

Above the Clouds: The Annual Cycle of the Tropical Tropopause Layer

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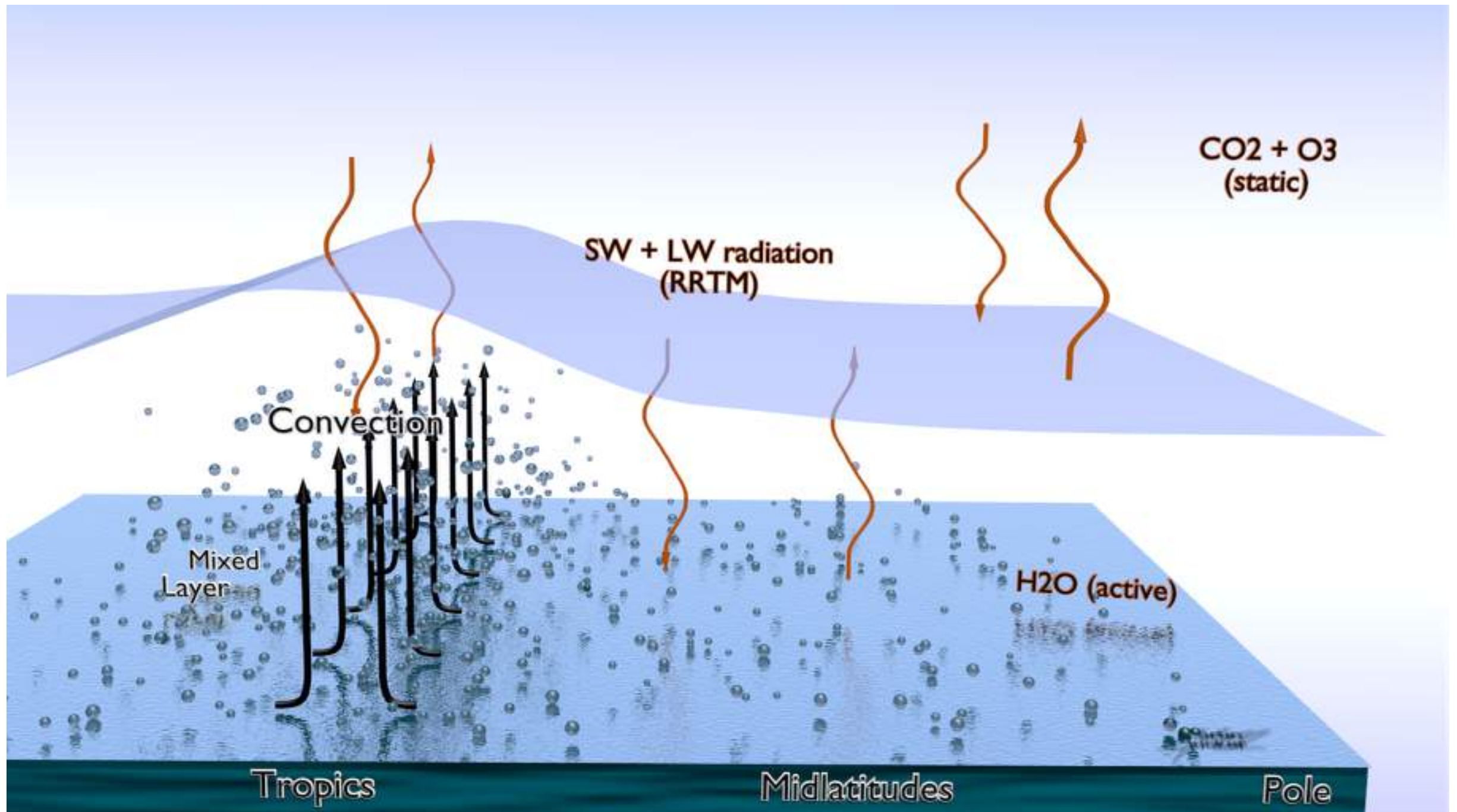
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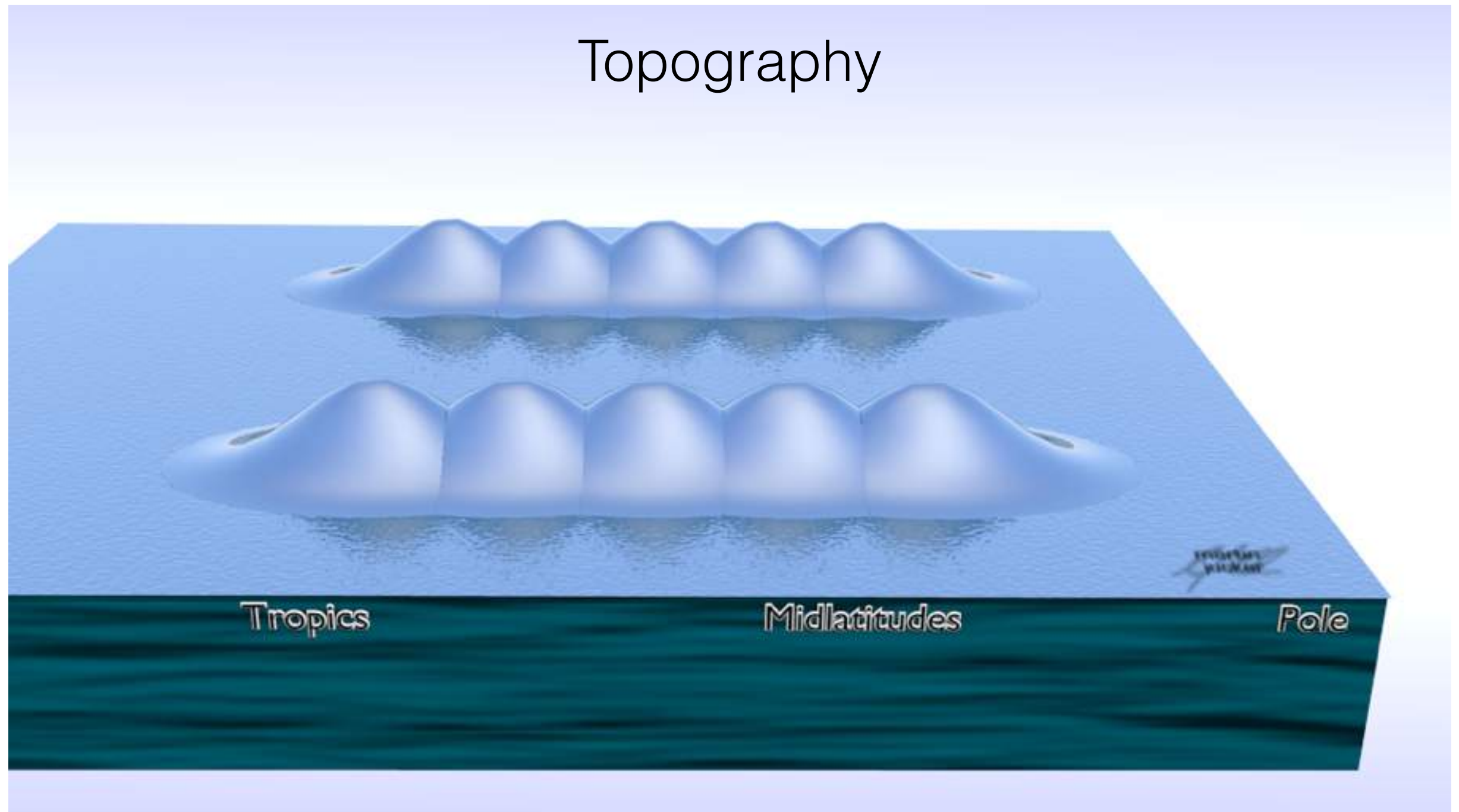
TTL Annual Cycle - Various theories, difficult to test

- High latitude planetary waves (NH-SH differences in orographic forcing) [Yulaeva et al. 1994, Ueyama and Wallace 2010]
- Seasonal cycle in baroclinic activity (NH-SH differences in land-sea contrast) [Jucker et al. 2013]
- Tropical clouds and convection (Monsoon, Warm Pool) [Kerr-Munslow and Norton 2006, Randel et al. 2008, Boehm & Lee (2003), Ortland and Alexander 2014]

Modeling an idealized Moist Atmosphere (MiMA)

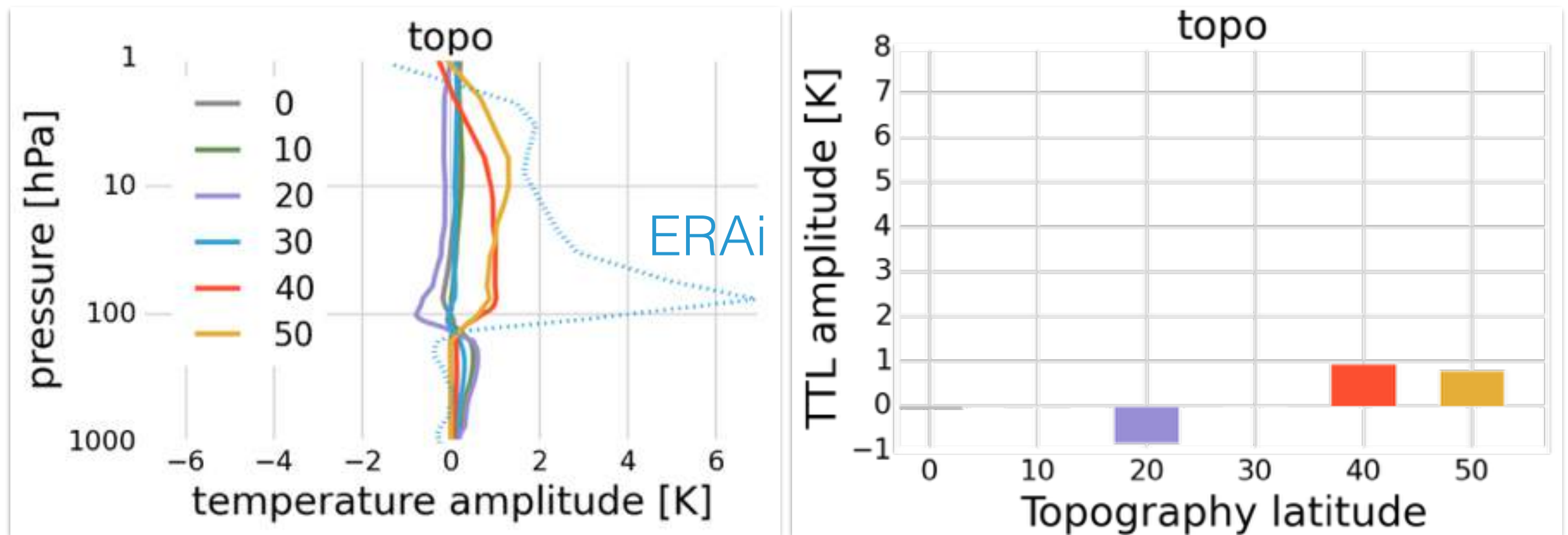


What effect does surface topography have on the tropics?



What determines the annual cycle of temperature in the TTL?

TTL amplitude

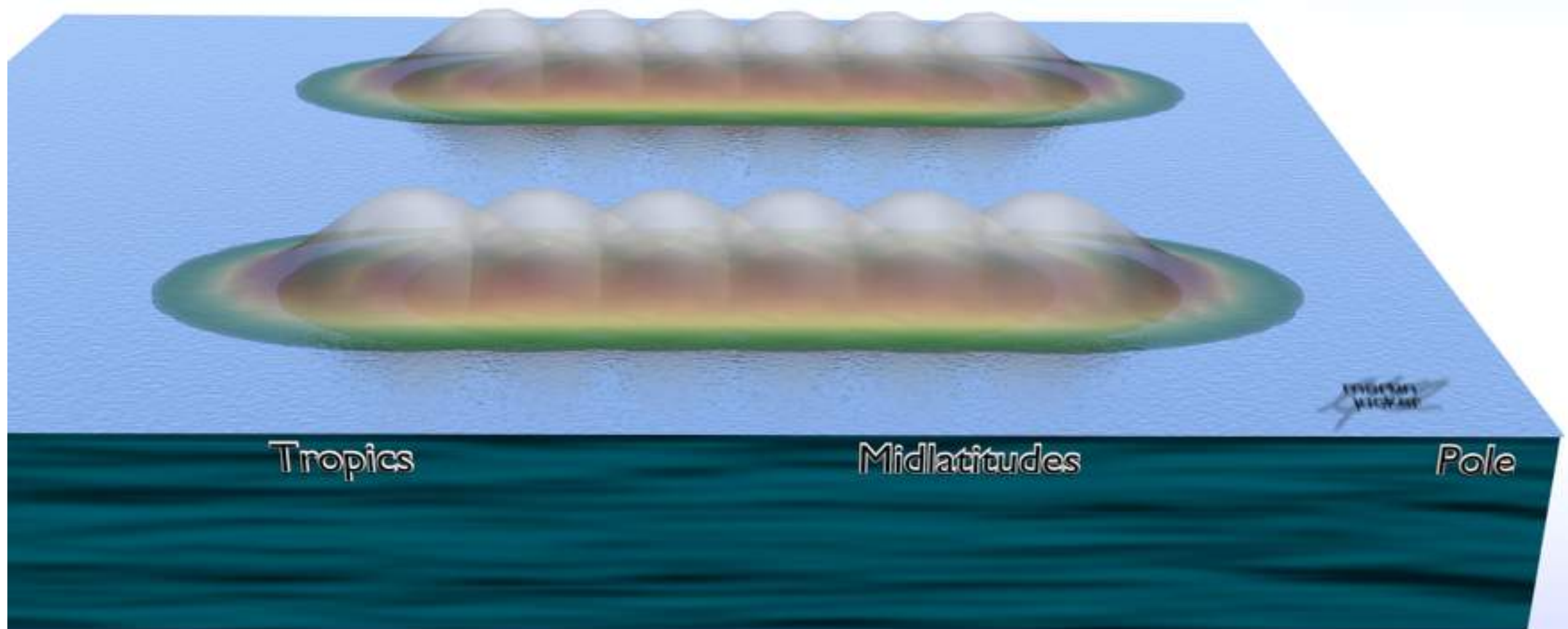


Topography: Small or even reverse SC¹ -
Rather different from observations

¹as described in e.g. Boehm & Lee (2003)

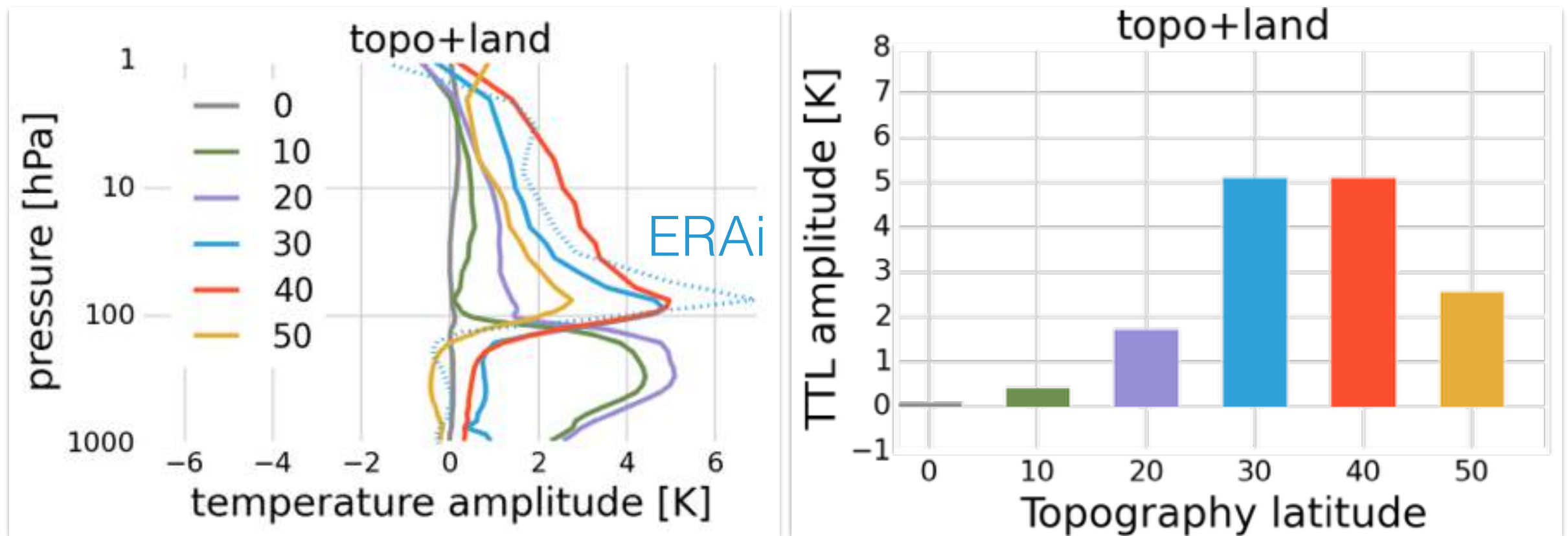
What effect do topography and land-sea contrast have on the tropics?

Topography + land-sea contrast



What determines the annual cycle of temperature in the TTL?

TTL amplitude



Topography + land-sea contrast: Clear shift from 20N to 30N, extratrop. forcing most realistic case

Wave analysis: mean upwelling from Eliassen-Palm flux divergence

- ‘downward control’, split into wave contributions

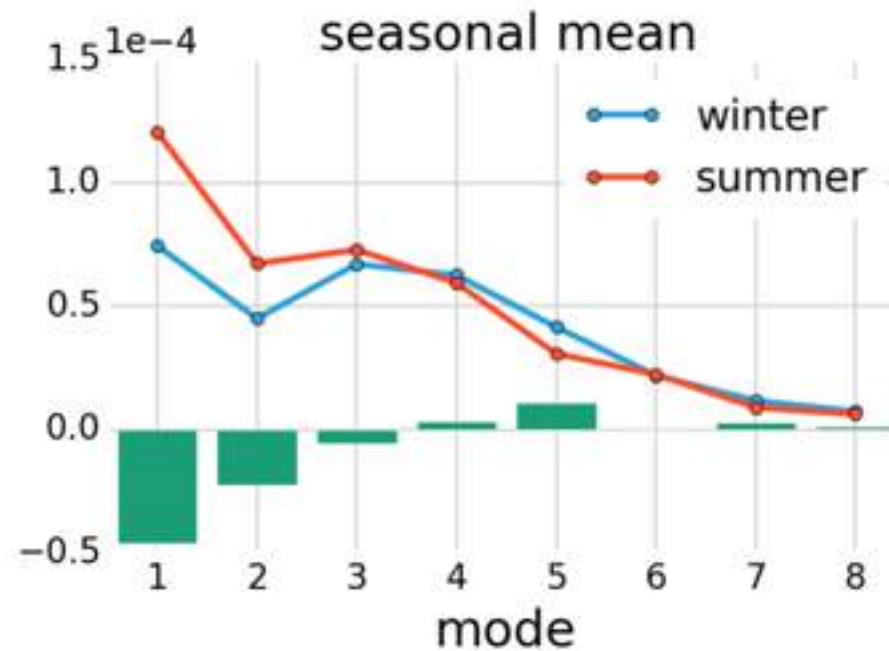
$$f^* \bar{v}^* \approx -\frac{\nabla \cdot \mathbf{F}}{a \cos \varphi} = -\frac{\sum_k \nabla \cdot \mathbf{F}_k}{a \cos \phi}$$

- mass conservation, average over tropics

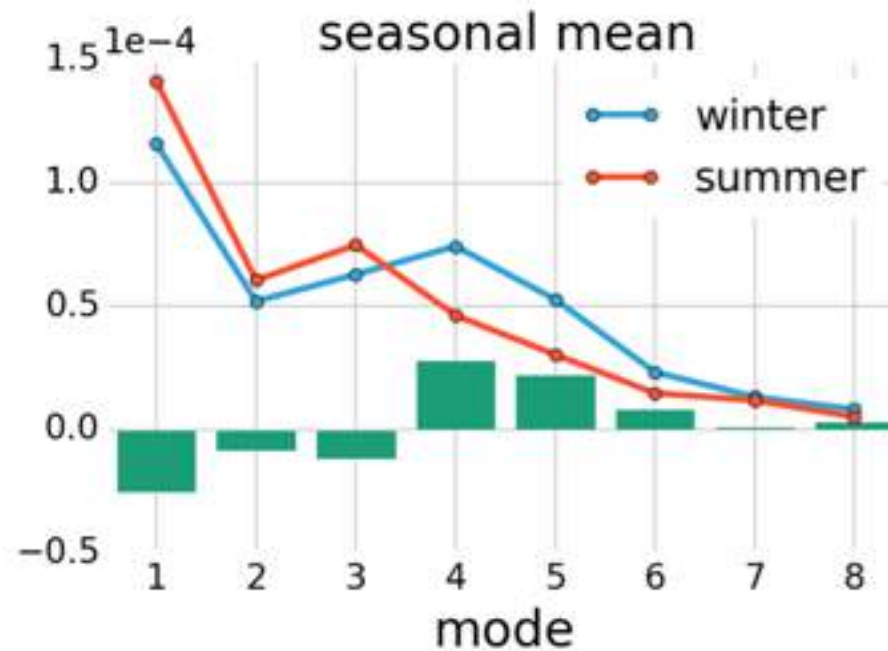
$$\langle \bar{w}_m^* \rangle(z) = \frac{\cos \phi_0}{\rho_0 \int_{-\phi_0}^{\phi_0} a \cos \phi d\phi} \int_z^\infty \rho_0 [\bar{v}^*(\phi_0) - \bar{v}^*(-\phi_0)] dz'$$

Wave Analysis

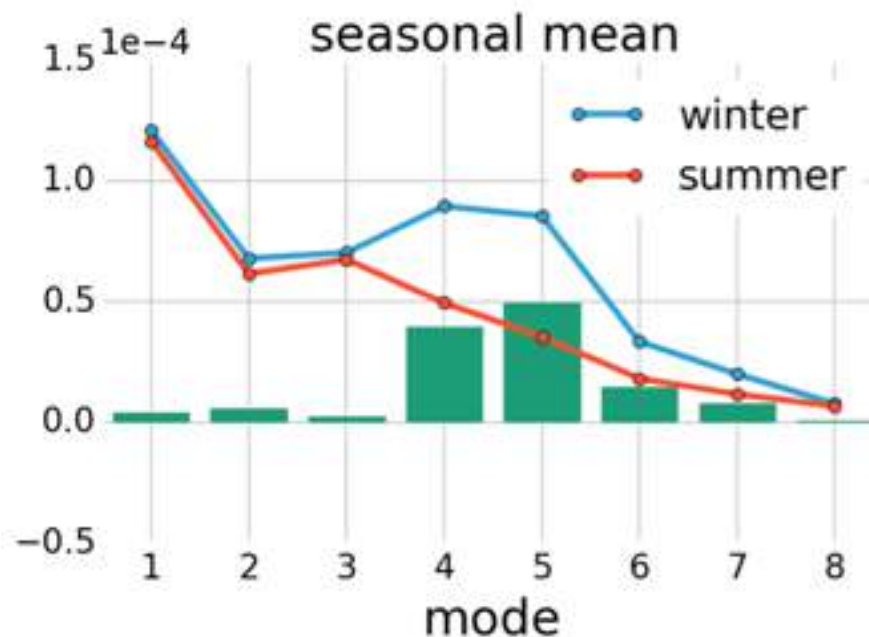
10N



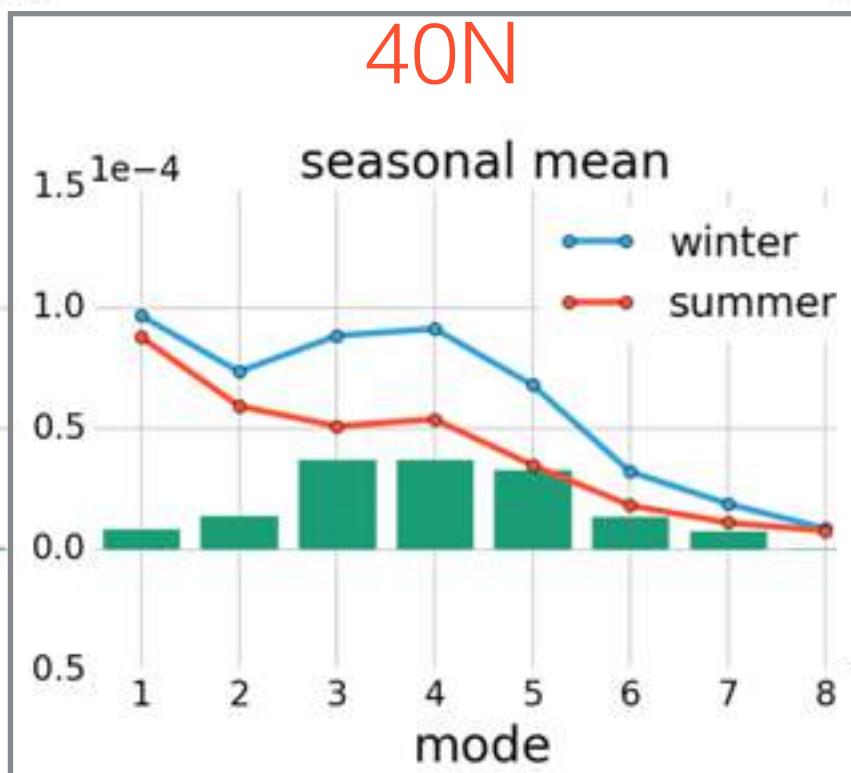
20N



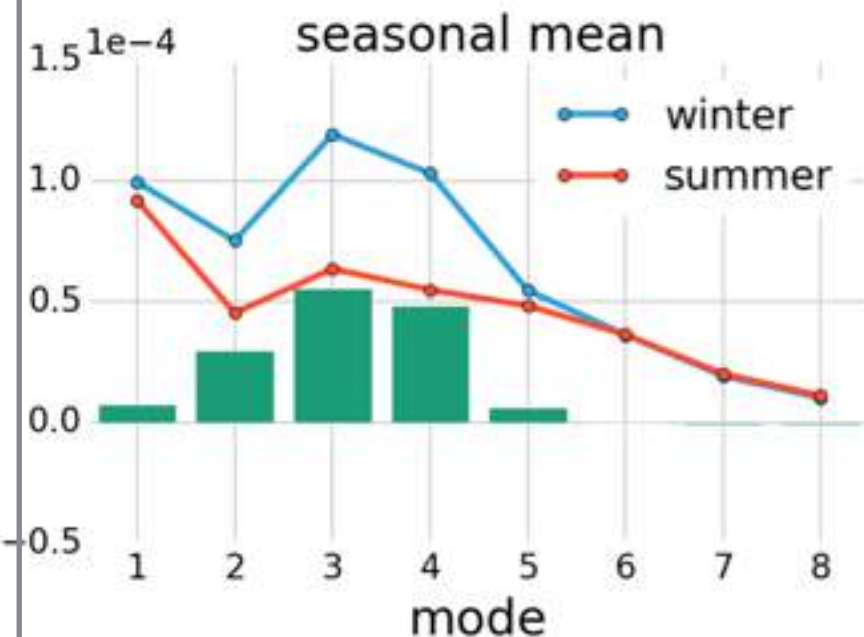
30N



40N



50N

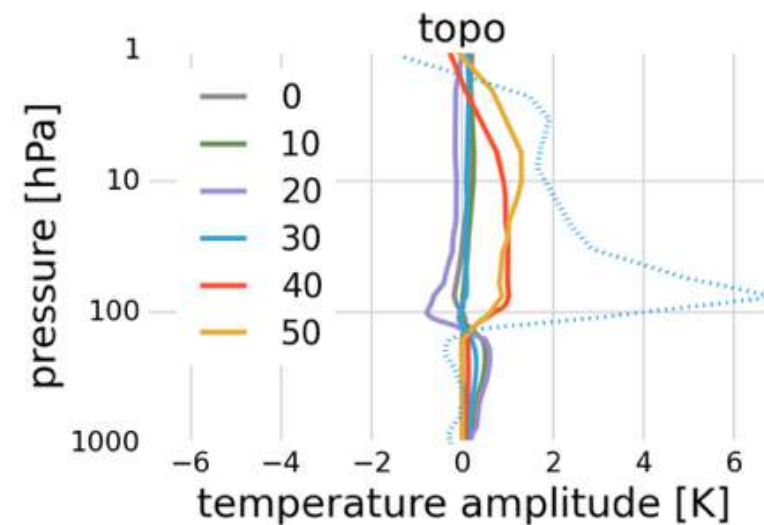


closest to reanalysis

Martin Jucker

Summary

- Topography alone
 - in tropics:
 - Zero or even reverse annual cycle
 - in extratropics:
 - Small stratospheric annual cycle



Summary

- Topography + land-sea contrast
 - in tropics:
 - Affects troposphere (and cold point)
 - planetary waves decrease annual cycle
 - in extratropics:
 - Affects TTL - most realistic cases
 - planetary waves add to annual cycle
 - smaller waves ($k = 3-5$) important drivers of seasonal differences

