Scales of Variability Determined from Numerical Models and Airborne Measurements: Application to the Design of Atmospheric Chemistry Measurements from a Geostationary Platform

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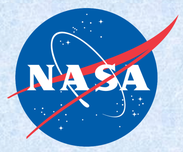

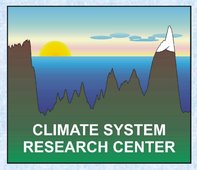

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Amherst

Background: Developing a "Truth" Atmosphere for GEO-CAPE

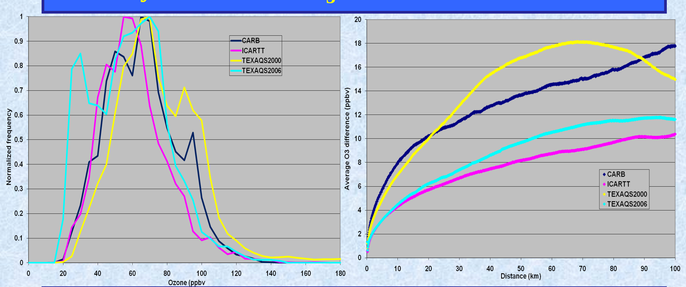
Using the Community Multiscale Air Quality (CMAQ) model, we examine scales of variability of key atmospheric trace gases that will be measured from a geostationary platform. The model resolution is 4 km and we focus over a region in eastern Texas during a time when aircraft measurements are available as part of several field campaigns. For the first part of our analysis, we search the plethora of *in* situ aircraft trace gas measurements and compare model-derived quantities with the observations.

Next, we examine the model results in light of the total tropospheric column amounts of O_3, CO and NO_2, and relate these integrated quantities to concentrations near the surface, boundary layer integrated amounts, and free tropospheric integrated amounts to see how these independent quantities relate to the tropospheric column amounts that would be measured from space. For comparison, we examine measurements from several flights in North America from the UV-DIAL (UV Differential Absorption Lidar) system aboard the DC-8, which provides continuous O_3 profiles throughout the troposphere. Examination these "curtains" provides a unique opportunity to quantify the spatial variability of the integrated tropospheric ozone column and then analyze this quantity with respect to the observed spatial variability in the planetary boundary, the free troposphere, and eventually even at the surface using information from existing air quality monitoring sites. For both the measured O_3 quantities and for the model-derived quantities, we can then statistically interpret the model-derived variability to see how well the model captures the observed variability.

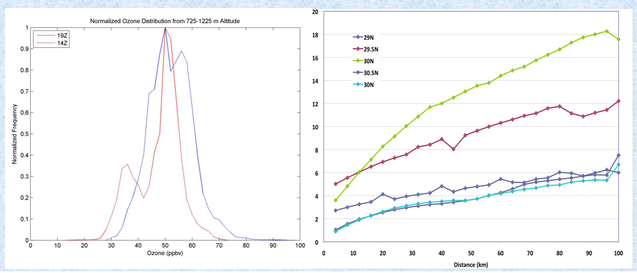
Preliminary analysis suggests that these parameters compare favorably for O_3 leading to the assumption that the regional and temporal variability for CO and NO_2 are similarly representative of the distributions of these species. We can then relate the integrated amounts of these species to what would be observed from space to provide information that can be used to determine the required precision for resolving these relatively small-scale features. **Please note that the information presented on this poster is preliminary; a more complete analysis will be provided at the forthcoming AGU Meeting.**

Comparing Model Data with Observations

Analysis of *in situ* O_3 Aircraft Measurements



Analysis of Model-generated O_3



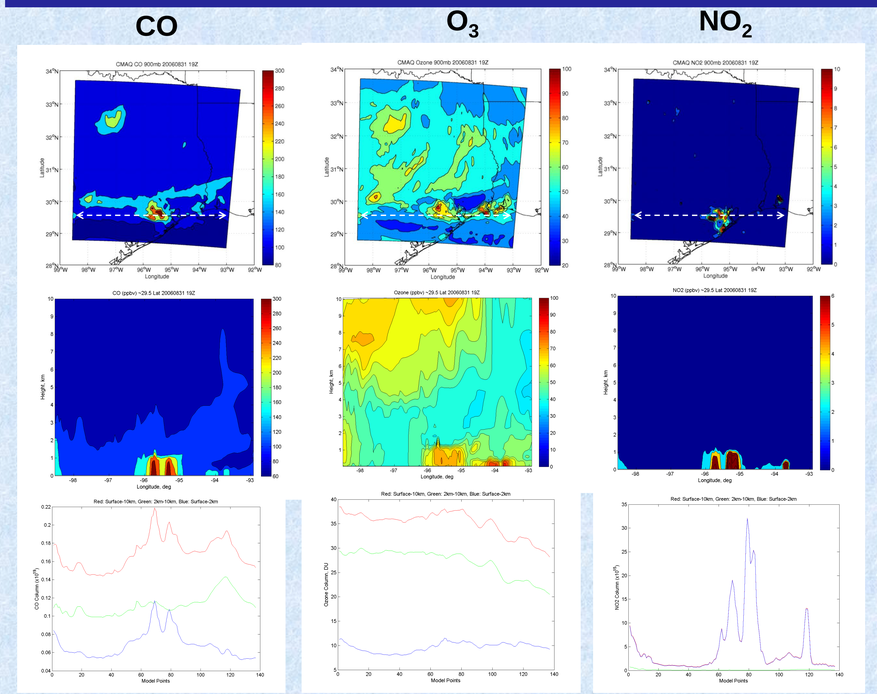
We display initial attempts comparing the model results with *in situ* observations. The left panels are population density diagrams from the observations (broken down by flight) and the CMAQ model. The individual curves for the observations are from four separate fights and include observations within the pbl. The two sets of curves shown in the lower left panel reflect the calculated at two distinct times, delineating morning (14Z) and mid-afternoon (19Z) concentrations.

The right panels show variogram calculations for the observed and model-derived data. The panel for the model shows calculations for four different cross sections (See depictions in the middle column on this poster); highest variations are for the two cross sections that intersect the Houston metro area (29.5° and 30°). The other three curves are for transects through primarily nonurban areas.

Bottom Line & Future Directions

Defining the requirements for GEO-CAPE requires applying retrieval algorithms and instrument models to trace gas and aerosol distributions that are representative of the spatial and temporal scales for which the instruments are being designed. We have developed such a dataset using the state-of-the-art CMAQ model, but verification of this model using observations within the troposphere has never been attempted. This study is the first of its kind to compare the model output with trace gas measurements from aircraft observations and to use this information as a validation product for the model simulations. Initial analyses using standard statistical techniques suggest that the CMAQ model provides trace gas distributions that represent realistic conditions. Future studies will focus on the validation of the model-derived output for use by the atmospheric composition community.

CMAQ Model Results: Horizontal Distribution, Cross Sections (Curtains), and Tropospheric Integrals



Model-generated trace gas fields for 19Z at 900 mba

Cross sections of CO, O_3 and NO_2 along 29.5° latitude line (dashed line in panels above)

Integrated quantities along 29.5° latitude:
Red – total column
Blue – pbl (0-2 km)
Green: free trop. (2-10 km)

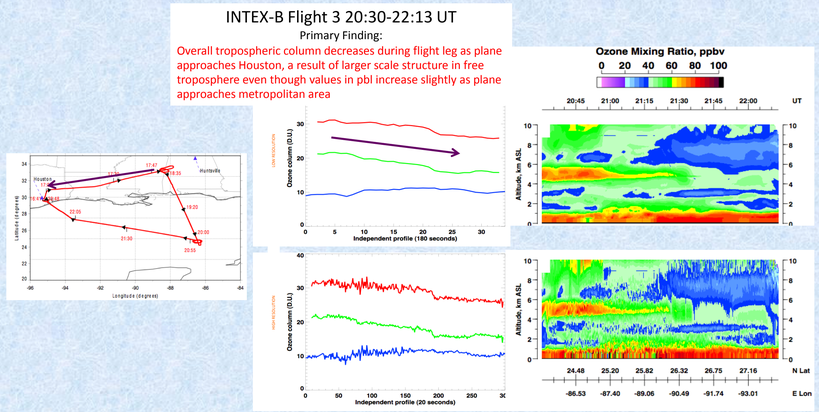
CMAQ results are shown here for 19Z (2:00 LT) on August 31, 2006. The top row of panels shows the calculated concentrations at 900 hPa. The middle row of panels depicts cross sections along the 29.5° parallel (dashed white arrows in top panels). The lowest row of panels shows the tropospheric integrals of these quantities integrated throughout most of the troposphere (red lines), the planetary boundary layer (0-2 km, blue lines), and the contribution from the free troposphere (2-10 km, green lines). For CO, these calculations show how both free tropospheric enhancements and urban scale boundary layer pollution contribute the total column. For NO_2, the amount in the pbl dominates the signal. For O_3, the tropospheric contribution by the pbl is overshadowed by the general decrease from west to east in free troposphere.

O_3 Cross Sections and Tropospheric Integrals from UV-DIAL

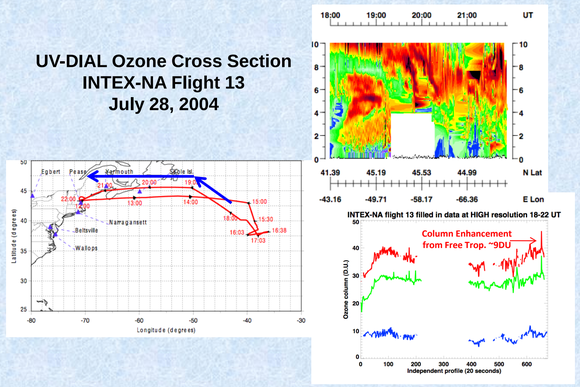
INTEX-B Flight 3 20:30-22:13 UT

Primary Finding:

Overall tropospheric column decreases during flight leg as plane approaches Houston, a result of larger scale structure in free troposphere even though values in pbl increase slightly as plane approaches metropolitan area



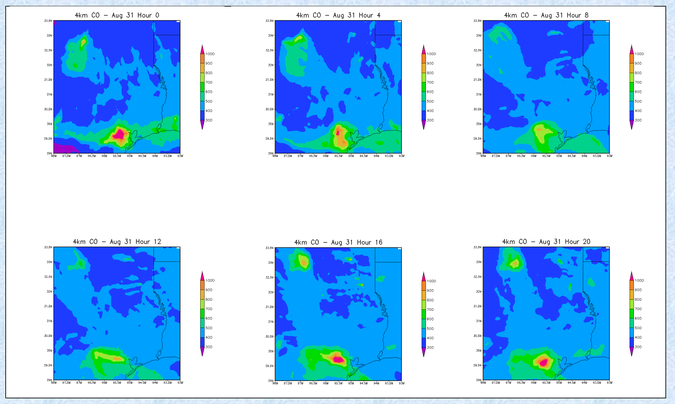
UV-DIAL Ozone Cross Section
INTEX-NA Flight 13
July 28, 2004



We have searched the UV-DIAL archives to find representative flights that provide verification data showing horizontal variability during long stretches of relatively level flight so that we can calculate integrated column variability along the flight path and then use the profile measurements to see which levels within the troposphere contribute most to the observed variability of the column, which is the quantity that would be measured by a mission such as GEO-TRACE.

Temporal Variability in the CMAQ Model

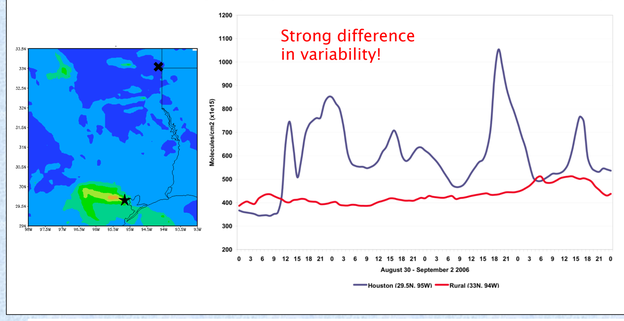
Hourly Calculations of CO



We use the Community Multiscale Air Quality (CMAQ) model to analyze the hourly variability in 4km CO in the lower most troposphere over east Texas. The above panels show the 4-hour variability in CO for the surface to 850mb layer on August 31, 2006 over our domain of east Texas.

CO Variability at Urban and Nonurban Sites

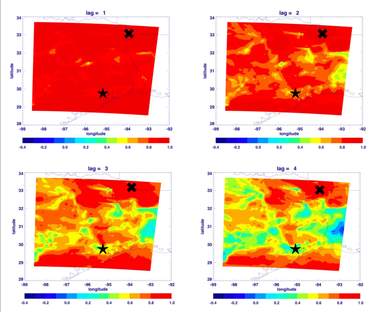
Comparison of Lower Most Tropospheric CO (surface-850hPa) over the Houston area (★, urban, strong emissions) versus a rural location (✖, background) (Aug 30-Sep 2 2006 4km CMAQ CO Data)



These plots show CO hourly time series from August 30-September 2 (2006) for two points within the model domain. The two regions are the Houston area (blue line) and a rural location northeast of Dallas (red line). 0

Correlograms for Urban and Nonurban Sites

4km Surface to 850 CO Autocorrelation for Lags 1-4 (30 Aug – 2 Sep)



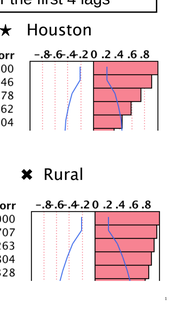
Correlograms for Houston and a rural location showing the temporal autocorrelation over the first 4 lags

★ Houston

Lag	AutoCorr
0	1.0000
1	0.9146
2	0.7478
3	0.5862
4	0.4504

✖ Rural

Lag	AutoCorr
0	1.0000
1	0.9707
2	0.9263
3	0.8804
4	0.8328



These plots show the first 4 temporal autocorrelation lags for the model-generated CO over east Texas and the associated variograms. The correlations for the Houston area break down much quicker than over the rural location potentially highlighting the difference in a background region versus an urban location with high emissions.