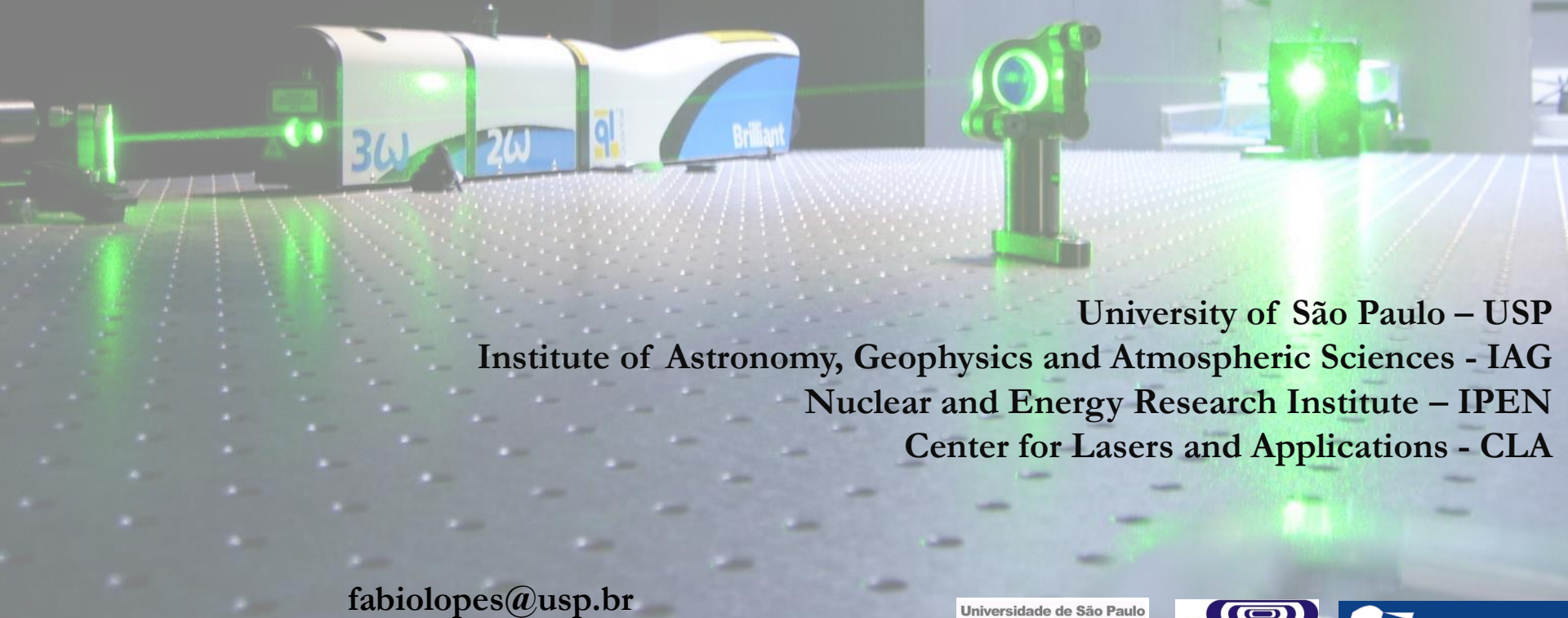# Synergy between multichannel Raman Lidar system and spaceborne remote sensing platforms applied to study aerosol optical properties at Metropolitan Area of São Paulo – Brazil
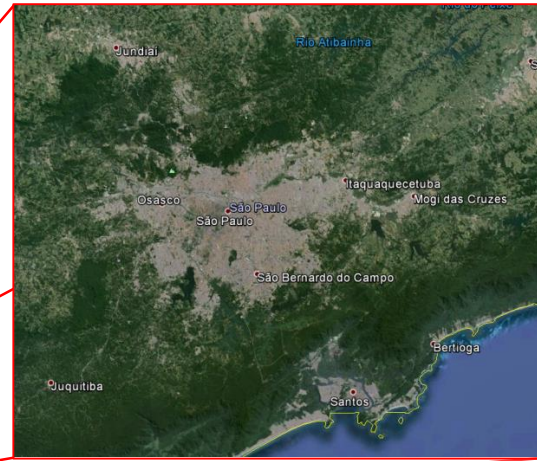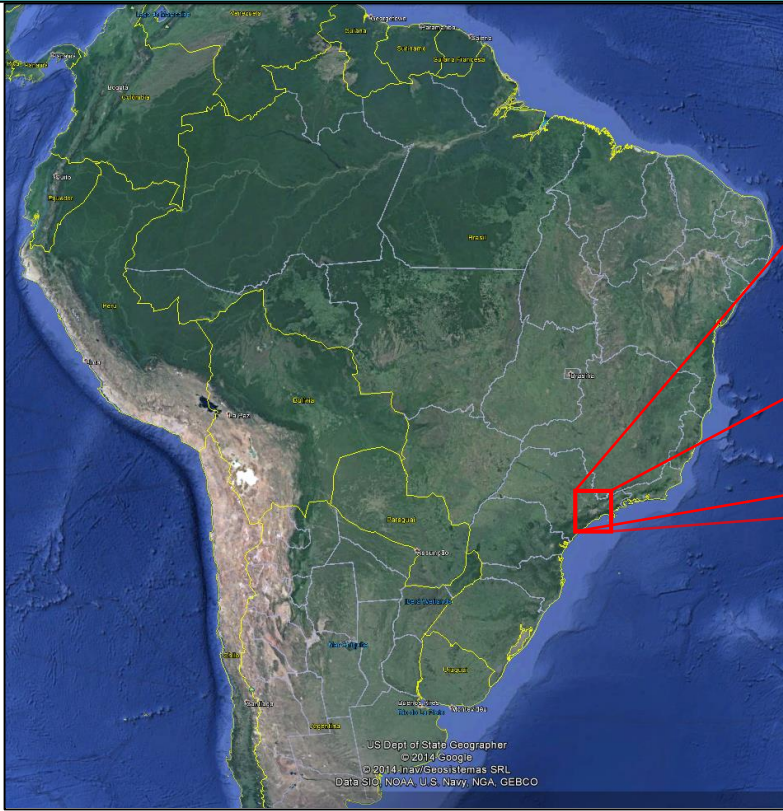
Fábio J. S. Lopes
Gregori A. Moreira, Felipe V. Araujo, Maria F. Andrade and
Eduardo Landulfo

University of São Paulo – USP
Institute of Astronomy, Geophysics and Atmospheric Sciences - IAG
Nuclear and Energy Research Institute – IPEN
Center for Lasers and Applications - CLA

fabiolopes@usp.br

VIII Workshop on Lidar Measurement in Latin America, Cayo Coco, Cuba, 6 - 10 April, 2015

Universidade de São Paulo
USP
ipen
FAPESP
SÃO PAULO RESEARCH FOUNDATION

Metropolitan Area of São Paulo (MASP)

- ✓ **85% light-duty vehicles**

- ✓ **6% heavy-duty vehicles**

- ✓ **9% motorcycles**

- ✓ **Unique fleet – ethanol or gasoline-ethanol mixture**

- ✓ **More than 20 millions of inhabitants**

- ✓ **Several sources of particulate matter pollution**

- ✓ **Main source: Automotive fleet ≥ 8 millions of vehicles**

- ✓ **Automotive fleet contributes to degrade of air quality at MASP**

- ✓ **Especially during the winter/dry season**

MASP air quality monitoring

26 air quality stations

NO O_3 $PM_{2.5}$
NO_2 SO_2 PM_{10}
NO_x
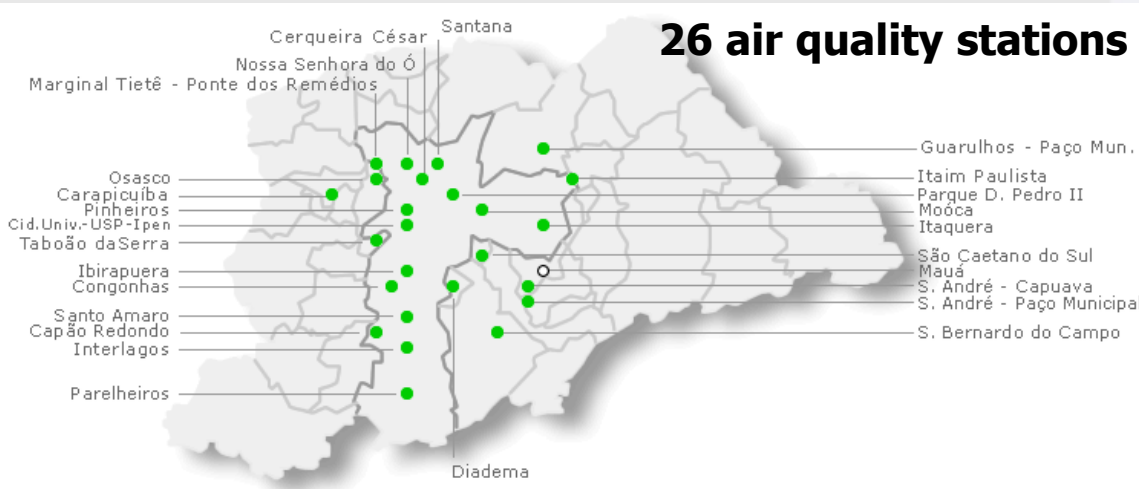
AIR QUALITY INDEX

| Air Quality Index (AQI) Values	Levels of Health Concern
0 to 50	Good
51-100	Moderate
101-150	Unhealthy for Sensitive Groups
151-200	Unhealthy
201-300	Very Unhealthy
301 to 500	Hazardous

✓ **Automotive fleet contributes to degrade of air quality at MASP**

✓ **Especially during the winter/dry season**

✓ **Highly favorable for air pollutant accumulation during episodes of intense temperature inversions**

✓ **Hourly air quality data provided by São Paulo Sanitation Technology Company (CETESB)**

MASP air quality monitoring

26 air quality stations
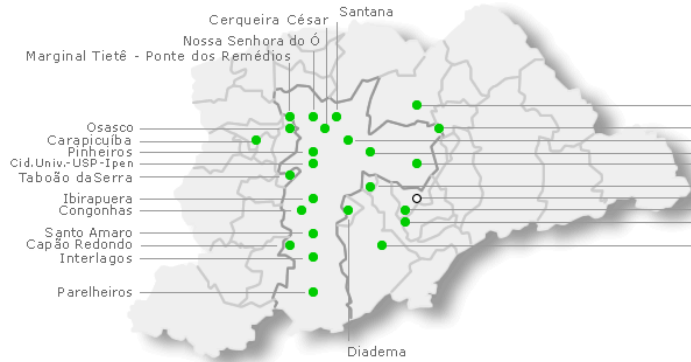
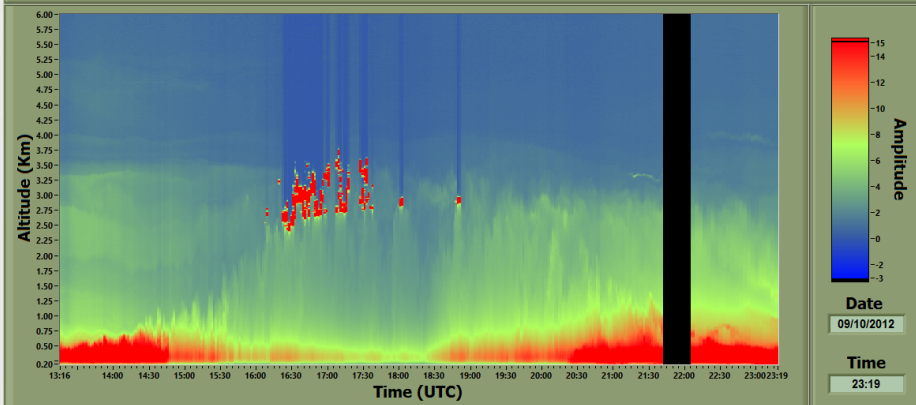## Particulate Matter distribution – CETESB
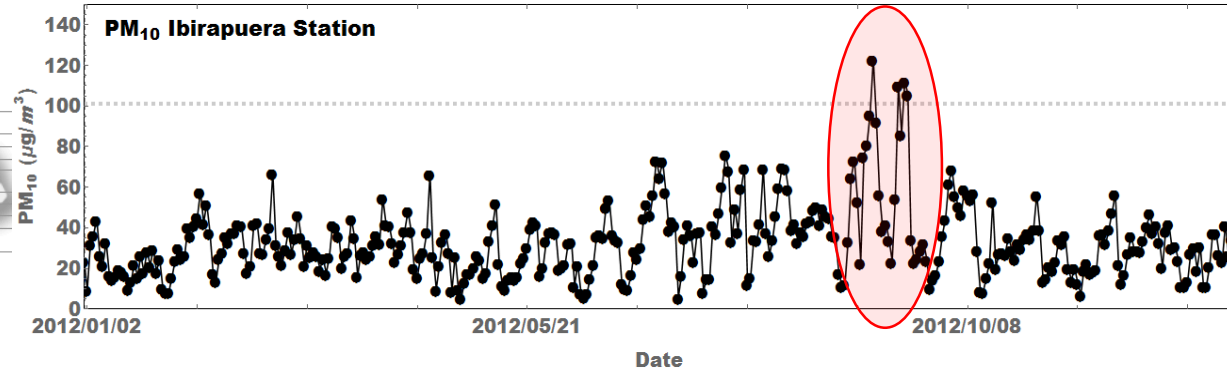
Local pollution ⇒ increase the particulate matter concentration

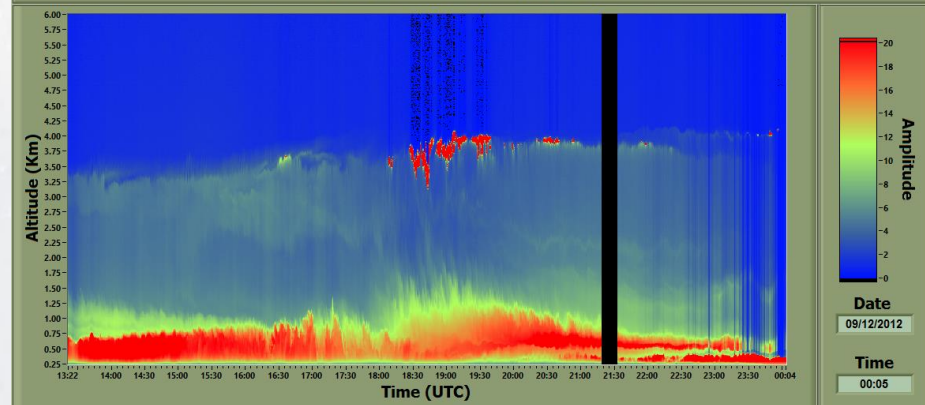**In some cases ⇒ related to the advection of aerosols transported from long-range distance areas**

Range corrected lidar measurements for 10th and 12th of September 2012

Elastic backscatter and Raman Lidar system

Nd:YAG laser – CFR200	120 mJ @ 532 nm
Channels	532 nm (FWHM 0.5 nm) 607 nm (FWHM 1.0 nm)
PMTs	Hamamatsu R9880U-110
Vertical Resolution	7.5 m

Elastic backscatter and Raman Lidar system

Nd:YAG laser – Brilliant B	400 mJ and 230 MJ @ 532 and 355 nm
Channels	532 nm (FWHM 1.0 nm) 607 nm (FWHM 0.25 nm) 660 nm (FWHM 0.25 nm) 355 nm (FWHM 1.0 nm) 387 nm (FWHM 0.25 nm) 408 nm (FWHM 0.25 nm)
PMTs	Hamamatsu PM-HV-P03-R7400 / PM-R9880-20
Vertical Resolution	7.5 m

Products

- ✓ Aerosol backscatter profiles (β)
- ✓ Lidar ratio profiles (LR)
- ✓ Aerosol extinction profiles (α)
- ✓ Water vapor profiles

Remote sensing instruments

CALIPSO - Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observation

Launched in 2006

NASA and CNES

collaboration

CALIOP - Cloud Aerosol Lidar with Ortogonal Polarization

Level 1 data	Level 2 data
Total attenuated backscatter profiles at 532 nm	Aerosol Optical Depth AOD at 532 nm
Aerosol and clouds profiles	Number of aerossol layers
	Aerosol subtype

AQUA satellite - MODIS instrument Moderate Resolution Imaging Spectroradiometer
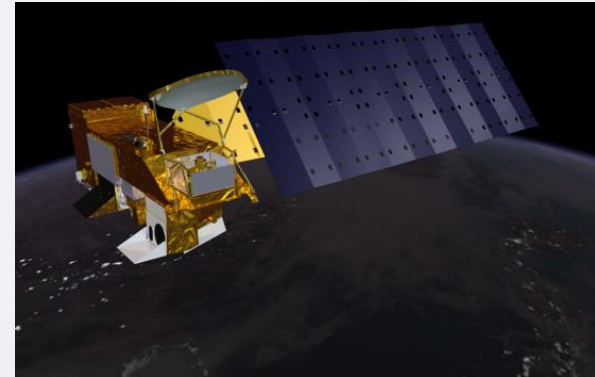
Aerosol Optical Depth at 550 nm

from atmosphere Level 2 aerosol products

51 Modis Collection

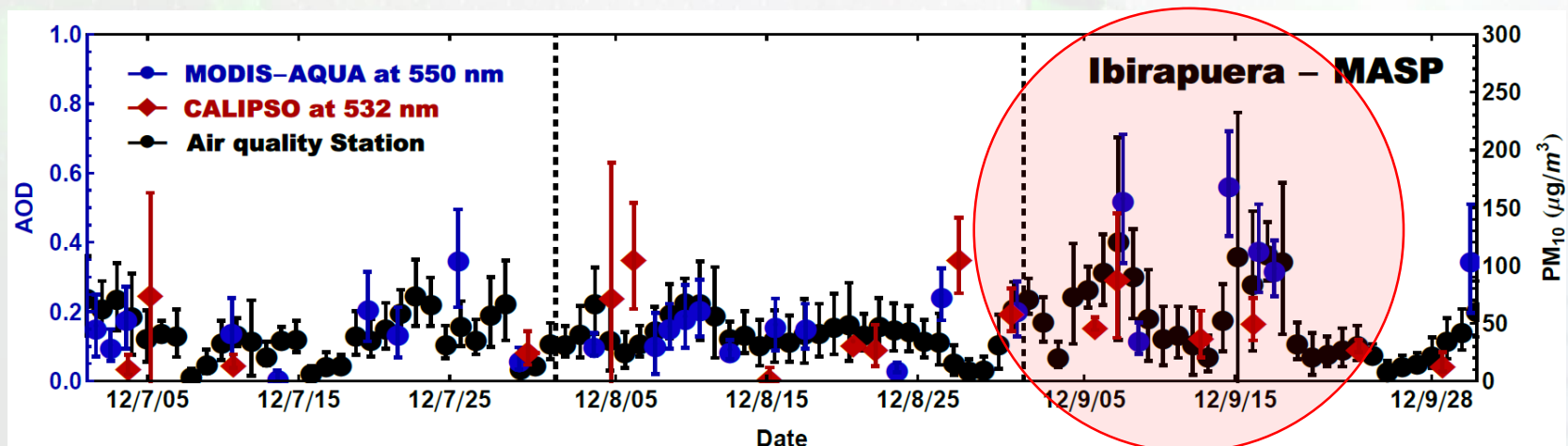**10 km AOD data resolution**

Selected area: 40 x 40 km

AERONET Sunphotometer

✓ **Aerosol optical Depth (AOD at 532 nm interpolated)**

✓ **Angstrom Exponent**

✓ **Lidar ratio**

$$S_{aeronet} = \frac{4\pi}{\omega(\lambda)\,P(180°)}$$

Focus fire in the Brazilian territory
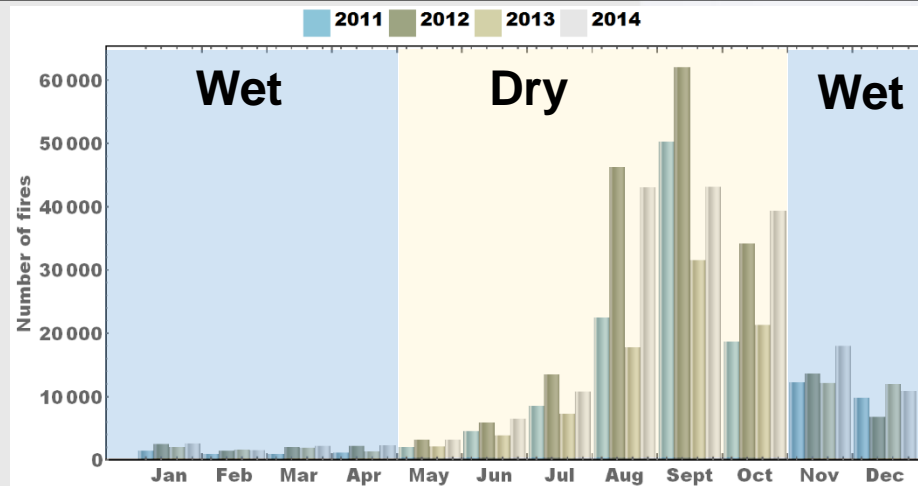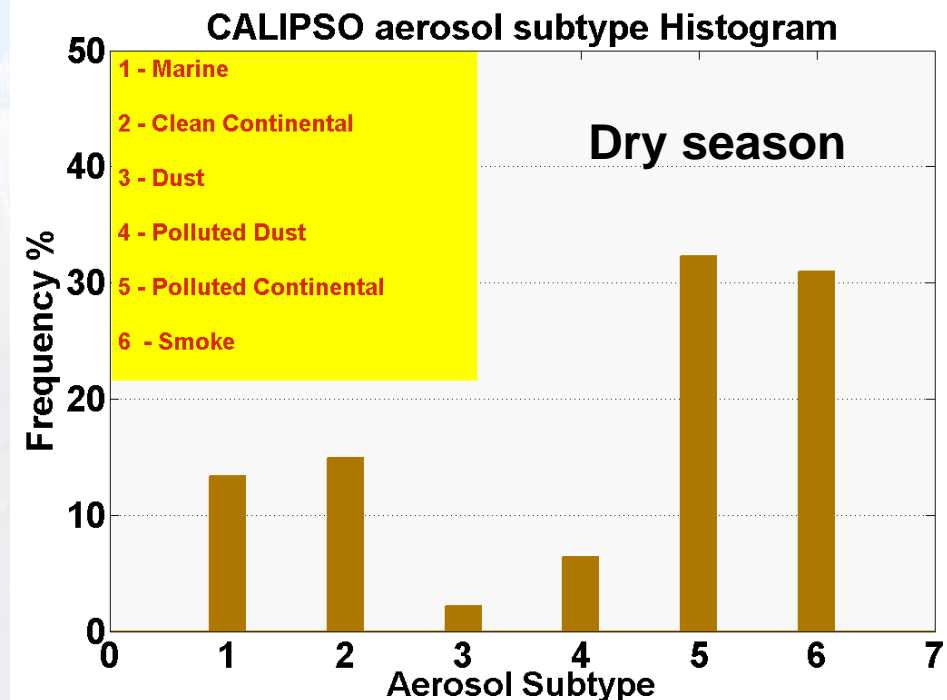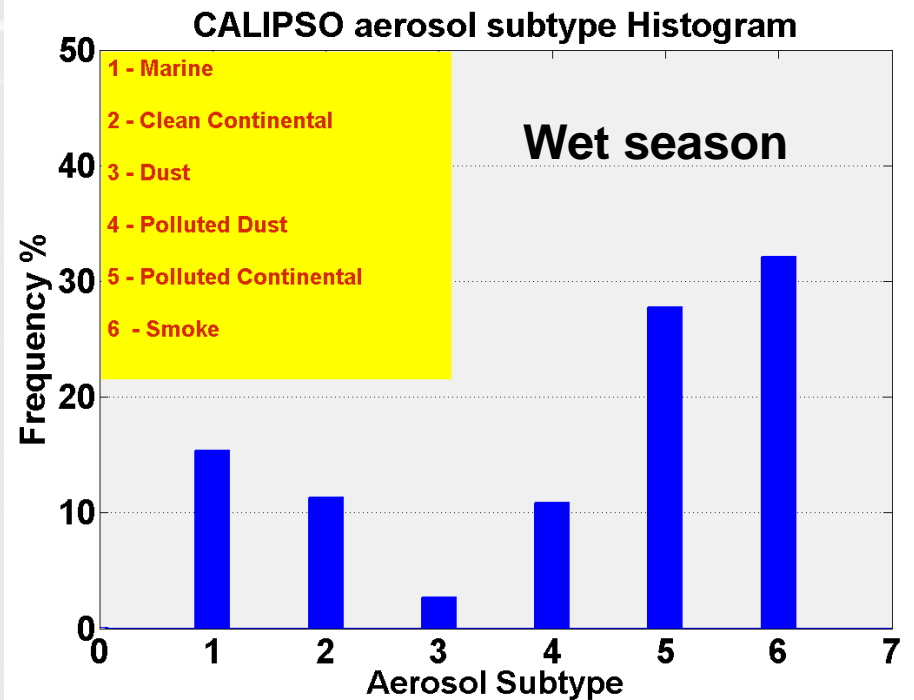

http://sigma.cptec.inpe.br/queimadas/estatisticas.php
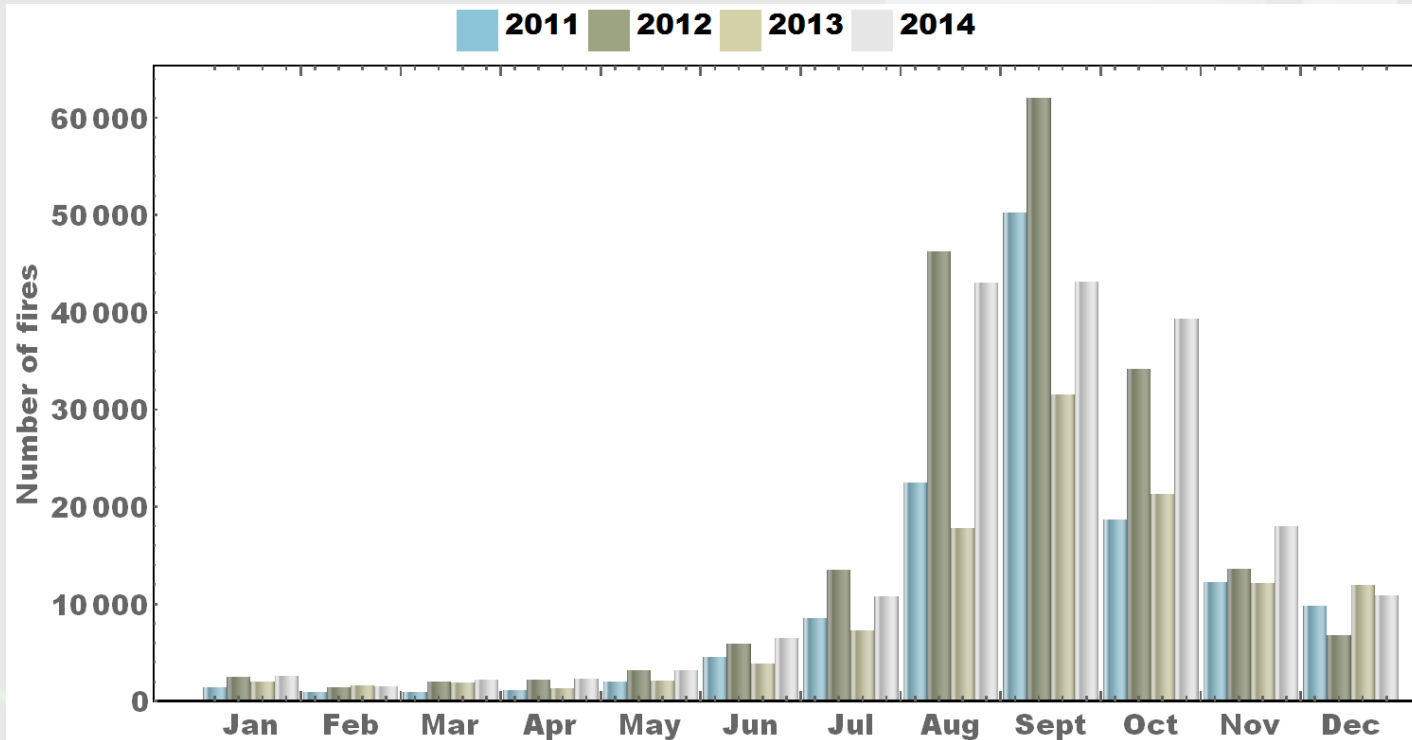
Focus fire increases ⇔ increases the AOD and particulate matter concentration
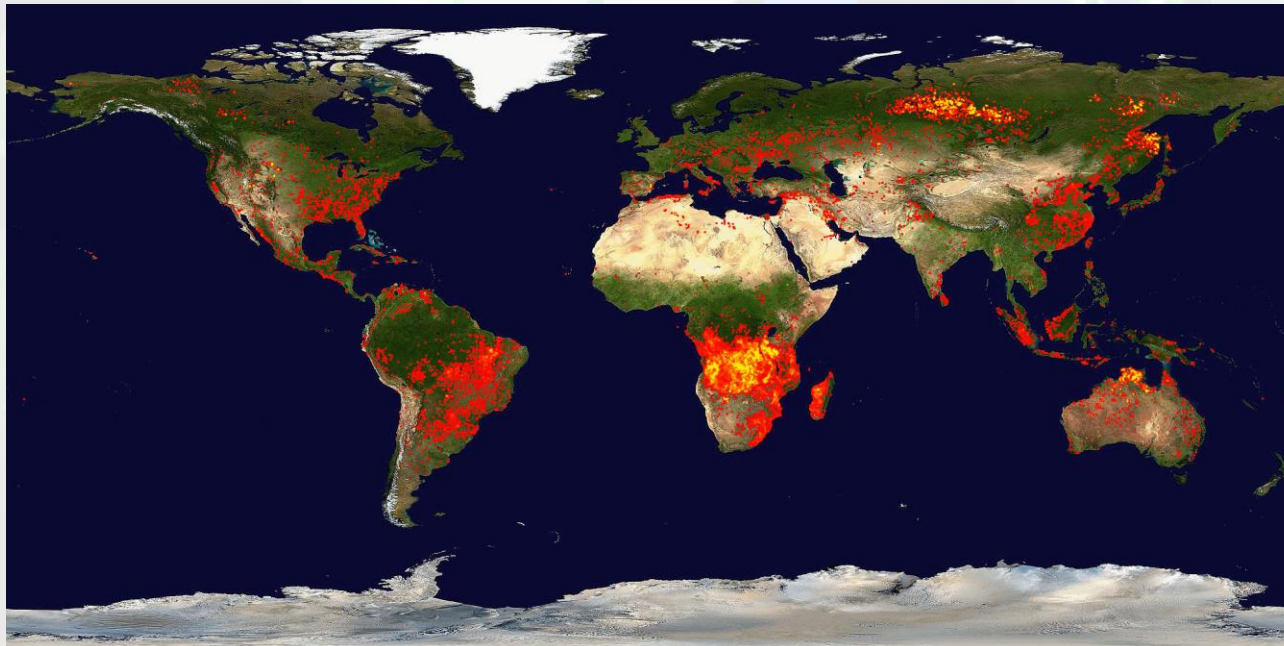
Focus fire in the Brazilian territory

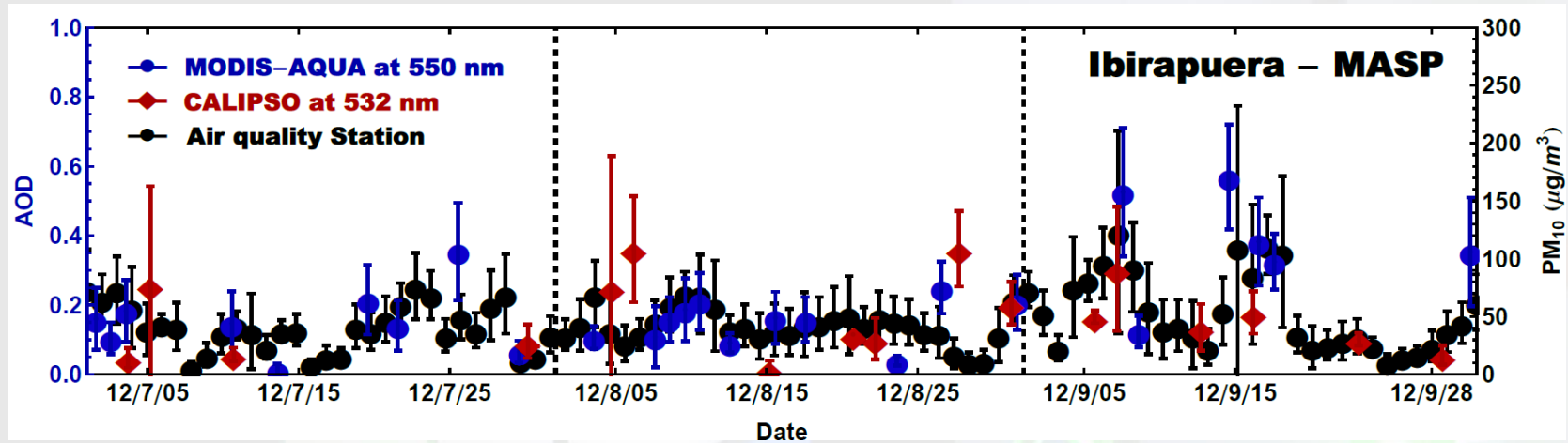**CALIPSO Aerosol type according to dry and wet season over MASP on the period of 2011-2014**
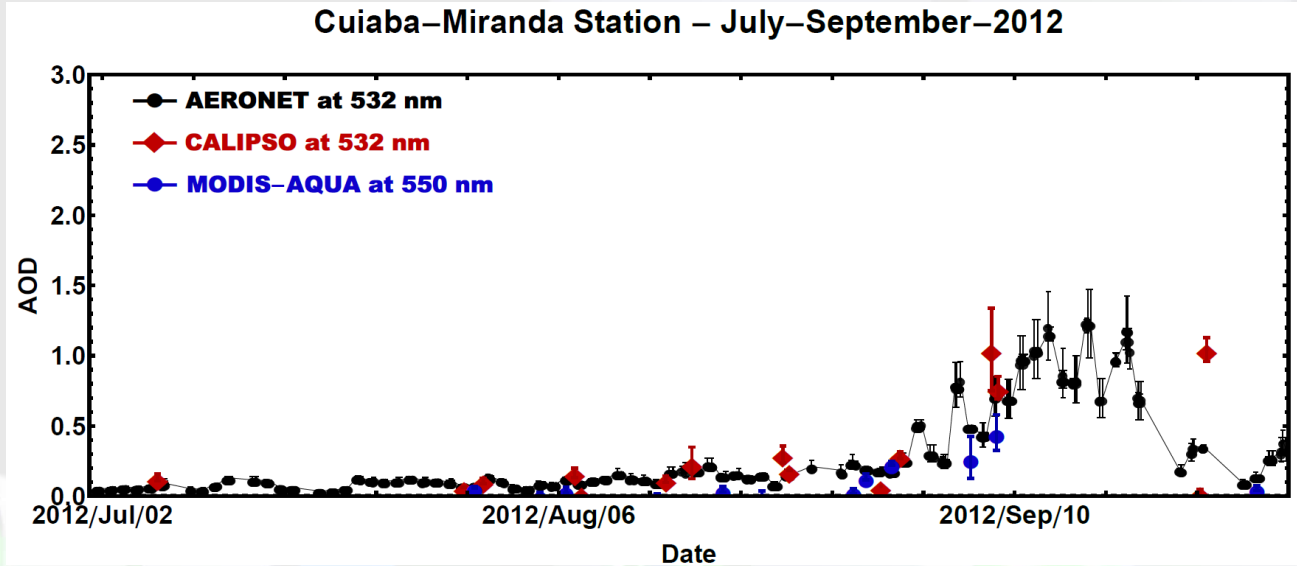
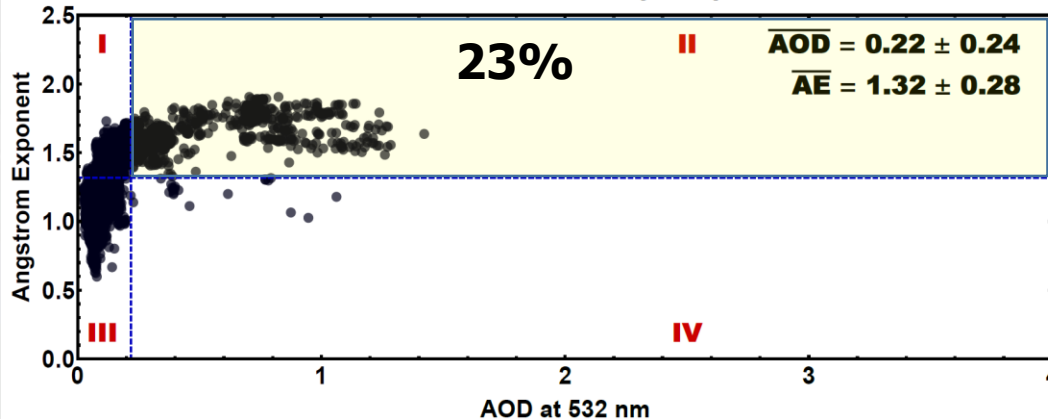## AOD and particulate matter concentration

Fire spots from July to September of 2012

# Investigating the scenario at Mid-Western and North of Brazil

Cuiaba–Miranda Station – July–September–2012
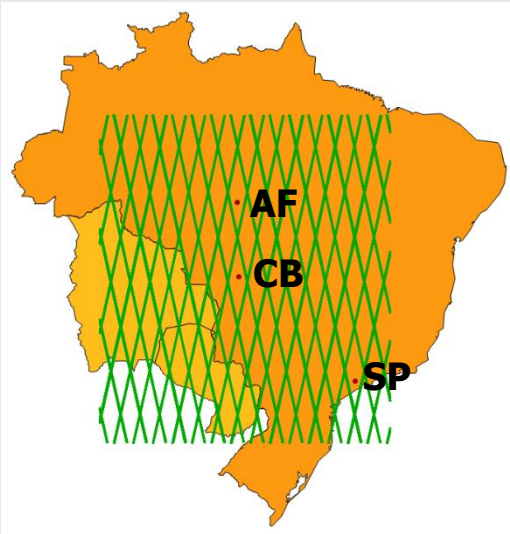
- AERONET at 532 nm
- CALIPSO at 532 nm
- MODIS–AQUA at 550 nm
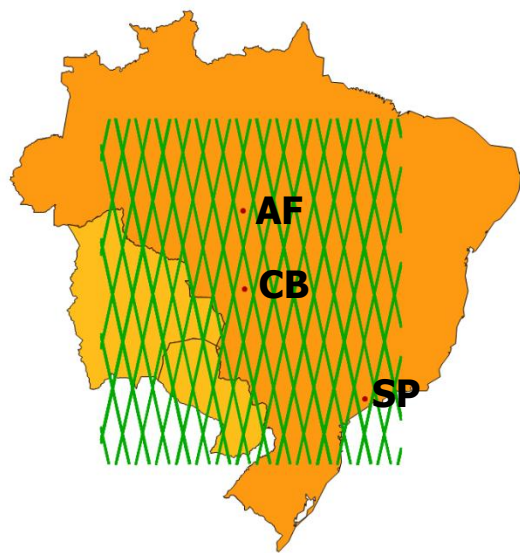
Cuiaba AERONET Station July–September 2012

23%

$\overline{AOD} = 0.22 \pm 0.24$

$\overline{AE} = 1.32 \pm 0.28$

✓ **Large values of AOD**

✓ **Large values of Angstrom Exponent (AE)**

✓ **Fine mode and high absorption aerosol type**

✓ **Biomass burning aerosol**

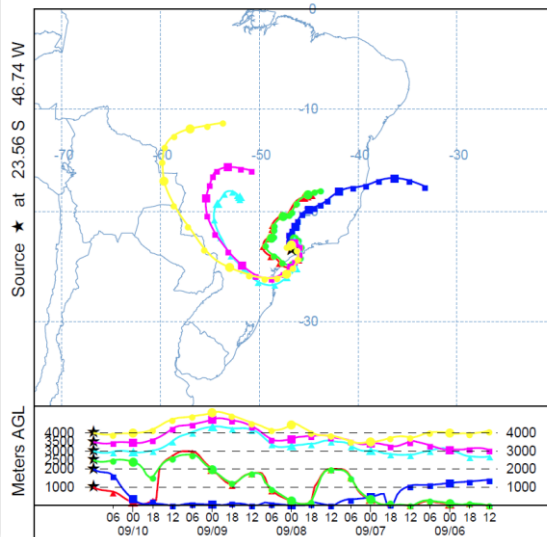# Investigating the scenario at Mid-Western and North of Brazil
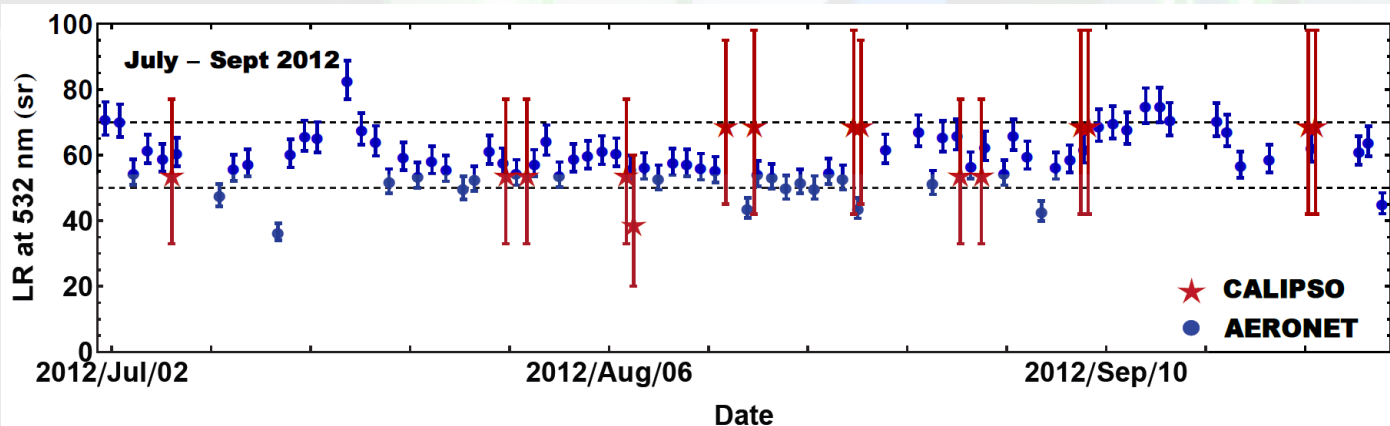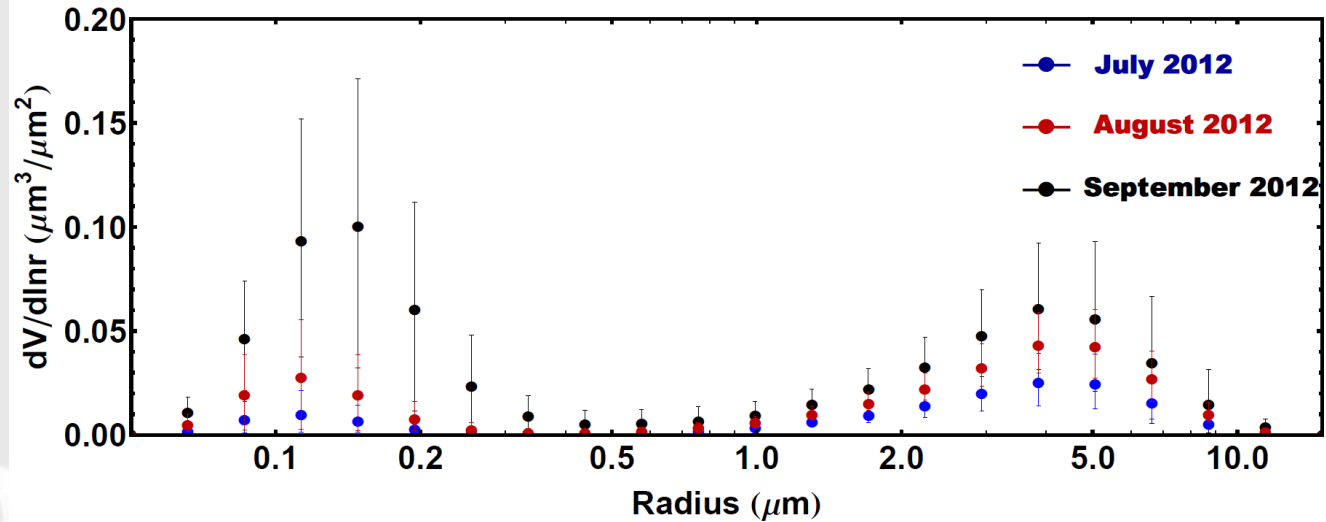
$$S_{aeronet} = \frac{4\pi}{\omega(\lambda)\,P(180°)}$$

✓ **Increasing of fine mode aerossol**

✓ **Lidar ratio CALIPSO – 70 sr**

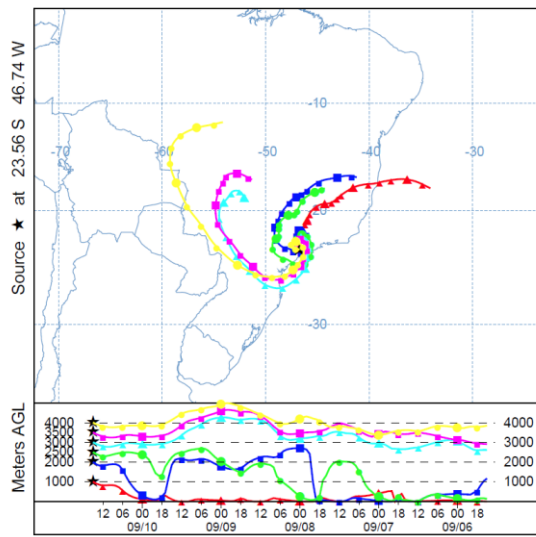✓ **Lidar ratio from AERONET ~ 70 sr**

✓ **Biomass burning aerosol**

HYSPLIT five-day backward trajectories

- ✓ **Global Data Assimilation System**

- ✓ **air masses backward trajectories starting at 12, 15, 18 and 21 UTC**

- ✓ **from 1000 to 4000 m altitude**

- ✓ **trajectories from 1000 to 2500 m a.g.l. altitude came originally from North and North-Western direction.**

- ✓ **trajectories from 3000 to 4000 m a.g.l. came originally from Central-Western part of Brazilian territory**
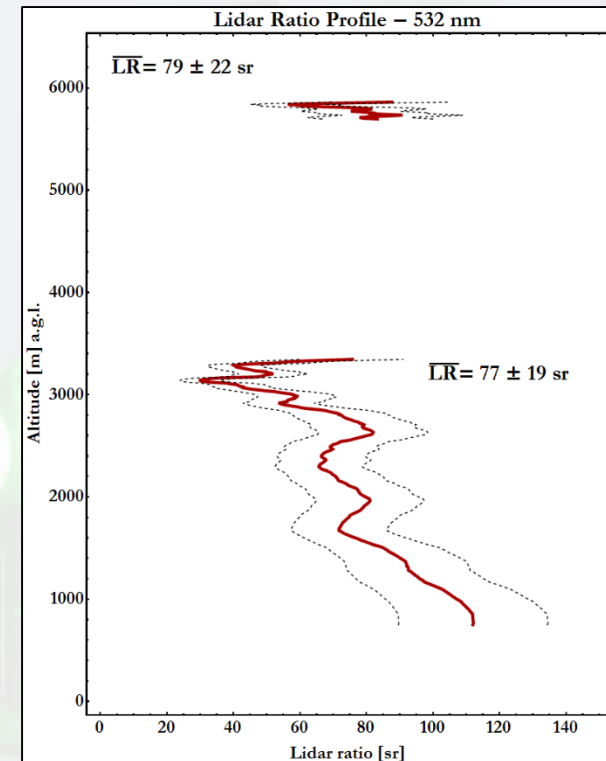
MSP-Lidar II system measurements

- ✓ **Lidar system measurements at September 10th of 2012**

- ✓ **PBL height calculated by WCT and Grad-log methods**

- ✓ **Air masses backward trajectories at 3000 to 4000 m a.g.l. came originally from Central-Western part of Brazilian territory**

- ✓ **Aerosol plumes above PBL**

Particulate backscatter, extinction and Lidar ratio profiles at 532 nm for September 10th of 2012 at MASP

✓ **Large quantities of aerosol up to 3000 m and thin aerosol layers above 3000 m**

✓ **Lidar ratio ranging between 60-70 sr at 3000 to 4000 m**

✓ **Biomass burning transported from central-Western of Brazilian territory**
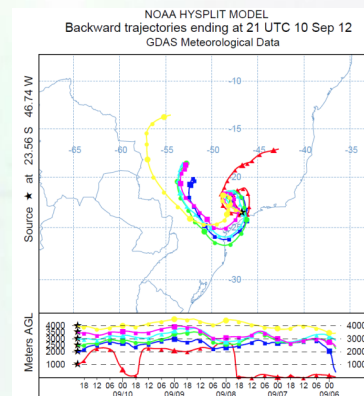
MSP-Lidar II system measurements

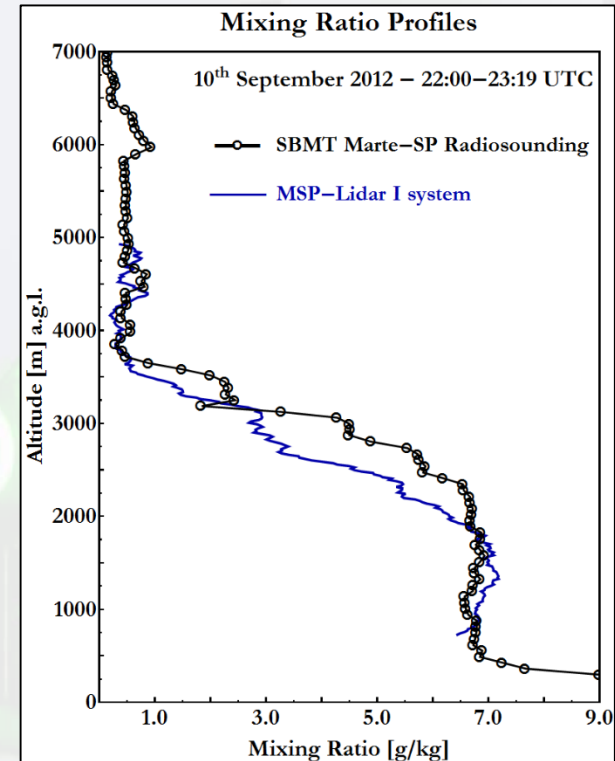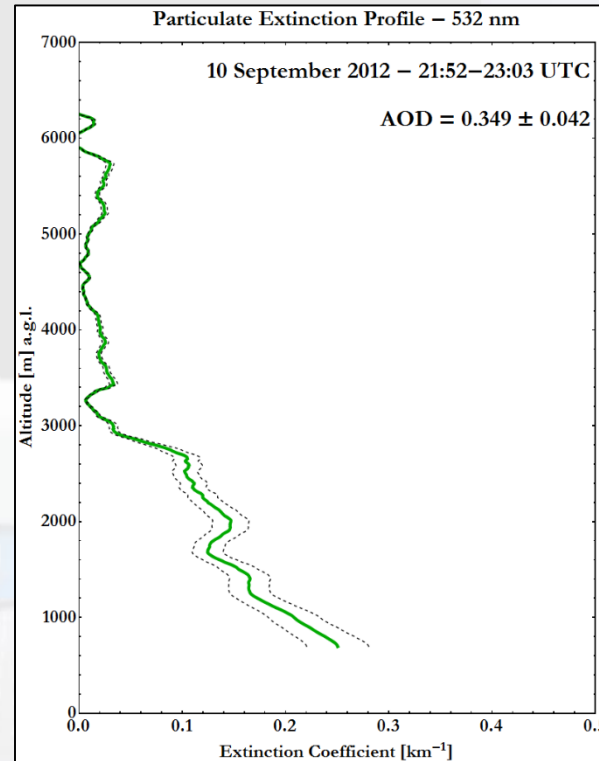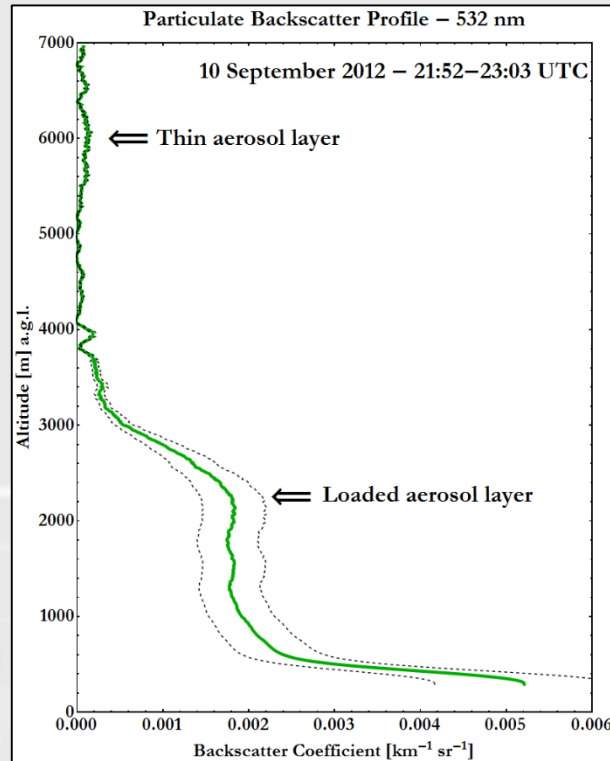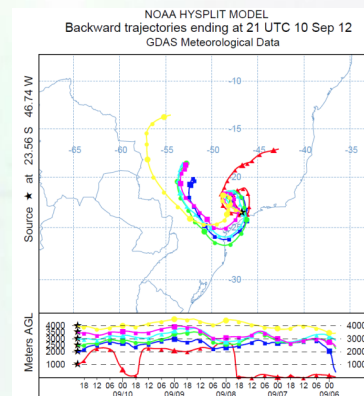## Particulate backscatter, extinction and Lidar ratio profiles at 532 nm for September 10th of 2012 at MASP

Particulate Backscatter Profile – 532 nm
10 September 2012 – 21:52–23:03 UTC
Thin aerosol layer
Loaded aerosol layer

Particulate Extinction Profile – 532 nm
10 September 2012 – 21:52–23:03 UTC
AOD = 0.349 ± 0.042

Mixing Ratio Profiles
10th September 2012 – 22:00–23:19 UTC
SBMT Marte–SP Radiosounding
MSP–Lidar I system

✓ **Relative humidity contributes to increase the backscatter coefficient**

✓ **Biomass burning transported from central-Western of Brazilian territory above 3000 m altitude**

✓ **Low relative humidity above 3000 m**

NOAA HYSPLIT MODEL
Backward trajectories ending at 21 UTC 10 Sep 12
GDAS Meteorological Data

Conclusions

✓ **Sinergy between satellite and ground-based systems is important to constrain physical and optical properties of aerosol.**

✓ **Increasing of fires focus and AOD during the period of September of 2012 at Central-Western region of Brazil**

✓ **Biomass burning advected to São Paulo according to HYSPLIT backward trajectories at 3000 to 4000 m of altitude**

✓ **Aerosol layers detected above the PBL at 3000 to 4000 m of altitude using MSP-Lidar II system**

✓ **Lidar ratio between 60 to 70 sr**

✓ **Large increasing of particulate matter concentrarion and AOD during this period of September of 2012 at MASP can be associated to the transport of biomass burning from Central-Western region of Brazil**
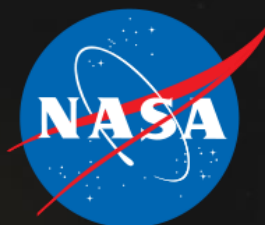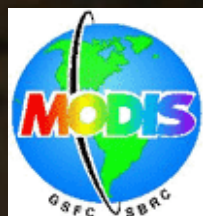
Acknowlegments

The authors would like to thank the support and data from the following agencies and research teams

The organizing committee