Validation of SCIAMACHY limb NO_2 and BrO operational data products 2002-2012

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Introduction/Objective

Validation of SCIAMACHY lifetime operational (ESA/DLR) limb NO_2 and BrO products with scientific IUP products and other independent measurements

ESA's SCIAMACHY long term validation, 2010 (SCILOV-10) and **ENVIVAL-LIFE** project

- **Evaluate, maintain and document the quality of the operational products**
- **Monitor the stability**

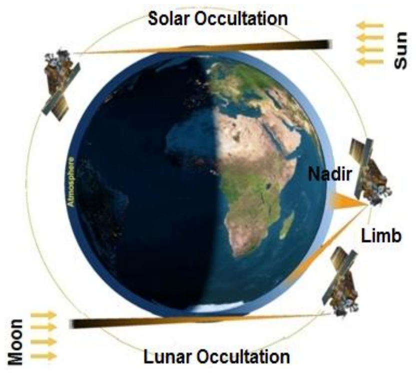
Decadal time series from SCIAMACHY are important building blocks in creating long term climate datasets and for long term trend assessments.

SCIAMACHY

SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY, aboard Envisat (decade, 2002 – 2012)

Limb Measurements:

- Vertically resolved information on the global scale.
- Typical Spatial resolution: 240km x 3km
- Spectral resolution: 0.24-1.5 nm
- Global coverage in 6 days



Gottwald et al, 2011 adaptation

Validation Strategy

SCIAMACHY coverage: *Profiles/day:* 1500
Profiles for Aug 2002 - Apr 2012: above 4.5 million
(IUP SCIAMACHY BrO, ¼ of the amount)

ESA – IUP Comparison criteria:
ESA SCIAMACHY Sub-sampling (allows for faster computation):

- Distance between two profiles is set larger than 5000 km
- A profile is not allowed in the same 5° latitude band as any of 26 profiles before
- One latitude band cannot have more than 20% of the average profiles in a latitude band

Subsampling results in 3% of the entire datasets well distributed over all latitudes, longitudes and time

ESA – IUP Collocation criteria: *distance* = 60km
Reason: Determination of the horizontal positions of the tangent point is different for both dataset

ESA-Other Collocation criteria: *time* = 6h, *distance* = 1000km

Comparison Statistics

The results are shown following the equations from Dupuy et al. (2009).

Mean relative difference

$$\Delta(z) = \frac{1}{N(z)}\sum_{i=1}^{N(z)} \delta_i(z) \quad \text{with} \quad \delta(z) = \frac{x_{SCIA}(z) - x_{comp}(z)}{x_{ref}(z)}$$

$$\text{and} \quad x_{ref}(z) = (x_{SCIA}(z) + x_{comp}(z)) * 0.5$$

Standard deviation of the bias corrected difference

$$\sigma(z) = \frac{1}{N(z)-1}\sqrt{\sum_{i=1}^{N(z)} (\delta_i(z) - \Delta(z))^2}$$

Standard error of the mean (too small to be visible on plots)

$$\mathrm{SEM}(z) = \frac{\sigma(z)}{\sqrt{N(z)}}$$

Additional Considered Criteria

1)- Strong diurnal variation of NO_2: Large gradient at sunrise and sunset, SZA ≥ 90 largely effected

1a)- Changing illumination conditions (SZA) along the line of sight → *Diurnal effect error* usually larger for occultation instruments below 25 km (*Bauer et al., 2012*)

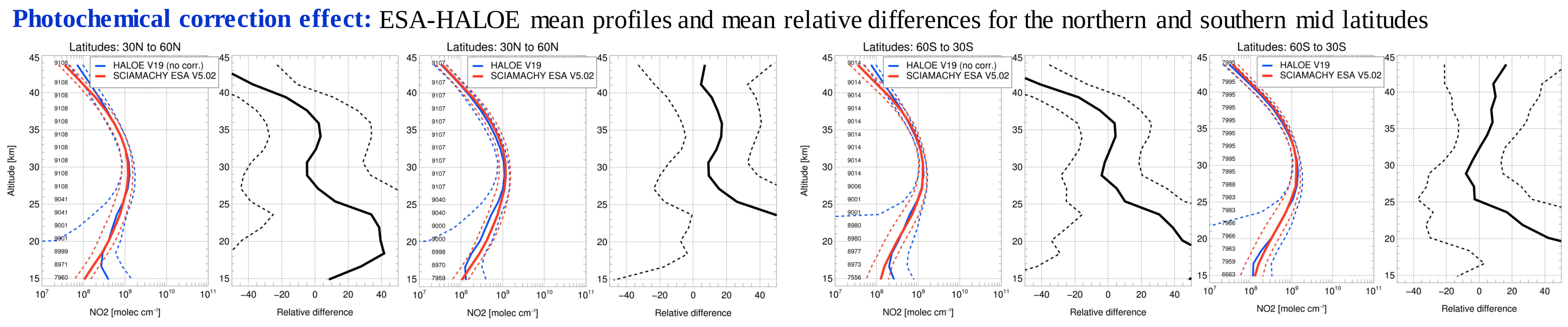
2a)- Different instruments measure at different SZA → *Photochemical correction needed*
Used Look up table with precalculated diurnal cycles provided by Chris McLinden, model from the University of California (see Bauer et al., 2012, McLinden et al, 2006, Prather 1992)

2)- Avoid comparison of profiles at vortex conditions and different air masses: Strong horizontal gradients at the edge of the polar vortex

- Modified potential vorticity (MPV) calculated from ECMWF-Interim data
- Profiles polewards of 35° latitude are excluded, if the MPV is > 30 and < 40 PVU (vortex edge) and their MPV differs by more than 3 PVU

Photochemical Correction and MPV applied for comparisons with other instruments
Examples: ESA V5.02-HALOE V19 Comparison :- HALOE V19 for 2002-2006

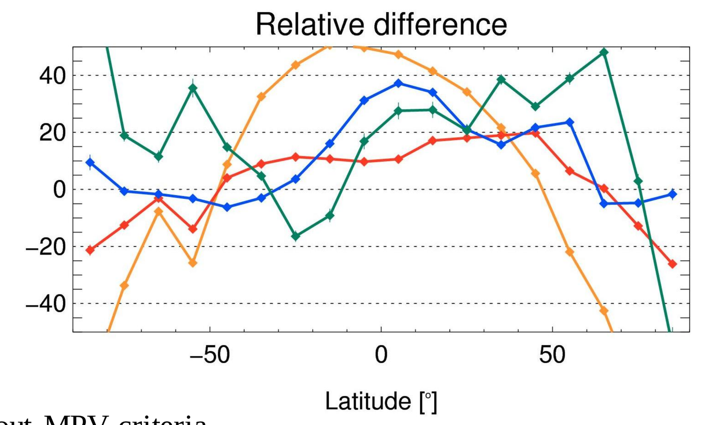
Photochemical correction effect: ESA-HALOE mean profiles and mean relative differences for the northern and southern mid latitudes



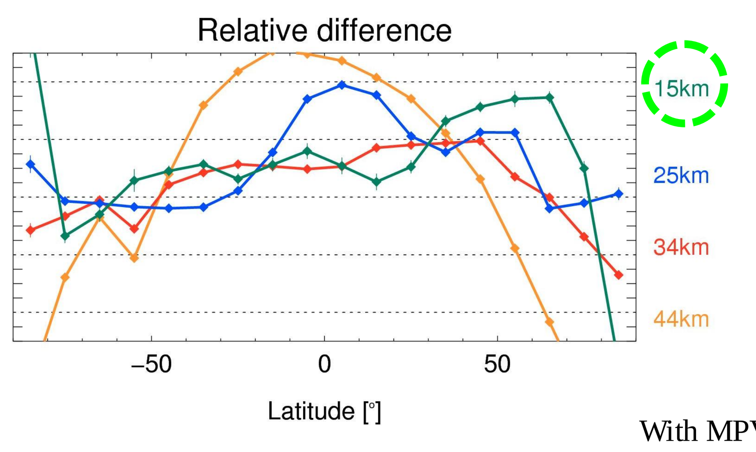
With Photochemical correction — With Photochemical correction

Photochemical correction improved comprasions from 25 km upwards.

MPV criteria effect: ESA-HALOE mean percental differences for selected altitudes (mean latitude-altitude cross section, monthly averages in 10° bins)



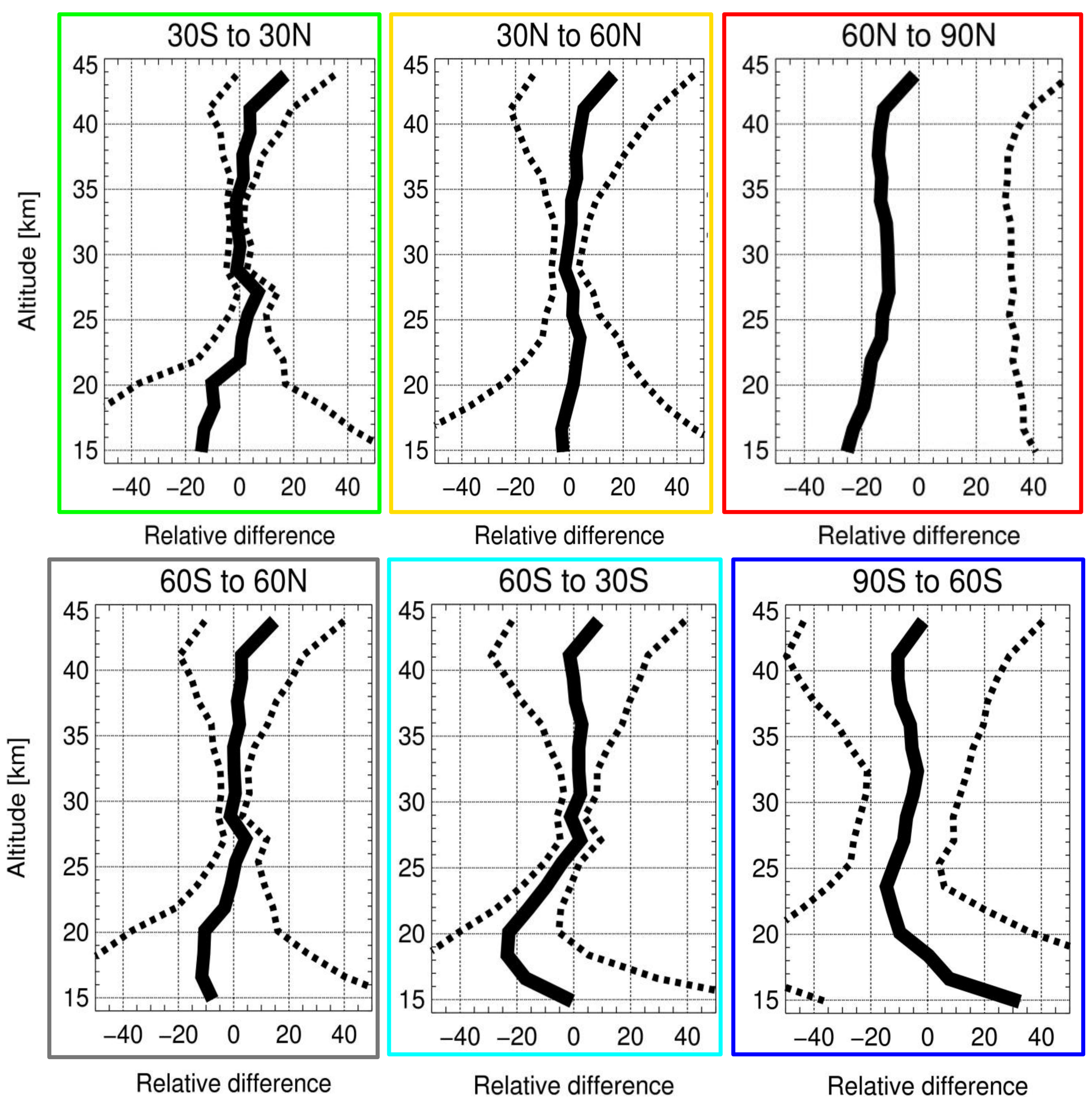
Without MPV criteria



With MPV criteria

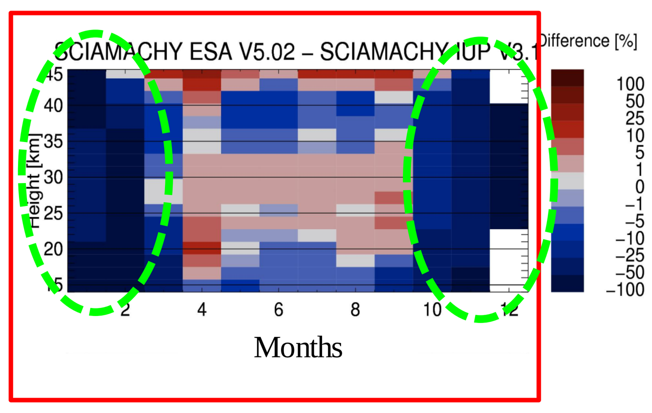
ESA V5.02 - IUP V3.1 NO_2 comparison

Mean relative difference — **Tropics (30°S-30°N)**, Near global (60°S-60°N), **NH mid latitudes (30°N-60°N)**, **SH mid latitudes (30°S-60°S)**, **NH high lat. (60°N-90°N)**, **SH high lat. (60°S-90°S)**

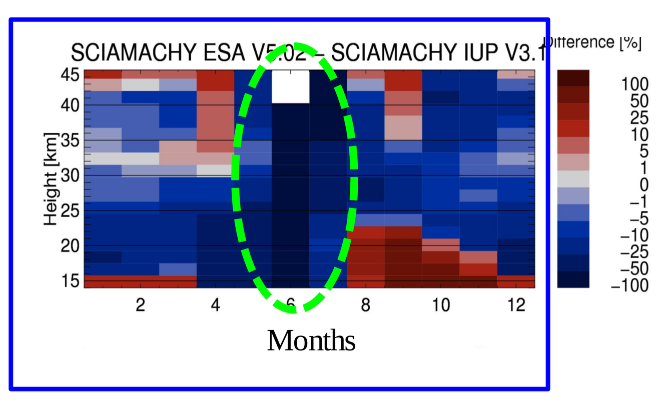


With the exception of high latitudes (NH and SH), the mean relative differences between ESA and IUP NO_2 products are within few percent for 25-40 km. Below 25 km and above 40 km, the differences are around 10% and within 20% respectively.

Focusing on the high latitudes



Annual cycle (based on monthly means) relative difference for ESA and IUP, 60°N to 90°N

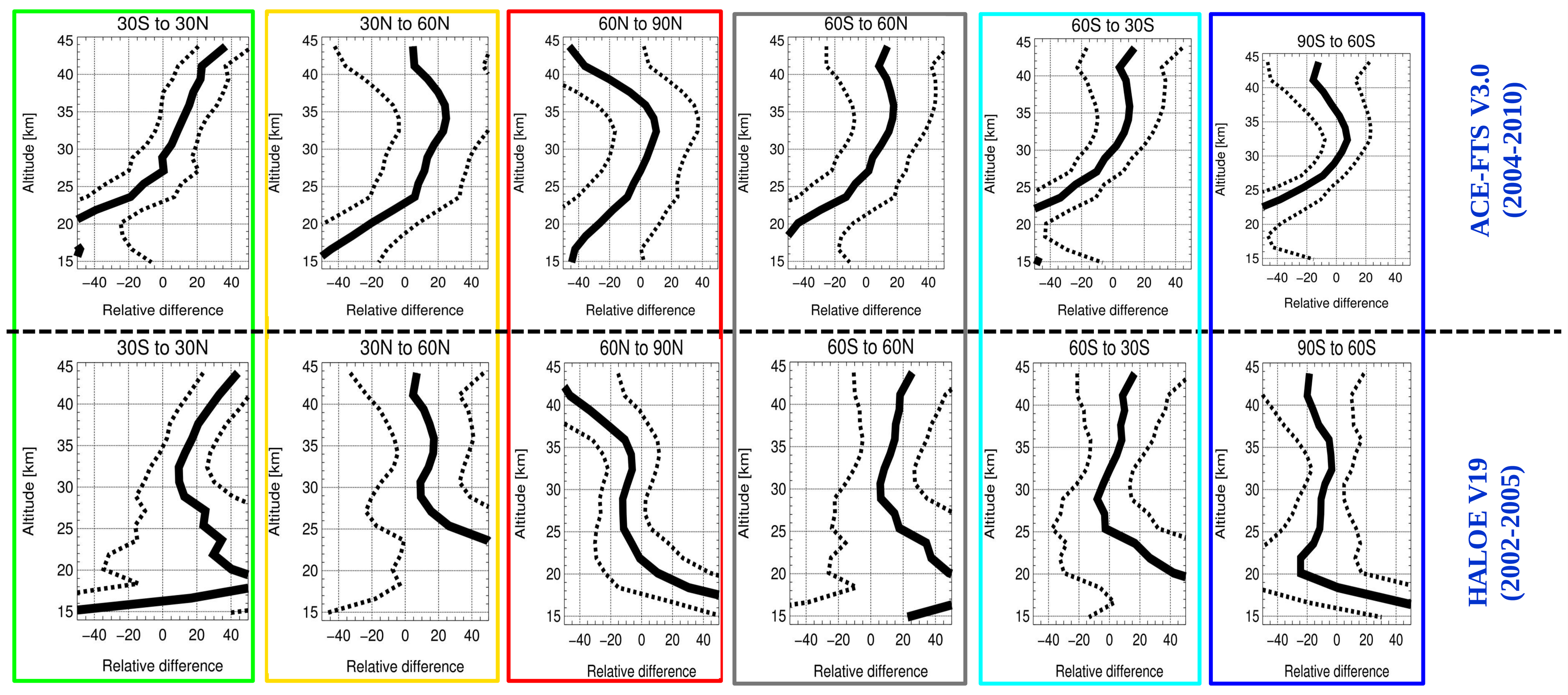


Annual cycle (based on monthly means) relative difference for ESA and IUP, 60°S to 90°S

The annual cycles for the high latitudes show largest differences in winter months (low NO_2 concentrations). Differences can be attributed to the retrieval sensitivity of ESA and IUP.

ESA SCIAMACHY NO_2 comparison with ACE-FTS and HALOE

Mean relative difference



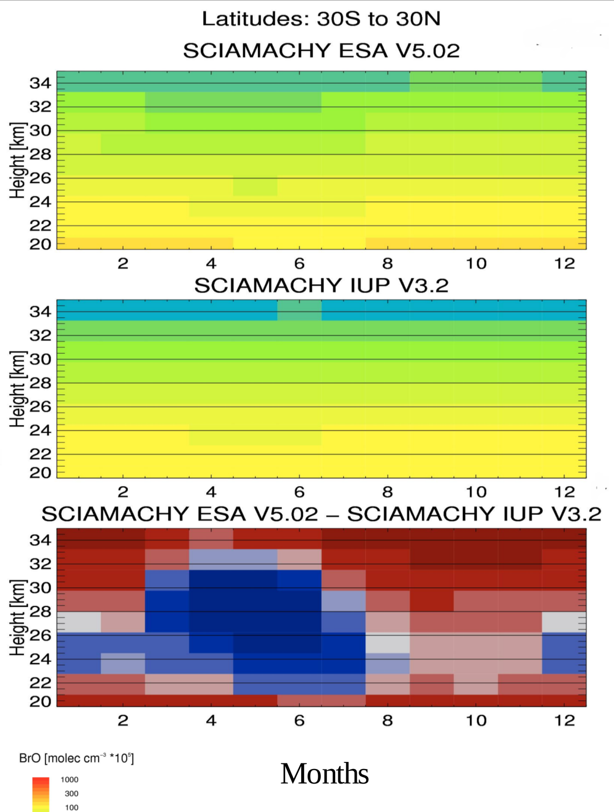
For each latitude band, ESA-ACE and ESA-HALOE differences are of about same order above 25 km and show opposite biases below this altitude. The aforementioned diurnal effect error partly contributes to larger differences with occultation instruments below 25 km (see Bauer et al. , 2012)

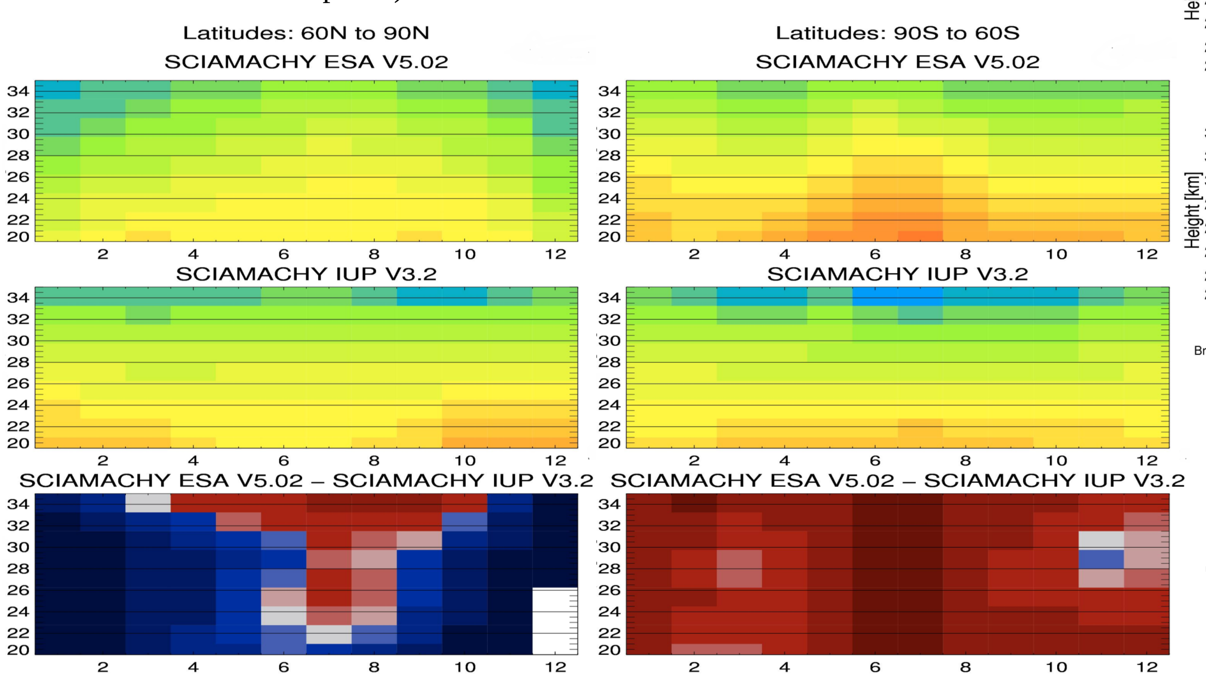
ESA V5.02 – IUP V3.02 BrO comparison

ESA-IUP BrO Annual cycle (based on monthly means) comparison:

In the figures, the upper panels show ESA SCIAMACHY V5.02 BrO absolute values, in [molec/cm³] for the altitude range 20-35 km, the middle panels show the BrO absolute amounts for IUP SCIAMACHY V3.2 and the lowest panels show the monthly mean percental difference among the two. The comparisons are shown for the tropics, northern and souther high latitudes.

Very large differences are observed among ESA and IUP BrO amounts for the NH and SH high latitudes prompting investigations on the quality of BrO data (averaging kernels, measurement content/response).





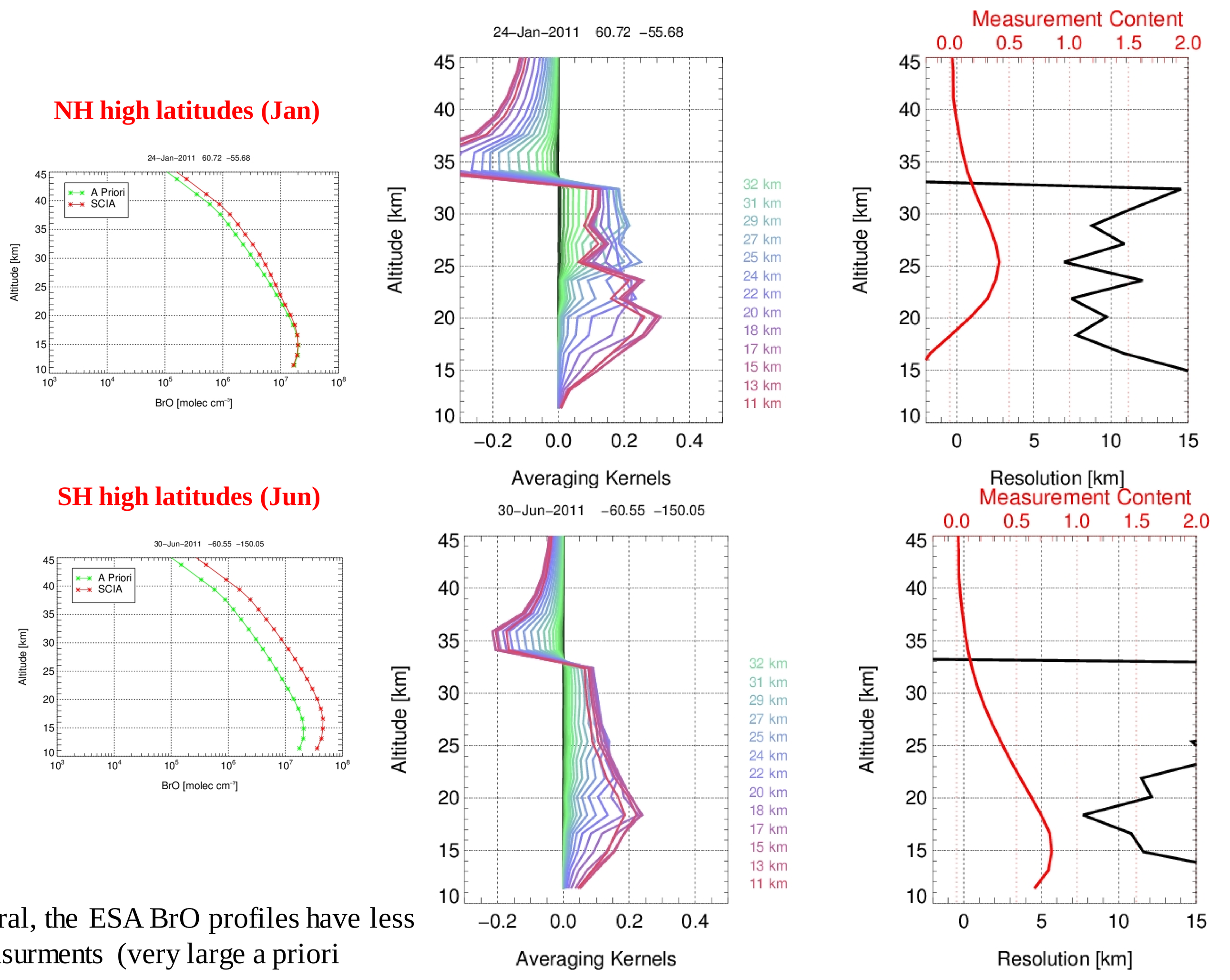
ESA BrO Averaging Kernels:

ESA BrO averaging kernels investigated for the NH and SH high latitudes for January & June 2011 respectively (months with high BrO amounts as BrO is anti-correlated with NO_2)

Left plots: number density profiles and the a priori

Middle plots: the corresponding averaging kernels. These are negative above 35 km which is the reference tangent height used in the retrieval

Left plots: the corresponding measurement content/response in red and the resolution in black. (Measurement content: Degree of contribution of measurement to the retrieval, when it is 1, there is no contribution from a priori)



The investigations show that in general, the ESA BrO profiles have less than 50% contribution from the measurments (very large a priori influence).

Conclusions and Outlook

Validation results of operational NO_2 product with IUP, ACE-FTS and HALOE are presented.

- With IUP, the comparison shows positive bias in ESA product at high latitutes at the time of NO_2 minima
- Comparison with ACE-FTS and HALOE are different at altitude ≤ 25 km
- Next, the NO_2 comparison will be performed with SAGE II and OSIRIS

Validation results of operational BrO product with IUP are presented.

- Retrieval differences evident in the comparison. ESA BrO data quality in question.

We are documenting and publishing the results on SCILOV-10 webpage, will be open soon

References

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