Supporting Information for "Poleward Shift of Northern Subtropics in winter: Time of Emergence of Zonal versus Regional Signals"

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Text S1: Forced Response and Internal Variance

The variance of the forced response is given by

$$FV = \frac{\sum_{i=i_1}^{i_2}(F_{fr}^i - F_{fr})^2}{i_2 - i_1} \ , \ F_{fr} = \frac{\sum_{i=i_1}^{i_2} F_{fr}^i}{i_2 - i_1 + 1} \ . \tag{1}$$

The internal variance is computed following the procedure described by Maher et al. (2019); Bellomo, Murphy, Cane, Clement, and Polvani (2018) as:

$$IV = \frac{\sum_{i=i_1}^{i_2}\sum_{e=1}^{e=100}(f_e^i - F_{fr}^i)^2}{100 * (i_2 - i_1)} \ . \tag{2}$$

The Total Variance, which is defined as

$$TV = \frac{\sum_{i=i_1}^{i_2}\sum_{e=1}^{e=100}(f_e^i - F_{fr})^2}{100 * (i_2 - i_1)} \ , \tag{3}$$

is then the sum of the forced and internal variances:

$$TV = FV + IV; \tag{4}$$

Here the time steps i_1 and i_2 delimit the period considered in the computation.

Text S2: Time series of zonally-averaged Northern subtropical margins.

Figure S1 shows time series evaluated by zonally averaging the Northern subtropical margins. Here most of the uncertainty on the shift is due to the internal climate variability for all metrics except OLR, which has a stronger sensitivity to the applied forcing than other metrics. In terms of total variance, the contribution of the forced response is smaller than that of the internal variability or even negligible with respect to it, ranging from a minimum 1% for P-E and MSLP in the Historical to a maximum 30% for OLR in the 1%CO2 experiment. However, in spite of the large ensemble spread, the poleward shift of Northern subtropical margins is clear for all metrics and it is progressively increasing with time.

References

Bellomo, K., Murphy, L. N., Cane, M. A., Clement, A. C., & Polvani, L. M. (2018). Historical forcings as main drivers of the Atlantic multidecadal variability in the CESM large ensemble. *Climate dynamics*, *50*(9-10), 3687–3698.

Maher, N., Milinski, S., Suarez-Gutierrez, L., Botzet, M., Dobrynin, M., Kornblueh, L., ... others (2019). The Max Planck Institute Grand Ensemble: Enabling the Exploration of Climate System Variability. *Journal of Advances in Modeling Earth Systems*, *11*(7), 2050–2069.

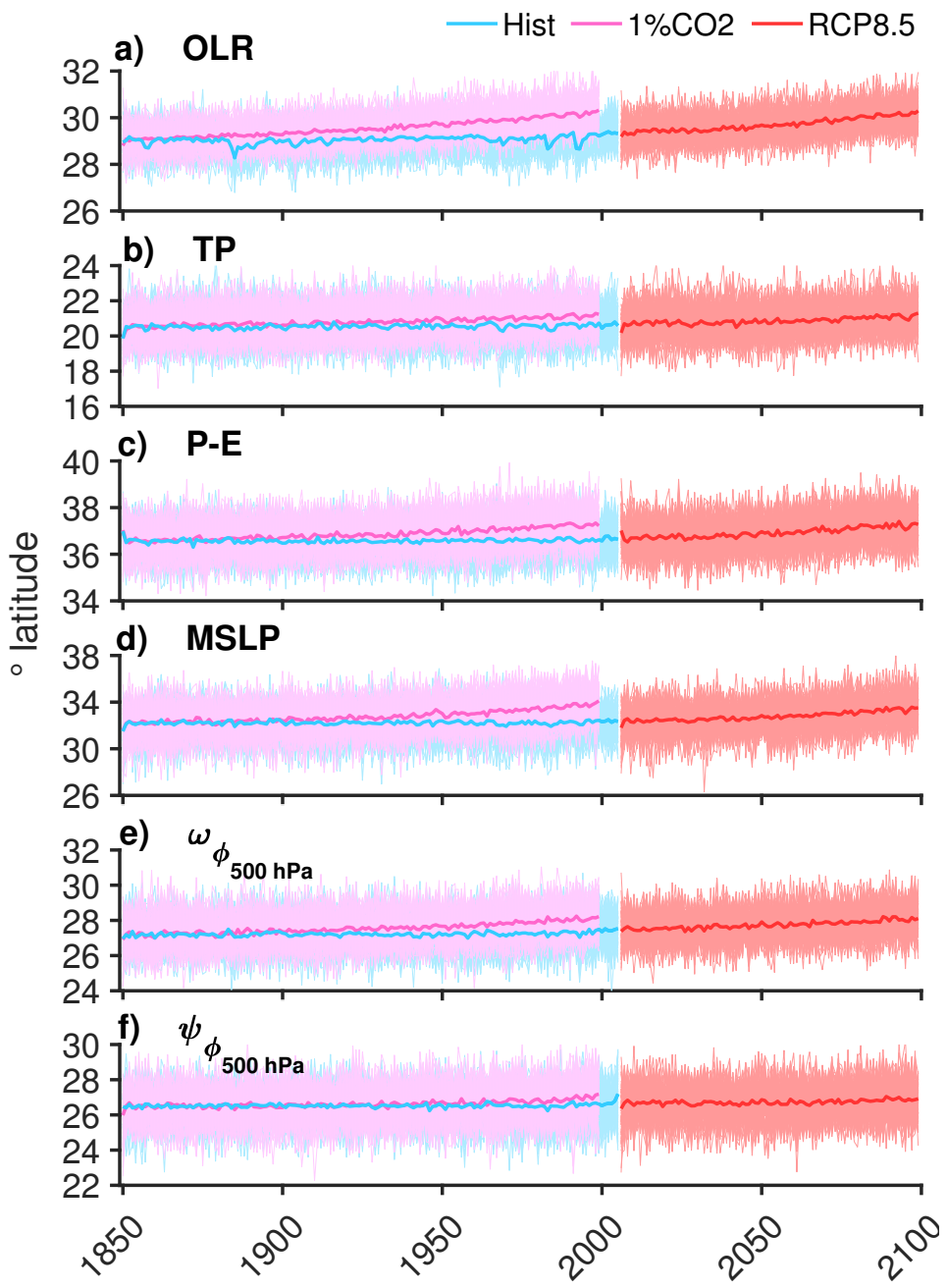

Figure S1. Time series of the zonally averaged Northern subtropical margins (on the left) and its mean over the whole length of the simulation (on the right). Left panels show results for different metrics (top-left labels) for the Historical (blue), 1%CO2 (purple) and RCP8.5 (red). Thick lines show the ensemble mean and the thin lines the ensemble members.