# A Numerical Model for Tropical and Subtropical Interactions

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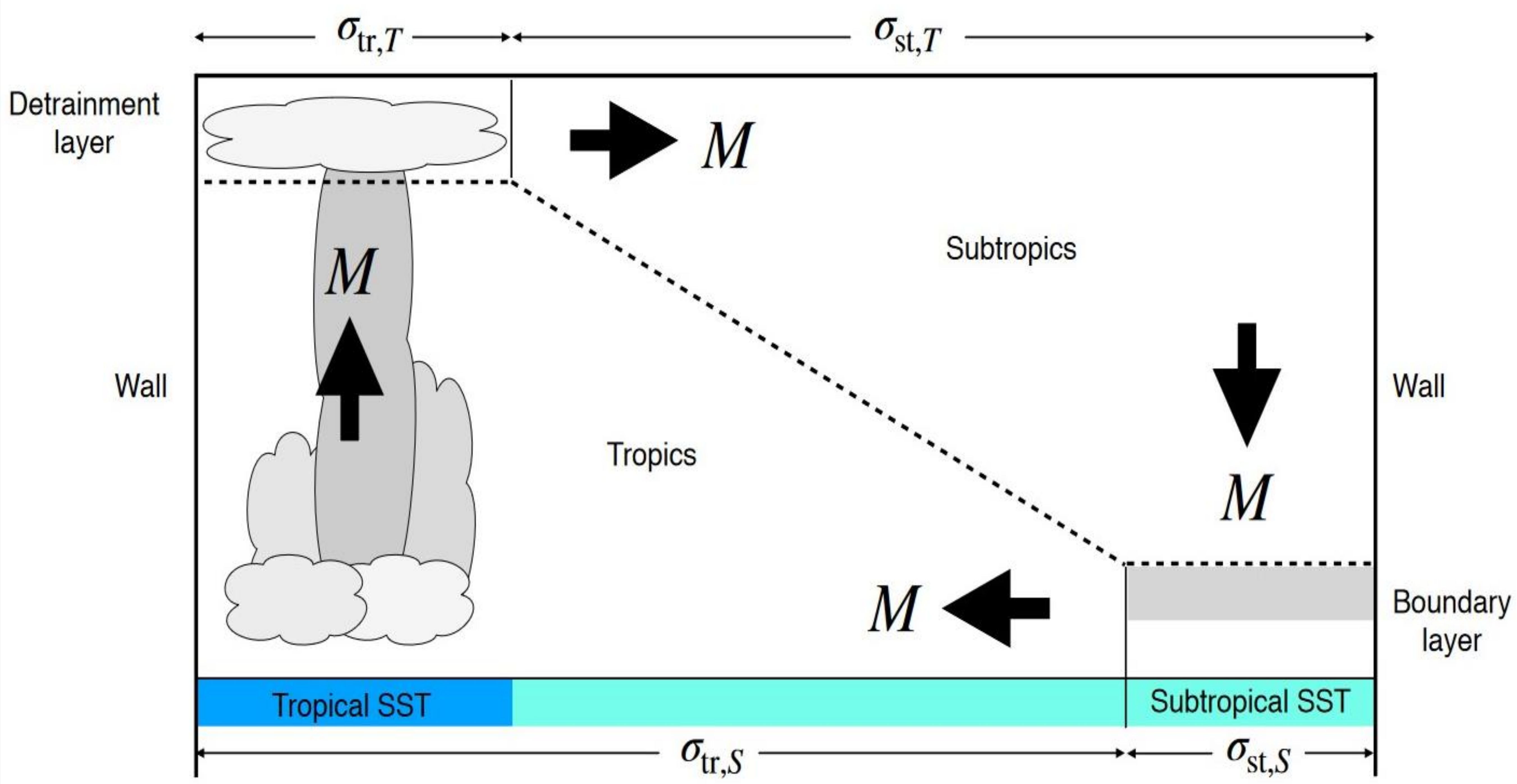
## Introduction

Our goal is to create a simple, conceptual model to describe how deep and stratocumulus convection influence the interactions of the tropical and subtropical climate system. To do this, we made three key assumptions:

1. Weak Temperature Gradient
2. Coupling through a Walker Cell
3. Slab Ocean

The model consists of a tropical and subtropical regime. The tropical domain is driven by the SST, while the subtropical domain is controlled by the mixed layer moist static energy and SST.




## Conclusions

Precipitation rate in tropics is an exponential function of column relative humidity (CRH) (Bretherton et al. 2004):

$$P = P_0 e^{\alpha_d CRH}$$

Deep convection couples the temperature and moisture soundings so that when the CRH approaches 1, the lapse rate approaches the moist adiabat.

Subtropical boundary layer depth is in equilibrium when:

$$E = \frac{M}{\sigma_{ST}}$$

Radiatively driven entrainment tries to deepen the boundary layer and dries it out.

## New Entrainment Parameterization

$$w_e^3 = \epsilon_0 G_0 + \epsilon_1 G_1 w_e$$

- Entrainment is shown to slow down when the inversion is stronger
- Entrainment speeds up when radiative cooling is stronger

## Coupling Process

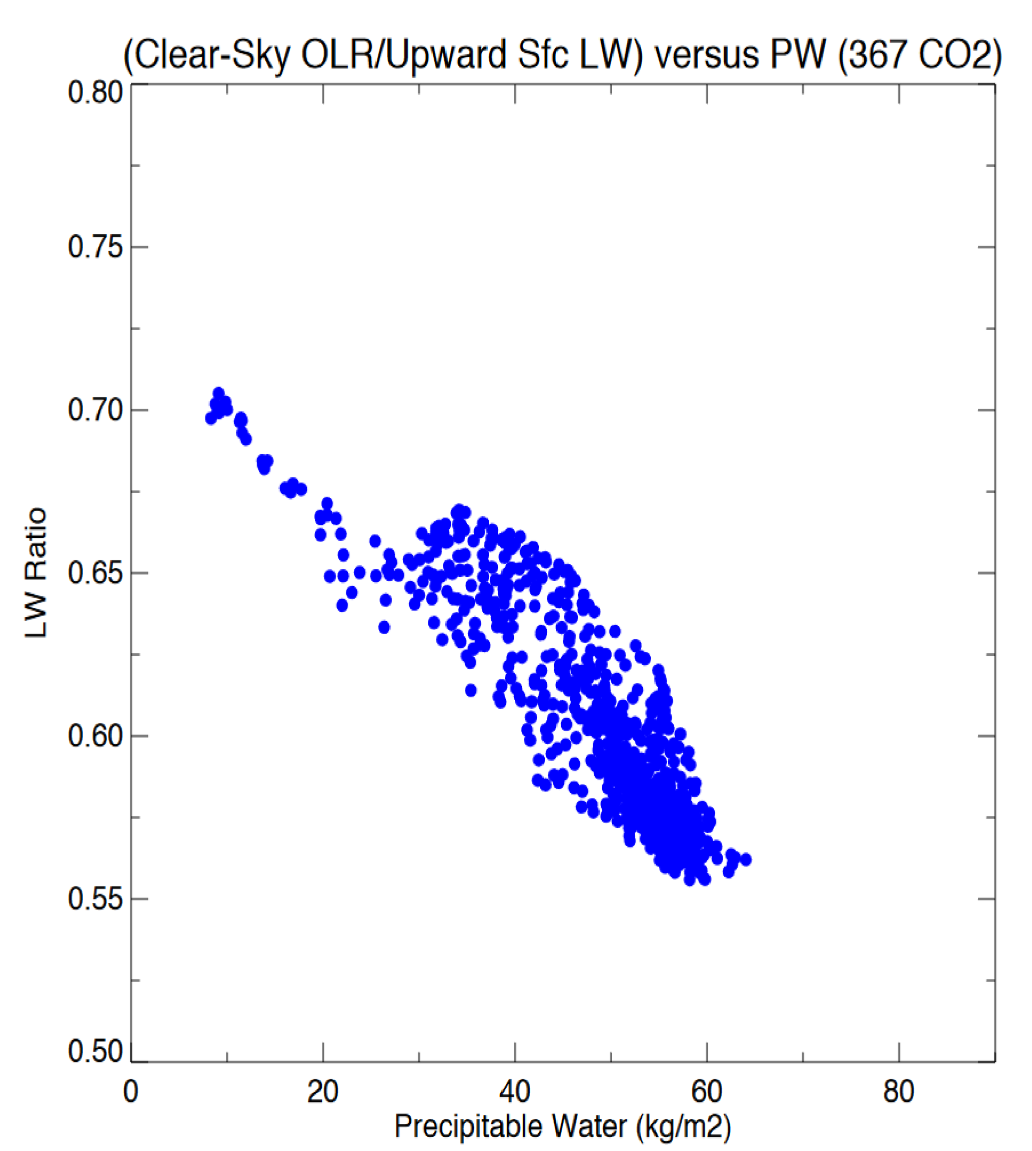
Coupling of Tropics to Subtropics is driven by radiative heating in tropics and radiative cooling in subtropics.

**Integrated Subtropical Cooling**

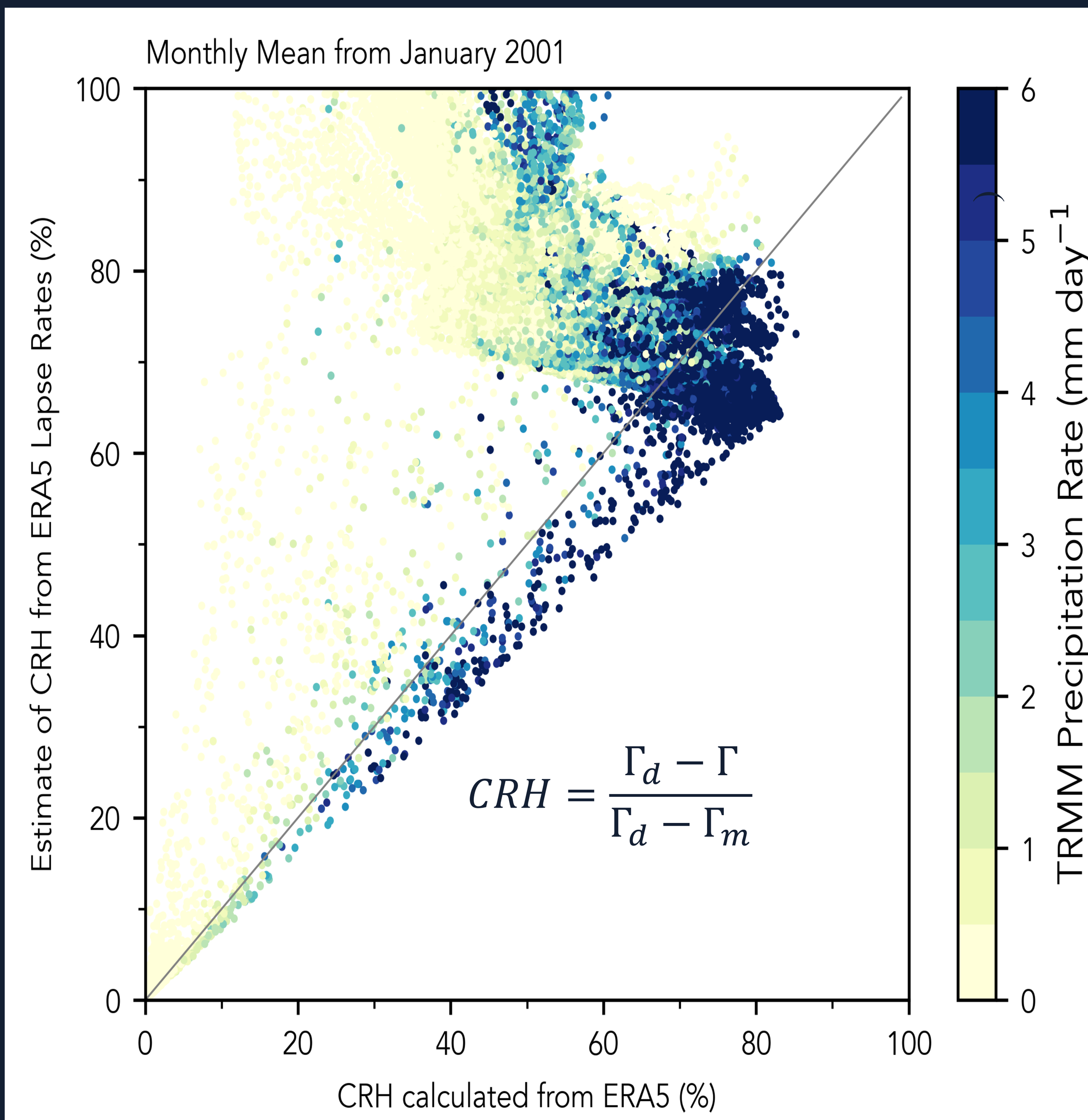
$$\int_{z_{B+}}^{z_T} Q_{ST} dz = R_{B_+} - R_{TOA} + S_{TOA} - S_{B_+}$$

**Integrated Tropical Heating**

$$\int_{z_{B+}}^{z_T} Q_{TR} dz = L P + R_{SFC} - R_{TOA} + S_{TOA} - S_{SFC}$$




**Radiative-Transfer**: We parameterize LW and SW fluxes through the atmosphere as functions of precipitable water in the column. Plotted is the ratio of clear-sky OLR to upward surface LW radiation over the Pacific Ocean taken from a CAM4 simulation at present-day $CO_2$.




**Test of Convective Closure**: Estimated Column Relative Humidity (CRH) from the above equation vs calculated CRH from ERA5 reanalysis. TRMM precipitation data is plotted for each estimated and calculated CRH. The one-to-one line matches tropical precipitation rates.

## Conclusions

Our model accurately simulates the tropical and subtropical domains when separate. More work is needed to couple the two. Future studies will include $CO_2$ forcing to study the stratocumulus cloud response, following Schneider et al. 2019.

## References

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