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The impact of rocket launches and space debris on ozone and climate

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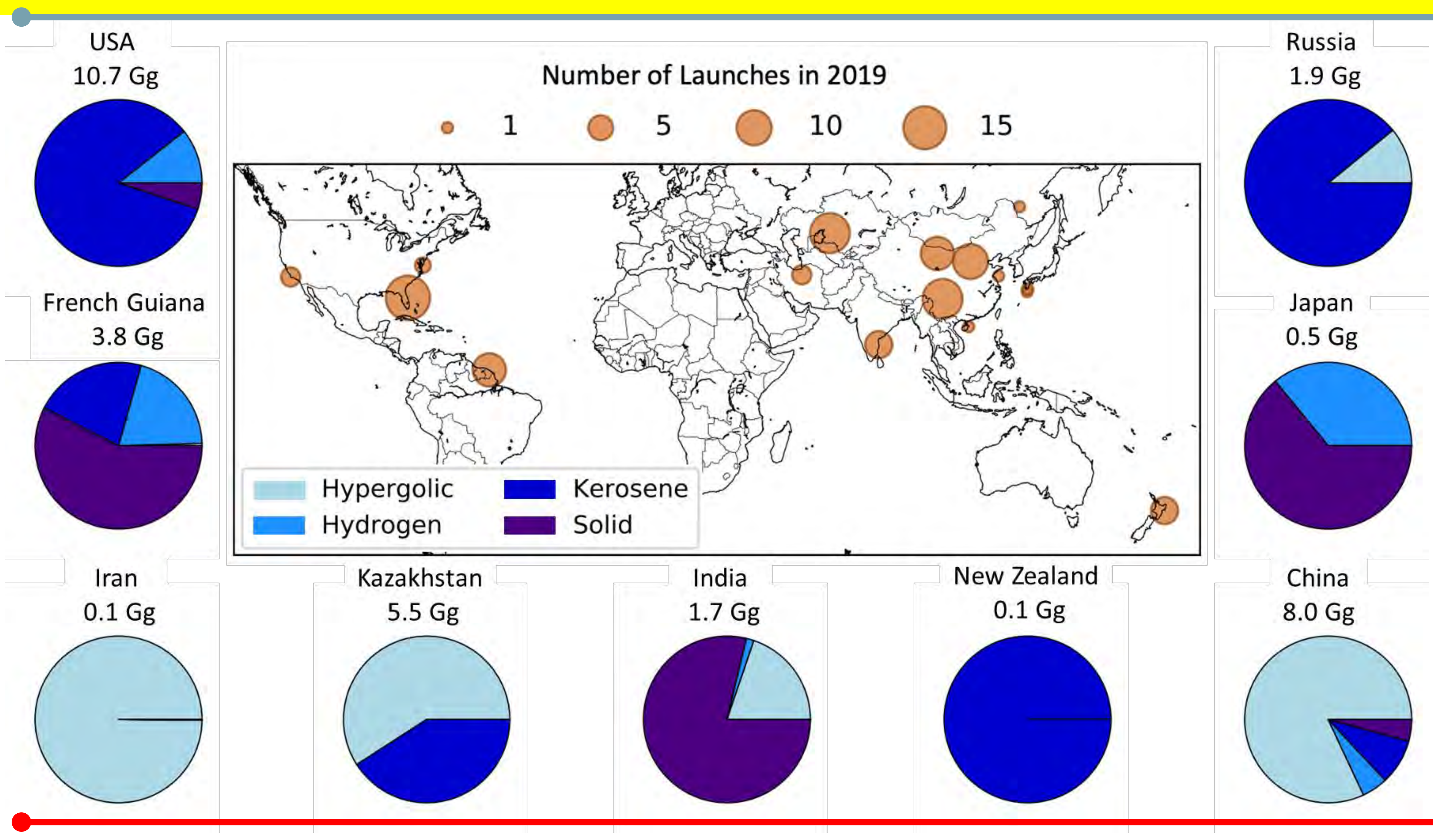


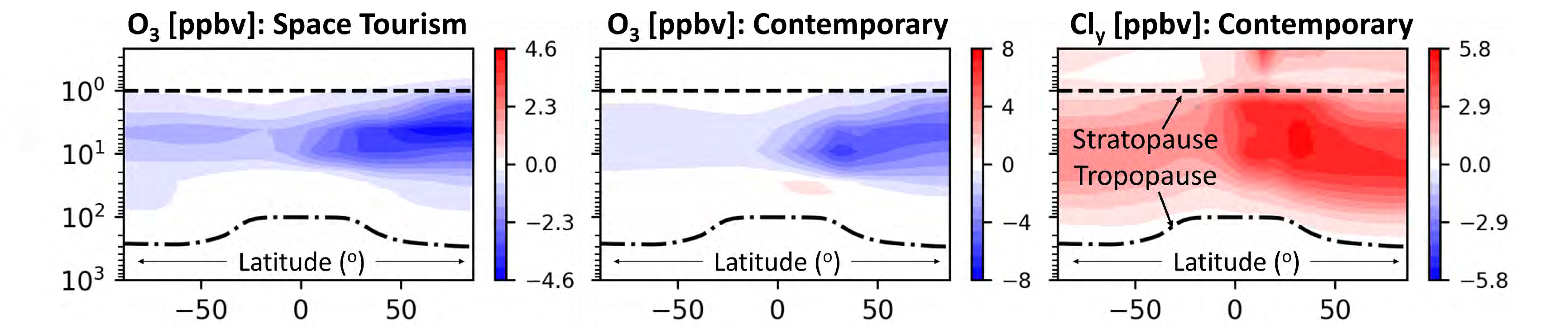
<u>Summary</u>

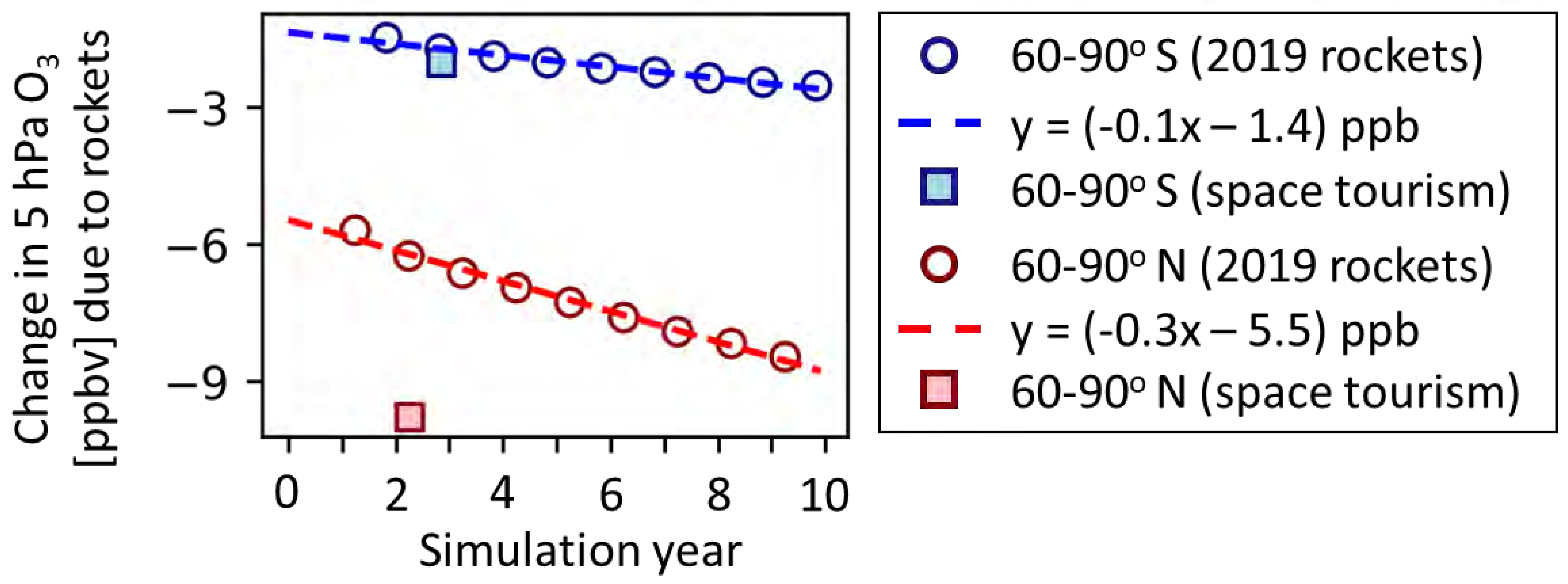
2019 rocket emissions inventory implemented in GEOS-Chem. Emissions specified by time, geolocation, fuel type, rocket stage, altitude. Key pollutants: nitrogen oxides (NO_x), chlorine (Cl_y), alumina (Al_2O_3), black carbon (BC) and water. We simulate a contemporary scenario of a decade of 5.6% a^{-1} growth on 2019 levels (103 launches), and a space tourism scenario (885 launches) which adds to the inventory daily launches by Virgin Galactic and Blue Origin and weekly launches by SpaceX.

NO_x and Cl_y cause the most O_3 loss. NO_x is released by launches (10 %) and re-entry heating (90 %).

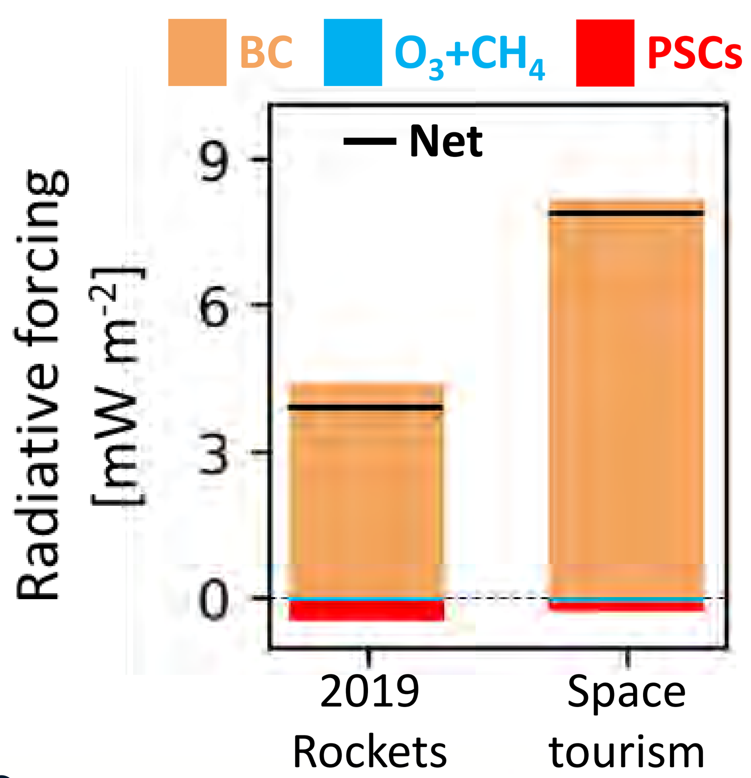
Largest O_3 depletion in the upper stratosphere, where the most significant post-Montreal Protocol gains have been made. Due to emission directly into the stratosphere, instantaneous radiative forcing from rocket BC is much more efficient per emitted mass than other sources

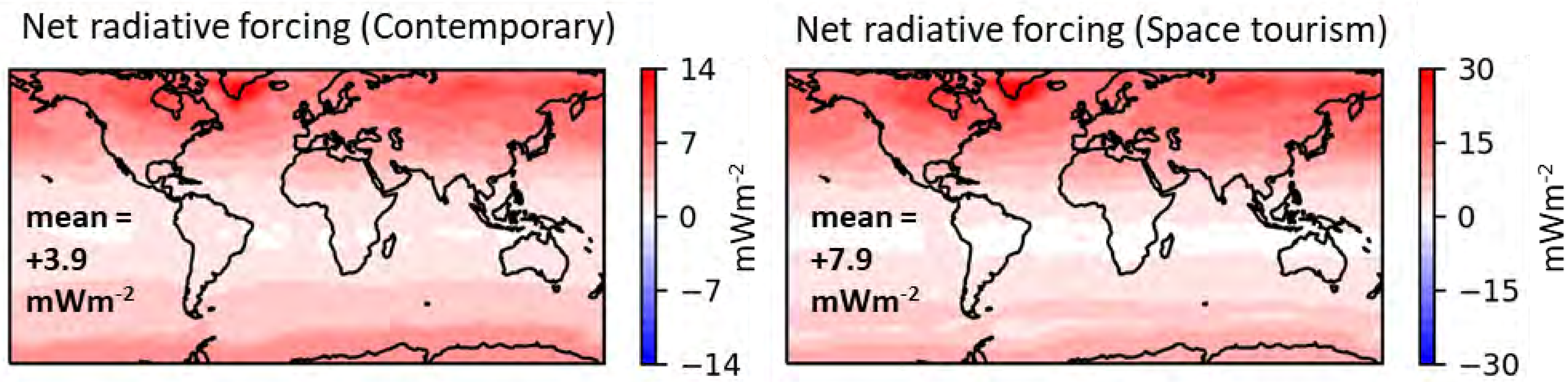
Potential to undermine ~20% of the gains made by the Montreal Protocol





Rocket BC warms the atmosphere 500 times more efficiently than soot from other sources





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