12 Reasons why stratospheric SRM is an unsuitable and even dangerous mean to stop climate warming

Tingzhen Ming School of Civil Engineering and Architecture, Wuhan University of Technology, Wuhan 430070, China, tzming@whut.edu.cn

Renaud Kiesgen de Richter Institut Charles Gerhardt, Université de Montpellier, Montpellier, France, <u>renaud.derichter@gmail.com</u>

Franz Dietrich Oeste gM-Ingenieurbüro, Tannenweg 2, 35274 Kirchhain, Germany, <u>oeste@gm-ingenieurbuero.com</u>

Nobel Prize winner Paul Crutzen recommended in 2006 stratospheric SRM by SO₂ emission into the stratosphere (Crutzen 2006). According to similarities of the H_2SO_4 aerosol generated by SO₂ oxidation from volcanic eruptions reaching the stratosphere Paul Crutzen supposed that artificial man-made H_2SO_4 aerosol would induce a similar cooling effect than volcanic eruption plumes. More than a decade later, Paul Crutzen's followers remain advocates of stratospheric SRM and compare the pretended climate cooling effect of huge volcanic eruption plumes acting in the stratosphere by generating sulfate aerosol plumes mirroring the sunlight back into the space (Kravitz et al, 2011; Weisenstein et al. 2015) (and references cited therein).

This simplistically comparison is not anymore admissible because eruption clouds have lots of other cooling effects which are active in the atmosphere, at and within the surfaces of continents and in the ocean which are different and much stronger than the poor physical mirror effect of simple stratospheric aerosol. Only five of these effects are listed below:

A) At least 5 reasons why stratospheric SRM has no similarity to volcanic eruption climate cooling

- Volcanic eruptions produce ash particles plumes containing soluble iron fertilizer. Further the ash contains fertilizing sulfates, phosphates, nitrates, silicates, and salts and oxides of iron, manganese, zinc, molybdenum and further micronutrients. Fallen onto the plants, the ground, and into the ocean it fertilizes plant and food chain growth by conversion of gaseous atmospheric CO₂ into organic, hydrogen carbonate and carbonate C. This climate cooling effect acts by reduction of the CO₂ greenhouse gas concentration in the atmosphere (Oeste et al. 2017 and references cited therein)
- 2. The phytoplankton growth induced by the fertilizing effect of volcanic ash activates the emission of Sulphur and Chlorine organic volatiles to the troposphere. The S depletion product forms Na₂SO₄ aerosol which acts as cloud condensation nuclei by increasing cloud albedo cooling in the lower troposphere. The CI depletion product forms HCI which acts by activating the generation of °CI atoms by sunlight radiation photolysis of Fe^(III) in the neighborhood of chloride. The °CI atoms induce a cooling effect by oxidative depletion of the greenhouse gases methane (CH₄) and VOCs 3) and references cited therein.
- 3. Volcanic eruption ash fallen onto continental plants and soil activates the plant root mechanical and chemical weathering of silicates by the fertilization effect of the ash on the plants (Oeste et al. 2017 and references cited therein). This climate cooling effect acts by conversion of gaseous atmospheric CO₂ into hydrogen carbonate and generates additional P and N containing fertilizers generating similar sustainable effects, with an additional reduction of the CO₂ greenhouse gas concentration in the atmosphere
- 4. Volcanic eruptions produce plumes containing gaseous HCl and much smaller concentrations of HBr. These components transform iron compounds of the ash particles at least by part into Fe^(III) halides. Fe halides become photolyzed by sun radiation into Fe(II) compounds and generation of gaseous atomic °Cl and atomic °Br. Atomic °Cl is a strong oxidant of the greenhouse gas components CH₄ and further volatile organic carbon (VOC) compounds Hossaini et al. 2016; Wittmer et al. 2015, 2016, 2017). Atomic °Br is a strong depletion catalyst of tropospheric ozone, also a potent greenhouse gas component. These climate cooling effects act by decreasing the CH₄ and O₃ concentration in the atmosphere (Oeste et al. 2017 and references cited therein).
- 5. As mentioned at 4 and 1, Volcanic ash contains soluble Fe salts. Fe is known as micronutrient to microbes acting as methane oxidizers in the suboxic wetland milieu. These red-ox milieu conditions are widespread in surface-near sediment milieu like wadden seas, mangrove forests, peat fens and rice paddies (Oeste et al. 2017 and references cited therein). Volcanic ash fall onto these ecosystems enhance the CH₄ depletion, decrease CH₄ emission to the atmosphere, thus cools the Earth by reducing the methane greenhouse gas content of the atmosphere.

According to our current knowledge there are several reasons why artificial sulfate aerosols - contrary to volcanic eruption plumes - might probably act to the opposite: inducing a climate warming instead of cooling:

B) At least 7 reasons why stratospheric SRM instead of cooling will warm up the Earth surface because it increases the GHGs content of the atmosphere

- 1. SRM reduces the solar radiation level at the globe surface (Crutzen 2006). Because this effect decreases the sunshine-driven assimilation-induced conversion of CO₂ carbon into organic C, an increase of the greenhouse CO₂ concentration will result.
- 2. SRM reduces the short-wave ratio of the sunlight radiation with lower UV and more long-wave. This induces a decrease of the °OH radical content in the troposphere Visioni et al., 2017). Because the lifetime / concentration of organic C constituents of the greenhouse gases like CH₄ and other VOCs and of the greenhouse-efficient C soot aerosol in the atmosphere mainly depends on the °OH radical content of the troposphere, the lifetime / concentration of these greenhouse components increase.
- 3. SRM reduces even the shorter wave part of the sun radiation Hossaini et al. 2016; Wittmer et al. 2015, Wittmer et al. 2014, Wittmer et al. 2016) responsible for the radiation-induced change of Fe^(III) to Fe^(III) contained in the tropospheric dust aerosols. This reaction generates °Cl atoms by chloride oxidation. Because °Cl atoms have at least an order of magnitude greater reactivity than hydroxyl radicals °OH their contribution to the methane tropospheric depletion is about 4 %, up to 10 % regionally. Radiation reduction will reduce the °Cl atom induced depletion of the GHG CH₄ and again increase the CH₄ lifetime / concentration in the atmosphere.
- 4. The SRM reduced sunshine has the further effect, that the insoluble Fe content of dust aerosols is increased. The Fe^(III) to Fe^(III) photolysis and its photo-Fenton re-oxidation with tropospheric oxidants activate the transformation of un-dissolved dust iron compounds into dissolved or dissolvable Fe compounds Rubasinghege et al., 2010). Because the sun radiation reduction deactivates both, a) generation of tropospheric oxidants and b) iron^(III) photolysis the generation of dissolved or dissolved or dissolved or dissolved Fe corresponding decreases. The result is an increase of the insoluble Fe fraction in the dust aerosol. Only the soluble Fe part in the dust particles acts as micronutrient, consequently the dust activation of CO₂ assimilation to organic C and carbonate C mainly within oceans but on continents as well will be both reduced. Further effect is the reduced immission of dissolvable Fe as micronutrient to the methane depleting microbes living in wetlands and peat fens which would result in a methane emission increase.
- 5. Because plant roots enhance the CO₂ conversion into hydrogen carbonate by active chemical and physical rock weathering to gain nutrients, any weakening of plant growth by a) light reduction and b) foliar fertilizing reduction Meena et al. 2014), Dakora & Philipps 2002), induces the decrease of the root-induced CO₂ transformation by root-induced silicate weathering to hydrogen carbonate. Especially plants living on alkaline soils are often deficient in Fe suffering from chlorosis. Any Fe foliar fertilization by dissolved Fe containing dust helps these plants to activate their CO₂ assimilation, growing and develop their weathering activating root system. Thus SRM-induced light reduction reduces the foliar fertilizing effect of dust on assimilation and root induced CO₂ transformation and enhances again the CO₂ concentration in the air.
- 6. Any installations of solar radiation transformation into electricity will see their efficiency reduced by sunlight reflection methods. If the compensation of the deficient energy becomes generated by fossil carbon combustion an additional CO₂ concentration in the troposphere results.
- 7. Because stratospheric aerosols have lifetimes of years, stratospheric SRM cannot be stopped at once. It lasts years until the stratosphere gets its original transparency back and abrupt SRM termination, cessation or suspension will induce a rapid global warming with difficult life adaptation.

Bibliography

XCrutzen, P.J., 2006. Albedo enhancement by stratospheric sulfur injections: a contribution to resolve a policy dilemma? Climatic change 77, 211-220.

Dakora FD & Philipps DA, 2002: Root exsudates as mediators of mineral acquisation in low nutrient environments. Plant and Soil, 245,35-47

Hossaini, R., Chipperfield, M.P., Saiz-Lopez, A., Fernandez, R., Monks, S., Feng, W., Brauer, P., Glasow,

R., 2016. A global model of tropospheric chlorine chemistry: Organic versus inorganic sources and impact on methane oxidation. Journal of Geophysical Research: Atmospheres 121.

Kravitz, B., Robock, A., Boucher, O., Schmidt, H., Taylor, K.E., Stenchikov, G., Schulz, M., 2011. The geoengineering model intercomparison project (GeoMIP). Atmospheric Science Letters 12, 162-167. Meena VS, Maurya BR, Verma JP, 2014. Does a rhizospheric microorganism enhance K+ availability in agricultural soils? Microbiological Research, 169, 337-347

Oeste, F.D., de Richter, R., Ming, T., Caillol, S., 2017. Climate engineering by mimicking natural dust climate control: the iron salt aerosol method. Earth System Dynamics 8, 1.

Rubasinghege G, Lentz RW, Scherer MM, Grassian VH, 2010: Simulated atmospheric processing of iron oxyhydroxide minerals at low pH: Roles of particle size and acid anion in iron dissolution. PNAS, 107(15), 6628-6633

Shi, Z., Krom, M.D., Bonneville, S., Baker, A.R., Bristow, C., Drake, N., Mann, G., Carslaw, K., McQuaid, J.B., Jickells, T., 2011. Influence of chemical weathering and aging of iron oxides on the potential iron solubility of Saharan dust during simulated atmospheric processing. Global Biogeochemical Cycles 25. Takahashi, Y., Higashi, M., Furukawa, T., Mitsunobu, S., 2011. Change of iron species and iron solubility in Asian dust during the long-range transport from western China to Japan. Atmospheric Chemistry and Physics 11, 11237-11252.

Visioni D, Pitari G, Aquila V, Tilmes S, Cionni I, Di Genova G, Mancini E, 2017: Sulfate geoengineering impact on methane transport and lifetime: results from the Geoengineering Intercomparison Project (GeoMIP). Atmos. Chem. Phys. 17, 11209-11226

Weisenstein, D.K., Keith, D.W., Dykema, J., 2015. Solar geoengineering using solid aerosol in the stratosphere. Atmospheric Chemistry and Physics 15, 11835-11859.

Wittmer, J., Bleicher, S., Ofner, J., Zetzsch, C., 2015. Iron (III)-induced activation of chloride from artificial sea-salt aerosol. Environmental Chemistry 12, 461-475.

Wittmer, J., Bleicher, S., Zetzsch, C., 2014. Iron (III)-induced activation of chloride and bromide from modeled salt pans. The Journal of Physical Chemistry A 119, 4373-4385.

Wittmer, J., Bleicher, S., Zetzsch, C., 2016. Report on the Photochemical Induced Halogen Activation of Fe containing Aerosols. Journal of Climatology & Weather Forecasting, 1-30.