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Project Title: Analysis of Precipitation in the Northern Peruvian Andes and Associated Atmospheric Circulation Patterns

Extended abstract

Precipitation in the northern Peruvian Andes exhibits a marked annual cycle, with most of the rainfall concentrated during the humid season (January - March), but minimal precipitation in the dry season (June - August). Rainfall is the primary source for fresh water in the densely populated Andean valleys. The Peruvian society currently undergoes a powerful evolution with increasing water demands after several decades of terrorism induced stagnation. Thus, water availability and management is of essential importance for the social and economic development of the country. The Cordillera Blanca (77° 30' W, 9° S) is the largest glaciated area not only in northern Perú, but the whole tropics (about 600 km^2, Georges accepted). It has a crucial impact on the water availability in the Callejon de Huaylas valley, which houses more than 200,000 people. During the dry season, water ressources in the valley result almost exclusively from glacier melt. The relation of climate, glacier runoff and water availability in the Cordillera Blanca and the Callejon de Huaylas has been studied exemplary for the low latitudes by the Tropical Glaciology Group Innsbruck (*http://geowww.uibk.ac.at/glacio/*) since the late 1980s (e.g. Kaser et al. 1990, in press). At present, the glaciers in northern Perú exhibit strong retreat rates with increased runoff. However, reduced glacierization will lead to decreased runoff in the near future. Consequently, studies on long term water availability must concentrate on precipitation.

Detailed analysis of rainfall formation, triggering atmospheric processes and connected anomalies of large-scale circulation is still missing for the Tropical Andes between 5° and 13° S. Intensive work on atmospheric conditions favoring precipitation has been carried out by Garreaud and co-workers (e.g. Garreaud 1999, Garreaud and Aceituno 2001) for the Central Andean Altiplano (15°–22° S) in summertime (i.e. humid season). It has been found that uplifting of moist air from the eastern lowlands with subsequent deep convection and cloudiness over the Altiplano only occurs, when high mixing ratios in the local boundary layer exist. Then, the strength and extent of varying flow over the eastern slope of the Andes is decisive for a rainy or dry period. The flow variation is mainly expressed in marked differences of the daily onset, intensity and decline of westerly/easterly winds in the Altiplano boundary layer which conforms with mid tropospheric levels. Turbulent momentum mixing from aloft into the convective boundary layer seems to cause these variations and hence varying moisture advection. The momentum mixing is determined by large-scale anomalies of circulation in the upper troposphere. Upper tropospheric anomalies are also reflected by the markedness and displacement of the so-called Bolivian High.

To gain insight into the linkage of the meso- and large-scale atmospheric circulation and rainfall formation in the northern Peruvian Andes a multiscaled statistical analysis is proposed. The prime objective is to investigate if relations between atmospheric circulation and precipitation found for the Central Andean Altiplano also exist for the northern Peruvian Andes. Altiplano summertime boundary conditions are likely to dominate in the northern Peruvian Andes all year round, since easterly flow in the lower troposphere prevails and no influence from mid-latitudinal westerlies with frontal activity is given as in winter on the Altiplano.

Major questions of concern are:

- What controls the amount and intensity of moisture advection?
- When and through which processes is low-level moisture transported up to mid-tropospheric levels (= summit level of the Cordillera Blanca)?
- What eastern Andean low-level mixing ratios enable the initialization of deep convection over the northern Peruvian Andes? Is there a minimum threshold value?
- What causes the occurrence of convectively active and inactive episodes?
- Do large-scale convective cloudiness measurements correlate with local radiation and/or precipitation intensities?
- When and why does moisture advection result in deep convection and rainfall?
- Is moisture advection/deep convection/rainfall in the northern Peruvian Andes regulated by upper tropospheric circulation?
- Does a relation exist between northern Peruvian highland precipitation and location and intensity of the Bolivian High?

Verfication will be based on statistical analysis of atmospheric state and in situ conditions during rainy and dry periods between September 1999 and August 2002 utilizing the ECMWF operational model archive, NOAA OLR satellite measurements and Cordillera Blanca AWS data (Georges and Kaser 2002). The resolution of the ECMWF operational model in space and time is considered to reveal sufficiently the anticipated spatio-temporal patterns. Additional meso-scale modelling may be necessary for insights into the processes involved. In a second step, results from the former analysis will be the basis for the investigation of long term trends, interannual variations, large-scale influences like Pacific SST and effects from ENSO. A complete 40-year series of monthly precipitation in the target region (Kaser et al. accepted) together with SST, OLR and ECMWF ERA-40 fields provides a promising database for statistical analysis in the space and time domains. Whereas the first part of the investigation concentrates on the recognition of meso-scale patterns, the second part is supposed to find large-scale remote forcings on precipitation in the northern Peruvian Andes.

Results are expected to be beneficial in several ways. Clarification of atmospheric conditions inducing precipitation will be helpful for regional water ressources management efforts and prognosis of water availability. Contribution will also be made to the scientific community by a detailed investigation on a tropical region, where we still know little about climate variability.

Finally, results are expected to be highly interesting for the understanding of the climate-glacier relationship in the low latitudes and low-latitude glacier modelling.

The research activities will benefit from existing local knowledge and the close cooperation with scientific institutions in Perú (INRENA – Instituto Nacional de Recursos Naturales *http://www.inrena.gob.pe*; INAGGA – Instituto Andino de Glaciologia y Geoambiente *http://www.itete.com.pe/inagga/*) and experiences on mountain meteorology at the University of Innsbruck/Austria (IMGI – Institut für Meteorologie und Geophysik Innsbruck *http://www2.uibk.ac.at/meteo/*). Access to the ECMWF facilities (MARS operational model and ERA-40 archives) will be essential for the proposed investigation.

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