NOTES AND CORRESPONDENCE

Intraseasonal Variability of Moisture and Rainfall over the South American Altiplano

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ABSTRACT

Precipitation over the South American Altiplano (about 4000 m above sea level) is mostly concentrated during the austral summer (December–January–February) when mean easterly flow in the middle and upper troposphere favors the moisture transport from the interior of the continent toward the central Andes. Within the wet season, rainy days tend to cluster in rainy episodes of about a week long, interrupted by somewhat longer dry periods. Based on one-site, research-quality observations over the western Altiplano, it has been suggested that occurrence of deep, moist convection is largely controlled by the availability of water vapor in the local boundary layer.

In this work the author evaluates the representativeness of the observations in the western Altiplano in a regional context and investigates if the hypotheses derived from these data are generally applicable to the rest of the plateau. The study is based on surface synoptic data and atmospheric reanalysis. The relationship between moisture fluctuations on the Altiplano and the lowlands to the east of the central Andes is also addressed. It is found that intraseasonal moisture fluctuations tend to be coherent on the Altiplano and closely related to basinwide episodes of active/suppressed moist convection. On the other hand, near-surface moisture variability over the lowlands to the east of the central Andes is too small and noisy to explain the persistent, large-amplitude fluctuations in the Altiplano. Thus, moisture and rainfall variability over the Altiplano is strongly dependent on the intensity of the moisture transport over the eastern slope of the Andes rather than the precise low-level conditions on the central part of the continent.

1. Introduction

Between 15° and 22°S the Andes Cordillera splits into two ranges embracing a high-level plateau known as the Altiplano, about 250 km wide and at an average elevation of 3800 m (Fig. 1). To the west of the central Andes the southeast Pacific subtropical anticyclone produces dry and very stable conditions, with cool, moist air confined below the base of the subsidence inversion at about 900 hPa. The lowlands to the east of the central Andes exhibit a tropical continental climate, with a peak in rainfall at the height of the austral summer (December–January–February, DJF) when low-level northwesterly flow transports warm, moist air from the Amazon Basin toward the subtropical part of the continent. Situated in between these contrasting conditions the Altiplano exhibits a distinctive climate, described by, among others, Schwerdtfeger (1976), Aceituno (1997), and Hardy et al. (1998). About 90% of the annual precipitation concentrates between November and March (austral summer season) in the form of intense thunderstorms (Schwerdtfeger 1976; Aceituno 1997). During this season an upper-level anticyclone is established to the southeast of the central Andes [the so-called Bolivian high (e.g., Lenters and Cook 1997)], and mean easterly flow prevails over the Altiplano. During the rest of the year, rainfall episodes are rare, average near-surface moisture drops below 3 g kg^{-1}, and tropospheric westerly flow prevails (e.g., Aceituno 1997).

Previous studies have revealed key aspects of the summertime rainfall on the Altiplano. On the basis of surface data, synoptic analyses, and in situ surveys, Fuenzalida and Rutllant (1987) concluded that the water vapor that precipitates over the Altiplano originates in the troposphere to the east of the central Andes from where it is transported by easterly flow. The continental origin of the moist air in the Altiplano has been confirmed by subsequent trajectory analyses (Vuille et al. 1998; Garreaud 1999) and isotopic analyses of the rainfall (Chaffaut et al. 1998). Observational evidence also indicates that within the Altiplano wet season, rainy days tend to cluster in ''rainy episodes'' lasting about a week, interrupted by somewhat longer dry periods when moist convection is suppressed or very isolated (Fuenzalida and Rutllant 1987; Aceituno and Montecinos 1993; Vuille et al. 1998; Lenters and Cook 1999). More recently, these rainy and dry episodes have been

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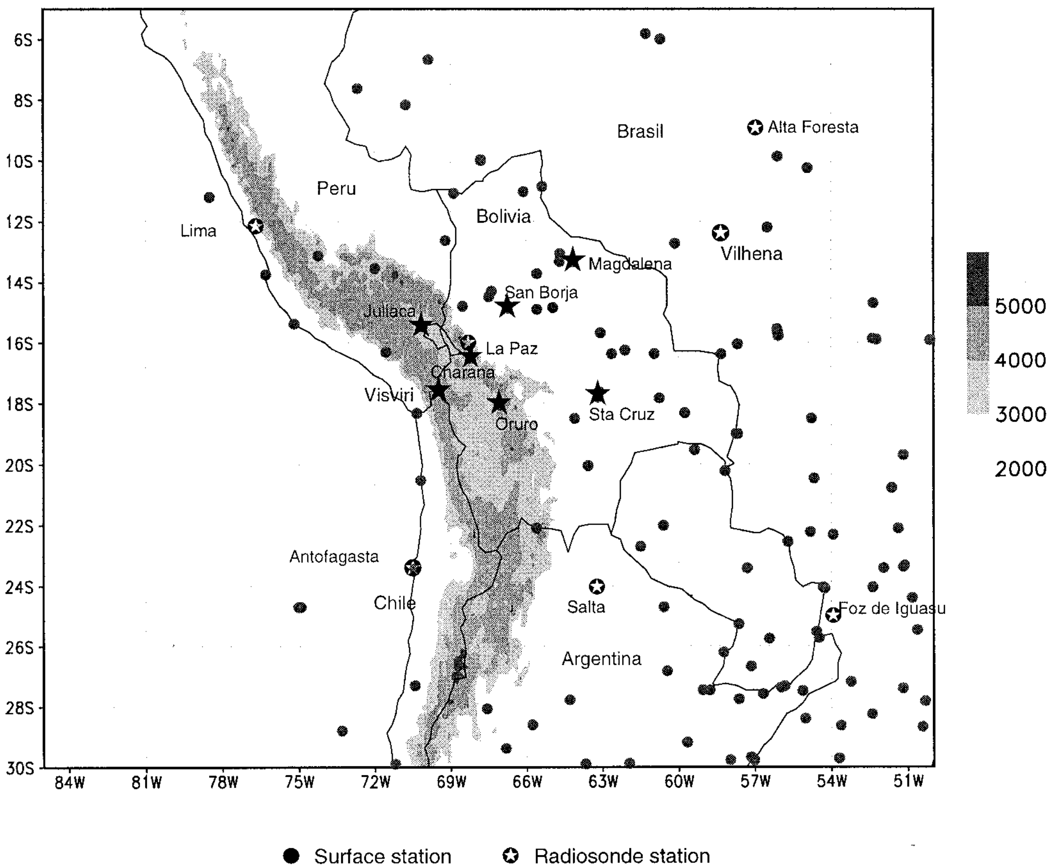

FIG. 1. Topographic map of the central Andes. Elevation scale (gray shading) in m above sea level. Small filled circles and stars indicate surface stations reporting data at 1200 UTC 26 Jan 1994. Open stars indicate radiosonde stations.

associated with continental-scale anomalies of the upper-tropospheric circulation, namely changes in the intensity and position of the Bolivian high, and the rainfall pattern (Aceituno and Montecinos 1993; Vuille et al. 1998; Lenters and Cook 1999; Garreaud 1999). Intraseasonal anomalies of the large-scale circulation over the central part of the continent are in turn associated with barotropic wave trains extending from the southern Pacific (Nogues-Paegle and Mo 1997; Garreaud 1999), presumably excited by intraseasonal oscillations in the equatorial western Pacific (Madden–Julian oscillation, MJO) (Mo and Higgins 1998; Aceituno and Montecinos 1997b). The direct effect of the MJO on the Altiplano, however, is likely to be small since their associated circulation anomalies over South America are mostly restricted to the equatorial belt (e.g., Hendon and Salby 1994).

Using surface and radiosonde data taken during two 2-week field experiments, Garreaud (1999) documented that the daytime lower troposphere is on the average conditionally unstable over the western Altiplano. The instability, however, can only be released in days in which the near-surface mixing ratio reaches high values ($\sim$7 g kg^{-1}) yielding near-surface air parcels positively buoyant at about 400 m above the ground (i.e., the profile exhibits a nonzero convective available potential energy, CAPE). Furthermore, it was noticed that rainfall occurred in almost all days with nonzero CAPE (Fig. 9 in Garreaud 1999), suggesting that daytime local circulation provides enough dynamical forcing to overcome the convective inhibition within the lowest 100 m of the local troposphere. Boundary layer moisture availability was postulated then as the key element in controlling the precipitation over the western Altiplano.

A major weakness of the previous findings on local conditions over the Altiplano is that they are mostly based on observations taken along the western border of the plateau (e.g., Fuenzalida and Rutllant 1987; Garreaud 1999) where drier conditions prevails. In this short contribution an expanded dataset (surface observations, and reanalysis and satellite data) is used to investigate whether the above-mentioned hypotheses are valid in a pan-basin context and then discuss the intraseasonal moisture and rainfall variability on the Altiplano. The focus here is on basin-scale conditions, since large-scale circulation patterns associated with wet and dry conditions on the Altiplano are described elsewhere. Datasets are described in section 2. The relationship between moisture variability in the western Altiplano and moisture and rainfall variability elsewhere in the plateau (section 3a) is then considered. The relationship between moisture fluctuations in the Altiplano and the lowlands to the east of the central Andes is documented in section 3b. A discussion of these results is presented in section 4, and concluding remarks are presented in section 5.

2. Datasets

Four datasets are used in this study. Surface data were obtained from an automatic weather station in Visviri (17.5°S, 69.5°W; 4070 m), a small town in the western Altiplano (Fig. 1), that recorded hourly values of 2-m air temperature, relative humidity, barometric pressure, solar radiation, wind, and precipitation. The station operated continuously from October 1993 to November 1995, but here only the two austral summer seasons (November/March) on record are used [analyses for the whole period are presented in Aceituno (1997)]. Because of its temporal resolution, continuity, and research quality, the observations at Visviri are chosen as the reference time series. Furthermore, 10-day intensive field experiments (including 6-h soundings) were conducted in Visviri in January 1993 and 1994 (Aceituno and Montecinos 1997a). Surface data for the rest of the Altiplano and the adjacent lowlands were obtained from operational synoptic observations (0000, 0300, . . . , 1800, 2100 UTC; most frequent reports at 0000 and 1200 UTC) transmitted via the global telecommunication system and archived at the National Center for Atmospheric Research. The standard report includes air temperature, dewpoint, pressure, wind, and present weather, but the amount and quality of these data are variable. The surface reports do not include precipitation, but daily records for selected stations were obtained from the National Climatic Data Center. Figure 1 includes the location of the surface stations reporting data on a particular day at 1200 UTC. There is a large number of surface stations in the Bolivian lowlands, fewer in northwestern Argentina and eastern Peru, and only four stations in the Altiplano region (listed in Table 1). Unfortunately, the only radiosonde station in the central Andes (La Paz) operated (or transmitted its data) less than 20% of the time during the summers of 1993/94 and 1994/95, while the rest of the radiosonde stations in the area shown in Fig. 1 are too far from the Altiplano region.

The large-scale tropospheric circulation was characterized using the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis fields, described in detail in Kalnay et al. (1996). The original fields have a 6-h resolution on a 2.5° latitude–longitude grid and include all mandatory pressure levels from 1000 to 100 hPa (300 hPa for humidity) as well as variables at the 0.995 sigma level (about 30 m above ground). For the austral

TABLE 1. Station coordinates. Also indicated for each station: mean ($\overline{q_{ns}}$) and standard deviation [$\sigma(q_{ns})$] values (g kg^{-1}) of the near-surface mixing ratio on the basis of daily records at 1800 UTC during the period 1 Dec 1993–28 Feb 1994. The rightmost column is the correlation coefficient (r) between daily values of near-surface mixing ratio at the corresponding station and near-surface mixing ratio at Visviri.

Station	Lat (S)	Long (W)	Elevation (m)	$\overline{q_{ns}}$	$\sigma(q_{ns})$	r
Visviri	17.51°	69.51°	4070	5.3	2.2	+1.00
Charaña	17.58°	69.45°	4057	6.1	1.8	+0.83
La Paz	16.52°	68.18°	4071	6.5	1.6	+0.53
Oruro	18.05°	67.07°	3702	6.3	1.7	+0.63
Juliaca	15.48°	70.15°	3827	6.7	1.3	+0.41
Santa Cruz	17.80°	63.17°	180	16.3	1.1	+0.11
Magdalena	13.33°	64.15°	141	17.3	0.9	−0.09
San Borja	14.87°	66.75°	194	17.4	1.0	+0.07

summer of 1993/1994, analysis of the convective cloudiness was also possible on the basis of *GOES-7* reduced resolution radiance images [the International Satellite Cloud Climatology Project (ISCCP) B3 product]. The B3 dataset (see Rossow and Schiffer 1991 for details) is a compressed version of the original satellite images to a nominal resolution of 30 km every 3 h (eight images per day beginning at 0000 UTC). In this study the 3-h pixel maps of infrared radiance (11.6 μm) are converted to a regular 0.5° latitude × 0.5° longitude grid of equivalent blackbody temperature (T_{bb}) following the procedure described in Garreaud and Wallace (1997).

3. Results

a. *Moisture and rainfall variability in the Altiplano*

The rainfall records in Visviri for the summer (November–March) of 1993/94 and 1994/95 (Fig. 2) reveal the episodic nature of the summertime precipitation over the western Altiplano, with most of the rainy days ($R \geq 1$ mm) clustered in episodes lasting about a week. Two other features are also evident in Fig. 2. The near-surface mixing ratio (q_{ns}) at 1500 LT exhibits well-defined periods of moist ($q_{ns} \geq 5$ g kg^{-1}) and dry ($q_{ns} \sim 3$ g kg^{-1}) conditions that are markedly associated with rainy and dry episodes, respectively. Such fluctuations of humidity are superimposed on a weak diurnal cycle of q_{ns} and they extend over the whole convective boundary layer over Visviri (reaching a maximum height of ~2 km above ground) according to the surface and radiosonde data analyzed by Aceituno and Montecinos (1997a). Second, the midafternoon time series of near-surface air temperature (T_{ns}) and mixing ratio are inversely correlated at a high degree ($r \sim -0.83$ for both summers). This association among rainfall, moisture, and temperature is consistent with the analyses of the local conditions presented by Fuenzalida and Rutllant (1987) and Garreaud (1999): the increase in q_{ns} overcomes the decrease of T_{ns} producing a net increase in low-level potential energy available for moist convec-

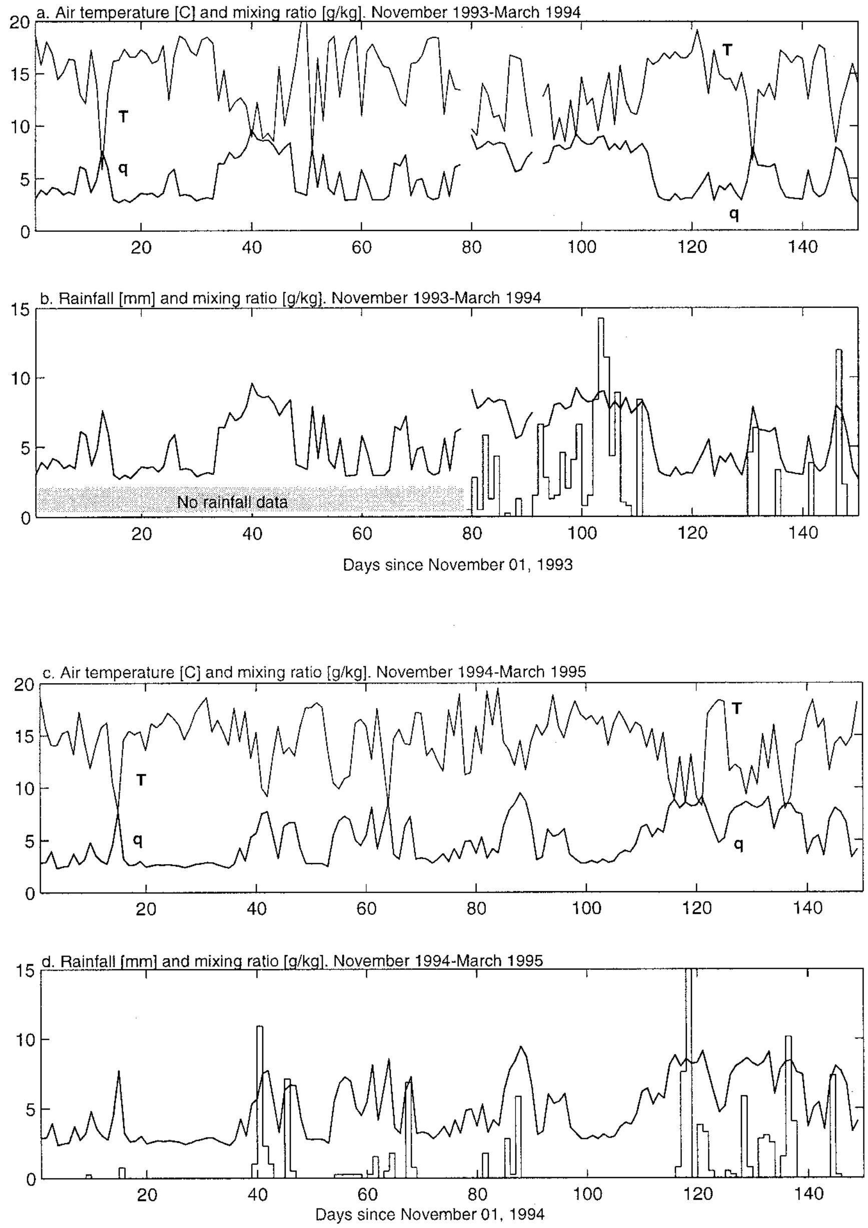

FIG. 2. Near-surface observations at Visviri (17.5°S, 69.5°W; 4070 m) during the austral summer of 1993/94 and 1994/95. (a) Air temperature (°C) (upper, thin line) and mixing ratio (g kg^{-1}) (lower, thick line) at 1500 LT (1800 UTC) from 1 Nov 1993 to 31 Mar 1994. (b) Mixing ratio (g kg^{-1}) (thick line) at 1500 LT (1800 UTC) and noon-to-midnight accumulated rainfall (mm) from 1 Nov 1993 to 31 Mar 1994. (c) As in (a) but from 1 Nov 1994 to 31 Mar 1995. (d) As in (b) but from 1 Nov 1994 to 31 Mar 1995.

tion (and therefore rainfall), which is triggered by local updrafts over this complex terrain. The decrease of T_{ns} during episodes of active convection is also consistent with the decrease of surface insolation, although evaporative cooling may also play a role. Composite soundings at Visviri also exhibit a midtropospheric warming during dry days (Fig. 10 in Garreaud 1999) that can results from the increased surface heating and/or enhanced subsidence over the Altiplano. This latter mechanism suggests an inverse relationship between convective activity over the central Andes and the Amazon Basin further discussed in section 4.

Near-surface moisture in the rest of the stations on the Altiplano is shown in Fig. 3. The alternance between dry and moist conditions is also apparent in the records of q_{ns} at La Paz and Oruro, although they exhibit smaller variance relative to the values at Visviri. Juliaca, in the northeastern extreme of the Altiplano, has a more erratic

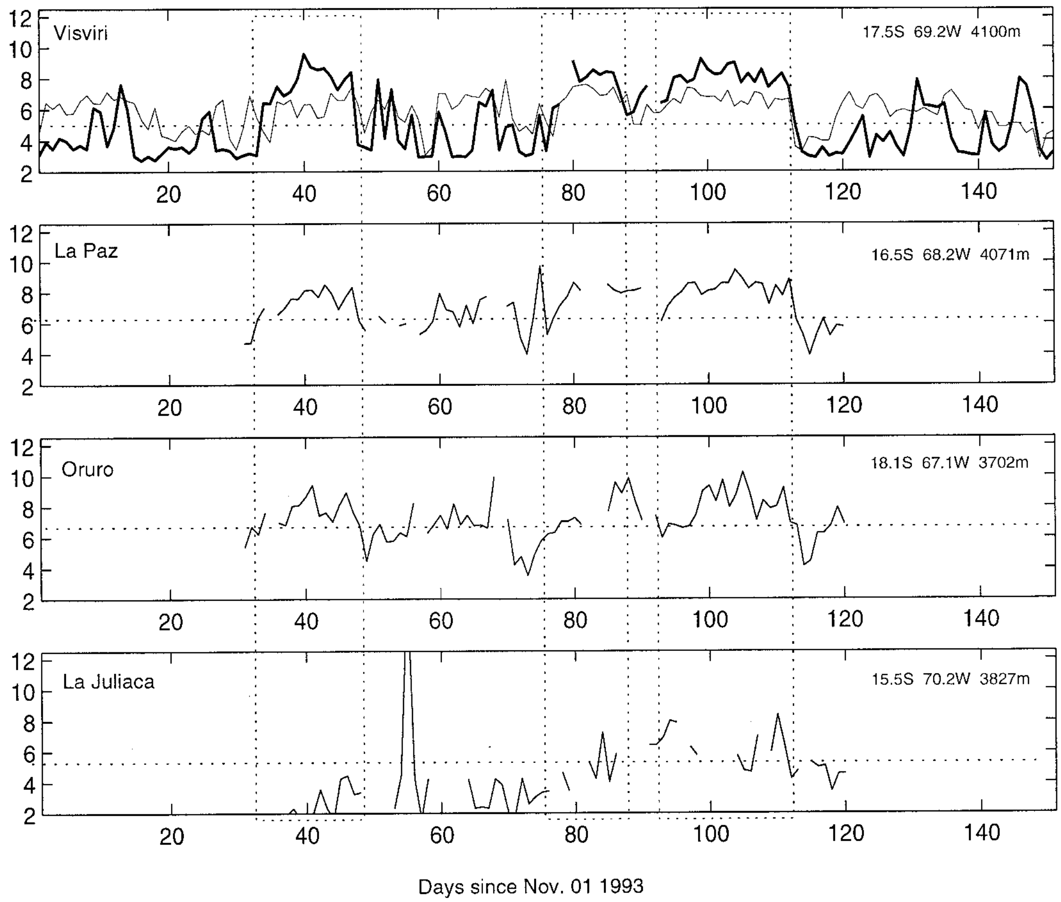

FIG. 3. Daily values of water vapor mixing ratio (g kg^{-1}) at 1800 UTC in Visviri (upper panel, thick line) and three other stations in the Altiplano region during the period 1 Nov 1993–31 Mar 1994. Station names and coordinates are indicated on the left and right side of each panel. The horizontal dotted lines indicate the seasonal mean and the vertical rectangles indicates moist periods inferred from the Visviri records. Upper panel also shows the near-surface mixing ratio in Visviri derived from 6-h NCEP–NCAR reanalysis (thin line; see section 3b for details).

behavior, but there is some coherence with Visviri in the second half of its record. Similar relationships are found in the summer of 1994/95 (not shown) and quantified in Table 1 by the correlation coefficients among the time series of q_{ns}. Thus, the episodic behavior of q_{ns} identified in Visviri appears as a characteristic mode of the summertime moisture variability on the Altiplano. Also notice that the seasonal mean of q_{ns} in Visviri (the farthest station from the continental moisture source) is smaller than $\overline{q_{ns}}$ in the rest of the stations (Table 1), so that larger increments of humidity are required to give rise to moist convection over the west side of the Altiplano.

Daily rainfall at the four other stations in the Altiplano and q_{ns} in Visviri are shown in Fig. 4b for the summer 1993/94. There is a tendency for a larger number of stations with precipitation during moist/rainy periods in Visviri. A similar tendency is observed in the next summer, but the small number of stations in this region hinders a statistical quantification. To complement the rainfall records, Fig. 4 also includes a longitude–time diagram of the *GOES-7* equivalent blackbody temperature (T_{bb}) averaged between 16° and 19°S. Of course is not possible to estimate rainfall on the basis of infrared measurement alone, but $T_{bb} < 235$ K signals deep, moist convection, while $T_{bb} > 260$ K implies suppressed or very localized convective activity. Low values of T_{bb} over the central Andes (between 70° and 65°W) also tend to last about a week and occur simultaneously with moist periods at Visviri.

The spatial pattern of the convective cloudiness during wet/dry periods on the Altiplano can be obtained from the one-point correlation map between the afternoon values of T_{bb} at a grid box over Visviri and T_{bb} elsewhere using both seasons of data (Fig. 5). The elongated pattern of high correlation is consistent with the occurrence of bands of deep convection along the central Andes (best developed between late afternoon and early night) during rainy episodes in the Altiplano, in contrast to cloud-free conditions during dry days (Garreaud 1999). Thus, both satellite infrared imagery and local rainfall records suggest the occurrence of rainy

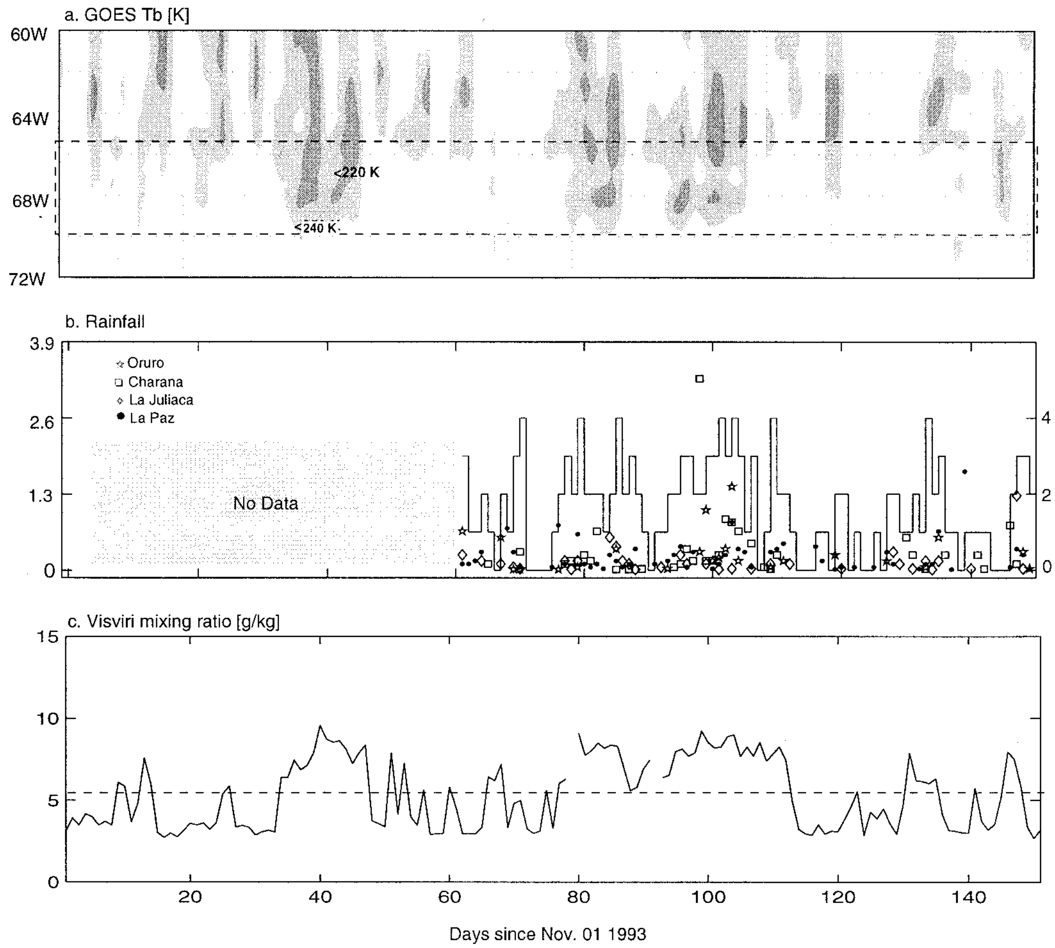

FIG. 4. Several meteorological variables over the Altiplano region from 1 Nov 1993 to 31 Mar 1994. (a) Longitude–time diagram of the equivalent blackbody temperature (T_{bb}) averaged between 16° and 19°S at 1800 UTC. Light and medium shading indicates T_{bb} less than 240 and 220 K, respectively. (b) Daily rainfall amounts measured in four stations are shown by symbols (square, Charaña; star, Oruro; circle, La Paz; diamond, Juliaca). Vertical scale is shown in the left side in units of mm day^{-1}. The solid line indicates the number of stations with nonzero rainfall for a given day. Scale is shown in the right side of the panel. (c) Water vapor mixing ratio in Visviri at 1800 UTC. Horizontal line indicates seasonal mean.

and dry episodes encompassing most of the Altiplano, whose timing and duration are in phase with the variability of the near-surface humidity over the plateau.

b. Altiplano–lowlands relationship

In order to assess whether the marked fluctuations of near-surface humidity within the Altiplano are produced by moisture variability in its source region, let us examine surface data from stations on the lowlands near the eastern slope of the central Andes. Figure 6 shows q_{ns} for Visviri and three stations in the Bolivian lowlands (marked in Fig. 1 and listed in Table 1) for the summer of 1993/94. The mixing ratio in the lowland stations has a seasonal mean two to three times larger than those observed on the Altiplano, but its standard deviation is only half of its counterpart at higher elevations (see Table 1), indicative of steady, very moist conditions over the rain forest. In fact, day-to-day fluctuations of the low-level thermodynamic conditions to the north of 20°S are rather small during summertime ($\delta\theta \sim 2$ K, $\delta q \sim 2$ g kg^{-1}), even those caused by cool air incursions (Garreaud and Wallace 1998). Moreover, there is no evidence of coherent, long-lasting moist and dry episodes as those so clearly defined in Visviri. Overall, near-surface humidity fluctuations over the lowlands to the east of the Andes seem too small in amplitude and dominated by high-frequency components to explain intraseasonal moisture variability in the Altiplano. Summertime precipitation on the Bolivian lowlands is also distributed over a large number of rainy days, in contrast with the more episodic nature of the Altiplanic rainfall (see, for instance, Fig. 4a).

To further explore the highland–lowland relationship, we used mixing ratio fields from the NCEP–NCAR reanalysis. Because of the relative abundance of surface

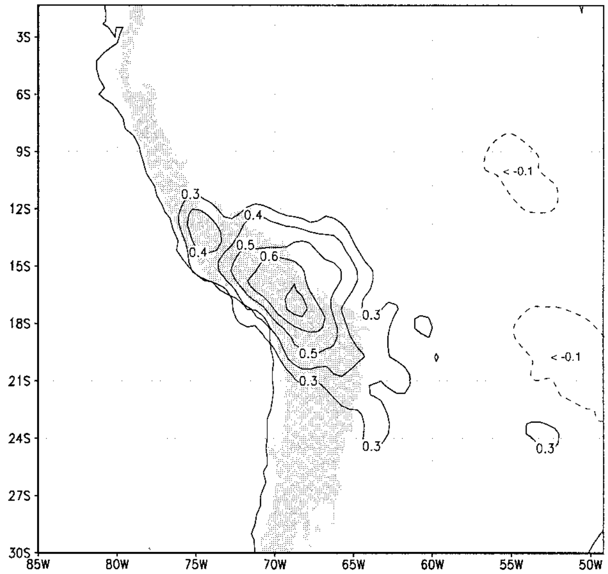

FIG. 5. Correlation coefficient (r) between equivalent blackbody temperature (T_{bb}) in a grid box over the Altiplano (centered at 17.5°S, 71°W) and T_{bb} elsewhere. Calculation is based on daily fields of T_{bb} at 2100 UTC during DJF 1993/94 and 1994/95. Contour interval is 0.1, beginning at $r = 0.3$ (significant at the 99% of confidence level). Dashed lines outline areas with $r \leq -0.1$. Light shading indicates terrain elevation in excess of 2000.

observations in this region (e.g., Fig. 1), mostly assimilated in the reanalysis, one hopes these fields capture essential features of the actual atmosphere, at least in the lower troposphere. For instance, the daily near-surface mixing ratio for the Altiplano (q_{rea}) is calculated as the reanalyzed specific humidity at the 0.995 sigma level averaged between 18°–15°S and 69°–67°W. The seasonal mean of q_{ns} and q_{rea} are very similar (5.3 and 5.8 g kg^{-1}, respectively) but the standard deviation of q_{rea} (0.92 g kg^{-1}) is less than half of the standard deviation at Visviri.[1] Nevertheless, the reanalysis do capture most of the intraseasonal variability of the low-level mixing ratio, as shown in Fig. 3a by the time series of q_{ns} and q_{rea} for the summer of 1993/94.

Figure 7a shows the correlation coefficient between q_{rea} and the near-surface mixing ratio elsewhere during the summer season. Consistent with the previous findings, the correlation coefficient is high over the Altiplano, but it sharply decreases away from the central Andes. In addition, q_{rea} was correlated with the mixing ratio at different pressure levels to produce the vertical cross section in Fig. 7b. Over the Altiplano, significant correlation ($r > 0.6$) extends up to about 450 hPa (coincident with the top of the observed daytime mixing layer). The correlation decays farther to the east to become near zero in the lower troposphere over the lowlands to the east of the central Andes. In summary, surface observations and reanalysis data indicate that intraseasonal moisture *variability* in the Altiplano is not directly related to moisture fluctuations over the eastern lowlands.

[1] The reanalysis data also underestimate the amplitude of the diurnal cycle of several variables over the western Altiplano by a factor of 2 or larger (P. Aceituno 1999, personal communication).

4. Discussion

Lenters and Cook (1999) have documented that rainy episodes on the Altiplano are associated with different synoptic-scale configurations over the central part of the continent, including northward incursions of extratropical cyclones, cold-core subtropical lows, and westward enhancement of the South Atlantic high. Similarly, Vuille et al. (1998) found three categories of large-scale circulation associated with snowfall episodes on the Sajama ice cap (Sajama, the highest volcano of Bolivia, is located in the southwestern side of the Altiplano: 18.1°S, 68.9°W; 6542 m). The categories differ by both the positioning of the Bolivian high and the circulation anomalies at the 700-hPa level. As shown in this work, however, near-surface moisture fluctuations on the Bolivian lowlands are too small and rapid to explain alone the large, persistent moisture fluctuations observed on the Altiplano.

Because of the position of the central Andes immediately to the west of the Amazon Basin one might speculate that widespread, deep convection over the latter region can modulate convective activity over the Altiplano throughout compensating subsidence. However, primitive equations modeling by Gandu and Silva Dias (1998), forced by a heat source that mimics deep convection over the central part of the continent, predicts compensating subsidence off the coast of Peru and northern Chile, too far to the west to cause a significant effect over the Altiplano (see for instance their Figs. 4 and 7). Furthermore, it is noted in Fig. 5 that the convective cloudiness over the Altiplano rapidly decorrelates from convective cloudiness over the Amazon Basin (a similar result emerged when using 10-yr record of outgoing longwave radiation, not shown), partially because convective activity over the latter region is dominated by high-frequency variability. Thus, no cause–effect relationship can be established between Altiplano and Amazon convective activity.

A common element during rainy (dry) episodes is the presence of easterly (westerly) flow in the middle and upper troposphere over the central Andes (e.g., Fuenzalida and Rutllant 1987; Vuille et al. 1998; Lenters and Cook 1999), associated with a reinforcement and southward displacement of the Bolivian high. Zonal wind anomalies aloft are also statistically significant in the compositing analysis of rainy and dry episodes presented by Aceituno and Montecinos (1993) and Garreaud (1999). As suggested by the modeling results in Garreaud (1999), the physical link between large-scale, midtropospheric flow and local moisture fluctuations on

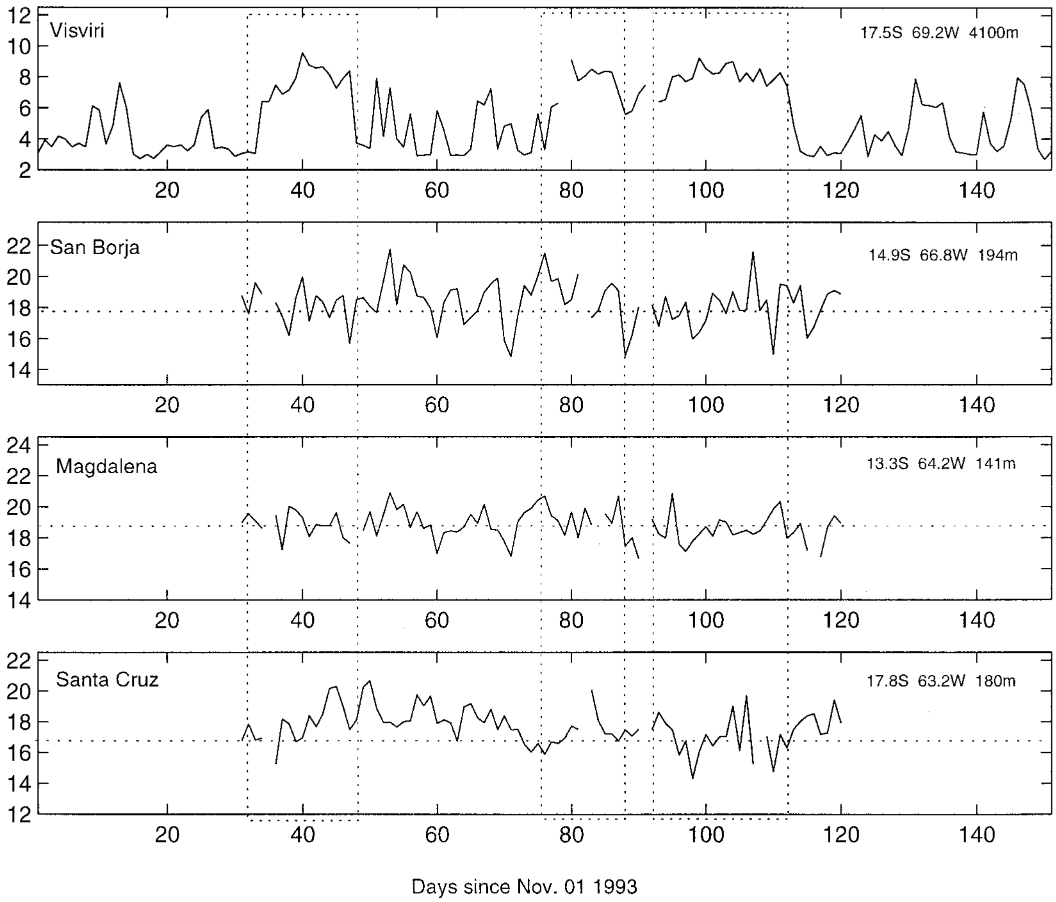

FIG. 6. Daily values of water vapor mixing ratio (g kg^{-1}) at 1800 UTC in Visviri (upper panel) and three stations in the Bolivian lowlands to the east of the central Andes during the period 1 Nov 1993–31 Mar 1994. Station names and coordinates are indicated on the left and right side of each panel. The horizontal dotted lines indicate the seasonal mean and the vertical rectangles indicate moist periods inferred from the Visviri records.

the Altiplano seems to occurs throughout the modulation of the strength of the regional upslope flow over the wet/eastern and dry/western slopes of the central Andes.[2] During periods of easterly flow aloft, downward momentum flux into the convective boundary layer tends to accelerate the upslope flow over the eastern slope, which in turn increments the low-level moisture transport from the lowlands into the Altiplano. Once over the plateau, moist air feeds widespread convective activity. In contrast, during periods of westerly flow aloft, moisture transport is restricted over the eastern slope and the Altiplano is flooded by dry air originating in the western foothills of the Andes. It is suggested that rainfall episodes on the Altiplano are rather insensitive to the low-level (below 700 hPa) synoptic conditions and convective activity over the central part of the continent, as long as they are associated with easterly flow aloft. The opposite holds during dry episodes associated with persistent, large-scale westerly flow crossing the central Andes.

[2] Midtropospheric zonal flow cannot explain the large fluctuations in humidity on the Altiplano directly by horizontal moisture advection because the moisture gradient is too small at this altitude.

5. Concluding remarks

Surface meteorological data, complemented with infrared satellite imagery and the NCEP–NCAR reanalysis, have been used to address several issues on the rainfall and moisture variability over the Altiplano within its rainy season. The main findings are as follows:

- Episodes of convective rainfall, lasting about a week, tend to encompass the whole plateau and the eastern slope of the central Andes, interrupted by longer periods in which moist convection on the Altiplano is very isolated or suppressed.
- Intraseasonal variability of the near-surface mixing ratio decreases from west to east (and possibly south–north) on the Altiplano, but a coherent alternance between dry and moist periods (as those previously doc-

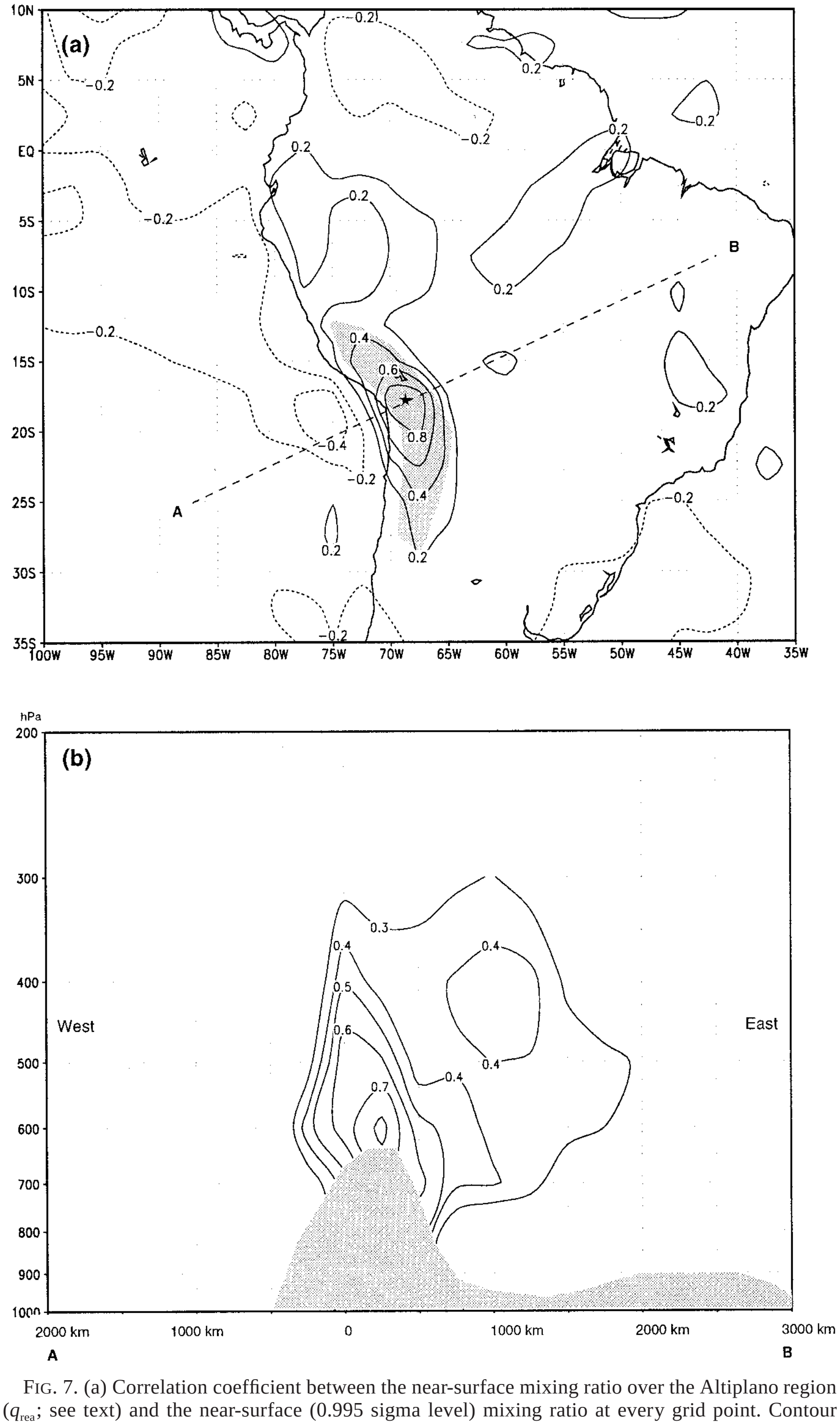

FIG. 7. (a) Correlation coefficient between the near-surface mixing ratio over the Altiplano region (q_{rea}; see text) and the near-surface (0.995 sigma level) mixing ratio at every grid point. Contour interval is 0.2, negative values are indicated by dashed lines, and the zero contour is omitted. The shaded area indicates terrain elevations in excess of 2000 m. Correlation coefficients in excess of 0.3 are statistically significant at the 95% confidence level. (b) Correlation coefficient between q_{rea} and the mixing ratio at every grid point and pressure surface along the transect AB (shown in the upper panel). Contour interval is 0.1. The topographic profile is shown in light gray. Analysis based on NCEP–NCAR reanalysis data for Jan and Feb of 1994 and 1995.

umented in Visviri) is observed at the four stations with available records over the plateau.

- Summertime periods with above (below) normal near-surface moisture are markedly associated with rainy (dry) conditions, lending support to the hypothesis that boundary layer moisture is the key factor in controlling basinwide rainfall over the Altiplano.
- Moisture variability in the lower troposphere to the east of the central Andes (the source region of moist air) is too small and concentrated in the high-frequency range to explain the large, intraseasonal fluctuations on the Altiplano. Thus, the moisture variability in the central Andes is likely caused by changes in the moisture transport over the eastern slopes, which in turn are related to large-scale circulation anomalies discussed elsewhere.

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