Atmos. Chem. Phys. Discuss.,
doi:10.5194/acp-2016-985-AC1, 2017

Atmospheric Chemistry and Physics Discussions

Interactive comment on “Sulfate geoengineering: a review of the factors controlling the needed injection of sulfur dioxide” *by* Daniele Visioni et al.

Daniele Visioni et al.

daniele.visioni@aquila.infn.it

Received and published: 12 January 2017

Response to referee #1 attached as supplement.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/acp-2016-985/acp-2016-985-AC1-supplement.pdf

---

Interactive comment on Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-985, 2016.

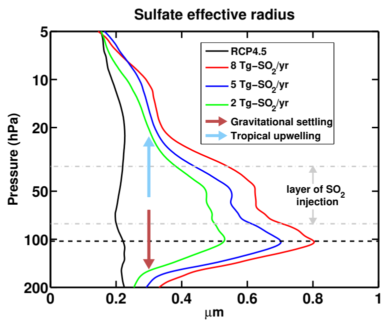
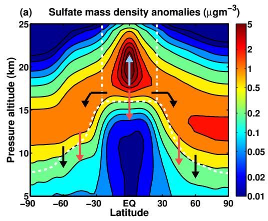


Figure 1. Annual averaged vertical profiles of aerosol effective radius (μm) in the tropical stratosphere (25S-25N), with increasing geoengineering injection of SO_2 (see legend). The heavy dashed line indicates the mean tropical tropopause. Profiles are calculated in the University of L’Aquila Chemistry-Climate Model (ULAQ-CCM), which includes explicit gas-particle conversion and aerosol microphysics (Pitari et al. (2014)).

5

Fig. 1.



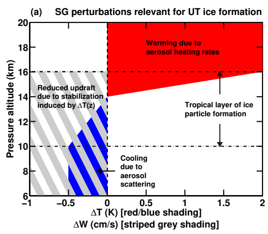
(b) Summary of SO_2 injection feedback mechanisms

	Dynamical effect	With increasing SO_2 injection:	Sulfate lifetime & optical depth
	Gravitational settling	Increases [Enhanced gas-particle conversion: larger particles]	Decrease
	Isentropic poleward transport & strat-trop exchange	Decreases [Prolonged QBO W phase: higher tropical confinement]	Increase
	Tropical gravitational settling	Increases [Higher sulfur confinement due to QBO effect: larger particles]	Decrease
	Tropical upwelling	Increases [Enhanced aerosol heating rates]	Increase

Figure 2. Panel (a): annually and zonally averaged sulfate mass density calculated anomalies (μg/m^3), due to a geoengineering injection of 5 Tg-SO_2/yr, with respect to a RCP4.5 background atmosphere. The aerosol mass density distribution is calculated in the Goddard Earth Observing System Chemistry Climate Model (GEOSCCM), with SG treated as described in Pitari et al. (2014). Arrows superimposed to the aerosol distribution indicate the main transport pathways of the aerosol particles, as explained in panel (b). The sensitivity of each dynamical effect to the SO_2 injection is highlighted in panel (b), along with the physical mechanisms driving the perturbation and the net effect on sulfate lifetime and optical depth.

8

Fig. 2.



(b) Summary of SO_2 injection feedback mechanisms

Thermal-Dynamical effect	With increasing SO_2 injection:	UT ice optical depth
Lower stratospheric & uppermost tropospheric warming	Increases [Enhanced aerosol heating rates due to LW radiation absorption]	Decreases [Faster depositional growth and lower nucleation rates]
Tropospheric cooling	Increases [Enhanced aerosol SW radiation scattering]	Increases [Slower depositional growth and higher nucleation rates]
Vertical velocity and water vapor updraft	Decreases [Enhanced tropospheric stabilization due to induced T(z) changes]	Decreases [Lower supersaturation: less ice crystals can nucleate]
Aerosol gravitational settling	Increases [Enhanced gas-particle conversion: larger particles]	Increases (?) [More UT sulfate aerosols, but inefficient IN for heterogeneous freezing]

Figure 3. Panel (a): schematic profile changes of upper troposphere-lower stratosphere temperature (K) and UT vertical velocity (cm/s) in the tropics, due to a geoengineering injection of 5 Tg-SO_2/yr. The perturbation scheme is based on the findings of Kuebbeler et al. (2012), Pitari et al. (2016c) and Pitari et al. (2014). The sensitivity of each thermal-dynamical effect to the SO_2 injection is highlighted in panel (b), along with the physical mechanisms driving the perturbation and the net effect on UT ice optical depth.

11

Fig. 3.

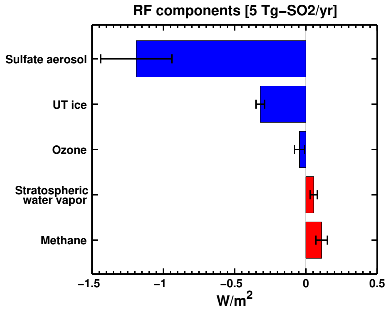


Figure 4. Summary of direct and indirect SG global TOA RF per component (see sections 2.1 - 2.2).

16

Fig. 4.