Validation of the global distribution of CO$_2$ VMR in the mesosphere and lower thermosphere from SABER


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SABER will begin its 15th year of data collection on January 15, 2016

- **SABER history**
  - Launched December 7, 2001
  - Data collection began January 15, 2002
  - Scan system and noise performance is excellent
  - Data collection is routine

- **No instrument anomalies**

- **Excellent continuing data set for study of trends in the upper atmosphere**

75 kg, 77 watts, 77 x 104 x 63 cm, 4 kbs
SABER CO$_2$ validation outline

- CO$_2$ and temperature retrieval approaches and accuracies
- SABER CO$_2$ and temperature comparisons with ACE-FTS
- CO$_2$ comparisons with SD-WACCM and ACE-FTS
- SABER, ACE and WACCM CO$_2$ correlations with solar F10.7 cm flux
- Summary
SABER CO₂ and temperature retrieval approaches

- **T and CO₂ retrieval uses infrared limb emission from CO₂**
  - Limb radiance measured in the 4.3 µm and 15 µm CO₂ bands
  - Limb CO₂ profile must be known to retrieve T and vice versa
  - CO₂ and T retrievals are interdependent

- **v2.0 operational retrieval**
  - T retrieval with 15 µm CO₂ band and SD-WACCM model for CO₂
  - Cloud top heights to 110 km
  - Night and day

- **“Two-channel” simultaneous retrieval of CO₂ and temperature**
  - CO₂ and T retrieved using the 4.3 µm and 15 µm bands
  - ~ 60 km to 110 km
  - Daytime only

Data are available at http://saber.gats-inc.com/
### SABER single profile CO₂ and temperature estimated accuracies

<table>
<thead>
<tr>
<th>Z (km)</th>
<th>15</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>110</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ (%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>15</td>
<td>12</td>
<td>21</td>
<td>32</td>
</tr>
<tr>
<td>T (K)</td>
<td>1.4</td>
<td>1.3</td>
<td>0.8</td>
<td>1.6</td>
<td>2.0</td>
<td>2.0</td>
<td>1.8</td>
<td>2.3</td>
<td>5.4</td>
<td>8.4</td>
<td>29.2</td>
</tr>
</tbody>
</table>
SABER and ACE-FTS CO$_2$ agree within the error bars and to within ~5% at 100km and below.
Global zonal mean SABER CO₂ for 2004 - 2012 raises questions to help improve SD-WACCM

- Seasonal variation and general circulation largely removed
- Profile shapes determined mainly by eddy and molecular diffusion
- WACCM falls off from uniform mixing ~ 5km lower than SABER and ACE
- Eddy diffusion too low in WACCM?
- Garcia et al. (2014) show better agreement using increased eddy mixing by reducing the Prandtl number

WACCM data sampled like SABER and ACE
SABER 2004 – 2012 zonal mean CO₂ shows seasonal features and two circulation patterns

- Below ~ 90 km: Descent in the winter polar regions and upwelling during summer
- Above 90 km: A second circulation pattern is obvious with ascent in the winter and descent in the summer at the opposite pole
- Change in sign occurs due to breaking gravity waves (Smith et al., 2011)
The WACCM TEM shows two circulation regimes in agreement with the SABER CO₂ distributions.
Comparison of SABER, ACE and WACCM 2004 – 2012 January zonal mean CO$_2$

- Effect of upwelling in polar summer extends to 20N in SABER data
- Model vertical gradient approaching polar winter much steeper than SABER or ACE
- Similar SABER/model vertical gradients in polar summer
- Model CO$_2$ decrease towards winter pole starts at a lower lat. than SABER or ACE

SABER and ACE in reasonable agreement
Comparison of SABER, ACE and WACCM 2004 – 2012 July zonal mean CO$_2$

- Effect of upwelling in polar summer extends to 40S in SABER data
- Model vertical gradient approaching polar winter is similar to SABER and ACE
- Similar SABER/model vertical gradients in polar summer
- Model CO$_2$ decrease towards winter pole starts at a lower lat. than SABER or ACE

SABER and ACE in reasonable agreement
Comparison of SABER, ACE and WACCM 2004 – 2012 September zonal mean CO$_2$

SABER and ACE in good agreement for $Z \geq 80$ km

- SABER CO$_2$ matches WACCM better than in the solstice months
- Similar SABER, ACE and model vertical gradients above ~85 km
Both SABER and SD-WACCM show negative correlations with the F10.7cm flux. SABER correlation is smaller and much more variable. Sun/dynamics interactions?
SABER, ACE and WACCM CO2 correlations with solar F10.7cm flux for $\pm 60^\circ$ latitude
SABER CO$_2$ validation summary

- SABER and ACE-FTS vertical profiles agree to within the error bars from 65 to 110km
- SABER and SD-WACCM are in overall agreement for seasonal variations and global mean vertical distributions
- SABER and ACE-FTS global mean profiles fall off from a constant mixing ratio ~ 5 km higher than the SD-WACCM distribution
- SABER zonal mean 2004 – 2014 CO$_2$ distributions show two circulation regimes with the break point being ~ 90 km in agreement with the SD-WACCM TEM circulation
- Comparison of SABER and SD-WACCM 9-year zonal mean CO$_2$ distributions show reasonable agreement but with important differences
- SABER and SD-WACCM zonal mean and globally averaged plots of the correlation between the solar F10.7cm flux and CO$_2$ both show negative correlations as expected
- ACE-FTS correlations with F10.7 cm are positive and not understood at present
BACKUP
SABER “Two Channel” T retrievals (red) compared to v2.0 operational T retrievals (blue)

9-year March and September mean temperature, i.e. equinox period

9-year January and July mean temperature i.e. summer solstice period
SABER Level 2A Routine Data Products

- Vertical profiles of the following parameters day and night:

- Kinetic T, P, density 15 - 110 km
- \( \text{O}_3 \) mixing ratio (9.6\( \mu \text{m} \)) 15 - 100 km
- \( \text{O}_3 \) mixing ratio (1.27\( \mu \text{m} \))* 50 - 95 km
- \( \text{H}_2\text{O} \) mixing ratio 15 - 95 km
- \( \text{CO}_2 \rho \) (4.3\( \mu \text{m} \) and 15 \( \mu \text{m} \)) 60 - 110 km
- NO 5.3\( \mu \text{m} \) VER** 100 - 250 km
- OH 1.6\( \mu \text{m} \) VER** 80 - 100 km
- OH 2.0\( \mu \text{m} \) VER** 80 - 100 km
- \( \text{O}_2(\text{^1}\Delta) \) 1.27\( \mu \text{m} \) VER** 50 - 105 km

* Day only
** Volume Emission Rate