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 (FOPH). 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 FOPH-laboratory in Berne and are analysed for radioisotopes using HPGe-Gamma-spectrometry.

1.1 Comments on the alpha/beta measurements 2022

Figure 1 (Jungfraujoch) and Figure 2 (Weissfluhjoch, the second high-altitude station operated by the FOPH, 2685 m a.s.l) show 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, 2022.

This figure highlights that:

- Natural alpha radioactivity, i.e. Radon daughter products (RDP), is mainly transported up to the Jungfraujoch by air masses from the lowlands, since the highest values are usually observed in summer (this year already since April and lasting until 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 RDP from the lowlands are kept below the Jungfraujoch altitude due to the thermic inversion in the lowlands. Another possible contribution to the lower concentrations of RDP for the winter period is that the dominant winds (edges of the Jetstream's) are stronger in winter than during spring to autumn and dilute the RDP concentrations.

  The highest alpha concentration values are observed in May, July and August probably due to the excessive heat of the summer of 2022 causing increased advective transport of ground-level air to the free troposphere (see upper part of Figure 1).

- The highest values of artificial beta mean concentration, about 0.2 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.
- The moving average ration of total α to total (natural) β-activity was reduced from about 8.0 to 0.7 following the change of the detector window and after a calibration.
- These same effects are also observed at the station of the Weissfluhjoch with the alpha concentration reaching values up to 30 Bq/m^3 (Figure 2).

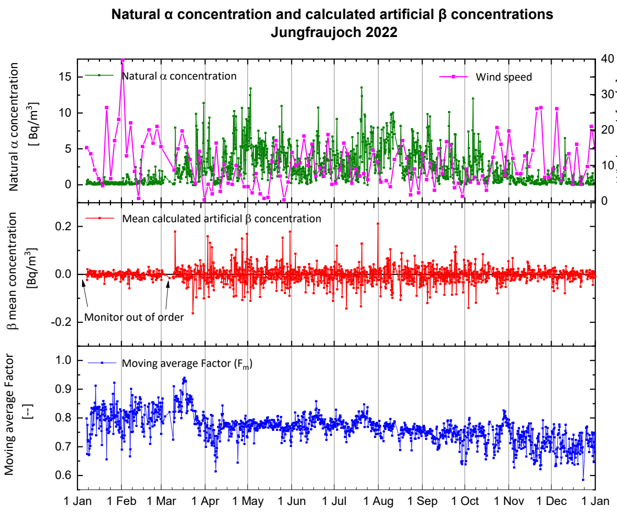

Figure 1. Results of Alpha-Beta monitor (FHT59S) measurements in 2022 at the Jungfraujoch. Top: total (natural) α-activity concentration; mid: calculated artificial β-activity concentration; bottom: moving average ratio of total α to total (natural) β-activity.

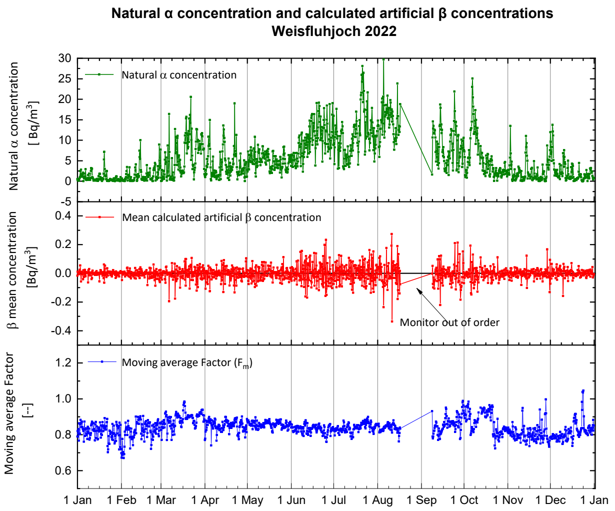

Figure 2. Results of Alpha-Beta monitor (FHT59S) measurements in 2022 at the Weissfluhjoch. Top: total (natural) α-activity concentration; mid: calculated artificial β-activity concentration; bottom: moving average ratio of total α to total (natural) β-activity.

A zoom of the data shown in Figure 1 from April 1 to 16 shows the effect of wind on the natural alpha concentration (Figure 3). Between April 3 and 4, in the absence of wind, the natural alpha concentration increases to 15 Bq/m3. Conversely, between the period April 7 to 12, with a sustained wind, the natural alpha concentration remains close to zero Bq/m³. The figure also shows an aerosol washing effect with the presence of precipitation.

Figure 4 shows that the natural alpha concentrations are dominantly transported to the Jungfraujoch in light to moderate winds and come predominantly from the South-East as well as to a lesser extent from the North-West.

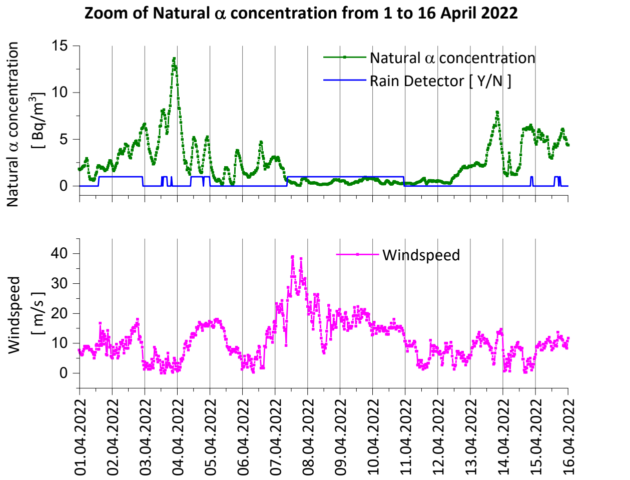

Figure 3. Top: Example of the peaks of the natural α concentration (April 1-16); Bottom: The windspeed at Jungfraujoch and also the precipitation (Yes=higher level/No=lower level) during the same period.

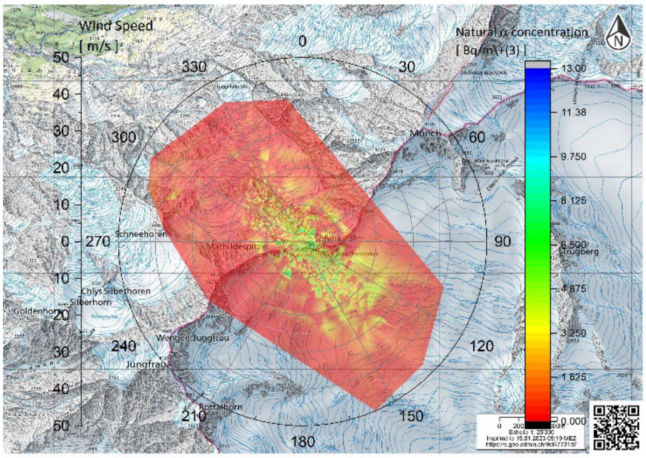

Figure 4. Observed natural Alpha Concentrations as a function of wind speed and direction of winds.

Figure 5 shows the histogram of the calculated artificial beta radioactivity in aerosol for 2022 (and 2021). 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 2022 were below 0.04 Bq/m³.
- The histogram recorded for 2022 is very symmetric; this shows that the automatic compensation technique was very good.
- Note that there are some values greater than 0.10 Bq/m³ (see Figure 1).

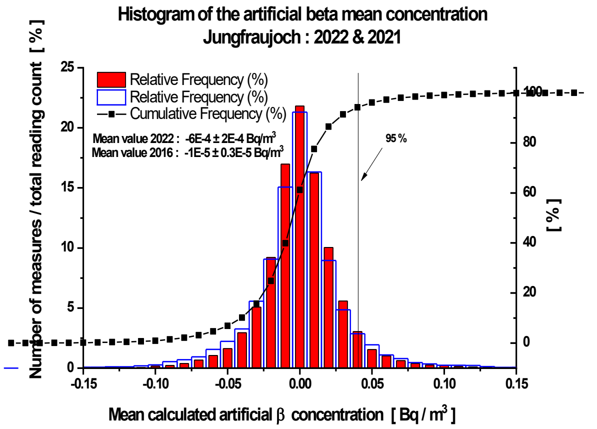

Figure 5. Histogram of calculated artificial beta concentrations at Jungfraujoch 2022.

- In most cases, when the alpha concentration increases slowly, the beta concentration is 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 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 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 (FHT59S):

After the change of the filter transport unit, there were almost no problems with the filter winding and the custodians handled the few filters break well.

The measurement rate is 93%, so very good compared to previous years. Thanks to the custodians for their help ☺

In conclusion, the air is good, so man can continue to eat the fruits of his garden.

2. Digitel Jungfraujoch 2022

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 corresponding half-lives 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.

Results

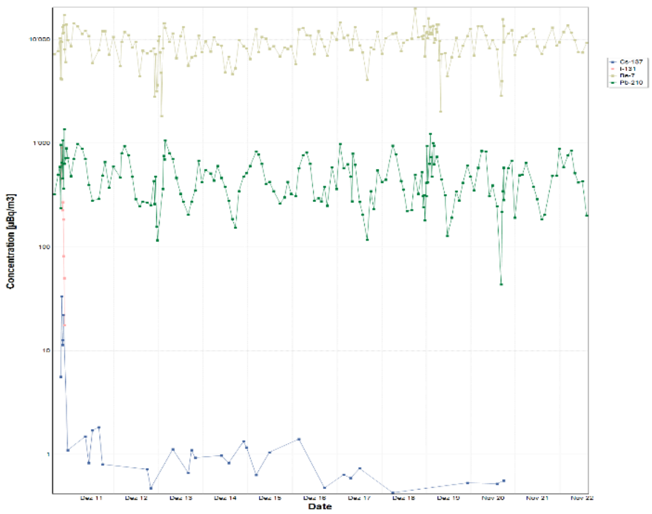

Figure 6. Concentration (µBq/m³) of ^{7}Be, ^{210}Pb, ^{131}I and ^{137}Cs between 2011 and 2022, Station Jungfraujoch.

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 of 2013 and 2019, 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.radenviro.ch

Collaborating partners / networks

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