

Modulation of the Monsoonal Hadley Circulation and its interconnected dynamics with the Arctic amplification.

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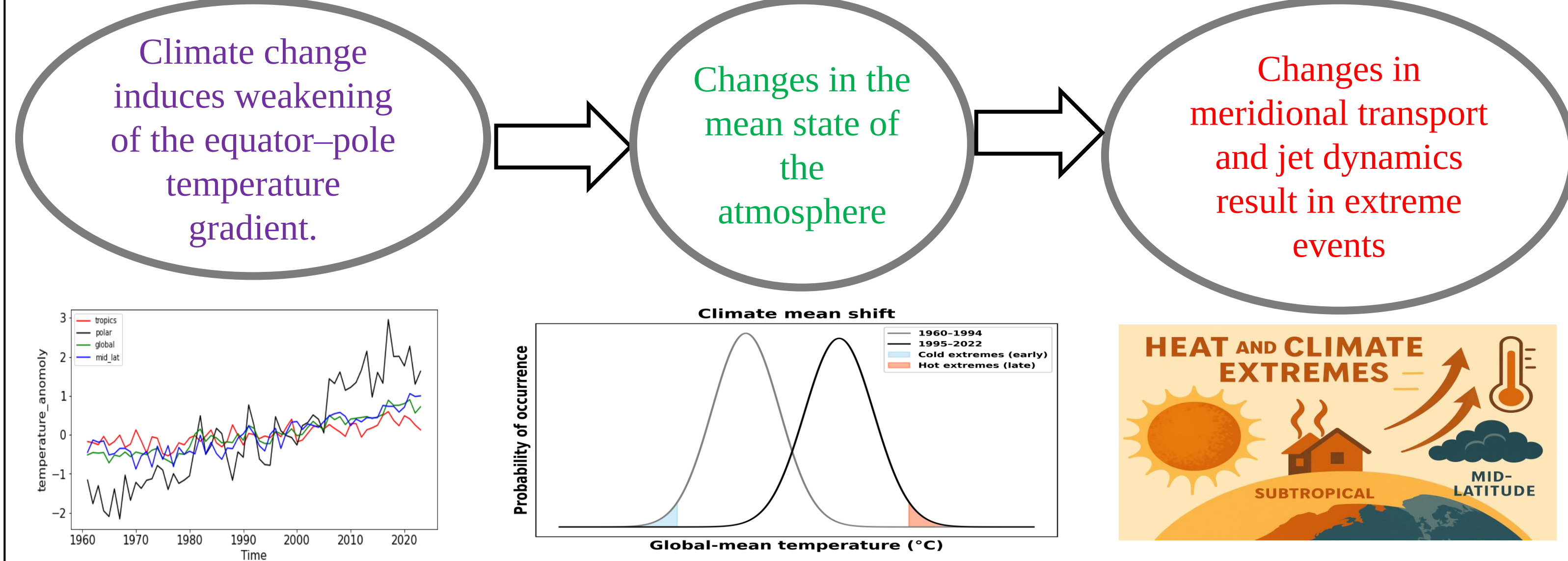
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Introduction

- Changes in the mean climate state arise from the combined effects of anthropogenic forcing and the climate system's inherent internal variability.
- Arctic amplification reduces the equator-to-pole temperature gradient, thereby changing the background mean state of the atmosphere.
- This study investigates how climate-induced changes in the mean state influence large-scale meridional heat transport and jet-stream dynamics, using a two-layer idealized quasi-geostrophic baroclinic model.

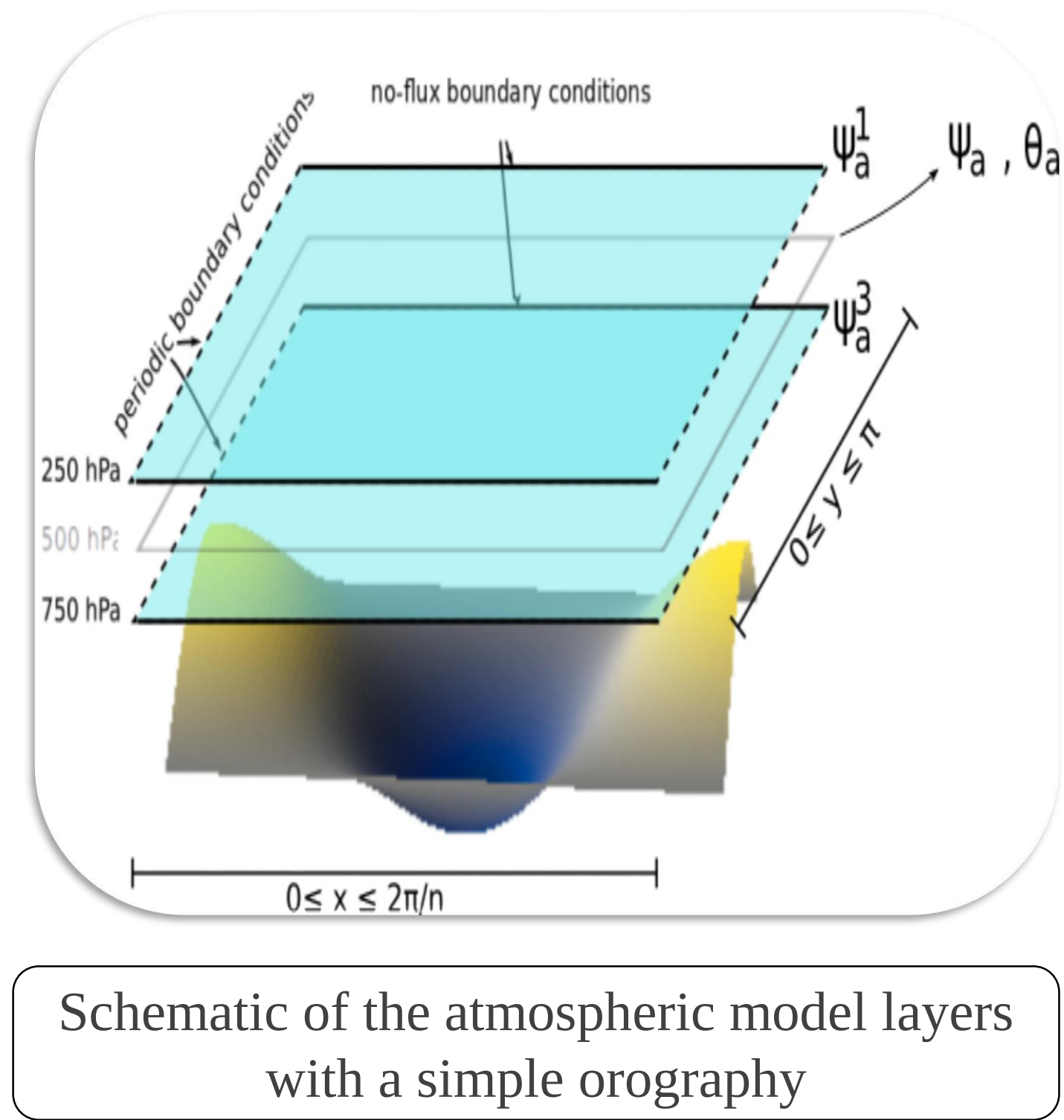


Model Description

- Sensitivity experiment using a two-layer quasigeostrophic baroclinic spectral model (QG) to study planetary-scale motions in a thermally driven atmosphere.

- Model is truncated at wavenumber 2 in both x and y , giving 10 spectral modes. Model uses a basis function with a purely zonal structure, making it ideal for representing equator-to-pole differential heating (F1).

- A non-dimensional heating profile (radiative equilibrium potential temperature) is given to the model.



Methodology

- The construction of the RMHC (Regional Monsoonal Hadley cell) using the divergent meridional wind $\mathcal{V}x$, and square brackets denote zonal average over the Indian region (50°E-110°E). Negative RMHC means anticlockwise circulation and Positive RMHC means clockwise circulation.

$$\psi(\phi, p) = \frac{2\pi a \cos \phi}{g} \int_0^p [\mathcal{V}x] dp$$

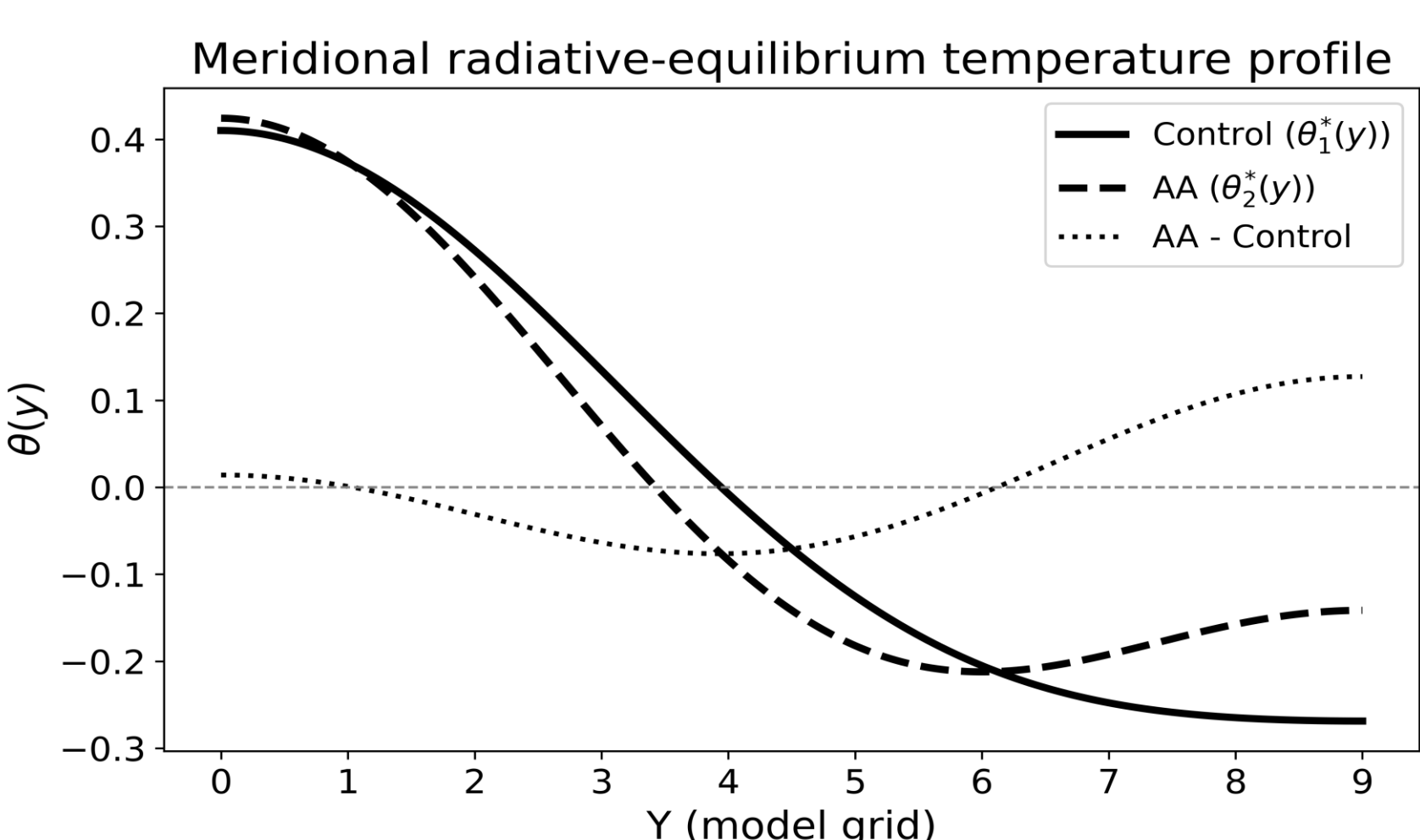
Experiment

Experiment name	Radiative-equilibrium temperature forcing	Basis function coefficient	Description
(i) Control experiment (CTRL)	$\theta_1^* = a_1 F_1 + a_2 F_2 + a_5 F_5$	$a_1 = 0.24; a_2 = 0.05; a_5 = 0.15$	Reference meridional temperature profile
(ii) Arctic Amplification experiment (EXP/AA)	$\theta_2^* = a_1 F_1 + a_2 F_2 + a_5 F_5$	$a_1 = 0.20; a_2 = 0.10; a_5 = 0.15$	Enhanced high-latitude warming and reduced equator-to-pole meridional temperature gradient, representing an idealized AA response

Basis Function

$$\begin{aligned} F_P^A(x, y) &= \sqrt{2} \cos(Py), \\ F_{M,P}^K(x, y) &= 2 \cos(Mnx) \sin(Py), \\ F_{H,P}^L(x, y) &= 2 \sin(Hnx) \sin(Py) \end{aligned}$$

Fig: Meridional profiles of the meridional temperature gradient by cooling the equator and warming the pole.



Result

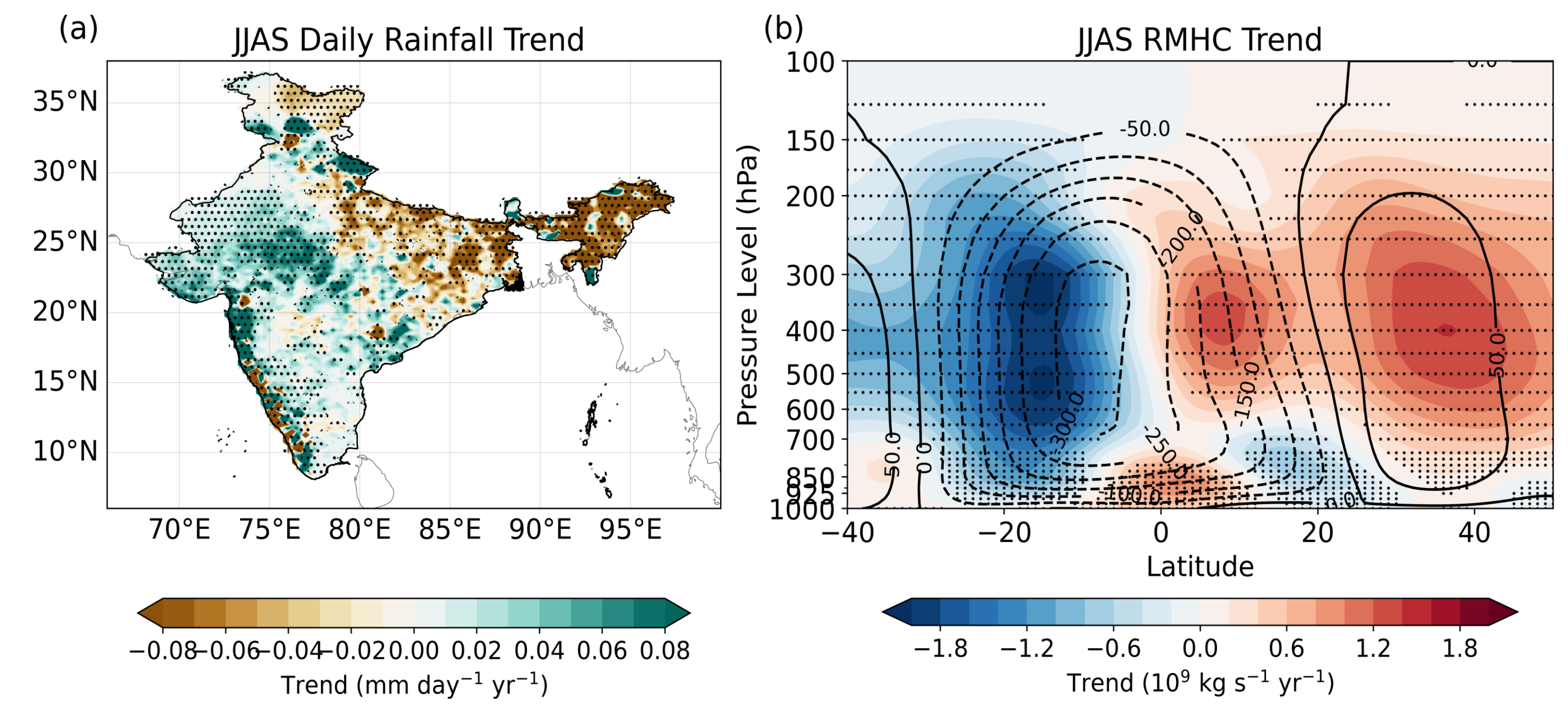


Fig: Rainfall and RMHC Trend. East-west asymmetry in the Rainfall Trend. (a) Increasing (decreasing) rainfall trend over northwest India (IGP), (b) RMHC Trend (shading). Stippling indicates the 95% confidence level.

Sensitivity Experiment

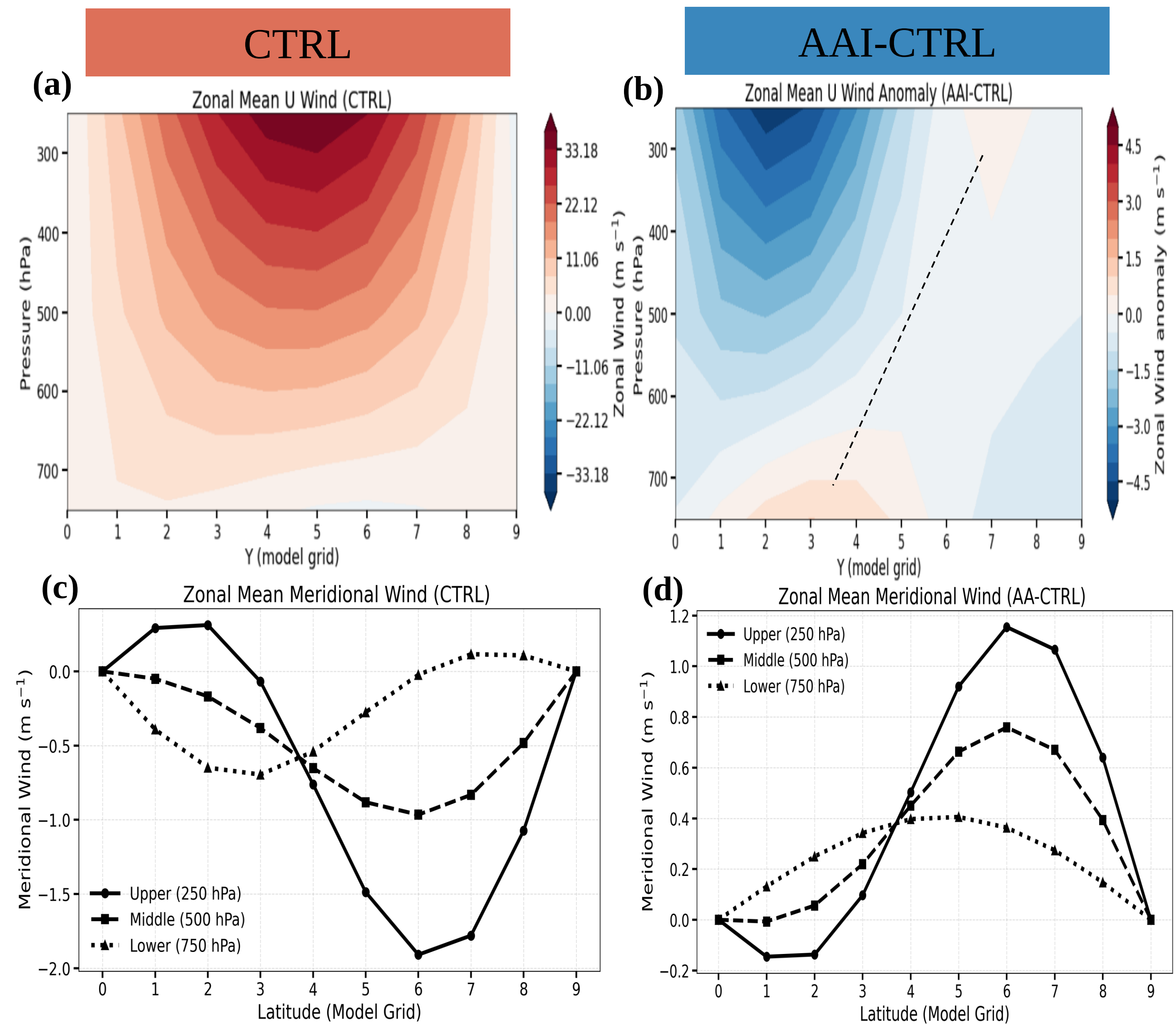


Fig: (a) CTRL simulation zonal wind (b) AA-CTRL simulation zonal wind. (c) CTRL simulation Meridional flow in upper, lower and middle levels. (d) AA-CTRL simulation Meridional flow in upper, lower and middle levels.

Conclusions

- East-west asymmetry in the rainfall pattern and a decreasing trend in the ascending branch of the RMHC, and an increasing trend in the descending branch.
- Climate change induces weakening of the equator-to-pole temperature gradient, which modifies the mean state of the meridional flow and jet dynamics.
- In (2,2) CTRL simulation: The net equatorward transport in the upper level and poleward transport in the lower level with realistic magnitude of the zonal wind.
- In (2,2) AA-CTRL response: Split of the zonal wind jet with easterlies in the equatorward and westerlies in the poleward side of the CTRL jet. Also, an intensification of poleward meridional flow at the upper level. This circulation change favors extreme midlatitude events by altering storm-track pathways.

Acknowledgement

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