Cosmogenic Proxies (COPROX)

Simulations of the Atmospheric Transport and Deposition of Cosmogenic Isotopes as Proxies for Solar Activity and Atmospheric Dynamics

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In Short

- Extracting information from cosmogenic isotopes such as ^{10}Be, ^{7}Be and ^{14}C in natural archives and near ground air
- Production of cosmogenic isotopes from solar proton events and galactic cosmic rays
- Atmospheric tracer transport
- Modeling with a modular climate chemistry model

Within the COPROX project, we model the transport and deposition of cosmogenic isotopes such as Beryllium-10 (^{10}Be), Beryllium-7 (^{7}Be) and Carbon-14 (^{14}C) produced by galactic cosmic rays (GCR) as well as solar proton events (SPE). After their production and transport the isotopes are deposited in natural archives e.g. ice cores or tree rings (see e.g. [4, 5]) or can be detected within near ground air. The concentration of cosmogenic isotopes within these archives varies on multiple time-scales and depends on the production rate. The aim of the project is to simulate and reproduce the data and pathways and extract information about solar and atmospheric activities from cosmogenic isotopes as proxies e.g. to explore the mass exchange between the stratosphere and troposphere and investigate the role of the seasonality, simulate the impact of man-made climate change on the transport and deposition of the isotopes, look at the impact of solar variations and improve the forecast of large scale weather systems such as monsoon [3, 1, 2]. The model simulations are performed with the climate chemistry (CCM) EMAC (ECHAM/MESSy Atmospheric Chemistry). EMAC is based on the ECHAM5 general circulation model (GCM) developed at the MPI for Meteorology, originally derived from the weather forecast model of the ECMWF ("European Centre for Medium-range Weather Forecasts"), and has been extended to a modular CCM at the MPI for Chemistry allowing the implementation of multi-institutional codes via the MESSy ("Modular Earth Submodel System") interface [6]. EMAC is specifically qualified for the goals of COPROX because it allows the description of the dynamics and chemistry of the stratosphere and troposphere coupled to the ocean system as well as the impact of solar variations on the Earth system.

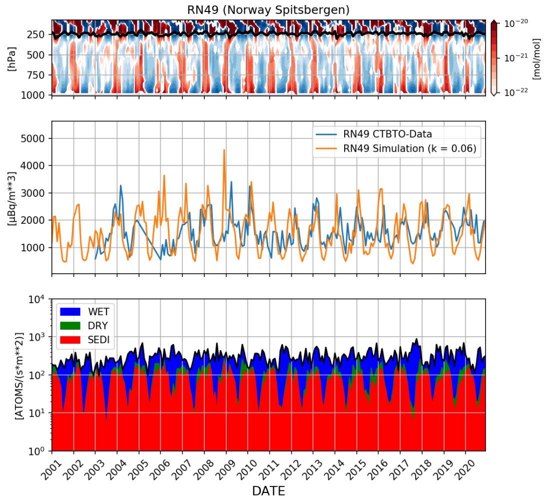

Figure 1: *Comparison of results of transient simulations for the near ground concentration of ^{7}Be with empirical data from CTBTO radio nuclide monitoring network station RN49 in Norway Spitsbergen. Top: Simulated tracer concentration over height and time. Middle: Comparison between the measured and simulated near ground concentration of ^{7}Be. The factor k is the factor required to scale the mean of the simulation result to the mean of the empirical data. Bottom: Simulated deposition separated by deposition mechanisms sedimentation (red), dry deposition (green) and wet deposition (blue) over time.*

Within in the last project period, we focused on e.g., on the following two different aspects of our COPROX project. 1) Transient simulations of ^{7}Be from GCR for the time period 1850 to 2100 under the shared socio-economic pathway (SSP) scenario 3.7. The results of the simulations are e.g., compared to data for the surface air concentration of ^{7}Be from the CTBTO radionuclide monitoring network for 2000 to 2020, with over 70 stations distributed all over the globe. 2) Further investigations on the atmospheric transport and deposition of ^{10}Be from GCR, with a specific focus on the conditions for detectability of SPE with GCR background under preindustrial conditions.

Results of our transient simulations are shown in Figure 1. The middle panel shows the direct comparison of the simulation output and measured data on ^{7}Be from Norway Spitsbergen. Qualitatively the simulation results and the data match quite well, because the amplitude of the seasonal variability is comparable after scaling and the variability of GCR production due to the variability of the solar Schwabe cycle is captured well. This is also given for many of the other CTBTO stations. However to improve the

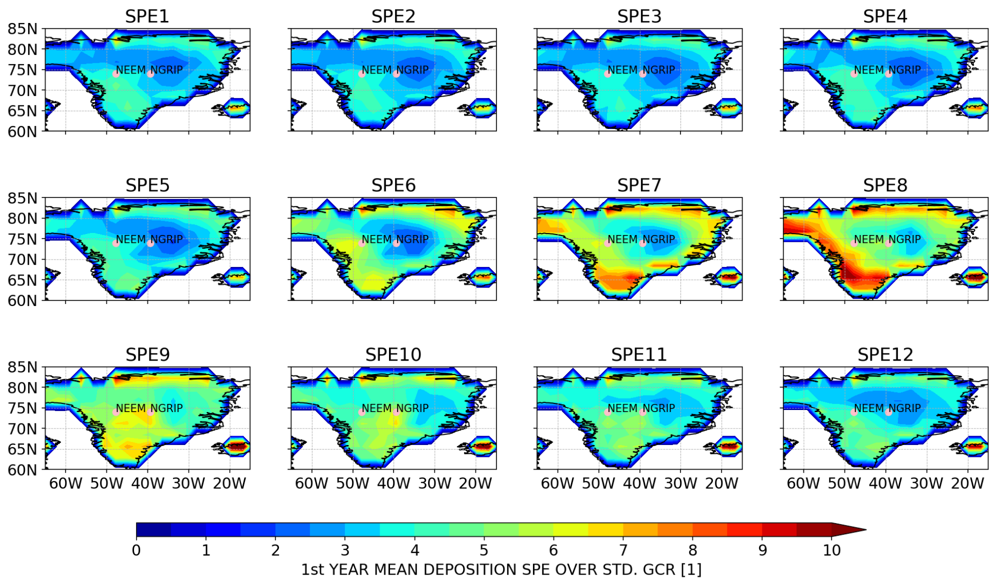

Figure 2: *Mean deposition of ^{10}Be from SPE in units of the standard deviation of ^{10}Be from GCR for Greenland. The title SPE1...12 marks the month in which the SPE was initialized. The pink dots mark the ice core drilling sites NEEM and NGRIP.*

quantitative results of our simulations and also evaluate the impact of climate change on the transport and deposition of ^{7}Be, further investigations are required. The first results of our simulations have been presented at the CTBTO science and technology conference 2023 (SnT2023) in Vienna.

Figure 2 is a result from our investigations on ^{10}Be. It shows the distribution of the deposition of ^{10}Be produced by a SPE in Greenland, initialized at different months from January (SPE1) to December (SPE12) within the first year of initialization relative to the amount of ^{10}Be from GCR that was deposited within that period. If this inverse coefficient of variance type of measure exceeds a certain threshold, which is e.g., typically around 3 for ice core data, the chances are high to detect the SPE within the respective data. Figure **??** indicates, that the detectability of SPE in Greenland is in general a bit better at NEEM than at NGRIP, but changes e.g. for SPE that occur in September (SPE9) and is generally influenced by multiple factors, such as the respective phase of the solar Schwabe cycle, the atmospheric conditions the SPE meets and the local synoptic dynamics. These results can help to e.g., identify unknown SPE, select suitable drilling sites for ice cores as well as improve the general understanding of SPE and ice core data. The results will be published in an upcoming publication.

WWW

https://www.geo.fu-berlin.de/met/index.html

More Information

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DFG Subject Area

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