Application of the GMI Combo Model to Hindcasts of Tropospheric Ozone and Related Species

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Hindcasts for 1990-present, driven by GEOS-5 MERRA fields.

- Evaluate Combo simulations driven by GEOS-5 DAS and GCM fields

- Test convection and large scale ascent in the UT using MLS CO and O$_3$ data and MOPITT and TES data in the LT (a much larger effort proposed to ROSES-09)

- Quantify the role of large IAV in biomass burning emissions in the tropics and boreal regions on tropospheric O$_3$

- Quantify the influence of changes in O$_3$ in the LS on tropospheric O$_3$ in the northern extratropics in the 1990s

- Quantify the effects of rapidly increasing Asian emissions and more slowly decreasing North American and European emissions on tropospheric O$_3$ and its precursors.

- In hindsight – examine effect of IAV in lightning
EMISSIONS

What is/will be available:

• RETRO, 1960-2000, yearly
• IPCC - AR5, decadal (not yet documented)
  – 1850-2000, with projections to 2100
  – For 2000, uses regional inventories when available,
  – Uses time trends from RETRO and EDGAR-HYDE
  – No plan to provide yearly emissions
• EDGAR v4.0 for 2005 (edgar.jrc.ec.europa.eu)
  – in progress
  – 0.1° x 0.1°
• GEOS-Chem emissions
GEOS-Chem emissions

- Base inventory is EDGAR3.2FT2000
- Overwritten with regional inventories
  - USA, Canada, Mexico, Asia (Streets), Europe (EMEP)
- Time dependence from regional inventories or CDIAC fossil fuel use elsewhere
- A paper is planned describing this in more detail (Randall Martin’s group).

- GFED2 (or 3) for biomass burning, 1997-2007
- For earlier years, use approach of Duncan et al. (2003), but change base emissions to mean of GFED
Model evaluation

2004-present:
- Standard evaluation of GEOS-5 simulations, DAS and GCM met fields (also ECMWF as available), for 2004 on:
  - Sondes, MOZAIC, surface sites etc
  - TES and MLS CO and O$_3$, OMI NO$_2$ (for DAS)

2000-present:
- Include MOPITT CO, EPTOMS TOC (merge with OMI/MLS TOC)
Model evaluation

1990-present:

• sondes, MOZAIC in trop. – examine consistency
• sondes and SAGE II in LS, also MLS in LS
• NOAA/GMD for CO
• GOME/SCIAMACHY/OMI NO$_2$ time series over major source regions

• Analysis of the consistency of the data sets is part of the planned work
Resources needed

- Multi-year runs of GMI Combo model driven by GEOS-5, MERRA
- 1990-present
- GCM runs for the same period
CO over South America in LT (TES) and UT (MLS)

Model lower than MLS in UT, peaks one month late in 2005 and 2006. Suggests a problem with convection, since LT looks good.

Good match with TES in LT in 2005-2006, GFED too high in 2007


GFED CO emissions
The GMI Combo model looks pretty good. Interannual variability driven by CO fire emissions, especially from Indonesia. Interannual variability in emissions in NH fire season apparent (Jan.-April). A tagged tracer analysis (sim. to Duncan et al., 2007 with GCM met. fields) would confirm this.
- Too much CO exported to the east equatorial Pacific. A similar overestimate is found in the LT comparing GEOS-Chem with MOPPIT data.

- Comparing with MLS data, GEOS-Chem CO maximum over South America in the UT occurs ~1 month late.
Aug & Sep:
Amazon: barely any convection, horizontal transport dominates in LT. Large amount of CO exported to the East equatorial Pacific.

Oct & Nov
ITCZ shifts southward, strongest convection appears in Nov, contributing the maximum CO mixing ratio in Nov. in the upper troposphere.

Contours: Convective mass flux of air (Pa/s): left and middle: 0.5Pa/s, right: 0.1Pa/s
Color: CO mixing ratio (ppbv), Fire occurs mainly in Aug/Sep. In South America, CO maximum occurs in Sep at 688hPa, in Oct. at 430hPa and in Nov. at 215hPa
South America:

- largest increase in deep convection in October
- most outflow is below 200 hPa
- convection reaches a higher altitude in November, when model CO peaks
Ozone over South America, Nov. 2004-Dec. 2008

In the model, ozone is related to lightning NOx (but not so simple)

LIS data show more lightning in 2006 than 2005.

TES data and OMI/MLS data show higher ozone in the South Atlantic region in 2005 and 2007.

Independent data from OMI/MLS confirms the IAV in the TES ozone data.
Differences between GEOS-Chem and GMI Combo model are caused by treatment of lightning NOx in the two models.

LNOx is higher in GEOS-Chem, particularly in 2006.

Local scaling to LIS/OTD in GEOS-Chem (to 11 year mean)
Regional scaling in GMI, with large regions

GEOS-Chem more closely follows the spatial pattern of LIS/OTD
GMI more closely follows the spatial pattern of the convective mass flux.
A detailed analysis of this region of the effects of the El Nino in late 2006 and the huge fires in Borneo is given in Nassar et al. (2009). (GEOS-Chem study)
Hindcast with GEOS-Chem – Lee Murray

- 1998-2006
- Picked for overlap of LIS data, GFED2, GEOS-4 met. fields at Harvard
- Run with LNOx with spatial scaling to LIS climatology, IAV only from local convection
- Run with local scaling, plus monthly scaling for large regions from LIS (35N – 35S)
Large inter-annual variability observed in tropical tropospheric ozone columns (EPTOMS)

GEOS-Chem run for 1998-2006 with GEOS-4

Lee Murray
Monthly anomalies in TOC and the effect of IAV in lightning NOx based on LIS data.

IAV in LNOx has a fairly small effect except in the Amazon region.

EPTOMS/OMI-MLS
GEOS-Chem, spatial scaling to LIS only
GEOS-Chem, Spatial and Temporal scaling to LIS
CO monthly anomalies and GMD data
IAV in extra-tropical ozone

Monthly anomalies over Europe

Sonde data

Analysis of data sets for trop. ozone – are they self-consistent?

MOZAIC data

Ozone in 3 km layers,
IAV in extra-tropical ozone

Comparison of sonde, nearby mountaintop station, and MOZAIC data.

Goal of the analysis is to come up with a robust record for ozone time series over various regions in the extratropics.
MLS and sondes in UTLS (Europe)

TES and OMI/MLS TOC