Introduction

Space borne (s-b) instruments such as the SCanning Imaging Absorption spectroMeter for Atmospheric CHartography (SCIAMACHY) measuring the composition of the Earth’s atmosphere ask for sufficient validation. Considerable effort has been invested in establishing ground-based (g-b) validation infrastructure such as the Network for the Detection of Atmospheric Composition Change (NDACC) or the Total Carbon Column Network (TCCON).

SCIAMACHY …
- observed the scattered and reflected solar spectral radiance transmitted through the atmosphere from the ultra violet (UV) to short wave infrared (SWIR) spectral range
- Channel 8 observed radiance in the SWIR range from 2259.36 nm to 2386.67 nm (4428 – 4191 cm⁻¹)

Accurate retrieval of CO from SCIAMACHY Channel 8 is demanding because of ...
- low optical depth of CO compared to the total optical depth
- temporal degradation of the detector affecting throughput
- amount of dead and bad pixels (≈ 50 pixels utilized for retrieval from 4280 to 4305 cm⁻¹ (Lichtenberg et al. 2010))

BIRRA - Beer InfraRed Retrieval Algorithm

- Forward – SWIR radiative transfer – Intensity I vs. wavemumber ν

\[ I(ν) = \frac{f(ν) \cdot I_{sun}(ν)}{\exp[\sum n m ν - δ(ν)] \cdot J(ν, γ) + δ(ν)} \] (1)

\[ τ_n(ν) = \int dz \left( \frac{1}{ρ} \right) \exp[ν] \quad \left[ \frac{\hat{v}(ν) I_{sun}(ν)}{\rho} \right] \] (2)

new scaling factor (in this work CO, CH₄, H₂O)
- molecular number density \( n_m \)
- absorption cross section \( J \)
- spectral response function (SRF)
- baseline
- inversion: separable least squares fit
- State vector \( x = (ν, J) \) of nonlinear (scaling factors) and linear (reflectivity \( r \), baseline parameters)
- BIRRA – two versions:
  - scientific prototype version (this work!)
  - operational at SCIAMACHY level 1b-2 processor (v7.0)

CO from SCIAMACHY and Ground-Based Networks

SCIAMACHY
- Calibrated spectra normalized by SCIA sun measured spectrum
- Actual dry air volume mixing ratio (VMR) \( f \) for CO:

\[ f_{CO} = \frac{N_{CO}}{m_{air}} \] (3)

NDACC
- CO and CH₄ from mid IR (unlike SCIA)
- some dozen stations, mostly operational for 2 decades

\[ f_{CO} = \frac{N_{CO}}{m_{baseline}} \] (4)

TCCON
- CO and CH₄ from near IR (like SCIA)
- most stations operational only in the last decades (few data for early SCIA years)

\[ f_{CO} = \frac{0.2095 N_{CO}}{m_{air}} \] (5)

Validation Methodology

Validation means …
- assessing the performance of a system against some equivalent information that is regarded as ‘truth’ reference (Einarsson 2005)
- quantifying differences due to errors in the acquisition or retrieval process, i.e. instruments or algorithms performance

An appropriate validation strategy therefore considers ...
- the mismatch of s-b and g-b measurements in time and space
- the different volume of air both address
- therefore, the incorporation of non-instrument comparison errors

A representative (optionally weighted with respect to time \( t \) and space \( m \)) average value \( \mu \) and std. deviation \( \sigma \) for both, s-b and g-b data was hence defined according to:

\[ \mu = \frac{\sum r \cdot \mu}{\sum r} \quad \sigma = \sqrt{\frac{\sum (r - \mu)^2}{\sum r}} \] (6)

Summary

- spatial and temporal averaging is required
- trade-off between incorporating high-quality observations and temporally & spatially representative ones for comparison (Fig. 1, 3 and 4)
- linear weighting gives slightly better agreements (Fig. 1 and 3)
- goodness of agreement w.r.t. NDACC or TCCON depends on the reference site (Fig. 2)

most SCIAMACHY CO values agree within std. dev. of the g-b observations

References & Further Information

- Borsdorff, T., P. Tol, J. E. Williams, J. de Laat, J. van de Brugh, P. Nédélec, I. Aben, and J. Landgraf, 2016: Carbon monoxide total columns from SCIAMACHY 2.3. Remote Sensing Technology Institute (IMF), German Aerospace Center (DLR), Oberpfaffenhofen, Germany
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