GoAmazon2014 Workshop, Washington DC, 26-27 July 2011

Tropical Aerosols, Clouds, and Precipitation in Amazonia

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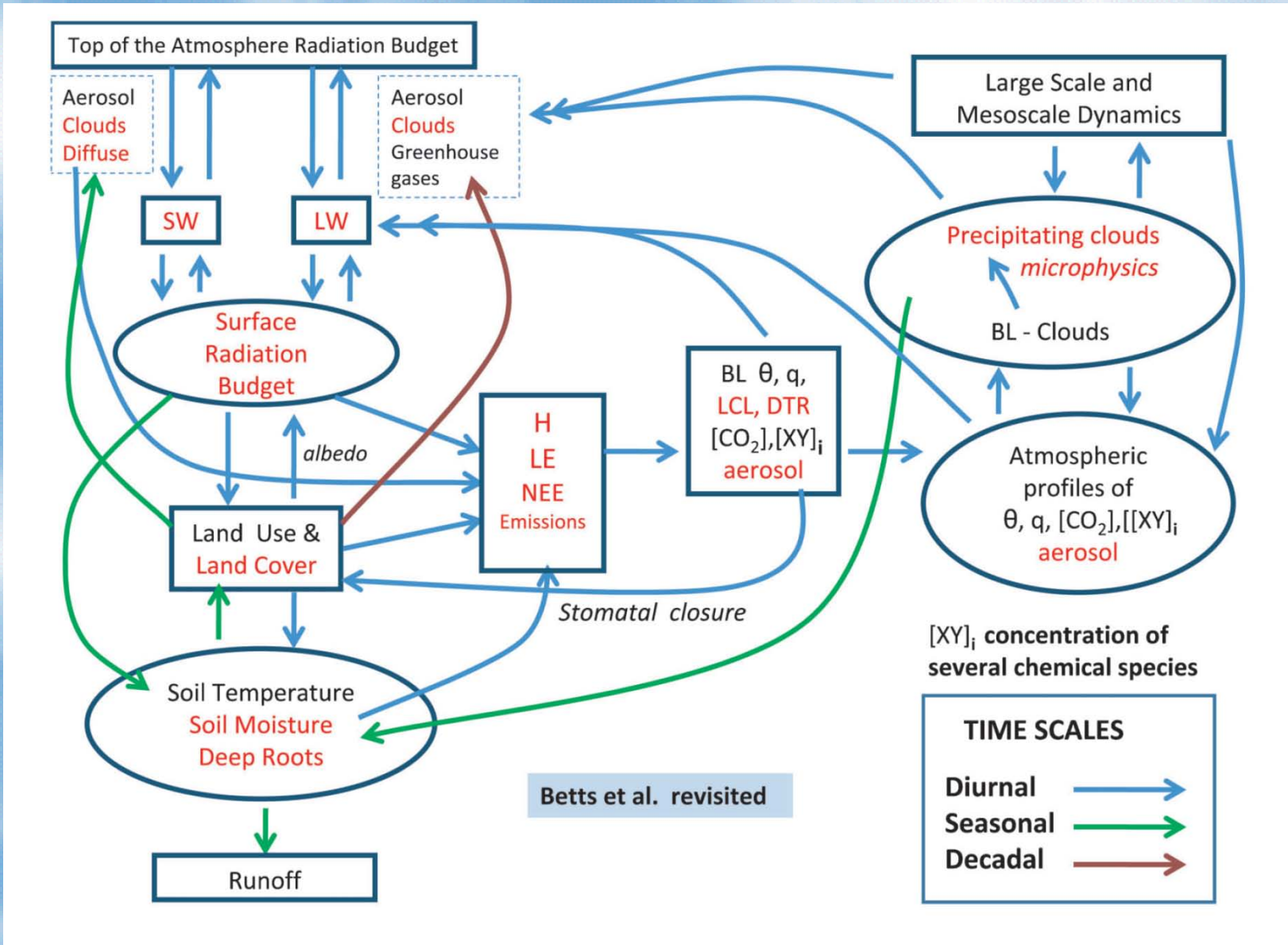
Focus of the Large Scale Biosphere Atmosphere Experiment in Amazonia Phase 2

Some key issues that are important from the scientific, public policies and conservation in Amazonia:

- Carbon cycling and the physiological and climatic controls
- Atmospheric chemistry in terms of oxidants and biosphere-atmosphere interactions (O_3, VOCs, NOx, etc)
- Aerosol-clouds interactions and aerosol radiative forcing
- Land Use Change and its effects, including carbon cycling, biomass burning emissions, modeling and social drivers.
- Role of disturbances (droughts of 2005 and 2010)
- Urbanization in Amazonia and its effects on regional chemistry, radiation balance and precipitation issues.
- Links between biology/ecosystem/chemistry/climate

Schematic of land-surface-atmosphere coupling from Betts et al. 2011



Meteorology, atmospheric chemistry, ecosystem function, radiation, etc. all very linked

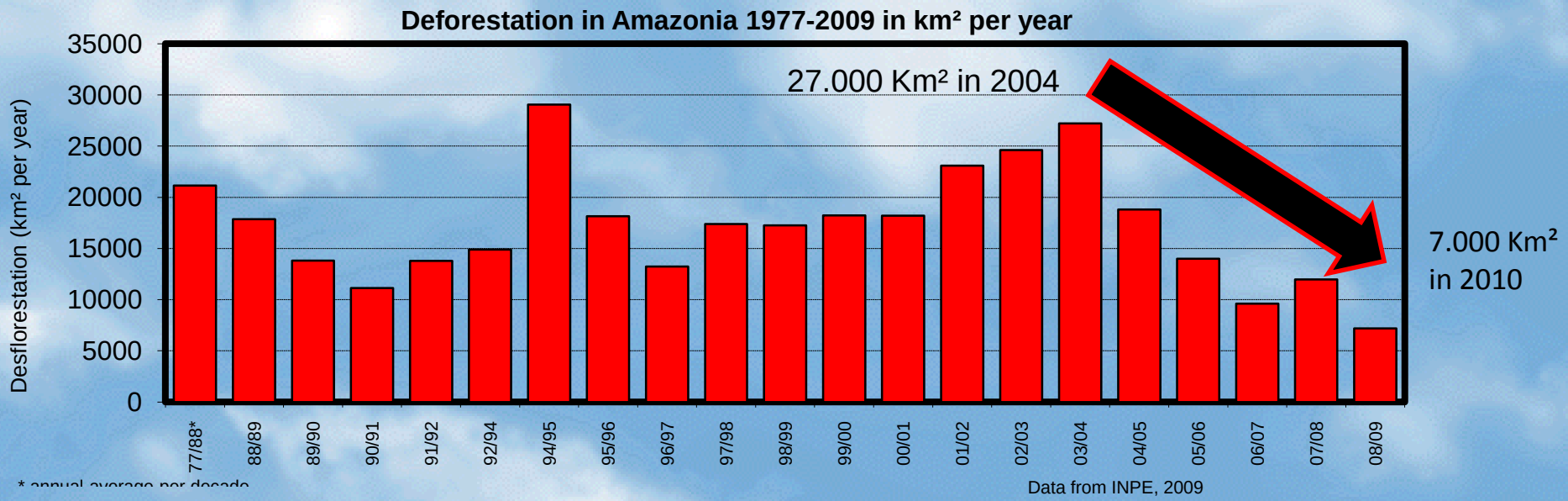
LBA Large atmospheric campaigns

Dates		Campaign	Location & Description	Ground	Airborne	Science Focus	Reference
Jul-Aug 1985	ABLE-2A	*Amazon Boundary-Layer Experiment - dry season*	dry season in Amazonia	Y (Manaus)	Y (ER-2 and Electra)	trace gas and meteorological measurements	[*Harriss et al*., 1988]
Apr-May 1987	ABLE-2B	*Amazon Boundary-Layer Experiment - wet season*	wet season in Amazonia	Y (Manaus)	Y (ER-2 and Electra)	trace gas and meteorological measurements	[*Harriss et al*., 1990]
Aug-Sep 1995	SCAR-B	*The Smoke, Clouds, and Radiation-Brazil*	dry season in disturbed southern Amazonia (Brasilia and Alta Floresta in southern Amazonia)	Y	Y (ER-2 and Convair)	effects of biomass burning on climate (direct effect)	[*Kaufman et al.* , 1998]
Mar-Apr 1998	CLAIRE-98	*The Cooperative LBA Airborne Regional Experiment*	wet season in undisturbed central Amazonia (Balbina in central Amazonia)	Y		chemistry and physics of biogenic aerosols	[*Avissar et al*., 2002]
Apr-May 1999 Sep-Oct 1999	LBA-EUSTACH	*European Studies on Trace Gases and Atmospheric Chemistry as a Contribution to the Large-Scale Biosphere-Atmosphere Experiment in Amazonia*	wet season in disturbed western Amazonia (FNS and RBJ in Rondônia in southwestern Amazonia; K34 and C14 in central Amazonia; Caxiuanã in eastern Amazonia)	Y	Y (Bandeirante)	chemistry and physics of wet season biogenic aerosols; trace gas emissions and reactivity	[*Andreae et al*., 2002]
Jul 2001	CLAIRE-01	*The Cooperative LBA Airborne Regional Experiment*	transition of wet-to-dry season in undisturbed central Amazonia (Balbina)	Y	Y (Bandeirante)	chemistry and physics of biogenic aerosols; trace gas emissions and reactivity	
Sep-Nov 2002	LBA-SMOCC	*The Large-Scale Biosphere-Atmosphere Experiment in Amazonia: Smoke, Aerosols, Clouds, Rainfall, and Climate field campaign*	dry season biomass burning experiment in pasture and forest sites in disturbed Amazonia (FNS and RBJ Rondônia)	Y	Y (Bandeirante)	effects of biomass burning on clouds (indirect effect)	[*Fuzzi et al*., 2007]
Aug-Sep 2004	TROFFEE	*Tropical Forest and Fire Emissions Experiment*	dry season in disturbed southern Amazonia (Alta Floresta)		Y (Bandeirante)	measurements of aerosol and trace gas emission factors from biomass burning	[*Yokelson et al*., 2007]
Feb-Mar 2008	AMAZE-08	*Amazonian Aerosol Characterization Experiment*	wet season in undisturbed central Amazonia (TT34 north of Manaus in central Amazonia)	Y	N	chemistry and physics of biogenic aerosols; trace gas emissions and reactivity	*Martin et al*. [in preparation]

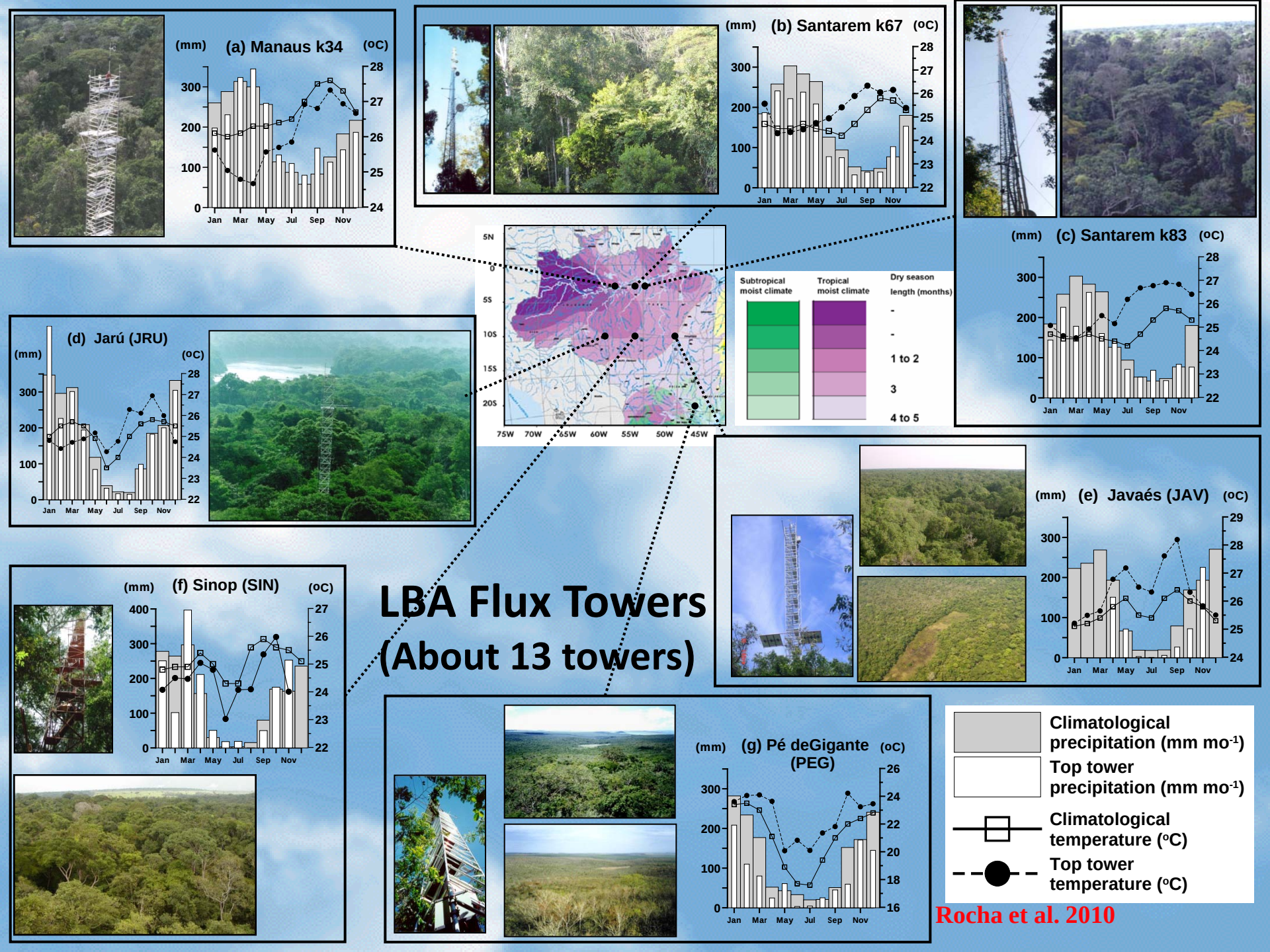
Running 13 towers. Now with permanent stations in Manaus, Porto Velho, future ATTO, etc.

Deforestation was reduced from 27,000 Km² in 2004 to 7,000 Km² in 2010.

A very dynamical system, and we need to know what effects on the ecosystem these changes have produced



What public policies are needed to sustain this reduction?



Rocha et al. 2010

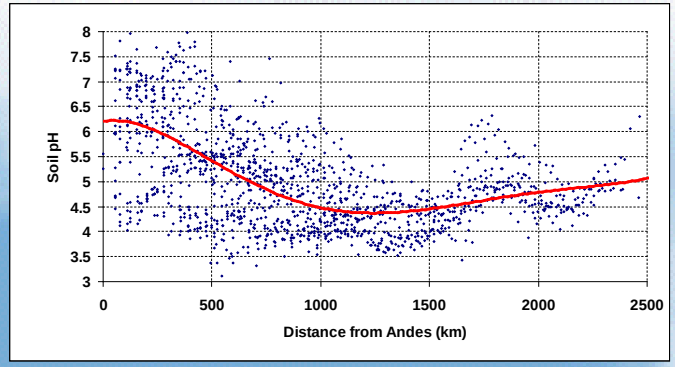
RAINFOR (Rede Amazonica de Inventários Florestais)

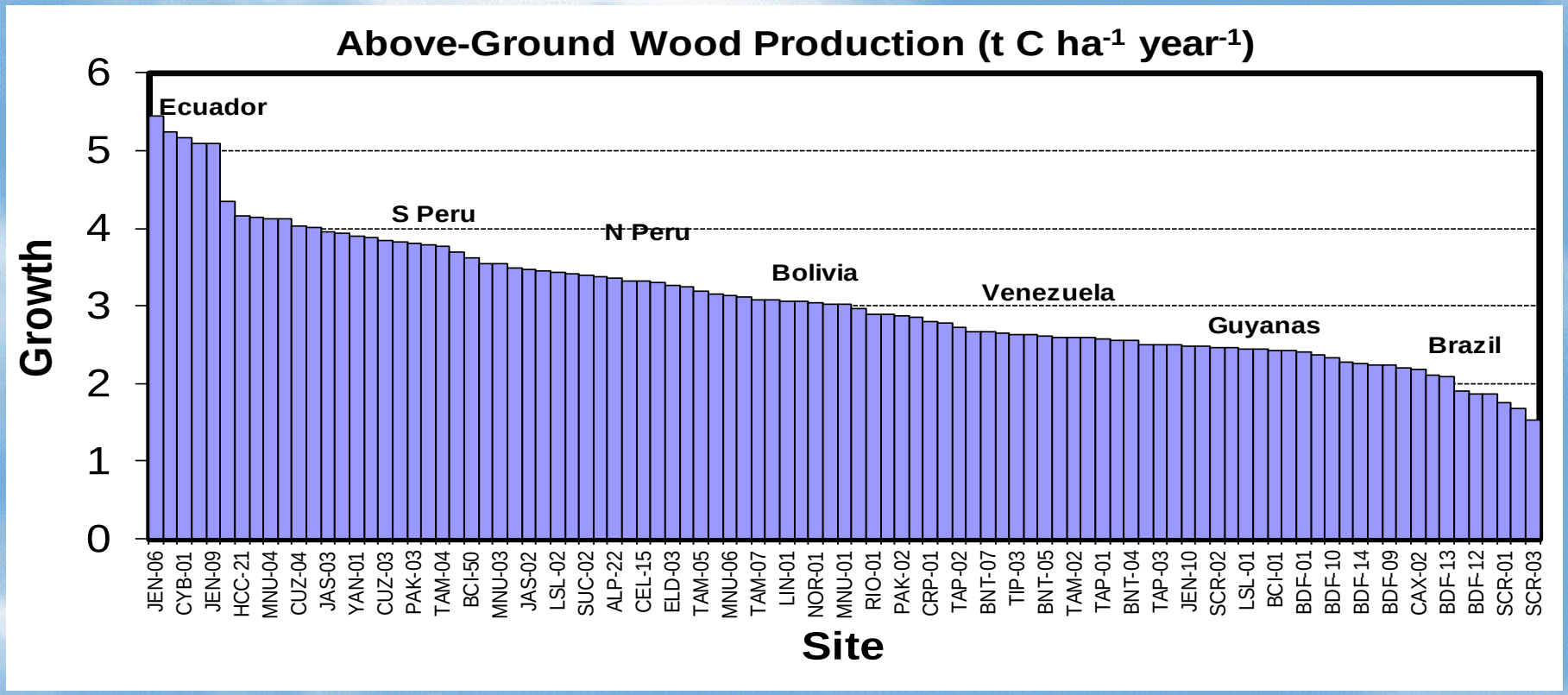
The Use of Biometric Techniques to Estimate the Carbon Balance and Carbon Dynamics of Amazonian Forests

Malhi et al 2010

LBA/RAINFOR - Aboveground wood production for 97 sites

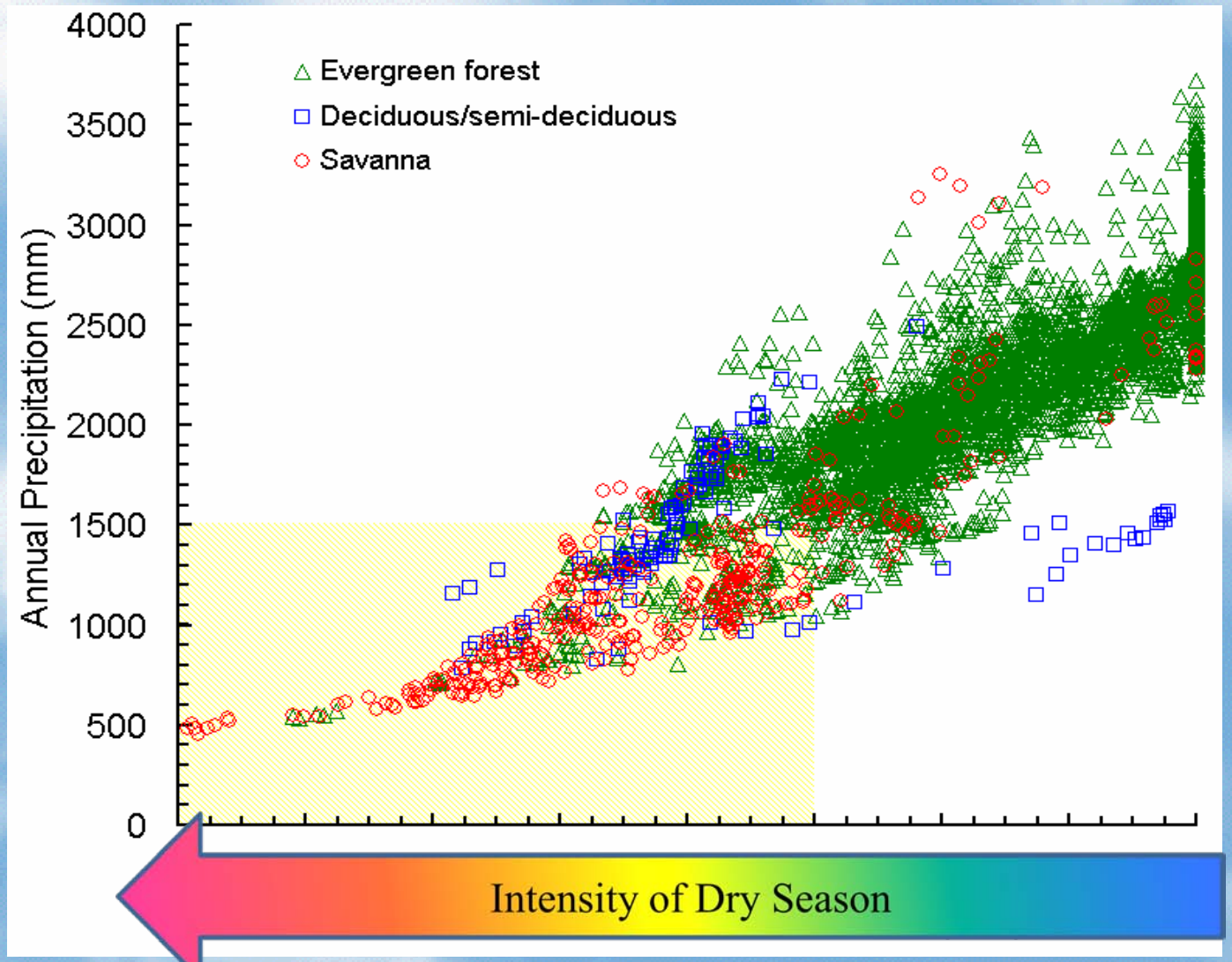
Malhi et al, 2010





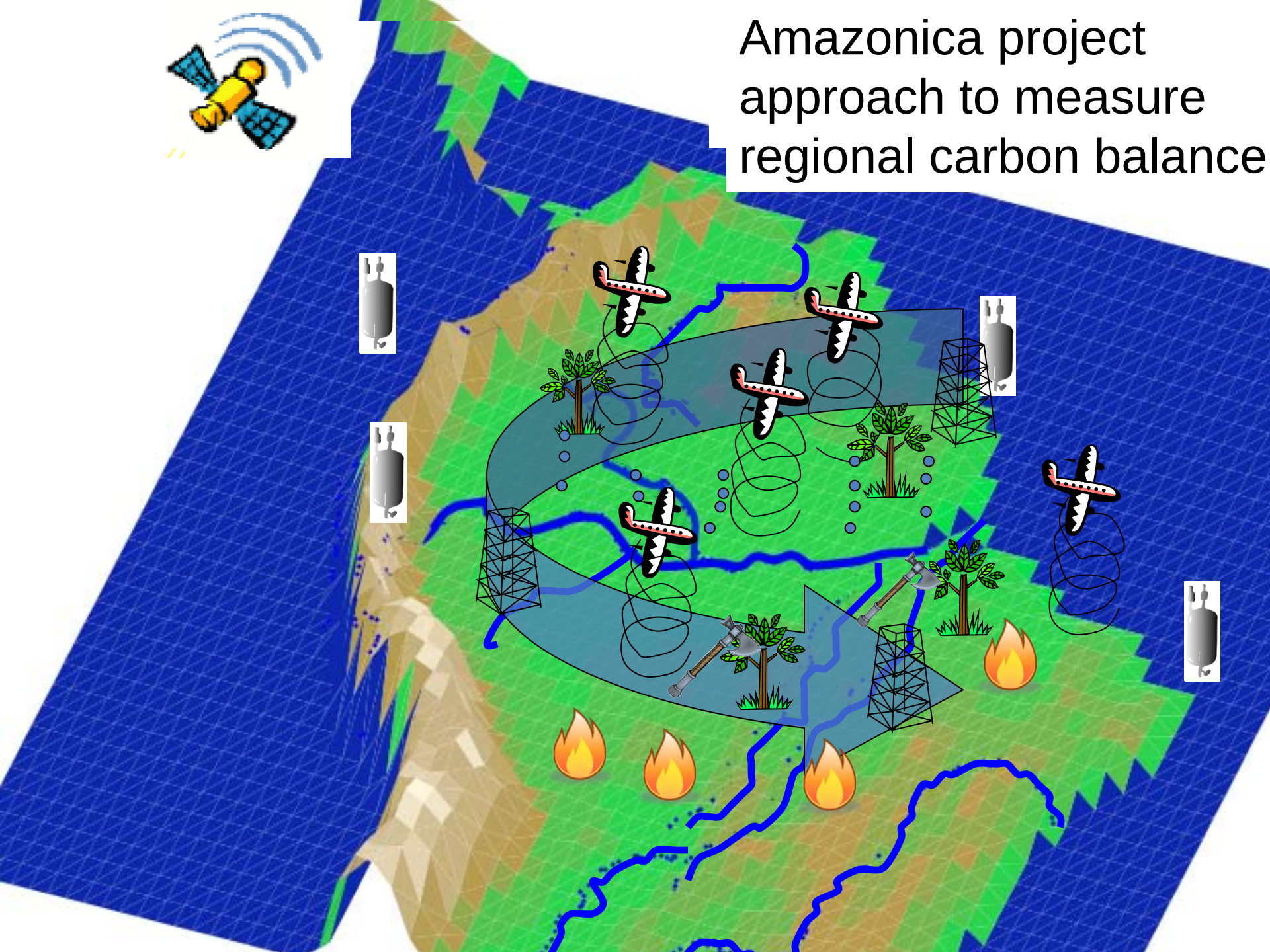
Forest in Amazonia appears to be accumulating carbon at a rate of about 0.5-0.7 tC/ha/year from 1998-2010

Linking biomass with precipitation in Amazonia: A rainfall biogeography of Amazonia



Source: Malhi *et al.*, **Exploring the likelihood and mechanism of a climate-change induced dieback of the Amazon rainforest,** *Proceedings of the National Academy of Sciences*, 2011 submitted

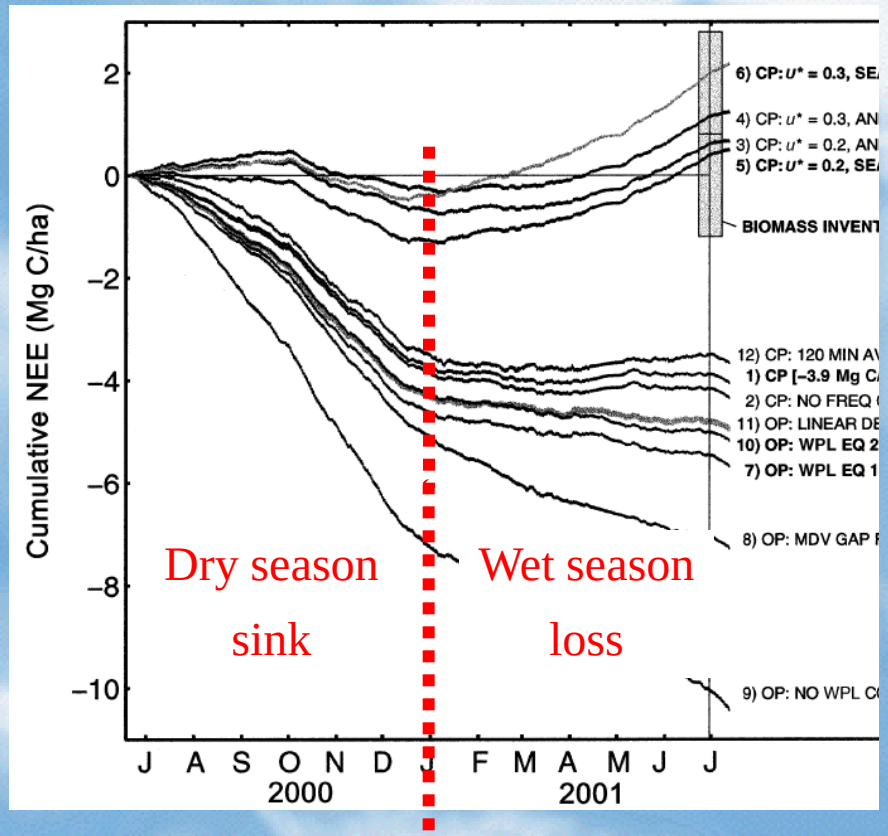
Amazonica project approach to measure regional carbon balance



CO_2 flux – tropical forest Santarem (k83)

CO2 fluxes: annual sum is prone to uncertainties

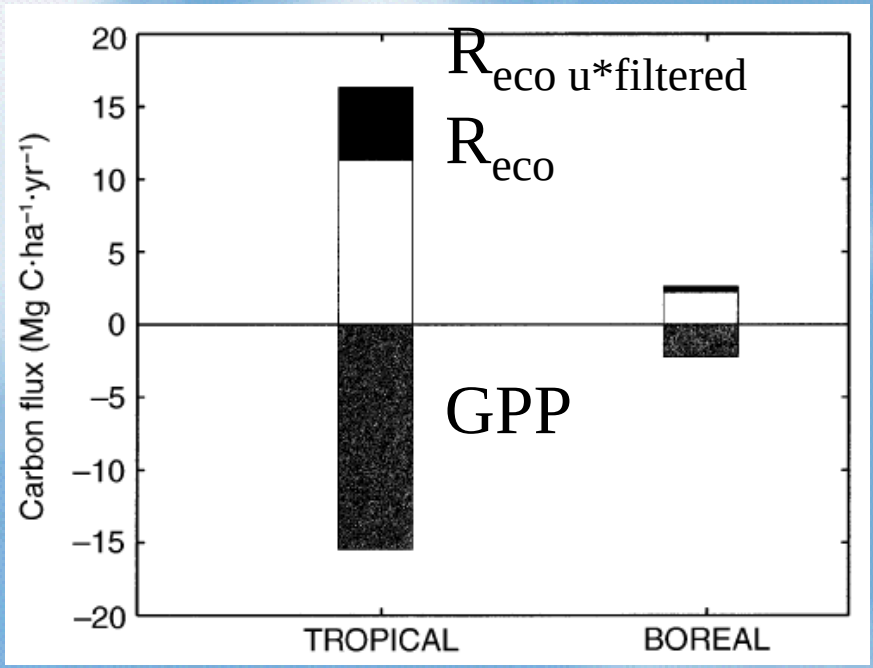
Miller 2004, Ecol Appl; Goulden 2004 Ecol Appl, 2006 JGR
Saleska 2003, Science; Hutyra 2007 JGR



R_{eco} ~ Respiration (nighttime flux)

GPP ~ daytime flux – R_{eco}

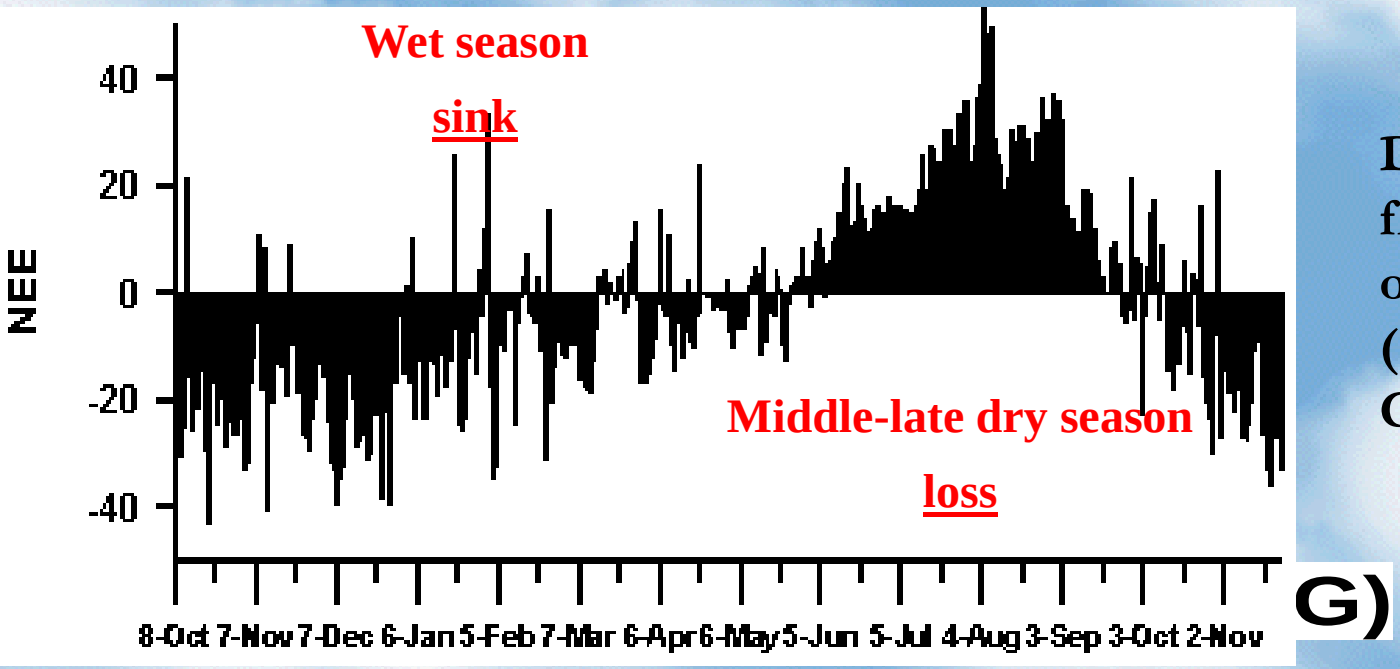
High numbers are observed in the tropics (Miller 2004, Ecol Appl)



... but leads to a reasonable interpretation of seasonality

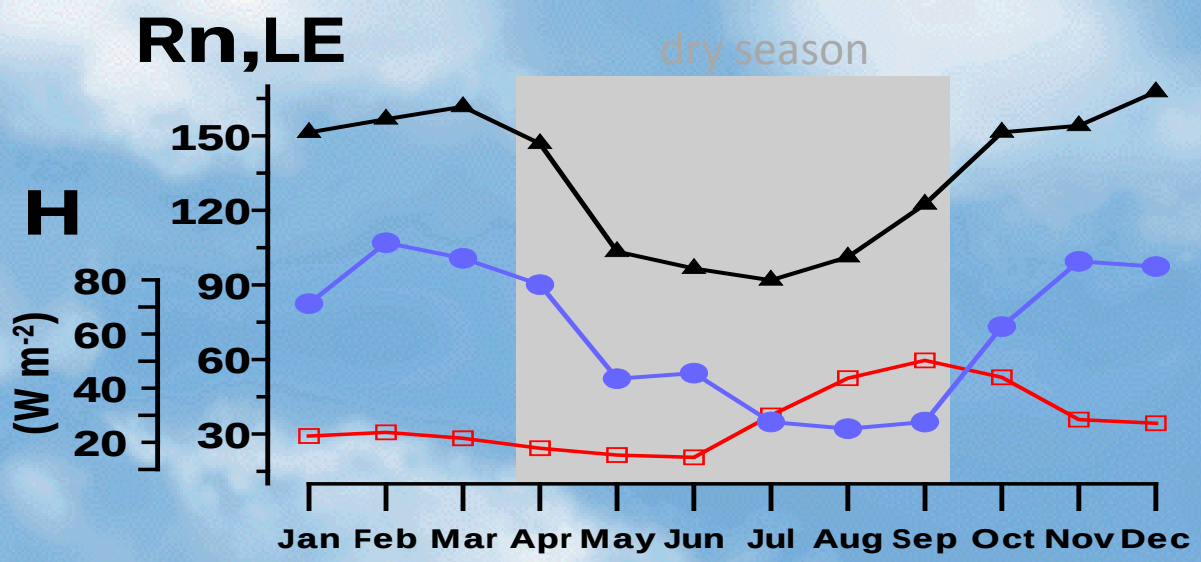
(Humberto Rocha, USP, 2011)

CO_2 flux - Cerrado sensu stricto (Pé de Gigante site, 20º S)



G)

Daily mean CO_2 flux (kg C ha^{-1} day^{-1}) over Cerrado s.s (Gleba Pé de Gigante.



Rn net radiation

Evapotranspiration

H Sensible heat flx

Rocha et al (2009)

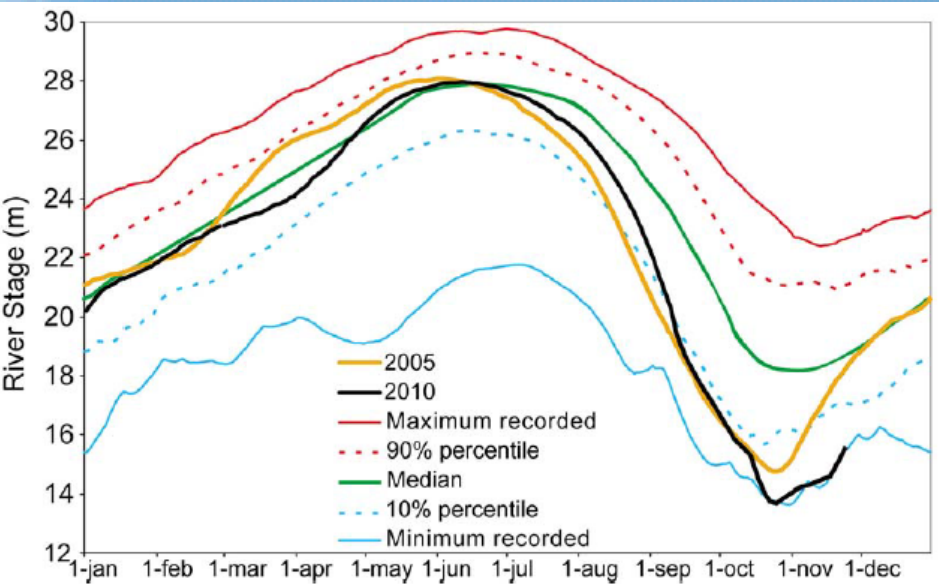
Two plots with rain exclusion (drought experiments) in Amazonia

Intact forests seem resilient to substantial seasonal drought, but begin to die back after several successive years of drought

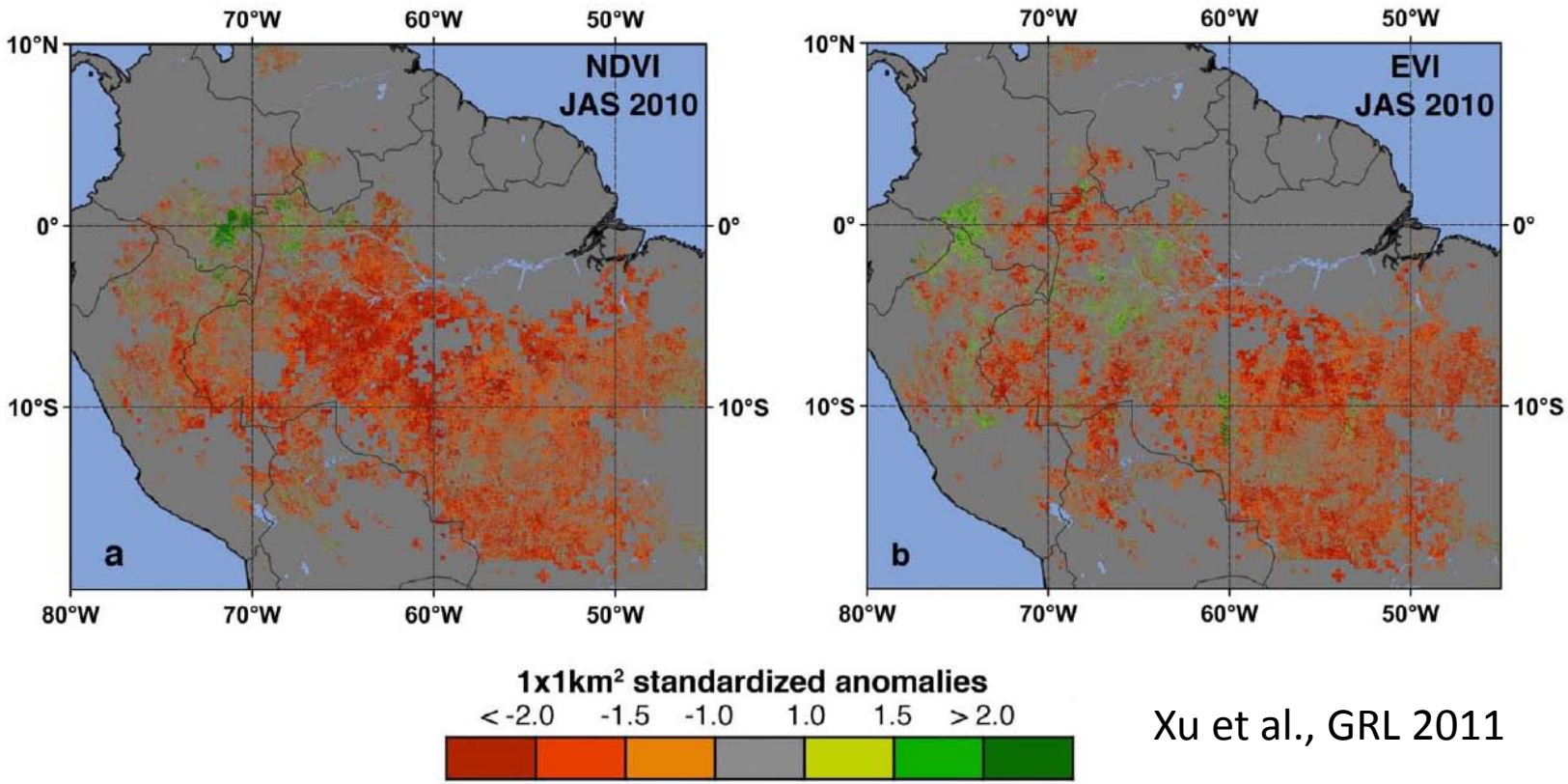
Nepstad et al (2007), Ecology, Fisher et al. (2007), Global Change Biology, Brando et al (2008), Philosophical Transactions of the Royal Society B, Sotta et al. (2008), Global Change Biology

Drought of 2010 in Amazonia

Manaus river level for 2005 and 2010

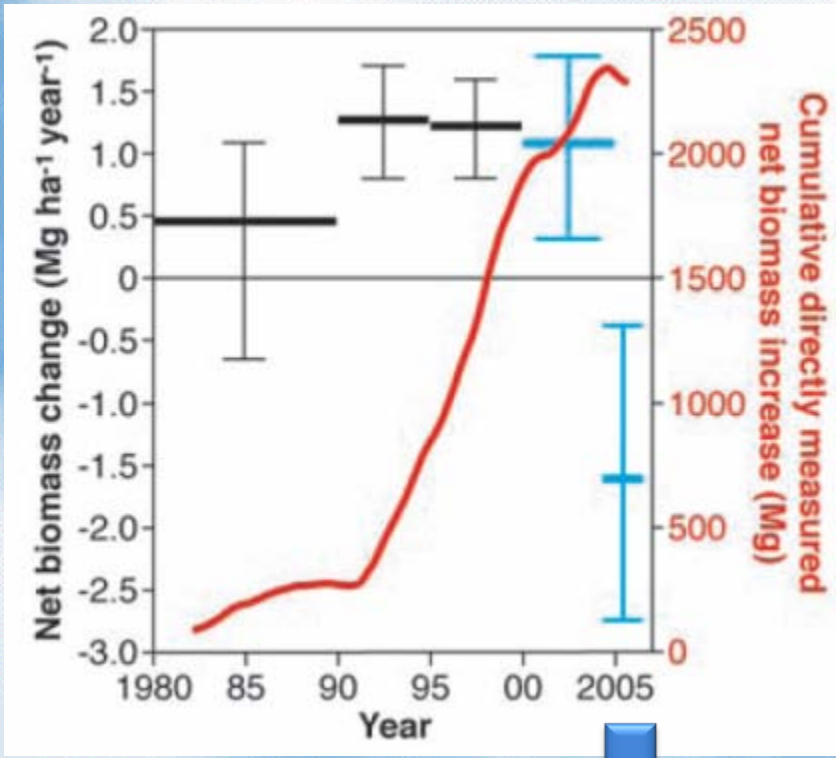


Spatial patterns of standardized anomalies of **normalized difference vegetation index** (NDVI) and **enhanced vegetation index** (EVI).

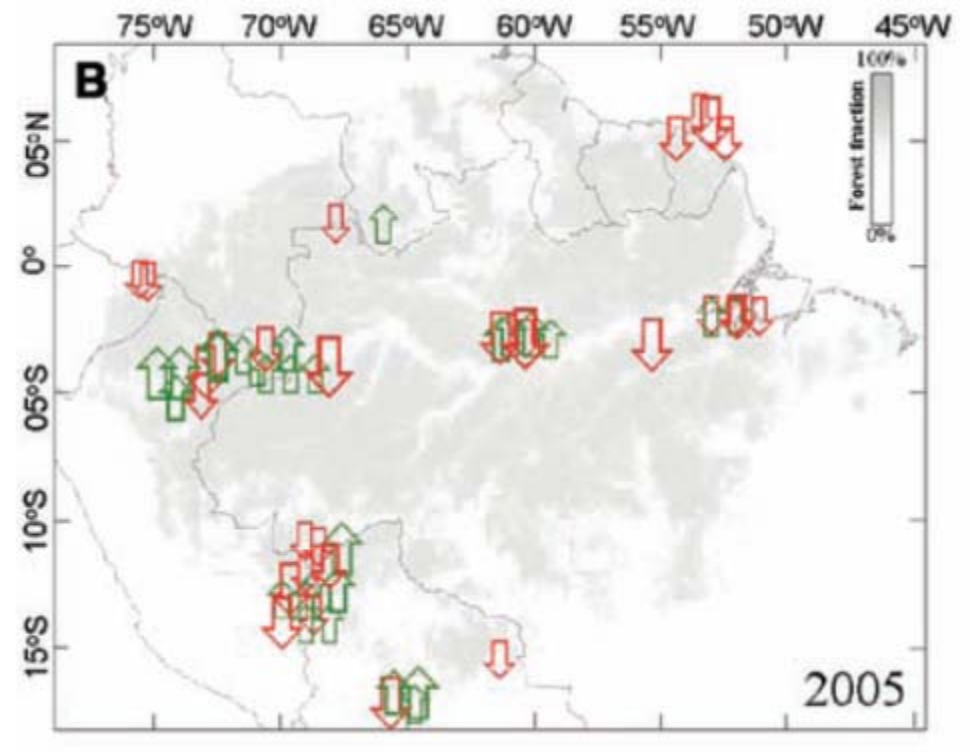


Xu et al., GRL 2011

Drought sensitivity of the Amazon Rainforest



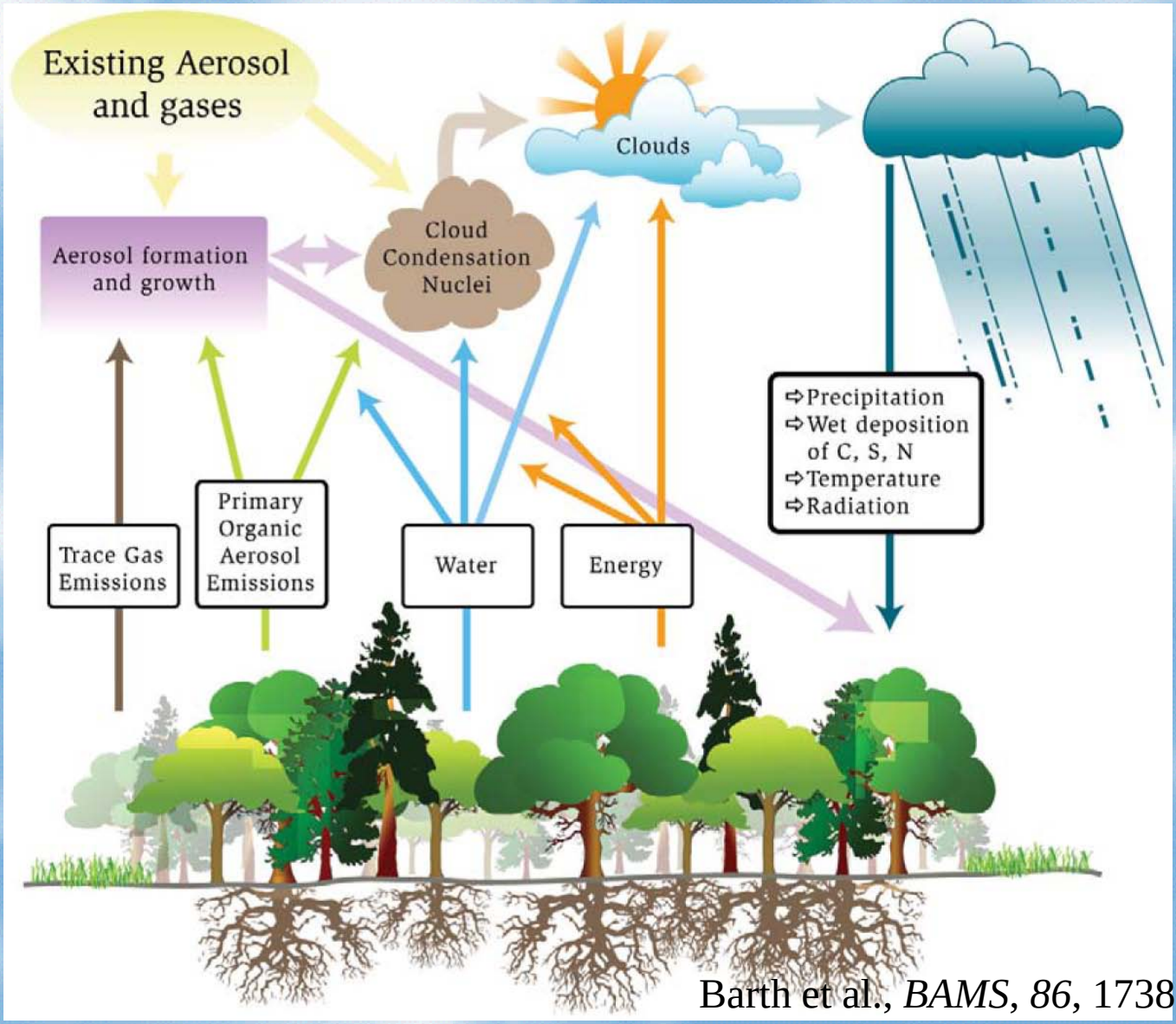
Annual aboveground biomass change during the 2005 interval.



Effect of the 2005 drought in the carbon balance in Amazonia

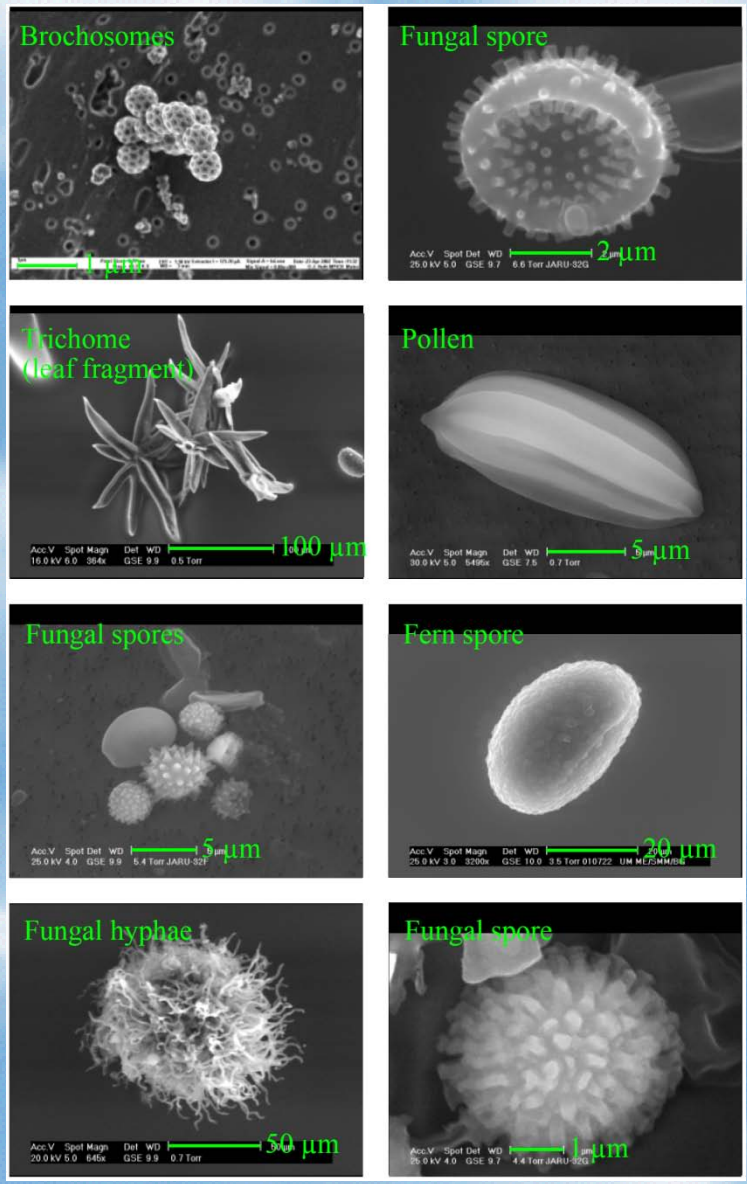
Phillips et al. 2009 *Science*

Aerosol Particles, energy and water vapor: Coupling of Terrestrial Ecosystems and the Hydrologic Cycle



Barth et al., *BAMS*, *86*, 1738-1742, 2005.

Aerosol particle types in Amazonia



Natural Conditions

Amazonian Biosphere
primary and secondary particles and components

African Dust
favored when ITCZ is south of equator

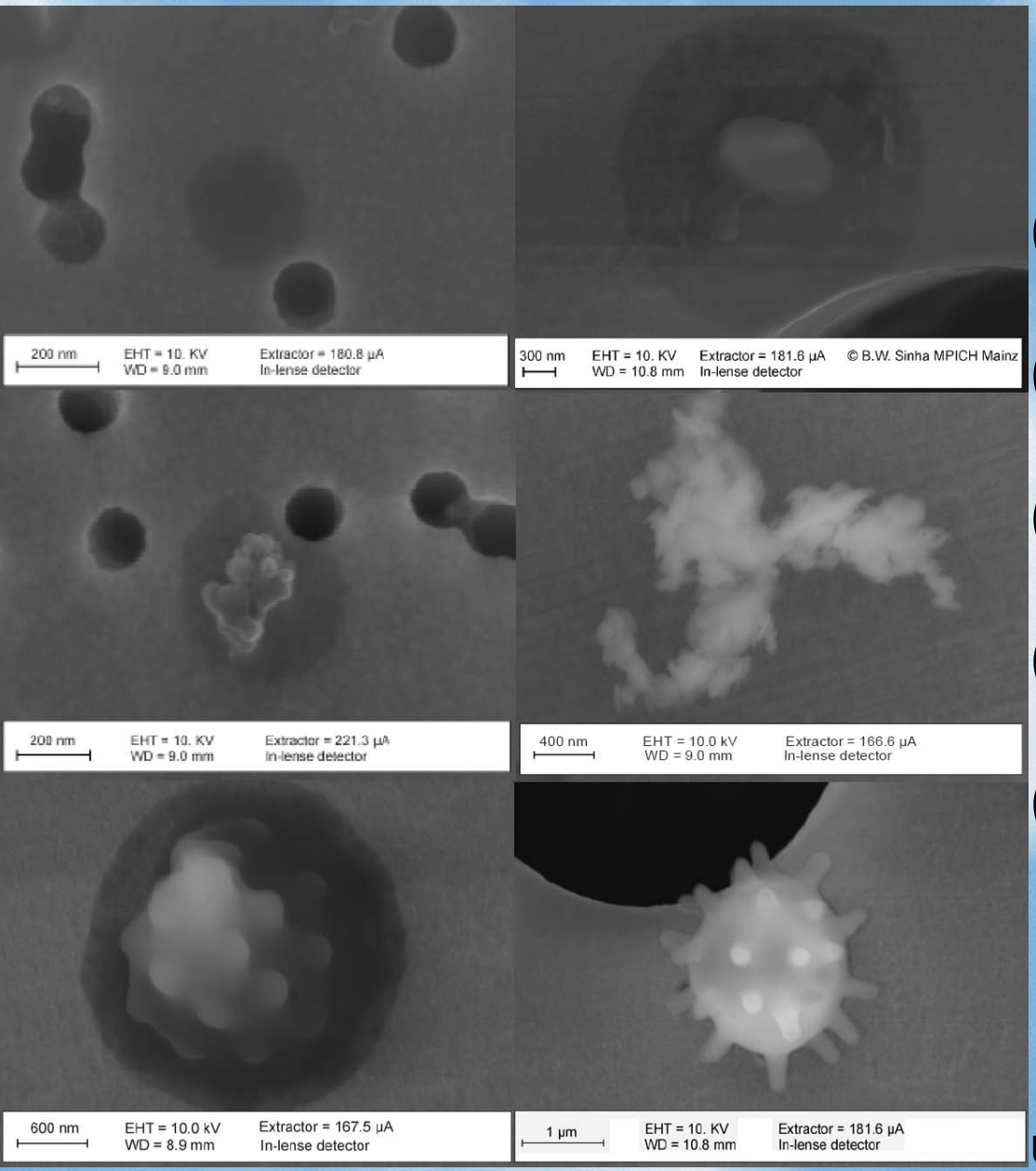
Atlantic Marine Aerosols

Anthropogenic Conditions

In-Basin Biomass Burning
favored in dry season

In-Basin Pollution
favored when downwind of Manaus or other cities and settlements, including those located in northeastern and southern Brazil

Central African Biomass Burning



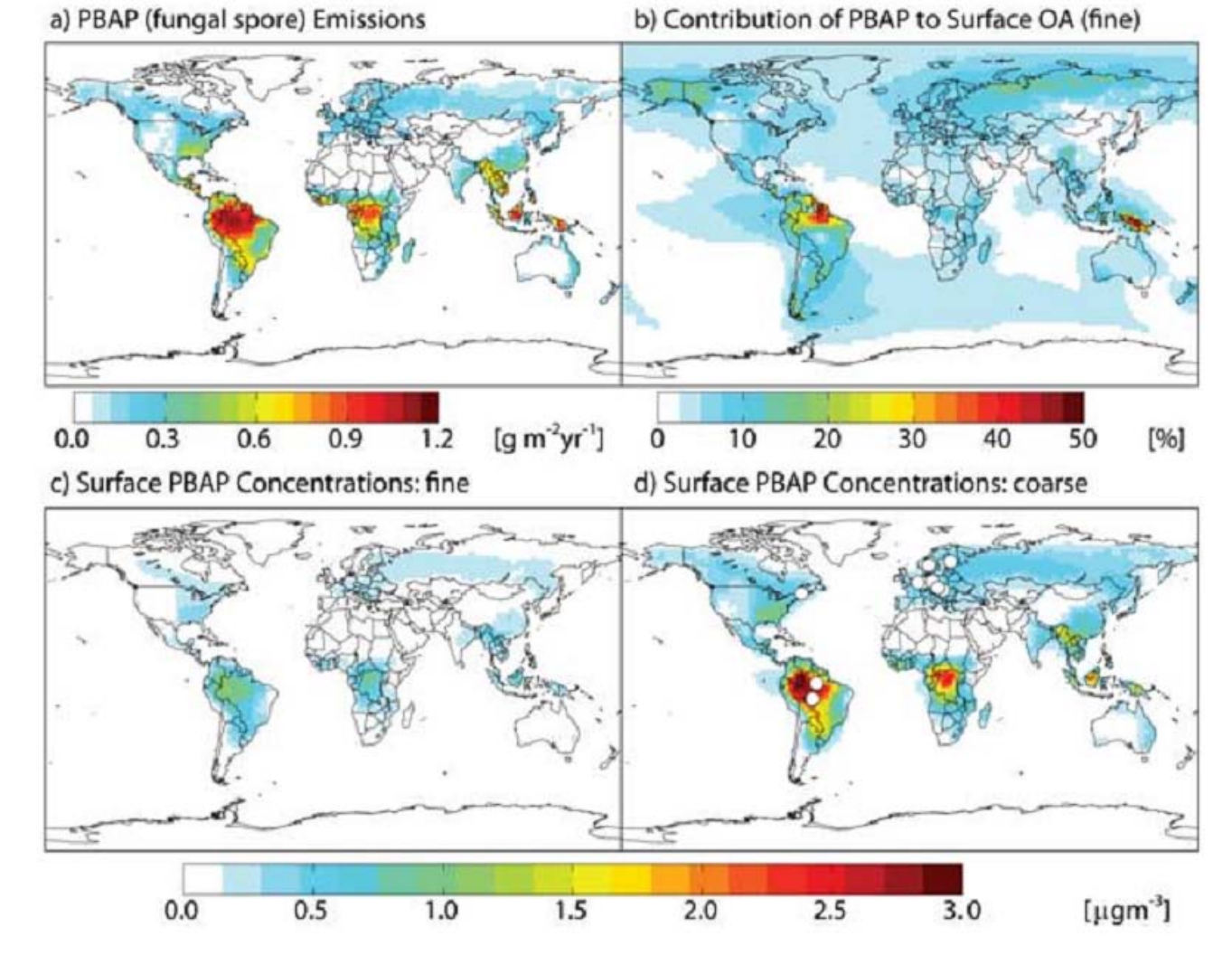
Amazon Particles

(A) secondary organic aerosol (SOA) droplet;
(B) mixed SOA-inorganic particle;
(C) pyrogenic carbon particle with organic coating;
(D) mineral dust particle without coating;
(E,F) primary biological aerosol (PBA) particle with and without organic coating).

Uli Pöschl, et al., 2011

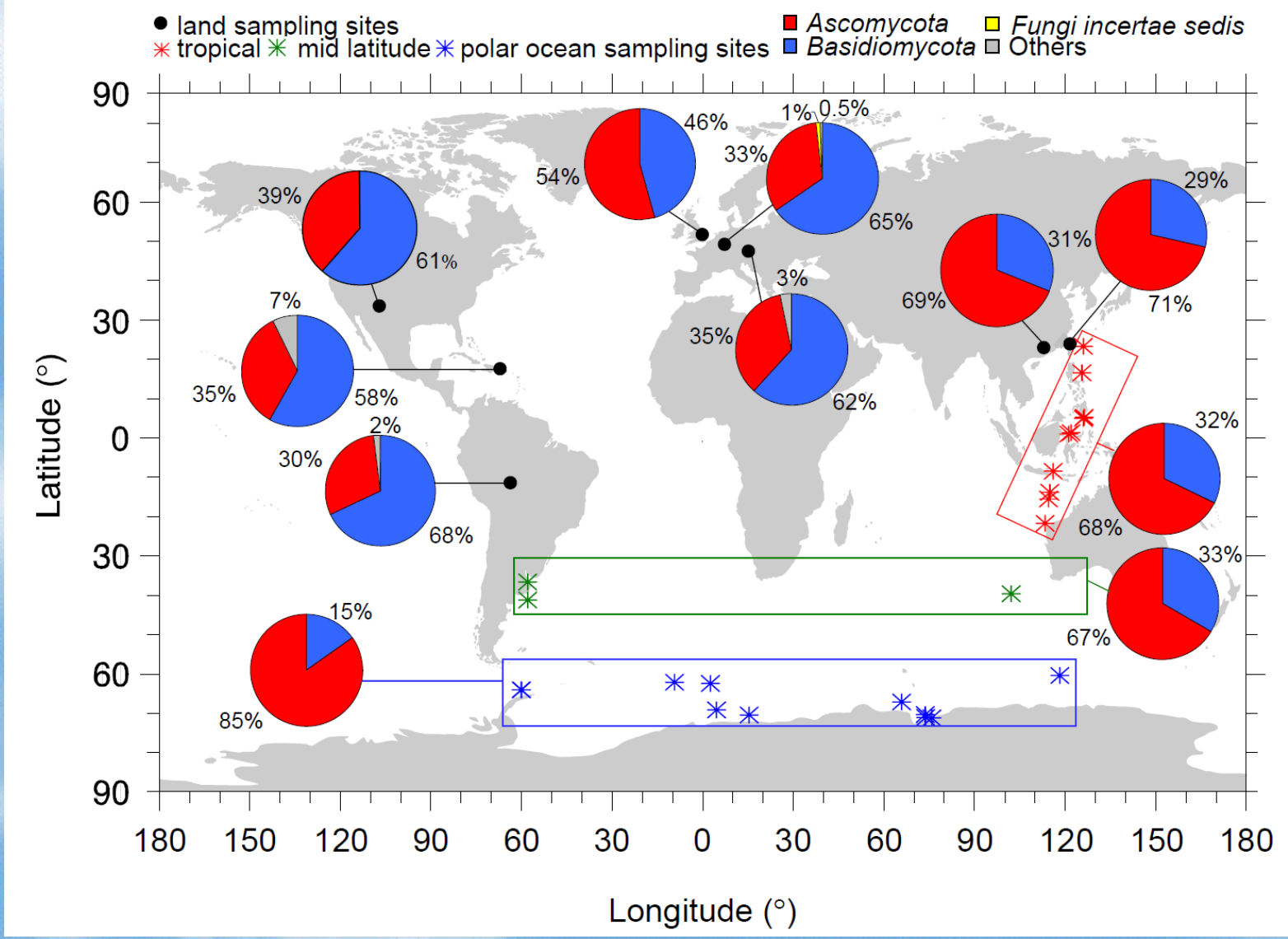
Biology matters

Atmospheric budget of primary biological aerosol particles from fungal spores



Annual mean of optimized GEOS-Chem simulation of fungal PBAP: (a) PBAP emissions, (b) percentage contribution of fungal PBAP to fine organic aerosol (OA) surface concentrations, (c) fine-mode fungal PBAP surface concentrations, and (d) coarse-mode fungal PBAP surface concentrations.

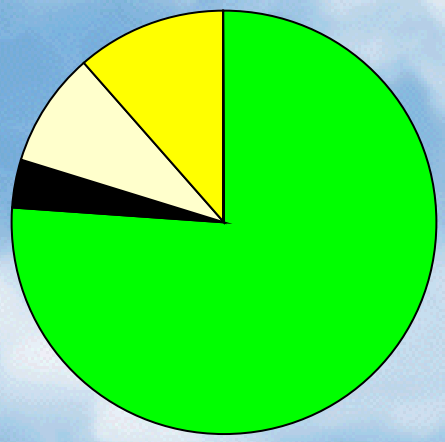
Biogenic aerosols: Diversity and biogeography of airborne microorganisms (fungi)

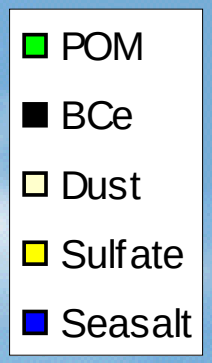


Geographical location and relative proportions of different phyla in continental, coastal, and marine (ocean) sampling locations.

Frohlich-Nowoisky, BGD 2011

Aerosol composition in wet-season Amazonia



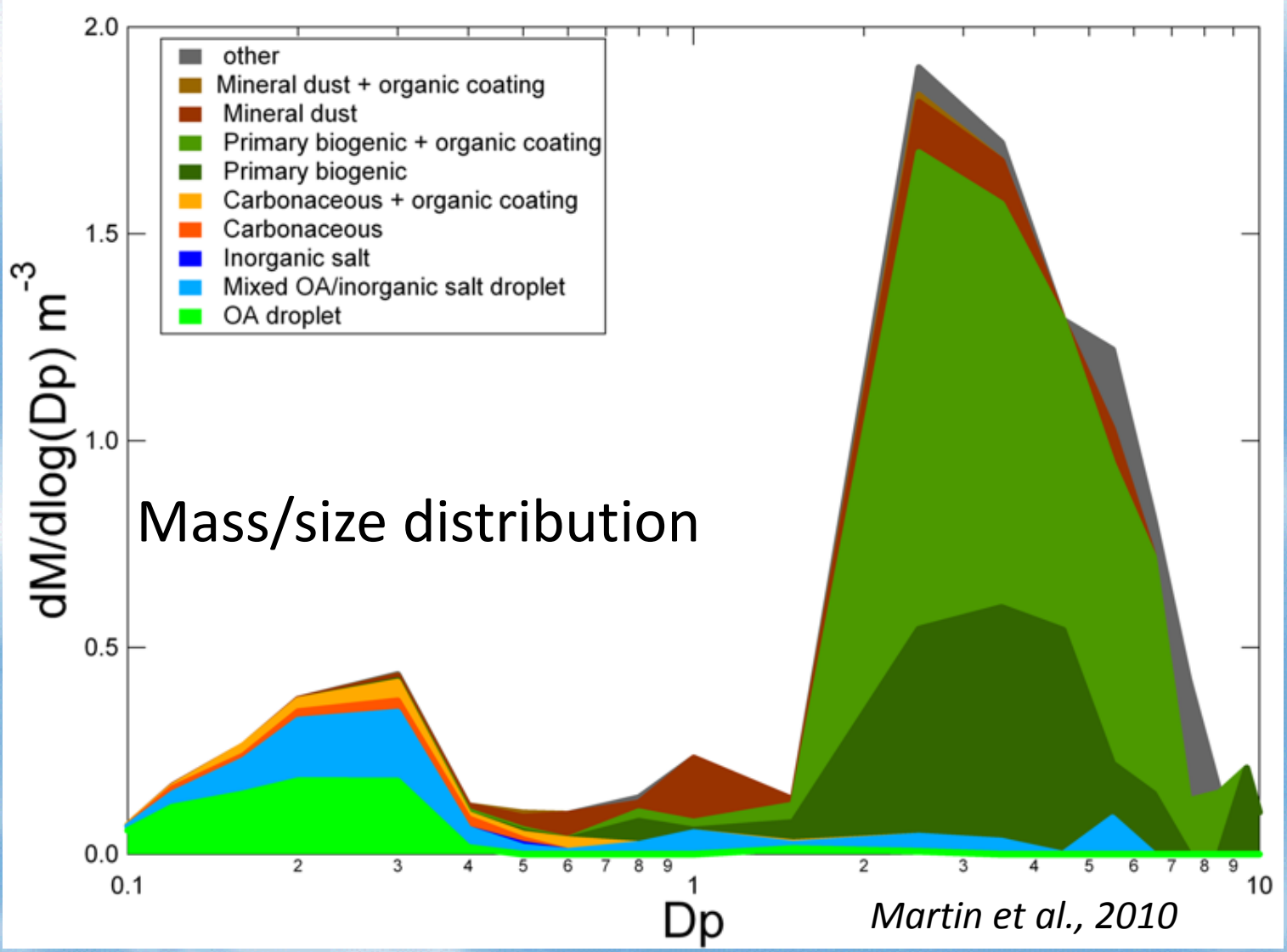


Fine Fraction
1.7 µg m^{-3}

Coarse Fraction
5.7 µg m^{-3}

Martin et al., 2010

Particles in clean air over Amazon



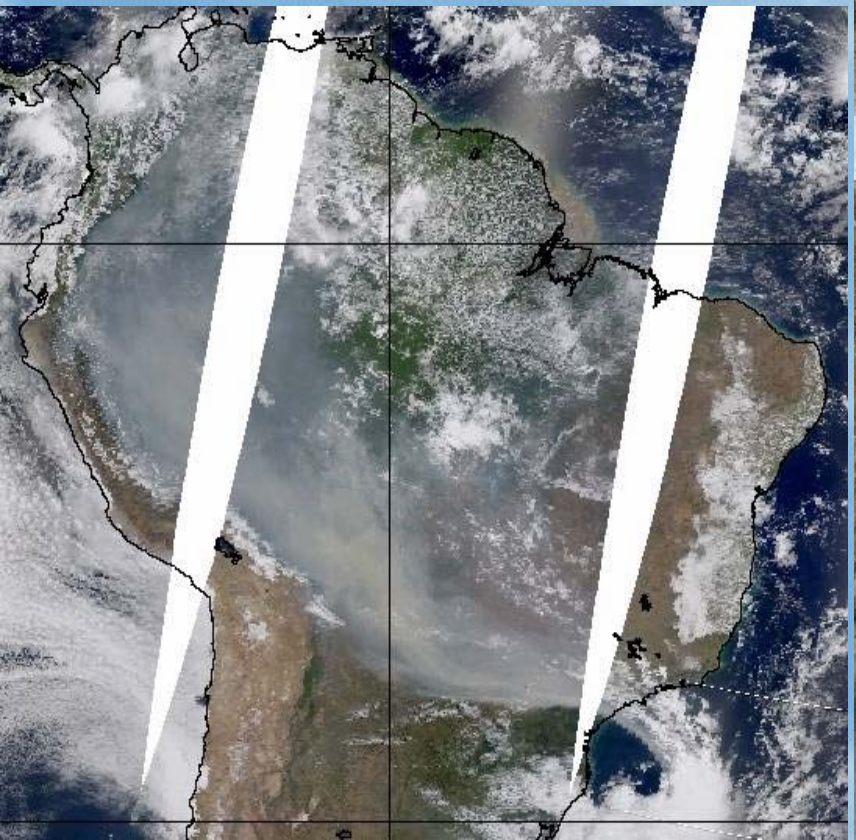
Biological, chemical, and physical processes over the Amazon form a closely coupled system

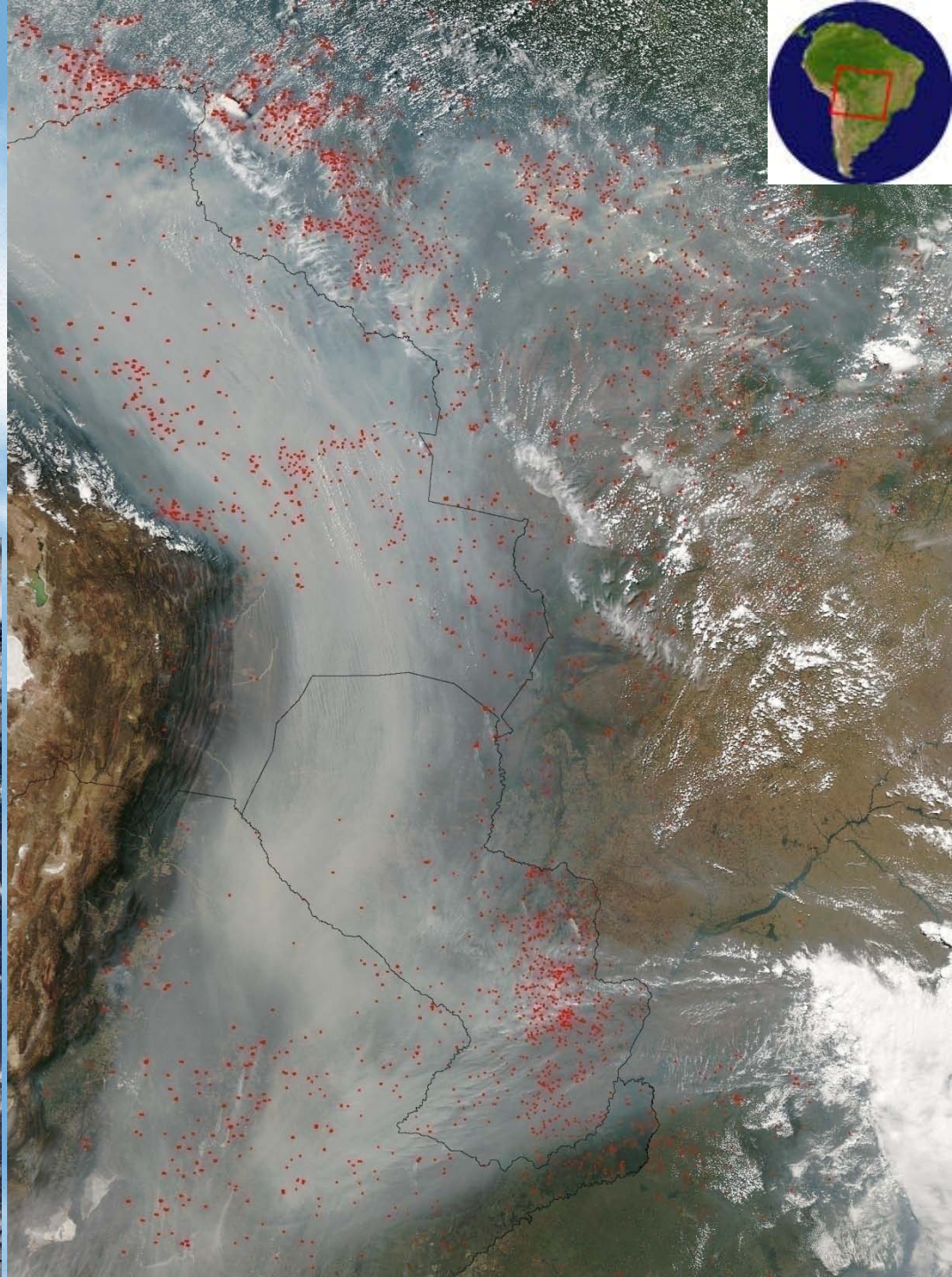
Aerosol-clouds interactions and aerosol radiative forcing

- 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
- Convective clouds physical properties and distribution coupled with cloud droplets microphysical properties.

Large scale aerosol distribution in Amazonia

- Severe health effects on the Amazonian population (about 20 million people)
- Climatic effects, with strong effects on cloud physics and radiation balance.
- Changes in carbon uptake and ecosystem functioning





Amazonia - Average aerosol forcing clear sky

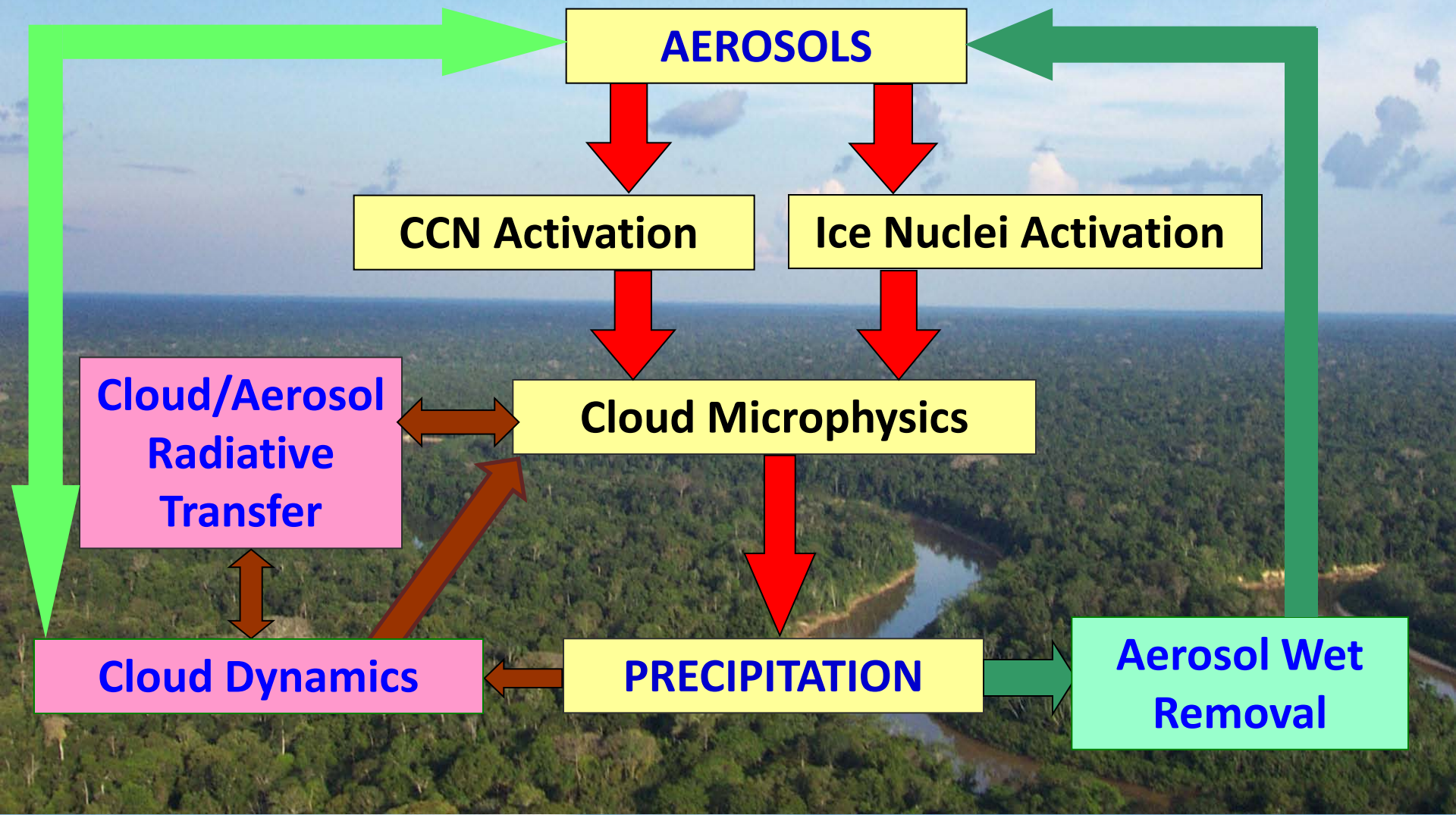
Top: - 10 w/m²

Surface: - 38 w/m²

Conditions: surface: forest vegetation AOT (τ=0.95 at 500nm); 24 hour average
7 years (93-95, 99-02 dry season Aug-Oct)

Aerosol-cloud-precipitation feedbacks

CCN = cloud condensation nuclei and IN = ice nuclei.



What controls CCN in the clean Amazonian atmosphere?

- Number concentrations of dust and salt particles are low, and decline during transport across the Amazon
- This leaves PBAP, biogenic SOA, and biogenic sulfates as potential CCN
- SEM observations show that the most abundant particles are SOA without identifiable cores
- In the CCN-active size range internal mixtures of (S)OA with inorganic salts or carbonaceous cores become more abundant with increasing size
- The location and mechanism of nucleation and new particle formation remains an enigma

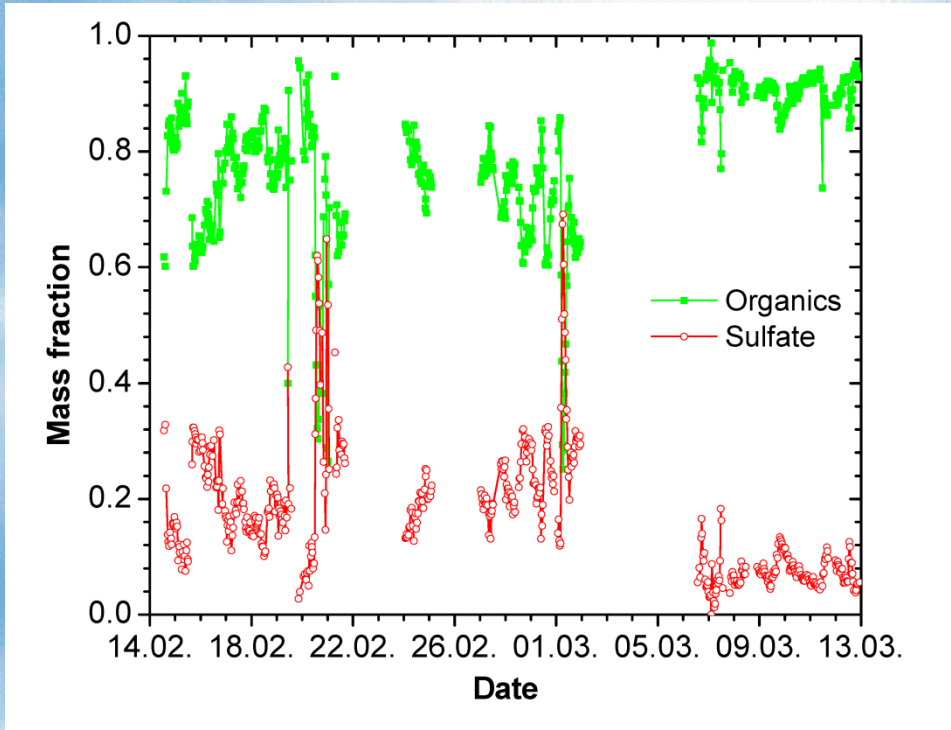
04 10 2002 21:55

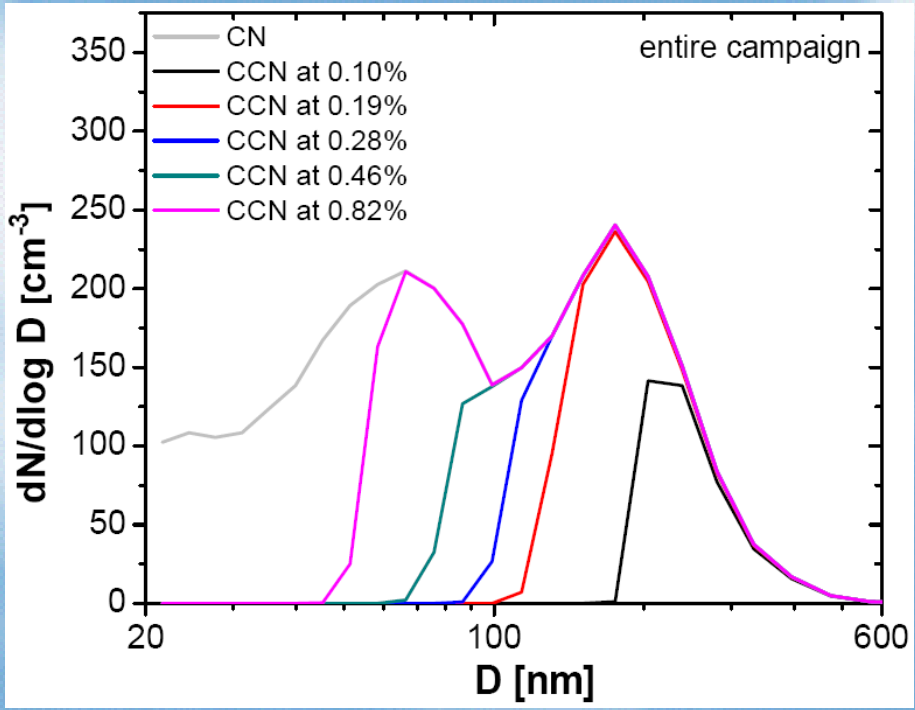
CCN activity for Amazonian aerosols

$N_{CN} \approx 200\ cm^{-3}$

$N_{CCN} \approx 75\text{-}120\ cm^{-3}$

Mass fraction by AMS



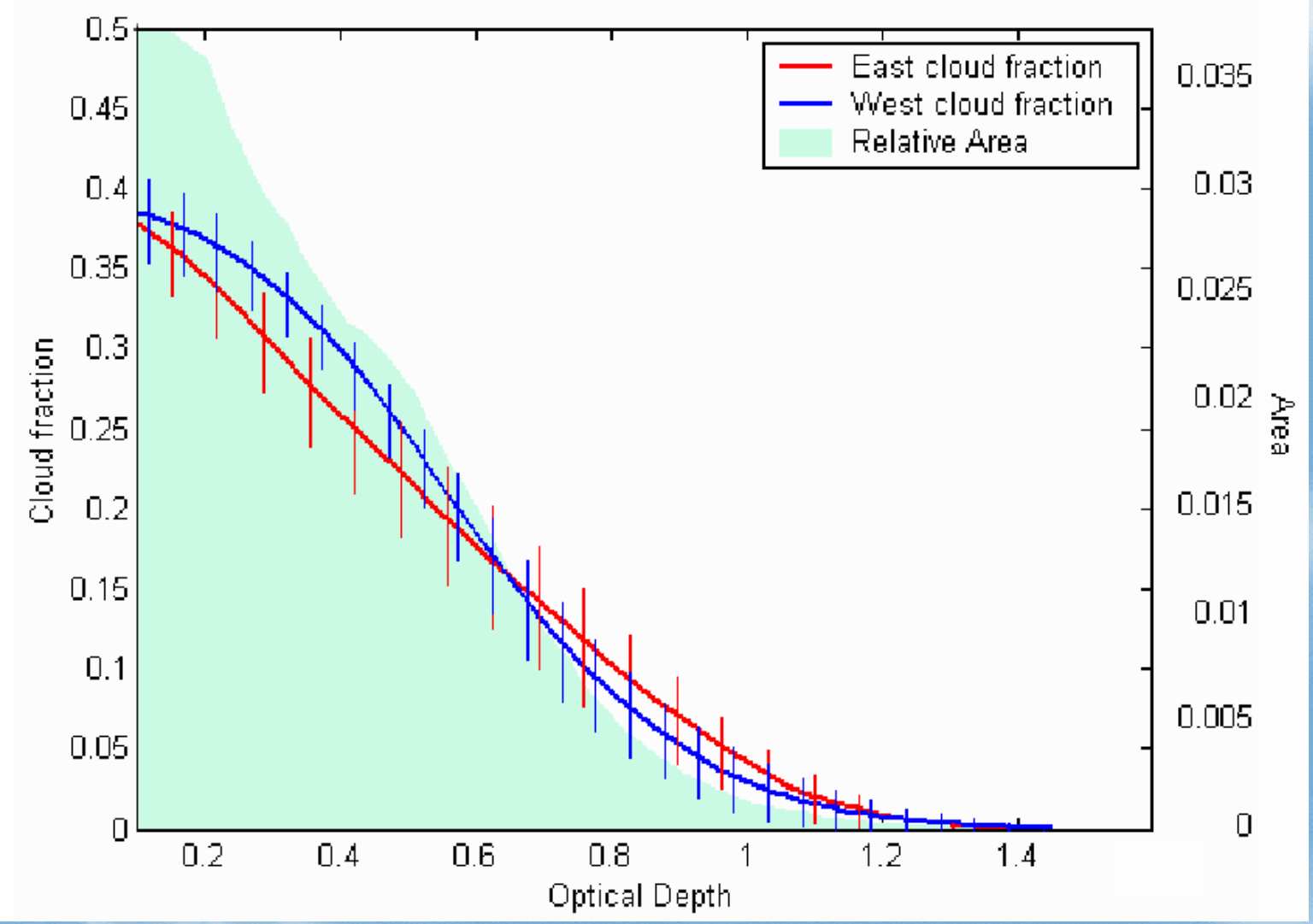


Scot Martin et al., 2010

Sachin Gunthe et al., 2009

Amazon aerosol hygroscopicity parameter: $\kappa \approx 0.15$ 0.10 (SOA)

Suppression of low cloud formation by aerosols in Amazonia



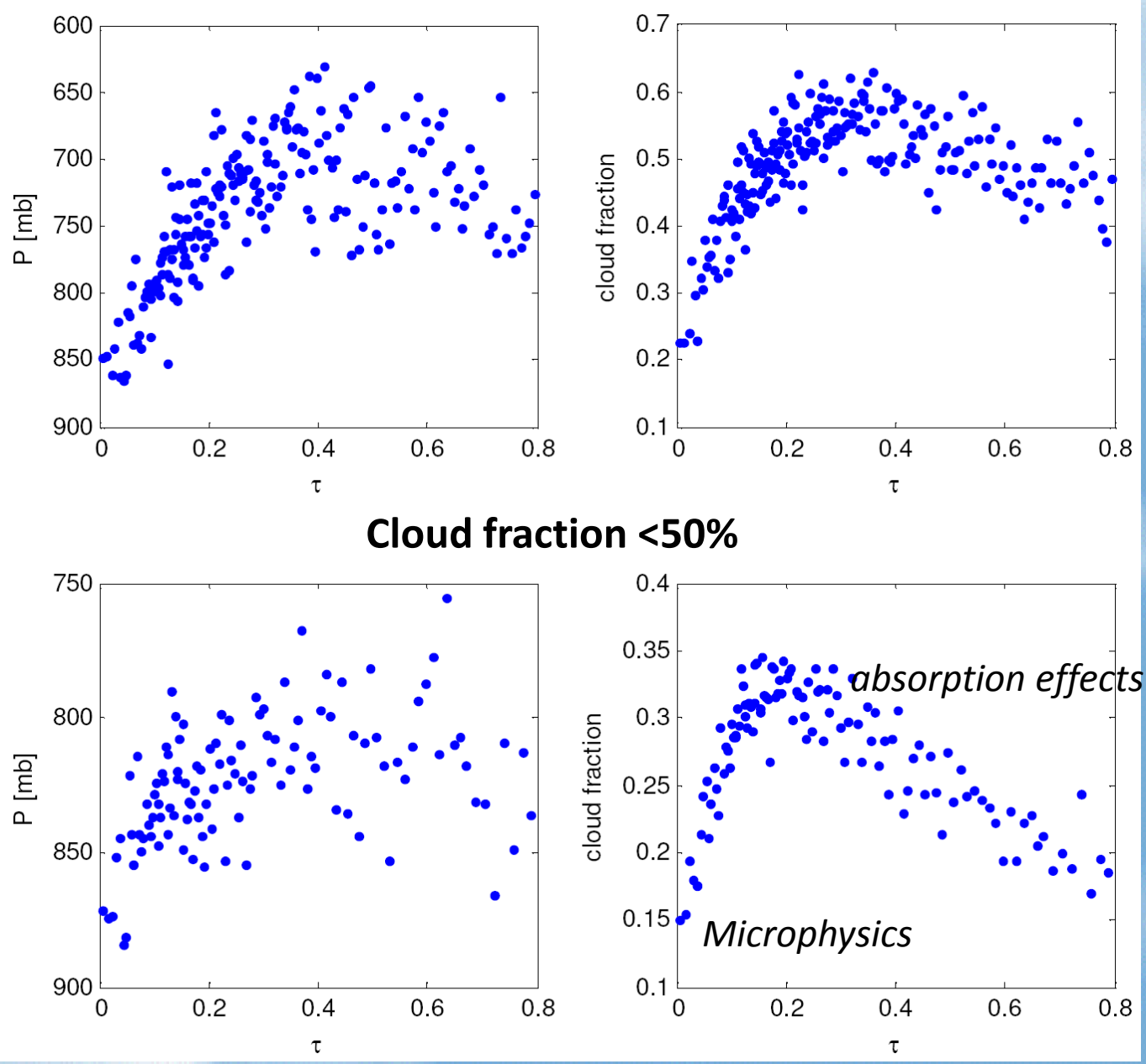
Cloud fraction as function of aerosol optical depth (OD). On average, the cloud fraction decreases to less than 1/8 of the cloud fraction in clean conditions when OD = 1. (Koren and Kaufman, 2003)

Relationships between cloud properties and aerosol loading in Amazonia

Left – cloud top pressure (P) vs. AOD. Lower P may indicate taller convective clouds.

Right – cloud fraction vs. AOD.

The upper row is for all data and the lower row is for data restricted to cloud fraction less than half.



Koren et al., Science 2008

nature geoscience

LETTERS

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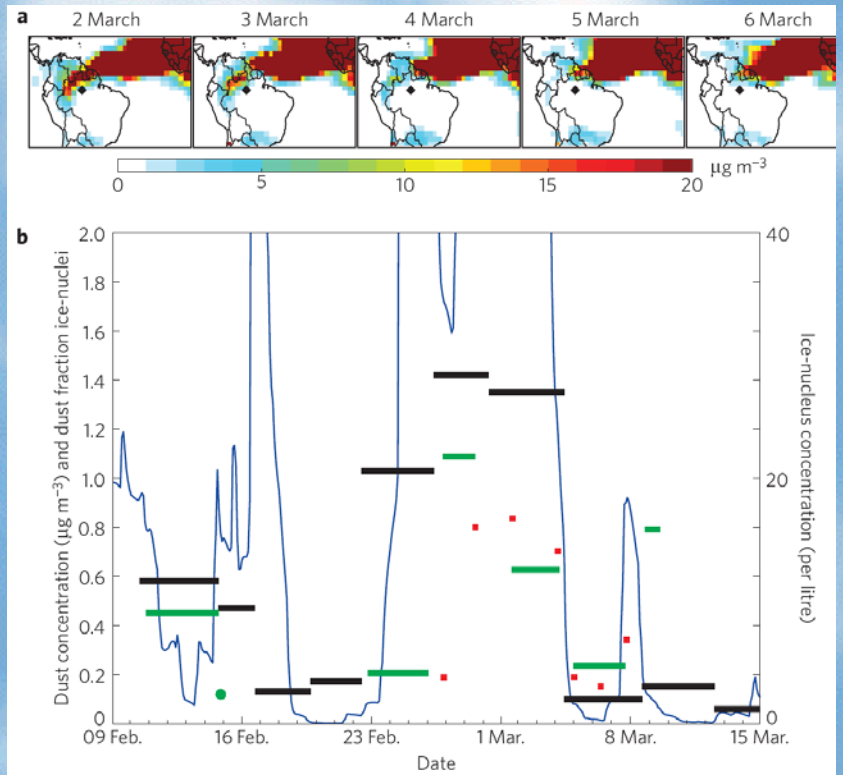
Relative roles of biogenic emissions and Saharan dust as ice nuclei in the Amazon basin

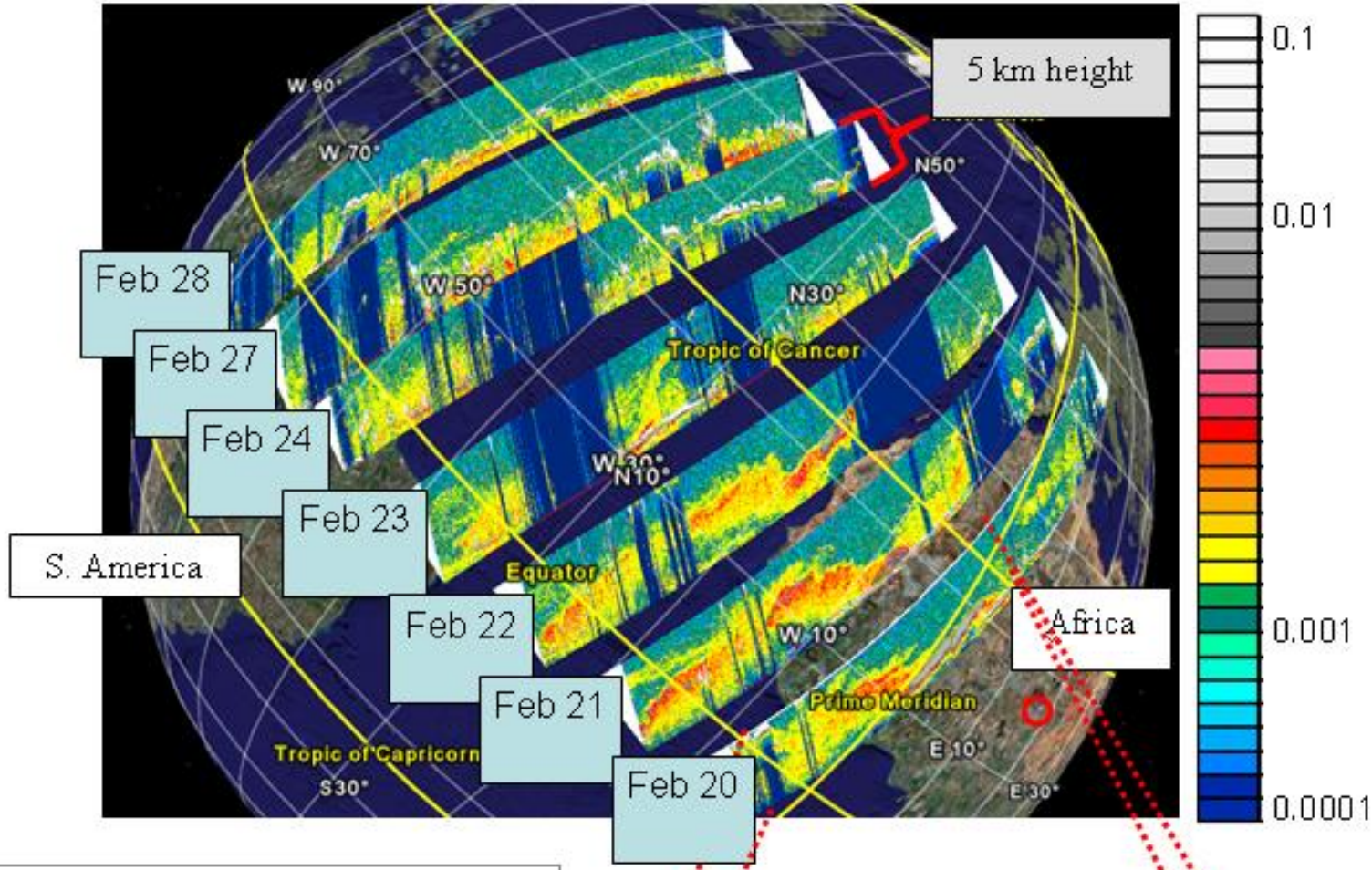
Anthony J. Prenni[1]*, Markus D. Petters[1], Sonia M. Kreidenweis[1], Colette L. Heald[1], Scot T. Martin[2], Paulo Artaxo[3], Rebecca M. Garland[4], Adam G. Wollny[4] and Ulrich Pöschl[4]

Ice nuclei from biogenic emissions and Saharay dust in Central Amazonia

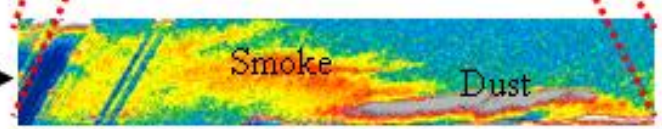
Dust relation to ice-nucleus measurements. Dust concentrations during AMAZE-08. a, GEOS-Chem simulated dust from 2–6 March at 18 UTC. The field site, shown as a black diamond, typically fell near the edge of the plumes. Fine-dust concentrations from PIXE measurements (black rectangles; µg/m³, dp<2µm.



Sahara dust transport to Amazonia



The dust-smoke interaction region (the dust is recognized by the strong backscattering signal relative to the smoke. The data was verified with MODIS image)



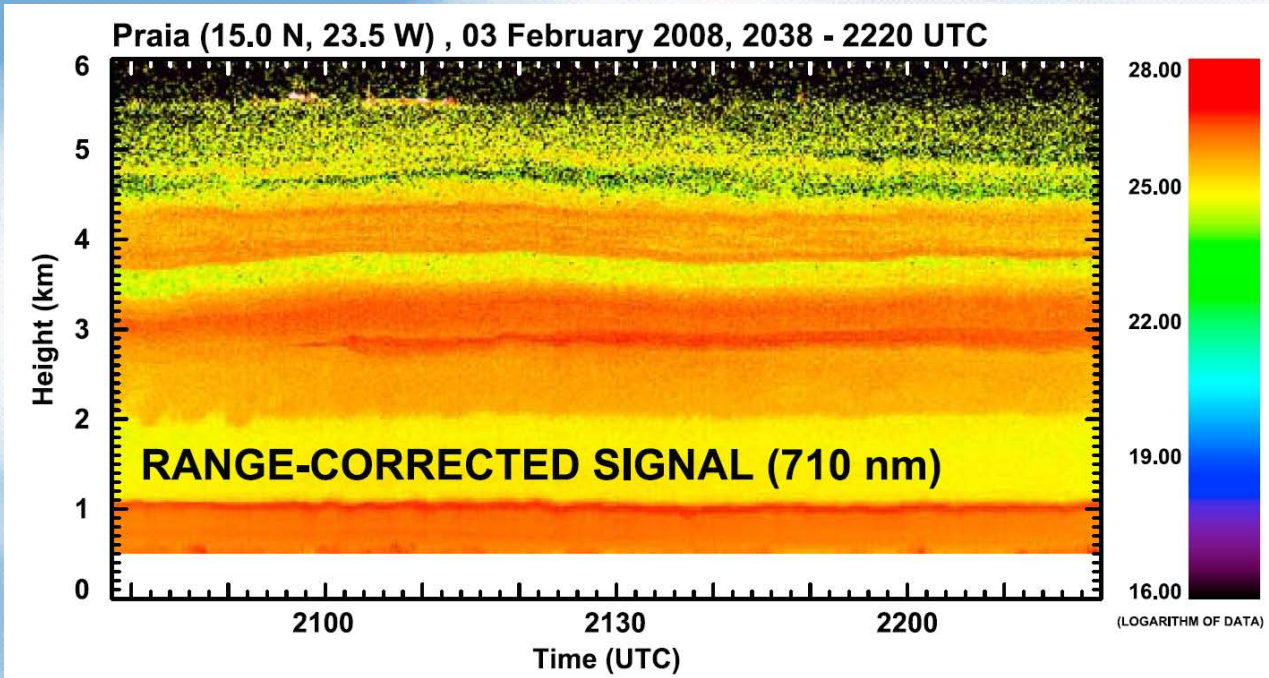
(Yuval et. al, in press).

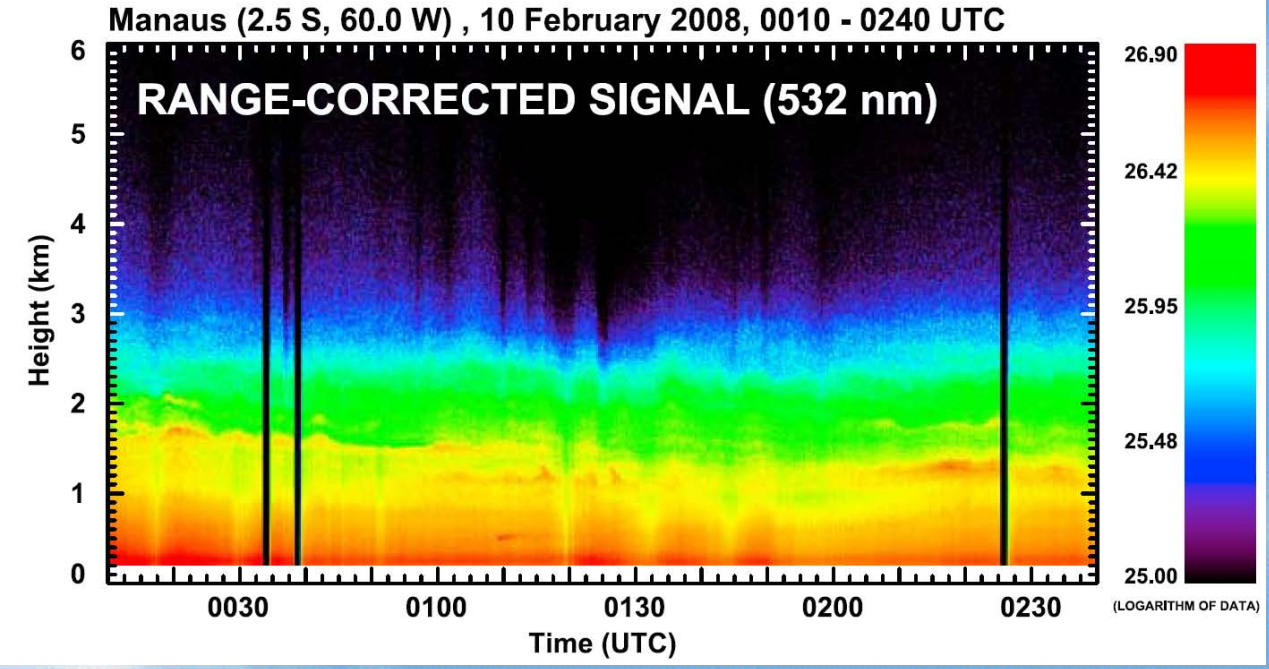
Raman Lidar observations of aerosols on Cape Verde and Manaus

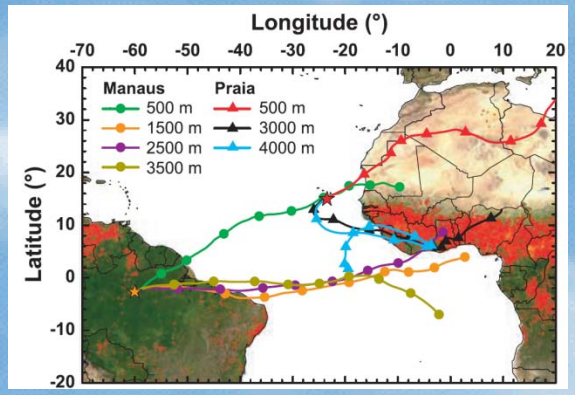
Range-corrected lidar signals

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

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







Ansmann et *al., GRL 2009*

CHUVA Project

WORKING GROUP – 1 CHARACTERISTICS OF THE PRECIPITATING SYSTEMS AS FUNCTION OF THE REGION AND LIFE STAGE Responsible : Luiz Machado
WORKING GROUP – 2 PRECIPITATION ESTIMATION – DEVELOPMENT AND VALIDATION ALGORITHM Responsible : Carlos Angelis
WORKING GROUP – 3 ELETRIFICATION PROCESS: MOVING FROM CLOUDS TO THUNDERSTORMS Responsible: Carlos Morales
WORKING GROUP – 4 CHARACTERISTICS OF THE BOUNDARY LAYER FOR DIFFERENT CLOUD PROCESSES AND PRECIPITATION REGIMES Responsible: Gilberto Fisch
WORKING GROUP – 5 MODEL IMPROVEMENTS AND VALIDATION, WITH FOCUS IN CLOUD MICROPHYSICS AND AEROSOL INTERACTIONS, FOR SATELLITE PRECIPITATION ESTIMATES IN BRAZIL Responsible: Maria Assunção Dias

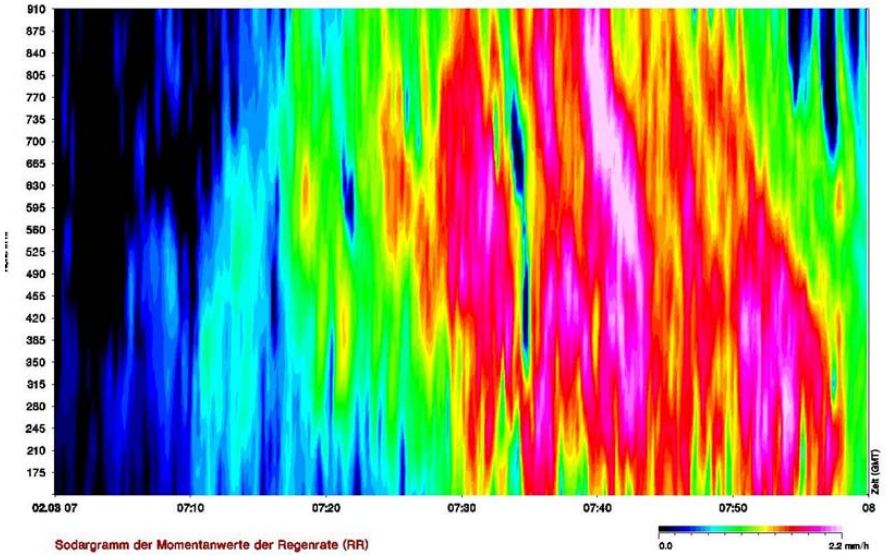
CHUVA Field Campaign Schedule

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEZ
2010			ALCANTARA									
2011		CHUVA WORKSHOP #1	FORTALEZA	FORTALEZA		BELÉM	BELEM				SAO LUIZ PARAITINGA	SAO LUIZ PARAITINGA
2012					CHUVA - WORKSHOP#2					FOZ DO IGUAÇU	FOZ DO IGUAÇU	FOZ DO IGUAÇU
2013	FOZ DO IGUAÇU									BRASÍLIA	BRASÍLIA	
2014	MANAUS	MANAUS	MANAUS	MANAUS								

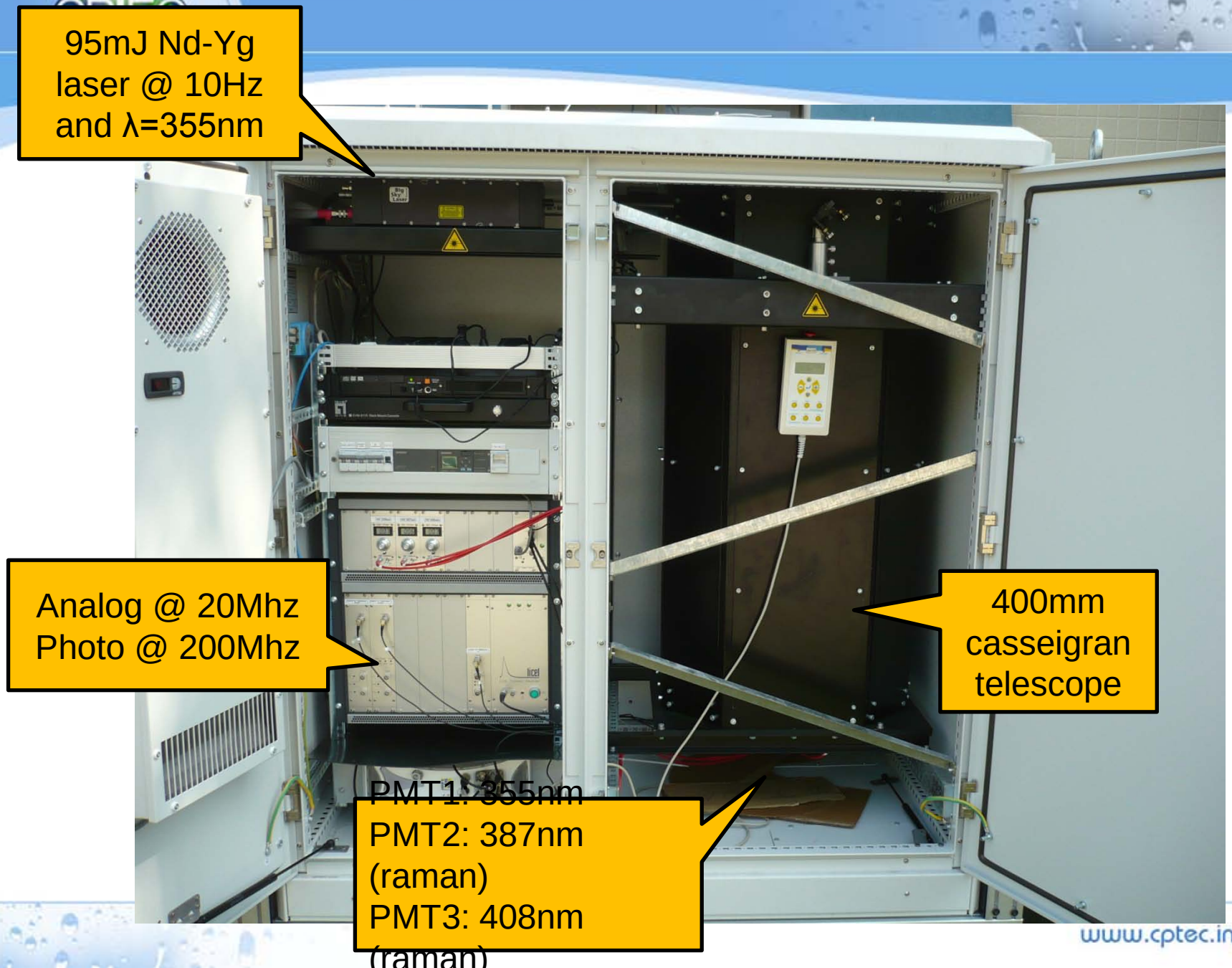
X-Dual POL Mobile Radar

CHUVA – Equipamentos

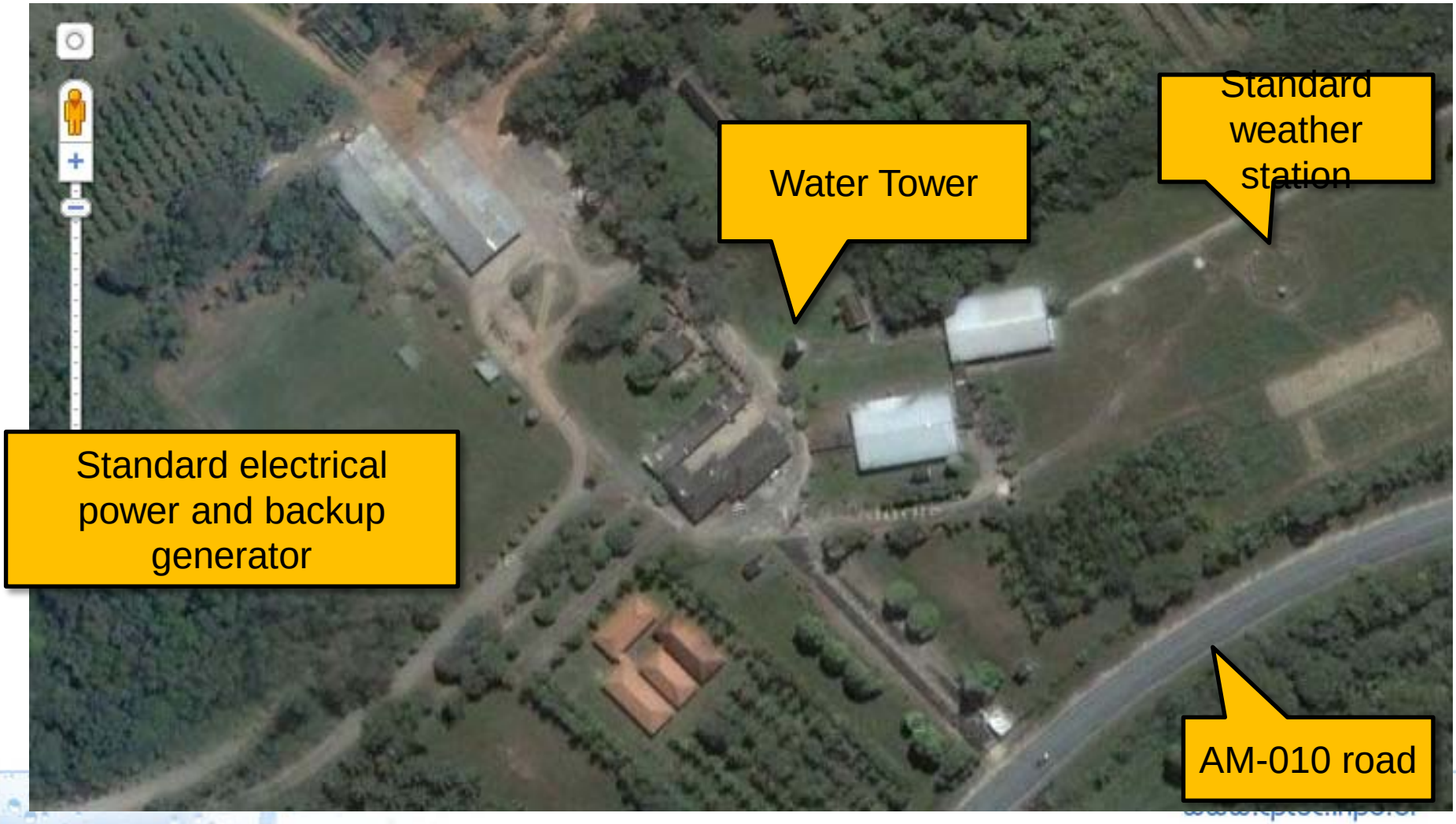
Vertical pointing micro Doppler rain radar Keplel – 24.1 Ghz



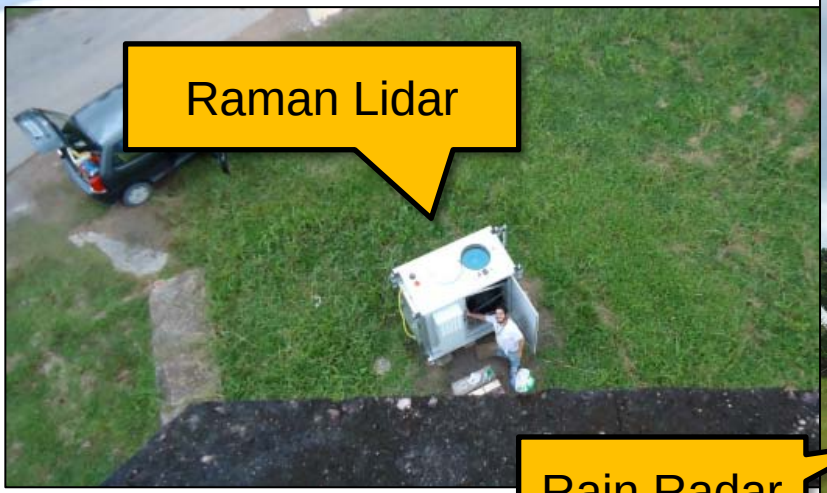
AEROCLIMA Raman Lidar

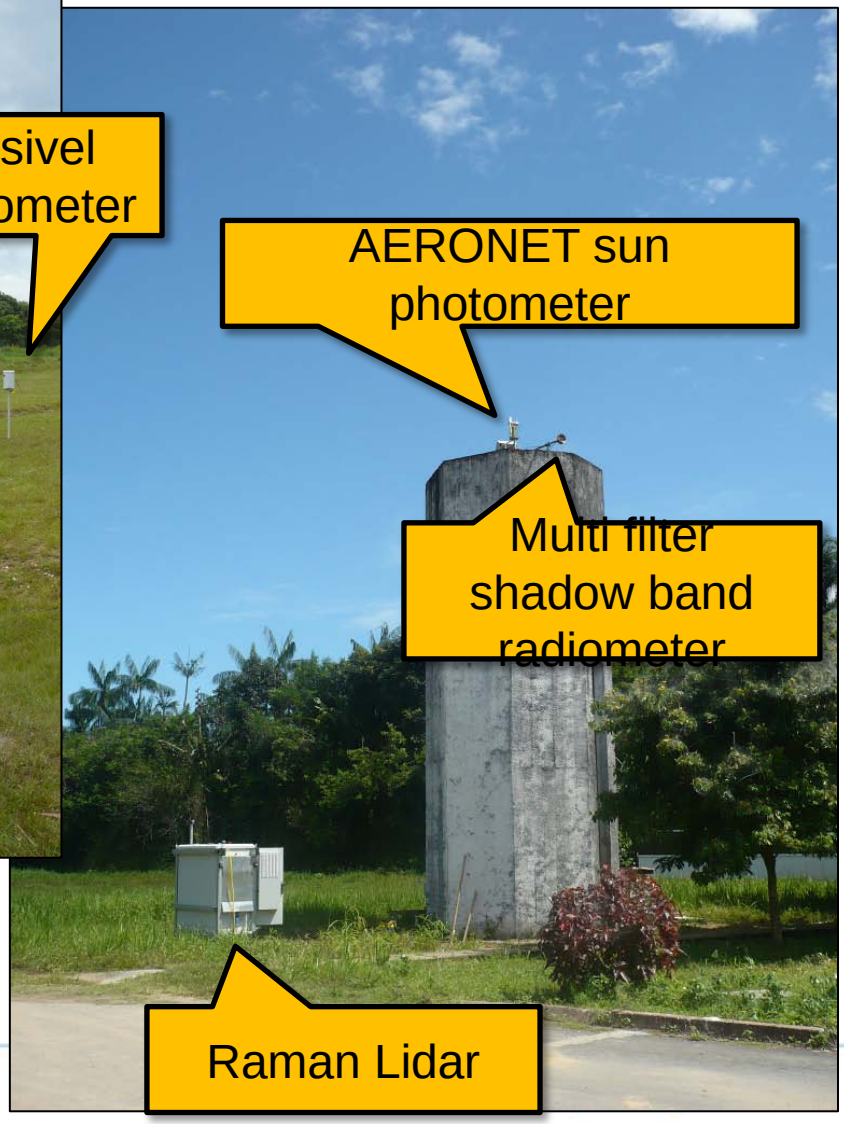

95mJ Nd-Yg laser @ 10Hz and λ=355nm
Analog @ 20Mhz
Photo @ 200Mhz
400mm casseigran telescope
PMT1: 355nm
PMT2: 387nm (raman)
PMT3: 408nm (raman)

Embrapa Site

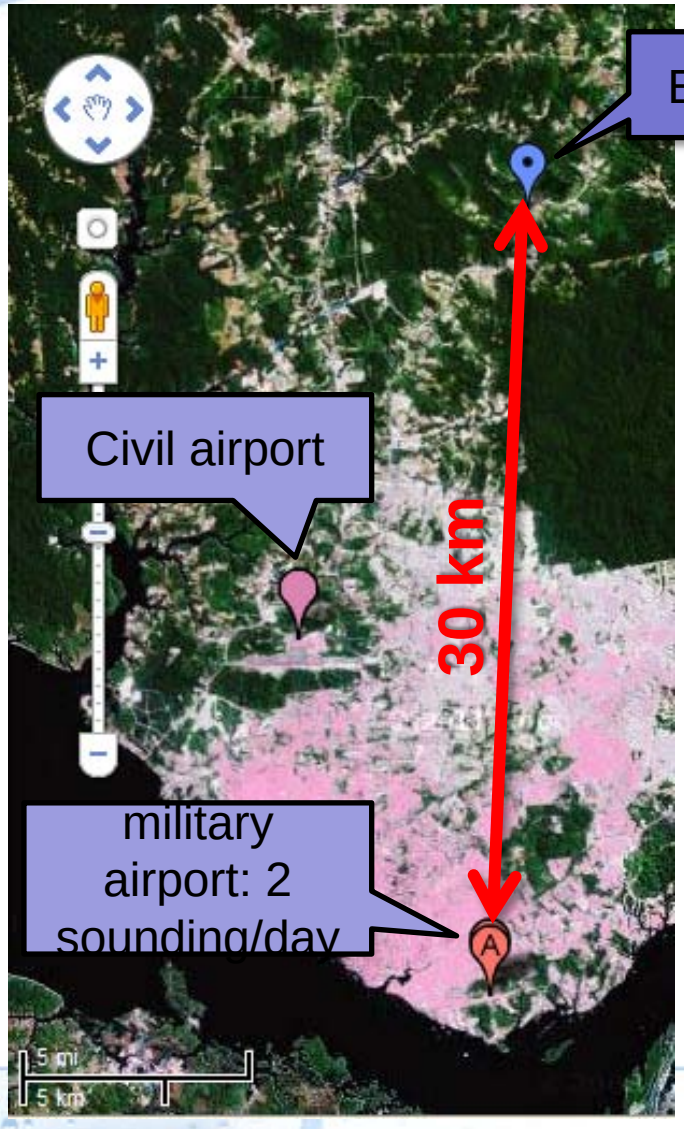


EMBRAPA Site

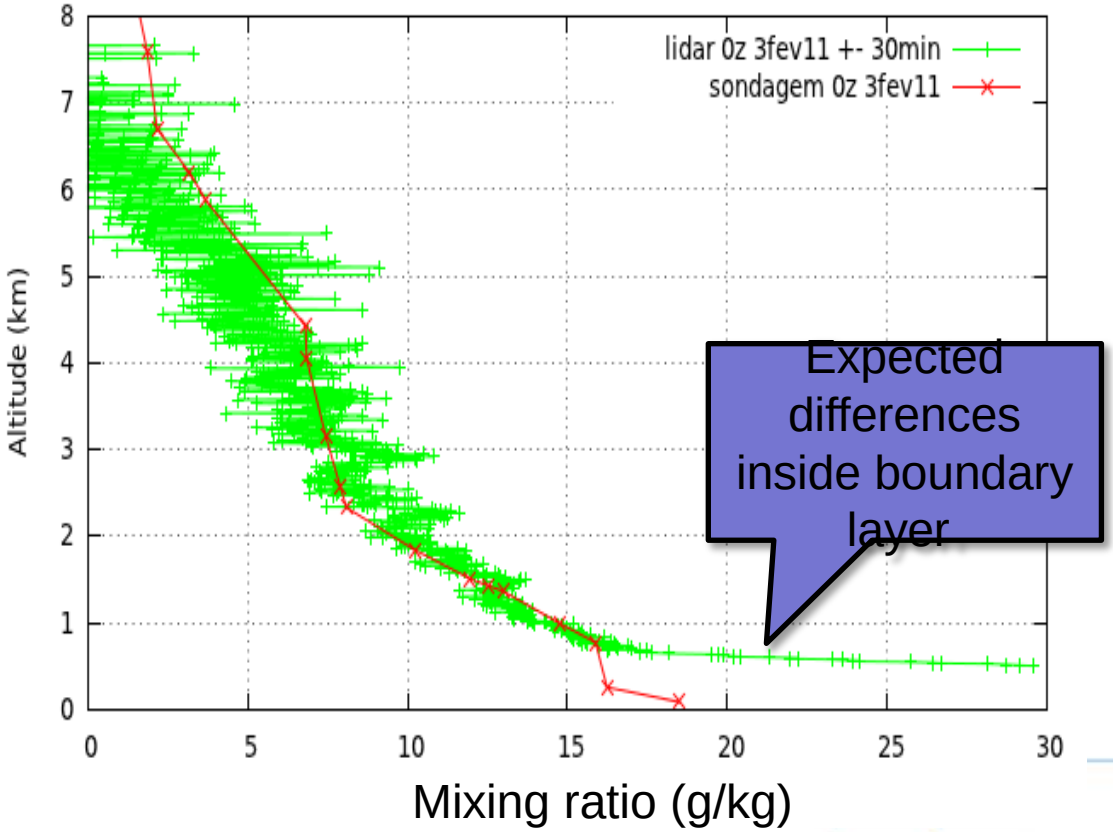




Example: Water Vapor Profiles



Lidar: 23h30 feb 2nd – 0h30 feb 3rd
Sounding: 00 Z feb 3rd



Rainfall trends in the Brazilian Amazon 1925-2008: Decreasing at Pará and Amazon states?

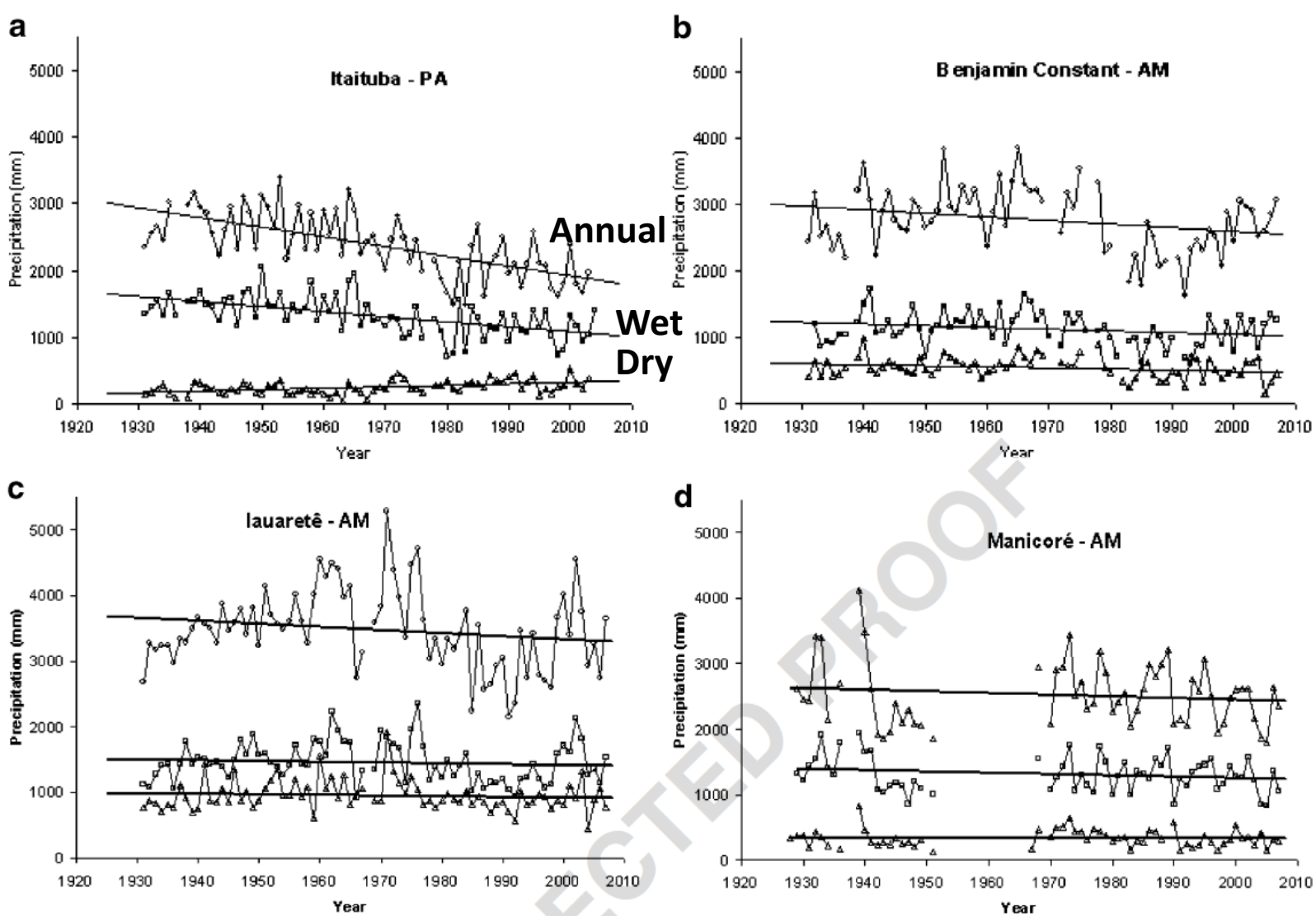


Fig. 2 Annual, wet-season, and dry-season rainfalls and trend lines for **a** Itaituba, **b** Benjamin constant, **c** Iaurete, and **d** Manicore stations

Satyamurty et al., 2010

Rainfall trends in the Brazilian Amazon 1925-2008: increasing?

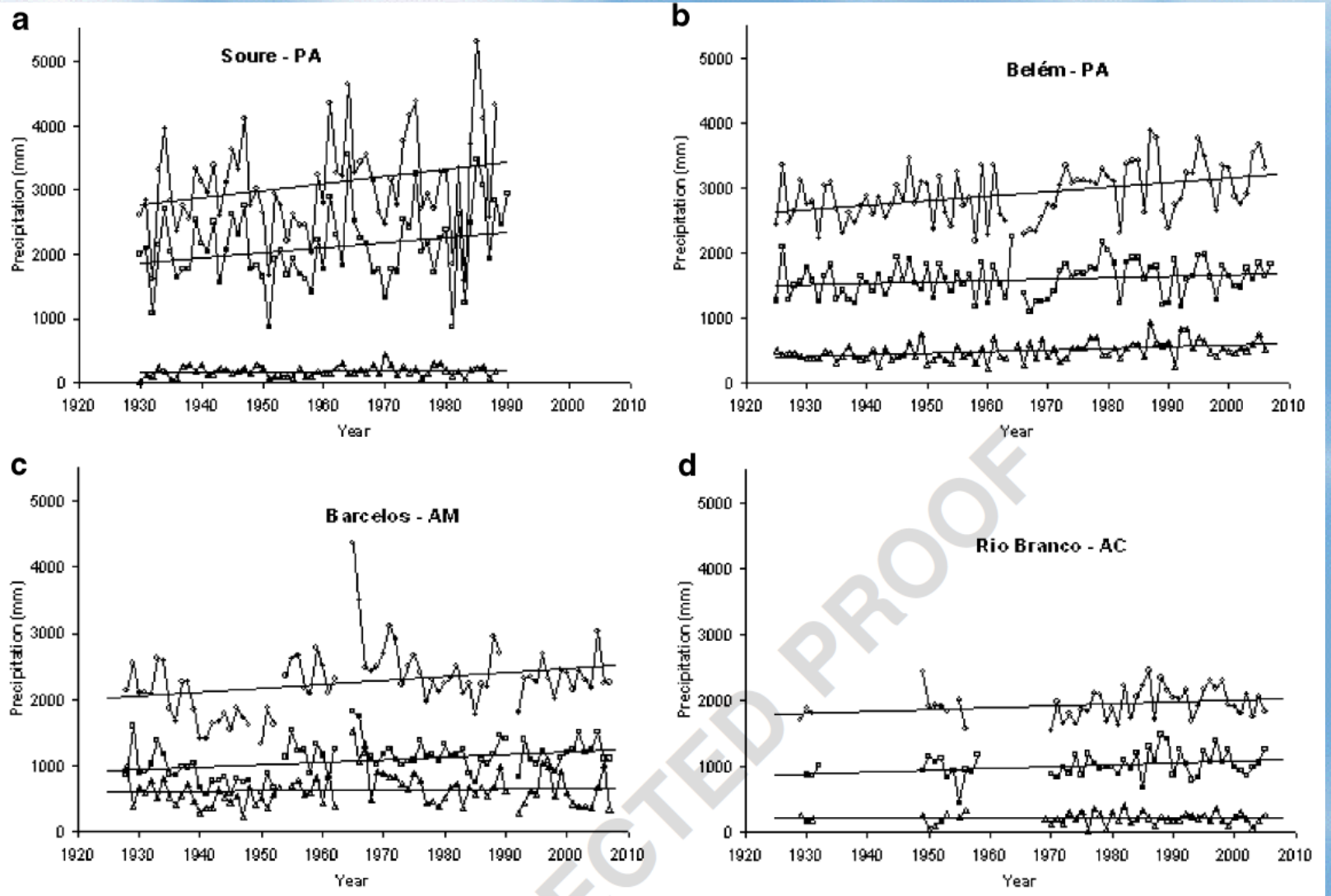


Fig. 3 Annual, wet-season, and dry-season rainfalls and trend lines for **a** Soure, **b** Belem, **c** Barcelos, and **d** Rio Branco stations

ECTED PROOF

Satyamurty et al., 2010

Rainfall trends in the Brazilian Amazon 1925-2008: whole region

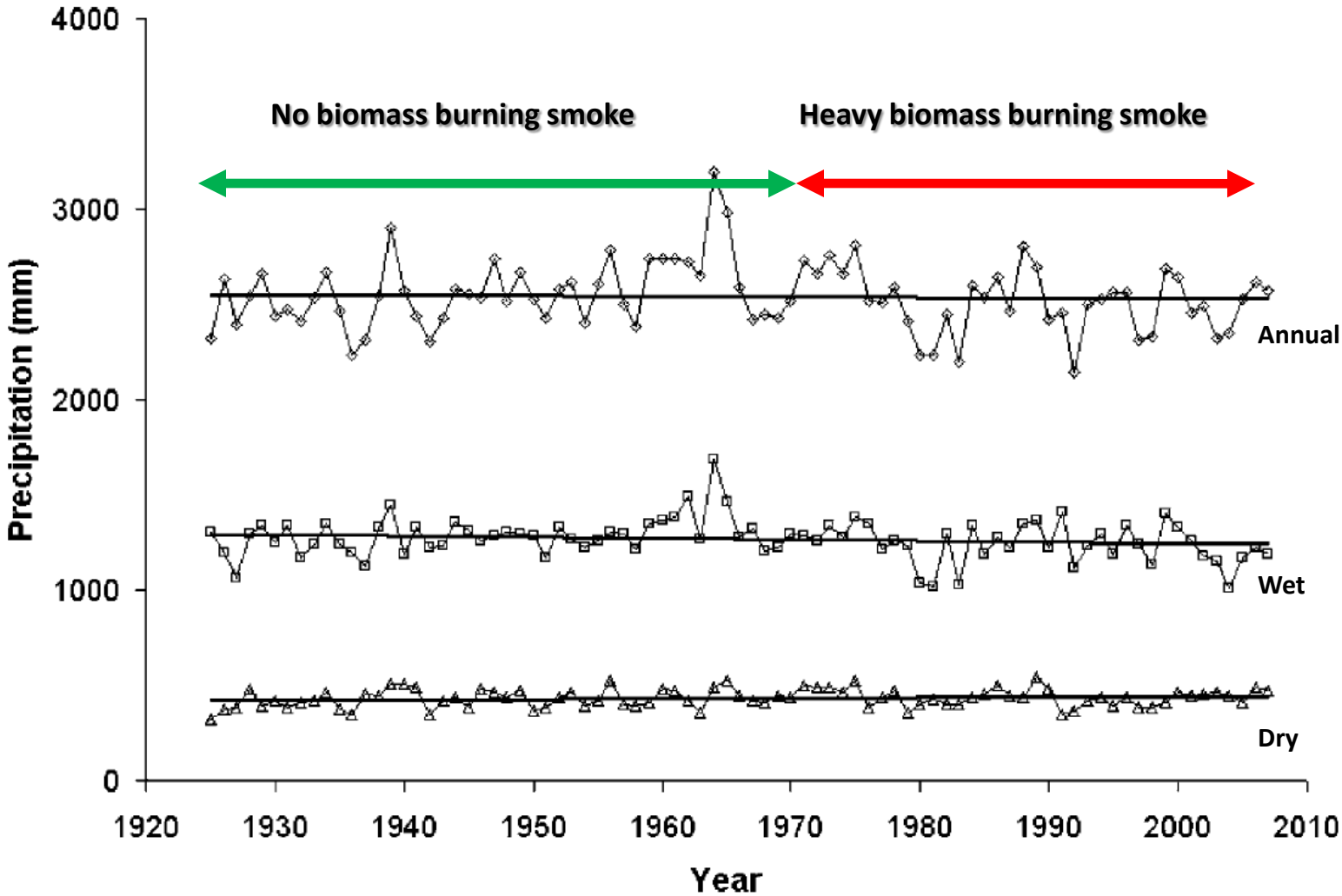
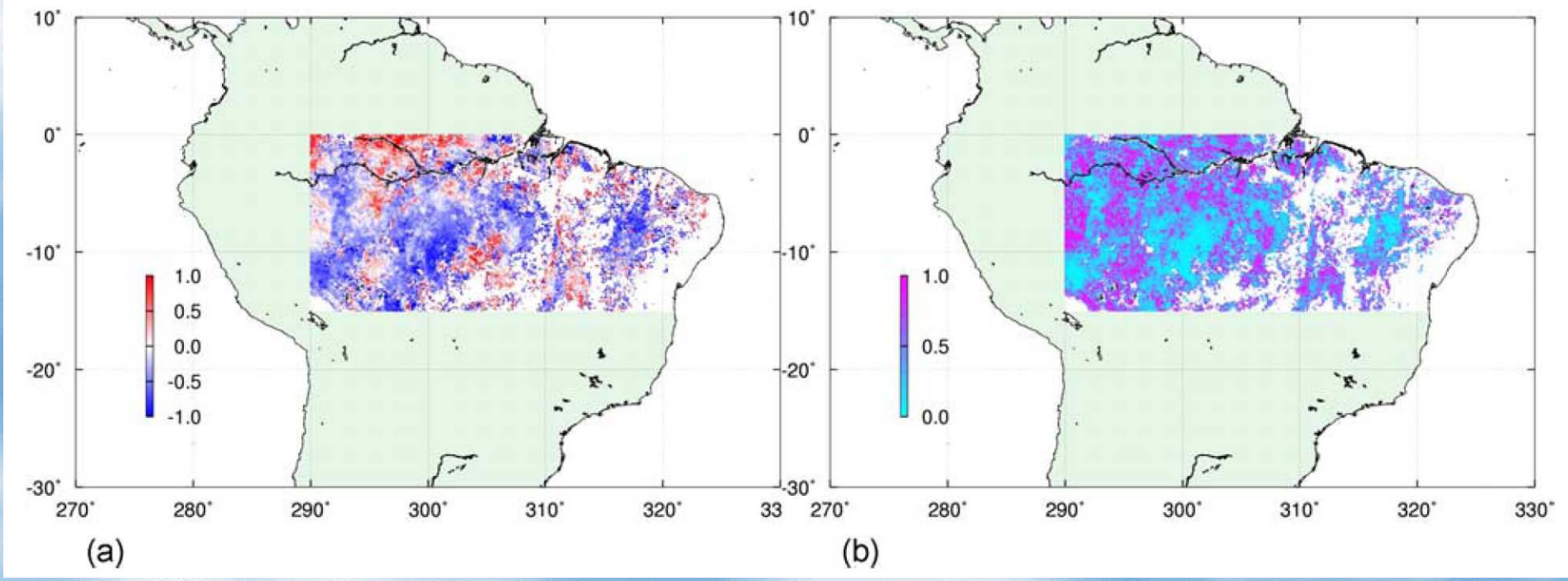


Fig. 4 Whole Region average annual and wet-season (JFMA) precipitation series and their linear-trend lines

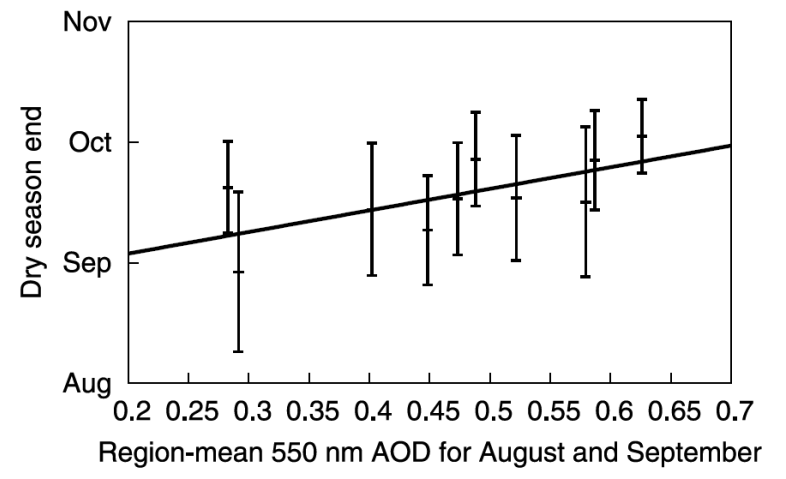
Satyamurty et al., 2010

Correlation between aerosols and precipitation in Amazonia



(a) Correlation coefficient between AOD and precipitation for September 1995–2007. (b) Correlation p value.

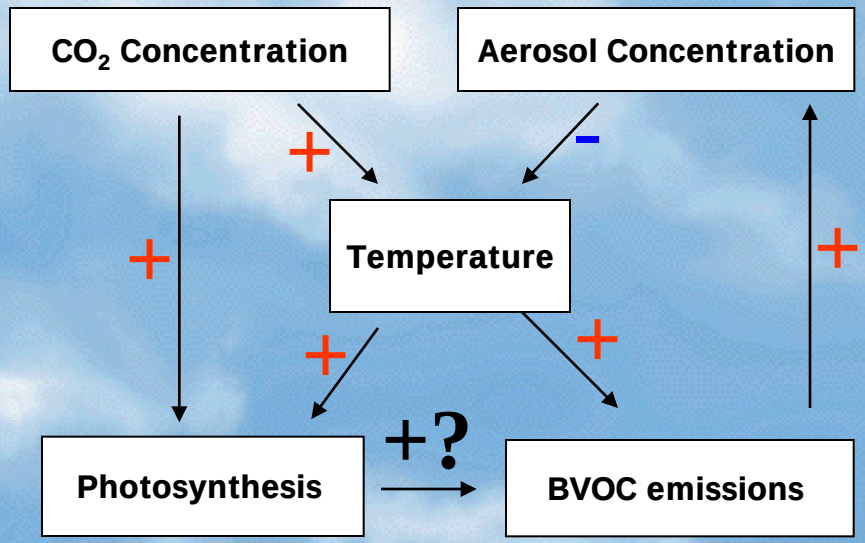
Aerosols extending duration of dry season



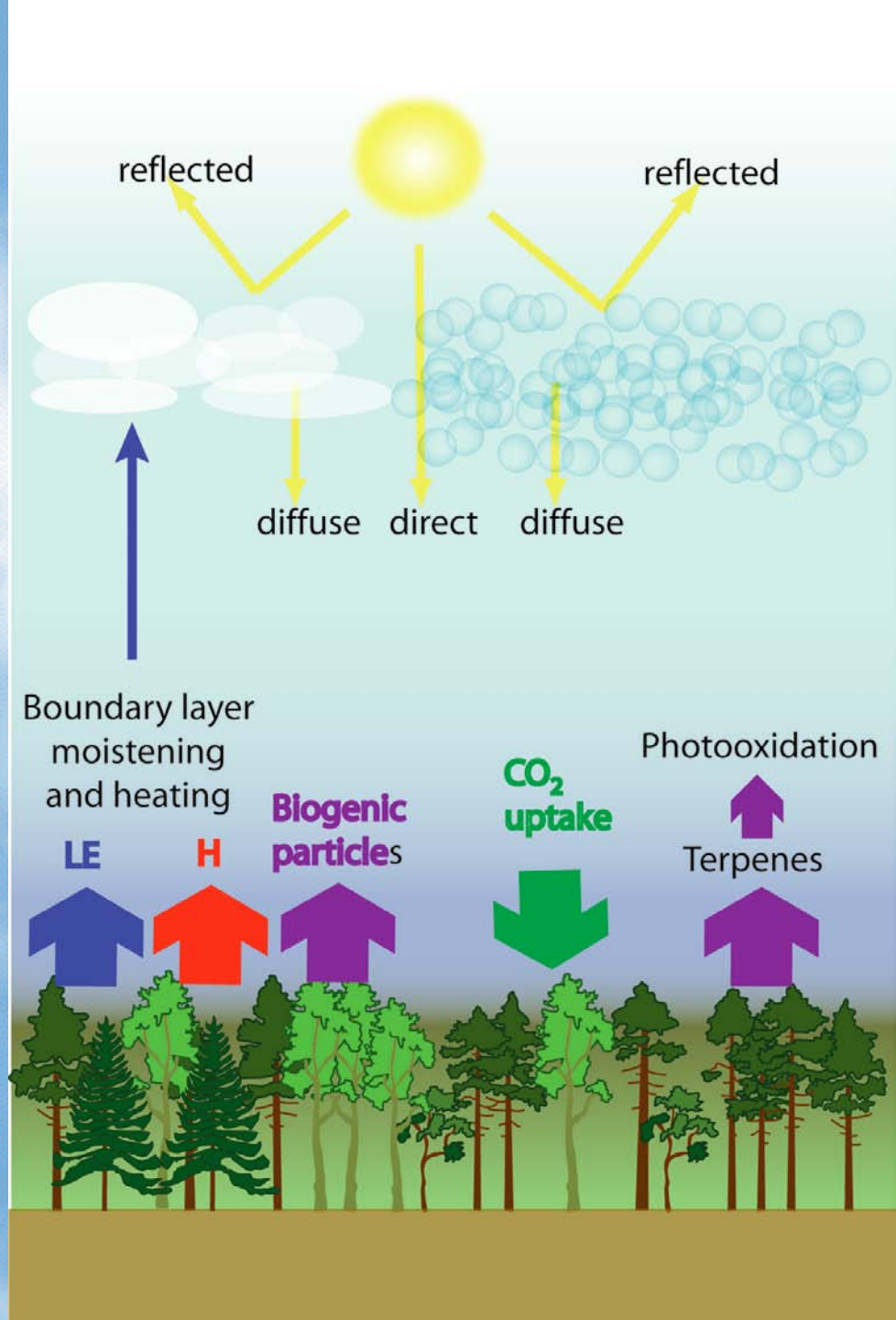
Region-mean end of dry season and corresponding 550-nm AOD.

Bevan et al., JGR May 2009

Aerosol effects on the Net Plant Productivity

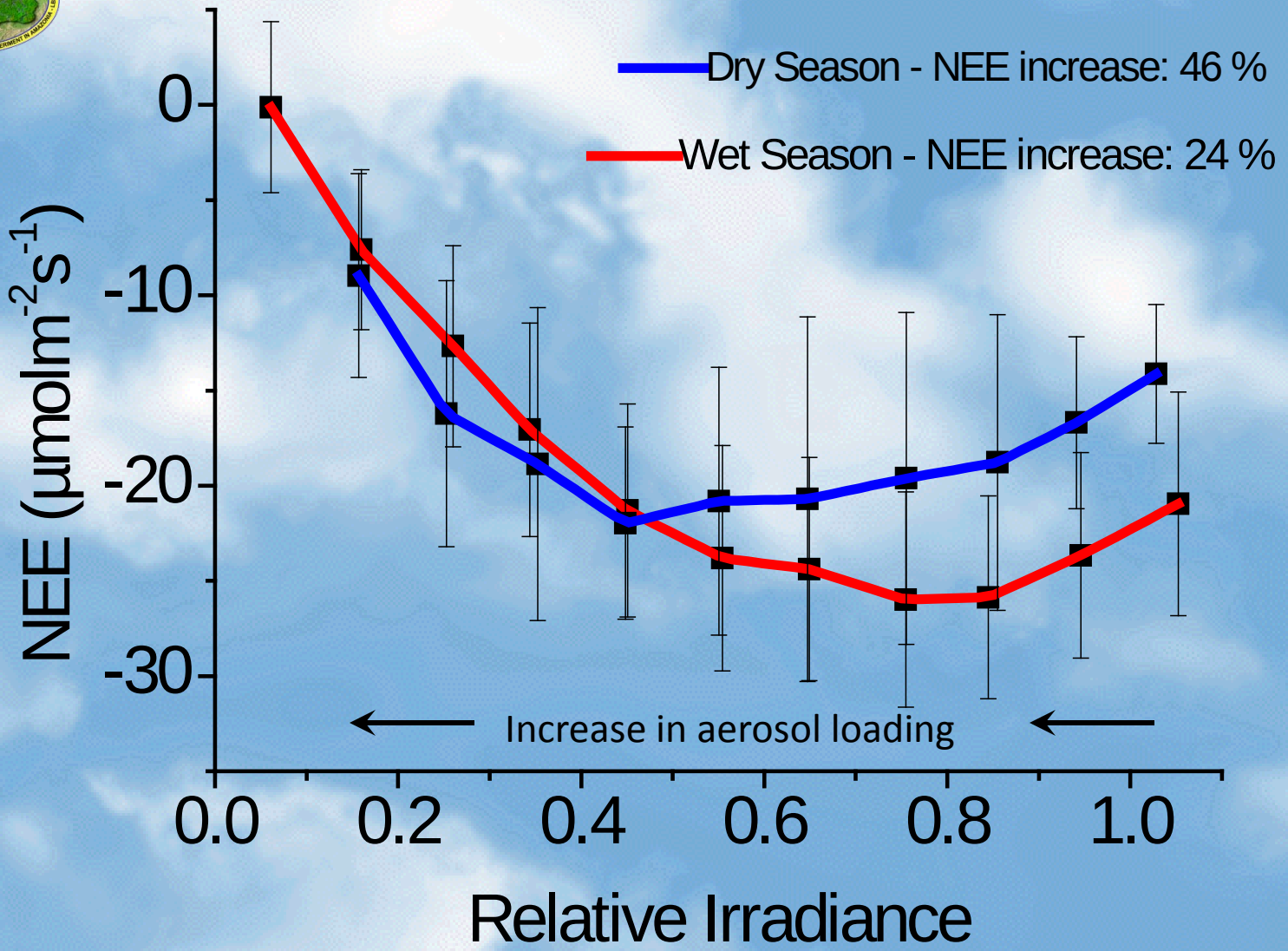


Kulmala et al., 2004

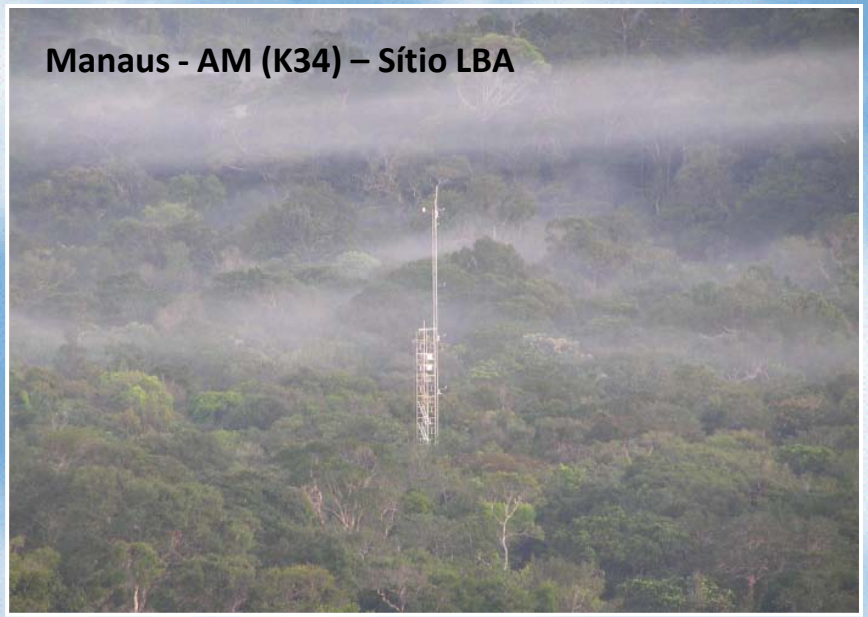


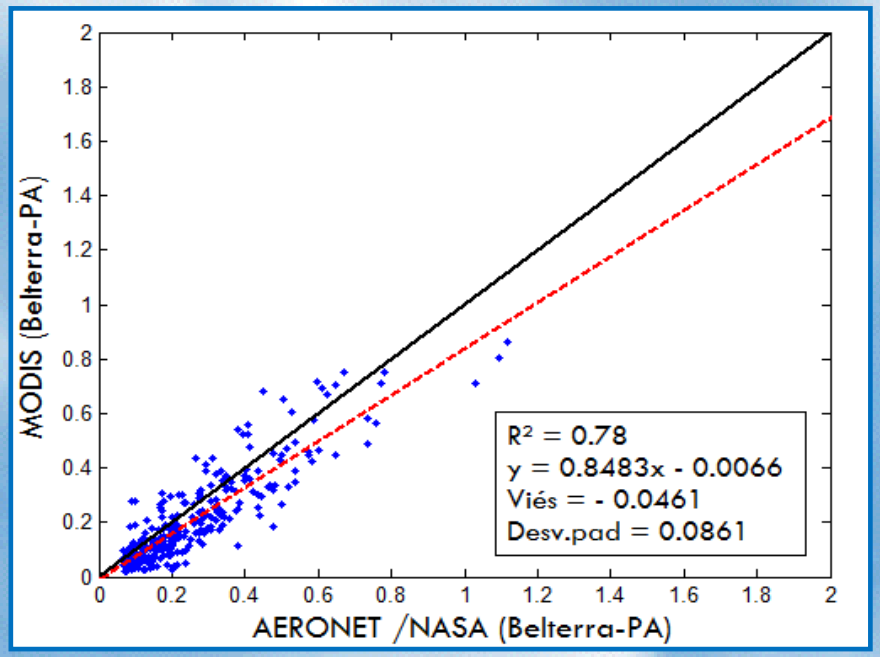
Strong aerosol effect on forest photosynthesis diffuse radiation have a large effect on CO2 fluxes

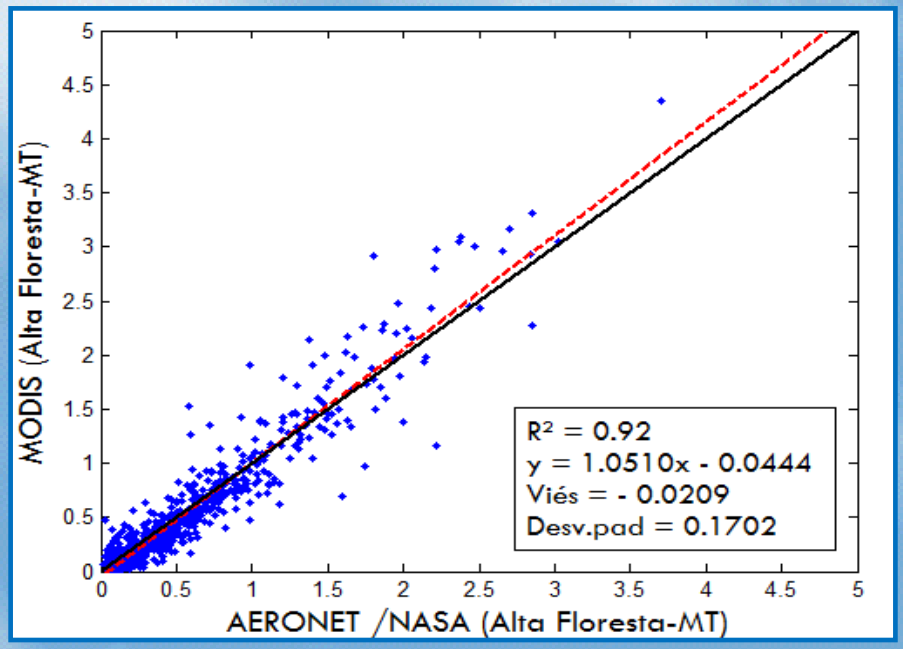
Amazonia Rondonia Forest site 2000-2001



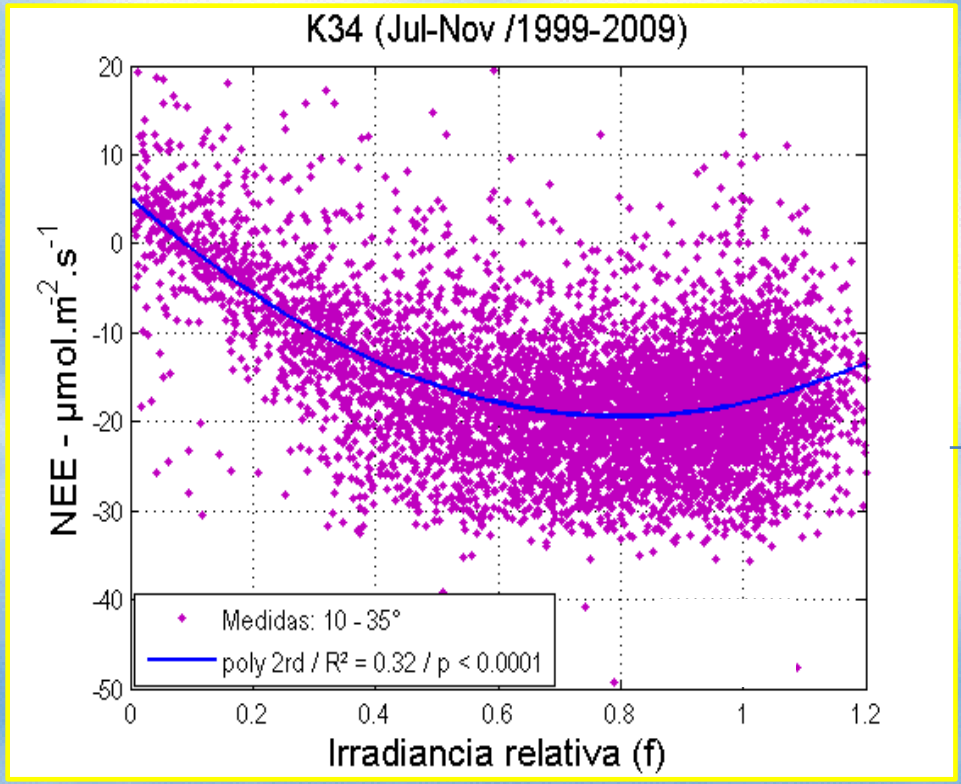
Carbon fluxes and aerosols with MODIS AOD





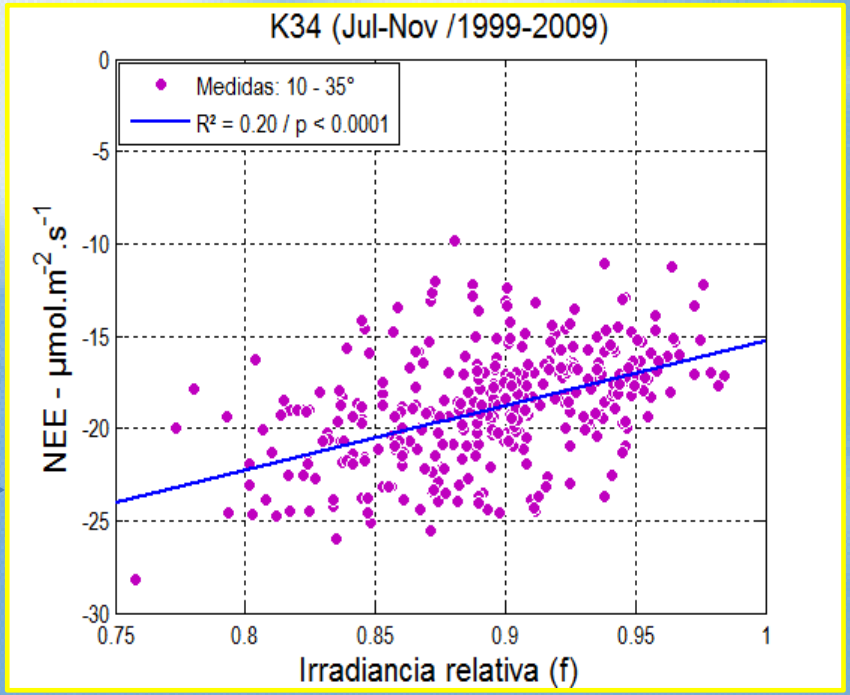


Aerosols effects on NEE – Manaus K34 tower

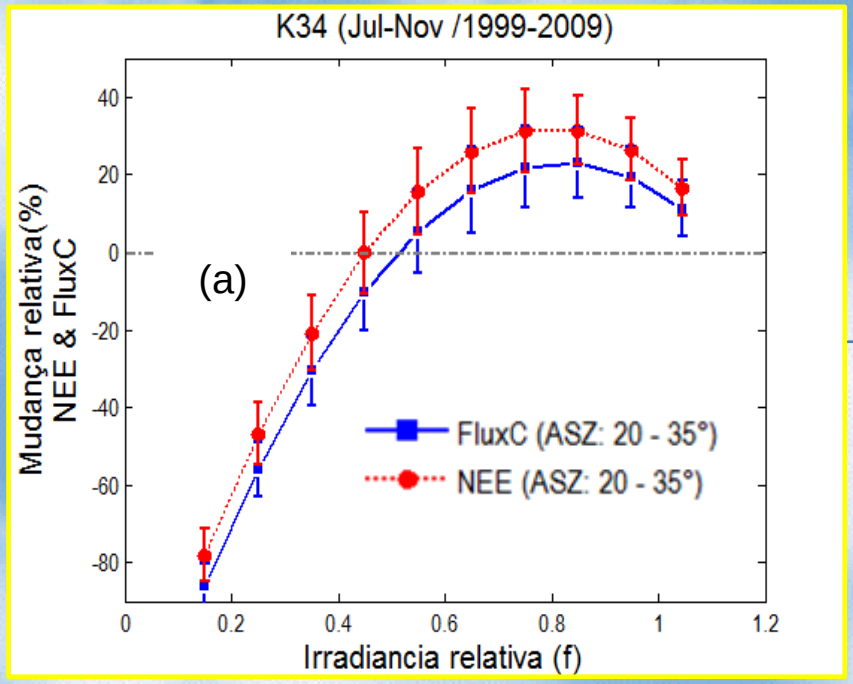


f max: ~ 0,80

NEE (max): ~ -20 µmol/m²s
AOT: ~ 0,5



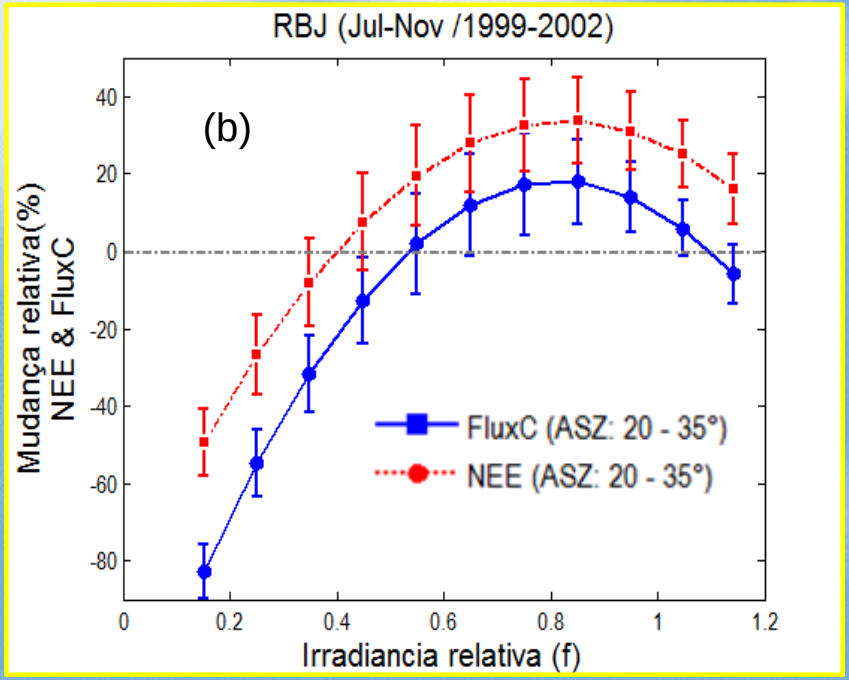
Manaus and Rondonia average effects of aerosols on carbon uptake



Manaus

Δ f ↓: 1,0 – 0,8 (~ 20%)

Δ NEE (%) ↑: ~ 26 %
Δ FluxC (%) ↑: ~ 17 %



Rondonia

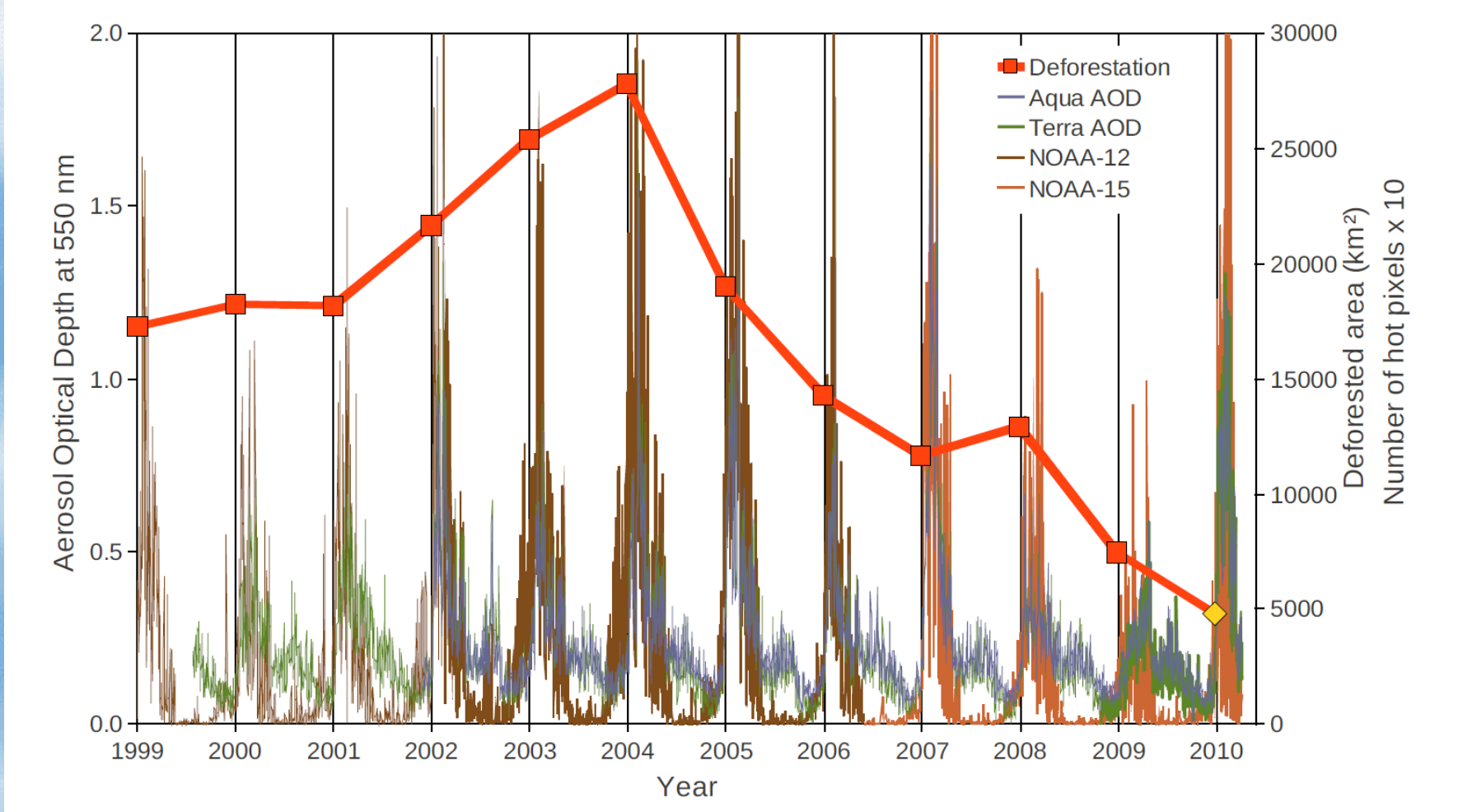
Δ f ↓: 1,2 – 0,8 (~ 20%)

Δ NEE (%) ↑: ~ 29 %
Δ FluxC (%) ↑: ~ 14 %

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.

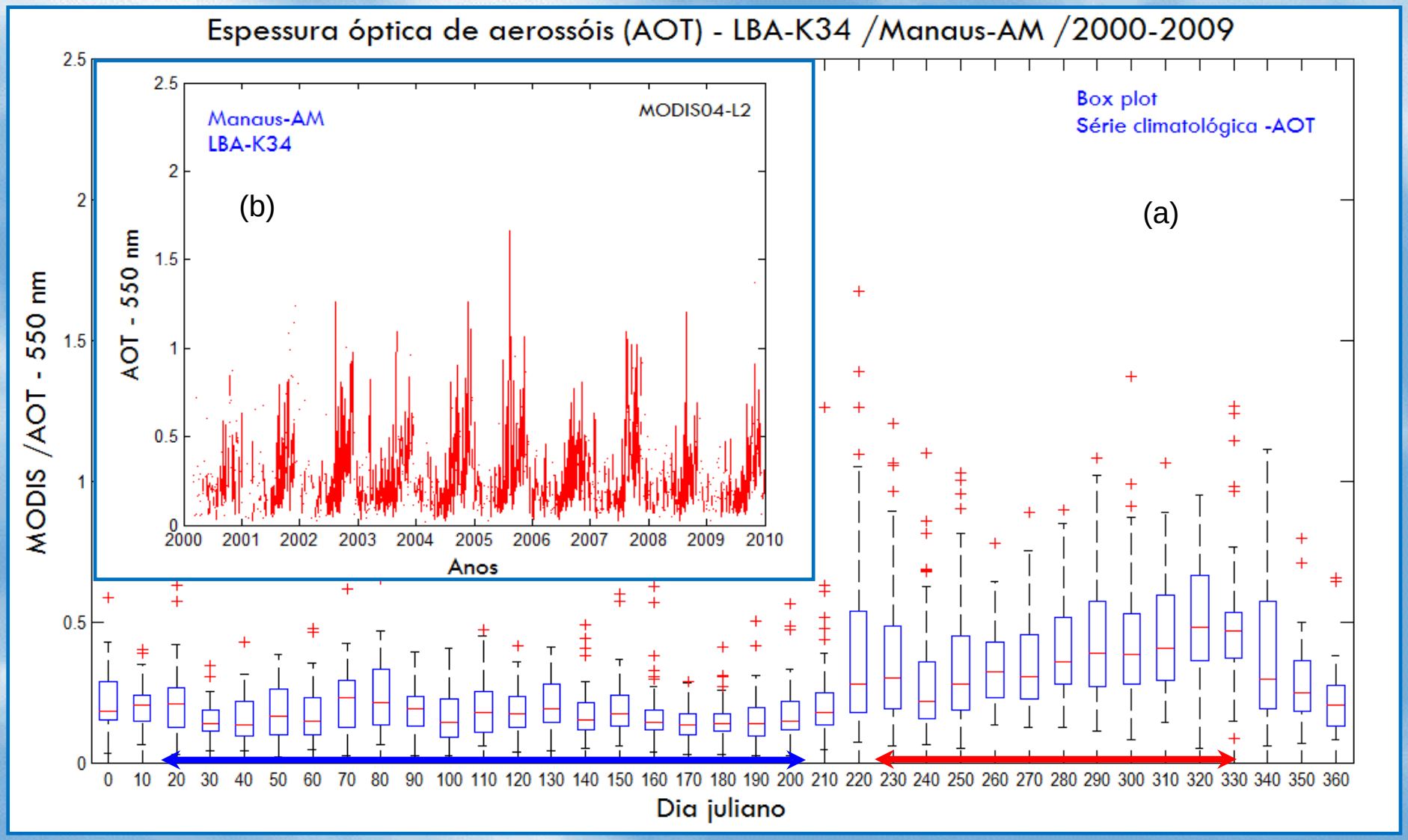
Medidas de espessura ótica de aerossóis (AOT) → (Comprimentos de onda: 340, 380, 440, **500**, 670, 870, 940 e 1020 nanômetros)

Yearly deforestation with MODIS AOD and hot pixels from NOAA-12/15

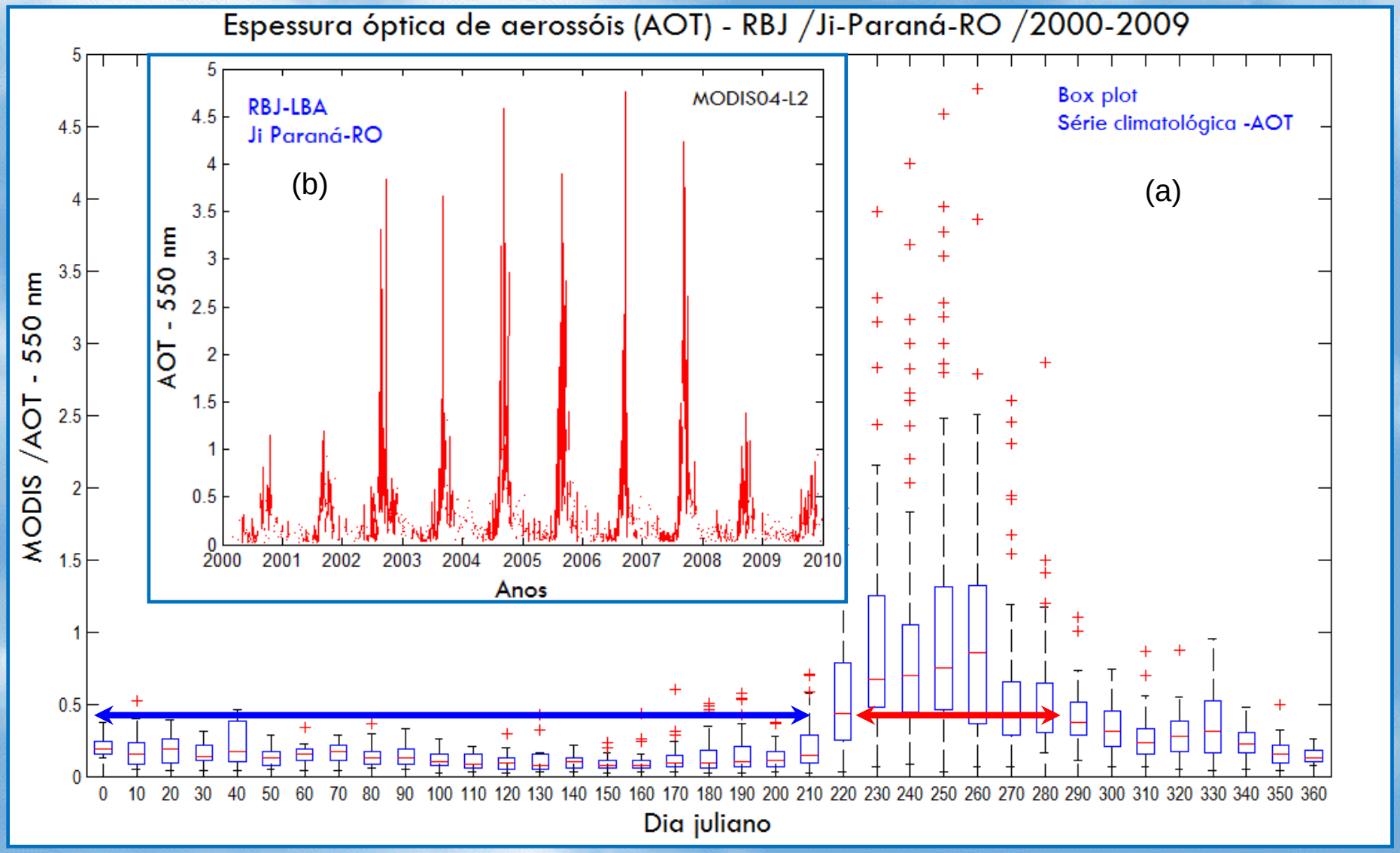


Yearly deforestation over the Brazilian Amazon region (INPE, 2010) compared to MODIS daily smoke optical depth and the daily number of hot pixels from NOAA-12 and NOAA-15. The results are shown according to the hydrological year, from August 1st of the previous year to July 31st of the years shown in the graph. The vertical lines indicate August 1st , which correspondă to the onset of the burning season.

Manaus AOD from MODIS: Time series and seasonality

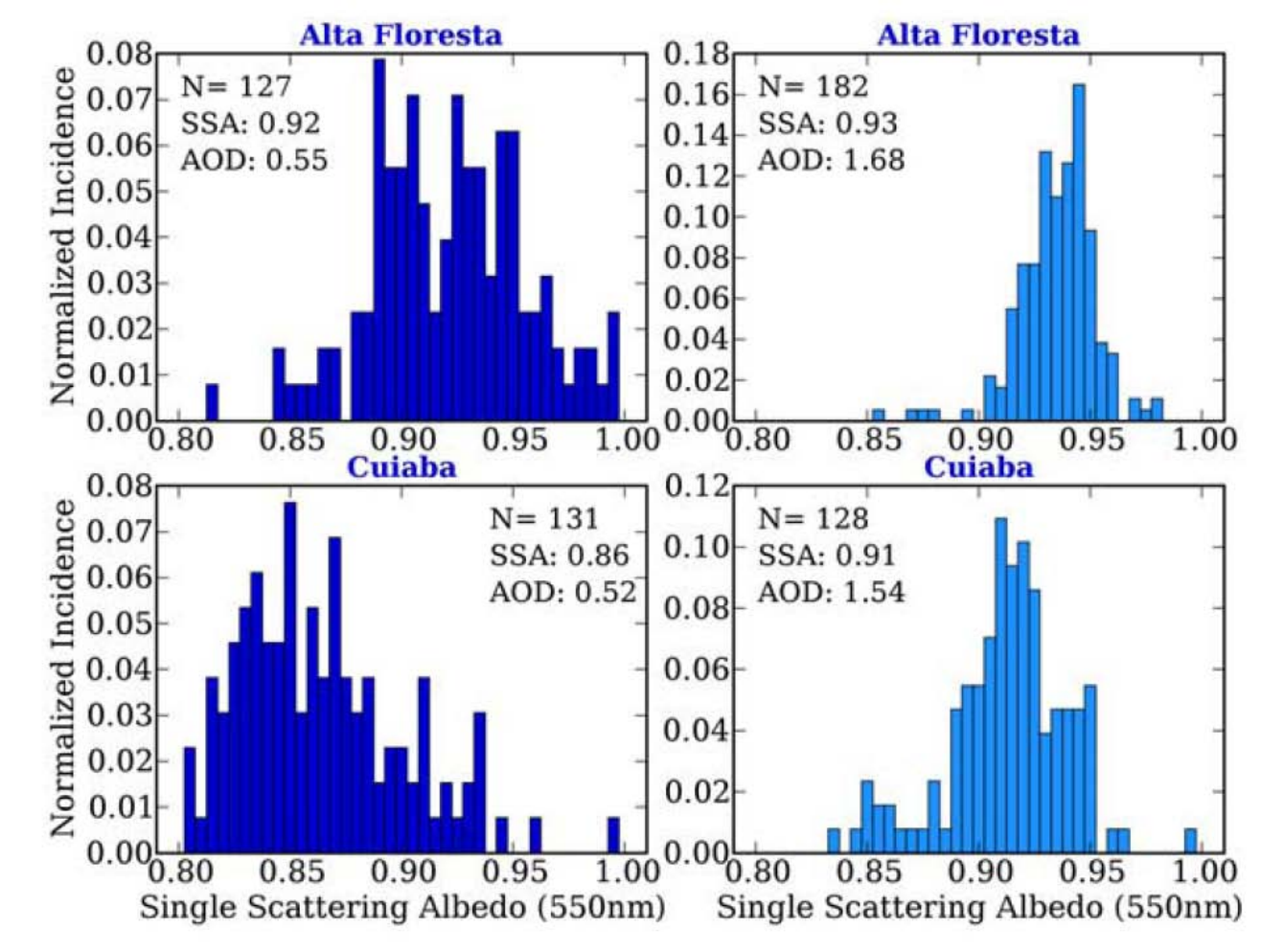


Rondonia AOD from MODIS: Time series and seasonality

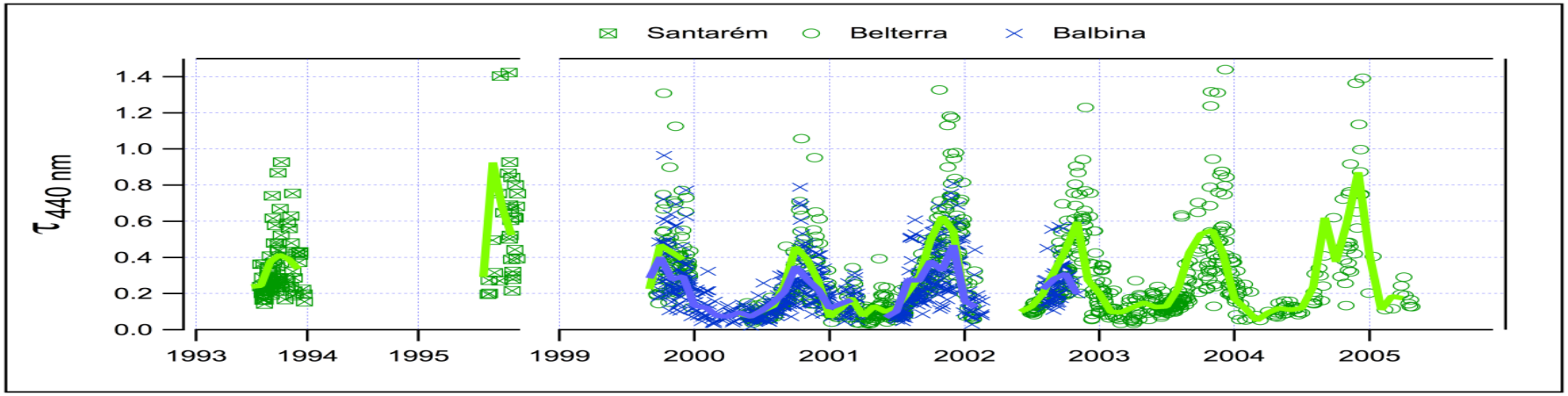


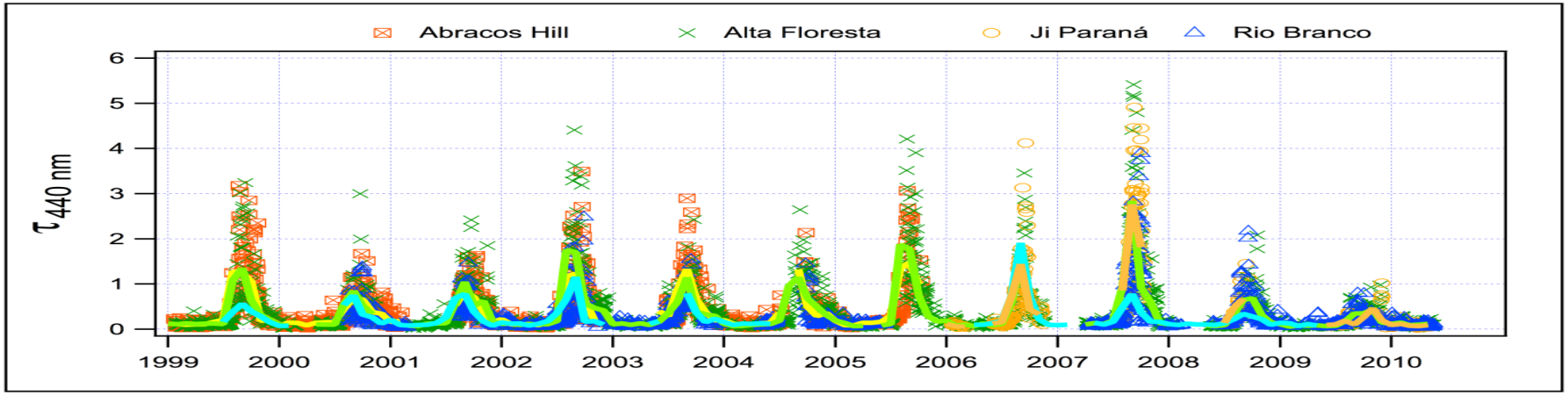
AERONET Single-scattering albedo (SSA550nm)

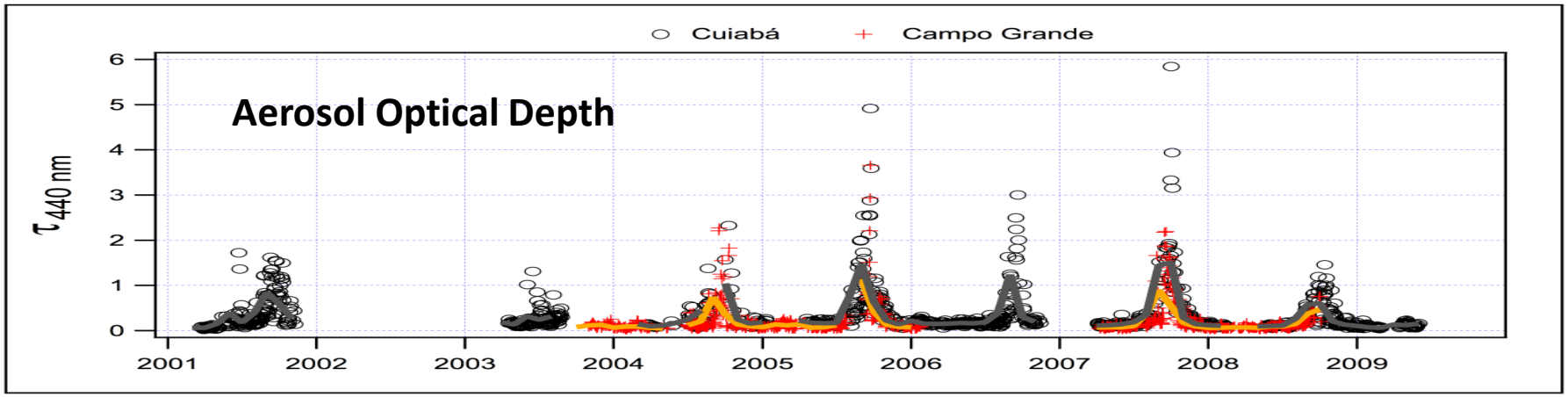
Low AOT, more absorbing High AOT, less absorbing

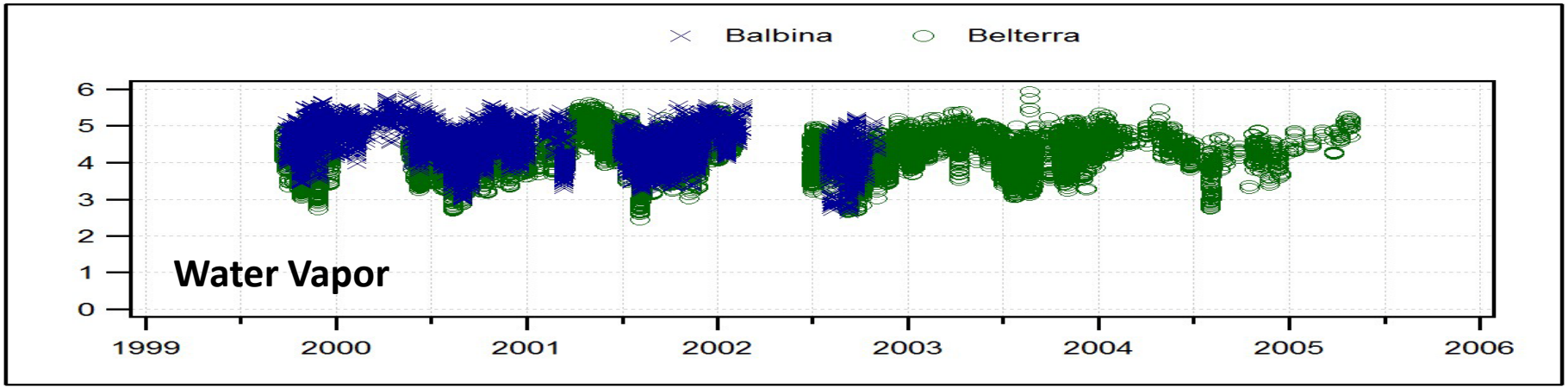


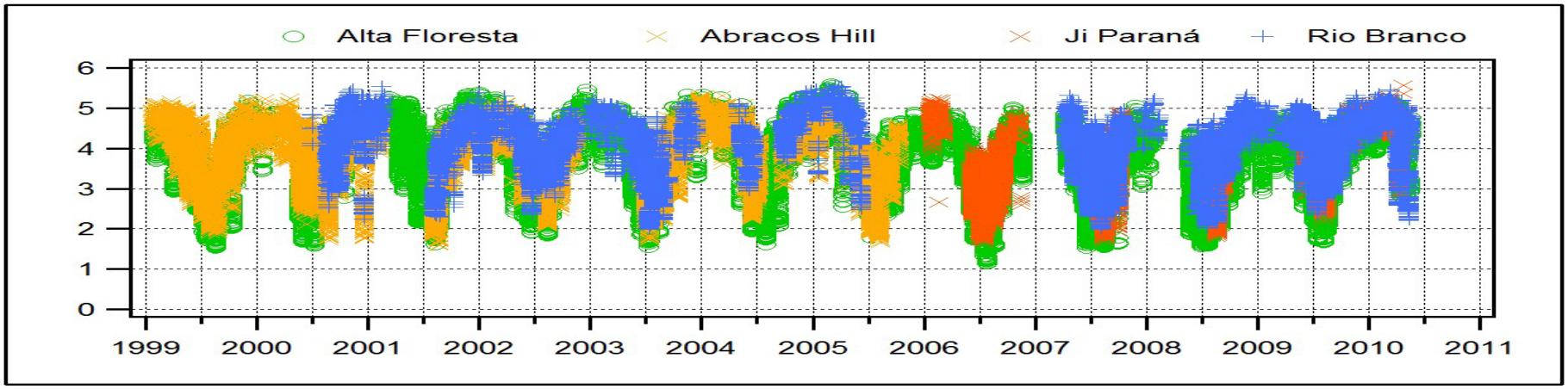
Histograms of single-scattering albedo (SSA550nm) measurements for Alta Floresta and Cuiaba´ (all years combined) partitioned into two AOD groups (moderate (AOD440nm = 0.4–0.7) plots on the left and high (AOD440nm >1.0) plots on the right).

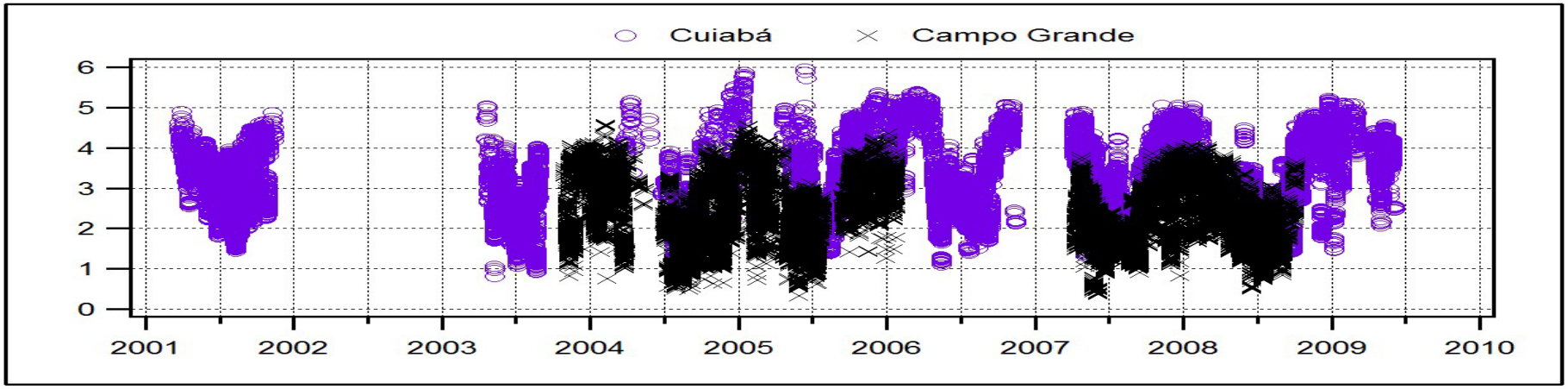

Santarém
Belterra
Balbina
$\tau_{440\,nm}$
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1993
1994
1995
1999
2000
2001
2002
2003
2004
2005


Abracos Hill
Alta Floresta
Ji Paraná
Rio Branco
$\tau_{440\,nm}$
6
5
4
3
2
1
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010

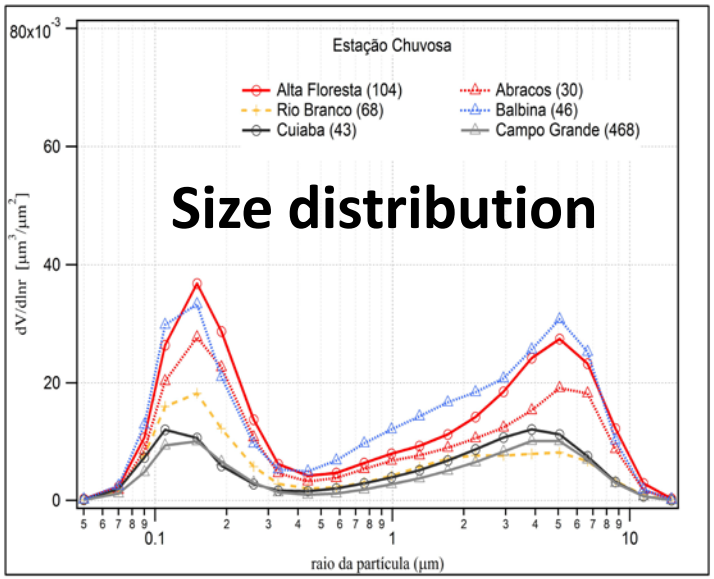

Cuiabá
Campo Grande
Aerosol Optical Depth
$\tau_{440\,nm}$
6
5
4
3
2
1
0
2001
2002
2003
2004
2005
2006
2007
2008
2009

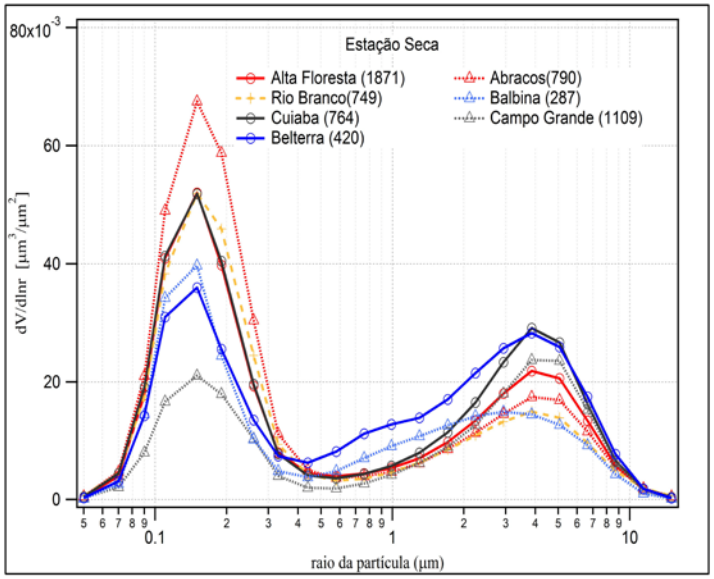

Balbina
Belterra
Water Vapor
0
1
2
3
4
5
6
1999
2000
2001
2002
2003
2004
2005
2006

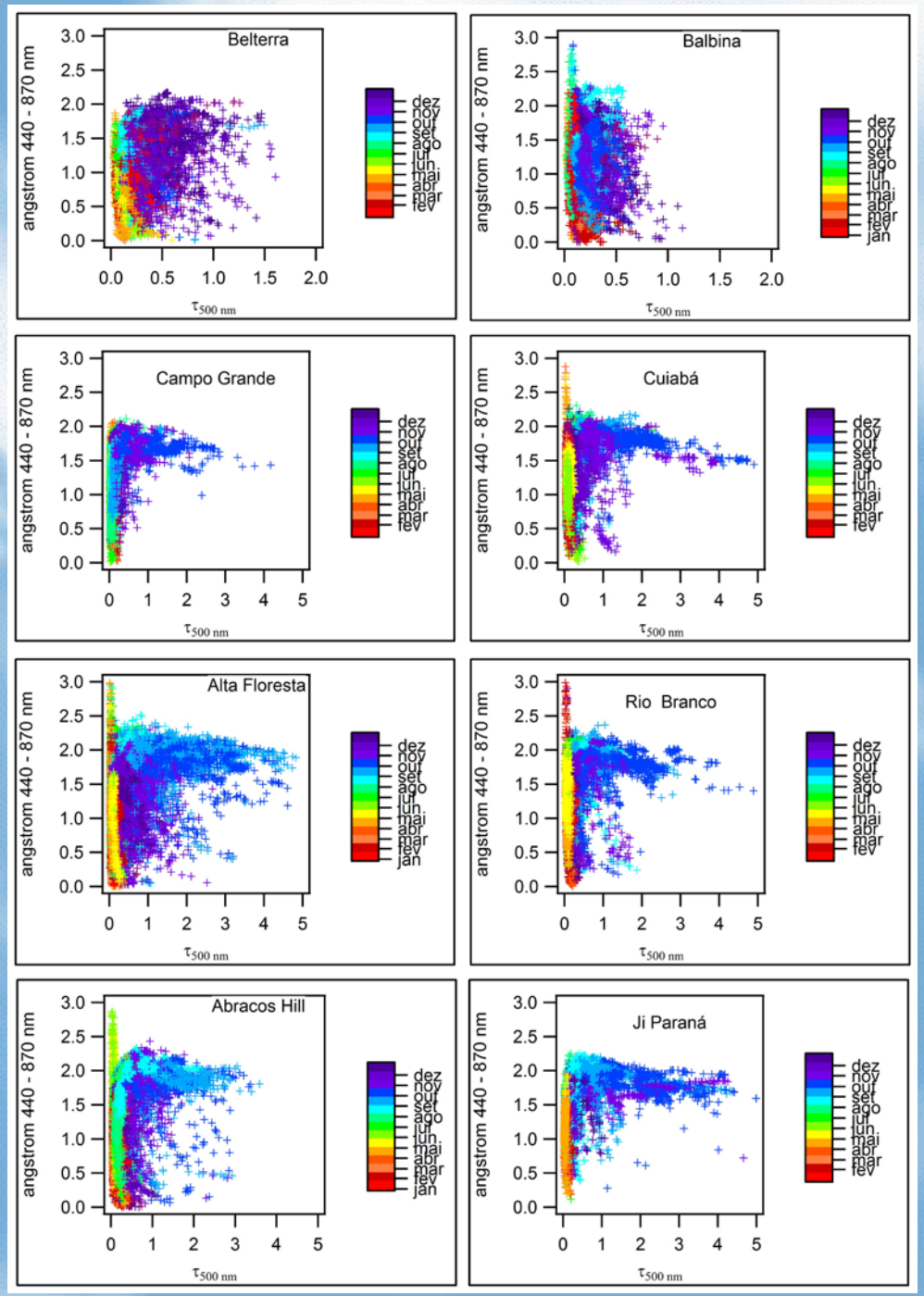

Alta Floresta
Abracos Hill
Ji Paraná
Rio Branco
0
1
2
3
4
5
6
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


Cuiabá
Campo Grande
0
1
2
3
4
5
6
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010

Angstrom coefficient as a function of AOT

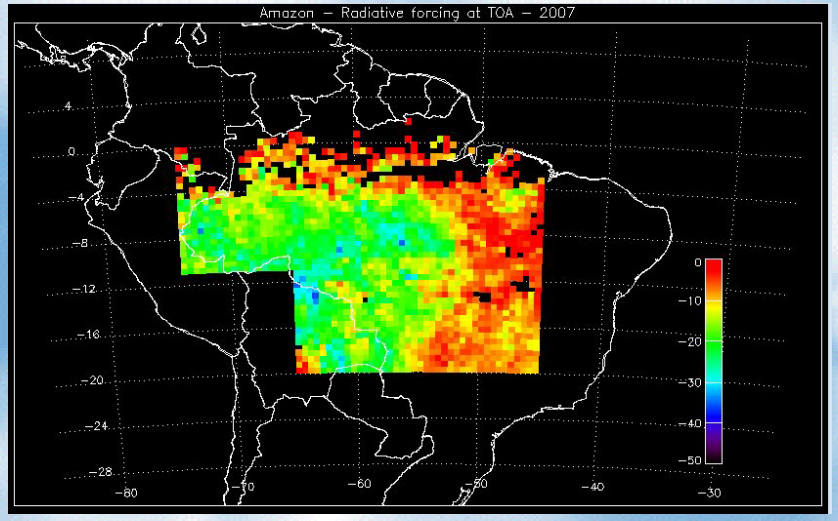


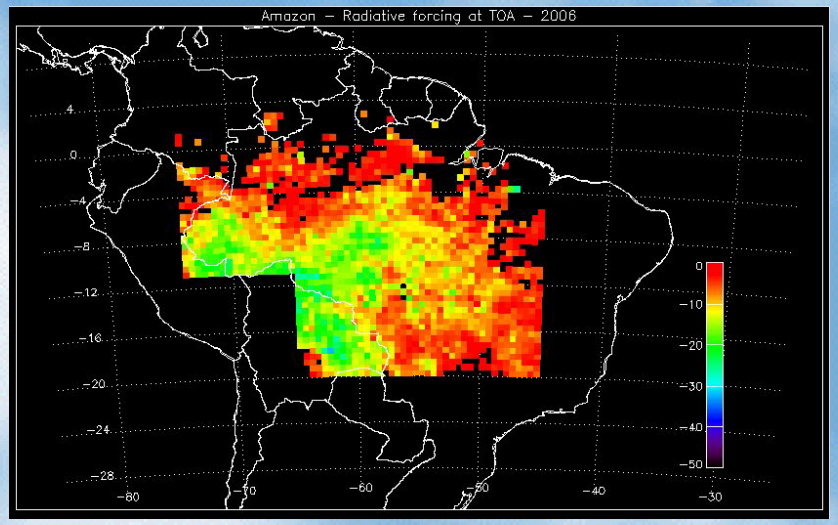


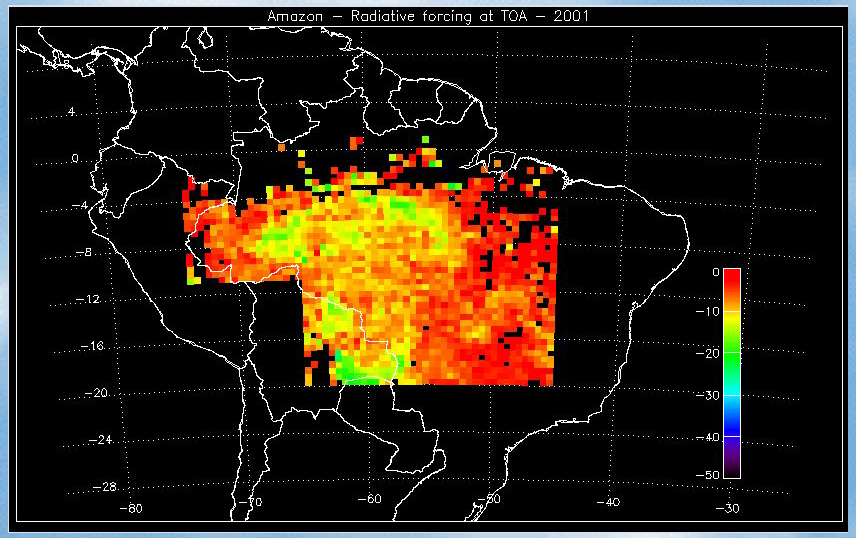


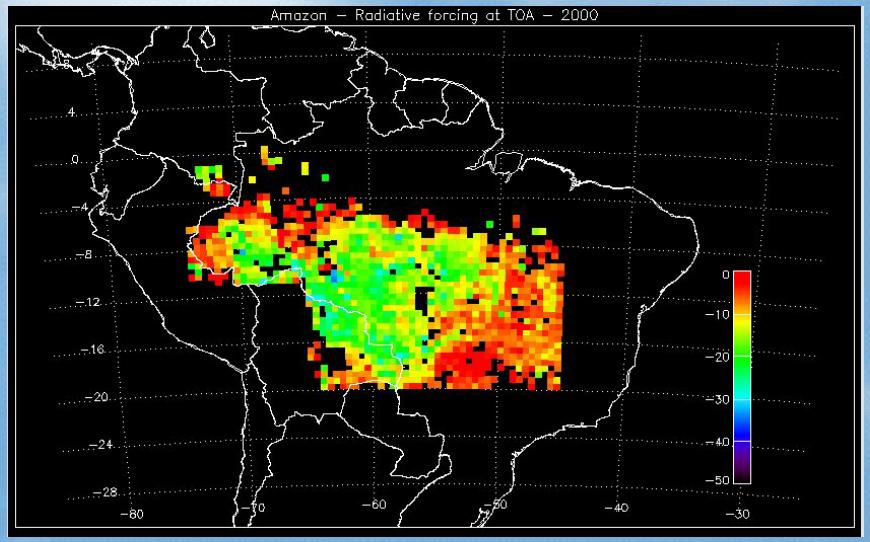
Large scale radiative forcing in Amazonia from 2000 to 2007

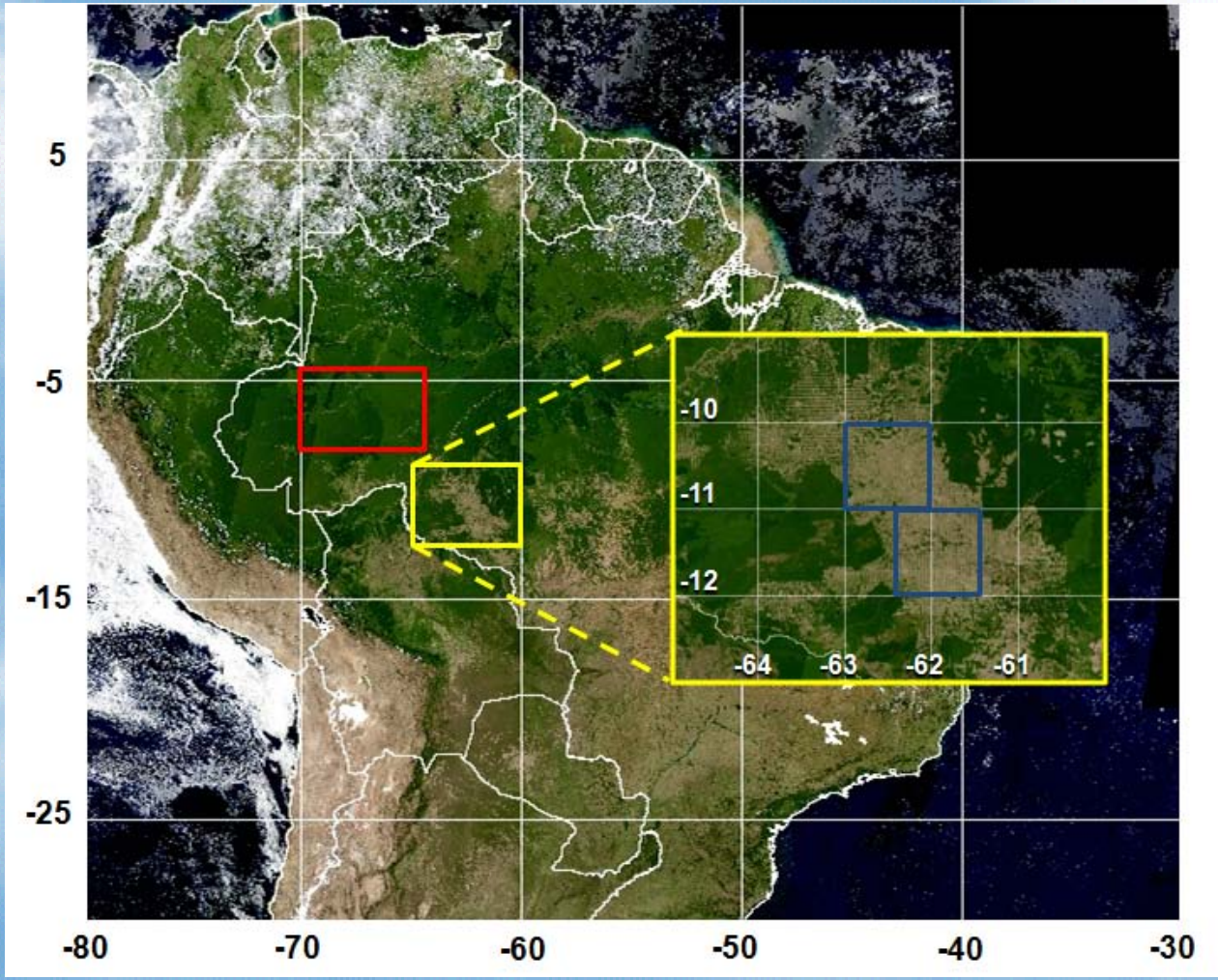
CERES *(Clouds and the Earth's Radiant Energy System) and MODIS*











Land-use change radiative forcing. Forested areas are selected in red and deforested areas are selected in blue.

Mean Diurnal Radiative Forcing due to changes in surface albedo: -8.0 ± 0.9 W/m²

Mean Diurnal Aerosol Forcing Efficiency:
Forest: -22.5 + 1.4 W/m²
Cerrado: -16.6 ± 1.7 W/m²

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.

	Forest		Cerrado	
Year	TOA Flux for AOD=0 (W/m^2)	Forcing efficiency ($W/m^2/AOD$)	TOA Flux for AOD=0 (W/m^2)	Forcing efficiency ($W/m^2/AOD$)
2000	145.76 ± 0.09	47.31 ± 0.27	159.26 ± 0.13	23.20 ± 0.54
2001	144.41 ± 0.06	36.25 ± 0.23	158.20 ± 0.09	18.64 ± 0.50
2002	145.26 ± 0.07	33.85 ± 0.15	156.35 ± 0.09	22.93 ± 0.31
2003	144.39 ± 0.07	38.90 ± 0.17	158.72 ± 0.10	21.13 ± 0.47
2004	150.11 ± 0.73	31.88 ± 1.10	178.48 ± 0.25	12.24 ± 1.06
2005	148.48 ± 0.07	32.95 ± 0.11	160.97 ± 0.08	23.61 ± 0.18
2006	148.18 ± 0.05	35.64 ± 0.12	159.99 ± 0.10	25.06 ± 0.30
2007	148.03 ± 0.06	32.33 ± 0.09	167.51 ± 0.08	19.91 ± 0.19
2008	150.87 ± 0.06	34.82 ± 0.18	165.57 ± 0.11	15.19 ± 0.58
2009	149.96 ± 0.06	45.63 ± 0.53	155.18 ± 0.12	29.16 ± 1.58
Average*	**147.3 ± 0.8**	**-37.5 ± 1.8**	**160.2 ± 1.3**	**-22.1 ± 1.3**

Yearly averages of the instantaneous flux for clean conditions and forcing efficiency for forest and cerrado regions

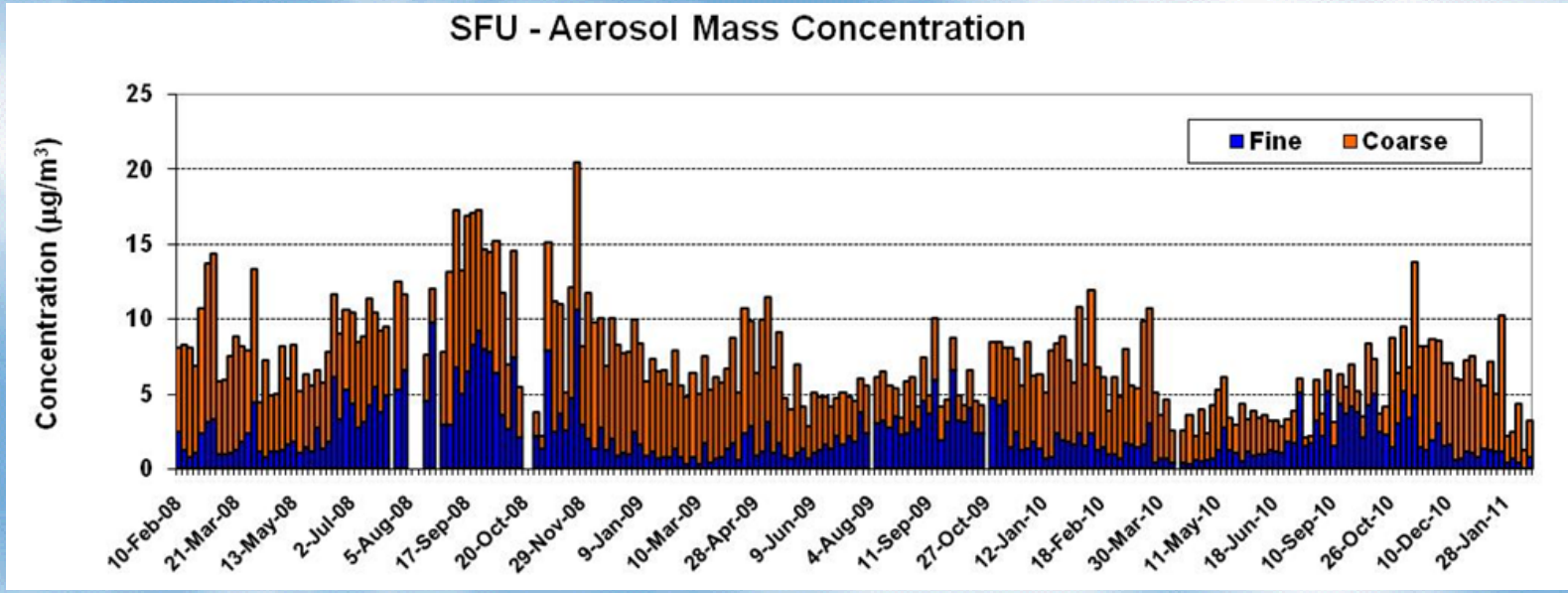
AEROCLIMA: Direct and indirect effects of aerosols on climate in Amazonia and Pantanal

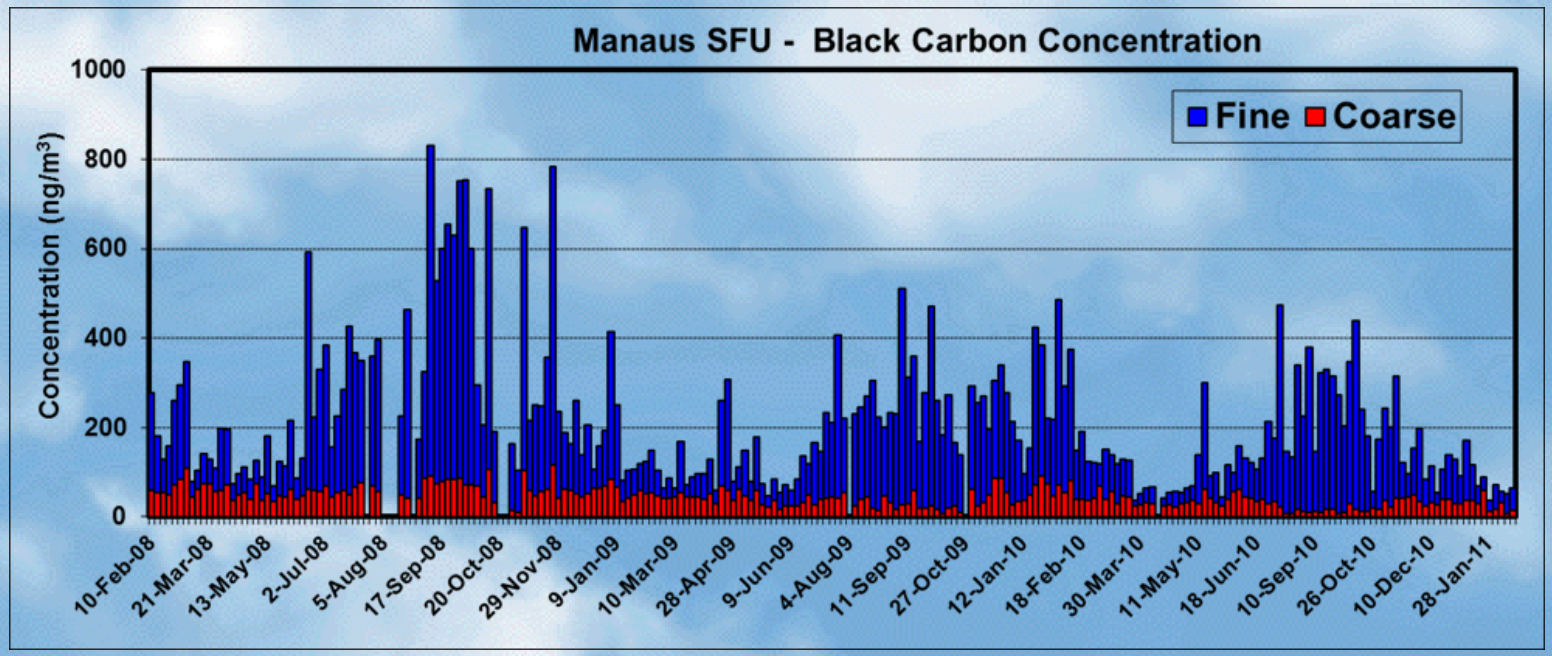
Objectives: Investigate the connection between the concentration and physico-chemical properties of biogenic and biomass burning aerosol particles in the radiation balance and climate, including effects on cloud development and microphysics for two important regions in South America: Amazonia and Pantanal.

Scientific Strategy: AEROCLIMA has 4 integrated components:

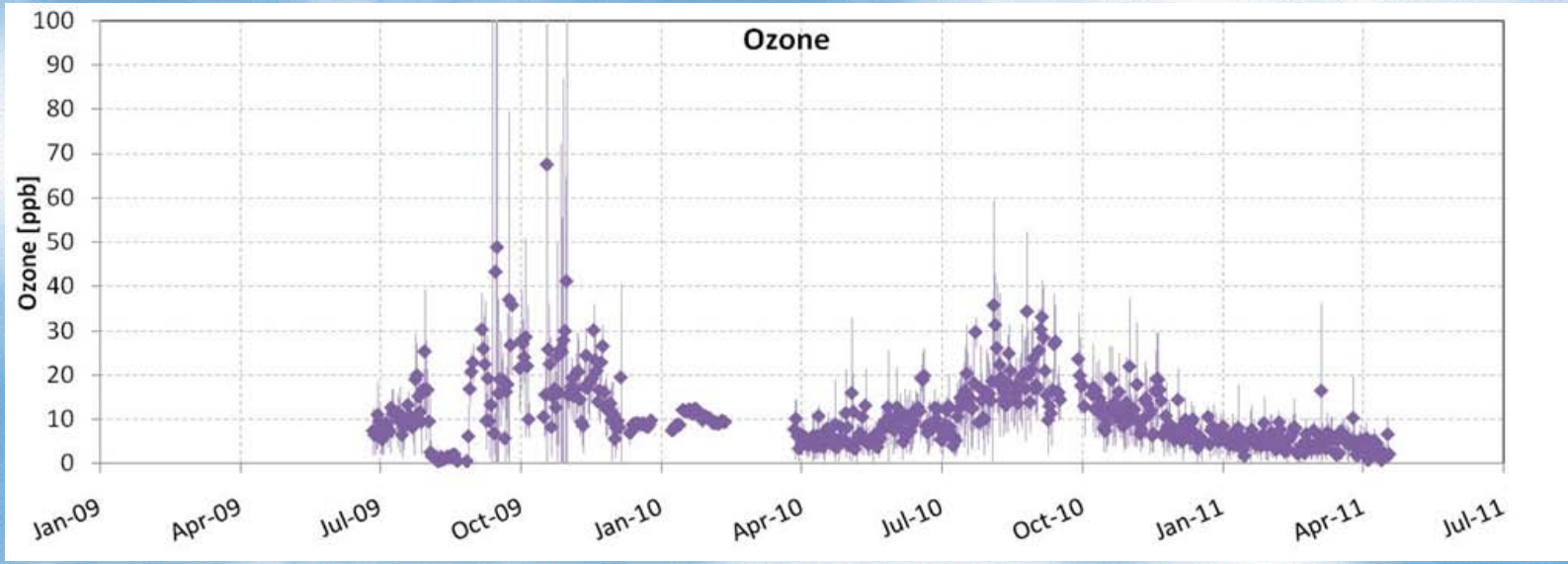
1) Observations of aerosols, clouds, trace gases and radiation (*Paulo Artaxo*)
2) Remote sensing of aerosols and clouds (*Alexandre Correia*)
3) Modeling of clouds dynamics and evolution and precipitation (*Maria Assunção F. Silva Dias*)
4) Large scale atmospheric transport modeling (*Henrique Barbosa,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

Manaus Fine and coarse mode aerosol mass and black carbon

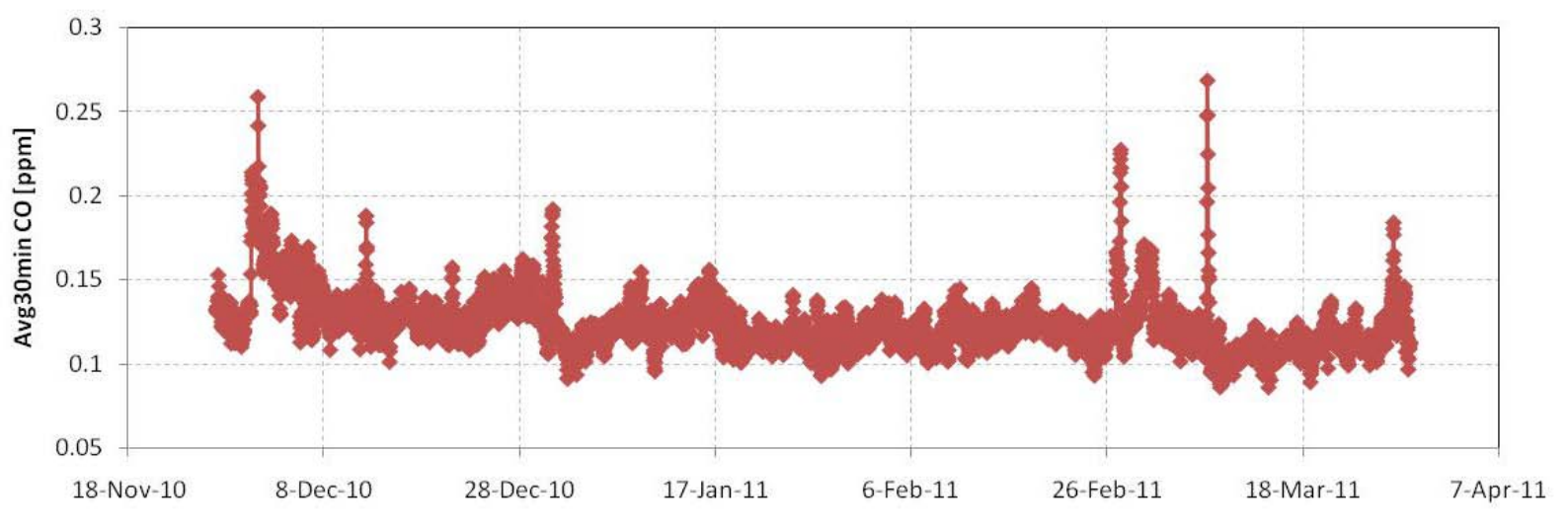




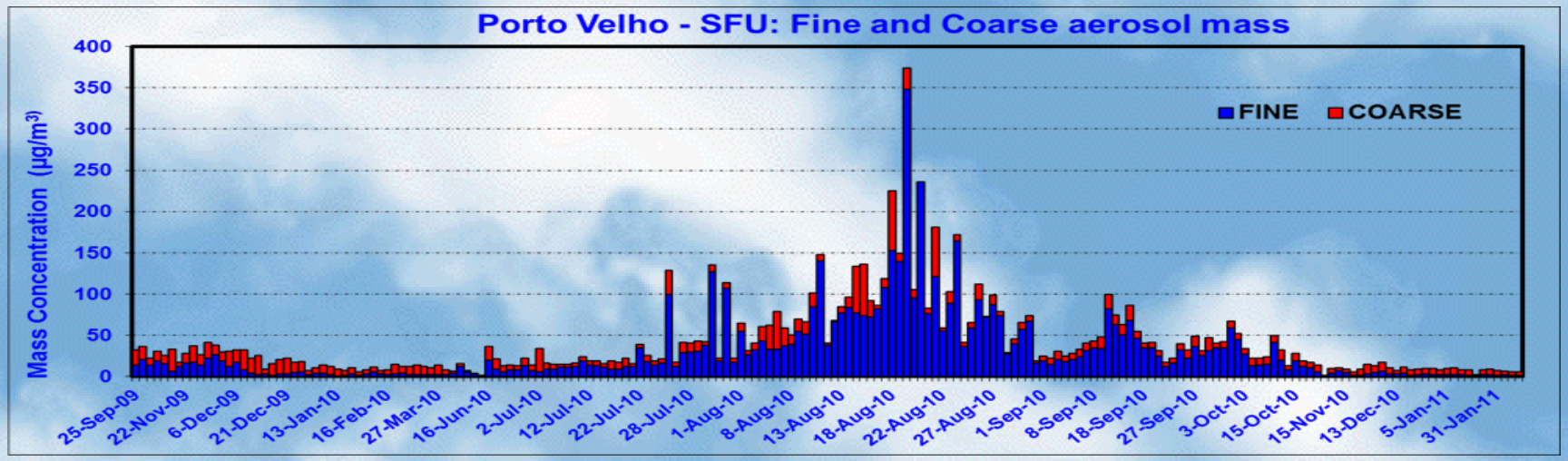
Manaus time series of ozone concentrations

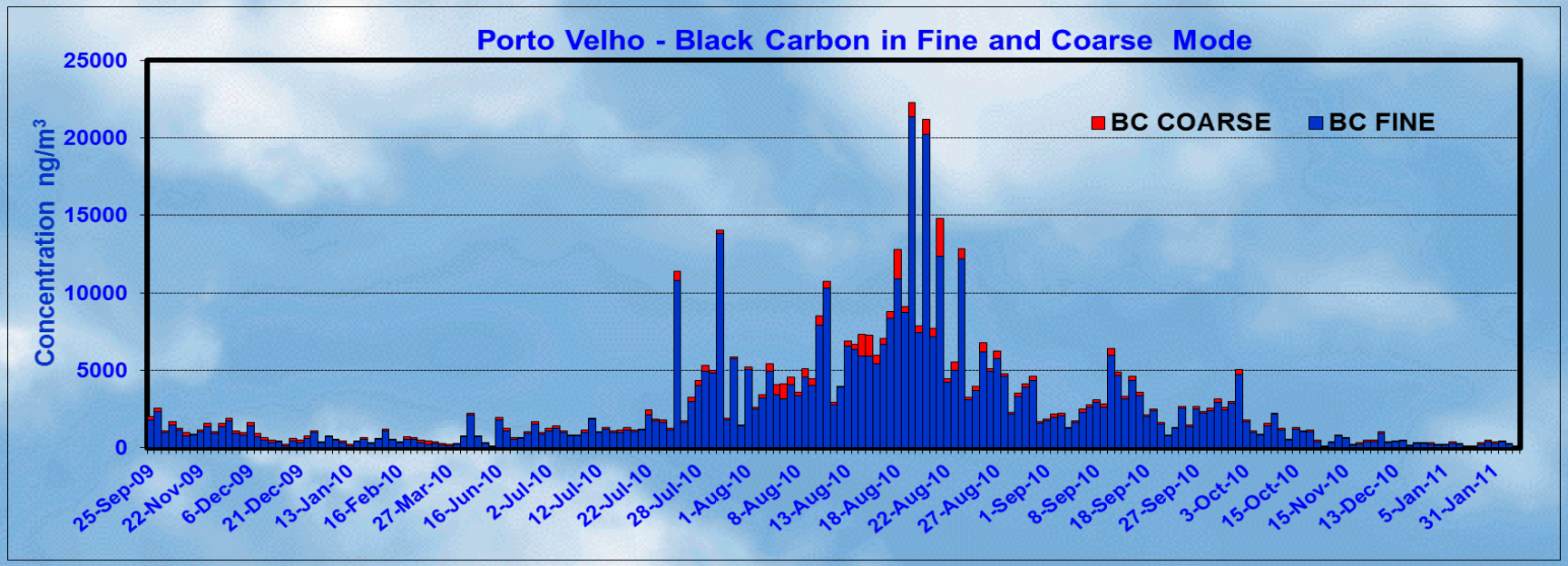


Manaus time series of CO concentrations

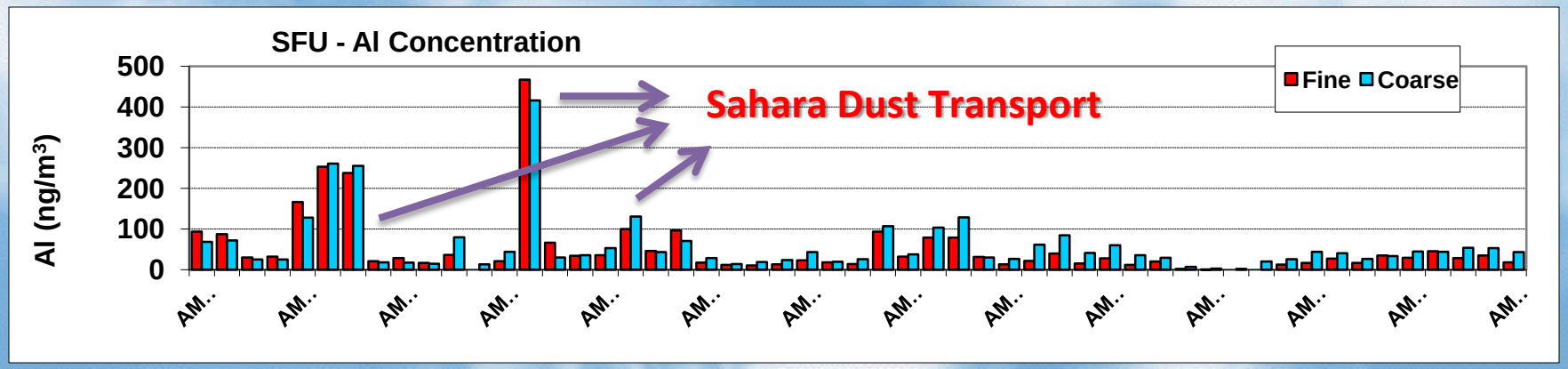


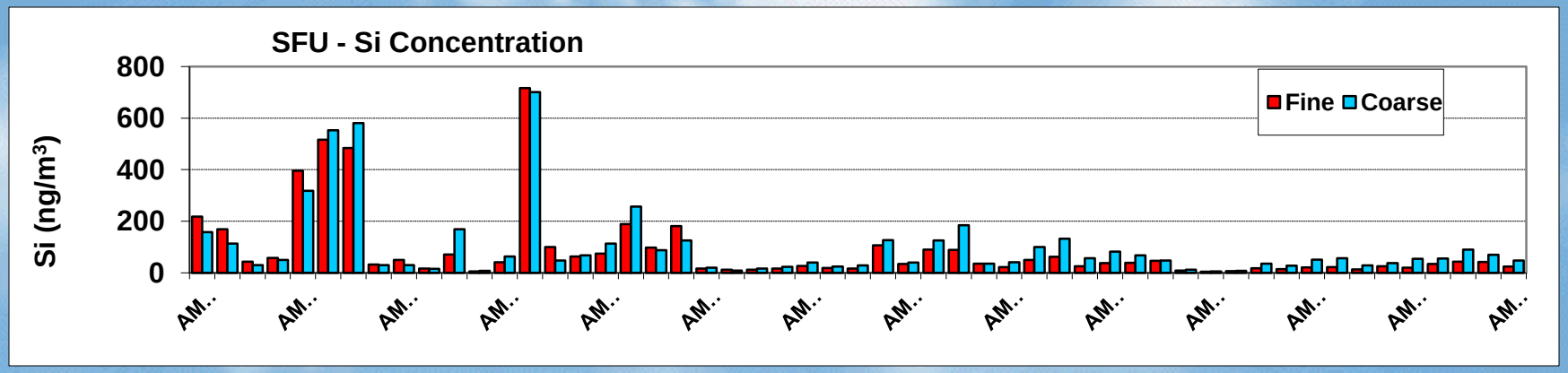
Porto Velho aerosol: $PM_{2.5}$, PM_{10} and BC 2009 - 2010

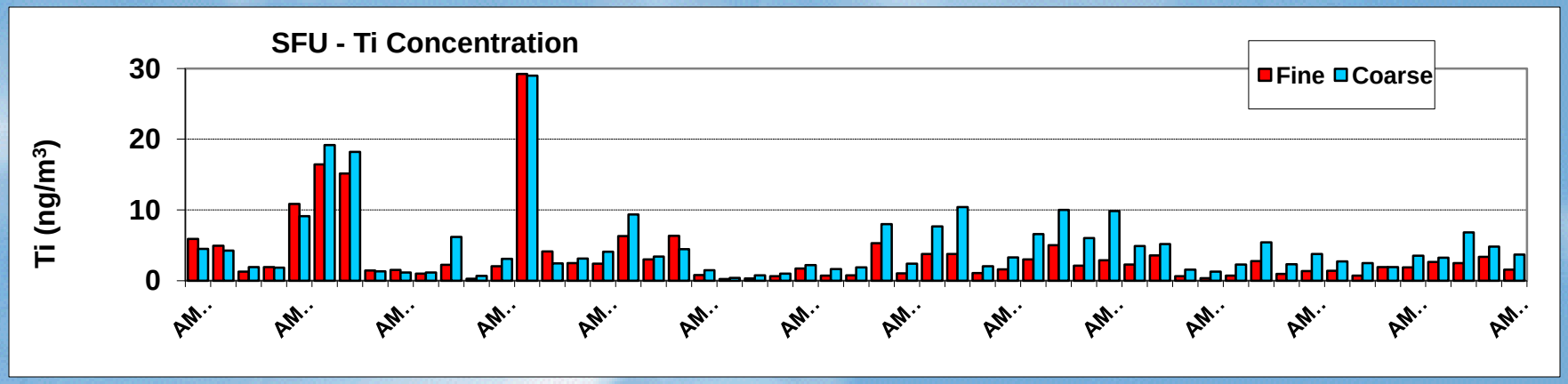




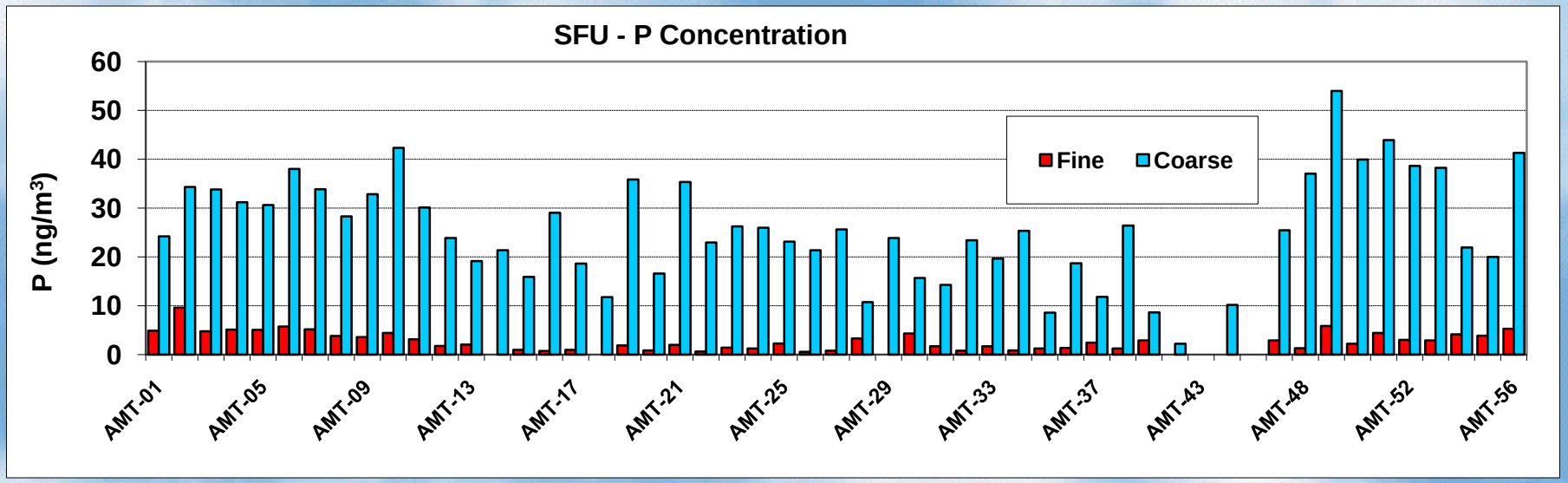
Al, Si and Ti elemental Ŏoncentration for fine and coarse mode aerosols Feb. to September

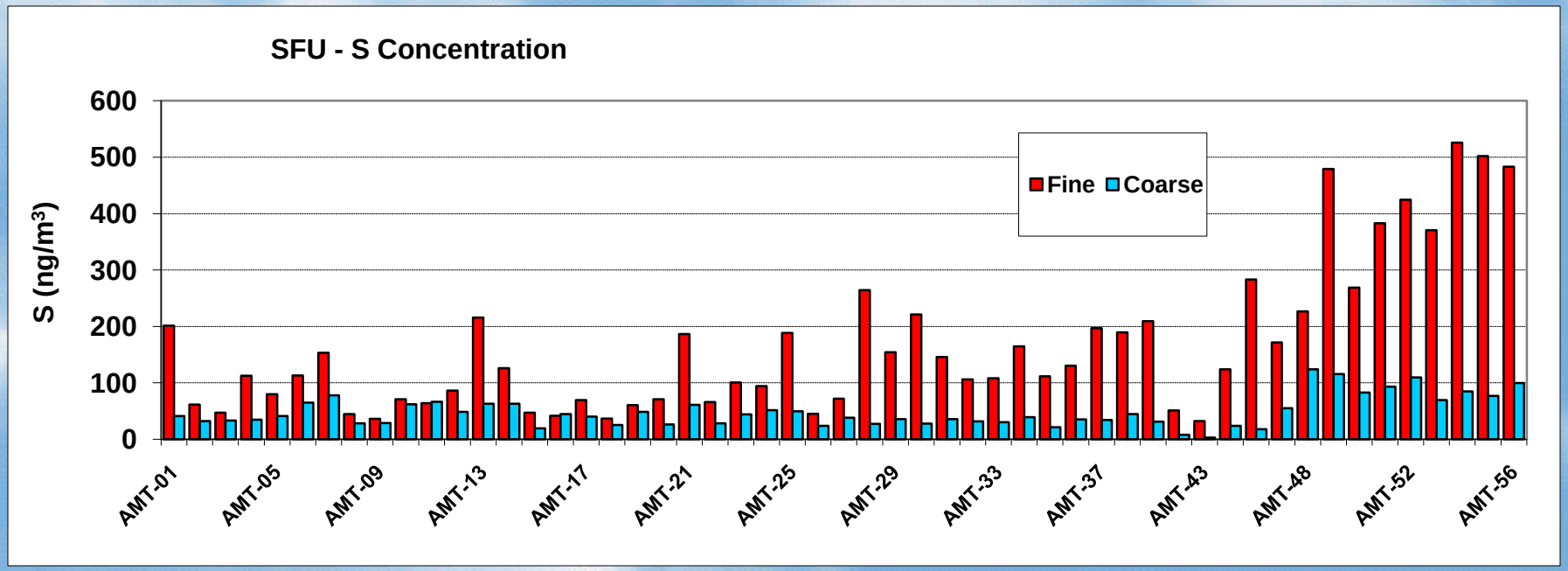






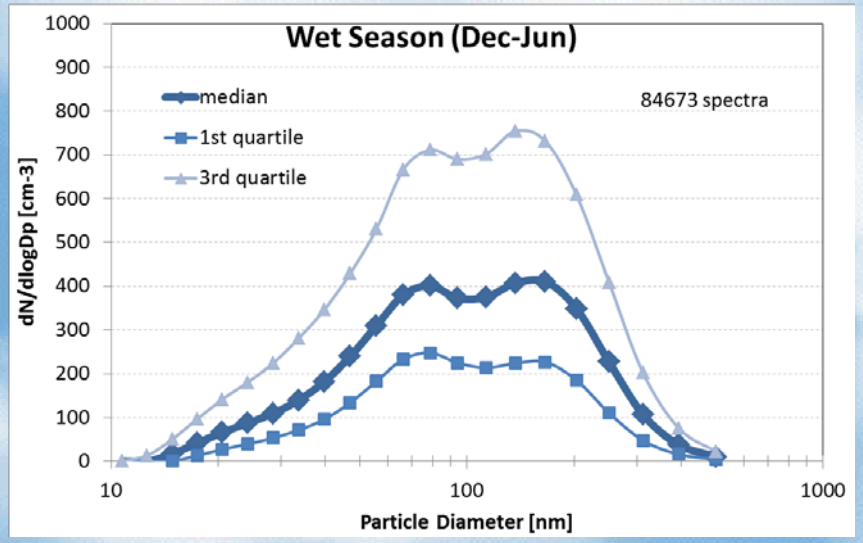
Phosphorus and Sulfur elemental concentrations for fine and coarse mode aerosols



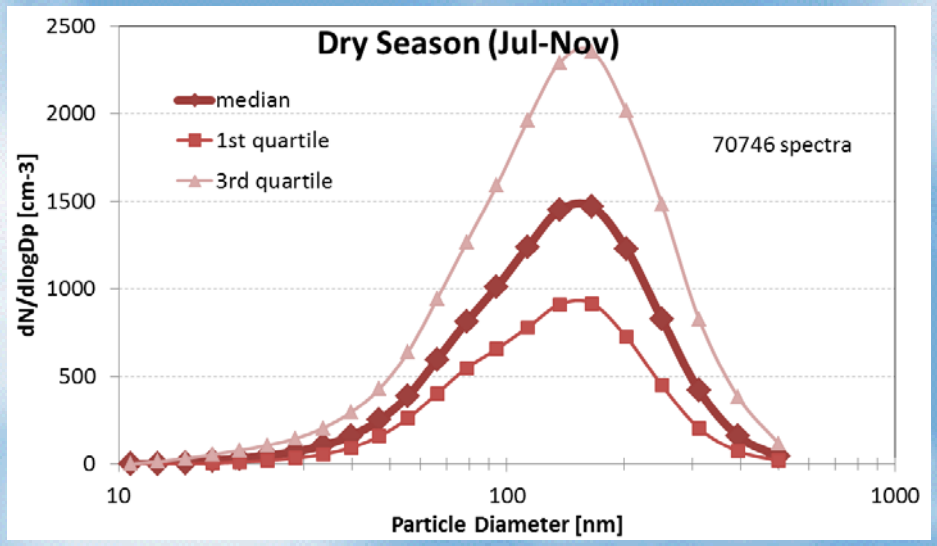


Amazonian aerosol size distributions 2008-2011

Wet season



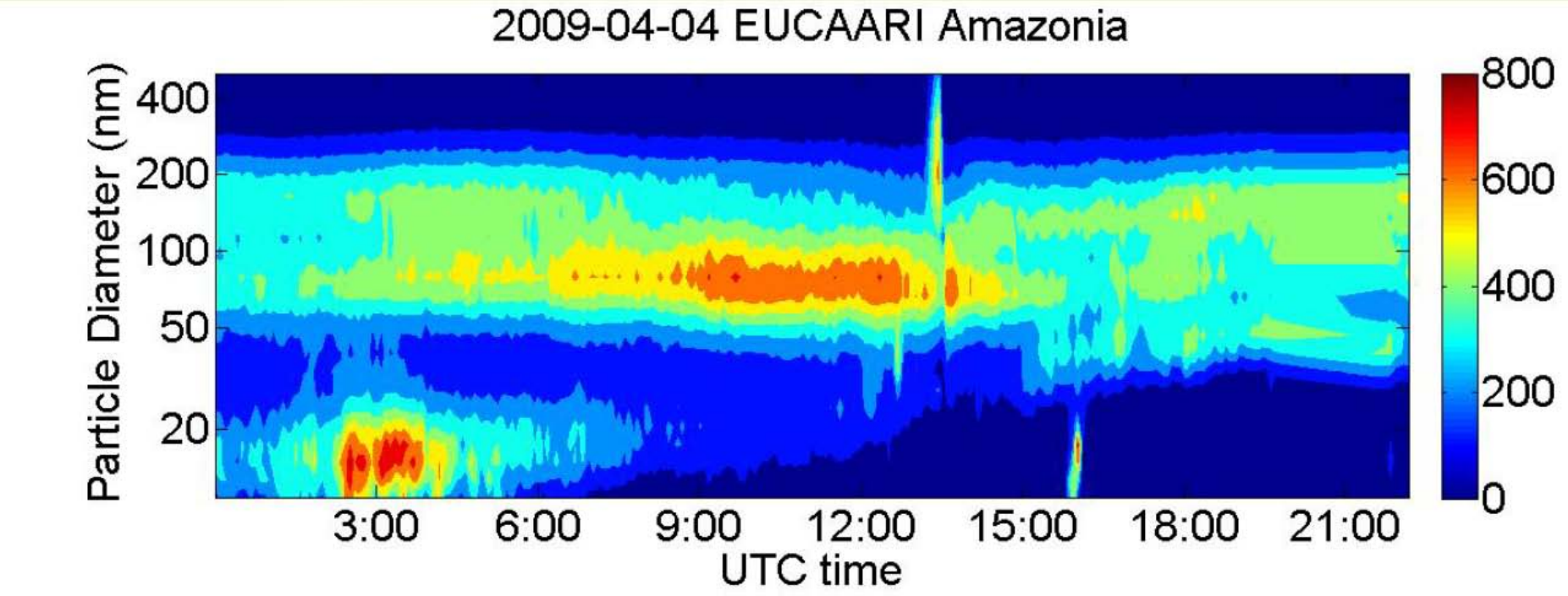
Dry season



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

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

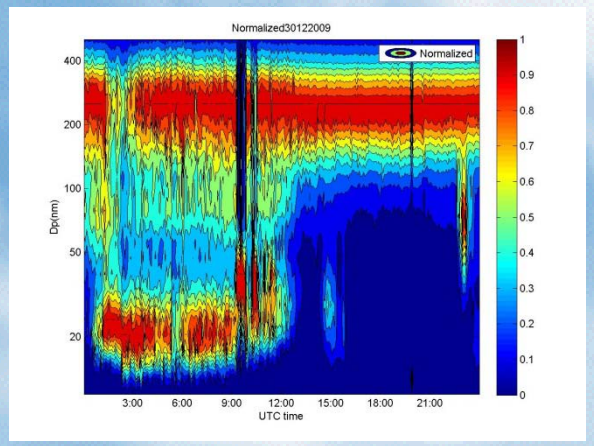


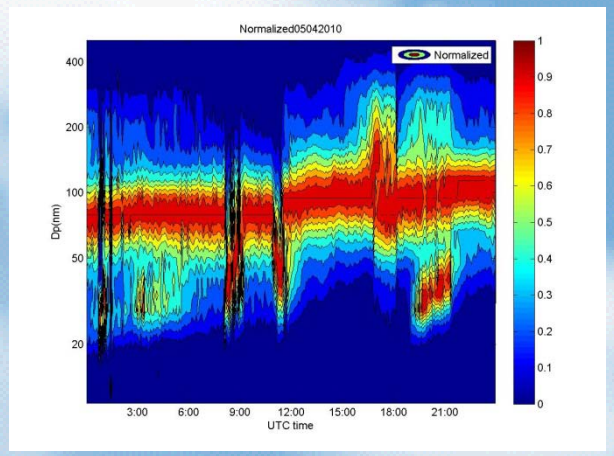
Aerosol size distributions measured in 2009 Apr 4th. There was a burst of ultrafine particles from 2:00 to 4:00 UTC time.

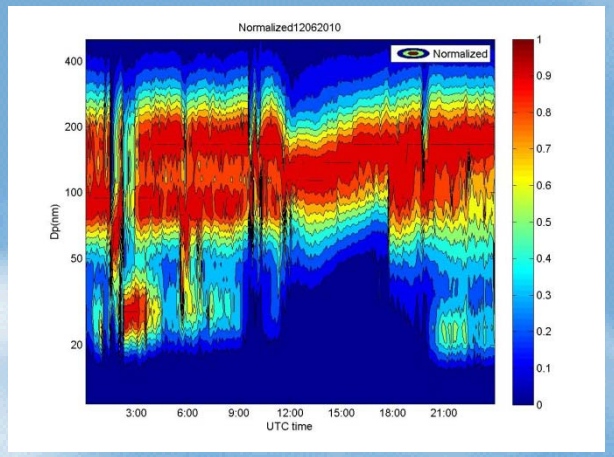
New particle formation and subsequent growth was seldom observed along two years of measurements. Nevertheless, in 70% of the days, bursts of particles with diameters in the range 10-40nm were detected. The events usually lasted from 20 to 120min, and the subsequent growth to larger sizes was not always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

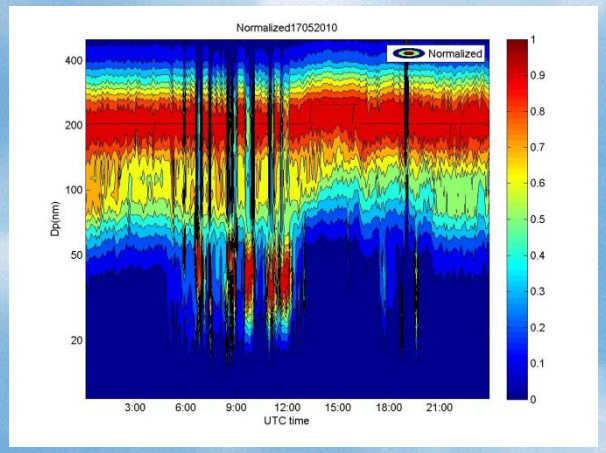
Particle production at about 20 nm

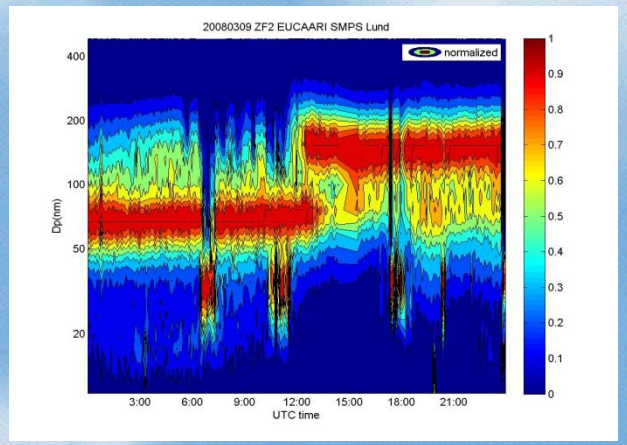
Which biological or atmospheric process is responsible for this new particle formation?

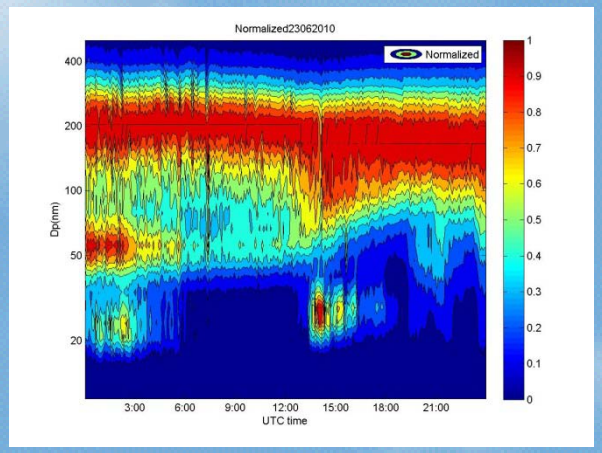




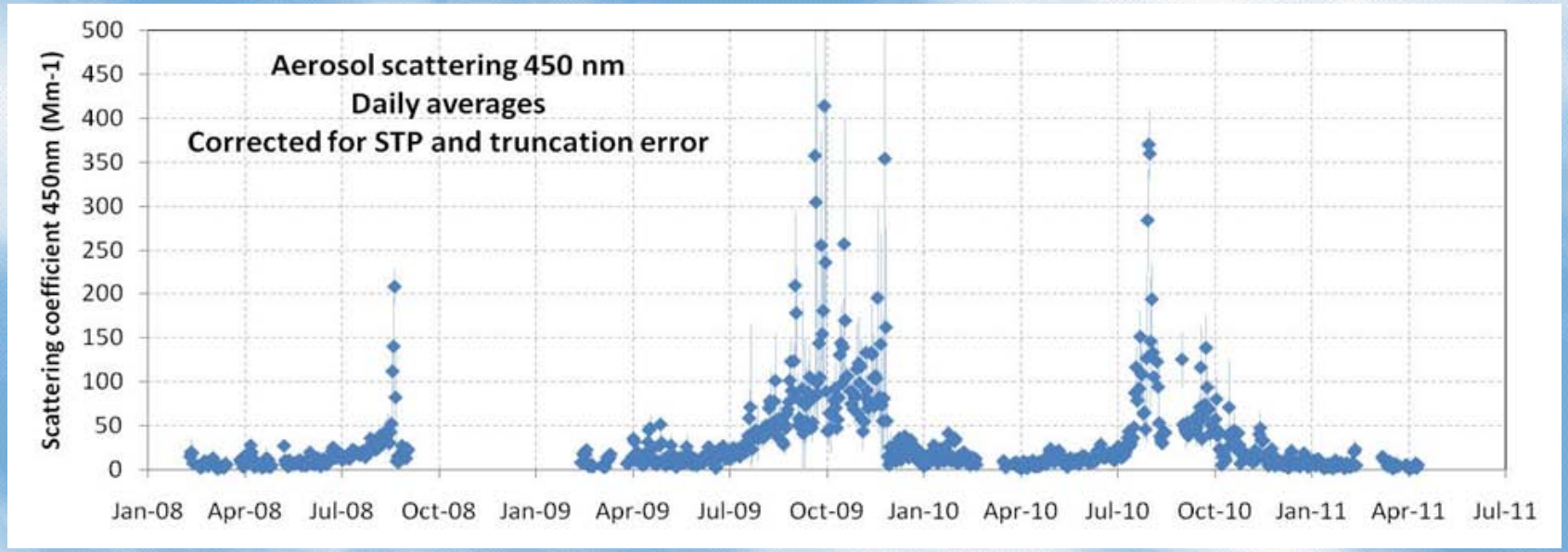




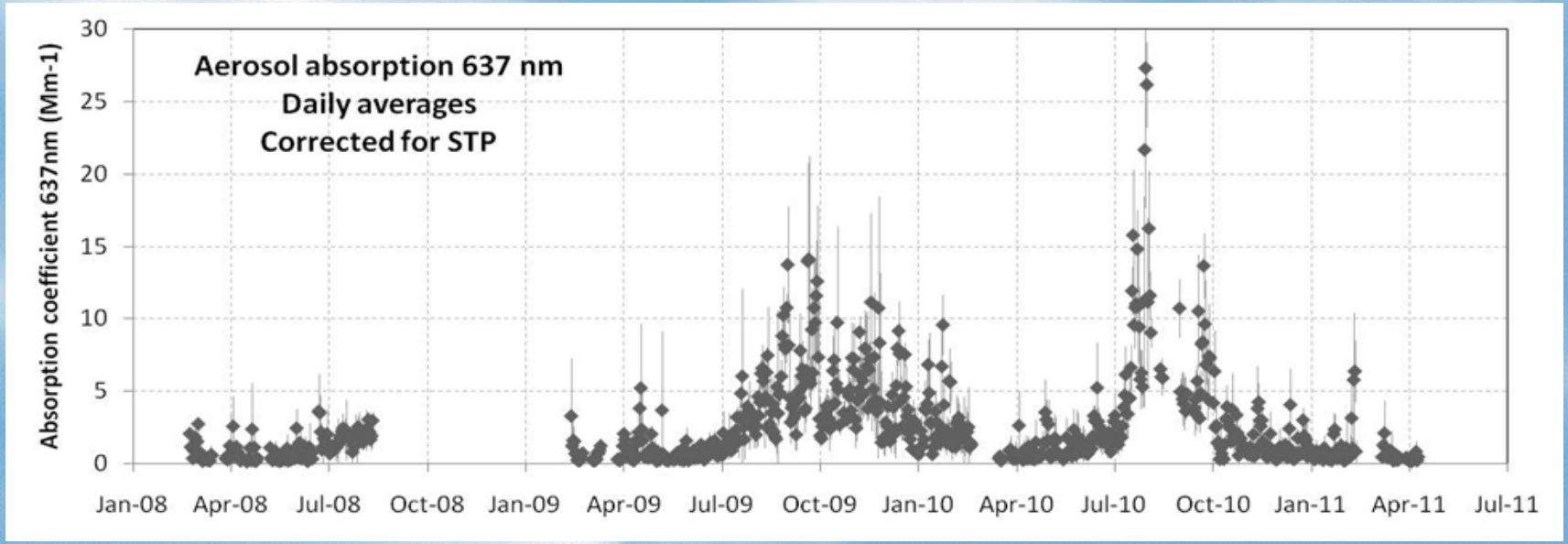




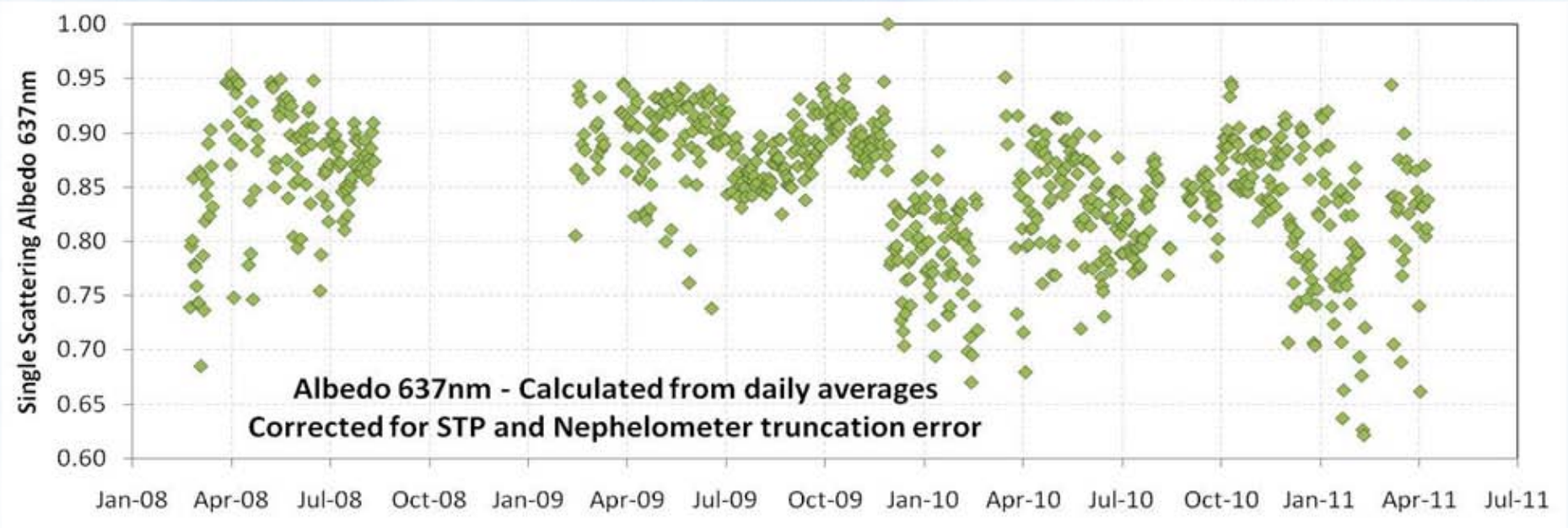
Manaus aerosol light scattering TSI Nephelometer 2008-2011



Manaus aerosol light absorption MAAP 2008-2011



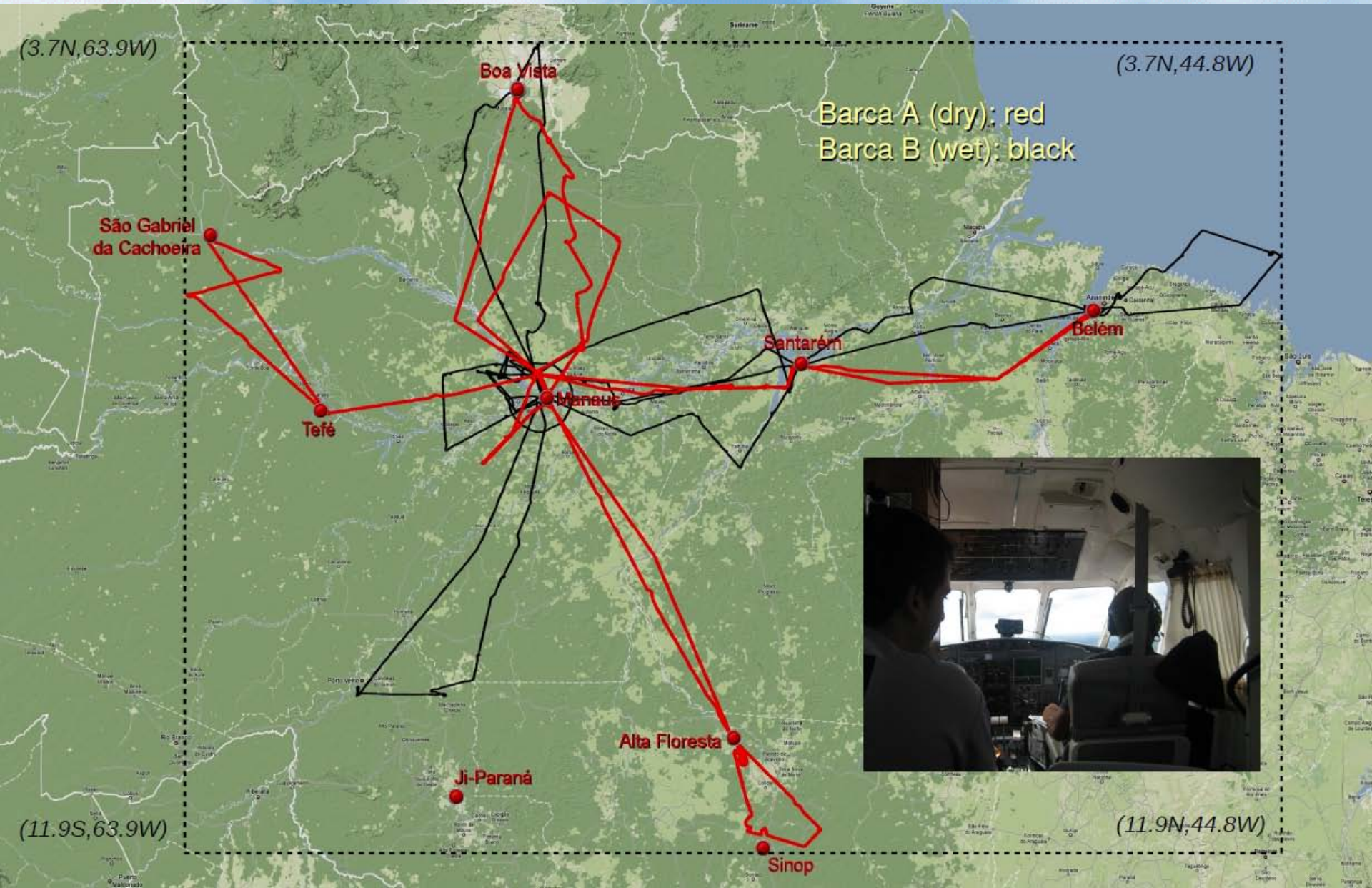
Manaus aerosol single scattering albedo at 637 nm 2008-2011



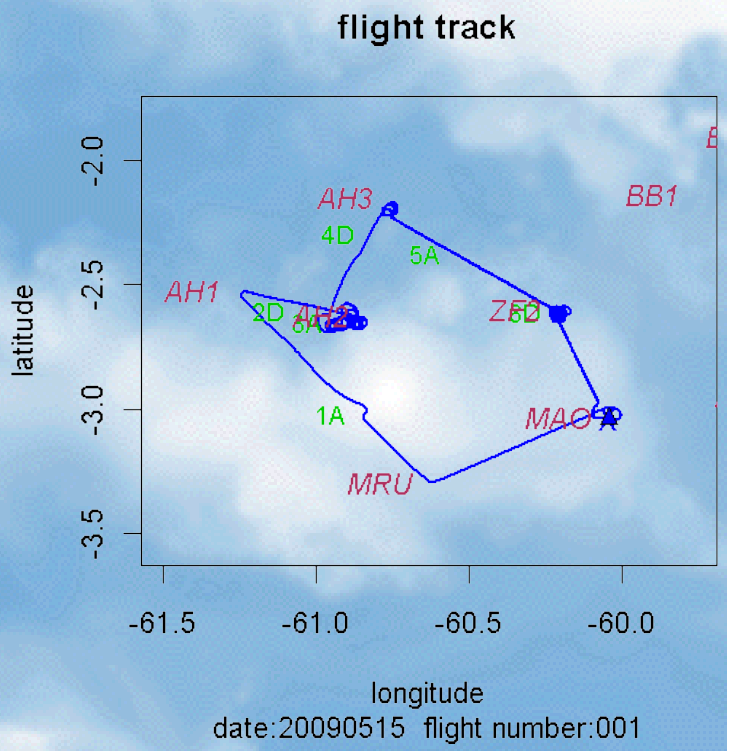
	Espalhamento 450nm [Mm^{-1}]			Expoente de Angstrom			Absorção 637 nm [Mm^{-1}]			Albedo simples 637 nm		
	total	dry	Wet	total	dry	Wet	total	dry	Wet	total	Dry	Wet
Média	34	58	14	1.8	1.9	1.6	2.5	4.1	0.9	0.86	0.86	0.86
Desvio padrão	47	58	22	0.4	0.2	0.4	3.1	3.8	0.8	0.05	0.04	0.06
Mediana	17	40	10	1.9	2.0	1.7	1.4	2.9	0.7	0.87	0.87	0.88
Quartil 25%	9	20	7	1.5	1.8	1.3	0.6	1.7	0.4	0.84	0.84	0.83
Quartil 75%	39	76	15	2.1	2.1	1.9	3.0	5.0	1.2	0.90	0.89	0.91
% cobertura de dados	73	76	72	73	76	72	58	64	54	58	64	54
# dias com observações	784	347	437	784	347	437	613	293	320	613	293	320

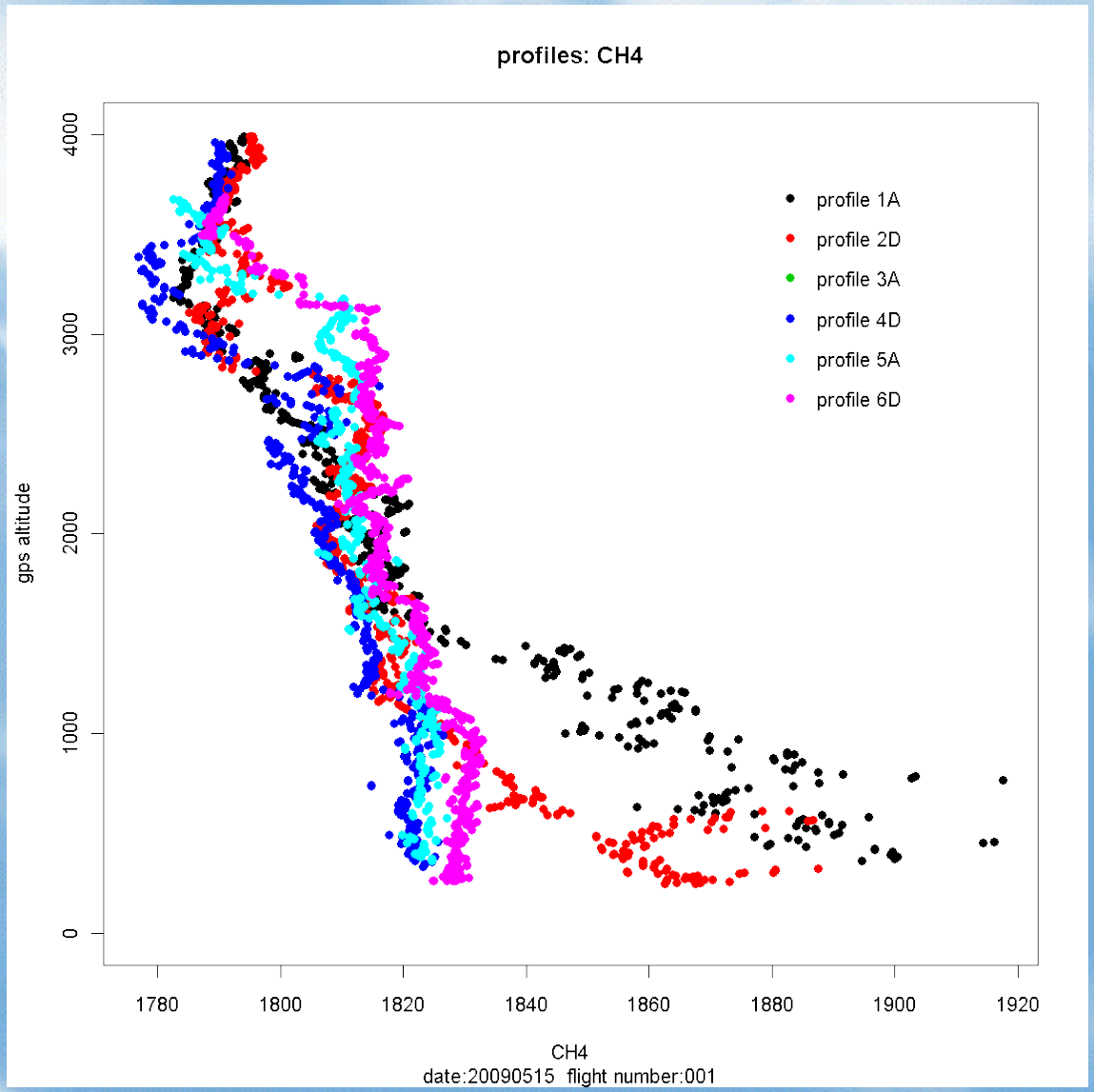
Summary of Aerosol Optical Properties in Manaus Feb. 2008 to Jan. 2011

Balanço Regional de Carbono na Amazonia BARCA



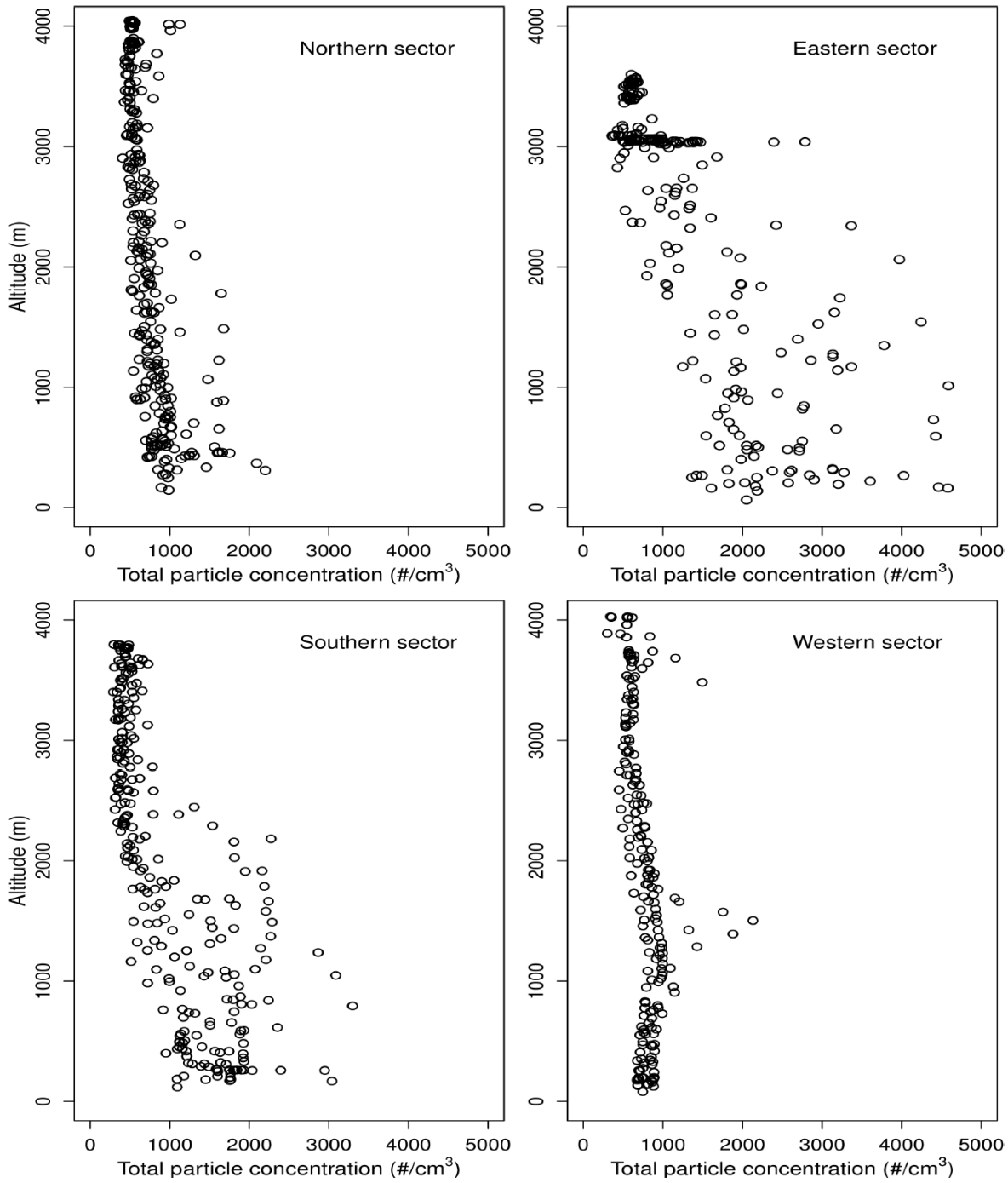
Anavilhanas survey spotted a strong methane source in the Amazon



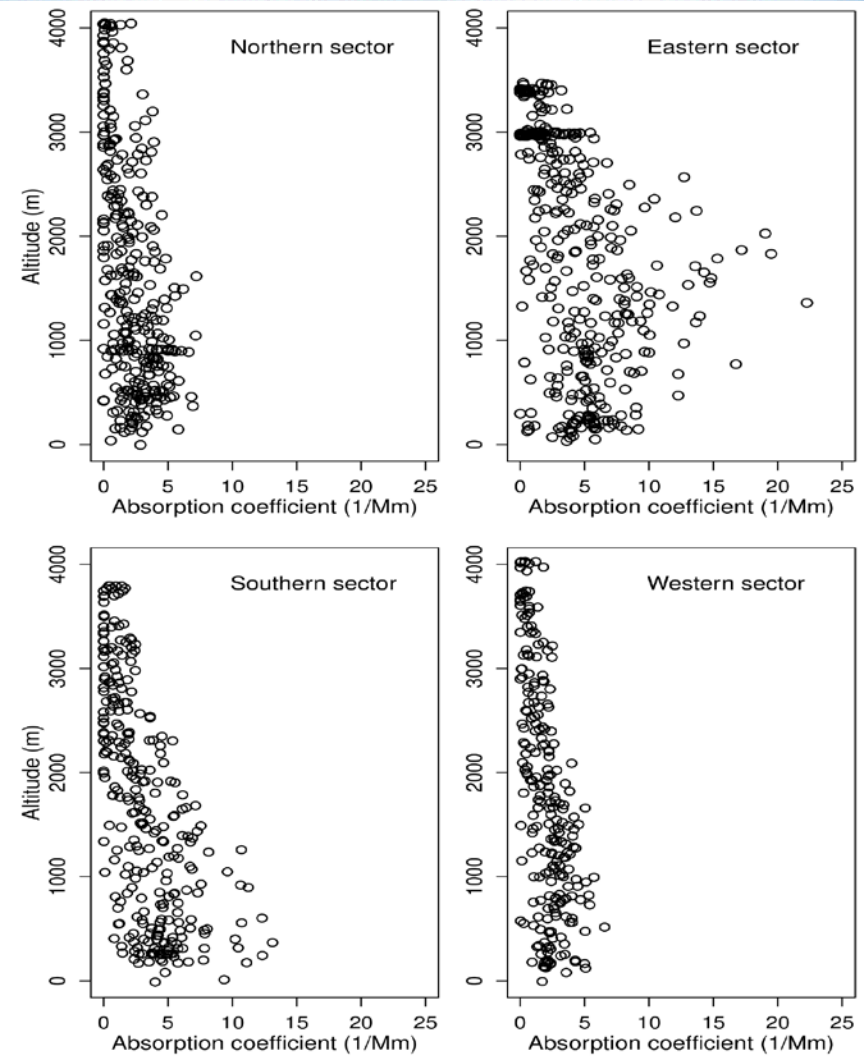


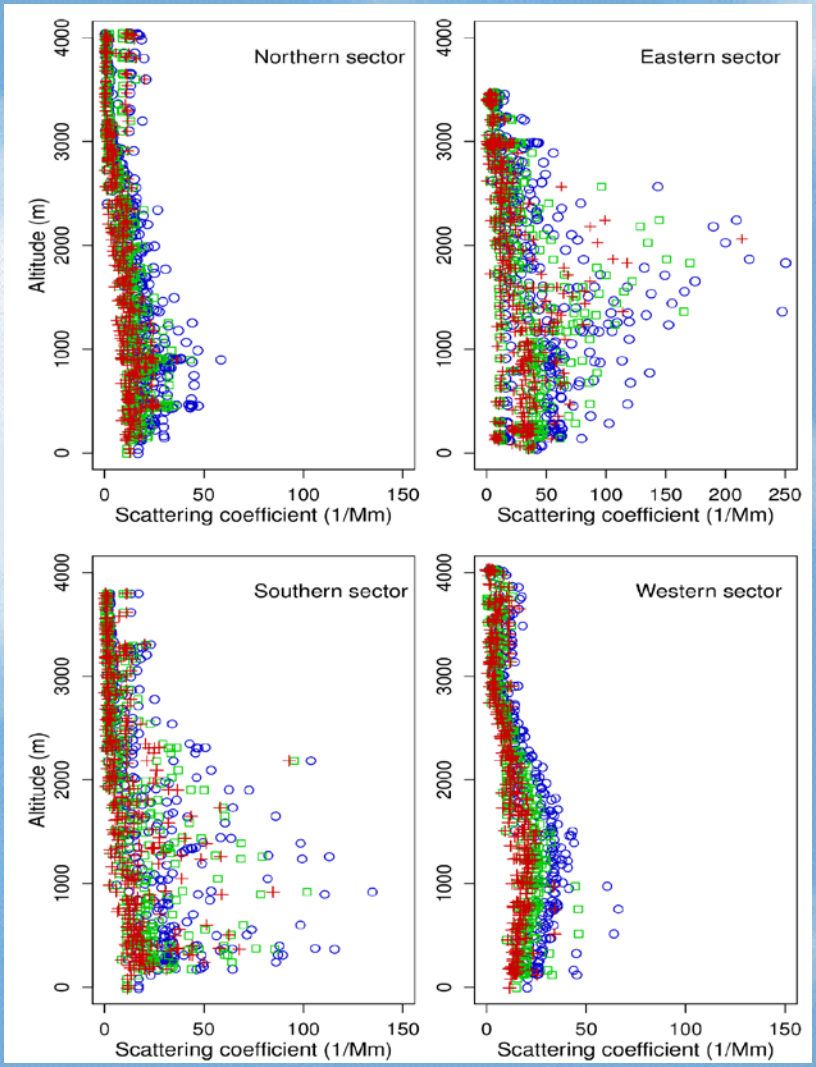
Vertical profile of CN particles (TSI 3010). Very good vertical mixing all the way to 4 Km.

Measurements reported for four sectors around Manaus.



Vertical profile of absorption and scattering coefficients. Very good vertical mixing all the way to 4 Km.

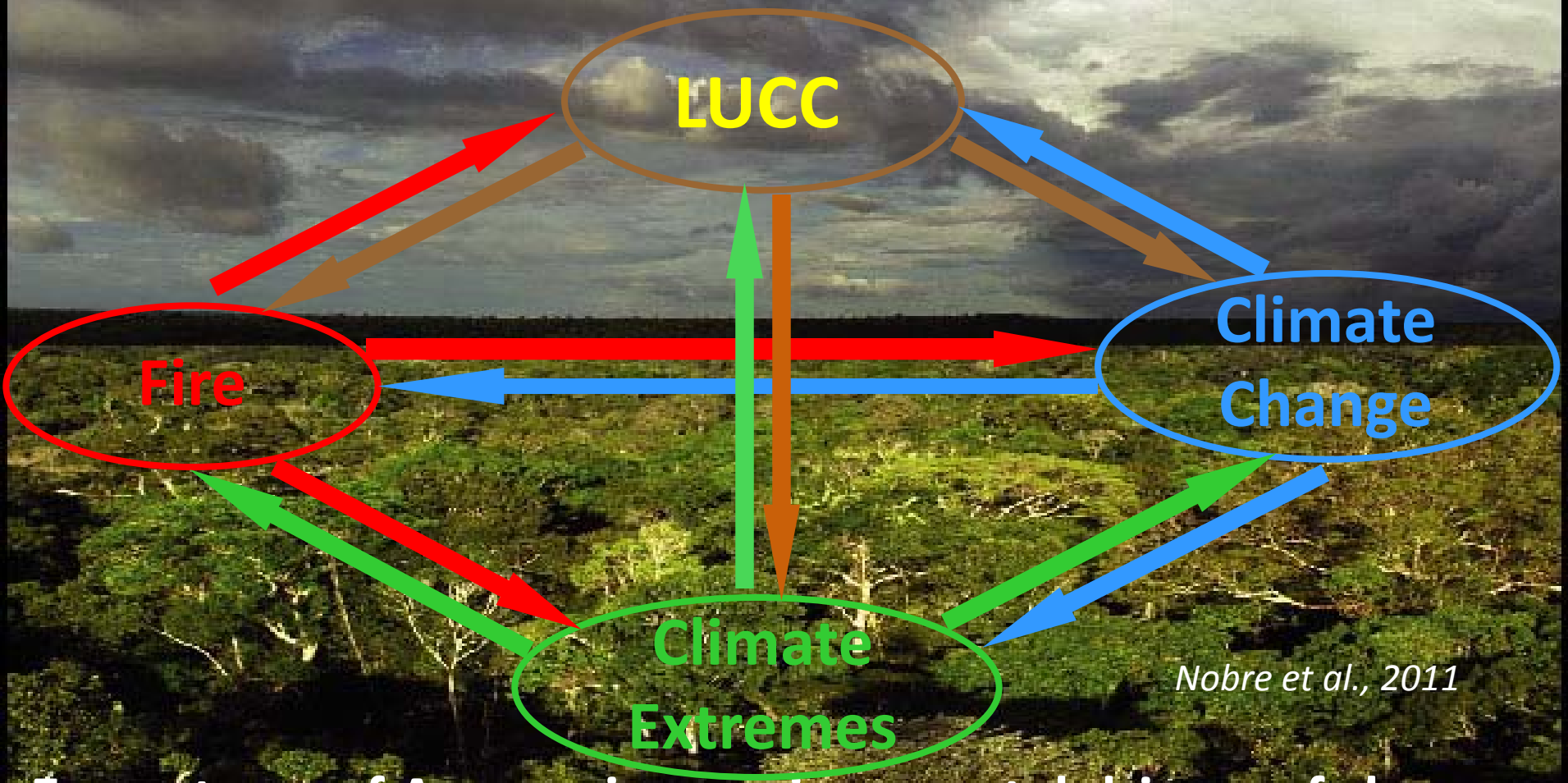




Kenia Wiedmand et al., to be submitted

Effects of climate change in Amazonia

Complex Earth System Models are needed to study
all these interacting and simultaneous drivers

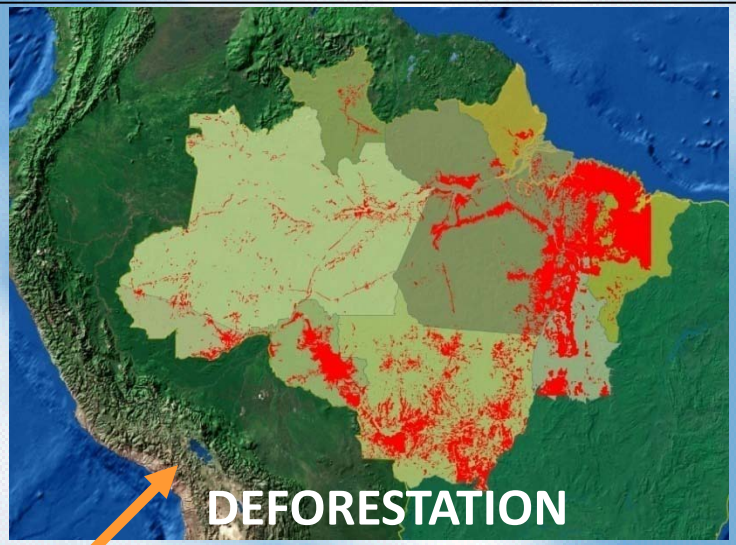


Nobre et al., 2011

Ecosystems of Amazonia - environmental drivers of change

Warming of 0.8°C in Amazonia ; IPCC AR4: 3°C to > 5°C in 2100!

Total deforested area (clear-cutting) is 730,000 km^2 in Brazilian Amazonia (18%) (INPE, 2008)

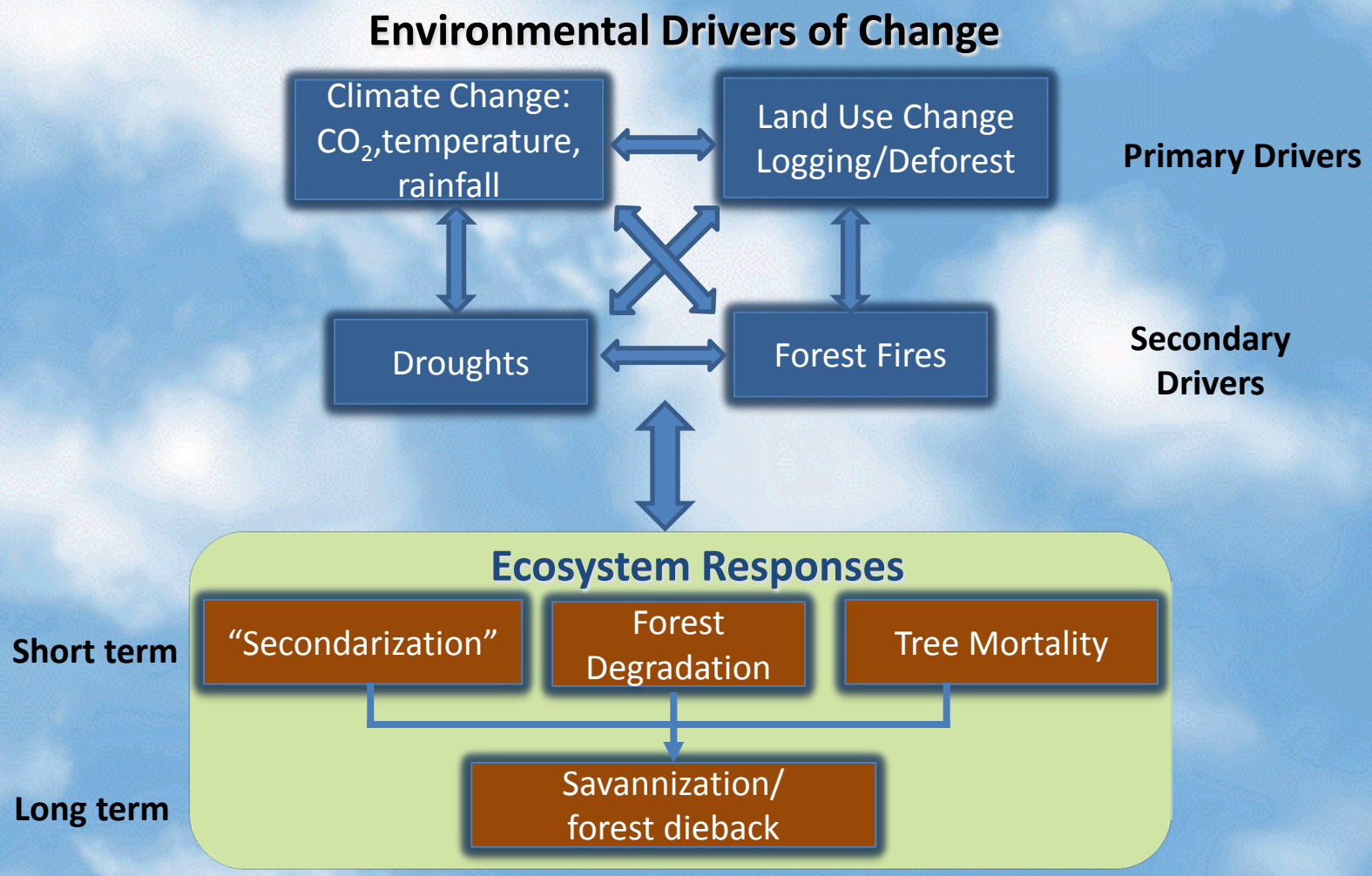


Anthropogenic and Natural Drivers of Environmental Change in Amazonia

Droughts (e.g., 2005) can become frequent (Cox et al., 2008 Nature)

Forest fire frequency ↑ (Nepstad et al., 2006)

What are the likely biome changes in Tropical South America due to a suite of environmental drivers of change?



Carlos Nobre, CCST, INPE, 2011

Amazonian Tall Tower Observatory
ATTO – 320 meters

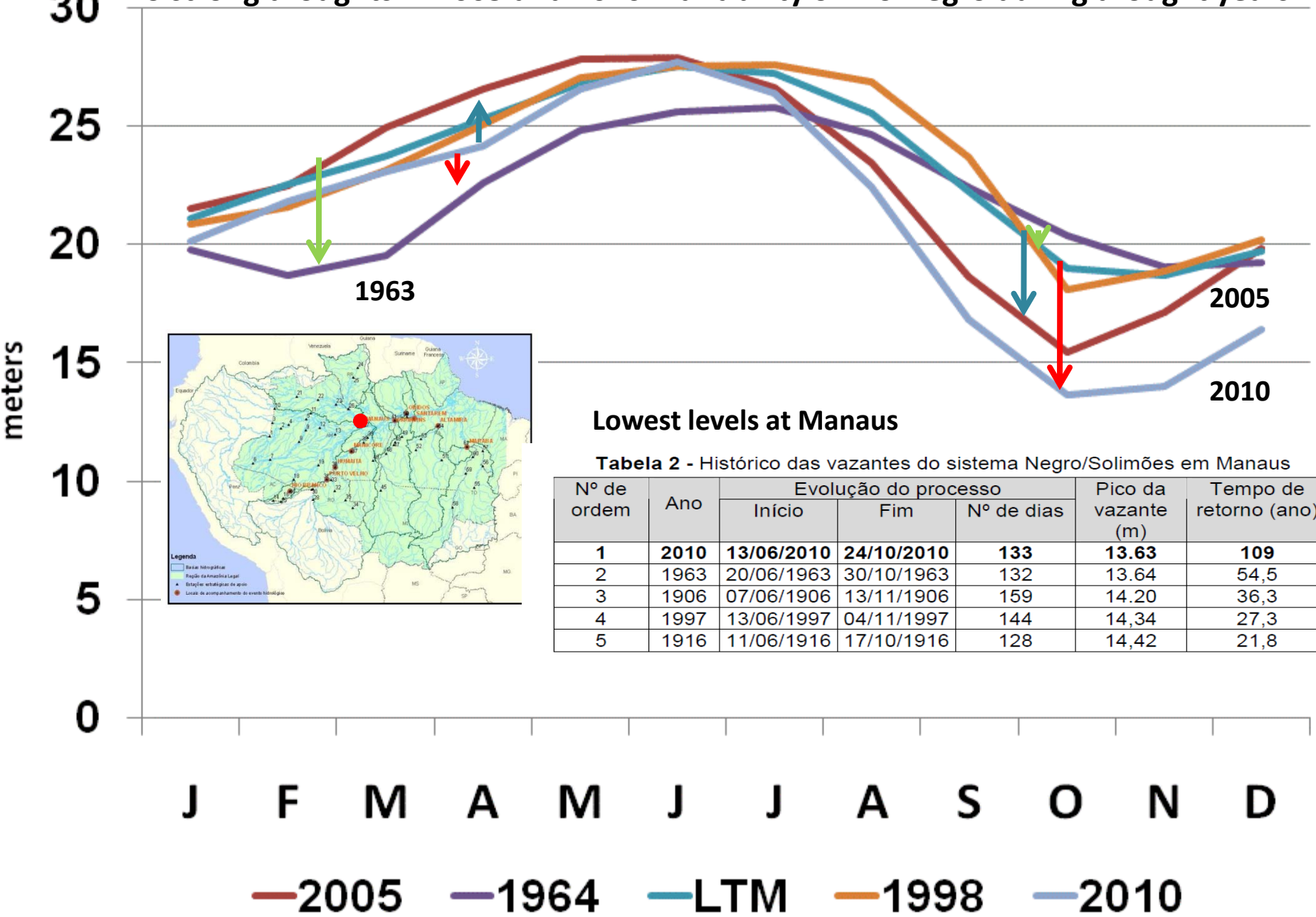
Long term broad objectives observatory

A few issues for research in Amazonia

- Biology-chemistry-climate: Where are the links?
- Study in detail the aerosol-cloud-thermodynamic precipitation links
- Urbanization in Amazonia and its effects on regional chemistry, radiation balance and precipitation issues.
- Atmospheric Chemistry in Amazonia: The relationship between vegetation VOC emissions, formation of Secondary Organic Aerosols, O_3, NO_x, CO and OH role.
- Carbon cycling on natural conditions with its ecophysiological drivers and the drought issue
- Regional and global climate modeling including socio-economic drivers

Thanks for the attention!!!

Two strong droughts in 2005 and 2010: Variability of Rio Negro during drought years

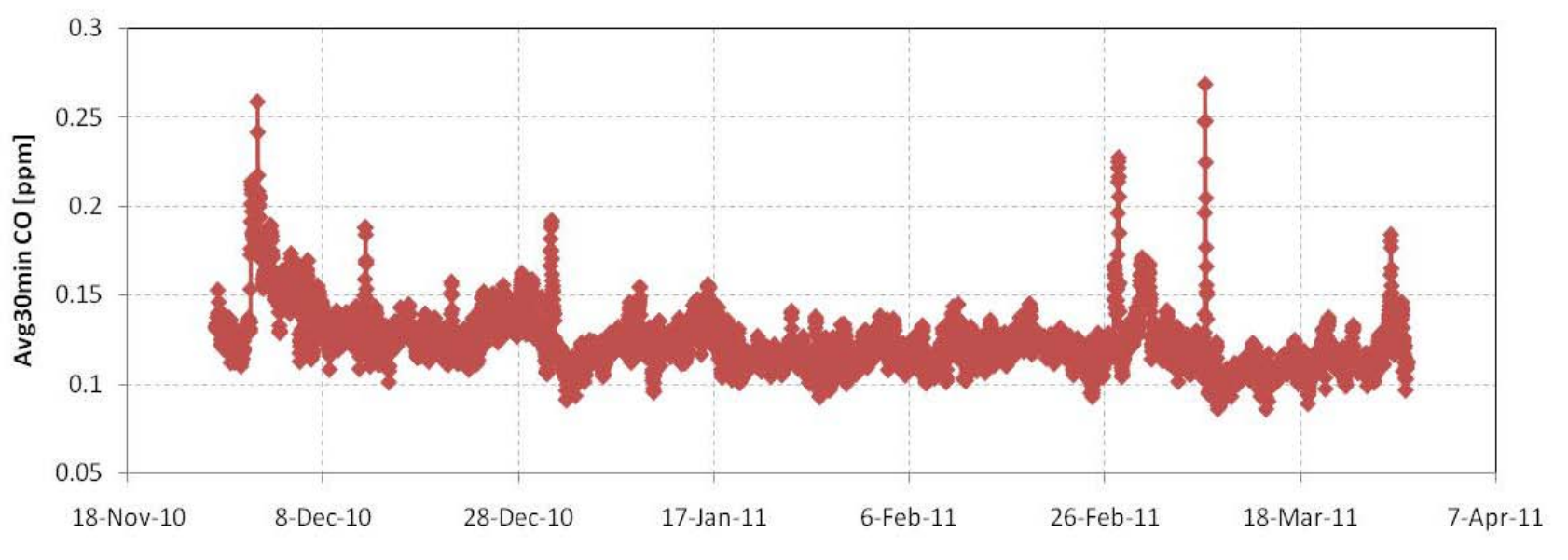


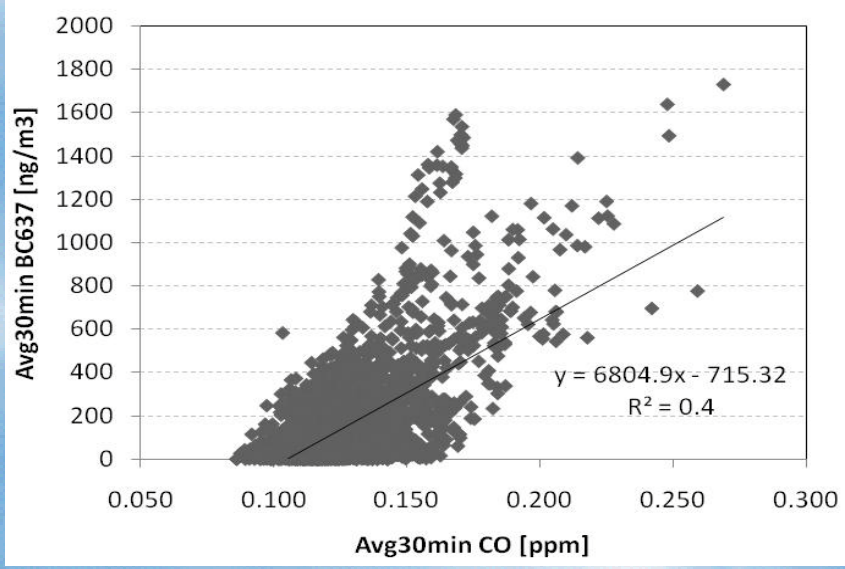
Lowest levels at Manaus

Tabela 2 - Histórico das vazantes do sistema Negro/Solimões em Manaus

Nº de ordem	Ano	Evolução do processo			Pico da vazante (m)	Tempo de retorno (ano)
		Início	Fim	Nº de dias		
1	**2010**	**13/06/2010**	**24/10/2010**	**133**	**13.63**	**109**
2	1963	20/06/1963	30/10/1963	132	13.64	54,5
3	1906	07/06/1906	13/11/1906	159	14.20	36,3
4	1997	13/06/1997	04/11/1997	144	14,34	27,3
5	1916	11/06/1916	17/10/1916	128	14,42	21,8

Manaus time series of CO concentrations





CO concentrations versus BC in Manaus