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Padrões de vento a nível de superfície para região da costa norte do Brasil

Surface wind patterns in the north coast region of Brazil

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Resumo

O escoamento atmosférico a nível de superfície e dentro da região da camada limite planetária (CLP) são investigados neste trabalho para região norte e costa do estado do Marahão. Próximo a costa o escoamento é predominantemente de nordeste, mas durante o dia a componente meridional do vento aumenta tornando o mesmo de norte-nordeste. Durante a noite a componente meridional diminui e o escoamento passa ser de nordeste-leste no inicio da manhã. O resultado disso é um pequena rotação no sentido anti-horário do vento entorno de nordeste. Através de uma análise extensiva de dados de radiosondagem fica evidente que o escoamento acima da região da CLP é predominantemente de vindo sudeste para toda região de estudo. Este escoamento é conseqüência do fluxo de massa de saída da parte descendente da circulação da célula de Hadley. Para estações mais a dentro do continente o vento é vindo de nordeste durante a manhã mas sofre uma rotação para se tornar de sudeste durante a tarde. No inicio da noite se torna de leste-sudeste para rapidamente se tornar de norte. A rotação do vento entre início da manhã e começo da noite é predominantemente uma resposta a um gradiente de pressão oscilatório. Durante a noite a tendência local do vetor vento não parece responder a este gradiente de pressão. Especula-se que a tendência local do vetor vento seja um efeito do empuxo negativo do ar próximo a superfície em regiões de terreno mais alto a sul da área de estudo. A força de empuxo pode ser um termo dominante da equação de momentum durante este período. O gradiente oscilatório próximo a superfície é conseqüência da circulação de brisa marinha existente na região. Na costa especula-se que este gradiente aponte na direção sul durante a maior parte do tempo apenas variando sua intensidade.

Abstract

The atmospheric flow near the surface and in the planetary boundary layer (PBL) are investigated for the coastal part of Maranhão state. Near the coast in the PBL the flow is predominantly from the northeast quadrant with its meridional component increasing during the day and being from north-northeast and decreasing during the course of the night to be from east-northeast at early morning. The result of this is a small counterclockwise rotation but with no flow reversals. Through an analysis of extensive radiosonde data it is found that the flow above the PBL is predominantly southeasterly for the region. It is consequence of the outflow from the descending branch of the large-scale circulation of the Hadley cell. For stations further inland the flow is from approximately northeast during period between morning to noon but rotating clockwise to become from southeast-east (SEE) sector at early evening. The clockwise rotation continues in the afternoon and the wind becomes from south, and later southwest when in the evening it quickly becomes from north. The wind rotation during this period is mainly determined by an oscillating surface pressure-gradient-force. During the night the local surface wind tendency is not controlled by the gradient-force probably because the air has to go against higher terrain and negative buoyancy becomes an important force of the momentum balance. The oscillating surface pressure-gradient-force is a response to a sea-breeze circulation. In the coast, we speculate that the flow does not reverse its meridional component because the surface pressure-gradient point south there for most of the time.

1. Introduction

The atmospheric flow on the north coast of Brazil, on Maranhão State (MA), and further inland is affected by the outflow from the descending part of the circulation of the Hadley and surface contrasts between land and ocean. In the coast the outflow from the Hadley cell takes the form of trades while further inland it is seen as large-scale southeast flow. The study region is centered 4 degrees south from the equator and is part of a large continental area (South America Continent). Its topography is shown in Figure 1.

Until now there was just a few relevant observational study (Kousky 1980; Planchon et al. 2006) of the atmospheric circulation for the north and northeast coasts of Brazil, which included MA state area. Kousky (1980) using a network of rain gauges spread in this region, concluded that typical temporal and spatial rain patterns were the result of the interaction between the trade winds and sea-land breeze circulations for points near the coast, and due to valley-mountain circulations for points far way from the coast. Planchon et al. (2006) using satellite images, in the visible region of the electromagnetic spectrum, showed that the sea breeze are common in the north coast of Brazil year around. Hence, the objective of the present work is to further understand the PBL atmospheric circulation in the region by investigating how the mesoscale and large-scale pressure gradients interact with each other. In the work we present some evidences that the investigating how the mesoscale and large-scale pressure gradients interact with each other. In the work we present some evidences that the daily near surface wind rotation at the coast and further inland are controlled by this interaction.

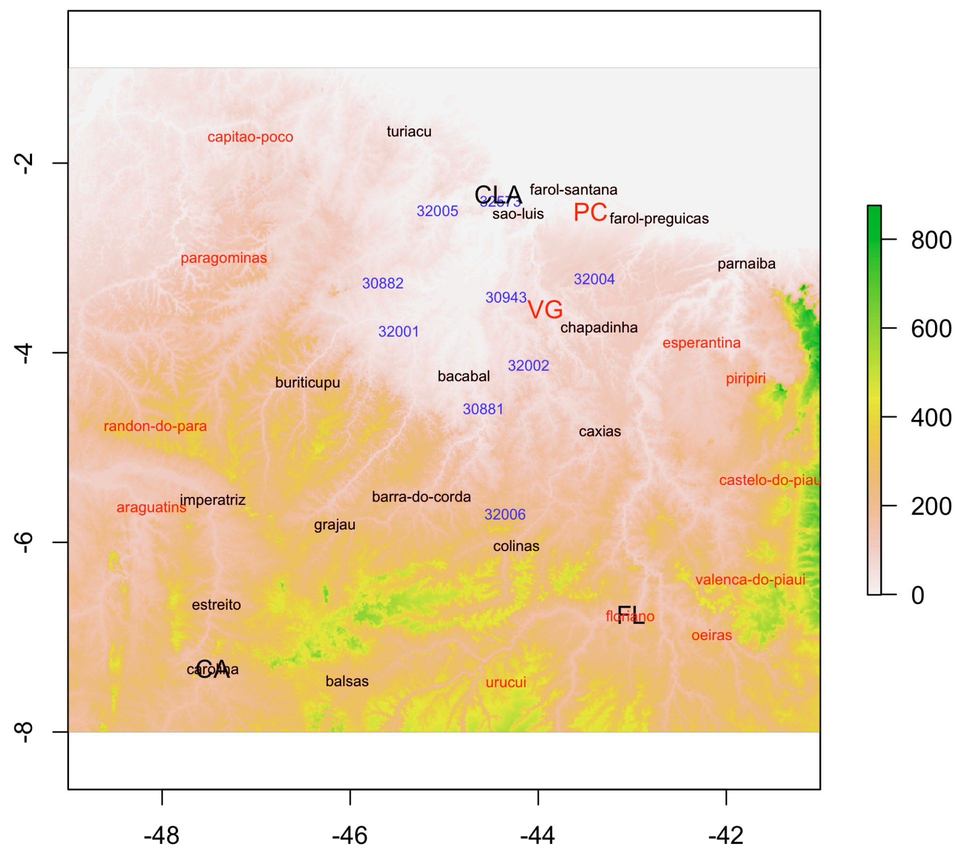

Figure 1: (a) Northern part of Maranhão state with observational displayed sites: CLA, Vargem Grande e Primeira Cruz. (b) Topography for an area of 100 km x 100 km centered at CLA.

2. Data

The data used for the work correspond to several years (1995 – 2005) of radiosonde, wind measurements from a 70 m tall tower, surface pressure, surface temperature, and surface wind data at the Brazilian Rocket Launching Center (CLA) at Alcântara, MA, and as well as surface weather and sounding data further inland surrounding CLA and way from it.

3. Results - *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 PC 750 m, and at VG 1750m, during January 26th and 31st of the year of 2000. In addition, the inversion layer during the night is thicker further inland. At CLA, only the bottom part of the layer below the first 600 m changes, being slightly stable at night and weakly convective during the day. The deeper convective boundary layer observed at VG and PC must be a result of large sensible heat convergence further inland.

Figure 3 shows an average hodograph for the tower highest levels 70 m, windroses for the mixing layer (ML), and residual layer (RL), and a layer above at early morning and early evening at CLA for all dry seasons available.

The wind near the surface and throughout the boundary layer (BL) at the CLA show 24-hours small rotation. From midnight to noon, the zonal component, which is from east (negative), increases and the meridional component, which is from north (negative), decreases. The net result is a clockwise rotation with a slightly increase in wind speed at the surface. From afternoon to late evening it does the opposite, it decreases its zonal component (negative) and increases its northerly component (negative), however the wind speed rather decreases, and the rotation is clockwise. The entire rotation is less than 45 degrees within the sector NEE, showing no flow reversal. Above the surface in the BL the wind shows smaller

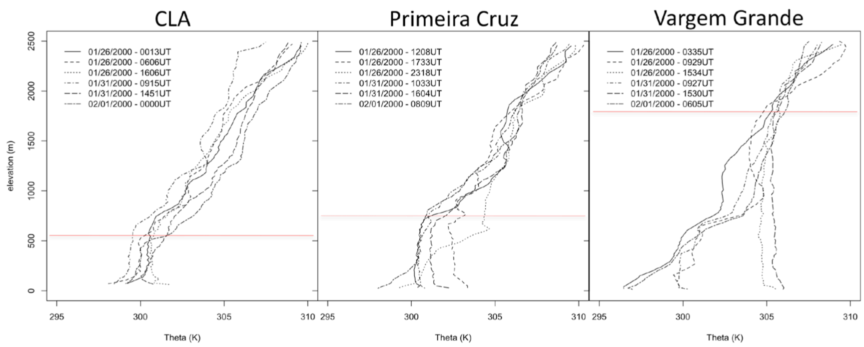

Figure 2: Vertical profiles of potential temperature for CLA, PC e VG.

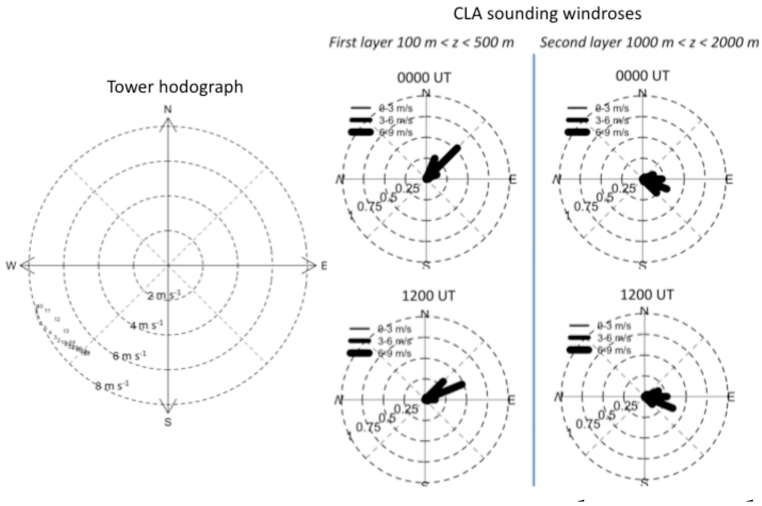

Figure 3: CLA tower's average hodograph and CLA windroses for the layer between 100m e 500m, and for the layer between 1000m and 2000m for 1200UT (0900LST) and 0000UT (2100 LST).

rotation, perhaps because it were used only the early morning sound 1200UT and early evening 0000UT, which might not be at the extremes of the entire rotation.

Table 2. All radiosondes that were done at CLA during no rainy days.

Radiosonde launching hour (UT)	Wet season		Dry season	
	Total soundings	Only southern flow	Total soundings	Only southern flow
00 - 03	38	4	49	0
03 - 06	4	0	4	0
06 - 09	11	0	12	0
09 - 12	424	45	549	38
12 - 15	90	12	199	8
15 - 18	15	4	32	0
18 - 21	7	0	15	0
21 - 24	278	16	479	3

The Table 2 shows that the majority of the soundings at CLA with southern flow happened during the months of May, June and July, with 78 out of total of 130 cases happening during these months. This period corresponds to the time of the year when the inter-tropical convergence zone is furthest north. It is possible that during cases with southern flow, the sea-breeze circulation might stay offshore, or even inexistent due to the strong offshore flow. It is likely that the intensity of the pressure gradient associated to the large-scale circulations decreases towards northern part of MA state (Figure 4).

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 flow characteristics 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. Nonetheless, for a few nights during stable conditions a southeasterly flow was observed at the VG and PC, for heights below 300 m (Figure 5).

Average pressure contour (not shown) for all dry seasons between the years of 2008 and 2012 shows that there is a meridional pressure gradient of about 0.4 hPa / 100 km between VG and PC, which points towards south in the afternoon 1800 UT and towards north in the morning 1200 UT. The dry season 24-hours average pressure-gradient-force and local wind tendency for Chapadinha (Figure 6), a location just south from VG, presents a better picture of this pattern.

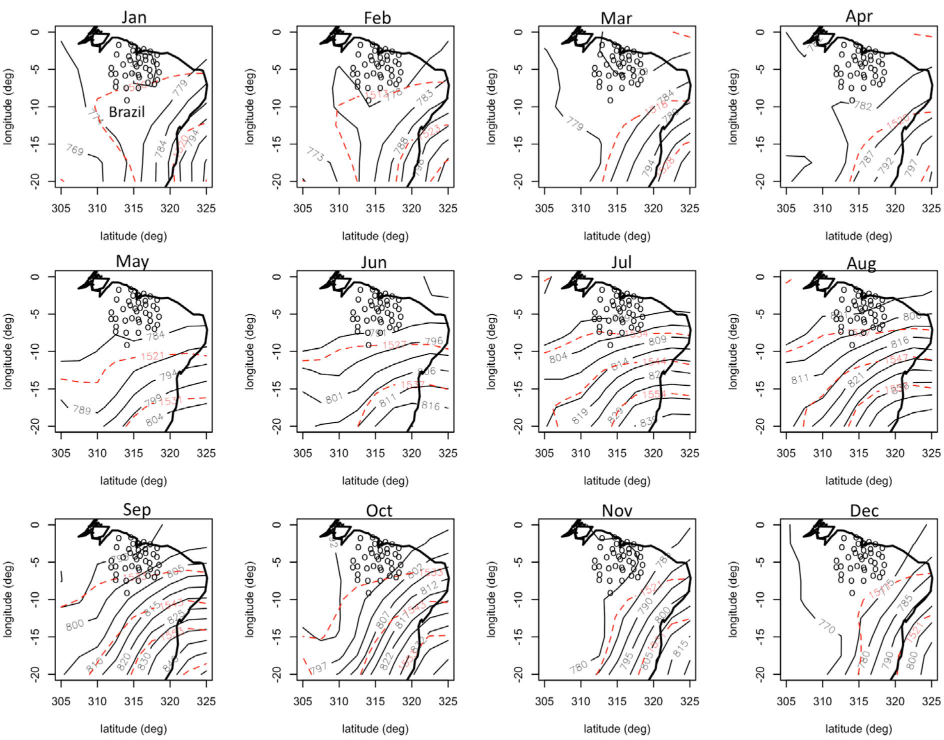

Figure 4: Geopotential height for 925 mb (black solid line) and 850 mb (red dashed line) pressure levels. Every panel corresponds to long term monthly average for the period between the years 2005 and 2011

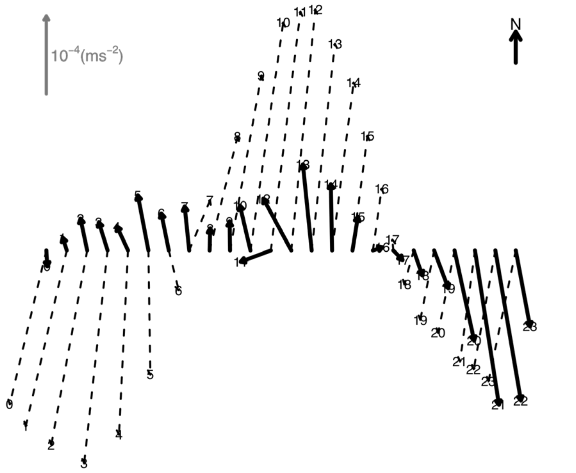

Figure 6: Near surface total wind vector tendency (solid arrows) and surface pressure-gradient-force (dashed arrows) for Chapadinha site. The number indicate the hour (GMT). This the gradient was obtained using the network of weather station from the INMET for the period between the years 2008 and 2012.

The near surface wind tendency at Chapadinha during morning and afternoon seems to be in phase with the surface pressure-gradient-force. We suspect that the low level southerly flow (Figure 5) observed during the night (around 0330 GMT) at VG and latter on at PC (0530 GMT), is consequence of a negative buoyancy force acting on the near surface air seating in the upslope (hills) located in the south of the region.

The average hodographs for the INMET surface stations (Figure 7), built for the period between March and June of the year 2012, indicate that the regional wind is typical from the sector northeast - southeast. The stations near the coast have smaller counterclockwise (except CLA) rotation within the sector NEE, while the ones further inland seems to have larger rotation but clockwise. The radiosondes launched in the afternoon of January 31, 2000 at PC and VG indicates the sea-breeze front was located between these two places. A preliminary simulation (result not shown) using the Weather Research and Forecasting model for the region shows the sea-breeze front moving inland slowly during the afternoon and quickly during the night. Nonetheless, during the night as it moves inland it decreases strength and becomes shallower. Radiosondes performed further south from Chapadinha, at Carolina (result not shown) during March of 2008 shows the northerly flow during late night for the levels below 500 meters.

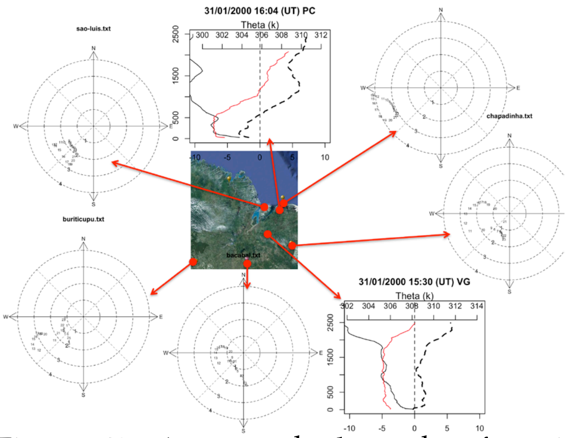

Figure 7: Average hodographs for six INMET surface stations for the period between 03/24/2012 and 06/06/2012.

4. Conclusions

Near the coast for the layer below 600 m, the flow performs a small rotation of 45 degrees about northeast, and above between 1500 m and 2500 m the flow is predominantly from southeast. We speculate that the northeast flow in PBL region (< 600 m) is a consequence of an almost permanent pressure-gradient-force pointing south. Further inland the flow is from the north during the night and from northeast during the morning to become from southwest during the afternoon. The result of this is a clockwise rotation. This wind rotation seems to be mainly controlled by a surface pressure-gradient-force, which we believe to be consequence of a differential heating/cooling between and continent and ocean (sea-breeze).

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