The Andes
Chap. 1 - Geographical context
Chap. 2 - Large scale climate

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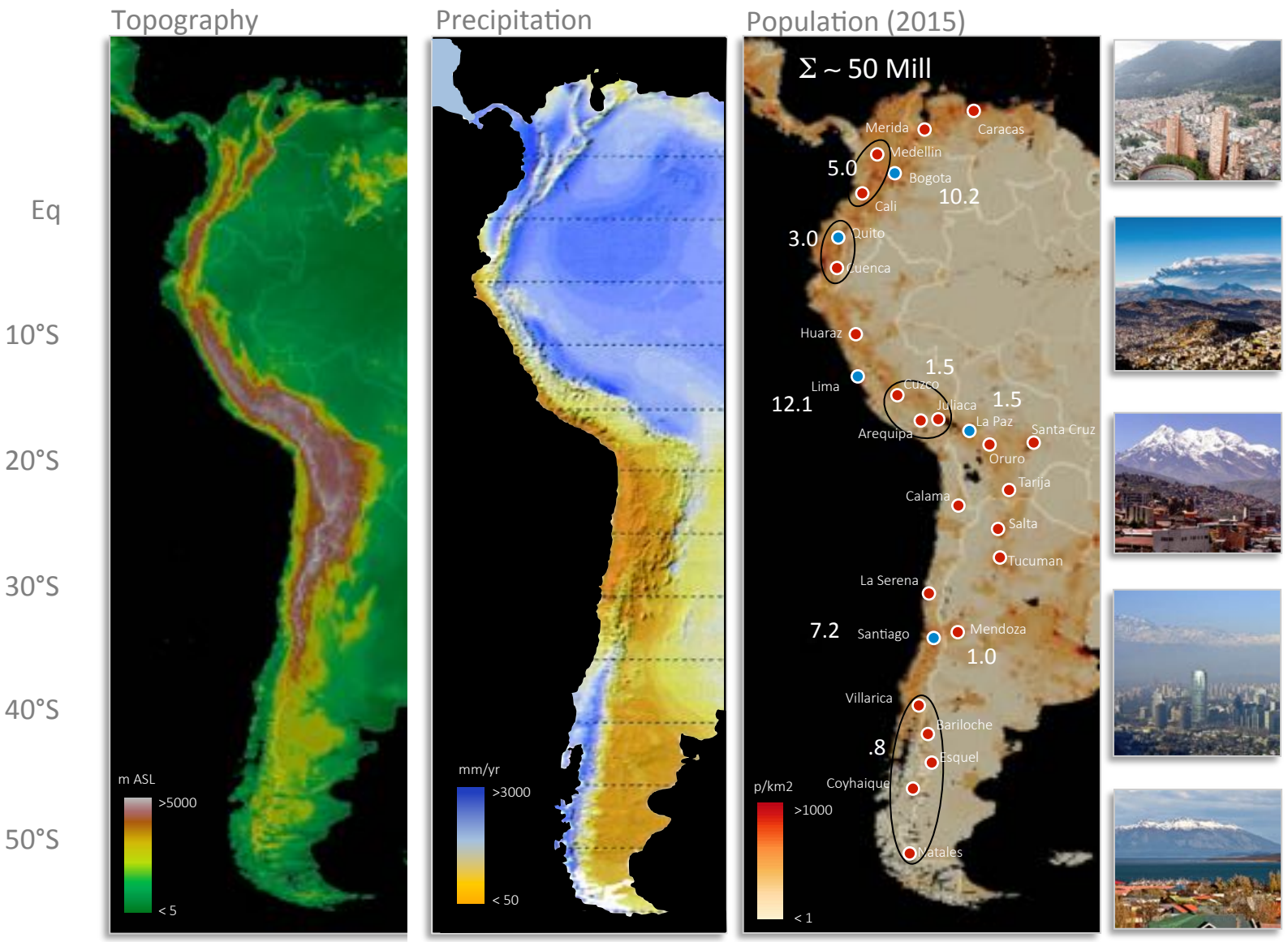
We all love the Andes.....

- More than 6000 km long, from the Caribbean sea to Patagonia
- Very tall mountain, specially at tropical/subtropical (>5000 m ASL)
- *Water tower for 50 Millions people in seven countries*
- A nearly 2D mountain when considering synoptic-scale flow
- Exposed to easterlies and deep convection at low latitudes
- Exposed to westerlies and frontal systems in midlatitudes
- Plenty of paleo-records (glaciers, trees, lake sediments….)
- Many mysteries to be solved

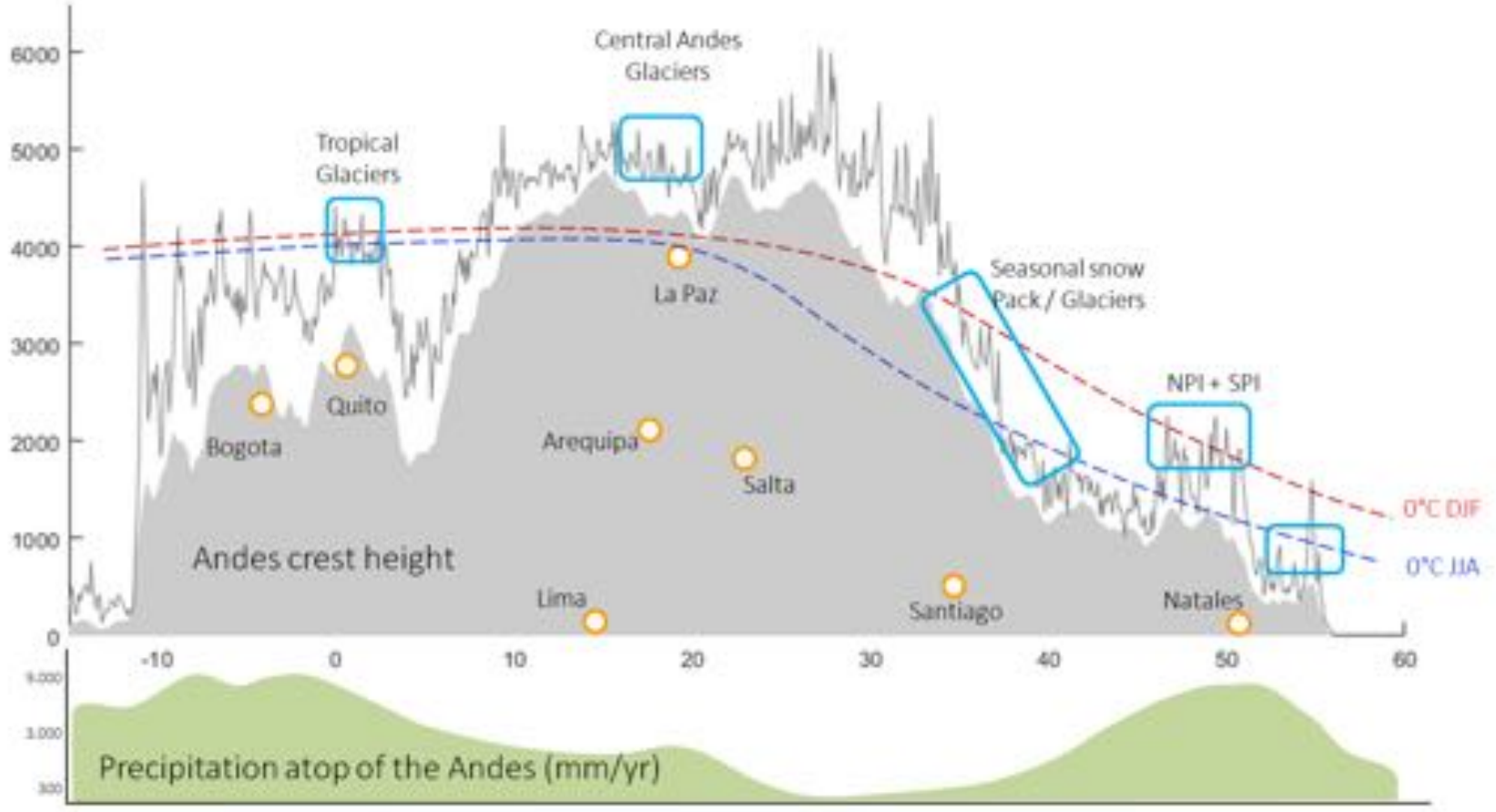
Nonetheless

- Its extreme geography set the stage for hydromet. hazards
- *Under sampled (meteorology + hidrology)*
- Highly sensitive to climate change

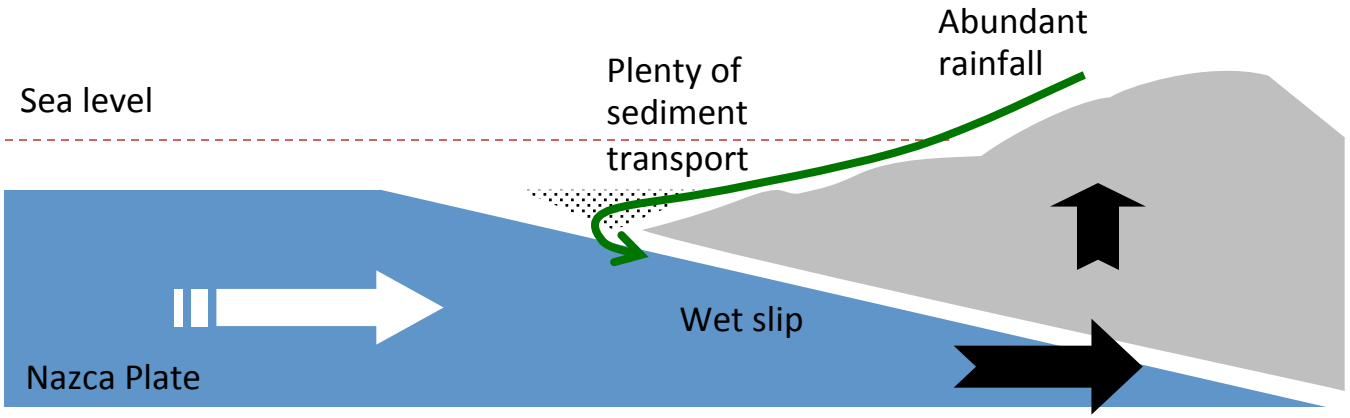
Basic Features

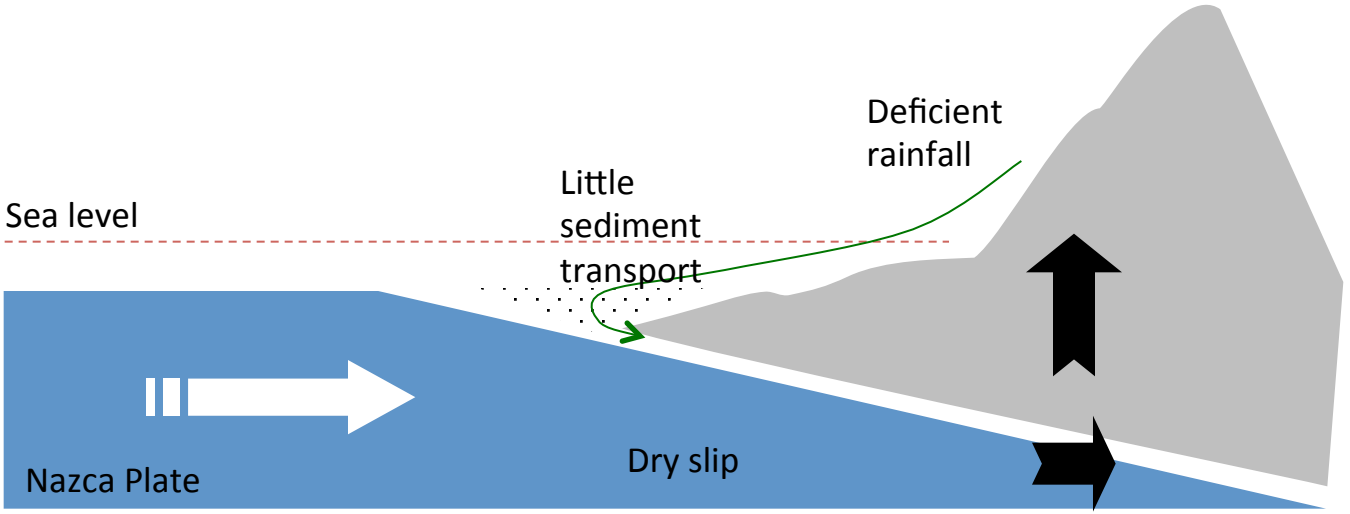


Basic Features

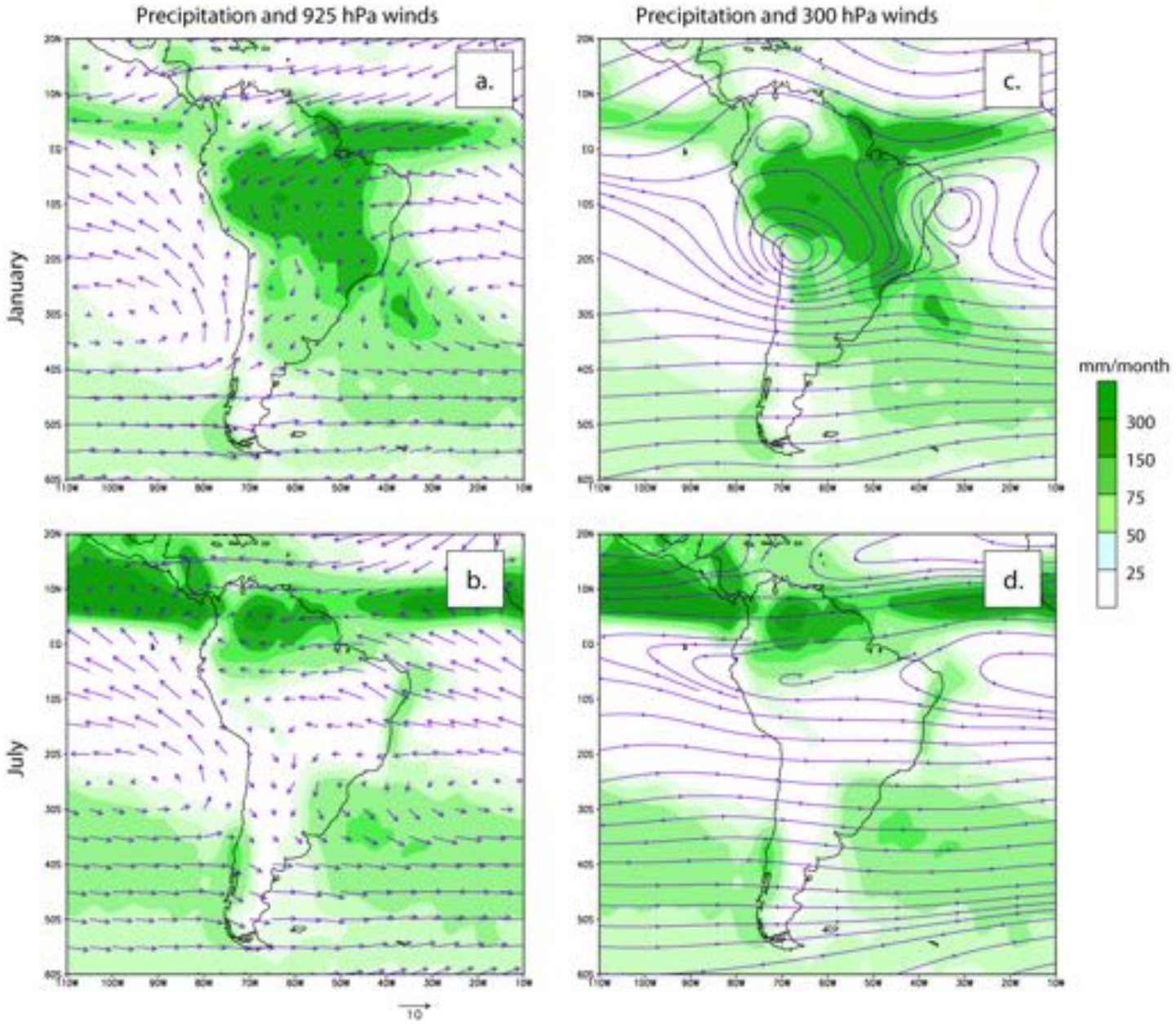


Climate – Tectonics - Geomorphology





Adapted from Lamb and Davis; Nature 2003

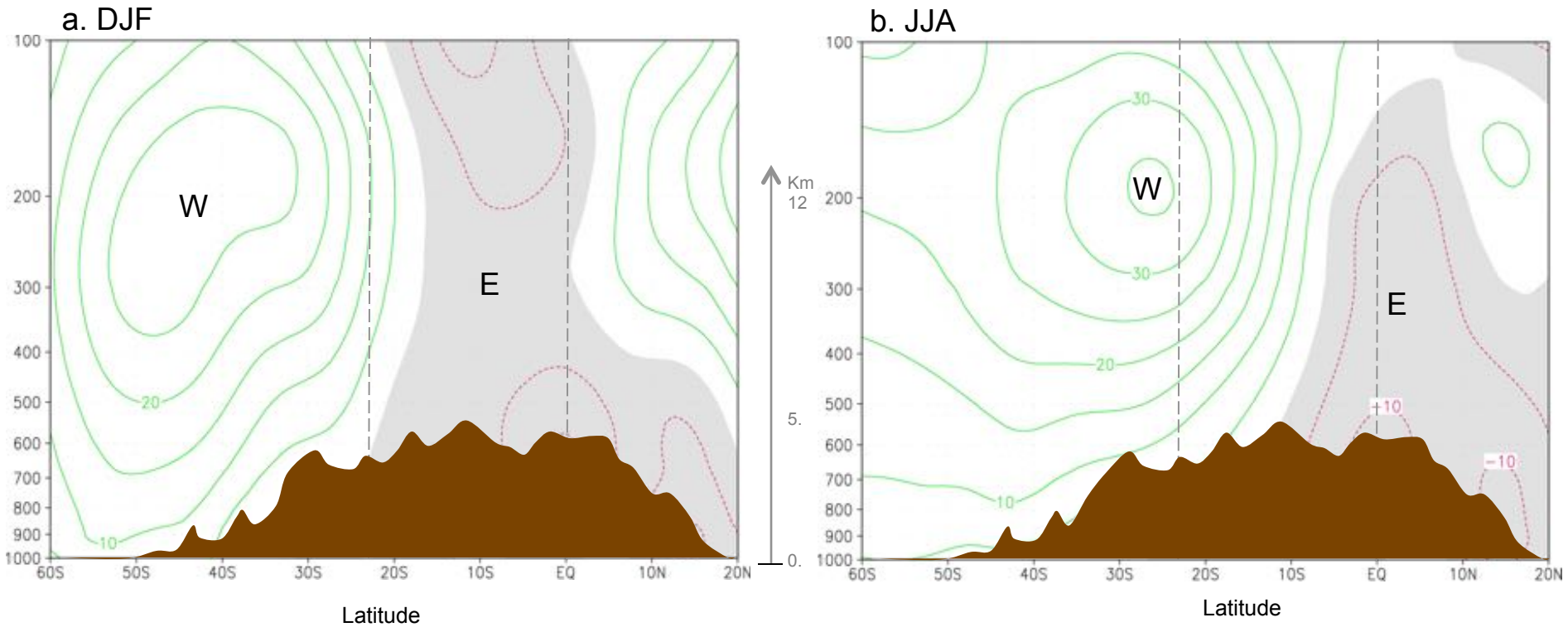


Garreaud et al. 2009

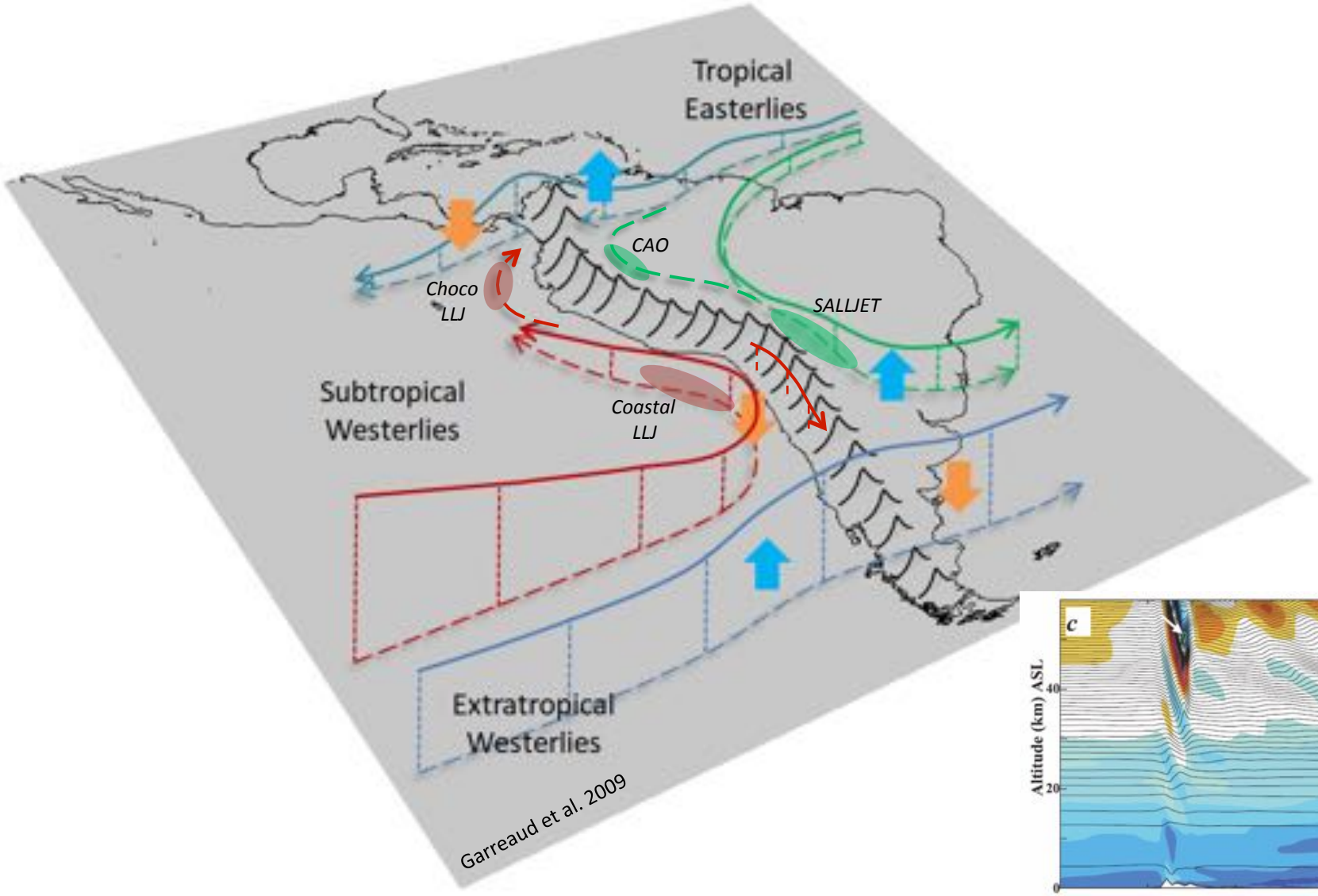
Zonal (east-west) mean flow over the Andes

Brown area: Terrain mean height

Dashed line: 500 hPa, half of the atmosphere below!



The complex mid- and low-level flow near the Andes



Jiang et al. 2013

Processes Controlling the Mean Tropical Pacific Precipitation Pattern. Part I: The Andes and the Eastern Pacific ITCZ

KEN TAKAHASHI AND DAVID S. BATTISTI

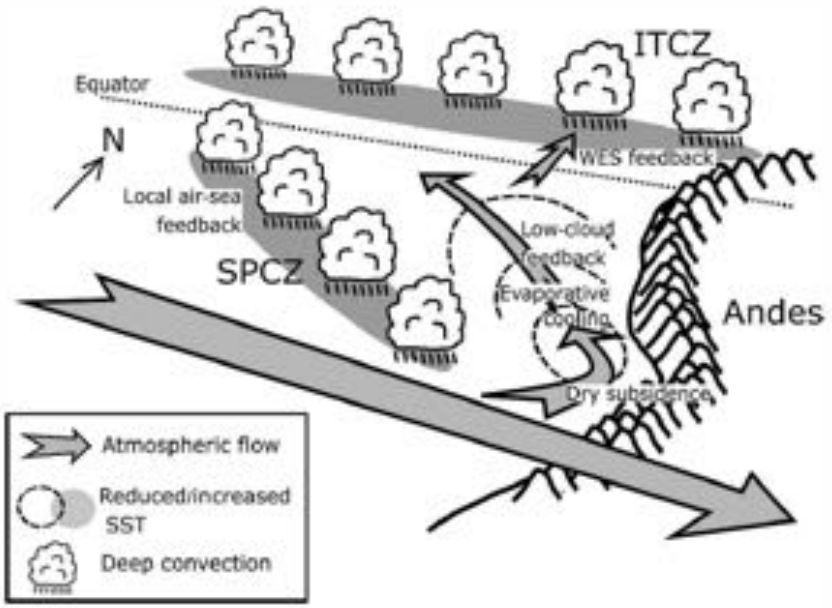


FIG. 13. Sketch summarizing some of the main processes discussed in the two parts of this study.

We showed that subsidence of low specific humidity air to the west of the Andes exerts a strong local control on SST through evaporation. The presence of the Andes is found to be sufficient for generating such a circulation, in agreement with Rodwell and Hoskins (2001), and the associated surface cooling is sufficient to create a north–south asymmetry, with the ITCZ in the Northern Hemisphere in the east Pacific, through feedbacks involving air–sea interactions (WES feedback; Xie and Philander 1994).

Another “ocean” to the east…. Andes-Amazon connections

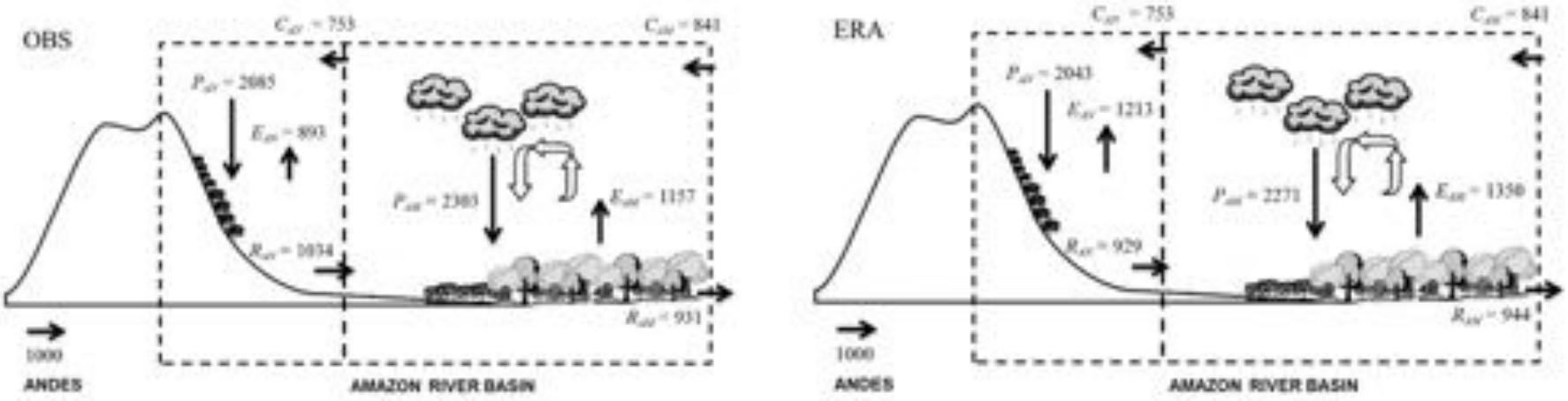


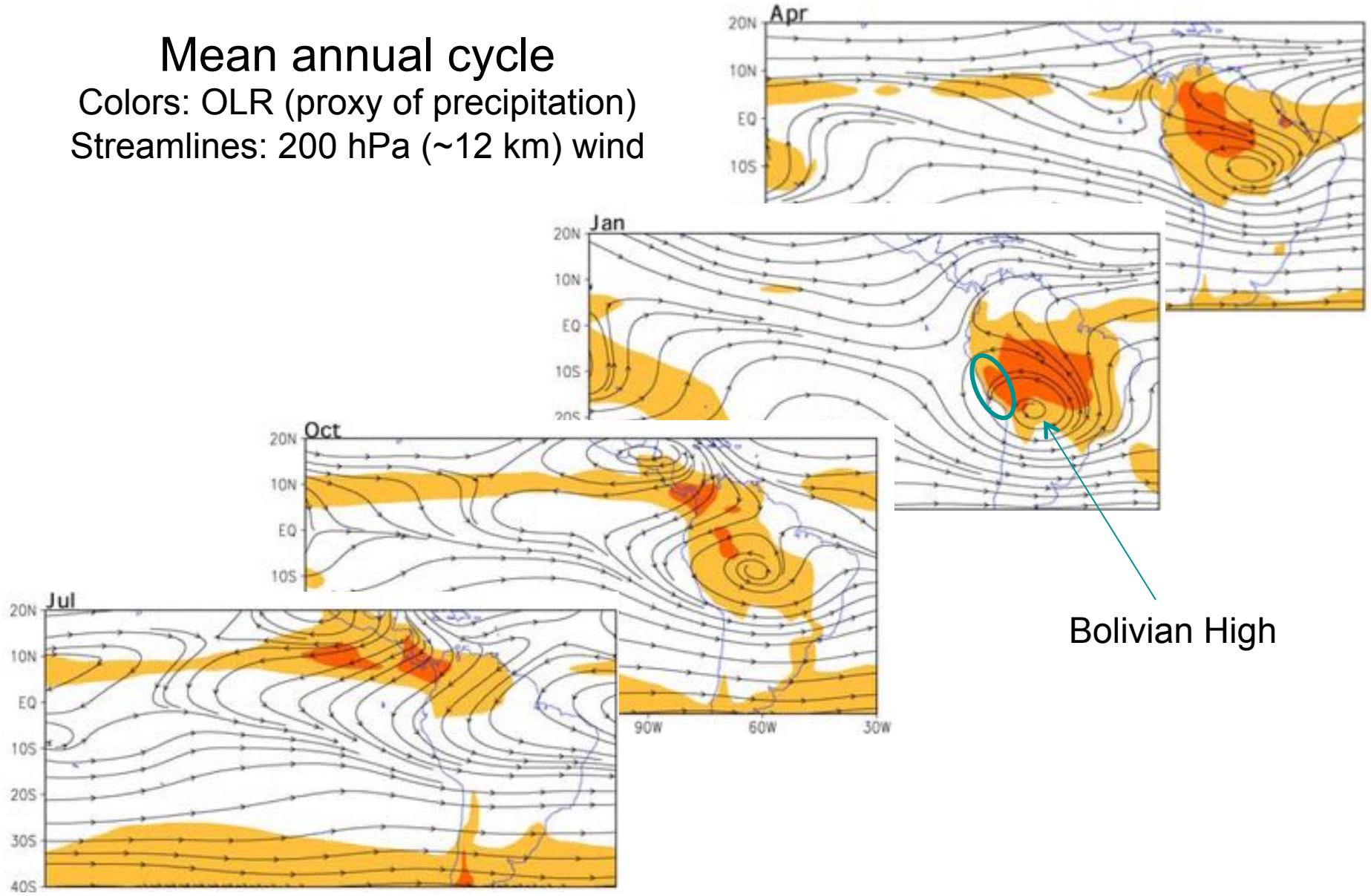
Illustration of the components of surface water balance and atmospheric water balance for the observations and reanalysis datasets in the Andes and Amazonia sub regions of the Amazon River basin. Values are in units of mm.y-1. The arrow convention on the bottom left represents 1000 mm.y-1. Data source: Builes-Jaramillo and Poveda, 2018.

South America monsoonal regime and Altiplano rainfall

Mean annual cycle

Colors: OLR (proxy of precipitation)

Streamlines: 200 hPa (~12 km) wind



Now you see it… now you don't

What controls the BH at submonthly timescales

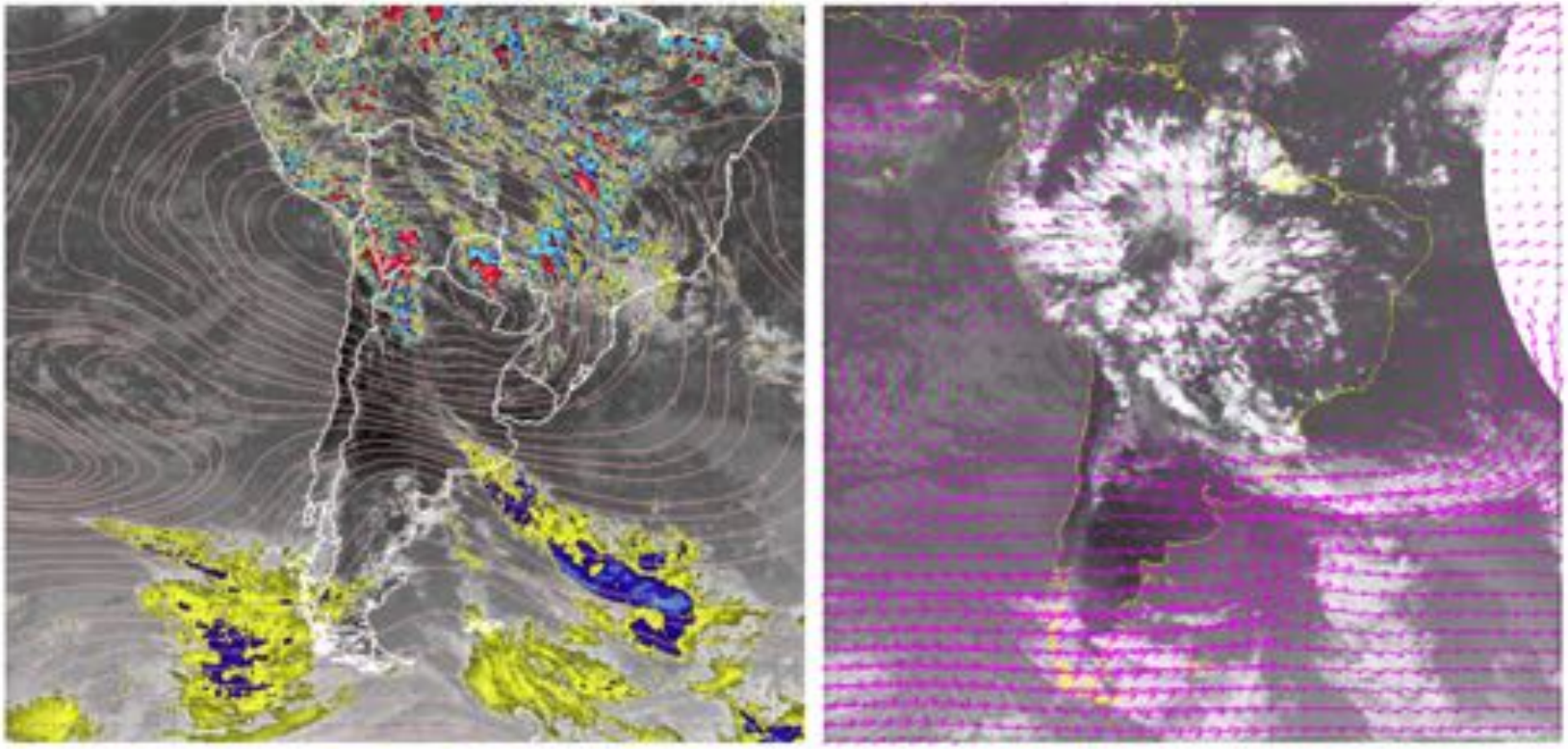
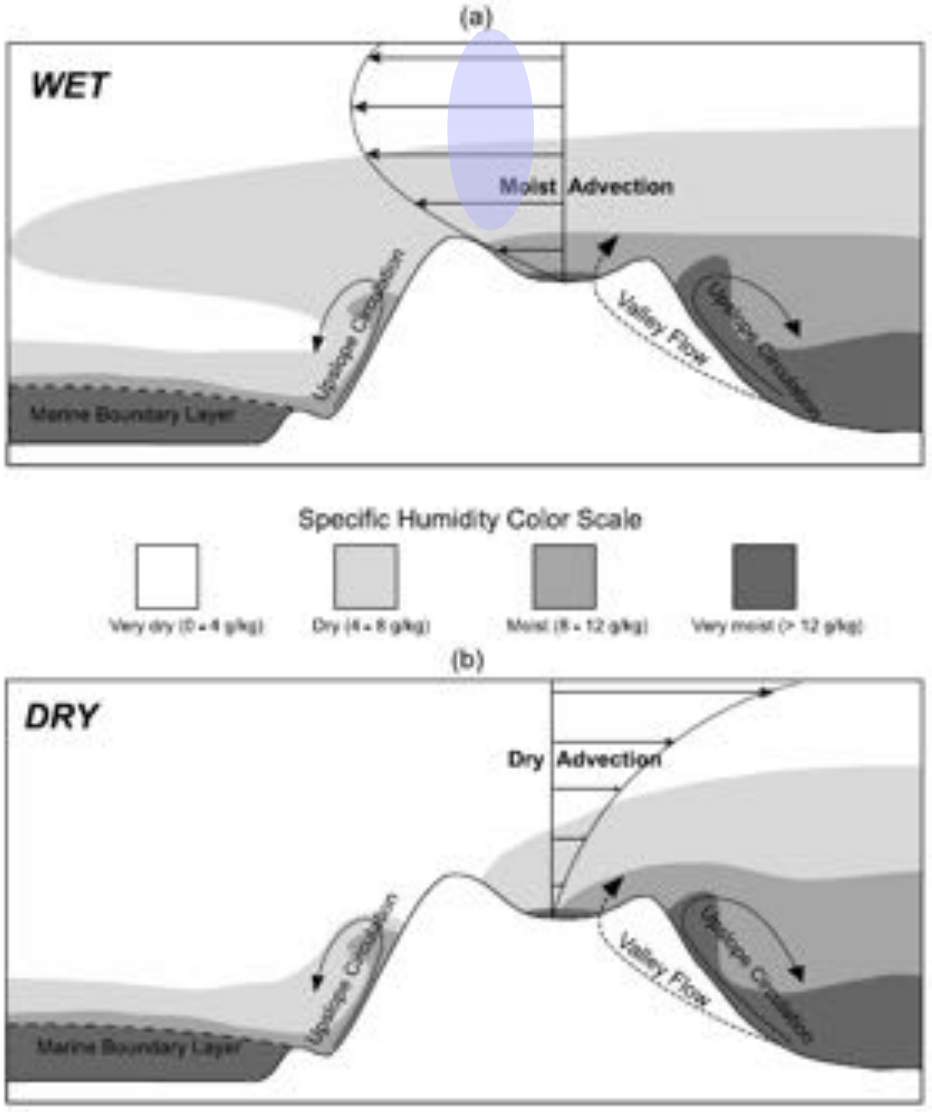


Figure 2.5: 200 hPa wind for two days in austral summer depicting a well developed (left) and mostly absent Bolivian High.

Summer Altiplano rainfall: Intraseasonal variability



Falvey and Garreaud 2005

Convective rainfall also exhibits a pronounced diurnal cycle

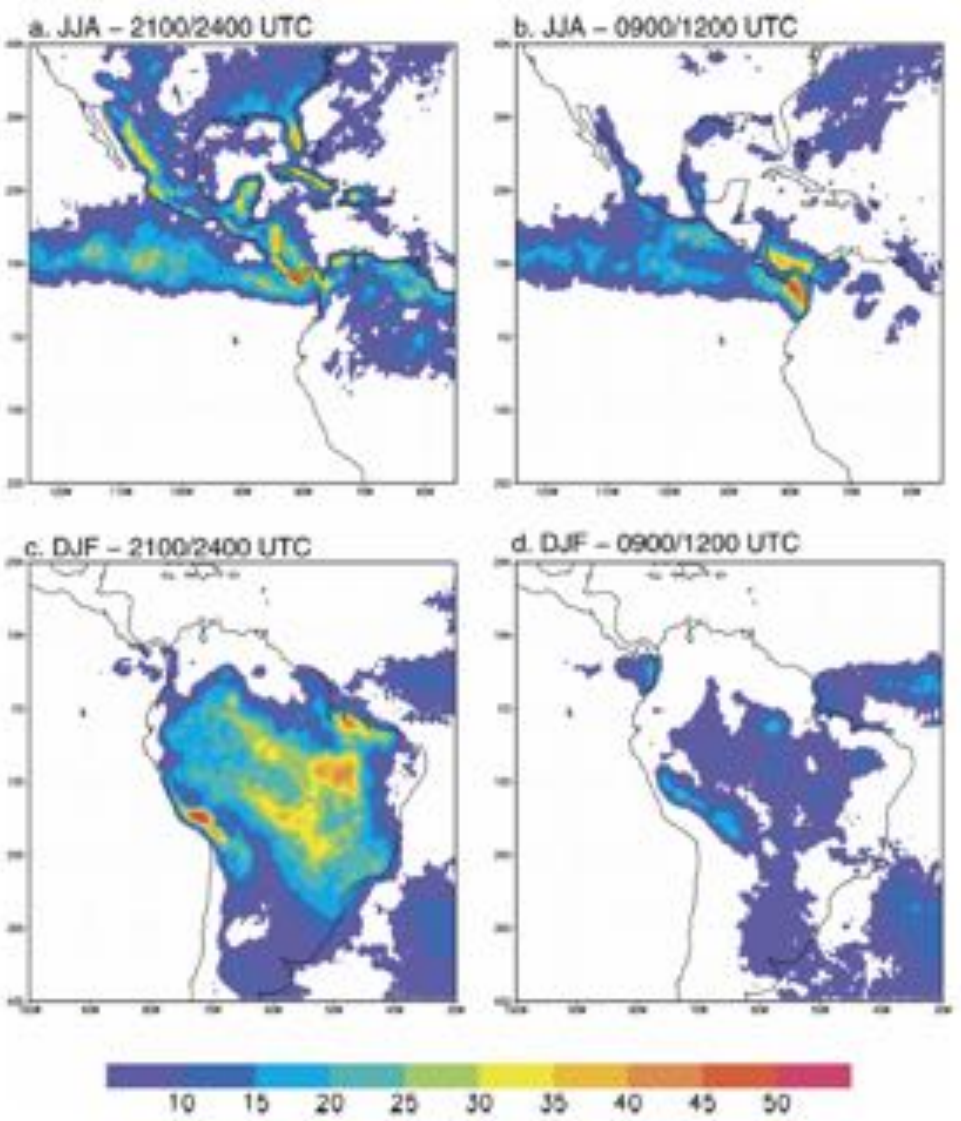
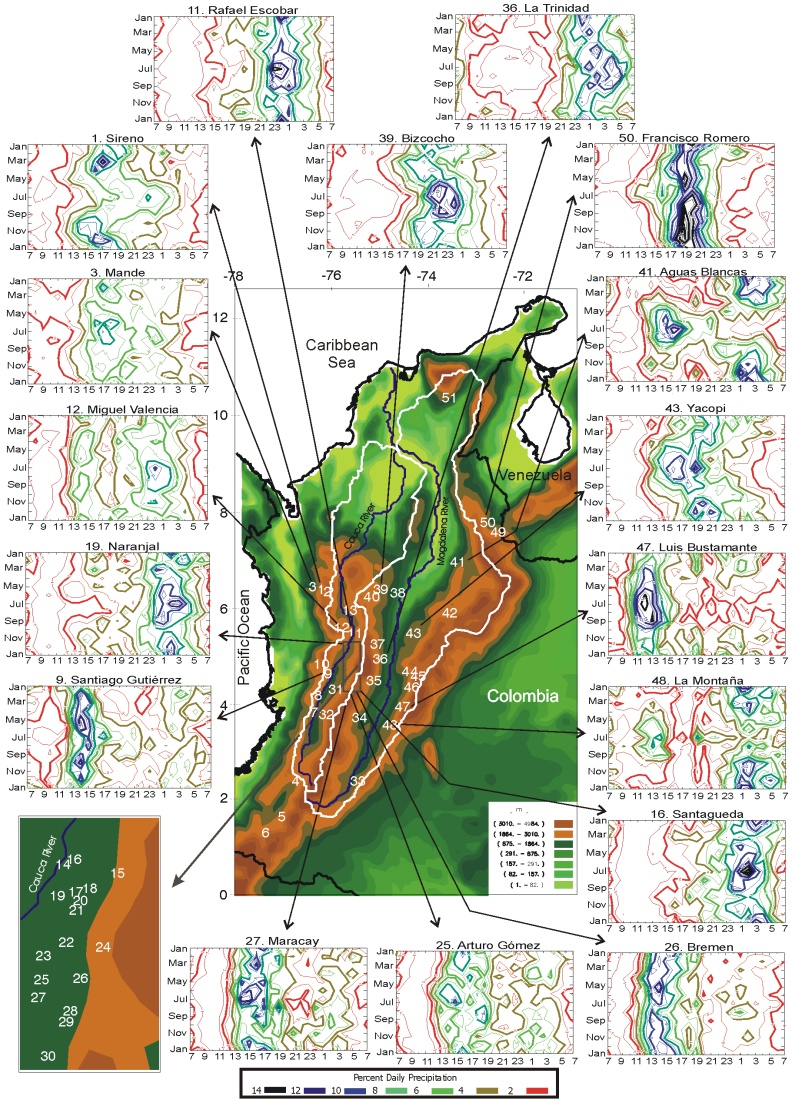


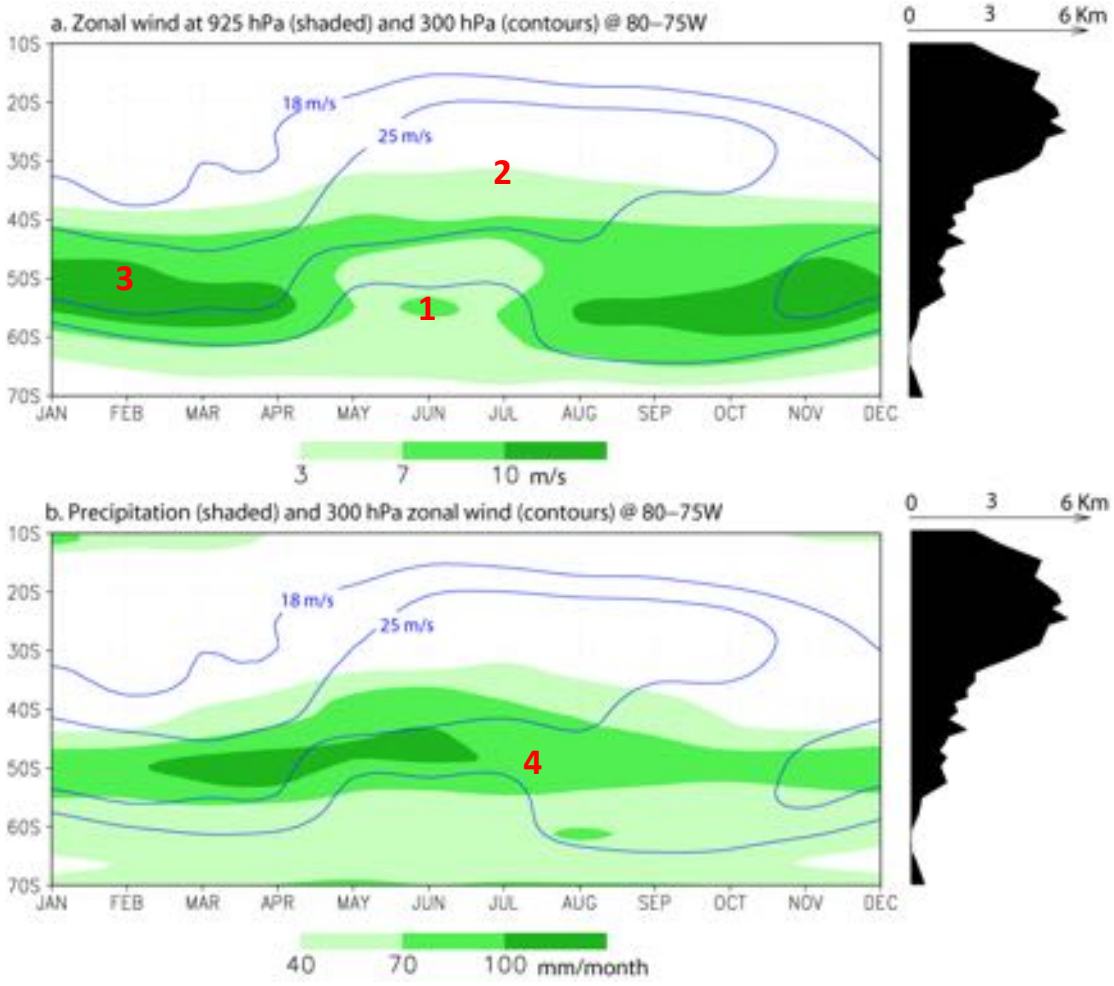
FIG. 5. Evening (2100–2400 UTC) temporal frequency of cold clouds (infrared brightness temperature $T_b < 235$ K) during the (a) boreal summer (JJA) and (c) austral summer (DJF). Pixel resolution is 0.5° × 0.5°. The period of analysis extends from 1983 to 1991. (b), (d) Same as in (a) and (c), respectively, but for late night and early morning (0900–1200 UTC).



Seasonal march of the diurnal cycle of rainfall at 17 selected stations in the tropical Andes of Colombia. The diurnal cycle is defined from 0700 to 0700 LST, and interpolated isolines indicate percent of total daily rainfall, with the color scale shown at the bottom. Boundaries of the neighboring (left) Cauca and (right) Magdalena River valleys are shown in white. The inset at the bottom left shows details of rain gauges located in the western flank of the Central range of the Andes. Source: Poveda et al. (2005).

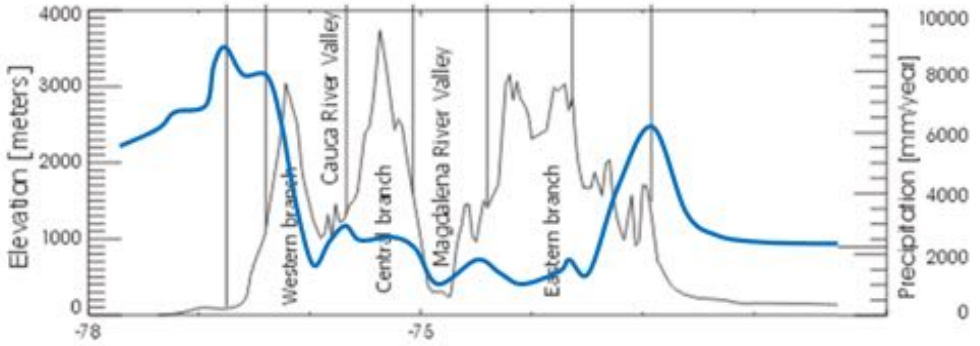
Precipitacion en Latitudes medias

Modest annual cycle in the extratropics



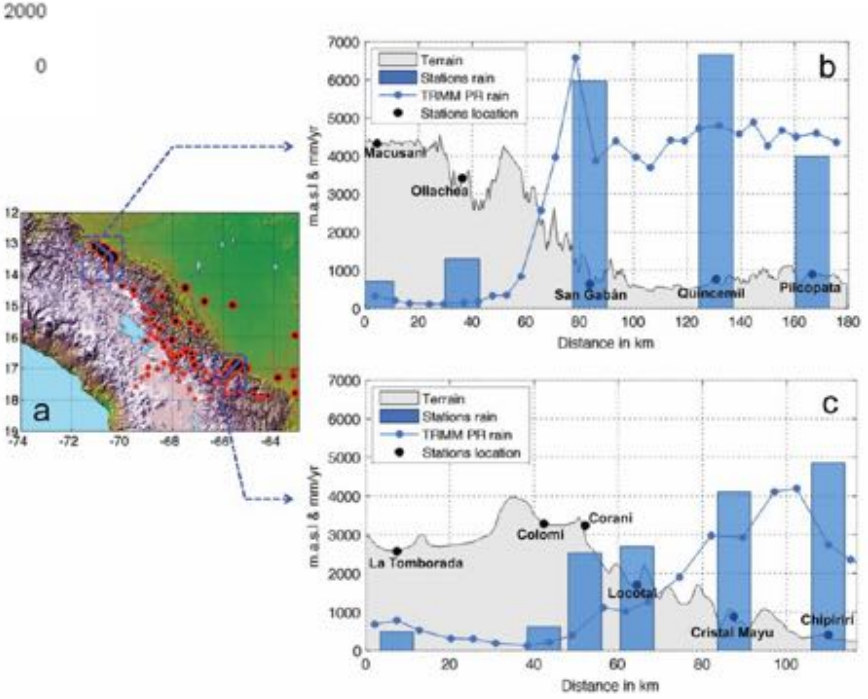
Where does it rain more?

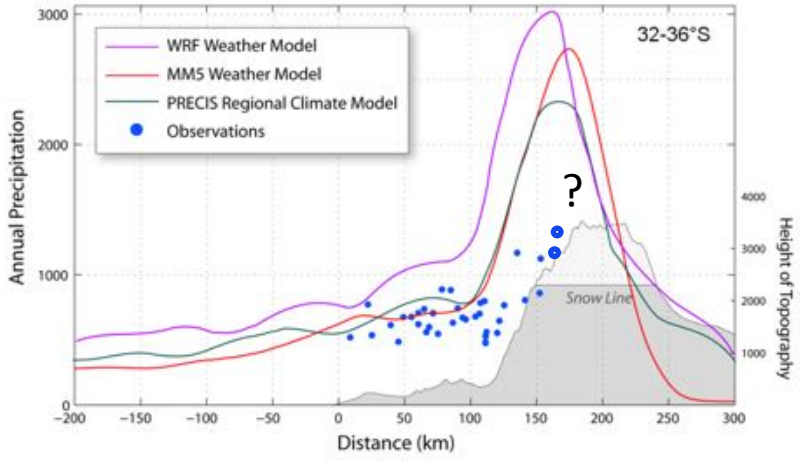
The elusive Orographic Precipitation Gradient (OPG(latitude))



Distribution of mean annual rainfall over transect (around 6°N) along the three ranges of the Colombian Andes (Poveda)

Espinonza et al. 2015

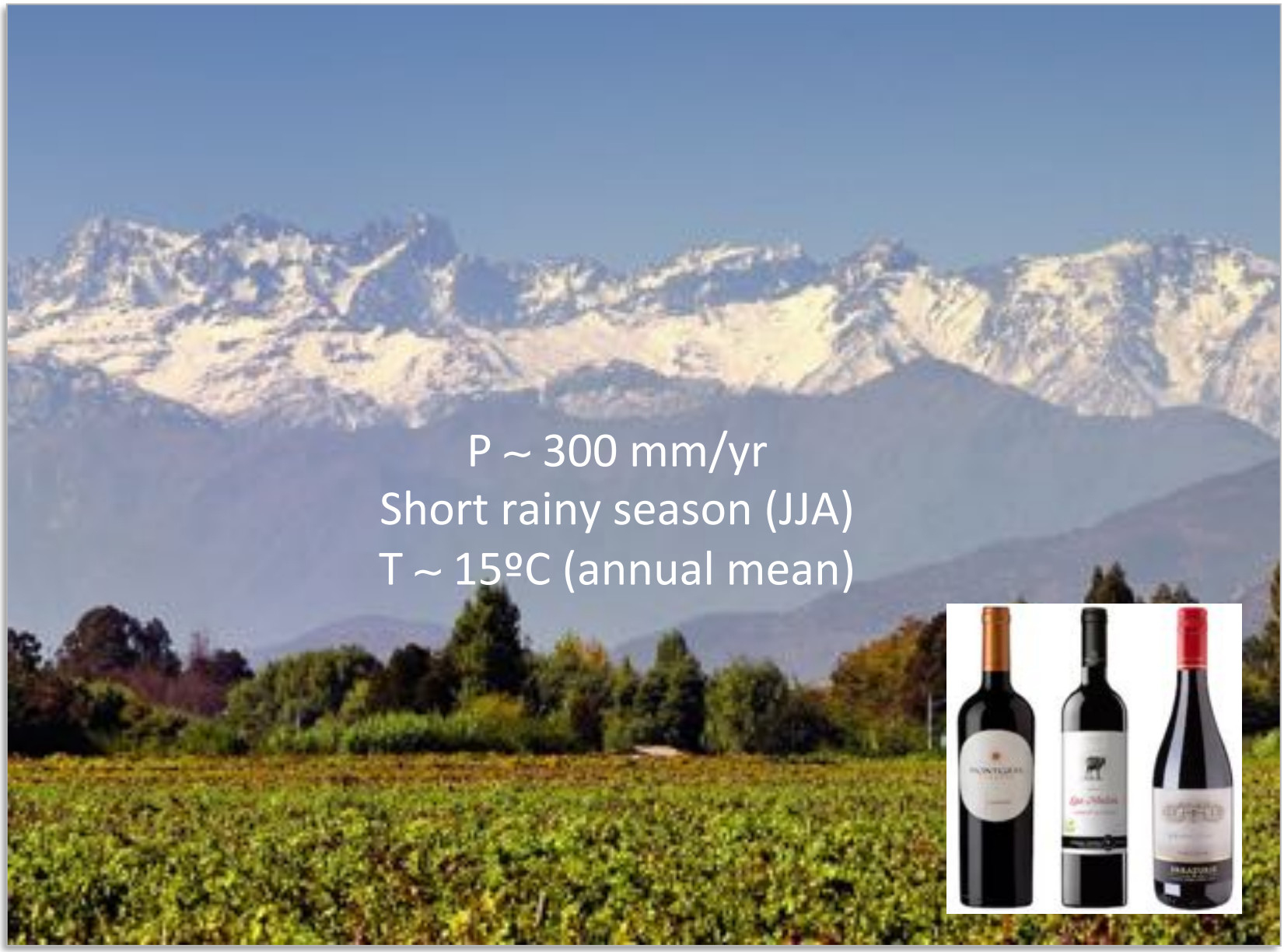




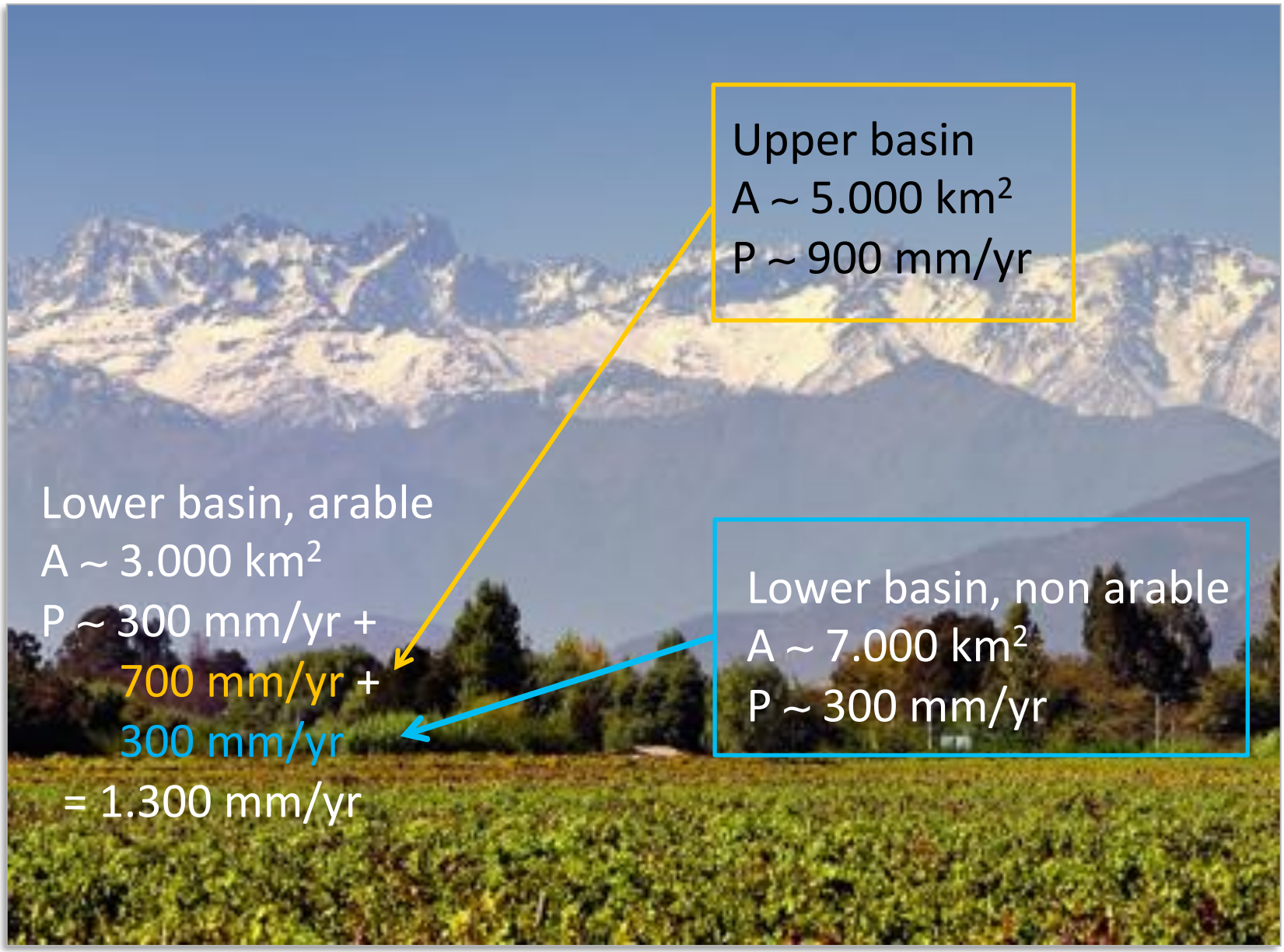
Distribution of mean annual rainfall over transect (around 33°S) along the subtropical Andes

Central Chile climate

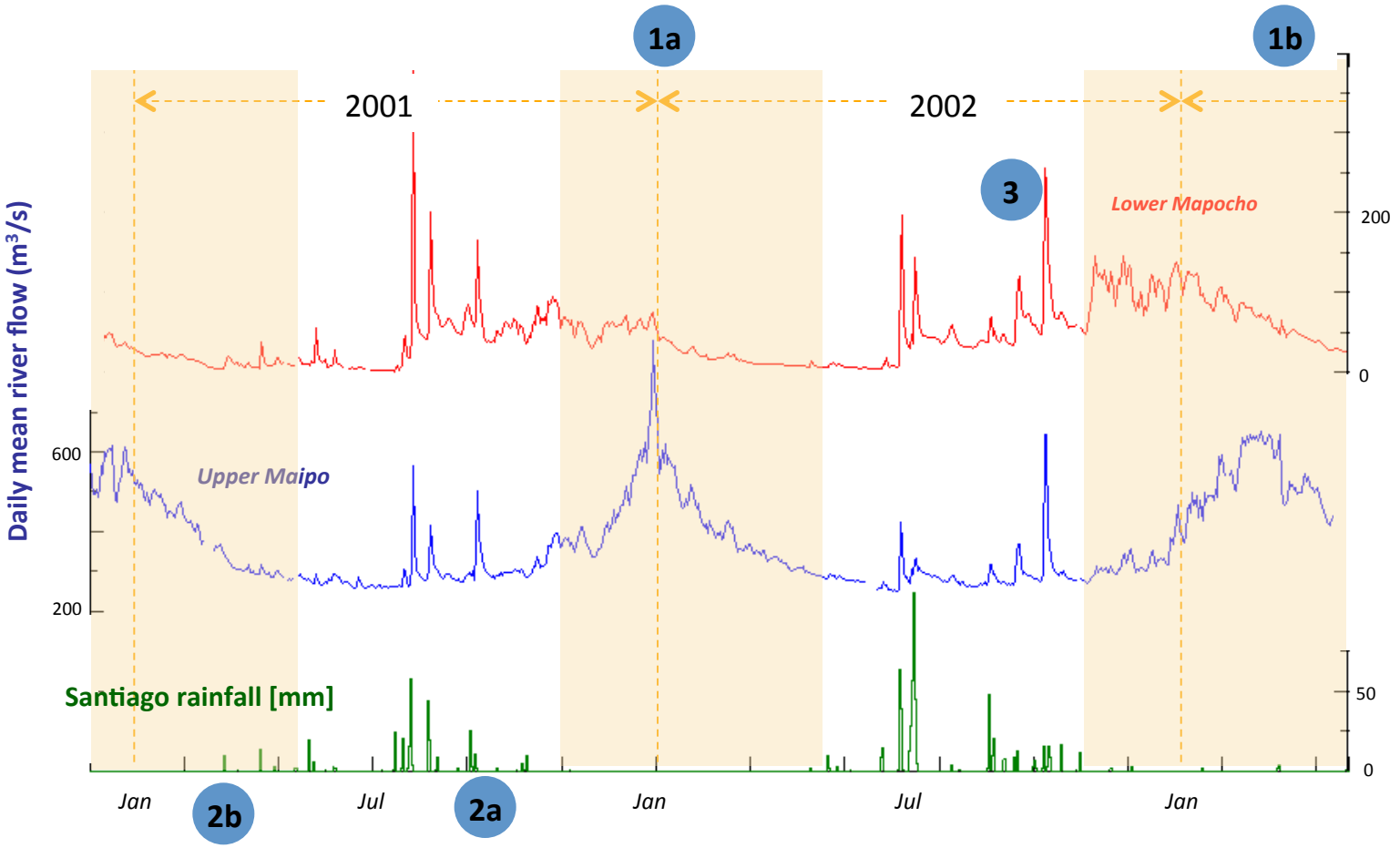
Central Chile Agriculture… a miracle?



The Andean Credit

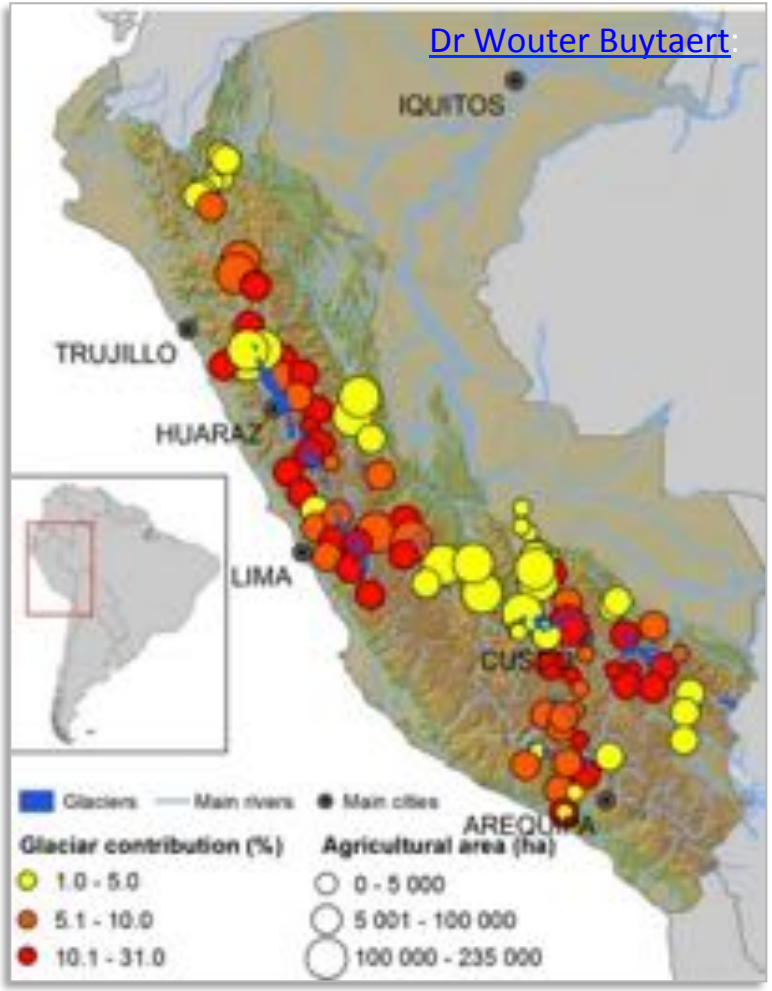


How does the spatial variability in surface parameters and meteorology affect water availability (e.g. river flow)?

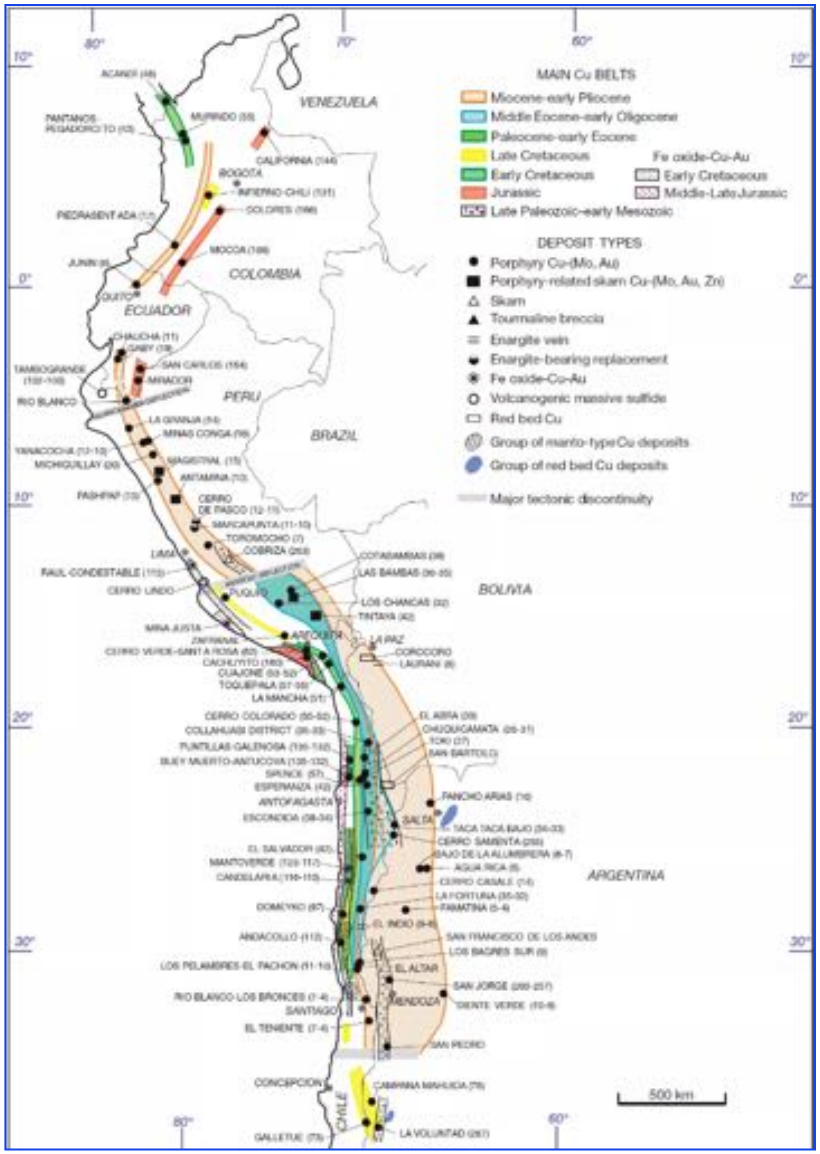


Snowmelt regime, with strong year-to-year variability (1a versus 1b)
Winter storms (2), non-linear (2a/2b), with sudden peak flow (3)

Other forms of Andean Credit



Other forms of Andean Credit



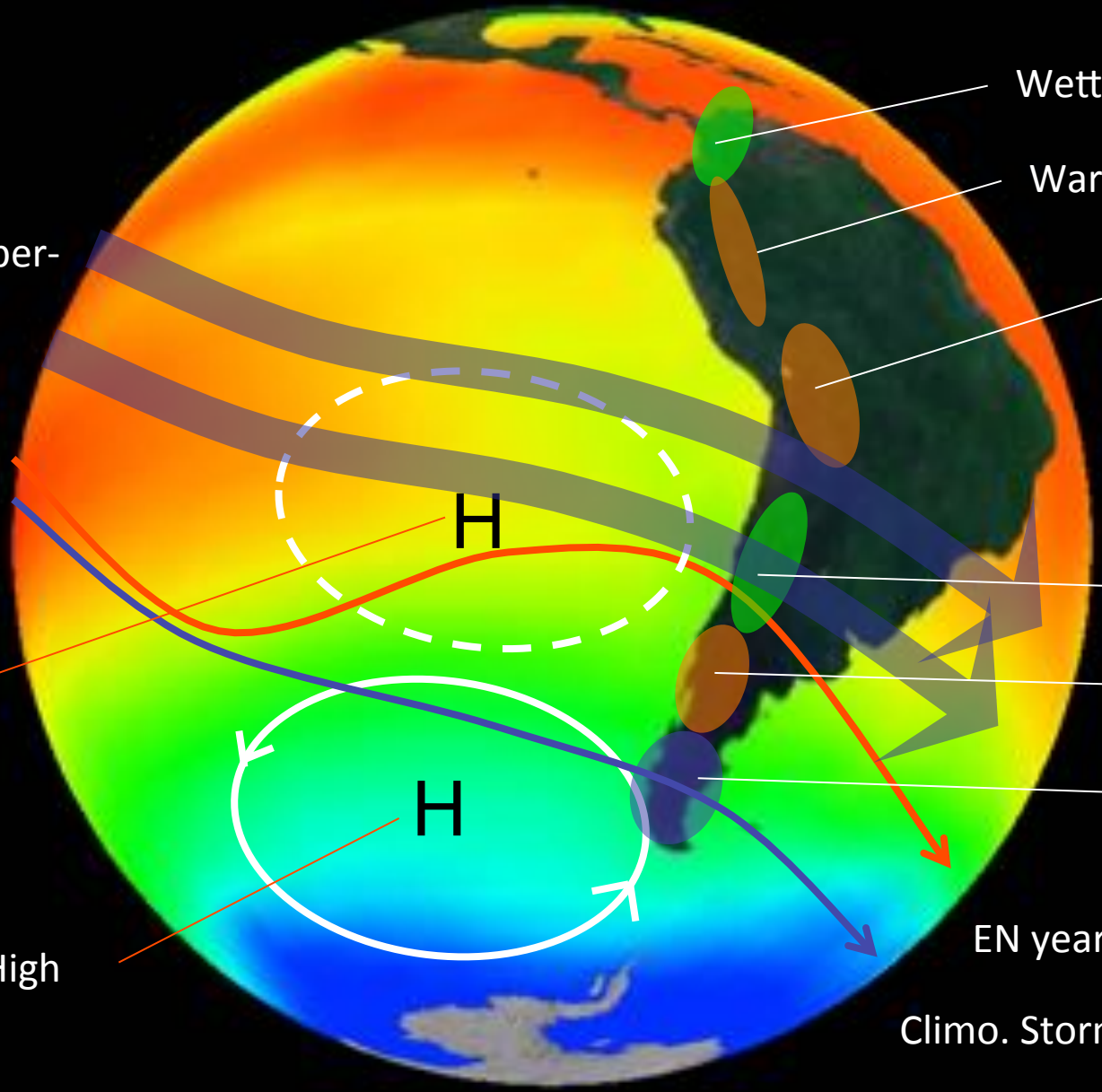
Sillitoe and Perello, 2005

But living close to the Andes has its risk

Flooding of Mocoa, Putumayo, Colombia,
on April 1st, 2017
At least 300 fatalities.

Landslide Santiago foothills, May 3, 1993
At least 100 fatalities.

Interannual variability : Major ENSO impacts along the Andes



Wetter-JFMA

Warmer - DJF

Drier/Warmer DJF

Wetter-OND

Wetter-JJA

Drier-DJF

Colder

EN years Storm Track

Climo. Storm Track

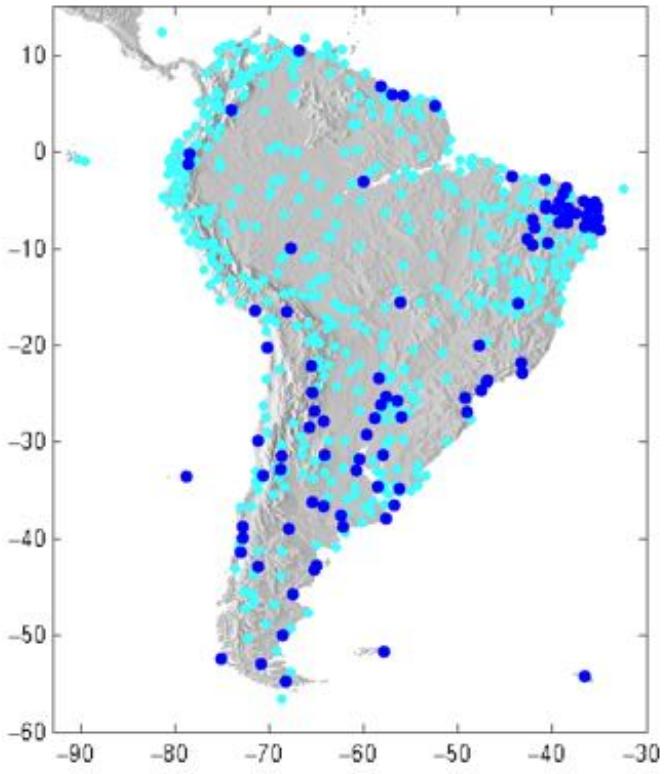
Stronger upper-Level ST Jet

Weakened ST High

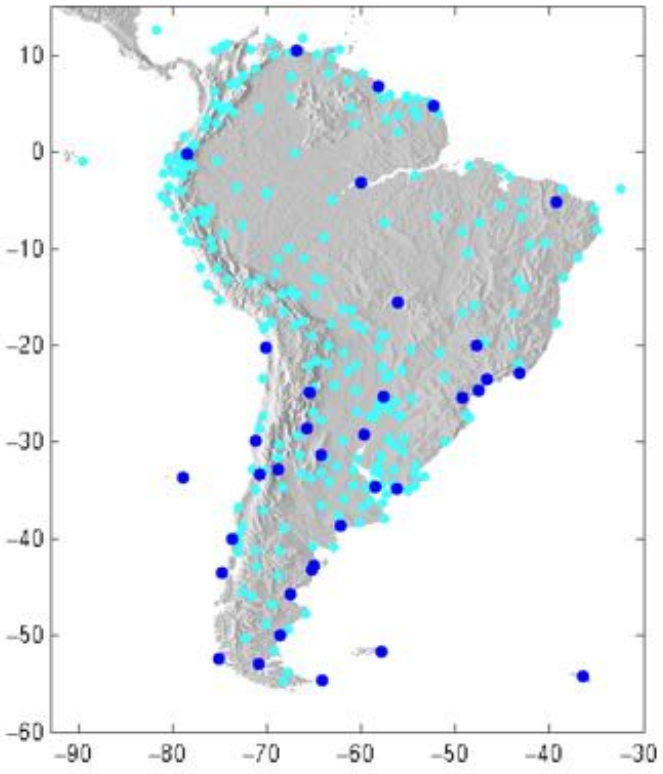
Blocking High

Global Historical Climate Network (GHCN)

Precipitation

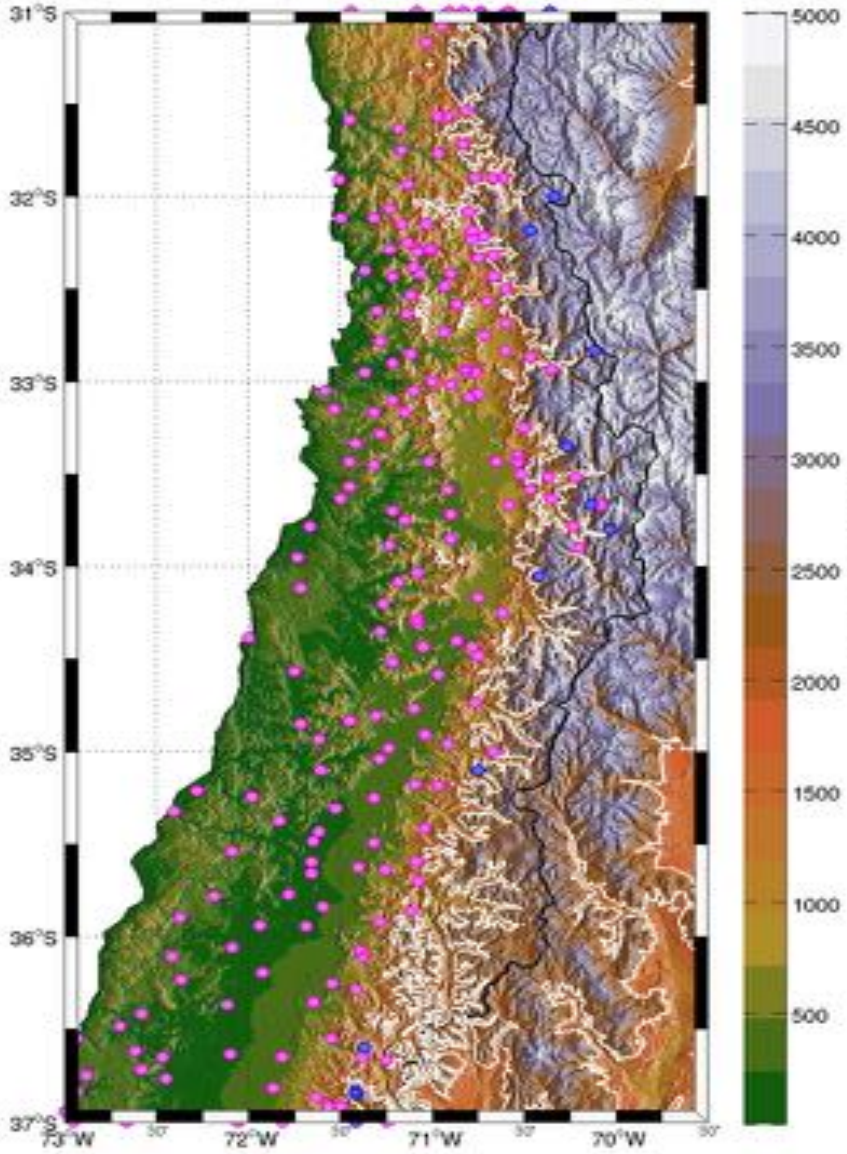


Mean Temperature

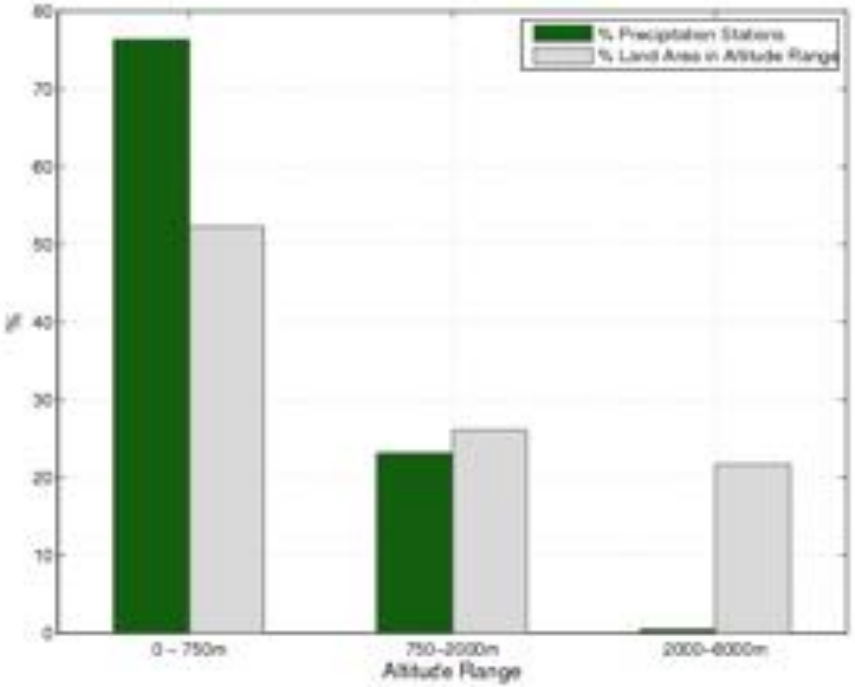


- All stations (anytime, any length)
- Century-long stations (Ti<1905, Tf>1995, missdata<20%)

Hydro/met observing system in the high Andes

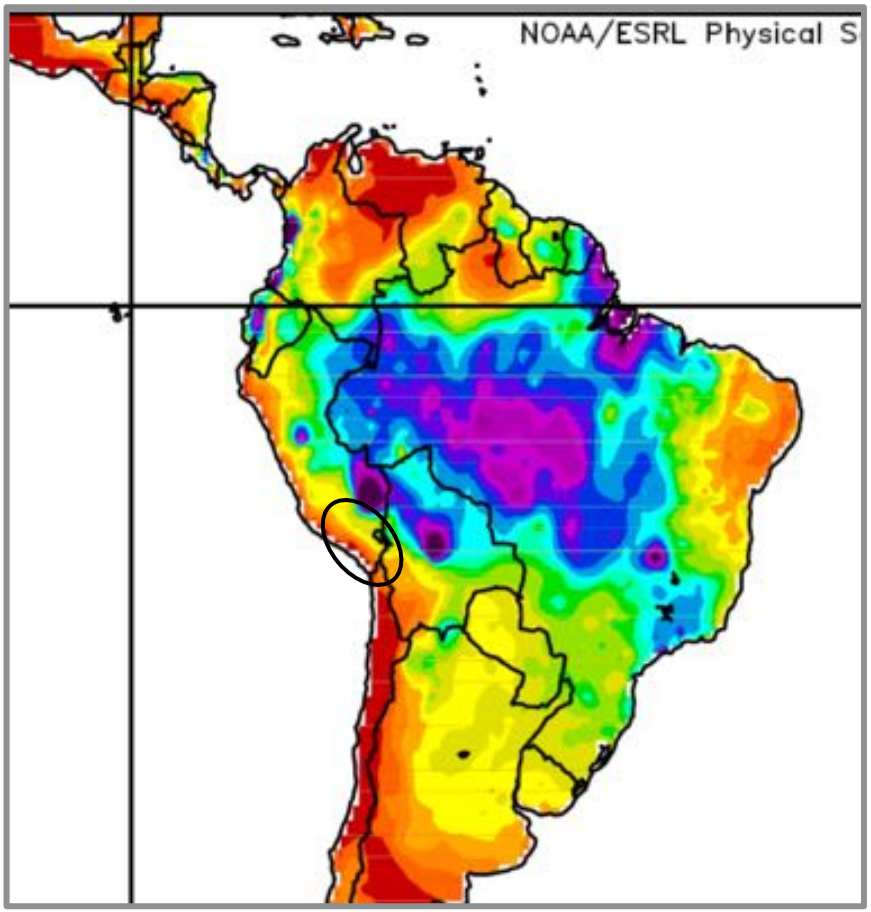


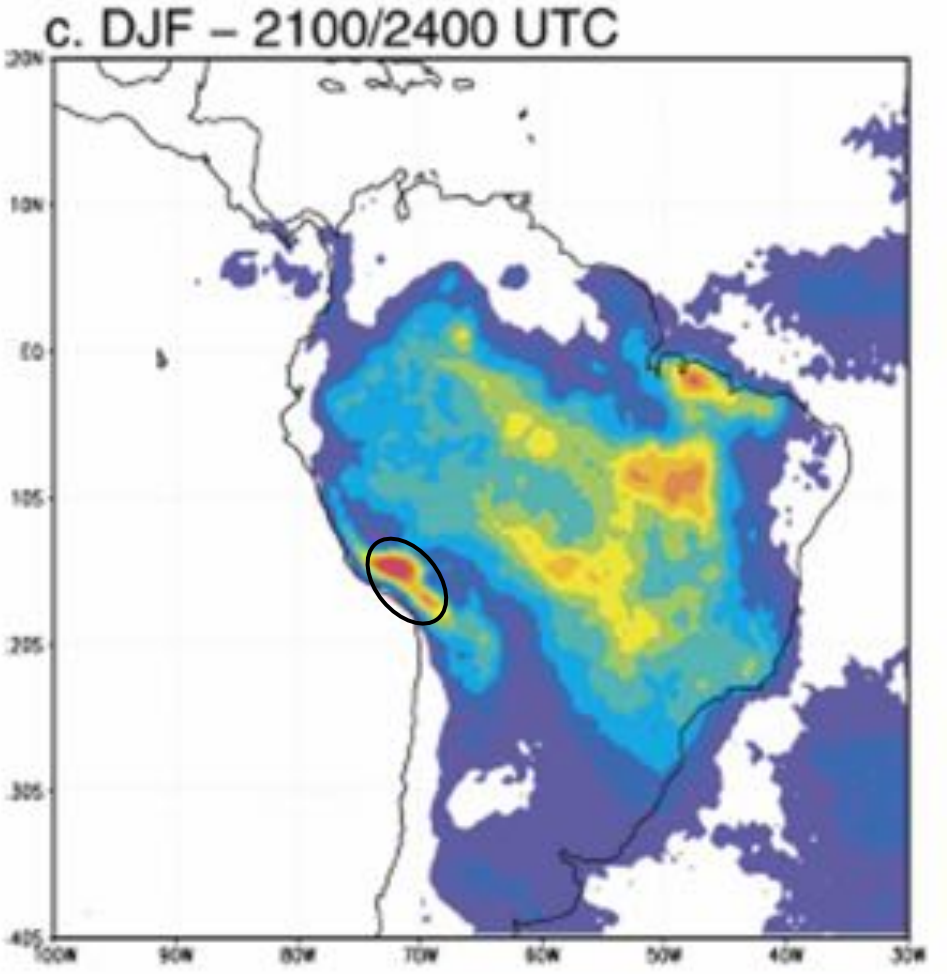
Current coverage (DGA+DMC, pink circles) is reasonable in the “central valley” but dramatically low at higher elevations, where most of the water accumulation takes place



How much really rains in the central Andes?

Different products, different places…





Regular sounding stations

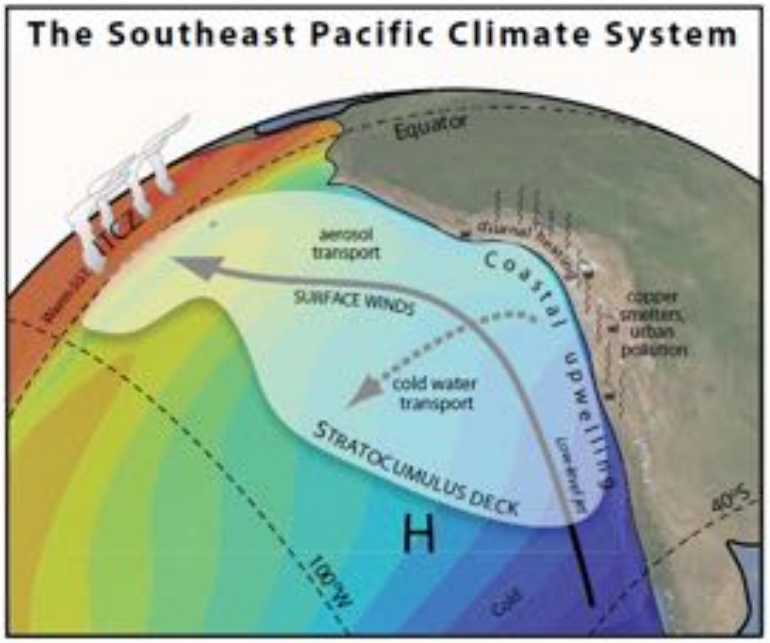


Fig. 1. Key features of the southeast Pacific (SEP) coupled climate system being explored in the VOCALS Program.

R. Wood et al.: VOCALS operations

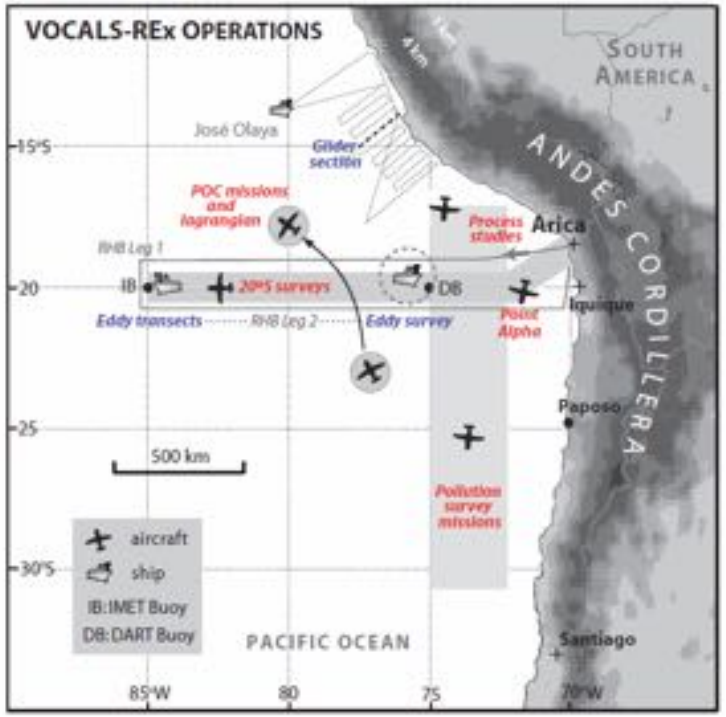
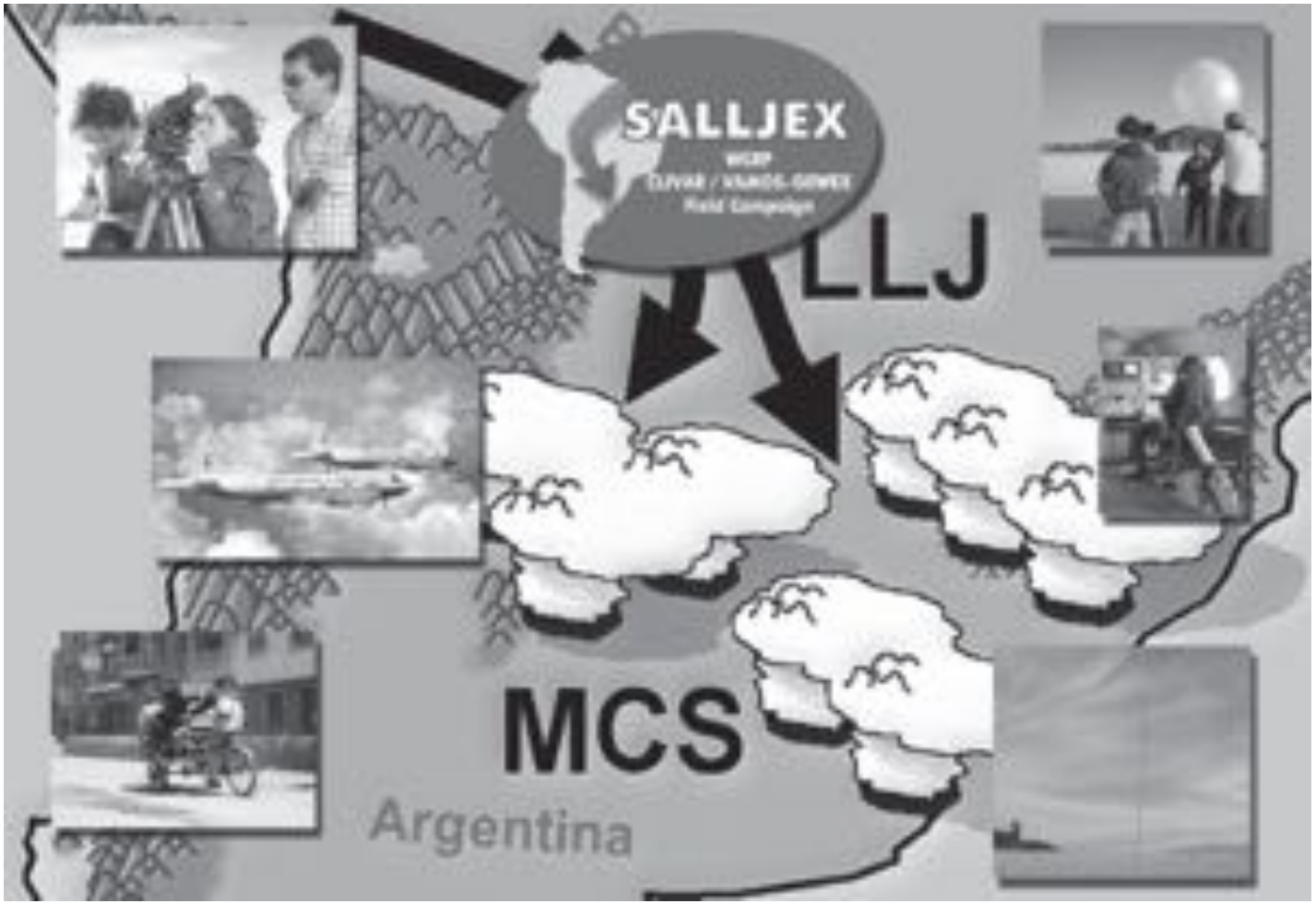
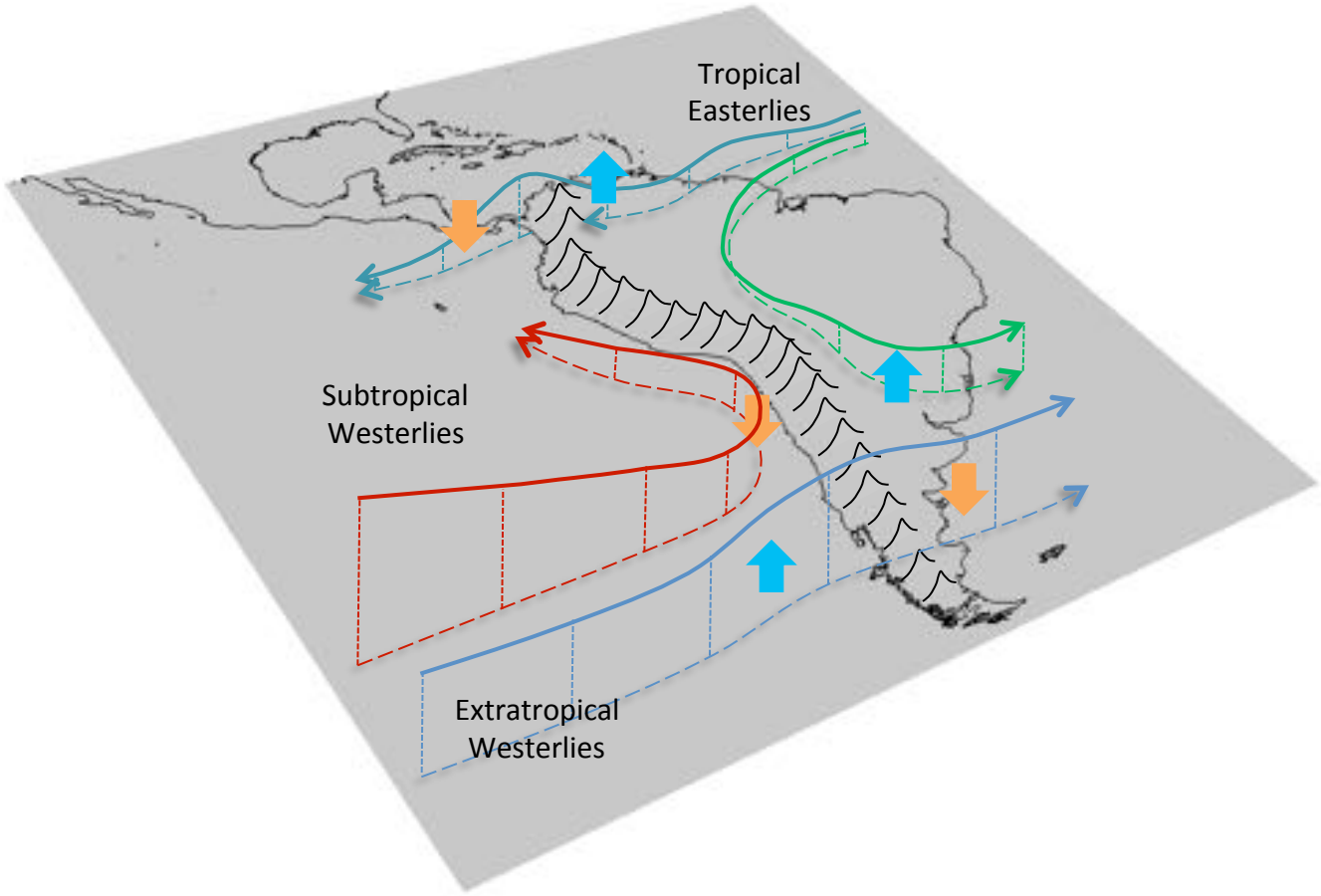


Fig. 2. VOCALS REx study region showing main sampling platforms and mission types. The land aerosol/meteorology site at Paposo, the sounding station at Iquique, and the instrumented IMET and DART buoys are also shown.


SALLJEX
LLJ
MCS
Argentina

Mountain induced circulation: subsidence west of the Andes



Basic Features