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ATMOSPHERIC CIRCULATION ASSOCIATED TO EXTREME RAINFALL EVENTS IN PIURA, PERU, IN 2002

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1. INTRODUCTION

The lowlands of Piura, on the northern coast of Peru, are strongly affected by El Niño events. Heavy rainfall can occur on this normally arid region when the nearby sea surface temperature (SST) is sufficiently high. Woodman (1999) has shown that rainfall can be expected when SST exceeds a threshold of around 26C. However, his analysis was done with monthly rainfall while heavy rainfall tends to occur in intense discrete events. In this work we try to determine which conditions favor some days over others with the occurrence of heavy rainfall given essentially the same SST conditions.

Our study was done for the period of March and April 2002. In this period, SST was favorable for rainfall, exceeding 26C from the end of February to mid April at a location south of Piura (6.5°S, 82.5°W), which Woodman (1999) highlighted as one with good correlation with rainfall. Pluviometric station and river discharge data corroborate that rainfall did occur in this period only.

There are two main mechanisms which have been proposed for the genesis of intense convective events in Piura (Horel and Cornejo Garrido (1986), Goldberg et al. (1987), Bendix and Bendix (1998)). One involves the thermally driven sea-breeze circulation which, in the afternoon, would bring low level moist air inland and help it rise up the western slope of the Andes mountains, which is the region of largest anomalous precipitation during El Niño. The other mechanism requires an extended atmospheric instability and is likely to be more important during strong El Niño events.

2. DATA AND METHODOLOGY

We have looked for systematic differences between the circulation in days that had rainfall and days that didn't. The data was composited according to instantaneous river discharge data (Fig. 2) measured at Puente Ñácara, on Piura River (Fig. 1), which served as a good proxy for rainfall (compare to Fig. 3). To do this, we first made a list of days considered rainy and days considered dry. For this classification we used the river discharge data as an indicator of rainfall. Days in which the following morning showed a peak in river discharge were taken as rainy. The magnitude of the peaks had to exceed 500 m^3/s in order to be considered. Conversely, days in which the following morning had discharges below 250 m^3/s and showed no hint of peaks were taken as dry. The consideration of the discharge data of the following morning instead of the same day was done because of the time delay between the signal in river discharge and the signal in rainfall, which can be of several hours.

The composites of the local circulation were made from hourly wind profiles from the Piura BLTR (Scipión et al., (2003)). The synoptic scale circulation composites were made from daily averaged NCEP/NCAR Reanalysis data (Kalnay et al. (1996)). The composition of hourly data was justified as long as the assumption that rainfall in this period had a diurnal variation locked to the insolation cycle through the sea-breeze circulation mechanism was dominant. This assumption was supported by the fact that the SST anomalies were moderate in this period and by the observed timing in the river discharge data.

3. RESULTS AND DISCUSSION

The results suggest that, given the favorable SST conditions, specific days are favored with rainfall over others through an enhancement of onshore flow near the top of the boundary layer (approximately 1.5 km above the surface) in the morning (Fig. 4, left). A way the enhanced onshore could favor rainfall is through an associated forced lifting of air parcels up the western slope of the Andes, which could trigger convection. This forcing would be more efficient when superimposed on the action of the sea-breeze circulation, which has been invoked previously as an important mechanism for the genesis and timing of the rainfall. It is interesting to note that the meridional wind seems to have little relevance to the occurrence of rainfall. This sheds new light on the statement by Eguiguren (1894), who said "...it is a constantly observed fact that it doesn't rain in Piura but when winds blow more or less strongly from the northwest" (translation by the present author). Eguiguren (1894) considered the northerly component of the wind to have the greater relevance to rainfall but in our study we found that the mean wind was essentially from the south and that the westerly component was the most relevant for the rain. It would appear that what is important is that the mean wind blows from the high moisture and heat source, as Woodman (1999) suggested, and that it is through enhancement of the westerly flow that rainfall can be triggered. After the convective systems have formed, they will tend to modify the regional circulation. Above 1.5 km the westerly flow was progressively replaced by easterly flow starting near 1.5 km at around noon and extending further up to around 5 km in the evening. We speculate that the progressively higher vertical extension of the westerly wind is due to convective transport of westerly momentum from the boundary layer into the mid-levels.

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In the period of study, the rainfall events on Piura tended to be clustered in time and these clusters had a recurrence time of about 10 days. The onshore low-level flow enhancement seems to be related to synoptic scale tropical systems which have similar spatial scales to the 10-day zonal wind oscillations reported in previous works (Wallace and Chang (1969)). Our results also show systematic differences in the circulation associated to the subtropical high, with an enhanced equatorward flow off the Peruvian coast in rainy days. The spatial scale of the disturbance allows us to associate it to a planetary wave number 5. Since these waves also have a period on 10 days (Figueroa (1999)), it is unclear if their phasing with the circulation changes over Piura is fortuitous or not. Similar studies of other years are needed to address this.

4. REFERENCES

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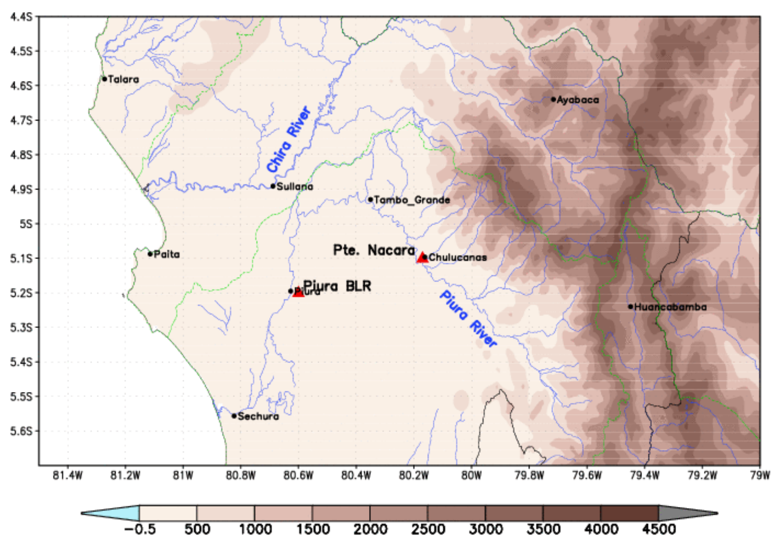

Figure 1: Region of study. Terrain elevation (m) is shown in shading, rivers are indicated in blue and data locations with red triangles. River basin boundaries are indicated in green.

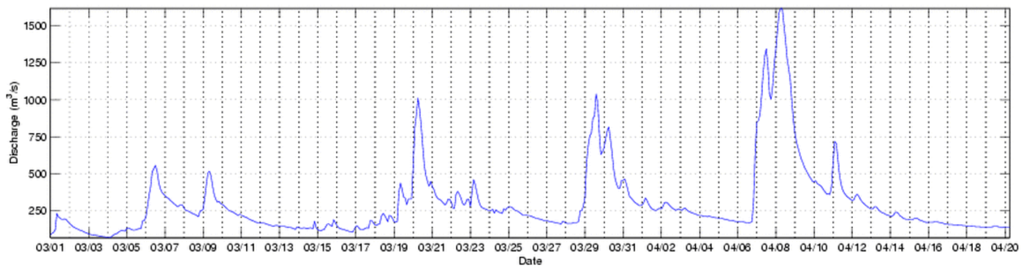

Figure 2: Two-hourly instantaneous discharge of Piura river measured at Puente Ñácara (local time).

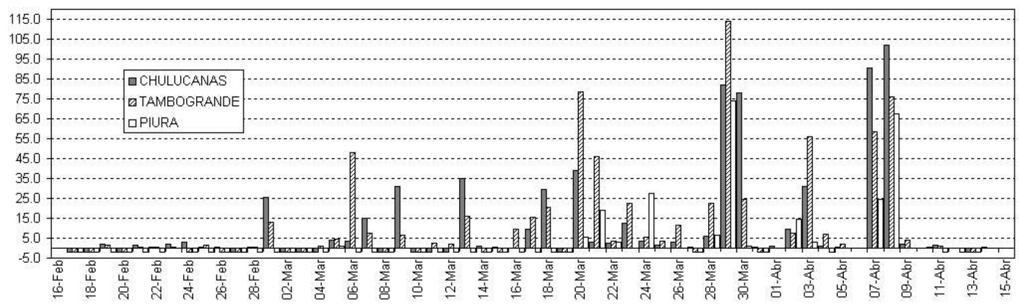

Figure 3: Daily rainfall (mm) measured at three stations. Reports are made at 7 am, negative values indicate missing data.

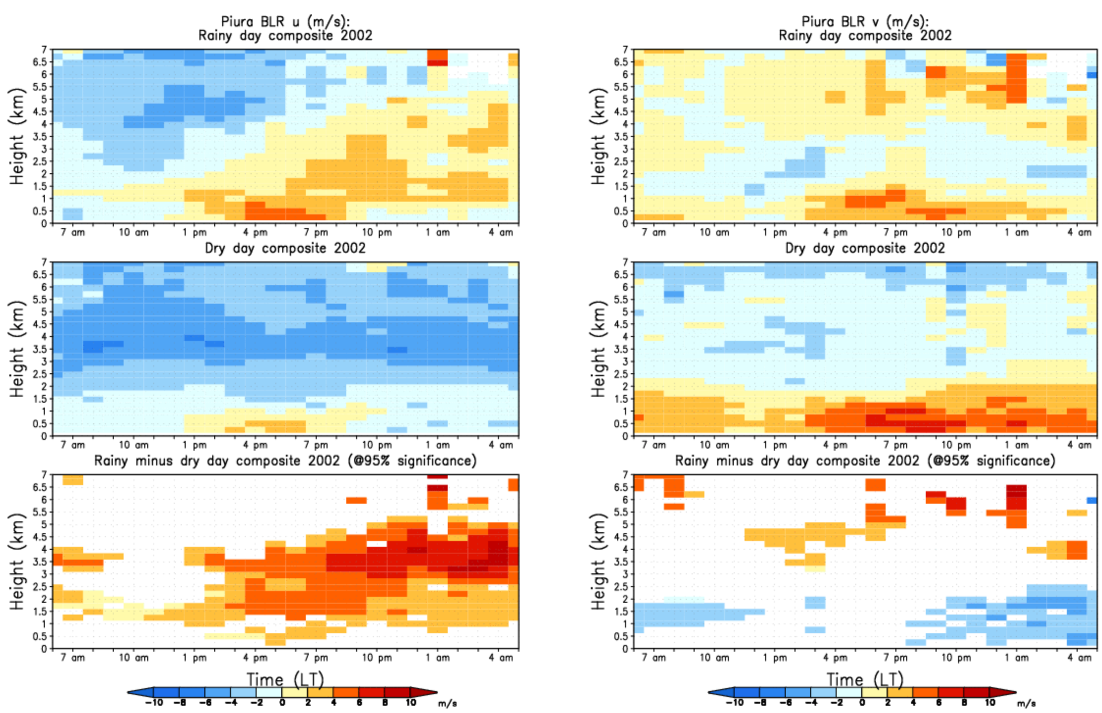

Figure 4: Diurnal evolution of zonal (left) and meridional wind (right) (m/s) in a) rainy days (top) and b) dry days (middle) and c) the difference between the two (bottom). Only differences that pass a Student *t* test at the 95% level are shown. Time is given in UTC (= Local + 5 hours) and height is given in km. Plus and minus signs indicate patches of positive and negative values.