Satellite Assimilation to Improve Cloud Simulation in WRF Model

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NSSTC

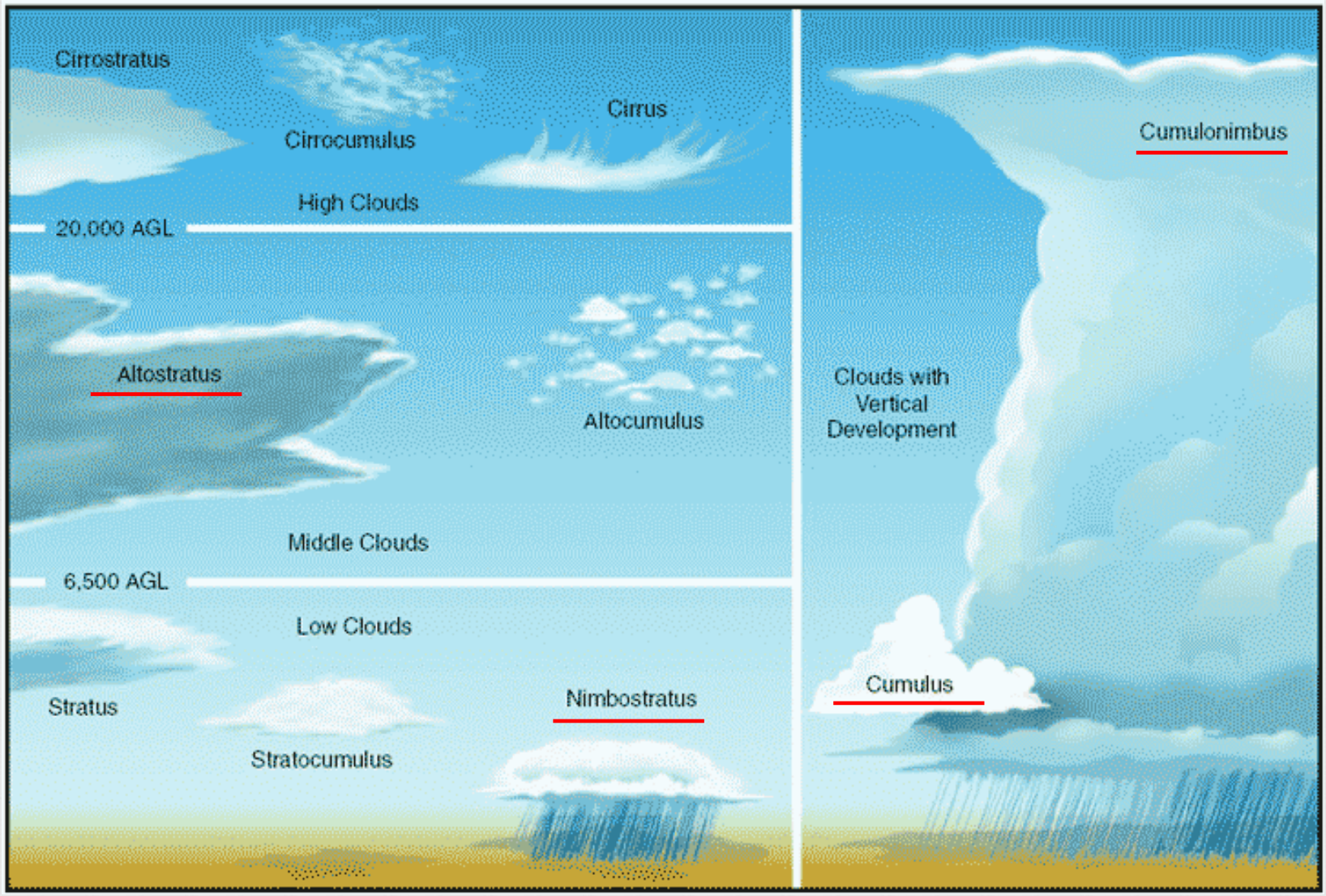
CONTEXT

- Scientific questions
- Data description and Model configuration
- Method of assimilating satellite data
- Analytical method
  - Over prediction
  - under prediction
- Results
- Conclusion

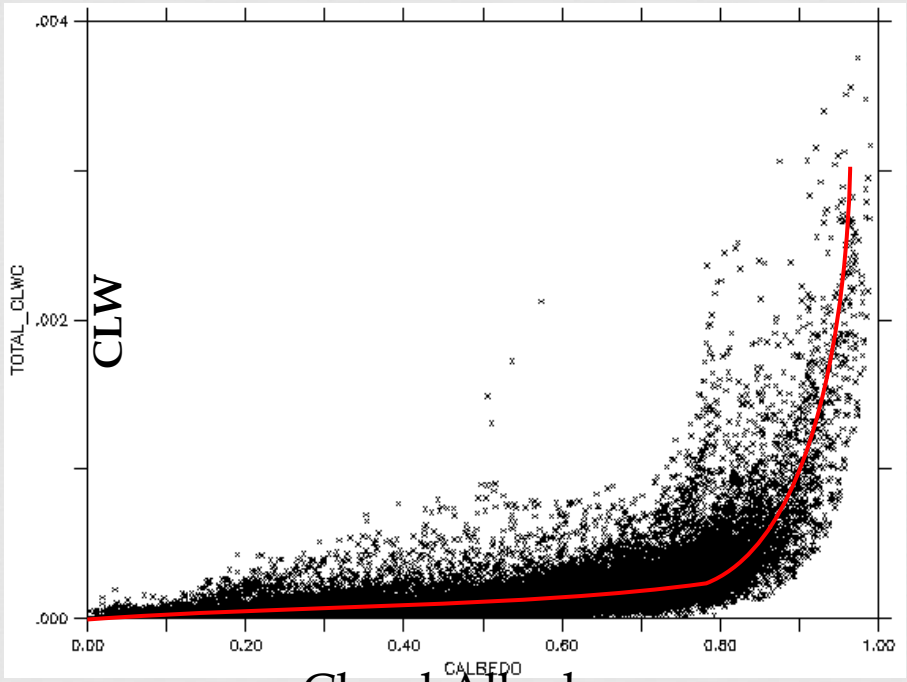
Scientific Question

- How are meteorological variables (e.g. cloud liquid water, vertical velocity) related to cloud fields?
- How to adjust meteorological fields in the model to satisfy realism of clouds?
- How to change dynamics in the model, based on the cloud types?

Cloud Types

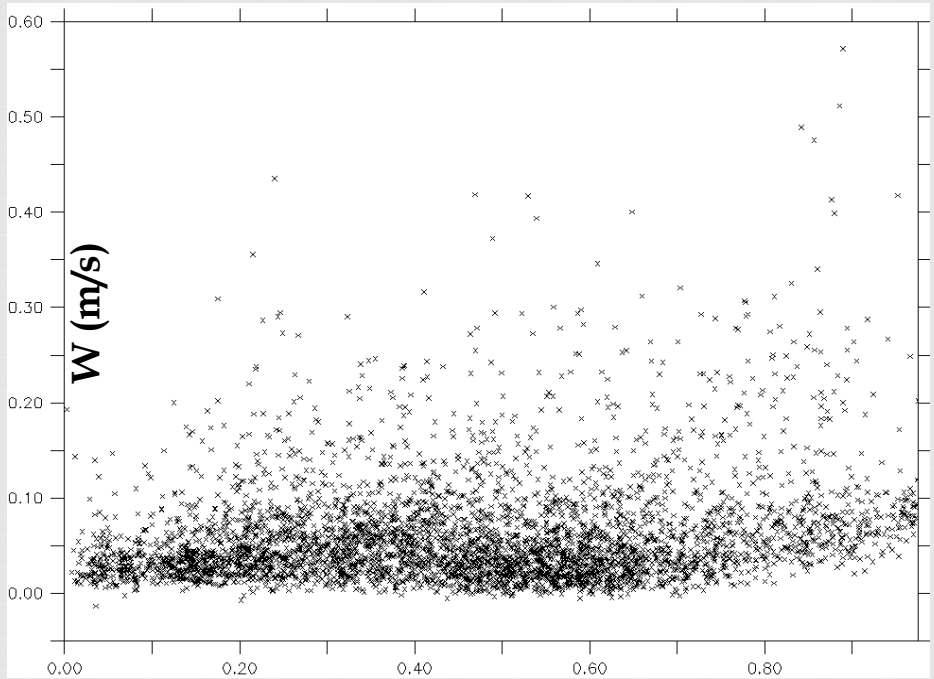

Cirrostratus
Cirrocumulus
Cirrus
High Clouds
20,000 AGL
Altostratus
Altocumulus
Middle Clouds
6,500 AGL
Low Clouds
Stratus
Nimbostratus
Stratocumulus
Cumulonimbus
Clouds with Vertical Development
Cumulus

Relationship among meteorological variables



Cloud Albedo

Distribution of the total cloud liquid water to cloud albedo



Cloud Albedo

Distribution of the **max vertical velocity** according to cloud albedo when cloud liquid water exists above the 1-km

Process to data assimilation

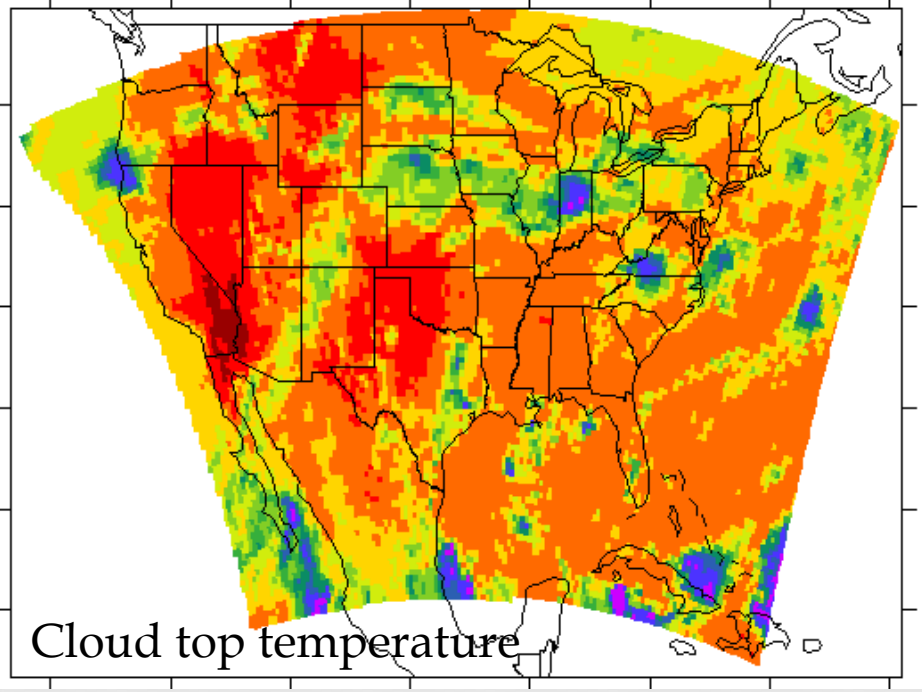
1. Compare cloud locations of the observation to the model
2. Identify discrepancies between the observation and the model clouds
   - Separate over-prediction and under-prediction
3. Based on the observation, estimate target vertical velocities
4. Adjust horizontal winds to sustain target vertical velocities

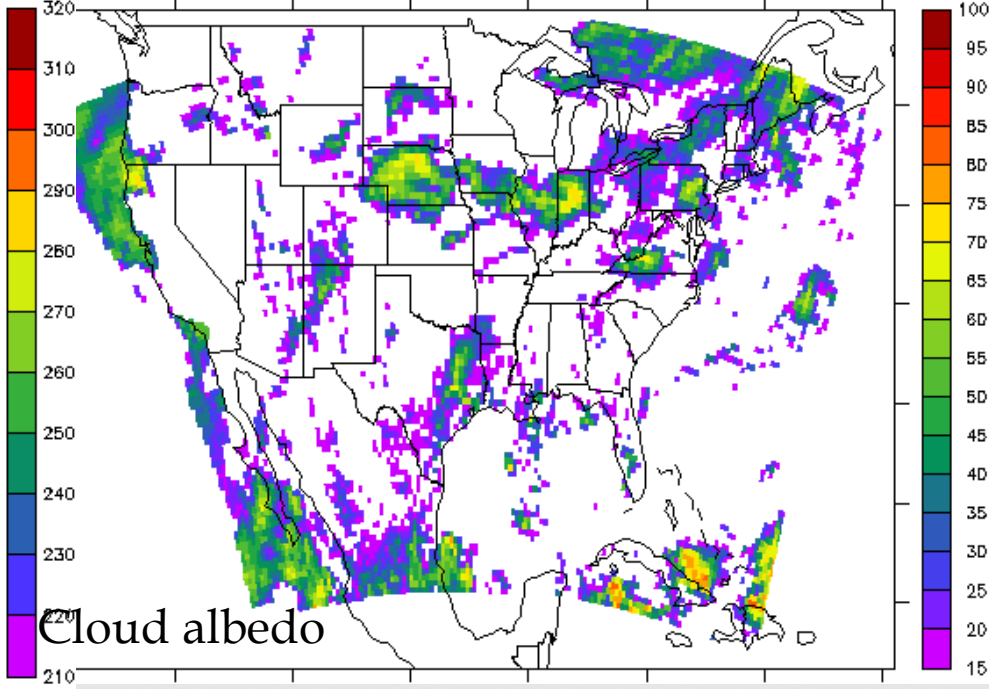
Data Description

- GOES product
  - Provided by SPoRT (Short-term Prediction Research and Transition Center) in NASA
  - Providing 4 km cloud products (e.g. **Cloud top temperature, cloud albedo**, insolation, surface albedo)
  - Assimilation time: during a daytime available for GOES cloud albedo
- WRF
  - Run time : a month in 2 hours segments with restart option

Model configuration

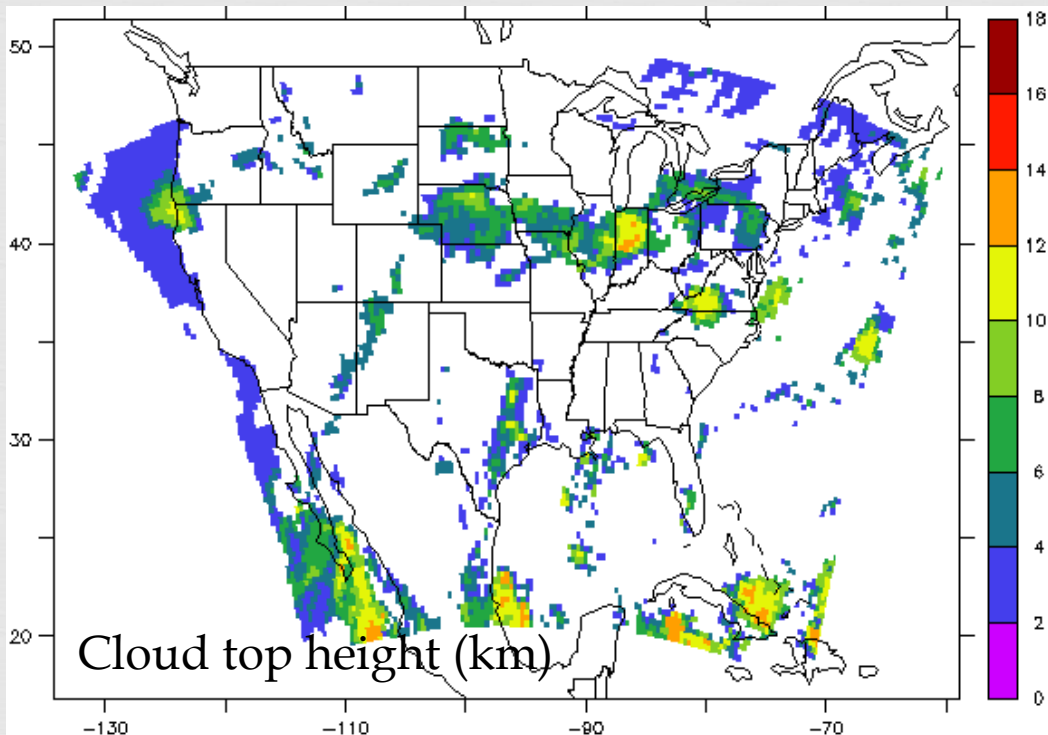
	Domain 01
Running period	August 4th – August 23th in 2006
Horizontal resolution	36 km
Time step	90s
Number of vertical levels	42
Top pressure of the model	50 mb
Shortwave radiation	Duhia
Longwave radiation	RRTM
Surface layer	Monin-Obukhov similarity
Land surface layer	Noah (4-soil layer)
PBL	YSU
Microphysics	LIN
Cumulus physics	Kain-Fritsch
Grid nudging	Horizontal wind
Meteotological input data	EDAS

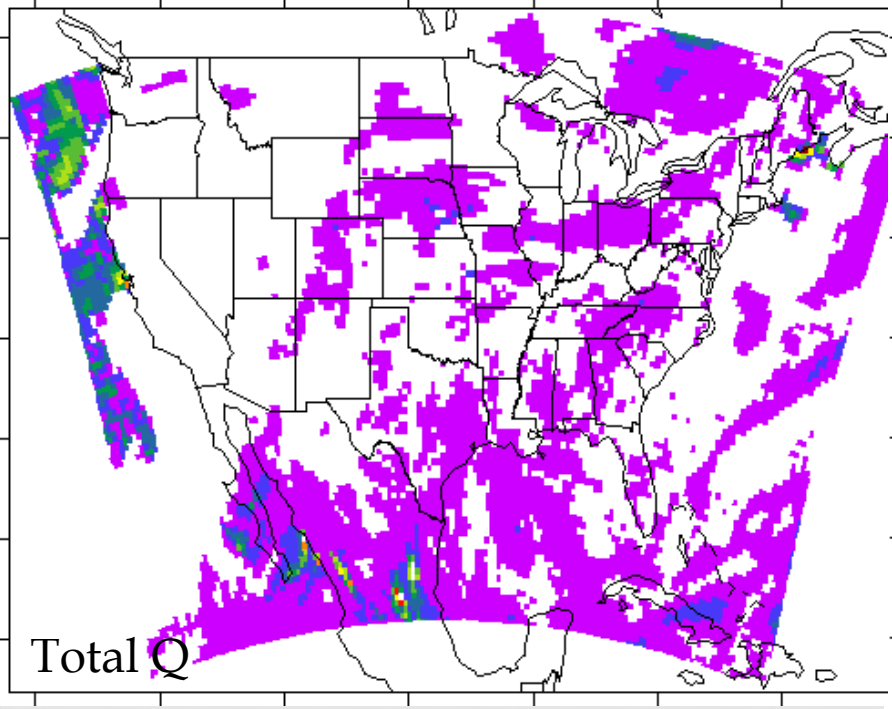


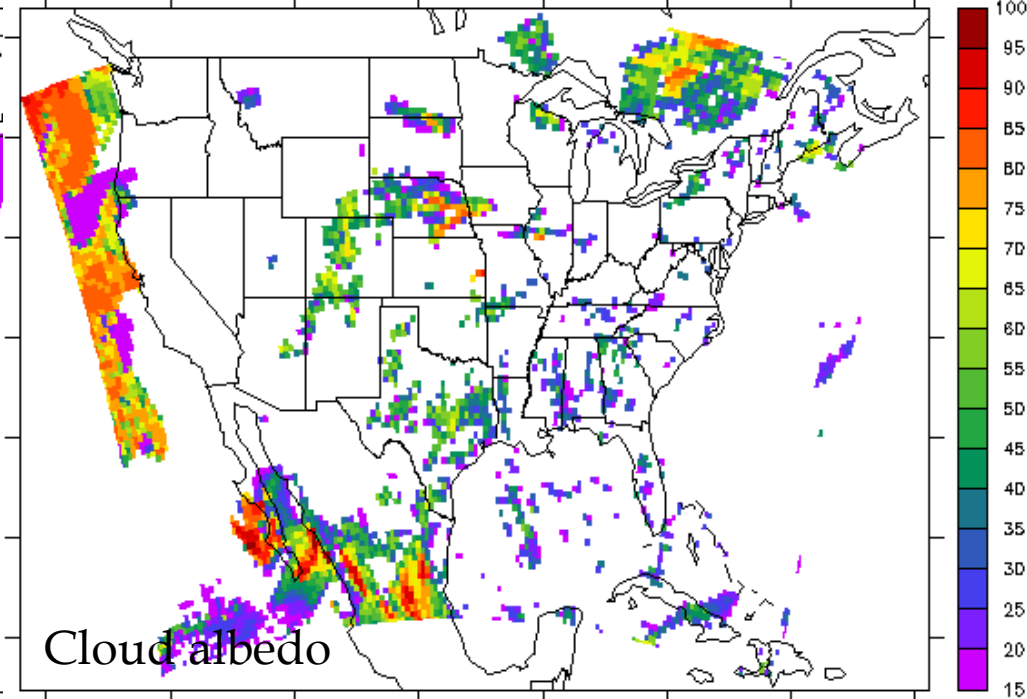


GOES retrieval data at August 7th, 2006 at 17 UTC

If cloud albedo is greater than 15, and cloud top temperature is less than that of height Z(km) ($0.5 \le Z \le 2.0$)
$Z=1.5x(3.5-\text{terrain height})/3.5+0.5$
Then, height corresponding the cloud top temperature is cloud top height.

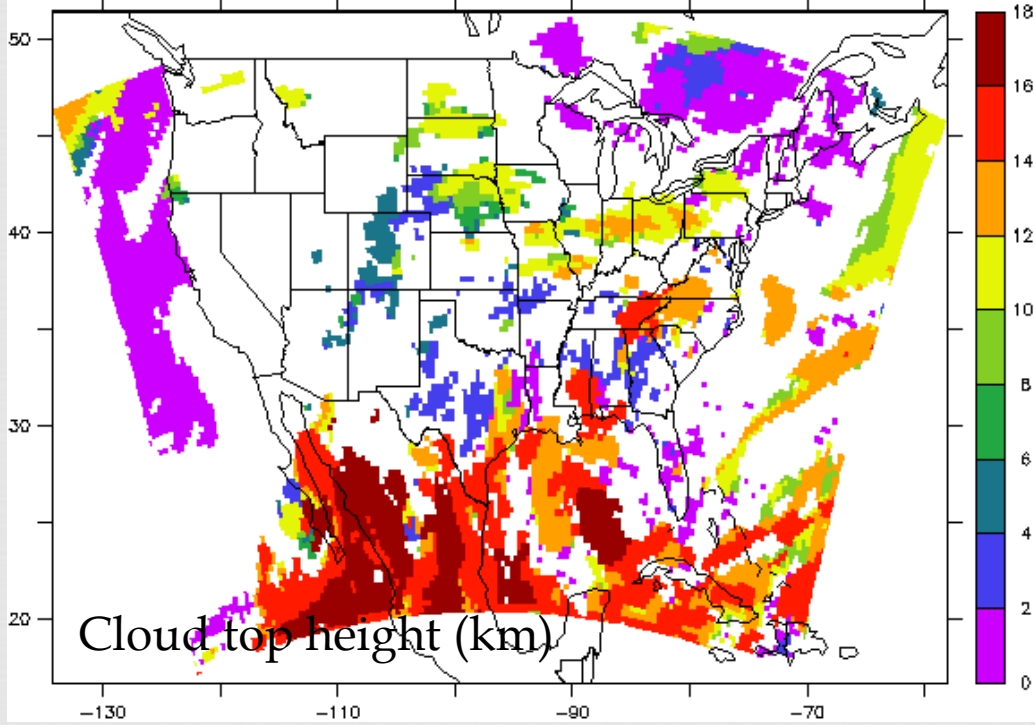






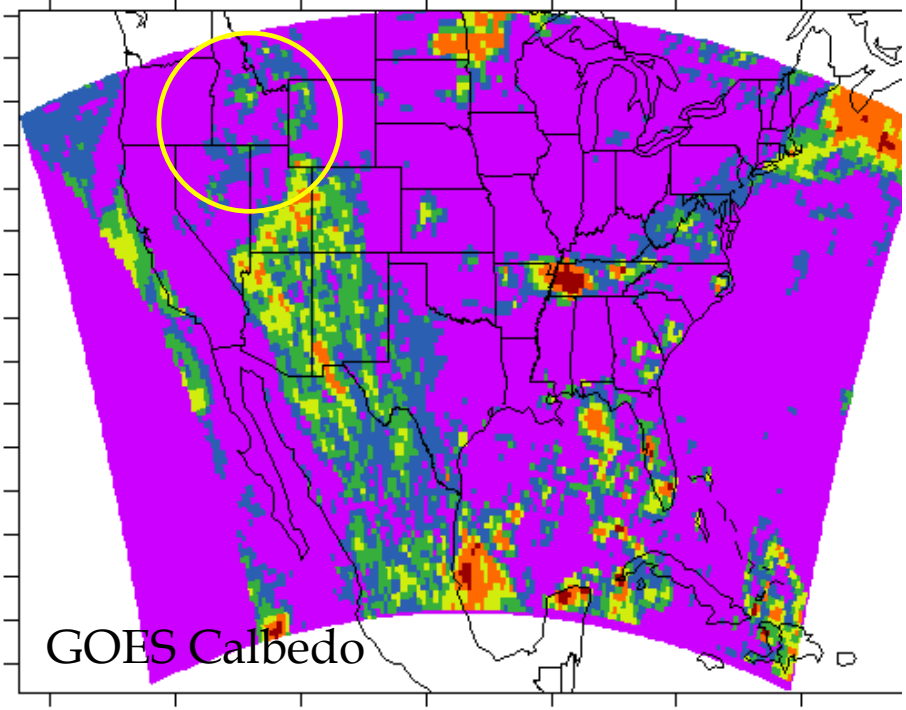
Model output at August 7th, 2006
at 17 UTC

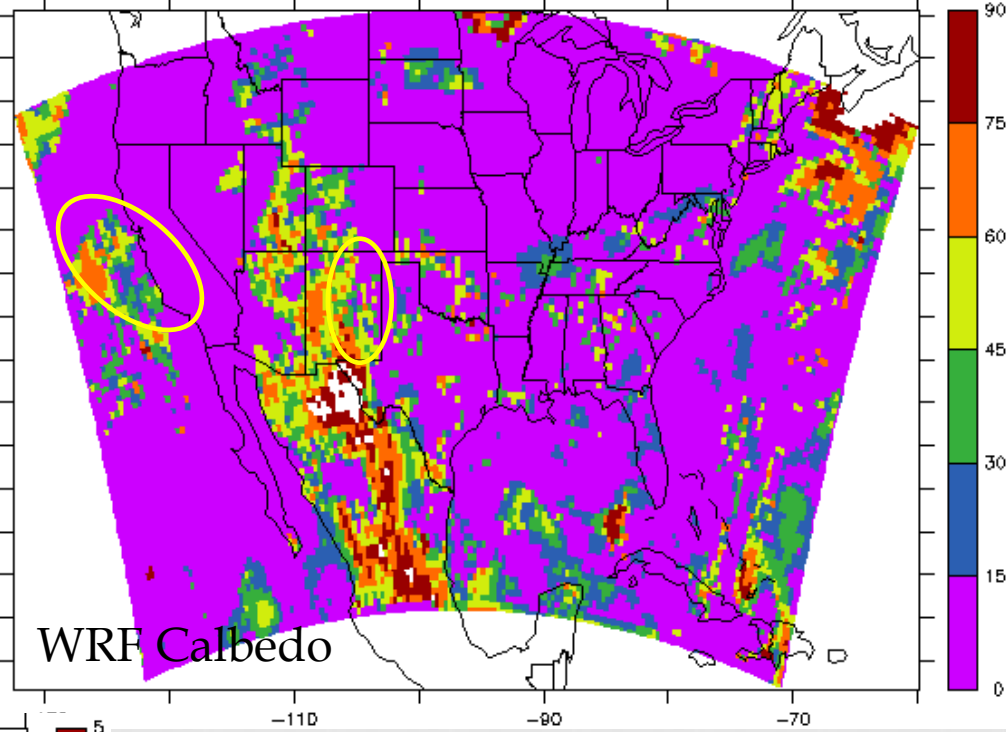
Total mixing ratio range from 10^{-6} to 0.005 (plots is total Q x 1000)
Cloud top height is in km

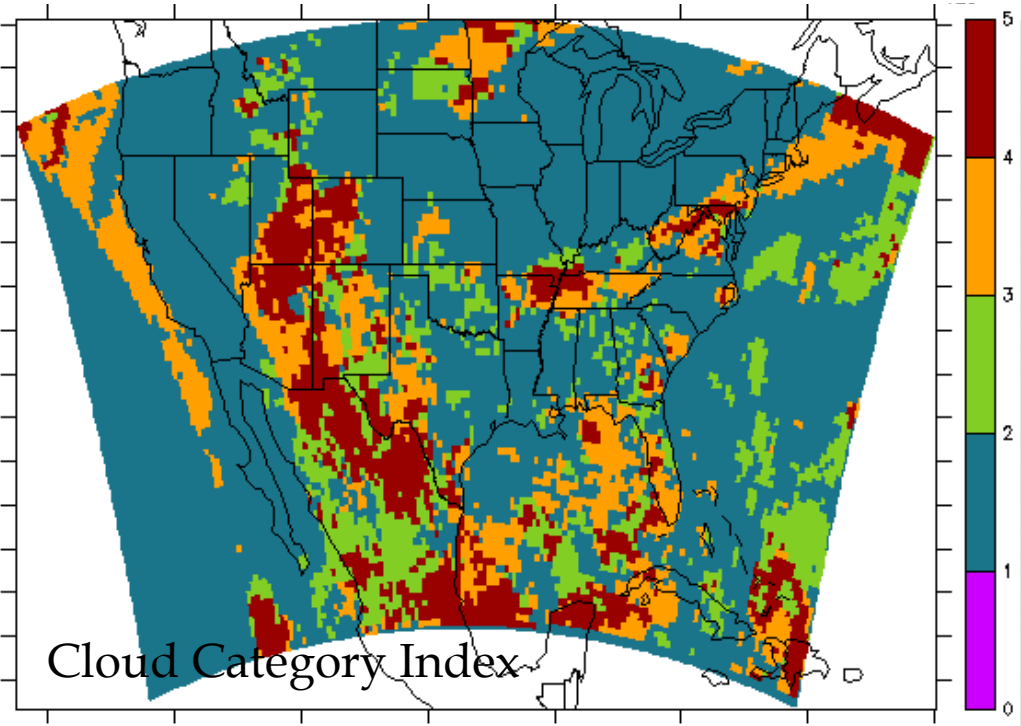


Determination for adjusting clouds

- Limit the cloud adjustment to high and thick clouds (e.g. Cumulonimbus, Altostratus)
- From GOES
  - Two parameters, cloud albedo and cloud top temperature, are used to determine clouds
    - Cloud albedo > 0.15
    - Height of cloud top temperature > (0.5 ~ 2km)
- From WRF
  - Total mixing ratio, sum of cloud mixing ratio and ice mixing ratio > 1.0E-6
  - Cloud albedo is calculated by 1- insolation/max_insolation
  - The height of maximum q > (0.5 ~ 2km)
- Clouds in the observation and the model can be classified to four categories.





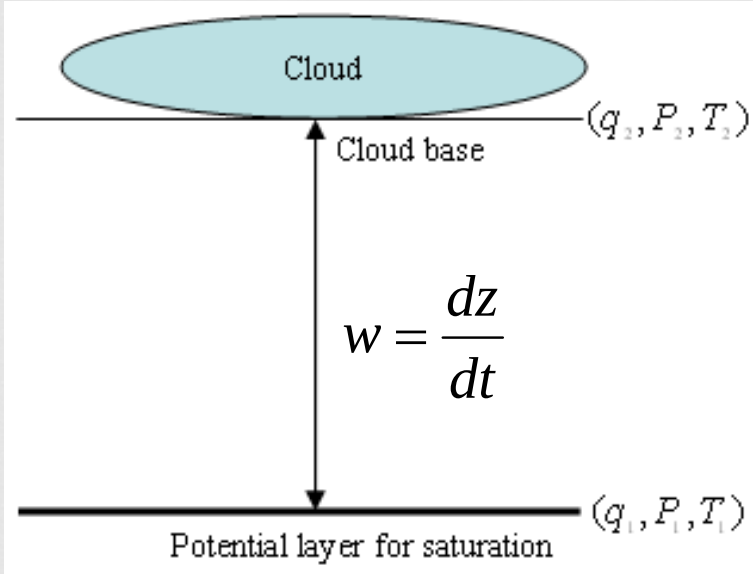


Cloud Category Index:
1(Blue): GOES clear & WRF clear
2(Green): GOES clear & WRF cloudy (over-prediction)
3(Yellow): GOES cloudy & WRF clear (under-prediction)
4(Red): GOES cloudy & WRF cloudy

Date: August 4th, 2006 at 20GMT

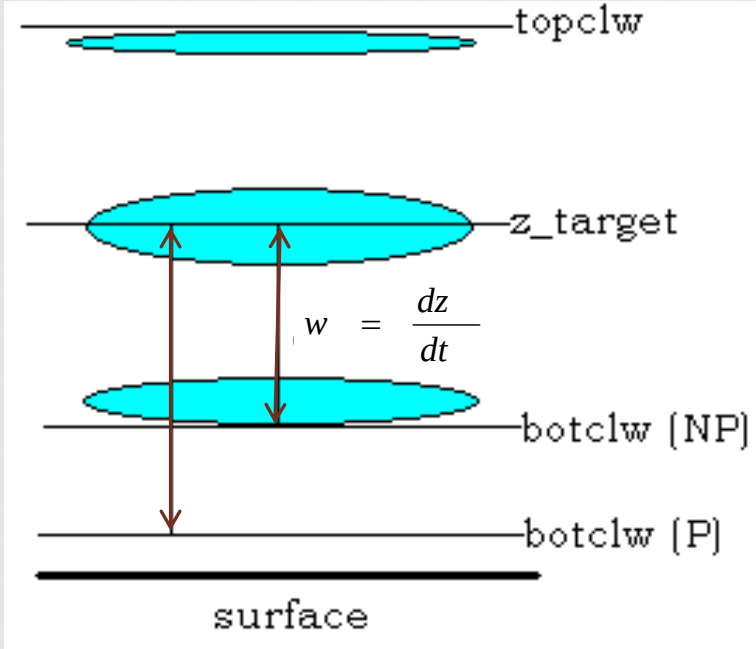
Analytical Approaches

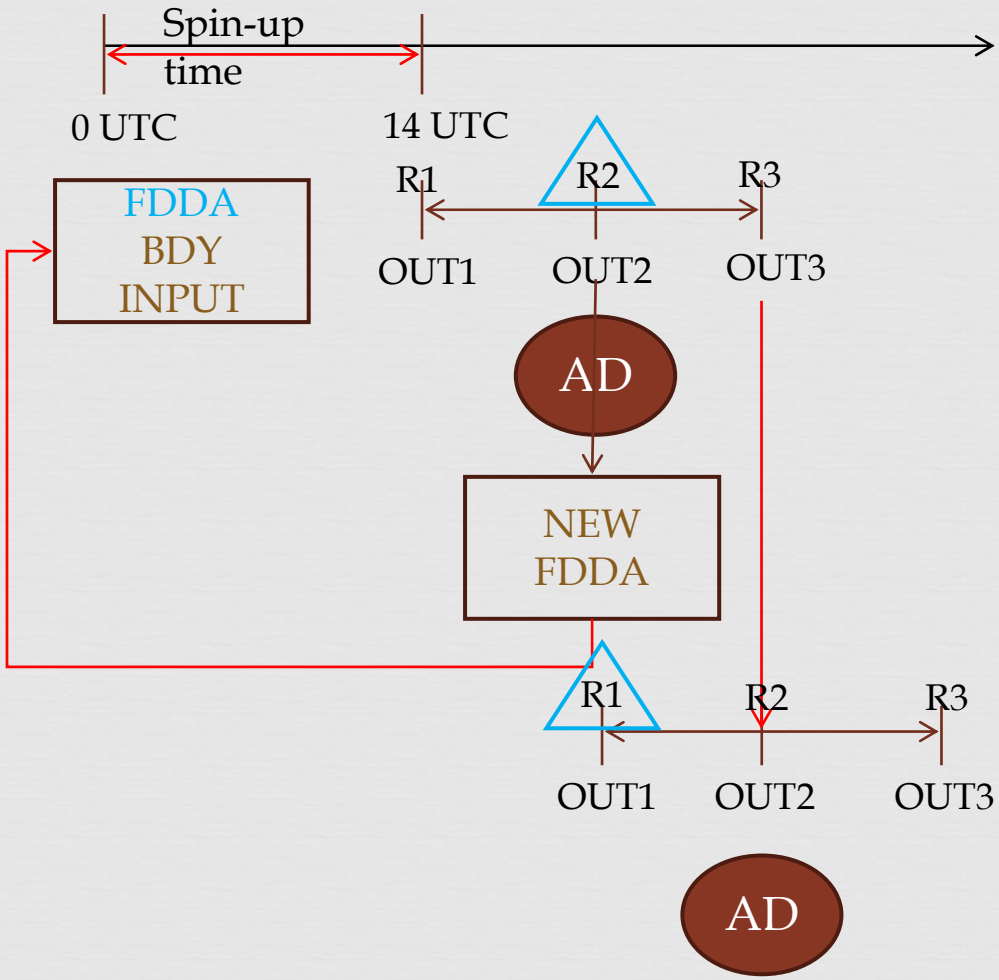
- **Under-prediction**
- Purpose : to generate clouds over the column
- Assumption
  - The clouds are in developing stage, meaning that maximum w is in the cloud base height.
  - A parcel at the cloud base should be saturated to form clouds



Analytical Approaches

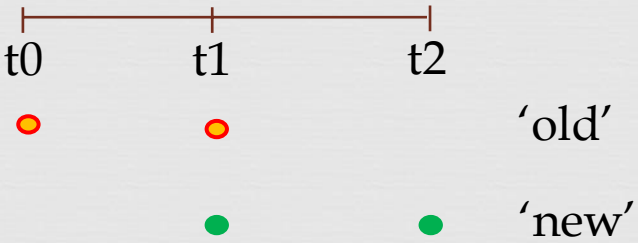
- **Over-prediction**
- technique: introducing subsidence to remove clouds
- Assumption
  - Separate non-precipitable (NP) and precipitable(P) clouds



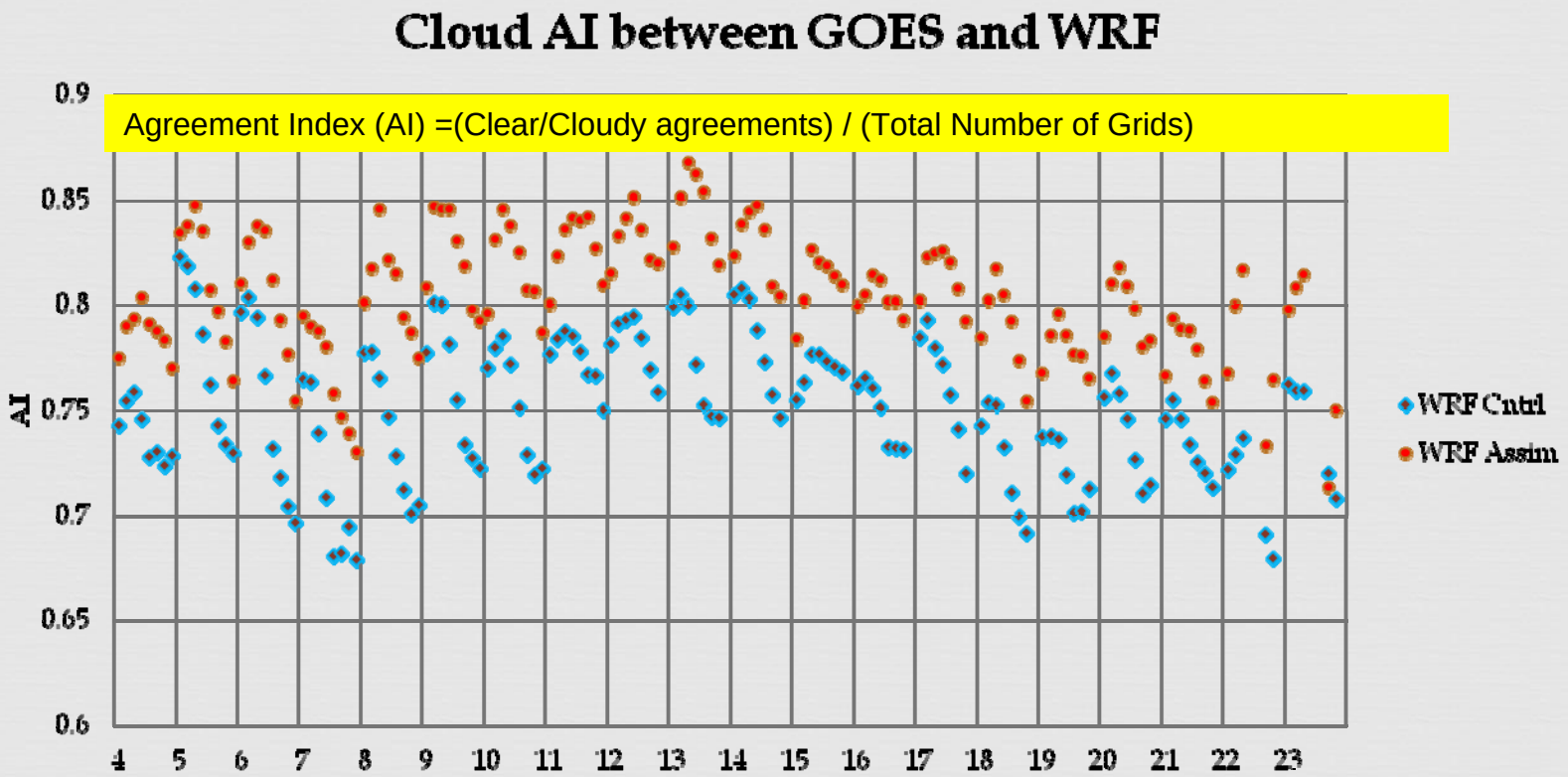


AD (Analytical methods for Disagreement areas)
-Take vertical velocities for under-prediction and over-prediction areas from the cloud category index

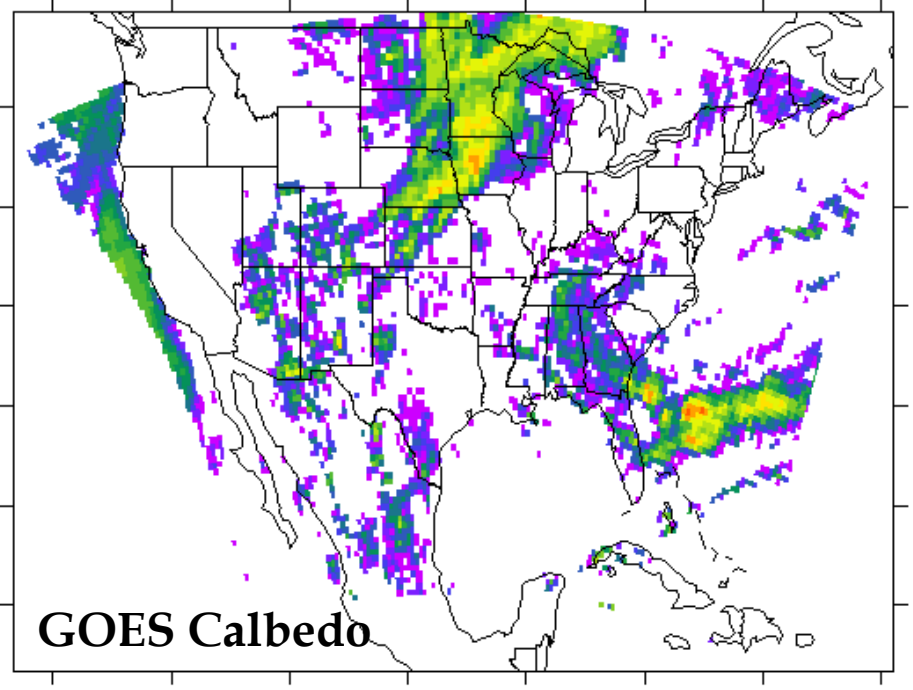
❖ FDDA nudging
Based on the 1Dvar output, U and V winds are changed

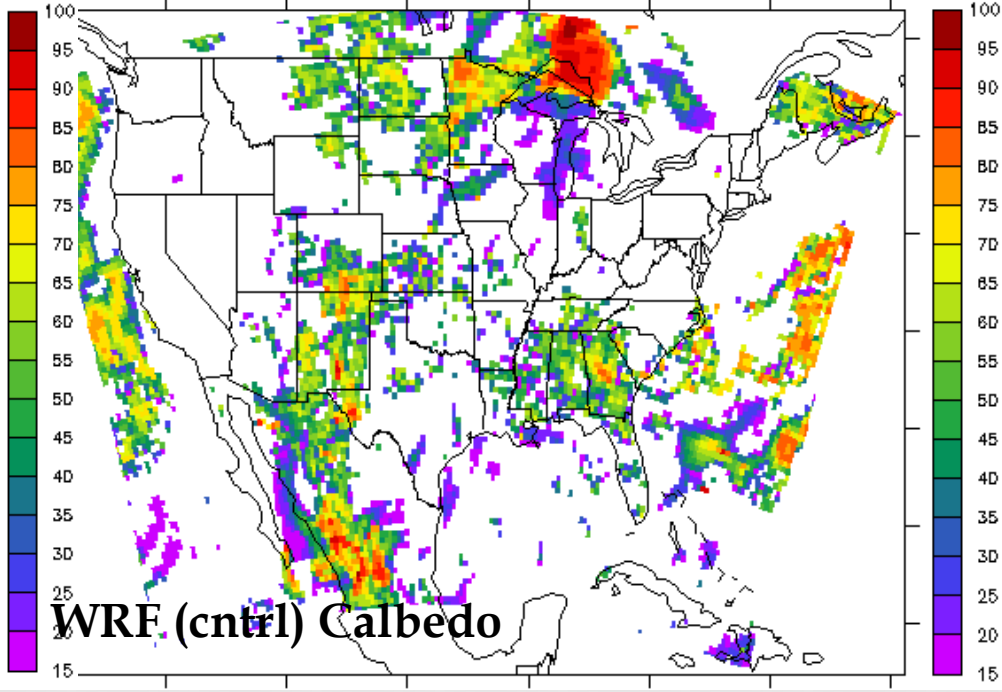


Time series for cloud evaluation

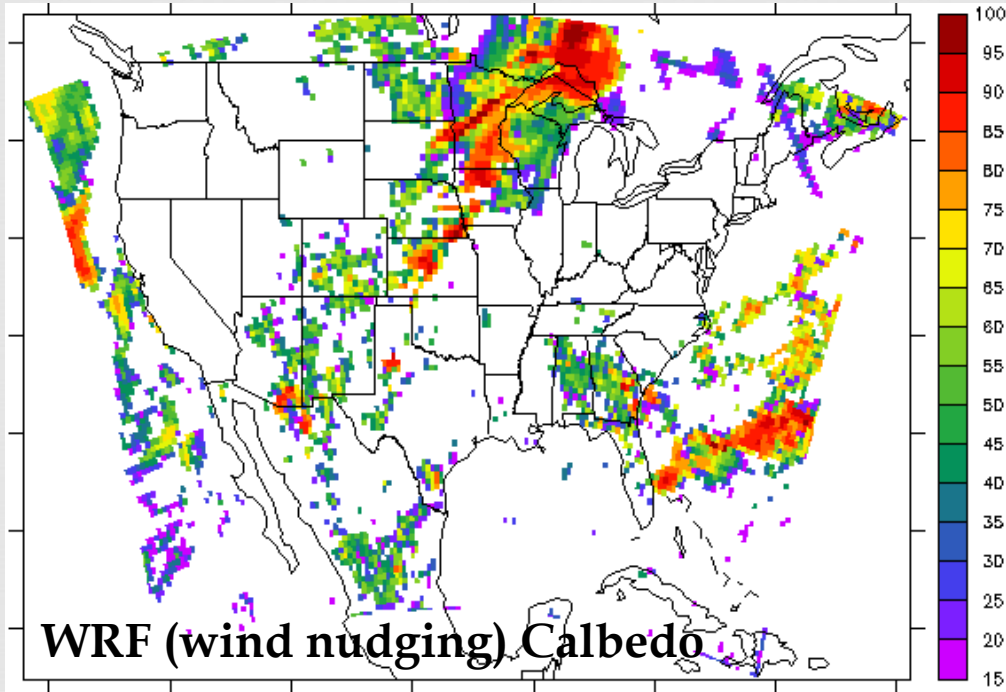


Each day, AI for 8 hours (16~23UTC) is distributed. Overall, AI between the observation and the model is increased by about 7%.

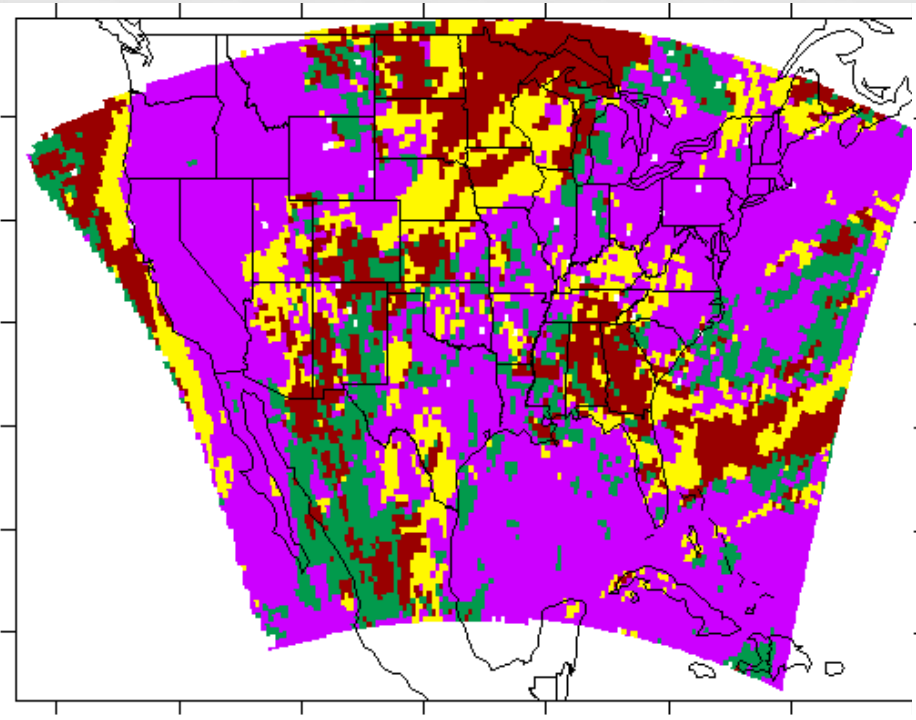


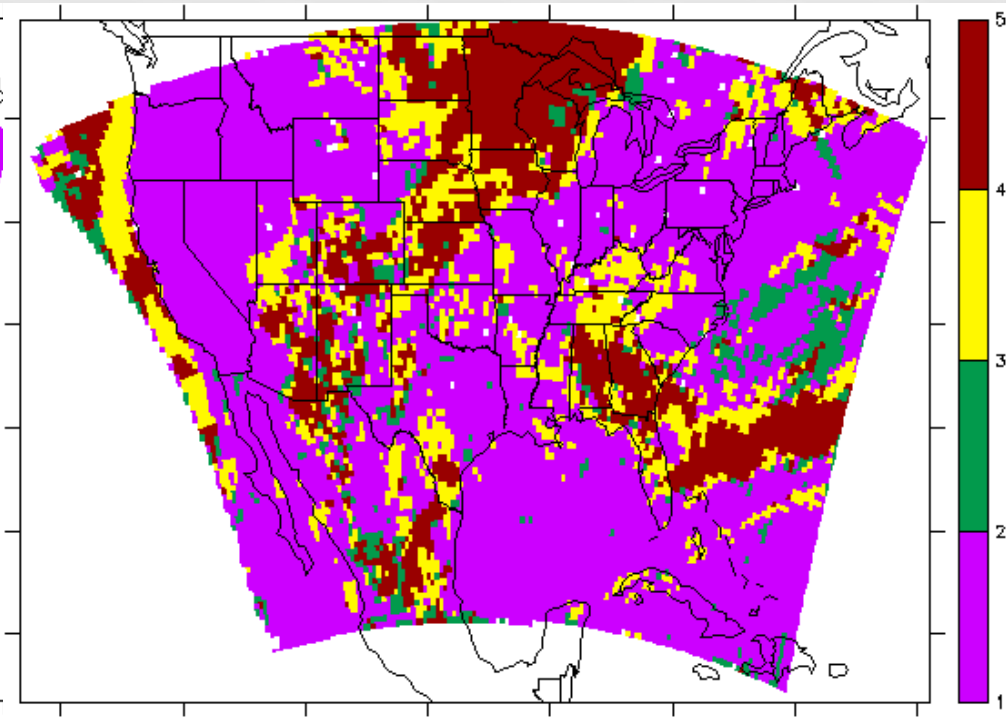


Date: August 13th , 2006 at 19 UTC



Agreement Index





AI for WRF_cntrl

GOES \ WRF	NC	C	
NC	7174	1824	8998
C	1943	2049	3992
	9117	3873	12990

AI for WRF_assim

GOES \ WRF	NC	C	
NC	8266	732	8998
C	1892	2100	3992
	10158	2832	12990

Conclusion

- **Cloud albedo has an exponential relationship with cloud liquid water, but there is no significant relationship between cloud thickness and the magnitude of vertical velocity.**
- **Analytical approach helped to improve cloud simulation in the model, AI is increased by about 7~10%.**
- **Dynamical adjustment improves clearing of clouds, but is not sufficient to generate clouds because of a lack of moisture.**

Acknowledgment

- **The findings presented here were accomplished under partial support from NASA Science Mission Directorate Applied Sciences Program and the Texas Commission on Environmental Quality (TCEQ).**

- **Note the results in this study do not necessarily reflect policy or science positions by the funding agencies.**