Cross-validation of recent satellite and ground-based measurements of ozone and water vapor in the middle atmosphere

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Overview

1) Cross-validation technique
2) NDACC/NDSC network of ground stations
3) Microwave radiometers SOMORA and MIAWARA in Switzerland
4) Satellite experiments Aura/MLS, ENVISAT/MIPAS, ACE/FTS, SAGE III, HALOE
5) Results of the cross-validations of $O_3$ and $H_2O$
6) Conclusions
Cross-validation of satellites by means of a ground station:
Difference of systematic errors of past satellite mission A and present mission B:

\[ e_A - e_B : \text{length difference of magenta lines} \]
Double difference operator $O$ for not coincident profiles $X$ of satellites $A$ and $B$:

$$O(X_A(t_1), X_B(t_2)) := [X_A(t_1) - X_G(t_1)] - [X_B(t_2) - X_G(t_2)]$$

$X_A(t)$: vertical profile of species $X$ observed by satellite $A$ over ground station $G$ at time $t$
What will be the result of *double differencing*?

\[
O(X_A(t_1), X_B(t_2)) := [X_A(t_1) - X_G(t_1)] - [X_B(t_2) - X_G(t_2)]
\]

\[
= [(X_{\text{true}}(t_1) + e_A) - (X_{\text{true}}(t_1) + e_G)] - [(X_{\text{true}}(t_2) + e_B) - (X_{\text{true}}(t_2) + e_G)]
\]

\[
= [e_A - e_G] - [e_B - e_G]
\]

\[
= e_A - e_B
\]

Result is the difference of the systematic errors \(e_A\) and \(e_B\) of satellite A and B (if systematic error \(e_G\) of instrument and retrieval are constant).
Network for the Detection of Atmospheric Composition Change

NDACC (formerly NDSC):

ground-based microwave radiometers, lidars, spectrometers (UV, V, FTIR), Dobson/Brewer, ...

Tasks of the NDACC:
1. detection of long-term trends
2. calibration and validation of satellite missions
3. understanding of climate and composition change
...
SOMORA ozone microwave radiometer

- Measurement of 142 GHz thermal emission of ozone
- Continuously operated at Payerne (46.82N, 6.95E) by MeteoSwiss
- Instrument design, construction, and software by IAP/University of Bern
- NDSC instrument
Ozone VMR in the SOMORA database:
MIAWARA radiometer

- 22.235 GHz emission of $\text{H}_2\text{O}$
- Broadband AOS and narrowband chirp transform spectrometer
- Retrieval of $\text{H}_2\text{O}$ volume mixing ratio with ARTS and Qpack software
- Altitude range 20-80 km
- New NDSC instrument, operated by IAP, Uni Bern since April 2002
Water vapor VMR in the MIAWARA database:

MIAWARA H₂O Volume Mixing Ratio

Altitude [Km]

Jul04  Sep04  Nov04  Jan05  Mar05  May05  Jul05  Sep05

ppm
Selected satellite experiments:

**Solar occultation** (absorption of solar radiation by the Earth's atmosphere):
- ACE/FTS (infrared)
- SAGE III (UV/visible)
- HALOE (infrared)

Passive sounding of atmospheric emission from the Earth's limb:
- Aura/MLS (microwave limb sounder)
- ENVISAT/MIPAS (infrared interferometer)
Result of the ozone measurements:

- Averaging kernel smoothing has been applied
- Horizontal distance < 800 km from SOMORA in Payerne
- Time difference < 1h between ground and satellite observation
- Data time intervals of the satellites are quite different

→ good agreement of all instruments at altitudes < 45 km
Result of the water vapor measurements:

- Averaging kernel smoothing has been applied
- Horizontal distance < 800 km from MIAWARA in Bern
- Time difference < 3h between ground and satellite observation
- Data time intervals of the satellites are quite different

Good agreement of all satellite instruments (within 10%) (probably a constant, systematic bias of the ground station)
Double differencing of MIPAS and MLS

The available MIPAS data set stops in March 2004 while the MLS data set starts in August 2004. Double differencing with respect to SOMORA and MIAWARA gives:

\[
\frac{(\text{MIPAS} - \text{SOMORA}) - (\text{MLS} - \text{SOMORA})}{\text{MLS}} \quad \frac{(\text{MIPAS} - \text{MIAWARA}) - (\text{MLS} - \text{MIAWARA})}{\text{MLS}}
\]

\[\Rightarrow\] The agreement of the H₂O measurements of MIPAS and MLS is excellent (within 4%).
Conclusions

- A cross-validation of 5 satellite experiments (ACE/FTS, MIPAS, MLS, SAGE III, HALOE) has been performed by means of the microwave radiometers SOMORA and MIAWARA in Switzerland.

- A good agreement is found for the ozone measurements at altitudes < 45 km.

- The water vapor measurements of all satellite experiments agreed within 10%.

- The double differencing method allows the cross-validation of not coincident data sets of satellites.