Geoengineering and Climate Change

Implications for Africa

In Brief: Some governments are exploring geoengineering as a way to reduce or delay climate change. Geoengineering could technically take climate decisions away from all but the richest countries. Computer models[1] show that stratospheric interventions to reduce sunlight and lower temperatures may benefit some temperate zones but negatively impact Africa with important social and agricultural consequences.

Terminology:

Geoengineering is the intentional large-scale technological manipulation of earth systems (in the stratosphere or ocean or in the ground) in an attempt to delay or reduce climate change.

Solar Radiation Management (SRM) is stratospheric geoengineering to block or deflect sunlight aiming to lower Earth's temperature.

Sulfate Aerosol Injection (the most economic and technically practical SRM) spreads sulfate "dust" 15–20 km up in the stratosphere to reduce sunlight and lower temperatures. "Dust" can be blown by a battery of pipes (like an artificial volcano) or via specially outfitted aircraft. Direct cost could be as low as $700 million the first year to tens of billions of dollars per annum later.

Net Primary Productivity (NPP): NPP is an indicator of the health of the terrestrial biosphere and its ability to take up CO_2. It can also provide an estimate of the impacts of geoengineering on agriculture (Kravitz et al. 2013).

Findings: Two peer-reviewed scientific papers published in 2013[2] and 2008[3] report on four climate model scenarios of sulfate aerosol injections in the Southern Hemisphere (SH), Northern Hemisphere (NH), the Tropics and the Arctic. The simulations show that if sulfate aerosol is injected in the SH, the Sahel region could experience an increase in NPP of up to 100% and precipitation of up to 100 mm/month while the Magreb and the Southwestern regions could experience a reduction in NPP of up to 60% and a reduction in precipitation up to 60 mm/month. However, if injections take place in the NH, the Sahel could see reductions in NPP of as much as 60-100%, and precipitation could be reduced by 20-80 mm/month. In the Tropical scenario, some regions could experience a precipitation reduction of up to 1 mm/day during Dec-Feb while in June-Aug some regions could experience an increase, and some a decrease in precipitation. The Arctic scenario during Dec-Feb shows similar results. However, during June-Aug, precipitation could be reduced with as much as 2 mm/day in some regions and there could also be a temperature increase in the Sahel region of 0.5˚C.

In the Sahel region, defined by low and unreliable annual rainfall ranging from 200 to 600 mm/year, over 70% of the population practices agriculture,[4] which accounts for over 40% of the regional GDP.[5] Increases or decreases in precipitation levels could have detrimental effects on the economy and livelihoods of the region. Many countries in the region lack plans for extreme weather events and past events show that rapid changes in weather and climate, including uneven and unreliable rainfall, has led to crop failure and floods.[6] Blasting sulfates into the stratosphere does not reduce CO_2 concentrations; it merely postpones the impact as long as the spraying continues, but can also result in additional climate change.

Policy: In 2010, the UN Convention on Biological Diversity (CBD) adopted decision X/33 – described as a de facto moratorium – requesting governments not to pursue geoengineering as a climate change strategy. Despite this, some scientists and governments continue to consider geoengineering a viable Plan B to slow climate change. African governments may wish to raise this issue during the climate change Summit to be held at the UN in New York September 23 – 24, 2014.

Computer Model Scenario Results: In 2013, a study was published showing the implications sulfate injections could have on NPP and precipitation patterns. Through their model simulation[7] the authors concluded that sulfate injections into the SH could increase precipitation in the **Sahel** region by up to 100 mm/month, but decrease precipitation in the South West by up to 60 mm/month (Figure 1). Similar results were found regarding NPP with an increase in the **Sahel** region by up to 100% but a decrease in the South West by up to 60% and also in the **Magreb** area of up to 20% (Figure 2). Note that **Brazil** could see a decrease in both NPP and precipitation.

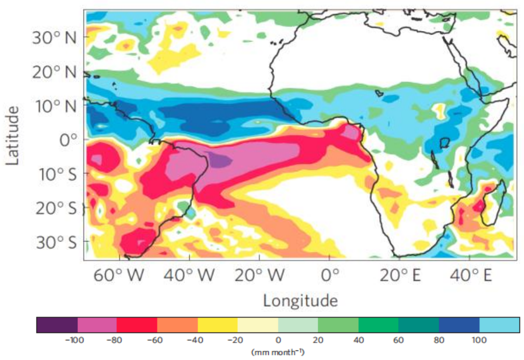

Figure 1. Showing change (color scale) of precipitation, in mm/month in a geoengineering scenario through stratospheric sulfate aerosol injections in the Southern Hemisphere. (Figure from Haywood et al. 2013)

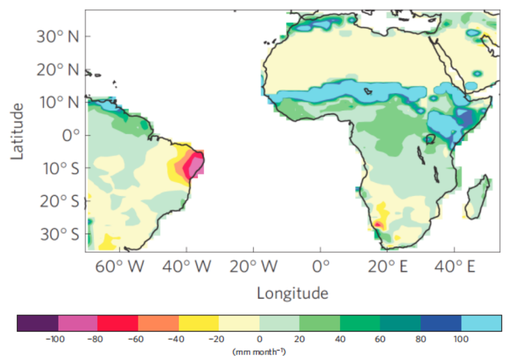

Figure 2. Showing change (color scale) of Net Primary Productivity, in percentage in a geoengineering scenario using stratospheric sulfate aerosol injections in the Southern Hemisphere. (Figure from Haywood et al. 2013)

In a scenario where sulfate is injected into the NH, the **Sahelian** region is subject to reductions in NPP by as much as 60-100% (Figure 3). The precipitation pattern in the region could be affected by a reduction of 20-80mm/month (Figure 4). In this scenario Southern Africa could see increases in both NPP and precipitation.

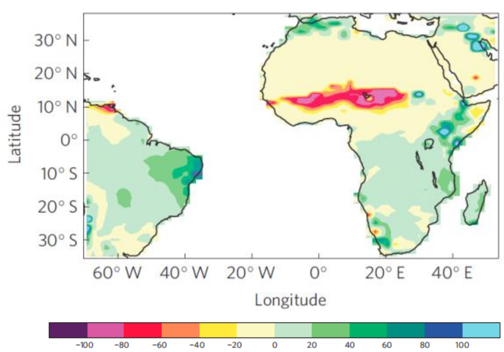

Figure 3. Showing percentage change (color scale) of net primary productivity in a geoengineering scenario in the Northern Hemisphere using stratospheric sulfate aerosol injections. (Figure from Haywood et al. 2013)

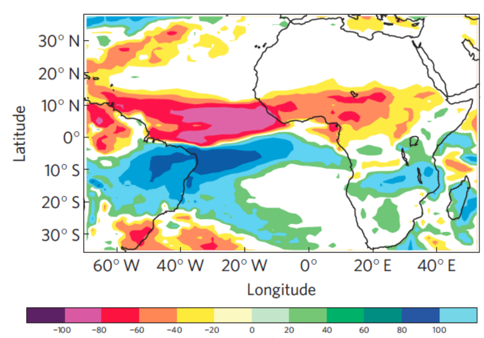

Figure 4. Showing change (color scale) of precipitation, in mm/month in a geoengineering scenario using stratospheric sulfate aerosol injections in the Northern Hemisphere. (Figure from Haywood et al. 2013)

The authors concluded that sulfate injections in the NH could cause **Sahelian** drought through dramatic reductions in NPP and precipitation. Similar results were found through a study published in 2008. Through their two model scenarios[8] with injection of stratospheric sulfate aerosols in the Arctic or in the Tropics, the authors concluded that precipitation could be significantly reduced in the **Sahel** region, as the injections could severely affect the African monsoon (June-Aug). In the Arctic scenario, precipitation could be reduced up to as much as 2 mm/day in the **Sahel** region during June-Aug (Figure 5). In particular, **Mauritania**, **Senegal**, **Guinea**, **Sierra Leone**, **Gambia**, **Guinea-Bissau**, **Mali**, **Burkina Faso**, **Benin**, **Nigeria**, **Niger**, **Chad**, **Sudan**, **Somalia** and **Kenya**. In the Tropical scenario, the results are similar with a reduction of up to 1 mm/day in some regions during June-Aug (Figure 6). In particular **Sudan**, **Chad**, **Niger**, **Nigeria**, **Mali**, **Burkina Faso**, **Benin**, **Ghana**, **Mauritania**, **Senegal**, **Guinea**, **Guinea-Bissau**, **Gambia**, **Sierra Leone**, **Somalia** and **Kenya**. In Dec-Feb during the Arctic scenario **Sudan**, **Ethiopia**, **Central African Republic**, **DR Congo**, **Congo**, **Nigeria**, **Cameroon**, **Kenya**, **Tanzania**, **Zambia**, **Angola**, **Namibia**, **Botswana** and **South**

Africa could experience a reduction in precipitation. On the other hand, **Ethiopia**, **Uganda**, **DR Congo**, **Zambia**, **Angola**, **Namibia**, **Zimbabwe**, **Botswana**, **Mozambique** and **Madagascar** could experience an increase (Figure 7). The Tropical scenario (Dec-Feb) show similar results with a decrease in precipitation in **Sudan**, **Ethiopia**, **Kenya**, **Tanzania**, **Malawi**, **Central African Republic**, **DR Congo**, **Congo**, **Angola**, **Namibia**, **Botswana** and **South Africa** (Figure 8). On the other hand, **DR Congo**, **Zambia**, **Zimbabwe**, **Botswana**, **Mozambique**, **Madagascar**, **Namibia** and **Angola** could see an increase.

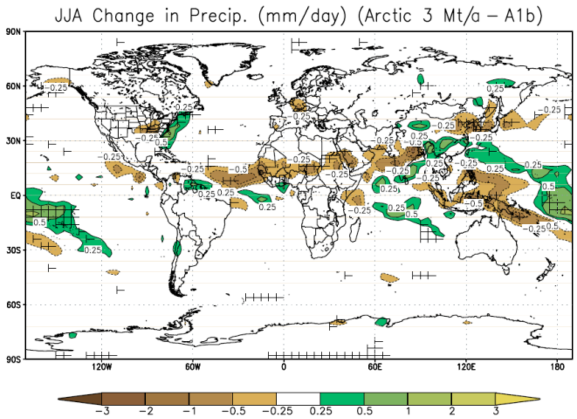

Figure 5. Showing change (color scale) of precipitation, in mm/day in a geoengineering scenario injecting stratospheric sulfate aerosol in the Arctic. The figure shows the change during June-Aug. (Figure from Robock et al, 2008)

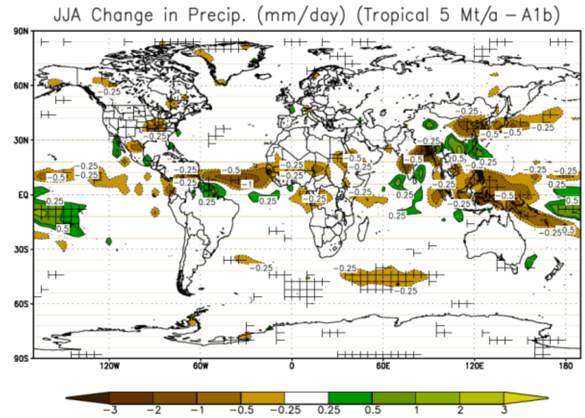

Figure 6. Showing change (color scale) of precipitation, in mm/day in a geoengineering scenario injecting stratospheric sulfate aerosol in the Tropics. The figure shows the change during June-Aug. (Figure from Robock et al, 2008)

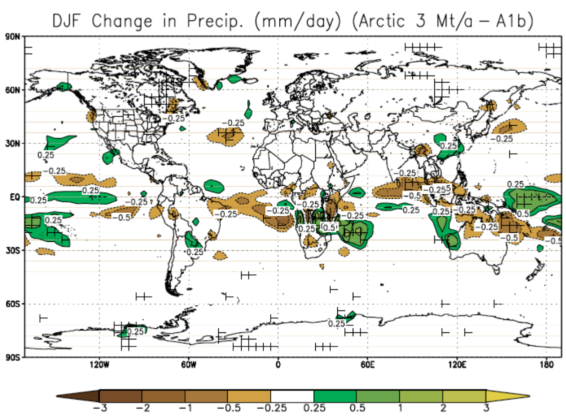

Figure 7. Showing change (color scale) of precipitation, in mm/day in a geoengineering scenario using stratospheric sulfate aerosol injections in the Arctic. The figure shows the change during Dec-Feb. (Figure from Robock et al. 2008)

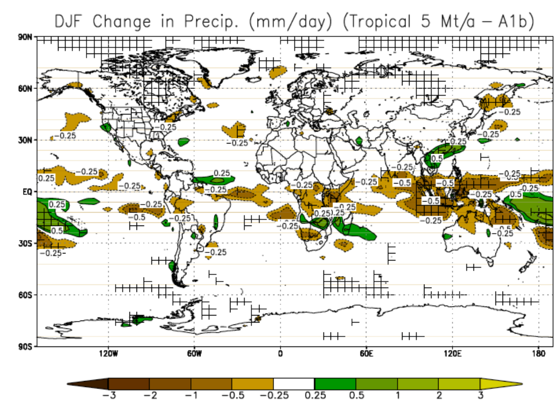

Figure 8. Showing change (color scale) of precipitation, in mm/day in a geoengineering scenario using stratospheric sulfate aerosol injections in the Tropics. The figure shows the change during Dec-Feb. (Figure from Robock et al. 2008)

Volcanic analogies: Stratospheric sulfate aerosol injection mimics volcanic eruptions that lower surface temperature by blowing sulfur into the stratosphere. In 1991 The Philippines Mt. Pinatubo blasted about 20 million tons of sulfur into the stratosphere, leading to a global average reduction in temperature of 0.4˚C. Apart from the temperature decrease major volcanic eruptions also affect precipitation patterns. In the year after the eruption of Mt. Pinatubo a substantial decrease in precipitation, and a record decrease in runoff and river discharge into the ocean was recorded.

This has led scientists to conclude that major adverse effects, including drought could arise from geoengineering by stratospheric sulfate aerosol injection since it would severely affect atmospheric fluxes and the global hydrological cycle. It has been shown that major volcanic eruptions in the Northern Hemisphere have been a harbinger of Sahelian drought in the past.

(Robock et al. 2008; NSF 2010; Trenberth & Dai 2007; Haywood et al. 2013)

The study also showed that in the Arctic scenario, sulfate injections could lead to a temperature increase of up to 0.5 ˚C in the Sahel region during June-Aug. It is worth noting that, with a few exceptions, in both the Arctic and the Tropical scenario, during June-Aug and Dec-Feb there is little to no change in precipitation over **Europe** and **North America**.

Conclusion: Climate change is an anthropogenic phenomenon arising from the unanticipated side effects of rapid technological transformations. Without immediate action to mitigate and adapt to climate change, the impact on the people, the economy and food supply of Africa could prove devastating. Sea levels will rise, crop yields will decline, weather patterns will be erratic and health will be at risk. In this light, geoengineering, specifically – but not exclusively – solar radiation management, can seem an inexpensive and technologically easy and effective interim quick-fix that could postpone change and buy time. But, the quick-fix could be worse than the problem. It is, once again, an anthropogenic techno-fix with potentially powerful side effects. Computer modeling scenarios all identify very real risks. Ultimately, however, perhaps the biggest risk is that developing countries will inevitably have to turn over control of the planetary thermostat to the technologically powerful nations and industries that caused climate change in the first place. Developing countries will be exposed to changes that – by intent – will be more rapid and extreme than is predicted for climate change.

The advocates of sulfate aerosol injection argue that the costs are much less than virtually every other adaptation or mitigation strategy. This is not true. Advocates have only calculated the relatively minor costs of pumping sulfates into the stratosphere. There are huge indirect costs including the damages that will be caused by solar radiation management. The cost will shift from the adaptation and mitigation expenses that should be borne by industrialized countries to become the costs and damages of those who did not cause the problem.

About ETC Group: The Action Group on Erosion Technology and Concentration (ETC Group) is an international non-profit civil society organization established in 1977 with ECOSOC status as well as observer status with many UN agencies including UNFCCC, FAO, CBD, UNEP, and UNCTAD. ETC is headquartered in Canada with regional offices in Africa, Asia, Latin America and USA. ETCs mandate is to monitor economic, environmental and technological developments important to the well-being of marginalized peoples around the world. For further information please go to: www.etcgroup.org. ETC's director for Africa is **Mariann Bassey (mariann@etcgroup.org)**

Acknowledgements: The research and writing process for this briefing was led by Linda Dubec who is a former intern, currently volunteering with ETC Group. She holds a B.Sc. in Environmental Science from Linköping University (Sweden) and a M.Sc. in Human Ecology from Lund University (Sweden).

References:

Haywood, Jim M., Andy Jones, Nicolas Bellouin & David Stephenson. 2013. Asymmetric forcing from stratospheric aerosols impacts Sahelian rainfall. *Nature Climate Change*, 3:660-665.

Kravitz, Ben, Ken Caldeira, Olivier Boucher, Alan Robock, Philip J. Rasch, Kari Alterskjær, Diana Bour Karam, Jason N. S. Cole, Charles L. Curry, James M. Haywood, Peter J. Irvine, Duoying Ji, Andy Jones, Jón Egill Kristjánsson, Daniel J. Lunt, John C. Moore, Ulrike Niemeier, Hauke Schmidt, Michael Schulz, Balwinder Singh, Simone Tilmes, Shingo Watanabe, Shuting Yang, Jin-Ho Yoon. 2013. Climate model response from the Geoengineering Model Intercomparison Project (GeoMIP). *Journal of Geophysical Research: Atmospheres,* vol. 118:8320-8332.

NSF. 2010. *Volcanic Eruptions Affect Rainfall Over Asian Monsoon Region – Some regions drier, others wetter*. Press release 10-209. November 4, 2010. http://www.nsf.gov/news/news_summ.jsp?cntn_id=118023.

Robock, Alan, Luke Oman, and Georgiy L. Stenchikov. 2008. Regional climate responses to geoengineering with tropical and ArcticSO_2 injections, *Journal of Geophysical Research*, vol. 113, D16101.

Trenberth, Kevin E. & Aiguo Dai. 2007. Effects of Mount Pinatubo volcanic eruption on the hydrological cycle as an analog of geoengineering. *Geophysical Research Letters*, vol. 34:L15702.

---

[1] Although there have been many studies using models in attempts to simulate SRM scenarios, in this briefing, the aim has been to pick scenarios that are realistic and that address injection of SO_2 specifically.

[2] Haywood, Jim M., Andy Jones, Nicolas Bellouin & David Stephenson. 2013. Asymmetric forcing from stratospheric aerosols impacts Sahelian rainfall. *Nature Climate Change*, vol. 3:660-665.

[3] Robock, Alan, Luke Oman, and Georgiy L. Stenchikov. 2008. Regional climate responses to geoengineering with tropical and Arctic SO_2 injections, *Journal of Geophysical Research*, vol. 113, D16101.

[4] Ickowicz A., V. Ancey, C. Corniaux, G. Duteurtre, R. Poccard-Chappuis, I. Touré, E. Vall and A. Wane. 2012.Crop–livestock production systems in the Sahel – increasing resilience for adaptation to climate change. In: FAO. 2012. *Building resilience for adaptation to climate change in the agriculture sector,* Proceedings of a Joint FAO/OECD Workshop 23–24 April 2012. http://www.fao.org/docrep/017/i3084e/i3084e.pdf

[5] IRIN. 2008. SAHEL: Backgrounder on the Sahel, West Africa's poorest region. *IRIN News.* 2008-06-02. http://www.irinnews.org/report/78514/sahel-backgrounder-on-the-sahel-west-africa-s-poorest-region

[6] IRIN 2008.

[7] The authors used the HadGEM2-ES climate model to perform two experiments that were variants of the Geoengineering Model Intercomparison Project (GeoMIP) G4 experiment. The level of sulfate aerosol injections in the experiments was 5 Tg SO_2/year.

[8] The authors used the NASA Goddard Institute for Space Studies ModelE atmosphere-ocean GCM (general circulation model) and based their experiments on a 40-year run using IPCCs A1B business-as-usual global warming scenario. The A1B is a scenario forced by greenhouse gases (CO_2, CH_4, N_2O, and O_3) and troposphere aerosols (sulfate, biogenic, and soot). The Arctic scenario is based on an injection of 3 Tg SO_2/year and the Tropical scenario is based on an injection of 5Tg SO_2/year.