Dependence of wet-season precipitation in the Central Andes on Pacific-SST anomaly patterns, tropospheric temperature, pressure and humidity fields

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Abstract

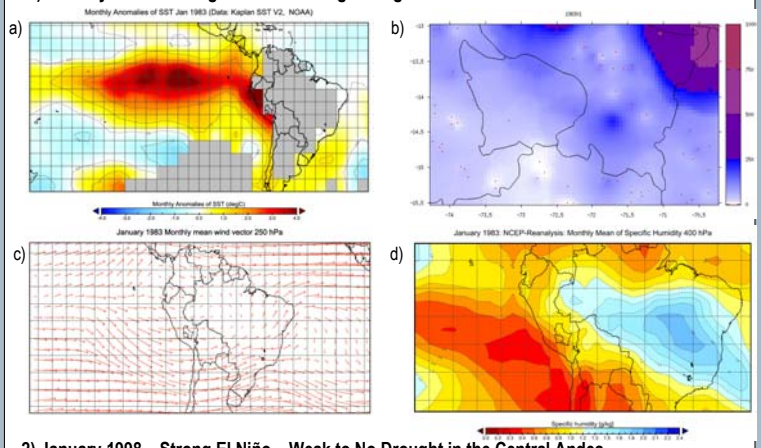
The Cusco and Apurimac regions in the Central Andes of Peru are characterized by distinct wet and dry seasons and are highly vulnerable to annual and inter-annual precipitation variability. This study aims at advancing knowledge on monthly wet-season precipitation patterns in these regions. We attempted to correlate interpolated daily and monthly precipitation fields with Pacific SST anomaly patterns taken from the Kaplan dataset and tropospheric temperature, pressure and humidity fields taken from the NCAR/NCEP reanalyses. Operational and historical daily precipitation gauge time series by the Peruvian Meteorological and Hydrological Service (SENAMHI) were available in the Cusco/Apurimac regions since January 1965. Although some changes in precipitation gauge distribution have taken place during the analysis period, daily and monthly interpolation fields could be calculated for more than 45 years. The results show a strong year-to-year variability in the distribution and amount of wet-season monthly precipitation over the central Andes part of Peru and only weak dependence on Pacific SST anomaly pattern.

El Niño events, such as the very strong ones in 1982/83 and 1997/98, do not show consistent wet-season precipitation amounts and distributions in this part of Peru. While in austral summer 1982/83 a severe drought occurred in Cusco and Apurimac, conditions were much closer to normal during austral summer 1997/98. Moreover, during the summer of 2009/10, a moderate El Niño event, January was the wettest month ever recorded in the central parts of Cusco since the beginning of the dataset in 1965, with exceptionally high precipitation amounts resulting in severe flooding of many smaller and major rivers. Pacific SST anomaly patterns, however, rather suggest below normal precipitation amounts during El Niño conditions for this region.

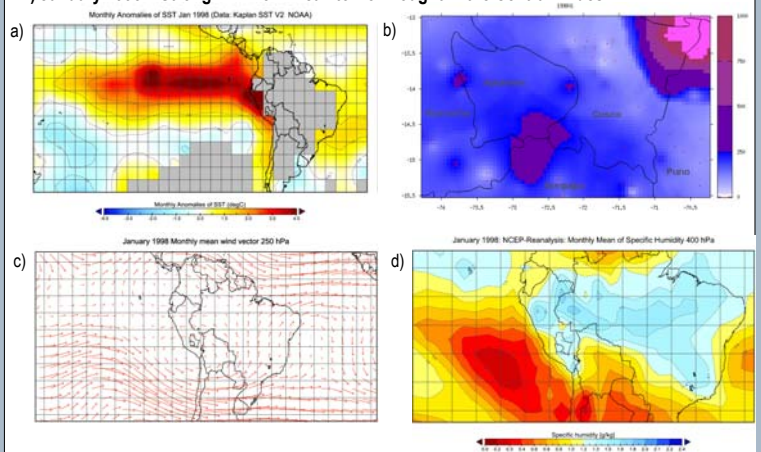
In agreement with modelling results by other studies (e.g. Garreaud, 1999; Lenters&Cook, 1999), here we show that temperature and wind conditions in the higher troposphere are stronger predictors wet-season precipitation amounts in the Andes regions of Cusco and Apurimac than Pacific SST anomaly patterns. Analysis of infrared and water vapour channel of GOES satellite data showed that moisture transport from Amazon rain forest by easterly winds is a main source for central Andes precipitation. Furthermore, it can be shown that precipitation conditions of wet-season months in Cusco and Apurimac primarily depend on the dynamics of planetary waves over central South America, with wet/dry conditions depending on zonality of flow. The results of this study are important for an improved understanding of present and future spatio-temporal precipitation distribution in a mountain region which is highly vulnerable to climate change. The findings thus contribute to ongoing climate change adaptation programmes jointly borne by the Peruvian and Swiss Governments (Salzmann et. al., 2009).

Strong El Niño Situation and January-Precipitation in 1983 and 1998

1) January 1983 – Strong El Niño – Strong Drought in the Central Andes



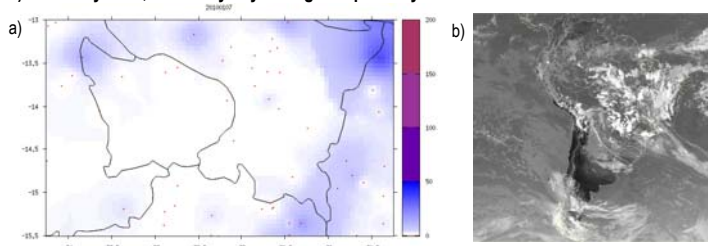
2) January 1998 – Strong El Niño – Weak to No Drought in the Central Andes



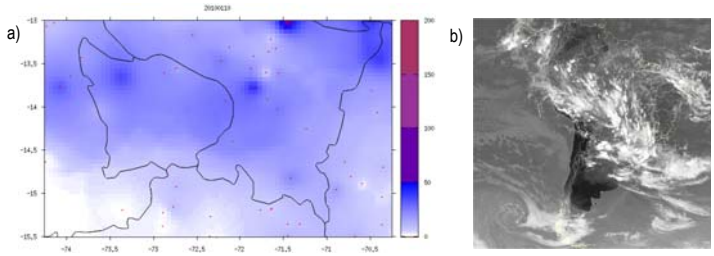
SST-anomaly for two extreme 'El Niño' – situations in January 1983 (1) and January 1998 (2) . Although SST anomaly-patterns and magnitude are comparable (a), drought conditions were completely different (b). In Jan. 1983 there was a severe drought in the Central Andes, whereas in Jan.1998 there was a weak drought at most. Interpolated precipitation at SENAMHI stations (b) reveals that S-Apurímac, N-Arequipa had almost no precipitation midst in wet season 1982/83. In Jan. 1998 the precipitation condition in that region was quite normal. High tropospheric circulation and humidity patterns show typical westward transport of Amazonian humidity for 1998, whereas in 1983 dry air from the Pacific was advected to the Central Andes (c,d). Data: Kaplan SST V2, SENAMHI & NCEP. **This means that changes in hydrological cycle of Amazon (cf. Marengo, 2006) can be essential for severety of future droughts in the Central Andes.**

Moderate El Niño Situation in January 2010: Daily & Monthly Precipitation

1) 7 January 2010; rather dry day during exceptionally wet month

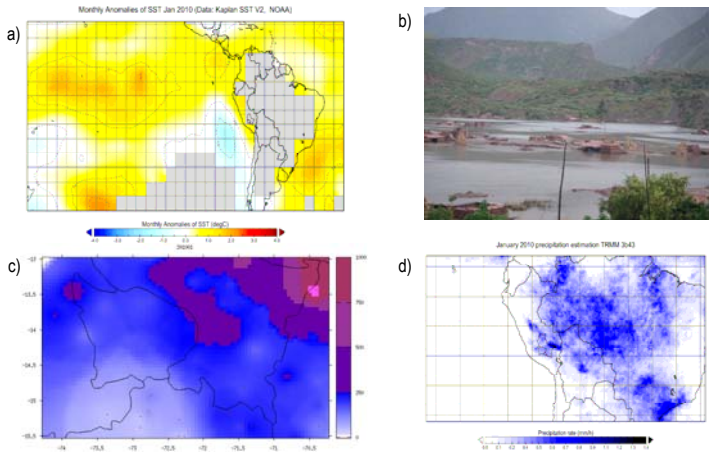


2) 10 January 2010; Wet day during exceptionally wet month



1) Even during the wet month January 2010 in mountainous Cusco and Apurímac some days are rather dry, as Jan. 7. (a) Interpolated station precipitation and (b) GOES 12 image at 18 UTC.
2) One of the wettest days was Jan. 10, for which the typical westward motion of the wet air is clearly visible in GOES12 products, as this 18UTC example (b). GOES images 15- minutes sequence reveals that humidity is advected primarily from the Amazon towards the central Andes (not shown). On the left-handside the respective interpolated daily precipitation sums of SENAMHI-stations (a). Data GOES12: CPTEC and NOAA

3) January 2010: Exceptionally wet month during moderate El Niño – 'Machu-Picchu Flood'



Sea surface temperature anomaly (a,Kaplan SST V2) and inundations of the Vilcanota river in January 2010 (b) . Despite the moderate El Niño - situation, one of the highest monthly precipitation sums since 1965 was measured in this valley (c, Data: SENAMHI). Satellite-based monthly estimation of Tropical Rainfall Measuring Mission (TRMM) also indicates unusually strong precipitation in this region (d, cf. Scheel et. al. 2010, Data: NASA).
In consequence, precipitation situation in this region – at least during austral summer months - is not strongly related to ENSO-cycle in this region, rather to tropospheric conditions of the atmosphere. Humidity advection seems to come primarily from the Amazon.

References

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