BUNIACCIC and SAMBBA workshops Manaus, Feb 15, 2012

AEROCLIMA - Direct and indirect effects of aerosols on climate in Amazonia and Pantanal

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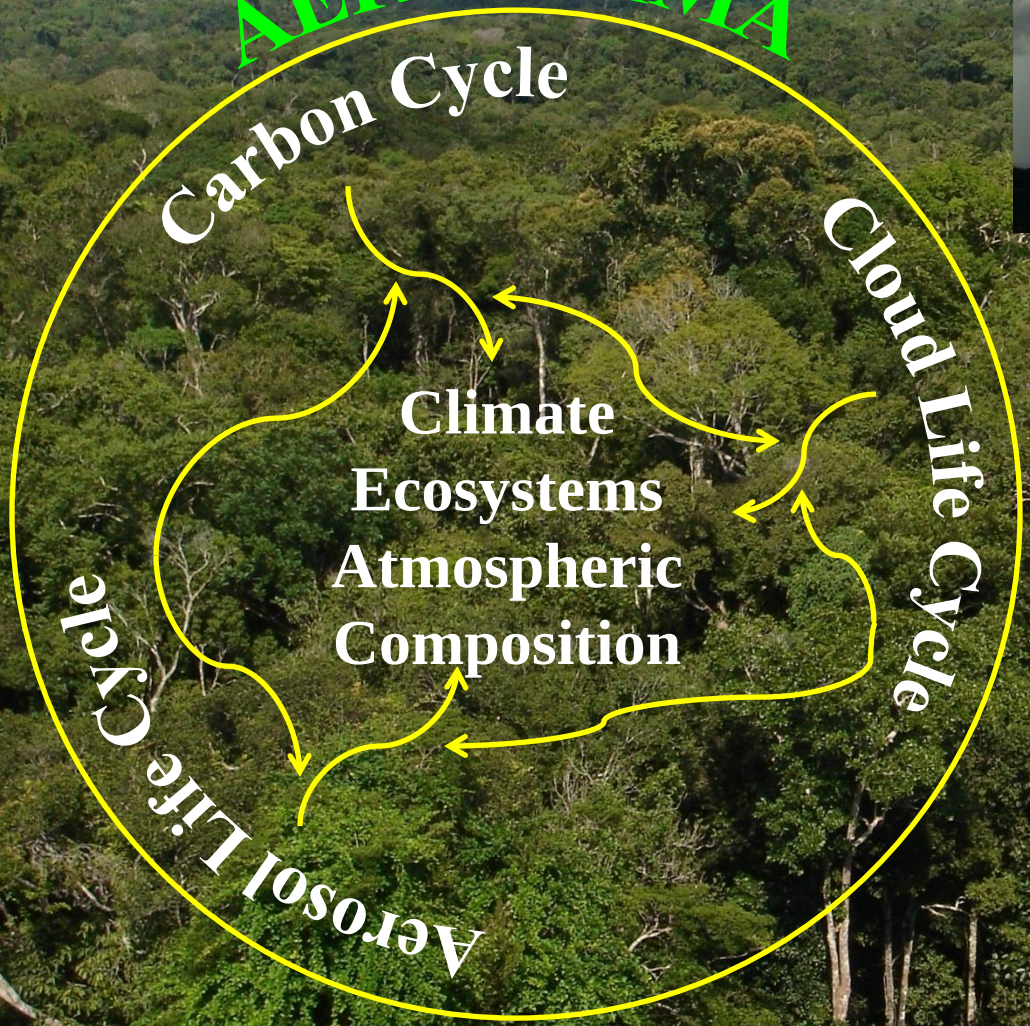
Meinrat O. Andreae (Max Planck Institute, Mainz, Germany), Scot T. Martin (Harvard University, USA), Steven Wofsy (Harvard University, USA), Markku Kulmala (University of Helsinki, Finland), José Vanderlei Martins (NASA Goddard, USA), William Cotton (Colorado State University (USA), George Grell (NOAA, USA).

Large number of students and Pos Docs

Observations and modeling of the Amazon atmosphere, radiation balance and precipitation



LBA
EXPERIMENTO DE GRANDE ESCALA DA BIOSFERA-ATMOSFERA NA AMAZONIA - LBA

AEROCLIMA: Direct and indirect effects of aerosols on climate in Amazonia and Pantanal

Objectives: Investigate the connection between the concentration and physico-chemical properties of biogenic and biomass burning aerosol particles in the radiation balance and climate, including effects on cloud development and microphysics for two important regions in South America: Amazonia and Pantanal.

Scientific Strategy: AEROCLIMA has 4 integrated components:

1) Observations of aerosols, clouds, trace gases and radiation (*Paulo Artaxo*)
2) Remote sensing of aerosols and clouds (*Alexandre Correia*)
3) Modeling of clouds dynamics and evolution and precipitation: (*Maria Assunção F. Silva Dias*)
4) Large scale atmospheric transport modeling (*Henrique Barbosa, Karla Longo and Saulo Freitas)*

AEROCLIMA Specific aims

The **overall objective** of AEROCLIMA is to *investigate the connection between the concentration and physico-chemical properties of biogenic and biomass burning aerosol in the radiation balance and climate, including effects on cloud development and microphysics for two important regions in South America: Amazonia and Pantanal.* The basic concept for AEROCLIMA is that of an integrated study, combining field studies, remote sensing and modeling. To achieve this goal, we will perform the following tasks:

•Calculate long term direct and indirect radiative forcing of aerosols in Amazonia and Pantanal, using a combination of measurements and modeling tools.

•**Characterize in detail physico-chemical properties of aerosol particles** that are relevant for their impact on the environment and climatic effects.

•**Install and operate three aerosol field measurement stations** that for one year will study detailed properties of aerosols: size distribution, absorption, scattering, composition, CCN activity and others. Aerosol and water vapor vertical profiles will be measured with a Raman Lidar. These stations will be installed at: Manaus, Porto Velho (biomass burning region) and Campo Grande (Pantanal).

•Implement **intensive measurement programs** such as the proposed LBA/CLAIRE2010, were more detailed aerosol properties will be measured including aerosol mass spectrometry, ion cluster measurements and detailed organic aerosol composition, VOC concentrations, among others.

•Perform **large scale aircraft measurements** using the INPE Bandeirante aircraft to measure the large scale and vertical distribution of aerosols. Develop innovative instrumentation to measure water phase and cloud droplets in convective and stratus clouds.

•Use **remote sensing measurements** with MODIS, CALIPSO and CERES to study large scale and long term aerosol and radiation fields in Amazonia and Pantanal. This will be used to quantify the effect of smoke aerosol on cloud properties.

•Develop and evaluate semi-empirical parameterizations for the cloud-aerosol-radiation interaction suitable for the Amazon basin and Pantanal region for different aerosol burden regimes.

•Model the effect of biogenic and biomass burning aerosol on cloud microphysics at the individual cloud and at regional level with spectral bin microphysics coupled to BRAMS. Perform sensitivity studies to investigate the relative importance of each variable.

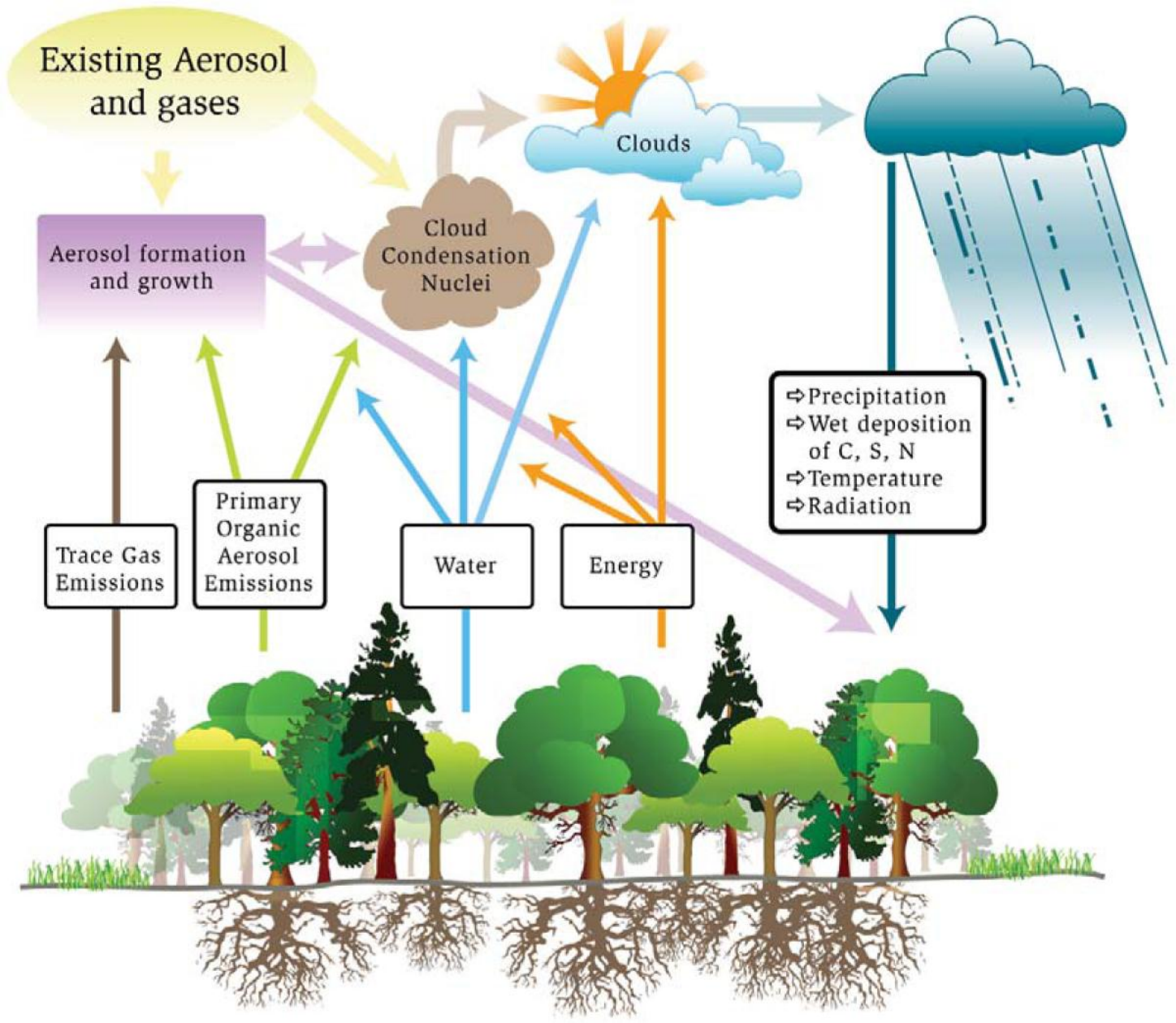
•Implement **regional models with full aerosol microphysics**, developed based on measurements in this project. The regional models will be based on CATT-BRAMS and WRF-CHEM models.

•To **contribute to the BMGCS development**, taking advantage of all expertise gained in the context of this proposal on the parameterizations for aerosol-cloud-radiation interactions and gaseous and aerosol chemistry.

AEROCLIMA measurements in Manaus and Porto Velho

- Continuous aerosol analysis is being done with:
- SFU for fine and coarse mode aerosols with analysis for trace elements.
- Organic and Elemental Carbon and ionic composition;
- MOUDI for aerosol size distribution
- TSI 3-Lambda Neph for light scattering
- MAAP (Multi Angle Absorption Photometer) for absorption
- Scanning Mobility Particle Sizer SMPS for aerosol size distribution (10-450nm)
- GRIMM OPC for 0.3-10 µm size distributions
- Cloud Condensation Nuclei (CCN) measurements.
- Ozone, CO, methane, CO_2 with Picarro CVRD.
- Raman Lidar continuosly up to 15 Km.
- Sun-photometry network (8 NASA AERONET instruments)
- Radiometers for visible and broadband radiation fluxes

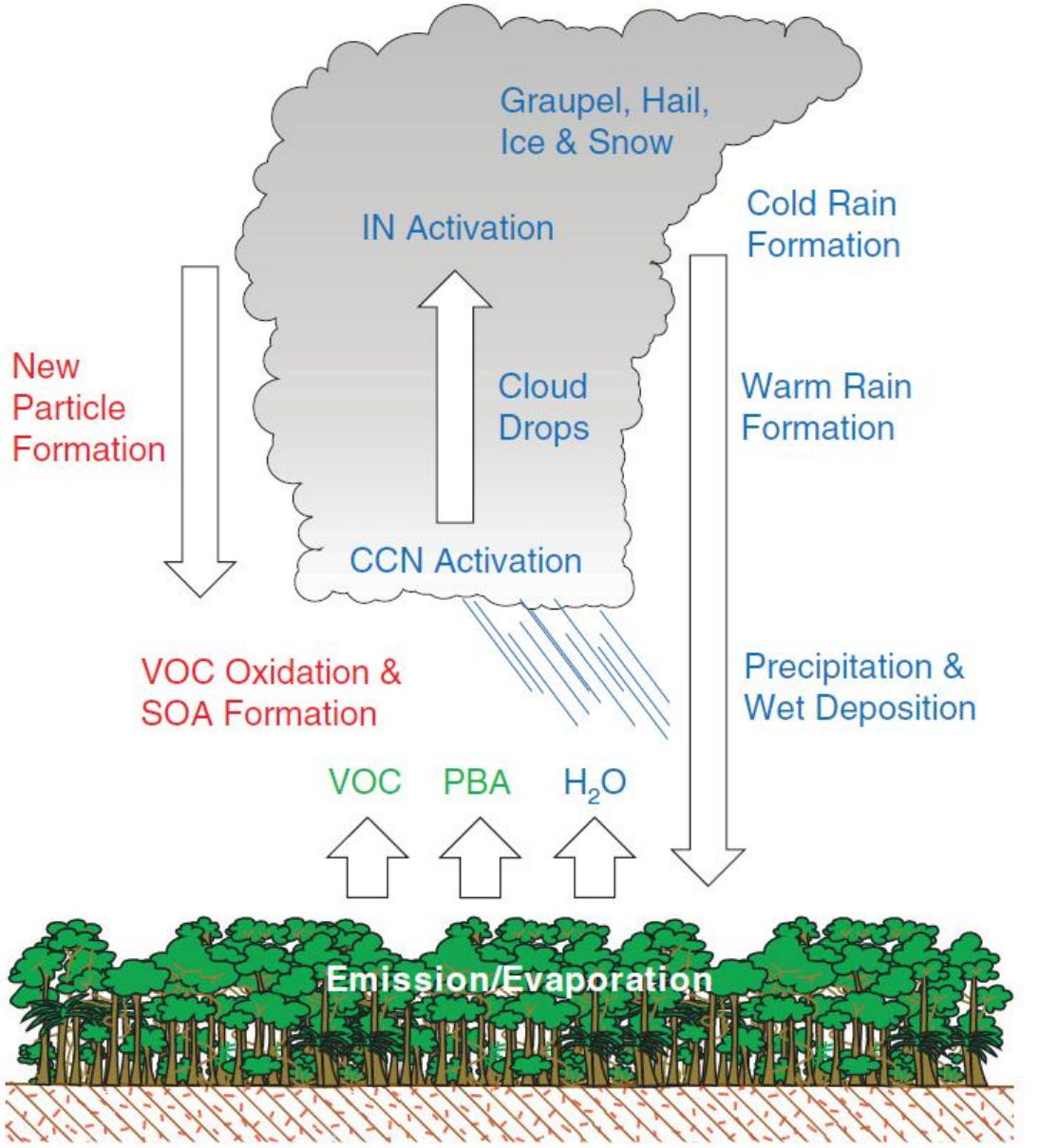
Amazonia has strong coupling between terrestrial ecosystem and the hydrologic cycle: The linkages among carbon cycle, aerosol life cycle, and cloud life cycle need to be understood and quantified.



Susceptibility and expected reaction to stresses of global climate change as well as pollution introduced by future regional economic development are not known or quantified at present time.

Aerosol and Water Cycling over the Pristine Rainforest

Secondary Organic Aerosols formed by photo-oxidation of volatile organic compounds (VOC) and PBA emitted from biota in the rainforest (plants and microorganisms) serve as biogenic nuclei for CCN and IN, which induce warm or cold rain formation, precipitation, and wet deposition of gases and particles.

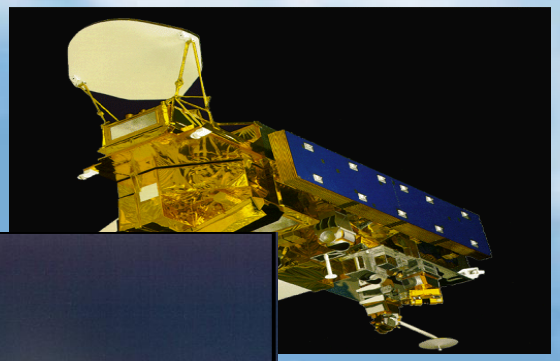


U. Pöschl, et al., "Rainforest aerosols as biogenic nuclei of clouds and precipitation in the Amazon," *Science*, 2010, 329, 1513-1516.

S.T. Martin, et al, "An Overview of the Amazonian Aerosol Characterization Experiment 2008 (AMAZE-08)," *Atmospheric Chemistry Physics*, 2010, 10, 11415-11438.

In AEROCLIMA, several scales are necessary to study atmospheric properties in the Amazon region

1000 km



10 km

Area of impact

ha

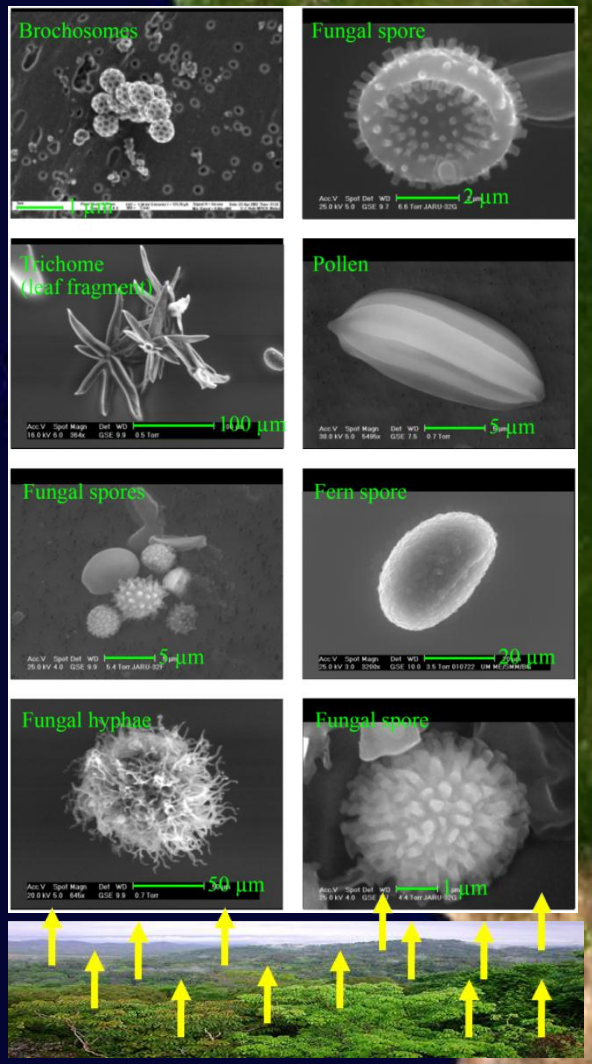
dm

µm

Biophysical Processes

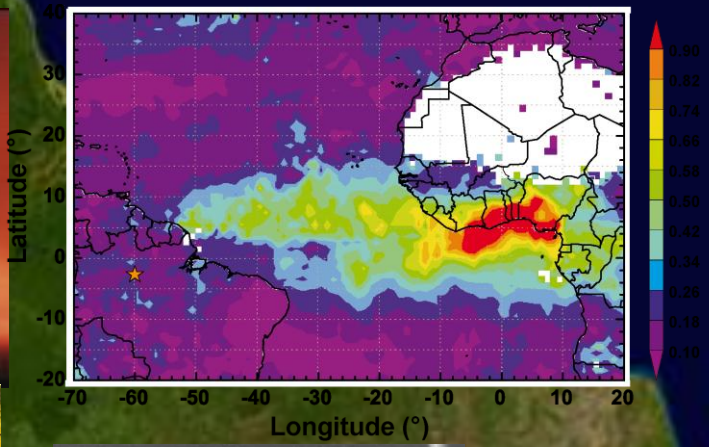
Amazonia: 3 different types of aerosols

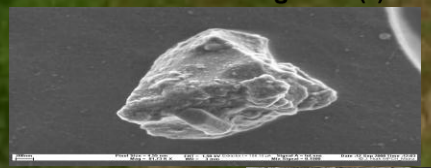
Biogenic (primary and SOA)

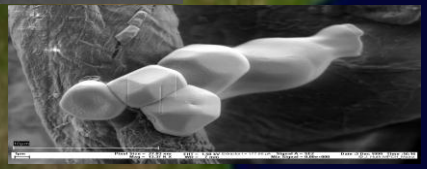


Biomass Burning

Dust from Sahara

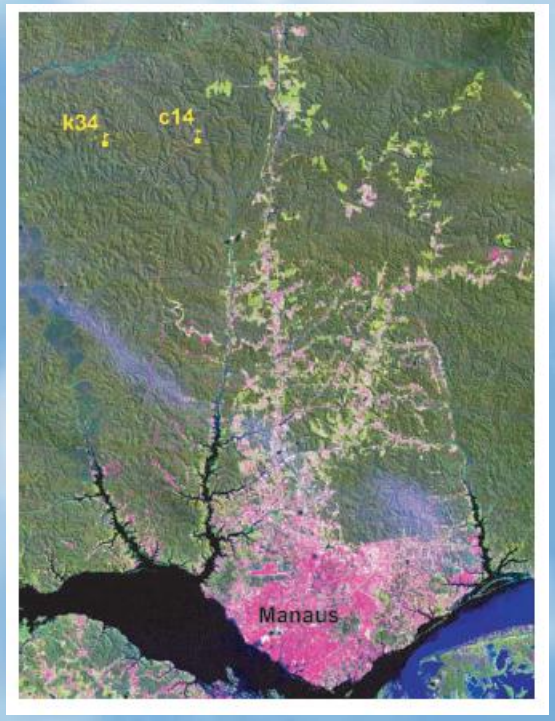




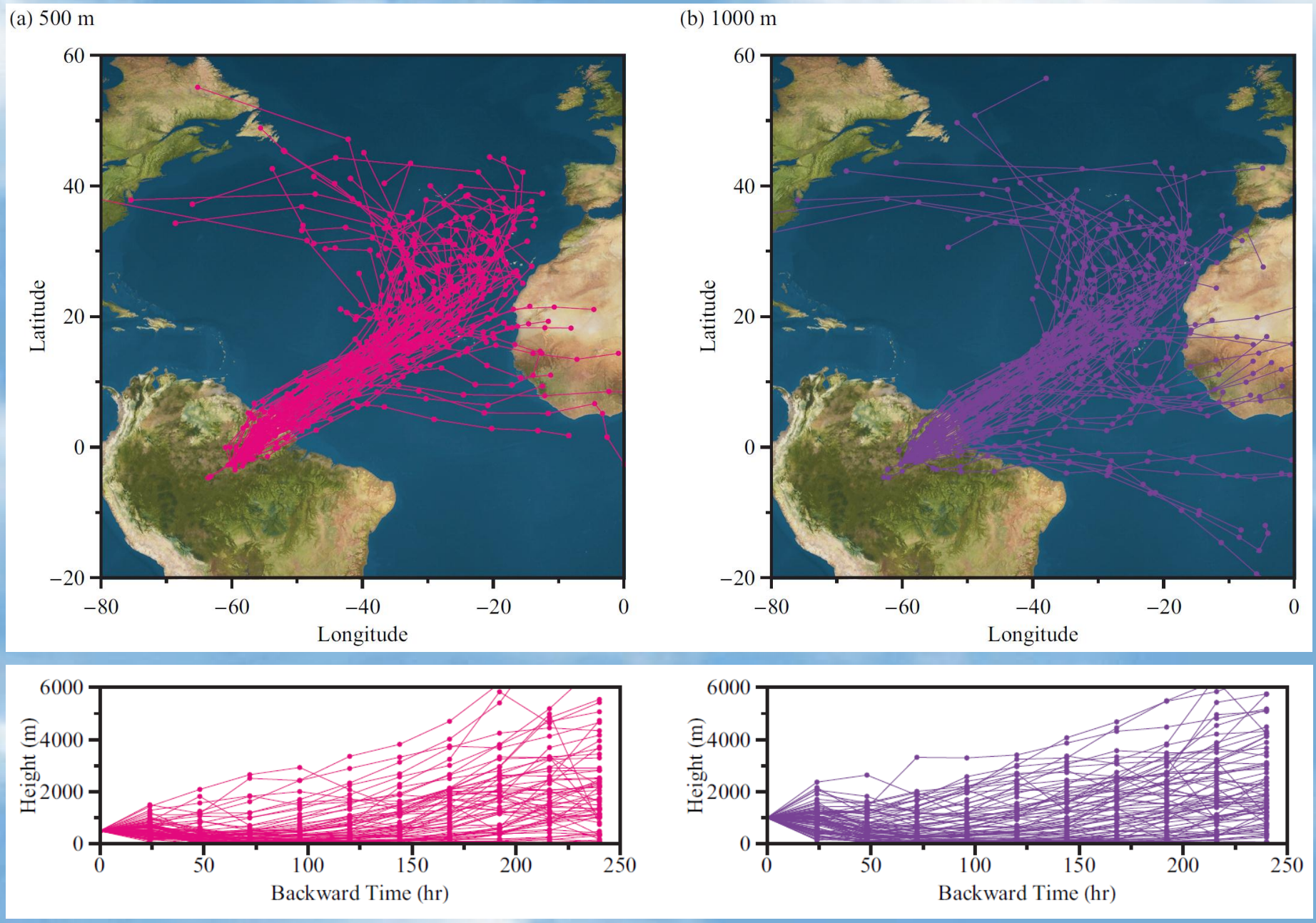


Each with VERY different properties and impacts

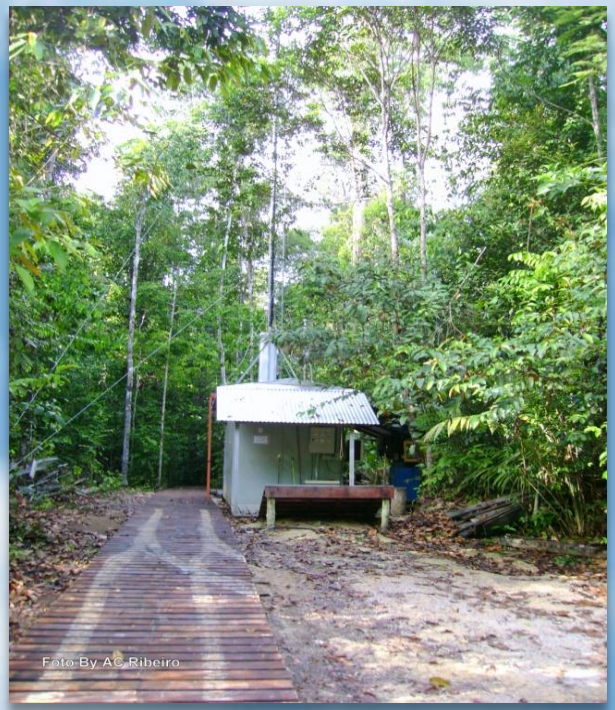
- Site: 100 Km North of Manaus. Measurements: from Feb 2008 up to now.
- Continuation as a permanent sampling site.
- Three towers at the site, from 35 to 55 meters.
- Dryer to get aerosol at 30-40% RH



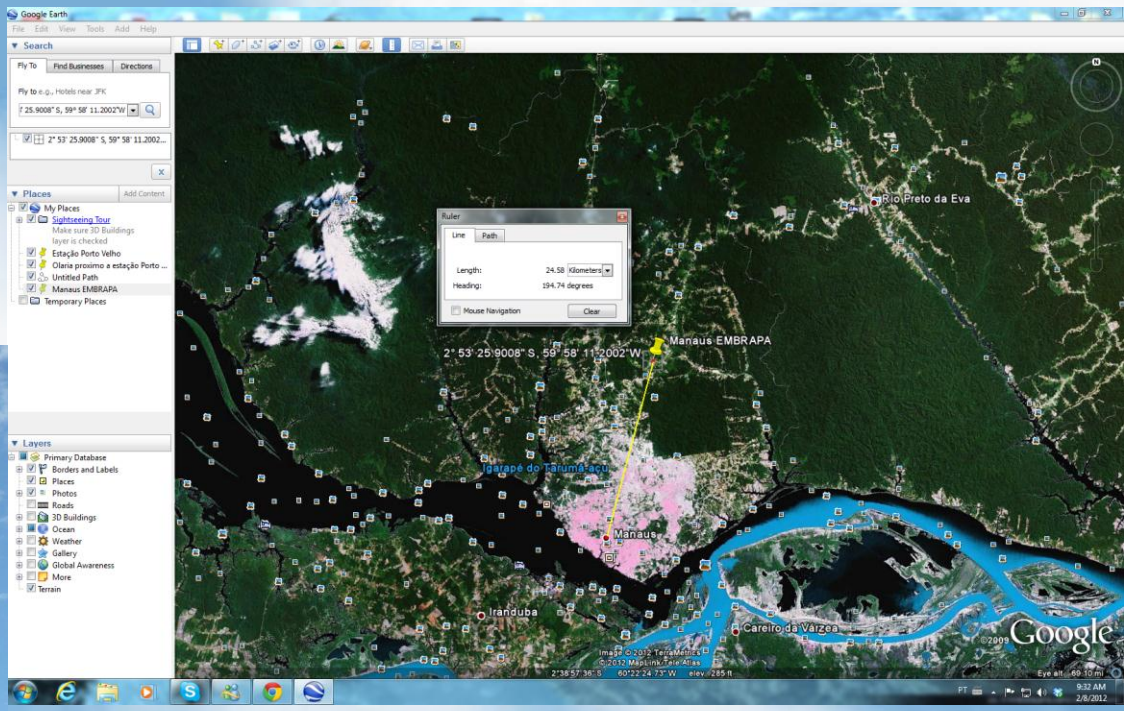
HYSPLIT air mass trajectories during for AEROCLIMA Manaus site

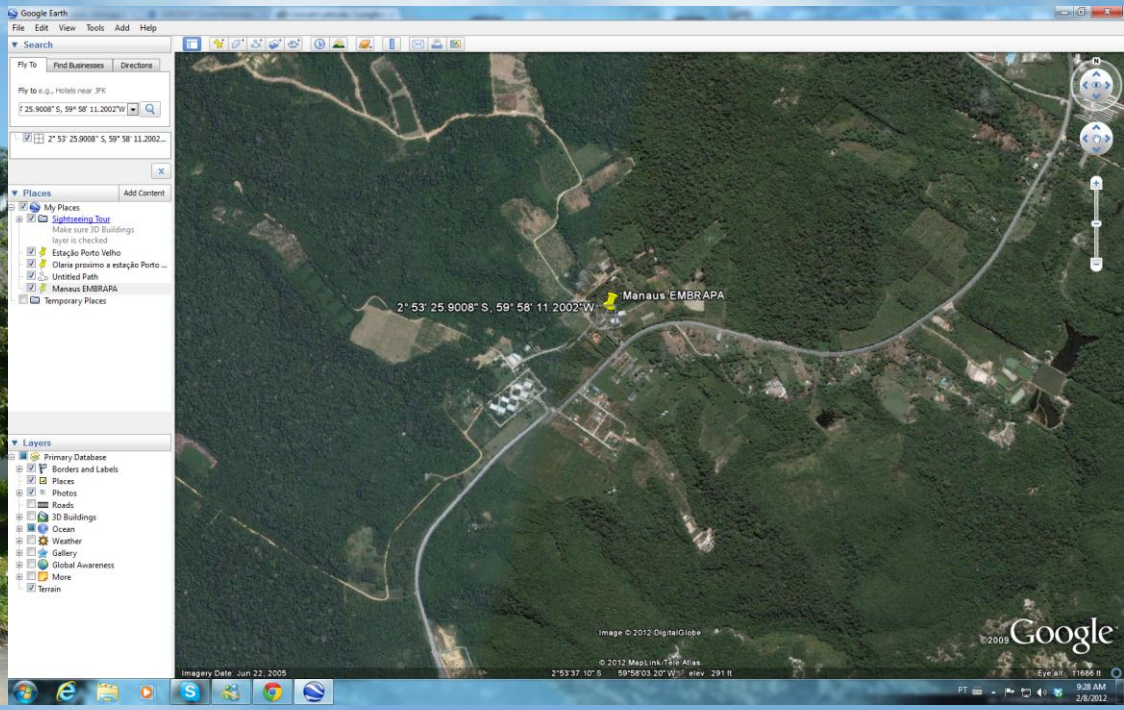


Container with equipment powered by generators



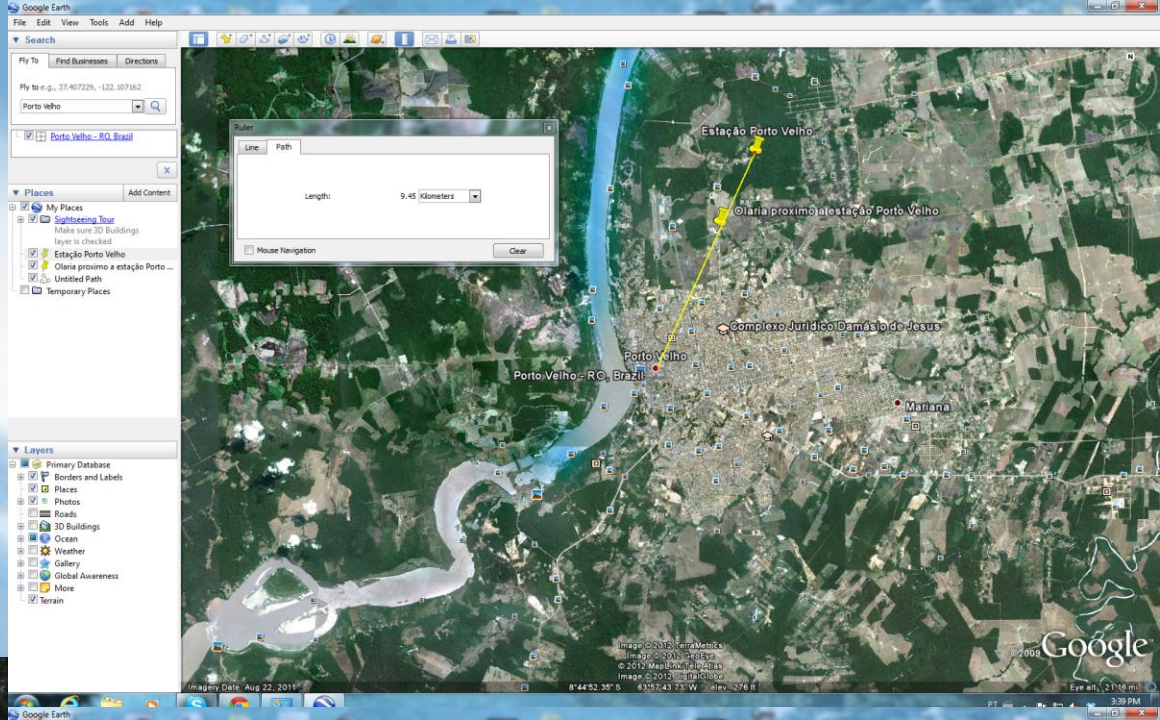
Manaus EMBRAPA AEROCLIMA site

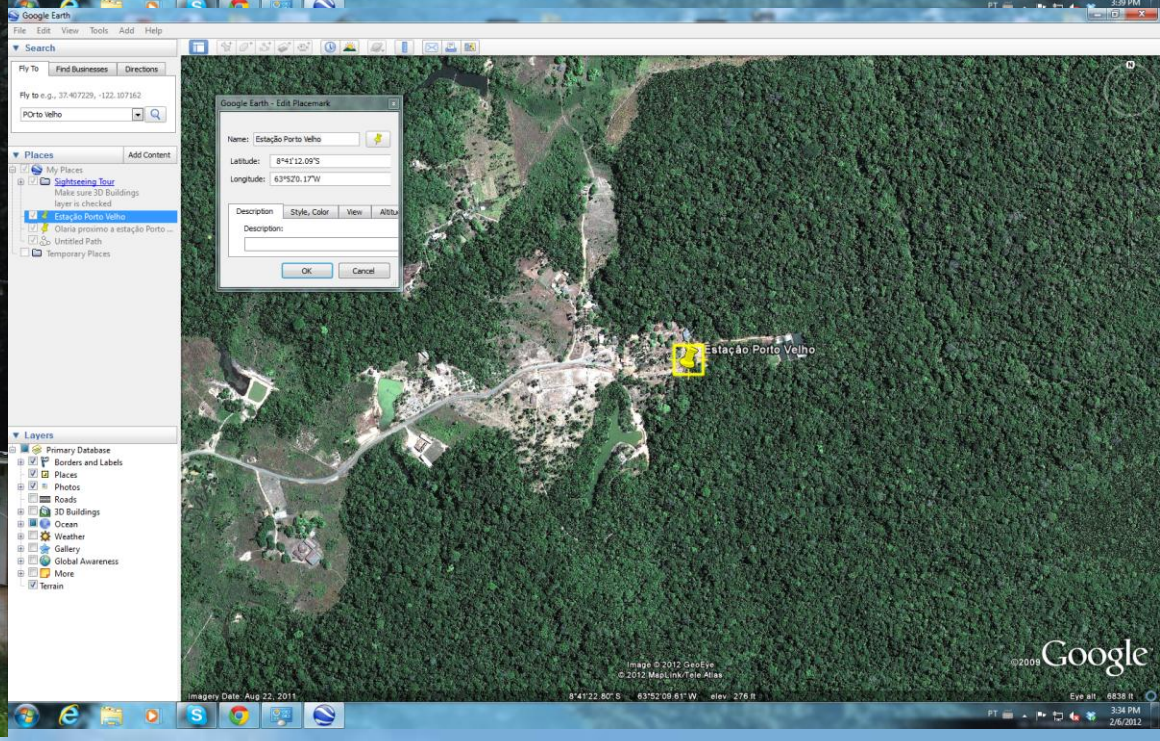




Rondonia - Porto Velho aerosol and trace gases measurement site

Porto Velho
AEROCLIMA site





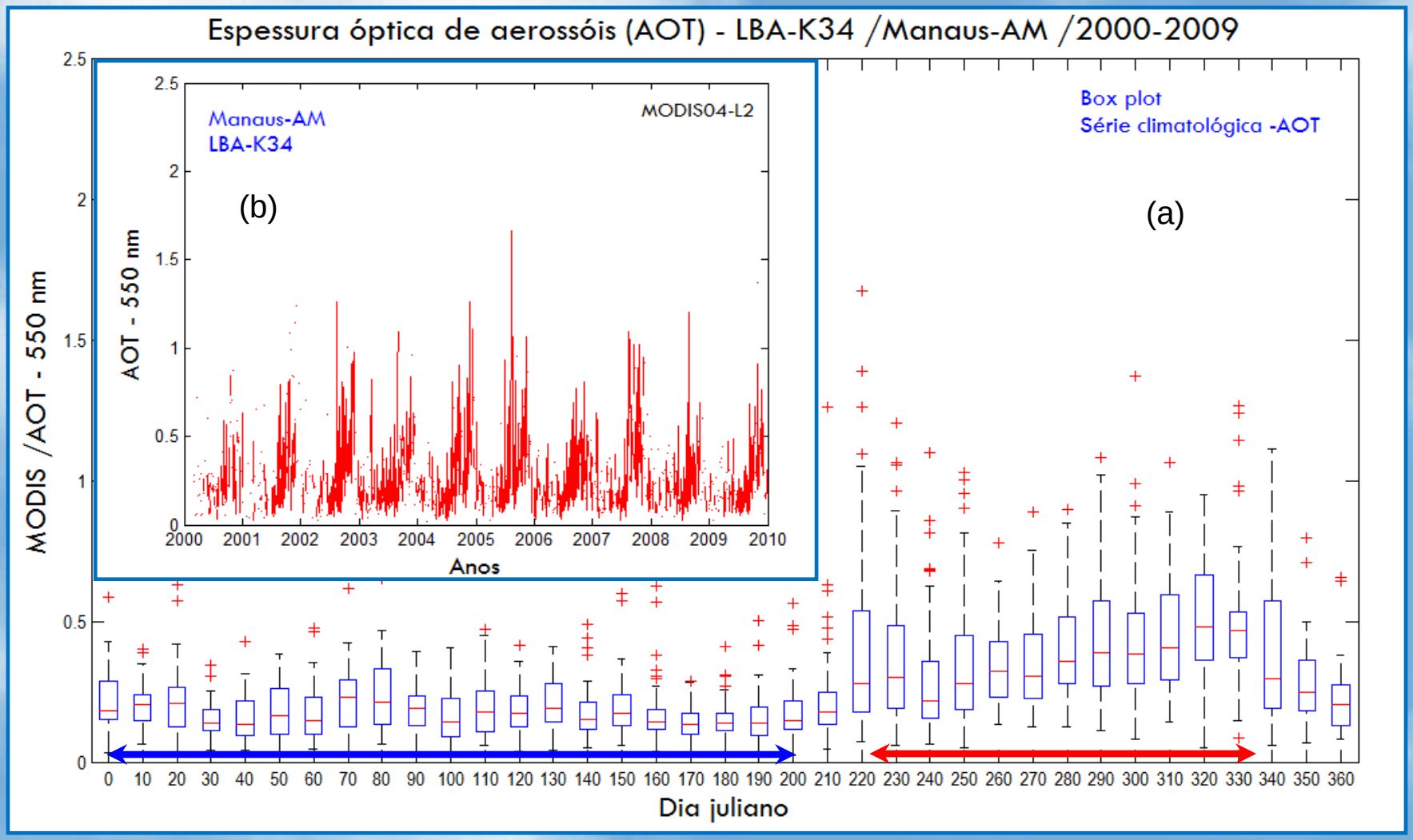
Medidas sendo realizadas em Porto Velho

- Concentração de massa de aerossóis com SFU PM_{10}, $PM_{2.5}$
- Composição elementar com PIXE (Sódio a Chumbo)
- Distribuição de tamanho com SMPS – Partículas de 10 nm a 800 nm
- Espalhamento ótico (nefelometro)
- Absorção ótica (Black Carbon) com MAAP e Aethalometro.
- Ozônio com 2B Tech
- A partir de Dezembro: Mercúrio total e particulado

Fotômetros solares da rede AERONET (*Aerosol Robotic Network*): um sistema de monitoramento e caracterização de aerossóis mantidos pela NASA, a partir de uma rede de radiômetros solares operados na Amazônia e outras regiões do planeta.

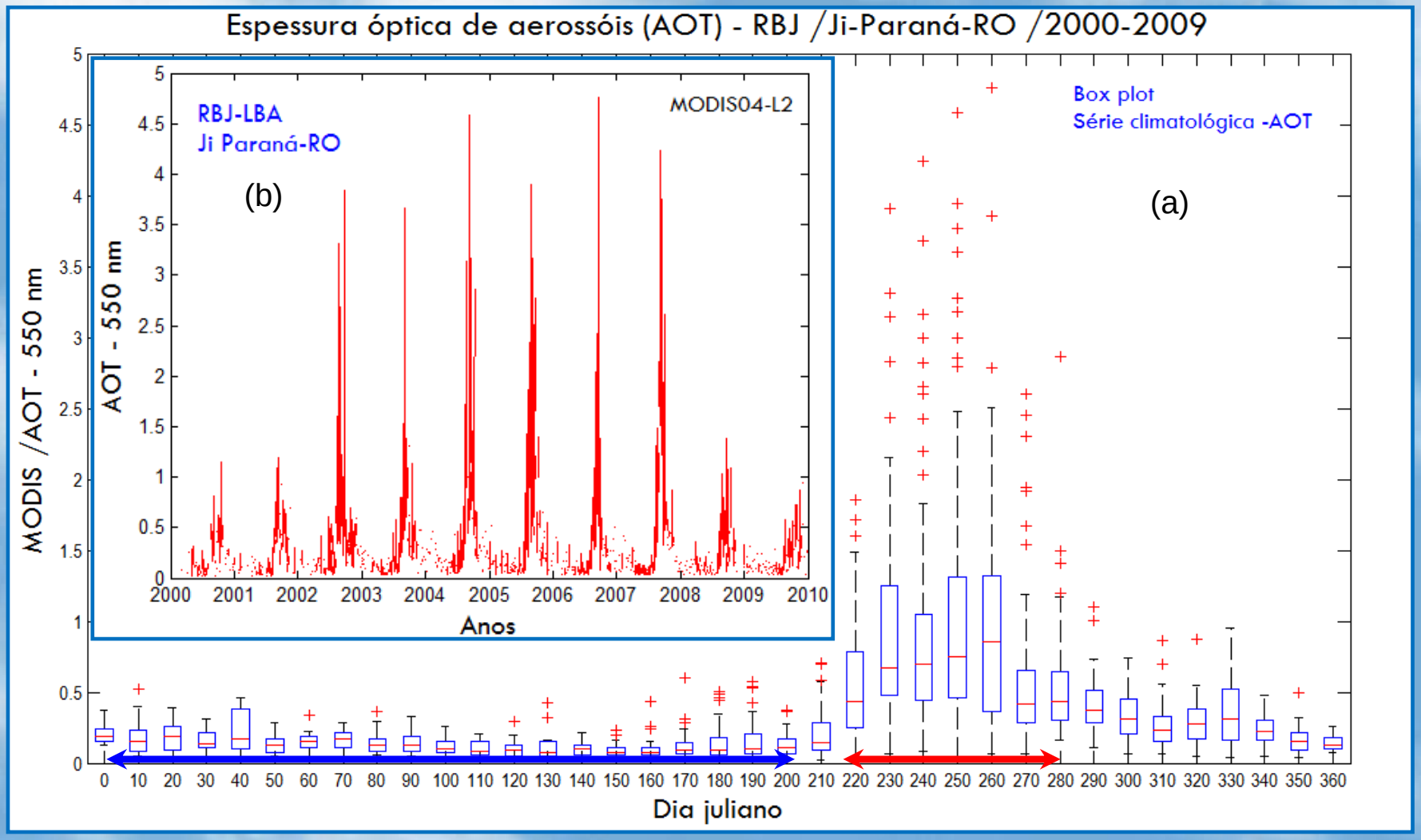
Medidas de espessura ótica de aerossóis (AOT) → (Comprimentos de onda: 340, 380, 440, **500**, 670, 870, 940 e 1020 nanômetros)

Aerosol optical thickness in Manaus

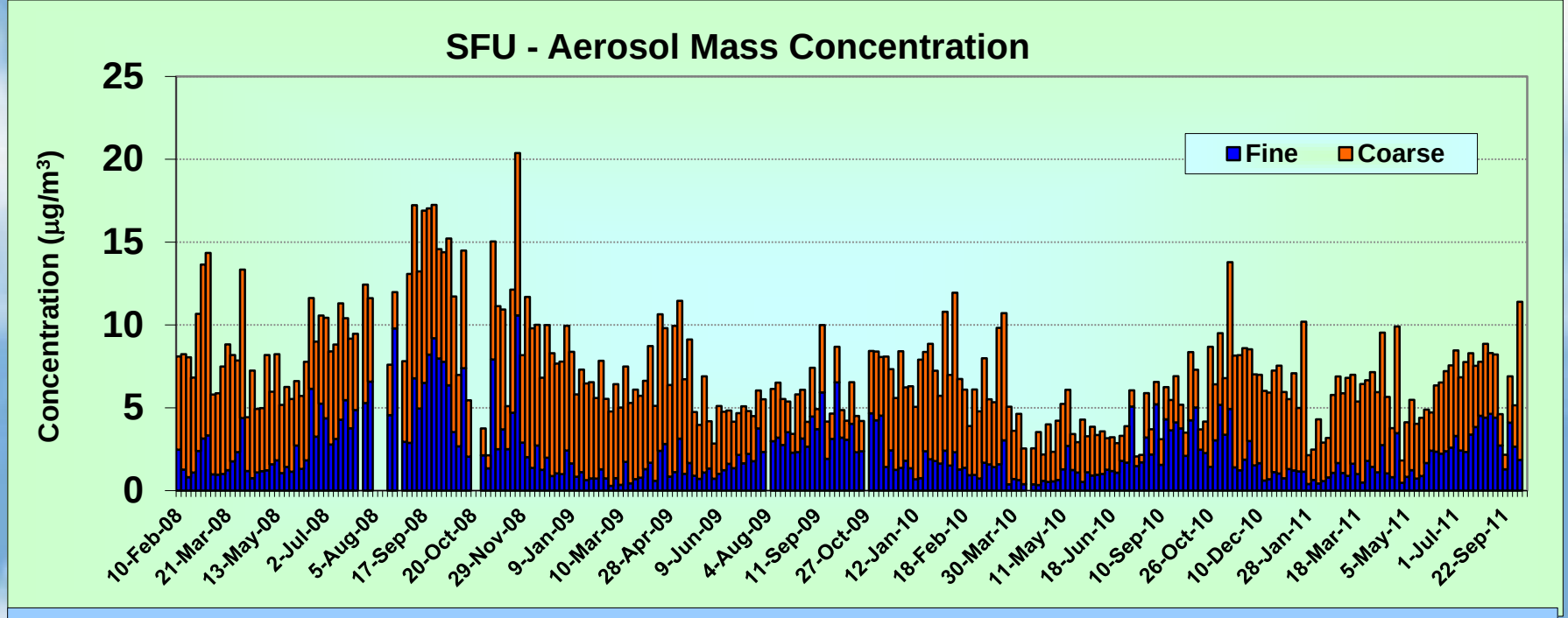


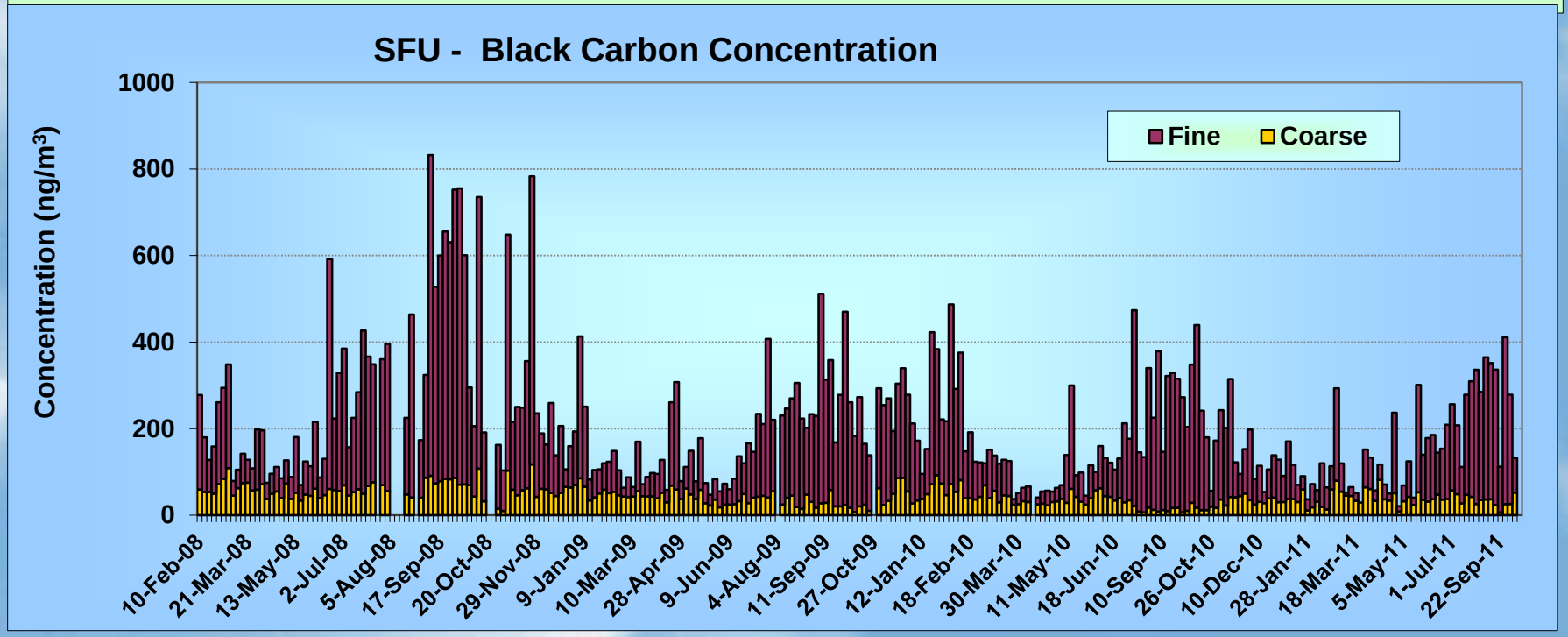
Glauber Cirino

Aerosol optical thickness in Rondônia

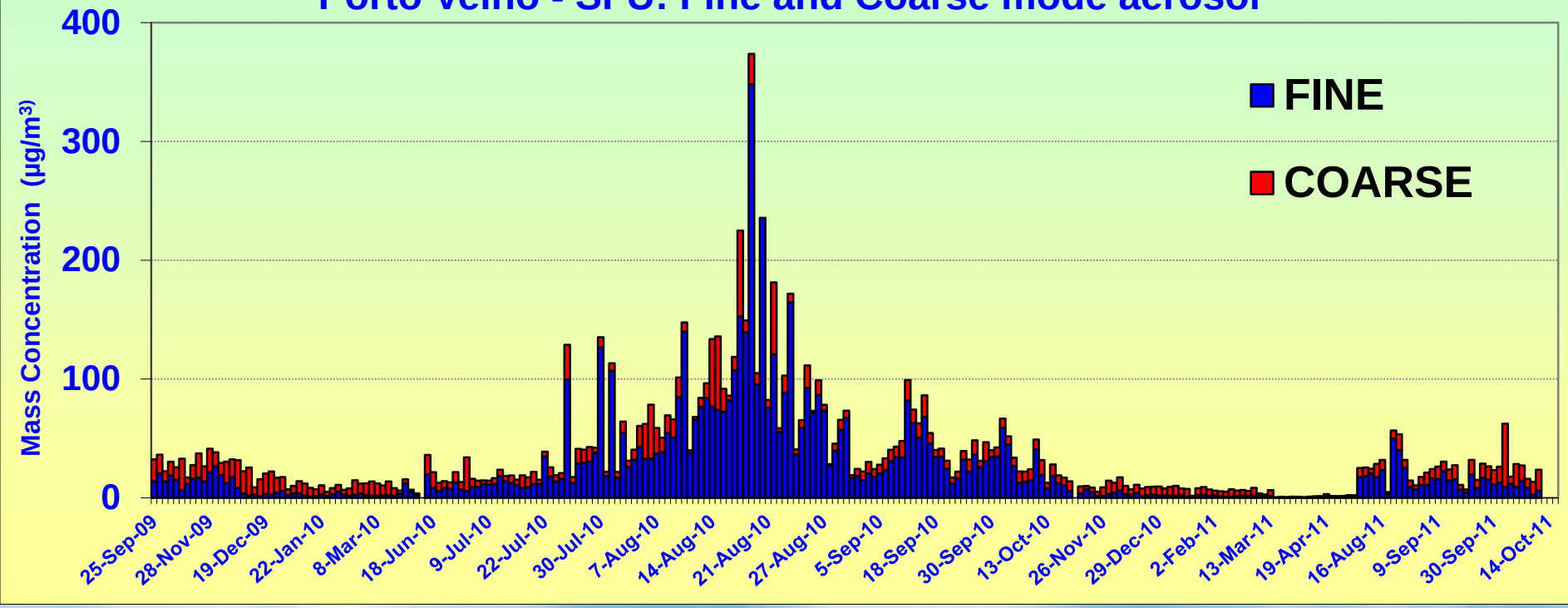


Glauber Cirino

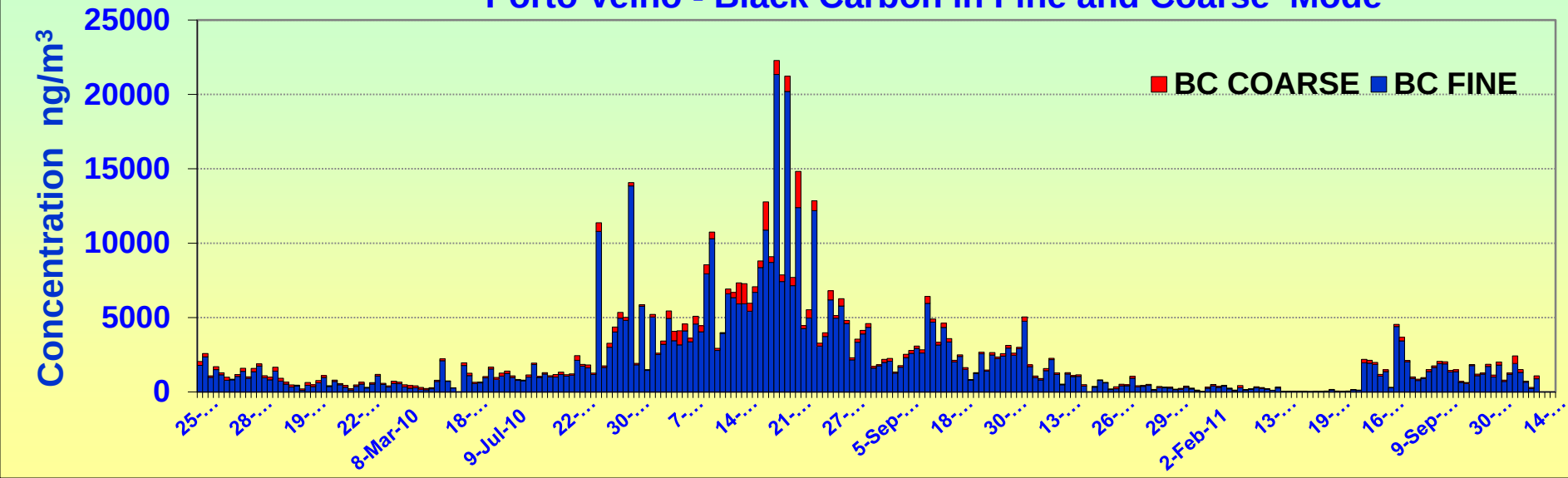

SFU - Aerosol Mass Concentration
Concentration (µg/m³)
25
20
15
10
5
0
Fine
Coarse
10-Feb-08
21-Mar-08
13-May-08
2-Jul-08
5-Aug-08
17-Sep-08
20-Oct-08
29-Nov-08
9-Jan-09
10-Mar-09
28-Apr-09
9-Jun-09
4-Aug-09
11-Sep-09
27-Oct-09
12-Jan-10
18-Feb-10
30-Mar-10
11-May-10
18-Jun-10
10-Sep-10
26-Oct-10
10-Dec-10
28-Jan-11
18-Mar-11
5-May-11
1-Jul-11
22-Sep-11


SFU - Black Carbon Concentration
Concentration (ng/m³)
1000
800
600
400
200
0
Fine
Coarse
10-Feb-08
21-Mar-08
13-May-08
2-Jul-08
5-Aug-08
17-Sep-08
20-Oct-08
29-Nov-08
9-Jan-09
10-Mar-09
28-Apr-09
9-Jun-09
4-Aug-09
11-Sep-09
27-Oct-09
12-Jan-10
18-Feb-10
30-Mar-10
11-May-10
18-Jun-10
10-Sep-10
26-Oct-10
10-Dec-10
28-Jan-11
18-Mar-11
5-May-11
1-Jul-11
22-Sep-11

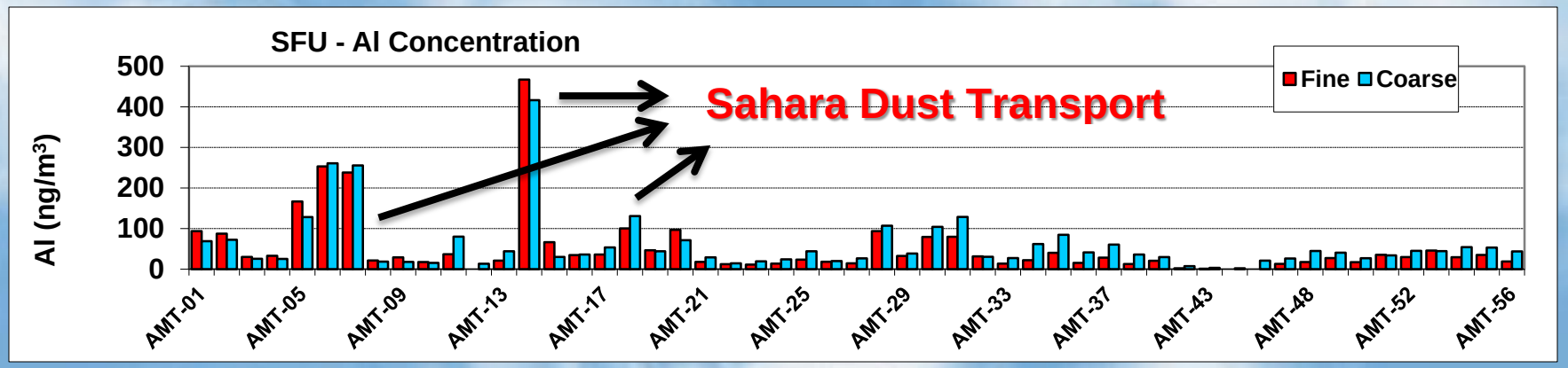
Porto Velho - SFU: Fine and Coarse mode aerosol

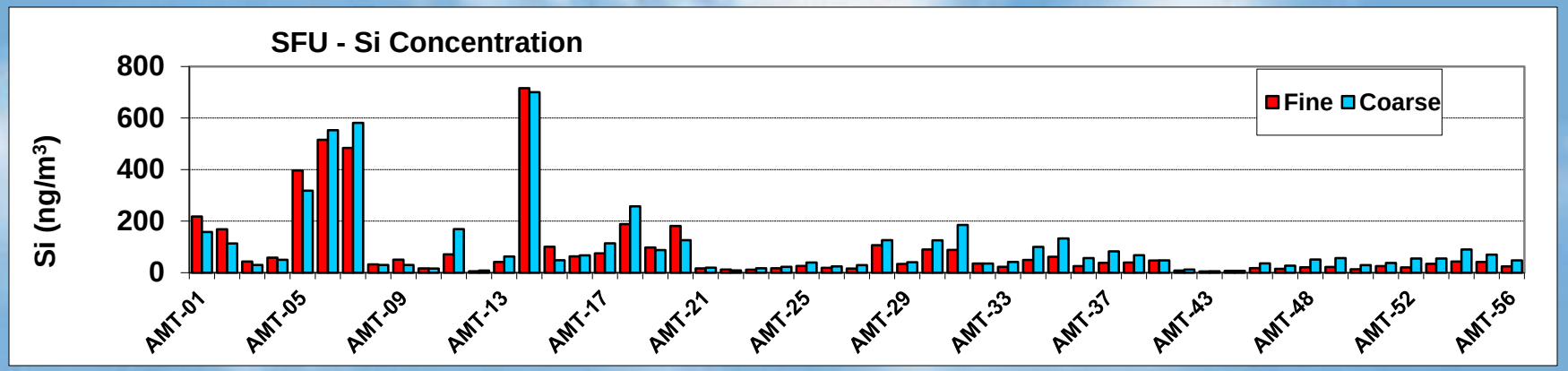


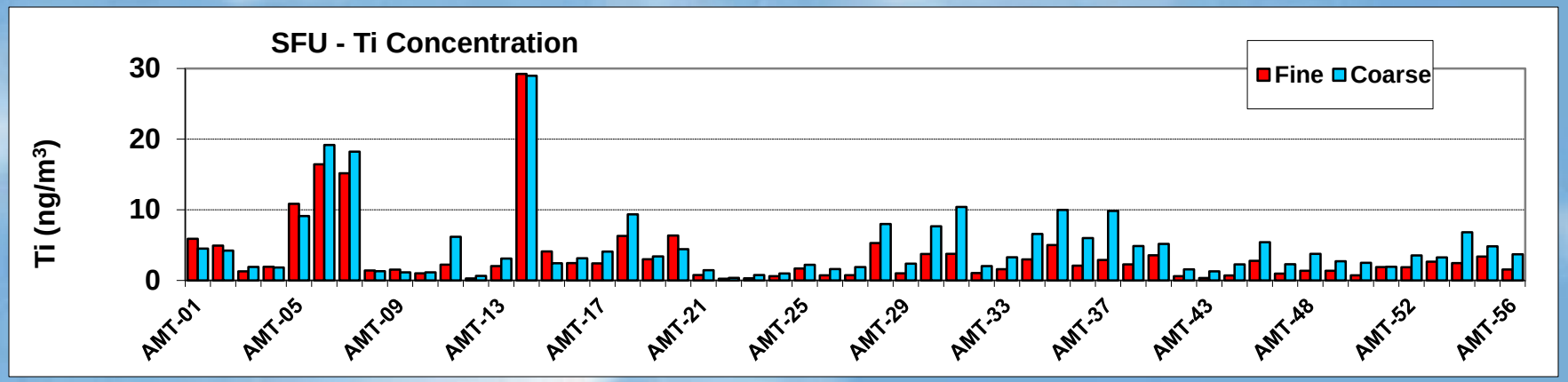
Porto Velho - Black Carbon in Fine and Coarse Mode



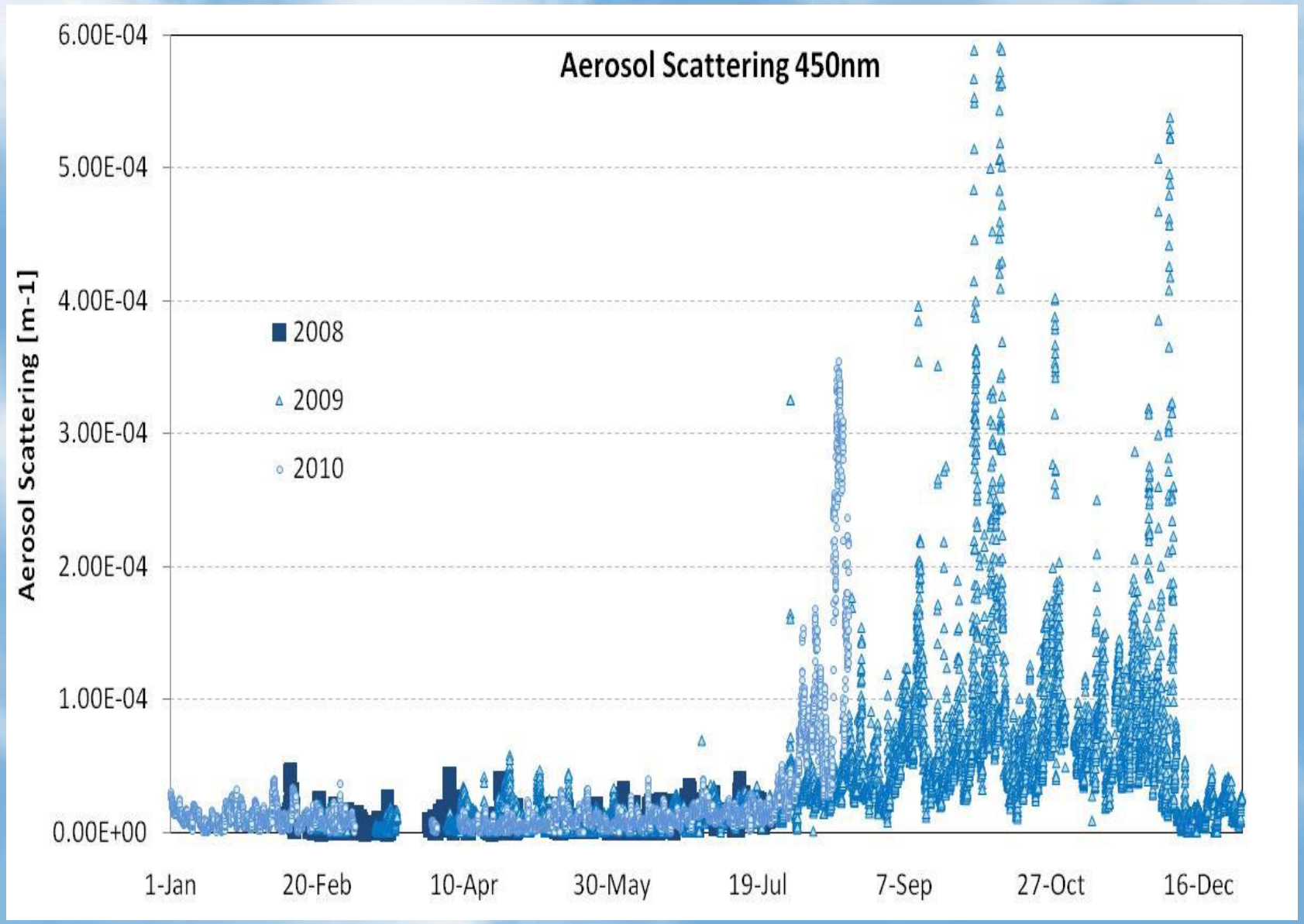
Al, Si and Ti elemental Concentration for fine and coarse mode aerosols Feb. to September



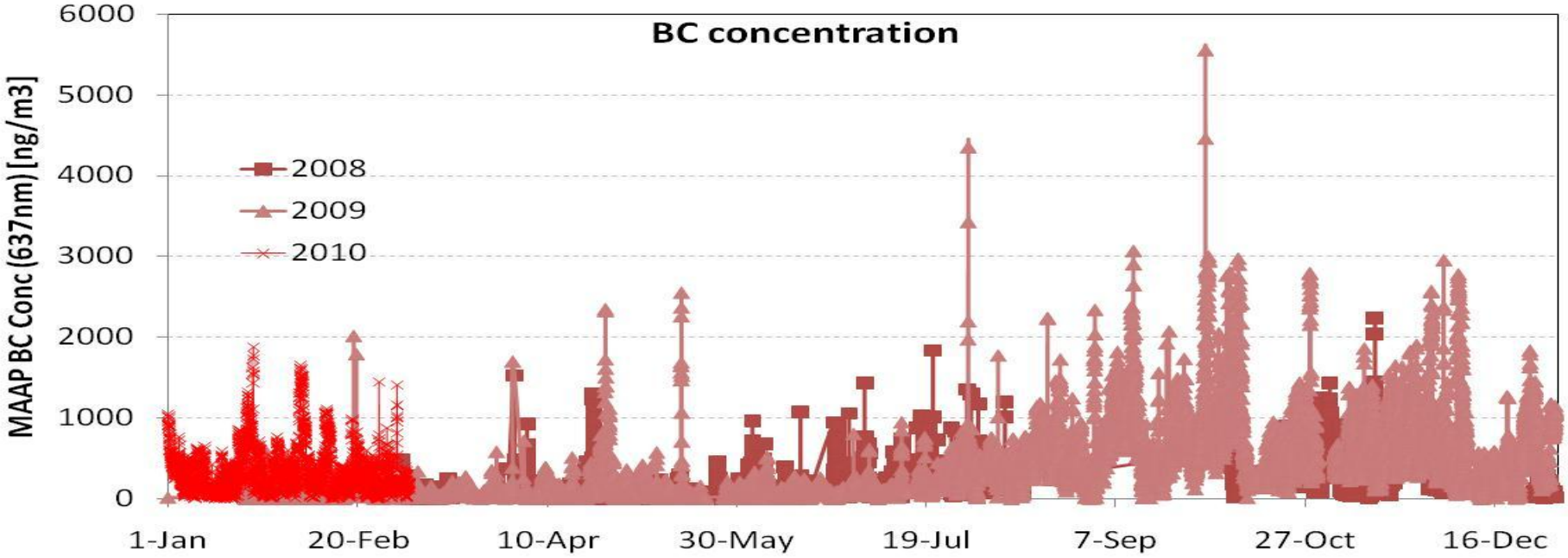


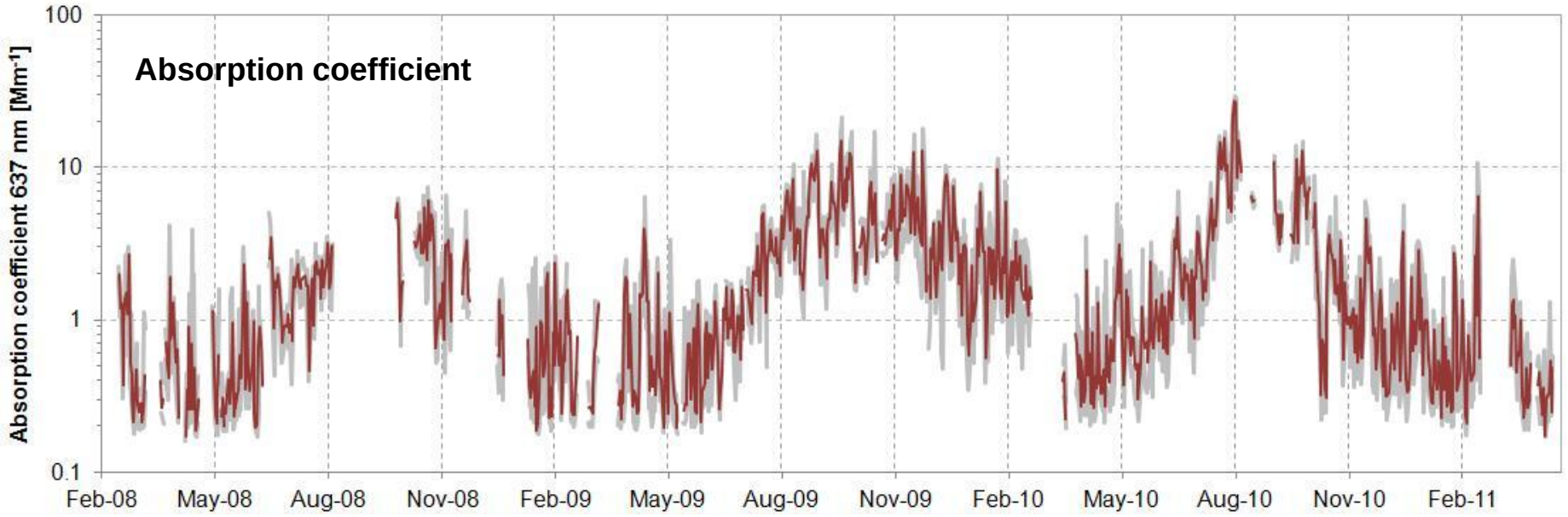


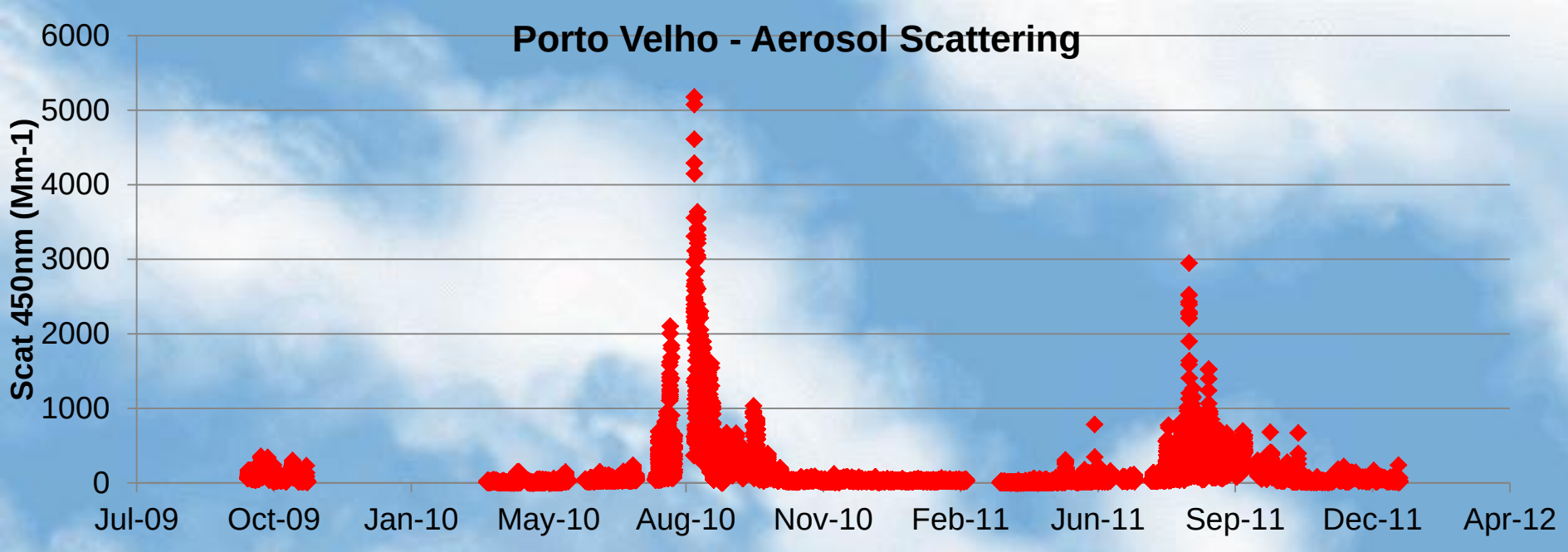
Manaus aerosol light scattering TSI Nephelometer 2008-2010

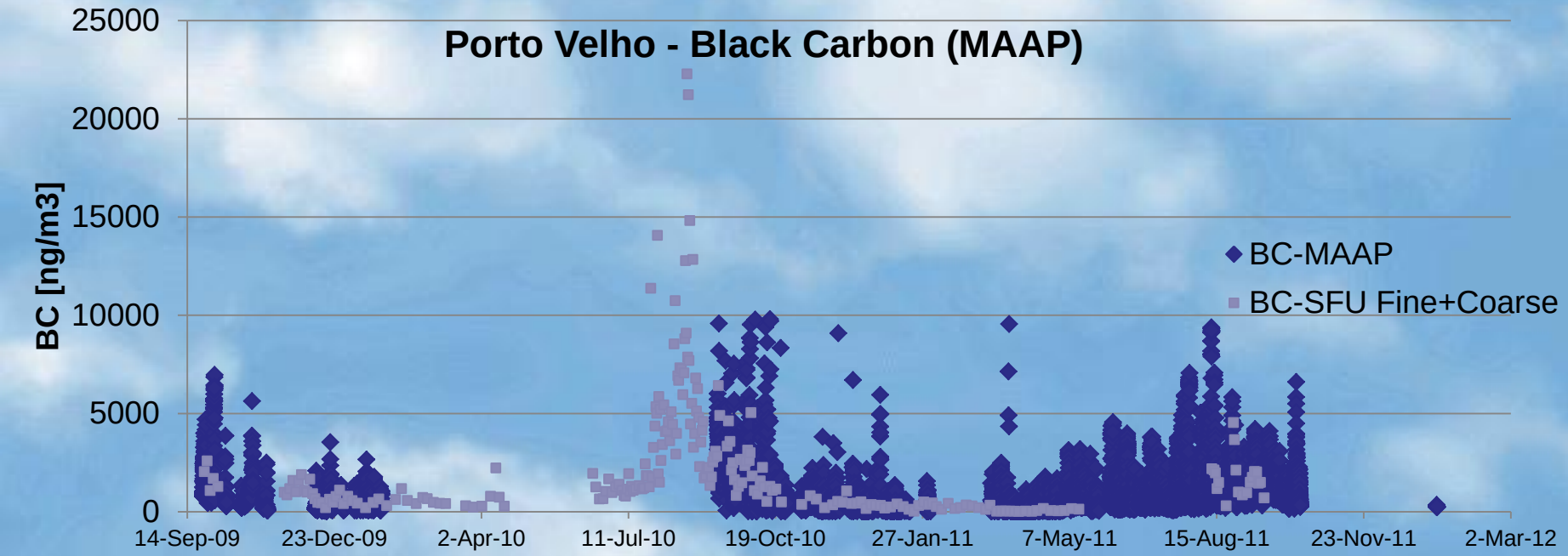


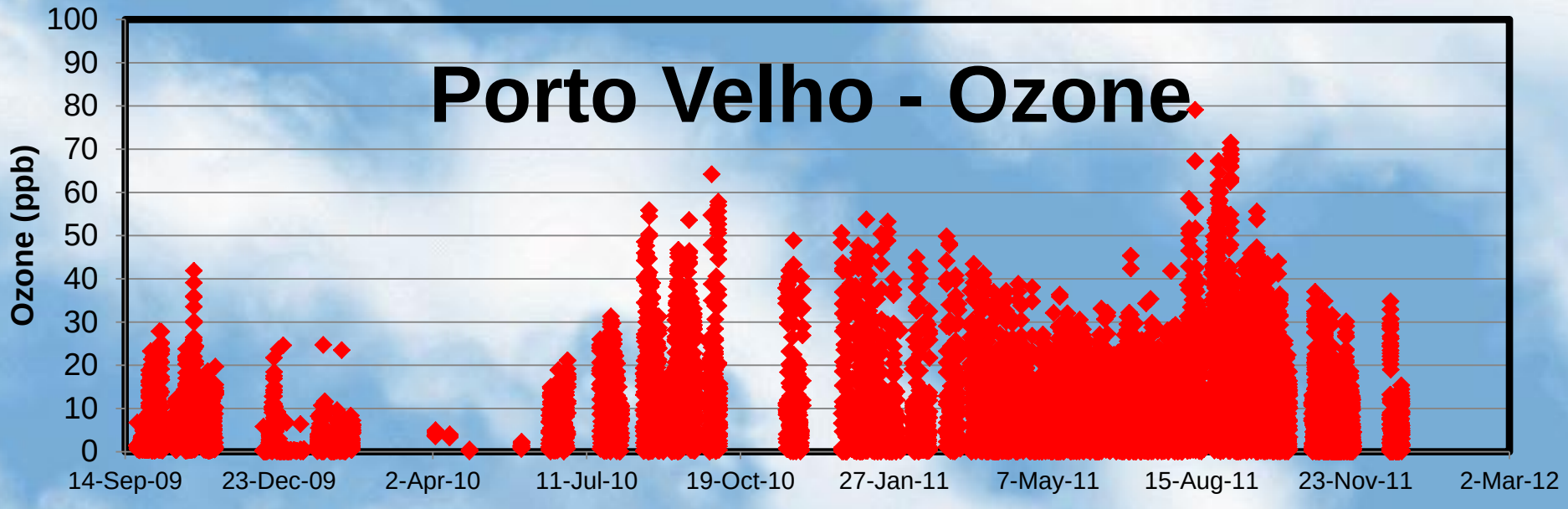
Manaus aerosol light absorption at 637 nm MAAP 2008-2010

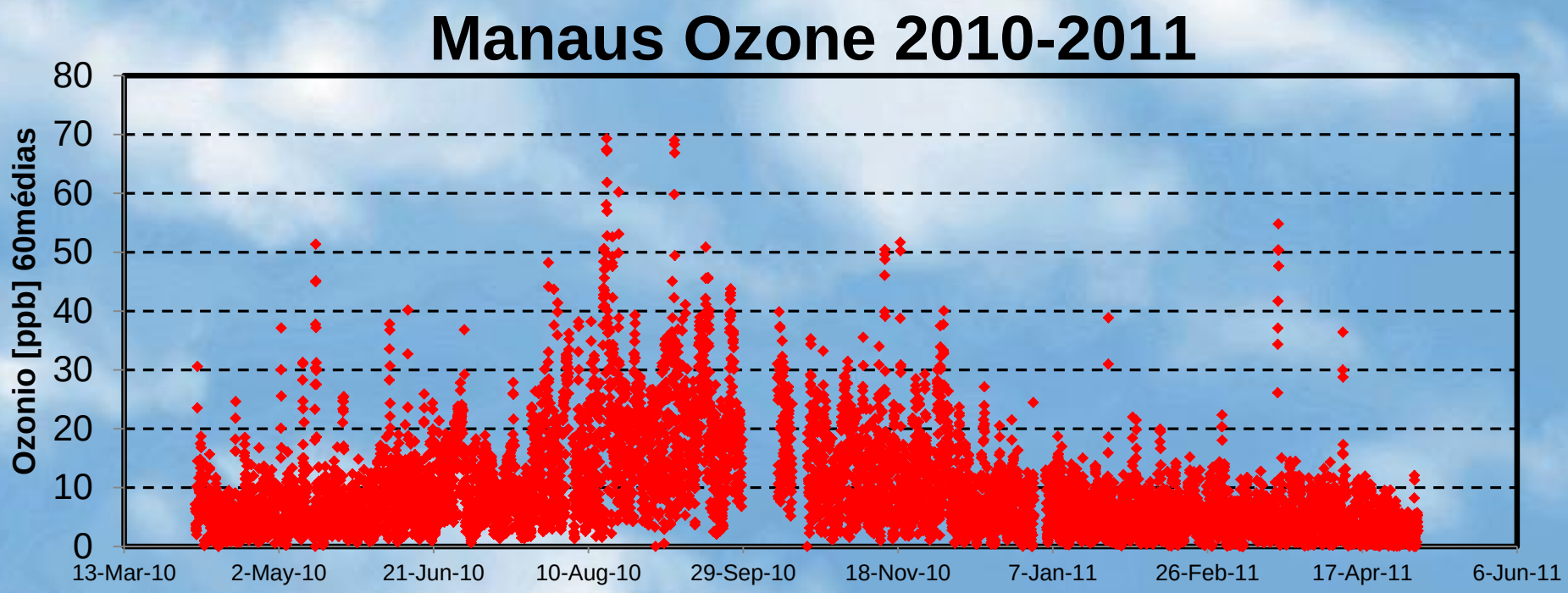





Porto Velho - Aerosol Scattering
Scat 450nm (Mm-1)
6000
5000
4000
3000
2000
1000
0
Jul-09
Oct-09
Jan-10
May-10
Aug-10
Nov-10
Feb-11
Jun-11
Sep-11
Dec-11
Apr-12

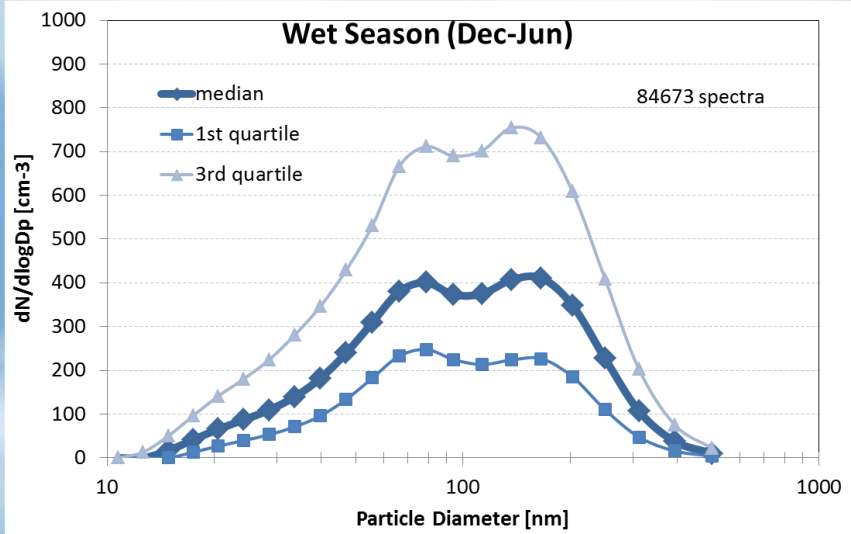

Porto Velho - Black Carbon (MAAP)
BC [ng/m3]
25000
20000
15000
10000
5000
0
BC-MAAP
BC-SFU Fine+Coarse
14-Sep-09
23-Dec-09
2-Apr-10
11-Jul-10
19-Oct-10
27-Jan-11
7-May-11
15-Aug-11
23-Nov-11
2-Mar-12


Porto Velho - Ozone
Ozone (ppb)
100
90
80
70
60
50
40
30
20
10
0
14-Sep-09
23-Dec-09
2-Apr-10
11-Jul-10
19-Oct-10
27-Jan-11
7-May-11
15-Aug-11
23-Nov-11
2-Mar-12

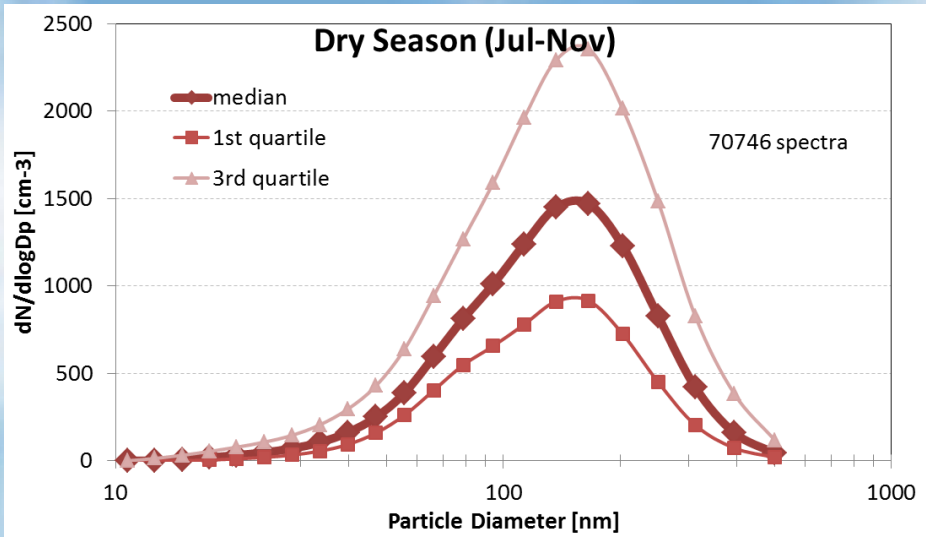

Manaus Ozone 2010-2011
Ozonio [ppb] 60médias
80
70
60
50
40
30
20
10
0
13-Mar-10
2-May-10
21-Jun-10
10-Aug-10
29-Sep-10
18-Nov-10
7-Jan-11
26-Feb-11
17-Apr-11
6-Jun-11

Amazonian aerosol size distributions 2008-2010

Wet season



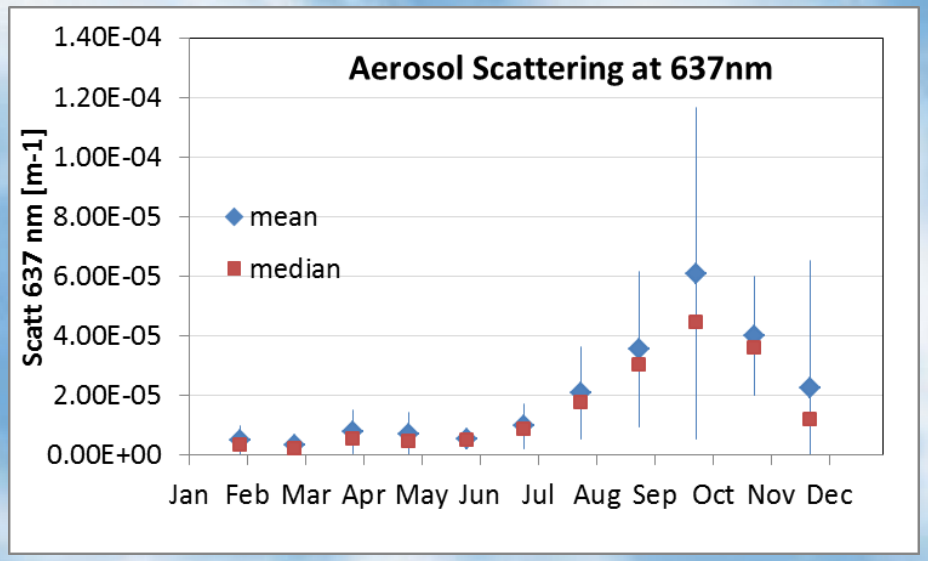
Dry season

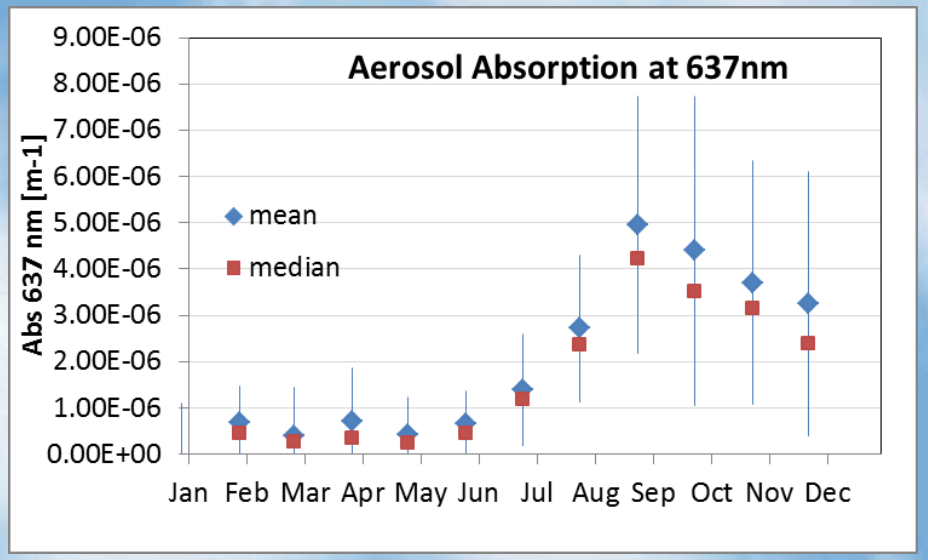


Fit Parameters for median size distributions:

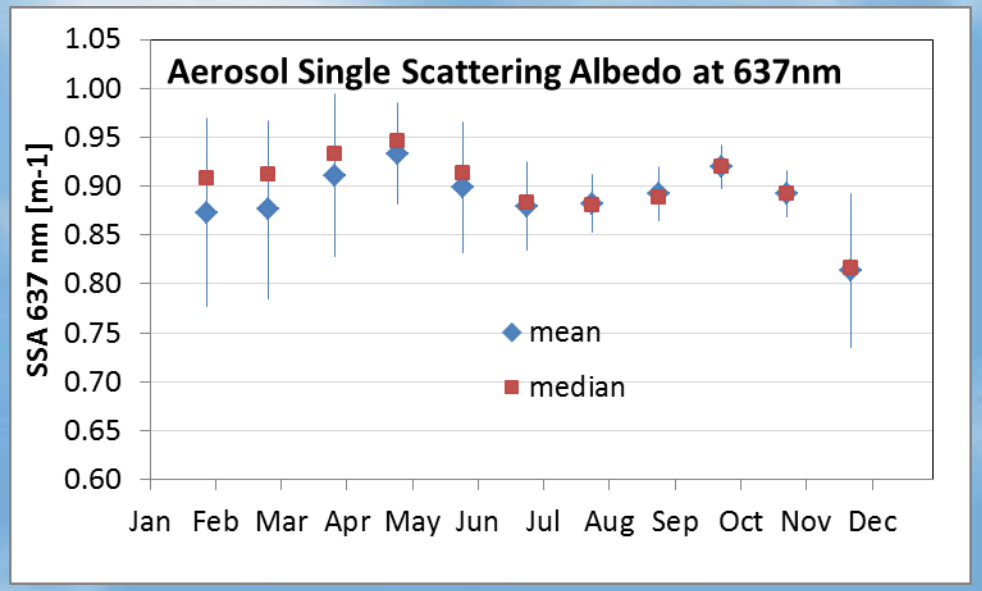
	Ultrafine mode			Aitken mode			Accumulation mode		
	N1 [cm-3]	Dpg1 [nm]	sg1	N2 [cm-3]	Dpg2 [nm]	sg2	N3 [cm-3]	Dpg3 [nm]	sg3
Wet season (Dec-Jun)	121	**34.9**	0.28	314	**71.0**	0.20	403	**163.5**	0.24
Dry season (Jul-Nov)				926	**117.3**	0.36	699	**175.9**	0.22

Monthly average optical properties





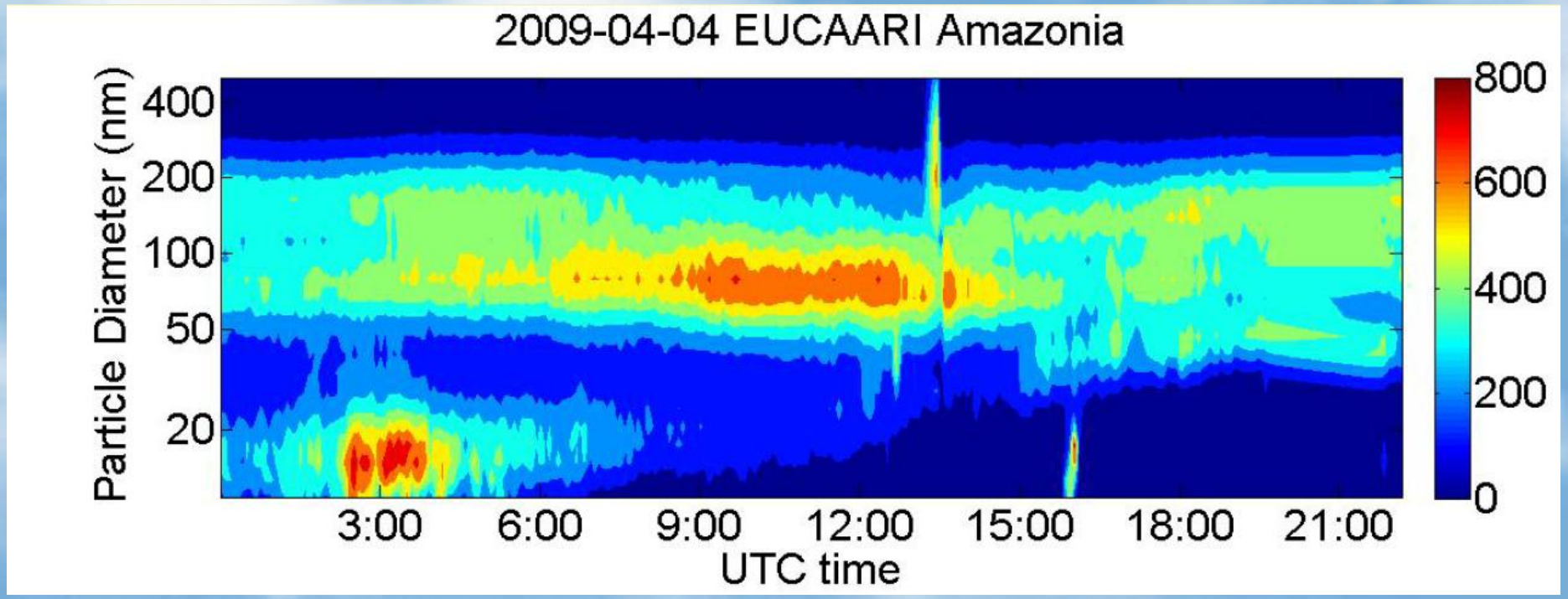
Single scattering albedo



Tambem:

Perfil vertical de aerossóis com Lidar até 15 Km
Vapor de água no perfil do Lidar
CCN continuamente
Cruzamento com medidas de CO, CO2, O3, VOCs contínuo
Etc…

New particle formation? Bursts of particles $10<D_p<40$ nm.

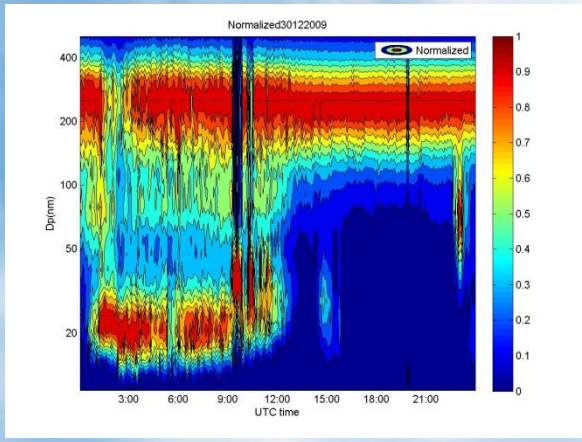


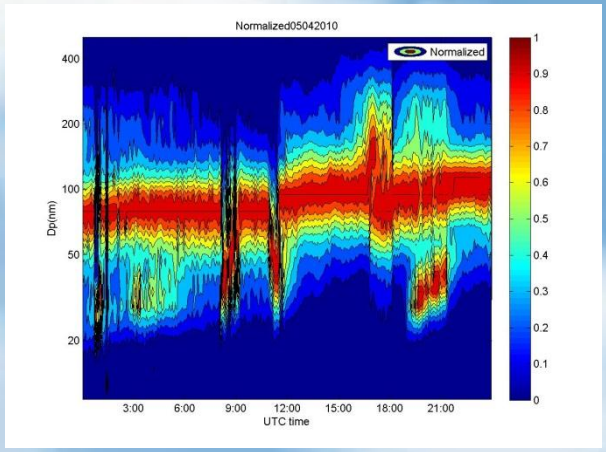
Aerosol size distributions measured in 2009 Apr 4th. There was a burst of ultrafine particles from 2:00 to 4:00 UTC time.

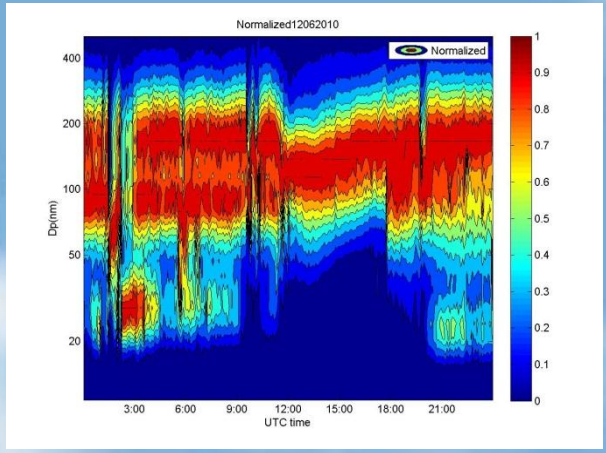
New particle formation and subsequent growth was seldom observed along two years of measurements. Nevertheless, in 70% of the days, bursts of particles with diameters in the range 10-40nm were detected. The events usually lasted from 20 to 120min, and the subsequent growth to larger sizes was not always clearly observed.

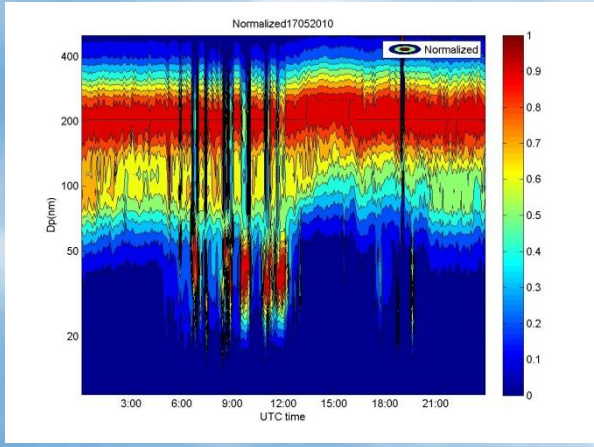
Particle production at about 20 nm

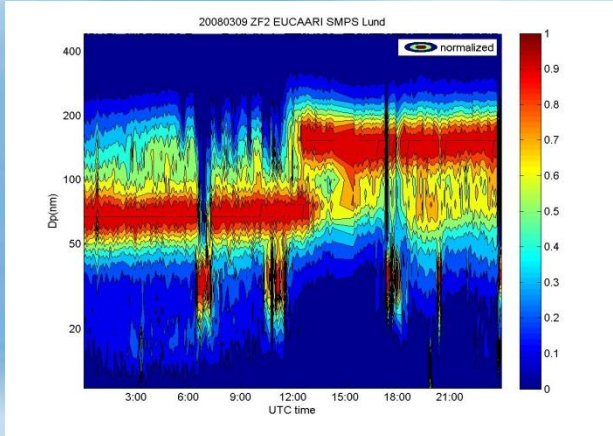
Which biological process is responsible for this new particle formation?

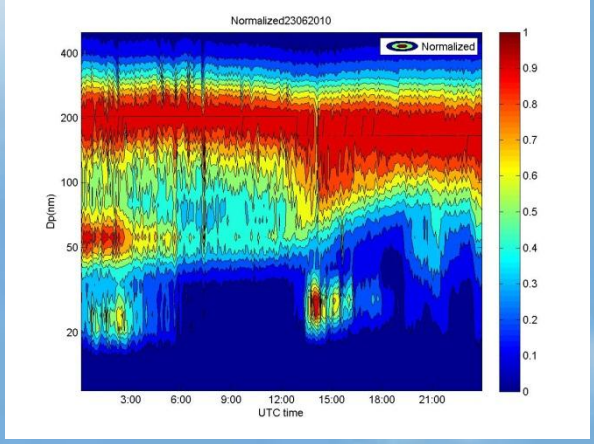


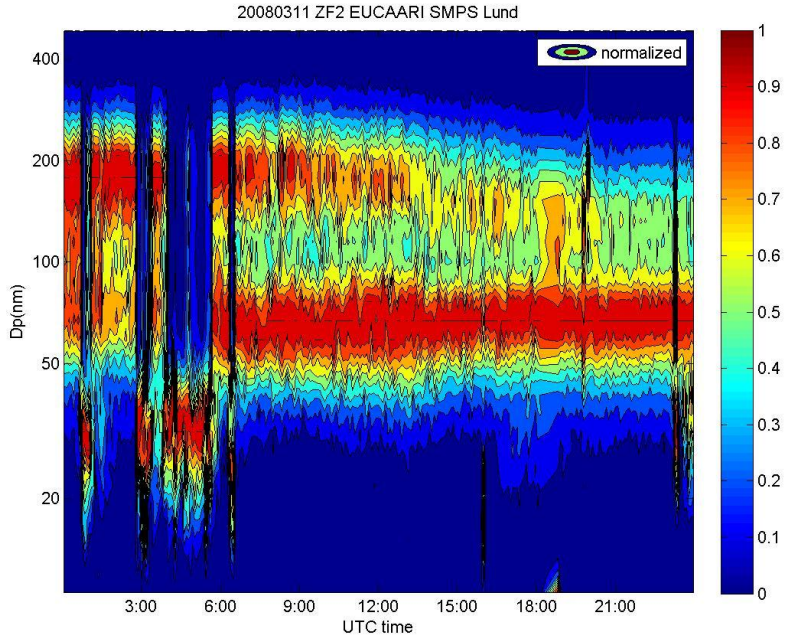


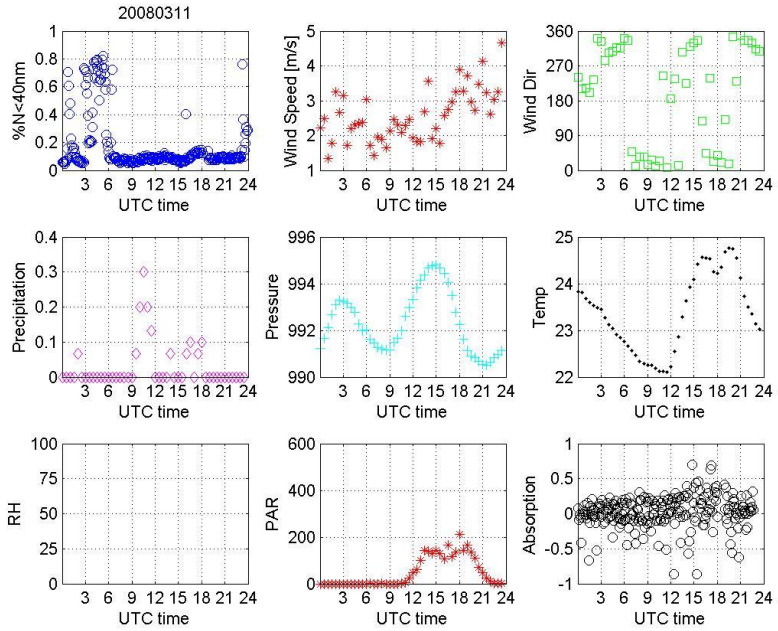


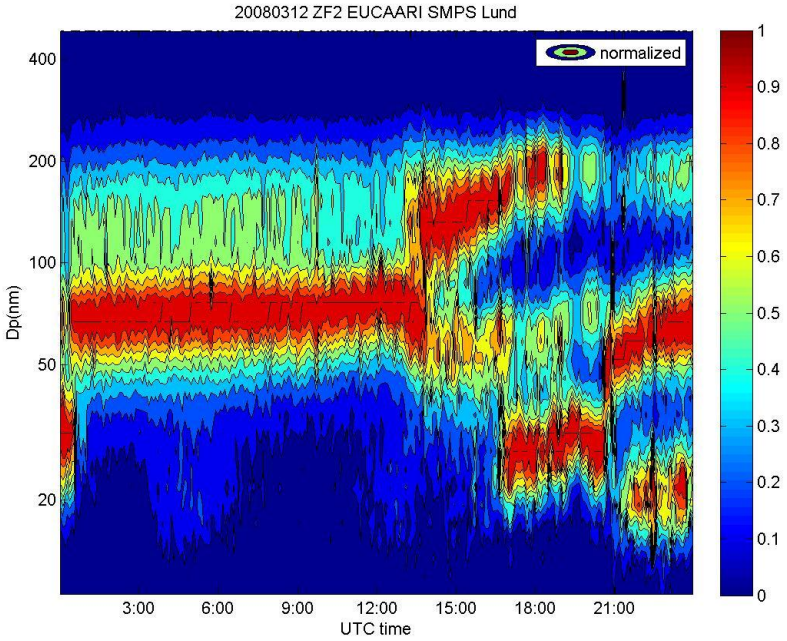


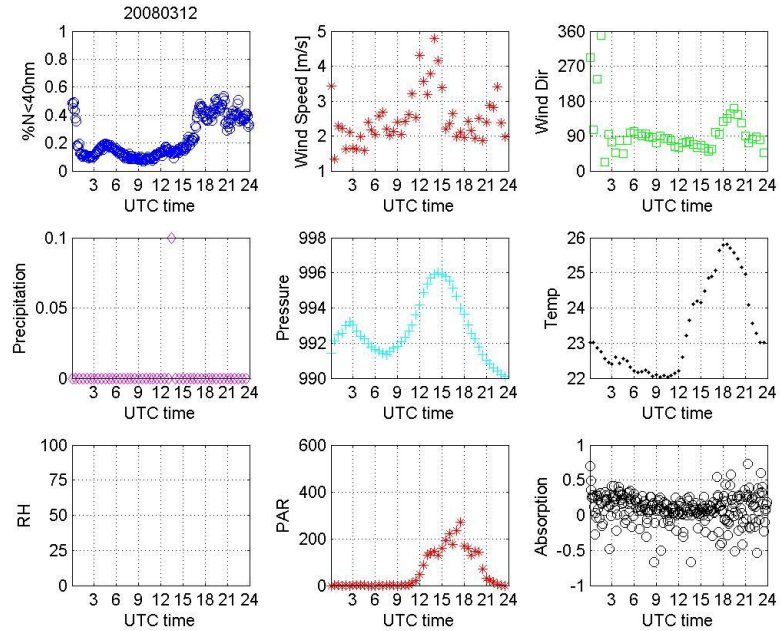




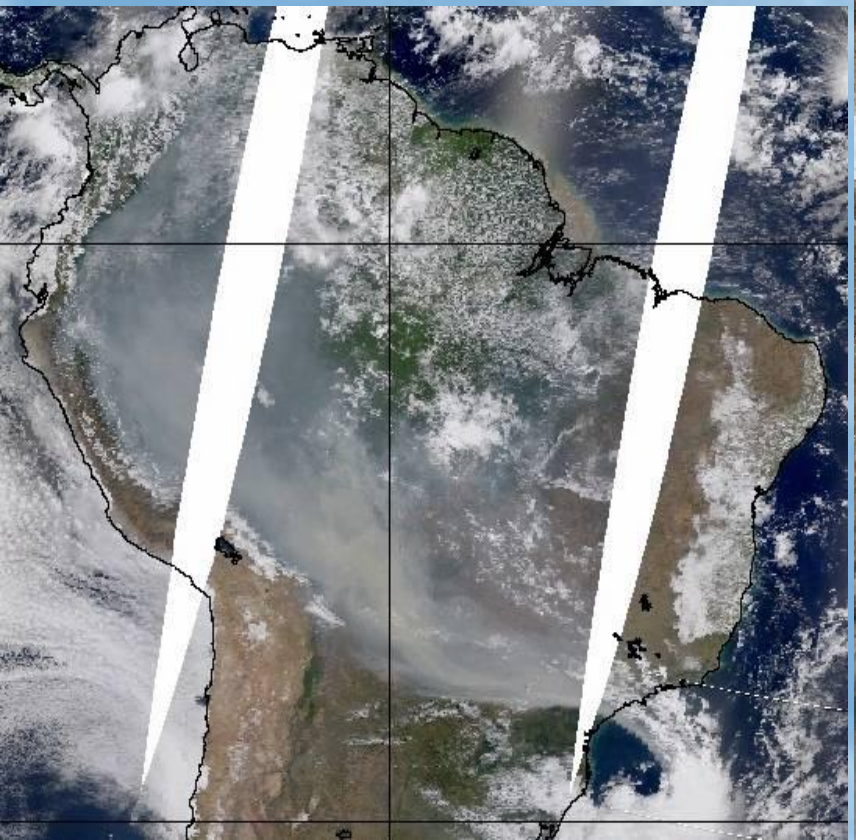

20080311 ZF2 EUCAARI SMPS Lund
normalized
Dp(nm)
UTC time

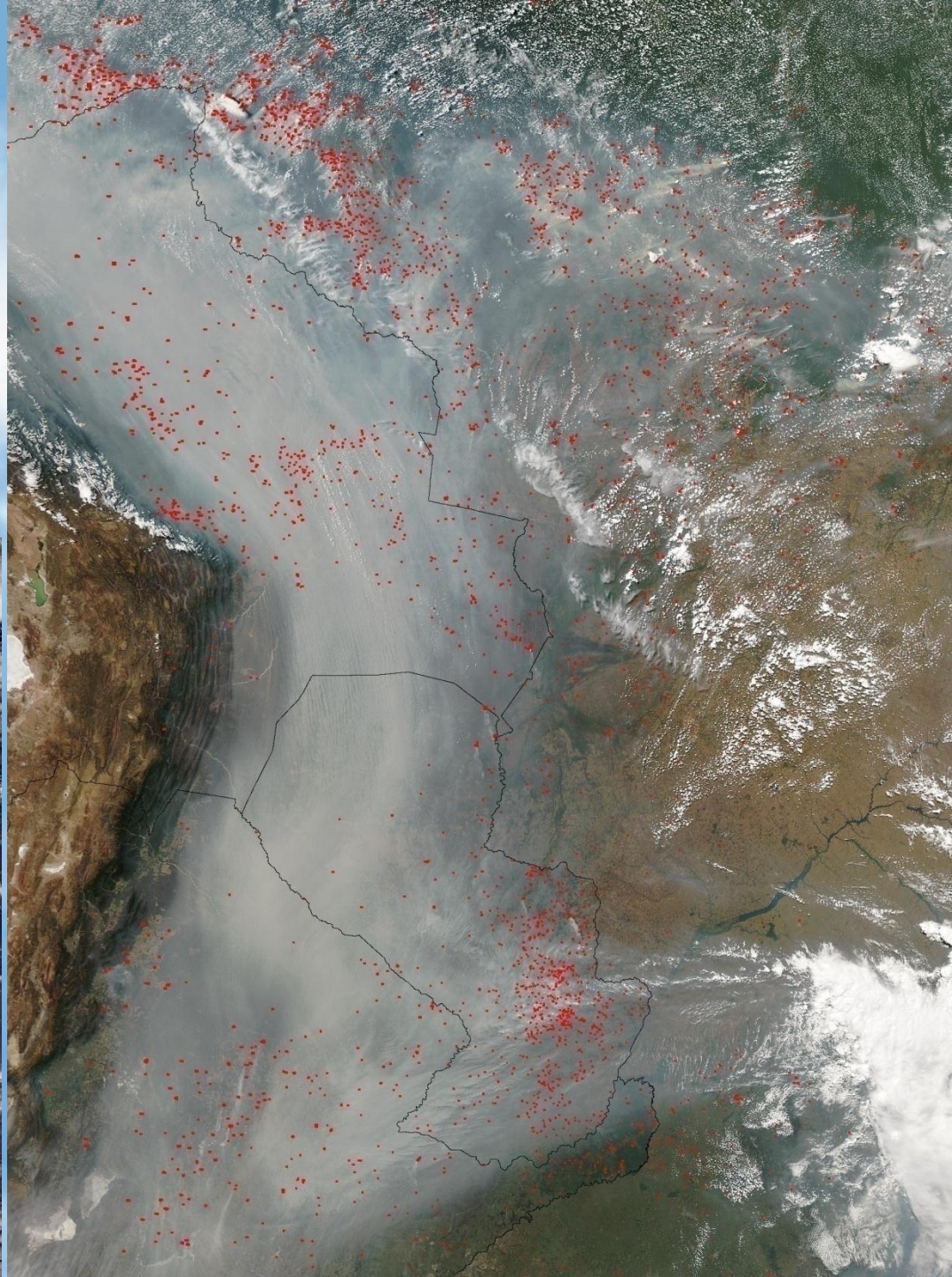

20080311
%N<40nm
Wind Speed [m/s]
Wind Dir
Precipitation
Pressure
Temp
RH
PAR
Absorption
UTC time


20080312 ZF2 EUCAARI SMPS Lund
normalized
Dp(nm)
UTC time


20080312
%N<40nm
Wind Speed [m/s]
Wind Dir
Precipitation
Pressure
Temp
RH
PAR
Absorption
UTC time

Large scale distribution of biomass burning aerosols in South America



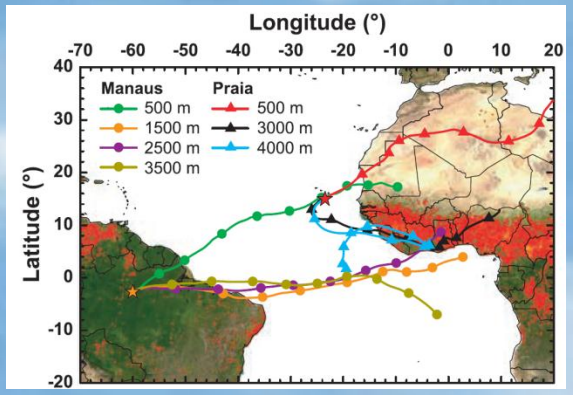


Raman Lidar observations of aerosols on Cape Verde and Manaus

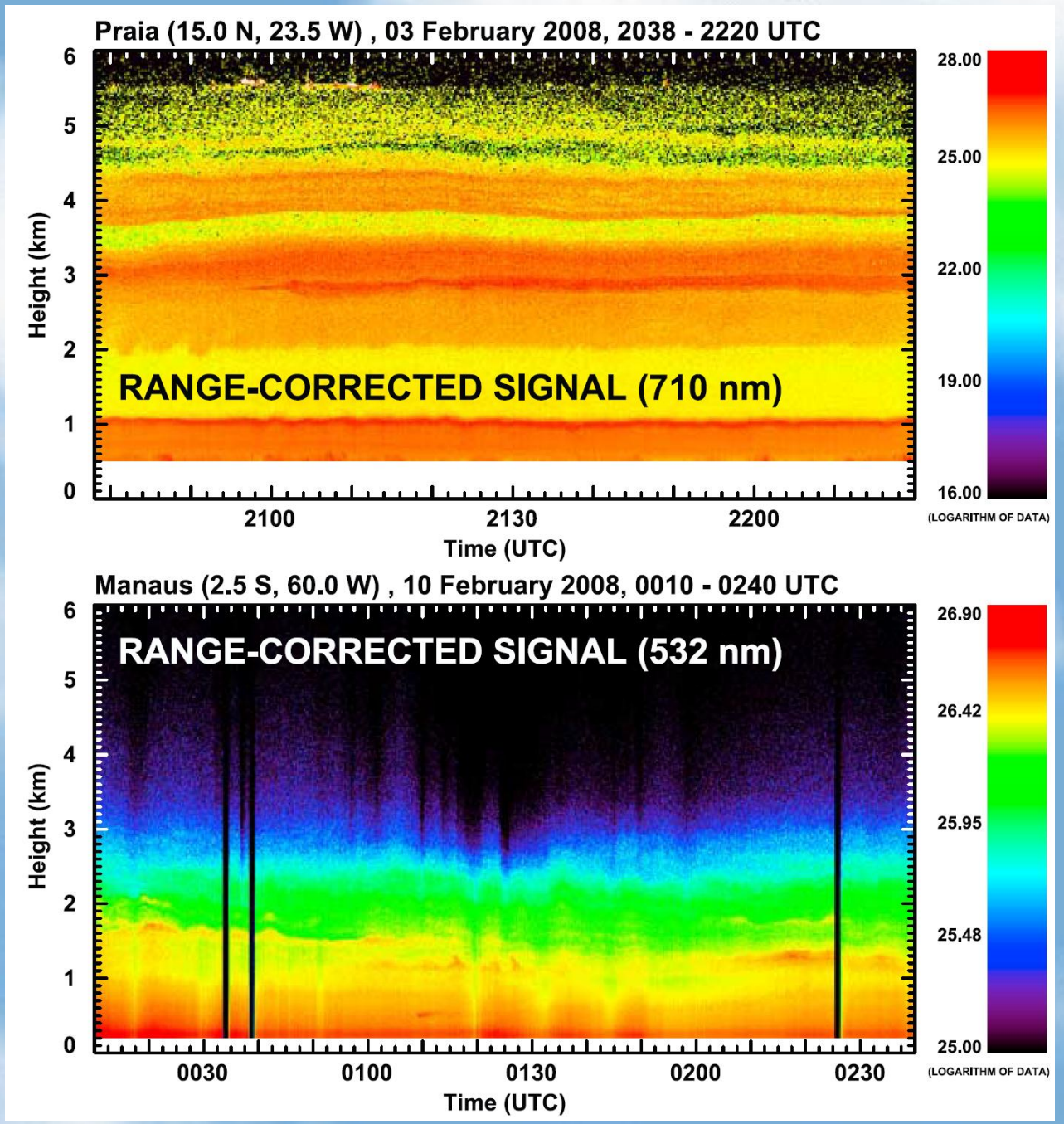
Range-corrected lidar signals

Complex vertical layering of dust and smoke up to 5.5 km height was observed over Praia, Cape Verde, on 3 February 2008. (top).

An homogeneous layer was observed in Manaus Feb. 10. (bottom)

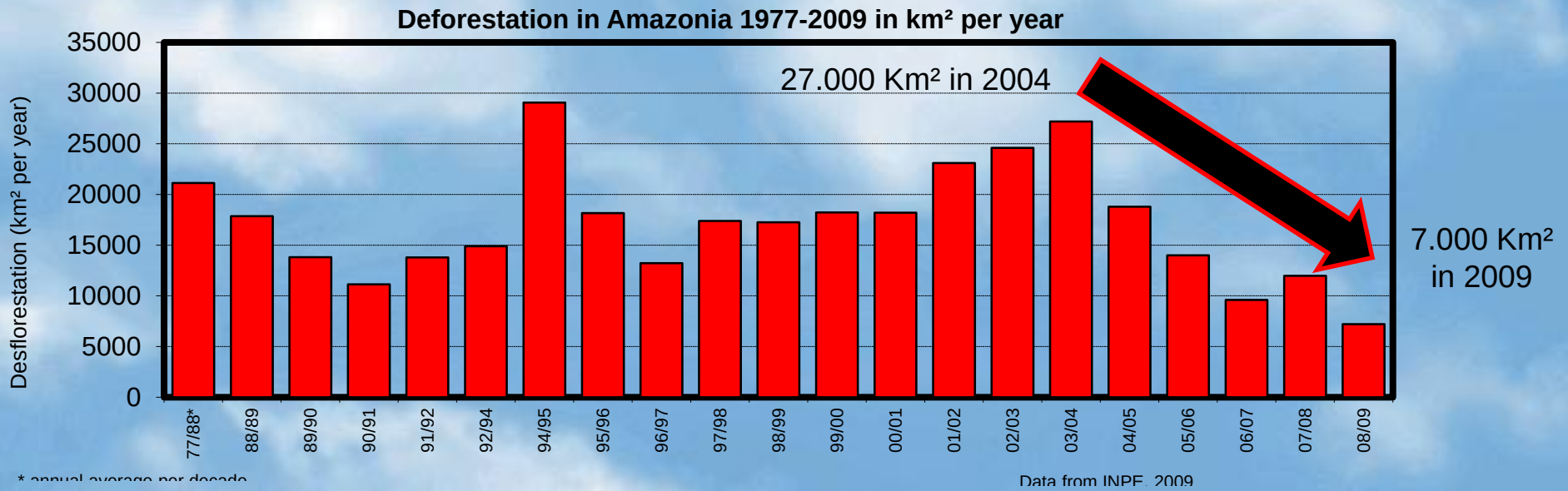


Ansmann et *al., GRL 2009*



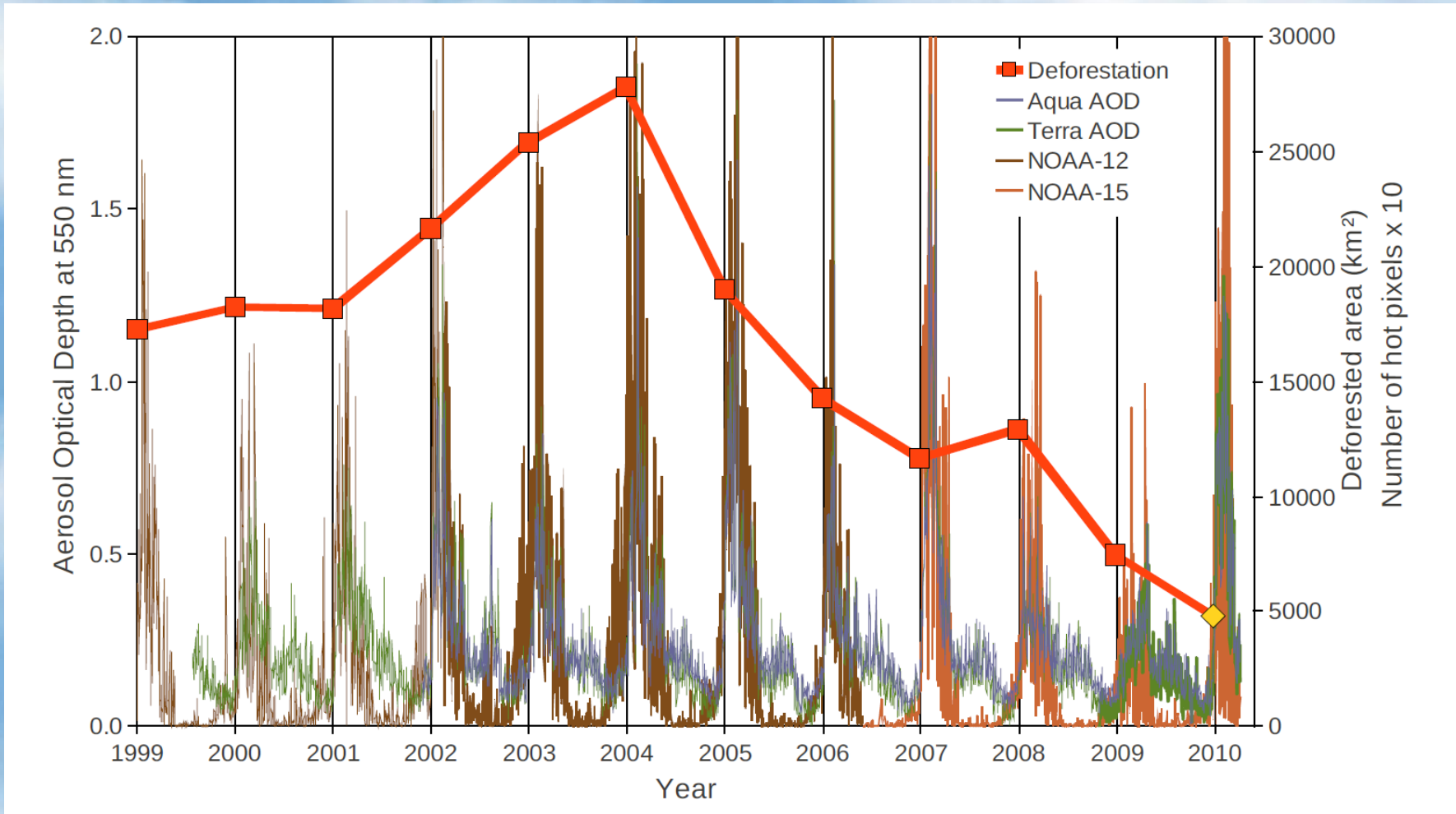
Deforestation was reduced from 27,000 Km² in 2004 to 7,000 Km² in 2009.

How much aerosols were reduced?



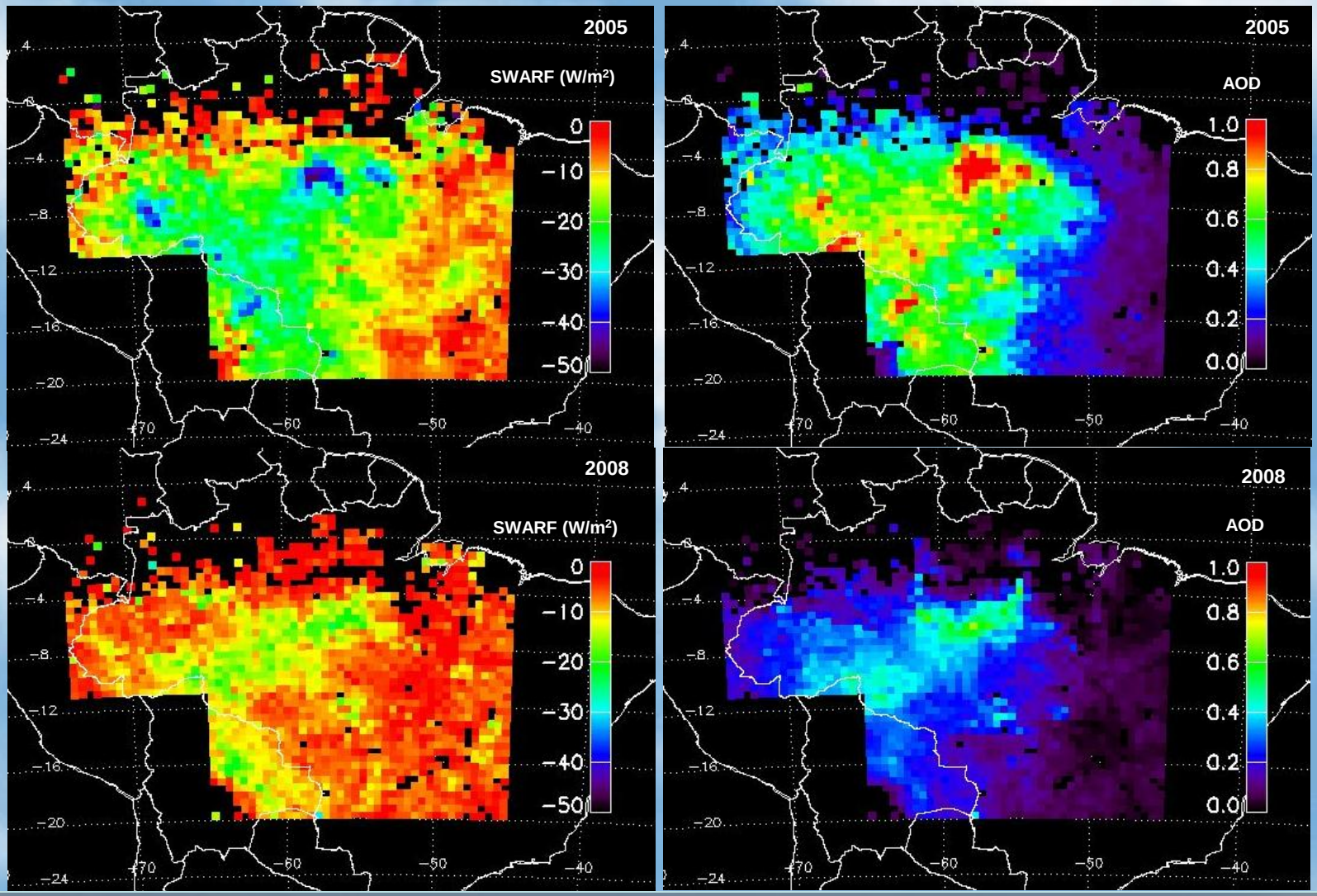
What public policies are needed to sustain this reduction?

Yearly deforestation with MODIS AOD and hot pixels from NOAA



Yearly deforestation over the Brazilian Amazon region (INPE, 2010) compared to MODIS daily smoke optical depth and the daily number of hot pixels from NOAA-12 and NOAA-15.

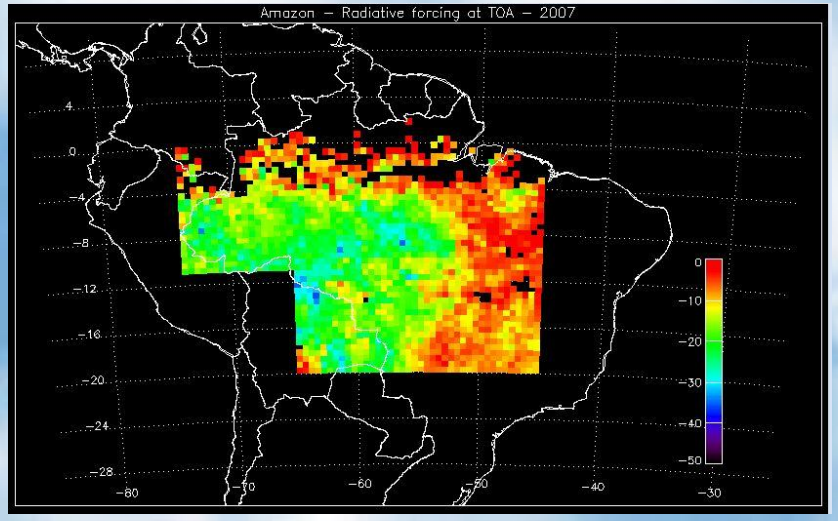
Examples of the spatial distribution of the SWARF at TOA

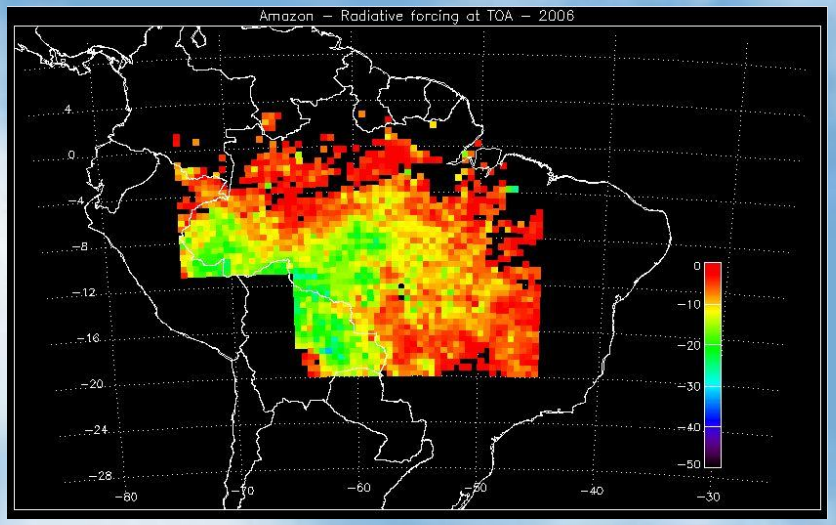


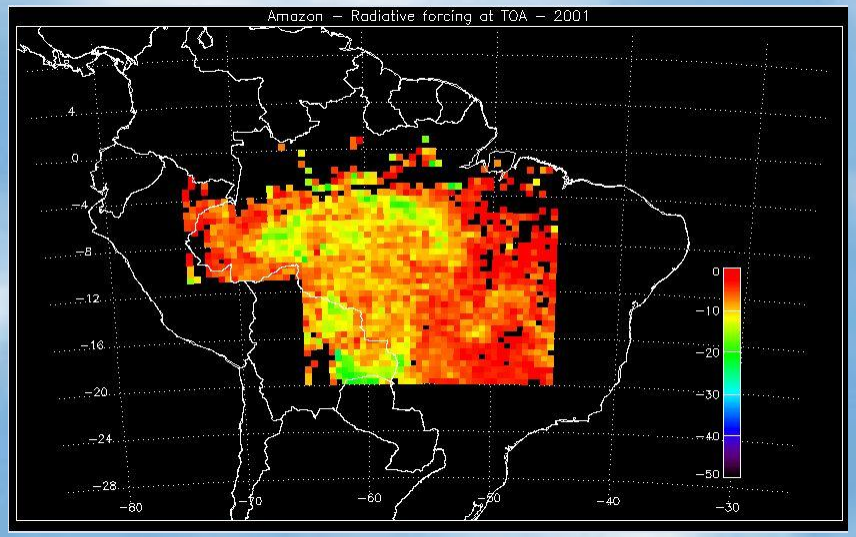
The higher the AOD the higher is the correlation between SWARF and AOD. For lower AOD values the influence of other parameters such as the surface reflectance also become important.

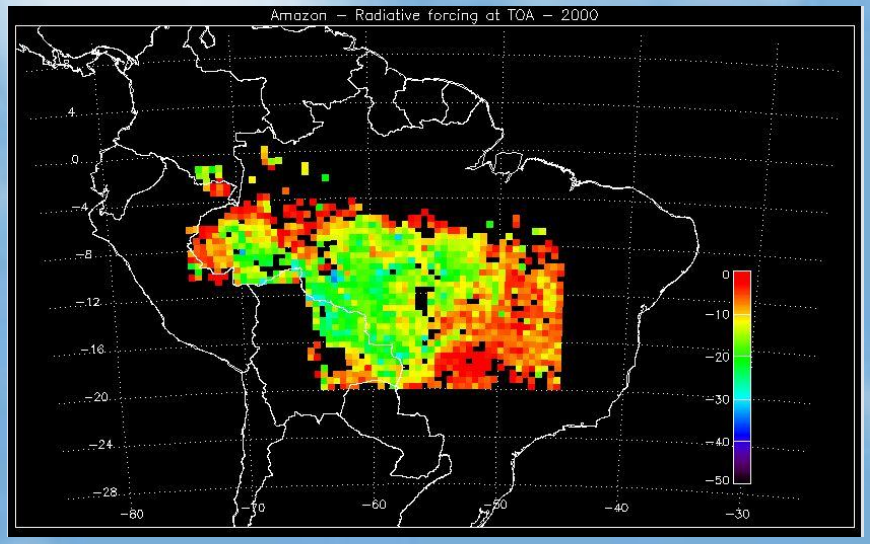
Large scale radiative forcing in Amazonia from 2000 to 2007

CERES *(Clouds and the Earth's Radiant Energy System) and MODIS*







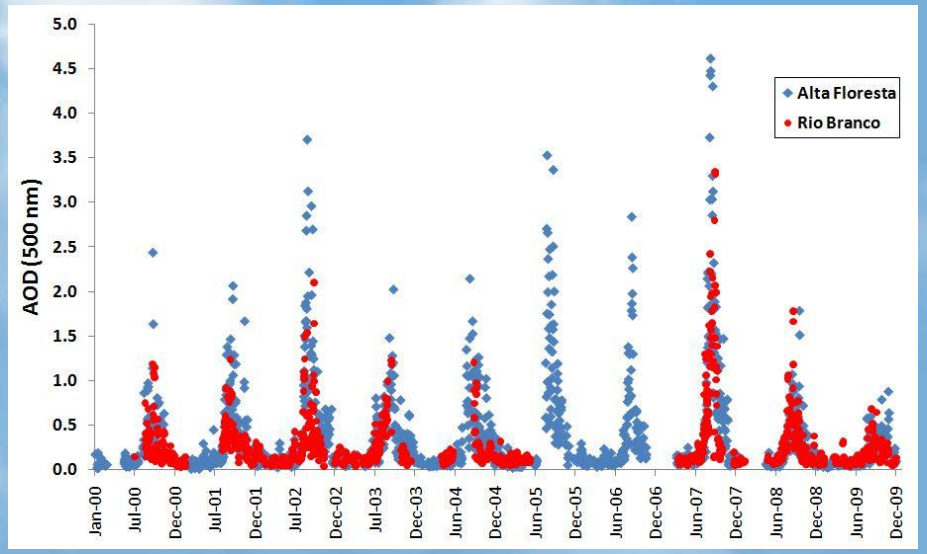


Elisa Thomé Sena, PhD Student IFUSP

Amazon shortwave aerosol radiative forcing (SWARF) at the top of the atmosphere (TOA) from 2000 to 2009 using shortwave (SW) flux at the TOA from the CERES sensor and AOD from MODIS.

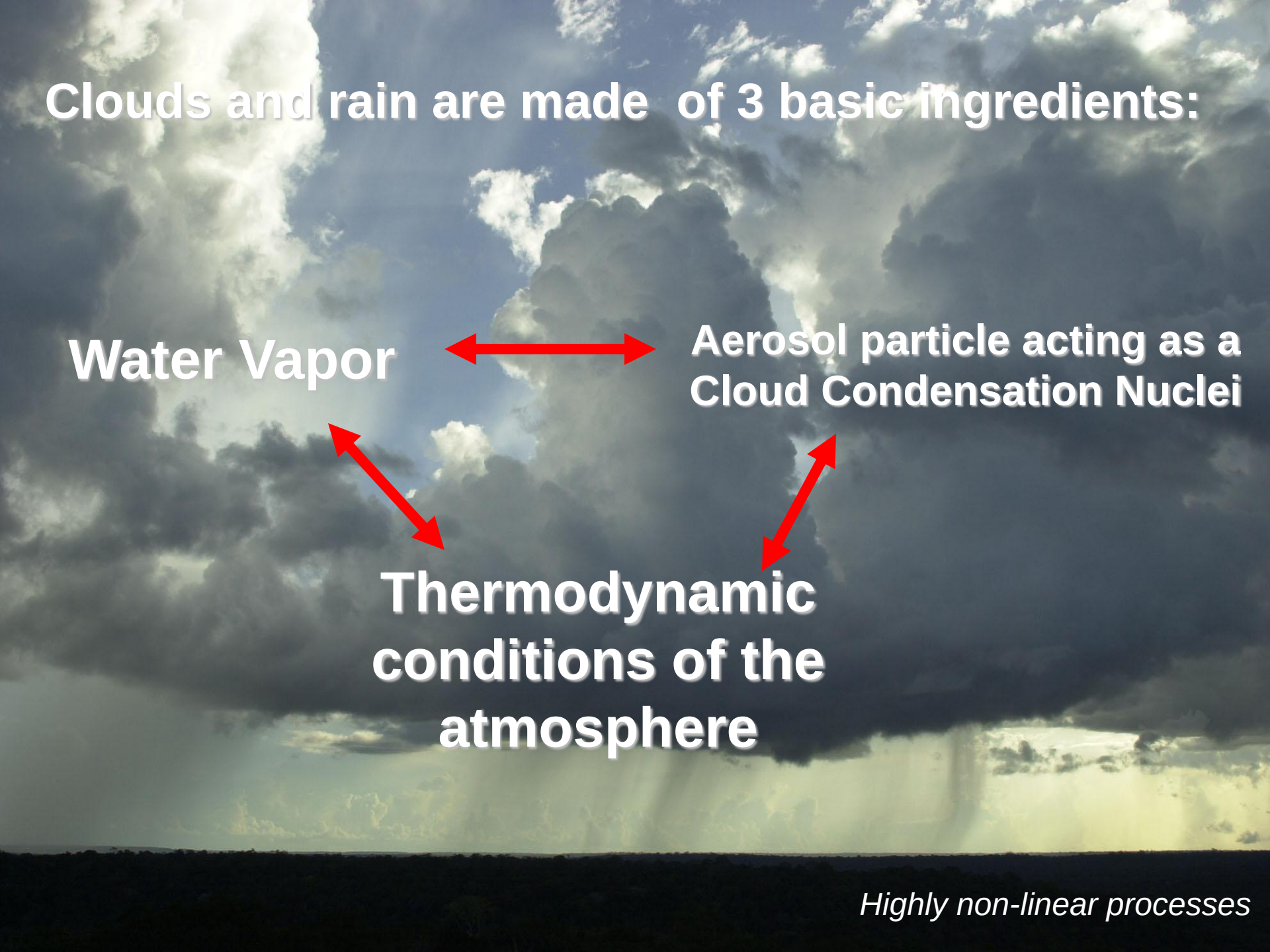
Table 1 *– Shortwave aerosol radiative forcing for Amazon region during the biomass burning season of the years 2000 to 2009.*

Year	Valid Cells	SWARF (W/m²)
2000	1163	-12.3 ± 12.5
2001	1492	-8.1 ± 13.3
2002	1447	-12.8 ± 11.8
2003	1392	-12.0 ± 12.5
2004	185	-13.4 ± 17.6
2005	1799	-15.0 ± 13.4
2006	1654	-9.5 ± 12.9
2007	1731	-13.9 ± 17.1
2008	1665	-8.2 ± 15.9
2009	1405	-4.7 ± 11.0
Average		**-10.6 ± 4.2**



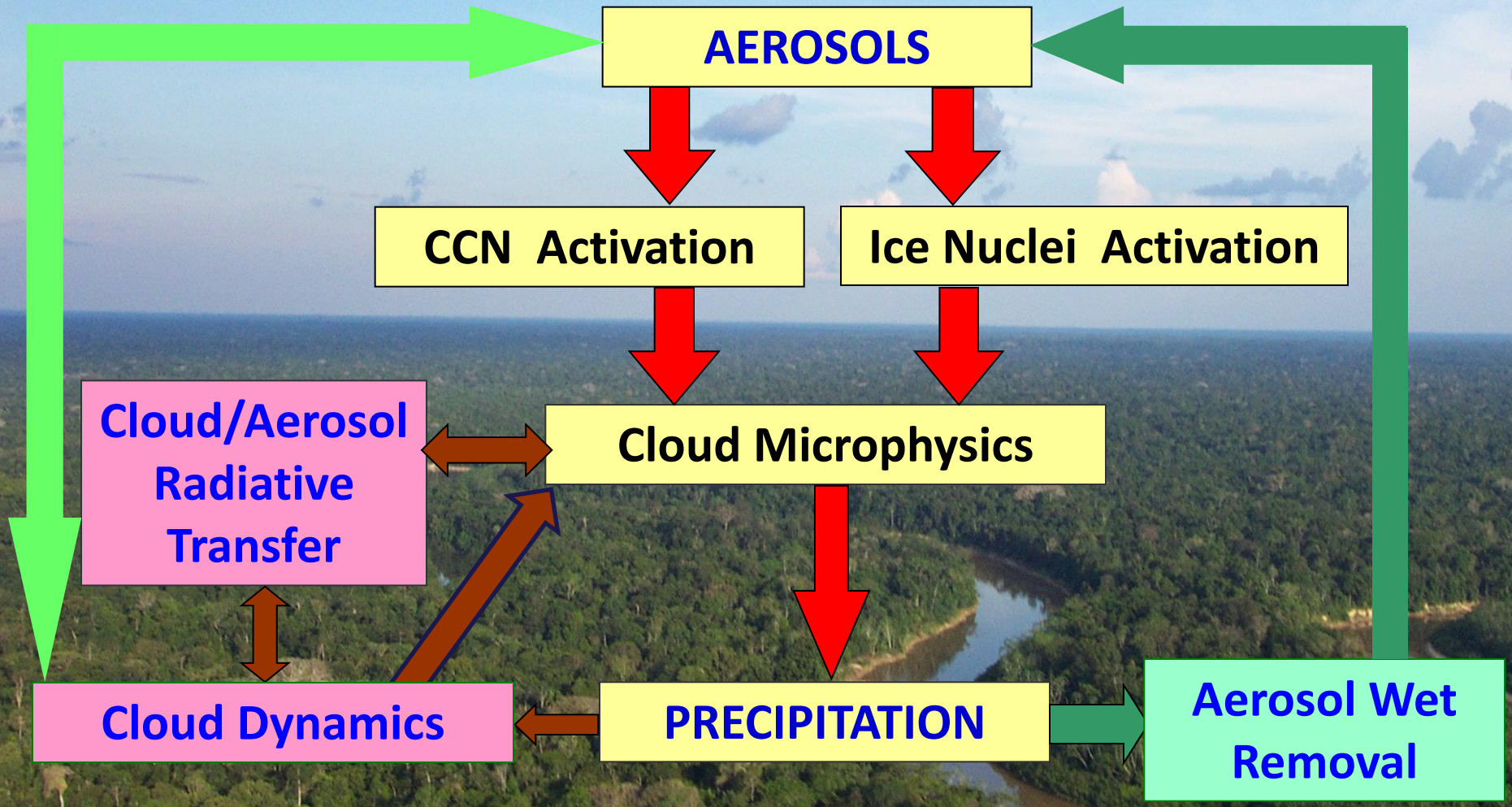
AERONET time series of the aerosol optical depth at 500 nm from 2000 to 2009 over two Amazon sites: Alta Floresta and Rio Branco.

Elisa Thomé Sena, PhD Student IFUSP


Clouds and rain are made of 3 basic ingredients:
Water Vapor
Aerosol particle acting as a Cloud Condensation Nuclei
Thermodynamic conditions of the atmosphere
Highly non-linear processes

Aerosol-cloud-precipitation feedbacks

CCN = cloud condensation nuclei and IN = ice nuclei.



Aerosol-clouds interactions and aerosol radiative forcing

- Optical, physical properties and chemical composition of biomass burning aerosols
- Properties of natural biogenic aerosols
- Cloud Condensation Nuclei (CCN) properties
- Long term measurements of ground, vertical distribution and column integrated optical properties
- Clouds physical properties and distribution coupled with cloud droplets microphysical properties.

nature geoscience

LETTERS

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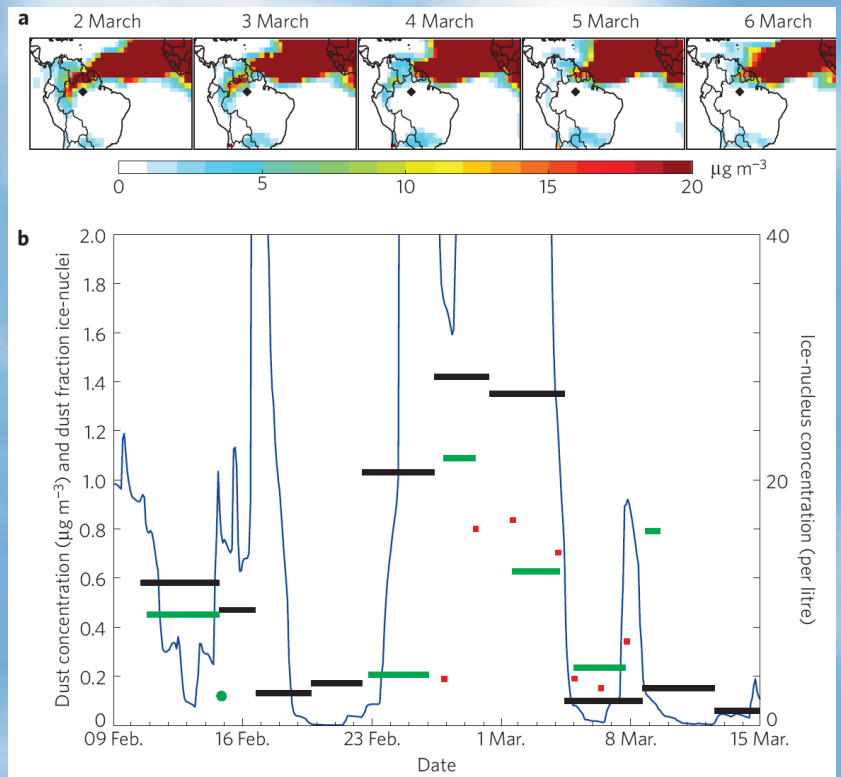
Relative roles of biogenic emissions and Saharan dust as ice nuclei in the Amazon basin

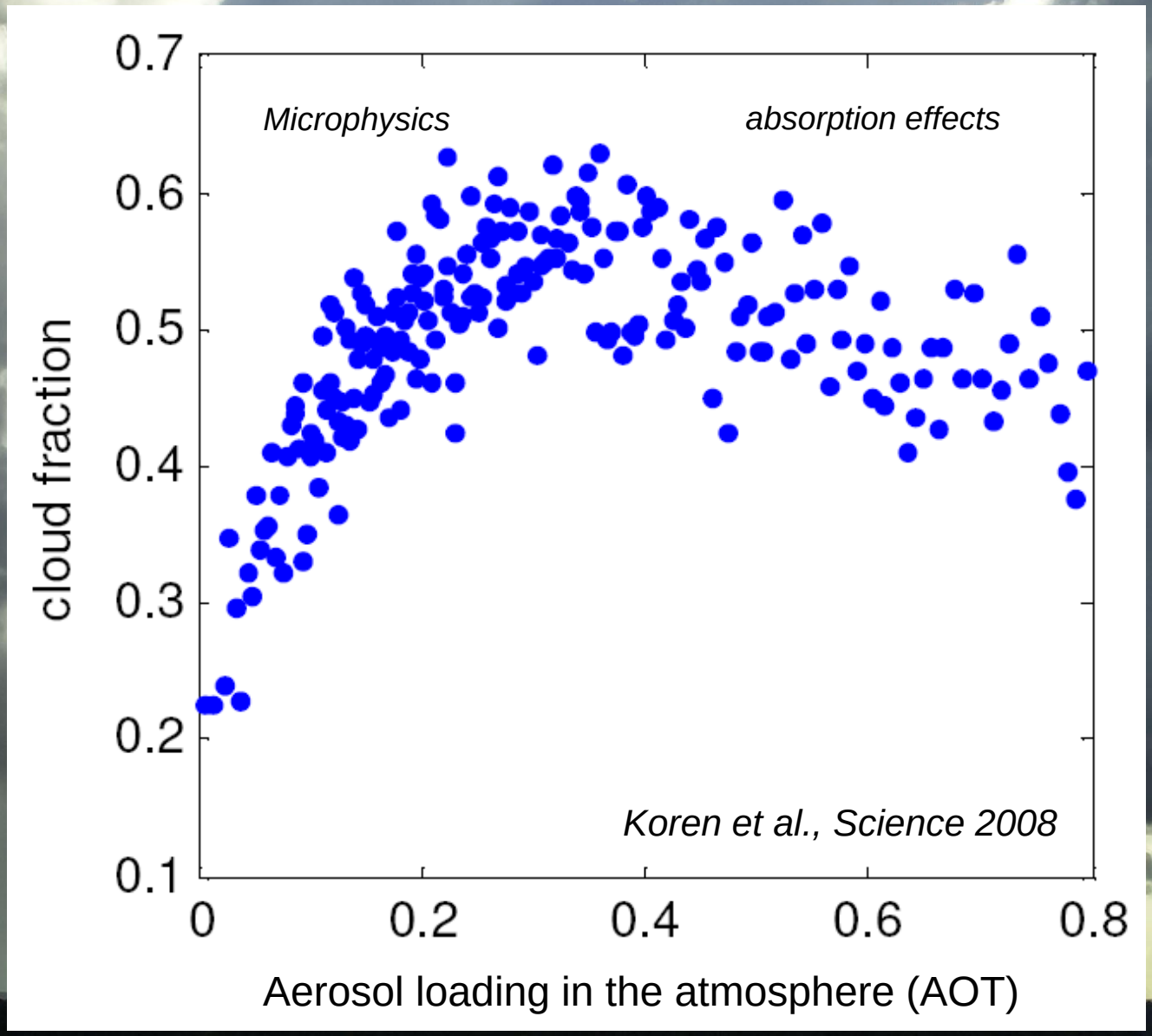
Anthony J. Prenni[1]*, Markus D. Petters[1], Sonia M. Kreidenweis[1], Colette L. Heald[1], Scot T. Martin[2], Paulo Artaxo[3], Rebecca M. Garland[4], Adam G. Wollny[4] and Ulrich Pöschl[4]

Ice nuclei from biogenic emissions and Sahara dust in Central Amazonia

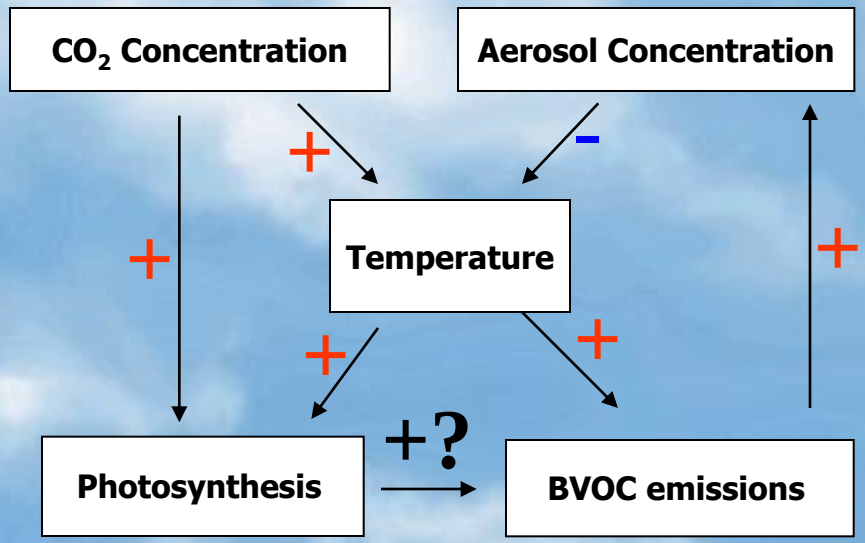


Dust relation to ice-nucleus measurements. Dust concentrations during AMAZE-08. a, GEOS-Chem simulated dust from 2–6 March at 18 UTC. The field site, shown as a black diamond, typically fell near the edge of the plumes. Fine-dust concentrations from PIXE measurements (black rectangles; μg/m³, dp<2μm.

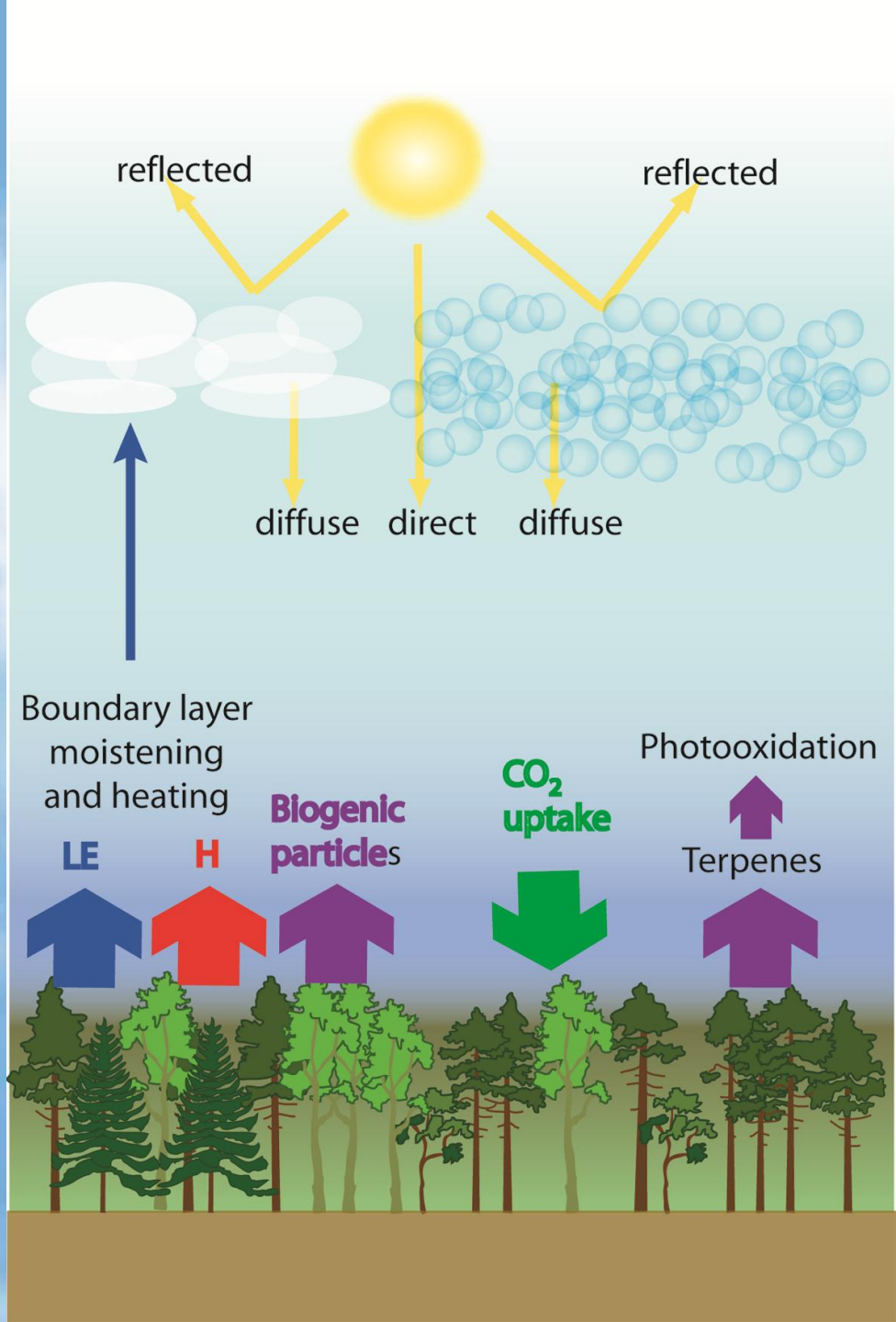
Relationships between cloud properties and aerosol loading in Amazonia



Aerosol effects on the Net Plant Productivity

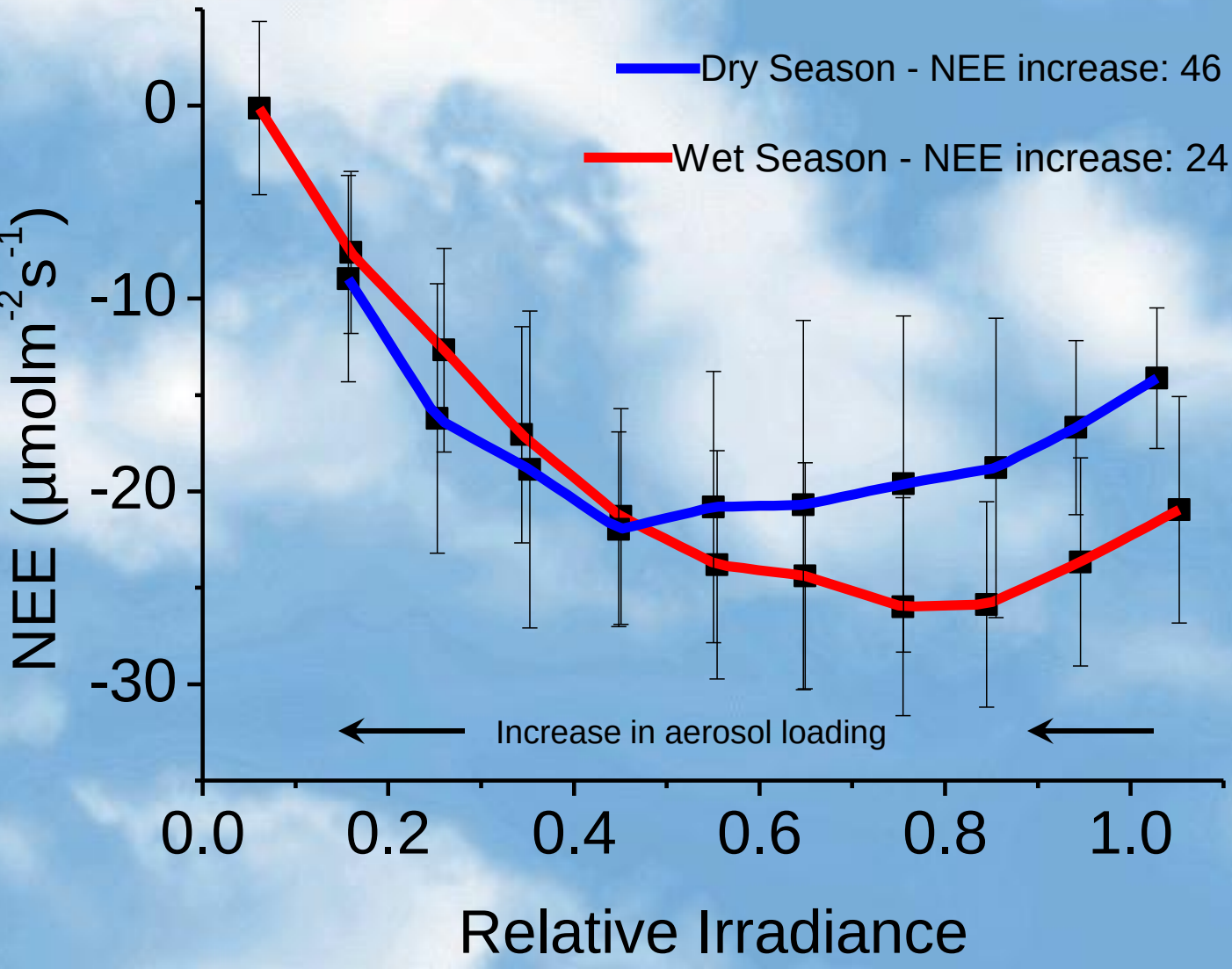


Kulmala et al., 2004



Strong aerosol effect on forest photosynthesis diffuse radiation have a large effect on CO2 fluxes

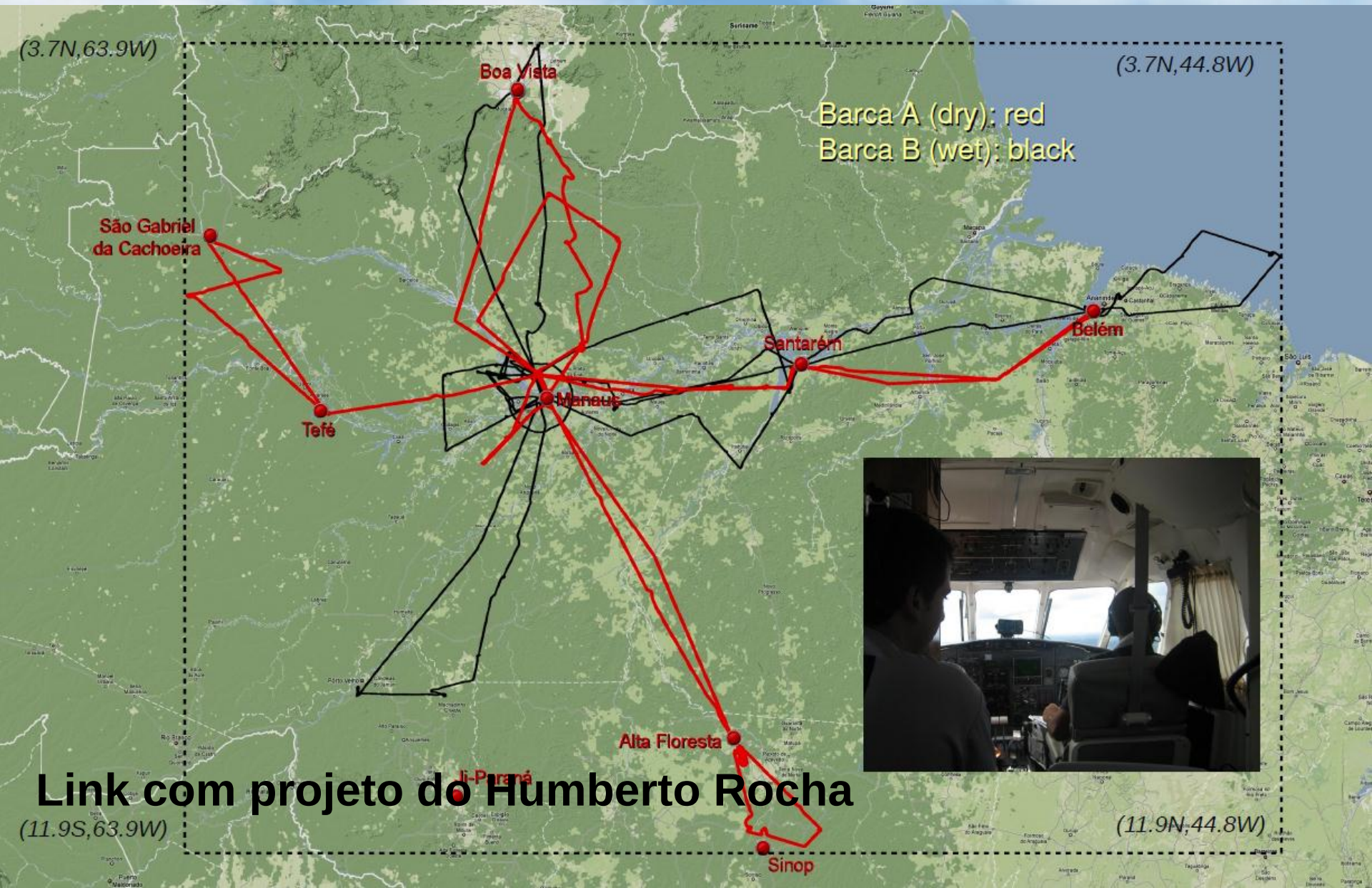
Amazonia Rondonia Forest site 2000-2001



LBA BARCA

Balanço Regional de Carbono na Amazonia
BARCA

Balanço Regional de Carbono na Amazonia BARCA



Link com projeto do Humberto Rocha

Thanks for the attention!!!