Global Distribution of CO_2 VMR in the Mesosphere and Lower Thermosphere and Long-Term Changes Observed by SABER

L. Rezac[a,b], J. Yue[b], J. Yongxiao[b], J. M. Russell[b], R. Garcia[c], M. Lopez-Puertas[d], M. G. Mlynczak[e] and A. Kutepov[f]

a) Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany;
b) Center for Atmospheric Science, Hampton University, Hampton, Virginia, USA
c) National Center for Atmospheric Research, USA
d) Inst. de Astrofisica de Andalucía, CSIC, Granada, Spain
e) NASA Langley Research Center, Hampton, Virginia, USA
f) Catholic University of America, Maryland/GSFC, USA

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 CO_2 VMR; validation and comparison with the ACE-FTS measurements, and the SD-WACCM global circulation model. We also discuss the seasonal and latitudinal CO_2 distribution and the long term changes in the MLT as observed by SABER.

2. SABER on board TIMED satellite

Latitudinal coverage

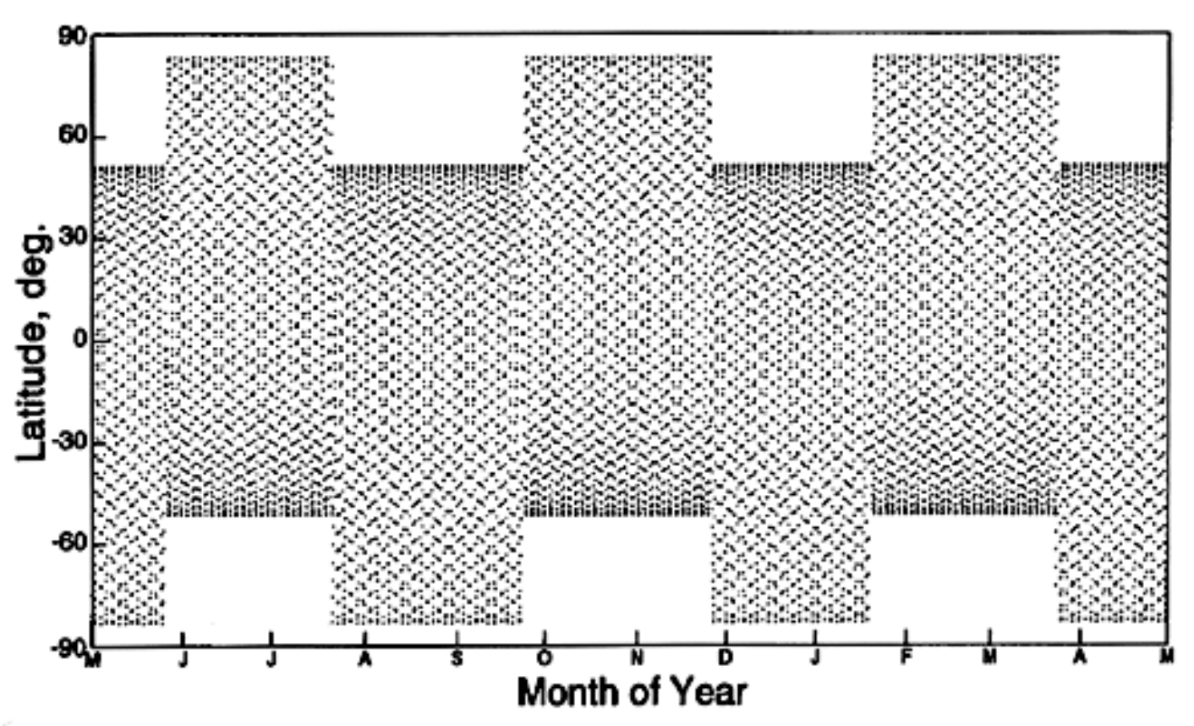
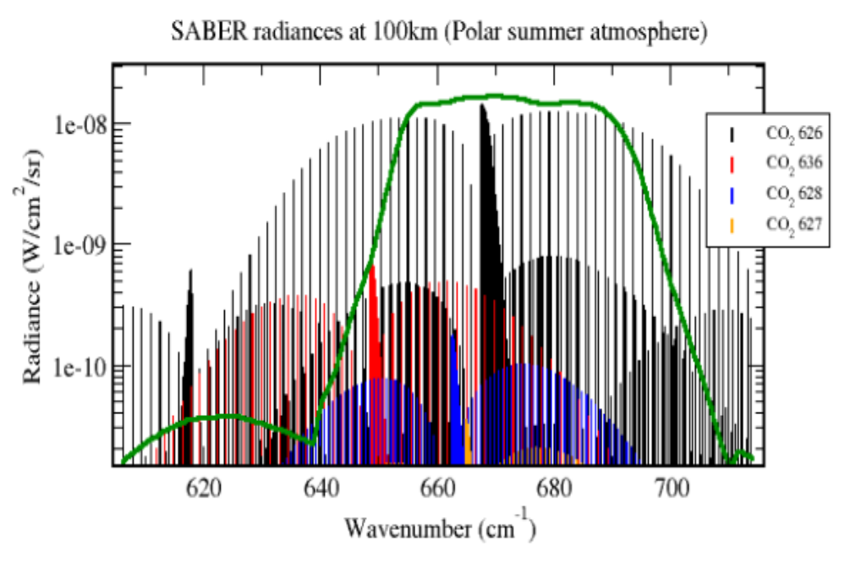
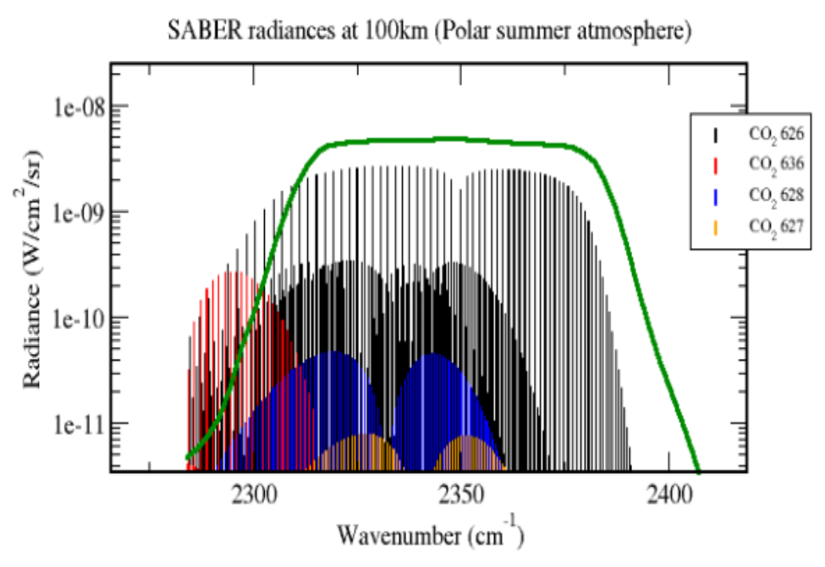


Figure 1: Latitude coverage distribution that SABER achieves given the orbit of the **TIMED** satellite. TIMED (Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics). Launched on Dec 7, 2001 and data available since January 2002. Four instruments: GUVI, SEE, TIDI, **SABER**.

- **SABER** (Sounding of the Atmosphere using Broadband Emission Radiometry)
- 10 infrared channels (1.27-17 μm)
- Temperature, O3, H_2O, OH, CO_2(in post processing), cooling/heating rates



15 μm



4.3 μm

3. SABER CO_2/Tk self-consistent retrieval

The v2.0 SABER limb radiance in 15 and 4.3 um are used in a post operational inversion to self-consistently obtain the vertical profiles of kinetic temperature and CO_2 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 CO_2) relying on operational T(p) and WACCM CO_2 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 CO_2 comparisons

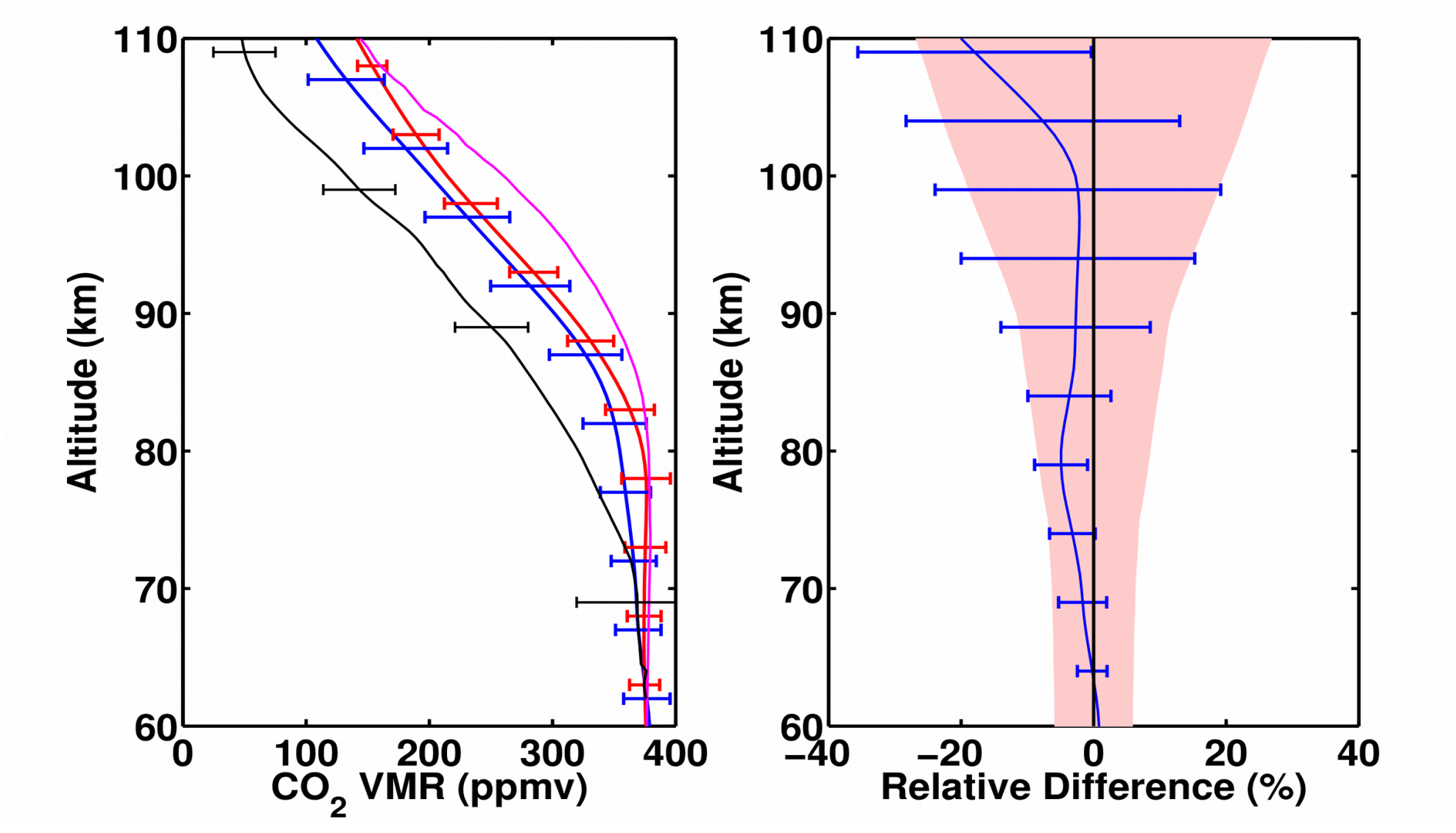


Figure 3: Comparison of mean CO_2 VMR profiles between SABER (blue line) and ACE-FTS (red line) assembled from the 9 years of coincident measurements as discussed in the text. Mean CO_2 VMR profiles from CRISTA-1 [Kaufmann et al., 2002] (black line) and the Rocket measurements [Wintersteiner et al., 1992] (magenta line) are shown for comparison. The uncertainties for each instrument are indicated by the error bars at the selected altitudes. All profiles are scaled to the same value at 60 km. (right) The mean relative difference between coincident SABER and ACE-FTS CO_2 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..

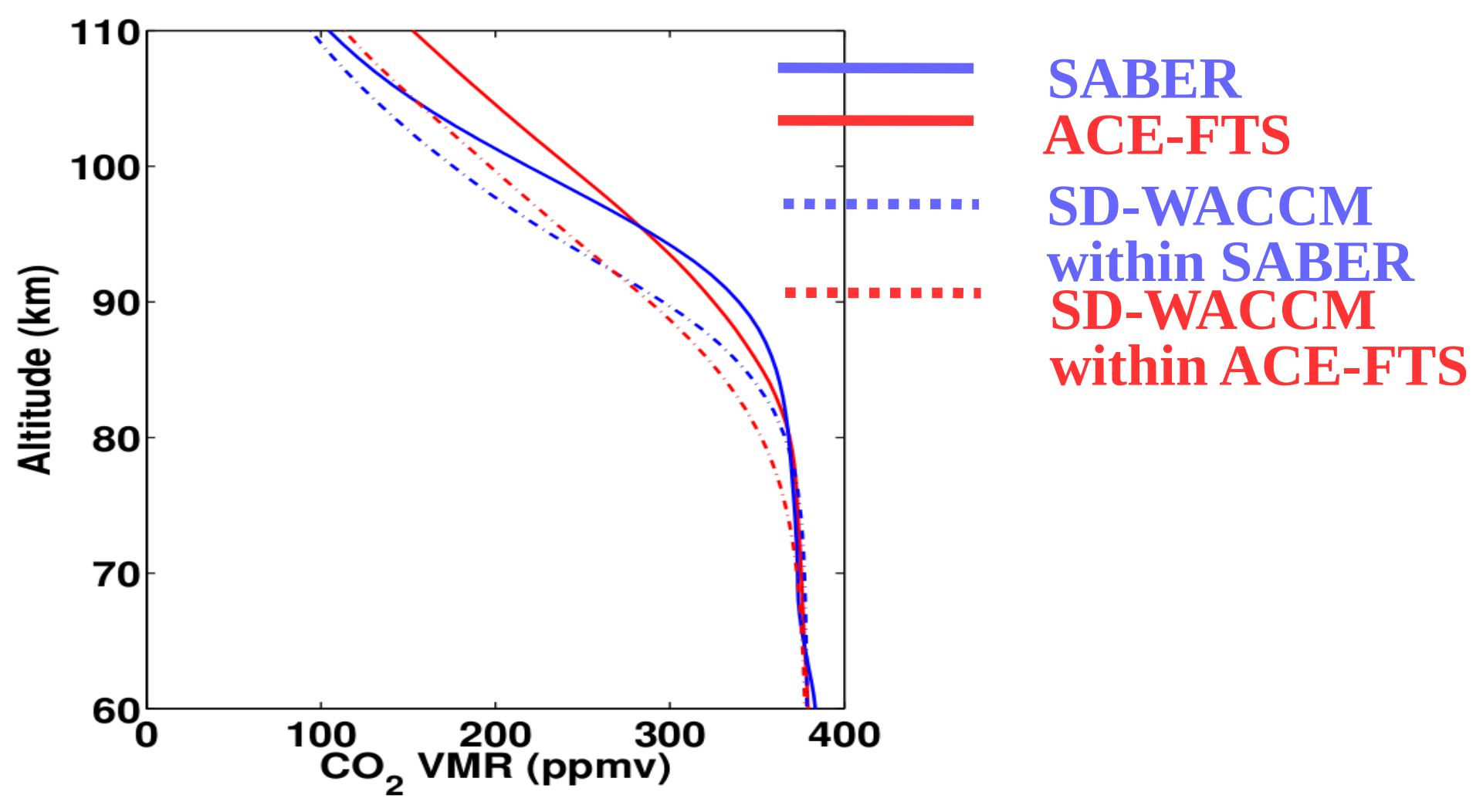


Figure 4: Global, 2004-2012 mean CO_2 VMR profiles from SABER (full blue) and ACE-FTS (full red). Two SD-WACCM mean CO_2 VMR profiles are shown as dashed lines. The SD-WACCM corresponding to the exact space and time sampling of the available SABER data (dot-dashed blue curve) and one for the ACE-FTS data availability (dot-dashed red curve.

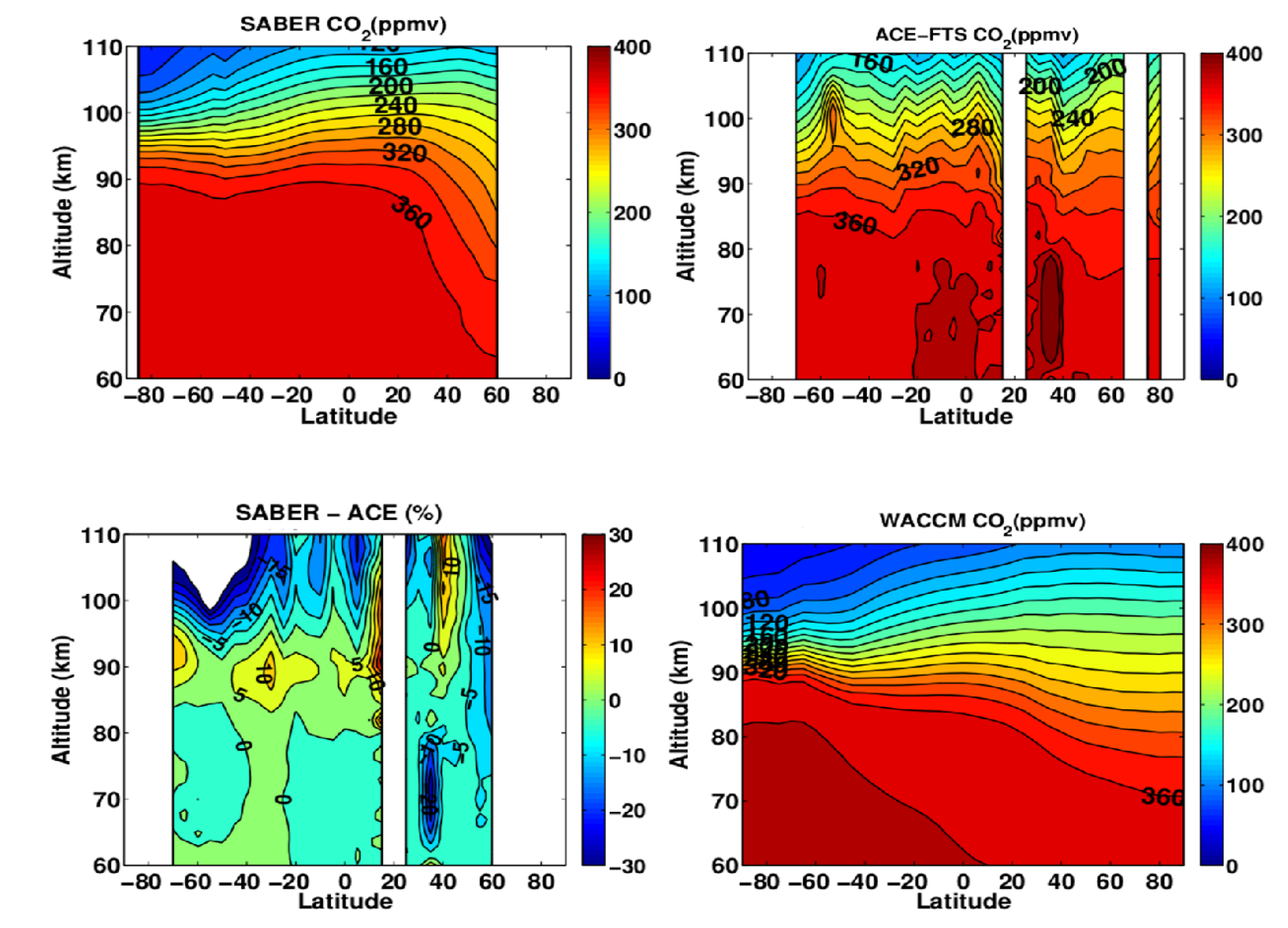


Figure 5: CO_2 zonal mean latitude cross-section for January (2004-2012), comparison of SABER, ACE-FTS, and SD-WACCM.

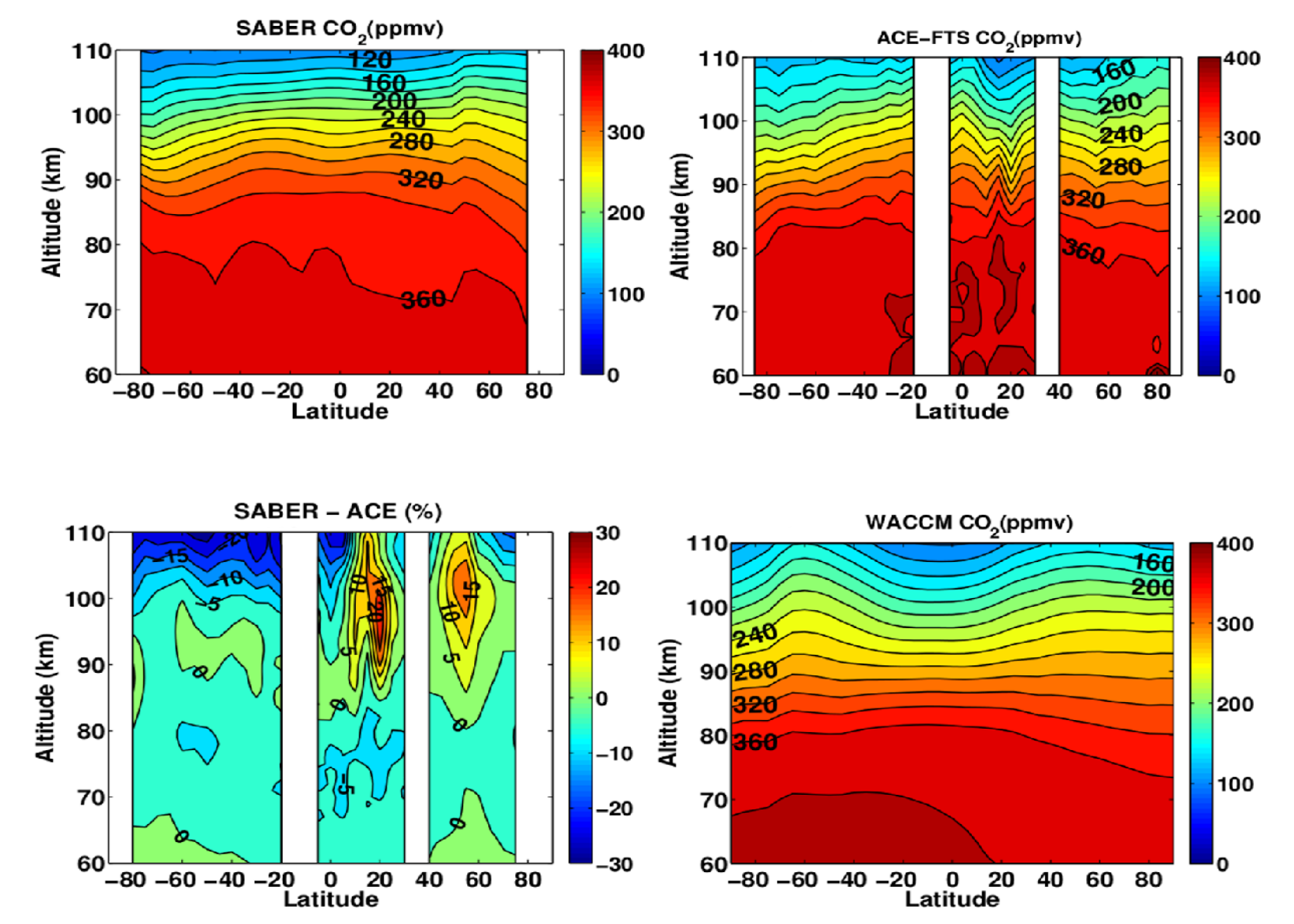


Figure 6: CO_2 zonal mean latitude cross-section for March (2004-2012), comparison of SABER, ACE-FTS, and SD-WACCM.

4. CO_2 trends in MLT from SABER

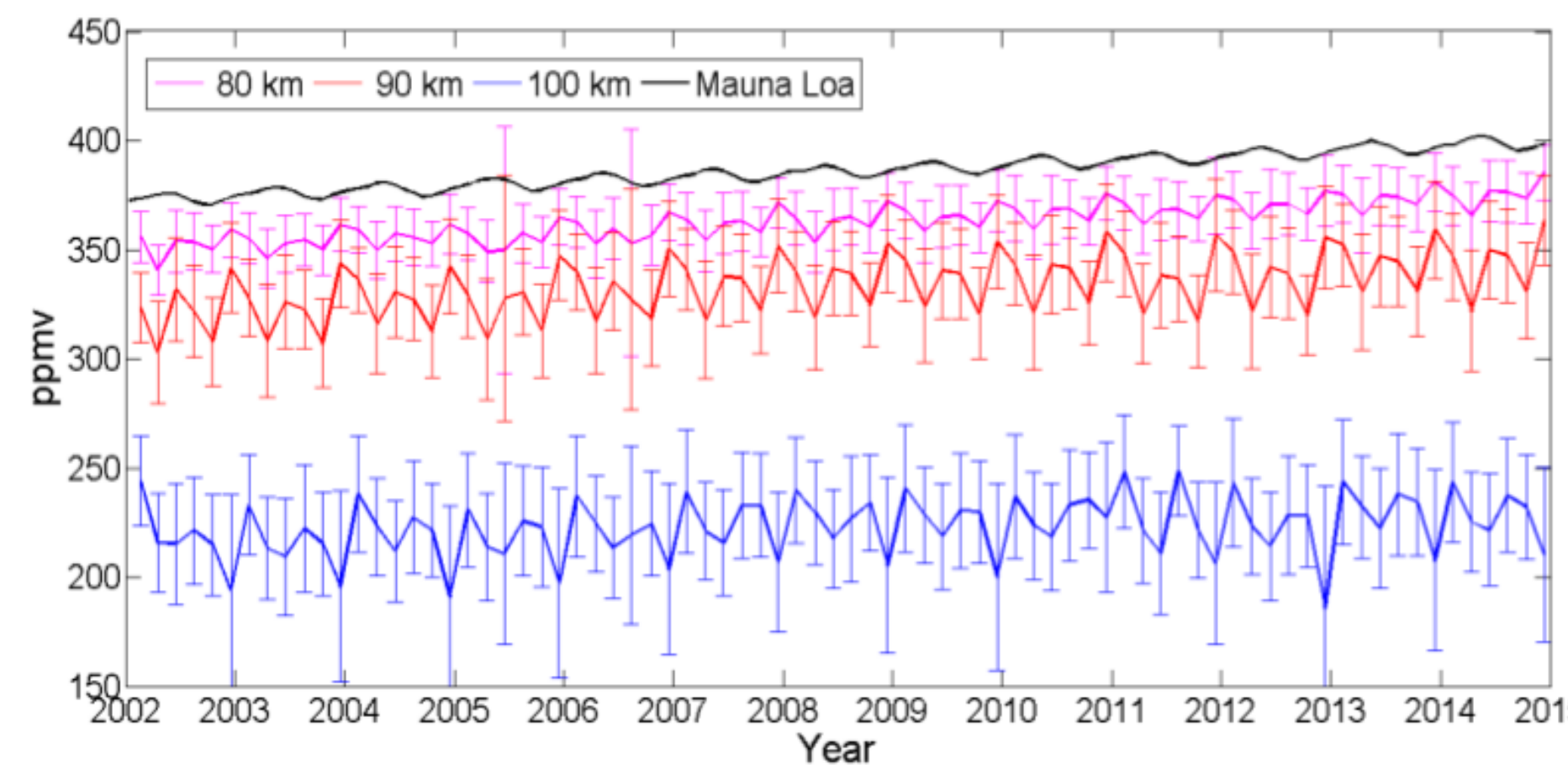


Figure 6: Time series of SABER CO_2 VMR averaged over 60 days (the SABER yaw cycle) and over latitude range +-54 deg. The different colors show different altitude regions. The time series of CO_2 measured at Mauna Loa Observatory is also shown for comparison (black curve). The uncertainty is the 2 standard deviation of the VMR data within the time/space bin.

The SABER CO_2 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.

CO_2 trend for the period 2002 - 2014

Altitude (km)	Trend (ppmv/decade)	Trend (%/decade)
110	12.8 +/- 3.7	11.8 +/- 3.4
100	19.9 +/- 5.5	11.8 +/- 3.4
90	19.5 +/- 4.5	5.8 +/- 1.6
80	20.6 +/- 3.0	5.0 +/- 1.6
Mauna Loa	~ 23	~ 5.9
ACE at 100 km (Emmert et al., 2012)	~ 23.5 +/- 6.3	

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.

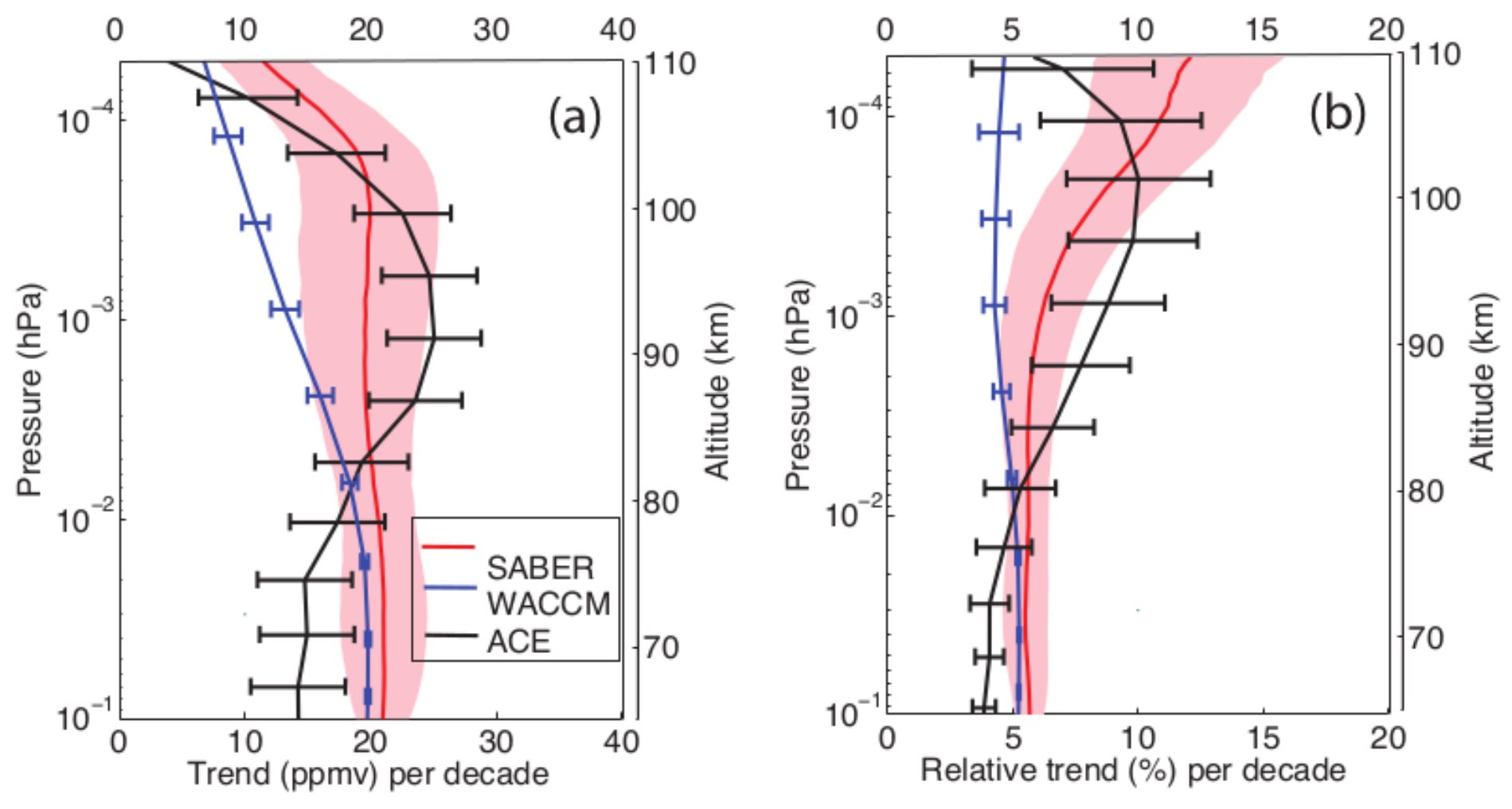


Figure 8: Vertical profiles of a) absolute trends of CO_2 VMR (ppmv per decade) obtained from SABER (red), ACE-FTS (black) and SD-WACCM (blue). Panel b) shows the same in relative units (% per decade). Shaded areas and error bars denote the uncertainty of the regression analysis.

5. Summary

- Simultaneous (daytime) two-channel retrieval of CO_2 VMR and Tk processed for entire SABER period (2002-2015)
- SABER and ACE-FTS CO_2 agree within the measurement uncertainties, with larger differences above 100-105 km.
- Distribution of CO_2 follows the general circulation (upwelling in the high latitudes polar summer and descending in winter MLT upper atmosphere)
- Long-term trend in CO_2 is consistent with lower atmosphere measurements
- Larger trend in observations compared to models

Mail: rezac@mps.mpg.de