

The relevance of gross moist stabilities in multiple equilibria

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Workshop on large-scale circulation in convecting
atmospheres

2D cloud resolving model (CRM)

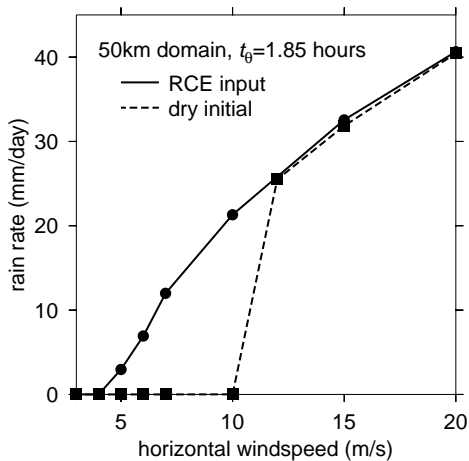
- Large scale circulations parameterized by weak temperature gradient (WTG) approximation (Sobel & Bretherton 2000)
- 20 km vertical
- 50, 100, 200 km horizontal
- fix SST @ 303 K
- vary surface wind speed 3-20 m/s
- vary initial moisture (Sobel, Bellon & Backmeister 2007)
 - dry
 - equal to moisture of reference profile

WTG implementation

- Reference profile is radiative convective equilibrium (RCE)
 - SST @ 303 K
 - surface wind speed of 5 m/s
- WTG simulations
 - Maintain fixed θ profile
 - Impose WTG vertical velocity sufficient to counteract buoyancy anomalies
- Relax θ to reference profile over time scale t_θ
 - $t_\theta = 0 \Rightarrow$ Strict enforcement of WTG
 - $t_\theta = \infty \Rightarrow$ RCE
 - Controls the imposed WTG vertical velocity, and also horizontal moisture advection via mass continuity

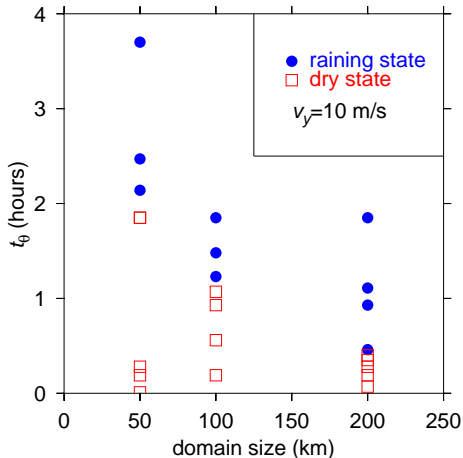
Multiple Equilibrium

Dependence on surface fluxes



Multiple Equilibrium in our model

Dependence on domain size, t_θ

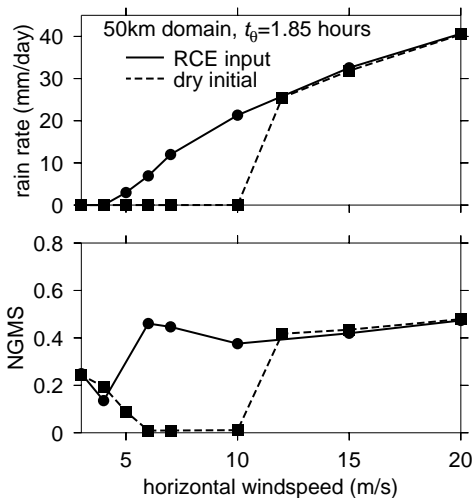


- All experiments are initially dry
- Boundary conditions determine single or multiple equilibria
- Initial conditions determine which state realized

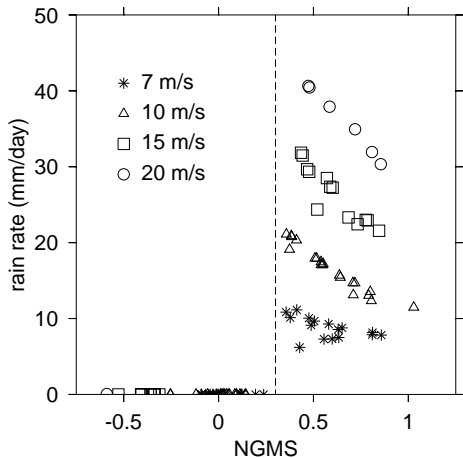
Normalized gross moist stability (NGMS)

- GMS based on moist static energy budget (Neelin & Held 1987)
- $$\text{NGMS} = \frac{T_R \frac{1}{g} \int \nabla \cdot (sv) dp}{-L \frac{1}{g} \int \nabla \cdot (rv) dp} = \frac{\text{moist entropy export}}{\text{moisture import}}$$
- Characterize equilibrium environment with NGMS

NGMS in the steady state

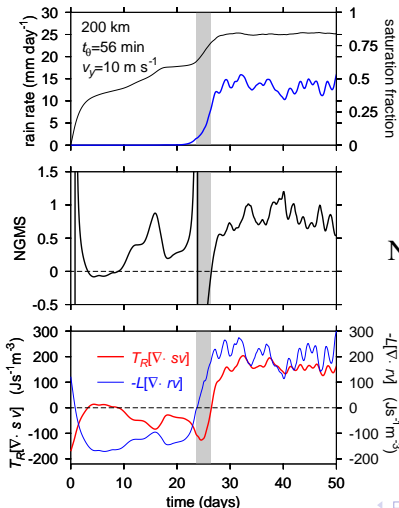


Steady state precipitation and NGMS



- Fixed $v_y \Rightarrow$
Rain $\sim (\text{NGMS})^{-1}$
- Fixed NGMS \Rightarrow Rain $\sim v_y$
- NGMS=0.3 divides equilibria
- Dry equilibrium
NGMS + or -

Transient NGMS



$$\text{saturation fraction} = \frac{\text{precipitable water}}{\text{saturated precipitable water}}$$

$$\text{NGMS} = \frac{T_R [\nabla \cdot (s \nu)]}{-L [\nabla \cdot (r \nu)]}$$

moist entropy
export

moisture import

Summary

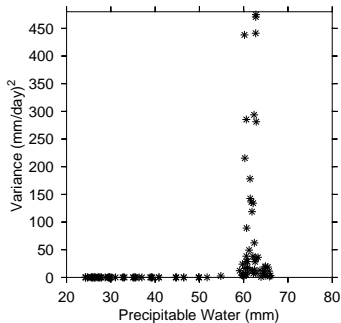
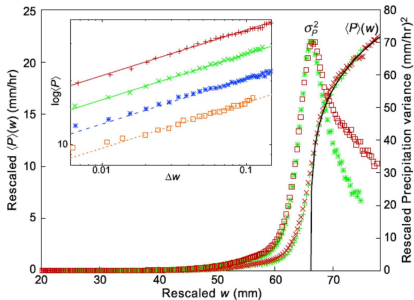
- Multiple equilibria in CRM
 - determined by domain size, surface fluxes, t_θ
 - initial moisture determines which state is realized
 - WTG is important
- NGMS
 - good diagnostic of steady state atmosphere
 - larger values for precipitating equilibrium
 - smaller or negative values for dry equilibrium
 - also characterize environment in developing (or decaying) stages of convection

Sessions, Sugaya, Raymond & Sobel, submitted to JGR

<http://www.physics.nmt.edu/~sessions>

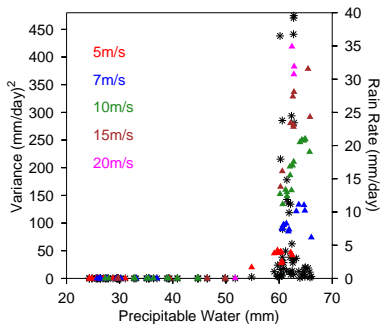
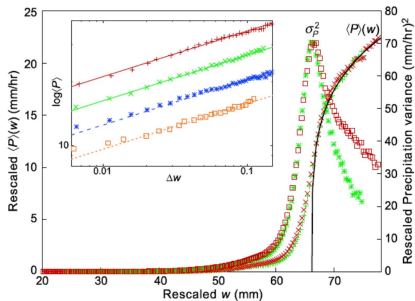
New Results

Peters & Neelin 2007

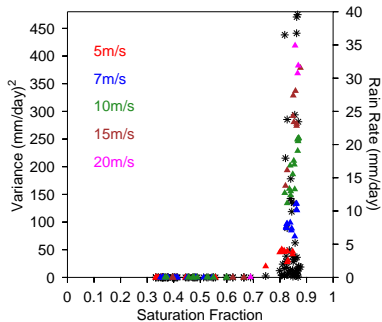


New Results

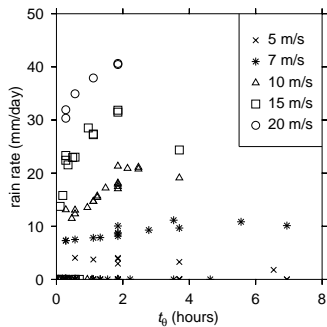
Peters & Neelin 2007



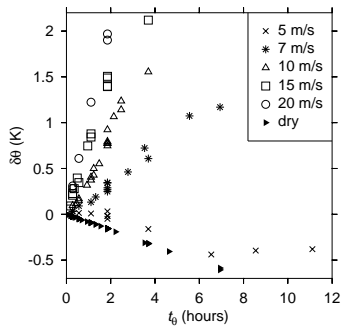
New Results



More Data



More Data



More Data

