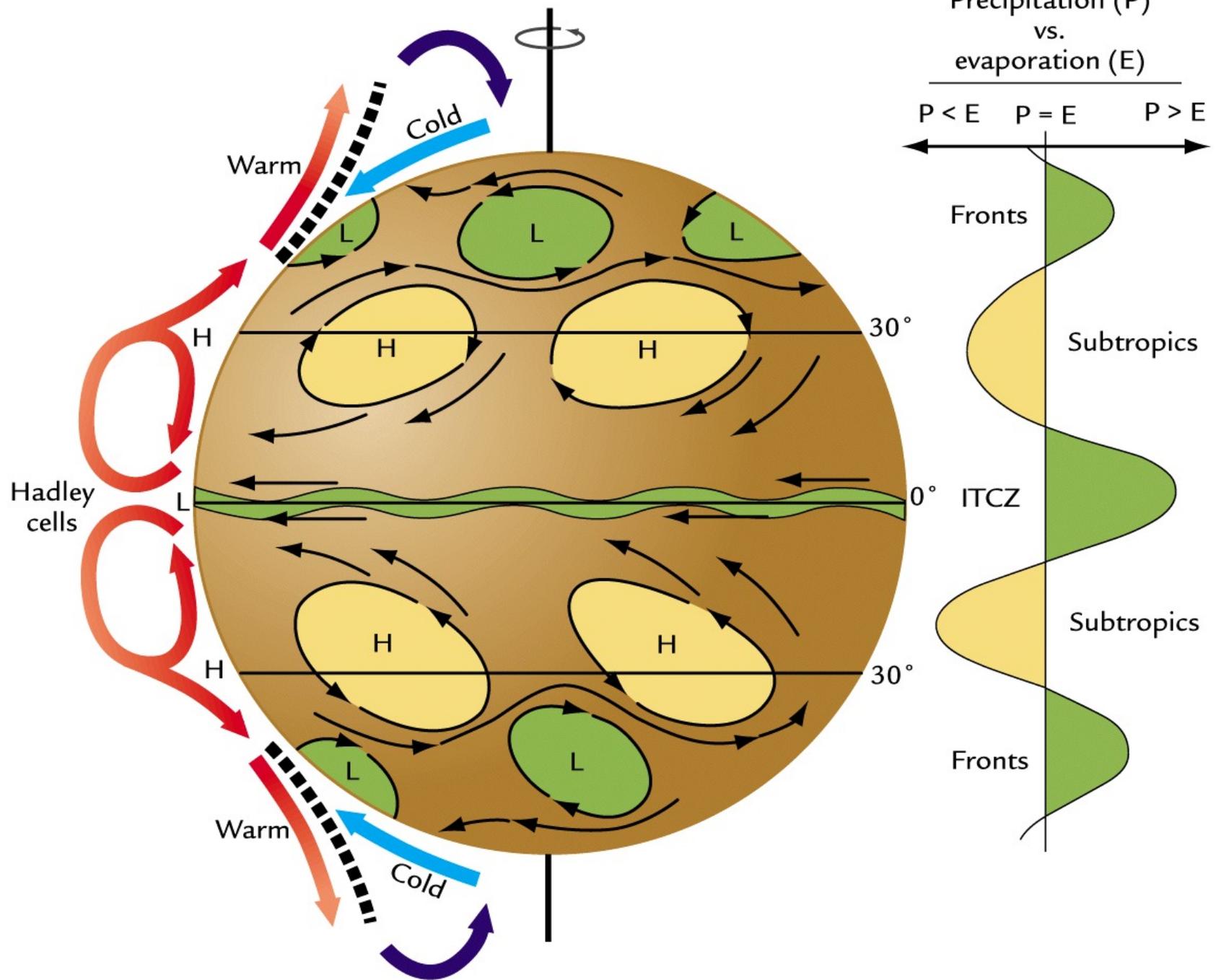
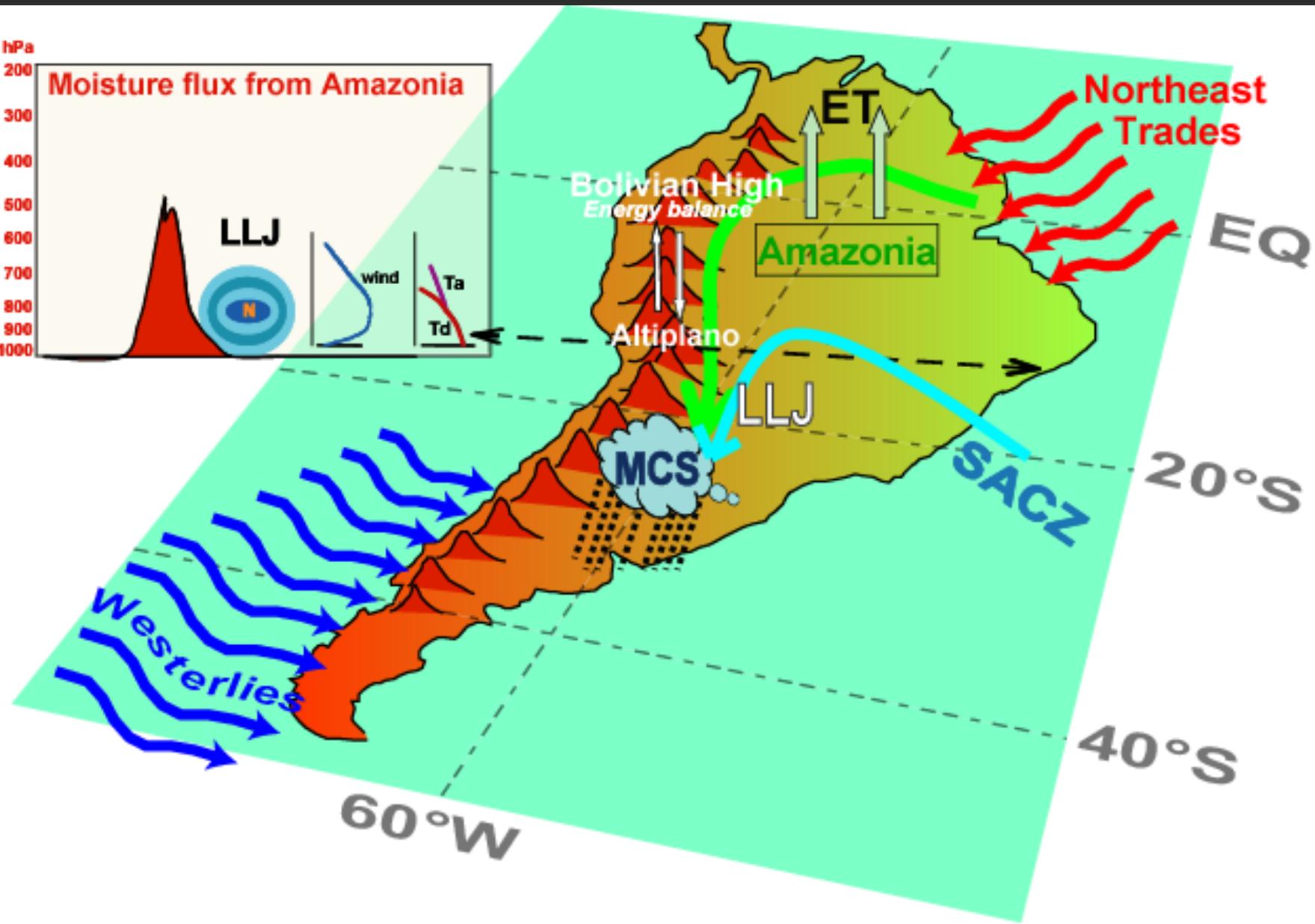
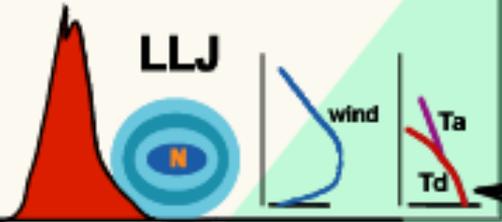


The Andes: Physical and climatic context

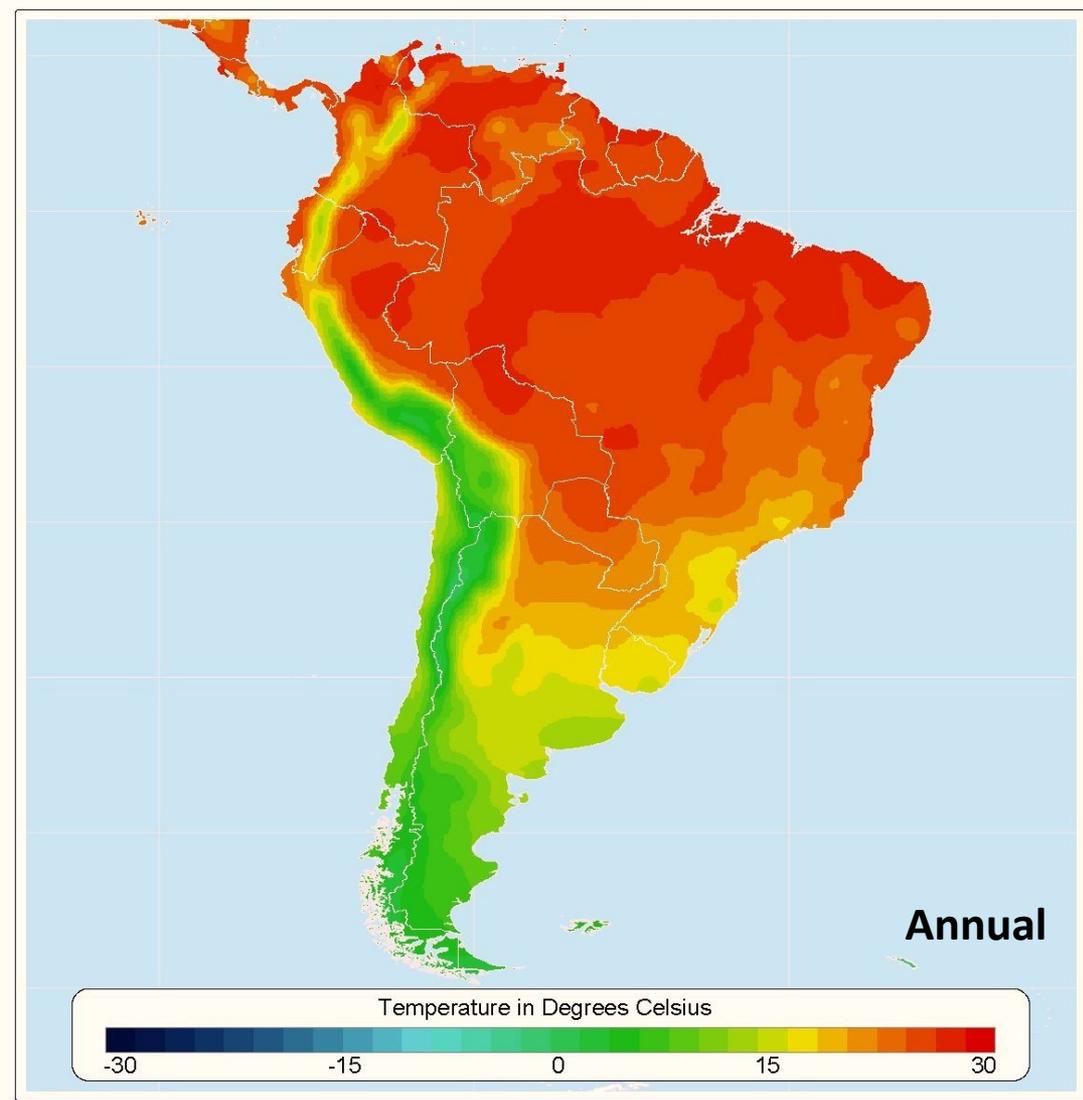


hPa
200
300
400
500
600
700
800
900
1000

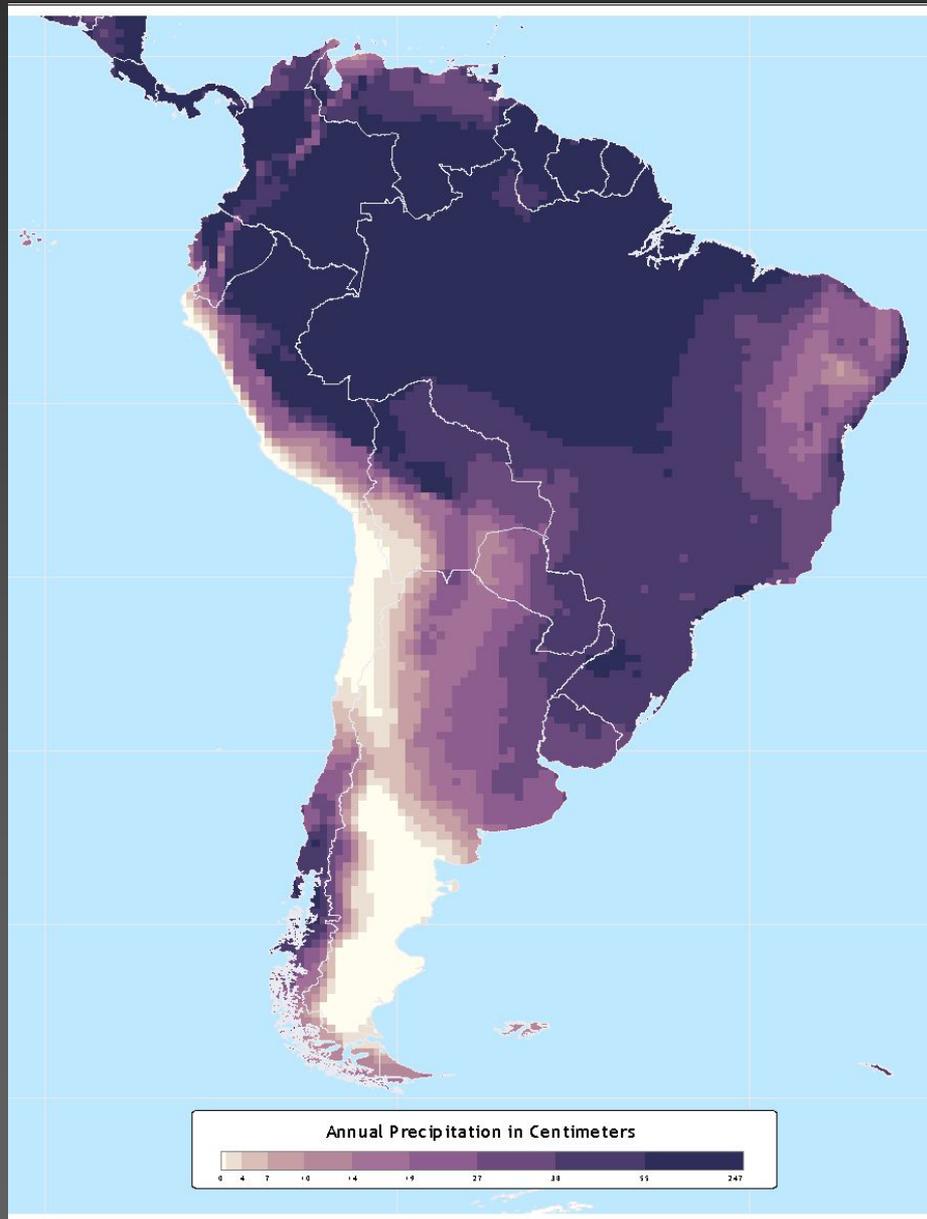
Moisture flux from Amazonia



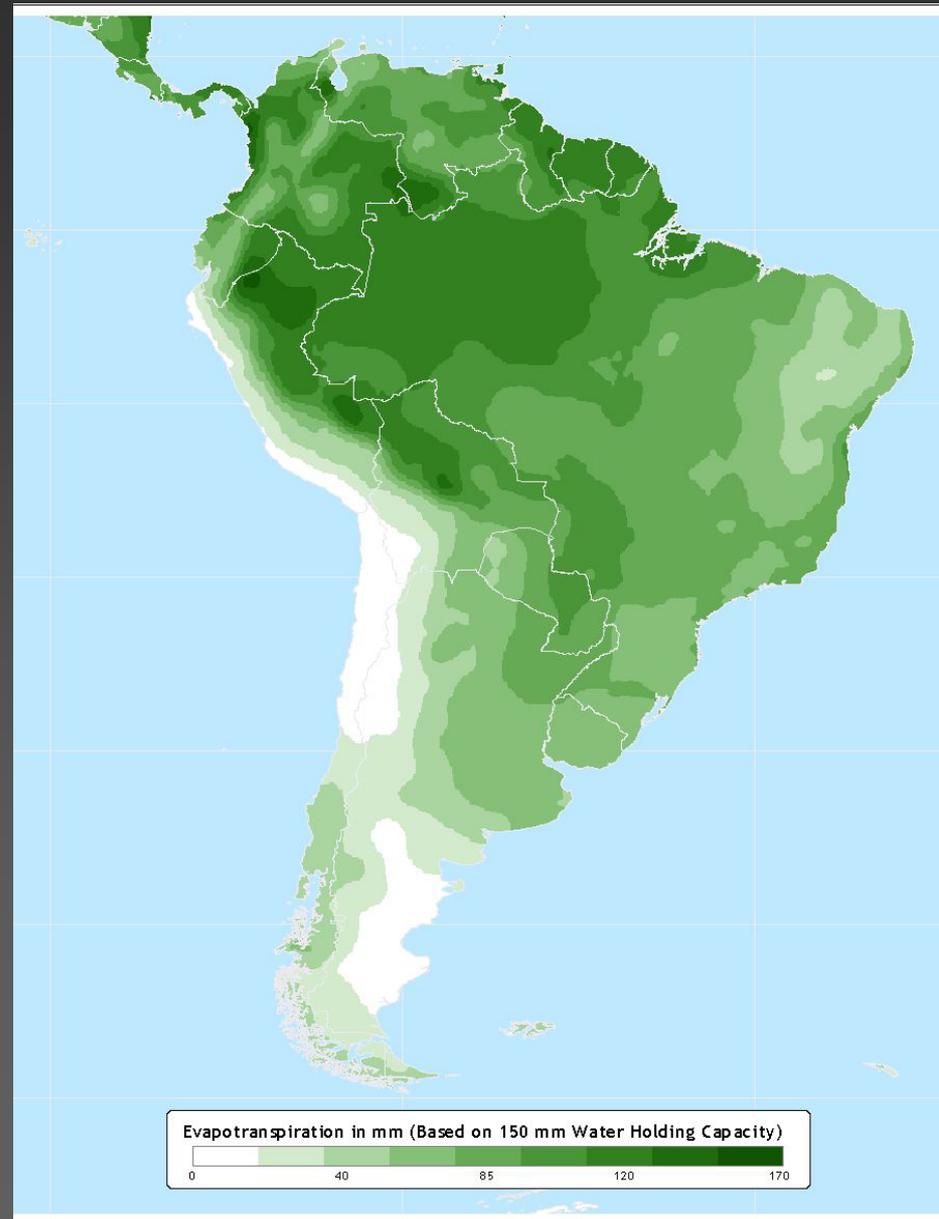
South America Temperature



Annual Precipitation



Annual Evapotranspiration

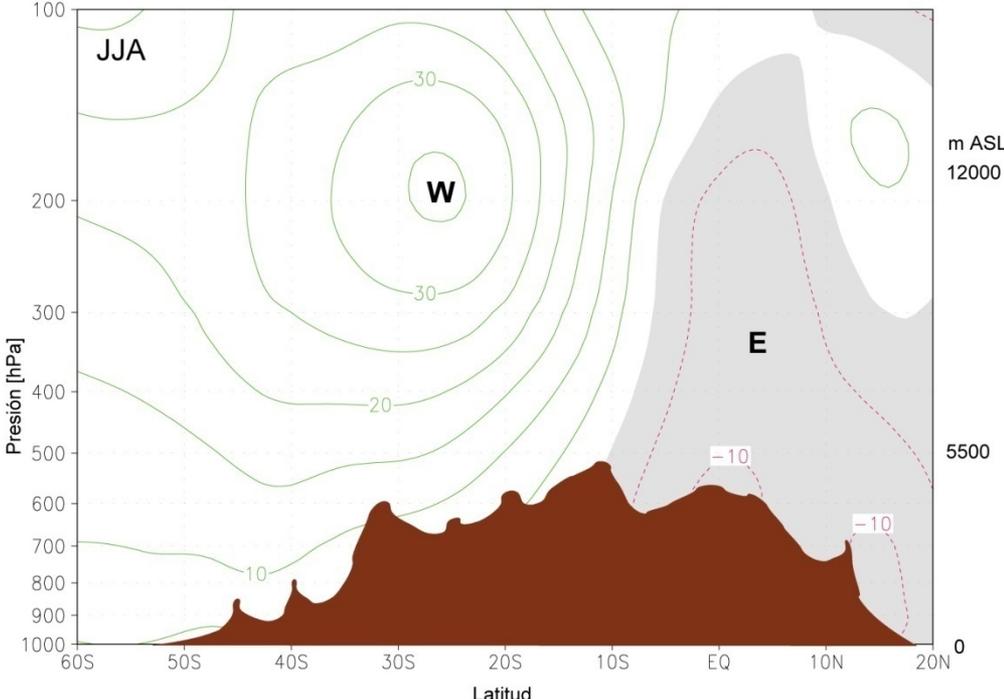
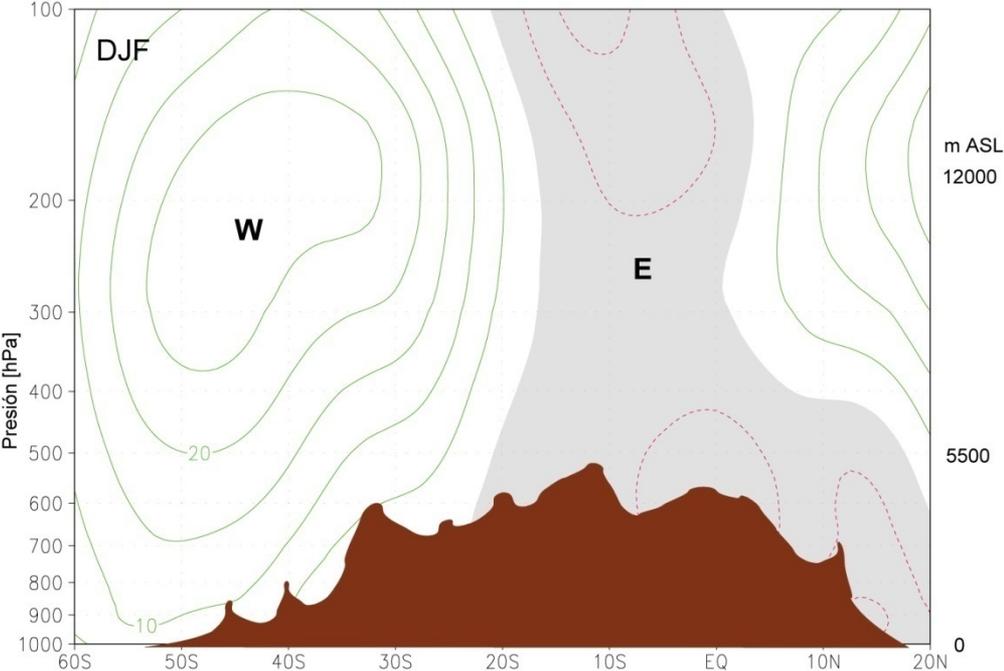




Mean zonal wind across the Andes averaged between 80–60W, for austral summer (DJF, top) and winter (JJA, bottom).

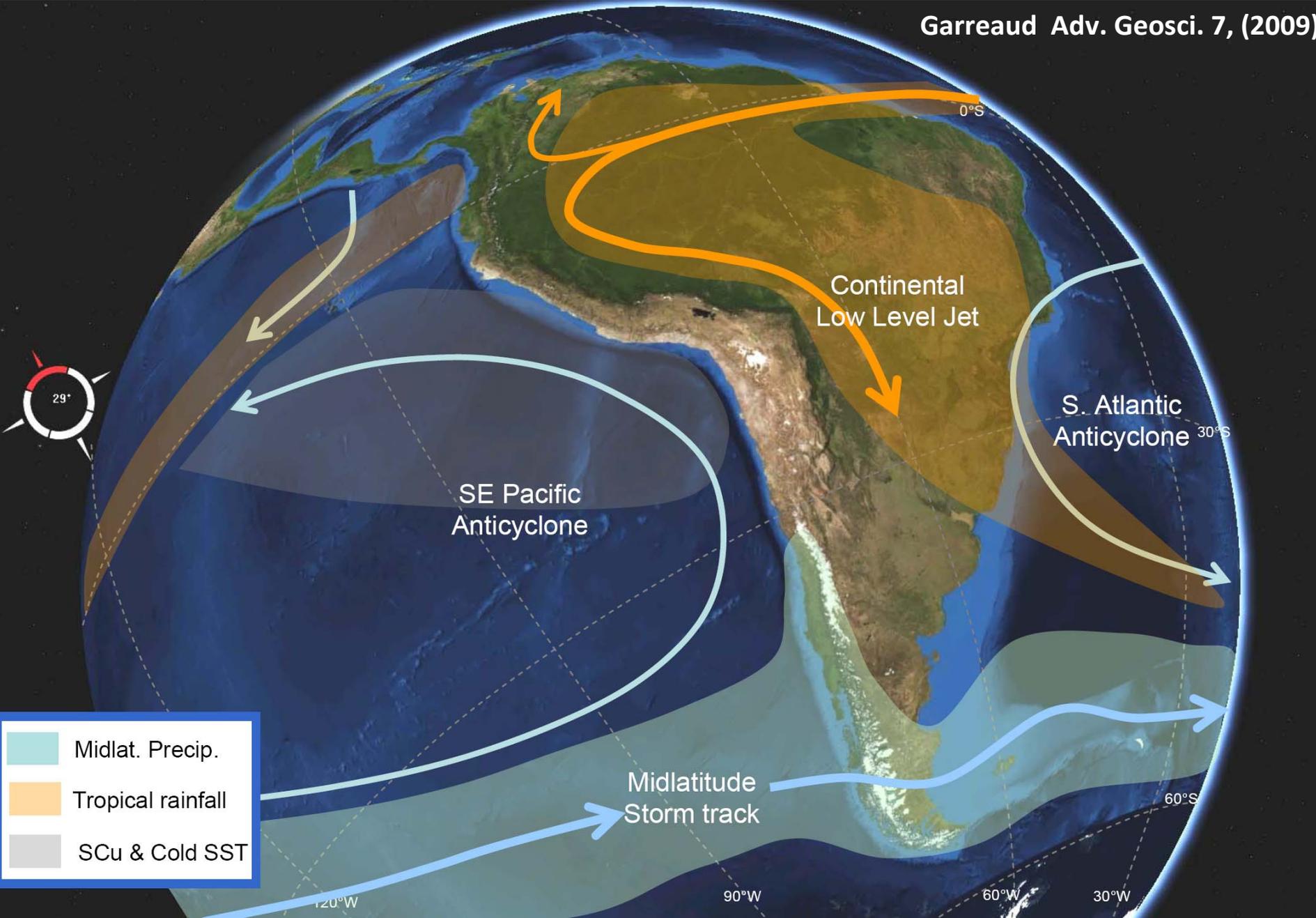
Data source: NCEP-NCAR reanalysis (Kalnay et al., 1996).

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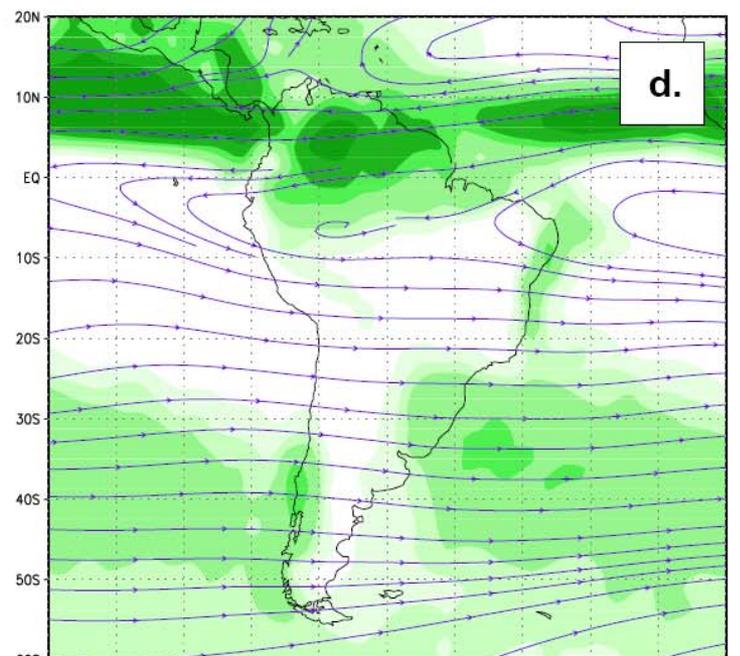
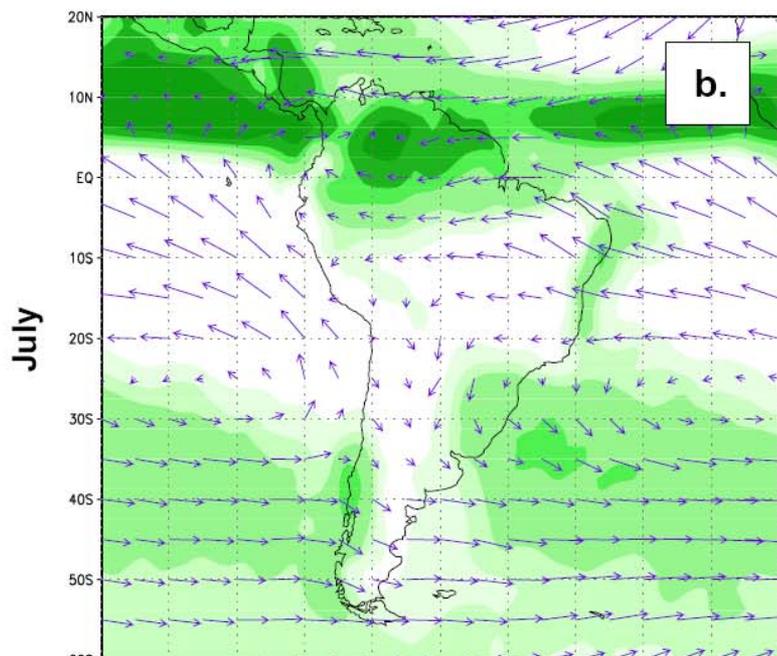
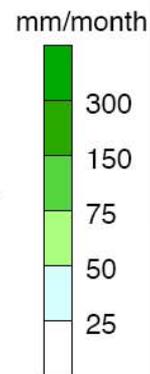
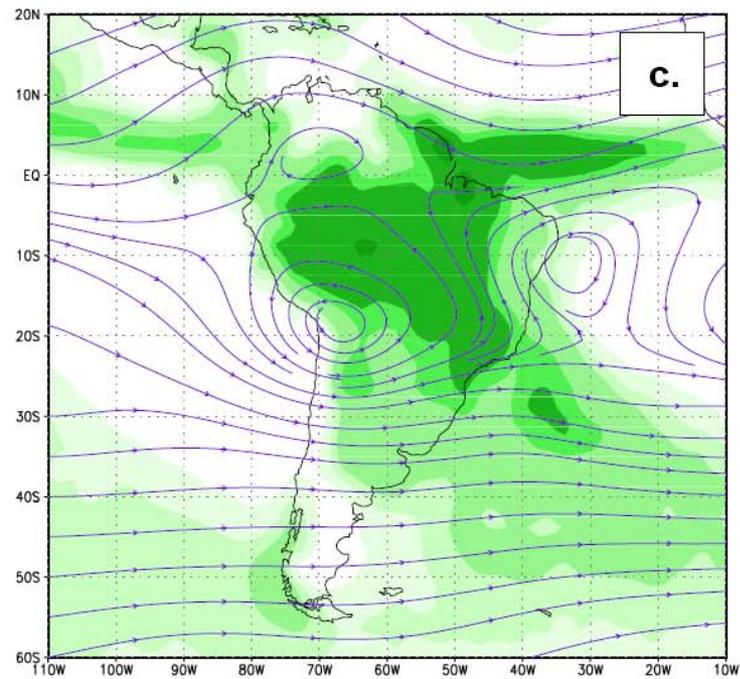
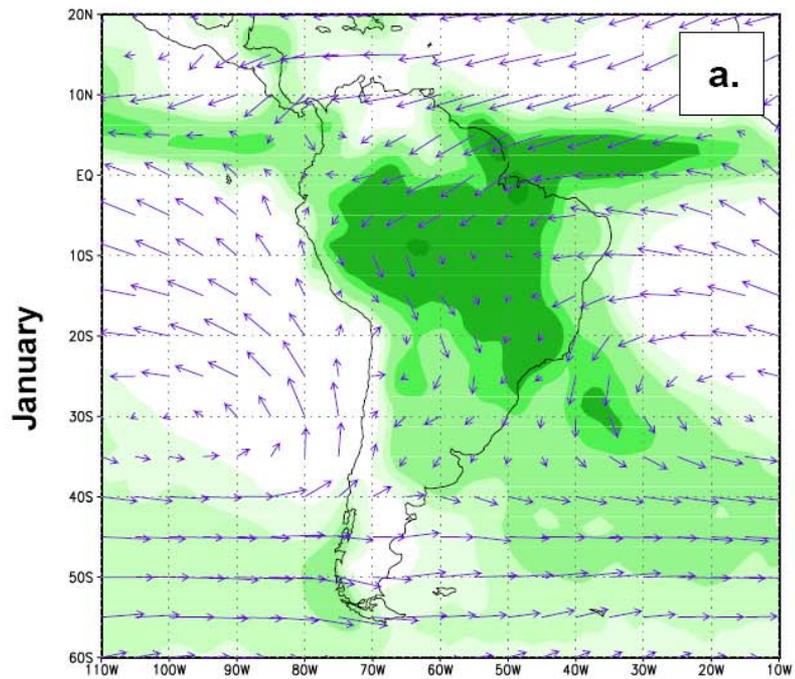
Low-level atmospheric flow around the Andes Cordillera (< 1.5 km)

Garreaud Adv. Geosci. 7, (2009)



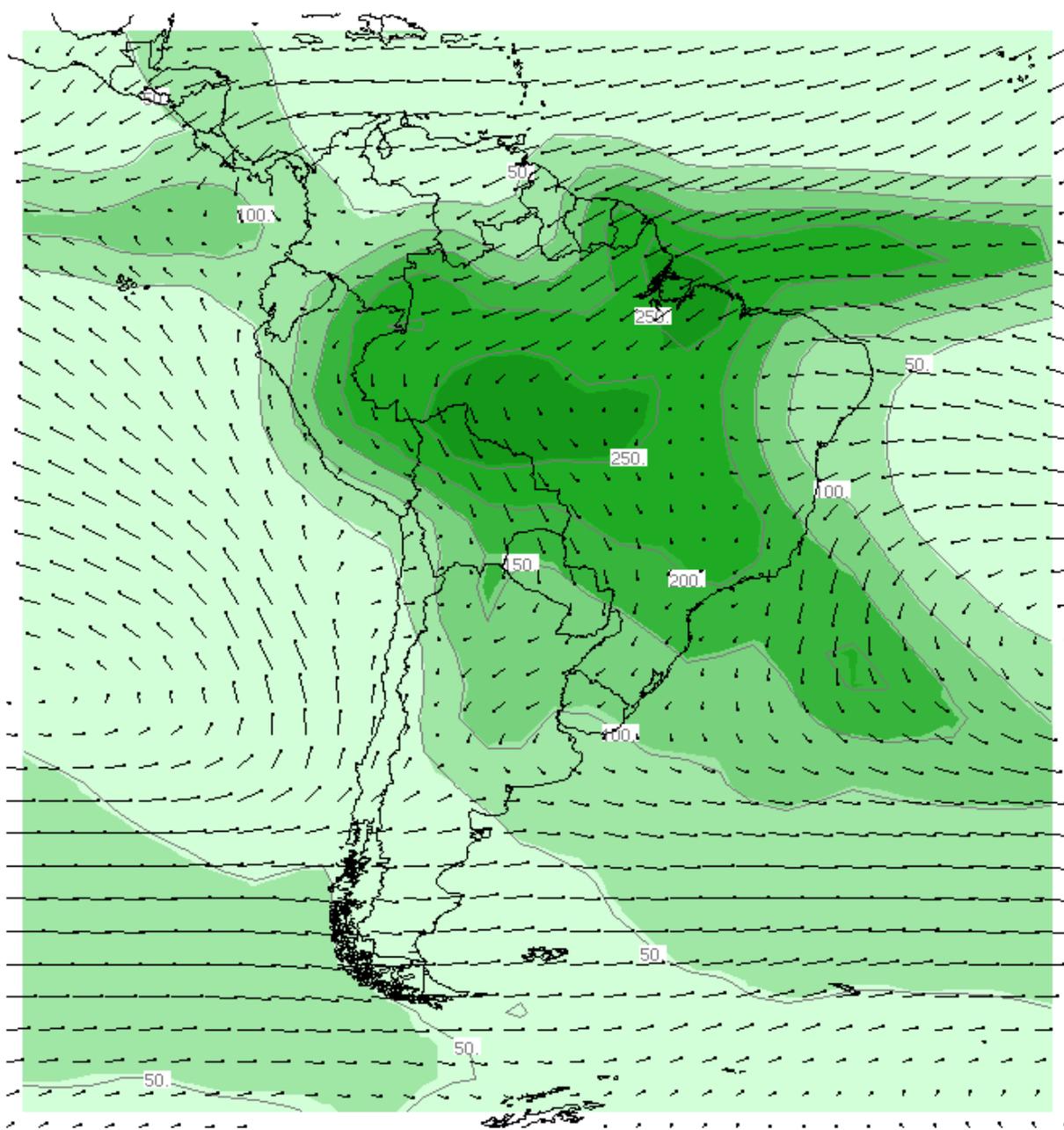
Precipitation and 925 hPa winds

Precipitation and 300 hPa winds

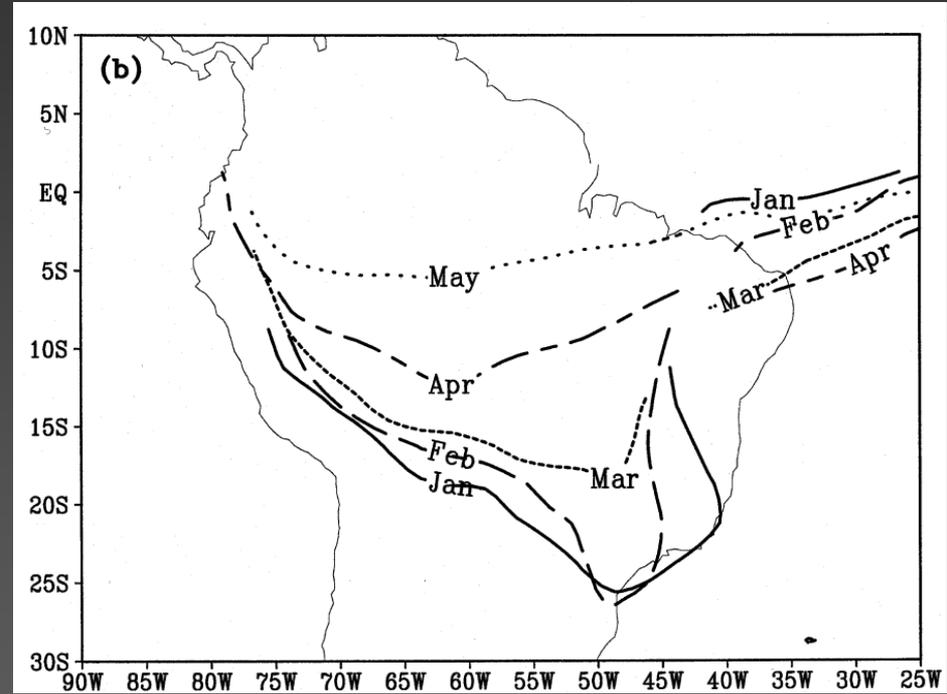
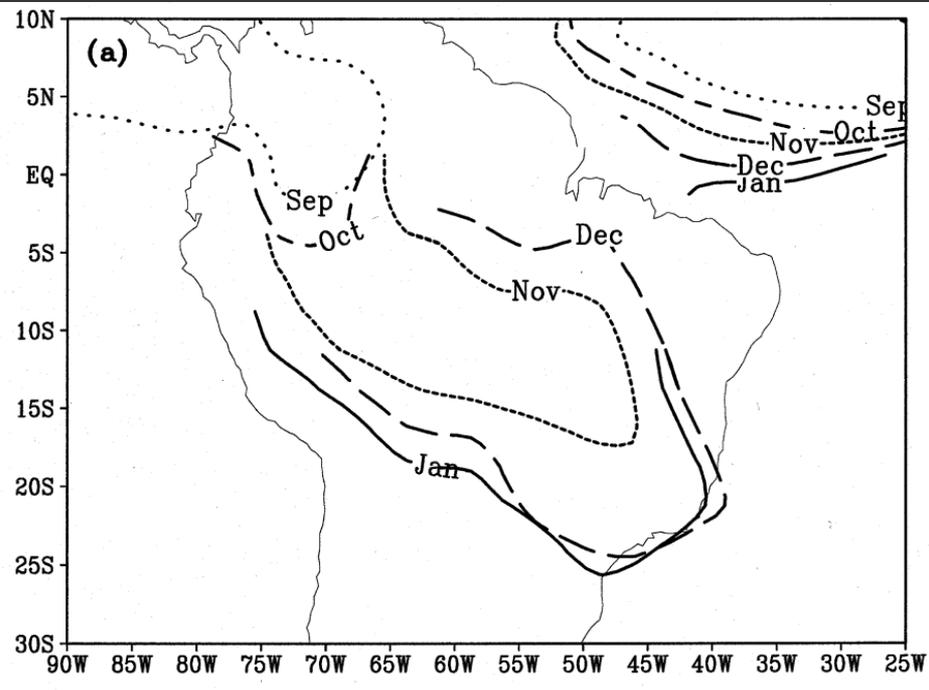




Instrumental records provide a comprehensive view of climate variations in South America during the past 40-60 years



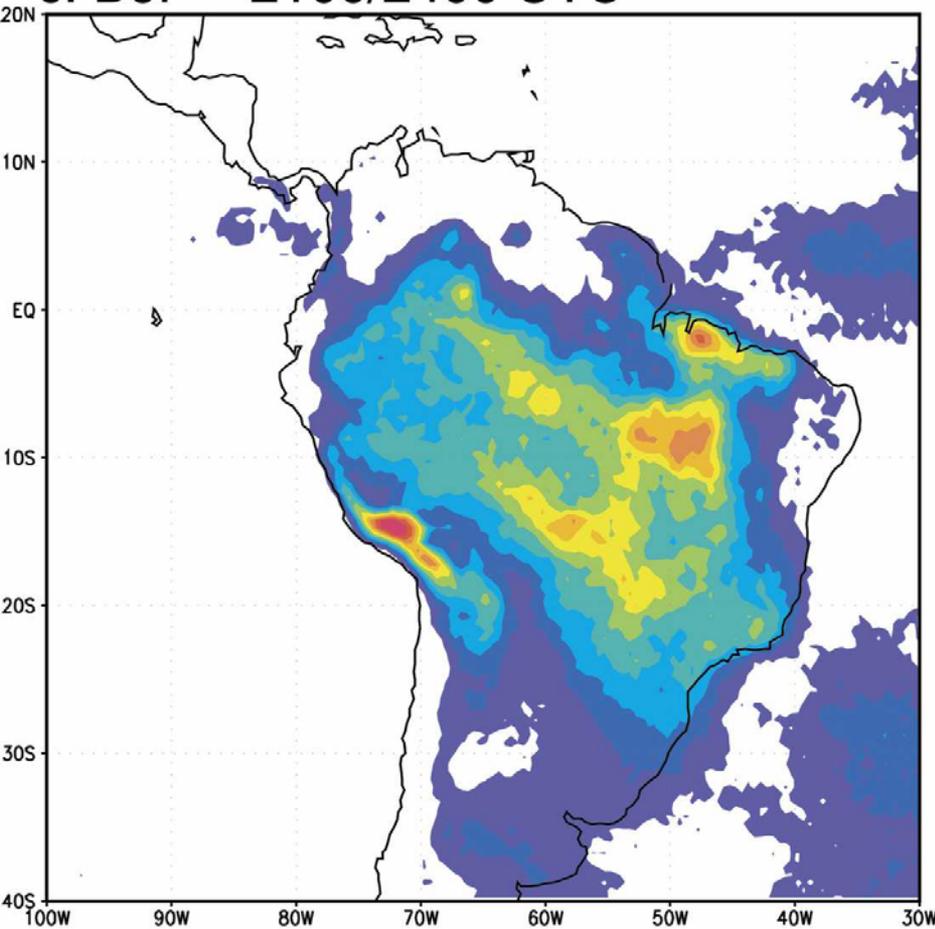
Monsoon rainfall over South America



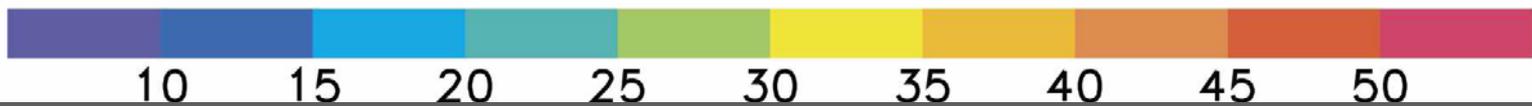
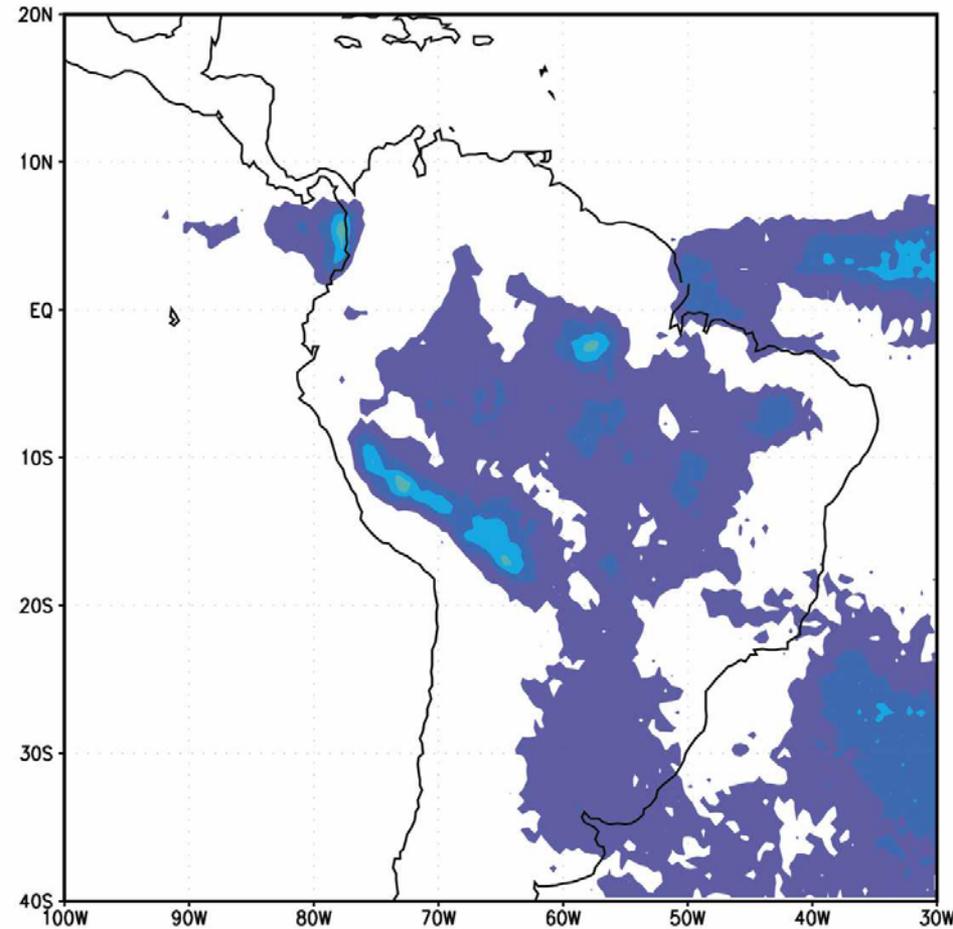
Ciclo diario del proceso convectivo tropical (ORL):

Tarde (2100–2400 UTC) *versus* madrugada-mañana temprana (0900–1200 UTC)

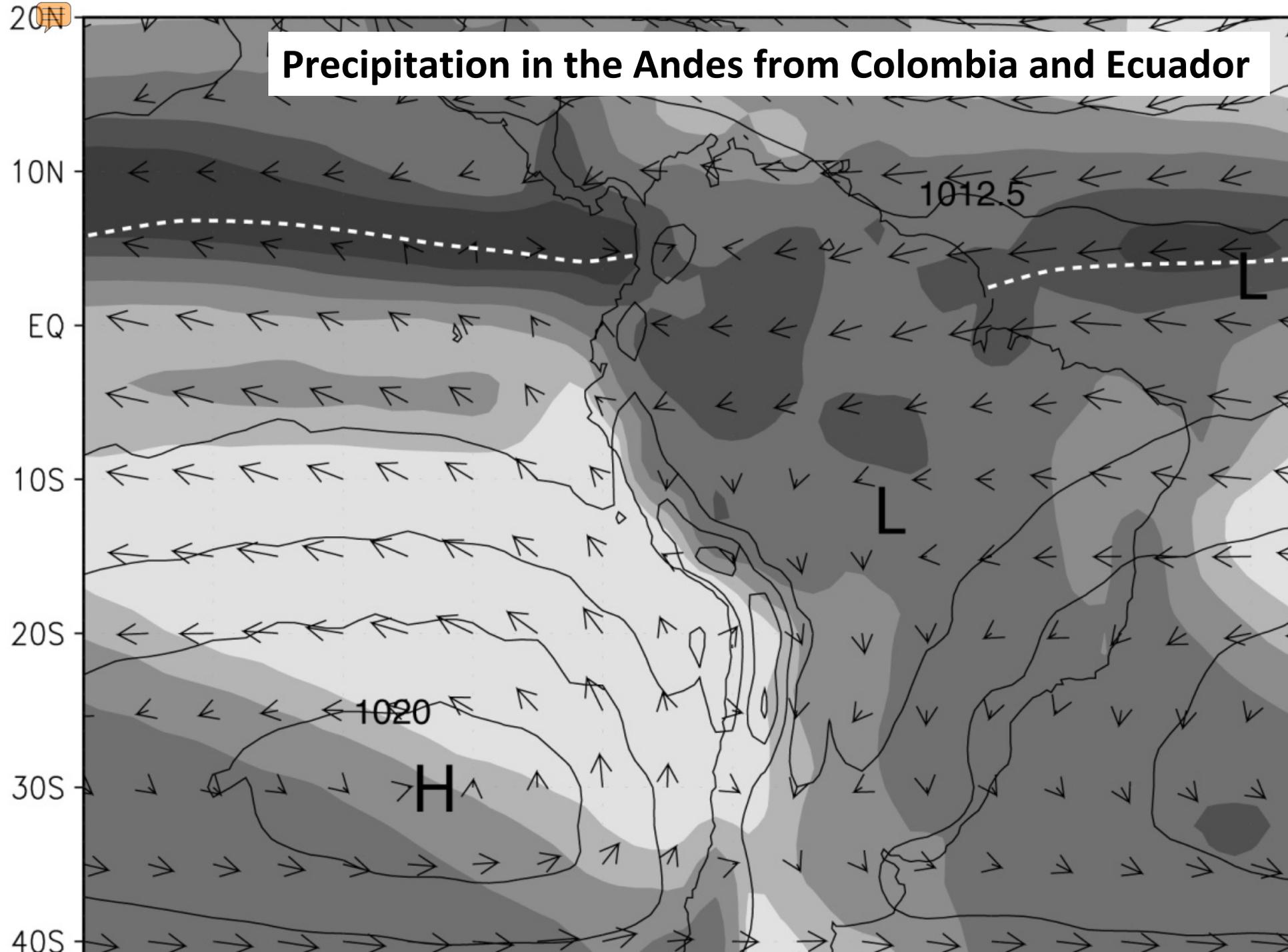
c. DJF – 2100/2400 UTC

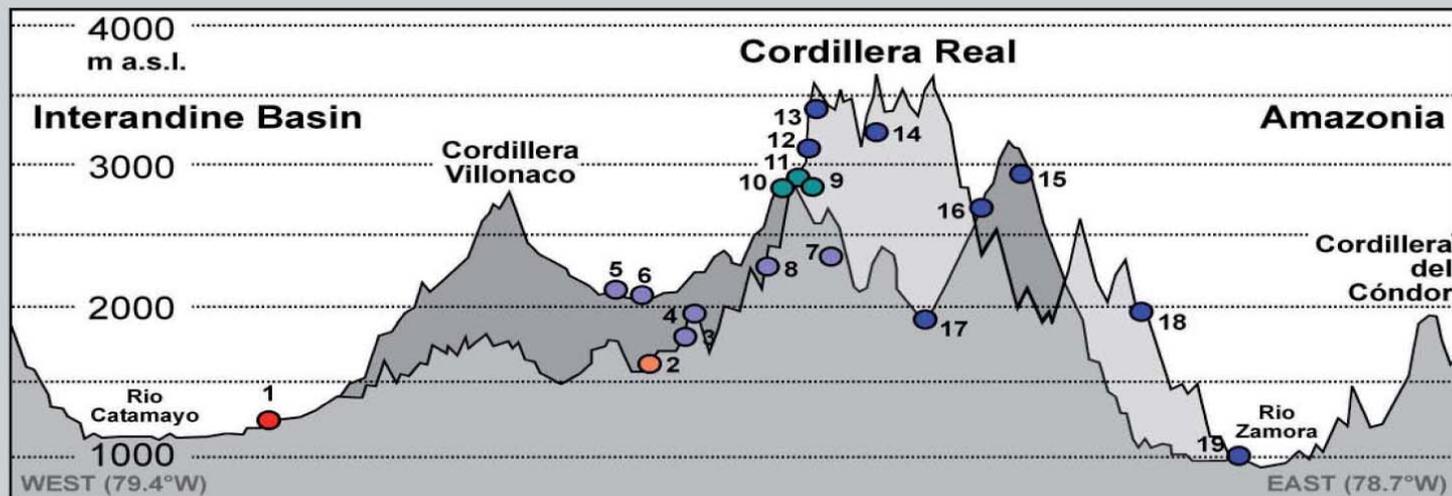
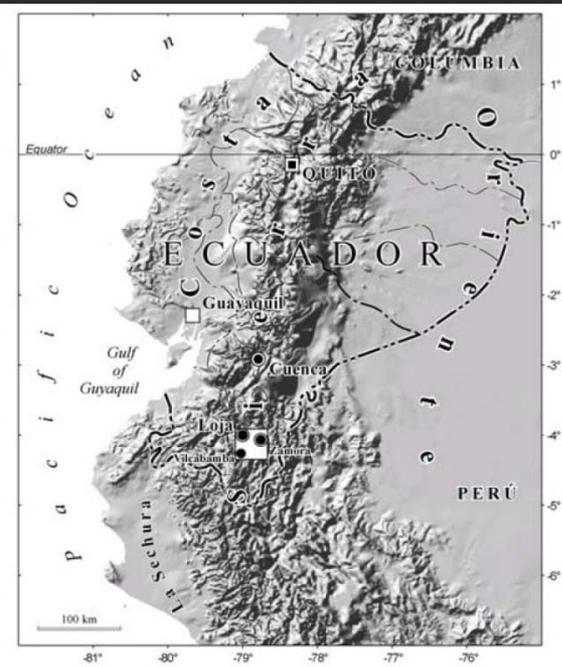


d. DJF – 0900/1200 UTC

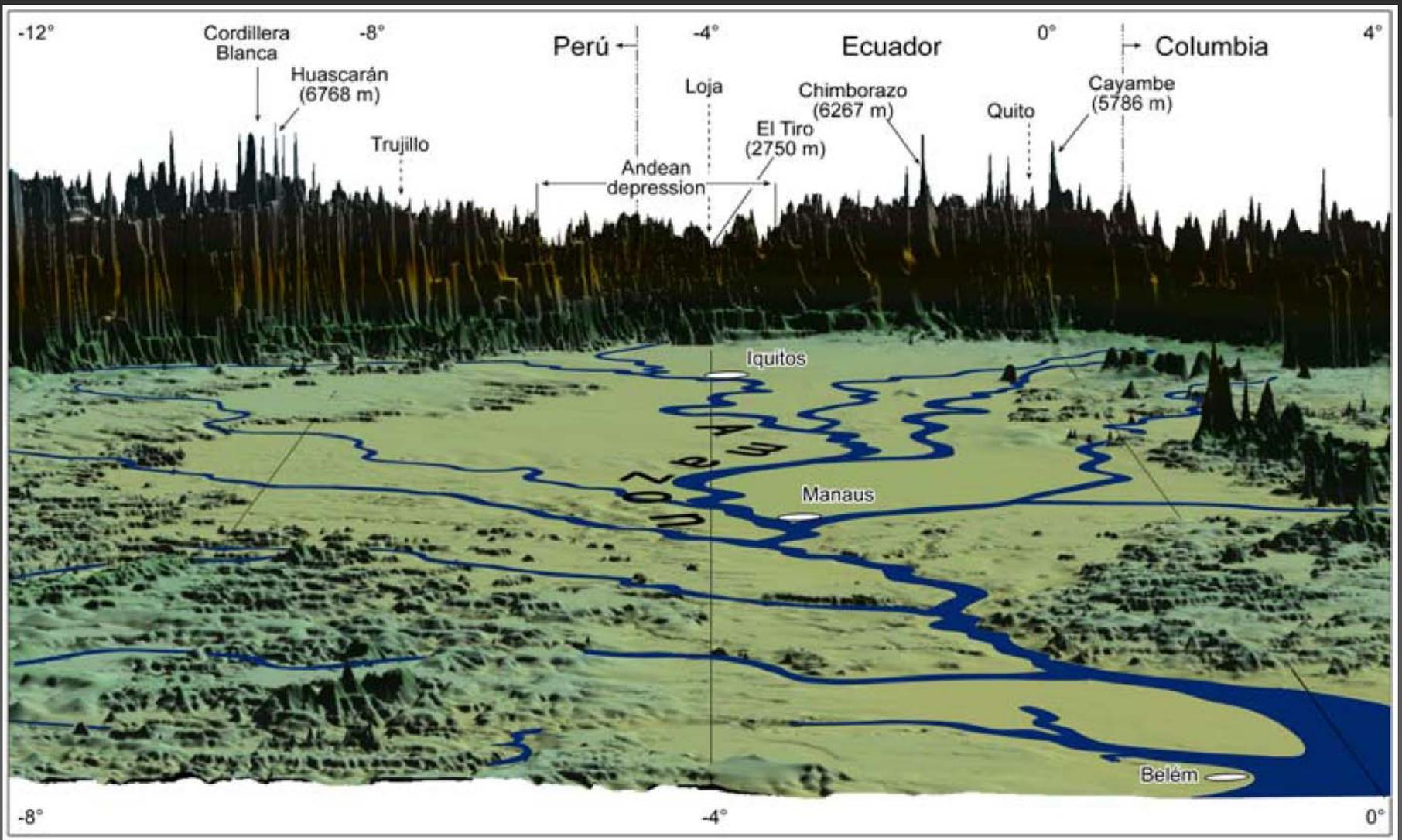


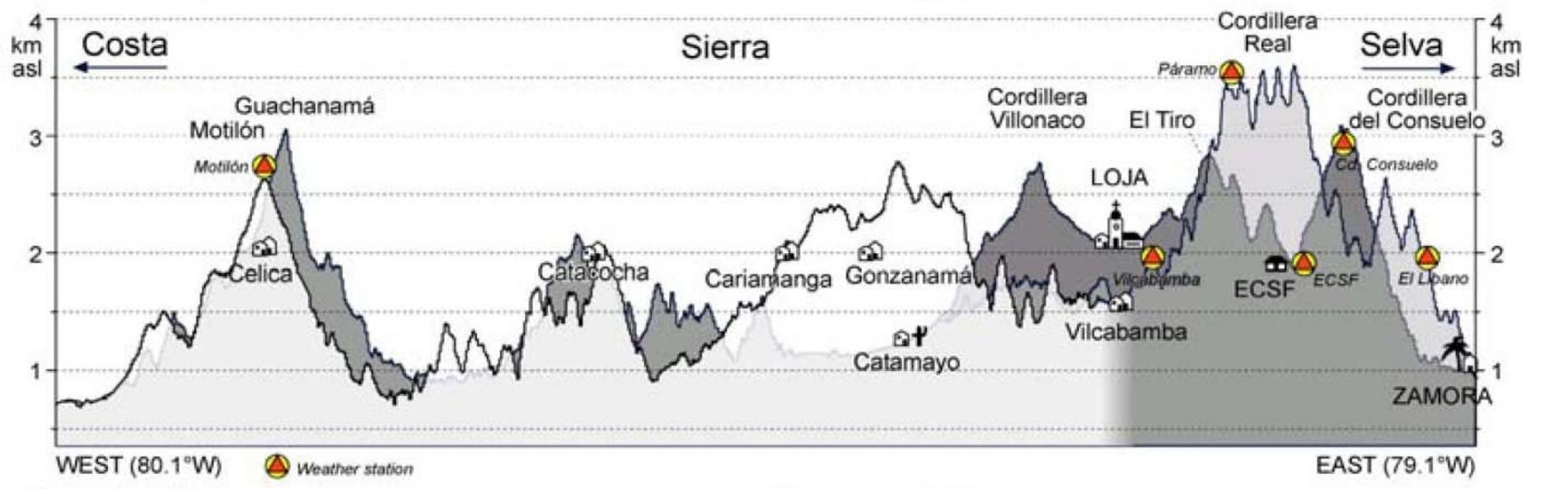
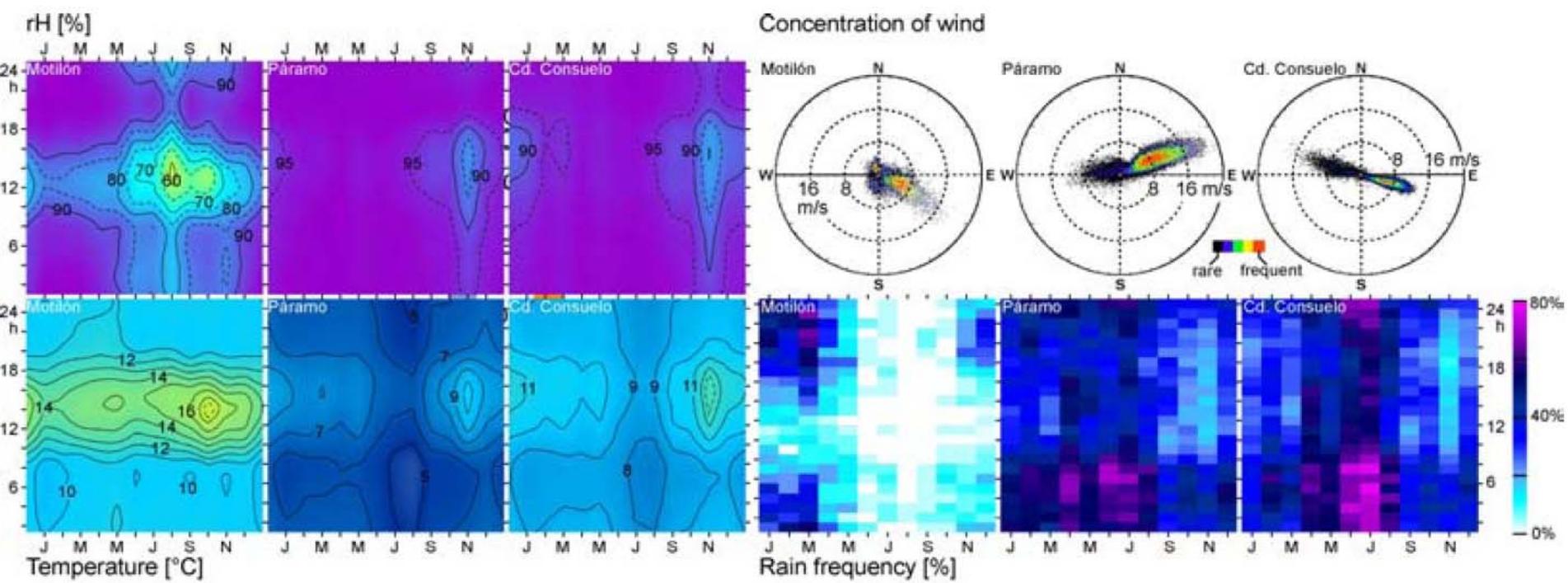
Precipitation in the Andes from Colombia and Ecuador

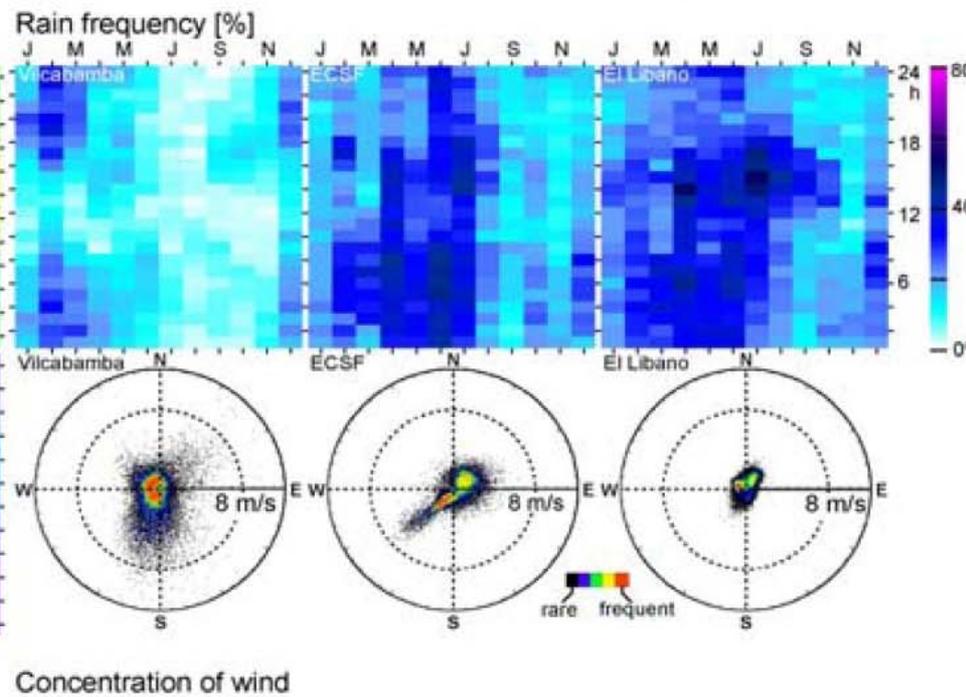
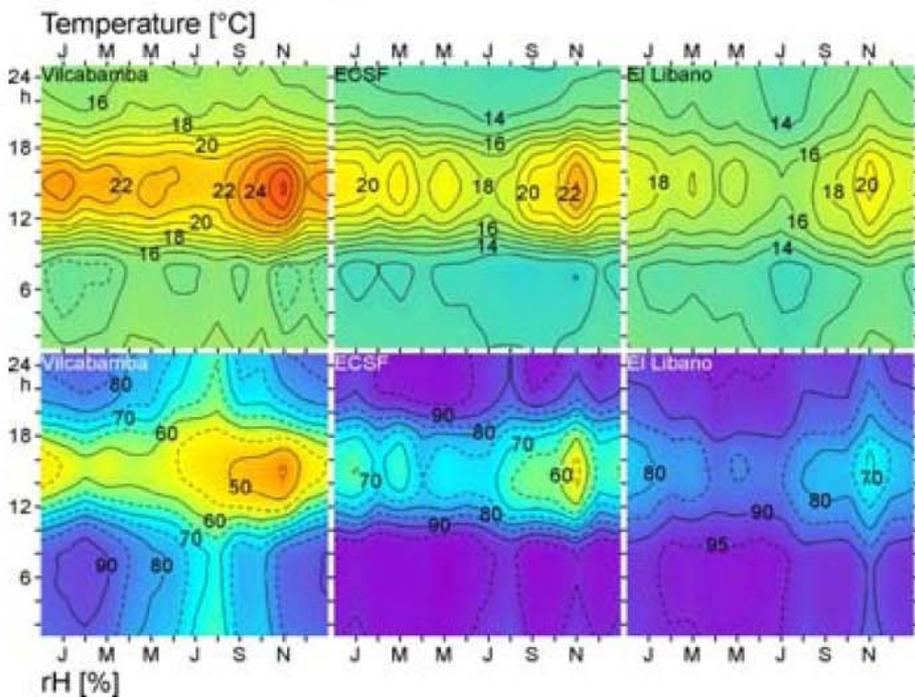
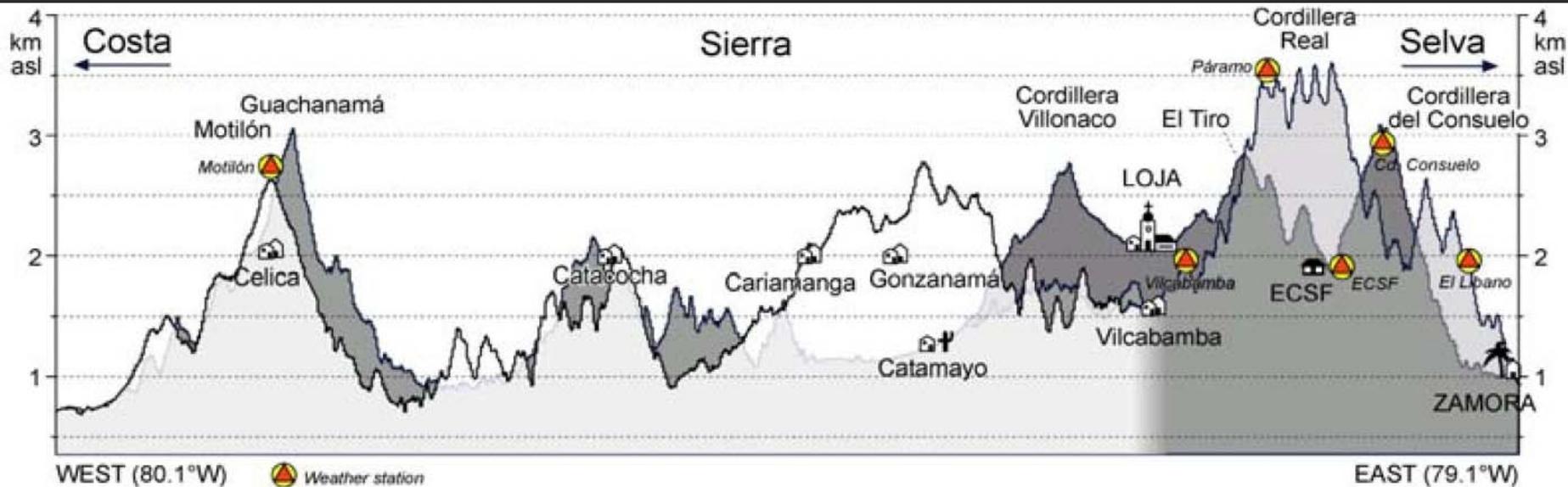


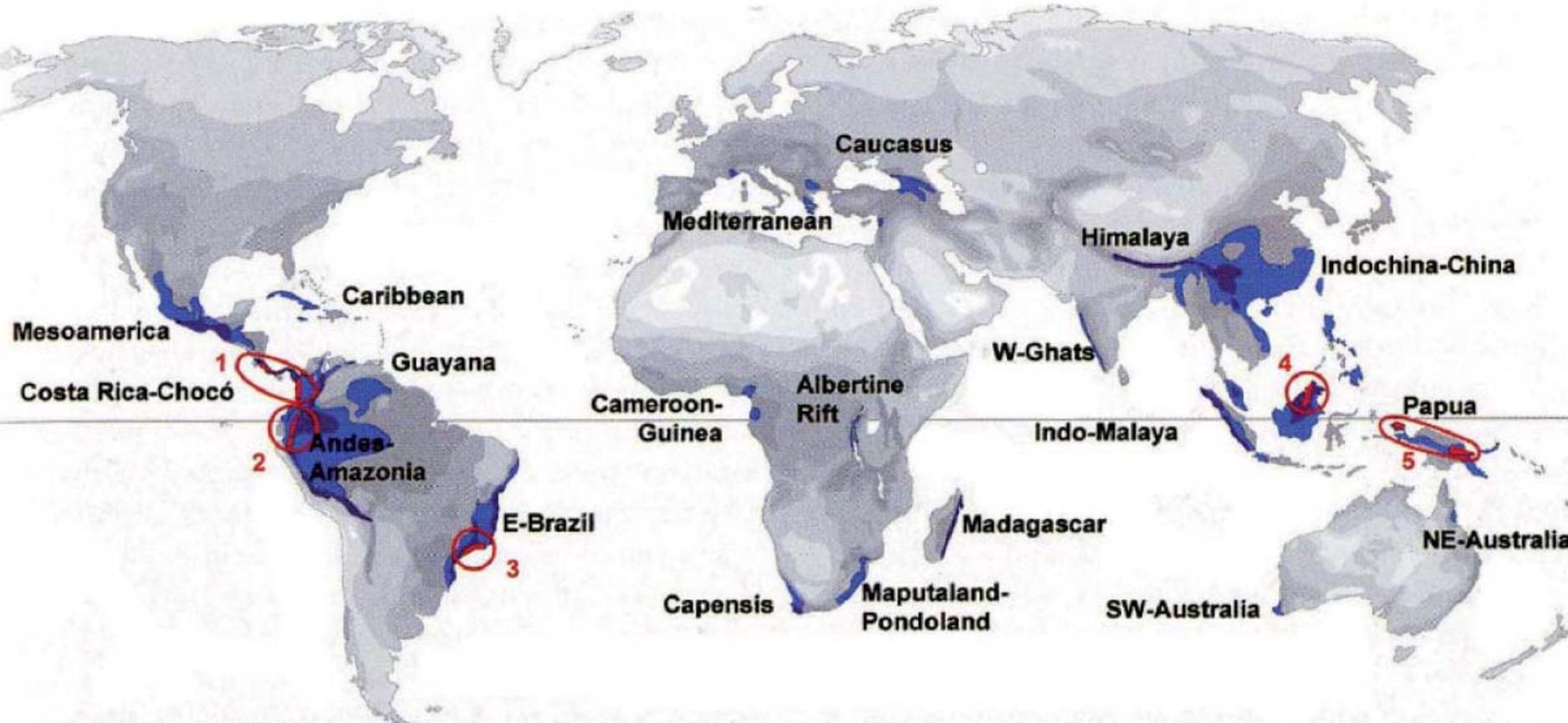


- | | | | |
|-------------------------|----------------------------|-----------------------------------|-----------------------------|
| 1 Catamayo | 7 Vilcabamba Gabino | 13 Cajanuma Páramo | 15 Cerro de Consuelo |
| 2 Malacatos | 8 Cajanuma Entrada | 14 Laguna de los Compadres | 16 RBSF TS1 |
| 3 Yangana | 9 El Tiro | | 17 ECSF |
| 4 Vilcabamba DFG | 10 Cajanuma Refugio | | 18 El Libano |
| 5 Loja Argelia | 11 Cajanuma Mirador | | 19 Zamora Bombuscara |
| 6 Loja La Paz | 12 Cajanuma Forest | | |
- climate stations**
(dry → wet)









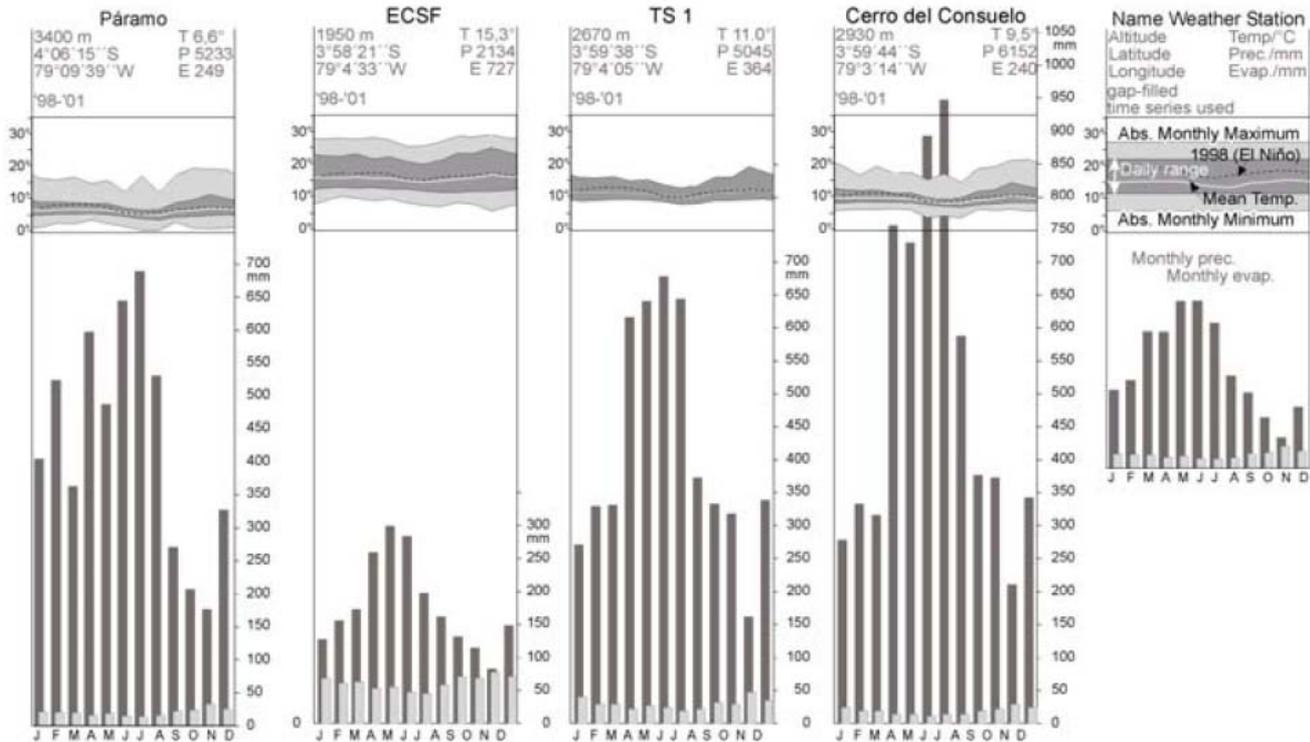
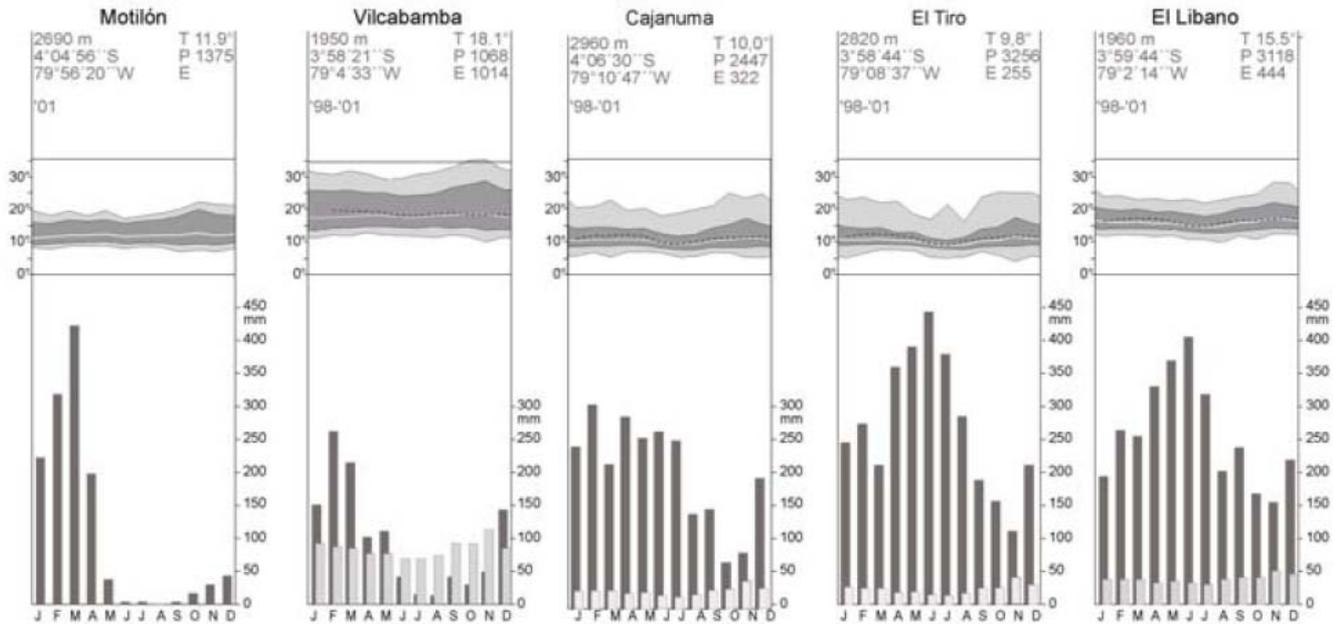
Diversity Zones (DZ): Number of species per 10,000 km²

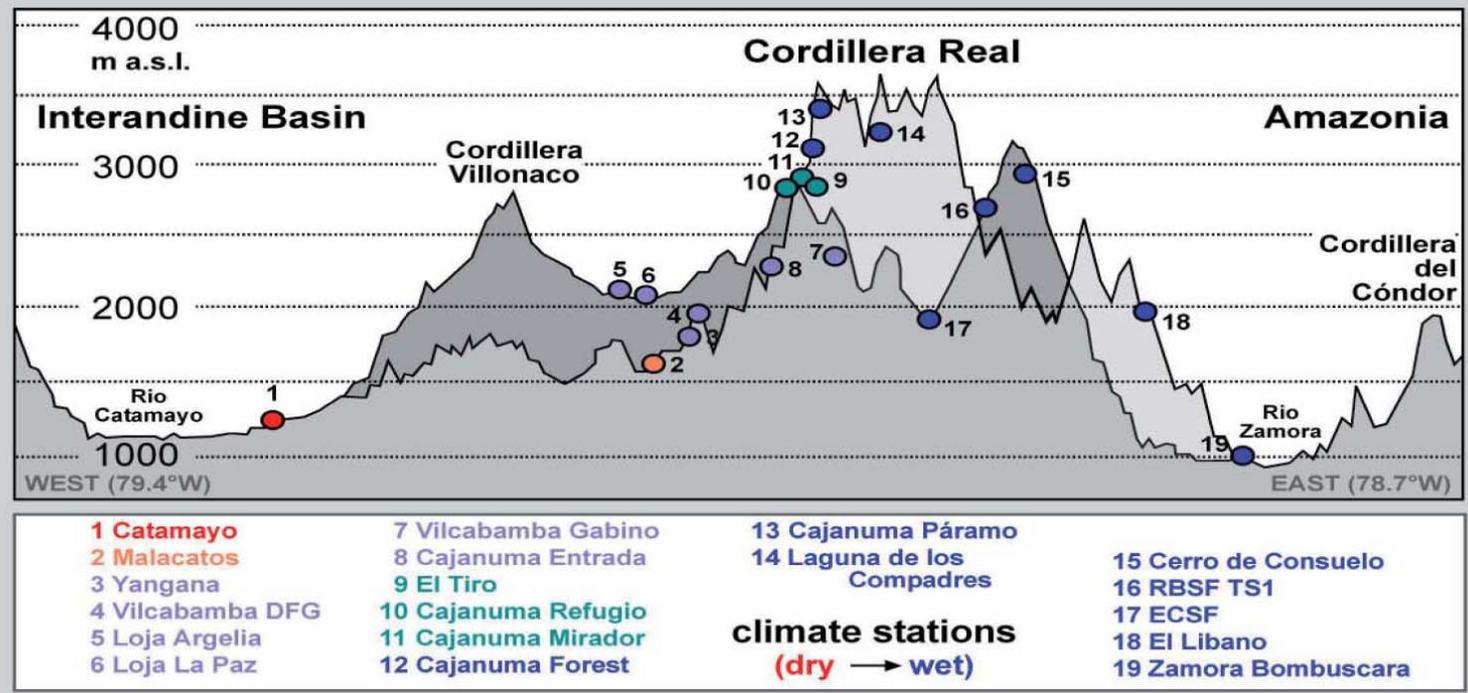
DZ 1	<20 spp.	DZ 5	1000-1500 spp.	DZ 9	4000-5000 spp.
DZ 2	20-200 spp.	DZ 6	1500-2000 spp.	DZ 10	>5000 spp.
DZ 3	200-500 spp.	DZ 7	2000-3000 spp.	Centres >5000 spp.;	
DZ 4	500-1000 spp.	DZ 8	3000-4000 spp.		

BARTHOLOTT, KIER, KREFT, KÜPER, RAFIQPOOR & MUTKE 2005
 Nees Institute for Biodiversity of Plants
 University of Bonn

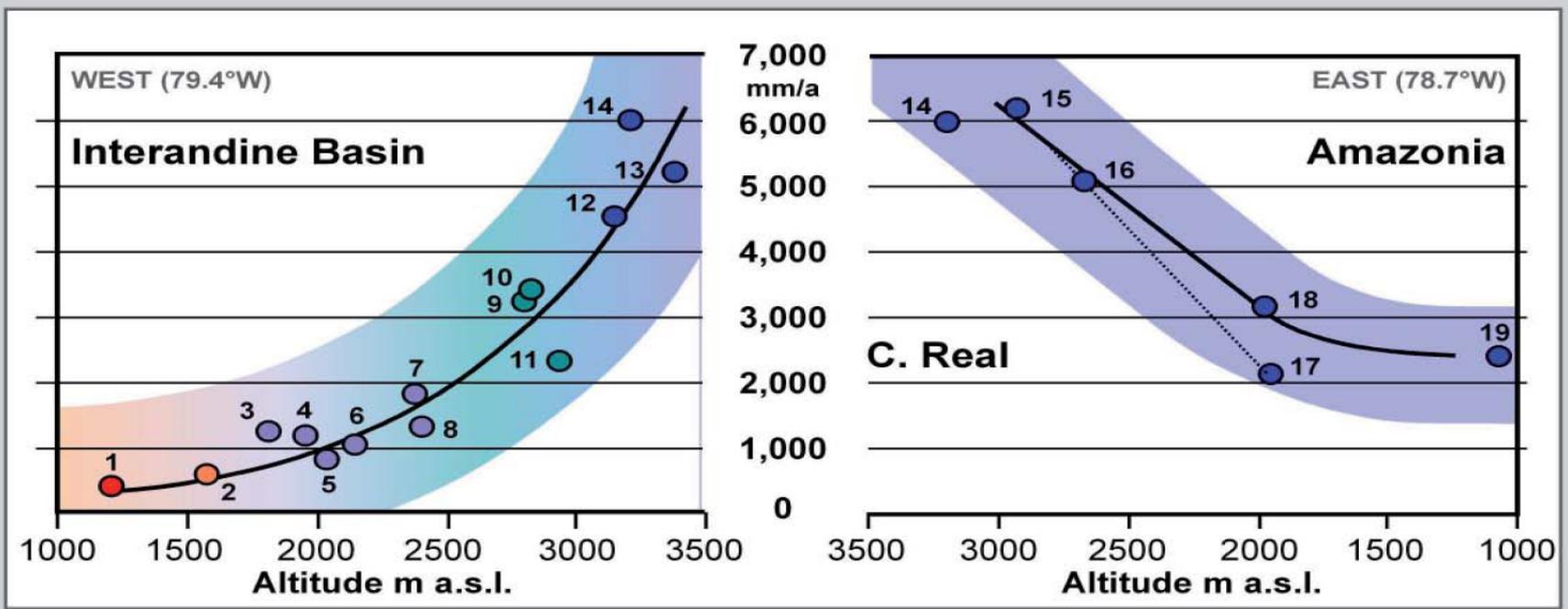
Robinson Projection
 Standard Lines 38°N and 38°S

Figure 1: Map of vascular plant species richness. The research area (RBSF) is centered within one of the five world's megadiversity hotspots. Apart from Ecuador the Costa Rica-Chocó area, south-eastern Brazil, northern Borneo and the New Guinea mountain range are among the other hotspots. From: Barthlott et al. (2007).

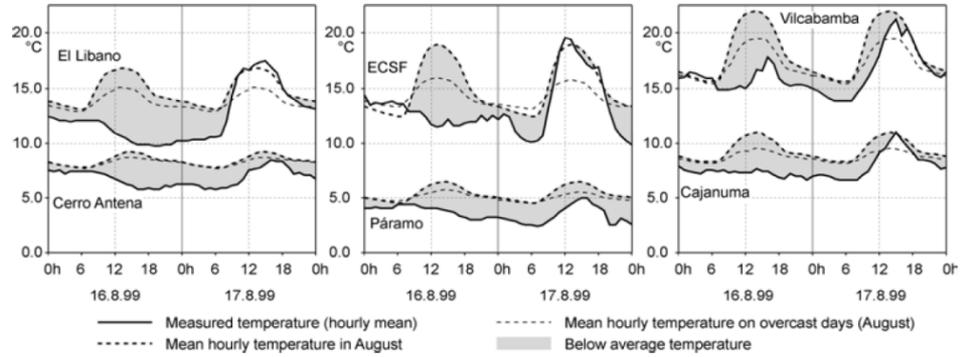
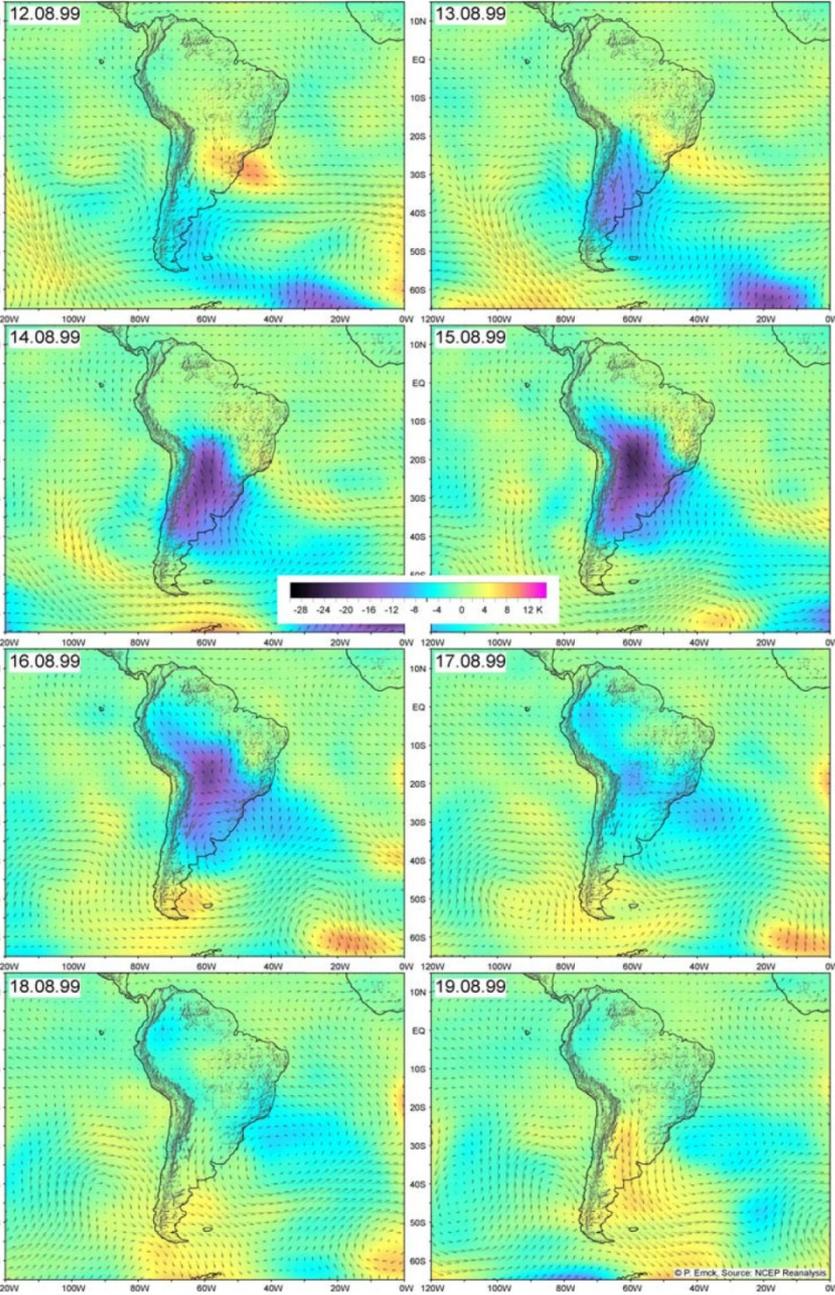




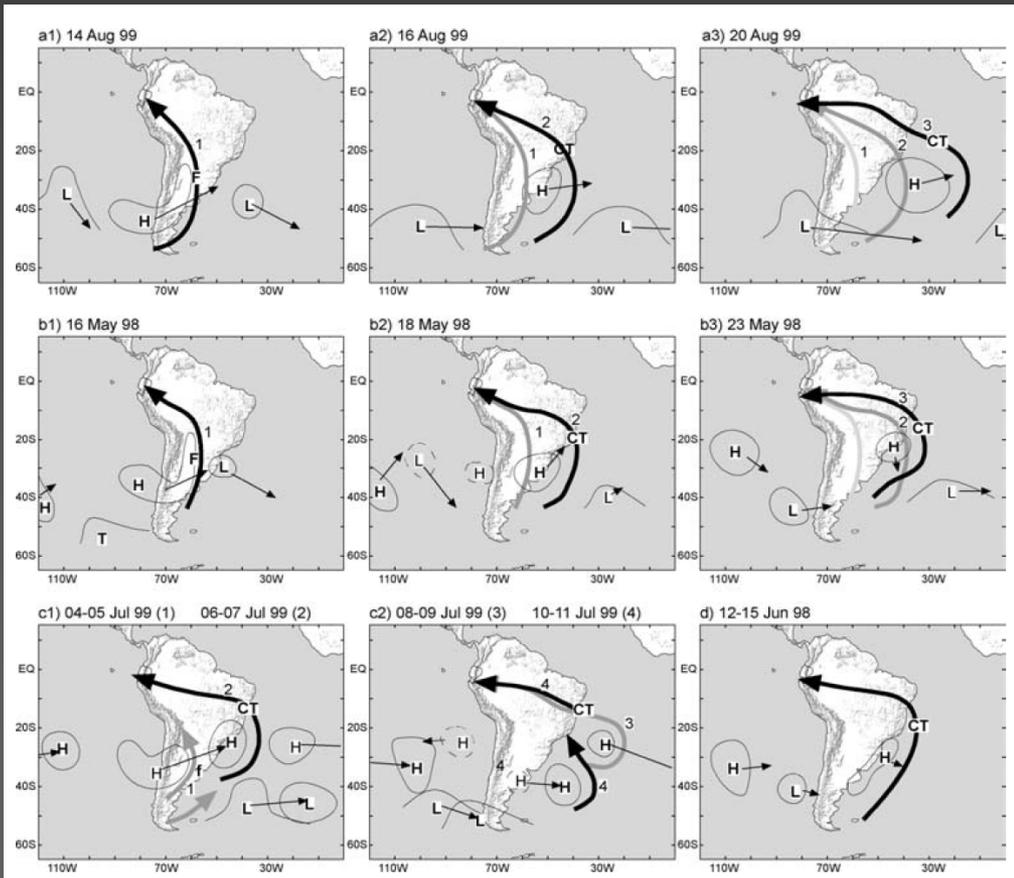
P. Emck
(2007)



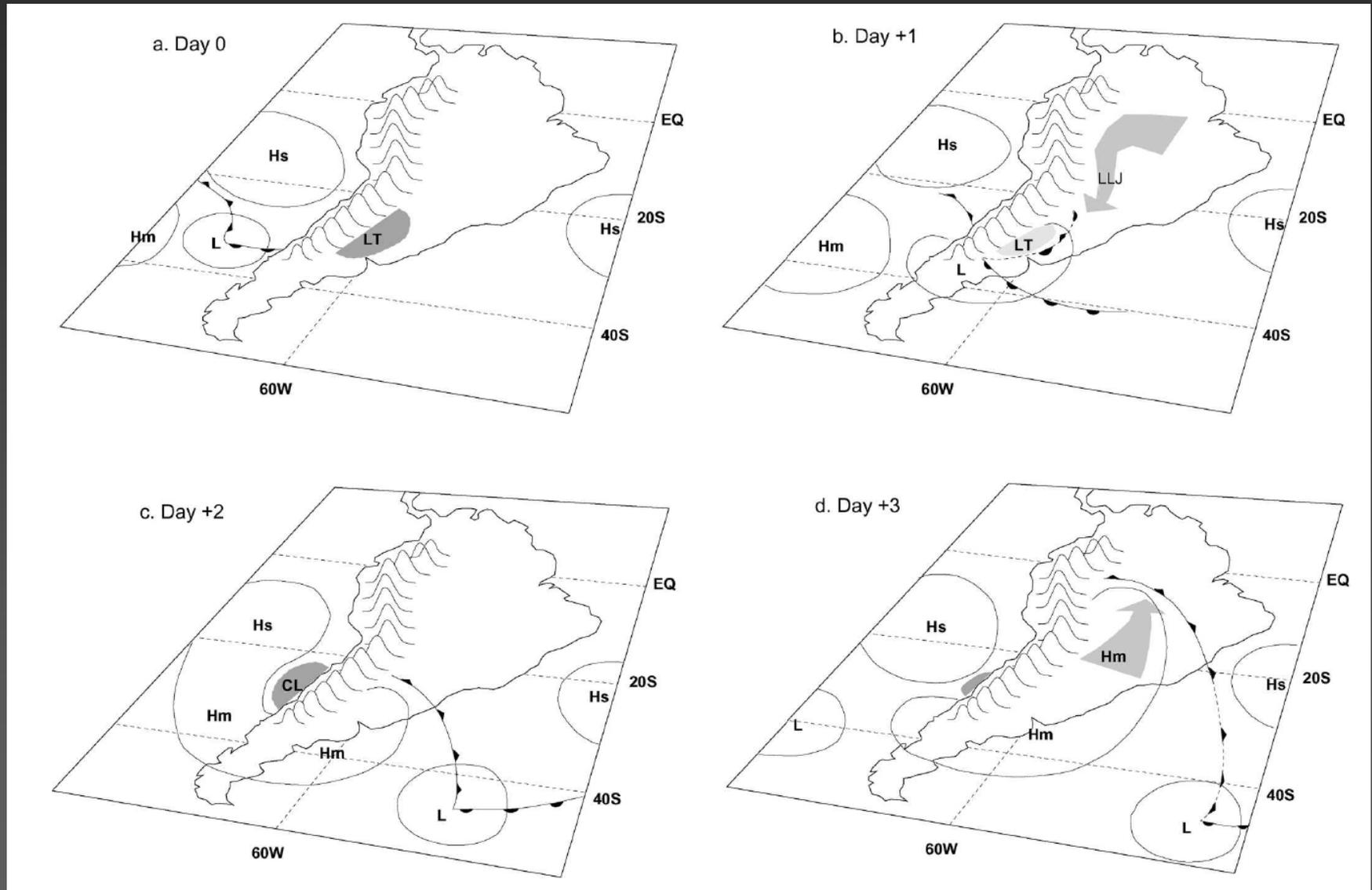
925 hPa



Paul Emck (2007)

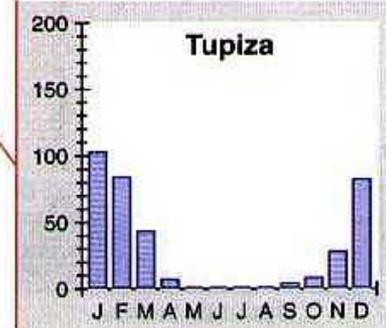
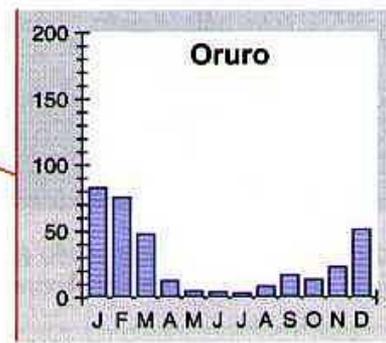
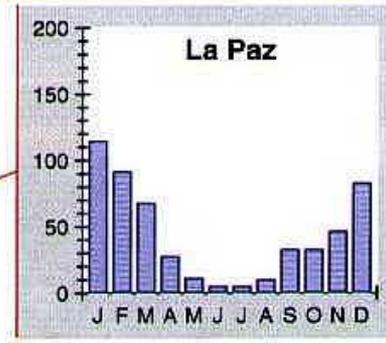
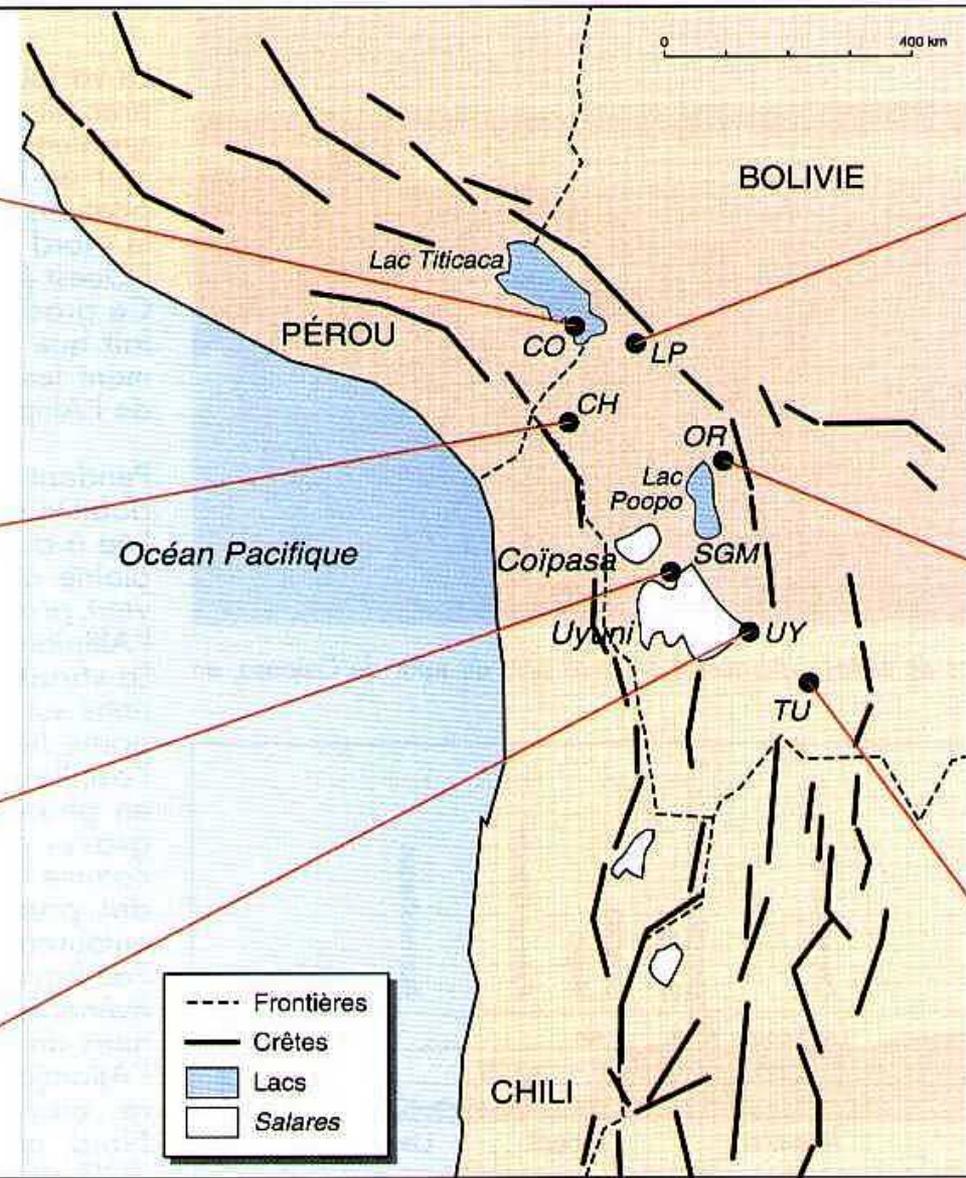
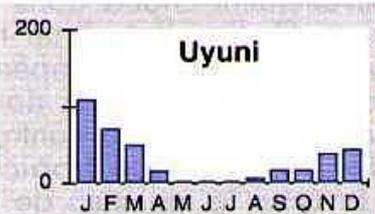
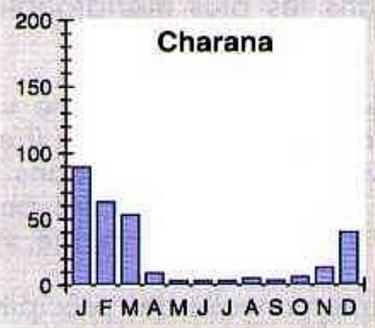
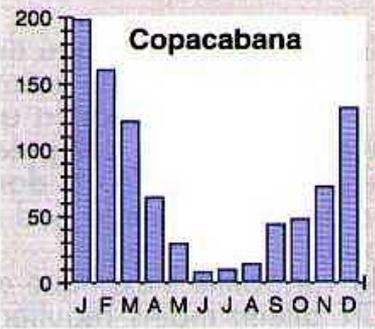


Los Andes: favorecen las interacciones trópico-extratropical en su flanco este



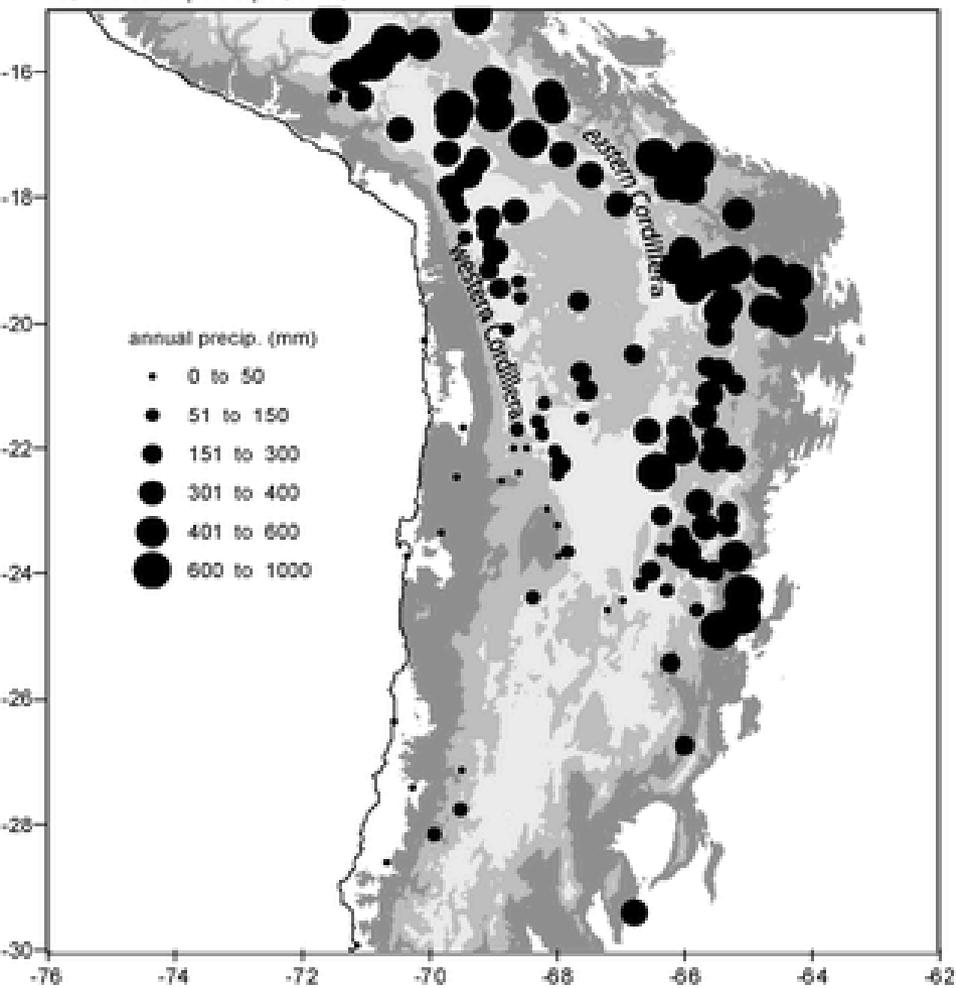
Schematic representation of the life cycle of surface low and high pressure systems moving across South America. The symbols are as follows: Hs = subtropical high, Hm = migratory high, L = migratory low, and LT = lee trough.



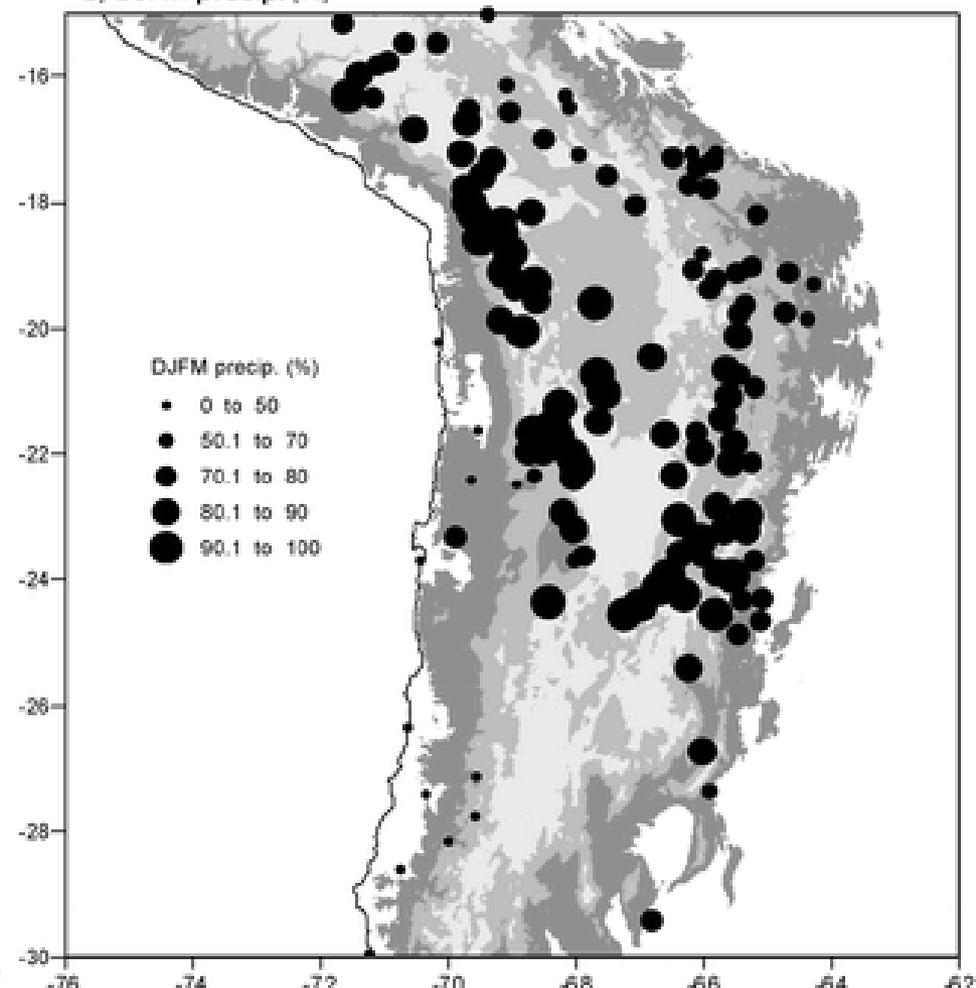


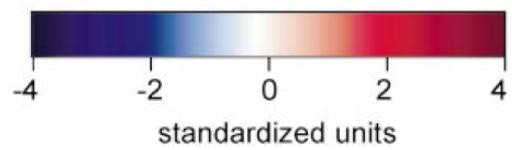
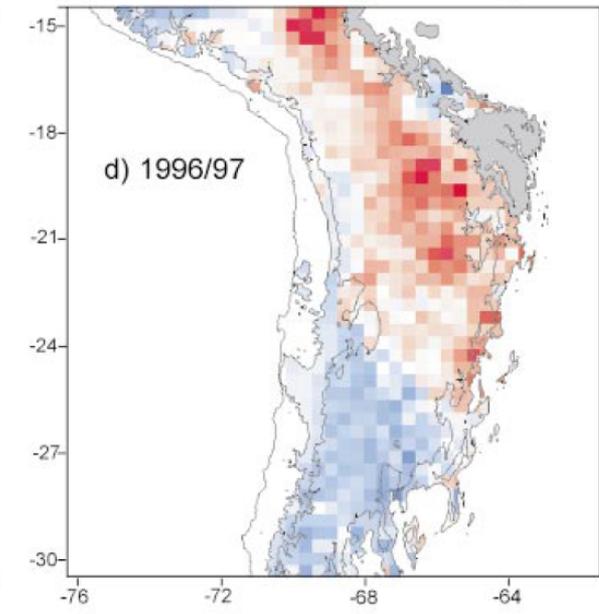
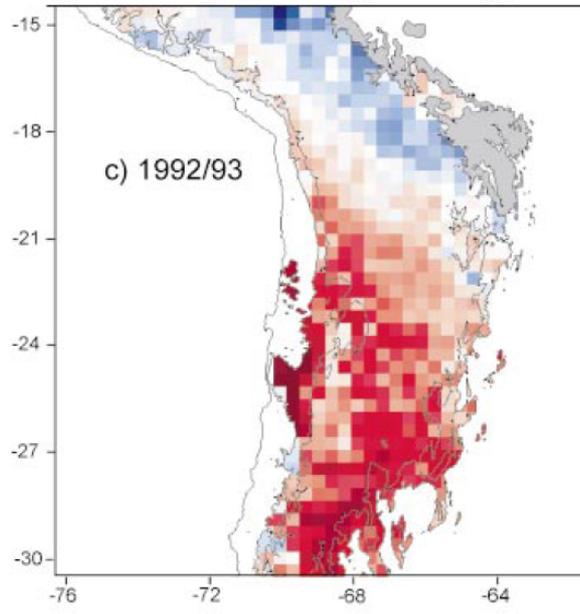
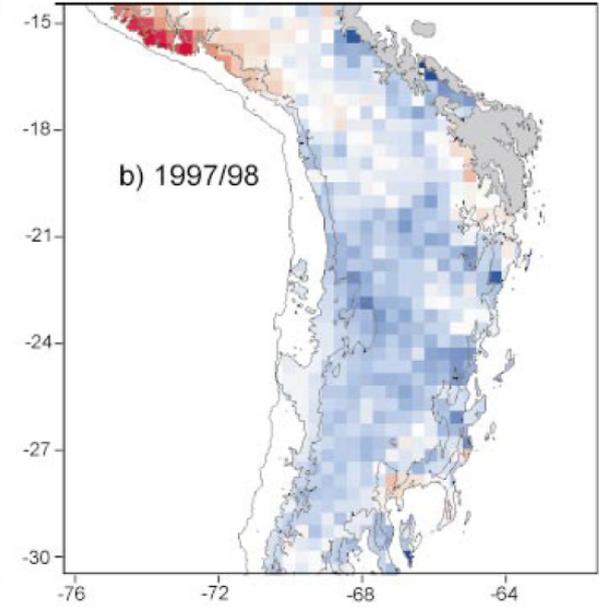
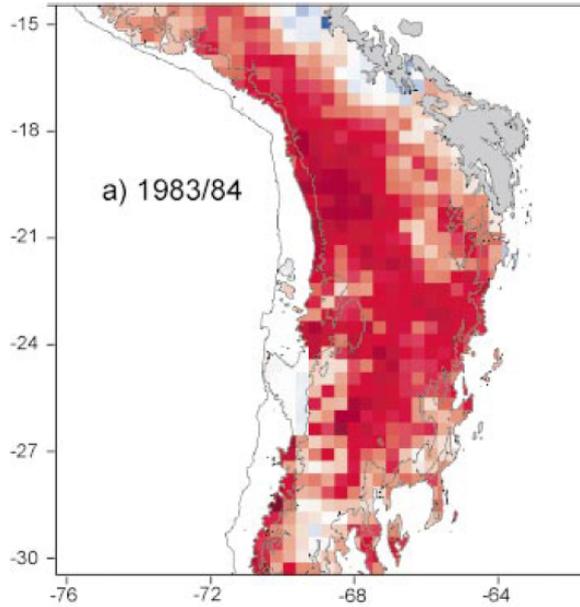
Tropical Andes from southern Peru, and Bolivia (18°S)

a) annual precip. (mm)

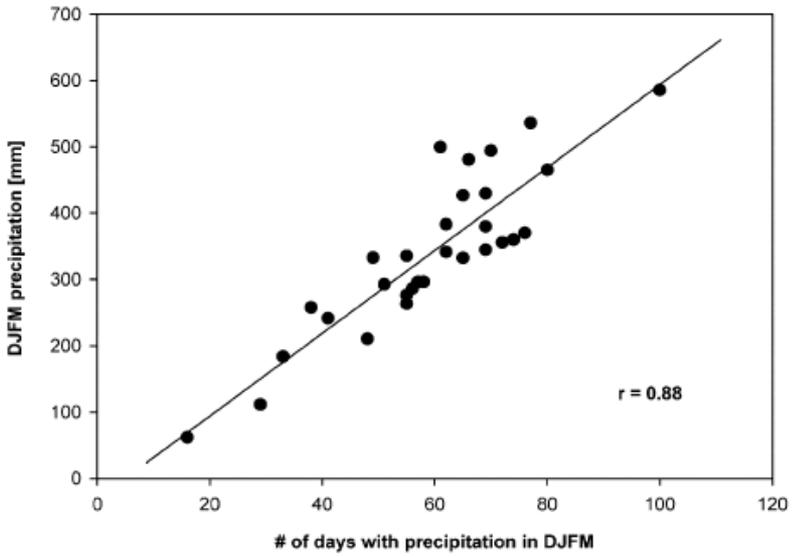
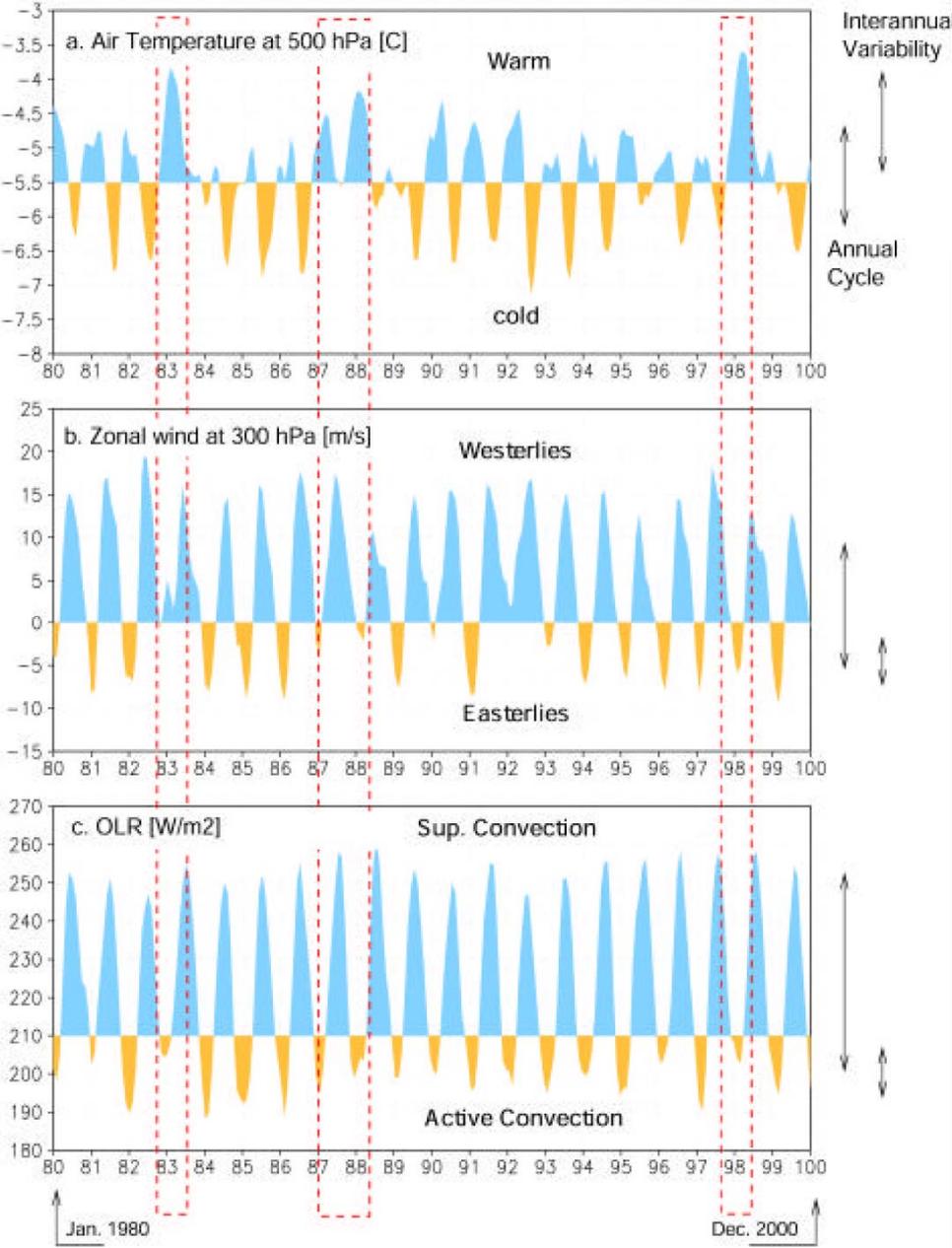


b) DJFM precip. (%)

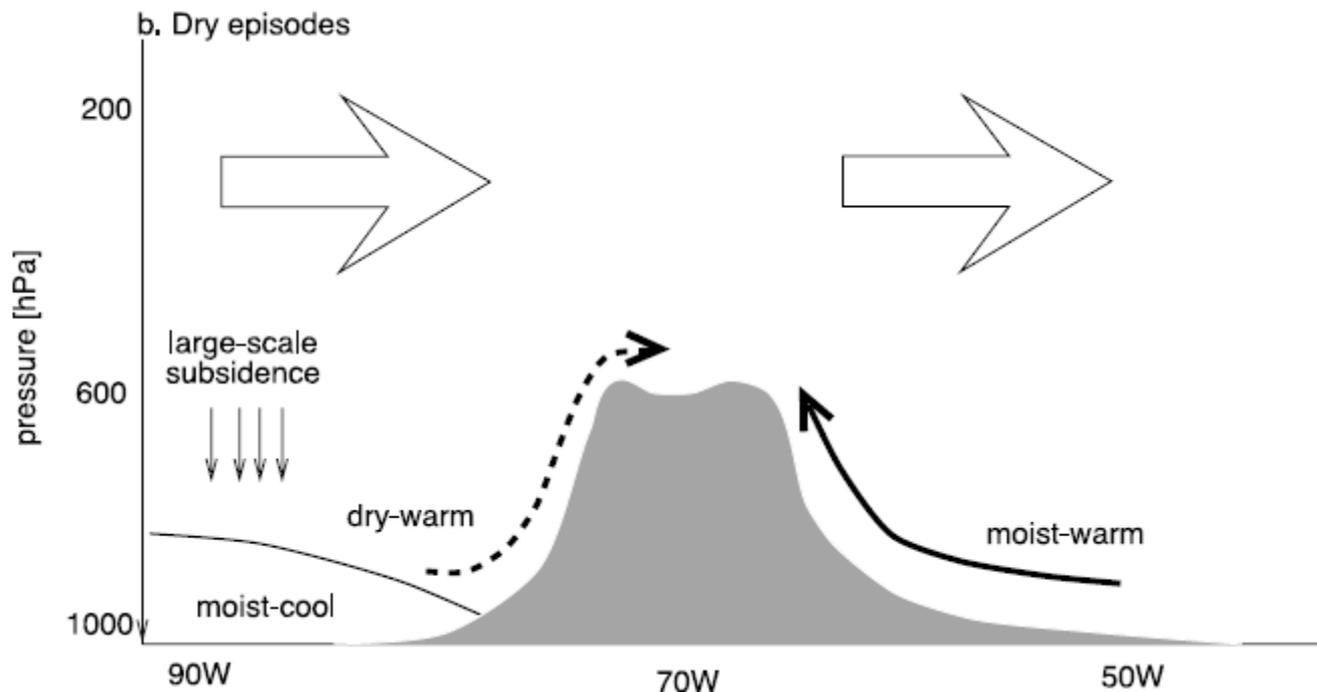
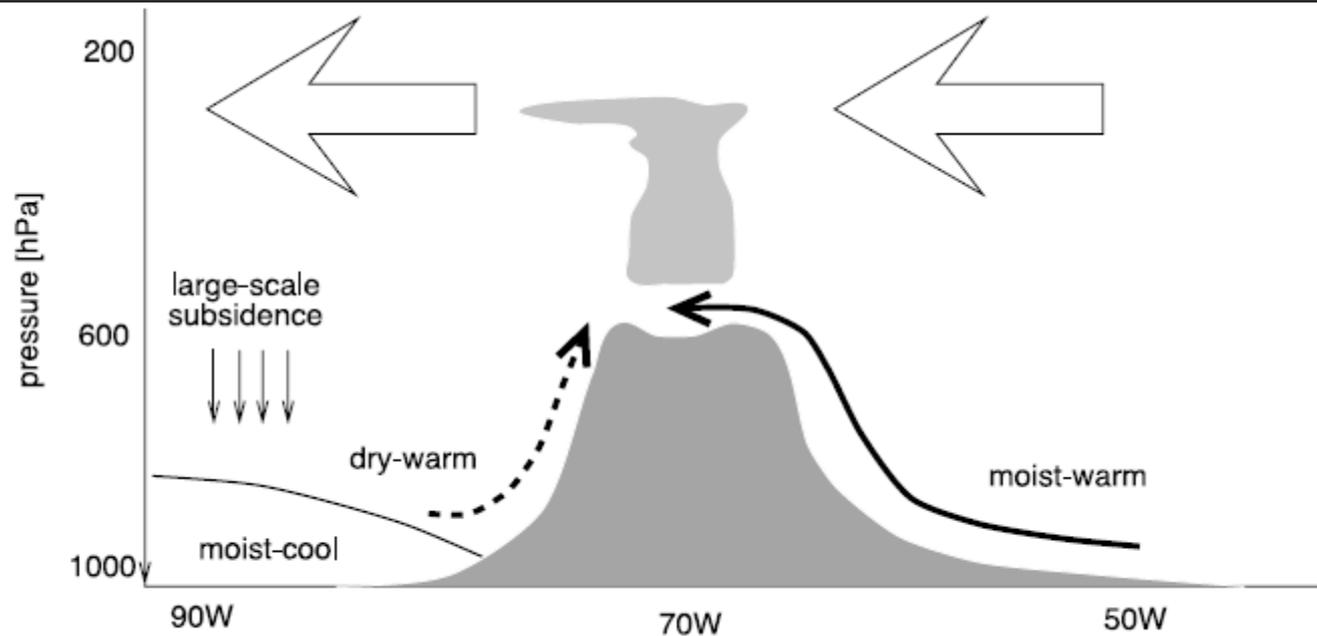




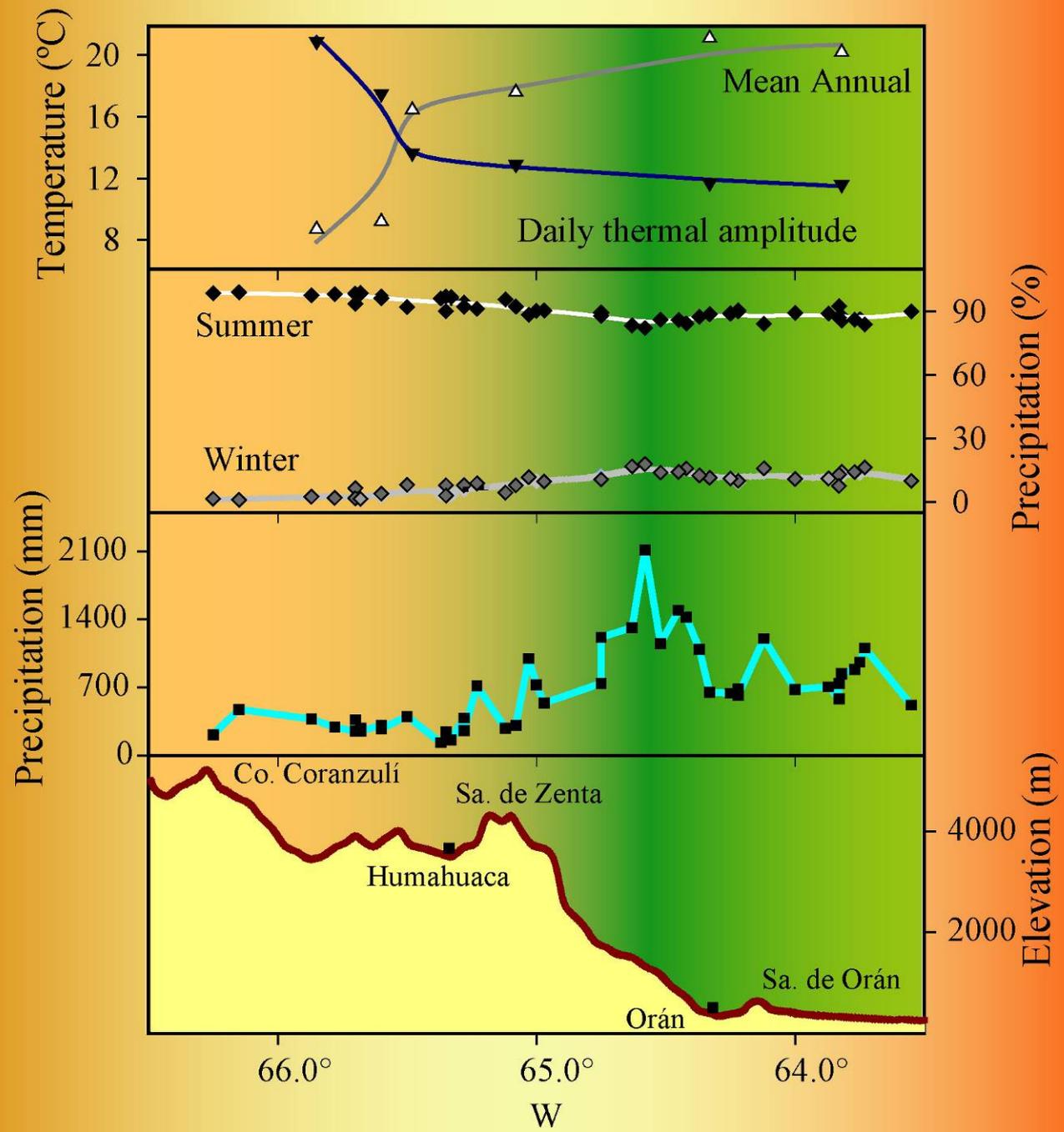
Atmospheric circulation over the Bolivian Altiplano



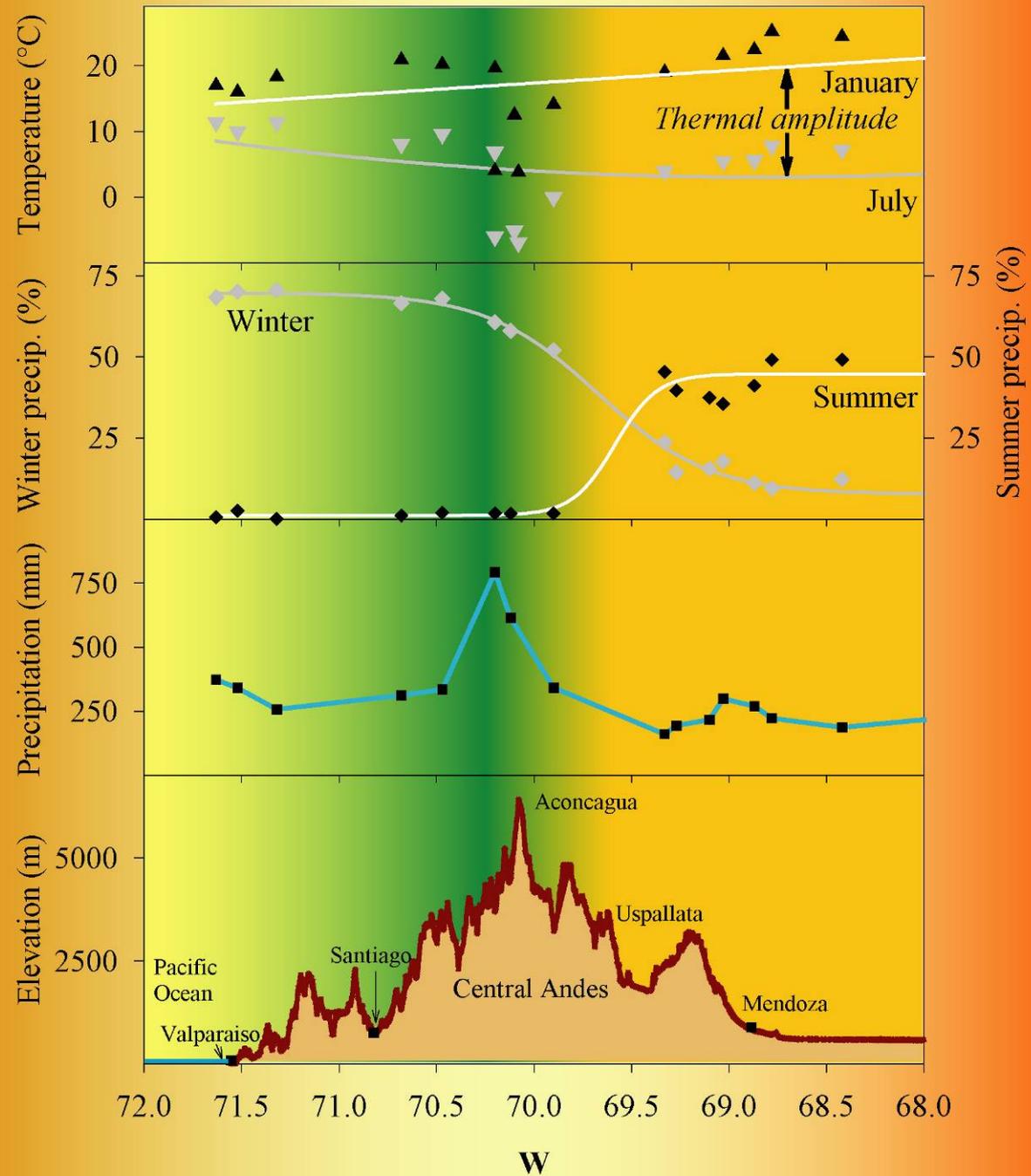
En conexión con la Alta Boliviana (Bolivian High), sobre el Altiplano se producen vientos del Este que favorecen el transporte de humedad continental. Esta humedad es crucial para el desarrollo del convección profunda sobre el Altiplano



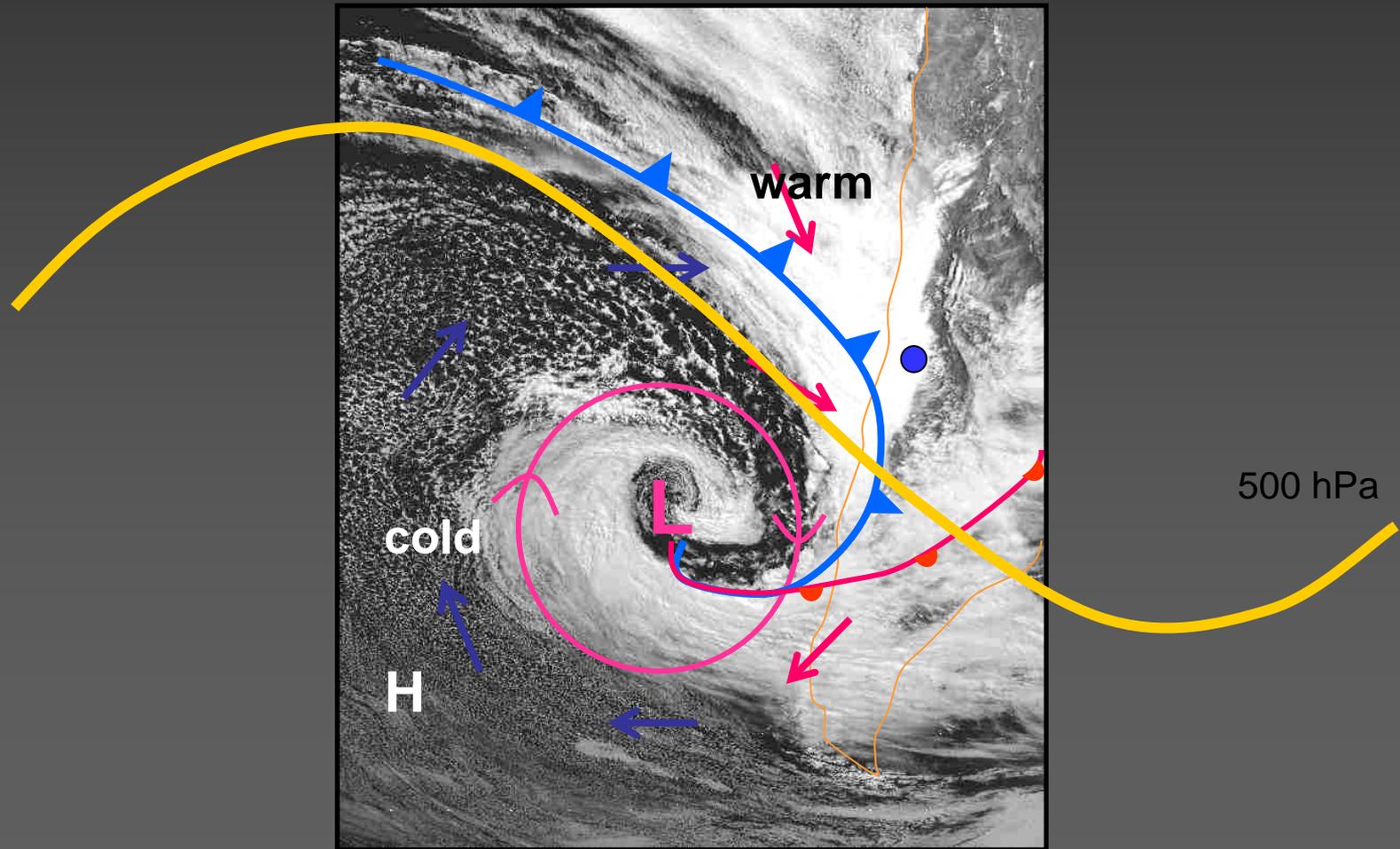
Southern Altiplano

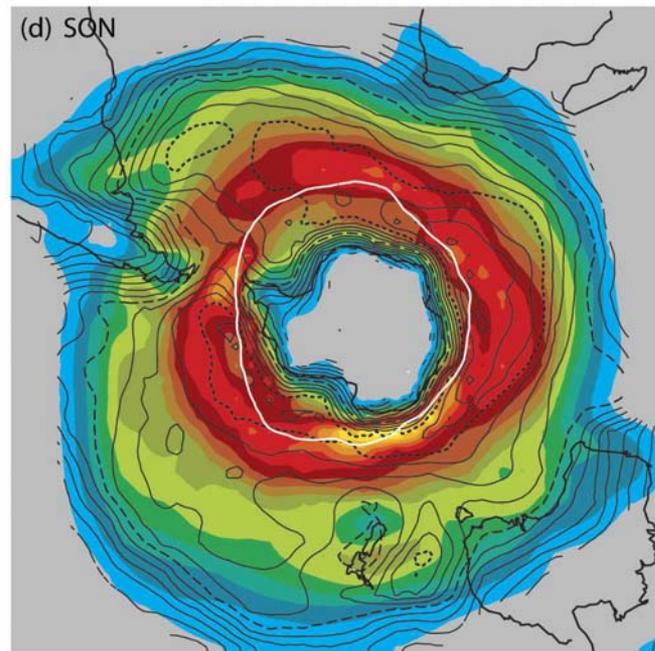
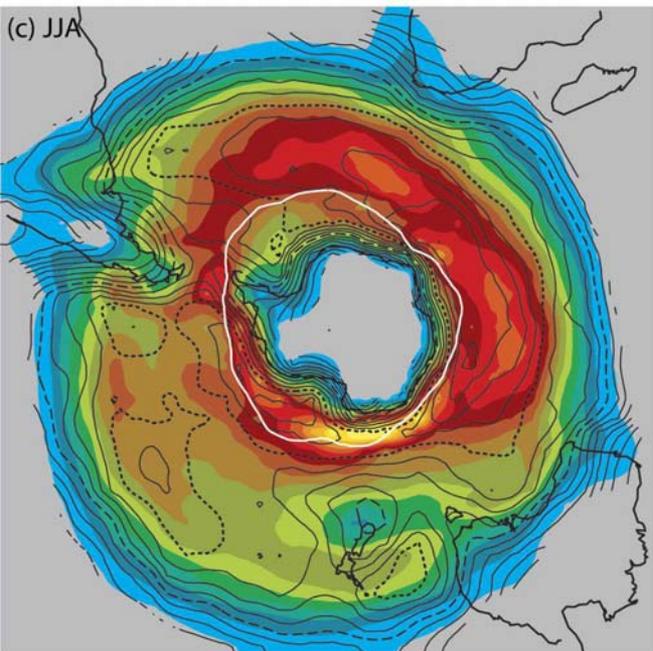
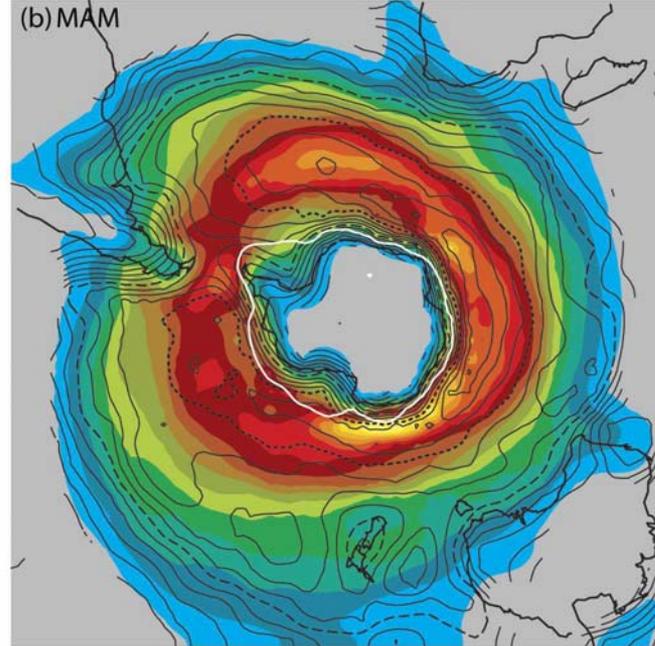
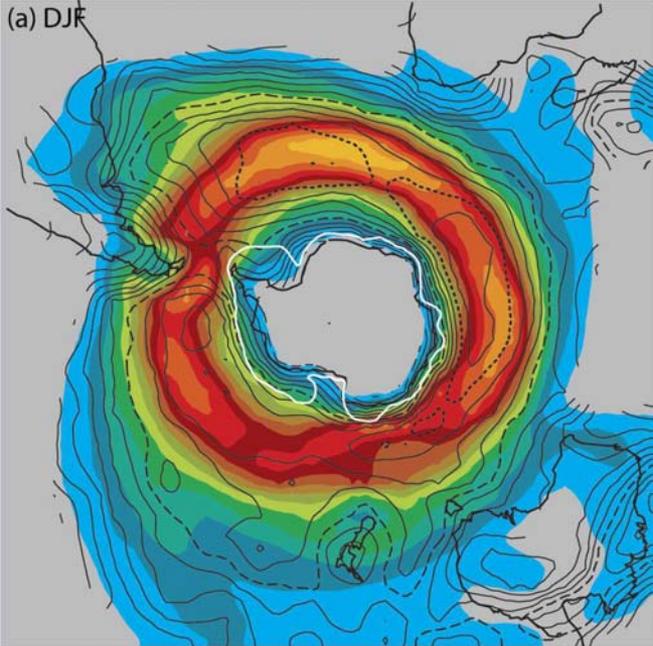


Andes Centrales de Chile-Argentina



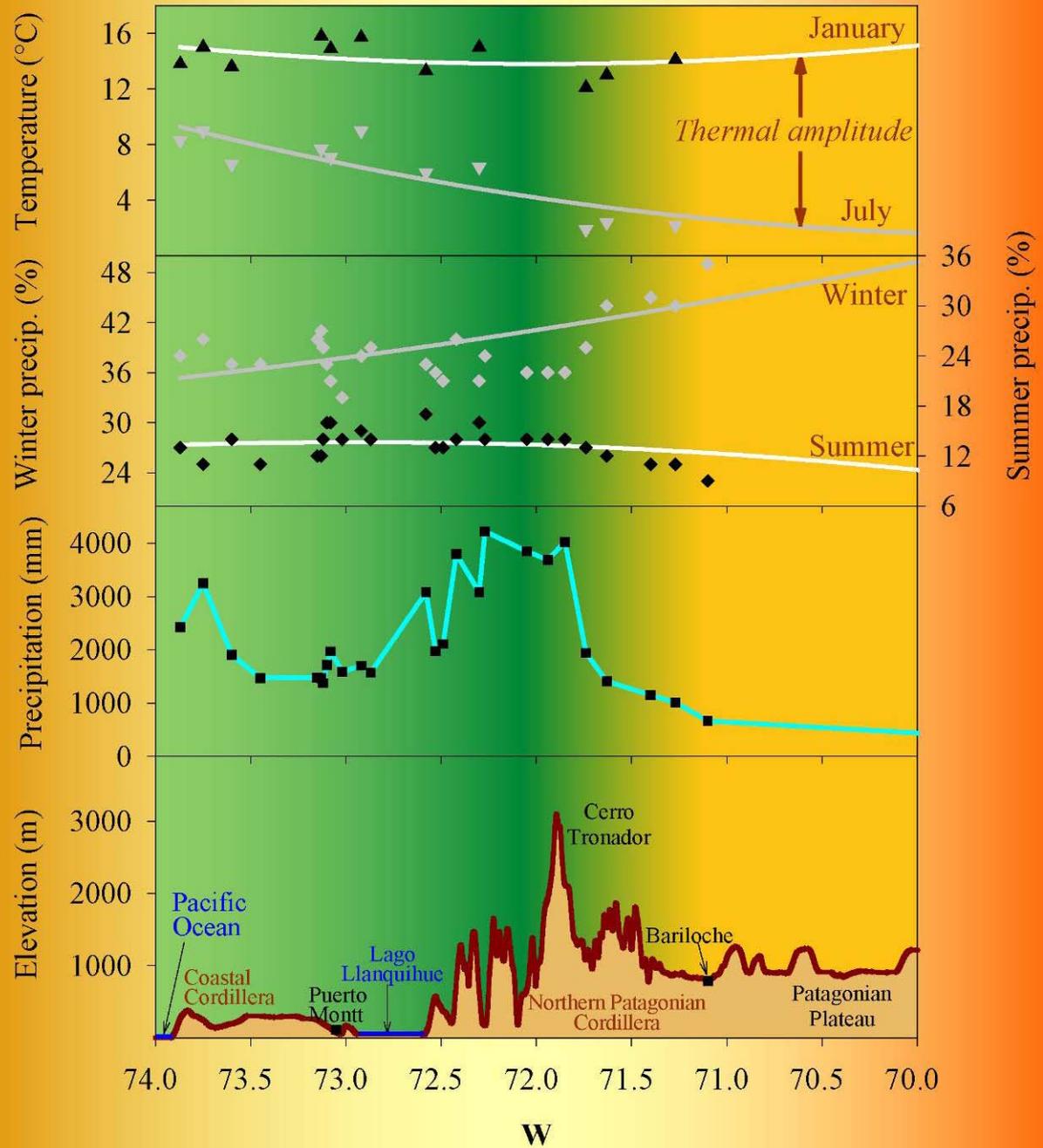
Extratropical precipitation is largely produced by deep, stratiform clouds that develop along warm and cold fronts. The **frontal systems** are in turn associated with surface cyclones, an integral part of the **baroclinic waves** that populates the midlatitudes





Los sistemas frontales están asociados con ciclones migratorios de superficie. Aún cuando cada sistema tiene un recorrido particular, tienden a propagarse hacia el este a lo largo de bandas latitudinales conocidos como "líneas de tormentas" (storm tracks).

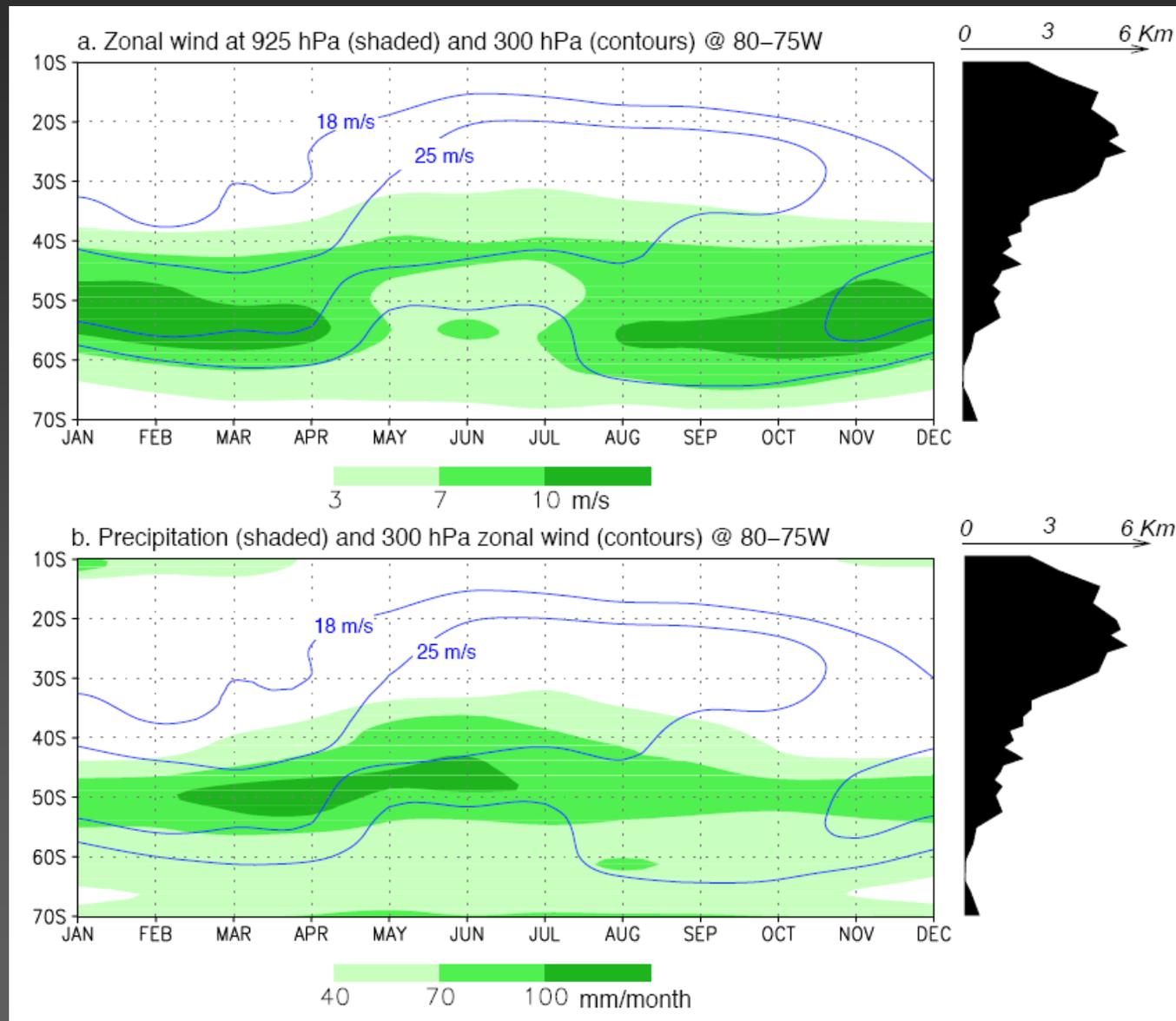
Northern Patagonia



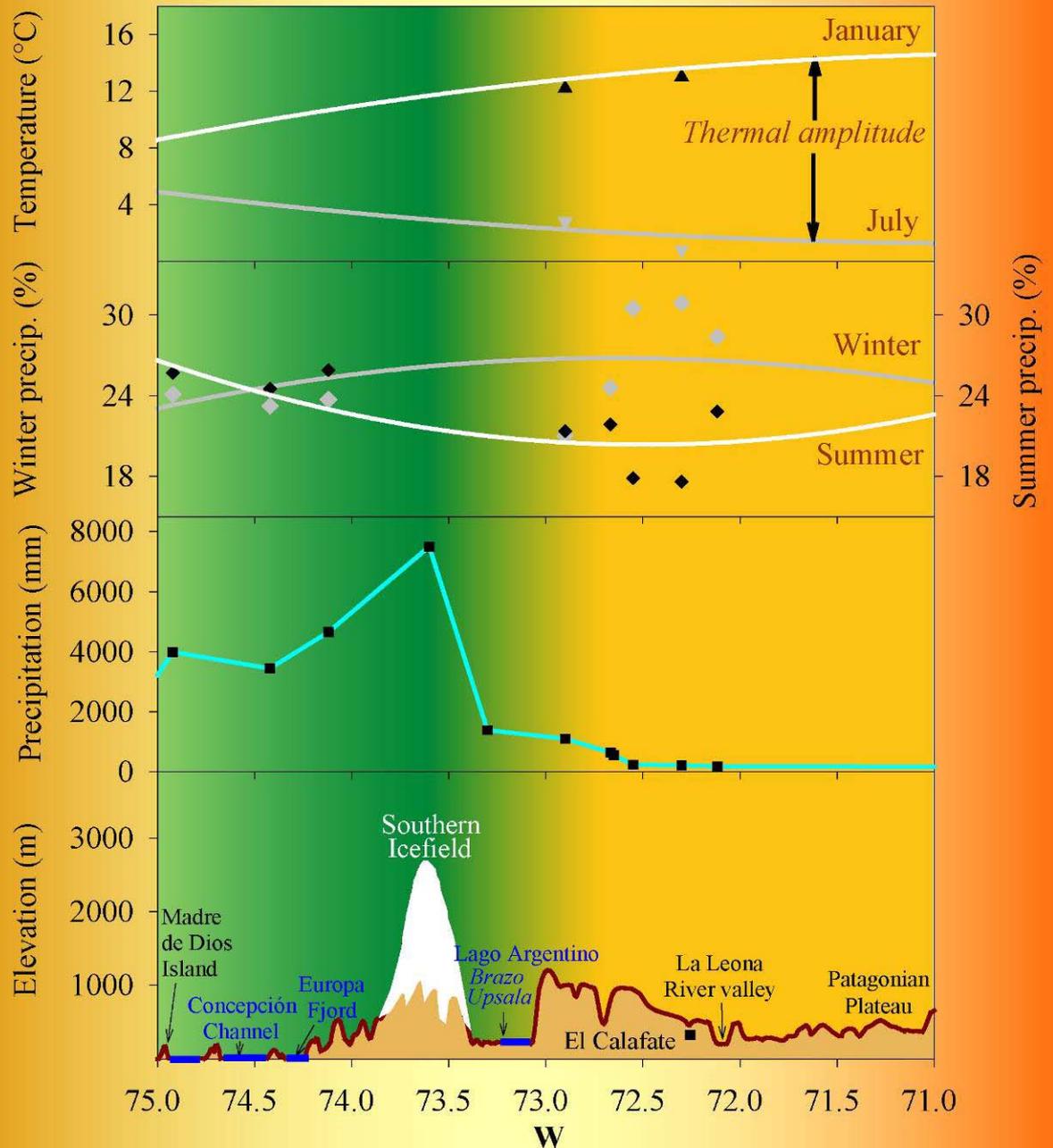


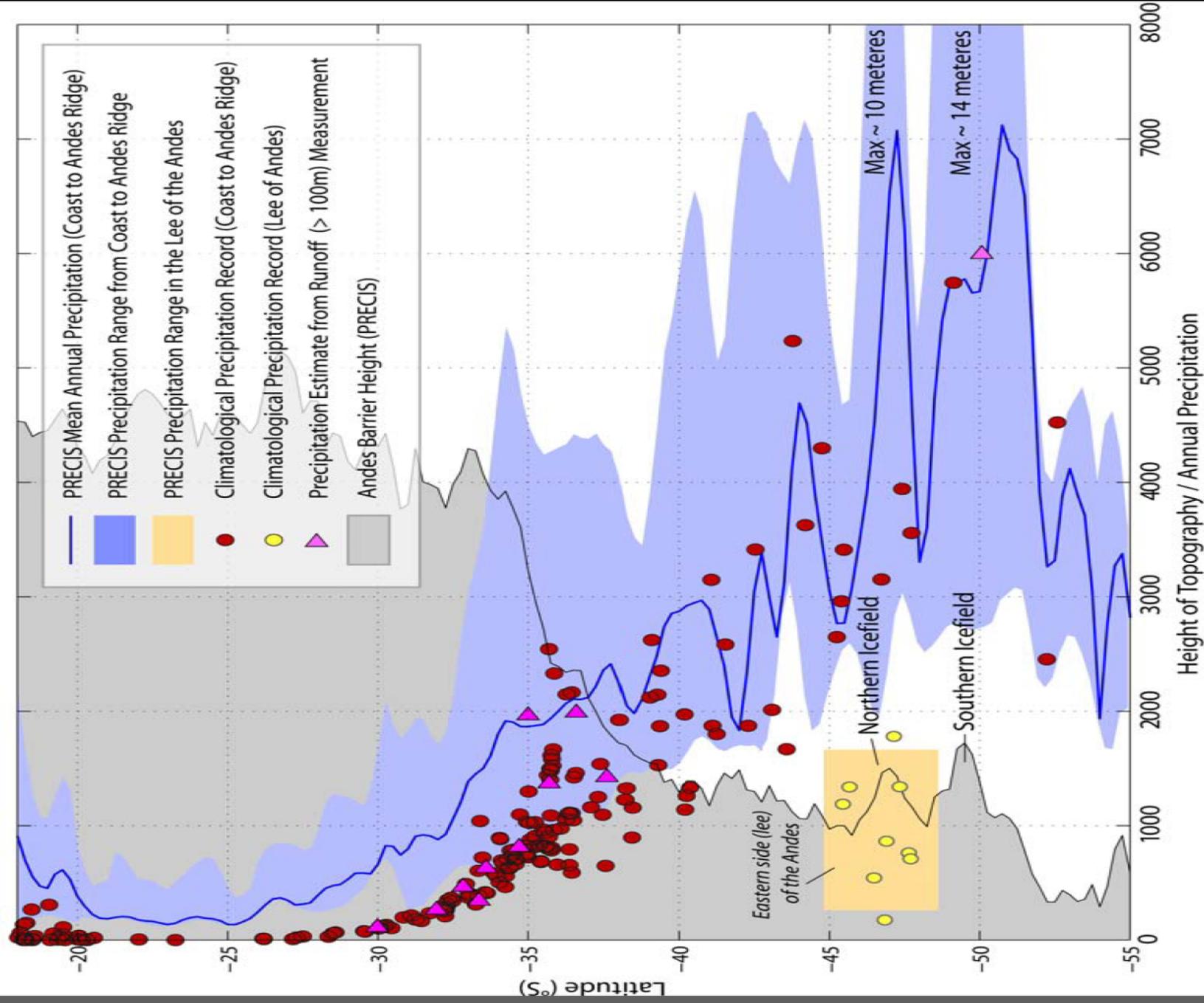
Sobre el extremo sur del continente los vientos del Oeste son mas fuertes en verano que invierno, alcanzando máximos valores entre los 45 y 55 S.

Durante el invierno, la corriente de chorro se expande hacia el ecuador pero es mas débil, particularmente a los 55 S.



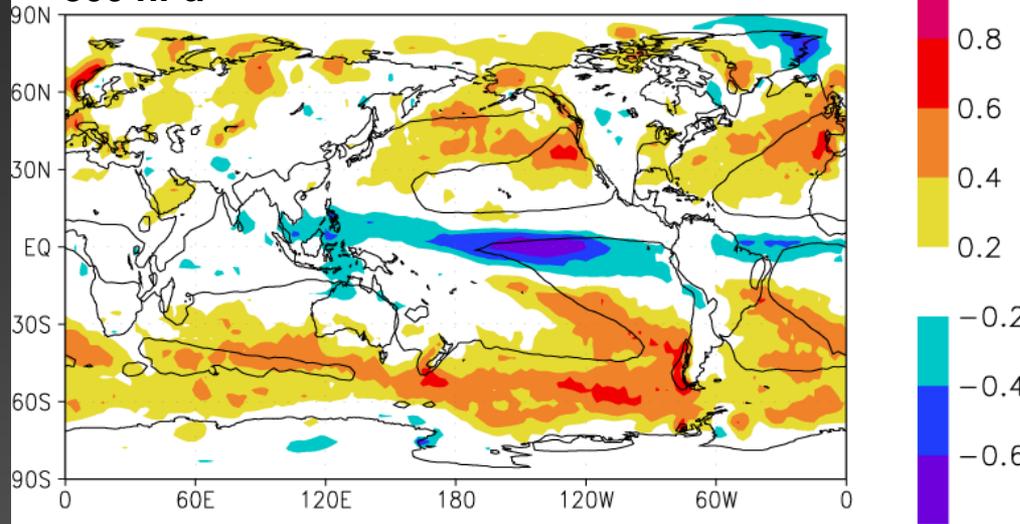
Southern Patagonia



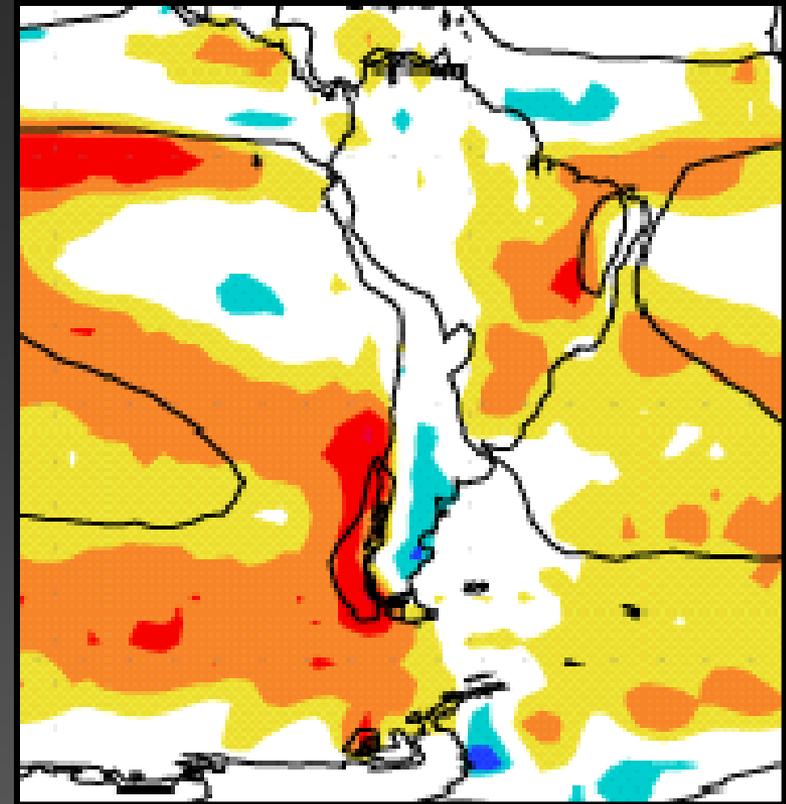
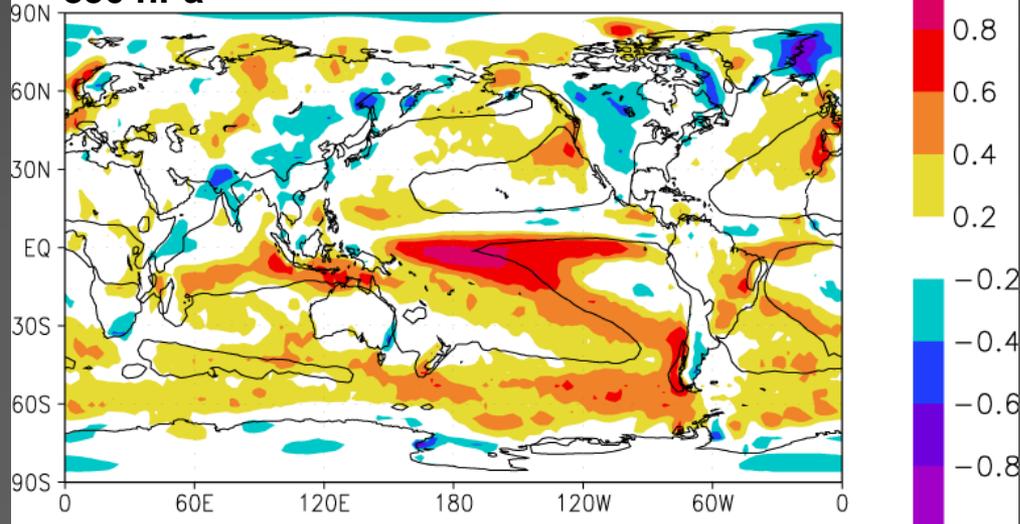


Local Correlation U850 – CMAP Precipitation using monthly anomalies (1979-2005)

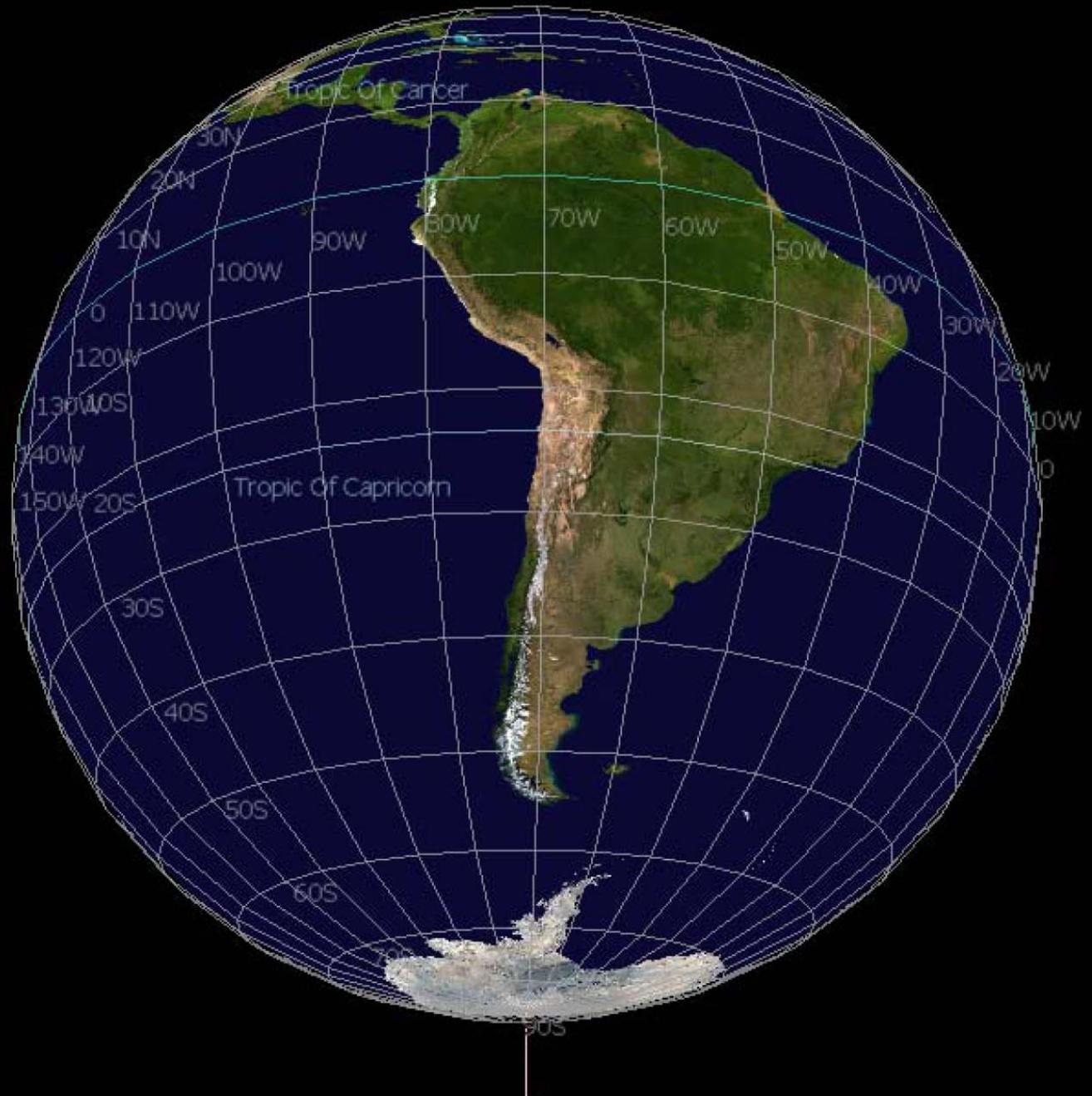
300 hPa



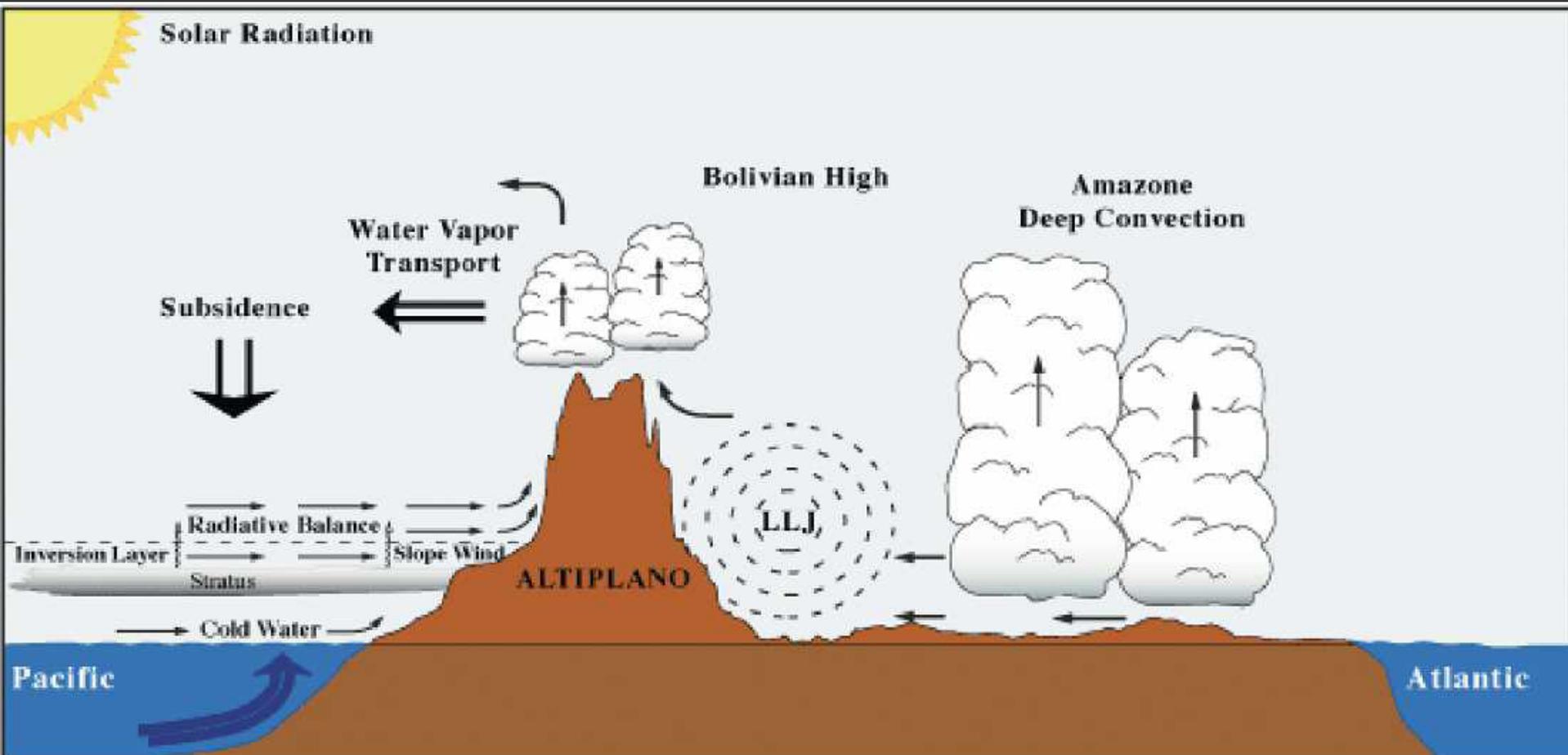
850 hPa



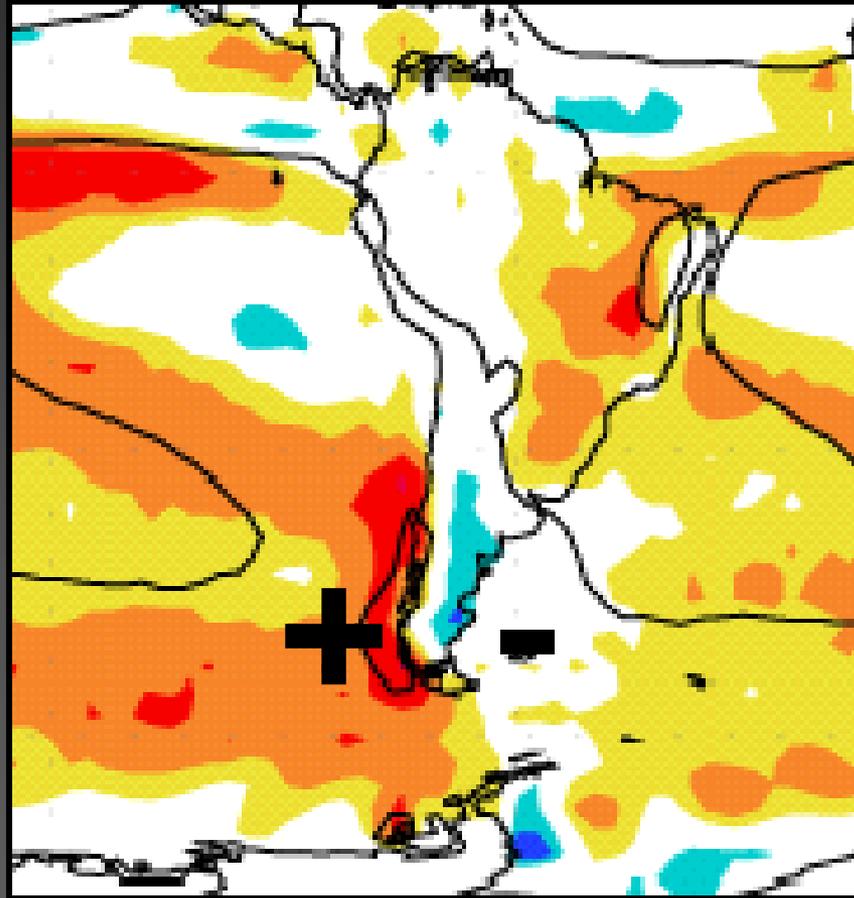
Stronger than normal Westerlies leads to rainy conditions over western Patagonia BUT drier conditions over eastern Patagonia...orographic effects: enhanced upslope rain / leeside rain shadow effect



1. Durante el verano, la baja sobre el Chaco fuerza la circulación con dirección este de los Alisios hacia el sur, la que es canalizada entre los Andes y el Escudo Brasileiro → Jet de baja altura
2. Durante el verano, el calor latente liberado por la convección sobre el Amazonas da origen a la formación de un anticiclón de altura, conocido como la Alta Boliviana (Bolivian High)



Local Correlation U850 – CMAP Precipitation using monthly anomalies (1979-2005)

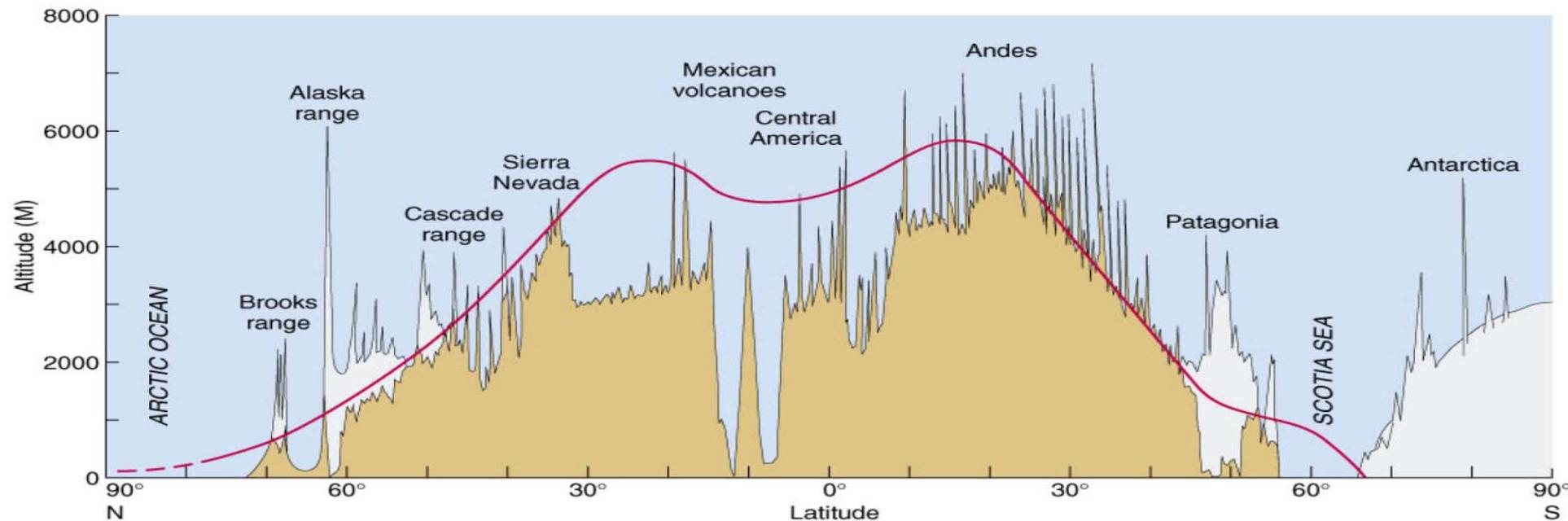


Stronger than normal westerlies leads to rainy conditions over western Patagonia
BUT drier conditions over eastern Patagonia....orographic effects: enhanced
upslope rain / leeside rain shadow effect

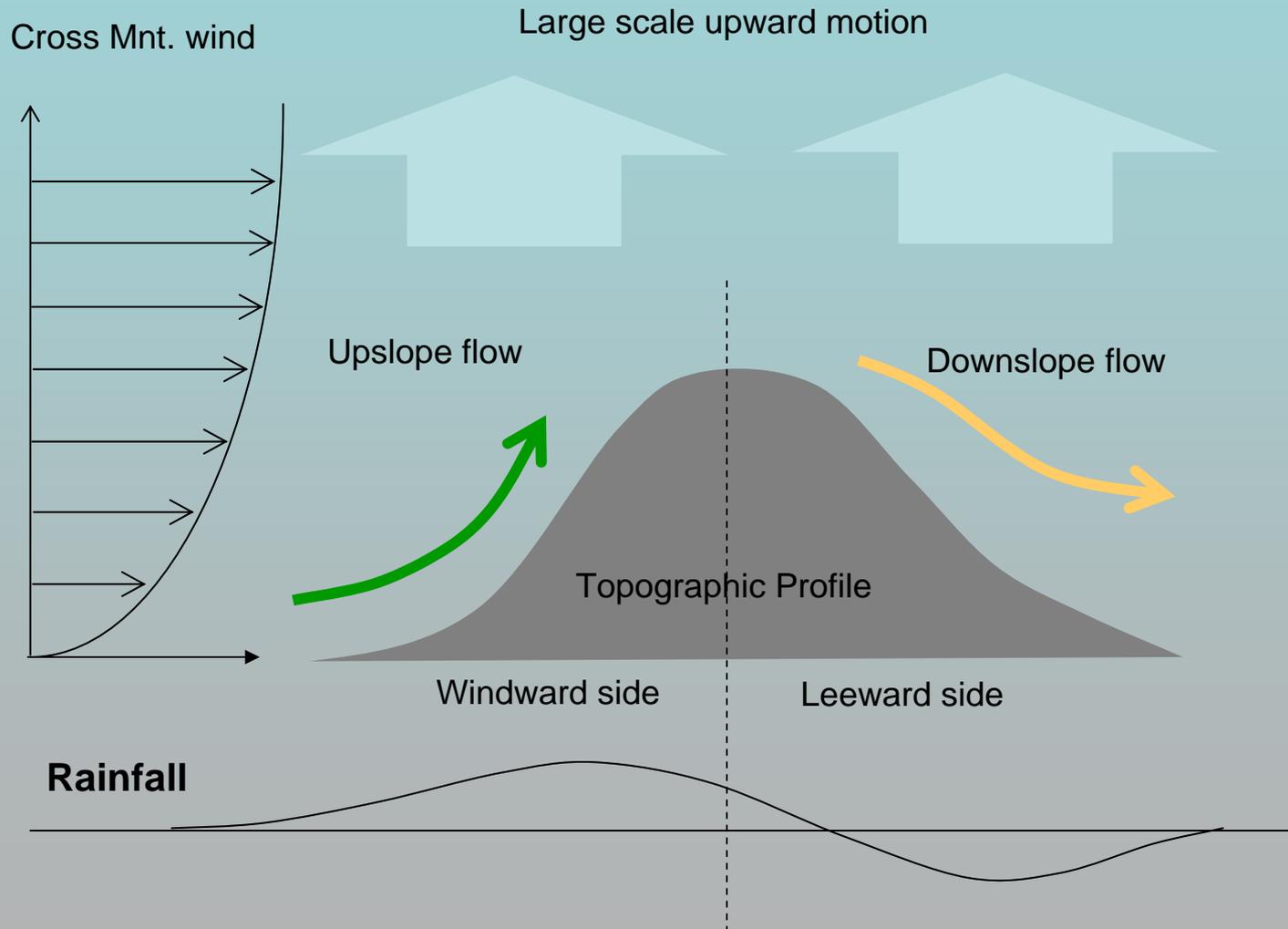
Los Andes: Contexto climático

La Cordillera de los Andes se extiende a lo largo de la Costa Oeste de América del Sur con elevaciones mayores a los 4km desde la región tropical hasta los 35-40°S.

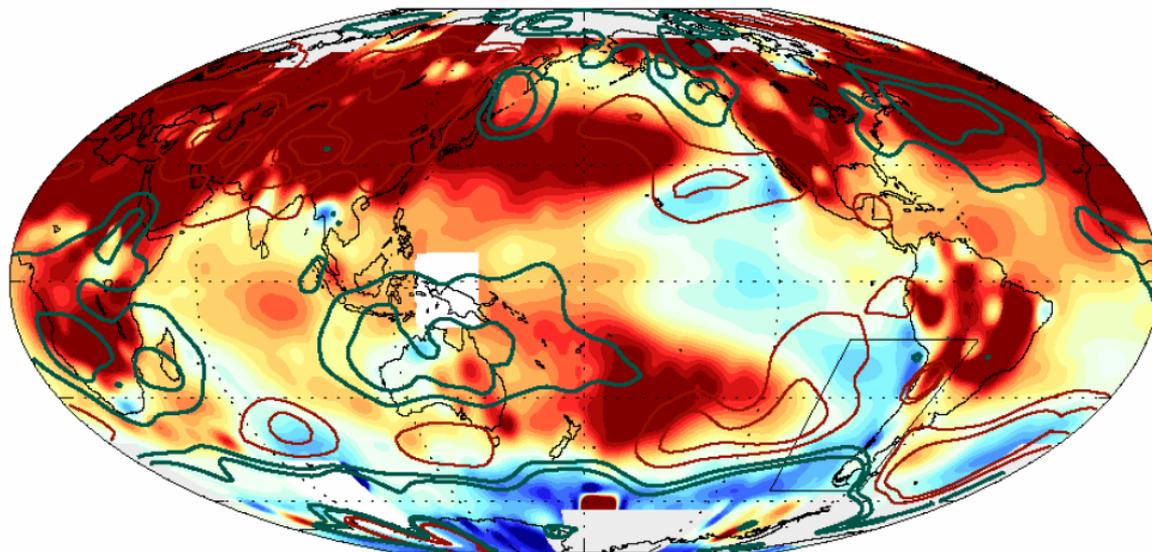
- Representa un obstáculo muy grande al flujo troposférico
- Es una barrera climática con distintas condiciones de humedad/temperatura en sus vertientes
- Favorece las interacciones trópico-extratropical en su flanco este (LLJ)



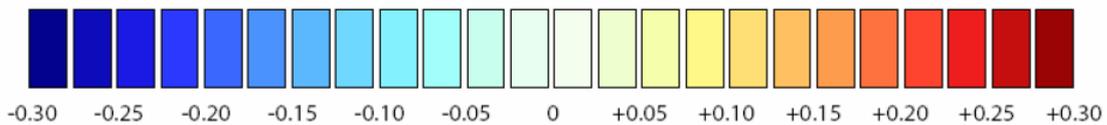
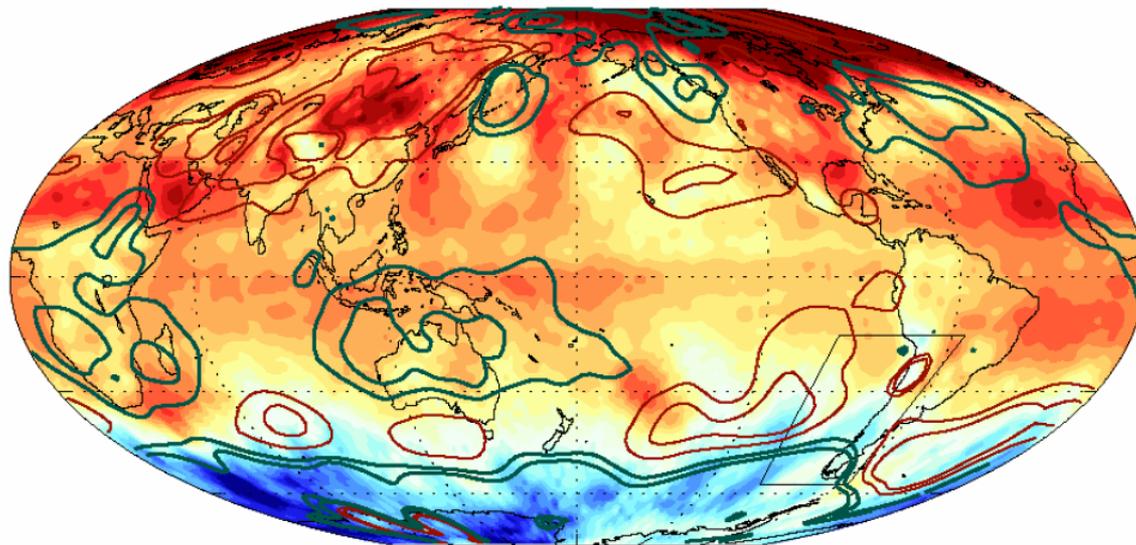
Orographic Effects



Surface Air Temperature and SST (NCDC)



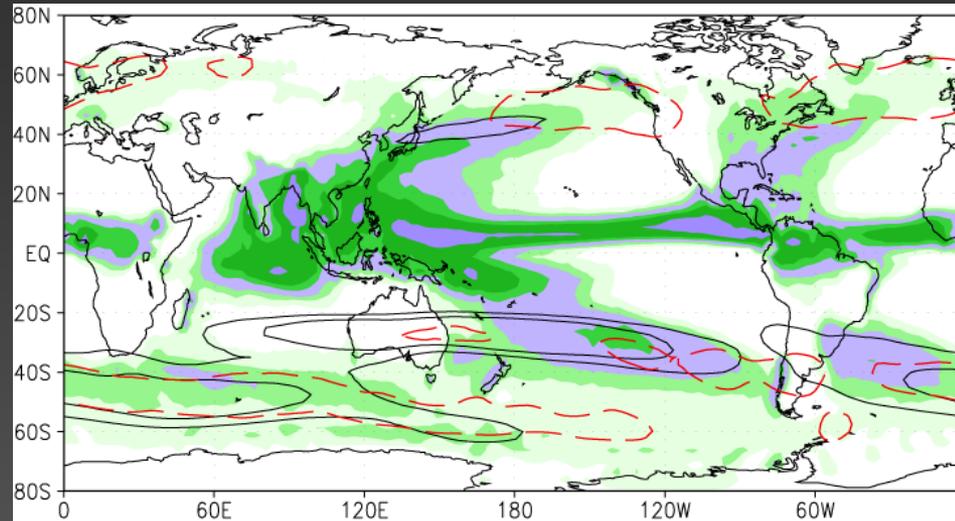
Mid-Troposphere Air Temperature (MSU)



Temperature Tendency 1979-2006 ($^{\circ}$ / decade)

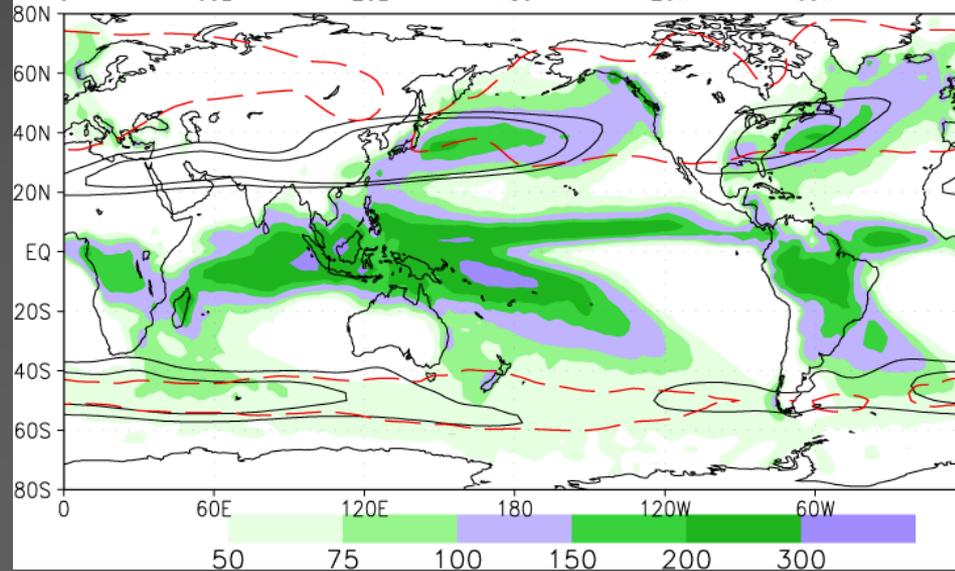
In real world the relation precipitation / storm activity /
precipitation is not so simple...

June

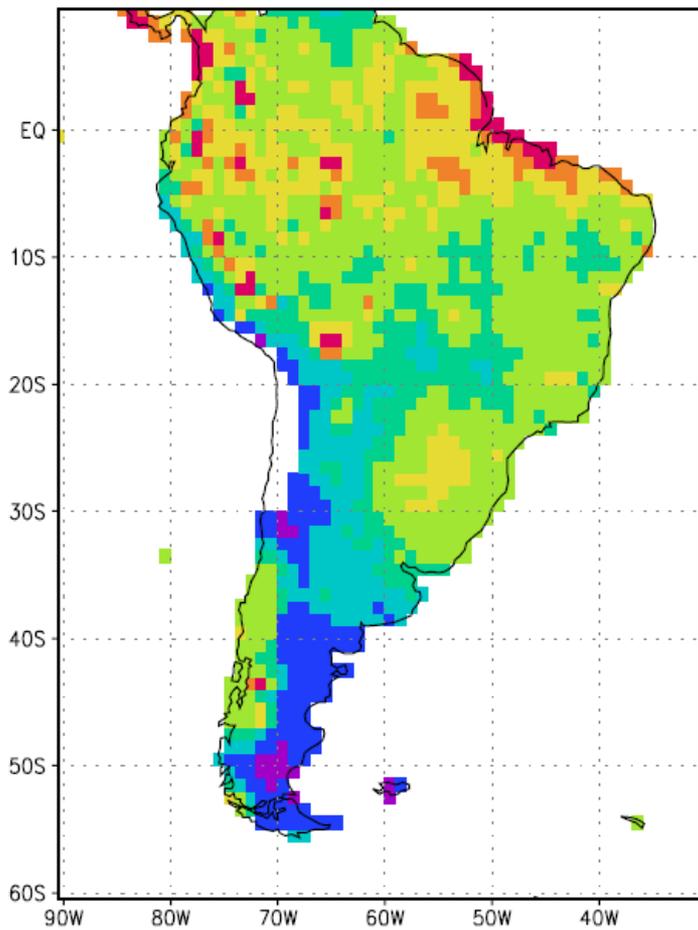


Jet streams
Storm Tracks
Rainfall

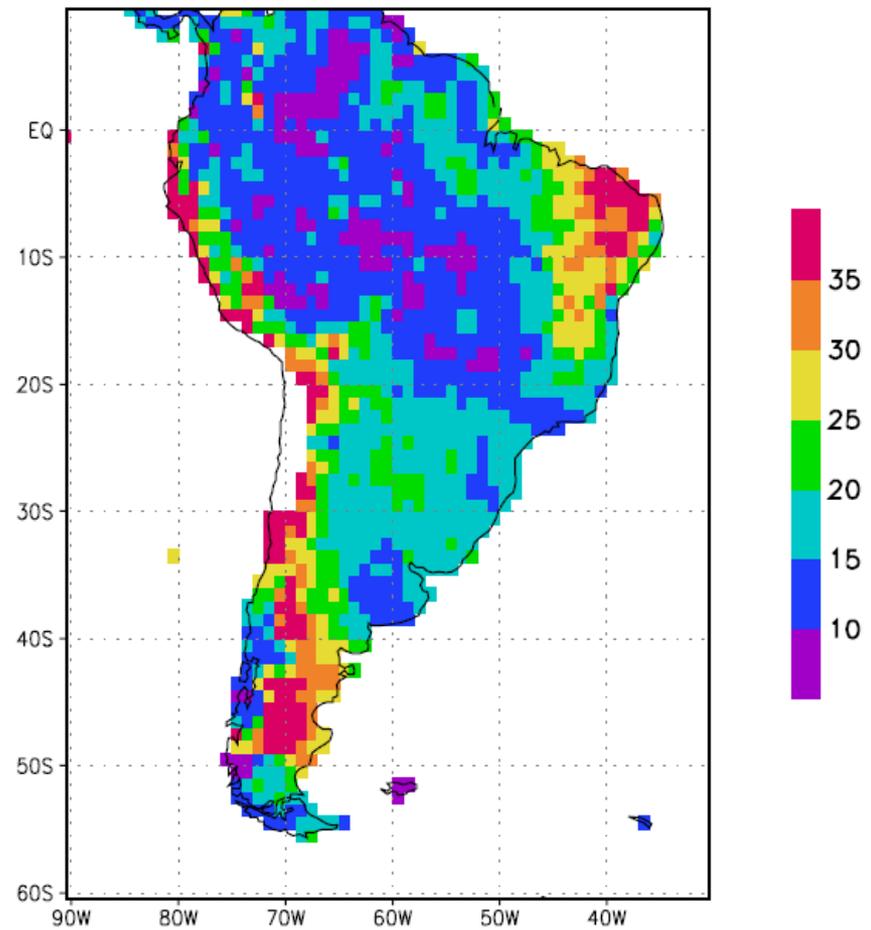
January



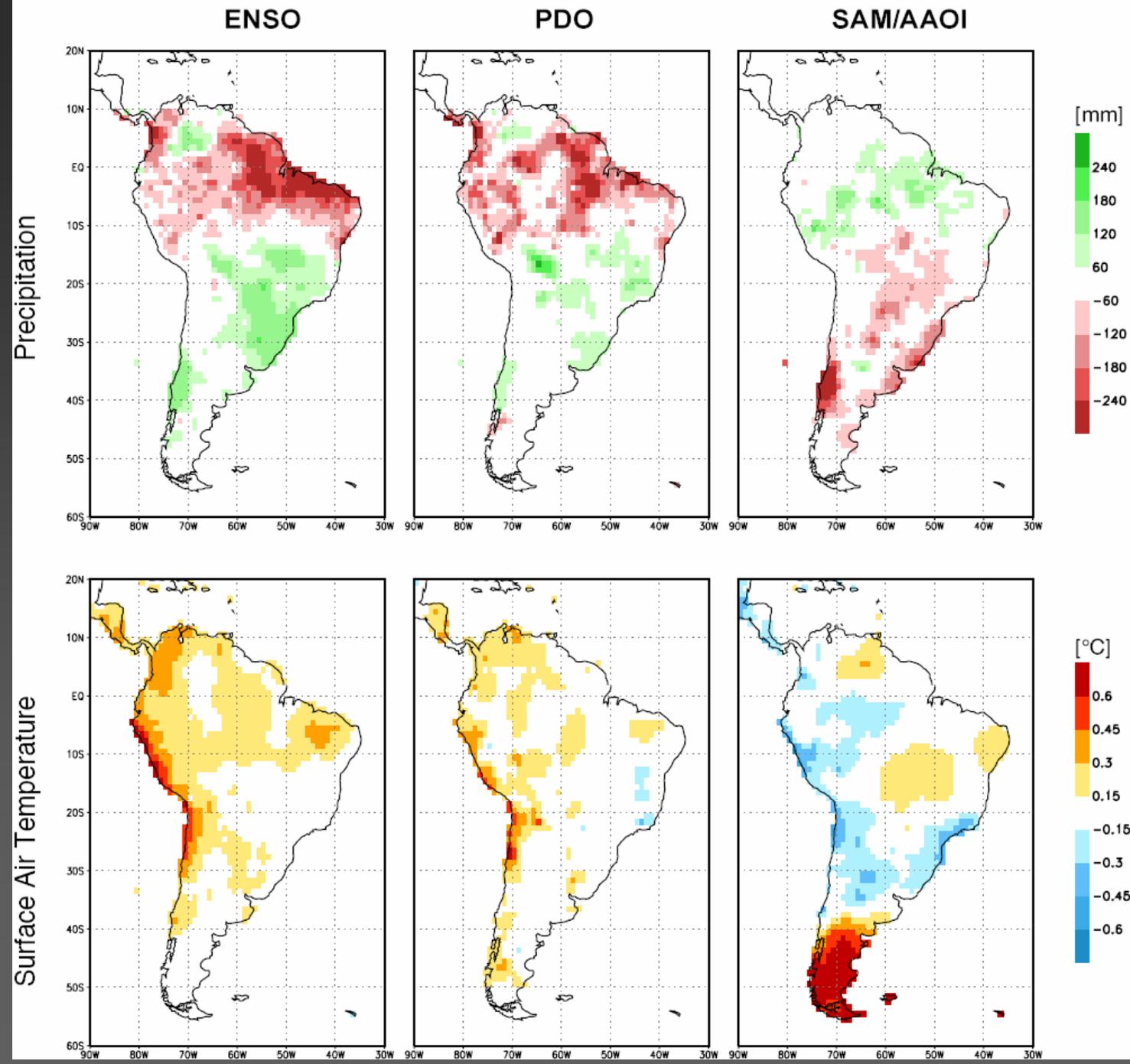
a. Interannual std. dev. [mm]



b. Isd / annual mean [%]



Anomalies of the AAO are related to significant changes on precipitation and temperature patterns across South America

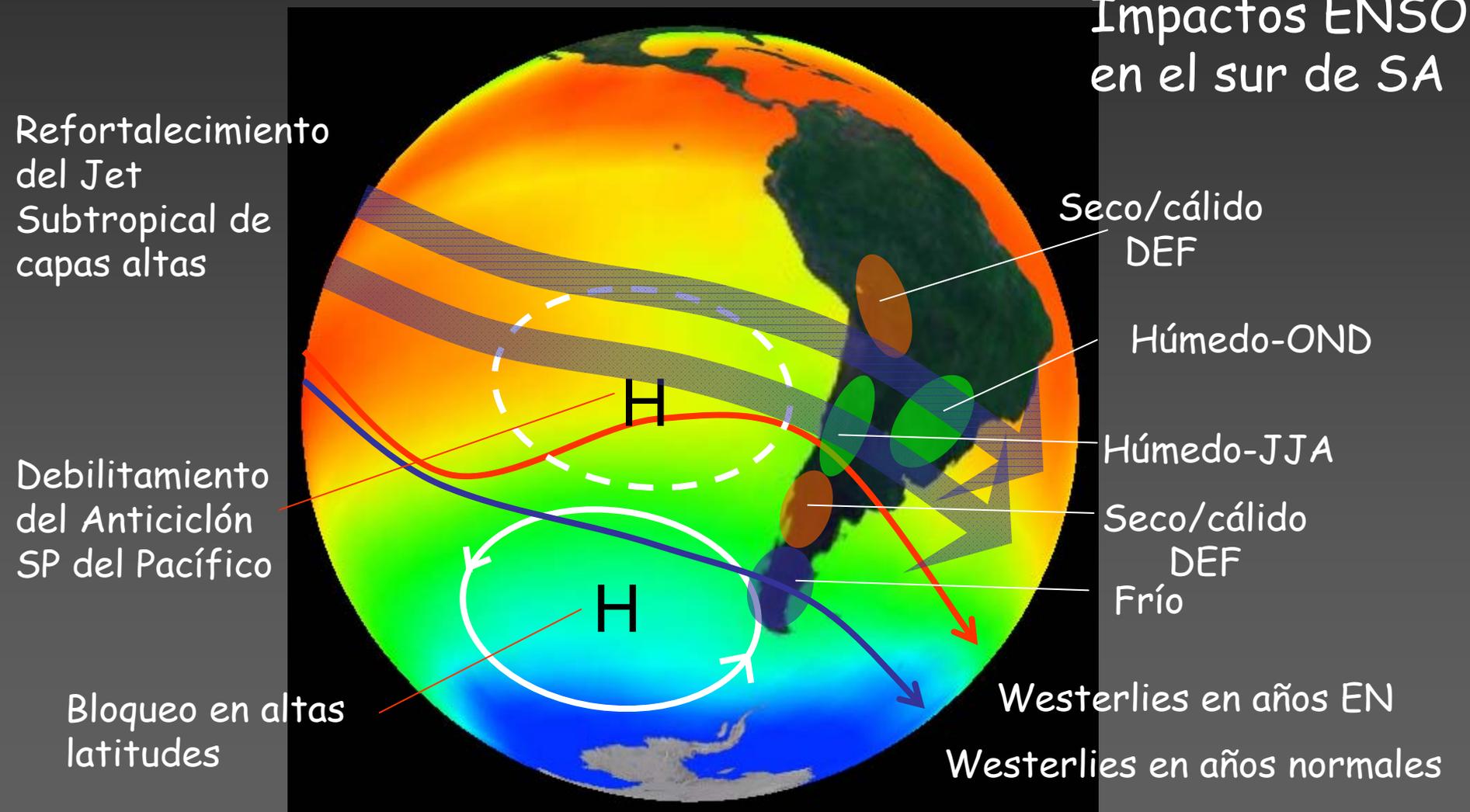


(from Garreaud et al. in press)

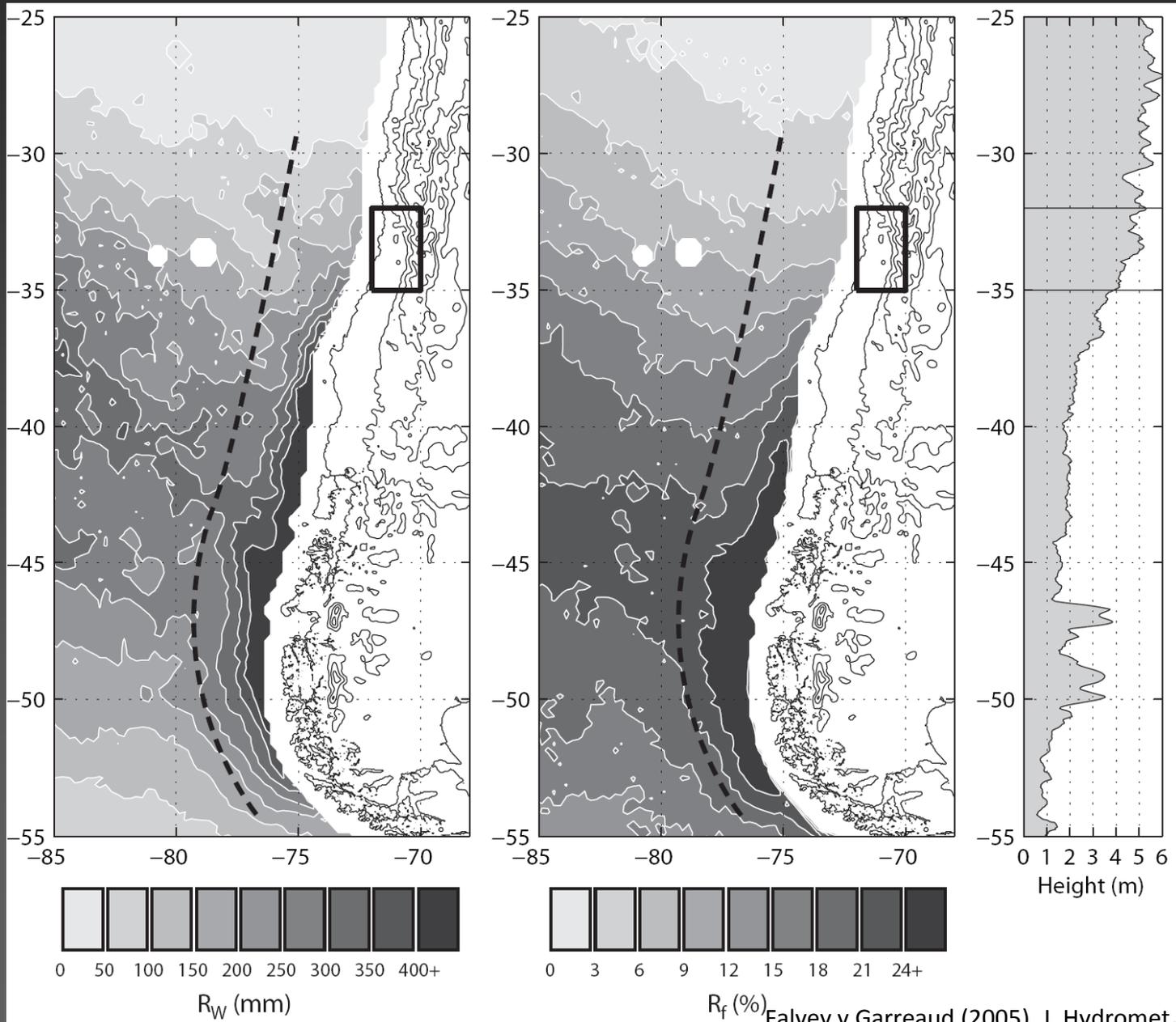
Algunos conceptos para ir entrando en calor...

6. Relacionar los cambios inter-regionales en base a nuestro conocimiento de la dinámica del sistema climático

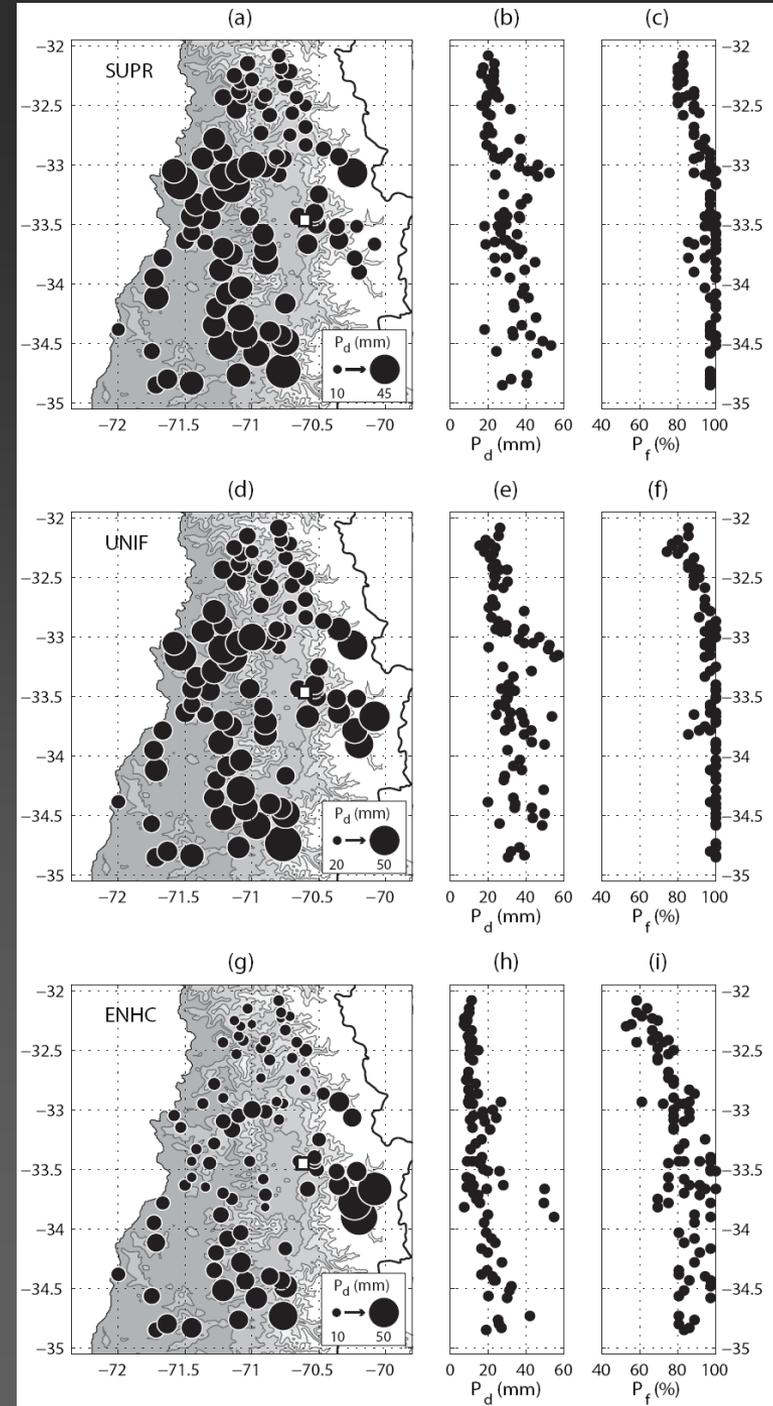
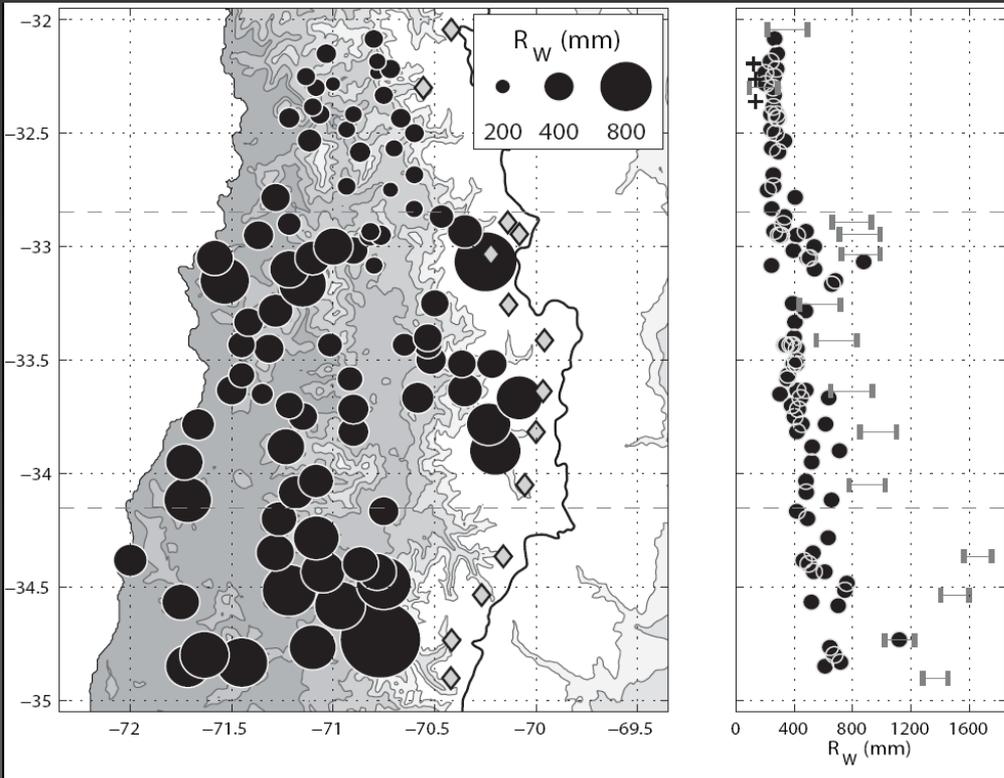
Impactos ENSO en el sur de SA



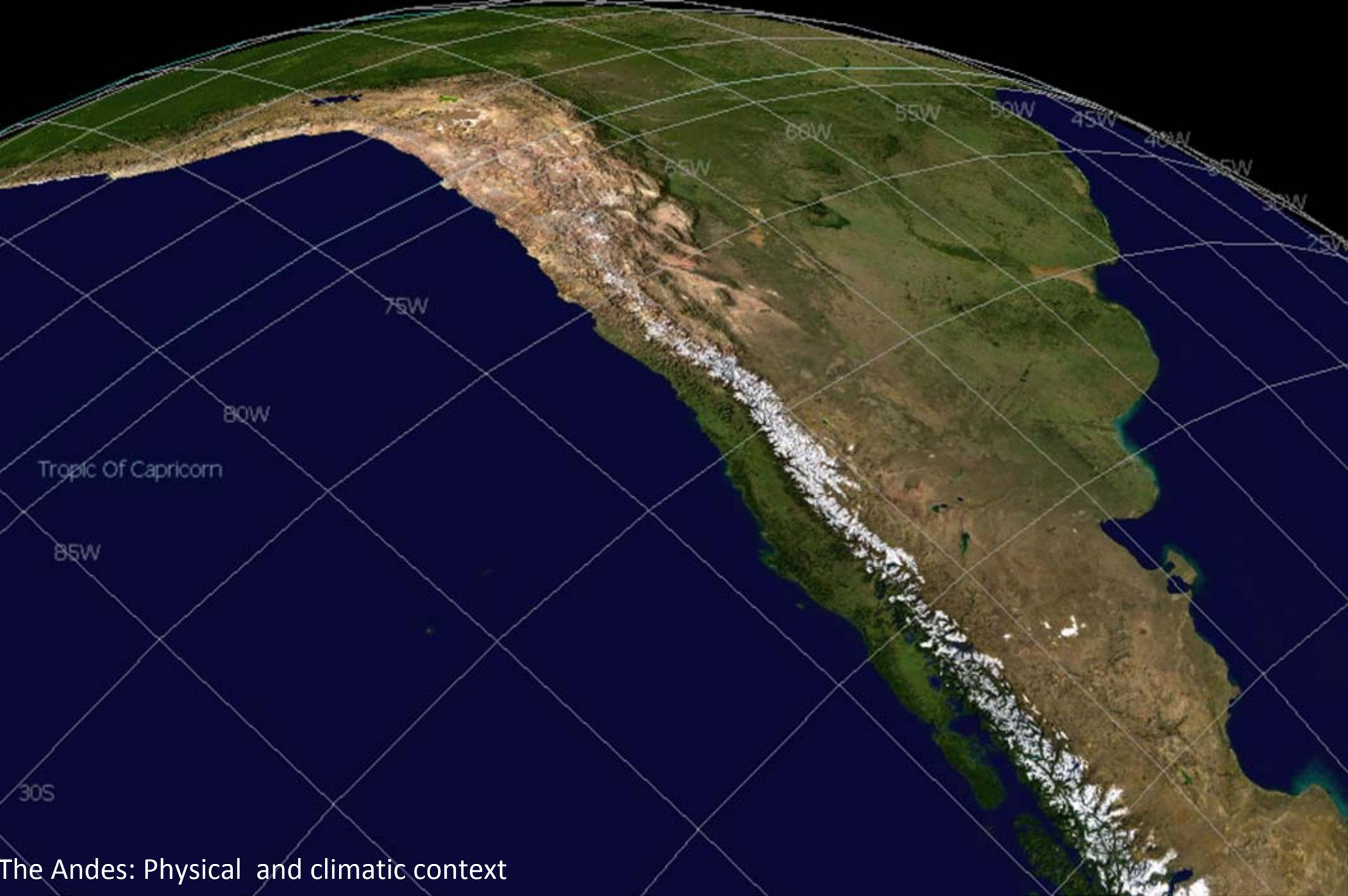
Influencia de los Andes en la precipitación de latitudes medias



Influencia orográfica en la precipitación de Chile Central



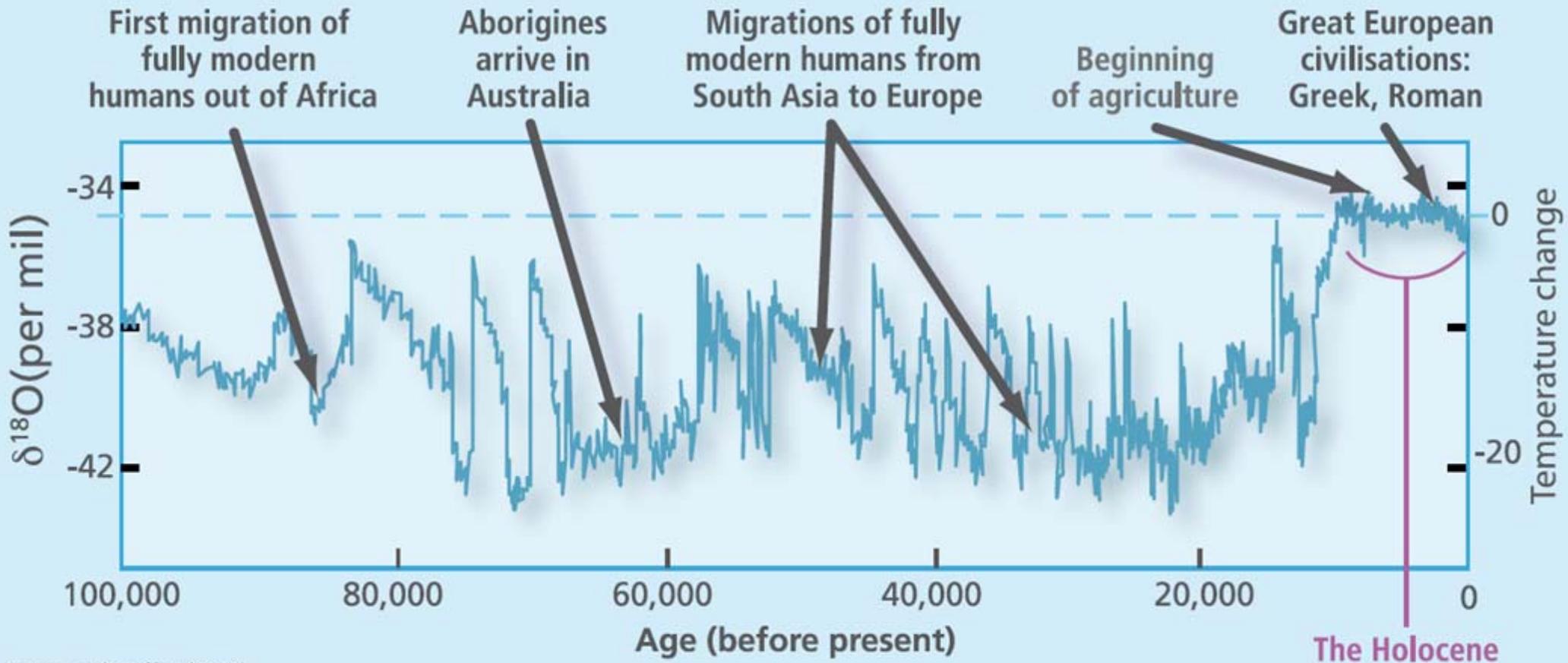
Falvey y Garreaud (2005), J. Hydromet.



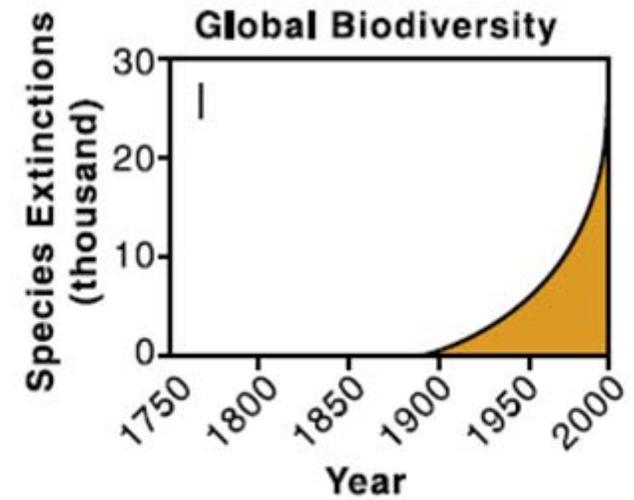
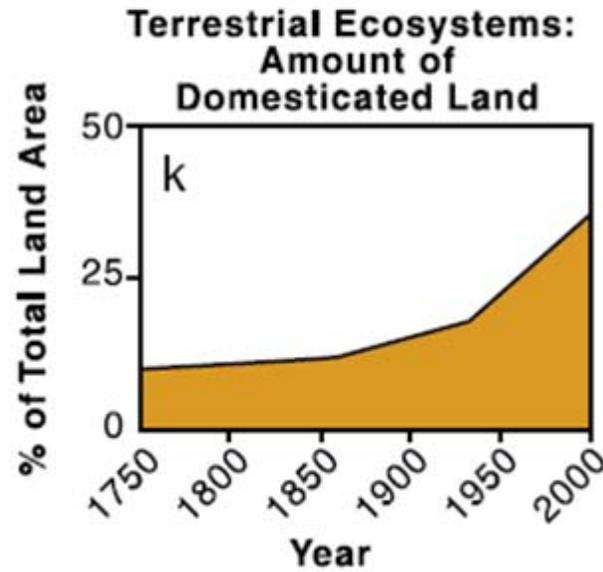
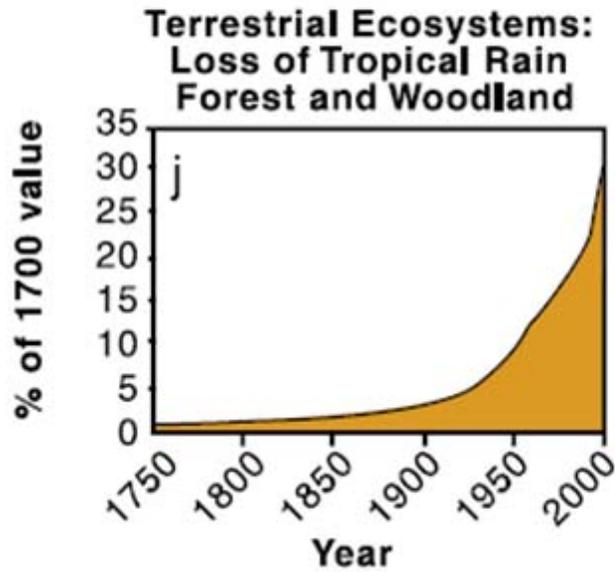
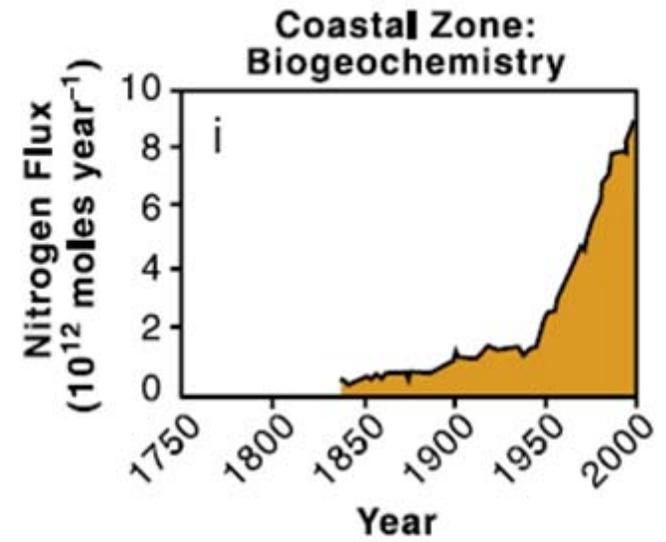
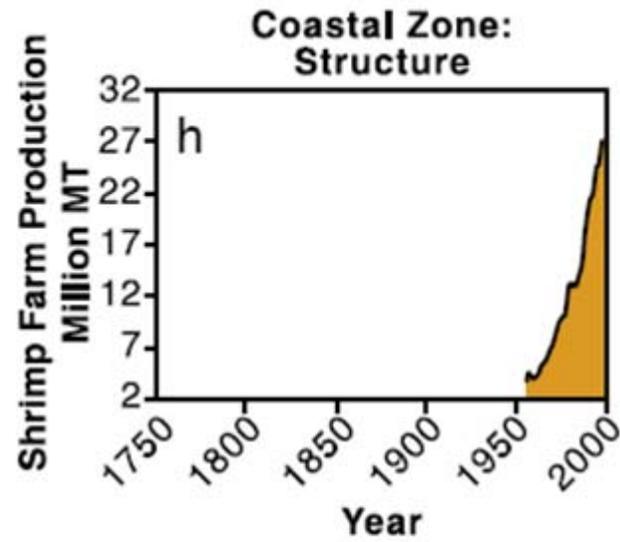
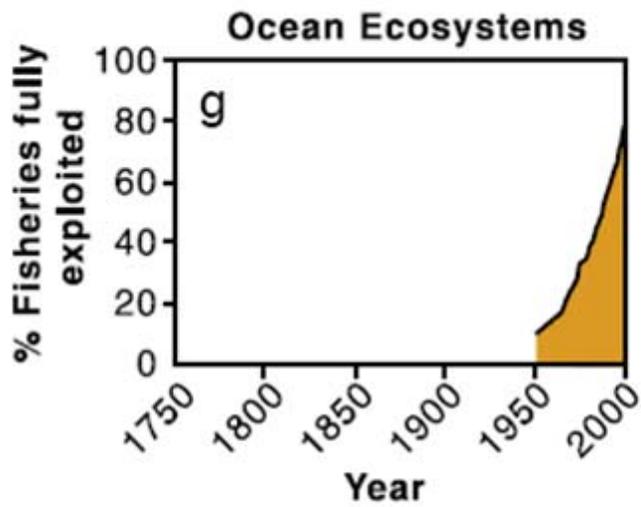
The Andes: Physical and climatic context



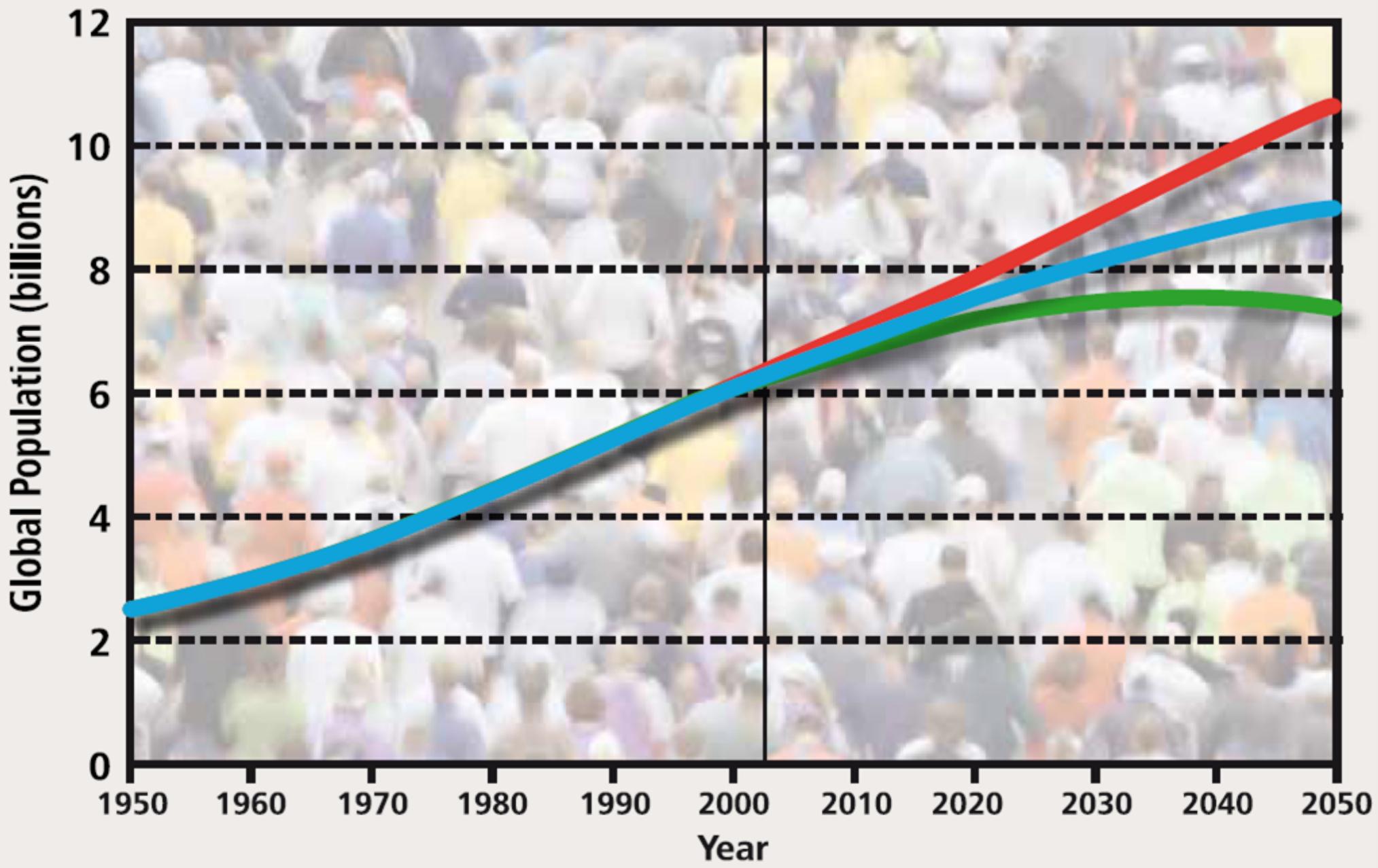
HUMAN DEVELOPMENT AND GLACIAL-INTERGLACIAL CYCLING



The period of stability — known to geologists as the Holocene — has seen human civilizations arise, develop and thrive

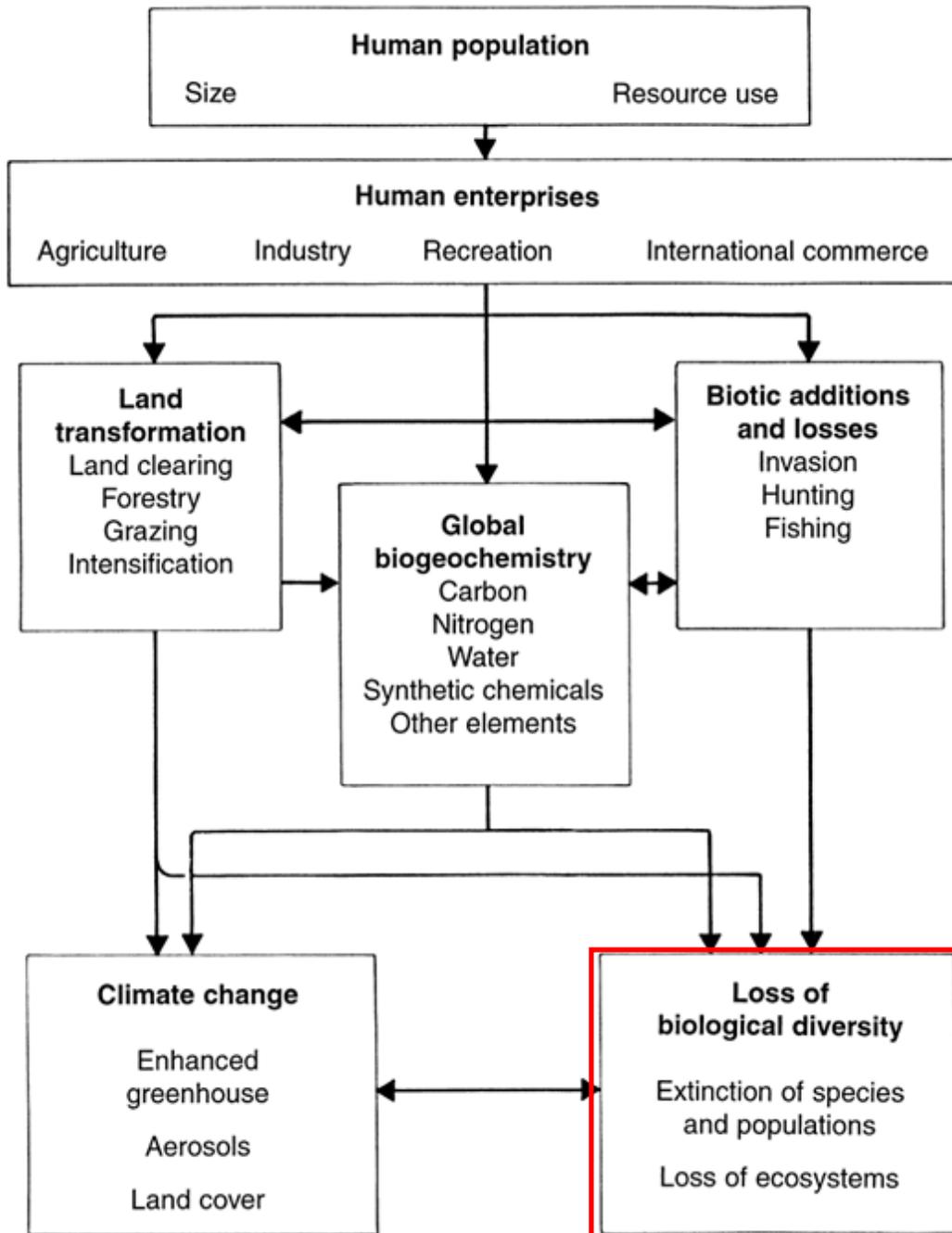


Human activities are the dominant forcing of environmental changes at global scale



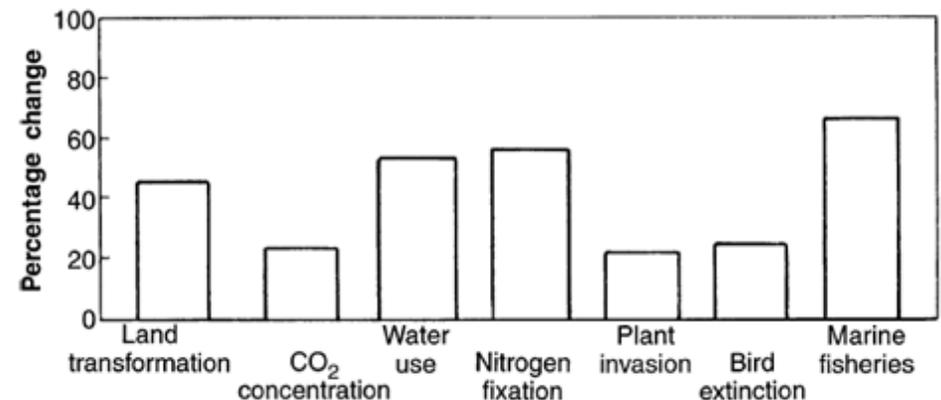
Human Domination of Earth's Ecosystems

Peter M. Vitousek, Harold A. Mooney, Jane Lubchenco, Jerry M. Melillo



Human alteration of Earth is substantial and growing. Between one-third and one-half of the land surface has been transformed by human action; the carbon dioxide concentration in the atmosphere has increased by nearly 30 percent since the beginning of the Industrial Revolution; more atmospheric nitrogen is fixed by humanity than by all natural terrestrial sources combined; more than half of all accessible surface fresh water is put to use by humanity; and about one-quarter of the bird species on Earth have been driven to extinction. By these and other standards, **it is clear that we live on a human-dominated planet.**

SCIENCE • VOL. 277 • 25 JULY 1997



Land-use changes in the Amazonia

2008



Land-use changes in the Amazonia

2008



Land-use changes in the Amazonia

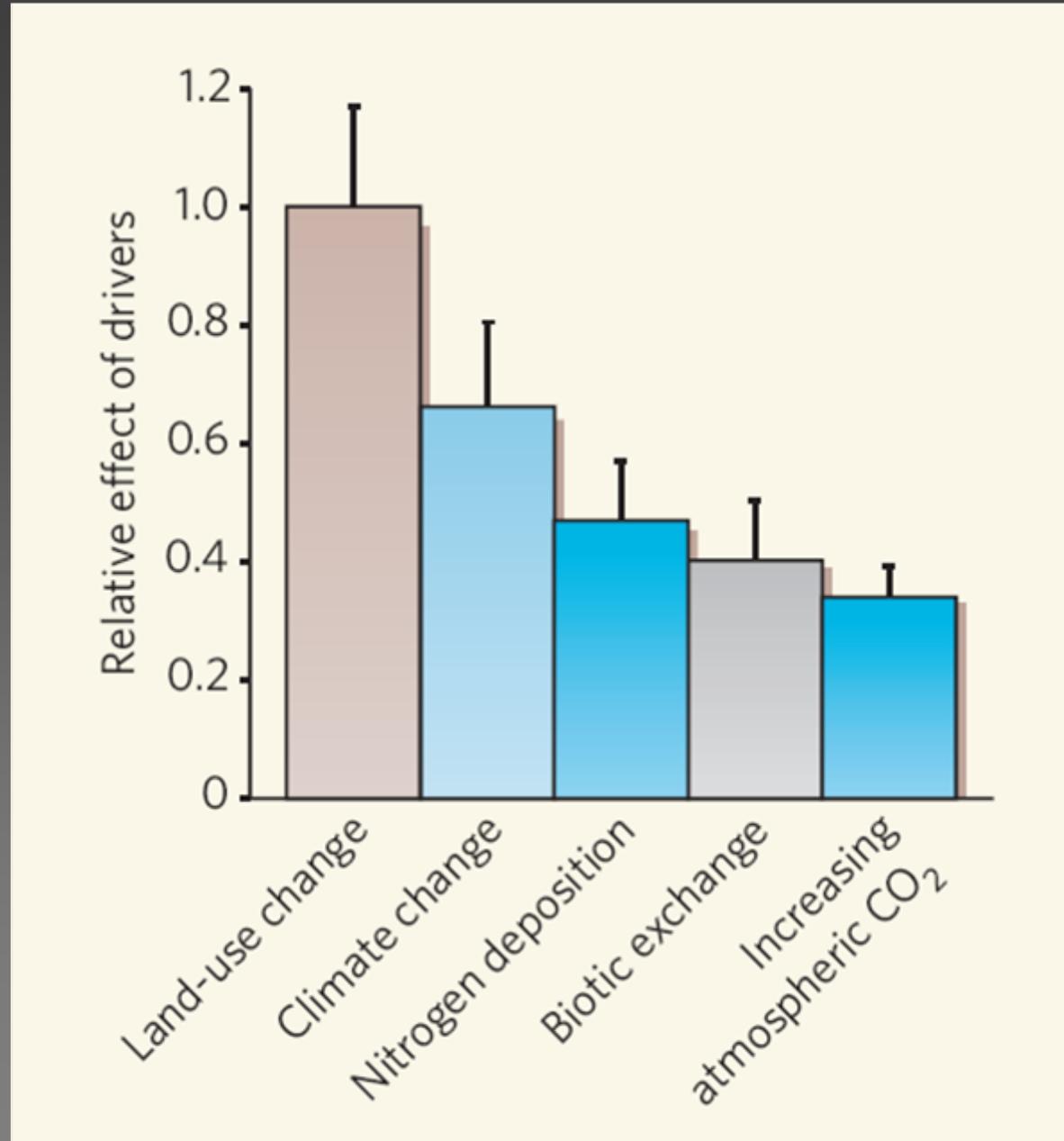
2008



The main factors, or 'drivers', affecting biodiversity.

This summary of the relative effects by the year 2100 is a composite derived from calculations carried out for 12 individual terrestrial and freshwater ecosystems by O. E. Sala *et al.* (*Science* 287, 1770–1774; 2000).

Overall, changes in land use constitute the main estimated impact on biodiversity, but the pattern varies considerably for different ecosystems. According to Sala and colleagues' calculations, climate change will have the strongest effect on Arctic, alpine and boreal ecosystems, whereas biotic exchange (that is, invasion by non-native species) will exert its main influence in lakes.

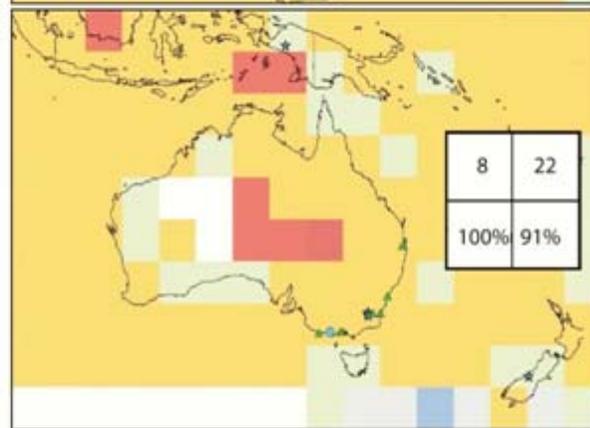
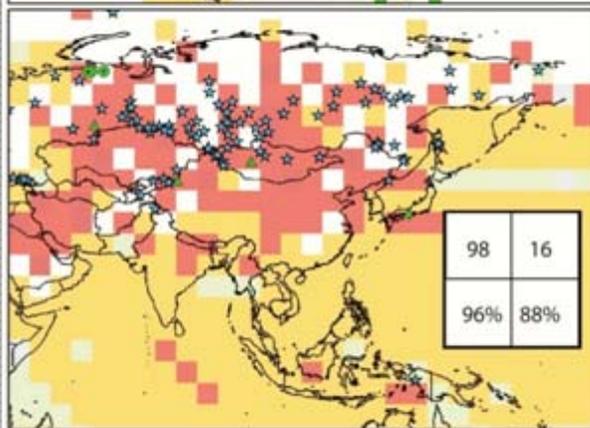
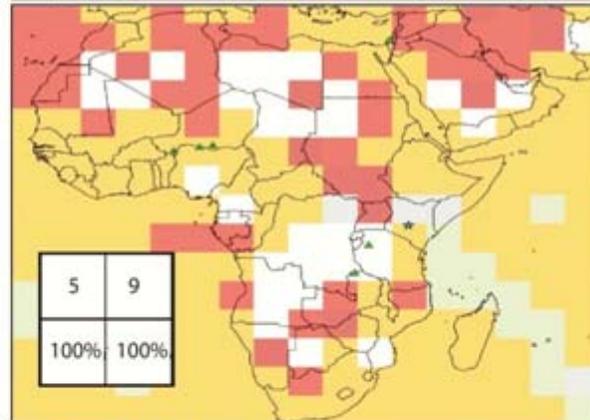
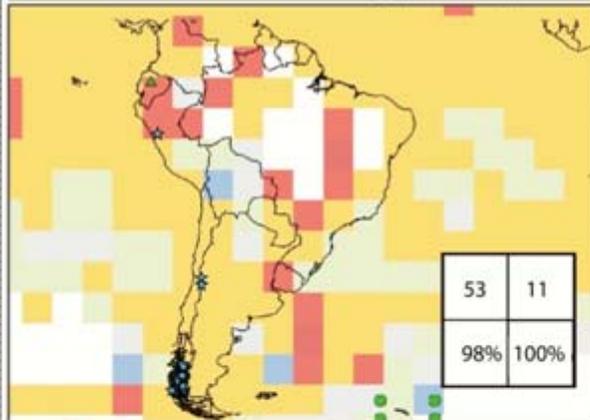
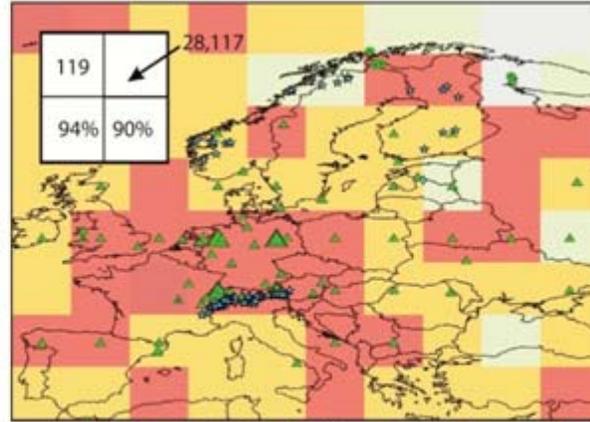
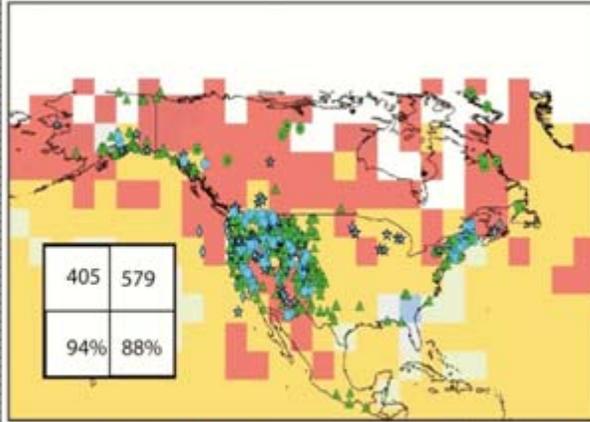


ARTICLES

Attributing physical and biological impacts to anthropogenic climate change

Cynthia Rosenzweig¹, David Karoly², Marta Vicarelli¹, Peter Neofotis¹, Qigang Wu³, Gino Casassa⁴, Annette Menzel⁵, Terry L. Root⁶, Nicole Estrella⁵, Bernard Seguin⁷, Piotr Tryjanowski⁸, Chunzhen Liu⁹, Samuel Rawlins¹⁰ & Anton Imeson¹¹

Significant changes in physical and biological systems are occurring on all continents and in most oceans, with a concentration of available data in Europe and North America. Most of these changes are in the direction expected with warming temperature. Here we show that these changes in natural systems since at least 1970 are occurring in regions of observed temperature increases, and that these temperature increases at continental scales cannot be explained by natural climate variations alone. Given the conclusions from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report that most of the observed increase in global average temperatures since the mid-twentieth century is very likely to be due to the observed increase in anthropogenic greenhouse gas concentrations, and furthermore that it is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica, we conclude that anthropogenic climate change is having a significant impact on physical and biological systems globally and in some continents.



- ★ Criósfera
- Hidrología
- ◇ Procesos costeros

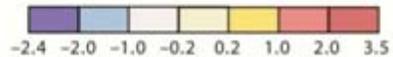
- ▲ Biología terrestre
- ▲ Agricultura

- Marinos
- Agua dulce

Número de estudios de biología terrestre en Europa

- ▲ 1-100
- ▲ 101-1,000
- ▲ 1,001-7,500

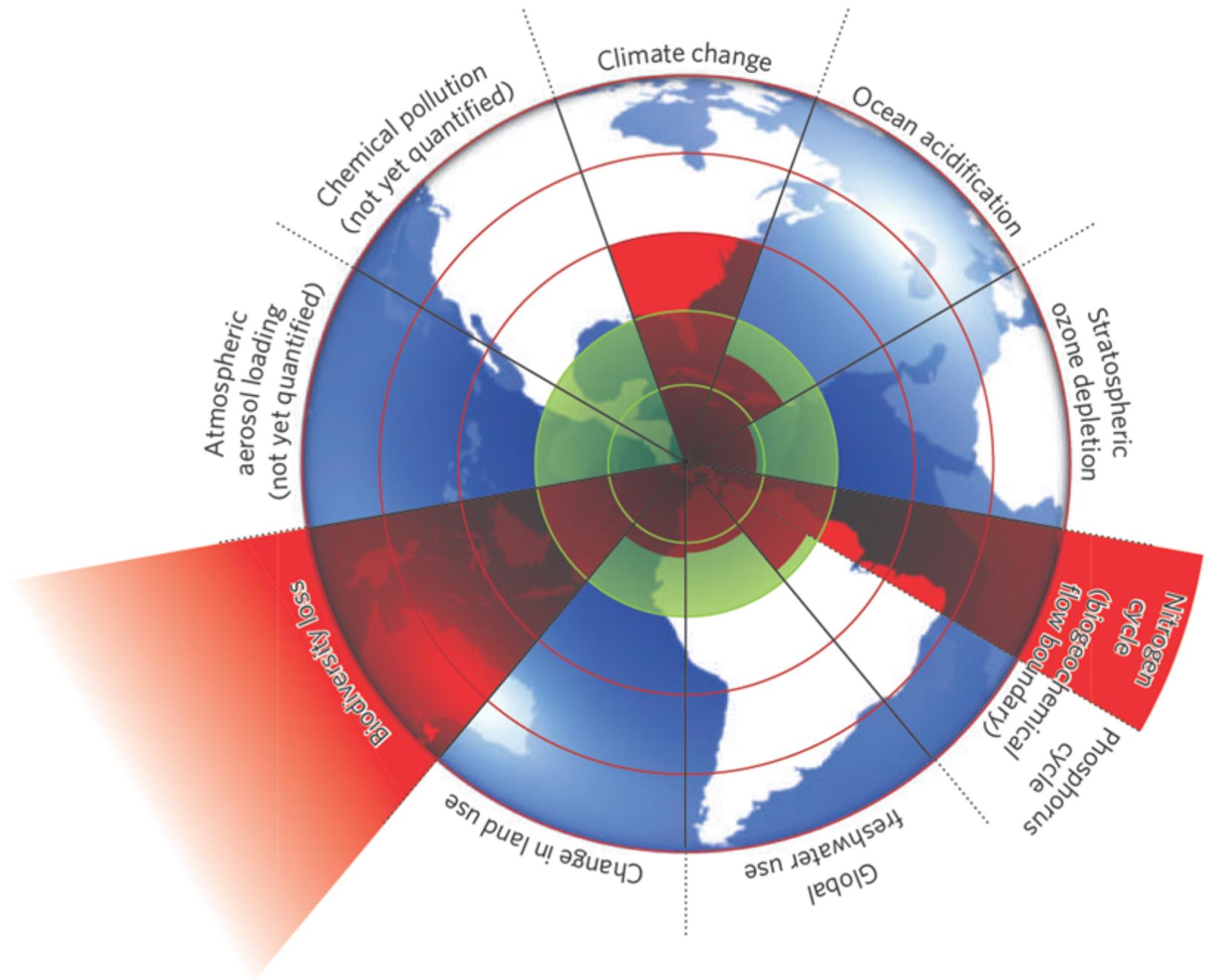
Cambios en temperatura (°C)
1970-2004



Sistemas físicos	Sistemas biológicos
Número de cambios observados significativos	Número de cambios observados significativos
Procentaje de cambios significativos consistenes con calentamiento	Procentaje de cambios significativos consistenes con calentamiento

A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue **Johan Rockström** and colleagues.



PLANETARY BOUNDARIES

Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per metre squared)	1	1.5	0
Rate of biodiversity	Extinction rate (number of species per million species per year)	10	>100	0.1-1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N ₂ removed from the atmosphere for human use (millions of tonnes per year)	35	121	0
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	11	8.5–9.5	-1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km ³ per year)	4000	2600	415
Change in land use	Percentage of global land cover converted to cropland	15	11.7	low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis	to be determined		

Human Domination of Earth's Ecosystems

Peter M. Vitousek, Harold A. Mooney, Jane Lubchenco, Jerry M. Melillo

Conclusions

The global consequences of human activity are not something to face in the future—as Fig. 2 illustrates, they are with us now. All of these changes are ongoing, and in many cases accelerating; many of them were entrained long before their importance was recognized. Moreover, all of these seemingly disparate phenomena trace to a single cause—the growing scale of the human enterprise. **The rates, scales, kinds, and combinations of changes occurring now are fundamentally different from those at any other time in history; we are changing Earth more rapidly than we are understanding it.**

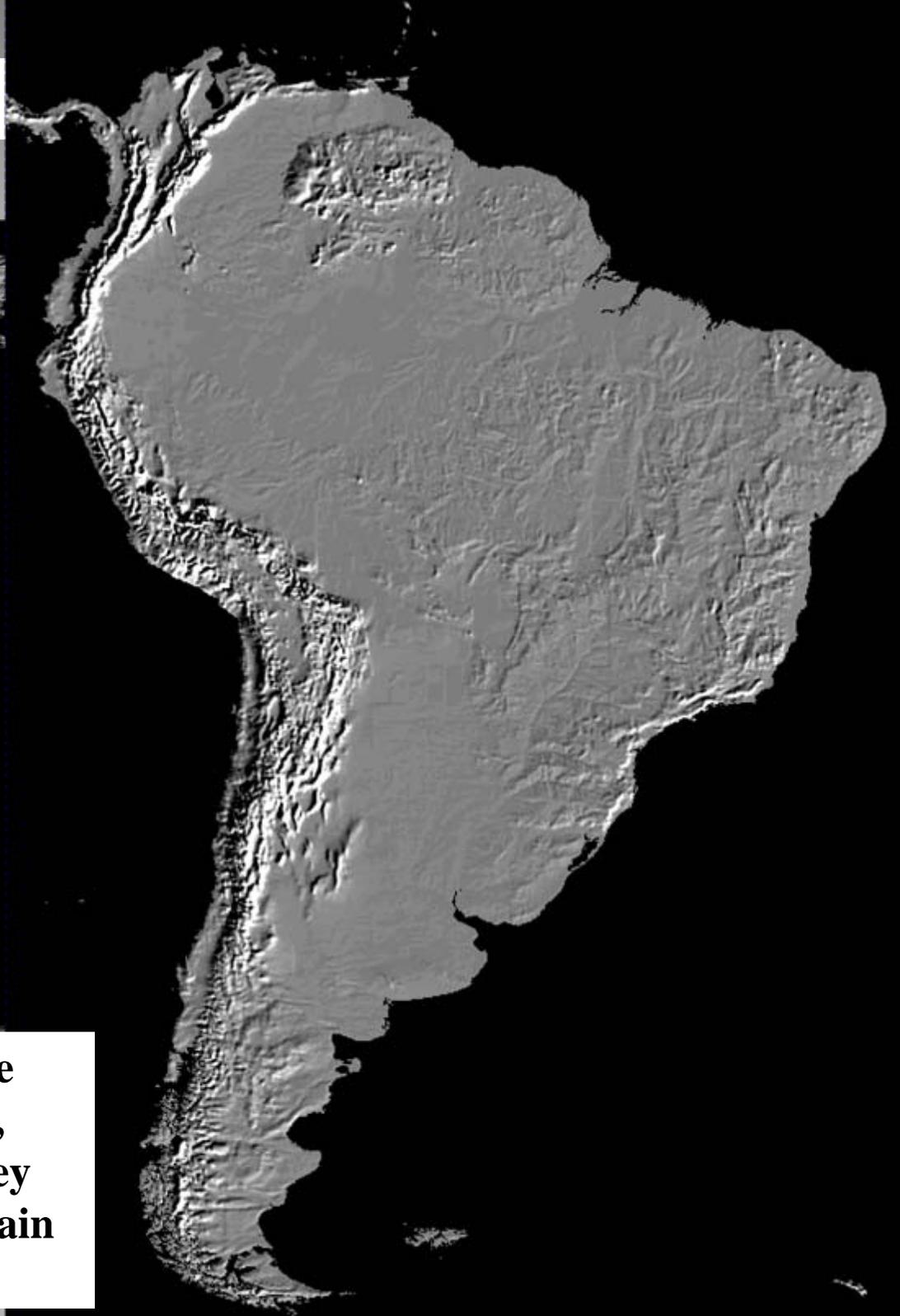
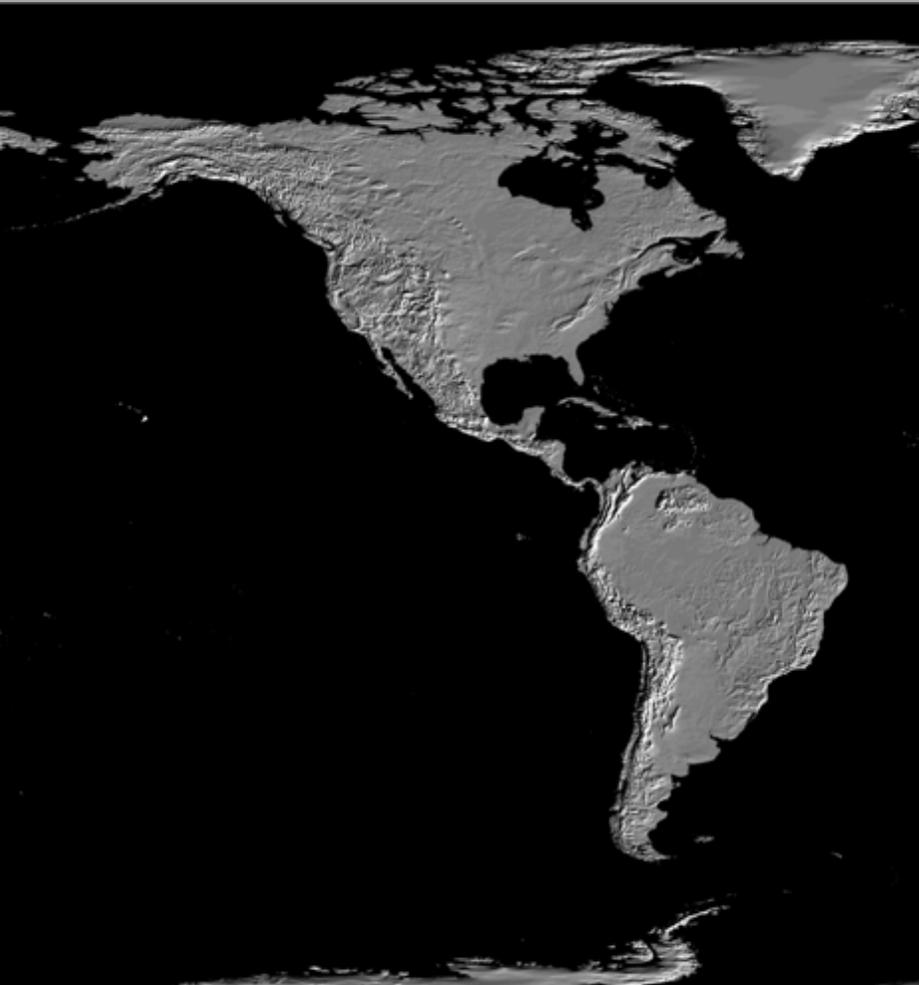
Conclusiones

Las consecuencias globales de la actividad humana no es algo que debamos enfrentar en el futuro, las estamos viviendo ahora. Todos estos cambios están ocurriendo y en muchos casos acelerándose; muchos ya ocurrían antes de que su importancia fuese reconocida. Además, todos estos procesos se relacionan a una única causa – la creciente corriente del desarrollo humano. Las velocidades, tipos y combinaciones de los cambios que están ocurriendo son fundamentalmente diferente de aquellos que ocurrieron en tiempos pasados; estamos cambiando el Planeta mas rápidamente de lo que lo estamos entendiendo.





The Andes are the most important



The Andes are a relatively narrow range with a typical width of less than 200 km, except at subtropical latitudes where they split into two mountain ranges and contain the Bolivian Altiplano

Climate, tectonics, and the morphology of the Andes

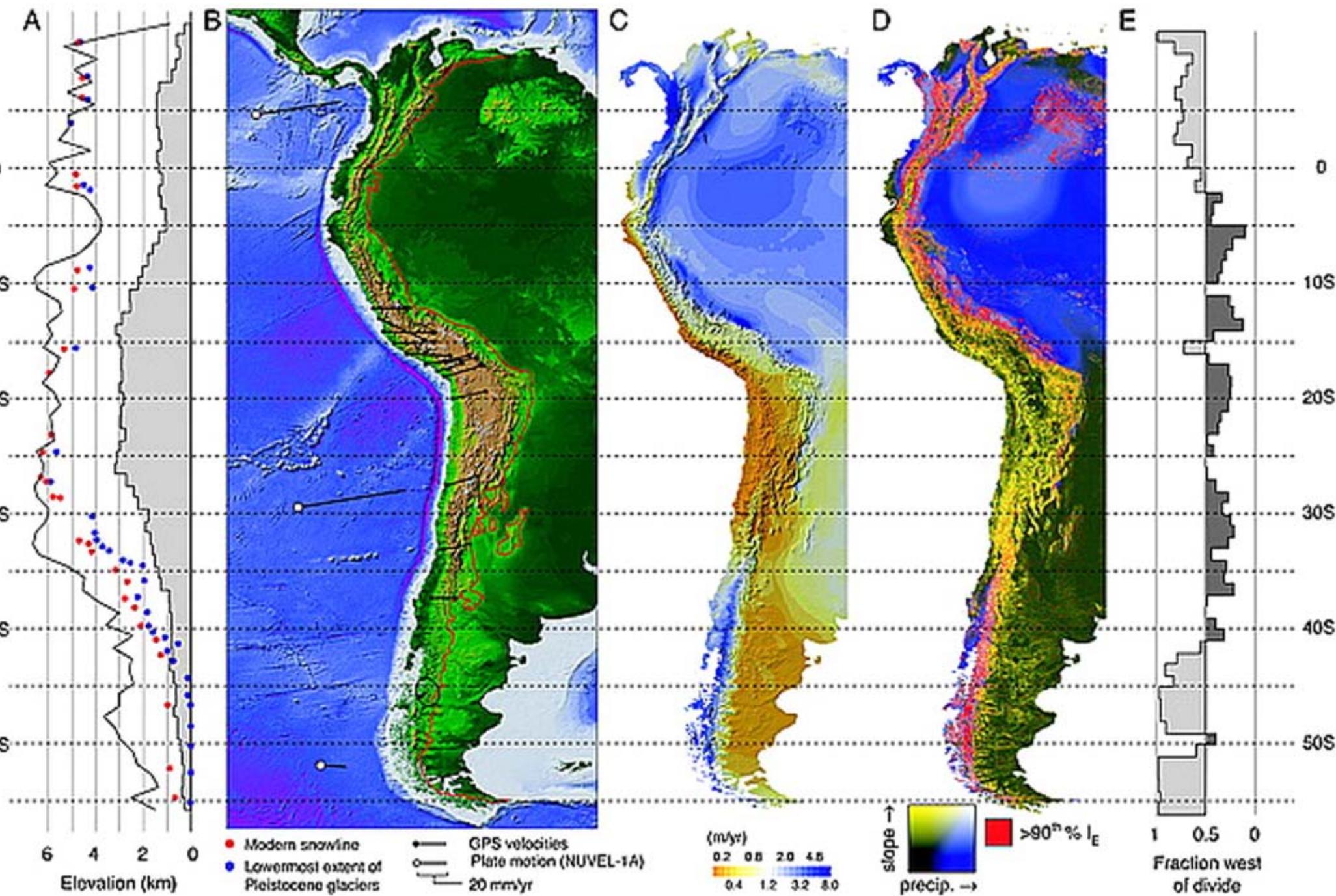
David R. Montgomery

Greg Balco

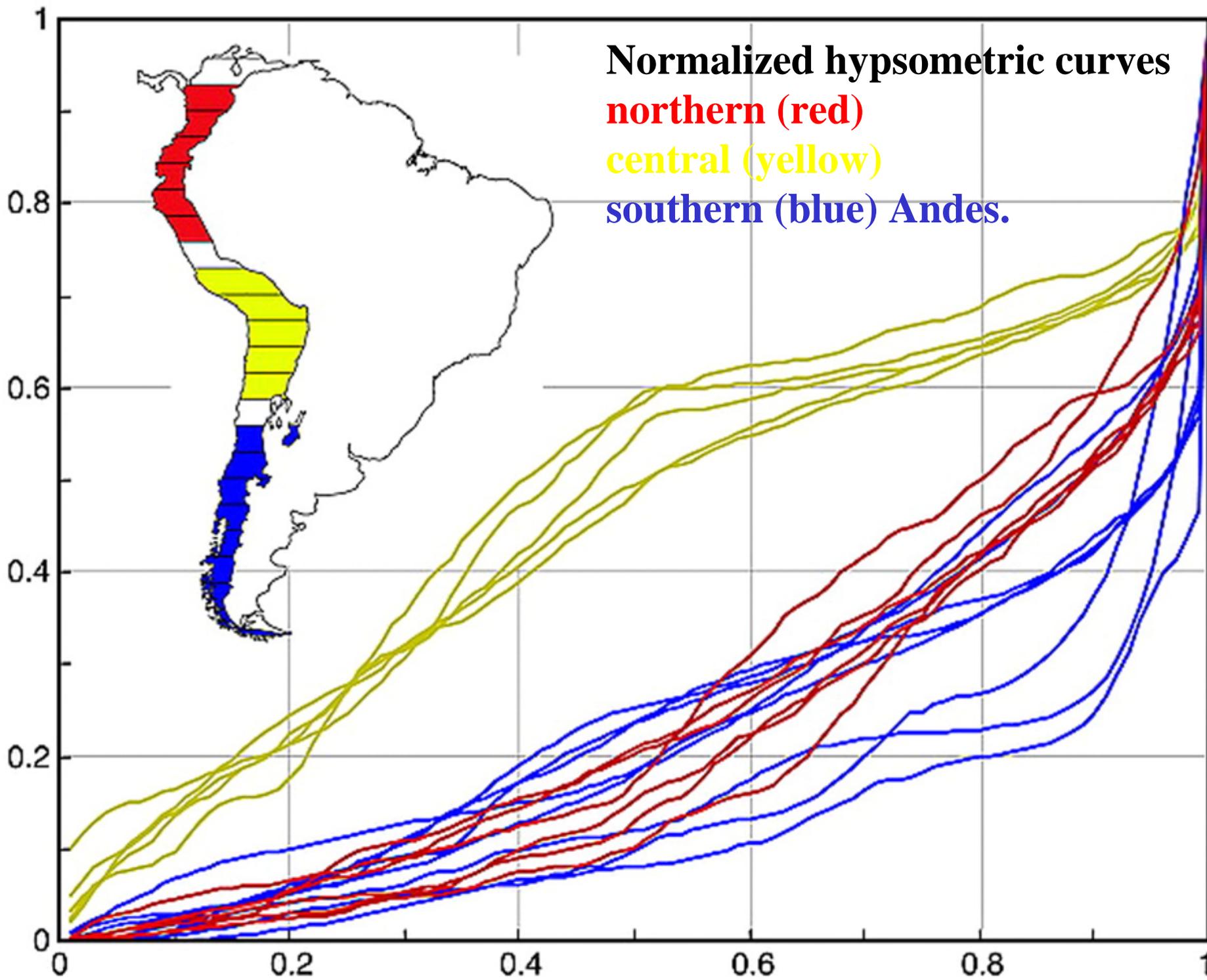
Sean D. Willett

Department of Geological Sciences, University of Washington, Seattle 98195-1310, USA

- **Large-scale topographic analyses show that hemisphere-scale climate variations are a first-order control on the morphology of the Andes.**
- **Zonal atmospheric circulation in the Southern Hemisphere creates strong latitudinal precipitation gradients that predict strong gradients in erosion rates both along and across the Andes.**
- **Cross-range asymmetry, width, hypsometry, and maximum elevation of the Andes reflect gradients in both the erosion index and the relative dominance of fluvial, glacial, and tectonic processes, and show that major morphologic features correlate with climatic regimes.**



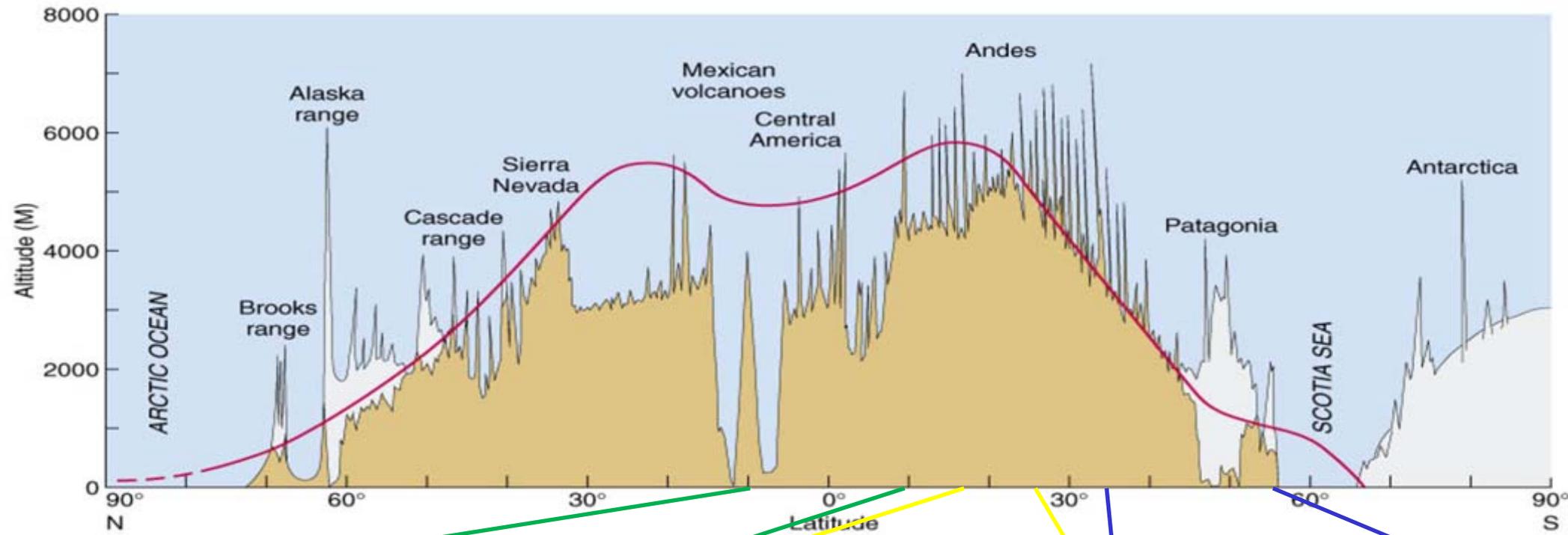
Fraction of Maximum Elevation



Normalized hypsometric curves
northern (red)
central (yellow)
southern (blue) Andes.

Cumulative Fraction of Total Area

Three types of climatic control on large-scale landscape form in the Andes



Fluvial erosion in the N. Andes where high precipitation rates maintain narrow mountain ranges

Tectonic dominance of landscape form in the central Andes with little erosion except in big river valleys

Glacial erosion preferentially erodes the highest ground in the southern Andes

The high Andes terminate at 35°S because they intersect the snowline at this latitude
The elevation of the perennial snowline tracks mountaintops

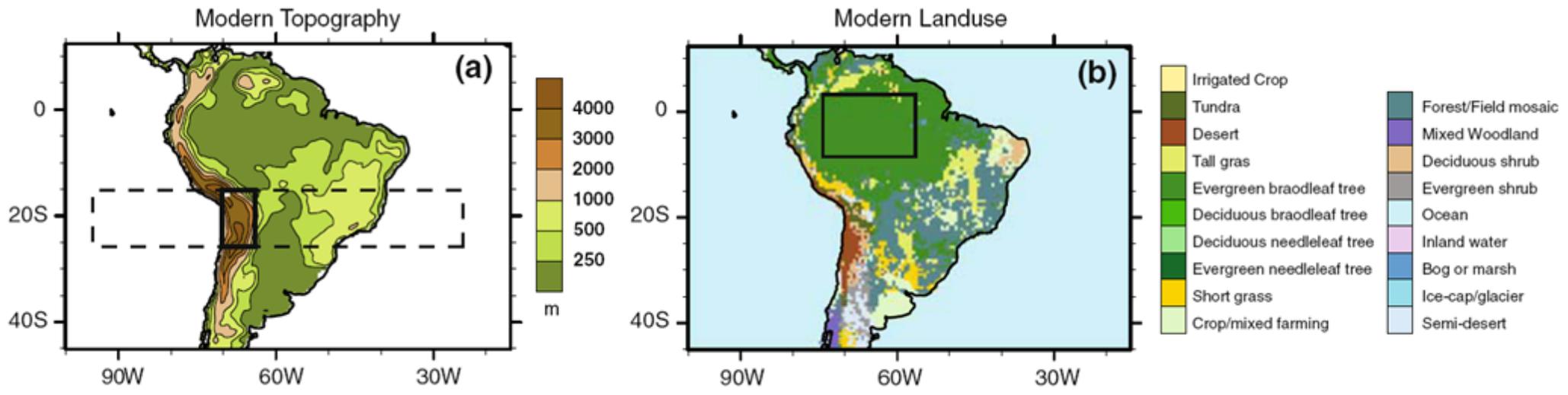
Mill, H.R., 1892, *The realm of nature: An outline of physiography*: New York, Charles Scribner's Sons.

Have the Andes any influence over South America large-scale atmospheric patterns?

Despite its enormity, previous studies have suggested the Andes Mountains have only a minor influence on large-scale atmospheric patterns over South America. The major stationary features, including the Bolivian High and the Nordeste Low, the low-level northerly flow over northern and central South America, and the large-scale precipitation are mainly products of diabatic heating over the Amazon Basin and are only marginally affected by the Andes (e.g. Figuerao et al. 1995; Kleeman 1989; Lenters and Cook 1995, 1997).

GCM experiments in which Andean heights are specified at 250 m, and 25, 50, 75, and 100% of their modern values

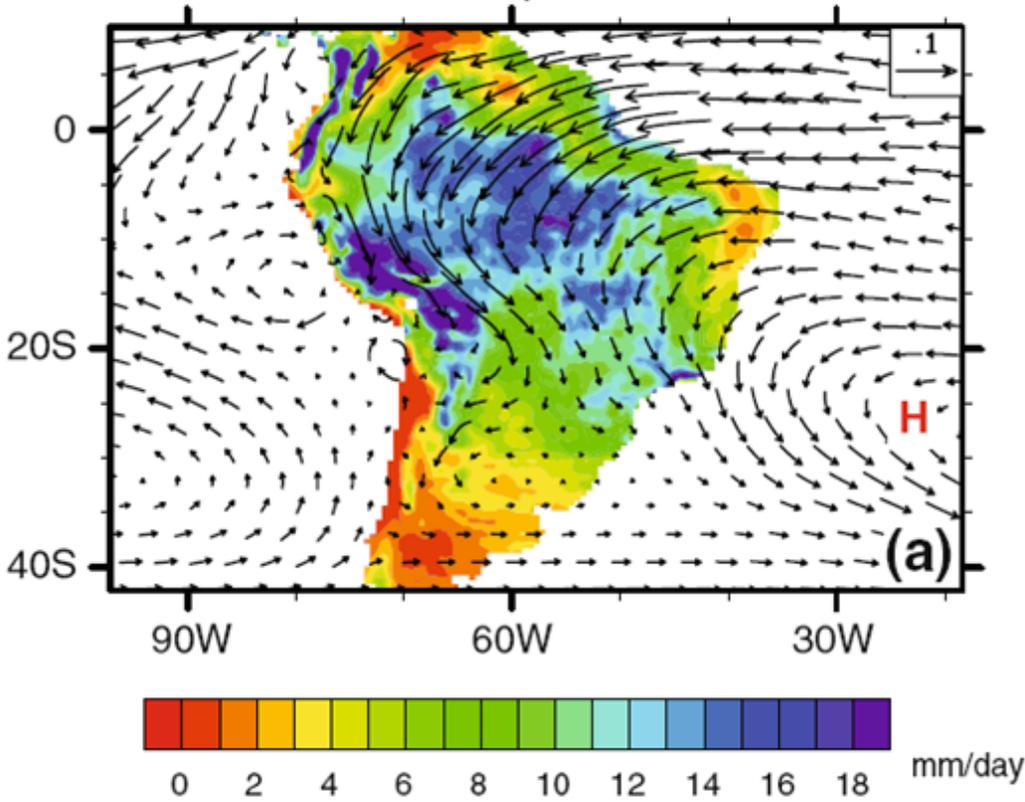
Insel et al. (2009)



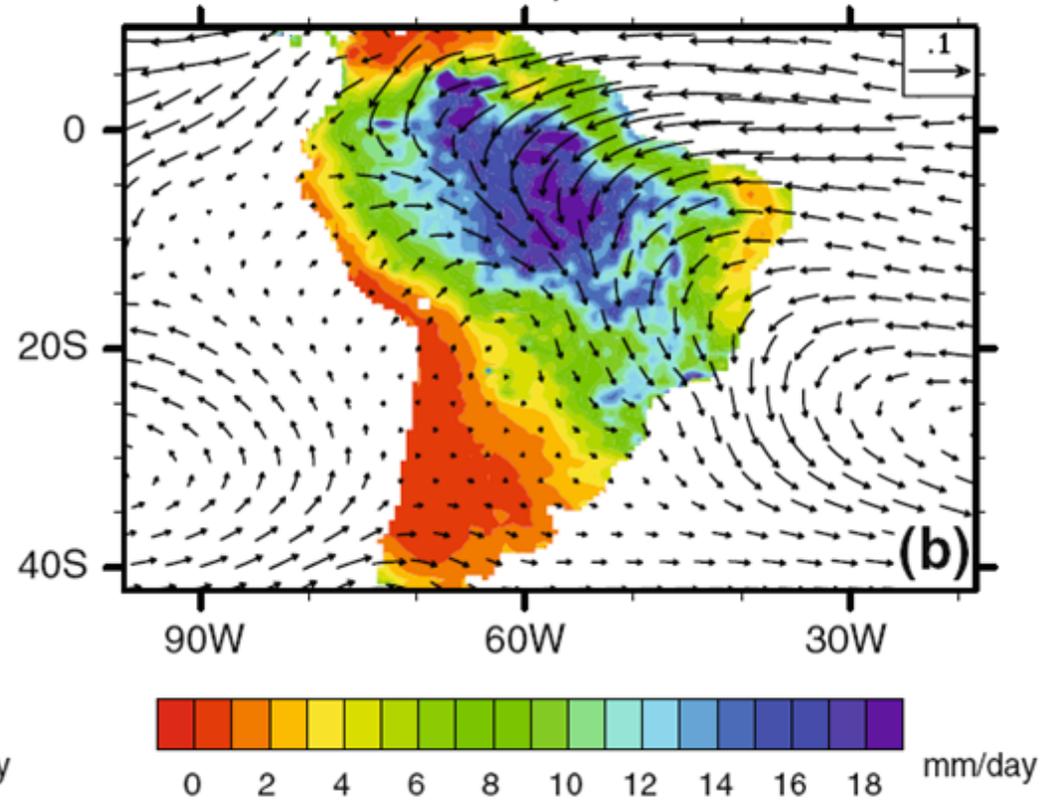
Low-level moisture transport/winds in South America

Simulations with modern (left) and no Andes (right)

Moisture transport for 100% AE

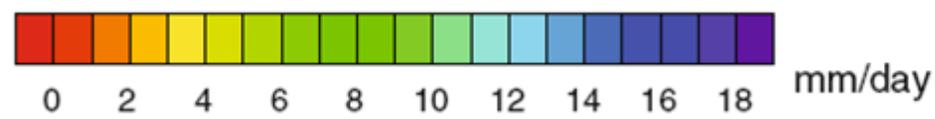
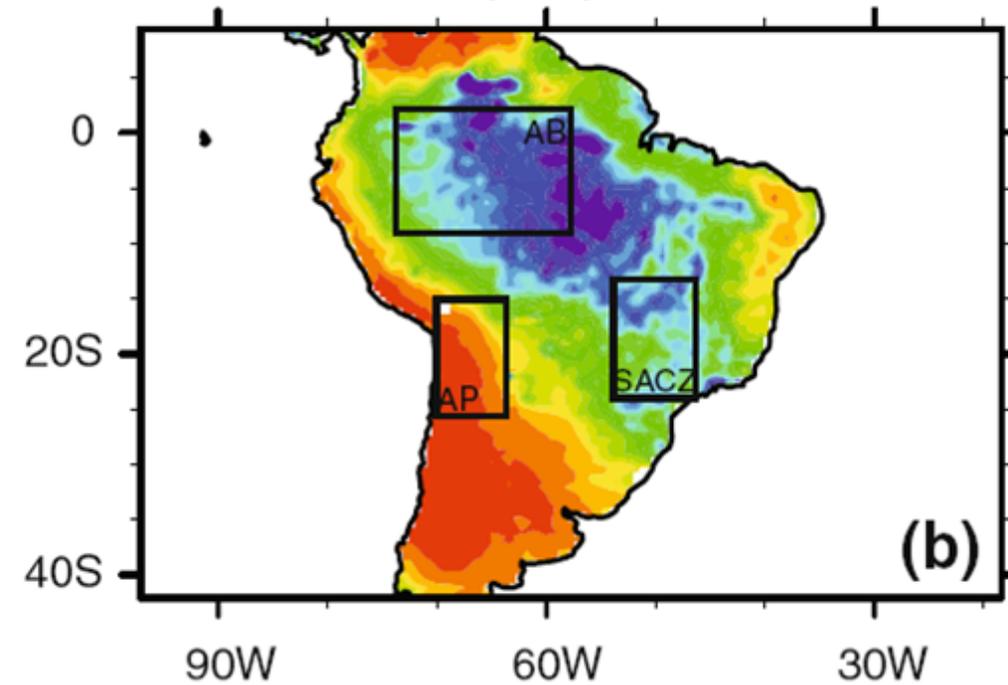
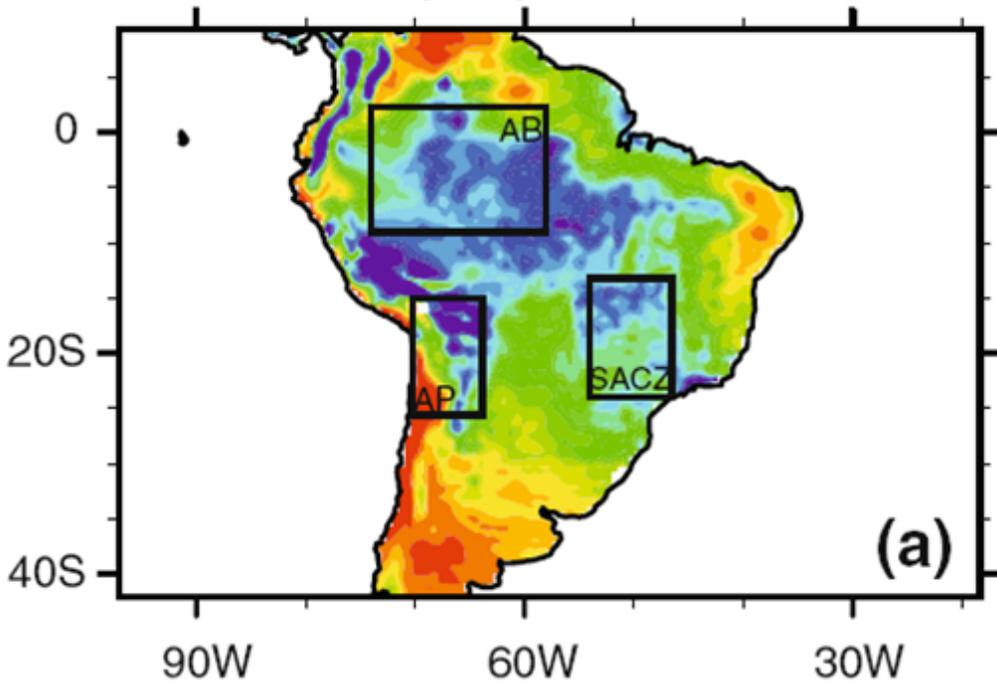


Moisture transport for 0% AE

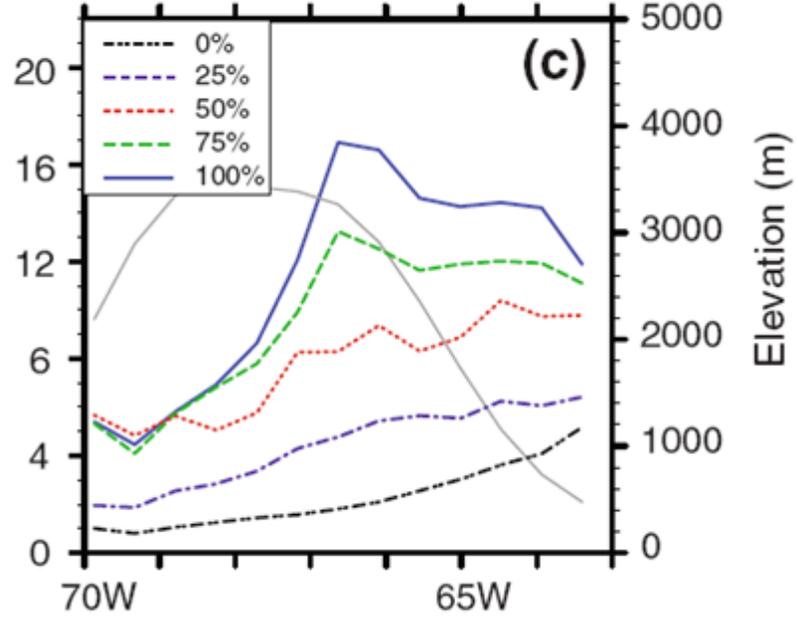


Summer precipitation for 100% AE

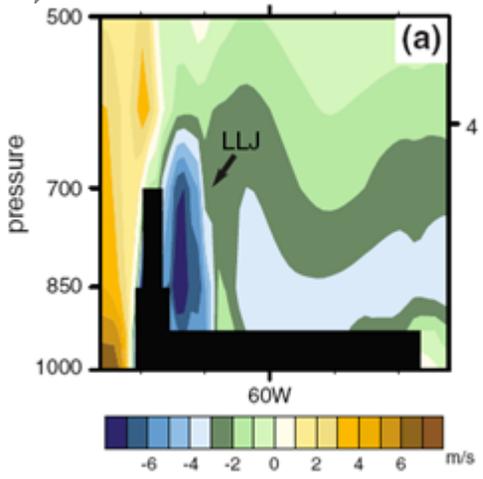
Summer precipitation for 0% AE



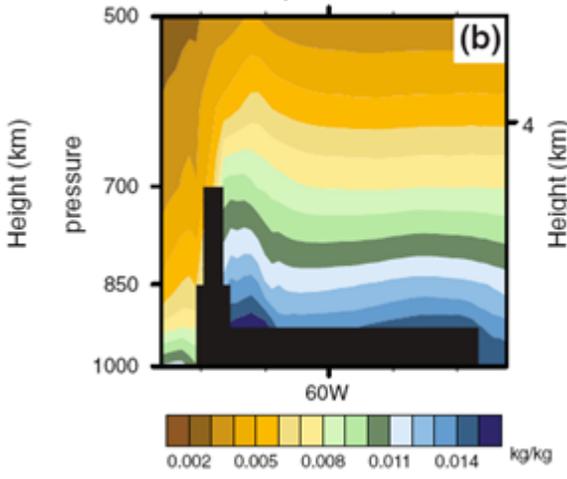
Summer precipitation for AP



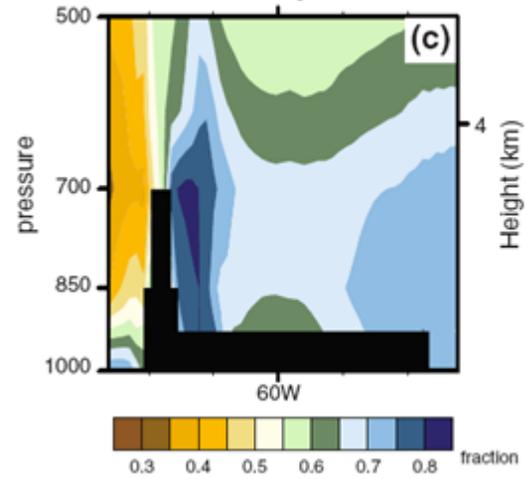
Meridional winds for 100% AE



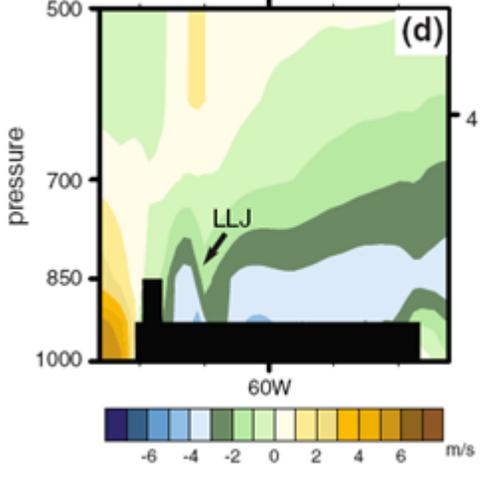
Water vapor for 100% AE



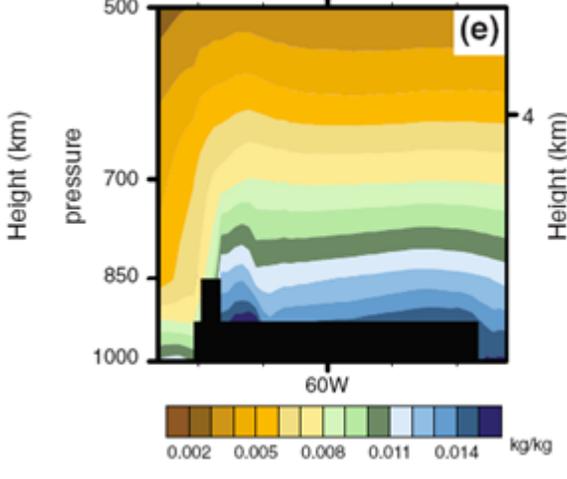
Relative Humidity for 100% AE



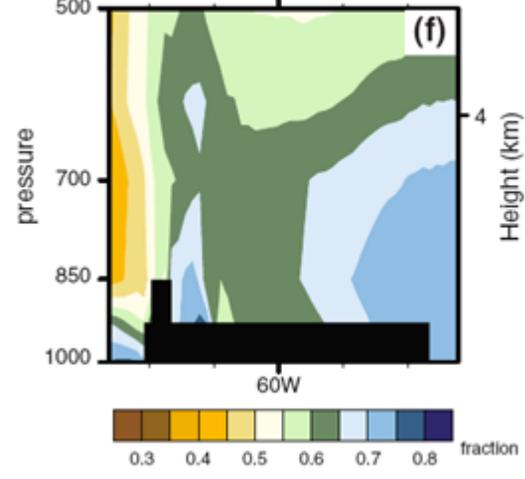
Meridional winds for 50% AE



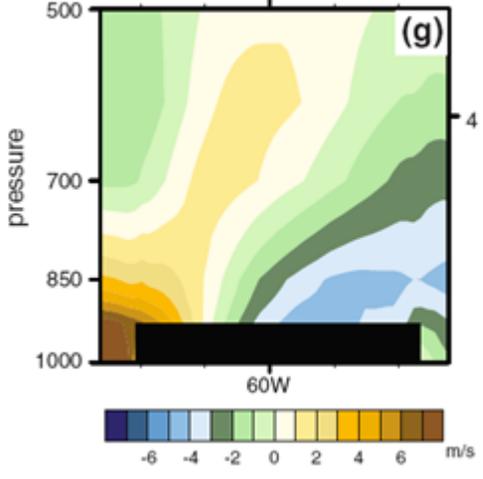
Water vapor for 50% AE



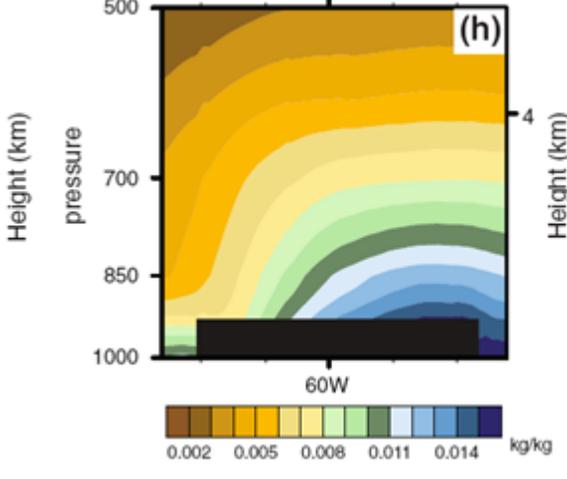
Relative Humidity for 50% AE



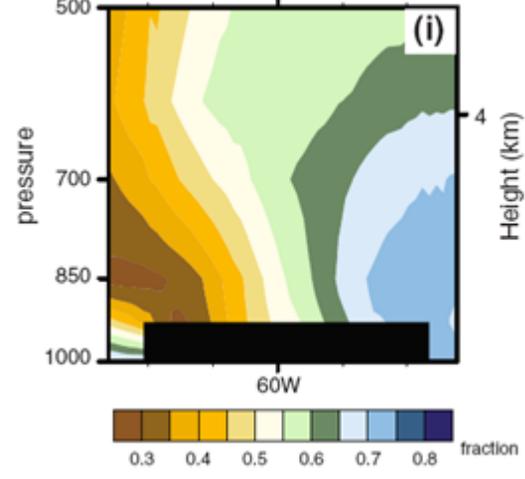
Meridional winds for 0% AE



Water vapor for 0% AE



Relative Humidity for 0% AE



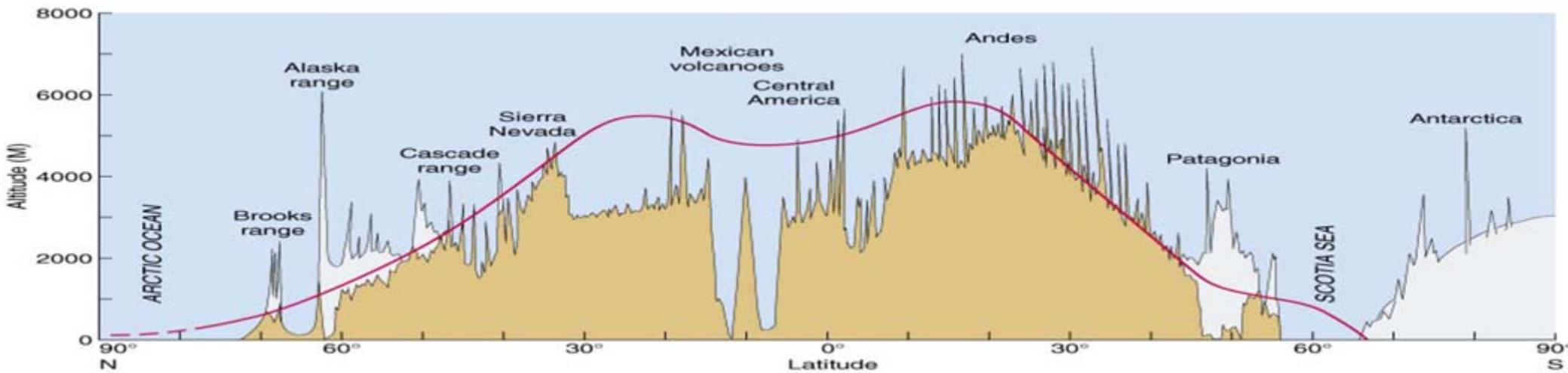
Meridional winds, water vapor and relative humidity across South America between 15 and 26°S during summer

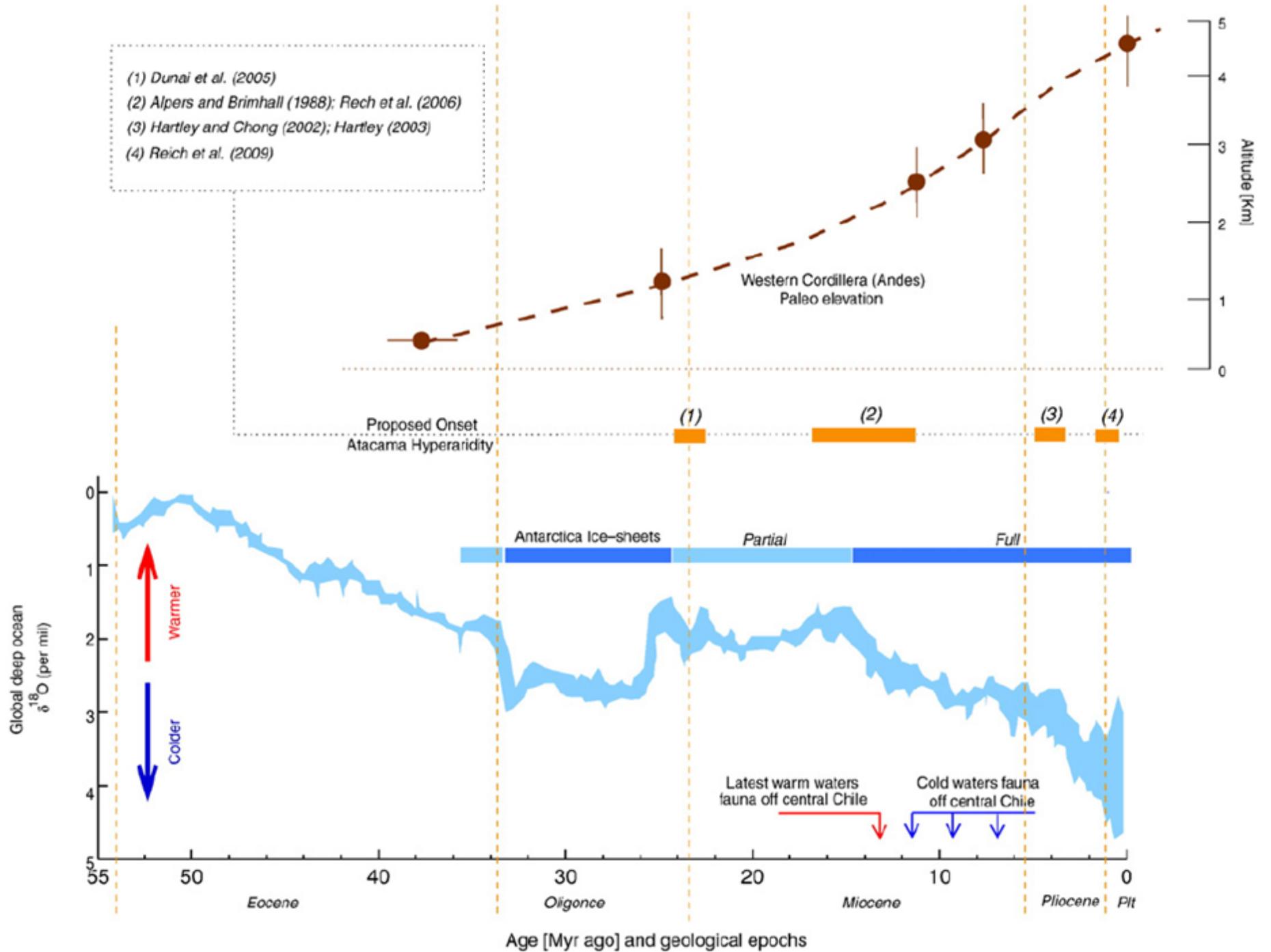
The Andes have a direct mechanical influence on the climatology of South America by forcing orographic precipitation along the eastern flanks in the tropical and subtropical latitudes and on the westerly flanks in temperate to high latitudes in South America

The Andes Mountains are critical to the development of the LLJ that draws in and transports moisture from the Amazon Basin to the Andean region.

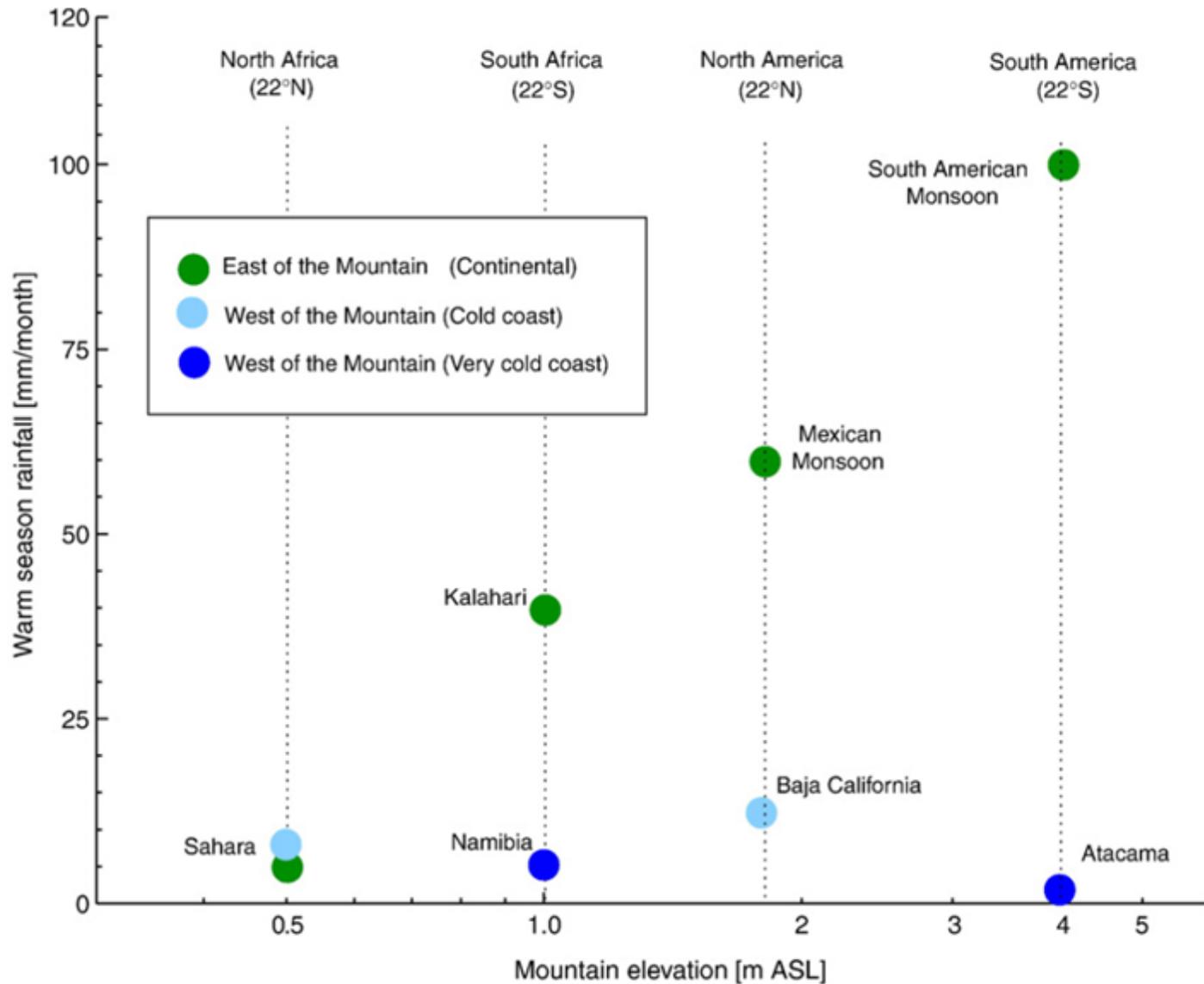
When the Andes are absent

1. The LLJ is absent
2. Southward moisture transport is low
3. Convection is suppressed
4. Precipitation decreases dramatically along the eastern flanks of the Andes.



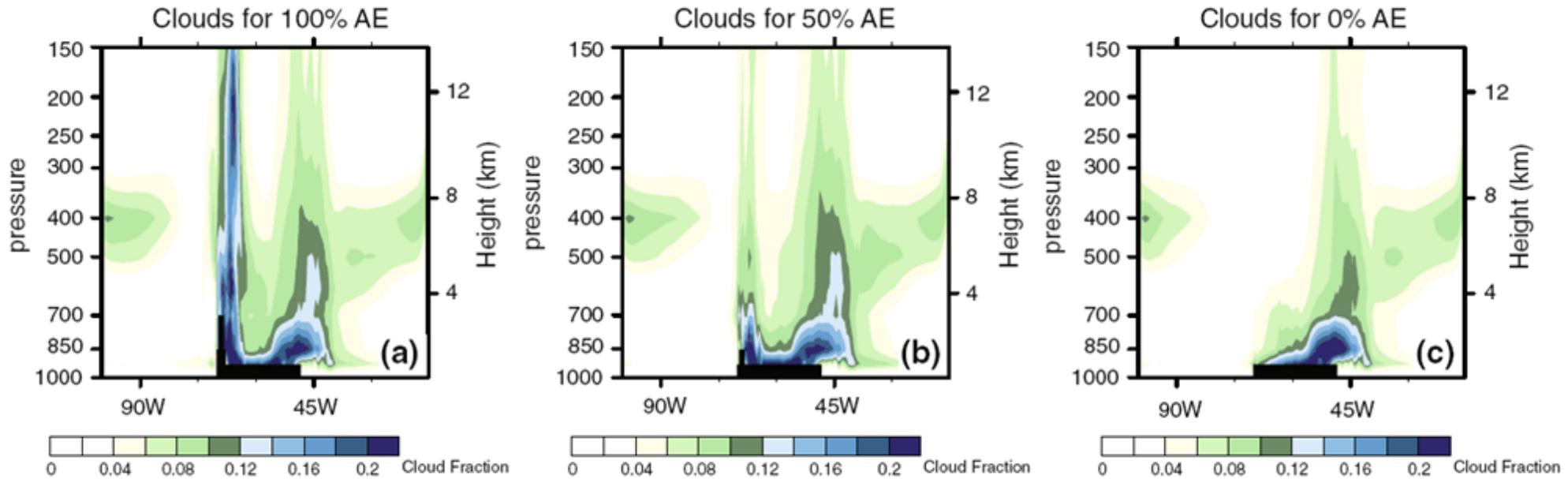


Elevación, temperatura de la superficie del mar y precipitación en los subtrópicos



La precipitación continental depende fuertemente de la altura de la cadena montañosa, mientras que la precipitación litoral no está asociada a la elevación

Nubosidad de verano sobre América del Sur (entre los 15 y 26°S)



A través del ascenso orográfico, los Andes fuerzan la condensación, la liberación de calor latente y la convección intensa

