MLS and TES data for tropical tropospheric ozone: a revealing test of vertical transport in chemical transport models.

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GMI Combo model

- Driven by the GEOS-4 and GEOS-5 assimilated meteorological fields

Convection schemes

- GEOS-4 – Zhang and McFarland (1995) (deep) and Hack et al. (1994) (shallow)
- GEOS-5 – a version of the Relaxed Arakawa Schubert scheme (Moorthi and Suarez, 1992) (plus many other improvements in GEOS-5)
Outline

1. Which model run matches the observations best?
   - Model evaluation using TES, MLS, and in-situ data

2. Why is model ozone different using GEOS-4 and GEOS-5 met. fields?
   - Analysis of dynamics
TES data at 500 hPa show GEOS-4 performs better than GEOS-5

GEOS-5 ozone > GEOS-4 in much of the tropics
MLS data show GEOS-4 performs better than GEOS-5

GEOS-5 ozone > GEOS-4 in much of the tropics, but GEOS-4 has regions of low biases compared to MLS.
Sonde data show GEOS-4 usually performs better in the tropics.

GEOS-5 > GEOS-4 in UT (except Kuala Lumpur)
Remarkable fidelity in matching month-month variability of ozone

TES (minus 5 ppb)
GEOS-4
GEOS-5

GEOS-5 > GEOS-4 mid-year, mid-Pacific
GEOS-5 ≈ GEOS-4, maritime continent
MLS ozone at 215 hPa: Jan-Dec in each box.

GEOS-5 > GEOS-4 in most of S. tropics and in N. sub-tropics
GEOS-5 ≈ GEOS-4 in maritime continent
Case study: Ozone in July

GEOS-4

GEOS-5

G5-G4

200 hPa

500 hPa
Vertical transport of air, July 2006

Convective mass flux (g/m²/sec)

GEOS-4

GEOS-5

Vertical mass flux: convection plus advection

Subsidence in southern sub-tropics

Red = upward flux, blue = subsidence
Chemical production of ozone in UT is similar in GEOS-4 and GEOS-5

(P-L) in ppb/day, zonal mean

The NOx source from lightning is similar in the two models.
Ozone, winds, and air mass flux, July 2006

White lines: air mass flux, solid=up, dotted=down; arrows are winds
Ozone, winds, and air mass flux, July 2006

GEOS-4

GEOS-5

AURA4 LS2 July 2006 O3 (ppb) 226 hPa

C5AURA July 2006 O3 (ppb) 226 hPa

200 hPa

N-S slice

E-W slice

AURA4 LS2 July 2006 O3 (ppb) 505 hPa

C5AURA July 2006 O3 (ppb) 505 hPa

500 hPa
Downward ozone fluxes are larger in GEOS-5 than GEOS-4.

Ozone fluxes (arrows)

E-W slice, 10°S – 20°S (arrows)

N-S slice, Eastern Pacific, 90° – 120°W (arrows)
Ozone and vertical transport

- Ozone is most similar within and downwind of regions of convection
- It is most different in regions of strong subsidence
- Chemical lifetime of ozone is months in the UT, so vertical transport controls lifetime
- Ozone is removed chemically in the lower troposphere
- Faster overturning of the atmosphere => lower ozone in GEOS-4
Case study: Ozone in January 2006

Very similar in January in S.H. at 500 hPa
Vertical air mass flux in GEOS-4 and GEOS-5: January 2006

Convective mass flux (g/m$^2$/sec)

Vertical mass flux: convection plus advection

Subsidence in northern sub-tropics (and also some in SH)
Ozone, winds, and air mass flux, January 2006
ITCZ far south

Ozone similar in convective regions at 500 hPa, now in S.H.
Concluding remarks

- GEOS-4 and GEOS-5 ozone are similar in regions of deep convection, and are most different in regions of subsidence.

- TES and MLS data show that vertical transport in GEOS-5 degrades the tropical simulations compared to GEOS-4.

- Conventional view that lightning NOx is the main factor controlling tropical ozone is simplistic – transport rules!

- Do the same problems exist in the GEOS-5 GCM using the same convective scheme? Coupled chemistry-climate models used for projections, so the stakes are high.

- CTM studies often identify problems with model transport – but they don’t necessarily lead to improvements in parameterizations inherent in global GCMs – 2 communities. GMAO always working on the next version (GEOS-6).