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

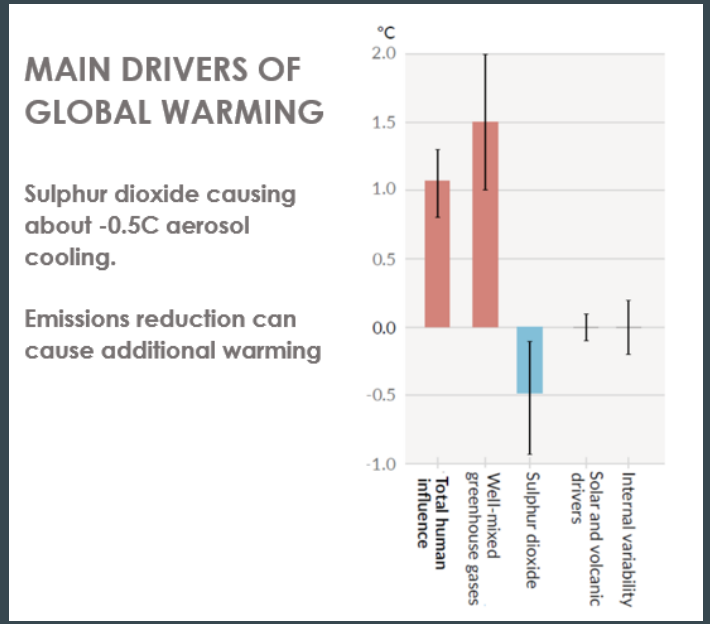
Leon Simons, James E. Hansen and Yann duFournet

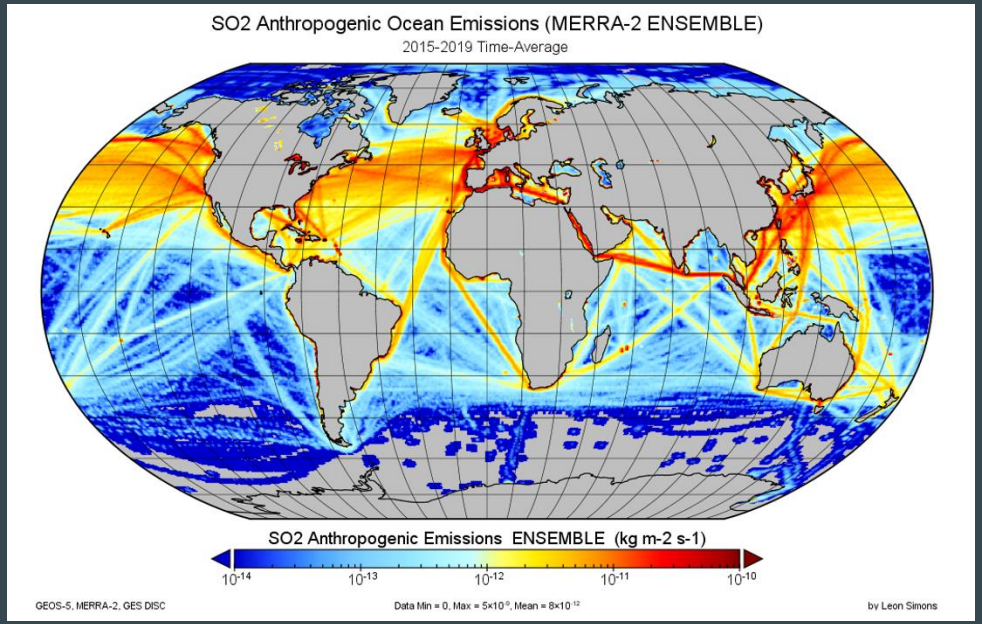
Correspondence: info@clubofrome.nl

Annual Aerosol Science Conference 2021

The Netherlands Association

Significant reduction in atmospheric sulphate aerosols contributes to albedo reduction, acceleration in Earth's Heating Rate and could cause an aerosol termination shock.

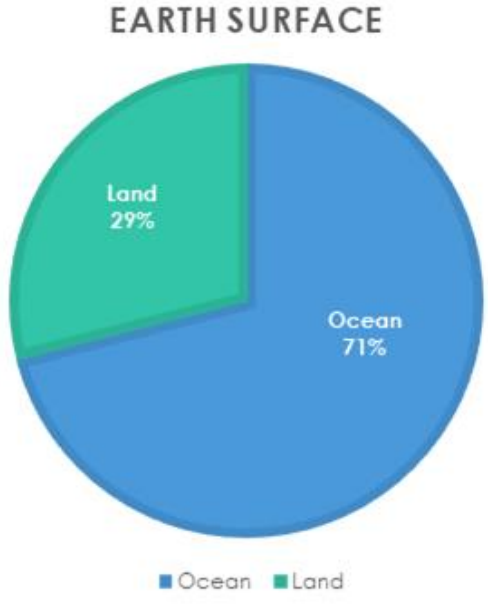


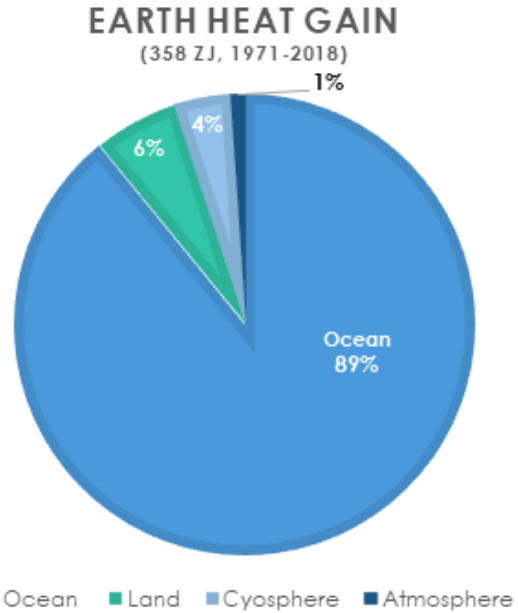


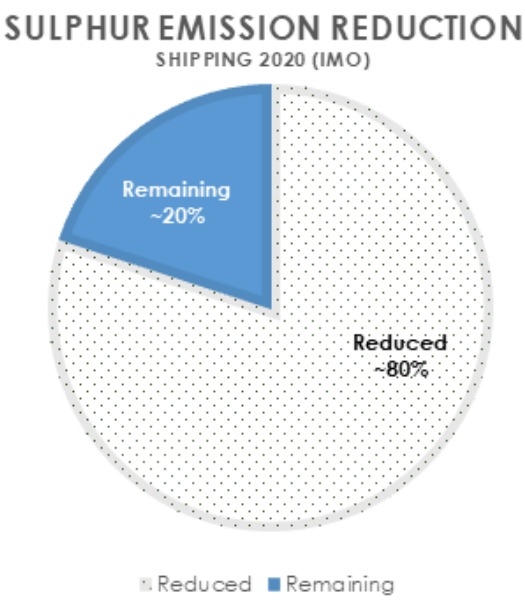
A large part of the planet is covered by oceans.

Most Earth Heat Gain warms oceans water

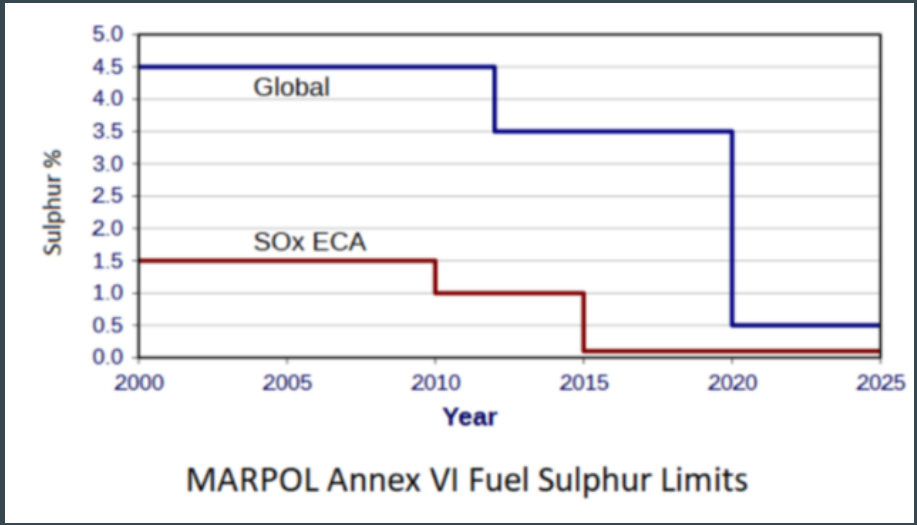
Sulphur emissions from shipping are reduced with ~80% from 2020

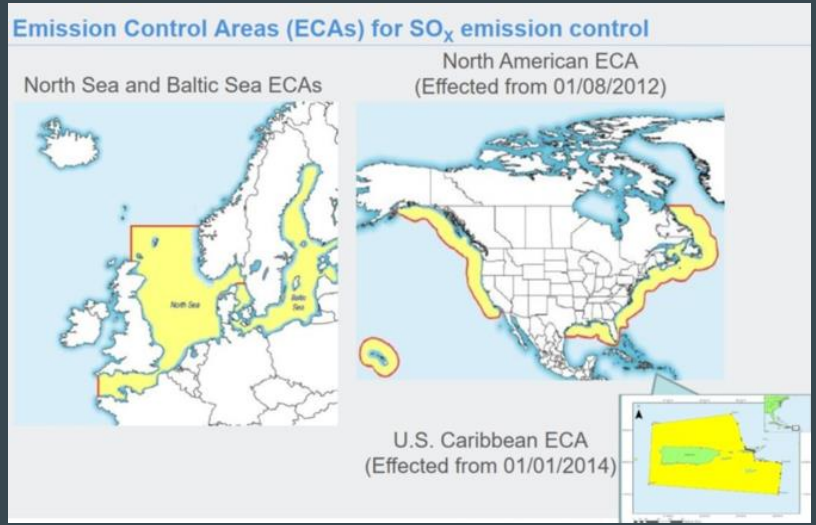




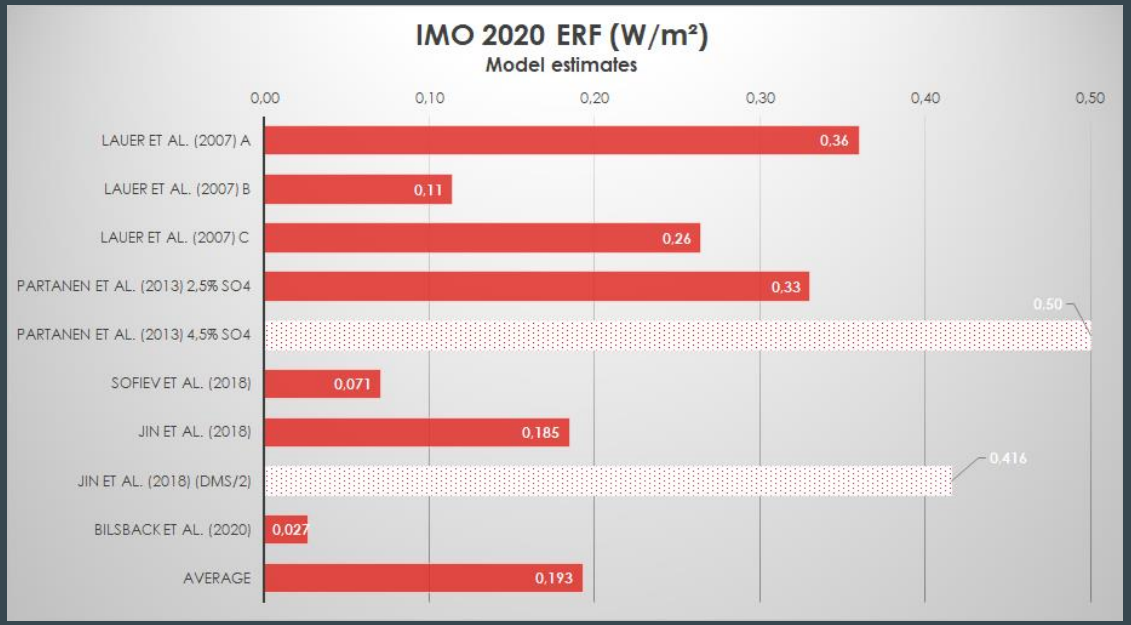


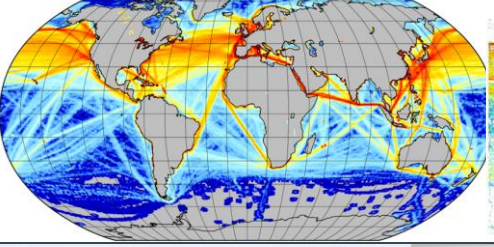
Regulation of the International Maritime Organization (IMO) significantly reduces sulfur emissions over seas and oceans, both over Emissions Control Areas and globally

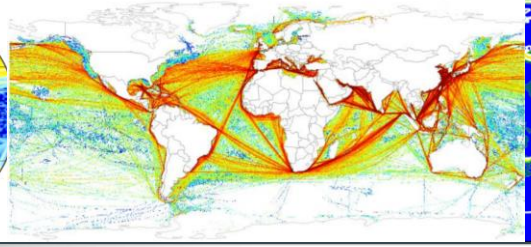


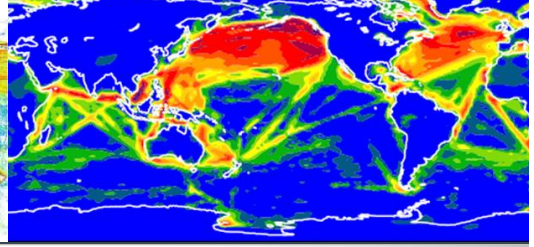


Models show large uncertainties in the effect of the ~80% reduction in global shipping. The low end would not be measurable and the high end could result in rapid warming









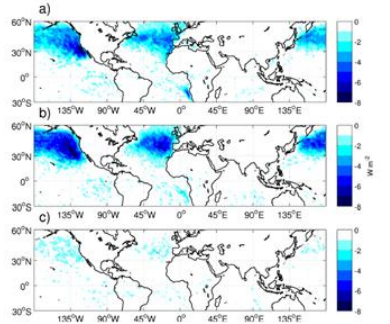
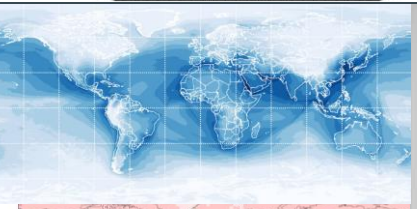
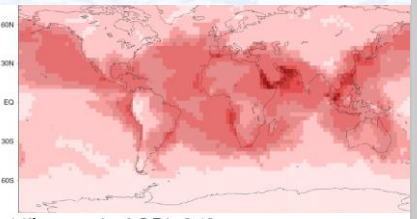
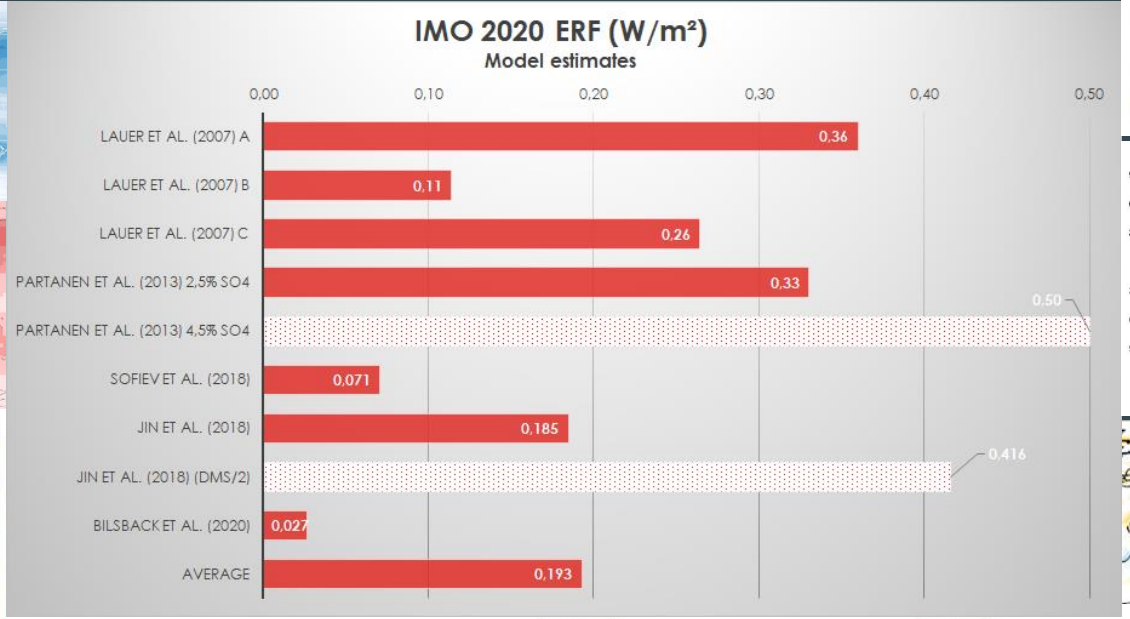
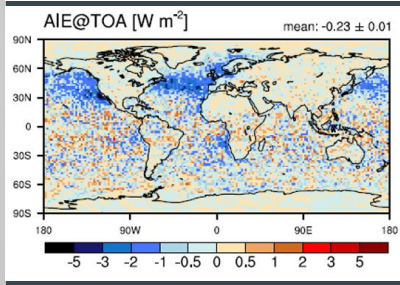


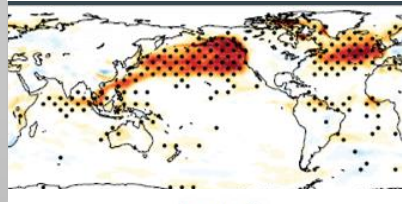
Fig. 4. 5 yr mean of effective radiative forcing compared to no-ships in simulations **(a)** ships-2010, **(b)** geo-wide and **(c)** ships-2020.

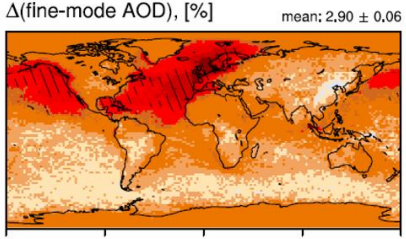


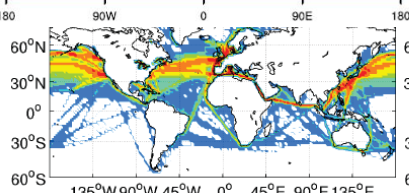




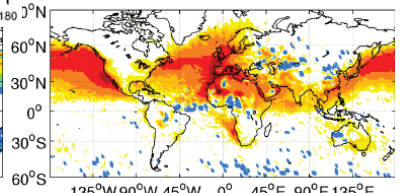


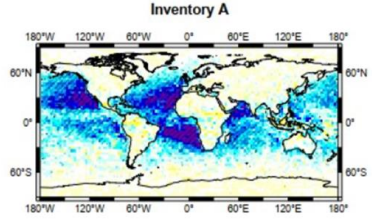


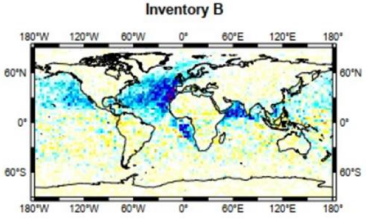


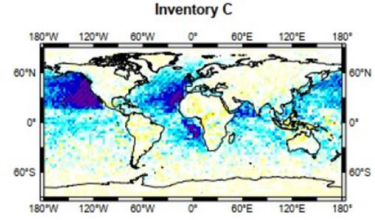


b)



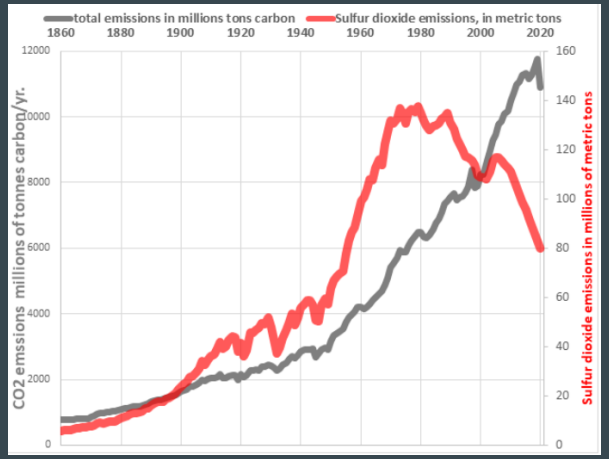




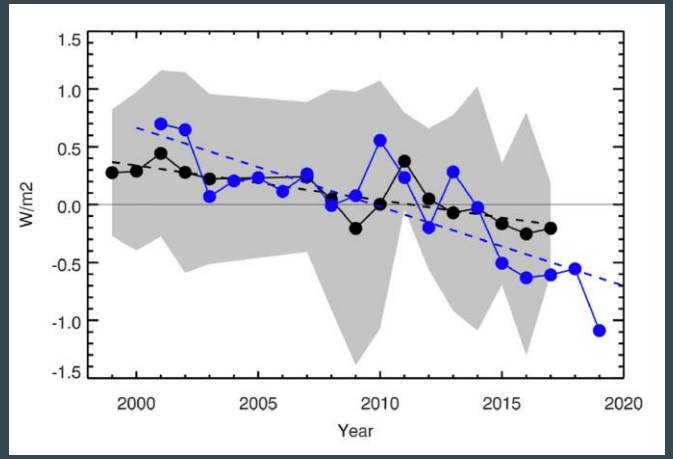


The past two decades saw an albedo decrease and an increase in planetary heat uptake, coinciding with a decrease in anthropogenic sulfur emissions.

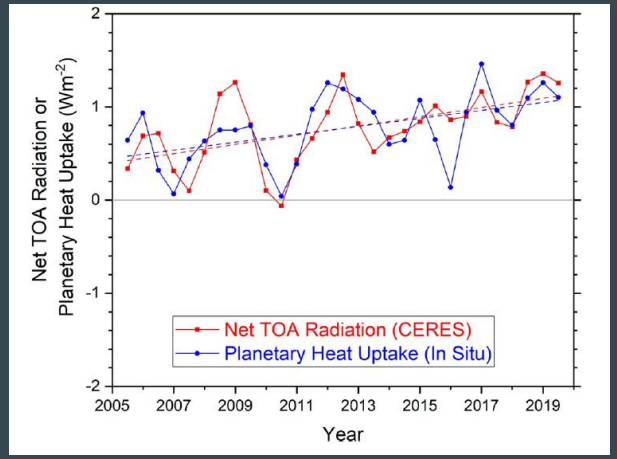
This trend could accelerate further with more sulfur emission reductions and an aerosol termination shock whereby rapid anthropogenic aerosol emission reductions cause rapid global warming, can not be excluded



Sulphur dioxide emission reductions

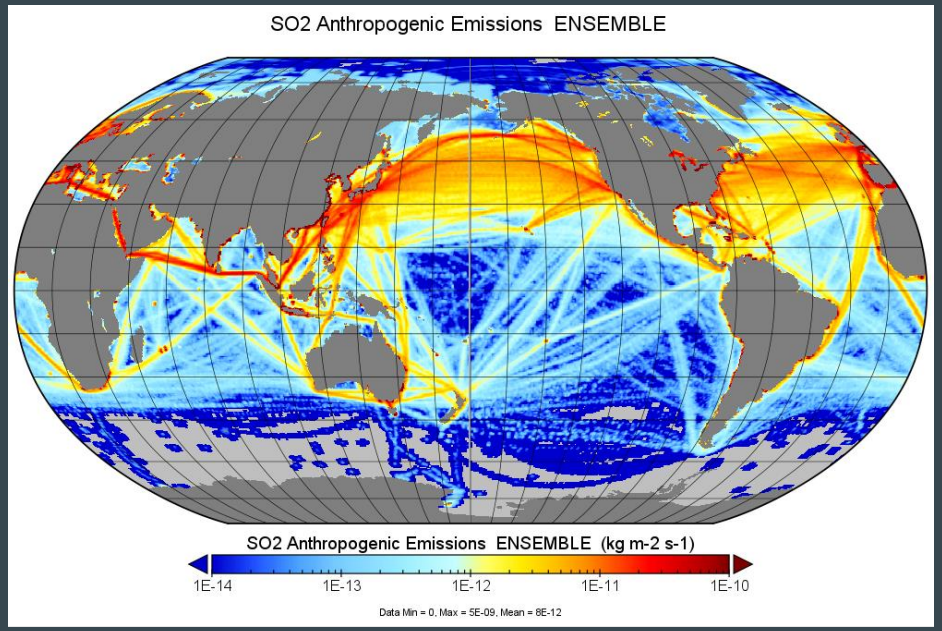


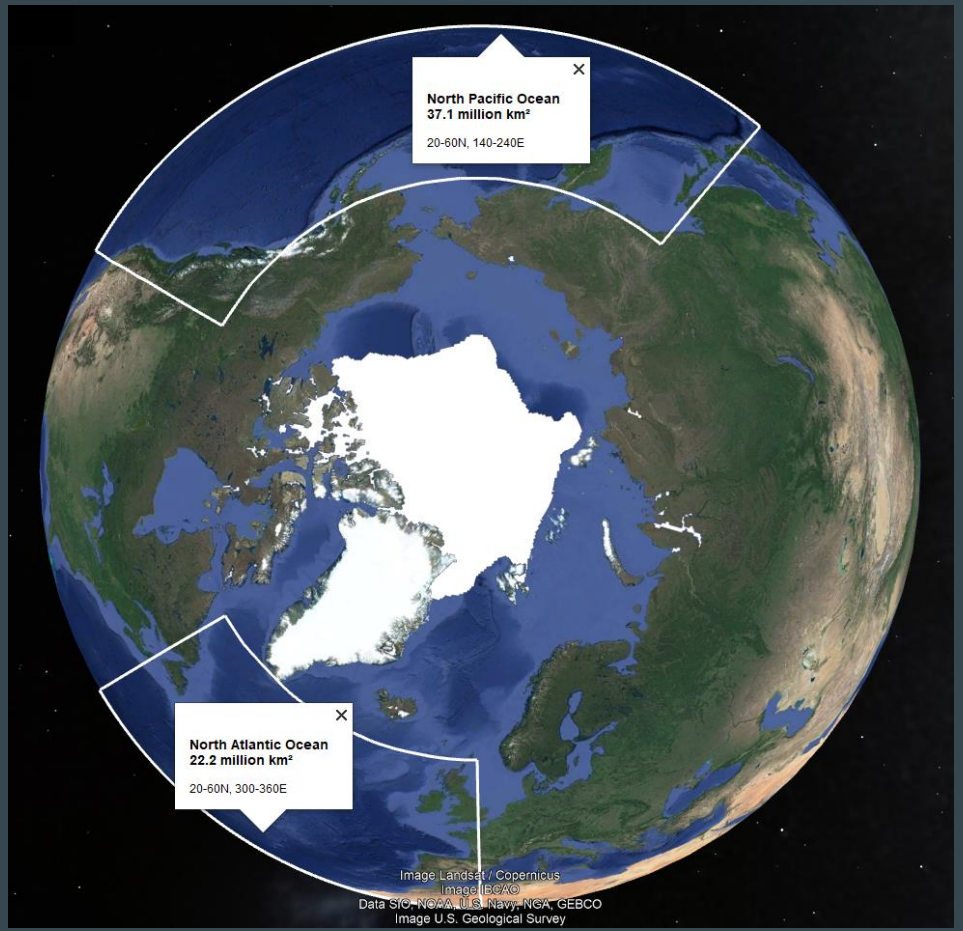
Earth albedo decrease



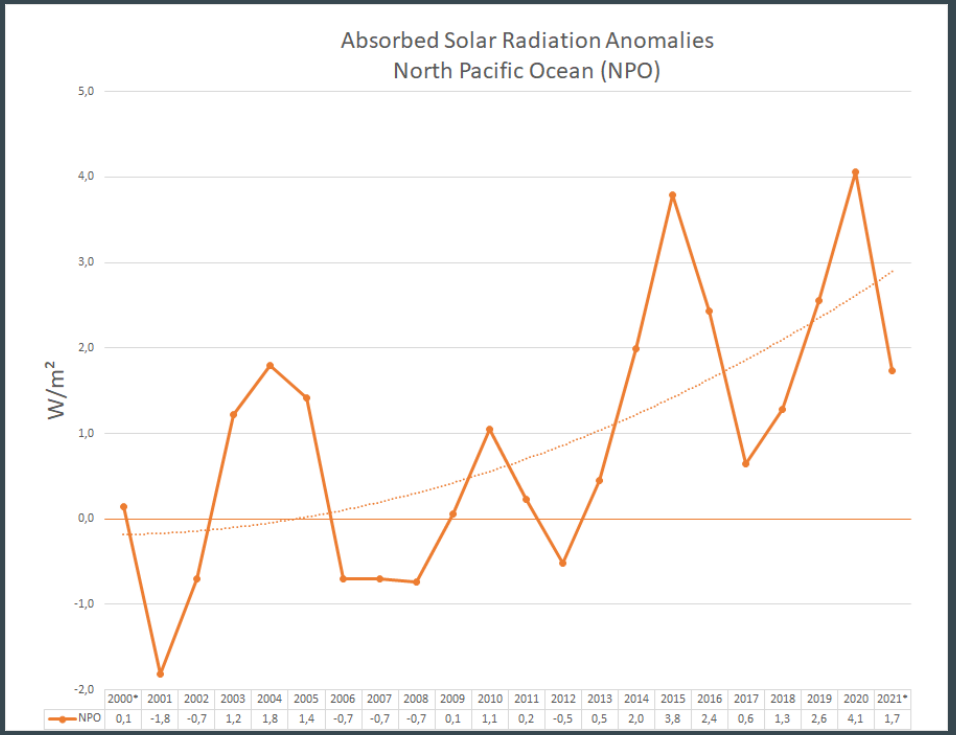
Planetary Heat Uptake rate increase

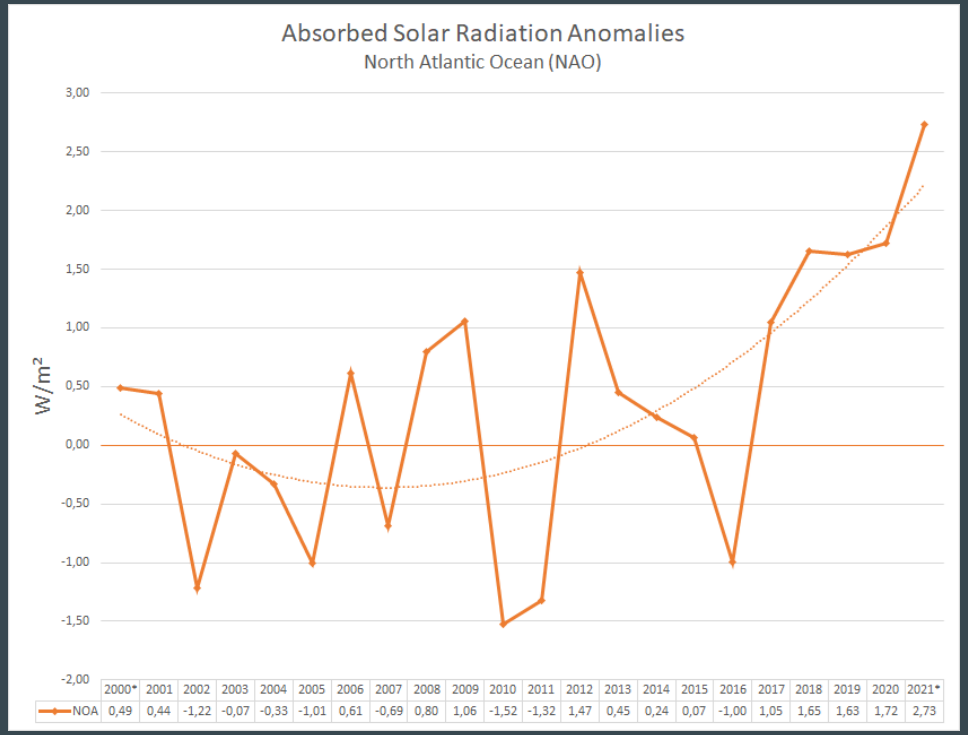
The North Pacific and Atlantic Oceans show dense shipping traffic and are expected to show effects of sulfur reductions.



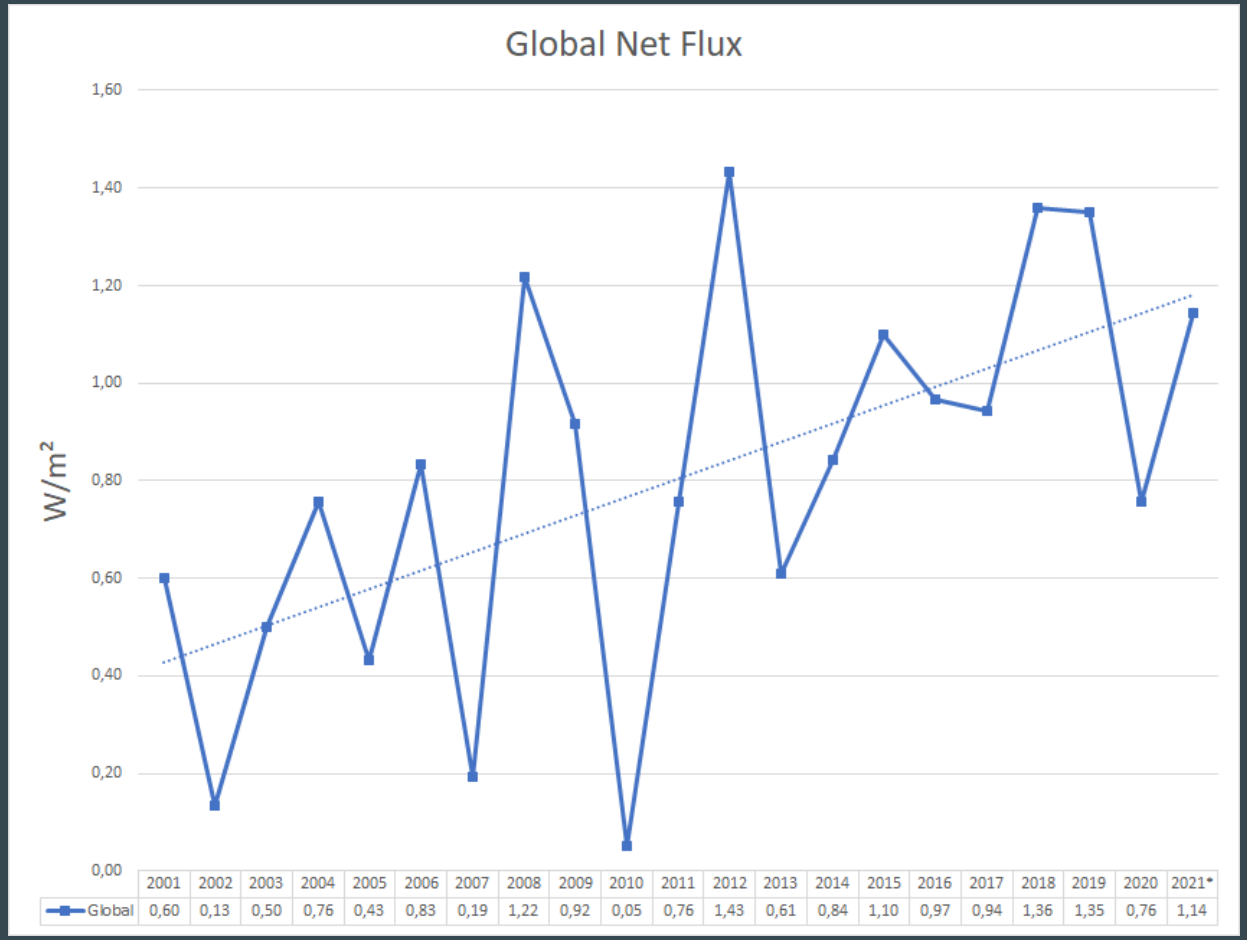


The North Pacific Ocean and North Atlantic Oceans show a significant increase in Absorbed Solar Radiation since 2010, coinciding with reduction in sulfur emissions from shipping.

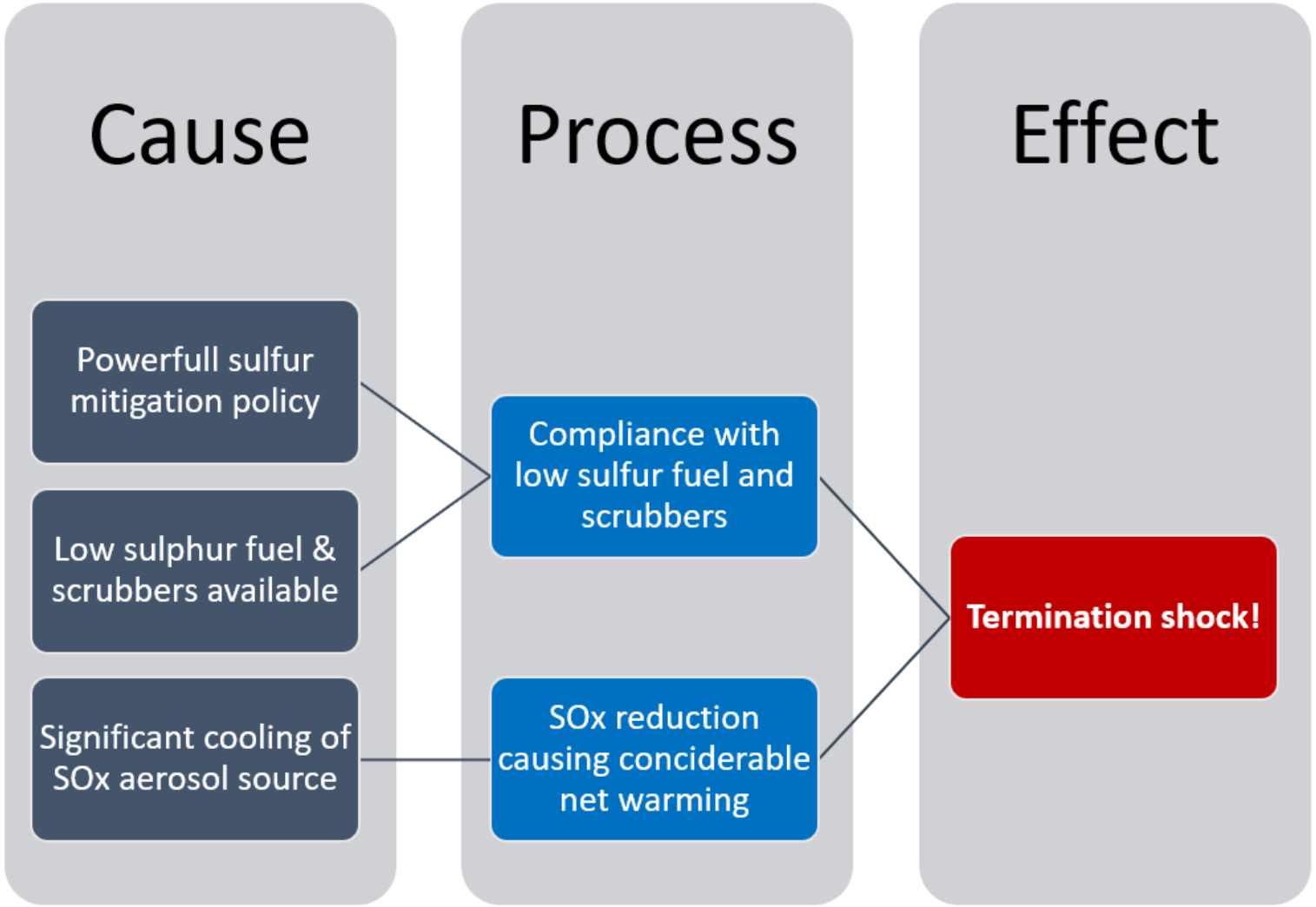




The Global Net Flux has increased significantly in the past 20 years



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021*
Global	0,60	0,13	0,50	0,76	0,43	0,83	0,19	1,22	0,92	0,05	0,76	1,43	0,61	0,84	1,10	0,97	0,94	1,36	1,35	0,76	1,14


Cause
Process
Effect
Powerfull sulfur mitigation policy
Low sulphur fuel & scrubbers available
Significant cooling of SOx aerosol source
Compliance with low sulfur fuel and scrubbers
SOx reduction causing conciderable net warming
Termination shock!

Thank you

Leon Simons, James E. Hansen and Yann duFournet

Correspondence: info@clubofrome.nl

Annual Aerosol Science Conference 2021

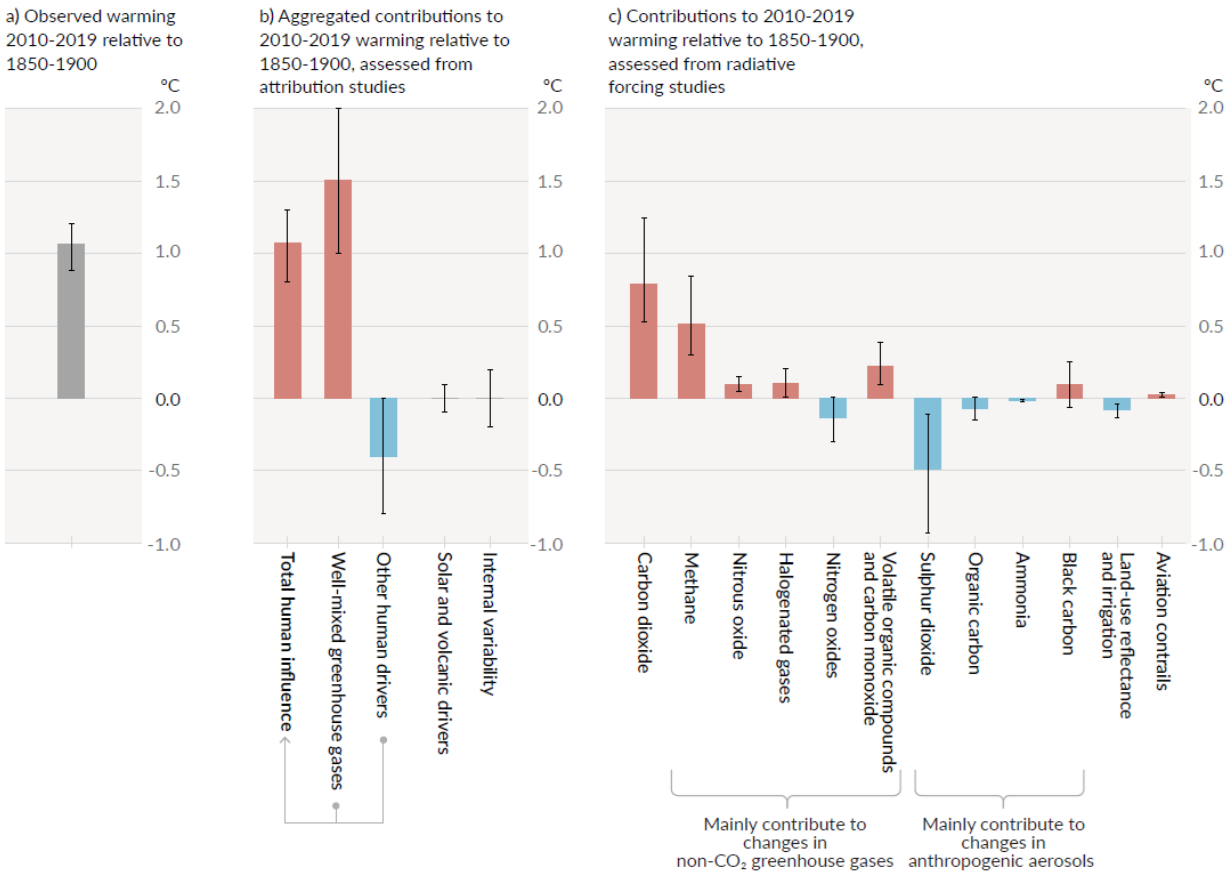
Annexures

- 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

Observed warming

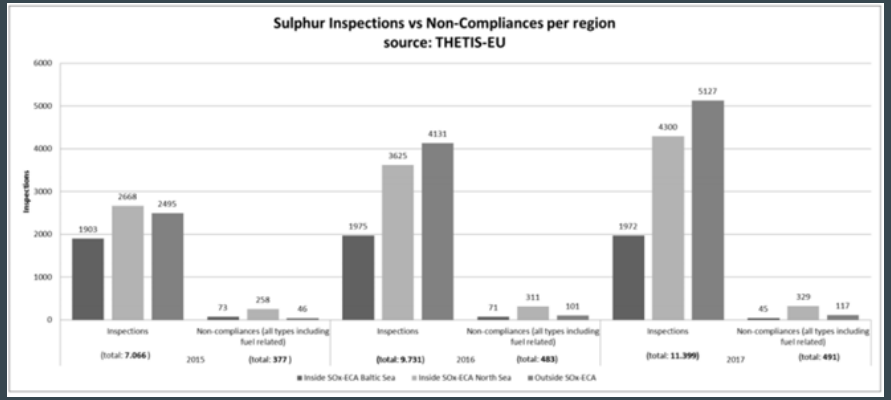
Contributions to warming based on two complementary approaches

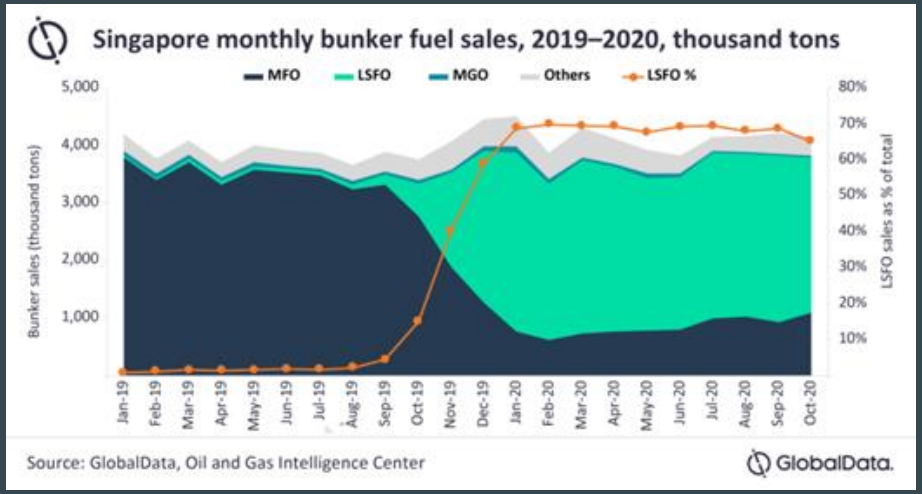


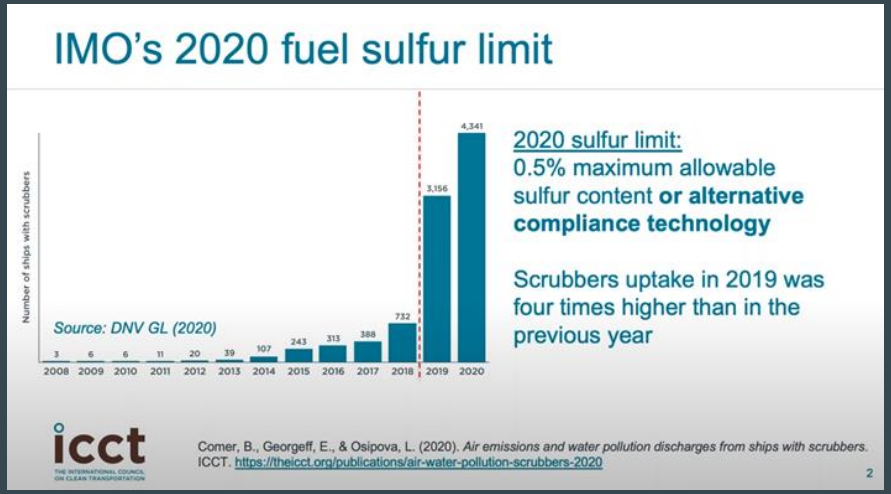
IPCC AR6 WG1 SPM.2

Compliance to shipping emission control regulations

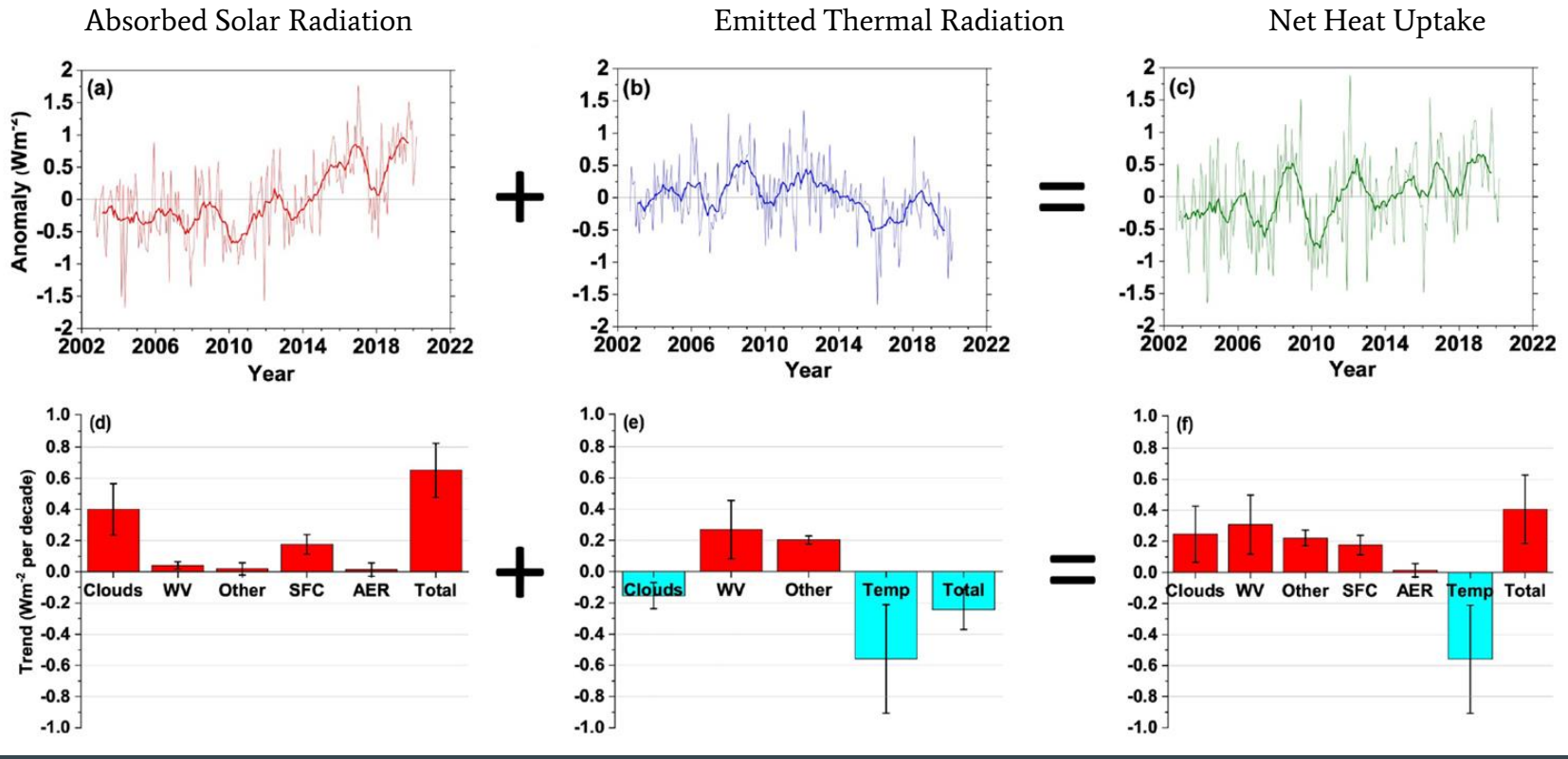
Inspections of compliance, low sulfur fuel sales and scrubber installations indicate strong compliance to sulphur fuel regulations.







Increase in Earth net heat uptake

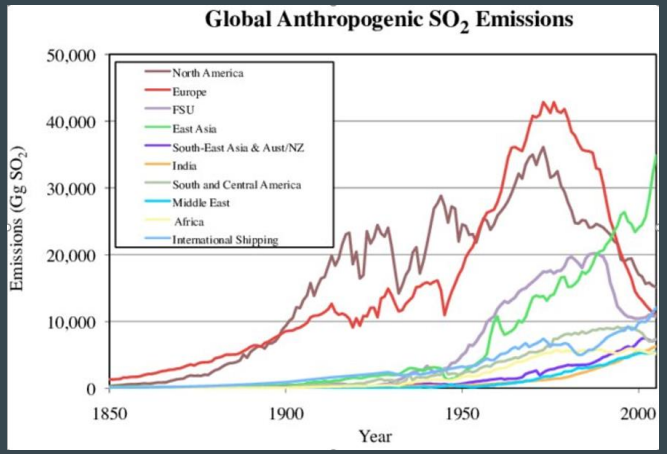


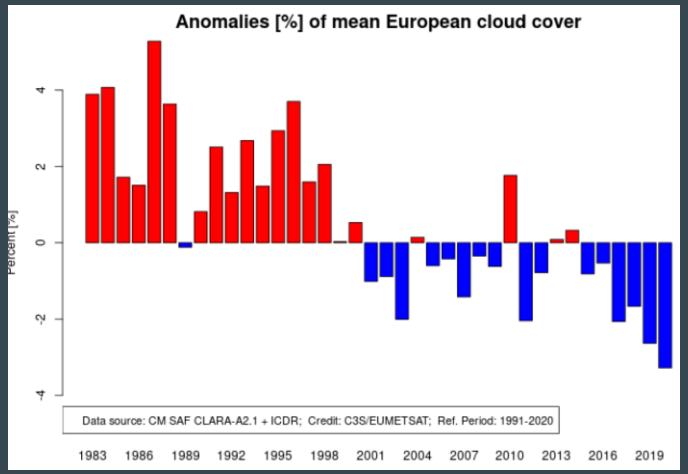
(2002/09–2020/03)

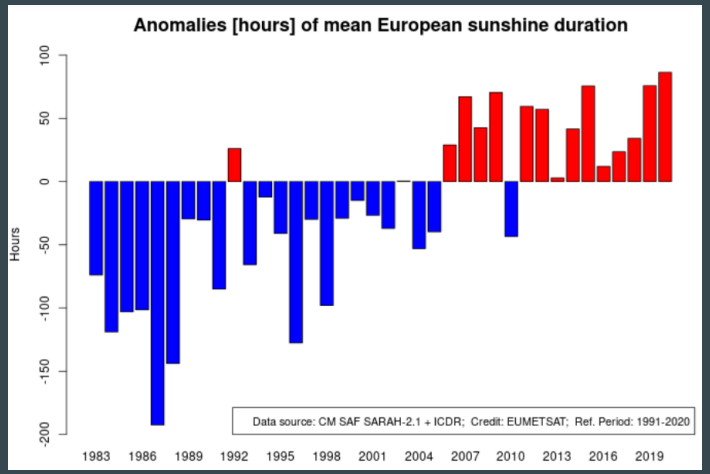
Loeb et al. 2021

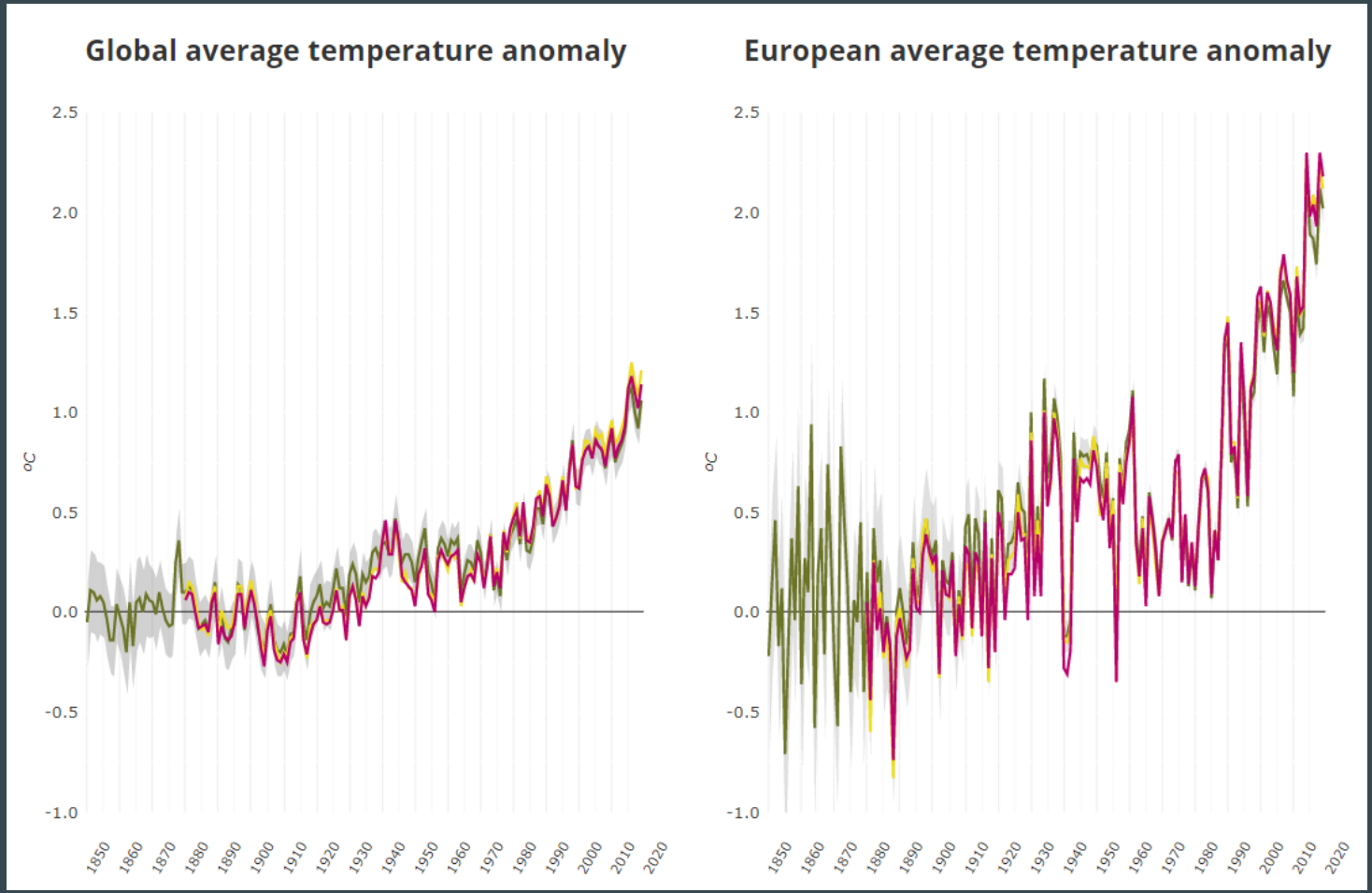
European SO2 decrease from 1980s

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.





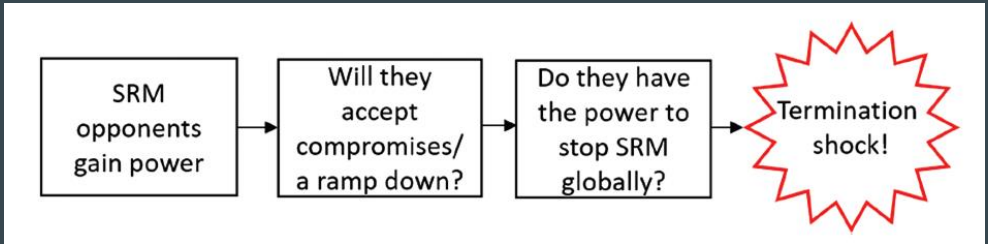



Global average temperature anomaly
°C
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
European average temperature anomaly
°C
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020

Aerosol termination shock

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.



Parket et al. (2018)