Project: **1171**

Project title: **Impact of SOlar, Volcanic and Internal variability on Climate (ISOVIC)**

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Our results on the importance of solar and volcanic variability compared to early 19th century internal climate variability show that large volcanic eruptions are the main drivers of cooling in the early 19th century, with maximum values of -0.82°K for the 1809 eruption and -13.5°K for the Tambora eruption (Fang et al. 2022; 2023). The two solar reconstructions (SATIRE and PMOD) each contribute ~0.05°K and ~0.15°K, respectively, to the surface cooling, and small to medium-sized eruptions provide an additional significant global surface cooling of ~0.07 K during the period 1812-1820. Volcano- and solar-induced cooling are generally additive in the ensemble mean, regardless of whether the forcing factors are combined or separated. However, regional changes in surface temperature can be significantly different when different forcing factors are combined.

To assess the contribution of natural factors in relation to anthropogenic climate change, we have conducted further experiments with 20 ensemble members under 4xCO_2 and present-day conditions where the solar and volcanic forcing corresponds to that of the early 19th century. A 30-member ensemble from MPI-ESM (Olonscheck et al. 2023) consisting of a combination of historical and ssp370 was chosen as a control simulation for the present climate. To obtain a control simulation with near steady-state conditions under high CO_2 concentration (4xCO_2), we had to additionally extend the abrupt CMIP6 4xCO_2 simulation by another 600 years. A comparison of these simulations with the simulations of the early 19th century will provide information on how the climate states affect climate changes due to natural external influences.

Figure 1 shows a 1st comparison of all three climate states for the surface temperature anomalies averaged globally and over the Northern Hemisphere (NH) extratropics, as well as the spatial patterns of change in sea ice cover and sea level air pressure. Since the ground state is different, Arctic sea ice in more southerly regions only exists in colder climates. This means that the Arctic sea ice in the experiment at the beginning of the 19th century extends up to 45 degrees north latitude in the Atlantic, while the sea ice increase in the 4xCO_2 experiment is limited to the Arctic region. The sea ice provides a colder surface than the open water outside the Arctic, resulting in a higher sea level pressure above them. As a result, sea level pressure shows a distinct pattern in the different climate states. However, although the patterns of change in Arctic sea ice cover and air pressure in the NH winter are different in the different climate states, there are no significant differences in the large-scale average temperature. A publication on the results of this work is in preparation and should be completed in the course of 2024 (Fang et al. in prep).

References,

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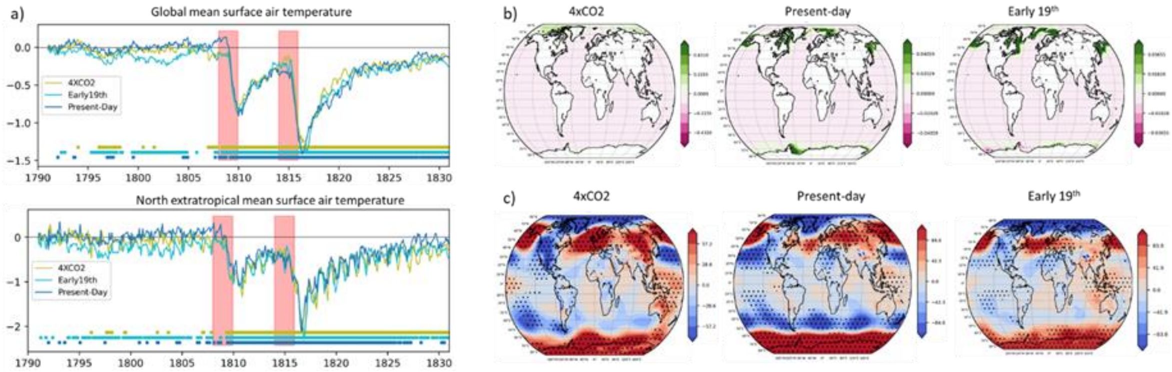

FIG. 1. (a) The difference in global mean surface air temperature with/without the early 19th century volcanic and solar forcing under (olive yellow) $4xCO_2$ condition, (light blue) present-day condition, (dark blue) early 19th century condition, for the global mean (upper panel) and for the northern extratropics (lower panel). The boxes below each panel indicate periods during which the ensemble means of the experiments are significantly different from the control run(b) The difference in winter sea ice extent (m^2) with/without the volcanic and solar forcing of the early 19th century (mean 1809-1825) under $4xCO_2$ conditions, present-day conditions and for early 19th century conditions. Same but for sea level pressure anomalies (Pa).