Aerosol Radioactivity Monitoring at the Jungfraujoch

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1. Alpha-Beta monitoring using the FHT59S monitor

An automatic aerosol radioactivity monitor FHT59S for the continuous detection of 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 URAnet 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 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 Berne and are analyzed for radioisotopes using HPGe-Gamma-spectrometry.

1.1 Comments on the alpha/beta measurements 2018

Figure 1 shows the natural alpha radioactivity, the calculated artificial beta radioactivity and the moving average of the ratio of total α-activity to total (natural) β-activity for the period January 1 to December 31, 2018.

This figure highlights 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 Mai to October) when thermal air convection is higher than in winter. It is the inverse from what is observed at the lowland sites. During autumn and winter, the Radon daughter products are kept below the Jungfraujoch altitude due to the thermic inversion in the lowlands (see upper part of Figure 1).
- The highest values of artificial beta mean concentration, about 0.3 Bq/m^3, occur during fast increases or decreases of the alpha concentration. This is an artefact due to the delay of the automatic compensation (see below).
- The highest ratios of total β-activity to total α-activity are observed when the (natural) alpha radioactivity concentrations are the lowest.

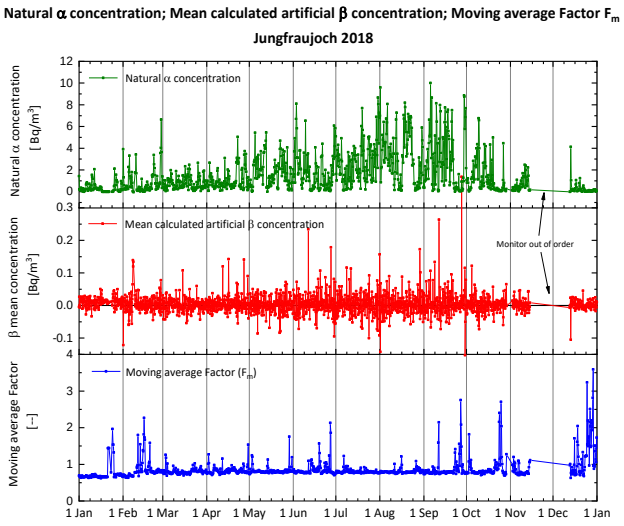

Figure 1. Results of RADAIR measurements in 2018. Top: total (natural) α-activity concentration; mid: calculated artificial β-activity concentration; bottom: moving average of total α to total (natural) β-activity. For a better readability, only 4 points per day are represented.

A zoom of the Figure 1 for September 11 shows the difficulty of the calculation of the artificial β-activity (Figure 2). After periods when the alpha concentration is almost zero, the moving average of the ratio α-activity / β-activity increases (F_m in Figures 1 and 2). As soon as the alpha concentration rises again, the moving average of F_m, used for the calculation of the beta concentration, becomes too high and the calculated artificial beta becomes too high as well.

Moreover, for the period shown in Figure 2, the moving average factor had drifted to values > 2 due to an error in the configuration file. Normally, the allowed ratio total α-activity / natural β-activity (F_m) is constrained to values <1.5.

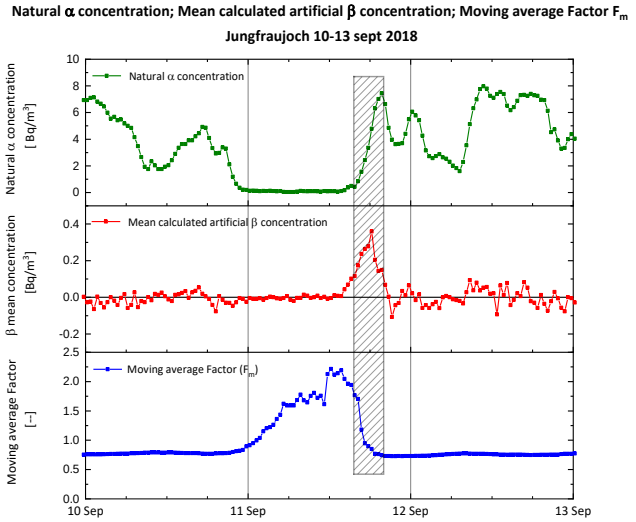

Figure 2. Difficulties of the calculation of artificial betas after period with low alpha concentration on September 11.

We also can observe that the highest total (natural) alpha concentrations are present when the wind blows approximately from a SW direction with wind speeds of 5-10 m/s. (Figure 3).

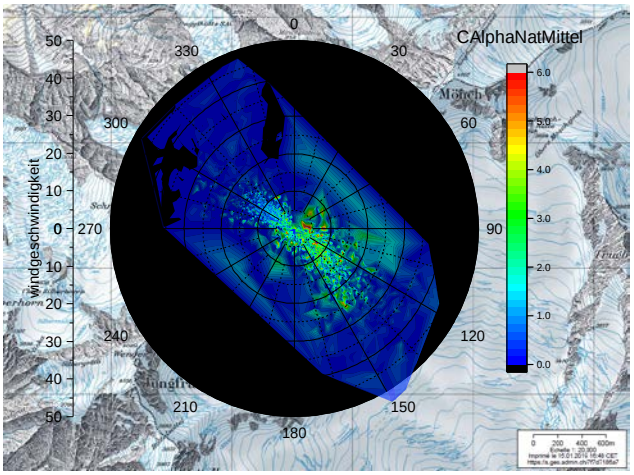

Figure 3. Distribution of (natural) total α concentration as a function of the wind direction.

Figure 4 shows the histogram of the calculated artificial beta radioactivity in aerosol for 2018 (and 2017). 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 2018 were below 0.05 Bq/m³.
- The histogram recorded for 2018 is rather symmetric; this shows that the automatic compensation technique was good.
- Note that some values are greater than 0.15 Bq/m³ (see Figures 1 and 2).

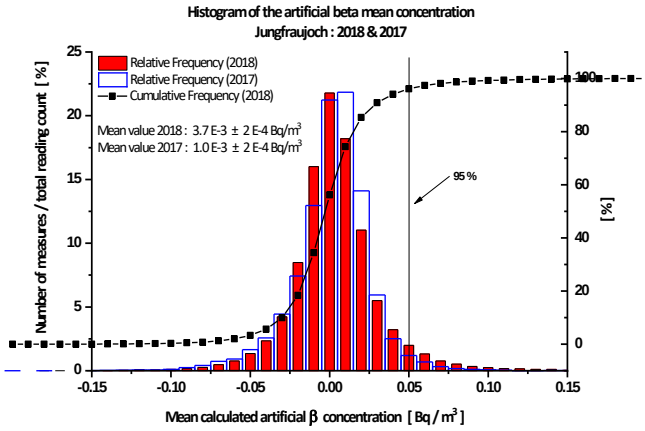

Figure 4. Histogram of calculated artificial beta concentrations.

In most cases, when the alpha concentration increases slowly, the beta concentration may be correctly compensated.

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 0.10 Bq/m³. At the top of Europe, a radiation incident causing an increase of the artificial beta radioactivity in the atmosphere of as low as 0.10 Bq/m³ would therefore be detected within 30 minutes.

1.2 Calculation of the artificial Beta-activity

Automatic α/β-compensation: this technique applied by our aerosol monitoring stations is based on the simultaneous 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 ratio (A_g/B_g) corresponds to the slope of the curve of the α-activities as a function of β-activities. The experience has shown that it is relatively constant and yields approximately 0.75.

With the current version of the software, the monitor calculates the average of the n (n>10) last ratios (A_g/B_g), as long as this latter is included between thresholds values (here 0.6 and 1.5). 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: $B_n = B_g – (A_g / F_m)$

1.3 Comments on technical aspects (RADAIR)

There were less power failures than the previous years. In January, snow entered the suction line and wetted the filter, which subsequently was torn apart and caused a stop of the measurements. In November, despite the heating of the suction line, an ice plug formed in the suction line for several days and the measurements was also interrupted.

2. Digitel Jungfraujoch 2018

2.1 Digitel High-Volume-Sampler: Introduction

The Digitel DHA-80 High Volume Sampler (HVS) is an automatic air sampler with a typical air flow rate of 0.6 m³/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 HPGe gamma-ray detector during 1-2 days. Thereafter, activities of radioactive isotopes are corrected by considering the corresponding half-lifes and the 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.

2.2 Results

Figure 5 shows the concentration (µBq/m^3) of ^{7}Be, ^{210}Pb, ^{131}I and ^{137}Cs between 2011 and 2018.

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 from the Plateau. ^{7}Be concentration seems to be slightly increased during summer, too. This is related to the tropopause thinning at mid-latitudes resulting in air exchange between stratosphere and troposphere.

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 in 2011 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 has not been since the end of April 2011. ^{137}Cs was occasionally detected also before March 2011.

Between Mai and August 2013, the filters were measured once a week in order to better follow possible inputs of stratospheric air over this time period.

Internet data bases

http://www.radair.ch
http://www.radenviro.ch
http://www.bag.admin.ch/ura

Collaborating partners / networks

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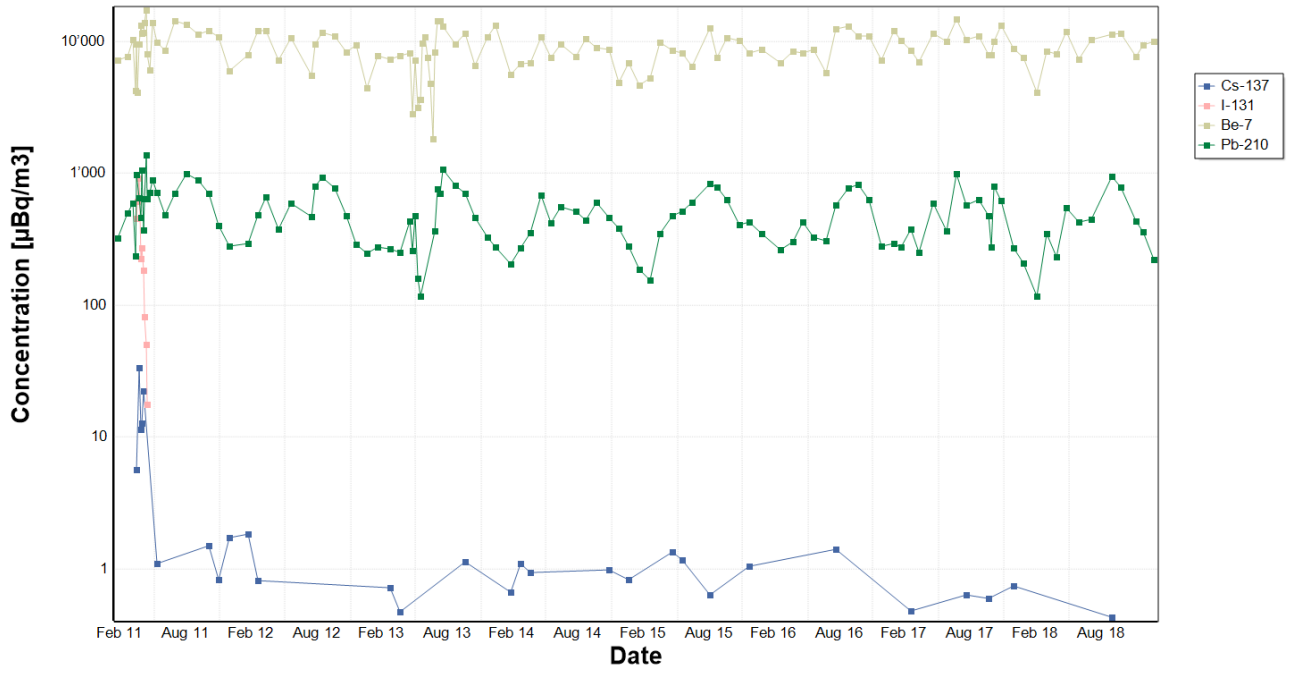

Figure 5. Concentration (µBq/m^3) of ^{7}Be, ^{210}Pb, ^{131}I and ^{137}Cs between 2011 and 2018, Station Jungfraujoch.