The 1991 Mount Pinatubo eruption and its effect on the atmospheric environment

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Mount Pinatubo is located within Botolan, Phillipines at latitude 15.13 N and longitude 120.35 E along the Ring of Fire, an area of high geologic activity. The volcano is characterized as a stratovolcano (composite) with a pre-eruption height of 1.745 kilometers (km) and post-eruption height of 1.485 km (USGS, 2009). The 1991 Mount Pinatubo eruption was statistically one of the most powerful volcanic events of the twentieth century. According to a study conducted several years after the eruption, the Mount Pinatubo eruption was found to be ten times stronger than that of Mount St. Helens, projected an ash cloud that rose 35 kilometers into the sky, and killed 300 people while threatening the lives of a million (Newhall and Punongbayan, 1996). From an atmospheric mindset, the Mount Pinatubo eruption provided a unique set of perturbations in the atmosphere resulting in changes in: aerosol content, dynamical processes, radiative properties and stratospheric processes.

The constituents of atmospheric interest that were ejected into the atmosphere from the eruption were predominantly: aerosols, water vapor and SO_2 gas which chemically changed into many forms including H_2SO_4 (McCormick, Thomason and Trepte, 1995). Mount Pinatubo produced an estimated peak aerosol mass loading of 30 x 10^{12} g or 30 teragrams (Tg) and is regarded as either the, or one of the, largest aerosol perturbations to the stratosphere in the 20^{th} century (McCormick et al., 1995). The aerosols were estimated to have circumnavigated the globe, in a westward direction, in approximately 22 days and was believed to have been concentrated between 20 to 27 km altitude, but reached as low as the tropopause and as high as 30 km in altitude (McCormick et al., 1995). The atmospheric transport of the volcanic gases and particles were primarily in the 20 S to 30 N latitude bands. Contrary to what one may perceive, numerical transport simulations suggested that the movement of the Mount Pinatubo aerosol plume was the result of meridional circulations created by local heating rather than planetary-scale transport systems (McCormick et al., 1995). In addition, a slow tropical aerosol transport towards the poles was found during the first six months after the eruption which resulted in a steep meridional gradient of aerosols at 20 N and 20 S (McCormick et al., 1995). The majority of removal of the aforementioned aerosols occurred due to gravitational sedimentation during the winter months and intermittent tropopause folding. The resultant of both removal systems resulted in an aerosol removal from 30 to five Tg two and a half years after the eruption (McCormick et al., 1995).

In addition to the aerosol and dynamical changes that occurred due to the Mount Pinatubo eruption, the Earth's radiative processes were impacted as well. The theory behind the change in the Earth's radiative processes was a resultant of H_2SO_4 which increased the planet's albedo, due to its efficient scattering and weak absorbing properties in the incoming solar radiation wavelength spectrum (McCormick et al., 1995). The greatest change in albedo, approximately 20 percent, was found in cloud-free regions and regions associated with deep convective cloud systems (McCormick et al., 1995). The increased albedo of the Earth resulted in an observed cooling of 8 W/m^2 from 5 S to 5 N and 4.3 W/m^2 from 40 S to 40 N from 1991 to 1993 (McCormick et al., 1995). Coupled with the aforementioned radiative changes, a mean tropospheric drop in temperature, factoring in the El Nino-Southern Oscillation (ENSO) phenomenon, was observed. The temperature drop, compared over a temperature baseline spanning the years 1958 to 1991, was 0.4 C in 1991, 0.5 C in 1992, and nearly evened out in 1993 at 0.1 C (McCormick et al., 1995).

The tremendously energetic eruption of Mount Pinatubo ejected volcanic gases and particles up into the stratosphere. The intrusion of the volcanic gases and particles within the stratosphere resulted in chemical interactions. The chemical changes that ensued included: ozone loss and elevated levels of chlorine dioxide. After the first several months it was found that the eruption resulted in a reduction of around six to eight percent of columnar ozone over the equatorial regions, predominately within 28 km altitude and was observed to be 20% near 24-25 km (Brasseur and Granier, 1992 and McCormick et al., 1995). According to McCormick et al., the ozone loss was likely attributed to a combination of stratospheric heating, due to the addition of new aerosols into the stratosphere, and from the additional SO_2 exposed to the stratospheric environment.

In conclusion, the Mount Pinatubo eruption of 1991 provided a unique opportunity to utilize all the tools of modern science to better understand the effects that volcanoes have on the planet's atmospheric environment. Through satellite imagery and remote sensing technologies, scientists found that the Mount Pinatubo eruption of 1991 transpired into planetary atmospheric changes including: aerosol content, dynamical processes, the Earth's radiative properties and stratospheric chemical makeup and processes. The knowledge attained from this geologic episode will provide invaluable input for future atmospheric modeling situations in which more accurate representations of how volcanic activity may impact the Earth's albedo, chemical makeup, or climactic perturbations is needed.

References

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