Ozone trends and variability in the tropical lower stratosphere from SAGE II satellite + SHADOZ ozonesonde data

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Background:

- Chemistry-climate models predict ozone loss in tropical lower stratosphere (response to increased tropical upwelling).

- Lack of continuous high vertical resolution ozone measurements in the tropics after the end of SAGE II satellite

*How do we monitor long-term tropical ozone variability?*

Objective here:

- Explore the use of SHADOZ ozonesondes to update and extend SAGE II measurements after 2005
Simulated ozone trends 1980-2005

Observations require: long, accurate records, high vertical resolution (~1 km)
Data:

- **SAGE II** satellite measurements for 1984-2005
  ~ monthly samples in tropics (covers 15-50 km)

- **SHADOZ** ozonesondes 1998-2010 (surface to ~35 km)
  use 7 stations within +/- 10° of equator

[Map showing SHADOZ stations]
Deseasonalized ozone anomalies from SHADOZ

strong QBO signal at 24 km

Color: individual stations

Black: average

24 km

20 km
Time series of SHADOZ data 1998-2009

Note downward propagating QBO signals in both ozone and temp.
Combining SAGE II and SHADOZ data

**SAGE II**

**SHADOZ**

Correlation for overlap period

24 km

![Graph for 24 km correlation](image)

Data void following Mt. Pinatubo

*note good agreement for overlap during 1998-2005*

20 km

![Graph for 20 km correlation](image)

r=0.84

r=0.83

SAGE II

SHADOZ

[Graphs show correlation data for 24 km and 20 km altitudes, with a focus on the correlation coefficients for the overlap periods.]
Time series of combined SAGE II + SHADOZ ozone anomalies (DU) for different altitude layers.

Ozone anomalies (DU) for different altitude layers:
- 29-35 km
- 22-28 km
- 17-21 km
Multivariate regression model fits for combined SAGE II + SHADOZ data 1984-2009

\[ O_3(t) = A \times \text{trend} + B \times \text{ENSO} + C \times \text{QBO1} + D \times \text{QBO2} \]

- Linear trend
- Multivariate ENSO proxy
- Orthogonal QBO proxies

**trend**

- Long-term ozone decrease in lower strat.

**ENSO**

- Ozone decreases for ENSO warm events
  * Response to increased upwelling. Randel et al GRL 2009

**QBO**

- Coherent QBO signal over 15-35 km
Components of ozone variability in tropical lower stratosphere

17-21km ozone anomalies

- total
- QBO
- trend
- ENSO
- residual
Trends from SAGE II + SHADOZ compared to results from CCMval2 models

Ozone trends in percent per decade for 1984-2009

Significant negative ozone trends in tropical lower stratosphere
**Key points:**

1) SHADOZ data provides opportunity to extend SAGE II record in the tropics. Note availability of many SHADOZ stations; continuity would be more difficult with few stations. (also ozonesonde sampling poor > 30 km)

   - long overlap (1998-2005) and similar high vertical resolution a key for combining data sets
   - excellent overlap agreement validates quality of both data sets
   - important to continue SHADOZ record to the future
   - tropical lower stratosphere is a complicated region (trends, ENSO, QBO effects)

2) Combined time series for 1984-2009 exhibit significant negative trends in tropical lower stratosphere (-3%/decade near 19 km).

   Reasonably consistent with results from CCMval2 models.

   Paper accepted in JGR. Please email or ask for a preprint.
ENSO fit for SHADOZ data 1998-2009

Zonally uniform response in lower stratosphere

Strong longitudinal variation in upper troposphere
CAM-chem model calculations: SST forcing for ENSO, but no variable emissions

Ozone decrease during ENSO ‘warm events’

courtesy JF Lamarque
Extra slides
Trends derived from SAGE I+II data expressed as net changes over 1979-2005
A large seasonal cycle in ozone above the tropical tropopause

Seasonal cycle at Nairobi

Seasonal cycle at 7 SHADOZ stations 10 N-S

large annual cycle at all stations, over narrow vertical layer

Randel et al, JAS, 2007
ENSO effects on zonal mean ozone

WACCM ozone

SAGE II observations 1984-2005

Units: ozone % / MEI

Randel et al, GRL, 2009