Balloon Observatories Needed for Future Volcanic Eruption Observations

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Abstract

In situ and remote sensing observations will be crucial to understand the evolution of sulfate aerosol production, fine ash emissions, and growth and transport of stratospheric aerosols. After the last large eruption, of Mt. Pinatubo in 1991, satellite observations were inadequate to measure the vertical distribution of the thick tropical aerosol cloud or the evolution of the aerosol size distribution. Balloon observations were only taken at mid-latitudes long after the eruption. These observations are crucial to evaluate climate model simulations of volcanic eruptions, which are also being used for sunlight reflection climate intervention (geoengineering) studies. There have been four eruptions since Pinatubo with stratospheric injections of more than 1 Tg of SO_2, and there will certainly be other larger eruptions in the future. Climate modeling groups are ready to simulate the response to the next eruption, but they will need data to initialize and evaluate their simulations. While existing and future satellite observations will be important, airplanes may or may not be able to quickly respond and ground-based lidar observatories, especially in the tropics are still sparse, one crucial missing piece of information can be provided by balloons. If we establish a network of balloon observatories, ideally spaced at 10° in latitude, with two on opposite sides of the world in each latitude band, using new, inexpensive instruments that measure particles, we can take regular observations every one or two months to establish background concentrations and to develop routine observational and analysis systems. Then we will be ready to launch much more frequently after the next large eruption, defined as more than 1 Tg of SO_2, as measured by OMI or another satellite system. This will allow detailed observations of the conversion of SO_2 to sulfate aerosols and the subsequent evolution of the aerosol size distribution. This poster is heavily dependent on Chapter 5 of NASA (2018) by Ru-Shan Gao, Jean-Paul Vernier, Lars Kalnajs, Terry Deshler, and Ross Salawitch.

I was once a balloonist, working for Terry Deshler's project in Antarctica (Fig. 1). And I have been frustrated for a long time with the lack of measurements of the thickest part of the 1991 Mt. Pinatubo eruption cloud (Fig. 2). While we attempted to fill in the SAGE II gaps with lidar at higher latitudes (Antuña et al., 2002, 2003), both lidar and balloon observations in the Tropics immediately after the next large eruption will be crucial for initializing and evaluating simulations of the evolution of the cloud and its climate impacts, and for understanding the microphysical process by which SO_2 converts to sulfate aerosols.

The current NASA (2018) plan is "Five to 10 sets of iMet/COBALD/POPS/O_3/SO_2/CFH/CN sondes should be stockpiled for rapid (0-30 days) response. We further recommend selecting a team of instrument PIs who will keep and maintain these instruments and corresponding calibration equipment and material in such conditions that they can be shipped within two days and will be ready for launch two days after arrival at the launch site." Table 1 shows the types of lightweight payloads that can be used and Table 2 shows candidates for sites for balloon launches.

This is an excellent plan, as far as it goes. The 5-10 sets of sondes need to include enough in each set to do frequent observations immediately upon deployment. Furthermore, regular launches need to be carried out approximately monthly starting now to make sure all the instruments work and transmit their data, and that the data can be processed accurately and quickly so that they can be used in a timely manner. Furthermore, it will be very valuable to have a background climatology for comparison to the observations after large eruptions and that can monitor natural variability and smaller stratospheric injections from volcanic eruptions and other sources.

The NASA (2018) report is close to completion (Paul Newman, personal communication). The next steps are:

- Integration with the SSiRC VolRes plan that is also under development and will be discussed on Thursday afternoon, to avoid duplication and to ensure all important measurements will be made.
- Funding of the NASA and VolRes plans so that the balloons and instruments can be purchased and the observatories can be set up, and so that we are ready before the next large volcanic eruptions.

Figure 1. About to launch an ozonesonde at McMurdo, Antarctica, August 25, 2004.

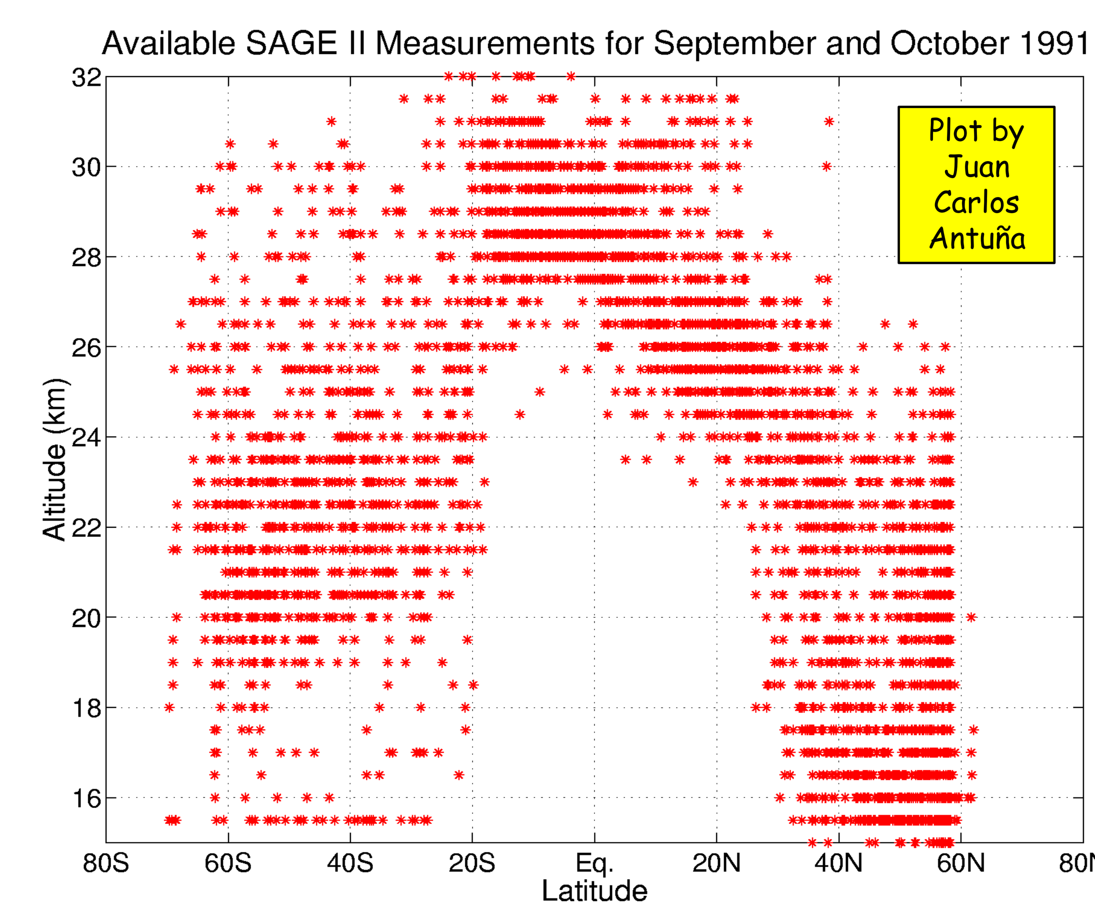

Figure 2. The gap in aerosol measurements following the 1991 Mt. Pinatubo eruption. There were no lidar observations in the Tropics, either.

Table 1. Listing of lightweight aerosol, ozone, and water vapor payloads that could be used for a rapid response after the next volcanic eruption. All particle measurements are in diameter. (Table 5 from NASA (2018)).

Payloads	Institute/Contact	Specifications	Weight	Cost
POPS	NOAA/Ru-Shan Gao	OPC, 0.14 – 3 μm, 8 – 25 channels	0.75 kg	$2K[a]
COBALD	ETH/Frank Wienhold	Backscatter at 455 and 870 nm	0.6 kg	$1.6K[b]
LPC	Univ. Colorado/Lars Kalnajs	OPC, 0.3 – 15 μm, 32 channels	4 kg	$6K[a]
LHI-PC	Univ. Colorado/Lars Kalnajs	OPC (heated inlet), 0.3 – 15 μm, 32 channels	4.5 kg	$7K[a]
LCN	Univ. Colorado/Lars Kalnajs	Condensation nuclei > 6 nm	2 kg	$3K[a]
LOPC	NASA Langley/Jean-Paul Vernier	OPC, 0.3 – 10 μm, 8 channels	4.2 kg	$3K[a]
LImpact	NASA Langley/Jean-Paul Vernier	3 stages cascade aerosol impactor	4 kg	$7K[a]
CFH	ENSCI	Water vapor sonde	1 kg	$3.2K[b]
FPH	NOAA	Water vapor sonde	1 kg	x[a]
Ozonesonde	ENSCI	Ozone	0.6 kg	$0.7K[b]
SO_2 sonde	St. Edward's Univ./Gary Morris	SO_2, ozone	2 kg	$2K[b]
iMet	InterMet	Radiosonde, p, T, RH	0.26 kg	$0.3K[b]
[a]Built in institute, labor cost excluded. [b]Commercially available.				

Table 2. Sites selected for balloon deployment. (Table 7 from NASA (2018)).

Location			Alternatives
Boulder, CO, USA	40.0°N, 105.3°W	NDACC - lidar, sondes, UV	Hampton, VA, USA (37.0 °N, 76.5°W)
Table Mountain Observatory, CA, USA	34.4°N, 117.7°W	NDACC - lidars, UV	Houston, TX , USA (29.8°N, 95.4°W)
Hilo, HI, USA	19.7°N, 155.1°W	NDACC - lidar, sondes, UV	Key West, FL , USA (24.6°N, 81.8°W)
Gadanki, India	13.4°N; 79.2 °W	Aerosol lidar	Barbados, San Jose, CR
San Cristobal, Ecuador	0.9°N, 89.4°W	Sondes (GAW regional station)	Manaus, Brazil (LALINET), Nairobi, Kenya (GAW)
Pago Pago, Am. Samoa	14.3°S, 170.7 W	Sondes (NOAA station)	Darwin, Australia (GRUAN)
Reunion Island, France	21.1°S, 55.5°E	NDACC - lidar, sondes, UV	
Buenos Aires, Argentina	34.5°S, 58.5°W	LALINET, multi-wave lidar	
Lauder, New Zealand	45.1°S, 169.7°E	NDACC site - FTIR, lidars, microwave, UV	

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