The radiotracer $^7\text{Be}$ in studying environmental processes

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Production of $^7\text{Be}$

$^7\text{Be}$ is a relatively short-lived ($T_{1/2}=53.3\text{ d}$) naturally occurring radionuclide of cosmogenic origin formed by spallation processes of light atmospheric nuclei, such as carbon, nitrogen and oxygen, when they absorb protons and even neutrons of the secondary component of cosmic radiation.

1. $^{14}\text{N} + ^1\text{n} \rightarrow ^7\text{Be} + ^8\text{Li}$, $Q = -25.7\text{ MeV}$

2. $^{14}\text{N} + ^1\text{p} \rightarrow ^7\text{Be} + 2^4\text{He}$, $Q = -10.4\text{ MeV}$

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>$T_{1/2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^3\text{H}$</td>
<td>12.33 y</td>
</tr>
<tr>
<td>$^7\text{Be}$</td>
<td>53.28 d</td>
</tr>
<tr>
<td>$^{10}\text{Be}$</td>
<td>1.6x10^6 y</td>
</tr>
<tr>
<td>$^{14}\text{C}$</td>
<td>5730 y</td>
</tr>
<tr>
<td>$^{22}\text{Na}$</td>
<td>2.60 y</td>
</tr>
<tr>
<td>$^{26}\text{Al}$</td>
<td>7.3x10^5 y</td>
</tr>
<tr>
<td>$^{32}\text{Si}$</td>
<td>280 y</td>
</tr>
<tr>
<td>$^{32}\text{P}$</td>
<td>14.28 d</td>
</tr>
<tr>
<td>$^{33}\text{P}$</td>
<td>25.3 d</td>
</tr>
<tr>
<td>$^{35}\text{S}$</td>
<td>87.2 d</td>
</tr>
<tr>
<td>$^{36}\text{Cl}$</td>
<td>3.01x10^5 y</td>
</tr>
<tr>
<td>$^{37}\text{Ar}$</td>
<td>34.8 d</td>
</tr>
<tr>
<td>$^{39}\text{Al}$</td>
<td>269 y</td>
</tr>
<tr>
<td>$^{81}\text{Kr}$</td>
<td>2.1x10^5</td>
</tr>
</tbody>
</table>
Production of $^7$Be

- The production features of cosmogenic nuclides depend primarily by **latitude and altitude**.
- $^7$Be is found both in the troposphere and the stratosphere, where the concentration ratio is longer.

- The $^7$Be concentration in the stratosphere is expected to remain stable over time, except for a few changes at a rate $\sim 10\%$, due to changes in the activity of sunspots.

- The main process in which the $^7$Be can penetrate the stratosphere in the troposphere is by mixing them, because of the folding of the tropopause.

The temporal variations of $^7$Be measured near the surface is a potential tracer of the dynamics of the troposphere, the stratosphere – troposphere coupling and the fluctuations in the flow of cosmic rays due to solar activity.
Radioactive aerosols

Once $^7\text{Be}$ is formed in the atmosphere it rapidly associates primarily with submicron-sized aerosol particles (Bondietti et al., 1987) particles and their fate is becoming the fate of their carrier aerosol particles.
Cosmogenic Isotope\(^{7}\)Be

The concentration of beryllium in the atmosphere depends on various weather and atmospheric factors as:

- **temperature** (Azahra M. *et al*, 2003)
- **atmospheric pressure** (Likuku A. S., 2006)
- **relative humidity** (Meresova J., 2008)
- **rainfall** (Al-Azmi D. *et al*, 2001)
- **snowfall** (Ioannidou A. & Papastefanou C., 2006)
- **cloudiness** (Durana L. *et al*, 1996)

\(^{7}\)Be has come to be recognized as a potential tool in studying environmental processes such as

- **aerosol transit and residence times in the troposphere** (Martell, 1970)
- **aerosol deposition velocities** (Young and Silker, 1980)
- **In models of climate changes** (Brost, Feichter)
- **Tropopause folding events**
The tropopause is the atmospheric limit between the troposphere and stratosphere. It does not present the same height everywhere (daily variations).

The stratosphere is found between the troposphere and the mesosphere. Its temperature increases with height due to sunlight absorption by ozone. The tropopause height decreases with an increase of geomagnetic latitude. Near the equatorial region, the tropopause is around 12-17 km, while near the poles, it is approximately 8-9 km.
The temperatures ranged between -70 °C and -80 °C above equatorial and about -55 °C at mid and high latitudes. So, the coldest part of the tropopause exists over the warmer part of the earth’s surface.

The tropopause in the mid latitudes shows discontinuity, so this transition layer is divided into Tropical and Polar Tropopause.

Strong relationship of the tropopause height with temperature.


"If we don’t do it either might or nobody will"
However, the $^7$Be concentration levels in near surface air are not expected to respond immediately to the change of elevation of the tropopause. This time is the “time lag”.

**Time lag**

- Tropopause elevation
-Stronger turbulences of air masses
-Higher concentrations of $^7$Be in surface air
EXPERIMENT - RESULTS

$^7$Be aerosol sampling at 40°N

- 52 weekly samples over the year 2009
- Duration of sampling 24 h
- Glaff Fiber Filters 20”x22”
- 60 cfm air flow rate ~ 1.7 m$^3$/h

60 cfm air sampler, Staplex
Glass Fiber Filter

HpGe Detector 42% efficiency

477.6 keV $^7$Be
Calculations of Tropopause height

The tropopause height was determined through a calculation program. The data needed for the calculation of the tropopause height were downloaded from an American online database, Earth System Research Laboratory (ESRL), where exists a large pool of data regarding meteorological factors such as temperature, air pressure et al.

Sensors are used for the determination of atmospheric factors in carefully selected areas. Based on that information and through a theoretical calculation model it is formed a statistically based world net that manages to cover every length and width of the planet with an extremely small error. Although, there are all the information regarding tropopause it is not listed its height.

After forming a small shell (longitude and latitude) that covers the area of Thessaloniki (40.50° N, 22.90° E) six different variables for each day of 2009 were downloaded. Once all the information needed were gathering calculated the tropopause height through the following equation was calculated:

\[
TropoHeight = \frac{Z_1 + Z_2}{2} \quad 287Temp_{1i} \quad \frac{Pr_{1i}}{Tropres_i} + GH_{1i}
\]

<table>
<thead>
<tr>
<th>Days</th>
<th>Daily Tropopause Height, km</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>100</td>
<td>13</td>
</tr>
<tr>
<td>200</td>
<td>12</td>
</tr>
<tr>
<td>300</td>
<td>11</td>
</tr>
<tr>
<td>400</td>
<td>10</td>
</tr>
</tbody>
</table>

Numbers 1 and 2 refer to the isobaric surfaces (Z) under and above tropopause. The variable (i) runs from 1 to 365 days of 2009. (GH) and (Pr) stand for the geopotential height and pressure of the closest isobaric levels respectively. (Tropotemp) refers to the air temperature at the tropopause plus the temperature at the nearest isobaric surface and the sum is divided by two. Finally, (Tropopres) refers to the air’s pressure at the tropopause levels.
These positive correlations confirm that the increased rate of vertical transport within the troposphere, especially during warmer months, has as a result the descent to the surface layer of air masses enriched in $^{7}\text{Be}$.

However, the atmosphere does not respond immediately to the change of the controlling meteorological factors. So, we are expecting a time lag between these two maximums that might be ranging from hours (highly unlikely) to days or weeks.

The time lag between the elevation of the tropopause and levels of $^{7}\text{Be}$ surface concentration represents the time required for the $^{7}\text{Be}$ concentration levels in the near surface air to respond to the change of the tropopause height.
The correlation coefficient (R) between $^7\text{Be}$ and the tropopause height was successively calculated for different time lags between 0 and 7 days.

For the determination of time lag a matlab program was created in order to calculate the correlation coefficient (corcoef).

The program’s structure goes as follows: The fist column consist of 52 weekly measurements of Beryllium-7 concentrations. This column does not change throughout the process. The second column is constantly changing selecting 52 daily calculations of tropopause heights out of the total 365 calculations of our data pool.

The correlation coefficient is calculated for each new column of daily data of the tropopause height.

The new columns are created by going back in time with a step of one day in order to find how many days we have to wait until the concentration of $^7\text{Be}$ responds to the fluctuations of the tropopause height.

For instance, the first calculation represents Zero Day Lag - each day of $^7\text{Be}$ concentration measurement is matched with the tropopause height calculation of the same day which reflects how well those two factors are interdependent the first 24 hours.

Then, moving one step (day) backwards the program repeats the same process in order to calculate the correlation coefficient matching the 52 stable $^7\text{Be}$ measurements with the 52 tropopause height determinations of the previous day (day lag 1) and so forth.
Calculation of the time lag

Two column of data

52 data of $^7$Be measurements

365 calculations of tropopause height

Program in Matlab for the calculation of the correlation coefficient (corcoef)

Day 0

Stable column of 52 data

Running 52 / 365 data

Correlation coefficient for every step
Correlation Coefficient – Time lag

The max value of corcoef at the third day equal with 0.44.

Plateau: The most striking feature of the data is the four day plateau (including the day of the measurement and the three previous days) revealing persistence in the state of the atmosphere.

In order to test and improve our results and confirm that the correlation depends on the successive waves of air masses of a four day period.

Calculation of Cumulative index

Small value of the calculated coefficient

Haotic behavior of the atmosphere

$^7$Be concentrations are influenced for many parameters

Statistical errors of the computational model
The results improved as the correlation coefficient hits a peak in the first calculation at 0.47 and 0.46 in the second one. This indicates that the time lag is 2 to 3 days as the first calculation refer to the correlation between the $^7$Be concentrations and a 4day average (3 previous days and the day we measured $^7$Be) measurements of tropopause heights.
7Be in Finland

60° N, the correlation is weak.

In Ivalo and Rovaniemi the Rmax were found in the fourth day.
For Kotka the Rmax was found in the first day (0.1751).

influence of air masses from the East has greater influence on 7Be concentrations instead of the tropopause height.

The factors affecting 7Be surface air concentrations in Finland are mainly of atmospheric origin and the observed differences in 7Be concentrations in surface air are mainly caused by the different climate/weather patterns during the time of observations.
Conclusions

- At mid latitudes at 40°N, the $^7$Be concentrations at surface air is expected to correspond within 3 days after the changes of the tropopause height.

- The positive correlation of the mean monthly activity concentration of $^7$Be with the tropopause height and with T (°C), confirms that the increased rate of vertical transport within the troposphere, especially during warmer months, has as a result the descent to the surface layer of air masses enriched in $^7$Be.

- In latitudes above 60°N, the correlation between the height of the tropopause and the $^7$Be concentrations is weak.

- Factors affecting the concentrations of $^7$Be in the surface layer, in Finland, are basically of atmospheric origin.

- Finland: changes in transport mode of air masses mainly related to NAO (North Atlantic Oscillation) has been determined to be the main factor in the variation of surface concentrations of $^7$Be.
Thank you for your attention