Global Distribution of CO₂ VMR in the Mesosphere and Lower Thermosphere and Long-Term Changes Observed by SABER

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1. Introduction

Aim: The infrared limb observations of the Earth’s Mesosphere and Lower Thermosphere by the SABER instrument on board TIMED satellite constitutes the longest data record (2002-2015 and counting) for monitoring the temperature, trace gas concentration, and energetics in the MLT. This presentation summarizes the results of the newly derived SABER CO₂ VMR, validation and comparison with the ACE-FTS measurements, and the SD-WACCM global circulation model. We also discuss the seasonal and latitudinal CO₂ distribution and the long term changes in the MLT as observed by SABER.

2. SABER on board TIMED satellite

Figure 1: Latitude coverage distribution that SABER achieves given the orbit of its TIMED satellite. TIMED (Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics) launched on Dec 7, 2001 and data available since January 2002. Four instruments: C2V, SEE, TES, SABER.

\* SABER (Sounding of the Atmosphere using Broadband Emission Radiometry)
\* 10 infrared channels (1.27-17 \(\mu\)m)
\* Temperature, O₃, H₂O, OH, CO (in post processing), cooling/heating rates

3. SABER CO₂/Tk self-consistent retrieval

The v2.0 SABER limb radiance in 15 and 4.3 \(\mu\)m is used in a post operational inversion to self-consistently obtain the vertical profiles of kinetic temperature and CO₂ VMR.
\* Currently applied only for the daytime conditions
\* Iterative switching over two global (all altitudes at once) relaxation modules.
\* Retrieval grid 65-115 km (up to 130 km for CO₂) relying on operational Tj and WACCM CO₂ below.
\* Additional control applied for similar convergence speed in both channels.
\* Methodology published in Rezac et al., (2015) JASTP.

3. SABER, ACE-FTS and WACCM CO₂ comparisons

Figure 3: Comparison of mean CO₂ VMR profiles between SABER (blue line) and ACE-FTS (red line) assembled from the 5 years of coincident measurements as discussed in the text. Mean CO₂ VMR profiles from CRISTA-1 [Kaufmann et al., 2002] (black dot) and the Rocket measurements [Wintersteiner et al., 1992] are indicated by the error bars at the selected altitudes. All profiles are scaled to the same value at 95 km. The mean relative difference between coincident SABER and ACE-FTS CO₂ pairs is plotted as the blue curve on the right and the error bars indicate the standard deviation of the difference. The combined uncertainty of SABER and ACE is indicated in shaded area.

Figure 4: Global, 2004-2012 mean CO₂ VMR profiles from SABER (full blue) and ACE-FTS (full red). Two SD-WACCM mean CO₂ VMR profiles are shown as dashed lines. The SD-WACCM corresponding to the exact space and time sampling of the available SABER data (dashed-dashed blue curve) and one for the ACE-FTS data availability (dashed-dashed red curve).

Figure 5: CO₂ radial mean latitude cross-sections for January (2004-2012), comparison of SABER, ACE-FTS, and SD-WACCM.

Figure 6: CO₂ radial mean latitude cross-sections for March (2004-2012), comparison of SABER, ACE-FTS, and SD-WACCM.

4. CO₂ trends in MLT from SABER

Figure 7: SABER observed trends in the MLT region in absolute and relative units. The comparison to the tropospheric trend and absolute trend from ACE-FTS is shown for comparison.

Figure 8: Time series of SABER CO₂ VMR averaged over 60 days (the SABER you cycle) and over latitude range ±54 deg. The different colors show different altitude regions. The time series of CO₂ measured at Mauna Loa Observatory is also shown for comparison (black curve). The uncertainty is the 2 standard deviation of the VMR data within the time/space bin.

The SABER CO₂ trends are derived through multiple-linear regression analysis (MLR) accounting for annual, semi-annual and quasi-biennial oscillations (AO, SAO, QBO), as well as solar cycle trend from the F10.7cm proxy.

5. Summary

\* Simultaneous (daytime) two-channel retrieval of CO₂ VMR and Tk processed for entire SABER period (2002-2015)
\* SABER and ACE-FTS CO₂ agree within the measurement uncertainties, with larger differences above 100-105 km.
\* Distribution of CO₂ follows the general circulation (upwelling in the high latitudes polar summer and descending in winter MLT upper atmosphere)
\* Long-term trend in CO₂ is consistent with lower atmosphere measurements
\* Larger trend in observations compared to models

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