UNDERSTANDING THE STRATOSPHERIC RESPONSE TO ARCTIC AMPLIFICATION

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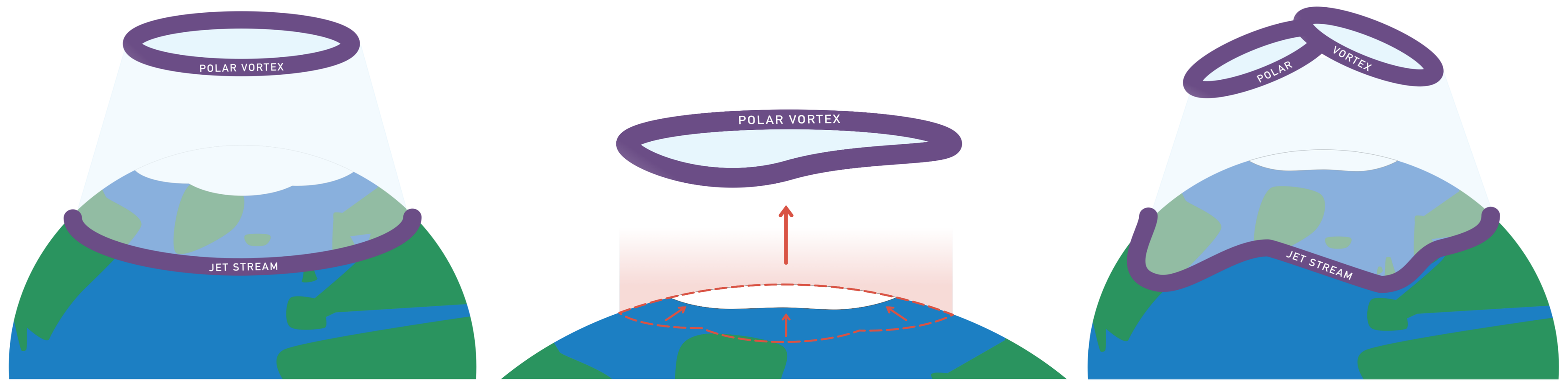
1. MOTIVATION



The Arctic is dramatically changing with rising emissions, warming almost four times as fast as the global average

Some studies propose that associated sea ice loss affects the stratospheric polar vortex by modulating upward propagating planetary waves

Others suggest that this could perturb the winter jet stream and affect surface weather, with higher chance of blocking

- In comprehensive model studies, such as PAMIP and CMIP, there are diverging stratospheric responses to future Arctic sea ice loss and climate change, respectively
- There is large intermodel spread in the depth (and strength) of the heat response to Arctic amplification - both between similar models, and when comparing atmosphere-only to fully coupled simulations
- Here, we investigate the extent to which such differences modulate the response of the stratospheric polar vortex to polar heating

2. METHODS

We use the idealised modelling framework Isca to:
- understand the fundamental mechanisms behind modelled responses;
- unravel the impact of model differences;
- help reduce biases in the complex, state-of-the-art models

1) a stratosphere

using Newtonian relaxation to an equilibrium temperature profile[1] representative of northern hemisphere winter and run for ~40y:

$$T_{eq}^{strat}(\phi,p) = [1 - W(\phi)]T_{US}(\phi) - W(\phi)T_{US}(p_T)\left(\frac{p}{p_T}\right)^{-R\gamma/g}$$

2) semi-realistic atmospheric variability

through careful model parameter selection and by introducing a wave-generating zonally asymmetric midlatitude heating[2]

3) Arctic amplification-representative heating

using a zonally symmetric pole-centred heating[3] that conserves total energy input for a given heating strength

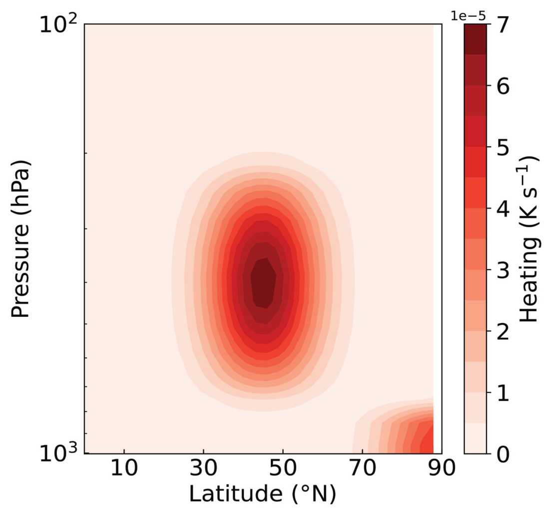
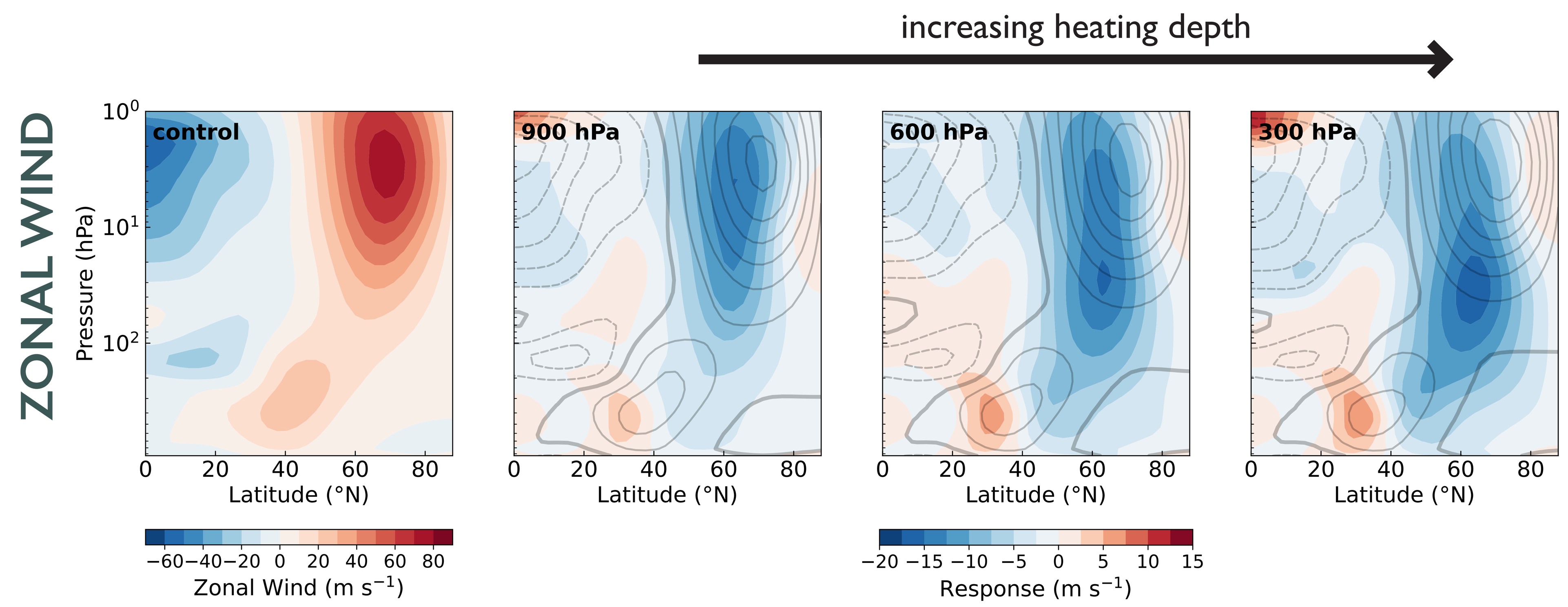


Fig 1: prescribed midlatitude and polar heating together

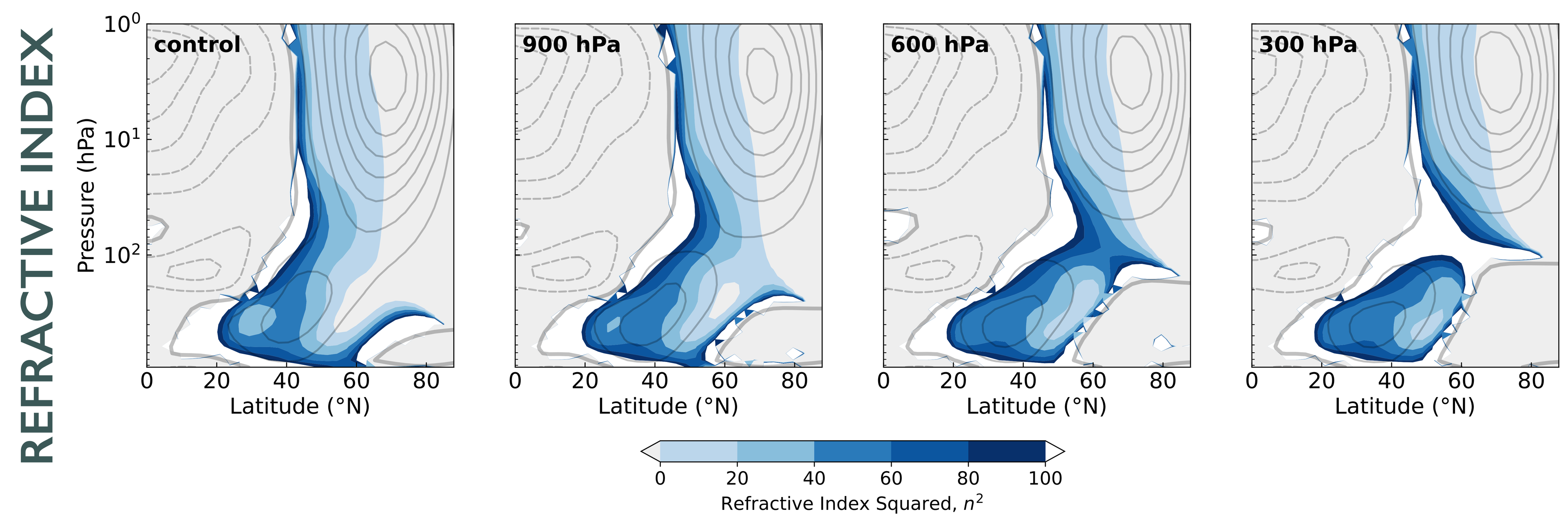
1 Polvani & Kushner, 2002, *Geophys. Res. Lett.* 2 Lindgren *et al.*, 2018, *J. Geophys. Res.* 3 Orlanski & Solman, 2010, *J. Atmos. Sci.*

3. VORTEX RESPONSE

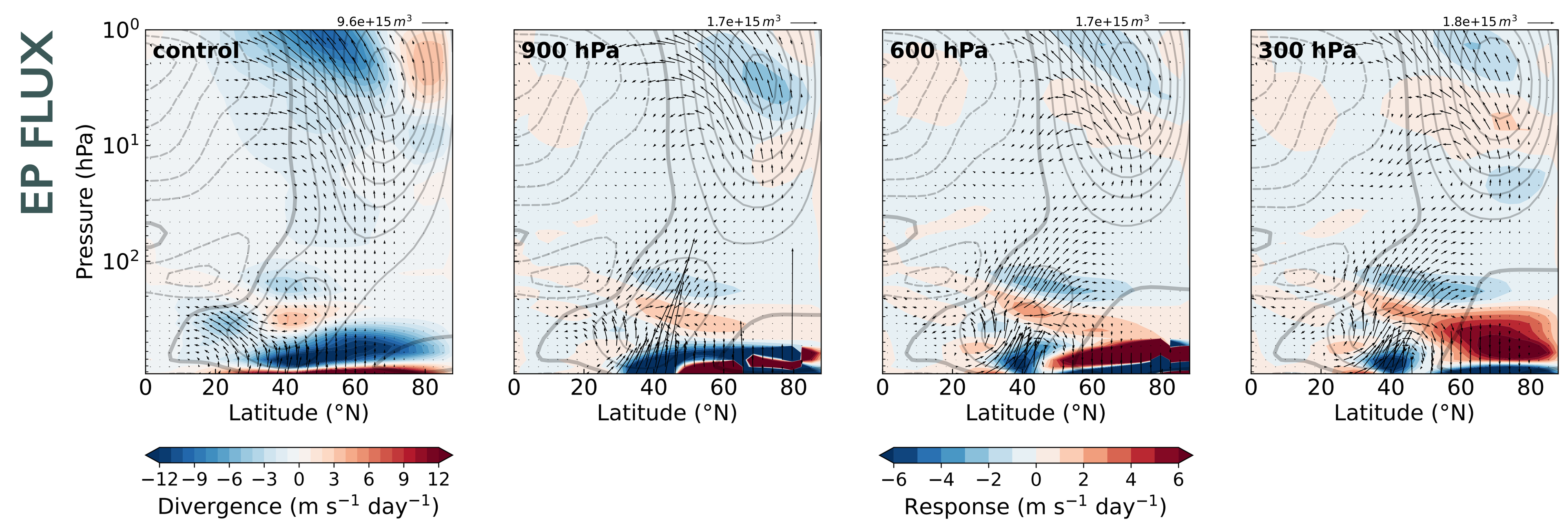
Increasing polar heating depth and strength reduces polar vortex variability, reflected in lower SSW frequency across the experiments (see Fig 3), for which we propose the following mechanism:



- polar heating modifies the meridional temperature gradient (ΔT_y)
- as heating depth/strength increases, ΔT_y weakens at increasingly higher levels in the troposphere



- through thermal wind balance, a region of easterlies and negative refractive index over the pole extends higher too
- the midlatitude UTLS "neck" narrows, as indicated by the zero-wind contour



- upward waves are forced through an increasingly narrow region, so break lower in the stratosphere
- thus, the stratospheric polar vortex is less disturbed

Fig 2: control and increasingly deep polar heating experiments overlaid with climatological time and zonal mean zonal wind contours (10 ms⁻¹ spacing, 0 ms⁻¹ thick line). Refractive index is wave-2. EP flux (arrows) and divergence (filled contours) is for all wave numbers.

4. SUMMARY

- In our idealised model, introduction of polar heating **weakens the stratospheric polar vortex**, consistent with other recent studies
- The structure of the weakening is **affected by the depth and strength** of the heating
- Deeper and stronger heating **reduces vortex variability** and sudden warming frequency by constraining the propagation of planetary waves into the stratosphere

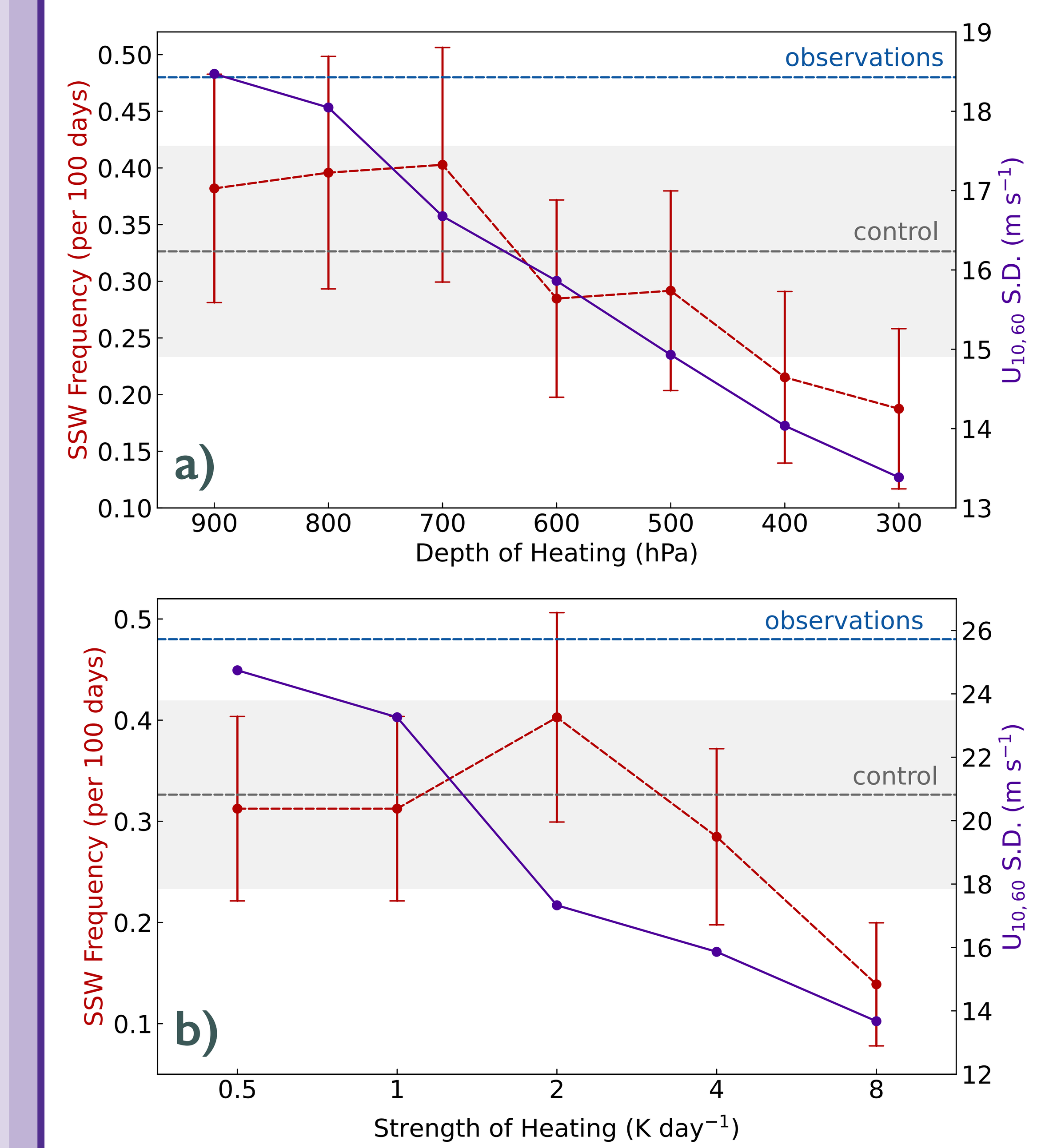


Fig 3: a) change in vortex S.D. (purple solid) and SSW frequency (red dash) with increasing heating depth and for MERRA2 (dash) and the control (grey)
b) same as a) for increasing heating strength

Sensitivity to the depth and strength of polar heating may be one of the drivers behind the intermodel spread in stratospheric response to future Arctic change

5. FUTURE

We will next investigate how the reponse of the polar vortex to heating depends on:
- heating location;
- vortex strength;
- QBO phase