CORRECTING CAMx CLOUD FIELD BASED ON GOES OBSERVED CLOUDS

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Motivation for Satellite Data Assimilation

- Good estimates of photolysis rates are essential in reducing the uncertainty in air quality modeling.
- Off-line air quality models such as CAMx use a two-step approach for correcting photolysis rates for cloud cover and they rely on meteorological models for cloud information.
- One of the weakest areas of meteorological models is the correct prediction of clouds at the correct time and position.
- Cloud correction in air quality models is highly parameterized and therefore introduces a large uncertainty.
- Unlike the limited sparse surface data, satellite data provide pixel integral quantity compatible with model grid.

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Correcting Clear Sky Photolysis Rates for Cloud Cover in CAMx (RADM Method)

Photolysis Rates for CAMx:

- Step 1: Clear sky rates are computed

$$J = \int_{\lambda_1}^{\lambda_2} \sigma(\lambda)\varphi(\lambda)F(\lambda)d\lambda$$

Where σ(λ) (*m2/molecule*) is the absorption cross-section for the molecule undergoing photodissociation as a function of wavelength λ (*μm*); φ(λ), quantum yield (*molecules/photon*), is the probability that the molecule photodissociates in the direction of the pertinent reaction; and F(λ) is the actinic flux (*photons/m2/s/μm*).

- Step 2: Rates are corrected for cloudy sky (Chang et al., 1987)

Cloud transmissivity

$$J_{below} = J_{clear}\left[1 + cfrac(1.6tr_{cld}\cos(\theta) - 1)\right]$$

$$J_{above} = J_{clear}\left[1 + cfrac((1 - tr_{cld})\cos(\theta))\right]$$

Getting Cloud Transmissivity in CAMx

Transmissivity calculation in CAMx (RADM parameterization):

1. From model specific humidity and temperature get liquid water content: L=f(q,T) (g/m^3)

2. Compute liquid water path: W=LΔz g/m^2 (Δz the cloud depth above the current grid cell)

3. Compute cloud optical thickness from an empirical formula (Stephens, 1978; ρ_w is the density of the liquid water (10^6 g/m^3), and *r* is the mean cloud drop radius (10^{-5} m)) .

$$\tau_c = \frac{3W}{2\rho_w r}$$

4. Finally, assuming a scattering phase-function asymmetry factor (β) of .86 (Chang et al., 1987; Hansen and Travis, 1974), cloud transmissivity is calculated by:

$$tr_{cld} = \frac{5 - e^{-\tau_{cld}}}{4 + 3\tau_{cld}(1-\beta)}$$

cloud information is obtained from the met. model

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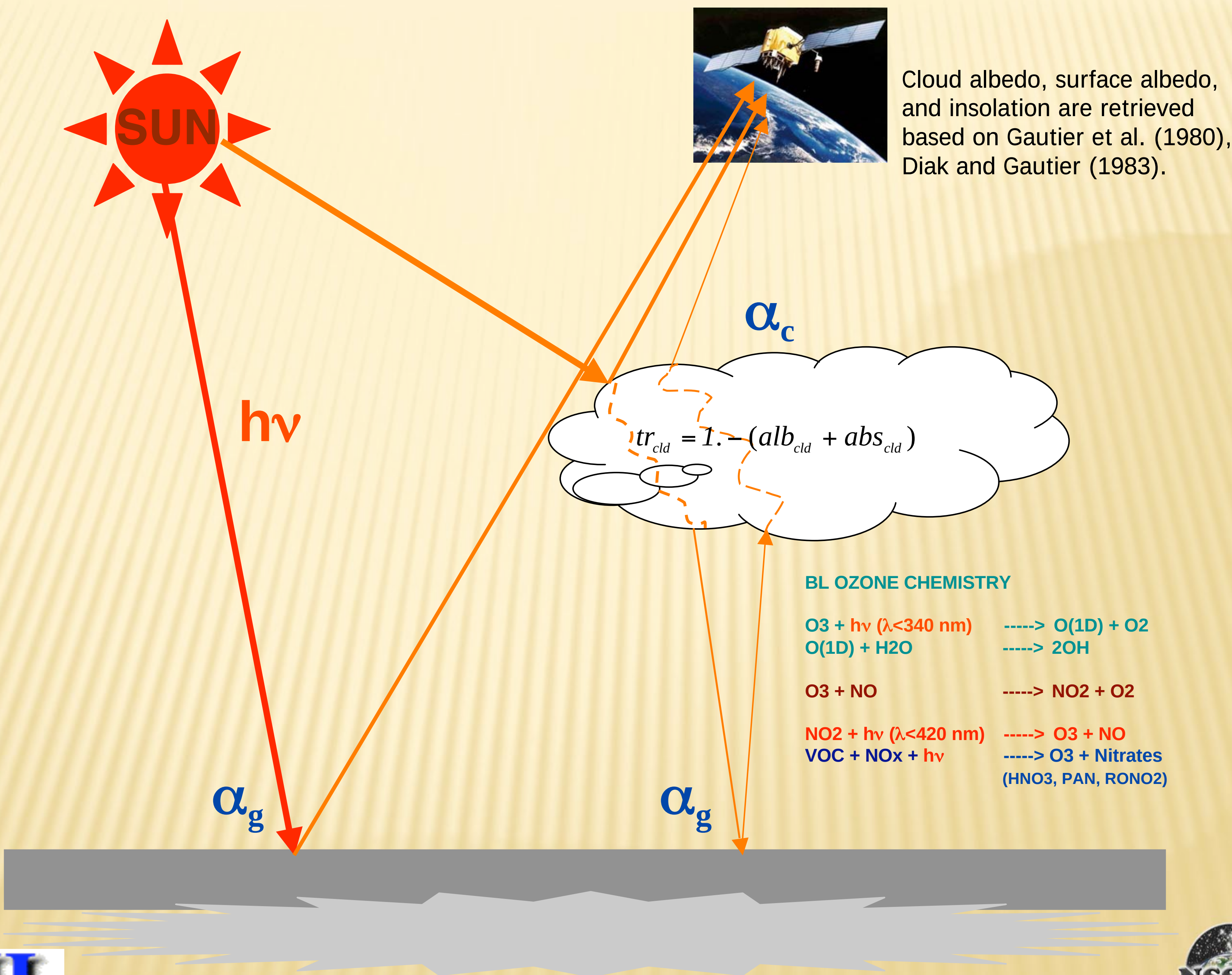
Retrieval of Cloud/Surface Albedo and Insolation



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GOES-CAMx INTERFACE

Cloud transmissivity (calculated from satellite retrieved cloud albedo), cloud top pressure, and cloud fraction are prepared for input to MM5CAMx

$$tr_{cld} = 1. - (alb_{cld} + abs_{cld})$$

MODIFIED MM5CAMx

GOES retrievals replaces MM5 cloud information being passed to CAMx. Cloud fraction, transmissivity, cloud base and top heights are used to calculate cloud transmissivity to be passed to CAMx.

READINP in CAMx

In subroutine READINP, clear sky photolysis rates will be adjusted for cloud cover based on GOES cloud fraction and cloud transmissivity information.

$$J_{below} = J_{clear}\left[1 + cfrac(1.6tr\cos(\theta) - 1)\right]$$

$$J_{above} = J_{clear}\left[1 + cfrac((1 - tr)\cos(\theta))\right]$$

Interpolated in between.

Cloud Base According to Lifting Condensation Level

$$T_c = B/\ln\left[\frac{A\varepsilon}{wp_0}\left(\frac{T_0}{T_c}\right)^{1/k}\right]$$

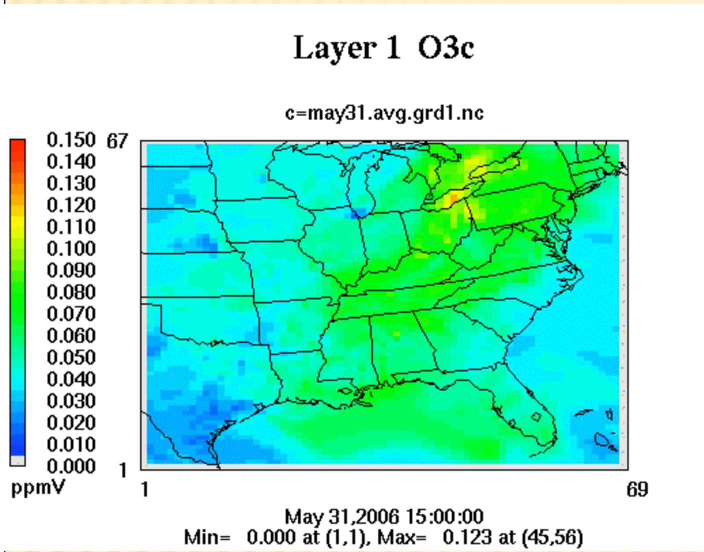
MODEL SIMULATIONS JUNE-SEPT 2006

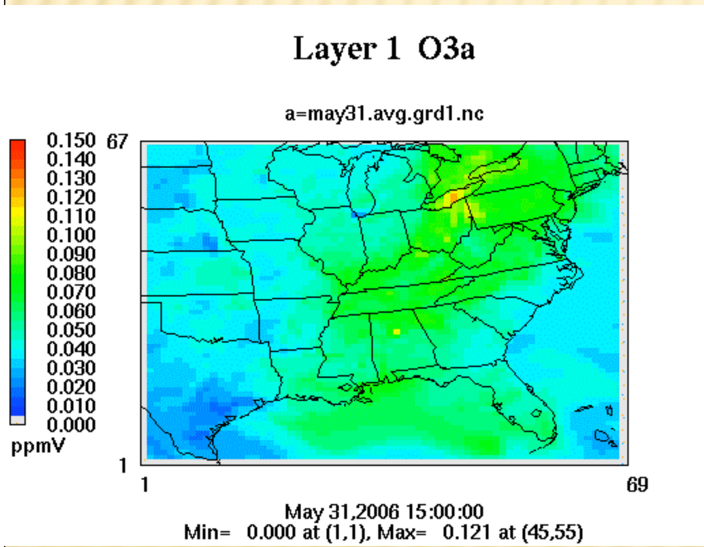
- MM5 Files were provided by TCEQ (Bright Dornblaser)
- Modified MM5CAMx
- CAMx configuration is similar to TCEQ CAMx simulations for June-aug 2006.

O3 Difference At 11:00 am, May 31, 2006 (SATCLD-CNTRL)

36-km grid

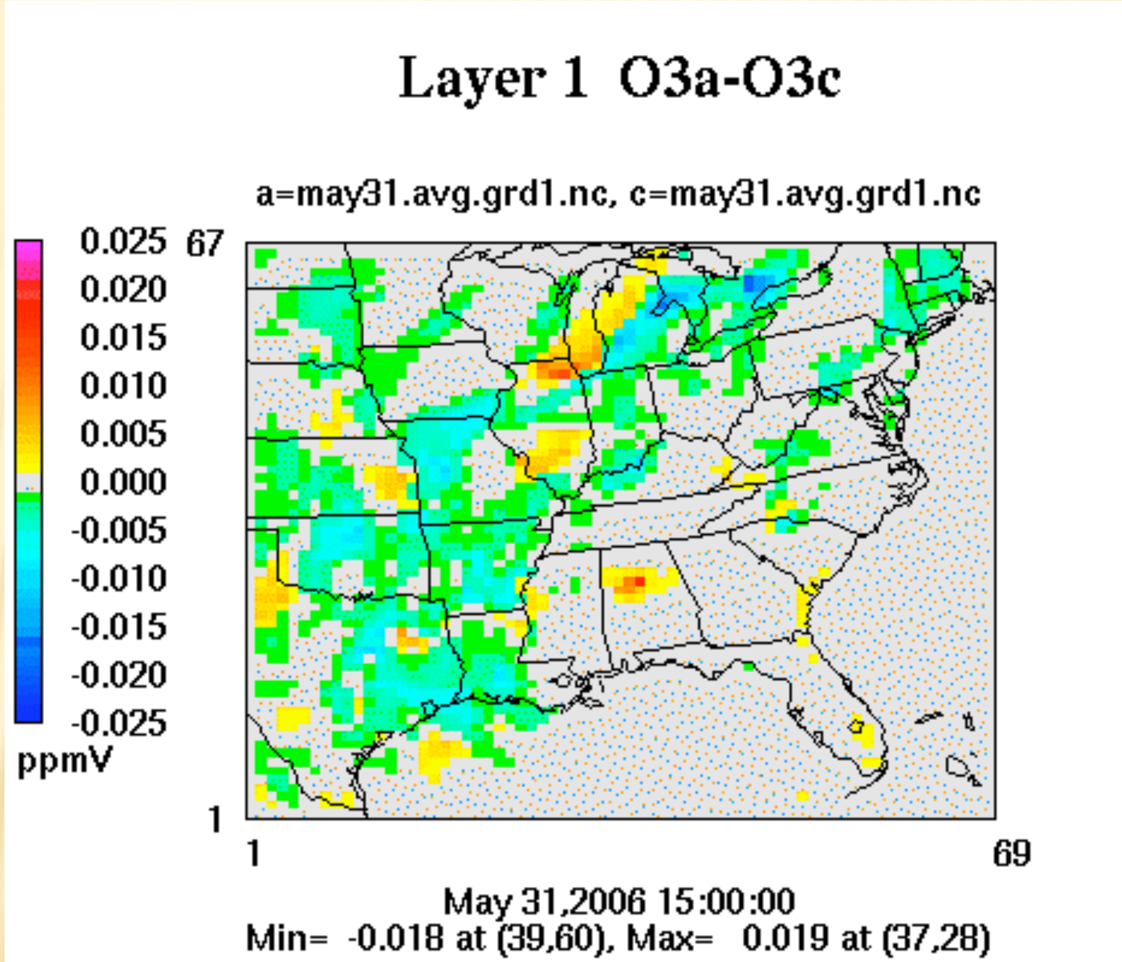
CNTRL





SATCLD

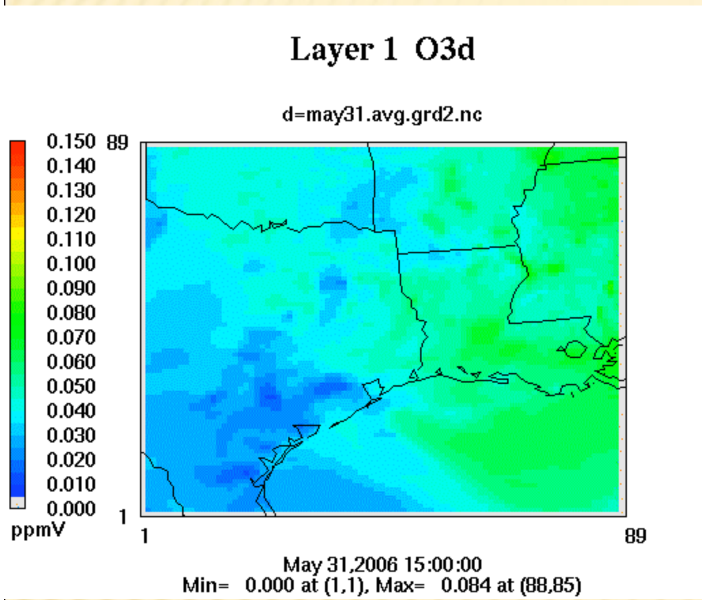
SATCLD - CNTRL

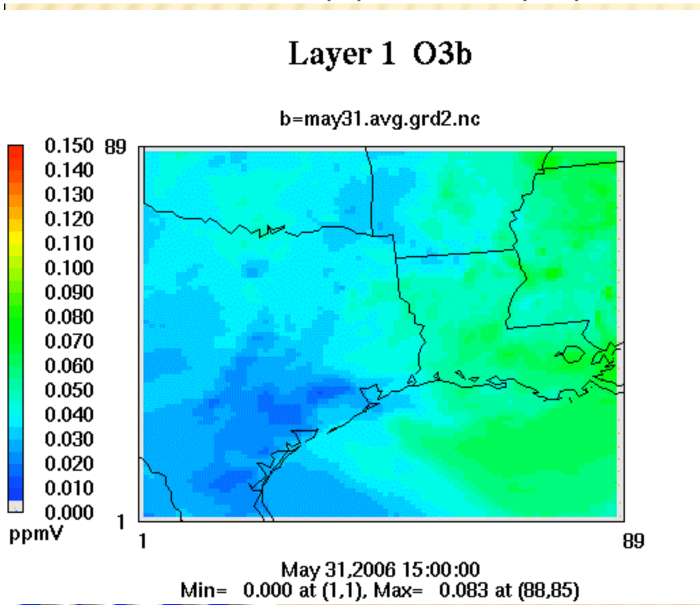


O3 Difference At 11:00 am, May 31, 2006 (SATCLD-CNTRL)

12-km grid

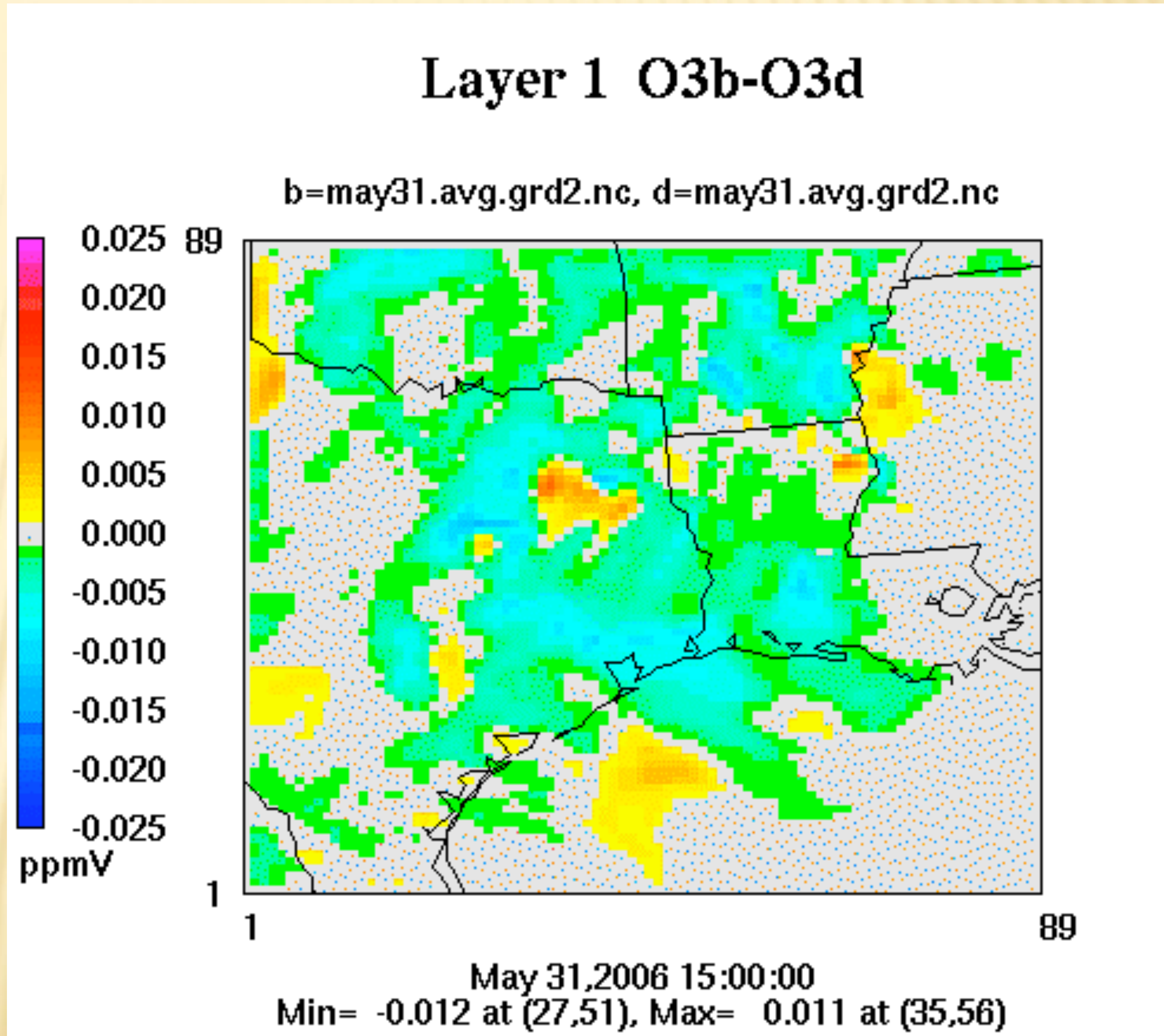
CNTRL





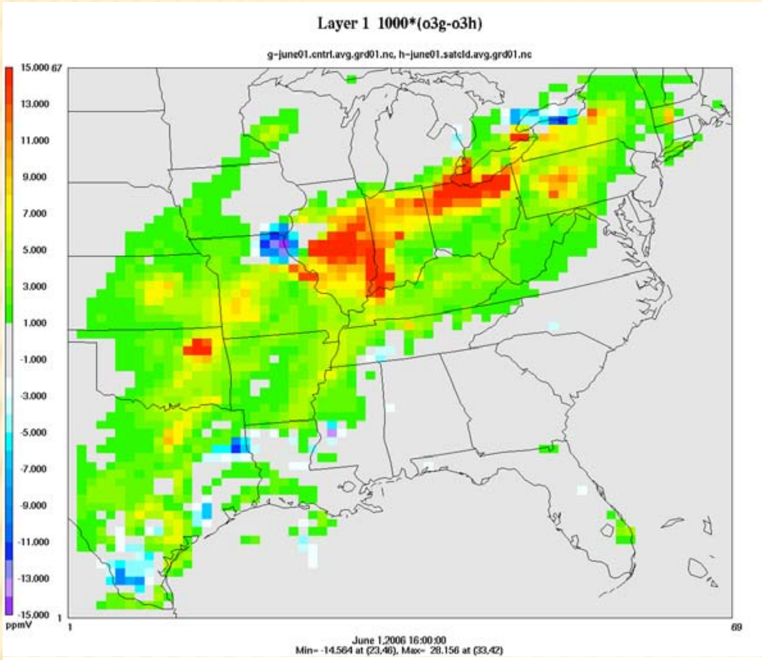
SATCLD

SATCLD - CNTRL

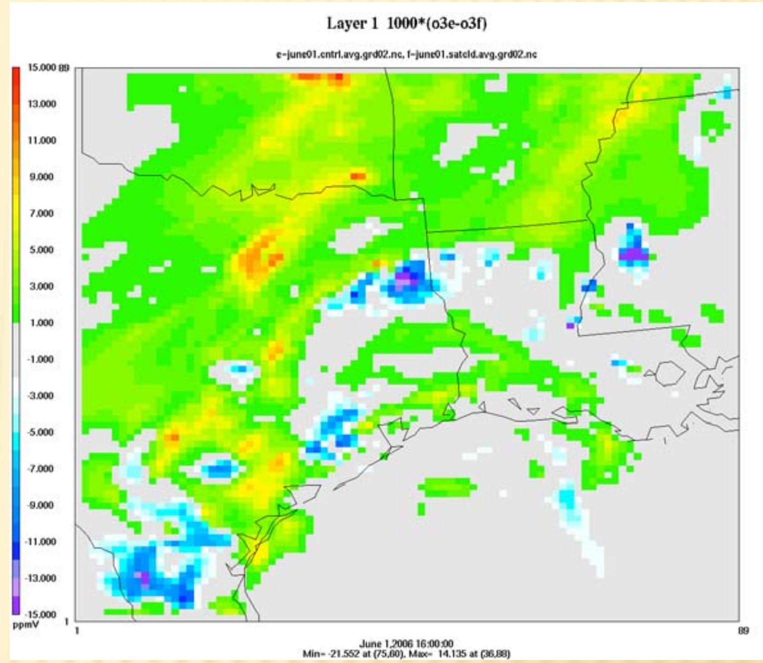


O3 Difference At 10:00 am, June 1, 2006 (CNTRL-SATCLD)

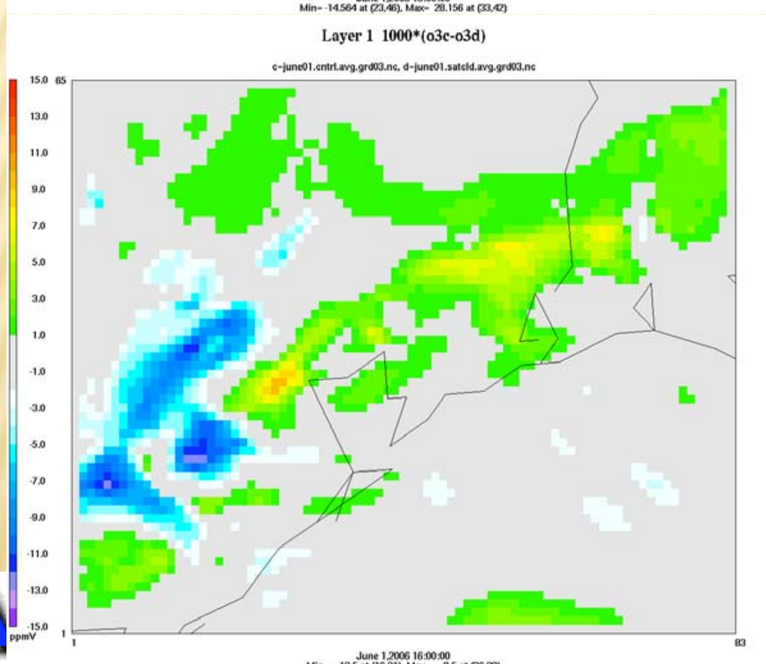
36-km



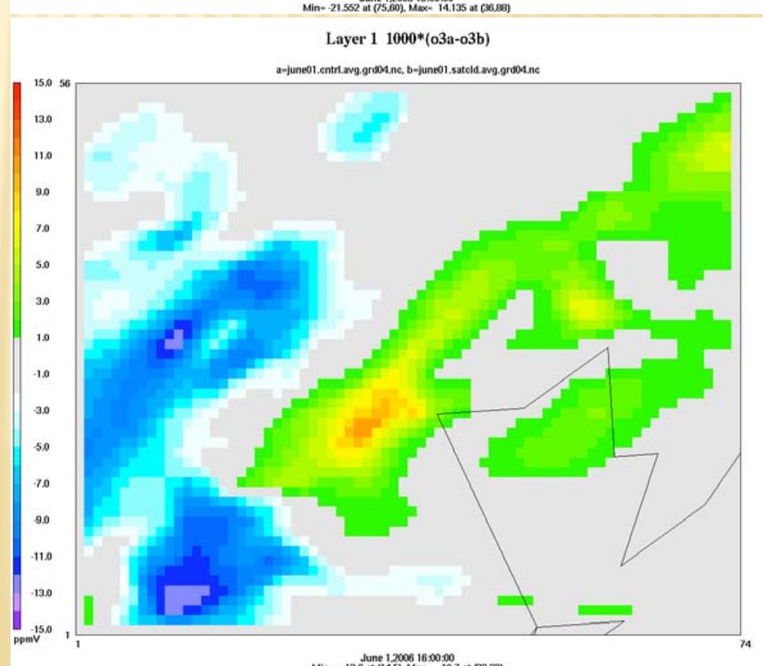
12-km



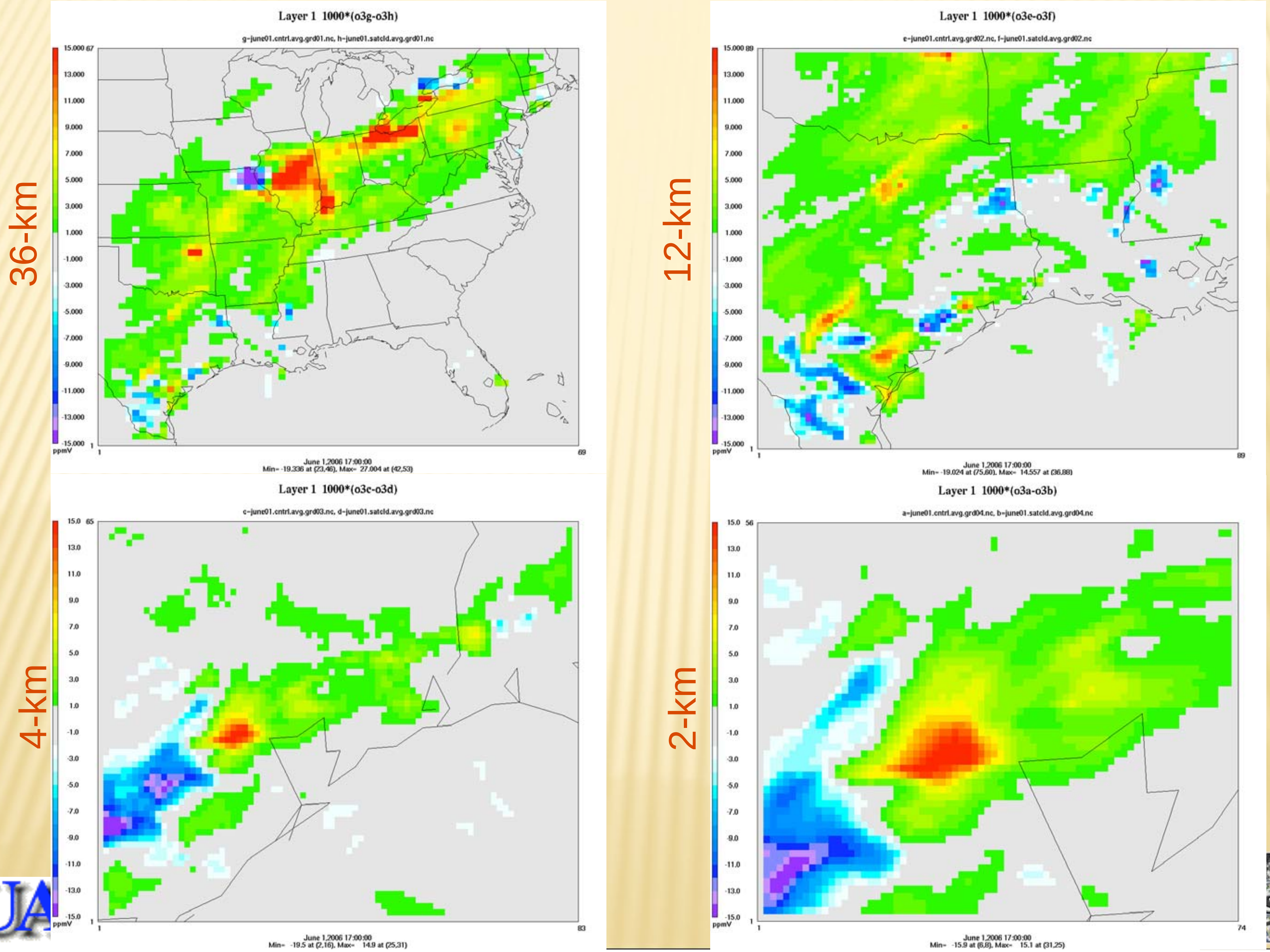
4-km



2-km

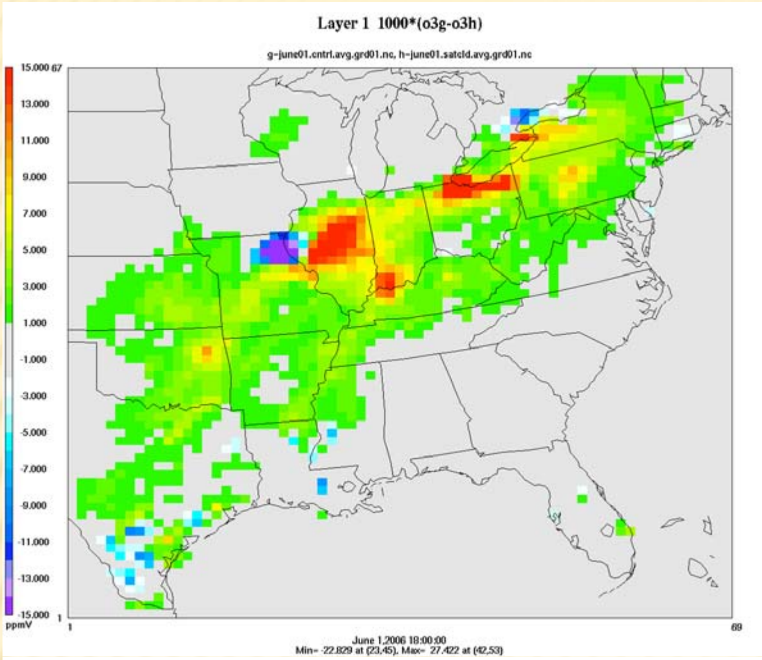


O3 Difference At 11:00 am, June 1, 2006 (CNTRL-SATCLD)

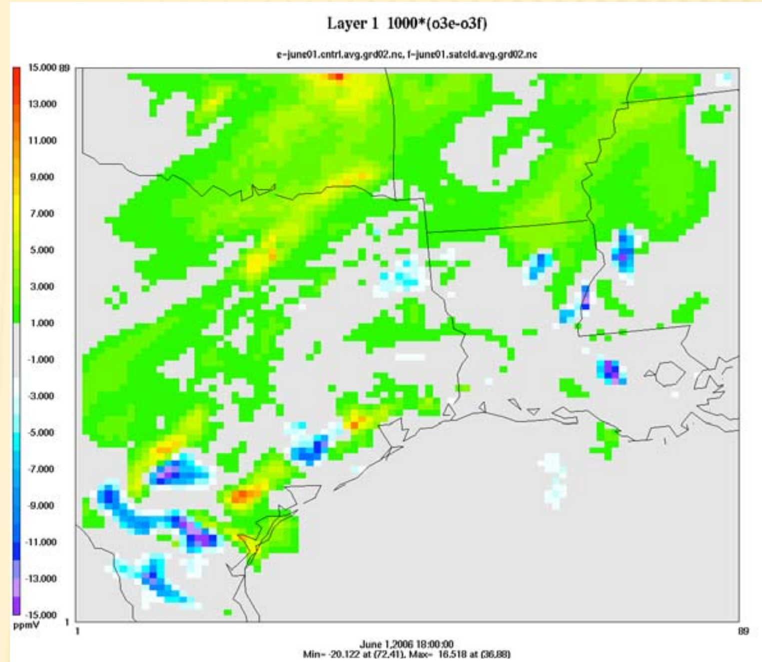


O3 Difference At 12:00 am, June 1, 2006 (CNTRL-SATCLD)

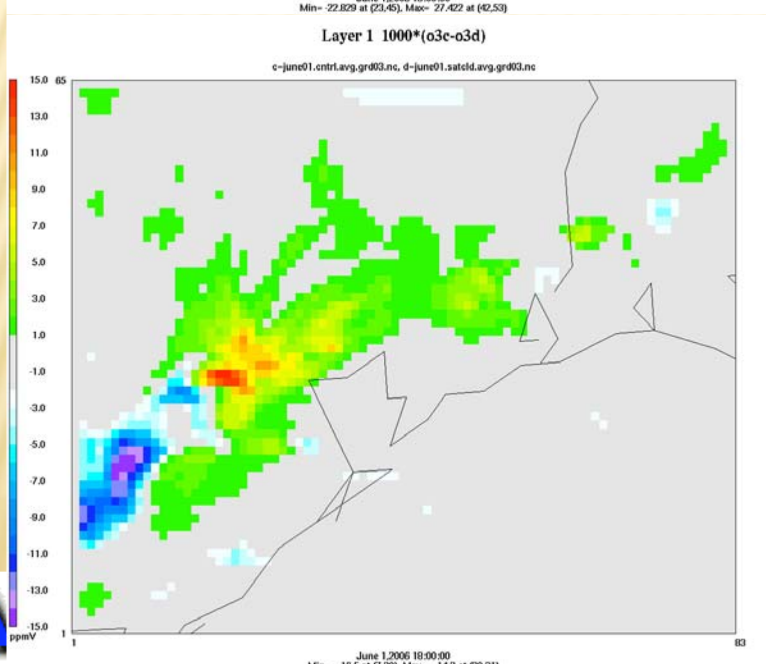
36-km



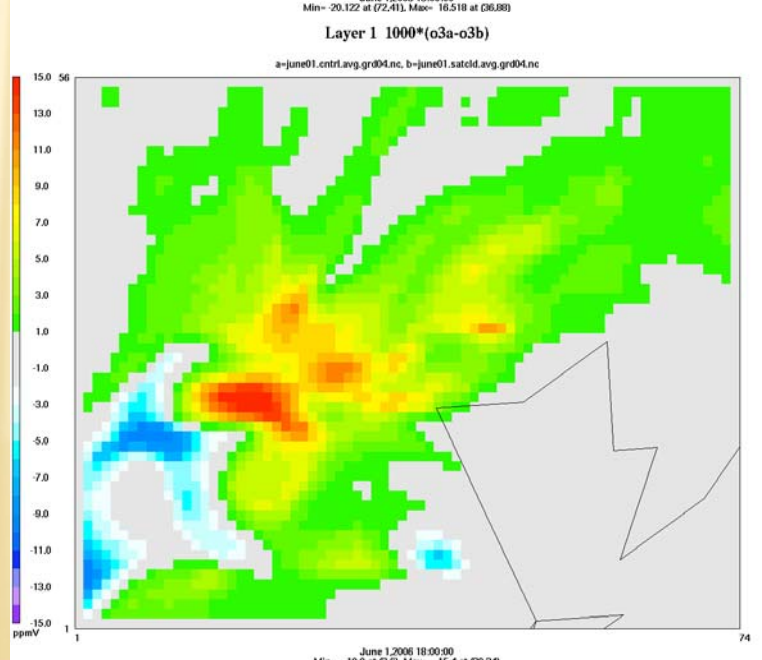
12-km



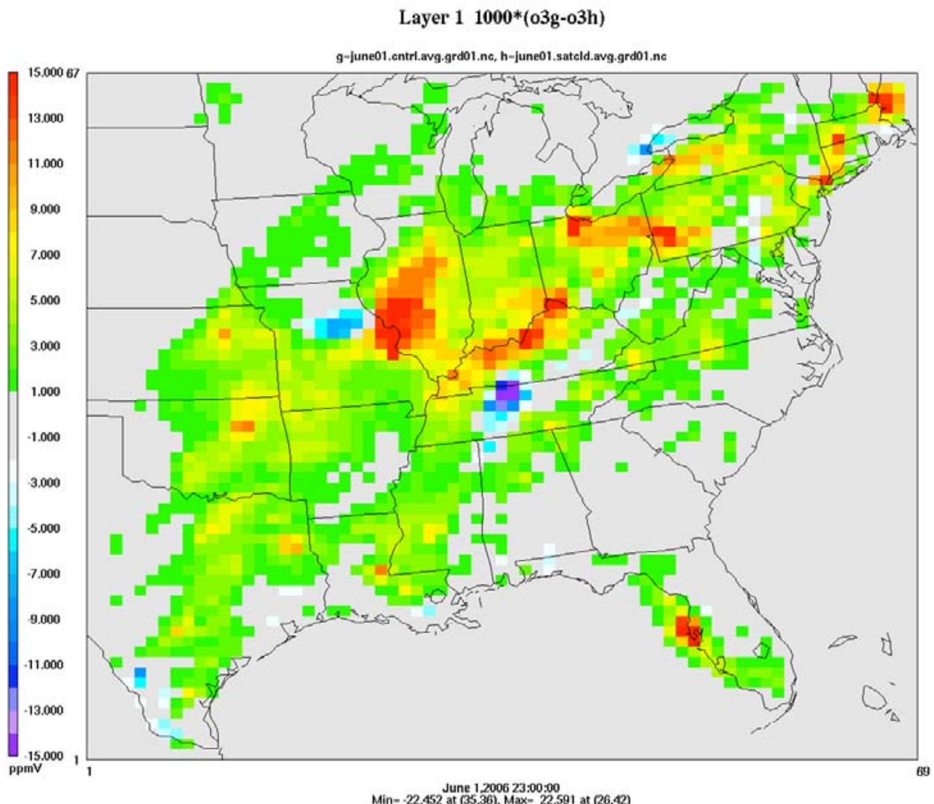
4-km



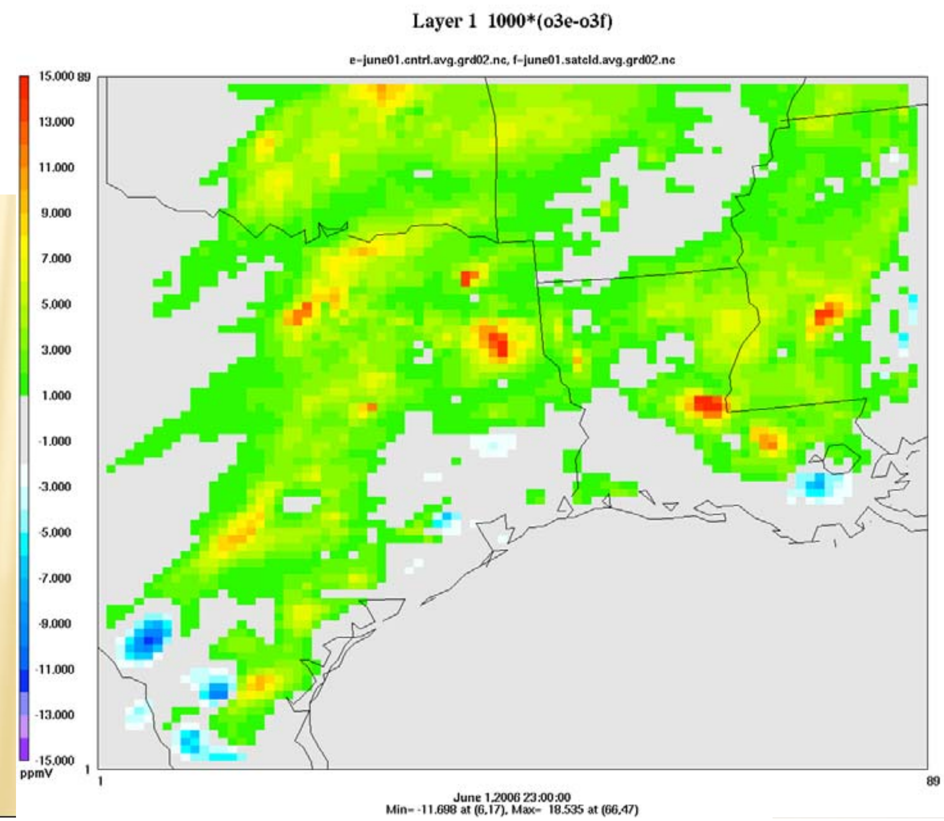
2-km



O3 Difference At 17:00, June 1, 2006
(CNTRL-SATCLD)



36-km



12-km

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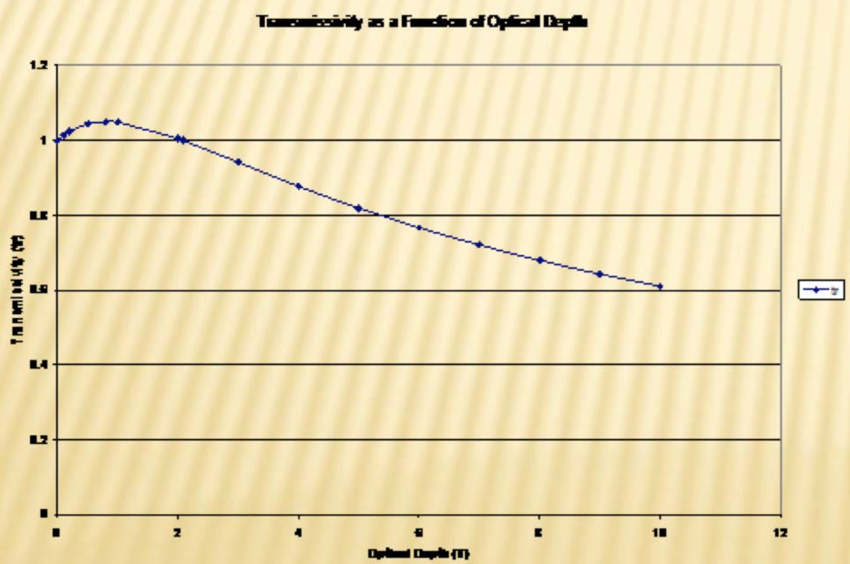
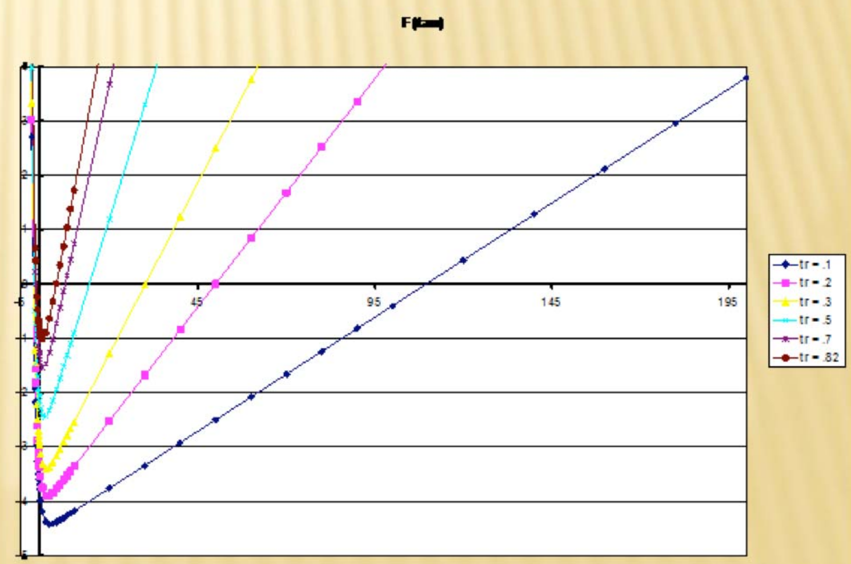
Retrieve Total Optical Depth From Satellite Retrieved Transmissivity

$$tr_c = \frac{5 - e^{-\tau_c}}{4 + 3\tau_c(1-\beta)}$$

OD can be obtained by finding the root of the following

$$f(\tau_c) = e^{-\tau_c} + \left[3(1-\beta)tr_c\right]\tau_c + (4\,tr_c - 5) = 0$$





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Retrieve Cloud Liquid Water From Total Optical Depth

$$T = \sum_{i=1}^{n} \tau_i = \tau_1 + \tau_2 + \ldots + \tau_n = $$

$$= \frac{3 w_1 \Delta z_1}{20} + \frac{3 w_2 \Delta z_2}{20} + \ldots + \frac{3 w_n \Delta z_n}{20}$$

Total Optical Depth

$$w = \frac{2 \rho_w r T}{3Z}$$

Cloud Liquid Water

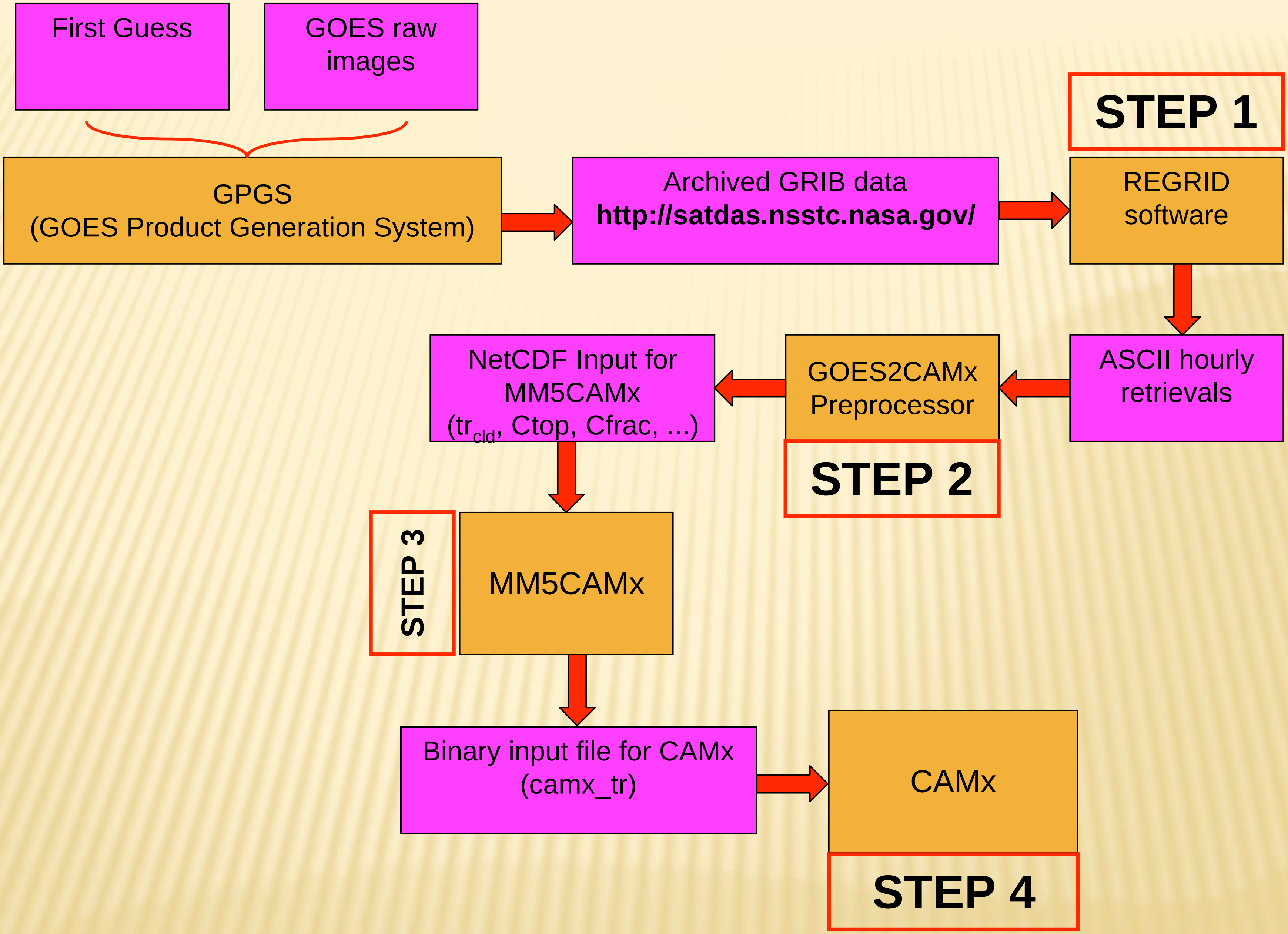
$$\tau_i = \frac{\Delta z_i}{Z} T$$

$$\text{where} \quad Z = \sum_{i=1}^{n} \Delta z_i = Z_{cloud\_top} - Z_{cloud\_base}$$

Optical Depth at Each Layer

MODIFICATIONS

- GOES2CAMx interface preprocessor was added to create NetCDF input containing sat. data for MM5CAMx.
- MM5CAMx was modified to accept the NetCDF input and output additional variable (cloud transmissivity).
  - In the presence of satellite retrievals, satellite derived transmissivity will be calculated and used for optical depth and cloud liquid water calculations.
  - Calculations of optical depth according to MM5 predictions are unaffected.


First Guess
GOES raw images
STEP 1
GPGS (GOES Product Generation System)
Archived GRIB data http://satdas.nsstc.nasa.gov/
REGRID software
NetCDF Input for MM5CAMx (tr_{cld}, Ctop, Cfrac, ...)
GOES2CAMx Preprocessor
ASCII hourly retrievals
STEP 2
STEP 3
MM5CAMx
Binary input file for CAMx (camx_tr)
CAMx
STEP 4
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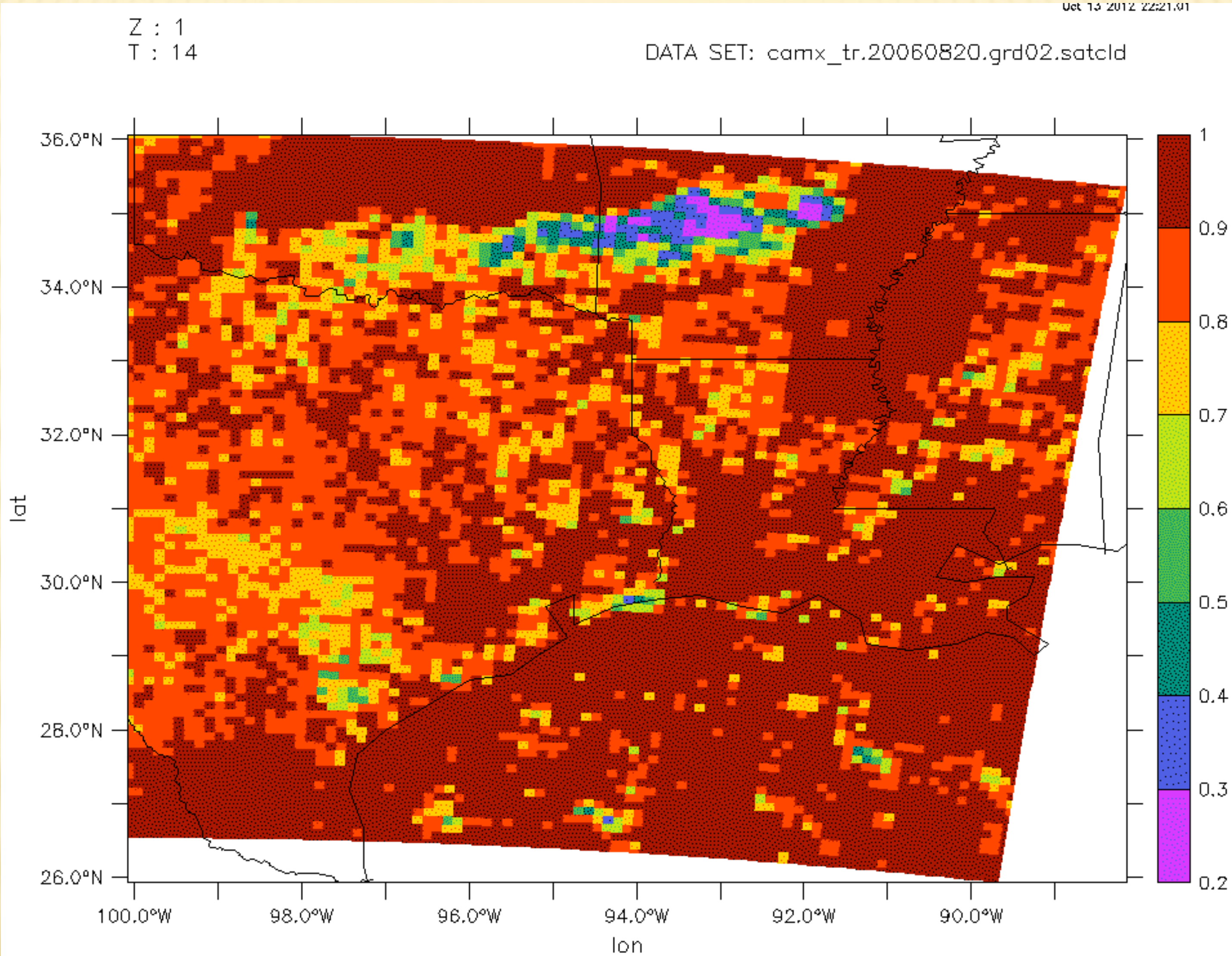
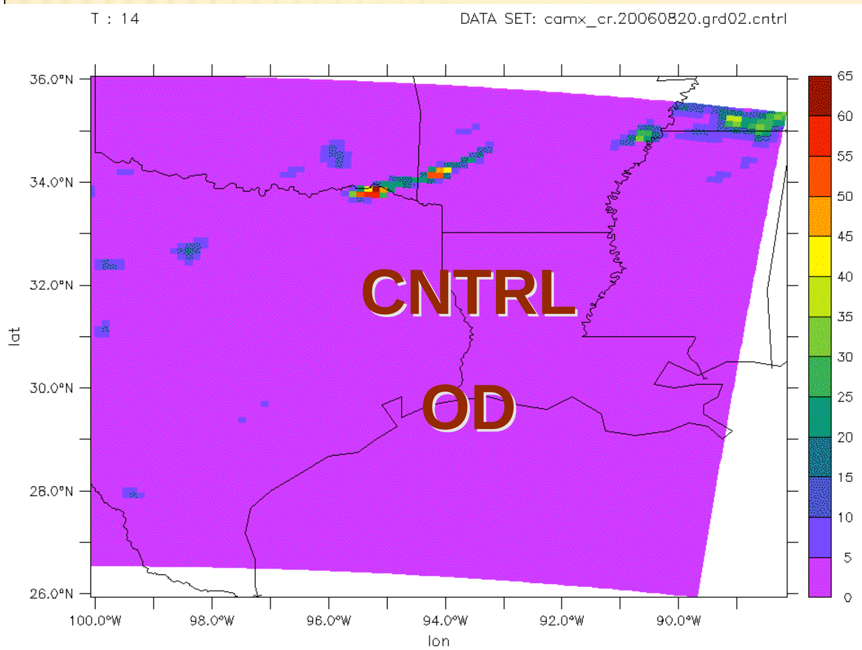
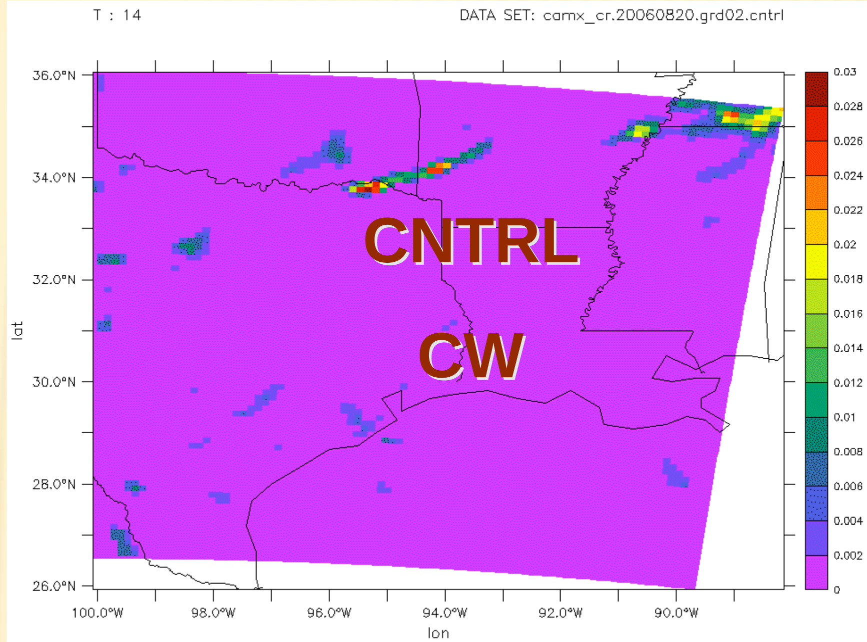
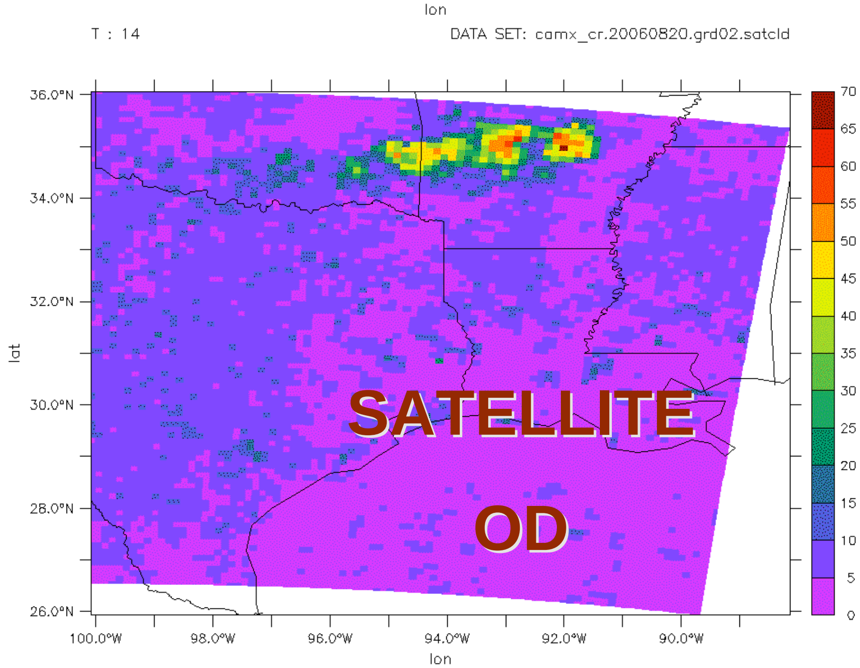
Satellite Retrieved Transmissivity

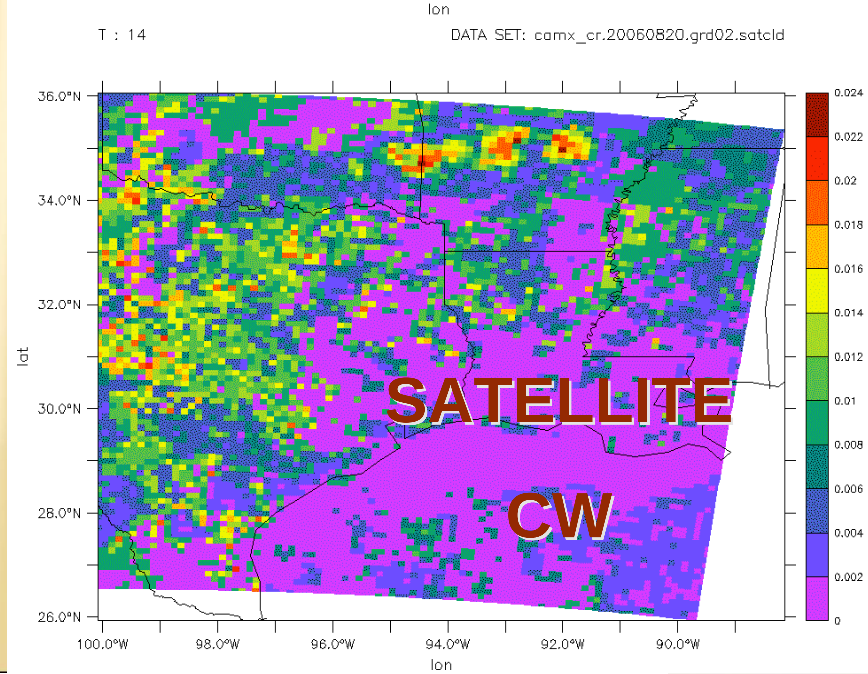


Cloud Optical Depth & Cloud Liquid Water Content









SUMMARY & FUTURE WORK

- Successfully implemented the assimilation of satellite retrieved cloud transmissivity, cloud top height, and cloud fraction in CAMx.
- Used transmissivity to retrieve cloud optical depth and cloud liquid water content.
- Performed preliminary CAMx simulations for summer of 2006.
- During this period satellite assimilation of transmissivityexhibited significant impact on the predicted atmospheric chemical composition within the boundary layer.
- Cloud impact was more pronounced over the regions with large sources of primary emissions.

- Redo the simulations with modified cloud optical depth and cloud liquid water and evaluate.

ACKNOWLEDGEMENT

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

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Thank You