Extreme Convection in Subtropical South America: TRMM Observations and Precipitation Bias

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Introduction

- **TRMM satellite observations have led to the realization that intense deep convective storms just east of the Andes in subtropical South America are among the most intense anywhere in the world (Zipser et al. 2006)**

- **South American MCSs:**
  - → ~ 60% larger than those over the United States (Velasco and Fritsch 1987)
  - → Hot spot of deep convection (Zipser et al. 2006)
  - → Larger precipitation areas than those over the United States or Africa (Durkee et al. 2009)
  - → Largest number of severe hailstorms globally (Cecil and Blankenship 2012)

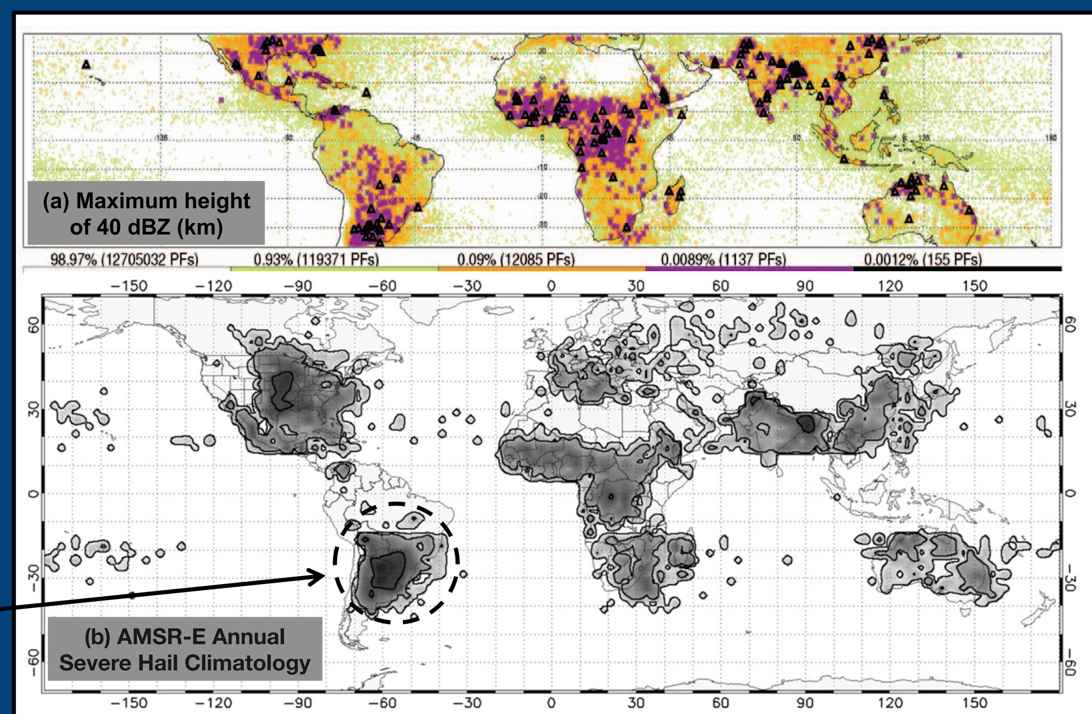


Figure 1. (a) Locations of intense convective events using the color code matching their rarity from Zipser et al. (2006). (b) AMSR-E annual severe hail (>1 in. diameter) climatology from Cecil and Blankenship (2012).

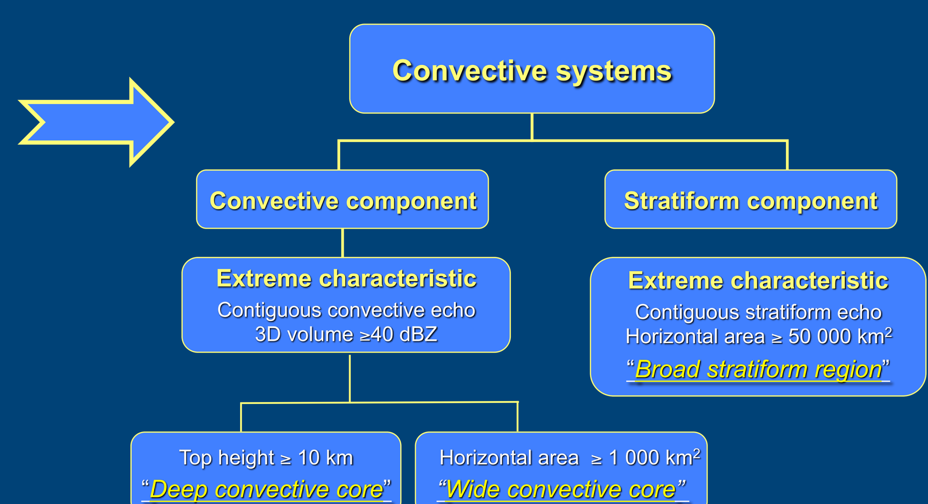
- **Despite the intensity of the storms, relatively few studies have been conducted**

- **Systematic negative bias in near-surface precipitation estimates in deep convection over land from the 2A25 algorithm have been partially attributed to errors in the DSD parameter and ice model (Iguchi et al. 2009)**

Background

UW methodology to separate TRMM Precipitation Radar (PR) echoes into three storm types (Houze et al. 2007): *deep convective cores, wide convective cores, and broad stratiform regions*

- South Asia: Houze et al. (2007), Romatschke et al. (2011a, b)
- South America: Romatschke et al. (2010), Rasmussen and Houze (2011), Rasmussen et al. (2013)



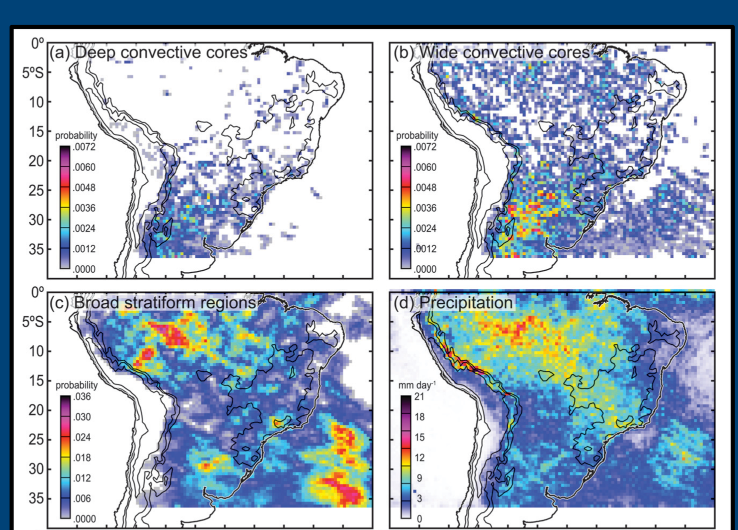


Figure 2. Locations of storm types in South America derived from TRMM PR data. From Romatschke and Houze (2010).

Storm evolution hypothesis presented in Romatschke and Houze (2010) and Rasmussen and Houze (2011):

- ***Deep convective cores* initiate along Andes foothills and secondary topo features**
- **Convection grows upscale, develops *wide convective cores*, and moves eastward**
- **Decaying convective elements move farther eastward and develop *broad stratiform regions***

→ The Andes Mountains funnel warm and moist air southward via the South American Low-level Jet (SALLJ)

South American MCSs

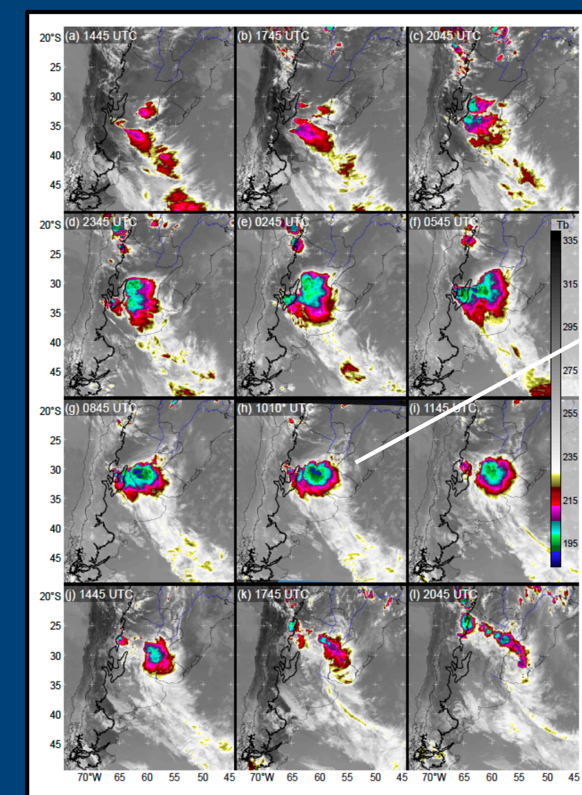


Figure 3. Sequence of infrared satellite images (K) showing storm initiation and evolution for the 26-27 December 2003 *wide convective core*. From Rasmussen and Houze (2011).

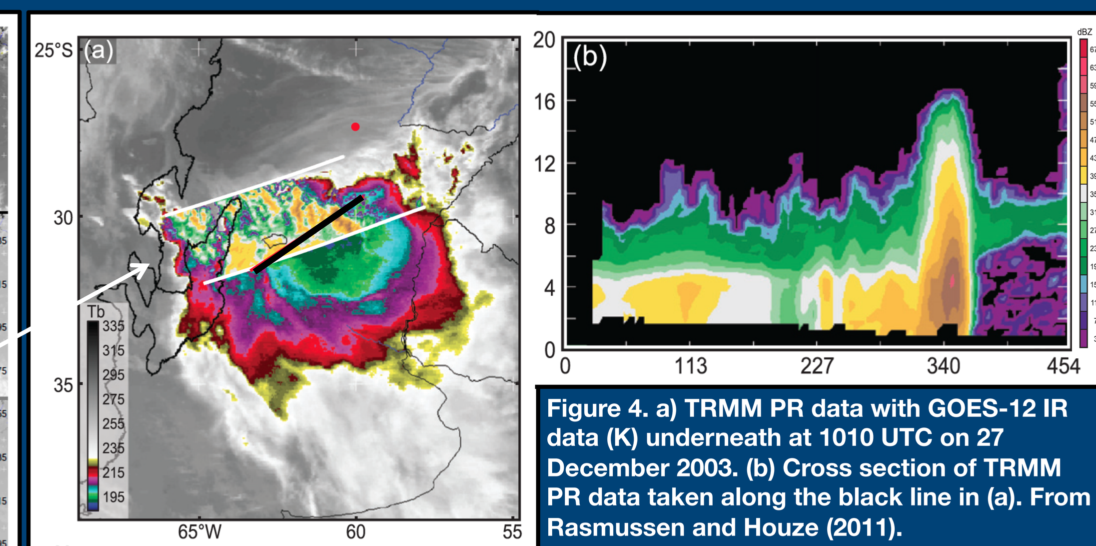


Figure 4. a) TRMM PR data with GOES-12 IR data (K) underneath at 1010 UTC on 27 December 2003. (b) Cross section of TRMM PR data taken along the black line in (a). From Rasmussen and Houze (2011).

- **Strong influence of the Andes foothills and the Sierras de Córdoba Mountains in convective initiation and maintenance of MCSs**
- **Storms with *wide convective cores* tend to be linearly organized**
- **South America MCSs similar in organization to leading-line/trailing-stratiform archetype identified in the United States (Houze et al. 1990; Rasmussen and Houze 2011)**

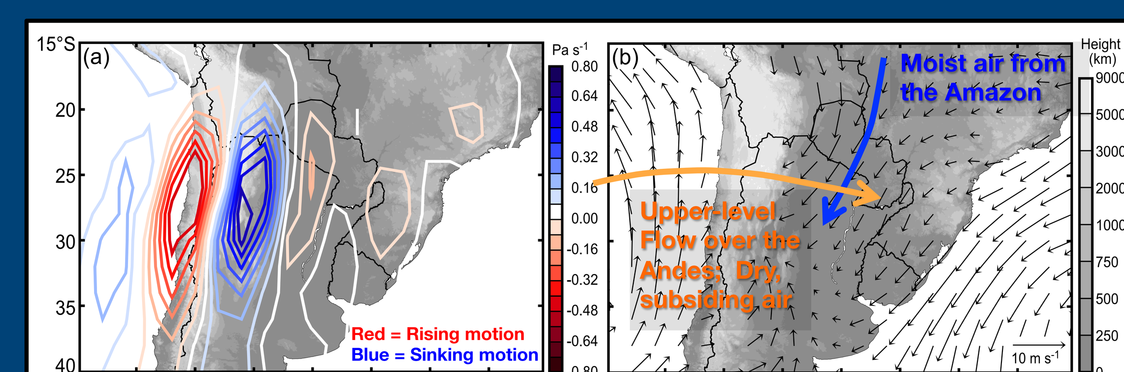


Figure 5. Climatological composite maps for days on which the TRMM PR showed storms containing *wide convective cores* over subtropical S. America. (a) Vertical motion (omega) and (b) 1000 mb winds. From Rasmussen and Houze (2011).

- **← Composite maps for days when TRMM observed a *wide convective core* show mid-level subsidence and low-level convergence in the lee of the Andes (Figure 5)**
- **← Partially confirmed with WRF model results**

TRMM Precipitation Bias

- **TRMM algorithm underestimates precipitation in regions of intense deep convection over land (Iguchi et al. 2009)**
- **Calculated precipitation from TRMM PR identified storms and cores using two methods to investigate the bias in South America :**
  - TRMM 2A25 near-surface rain from algorithm
  - Traditional Z-R technique up to 2.5 km using parameters defined in Romatschke and Houze (2011) for subtropical land regions
- **Compared to the Z-R method, we found a significant negative bias of precipitation amounts from the TRMM 2A25 algorithm independent of the season (Fig. 6)**
- **The deeper the convection, the greater the bias (up to 43% in deep convective cores!)**

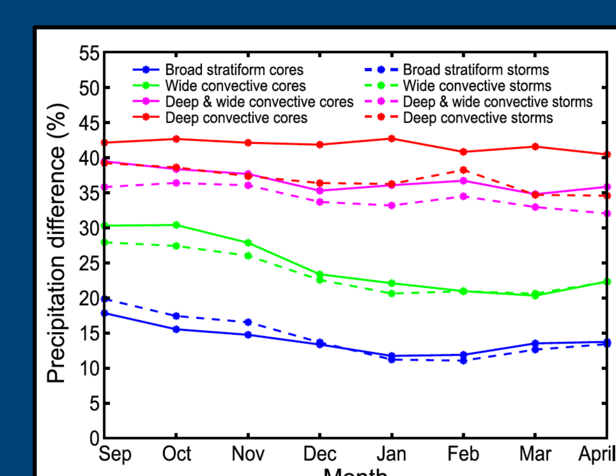


Figure 6. Normalized difference in volumetric precipitation amounts (Z-R – 2A25). Dashed lines indicate precipitation from cores and solid lines are from the full storm that the core is embedded within.

★ The TRMM precipitation algorithm underestimates near-surface precipitation in deep convection over land! ★

South American Precipitation

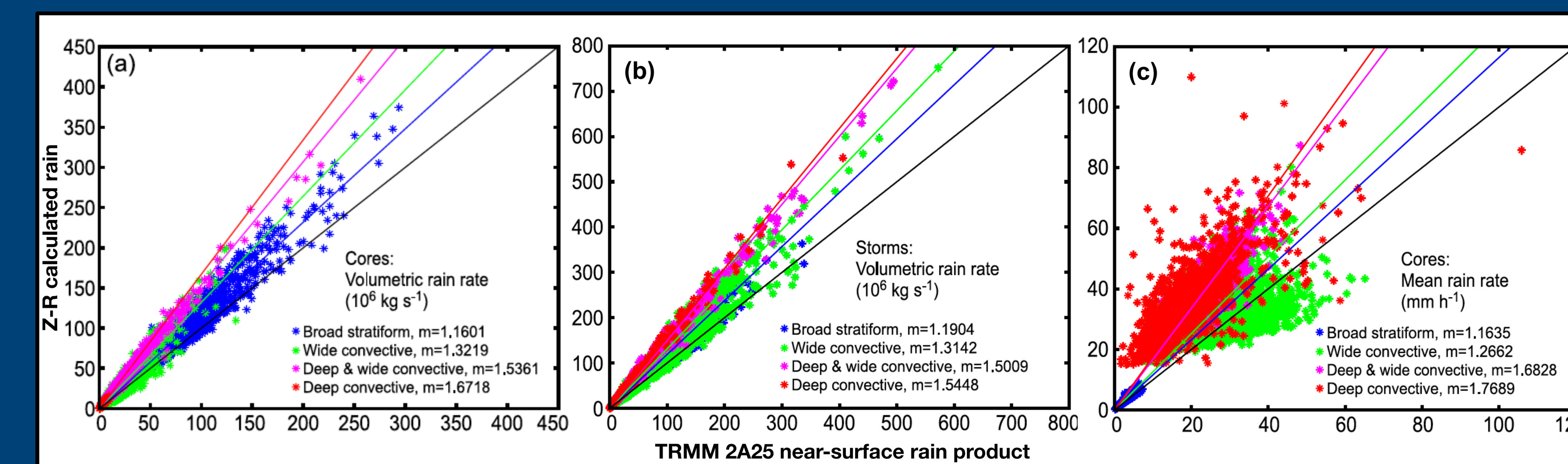


Figure 7. Volumetric and mean rain rates for various storm types in South America. (a) Volumetric rain rates from TRMM identified echo cores. (b) Volumetric rain rates from the full storm identified by TRMM that the echo cores are embedded within. (c) Mean rain rates from TRMM echo cores.

- **For the TRMM echo cores and storms, *deep convective storms have the largest bias in precipitation* (Figure 7a, b)**
- **Within the TRMM identified ≥ 40 dBZ convective echo cores, the TRMM algorithm produces mean rain rates < 5 mm hr^{-1} → significant underestimation of intense precipitation (Fig. 7c)**

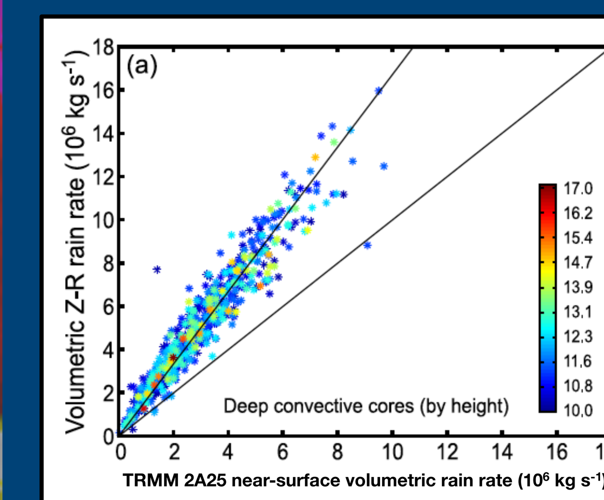


Figure 8. Volumetric rain rate comparison by 40 dBZ storm height for deep convective cores.

- **Bias in deep convective cores is independent of height**
- **Rain rate estimation is highly sensitive to the attenuation correction, the DSD, and microphysical parameters used in the TRMM algorithm**

★ Significant implications for TRMM precipitation applications over land ★

Conclusions

- **Deep convection initiates near the Sierras de Córdoba Mountains and Andes foothills, grows upscale into eastward propagating MCSs, and decays into stratiform regions**
- **Storm organization is similar to that observed in the U.S. and lee subsidence provides a capping inversion**
- **Compared to a more traditional Z-R calculation of precipitation, the TRMM PR near-surface rain product generally underestimates the volumetric and mean rain rates in all storm categories**
- **The bias gets worse as the storms become deeper and more intense, especially over land**

Acknowledgements

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