Mid-Level Vorticity, Moisture, and Gross Moist Stability in the Tropical Atmosphere

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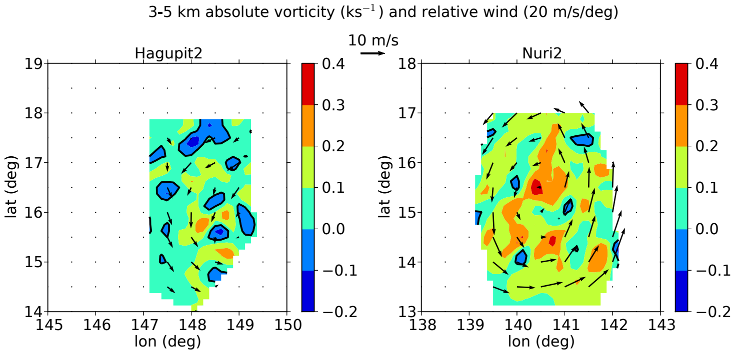
Showers and rains:

- Ramage (1971) divides tropical precipitation into two regimes:
  - Showers: Fine weather with relatively dry conditions, high CAPE, low shear;
  - Rains: Cloudy weather with moist conditions, low CAPE, higher shear;
  - The rains regime produces more average rainfall;
  - The showers regime produces higher peak rainfall.
- 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?

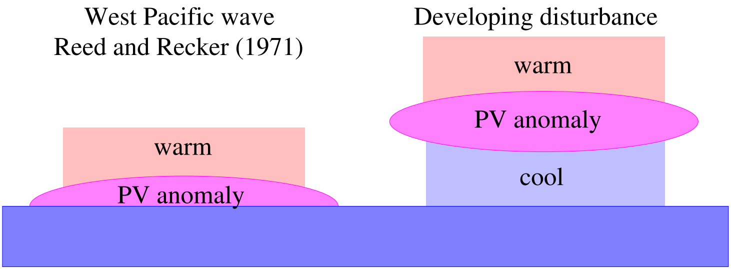
In situ measurements:

- TPARC/TCS08 (2008) project in western Pacific
  - ELDORA radar (NRL P-3)
  - Dropsondes from 10 km (Kessler C-130Js)
- PREDICT/GRIP/IFEX (2010) project in western Atlantic and Caribbean
  - Dropsondes from 12-13 km (NSF/NCAR G-V, NASA DC-8)

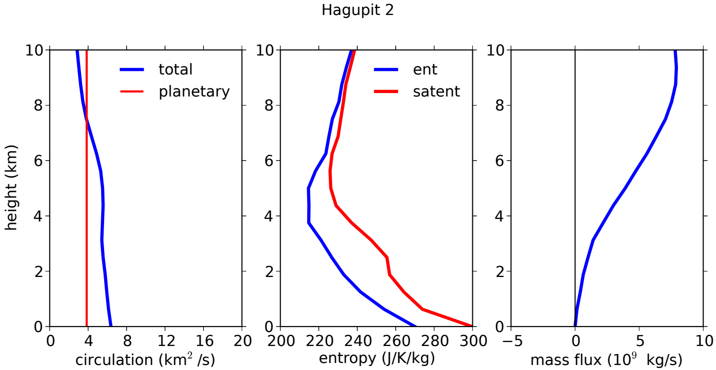
Two examples; Hagupit2 and Nuri2:



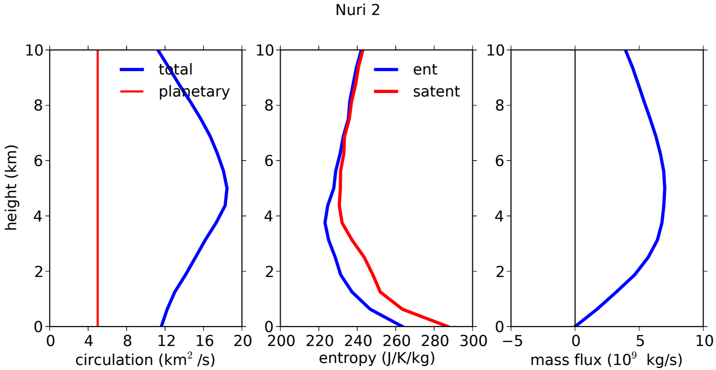
Thermodynamic Effect of Vortices



Hagupit2 dynamics:



Nuri2 profiles:



Thermodynamics:

Instability index:

$$\mathcal{I} = s^*_{lo} - s^*_{hi}$$

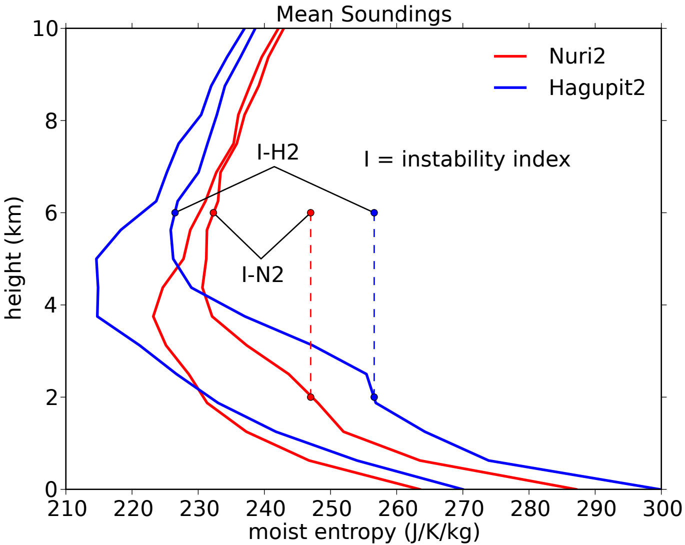
s^*_{lo}: average s^* over $[1, 3]$ km
s^*_{hi}: average s^* over $[5, 7]$ km

Saturation fraction:

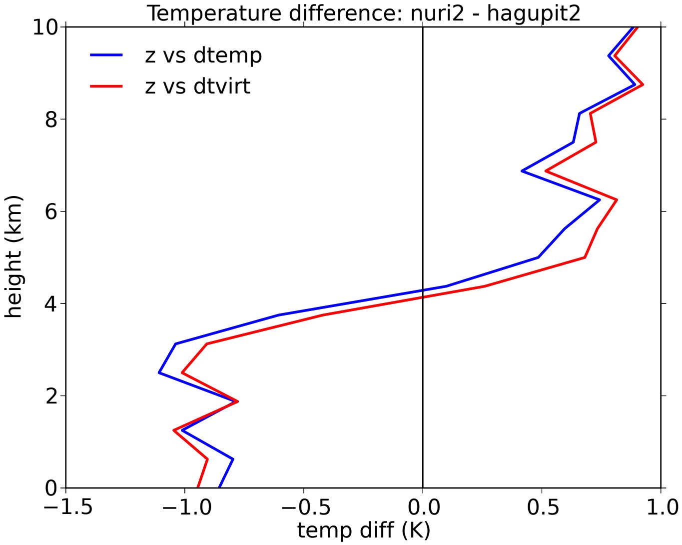
$$\mathcal{F} = \int r dp \bigg/ \int r_S dp \approx \int (s - s_d)\, dp \bigg/ \int (s^* - s_d)\, dp$$

r: mixing ratio
r_S: saturation mixing ratio
s_d: dry entropy
s: moist entropy
s^*: saturated moist entropy

Instability index:



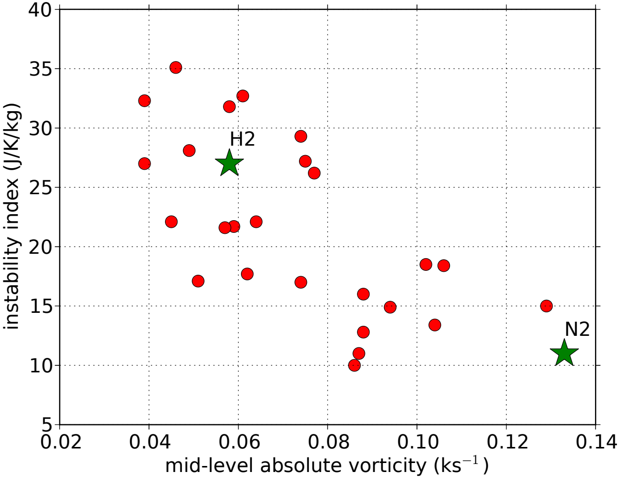
Mean Nuri2 - Hagupit2 temperatures:



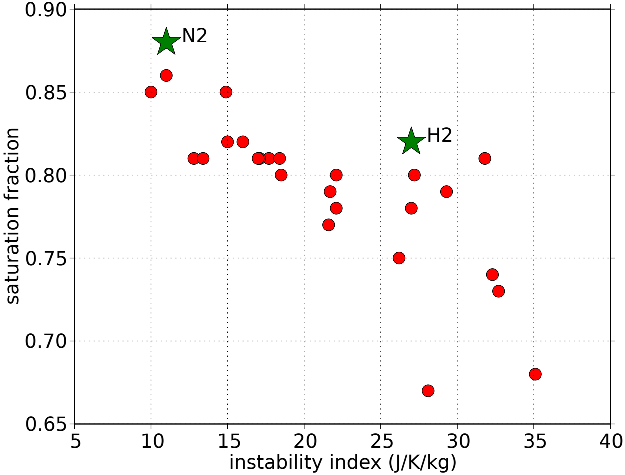
Differences quantified:

	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

TCS08/PREDICT: Instability index vs mid-level vorticity



TCS08/PREDICT: Saturation fraction vs instability index

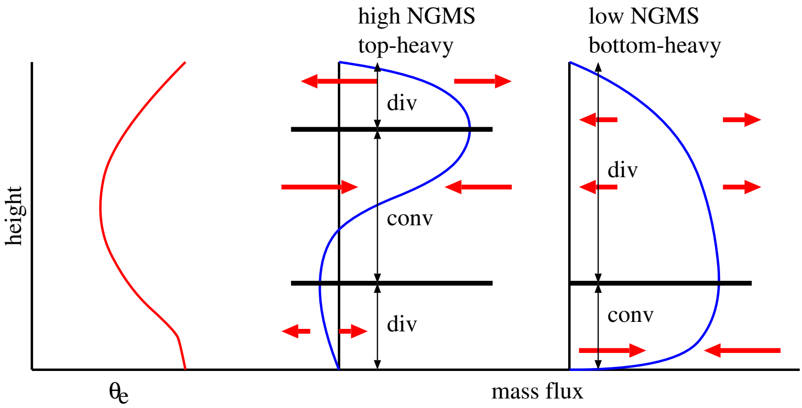


Normalized Gross Moist Stability (*NGMS*)

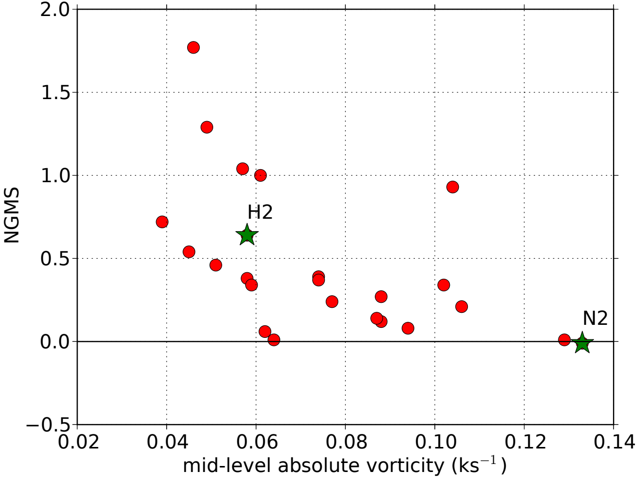
$$NGMS = -\left(\frac{T_R}{L}\right)\left(\frac{[\nabla_h \cdot (\rho \mathbf{v}_h s)] + \overline{\rho v_z s}|_{top}}{[\nabla_h \cdot (\rho \mathbf{v}_h r)] + \overline{\rho v_z r}|_{top}}\right)$$

- $[\chi]$: Horizontal average and vertical integral of χ.
- $\overline{\chi}|_{top}$: Horizontal average of χ at domain top.
- T_R: Constant reference temperature; L: Latent heat constant; ρ: Density; s: Specific moist entropy; r: Water vapor mixing ratio; $\mathbf{v}_h$: System-relative horizontal wind; v_z: Vertical wind.

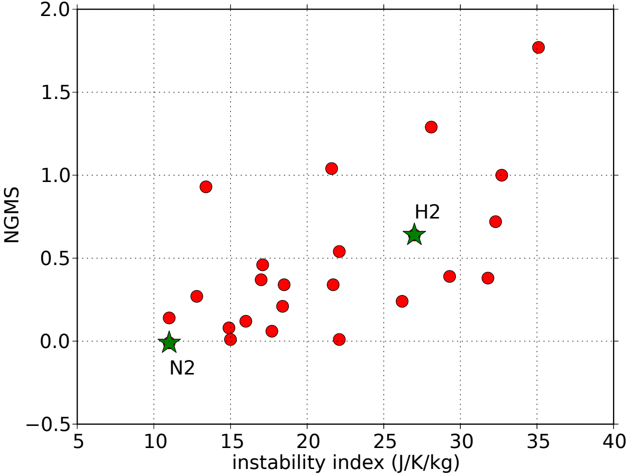
NGMS and the mass flux profile:



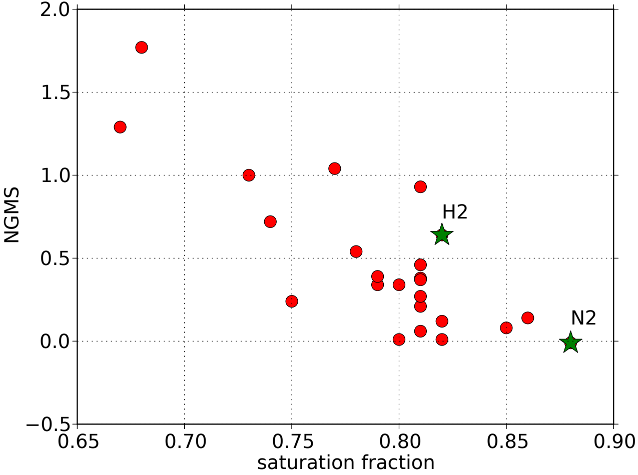
TCS08/PREDICT: *NGMS* vs mid-level vorticity



TCS08/PREDICT: *NGMS* vs instability index

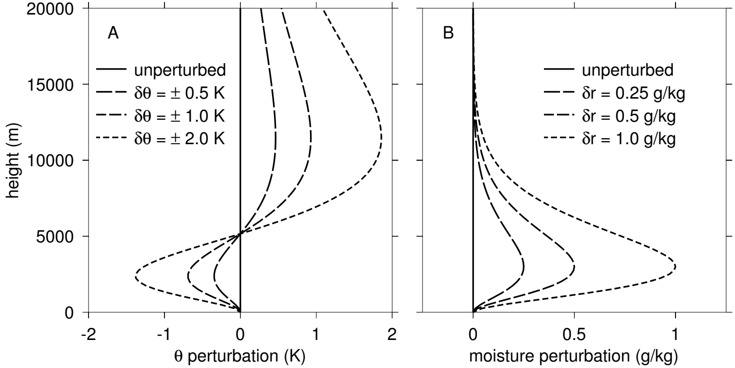


TCS08/PREDICT: *NGMS* vs saturation fraction

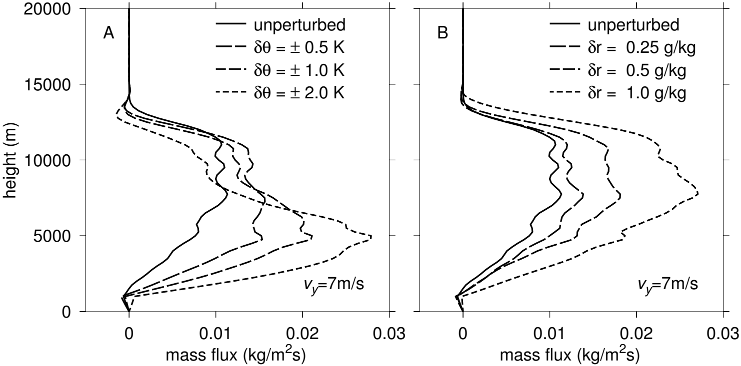


Rain and mass flux profiles from WTG cloud simulations:

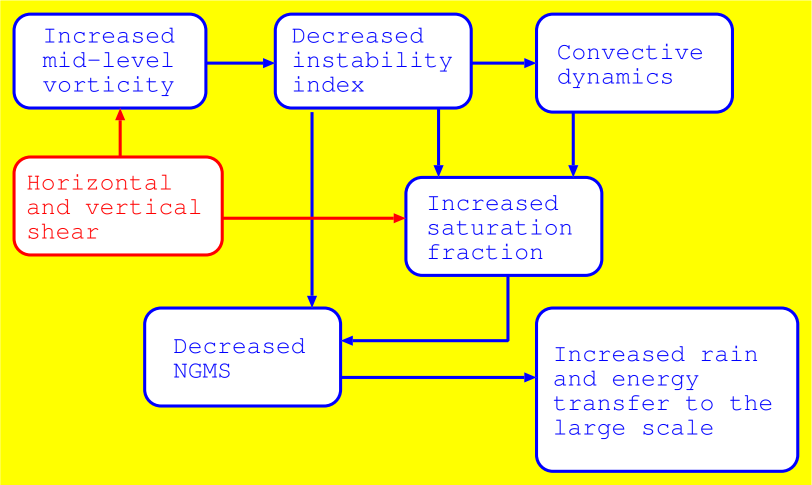
(Raymond, D. J. and S. L. Sessions, 2007)



Rain and Mass Flux Profiles (cont...)



Chain of causality



References

Raymond, D. J. and S. L. Sessions, 2007: Evolution of convection during tropical cyclogenesis. *Geophys. Res. Letters*, **34**, L06811, doi:10.1029/2006GL028607.

Ramage, C. S., 1971: *Monsoon Meteorology*. Academic Press, New York, 296 pp.

Williams, E. R., S. A. Rutledge, S. G. Geotis, N. Renno, E. Rasmussen, and T. Rickenbach, 1992: A radar and electrical study of tropical "hot towers". *J. Atmos. Sci.*, **49**, 1386-1395.