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

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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]

Modeling an idealized Moist Atmosphere (MiMA)
What effect does surface topography have on the tropics?

Topography
What determines the annual cycle of temperature in the TTL?

Topography: Small or even reverse SC\(^1\) - Rather different from observations

\(^1\)as described in e.g. Boehm & Lee (2003)
What effect do topography and land-sea contrast have on the tropics?

Topography + land-sea contrast

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What determines the annual cycle of temperature in the TTL?

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

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

- 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

Closest to reanalysis

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Summary

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

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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

Data & code: doi 10.6084/m9.figshare.1448883