Climate Impact of Decreasing Atmospheric Sulphate Aerosols and the Risk of a Termination Shock

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Significant reduction in atmospheric sulphate aerosols contributes to albedo reduction, acceleration in Earth’s Heating Rate and could cause an aerosol termination shock.
A large part of the planet is covered by oceans.
Most Earth Heat Gain warms oceans water
Sulphur emissions from shipping are reduced with ~80% from 2020
Regulation of the International Maritime Organization (IMO) significantly reduces sulfur emissions over seas and oceans, both over Emissions Control Areas and globally.
Models show large uncertainties in the effect of the ~80% reduction in global shipping. The low end would not be measurable and the high end could result in rapid warming.
### IMO 2020 ERF (W/m²)

<table>
<thead>
<tr>
<th>Model Estimates</th>
<th>ERF (W/m²)</th>
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</thead>
<tbody>
<tr>
<td>LAURER ET AL. (2007) A</td>
<td>0.36</td>
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<tr>
<td>LAURER ET AL. (2007) B</td>
<td>0.11</td>
</tr>
<tr>
<td>LAURER ET AL. (2007) C</td>
<td>0.26</td>
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<tr>
<td>PARTANEN ET AL. (2013) 2.5% SO4</td>
<td>0.33</td>
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<tr>
<td>PARTANEN ET AL. (2013) 4.5% SO4</td>
<td>0.56</td>
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<tr>
<td>SOEFFVET AL. (2018)</td>
<td>0.071</td>
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<tr>
<td>JIN ET AL. (2018)</td>
<td>0.185</td>
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<tr>
<td>JIN ET AL. (2018) (DMS/2)</td>
<td>0.416</td>
</tr>
<tr>
<td>BILSBACK ET AL. (2020)</td>
<td>0.037</td>
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<tr>
<td>AVERAGE</td>
<td>0.193</td>
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</tbody>
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**Fig. 4.** 5yr mean of effective radiative forcing compared to no-ships in simulations (a) ships-2019, (b) geo-wide and (c) ships-2020.
The past two decades saw an albedo decrease and an increase in planetary heat uptake, coinciding with a decrease in anthropogenic sulfur emissions.

This trend could accelerate further with more sulfur emission reductions and an aerosol termination shock whereby rapid anthropogenic aerosol emission reductions cause rapid global warming, can not be excluded.
The North Pacific and Atlantic Oceans show dense shipping traffic and are expected to show effects of sulfur reductions.
The North Pacific Ocean and North Atlantic Oceans show a significant increase in Absorbed Solar Radiation since 2010, coinciding with reduction in sulfur emissions from shipping.
The Global Net Flux has increased significantly in the past 20 years.
Cause:
- Powerfull sulfur mitigation policy
- Low sulphur fuel & scrubbers available
- Significant cooling of SOx aerosol source

Process:
- Compliance with low sulfur fuel and scrubbers
- SOx reduction causing considerable net warming

Effect:
- Termination shock!
Thank you

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Annexures

- Drivers of global warming
- Compliance to shipping emission control regulations
- Increase in Earth net heat uptake
- European SO2 emission decrease from 1980s
- Aerosol termination shock
Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling.
Compliance to shipping emission control regulations

Inspections of compliance, low sulfur fuel sales and scrubber installations indicate strong compliance to sulphur fuel regulations.

IMO’s 2020 fuel sulfur limit

2020 sulfur limit: 0.5% maximum allowable sulfur content or alternative compliance technology

Scrubbers uptake in 2019 was four times higher than in the previous year
Increase in Earth net heat uptake

Absorbed Solar Radiation + Emitted Thermal Radiation = Net Heat Uptake

(2002/09–2020/03)

Loeb et al. 2021
European SO2 decrease from 1980s

Large scale reduction in SO2 emissions over Europe coincided with a cloud cover reduction of ~5% and an increase of annual sunshine hours of ~75 hours per year.
The term termination shock is generally used to describe effects from sudden abruption of intentional Solar Radiation Management (SRM) such as stratospheric aerosol injections. Past and current anthropogenic SOx emissions could be classified as unintentional SRM and rapid abruption could cause a similar thermal shock. Research suggests a threshold at 0.2°C of warming per decade.

Parket et al. (2018) showed that for a termination shock to occur, ramp down of emissions need to be sudden, which would require the will and power to stop SRM globally. The rapid reduction of SOx emissions from global shipping could prove unintentional abrupt cessation of SRM. If the higher range ERF effects of IMO 2020 are a reality, this could be quantified as a termination shock, even more so when combined with other SOx reduction effects.