Long-term variability of cosmogenic and terrigenous radionuclides observed in the coastal Antarctic troposphere

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1. Background and objective

Fig. 1: Air chemistry observatory at Neumayer Station - updated 2008.

Different to various chemical aerosol components, cosmogenic ^{7}Be or ^{10}Be and terrigenous ^{210}Pb radioisotopes offer relatively well known spatio-temporal source distributions on the global scale. As carried by the sub-micron aerosol fraction these isotopes constitute thus a unique tracer system for studying the meridional long range transport to Antarctica as well as the stratosphere/troposphere air mass exchange.

Aimed at deploying this approach on a climatological time scale, continuous 25 years records of these nuclides we obtained at the coastal Antarctic Neumayer Station (concurrently with chemical aerosol records) are presented.

2. Long-term variability of aerosol-borne radionuclides at Neumayer Station

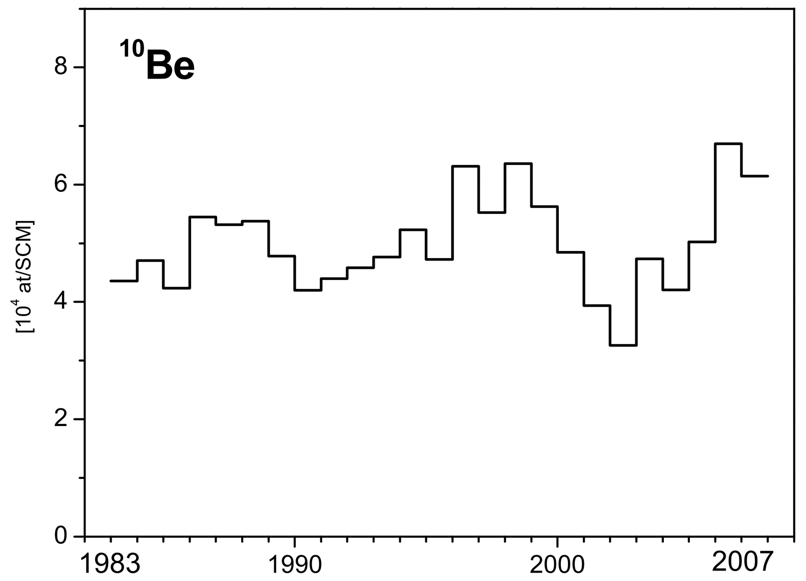

Fig. 3: Yearly means of atmospheric ^{10}Be (commonly analysed in ice cores as well).

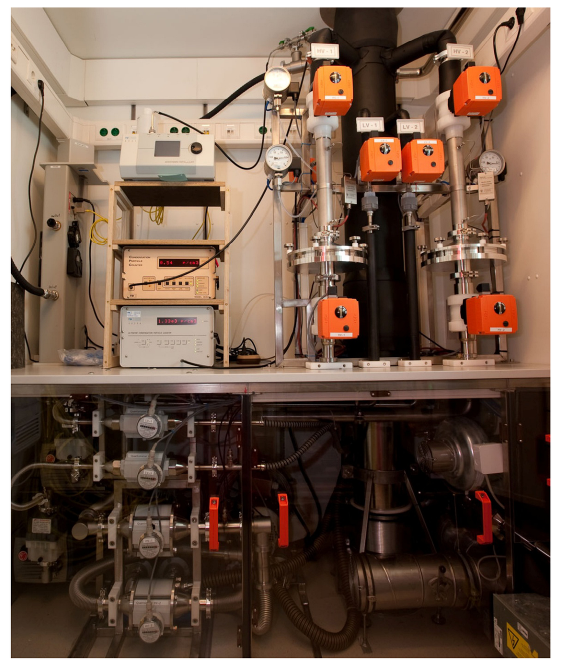

Fig. 2: High-volume aerosol sampling facility of Neumayer Station.

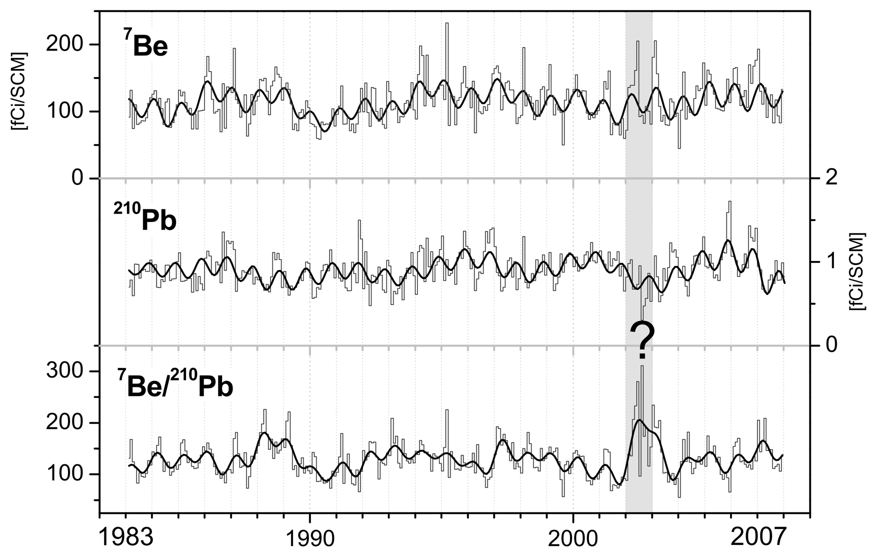

Fig. 4: ^{7}Be, ^{210}Pb and $^{7}Be/^{210}Pb$ time series collapsed into monthly means and highlighted by smoothing. Note the conspicuous anomaly in 2002 and that the $^{7}Be/^{210}Pb$ ratio is expected a surrogate for the stratospheric air mass influence.

3. How do the Neumayer records fit to those from other Antarctic sites?

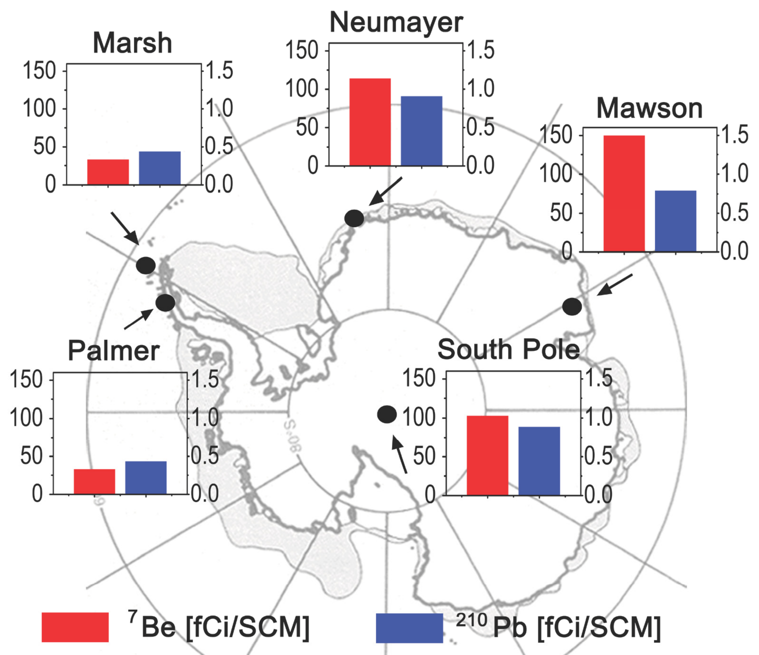

Fig. 5: Overall mean of atmospheric ^{7}Be and ^{210}Pb activities at Neumayer Station compared with those at other Antarctic sites (US-EML data base).

<u>Coastal:</u> Mean activity levels of ^{7}Be and ^{210}Pb at Neumayer are substantial higher compared to the (relatively short) records at the more northward sites.

<u>Inland:</u> Comparison with South Pole, the only other Antarctic site with long-term ^{7}Be and ^{210}Pb records revealed broadly similar mean levels (though partly disturbed by missing S.Pole data) and common multi-annual changes in case of ^{7}Be.

The atmospheric radioisotope data at Neumayer provide the most comprehensive record of such observations in Antarctica over the last 27 years, moreover including up to now the only ^{10}Be atmospheric data.

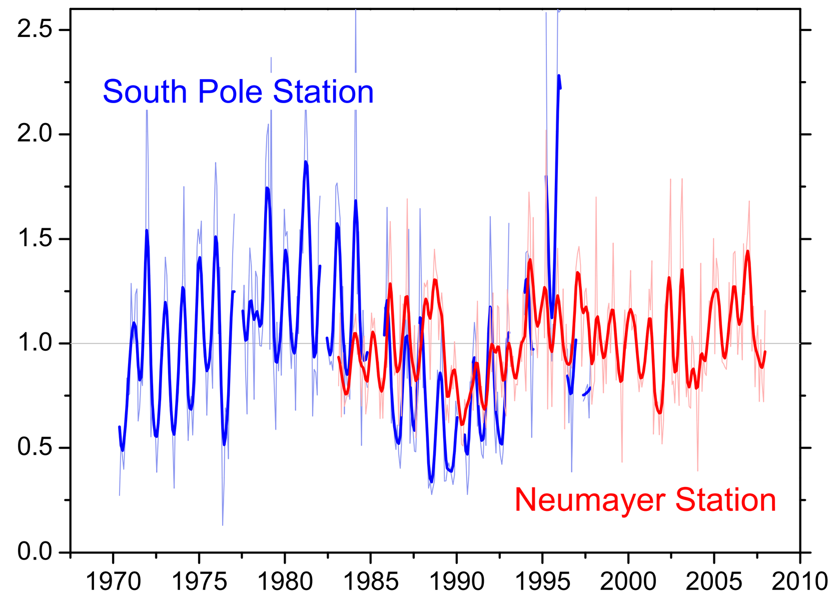

Fig. 6: Comparison of normalized ^{7}Be time series at Neumayer with South Pole Station along with 0.25 years smoothed lines. Note the relatively large scatter at South Pole.

4. Decoding the information by dedicated time series analysis

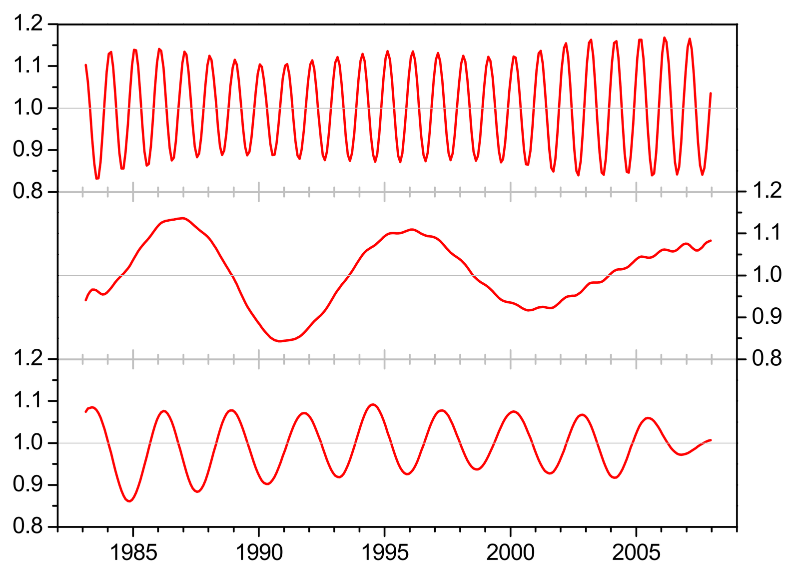

Fig. 7: First three components of a (Monte Carlo) Singular Spectrum Analysis of the ^{7}Be data set. While the seasonal and 10 years signals are clearly significant, the 2-3 years signals one remains ambiguous.

<u>In the ^{7}Be time</u> series Singular Spectrum Analysis (the MultiTaper Method and Wavelet Analysis) points to three major signals:

- → Seasonal cycle
- → ca. 10 years periodicity
- → 2-3 years signal

<u>For ^{210}Pb</u> again the seasonal cycle is evident, but here, on top of a 3-4 years oscillation. The latter is typical for various Antarctic circulation indices though no statistically robust coherence could be found.

Table: Explained variances of different signals detected in the ^{7}Be data of South Pole (Koch and Mann, 1996) and Neumayer Station.

	South Pole Station (Koch and Mann, 1996)	Neumayer Station
Seasonal cycle	27.9%	13%
Decadal cycle	14.3%	11%
2-3 years signal	0.4%	6%

5. Can we identify the main causes for the radioisotope variability?

^{7}Be seasonality: Yes!

Stratosphere- troposphere exchange (STE) indicated by $^{7}Be/^{210}Pb$ and $^{10}Be/^{7}Be$ point to stronger stratospheric impact during Antarctic summer/autumn than during winter/spring.

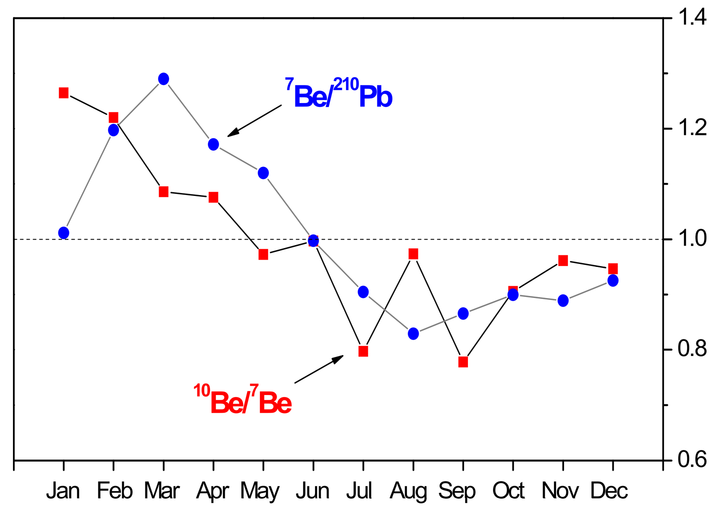

Fig. 8: 25 years averaged seasonal cycles of $^{10}Be/^{7}Be$ and $^{7}Be/^{210}Pb$ established from detrended data.

^{210}Pb seasonality: No!

Relative contribution of source and long range transport changes not clear, yet.

^{7}Be, ^{10}Be decadal cycle: Yes!

- The 9-11 years periodicity seen in the Be-isotope records stongly correlates with (Antarctic) McMurdo neutron monitor data which mainly reflect the change in the cosmic ray flux, modulated by decadal solar activity (sun spot) cycle.
- There is no extraordinary phase lag to the solar activity-driven production change, indicating a merely polar significance of the Be-isotope signal.

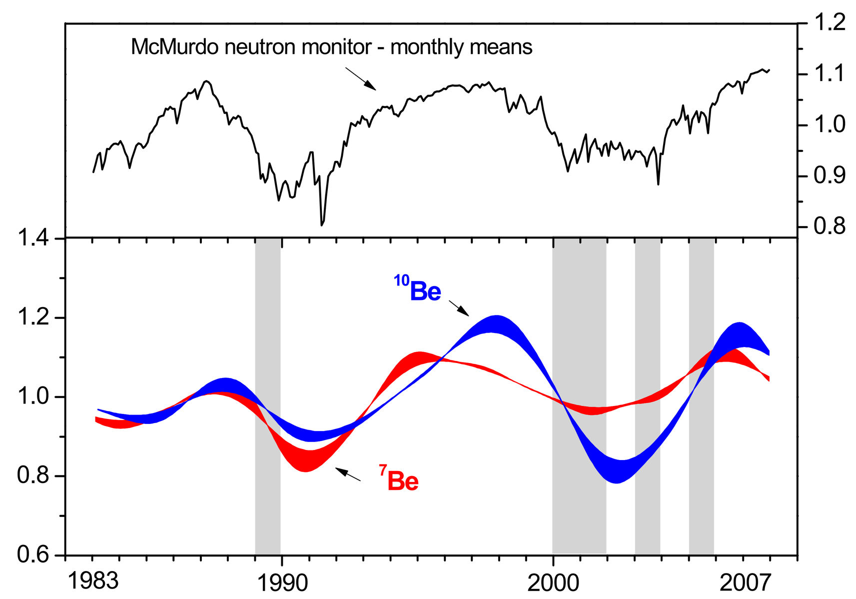

Fig. 9: ^{7}Be and ^{10}Be decadal changes compared to McMurdo Neutron monitor data serving as proxy for the cosmic ray flux variability. In highlighting the decadal signal, the atmospheric data are simply filtered by 2 and 3 years Gaussian smoothing (to respect the diverse time resolution of the isotope records). Note that strong Solar Proton Events periods indicated by grey bars are likely to detract from the common covariance between both radioisotopes.

Interannual oscillations of continental or stratospheric airmasses: No!

There is no local meteorological effect identified that is able to drive the observed interannual changes. This suggests long-range, meridional and large-scale, vertical (cross-tropopause) air mass transport to be the main player in the multi-year variability.

Exemplary modelling attempt

A prima facie approach based on a 28-box global atmospheric transport model (Levin et al., 2010) and on Be-isotope production rates calculated by Usoskin and Kovaltsov (2008) was performed, with the southern hemisphere STE being calibrated by the Neumayer $^{10}Be/^{7}Be$ ratio.

→ Residuals between modeled and observed ^{7}Be variability confirm upper qualitative findings on the seasonality and production signal. Again, a 2-3 years signal remains in residual time series, indicating, among others, a realistic simulation of the seasonal (transport related) and the 11 years solar (source related) cycles.

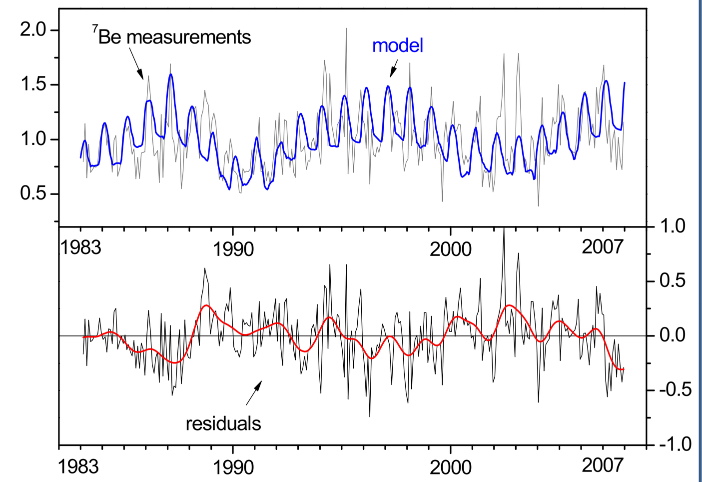

Fig. 10: Model based reconstruction of the recent Antarctic ^{7}Be time series compared to normalized ^{7}Be observations at Neumayer station, along with model-observation residuals highlighted by a 0.5 year smoothing.

References

Koch, D.M., and M.E. Mann (1996), Spatial and temporal variability of 7Be surface concentrations, *Tellus*, 48B, 387-396.

Levin, I., Naegler, T, Kromer, B., Diehl, M., Francey, R.J., Gomez-Pelaez, A.J., Steele, L.P., Wagenbach, D., Weller, R., Worthy, D.E. (2010), Observations and modelling of the global distribution and long-term trend of atmospheric $^{14}CO_2$, *Tellus*, 62B(1), 26-46.

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