

ANDEX: A Hydroclimate Research Program for the Andes and a Prospective GEWEX Regional Hydroclimate Project (RHP)

Germán Poveda

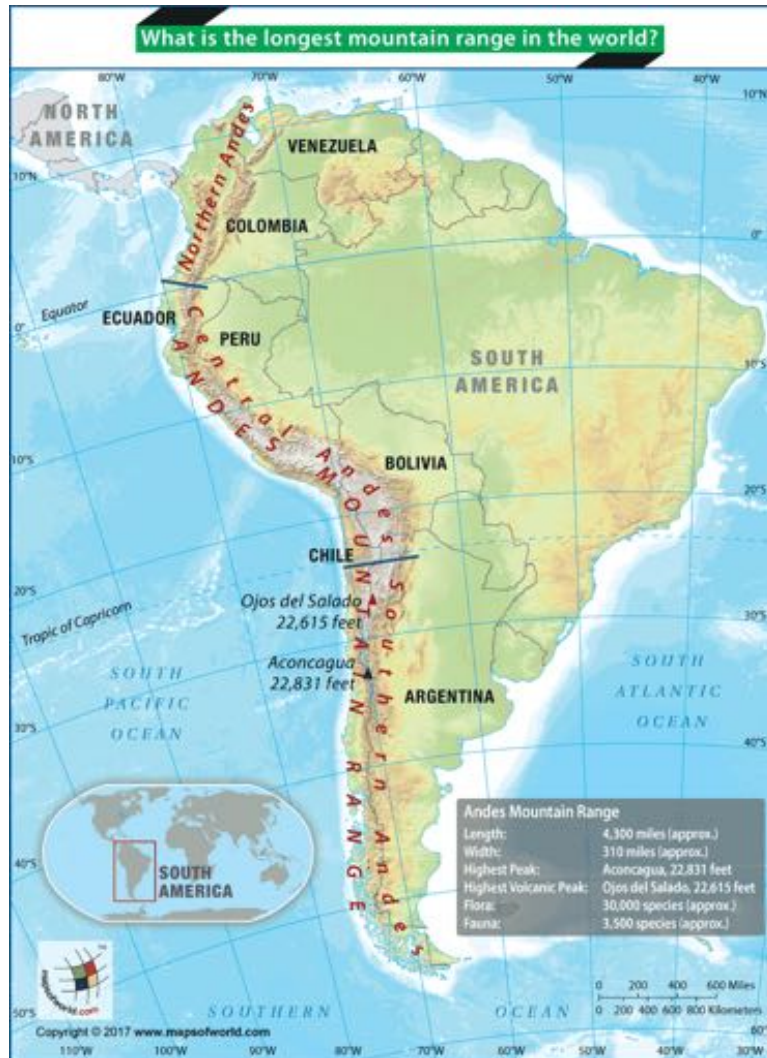
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Peter J. van Oevelen, Paola A. Arias, Jorge Molina, José D. Pabón,
& Sara M. Vallejo



The Andes



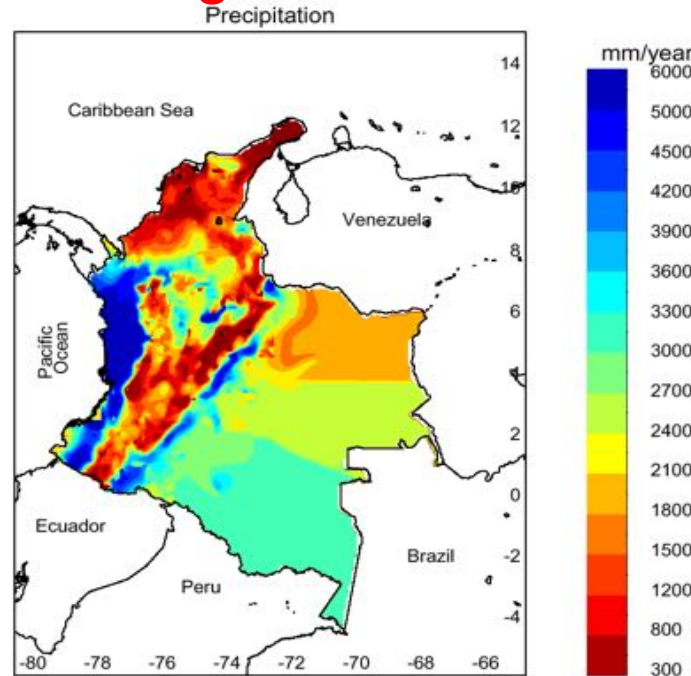
- World's longest mountain range: 7,242 km (10N to 46S).
- Seven countries: Colombia, Venezuela, Ecuador, Peru, Bolivia, Argentina and Chile.
- About 200 to 700 km wide (widest between 18°S-20°S), and average height 4,000 m. Aconcagua: 6,962 m.
- It contains glaciers, volcanoes, deserts, high plateaus, lakes, *páramos*, *yungas*, *punas*, cloud forests, tropical rainforests, dry forests, savannas, and intra-mountainous valleys.
- Strong hydroclimatic variability associated with Latitudinal and Hemispheric location, but also with Aspect, Slope and Elevation.

ANDEX

Main Overarching Scientific Questions

1. What are the main physical processes driving the water and energy budgets of the Andes (as a singular cordillera) at a broad range of spatial and temporal scales, and their interactions with the neighboring Pacific and Atlantic Oceans and major river basins of South America?
2. How climate change, deforestation and land use changes are affecting the hydroclimatological functioning of the Andes across the altitudinal gradients, from glaciers, to paramos, punas, cloud forests, rainforests, dry forests, deserts?

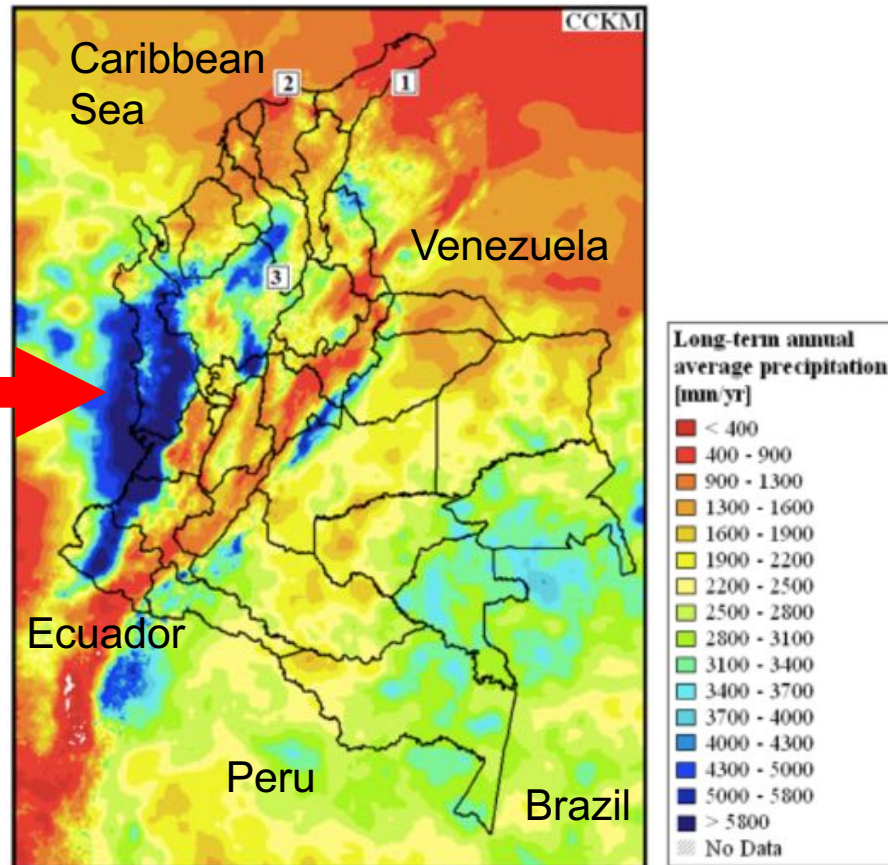
Specific questions through a geographic journey e.g. Colombia



What are the dynamical and thermodynamical mechanisms explaining the spatial distribution of rainfall in the Andes across a wide range of spatiotemporal scales?

The Pacific coast of Colombia:
The rainiest place on Earth:
13,000 mm/yr

*Poveda & Mesa,
GRL, 2000*

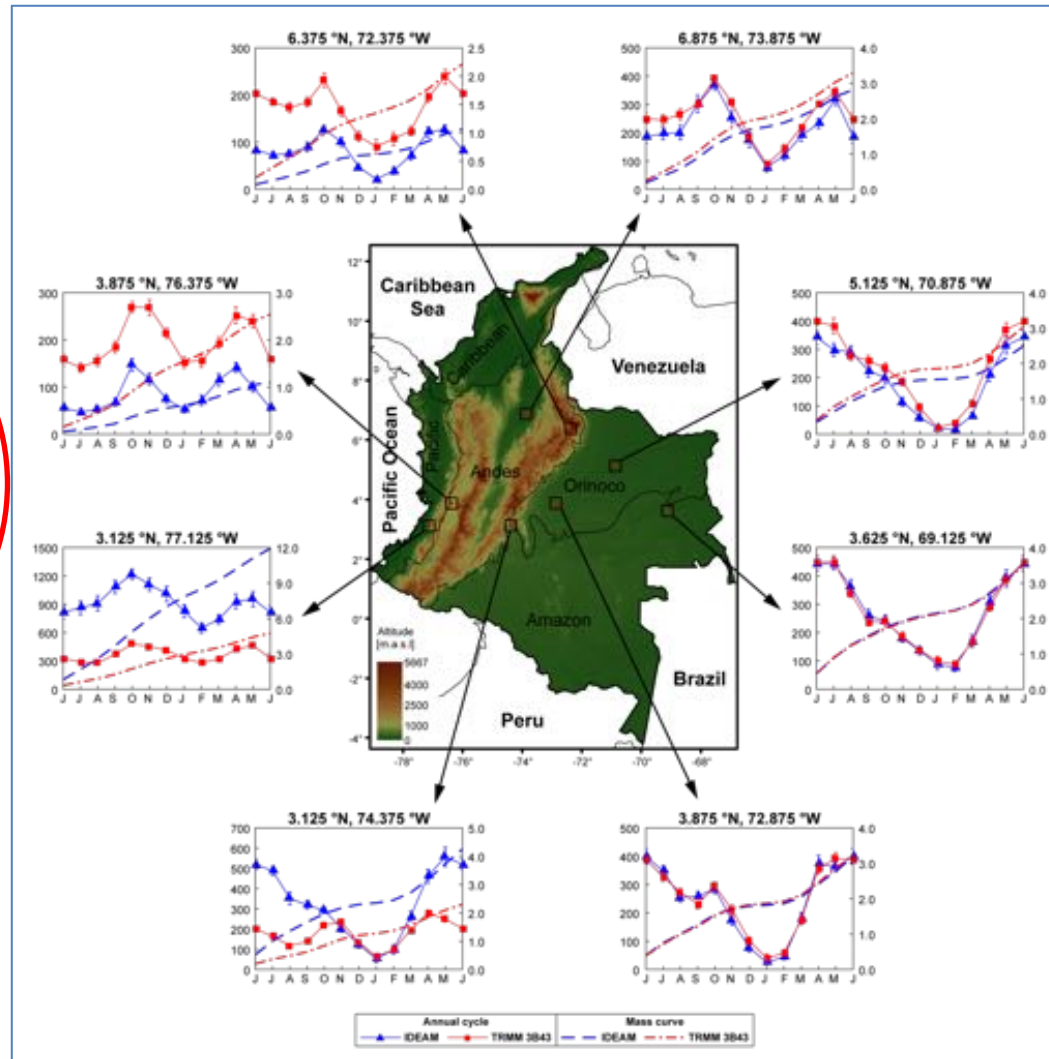


TRMM Fails in Capturing the Annual Cycle of Rainfall over the Andes. What about GPM IMERG?

TRMM vs. Raingauges in Colombia.

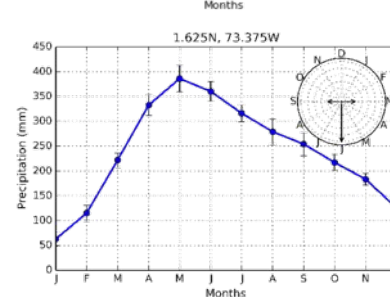
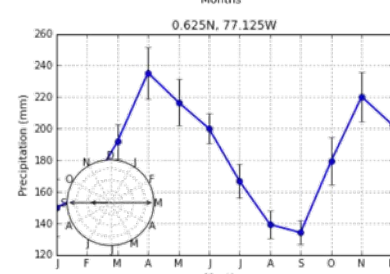
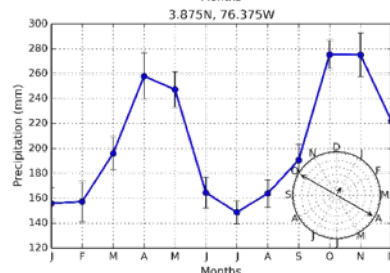
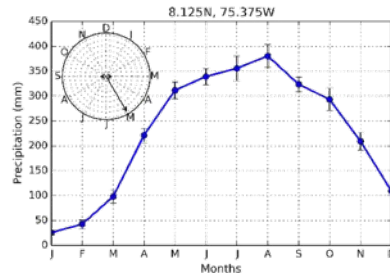


**Very Poor
Performance
Over the Andes**

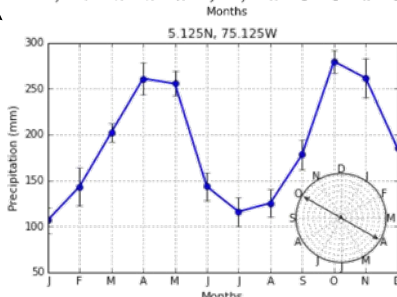
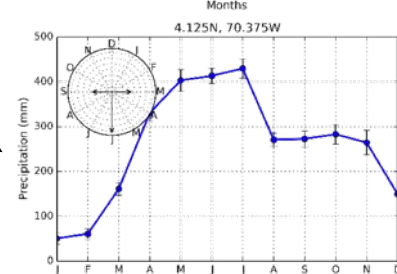
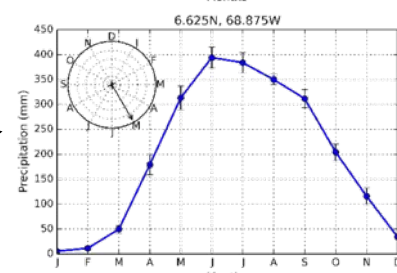
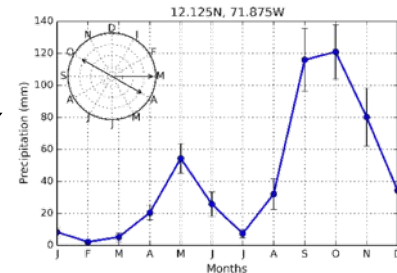
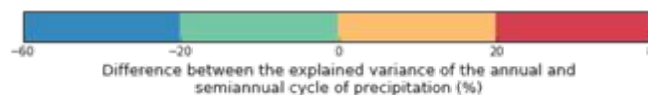
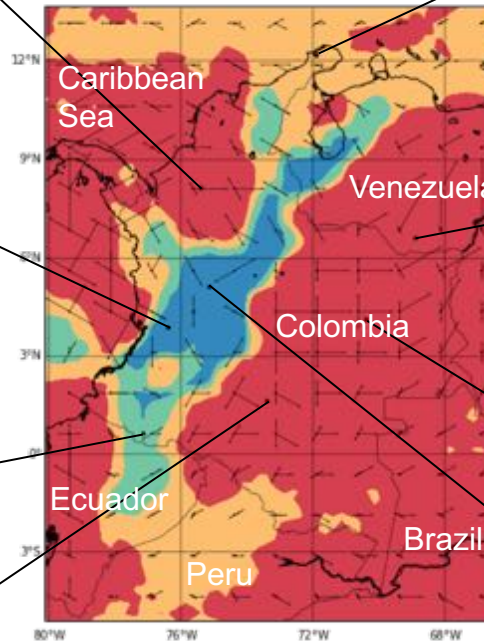


**Very Good
Performance
Over
Low & Flat
Lands**

Why is the bimodal annual cycle of rainfall constrained just to the Andes? (and Unimodal outside)



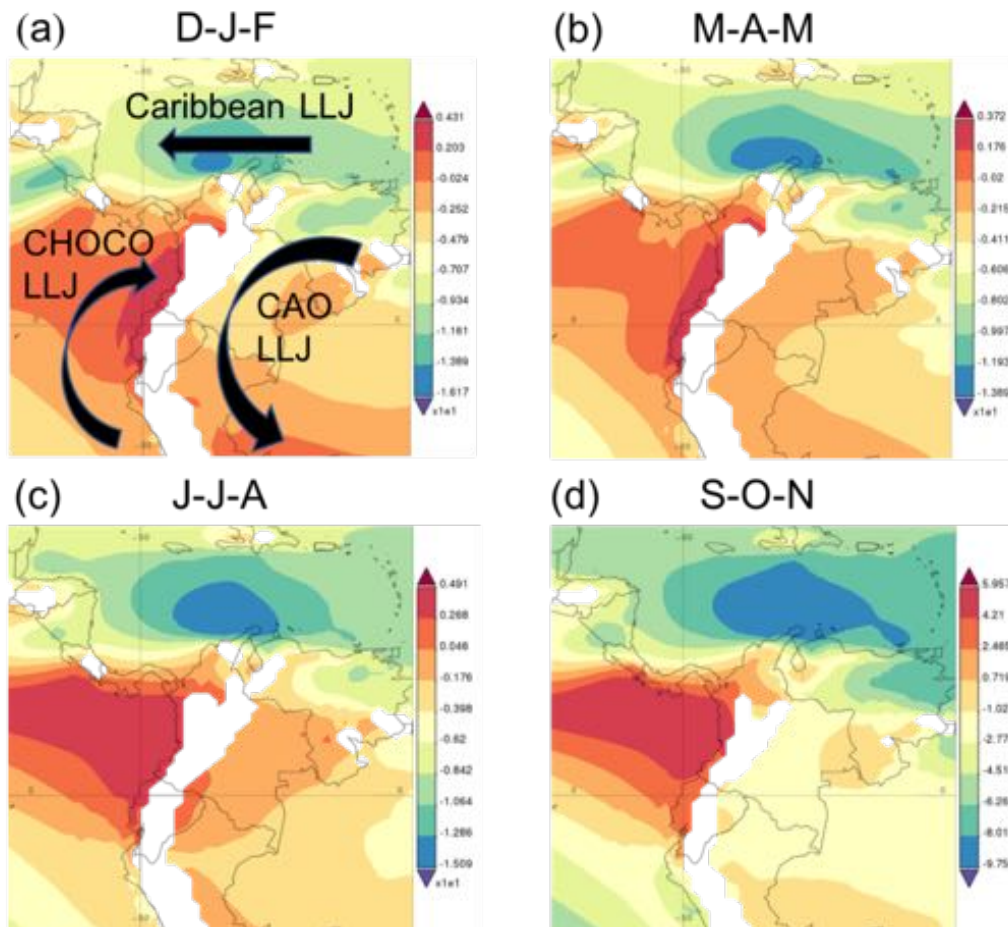
More than the ITZC
oscillation



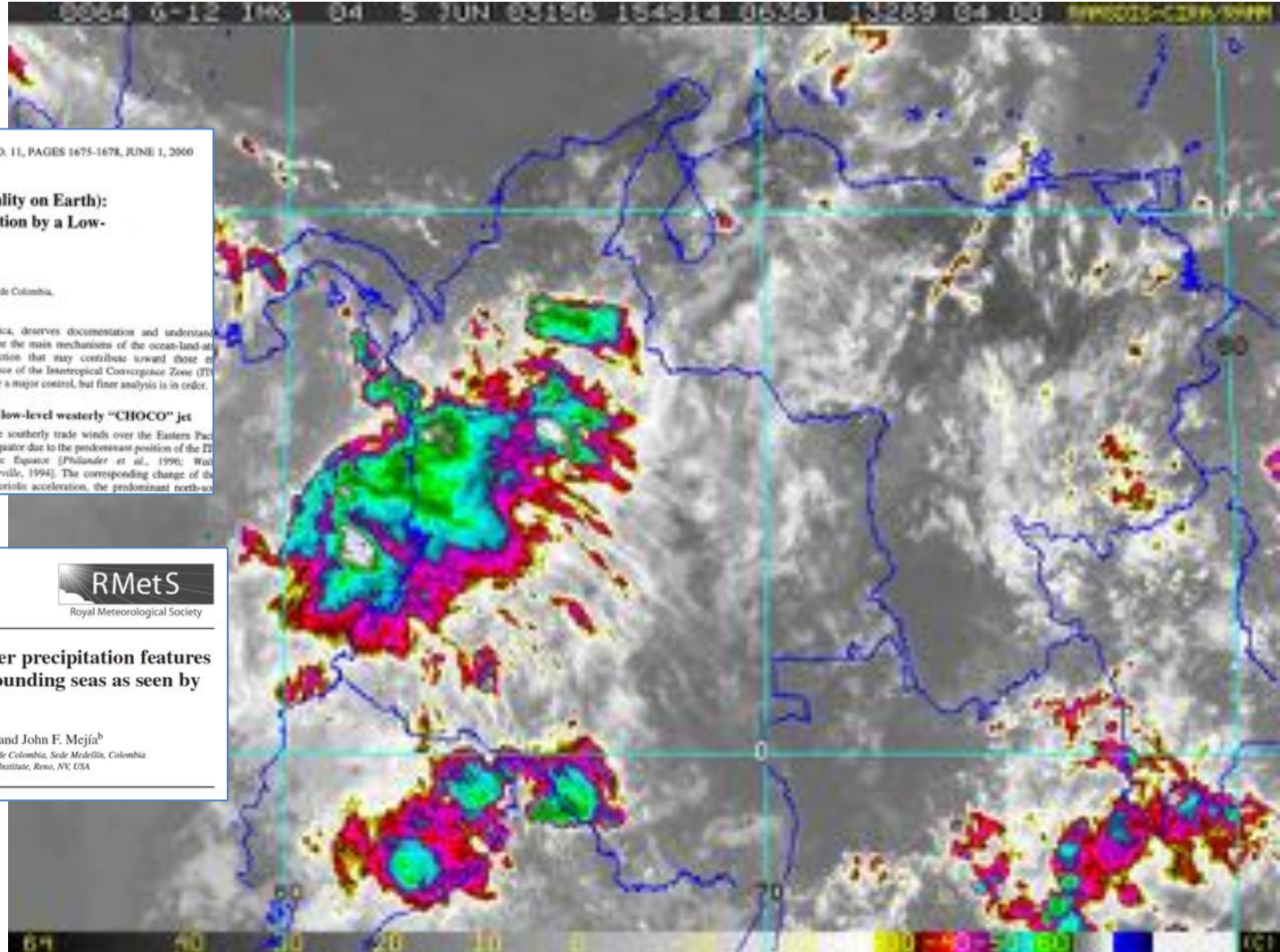
Poveda *et al.*, in review

What is the role of three South American Low-level Jets in the transport of moisture to the Andes?

Zonal winds @ 925 hPa



What are the dynamics and thermodynamics of 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

Posgrado en Aprovechamiento de Recursos Hídricos, 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°12'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 understanding to explore the main mechanisms of the ocean-land-atmosphere interaction that may contribute toward those of the Intertropical Convergence Zone (ITCZ) course a major control, but finer analysis is in order.

The low-level westerly "CHOCO" jet

The southerly trade winds over the Eastern Pacific the Equator due to the predominant position of the ITCZ of the Equator (Philander *et al.*, 1996; Wai, Semoville, 1994). The corresponding change of the Coriolis acceleration, the predominant north-

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



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

Liliana Jaramillo^{a*}, Germán Poveda^a and John F. Mejía^b

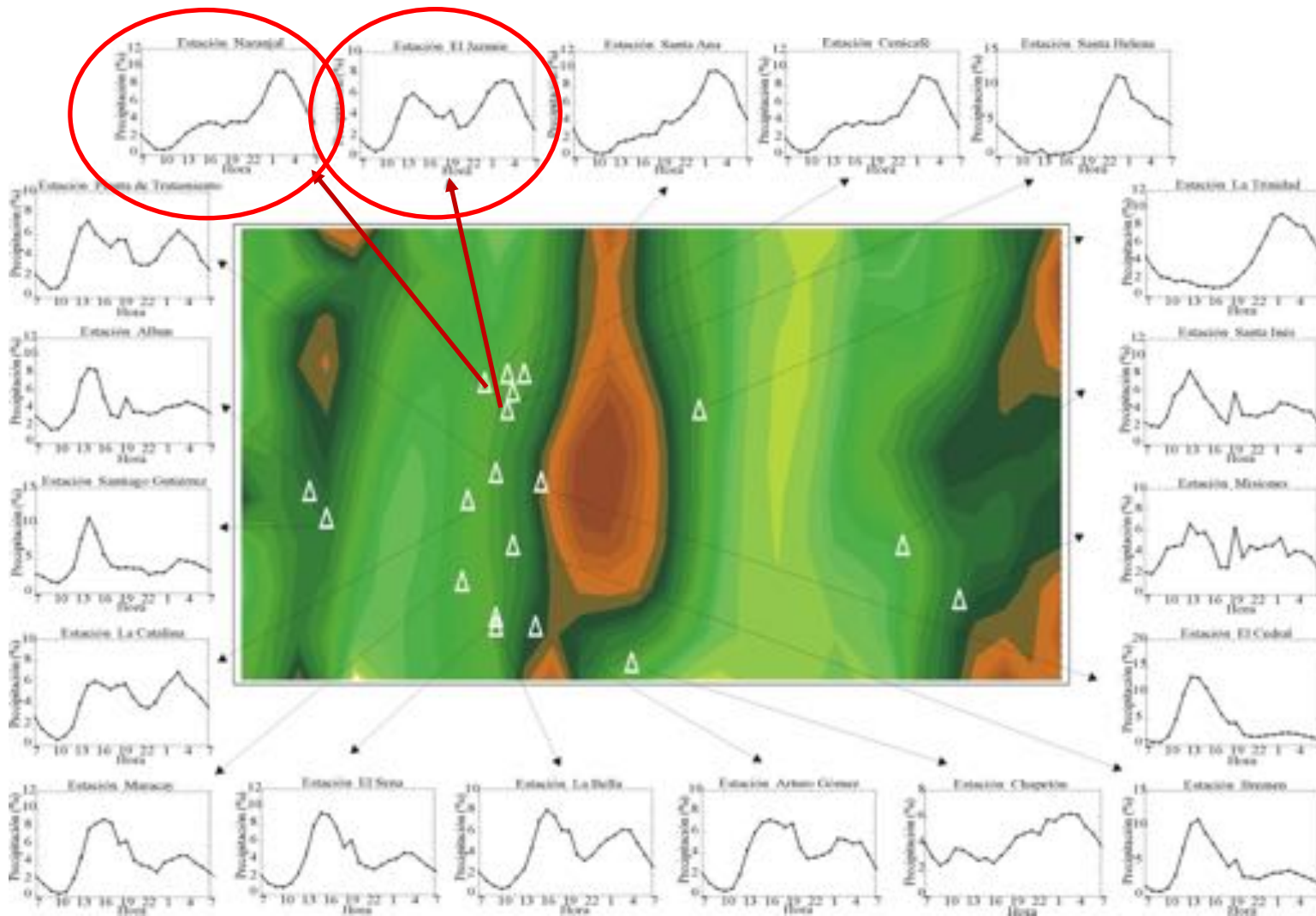
^a Department of Geosciences and Environment, Universidad Nacional de Colombia, Sede Medellín, Colombia

^b Department of Atmospheric Sciences, Desert Research Institute, Reno, NV, USA

What Mechanisms Explain the Diurnal Cycle of Rainfall?

Uni-modal or Bi-modal, even at nearby raingauges

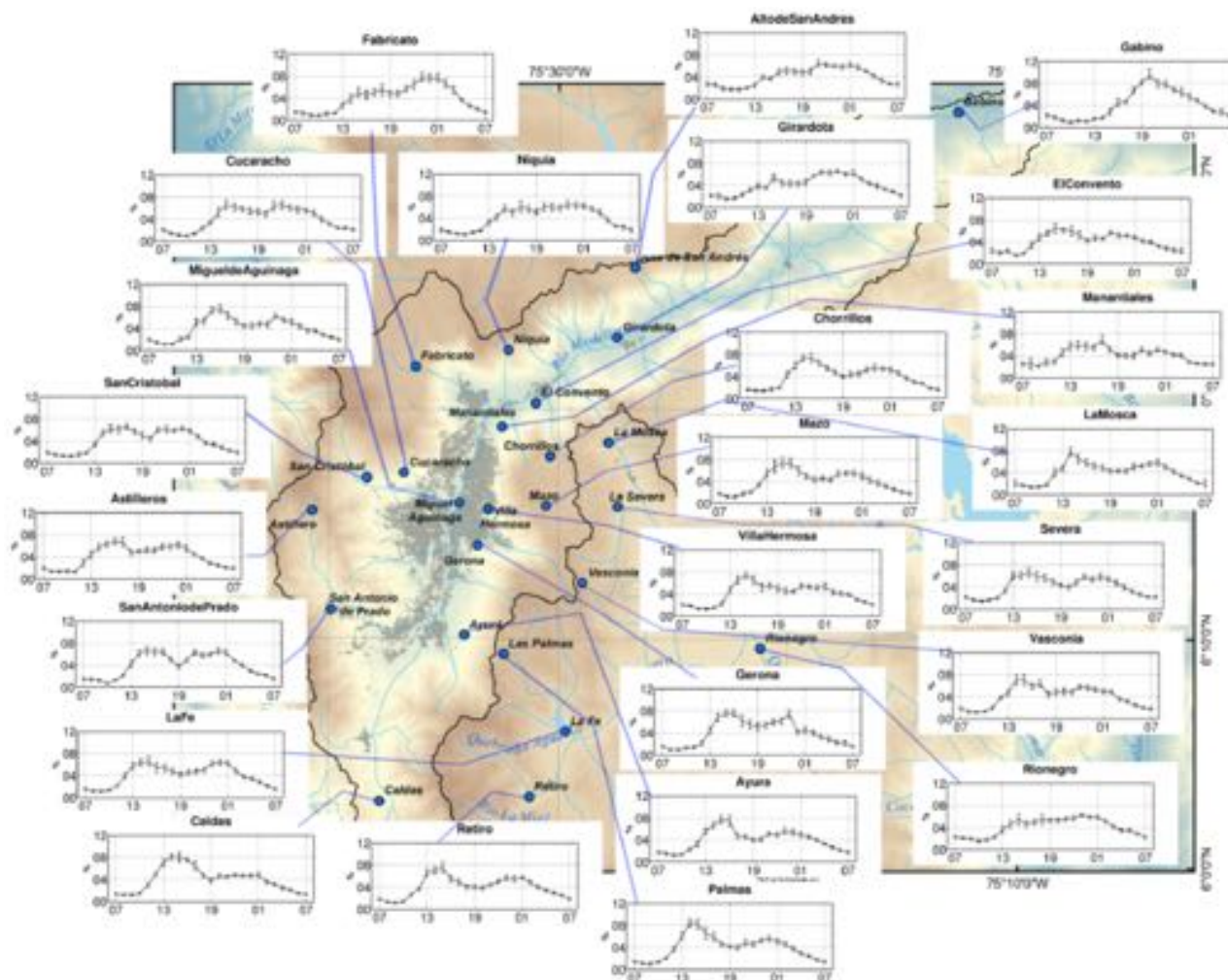
Excellent Test-bed for CPMs!



Typical Intense Afternoon Storm over Medellin. October 10th, 2017



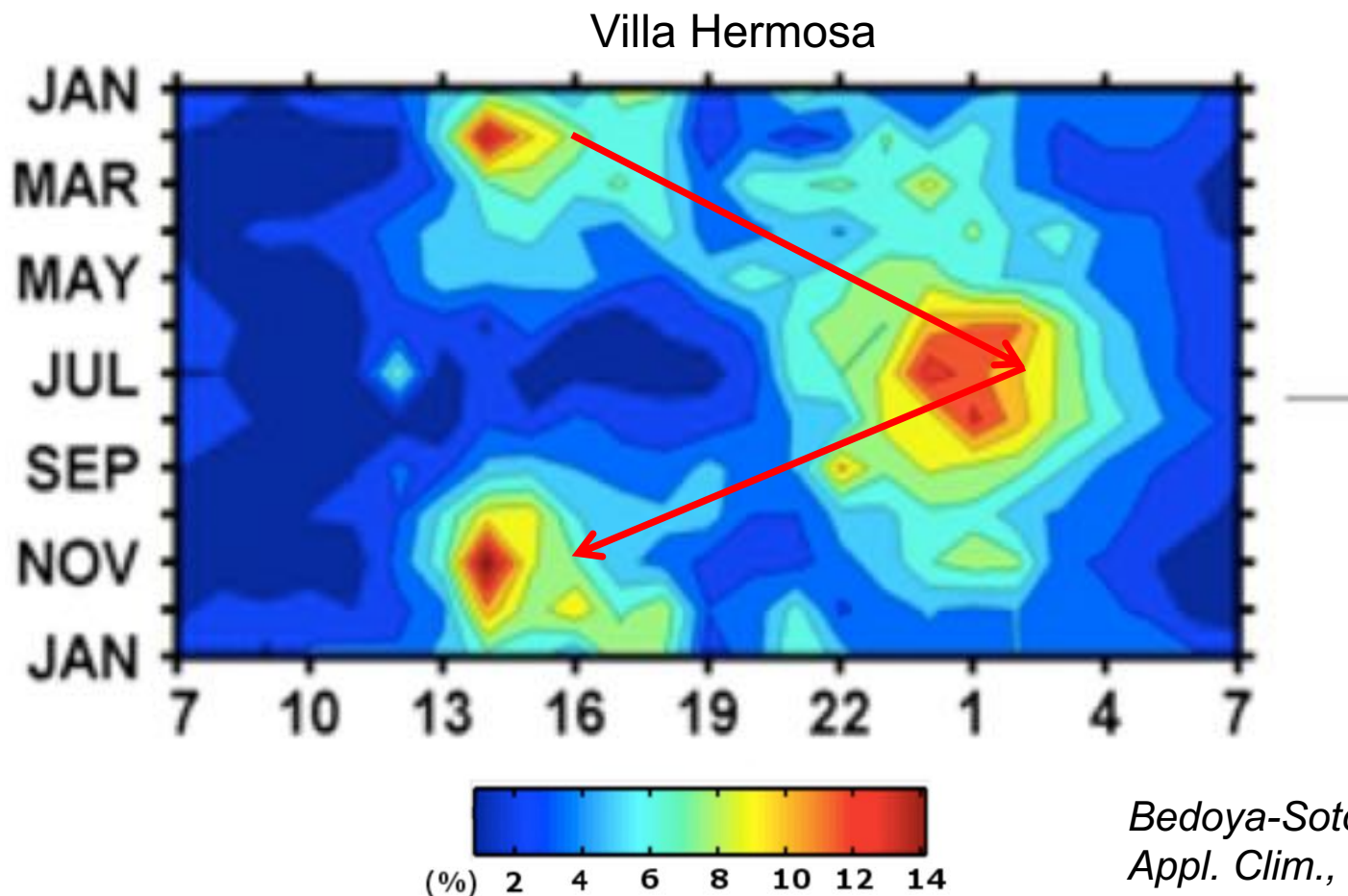
Long-Term Mean Diurnal Cycle of Rainfall at Medellin Valley's Apparent bi-modal (afternoon and mid-night)



What are the mechanisms affecting the seasonal change in the diurnal cycle of rainfall?

Afternoon Peak: September-October to April-May

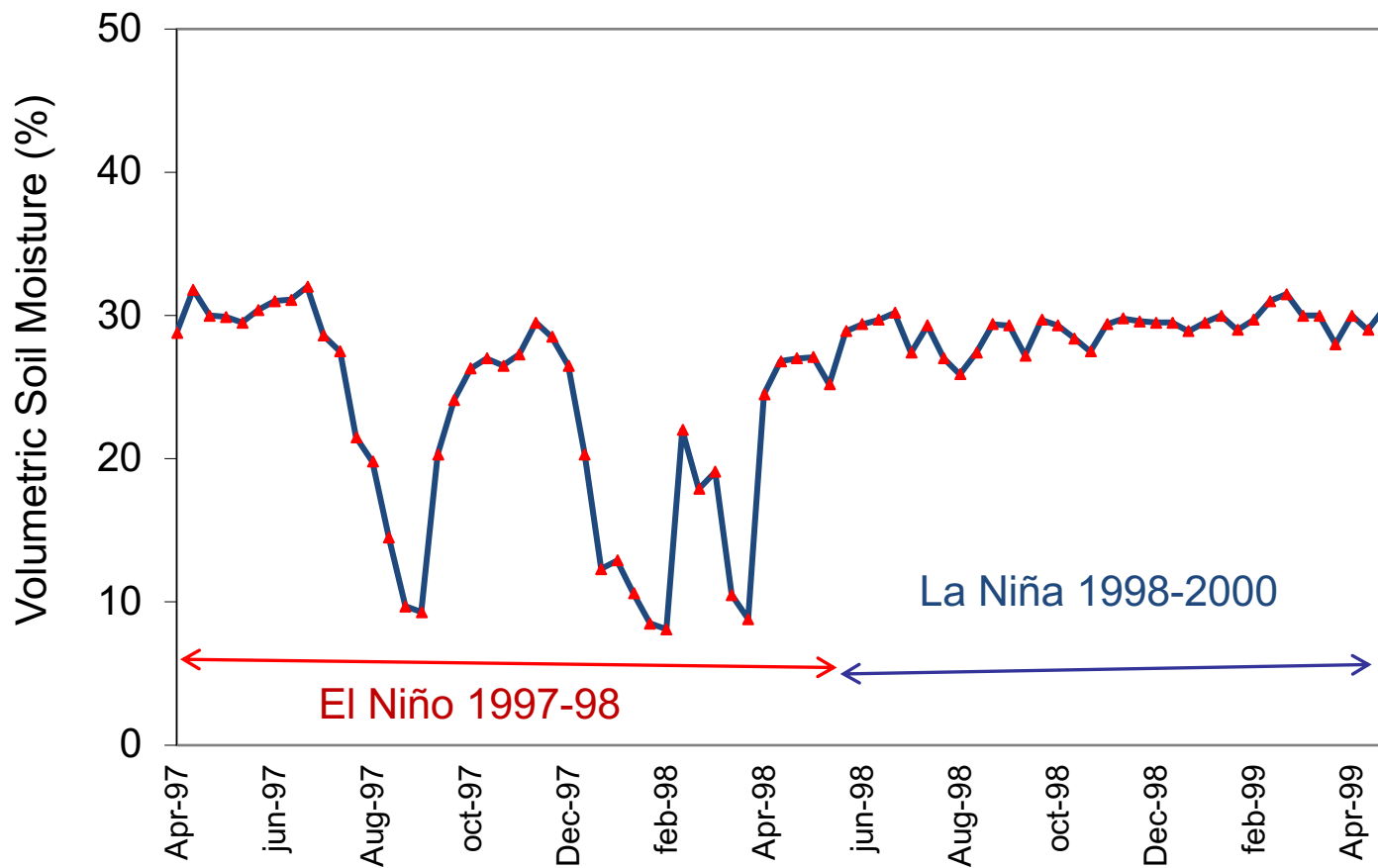
Midnight-dawn Peak: April-May to September-October



Bedoya-Soto et al., Theor. Appl. Clim., in review

Soil moisture dynamics at seasonal and interannual (ENSO) timescales on the Colombian Andes

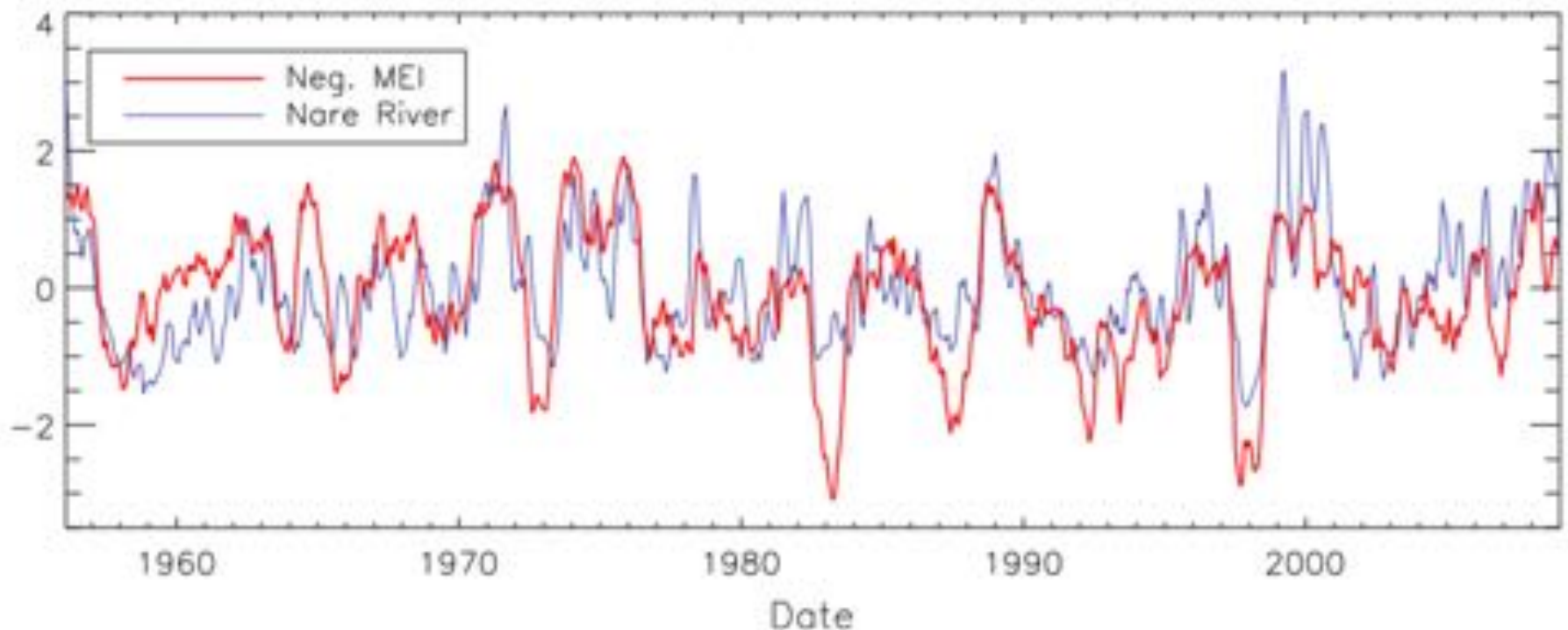
El Niño enhances deficits and La Niña saturates the soil



Interannual Variability of River Flows:

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



26 © GLOBO

CIÊNCIA

TEMOR NOS ANDES

Fora de Martin Medina



CAMPESINOS colhem batatas em Huacavelica, nos Andes do Peru. No detalhe, exemplos de batatas do país, que tem 300 variedades, a maioria em cultivo andino

Um drama sul-americano

Perda de geleiras ameaça cidades, agricultura e oferta de energia

Ana Carolina Azevedo

A paisagem dos vales andinos, onde emergiu o império inca, está em mutação. Transforma-se mais depressa do que estimam os estados sobre o aquecimento global, com consequências econômicas e sociais. Da Colômbia ao Chile, as geleiras dos Andes recuam. Com elas se vai a água da qual dependem capitais como La Paz, na Bolívia, e Quito, no Equador. Geleiras são importantes reservatórios de água, muitas vezes a principal fonte na estação seca. Por isso, esgotam-se os recursos que ajudam a sustentar a agricultura.

Edo Landerer



do Centro Austral de Investigación Científica, em Ushuaia, Argentina.

— A geração hidroelétrica em toda a região será afetada — diz Iturange.

Povos alertas para as consequências sociais e econômicas da redução de oferta de água em capitais como Bogotá, Quito e La Paz. E são muitas as cidades afetadas. Exemplos: são Medellín e Cali, na Colômbia; Cuzco e Arequipa, no Peru; Cochabamba, na Bolívia; Riobamba, no Equador.

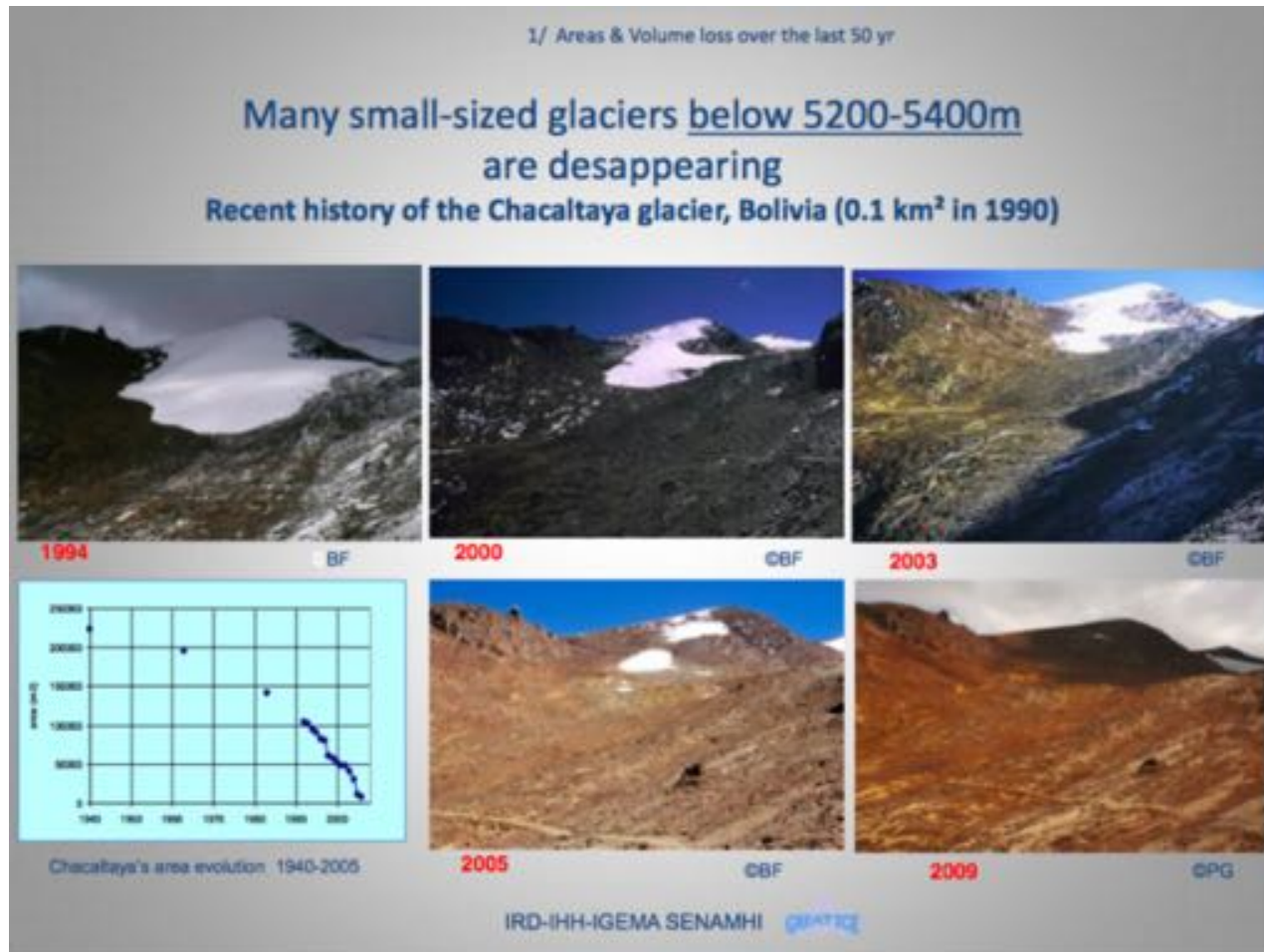
— Há centenas de cidades médias e pequenas que precisam cada vez mais de recursos — diz Poveda.

Na Bolívia, o fim de

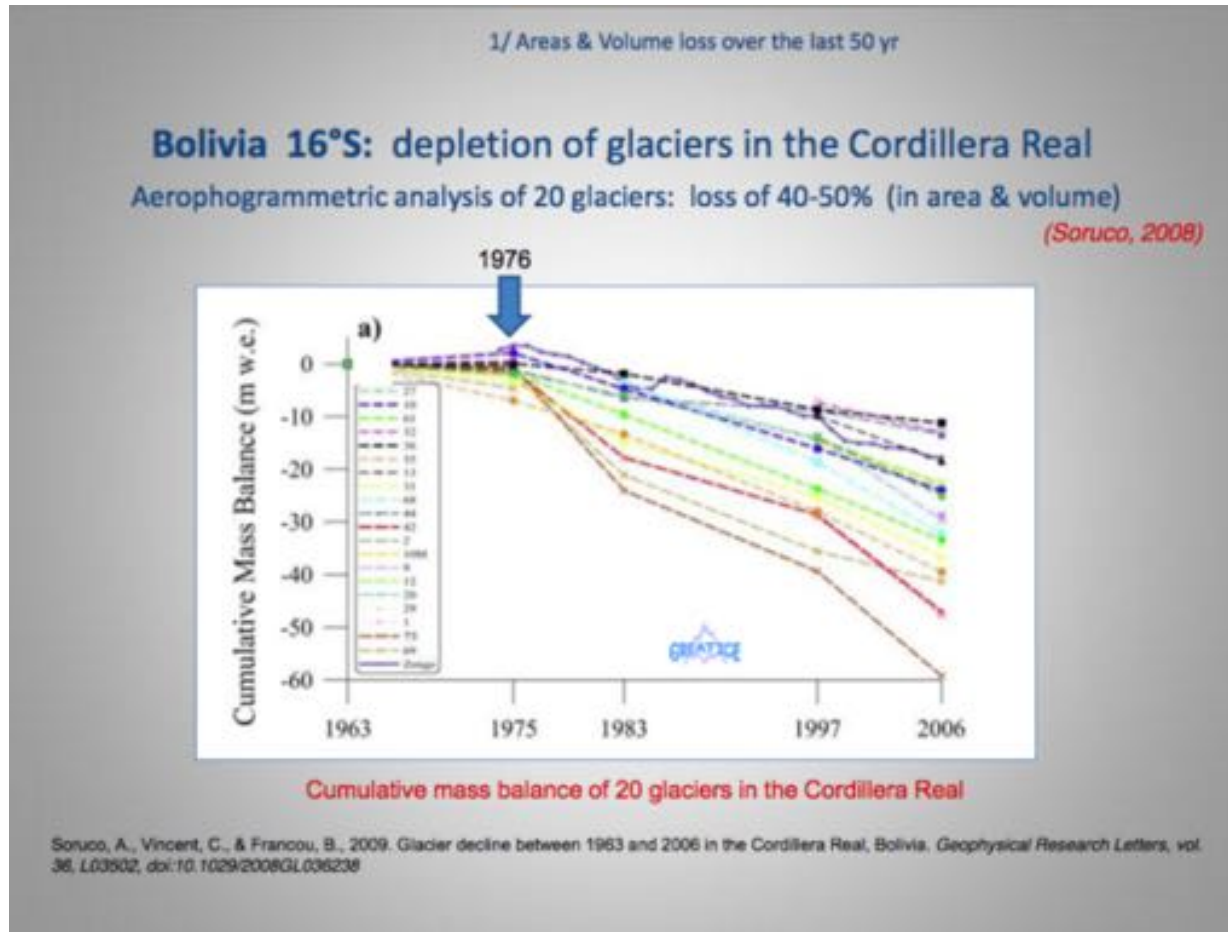
Glaciers are receding all over the Andes

“Glacier Loss
A South American Drama
threatening cities, agriculture
and hydropower”

Andean Glaciers are Disappearing due to Global Warming (1)



Andean Glaciers are Disappearing due to Global Warming (2)



What is the Fate of Andean Glaciers, Paramos, Yungas, Punas, & Cloud Forests?

Vanishing glaciers in the Colombian Andes^{47 48}



1946



2006



2021?

Photos: (from left to right): Erwin Kraus (1946, reprinted with permission from Diego Samper Editores); Oliver Hill / Roberto Ariano (2006), and; Photoshop editing courtesy of John French (2006).

What is the functioning of hydroclimatic feedbacks between Andes-Amazon?

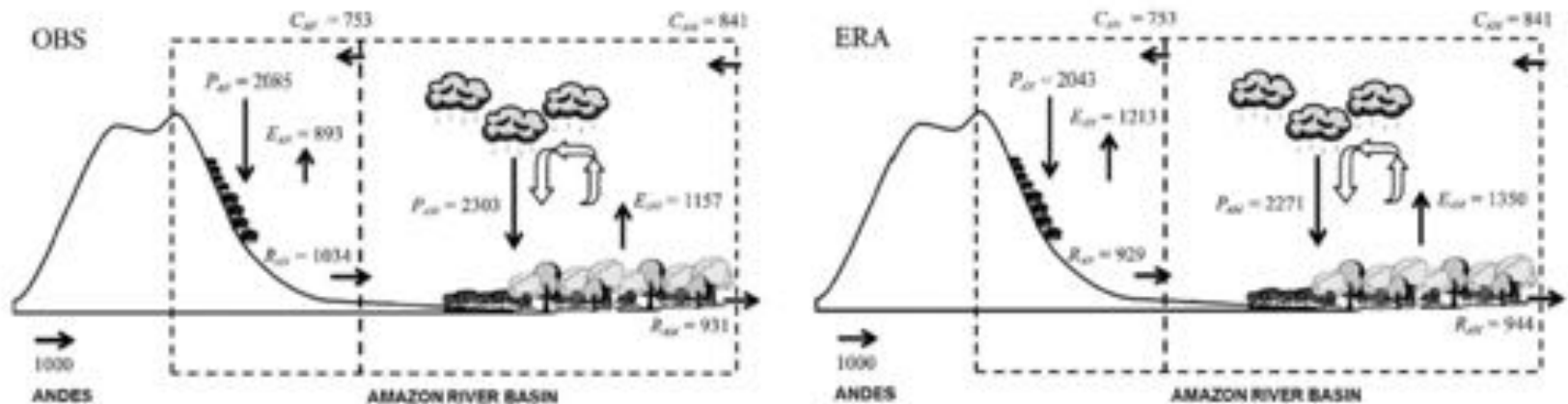
Water Resources Research

10.1029/2017WR021338

Conjoint Analysis of Surface and Atmospheric Water Balances in the Andes-Amazon System

A. Builes-Jaramillo^{1,2} and G. Poveda²

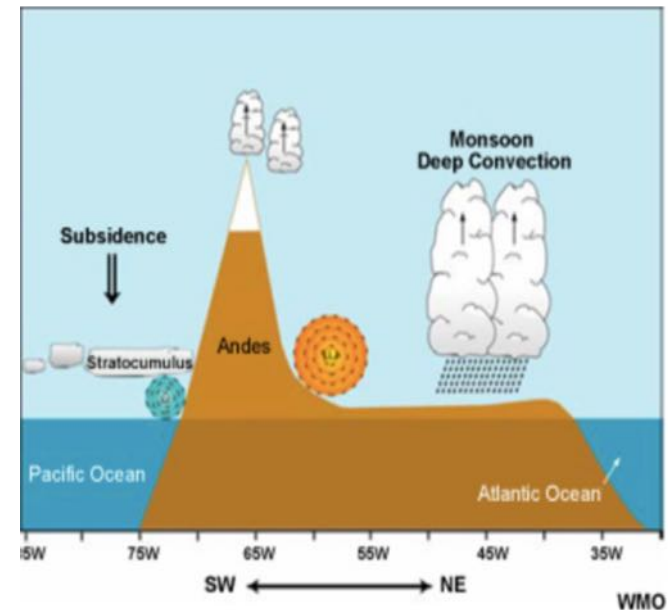
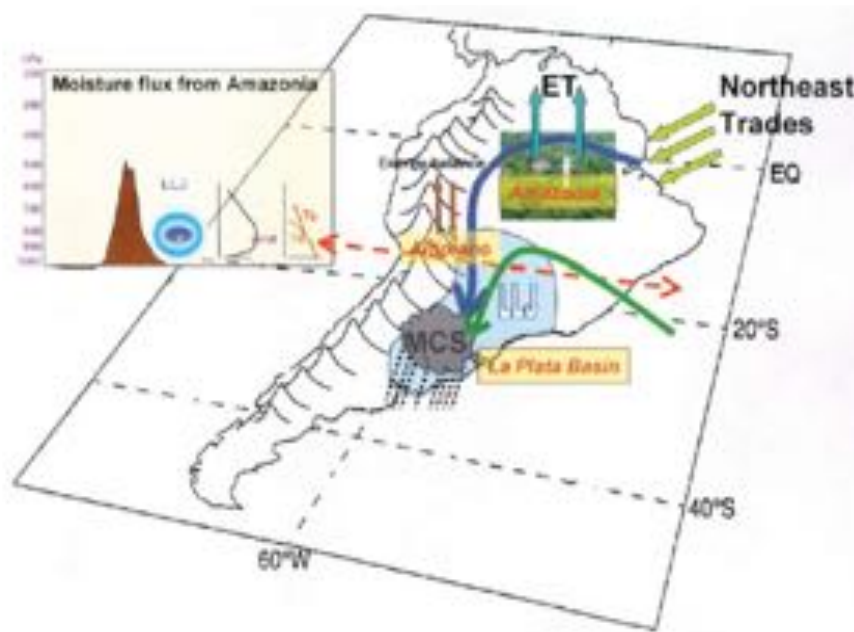
¹Department of Geosciences and Environment, Facultad de Minas, Universidad Nacional de Colombia, Sede Medellín, Medellín, Colombia, ²Facultad de Arquitectura e Ingeniería, Institución Universitaria Colegio Mayor de Antioquia,



“Results highlight the importance of the Andean region for the hydrological integrity of the entire Amazon River basin”.

What is the functioning of hydroclimatic feedbacks between Andes-La Plata Basin?

Schematics of the winds connecting the Atlantic Ocean with the Andes across the Amazon and Orinoco River basin with the Andes and to La Plata River basin.



Marengo et al. (2004)

The Southern Tropical Andes (Peru)



- What is the role of the atmospheric dynamics on water resources in high-mountain river basins, in particular through (a) localized orographic mechanisms and (b) climate teleconnection processes acting at global, regional and local scales?
- What are the contribution of moisture from the Pacific vs the Atlantic and vs the Amazon rainforest in the central Andes? What is the spatiotemporal variability of these contributions and their interactions?

The Bolivian Andes



- What are the main drivers of climate variability in the eastern Andes at different time and spatial scales? How they may change in the future?
- GCM models (IPCC-AR5) predict divergent precipitation changes in the Central Andes. How to deal with these uncertainties from a water management perspective?
- How to get improved prediction of hydroclimatic changes induced by land use change (i.e deforestation) and infrastructure building (i.e. dams) at the Amazon scale?

The subtropical/extratropical Andes (Chile-Argentina)



- The water balance is largely unknown in this region. Of particular relevance are the snow accumulation and sublimation. What is the temporal and spatial variability of these terms? How they may change in the future climate?
- How the subtropical Andes affect the continental low (which in turn drives the Low-Level Jet east of the Andes)?
- Which is the moisture pathway from the Amazon basin toward the Altiplano? Does it follow the topography or does it occur at higher levels?

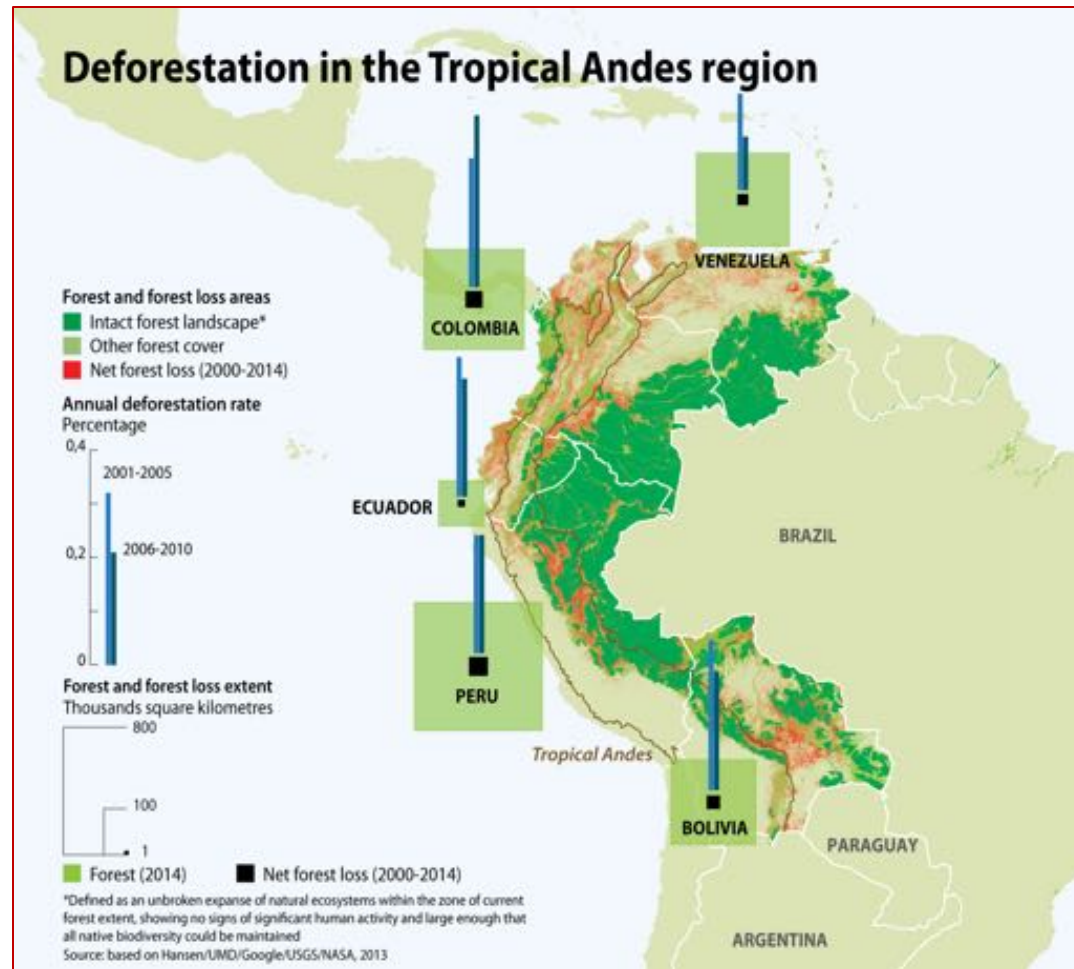
But, guess what? The Andes are a very crowded place +80M people



Photo from Schoolmeester et al., 2016

Deforestation in the Tropical Andes

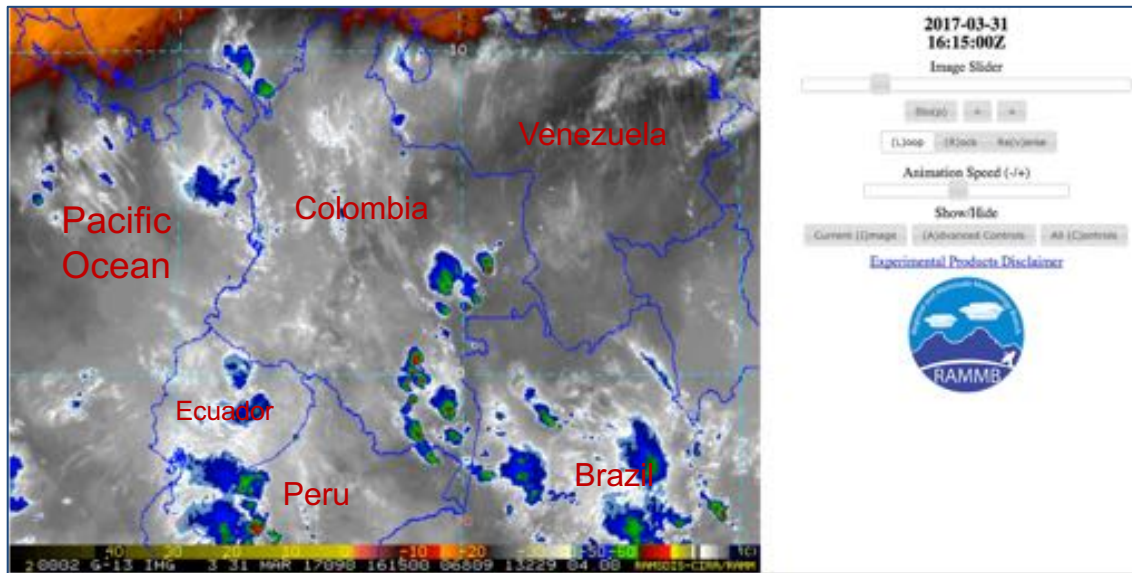
The most critical hotspot for biodiversity on Earth



Threats from Climate Change and Hydroclimatic Variability and Deforestation

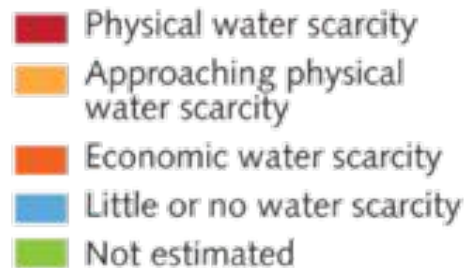
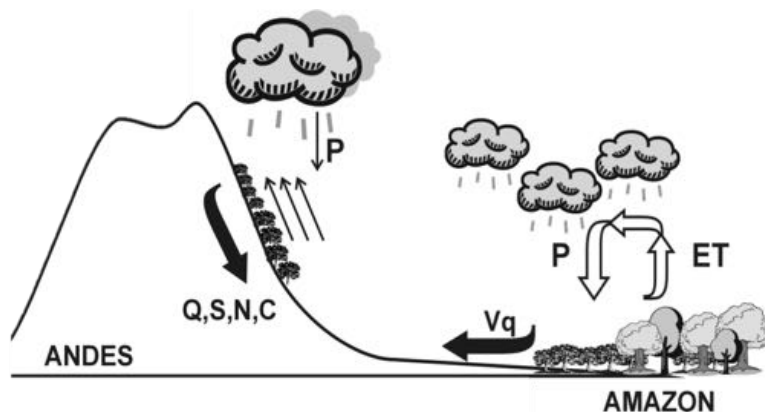
Intensification of Storms and Floods

A MCS triggered the flooding that destroyed Mocoa, Colombia
April 1st, 2017 (+400 dead people)



Water Scarcity in Latin-America

- How stable under climate change?
- How could it change?
- What is it that needs to be adapted to?
- What can be mitigated?



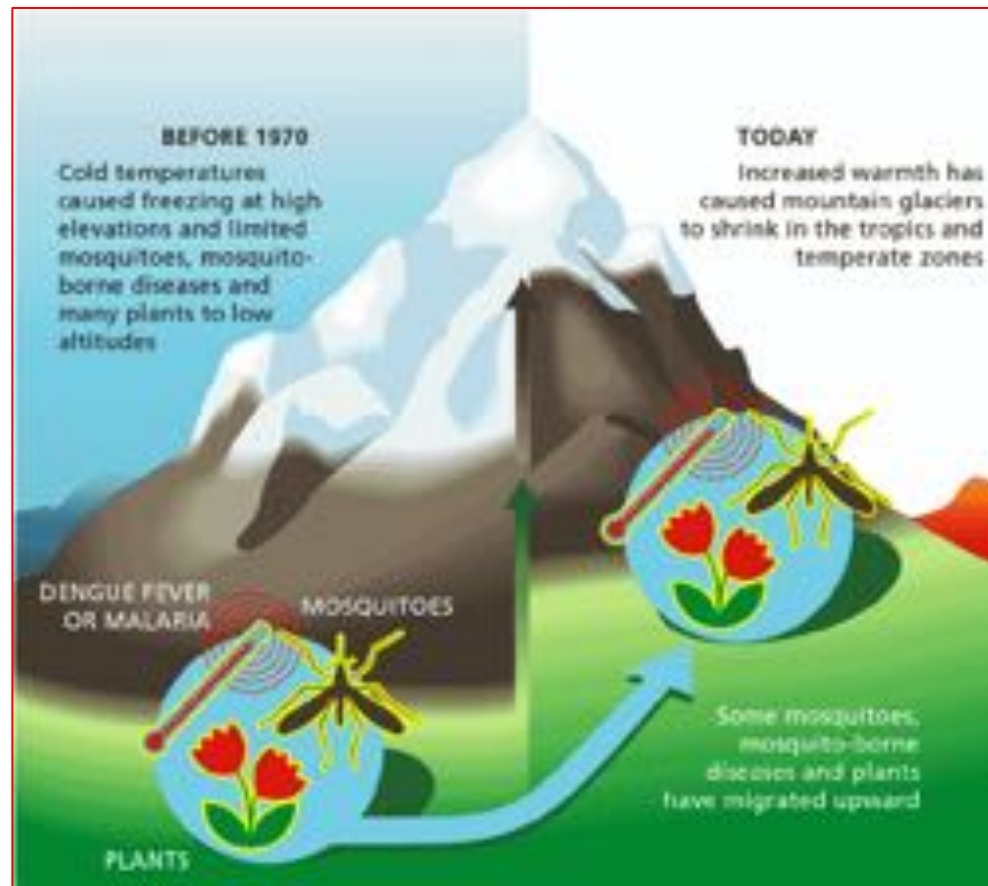
Environmental Devastation – Mining

Nuestro El daño ambiental de la minería ilegal

Mayor Investigaciones dan cuenta de 6.330 puntos dedicados a la extracción ilegal de oro. Ya son cerca de 200 mil hectáreas de ríos y zonas selváticas seriamente deterioradas por esta actividad galopante.



Mosquito-borne dengue (a urban disease) is migrating upward due to warming



Start-Up Activity

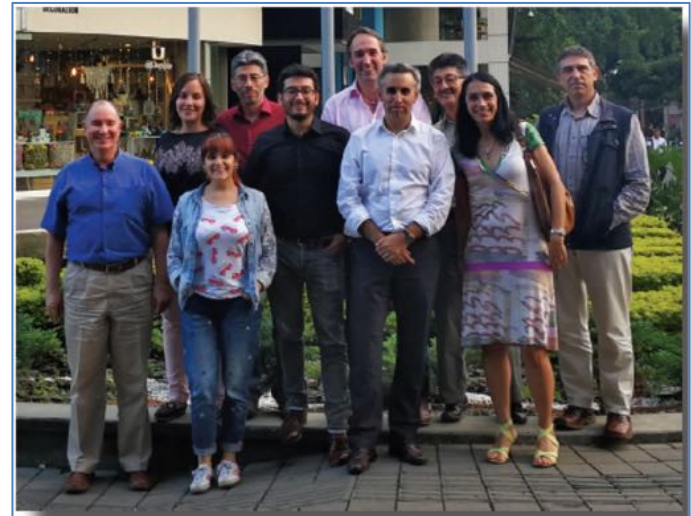
Workshop held in Medellín, Colombia
December 4th-7th, 2017



ANDEX: A Prospective GEWEX Regional Hydroclimate Project in the Andes

Germán Poveda¹, René Garreaud², Silvina Solman³, Jhan Carlo Espinoza⁴, Joan Cuxart⁵, Peter J. van Oevelen⁶, Paola A. Arias⁷, Jorge Molina⁸, José D. Pabón⁹ and Sara M. Vallejo¹

¹Universidad Nacional de Colombia, Medellín, Colombia; ²Universidad de Chile, Santiago, Chile; ³Universidad de Buenos Aires, Buenos Aires, Argentina; ⁴Instituto Geofísico del Perú, Lima; ⁵Universitat de les Illes Balears, Palma, España; ⁶International GEWEX Project Office, Washington DC, USA; ⁷Universidad de Antioquia, Medellín, Colombia; ⁸Universidad Mayor San Andrés, La Paz, Bolivia; ⁹International Research Centre on El Niño (CIIFEN), Guayaquil, Ecuador



Participants of the ANDEX Workshop.

First term co-chairs (3 years): Germán Poveda (Colombia) and René Garreaud (Chile).

White Book – In Preparation

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1. The hydroclimate of the Andes

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7. Actions and challenges

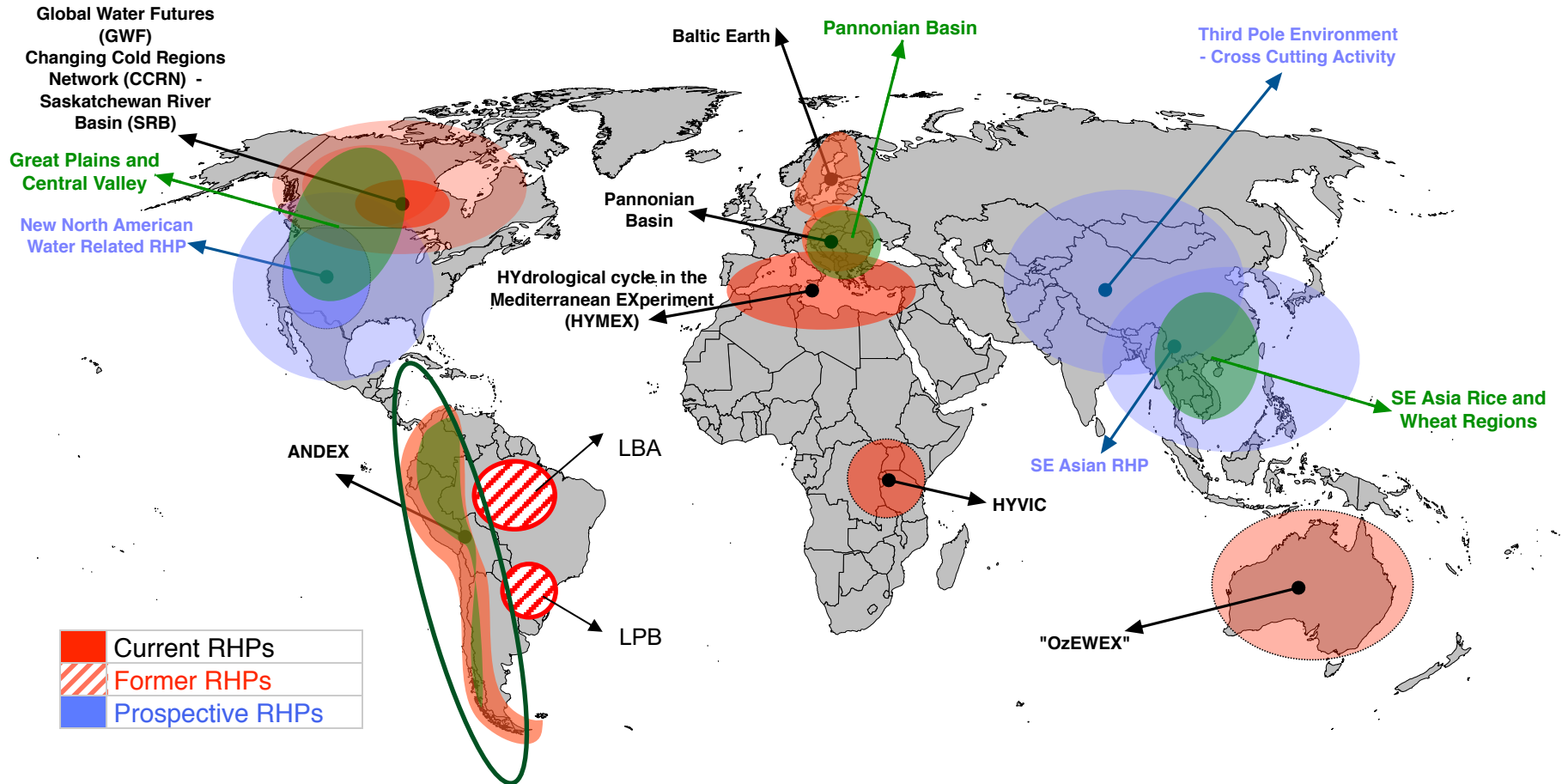
**Leading authors confirmed.
Still accepting contributing authors for chapters**



ANDEX activities for 2018:

- May 7-11: ANDEX presentation at the 8th GEWEX Science Conference in Canmore, Alberta, Canada.
- Mid-August: WB Chapters drafts available.
- Early September: WB first version compiled and edited.
- Mid-September: Workshop agenda ready.
- October 22-26: 1st ANDEX Workshop (very likely combined with GHP meeting) Santiago, Chile.

Regional Hydroclimate Projects



A satellite image of South America, showing the continent's green landmass against the dark blue of the surrounding oceans. The text "Thank you!" is centered over the continent in white. The image has a slightly grainy, high-resolution appearance.

Thank you!