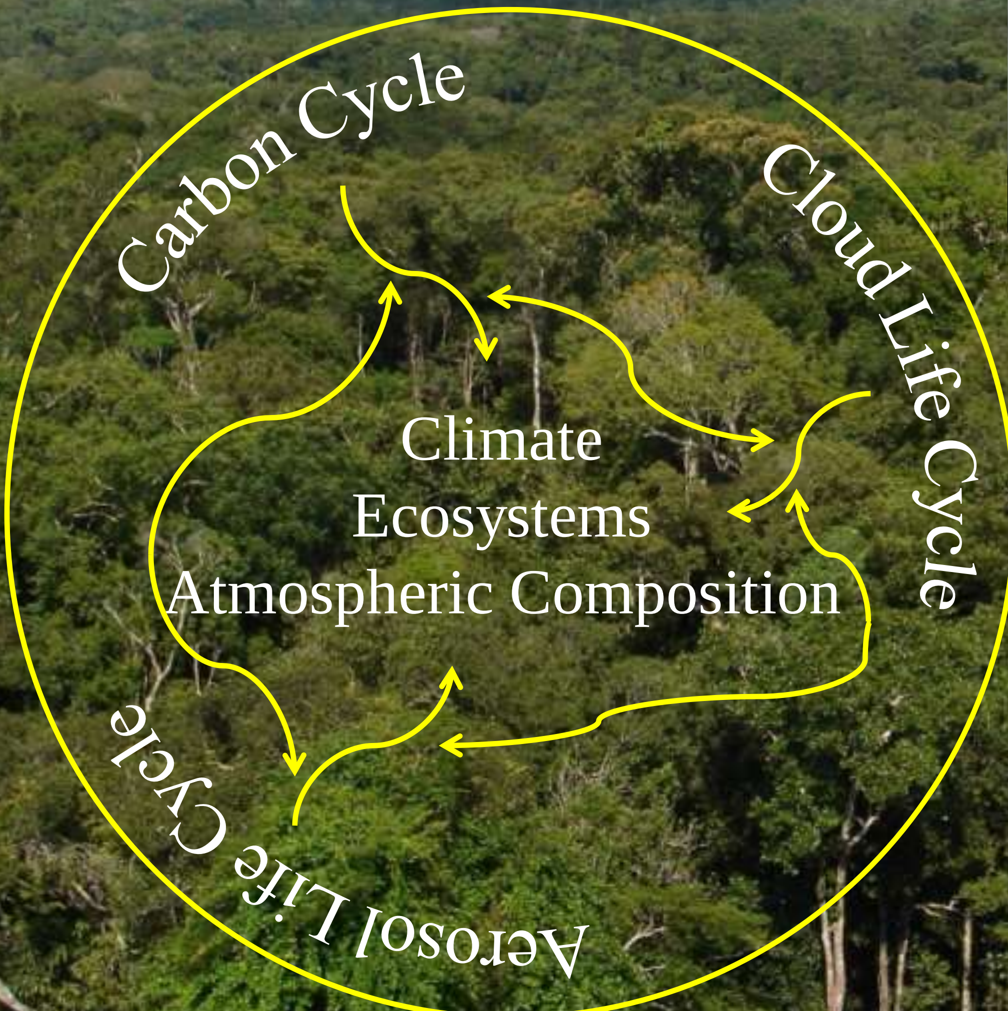
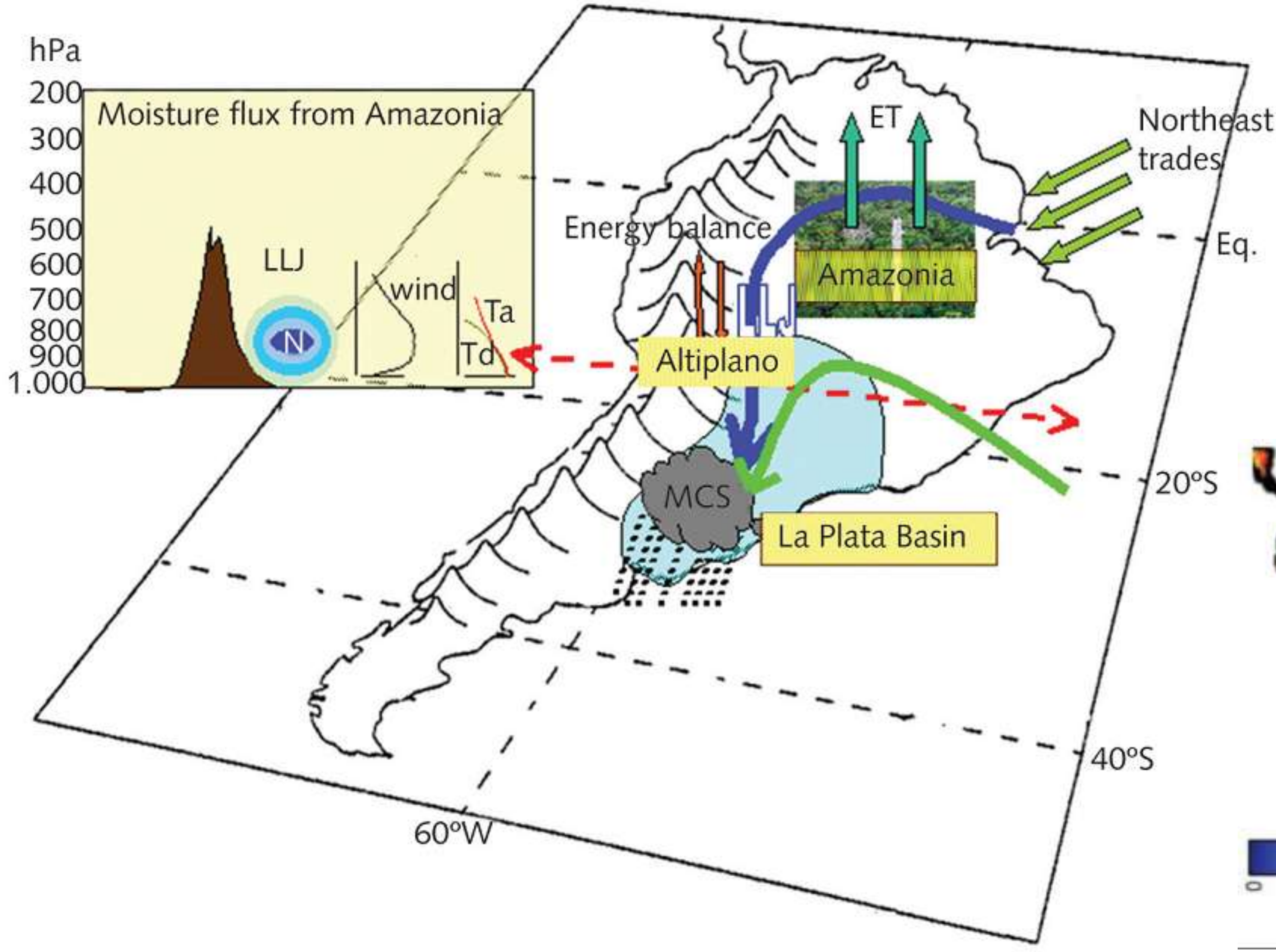
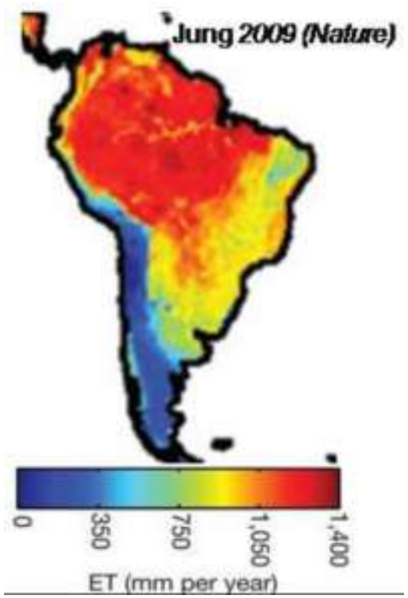
Ecosystems, Atmosphere Composition, and Climate in Amazonia



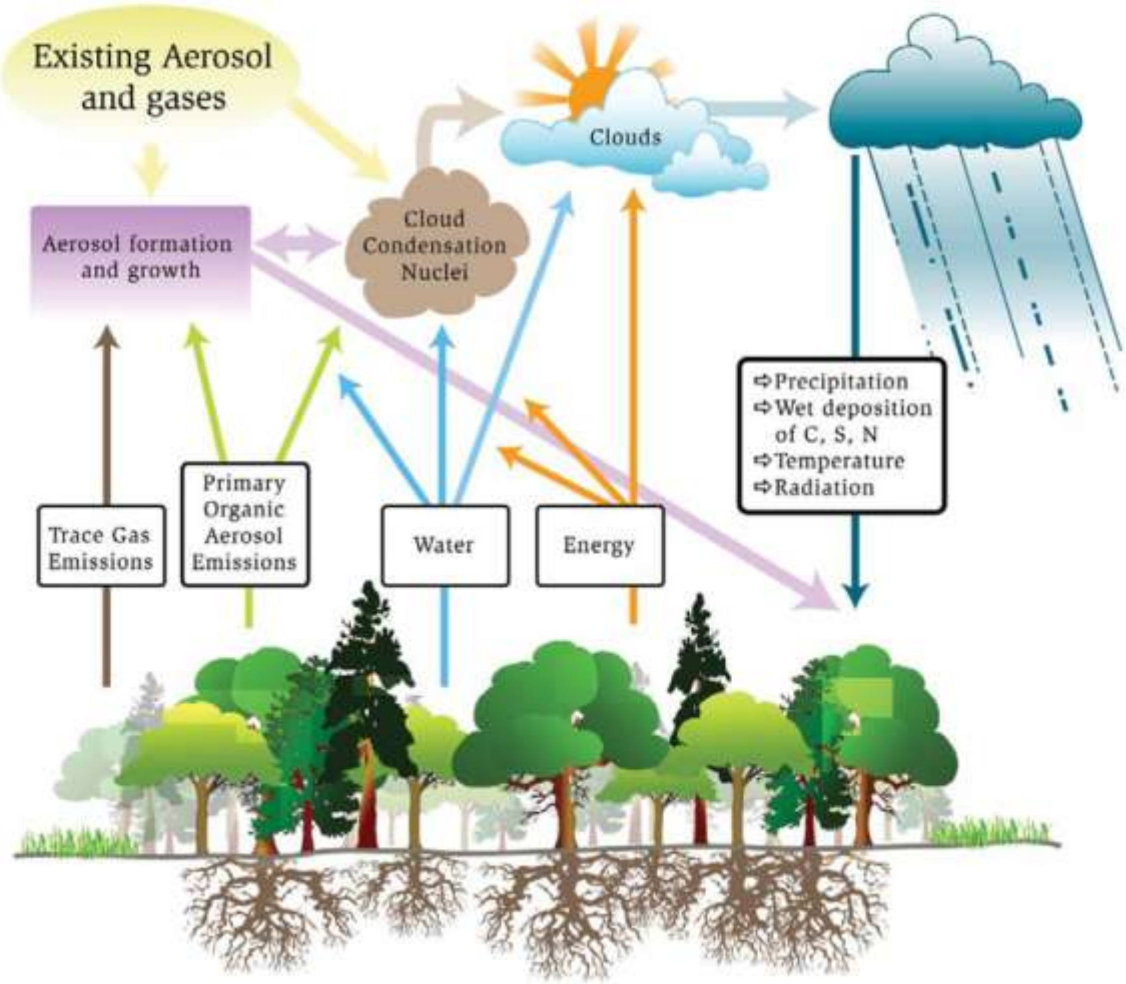
Presented by Paulo Artaxo, (July 2012)

Prevailing Patterns of Wind, Water, and Energy Flows in the Amazon Basin





Amazon Basin 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.



Source: Barth et al., "Coupling between Land Ecosystems and the Atmospheric Hydrologic Cycle through Biogenic Aerosol Particles," *BAMS*, *86*, 1738-1742, 2005.

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.

Changes in Net Primary Productivity with Radiation Field
The future of Amazon forests with increased human activities?

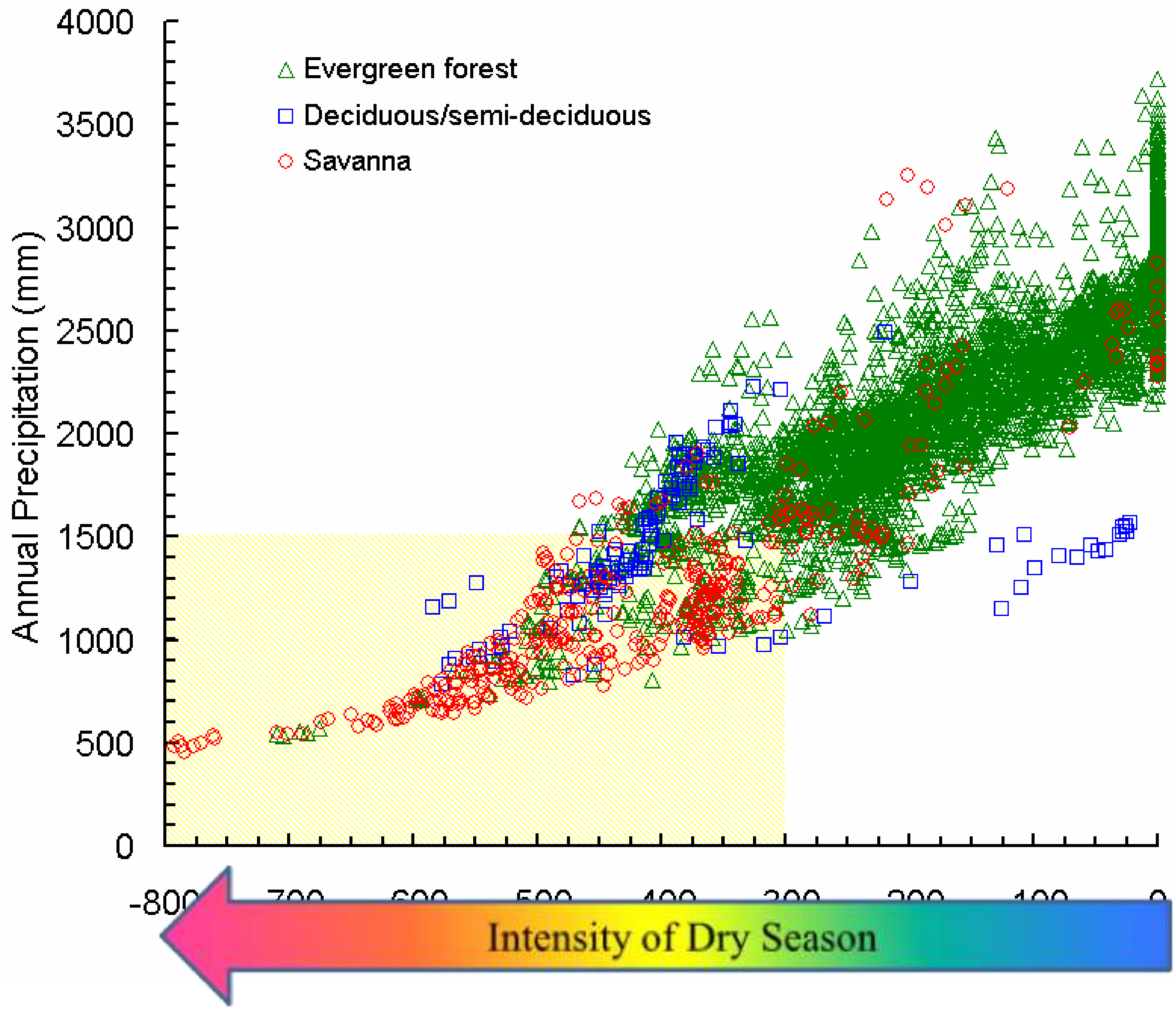
Many studies outside of the tropics have found an increase in whole-canopy and shade leaf photosynthesis under conditions that enhance the diffuse fraction of irradiance from clouds or aerosols (Gu et al. 2003; Still et al. 2009).

However, recent work in Amazon forests near Santarem, Brazil, found that photosynthesis in old-growth tropical forests exhibited complex relationships with the quality of solar radiation (Doughty and Goulden 2008; Doughty et al. 2010).

The daily cycle of BVOC emissions between tropical and temperature forests are also very different (i.e., correlation vs. anticorrelation, respeictively, between isopene and terpene emissions).

Source: Mercado et al., iLEAPS 2009, Melbourne, 27.08.2009

A Rainfall Biogeography of Amazonia

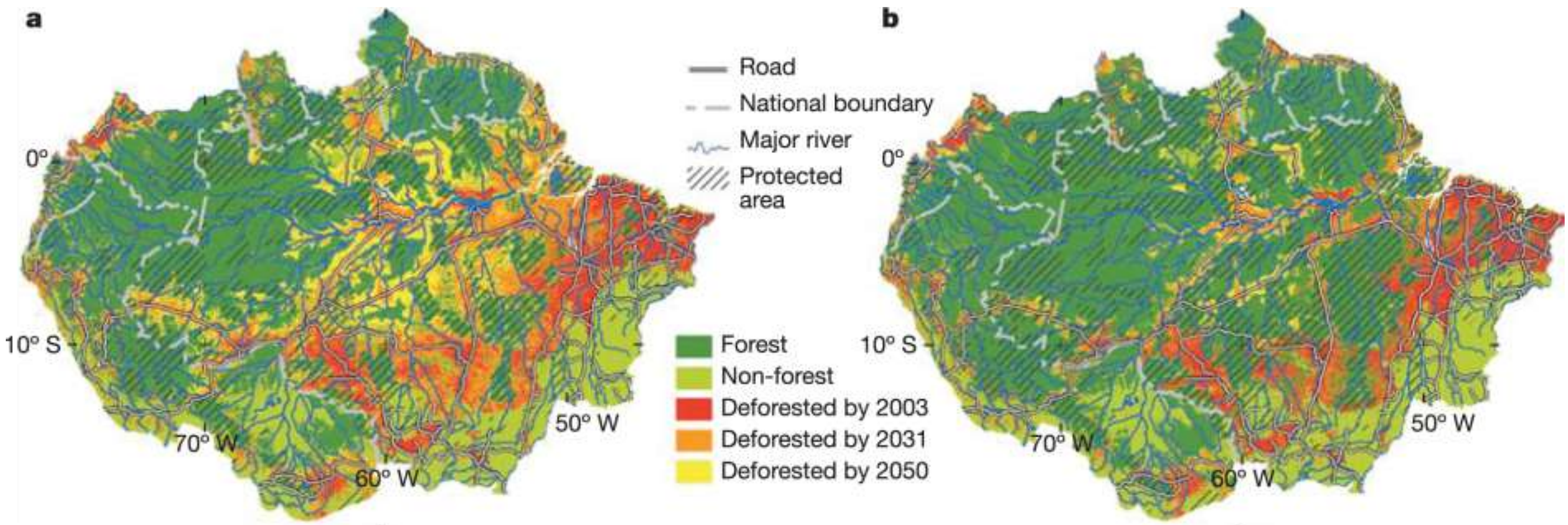


Source: Malhi *et al.*, **Exploring the likelihood and mechanism of a climate-change induced dieback of the Amazon rainforest,** *Proceedings of the National Academy of Sciences*, submitted

Amazon forest dieback hypothesis

The future of Amazon forests under climate change?

Simulations of Forest Cover for Year 2050



Business As Usual

Good Governance

Soares-Filho, B. S., D. C. Nepstad, L. M. Curran, G. C. Cerqueira, R. A. Garcia, C. A. Ramos, E. Voll, A. McDonald, P. Lefebvre, and P. Schlesinger (2006), Modelling conservation in the Amazon Basin, *Nature*, **440**, 520–523, doi:10.1038/nature04389.

AMAZE2008

Amazonian Aerosol Characterization Experiment

7 Feb - 15 Mar 2008

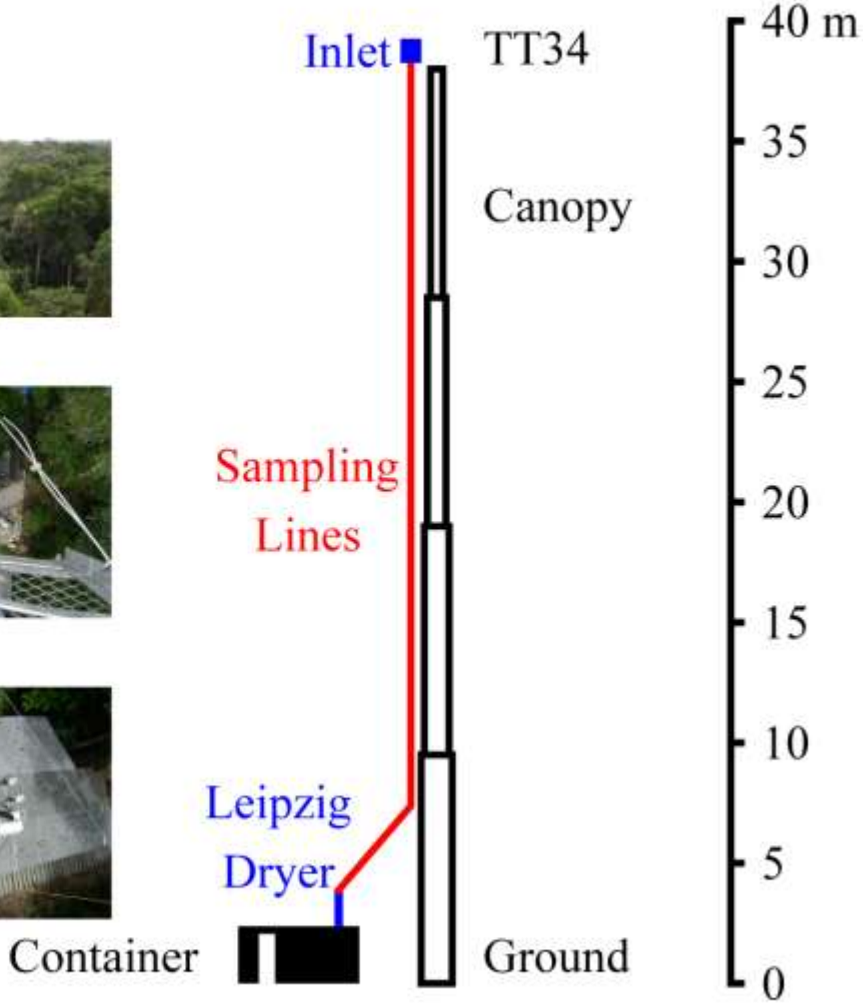
Science Focus on Natural Ecosystem Functioning

Amazonian Aerosol Characterization Experiment (AMAZE-08)

Wet Season of Central Amazônia in January – March 2008

S.T. Martin, M.O. Andreae, D. Althausen, P. Artaxo, H. Baars, S. Borrmann, Q. Chen, D.K. Farmer, A. Guenther, S. Gunthe, J.L. Jimenez, T. Karl, K. Longo, A. Manzi, T. Pauliquevis, M. Petters, A. Prenni, U. Pöschl, L.V. Rizzo, J. Schneider, J.N. Smith, E. Swietlicki, J. Tota, J. Wang, A. Wiedensohler, S.R. Zorn, "An Overview of the Amazonian Aerosol Characterization Experiment 2008 (AMAZE-08)," *Atmospheric Chemistry Physics*, 2010, *10*, 11415-11438

Telescopic Tower at km 34 (TT34)

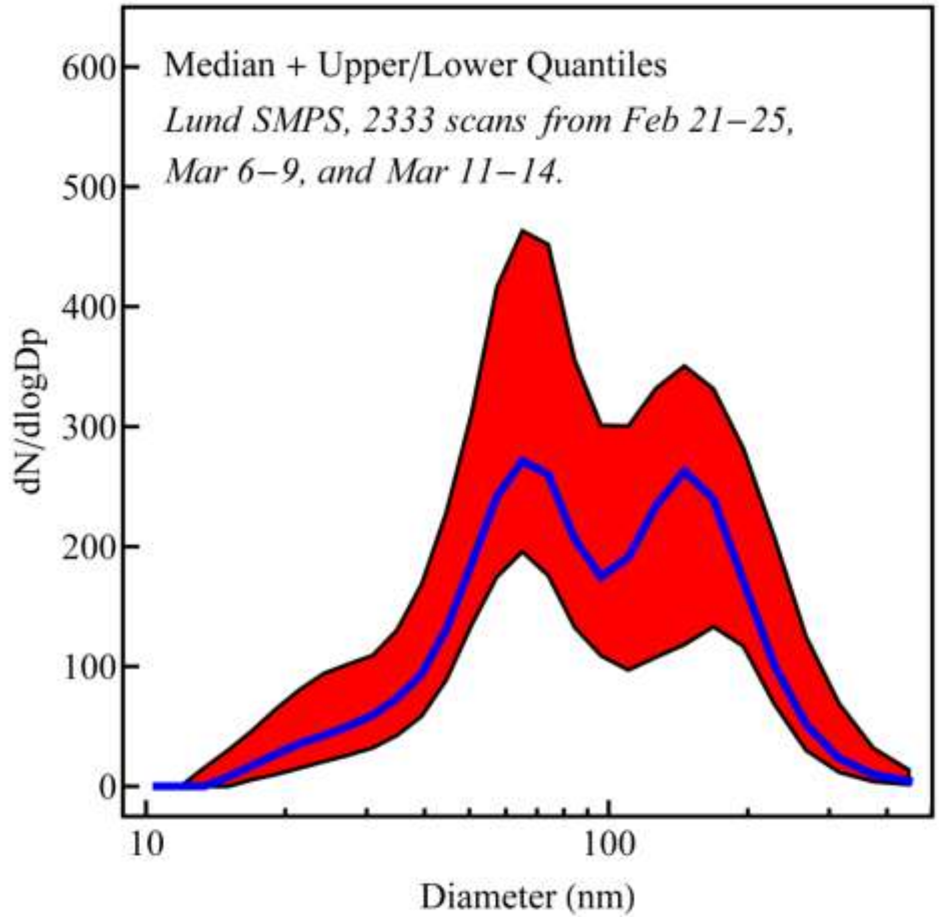


Location of TT34 in Amazon Basin

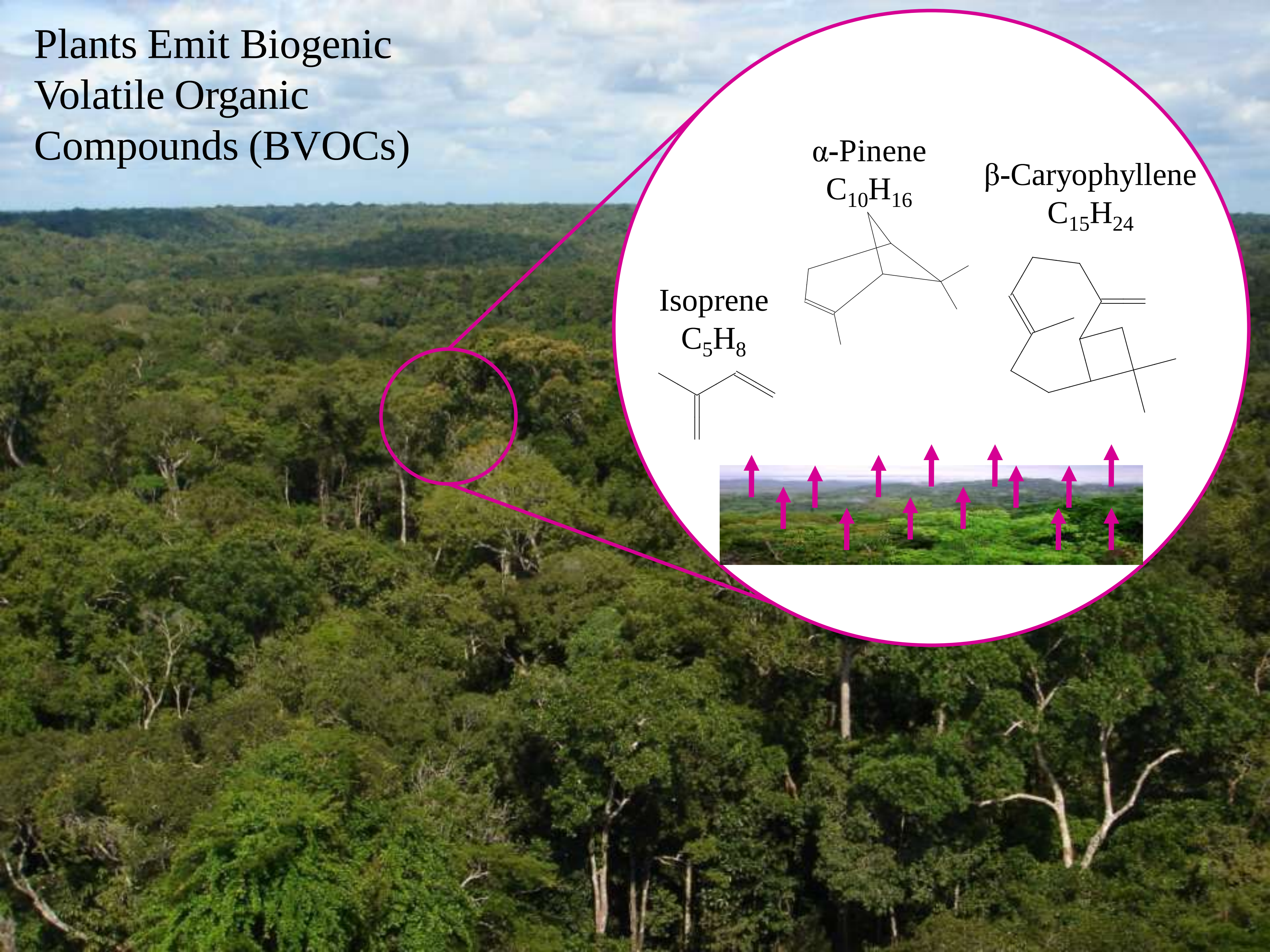
- Measurement period in wet season from Feb 7 – Mar 14, 2008.
- Prevailing 500-m winds shown by yellow arrows.
- The locations of the 40-m tower and of Manaus are marked.

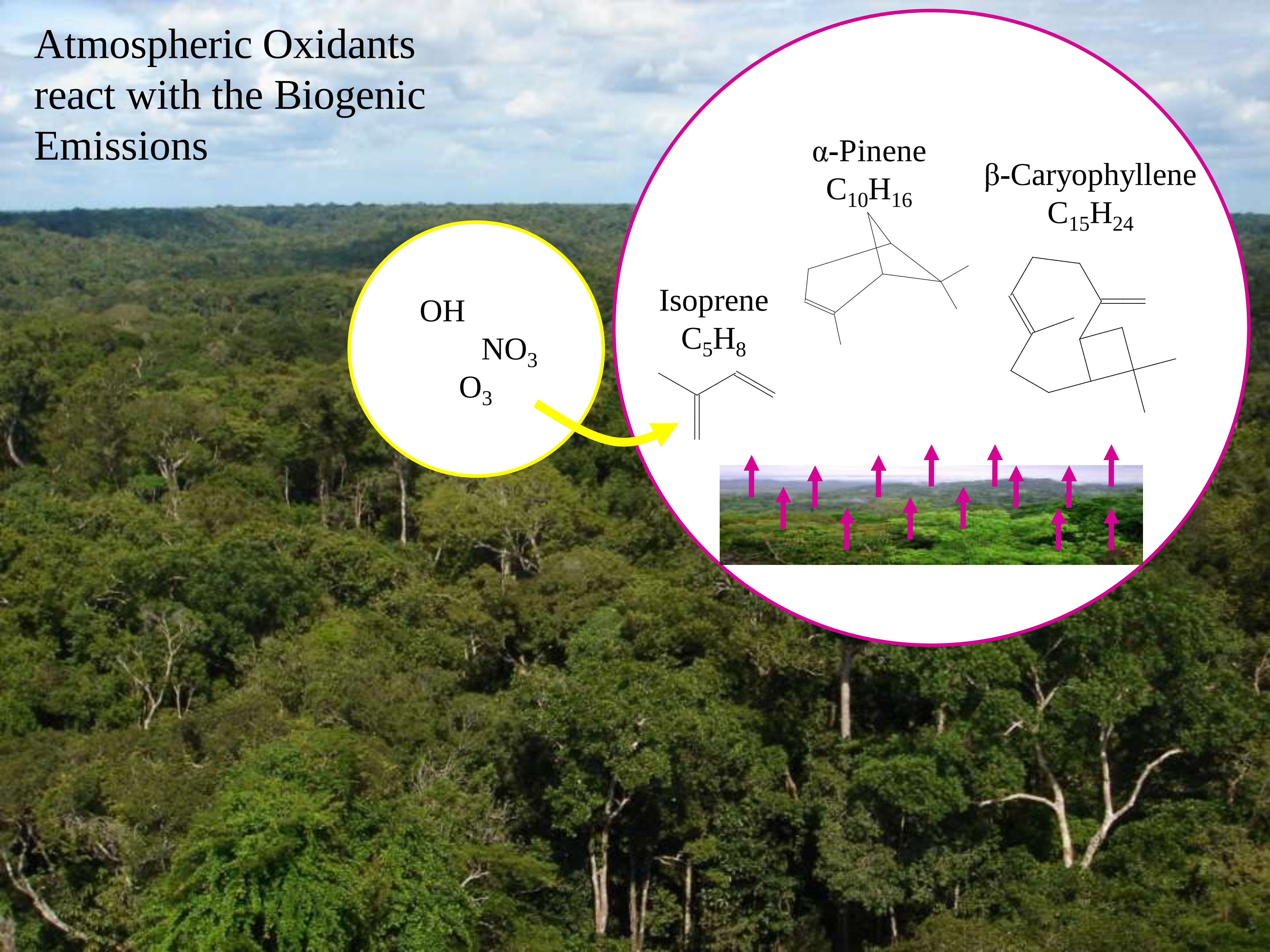
Submicron Number-Diameter Distributions

Climate-Active Size Fraction

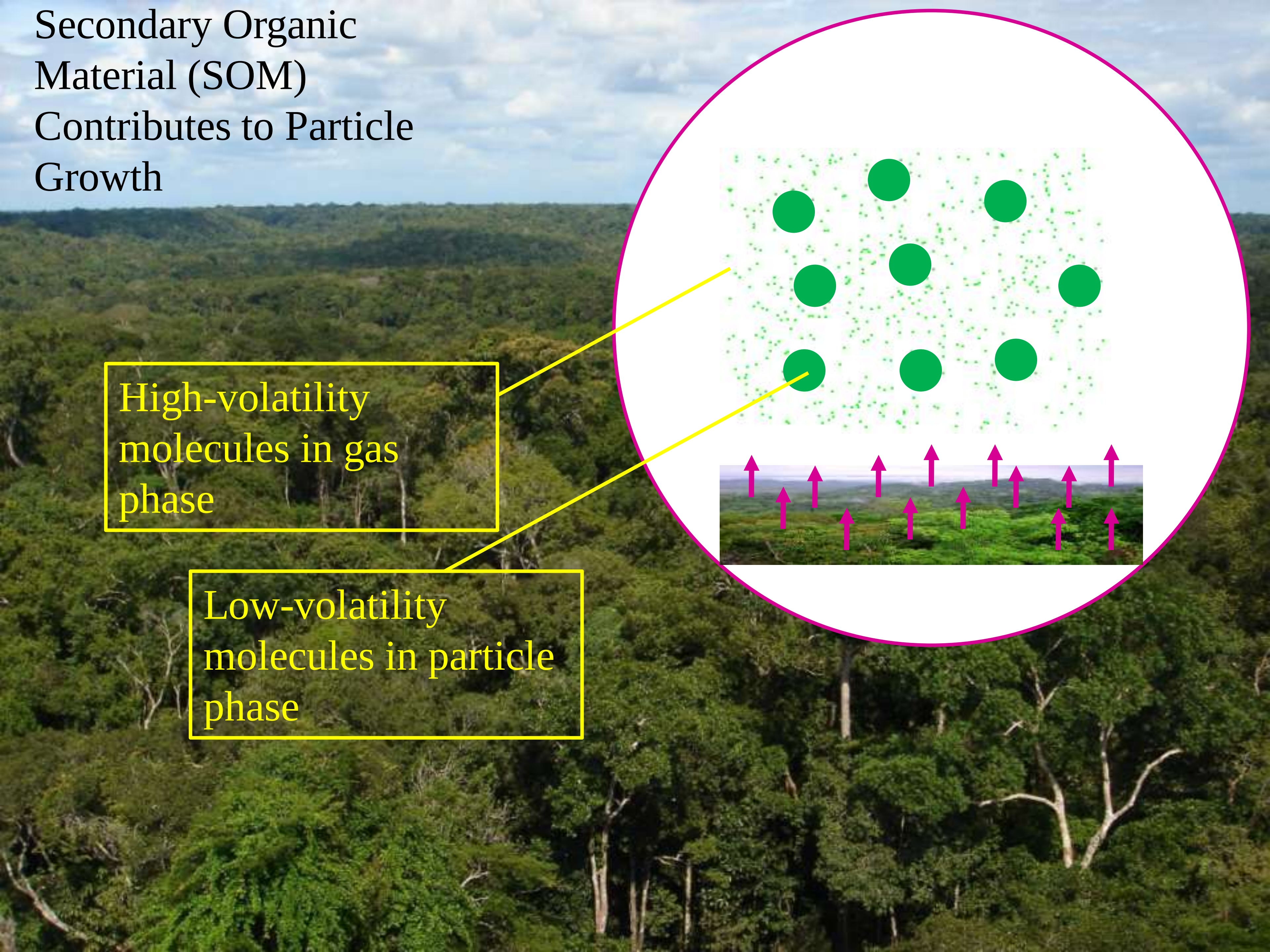


Data of E. Swietlicki presented in S.T. Martin, M.O. Andreae, D. Althausen, P. Artaxo, H. Baars, S. Borrmann, Q. Chen, D.K. Farmer, A. Guenther, S. Gunthe, J.L. Jimenez, T. Karl, K. Longo, A. Manzi, T. Pauliquevis, M. Petters, A. Prenni, U. Pöschl, L.V. Rizzo, J. Schneider, J.N. Smith, E. Swietlicki, J. Tota, J. Wang, A. Wiedensohler, S.R. Zorn, "An Overview of the Amazonian Aerosol Characterization Experiment 2008 (AMAZE-08)," *Atmospheric Chemistry Physics*, 2010, *10*, 11415-11438

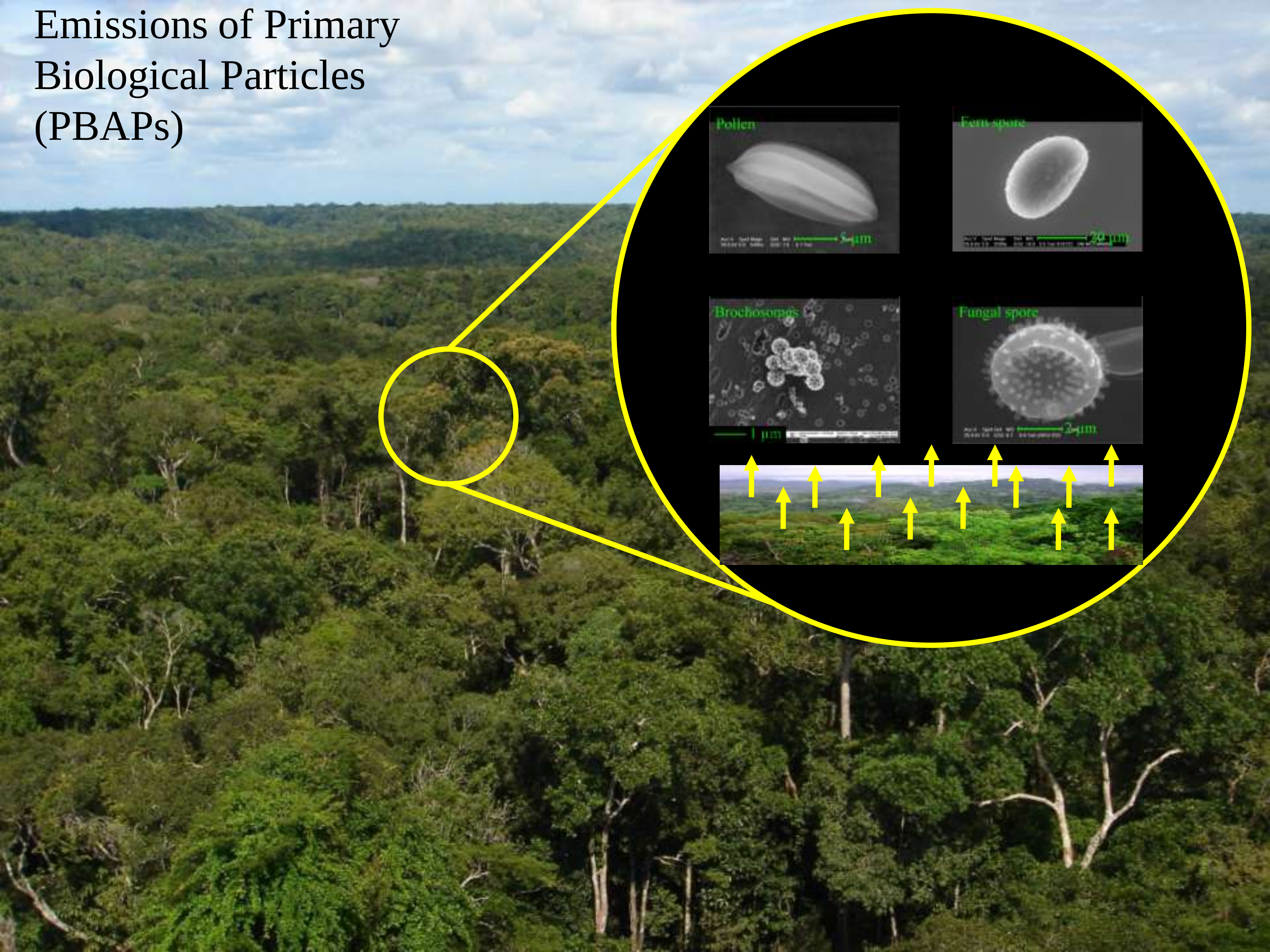

Plants Emit Biogenic Volatile Organic Compounds (BVOCs)
α-Pinene
$C_{10}H_{16}$
β-Caryophyllene
$C_{15}H_{24}$
Isoprene
C_5H_8


Atmospheric Oxidants react with the Biogenic Emissions
OH
NO_3
O_3
Isoprene
C_5H_8
α-Pinene
$C_{10}H_{16}$
β-Caryophyllene
$C_{15}H_{24}$

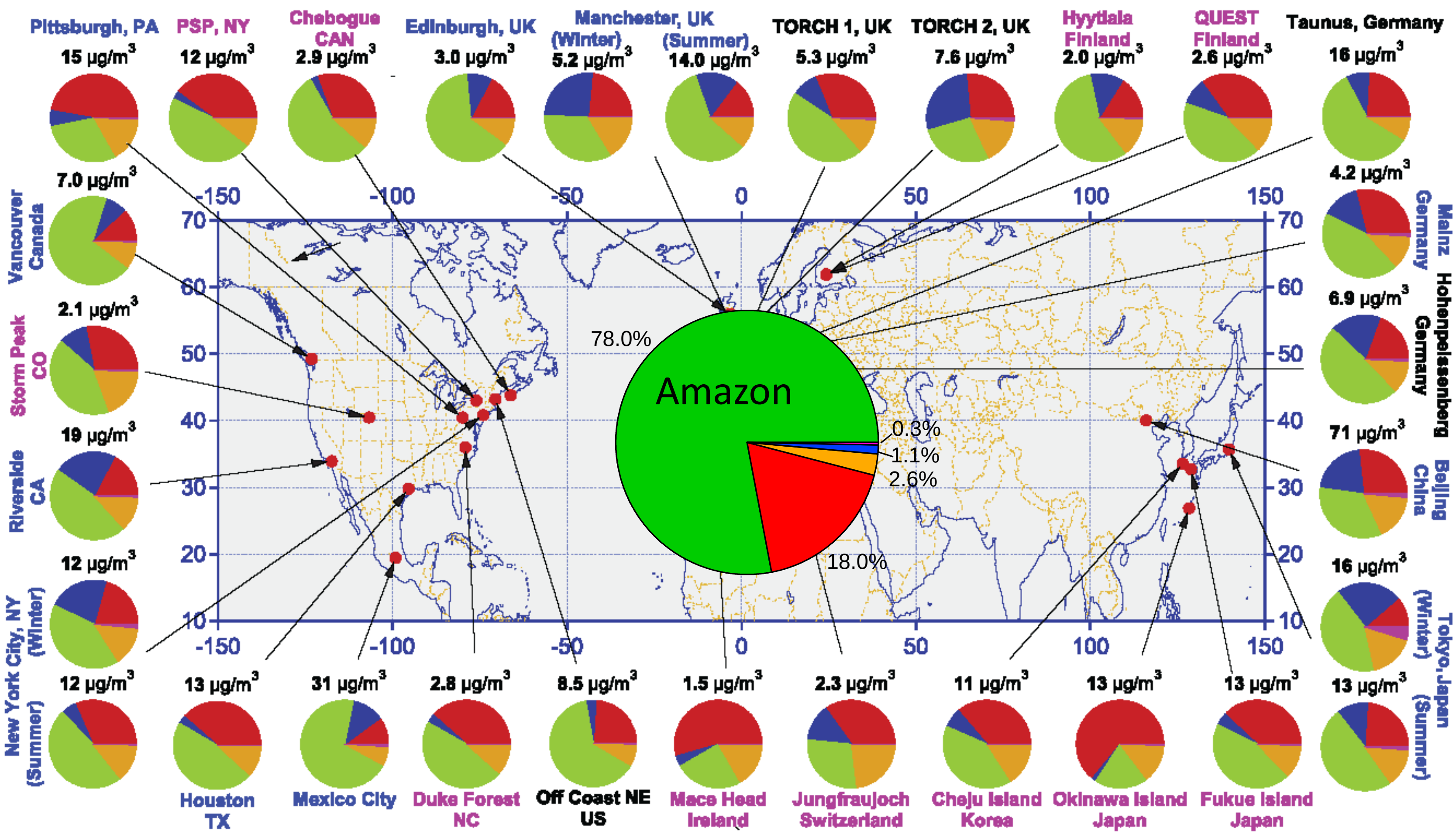
Secondary Organic Material (SOM) Contributes to Particle Growth



Emissions of Primary Biological Particles (PBAPs)



Amazon: Highest proportion of organic material.

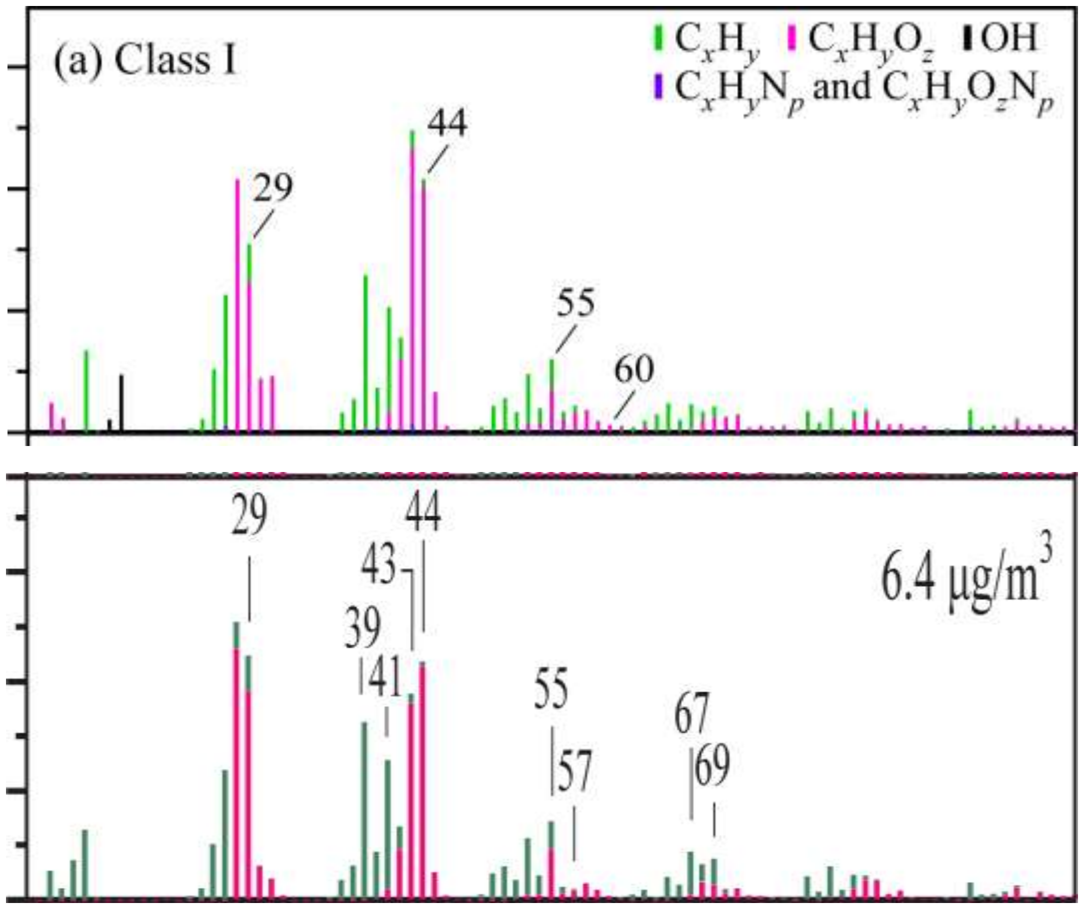


Adapted from Zhang et al., *Geophys. Res. Lett.*, 2007.

Similarity Between Mass Spectra Observed in AMAZE-08 and SOM Particles Generated in Environmental Chamber

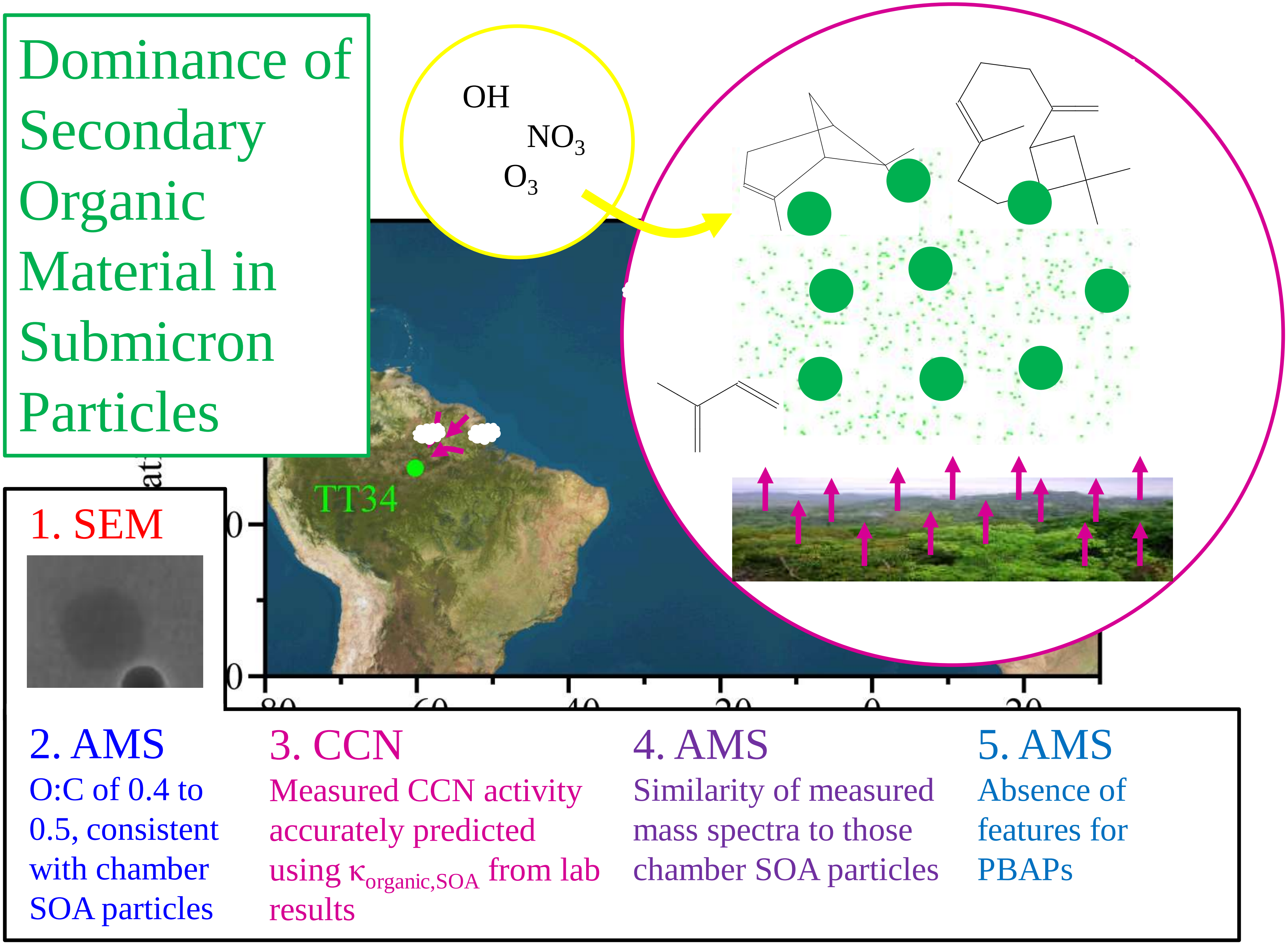
AMAZE-08 in Central Amazonia

Harvard Environmental Chamber



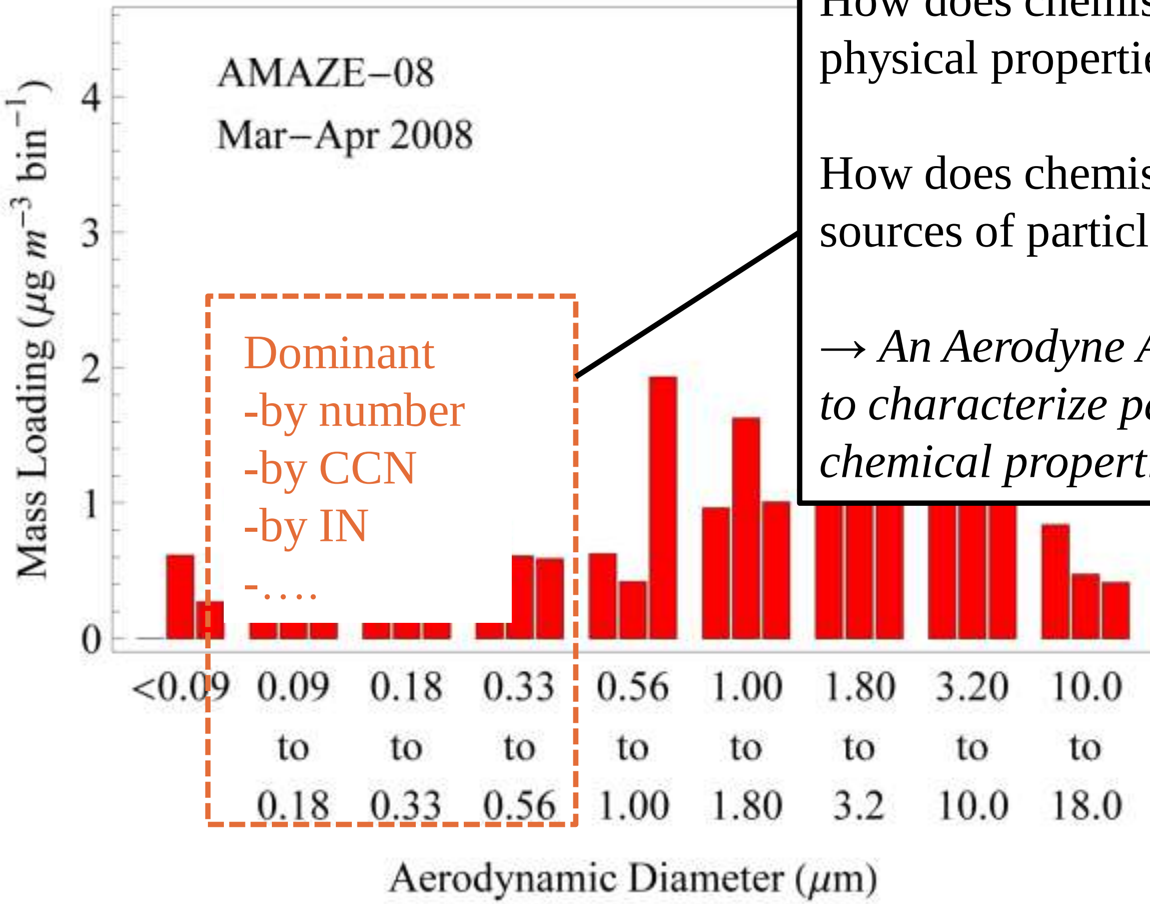
SOM Particles of Ozonized α-Pinene

Adapted from Chen et al., *Geophys. Res. Lett.*, **2009**, *36*, L20806 and Shilling et al., *Atmos. Chem. Phys.*, **2009**, *9*, 771-782.


Dominance of Secondary Organic Material in Submicron Particles
OH
NO_3
O_3
TT34
1. SEM
2. AMS
O:C of 0.4 to 0.5, consistent with chamber SOA particles
3. CCN
Measured CCN activity accurately predicted using $\kappa_{organic,SOA}$ from lab results
4. AMS
Similarity of measured mass spectra to those chamber SOA particles
5. AMS
Absence of features for PBAPs

Mass-Diameter Distributions

Background Conditions Prevailing



How does chemistry affect physical properties?

How does chemistry constrain sources of particles?

→ *An Aerodyne AMS was used to characterize particle chemical properties*

Data of P. Artaxo presented in S.T. Martin, M. O. Andreae, P. Artaxo, D. Baumgardner, Q. Chen, A. H. Goldstein, A. Guenther, C. L. Heald, O. L. Mayol-Bracero, P. H. McMurry, T. Pauliquevis, U. Poeschl, K. A. Prather, G. C. Roberts, S. R. Saleska, M. A. S. Dias, D. V. Spracklen, E. Swietlicki, and I. Trebs, "Sources and Properties of Amazonian Aerosol Particles," *Reviews of Geophysics*, 2010, *48*, RG2002.

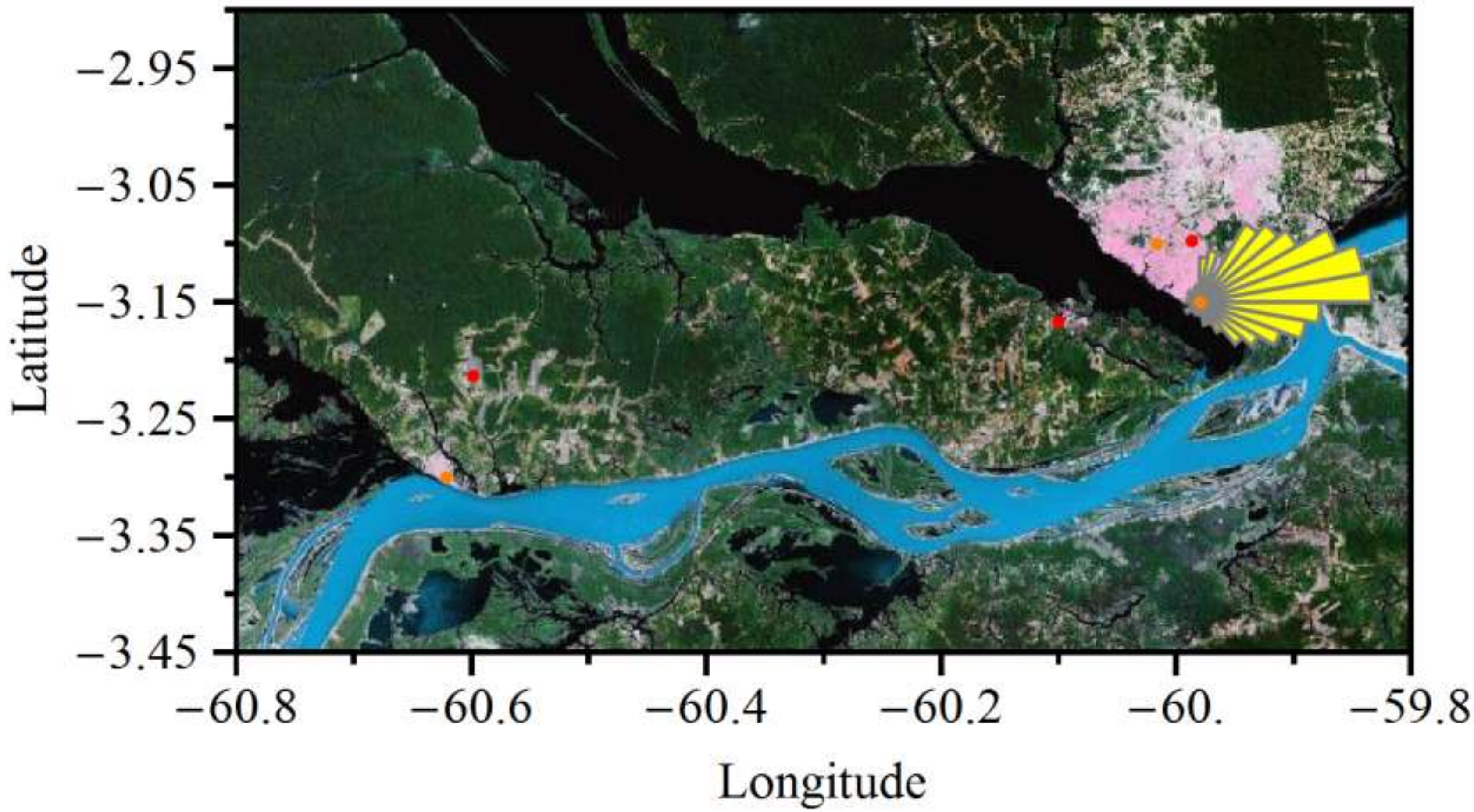
GoAmazon2014

Observations and Modeling of the Green Ocean Amazon

1 Jan - 31 Dec 2014

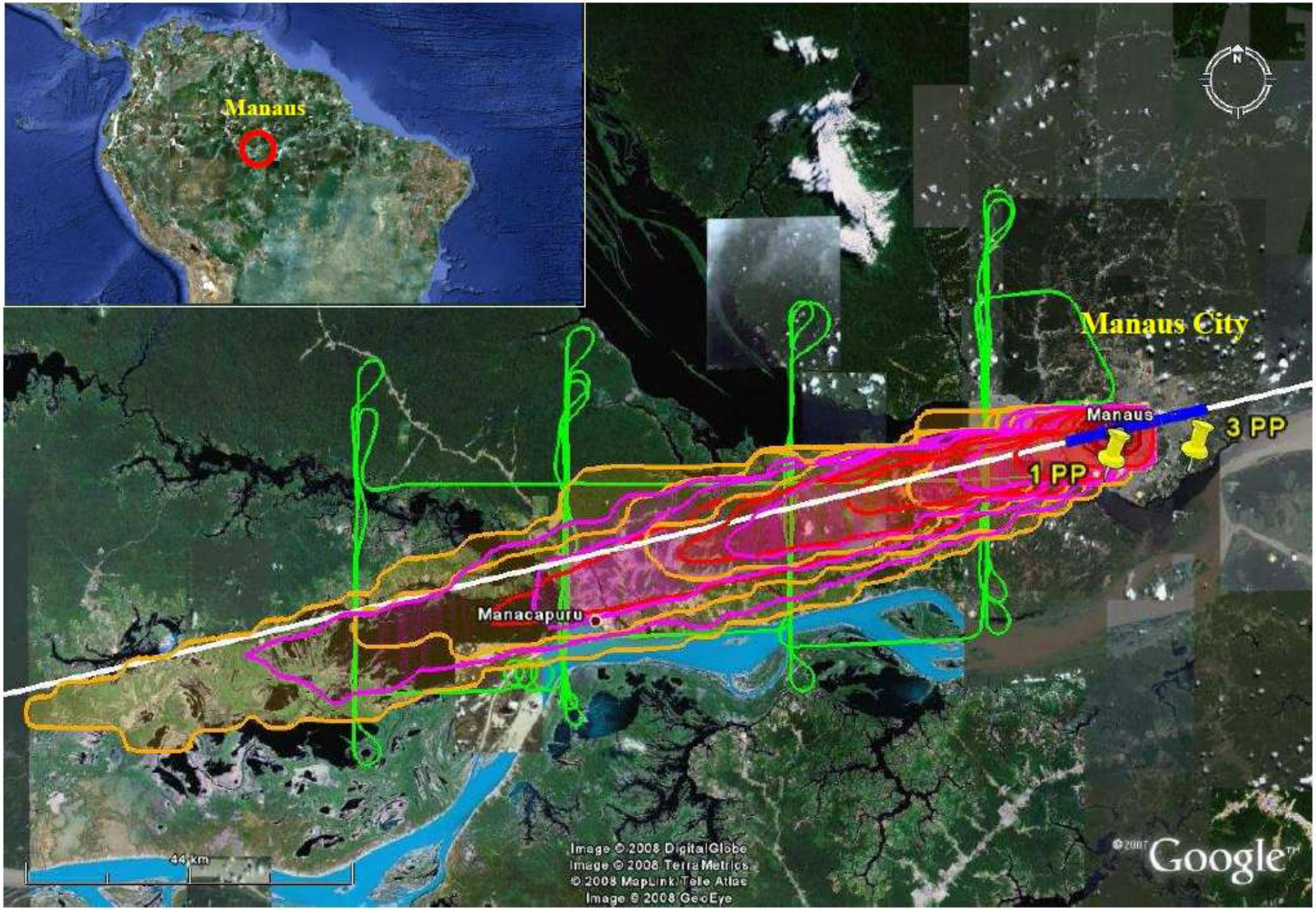
Science Focus on Effects of Pollution on Ecosystem Functioning

Downwind of Manaus

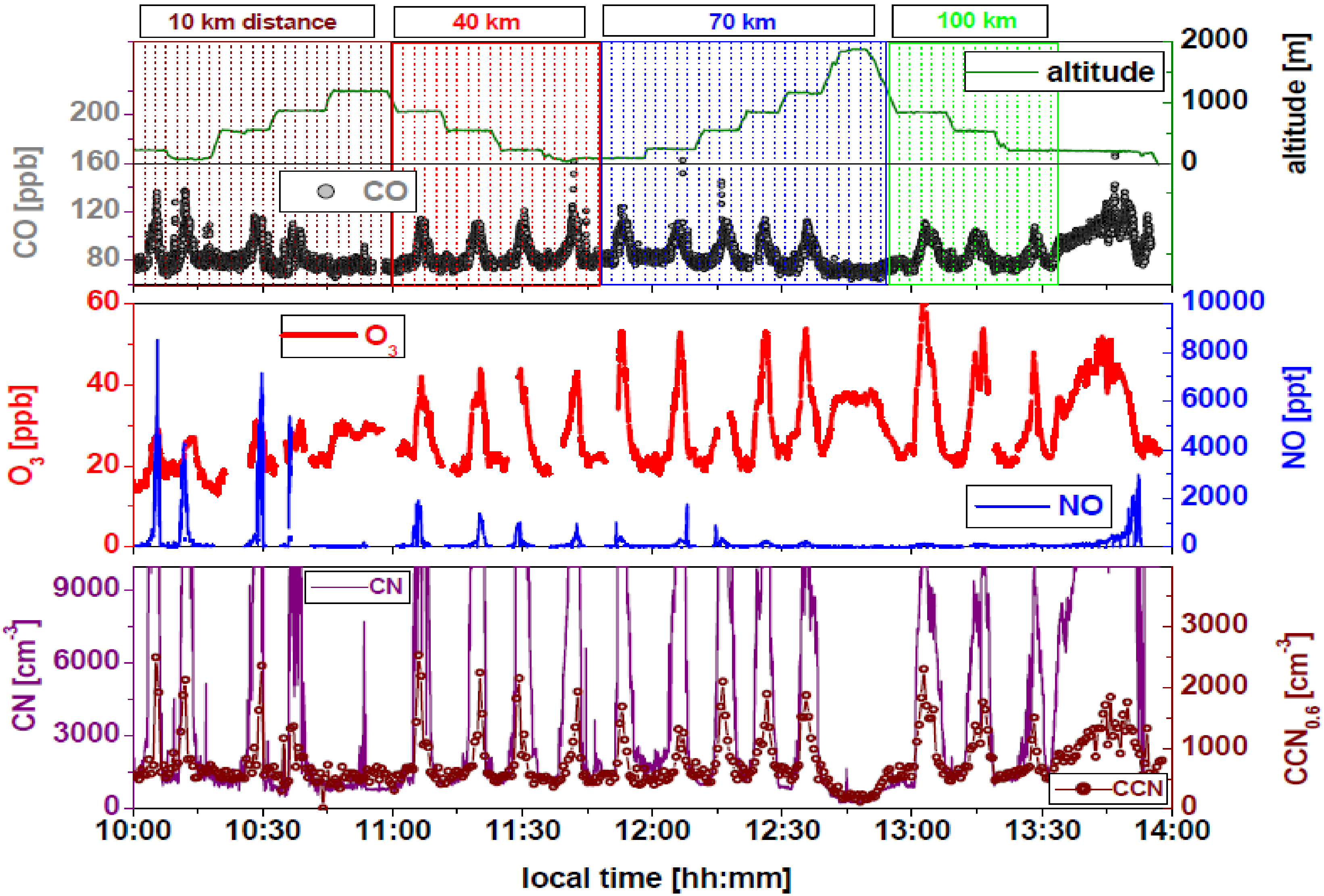


(−3.21328 , −60.5987)	DOE ARM ACRF	T3
(−3.16667 , −60.1)	TBD	T2
(−3.09722 , −59.9867)	INPA/UEA	T1
(−2.14663 , −59.005)	ATTO	T0
(−2.60908 , −60.2093)	K34	K34
(−2.59458 , −60.2093)	AMAZE08	TT34

- 111 by 60.8 km represented by this box.
- Wind speeds at 1 km altitude are typically 10 to 30 kph.
- T2→T3 transit time of 2 to 6 hr.

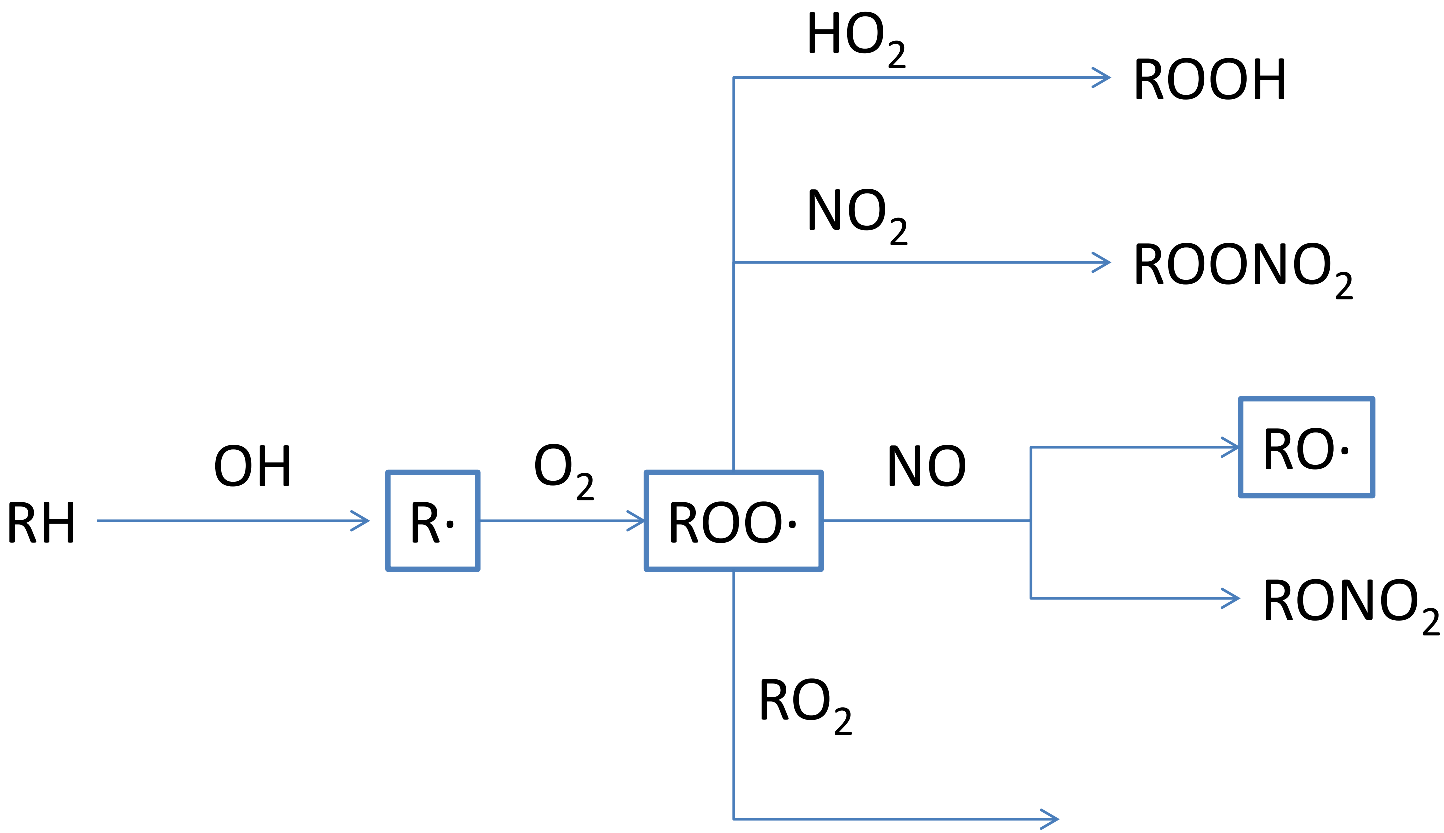


Reference: Kuhn, U.; Ganzeveld, L.; Thielmann, A.; Dindorf, T.; Welling, M.; Sciare, J.; Roberts, G.; Meixner, F. X.; Kesselmeier, J.; Lelieveld, J.; Ciccioli, P.; Kolle, O.; Lloyd, J.; Trentmann, J.; Artaxo, P.; Andreae, M. O., "Impact of Manaus City on the Amazon Green Ocean atmosphere: Ozone production, precursor sensitivity, and aerosol load," *Atmos. Chem. Phys.* **2010**, *10*, 9251-9282.

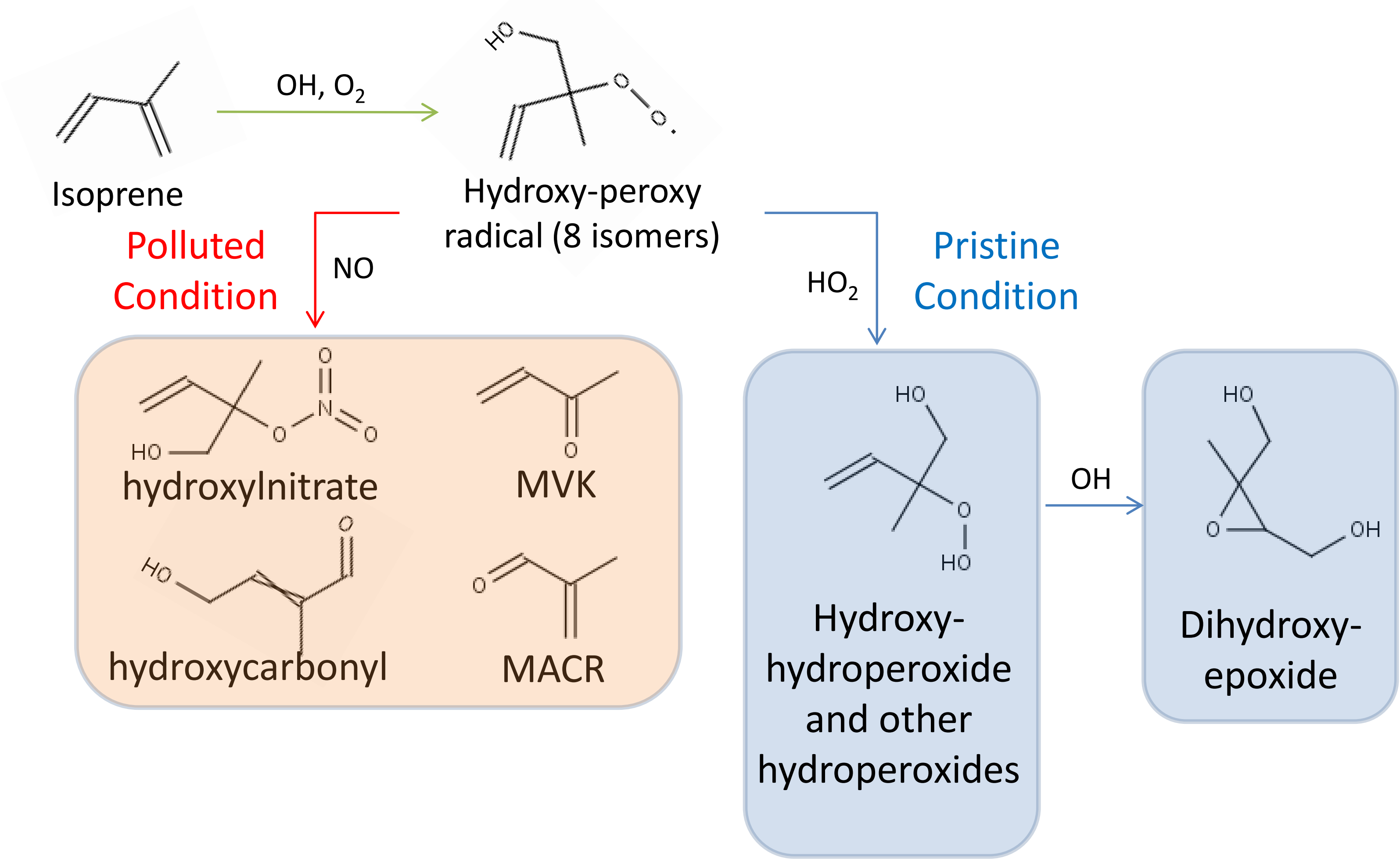


Reference: Kuhn, U.; Ganzeveld, L.; Thielmann, A.; Dindorf, T.; Welling, M.; Sciare, J.; Roberts, G.; Meixner, F. X.; Kesselmeier, J.; Lelieveld, J.; Ciccioli, P.; Kolle, O.; Lloyd, J.; Trentmann, J.; Artaxo, P.; Andreae, M. O., "Impact of Manaus City on the Amazon Green Ocean atmosphere: Ozone production, precursor sensitivity, and aerosol load," *Atmos. Chem. Phys.* **2010**, *10*, 9251-9282.

The chemistry can be completely shifted under anthropogenic influences… NO_x concentration, SO_2/H_2SO_4 particles



The chemistry can be completely shifted under anthropogenic influences… NO_x concentration, SO_2/H_2SO_4 particles



Manaus: Vehicle Fleet 2010

Frota de Veículos ·

	Quantidade
Motoneta	8.563
Motocicleta	83.459
Automóvel	252.274
Microônibus	2.334
Ônibus	5.807
Reboque	1.677
Semi-reboque	9.754
Camioneta	18.812
Caminhão	14.631
Caminhão-Trator	2.019
Caminhonete	49.981
Ciclomotor	329
Trator rodas	48
Triciclo	100
Utilitários	2.403
Outros	109
	452.300

Fonte: DETRAN/AM

FUEL MIX:

-tractor, truck and bus: almost 100% diesel

-car and bikes : > 60% gasoline (*)

(*) Ethanol price is very high in Manaus and gasoline is preferred by the consumer.

Acknowledgments: Rodrigo Souza, UEA

Manaus: Power Plant 2009: Fuel Oil

TABELA 1 - CONFIGURAÇÃO DO PARQUE GERADOR DO SISTEMA MANAUS AMAZONAS - AGOSTO DE 2009

Usina		Potência do Sistema (MW)			Tipo de UG	Tipo de óleo
		Nominal	Efetiva	Disponível		
Geração hídrica	**UHE Balbina**	250,0	250,0	250,0	Turbina hidráulica	
Geração Térmica	Aparecida	198,0	172,0	75,0	Turbina a Gás	PTE
	Mauá	452,4	437,0	259,6	Turbina a Vapor, Gás e Motor	Combustível, PTE e PGE
	Electron	120,0	102,2	0,0	Turbina a Gás	PTE
Diesel	UTE*	149,8	120,8	94,2		Óleo
TOTAL GERAÇÃO PRÓPRIA		1.170,6	1.081,3	678,45		
Produtor Independente	Breitener Tambaqui	83,5	60,0	60,0	Turbina a Gás	OCA-1
	Breitener Jaraqui	83,5	60,0	56,7	Turbina a Gás	OCA-1
	Manauara	85,4	60,0	60,0	Turbina a Gás	OCA-1
	Rio Amazonas	85,4	65,0	65,0	Turbina a Gás	OCA-1
	GERA	85,4	60,0	60,0	Turbina a Gás	OCA-1
TOTAL DE COMPRAS		423,1	305,0	301,7		
TOTAL GERAL DO SISTEMA		1.593,7	1.386,3	980,2		

* inclui as UTE-Cidade Nova, UTE-São José e UTE-Flores
Fonte: Adaptado das informações obtidas junto a Eletrobras Amazonas Energia

Hydropower

Oils of different grades

PTE - óleo leve "Para Turbina Elétrica"

PGE - óleo combustível "Para Gerador Elétrico"

OCA-1 = Óleo Combustível com Alto teor de enxofre = Fuel Oil with High Sulfur

Acknowledgments: Rodrigo Souza, UEA

Large Point Source of Pollution in Manaus:
High-Sulfur Diesel for Electricity

Outflow from Manaus first Crosses River: 2 to 10 km wide

Manaus Outflow Continues Across 60 km Forest

Arrival at AAA Large Pasture Site:
Location of ACRF Deployment

December 2011: Fence and Weather Station

Dates of GoAmazon2014

AMF Operations (T3 ground site)

- 1 January until 31 December 2014

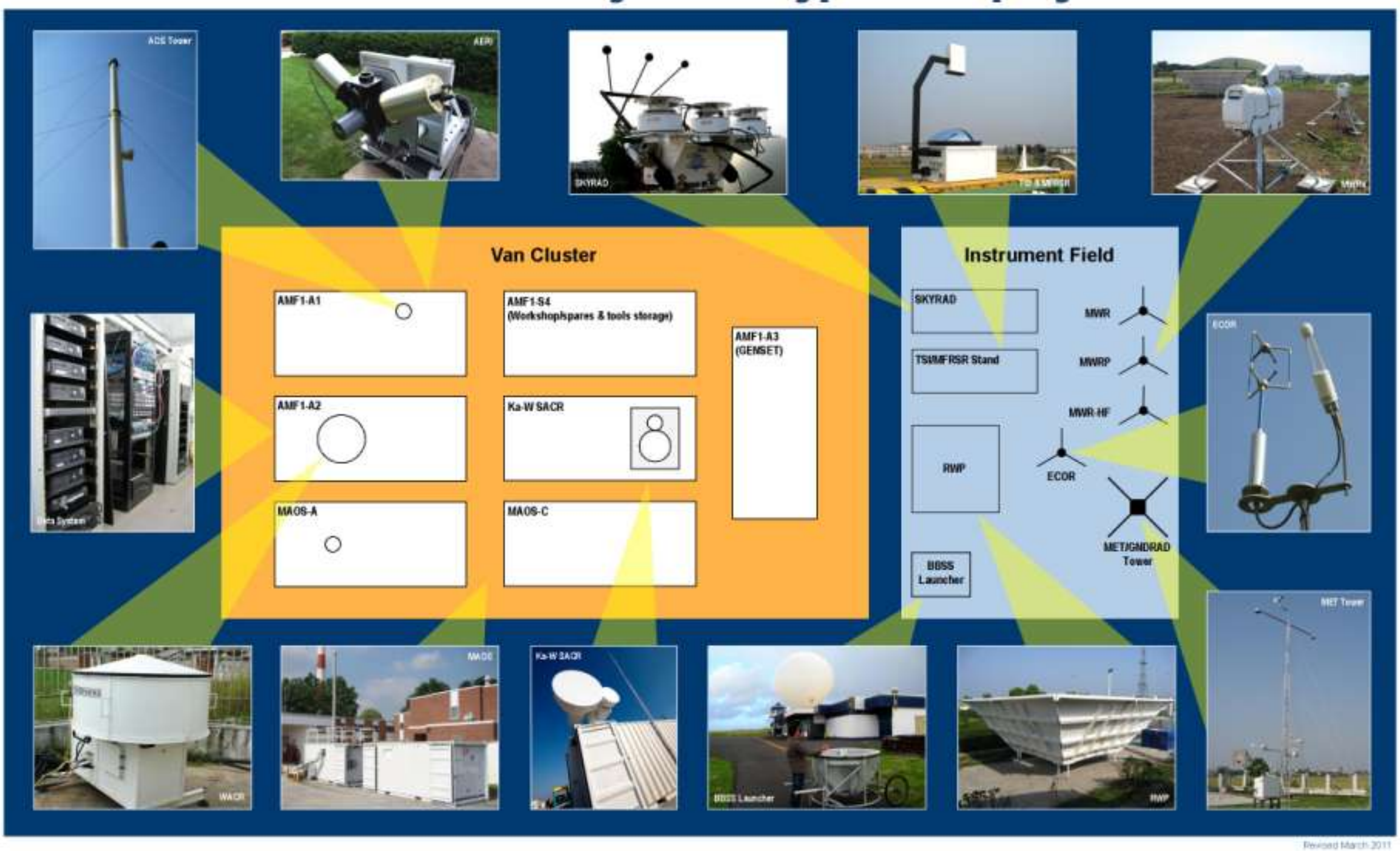
AAF Operations (aircraft)

- 15 February until 26 March 2014 (wet season) (75 hrs)
- 1 September until 10 October 2014 (dry season) (75 hrs)

Aircraft operations correspond to the two *intensive operating periods* planned for the experiment.

ARM Mobile Facility in Amazônia (AMFA)

ARM Mobile Facility One - Typical Deployment



“Intensive Airborne Research in Amazonia 2014” (IARA-2014)

The ARM Aerial Facility (AAF) in Brazil

LBA: A Program of the Ministry of Science and Technology (MCT)

Main research foci:

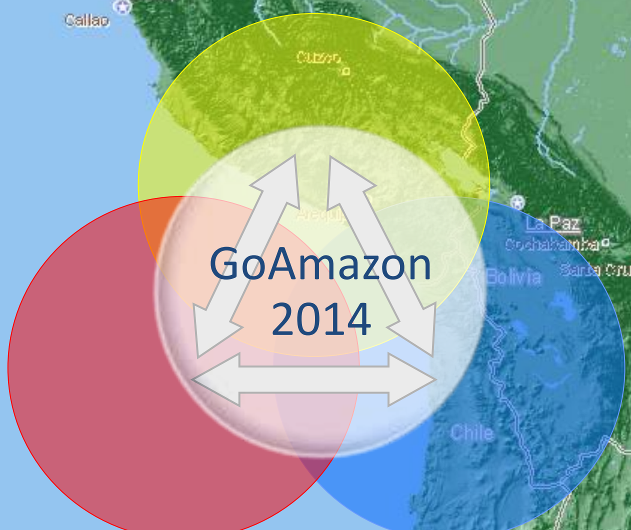
- The changing environment of Amazonia
- Environmental sustainability and the sustainability of current terrestrial and aquatic production systems
- Variability and changes in climatic and hydrologic systems – feedback, adaptation and mitigation

Integrated and interdisciplinary investigations:

Yellow: multi-scale physico-chemical interactions at biosphere-atmosphere interface;

Red: physico-chemico-biological processes in aquatic and terrestrial ecosystems and their interactions;

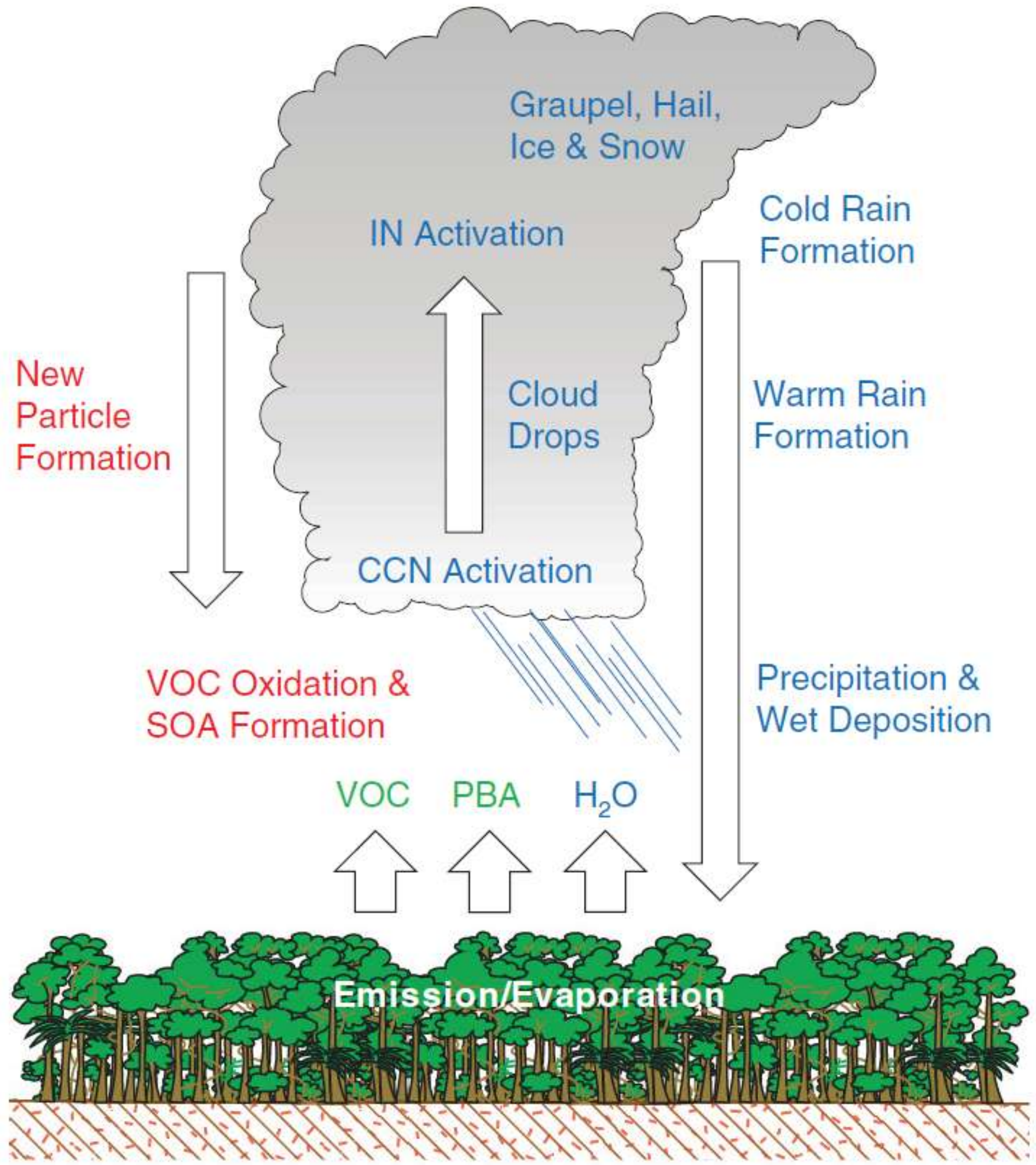
Blue: the social dimensions of environmental change and the dynamics of land cover change



Acknowledgments: Laszlo Nagy, INPA/LBA

Cloud Life Cycle, Aerosol Life Cycle, Aerosol-Cloud-Precipitation Interactions, Carbon Cycle are all represented in this schematic.

GoAmazon2014: *What is the effect of pollution on*… these cycles and the coupling among them?



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

Scientific Questions for GoAmazon2014

Note: Non-exhaustive selected list. Further development anticipated.

Carbon Cycle - improve Community Earth System Model (CESM) for land-atmosphere processes in the Amazon Basin, including aerosol-cloud-precipitation connections

- Objective - Reduce uncertainties in our knowledge of feedbacks between vegetation-hydrology that underlie the Amazon forest dieback hypothesis. The uncertain range of feedbacks at present leads to large differences in ESM predictions.
- Objective - Response of photosynthesis and transpiration, including BVOC emissions, to changes in the direct and diffuse components of incoming solar radiation, i.e., in the context of current and future scenarios of aerosols and clouds in the Amazon Basin.

Aerosol Life Cycle - accurate modeling of aerosol sources/sinks and aerosol optical, CCN, and IN properties, as affected by pollution of pristine tropical environments

- Objective - The interactions of the urban pollution plume with biogenic volatile organic compounds in the tropics, especially the impact on the production of secondary organic aerosol, the formation of new particles, and biogenic emissions of aerosols and their precursors..
- Objective - Influence of anthropogenic activities on aerosol microphysical, optical, cloud condensation nuclei (CCN), and ice nuclei (IN) properties in the tropics.

Scientific Questions for GoAmazon2014

Note: Non-exhaustive selected list. Further development anticipated.

Cloud Life Cycle - development of a knowledge base to improve tropical cloud parameterizations in GCMs

- Objective - The transition from shallow to deep cumulus convection during the daily cycle of the Amazon Basin, with comparison and understanding to other environments.
- Objective - The role of landscape heterogeneity—the Manaus urban area as well as the 10-km-scale of river width—on the dynamics of convection and clouds (+carbon cycle)
- Objective - The evolution of convective intensity from severe storms in the dry season to moderate storms in the wet season.

Cloud-Aerosol-Precipitation Interactions - improvement of parameterizations of aerosol-cloud interactions in climate models

- Objective - Aerosol effects on deep convective clouds, precipitation, and lightning under different aerosol and synoptic regimes, including the roles of aerosols in changing regional climate and atmospheric circulation.
- Objective - Data-driven improvement of parameterizations of aerosol-cloud interactions in the climate models.

FAPESP

FAPESP RESEARCH PROGRAM ON GLOBAL CLIMATE CHANGE

STEERING COMMITEE

Reynaldo Luiz Victoria - USP
Paulo Artaxo - USP
Humberto Rocha - USP
Carlos Afonso Nobre - INPE
Gilberto Câmara - INPE
Newton LaScala Jr - UNESP
Gilberto Januzzi – UNICAMP

RESEARCH TO ADVANCE THE KNOWLEDGE ON CLIMATE CHANGE

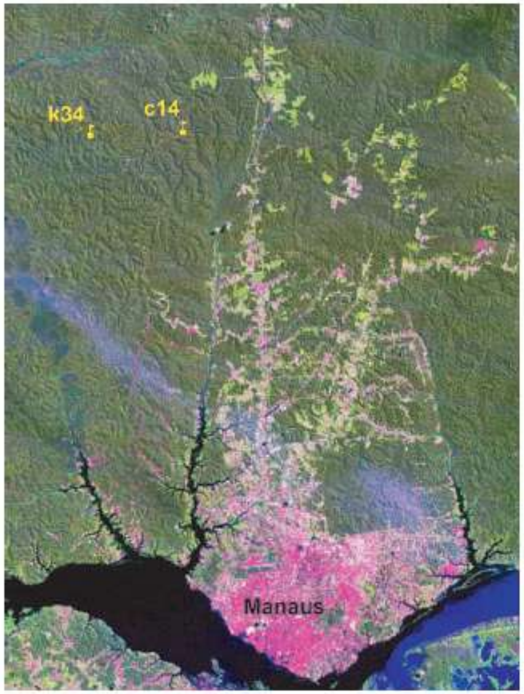
AEROCLIMA - Direct and indirect effects of aerosols on climate in Amazonia and Pantanal

Team: Paulo Artaxo (IFUSP), Maria Assunção F. da Silva Dias (IAG-USP),

Henrique M. J. Barbosa , (IFUSP), Luciana V. Rizzo (UNIFESP-Diadema), Theotonio Pauliquevis (UNIFESP-Diadema), Márcia A. Yamasoe (IAG-USP), Karla M. Longo (INPE), Saulo de Freitas (INPE), Plínio Alvalá (INPE), Ênio B. Pereira (INPE), Judith Hoelzemann (UFRGN), Rodrigo de Souza (UEA, Manaus), David Adams (UEA, Manaus), Wanderlei Bastos (UNIR, Rondônia), Sandra Hacon (FIOCRUZ), Hillândia Brandão (INPA-LBA), Fernando Gonçalvez (IFUSP), Alcides C. Ribeiro (IFUSP), Ana L. Loureiro (IFUSP), Fábio Jorge (IFUSP).

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),

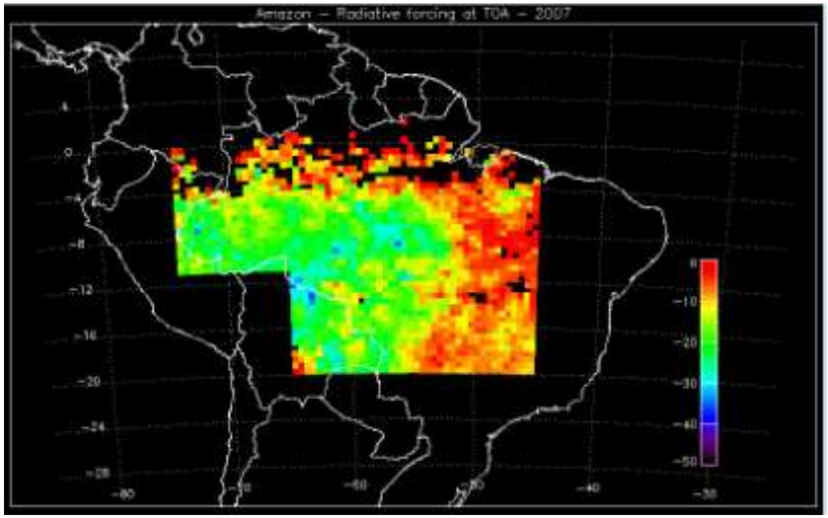
- Site: 100 Km North of Manaus. Measurements: from Feb 2008 up to now.
- Continuation as a permanent sampling site.
- Three towers at the site, from 35 to 55 meters.
- Dryer to get aerosol at 30-40% RH

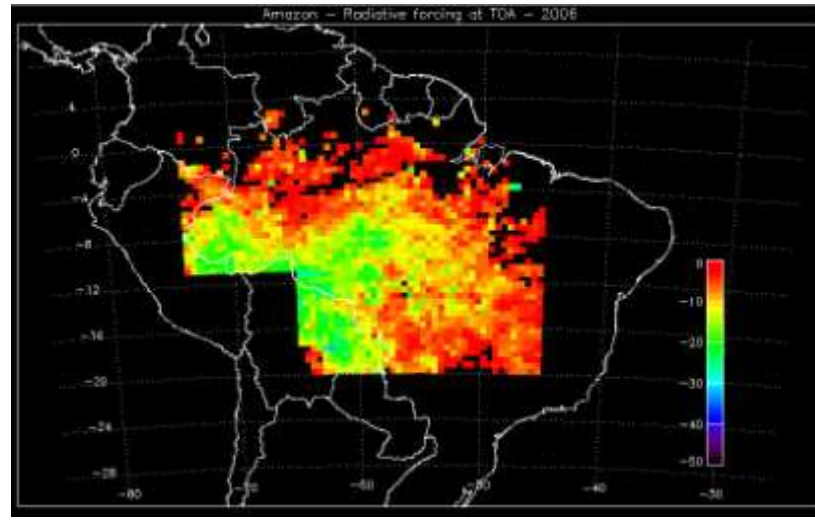


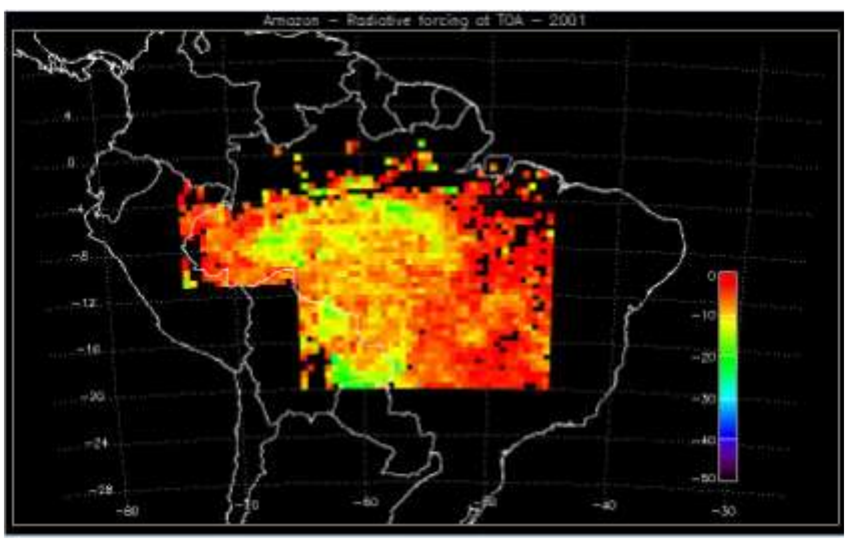
Rondonia - Porto Velho aerosol and trace gases measurement site

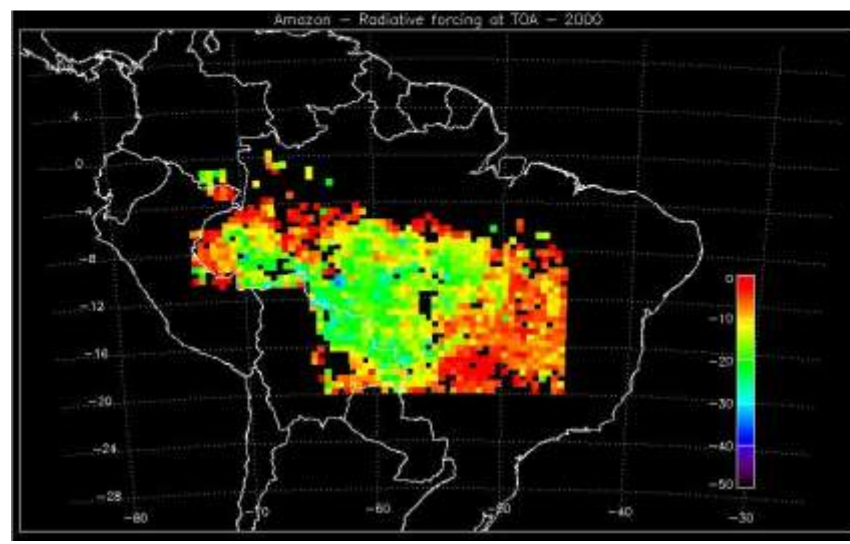
Large scale radiative forcing in Amazonia from 2000 to 2007

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



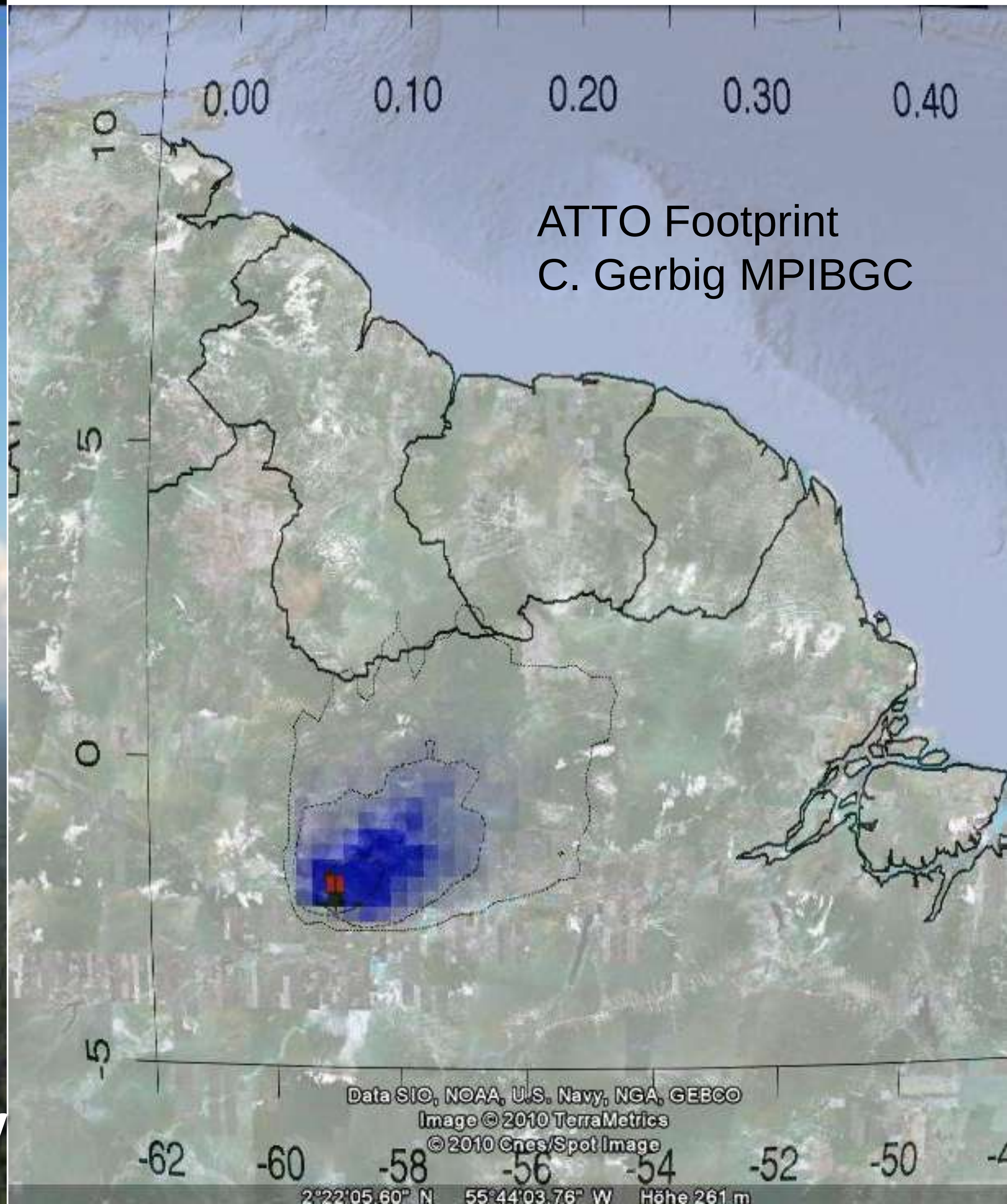


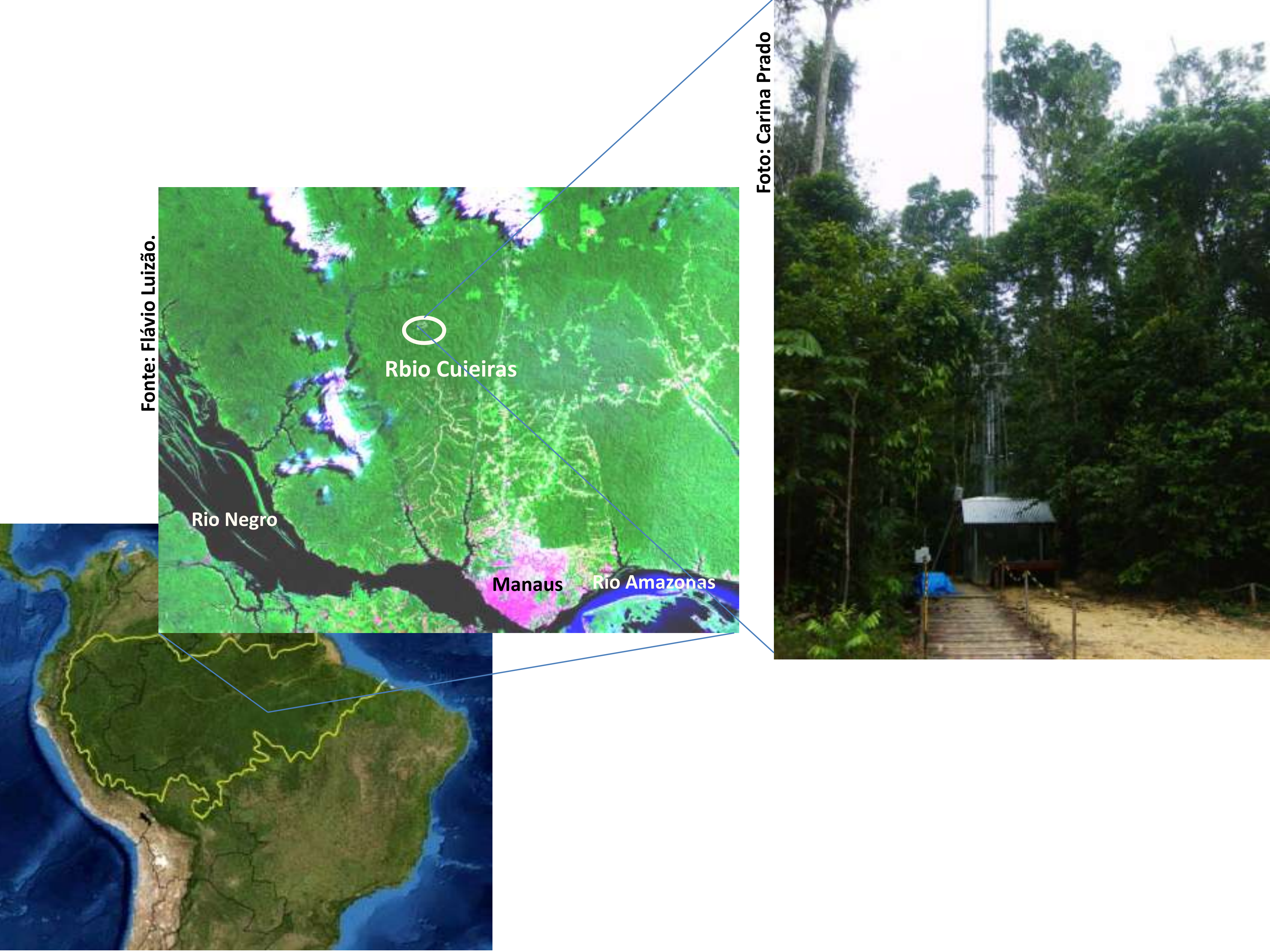


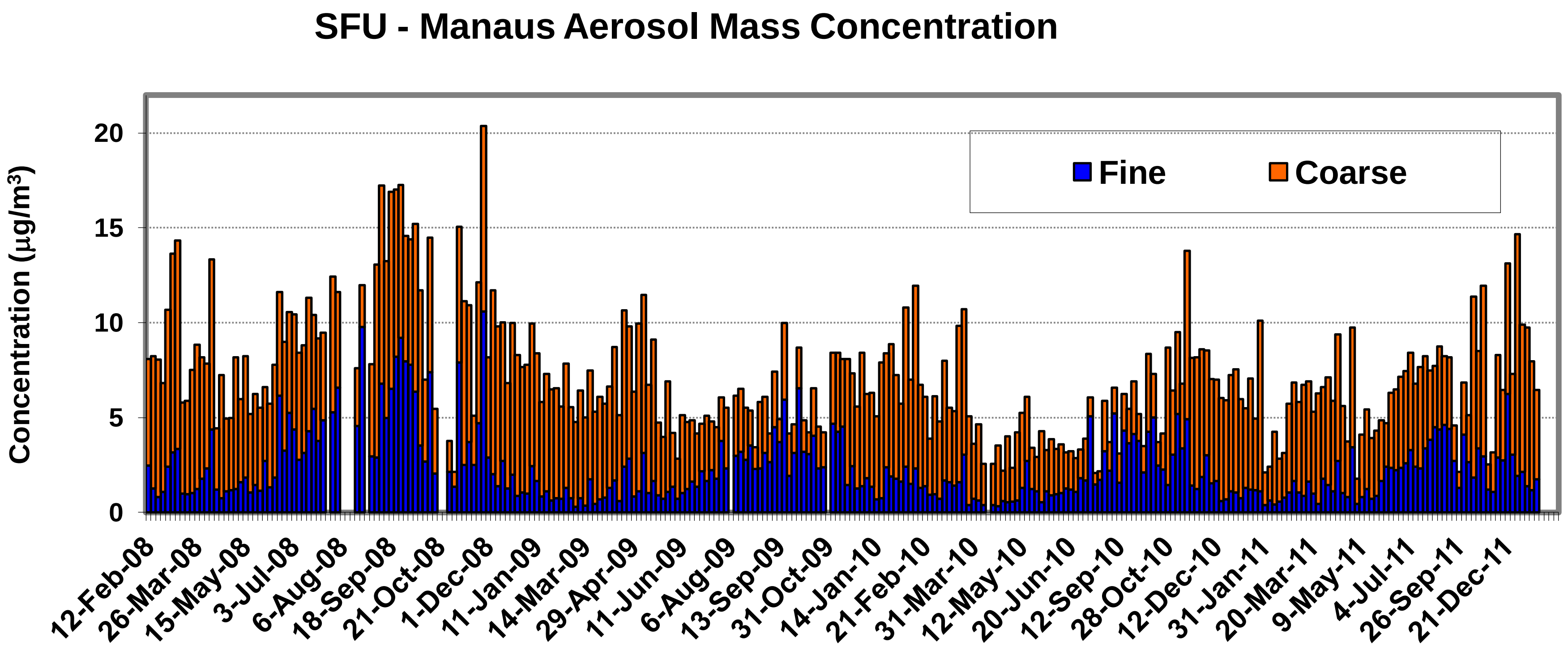


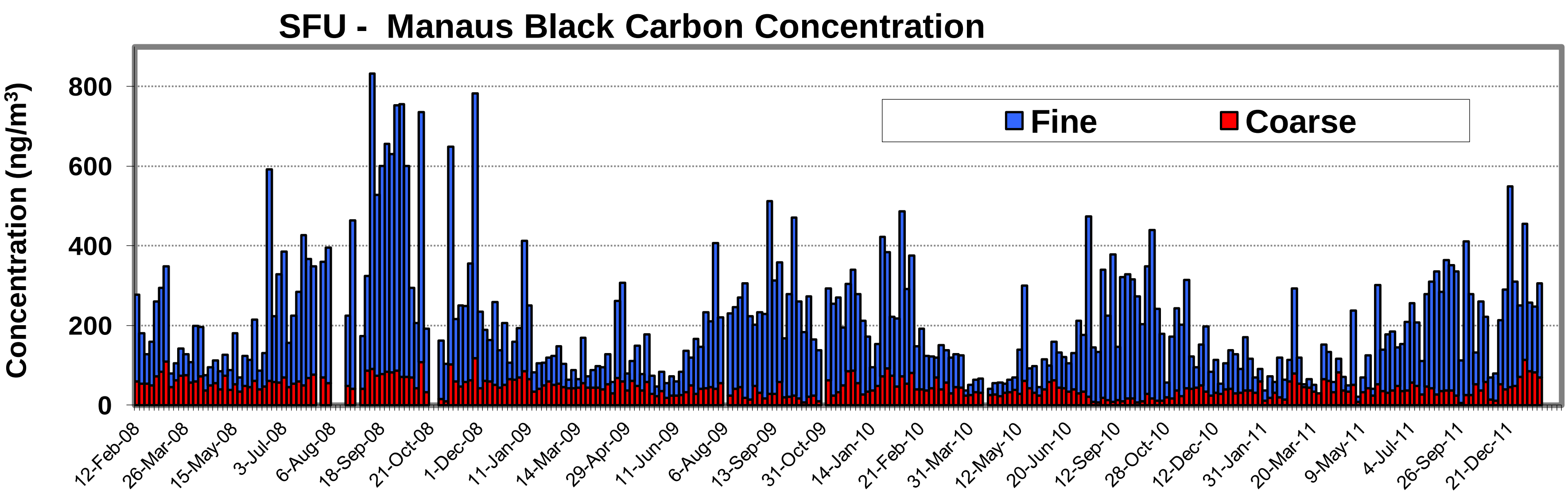
Elisa Thomé Sena, PhD Student IFUSP

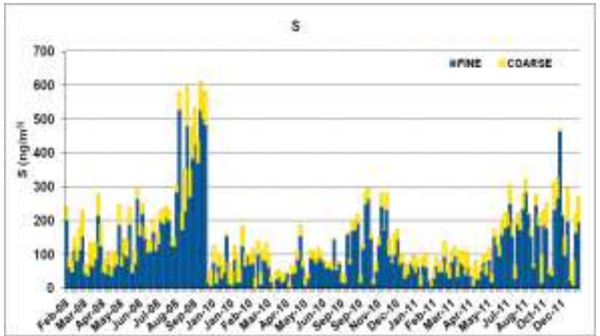
Amazonian Tall Tower Observatory
ATTO – 320 meters
Long term broad objectives observatory

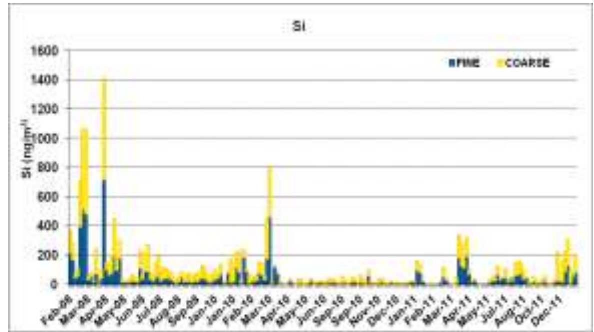



Fonte: Flávio Luizão.
Rbio Cuieiras
Rio Negro
Manaus
Rio Amazonas
Foto: Carina Prado

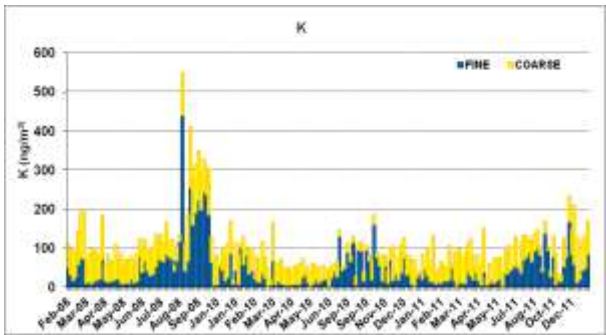

SFU - Manaus Aerosol Mass Concentration
Concentration (µg/m³)
20
15
10
5
0
Fine
Coarse
12-Feb-08
26-Mar-08
15-May-08
3-Jul-08
6-Aug-08
18-Sep-08
21-Oct-08
1-Dec-08
11-Jan-09
14-Mar-09
29-Apr-09
11-Jun-09
6-Aug-09
13-Sep-09
31-Oct-09
14-Jan-10
21-Feb-10
31-Mar-10
12-May-10
20-Jun-10
12-Sep-10
28-Oct-10
12-Dec-10
31-Jan-11
20-Mar-11
9-May-11
4-Jul-11
26-Sep-11
21-Dec-11

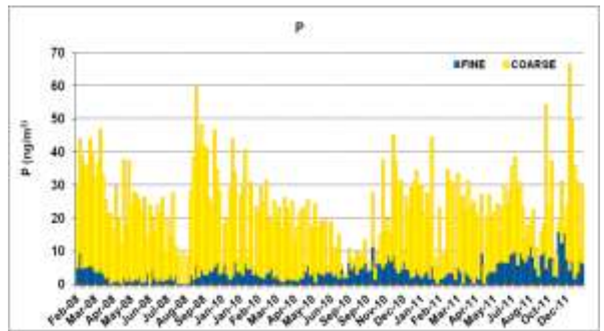

SFU - Manaus Black Carbon Concentration
Concentration (ng/m³)
800
600
400
200
0
Fine
Coarse
12-Feb-08
26-Mar-08
15-May-08
3-Jul-08
6-Aug-08
18-Sep-08
21-Oct-08
1-Dec-08
11-Jan-09
14-Mar-09
29-Apr-09
11-Jun-09
6-Aug-09
13-Sep-09
31-Oct-09
14-Jan-10
21-Feb-10
31-Mar-10
12-May-10
20-Jun-10
12-Sep-10
28-Oct-10
12-Dec-10
31-Jan-11
20-Mar-11
9-May-11
4-Jul-11
26-Sep-11
21-Dec-11

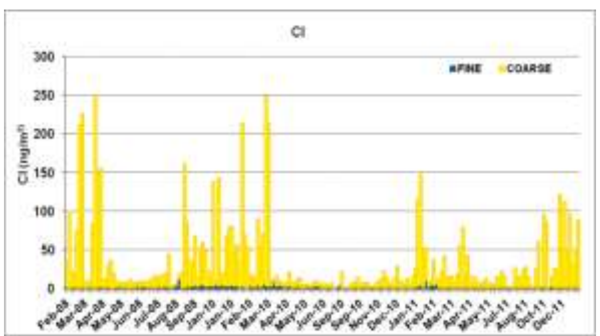




Trace elements time series for S, Si, K, P, Cl
Fine Mode: Blue,
Coarse mode: yellow







Manaus

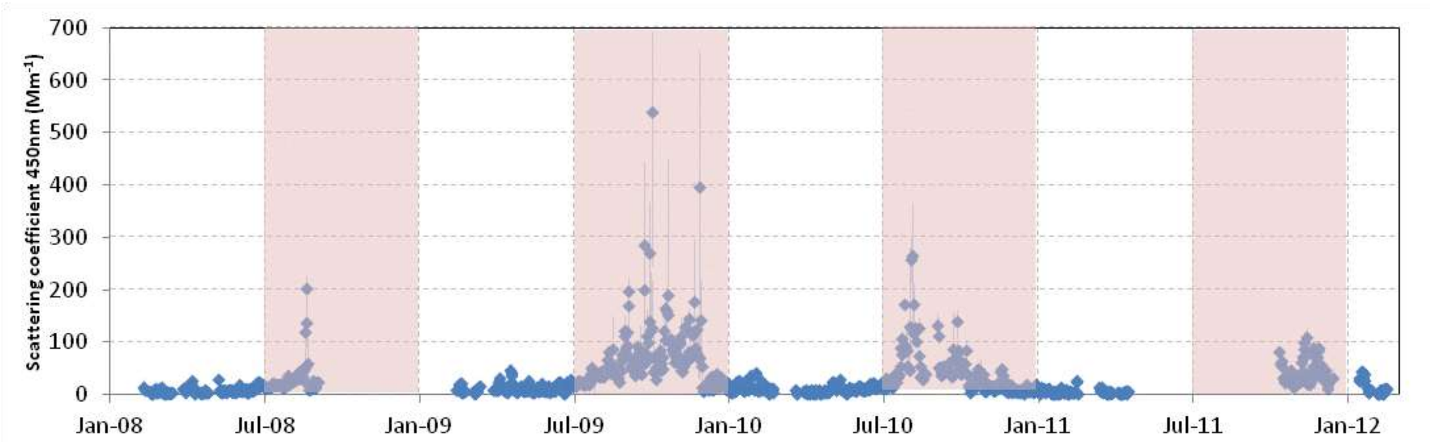


Figure 3.1.1.1: Medianas diárias do coeficiente de espalhamento medido em 450 nm, de Fev 2008 a Fevereiro de 2012. As barras de erros representam o primeiro e terceiro quartil. As áreas sombreadas representam os períodos da estação seca (Julho a Dezembro).

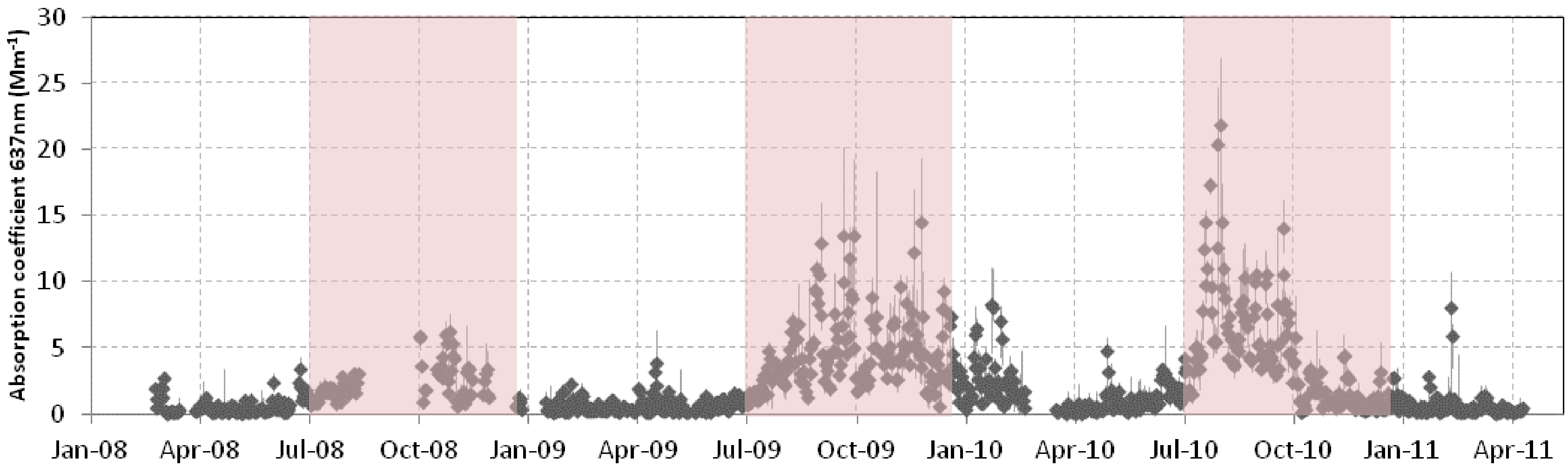


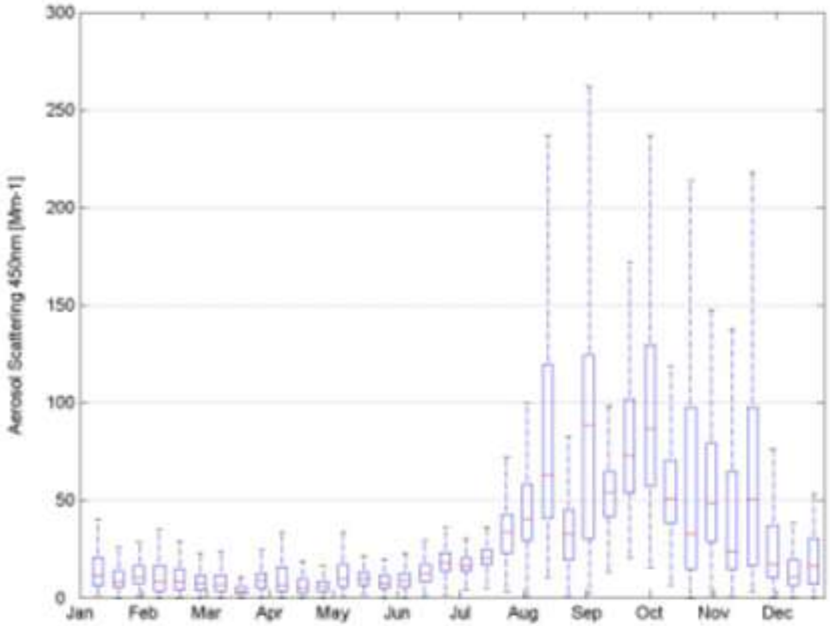
Figura 3.1.1.2: Medianas diárias do coeficiente de absorção medido em 450 nm, de Fev 2008 a Fevereiro de 2012. As barras de erros representam o primeiro e terceiro quartil. As áreas sombreadas representam os períodos da estação seca (Julho a Dezembro).

	Aerosol Scattering 450 nm [Mm^{-1}]				Aerosol Absorption 637 nm [Mm^{-1}]			
	median	1st quartile	3rd quartile	coverage	median	1st quartile	3rd quartile	coverage
Dry 2008	21	15	29	36.4%	1.86	1.13	2.92	51.1%
Dry 2009	47	26	84	98.9%	3.69	2.06	6.07	95.1%
Dry 2010	24	13	47	84.8%	3.00	1.15	5.62	98.4%
Wet 2008	7.5	4.0	12	59.9%	0.34	0.16	0.80	59.3%
Wet 2009	10	6	18	58.6%	0.41	0.22	0.88	85.6%
Wet 2010	10	6	16	82.3%	0.95	0.34	2.22	84.0%
Wet 2011	5.4	2.9	8.9	51.1%	0.37	0.17	0.79	67.0%
All data	15	7.3	31	73.2%	1.11	0.36	3.02	87.4%
Dry season	31	17	59	73.3%	2.85	1.38	5.18	81.5%
Wet season	8.3	4.7	14	73.1%	0.47	0.21	1.12	93.1%

Tabela 3.1.1.1: Manaus: Variabilidade ano a ano nos coeficientes de espalhamento e de absorção, e respectiva porcentagem de cobertura de dado.

	Ångström exponent				Single Scattering Albedo			
	median	1st quartile	3rd quartile	coverage	median	1st quartile	3rd quartile	coverage
All data	1.45	1.15	1.80	73.2%	0.88	0.83	0.91	69.5%
Dry season	1.53	1.28	1.86	73.3%	0.88	0.84	0.91	68.3%
Wet season	1.36	1.01	1.74	73.1%	0.88	0.81	0.93	70.6%

Tabela 3.1.1.2: Estatísticas do expoente de Ångström e do albedo de espalhamento único de Fev 2008 a Fev 2012 em Manaus.



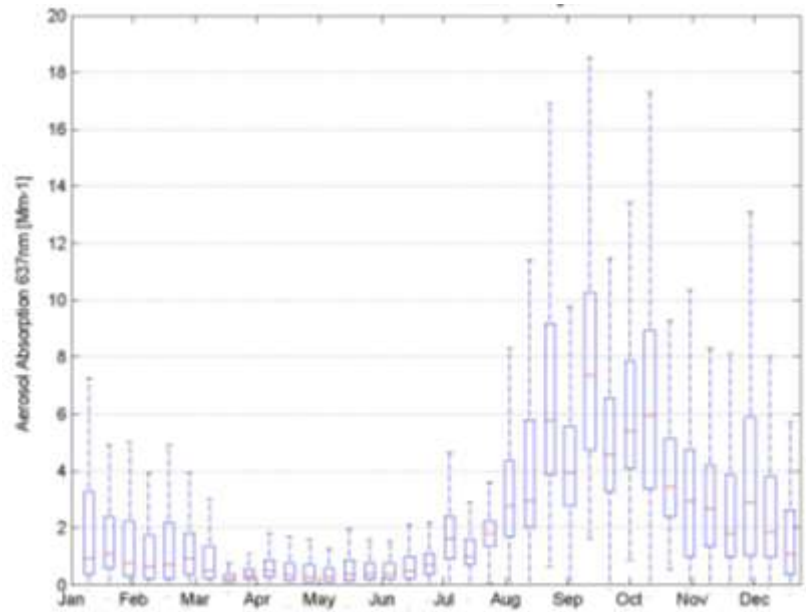


Figura 3.1.1.3 (esquerda) e Figura 3.1.1.4 (direita) mostram a forte sazonalidade do coeficiente de espalhamento em 450 nm e de absorção em 637 nm de Fev. 2008 a Fev. 2012. Médias a cada 10 dias julianos de 2008 a 2012.

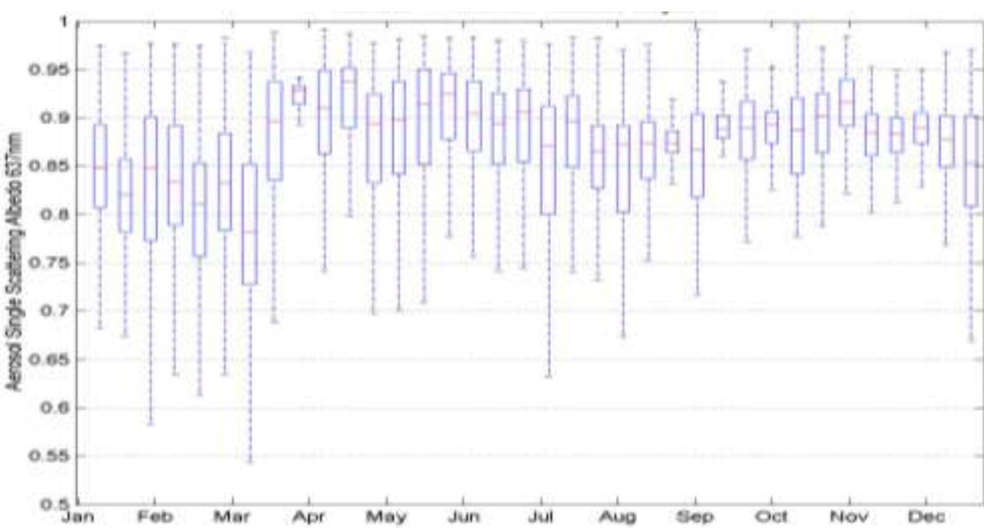


Figura 3.1.1.5: Variabilidade anual do albedo de espalhamento único em 637 nm de Fev. 2008 a Fev. 2012. Médias a cada 10 dias.

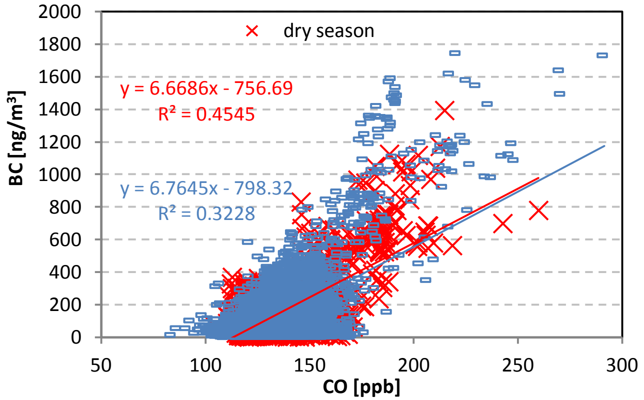
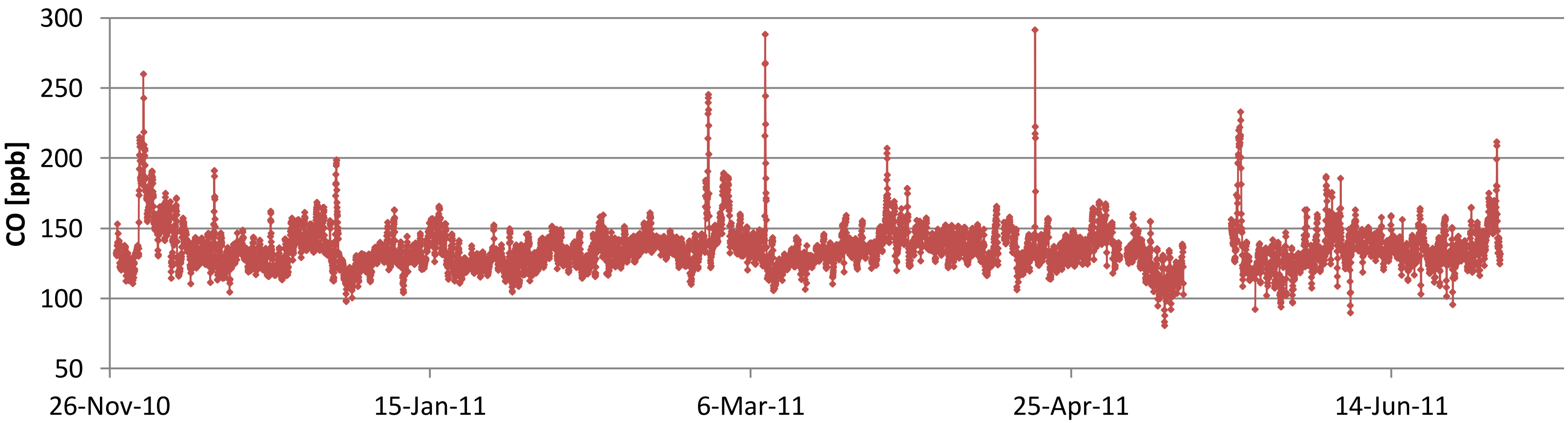


Figura 3.1.2.4: Correlação entre as concentrações de Black Carbon e CO, medidas na TT34 entre novembro de 2010 e junho de 2011.

Estação	Período	Concentração (cm^{-3})	Black carbon ($\mu g/m^3$)	Espalhamento 530 nm (10^{-6} m^{-1})
Amazônia ZF2, TT34	Estação chuvosa 2008-2011	480 ± 500	0,14 ± 0,22	8 ± 9
	Estação seca 2008-2011	1400 ±1000	0,59 ± 0,55	38 ± 64
Porto Velho	Estação chuvosa 2010-2012		0,37 ± 0,85	26 ± 21
	Estação seca 2009-2011		1,4 ± 2,7	160 ± 270
Pantanal	Estação chuvosa 2012	1100 ± 430	0,15 ± 0,16	6,5 ± 3,5

Tabela 3.1.1.3 – Médias dos valores de concentrações de partículas, Black Carbon e coeficiente de espalhamento para as 3 estações do projeto AEROCLIMA.

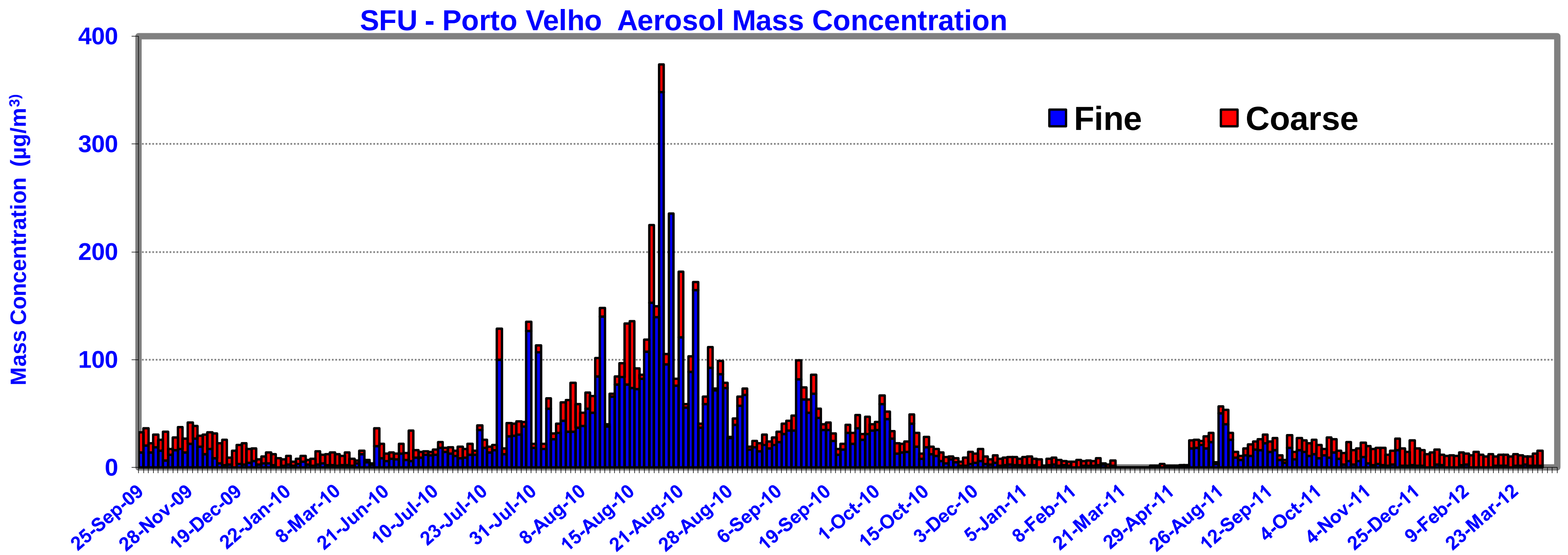


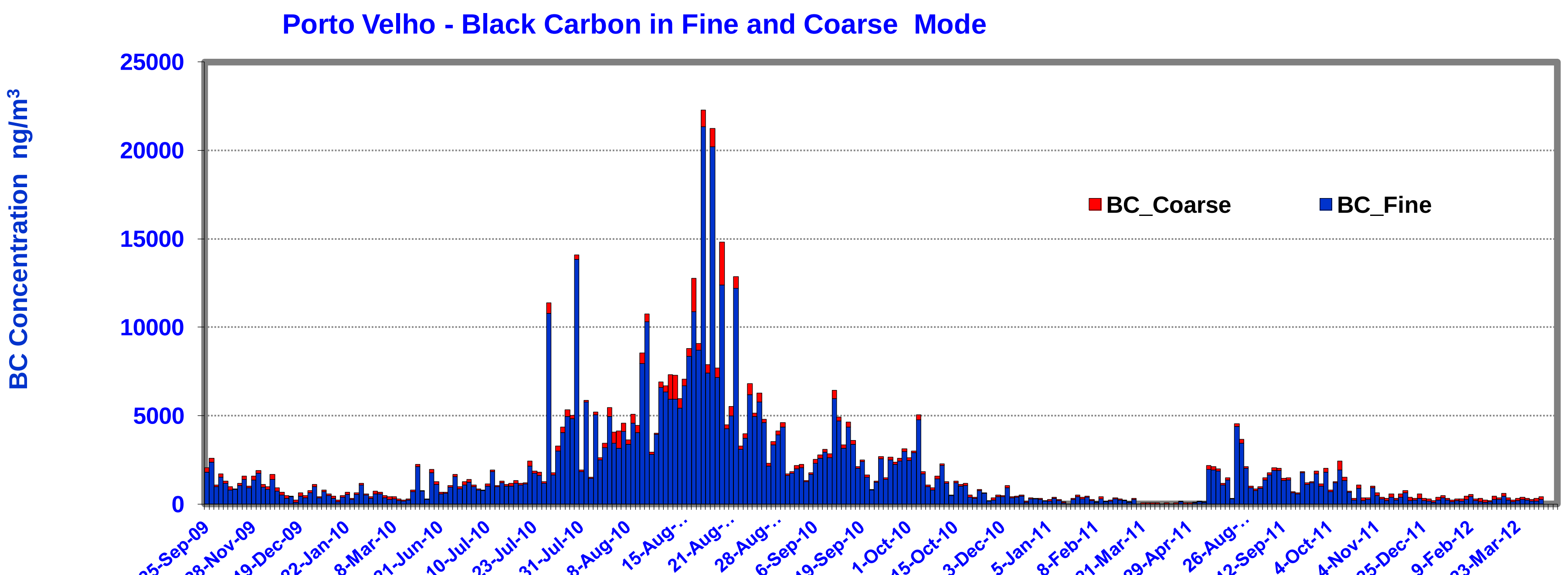
Séries temporais de CO

Figura 4.1: a e b) Parque Natural de Porto Velho; c) Estação com temperatura e umidade controlada para abrigar os equipamentos.


1
2
3
4
5
6
7
8
9
10
11
FOTO BY AC RIBEIRO

Porto Velho


SFU - Porto Velho Aerosol Mass Concentration
Mass Concentration (µg/m³)
400
300
200
100
0
Fine
Coarse
25-Sep-09
28-Nov-09
19-Dec-09
22-Jan-10
8-Mar-10
21-Jun-10
10-Jul-10
23-Jul-10
31-Jul-10
8-Aug-10
15-Aug-10
21-Aug-10
28-Aug-10
6-Sep-10
19-Sep-10
1-Oct-10
15-Oct-10
3-Dec-10
5-Jan-11
8-Feb-11
21-Mar-11
29-Apr-11
26-Aug-11
12-Sep-11
4-Oct-11
4-Nov-11
25-Dec-11
9-Feb-12
23-Mar-12


Porto Velho - Black Carbon in Fine and Coarse Mode
BC Concentration ng/m³
25000
20000
15000
10000
5000
0
BC_Coarse
BC_Fine
25-Sep-09
28-Nov-09
19-Dec-09
22-Jan-10
8-Mar-10
21-Jun-10
10-Jul-10
23-Jul-10
31-Jul-10
8-Aug-10
15-Aug-..
21-Aug-..
28-Aug-..
6-Sep-10
19-Sep-10
1-Oct-10
15-Oct-10
3-Dec-10
5-Jan-11
8-Feb-11
21-Mar-11
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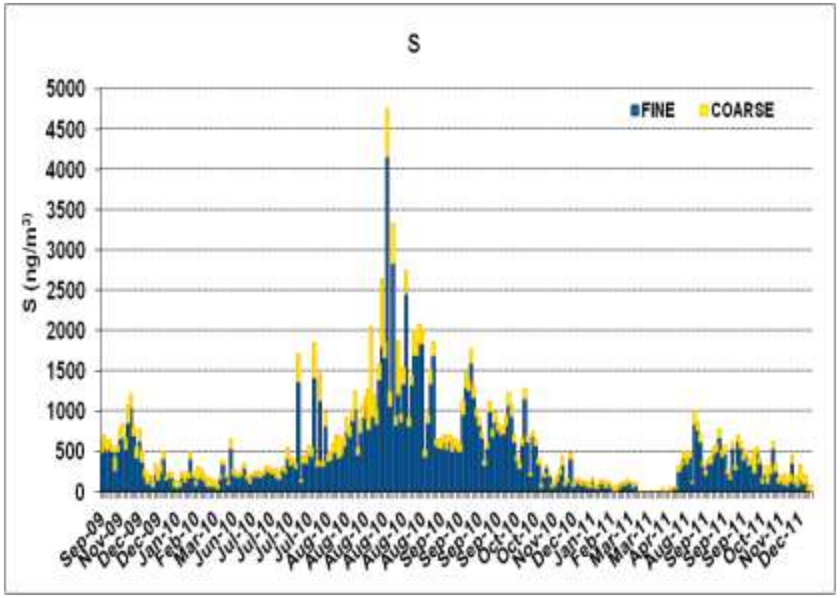
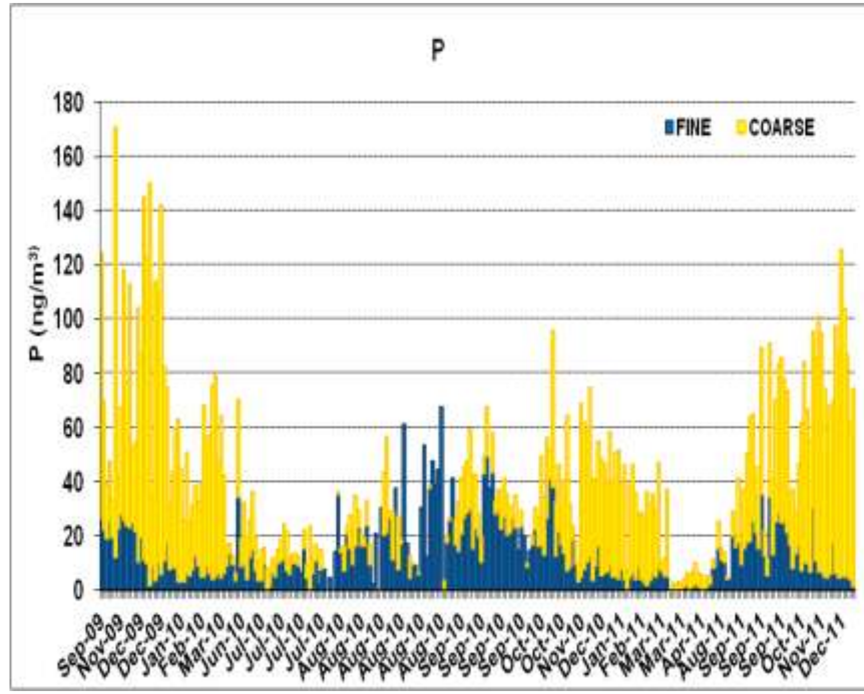
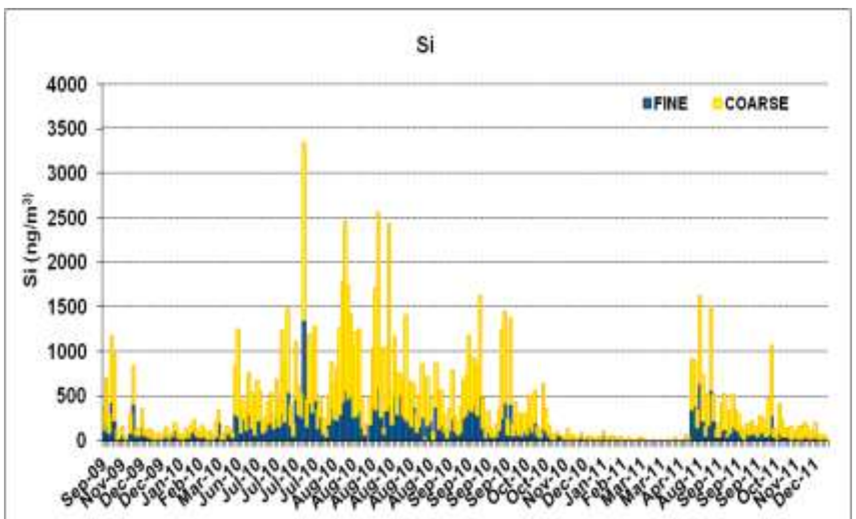
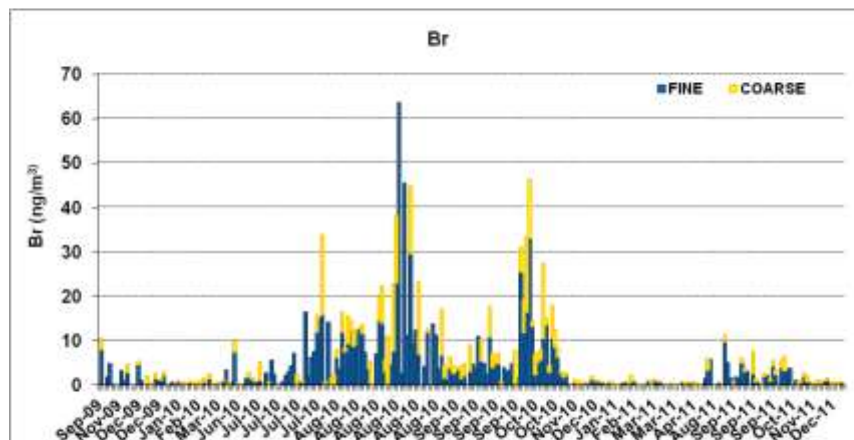
25-Dec-11
9-Feb-12
23-Mar-12


S
FINE
COARSE
S (ng/m³)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0


P
FINE
COARSE
P (ng/m³)
180
160
140
120
100
80
60
40
20
0


Si
FINE
COARSE
Si (ng/m³)
4000
3500
3000
2500
2000
1500
1000
500
0


Br
FINE
COARSE
Br (ng/m³)
70
60
50
40
30
20
10
0

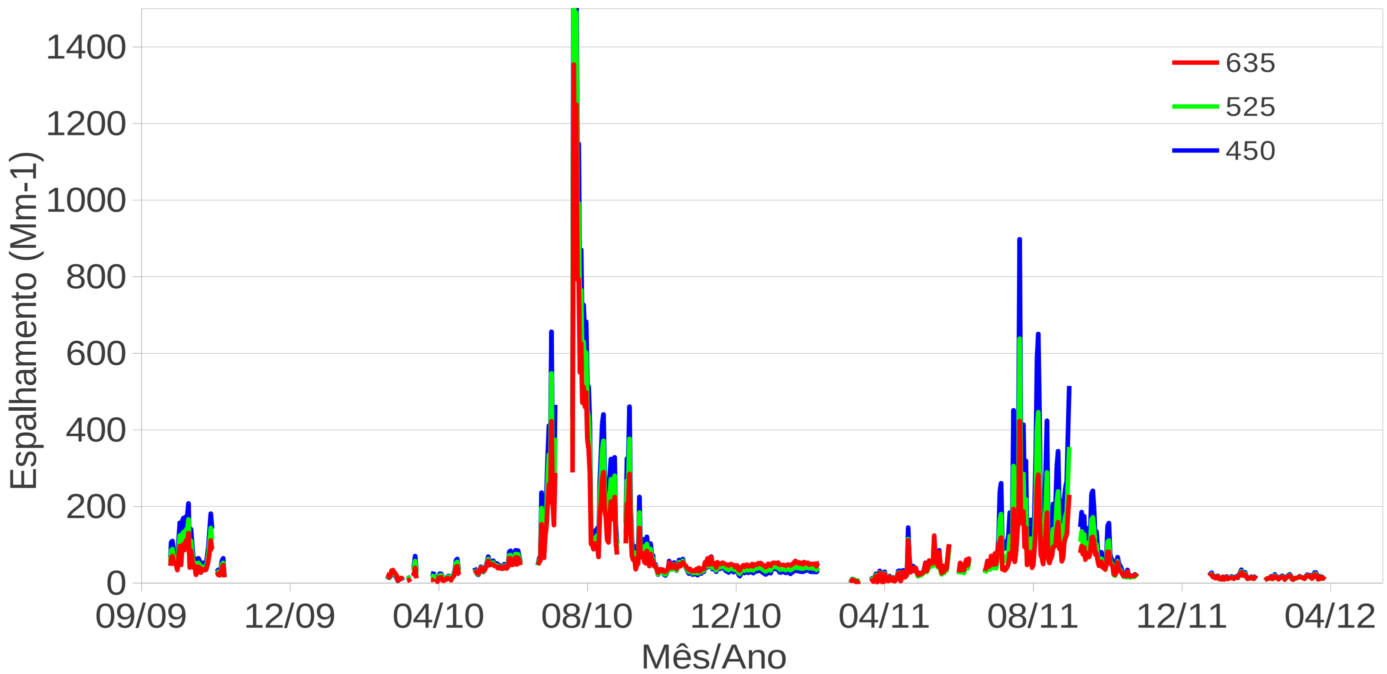
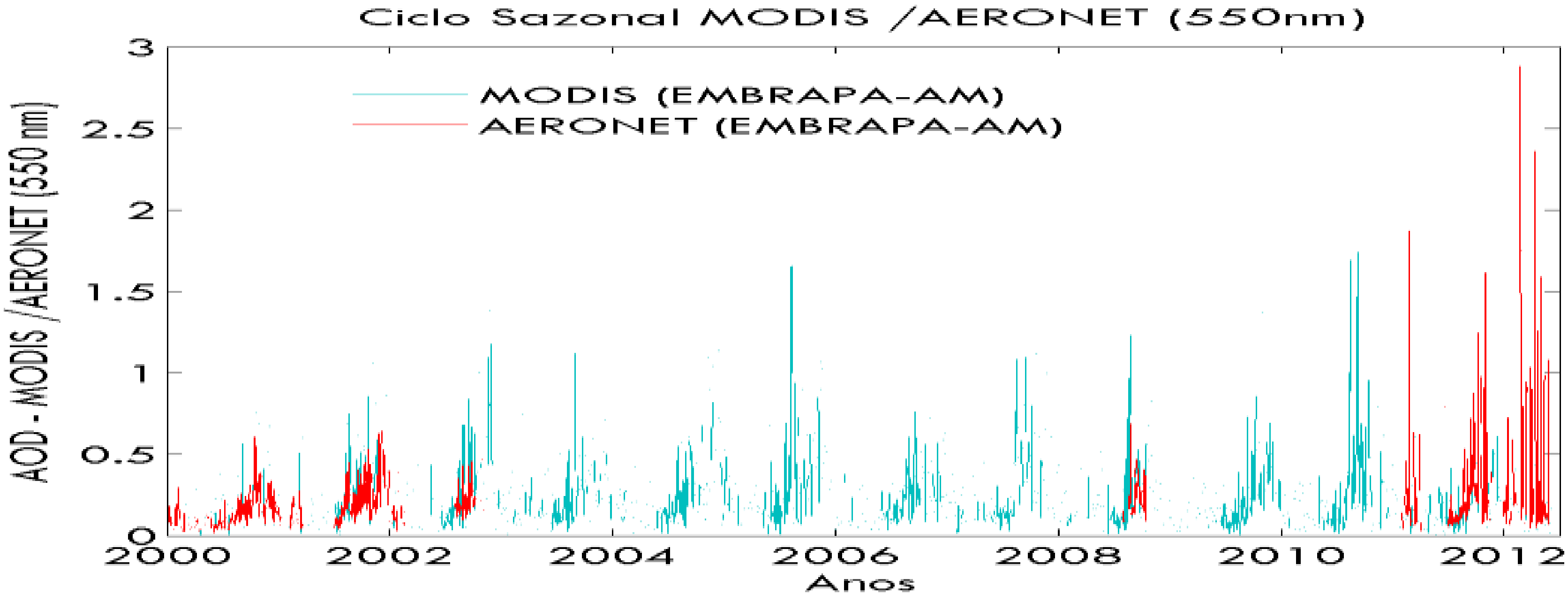
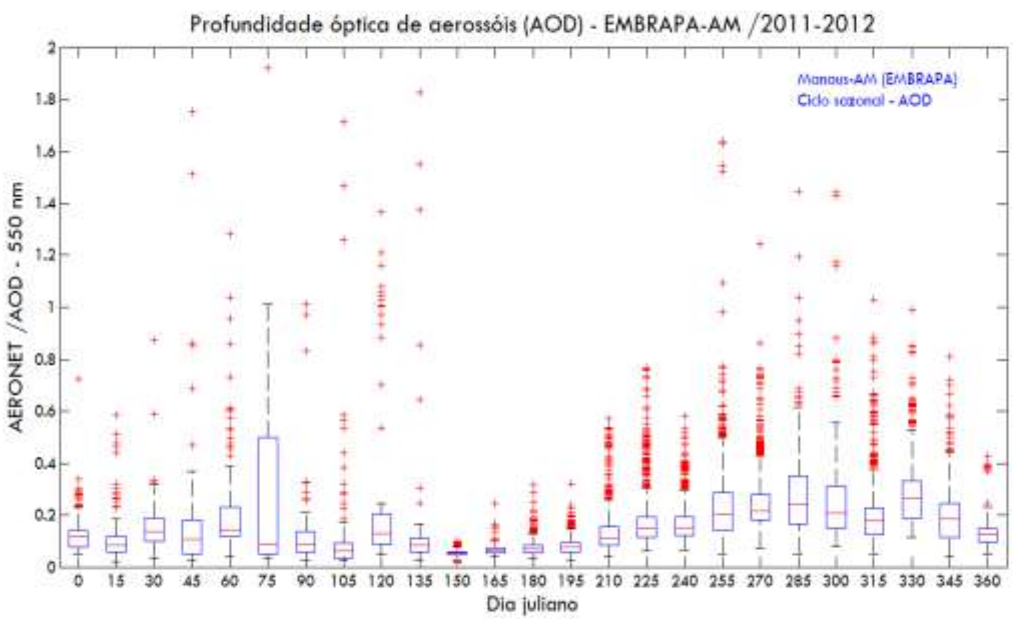


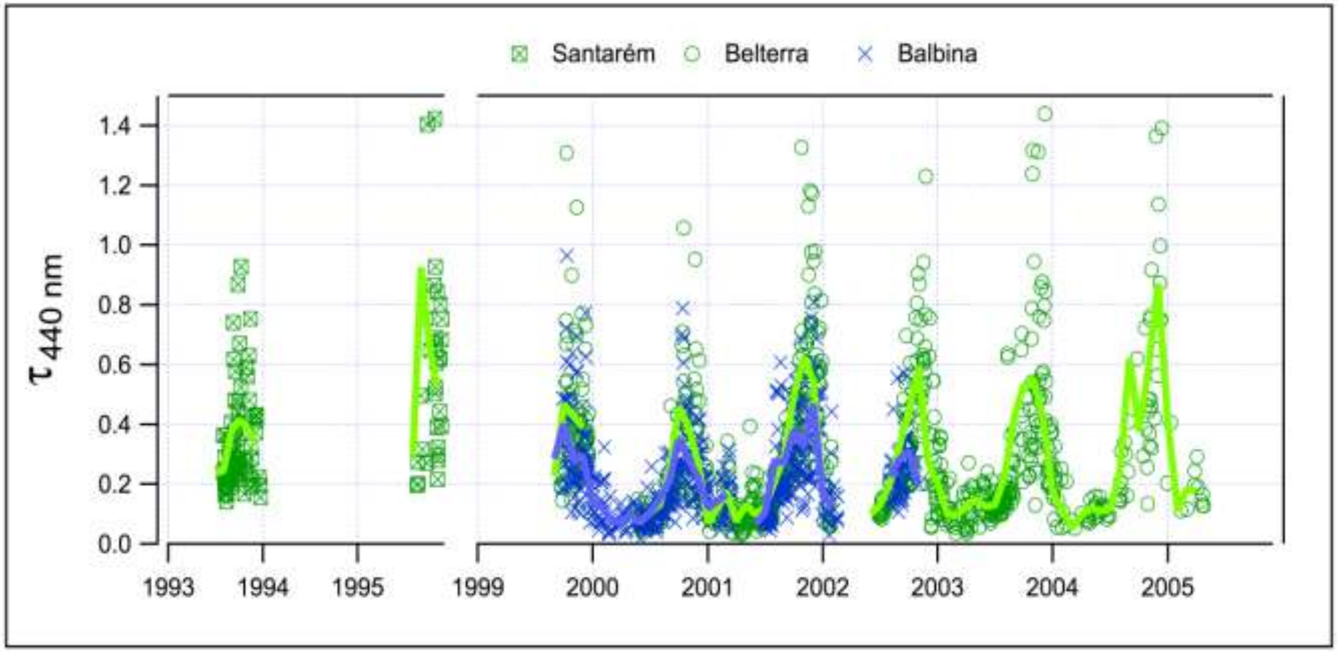
Figura 1. Série temporal de médias diárias do espalhamento de radiação pelo aerossol em Porto Velho, de 2009 a 2012. Os comprimentos de onda são indicados em nm na legenda.

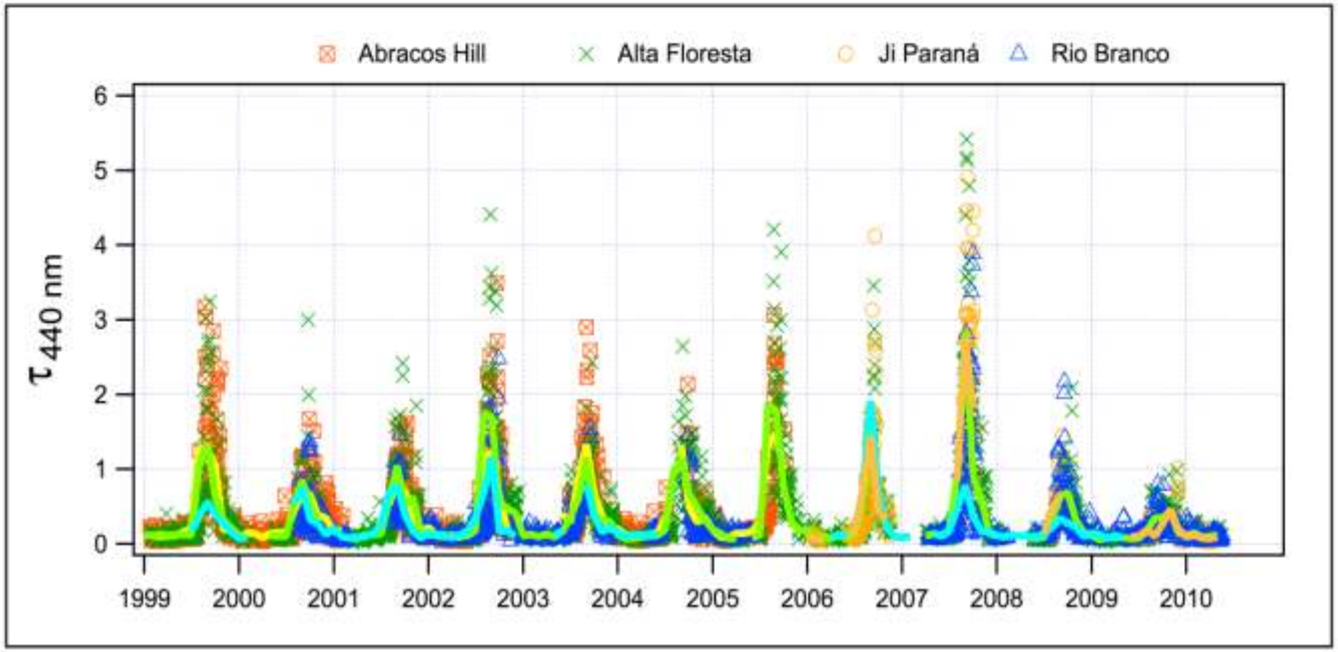
	Espalhamento de radiação (Mm-1)					
Ano	Estação seca			Estação úmida		
	450 nm	525 nm	635 nm	450 nm	525 nm	635 nm
2009	97,2±60,0	77,2±47,2	60,6±35,9	--	--	--
2010	284±445	244±388	199±311	28,8±27,5	26,4±23,8	22,8±22,1
2011	174±200	123±139	87,4±88,9	29,9±23,3	31,2±21,2	36,6±27,7
2012	--	--	--	15,4±9,13	13,9±7,47	13,8±6,8
No. pontos	10713	10713	10713	19024	19024	19024
Média	205±318	164±270	127±213	26,1±22,8	25,8±20,8	27,8±24,9

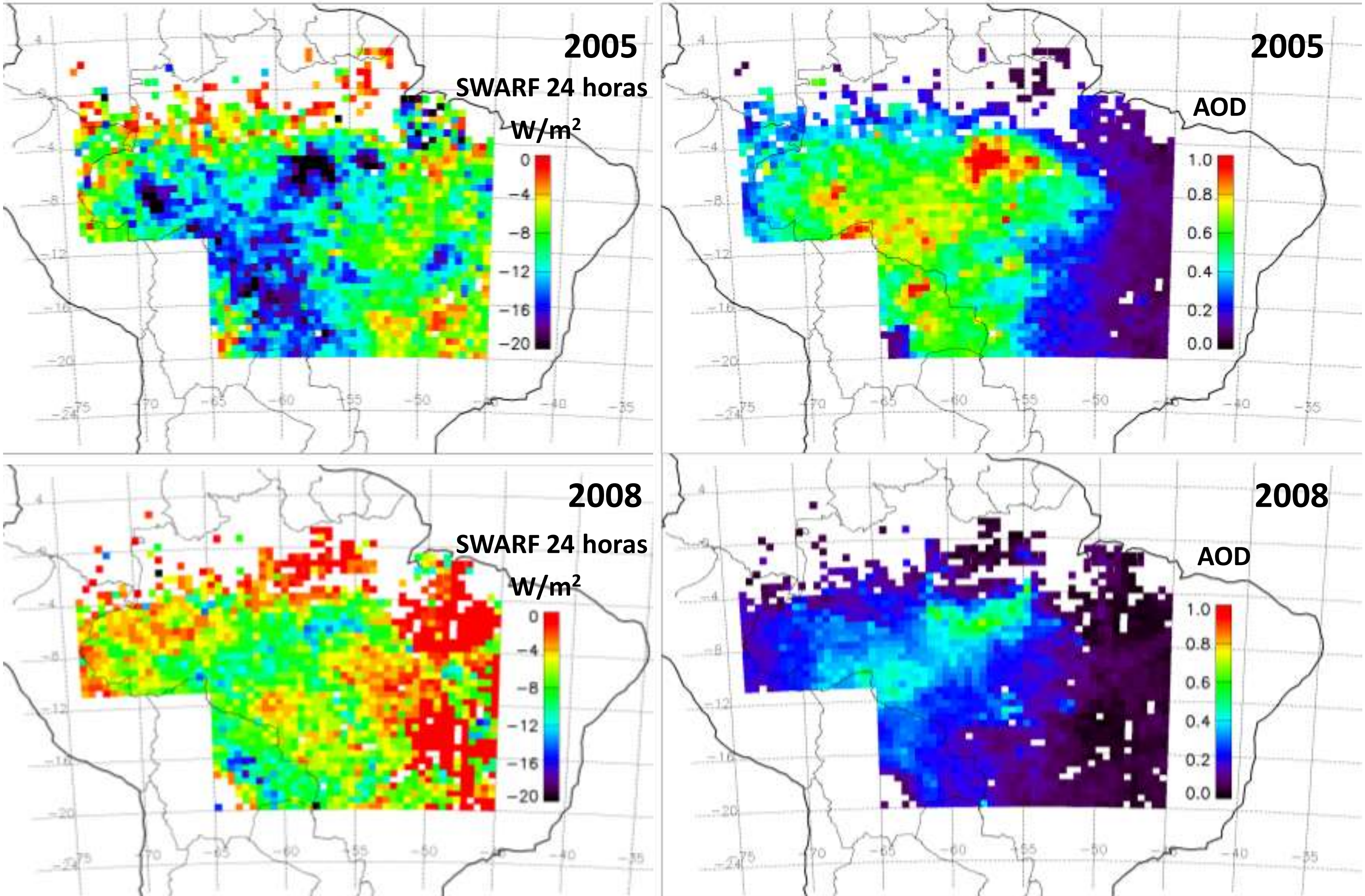
Tabela 3.2.1.1. Valores médios e desvio padrão do espalhamento de radiação pelo aerossol em Porto Velho, segundo ano, estação e comprimento de onda.

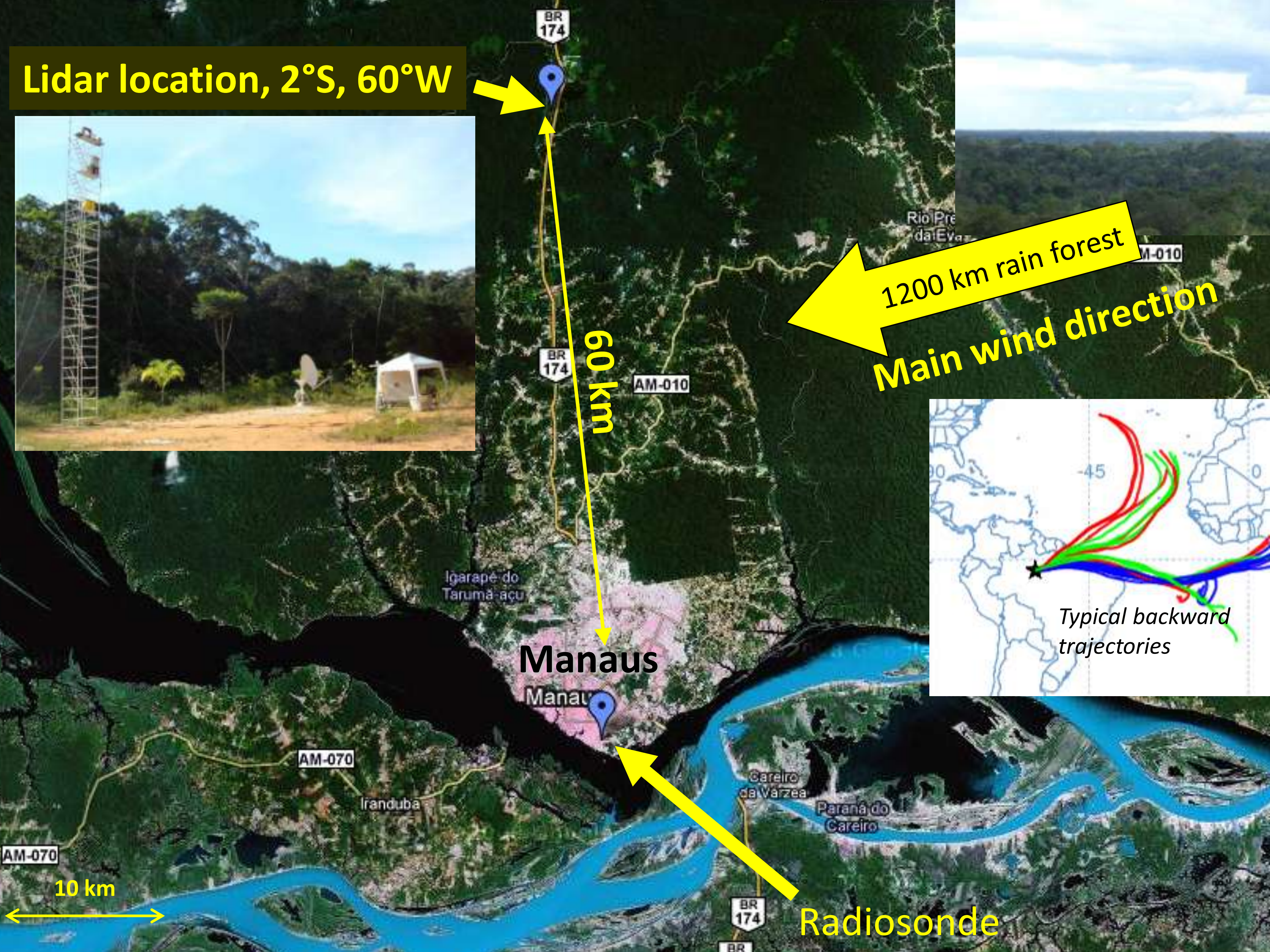

Ciclo Sazonal MODIS /AERONET (550nm)
MODIS (EMBRAPA-AM)
AERONET (EMBRAPA-AM)
AOD - MODIS /AERONET (550 nm)
Anos
0
0.5
1
1.5
2
2.5
3
2000
2002
2004
2006
2008
2010
2012


Profundidade óptica de aerossóis (AOD) - EMBRAPA-AM /2011-2012
Manaus-AM (EMBRAPA)
Ciclo sazonal - AOD
AERONET /AOD - 550 nm
Dia juliano
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360


Santarém
Belterra
Balbina
τ 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

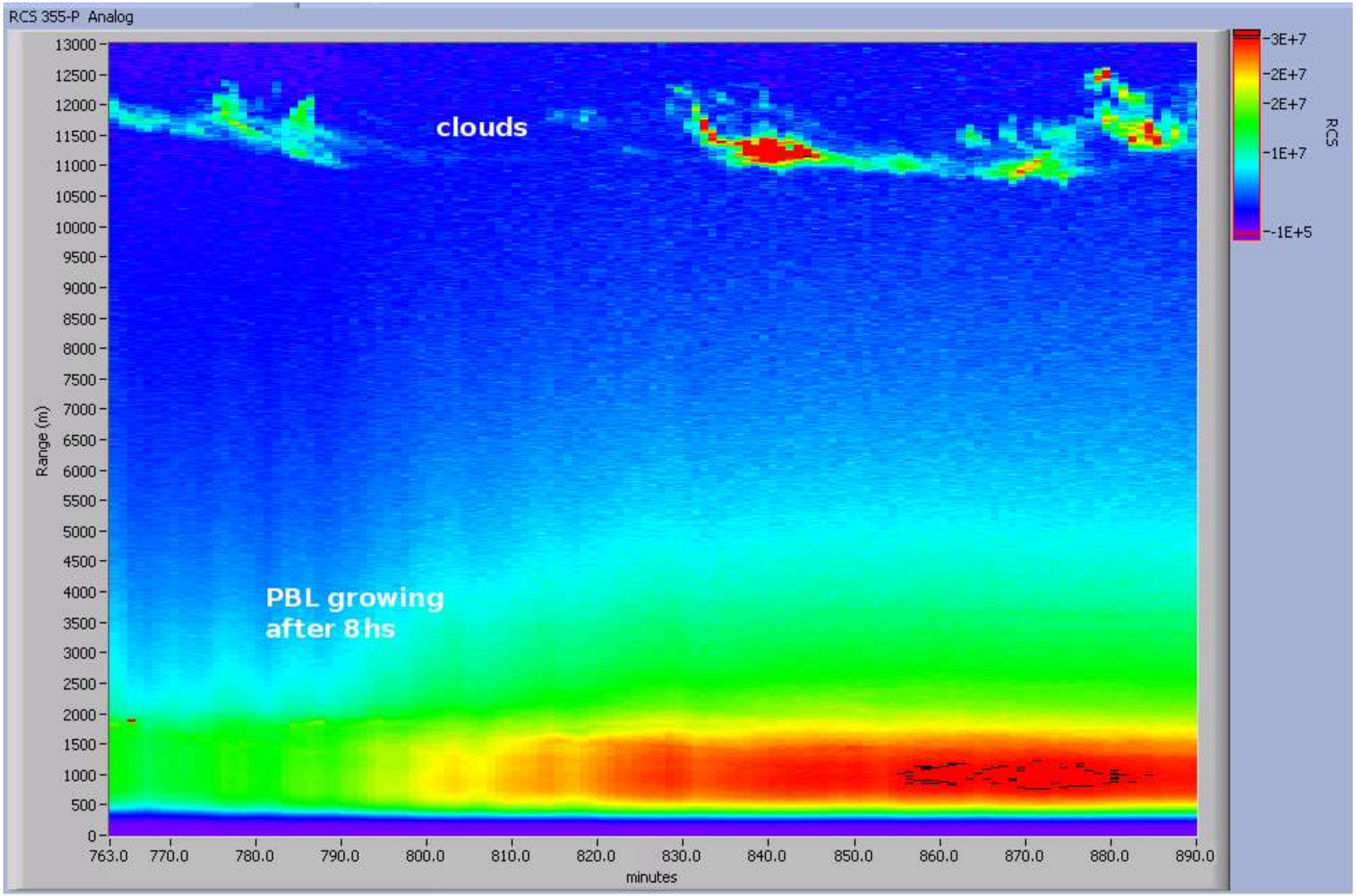

Abracos Hill
Alta Floresta
Ji Paraná
Rio Branco
τ 440 nm
6
5
4
3
2
1
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


2005
SWARF 24 horas
W/m²
0
-4
-8
-12
-16
-20
2005
AOD
1.0
0.8
0.6
0.4
0.2
0.0
2008
SWARF 24 horas
W/m²
0
-4
-8
-12
-16
-20
2008
AOD
1.0
0.8
0.6
0.4
0.2
0.0



Lidar location, 2°S, 60°W
BR 174
60 km
1200 km rain forest
Main wind direction
AM-010
-45
0
Typical backward trajectories
Igarapé do Tarumã-açu
Manaus
Manaus
AM-070
Iranduba
Careiro da Várzea
Paraná do Careiro
AM-070
10 km
Radiosonde

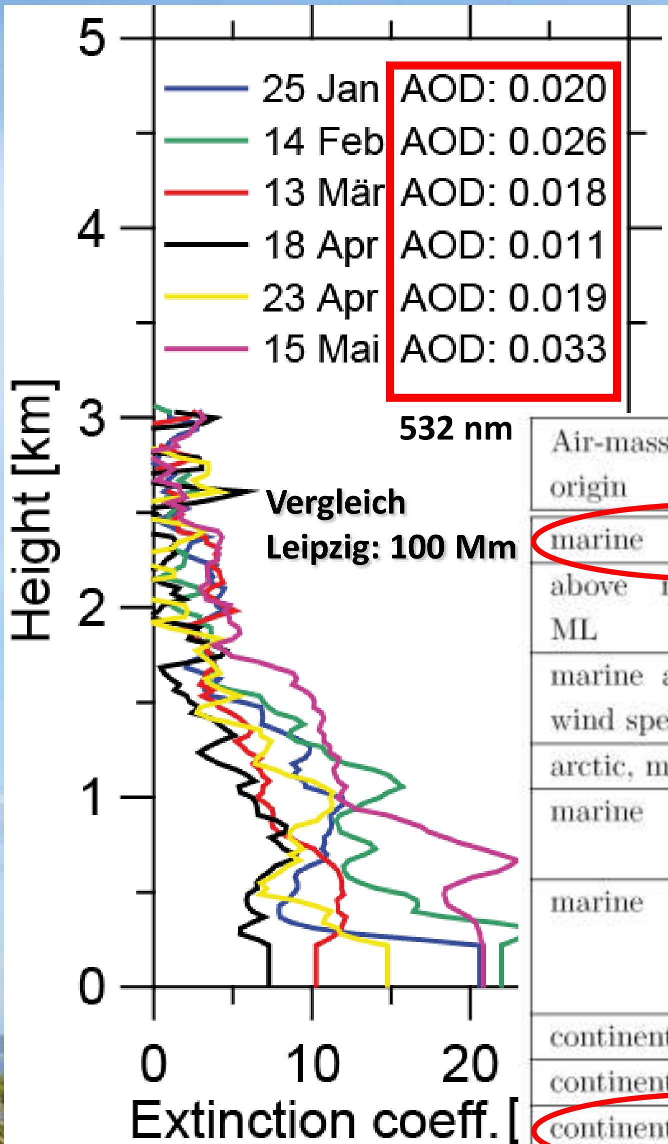
Raman Lidar: aerosols and water vapor up to 13 Km in Manaus



7h40 8h40 9h40

Henrique Barbosa, 2012

Cleanest aerosol conditions



6 cleanest cases

- very low Extinction coeff.: 10–20 Mm^{-1}

→ Visibility ≅ 130 – 200 km

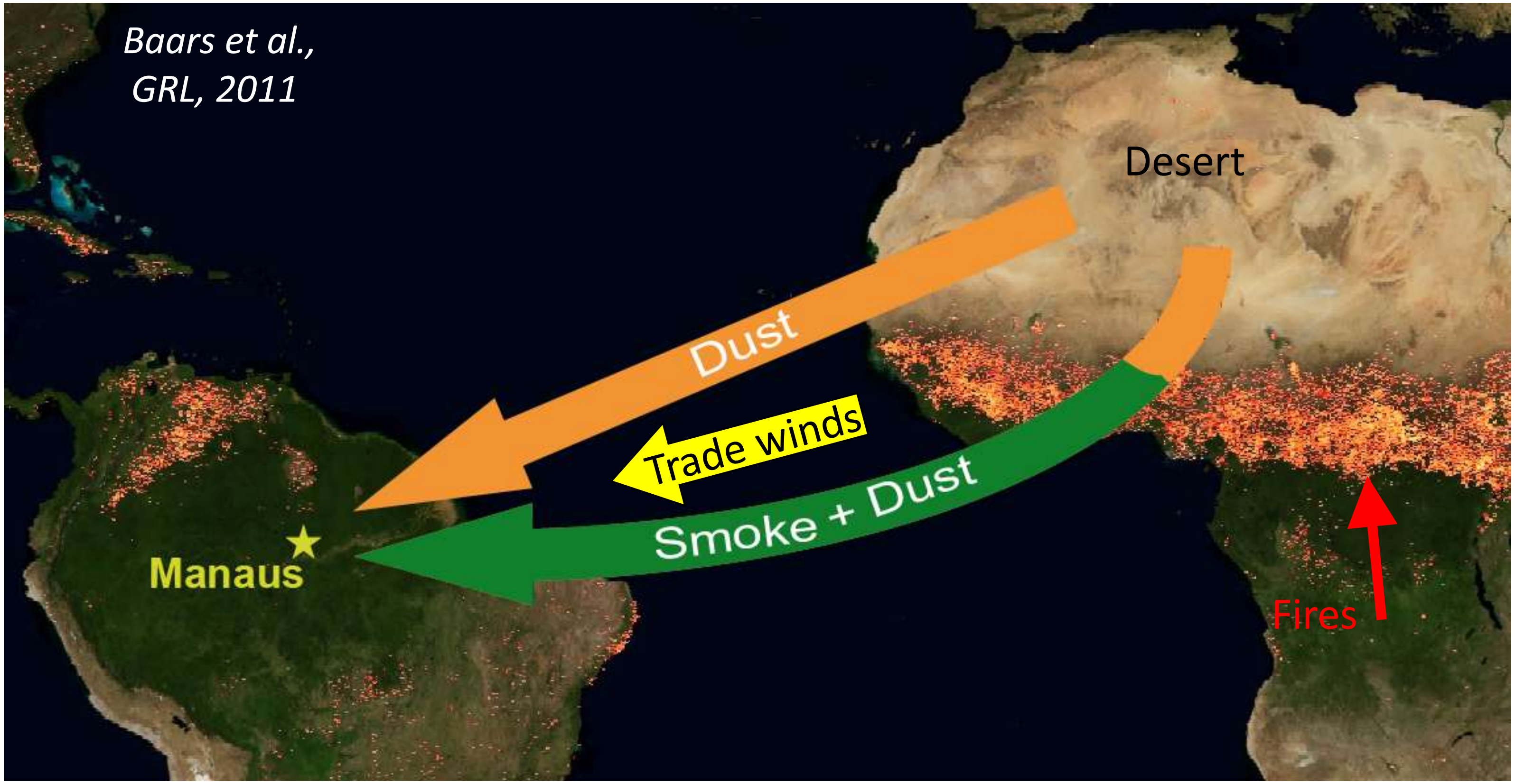
- Aerosol always below 2.5 km
- very low AOD

→ lower AOD than for marine background

→ lowest AOD values on a continent

Air-mass origin	Minimum AOD	Location, time period, and further notes	Reference
marine	0.05	Portugal, 1997	*Ansmann et al.* (2001)
above marine ML	0.013	5-year mean (1994–1999) for August at Mauna Loa (3.4 km agl), Hawaii	*Holben et al.* (2001)
marine at low wind speed	0.05	Atlantic Ocean, RV Polarstern transects	*Kanitz* (2011)
arctic, marine	0.02–0.03	near the coastline of Antarctica	*Smirnov et al.* (2009)
marine	0.04–0.08	southern Atlantic, October–December 2004	*Smirnov et al.* (2006)
marine	0.01	Mean value for July at Cape Grim, Tasmania for 1986–1999. Pinatubo affected periods have been removed.	*Wilson and Forgan* (2002)
continental	0.05	Beijing, January 2005	*Tesche et al.* (2007)
continental	0.011	Amazon rain forest, wet season 2008	this study
continental	0.06	5-year mean (1994–1999) for December–January at the CART Site, Oklahoma, USA	*Holben et al.* (2001)

Smoke and Dust transport towards Amazonia



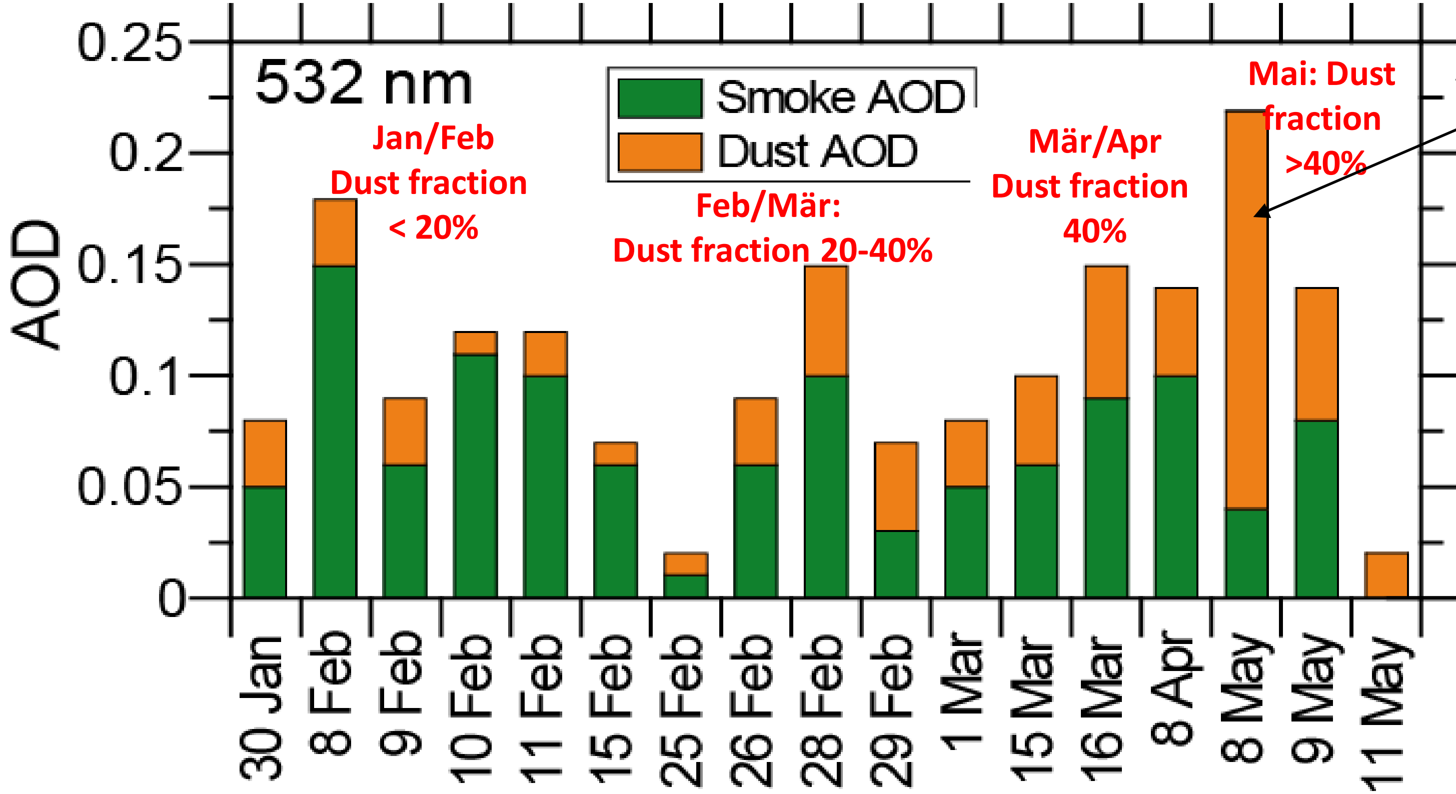
- already known: Saharan dust is transported over the Atlantic Ocean and fertilizes the Amazon rain forest
- unknown so far: huge amounts of smoke are transported, too

→could be quantified the first time with the lidar measurements

- Example of 10 February 2008

Smoke and Dust transport towards Amazonia

All cases of African aerosol advection



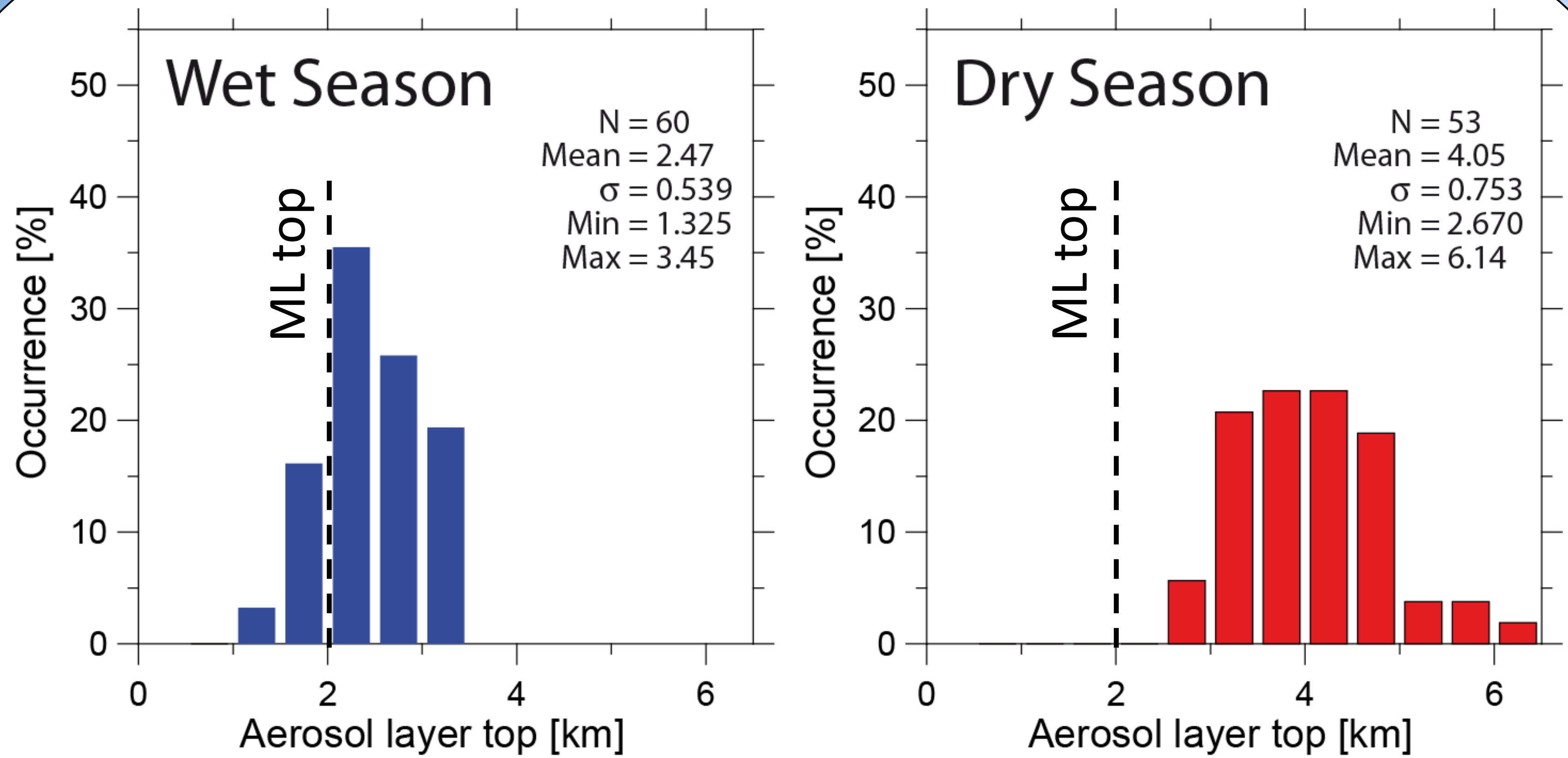
Also observed at Barbados

Dust and smoke-AOD Baars et al., GRL, 2011

- Smoke mostly the dominant aerosol species
- Dust fraction larger at the end of the wet season
- first time of documentation of significant smoke contribution

→Influence on clouds?

Statistic: Vertical aerosol distribution



- Wet and dry season: strong contrast
- Local Mixing layer does not limit vertical aerosol distribution
- Wet season: <3.5 km, dry season: <6.5 km
- No aerosols above 6.5 km
- First long-term statistics concerning vertical aerosol distribution


Thanks for the attention!!