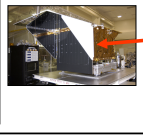
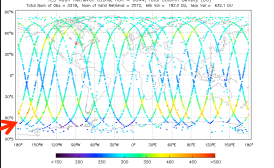
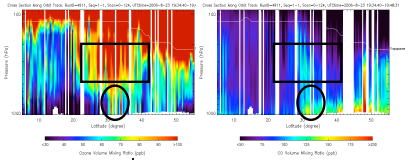
Impact of long range transport on surface air quality in the US: Recent insights from satellite assimilation

G.B. Osterman[1] for K.W. Bowman[1], M. Parrington[2], D.B.A Jones[2]
[1]Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA
[2]Department of Physics, University of Toronto, Toronto, Ontario


- The Tropospheric Emission Spectrometer is a high spectral resolution infrared Fourier transform spectrometer
  - Measures from 650-3050 cm^{-1} with 0.1 cm^{-1} apodized spectral resolution
- TES was launched on board the NASA Aura satellite on July 15, 2004
  - Measurements made at ~1:30 AM/PM local time
  - Standard measurements called the "Global Survey" with 16 orbits over ~26 hours (started every other day)
  - Nadir footprint is 5x8 km
  - ~180 km between profiles
- TES measures in nadir mode:
  - Ozone
  - Carbon Monoxide
  - Water Vapor and HDO
  - Atmospheric Temperature
  - Methane
  - Sea Surface Temperature
  - Coming soon: Ammonia & Carbon Dioxide

TES data has been assimilated into several models:

Estimating the summertime tropospheric ozone distribution over North America through assimilation of observations from the Tropospheric Emission Spectrometer
M. Parrington, D. B. A. Jones, K. W. Bowman, L. W. Horowitz, A. M. Thompson, D. W. Tarasick, and J. C. Witte
→ GEOS-Chem AM2-Chem

Impact of the assimilation of ozone from the Tropospheric Emission Spectrometer on surface ozone across North America
M. Parrington, D. B. A. Jones, K. W. Bowman, A. M. Thompson, D. W. Tarasick, J. Merrill, S. J. Oltmans, T. Leblanc, J. C. Witte, and D. B. Miller
→ GEOS-Chem

Impacts of background ozone production on Houston and Dallas, Texas, air quality during the Second Texas Air Quality Study field mission
R. Bradley Pierce, Jassim Al-Saadi, Chieko Kittaka, Todd Schaack, Allen Lenzen, Kevin Bowman, Jan Szykman, Amber Soja, Tom Ryerson, Anne M. Thompson, Pawan Bhartia, and Gary A. Morris
→ RAQMS

In this presentation we focus on the GEOS-Chem work done by Parrington, Jones and Bowman

Chemical Data Assimilation Methodology:

Sequential Sub-optimal Kalman filter

$$\hat{\mathbf{x}}_k^a = \mathbf{x}_k^f + \mathbf{K}_k[\mathbf{y}^{obs} - \mathbf{H}_k\mathbf{x}_k^f]$$

Kalman Gain Matrix: $\mathbf{K}_k = (\mathbf{H}_k\mathbf{P}_k^f\mathbf{H}_k^T + \mathbf{R}_k)^{-1}\mathbf{P}_k^f\mathbf{H}_k^T$

Analysis Error Cov. Matrix: $\mathbf{P}_k^a = (\mathbf{I} - \mathbf{K}_k\mathbf{H}_k)\mathbf{P}_k^f$

- Observation operator (**H**) accounts for TES averaging kernels and a priori profiles
- Analysis error variance transported as a passive tracer

Models and Data Streams

- GEOS-Chem with full nonlinear tropospheric chemistry
- O_3 and CO profile retrievals from TES for July 1 through August 31 2006
- 6-hour analysis cycle
- Assumed forecast error of 20% for CO and 50% for O_3
- Neglected horizontal correlations in forecast and observation error covariance matrices
- Results presented for 15 August 2006

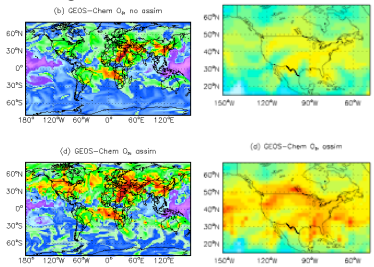
GEOS-Chem

- Chemical transport model
- 2.0° latitude x 2.5° longitude or 4° latitude x 5° longitude, 55 vertical levels (top level approx. 0.01 hPa)
- Model transport driven by GEOS-4 GMAO analyses
- Linoz parameterization of stratospheric ozone vertical distribution

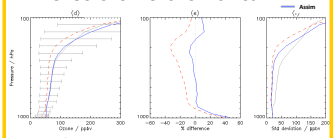
Results

Impact of ozone assimilation at 5km

Aug 15, 2006

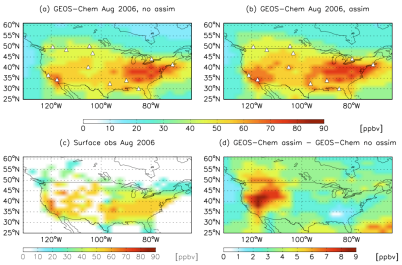


GEOS-Chem Ozone Profiles

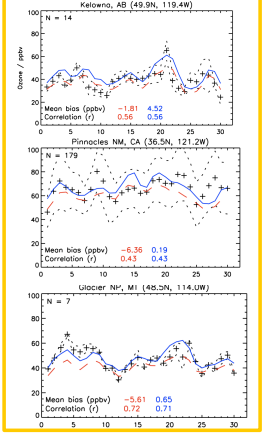


- Significant improvement in mid-tropospheric ozone distribution following assimilation.
- Marginal improvement in mid-tropospheric ozone variance following assimilation.

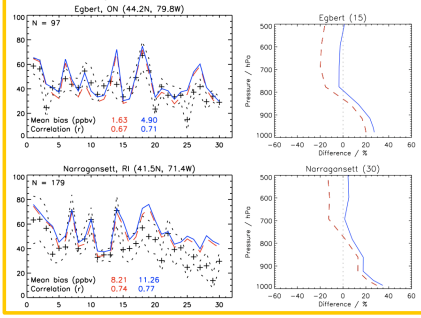
Impact of assimilation on surface ozone



Comparison to Western North America surface sites



Comparison to Eastern North America sites



Future Work

The TES team at JPL is working with collaborators at Virginia Tech University to develop 3D- and 4D-Var assimilation of TES data into GEOS-Chem

Conclusions

- Spatiotemporal sampling of TES is sufficient to constrain tropospheric ozone distribution in the model
- Assimilation reduces the negative bias in free troposphere, enhancing the flux into the boundary layer.
- Surface ozone increased by ~9 ppb over Western North America and by ~2 ppb over the Southeastern US
- Estimated total background ozone of 20-40 ppb
- Comparisons of model to surface sites were improved in the Western US, wore in the Eastern US after assimilation