Name of research institute or organization:

Empa, Swiss Federal Laboratories for Materials Science and Technology

Title of project:

National Air Pollution Monitoring Network (NABEL)

Project leader and team:

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Project description:

The National Air Pollution Monitoring Network (NABEL) is run by Empa jointly with the Swiss Federal Office for the Environment (BAFU/FOEN). The NABEL network was established in 1978 with initially 8 sites emerging from activities that started already in 1968 as contributions to international WMO and OECD observation networks. In-situ measurements by Empa at Jungfraujoch began in 1973. Early activities mainly focused on sulphur dioxide and particulate matter. In 1990/1991 the NABEL network was extended to 16 monitoring stations that are distributed all over Switzerland. The locations of these monitoring stations are representative for the most important air pollution levels ranging from the urban kerbside to remote free tropospheric background. The NABEL site at Jungfraujoch is a very low polluted site, representing a background station for the lower free troposphere in central Europe.

The current measurement program at Jungfraujoch includes continuous *in-situ* analyses of ozone (O_3), carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), the sum of nitrogen oxides (NO_y), sulphur dioxide (SO_2), methane (CH_4) and carbon dioxide (CO_2). These data are stored as 10-min averages. Furthermore, the concentrations of CH_4 are measured in 24 min intervals along with nitrous oxide (N_2O) and sulphur hexafluoride (SF_6). Molecular hydrogen (H_2) is also semi-continuously monitored in 30-min intervals. An extended set of halocarbons and a selection of volatile organic compounds (VOCs) (alkanes, aromatics) are measured with a time resolution of two hours. The concentrations of particulate matter < 10 μm (PM10) are determined both continuously and in 24-hour integrated samples. Daily samples are taken to quantify particulate sulphur.

The integration of observations of surface-based, balloon-borne, aircraft, satellite and other remote sensing observations is one of the main long-term strategic objectives of the Global Atmosphere Watch (GAW) Programme. Being one of the currently 29 global GAW stations, Jungfraujoch is a well suited location to advance such activities due to the available remote sensing Fourier-transform infrared (FTIR) spectrometer observations collocated with Empa's ground-based in-situ measurements. The FTIR observations are part of the Network for the Detection of Atmospheric Composition Change (NDACC) that are run by the Université de Liège (ULg) and are jointly exploited by ULg and the Belgian Institute for Space Aeronomy.

Recent activities were also motivated by the European Commission's Framework Programme 7 NORS (Demonstration Network Of ground-based Remote Sensing Observations in support of the GMES Atmospheric Service, http://nors.aeronomie.be/) project and in particular by its work package "tropospheric products" that aims at comparing and integrating surface in-situ observations and remote sensing observations in the troposphere. One of the NORS objectives is the further characterisation and validation of ground-based remote sensing data. To do so, the surface in-situ observations are seen as a reference measurement because they can be traced back to international standards and exhibit relatively small measurement uncertainties. However, surface observations are usually not representative for extended vertical regions. Next to Izaña (Tenerife Islands, Spain), Jungfraujoch was selected for an inter-comparison within NORS. The two chosen sites are usually situated above the planetary boundary layer and as such are not directly influenced by strong surface fluxes (emissions or deposition). Hence, it is usually assumed that they are horizontally representative of a larger area than boundary layer sites. Nevertheless, the vertical representativeness needs to be carefully addressed when their surface in-situ observations should be compared with remote sensing profile retrievals.

Previous inter-comparison exercises, which were done at Jungfraujoch [Barret et al., 2003; Dils et al., 2011] and Izaña [Sepúlveda et al., 2012], relied on the assumption that the surface observation is representative of the (lower) free troposphere and that the remote sensing observation provided one independent piece of information in the lower free troposphere that could be directly compared to the in-situ observation. While in general these studies showed good correlation between FTIR and surface observations, they did not provide linear regression slopes between FTIR and in-situ observations that were close to unity and even revealed different long term behavior [Dils et al., 2011]. Hence, these comparisons cannot serve as an absolute validation of the FTIR observation. This is not surprising since the comparison approach from Dils et al. mostly neglects any vertical variability of the target species within the troposphere and also the integrating nature of the remote sensing retrieval, which is expressed by its averaging kernels. A fair comparison of the remote sensing data with a reference data set needs to take these averaging kernels into account. However, this is only possible if more than a point observation at the surface is available as reference. By producing reference profiles that are "calibrated" with the surface in-situ observation, the present study aims to overcome these limitations. Therefore, a method was developed that combines surface in-situ observations with dedicated atmospheric transport simulations in order to describe vertical representativeness and transfer the surface in-situ observation in the vertical dimension. The product of this surface data extrapolation is a dataset of vertical profiles of selected trace gases at the times of the remote sensing observations. Since these profiles were "calibrated" against the surface in-situ observations they present reference profiles that can be used to validate the remote sensing observations. In total 36 yearly reference datasets were generated for the CO, CH_4 and O_3 remote sensing observations at Jungfraujoch and Izaña performed by FTIR during the period 2009 to 2011.

The comparison between FTIR observations, "raw" in-situ and "calibrated" profile data are shown in Figure 1. Here the FTIR data were averaged over the lowest sub-column of the retrieval for which the retrieval obtained 1 and 2/3 degrees of freedom (independent pieces of information) for CO and CH_4, O_3, respectively. "Calibrated" profile data were first folded with the FTIR averaging kernels and then the same vertical averaging was applied as for the FTIR profile. Simulated CO and CH_4 profiles were obtained from FLEXPART [Stohl et al., 2005] backward simulations with initial conditions taken from FLEXCTM [Henne et al., 2013] simulations, while O_3 initial conditions were taken from MACC re-analysis [Inness et al., 2013]. The simulated profiles were then adjusted towards the surface in-situ observations at levels for which the surface observations were estimated to be representative of.

In general FTIR CO observations correlated fairly well with the surface in-situ data (Figure 1, top). This correlation was improved when comparing against the "calibrated" profile data set. Also the regression statistics became more favorable with a slope very close to 1. A similar picture was also derived for CH_4 and O_3, in the sense that the comparison with the "calibrated" profiles was in better agreement than the direct comparison with in-situ data. However, the relatively weak correlation in the case of CH_4 and an overestimation of the variability by the FTIR as compared with the "calibrated" profiles may indicate difficulties of the FTIR to estimate near-surface CH_4, which is consistent with a weak sensitivity of the CH_4 averaging kernels close to the surface.

The "calibrated" reference profiles are currently used to further validate and improve the FTIR retrieval algorithms. Detailed results of the production of "calibrated" profiles are available from http://lagrange.empa.ch/NORS_browser/.

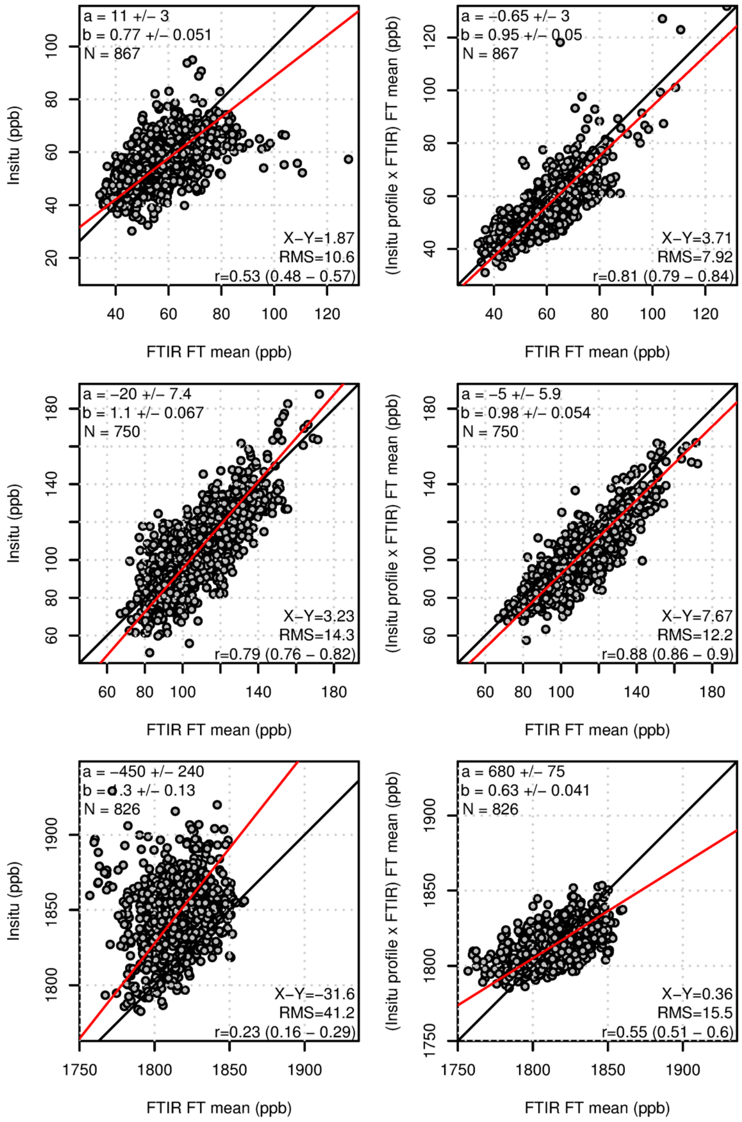

Figure 1. Inter-comparison between (left) surface in-situ observations and FTIR lower free troposphere (FT) sub-column and (right) "calibrated" reference profile sub-column mean and FTIR lower free troposphere sub-column for (top) CO, (middle) O_3 and (bottom) CH_4 at Jungfraujoch during the period 2009 to 2011. Each data point represents an individual FTIR observation or an hourly average when more than one FTIR observation was available within this period.

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Atmospheric chemistry, air quality, trace gases, long-term monitoring

Internet data bases:

http://www.empa.ch/nabel
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Collaborating partners/networks:

Bundesamt für Umwelt (BAFU)/ Federal Office for the Environment (FOEN)
Global Atmosphere Watch (GAW)
Belgian Institute for Space Aeronomy, Brussels
Institut d'Astrophysique et de Géophysique, Université de Liège
Labor für Atmosphärenchemie, Paul Scherrer Institut
MeteoSchweiz
Climate and Environmental Physics, University of Bern

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