Atmos. Chem. Phys. Discuss., 13, C12767–C12773, 2014
www.atmos-chem-phys-discuss.net/13/C12767/2014/

Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Dispersion of the Nabro volcanic plume and its relation to the Asian summer monsoon" *by* T. D. Fairlie et al.

T. D. Fairlie et al.

t.d.fairlie@nasa.gov

Received and published: 7 March 2014

Response to referees

We thank the two referees for their comments on our manuscript.

Referee 1: M. von Hobe

Thanks to Dr. von Hobe for his introductory remarks.

Response to Minor Comments:

A) Entrainment in the Asian anticyclone

We use "entrained by" simply to mean drawn into the anticyclonic flow. We consider

material that is "entrained" can later be "detrained," and go on to describe detrainment pathways across the Northern Pacific and tropical Atlantic, leading to hemispheric dispersion of the plume (p. 33179). Nevertheless, the referee makes a good point. The stratospheric component of the plume, at least, lies beyond the strong PV gradient that serves as a barrier to transport on the upper and northern flanks of the anticyclone. "Containment" is a poor choice in this context, and we will remove it in the final version. To explore the reviewer's idea further, we extended our source simulation out to 8 weeks. We found that parcels initialized between 360 and 380K were more likely to remain in the region of the Asian anticyclone [10-50oN, 0-120oE] than those initialized between 380 and 390K (30% vs. 12% after 8 weeks).

We will make the appropriate changes to the text. i.e. "The volcanic plume was initially entrained by the flow surrounding the Asian anticyclone . . .. . ." and we will remove the sentence with "containment."

B) Magnitude of radiative forcing

We use the term "relatively small" in the context of large eruptions such as Mt. Pinatubo in 1991, as stated in the abstract and on page 33191. Although we show peak values of $\sim$ -1.6 Wm-2 in the July map (Fig. 8), we find that on a larger scale, i.e. 50oS – 50oN, the CALIPSO data yields monthly TOA clear-sky radiative forcing due to stratospheric aerosol of only -0.20, -0.27, -0.26, and -0.25 Wm-2 respectively for June – September 2011. These estimates include the background stratospheric aerosol, and are only modestly larger than the -0.2 Wm-2 radiative forcing estimated by Solomon et al. (2011) from CALIPSO and GOMOS data for the years immediately prior to the Nabro eruption. In addition, it is difficult to distinguish the impact of the Nabro plume from natural variability in the Earth's SW radiative flux. Figure S1 (below) shows a time series of monthly-mean CERES TOA outgoing SW radiative flux anomalies, between 50oS and 50oN. Standard deviation (s.d.) of the monthly values is $\sim$0.2 Wm-2. The figure shows generally positive anomalies from mid 2010 – mid 2012, but the increase does not coincide with the Nabro eruption, but precedes it.

p.33179, line 9: We will substitute Vernier et al. 2011a, and remove the reference to Bourassa et al., 2013 here.

p.33183, line 3: agreed

p.33184, lines 18-28: We agree, and will remove unnecessary repetition from the text.

p.33186, line 3: we will add the Umlaut.

p.33191, line 13: agreed

p. 33191, line 16: agreed

Also note that p.33191: line 19 should read "Peak values of ∼ -1.6 Wm-2 are found locally over Asian and Europe during July.

Acknowledgement: We acknowledge helpful discussions with our CERES colleagues, P. Taylor, N. Baker, S. Kato, on the CERES data.

Response to anonymous referee 2

p. 33181: re -ash as a minor component of the Nabro plume

Figure S2 shows a scatter plot of volume depolarization ratio, , vs. scattering ratio (SR) at 532 nm from CALIPSO observations made between 14 and 20 km altitude in the domain 0-60oN, 0-150oE for the first 20 days following the Nabro eruption. The data are colored by 1064/532 nm color ratio (CR). Two main clusters are evident in Fig. S2: (i) low (<∼5%) with CR values of ∼0.2-0.3, characteristic of sulfate aerosol, and (ii) relatively high increasing with SR, characteristic of ice clouds. In the first few days after the eruption, the plume occasionally showed depolarization values greater than 5%, likely due to the presence of ash particles (points with > 5% but below the black line in Fig. S2). We find ash to be a minor component of the volcanic plume in this case; hence we use the more restrictive constant threshold of = 5% to isolate the volcanic plume (mainly sulfate) from the ice clouds.

p. 33186, re lidar ratio for Nabro plume.

Sawamura et al. (2012) refer to the Raman lidar measurements made at Consiglio Nazionale delle RicercheâĂŤIstituto di Metodologie per l'Analisi Ambientale (CNR-IMAA), Italy, where lidar ratios of 48 at 532 nm were measured for the Nabro plume, close to the value for aged sulfate of 50 (Mueller et al., 2007). We will refer to these also.

[CNR-IMAA: C.da S.Loja, I-85050 Tito Scalo, Potenza, Italy.]

p. 33191. The correct number is -1.6 Wm-2 . The value -0.6 is not correct - it appears to have crept in at final typesetting. The sentence following was included in response to an editorial request for a range of uncertainty in the lidar ratio. We will simplify it.

Abstract: re "15% due to self-lofting:" This is a rough estimate based on differences in mean diabatic heating rate profiles obtained with and without stratospheric aerosols from the radiative forcing calculations. It is not essential to the message of the paper, so we will remove it.

Figure Legends:

Figure S1: Time series of zonal-mean, monthly-mean TOA outgoing SW radiative flux anomalies from CERES observations, averaged between 50oS and 50oN from 2000 through 2013. Anomalies are obtained by removing the 13-year monthly mean from each month's data, which de-seasonalizes the data. Monthly means are shown in black; six-month box-car averages are shown by blue curve; time of Nabro eruption is shown by vertical purple line; ticks on the abscissa mark March means for each year.

Figure S2: Scatter plot of CALIPSO 532nm volume depolarization ratio vs. scattering ratio for 15 June – 5 July, 2011 for 14-20 km altitude in the domain 0-60oN, 0-150oE. The data are averaged in 1 deg. latitude and 200m altitude intervals on orbital tracks, and are colored by 1064/532 color ratio. The black line represents an empirical separation between the volcanic plume and ice clouds. Points associated with very low depolarization (< 5%) have the optical characteristics of sulfate aerosol.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 33177, 2013.

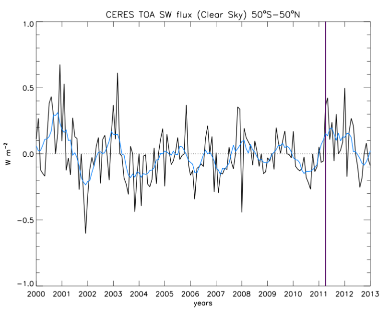

Figure S1: Time series of zonal-mean, monthly-mean TOA outgoing SW radiative flux anomalies from CERES observations, averaged between 50°S and 50°N from 2000 through 2013. Anomalies are obtained by removing the 13-year monthly mean from each month's data, which de-seasonalizes the data. Monthly means are shown in black; six-month box-car averages are shown by blue curve; time of Nabro eruption is shown by vertical purple line; ticks on the abscissa mark March means for each year.

Fig. 1.

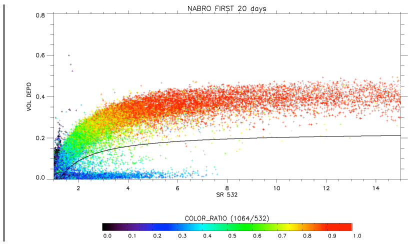

Figure S2: Scatter plot of CALIPSO 532nm volume depolarization ratio vs. scattering ratio for 15 June – 5 July, 2011 for 14-20 km altitude in the domain 0-60°N, 0-150°E. The data are averaged in 1 deg. latitude and 200m altitude intervals on orbital tracks, and are colored by 1064/532 color ratio. The black line represents an empirical separation between the volcanic plume and ice clouds. Points associated with very low depolarization (< 5%) have the optical characteristics of sulfate aerosol.

Fig. 2.