

Interactive comment on “Stratospheric aerosols from the Sarychev volcano eruption in the 2009 Arctic summer” by F. Jégou et al.

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Answer to M. von Hobe

All the technical notes have been taken into account.

“Page 3617, line 7: there is currently a debate on the actual emission altitude of the Nabro volcano (several technical comments on the Bourassa et al. paper appeared in SCIENCE in two months ago).” The altitude of the Nabro plume has been updated from Sawamura et al. (2012).

“Page 3617, line 10 to page 3618, line 3: this paragraph seems somewhat redundant to the information given in the abstract, and the detailed descriptions are/should be given

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in Section 2. I suggest shortening this in the introduction.” The sentences between lines 15 to 24 have been removed. The line 14 has been completed.

Page 3620, lines 15/16: The way this is written, it is not entirely clear, whether the ozone profile is perturbed, or just the spectroscopic measurements thereof. The word “profile” has been replaced by the word “spectrum”.

Page 3622, lines 18-22 : I do not understand why the meteorological conditions should not be identical, if the nudging is done in the same way in both simulations. Please explain. By definition, fully driving the HadGEM2 GCM by ECMWF reanalyses would not have allowed to derive a radiative forcing from the volcanic aerosols. Nudging is used to reduce possible problems of temperature drifts in the simulations. The major difference between the two simulations is that the simulation taking into account the volcanic eruption (so as to estimate its radiative impact) calculates the feedback on the temperatures which impacts the model dynamics between two nudging procedures.

These lines have been modified to clarify the simulation: “The model is only nudged to the ECMWF reanalyses rather than overwritten by them in the free troposphere and stratosphere and no nudging is applied directly near the surface. The radiative heating calculated by the model from volcanic aerosols is used to change the temperatures of the simulation, impacting the calculated meteorological conditions, and allows the model to compute some of the climate response due to the eruption.”

Page 3624, line 17: “...at latitudes north of the volcano,...”. And I do not understand what exactly you want to say with the part of the sentence following “..., but...”. The first sentence have been modified. We want to say with the following sentence that in some cases meteorological conditions could explain a transport to latitudes south of the Sarychev. The situation over the North Atlantic during the 26 June-2 July period is a good example.

Page 3625, line 7: because your study is really focused on high latitudes, the tropical tropopause is not relevant here. Just focus on what the 380 K means for high and

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mid-latitudes. The reference to the tropical tropopause has been removed.

Figure 3: It may be interesting to add a panel with vertically integrated columns that can be more easily compared to the IASI data in Figure 1. A new panel with vertically integrated columns has been added to figure 3.

Figures 11 and 12: they are almost impossible to read and should be enlarged. The page orientation concerning the figures 11 and 12 has been changed to “landscape” .

Answer to referee 1

1 General comments

I would recommend to separate the main conclusions focussing on the new combination of observations and model results from the last section and move parts of the discussion to the introduction. The conclusion has been reorganized: 1) model results have been gathered, 2) the first section has been simplified to avoid redundant information with the introduction.

2 Specifics comments

In the abstract also the ground-based observations might be mentioned. The OHP lidar is now mentioned in the abstract.

Please give more details in line 3621/16, to what refers the resolution here? In lines 3221/12-13 the CALIOP vertical and horizontal resolutions are already detailed.

I suppose HadGEM2 is a general circulation model (or climate model, line 3622/2f). HadGEM2 is a general circulation model which can be used with other components of the Earth system to simulate the climate.

Do you mean liquid H₂SO₄ (line 13)? Line 13 have been completed to clarify the treatment of liquid H₂SO₄. New line 13 : “The sulphur scheme was originally designed to investigate tropospheric aerosols where H₂SO₄ is assumed to be fully neutralized by NH₃ and assumed to exist as (NH₄)₂ SO₄. This assumption has been removed so

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that sulphate is treated as H₂SO₄ throughout the stratosphere.”

I suppose calculated aerosol radiative heating does not feedback on dynamics because the model is nudged. Please address this explicitly (line 18). This paragraph has been modified. See the answer to M. Von Hobe concerning this point.

Shouldn't be MIMOSA also mentioned in the model description section? The description of the MIMOSA model has been added.

Why do you need two models? Usually PV can be also provided from a GCM (line 3630/9). HadGEM2 model has been used to calculate sulphur mass injected in the atmosphere by the Sarychev eruption. The HadGEM2 data were provided by J. Haywood and A. Jones. This model is not used routinely in the LPC2E laboratory contrary to the MIMOSA model. The HadGEM2 model is able to calculate the PV fields but MIMOSA is a trustworthy tool commonly used in our published works to identify airmasses and their evolution.

Please say more why the total SO₂ used in the model differs from Figure 1 and other studies (section 3) It is actually tricky to accurately estimate the quantity of SO₂ injected in the stratosphere when several eruptions occurred within a few days. The 0.9 Tg quantity corresponds to a maximum observed (as seen in Fig. 1) but the total amount is likely to be underestimated if we add smaller contributions (of about 0.1 Tg as seen in Fig.1) before the main eruption but more difficult to detect by IASI. The 1.2 Tg value can be therefore considered as an upper limit of the total amount of SO₂ injected in the stratosphere by the Sarychev.

page 3623 we have modified the sentence: “the IASI data used in this study differ from the data used in the HadGEM2 simulation essentially by the maximum value, 0.9 Tg on 15–16 June (black line Fig. 1), which is retrieved from IASI new version 2.004. This version is presumed to be more accurate, with smoother time series (Clarisse et al., 2012). However we have chosen to use the 1.2 Tg total value computed by Haywood et al. (2010). Taking into account the Sarychev eruption as a whole (between 11 and 16

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June 2009), the total amount of SO₂ released in the stratosphere is likely to be higher than the maximum observed value of 0.9 Tg (Clarisse et al., 2012) if we consider the smaller injections (of about 0.1 Tg) prior to the main eruption but more difficult to detect by IASI. Then the 1.2 Tg value can be considered as a maximum contribution of the Sarychev eruption.”

Is ‘median’ radius in this study the same as ‘wet’ radius in Kravitz et al. (2011)? In Kravitz et al. (2011) is a strong dependence of the wavelength conversion factor (Eq.1) on particle size. The median radius in this study is the same as ‘wet’ radius in Kravitz et al. (2011). In Kravitz et al. (2011) these sentences are present page 8 : “Using ModelE’s radiation code, we specified a dry radius of 0.07 μm, which is less than one third our initial estimate of dry radius. This results in a hydrated aerosol radius of approximately 0.08– 0.10 μm. We chose this radius to match the balloon-borne measurements of aerosol median radius, which are discussed in section 4.” We found a similar aerosol median radius with our balloon-borne measurements justifying the use of the Eq. 1 corresponding to the Eq. 3 in Kravitz et al. (2011).

Is entire stratosphere defined in Fig.8 and line 3629/23 with a variable tropopause? Or troposphere and UTLS as given in caption? Here is a contradiction. The article has been corrected in line 3629/23 to remove the contradiction.

Soufriere Hills should be mentioned explicitly here (line 3638/8). The Soufriere Hills eruption has been mentioned in the conclusion.

Gaseous sulphuric acid in the lowermost stratosphere should be almost immediately converted to aerosol (line 3638/18). The line 3638 has been modified: “the injected SO₂ amounts were oxidized to gaseous sulphuric acid that almost immediately condensed into an H₂SO₄-H₂O liquid aerosol”.

Technical corrections

Please use days and months in Figures 1, 3 and 7. We decided not to change the

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‘days number’ in Figure 1, 3 and 7 but information about the dates has been added in the legend of Fig. 1 and in Fig. 3.

Better use a logarithmic colour scale instead of the irregular one in Fig.2 (or was it intended to reproduce Fig.3 of Haywood et al. (2010))? The linear colour scale has been chosen to match the Figure 3 of Haywood et al. (2010).

In the caption of Fig.5 the unit is missing, longitudes instead of latitudes! The unit has been added to the caption of Fig.5. The word “latitudes” has been replaced by “longitudes”.

Answer to referee 2

All the technical notes have been taken into account.

3617.7 – This is not correct. Aerosols from Nabro were observed higher than the altitude stated here. The altitude of the Nabro plume has been updated from Sawamura et al. (2012).

3623.17 – What IASI data is identified as having a maximum? Is this a retrieved quantity or primary measurement? The word “SO₂” has been added to clarify the sentence.

3623.19 – What is meant by DU? Is this Dobson unit applied to SO₂ column? I know it is done, but it is a bit unconventional. A more standard unit should be used. We decided not to change the SO₂ unit because this is an usual unit to express the SO₂ emissions. But we added details about the Dobson unit in page 3623 Line 18: “1 Dobson Unit (DU) is equivalent to approximately 0.0285 g SO₂ m⁻² .”

3626.29 – Clarify not high enough, stating, “...as soon as the aerosol is not above the detection threshold for daytime measurements during the permanently...” The sentence has been modified: “In this case, an artificial “aerosol hole” can appear as soon as the aerosol loading is not above the detection threshold for daytime measurements during the permanently illuminated polar summer.”

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Fig. 7 caption – What is meant by the dates of the flights? What flights? None are mentioned in the text. “STAC” has been added before “flight” to refer to the 8 flights planned during the STRAPOLETE campaign. These flights have been presented in the abstract and in the introduction.

3629.21 – How does Fig. 8 shows different “examples of isentropic transport”, each panel in the figure is a one day snapshot. The sentence has been modified: “Figure 8 shows cross-sections of the HadGEM2 AOD over Europe on 2, 7, 18 and 24 August 2009 representing 4 different snapshots of the atmosphere during the StraPoLETé campaign (black cross, Kiruna station).”

Author comments

Daniel Daugeron from the LPC2E laboratory (France) has been added in the author list.

This line has been added to the acknowledgements: “This study was supported by the French VOLTAIRE Labex (Laboratoire d’Excellence ANR-10-LABX-100-01) managed by University of Orleans.”

Sawamura et al. (2012) has been added to the bibliography.

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