ANDEX White Book
Chapter 4: High Impact Events

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White Book Content

1. Severe Weather: Intense Storms, Cold Spells, Frosts, Hail Storms, & Zonda Wind, & Lightning.
2. Mesoscale Convective Systems.
3. ENSO and Extreme Events.
4. Floods.
5. Landslides, Mudslides and Avalanches.
6. Droughts, Heat Waves and Fires.
7. Knowledge Gaps and Relevance.
8. Potential Activities.
9. Expected Outcomes of the ANDEX program.

Severe Weather – Intense Storms

Medellin collapsed by storm and hail

Medellin, February 21, 2017

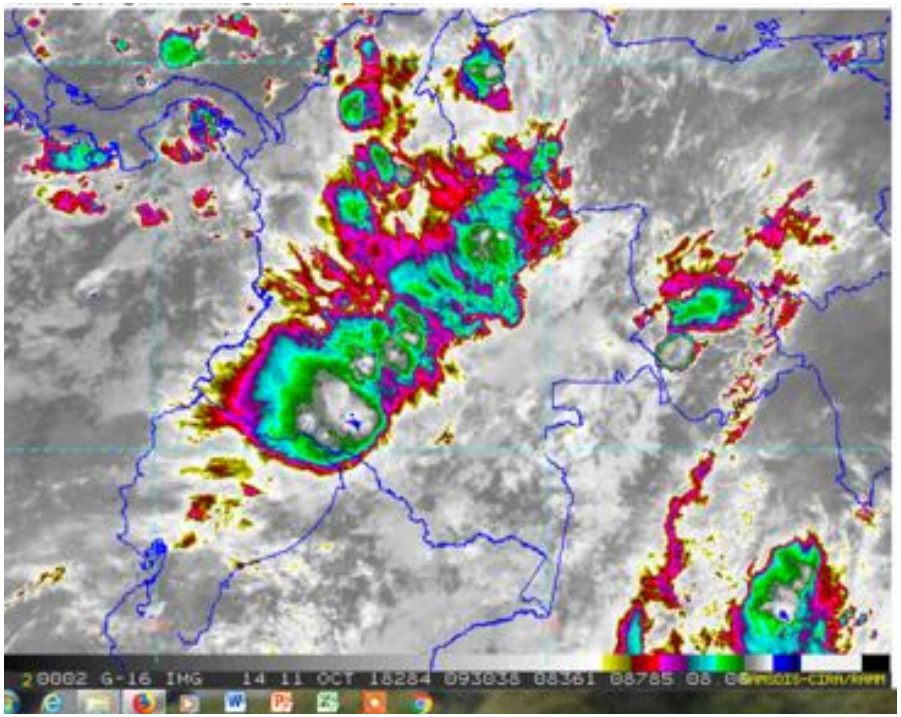
HISTÓRICO

Medellín colapsó por tormenta y granizada

Severe Weather – Intense Storms

Twelve dead and six missing

October 11, 2018



Más de diez muertos tras deslizamiento en Marquetalia, Caldas

El alcalde del municipio, Luis Carlos Betancourt Flórez, confirmó que entre los fallecidos a causa de la emergencia hay cinco niños. Seis viviendas fueron completamente destruidas.

EL ESPECTADOR

Severe Weather – Hail Storms

- Huge economic losses. Affecting infrastructure, houses, vehicles, tress, and triggering chaos in urban mobility.
- Tropical cities are not prepared to cope with it.

Bogotá, March 23, 2015

T. TODAY COLOMBIA

Colombia's second largest city Medellin stopped being the "city of eternal spring" for an hour on Wednesday after a torrential hail storm covered parts of the city in ice, while causing dozens of emergencies due to floods.

Snowmen In The Tropics; Medellin Turns White After Torrential Hail Storm

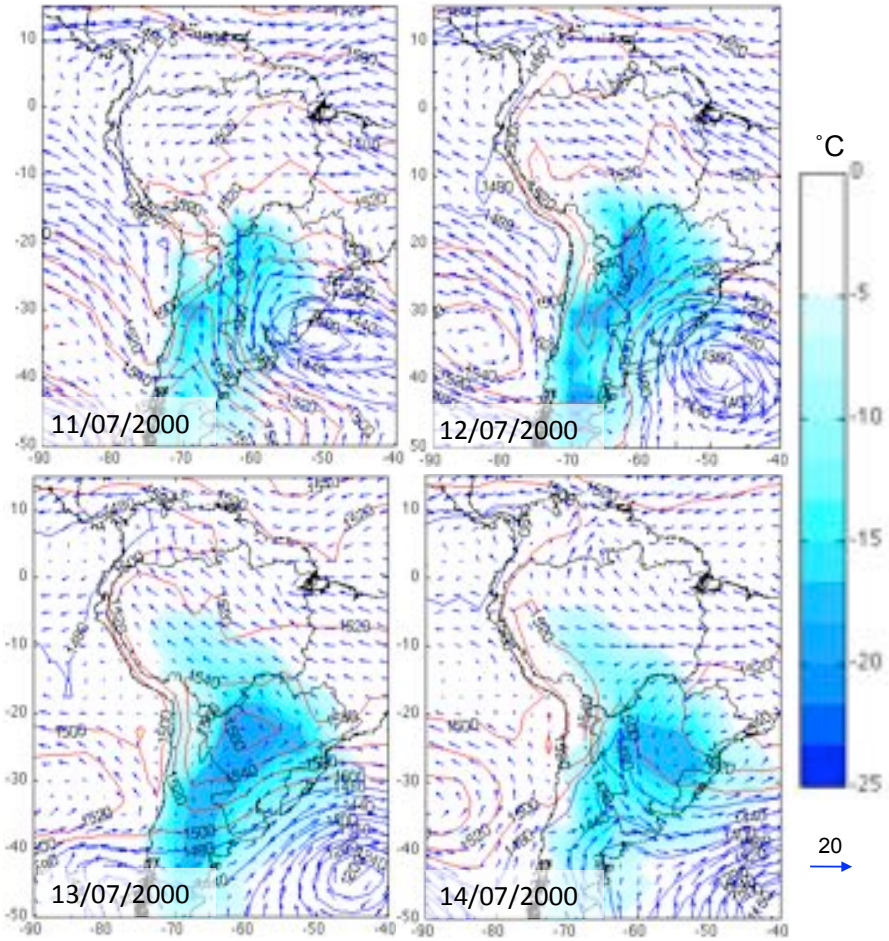
October, 2018

Severe Weather – Frosts

- Typical during the dry seasons due to intense radiative cooling of the surface during the night and very low cloud cover.

- Huge losses economic losses to rural communities in the Andes because the destruction of crops and pastures for cattle ranching.

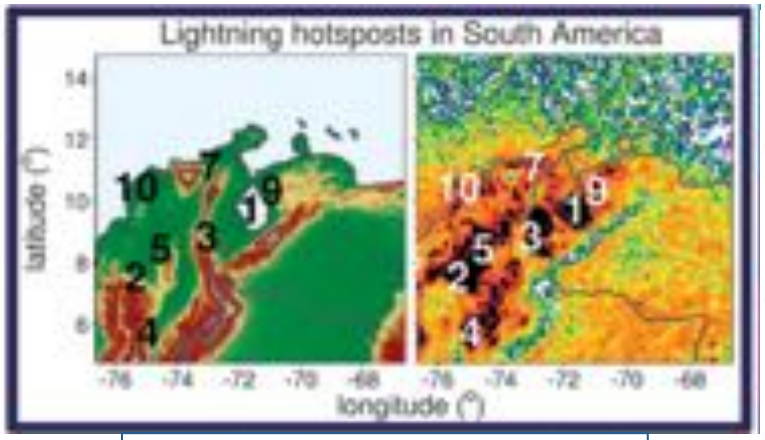
Severe Weather – Cold Spells



"*Surazos*" (Spanish) or "*Friajes*" (Portuguese). Characterized by sudden and severe drops in temperature, as much as 10°C in few hours. Affecting people and crops. During the austral winter 52 % of cold episodes recorded in southern Argentina propagate northward to the northern Peruvian Amazon.

Espinoza et al. (2013b)

Lightning



Albrech et al., BAMS (2016)

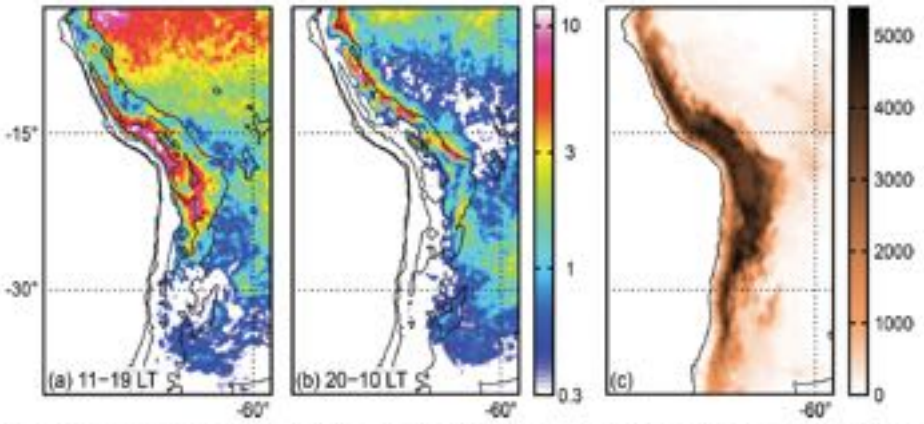


FIG. 7. (a),(b) WWLLN lightning stroke frequency (km^{-2} yr^{-1}; 0.25° × 0.25° resolution) over the central Andes for indicated time intervals during Nov–Mar. Local time given for Lima, Peru. Black contours indicate the 500- and 4000-m elevation. (c) Elevation (m).

Virts et al., BAMS (2013)

- Human and Animal Lives.
- Destruction of Infrastructure.
- Failures of Electric Systems and Grids & Electricity Shortages.
- RELAMPAGO (Remote Sensing of Electrification, Lightning, And Mesoscale/ microscale Processes with Adaptive Ground Observations) field campaign: Austral summer of 2018, aims to deepen the understanding of the lifecycle of the region's convective storms through direct observations. (https://www.eol.ucar.edu/field_projects/relampago).

Zonda Wind

- Strong, warm and very dry wind associated with adiabatic compression upon descending on eastern slopes of the central Argentina Andes.
- Zonda wind events more frequent during winter and spring seasons between 33ºS-32ºS nearby densely populated cities.

Courtesy of Norte, 2015

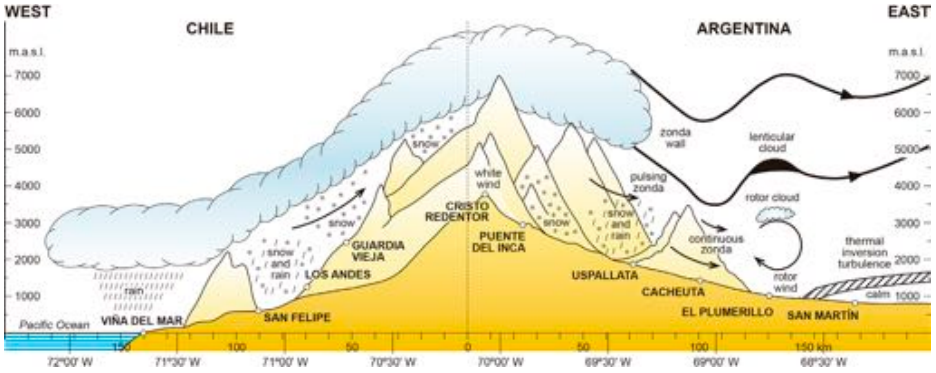


Figure 4. Typical scheme or conceptual model of zonda wind at Mendoza Aero latitude.

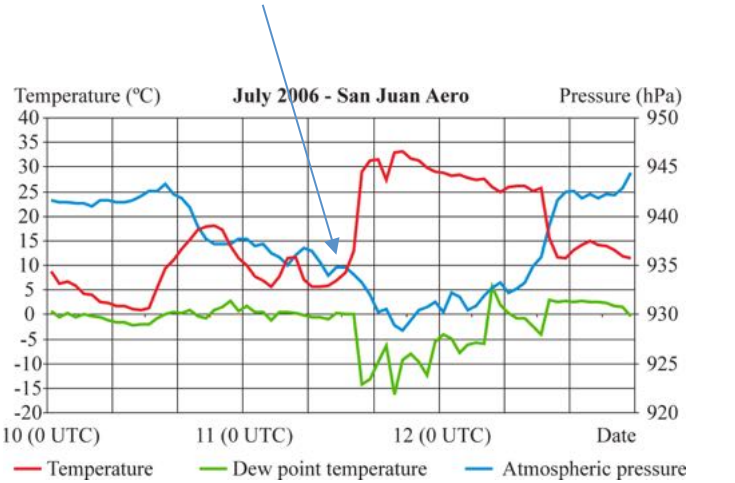


Figure 10. Atmospheric pressure, temperature and dew point evolution before, during and after zonda event of July 11th, 2006, in San Juan Aero.

High impact events affecting:

- Agriculture
- Human health
- Infrastructure

- Temperature rises up to 31ºC, humidity drops to 10%
- Maximum wind gust 60km/h
- Lasting 10 hours

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Zonda Wind

Favourable synoptic enviroments:

- Mid- level tropospheric disturbance that crosses over the Andes
- A polar jet stream associated to a cold front moving from the southwest
- A surface low ahead of the cold front causing an intese zonal pressure gradient that accelerates downslope wind

Challenges:

- Scarcity of observational data over the mountains.
- High-resolution models to improve Zonda forecasting (where, when, how long, intensity and offsett).

Severe Weather (SW) Research Questions

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- What are the physical processes (dynamics and thermodynamics) conductive to and during intense Rain Storms, Hail Storms, Frosts, Fog and Cold Spells across a wide range of spatio-temporal scales?
- Overarching topic: What are the roles of topography and elevation?
- What are the statistical and scaling properties of intense storms and rainfall in space and time (4-D)?
- How to link the physical and statistical scaling properties of intense storms?
- What are the spatial and temporal limits (scales) of predictability of severe weather phenomena in the Andes?
- What are the best diagnostics, modelling and prediction tools of SW phenomena? How to improve them?

Severe Weather (SW) Research Questions

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- What are the existing measuring capabilities of SW events in the region?
- What are the main instrumental gaps?
- What are the causes of the low skill of satellite information (TRMM, GPM) in capturing rainfall and intense storms along the Andes ranges and valleys?
- How to improve satellite estimates with in-situ measurements?
- What is the optimal network of raingauges in the Andes?
- What would be the optimal network of meteorological radars along the Andes? It is compulsory to implement such network.
- How to link intense storms with floods and landslides through an appropriate hydrological modelling framework?
- What should be such appropriate hydrological framework? Physics vs. Calibration?
- What are the effects of climate change on all of the above?
- What are the effects of deforestation and land use change on all of the above?

Mesoscale Convective Systems

GEOPHYSICAL RESEARCH LETTERS, VOL. 27, NO. 11, PAGES 1675-1678, JUNE 1, 2000

On the Existence of Lloró (the Rainiest Locality on Earth): Enhanced Ocean-Land-Atmosphere Interaction by a Low-Level Jet

Germán Poveda and Oscar J. Mesa

Postgrado en Aprovechamiento de Recursos Hidráulicos, Universidad Nacional de Colombia, Medellín, Colombia

Abstract. The department of Chocó, on the Colombian Pacific coast experiences 8,000 to 13,000 mm of average annual precipitation. Lloró (5°30'N, 76°32'W, 120m) has received above 12,700 mm (1952-1960). Using the NCEP/NCAR Reanalysis data, we show that the ocean-land-atmosphere interaction over the easternmost fringe of the tropical Pacific, enhanced by the dynamics of a low-level westerly jet ("CHOCO"), contributes to explain the existence of such record-breaking hydrological region. Deep convection develops from low-level moisture convergence by the CHOCO jet, combined with high-level easterly trade winds, orographic lifting on the western Andes, low surface pressures and warm air. Precipitation is organized in

America, deserves documentation and understand explore the main mechanisms of the ocean-land-at interaction that may contribute toward those e presence of the Intertropical Convergence Zone (IT course a major control, but finer analysis is in order.

The low-level westerly "CHOCO" jet

The southerly trade winds over the Eastern Pac the Equator due to the predominant position of the IT of the Equator [*Philander et al.*, 1996; Wa *Somerville*, 1994]. The corresponding change of th the Coriolis acceleration, the predominant north-so

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2017)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.5009

RMetS
Royal Meteorological Society

Mesoscale convective systems and other precipitation features over the tropical Americas and surrounding seas as seen by TRMM

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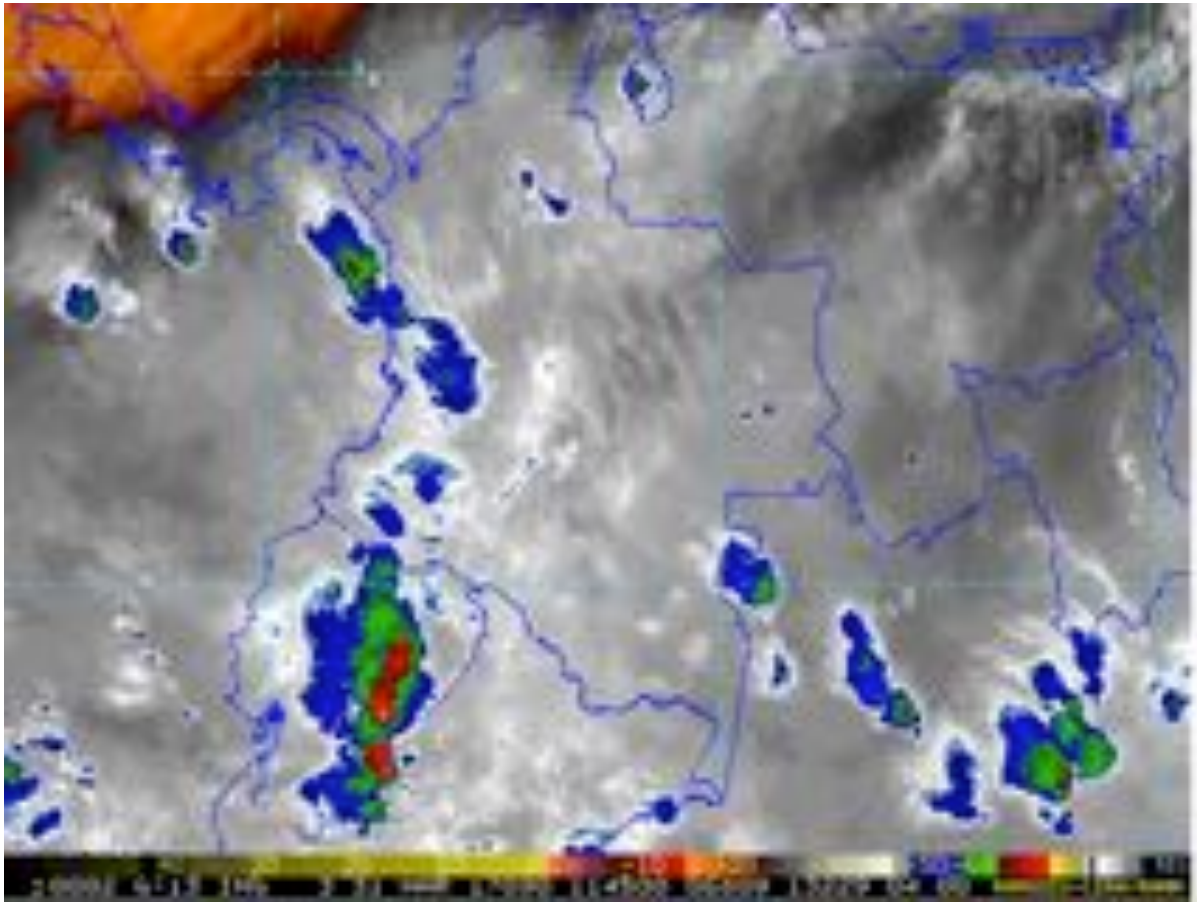
[a] *Department of Geosciences and Environment, Universidad Nacional de Colombia, Sede Medellín, Colombia*
[b] *Department of Atmospheric Sciences, Desert Research Institute, Reno, NV, USA*

Mesoscale Convective System that triggered the flooding of Mocoa, Colombia
March 30th, 2017

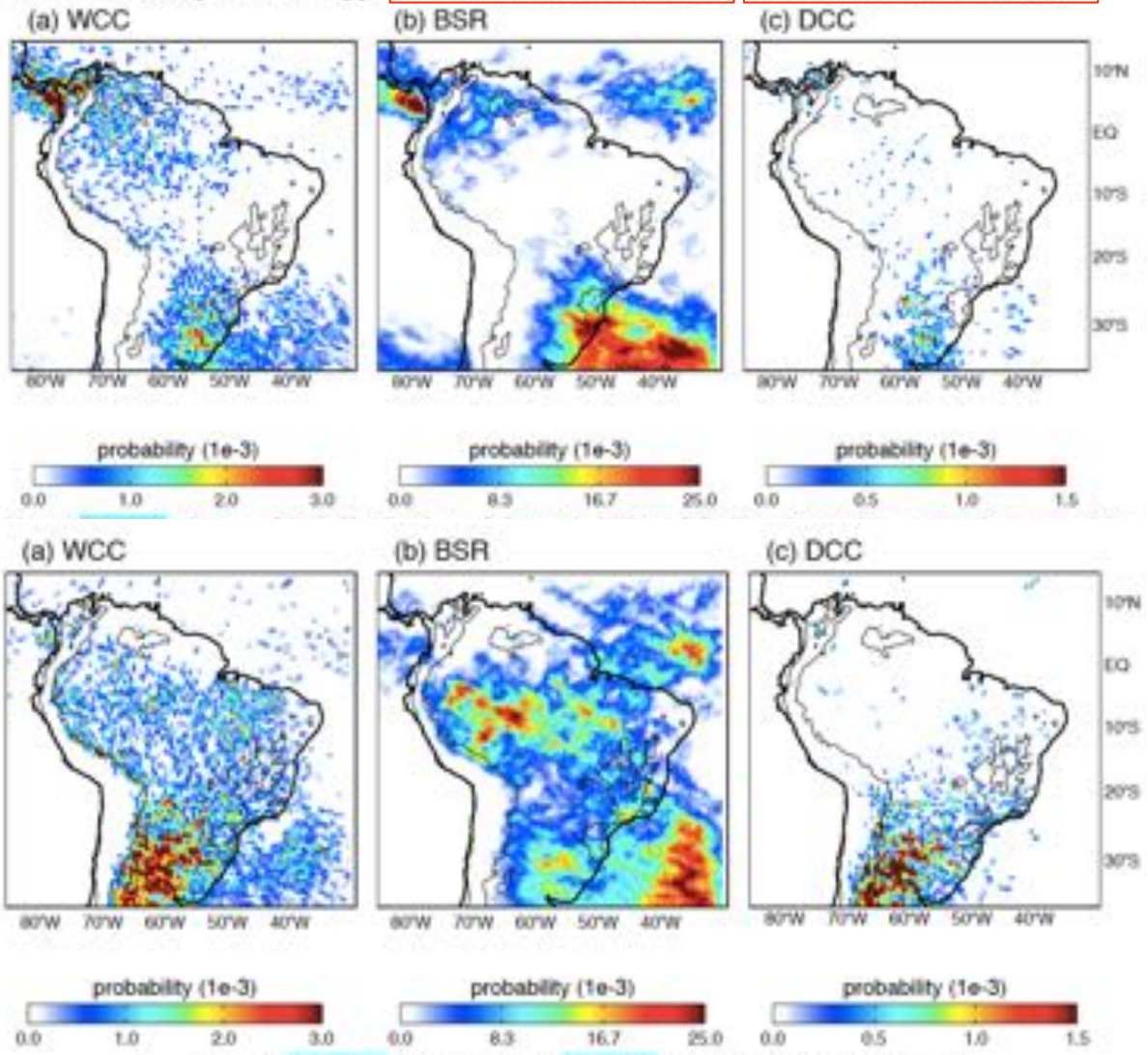


Precipitation Features

Wide Convective | Broad Stratiform | Deep Convective

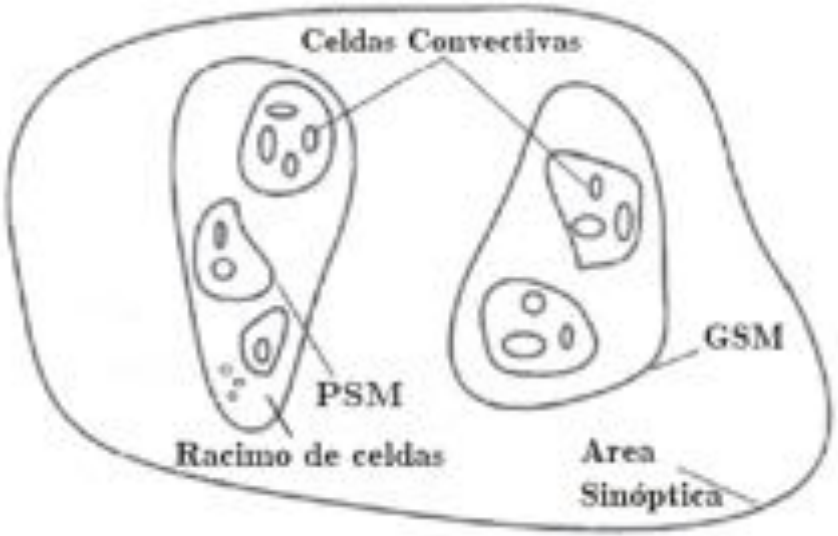
JJA

DJF



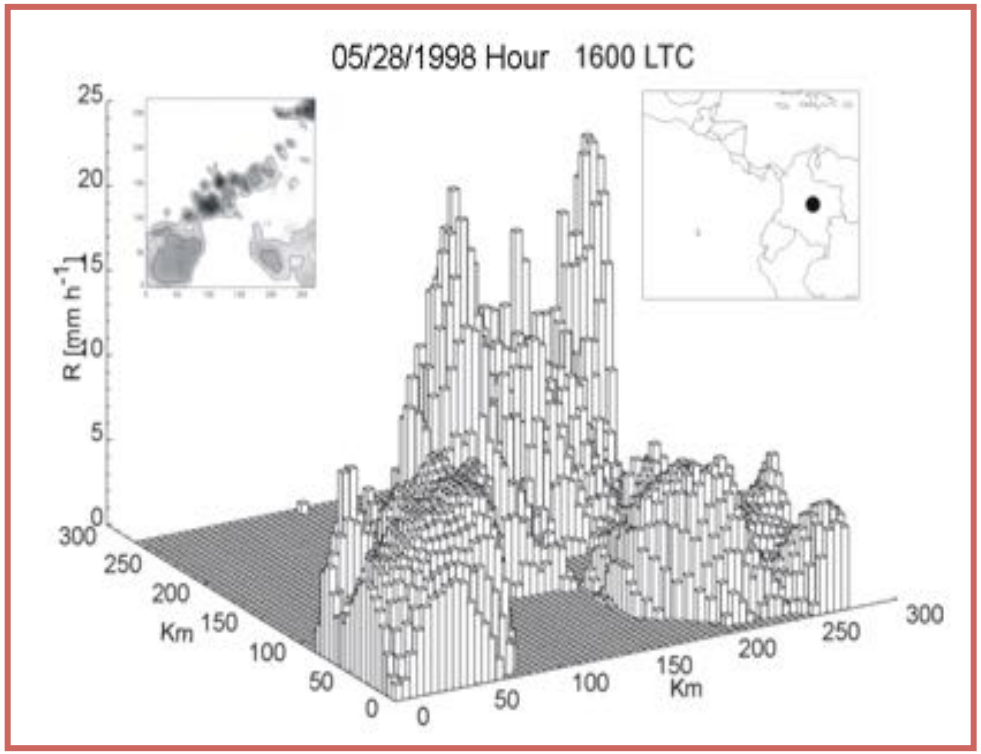
Adapted from Zuluaga and Houze (2015)

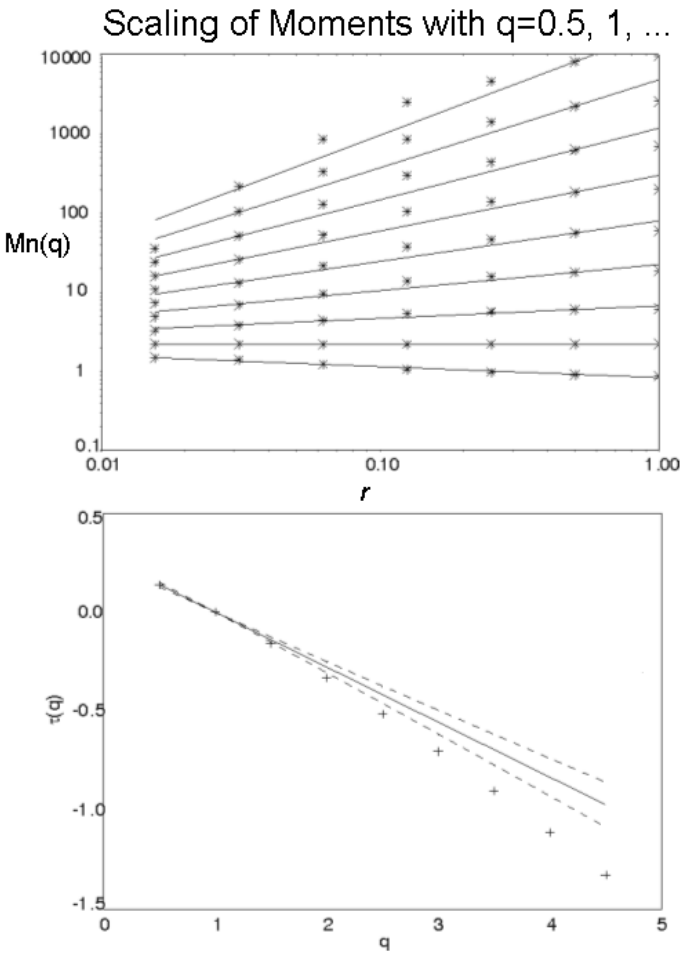
MCSs make part of the Multiscaling Properties of Rainfall



- Hierarchichal and self-similar organization structure
- Random self-similar cascades.

Multi-scaling properties of spatial distribution of rainfall intensity within MCSs in Colombia





Mejia and Poveda, *Advan. Rec. Hidr.*, (2002)

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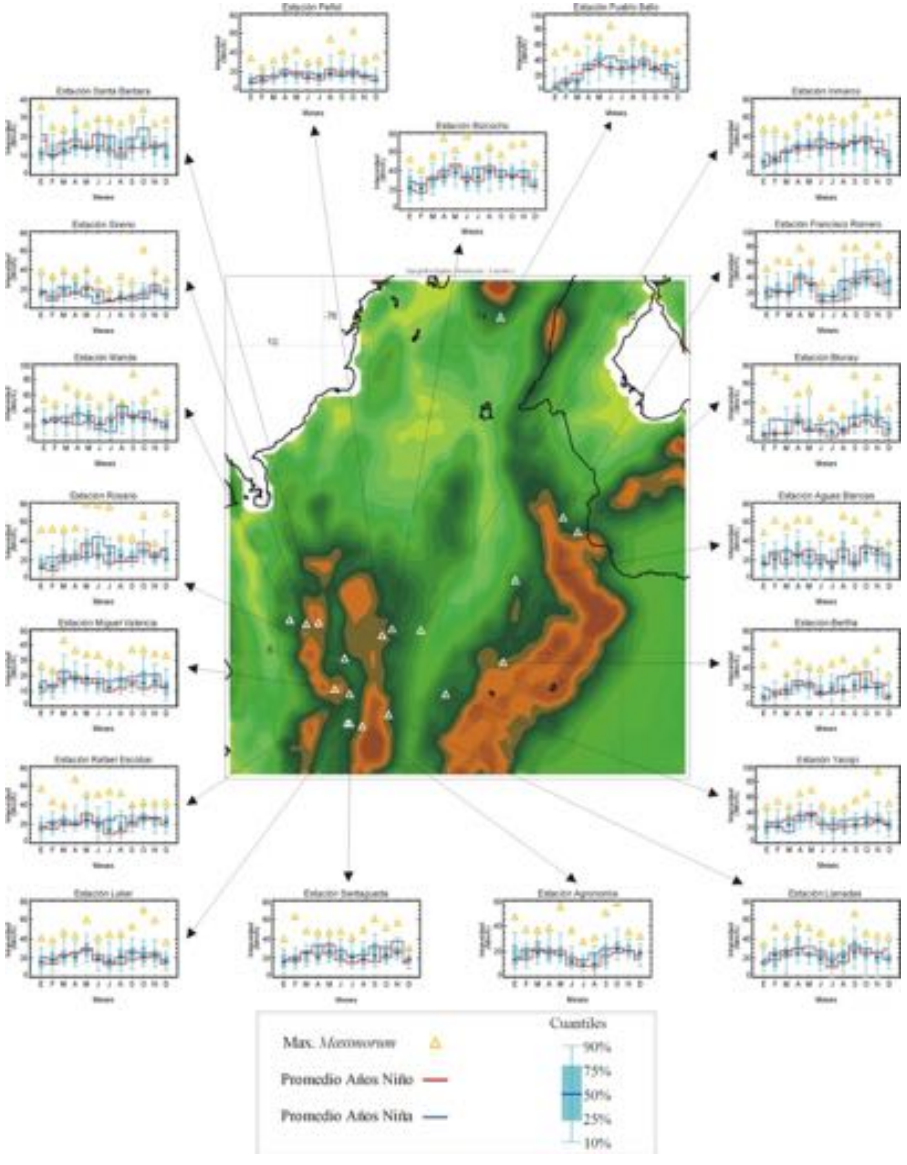
Mesoscale Convective Systems Knowledge Gaps and Relevance

- Lack of understanding of the physical mechanisms responsible for the occurrence of mesoscale convective systems, in particular nearby the Andes ranges.
- 2. Scarcity of comprehensive in-situ measurements during the occurrence of MCS, in special from those that include the vertical distribution of thermodynamic variables that can be used for the assessment of the environmental conditions leading to the formation of extreme convective rain.
- 3. Assessments of the potential changes in the timing, frequency, location, structure and intensity of convective storm categories in scenarios of climate change, in special for regions that are routinely affected by extreme convective precipitation

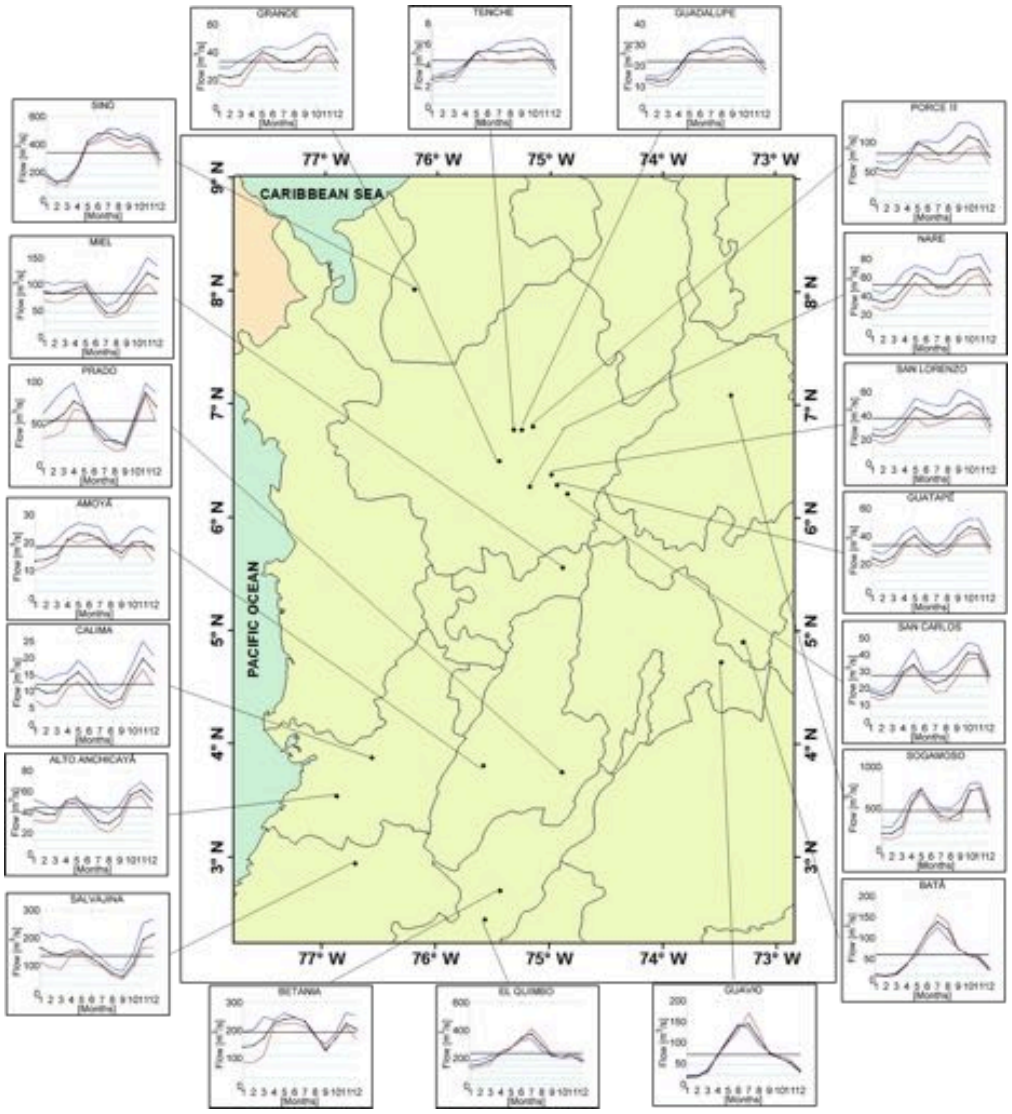
ENSO Impacts on Extreme Events (1)



ENSO effects on the annual cycle of the PDF of 1-h rainfall events at selected raingauges over the Andes of Colombia.

Poveda et al. (2002c)

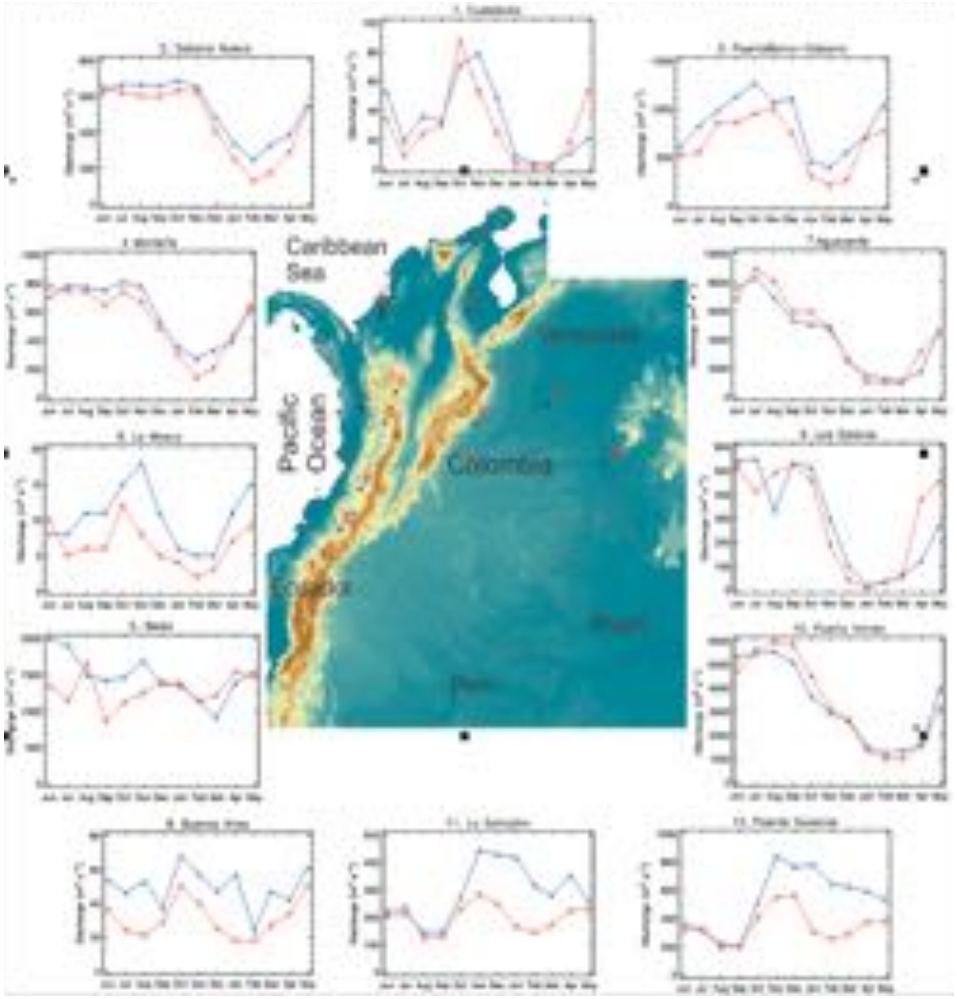
ENSO Impacts on Extreme Events (2)



El Niño and La Niña Effects on River Discharges in Colombia

Gómez, Ochoa & Poveda (2016)

ENSO Impacts on Extreme Events (3)

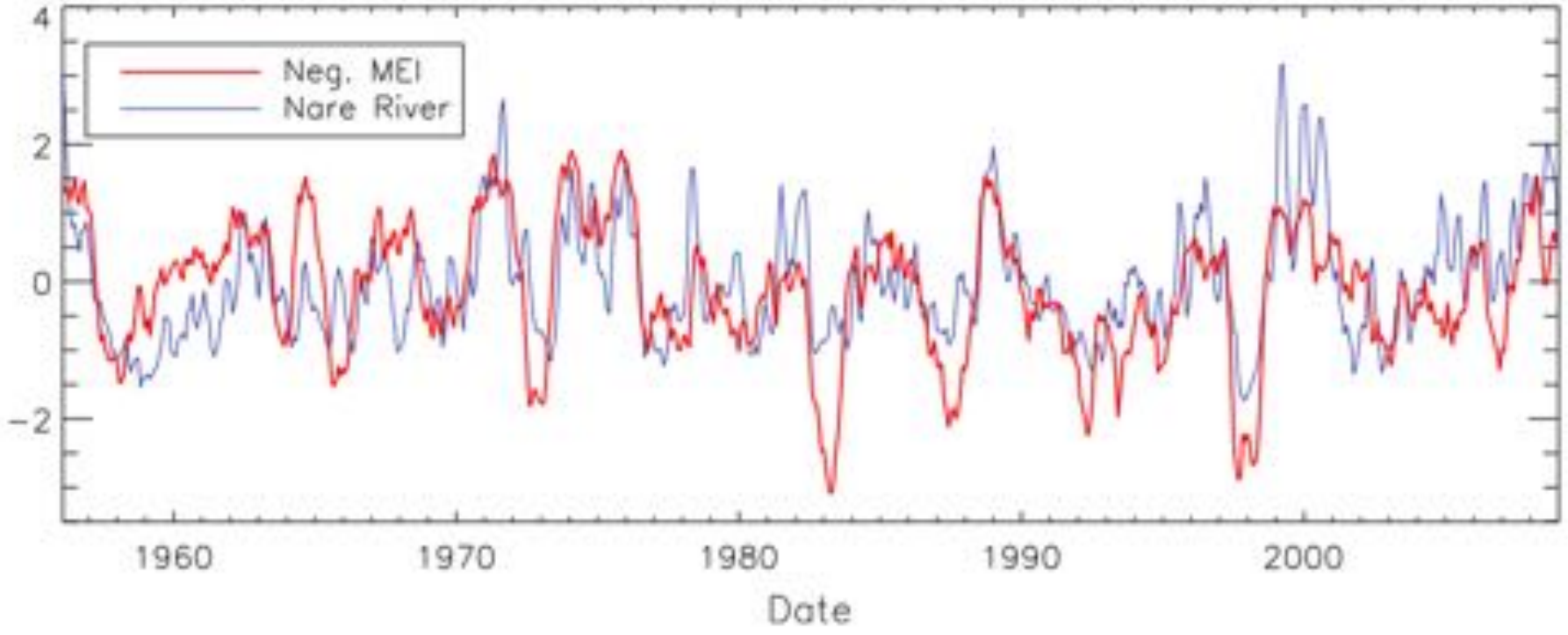


ENSO effects on the annual cycle of average maximum daily flows during El Niño (red), and La Niña (blue) for selected rivers throughout Colombia

Poveda et al., Clim. Dyn. (2011)

ENSO Impacts on Extreme Events (4)
What are the combined effects of different phases of ENSO, NAO, PDO, AMO? (and Why?)

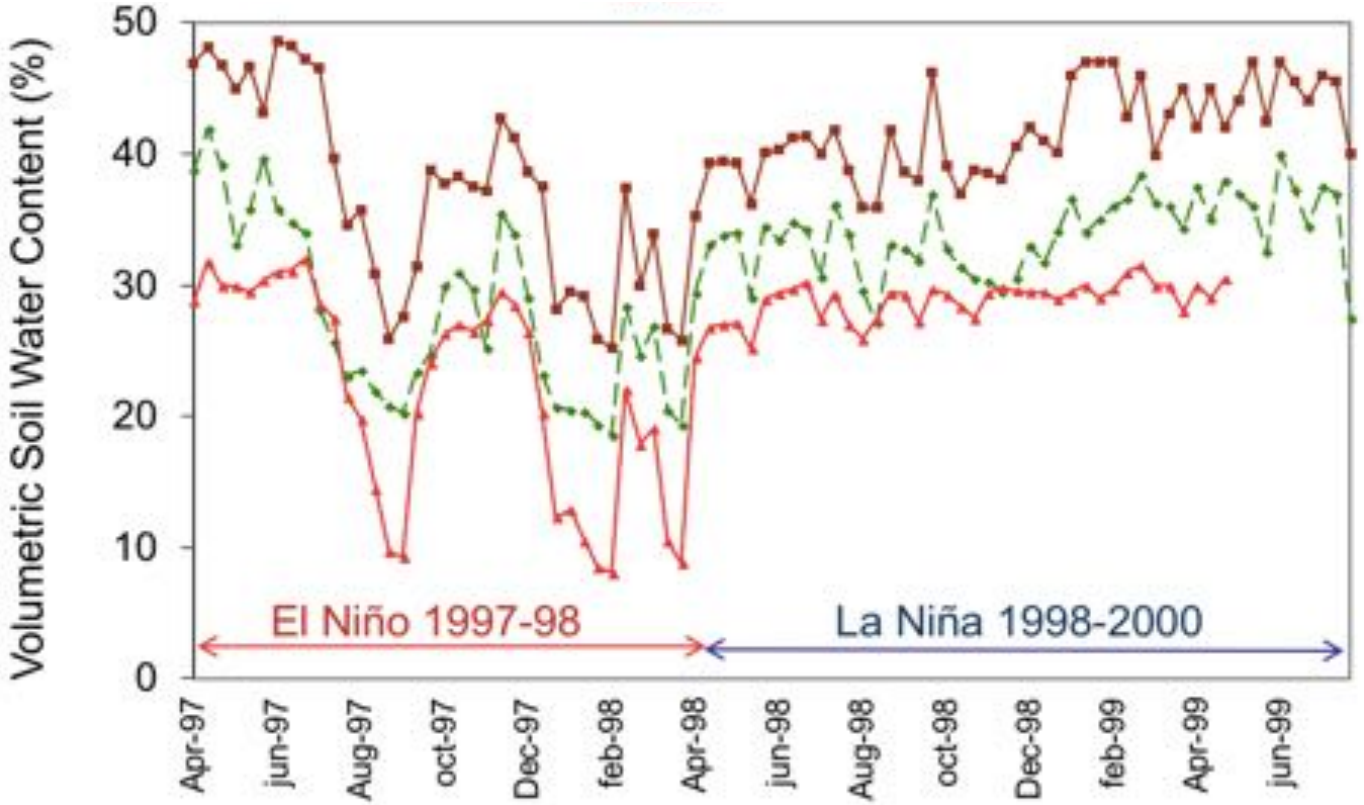
G. Poveda et al.: Hydro-climatic variability over the Andes of Colombia associated with ENSO



Poveda et al., Cim. Dyn. (2011)

ENSO Impacts on Extreme Events (5)

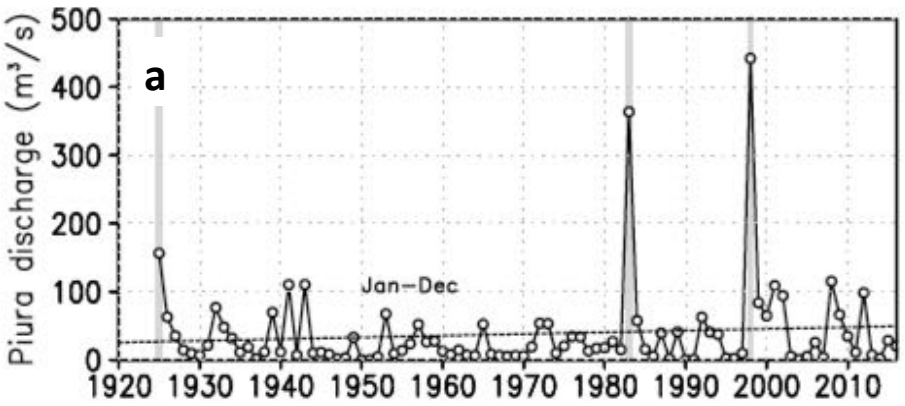
El Niño and La Niña affect Soil Moisture (depending on Land Cover type)

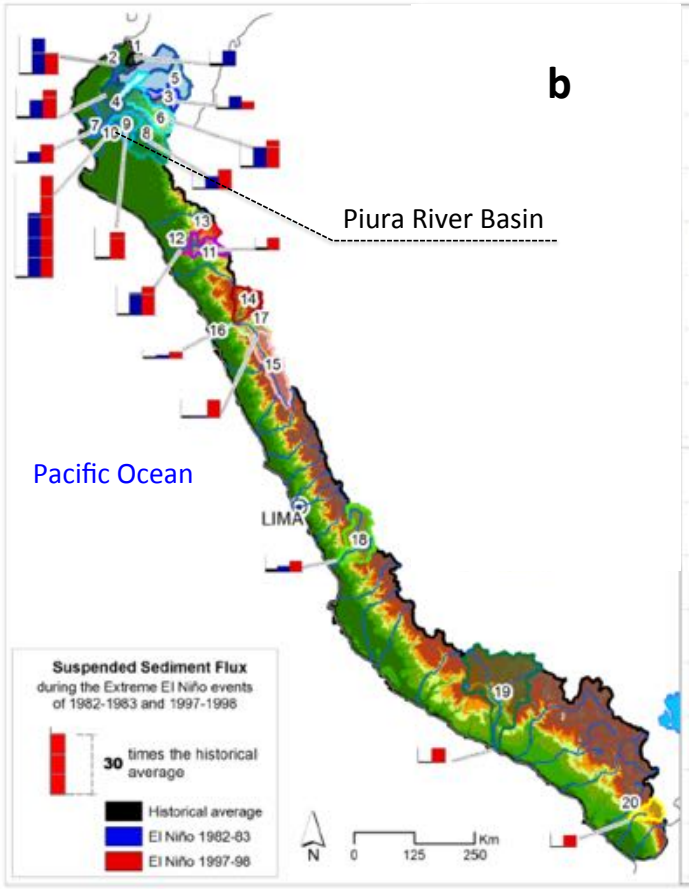


Poveda et al., Clim. Dyn. (2011)

ENSO Impacts on Extreme Events (6)

El Niño effects on Sediment Rates



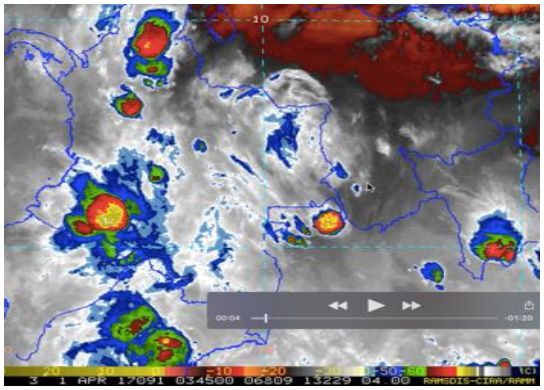


Adapted from Morera et al. (2017).

ENSO Impacts on Extreme Events Knowledge Gaps

- Is there coherence between the observed anomalies of rainfall, evapotranspiration, soil moisture and runoff in river basins of increasing order during both phases of ENSO?
- What are the physical processes involved in the dynamics of teleconnections linking the Tropical Pacific and the Andes?
- What is the role of land surface-atmospheric feedbacks in the observed hydrologic anomalies during El Niño and La Niña?
- How the different flavors of ENSO impact diverse hydroclimatic processes along the Andes?
- Is the identified intensification of El Niño and La Niña by global warming being reflected into the Andean hydrological processes?

Floods



March 31, 2017:

- Flooding of Mocoa, Colombia.
- 310 dead, 200+ missing

Vilcanota River, Machu Picchu, Peru 2010

Annual Peak Flows - Scaling Relation
$\langle Q_{max} \rangle$ vs. Q_{mean}

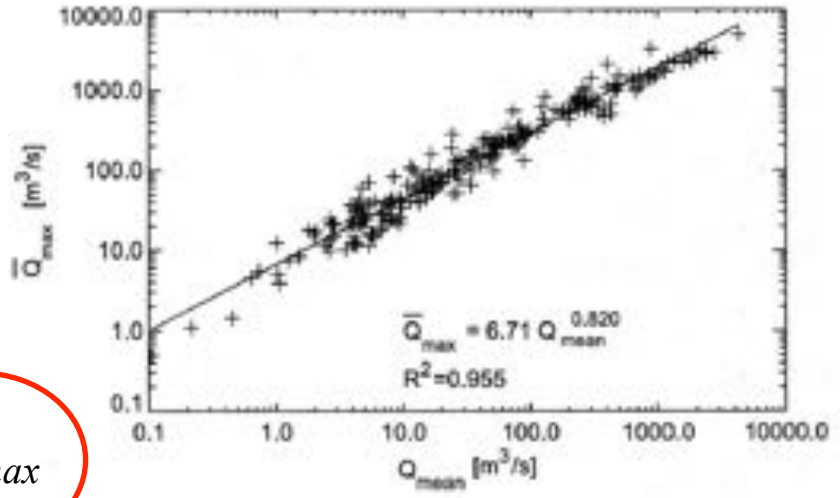
Estimation of peak flows of any return period (Tr), as (Chow, 1951; Poveda et al. 2007):

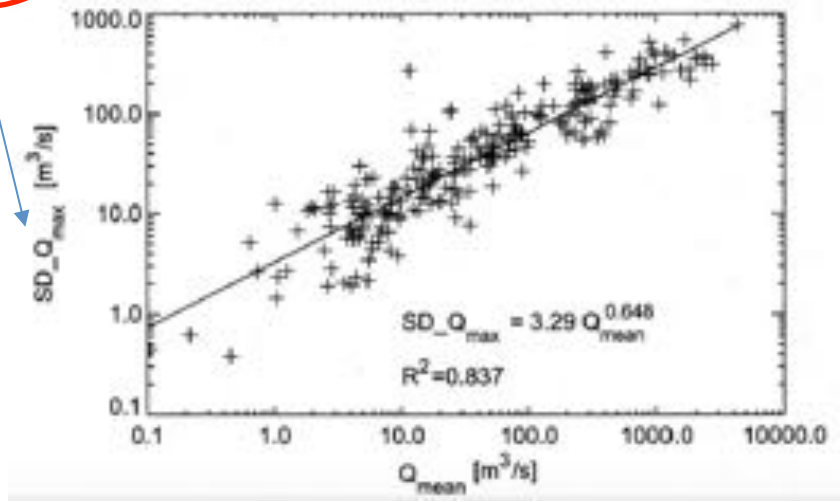
$$Q_{max}(Tr) = \langle Q_{max} \rangle + k(Tr, PDF)\, SD_{Qmax}$$

$$\langle Q_{max} \rangle = \boldsymbol{\alpha}_1 [Q_{mean}]^{\boldsymbol{\theta}1}$$

$$SD_{Qmax} = \boldsymbol{\alpha}_2 [Q_{mean}]^{\boldsymbol{\theta}2}$$

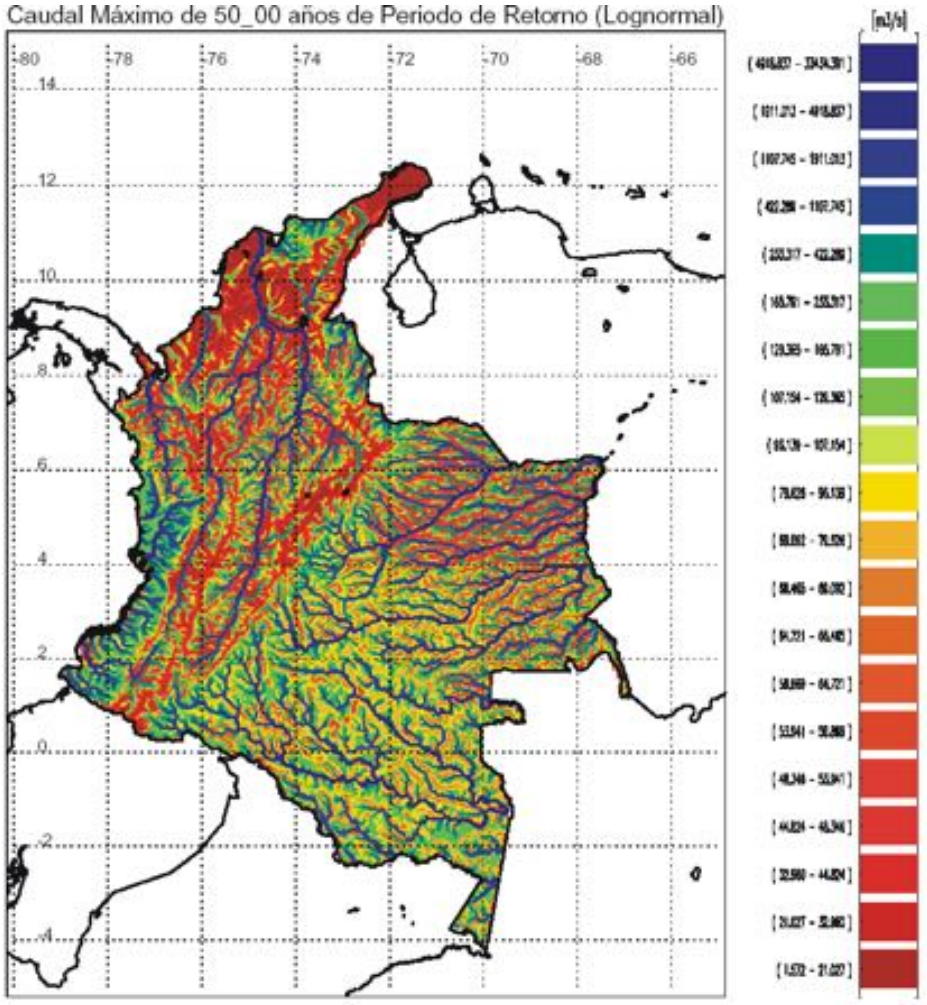
$$Q_{mean} = [P\text{-}ET]A$$





Poveda et al., *Jour. Hydrol. Eng.* (2007)

Q max, *Tr* = 50 yr (LogNormal)



Poveda et al., *Jour. Hydrol. Eng*. (2007)

Floods – Research Questions

- What is the most appropriate framework to understand, model and predict floods along the Andean gradients and valleys?
- How to overcome the curse of parameter calibration in hydrological distributed models?
- How to link the physical understanding of hydrological processes over hillslopes and drainage network in prediction of peak flows?
- Where does the scaling of peak river flows come from as a result of downstream aggregation processes?
- What is the best way of combining satellite and radar rainfall with hydrological models to predict peak flows?
- What are the best satellite information to quantify evapotranspiration and soil moisture along the Andes?
- How to optimally combine hydrological and hydraulic models to understand and predict flash floods on the Andean slopes?
- What are the impacts of climate change and deforestation and land use change on the magnitude, intensity and frequency of floods?
- Hydrologic design in a non-stationary world (Return Period?).

Landslides, Mudslides, Avalanches

Landslide over the water treatment plant of Manizales, Central Andes of Colombia, on October 19th, 2011.

Landslide at El Troje, Quito, Ecuador, December 5th, 2017.

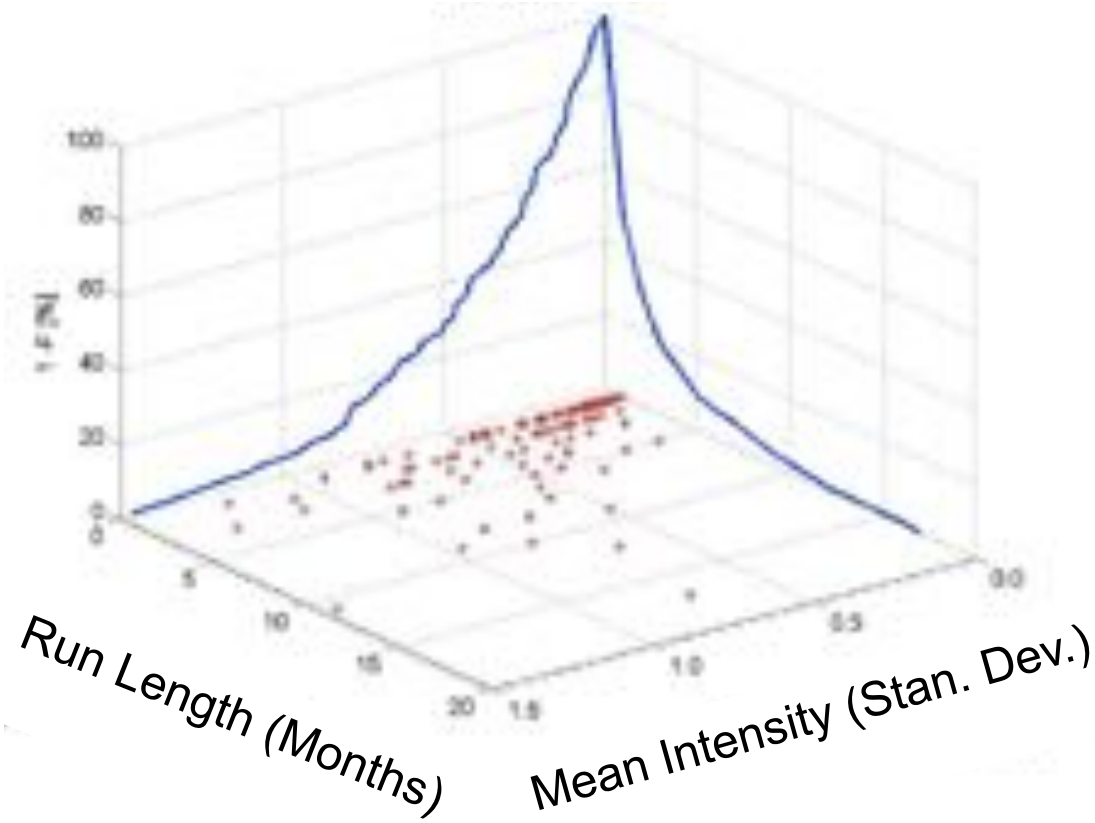
Source: El Comercio newspaper.

Droughts, Heat Waves & Fires

- Demise and collapse of pre-Columbian civilizations due to extensive droughts in the Central Andes.
- In Colombia & Venezuela: Associated with El Niño.
- Droughts in Ecuador have been intensifying in frequency and duration since the middle of the 20th century, compared with the last 400 years.
- Strong impact on hydrology of *Páramos*.
- Tropical cloud forests are facing huge threats from fires, deforestation and climate change.

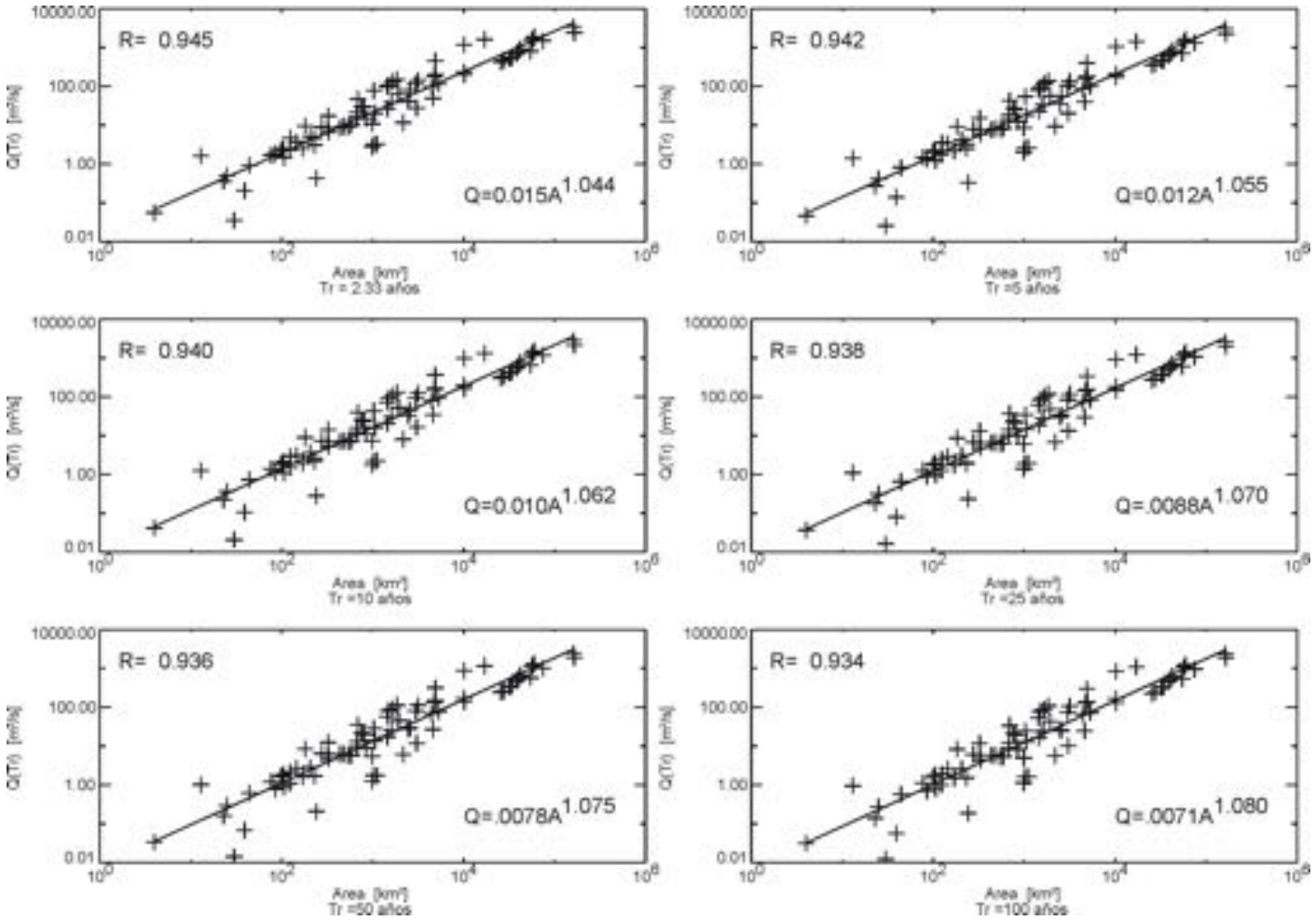
Intensity-Duration-Frequency Curves for Dry River Flow Periods

IDF Curve for drought below -0.5sigma
Guadalupe River



Gómez, Ochoa & Poveda (2016)

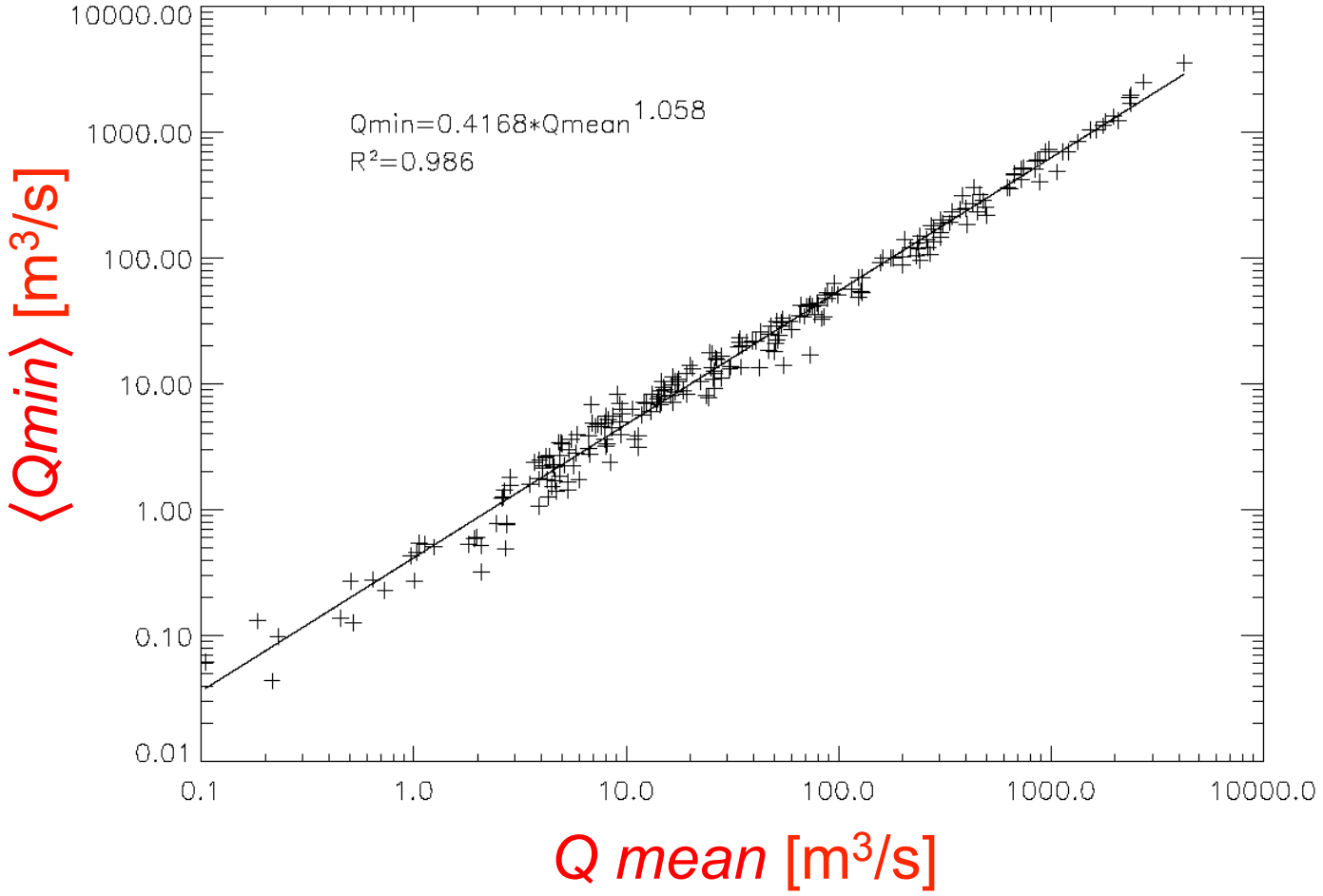
Scaling of Low Flows *vs*. Drainage Area for Different Return Periods



Poveda et al., *Jour. Hydrol. Eng*. (2007)

Low Flows -Scaling Relation
⟨*Qmin*⟩ vs. *Q mean*

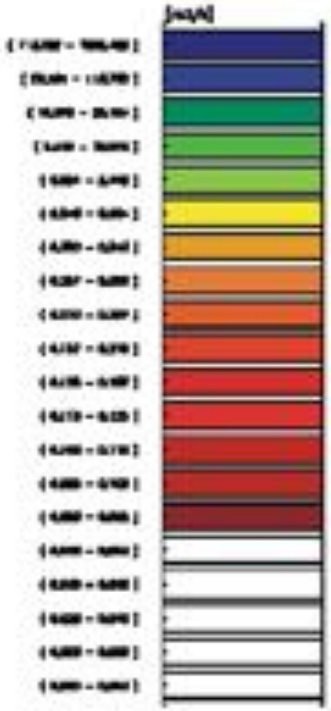
240 river gauges in Colombia



Poveda et al., *Jour. Hydrol. Eng.*, 2007)

Q min, Tr = 50 yr (LogNormal)

[m³/s]



Low Flows – Research Questions

- What is the most appropriate framework to understand, model and predict low flows along the Andean gradients and valleys?
- How to link the physical understanding of hydrological processes over hillslopes and drainage network in prediction of peak low flows?
- Where does the scaling of low flows with drainage area come from as a result of downstream aggregation processes?
- How to estimate base flows using satellite data?
- What are the impacts of climate change and deforestation and land use change on the magnitude, intensity and frequency of droughts and dry spells?
- Hydrologic design in a non-stationary world (Return Period?).

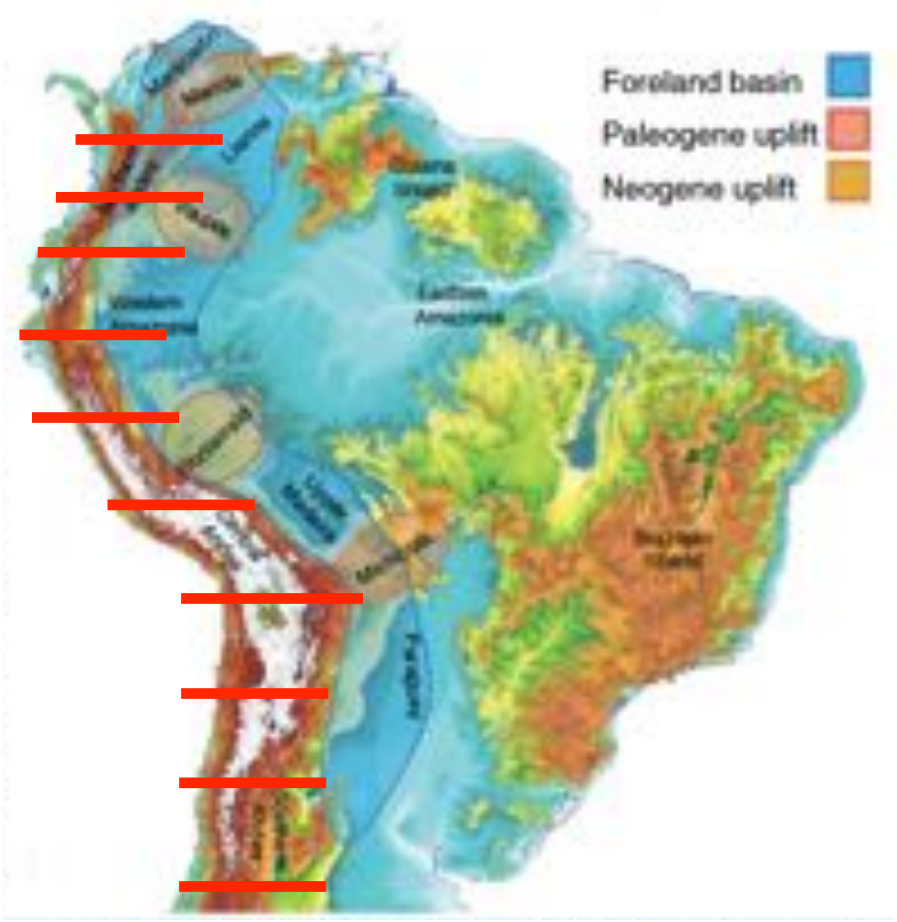
Knowledge Gaps and Relevance (2)

- Validity of the rational formula, $Q=cIA$, to estimate peak flows having in mind land use change and climate change. Dynamic variables.
- Interactions Hydrology-Vegetation (cloud forests, dry forests, tropical mountain forests, Mediterranean high-elevation habitats).
- Linkages between vegetation indices (NDVI, EVI, SIF) and precipitation, river discharges and soil moisture in the Andes.
- ENSO effects on Actual and Potential ET.
- The entire hydrology of wetlands and their ecological functioning

Potential Activities (1)

- To implement an experiment to carry out several simultaneous Intensive Operational Programs (IOPs) (radiosoundings, and in-situ measurements) across longitudinal transects along the whole Andes, from Colombia-Venezuela to Chile-Argentina, with the aim of capturing the interannual, annual, seasonal, and diurnal variability of atmospheric and land-surface processes.

Radiosoundings and Surface Measurements Along the Andes
Why? How Many? Where?



Adapted from Antonelli et al., PeerJ (2018)

Potential Activities (2)

- To implement a research program to further understand, model and predict intense rainfall events and Mesoscale Convective Systems over the Andes and their connection with the Amazon and La Plata River basin, and the Pacific Ocean.

- To implement a research program to understand, model and predict floods and droughts over river basins of increasing order along the Andes gradients and valleys, including their connection with the Amazon and La Plata River basins, and the Pacific slopes.

- To implement a research project to design an optimal network of meteorological radars over the entire Andes ranges.

Expected Outcomes

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Thank you!