A study of regional-scale variability of *in situ* and model-generated tropospheric trace gases: Insights into observational requirements for a satellite in geostationary orbit

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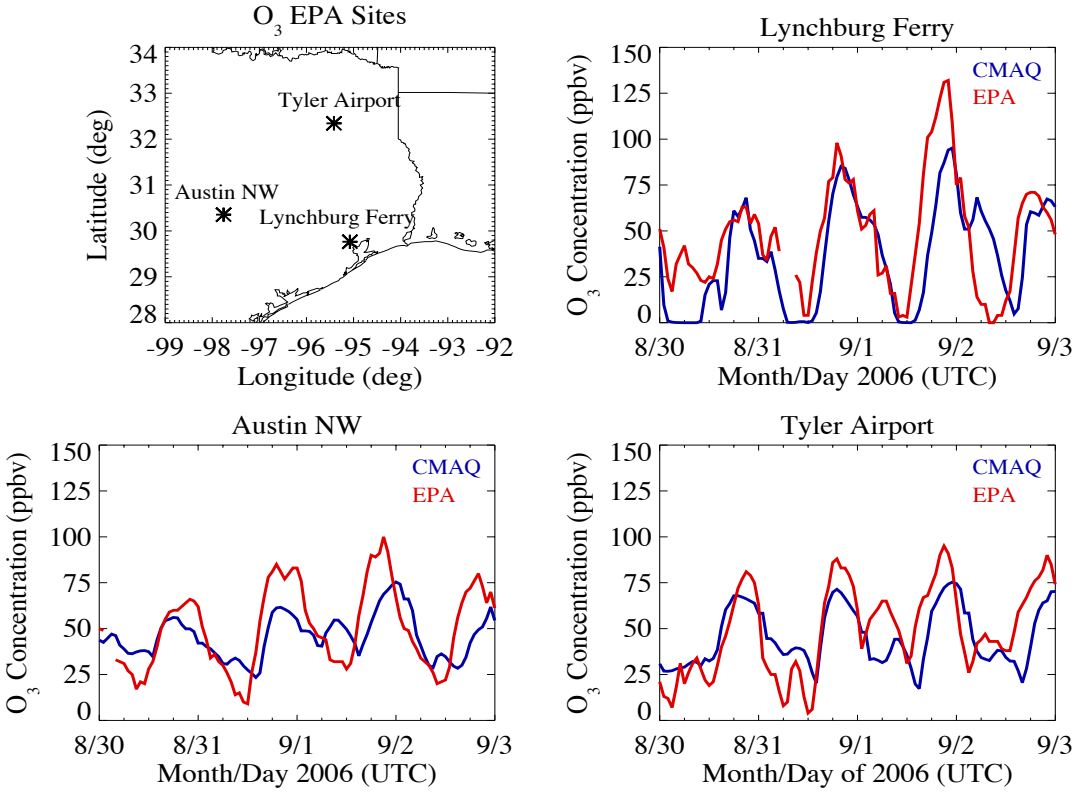
Two Fundamental Objectives

(from Fall 2009 AGU Special Session on GEO-CAPE)

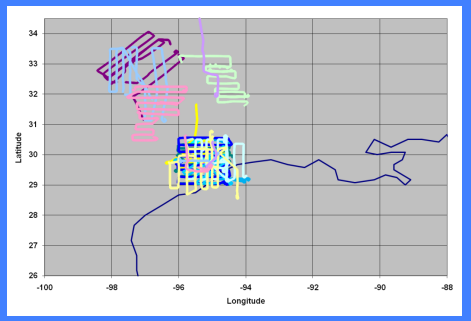
- **Develop Small Scale "Nature" Atmosphere for Testing Retrieval Algorithms**
  - Validate results with available aircraft and surface measurements
  - Use model to generate representative column integrals and profiles
  - 4-km integration 30 August-3 September 2006
  - Coincident with TexaxAQS field mission
  - Model run at University of Houston under supervision of Daewon Byun
  - Original intent was to compare aircraft observations with model results, but coincident measurements too few to provide credible analysis

- **Examine Relationship between Space Observations and Surface Concentrations**
  - Use model to provide understanding of relationship between surface concentrations and calculated integrals
  - Use available data with appropriate resolution to study relationship between total tropospheric column, boundary layer, and free troposphere

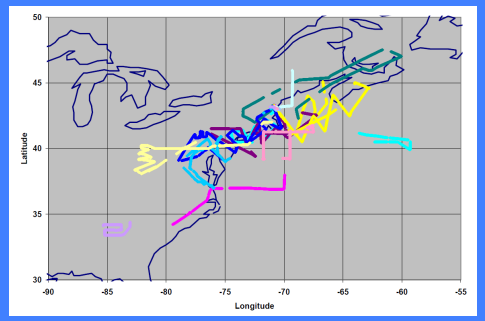
Use Validated Model that Has been Compared with Observations: Success Determined by Comparison with Ground-Based Measurements



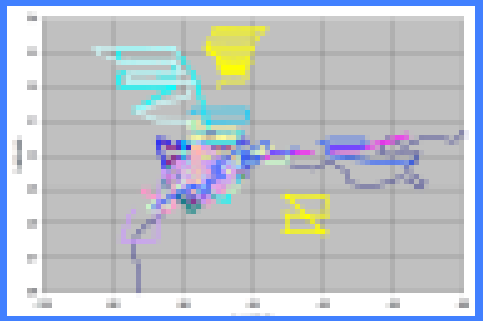
Construct Variograms from Four Measurement Campaigns for NO_2, CO, and O_3



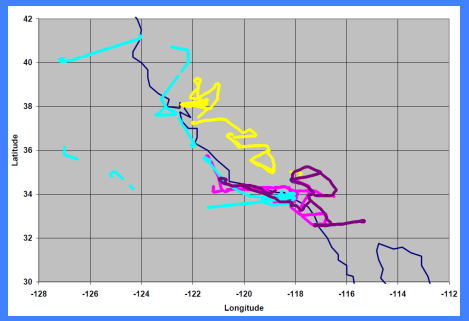
TexasAQS-2000



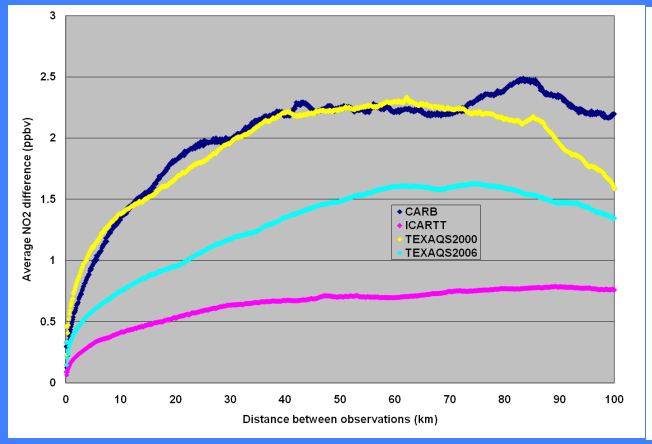
ICARTT (2004)



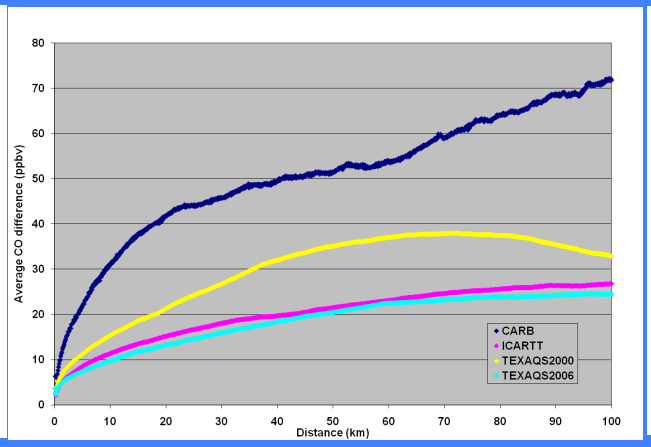
TexasAQS-2006



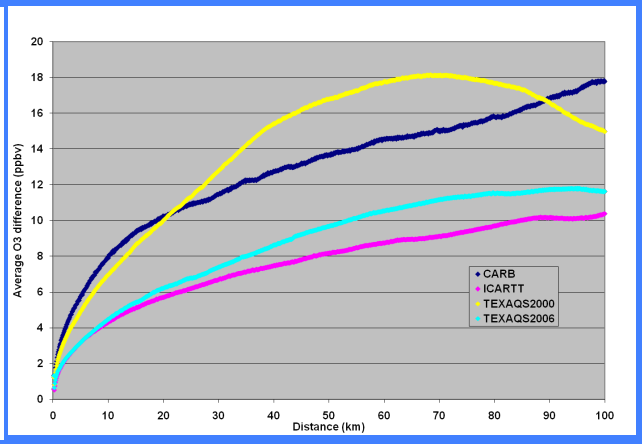
California-ARCTAS 2008



NO_2



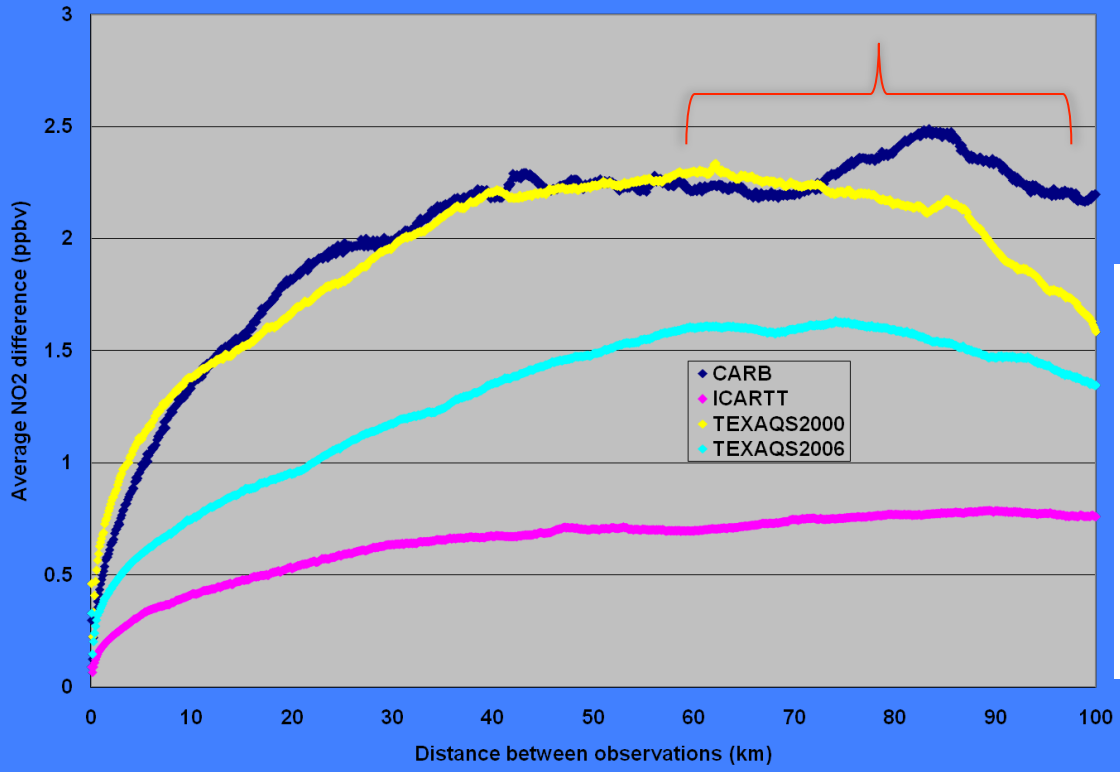
CO



O_3

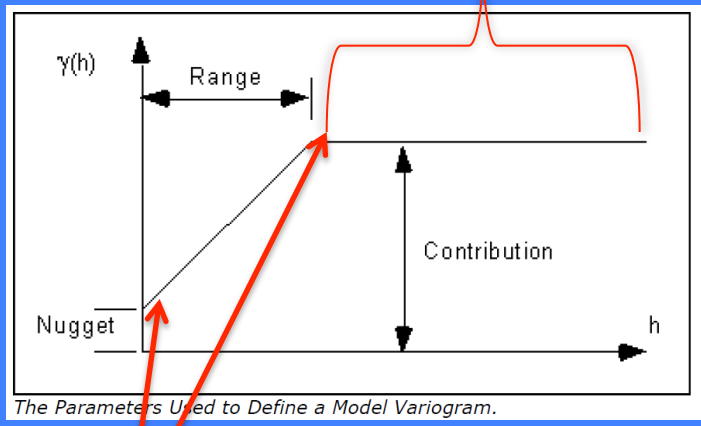
For additional details, see Crawford et al. (A53A-0237)

Calculated Variograms Approach Shape of Idealized Variogram,,



(technically defined "semimadogram")

Flat portion of variogram (sill) not attained in current calculations because of sampling procedure used to analyze aircraft data



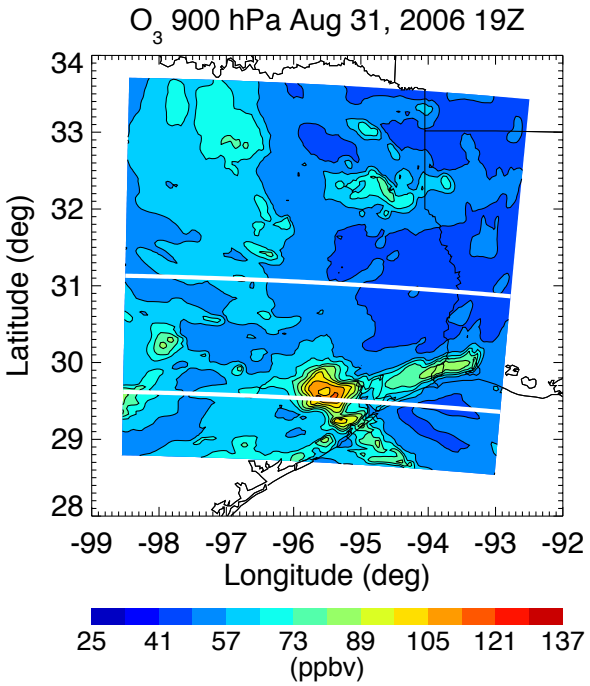
The Parameters Used to Define a Model Variogram.

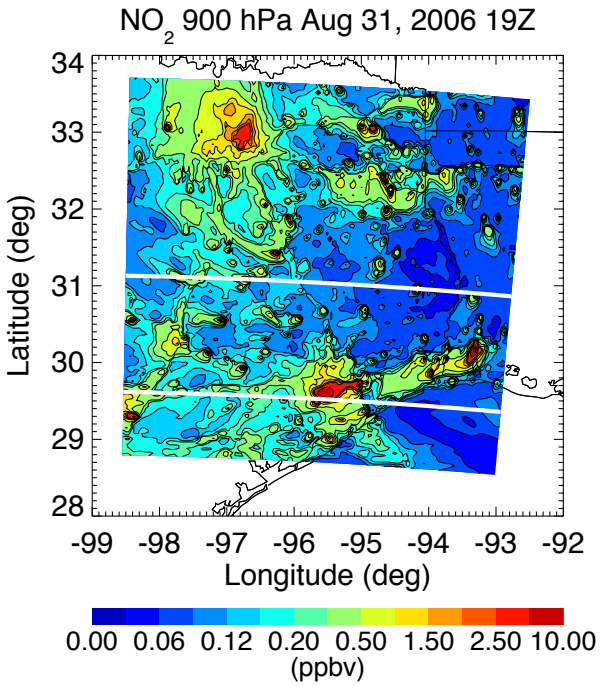
For GEO-CAPE related analysis, this portion of the variogram (range) provides the needed information for instrument requirements related to mission requirements

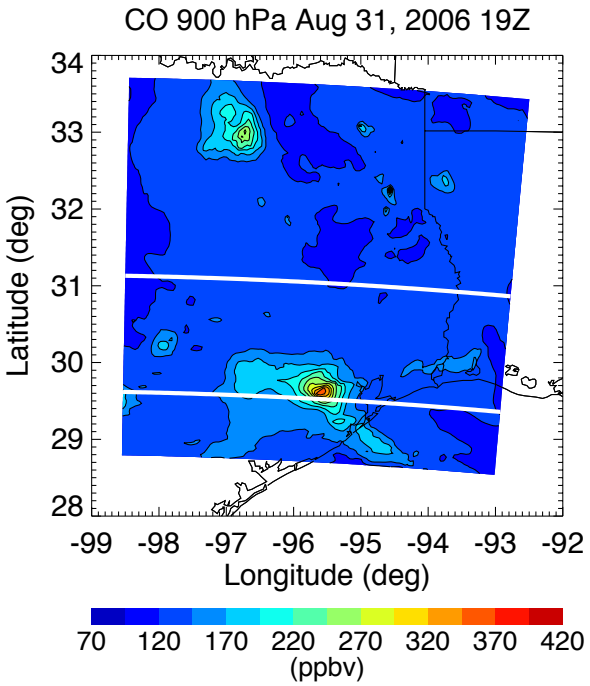
- Shape and absolute value of variograms differ because of airmass being sampled and variability of flight patterns during sampling

For additional details, see Crawford et al. (A53A-0237)

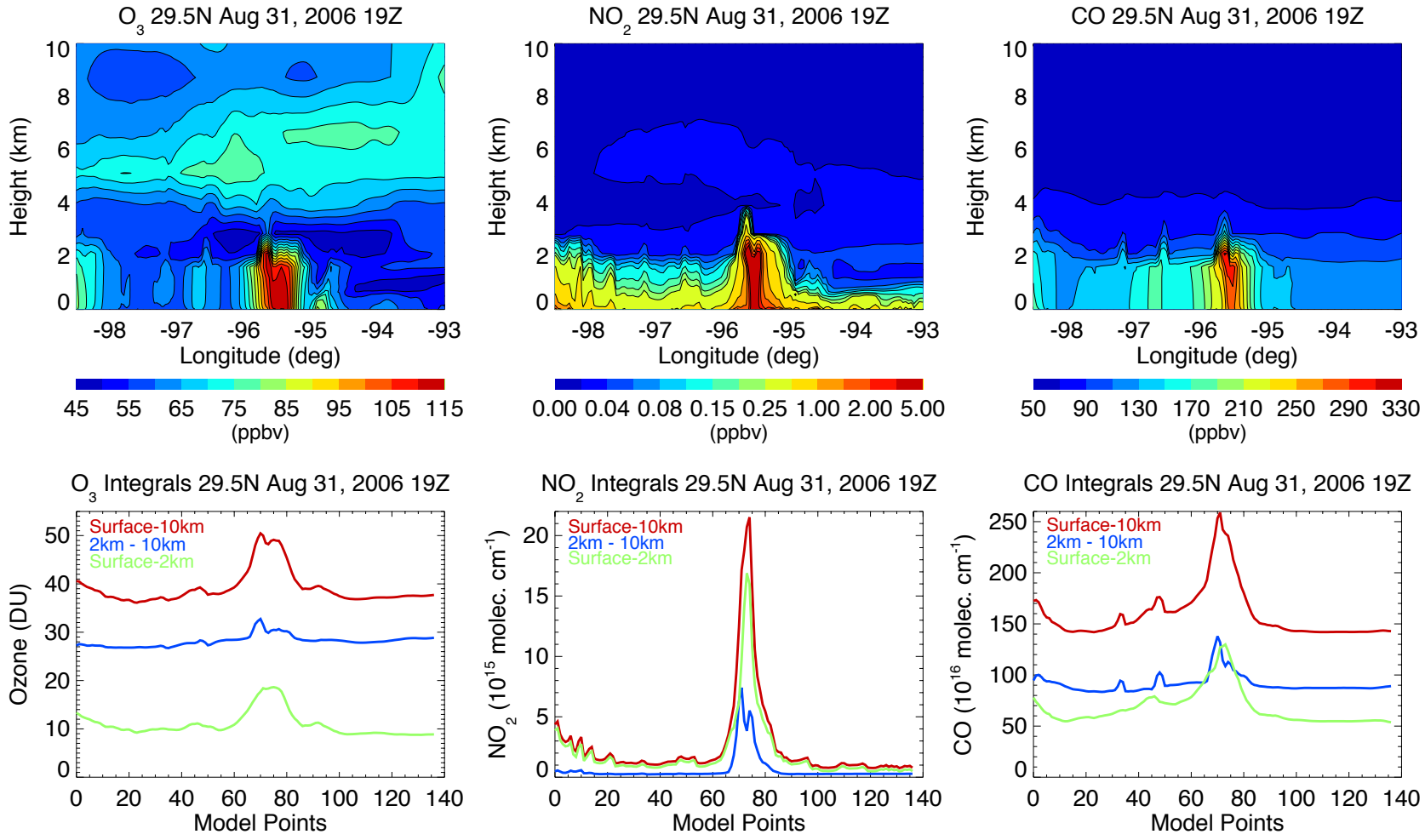
Model Results at 900 hPa



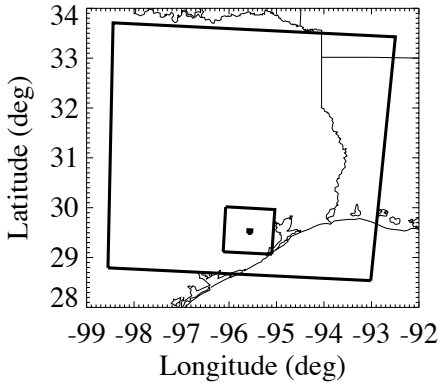


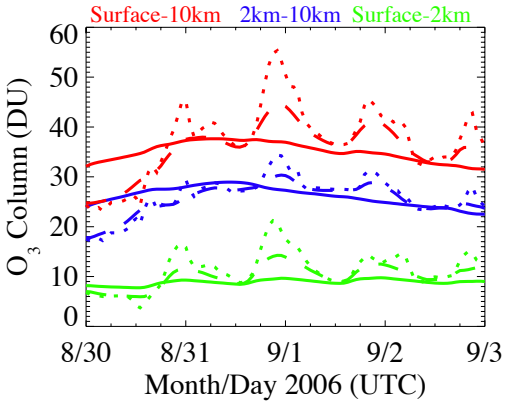


Cross sections through Houston and calculated integrals

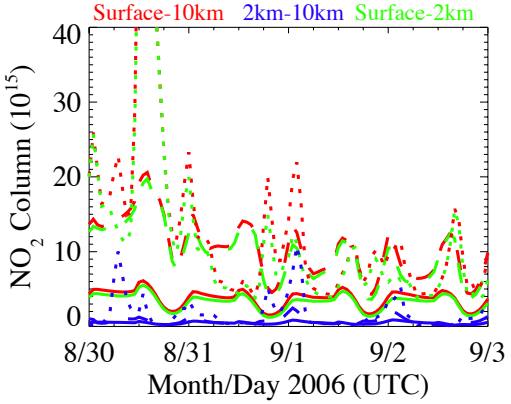


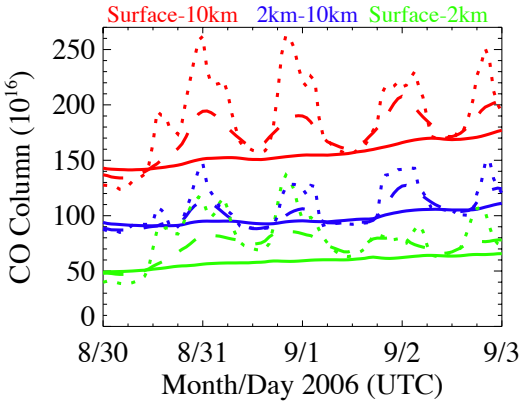
Temporal Variability of Integrated Quantities Increases as Spatial Resolution Gets Smaller





O_3 Daily Enhancement:
7 DU @ 100 km (~20%)
18 DU @ 8 km (~54 %)





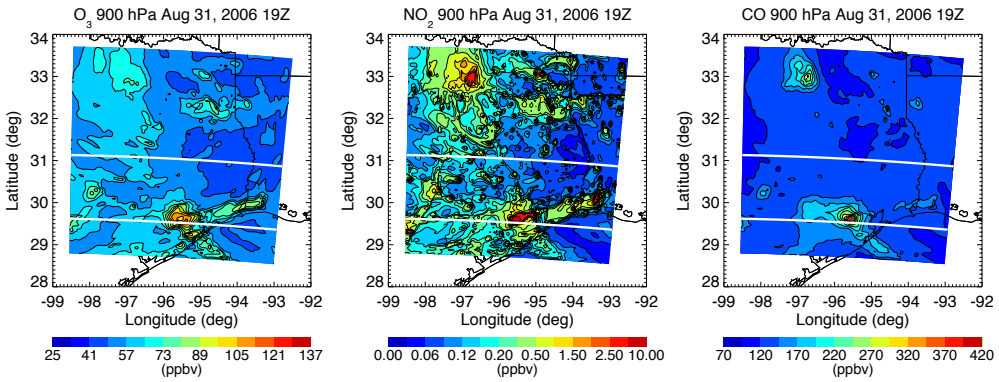
CO Daily Enhancement:
~26% @ 100 km
~70% @ 8 km

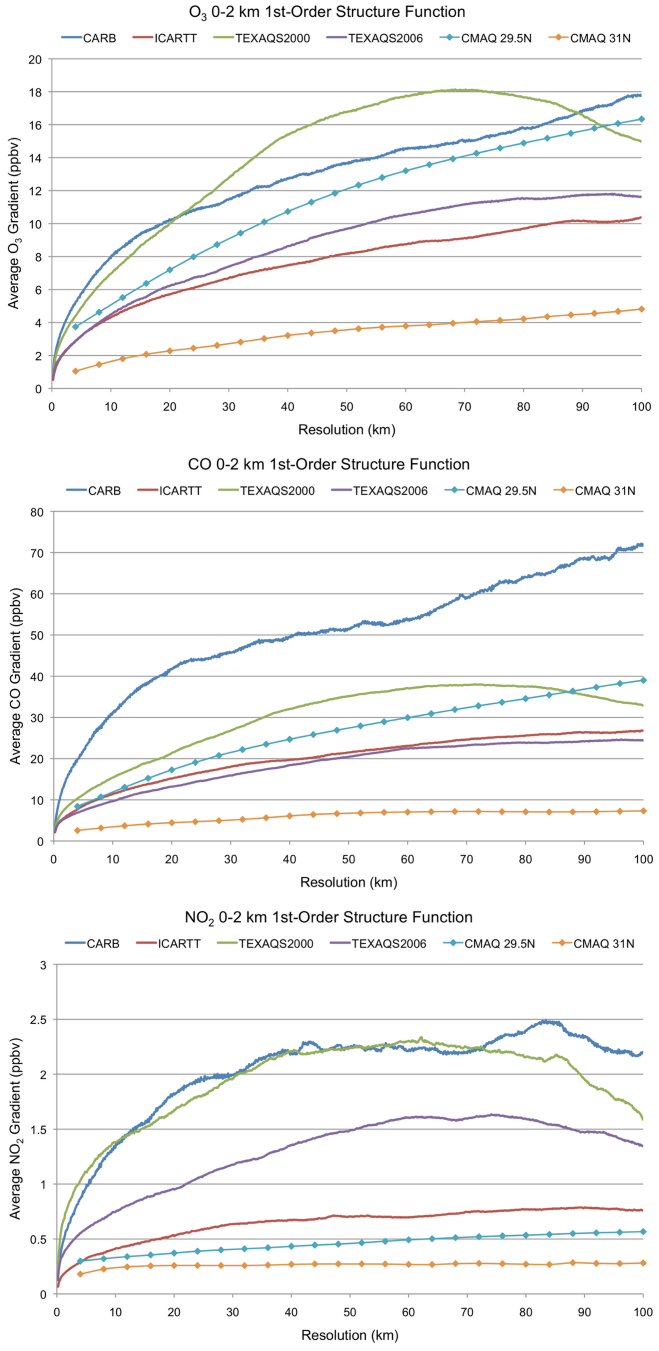
Entire Domain

100-km box

8-km box

First-Order Structure Functions from Trace Gas Measurements during Field Campaigns Compared with Model-Derived Measurements through Two “Flight Paths”



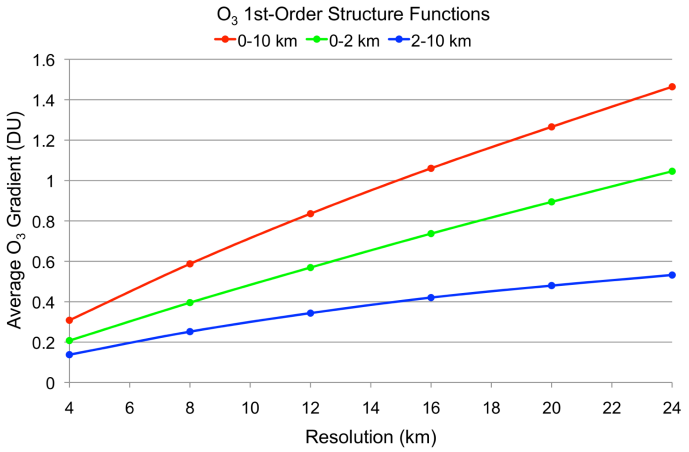


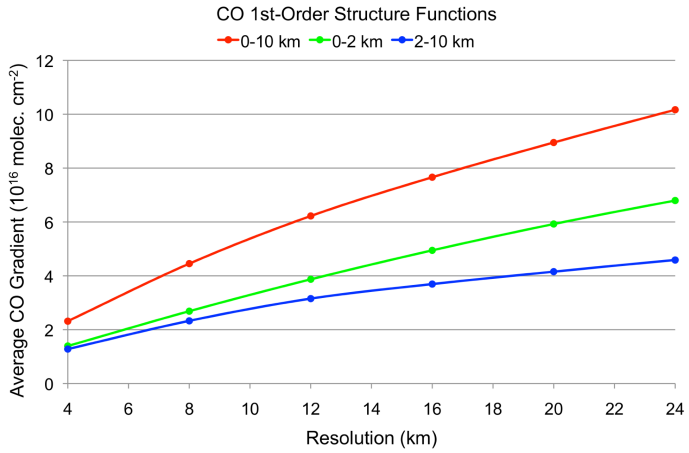
Model Can Examine Variability of Individual Layers within the Computational Domain

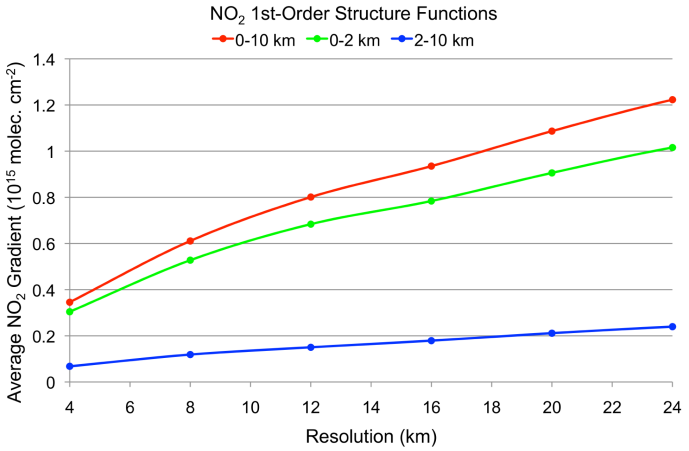
- Free tropospheric contribution is most pronounced for CO

- Nearly all variability for tropospheric NO2 is due to variability in the pbl (no surprise)

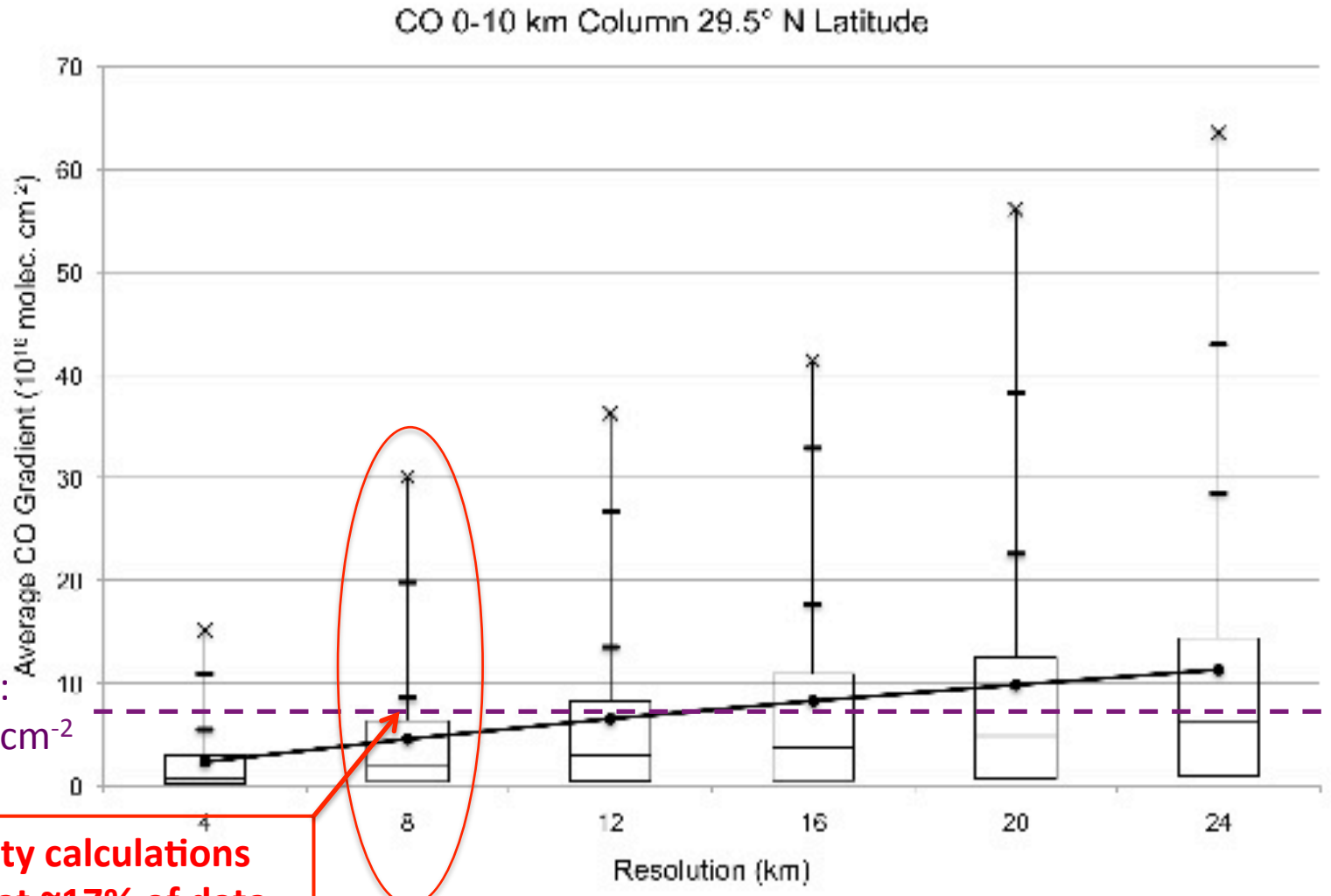
- Variability of tropospheric O3 primarily due to pbl variability, but not totally controlled by processes occurring in pbl







Box and Whisker Plot of Variability

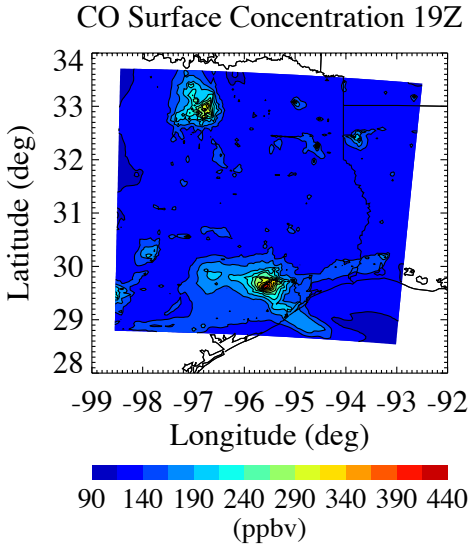


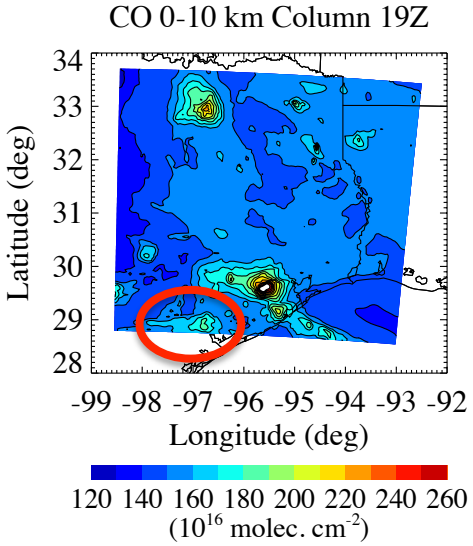
CO threshold:
8 x 10^{16} mol. cm^{-2}

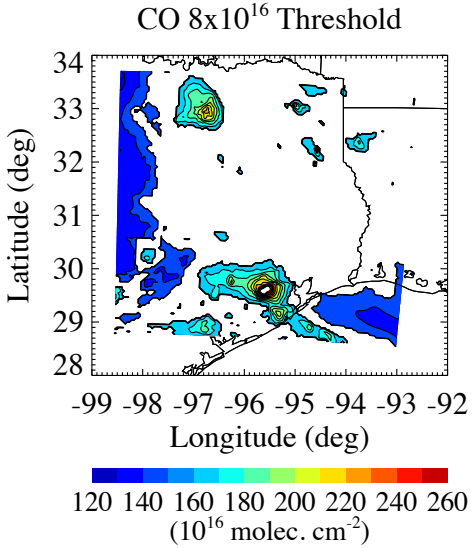
Variability calculations show that ~17% of data are above threshold

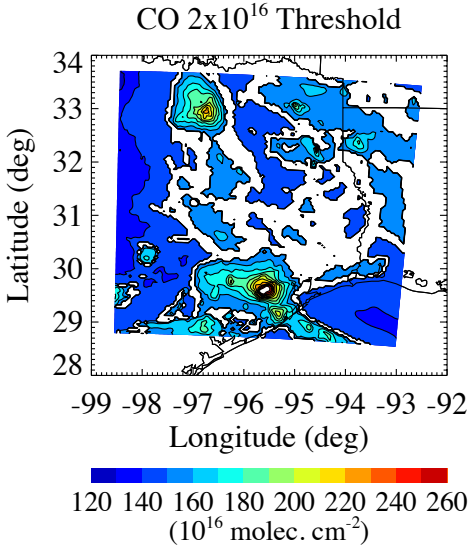
Box and Whisker Legend: Lower box – 25 percentile; Line in box – 50 percentile
Upper box line – 75 percentile; first tic - 85 percentile; second tic – 95 percentile

Features Can Be Seen from a Geostationary Platform as a Function of Prescribed Requirements?









- Tropospheric column captures distribution at surface

- Feature inside circle is not seen at the surface because it is a remnant of emissions from previous day

- Threshold of 8 x 10^{16} provides sufficient information to capture regional enhancement ***despite ~90% of region below specified threshold of instrument***

- Threshold of 2 x 10^{16} captures ~50% of the region

Summary and Key Findings

• Provided key analysis tool to compare *in situ* trace gas measurements with model results

• 4-km model generates viable variability statistics for CO and O_3, but not NO_2

• Model provides important insight into how much total tropospheric column variability is controlled by boundary layer vis à vis free troposphere

- **NO_2 tropospheric variability completely dominated by pbl (no surprise)**
- **variability of tropospheric CO and O_3 columns primarily driven by pbl**
- **free tropospheric measurement of CO would provide more insight into into column variability than free-tropospheric measurement of O_3**

• With respect to relationship between variability and setting STM requirements:

- **probabilistic distribution of variability provides more insightful information than average variability statistics for assessing what can be observed as a function of spatial resolution**
- **this is only <u>one</u> model study; others needed**

Variability is Also Function of Time of Day