Tropical precipitation and Sea-surface temperatures

Outline

1. Words: Wet vs dry tropics, the ITCZ and monsoons, modes of variability, Easterlies and the Doldrums.
2. Stating the Problem: Where should it rain over the tropics?
3. Main biases in the representation of tropical precipitation and sea-surface temperatures
4. Physics: Theoretical frameworks and understanding of processes influencing the distribution of deep convection
5. Convective parameterization: The holy grail or an ill-posed problem?

Concepts

- Convective Adjustment
- The convective parameterization problem
- Coupling of convection to the large-scale circulation
- Modes of coupling to the ocean

Reading

I recommend reading the papers by Stevens (2005), Back and Bretherton (2009), Chou and Neelin (2004) and Oueslati and Bellon (2015), but also the classic paper by Riehl and Malkus (1958).

Exercises

1. If the cooling rate of the troposphere is $1.5\,\mathrm{K\,d^{-1}}$ and this is confined to the atmosphere at pressures greater than $200\,\mathrm{hPa}$ can you estimate: (i) what is the average surface precipitation; (ii) what is the subsidence velocity? (iii) what is the updraft area? (iv) If the precipitation efficiency measures the fraction of lifted moisture to the fraction of precipitated moisture, how does the updraft area depend on precipitation efficiency?

2. Show that one can approximate the value of boundary layer θ_e, as

$$\theta_\mathrm{e,bl} = \frac{V\theta_\mathrm{e,sfc} - E\theta_\mathrm{e,ft}}{V+E}. \tag{1}$$

   In this equation $\theta_\mathrm{e,sfc}$ is the value at the saturated surface and $\theta_\mathrm{e,ft}$ denotes the value just above the sub-cloud layer, and mostly differs from the value in the subcloud layer by virtue of how much drier the free troposphere is. If $V = 0.0015\|V\|$ is a surface exchange velocity, where$\|V\|$ is the surface wind speed, and $E = 2\,\mathrm{mm\,s^{-1}}$ is an entrainment velocity, then how much would the wind-speed have to change to compensate for a $1\,\mathrm{K}$ change in surface temperature in determining $\theta_\mathrm{e,bl}$.

3. If deep convection forms over the region with the largest boundary layer θ_e would you expect convection to be favored over the poleward or equatorward flank of the ITCZ? Why?

4. Describe different ways in which deep convection might affect sea-surface temperatures remotely and locally

References

Back, L. E., and C. S. Bretherton, 2009: A Simple Model of Climatological Rainfall and Vertical Motion Patterns over the Tropical Oceans. *Journal of Climate*, **22 (23)**, 6477–6497.

Chou, C., and J. D. Neelin, 2004: Mechanisms of Global Warming Impacts on Regional Tropical Precipitation*. *Journal of Climate*, **17 (13)**, 2688–2701.

Oueslati, B., and G. Bellon, 2015: The double ITCZ bias in CMIP5 models: interaction between SST, large-scale circulation and precipitation. *Climate Dynamics*, **44 (3-4)**, 585–607.

Riehl, H., and J. S. Malkus, 1958: On the heat balance in the equatorial trough zone. *Geophysica*, **6**, 503–538.

Stevens, B., 2005: Atmospheric Moist Convection. *Annu. Rev. Earth Planet. Sci.*, **33 (1)**, 605–643.