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:

Dr. Martin Steinbacher, Dr. Christoph Hüglin (project leader)

Project description:

The National Air Pollution Monitoring Network (NABEL) is run by Empa together 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. These monitoring stations represent the most important air pollution levels from 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 also 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 long-term evolution of tropospheric ozone mole fractions at Jungfraujoch (see Figure 1) and other elevated measurement stations is of vivid scientific interest as ozone is an efficient greenhouse gas and plays a crucial role in tropospheric chemistry. Being a so-called secondary air pollutant produced in the atmosphere from precursors such as VOCs and nitrogen oxides under the presence of sunlight, its variations over time mainly reflect the response to the pronounced changes in the ozone precursors during the past decades. Various international efforts were recently made to analyze the long-term changes of ozone over the Alpine region [*Gilge et al.*, 2010], over Europe [*Logan et al.*, 2012], and over the Northern Hemisphere [*Parrish et al.*, 2012].

Gilge et al. [2010] focused on the measurement stations of the DACH-cooperation (Germany: D, Austria: A, Switzerland: CH), namely Zugspitze, Hohenpeissenberg, Sonnblick and Jungfraujoch. Data from 1995 till 2007 were considered in this publication to have a consistent dataset for all stations. Linear trend analyses were performed for a variety of percentile classes. Jungfraujoch (the most elevated of the stations) reveals consistent but insignificant negative trends for all percentiles while the lower percentiles at the other less elevated stations slightly increase and the upper percentiles come down. The different patterns can be explained by the more dominant influence of ozone loss due to NO titration at lower altitudes. This loss process mainly plays a role in polluted environments in the atmospheric boundary layer (ABL) while air masses from the ABL only occasionally reach the Jungfraujoch. Reduced NO emissions in the ABL make the loss process less prevalent and thus favour positive ozone trends. The specific analysis by *Gilge et al.* [2010] for

Jungfraujoch also pointed out that the 1986-1994 trend at Jungfraujoch was (insignificantly) negative due to the observation of high mole fractions in the early years of the time series.

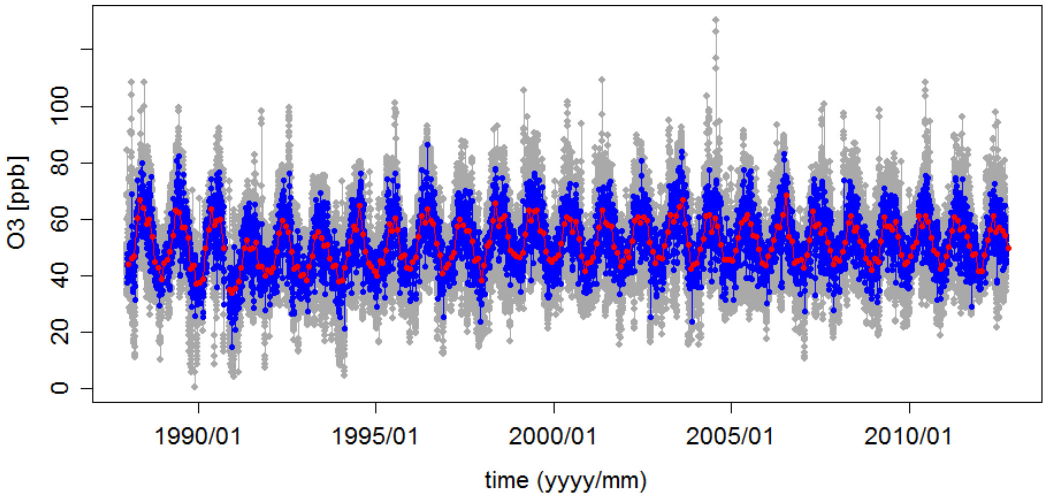

Figure 1. Time series of hourly (grey), daily (blue) and monthly (red) averages of continuously measured in-situ ozone at Jungfraujoch from 1988 to 2012.

Logan et al. [2012] carefully analysed ozone time series in the free troposphere from various networks (ozone sondes, aircrafts, and Alpine surface sites) back to the 1970ies. Intercomparison of the various datasets revealed very coherent features above Europe since about 1998, providing good confidence in the data quality of the various measurements. Prior to 1998, differences between the time series were more pronounced due to less precise measurement equipment and less sophisticated quality control procedures. Within NABEL, a complete traceability chain for ozone was established in 1993 when purchasing a standard reference photometer while the measurements before relied on comparison with transfer instruments that were calibrated by the manufacturer. Overall, Logan et al. [2012] state that the trends in ozone precursor emissions and of ozone in the lowermost stratosphere (from where ozone can be transported into the free troposphere) cannot fully explain the observed ozone evolution. More dedicated modeling efforts might be needed to get better insight in the underlying processes.

A similar point is made by *Parrish et al.* [2012] who also aim at providing robust ozone datasets for comparison with model outputs. They studied time series from six European low polluted and elevated measurement sites along with three North American and two Asian long-term ozone time series. The authors state that systematic long-term measurement-model comparisons covering various decades are necessary to fully understand the ozone budget. *Parrish et al.* [2012] conclude that the ozone time series increased rather linearly at all sites in the last decades of the last century while a remarkable slow down can be observed afterwards leading to decreasing growth rates. The slowdown of the growth rate can particularly be seen over Western and Central Europe while it is less pronounced over North America and Japan. Within this study, NABEL’s continuous ozone time series since 1990 were jointly analyzed with sporadic historic data taken in summer 1934 and 1938 at Jungfraujoch (taken from *Crutzen* [1988] and *Staehelin et al.* [1994]) (see Figure 2). This combined view confirms the significant increase of ozone at Jungfraujoch in the last century with an approximate doubling of the ozone burden between the 1930ies and the year 2000.

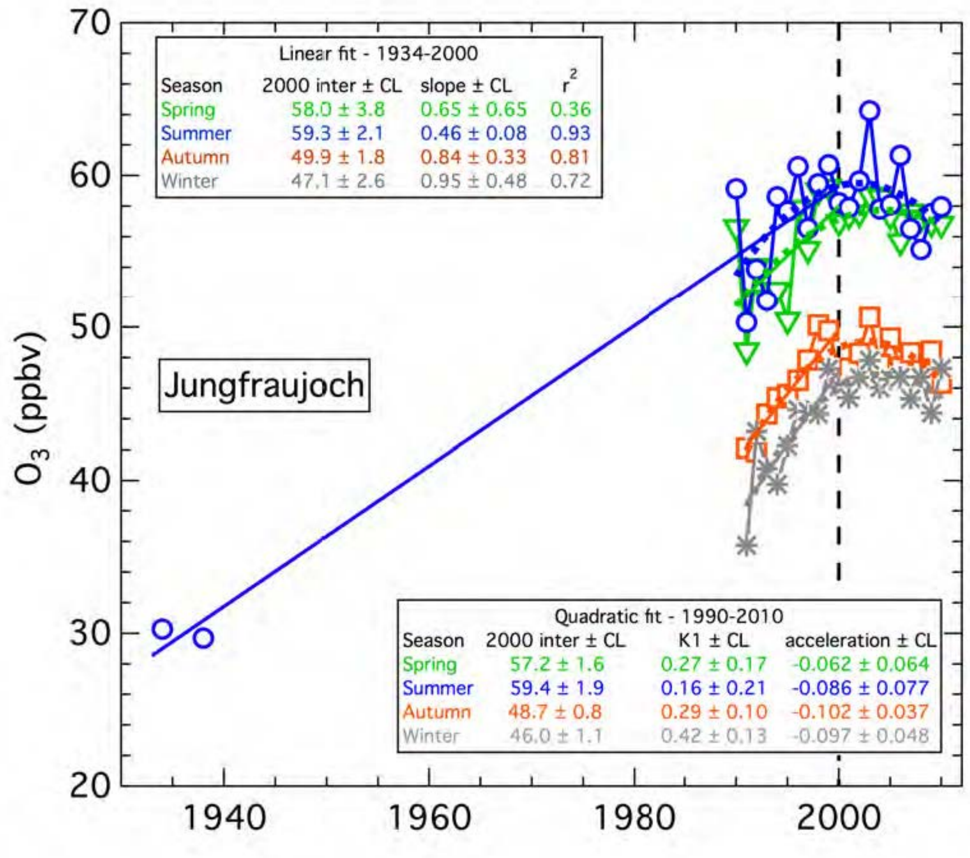

Figure 2. Time series of seasonal ozone averages at Jungfraujoch from 1990 to 2010 along with sporadic historic data from summer 1934 and summer 1938. The solid lines illustrate linear regressions for the data prior to 2001, the dotted lines indicate the quadratic regressions for the 1990 to 2010 datasets. Figure courtesy of David Parrish [Parrish et al., 2012].

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Key words:

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)
Labor für Atmosphärenchemie, Paul Scherrer Institut
MeteoSchweiz
Climate and Environmental Physics, University of Bern

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