Short Term Variations in Middle Atmospheric Ozone from SCIAMACHY and SABER

Sebastian Dikty[1], M. Weber[1], H. Winkler[1], T. Sonkaew[1], C. v. Savigny[1], A. Rozanov[1], M. Sinnhuber[1],
M. G. Mlynczak[2], J. P. Burrows[1]
(1) Institute for Environmental Physics, University of Bremen, (2) Langley Research Center, NASA
Contact: dikty@iup.physik.uni-bremen.de

Motivation and Introduction

SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Cartography) aboard ENVISAT and SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) aboard the TIMED satellite, have been launched in 2002 and 2001, respectively. They provide high altitude ozone profiles from the stratosphere into the mesosphere . Due to their high global sampling their data are well suited for studying short-term variations in ozone related to the 27-day solar rotation period and diurnal variations.

Daily solar observations from GOME and SCIAMACHY allow the calculation of a long-term time series of the MgII index (@ 279.9 nm) as a proxy for solar UV irradiance variability. (Skupin et al. 2005). Effects on short timescales (27-day solar rotational cycle) are up to half the order of magnitude of the 11- year cycle. The MgII index has been shown to track the solar UV irradiance changes throughout the UV region. A change of 1 % in the MgII index corresponds to a 0.61 % change in solar irradiance at 205 nm (also often used as solar proxy). The MgII index has been correlated with SCIAMACHY ozone observations

The diurnal solar signal response on ozone can be investigated with SABER data since the TIMED satellite is in a non-sun synchronous orbit . It covers any given latitude at different local times within a period of about 60 days. Diurnal and short term solar variations and their impact on ozone are also studied with the Bremen 2D Chemistry-Transport-Model (B2dCTM) and compared with satellite observations.

Ozone Anomalies and QBO

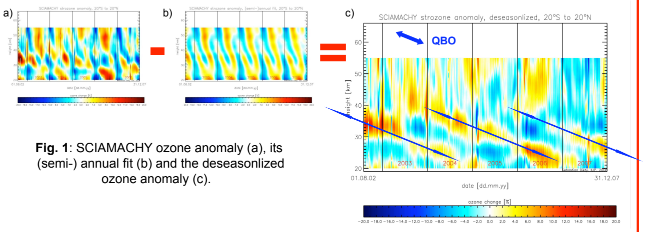


Fig. 1: SCIAMACHY ozone anomaly (a), its (semi-) annual fit (b) and the deseasonlized ozone anomaly (c).

Ozone profiles between 20 and 65 km have been retrieved using SCIAMACHY limb spectra and the knowledge about absorption features of ozone in the Hartley and Chapuis bands. The profiles were used to calculate daily area weighted zonal mean profiles. Fig. 1c shows the ozone anomaly in the tropics and their temporal evolution from August 2002 to December 2007.

In addition, version 1.06 ozone profiles between 25 and 105 km from the SABER instrument onboard NASA's TIMED mission were used. In contrast to SCIAMACHY, SABER measures ozone at night as well (absorption feature of ozone at 9.6 μm, 25-105 km). Daytime $O_2(^1\Delta)$ airglow emissions (at 1.27 μm) make the retrieval of ozone profiles possible at altitudes above 70 km (Mlynczak et al., 2007). Yaw maneuvers of the TIMED satellite constrict the analysis of continues time series to latitudes between 52°S and 52°N. Area weighted zonal mean profiles could be calculated in 5° bins. As for SCIAMACHY the ozone anomaly for SABER can be seen in Fig. 2c.

Ozone anomalies (%-deviation from the mean) are based on area weighted zonal mean profiles from SCIAMACHY and SABER. A (semi-)annual fit was subtracted to get a better look at the QBO signal. High ozone values correspond to QBO west phases. The anomalies form the basis for further investigations on diurnal variations and response to solar signal (see '*Ozoe Response to Solar Variability*').

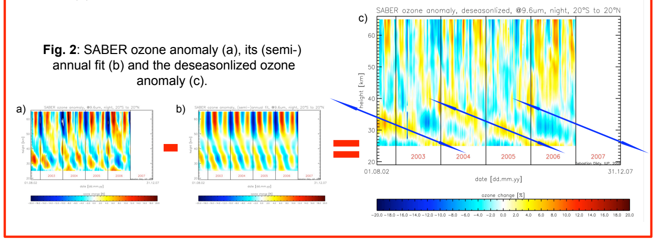


Fig. 2: SABER ozone anomaly (a), its (semi-) annual fit (b) and the deseasonlized ozone anomaly (c).

Outlook

In addition to further adjustments to the model (solar and daily variability), future investigations will concentrate on the decomposition of the time series by a multivariate least square fit in order to better separate 27-day solar cycle variability, instrumental features (60 -day cycle for SABER), and QBO. It is planned to implement UV/vis/NIR solar spectral variation with solar cycle as derived from SCIAMACHY solar observations into the model and compare with ozone observations.

Selected References

Hood, L. L., 1986: *Coupled Stratospheric Ozone and Temperature Responses to Short-Term Changes in Solar Ultraviolet Flux: An Analysis of Nimbus 7 SBUV and SAMS Data*. J. Geophys. Res., 91, pp. 5264-5276

Huang, F. T., Mayr, H., Russell, J. M., Mlynczak, M. G., Reber, C. A., 2008b. *Ozone diurnal variations and mean profiles in the mesosphere, lower thermosphere, and stratosphere, based on measurements from SABER on TIMED*. J. Geophys. Res., doi:10.1029/2007JA012739.

Huang, F. T., Mayr, H., Reber, C. A., Russell, J. M., Mlynczak, M. G., Mengel, J. G., 2008b. *Ozone quasi-biennial oscillations (QBO), semiannual oscillations (SAO), and correlations with temperature in the mesosphere, lower thermosphere, and stratosphere, based on measurements from SABER on TIMED and MLS on UARS*. J. Geophys. Res., 113, A01316, doi:10.1029/2007JA012634.

Hood, L. L., Zhou, S., 1998. *Stratospheric effects of 27-day solar ultraviolet variations: An analysis of UARS MLS ozone and temperature data*. J. Geophys. Res., 103, D3, 3629--3638.

Mlynczak, M. G., Marshall B. T., Martin-Torres, F. J., Russel III, J. M., Thompson, R. E., Remsberg E. E., Gordley, L. L., 2007. *Sounding of the Atmosphere using Broadband Emission Radiometry observations of daytime mesospheric $O_2(^1\Delta)$ 1.27 μm emission and derivation of ozone, atomic oxygen, and solar and chemical energy deposition rates*. J. Geophys. Res., 112, D15306.

Sinnhuber M., Burrows, J. P., Chipperfield, M. P., Jackman, C. H., Kallenrode, M.-B., Künzi, K. F., Quack, M., 2003. *A model study of the impact of magnetic field structure on atmospheric composition during solar proton events*. Geophys. Res. Lett., 30(15), 1818, doi :10.1029/2003GL017265.

Skupin, J., M. Weber, S. Noel, H. Bovensmann, J. P. Burrows, 2005: *GOME and SCIAMACHY solar measurements: Solar spectral irradiance and Mg II solar activity proxy indicator*, Memorie della Societa Astronomica Italiana, 76, pp. 1038-1041

Winkler, H., Sinnhuber, M., Notholt, J., Kallenrode, M.-B., Steinhilber, F., Vogt, J., Ziegler, B., Glassmeier, K.-H., Stadelmann, A., 2008. *Modeling impacts of geomagnetic field variations on middle atmospheric ozone responses to solar proton events on long time scales*. J. Geophys. Res., 113, D02302, doi:10.1029/2007JD008572.

Diurnal Variations

Recently Huang et al. (2008a,b) also investigated diurnal ozone variations from SABER. In general the match between Huang et al. and our study is good. Here we focused in on ozone profiles retrieved at 1.27 μm and also compared our results to the output of the B2dCTM. Except for 76 km and 80 km the comparison to the data looks promising (cf. Fig. 4). Sensitivity studies are underway to better understand the observed differences between 2D models and observations.

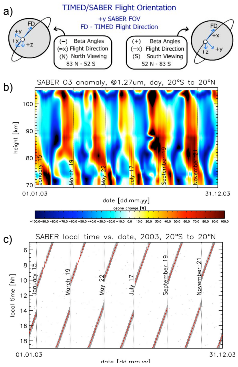


Fig. 3 (above): Flight pattern of TIMED (http://saber.larc.nasa.gov), ozone anomaly daytime data (b) and local time dependence of measurements (c)

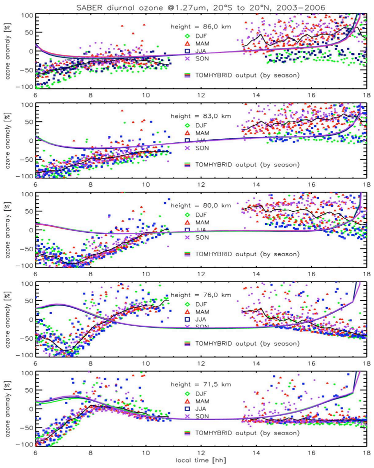


Fig. 4 (top right): SABER diurnal ozone anomaly [%] between 20°S and 20°N derived from $O_2(^1\Delta)$ airglow emissions at 1.27 μm. The seasonal component is highlighted with colored symbols. The solid black line denotes the 30 min running mean for all seasons. Indicated with colored solid lines are the seasonal and diurnal variations from the B2dCTM (Sinnhuber et al., 2003, Winkler et al. 2008).

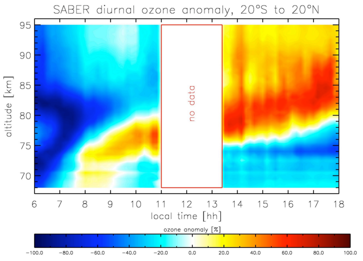


Fig. 5 (right): SABER height dependent diurnal ozone anomaly between 20°S and 20°N. The 30 min running mean for all seasons from Fig. 4 has been plotted against altitude in 0.5 km steps between 65 km and 95 km.

Ozone Response to Solar Variability

The results of the impact of solar variability on tropical ozone are illustrated in Fig. 7.They show good agreement to previous studies from Hood (1986) and Hood and Zhou (1998). Fig. 6 shows an example of the decomposition of a time series at 40 km.

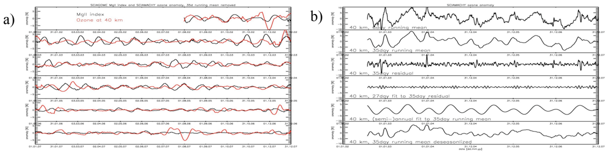
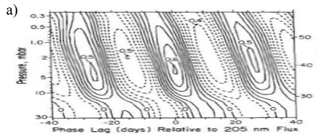


Fig. 6: SCIAMACHY ozone at 40 km and MgII index time series from August 2002 to December 2007 (a). A 35-day running mean has been subtracted to eliminate variations on longer time scales. Both show especially during solar maximum some correlation Fig. 6b shows SCIAMACHY ozone time series at 40 km after applying different filters.



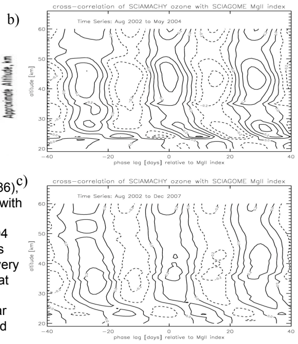


Fig. 7: Cross-correlation of solar UV signal with stratospheric ozone. Fig. 7a was taken from Hood (1986), where SBUV ozone data (1979-1980) was correlated with the solar 205 nm flux. In the right hand figures the correlation of SCIAMACHY ozone data (b → 2002-2004 and c → 2002-2007) with the SCIAGOME MgII index is shown. The overall match between the two studies is very good except for the fact that the maximum correlation at solar maxmimum is weaker during 2002-04 than in 1978-79. It is less pronounced when the entire five year SCIAMACHY data (from solar max to solar min) is used (cp. Fig. 6a and 6b).

See also: www.iup.uni-bremen.de/UVSat

Dikty_Bologna2008.ppt presented at the SPARC General Assembly, Bologna, 31 August - 5 September 2008