Reduced cooling in response to future volcanic eruptions

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Introduction

Volcanic eruptions are an important influence on decadal to centennial climate variability. Large eruptions lead to the formation of a stratospheric sulphate aerosol layer which can cause short-term global cooling. This response is modulated by feedback processes in the Earth system, but the influence of background climate state, in particular in response to future change has not been assessed before.

We performed 16 simulations using HadGEM2-ES (see box) prescribed with Tambora 1815 eruption stratospheric aerosol optical depth (Crowley & Unterman, 2013). The background climate is either (i) pre-industrial (AD 1860) and (ii) Representative Concentration Pathway 6 (year AD 2045). 5 ensemble members were performed for each eruption and for the no-eruption RCP6 simulation.

HadGEM2-ES:
A coupled AOGCM (HadGEM2 Development Team, 2011; Collins *et al.*, 2011) with interactive tropospheric aerosols (Bellouin *et al.*, 2011) and chemistry (O'Connor *et al.*, 2014), dynamic land surface and vegetation (Cox, 2001). The model's climate sensitivity is 4.6°C (Andrews *et al.*, 2012).

Climatic response

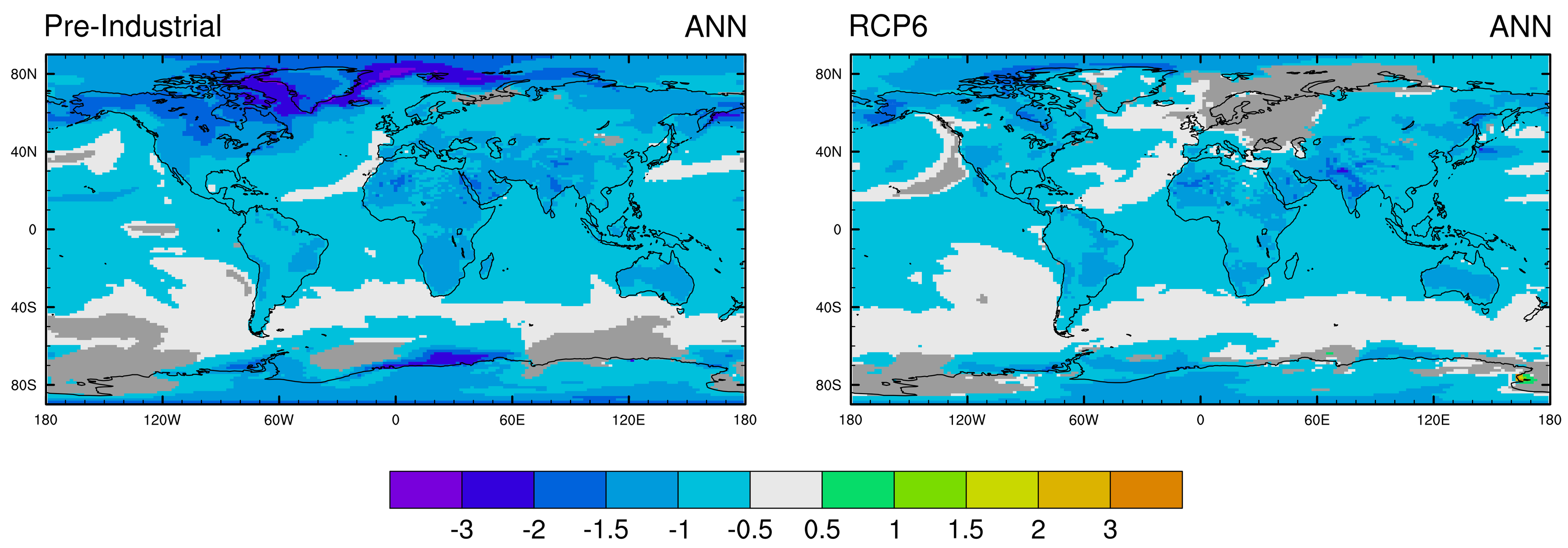

Figure 1: Pre-industrial (left) and future RCP6.0 (right) eruption-induced cooling.

The eruption-induced cooling is 8% smaller in the future scenario, with the much less cooling over the Arctic and northern Europe.

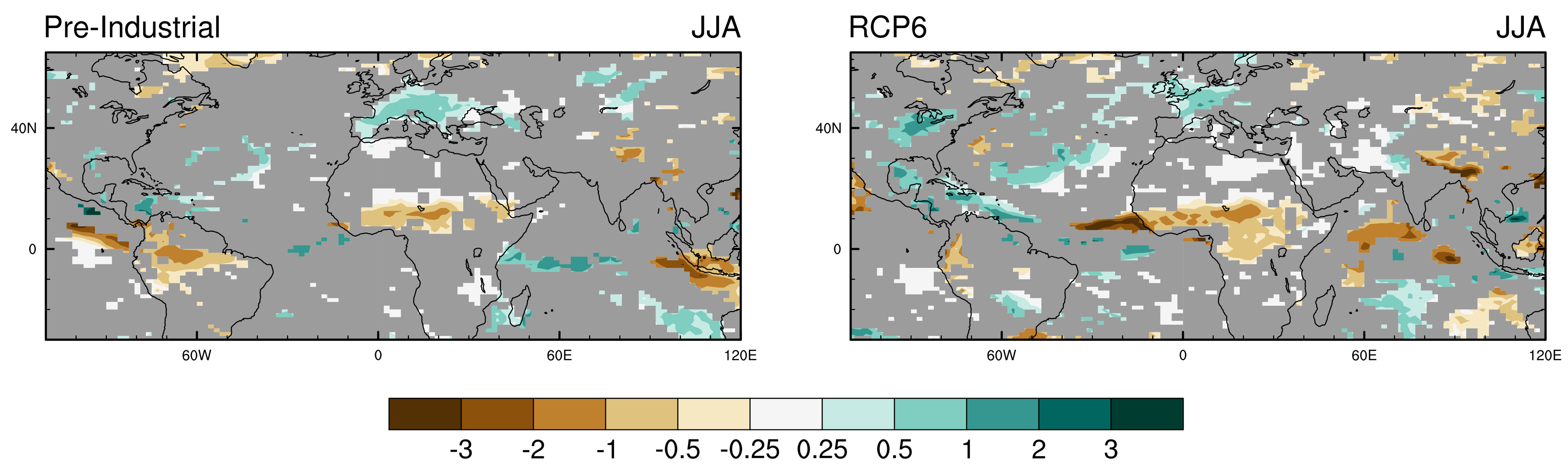

Figure 2: Pre-industrial (left) and future RCP6.0 (right) eruption-induced precipitation change (mm yr^{-1}.

The rainfall anomaly is also different, but with the small ensemble size (5 members), it is difficult to robustly attribute this. The rainfall reduction over the Amazon is smaller in the future and this is likely related to a more modest eruption-induced cooling over the tropical Atlantic.

Radiative feedback analysis

A short-wave radiation budget analysis (Taylor *et al.*, 2007) shows strong changes over tropical oceans.

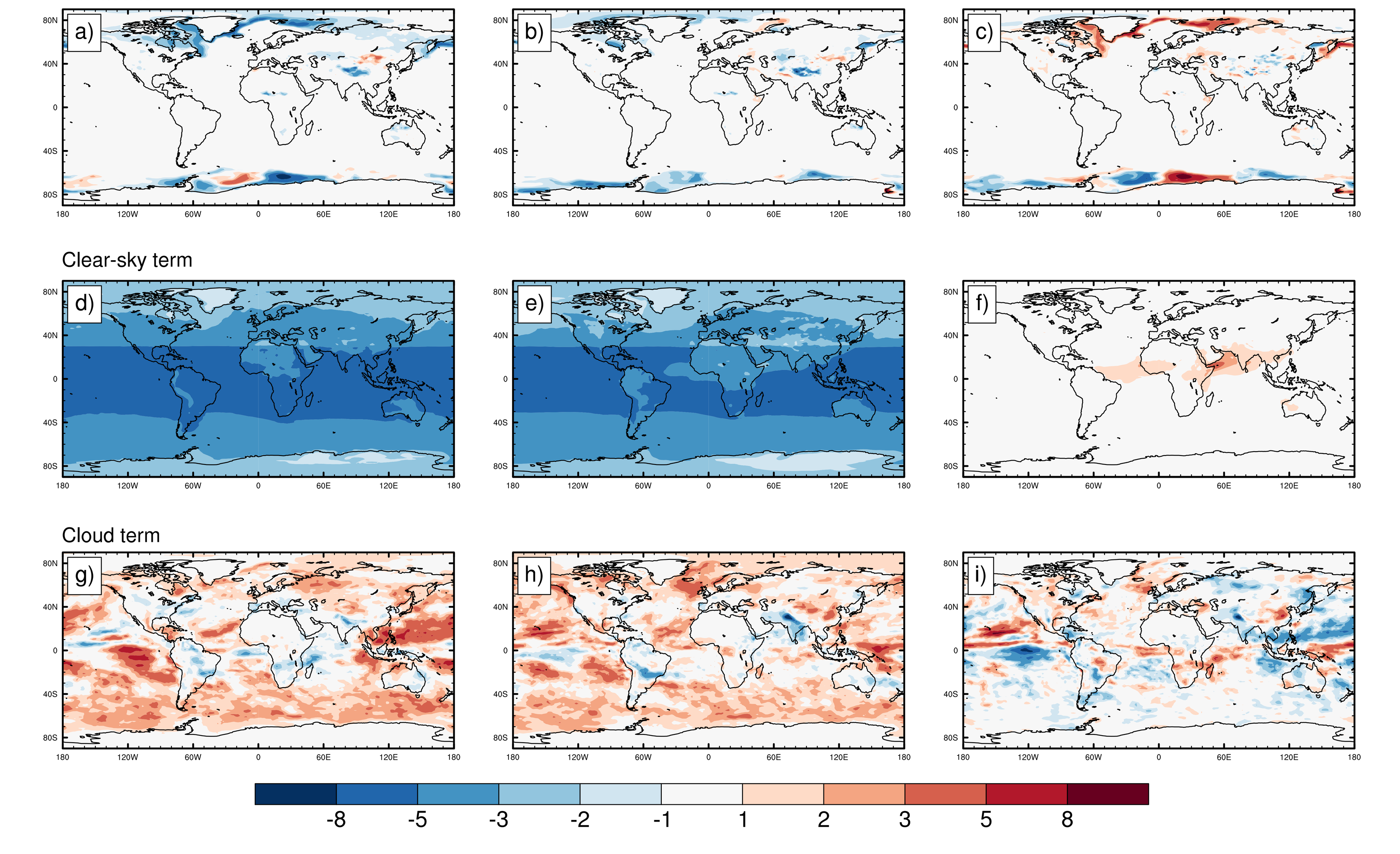

Figure 3: Surface (top), clear-sky (middle) and cloud (bottom) contributions to the SW radiation volcanic eruption response. Left: pre-industrial. Middle: future. Right: future minus pre-industrial.

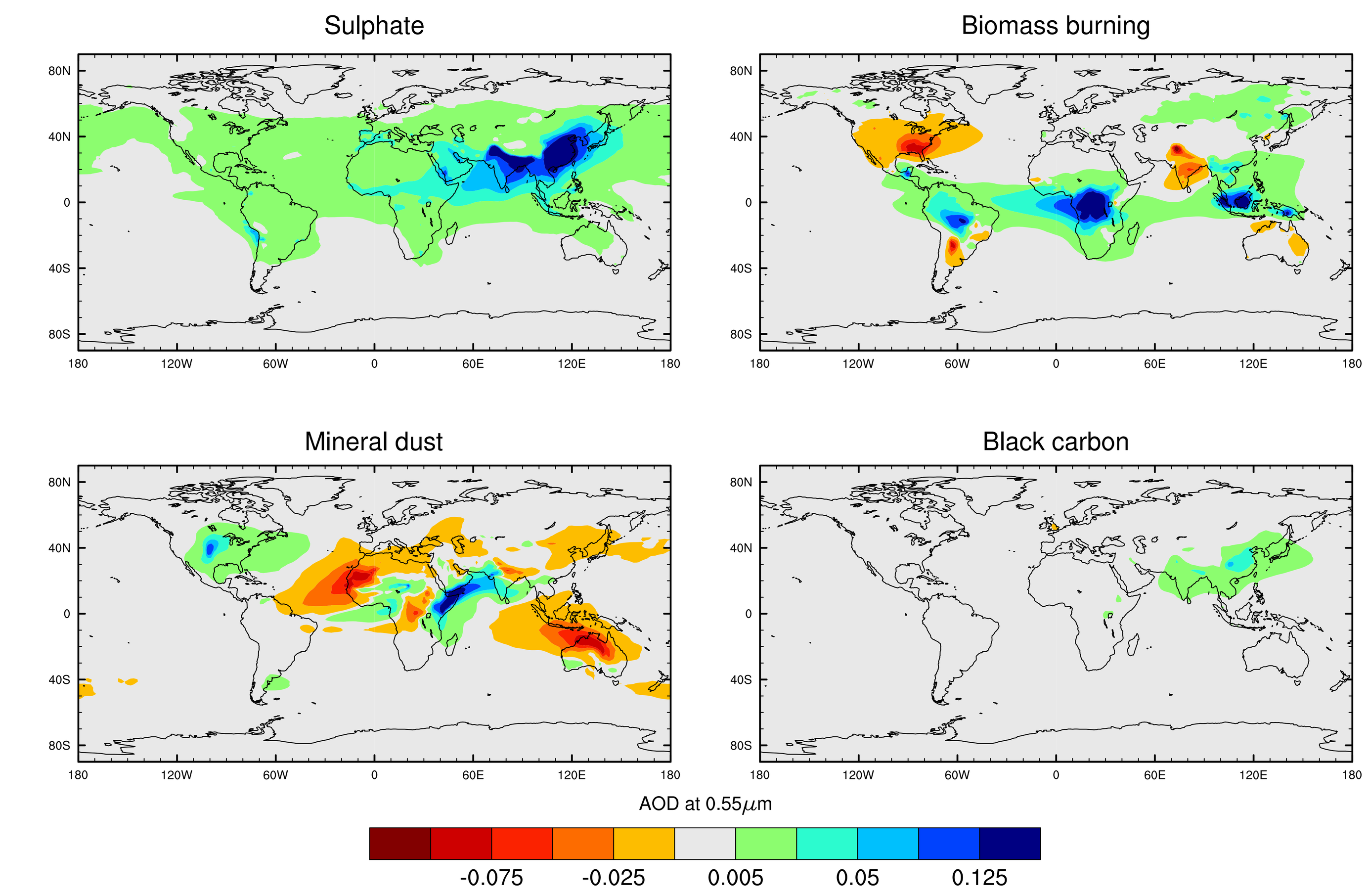

Figure 4: Future (RCP6 AD 2050) minus pre-industrial aerosol optical depth (AOD).

This clear-sky anomaly resembles the tropospheric aerosol change between the pre-industrial and future simulations, shown above. Offline radiation code experiments show that tropospheric aerosol changes can reduce the radiative forcing from an eruption by around 25% through a combination of direct and indirect effects.

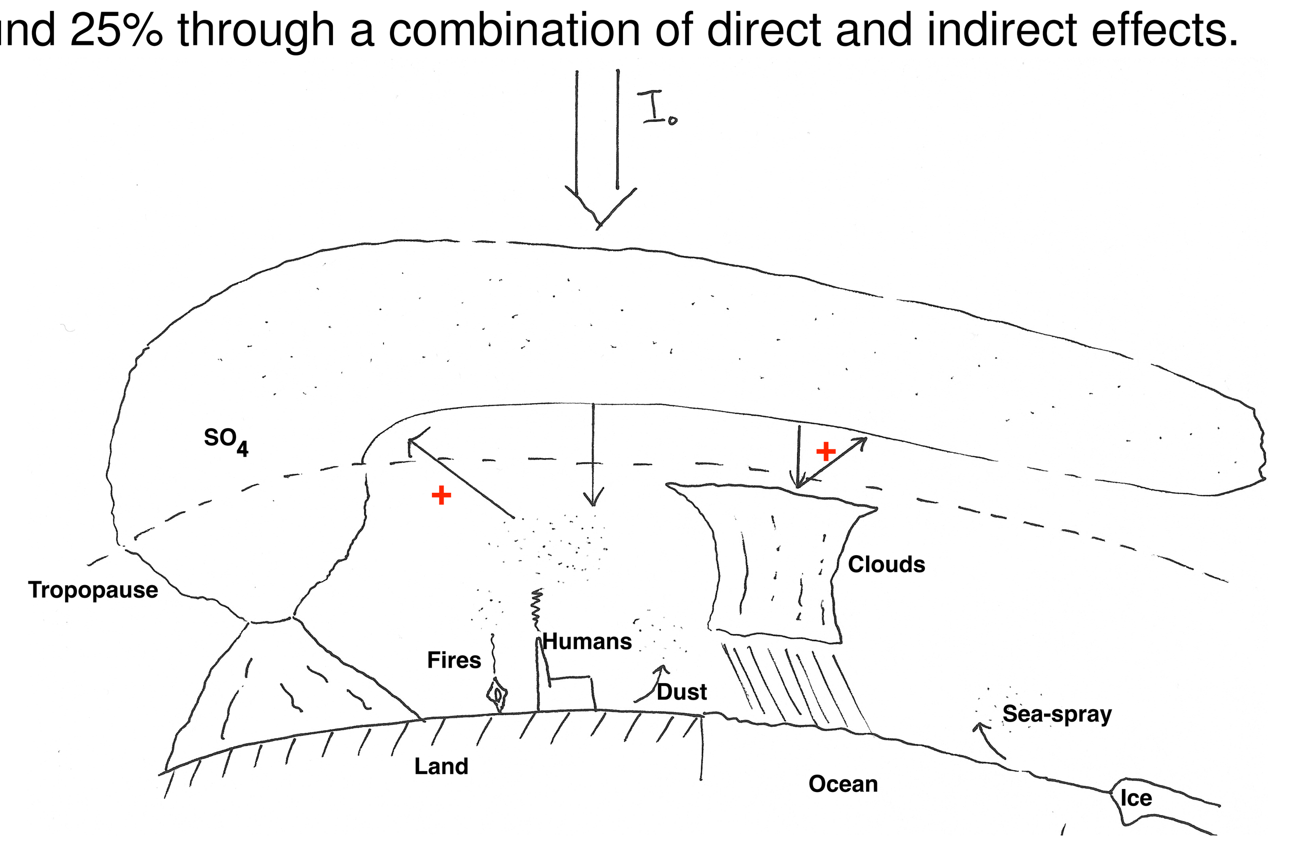

Figure 5: Schematic of the interaction between tropospheric and stratospheric aerosols.

Dynamic features

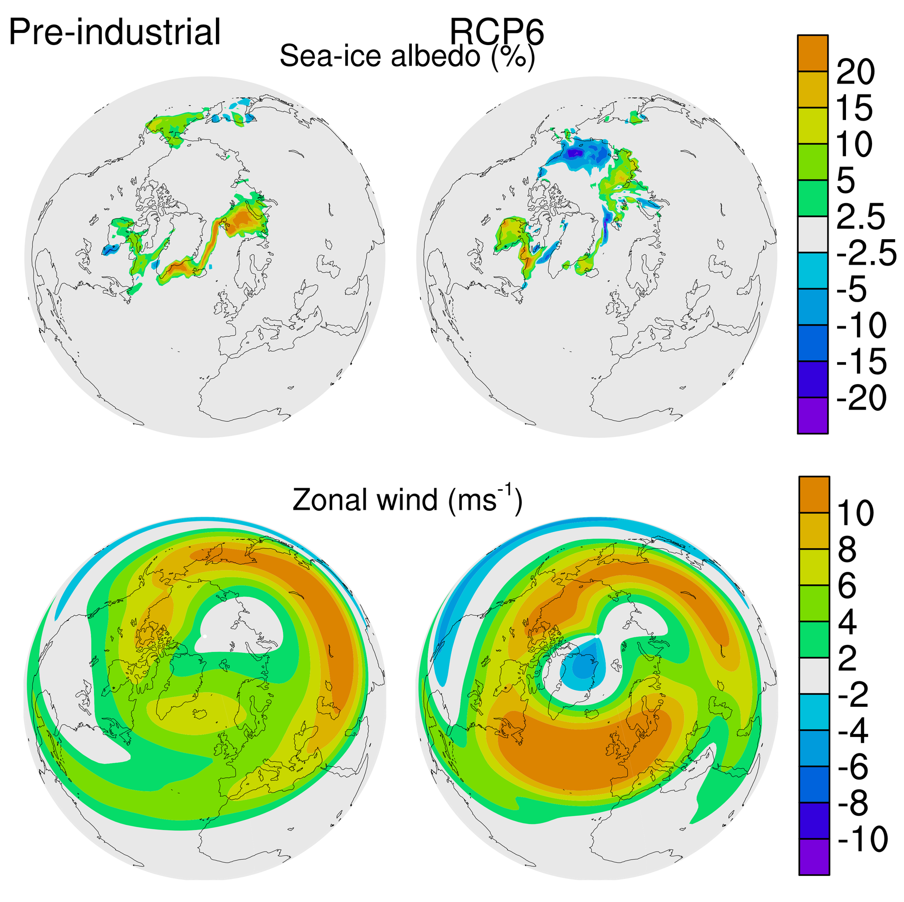

Figure 6: Pre-industrial (left) and future RCP6.0 (right) northern hemisphere winter sea-ice and polar vortex

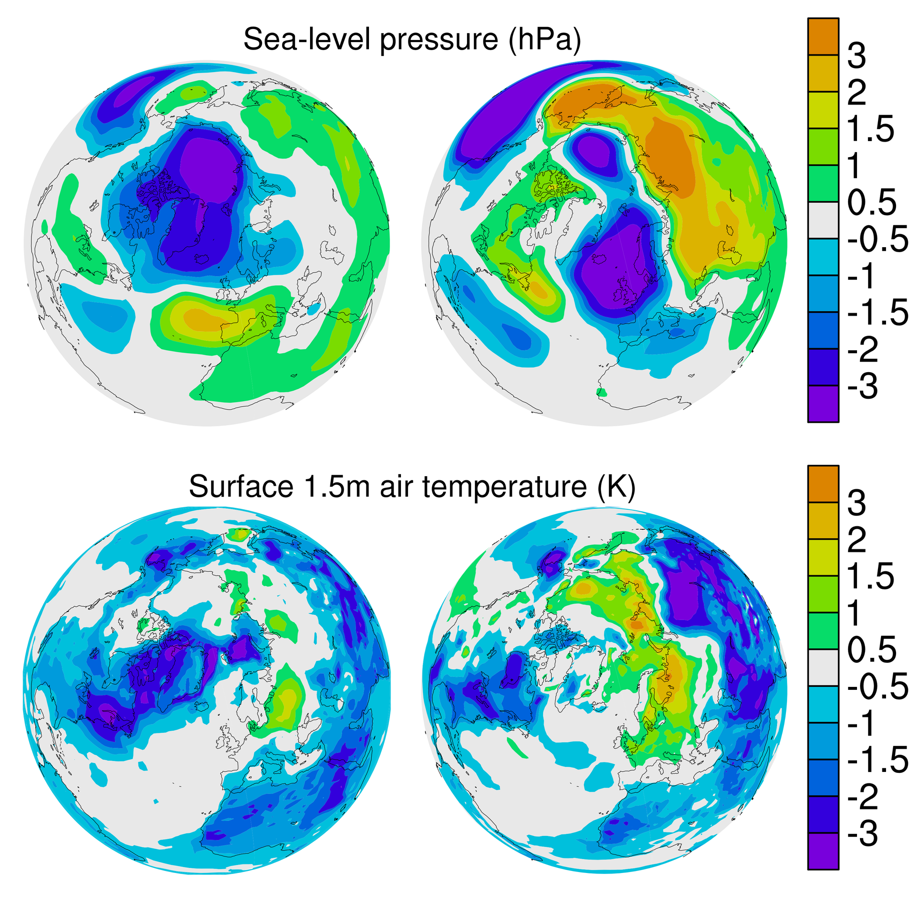

Figure 7: Pre-industrial (left) and future RCP6.0 (right) northern hemisphere winter sea-level pressure and temperature.

Northern hemisphere winter warming is amplified in the future simulation. Separate atmosphere-only simulations show that this is due to the particular pattern of sea-ice expansion following the future eruption. This mechanism resembles that described by Kim *et al.* (2014).

Summary

- In a more polluted atmosphere, tropospheric aerosol loading reduces the effective radiative forcing from a volcanic eruption.
- Dynamically HadGEM2-ES also simulates a persistent winter warming effect in the northern hemisphere.
- Reduced northern hemisphere sea-ice coverage in a warmer climate contributes to the dynamic response, and also significantly weakens the high-latitude response to an eruption.

References

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