Equatorward dispersion of a high-latitude volcanic plume and its relation to the Asian summer monsoon: a case study of the Sarychev eruption in 2009

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Tropical volcanic eruptions have been widely studied for their significant contribution to stratospheric aerosol loading and global climate impacts, but the impact of high-latitude volcanic eruptions on the stratospheric aerosol layer is not clear and the pathway of transporting aerosol from high latitudes to the tropical stratosphere is not well understood. In this work, we focus on the high-lat. volcano Sarychev (48.1° N, 153.2° E), which erupted in June 2009, and the influence of the Asian summer monsoon (ASM) on the equatorward dispersion of the volcanic plume. First, the sulfur dioxide (SO2) emission time series and plume height of the Sarychev eruption are estimated with SO2 observations of the Atmospheric Infrared Sounder (AIRS) and abackward trajectory approach using the Lagrangian particle dispersion model Massive–Parallel Trajectory Calculations (MPTRAC). Then, the transport and dispersion of the plume are simulated using the derived SO2 emission time series. The transport simulations are compared with SO2 observations from AIRS and validated with aerosol observations from the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS). The MPTRAC simulations show that about 4% of the sulfur emissions were transported to the tropical stratosphere within 50 days after the beginning of the eruption, and the plume dispersed towards the tropical tropopause layer (TTL) through isentropic transport above the subtropical jet. The MPTRAC simulations and MIPAS aerosol data both show that between the potential temperature levels of 360 and 400 K, the equatorward transport was primarily driven by anticyclonic Rossby wave breaking enhanced by the ASM in boreal summer. The volcanic plume was entrained along the anticyclone flows and reached the TTL as it was transported southwestwards into the deep tropics downstream of the anticyclone. Further, the ASM anticyclone influenced the pathway of aerosols by isolating an "aerosol hole" inside of the ASM, which was surrounded by aerosol-rich air outside. This transport barrier was best indicated using the potential vorticity gradient approach. Long-term MIPAS aerosol detections show that after entering the TTL, aerosol from the Sarychev eruption remained in the tropical stratosphere for about 10 months and ascended slowly. The ascent speed agreed well with the ascent speed of the water vapor tape recorder. Furthermore, a hypothetical MPTRAC simulation for a wintertime eruption was carried out. It is shown that under winter atmospheric circulations, the equatorward transport of the plume would be suppressed by the strong subtropical jet and weak wave breaking events. In this hypothetical scenario, a high-latitude volcanic eruption would not be able to contribute to the tropical stratospheric aerosol layer.

Key words: Asian summer monsoon, volcanic aerosol, Lagrangian particle dispersion model, inverse modeling