Spatial Structures in Lower-Stratospheric Temperature Trends and Ozone

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MOTIVATION & BACKGROUND

The goal of this project is to examine the spatial structure of lower-stratospheric temperature trends in detail, and to compare them to trends in a new ozone vertical profile data set.

- Lower-stratospheric temperature trends from the Microwave Sounding Unit (MSU4) from 1979-2006 show stronger cooling in the extratropics relative to the cooling in the tropics, a pattern thought to be related to an expansion of the Hadley cell [*Fu et al.*, 2006].
- Relationship of lower-stratospheric temperatures to total column ozone has been examined [*Randel and Cobb*, 1994], but not to vertical profile ozone data.
- A new vertical ozone profile data set has been created that includes both satellite (HALOE, SAGE I/II, POAM II/III) and ozonesondes [*Hassler et al.*, 2008]. Using this new data, trends in vertical profile ozone data and MSU4 can be compared.
- The new vertical profile ozone data may also provide observational evidence of trends in the Brewer-Dobson circulation, which is predicted to increase in climate change simulations [*Li et al.*, 2008].

SPATIAL STRUCTURES IN MSU4 TRENDS AND SEASONALITY

Data from Remote Sensing Systems (RSS), MSU4

Linear trends from 1979-2006

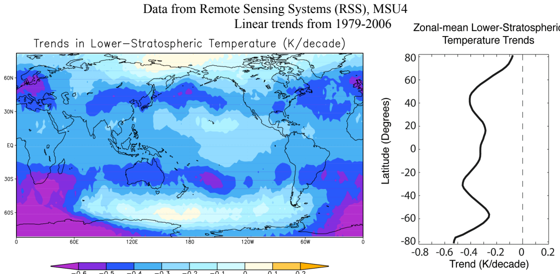


Figure 1. (left) MSU4 linear temperature trends, 1979-2006, K/decade. (right) Zonal-mean MSU4 temperature trends, K/decade. Blue arrows indicate cooling maxima in extratropics.

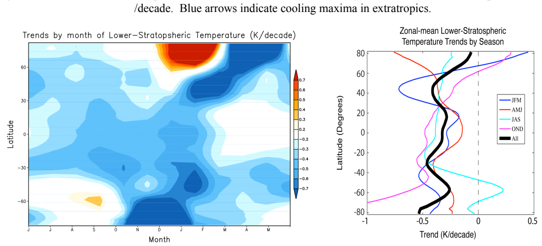


Figure 2. (left) MSU4 temperature trends as a function of month and latitude, K/decade. (right) Zonal-mean MSU4 temperature trends by seasonal average, K/decade.

NH extratropical cooling maximum occurs mostly in JFM.

SH extratropical cooling maximum occurs year-round at shifting latitudes.

Overall, bimodal cooling structure is most apparent in NH winter (JFM).

Warming trend at polar latitudes occurs in winter hemisphere.

OZONE TRENDS: TOTAL COLUMN & BDBP VERTICAL PROFILE DATA

Data from Binary DataBase of Profiles (BDBP), *Hassler et al.* (2008). Data has been averaged into 5° latitude bins. Linear trends from 1979-2006. Seasonal cycle removed. QBO signal removed by lagged best fit as a function of height and latitude. 40% of data must be present to calculate trend.

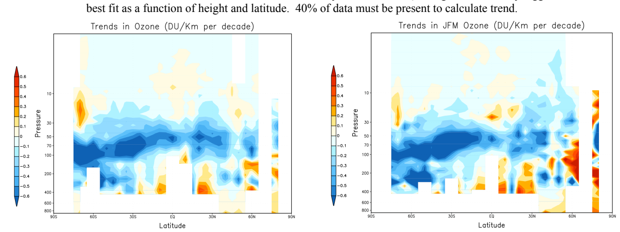


Figure 3. (left) Vertical profile linear ozone trends, 1979-2006, DU/decade. (right) Same as (left) but JFM only.

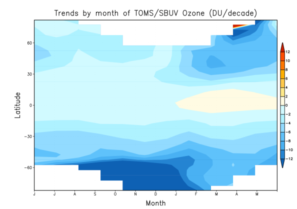


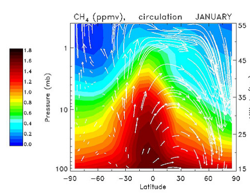
Figure 4. TOMS/SBUV total column ozone linear trends, 1979-2006, QBO signal removed.

Vertical Profiles show ozone depletion occurring throughout the lower stratosphere, *including in the tropics*.

Seasonality in total column ozone trends match well with seasonality in lower-stratospheric temperature trends (see Figure 2), except in tropics where total column ozone trends are near zero.

In JFM, trends indicate strong ozone loss from 1979-2006 in SH midlatitudes, with ozone increases at ~60°N (Figures 3 and 5).

Trends Related to Trends in Brewer-Dobson Circulation?



Color contours of methane concentrations and arrows depicting the Brewer-Dobson circulation in January, from *Stratospheric Ozone: An Electronic Textbook, NASA GSFC.* Note that upwelling occurs from 30S-30N.

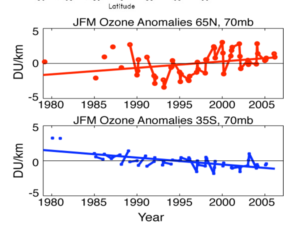


Figure 6. JFM ozone anomalies at 70 mb and (top) 65°N (bottom) 35°S.

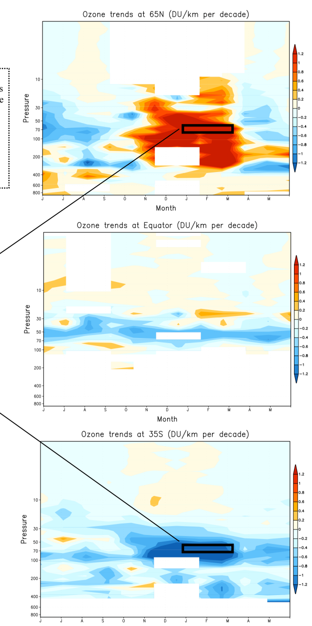


Figure 5. (top) Ozone vertical profile trends as a function of pressure and month at 65°N. (middle) Same as (top) but at equator (note: here only 35% of data was required to calculate trend). (bottom) Same but for 35°S.

Increase in ozone at ~60°N and decrease at 35°S in DJFM possibly associated with Brewer-Dobson Circulation (BDC).

Ozone trends suggest an increase in the BDC from 1979-2006 (and thus an increase in wave driving).

This would also explain warming at ~60°N and cooling at 35°S in JFM in MSU4, but not cooling at 35°N.

RELATIONSHIPS BETWEEN MSU4 & OZONE

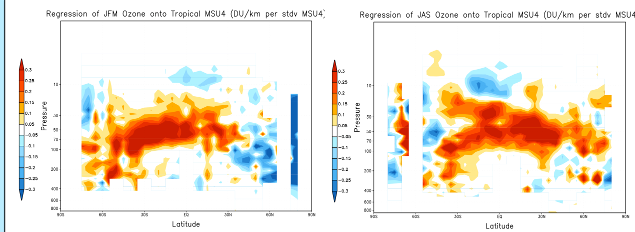


Figure 7. (left) Regression coefficients of JFM Ozone onto standardized JFM 30ºS-30ºN zonal-mean MSU4. Units are DU/km per standard deviation of MSU4. QBO signal has been removed from data sets. 35% of data necessary to calculate regression coefficient. (right) Same as (left) but for JAS. 3 years after volcanic eruptions have been removed from MSU4.

Lower-stratospheric JFM temperatures from 30ºS-30ºN vary in phase with lower-stratospheric ozone from 60ºS-40ºN, but out of phase with ozone at latitudes >40ºN. Opposing pattern in JAS.

In agreement with the BDC: as tropical temperatures decrease with upwelling, ozone decreases in the tropics but increases at the pole.

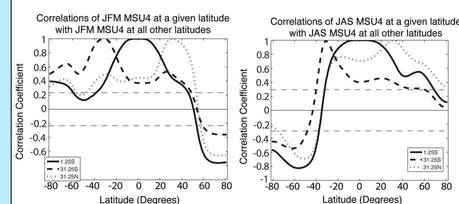


Figure 8. (left) Correlation Coefficients of JFM MSU4 at 3 different latitudes with JFM MSU4 at all other latitudes. (right) Same but for JAS. QBO signal has been removed. 3 years after volcanic eruptions have been removed from MSU4. Dashed lines represent 95% significant correlations.

Tropical MSU4 temperatures correlate negatively with winter hemisphere polar MSU4 temperatures.

Subtropical MSU4 temperatures in the summer hemisphere correlate negatively with winter hemisphere polar MSU4 temperatures.

CONCLUSIONS

- Strongest spatial patterns in both lower-stratospheric temperatures and ozone occur in JFM.
- Spatial patterns in ozone trends, with cooling near 35°S and warming near 60°N, may indicate an increase in the Brewer-Dobson circulation from 1979-2006. This may also explain the observed ozone depletion in the tropical lower stratosphere, as an increase in tropical upwelling would remove ozone from its source region [*Thompson and Solomon*, 2008].
- Mid-latitude/polar ozone in the winter hemisphere has an out-of-phase relationship with tropical stratospheric temperatures, likely due to the dynamical effects of the Brewer-Dobson circulation.
- It is likely that some of the spatial structure in zonal-mean MSU4 trends can be explained by changes in the Brewer-Dobson circulation. An increase in the BDC would decrease tropical and subtropical stratospheric temperatures while increasing polar stratospheric temperatures. Whether an increase in the Brewer-Dobson circulation relates to the expansion of the Hadley cell is unclear.

REFERENCES & ACKNOWLEDGEMENTS

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