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Supplementary Material for

Large Volcanic Aerosol Load in the Stratosphere Linked to Asian Monsoon Transport

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Figs. S1 to S4

Supporting Online Material for “Large Volcanic Aerosol Load in the Stratosphere Linked to Asian Monsoon Transport”, Adam E. Bourassa, Alan Robock, William J. Randel, Terry Deshler, Landon A. Rieger, Nicholas D. Lloyd, E.J. (Ted) Llewellyn, and Douglas A. Degenstein

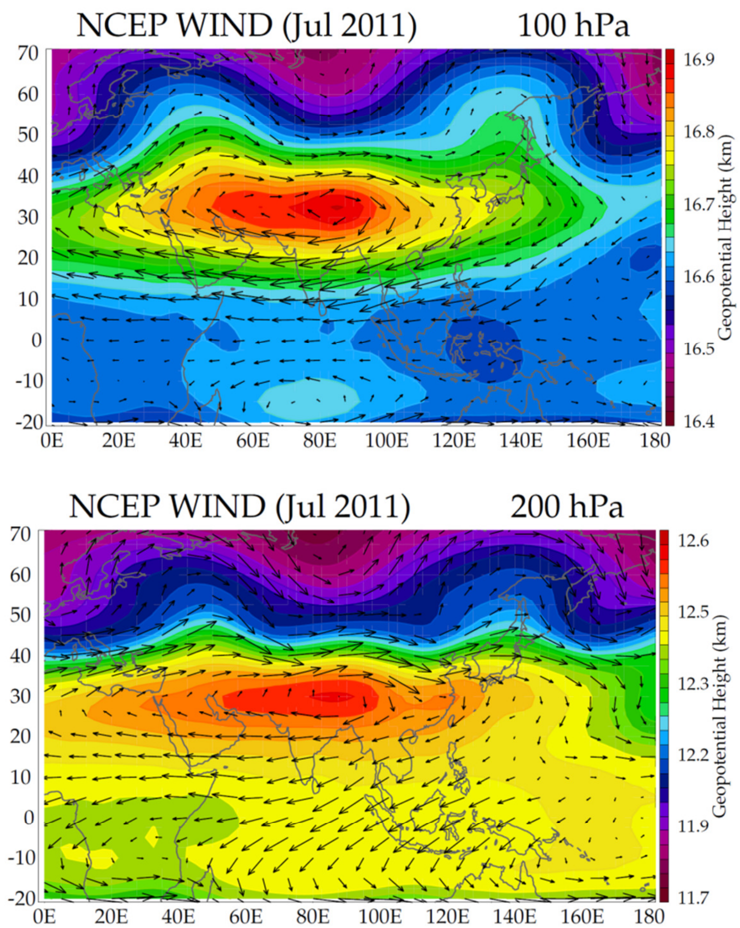

Fig S1. A vector plot of the average zonal and meridional NCEP winds and contours of geopotential height at 100 hPa (top) and 200 hPa (bottom) for July 2011.

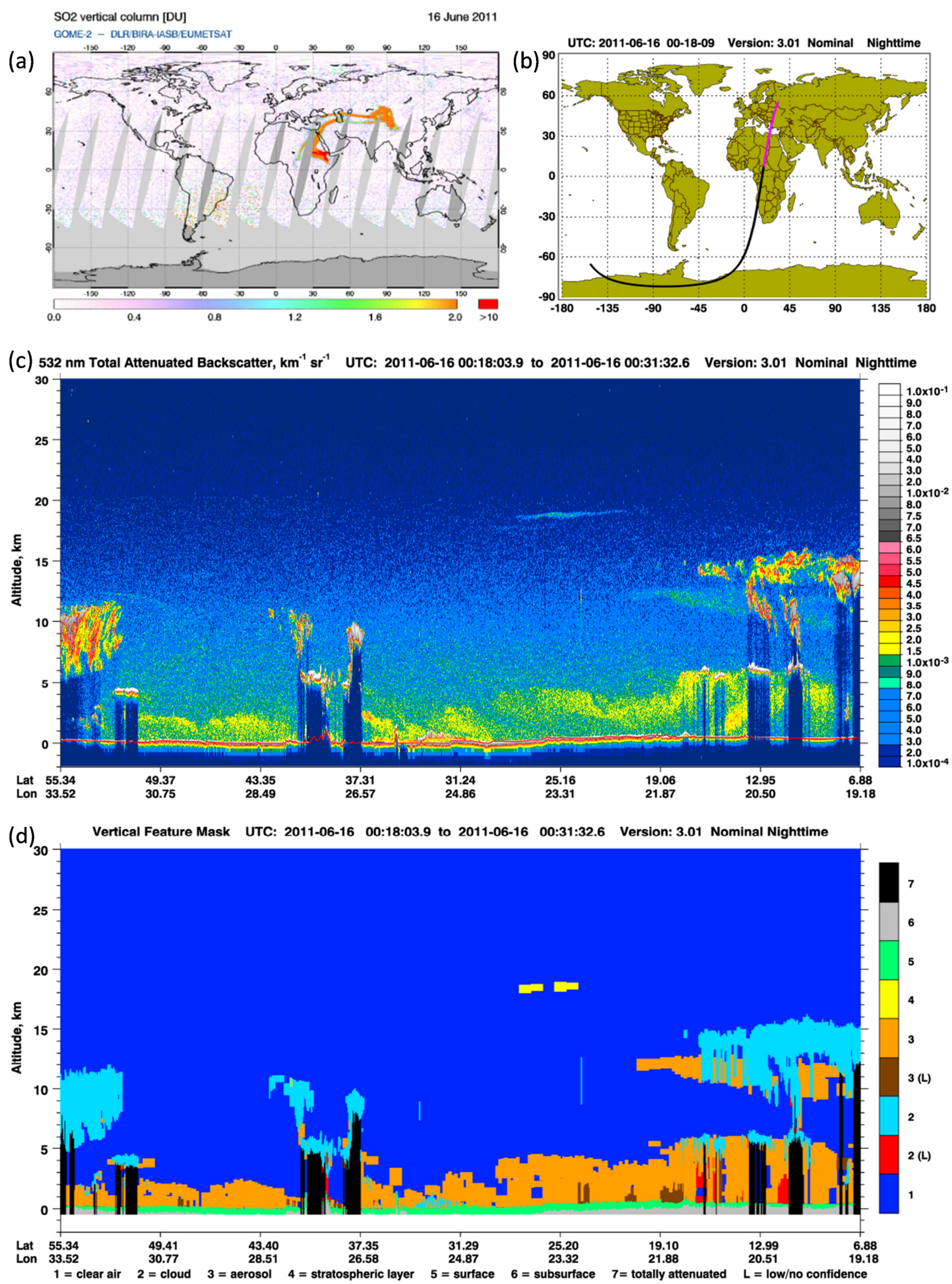

Fig S2. (a) GOME 2 total column SO_2 measurements from June 16, three days after the Nabro eruption. After initially traveling northwest, the eruption plume was transported eastward to the region of the monsoon anticyclone. This correlates well with the wind directions at 13.5 km (200 hPa) shown in Fig. S1. (b) A segment of a CALIPSO orbit track from the same day; the pink segment corresponds to the orbit track of the measurements in (c) and (d). (c) CALIPSO backscatter measurements. (d) CALIPSO vertical feature mask. The bulk of the Nabro aerosol indicated in orange appears south of 20^o N latitude and between 10 and 13 km altitude. A small stratospheric layer also appears at approximately 19 km. GOME 2 observations from Support to Avian Control Service, Belgian Institute for Space Aeronomy. CALIPSO observations from CALIPSO Lidar Browse Images Production, National Aeronautics and Space Administration.

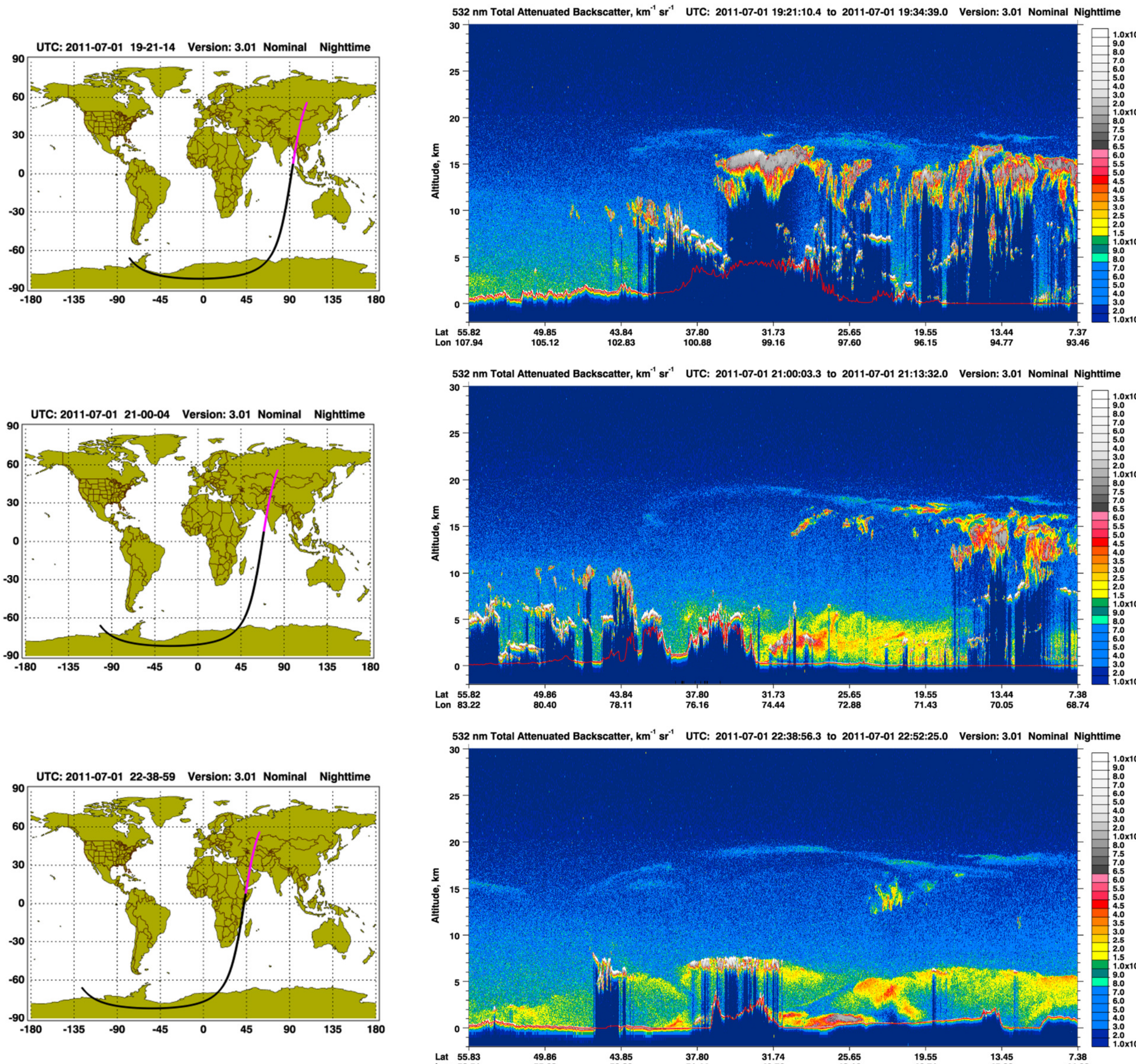

Fig. S3. CALIPSO measurement from orbit segments on July 1, 18 days after the eruption. These locations, marked by the pink orbit track in the left column of figures, correspond to the enhanced regions of stratospheric aerosol initially observed by OSIRIS on this day (see Fig. 3). Deep convection is evident, marked by high altitude cloud layers up to 17 km altitude. Extended stratospheric aerosol layers are observed reaching altitudes of approximately 20 km. CALIPSO observations from CALIPSO Lidar Browse Images Production, National Aeronautics and Space Administration.

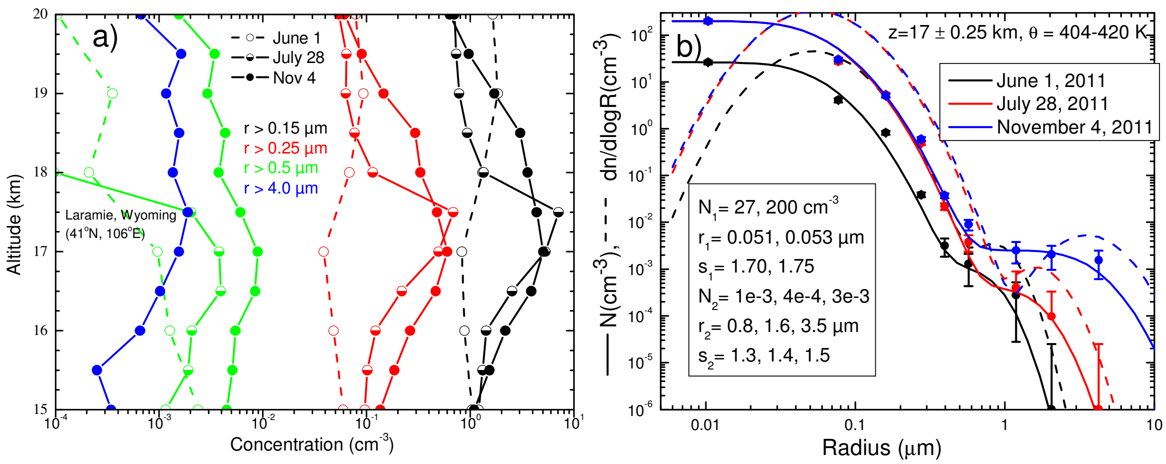

Fig. S4: a) One half kilometer averages of aerosol concentration, above Laramie, Wyoming, for June 1, July 28, and November 4, 2011, for aerosol with radii > 0.15, 0.25, 0.5 and 4.0 µm. Tropopause heights were 13, 15, and 11 km for June 1, July 28, and November 4. Particles as large as 4.0 µm were not observed on June 1 and July 28. b) Bimodal lognormal size distributions at 17 ± 0.25 km from the three profiles. Parameters of the size distributions are shown in the legend. In July the layer is fairly narrow around 420 K, 17 km, with the effects limited to the concentration of particles < 1.0 µm. By November the layer has broadened, extending to 20 km, with significant concentrations of particles > 0.5 um and up to 4.0 µm. The large particles in November are assumed to be volcanic ash. Purely sulfuric acid aerosol would not be expected to grow to such large sizes in 140 days. These large particles further support the importance of the Asian monsoon as a pathway to the stratosphere, lifting both gases and particles. Such concentrations of large particles would not have been missed in the very early observations of Nabro if the eruption had directly penetrated into the stratosphere.