

# CHARACTERISTICS OF WET AND DRY PERIODS OVER THE SOUTH AMERICAN ALTIPLANO OBSERVED DURING THE SOUTH AMERICAN LOW LEVEL JET EXPERIMENT (SALLJEX)

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## 1. INTRODUCTION

The South American Altiplano experiences a summertime rainy period resulting from seasonal changes in the upper-air circulation patterns associated with the South American monsoon. During this period the precipitation exhibits a marked intra-seasonal variability which has been shown to be strongly related to alternating moist and dry conditions at stations on the western rim of the plateau (e.g., Garreaud 1999).

In this study we examine the moisture variability over the Altiplano during the summer of 2002-2003 using observational data from the South American Low-Level Jet (SALLJEX) experiment (Vera, 2004) along with satellite based estimates of precipitable water (PW) from Global Positioning System (GPS) and Moderate Resolution Imaging Spectrometer (MODIS) instruments. The work presented here is based largely on past results documented in Falvey and Garreaud (2005) and for more detailed information this reference should be consulted.

## 2. INTRA-SEASONAL MOISTURE VARIABILITY

We begin by examining the variability of surface water vapor during the SALLJEX season at stations on the western (Chungara) and eastern (La Paz) rims of the Altiplano (Figure 2).

Chungara is situated at 5000 m a.m.s.l at on the western cordillera, near to the locations of the surface observations presented in the prior studies of Aceituno (1998), Hardy et al (1998) and Garreaud (2000). As was also found in these studies for other seasons, the specific humidity shows pronounced fluctuations (Figure 2a), particularly early in the season between November 15 and January 7. The variability in surface water vapor shows a remarkable correspondence to the GPS PW (Bevis et al, 1992) measured at Arequipa, some 200 km to the north. There is a

clear tendency for rainfall in the vicinity of Chungara to occur during moist episodes: non-zero precipitation was recorded at least once during each of the four wet periods prior to 7 January, and never on any of the dry days when the mean  $q_v$  fell below 4 g/kg.

The temporal variation of water vapor is quite different at La Paz, where both the surface moisture and total PW are quite stable during the study period. The dry episodes that punctuate the time series at Chungara evidently do not affect the eastern side of the Altiplano. Consistent with the higher moisture at this site, precipitation is more frequent at La Paz. The distribution of rainy days is not uniform but tends to be bunched around the moist periods observed on the western plateau.

Although station data is limited over the Altiplano the analysis of water vapor can be extended to encompass the whole plateau by making use of the 1-km resolution MODIS near-infrared precipitable water (PW) product. This is available twice per day at 1530 and 1830 UTC from the TERRA and AQUA satellite platforms, respectively. The high accuracy of the MODIS PW is evidenced from an excellent comparison (rms difference < 2mm) with the GPS data at Arequipa (not shown). The close correspondence of the PW with the surface moisture at both Chungara and La Paz indicates that the surface variations are representative of variability throughout the entire atmospheric column.

Wet and dry days are identified as the upper and lower terciles of the daily mean PW at Arequipa (Figure 2). Composites of the wet and dry PW fields from MODIS are shown in Figure 3. During wet periods (Figure 3a), the PW is approximately uniformly distributed across the plateau, with a mean value of ~12 mm. Due to the strong dependence of PW on altitude, PW is lower over the western and eastern cordilleras, and increases rapidly down the western slopes of the Altiplano. In the dry composite, the PW is generally lower over the plateau, with a mean value of roughly 8 mm. However, there is clear spatial variation in this case, the PW decreasing across the plateau both north to south and west to east, from values close to 12 mm north of Titicaca to as little as 4 mm over Salar Uyuni. The difference in PW between the wet and dry composites is therefore most marked along the

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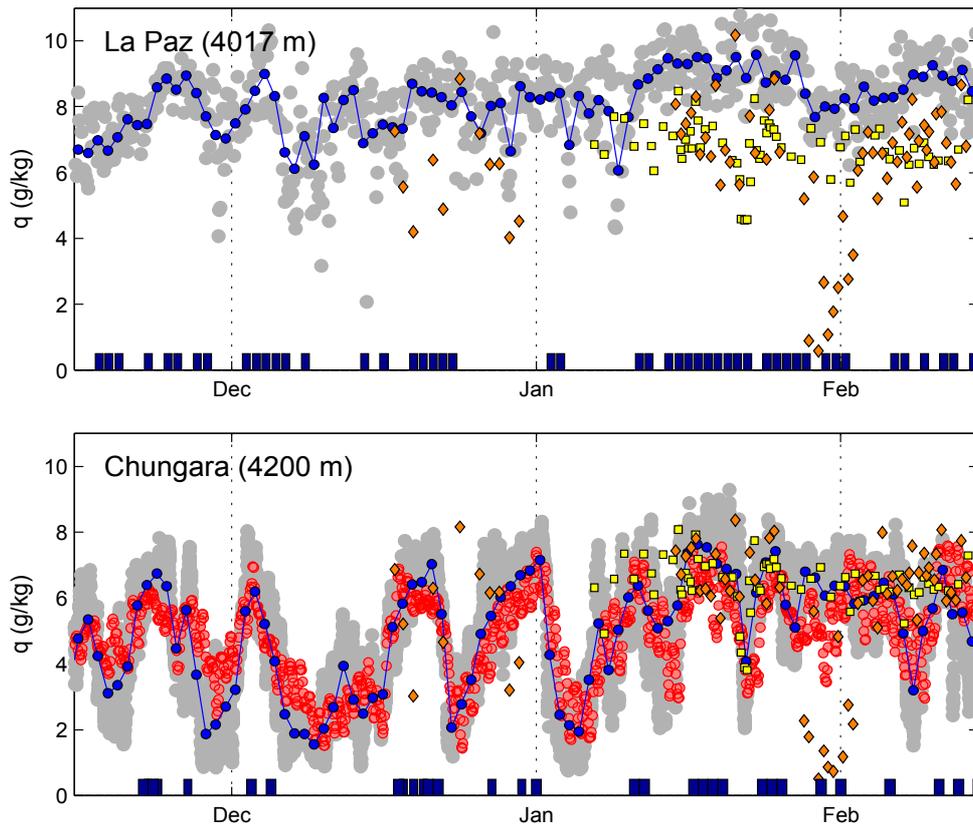
western rim of the Altiplano and over the dry southern plateau, whilst, as suggested by the surface observation in Figure 2, the PW is relatively invariant in the Titicaca basin, especially on its eastern side. A similar pattern has also been noted in the long term variability of convective cloudiness over the plateau (Vuille and Kemming 2004)

### 3. TRANSPORT MECHANISMS

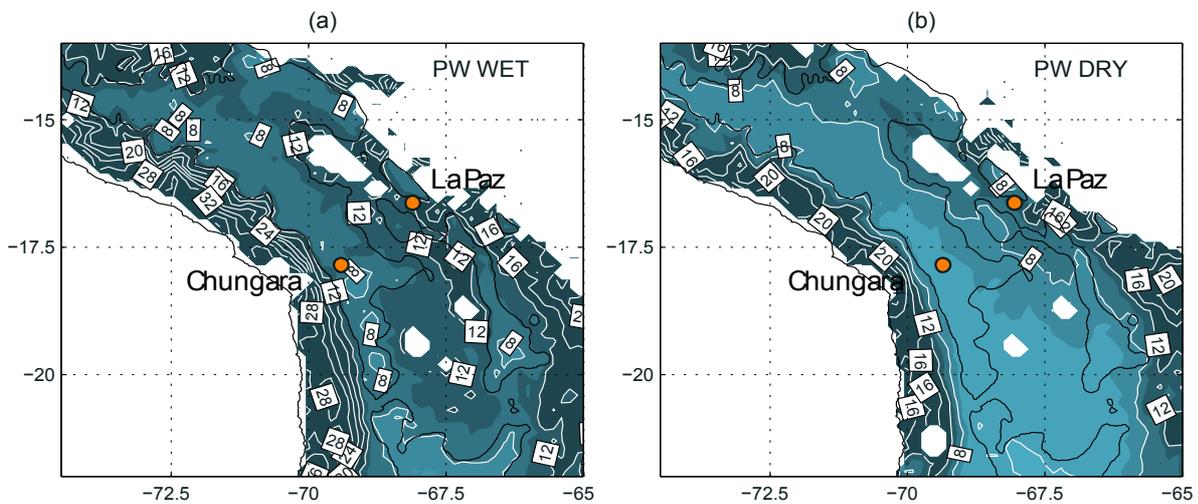
Based largely on numerical modeling, Garreaud (1999) suggested that moisture transport by thermally driven diurnal flows on the slopes of the Altiplano played a fundamental role in the transport of moisture to the plateau. The SALLJEX radiosonde data at Santa Cruz (Figure 1) and other sites in the Amazon Basin (not shown) show that during wet periods, the moisture content above the Altiplano is in fact comparable to that at the same altitude over the continent. Winds measured by SALLJEX PIBAL's (Douglas et al 1996) in the northern Altiplano basin and at Arequipa on its northwestern flank, show consistent low level easterly flow on wet days. Thus simple horizontal advection may provide an

adequate explanation for the levels of moisture over the Altiplano on *wet* days. During *dry* periods, westerlies are observed at upper levels but the mean flow is negligible in the basin, consistent with the fact that dry air does not appear to cross to the eastern plateau during dry days.

The simple advection transport mechanism is further supported by the fact that the easterly winds were observed in the early morning, when upslope flows are expected to be weakest. Diurnal variations in PW can also be inferred from the MODIS PW dataset, by calculating the difference in PW between same day AQUA (1830 UTC) and TERRA (1530 UTC) passes. Figure 3 shows the PW at all points where a statistically significant mean value could be obtained. Zones of significant afternoon variation are seen on both the eastern and western slopes of the Altiplano. The PW difference at points near Arequipa (~2 mm) compare well with those inferred from the GPS data (see Figure 3). There is no indication of a significant diurnal variation in PW over the Altiplano itself.



**Figure 1:** Surface specific humidity at La Paz (upper) and Chungara (lower), the grey dots showing individual measurements and the blue dots daily means. Also shown are the specific humidity measured by radiosonde at Santa Cruz (orange) and Rio Branco (yellow). The GPS PW estimates at Arequipa are shown on the Chungara plot.



**Figure 2:** Composite MODIS PW (mm) during moist (WET) and dry (DRY) periods on the western Altiplano.

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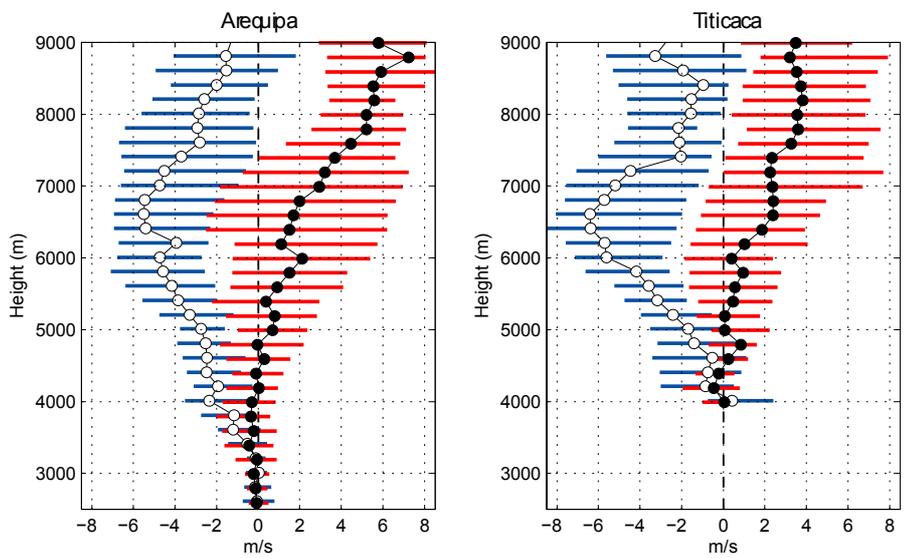
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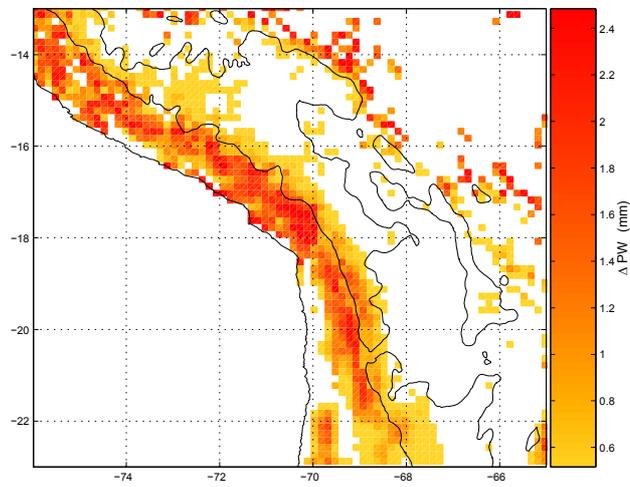
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**Figure 3:** Composite 0800 AM LTC wind profiles for WET (open circle) and DRY (closed circle) periods from PIBAL stations at Arequipa and in the Titicaca Basin. The Red and blue bars show the inter-quartile ranges of the composites.



**Figure 4:** Diurnal variability as inferred from the mean difference in PW from MODIS passes at 1530 and 1830 (UTC).