The Impact of the Asian Summer Monsoon Circulation on the Tropopause

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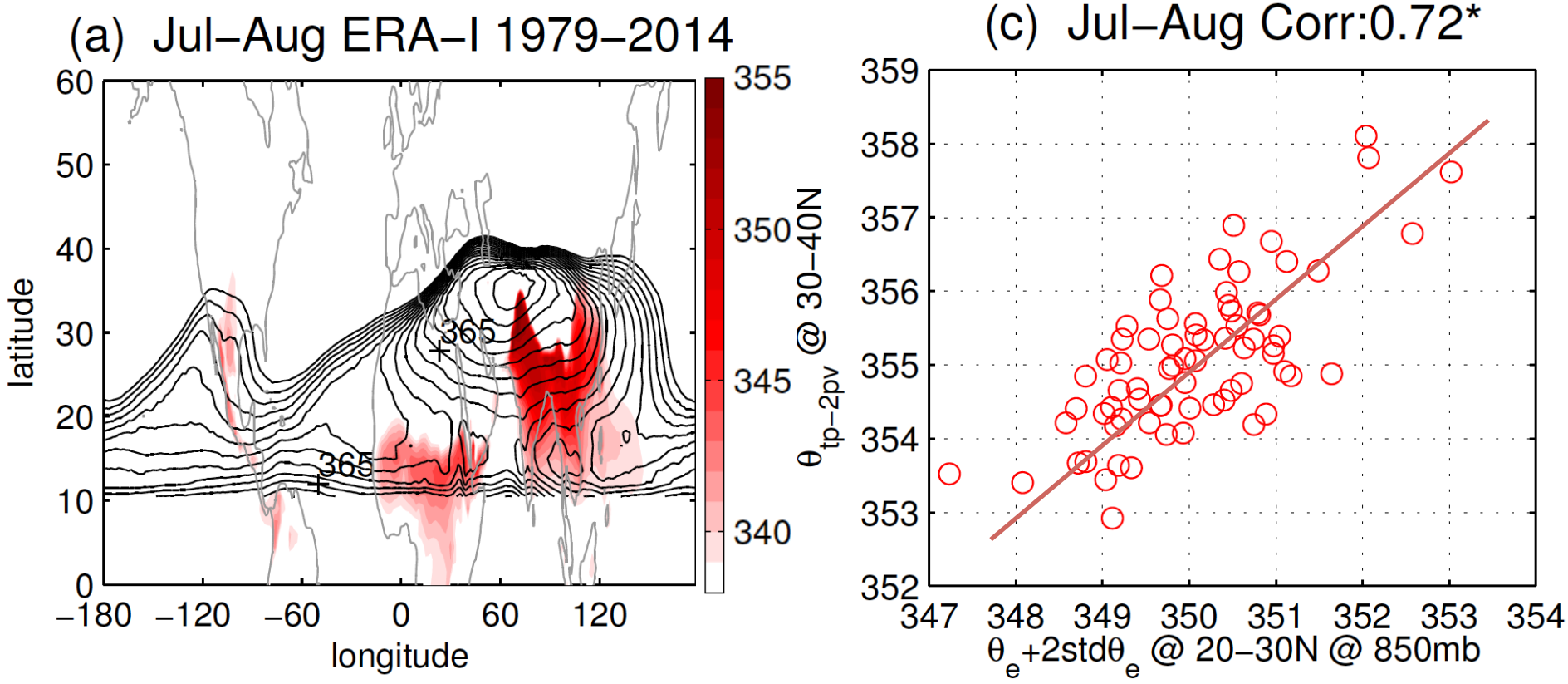
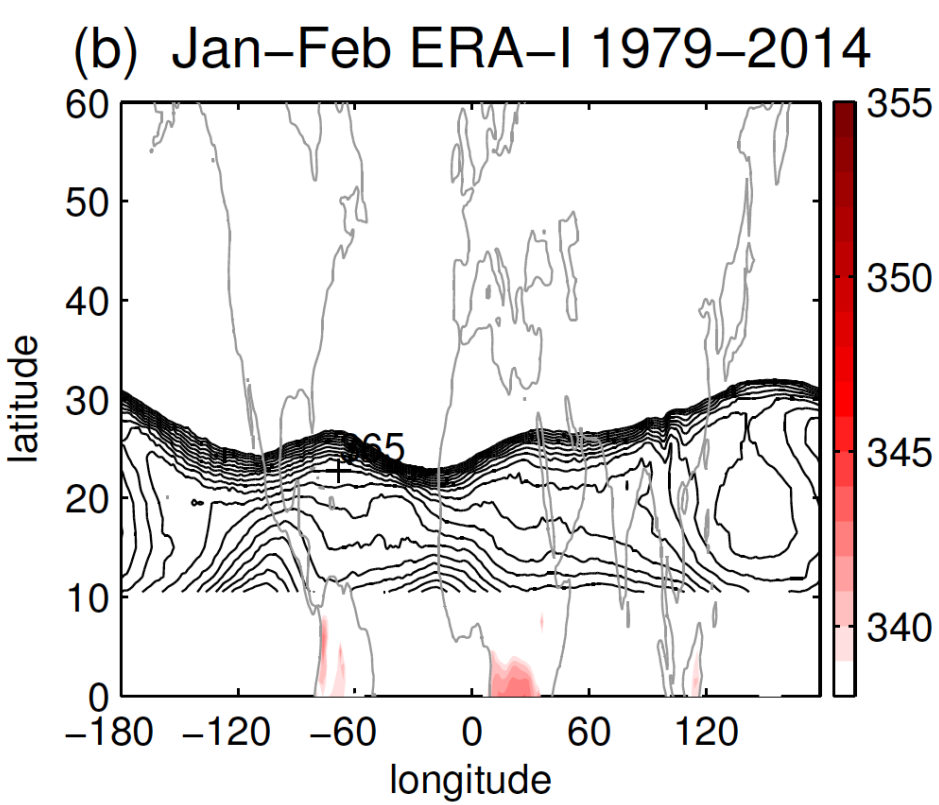
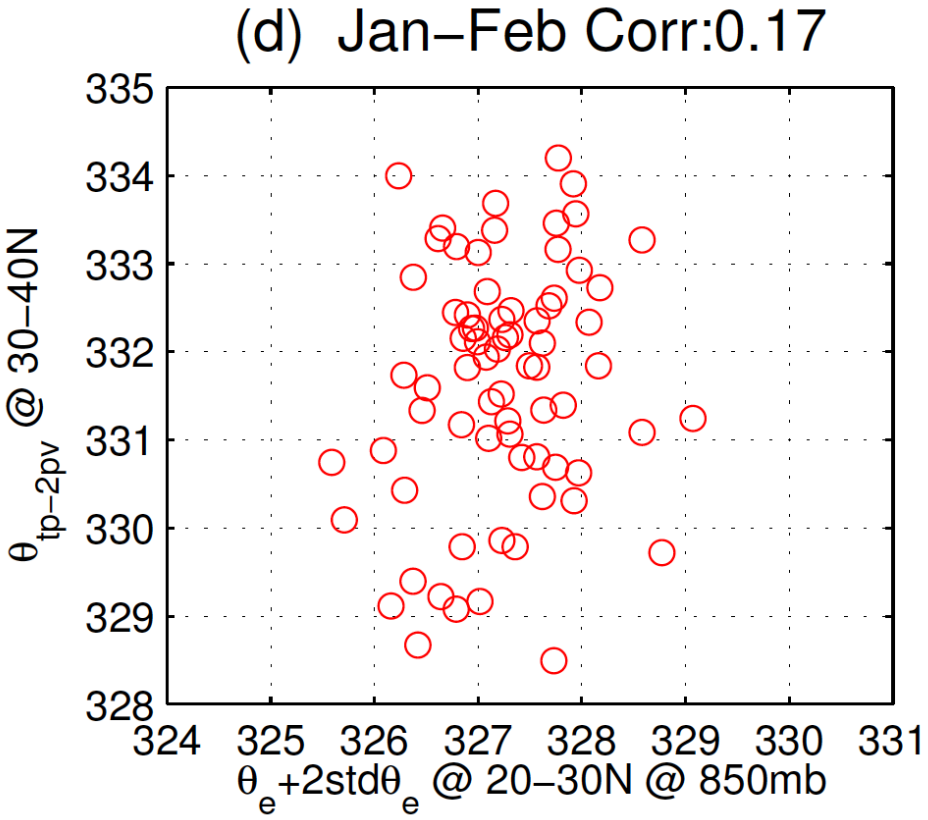
Motivation:
An Observed Strong Moisture-Tropopause Linkage in Northern Summer



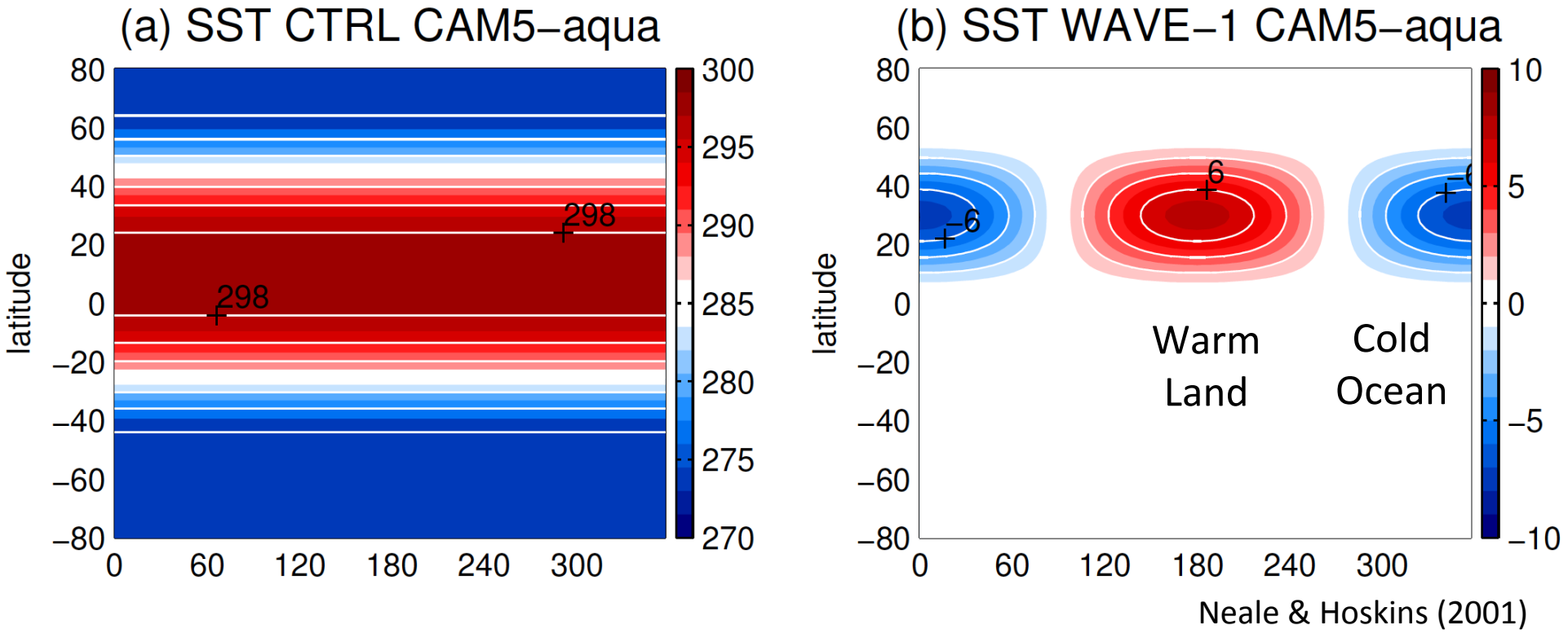
No Moisture-Tropopause Relationship in Northern Winter



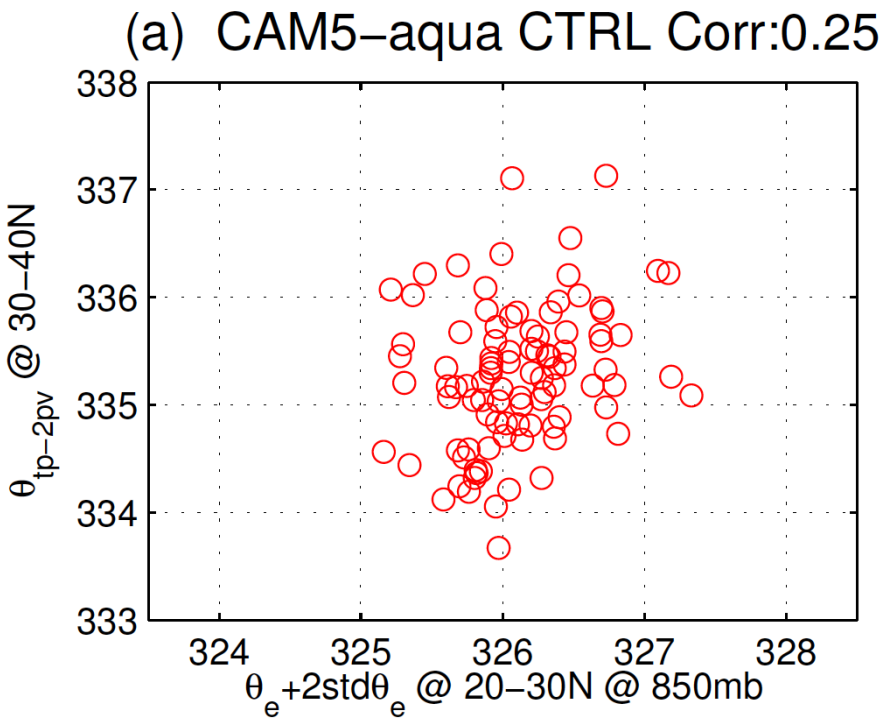


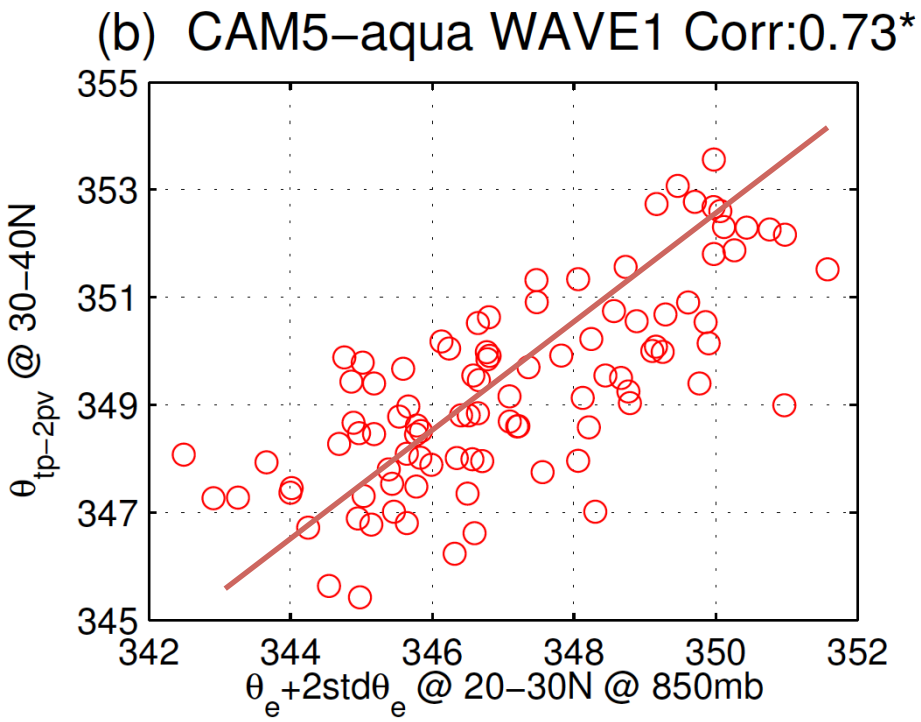
Hypothesis:
Asian summer monsoon plays a critical role in determining the tropopause

- Idealized model experiments: CAM5 aquaplanet model with a prescribed subtropical wave-1 SST perturbation (Shaw 2014)

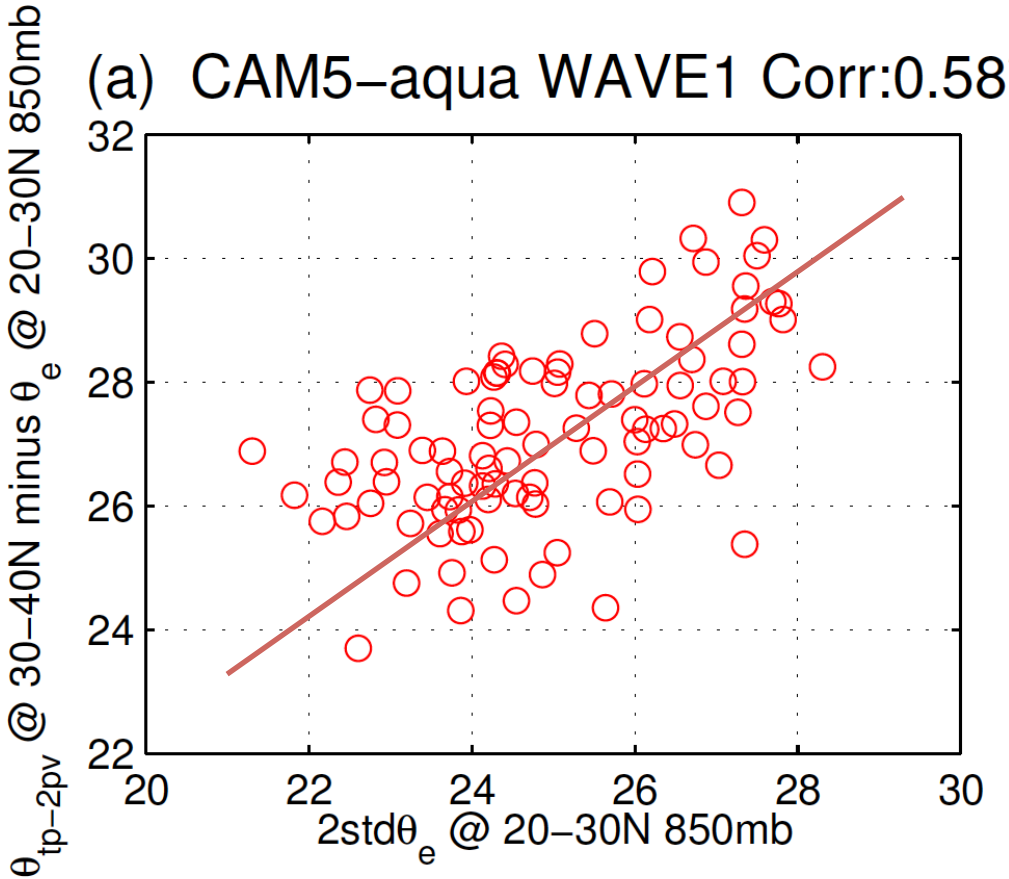


- Development of a strong moisture-tropopause connection as a monsoon-like SST perturbation is introduced

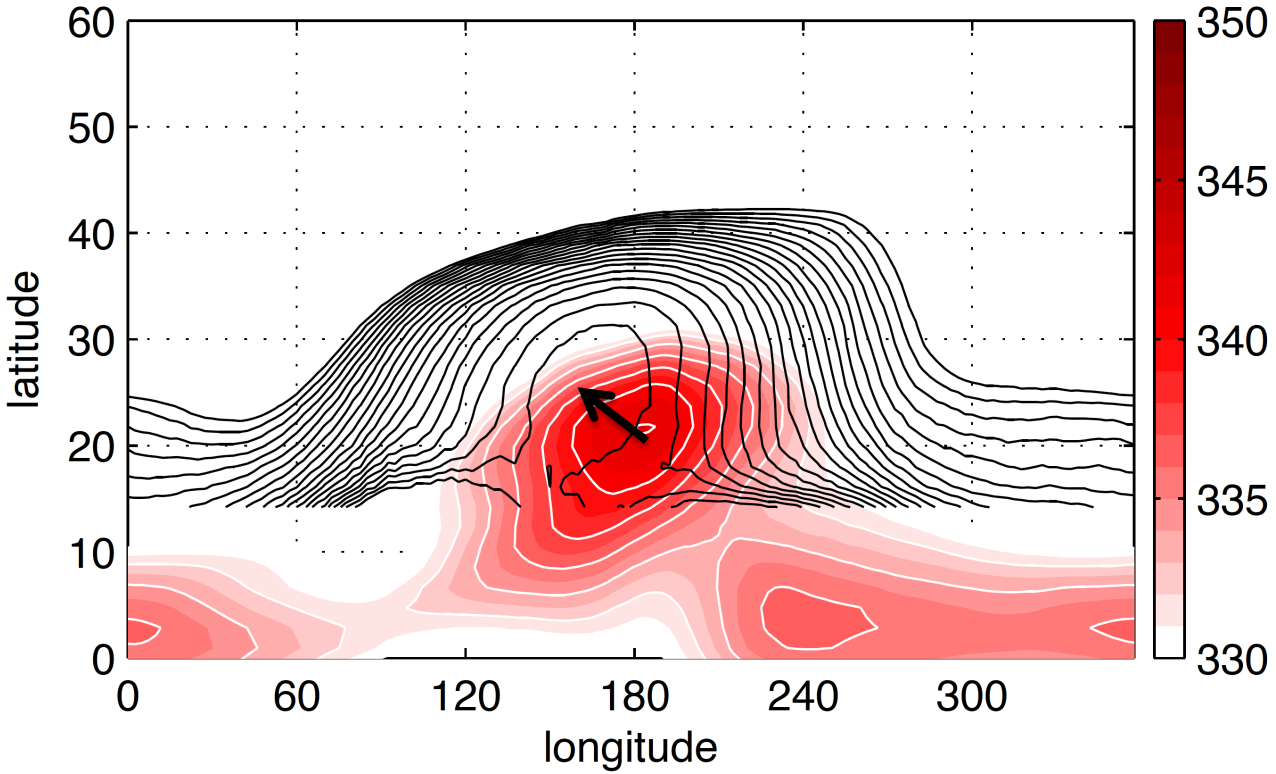




- Importance of planetary-scale eddies on thermal stratification



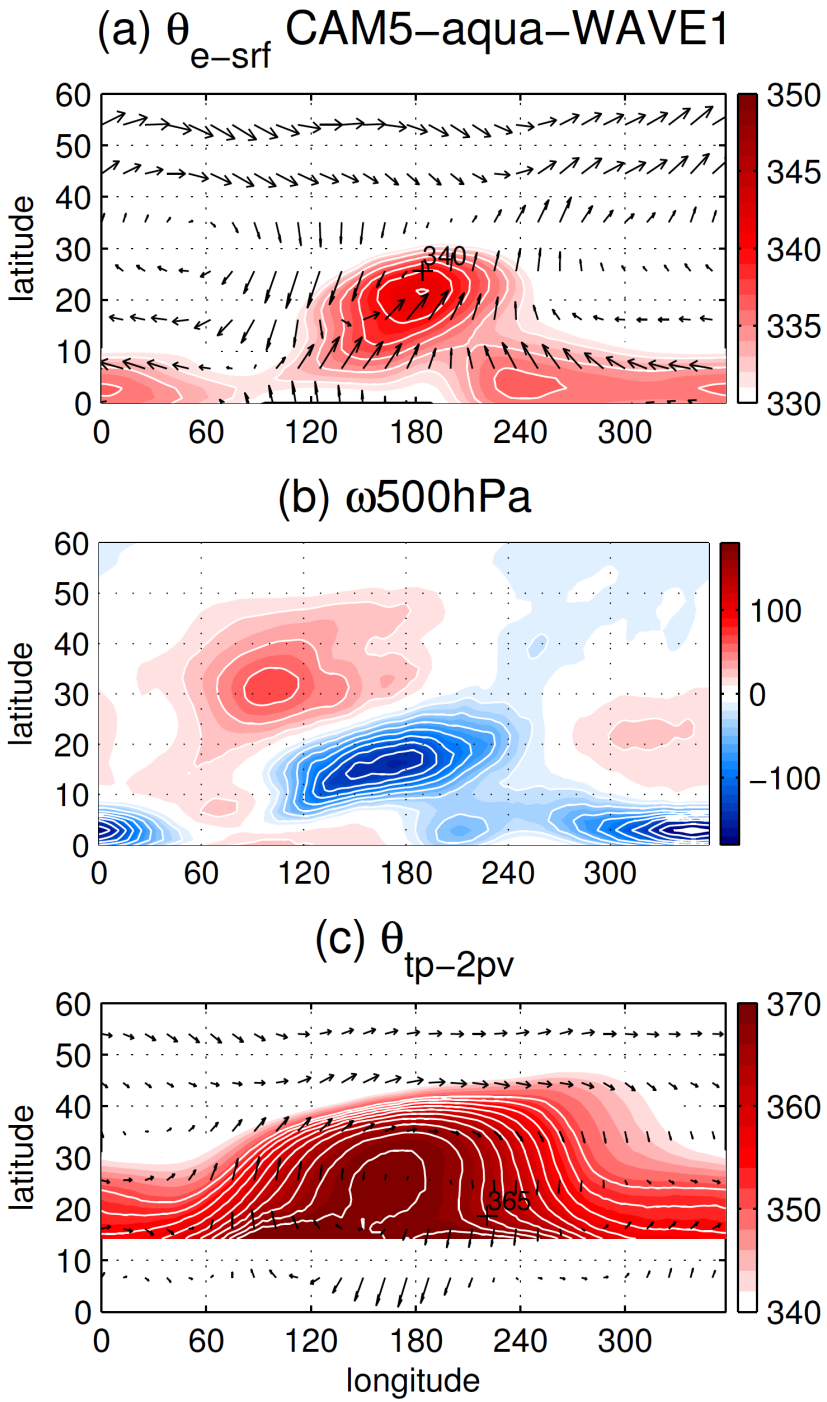
- The maximum of mean tropopause is not co-located with, but is shifted to the north-west of maximum low-level mean equivalent potential temperature



Questions to address

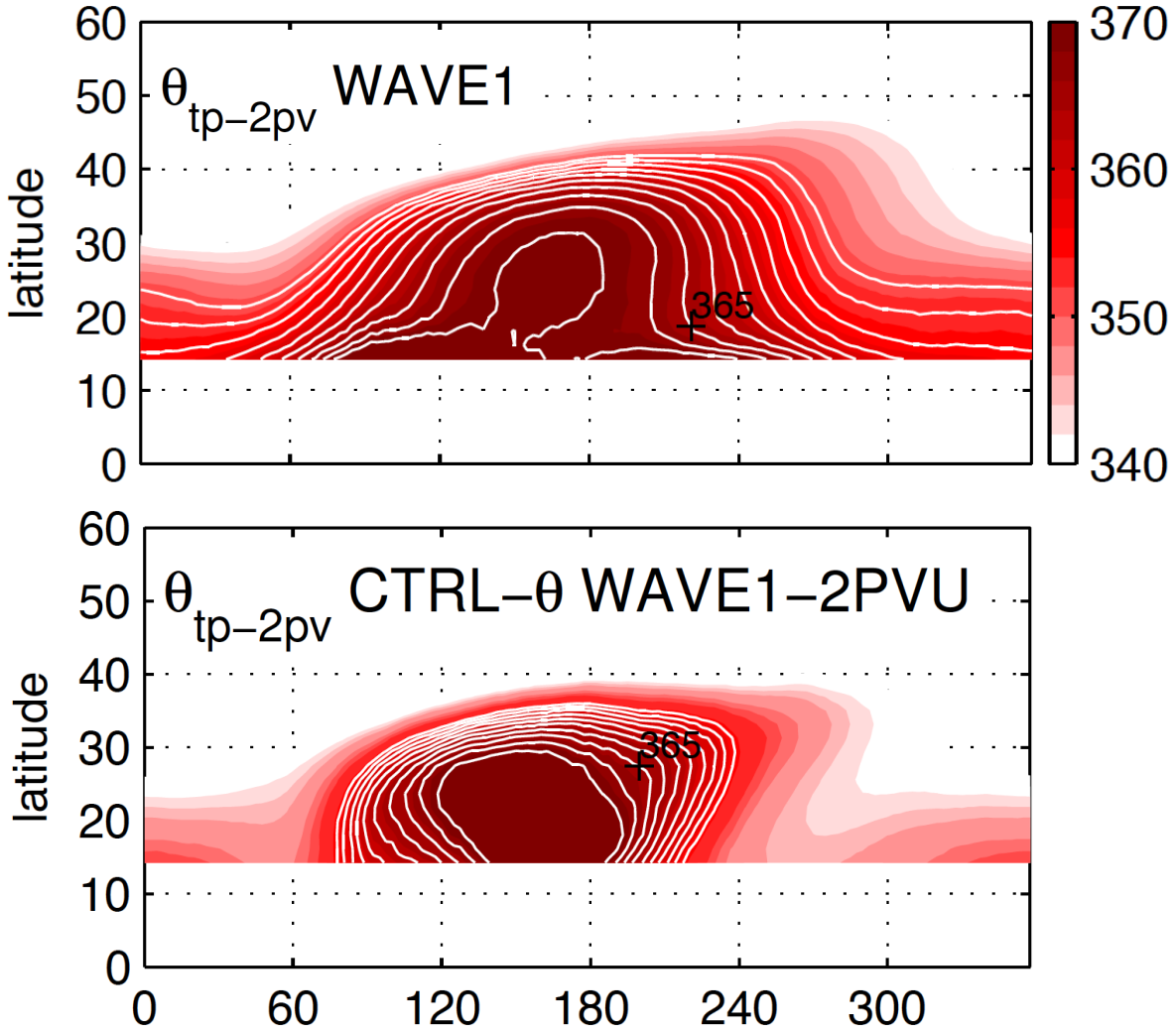
- Why is there a strong moisture-tropopause correlation during northern summer?

- Why is there an increase and north-west shift of maximum tropopause potential temperature?



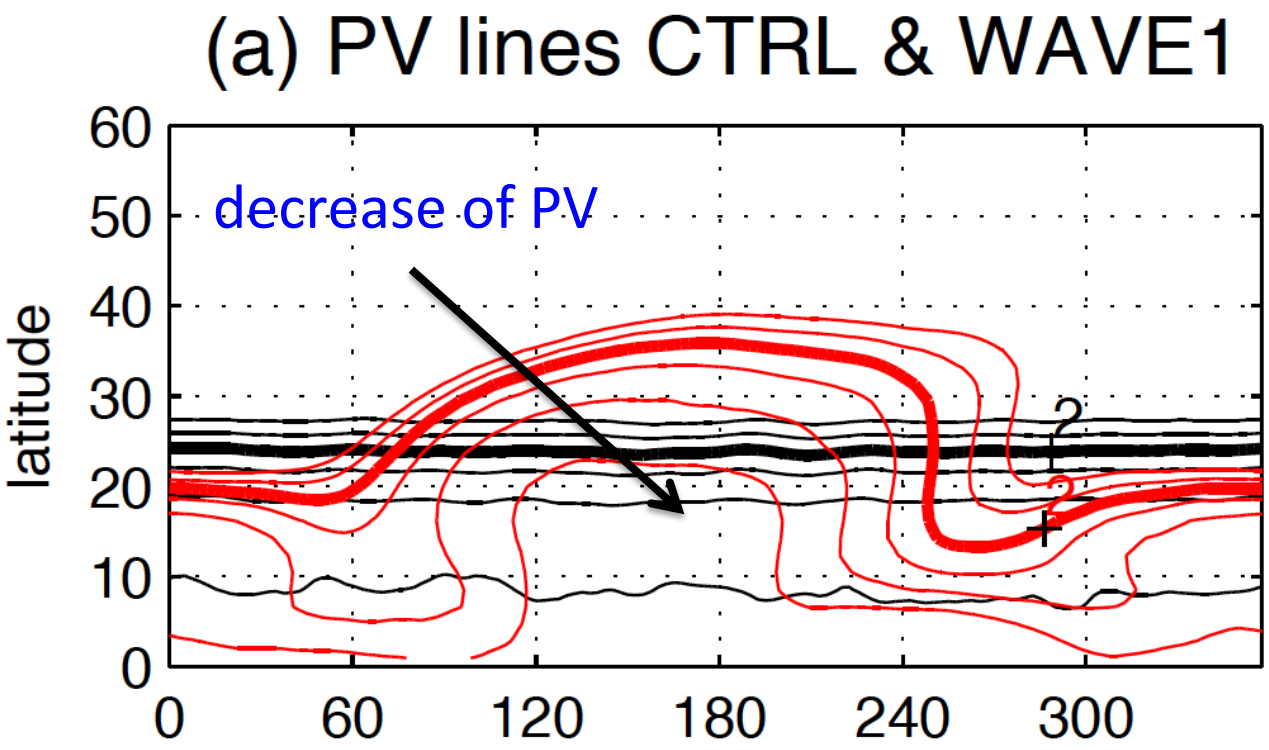
- The aquaplanet WAVE1 experiment is able to capture the monsoon-desert relationship as in Rodwell and Hoskins (1996, 2001)

- The increase and north-west shift of 2 PVU tropopause is primarily due to the change of PV



- What causes the change of PV?

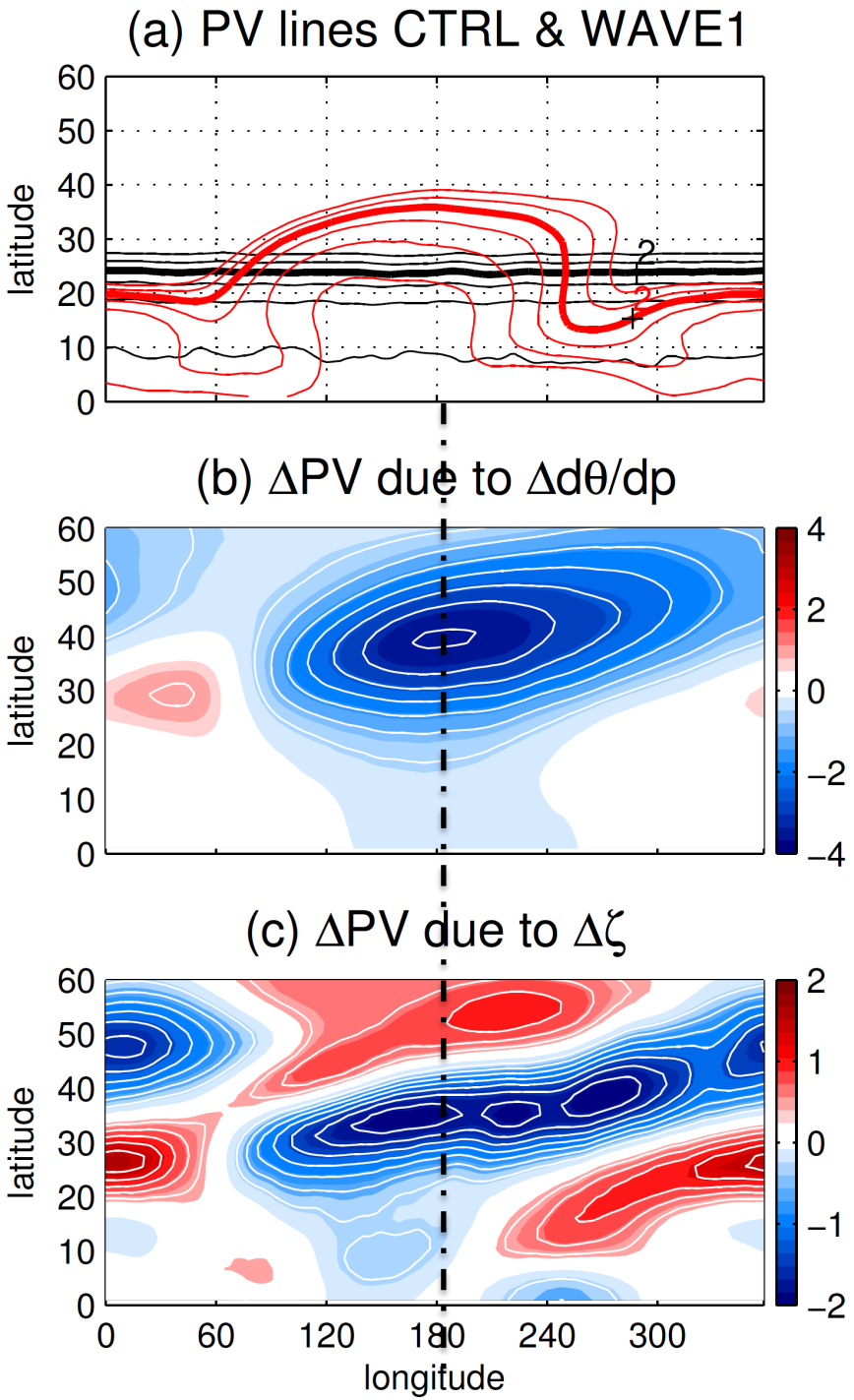
$$PV = -g(f + \zeta)\frac{\partial \theta}{\partial p}$$



$$-g(f+\zeta_c)\delta\left(\frac{\partial\theta}{\partial p}\right)$$

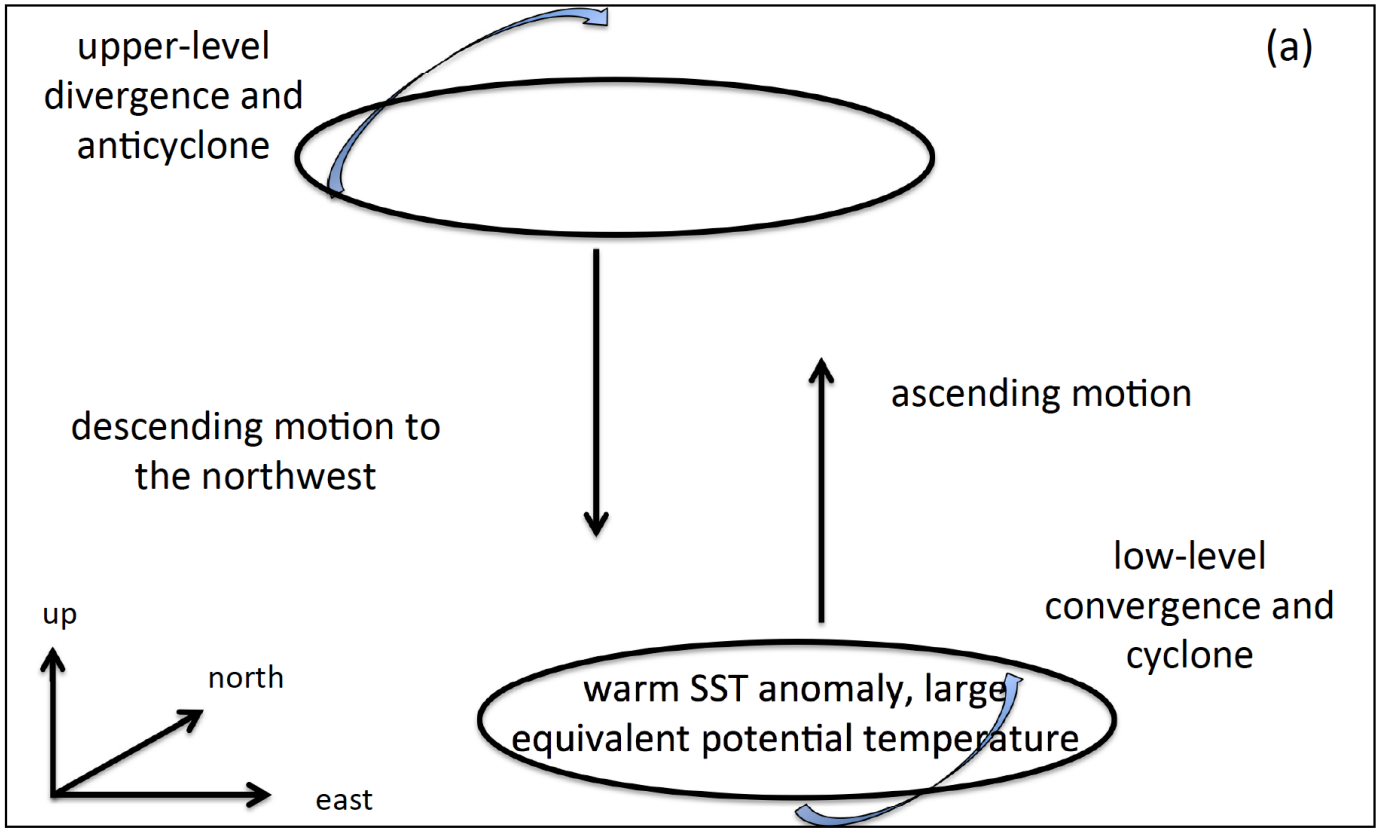
$$-g(f+\delta\zeta)\left(\frac{\partial\theta}{\partial p}\right)_c$$

north-west shift via upper-level anticyclonic vorticity



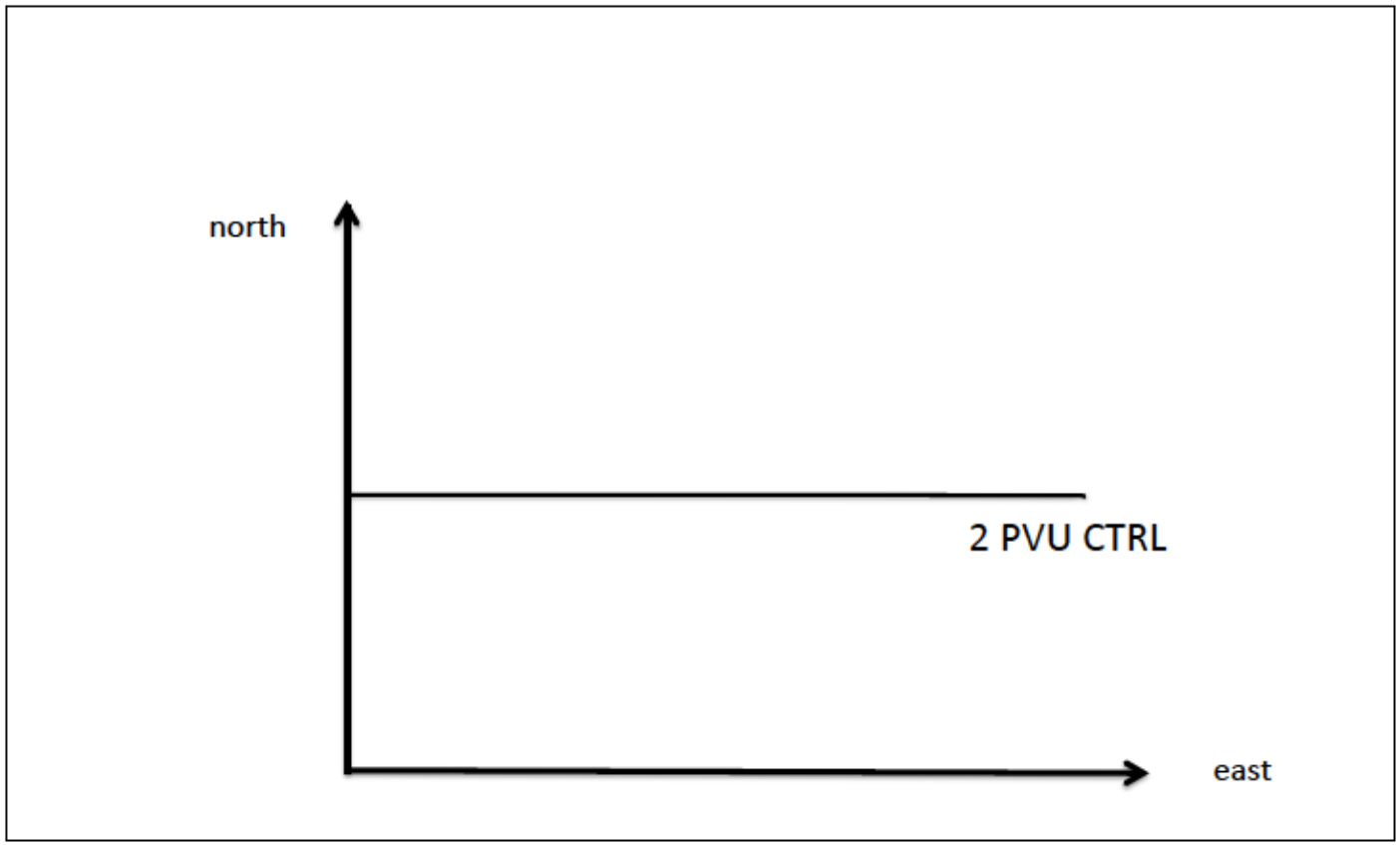
Schematic

- Why a strong moisture-tropopause correlation? – The coupling of low-level cyclonic circulation and upper-level anticyclonic circulation



Schematic

- Why an increase and north-west shift of tropopause potential temperature?



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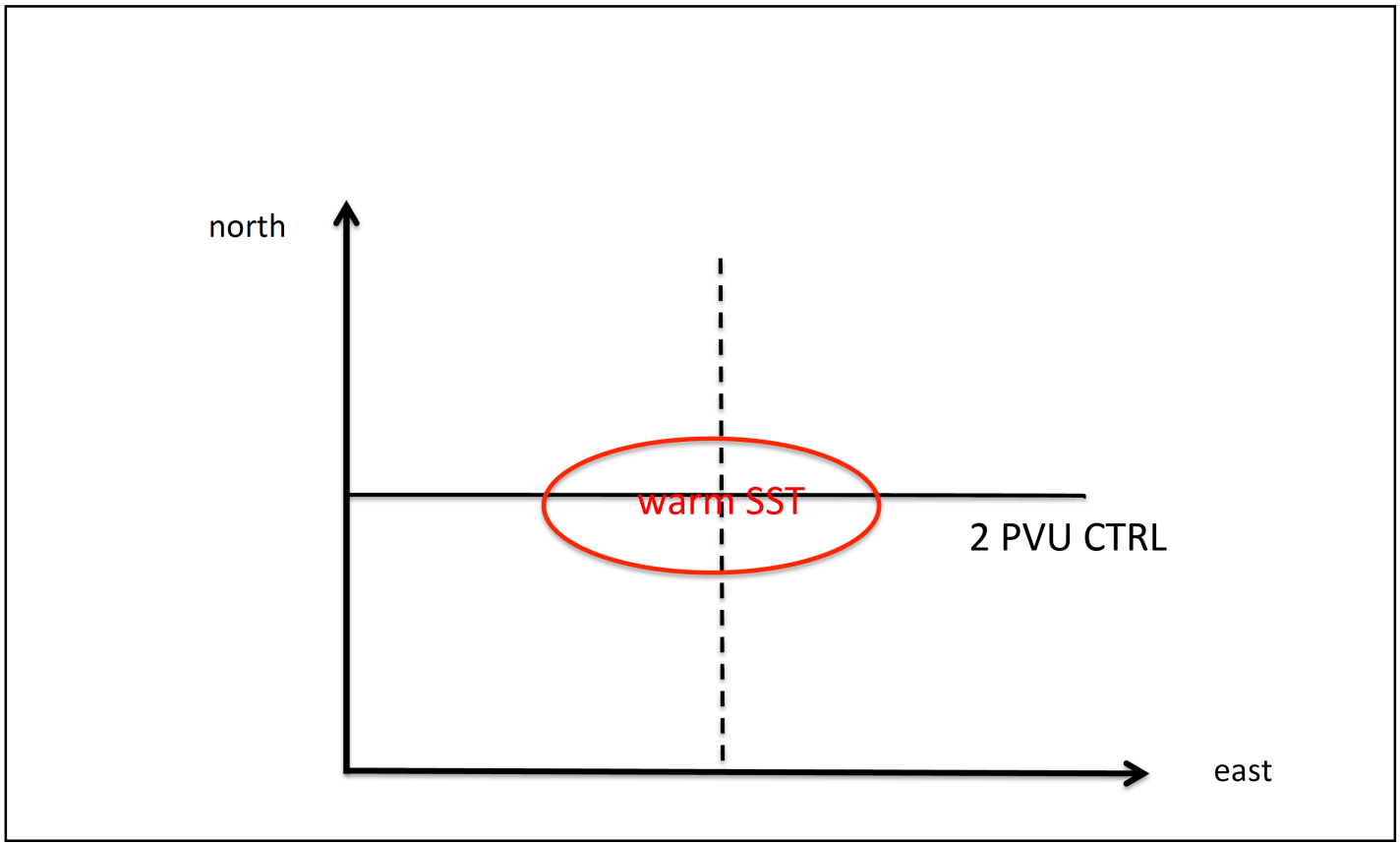

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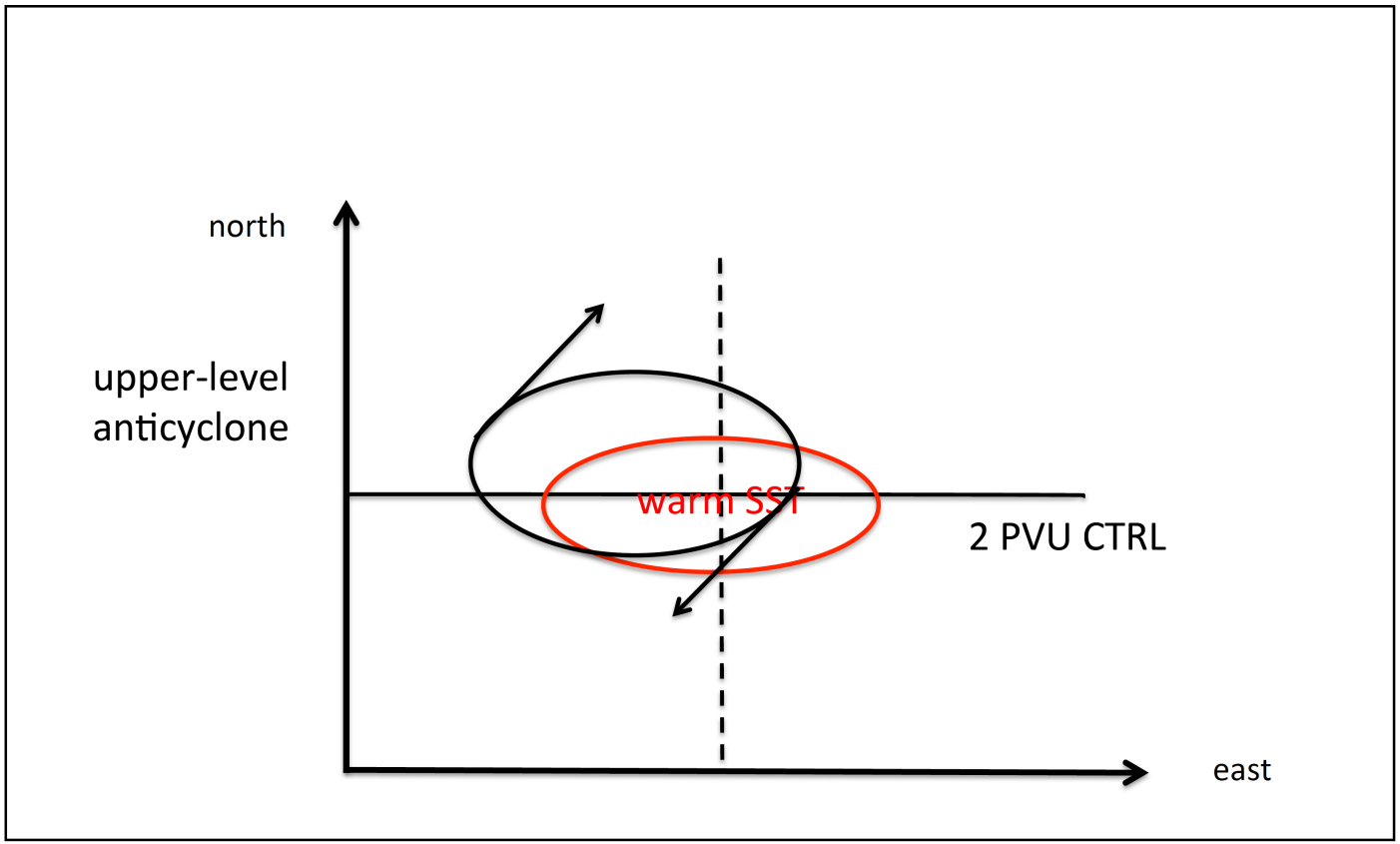

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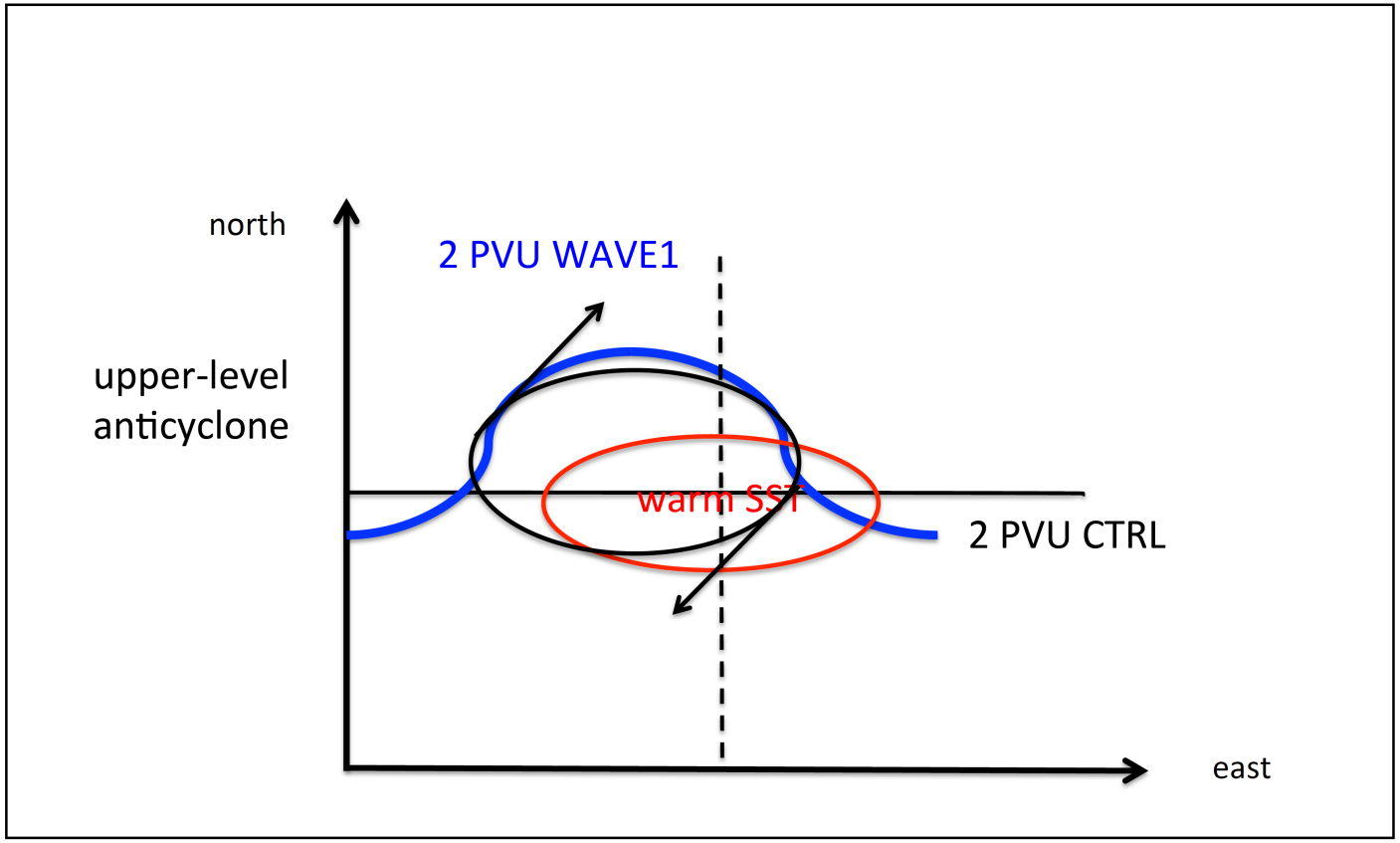
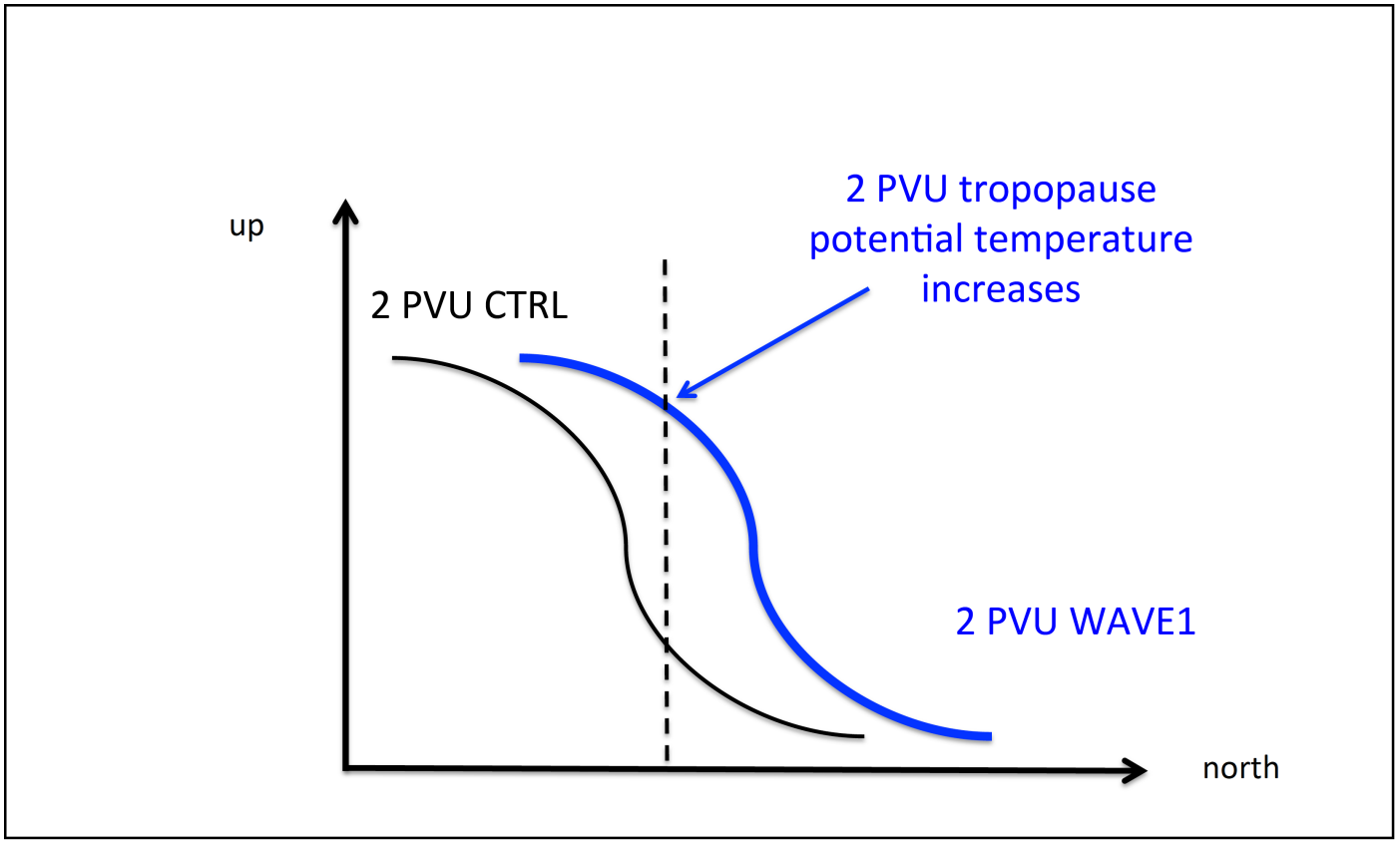
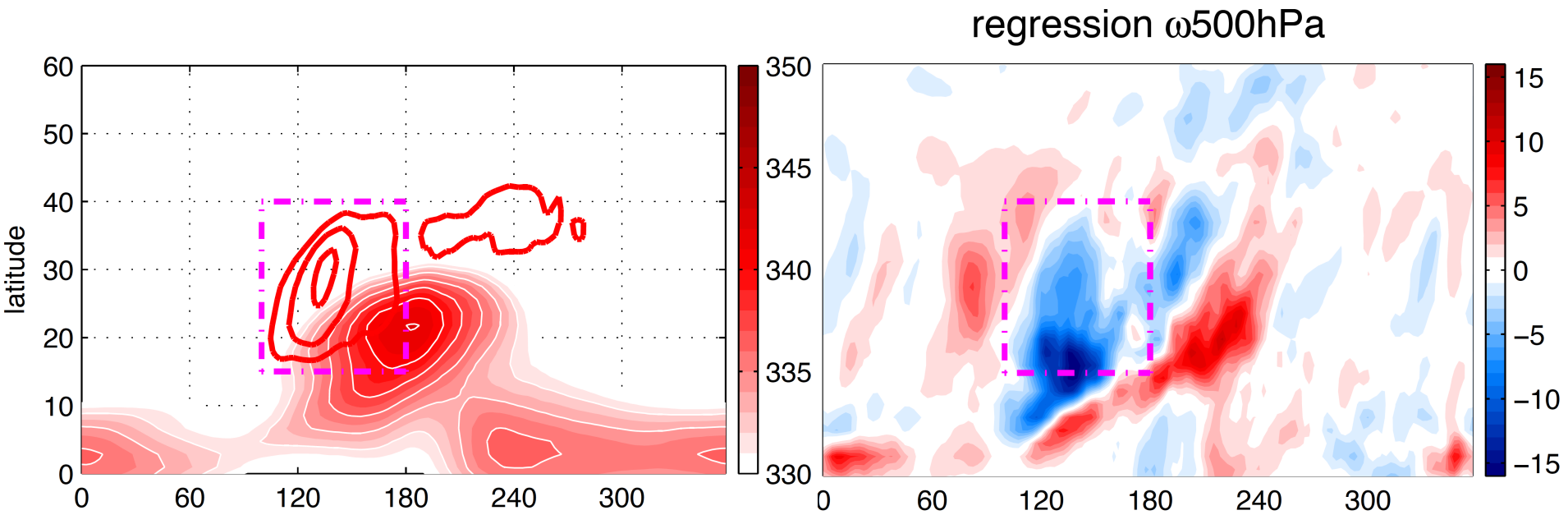


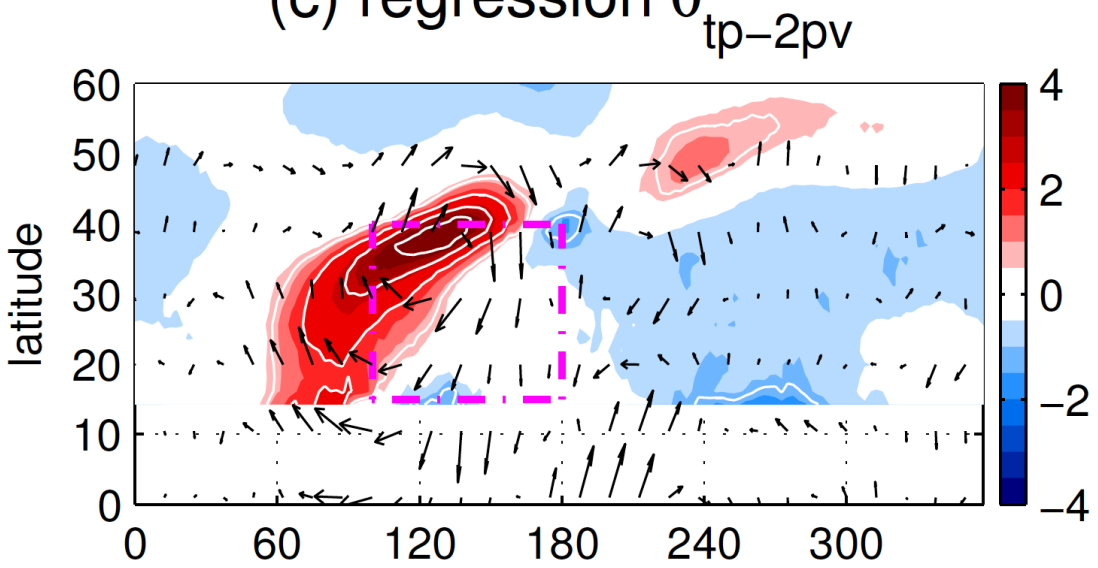
Schematic

- Why an increase and north-west shift of tropopause potential temperature? – The upper-level anticyclonic vorticity lowers the PV to the north-west of the surface heating

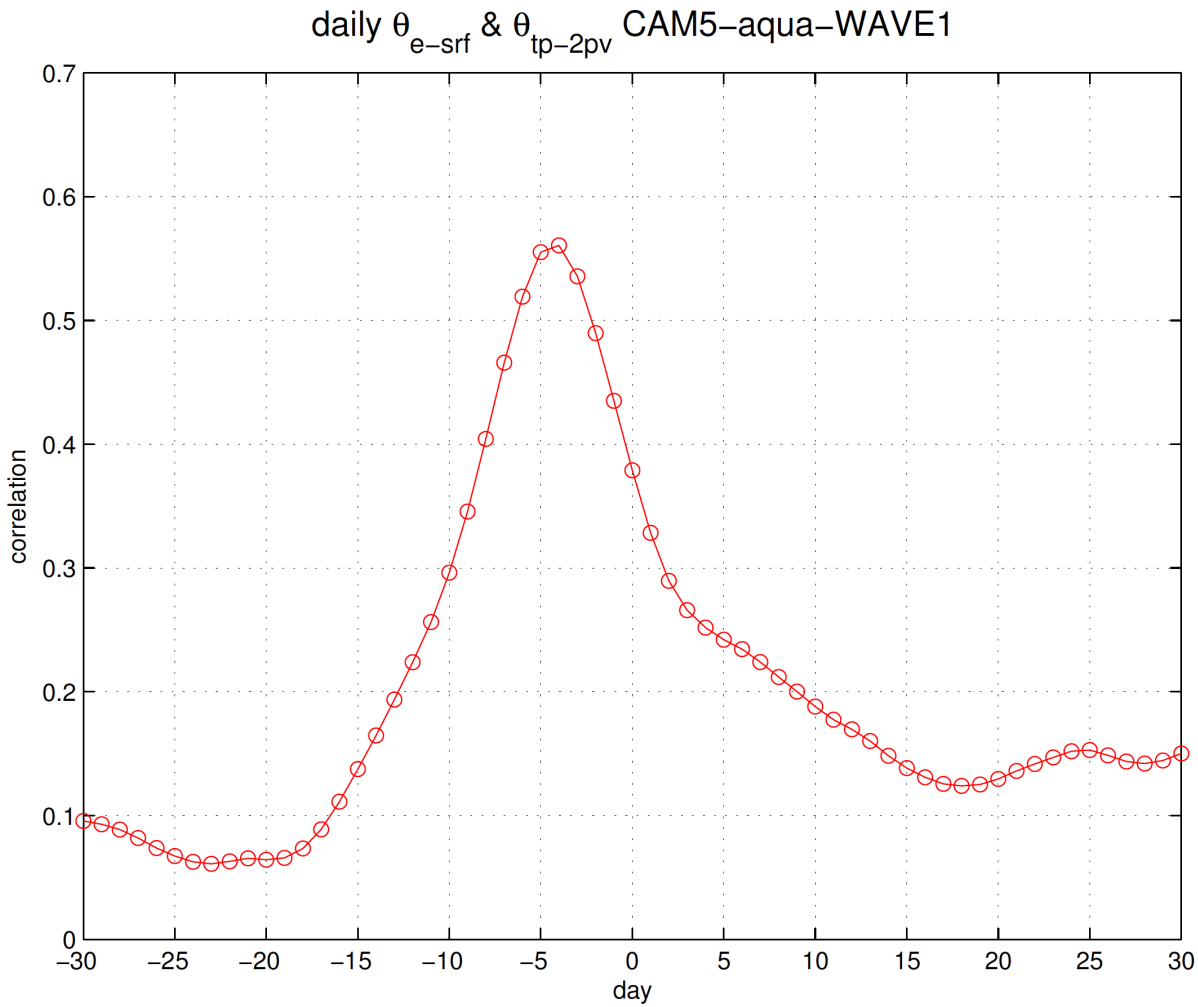


- Mechanism also works for temporal variability

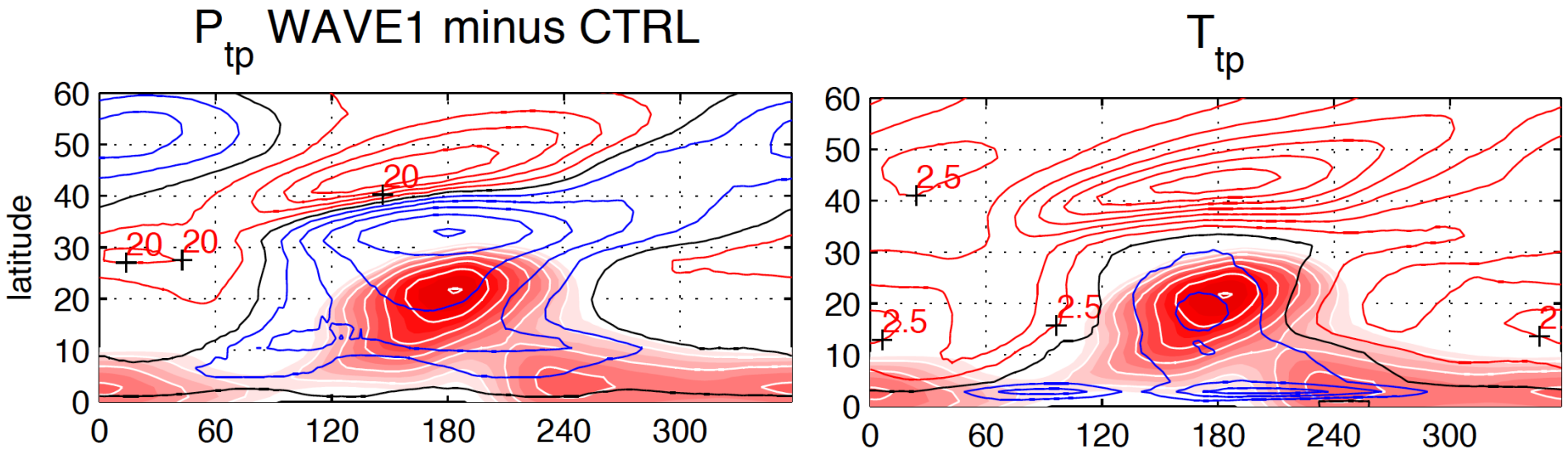




- A maximal correlation of 0.5-0.6 when near-surface equivalent potential temperature leads tropopause potential temperature by about 5 days



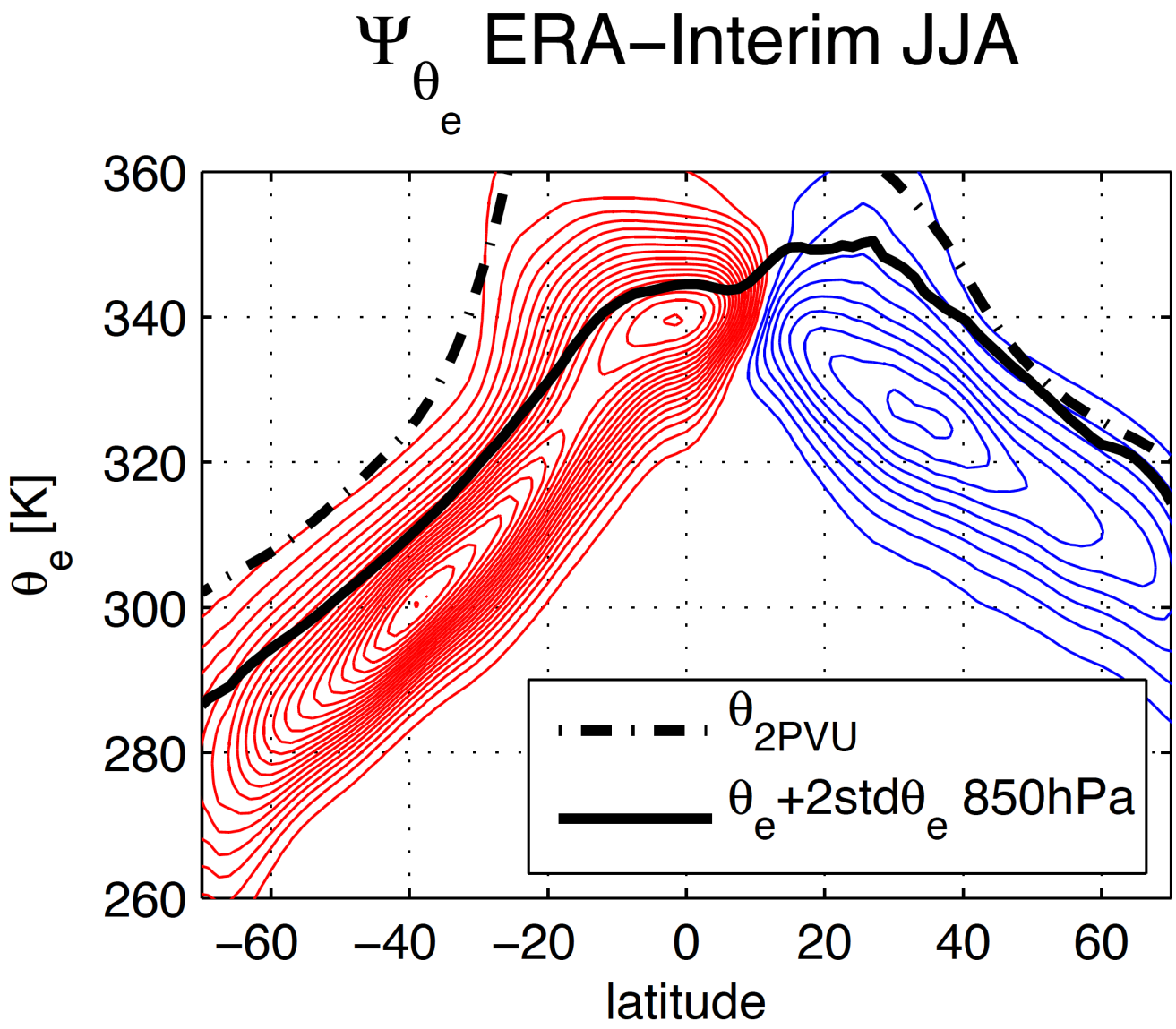
- The increase of tropopause potential temperature is associated with a rise of tropopause height and a decrease of tropopause temperature



Conclusions

- An observed strong moisture-tropopause linkage in northern summer suggests the importance of Asian summer monsoon circulation
- An idealized aquaplanet model experiment forced with a wave-1 SST perturbation is able to capture this moisture-tropopause connection
- A possible mechanism is related to the coupling of the low-level cyclonic circulation and upper-level anticyclonic circulation. The upper-level anticyclonic vorticity lowers the PV to the north-west of the surface heating, leading to an increase and north-west shift of the tropopause potential temperature.

Wu and Shaw (2016, to be submitted)



Wu and Pauluis (2014)