Introduction
While the usage of space-borne instruments has become increasingly important for measuring the atmospheric composition on a global scale, ground-based measurements are still crucial. Ground-based measurements often provide highly accurate data with high time resolution, ideally suited for validation purposes. Here we present preliminary results from an inter-comparison of two CO time series (1997-2004) observed at the Jungfraujoch with in situ Non-Dispersive Infrared (NDIR) technique and remote sensing Fourier Transform Infrared (FTIR) solar absorption spectrometry.

The Jungfraujoch Station
The Jungfraujoch station (46.5° N, 8° E, 3580 m above sea level) is located on a mountain saddle between the Jungfrau (4158 m asl) and Mönch (4099 m asl) peaks in the Swiss Alps. Due to its unique place, the year-round accessibility, and the excellent infrastructure, the Jungfraujoch research station is well suited for long-term ground-based in-situ as well as remote sensing monitoring of trace gases with only little influence of pollution from the atmospheric boundary layer.

In situ NDIR technique
- Operated by Empa
- Cross Flow Modulated NDIR Absorption technology (Horiba APMA-360)
-Uses a built-in IR light source and samples in situ ambient air
- Sample gas and reference gas are injected alternately into the measurement cell. Sample air is taken to generate CO-free reference gas by using a catalyst to oxidise CO to CO2.
-Data are 10 minutes averages of the local CO concentration at 3580 m asl.
The overall measurement uncertainty for these 10 minutes mean values is estimated to be <1% below 100 ppbv and <5% above 100 ppbv.

Remote sensing FTIR solar absorption spectrometry
- Performed by the University of Liège (ULg) in collaboration with BIRA-IASB
- FTIR detects the downwelling direct solar radiation.
  (Requires clear sky conditions)
- Retrieval of CO profile: SRT2 algorithm + HITRAN2004
- Retrieved profile has a limited vertical resolution (typical DOF = 2.18)
-Information content is determined by the Averaging Kernels [Rodgers, 2000]. The retrieved volume mixing ratio (vmr) profile is as thus related to the true profile x and to the a priori profile xa by:
  \[ x_{\text{retrieved}} = A(x_{\text{true}} - x_{\text{a priori}}) + \text{a priori} \]

The DOF of this merged layer would depend too much on the a priori information.

Kolmogorov-Zurbenko filter
The KZ filter is a low pass filter which separates the time series at a selected cutoff frequency. The thus obtained long term trend (cutoff frequency = 1.7 years) is shown in Fig. 5. Apart from the year 2000 (which featured some unusually high NDIR data), the NDIR-FTIR seems to be gradually decreasing until mid 2003. Apart from 1998 and 2000-2003 (large biomass burning events), the overall trend is negative.

Also clear is that from 2001 onwards, (3.56-7km averaged) FTIR CO values are in fact higher than those measured by in situ NDIR! The mean diurnal variability of CO (max-min NDIR CO for each day, using only days which feature a FTIR measurement) is 67 ppm.

FTIR window selection
Retrieval from the 2050-2160 cm⁻¹ window (using 12CO and 13CO absorption lines) as used throughout this poster yields a trend of -0.83 ppb/year. [only FTIR data, taken within 1/2h of a 4250 cm⁻¹ measurement] Retrievals near 4250 cm⁻¹ (using 12CO lines only) yield a trend of -1.5 ppb/year. The cause of this significant difference is under investigation.

Conclusions
- The correlation between NDIR and FTIR measurements (3.6-7.0 km) is very good (R²=0.72).
- However the different trends for NDIR and FTIR data remain unclear and further research into the cause is ongoing.
- Given the difference in sampled air masses it is not unlikely for such a difference to occur, however...
- Removing PBL contaminated air from the NDIR dataset, does not significantly impact the overall trend.
- The trend difference is gradual and features no strong seasonal dependence (unlike the trends themselves)
- FTIR window selection impacts the CO trend.

Acknowledgements

Fig. 1: Location of the Jungfraujoch site

Fig. 2 (a) and temporally overlapping (b) FTIR (3.58-7km averages) and NDIR data

Fig. 3 Histogram of CO daily range (max-min CO) – gaussian distribution

Fig. 4 Jan-Apr (a) and Jun-Sep (b) CO values and trends (in ppb/year, overlapping data only)

Fig. 5 KZ filtered NDIR and FTIR data (cutoff at 1.7 years) and its difference

Fig. 6 Impact of subjective selection upon the CO retrieval. Green data points are the ‘standard’ CO data retrieved according to the UFTIR project [ftp://www.co.umbc.edu], while the red data points are downsampled taking CO data lines only.