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Extension of volcanic forcing data back to 100 BC using the Analog method

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Present reconstructions of volcanic forcing to be used for climate simulations so far extend back until 500 AD for stratospheric aerosol sulphate injection (Gao et al., 2008), and back until 800 AD for aerosol optical depth and effective radius (Crowley et al. 2012; ICI5 data set). Here, we aim to extent the volcanic data set of Crowley et al. (2012) back to 100 BC. This data sets originally starts in 800 AD, for aerosol optical depth and effective radius. The method we apply is the Analog method, using information in the already existing reconstruction and extending it back in time by using information of long volcanic sulphate contained in Greenland and Antarctic Ice cores published in previous studies.

The reconstruction of the volcanic forcing in first millennium is based on the search of analogs in the second millennium. The pool of analogs includes the ICI5 data set for the period 800–2000 AD. The basic philosophy is to find volcanic events with the same or similar magnitude in terms of volcanic sulphate deposition in Greenland and Antarctic ice cores. For the Northern Hemisphere the estimated maximum total stratospheric sulphate loading from Zielinski (1995) is used. For the Southern Hemisphere the Plummer et al. (2012) data set and the Ferris et al. (2011) data set are used in terms of sulphate deposition. To ensure that the volcanic event was large enough in magnitude, a certain threshold is applied to the analog selection. The extension, i.e. the analog search, is carried out separately for the four different latitudinal bands of the ICI5 data set. The method can be applied when better records than the Zielinski et al. (1995), record for the Northern Hemisphere become available.

The analogs are selected based on the comparison between the information contained in the ice cores in the pre-800 AD period and post-800 AD period. For each event in the pre-800 AD period (the target), the most similar event (the analog) in the post-800 AD pool in terms of ice-core sulphate is identified. The forcing data (effective radius and aerosol optical depth) of the ICI5 data set for that analog event is then used as a surrogate for the target event. In the case that the analog does not exactly match the amplitude of the pre-800 AD event a scaling correction factor is applied, taking into account the relative difference of ice-core sulphate between the analog and the target.

Although the method does not take into account the specific structure of each volcanic event, the basic patterns are reproduced reasonably well for a validation period in the second millennium AD. The largest uncertainties relate to the dating of each volcanic event, including the season of the eruption, the synchronization of hemispheric versus global eruptions and the translation of the ice core volcanic sulphate concentrations into stratospheric aerosol loadings. However, these uncertainties will essentially remain using different methods based on the sulphate information contained in Antarctic and Greenland ice cores.