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Uncertainties in modelling Mt. Pinatubo eruption with 2-D AER model and CCM SOCOL

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Large volcanic eruptions may introduce a strong forcing on climate. They challenge the skills of climate models. In addition to the short time attenuation of solar light by ashes the formation of stratospheric sulphate aerosols, due to volcanic sulphur dioxide injection into the lower stratosphere, may lead to a significant enhancement of the global albedo. The sulphate aerosols have a residence time of about 2 years. As a consequence of the enhanced sulphate aerosol concentration both the stratospheric chemistry and dynamics are strongly affected. Due to absorption of longwave and near infrared radiation the temperature in the lower stratosphere increases. So far chemistry climate models overestimate this warming [Eyring et al. 2006].

We present an extensive validation of extinction measurements and model runs of the eruption of Mt. Pinatubo in 1991. Even if Mt. Pinatubo eruption has been the best quantified volcanic eruption of this magnitude, the measurements show considerable uncertainties. For instance the total amount of sulphur emitted to the stratosphere ranges from 5–12 Mt sulphur [e.g. Guo et al. 2004, McCormick, 1992]. The largest uncertainties are in the specification of the main aerosol cloud. SAGE II, for instance, could not measure the peak of the aerosol extinction for about 1.5 years, because optical termination was reached. The gap-filling of the SAGE II [Thomason and Peter, 2006] using lidar measurements underestimates the total extinctions in the tropics for the first half year after the eruption by 30% compared to AVHRR [Rusell et. al 1992]. The same applies to the optical dataset described by Stenchikov et al. [1998]. We compare these extinction data derived from measurements with extinctions derived from AER 2D aerosol model calculations [Weisenstein et al., 2007]. Full microphysical calculations with injections of 14, 17, 20 and 26 Mt SO2 in the lower stratosphere were performed.

The optical aerosol properties derived from SAGE II measurements and from AER model calculation serve as input for the 3D chemistry climate model (CCM) SOCOL [Schraner et al., 2008]. The heating rates, calculated with SOCOL, are compared with a reference radiative transfer model LibRadtran [Mayer and Kylling, 2005]. This comparison suggests that SOCOL underestimates the net heating rate by 10-20%. In stark contrast, the temperature increase in the lower stratosphere due to absorption of longwave and near infrared radiation is overestimated by all SOCOL scenarios. This lets us conclude that SOCOL, and similarly other state-of-the-art CCMs, misrepresent processes required to model the effect of volcanic eruptions on the lower stratosphere and tropopause region. Possible reasons for model deficiencies could be too coarse vertical resolution or missing dynamical feedbacks near the tropopause and in the lower stratosphere. Another important feature is the warming of the tropical troposphere, which is present in the model simulation but was not observed with comparable amplitude in reality. The heating of the lower stratosphere in the models leads to an increase of stratospheric water vapour and influences the radiative and chemical properties of the stratosphere.

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