Abstract

Volcanic eruptions are an important natural cause of climate variations. The climate response to explosive volcanic eruptions has been studied extensively on a hemispherical and global scale within the instrumental period. A new compilation of 500 year spatio-temporal highly resolved reconstructions, recently developed for Europe, offers extended insight into the impact of major volcanic eruptions on a continental scale. The reconstructions include monthly temperature and precipitation fields (seasonal before 1658) over the European land areas as well as sea level pressure and 500 hPa geopotential height fields over the North Atlantic / European region. These reconstructed fields are used to precisely investigate the seasonal climate response to major volcanic eruptions on a regional scale.

I calculated seasonal anomalies of European climate following selected major volcanic eruptions over the last centuries. Composite analysis is performed to identify the mean climate response to large volcanic eruptions. Statistical significance of the anomalies is established at every grid point using the non-parametric Mann-Whitney test and a Monte Carlo resampling procedure.

The composite temperature field for the first and second summer after an eruption reveals cooling in most parts of Europe, with a significant maximum during the second post-eruption summer. The negative temperature anomalies are found to be most pronounced over southern Scandinavia and the Baltic. The cooling is suggested to be caused by radiative forcing due to scattering of stratospheric aerosols. The mean winter temperature pattern in the two years following tropical eruptions is dominated by a strong warming, in particular over Northern Europe (more than +2°C), and somewhat cooler conditions over the eastern and western Mediterranean. These findings are consistent with previous observational and GCM studies. Furthermore, they provide more evidence on the spatial distribution of the post-eruption temperature anomalies.

The winter warming is associated by a SLP pattern resembling a strong positive NAO mode. The composite NAO index, reconstructed over the past five centuries, revealed to be significantly positive during the second winter following the selected volcanic eruptions. The geopotential height field shows similar centres of negative and positive anomalies indicat-

ing a strong north-south pressure gradient over Europe. This gradient leads to enhanced geostrophic west winds, which are suggested to transport warm and moist air to the areas of maximum winter warming. The composite precipitation field during winter shows positive precipitation anomalies over the British Isles and Scandinavian west coast and drier conditions over the Eastern Mediterranean.

Finally, the results suggest a reversal of the primary response of the winter NAO index and summer and winter temperature to opposite conditions in the third, fourth or fifth year. This finding is independent from previous analyses on the European volcanic signal. A similar post-eruption alteration has recently been detected in the ENSO.

The results reveal a large potential of the composite analysis of climate reconstructions to identify the volcanic effects on climate. Combined with model simulations the method would provide optimal skills for an integrated understanding of volcanic effects on climate at the continental scale.