Atmospheric aerosols in Amazonia

Course on atmospheric aerosols and clouds with introduction to process oriented modeling

16 – 27 March 2015

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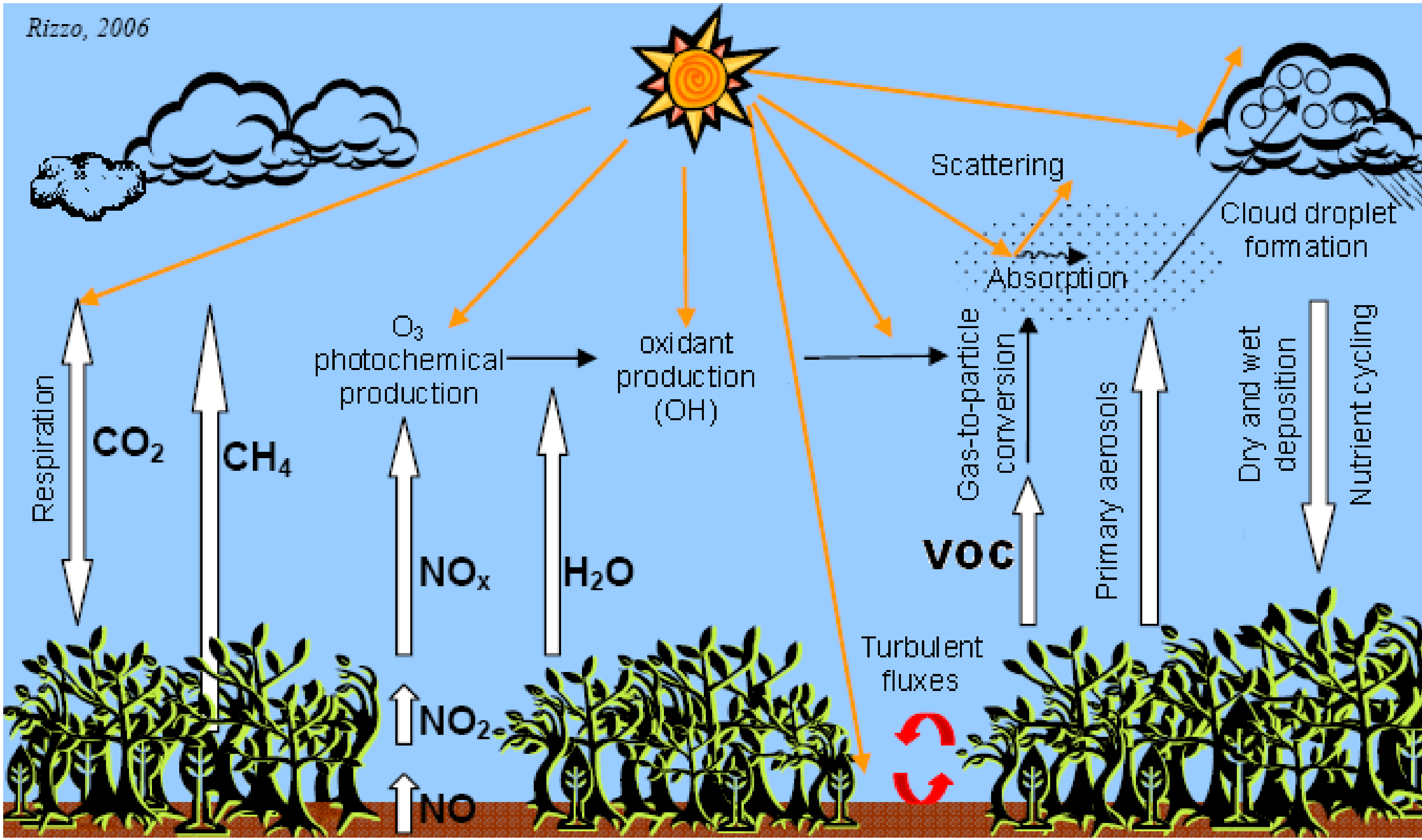
STINT
The Swedish Foundation for International Cooperation in Research and Higher Education

Outline

1. Introduction: aerosol sources in Amazonia
2. Aerosol physical characterization
3. Aerosol chemical characterization
4. Aerosol dynamical processes

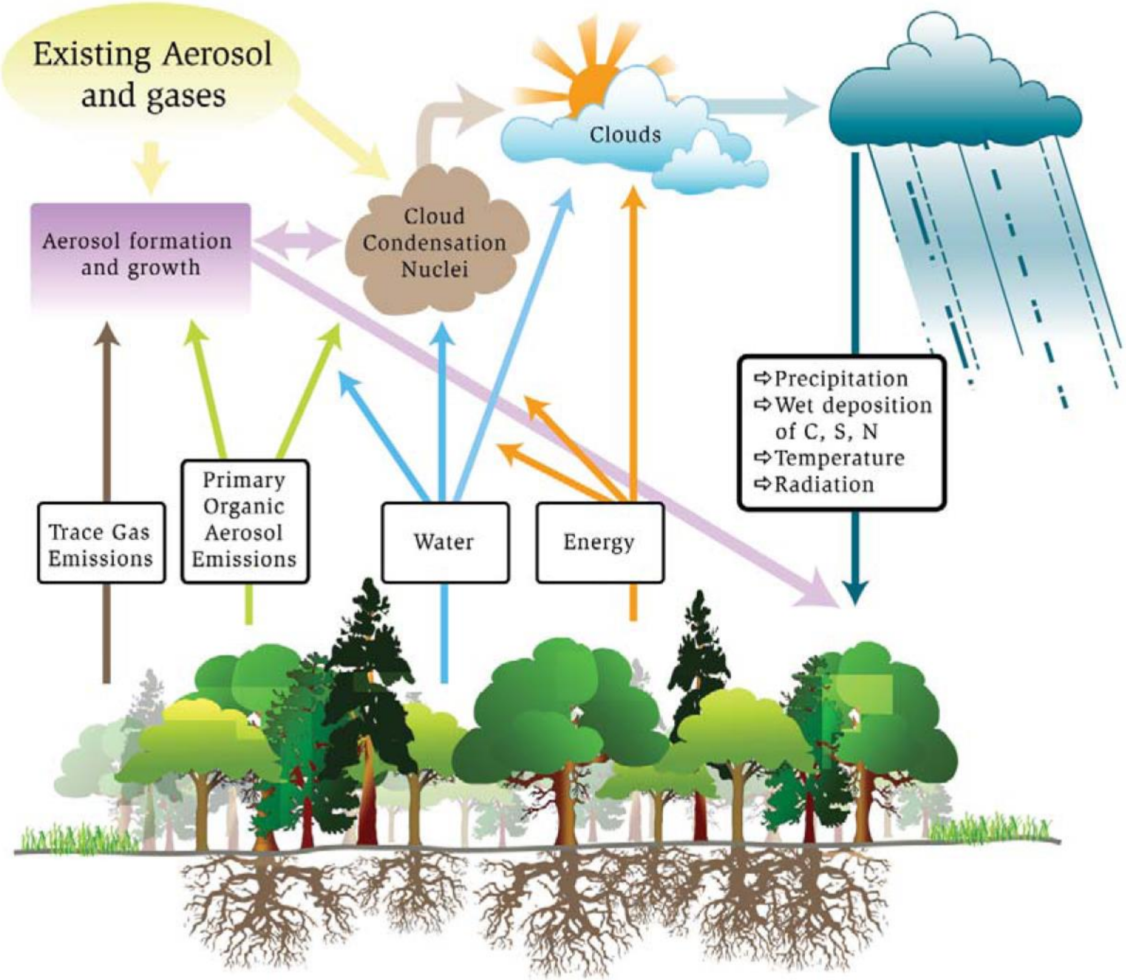
1) INTRODUCTION: AEROSOL SOURCES IN AMAZONIA

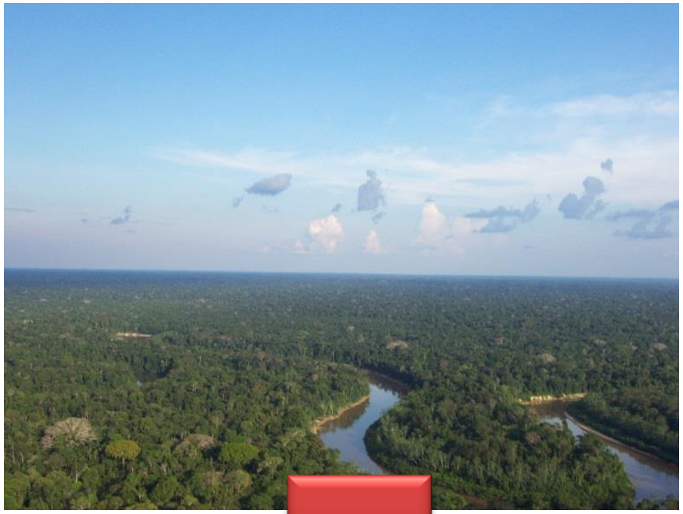
Biosphere-atmosphere interactions



Naturally, the Amazon forest interacts strongly with the atmosphere and climate. There are strong and complex links between the forest biology, and the atmospheric physics and chemistry

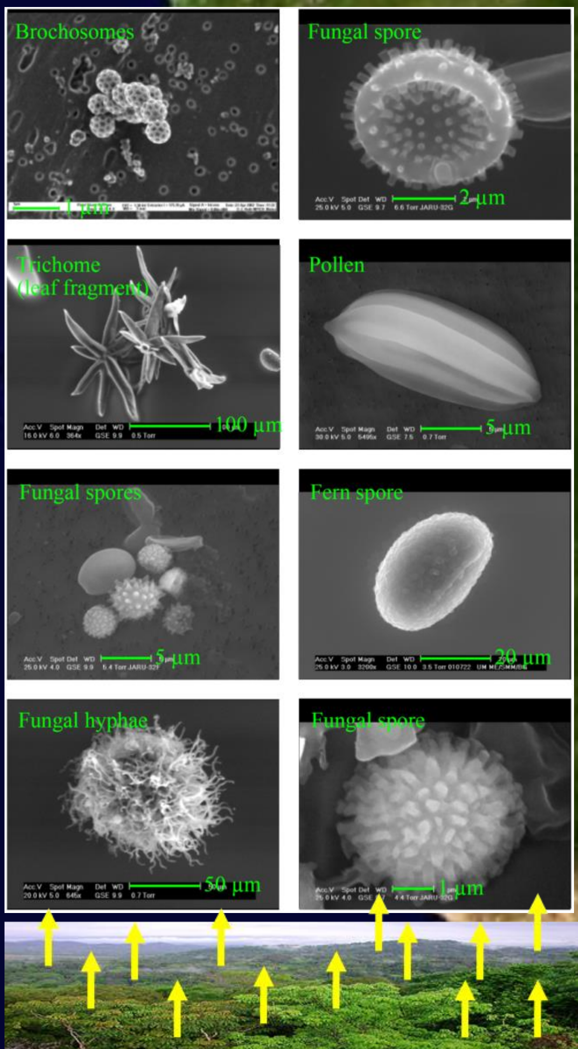
Natural System

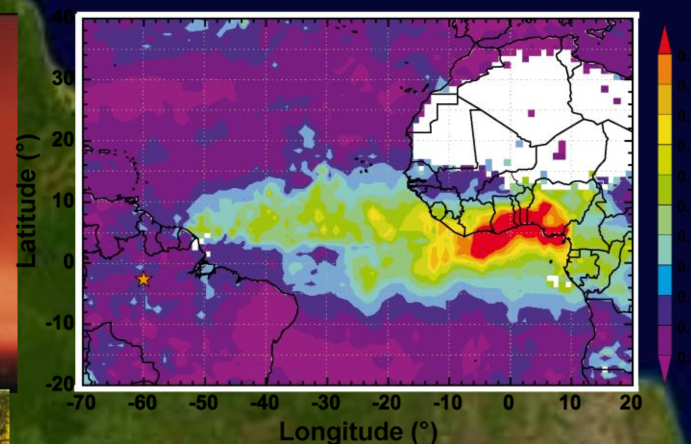


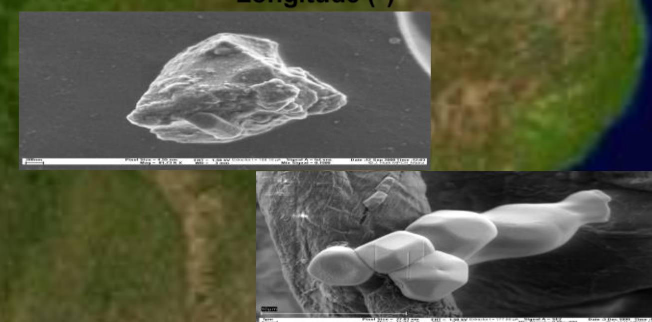


Amazonia: 3 types of aerosol particles

Biogenic (primary and SOA) | **Biomass Burning** | **Dust from Sahara**



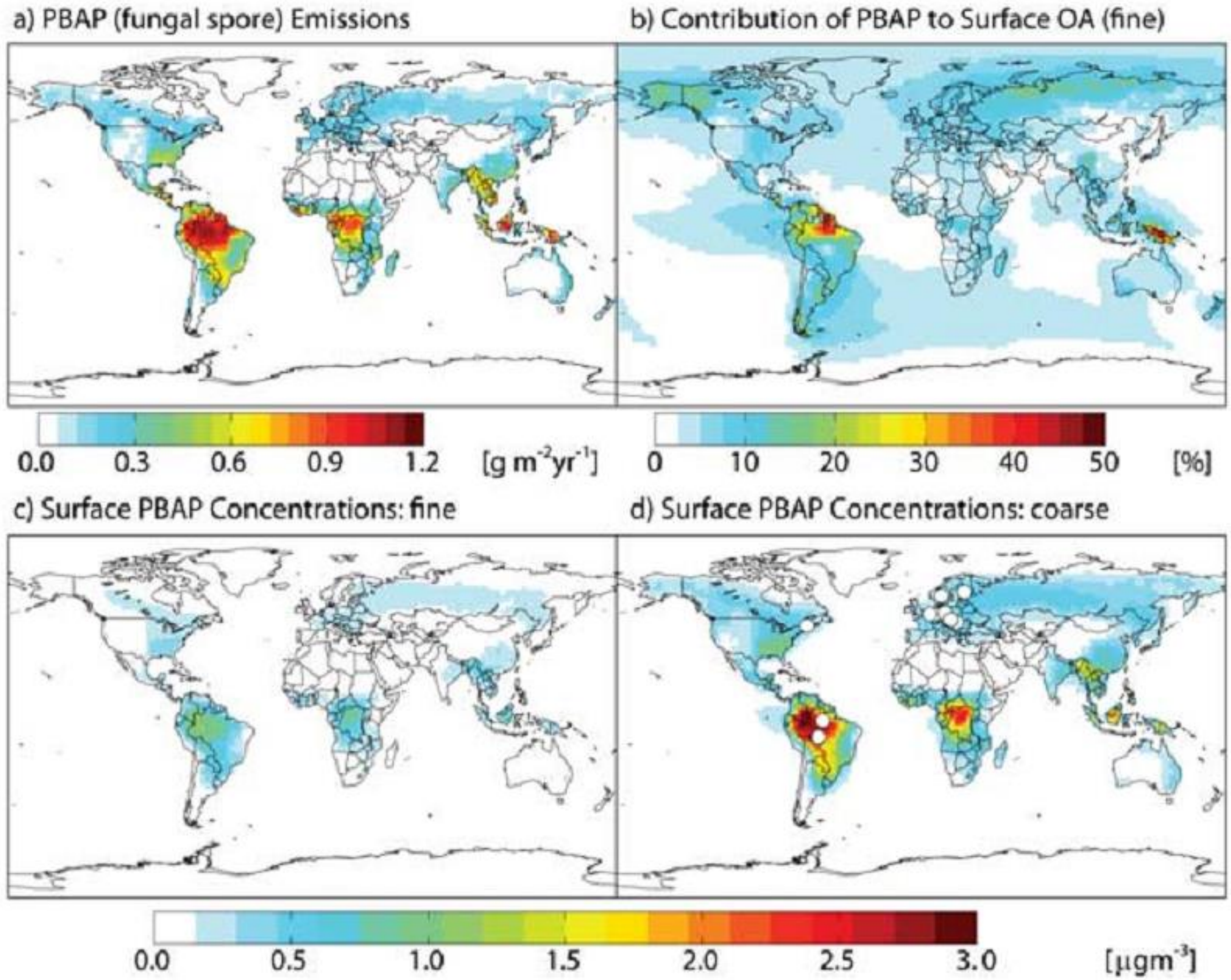




Each with VERY different properties and impacts
Size: from 1 nanometer to 10 micrometers

Biogenic aerosol

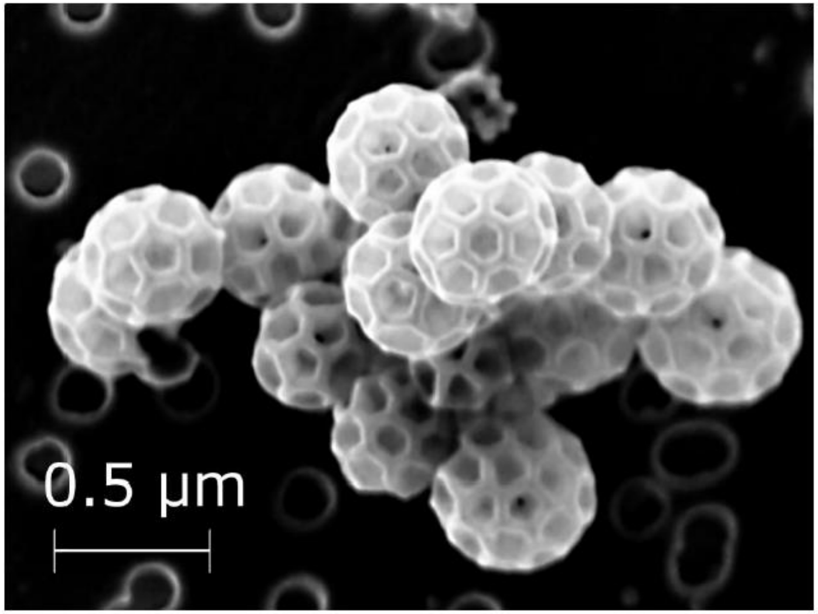
Atmospheric budget of primary biological aerosol particles from fungal spores



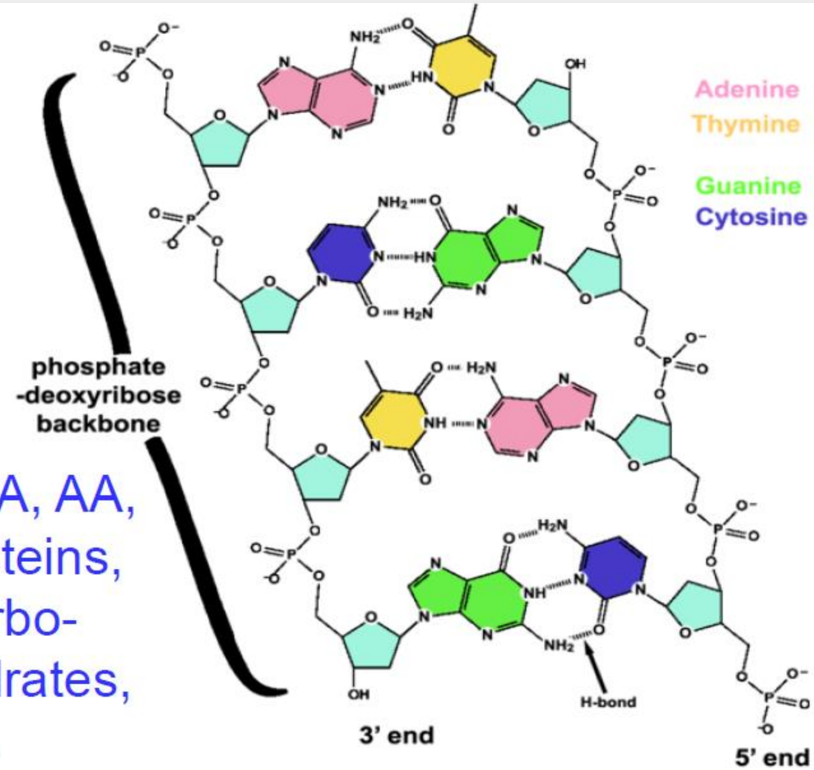
Annual mean of optimized GEOS-Chem simulation of fungal PBAP: (a) PBAP emissions, (b) percentage contribution of fungal PBAP to fin e organic aerosol (OA) surface concentrations, (c) fine-mode fungal PBAP surface concentrations, and (d) coarse-mode fungal PBAP surface concentrations.

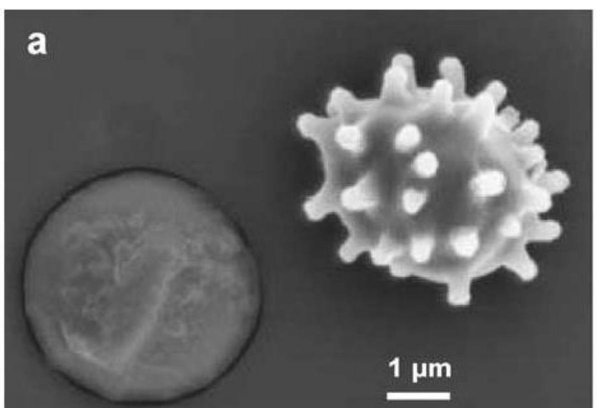
Biogenic aerosols

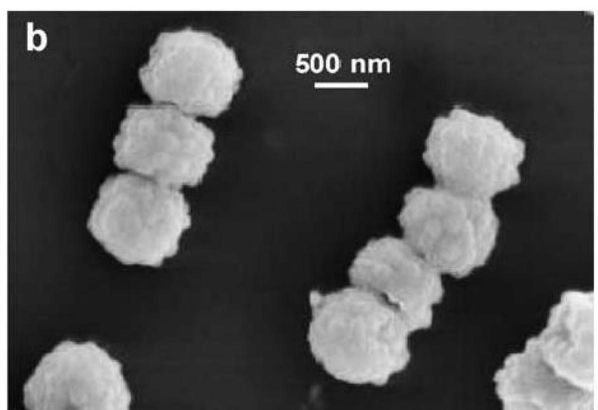
Bacteria, Brochosomes, Spores, Pollen, Plant Debris, etc.

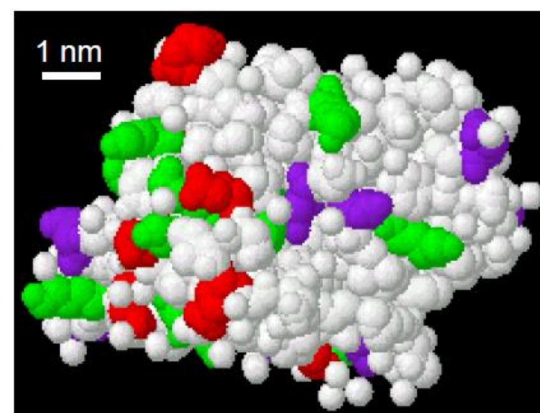


DNA, AA, Proteins, Carbo-hydrates, etc.







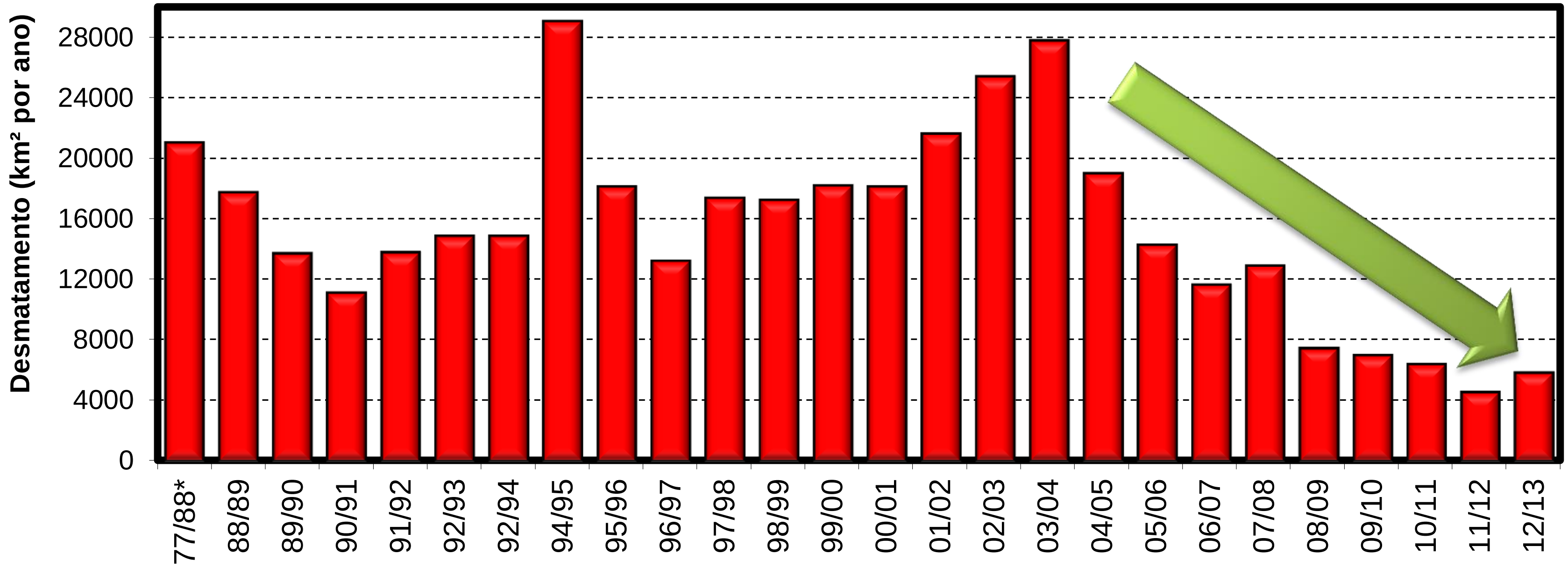


Uli Pueschl, 2012

Biomass burning

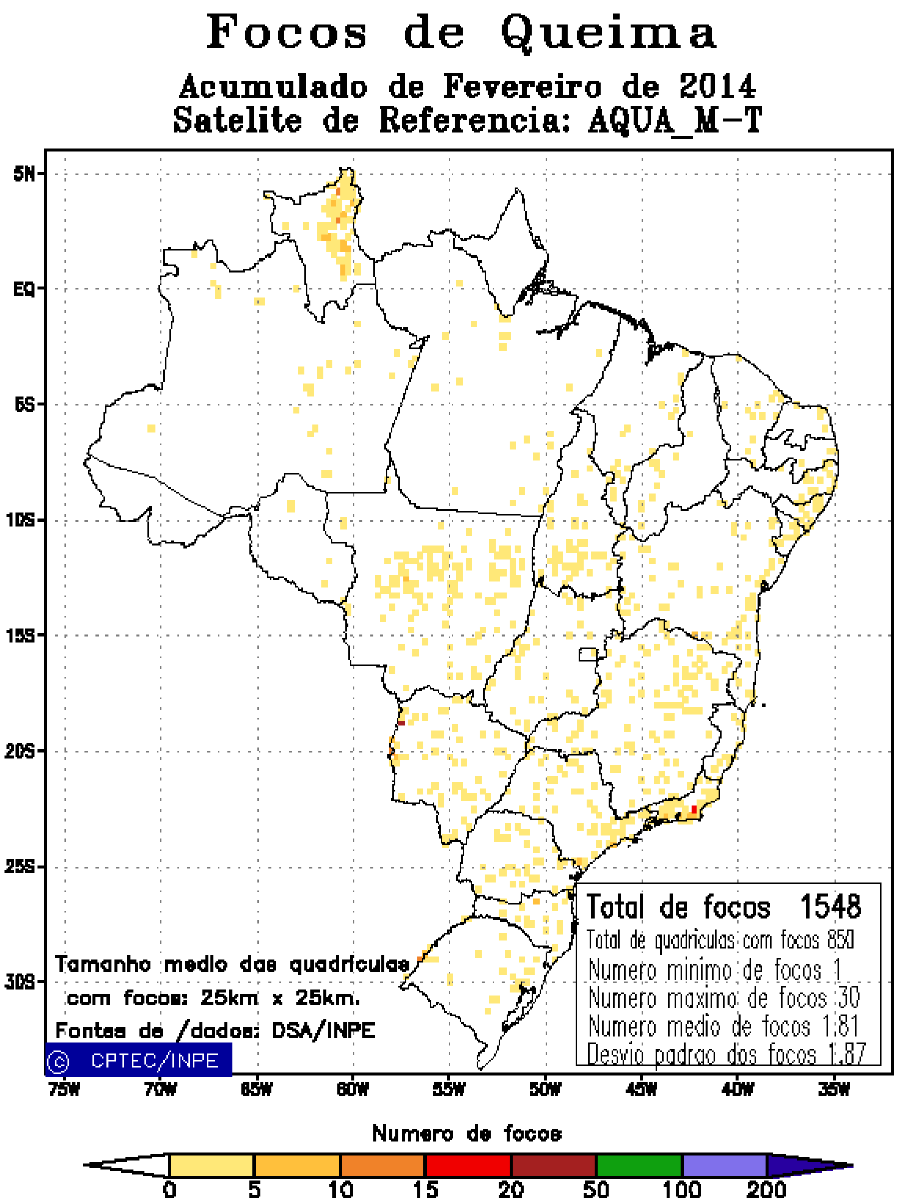
Deforestation was reduced from 27,700 km² in 2004 to 5,000 km² in 2013.

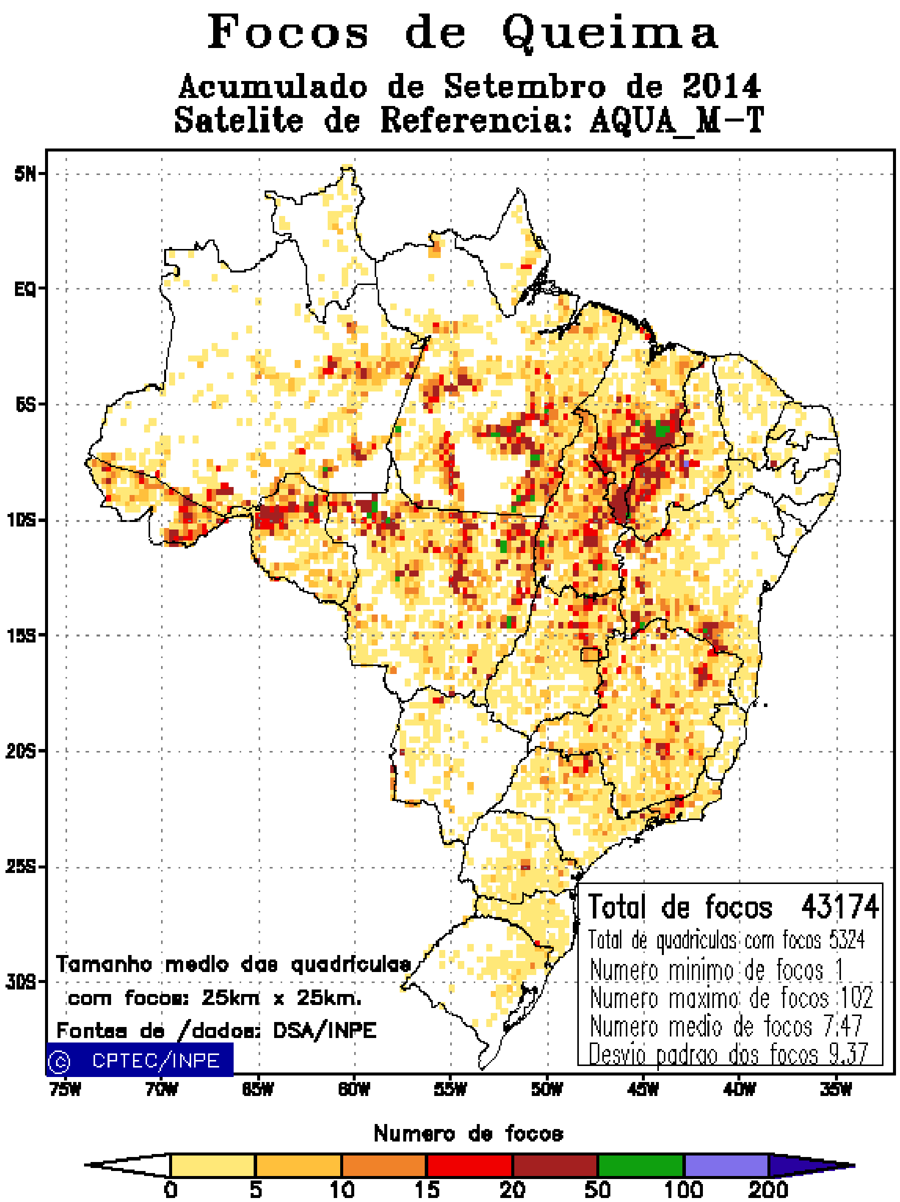
Deforestation in Amazonia 1977-2013 in km² per year



Wet season

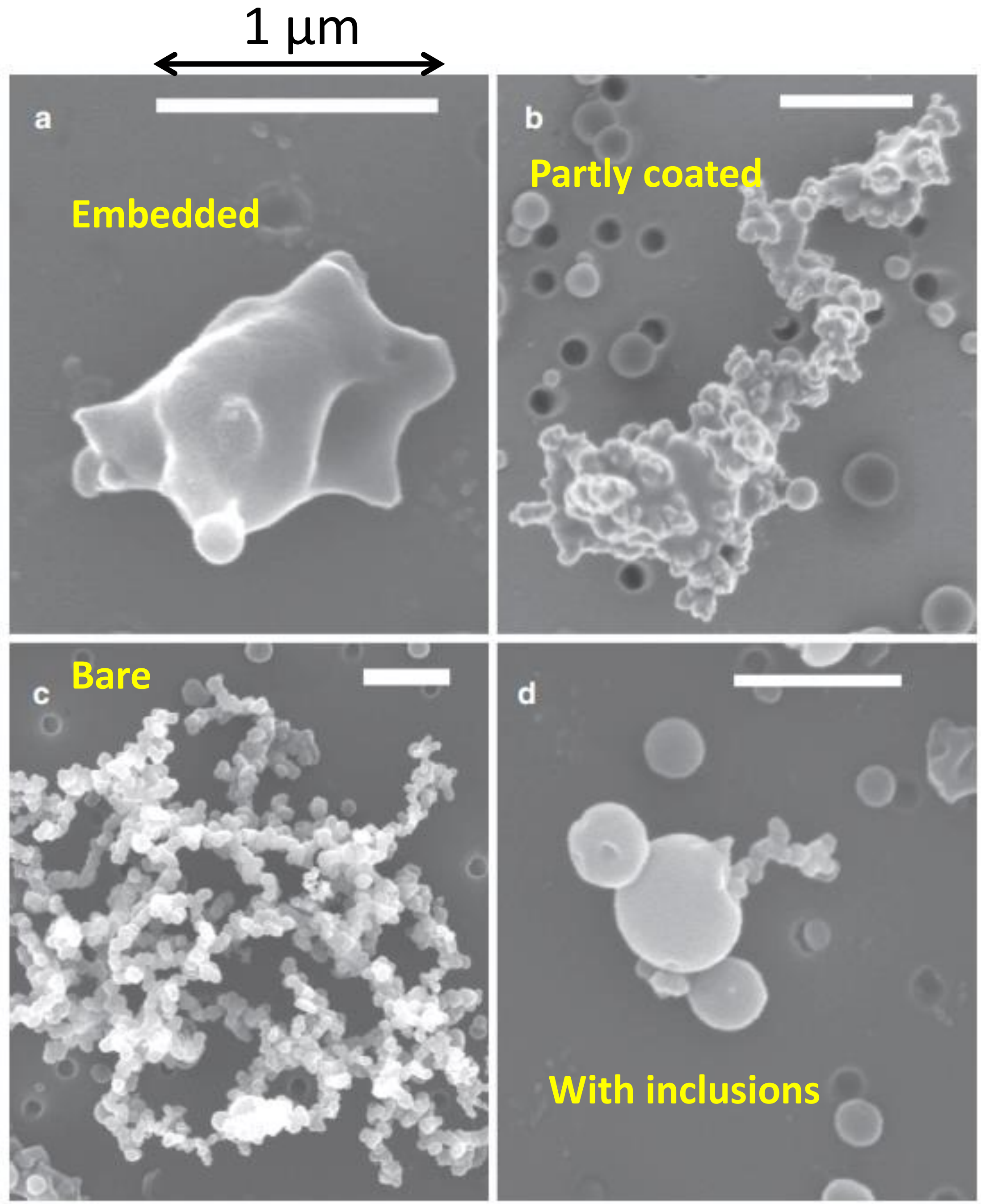
Dry season





Biomass burning aerosols

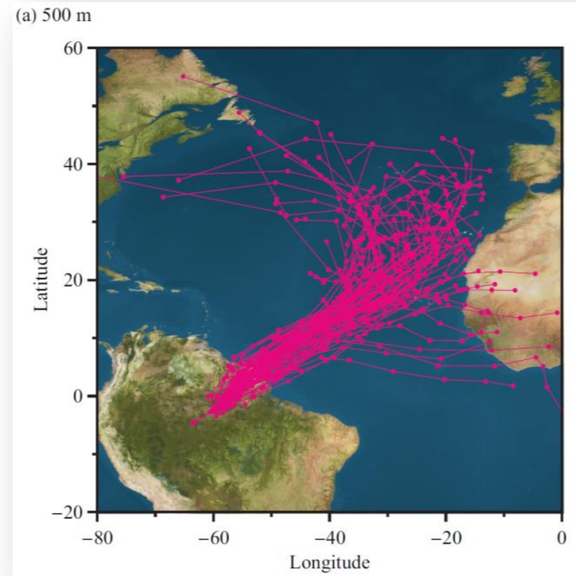
- Smoldering phase
- 1-2 h aged
- Coating and type of mixture affects particle optical properties

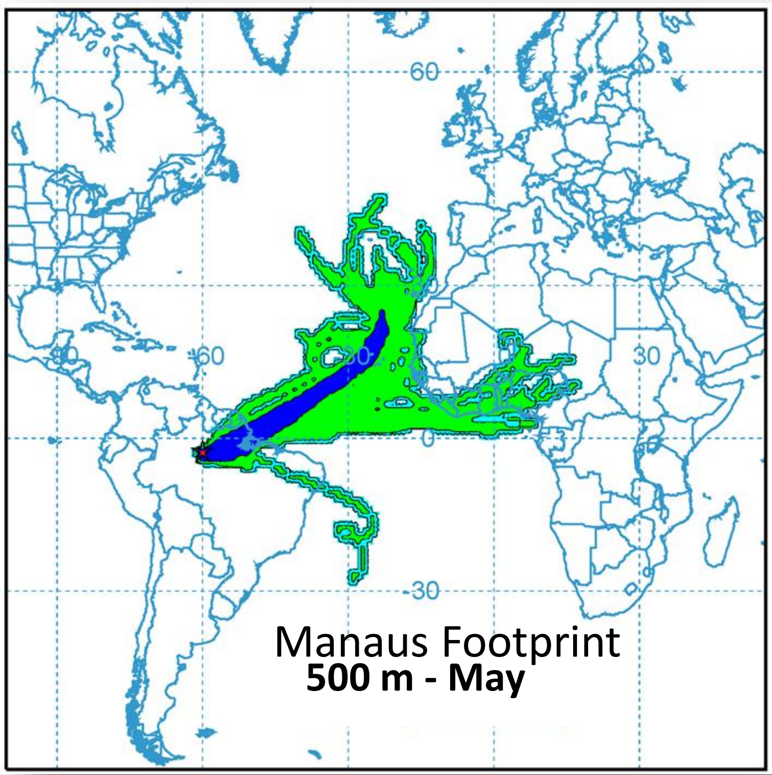


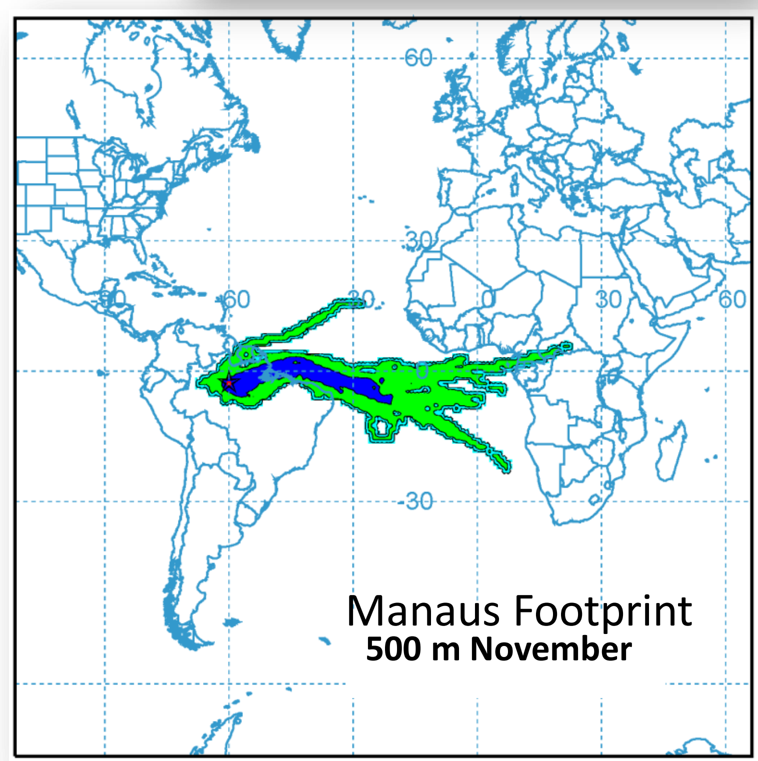
Las Conchas wildfire in 2011

(China et al., 2014)

Air Mass Trajectories (10 days) and Footprint

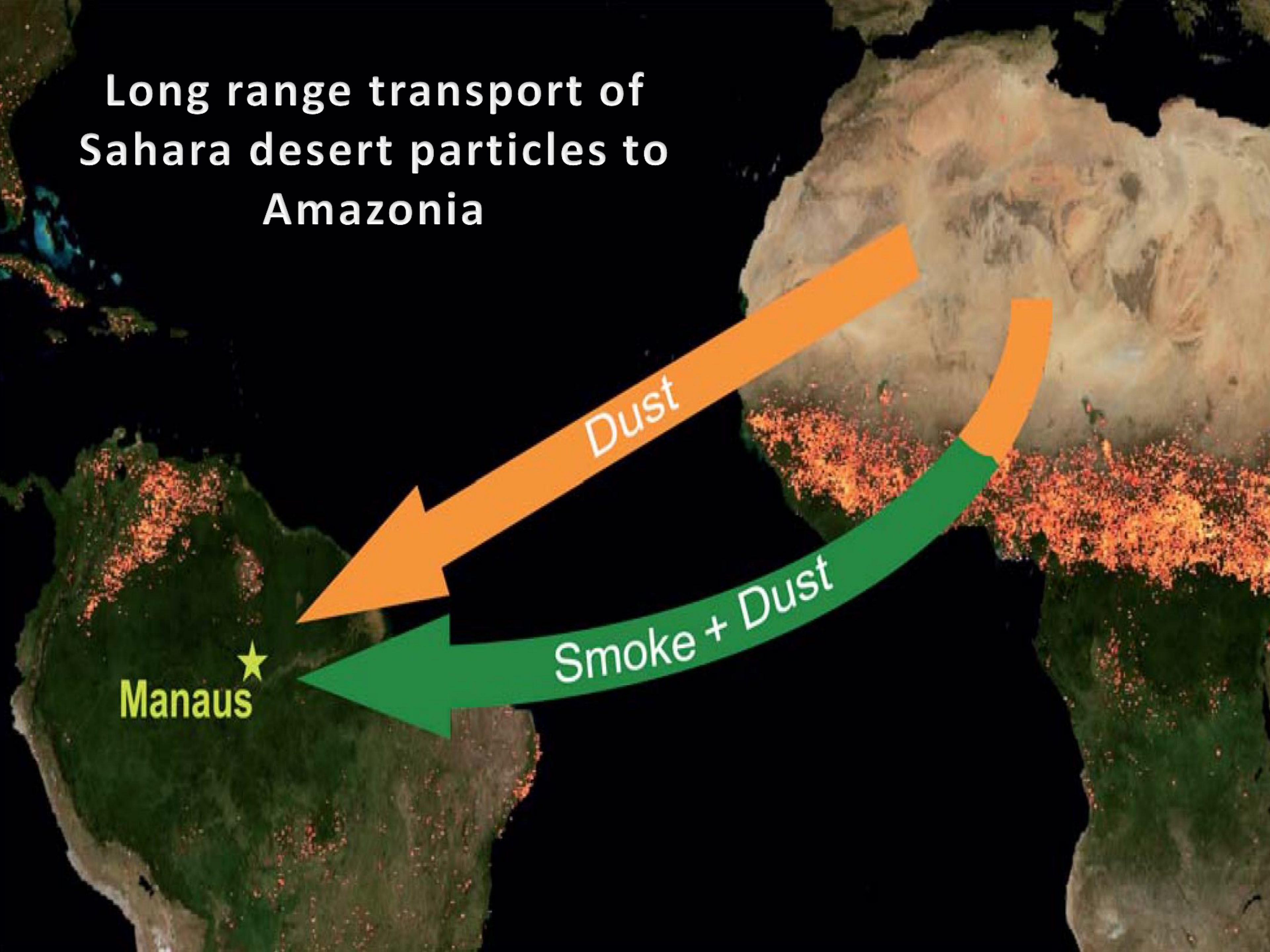




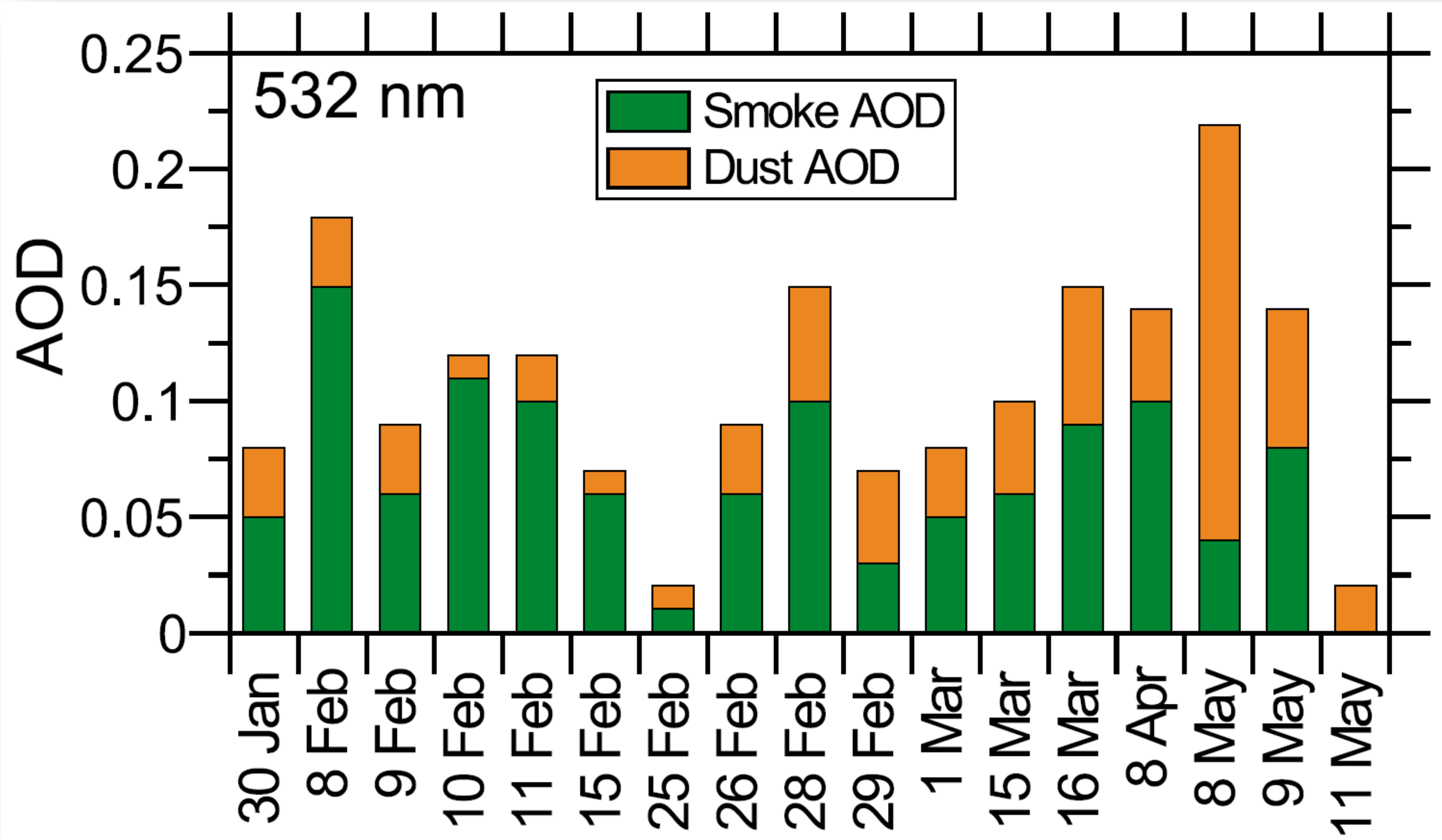


Andreae, 2015

Long range transport of Sahara desert particles to Amazonia



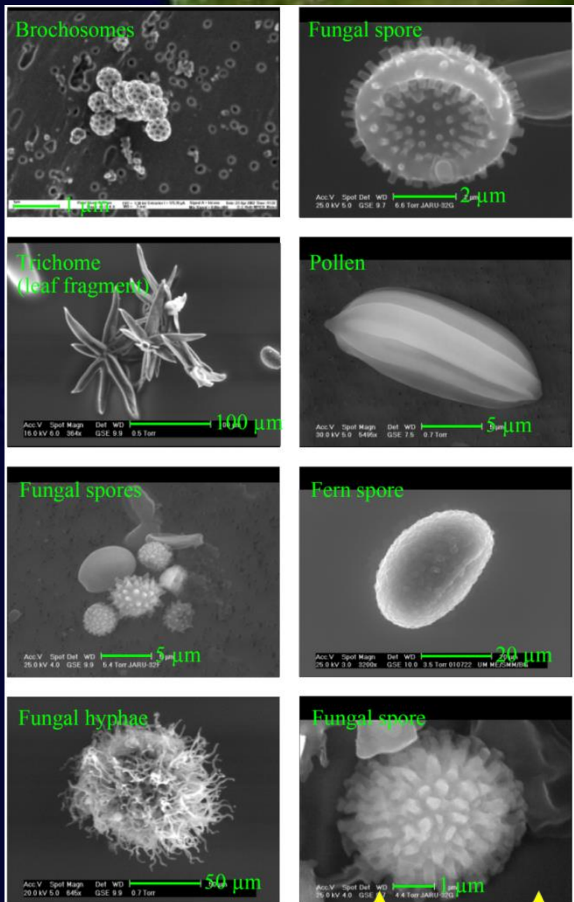
African aerosol in central Amazonia



Smoke and dust AOD for the 17 observation cases in 2008 indicating the advection of African aerosol toward Amazonia (Baars, 2011).

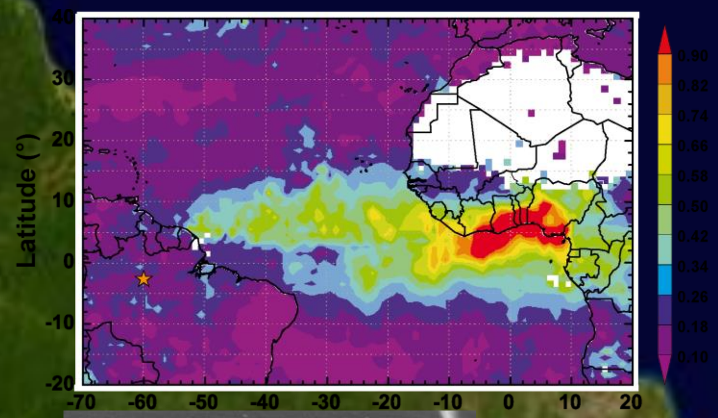
Amazonia: 4 types of aerosol particles

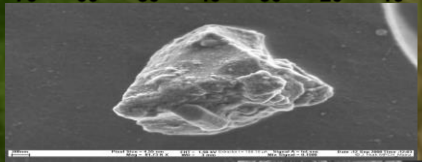
Biogenic (primary and SOA)

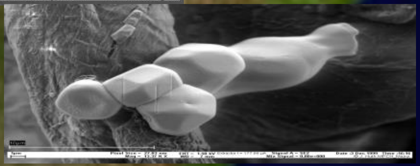


Biomass Burning

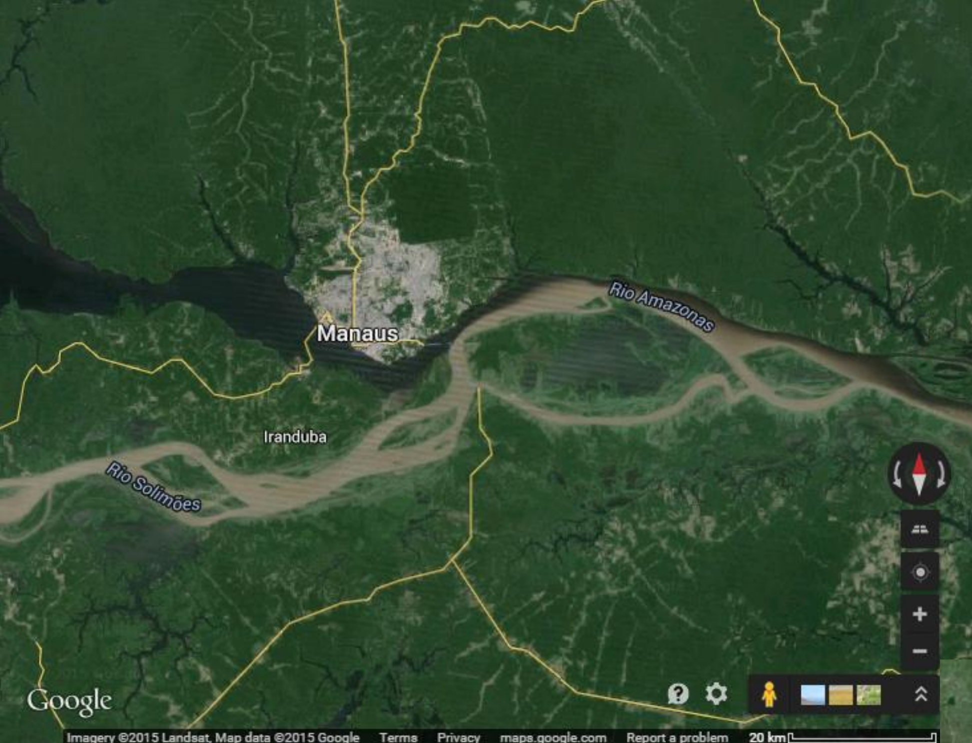
Dust from Sahara







Urban emissions



Manaus metropolis

2.4 million people

100 000 km^2

620 000 vehicles

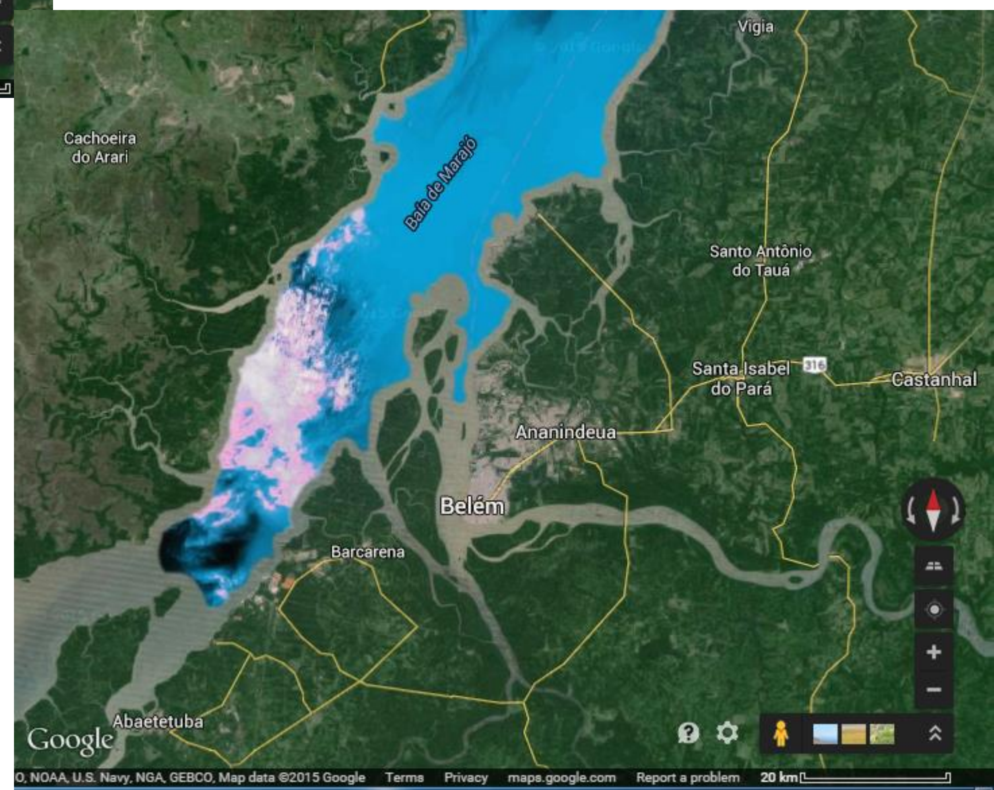
Power plants

Belém metropolis

2.6 million people

3.600 km^2

1.3 million vehicles



2 - AEROSOL PHYSICAL PROPERTIES

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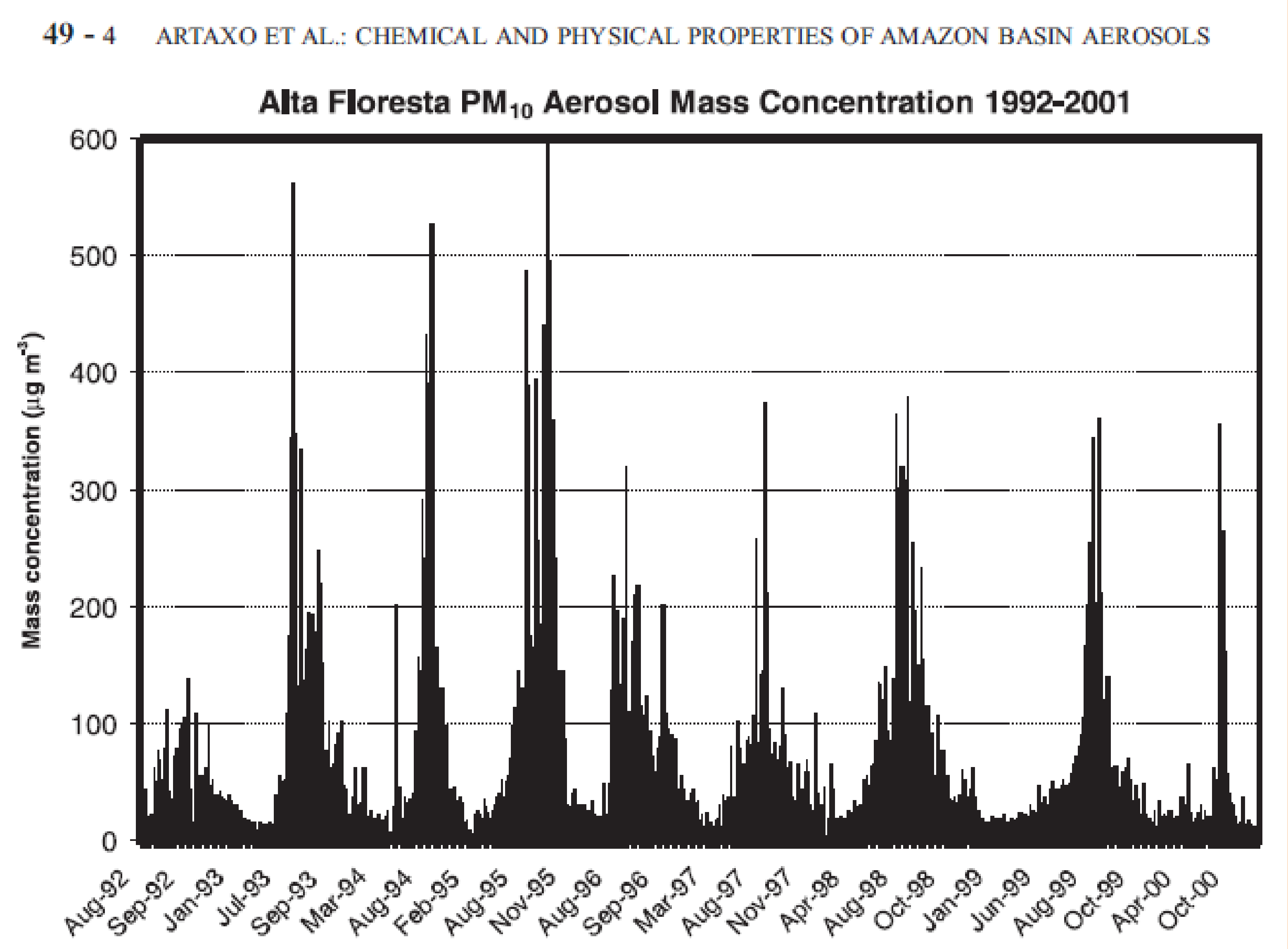
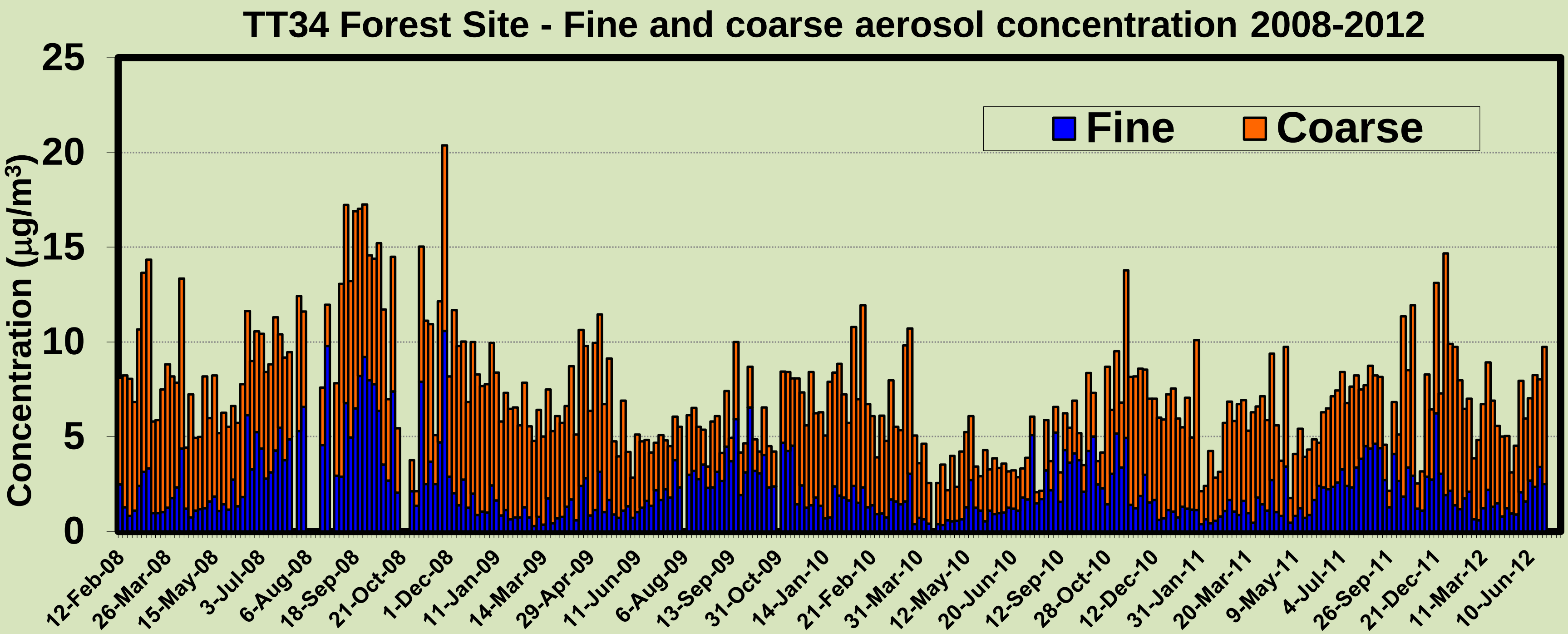
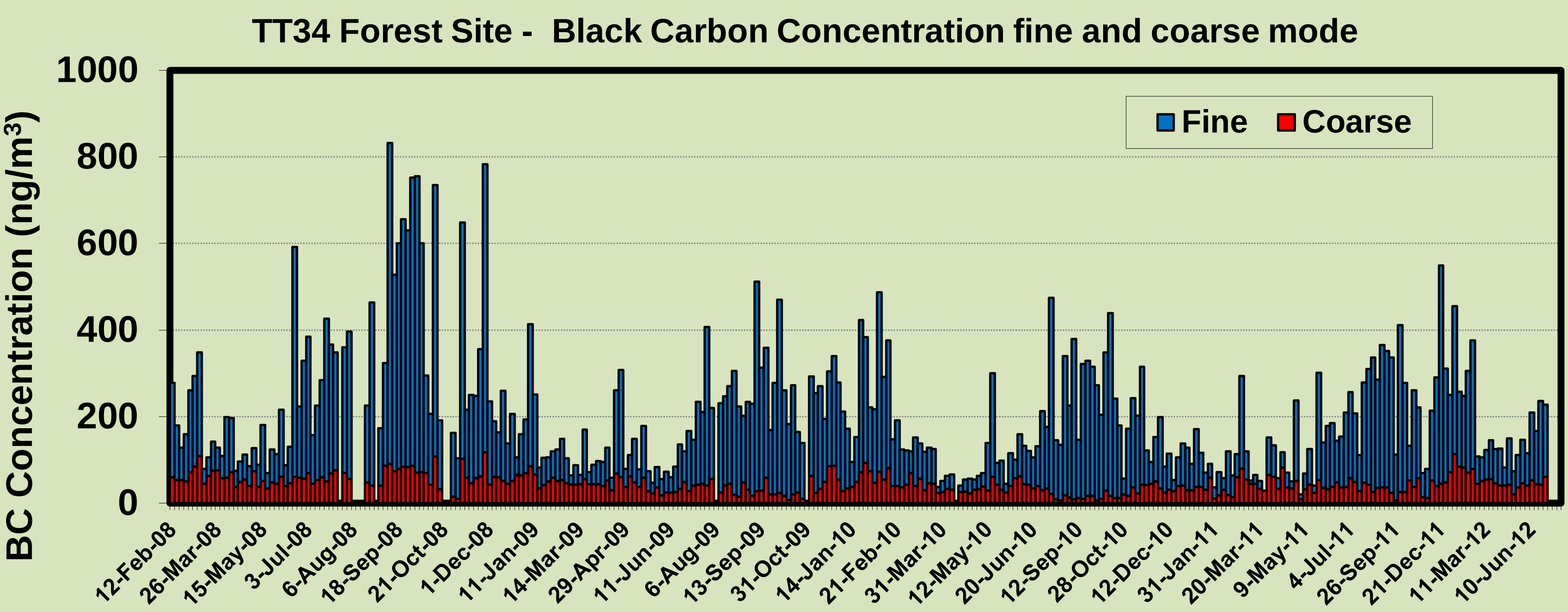
2A – PARTICLE LOADING

PM10 concentration: Arc of deforestation

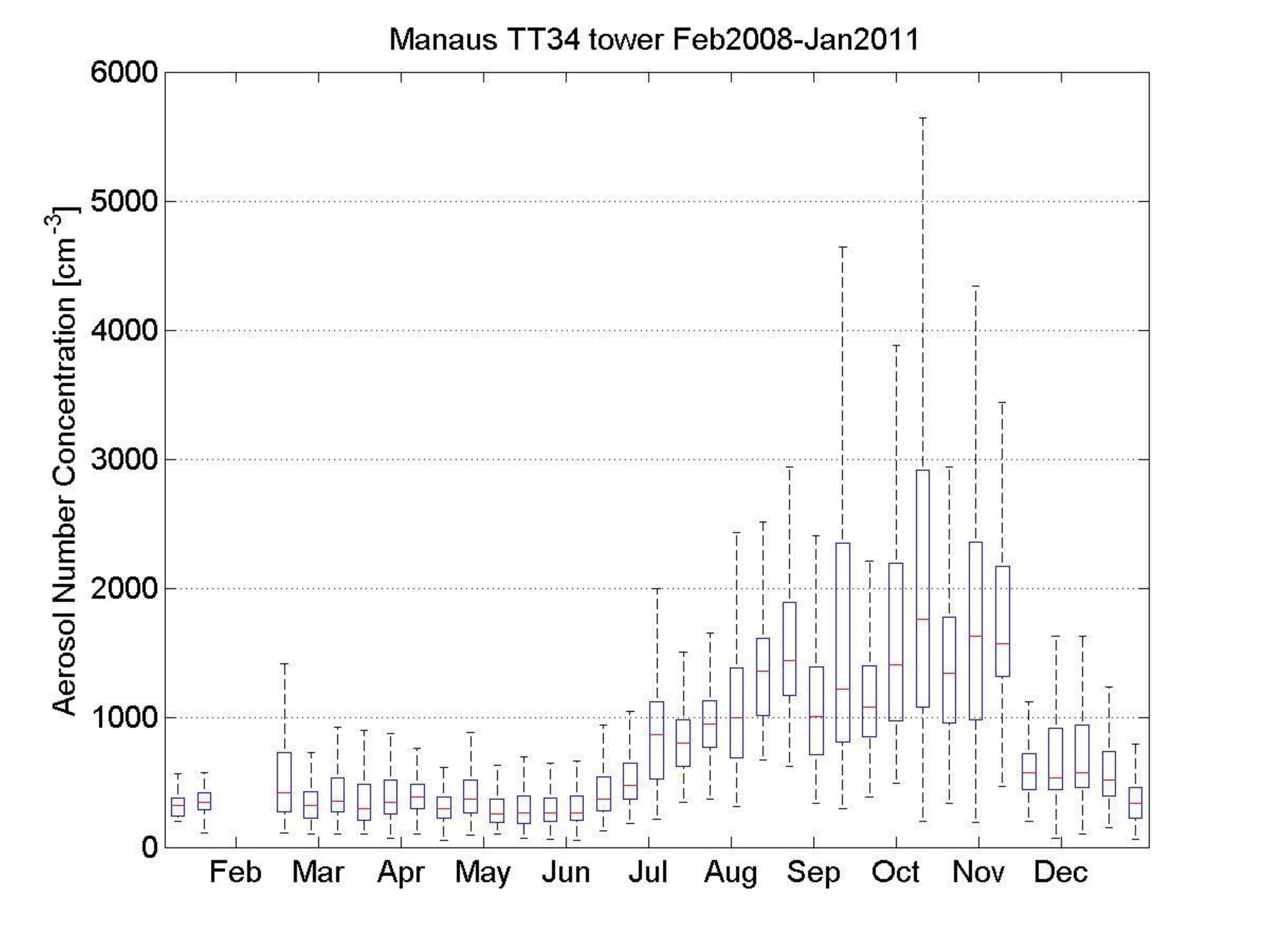


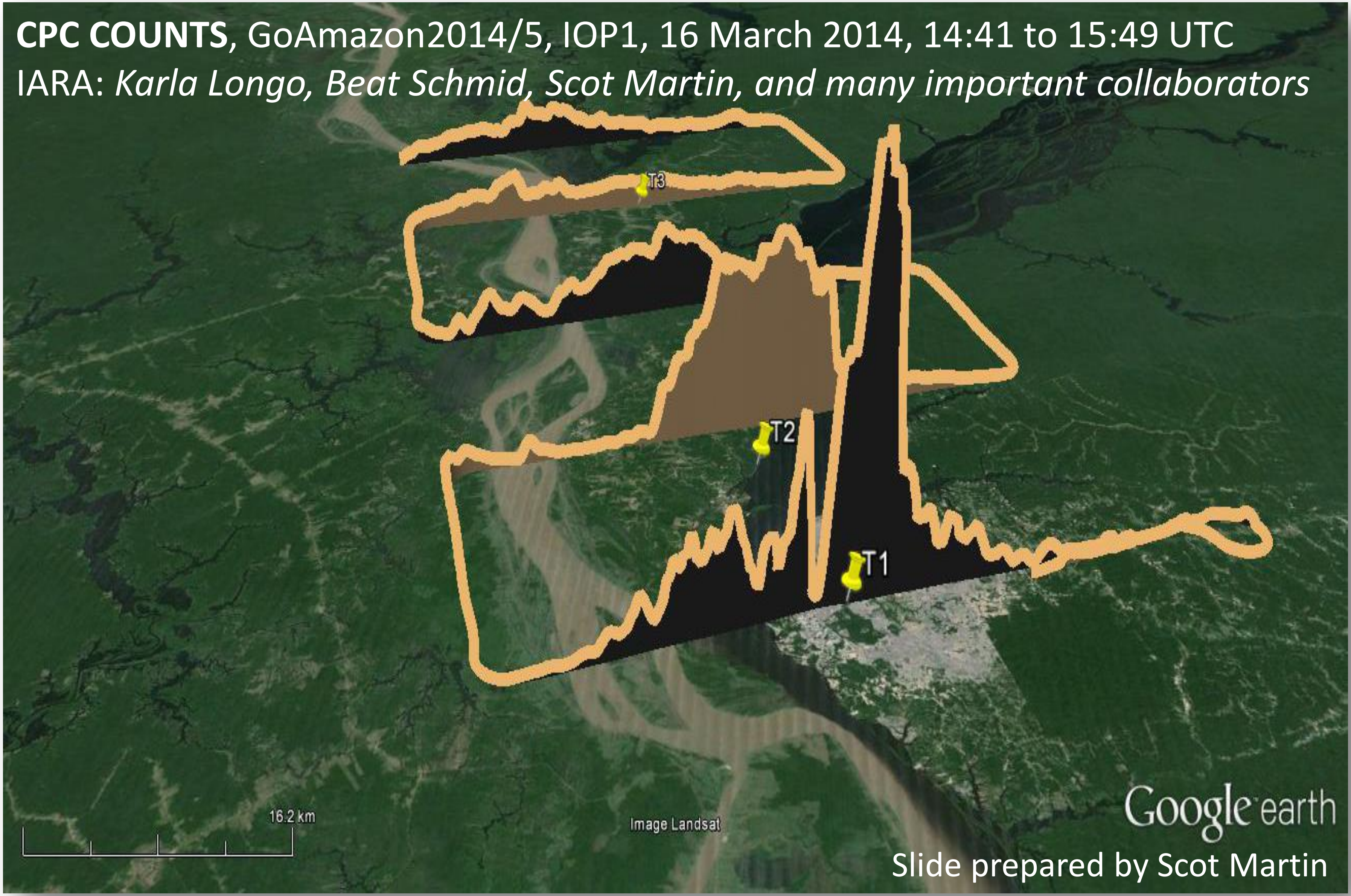

TT34 Forest Site - Fine and coarse aerosol concentration 2008-2012
Concentration (µg/m³)
Fine
Coarse
0
5
10
15
20
25
12-Feb-08
26-Mar-08
15-May-08
3-Jul-08
6-Aug-08
18-Sep-08
21-Oct-08
1-Dec-08
11-Jan-09
14-Mar-09
29-Apr-09
11-Jun-09
6-Aug-09
13-Sep-09
31-Oct-09
14-Jan-10
21-Feb-10
31-Mar-10
12-May-10
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
11-Mar-12
10-Jun-12


TT34 Forest Site - Black Carbon Concentration fine and coarse mode
BC Concentration (ng/m³)
Fine
Coarse
0
200
400
600
800
1000
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
11-Mar-12
10-Jun-12

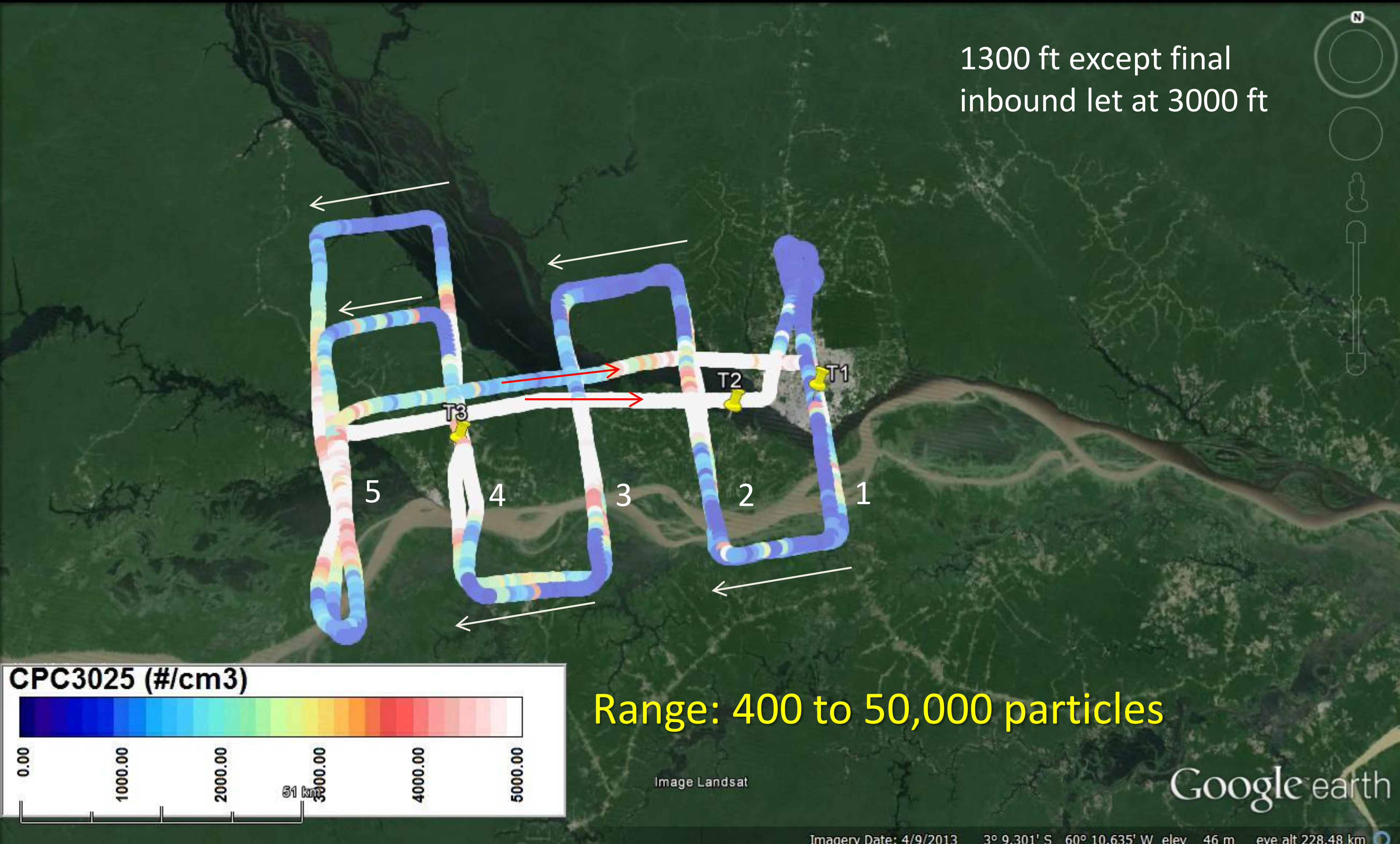
Arana, 2014

TT34 forest site: particle number concentration



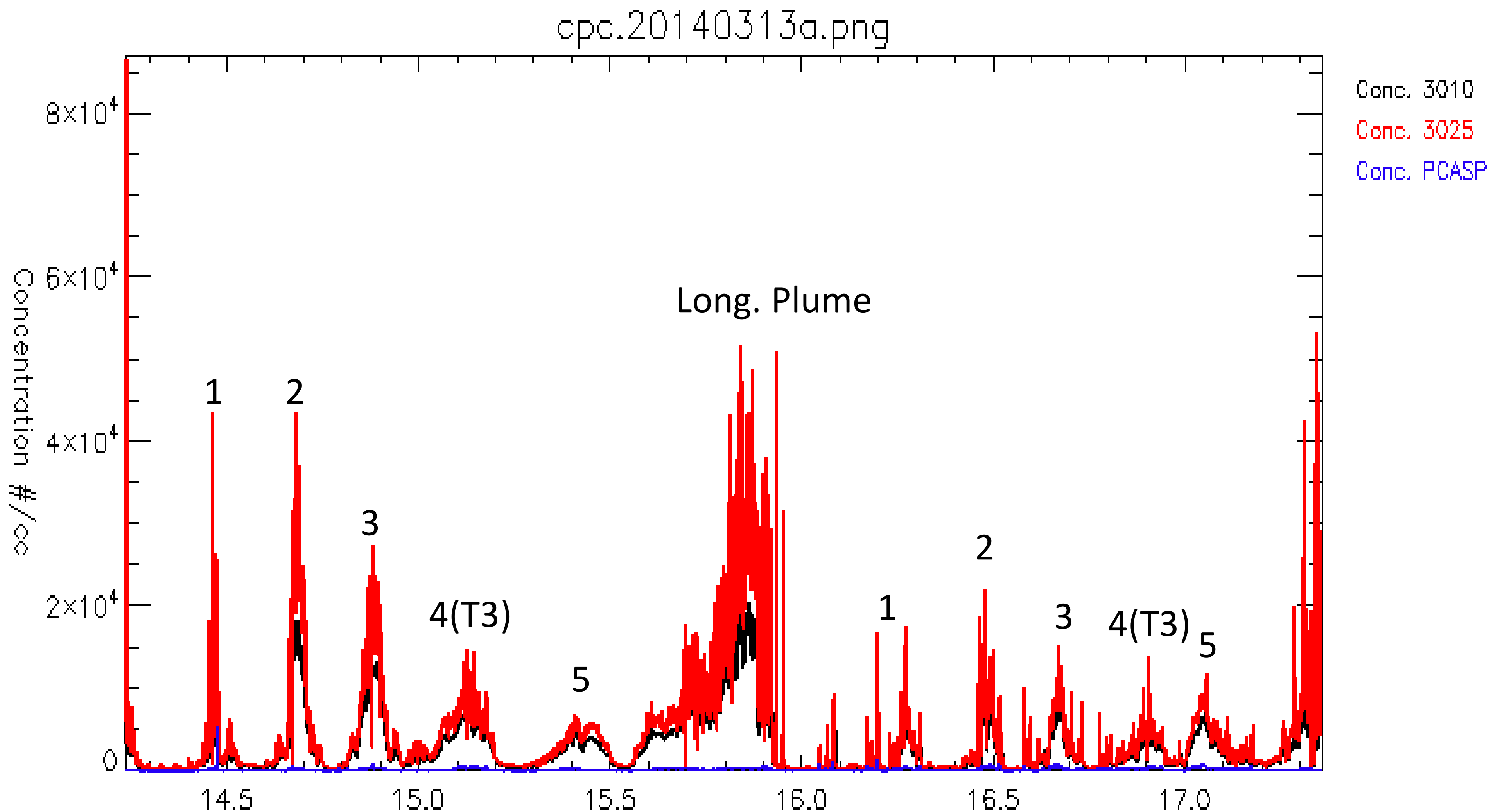

CPC COUNTS, GoAmazon2014/5, IOP1, 16 March 2014, 14:41 to 15:49 UTC
IARA: *Karla Longo, Beat Schmid, Scot Martin, and many important collaborators*
T3
T2
T1
16.2 km
Image Landsat
Google earth
Slide prepared by Scot Martin

Particle Counts, +/- local noon, 13 March 2014



Range: 400 to 50,000 particles

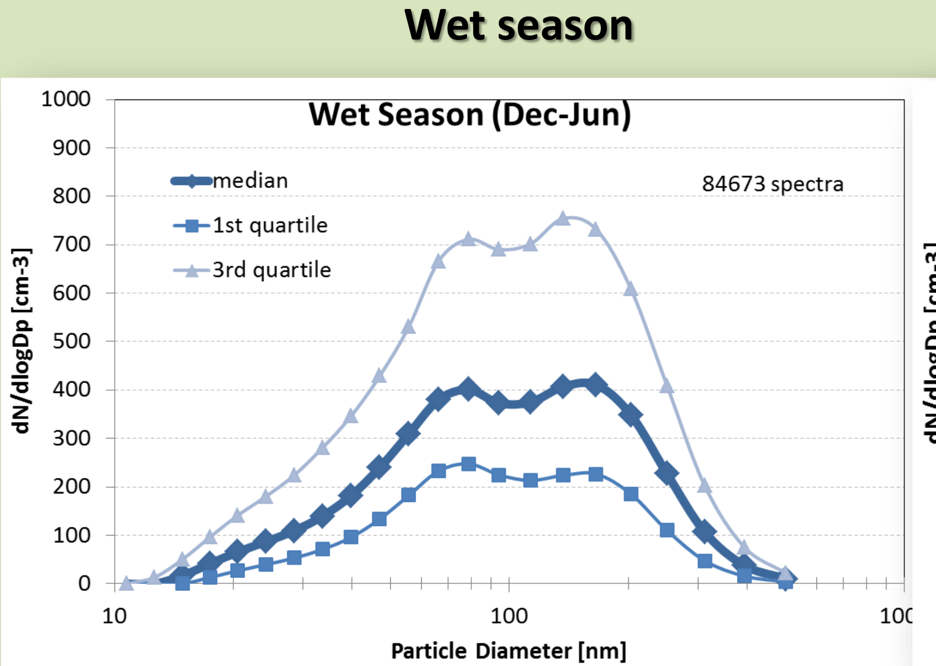
Particle Counts along Flight Path

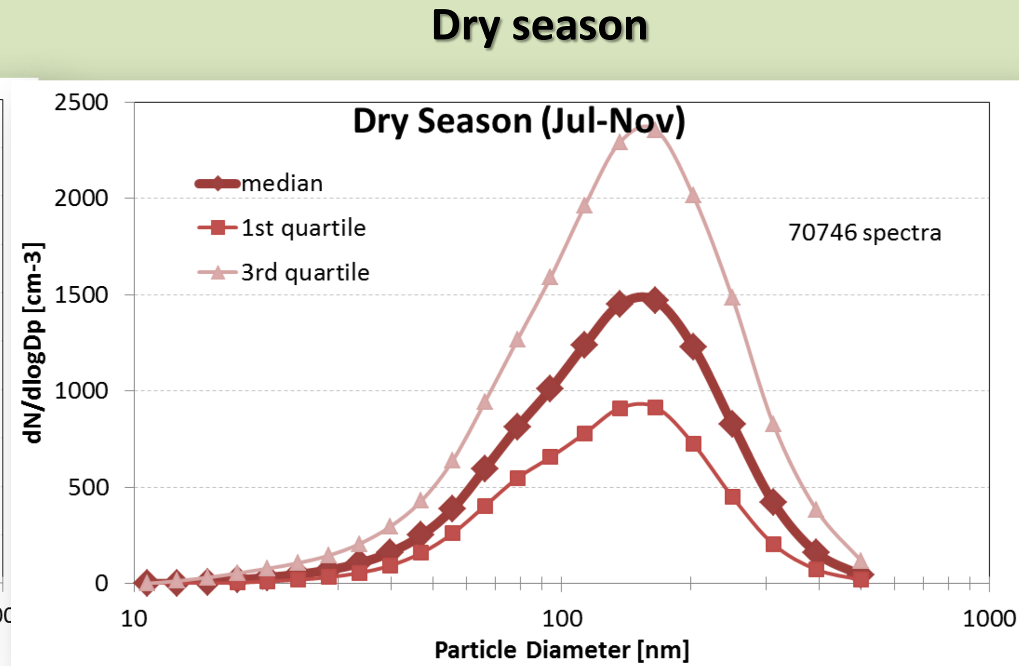


2 - AEROSOL PHYSICAL PROPERTIES

2B – PARTICLE SIZE DISTRIBUTION

TT34 forest site aerosol size distributions 2008-2011



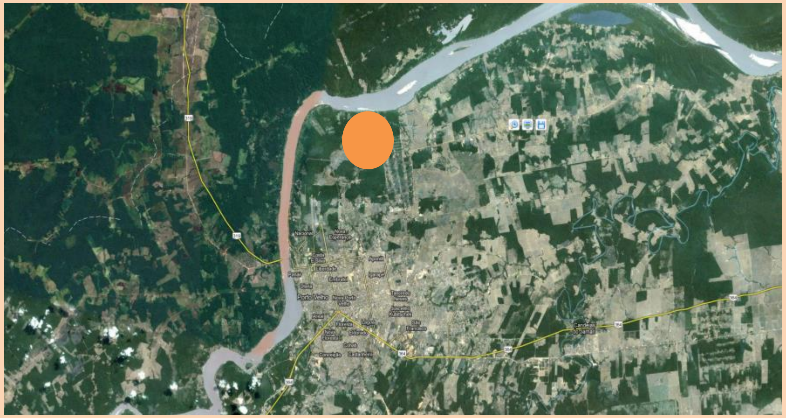


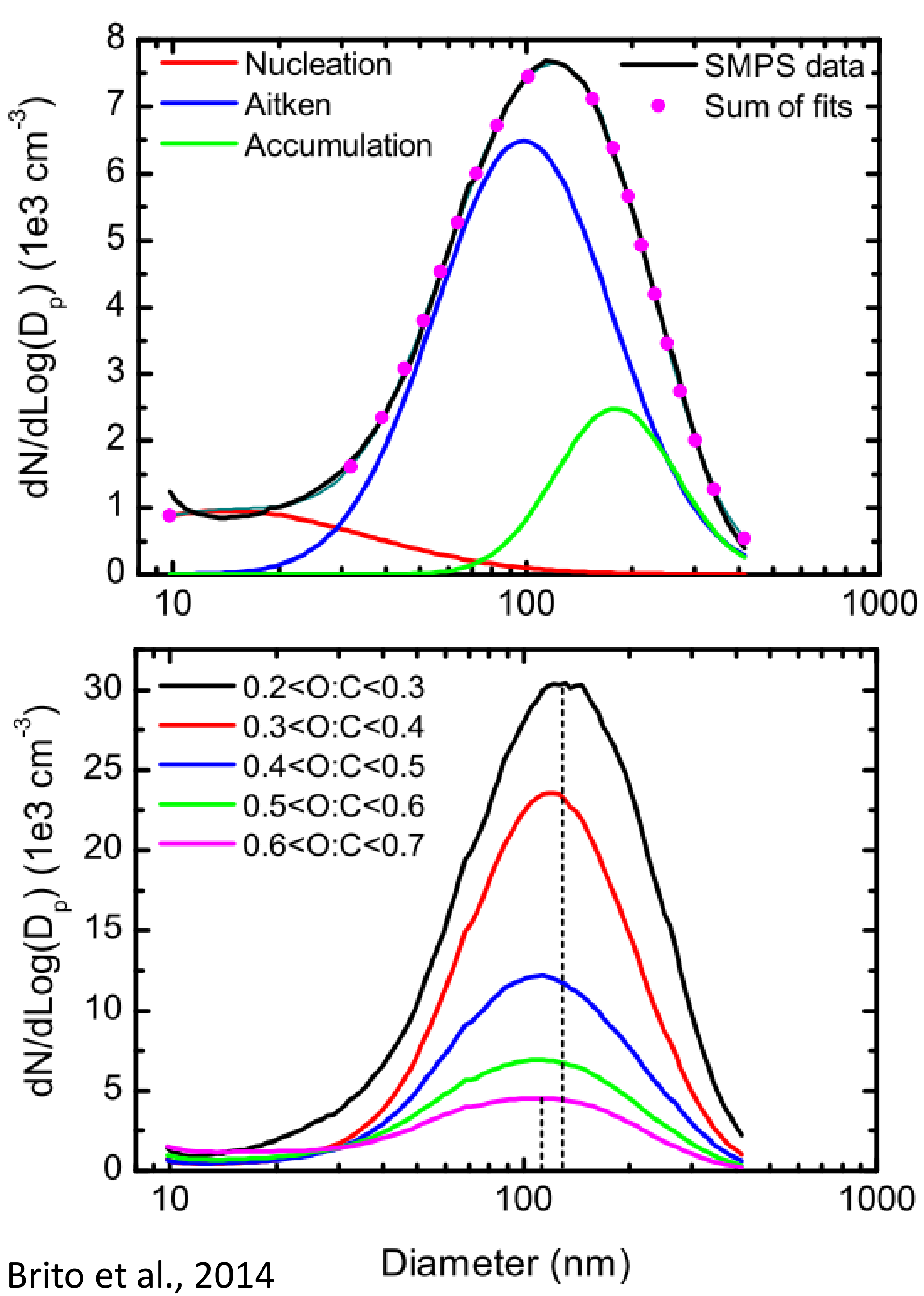
Fit Parameters for median size distributions:

	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

SAMBBA
Porto Velho

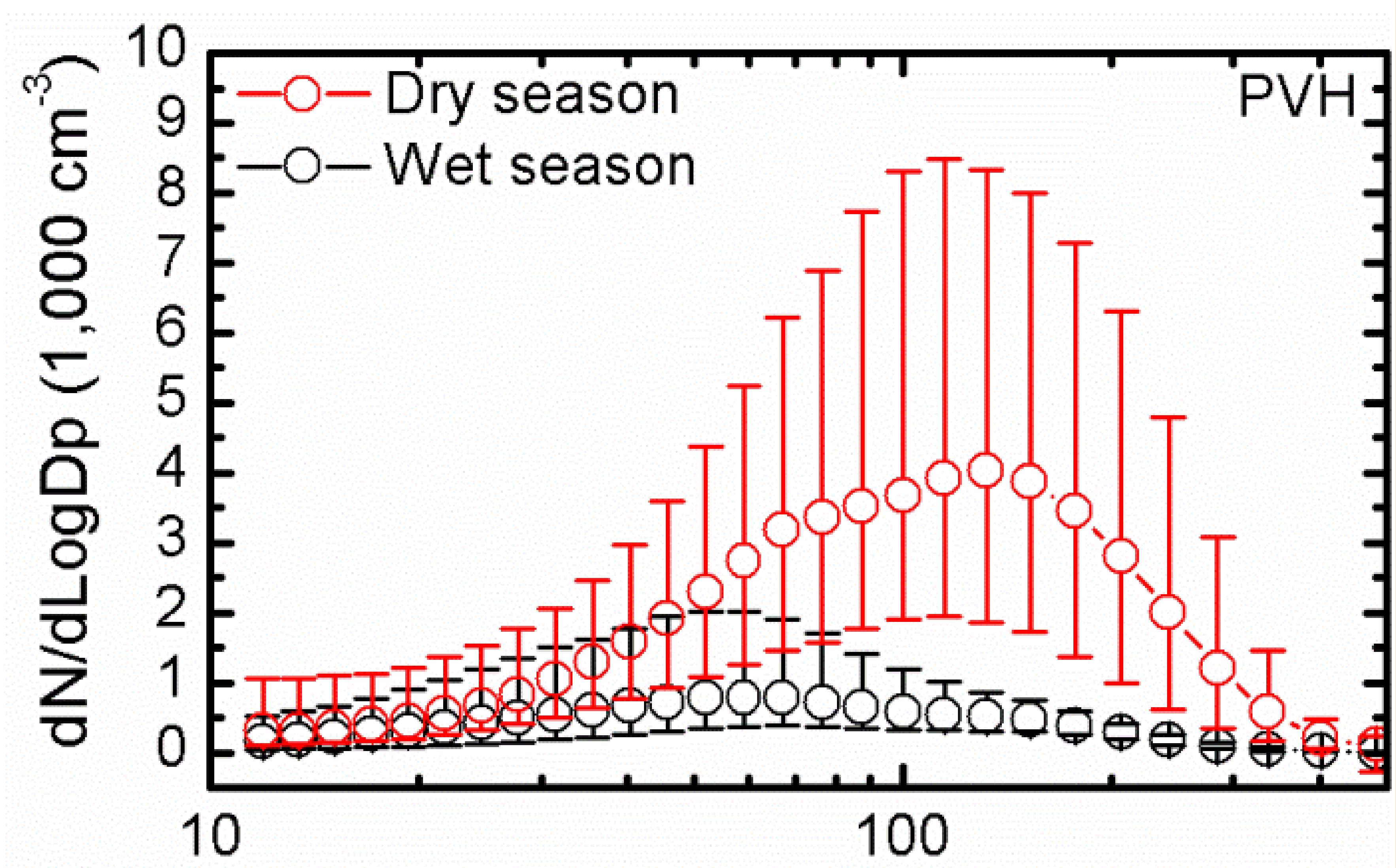
Single mode size distribution: processing leads to small changes in size distribution shape





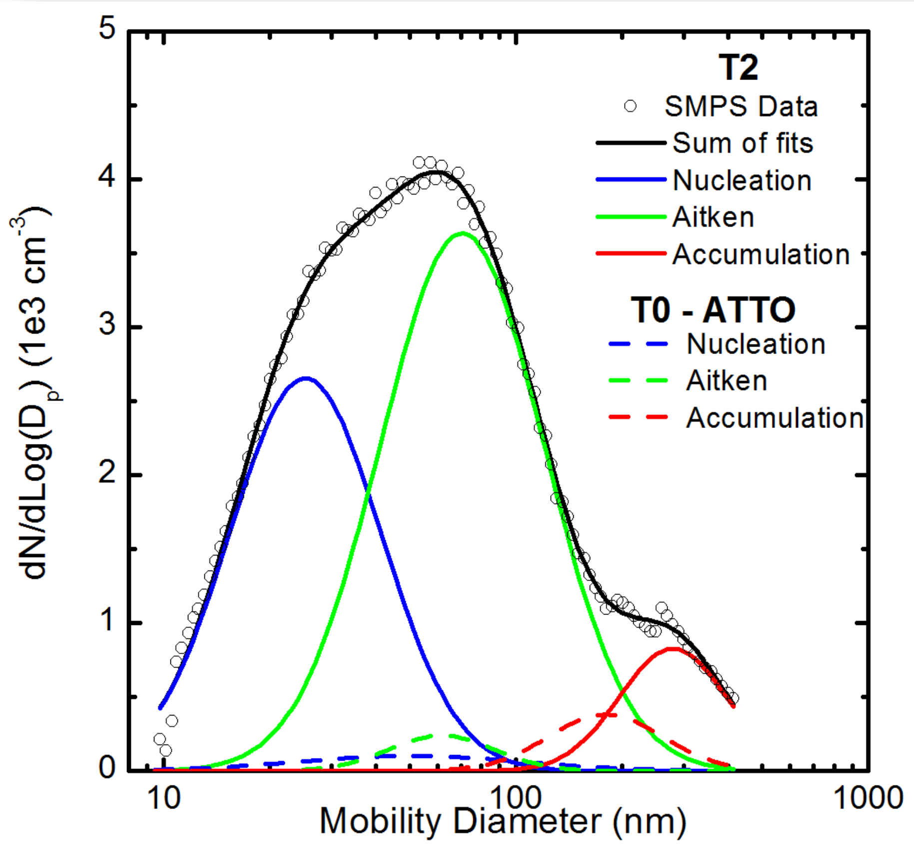
Brito et al., 2014

SAMBBA Porto Velho aerosol size distributions
Dry versus wet season

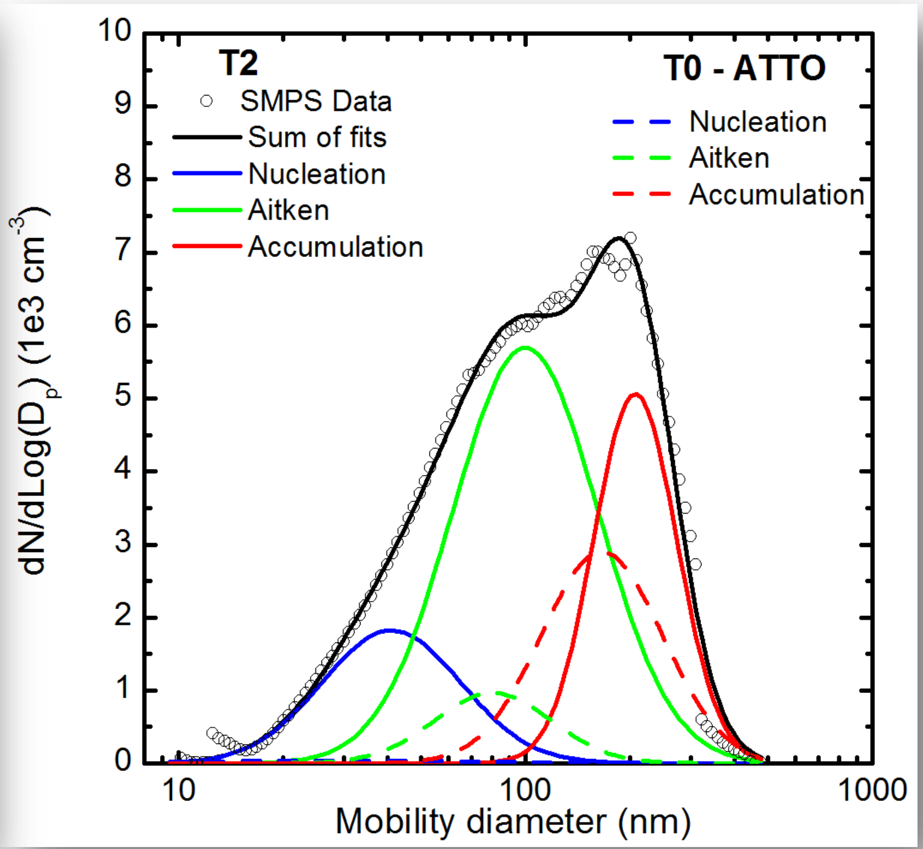


Aerosol size distribution
T0a (ATTO) versus T2 (urban)

Wet season

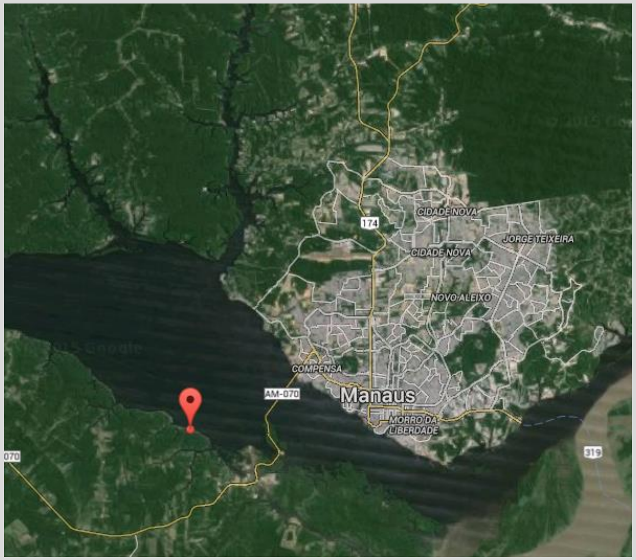


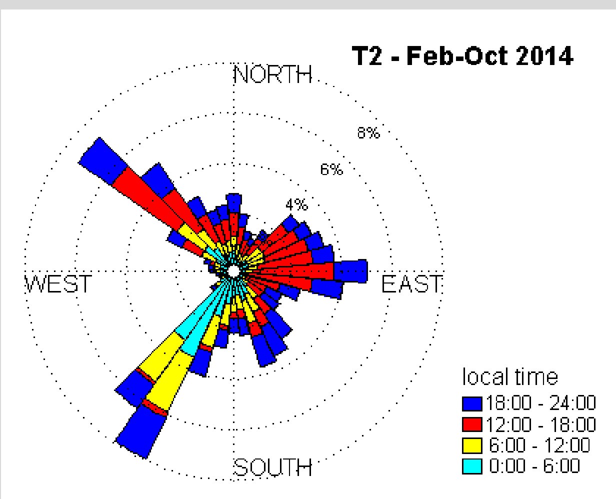
Dry season

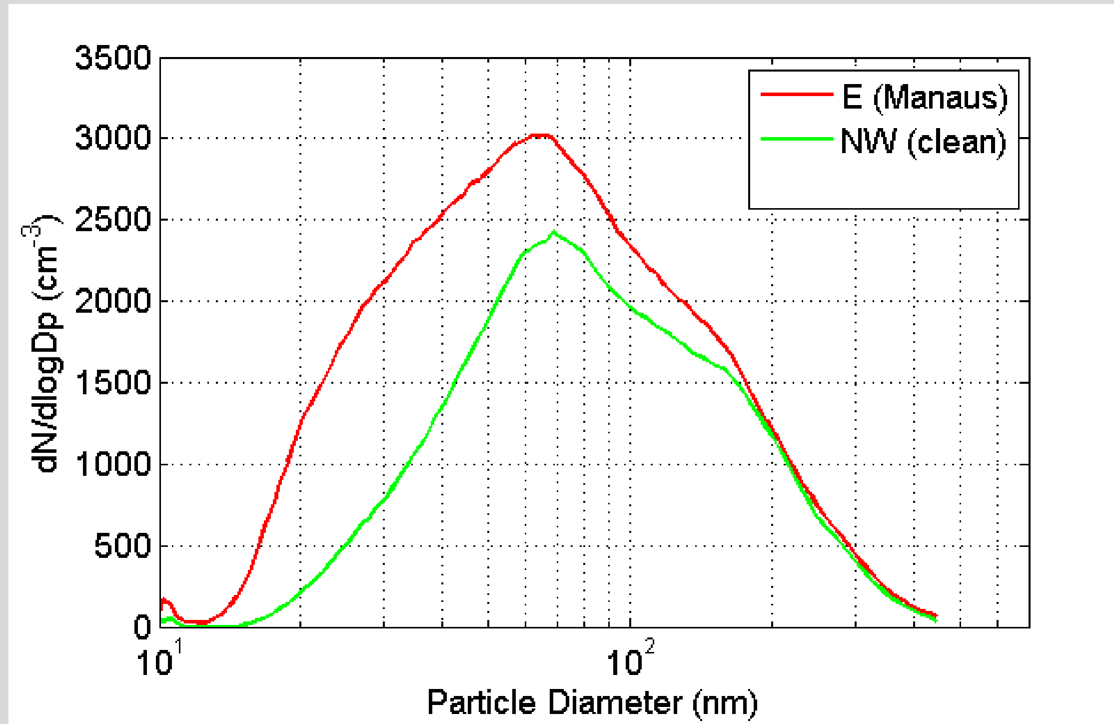


(Joel Brito results)

Aerosol size distribution at T2 (urban)



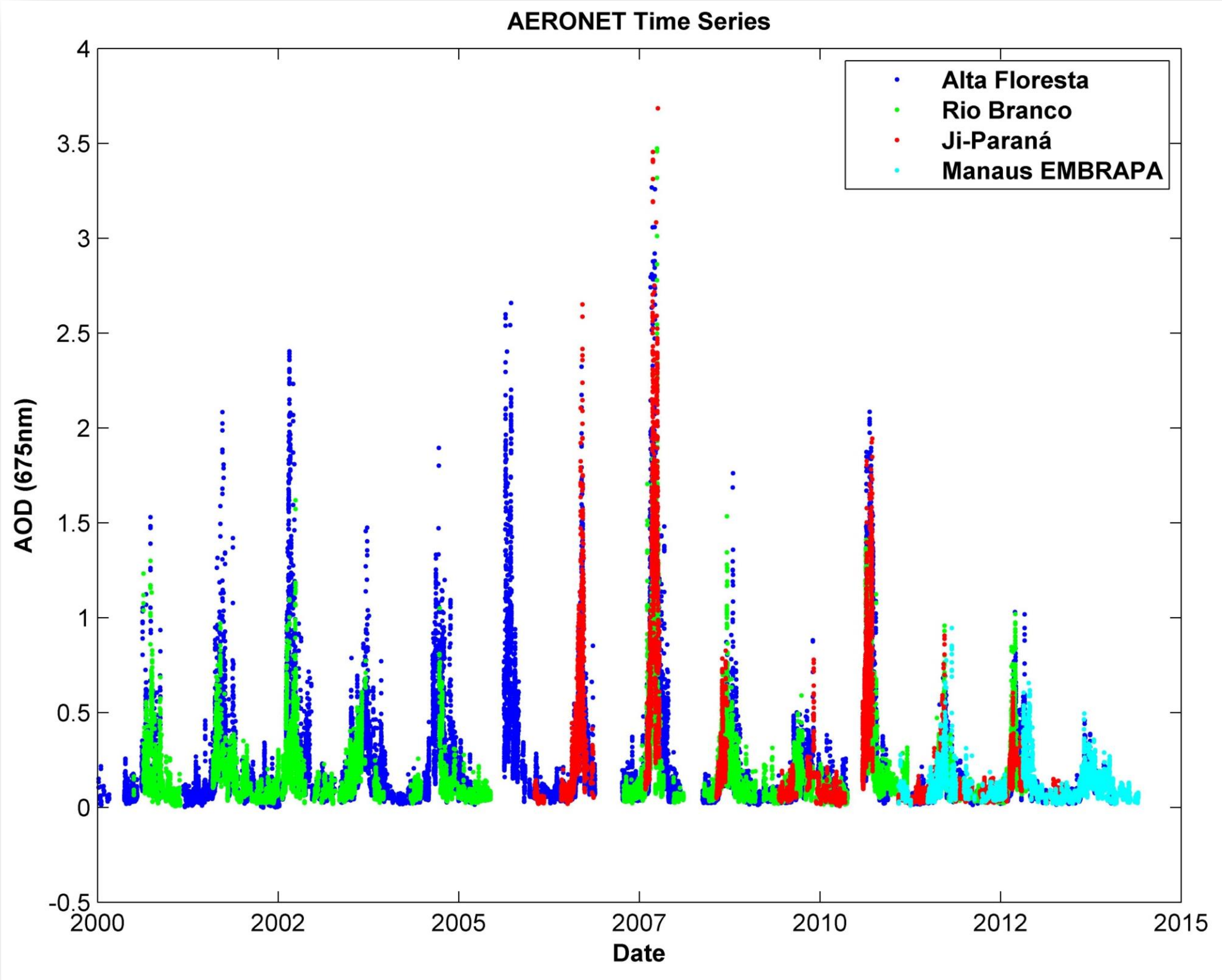




2 - AEROSOL PHYSICAL PROPERTIES

2B – PARTICLE OPTICAL PROPERTIES

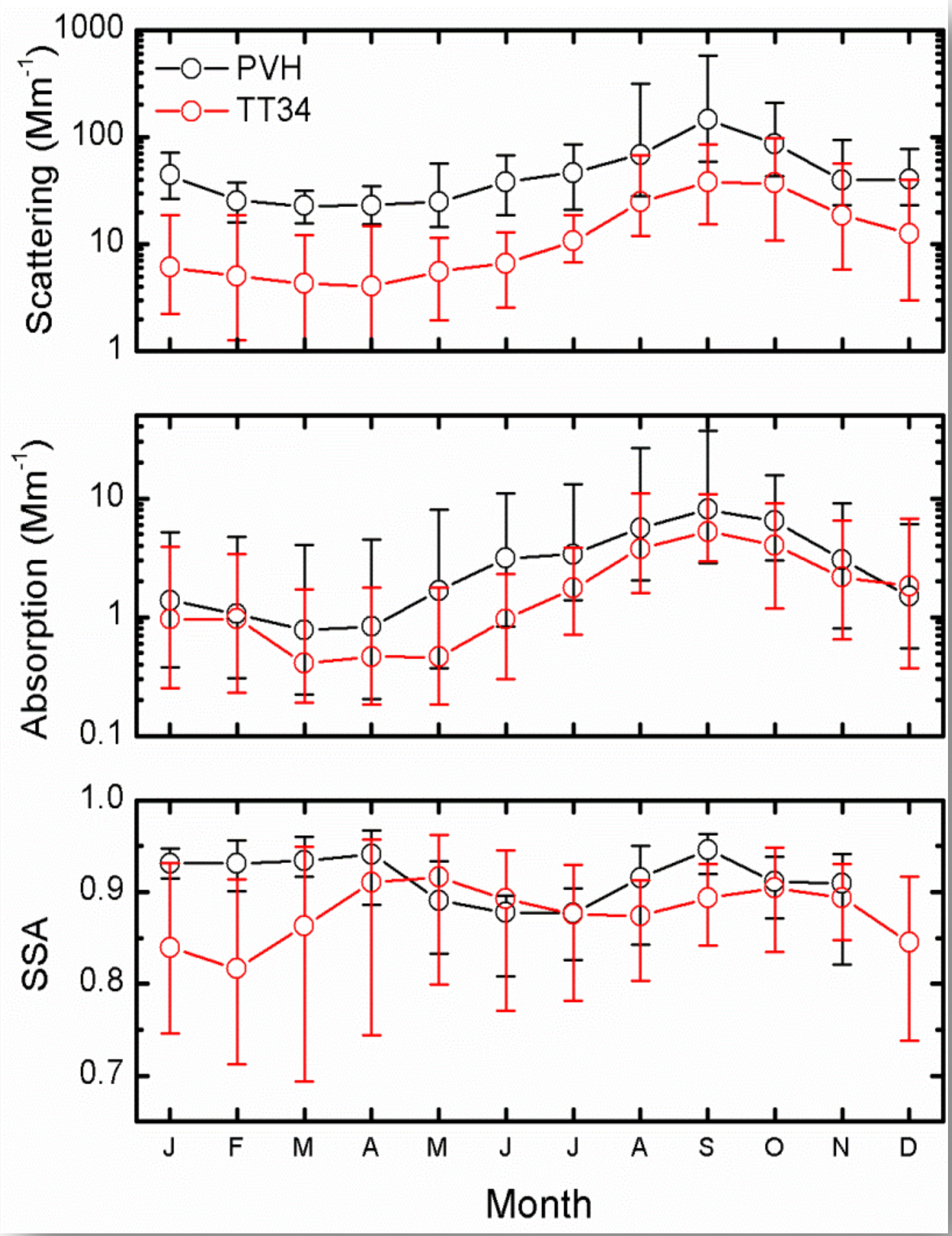
14 years of AERONET measurements in Amazonia



(Fernando Morais e Bruna Holanda , 2014)

Scattering, absorption and SSA in TT34 forest site and Porto Velho

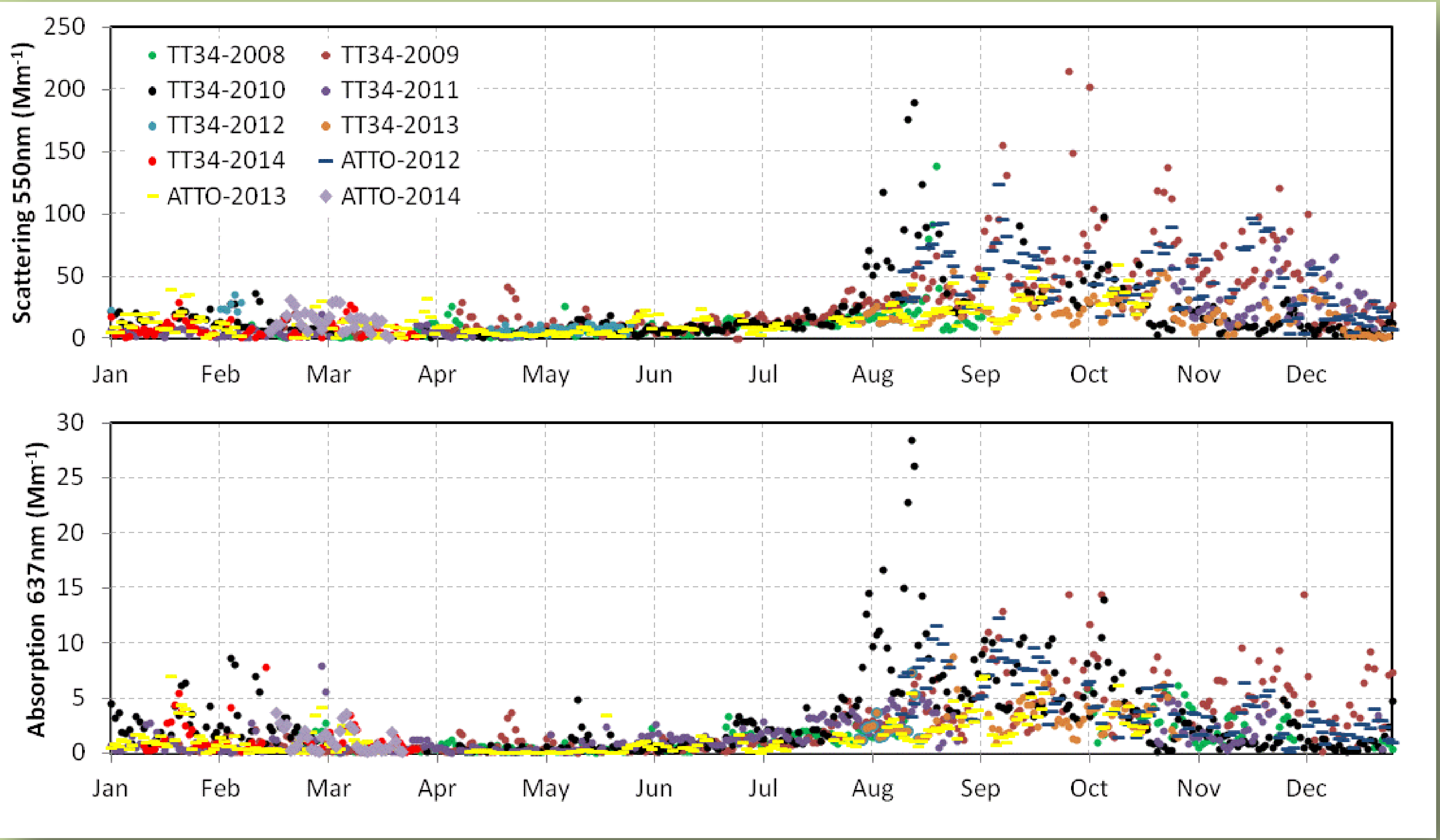
Monthly statistics (2009 – 2012) for light scattering coefficient σ_s at 637 nm and light absorption coefficient σ_a at 637 nm in Mm^{-1} for Porto Velho (PVH, in black) and central Amazonia (TT34, in red).



Single Scattering Albedo Lower at the pristine site

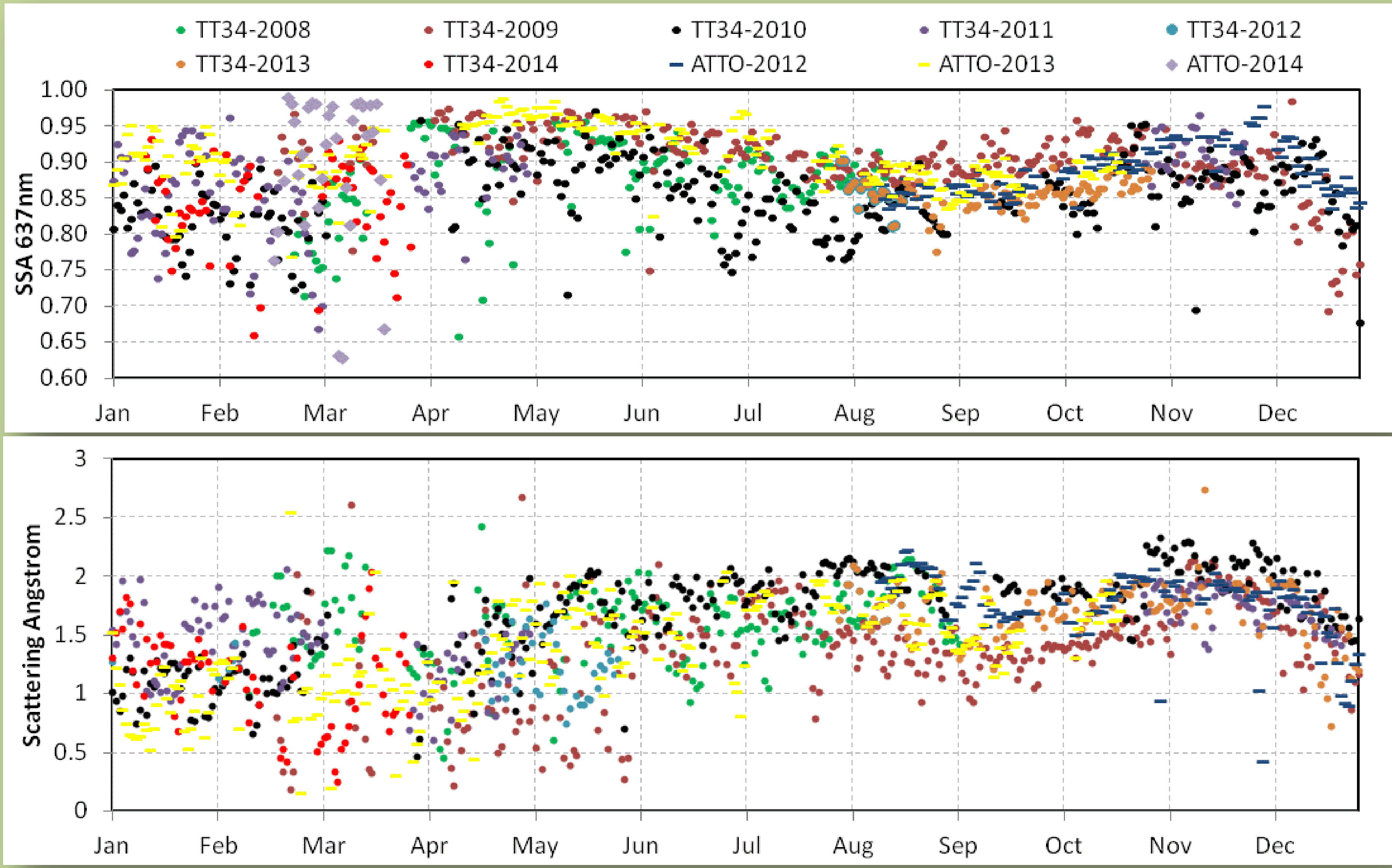
Artaxo et al., 2013

Forest sites - scattering and absorption comparison (2008-2014)



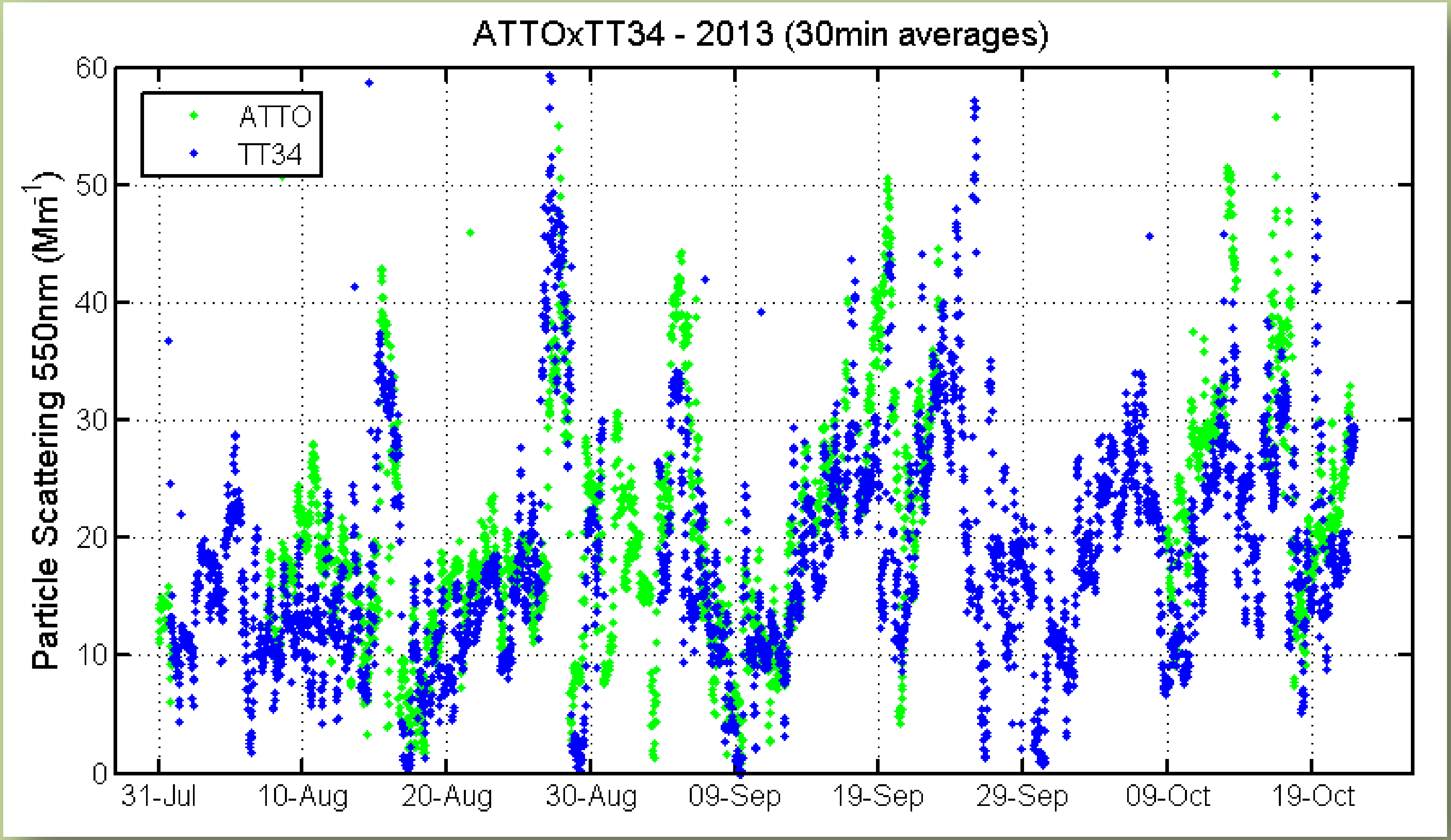
All data corrected for STP (1013 mbar, 0C).

Forest sites - Single scattering albedo and scattering angstrom comparison (2008-2014)



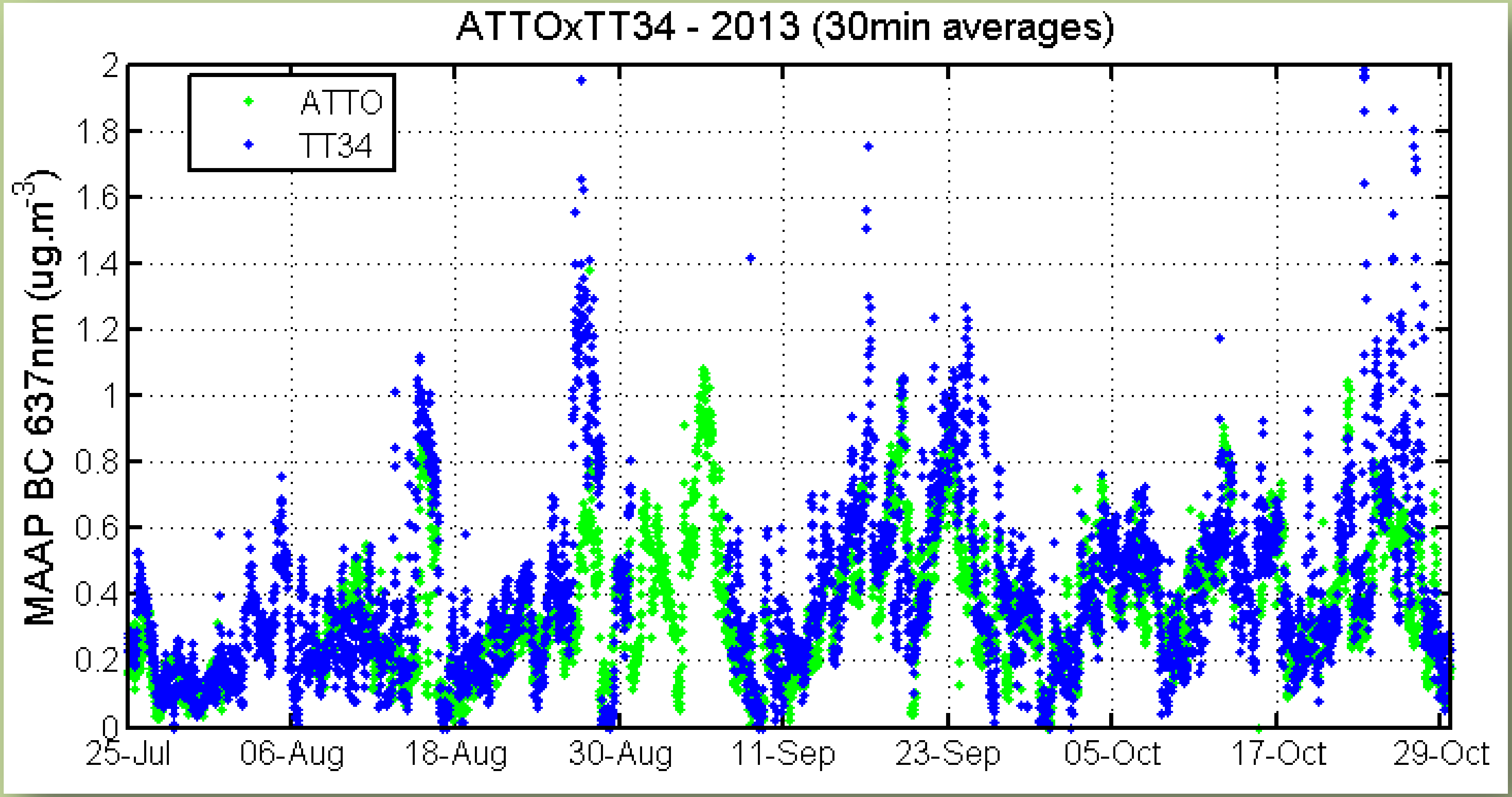
Forest sites: a zoom in the dry season

Light scattering

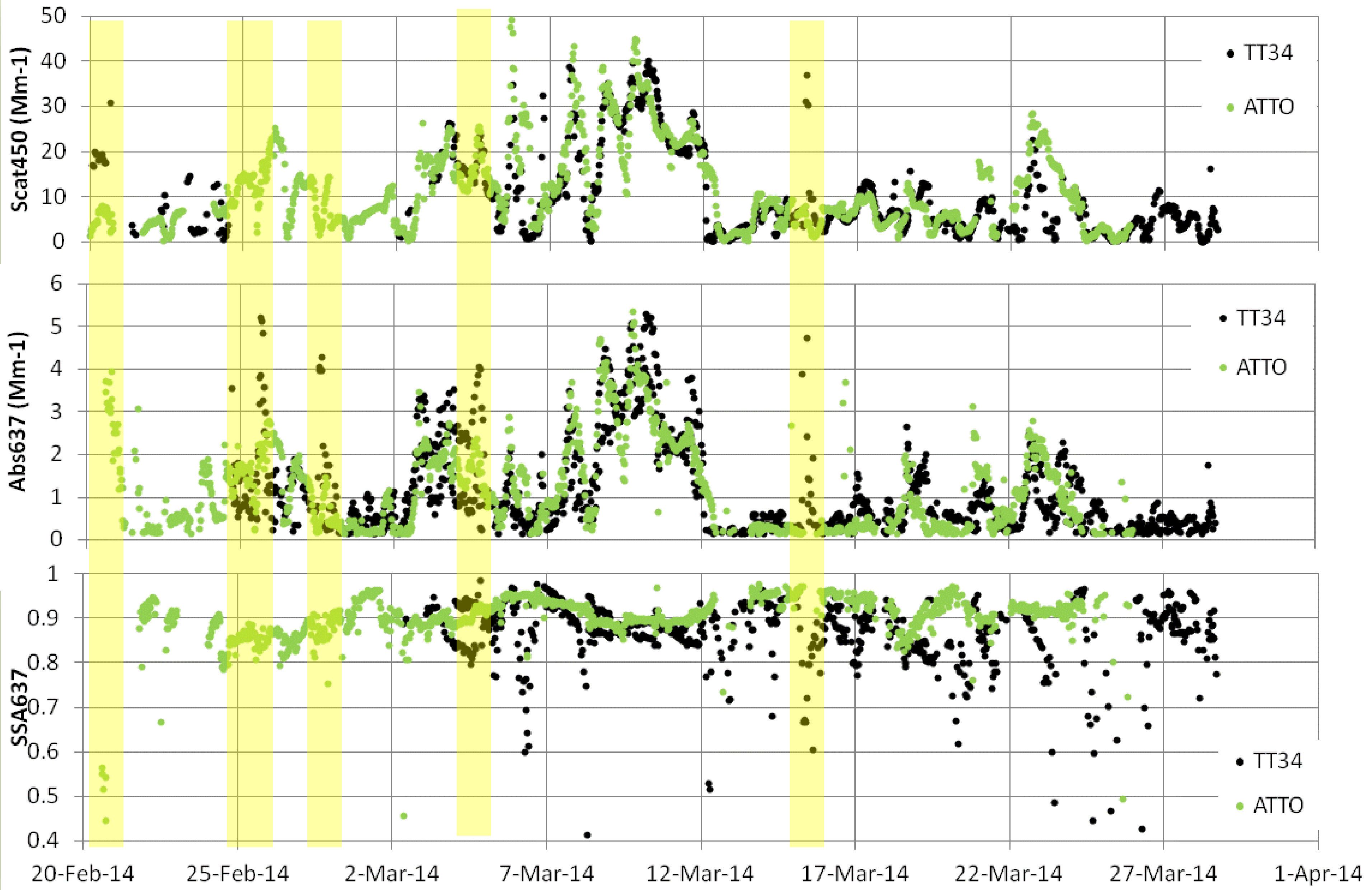


Forest site: a zoom in the dry season

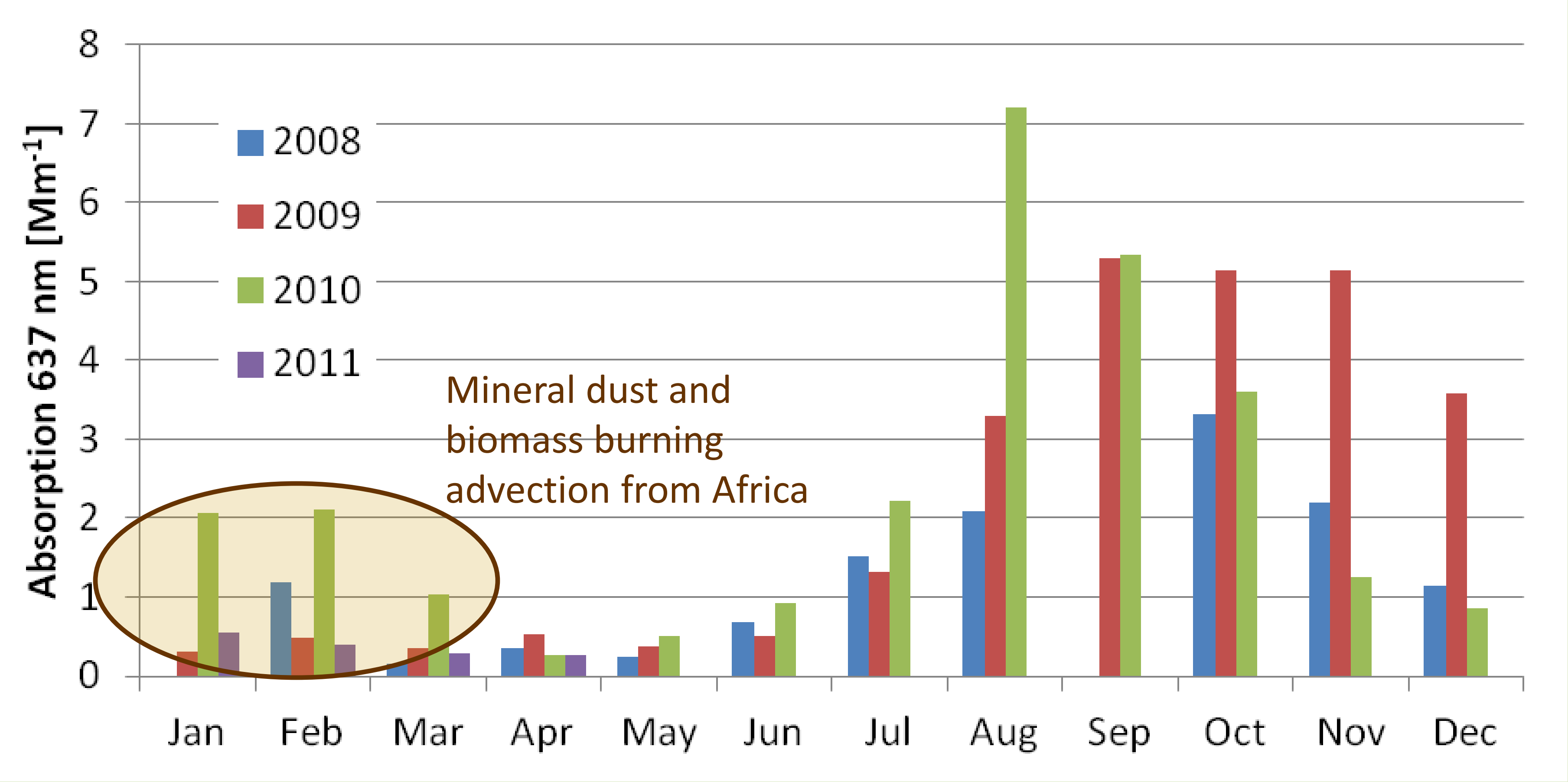
Black Carbon



A zoom in the wet season (TT34xATTO)



Aerosol absorption at TT34 forest site



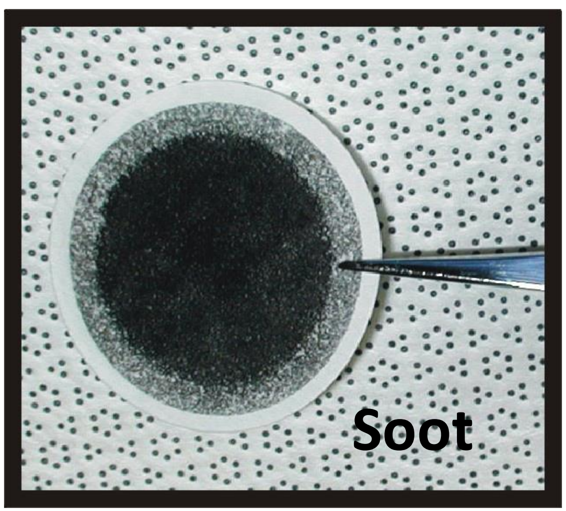
Rizzo et al., 2012

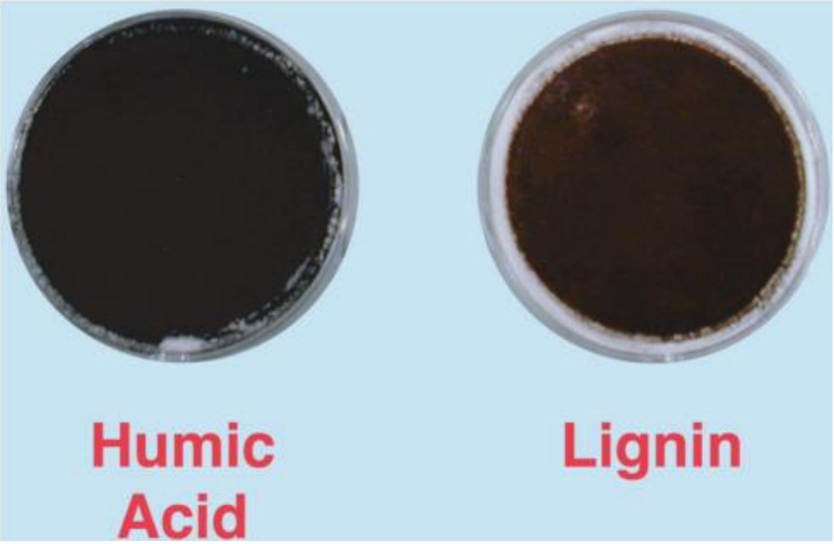
Under the influence of African advection:

- Absorption increase by a factor of 2.0
- Albedo descrease by 7%

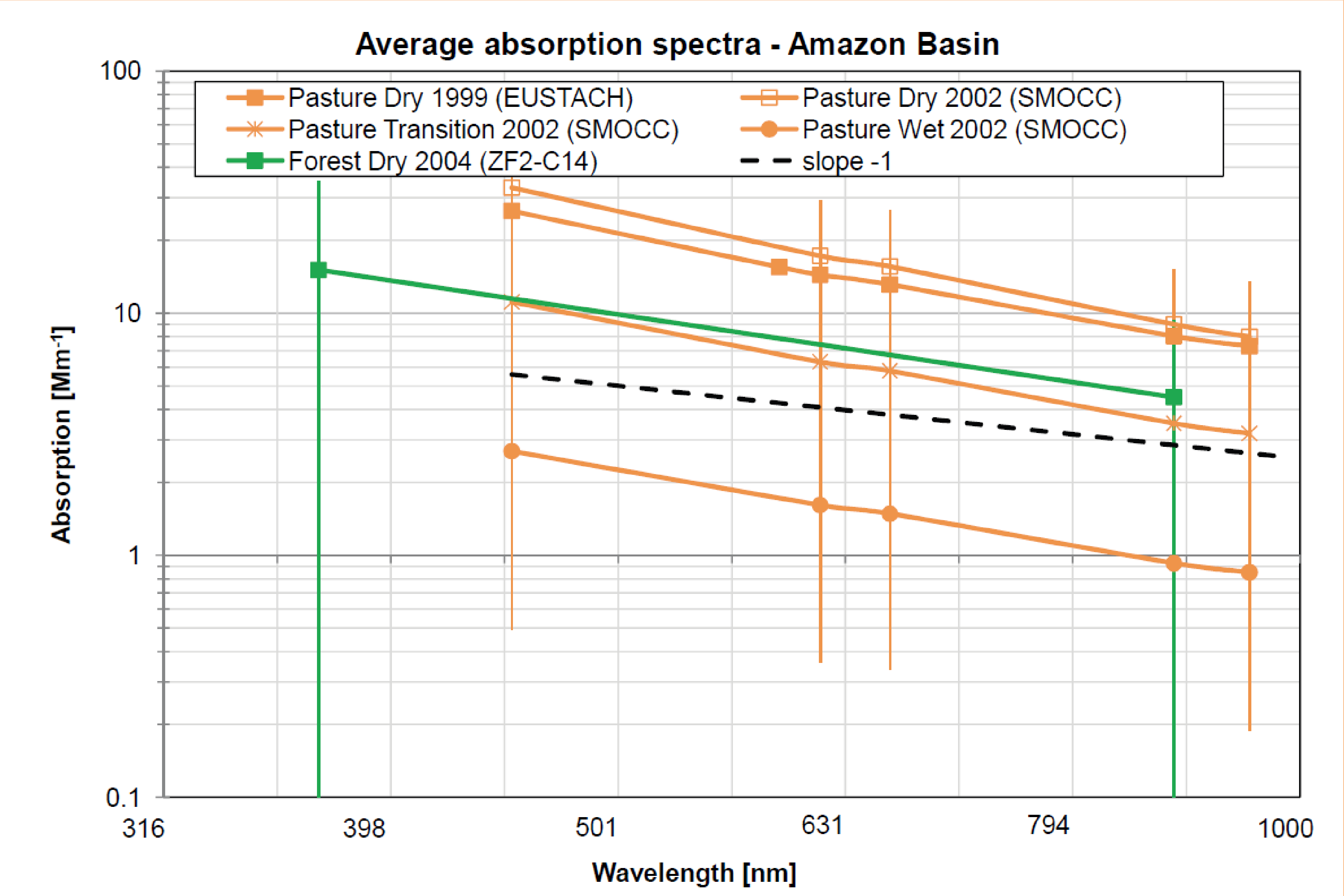
Refractory aerosols

- Thermically inerts (oxidize above ~ 600 ^{o}C)
- Strong light absorption
- Examples: graphite, soot, policyclic aromatics, HULIS (humic-like), biopolimers





Aerosol absorption spectra – pasture site



Rizzo et al., 2011

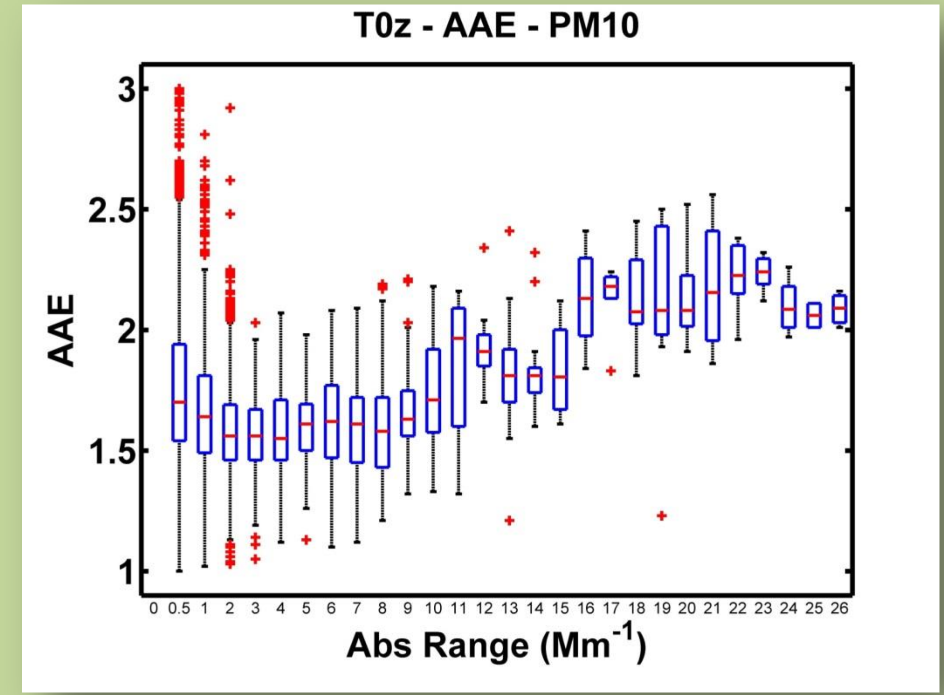
Angstrom exponent for absorption

Experiment	σ_{abs} (450) Mm^{-1}	Ångström Linear Fit ($\mathring{a}_{lin}$)
Forest Dry 2004 (ZF2-C14)	$11 \pm 8^{*}$	$1.3 \pm 1.3^{**}$
Pasture 2002 (SMOCC)	21 ± 22	1.7 ± 0.4
Pasture Dry 2002 (SMOCC)	33 ± 5	1.8 ± 0.4
Pasture Transition 2002 (SMOCC)	$11 \pm$	1.6 ± 0.4
Pasture Wet 2002 (SMOCC)	2.7 ± 0.2	1.5 ± 0.4
Pasture Dry 1999 (EUSTACH)	26 ± 1	1.7 ± 0.4

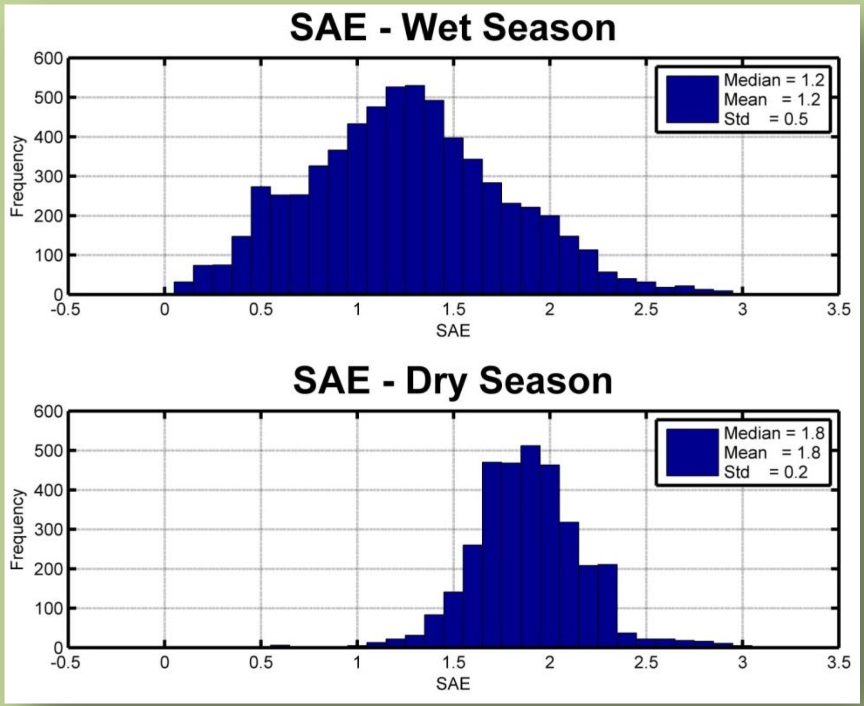
Rizzo et al., 2011

- å = 1.0 → soot carbon
- å > 1.0 → "brown carbon": HULIS, dust, biomass burning aerosols

Forest Site (ATTO) Absorption and scattering Angstrom exponent



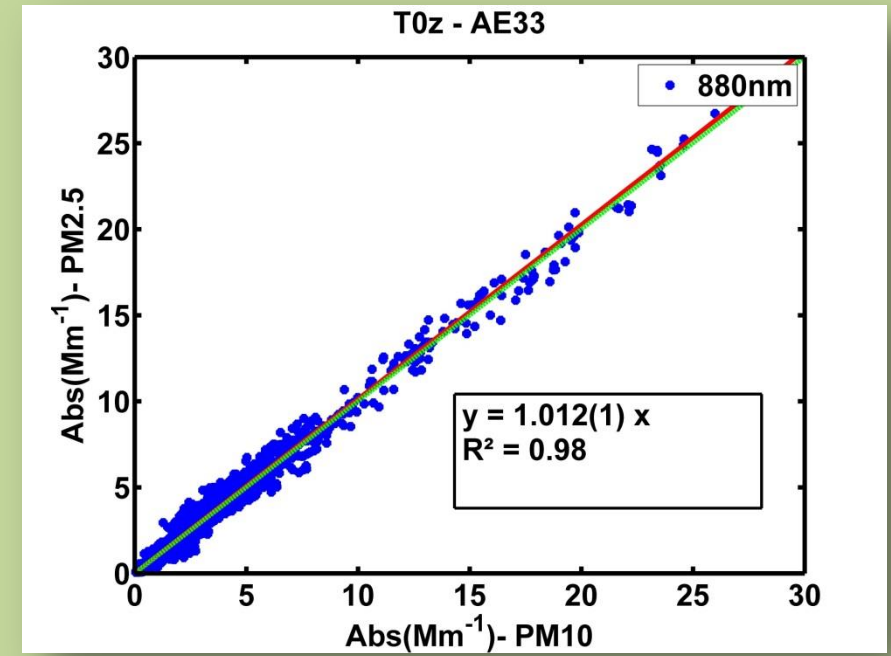
Plots of AAE for different ranges of absorption coefficients for PM 10 inlet.

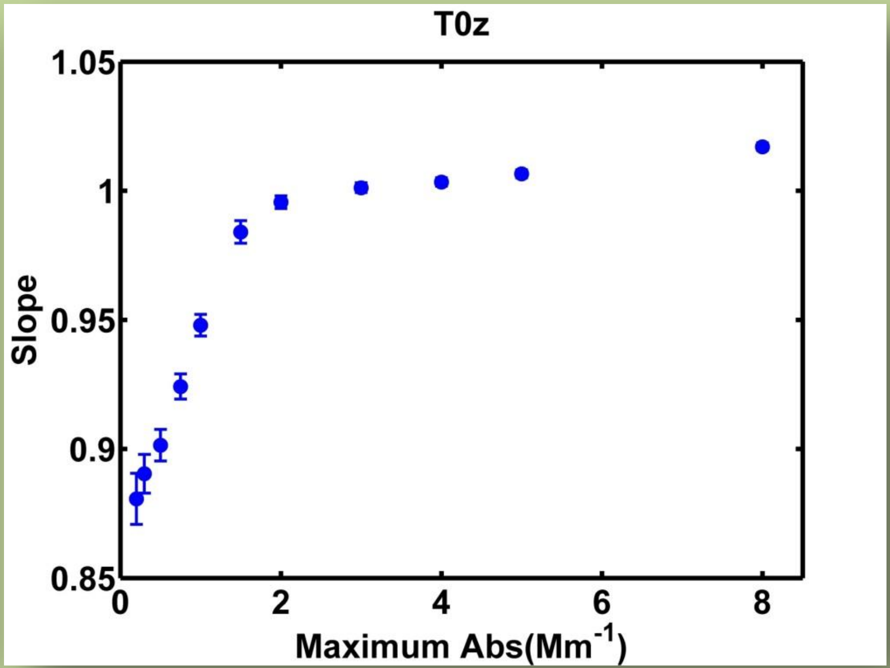


Histograms of Scattering Angstrom exponents

Bruna Holanda data

T0z – PM10 versus PM2.5 absorption





Comparison of the light absorption coefficients at 880nm between AE33 with PM10 and PM2.5 inlets, showing 30 min averages of data compensated for the loading effect and multiple scattering.

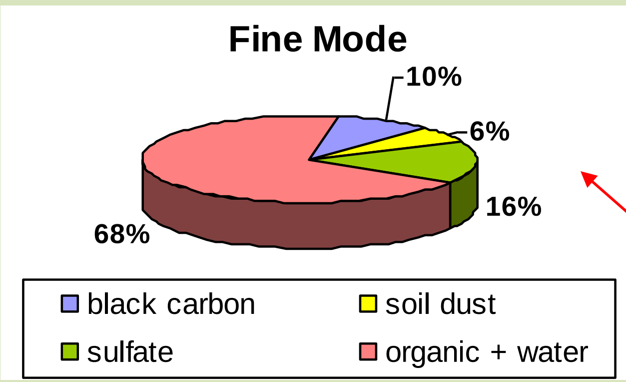
Slopes of the correlation between light absorption coefficients at 880nm measured by AE33 with PM10 and PM2.5 inlets, as a function of the maximum abs used in the regression.

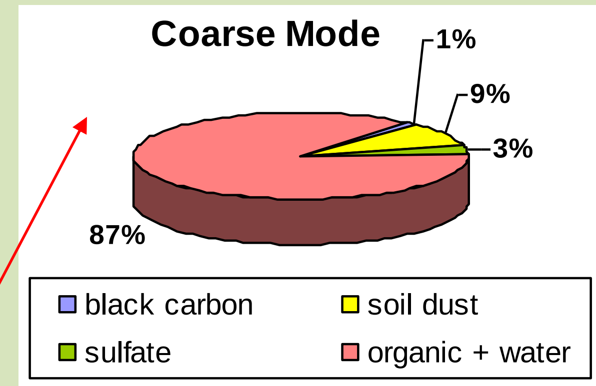
Bruna Holanda data

3 - AEROSOL CHEMICAL CHARACTERIZATION

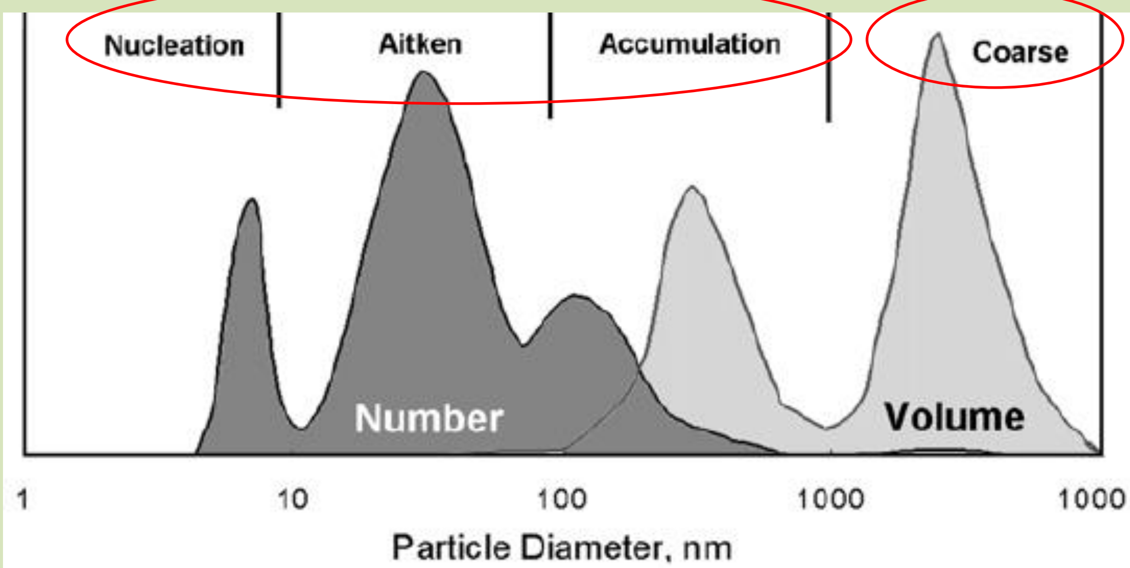
Biogenic aerosols in Amazonia (C14 forest site)

- Mass: 10-15 $\mu g/m^3$, Number: 300-500 cm^{-3}
- 70% of the mass on the coarse mode
- Organic matter = 60-70% FPM and 70-85% of CPM





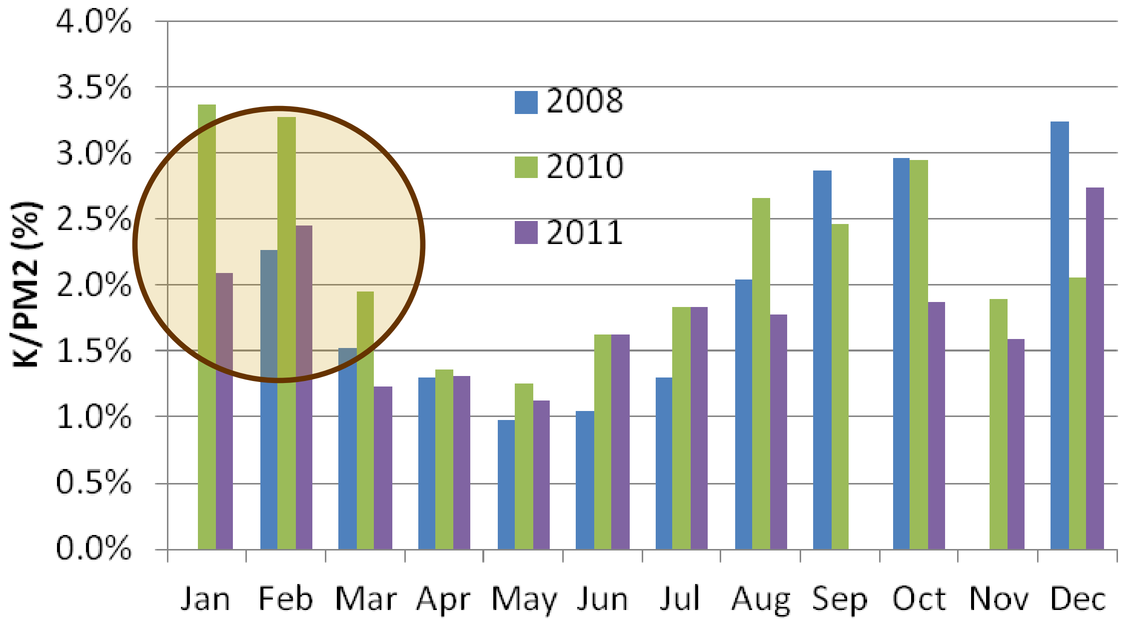
Rizzo et al., 2010

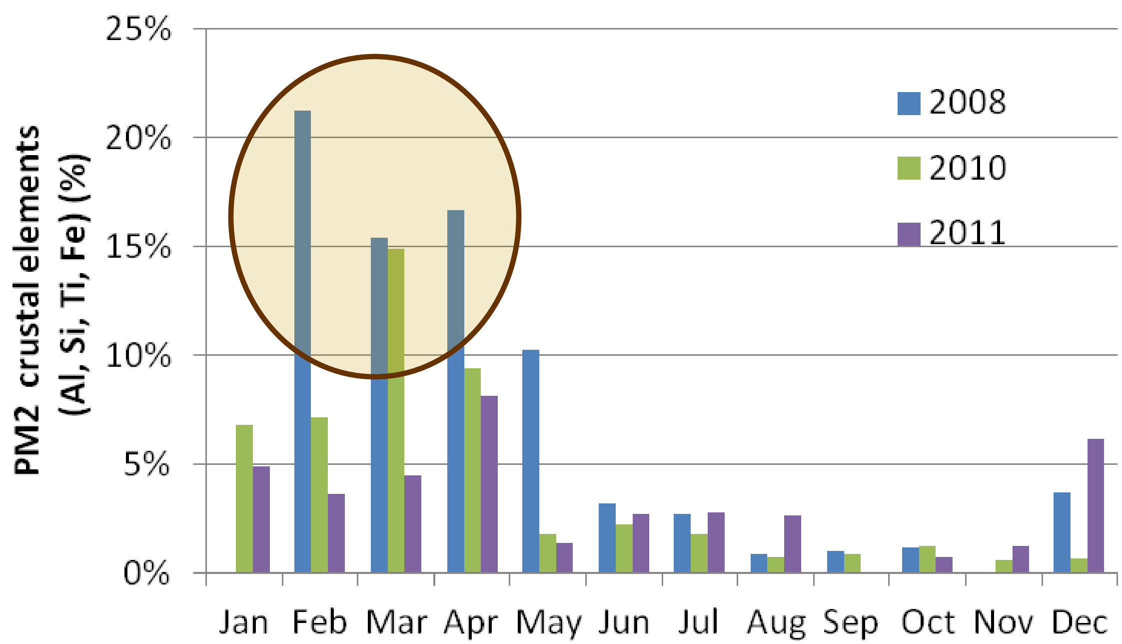


TT34 forest site: Aerosol elemental composition

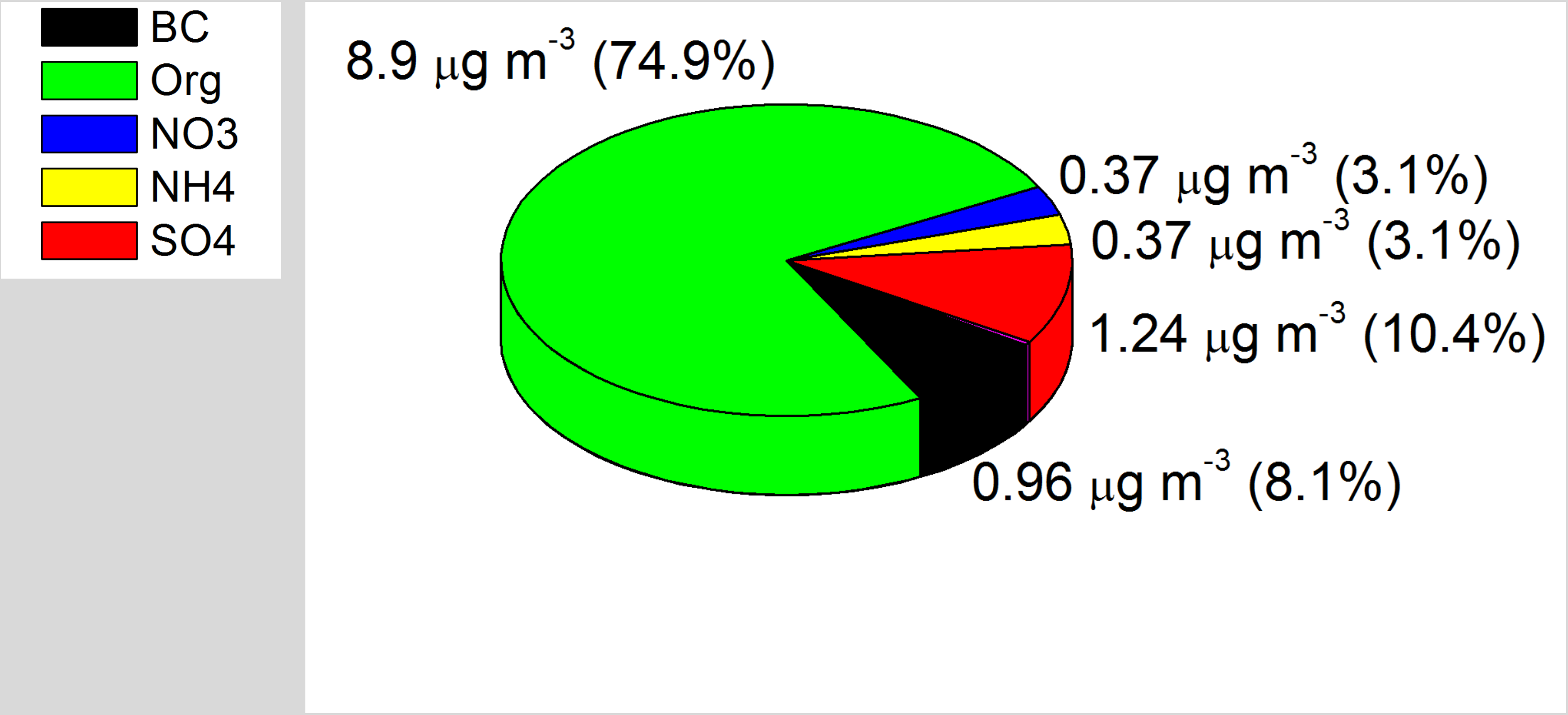
K (fine mode): tracer for biomass burning and for biogenic aerosols
Al, Si, Ti, Fe (fine mode): tracer for soil dust

Rizzo et al., 2012





Composition – Dry Season at T2 (urban)



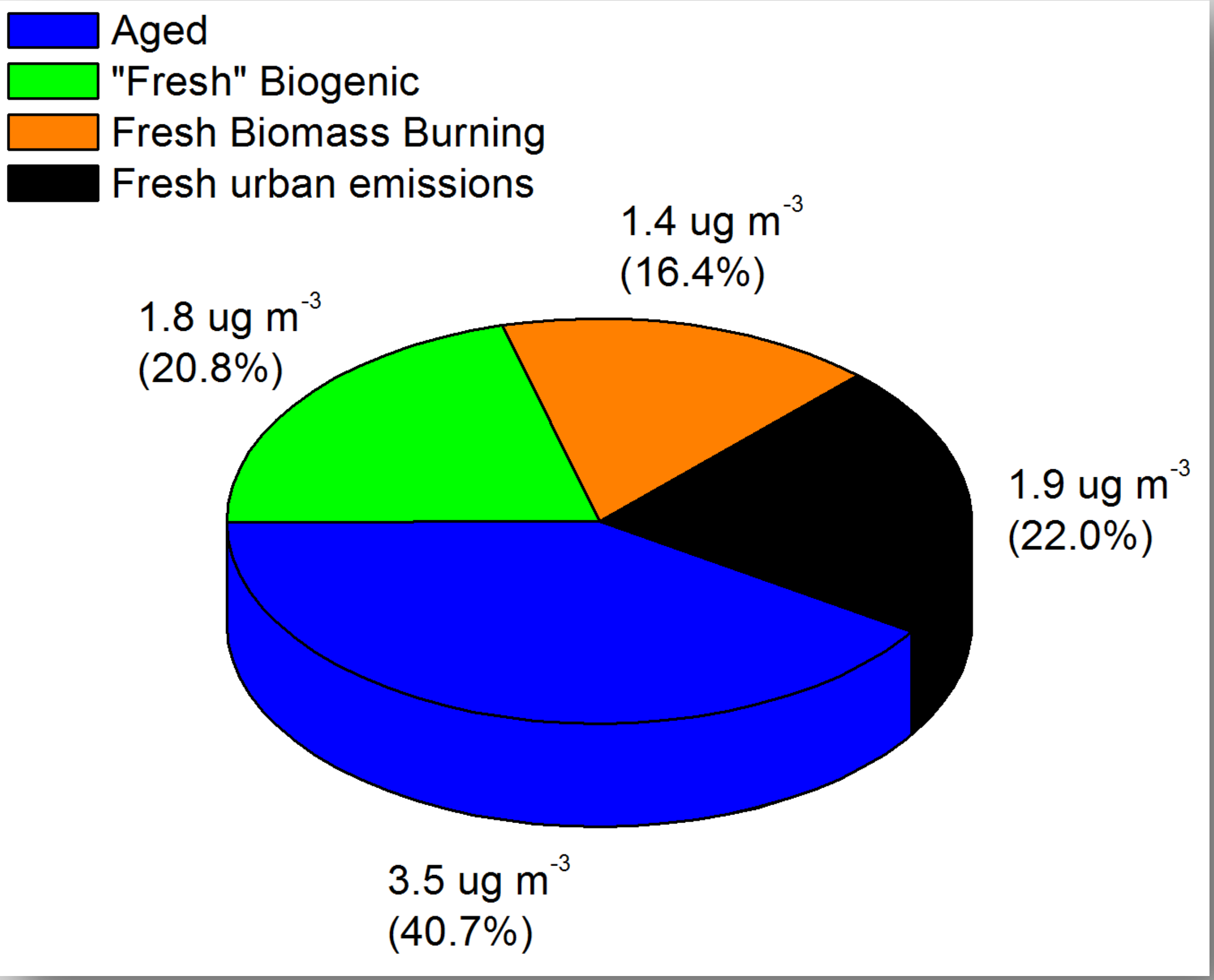
Brito, 2014

T2 - Organic aerosol source apportionment

T2 – dry season

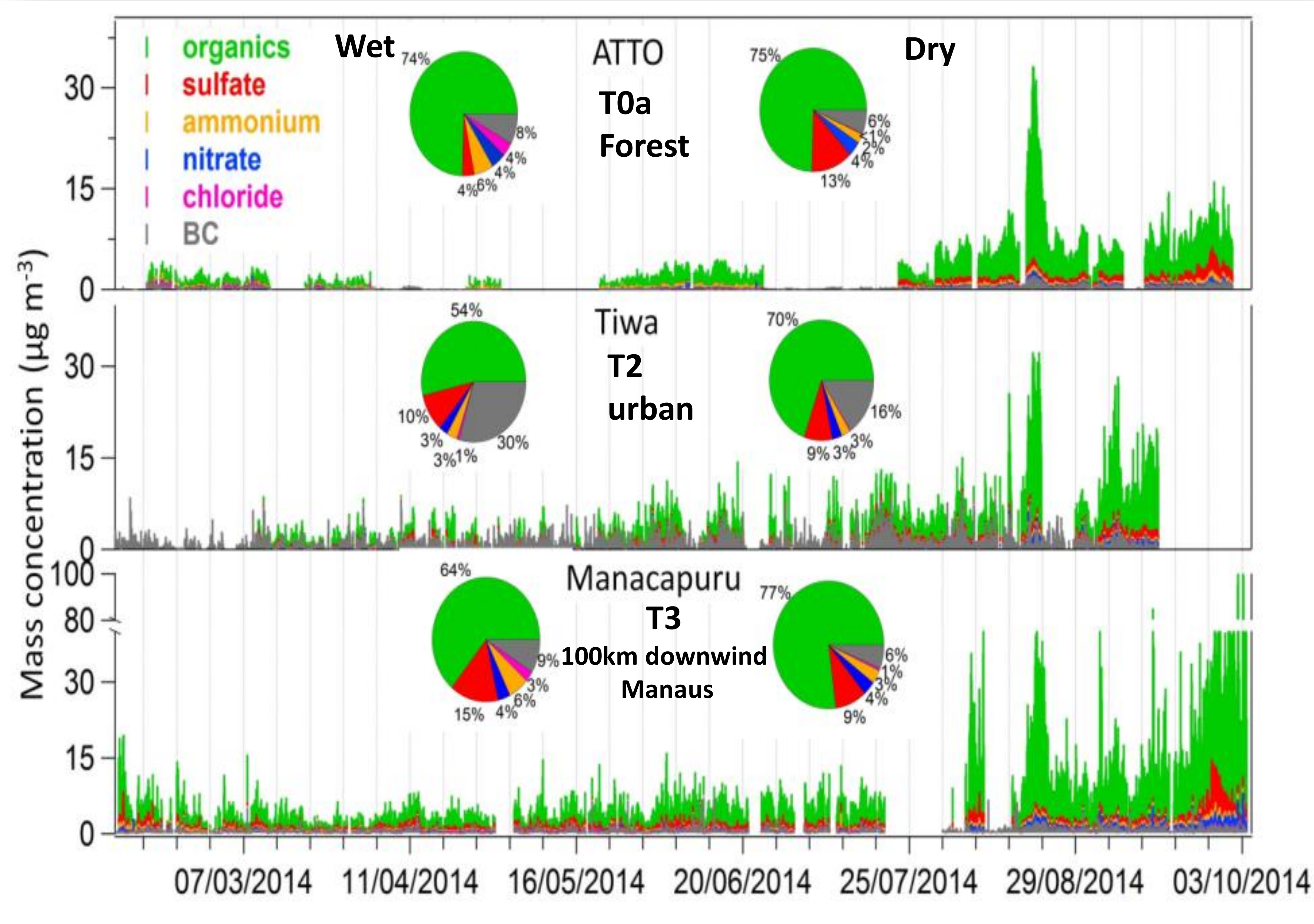
***Positive Matrix Factorization analysis* four factors:**

- **HOA (Urban),**
- **BBOA (biomass burning)**
- **Fac82 (isoprene SOA under low NOx condition)**
- **OOA (oxidized aerosols).**



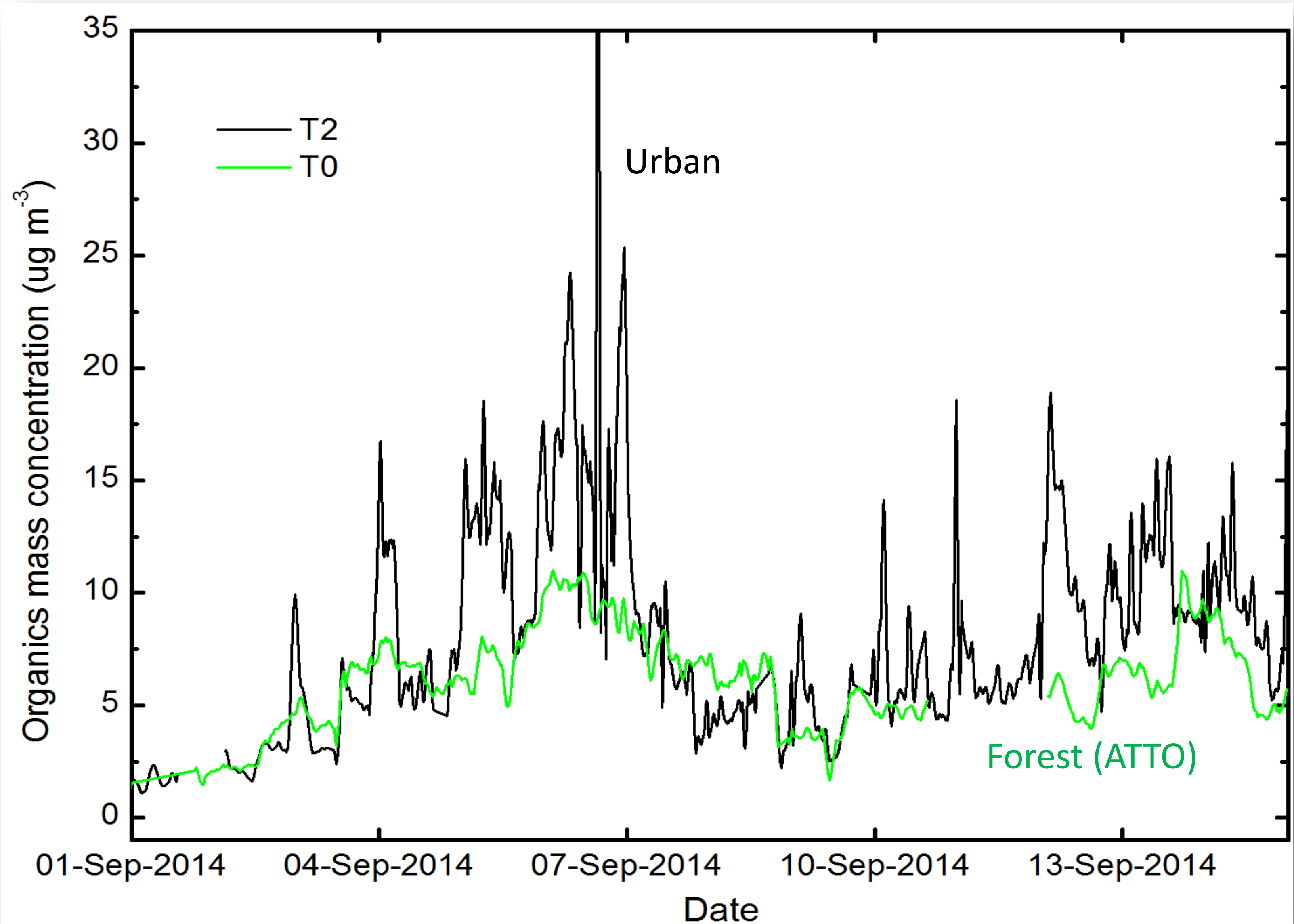
(Joel Brito results)

Organic aerosols from ATTO to Tiwa and Macapuru (with BC)

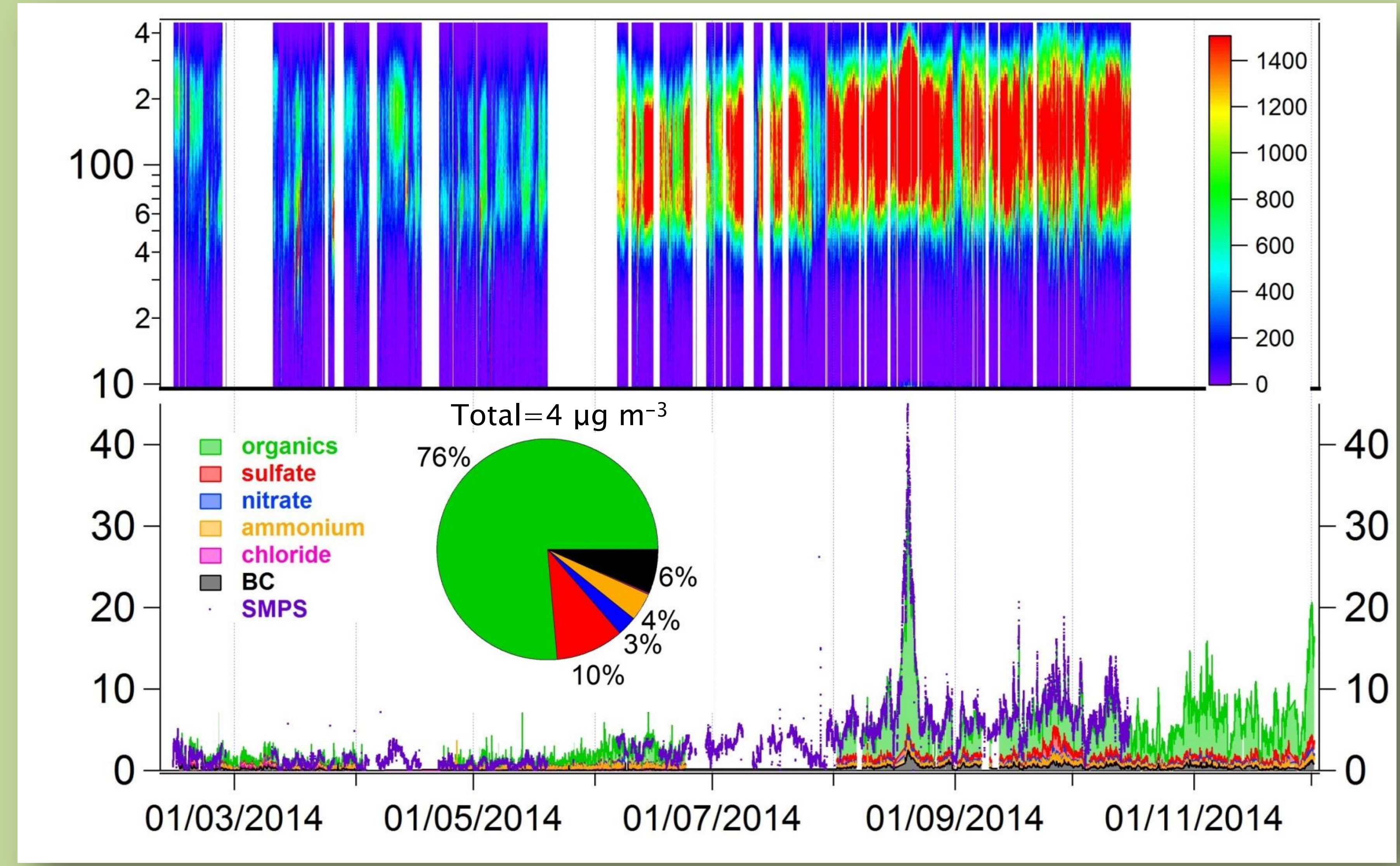


Carbone, 2015

Regional background under Manaus plume



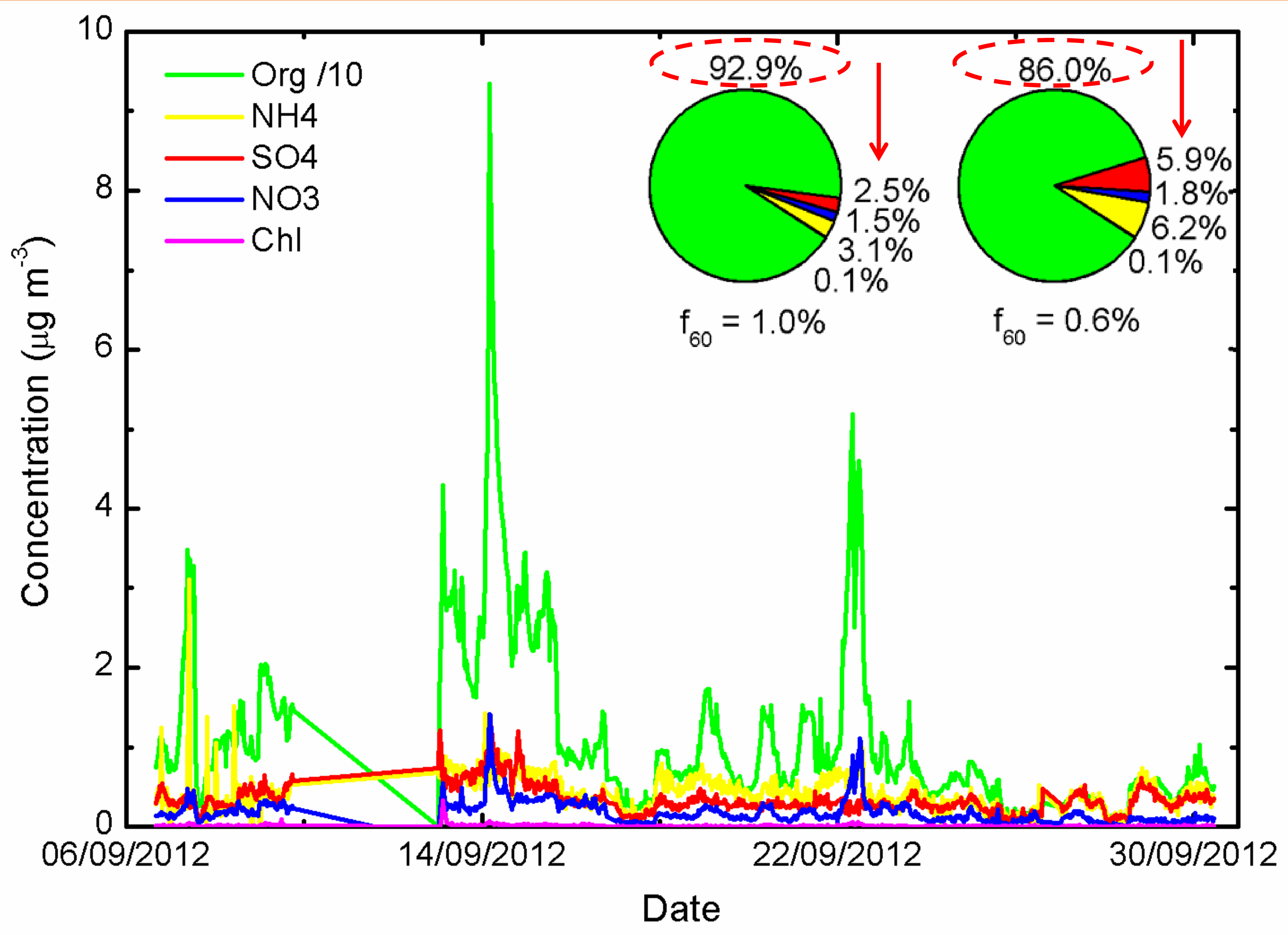
T0a – ATTO aerosol properties SMPS versus ACSM



Samara Carbone

SAMBBA Aerosol composition

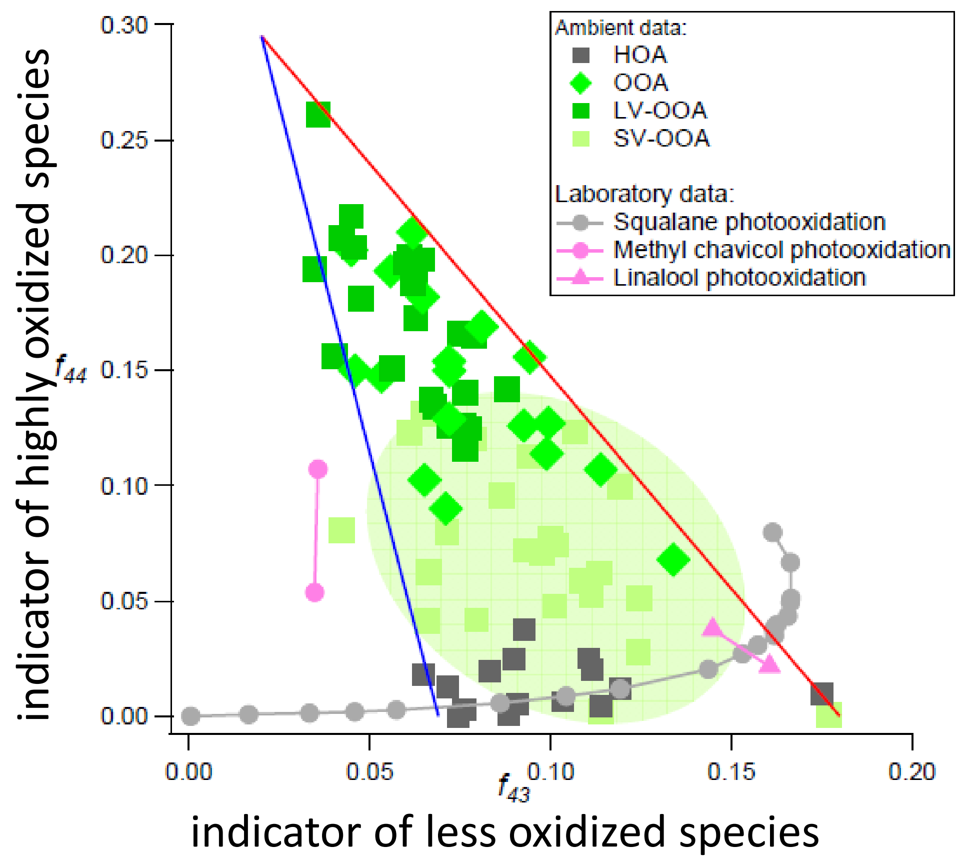
12.8 μg m^{-3} **5.2 μg m^{-3}**



Triangle plots

- All Organic Aerosol (OA) components fall within a triangular space
- Hydrocarbon like OA (HOA): f44 < 0.05 (mostly primary)
- OOA: oxigenated OA (mostly secondary)
- LV-OOA: low volatile
- SV-OOA: semi volatile

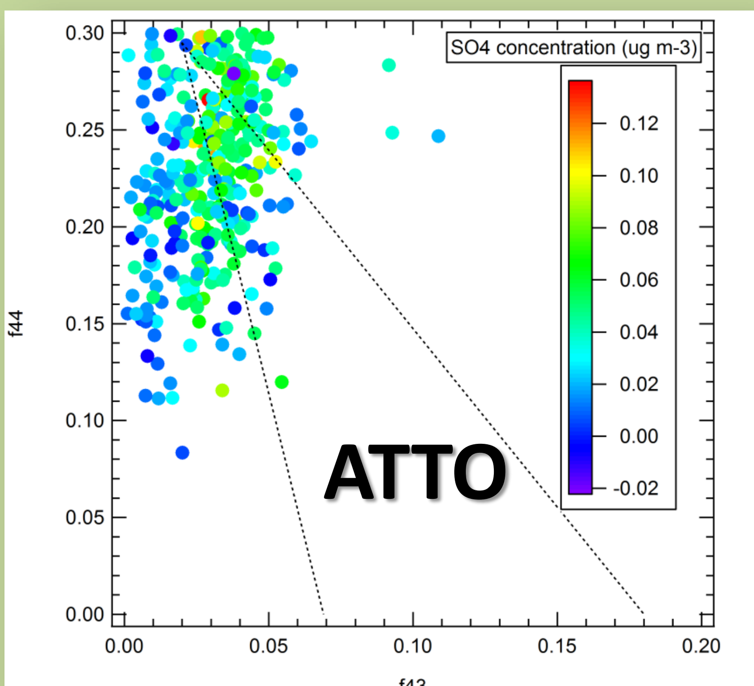
N. L. Ng et al.: Changes in organic aerosol composition

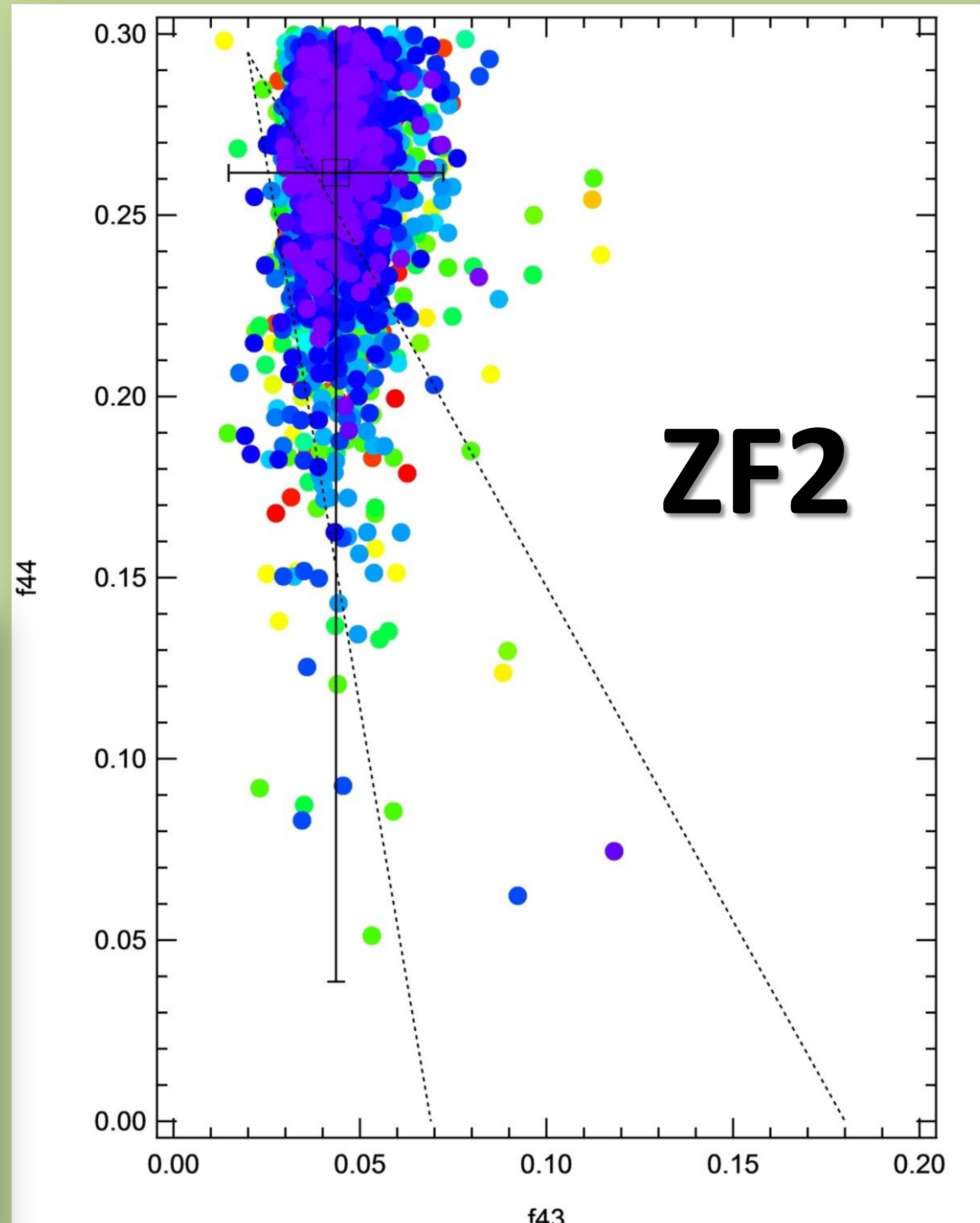


A highly oxidized aerosol at ZF2 (July-Dec 2013) and ATTO (Jan-Mar 2014)

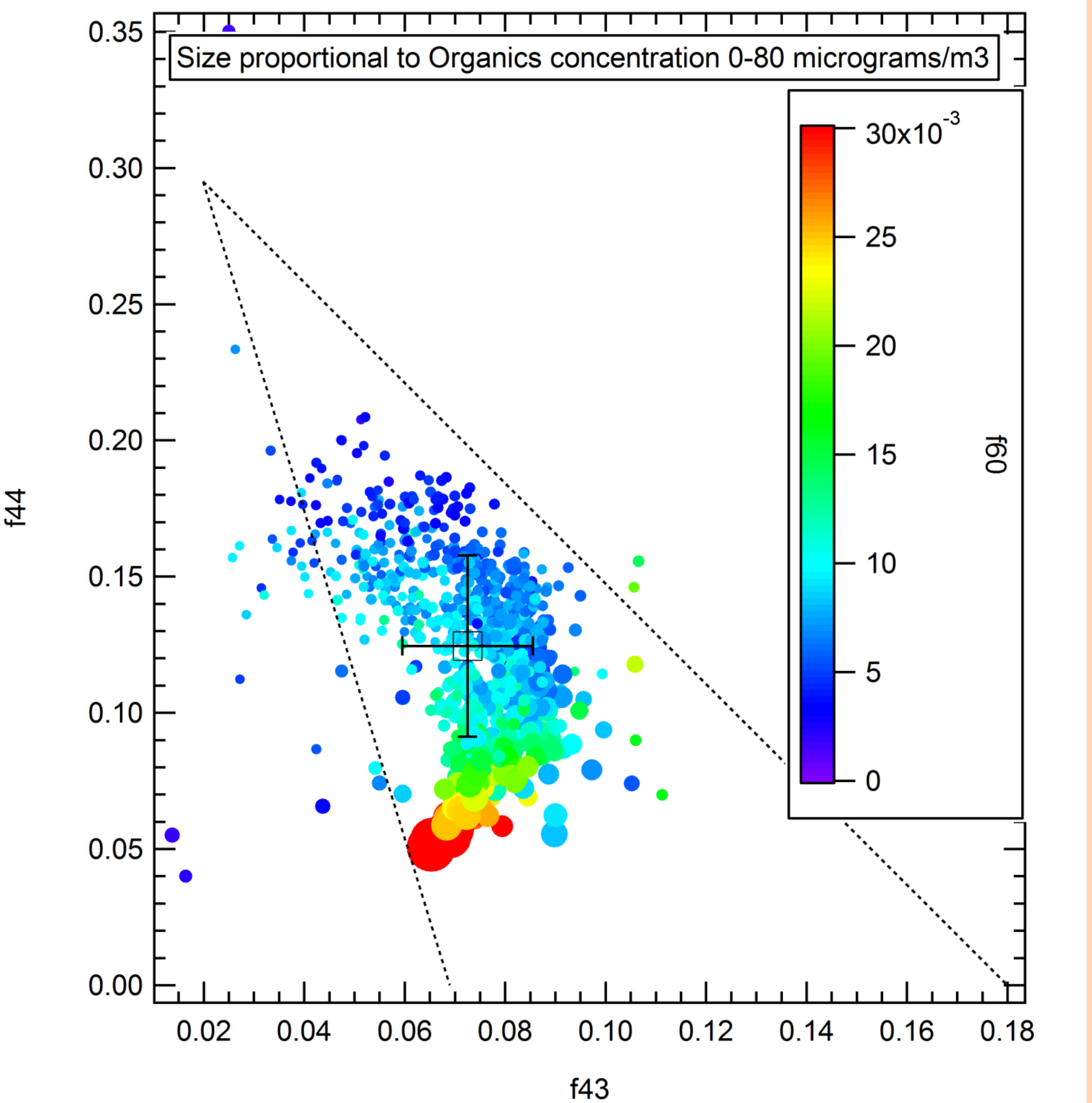
f44 = mainly CO_2^{+}, an indicator of highly oxidized species

f43 = mostly due to $C_2H_3O^{+}$, an indicator of less oxidized species.





SAMBBA Biomass Burning f44/f43 plot ACSM



f44 = mainly CO_2^+, an indicator of highly oxidized species

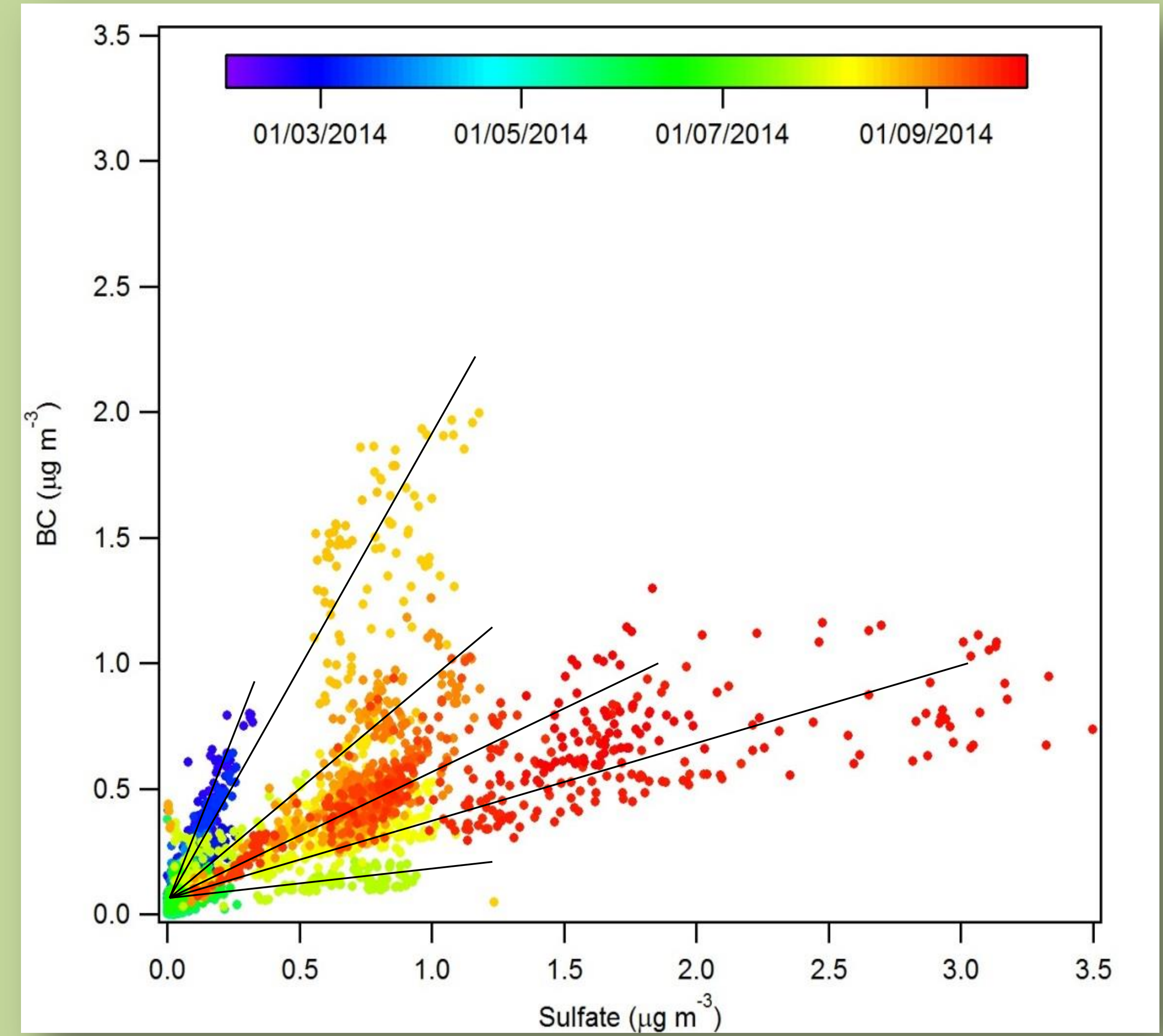
f43 = mostly due to $C_2H_3O^+$, an indicator of less oxidized species.

f60 = biomass burning marker

Brito, 2013

Sulfate is intimately related to BC, but with various ratios

The different slopes likely represent episodes of LRT pollution

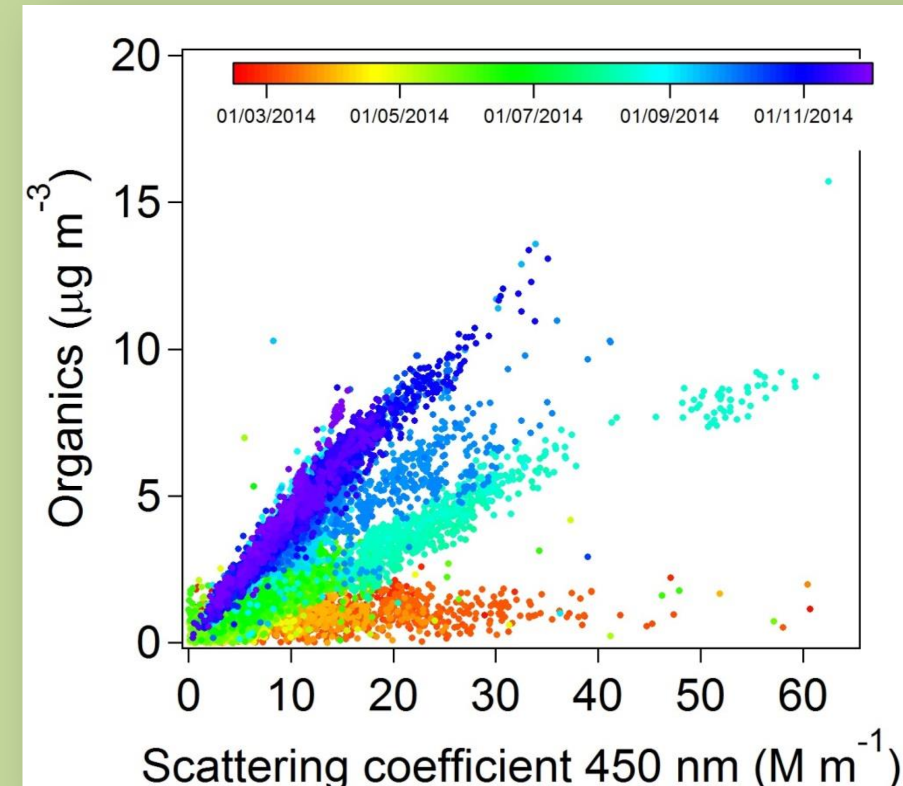


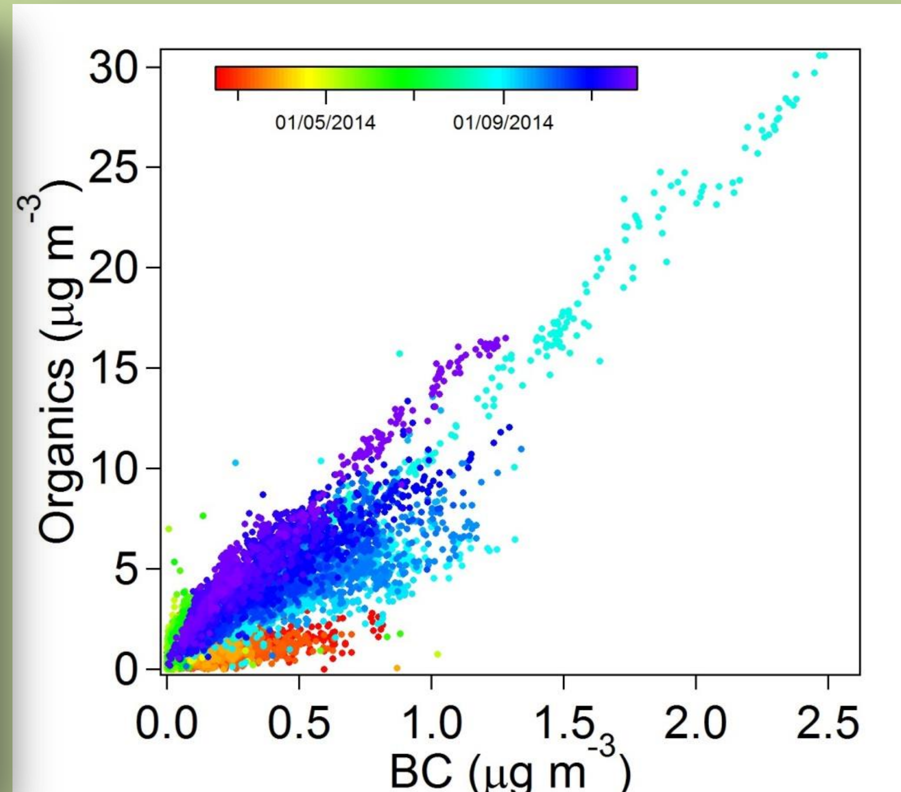
ATTO Forest site

Carbone, 2014

What drives light scattering and absorption for PM1?

T0a - Organics versus light scattering and absorption

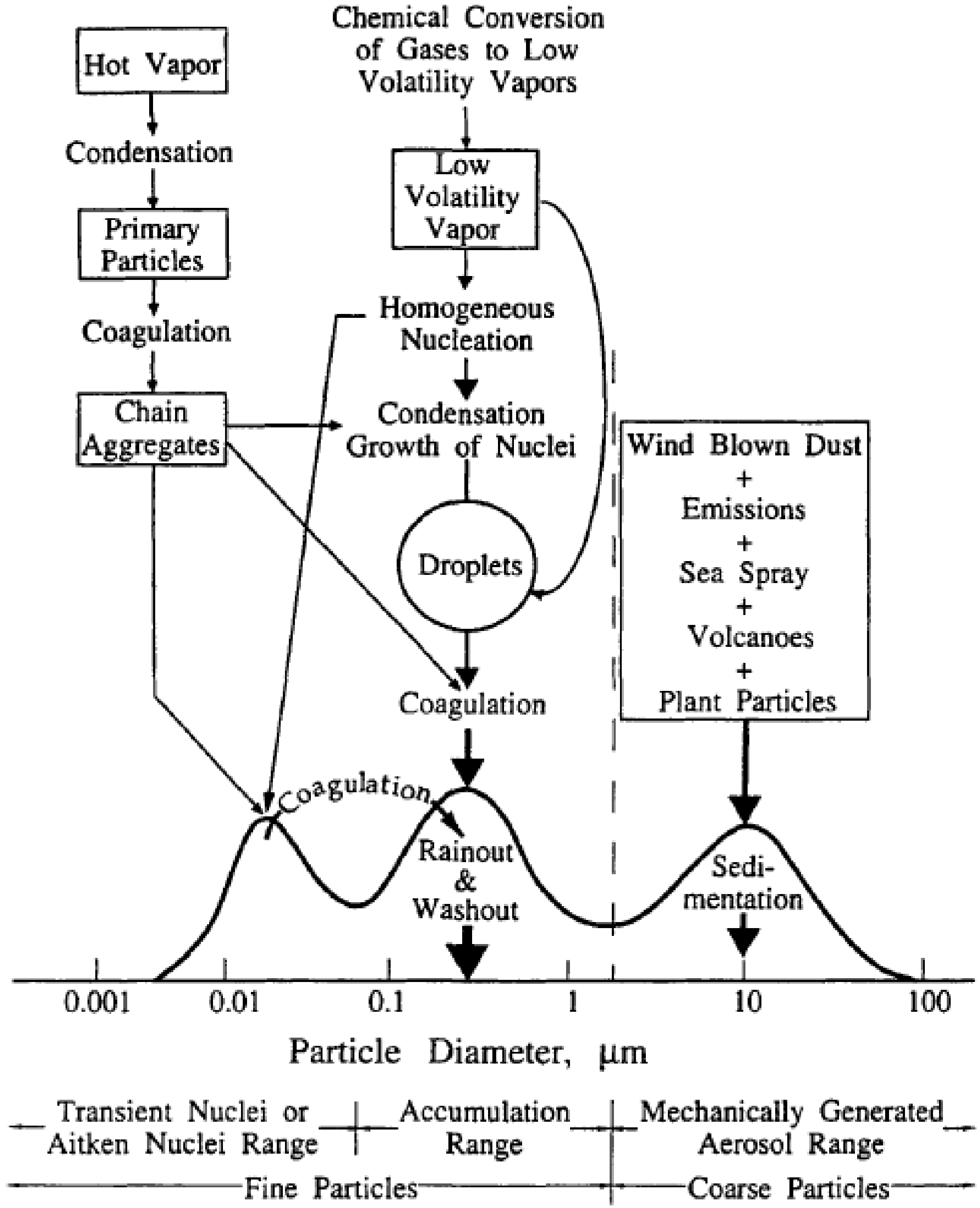




The organics made up to 76% of the fine particles and when investigated as a function of the scattering coefficient (σ_{450}) different patterns (with different slopes) were observed over time. BC also shows different patterns but less pronounced

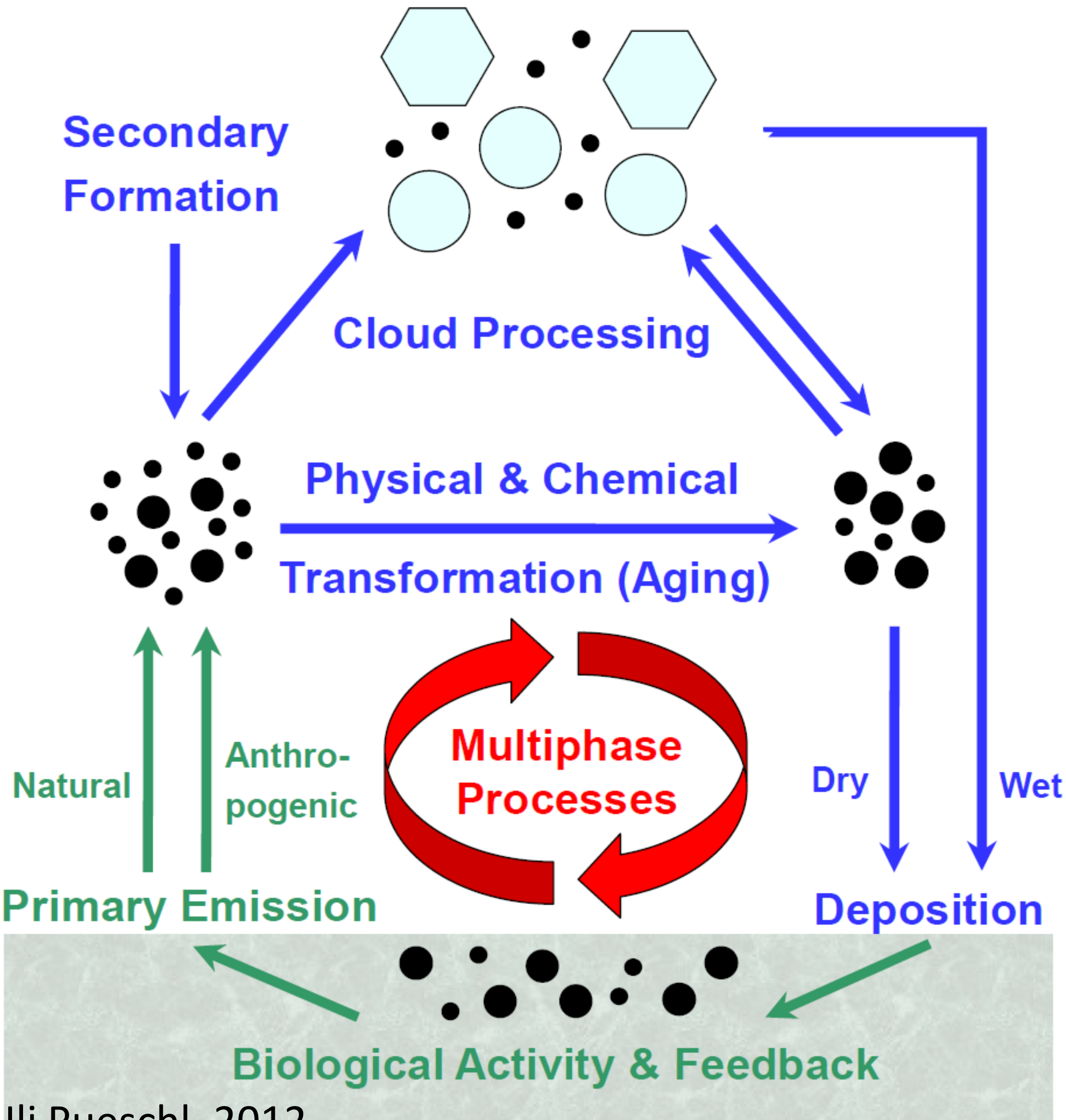
Carbone, 2014

4 - AEROSOL DYNAMICAL PROCESSES IN AMAZONIA



(Seinfeld e Pandis, 2006)

Aerosol cycling in Amazonia



Uli Pueschl, 2012

Atmosphere & Climate

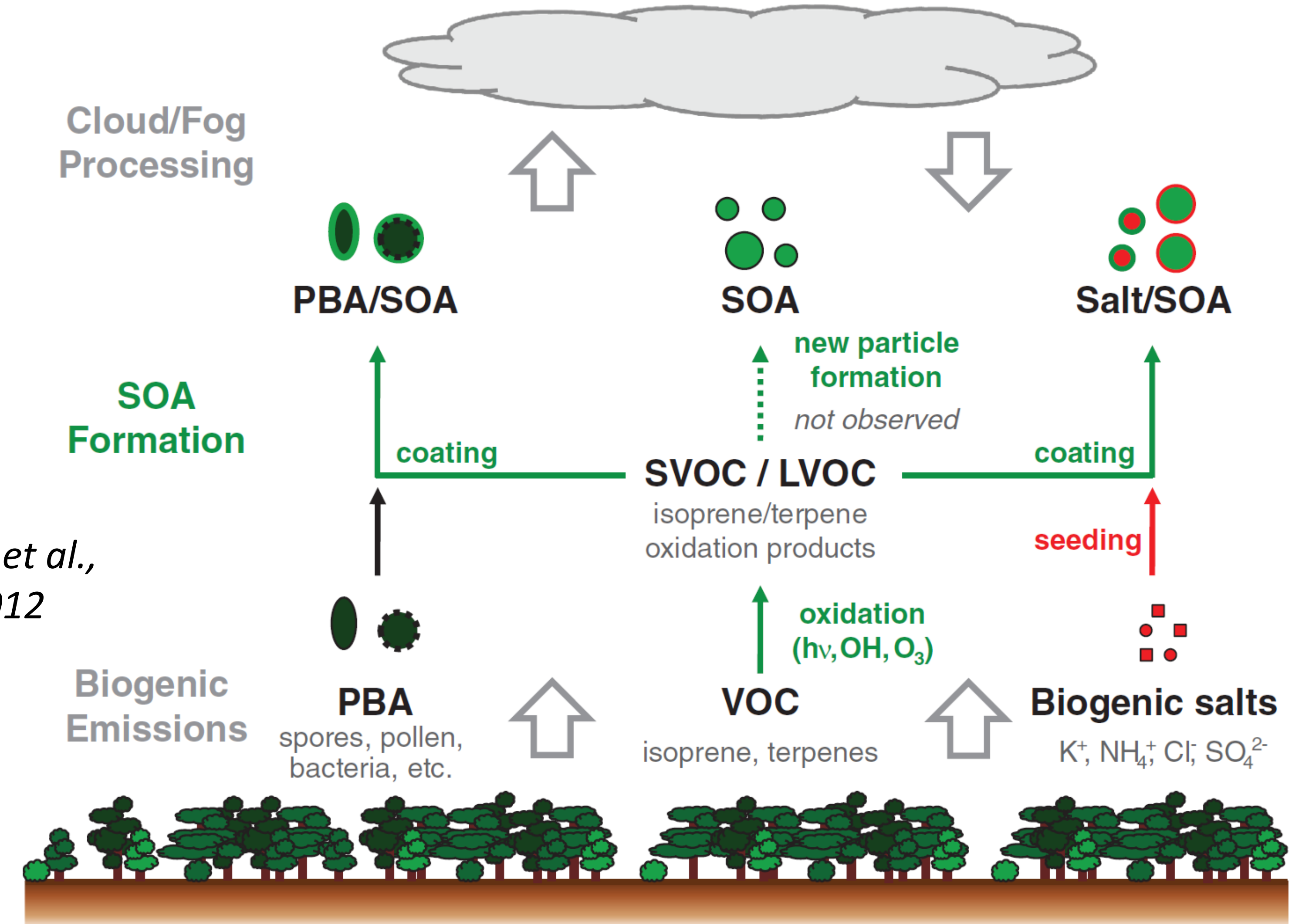
- aerosols & gases
- clouds & precipitation
- radiation & dynamics

Mechanistic understanding, quantitative prediction & human influence ?

- spread & change of organisms & ecosystems
- human, animal & plant diseases

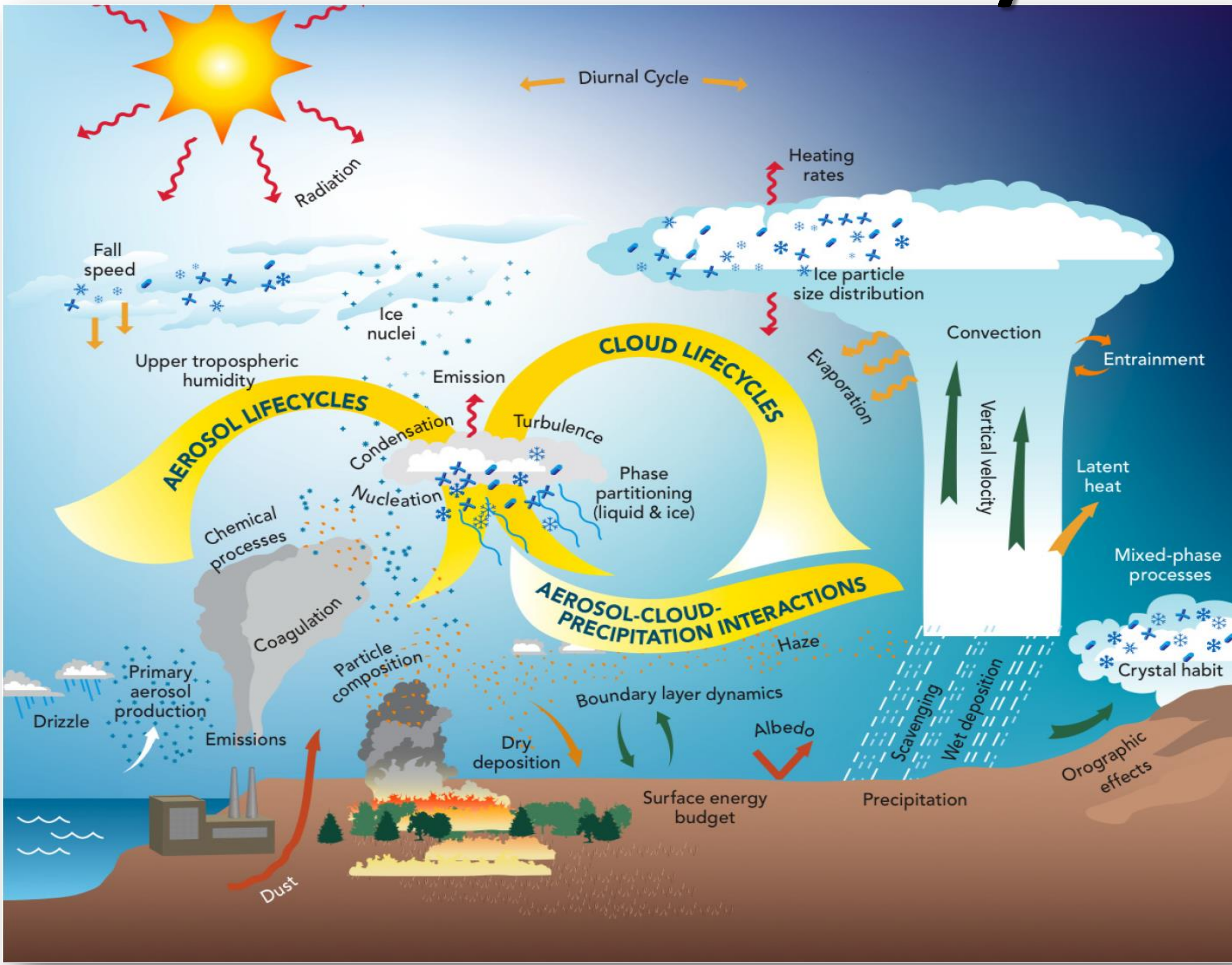
Biosphere & Public Health

Sources and processing of organic aerosol in pristine Amazonian boundary layer air

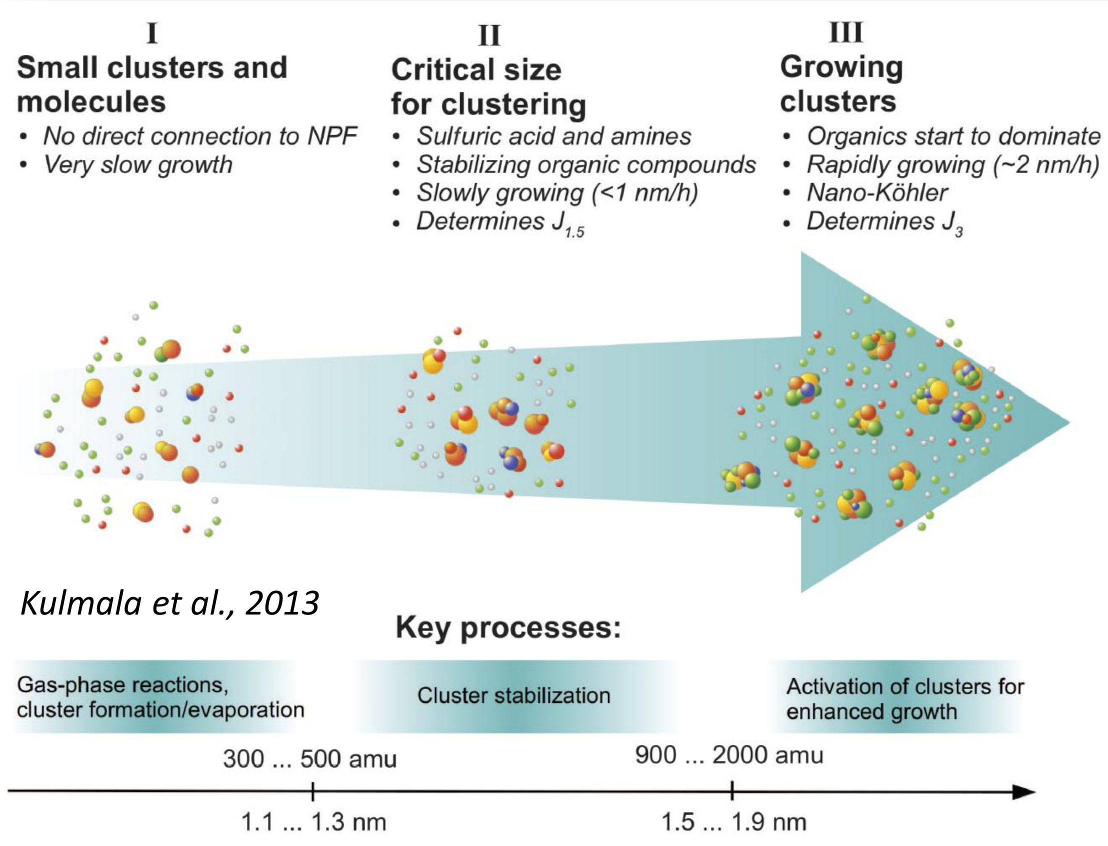


C. Pöhlker et al., Science 2012

Aerosol and cloud lifecycles



Few events of new particle formation observed at surface under pristine conditions in Amazon



New particle formation: a two-step process:

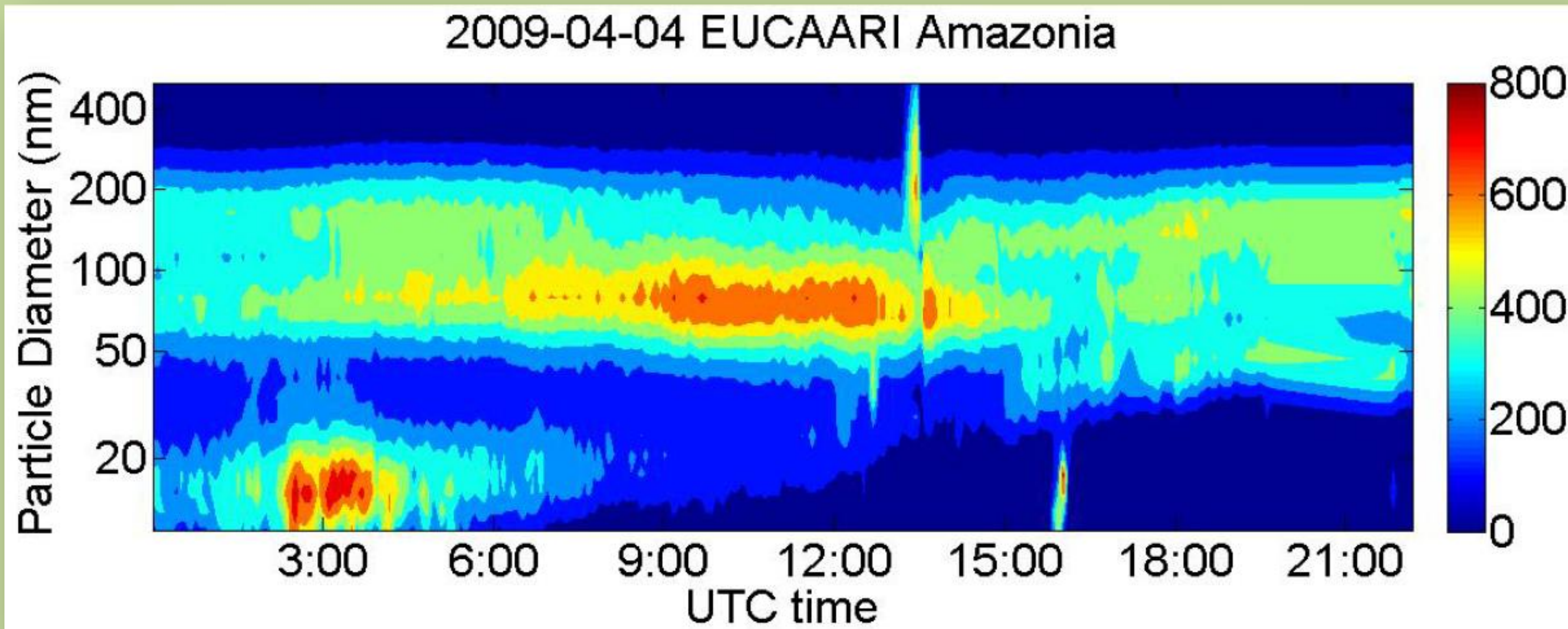
- **1st step: sulfuric acid and amines, ammonia, or organic vapor form stable clusters**
- **2nd step: organic vapor leads to enhance growth rate of the clusters to larger sizes.**

Why no new particle formation?

- **Low SO_2 concentration (20-30ppt) suggests the concentration of H_2SO_4 is low**
- **Organic concentration may be low for the growth of stable clusters.**

What is the impact of Manaus plume on NPF?

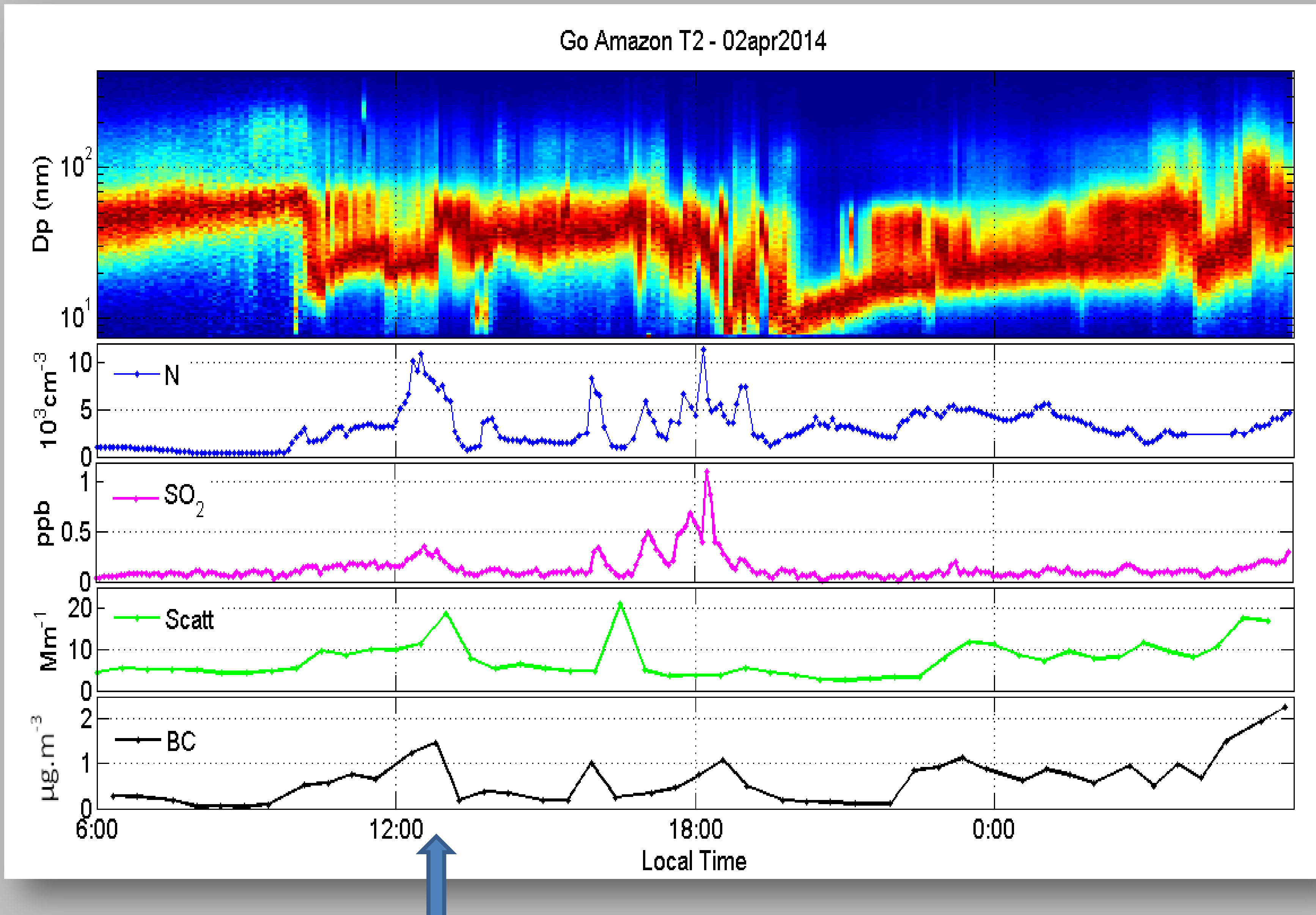
New particle formation? Bursts of particles $10<D_p<30$ nm.



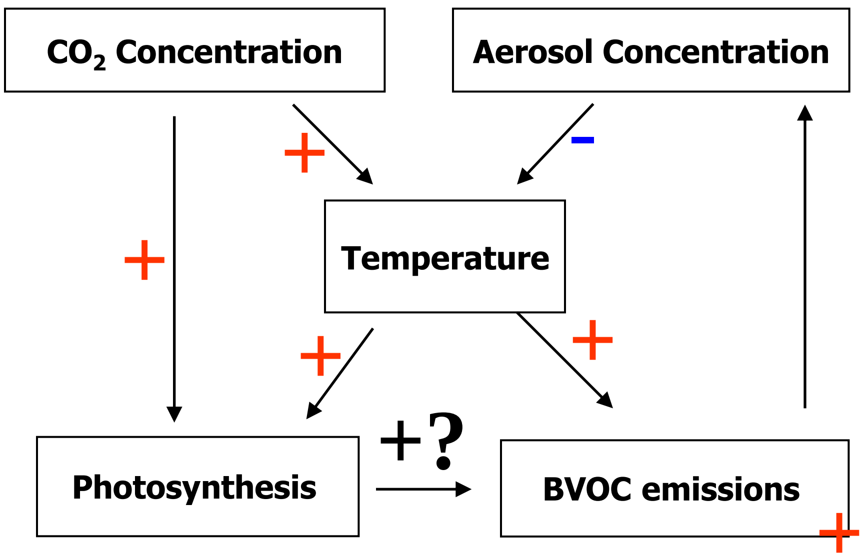
Aerosol size distributions measured in 2009 Apr 4th. There was a burst of ultrafine particles from 2:00 to 4:00 UTC time.

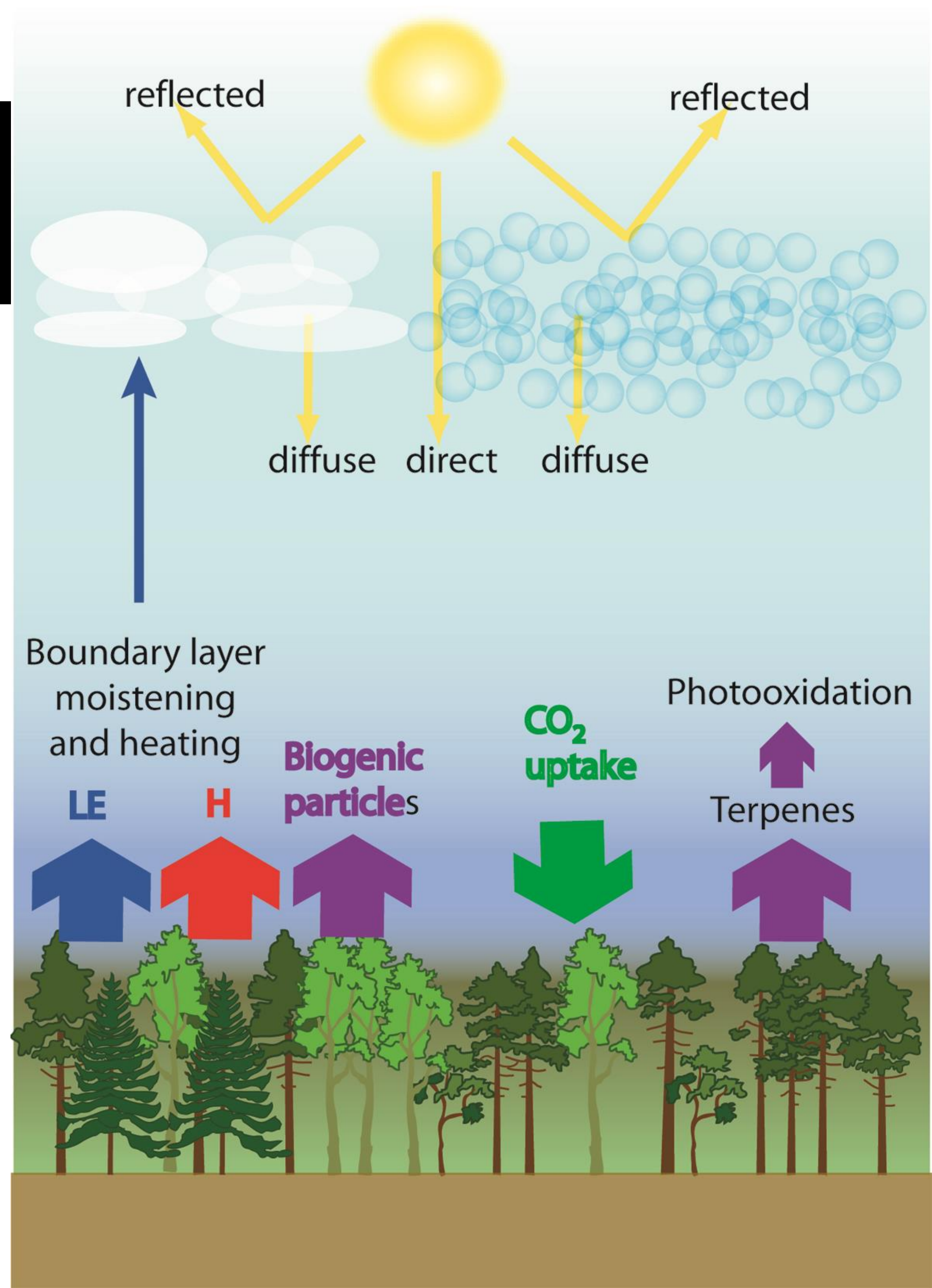
New particle formation and subsequent growth was seldom observed along two years of measurements. Nevertheless, in 70% of the days, bursts of particles with diameters in the range 10-40nm were detected. The events usually lasted from 20 to 120min, and the subsequent growth to larger sizes was not always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

New particle formation events at T2 (urban)



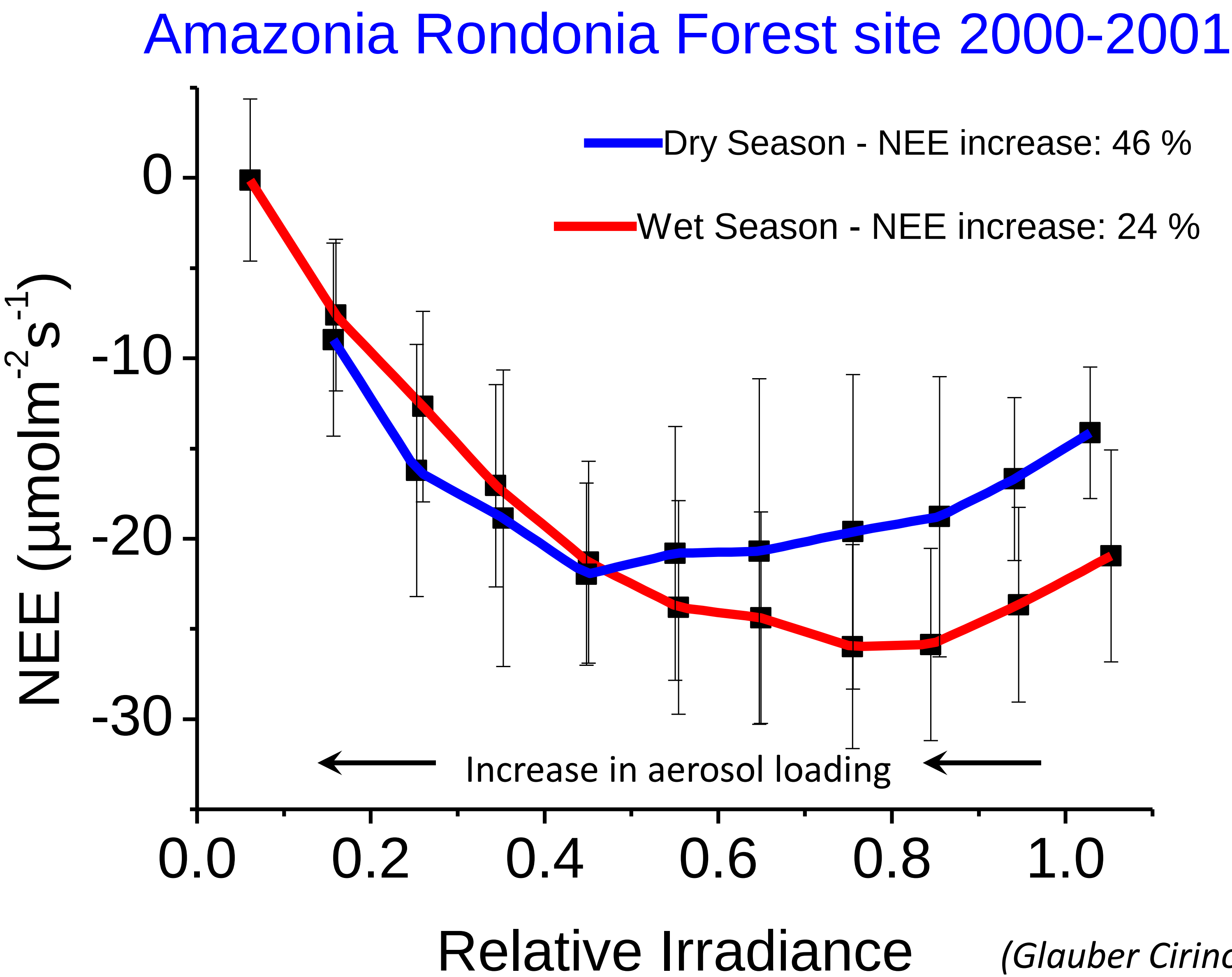
Aerosol Effects on Net Plant Productivity





Kulmala et al., 2004

Aerosol impact on photosyntesis



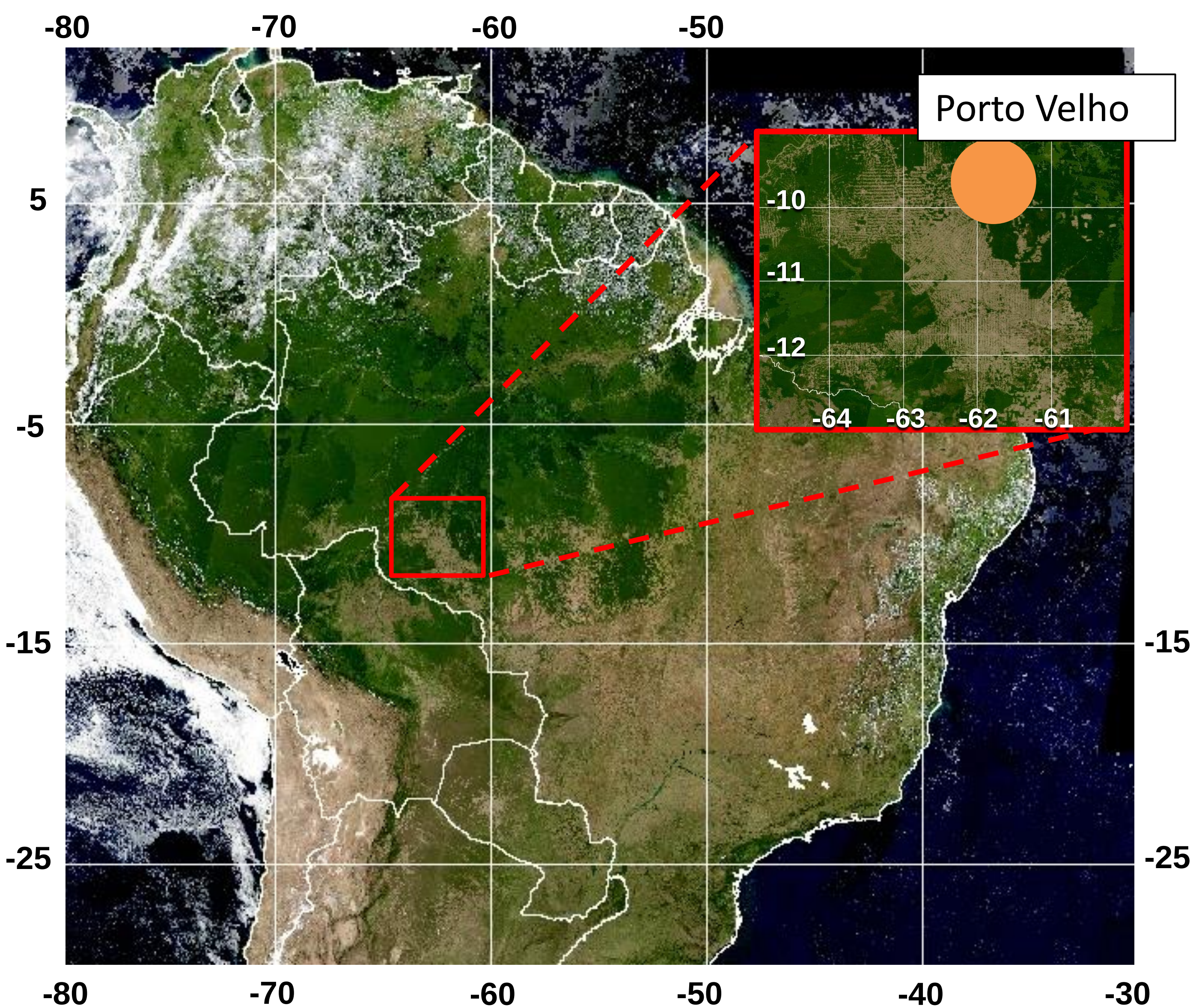
(Glauber Cirino, 2014)


Thanks for the attention!
lrizzo@unifesp.br

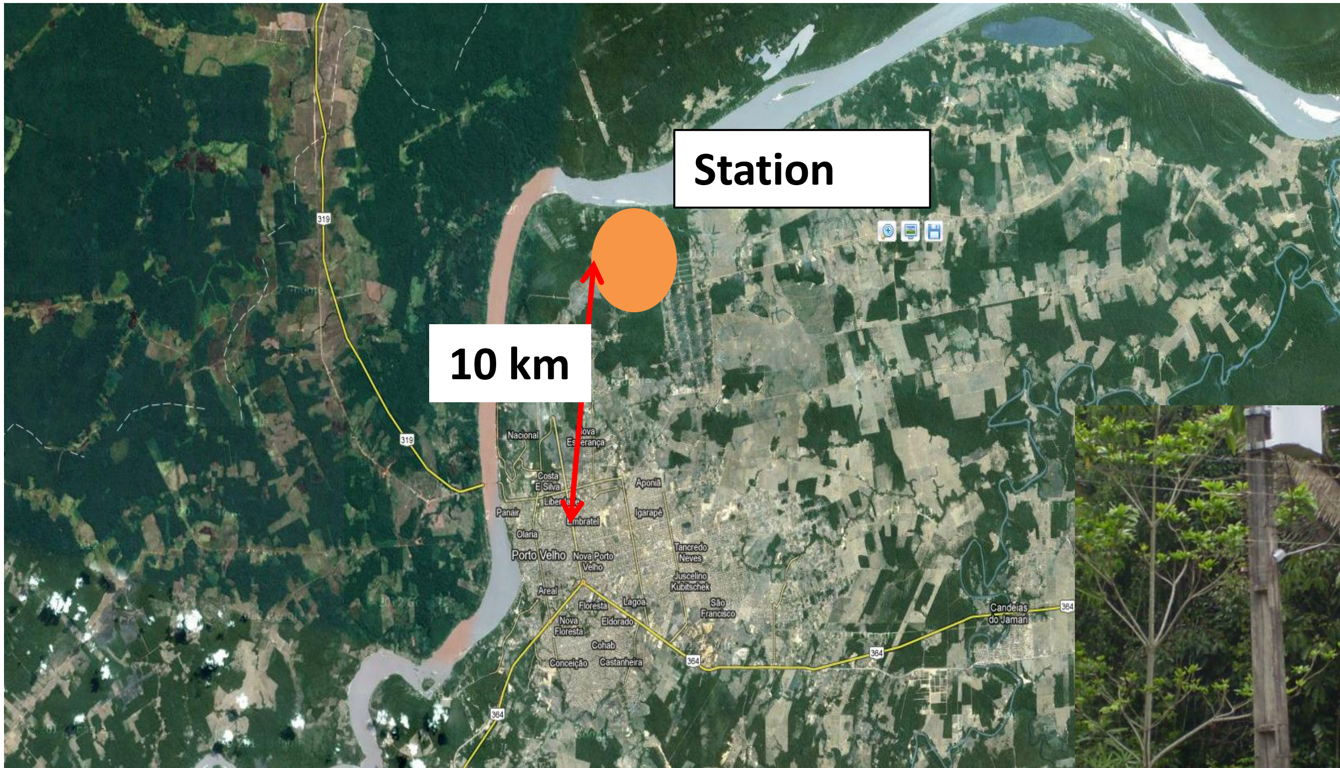
GoAmazon T2 site Tiwa Hotel

GoAmazon 2014/5 sampling sites

Porto Velho aerosol and trace gases sampling location



Sampling location at Porto Velho zoo botanic park



Continuous aerosol and trace gas analysis from Sept. 2009-Oct. 2012