COLOMBIA'S HYDROCLIMATOLOGY

Julián David Rojo Hernández
C.E. MSc. Water Resources

National University of Colombia
School of Geosciences and Environment-School of Mines

Medellín
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IAI

POSGRADO EN APROVECHAMIENTO DE RECURSOS HIDRÁULICOS

The general rule

"… Las estaciones se suceden de la misma manera que en la mayor parte de la zona tórrida; esto es, se conocen dos, verano é invierno: la última cuando llueve y la otra cuando deja de llover.

Los meses de lluvia en Antioquia principian a mediados de Marzo y terminan a mediados de Junio, para comenzar luego en Septiembre y acabar en los primeros días de Diciembre; pero esta regla está sujeta a numerosas variaciones, pues con frecuencia se invierten los tiempos, volviéndose lluviosos los días de verano y viceversa. A veces el año es húmedo en su mayor parte, y en ocasiones notable por su excesiva sequedad, muchos de los viejos habitantes del país creen haber observado, y aún lo afirman por la tradición de sus mayores, que los tiempos de lluvia abundante y de gran sequedad, están divididos por períodos casi fijos de siete a ocho años. Nos parece que tienen razón."

Manuel Uribe Ángel (1881).

COLOMBIA'S HYDROCLIMATOLOGY

CIENCIAS DE LA TIERRA

LA HIDROCLIMATOLOGÍA DE COLOMBIA: UNA SÍNTESIS DESDE LA ESCALA INTER-DECADAL HASTA LA ESCALA DIURNA

por

Germán Poveda[1]

Resumen

Poveda, G.: La hidroclimatología de Colombia: una síntesis desde la escala inter-decadal hasta la escala diurna. Rev. Acad. Colomb. Cienc. **28** (107): 201-222, 2004. ISSN: 0370-3908.

Se hace una revisión de la variabilidad de la hidro-climatología de Colombia, en escalas temporales que incluyen la escala interdecadal, principalmente afectada por la presencia de tendencias en las variables del clima del país, que evidencian el cambio climático. El análisis de la escala de tiempo interanual se centra en el estudio del fenómeno El Niño/Oscilación del Sur (ENSO) y la consistencia de sus efectos sobre las principales variables del ciclo hidrológico: precipitación, caudales medios y extremos de ríos, humedad de suelo y actividad vegetal. La escala de tiempo anual se centra en el análisis de la migración latitudinal de la Zona de Convergencia Intertropical, asociada con la actividad de los vientos alisios del este. Se precisa la influencia del chorro del Chocó sobre el ciclo anual de la hidroclimatología de Colombia, y se cuantifica el balance anual de largo plazo de la humedad atmosférica. La dinámica de los Sistemas Convectivos de Mesoescala se presenta en relación con el ciclo anual y con la actividad del chorro del Chocó. A la escala de tiempo intra-anual se presentan las evidencias de los efectos de la oscilación de 30-60 días y de las ondas tropicales del este sobre los registros de precipitación en Colombia. A la escala de variabilidad diurna se presentan las evidencias de la alta variabilidad de la precipitación sobre los Andes tropicales.

Palabras clave: Hidroclimatología, cambio global, El Niño/Oscilación del Sur (ENSO), Zona de Convergencia Intertropical, chorro del Chocó.

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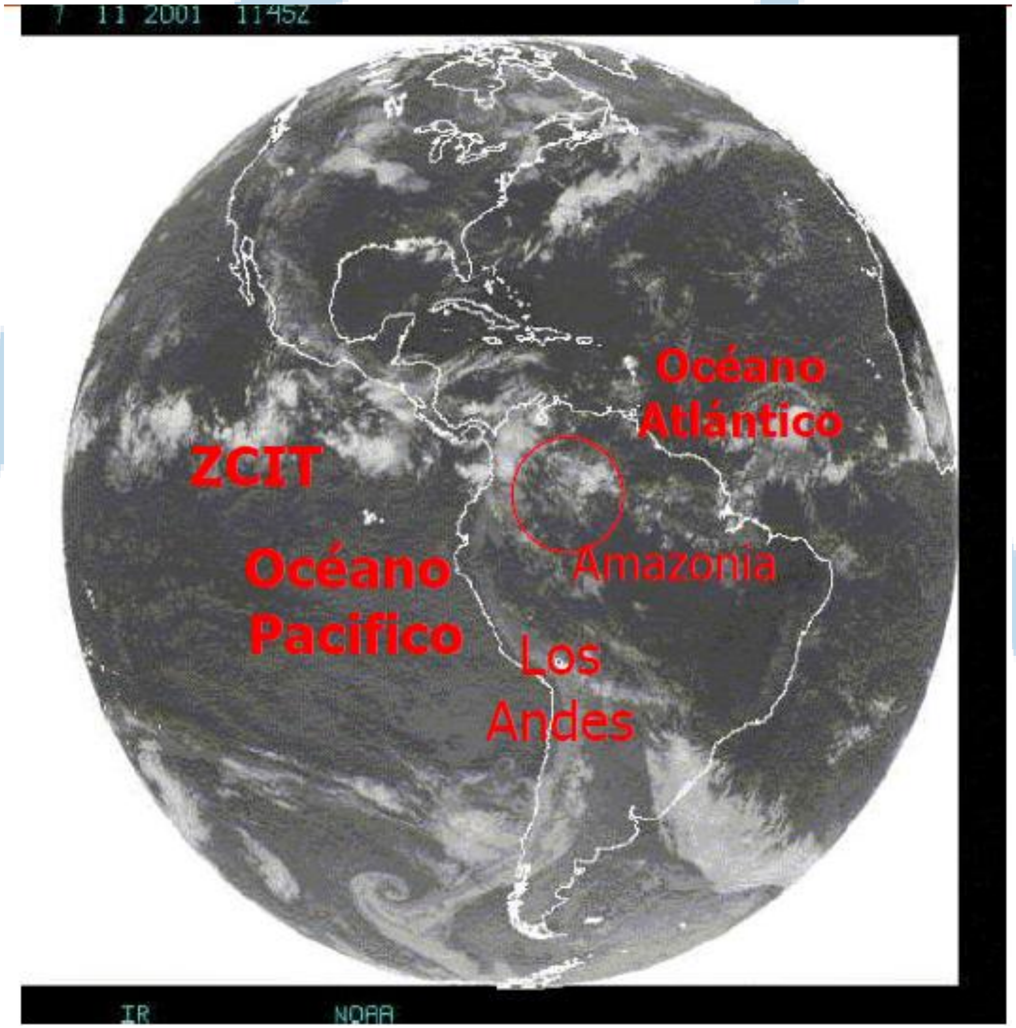
COLOMBIA'S HYDROCLIMATOLOGY (I)



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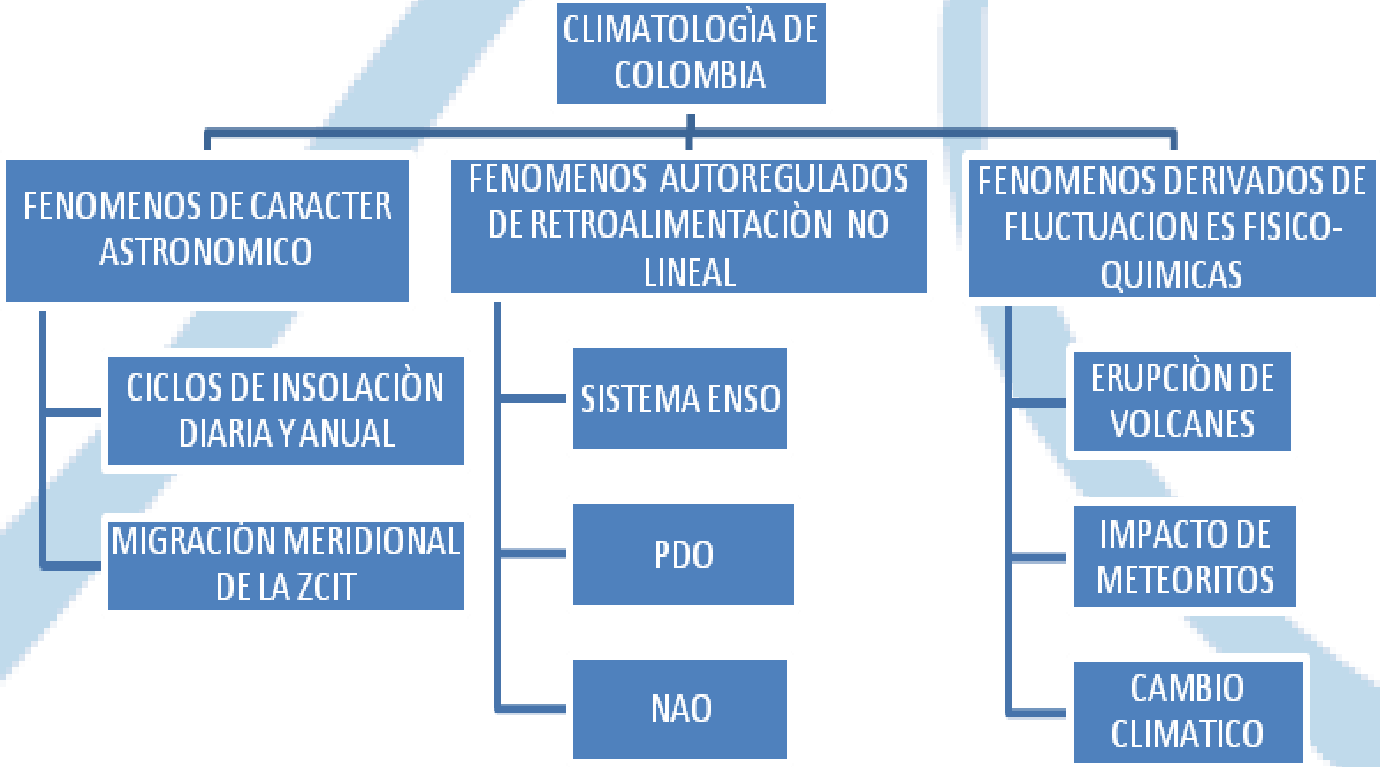
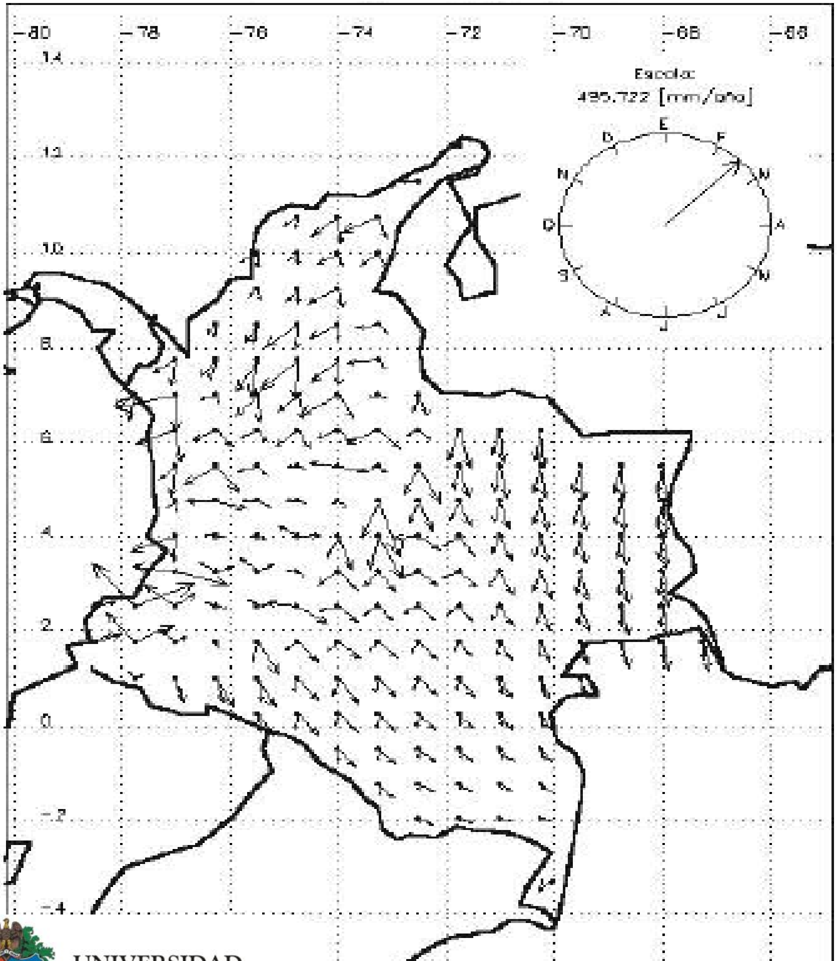
COLOMBIA'S HYDROCLIMATOLOGY (II)



(Poveda, 2004)

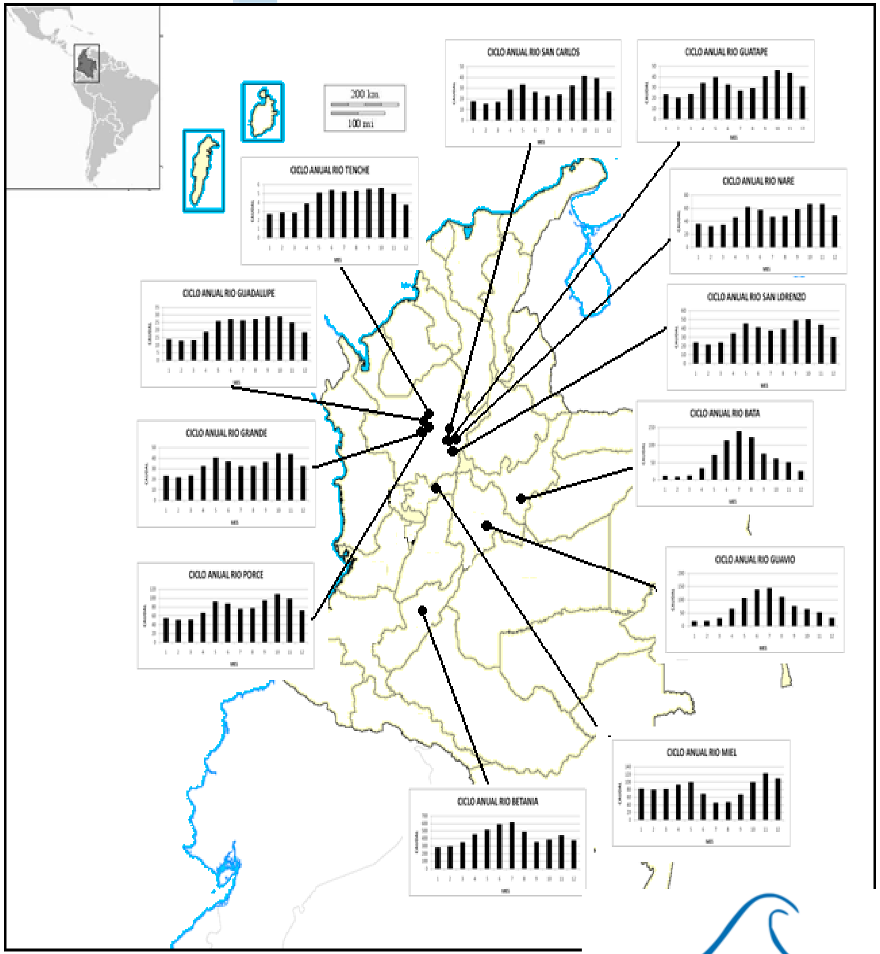
COLOMBIA'S HYDROCLIMATOLOGY (III) ANNUAL CYCLE

Precipitation



Mejía et al. (1999)

River discharges



Rojo & Carvajal. (2010)

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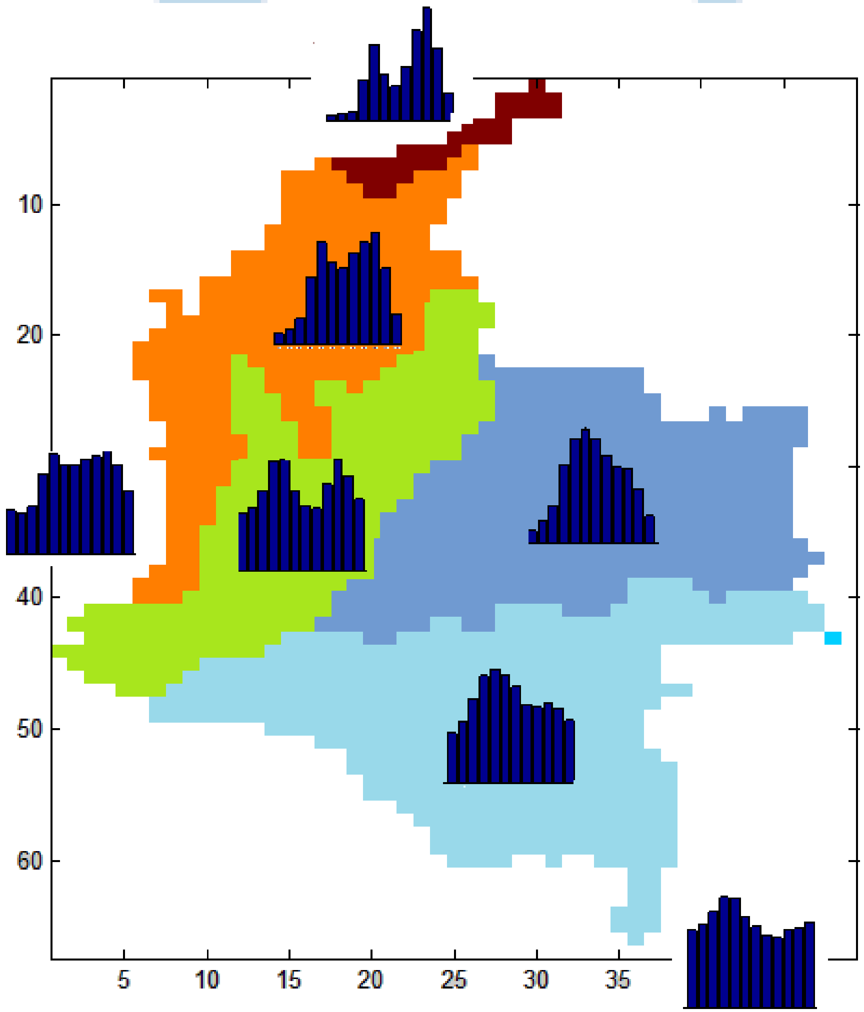
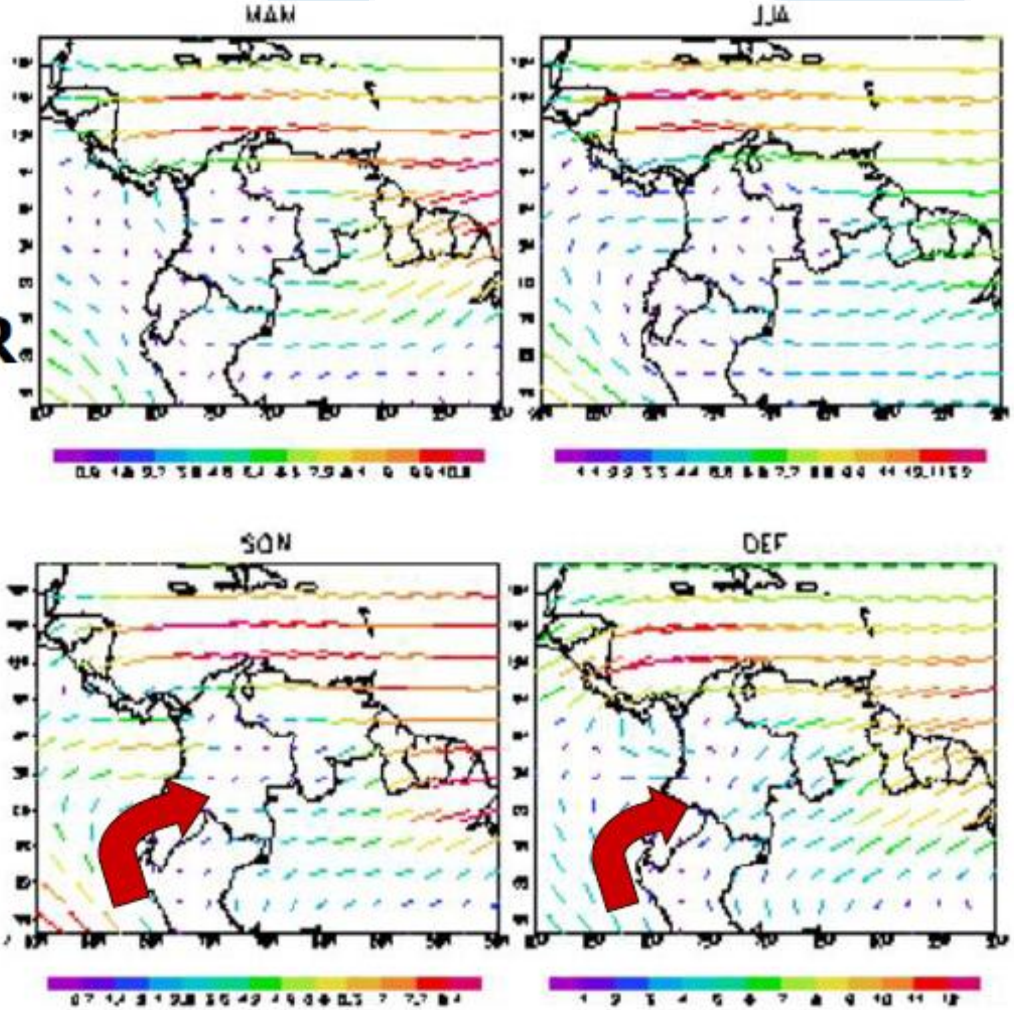
COLOMBIA'S HYDROCLIMATOLOGY (IV) ANNUAL CYCLE



COLOMBIA'S HYDROCLIMATOLOGY (IV)-CHOCO LOW-LEVEL JET

Datos: Reanálisis NCEP/NCAR 1950-1998



Poveda (1998)

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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 mesoscale convective complexes, in turn dynamically linked to the jet. The strength of the CHOCO jet (centered at 5°N) is associated with the gradient of surface air temperatures between western Colombia and the Niño 1+2 region, thereby exhibiting strong annual and interannual variability, which contributes to explaining Colombia's hydro-climatology and ınomalies during ENSO.

America, deserves documentation and understanding. We explore the main mechanisms of the ocean-land-atmosphere interaction that may contribute toward those ends. The presence of the Intertropical Convergence Zone (ITCZ) is of course a major control, but finer analysis is in order.

The low-level westerly "CHOCO" jet

The southerly trade winds over the Eastern Pacific cross the Equator due to the predominant position of the ITCZ north of the Equator [*Philander et al.*, 1996; *Waliser and Somerville*, 1994]. The corresponding change of the sign of the Coriolis acceleration, the predominant north-south coast orientation, the land-sea temperature, and friction gradients contribute to explain the westerly winds prevailing once they enter the northern hemisphere tropics [*Schott*, 1931; *Hastenrath and Lamb*, 1977; *Hastenrath*, 1991]. This explains the curvature of the trade winds coming from the Southern Hemisphere once they cross the Equator. Howe explain the curvature of the trade wind jet co Caribbean, across the Central American isthmı

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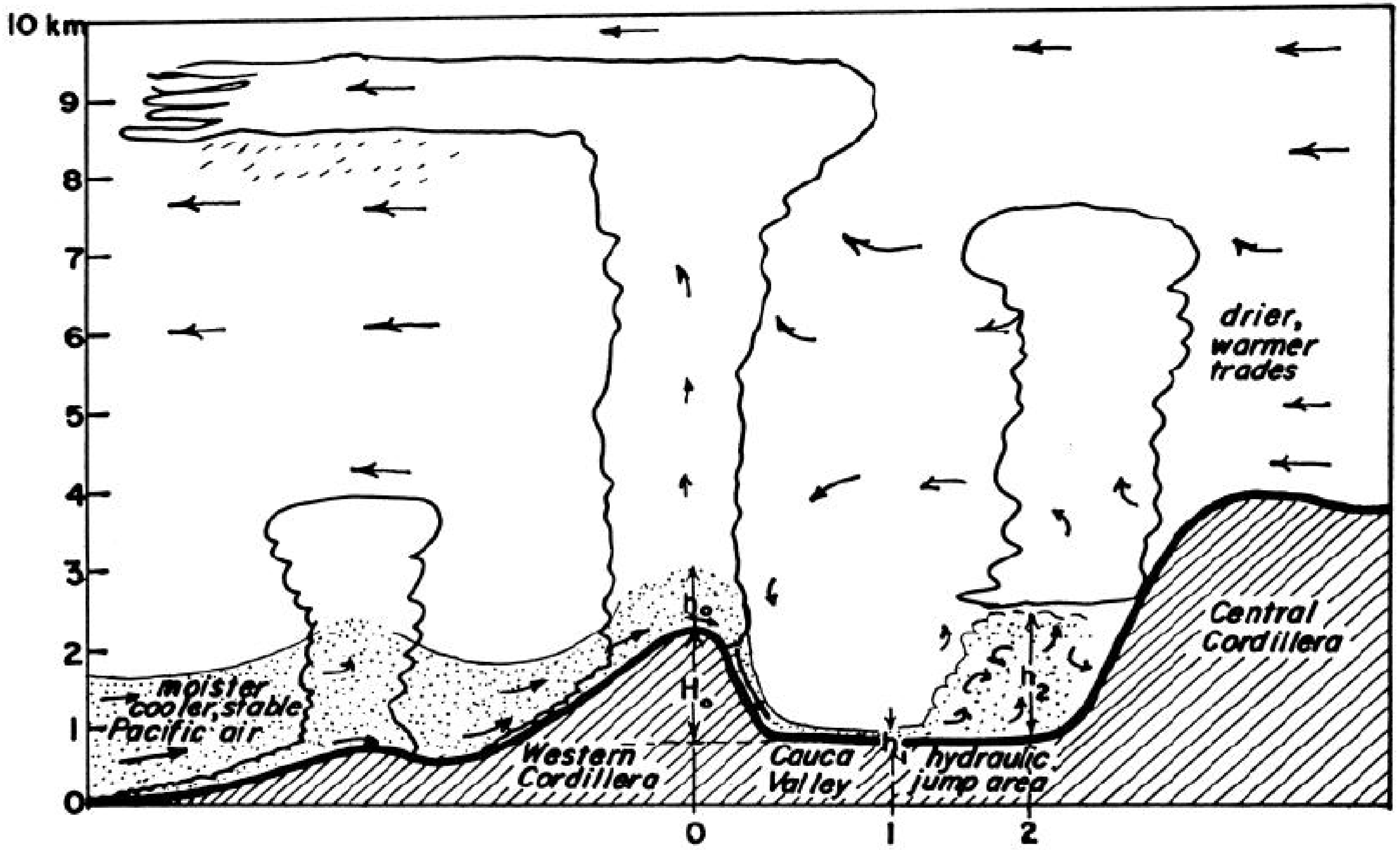
CHOCO LOW-LEVEL JET & ANDES



(López & Howell, 1967)

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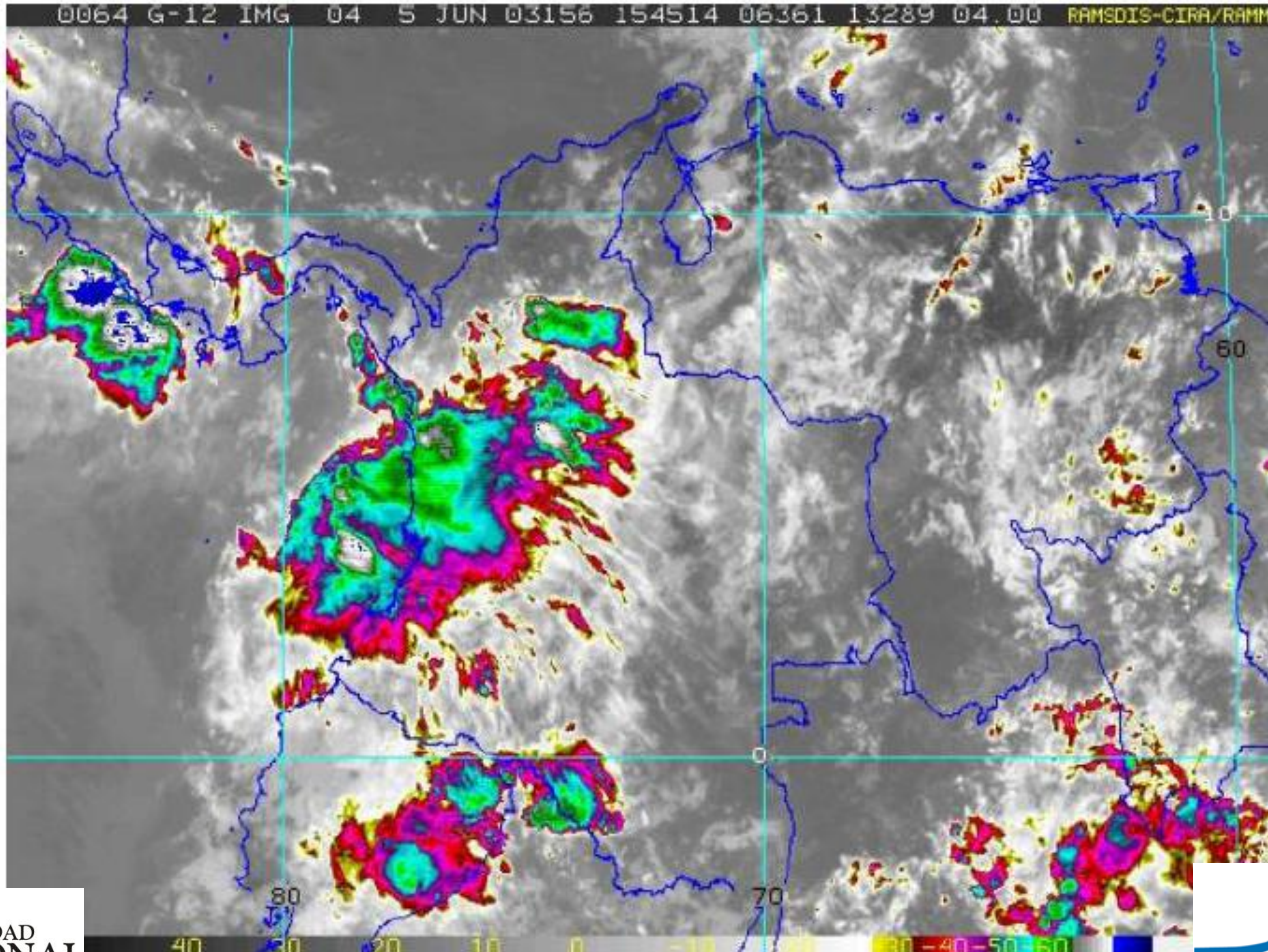
CHOCO LOW-LEVEL JET & MESOSCALE CONVECTIVE SYSTEM



Poveda et al (2006)

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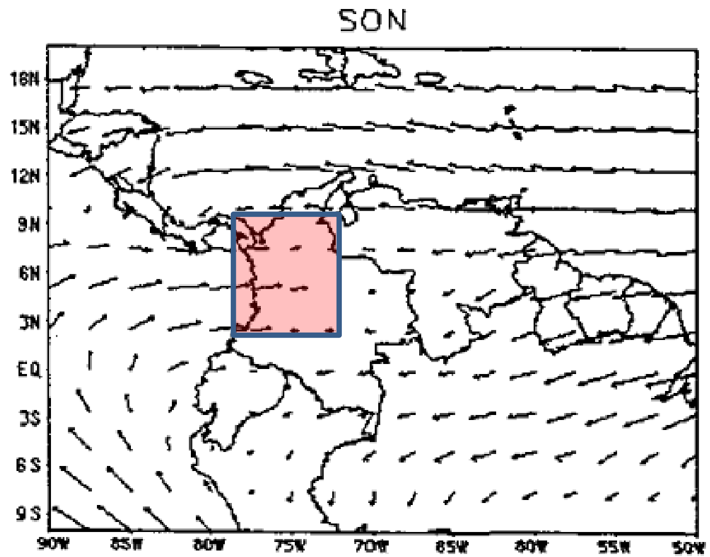
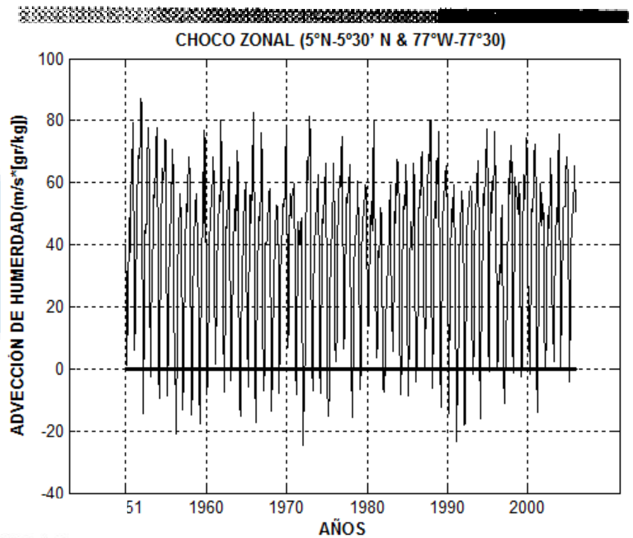
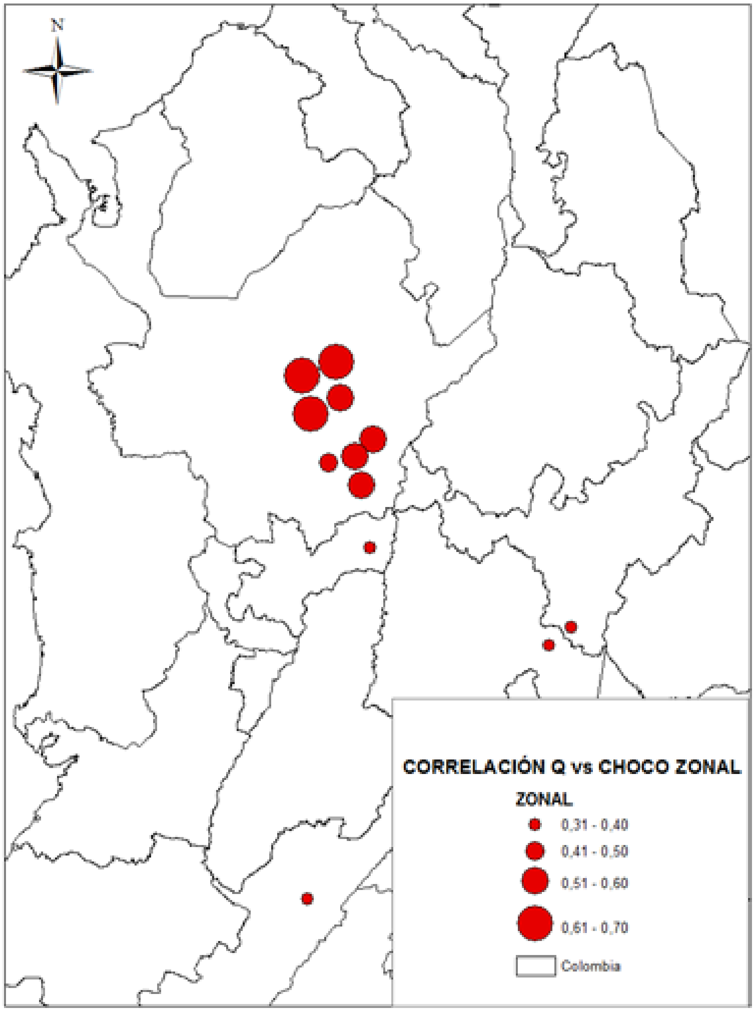
POSGRADO EN APROVECHAMIENTO DE RECURSOS HIDRÁULICOS

CHOCO LOW-LEVEL JET INDEX







(Rendón, 2001), Poveda et al (2006)

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Characteristics of Amazonian Climate: Main Features

Carlos A. Nobre, Guillermo O. Obregón, and José A. Marengo

Centro de Ciências do Sistema Terrestre, Instituto Nacional de Pesquisas Espaciais, Cachoeira Paulista, Brasil

Rong Fu

Jackson School of Geosciences, University of Texas at Austin, Austin, Texas, USA

Gérman Poveda

Escuela de Geociencias y Medio Ambiente, Universidad Nacional de Colombia, Medellín, Colombia


This chapter summarizes our current knowledge on the mean climatological features of Amazonia. Significant uncertainties remain in our understanding of the complex dynamics of climate and climate variability in that region, which are due, in part, to the lack of observational data. The strong seasonality of the rainfall and the relatively rapid transition between the wet and dry season associated with onset of the rainy season is related to the establishment of the South America Monsoon System (SAMS). The SAMS is controlled by large-scale thermodynamic conditions influenced by the near-equatorial sea surface temperature (SST). It has been suggested that land-surface dryness in the dry season is the main cause of the delay in the onset of the subsequent wet season. The 30- to 60-day oscillation is the major mode of intraseasonal variability. Interannual variability of the hydroclimatic system is strongly related to El Niño–Southern Oscillation. More generally, tropical Pacific and Atlantic SSTs control rainfall variability in Amazonia, and SW Atlantic SST anomalies influence the variability of the South Atlantic Convergence Zone (SACZ). Land surface-atmosphere interactions have been proposed as a possible dynamical mechanism for the unexplained variance at the annual and interannual timescales. At decadal and interdecadal timescales, rainfall variability is related to the Pacific Decadal Oscillation mainly over the southern portions, and linked to the North Atlantic Oscillation. At paleoclimate timescales, there is large uncertainty on major aspects of rainfall variability over tropical South America. For instance, there remains uncertainty on the basic character of rainfall anomalies over Amazonia, whether drier or wetter, during the Last Glacial Maximum, and paleoclimate reconstructions still suffer from lack of data.

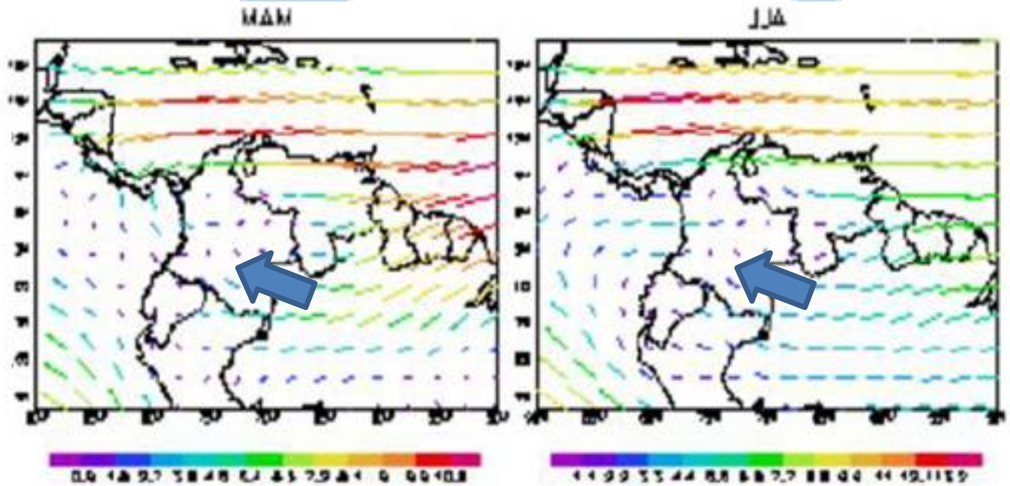
1. INTRODUCTION

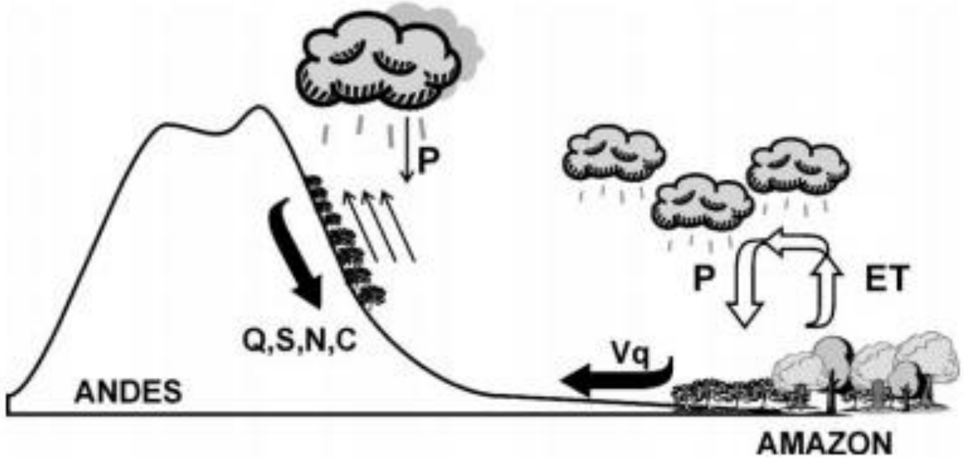
The Amazon basin is one of the three quasi-permanent centers of intense convection embedded in the equatorial trough zone. It plays a pivotal role in the functioning of the

Amazonia and Global Change
Geophysical Monograph Series 186

10.1029/2008GM000720

COLOMBIA'S HYDROCLIMATOLOGY (V) LAND SURFACE–ATMOSPHERE INTERACTIONS IN THE AMAZON REGIÓN OF COLOMBIA





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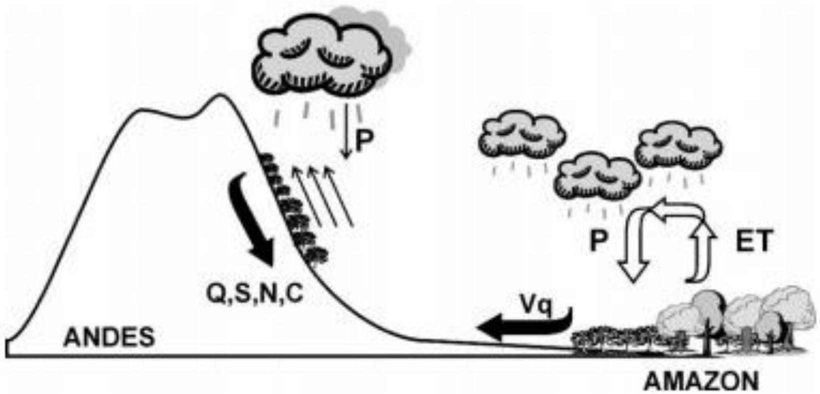
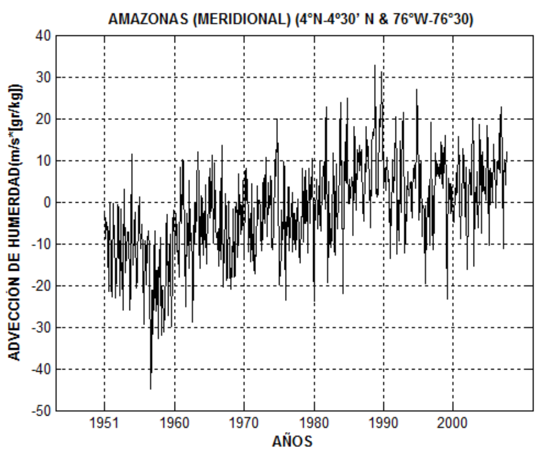
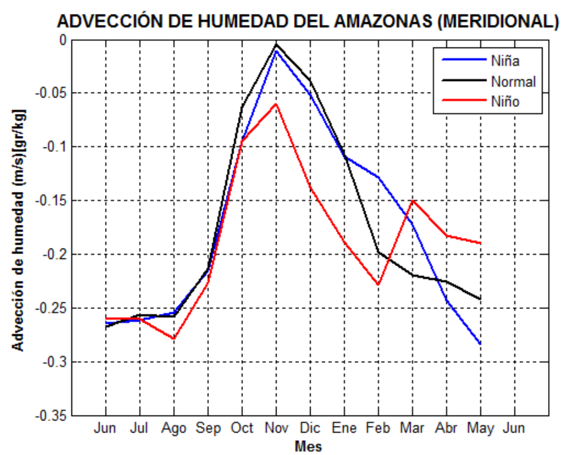
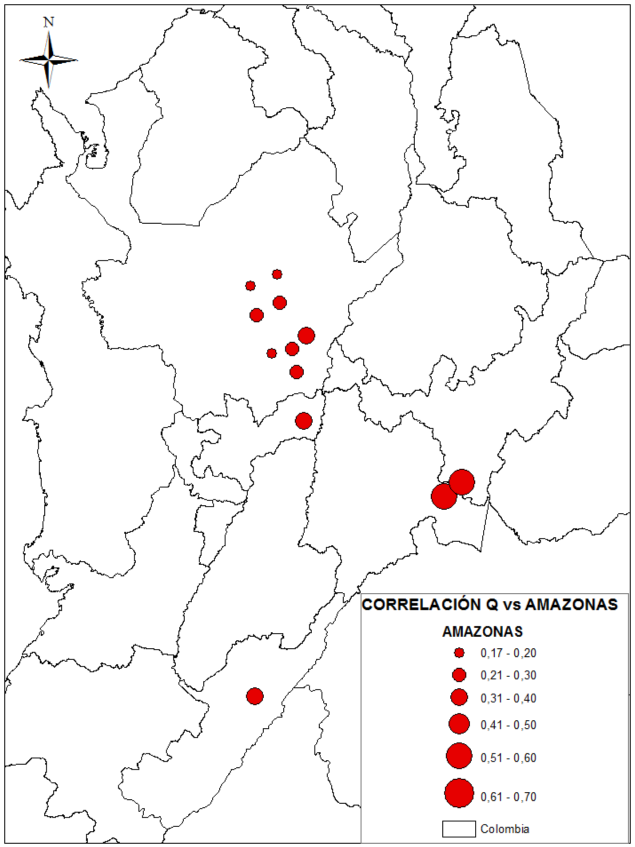
AMAZON MOISTURE TRANSPORT BY THE TRADE WINDS IN COLMOBIA









Poveda et al. (2006)

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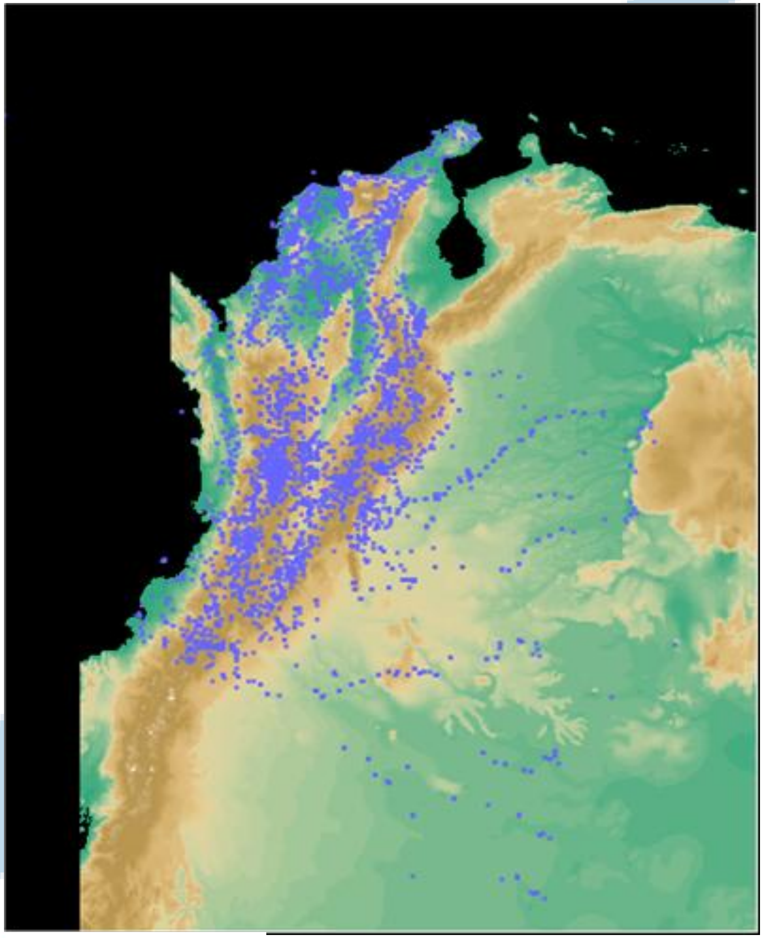
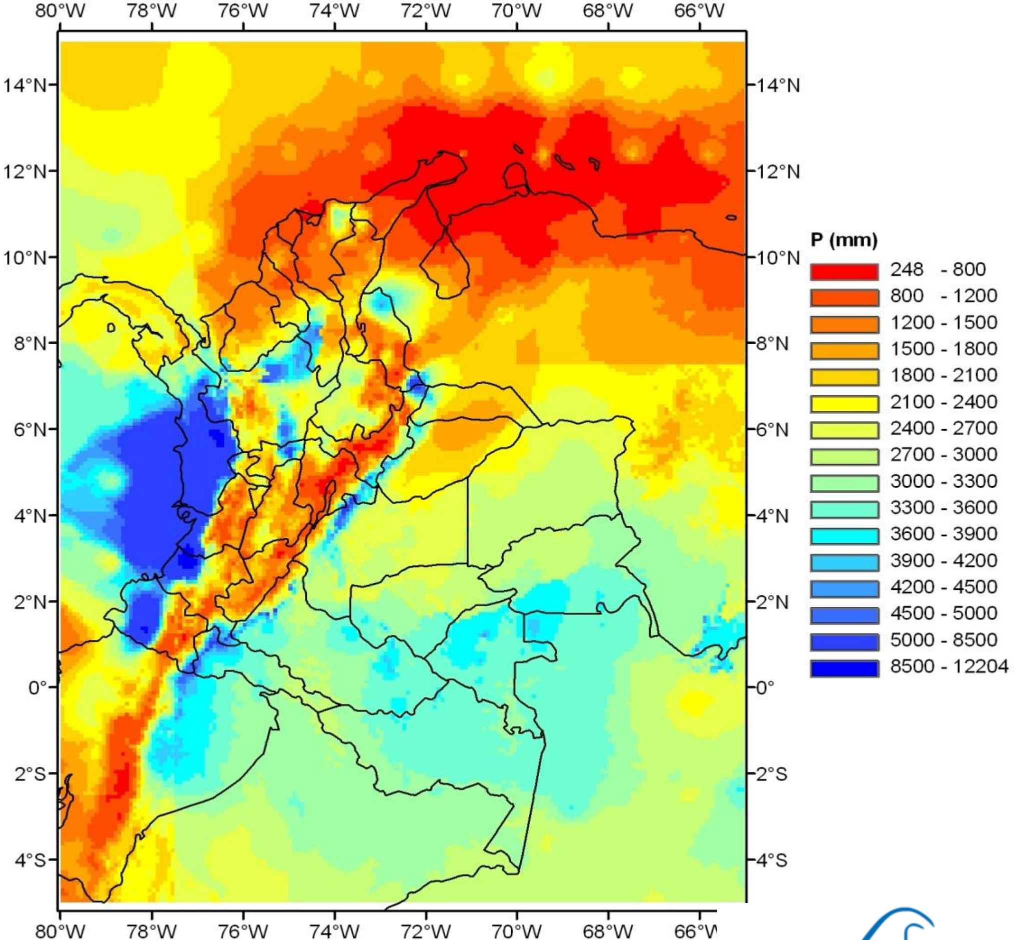
COLOMBIA'S HYDROCLIMATOLOGY (IV)-DISTRIBUTION OF PRECIPITATION





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WATER RESOURCES RESEARCH, VOL. 37, NO. 8, PAGES 2169–2178, AUGUST 2001

Seasonality in ENSO-related precipitation, river discharges, soil moisture, and vegetation index in Colombia

Germán Poveda

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

Alvaro Jaramillo

Centro Nacional de Investigaciones del Café, Cenicafé, Chinchiná, Colombia

Marta María Gil, Natalia Quiceno, and Ricardo I. Mantilla

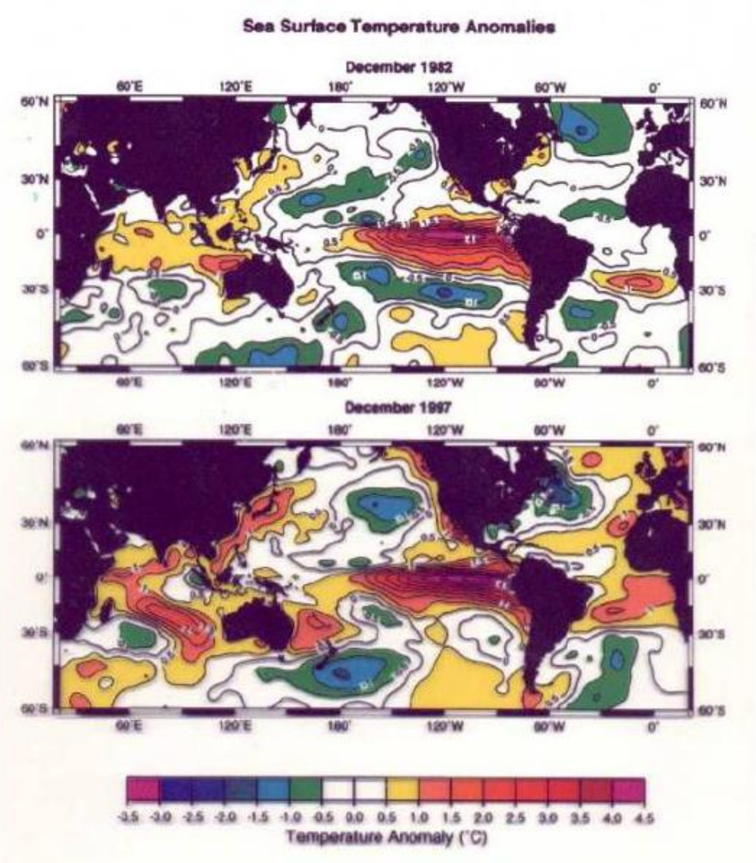
Posgrado en Aprovechamiento de Recursos Hidráulicos, Universidad Nacional de Colombia, Medellín, Colombia

Abstract. An analysis of hydrologic variability in Colombia shows different seasonal effects associated with El Niño/Southern Oscillation (ENSO) phenomenon. Spectral and cross-correlation analyses are developed between climatic indices of the tropical Pacific Ocean and the annual cycle of Colombia's hydrology: precipitation, river flows, soil moisture, and the Normalized Difference Vegetation Index (NDVI). Our findings indicate stronger anomalies during December–February and weaker during March–May. The effects of ENSO are stronger for streamflow than for precipitation, owing to concomitant effects on soil moisture and evapotranspiration. We studied time variability of 10-day average volumetric soil moisture, collected at the tropical Andes of central Colombia at depths of 20 and 40 cm, in coffee growing areas characterized by shading vegetation ("shaded coffee"), forest, and sunlit coffee. The annual and interannual variability of soil moisture are highly intertwined for the period 1997–1999, during strong El Niño and La Niña events. Soil moisture exhibited greater negative anomalies during 1997–1998 El Niño, being strongest during the two dry seasons that normally occur in central Colombia. Soil moisture deficits were more drastic at zones covered by sunlit coffee than at those covered by forest and shaded coffee. Soil moisture responds to wetter than normal precipitation conditions during La Niña 1998–1999, reaching maximum levels throughout that period. The probability density function of soil moisture records is highly skewed and exhibits different kinds of multimodality depending upon land cover type. NDVI exhibits strong negative anomalies throughout the year during El Niños, in particular during September–November (year 0) and June–August (year 0). The strong negative relation between NDVI and El Niño has enormous implications for carbon, water, and energy budgets over the region, including the tropical Andes and Amazon River basin.

El Fenómeno del el Niño (ENSO)

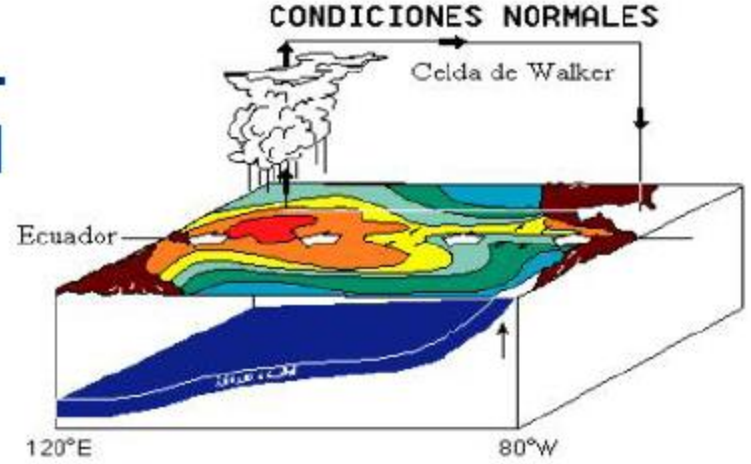
El Niño - Oscilación del Sur (ENSO)

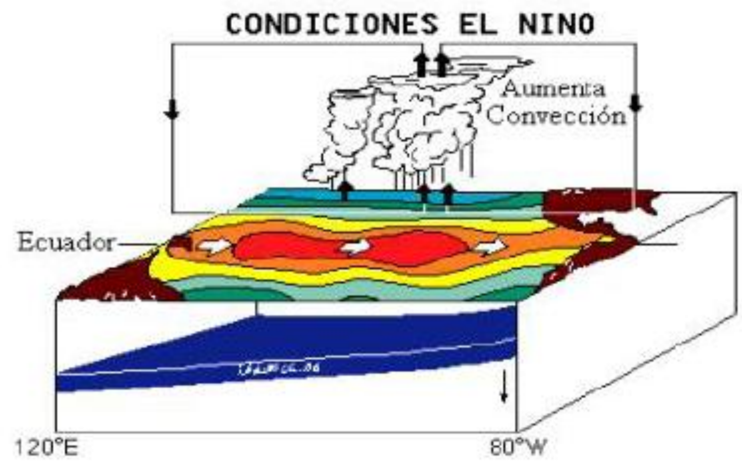
- El Niño
- La Niña



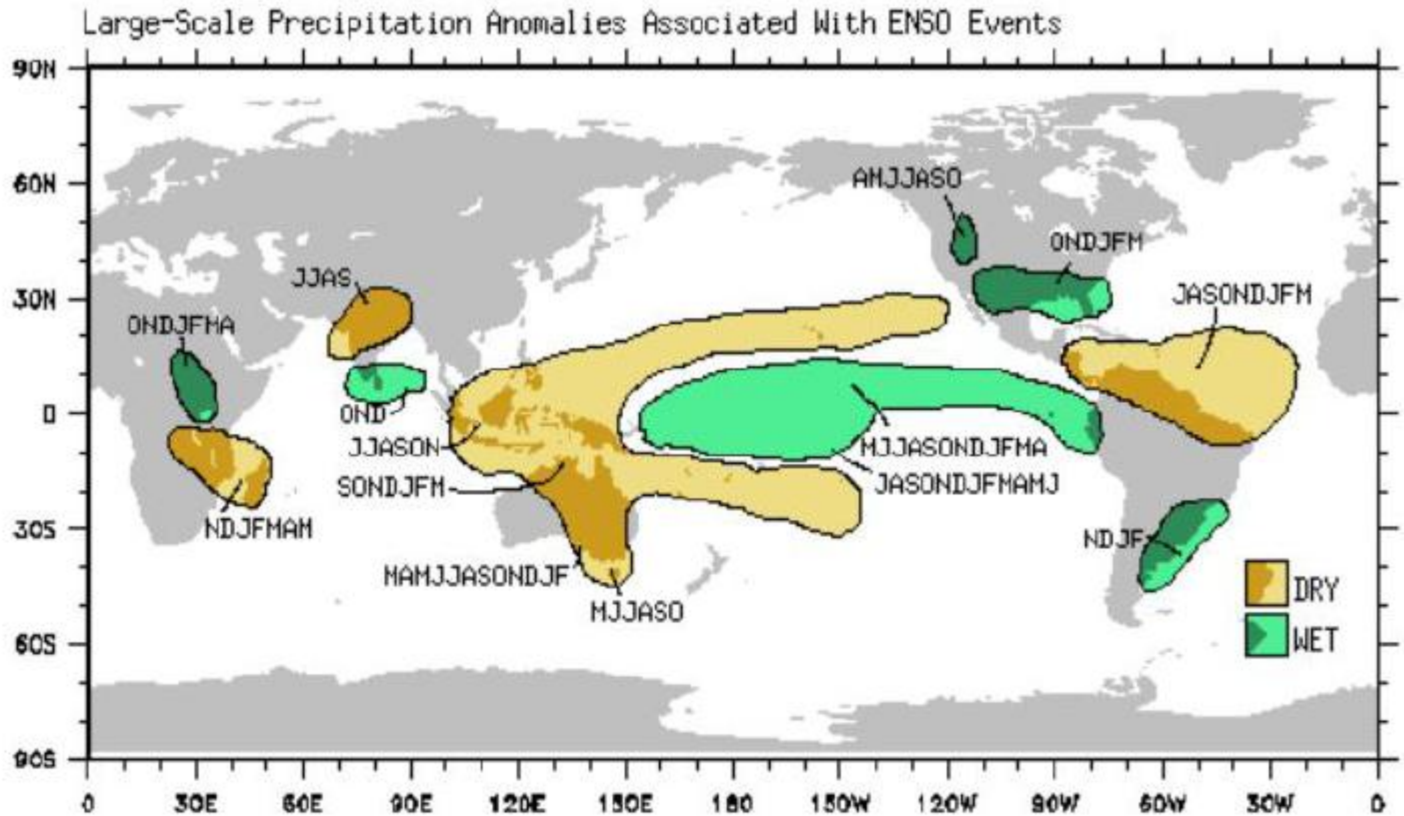
El Niño/Oscilación del Sur (ENSO)

- Fenómeno natural océano-atmósfera Pacífico tropical
- Frecuencia 3-4 años
- El Niño: Calentamiento aguas del mar.
- La Niña: Enfriamiento
- Oscilación Sur: Presiones atmosféricas (SOI).
- Control interanual clima de la Tierra.



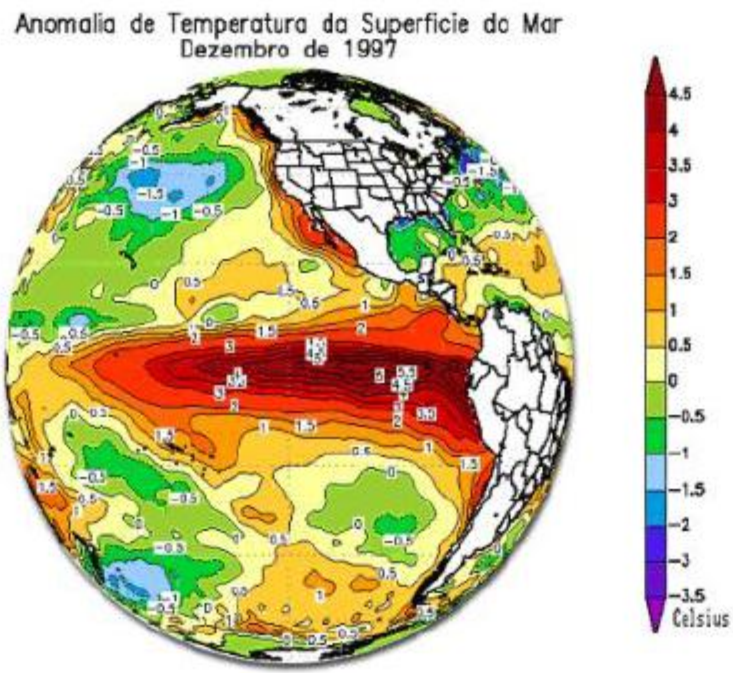


Efectos de El Niño en la Precipitación Global

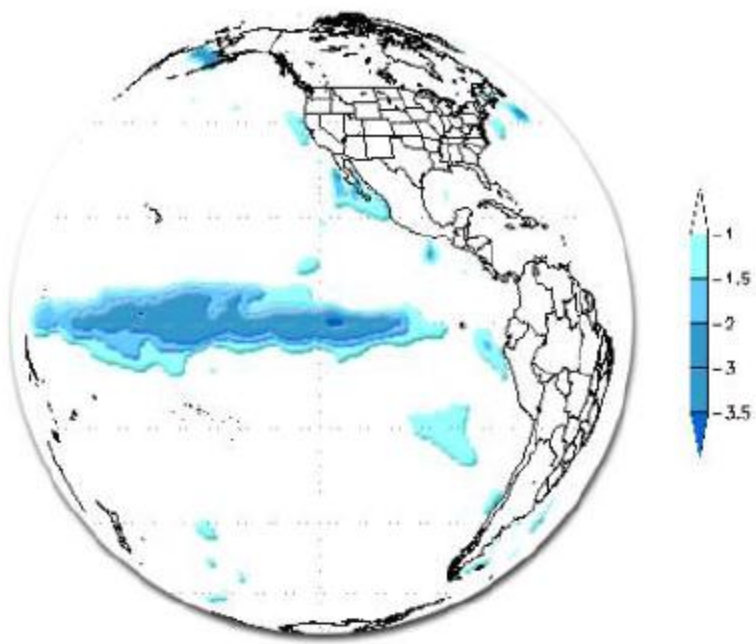


El Niño y La Niña

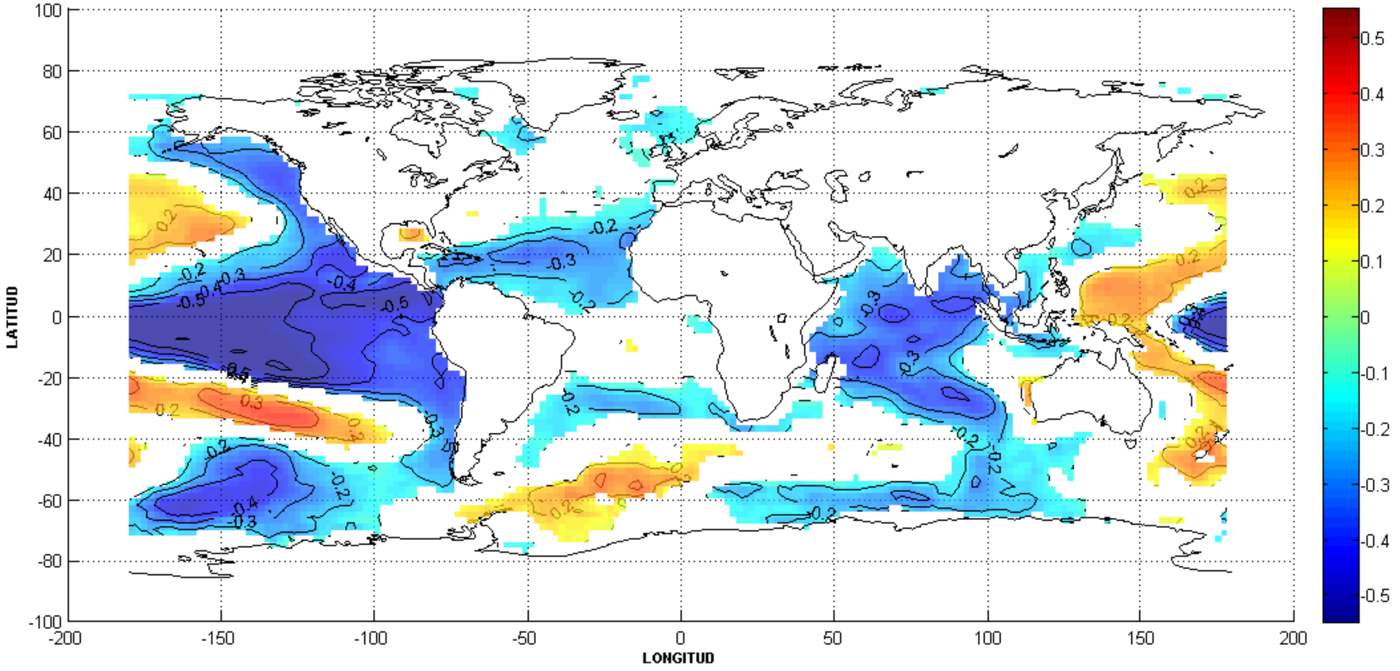
El Niño



La Niña



Maps of seasonal cross-correlations between the anomalies of sea surface temperature (SST) and river discharge anomalies of Guadalupe river



Rojo & Ferrerira. (2012)

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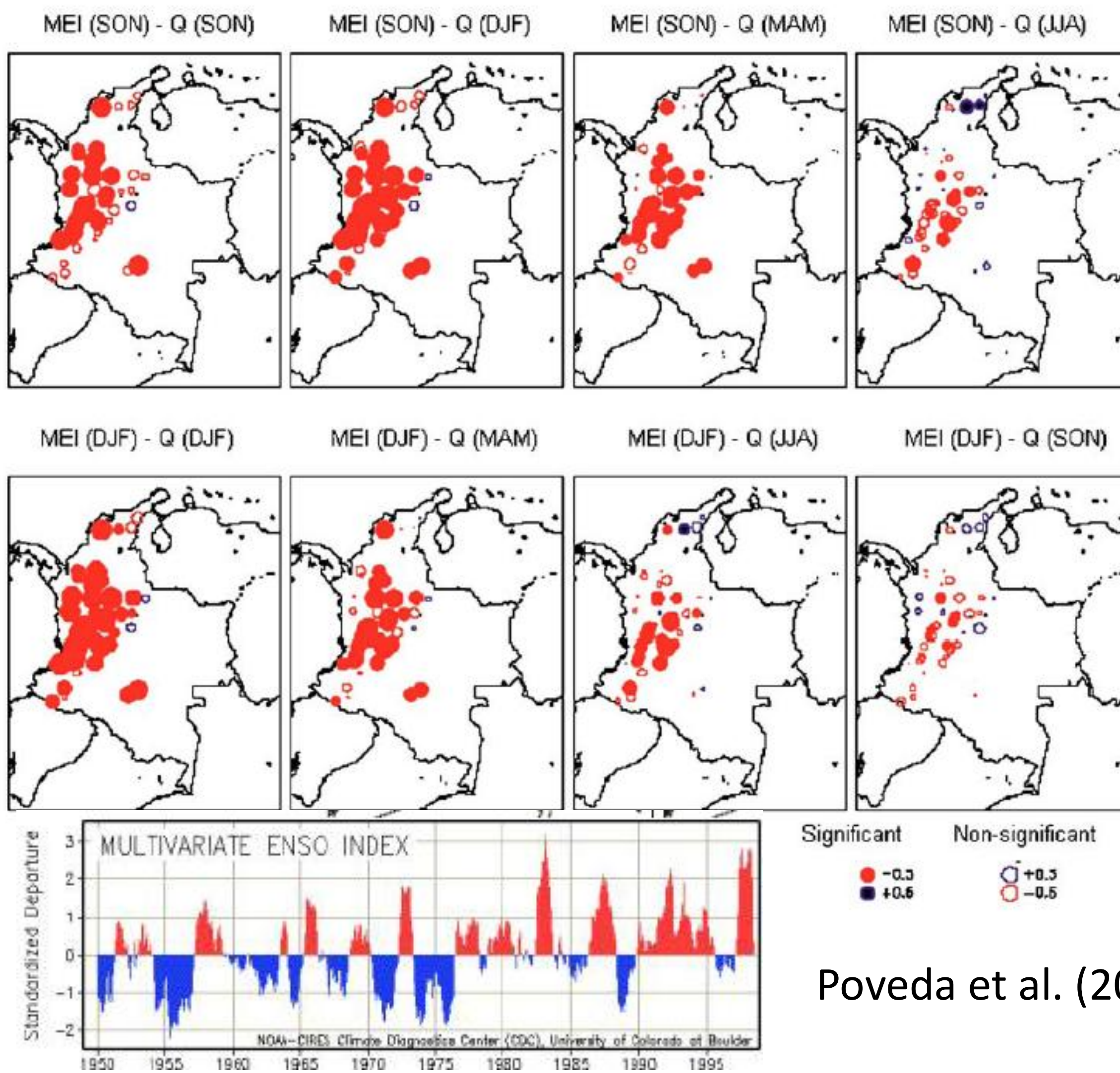
COLOMBIA'S HYDROCLIMATOLOGY (V)
HYDRO-CLIMATIC VARIABILITY OF COLOMBIA ASSOCIATED WITH ENSO



Poveda et al. (2001)

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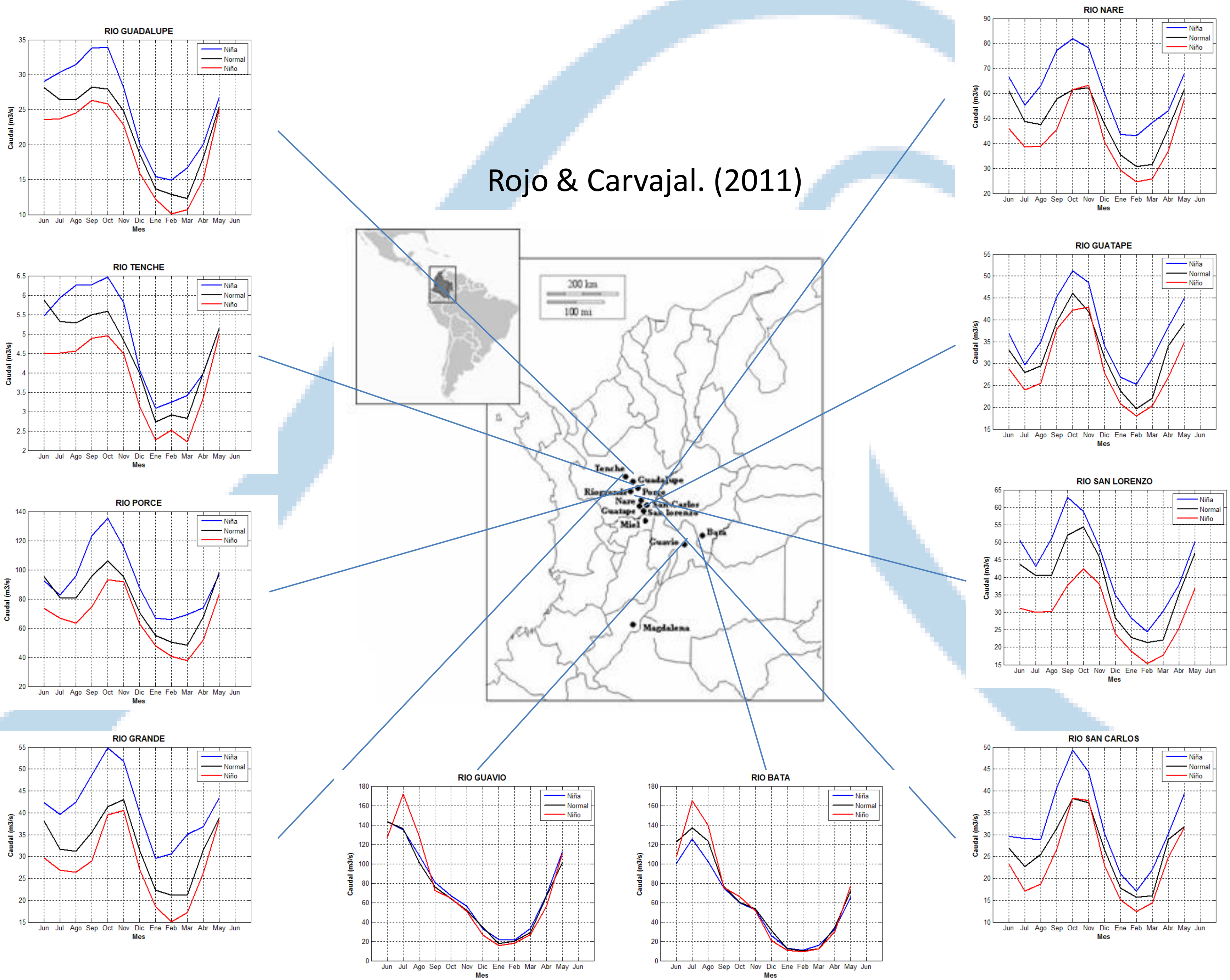
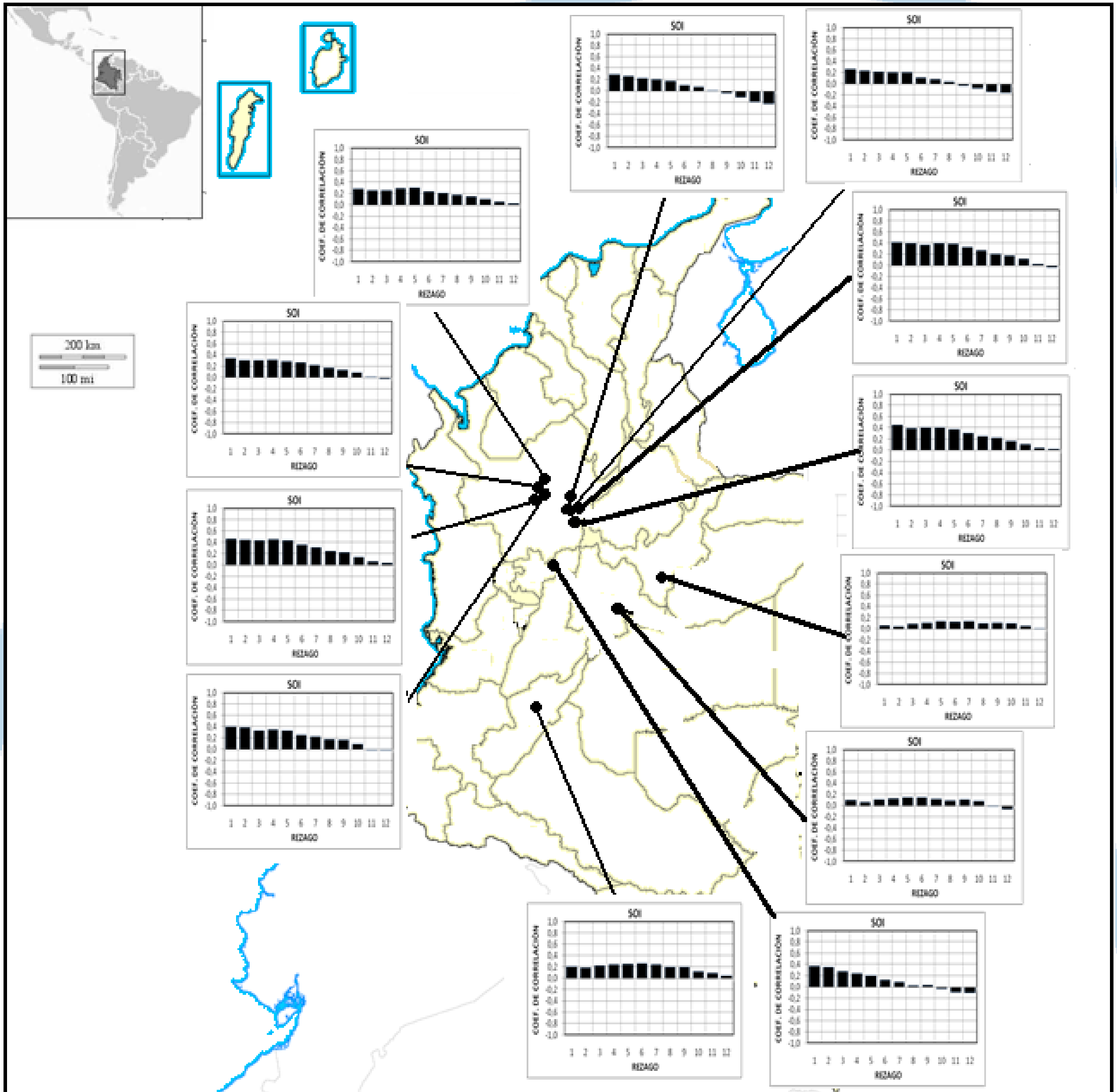
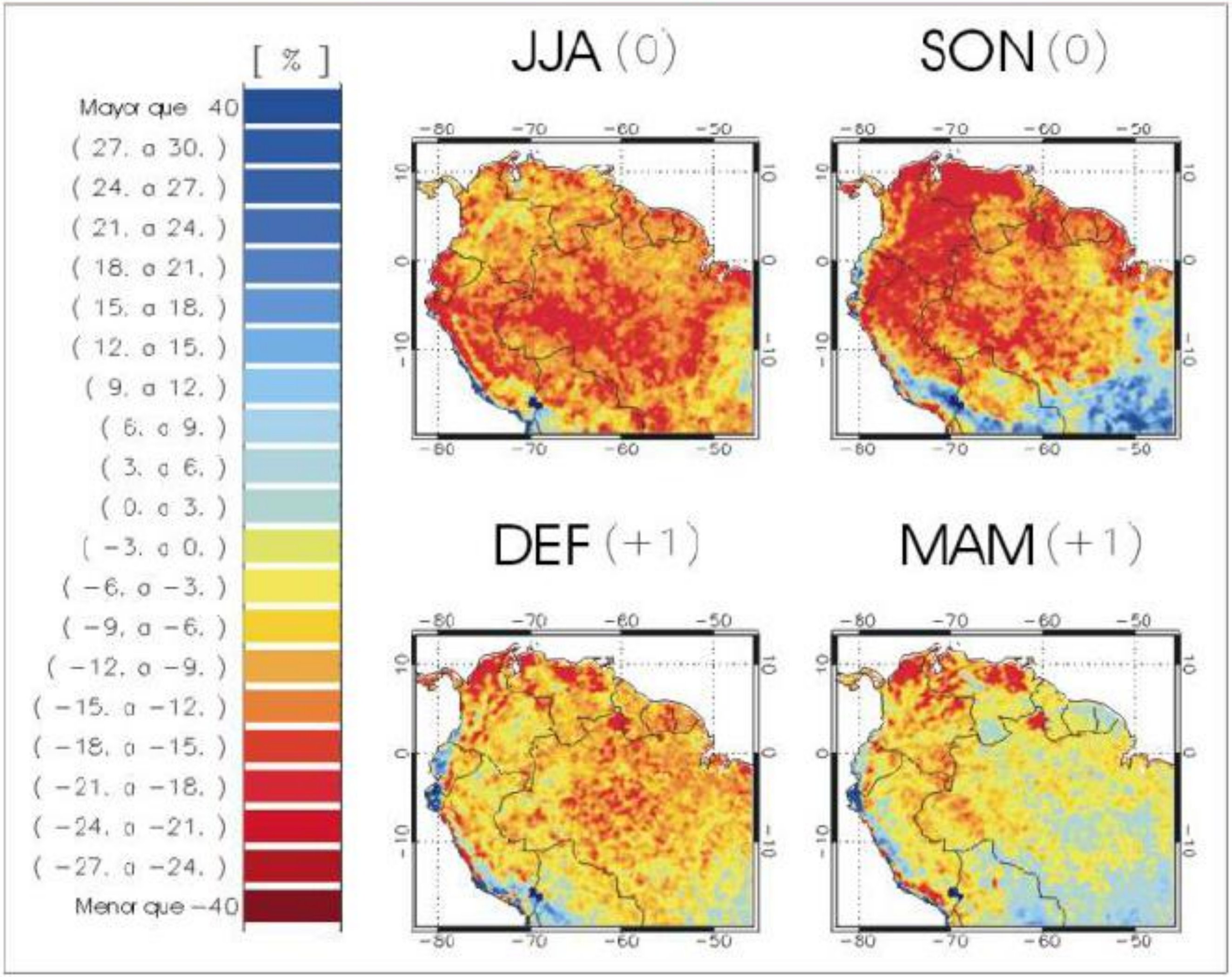
Rojo & Carvajal. (2011)





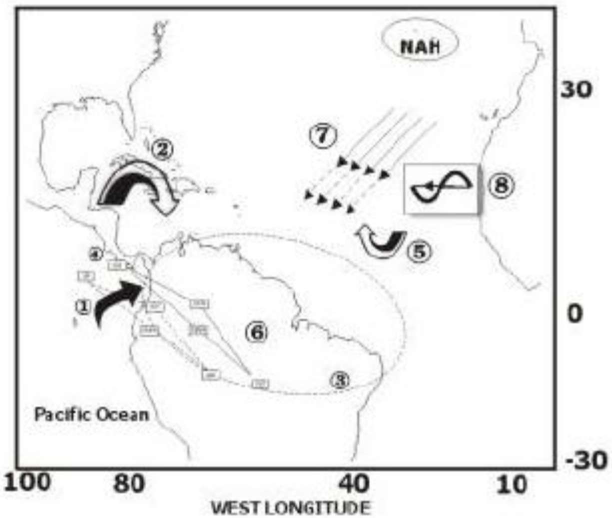
Rojo & Carvajal. (2010)

Actividad de las plantas (NDVI) disminuye durante El Niño



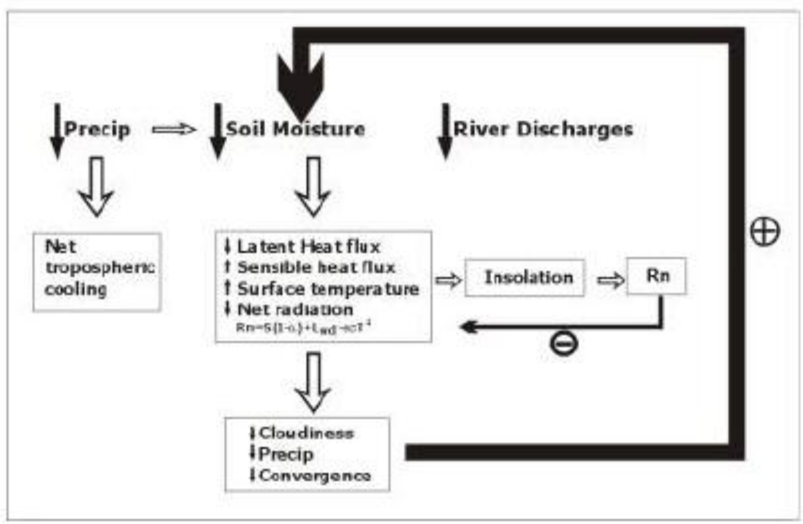
Poveda et al., (2001)

Por qué hay sequías en Colombia durante El Niño?



1. Choco Jet weakens - MCC´s
2. Reversed Hadley cell - Upper convergence
3. High Surface Pressure (DJF(+1))
4. ITCZ shifted to S-W
5. Hadley cell ⇔ Precipitation: Feedback
6. Land-Atmosphere Interaction

7. Low SLP at NAH & High T.South America
   ⇒ Weaker trades ⇒ Warming of tropical north Atlantic SST´s
8. Diminished activity of easterly waves (JJASON (O))



t al. (1998)

Impactos de El Niño en Colombia

- Producción Agrícola (Café!) y Ganadera.
- Generación de Energía Eléctrica.
- Salud Humana: Malaria, Dengue, etc.
- Transporte Fluvial.
- Incendios Forestales (1997/98 !!).
- Pesca fluvial y oceánica.
- Construcción.
- Ecosistemas, Calidad de agua.
- La Niña: Desastres naturales - Vulnerabilidad

Índice de Transmisión de Malaria - Colombia
Epidemias durante El Niño

Poveda y Rojas, 1996

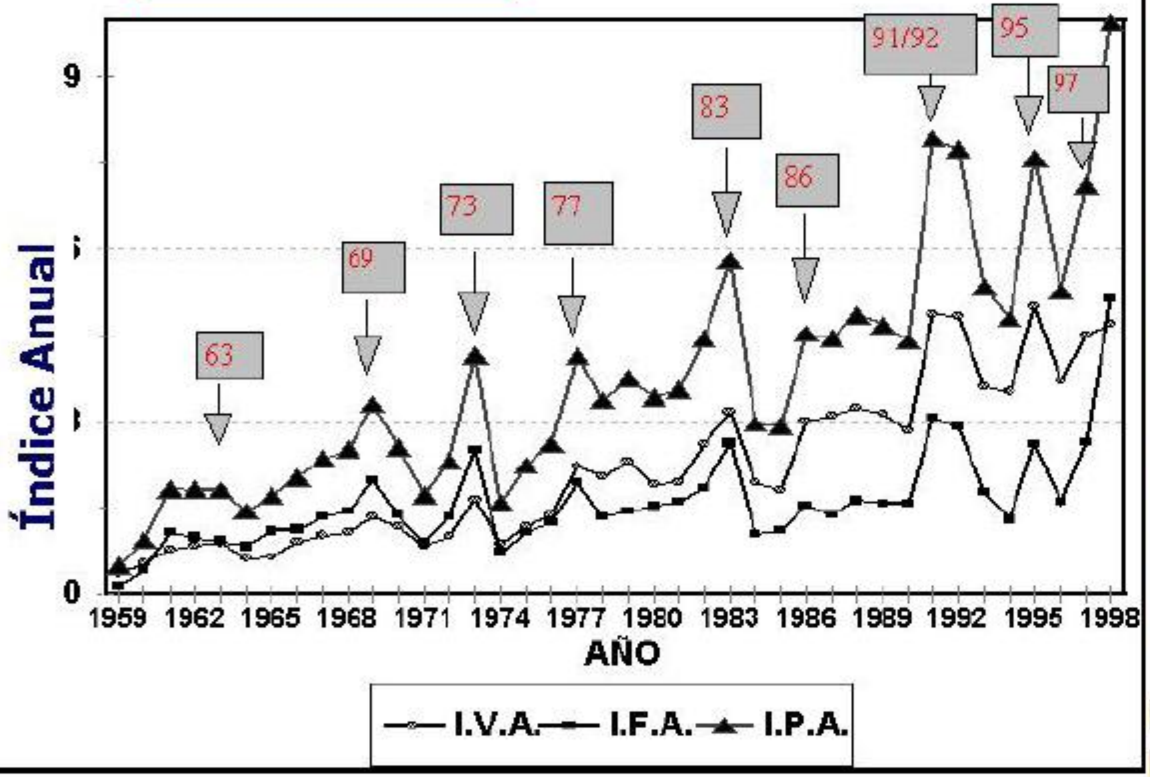
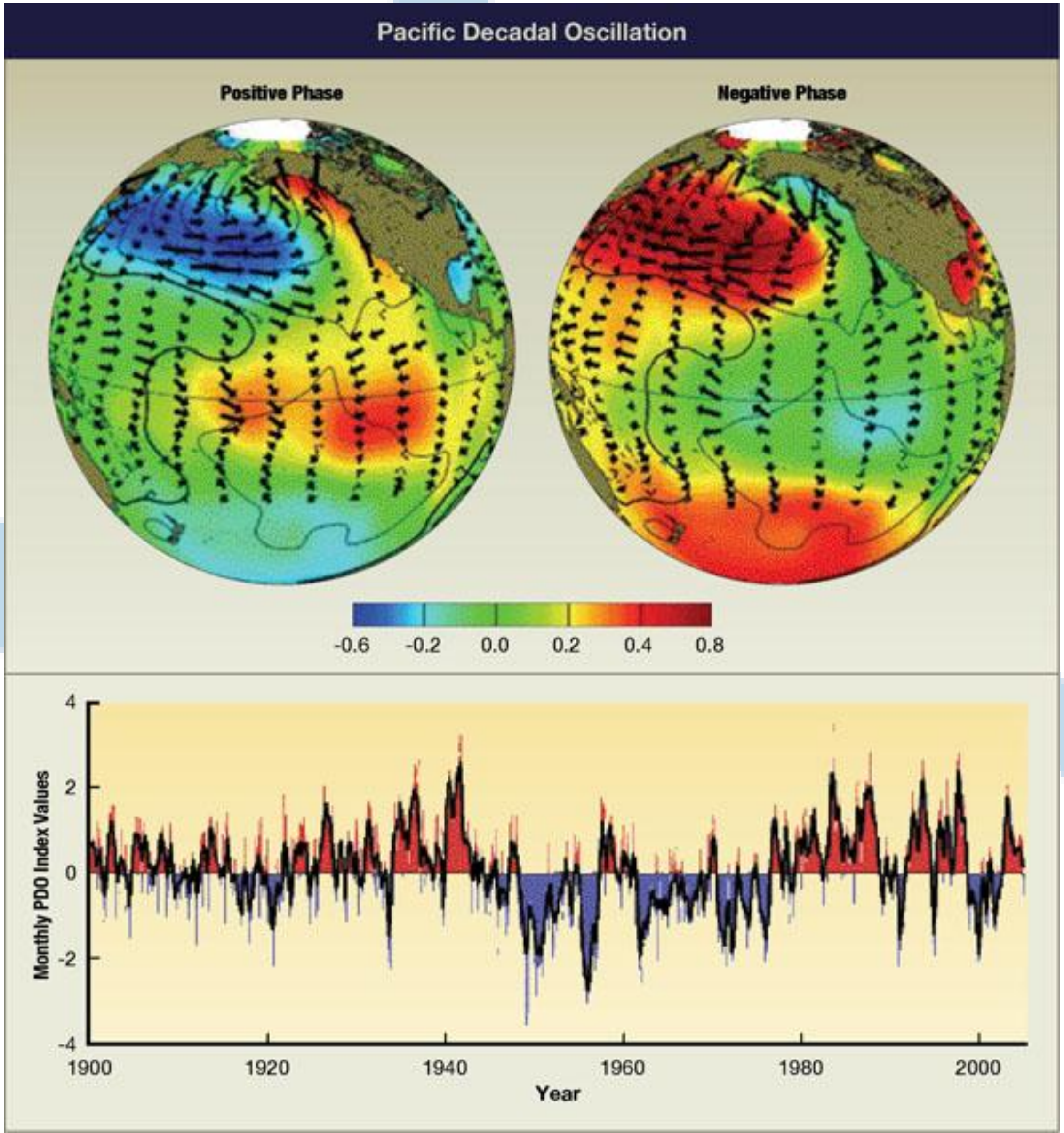


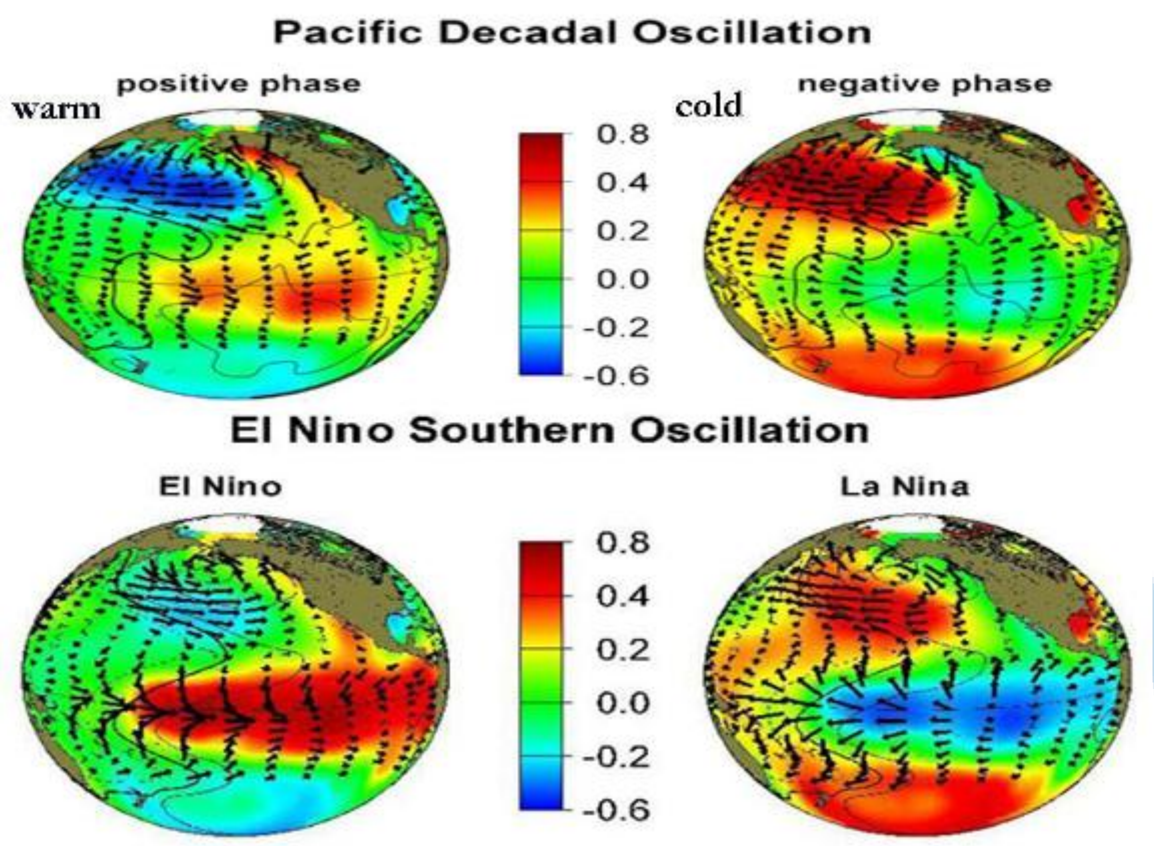
Foto del día Ciencias de la Tierra NASA, Mayo 23, 2003.

Poveda et al. 2001

The Pacific Decadal Oscillation

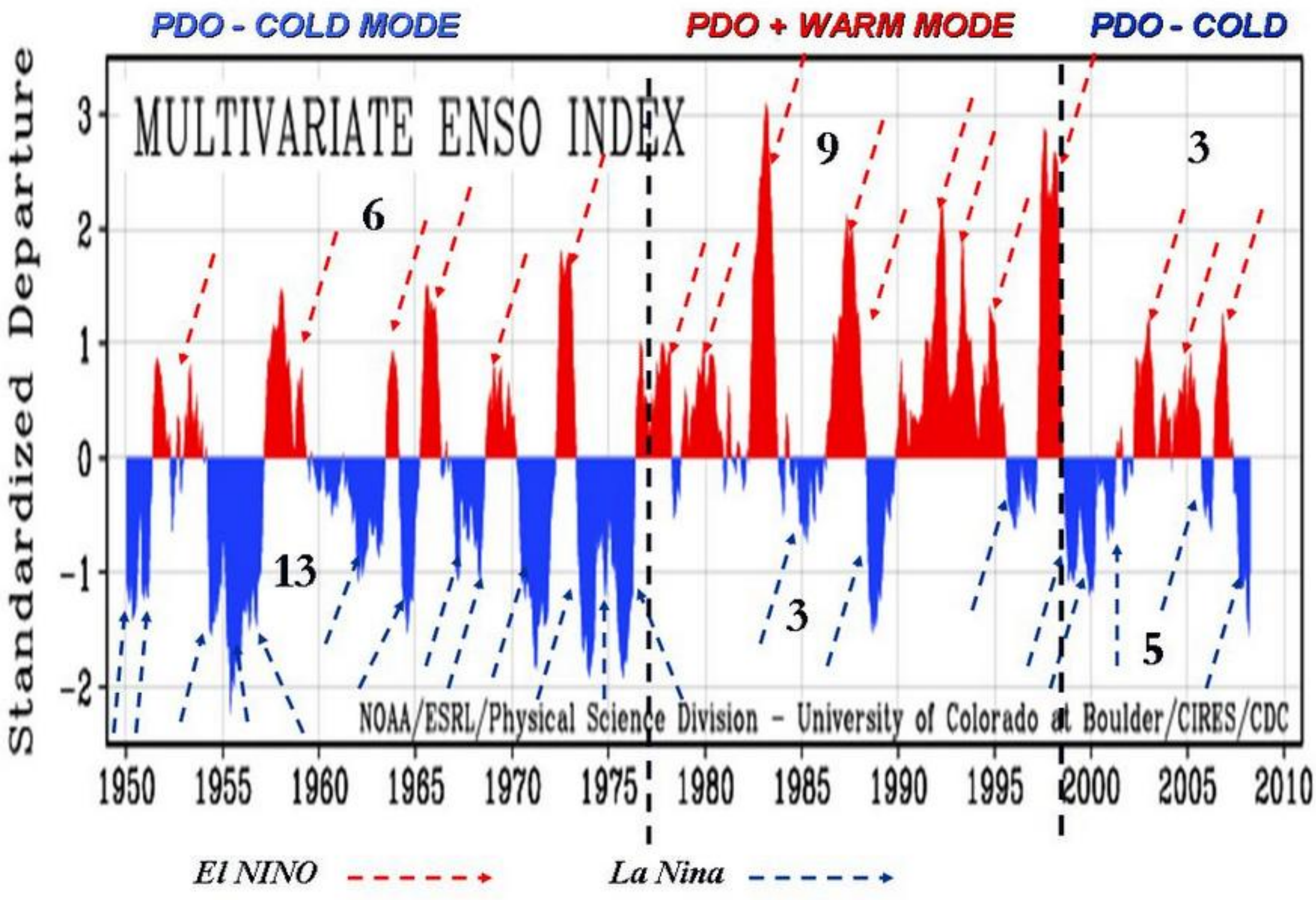


PDO & ENSO



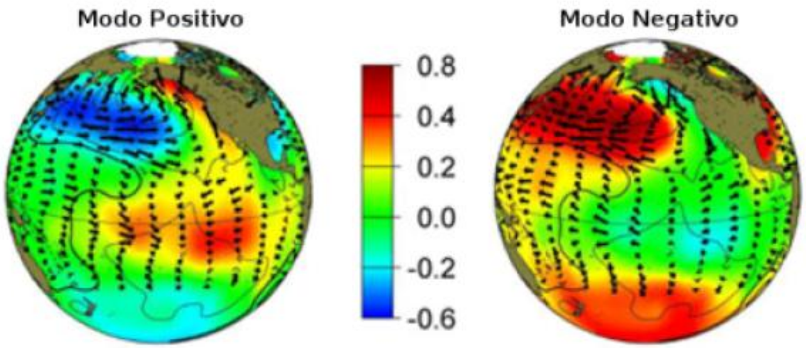
Pacific Decadal Oscillation
positive phase
warm
negative phase
cold
0.8
0.4
0.2
0.0
-0.2
-0.6
El Nino Southern Oscillation
El Nino
La Nina
0.8
0.4
0.2
0.0
-0.2
-0.6

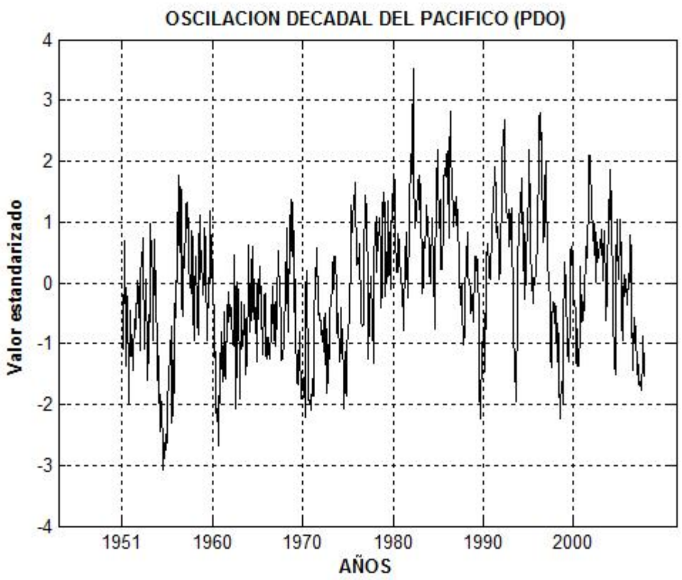
PDO & ENS0

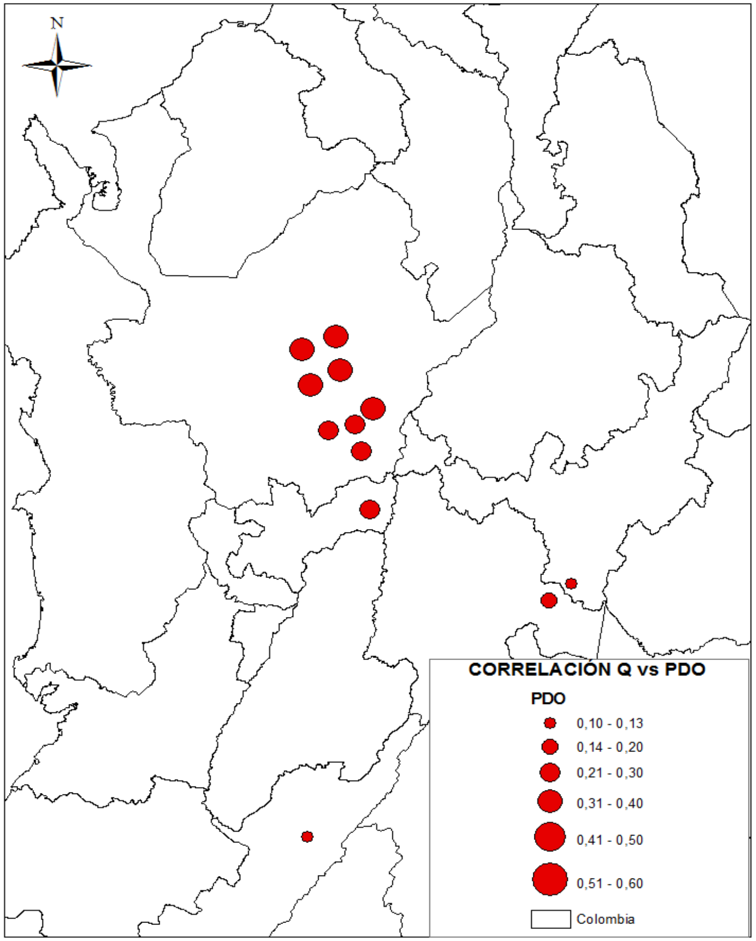


PDO - COLD MODE
PDO + WARM MODE
PDO - COLD
MULTIVARIATE ENSO INDEX
Standardized Departure
3
2
1
0
-1
-2
6
13
9
3
3
5
NOAA/ESRL/Physical Science Division - University of Colorado at Boulder/CIRES/CDC
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
El NINO
La Nina

PACIFIC DECADAL OSCILLATION (PDO)





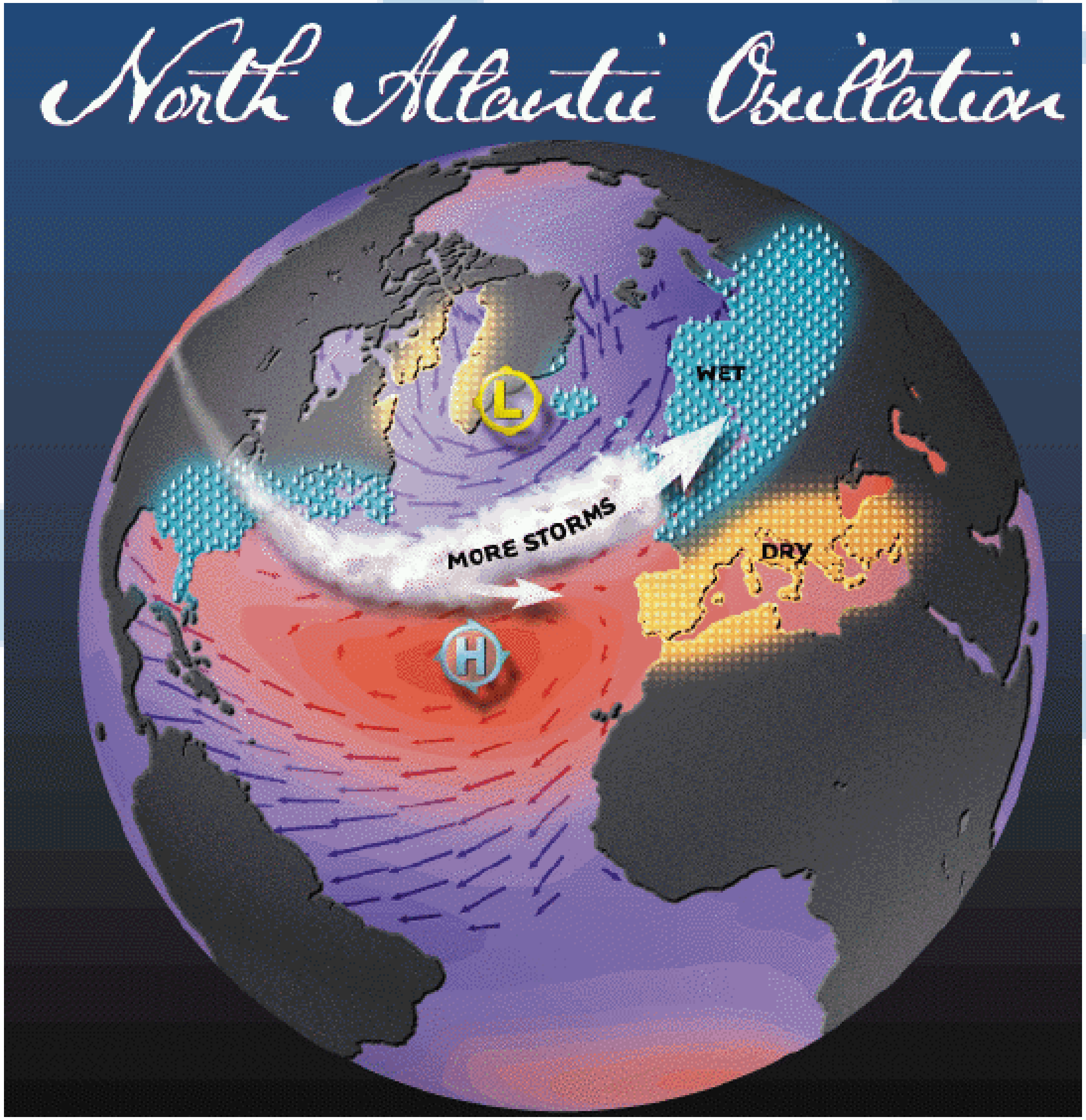


Rojo & Carvajal . (2011)

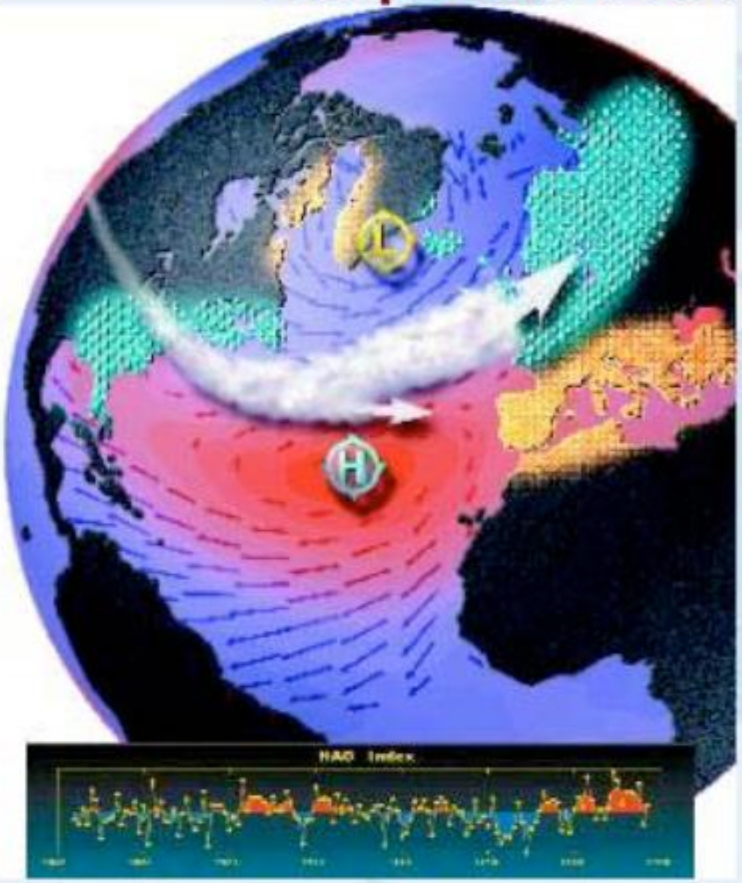
UNIVERSIDAD NACIONAL DE COLOMBIA SEDE MEDELLÍN

POSGRADO EN APROVECHAMIENTO DE RECURSOS HIDRÁULICOS

North Atlantic Oscillation (NAO)



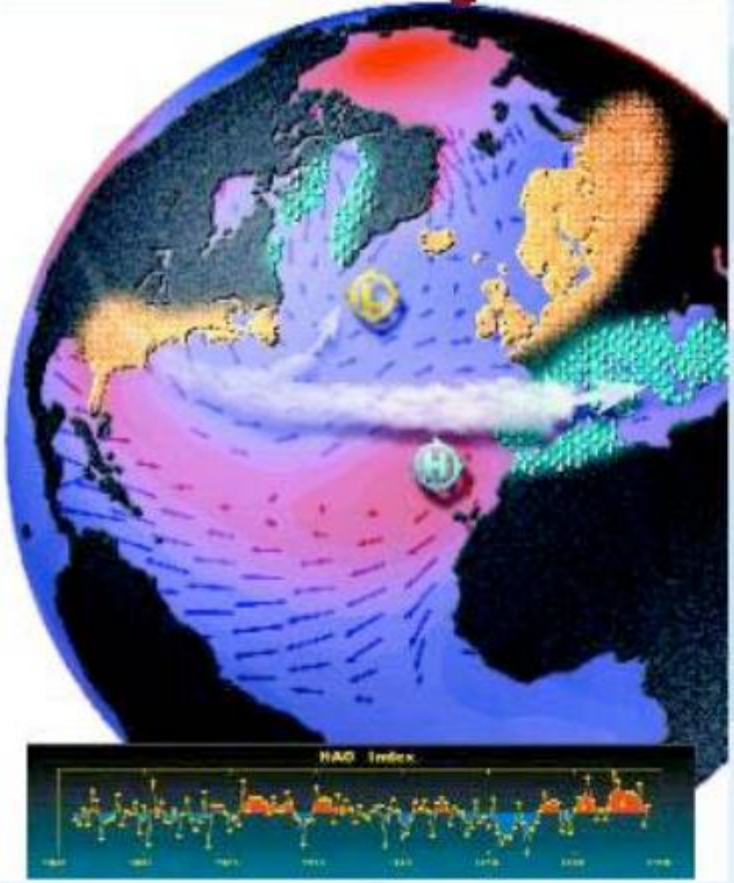
The positive NAO index phase



- The positive NAO index phase shows a stronger than usual subtropical high pressure center and a deep than normal Icelandic low.
- The increased pressure difference results in more and stronger winter storms crossing the Atlantic Ocean on a more northerly track.
- This results in warm and wet winters in Europe and in cold and dry winters in northern Canada and Greenland.
- The eastern US experiences mild and wet winter conditions.

Martin Visbeck Feb04, 2000

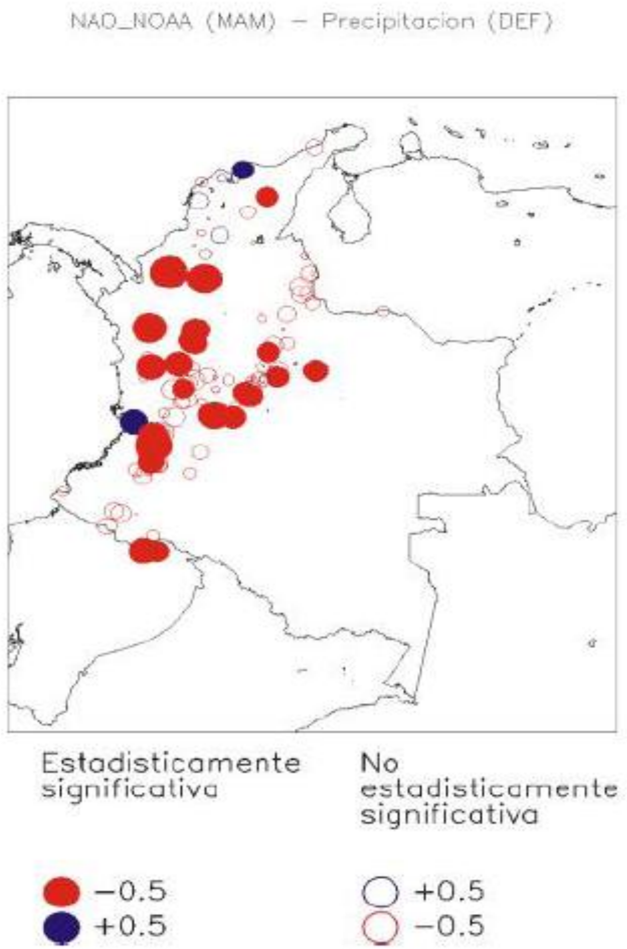
The negative NAO index phase

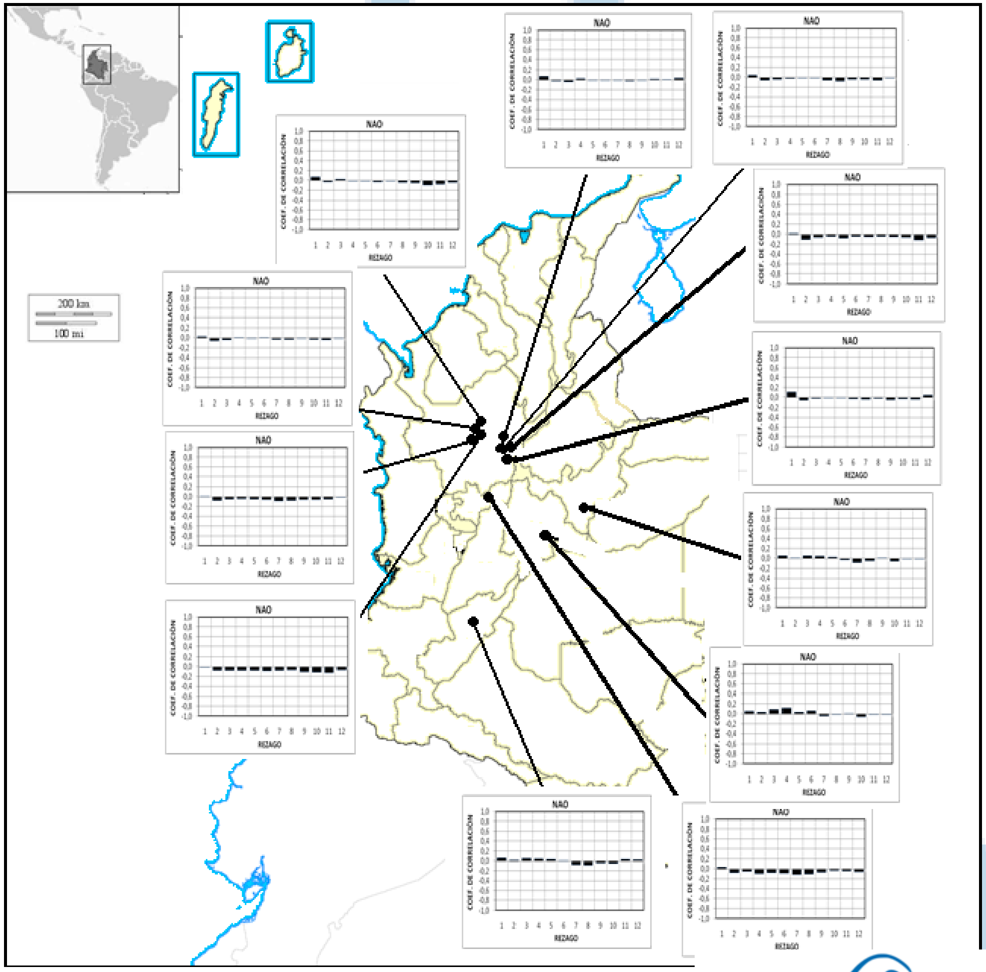


- The negative NAO index phase shows a weak subtropical high and weak Icelandic low.
- The reduced pressure gradient results in fewer and weaker winter storms crossing on a more west- east pathway.
- They bring moist air into the Mediterranean and cold weather to northern Europe.
- The US east cost experiences more cold air outbreaks and hence snowy winter conditions.
- Greenland, however, will have milder winter temperatures.

Martin Visbeck Feb04, 2000

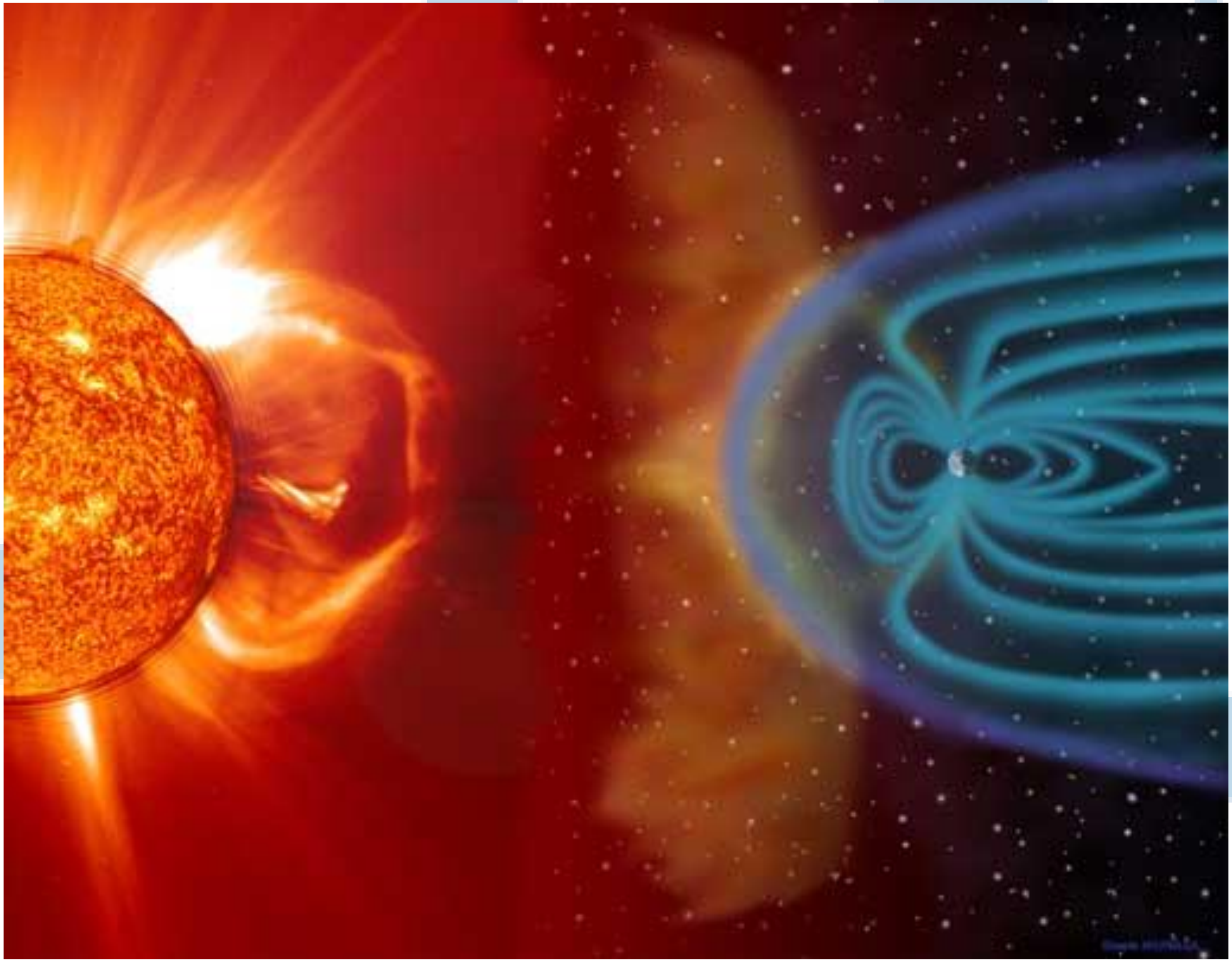
THE NORTH ATLANTIC OSCILLATION (NAO)



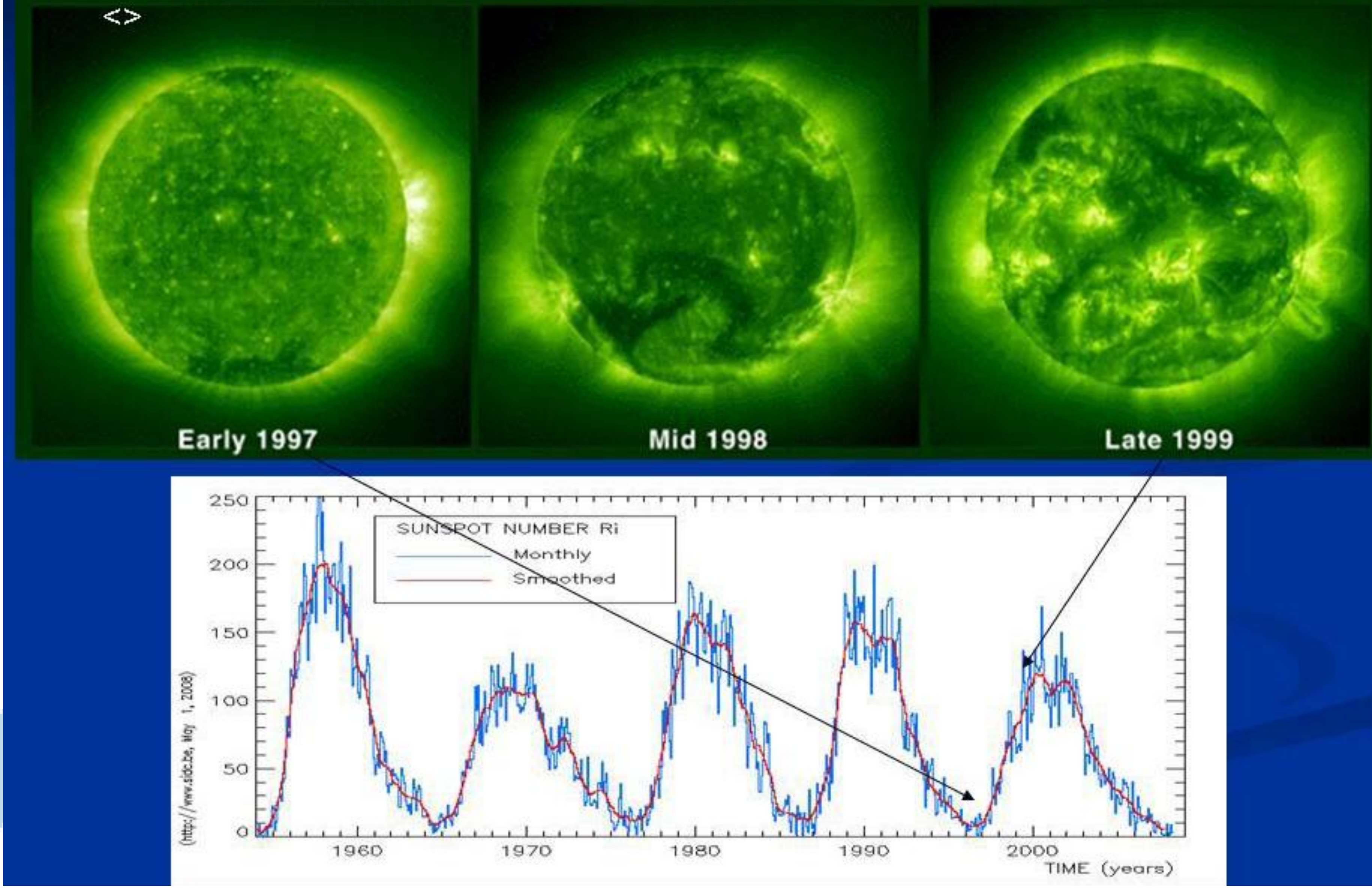


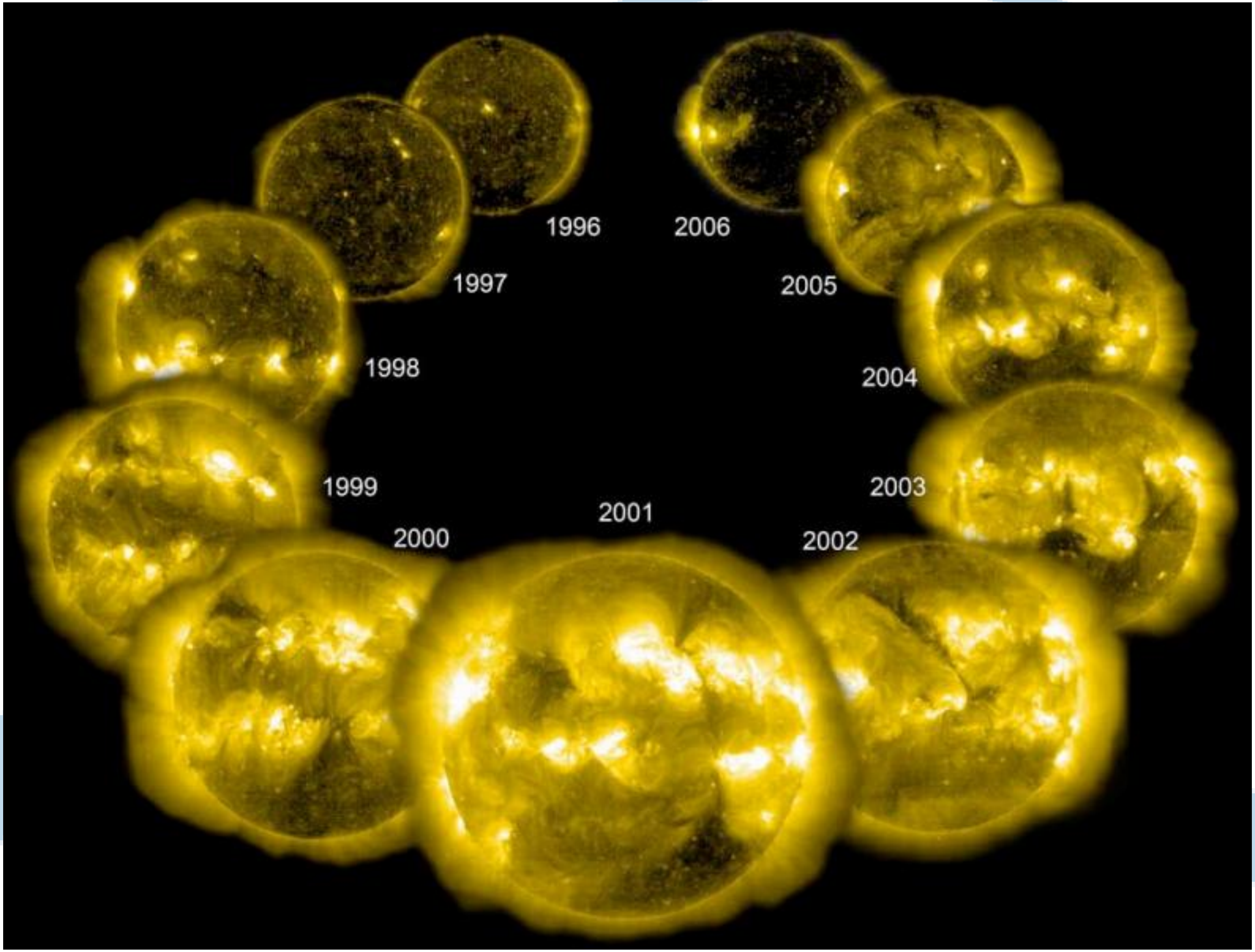
Poveda . (2004)

THE SUN

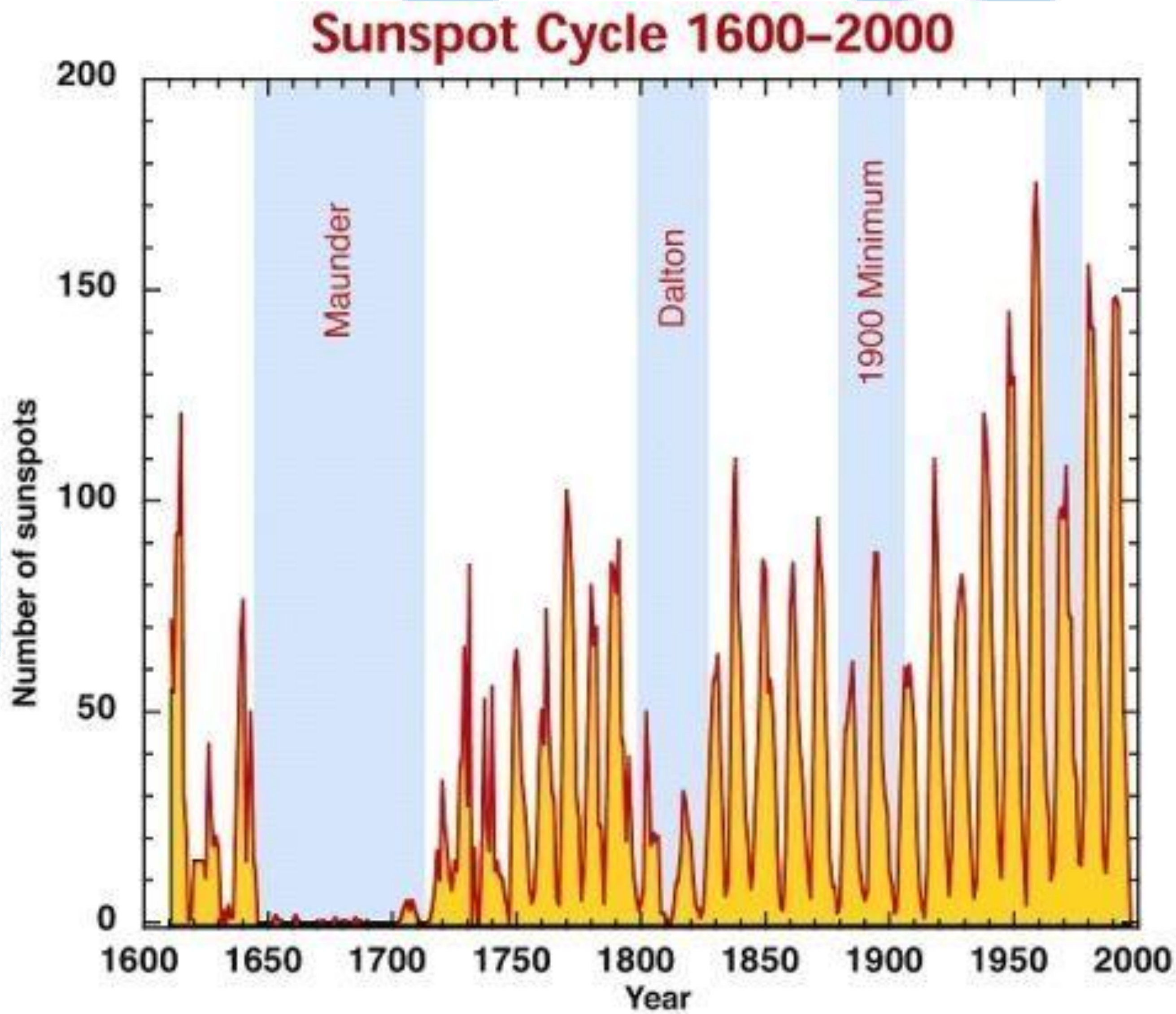


11 YEAR SOLAR SUNSPOT CYCLE

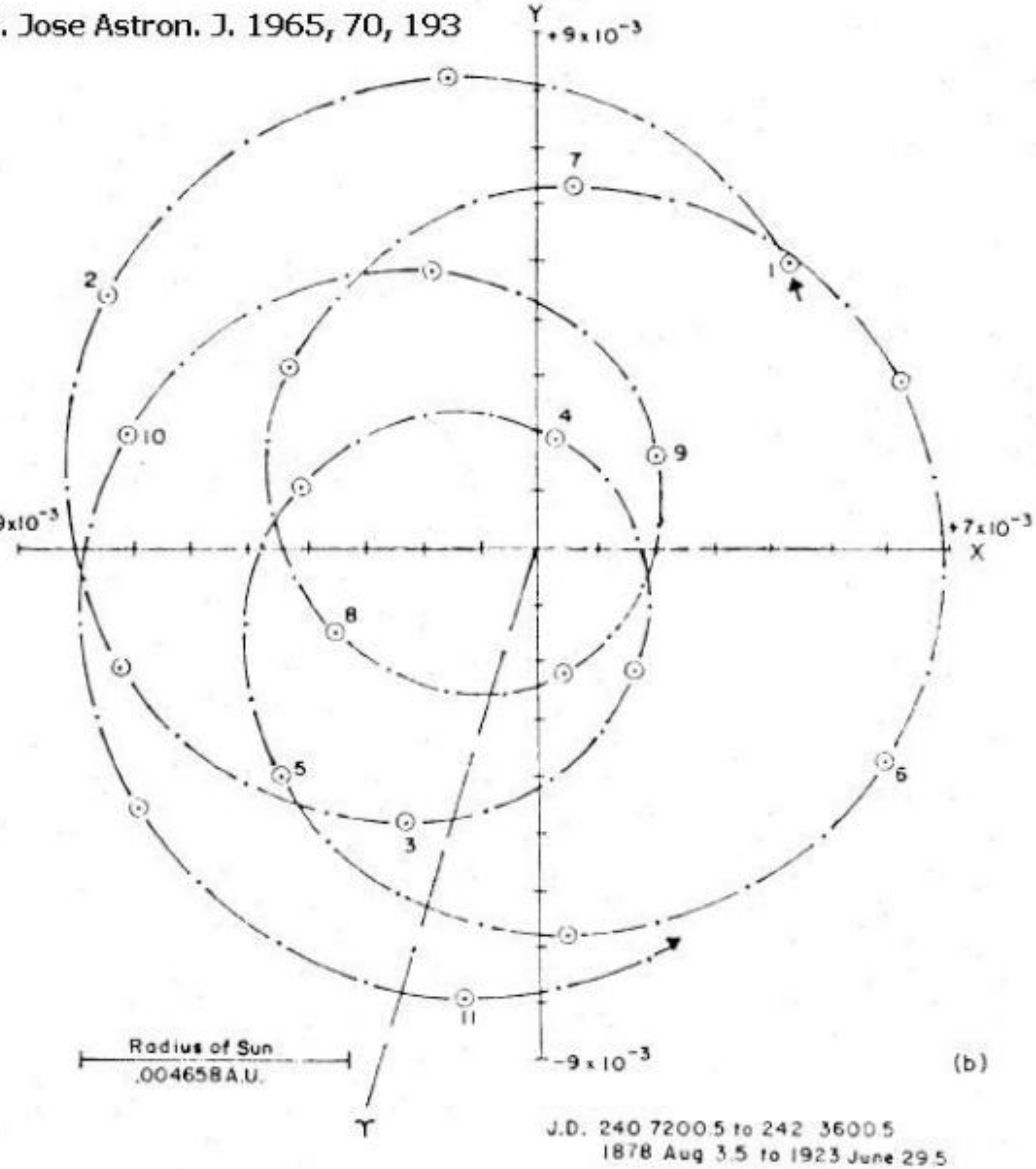



1996
2006
1997
2005
1998
2004
1999
2003
2001
2000
2002

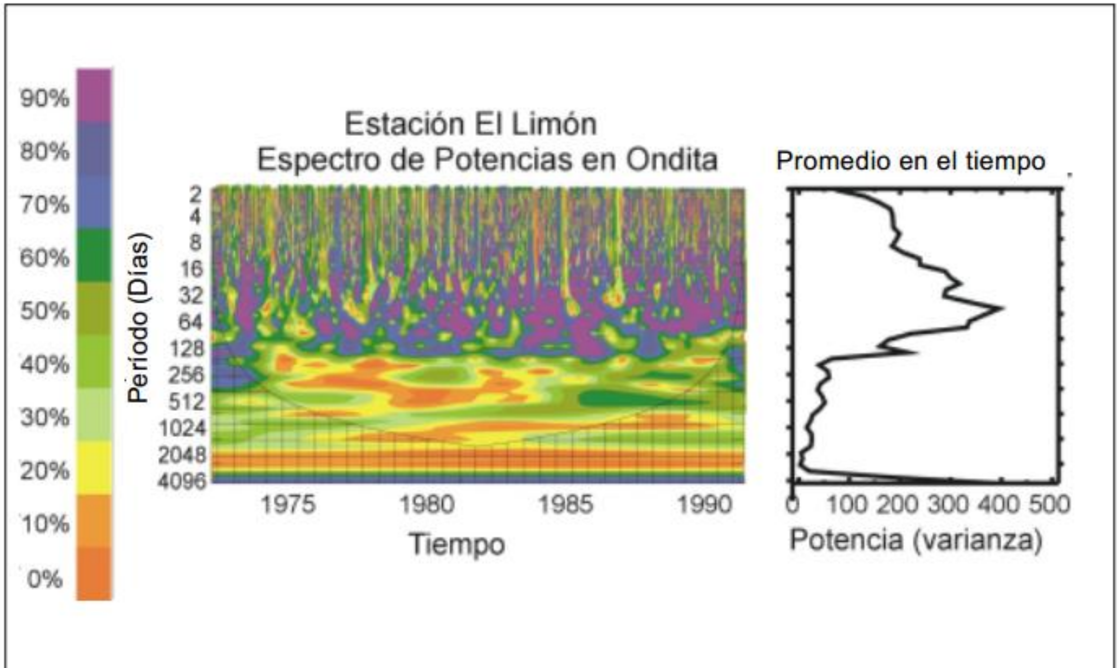
Sunspot Cycle 1600-2000

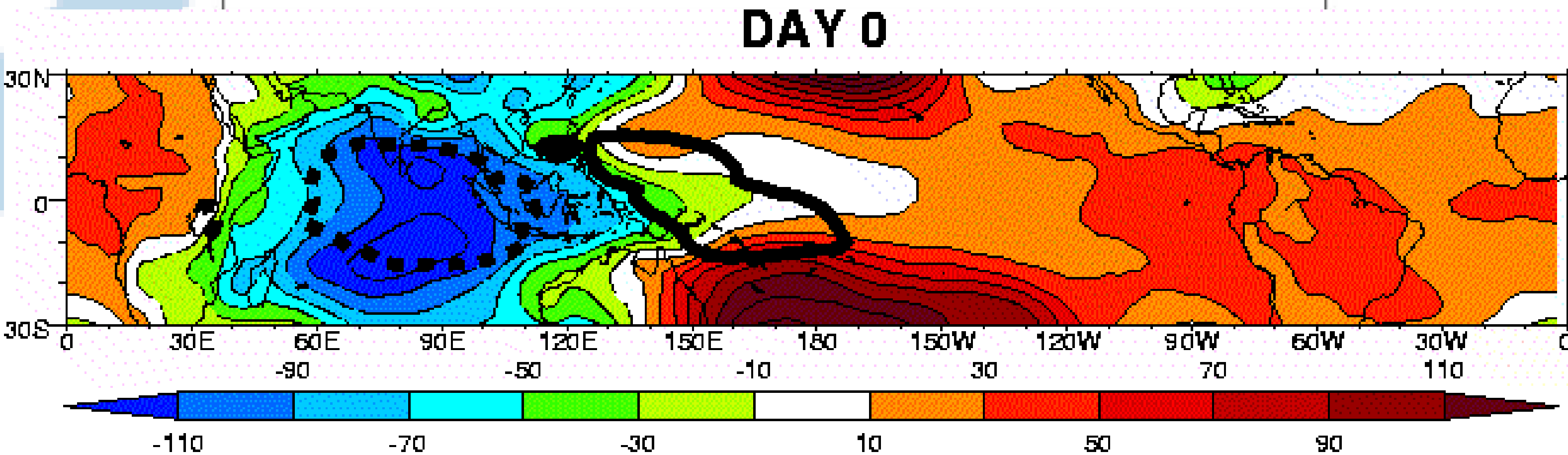


P. Jose Astron. J. 1965, 70, 193



Madden Julian Oscillation





Diurnal Cicle - ENSO

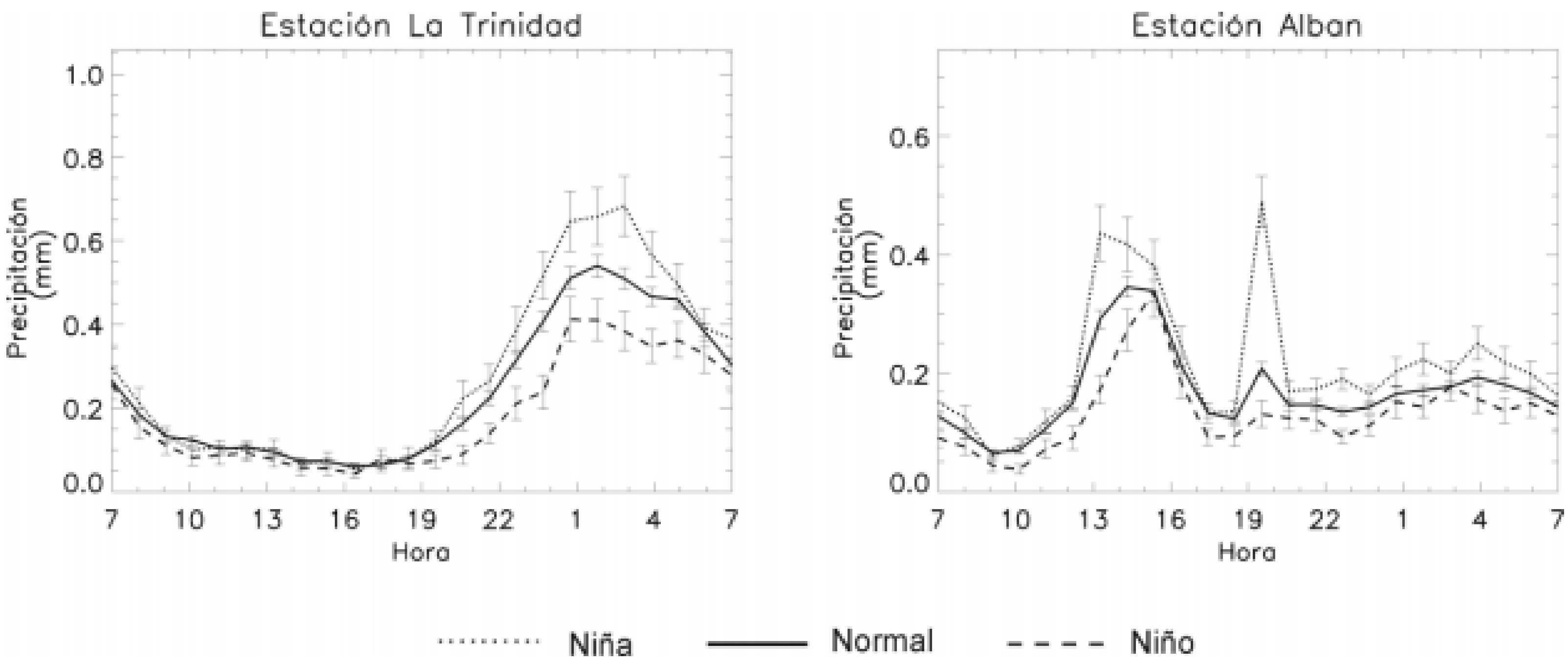


Figura 1. Ciclo diurno multianual durante las fases del ENSO y en años normales para las estaciones La Trinidad y Alban

Diurnal Cicle - MJO

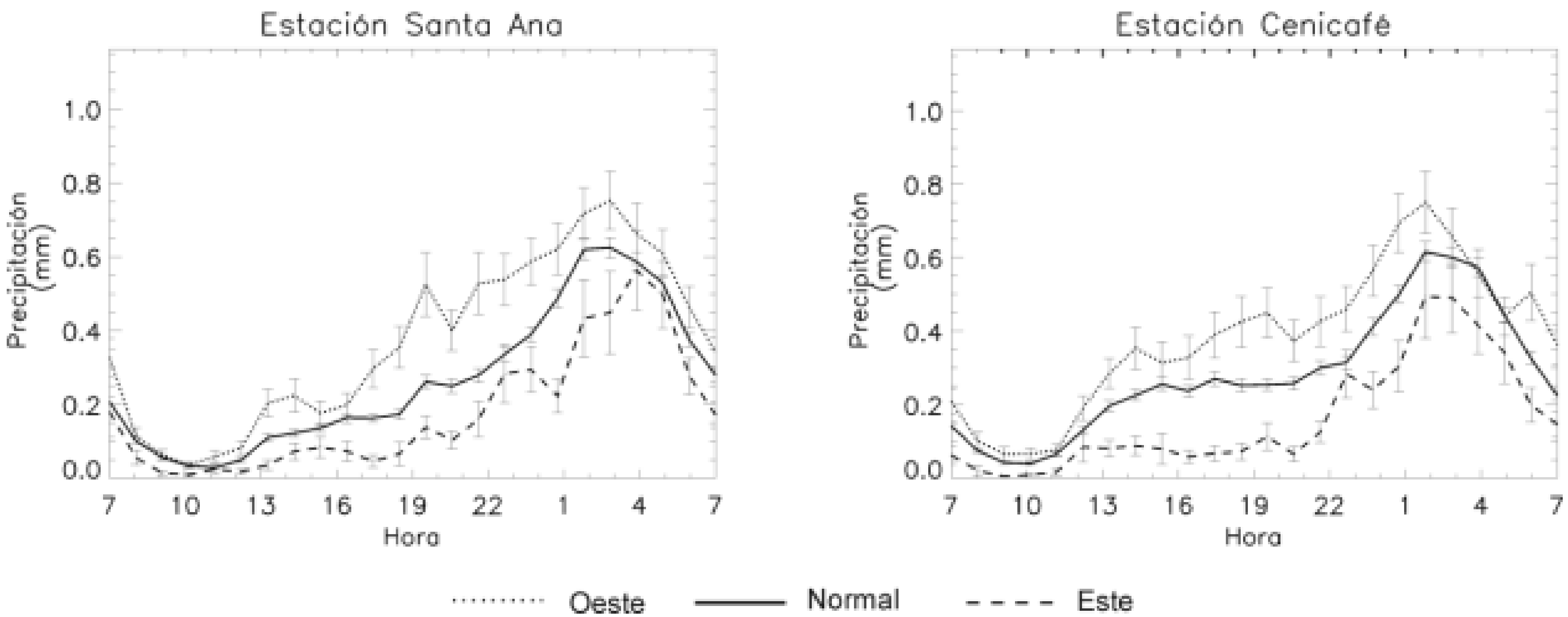
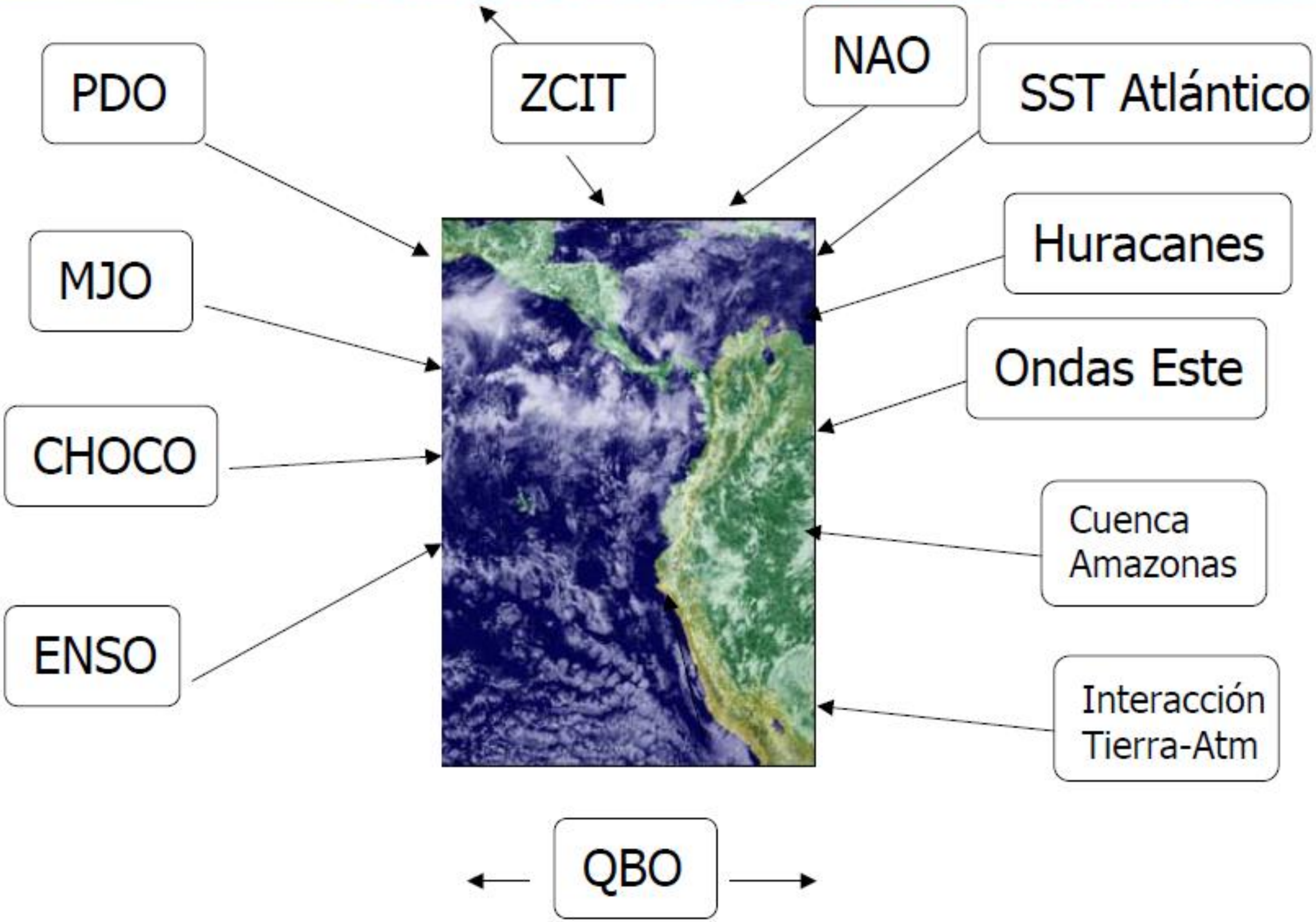


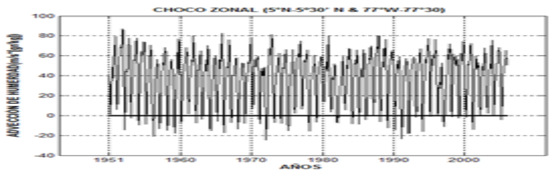
Figura 2. Ciclo diurno multianual durante la fase este y la fase oeste de la MJO y en períodos normales, para las estaciones Santa Ana y Cenicafé

No solo es ENSO. Hay una combinación de fenómenos de distintas frecuencias

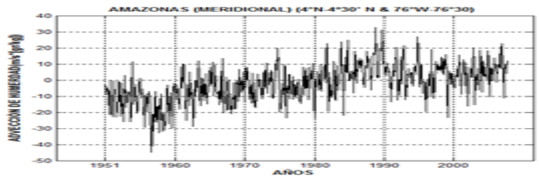


THE LONGER LEAD HYDROLOGY

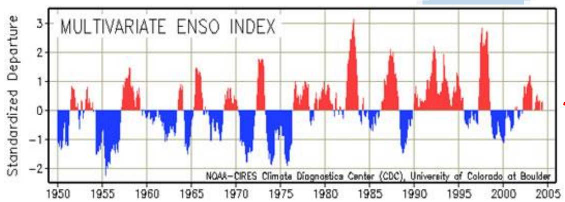
CHOCO



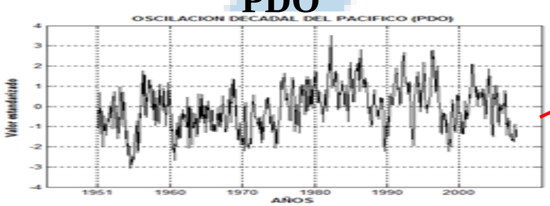
AMAZONAS



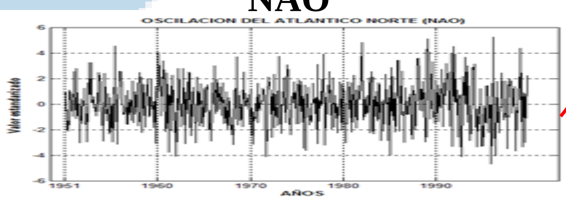
MEI



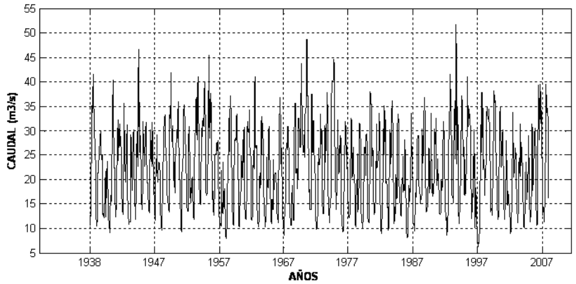
PDO



NAO



$$f(\ldots)+\varepsilon=$$



$$Caudales_t = f\left(Caudales_{t-j}, ENSO_{t-k}, CHOCO_{t-l}, \ldots\right)+\varepsilon$$

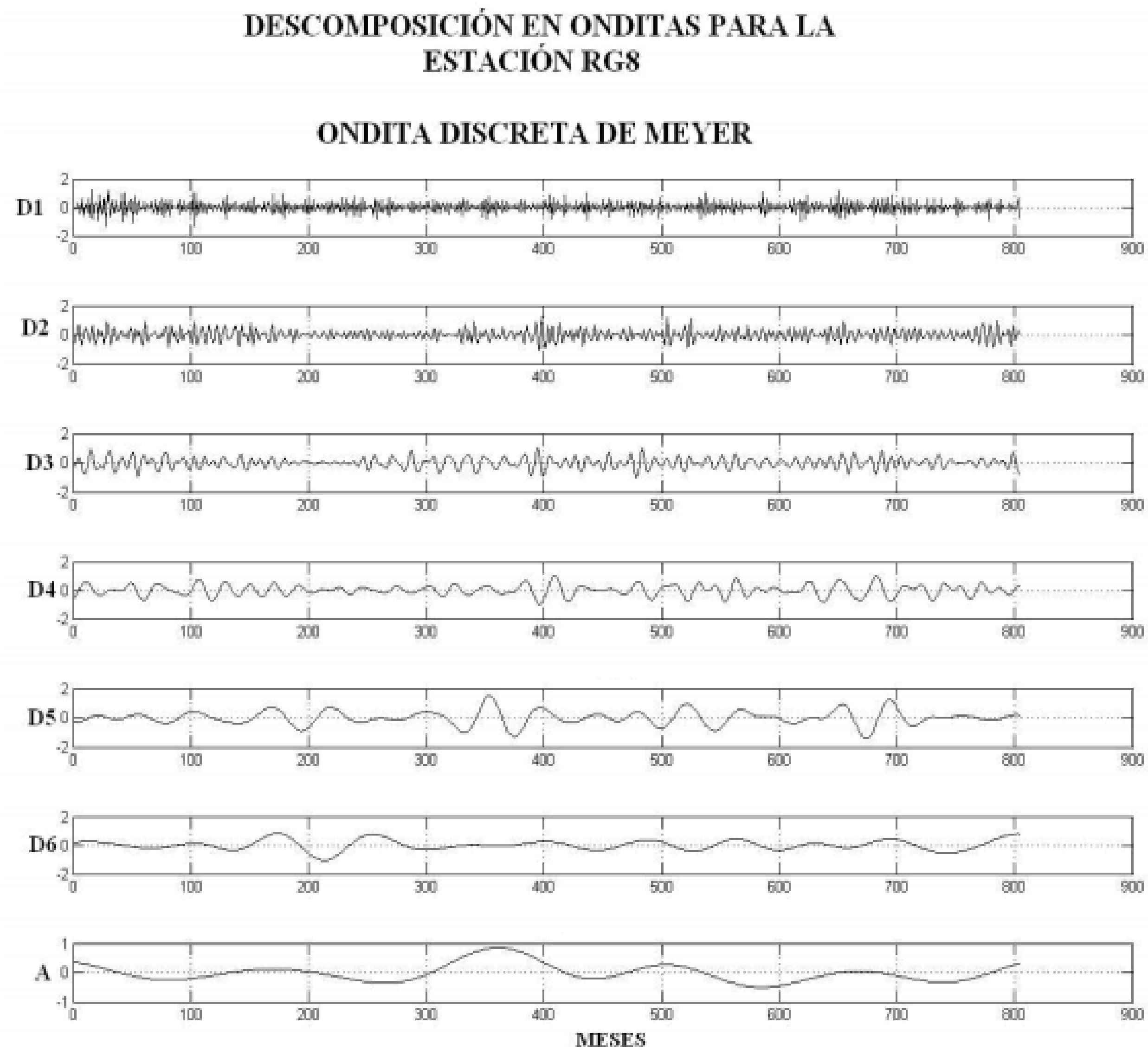


Figura 4.- Descomposición en onditas de la serie RG8 (río Grande) usando la ondita discreta de Meyer

AGRADECIMIENTOS

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Libertad y Orden

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IAI

UNIVERSIDAD NACIONAL DE COLOMBIA
SEDE MEDELLÍN

TRABAJO Y RECTITUD
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MEDELLIN - COLOMBIA

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