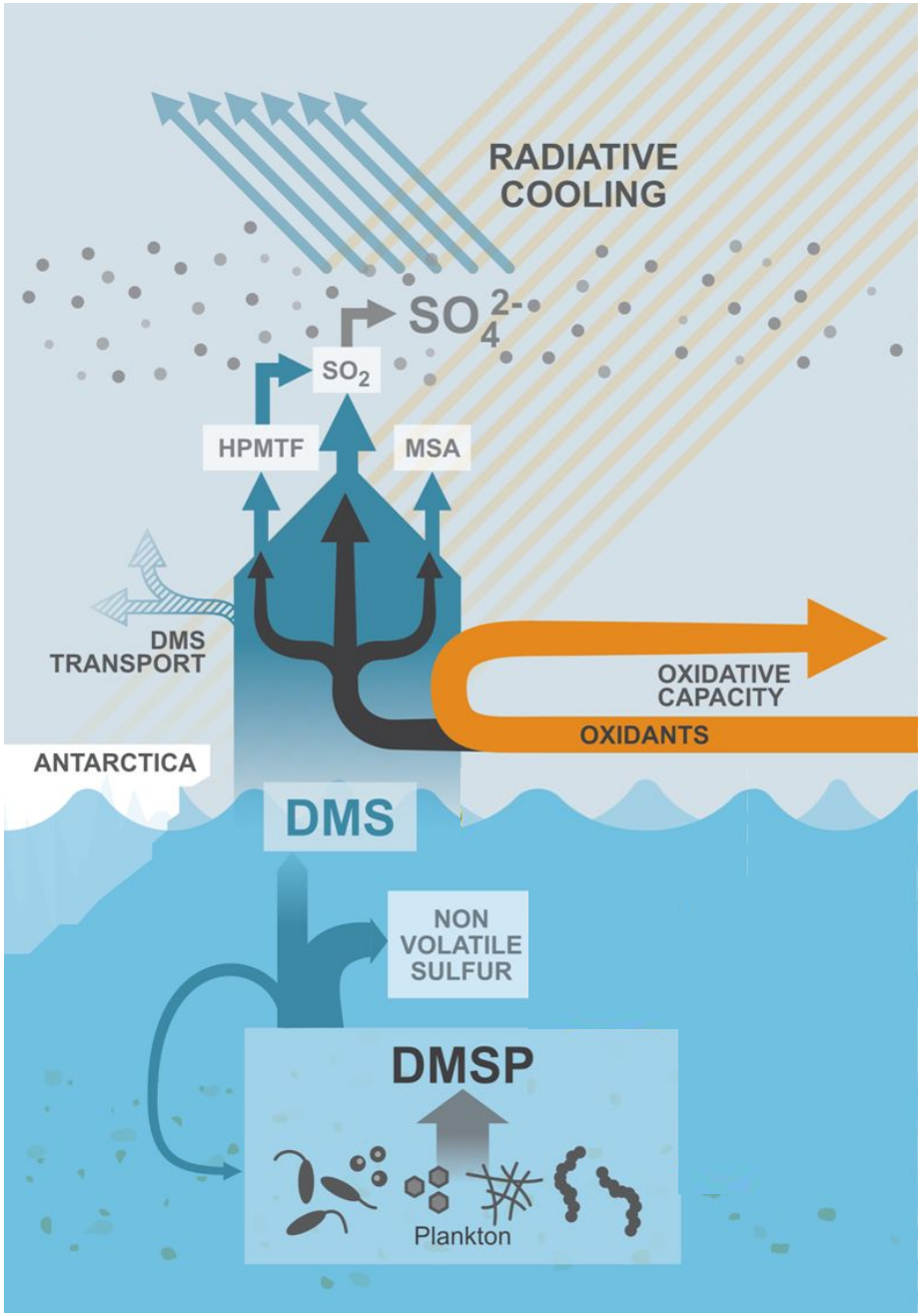
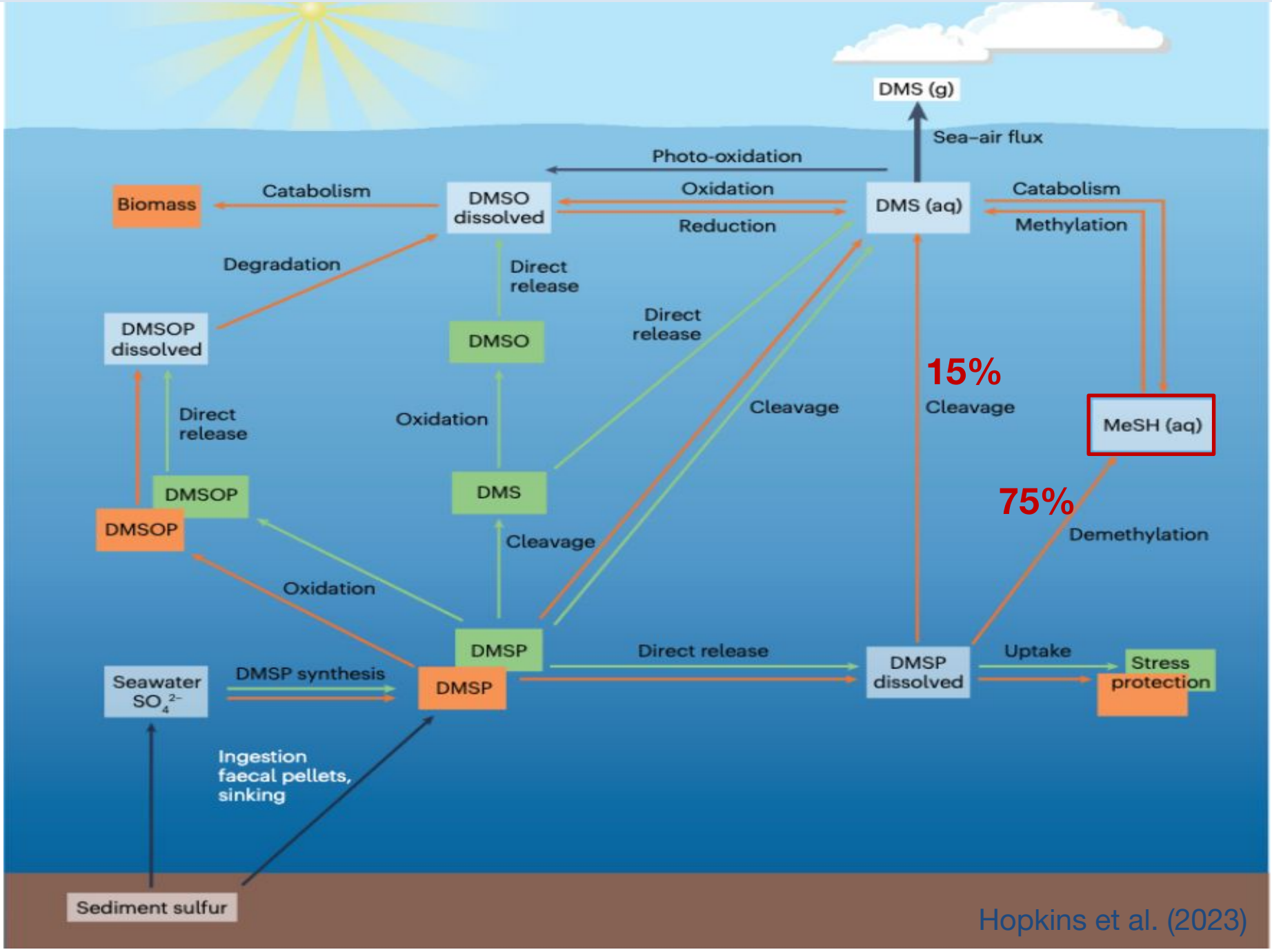
Marine emissions of methanethiol increase aerosol cooling in the Southern Ocean

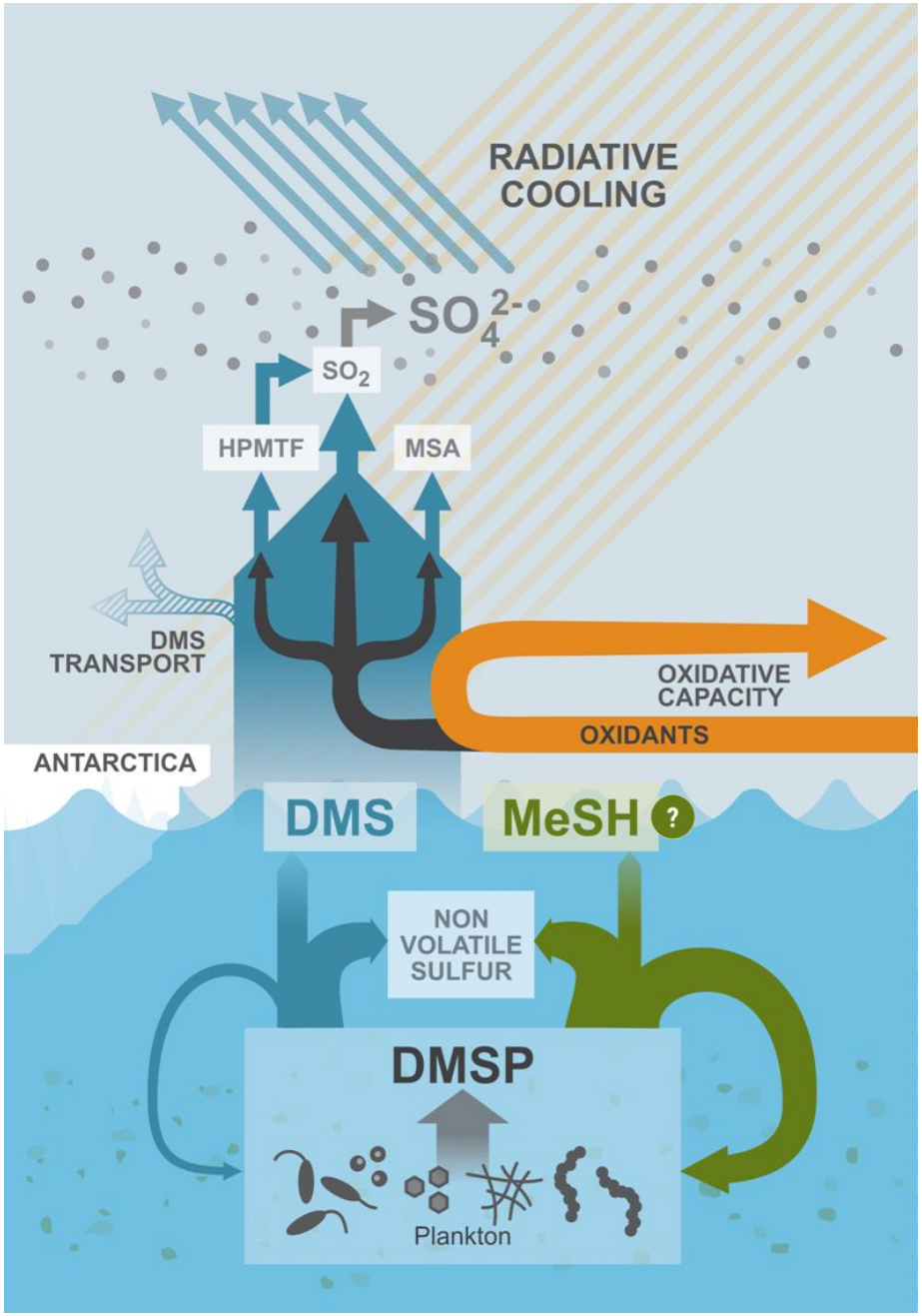
Julián Villamayor*, Charel Wohl*, Martí Galí*, Anoop S. Mahajan, Rafael P. Fernández, Carlos A. Cuevas, Adriana Bossolasco, Qinyi Li, Anthony J. Kettle, Tara Williams, Roland Sarda-Esteve, Valérie Gros, Rafel Simó* and Alfonso Saiz-Lopez*



Wohl, Villamayor, Gali et al. (2024)



Hopkins et al. (2023)



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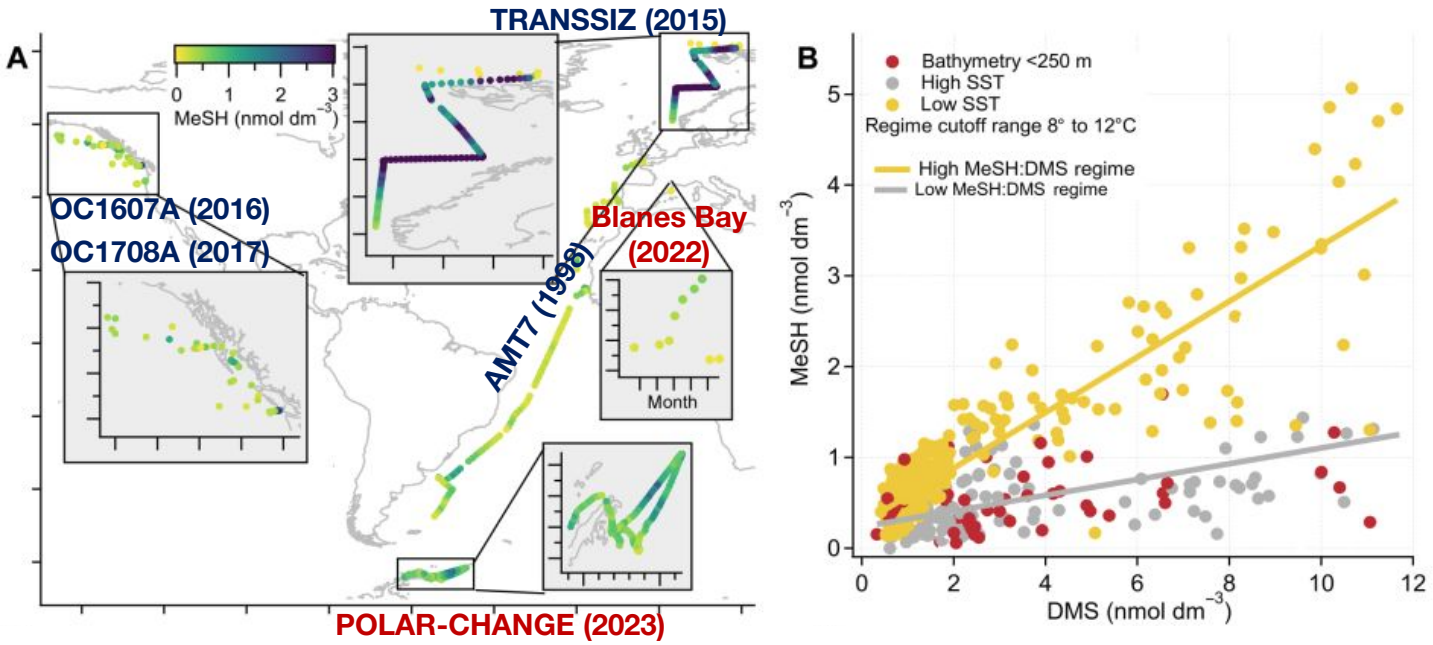
2. Results: MeSH flux



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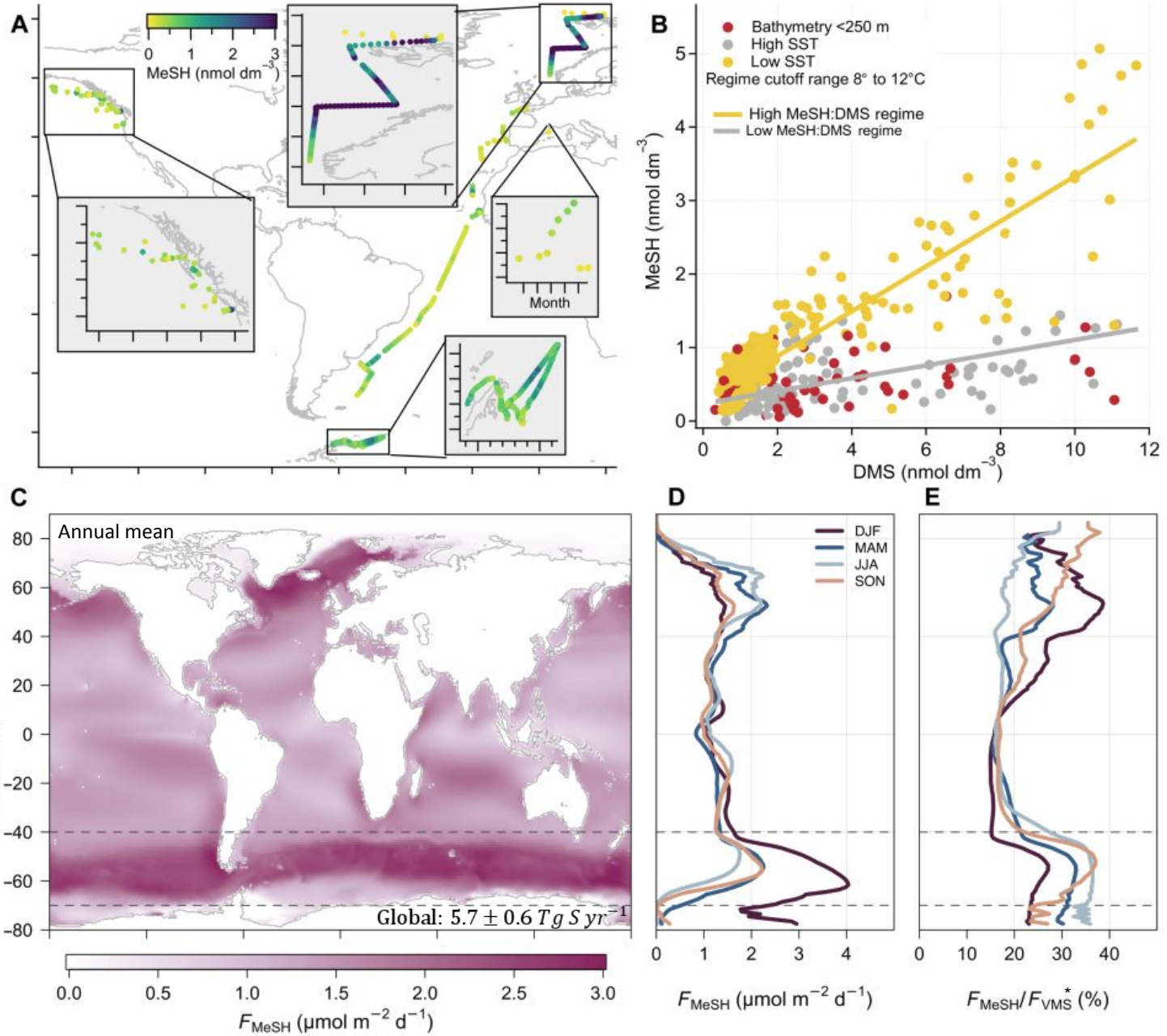
2. Results: MeSH flux

MeSH flux



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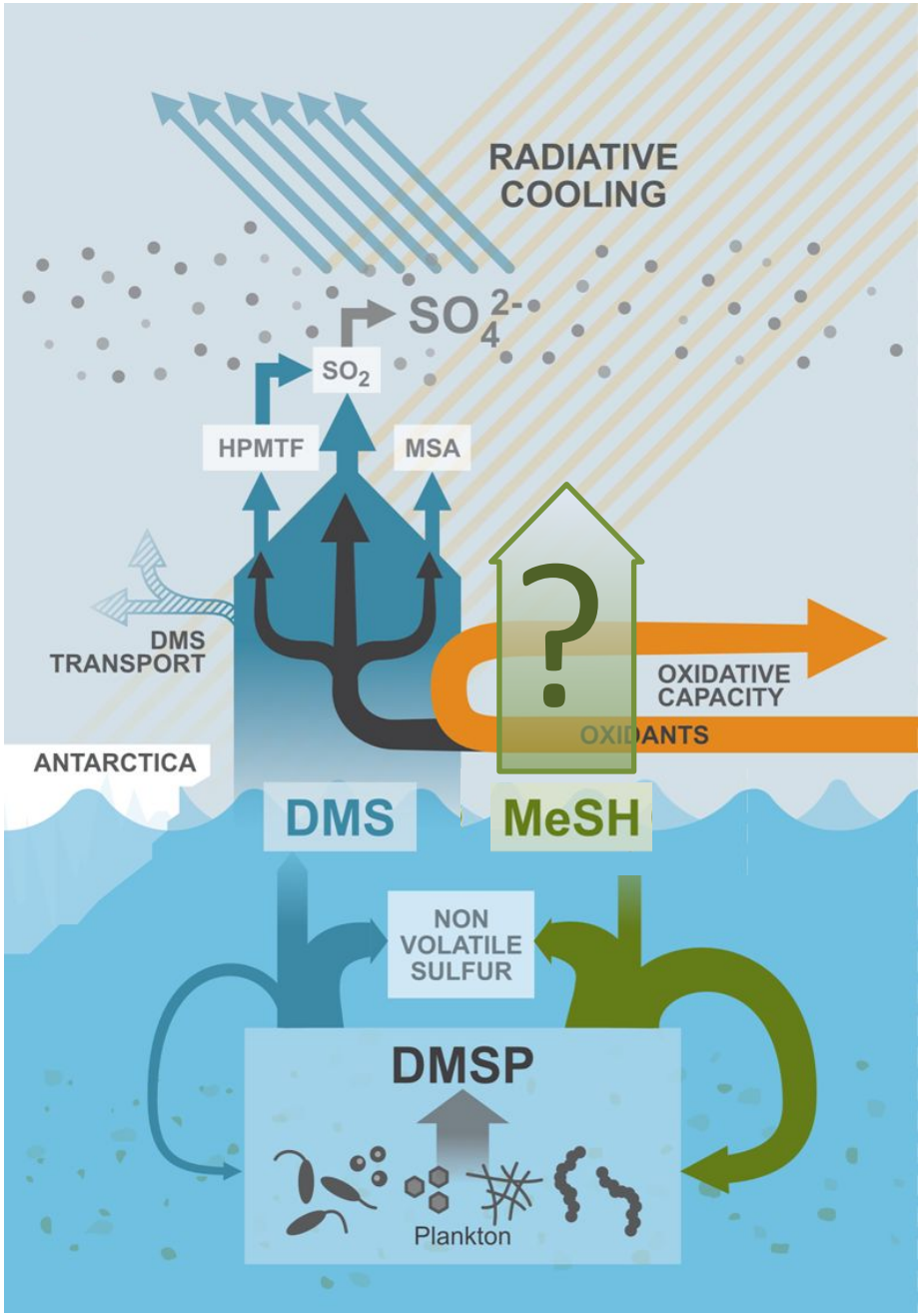
* VMS = MeSH + DMS

2. Results: MeSH flux



Wohl, Villamayor, Gali et al. (2024)

CAM-Chem v4

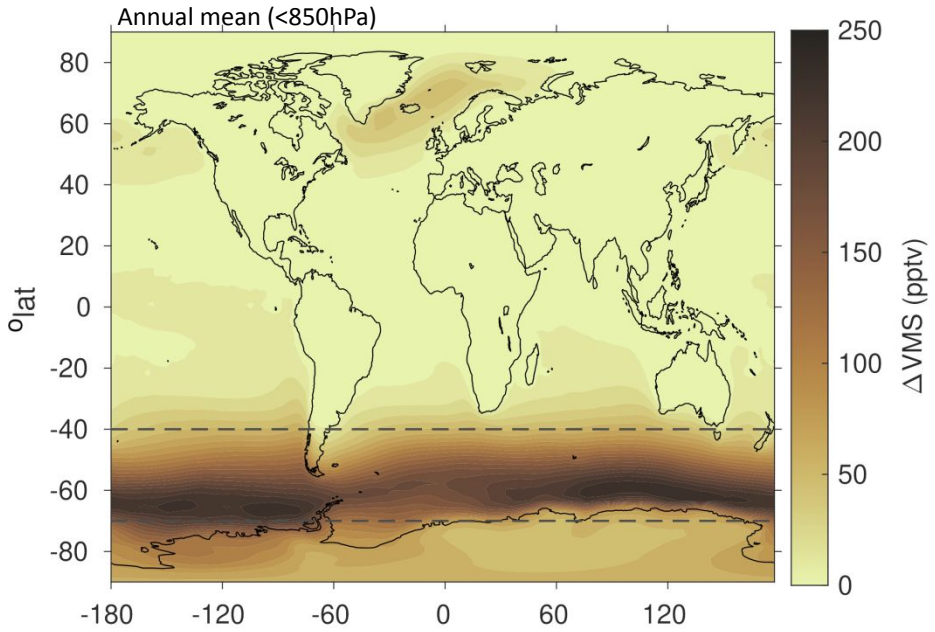
- Updated chemical scheme including MeSH.
- SD setup: Atmospheric nudging to MERRA2.
- Radiative transfer model (RRTMG).
- 5-year climatology (2018-2022).
- Experiments: '*MeSH*' and '*NoMeSH*'.

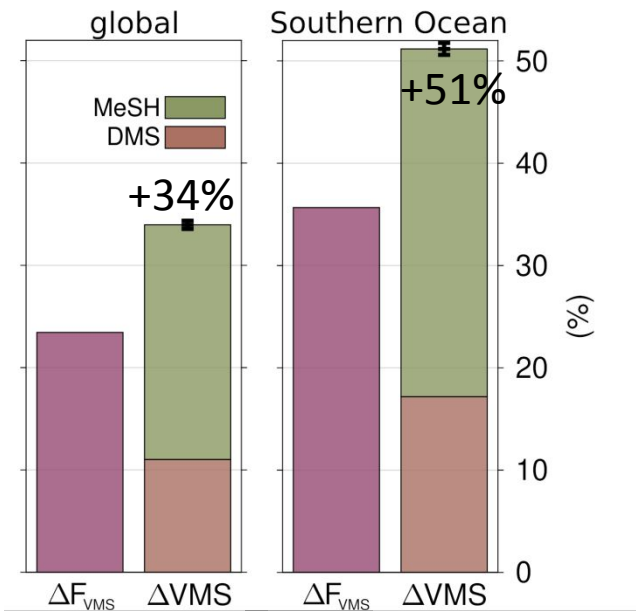
MeSH chemical scheme based on Novak et al. (2022) and Berndt et al. (2023).

Reaction	Rate
$MeSH + OH \rightarrow CH_3S + H_2O$	$9.9 \times 10^{-12} \times \exp(360/T)$
$MeSH + BrO \rightarrow CH_3S + HOBr$	$2.2 \times 10^{-15} \times \exp(830/T)$
$MeSH + NO_3 \rightarrow CH_3S + HNO_3$	9.2×10^{-13}
$MeSH + Cl \rightarrow CH_3S + HCl$	$1.2 \times 10^{-10} \times \exp(150/T)$
$CH_3S + NO_2 \rightarrow CH_3SO + NO$	$6.0 \times 10^{-11} \times \exp(240/T)$
$CH_3S + O_3 \rightarrow CH_3SO + O_2$	$1.15 \times 10^{-12} \times \exp(430/T)$
$CH_3S + O_2 \rightarrow CH_3SOO$	$1.2 \times 10^{-16} \times \exp(1580/T)$
$CH_3SO + O_2 \rightarrow CH_3S(O)OO$	$3.12 \times 10^{-16} \times \exp(1580/T)$
$CH_3SO + O_3 \rightarrow CH_3O_2 + SO_2$	4.0×10^{-11}
$CH_3SO + NO_2 \rightarrow 0.75 \times CH_3S(O)O + 0.25 \times CH_3O_2 + 0.25 \times SO_2 + NO$	1.2×10^{-11}
$CH_3SOO + NO \rightarrow NO_2 + CH_3SO$	1.1×10^{-11}
$CH_3SOO + NO_2 \rightarrow NO_3 + CH_3SO$	2.2×10^{-11}
$CH_3SOO \rightarrow CH_3O_2 + SO_2$	$5.6 \times 10^{16} \times \exp(-10870/T)$
$CH_3SOO \rightarrow CH_3S$	$3.5 \times 10^{10} \times \exp(-3560/T)$
$CH_3S(O)O + O_3 \rightarrow CH_3SO_3$	3.0×10^{-13}
$CH_3SO_3 + HO_2 \rightarrow CH_3SO_3H + O_3$	5.0×10^{-11}
$CH_3SO_3 \rightarrow CH_3O_2 + SO_3$	$5.0 \times 10^{13} \times \exp(-9946/T)$
$CH_3S(O)O + O_3 \rightarrow CH_3O_2 + SO_2$	$5.0 \times 10^{13} \times \exp(-9673/T)$

2. Results: atmospheric burden of volatile methylated sulfur (VMS)

Increase of VSM accounted for by MeSH

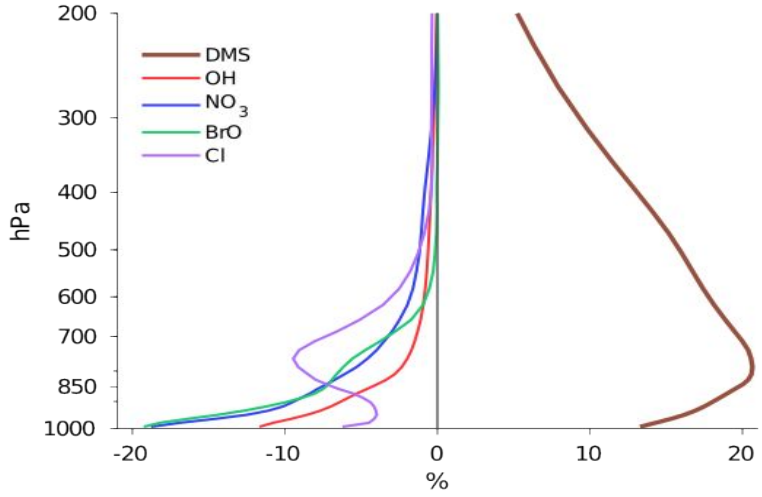


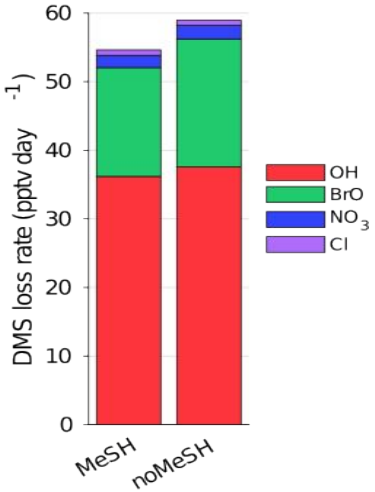


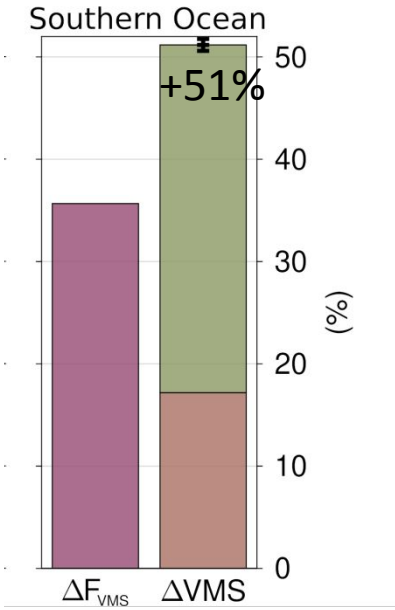
$$\mathrm{VMS} = MeSH + DMS$$

$$\Delta\mathrm{VMS} = VMS_{MeSH} - VMS_{noMeSH}$$

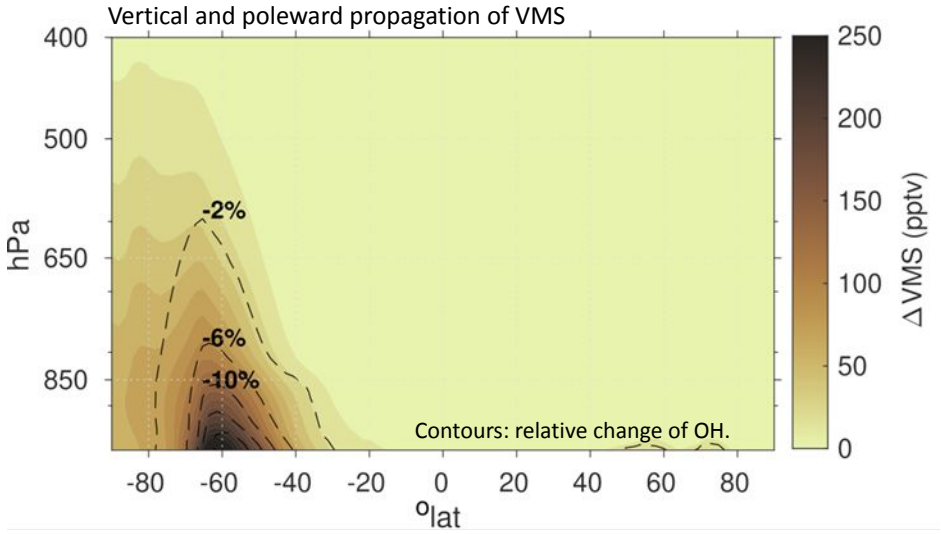
Impact of MeSH on oxidants and DMS





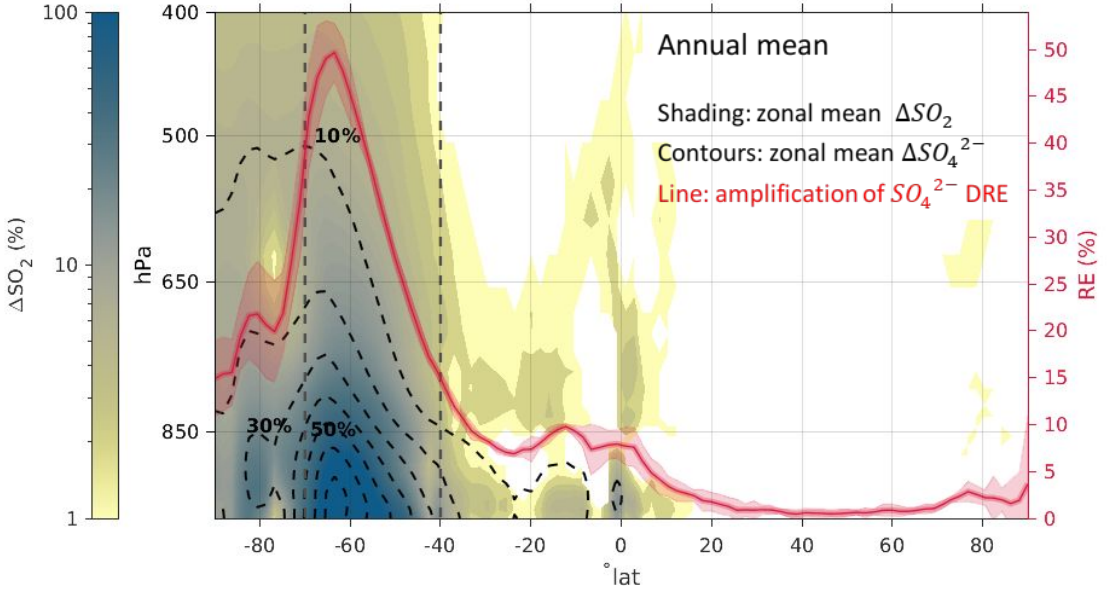


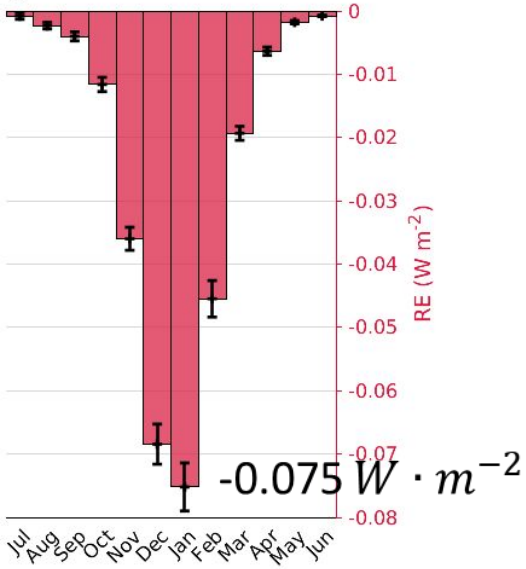
- MeSH increases DMS local chemical lifetime by 1.2 days in SO.



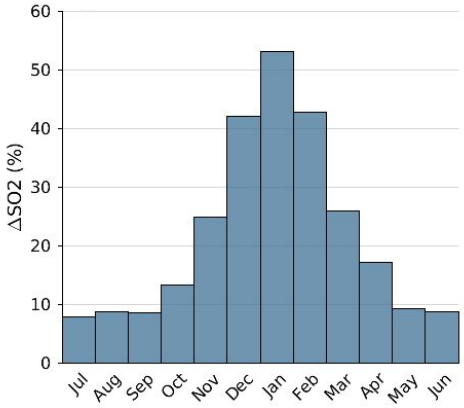
2. Results: Direct Radiative Effect of sulfate aerosol.

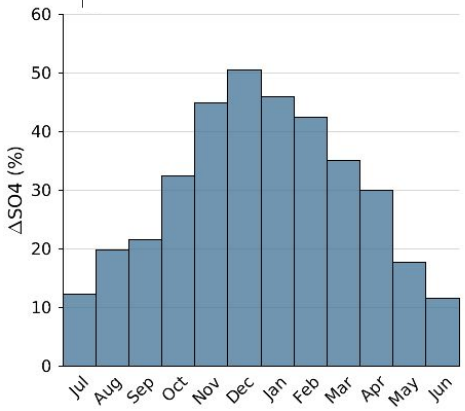
MeSH emissions enhance SO_2 and SO_4^{2-} burdens and the SO_4^{2-} direct radiative effect





Southern Ocean lower troposphere (<850hPa) mean





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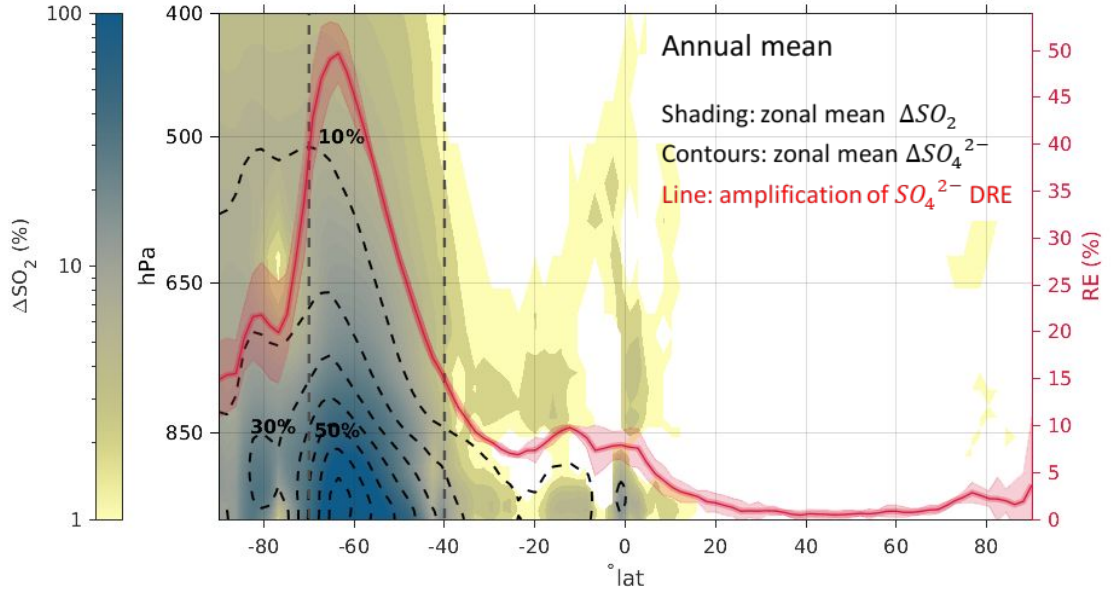
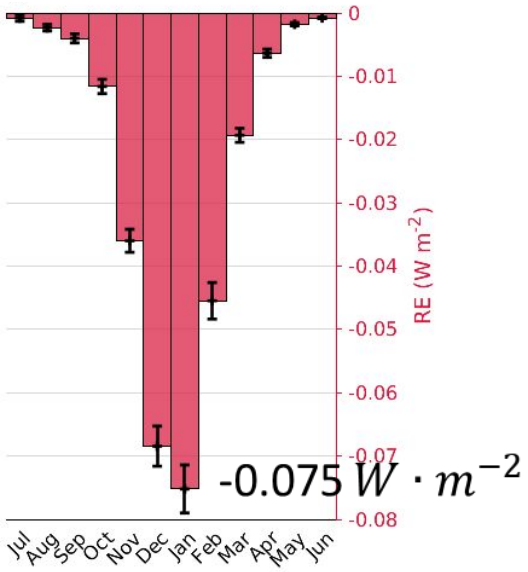
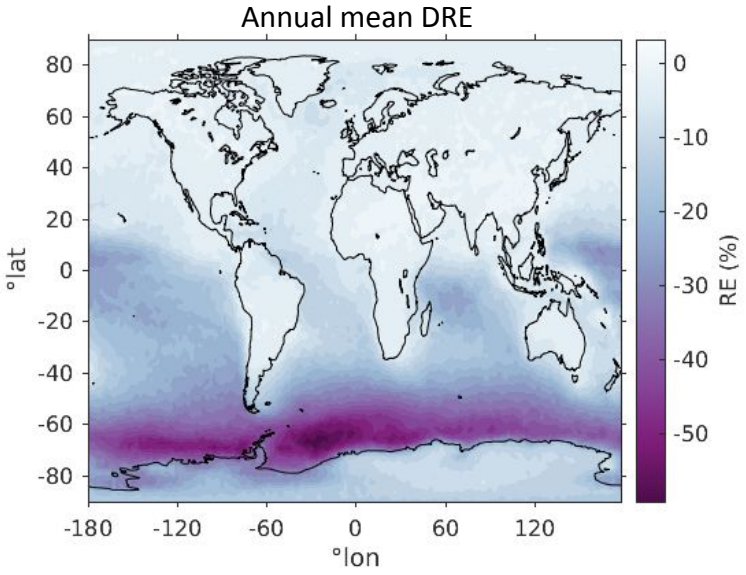
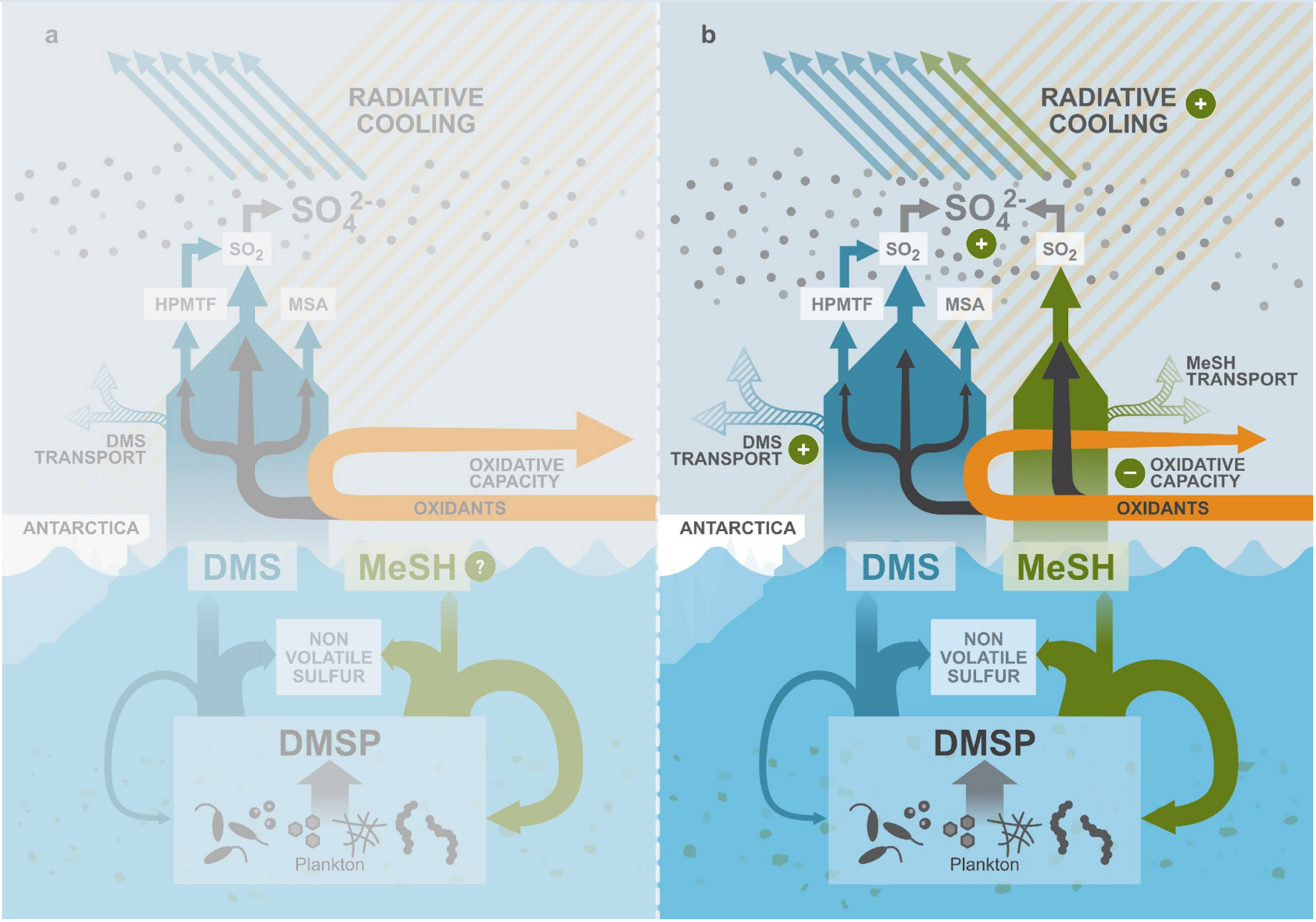




- **Globally**, MeSH increases SO_4^{2-} direct radiative effect by 4% (-0.016 $W \cdot m^{-2}$).
- ~1/3 the effect of anthropogenic SO2 mitigation in 1900-2015 (+0.05 $W \cdot m^{-2}$; Myhre et al. 2017).



3. Conclusions:



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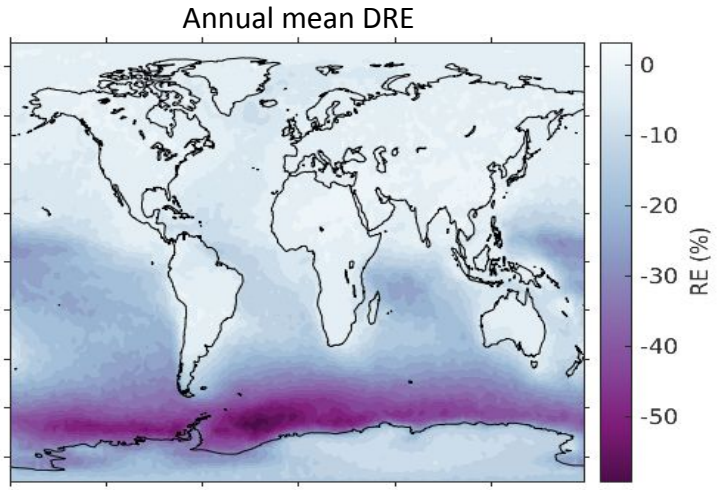
4. Discussion: MeSH emissions increase aerosol cooling in the Southern Ocean

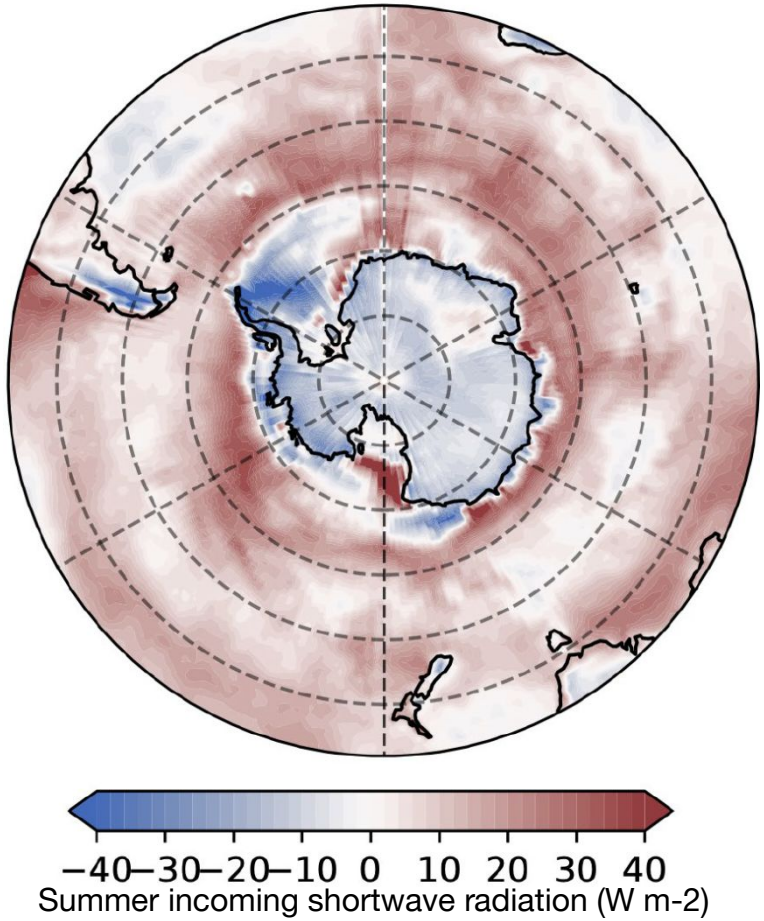


- MeSH-induced **indirect radiative effect** is estimated between -0.3 and -1.5 $W \cdot m^{-2}$ in January in the SO.

- Global climate models simulate an excess of summer incoming solar radiation in SO between 4 and 15 $W \cdot m^{-2}$.

Bias in simulated energy balance

CMIP6 MMM – satellite obs. (CERES-EBAF)



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Thank you!

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