SHADOZ Temperature and Ozone Anomalies Associated with QBO and ENSO

Sukyoung Lee, David M. Shelow, Anne M. Thompson, Sonya K. Miller

Department of Meteorology, Pennsylvania State University

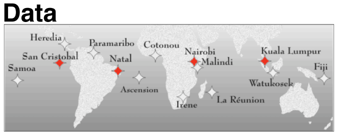
Abstract

Temperature and ozone profiles from SHADOZ (1998-2005) radiosonde and ozonesonde soundings are analyzed. Principal components of the ozone profile time series at Kuala Lumpur (3N, 101E) are adopted as a stratospheric QBO index to study tropospheric temperature and ozone signatures associated with the QBO. A downward propagating QBO ozone signal extends to the mid-troposphere.
The maximum tropospheric ozone anomalies associated with the QBO are ~ 8 ppbv, about 10-20% that of typical tropical tropospheric ozone values.

Temperature and ozone fields, linearly regressed against the QBO index, suggest that dynamical processes, including horizontal transport, play an important role for the observed tropospheric ozone anomalies.

Temperature profiles, regressed against the Southern Oscillation Index (SOI), reveal anomalously cool, but also wavy lower stratospheric temperature anomalies. Tropospheric ozone profiles associated with the SOI show a statistically significant signal that is consistent with anomalous vertical motions that are known to occur during ENSO.

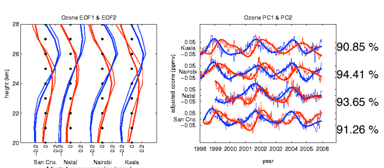
Data



The SHADOZ (Southern Hemisphere Additional Ozonesondes) network has collected over 4000 profiles over 14 stations from 1998-2007 (Thompson et al., 2003). The ozone measurement is made with electrochemical concentration cell ozonesondes (precision is 5-7%). Temperature and pressure are recorded by standard radiosondes from Vaisala at all sites except Ascension and Natal, where Sippican instruments are used. These data are archived at http://croc.gsfc.nasa.gov/shadoz.

A. M. Thompson, et al. Southern Hemisphere ADditional Ozonesondes (SHADOZ) 1998-2000 tropical ozone climatology. 1. Comparison with TOMS and ground-based measurements, J. Geophys. Res., 108, 8238, doi: 10.1029/2001JD000967, 2003.

EOF analysis



$$O(z,t) = \sum_{i=1}^{N} EOF_i(z) PC_i(t)$$

Figure 1. First two EOFs (left) and corresponding PCs (right panel) of the ozone profiles. The first (second) EOF and PC are indicated by blue (red), and the thin (thick) lines are from deseasonalized (low-pass filtered) data. The fractional variances explained by the first two EOFs are indicated in the right margin of the right panel.

QBO signal

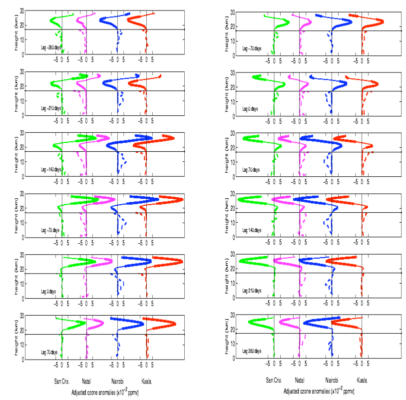


Figure 2. Ozone profiles linearly regressed against the stratospheric ozone-based QBO index. Values that exceed the 95% confidence level are indicated by a thick curve. The units for the dotted curve are ppbv.

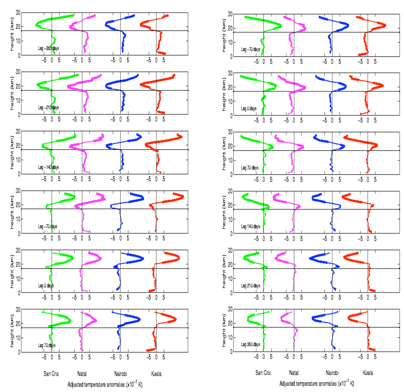


Figure 3. Temperature profiles linearly regressed against the stratospheric ozone-based QBO index. Values that exceed the 95% confidence level are indicated by a thick curve.

ENSO signal in temperature

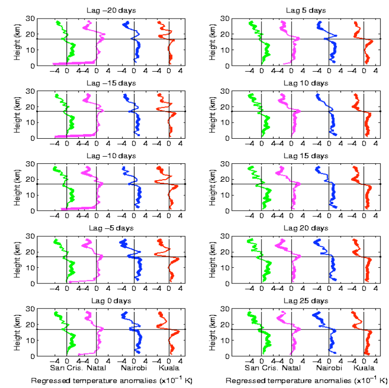


Figure 4. Temperature profiles linearly regressed against the daily inverted Southern Oscillation Index. Values that exceed the 95% confidence level are indicated by a thick curve. Note that the profiles at Nairobi and Kuala Lumpur undergo significant changes on intraseasonal time scales.

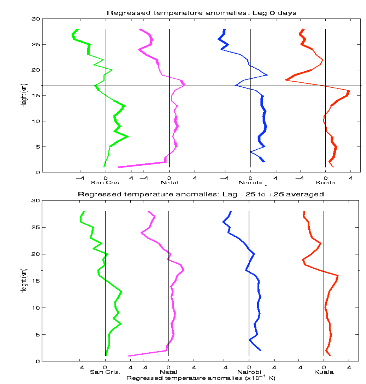


Figure 5. (Top panel) Temperature profiles linearly regressed against the low-pass (period greater than one year) inverted Southern Oscillation Index. Values that exceed the 95% confidence level are indicated by a thick curve. In general, the troposphere is anomalously warm and the stratosphere is anomalously cold. The wavy structure in the UT/LS region may reflect a vertically propagating Kelvin wave. (Bottom panel) Composite profile of all lags shown in Fig. 4. The similarity between the top and bottom panels indicates that the interannual time-scale ENSO signal represents an aggregated effect of intraseasonal time-scale fluctuations.

ENSO signal in ozone

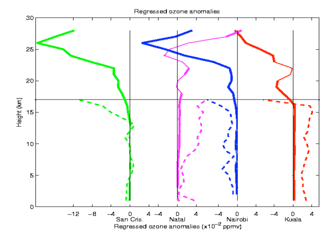


Figure 6. Ozone profiles linearly regressed against the low-pass (period greater than one year) inverted Southern Oscillation Index. Values that exceed the 95% confidence level are indicated by a thick curve. The units of the dotted curves are ppbv.

The positive tropospheric ozone anomalies over Natal and Kuala Lumpur are consistent with anomalous downwelling; the negative tropospheric ozone anomalies over Nairobi are consistent with anomalous upwelling that are expected during ENSO events.

Conclusions

1. The first two principal components of the ozone profiles from the SHADOZ (1998-2005) program are shown to be a viable QBO index. The combined fractional variance of the first two EOFs exceeds 90% for all four sites examined in this study.

2. The maximum tropospheric ozone anomalies associated with the QBO are ~ 8 ppbv, ie 10-20% that of typical tropospheric ozone values. Furthermore, their zonal variation implies that the tropospheric ozone anomalies are regulated by processes other than photochemical responses to the stratospheric ozone anomalies.

3 Temperature regression based on the inverted SOI confirms the tropospheric warming and stratospheric cooling associated with the ENSO. In addition, the UT/LS region reveals a wavy structure, implying a possible role by vertically propagating tropical waves in the UT/LS.

4 In Nairobi and Kuala Lumpur, the temperature response to the ENSO reflects the aggregated effect of intraseasonal time-scale processes.

Acknowledgments: This work is in part based on David Shelow's M.S. thesis research with SL. SL was supported by the National Science Foundation under Grant ATM-0647776. AMT and SKM were supported by NASA Grants NNG05GP22G and NNG05G062G (M. Kurylo & K. Jucks).

For a full list of references, see the corresponding manuscript which will be submitted to *JGR*. The manuscript will be posted on www.meteo.psu.edu/~sl within the next few months.