CONTINUOUS MONITORING OF THE LOWER BOUNDARY LAYER IN THE CENTRAL STATE OF SÃO PAULO, BRAZIL, WITH A SODAR

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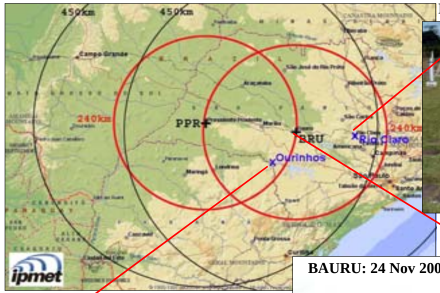
INTRODUCTION

- The increased demand worldwide for petroleum products derived from non-renewable resources and also its supply being susceptible to politics, resulted in a drastically increased production of ethanol from sugar cane in several regions of Brazil, especially in the central and western parts of the State of São Paulo.
- This not only entailed agricultural problems, but also wide-ranging environmental problems, due to the practice of burning the sugar cane fields prior to manual harvesting, resulting in vast emissions of biomass-burning products, such as aerosols and various greenhouse gasses.
- With this in mind, the Brazilian state-owned Oil Producer and Refinery Owner, Petrobras, approved an Infrastructure Project in 2008, submitted by five research groups (Landulfo *et al*., 2010; SPIE Proc.), through which a medium-sized Sodar, a mobile Lidar and air quality monitoring laboratory were acquired.
- The Meteorological Research Institute (IPMet) of the São Paulo State University (UNESP) has been monitoring the three-dimensional structure of severe thunderstorms since 1992, using two S-band Doppler radars in the central and western part of the State of São Paulo.
- In the absence of rain, especially during the dry winter months (April to September), the radars are well suited to monitor the plumes from large biomass fires ("queimadas"), which will facilitate the quantification of emissions from such fires.
- Within this infrastructure project, IPMet acquired a medium-sized Sodar for monitoring the vertical distribution of wind (u, v, w) within the lower Planetary Boundary Layer (PBL; up to 500–800 m above ground level (AGL), depending on the meteorological conditions). Average vertical profiles were recorded every 30 min.
- During specific campaigns, the Sodar was co-located with the mobile Lidar, which monitored aerosol layers within the PBL and the Sodar-derived wind profiles were used to identify the directions from which they came, subsequently identifying the biomass fires on the radar images.

OBJECTIVES

- **To present a climatology of Sodar observations in the central interior of the State of São Paulo for the period of June 2009 to January 2011;**
- **Three different sites where monitoring took place (sequentially);**
- **Emphasis on nocturnal stable conditions of the Planetary Boundary Layer (PBL);**
- **To estimate the possible impact of biomass-burning on regional and distant urban areas and the population in general (Held *et al*., 2011).**

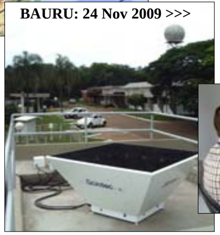
LOCATION OF MONITORING SITES



RIO CLARO: 15 June – 14 Oct. 2009

OURINHOS: 02 Aug – 02 Sept 2010

BAURU: 24 Nov 2009 >>>



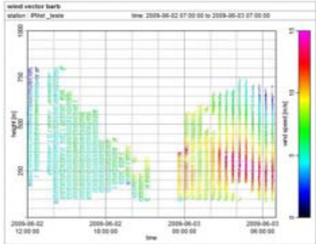
OBSERVATIONS

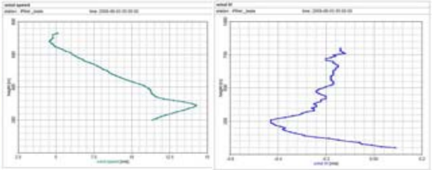
The formation of Low-Level Jets (LLJs)

- The LLJ is a lower-troposphere maximum in the vertical profile of the horizontal winds, which can occur under favourable synoptic conditions anywhere in the world, but most commonly is a nocturnal phenomenon.
- No single mechanism appears to be responsible for the formation of the LLJ, but Blackadar (1957), Wexler (1961), Bonner (1968) and other authors, suggested inertial oscillation in the momentum field initiated by a decrease in turbulent eddies due to the formation of a radiation inversion.
- Another mechanism could be thermal forcing due to differences in the cooling of regionally sloped terrain, which results in a tilted density field, enhancing the vertical shear of the geostrophic wind at the inversion level (e.g., Holton, 1967).
- Held *et al.* (1990) and Tosen *et al.* (1990), using up to four Tethered Balloons simultaneously on the South African Plateau, concluded large-scale cooling of regionally sloped terrain causing the formation of LLJs there.

The first Low-Level Jet observed in Bauru (03 June 2009, early morning)

… came as a big surprise during the testing of the newly installed Sodar and immediately prompted the initiation of a small project to study LLJs in the central interior of the State!

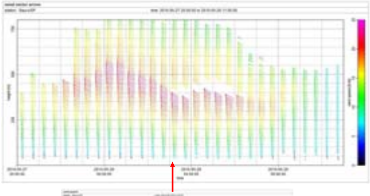


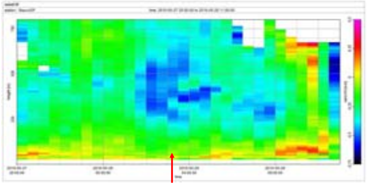


Profile of Wind Speed and Vertical Velocity W: 03/06/2009 – 05:00 LT

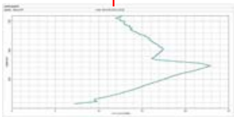
<<<<< Vertical Wind Profiles, Bauru, 02/06/2009 – 12:00 to 03/06/2009 – 07:00 LT

Typical Low-Level Jet observed in Bauru



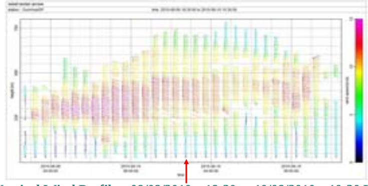


Vertical Velocity W: 27/05-20:00 to 28/05-11:00 LT

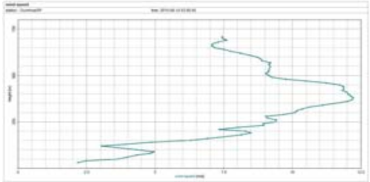


28 May 2010 - 03:30 LT:
Maximum velocity 23 $m.s^{-1}$ from east-south-east

Typical Low-Level Jet observed in Ourinhos



Vertical Wind Profiles: 09/08/2010 – 18:30 to 10/08/2010 – 10:30 LT



Profile of Wind Speed: 10/08/2010 – 03:00 LT (>12 $m.s^{-1}$)

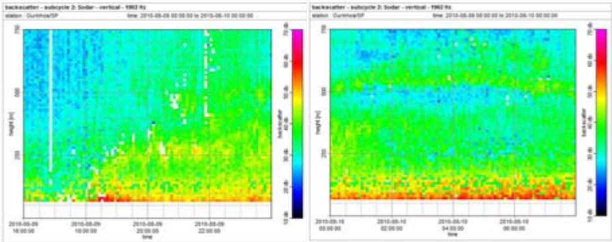
Detection of the thermal inversion using Wind Sodar only (Experimental)

Sodar Settings:

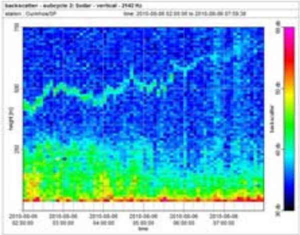
- **Averaging period 60 min with sliding means providing a vertical profile every 30 min;**
- **Vertical averaging in 10 m intervals, starting at 30 m AGL up to 800 m AGL;**
- **Nominal correction for mean atmospheric pressure, temperature and humidity (winter & summer mode);**
- **Emitting 10 frequencies from 1662 to 2742 Hz;**
- **Facility to generate expert products during re-processing, like Backscatter Signal for each frequency separately; wind shear/direction; sigma speed; sigma lateral; sigma Phi; sigma Theta; turbulent kinetic energy; eddy dissipation rate; PG Stability Profile; etc.**

Example of Back Scatter Signal in Ourinhos:

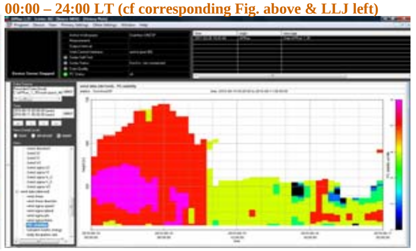
09/08/2010-16:00 to 10/08/2010-08:00 LT at 1902 Hz (cf corresponding figure of LLJ in the middle column)



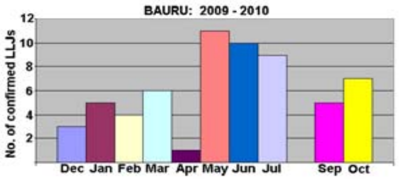
06/08/2010: 02:00 - 08:00 LT at 2142 Hz



Example of PG Classification in Ourinhos: 10/08/2010 00:00 – 24:00 LT (cf corresponding Fig. above & LLJ left)



PRELIMINARY CONCLUSIONS



- **Strong nocturnal LLJs develop throughout the year shortly before midnight with max. velocities ranging from 12 – 25 $m.s^{-1}$;**
- **The most common direction is from ESE;**
- **Velocities during the austral winter were higher than in summer, viz. 18 – 25 $m.s^{-1}$;**
- **In Bauru the frequency of occurrence varied from about 10% during the summer months up to 35% in May;**
- **During August 2010, LLJs were recorded at Ourinhos on >50% of the days, but with lesser intensity;**
- **The progressive development of the thermal inversion height can usually be identified from Backscatter Signals at different frequencies;**
- **The height of the velocity maximum varied from 250 m to 500 m AGL;**
- **The indicated PG Stability coincides well with the development of the strongest part of the LLJ;**
- **Based on the various hypothesis on the formation process of LLJs, it is proposed, that in the central State of São Paulo the mechanism is that of thermal forcing due to differences in the cooling of regionally sloped terrain, which results in a tilted density field, enhancing the vertical shear of the geostrophic wind at the inversion level.**

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