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Validation of HNO3, CO and CH4 column amounts from IASI using ground-based FTIR data

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Summary:

1. G-b FTIR measurements
2. Validation problems
3. FORLI IASI retrievals
   Validation of HNO3
   Validation of CO
4. ASIMUT IASI retrievals
   Validation of CH4
5. Summary

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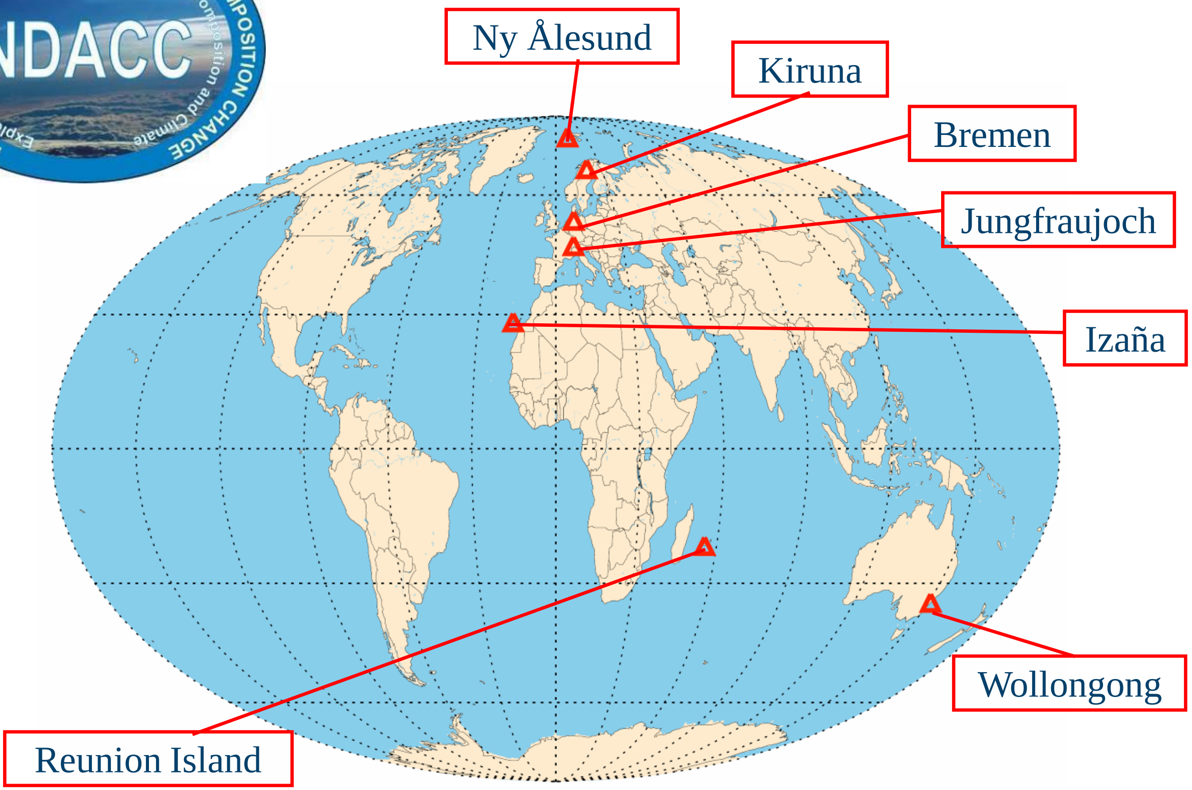
G-b FTIR network



For the validation of IASI retrieved HNO3, CO and CH4 the ground-based FTIR network from the Network for the Detection of Atmospheric Composition Change (NDACC) was used.

Data were taken using either Bruker or Bomem FTS (resolution 0.004 cm^{-1}) and were analysed using SFIT2 or PROFITT (Izaña and Kiruna).

The CH4 data is harmonised within the HYMN project.

Colocation: same day IASI pixels, up to 100 km from ground-based stations.

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Comparisons are not straight forward

- Ground-based measurements are conducted at one altitude level and give therefore generally a different total column than satellite based measurements that have pixel sizes of more than 12 km and that are up to 100 km away from the ground-based measurement and might be at locations of different altitudes from the g-b measurements. => ALTITUDE CORRECTION (using a digital terrain model to find pixel altitudes)
- The vertical (altitude) sensitivities of the g-b measurements and the satellite borne measurements can be different => AVERAGING KERNEL SMOOTHING
- **BUT:** Averaging kernel smoothing requires information about the real vertical profile (e.g. information about the g-b measurements between a lower laying satellite pixel and a g-b site at altitude).

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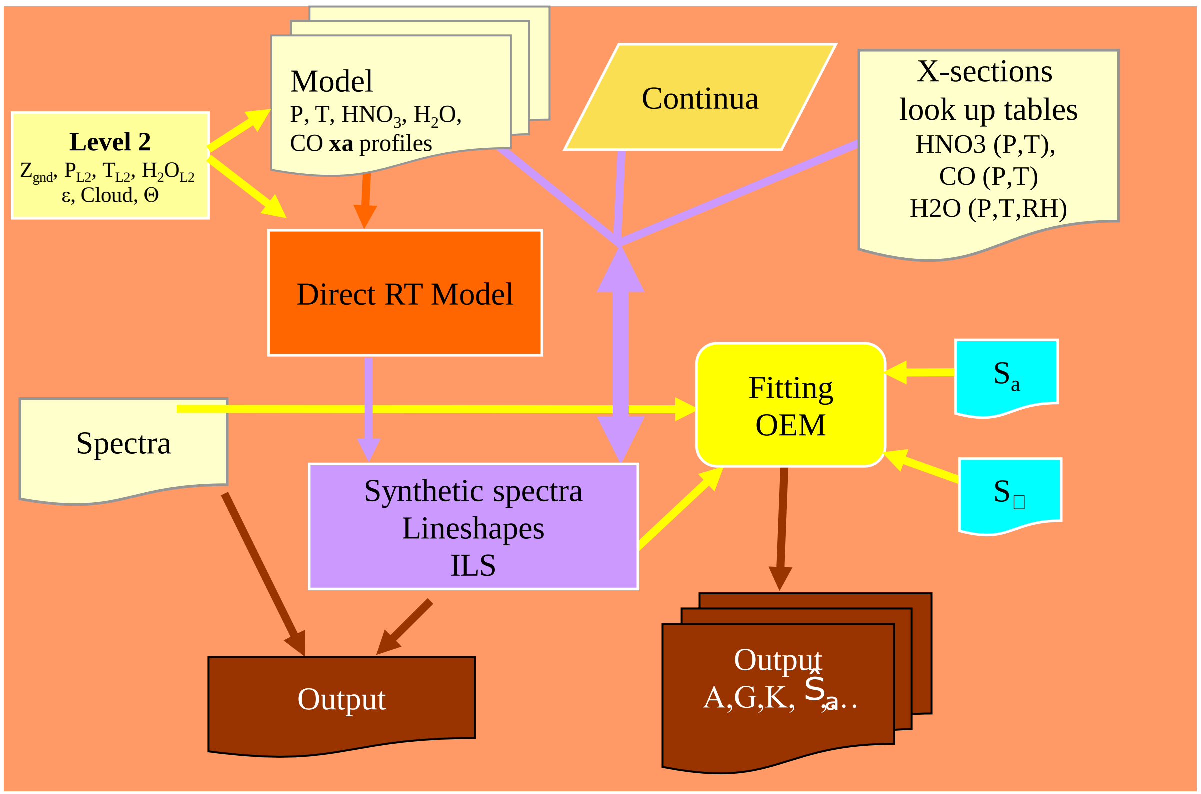
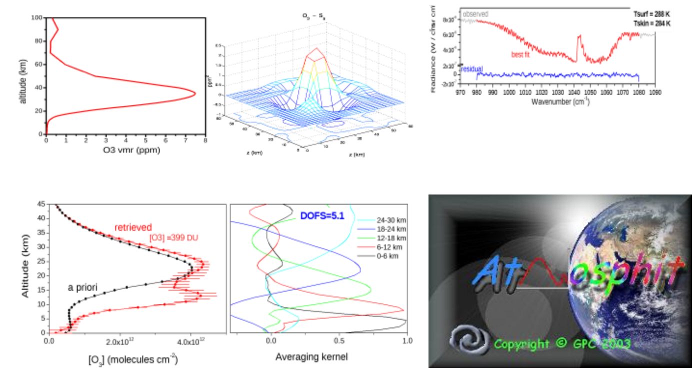
Retrievals of HNO3 (poster #25) columns and CO (poster #28) profiles from IASI

1.3 10^6 spectra/day for processing

➔Near real time processing based on the OEM:
➔FORLI-HNO_3 and FORLI-CO
(poster #2 of J. Hadji-Lazaro)





NRT processing

CO (M. George poster 28)

HNO3 (C. Wespes poster 25)

O3 (S. Turquety)

Offline (very) slow processing

H2O

CH4 (A. Razavi poster 20)

CO: total columns, errors, total col AKs, one AP

HNO3: total colums, errors, one typical AK, one AP

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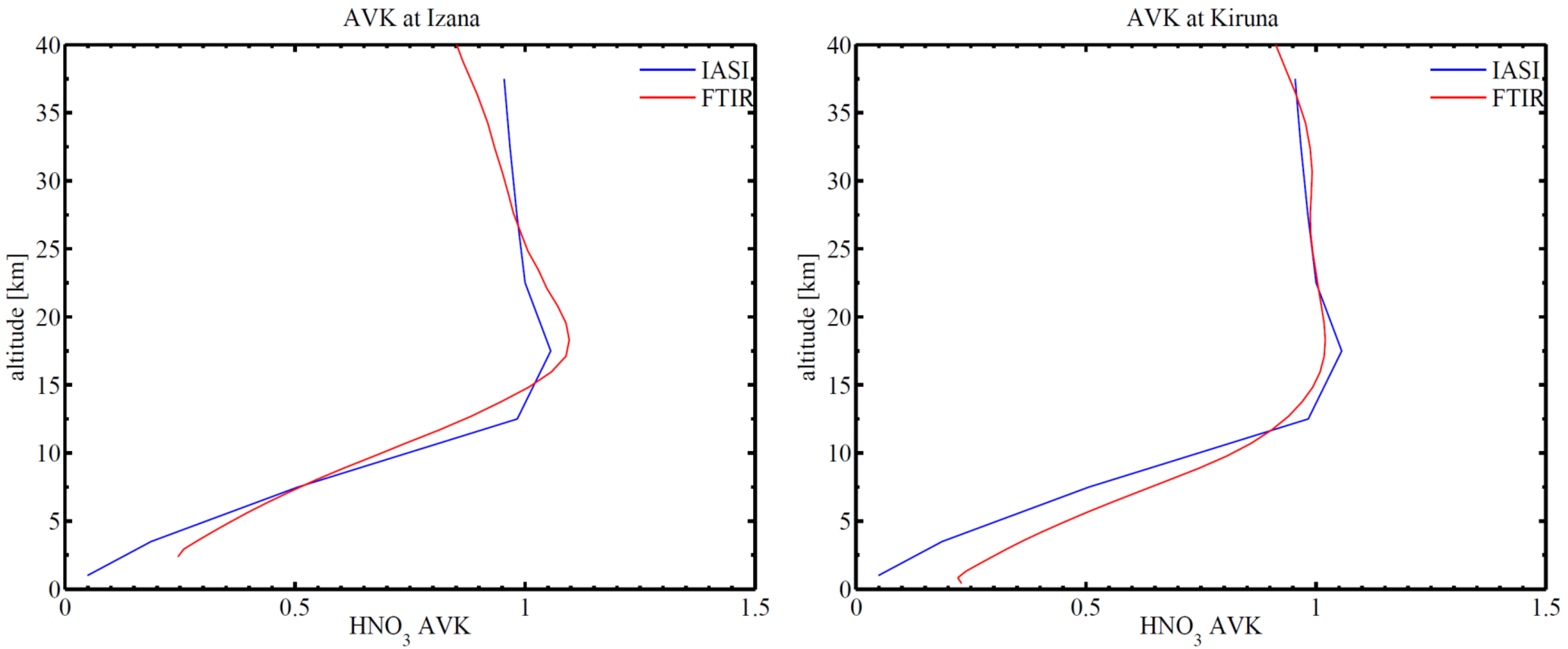
Validation of HNO3 columns: typical sensitivity profiles at Izaña and Kiruna



The total column sensitivities are similar for the HNO3 retrievals from ground-based solar absorption spectra and from IASI radiances. They show that the retrievals are most sensitive in the stratosphere. This means that tropospheric HNO3 has a minor influence on total column HNO3, and topographical differences have only secondary influence on the total column.

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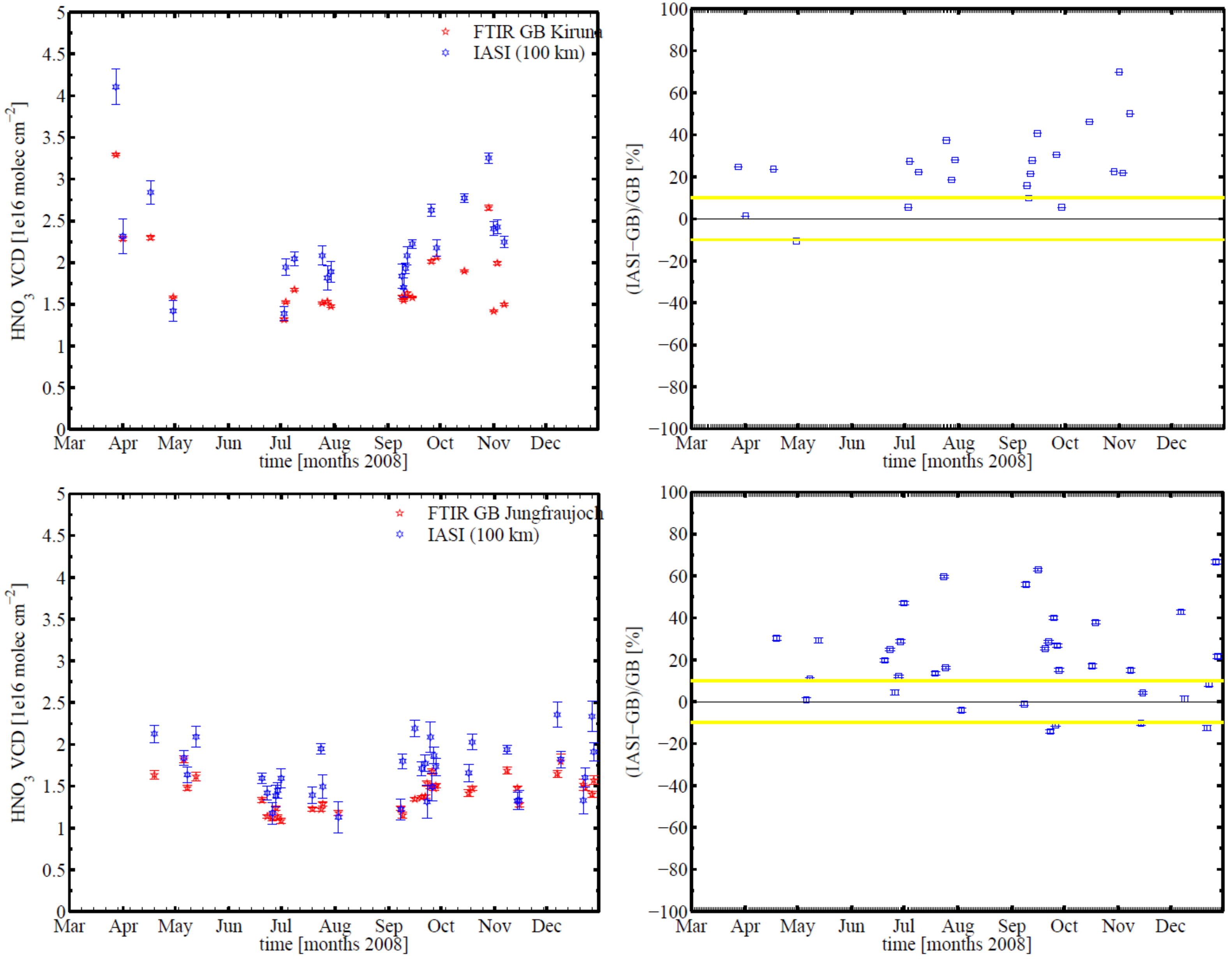
Total HNO3 column comparisons



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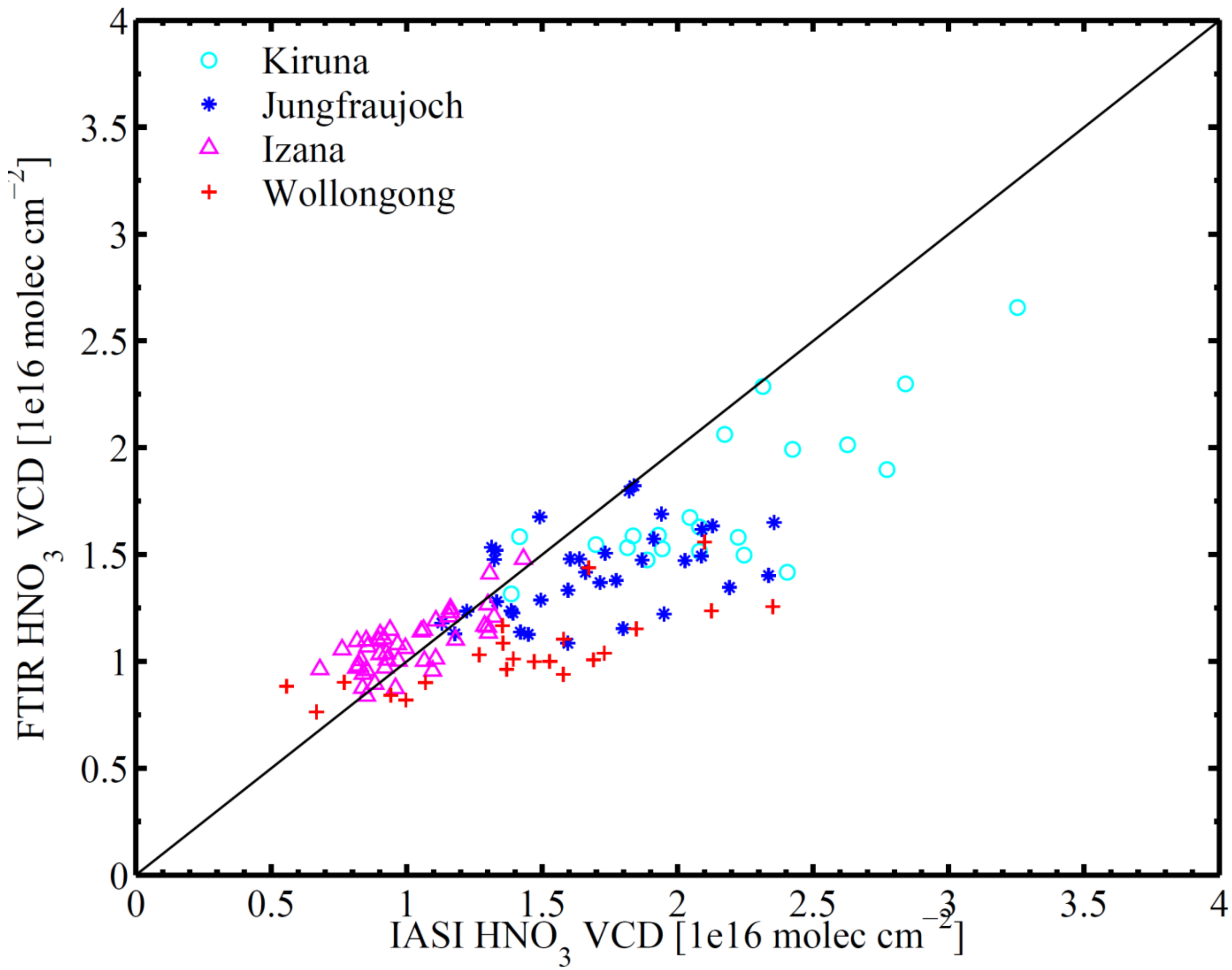
HNO3 validation: comparisons for 4 NDACC stations

The scatter plot of the comparisons shows that the IASI retrievals capture the station-to station differences.
IASI HNO3 columns appear to be overestimating the ground based columns and they show a large scatter.
The altitude correction has been verified; it accounts for max. 2% of the differences.



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HNO3 results

	diff[%]	diff[1e15]	std[%]	std[1e15]	corr
Kiruna	**24.5**	4.3	**17.6**	2.9	**0.89**
Jungfraujoch	**20.4**	2.7	**21.7**	2.9	**0.47**
Izaña	**-7.0**	-0.7	**11.6**	1.2	**0.74**
Wollongong	**34.0**	3.8	**31.1**	3.4	**0.77**
All	**13.9**	2.0	**25.7**	3.3	**0.85**

Differences are mean differences, first in % then in molecules/cm^2.

The percentage values are taken wrt ground base measurements.

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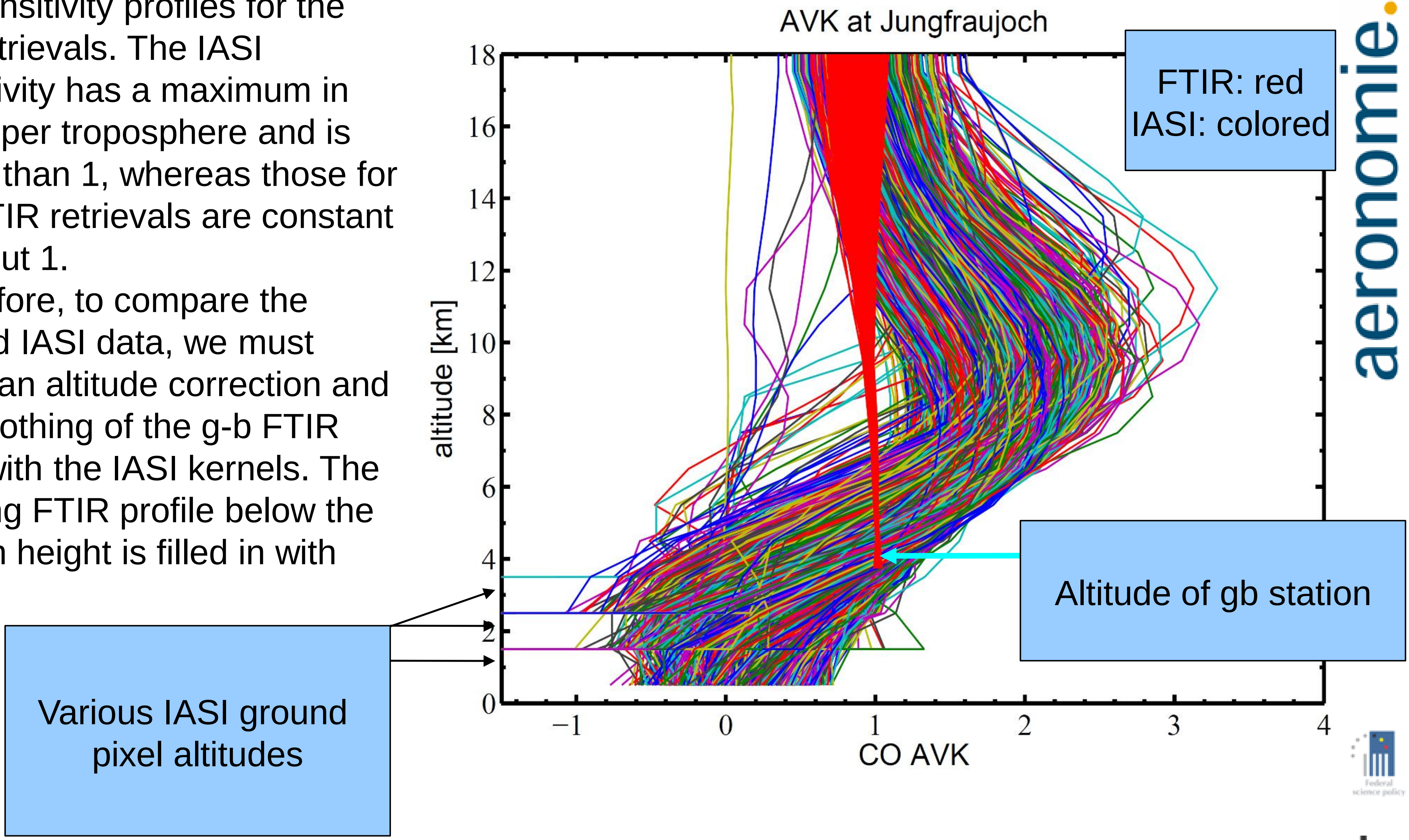
CO validation: sensitivity differences

There are large differences in the sensitivity profiles for the CO retrievals. The IASI sensitivity has a maximum in the upper troposphere and is larger than 1, whereas those for the FTIR retrievals are constant at about 1.
Therefore, to compare the gb and IASI data, we must apply an altitude correction and a smoothing of the g-b FTIR data with the IASI kernels. The missing FTIR profile below the station height is filled in with zeros.



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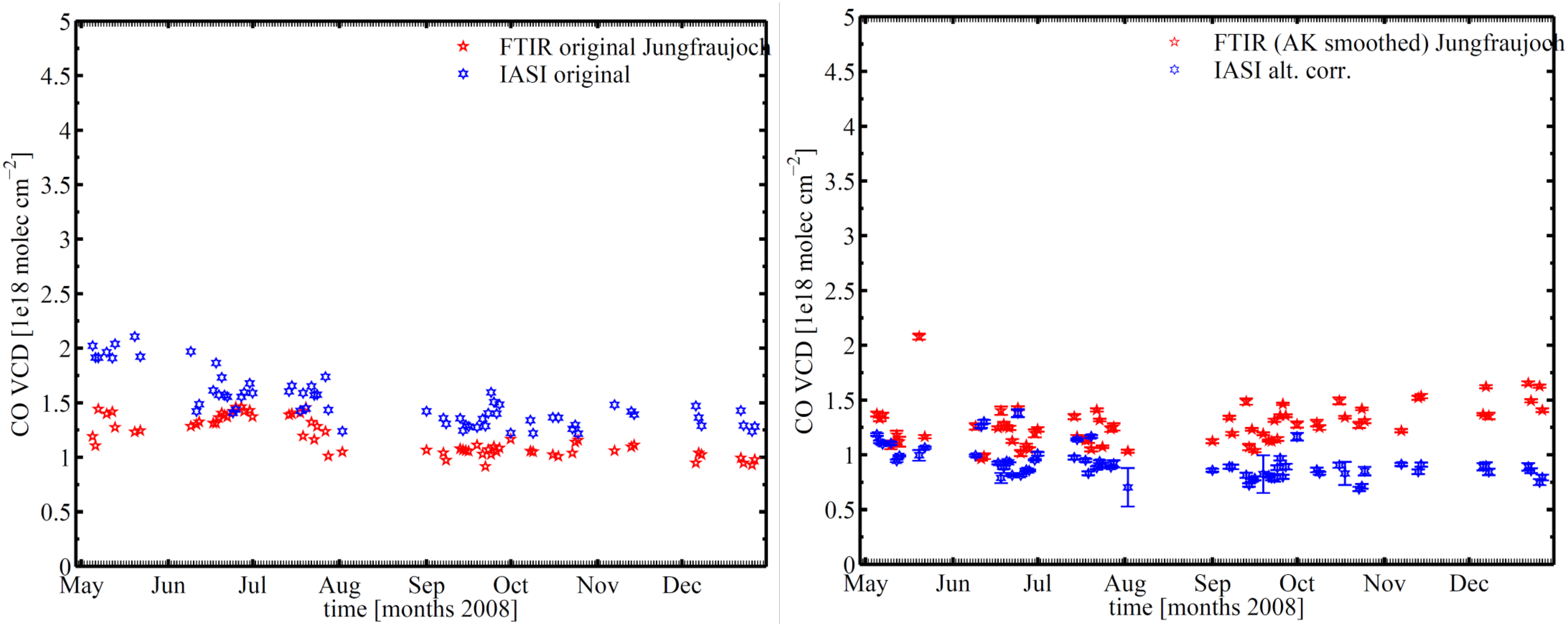
CO validation: averaging kernel smoothing of FTIR data and IASI altitude correction



As expected from the averaging kernels we see an increase of the FTIR CO total columns after the smoothing. Also expected for the mountain site Jungfraujoch (3580 masl) when the IASI total columns are corrected to the altitude of the gb FTIR site, the columns decrease. The altitude correction is done using the TM4 model by calculating a correction factor based on the ratio of the total column over the g-b site's altitude to the total column over the IASI pixel altitude.

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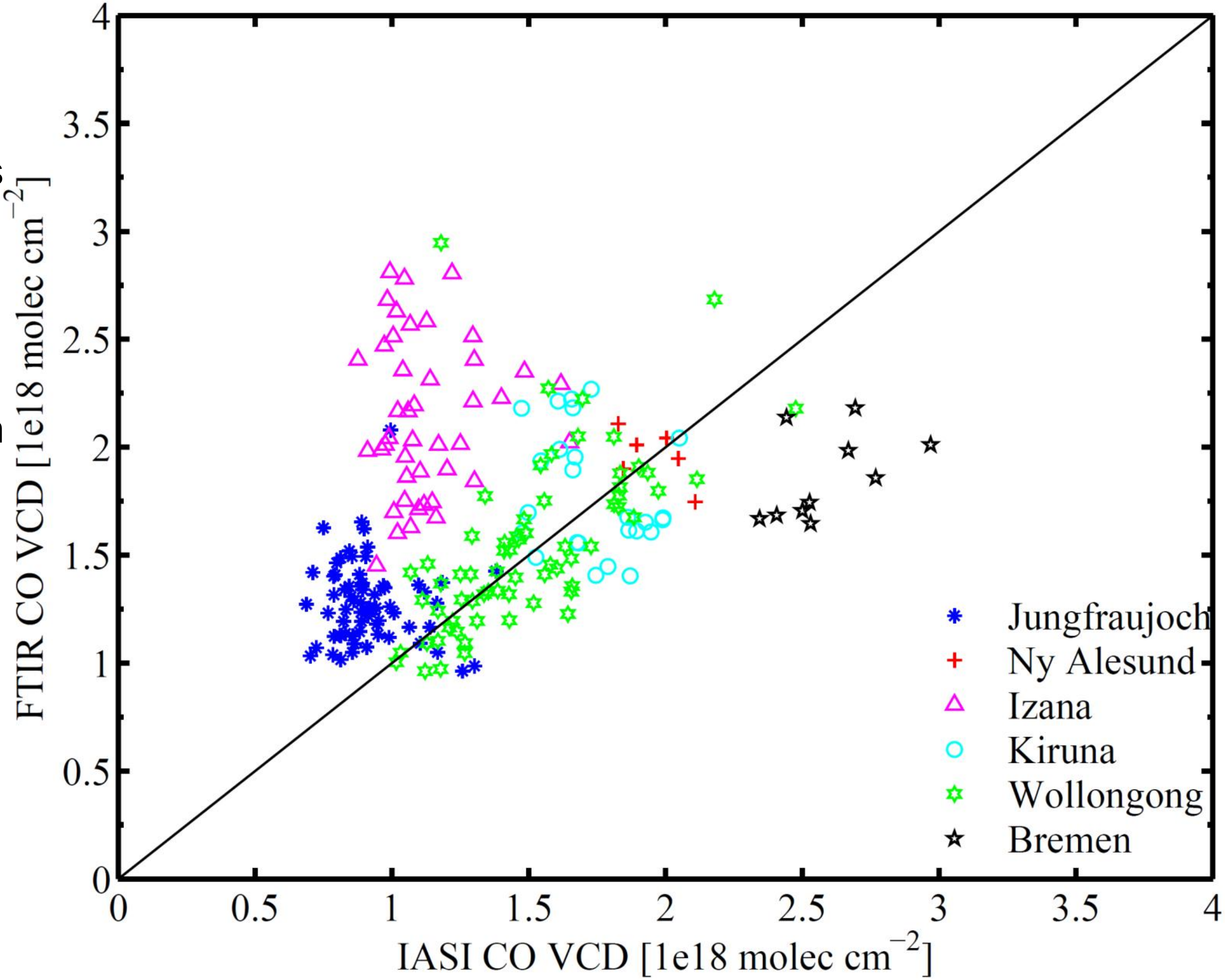
CO validation: comparisons for 6 NDACC stations

The approach presented for the comparisons seems to work well for some stations, especially Wollongong, but we still observe large differences between the gb and IASI data, especially at Izana, Jungfraujoch and Bremen.



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CO results

	diff. [%]	diff[1e17]	std[%]	std[1e17]	corr
Ny Ålesund	**0.3**	-0.05	**11.6**	2.8	**-0.62**
Kiruna	**0.1**	-0.5	**19.8**	3.7	**-0.28**
Bremen	**39.7**	7.2	**12.4**	2.0	**0.50**
Jungfraujoch	**26.7**	3.6	**16.6**	2.5	**-0.09**
Izaña	**-46.1**	-10.2	**11.3**	3.9	**0.06**
Wollongong	**-0.7**	3.1	**15.6**	0.05	**0.62**
all	**-15.2**	-3.0	**26.5**	5.2	**0.64**

Differences are mean differences, first in % then in molecules/cm^2.

The percentage values are taken wrt ground base measurements.

Correlations that are not significant are indicated in red.

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Retrievals of methane profiles from IASI

- IASI **Methane** profile retrievals are performed using the line-by-line retrieval code **ASIMUT** developed at BIRA.
  - ASIMUT uses OEM or Tikhonov regularisation

- The IASI retrievals are done in a **two stage process**:
  - first the surface temperature, H_2O profile in 36 layers and the O_3 column in the following 2 windows, **1084.0—1134.0 cm^{-1}** where mainly CO_2, H_2O and O_3 are present (noise = 0.5 10^{-7} W/cm^2/Sr/cm^{-1}) and **1392.0—1442.0 cm^{-1}** with mainly H_2O and noise = 0.2 10^{-7} W/cm^2/Sr/cm^{-1}.
  - The results from the first stage are used to retrieve CH_4 profile in 36 layers and the N_2O column in the following 3 windows:
    - **1175.5—1185.5 cm^{-1}** mainly H_2O and N_2O, noise = 0.4 10^{-7} W/cm^2/Sr/cm^{-1}
    - **1228.0—1238.0 cm^{-1}** mainly CH_4 and H_2O, noise = 0.2 10^{-7} W/cm^2/Sr/cm^{-1}
    - **1299.0—1309.0 cm^{-1}** mainly CH_4 N_2O and H_2O, noise = 0.2 10^{-7} W/cm^2/Sr/cm^{-1}

- The ground based a priori profiles are used for the retrievals

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Retrievals of methane profiles from IASI cont.

- Monthly MODIS surface emissivities on a 0.5° lat/lon grid (MYD11C1) are used for the retrievals.

- Retrievals were filtered using
  $\chi^2 <$ # of spectra,
  $\chi^2 <$ # of levels and
  RMS< median(RMS)+1σ.

- Nadir and offaxis pixels are used for the retrievals.

- Cloudy pixels were filtered by comparing the retrieved surface temperature with the ECMWF surface temperature
  (given on a 0.25° lat/lon grid).

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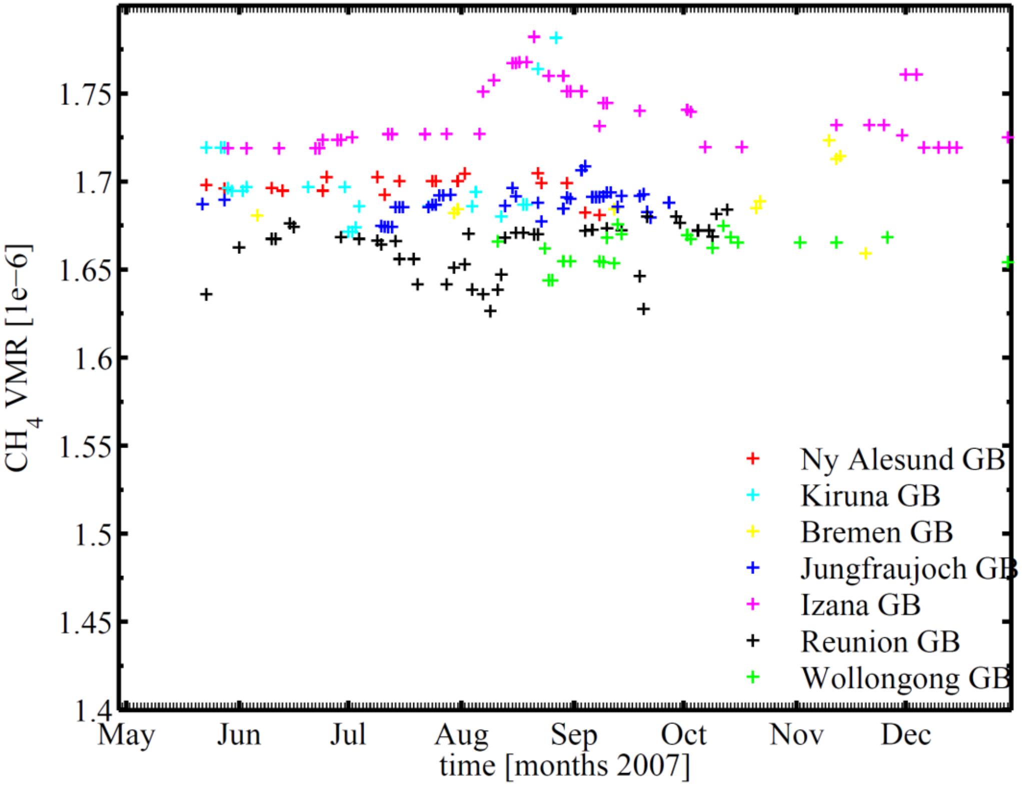
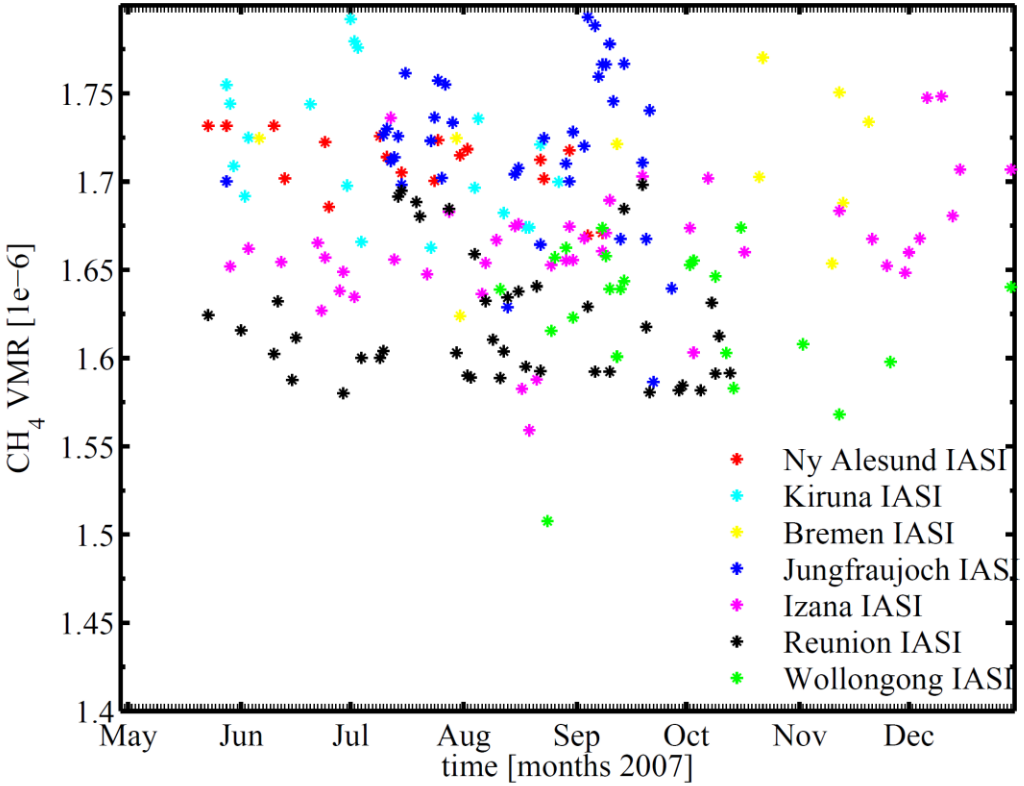
Original CH4 total column time series





Column averaged CH4 mixing ratios show a North-South gradient, in both, the g-b and satellite borne data. The FTIR at Izaña measures unexpectedly high CH4.

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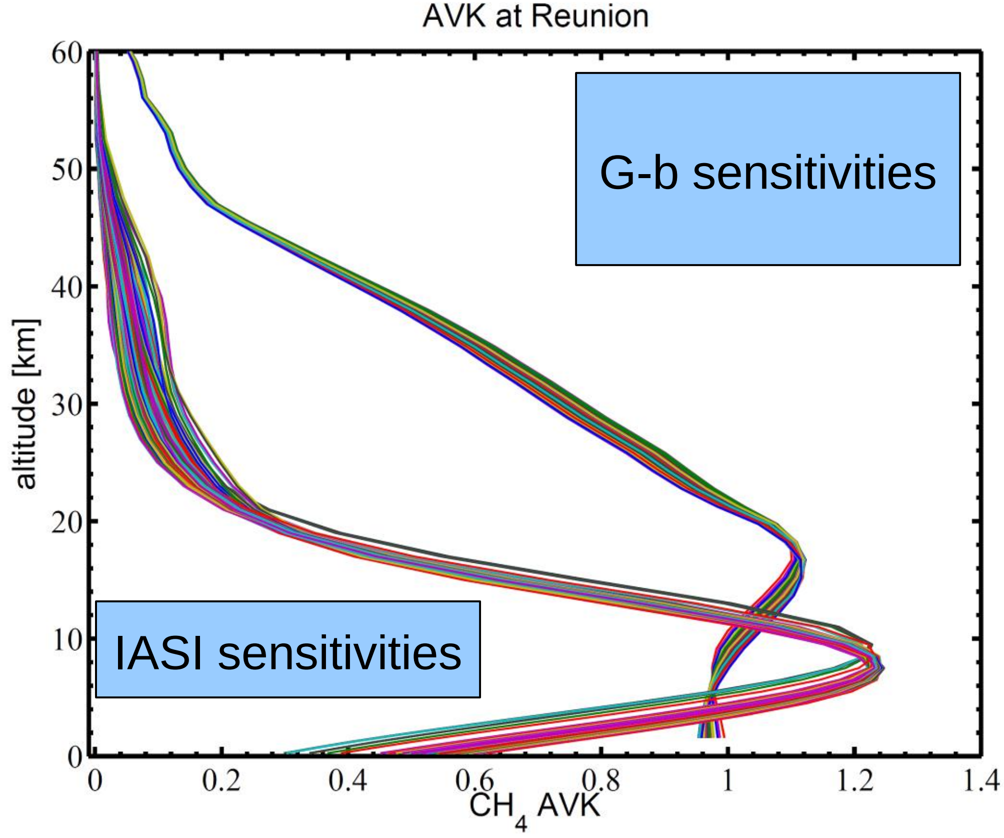
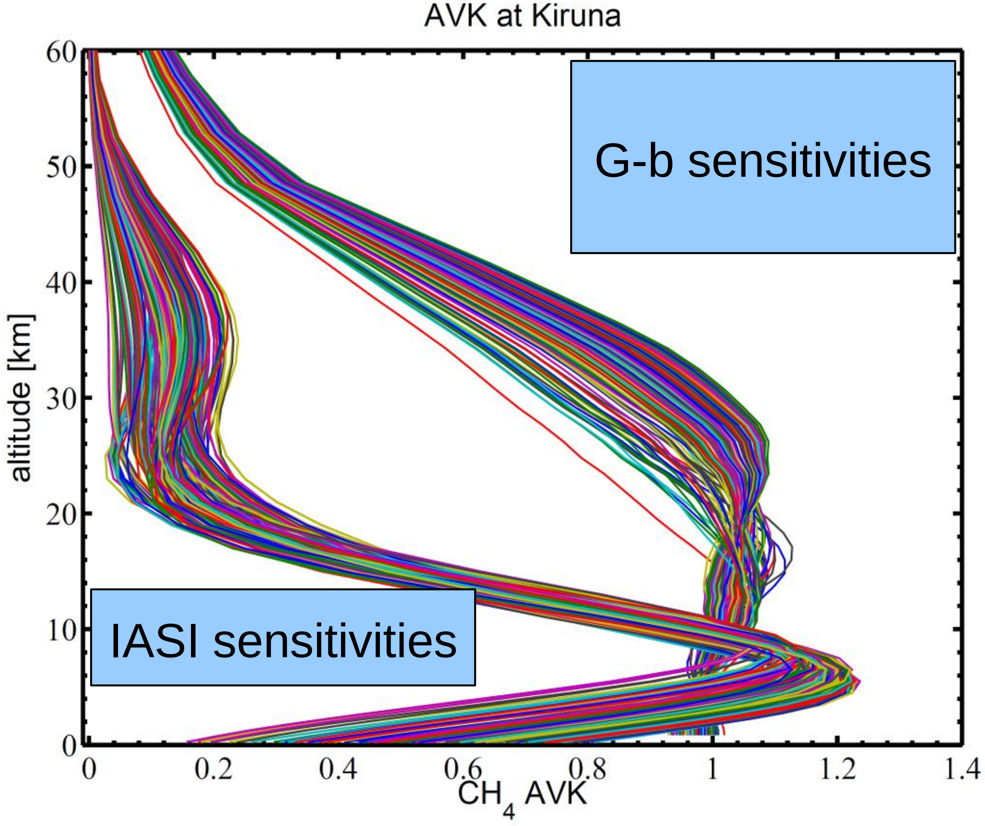
CH4 profile retrievals: sensitivities





IASI has 2 to 1.7 DOF. It mainly sees the troposphere

The ground-based measurements have DOF of 2.5 to 2.4. The FTIR also sees the lower stratosphere.
An averaging kernel smoothing is necessary, therefore IASI profiles are convolved with the FTIR averaging kernel and FTIR profiles with the IASI averaging kernels.

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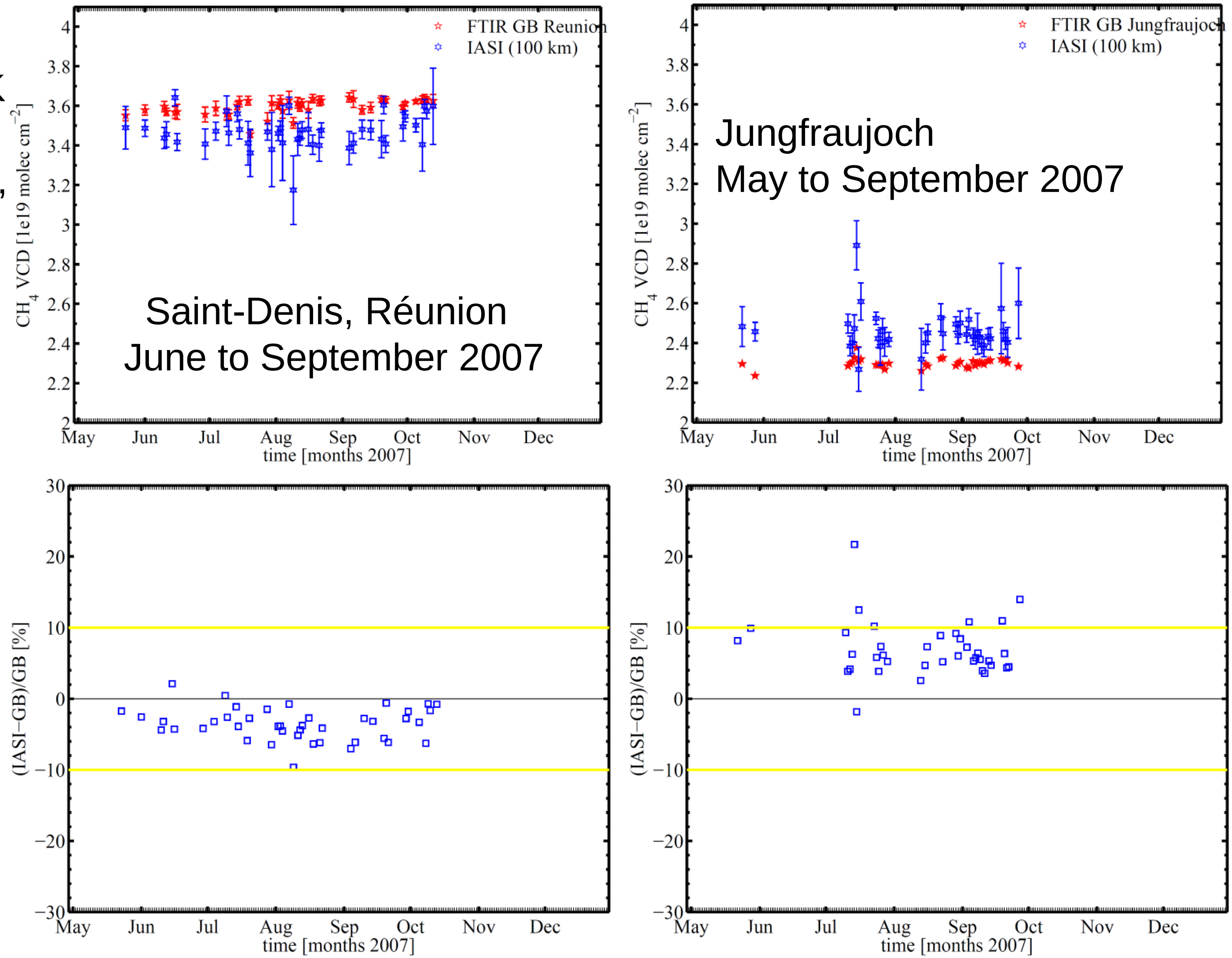
Time series of total vertical columns (VCD) of CH4 and percent differences

Daily means of methane VCD (AK smoothed and altitude corrected), the error bars represent the total random error.

Percent differences between the daily means. The differences are calculated with respect to the ground-based measurements.



The horizontal yellow lines indicate ±10% in all panels.

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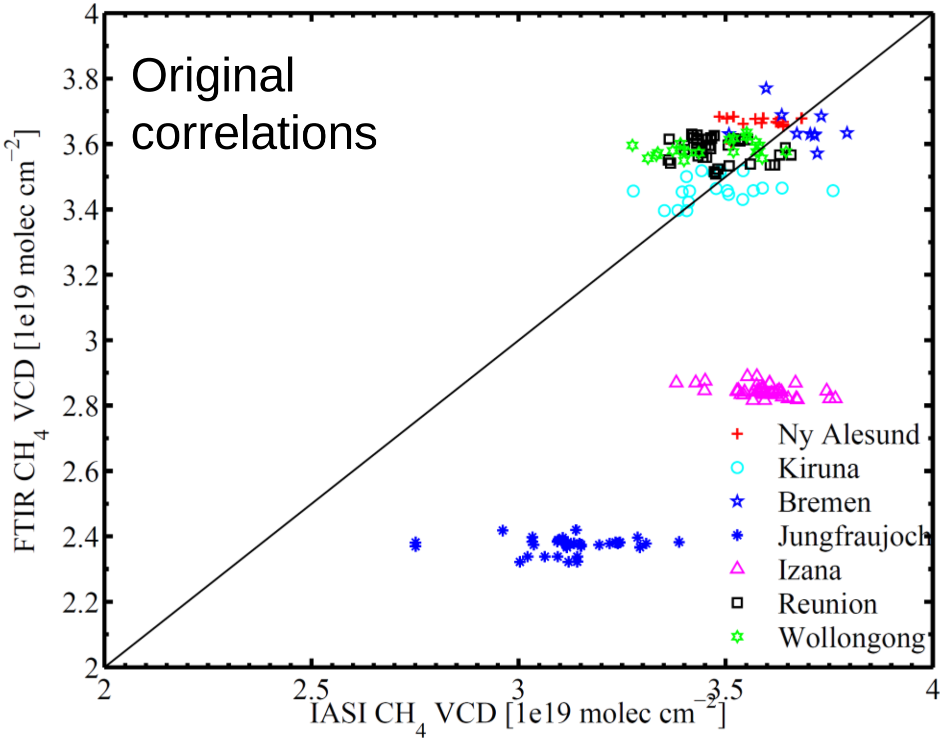
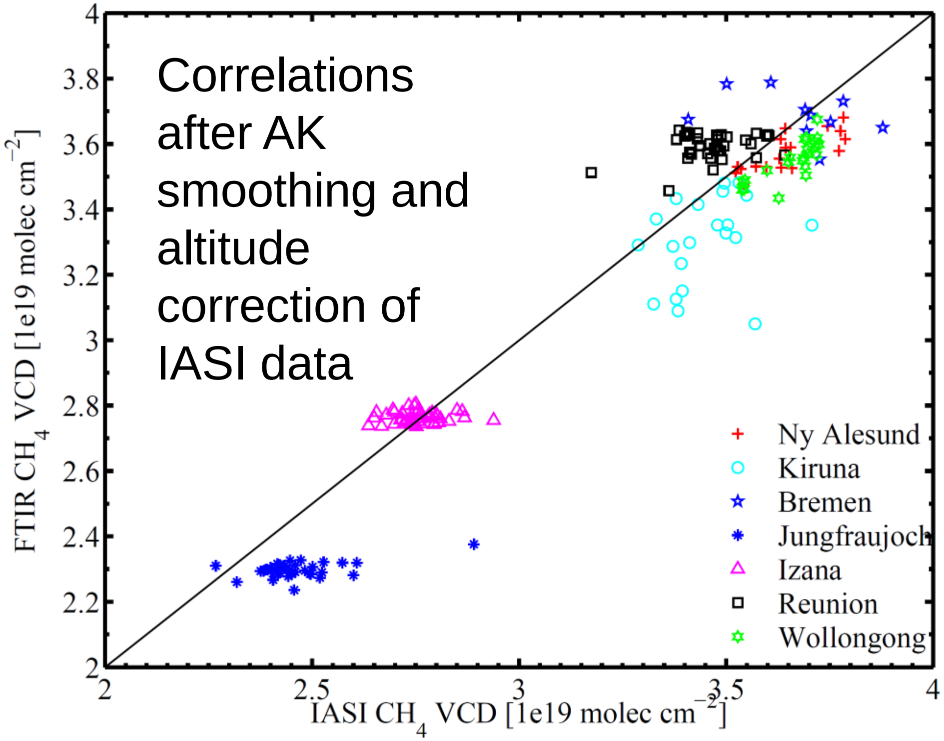
CH4 validation: comparisons for 7 NDACC stations before and after smoothing and altitude correction





The effect of the altitude correction can mainly be seen for Jungfraujoch and Izaña whereas the effect of the averaging kernel smoothing is present for all stations.

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CH4 results

	diff[%]	diff[1e17]	std[%]	std[1e17]	corr
Ny Ålesund	**2.1**	0.7	**1.6**	0.6	**0.78**
Kiruna	**4.5**	1.4	**4.5**	1.4	**0.30**
Bremen	**-0.3**	-0.1	**4.7**	1.8	**-0.37**
Jungfraujoch	**6.9**	1.6	**3.9**	0.9	**0.49**
Izaña	**-0.3**	-0.1	**2.2**	0.6	**0.06**
Saint-Denis	**-3.6**	-1.3	**1.2**	0.8	**0.28**
Wollongong	**3.1**	1.1	**2.3**	0.4	**0.80**
all	**1.5**	3.5	**4.7**	13.8	**0.97**

Differences are mean differences, first in % then in molecules/cm^2.

The percentage values are taken wrt ground base measurements.

Correlations that are not significant are indicated in red.

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CONCLUSIONS

- For Nitric acid(retrieved with FORLI-HNO3):
  - The differences between the vertical sensitivities of the ground-based and the IASI retrievals are small.
  - The IASI retrievals are able to see station-to-station differences but they show quite large differences with the ground-based data and they show a large scatter.

- For Carbon monoxide(retrieved with FORLI-CO):
  - There are strong differences, especially in the upper troposphere/lower stratosphere, between the sensitivities of ground-based and IASI retrievals.
  - The IASI data above Wollongong appear most reliable; at other stations we still find significant differences between the ground-based and the IASI data.

- For methane (retrieved with ASIMUT):
  - We have more than 2 degrees of freedom for signal for the ground-based retrievals and 1.5 to 2 for the IASI retrievals. The sensitivity of IASI is limited to the troposphere; the ground-based sensitivity goes up to the lower to middle stratosphere.
  - Comparisons of the ground-based and IASI methane time series show good agreement, after altitude corrections and averaging kernel smoothing. Still the IASI data show a higher scatter than the ground-based data. IASI sees the north-to-south gradient.

- A detailed error budget evaluation is under way to refine the comparisons and to evaluate the precision of the IASI trace gas data products under consideration.

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CH4 profile retrievals: Averaging kernels

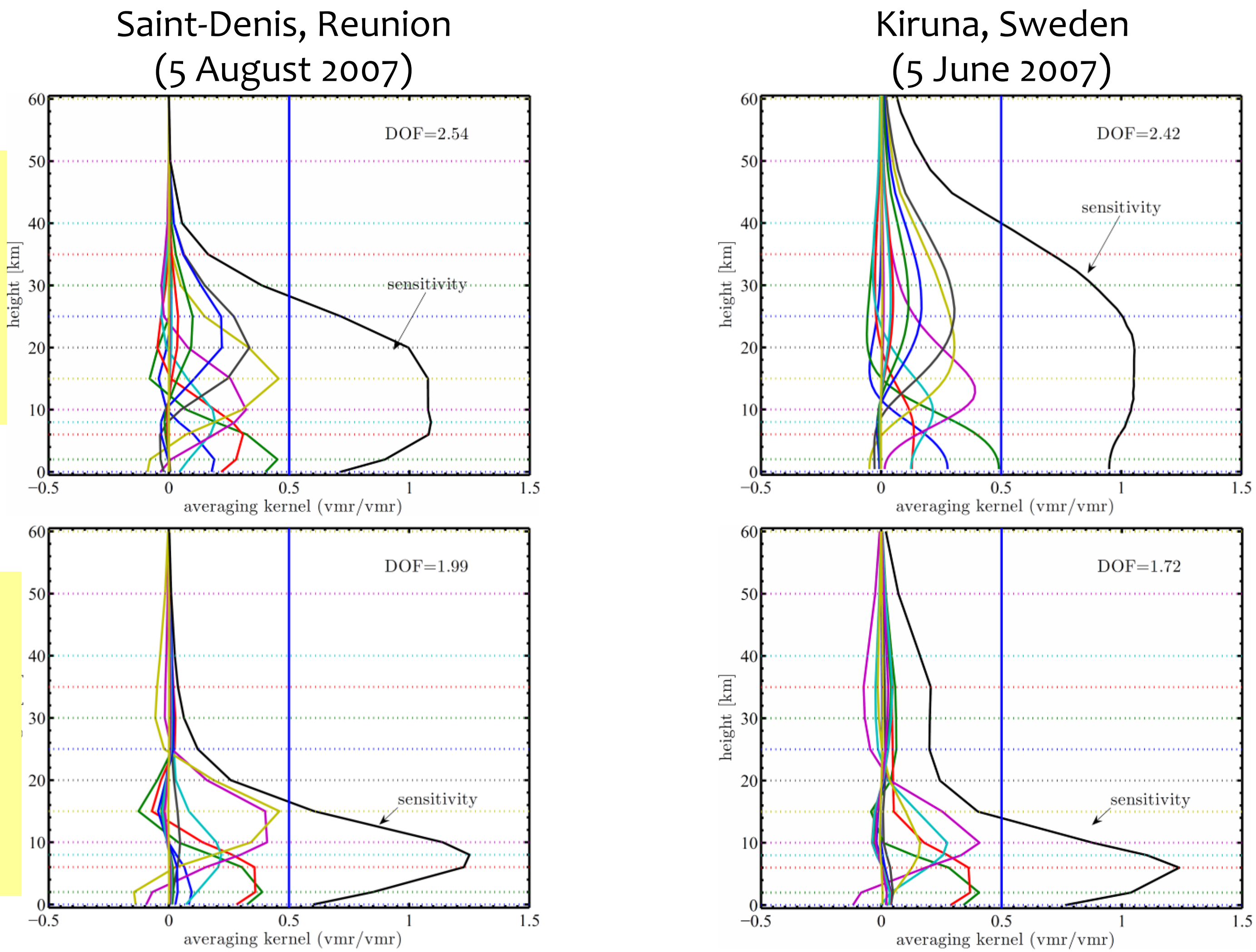
Ground-based

DOF 2.5 to 2.4

IASI

DOF 2 to 1.7

Troposphere only



The colored horizontal dashed lines indicate the height for which the corresponding colored kernel is active. The sum of the rows of the averaging kernels is indicated in black. The numbers of degrees of freedom for signal (DOF) are shown in the plots

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