Integrating satellite observations for assessing air quality over North America with GEOS-Chem

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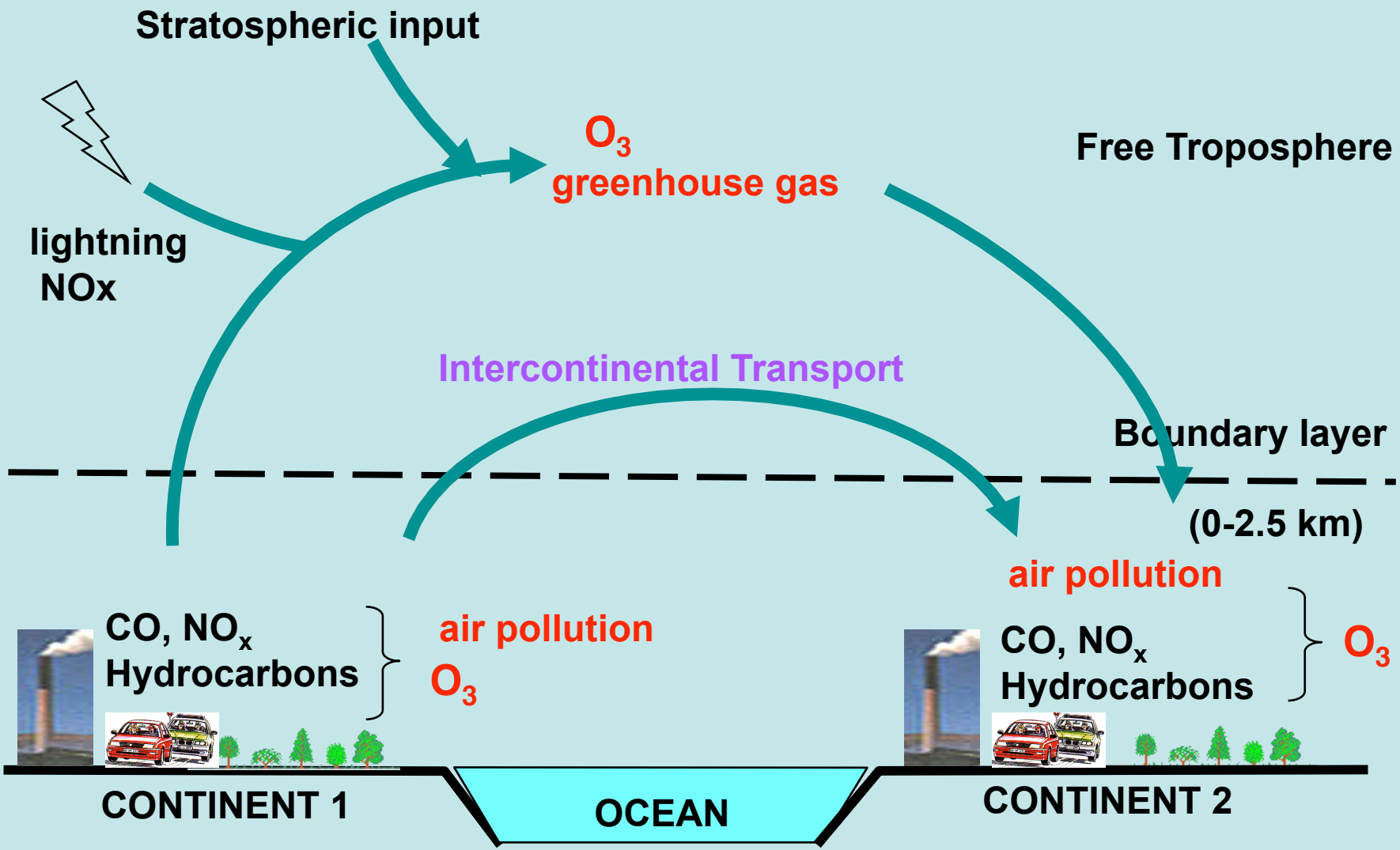
Processes Influencing the Global Distribution of Tropospheric O_3



Tropospheric O_3 is influenced by a number of factors each of which is highly uncertain.

Integrating satellite data and models provides a powerful tool for evaluating these uncertainties.

Model set-up and satellite data

Model

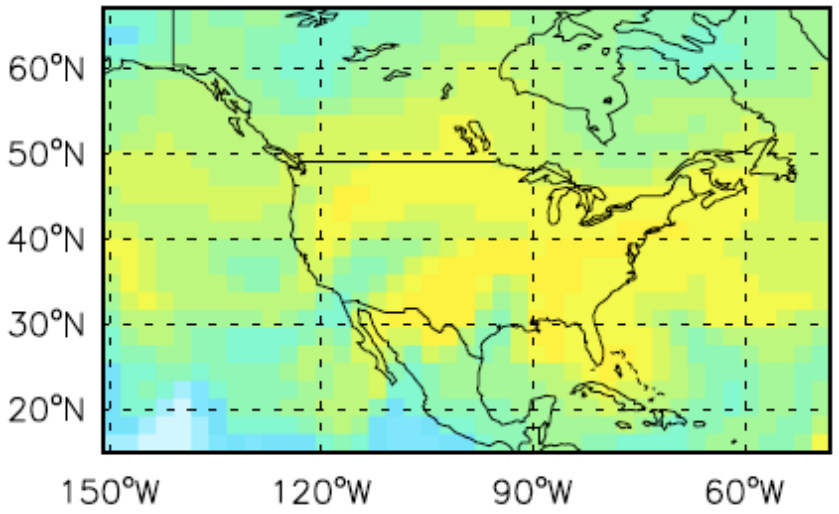
- **GEOS-Chem model (v7-02-04) with detailed nonlinear tropospheric chemistry.**
- **Updates to NEI99 emissions following Hudman et al. [2007].**
  - **Industrial NO_x emissions reduced by 50%; anthropogenic CO emissions reduced by 60%.**
- **Linearized (LINOZ) O_3 chemistry in the stratosphere.**
- **Model transport driven by GEOS4 assimilated meteorological fields (at a resolution of 4° × 5° for this work).**

Satellite data

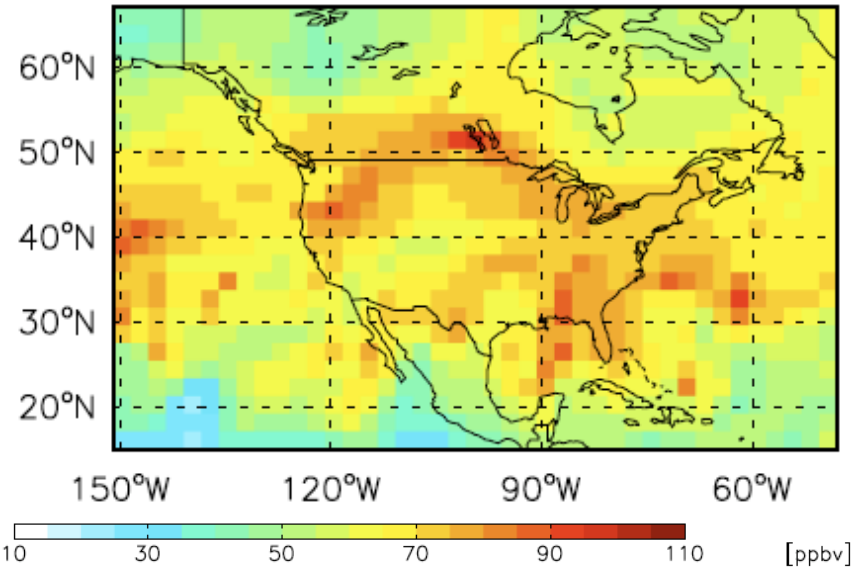
- **O_3 and CO profiles, retrieved from TES, assimilated globally using sub-optimal Kalman Filter.**
- **Top-down emissions inventories for NO_x, derived from SCIA NO_2, and isoprene, derived from OMI HCHO, applied across North America.**
- **Satellite data integrated between from 1 July through to 31 August 2006.**

Assimilation of TES data to constrain background ozone

O_3 at 500 hPa, no TES assimilation

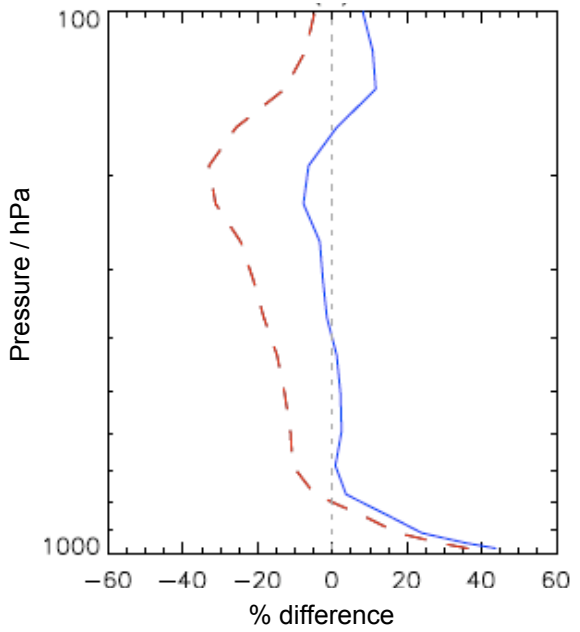


O_3 at 500 hPa, TES assimilation



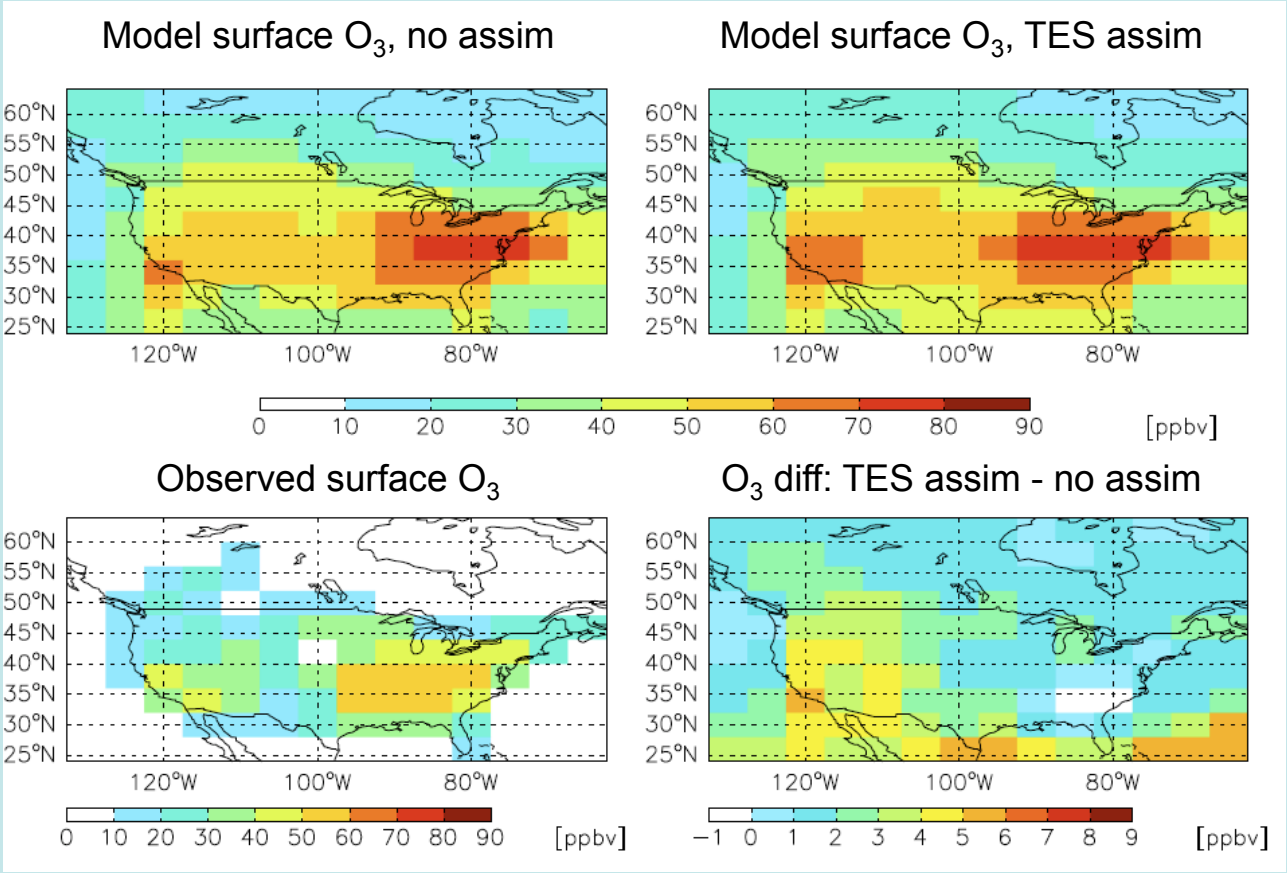
- Figures show August 2006 monthly means.
- Assimilation of TES O_3 data into GEOS-Chem increases free tropospheric O_3 abundance, improving its modelled distribution over North America relative to IONS-06 ozonesonde data.
  - Discrepancy associated with underestimate of NO_x emissions from lightning in this version of the model (e.g. Lee Murray's presentation this morning).
- Limited TES sensitivity in PBL cannot directly improve model overestimate of O_3 below 800 hPa.

O_3 bias relative to ozonesondes



Parrington, et al., JGR, 2008

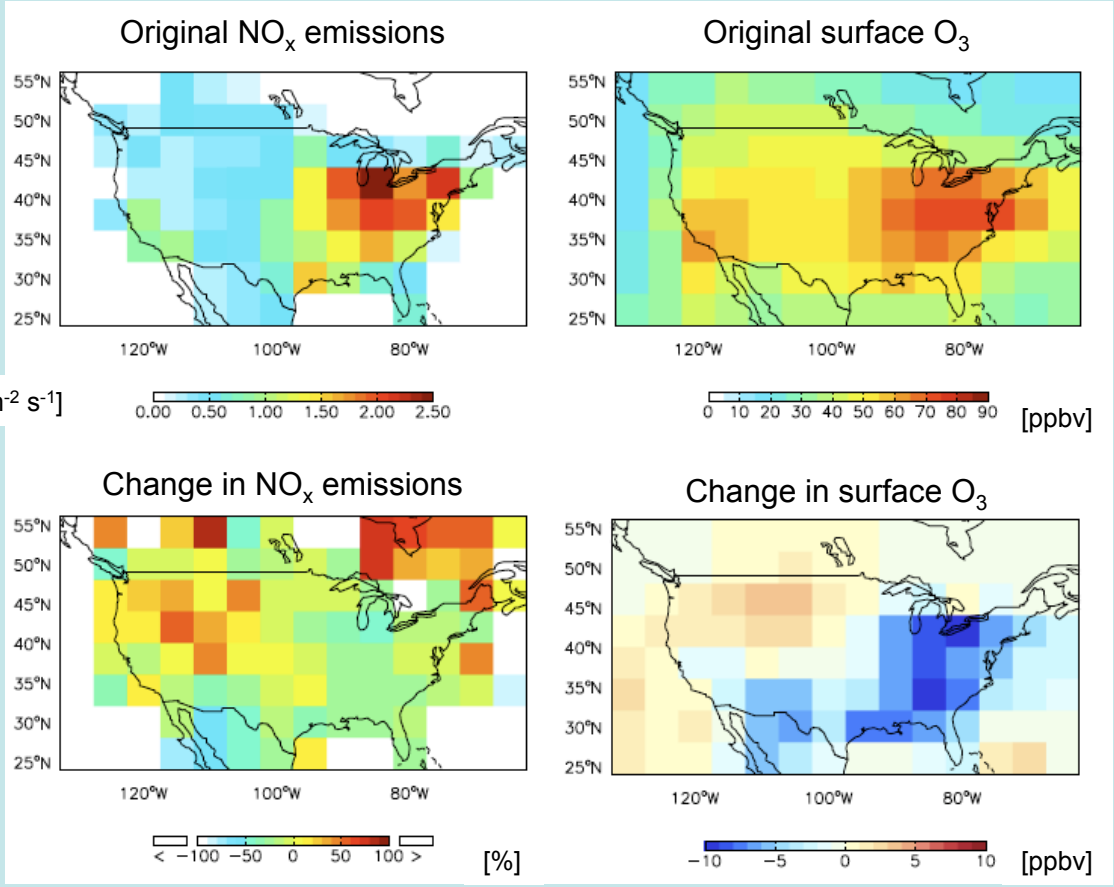
Impact of TES assimilation on model surface ozone



- Impact on modelled surface O_3 through increased ozone mass flux across PBL, greater in west due to longer O_3 lifetime and deeper mixing layer.
- Overestimate in eastern USA decreased by less than 1 ppbv by TES assimilation.
- Integration of additional satellite observations, to constrain surface precursor emissions, will isolate errors in the modelled surface O_3 abundance.

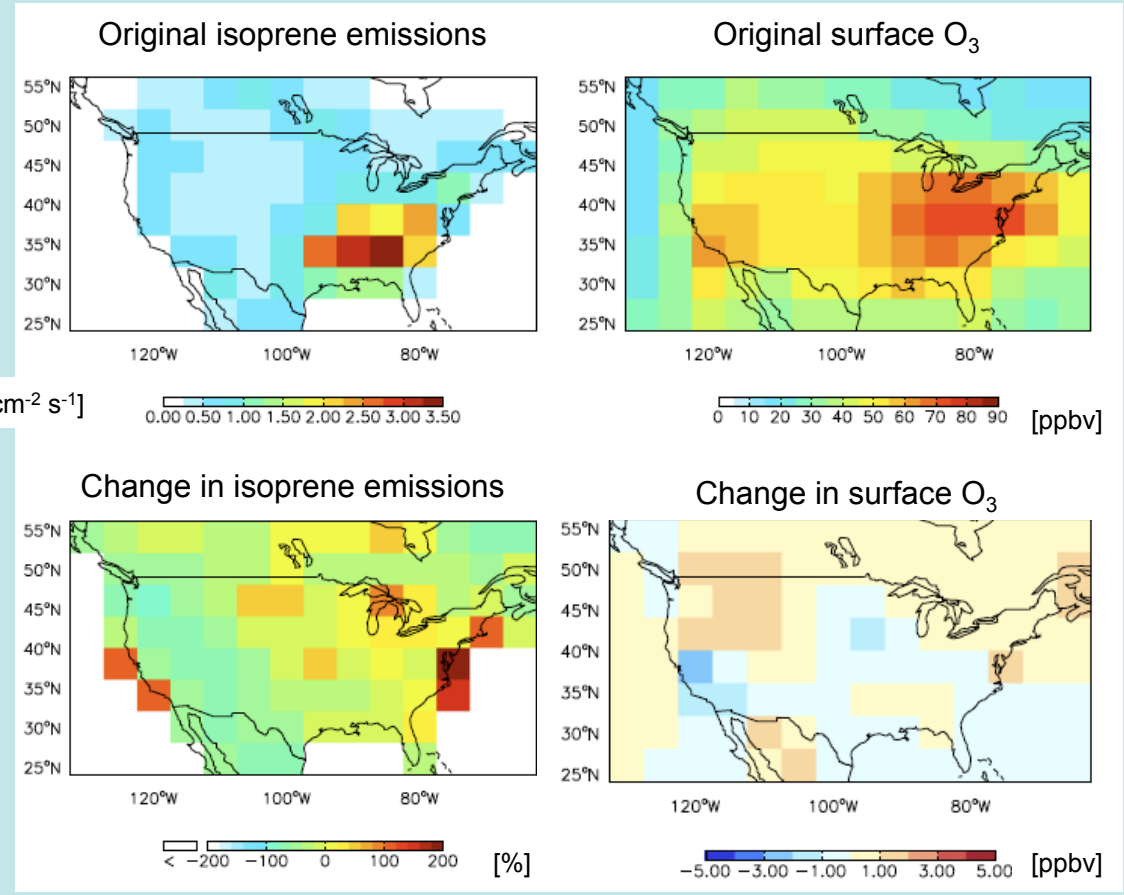
Parrington, et al., GRL, 2009

Top-down NO_x emissions



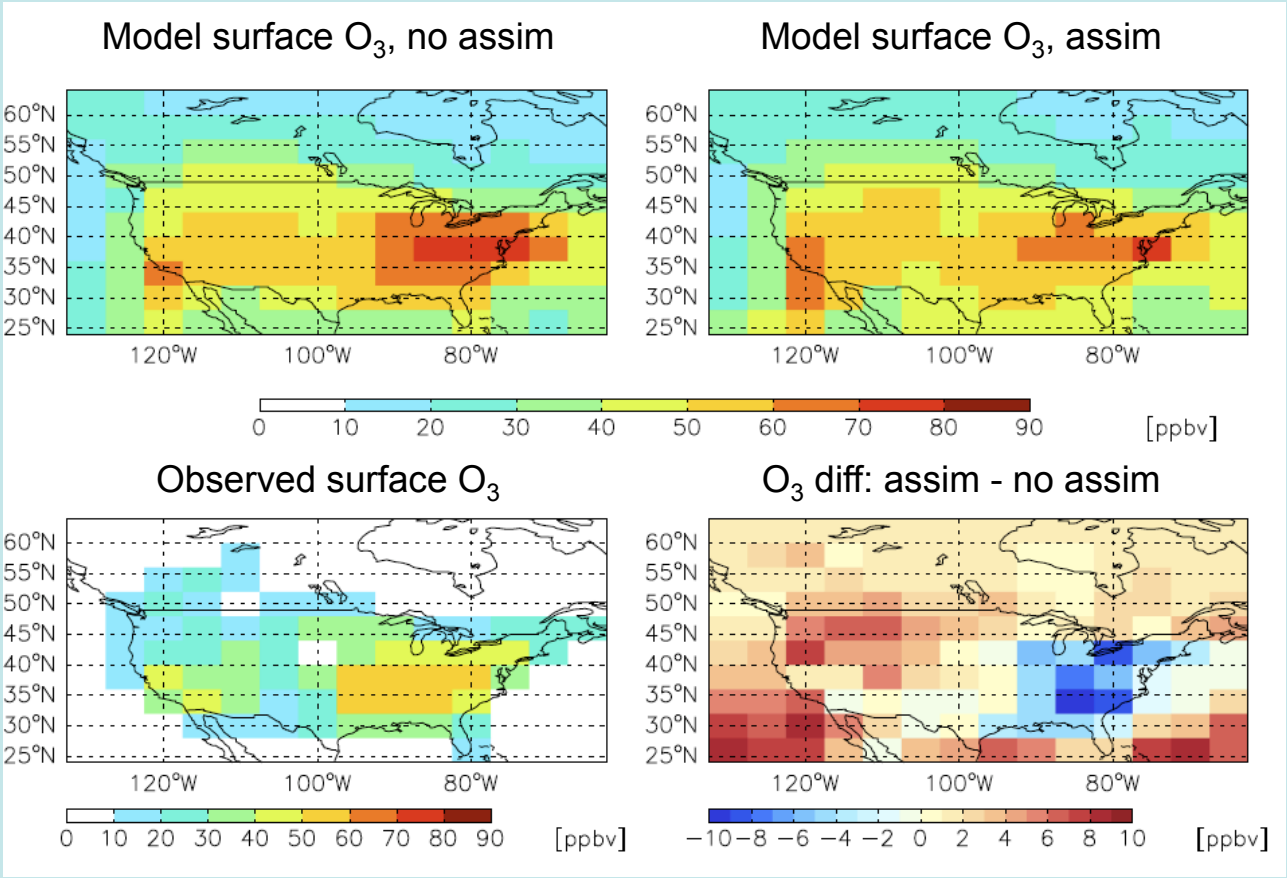
- Top-down NO_x emissions estimates, derived from SCIA NO_2 data, used to overwrite surface NO_x emissions sources.
- NO_x emissions for August 2006 reduced across eastern US by 20-50% but increased in west by 20-100%.
- Largest surface ozone response in eastern US (decreased by up to 10 ppbv), with smaller (< 5 ppbv) increase in north/central US.

Top-down isoprene emissions



- Top-down isoprene emissions estimates, derived from OMI HCHO data, used to determine scaling factors, applied to GEIA isoprene emissions.
- Isoprene emissions decreased across western North America and increased in the east.
- Surface ozone responses are less than 5 ppbv across the continent.

Combined impact of integrated satellite data on modelled surface ozone



- Total impact of integrating the TES, SCIA and OMI data leads to a reduction in modelled surface ozone in the eastern USA of up to 10 ppbv, due to the improved NO_x emissions, leading to an improved comparison relative to the surface observations but do not account for all of the difference.
- Increases to the modelled surface O_3 over the western continent suggest potential errors in other model processes.
- Boundary layer depth is a major source of uncertainty in modelled surface O_3 [e.g. Jintai Lin's presentation yesterday].

Summary

- Integrating satellite data into atmospheric models has considerable potential for evaluating uncertainties in our understanding of the chemical and physical processes controlling air quality.

- SCIA-derived NO_x emissions reduce and improve the modelled surface O_3 abundance relative to observations in the eastern US, with a slight increase in the west.

- OMI-derived isoprene emissions have a smaller impact (1-2 ppbv) on modelled surface O_3 across North America.

- The combined impact of the TES, SCIA and OMI data do not completely account for the differences between the modelled and observed surface O_3 - inferring errors in other model parameters (such as mixing layer depth, vertical mass fluxes).