Response to Referee #1.

Thank you very much for reviewing our manuscript.

Interactive comment on "Global temperature response to the major volcanic eruptions in multiple reanalysis datasets" by M. Fujiwara et al.
Anonymous Referee #1
Received and published: 15 June 2015

General Comments

This paper analyses the representation of changes to temperature in several reanalysis datasets to different recent and significant volcanic eruptions, mainly Mount Augung, El Chichon and Pinatubo. The temperature response to volcanoes is examined by removing signals from other sources of variability using linear regression. It is found that the reanalyzes have similar responses in the lower stratosphere and in the upper troposphere for a given eruption but there are differences in the response between individual eruptions.

In terms of the stated goal to evaluate the reanalyzes the paper does a good job in a clear and systematic manner. Below are a few comments.

Specific Comments

page 13318, line 15: As pointed out here differences in the response of each reanalysis may be a product of issues with the observations, the model or a combination of both. Since this paper is focused on temperature, albeit a spatial distribution, it would be useful to have some indication of the diversity of the observations used by the reanalyzes. Is there some indication that the response seen in the paper is more affected by the observations or the model?

The major observational sources of atmospheric (upper-air) temperature are radiosondes and satellite microwave and infrared sounders. The latter satellite sounders include the SSU and MSU instruments (in the TOVS[*1)] suite) on several operational satellites (mostly the "NOAA" satellites) from 1979, and AMSU-A instrument (in the ATOVS[*2)] suite) on several operational satellites from 1998. All the reanalysis datasets except the 20CR assimilated these datasets. (Note that the NCEP-1 and NCEP-2 used retrieved temperature data from these satellite instruments, while the others, i.e., the newer ones, directly assimilated original radiance data by using a radiative transfer model.) In addition, aircraft

temperature observations were also assimilated in most reanalysis datasets (except for JRA-25, JRA-55, and 20CR), but their impacts are limited to the region around 200-300 hPa and mostly to the Northern Hemisphere (see, e.g., discussion by Rienecker et al. (2011) for their Fig. 16). Also, the ERA-Interim, NCEP-CFSR, and JRA-55 assimilated data from the GNSS[*3)]/GPS[*4)] Radio Occultation temperature measurements from 2001 onward (CHAMP[*5)]: 2001-2008; FORMOSAT-3/COSMIC[*6)]: from 2006 onward; and MetOp-A[*7)]: from 2008 onward), but these observations do not cover the periods of the volcanic eruptions considered in this study; thus, their impacts on our results are only indirect through the evaluation of other forced variabilities. In summary, the original upper-air temperature data assimilated are basically common for all the reanalysis datasets except for the 20CR.

[*1)]TOVS: Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder

[*2)]ATOVS: Advanced TIROS Operational Vertical Sounder

[*3)]GNSS: Global Navigation Satellite System

[*4)]GPS: Global Positioning System

[*5)]CHAMP: CHAllenging Minisatellite Payload

[*6)]FORMOSAT-3/COSMIC: Constellation Observing System for Meteorology, Ionosphere, and Climate on the Republic of China Satellite (ROCSat) renamed to FORMOSAT

[*7)]MetOp-A: MetOp is a series of three polar orbiting meteorological satellites operated by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)

There are three components that differ in different reanalysis systems: (1) detailed “bias correction” methods (or, quality control, in other words) for the original radiosonde and microwave/infrared sounder data before the assimilation, (2) the assimilation scheme, and (3) the forecast model. Therefore, we can say that the main causes of the overall temperature difference among the reanalysis datasets (except for 20CR) are these three factors rather than the choice of original observations. For the temperature response to the volcanic eruptions, the same can be said. The reanalysis system is an operational analysis system at a particular time (see Table 1, the fourth column, of Mitchell et al. (2015)), and the operational analysis system has been continuously improved over time with the main motivation to improve the tropospheric weather prediction (at least at the ECMWF, JMA, and NOAA). Therefore, in principle, newer reanalysis datasets are considered to be better at all the above three components, and this would explain the differences shown in our study between the older (e.g., NCEP-1, NCEP-2, ERA-40, and JRA-25) and the newer (ERA-Interim, NCEP-CFSR, MERRA, and JRA-55) reanalysis datasets. The differences among the newer reanalysis datasets, which are smaller, are also due to the differences at these three components.

We will add a paragraph discussing these points in Introduction of the revised manuscript.

page 13320, line 5: Same question as above. Do all of the reanalyzes assimilate the datasets?

Please see above.

page 13320, line 7: It is mentioned here and elsewhere in the text that 20CR uses annual average volcanic aerosols. Is there a reference how this is done? It is not clear in Compo et al., 2011 or Saha et al., 2010. Could this affect your analysis applied to this reanalysis? For example, if we assume that an annual average is for the period January to December of a given year then for Pinatubo the model erupted in January rather than June of 1991. Given the method to determine the volcanic signal (Page 13321, line 25) won't the pre-eruption period be affected?

This is a very good point.
We communicated with Gilbert Compo and Craig Long again and found that the descriptions in Compo et al. (2011) need to be revised. The following is the correct one, which will be included in our revised manuscript:

The atmospheric forecast model of the 20CR v2 is nearly the same as used in the NCEP-CFSR but with a lower resolution. For both reanalysis datasets, monthly latitudinally-varying distributions of volcanic aerosols (averaged for 4 bands, i.e., 90N-45N, 45N-equator, equator-45S, and 45S-90S) were specified based on data from Sato et al. (1993), and a monthly climatological global distribution of aerosol vertical profiles on a 5^{o} grid was specified based on data from Koepke et al. (1997) (G. Compo and C. Long, private communication, 2015).

Koepke, P., Hess, M., Schult, I., and Shettle, E. P.: Global aerosol data set, Report No. 243, Max-Planck-Institut für Meteorologie, Hamburg, ISSN 0937-1060, 44 pp., 1997.

page 13323, line 10: Which aerosol dataset does 20CR use? It is not clear in Compo et al., 2011 and Saha et al., 2010.

Please see above.

Technical corrections

page 13323, line 25: "SD" is not defined in the paper.

SD means standard deviation. We will define it where it first appears.