MEERTALK

SULFUR AEROSOLS, GLOBAL DIMMING, AND THE RISK OF A WARMING PLANET

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SUMMARY

Earth's energy balance is now greater than 1.6 W/m^s. Between 1960 and 2010, the imbalance was about 0.4 W/m^2, meaning that the rate of warming has been increasing in the last 20 years. During the past two decades, we have also seen a decrease in anthropogenic sulfur emissions coincide with a decrease in albedo and an increase in planetary heat uptake. This trend could accelerate further with more sulfur emissions reductions on the horizon. Unfortunately, a termination shock, defined as a minimum global rise of 0.2C per decade, resulting from these reductions cannot be ruled out.

The culprit for much of this recent rise is a recent policy change initiated by the International Maritime Organization that adjusted the allowed sulfur content in bunker fuels. This resulted in an 80% reduction of sulfur emissions, and while there is large uncertainty of the effect of this reduction on global warming and the low end of the effects wouldn't be measurable, the high end could lead to rapid warming. The IPCC is aware of this uncertainty and has suggested that between 0.2 and 0.9 degrees Celsius of warming may be obscured by sulfur aerosols.

The Northern Pacific and Atlantic Oceans have shown a significant increase in absorbed solar radiation since 2010. While more research is needed, this perfectly coincides with an ongoing reduction in sulfur emissions from shipping. The sheer size of these areas, which are many times larger than the USA, suggests that if there is a signal to be found, it will be visible in those regions.

STUDENT QUESTIONS

Q How much do these sulfur dioxide emissions mix in the atmosphere?

A: The lifetime of sulfur dioxide is only about 7 days, meaning that the effects are much more regional than the effects of long-lived GHGs. That said, large-scale reduction in sulfur dioxide emissions over Europe coincided with a cloud cover reduction off 5% and an increase of annual sunshine of 75 hours per year.

Q Is change in effective radiative force local or a global average?

A: Global. Leon's estimated range varies from very little to 0.5C.

Q Why was there a hiatus of sulfur concentrations in 2002?

A: This was just natural variability.

Q Have you taken into account the fluctuation of additional factors such as the Madden-Julien oscillations?

A: Yes, they have taken many factors into account.

Q Could you clarify what a global reduction in Albedo means?

A: Albedo is the amount of light reflected from the planet. If you have a black surface, albedo is low. If you have a light surface, albedo is high and much light is reflected. You can calculate albedo by dividing the outgoing light by the ingoing light, as a percentage. Albedo has decreased by about 0.5%, which is very significant in practical terms.

Q [From Dr. Tao] Could we achieve a better distribution of global sulfur particles? For example requiring different sulfur content in vessels in the southern oceans or planes?

A: If particles are emitted higher in the atmosphere you will see warming rather than cooling. The effect will be especially strong in regions with low cloud formation and less aerosols from natural sources. There is a modeling study on altering fuel policy in less populated areas. Policy will be more responsive when more data are available. There is currently far too little understanding, and it might not be effective to campaign for this when there are so many other measures, particularly given the environmental and public health concerns of sulfur pollution.

AUDIENCE QUESTIONS

Q What is the source of anthropogenic sulfur dioxide emissions?

A: Oil derived from fossil fuels, particularly bunker fuel from maritime vessels, which is basically a tar and has an extremely high sulfur content of 3.5%. After the sulfur is burned, it reacts with oxygen to become sulfur dioxide and can reflect light directly, or lead to cloud formation and reflect light that way.

Q Was the shipping reduction in 2020 from a reduction in demand?

A: Somewhat. People at home also ordered things, leading to much more demand from container ships (even if demand for cruise ships fell). This effect on the climate was negligible compared to the sulfur content change, however.

Q Is it correct that you have to remove 20 times as much CO2 from the atmosphere than you have to put sulfur in the air as discussed in the book "Termination Shock"?

A: Sulfur has a much shorter residence time in the atmosphere. We don't exactly know how much cooling sulfur causes, but we do know how much warming CO2 causes, which in any case stays in the atmosphere for millennia. It is challenging to compare the two since their atmospheric residence times are very different.

Q If so much more warming is due to the scrubbing of aerosols from shipping containers, why did policy makers permit that to happen? Were they just unaware of the unintended consequences?

A: In general, negative forcing agents are not really the focus of policy or even scientific discussions. That is one of the purposes for MEERTALK, to shine a light on these forcing agents. Policy makers are likely not aware of the climate impacts to the same extent as the health impacts on the population.

Q Does the Increased evaporation over the ocean have an effect on reflecting sunlight?

A: This is very uncertain as well. Increasing evaporation increases water vapor in the atmosphere, but that rains out. If there are fewer aerosols to condensate on, there will be less condensation. Less water vapor doesn't necessarily mean that clouds have increased. Over time, as temperature of the atmosphere increases it can contain more water content.

AUDIENCE QUESTIONS (CONT.)

Q [Question for Dr. Tao] What is the desired cooling effect required to bring the earth into a sustainable state? How many mirrors are needed to bring this in? How much will this cost? What is the implementation strategy?

A: First we must define a sustainable state. Dr. Tao defines as the point once earth's energy imbalance goes to zero, meaning that there is no additional heat coming into the system. There will still be internal equilibration at this point, but from a black box perspective, we will enter a more sustainable or steady state. The earth is currently at a radiative imbalance of about 1.3 W/m^2. That means that on average, every square meter is being heated by that amount. In the best-case scenario, we are hoping to implement mirrors over 10-20% of global cropland to rectify the imbalance.

Q When you have smaller sulfur particles, and therefore smaller water droplet clouds, will those clouds reflect more incoming sulfur radiation?

A: Yes, we don't know the exact number, but research shows that the cumulative cooling effect of sulfur is about half of a degree Celsius. About 20% of this is caused by direct reflection of the particles, and 80% of that is caused by the effect on cloud formation; Bigger clouds, which are whiter, reflect more light to space, leading to a cooling effect.