Name of research institute or organization:

Bundesamt für Gesundheit, Sektion Umweltradioaktivität, Bern

Title of project:

Aerosol radioactivity monitoring RADAIR and DIGITEL

Project leader and team:

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Project description:

Aerosol Radioactivity Monitoring at the Jungfraujoch:
An automatic aerosol radioactivity monitor FHT59S (total alpha and total beta activity) is operated at Jungfraujoch research station by the Swiss Federal Office of Public Health. This monitor is part of the Radair Network and has the following particular features:

- Real-time (30 min) detection of any increase of radioactivity in the air at the altitude of 3400 m above sea level.

- A detection limit for artificial beta radioactivity as low as 0.1 Bq/m^3. Such a high sensitivity is made possible due to the very low Radon daughter concentration at this altitude.

Additional aerosol samples are taken using a Digitel High-Volume-Sampler. These samples are sent to the laboratory in Bern and are analyzed for radioisotopes using HPGe-Gamma-spectrometry.

Comments on the alpha/beta (Radair) measurements performed in 2012:
Figure 1 shows the natural alpha radioactivity, the calculated artificial beta radioactivity and the ratio between α and β activities during the period January 1 to December 31, 2012.

This figure shows that:

- Alpha radioactivity – i.e. Radon daughter products - is mainly transported up to the Jungfraujoch by air masses from the lowlands, since the highest values are usually observed in summer (from April to September) when thermal air convection is higher than in winter (see upper part of Figure 1).

- The highest α/β activities ratios are observed when the (natural) alpha radioactivity concentrations are the lowest. The α/β activities ratio fluctuates then between -50 and +50. The values lower than 0.55 and greater than 1.5 were removed, since those are not significant.

- At the end of January, the values of alpha concentration, relatively high for the season, are due to the passage of a cold front where the air of the plain, relatively rich in Radon, was transported to the high altitude. This phenomenon was also observed with a same monitor situated at Weissfluhjoch (Davos).
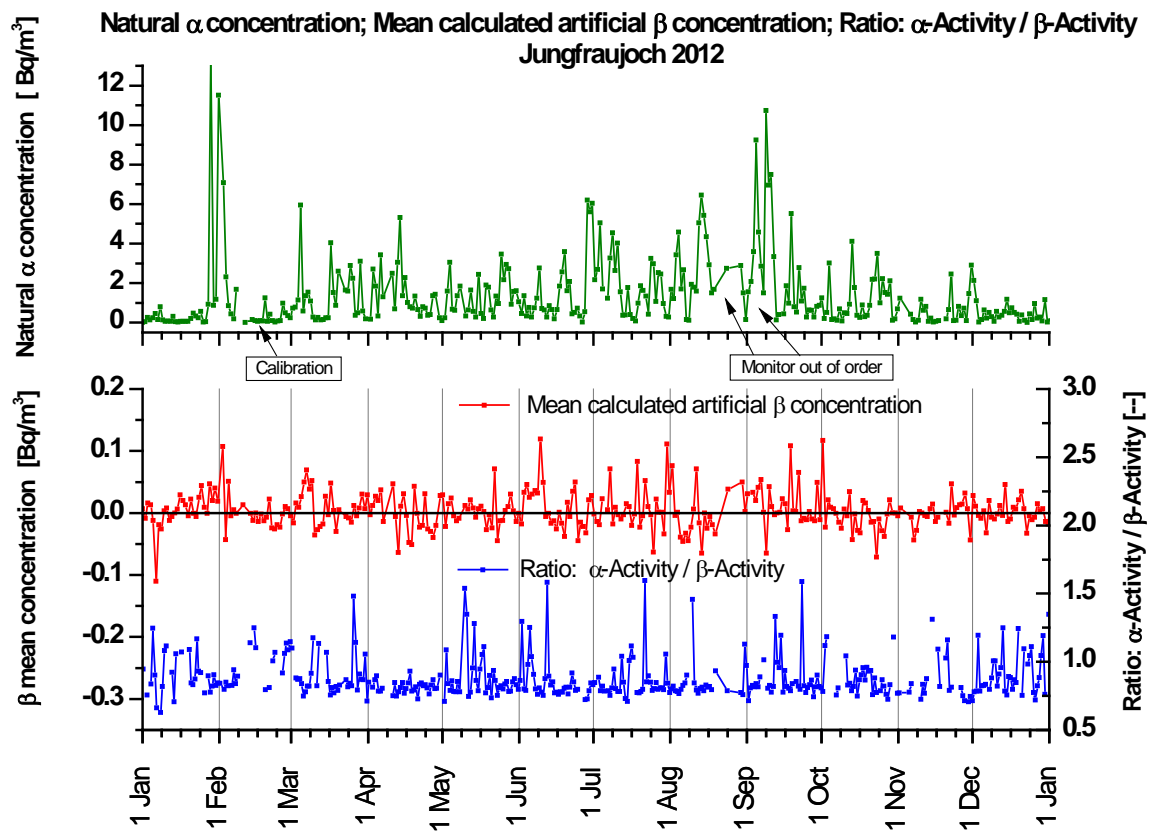
Figure 1: *Results of Radair measurements in 2012.*

Note: For a question of clarity of the graph, not all values are represented.

Figure 2 (top panel) shows the natural alpha concentration as a function of the wind direction and wind speed. We observe that when the main winds blow strongly, the natural radioactivity decreases due to strong mixing of the Radon-rich low altitude air with Radon-poor high altitude air. The highest concentrations are recorded with more gentle South-South-Easterly winds.

Natural α concentration depending on the wind speed and direction
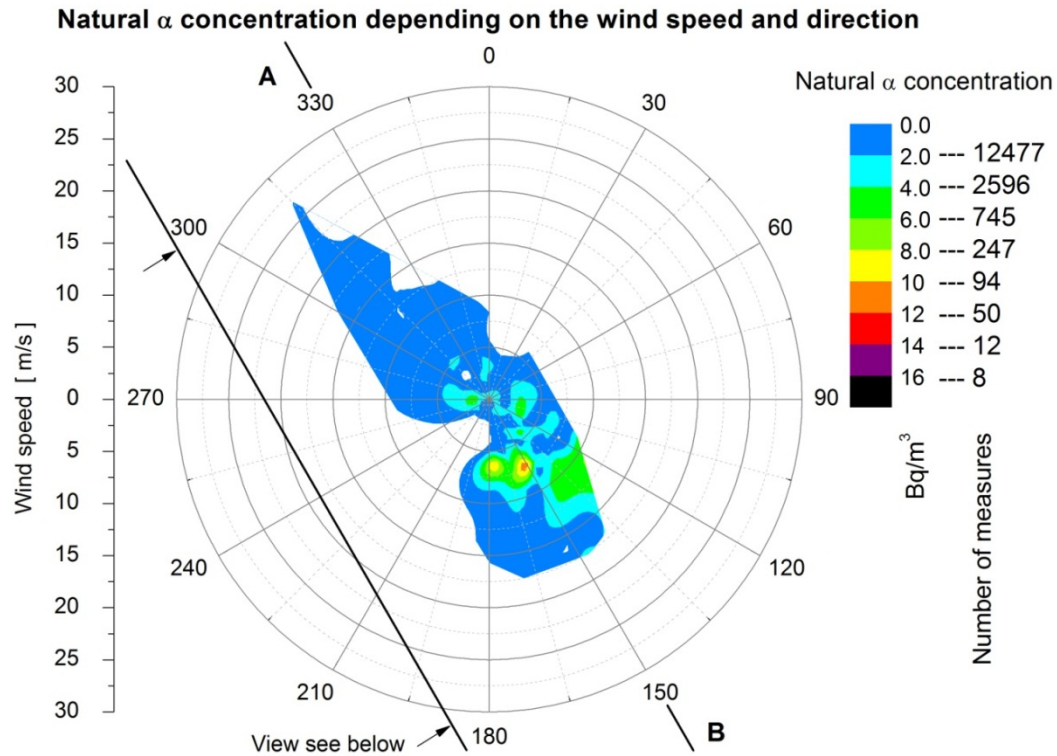
View on section: A – B (top panel):
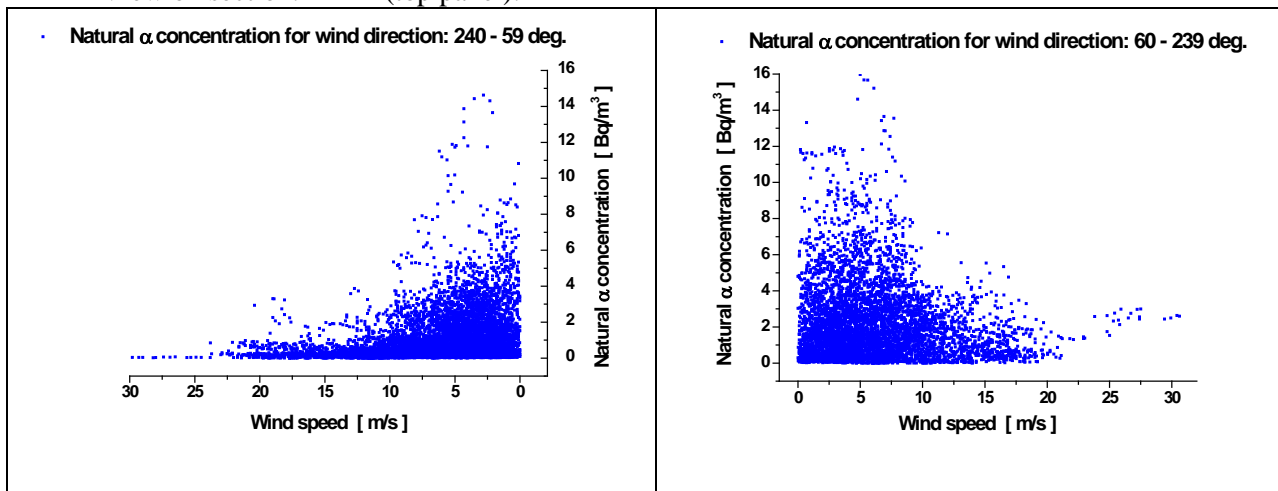
***Figure 2:** Natural alpha concentrations and prevailing winds.*

Figure 3 shows the density of the natural alpha concentration as a function of the wind direction. We observe that the density of natural alpha concentration is more important when the prevailing wind comes from North-North-East. On the other hand, the highest values of concentration meet when the wind comes from South-South-Easterly.

Density of natural α concentration depending on wind direction
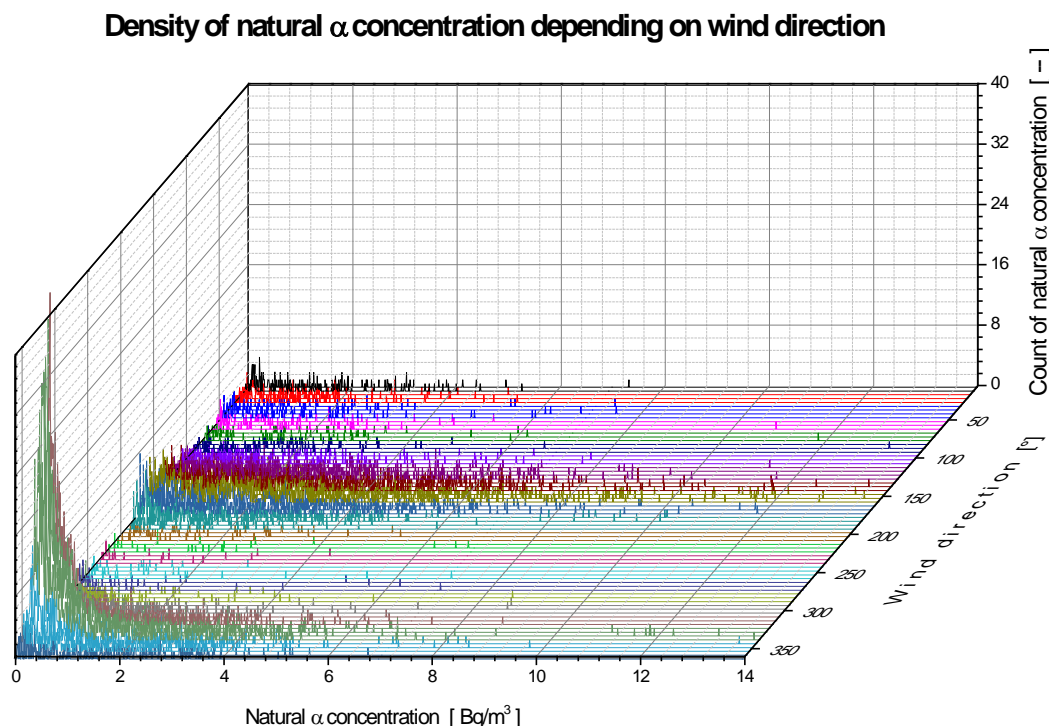
Figure 3: Density of natural alpha concentrations and prevailing winds

Figure 4 shows the histogram of the calculated artificial beta radioactivity in aerosol for 2012 (and 2011). The calculation is done automatically by the monitor by applying an α/β-compensation technique (see below for more details).

- No calculated artificial beta concentration above the detection limit (i.e. the background signal) was observed.

- 95 percent of the beta concentrations recorded in 2012 were below 0.08 Bq/m^3.

- The histogram recorded for 2012 is rather symmetric; this shows that the automatic compensation technique was good. Note that even if the histogram recorded for 2012 is slightly less symmetric than the one recorded for 2011, the compensation technique can however be generally considered as adequate.

- The values of the histogram 2012 are better centered than those of 2011, thanks to the application of the new mean factor α/β used in the formula of compensation. See below, under "Technical improvement".

- The tail on the right side has to do with the fact that beta concentrations are more difficult to compensate when the alpha concentrations are a little higher than normal. When the alpha concentration decreases quickly, the compensation technique can't follow. Some values are therefore greater than 0.1 Bq/m^3.

Histogram of the artificial beta mean concentration
Jungfraujoch : 2011 & 2012
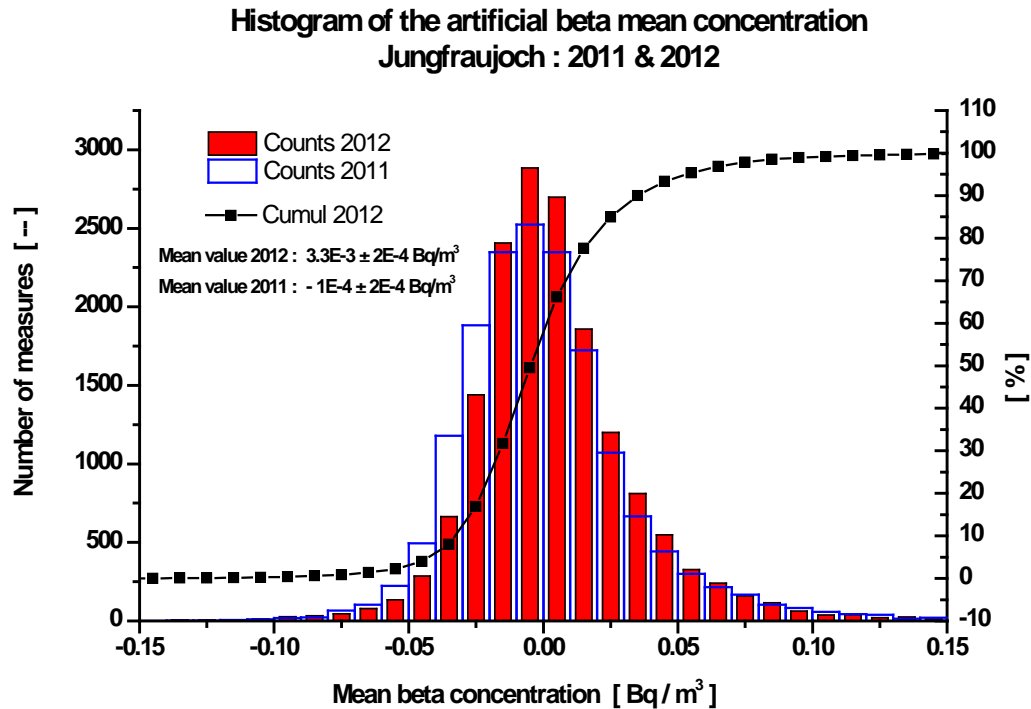
*Figure 4: Histogram of calculated artificial beta concentrations*

For normal situations, i.e. with no artificial radioactivity in the air, the net Beta radioactivity at the Jungfraujoch, calculated using the Alpha-Beta compensation technique, is less than 0.15 Bq/m^3. At the top of Europe, a radiation incident causing an increase of the artificial beta radioactivity in the atmosphere of as low as 0.15 Bq/m^3 could therefore be detected.

Automatic α/β-compensation: this technique applied by our aerosol monitoring stations is based on the simultaneously measurements of gross Alpha (A_g) and gross Beta (B_g) radioactivity of the aerosols collected on a filter. The net (artificial) Beta radioactivity (B_n) is then calculated by the following formula: $B_n = B_g – (A_g / F)$. The constant factor α/β (F) can be adapted either by the software program or by the operator. The factor α/β (F) was periodically adjusted for each monitor in the previous year. This is no longer necessary with the new algorithm, see below.

Technical improvement:
Figure 5 shows how the factor α/β (F) is determined.

We observe that the ratio: [α-Activities / β-Activities] is relatively constant and yields approximately 0.8. On the other hand, we see that the lower the natural α concentration is, the larger is the dispersal. On the right part of the graph, the ratio (A_g/B_g) corresponds to the slope of the curve of the α-Activities depending on β-Activities.
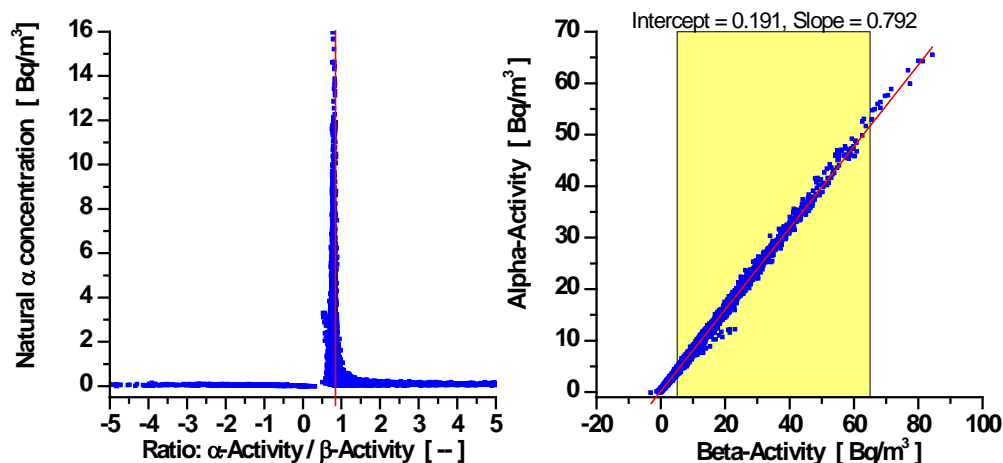
Figure 5: Correlations between:
- *The ratio of α-Activity / β-Activity with the 2012 measurements of natural α concentration. (left)*
- *The α-Activity and β-Activity. (right)*

The idea is to have a factor F which predicts the ratio (A_g/B_g) of the current measurements. With the improved version, the monitor calculates the average of n (n>10) last ratios, as far as this latter is included between threshold values (here 0.6 and 1.2). This mean ratio will give the factor F_m with which the net (artificial) Beta radioactivity (B_n) will be calculated.

This gives a new correction equation: $B_n = B_g - (A_g / F_m)$

Comments on technical aspects (Radair):
In August, the computer of the monitor shut down several times because of the too high temperature of the small room.

In December, the flow decreased strongly after the introduction of snow in the suction line. Subsequently, the monitoring system of the flow opened the bypass until the line was free again (see figure 6).
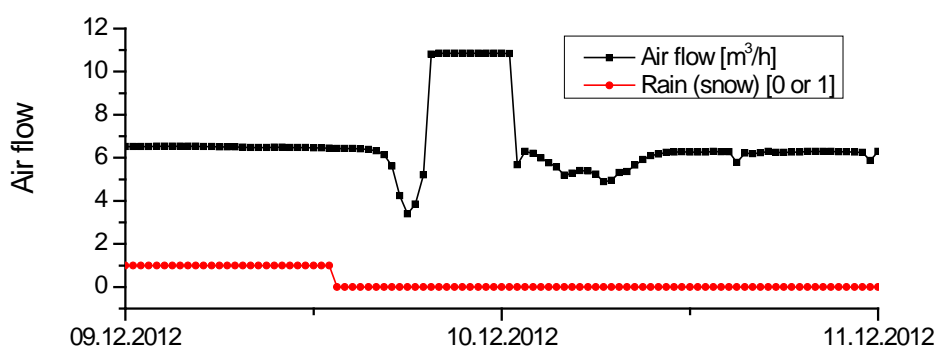
Figure 6:

Except some power cuts and a problem of automatic restart of the computer after a power outage, there was no major breakdown of the aerosol monitor in 2012.

Digitel High-Volume-Sampler: Introduction
The Digitel DHA-80 High Volume Sampler (HVS) is an automatic air sampler with a typical air flow rate 0.6 m^3/min. Aerosols are collected on glass fibre filters of 150 mm in diameter. The pump maintains a constant flow rate independent of dust load on the filter. Filter change intervals are programmed in advance and the sampler is controlled remotely by an internet connection.

The filters are automatically changed once a week and are measured at the end of the month in the laboratory using a coaxial high purity germanium gamma-ray detector during 1-2 days. Thereafter activities of radioactive isotopes are calculated by considering corresponding half-life's and time between sampling and measuring.

^{7}Be and ^{210}Pb are naturally occurring nuclides. ^{7}Be has a cosmogenic origin. Around 70% of ^{7}Be is produced in the stratosphere by spallation of carbon, nitrogen and oxygen. ^{210}Pb is a long-lived decay product of uranium series (^{238}U) which gets into the air from radioactive noble gas ^{222}Rn exhaled from the Earth's Crust [Sykora et al. 2009-2010].

Results
Fig. 7 shows the concentration (μBq/m^3) of ^{7}Be, ^{210}Pb, ^{131}I and ^{137}Cs between 2010 and 2012.

Concentrations of ^{7}Be and ^{210}Pb remained quasi constant. A slight increase of ^{210}Pb during summer can be observed, which is due to convection of ^{210}Pb-rich air masses. ^{7}Be concentration seems to be slightly increased during summer too. This can be related to the tropopause thinning at mid-latitudes resulting in air exchange between stratosphere and troposphere [Sykora et al. 2009-2010].

As a consequence of the nuclear accident of Fukushima in March 2011, filters were measured directly after changing (once a week) in order to detect radioactive isotopes released by the nuclear power plant more quickly. Therefore time between sampling and measuring was significantly smaller than before.

The increased concentration of ^{131}I and ^{137}Cs can be clearly related to the nuclear accident of Fukushima. First increased concentrations were measured by the end of March 2011 and achieved a maximum at the beginning of April. ^{131}I could never be detected at Jungfraujoch before the nuclear accident and haven't been since the end of April 2011. ^{137}Cs is rarely detected before and after March/April 2011.
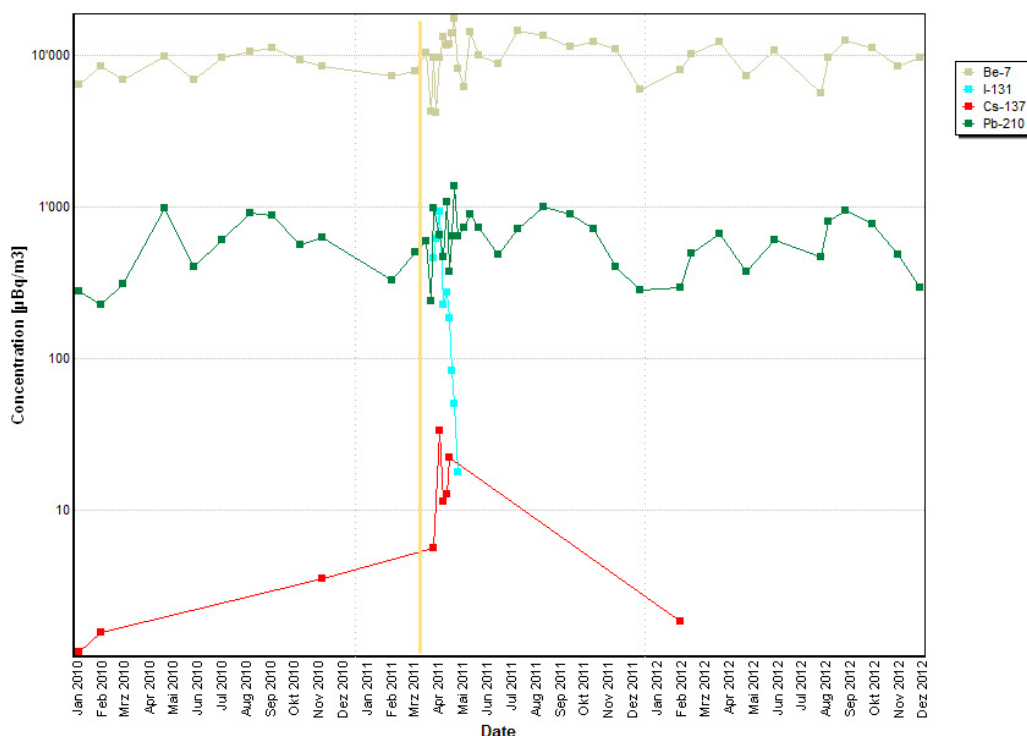
Fig.7*: Concentration (µBq/m³) of ⁷Be, ²¹⁰Pb, ¹³¹I and ¹³⁷Cs between 2010 and 2012, Station Jungfraujoch. The yellow line indicates the date of nuclear accident at the Fukushima Daiichi plant (March 11ᵗʰ 2011).*

Key words:

RADAIR, Digitel, Radon, radioactivity, aerosols, radioisotope

Internet data bases:

http://www.radair.ch

http://www.bag.admin.ch/themen/strahlung/00043/00065/02239/index.html?lang=de

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