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Stratospheric aerosol enhancements from the Nabro eruption in 2011: an investigation of possible transport pathways using trajectory ensembles

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Based on OSIRIS satellite observations, Bourassa et al. (2012) suggested that the June 2011 eruption of the Nabro volcano had the strongest impact on stratospheric aerosol since Pinatubo. Based on a reported visible plume height of 13 km, they claimed that no direct stratospheric injection of ash, sulfate and SO_2 occurred, and that volcanic material was transported to the stratosphere exclusively via the Asian summer monsoon anticyclone. In contrast, Sawamura et al. (2012) and Vernier et al. (2012) present undisputable evidence for a direct injection contribution using back trajectory calculations from ground based lidar and space-borne CALIOP observations within the first few days after the eruption.

To assess which pathway – direct injection (DI) or uplift via the Asian monsoon (AMU) – dominated transport of Nabro sulfur and aerosol to the stratosphere, we use a trajectory ensemble approach. Forward trajectories were started from Nabro at the time of eruption, and the distribution of air parcels in the stratosphere was monitored separately for trajectories initial-ized in the stratosphere (corresponding to DI) and in the troposphere (some of which reaching the stratosphere by AMU). While the path of a single trajectory tends to become rather uncertain after several days, the ensemble approach allows for a statistical analysis where random errors are expected to average out.

During the first week after the eruption, only DI air parcels are found in the stratosphere, in agreement with satellite observations of SO_2 (MIPAS) and aerosols (MIPAS, CALIOP). About a week after the eruption, the first trajectories initialized in the troposphere reach the stratosphere inside the Asian monsoon anticyclone. By the end of July, the pattern of the AMU air parcels resembles the observed distribution of stratospheric aerosol much more closely than the pattern of the DI air parcels does.

The simulations further show that some of the air parcels that entered the stratospheric part of the TTL rise further when upwelling intensifies with the onset of boreal winter. The observation of stronger aerosol signatures in MIPAS spectra for tangent altitudes above 20 km in the tropics in winter 2011/12 compared to other years suggests that aerosol originating from Nabro may enter the upper branch of the BD-circulation.

This study has implications beyond revealing the transport pathway of a stratospheric aerosol plume from the Nabro volcano. Because the aerosol signal is readily picked up by satellites, it represents an ideal case study to investigate the efficiency of the Asian monsoon as a transport pathway to the stratosphere in general, e.g. for anthropogenic SO_2 and other pollutants.

Bourassa, A. E., et al.: Large Volcanic Aerosol Load in the Stratosphere Linked to Asian Monsoon Transport, Science, 337, 78-81, 2012.

Sawamura, P., et al.: Stratospheric AOD after the 2011 eruption of Nabro volcano measured by lidars over the Northern Hemisphere, Environ. Res. Lett., 7, 2012.

Vernier, J.-P., et al.: Comment on "Large volcanic aerosol load in the stratosphere linked to Asian Monsoon Transport" by Bourassa and co-authors. Accepted for publication Science (December 2012).