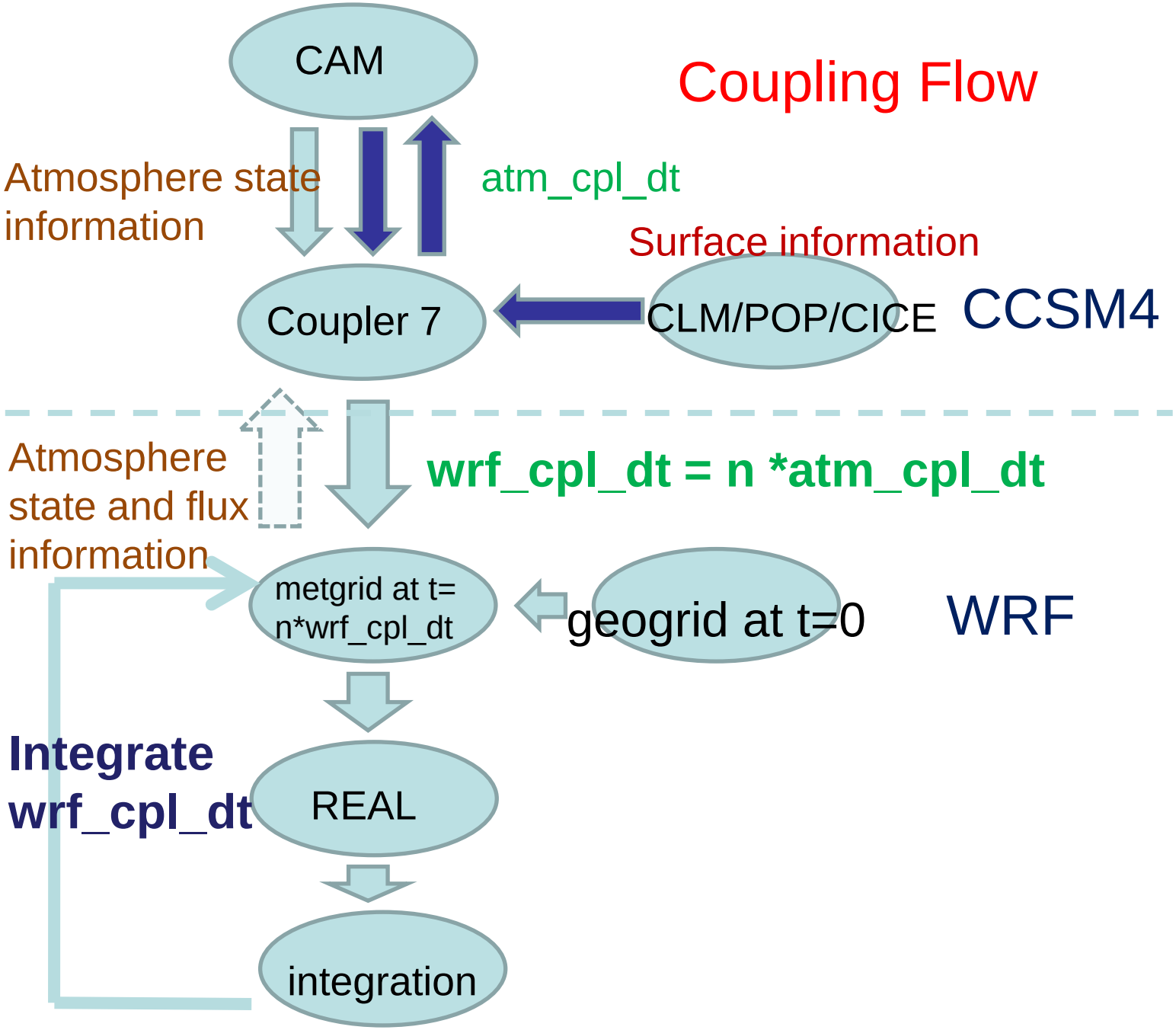
Mathematically incompatible between the two models.

The advantage: suitable for practical applications now.


CAM
CICE
CLM
CPL7
POP
WRF
GLC

WRF Modeling System Flow Chart




CAM
Coupling Flow
Atmosphere state information
atm_cpl_dt
Surface information
Coupler 7
CLM/POP/CICE
CCSM4
Atmosphere state and flux information
wrf_cpl_dt = n *atm_cpl_dt
metgrid at t= n*wrf_cpl_dt
geogrid at t=0
WRF
Integrate wrf_cpl_dt
REAL
integration

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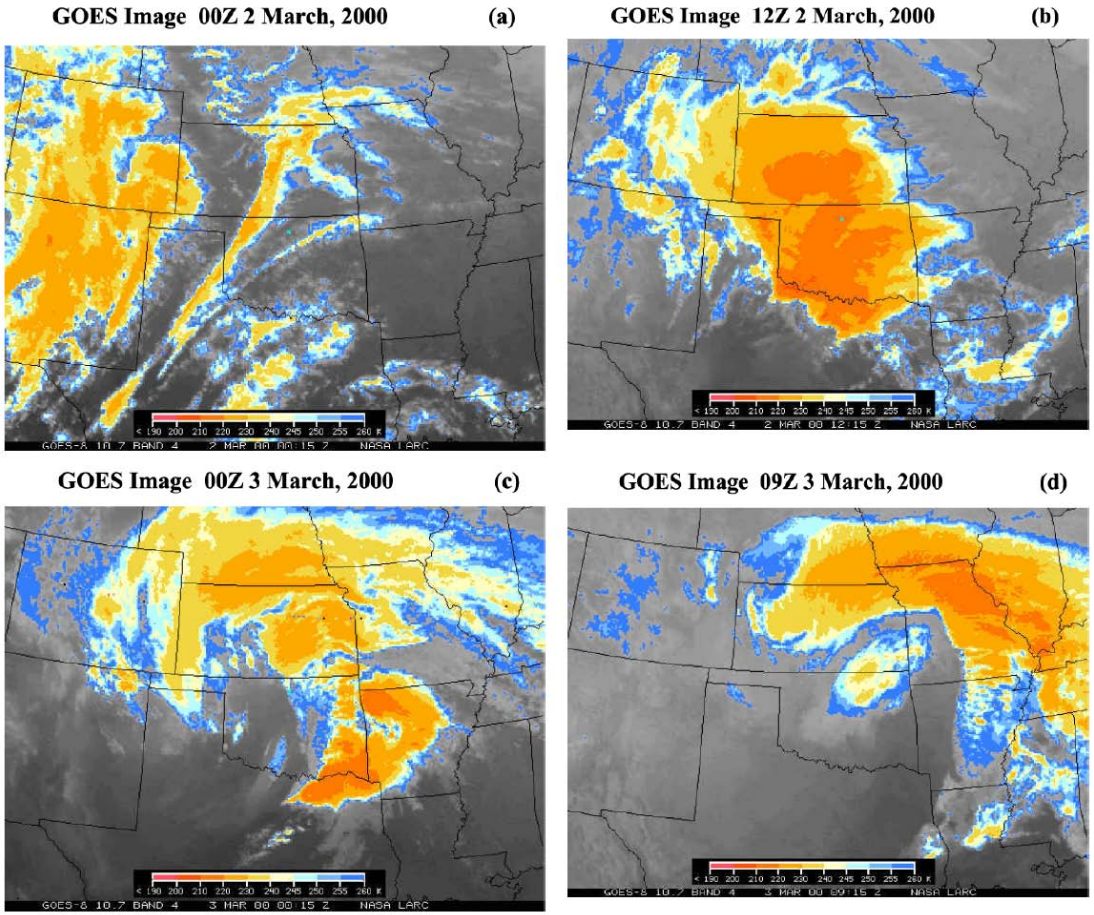
March 2000 ARM IOP

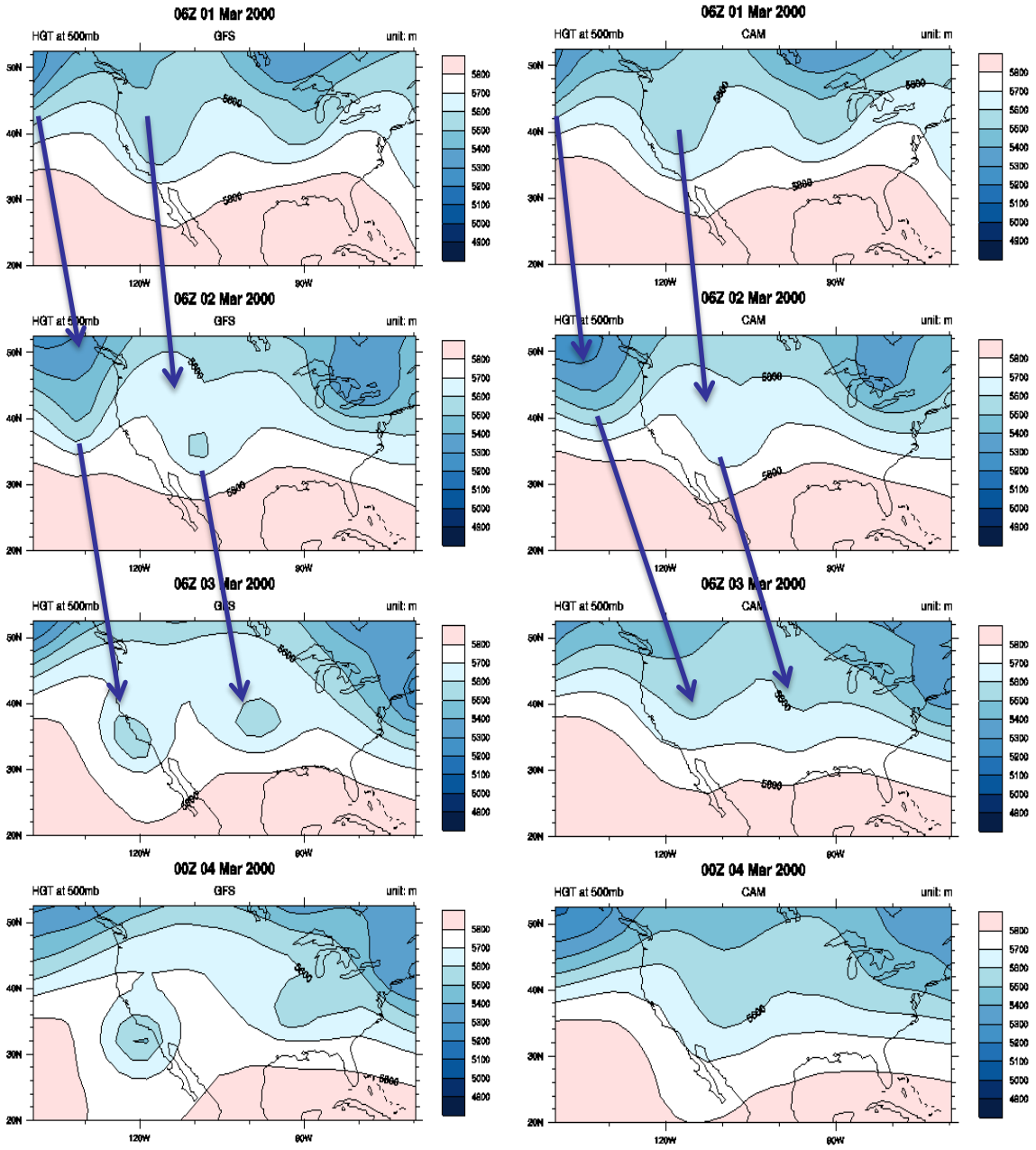


GOES satellite infrared images over the Southern Great Plain 3/2-3/3/2000

GFS

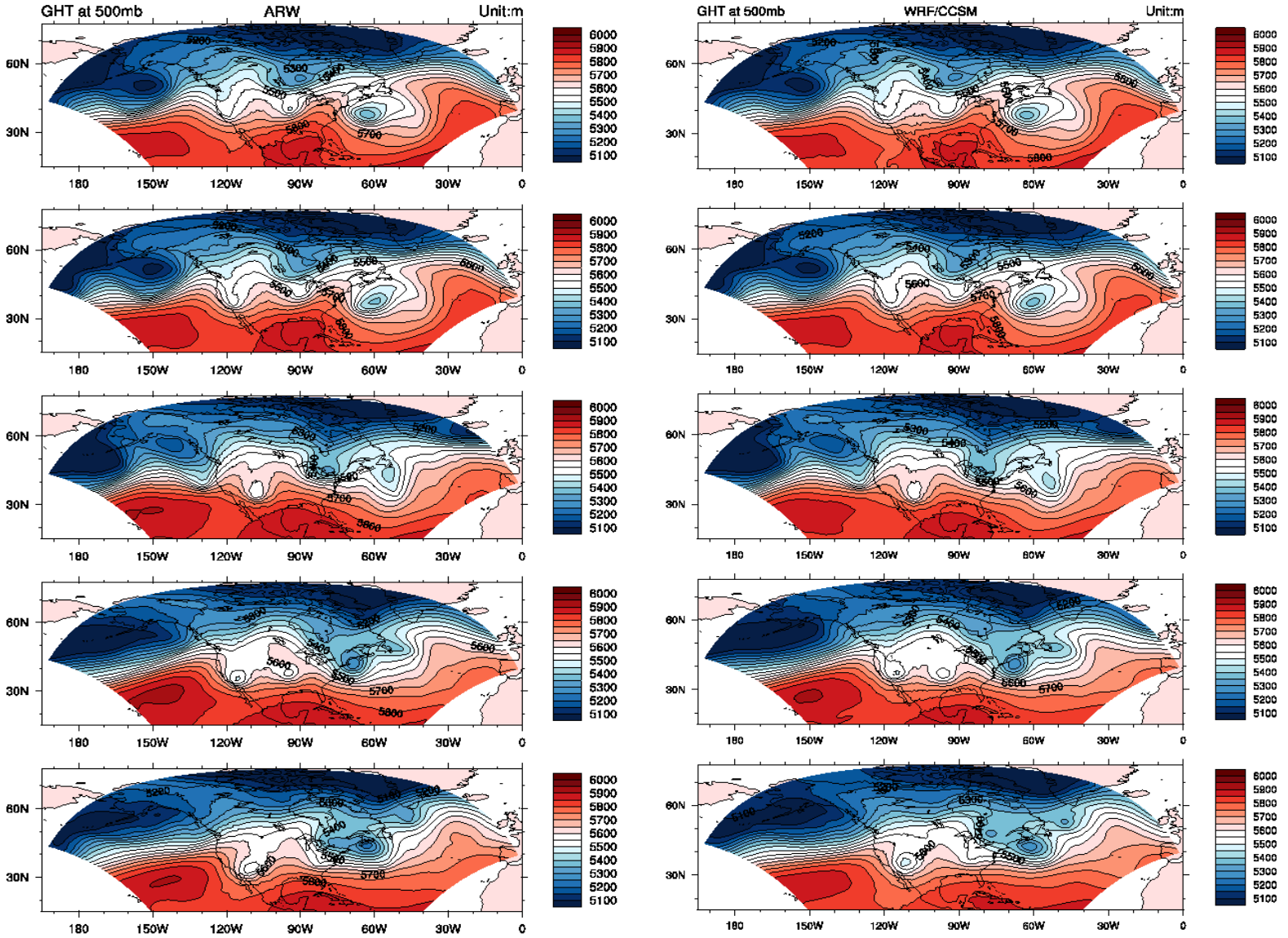
CAM4

500mb Geopotential Height
March 1st to 4th



WRF forced by CFS

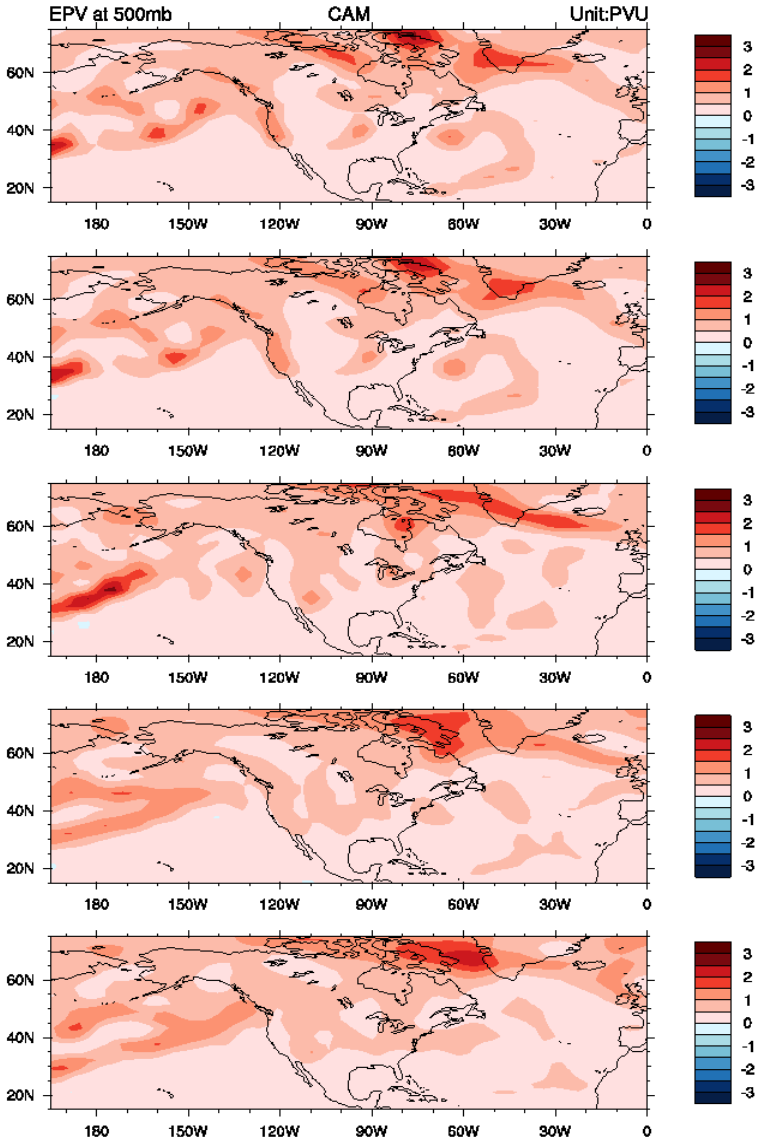
WRF within CCSM



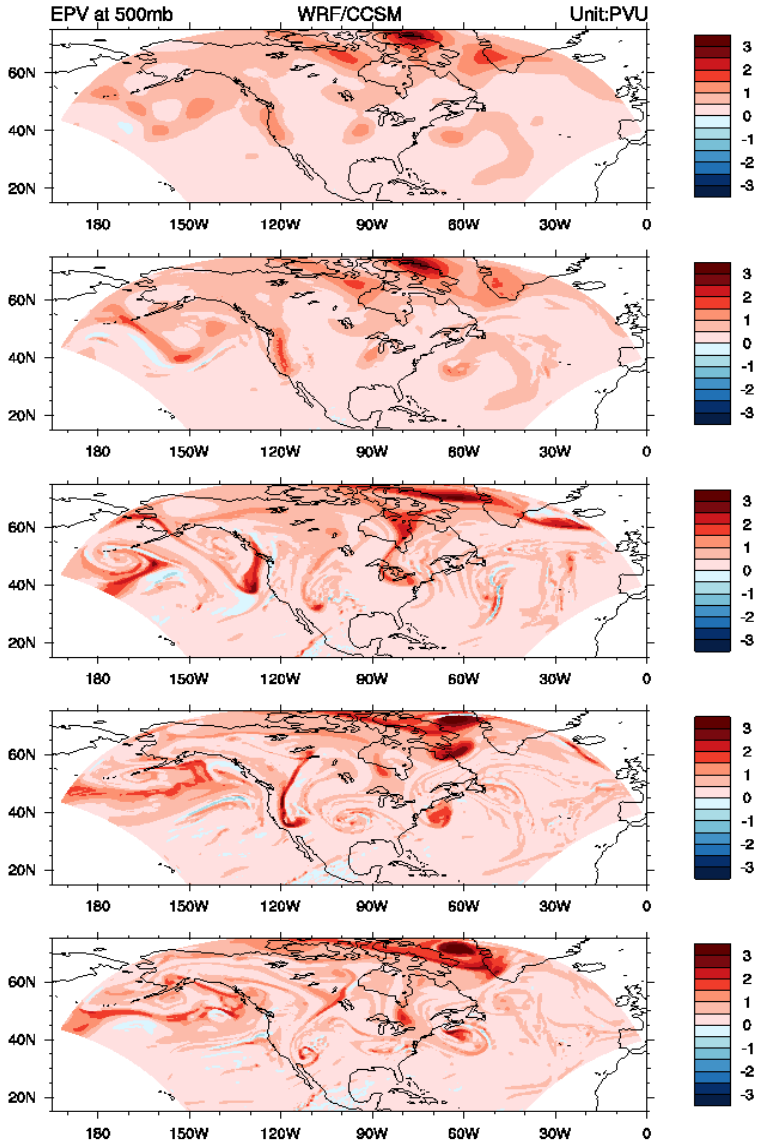
(He et al. 2011)

Evolution of Potential Vorticity 3/1-3/5

CAM4



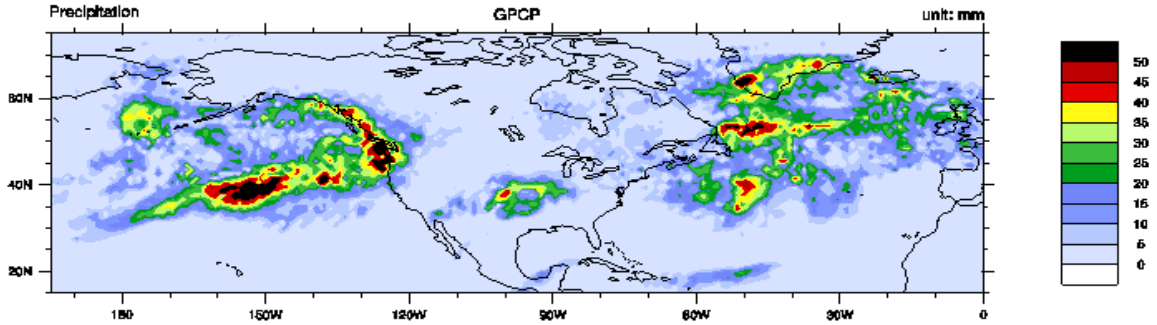
WRF within CCSM



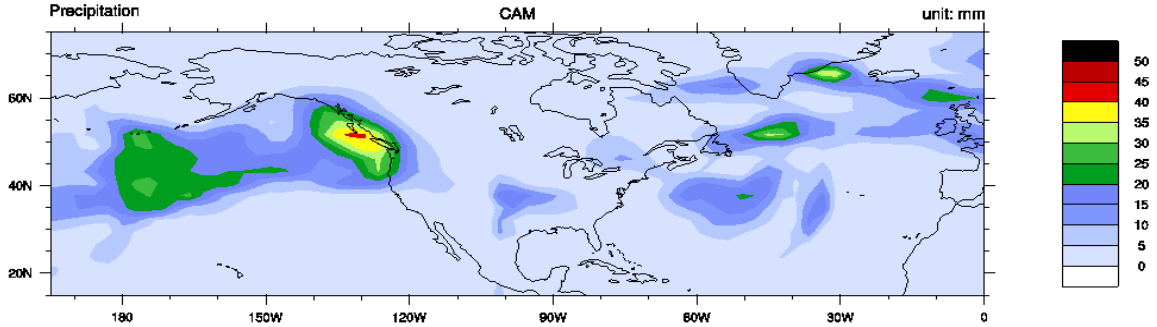
(He et al. 2011)

Accumulated precipitation from 3/1-3/3

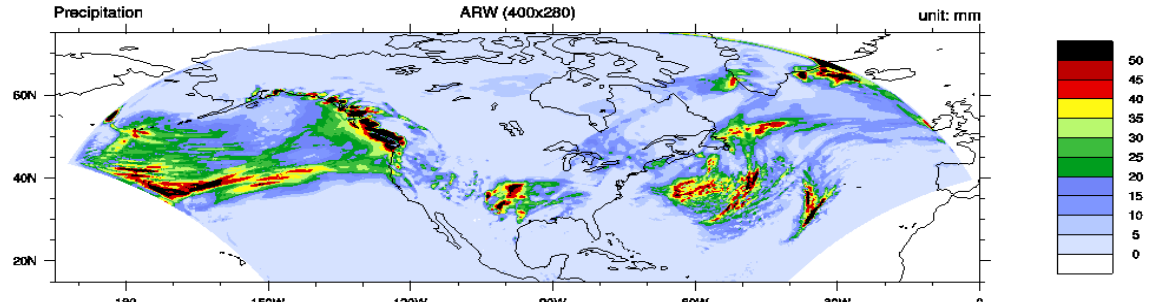
GPCP



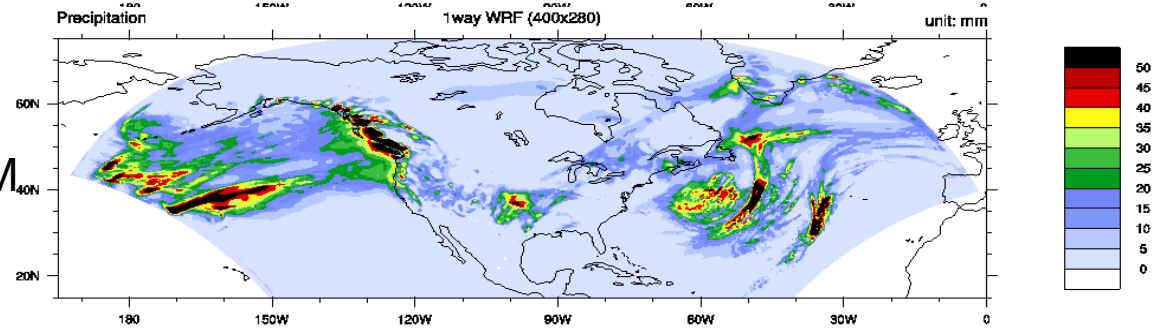
CAM4



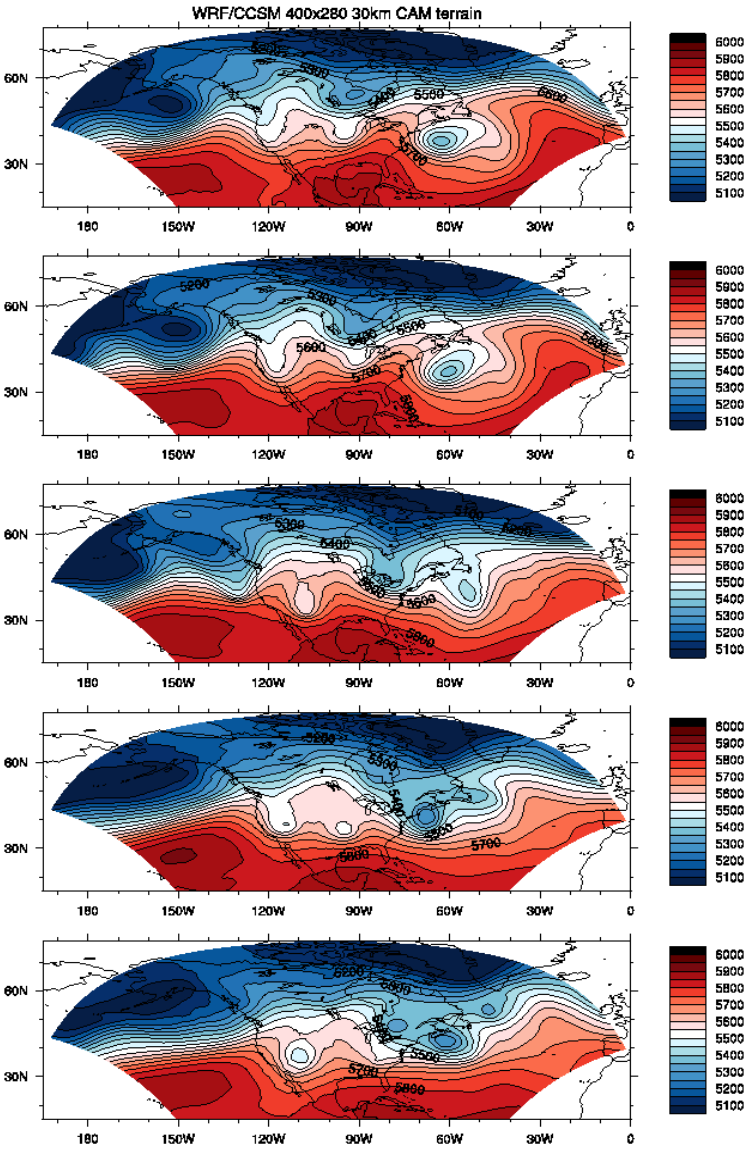
WRF/GFS



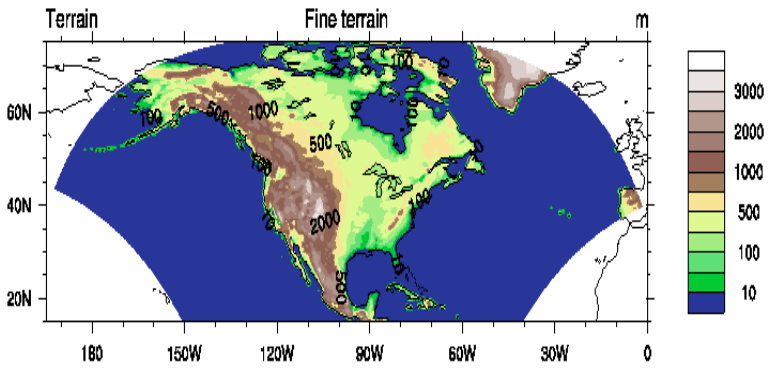
WRF/CCSM



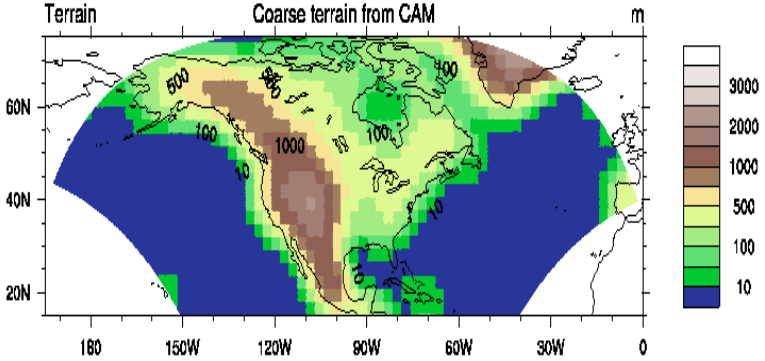
Impact of Terrain 3/1-3/5



WRF



CAM4



(He et al. 2011)

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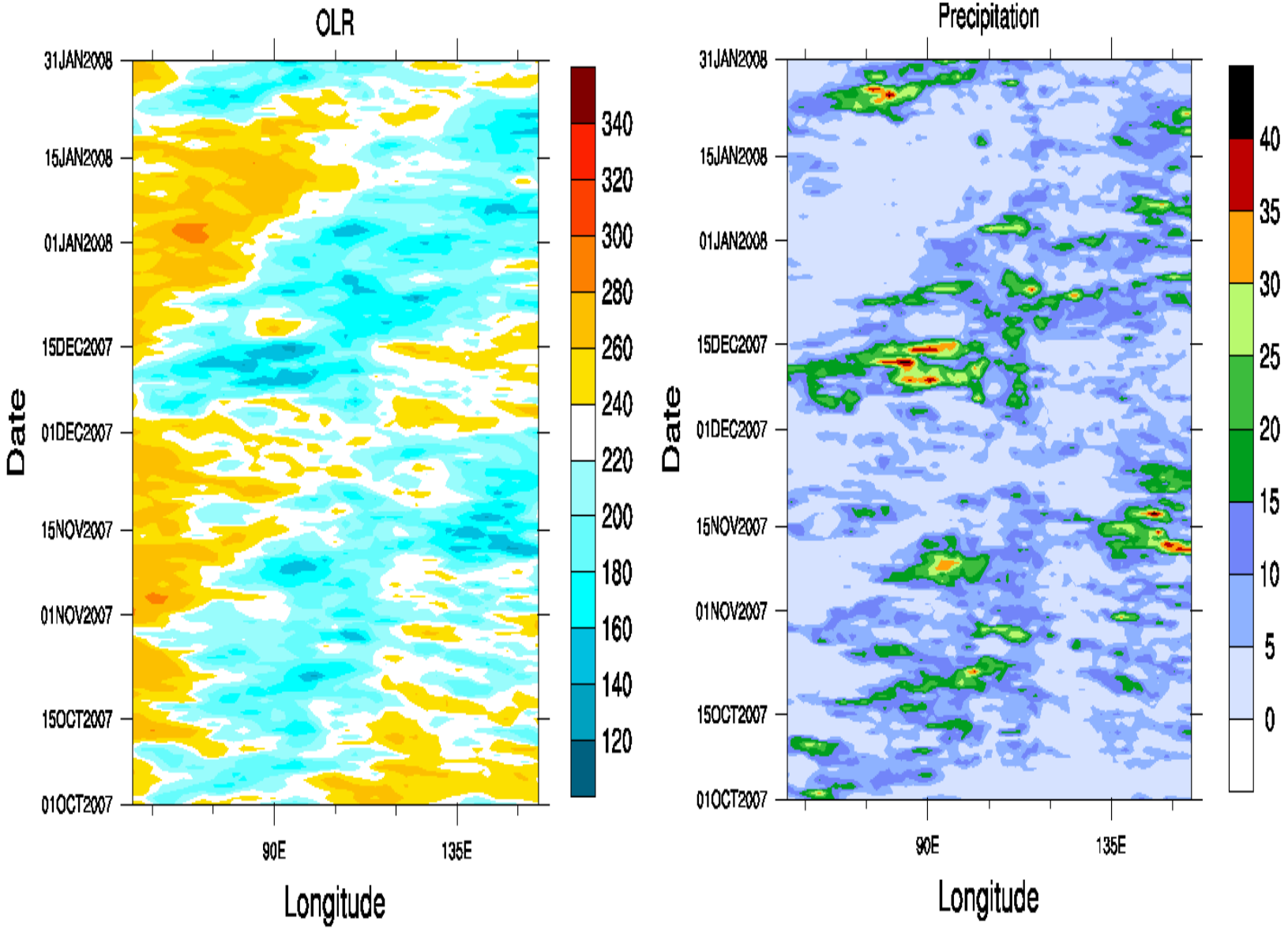
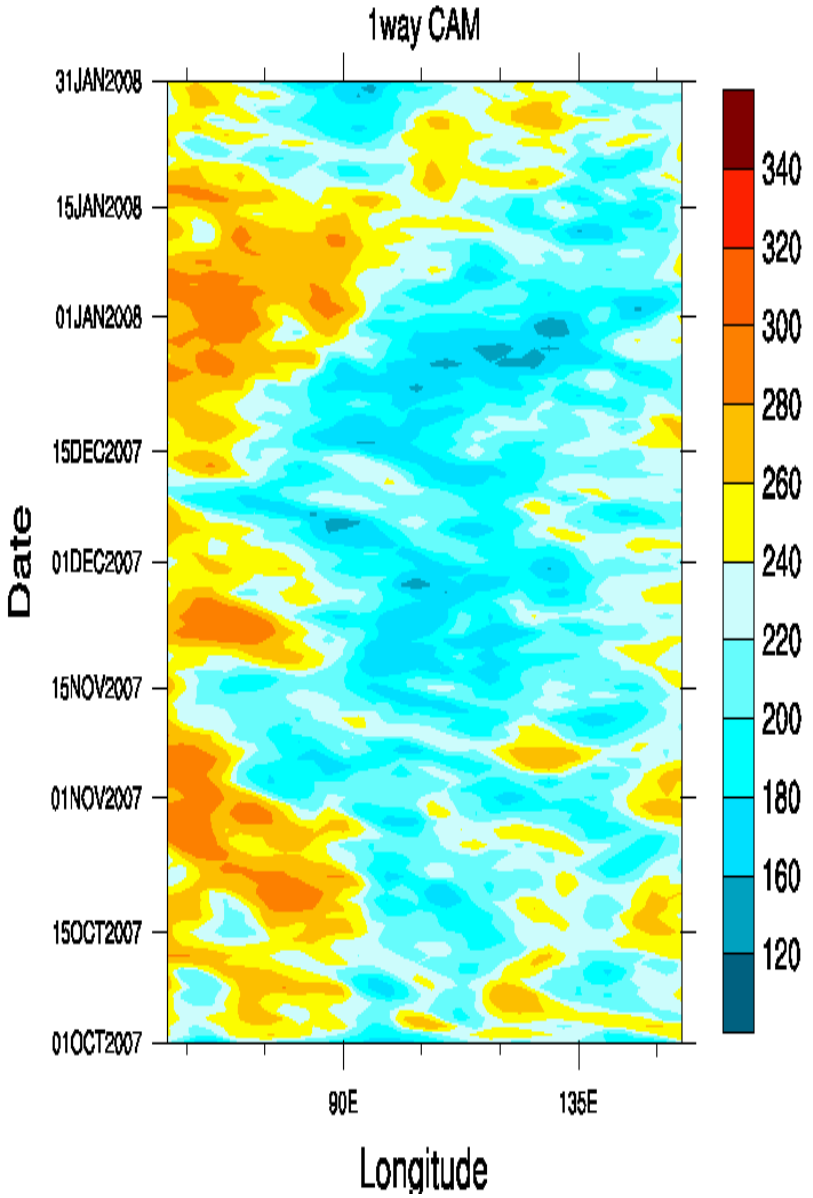
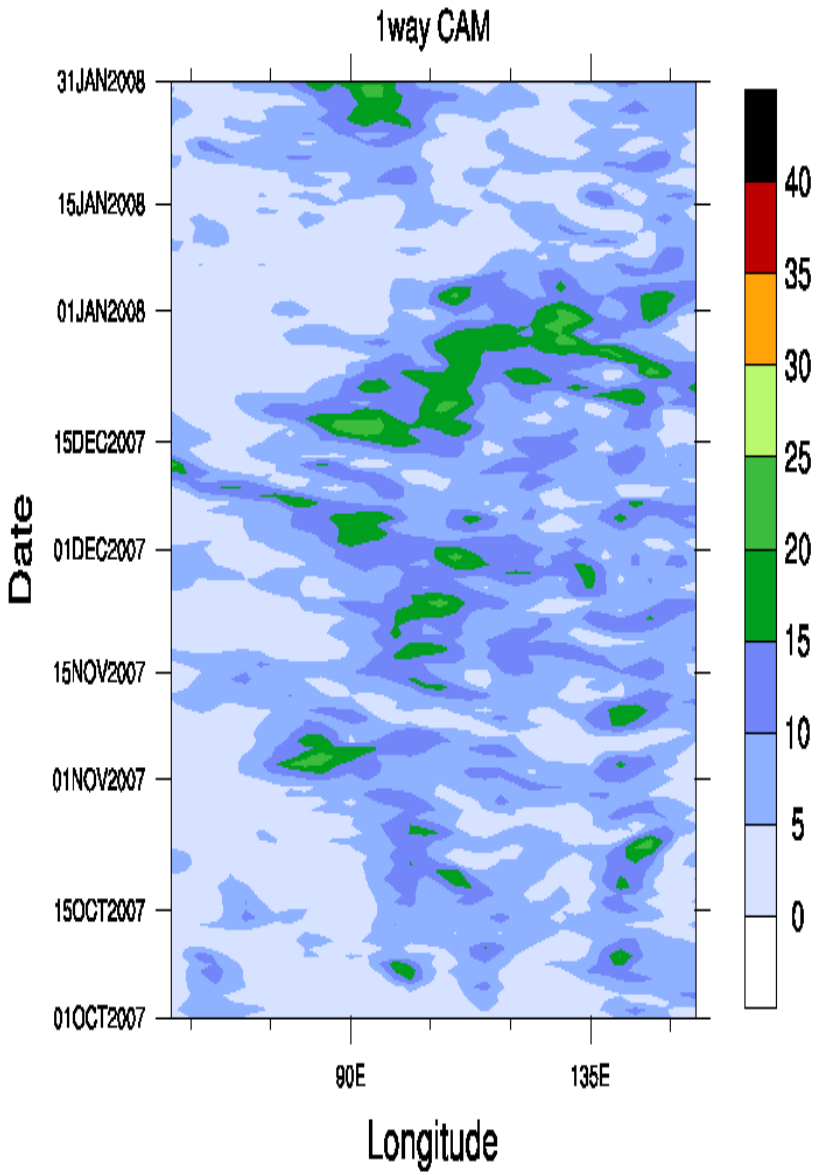
Observation



(Leung et al. 2011)

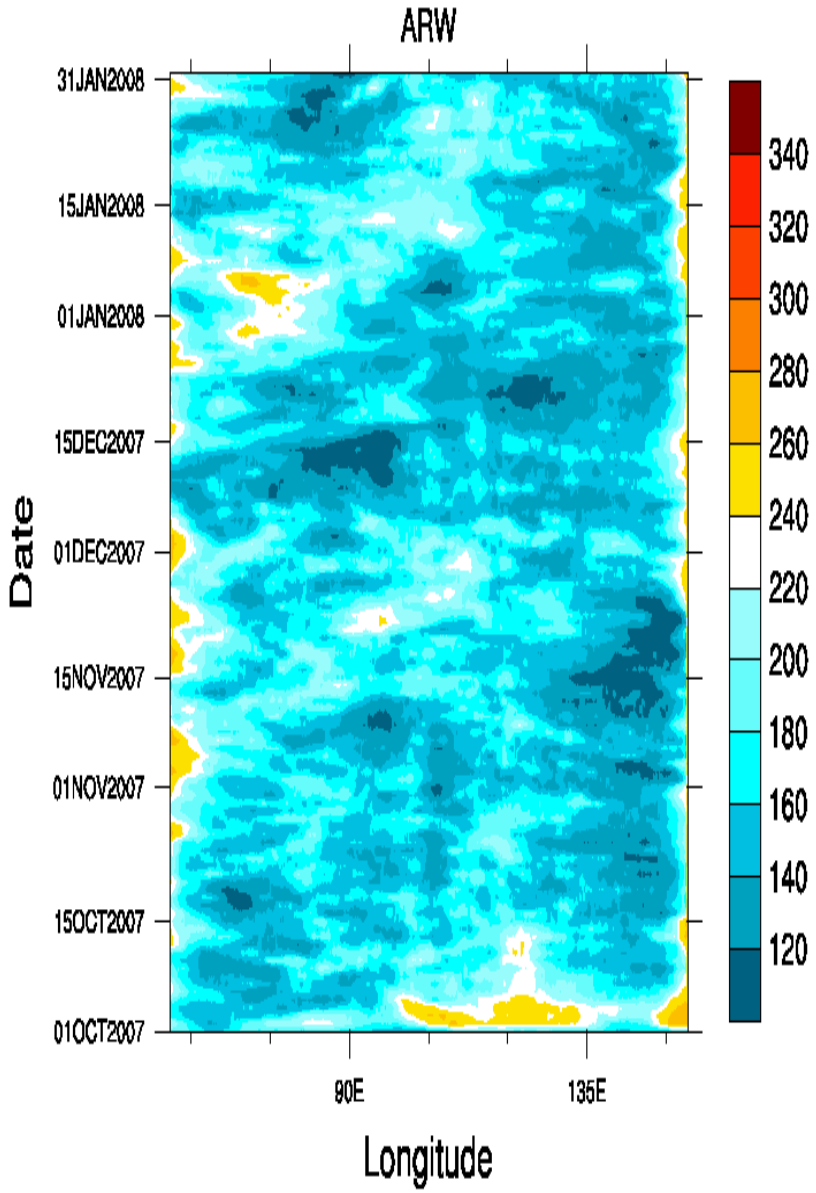
CAM4


1way CAM
31JAN2008
15JAN2008
01JAN2008
15DEC2007
01DEC2007
15NOV2007
01NOV2007
15OCT2007
01OCT2007
Date
90E
135E
Longitude
340
320
300
280
260
240
220
200
180
160
120

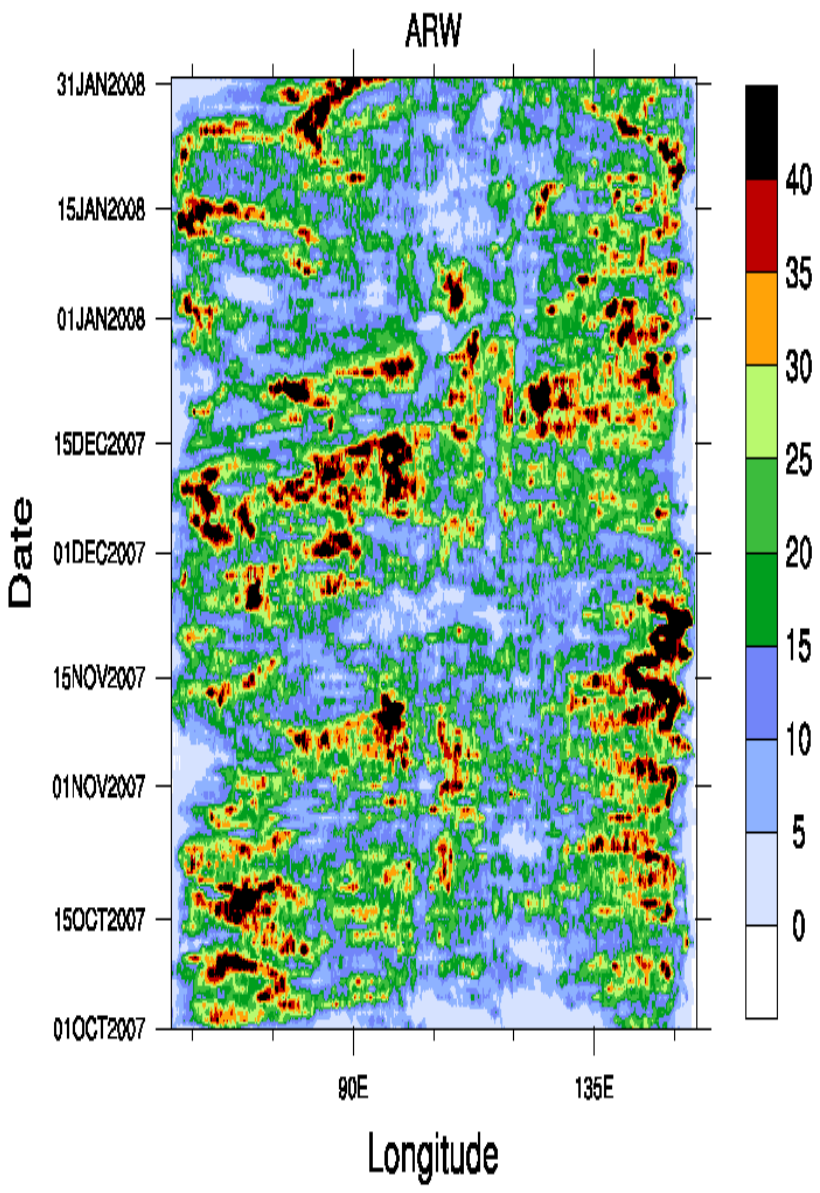

1way CAM
31JAN2008
15JAN2008
01JAN2008
15DEC2007
01DEC2007
15NOV2007
01NOV2007
15OCT2007
01OCT2007
Date
90E
135E
Longitude
40
35
30
25
20
15
10
5
0

OLR

WRF/GFS

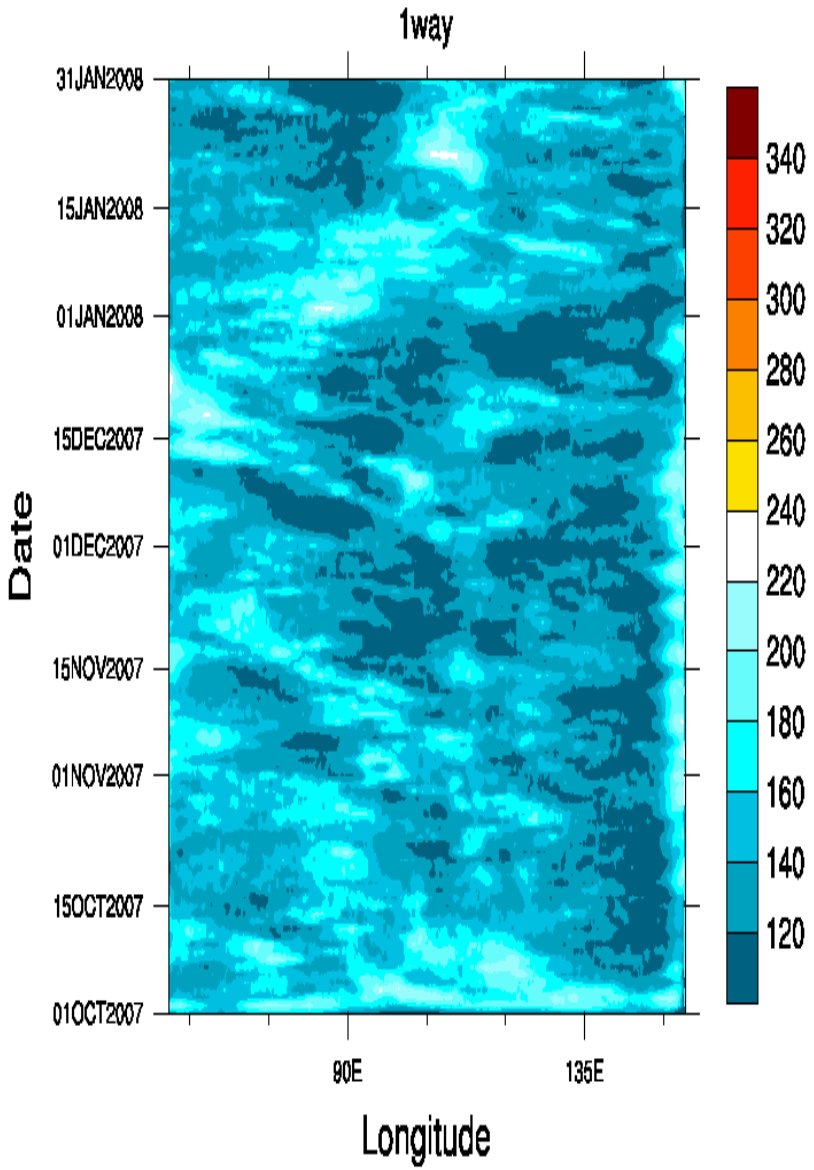


OLR

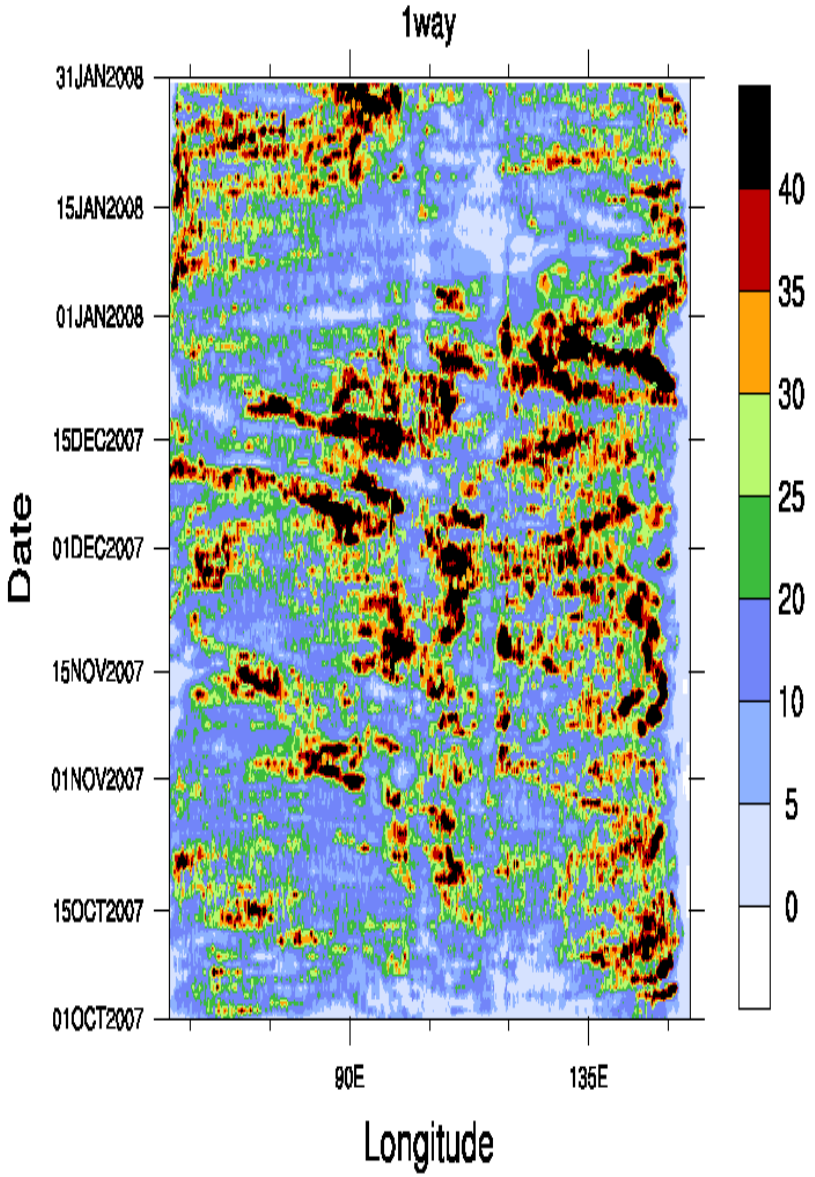


Precipitation

1WAY WRF/CCSM

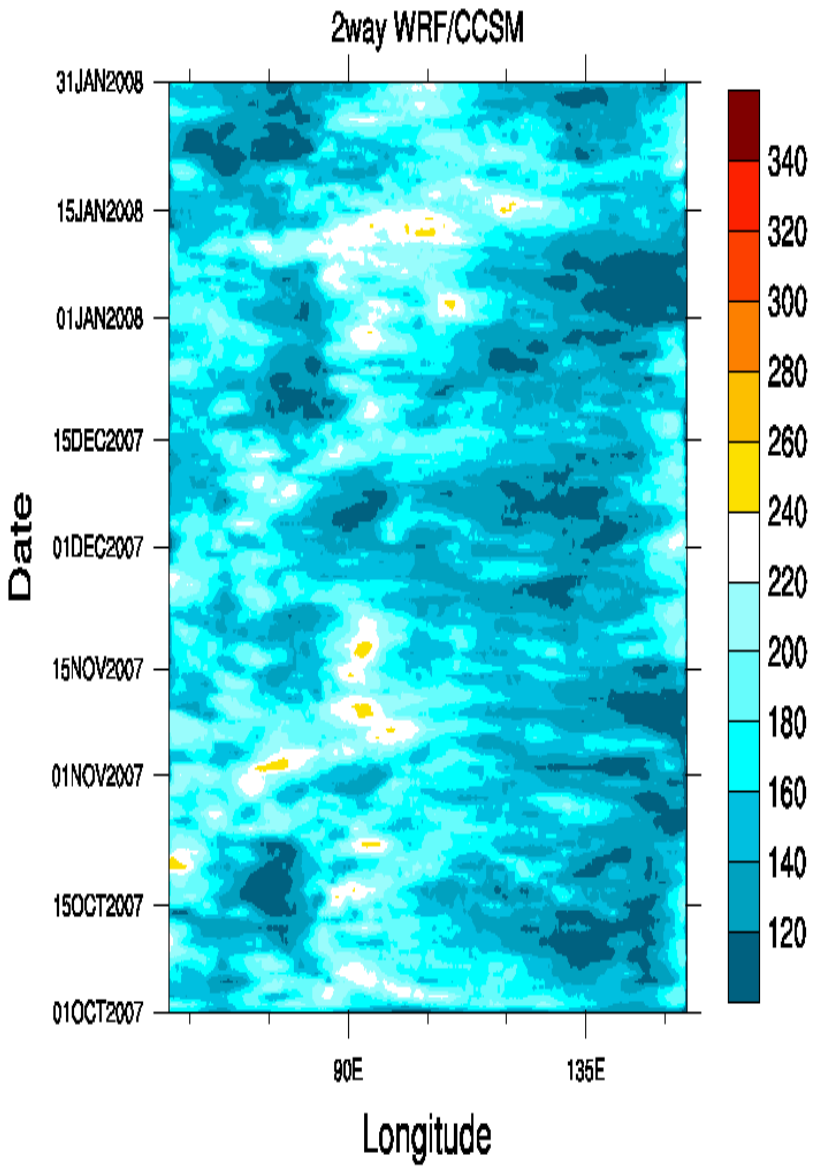


OLR

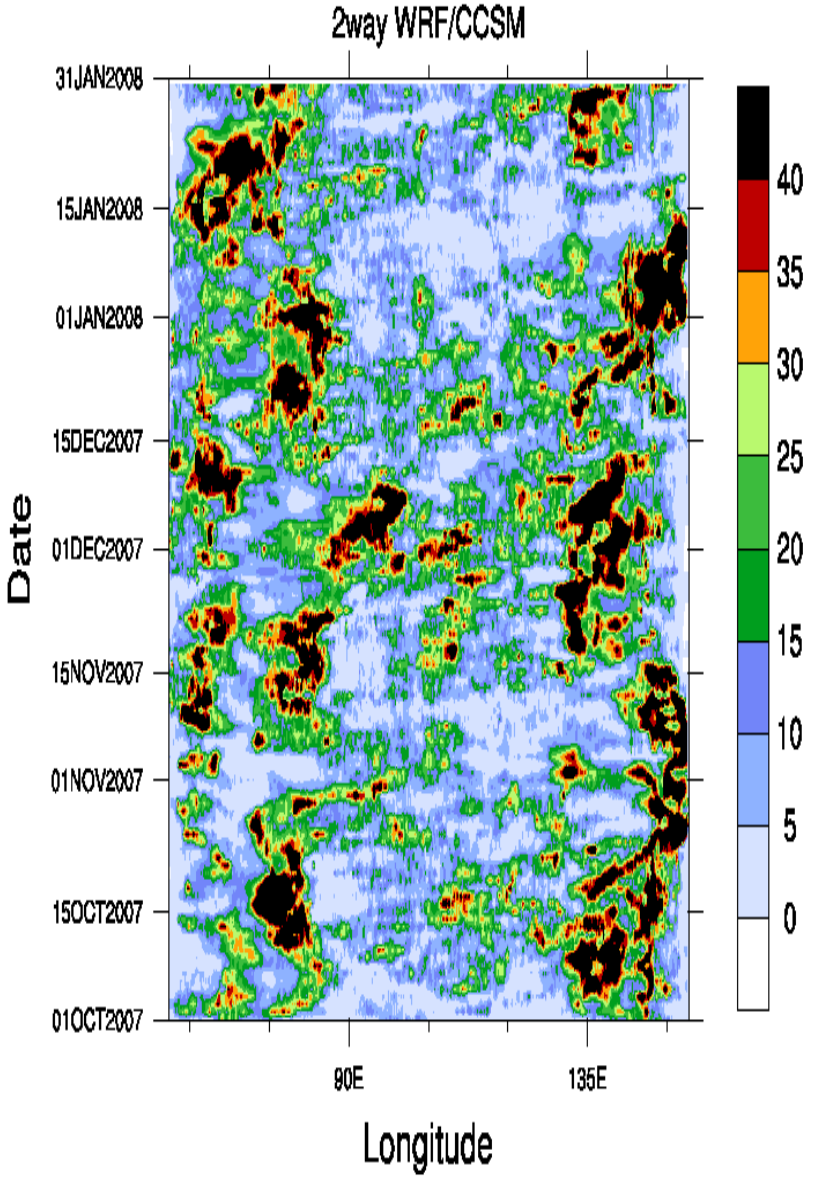


Precipitation

2WAY WRF/CCSM

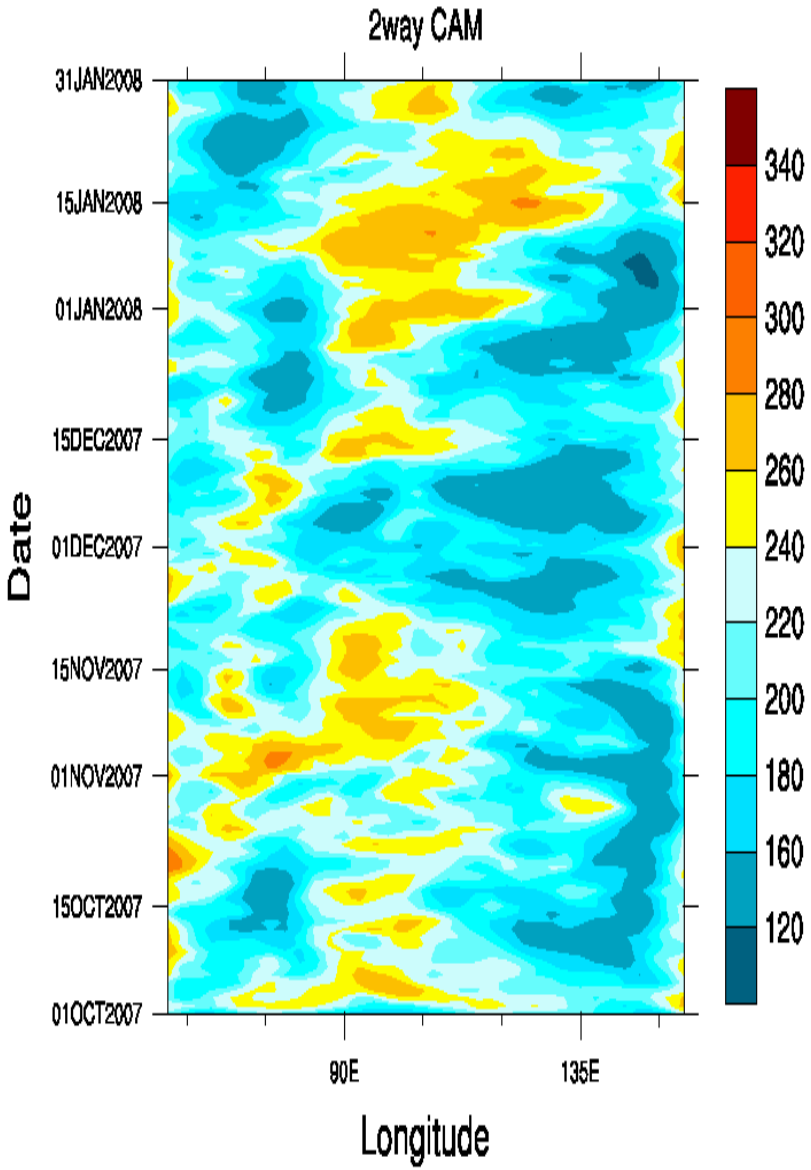


OLR

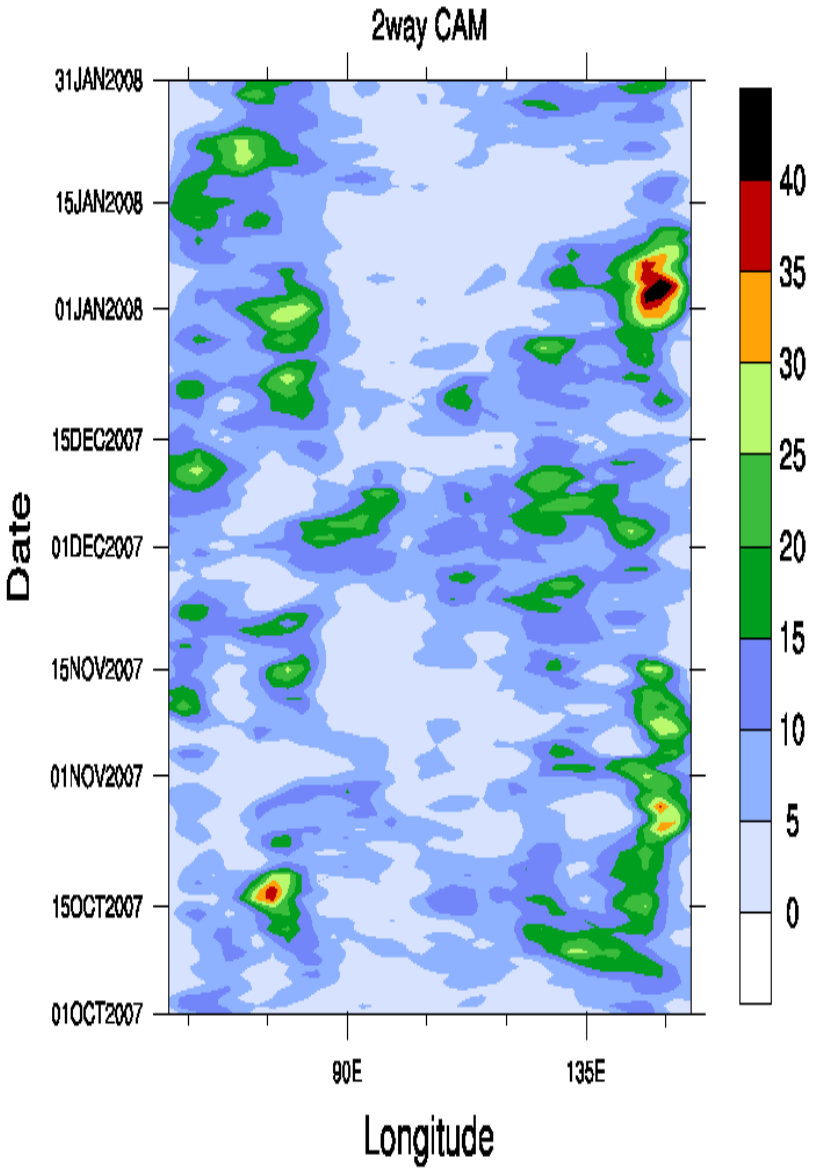


Precipitation

2WAY CAM4



OLR



Precipitation

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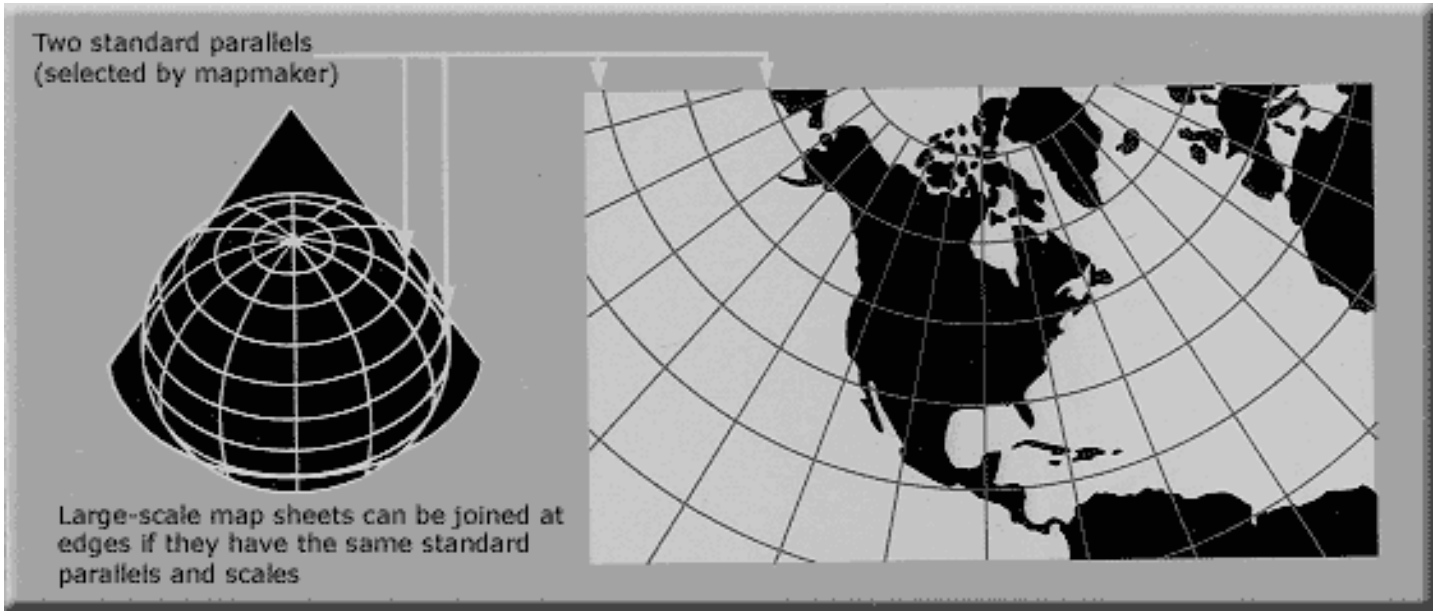
WRF-CAM
Mapping



(Chen et al. 2011)

Mapping WRF-CAM

Source function

$$f = \sum_{i=1}^{m} \phi_i f_i$$

ϕ_i, f_i

Basis function, and value of the source function at the i vertex of the source mesh

Target function

$$g = \sum_{j=1}^{n} \psi_j g_j$$

ψ_j, g_j

Basis function, and value of the target function at the j vertex of the target mesh

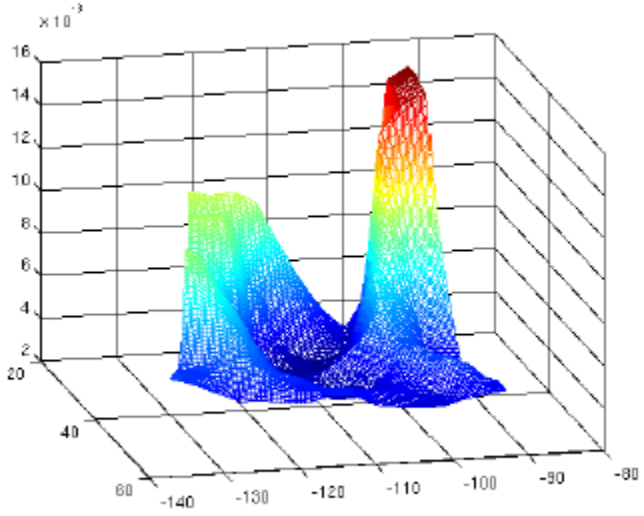
$$\partial \int_{\Omega} (g - f)^2 / \partial g_i = 0$$

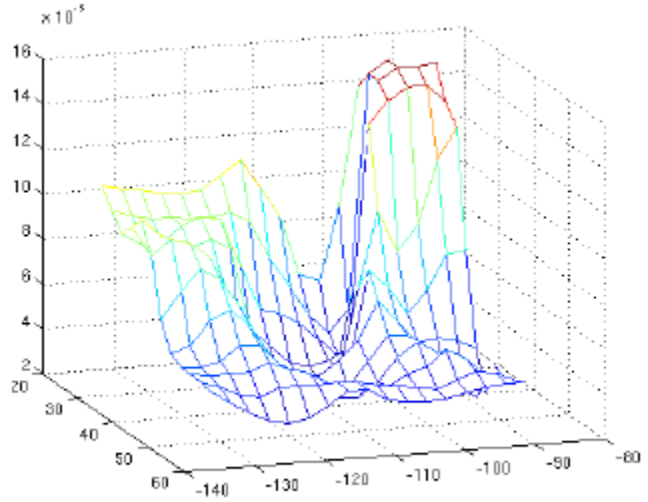
Encompasses many other interpolation schemes

$$\begin{bmatrix} \int_\Omega \psi_1\psi_1\cdot|J|dx & \int_\Omega \psi_1\psi_2\cdot|J|dx & \cdots & \int_\Omega \psi_1\psi_n\cdot|J|dx \\ \int_\Omega \psi_2\psi_1\cdot|J|dx & \int_\Omega \psi_2\psi_2\cdot|J|dx & \cdots & \int_\Omega \psi_2\psi_n\cdot|J|dx \\ \cdots & \cdots & \cdots & \cdots \\ \int_\Omega \psi_n\psi_1\cdot|J|dx & \int_\Omega \psi_n\psi_2\cdot|J|dx & \cdots & \int_\Omega \psi_n\psi_n\cdot|J|dx \end{bmatrix} \begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_n \end{bmatrix} = \begin{bmatrix} \int_\Omega \psi_1(\sum_{i=1}^m \phi_i f_i)\cdot|J|dx \\ \int_\Omega \psi_2(\sum_{i=1}^m \phi_i f_i)\cdot|J|dx \\ \vdots \\ \int_\Omega \psi_n(\sum_{i=1}^m \phi_i f_i)\cdot|J|dx \end{bmatrix}$$

Integration using Gaussian weights in triangles on common refinement grids

Water vapor field





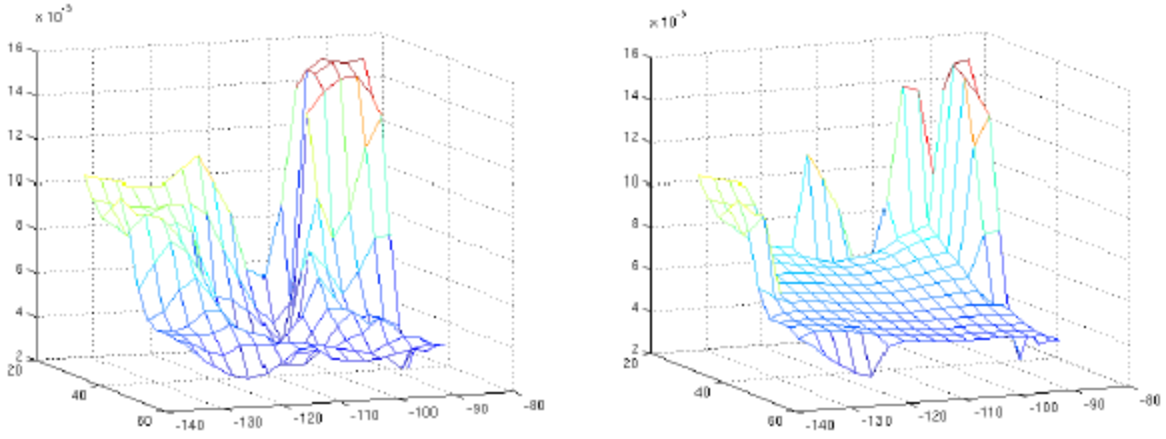


Figure 4.16: Left to right: (a). original water vapor in CAM's domain; (b). after 1000 steps transfer with area weighted method

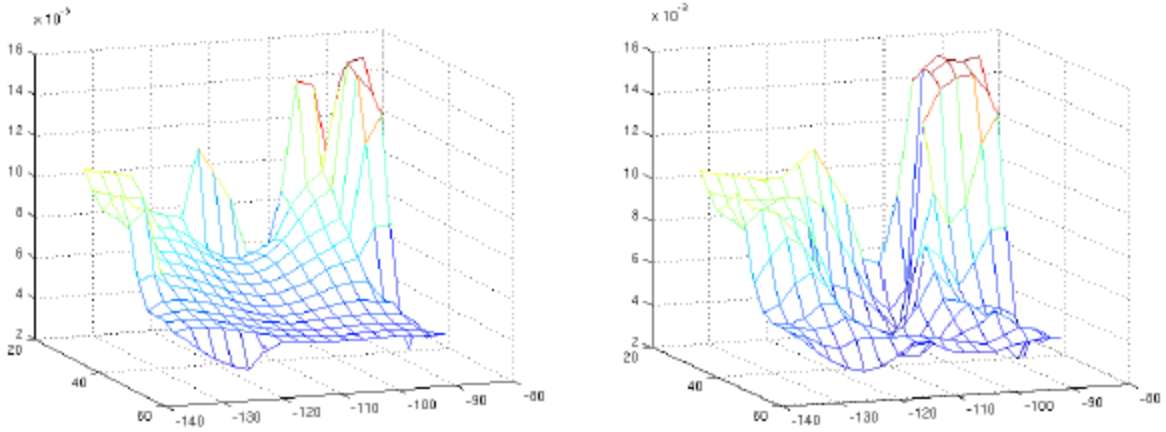


Figure 4.17: Left to right: (a). 1000 steps transfer with 2nd order monotonic method; (b). 1000 steps transfer with L_2 minimization method

Summary

1. CESM capability of simulating regional climate by online downscaling.

2. Two-way still very preliminary. Problems in the compatibility in physics, and conservation preservation in the CAM require further research.

3. A new WRF-CAM mapping algorithm.