MCITY BRAZIL PROJECT: ASSESSING URBAN CLIMATE FEATURES OF SÃO PAULO AND RIO DE JANEIRO

Amauri P. de Oliveira[1]*, Edson P. Marques Filho[2], Mauricio J. Ferreira[1], Jacyra Soares[1], Georgia Codato[1], Eduardo Landulfo[3], Flávia N. D. Ribeiro[1], Eleonora S. Assis[4], Maxsuel M. R. Pereira[5], João F. Escobedo[6], Primoz Mlakar[7], Marija Z. Boznar[7]

University of São Paulo, São Paulo, Brazil[1]
Federal University of Rio de Janeiro, Rio de Janeiro, Brazil[2]
Institute of Nuclear Energy Research, São Paulo, Brazil[3]
Federal University of Minas Gerais, Minas Gerais, Brazil[4]
Federal University of Espirito Santo, Espirito Santo, Brazil[5]
State University of São Paulo, Botucatu, Brazil[6]
MEIS d.o.o., Mali Vrh pri Smarju, Slovenia[7]

FINANCIAL SUPPORT

State of São Paulo Research Fundation (**FAPESP**) (*Grant N. 2011/50178-5*).

State of Rio de Janeiro Research Fundation (**FAPERJ**) (*Grant N. E26/111.260/2011 and E-26/110449/2007*).

National Council for Scientific and Technological Development (**CNPq**). (*Grant N. 476812/2011-9*).

BRAZILIAN RESEARCH INSTITUTIONS

University of *São Paulo* (USP)

State University of *São Paulo* (UNESP)

Institute of Nuclear Energy Research (IPEN)

Federal University of *Rio de Janeiro* (UFRJ)

Federal Rural University of *Rio de Janeiro* (URFRJ)

Federal University of *Minas Gerais* (UFMG)

INTERNATIONAL COLLABORATION

Bob Bornstein (SJSU, USA)

Júlia Hidalgo (Meteo-France, France)

Primoz Mlakar and Marija Boznar (MEIS, Slovenia)

Claudia Furlan (Padova University, Italy)

Monique Leclerc (GSU, USA) (INITIAL PHASE)

TOPICS

1. MAIN GOAL
2. MOTIVATION
3. URBAN EFFECTS ON CLIMATE
4. MCITY PROJECT
5. MICROMET NETWORK &FIELD CAMPAIGNS
6. PRELIMINAR RESULTS
7. CONCLUSION

1. MAIN GOAL

Urban heat island

Surface energy balance

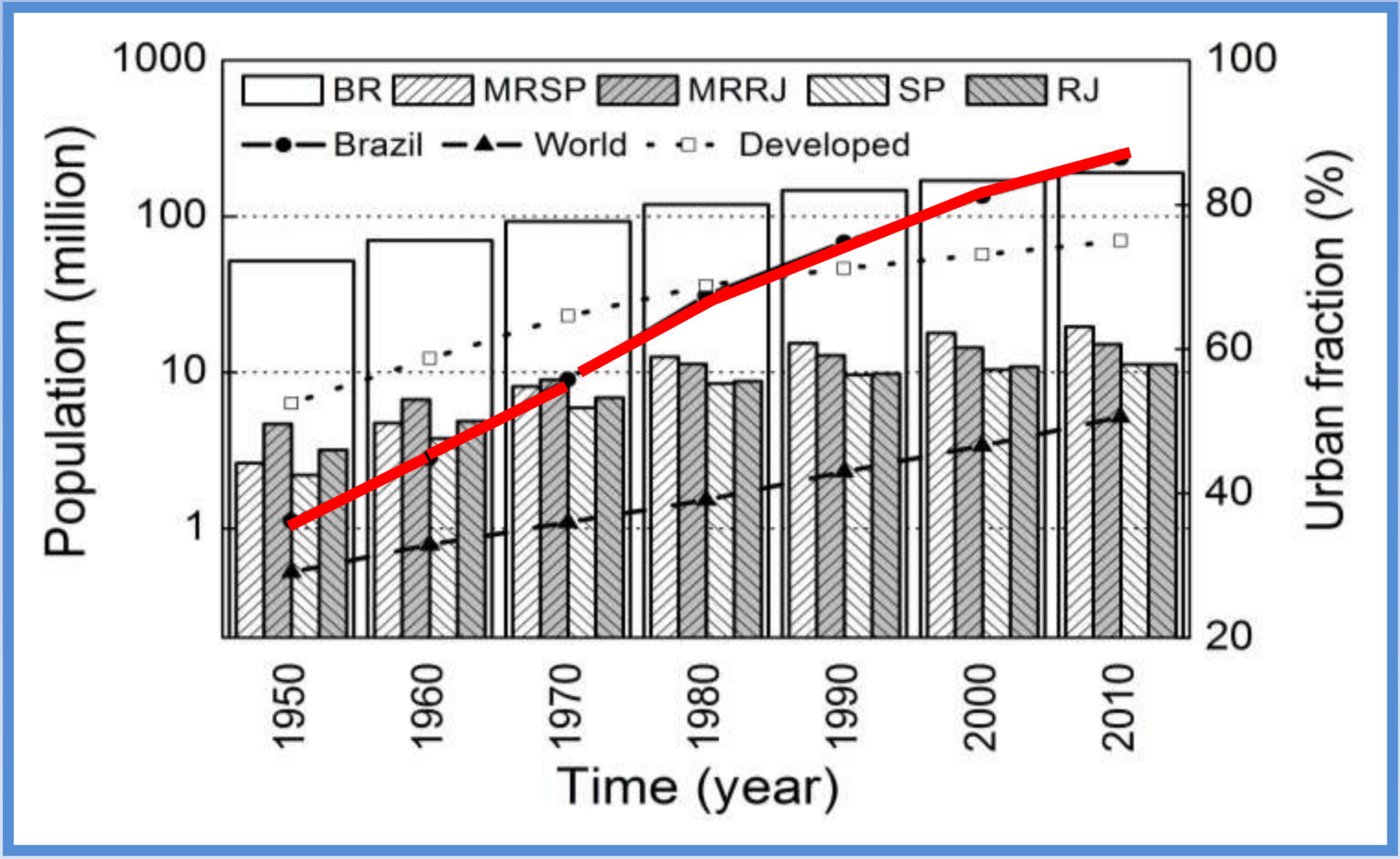
Urban Boundary Layer

Landuse characterization

2. MOTIVATION

The investigation of urban heat island and other urban effects on the climate of cities located at tropical and subtropical areas have received less attention than in other latitudes, as result much less is known about urban climate in these regions.

85% BRAZILIAN POPULATION ARE "LIVING" IN URBANS AREAS



SOCIAL AND ECONOMICS

Descrição	RMSP	RMRJ
CITIES	38	20
AREA (km^2)	7,944 km^2	5.682 km^2
POPULATION	19,672,582	15,180,636
VEHICLES	6.900.000	3.630.678
BRAZILINA GPD	33.9%	11.2%

IBGE(2010)

GPD : GROSS DOMESTIC PRODUCT

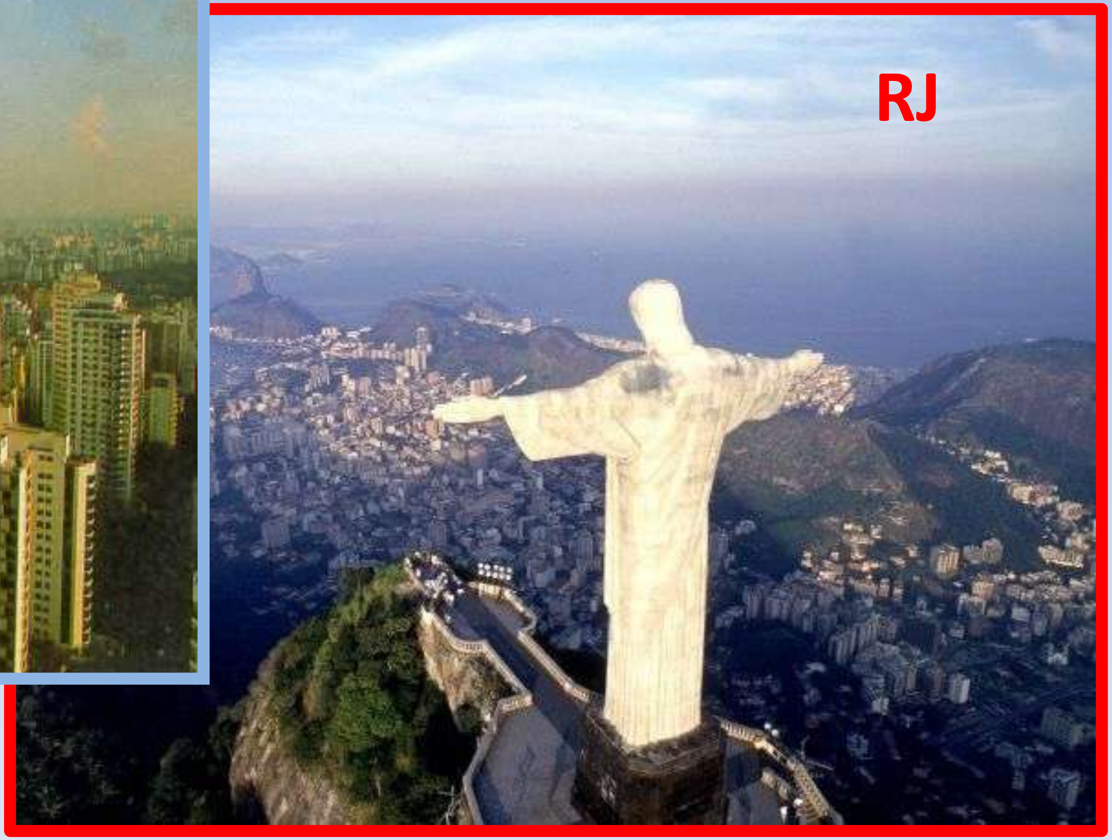
GREEN HOUSE GAS EMISSION

TABLE 2
Selected urban greenhouse gas emissions

City (date of study)	Total GHG emissions (million tonnes CO_2 equivalent)*	GHG emissions per capita (tonnes of CO_2 equivalent)	National GHG emissions per capita (tonnes of CO_2 equivalent)[11]	City emissions as percentage of national emissions (per capita)
European cities				
Barcelona (1996)[1]	5.1	3.4	10.03 (2004)	33.9%
Glasgow (2004)[2]	12.5	8.4	11.19 (2004)	75.1%
London (2006)[3]	44.3	6.2	11.19 (2004)	55.2%
North American cities				
District of Columbia (2005)[4]	11.3	19.7	23.92 (2004)	82.4%
New York City (2005)[5]	58.3	7.1	23.92 (2004)	29.7%
Toronto (2001)[6]	37.1	8.2	23.72 (2004)	34.4%
South American cities				
Rio de Janeiro (1998)[7]	12.8	2.3	8.2 (1994)	28.0%
São Paulo (2003)[8]	15.7	1.5	8.2 (1994)	18.3%

Dodman D. Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories, Environment and Urbanization, 2009; 21(1): 185-201.

POLLUTION – WINTER (OZONE)



11

SEVERE WEATHER (SUMMER FLOAD)

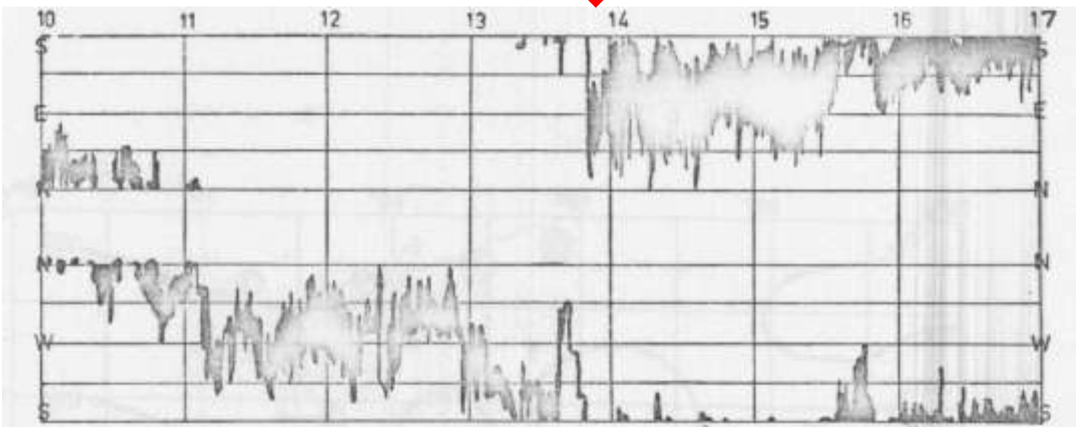
São Paulo on May 25, 2005.

3. URBAN EFFECTS ON CLIMATE

What we now about urban effects on the climate of São Paulo and Rio de Janeiro?

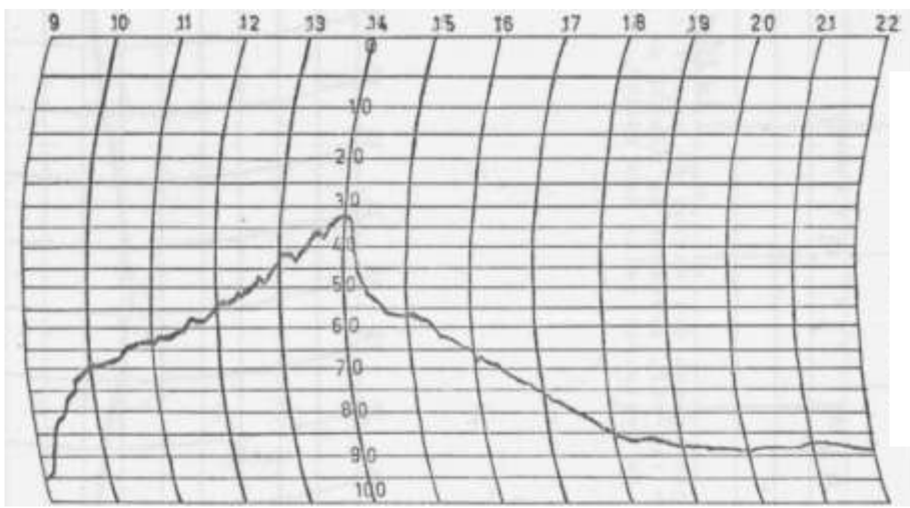
Sea Breeze in São Paulo

Local time



Wind Direction Shits from NE to SE

Local time



Relative Humidity increases

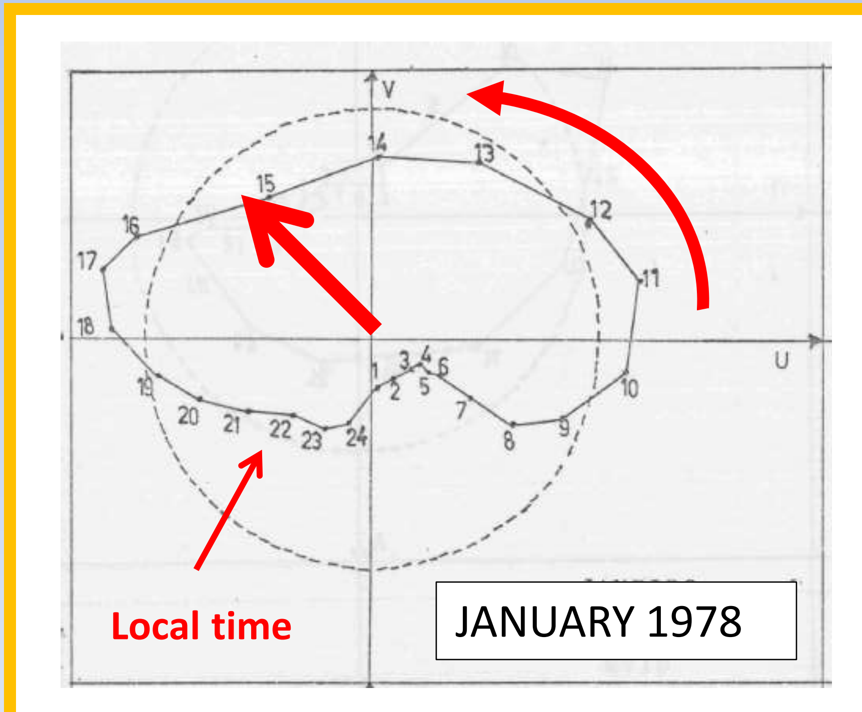
Temperature Decreases.

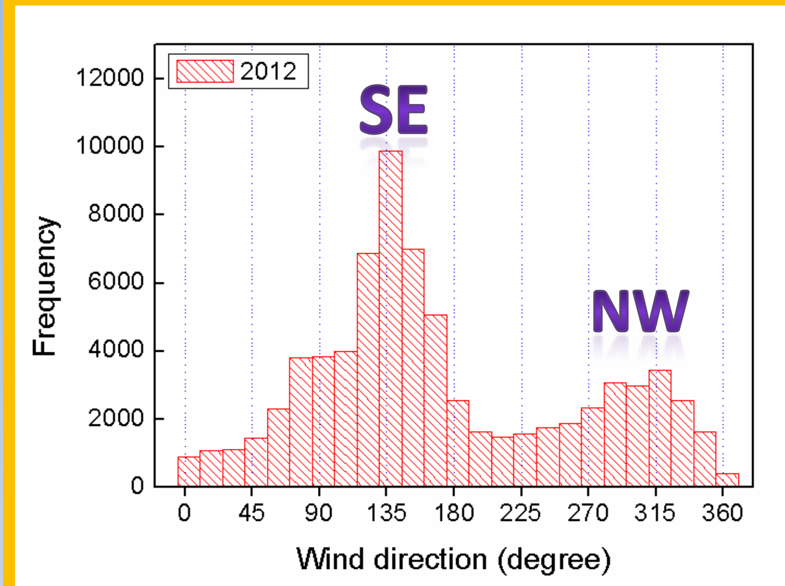
Sea Breeze - São Paulo

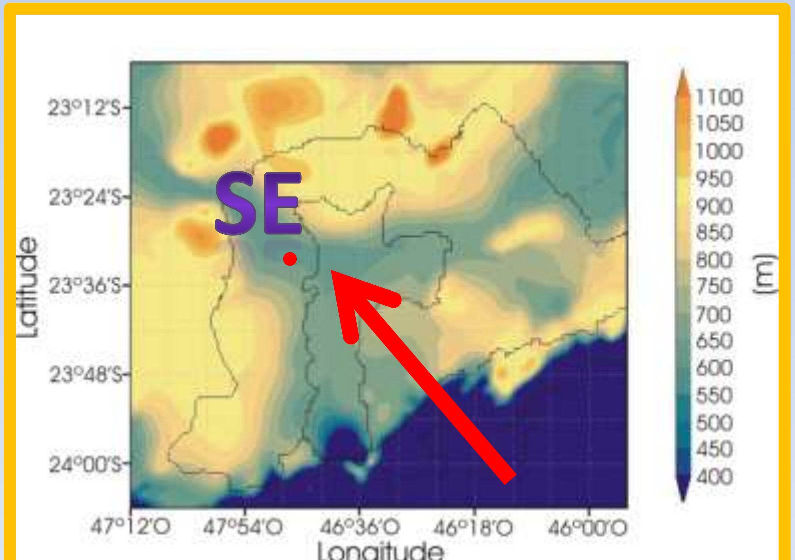
Hodograph

Elliptical shape

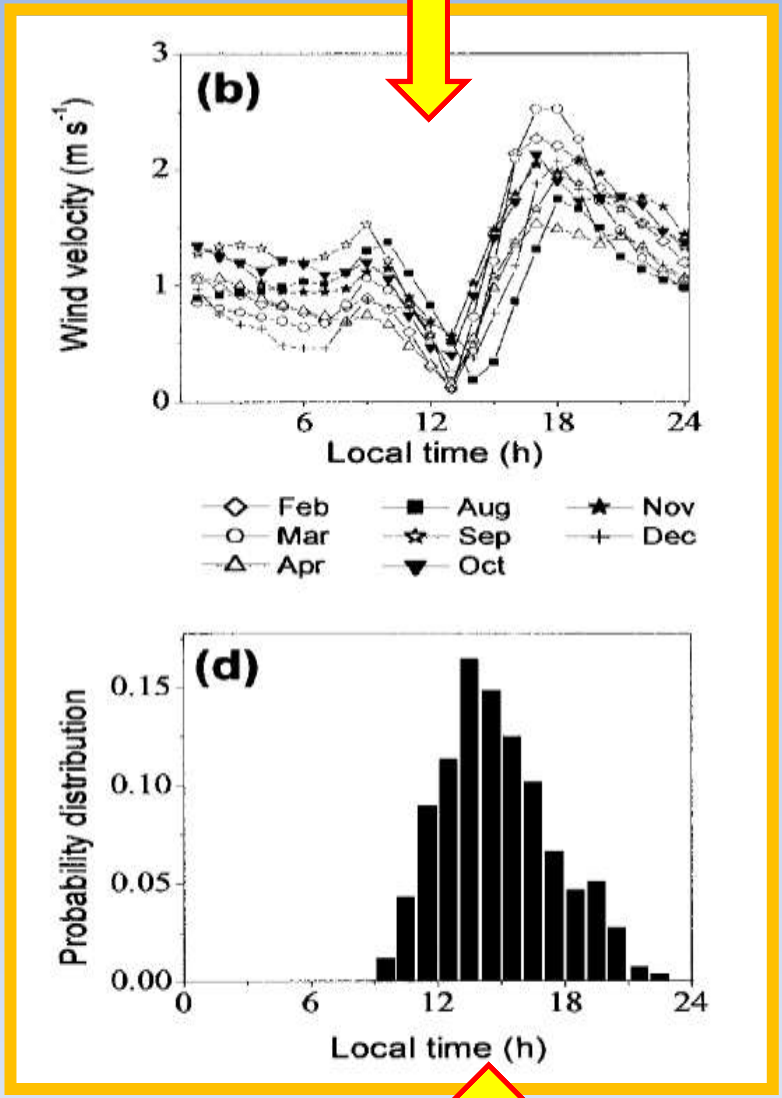
Counter clockwise (SH)



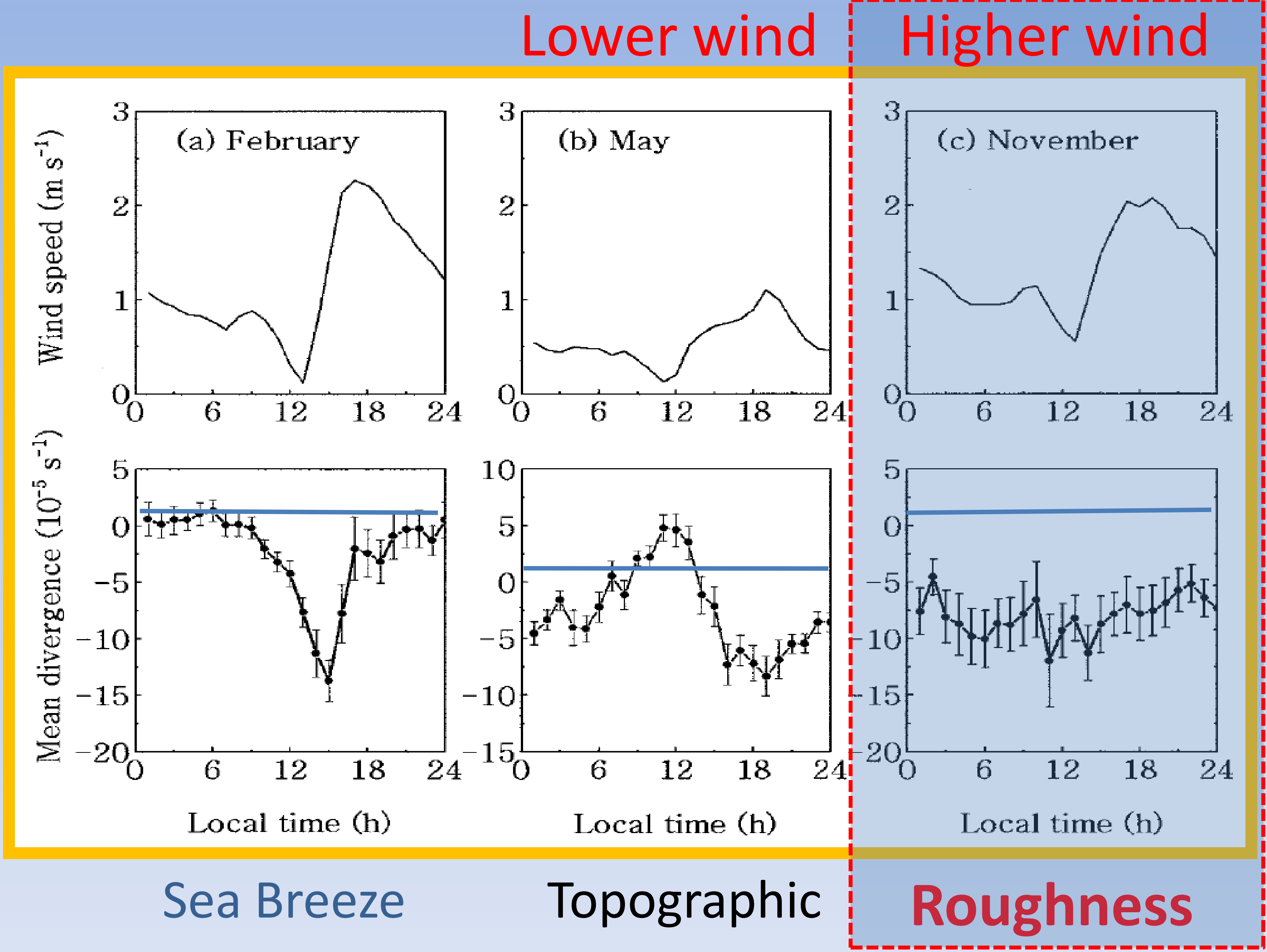




Sea Breeze - São Paulo

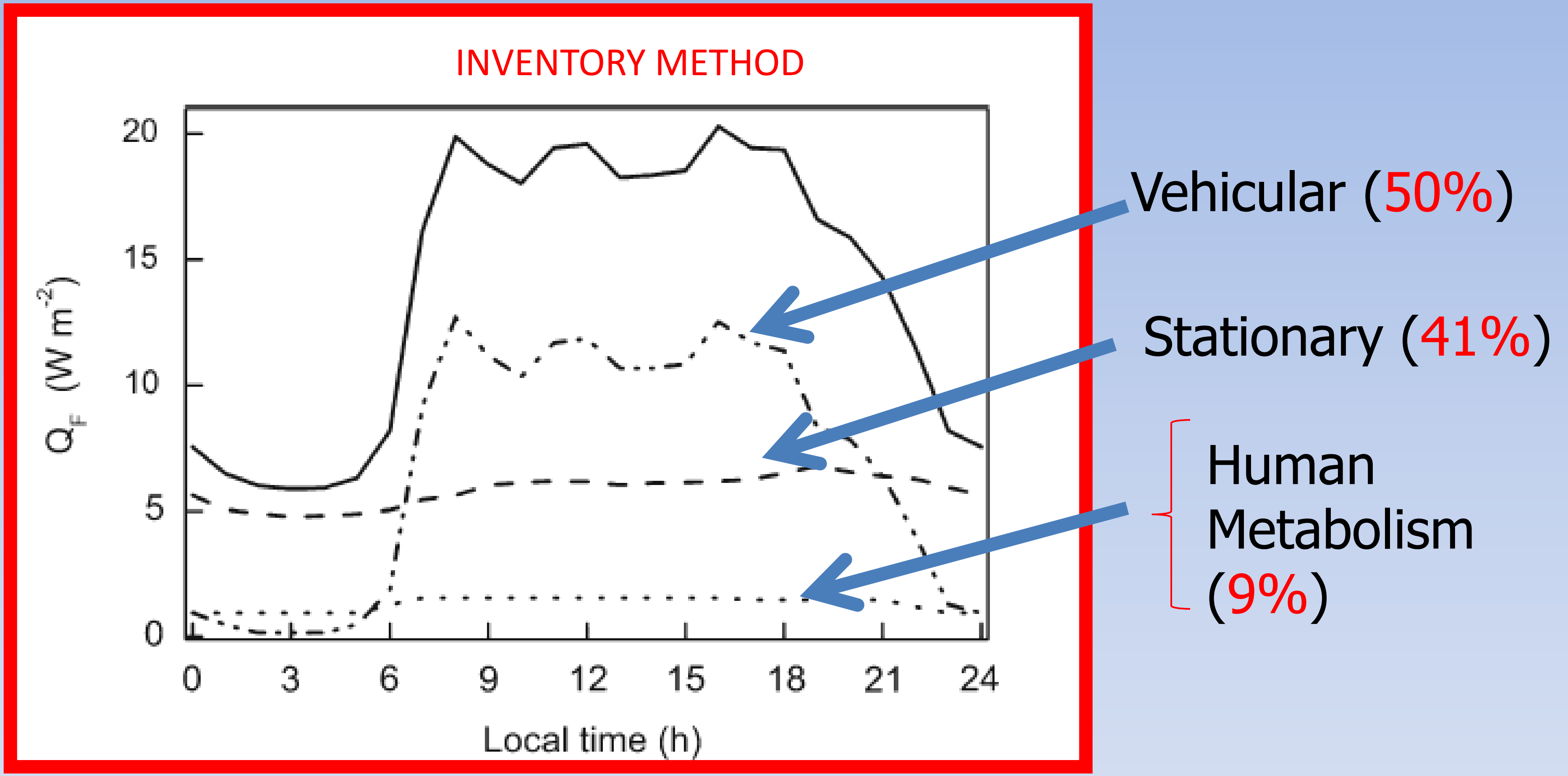


PENETRATES AROUND 14:00 LT



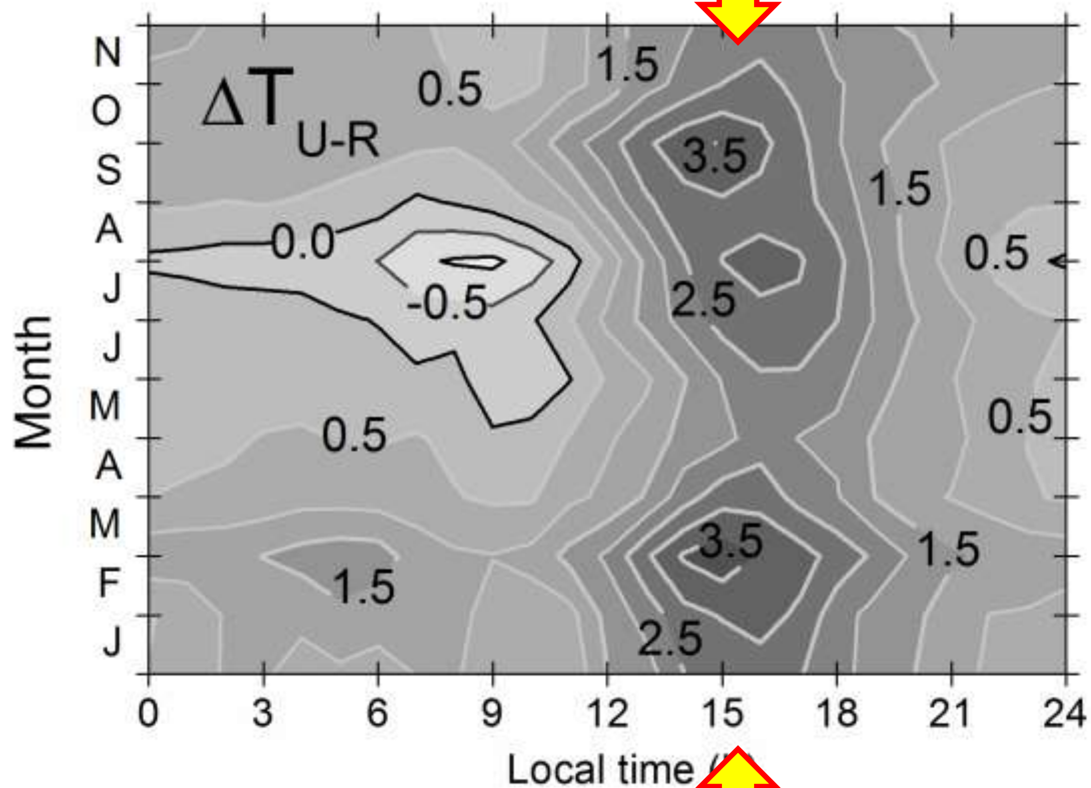
Lower wind
Higher wind
(a) February
(b) May
(c) November
Wind speed (m s-1)
Mean divergence (10-5 s-1)
Local time (h)
Local time (h)
Local time (h)
Sea Breeze
Topographic
Roughness

ANTHROPOGENIC HEAT IN SÃO PAULO



Ferreira, M.J., Oliveira, A.P. and Soares J., 2011. Anthropogenic heat in the City of São Paulo, Brazil. *Theoretical and Applied Climatology*, **104**, 43-56.

SÃO PAULO: ΔT_{U-R} MAX DAYTIME

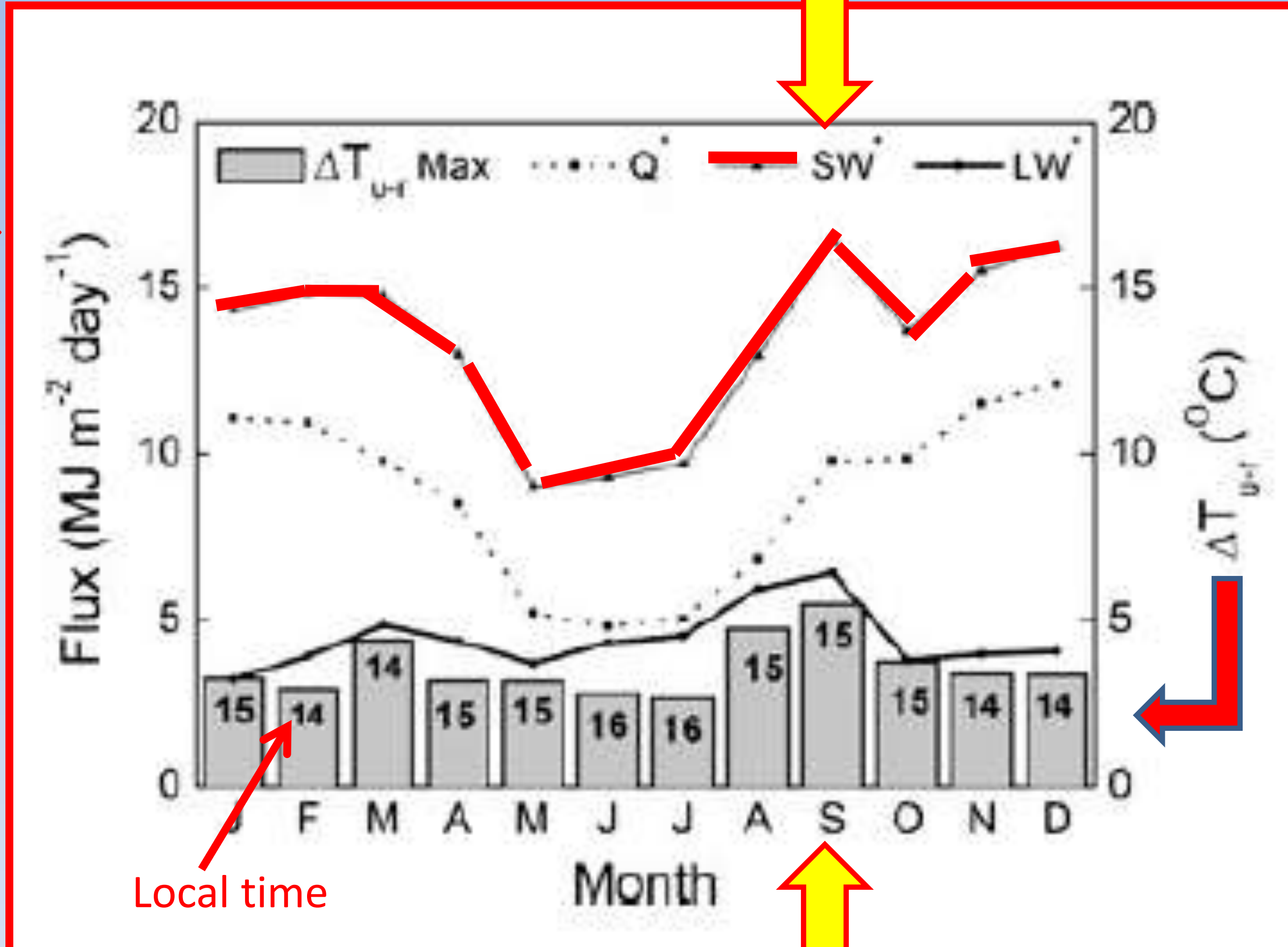


ΔT_{U-R} MAX VARIED FROM 2°C TO 6°C.

Ferreira, M.J., Oliveira, A.P., Soares, J., Codato, G., Bárbaro, E.W., and Escobedo, J. F., 2012: Radiation balance at the surface in the City of São Paulo, Brazil. Diurnal and seasonal variations. *Theoretical and Applied Climatology*. 107 (1), 229-246.

SÃO PAULO: ΔT_{U-R} MAX SOLAR HEATING

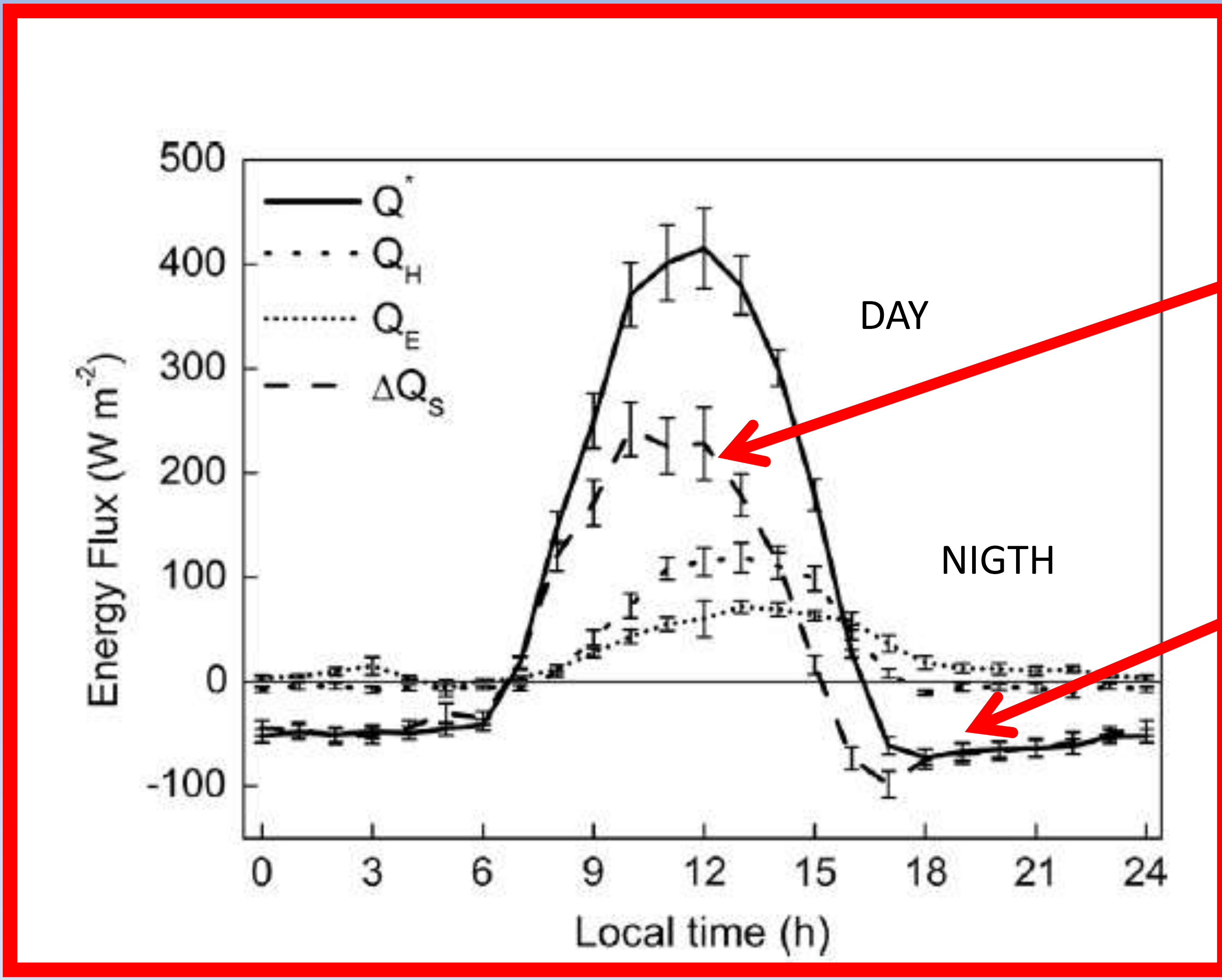
SW*=SW↓+SW↑



Ferreira, et al. (2012)

SW=SHORT WAVE RADIATION

ENERGY BALANCE IN SÃO PAULO



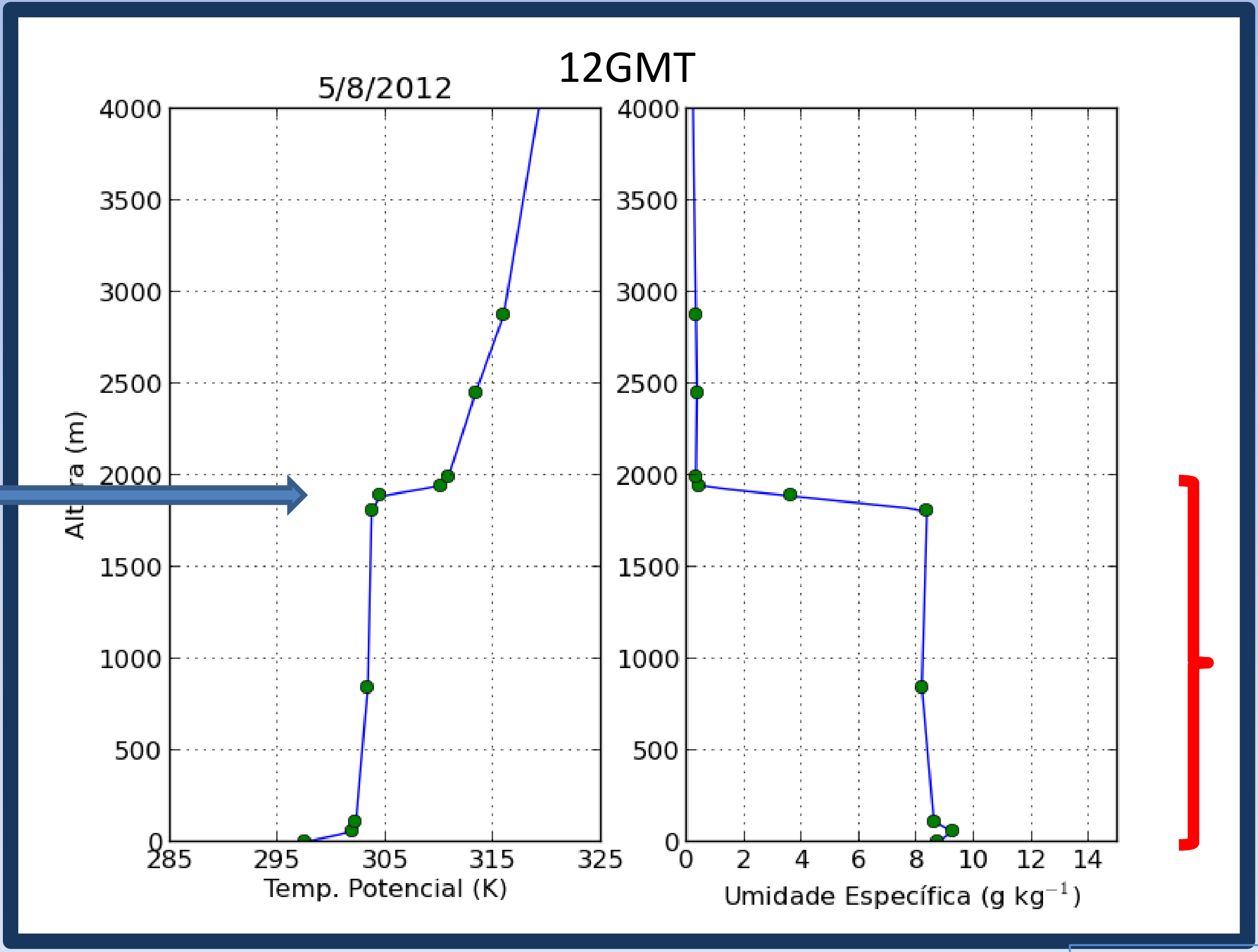
ΔQs= 50% Q*

ΔQs= 100% Q*

Ferreira, M.J., Oliveira, A.P., Soares, J., 2013: Diurnal variation in stored energy flux in Sao Paulo city, Brazil. *Urban Climate,* 5, 36-51 .

PBL HEIGHT AND STRUCTURE (00 and 12 GMT)

TOP

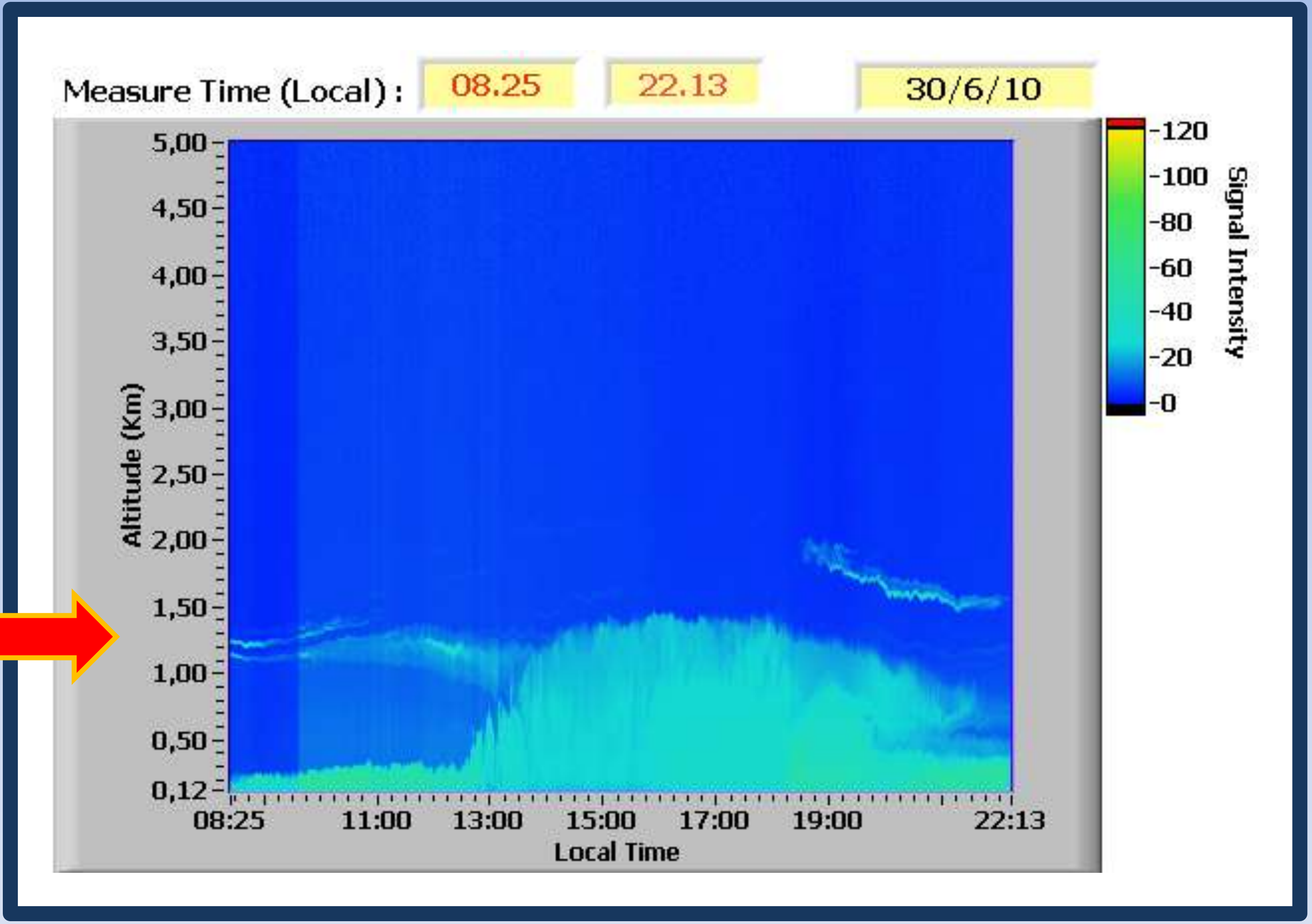


RESIDUAL MIXED LAYER

Valença., 2013

LIDAR PBL ESTIMATES

TOP



Landulfo *et al.*, 2010

WHAT WE KNOW ABOUT SÃO PAULO

- Surface wind patterns are associated to sea-breeze, topographic (Mountain-Valley thermal circulation) and landuse (Roughness) effects;

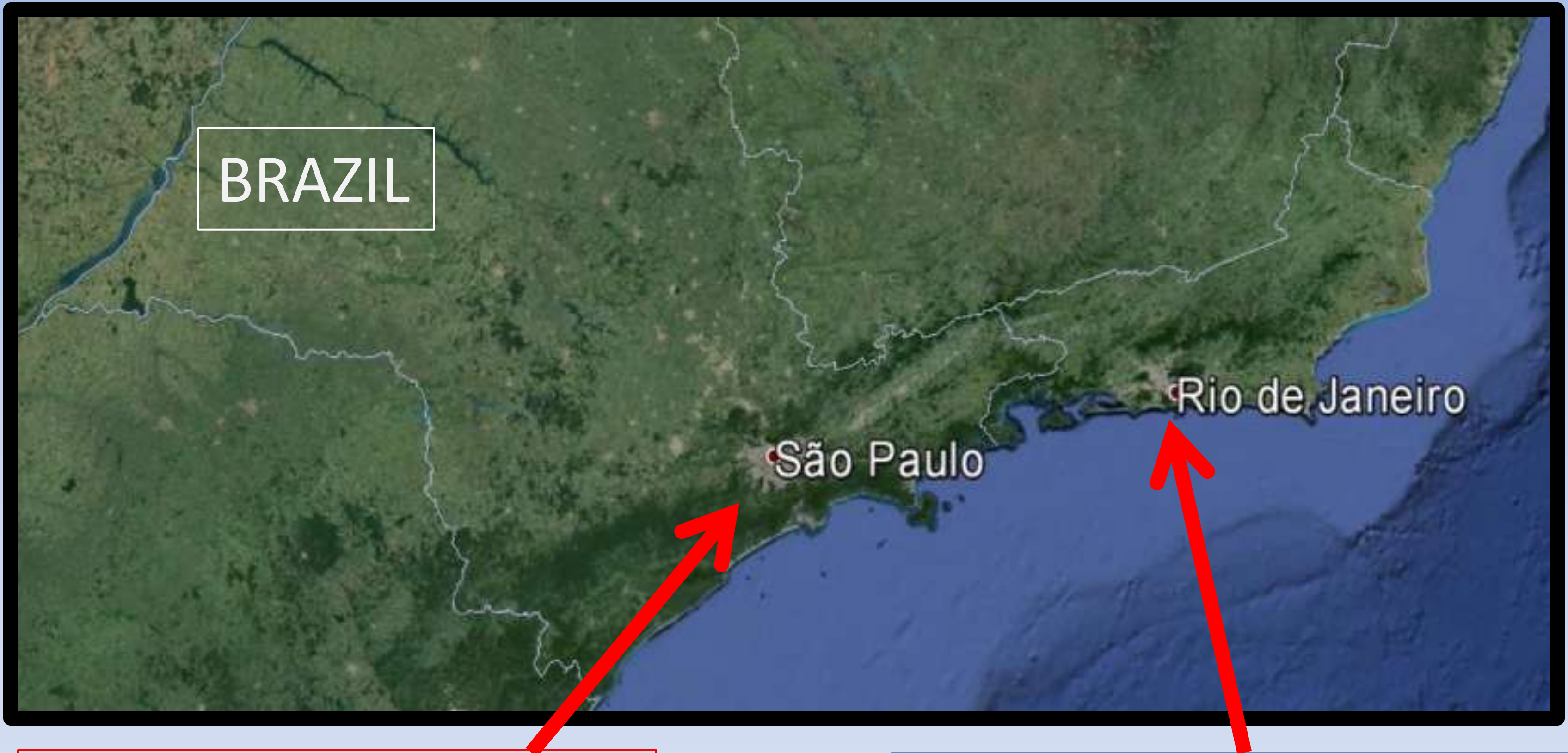
- UHI maximum occurs between 14:00-16:00LT (daytime), varied from 2 to 6.5^0C (monthly average) and is driven by the net solar radiation;

- Anthropogenic energy flux (diurnal evolution amplitude 20 Wm^{-2}) 50 % Vehicular, 41% Stationary and 9% Human metabolism;

- Stored energy flux correspond to 50% of net radiation during daytime and 100% during nighttime.

- PBL height (100-2500m) and Low Level Jet (10-15 ms^{-1}, 300-600m, NE).

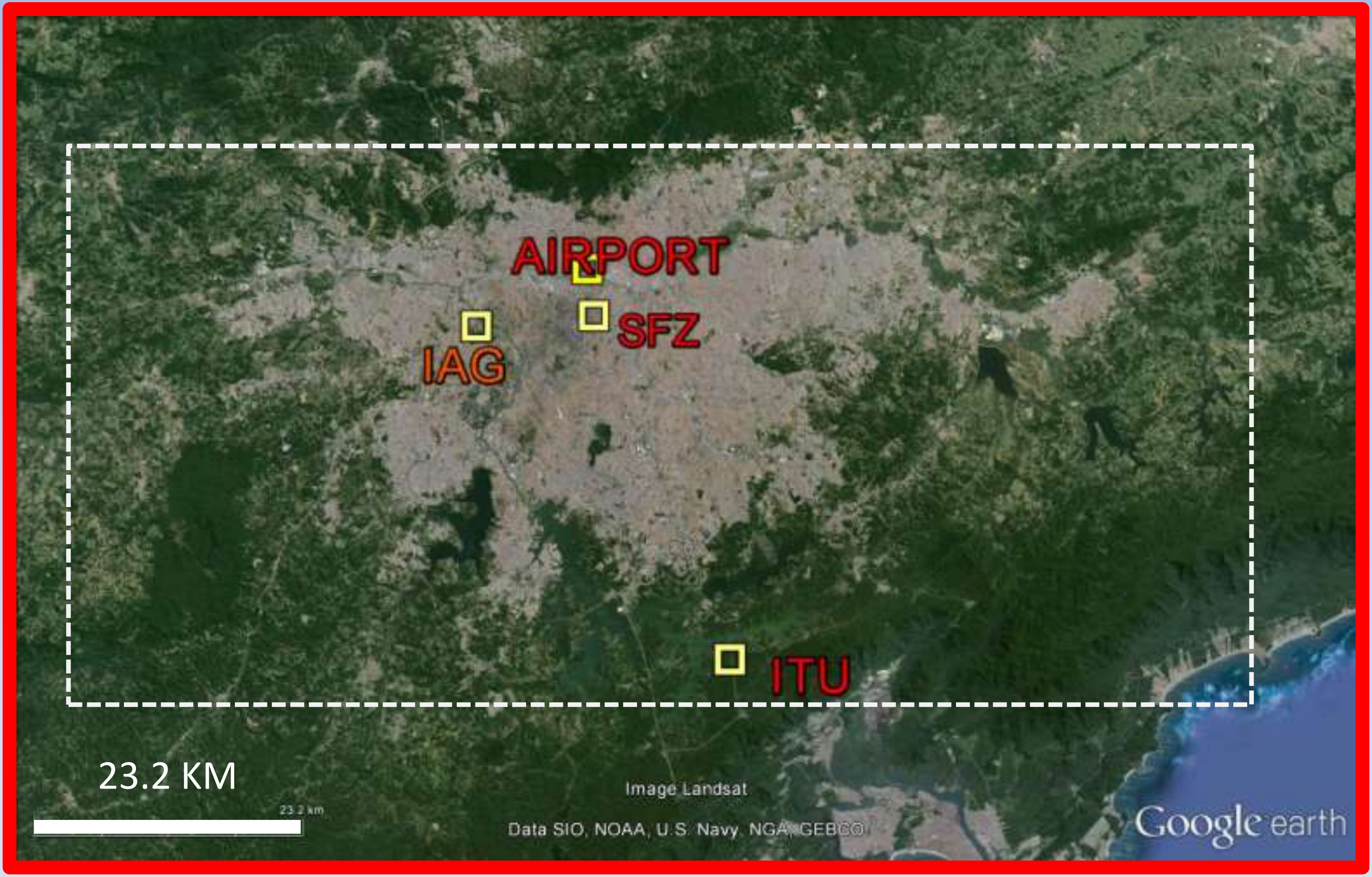
4. MCITY BRAZIL PROJECT



23º32'36“ S 46º37'59“W

22° 54′ 10″ S, 43° 12′ 28″ W

MCITY NETWORK – SÃO PAULO



MCITY NETWORK - RIO DE JANEIRO

PROJETO MCITY BRAZIL

Metropolitan Region of São Paulo					
Site	**landuse**	**height**	**Latitude**	**Longitude**	**Altitude***
IAG	Suburban	17 m	23º 33' 34'' S	46º 44' 01'' W	744 m
ITU	Rural	0 m	23° 49' 32'' S	46° 30' 32‟ W	760 m
SFZ	Urban	77 m	23 33' 01'' S	46 37' 49'' W	741 m
AIRPORT Campo de Marte	Suburban	0 m	23º 30' 32'' S	46º 38' 04'' W	722 m
Metropolitan Region of Rio de Janeiro					
Site	**landuse**	**height**	**Latitude**	**Longitude**	**Altitude***
IGEO	Suburban	12.5 m	22° 51' 26'' S	43° 14' 01'' W	10 m
AIRPORT Galeão	Suburban	0 m	22° 48' 32'' S	43° 14' 59'' W	10 m

(*) Above the mean sea level

MCITY NETWORK IN SÃO PAULO

- IAG (23°33’34” S; 46°44’01” W; 744 m)
- ITU (23°49'32"S ;46°30'32“W ;760 m)
- SFZ (23°33'0.23"S; 46°37'48.85“W; 758 m)

IAG

ITU

SFZ

MCITY NETWORK IN RIO DE JANEIRO

- IGEO (23°33’34” S; 46°44’01” W; 744 m)
- ITU (23°49'32"S ;46°30'32“W ;760 m)
- SFZ (23°33'0.23"S; 46°37'48.85“W; 758 m)

IAG

ITU

SFZ

IGEO MICROMETEOROLOGICAL PLATFORM

SUBURBAN SITE
IAG MICROMETEOROLOGICAL PLATFORM

IAG – INSTITUTE OF ASTRONOMY, GEOPHYSICS AND ATMOSPHERIC SCIENCES

IAG

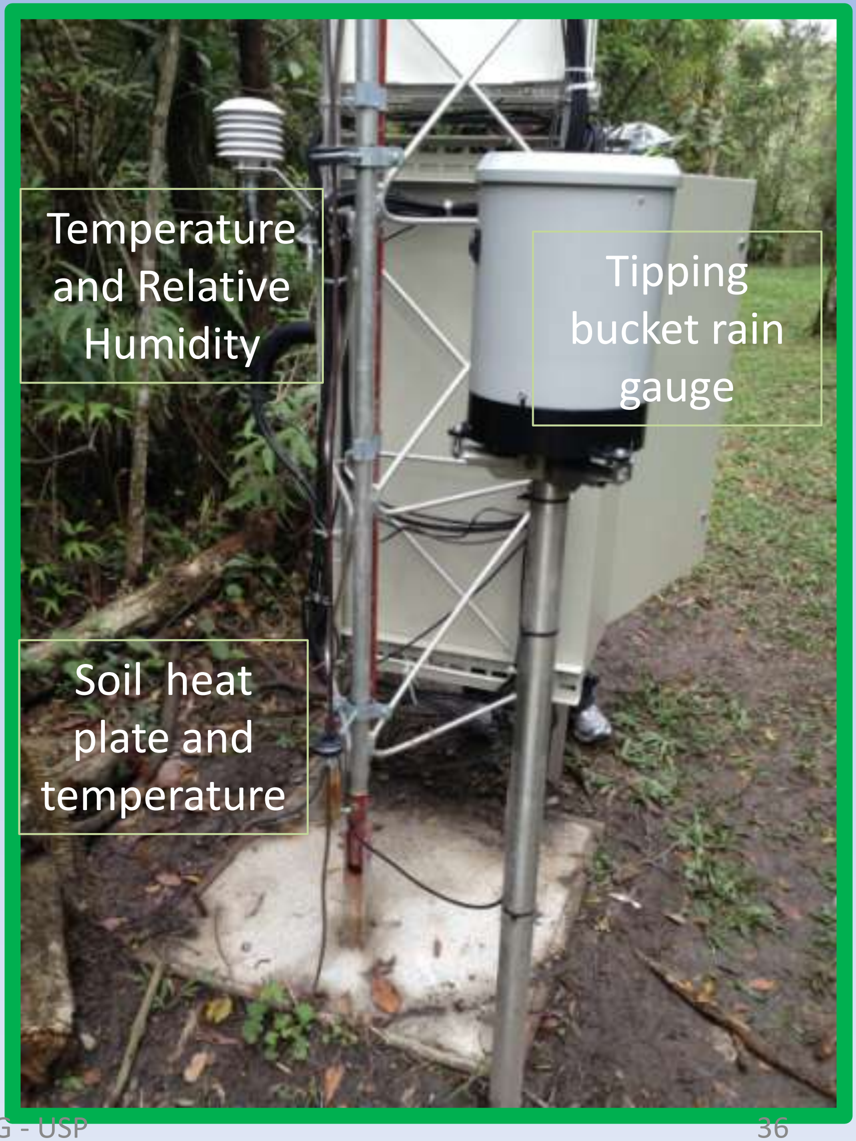
SUBURBAN SITE MEASUREMENTS DECEMBER, 2012

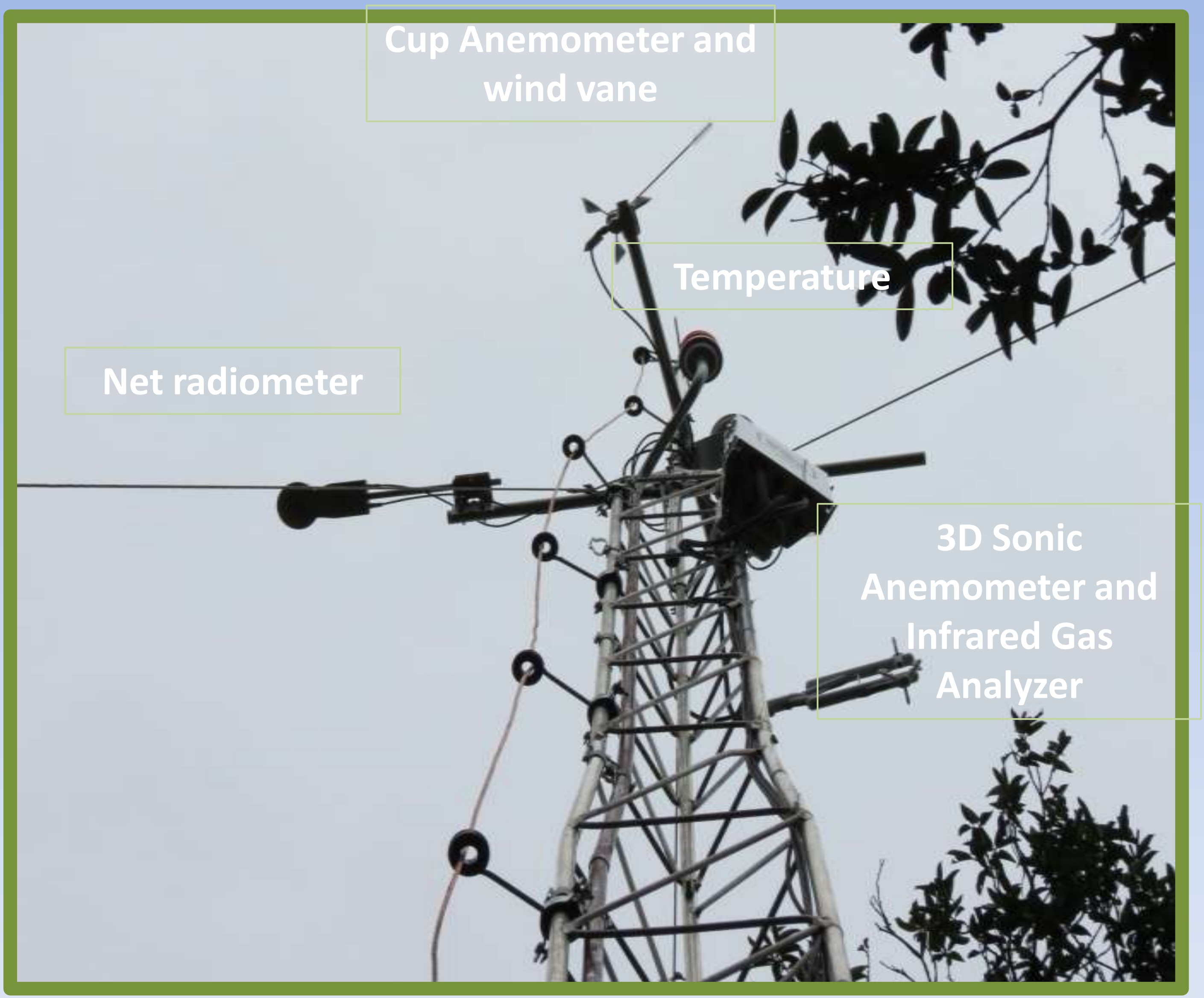
ITUTINGA MICROMETEOROLOGICAL PLATFORM

ITUTINGA PILÕES PARK

ATLANTIC FOREST

ITU - MICROMETEOROLOGICAL TOWER (10 m)




Cup Anemometer and wind vane
Temperature
Net radiometer
3D Sonic Anemometer and Infrared Gas Analyzer

ITU

RURAL SITE MEASUREMENTS APRIL 1, 2013

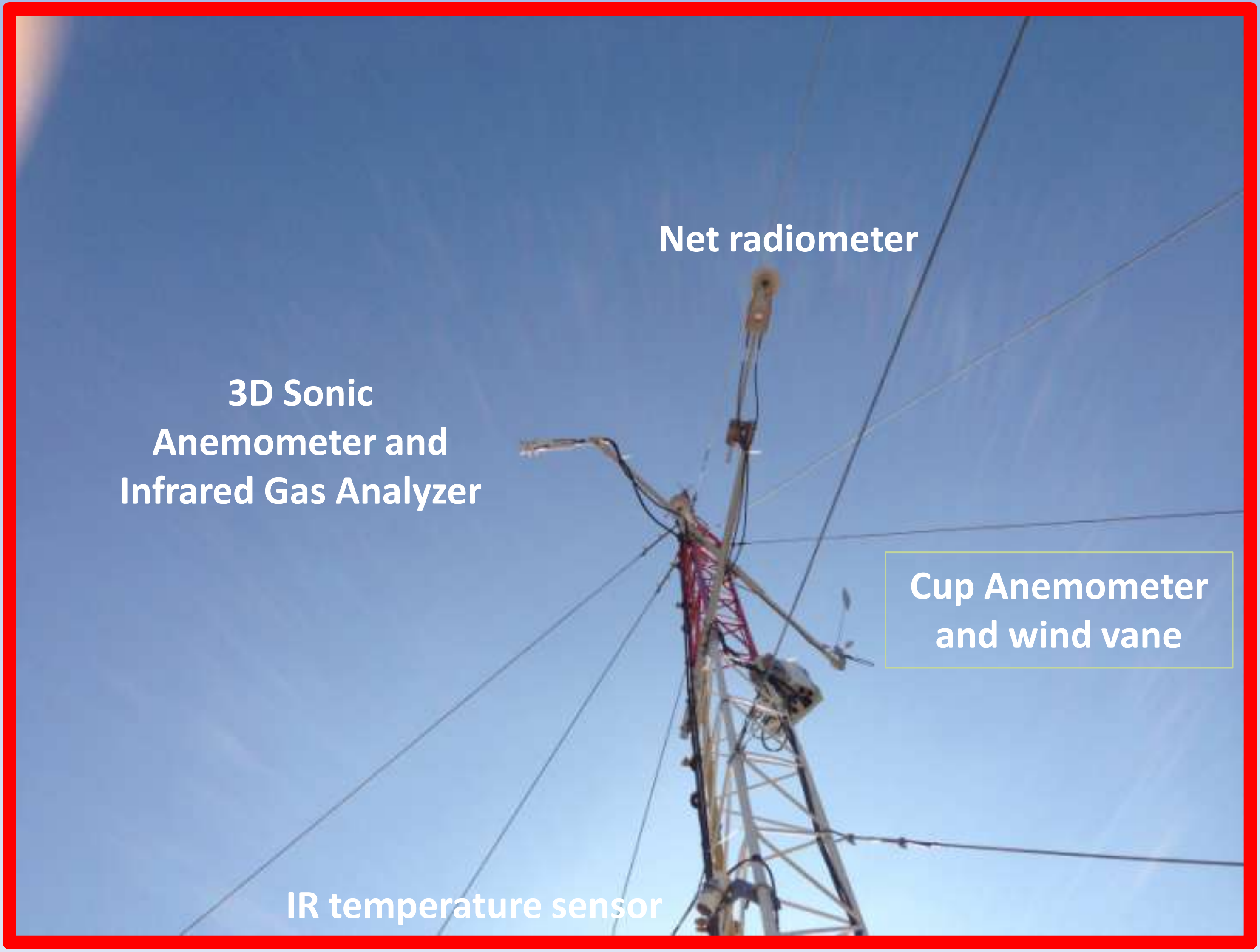
LABMICRO TEAM

URBAN SITE (SP DOWNTOWN)
SECRETARIA DA FAZENDA BUILDING
MICROMETEOROLOGICAL PLATFORM

SFZ

(70 m)

SFZ - URBAN SITE - SENSORS

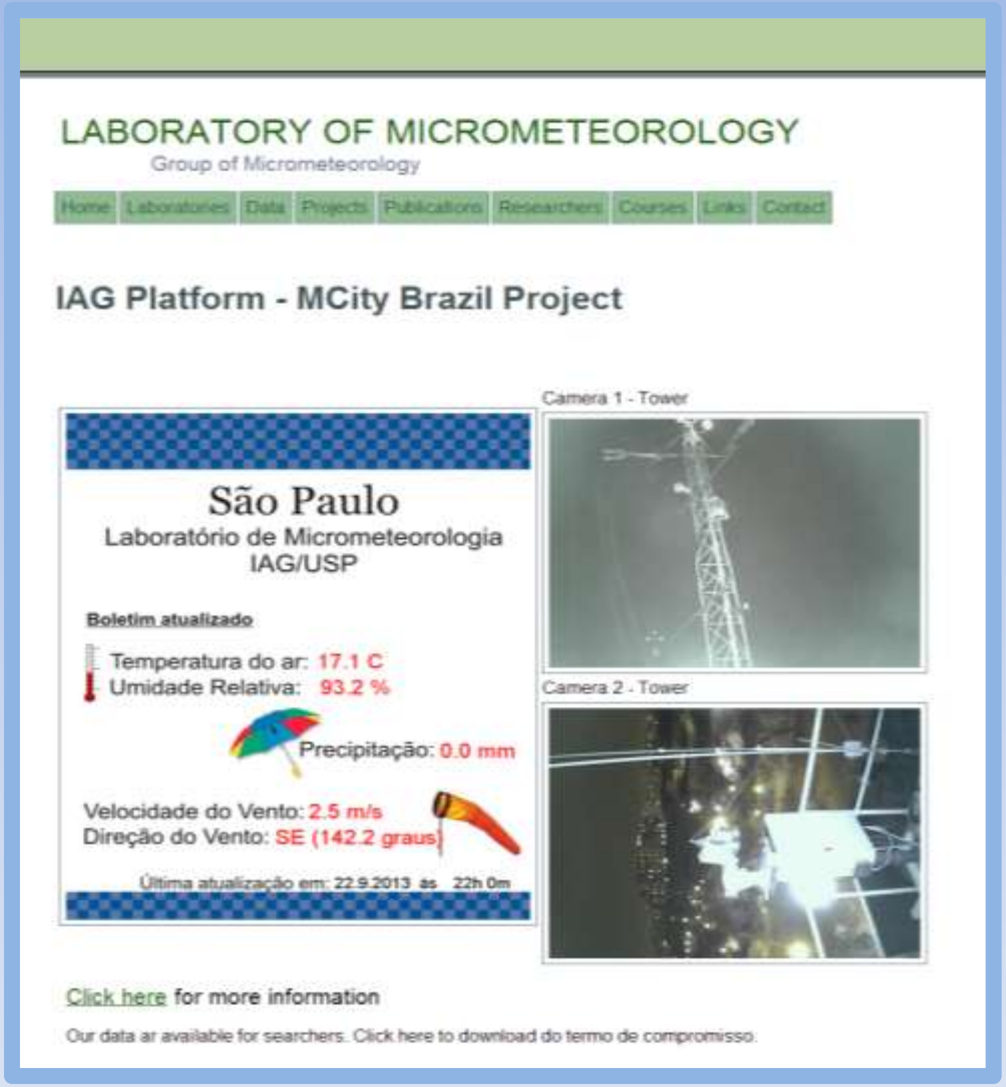


SFZ URBAN SITE - SENSORS

SFZ

URBAN SITE MEASUREMENTS JULY 3, 2013

(http://www.iag.usp.br/meteo/Labmicro/Data/Imagens/ImagesMP.html)

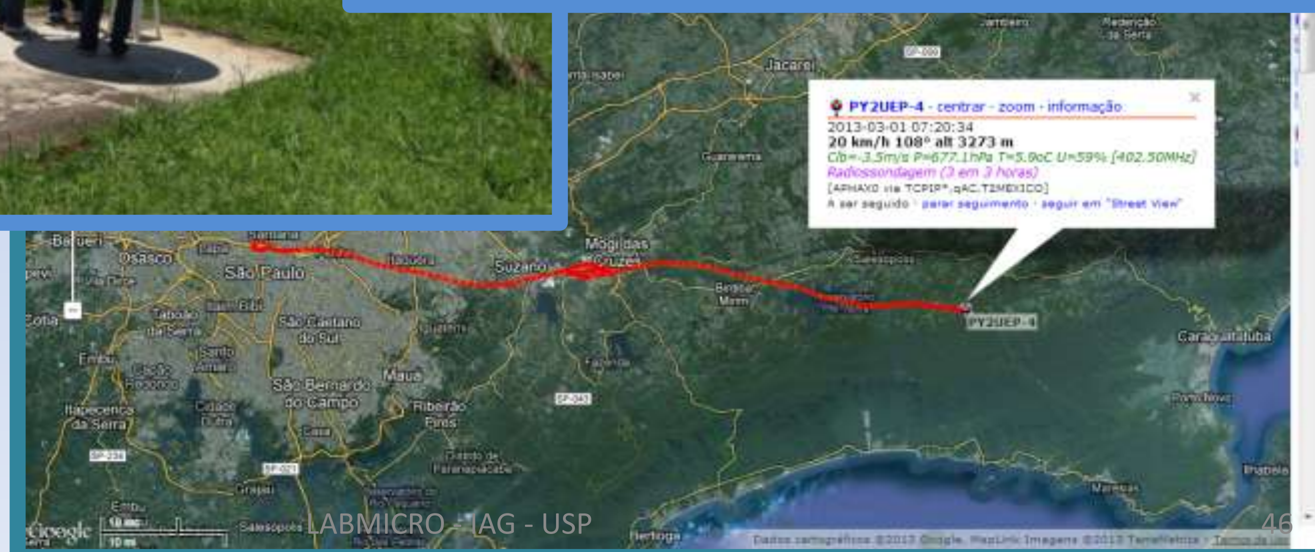


DATA AND IMAGE ARE AVAILABLE AT THE INTERNET FOR ALL SITES OF SP AND RJ.

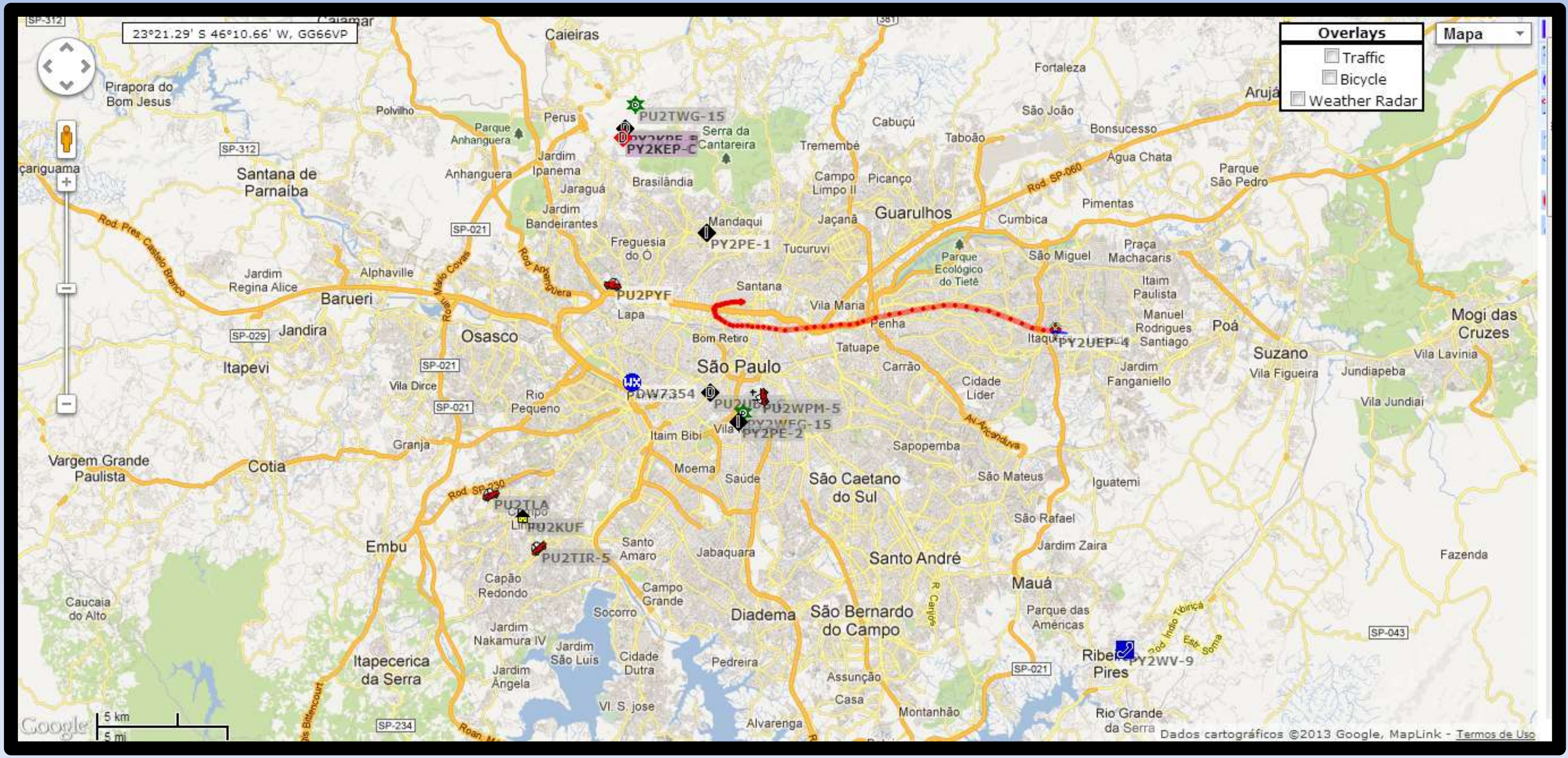
5. FIELD CAMPAIGNS

- RADIOSONDES (VAISALA)
- FEB 19-28: SUMMER CAMPAIGN
- AUG 06-15:WINTER CAMPAING
- 80 RELEASES (EACH 3 HOURS) PER CAMPAIGN
- LIDAR
- FEB: SUBURBAN SITE
- AUG: 3 SITES (URBAN, RURAL AND SUBURBAN)

FIELD CAMPAIGN IN SÃO PAULO AT THE CAMPO DE MARTE AIRPORT

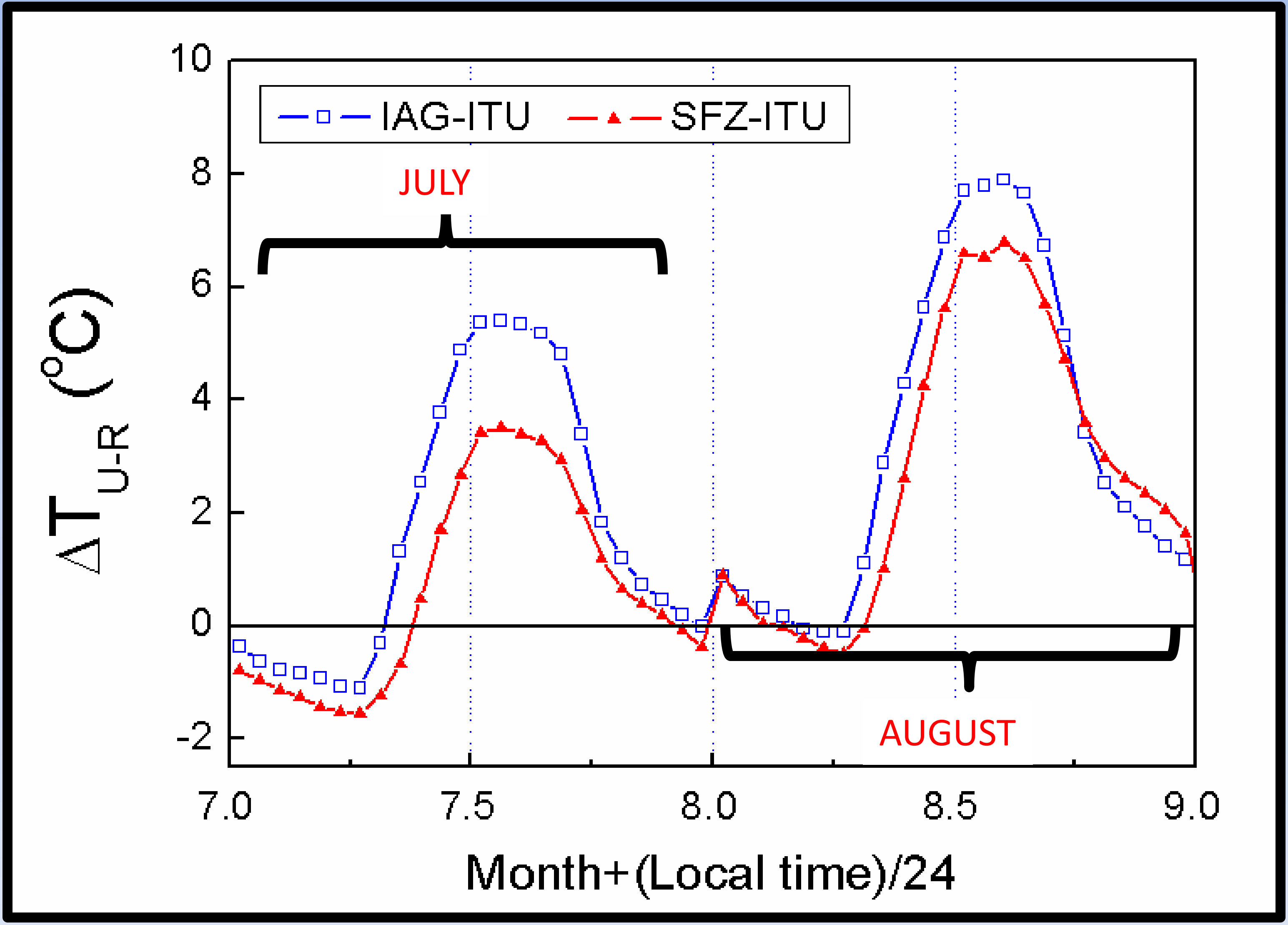


MOST OF THE TRAJECTORIES WERE LOCATED OVER THE URBAN AREA (Z<4000 M)

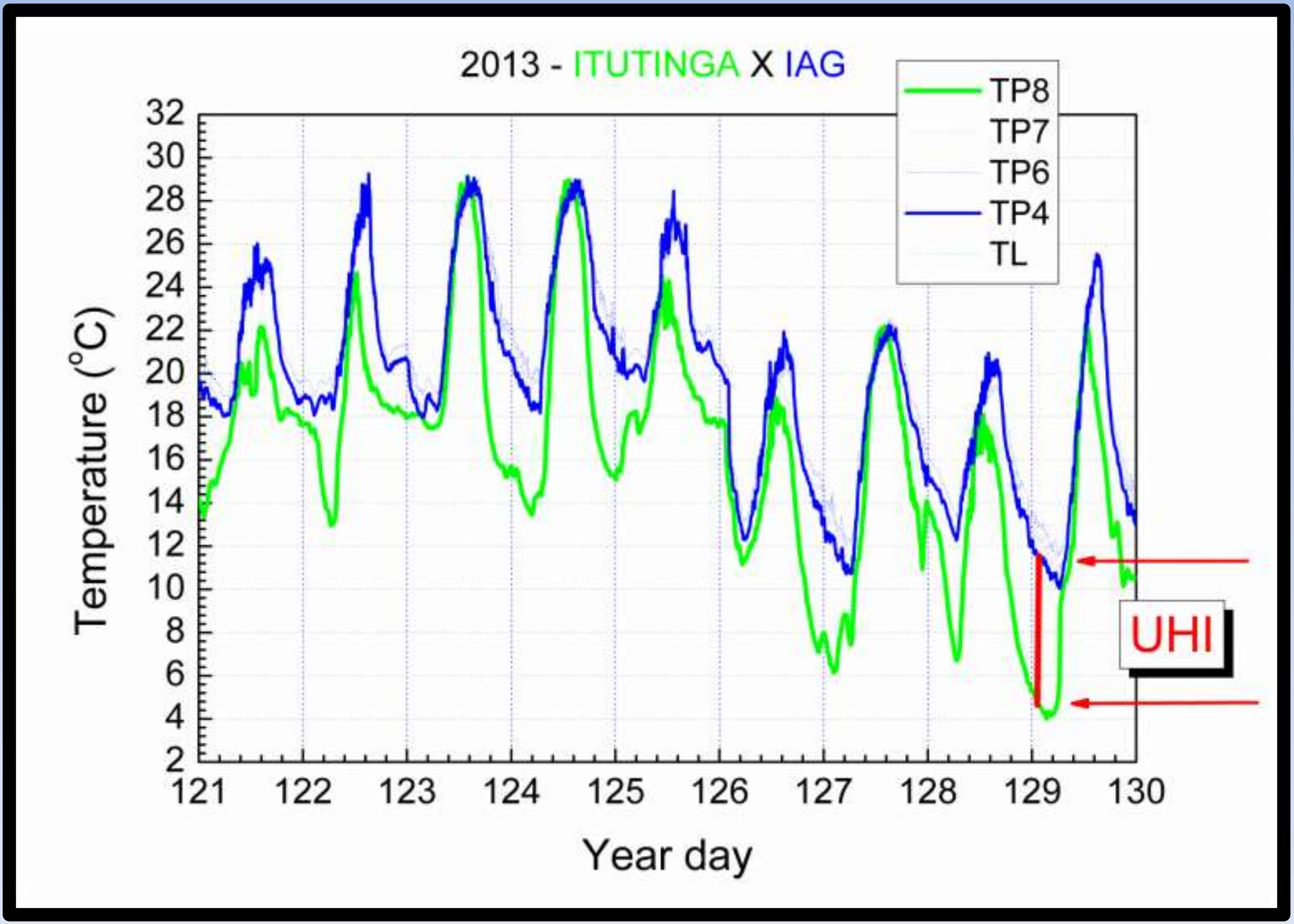


6. RESULTS

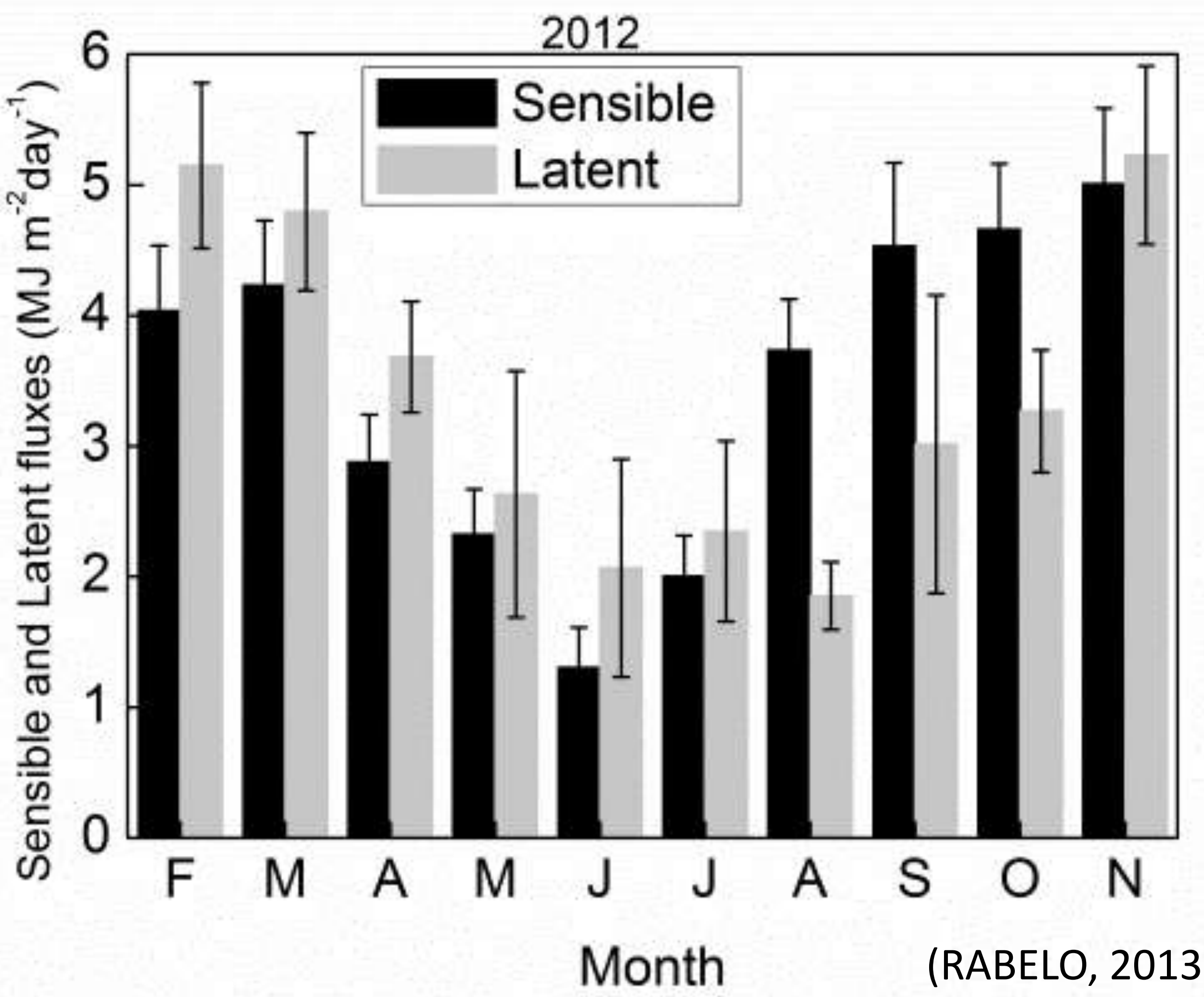
UHI IN SÃO PAULO (Monthly average)



UHI IN São Paulo (hourly values)

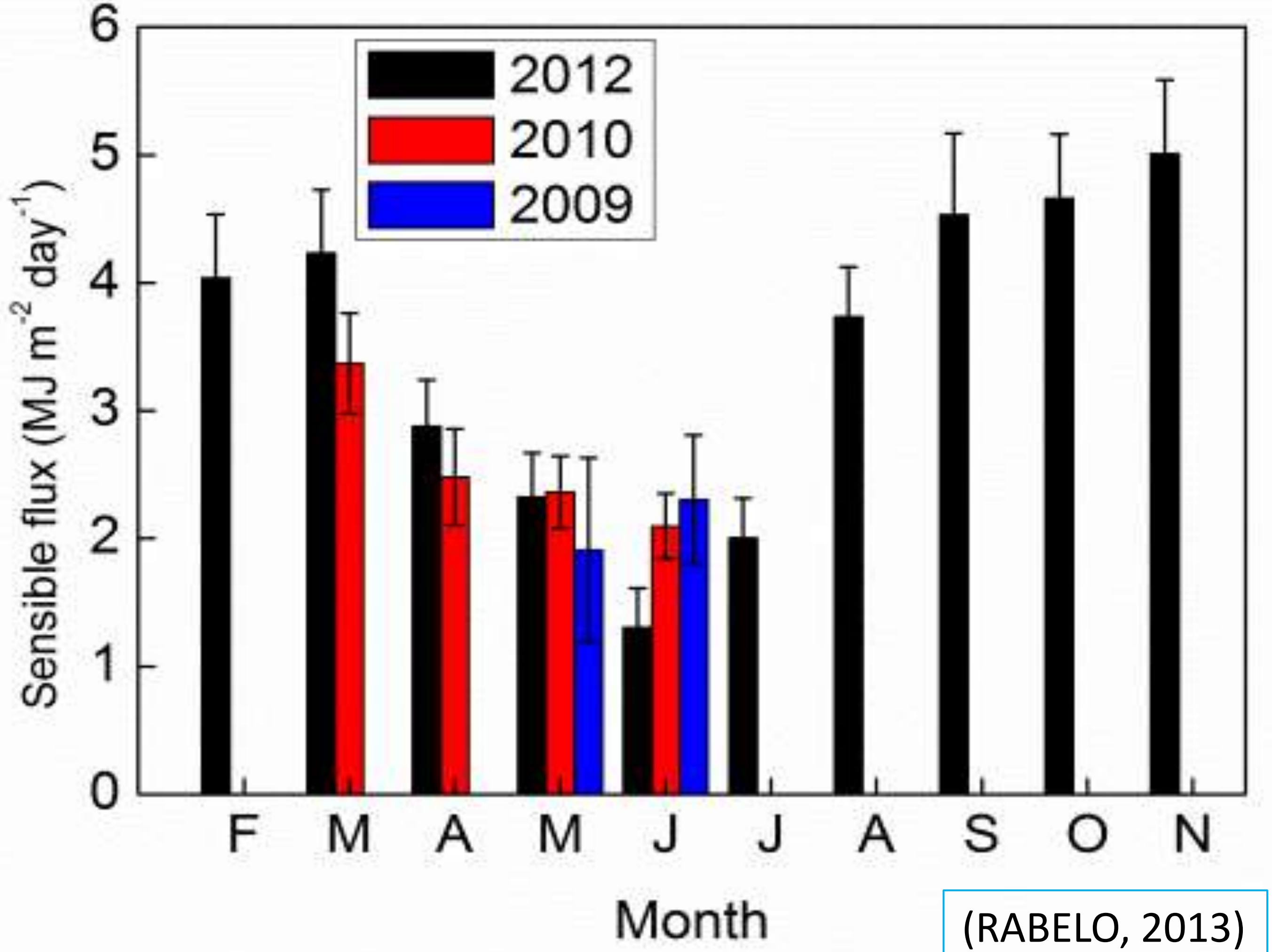


SEAZONAL VARIATION H AND LE IN SÃO PAULO



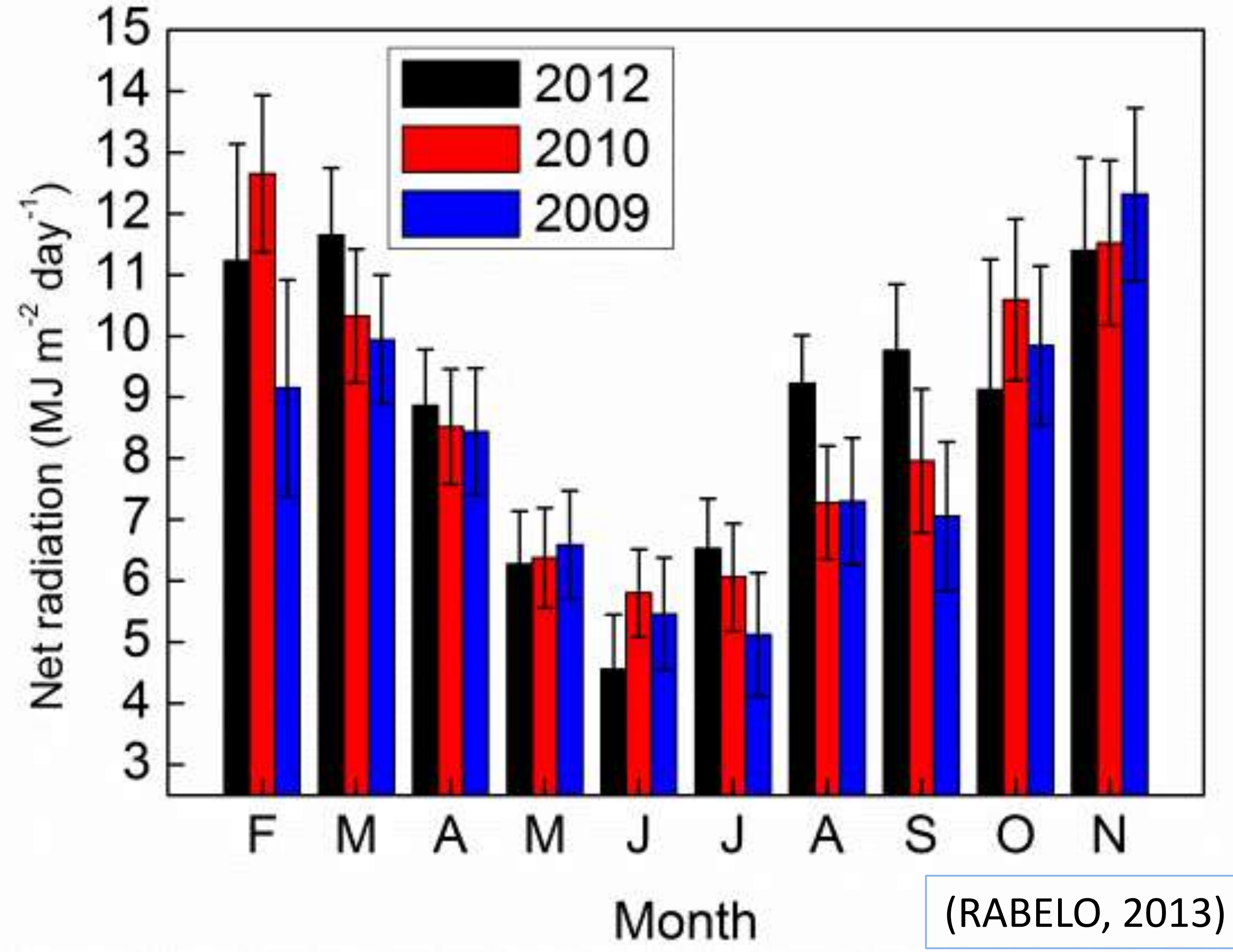
(RABELO, 2013)

INTERANUAL VARIATION IN SÃO PAULO



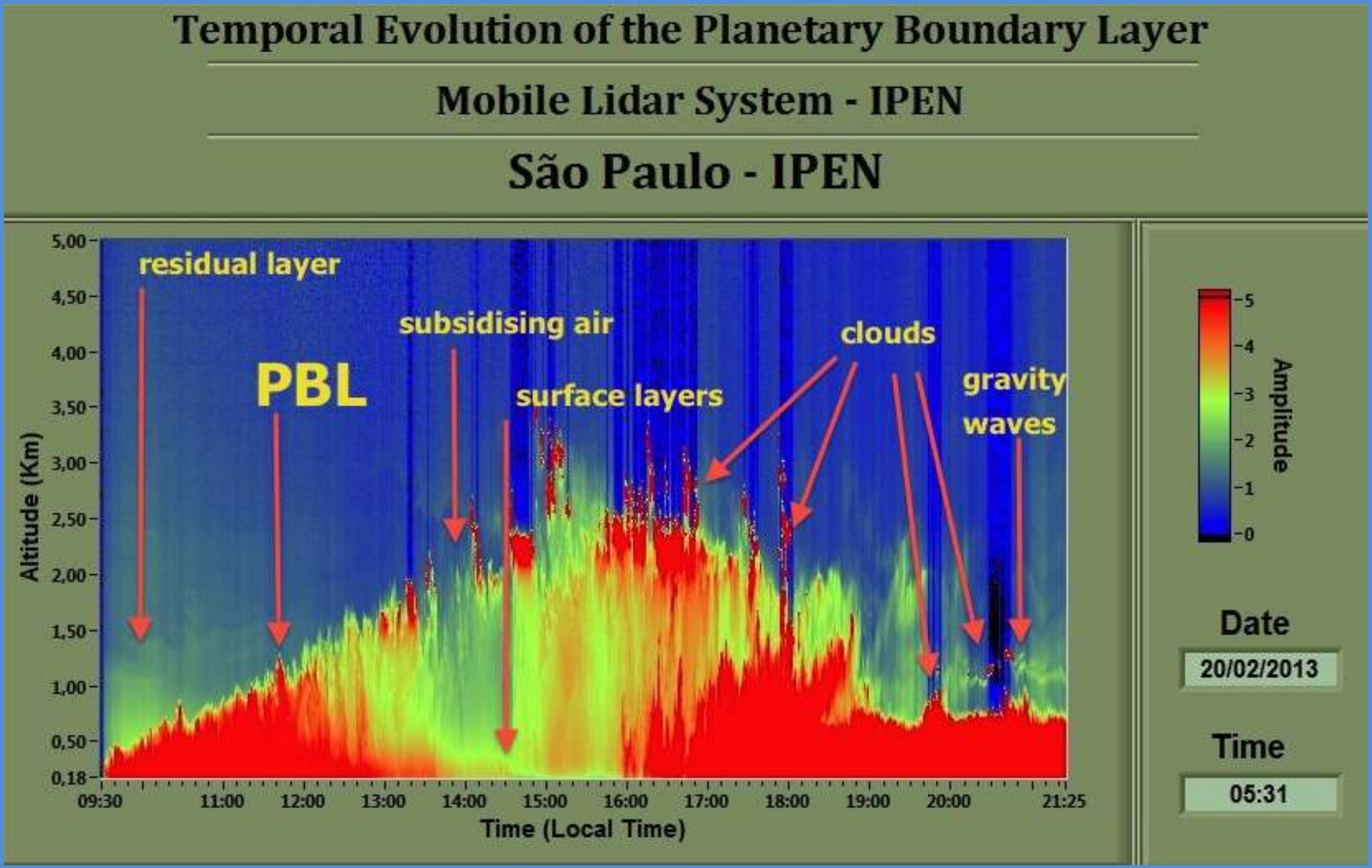
(RABELO, 2013)

NET RADIATION AT SURFACE SÃO PAULO

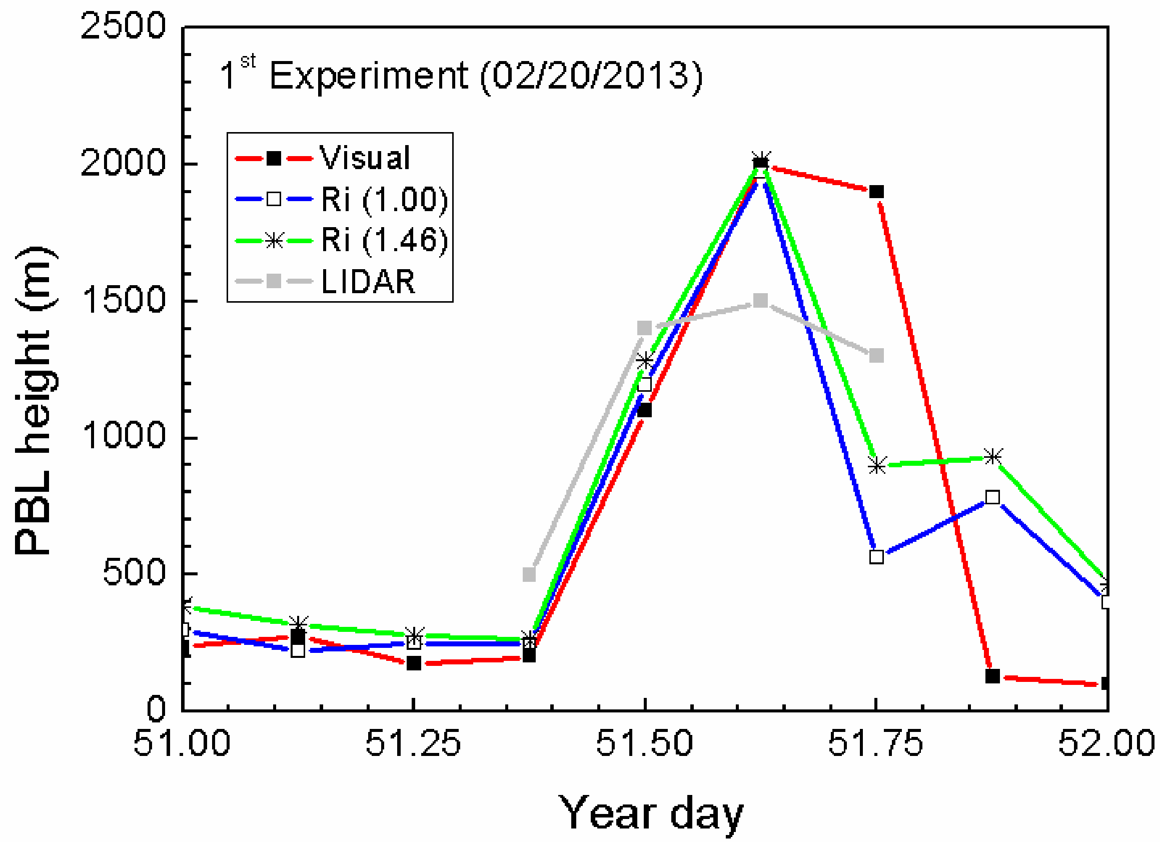


(RABELO, 2013)

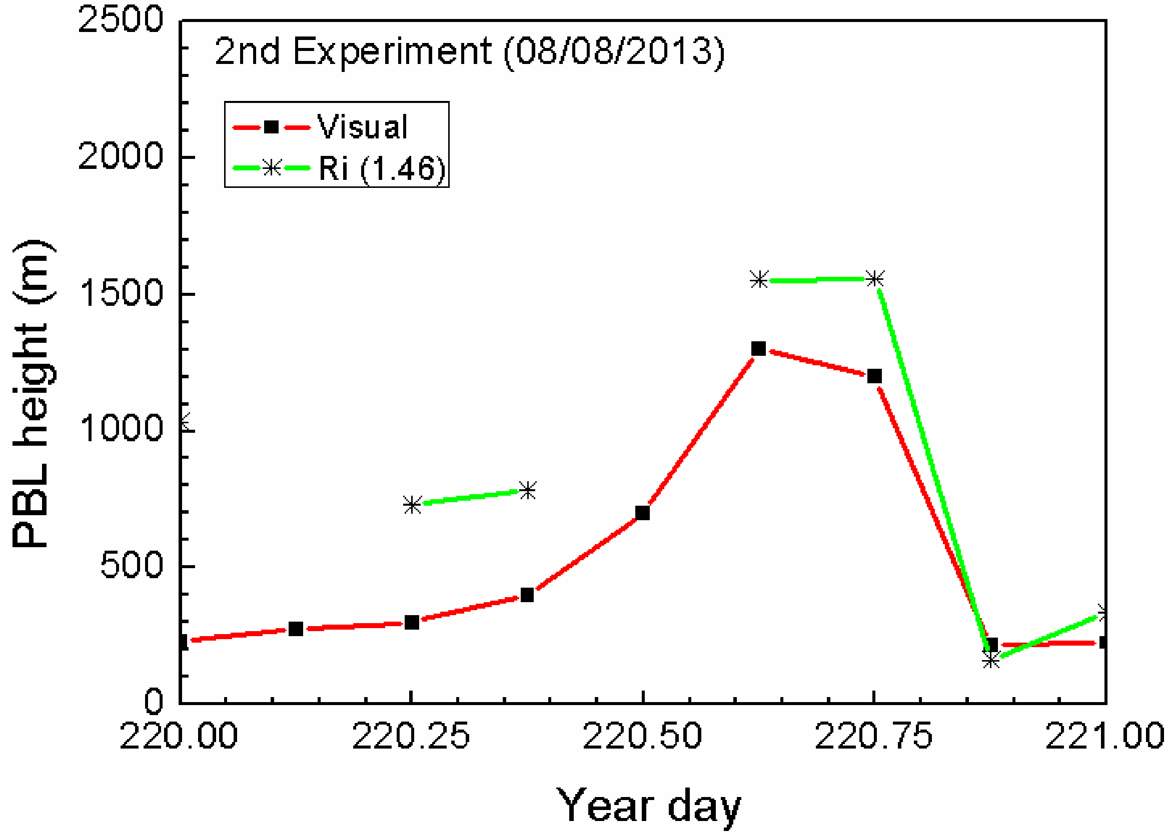
LIDAR MEASUREMENTS IN SÃO PAULO



SUMMER CAMPAIGN IN SÃO PAULO



WINTER CAMPAIGN SÃO PAULO



CONCLUSION

- MCITY BRAZIL ACCOMPLISHED ALL GOALS
- SÃO PAULO FLUX NETWORK: URBAN, SUBURBAN AND RURAL ARE OPERATING.
- 4 FIELD CAMPAIGN: FEBRUARY (SUMMER) AND AUGSTU (WINTER). 162 RADIOSSONDES DURING 20 DAYS, EACH 3 HOURS.
- LIDAR MEASUREMENTS IN SÃO PAULO AND RIO DE JANEIRO

CONCLUSION

Urban heat island: Nighttime also

Surface energy balance: $H_{URBAN} < H_{RURAL}$

Urban Boundary Layer: PBL height (100-2500) Low Level Jets (nocturnal) more evident in winter.

Landuse characterization: we still need to work on that.