# CHARACTERIZATION OF THE LOWER BOUNDARY LAYER BASED ON SODAR OBSERVATIONS (2010-2013) IN BAURU, SÃO PAULO, BRAZIL

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## INTRODUCTION

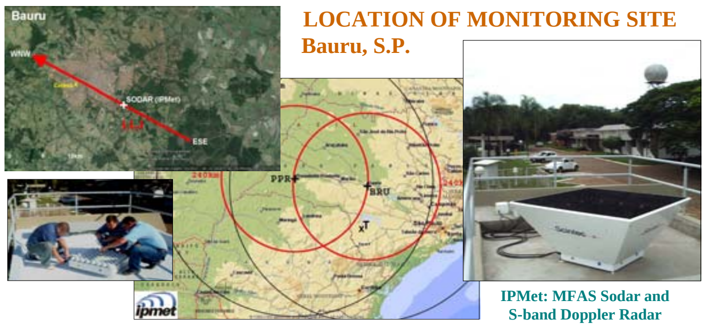
- The increased demand worldwide for petroleum products derived from non-renewable resources and also its supply being susceptible to politics, resulted in a drastically increased production of ethanol from sugar cane in several regions of Brazil, especially in the central and western parts of the State 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, 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) is specialized in Nowcasting and as such 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. However, from 2009 to 2013, IPMet has also been responsible for the operation of the Sodar, installed at its premises in Bauru and monitoring the local circulation up to 500-800 m above ground level (AGL) ), depending on the meteorological and atmospheric conditions.

## OBJECTIVES

- To present a climatology of Sodar observations in the central interior of the State of São Paulo for the four-year period from January 2010 to December 2013;
- Specifically, to generate windroses at heights of up to 550 m AGL;
- To investigate the nocturnal stable conditions of the Planetary Boundary Layer (PBL) and quantify the frequency of the extreme stable and unstable PG Classes;
- To characterize and quantify the occurrence of nocturnal Low-Level-Jets (LLJ);
- To provide information for the parameterization of the lowest layers of the PBL for dispersion modelling.

## LOCATION OF MONITORING SITE

Bauru, S.P.



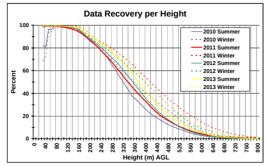

IPMet: MFAS Sodar and S-band Doppler Radar

## OPERATIONAL SETTINGS OF MFAS SODAR

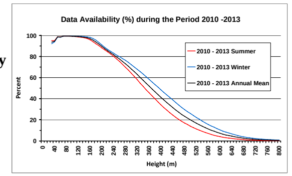
- Station height: 620 m amsl + 3 m;
- Maximum beam range limited to 800 m above ground level (AGL);
- Averaging interval 1 hour with output every 30 min (sliding mean);
- Vertical resolution in 10 m layers;
- Parameters monitored: wind vector (u, v, w), wind speed (scalar) & direction, wind shear, standard deviations (sigma) and backscatter signals;
- Parameters derived: Pasquill-Gifford stability, wind turbulence intensity, turbulent kinetic energy, eddy dissipation rate, as well as non-profile variables, like surface heat flux, Monin Obukov Length and friction velocity, etc, being extremely useful for dispersion modeling.

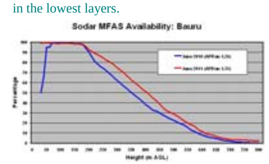
## DATA RECOVERY

- Data acquisition in Bauru from 24 Nov. 2009 to 06 Jan. 2014
- Data processed for this presentation: 01 Jan. 2010 to 31 Dec. 2013
- Sodar operation: on 1330 days of 1459 days during the above period; however, the Sodar was deployed in other locations on 76 days, resulting in only 53 days (0,036%) lost due to technical problems;
- Data recovery for the Bauru study during the 4-year period: 91,3%;
- Operational data recovery: >99% up to 150-200 m AGL (except in 2010), with a gradual decline to 12,6% at 550 m AGL, above which wind roses could be biased towards stronger wind speeds due to light wind speeds possibly not having been detected.
- For practical considerations, the years were divided into "summer" (wet season, characterized by tropical conditions with strong convection) and "winter" (mostly dry months from April to September, with occasional strong baroclinic systems moving across the State from southwest. Data recovery during winter was consistently better!



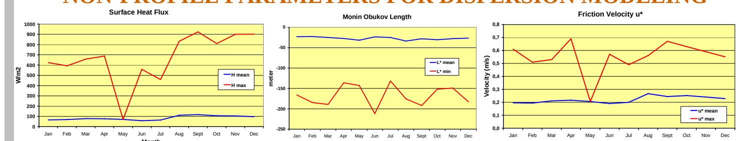

Data recovery from 30–800 m AGL per year. Operated with APRun-1.26 until 31 July 2010, there-after APRun-1.35, resulting in significantly improved data recovery, especially in the lowest layers.



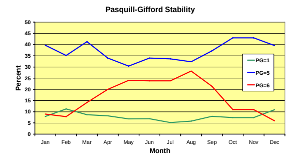




Comparison of APRun-1.26 and APRun-1.35

## NON-PROFILE PARAMETERS FOR DISPERSION MODELING

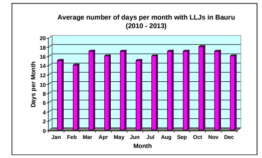


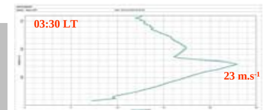

The above parameters are only being calculated under convective conditions, viz. mostly during midday. The Sodar Software also generates the "Estimated height of the lowest temperature inversion", as well as the "Estimated mixed layer depth", but these were found to be rather unreliable, necessitating a more detailed verification.



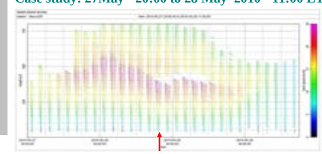

## LOW-LEVEL JETS OBSERVED IN THE BAURU REGION

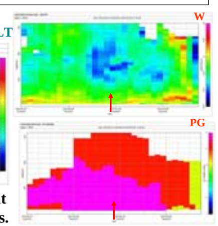
- The LLJ is a lower-tropospheric maximum in the vertical profile of the horizontal winds, which can occur under favourable synoptic conditions anywhere in the world, but most commonly it is a nocturnal phenomenon.




Case study: 27May - 20:00 to 28 May 2010 - 11:00 LT

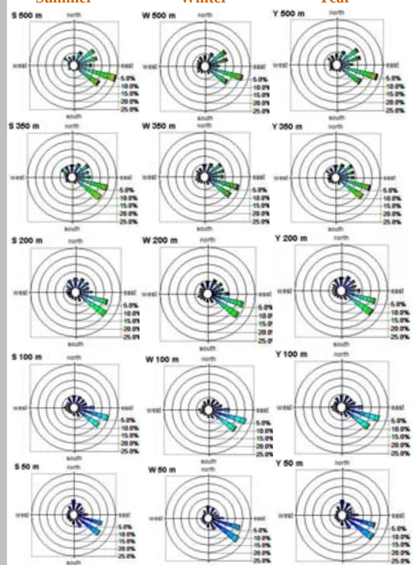


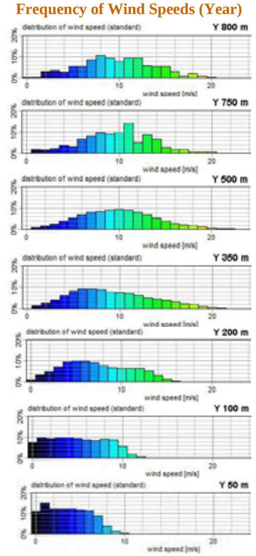



- LLJs are more common in the Bauru region than initially perceived, viz. on average 50% of all nights! This also in agreement with the high frequency of a stable (PG=5) and absolutely stable (PG=6) PBL conditions.

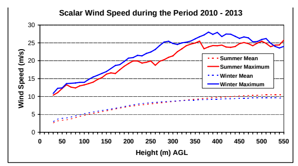
## DISTRIBUTION OF WIND WITH HEIGHT (Means 2010 – 2013)

Summer | Winter | Year | Frequency of Wind Speeds (Year)




- Almost no seasonal difference




## CONCLUSIONS

- Four years of vertical wind profiles and related parameters, obtained from Sodar observations in the central State of São Paulo, provide excellent data for dispersion modeling;
- Dominant wind directions are from SE (35-40%) and ESE (15-20%) at all heights up to about 350 m AGL, but during the 6-month winter period, their frequency increases to 20-25% above 350 m AGL;
- Scalar mean wind speeds increase from 2,5-3 m.s$^{-1}$ at 30 m AGL to around 10 m.s$^{-1}$ at 500 m AGL, but decrease slightly above 550 m AGL, while maximum wind speeds stay around 35-40 m.s$^{-1}$ at all heights, with little seasonal variation;
- Strong nocturnal LLJs from ESE develop throughout the year shortly before midnight, during about 50% of the nights, with max. velocities ranging from 15 – 29 m.s$^{-1}$ (4-year mean 16 m.s$^{-1}$); the mean height of the wind maximum is 308 m; no clear seasonal variation was found;
- The formation of LLJs in the central State of São Paulo is driven by 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;
- The P-G Stability shows a distinct seasonal variation, especially PG=6 increases from ±10% during summer to >20% during the 6 winter months, peaking in August with 28,2%, while unstable conditions have a frequency of only ±10% in summer with a minimum of 5,2% in July;
- The estimated mean values of the principal Non-Profile parameters (above) do not show a significant seasonal variation.