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Mountain Tropical Rainfall: Phase-Locking between the Diurnal, Annual and Interannual Cycles in the Andes of Colombia

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Objectives

Given that:

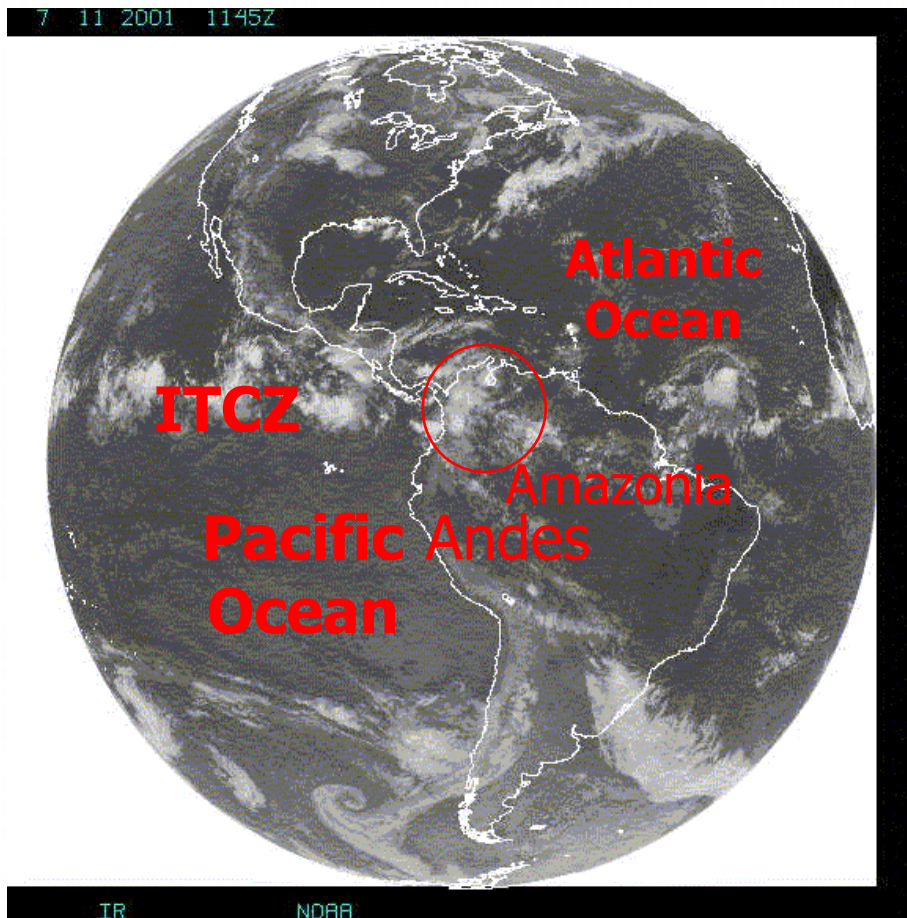
1. The diurnal cycle is the most dominant climatic feature in the tropics,
2. Mountain tropical rainfall is a highly intermittent phenomenon in space-time.

We aim at:

1. Finding a spatially coherent pattern of the diurnal cycle of rainfall in the tropical Andes of Colombia. Pretty difficult after Poveda *et al.* (Mon. Wea. Rev., 2005).
2. Quantifying the simultaneous dynamics of rainfall over the study region at annual, interannual (ENSO), and diurnal timescales.
3. Studying whether the dynamics of rainfall, associated with those three timescales (oscillators), exhibit some kind of phase-locking among them.

Annual Cycle of Rainfall in Colombia

Main Controlling Factors:

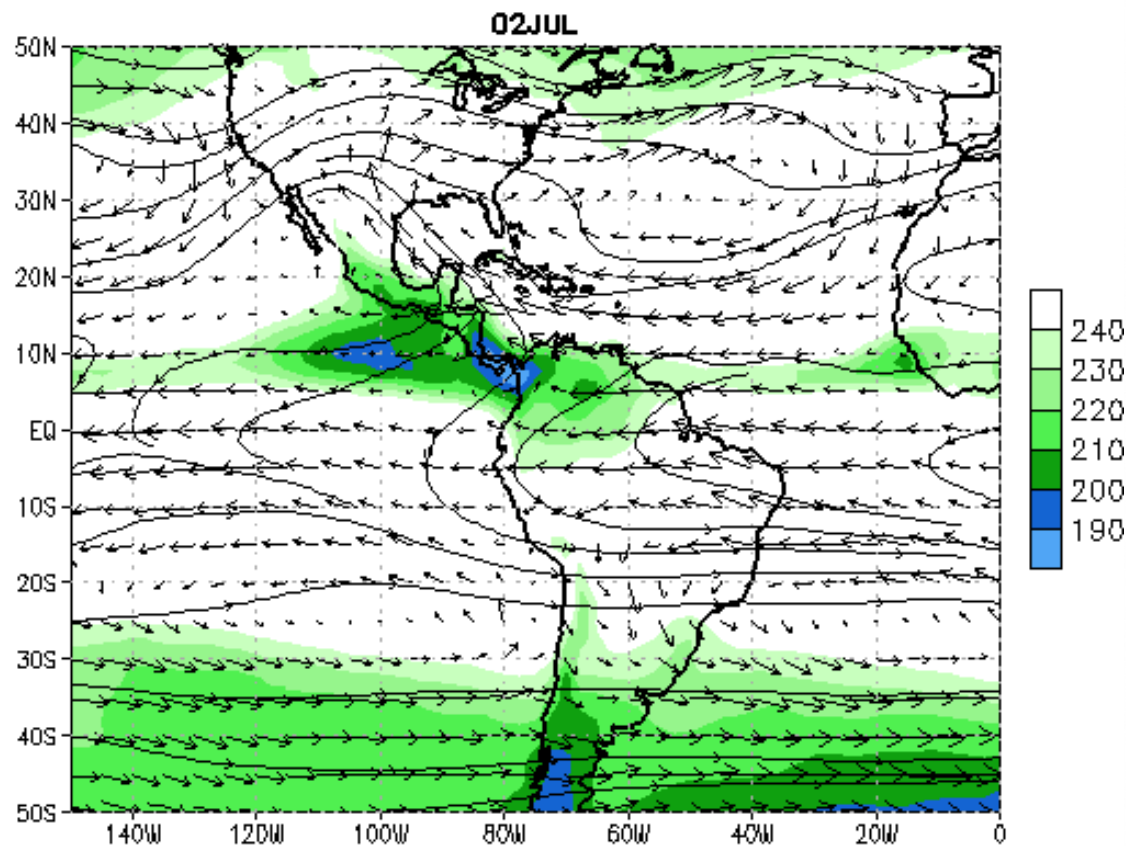


Location: Tropical South America,
and thus:

- | Dynamics of the trade winds
- | Atlantic Ocean – Caribbean Sea
- | Far Eastern Pacific Ocean
- | Amazon River Basin
- | Andes Mountains
- | Intertropical Convergence Zone
- | Diverse Low-level Jets
- | Shallow and Deep Convection
- | Mesoscale Convective Systems

Annual Cycle of Rainfall: Meridional Oscillation of the ITCZ + *et al.*

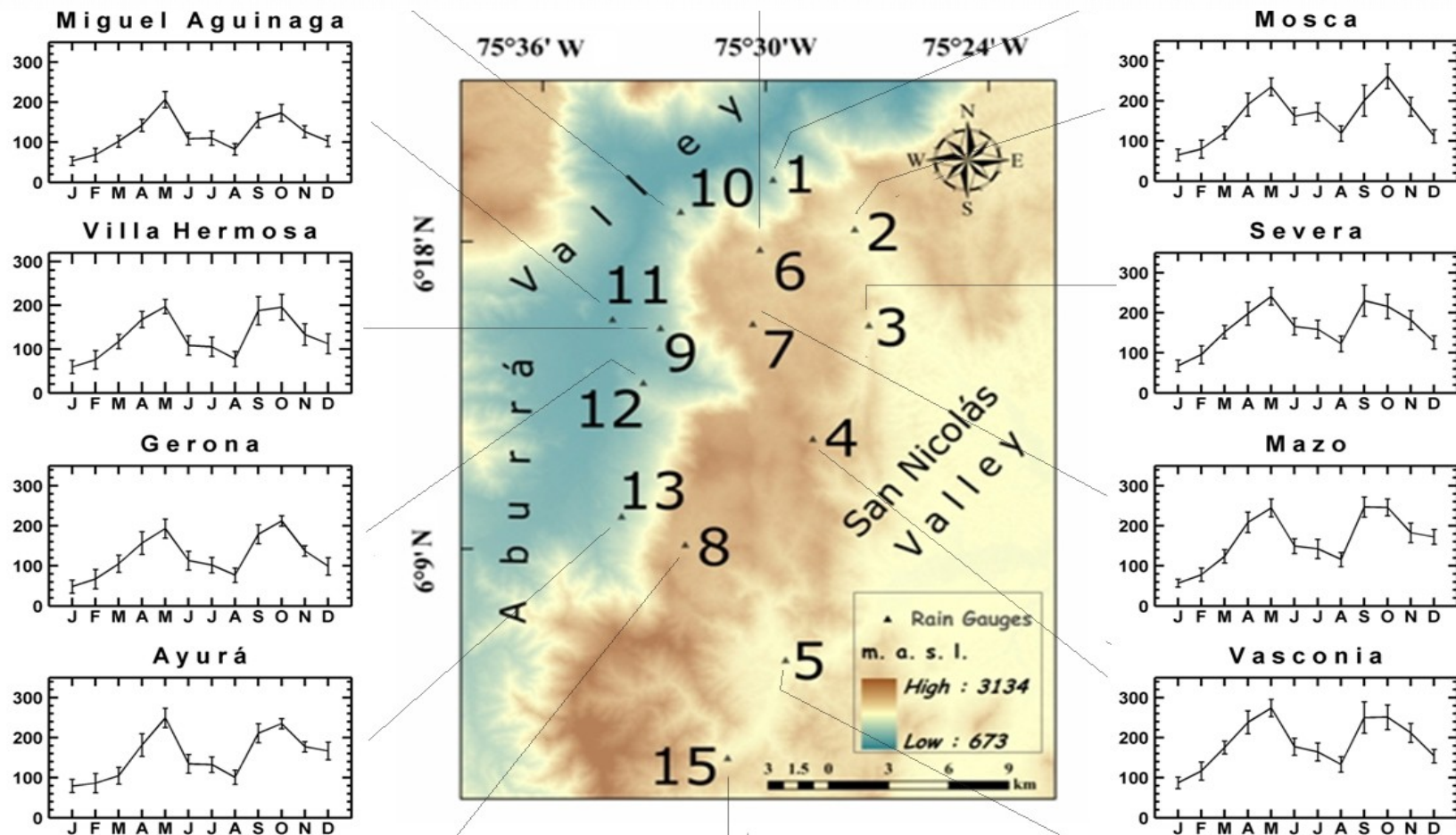
OLR, 200-hPa Streamlines and 850-hPa Wind Clim (1979–1995)



Data Sources: OLR – NESDIS/ORA, Winds – NCEP CDAS/ Reanalysis

Annual Cycle of Rainfall – Central Colombia

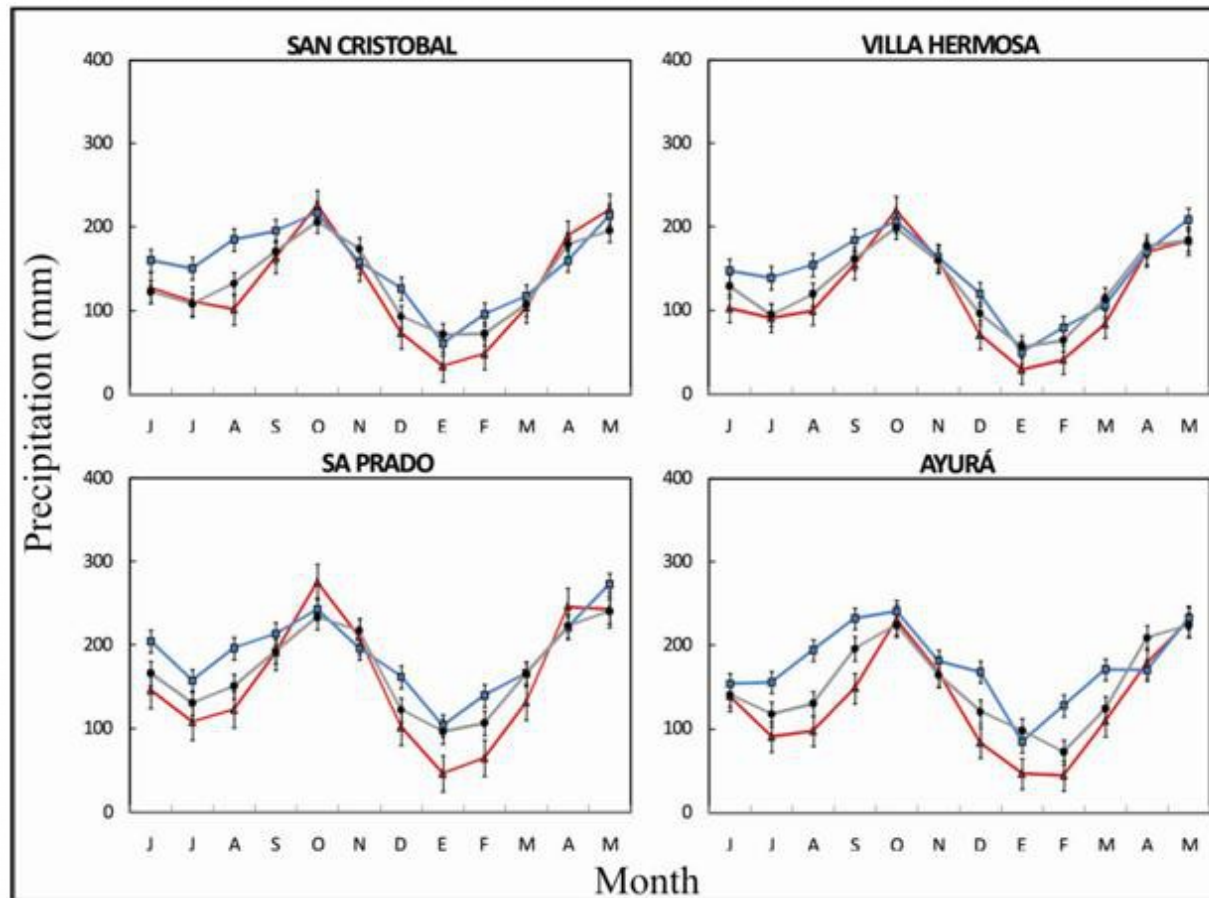
Bimodal – Maxima during MAM & SON



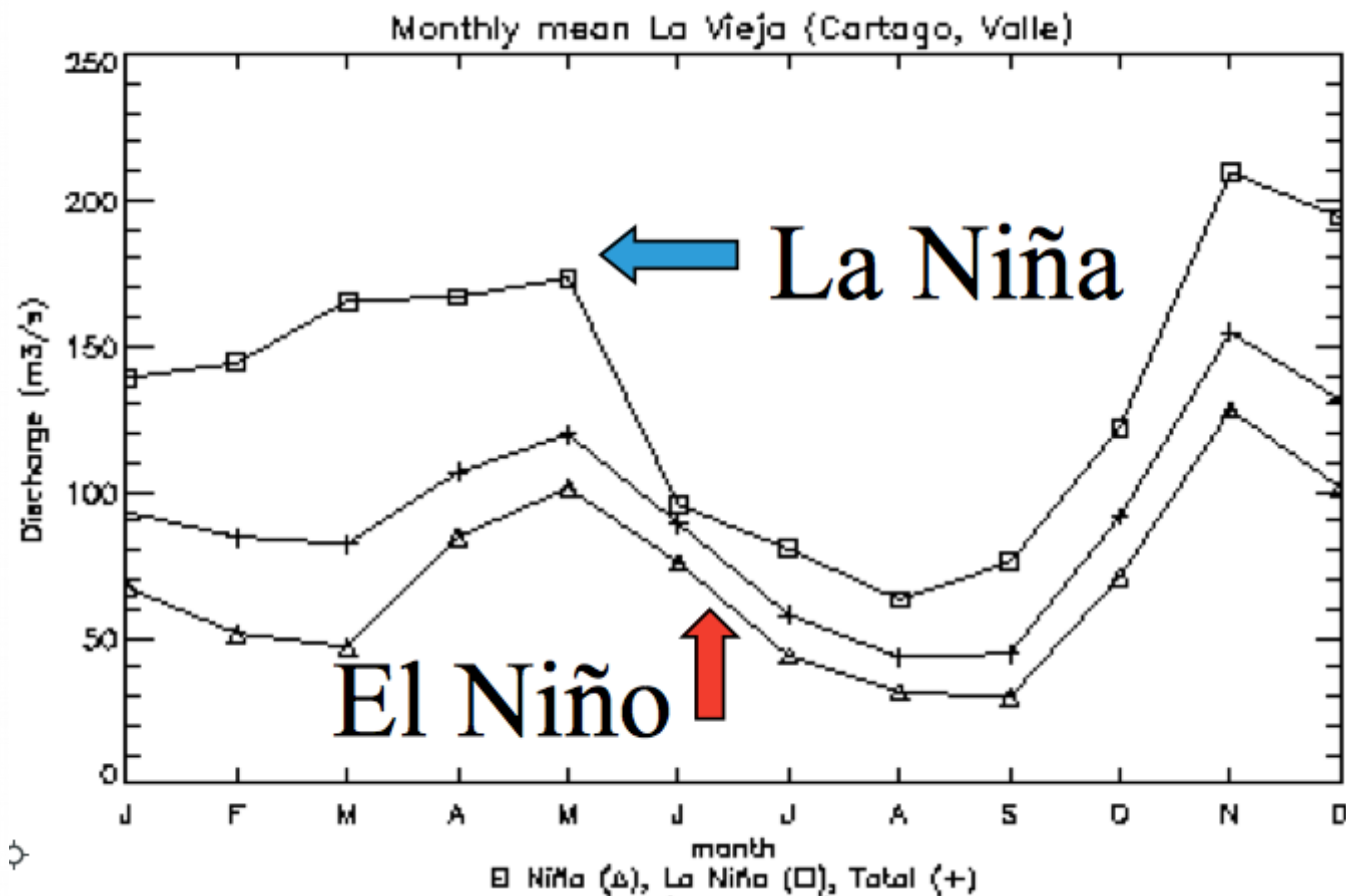
Phase-Locking between Annual and Interannual ENSO Timescales

The dynamics of ENSO itself is phase-locked to annual cycle.

La Niña (blue); El Niño (Red); Normal (black)

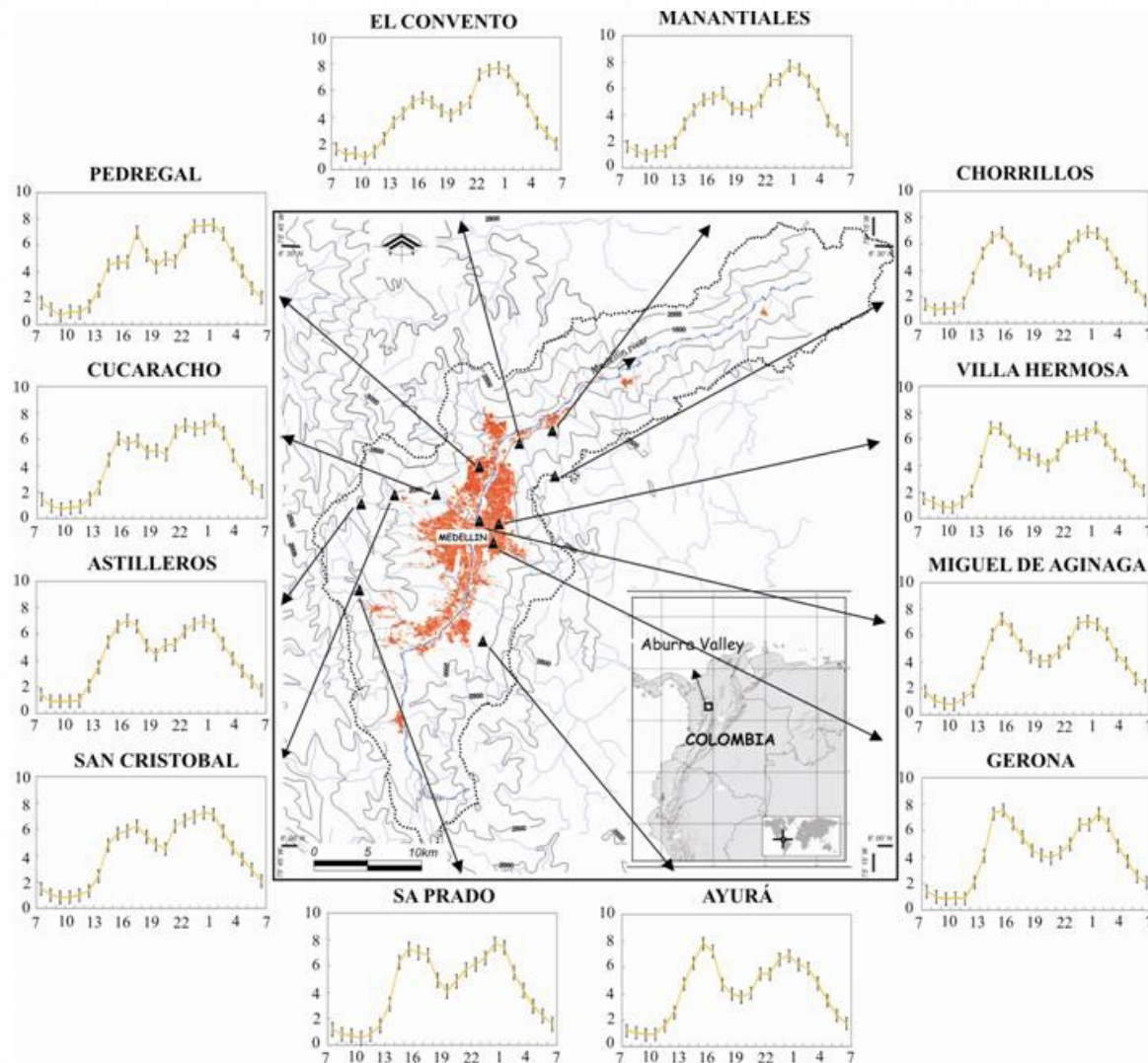


Rainfall & River Flows in Colombia: Phase-Locking Between Annual and Interannual (ENSO) Timescales



Long-term Mean Diurnal Cycle of Rainfall

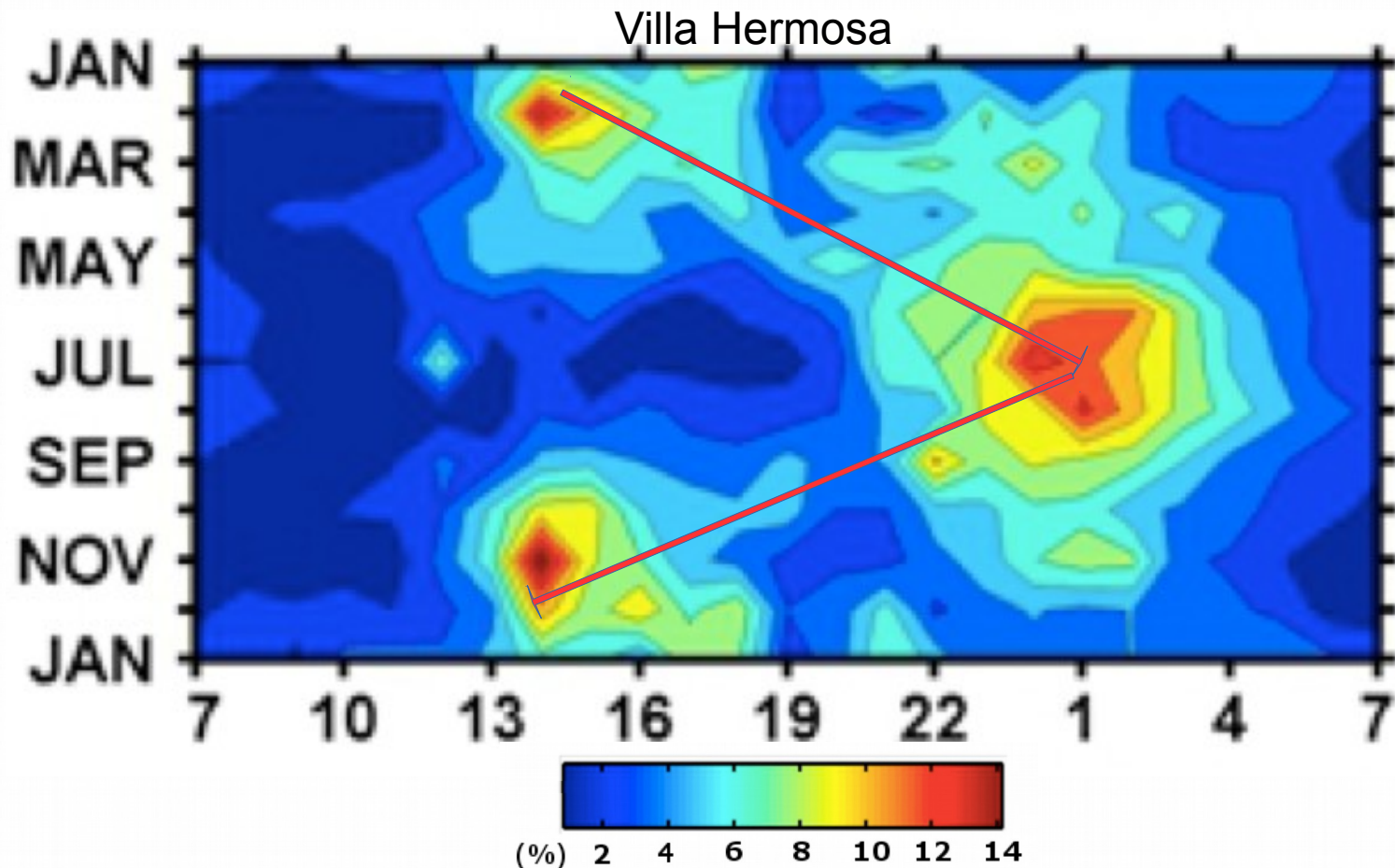
Apparently Bi-Modal (afternoon and mid-night)



A Careful Examination of Diurnal Cycle: Uni-modal but shifting phase with the annual cycle

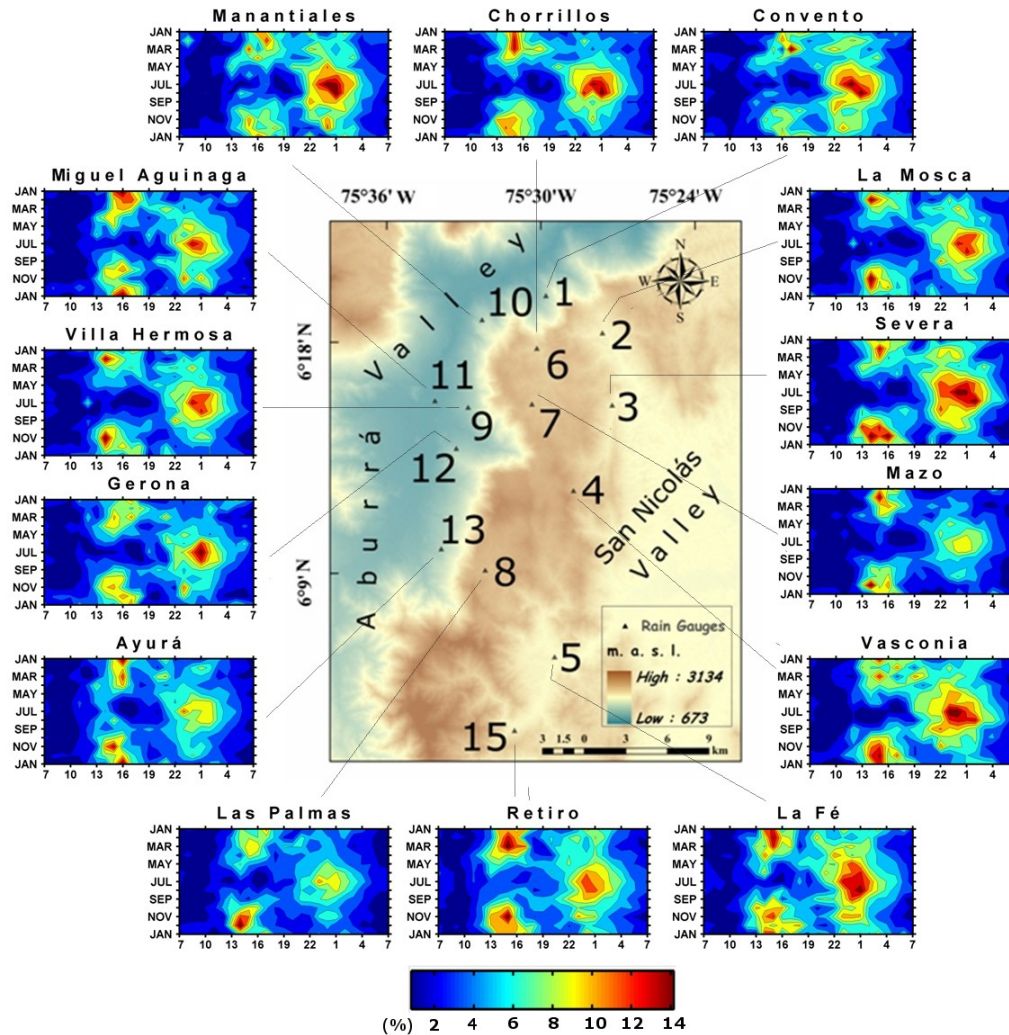
Afternoon Peak: September-October to April-May

Midnight-dawn Peak: April-May to September-October



Spatially Coherent in Medellin's Valley

Bi-modal during short transition periods



Typical Afternoon Storm over Medellin



Courtesy: Prof. José F. Jiménez

Physical Mechanisms and Controlling Factors

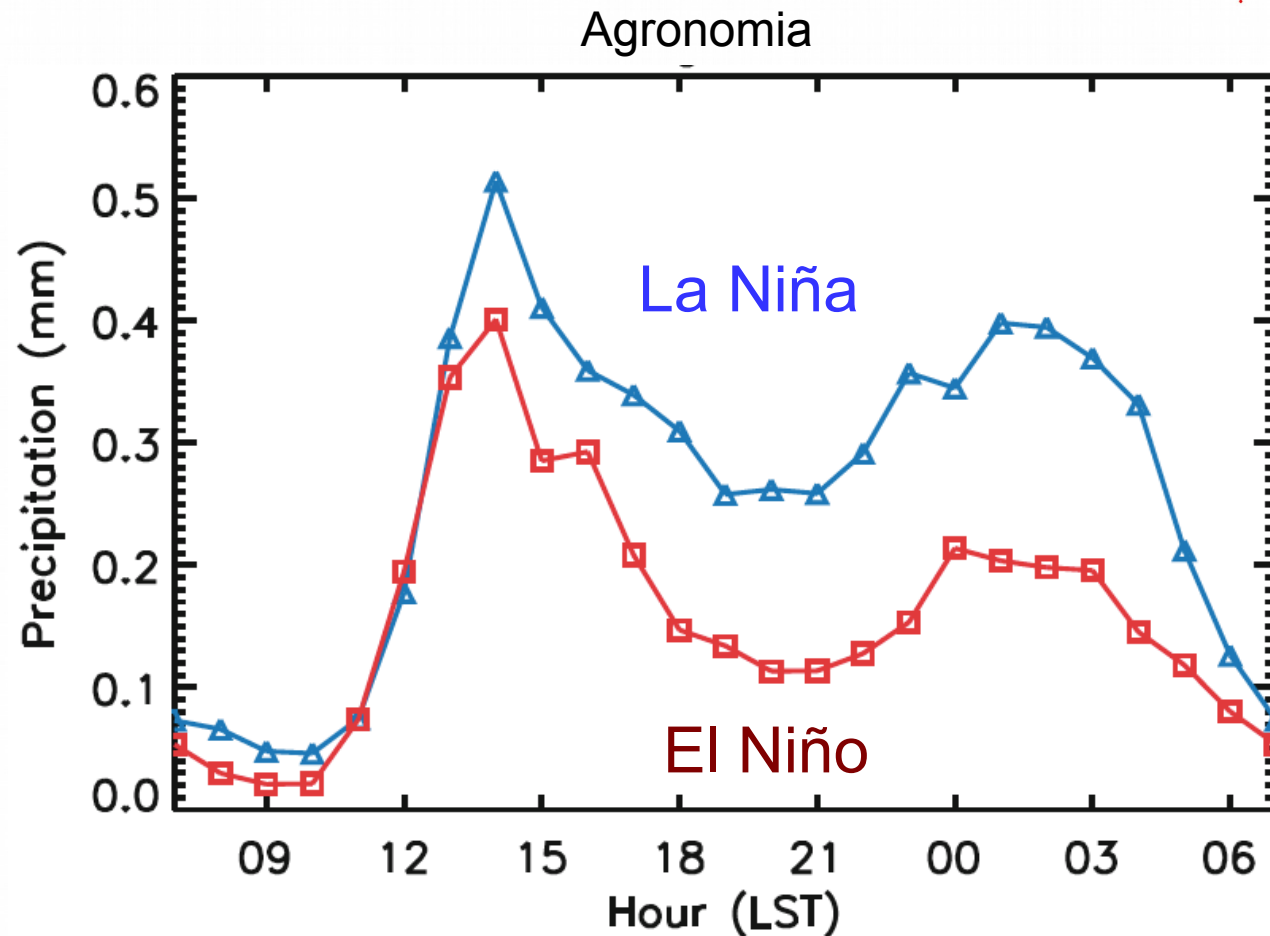
Afternoon rainfall:

1. Diurnal cycle of Insolation @ Morning and early afternoon
2. Surface Convergence
3. Ascent of Moisture: Buoyancy + ABL dynamics + Shallow and Deep Convection

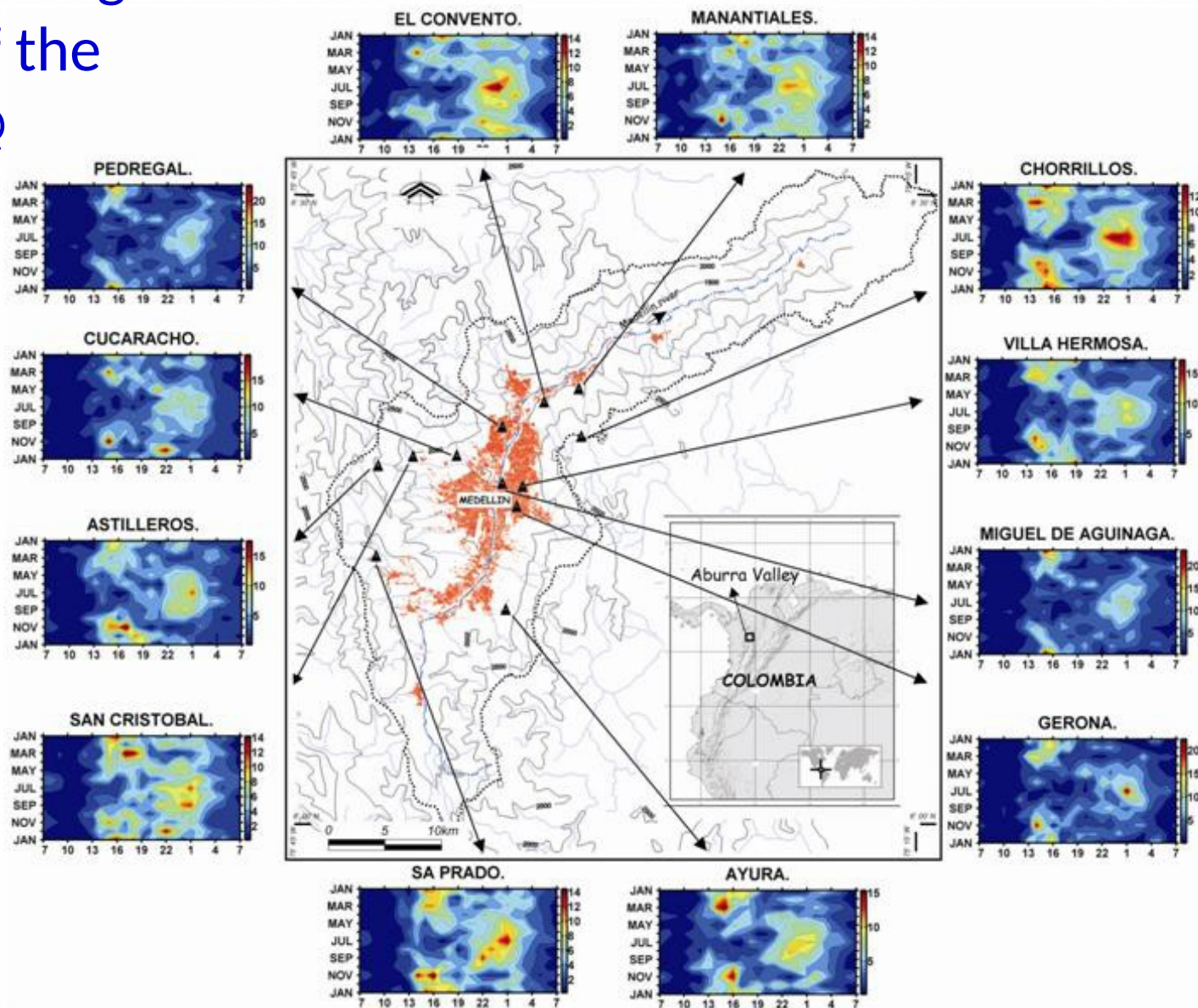
Midnight-Early Dawn rainfall:

1. Mesoscale Convective Systems?
2. Transport of Moisture from Magdalena River Valley?
3. Ascent by orography and rain during night?
4. Lots of work to be done. MounTrain Project.

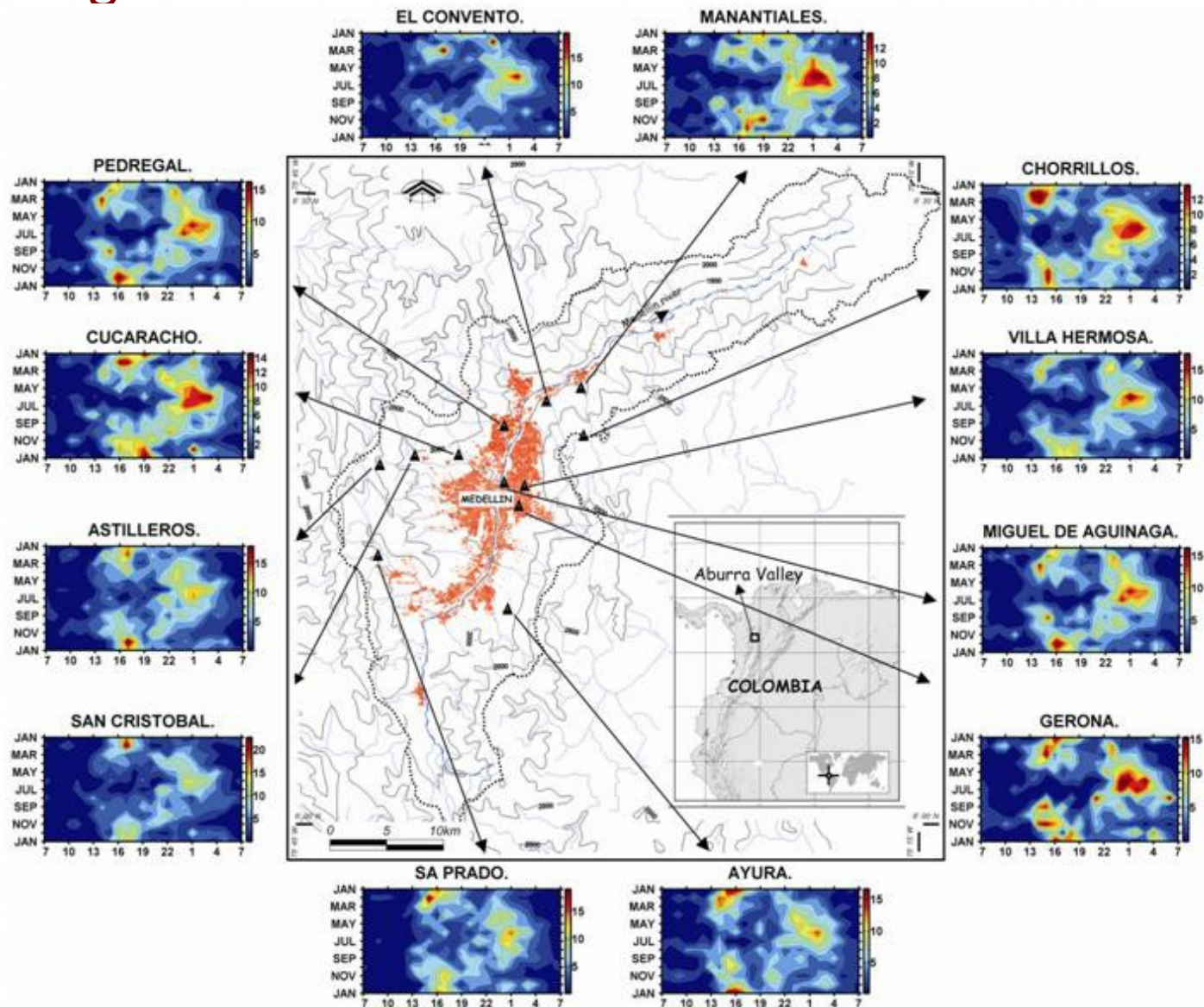
Phase-Locking between Diurnal and Interannual (ENSO) Timescales



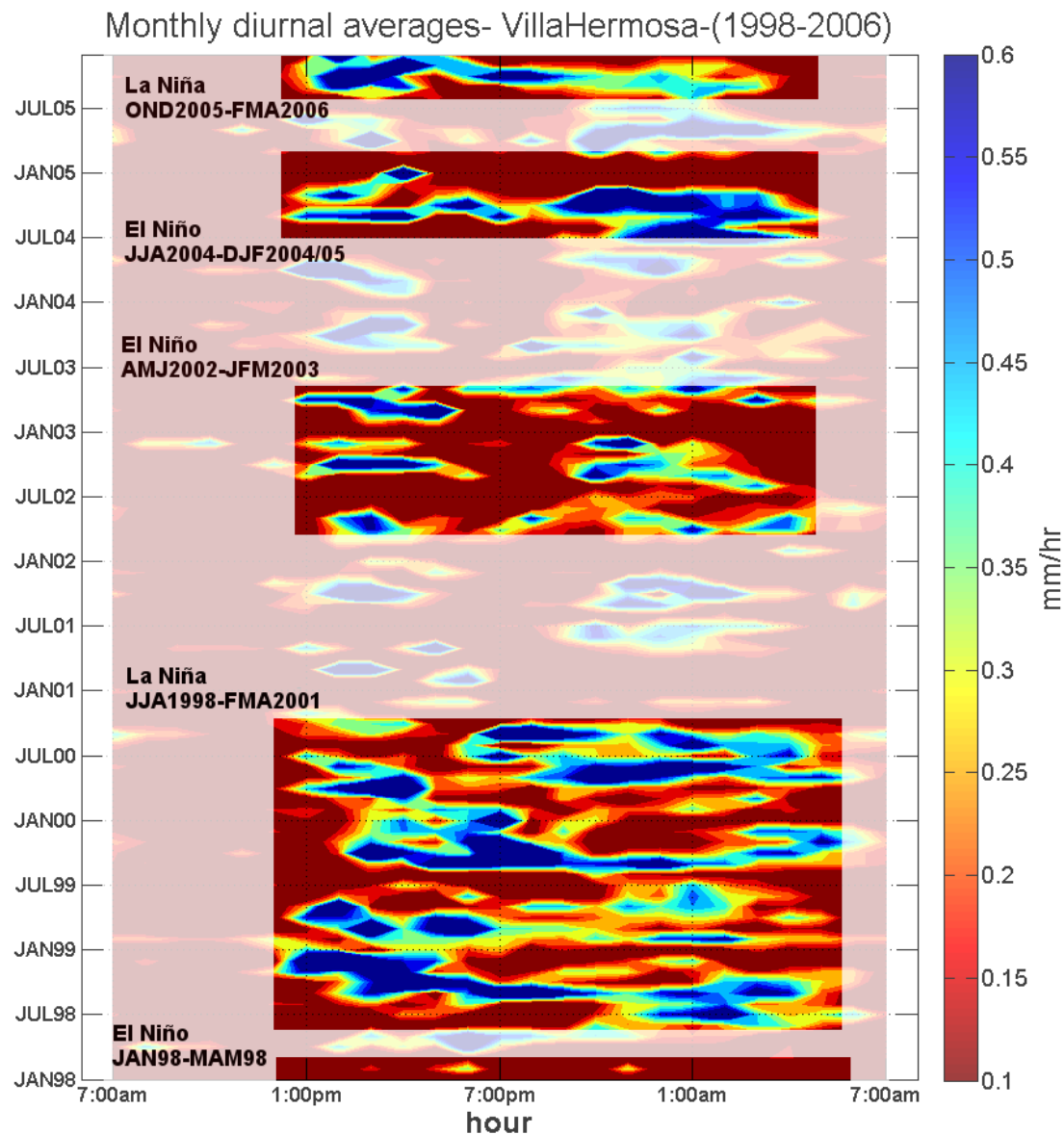
Triple Phase-Locking: Annual Cycle of the Diurnal Cycle @ La Niña



Triple Phase-Locking: Annual Cycle of Diurnal Cycle @ El Niño



Interannual variability of Diurnal Cycle Rainfall Intensity (mm/h) Villahermosa

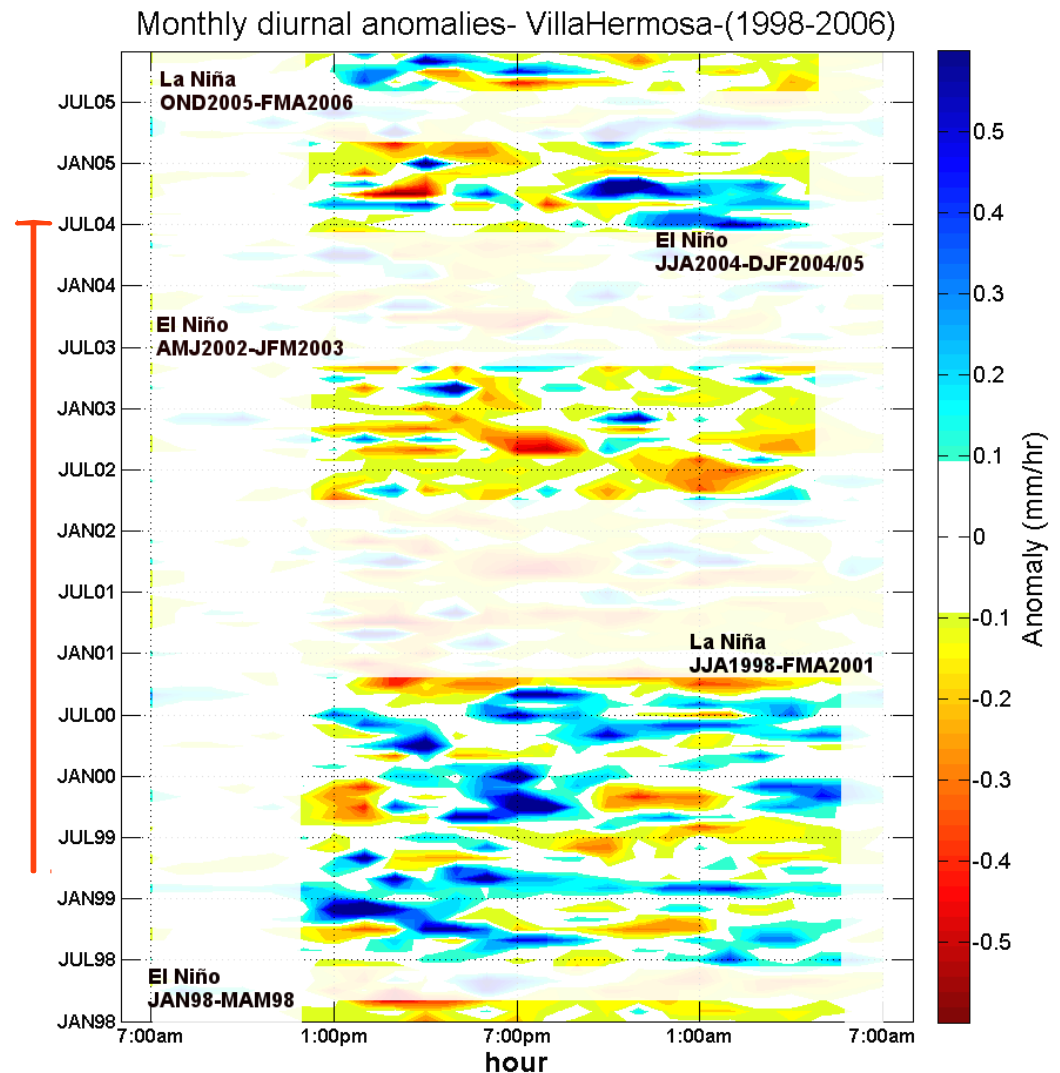


Interannual variability of Diurnal Cycle

Monthly diurnal Anomalies (mm/h) Villahermosa

ENSO affects the amplitude of the diurnal cycle, with below normal rainfall during El Niño and above normal during La Niña.

Such modulation is stronger during the afternoon showers, which could be explained by land surface-atmosphere interactions.



Conclusions

1. We have found a spatially coherent region in the diurnal cycle of rainfall in the tropical Andes of Colombia.
2. Rainfall exhibits strong variability at annual, interannual and diurnal timescales over the study region.
3. We have shown evidences of phase locking among the three timescales (oscillators).
4. We have found that rainfall in the tropical Andes exhibits phase-locking:

Between annual and interannual (ENSO) timescales.

Between annual and diurnal timescales.

Between diurnal and interannual timescales.

5. On-going work. Physical mechanisms involved.