The Control of Tropical Convection[1]

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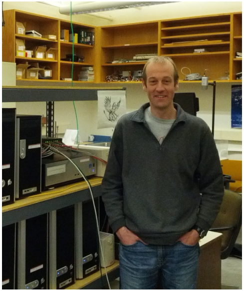
Thanks to Collaborators

- Saška Gjorgjievska
- Sharon Sessions
- Carlos López Carrillo
- Mike Herman



Showers and Rains

- Ramage (1971) divides tropical precipitation into two regimes:
  - Showers: Fine weather with relatively dry conditions, high CAPE, low shear; isolated storms, low average rain.
  - Rains: Cloudy weather with moist conditions, low CAPE, higher shear; widespread showers, high average rain.
- Williams et al. (1992) make similar distinction and correlate higher lightning rates with the showers regime.
- Is low CAPE and high moisture a cause or an effect of convection with higher average rainfall?

Thermodynamic Indices

Instability index (s^* is saturated moist entropy):

$$\Delta s^* = s^*_{1-3km} - s^*_{5-7km}$$

Saturation fraction (column relative humidity):

$$\mathcal{S} = \frac{\textit{precipitable water}}{\textit{saturated precipitable water}}$$

Normalized Gross Moist Stability (*NGMS*)

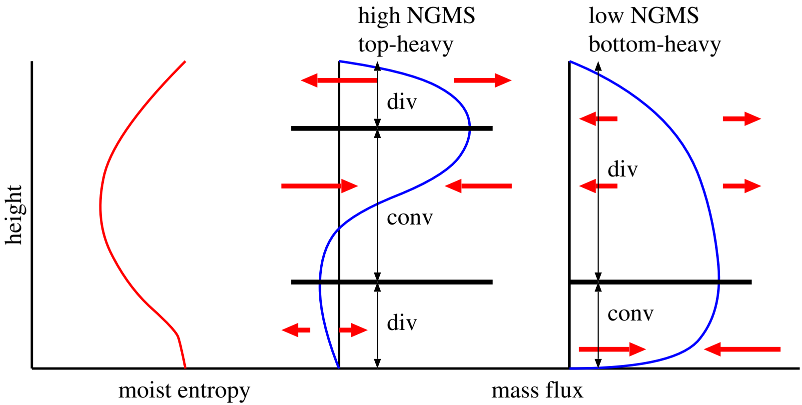
$$NGMS = \frac{lateral\ entropy\ div}{lateral\ vapor\ conv} = \frac{(surf - top)\ ent\ flux}{rain - evap} = \frac{\Delta F_{ent}}{R - E}$$

$$\Longrightarrow$$

$$R = E + \frac{\Delta F_{ent}}{NGMS}$$

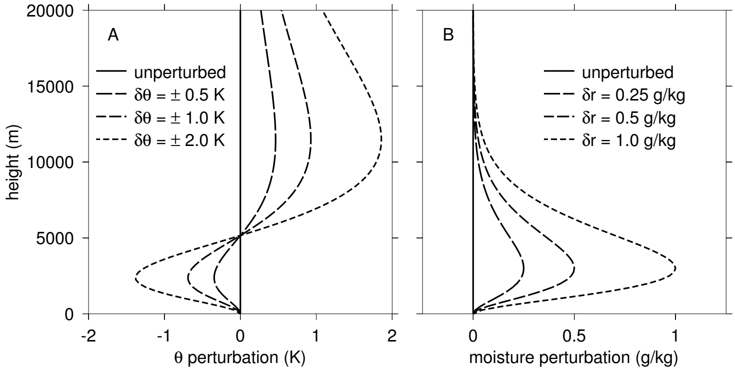
(Noted by Neelin and Held, 1987.)

NGMS and the Mass Flux Profile



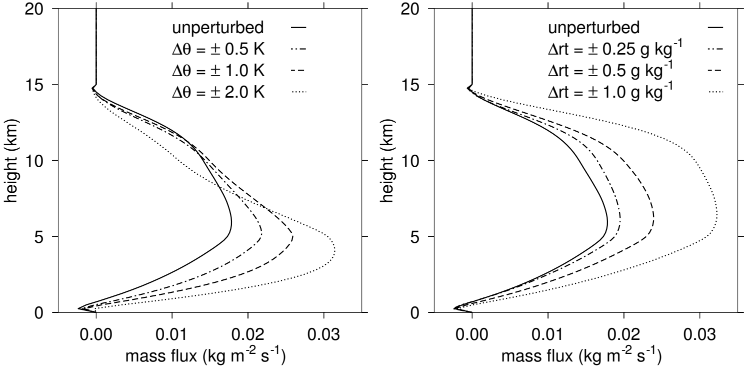
Modeled Convection as a Function of $\mathcal{S}$ and Δs^* (Raymond and Sessions 2007)

Potential temperature and mixing ratio perturbations relative to undisturbed tropics (typical of easterly wave conditions):



Bigger $\delta\theta \Longrightarrow$ smaller Δs^*; bigger $\delta r \Longrightarrow$ bigger $\mathcal{S}$

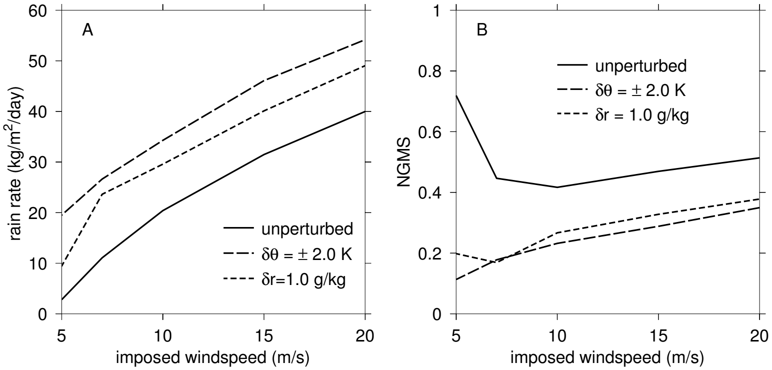
Mass Flux Profiles (Updated WTG, Mike Herman)



Surface wind: 7 m s^{-1}; RCE surface wind: 5 m s^{-1}

Rainfall and *NGMS*

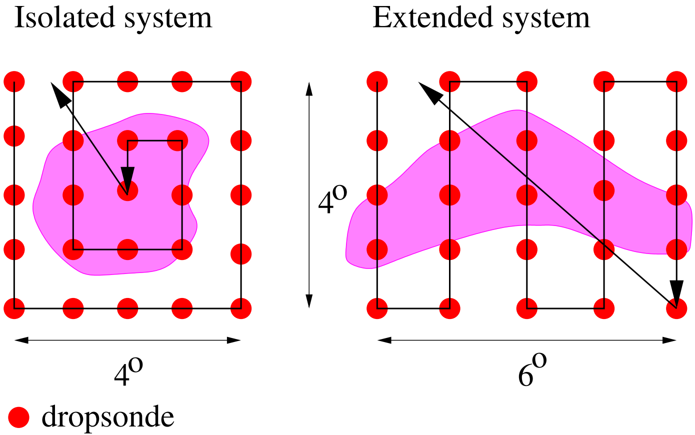
Rain as function of $\delta\theta$, δr, and ambient wind speed:



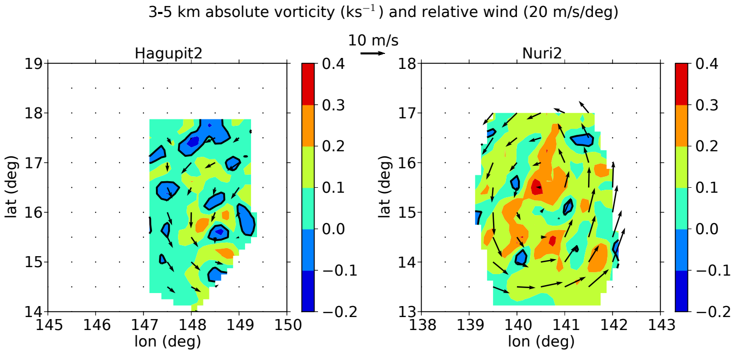
In Situ Measurements

- TPARC/TCS08 (2008) project in western Pacific
- PREDICT/GRIP/IFEX (2010) project in western Atlantic and Caribbean

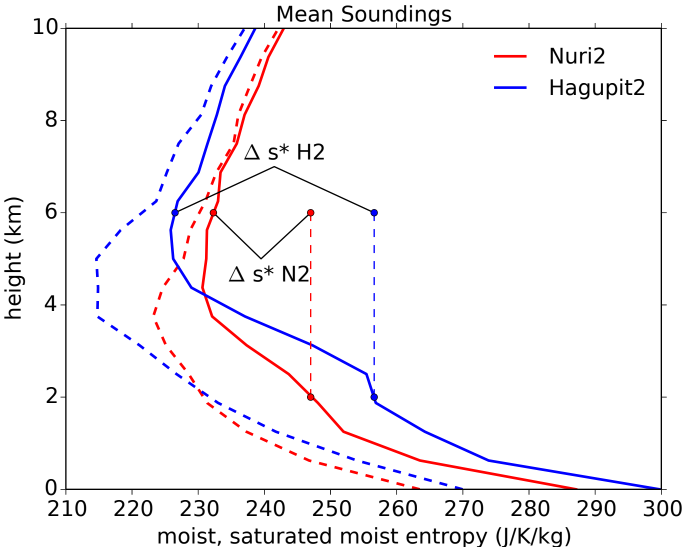
Dropsonde Patterns



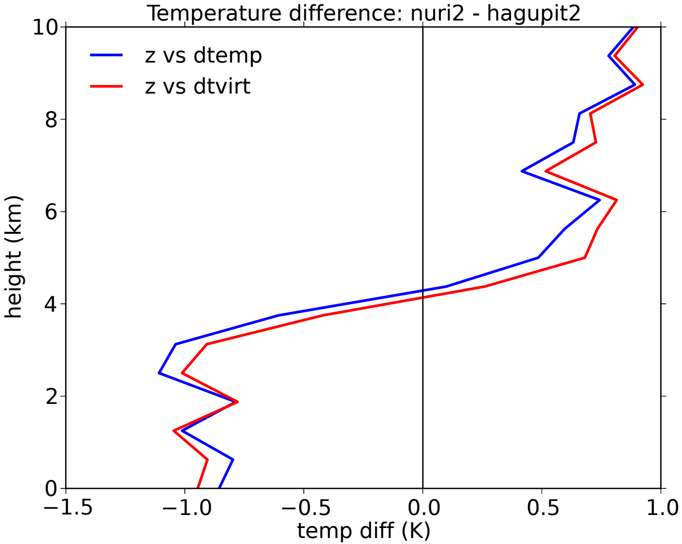
Two Examples; Hagupit2 and Nuri2



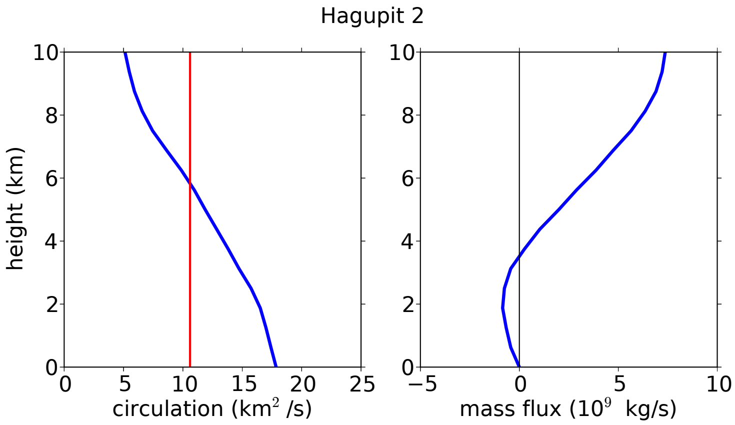
Instability Index (Δs^*) for Hagupit2 and Nuri2



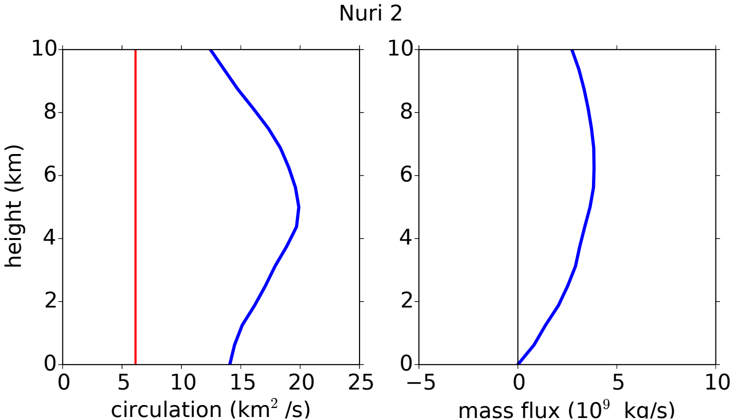
Mean Nuri2 - Hagupit2 Temperatures



Hagupit2 Circulation and Mass Flux



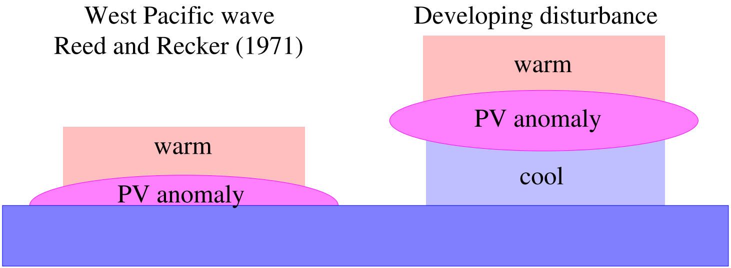
Nuri2 Circulation and Mass Flux



Mid-Level Vorticity/Circulation and Mass Flux

Is there a relationship between the two???

Thermodynamic Effect of Vortices

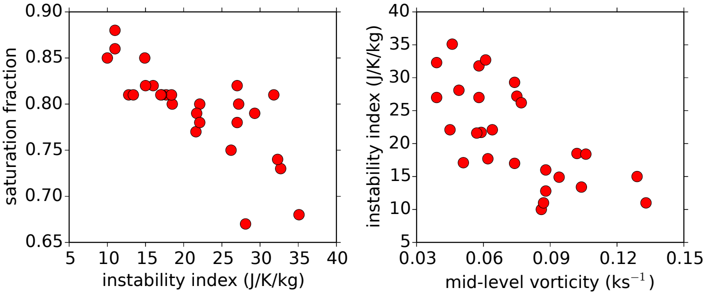


- Low-level vortex results in large instability index.
- Mid-level vortex produces small instability index.

Differences Quantified

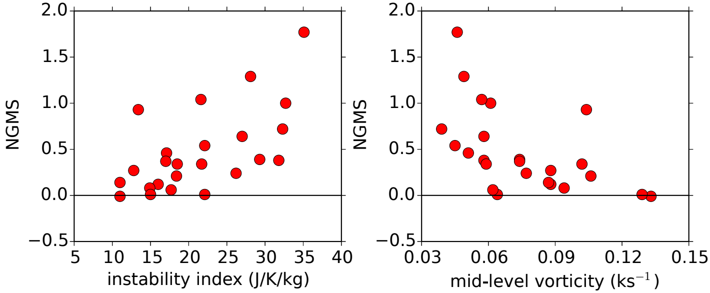
	Nuri2	Hagupit2
Instability index	11 J/ K/ kg	27 J/ K/ kg
Saturation fraction	0.88	0.82
Normalized GMS	-0.01	0.64
Mass flux	bottom-heavy	top-heavy
Vorticity maximum	middle levels	surface (weak)
Fate	rapid devel	delayed devel

Results from TCS08 and PREDICT (Saška Gjorgjievska)



See Singh, M. S., and P. A. O'Gorman, 2013: Influence of entrainment on the thermal stratification in simulations of radiative-convective equilibrium. *Geophys. Res. Letters*, **40**, 4398-4403.

Results from TCS08 and PREDICT (continued)



Conclusions

- The thermodynamic effect of strong mid-level vorticity is small instability index.
- From modeling and theory, small instability index ==> small *NGMS* and high saturation fraction. (See talk by Sharon Sessions, paper by Singh and O'Gorman.)
- Convection has the strongest effect on the environment when the *NGMS* is small (intense rain, tropical cyclogenesis – see Saška Gjorgjievska's talk).
- ==> The mid-level vorticity distribution exerts a strong control over the character of tropical, oceanic convection.
- Colin Ramage vindicated (after 40 years)!