Low atmosphere flow at the Alcântara Space Center

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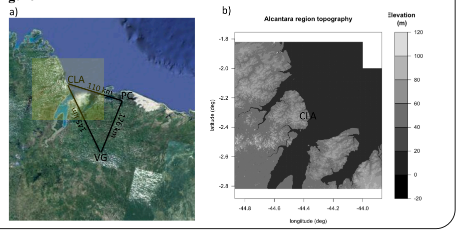
1. Introduction

The atmospheric flow in the region where the main Brazilian Space Launching Center (CLA) is located, Alcântara, MA, Brazil, is influenced by strong trade winds (> 5 m s^{-1}) and surface contrasts. The CLA is located near the equator (2 19' 10'' S) right at the coastal line. Figure 1 is a satellite imagery showing the north region of Maranhão state with CLA and surrounding sites, and the highlighted inset shows the topographic of an area of approximately 110 km x 110 km centered at CLA. The water body in the NW and N represents a small ocean branch projecting southwest (SW) inland, while the area in the south (S) is a major bay and in the east is the Atlantic Ocean. The fact that CLA is near the equator, in a large continental region, with strong trade winds, and with complex coastal contour, makes it a unique site in terms of thermal induced circulations cases (e. g. sea–land breezes) already studied. Garratt and Physick (1985) have investigated the penetration of of sea breeze as far as 280 km inland under the influence of strong background flows, however at 15S. For instance a series of works done for Kennedy Space Center at Cape Canaveral in (Zhong and Takle 1993) have dealt with the issue of complex coastal region and moderate to strong background flows, but away from the equator and bounded by smaller continental area. Oliveira and Fitzjarrald (1993) have investigated the land-river breezes in a river delta region, near the equator in the Amazon, but with no strong background flows. Thus, the objective of the present work is to characterize the local flow and to determine to what extend the local thermal contrasts affect the macroscale circulation (trades) at the region.

Figure 1



2. Data

The data used for the work correspond to several years of radiosonde at CLA and surroundings onshore locations, wind measurements from a 70 m tall tower at CLA, surface pressure and wind measurements from several weather stations around CLA region. Details of the observation periods are given below (Table 1).

Table 1

Site	Observation type	Variables	Period of observation
CLA	sounding	U, V, T , q, and P	05/17/1999 – 06/27/1999 01/26/2000 – 02/06/2000 01/01/2005 – 12/31/2011
Vargem Grande (VG)	-	-	01/24/2000 – 02/01/2000
Primeira Cruz (PC)	-	-	-
CLA	tower	U and V	01/01/1995 – 12/31/2005
INMET	surface station	U, V, and P	01/01/1995 – 12/31/2011 24/03/2012- 06/22/2012

The sites Vargem Grnade, Primeira Cruz, and some of the INMET stations are shown in Figure 1.

3.Results

3.1. Regional boundary layer and flow at CLA

Potential temperature profiles during three days at CLA and surrounding locations (Figure 2) indicate that the thickness of the convective boundary layer (CBL) increases further inland. At CLA it is about 600m, at Primeira Cruz (PC) 750 m, and at Vargem Grande (VG)1750m, during January 26th and 31st of the year of 2000. In addition, the inversion layer durirng the night becomes thicker further inland. At CLA, only the bottom part of the boundary layer changes being slightly stable at night and weakly convective during the night.

Figure 2

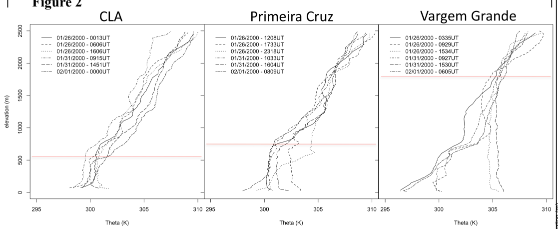
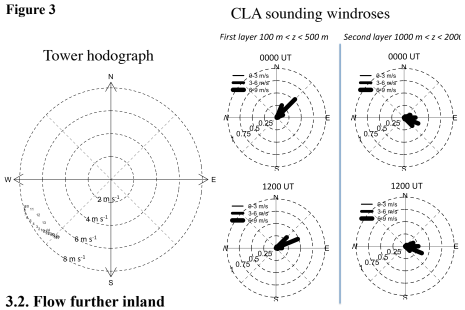


Figure 3 shows an average hodograph for the tower highest levels 60 m and windroses for the mixing layer and residual layer and a layer above at early morning and early evening at CLA for all dry seasons available (Table).

The winds near the surface and throughout the boundary layer (BL) at the CLA show 24-hours cycles. From midnight to noon, the easterly component increases and the northerly component decreases, the net result is a clockwise rotation with an increasing in wind speed of the surface wind. From afternoon to late evening it does the opposite, it decreases its easterly component and increases the northerly component, however the wind speed rather decreases, and the rotation is clockwise. The entire rotation is less than 45 degrees around NEE, showing no flow reversal. Above the surface the wind shows smaller rotation, perhaps because it were used only the early morning sound (1200UT or 0900LST) and early evening (0000UT), which might not be at the extremes of the entire rotation arc. The wind roses indicate that wind speed above the surface is larger than 6 m s^{-1}.

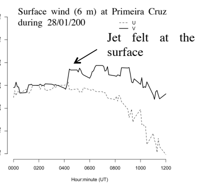
Figure 3



3.2. Flow further inland

The majority of the radiosondes launched between 01/26/2000 and 02/06/2000 at PC, and at VG during convective and stable times show similar wind than the one observed at CLA, e. g. northeast flow below approximately 600 m and southeast flow for the layer between 1000 m and 2000 m. However, for a few nights during stable conditions a southeasterly flow was observed at the Vargem Grande and Primeira Cruz, for heights below 300 m. Average pressure contour for all dry seasons between the years of 1995 and 2011 shows that there is merdional pressure gradient of about 0.4 hPa / 100 km between VG and PC, which points towards south at early evening and towards north at early morning.

Figure 4



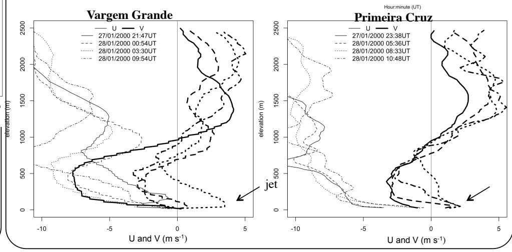
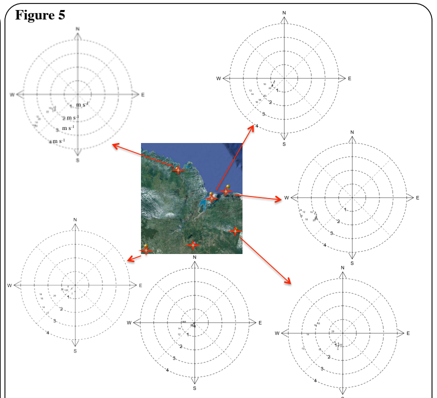


Figure 5



The average hodographs for the INMET surface stations, built for the period between March and June of the year 2012, indicate that the regional wind is typical from the sector northeast – east. The stations near the coast have smaller rotation within, while the ones further inland seems to have larger rotation. Near the coast the wind rotates counterclockwise and further inland clockwise (Figure 5).

Summary

Near the coast the flow is from northeast within the first 600 m (e. g. in the boundary layer region) and above it until 2000 m – 2500 m from southeast. Further inland during convective conditions this may change if the layer grows deep enough to mixing momentum from both layers. The clockwise rotation shown by the hodographs of the stations further inland suggests that southeasterly momentum is mixed down causing the surface winds to be from east or southerly east. The counterclockwise at the surface stations near the coast, except at CLA, suggests that the convective boundary layer does not grow deep enough to mixing the northeasterly and southeasterly momentum from different layers. These stations and CLA rather show the northerly component of the wind increasing during the course of the day. Perhaps the deeper CBL further inland is associated with surface low pressure. The fact that at CLA the wind rotates clockwise maybe because the measuring height there is 60 m while for the other stations it is 10 m. It is possible that at 10 m the flow disconnects from the flow aloft. The wind rotation is less defined at this level during the night. The low level wind observed at VG and PC might be result of the establishment of deeper stable boundary layer further inland, which is perhaps associated to surface high pressure. This low level flow might cause the northeasterly to decrease is northerly component through mixing.

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References: Garratt, J. R., Physick, W. L., 1985: The inland boundary layer at low latitudes: II Sea-breeze influences, *Bound.-Layer Meteor.*, **33**, 209 – 231pp; Oliveira, A. P., Fitzjarrald, D. R. (1993): The Amazon River breeze and the local boundary layer: I. Observations, *Bound.-Layer Meteor.*, **63**, 141 – 162 pp; Zhong, S., Takle, E. S., (1993): The effects of large-scale winds on the sea-land-breeze circulations in an area of complex heating, *J. Appl. Meteor.*, **32**, 1181 – 1195pp.