

Water vapor impacts from the 2022 Hunga eruption on the Arctic stratospheric polar vortex and surface temperatures

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Introduction

- The January 2022 eruption of the Hunga Tonga–Hunga Ha’apai submarine volcano resulted in an unprecedented injection of water vapor into the stratosphere. The excess water vapor from this event stayed in the stratosphere for several years, but the extent to which it influenced surface climate conditions remains unclear.
- In this study, we investigate the impacts of the anomalous Hunga water vapor on the variability of the Arctic stratospheric polar vortex and its downward influence on extratropical surface climate.



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Model experiments

- Using the coupled Community Earth System Model version 2 and the high-top Whole Atmosphere Community Climate Model version 6 (CESM2/WACCM6) with fully interactive chemistry, we conduct a 12-member ensemble of 3-year-long idealized water vapor perturbation simulations that mimic the eruption with total injections of ~ 140 Tg water vapor over 30°S – 5°N and 40 – 15 hPa.
- We also perform a 20-year-long control simulation under pre-industrial boundary conditions. All the water vapor perturbation simulations start from different initial conditions selected at one-year intervals from the control simulation.

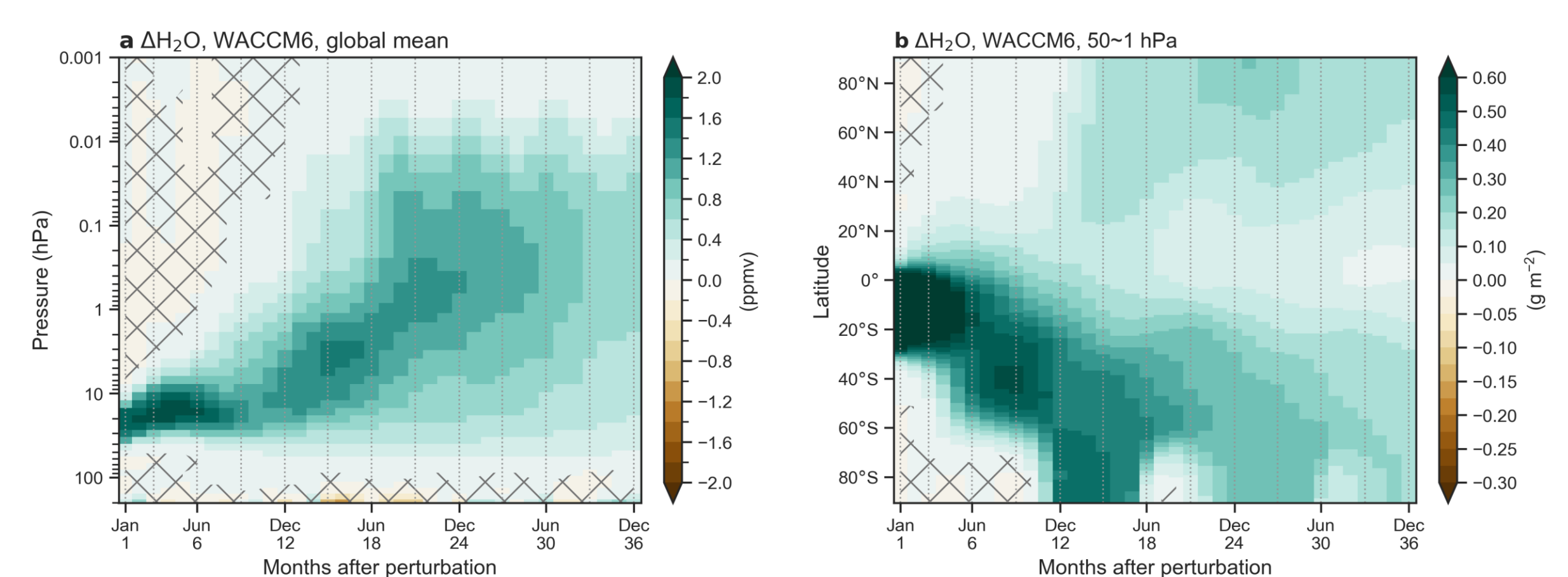


Figure 1. Evolution of the injected water vapor in the stratosphere over the 3 years following the eruption.

Results

Weakening of the Arctic stratospheric polar vortex

- Hunga water vapor-induced upper stratospheric cooling significantly weakens the Arctic stratospheric polar vortex in the first post-eruption winter (DJF1, months 12–14), with weaker influences in the winter of the eruption year (JF0, months 1–2) and the second post-eruption winter (DJF2, months 24–26).

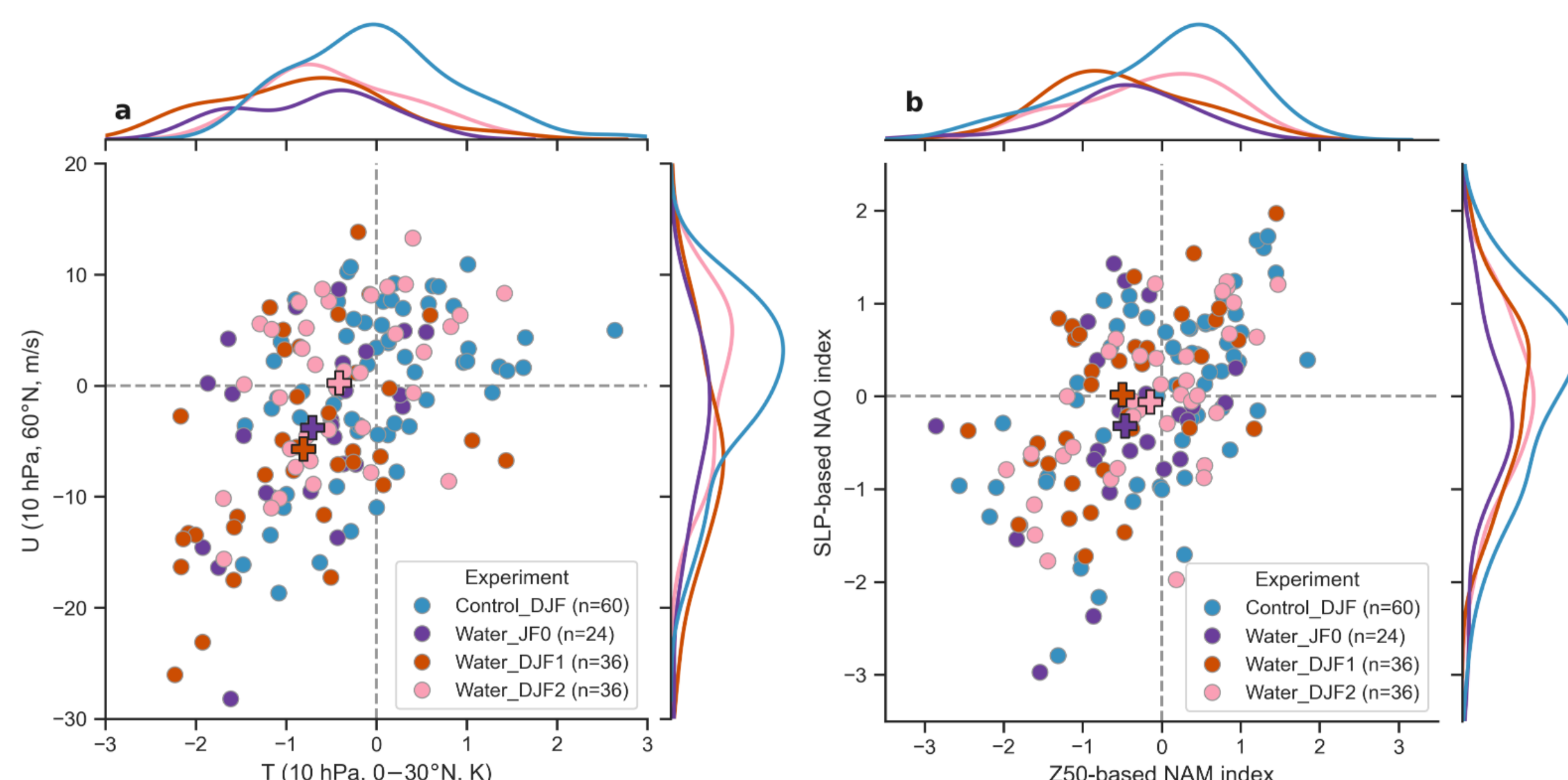


Figure 2. Arctic stratospheric polar vortex and its downward influence during post-eruption winters.

- The weakening of the Arctic polar vortex is driven by a reduced equator-to-pole temperature gradient in the upper stratosphere, accompanied by pronounced warming throughout the polar stratosphere.

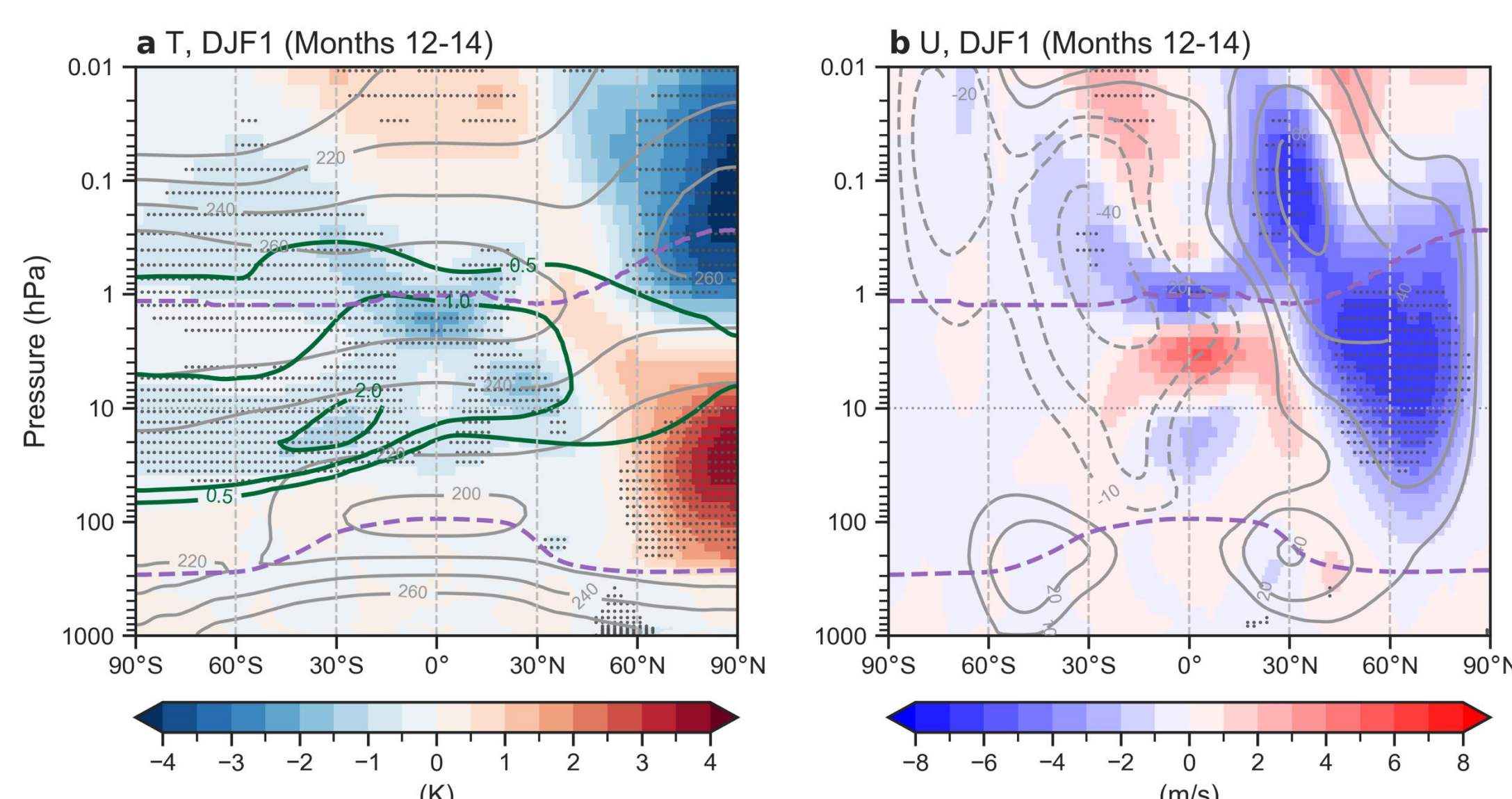


Figure 3. The weakened Arctic stratospheric polar vortex in the first post-eruption winter.

Post-eruption winter cooling over northern Eurasia

- Consistent surface cooling over northern Eurasia is simulated for all three winters, though it is more robust in the first post-eruption winter (DJF1).

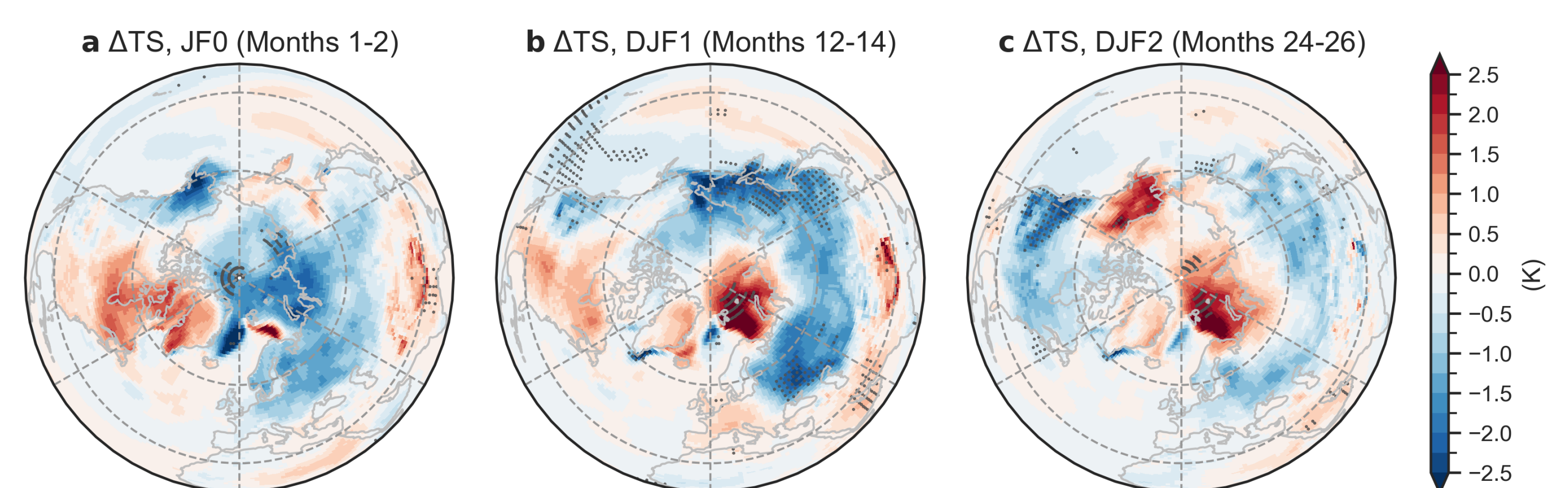


Figure 4. Surface temperature response to the weakened Arctic stratospheric polar vortex during post-eruption winters.

- We identify more frequent occurrences of colder-than-normal winters over the northern Eurasian continent, particularly during the first post-eruption winter (DJF1).

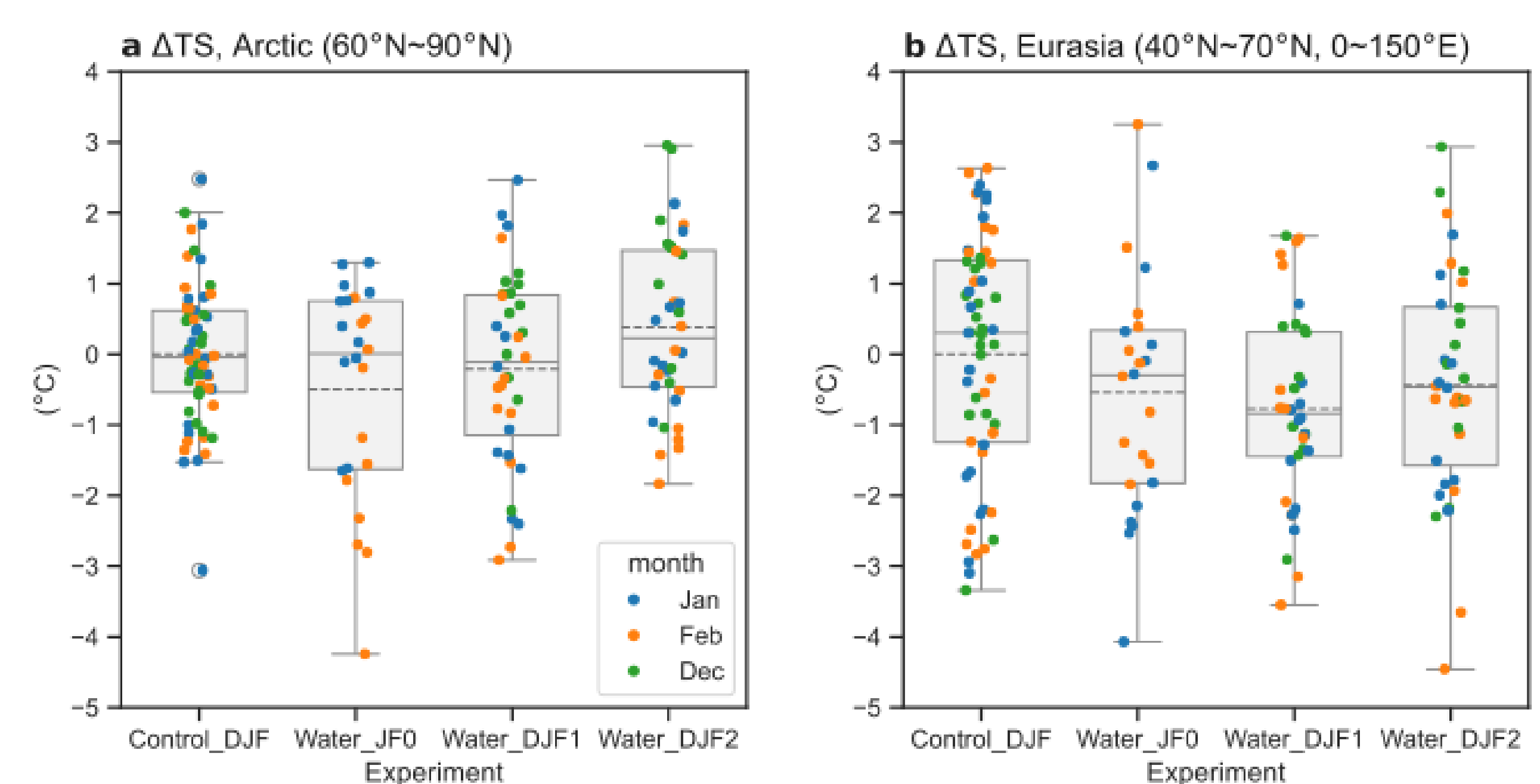


Figure 5. Variability of wintertime surface temperature over the Arctic (60°N – 90°N) and northern Eurasia (40°N – 70°N , 0 – 150°E).

Summary

- Our ensemble simulations suggest that the Hunga water vapor forcing weakened the Arctic stratospheric polar vortex and slightly increased the chance for Eurasian winter cooling, although with a weak signal-to-noise ratio.

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