Carbon dioxide in the polar stratosphere from AIM/SOFIE measurements

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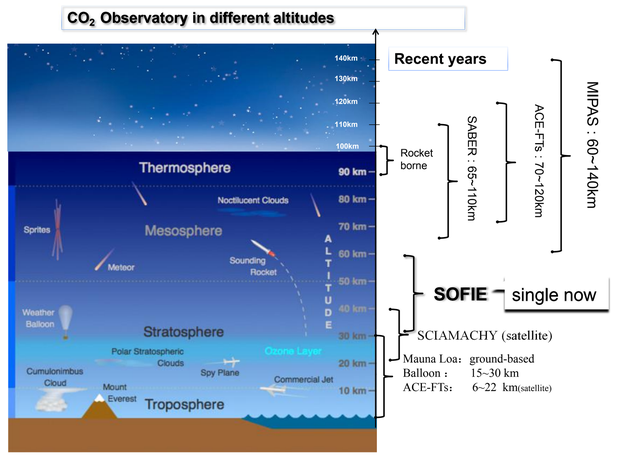
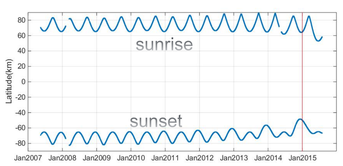
Abstract

Carbon dioxide (CO_2) is an important greenhouse gas and it is key to the energetics and dynamics of the stratosphere and mesosphere. Distributions of the CO_2 volume mixing ratios (VMR) in the stratosphere (from 30 up to ~ 60 km) have been measured from the CO_2 4.3 μm band by Solar Occultation for Ice Experiment (SOFIE) onboard the Aeronomy of Ice in the Mesosphere (AIM) satellite. This is the first time that the CO_2 VMR has been retrieved from space in the 30-60 km altitude range. The data set spans from April 2007 to current date. The retrieval of CO_2 is performed by using a non-local thermodynamic equilibrium (non-LTE) scheme and refraction derived temperature. In this paper we present SOFIE CO_2 VMR time series and its seasonal variation. The agreement between the SOFIE CO_2 trend and Mauna Loa surface measurement suggests that the retrieval algorithm is reliable. Seasonal variation of CO_2 is compared with simulations using the Specified Dynamics version of the Whole Atmosphere Community Climate (SD-WACCM). The CO_2 distribution is driven by the general circulation, ascending in southern summer (March to May) polar region, and decending in southern winter (July, August and September). The Stratospheric sudden warming (SSW) causes strong CO_2 variations in the northern hemisphere. At last, we report the variations of CO_2, H_2O, NO and temperature after two SSW events in 2009 and 2013, and discuss about the dynamical mechanisms with the help of SD-WACCM.

Introduction

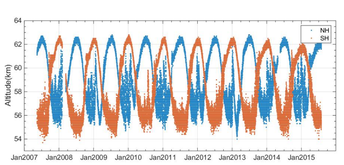


SOFIE measurement



The data after 1st, 2015 is ignored because of the decending orbit.

Figure 1. Latitude coverage of SOFIE measurements. The red line denotes Jan 1st, 2015.



Above top height, CO_2 data is not valid

Figure 2. Time series of the CO2 retrieval top height. Red indicate the Southern Hemisphere, and blue indicate the Northern Hemisphere. The bottom height is 30 km.

Results

Seasonal variation of SOFIE CO_2

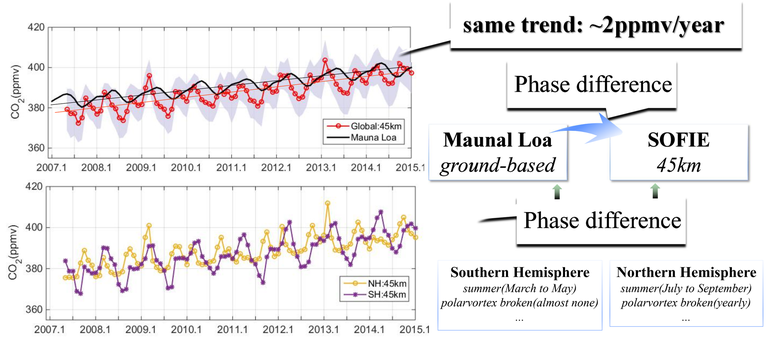


Figure 3. Time series of SOFIE CO_2 VMR averaged over a month at 45km. (Mauna Loa Observatory: black, SOFIE Globle Mean: red, Southern Hemisphere: purple, Northern Hemisphere: Yellow)

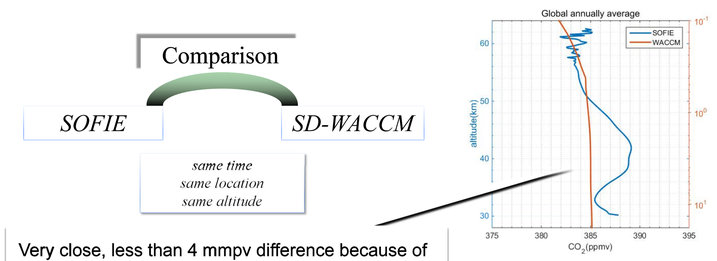


Figure 4 Comparison between SOFIE CO_2 profiles and SD-WACCM CO_2 profiles

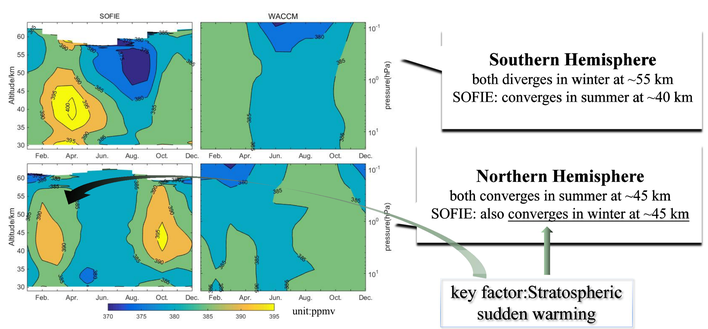


Figure 5 SOFIE annual meanand CO_2 and SD-WACCM annual meanand CO_2 as functions of month and height. (upleft: SOFIE Southern Hemisphere, upright: SD-WACCM Southern Hemisphere, downleft: SOFIE Northern Hemisphere, downright: SD-WACCM Northern Hemisphere,)

References

- *Gordley L L, Hervig M E, Fish C, et al. The solar occultation for ice experiment[J]. Journal of Atmospheric and Solar-Terrestrial Physics, 2009, 71(3): 300-315.*
- *http://sofie.gats-inc.com/sofie/index.php*

CO_2 variation in SSW events

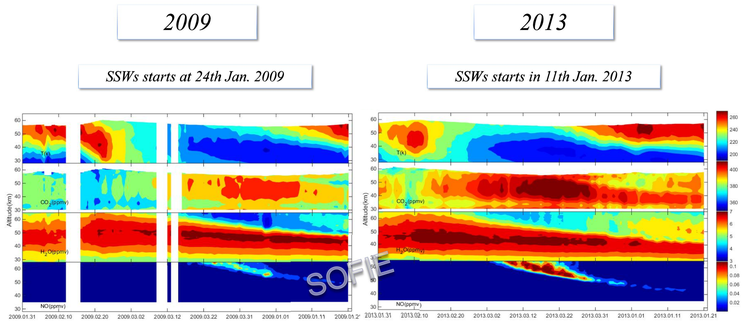


Figure 6. Contour images of mixing ratio vertical profiles for Temperature, carbon oxide (CO_2), water (H_2O), nitric oxide (NO) observed by Solar Occultation for Ice Experiment (SOFIE) during the first three months of 2013. Units are labeled in the bottom left of each panel.

SOFIE
T: reduced after SSWs at 45 km
CO_2: increased after SSWs at ~45 km
H2O: decrease after SSWs at ~55 km
NO: increased after SSWs at ~55 km

SD-WACCM
Very similar to SOFIE
But the CO_2 increased at different time

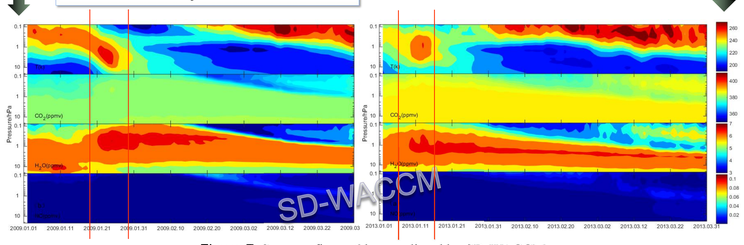


Figure 7. Same as figure 6 but predicted by SD-WACCM.

The change of mean residual circulation

2009-01-19(left) 2009-01-29(right) *2013-01-06(left) 2009-01-16(right)*

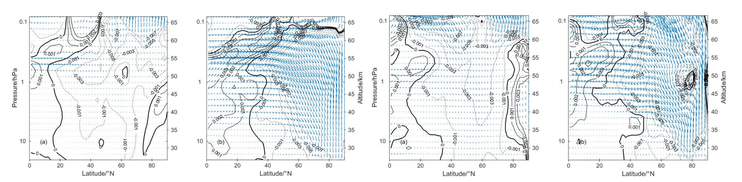


Figure 8. Mean residual circulation in the stratosphere before SSWs and after SSWs. A view factor has been multiplied b the vertical velocity to compensate for the biased aspect ratio. Contour line is the vertical speed.

After SSWs
Polar vortex: broken down
Poleward/downward circulation: enhanced
Stratospheric air: downward

Conclutions

- *SOFIE CO_2 trend at 45 km : ~2ppmv/year ≈ MLO CO_2 trend.*
- *SOFIE global annually average profile bigger than SD-WAACM profile ~4 ppmv at ~40 km.*
- *SH: SOFIE CO_2 ascending in March to May at ~40 km, decending in July, August and September at ~50 km.*
- *NH: SOFIE CO_2 increased after SSWs at ~45 km.*