Amazonia: biological and urban interactions with atmospheric chemistry

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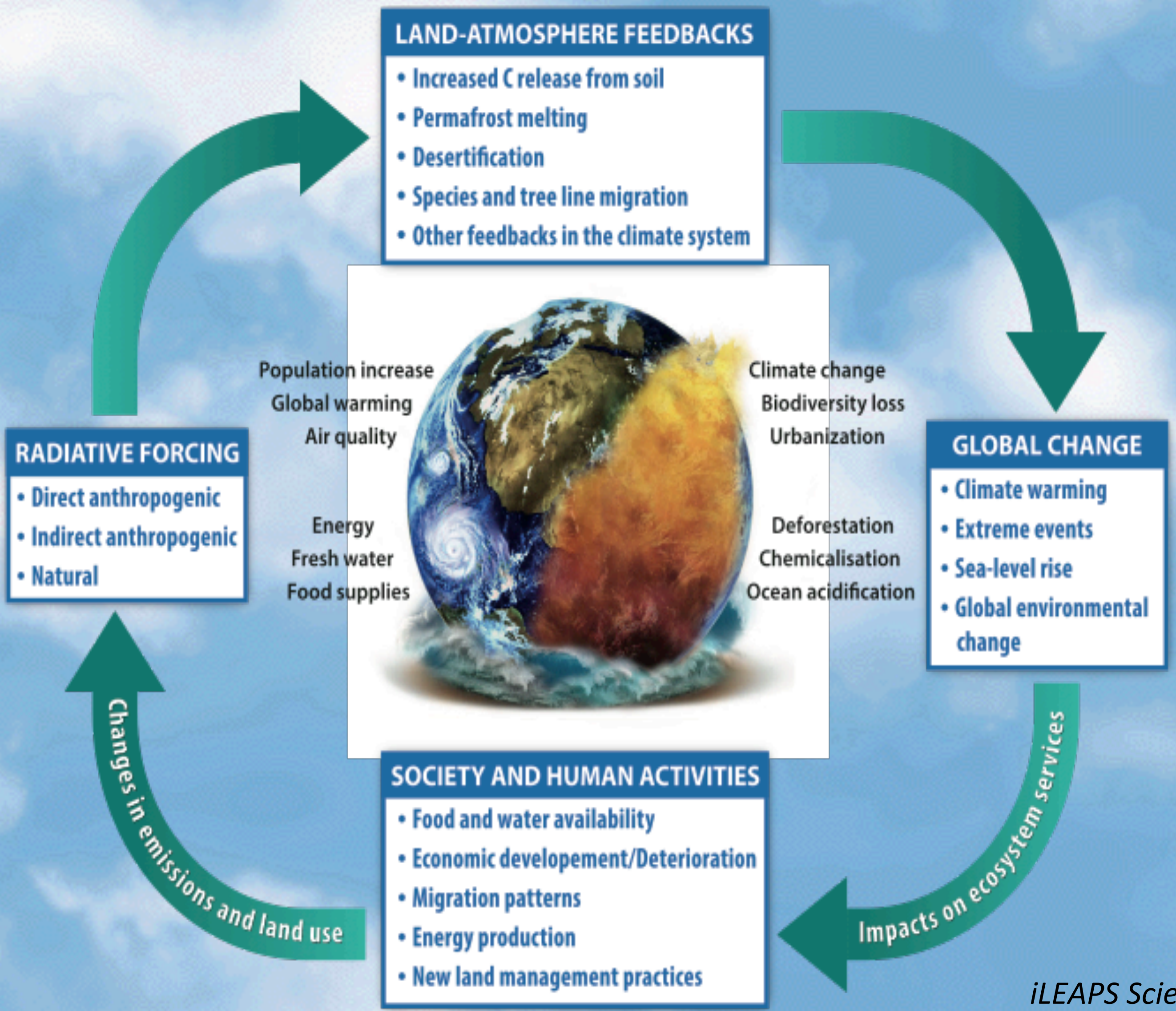
Global and regional links between ecosystems and climate

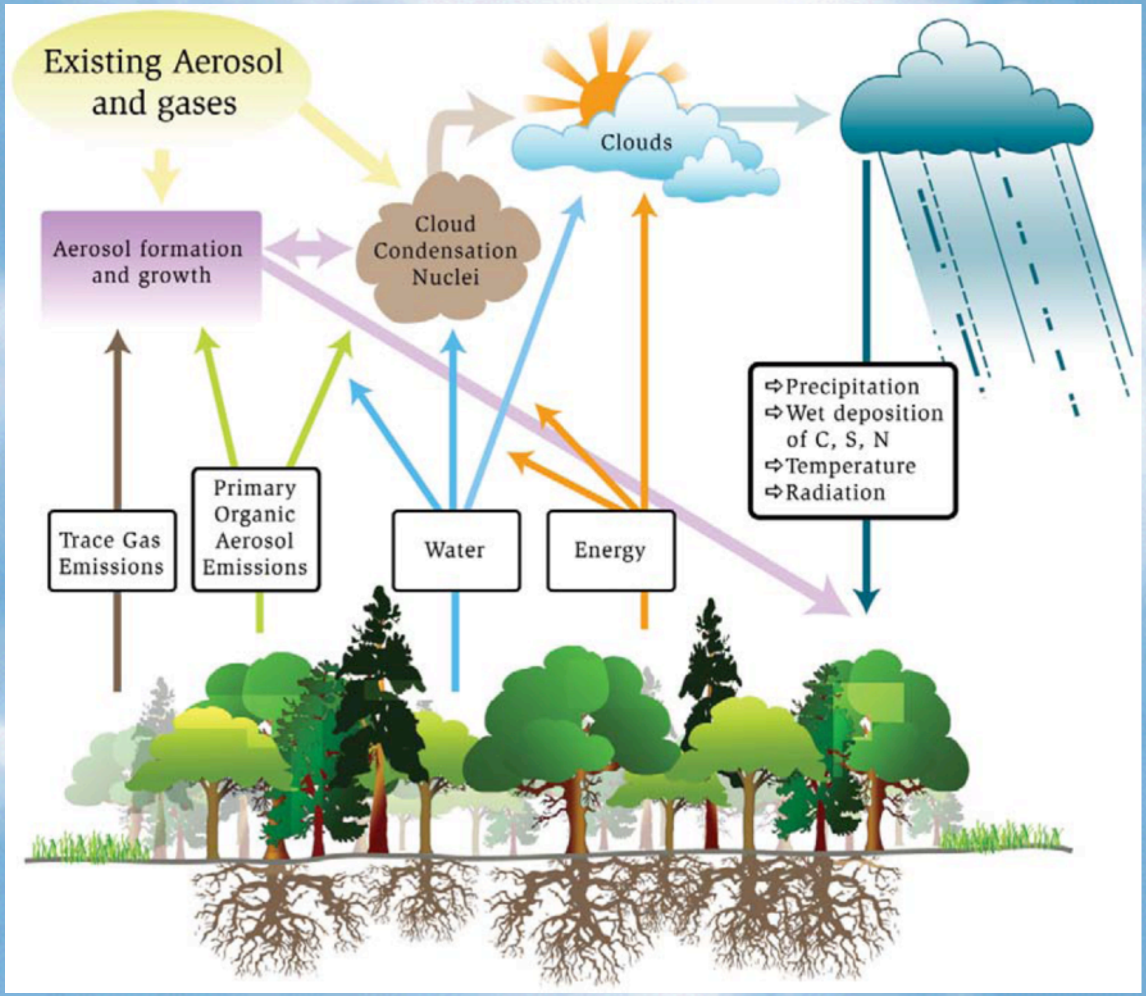
REGIONAL FOCUS TO BECOME IMPORTANT…



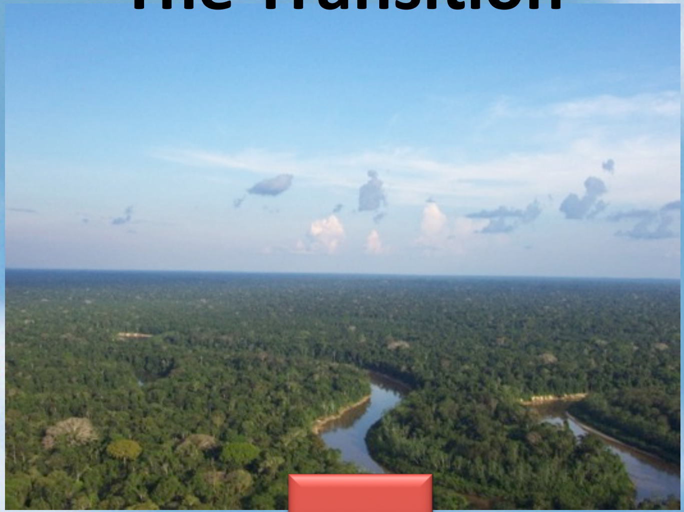
iLEAPS Science Plan 2014

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

Natural System



The Transition



Amazonia as a Complex Nonlinear Interactive System

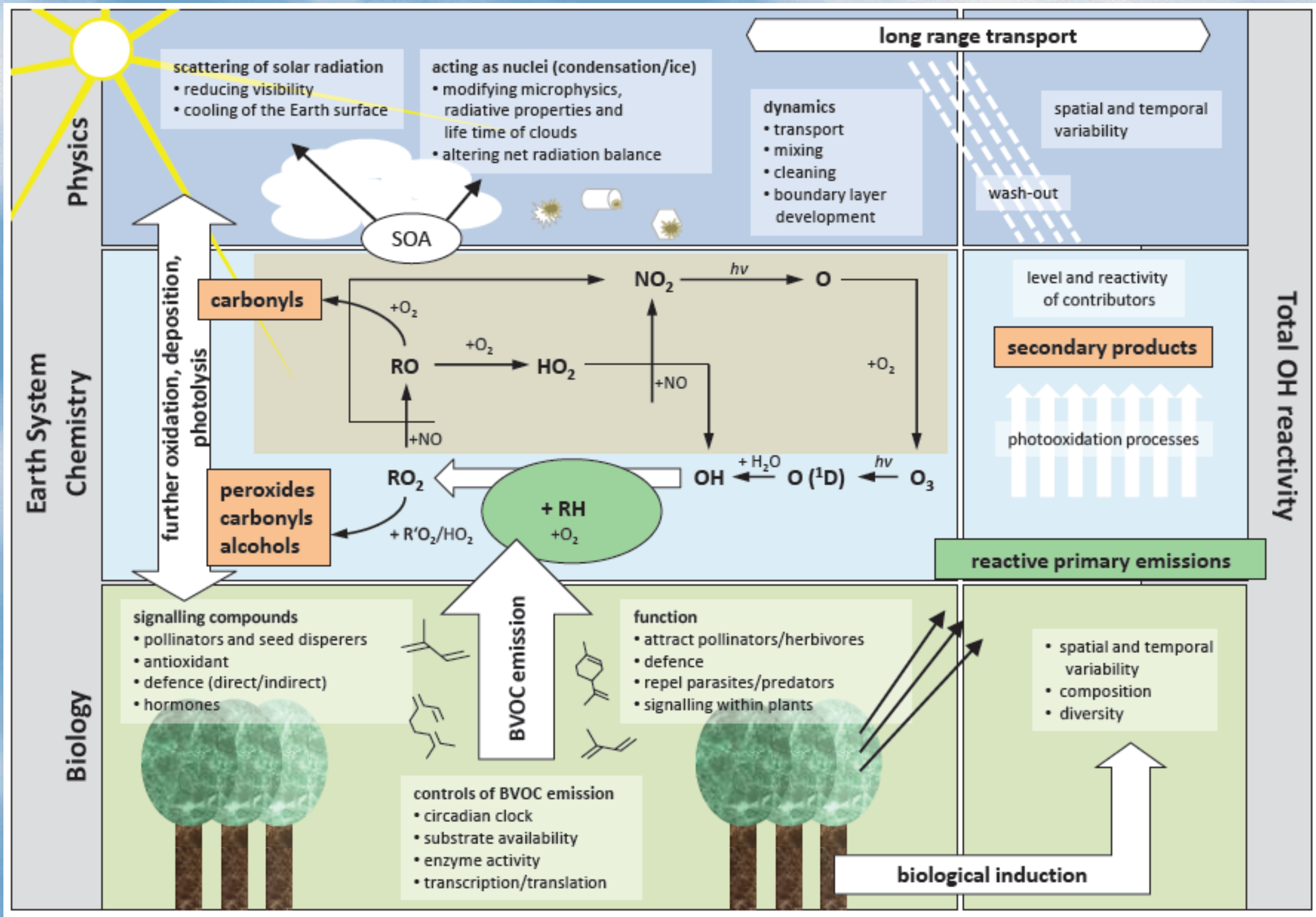
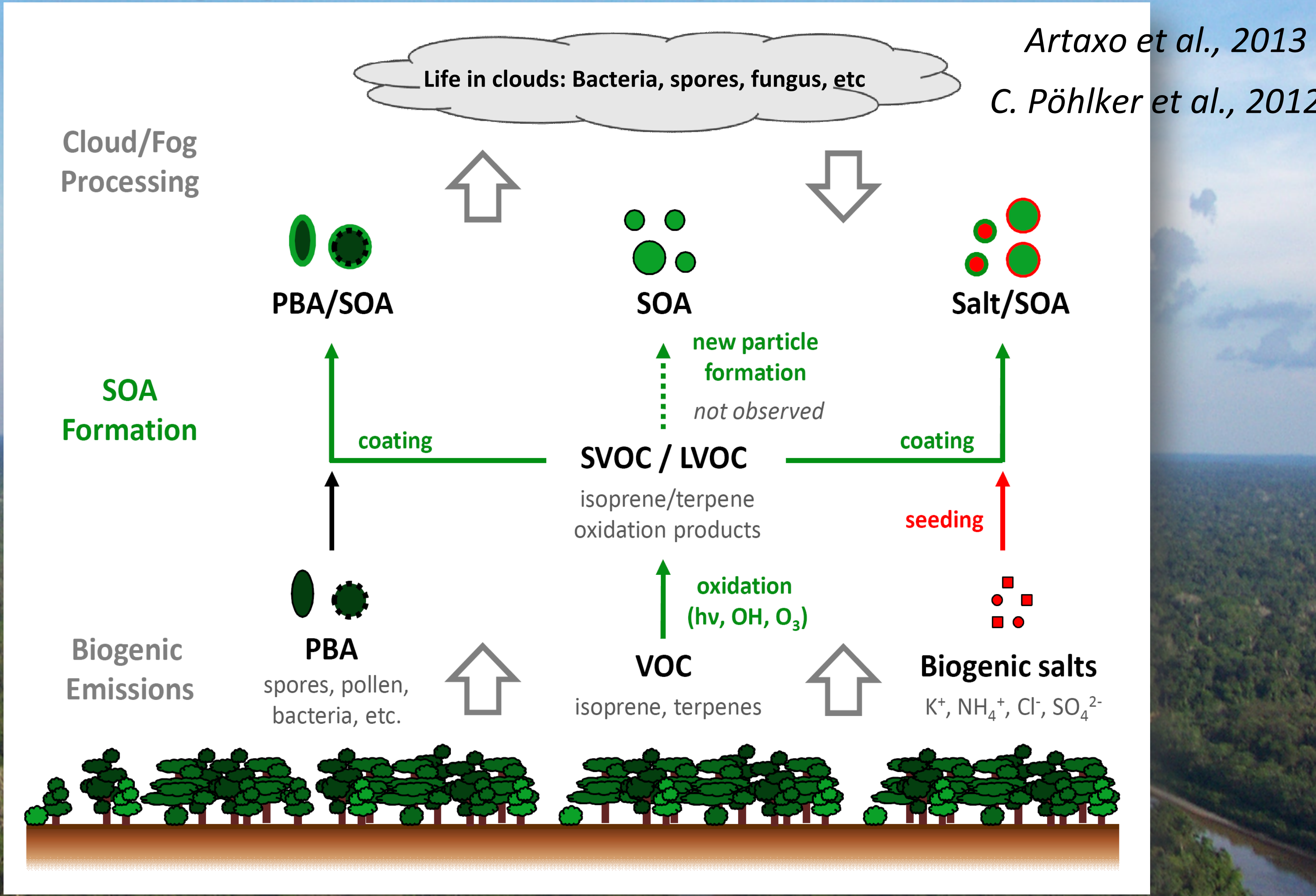


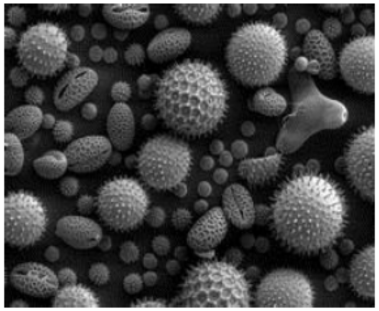
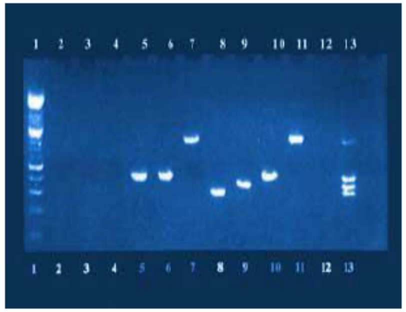
Illustration from Anke Nölscher

The biology of the forest partially controls the chemistry and physics of the atmosphere in Amazonia

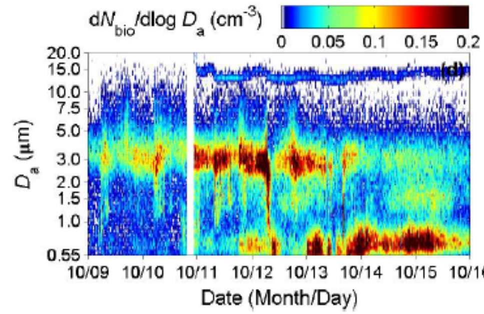


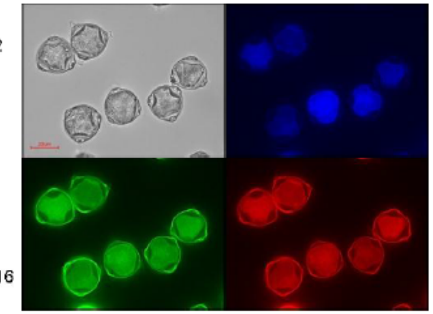
Strong interactions between forest biology, physics and chemistry of the atmosphere

Life is in the air and it does interact with precipitation

DNA & Protein Analysis





Fluorescence Spectroscopy & Microscopy

High abundance, diversity & emission fluxes of airborne fungi & bacteria:

~1 µg m^{-3}, ~10 L^{-1}, **~10^2 m^{-2} s^{-1}**, >10^3 species (urban PM)

Elbert ACP 2007, Fröhlich-Nowoisky PNAS 2009, Burrows ACP 2009, Huffman ACP 2010

Information: ~10 ng m^{-3} DNA

⇒ inhalation of ~1 µg/day ≡

~10^8 bacterial genomes/day

Despres BG 2007

Pathogens: permanent challenge

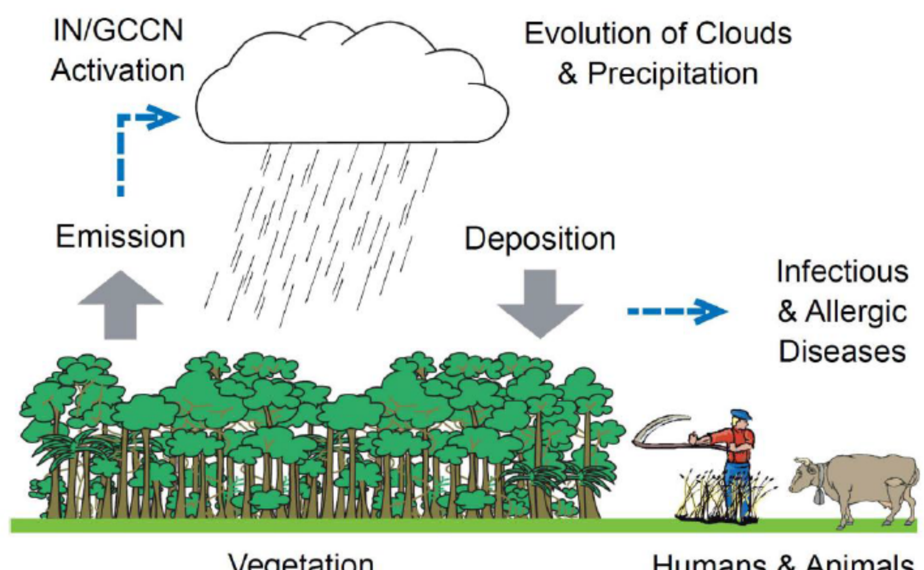
⇒ infectious & allergic diseases

Cloud condensation & ice nuclei:

co-evolution of life & climate

⇒ bioprecipitation cycle

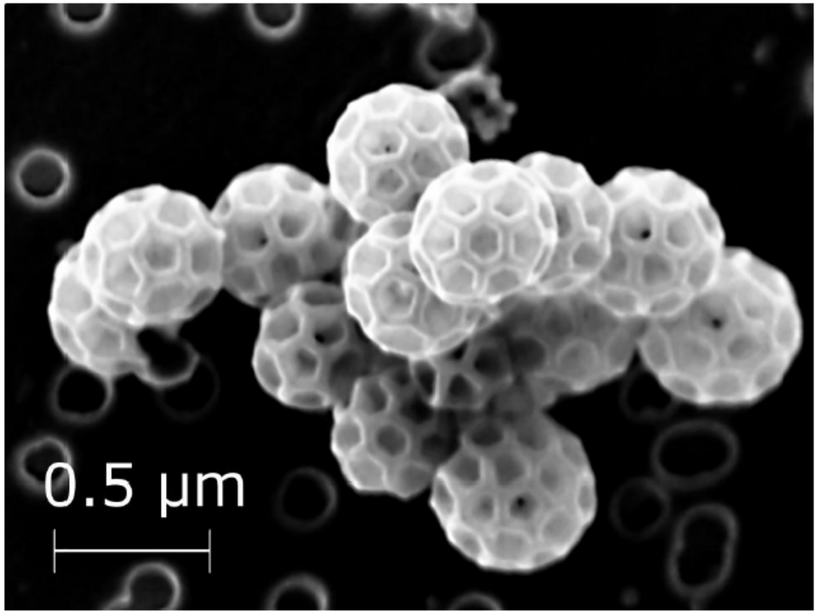
Sands J Hung Met Serv 1982



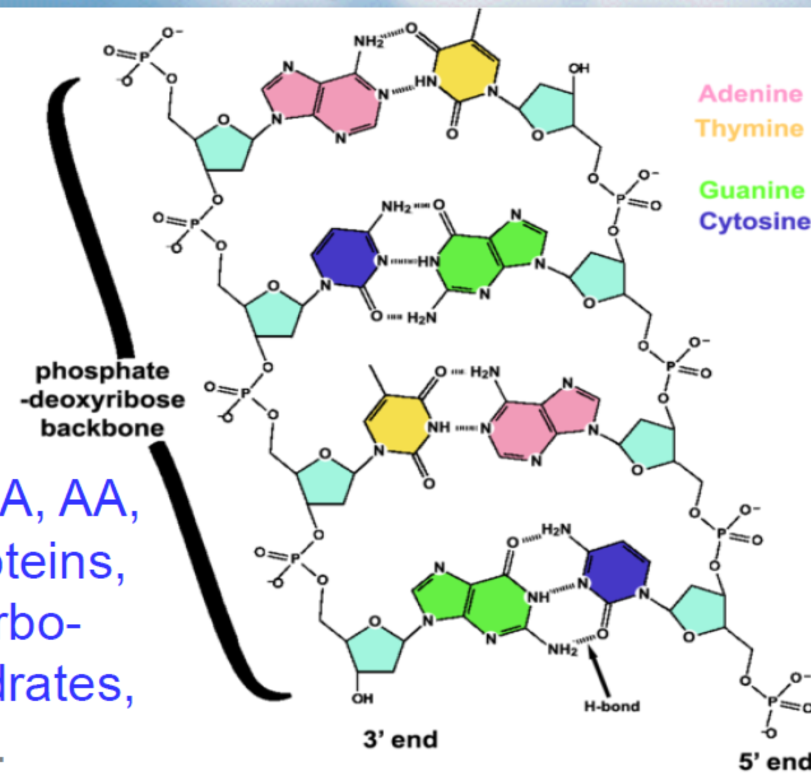
Poschl et al., 2012, Artaxo, 2013

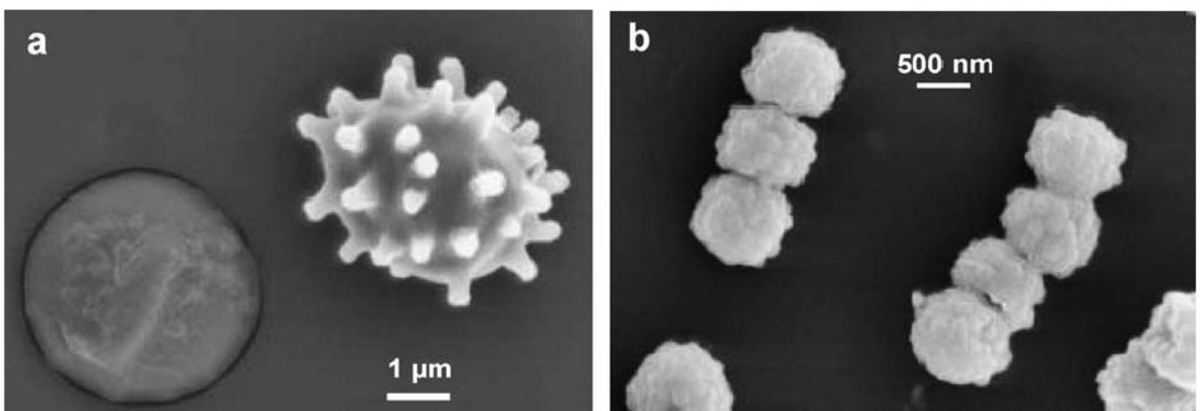
The biology of aerosol particles

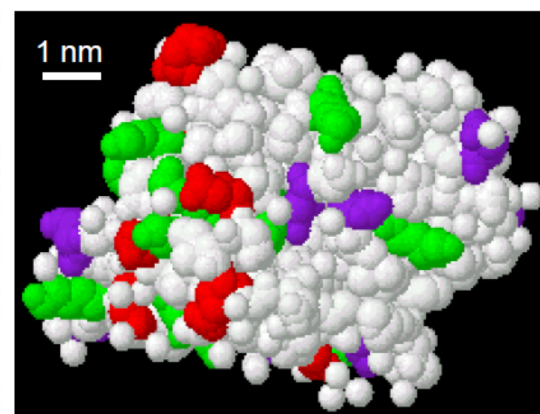
Bacteria, Brochosomes, Spores, Pollen, Plant Debris, etc.



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



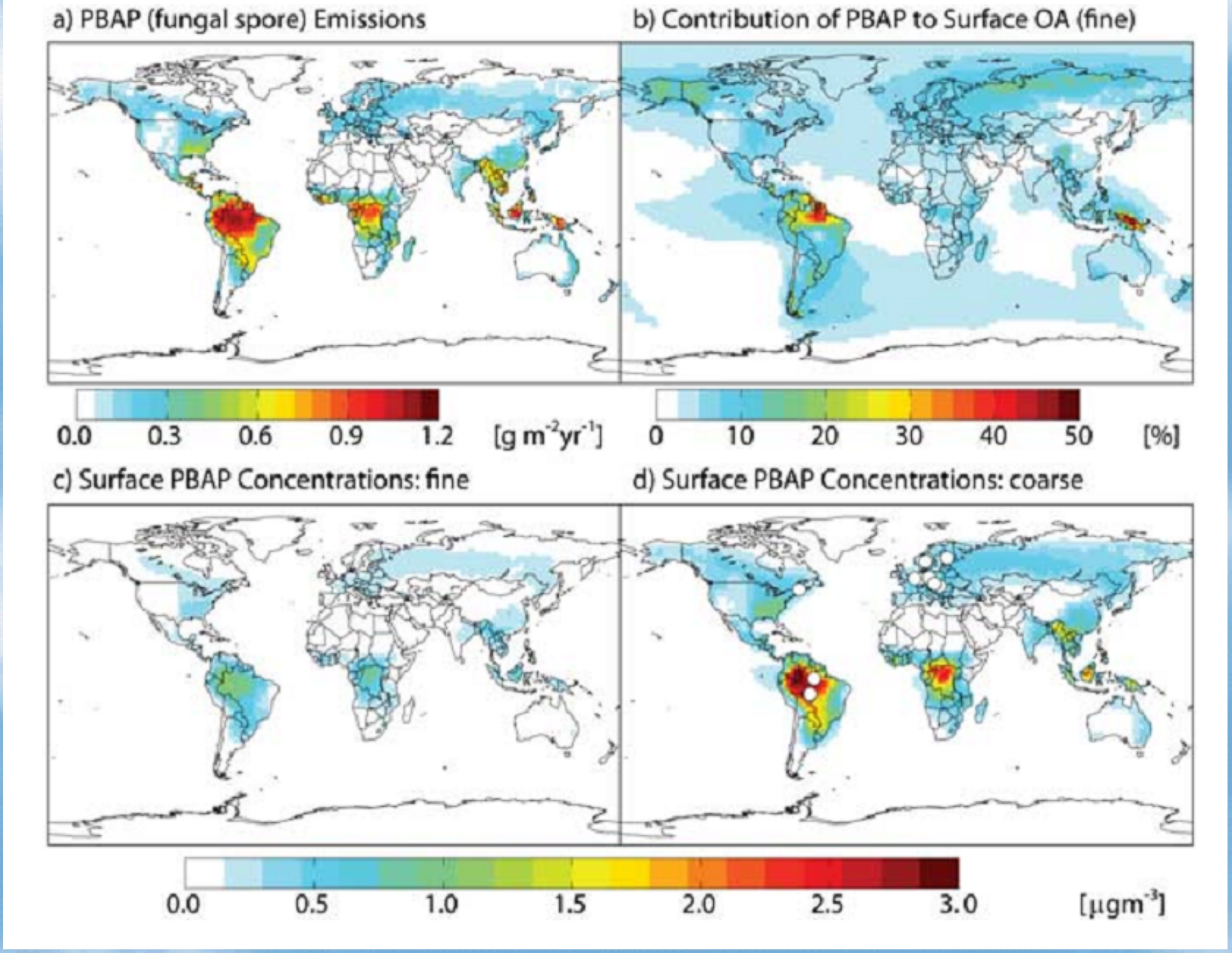




Uli Pueschl, 2012

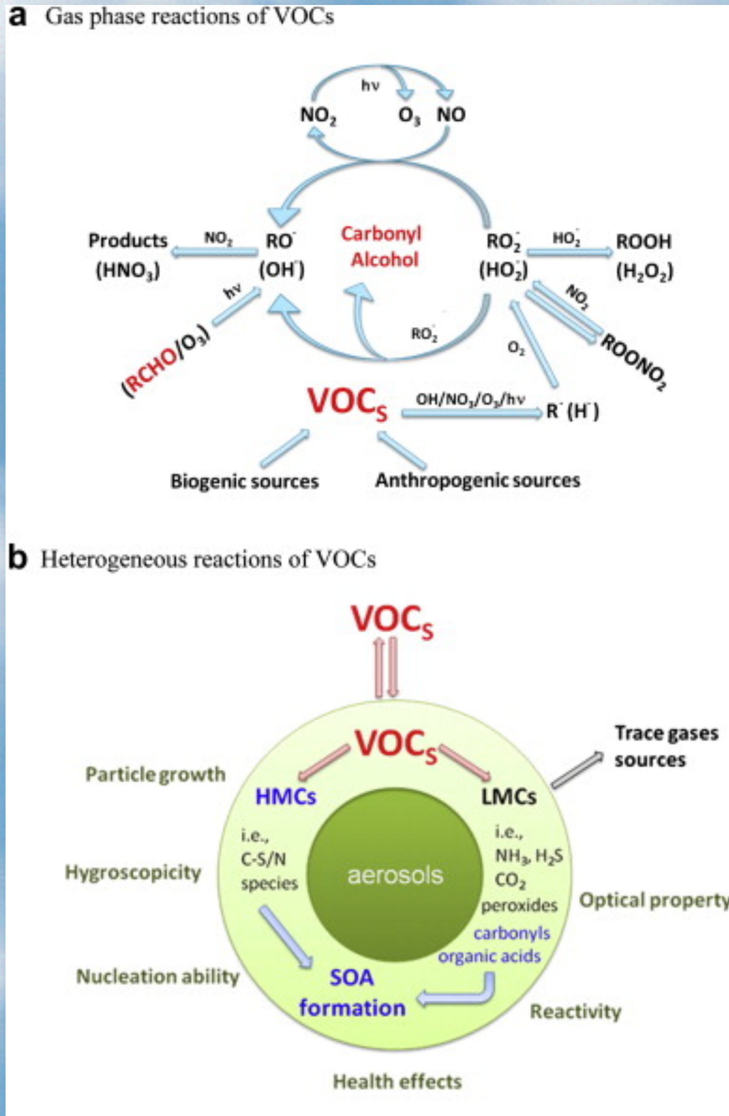
Biology matters on airborne aerosol particles

Atmospheric budget of primary biological aerosol particles from fungal spores

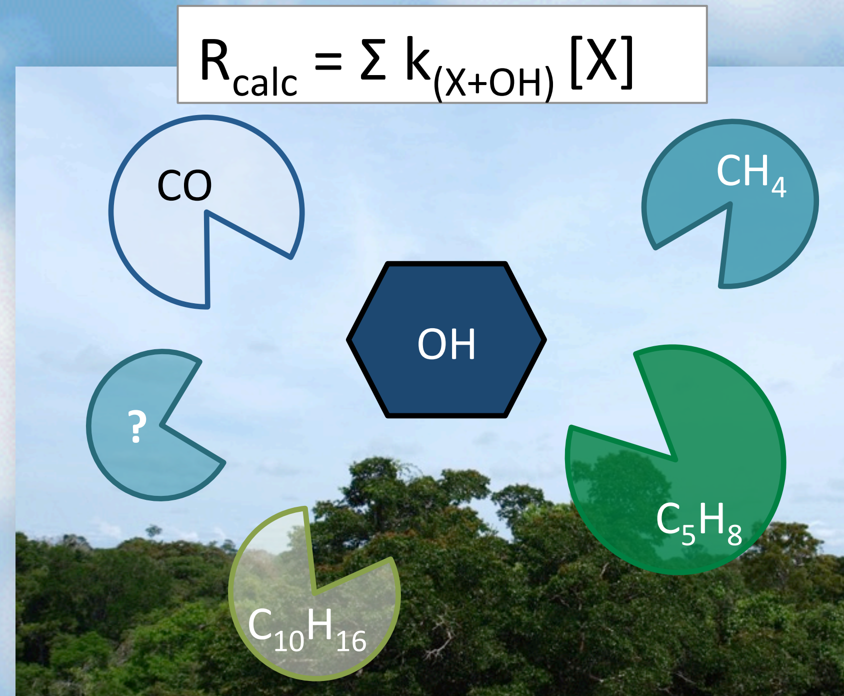


Annual mean of optimized GEOS-Chem simulation of fungal PBAP: (a) PBAP emissions, (b) percentage contribution of fungal PBAP to fin e organic aerosol (OA) surface concentrations, (c) fine-mode fungal PBAP surface concentrations, and (d) coarse-mode fungal PBAP surface concentrations.

Volatile Organic Compounds (VOC) and aerosols



HMCs: high molecular weight compounds; LMCs: low molecular weight compounds



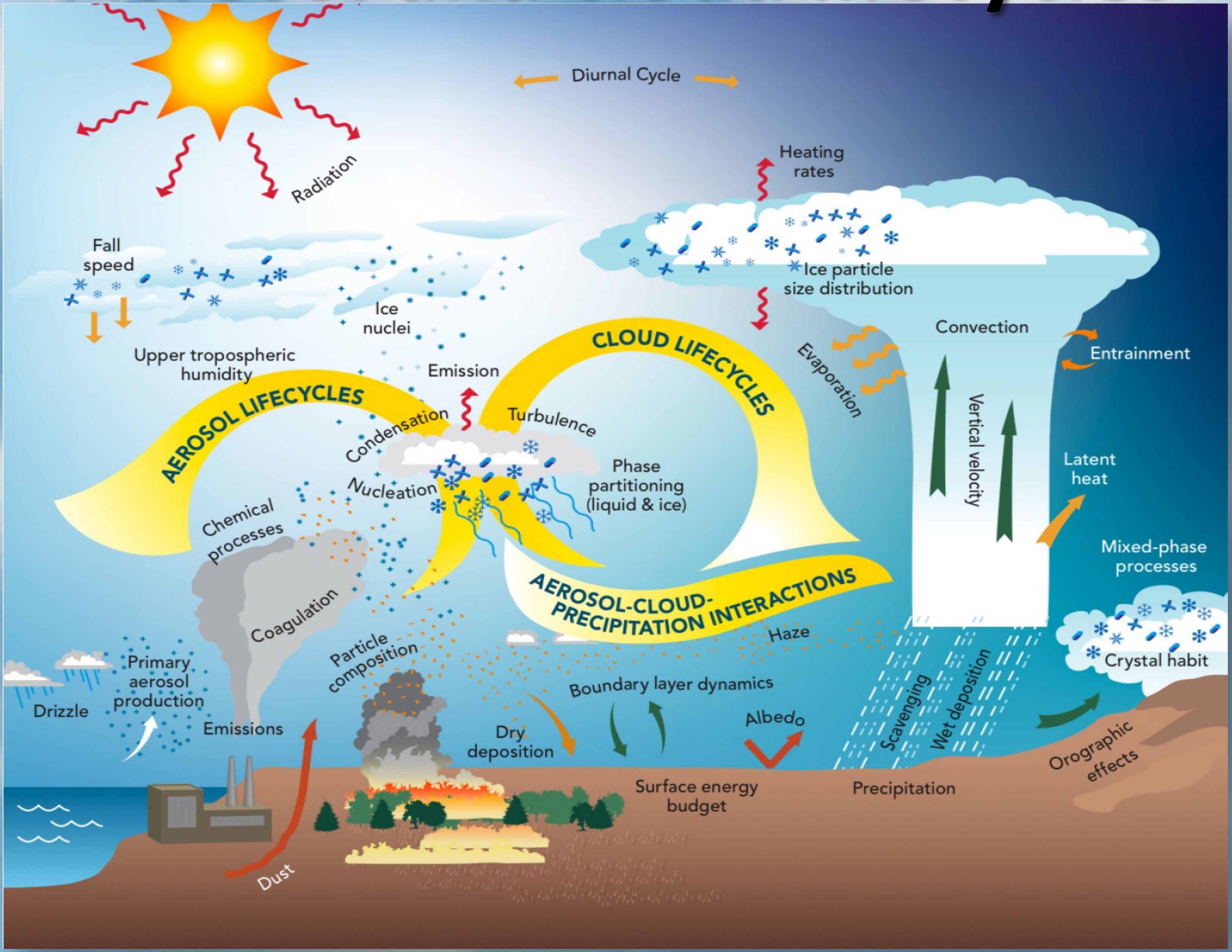
Dominant OH sink in the rainforest: Isoprene

How secondary forests process BVOCs?

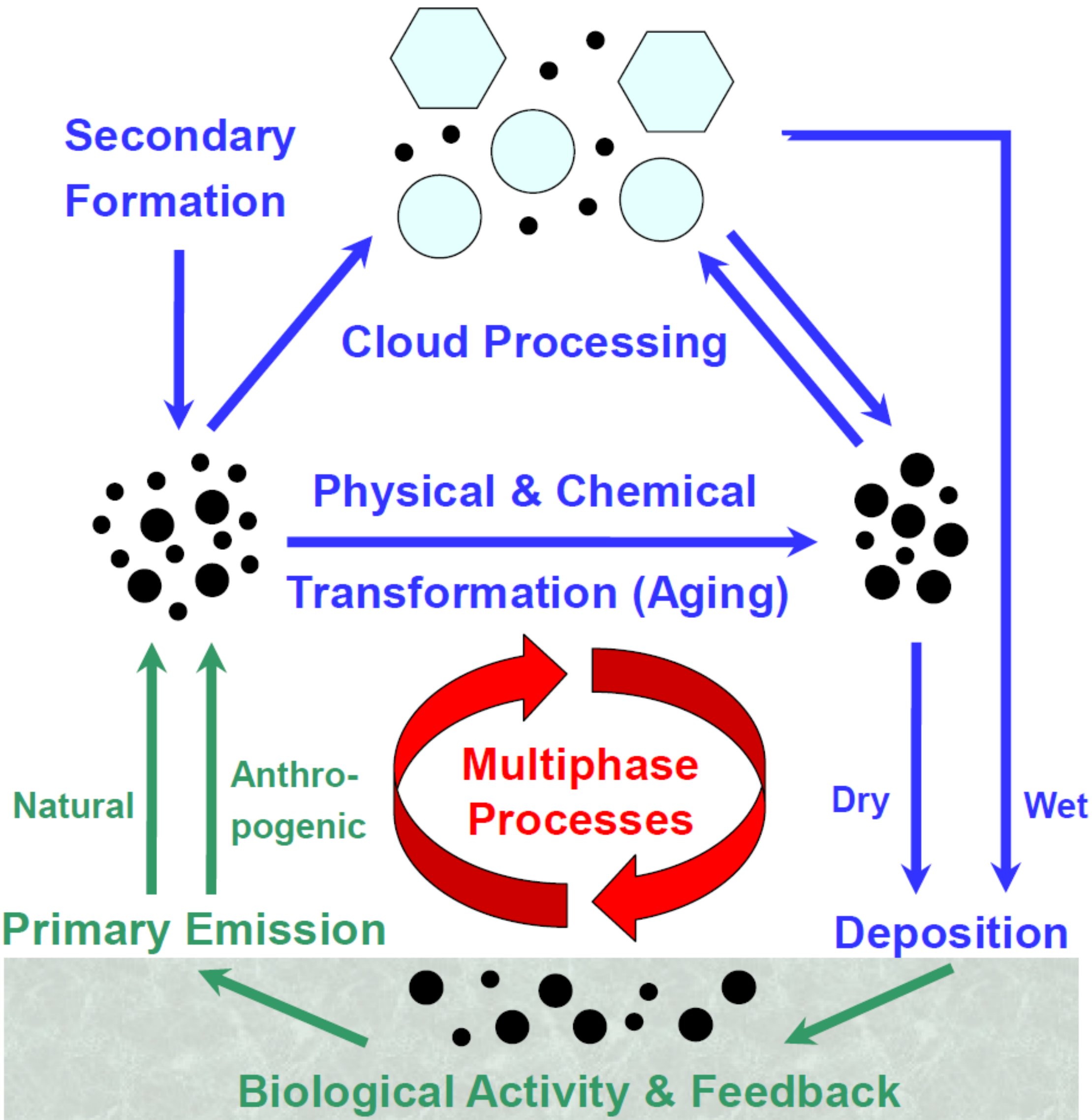
How are the emissions of plantations in Amazonia regarding VOC emissions?

Effects on ozone? Aerosols? OH?

Aerosol and cloud lifecycles



Aerosol cycling in Amazonia



Uli Pueschl, 2012

Atmosphere & Climate

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

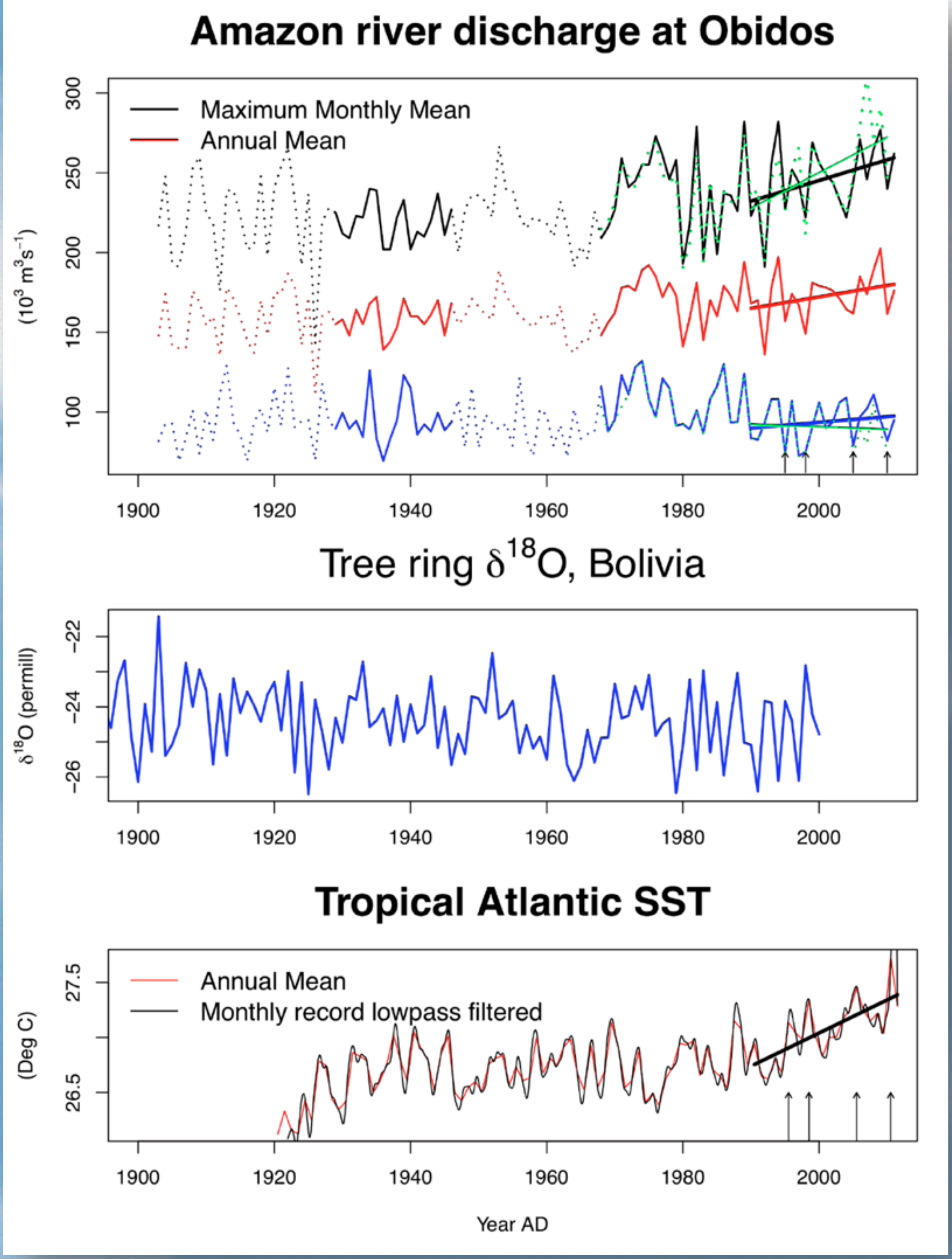
Mechanistic understanding, quantitative prediction & human influence ?

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

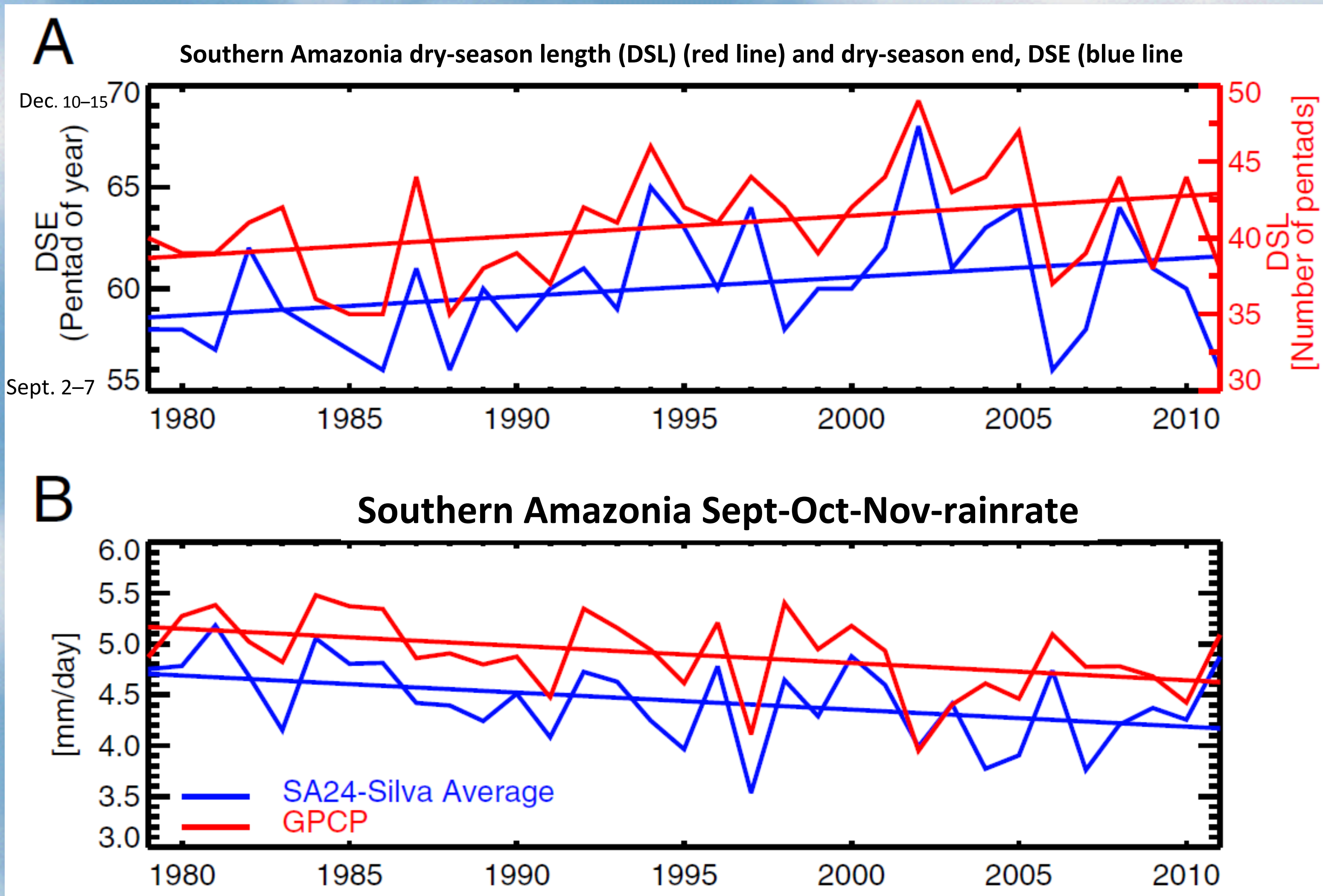
Biosphere & Public Health

Is the Amazonian hydrological cycle intensifying?

Maximum monthly, annual mean and minimum monthly mean Amazon river discharge at Óbidos and in green maximum and minimum daily mean river discharge, (b) δ^{18}O in precipitation in Bolivia derived from tree rings (Brienen et al. 2012) and (c) tropical Atlantic sea surface temperature from Extended reconstructed sea surface temperature) (Gloor et al. 2013).



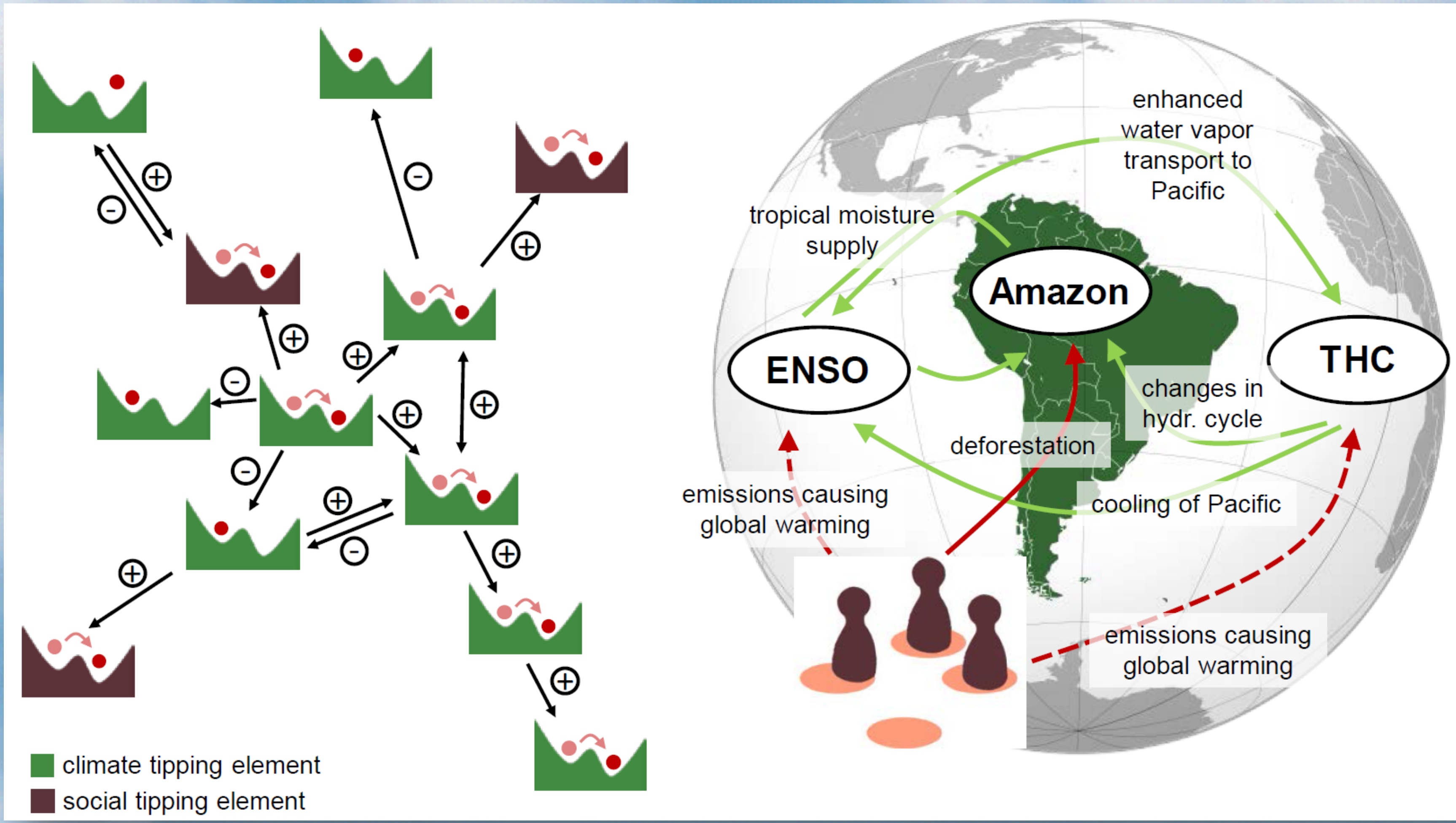
Dry season length is increasing in Amazonia



(A) Annual time series of the dry-season length (DSL) (red line) and dry-season end, DSE (blue line) dates derived from the PM daily rainfall data over the southern Amazonian domain show a decrease of DSL due to a delay of DSE. The unit is pentad (5 d). On the left axis, the 55th pentad corresponds to September 2–7 of the calendar date and the 70th pentad corresponds to December 10–15. (B) Time series of austral spring seasonal rainfall over southern Amazonia derived from the PM and GPCP datasets show decrease of rainfall consistent with the delay of DSE shown in (A). Trends are significant at $P < 5\%$.

Rong Fu, PNAS 2013

Climate tipping points: The Amazon within the Earth system



Network of tipping elements with possible enforcing (+) or dampening (-) effects

Example for a tipping network: Amazon – Thermohaline Circulation – El Niño Southern Oscillation – social sphere

Fu, Rong et al. 2013, Lenton et al., 2008, Winkelmann and Donner, 2014

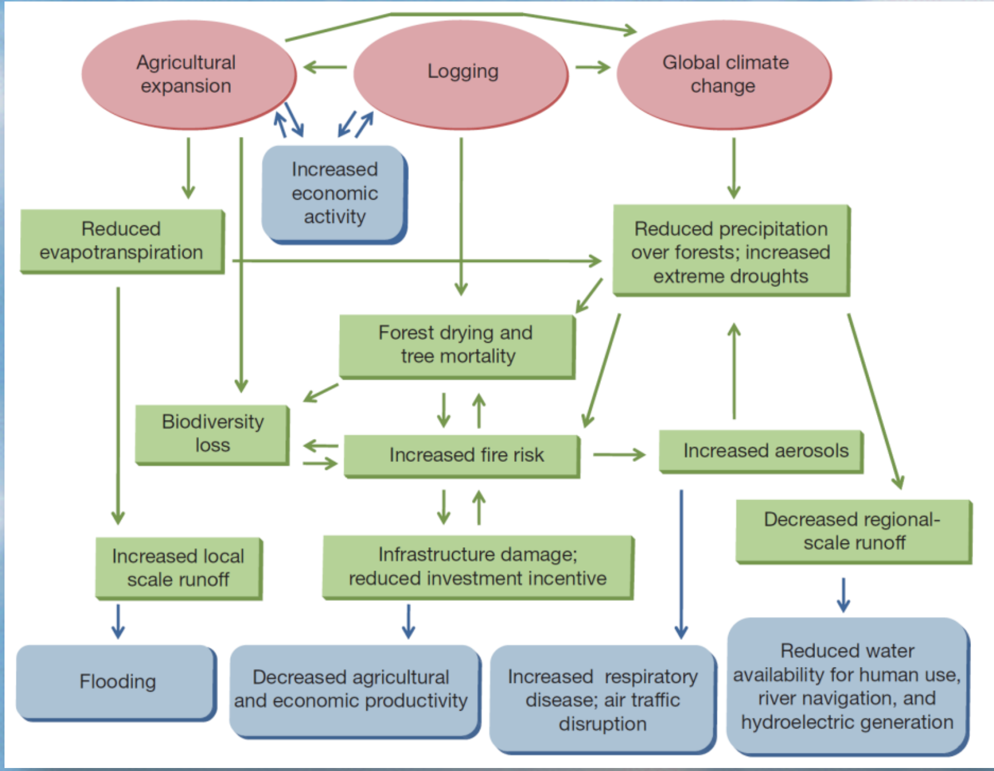
REVIEW

doi:10.1038/nature10717

The Amazon basin in transition

Eric A. Davidson[1], Alessandro C. de Araújo[2,3], Paulo Artaxo[4], Jennifer K. Balch[1,5], I. Foster Brown[1,6], Mercedes M. C. Bustamante[7], Michael T. Coe[1], Ruth S. DeFries[8], Michael Keller[9,10], Marcos Longo[11], J. William Munger[11], Wilfrid Schroeder[12], Britaldo S. Soares-Filho[13], Carlos M. Souza Jr[14] & Steven C. Wofsy[11]

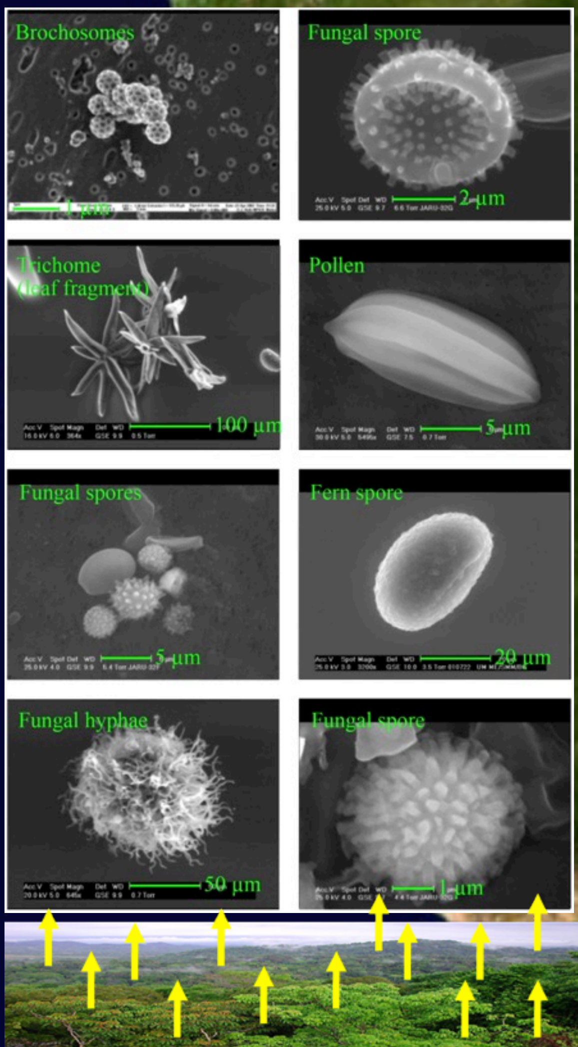
Agriculture expansion and climate variability are critical ingredients on Amazonian transition. Energy balance and hydrological cycles changes are already observed in Amazonia.

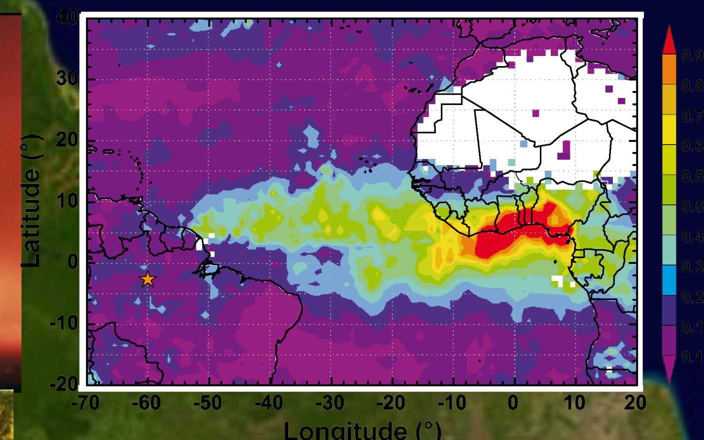


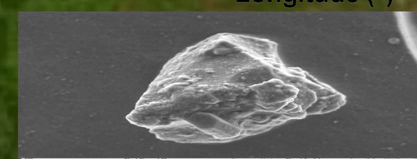
Interactions between land use change and climate change are major drivers for changes in Amazonia.

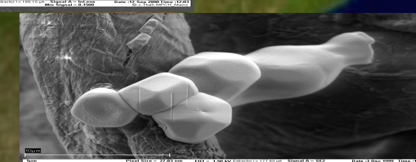
Amazonia: 3 types of aerosol particles

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

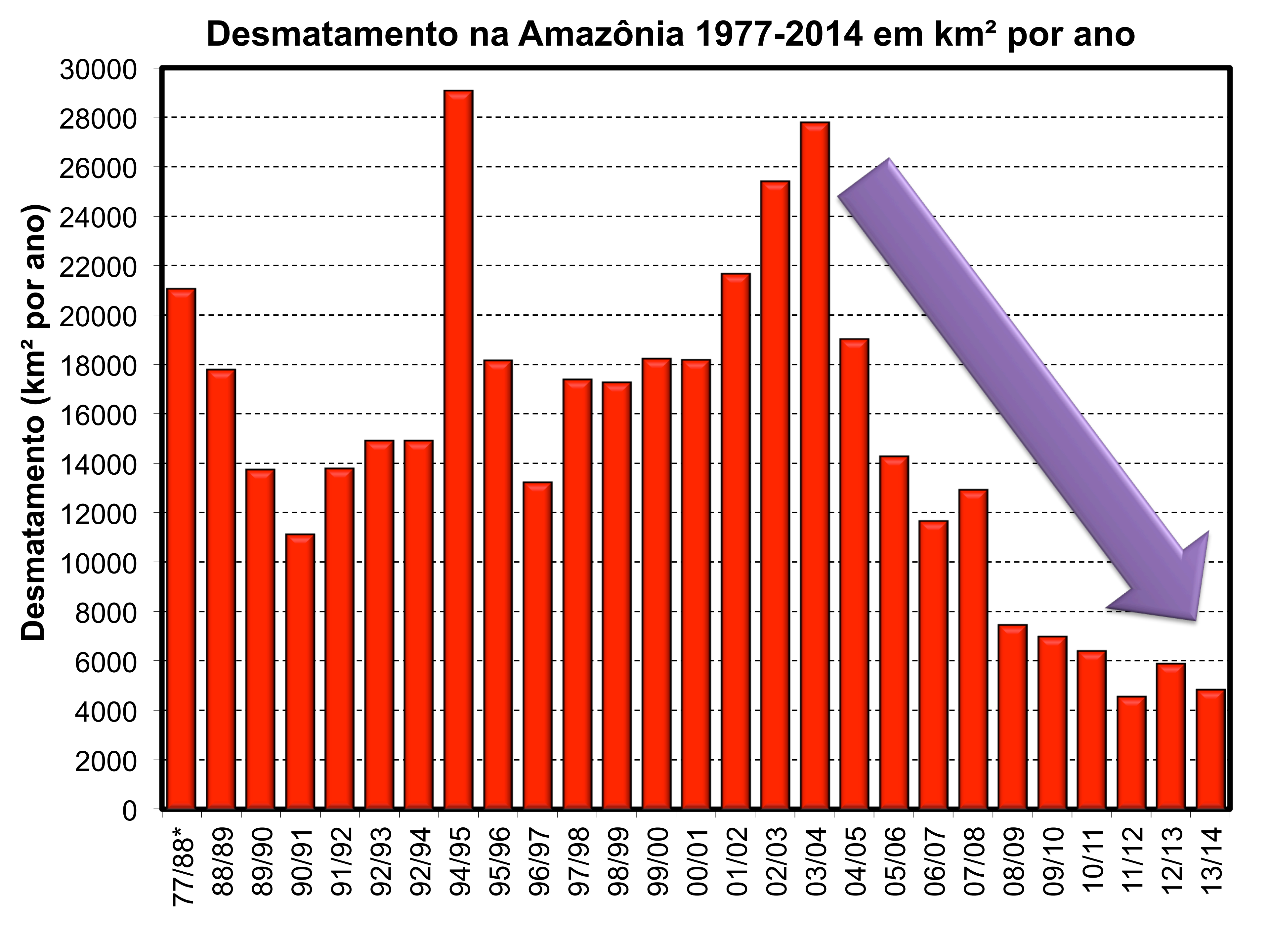








Each with VERY different properties and impacts
Size: from 1 nanometer to 10 micrometers

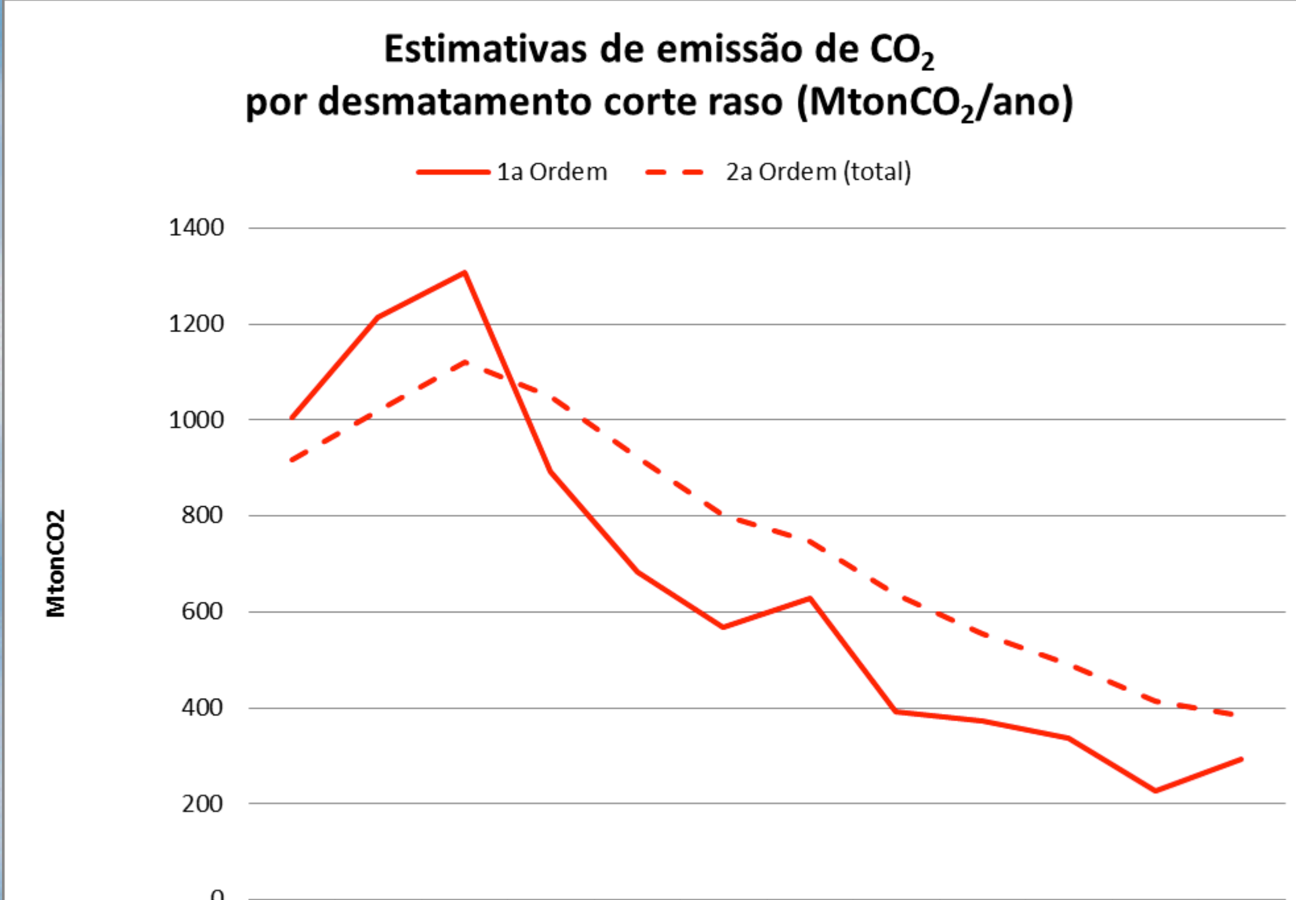


Desmatamento na Amazônia 1977-2014 em km² por ano
Desmatamento (km² por ano)
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
77/88*
88/89
89/90
90/91
91/92
92/93
92/94
94/95
95/96
96/97
97/98
98/99
99/00
00/01
01/02
02/03
03/04
04/05
05/06
06/07
07/08
08/09
09/10
10/11
11/12
12/13
13/14

INPE-EM: Estimativa de emissões dos gases do efeito estufa (GEE) por mudanças de cobertura da terra

Ometto, 2014, Aguiar 2012

Redução de emissões de 65 a 78% (2ª e 1ª ordem)



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1a Ordem	1005	1213	1309	892	683	568	629	392	374	338	228	294
2a Ordem (total)	916	1018	1120	1049	923	802	746	637	555	492	415	384

Estimativas de 1ª Ordem: Supõe de modo simplificado que 100% das emissões ocorram no momento da mudança de uso/cobertura.

Estimativas de 2ª Ordem: Buscam representar o processo gradativo de liberação e absorção do carbono como ocorre de fato.

Caracterização do processo de desmatamento na Amazônia legal

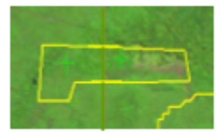
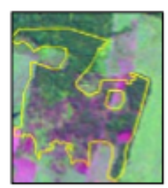
O processo de desmatamento se dá em quatro estágios:

(i) degradação florestal de intensidade leve, onde são identificadas clareiras pequenas;

(ii) degradação florestal de intensidade moderada, estágio intermediário em que ainda são encontradas árvores de grande porte e sub-bosque conservado;

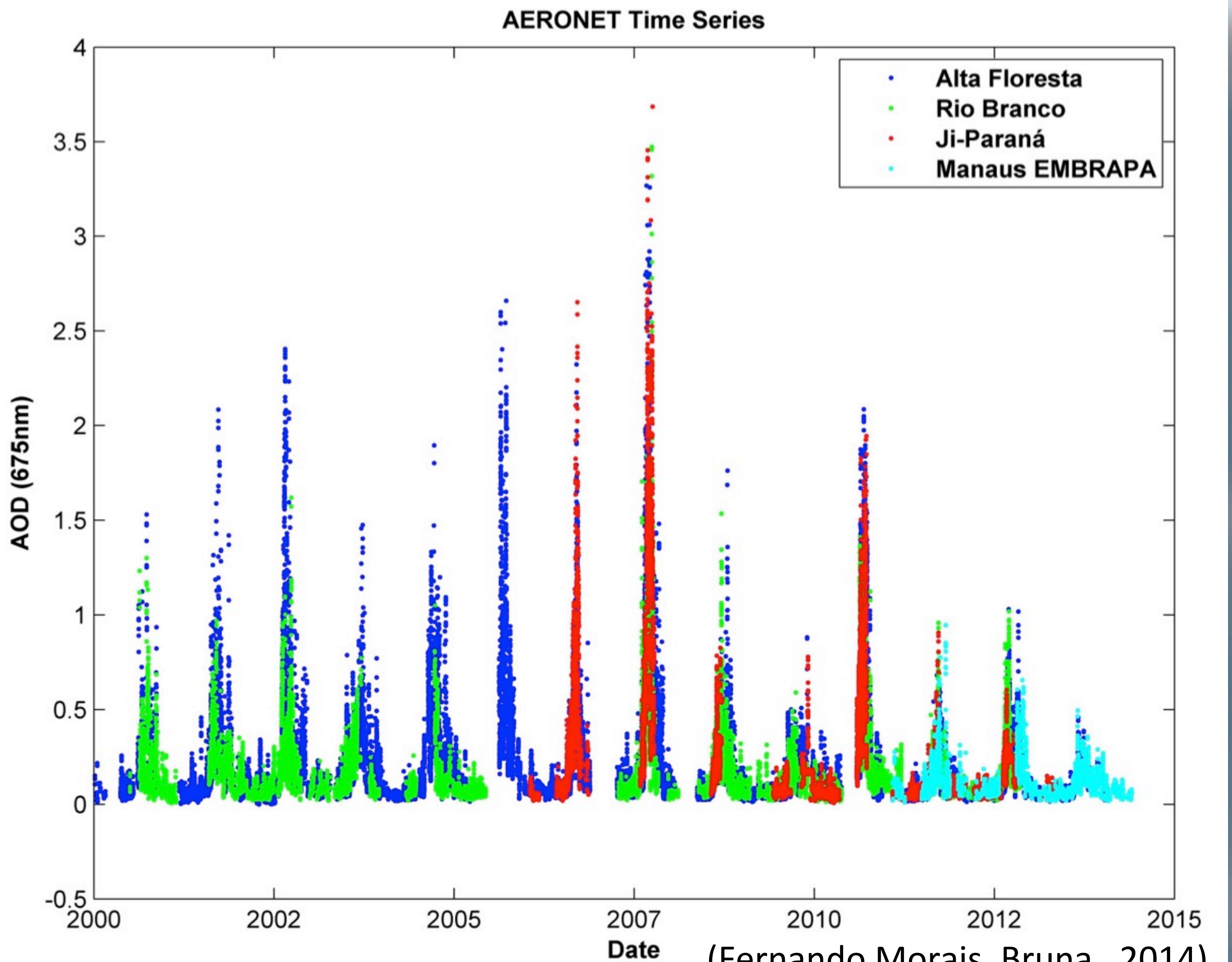
(iii) degradação florestal de intensidade alta, onde há perda significativa das árvores de grande porte, com perda concomitante do sub-bosque, e muitas árvores mortas por queimadas contínuas permanecem em pé;

(iv) corte raso (desmatamento), quando ocorre a retirada completa da vegetação original (MCT/INPE, 2008).

	Predomínio de tonalidade verde, textura rugosa e sombra. Padrão semelhante às florestas da região. Maioria do perímetro contíguo tem o mesmo padrão.	Cobertura florestal , textura heterogênea, com sombra, indicando a estrutura florestal complexa e não alterada.	Floresta não alterada
	Tonalidade magenta, ou verde muito claro (esmaecido). Forma regular, textura lisa, limites bem definidos entre o polígono (solo exposto) e a matriz florestal.	Predomínio de solo exposto ou pastagem em formação.	Corte Raso
	Predomínio de tonalidade verde e padrão de floresta, com presença de feições de tonalidade magenta ou roxa de tamanho pequeno, com baixa densidade e freqüência.	Predomínio de cobertura florestal com manchas de solo exposto indicando a presença de pátios e indícios de acesso.	Floresta Degradada de Intensidade Leve
	Predomínio de tonalidade verde e padrão de floresta, com presença de feições de tonalidade magenta ou roxa, de tamanho médio, com média densidade e freqüência.	Predomínio de cobertura florestal com manchas de solo exposto indicando a presença de pátios de estocagem de madeira, ramais e clareiras.	Floresta Degradada de Intensidade Moderada
	Predomínio de tonalidade magenta/roxa (clareiras grandes com indicação de fogo) ou verde (com textura lisa) em associação com manchas que apresentam padrão de floresta.	Presença de grandes clareiras com solo exposto, vegetação secundária e/ou área extensa de cicatriz de fogo florestal, combinadas com manchas florestais.	Floresta Degradada de Intensidade Alta

Características da Cobertura Vegetal em Diferentes Estágios de Perturbação Florestal. **Fonte:** MCT/INPE, 2008.

14 years of AERONET measurements in Amazonia

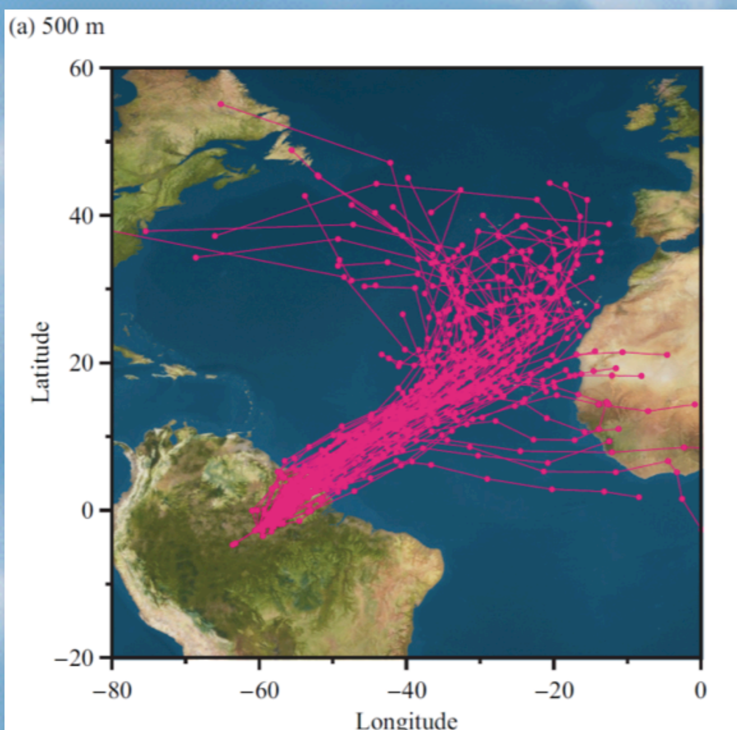


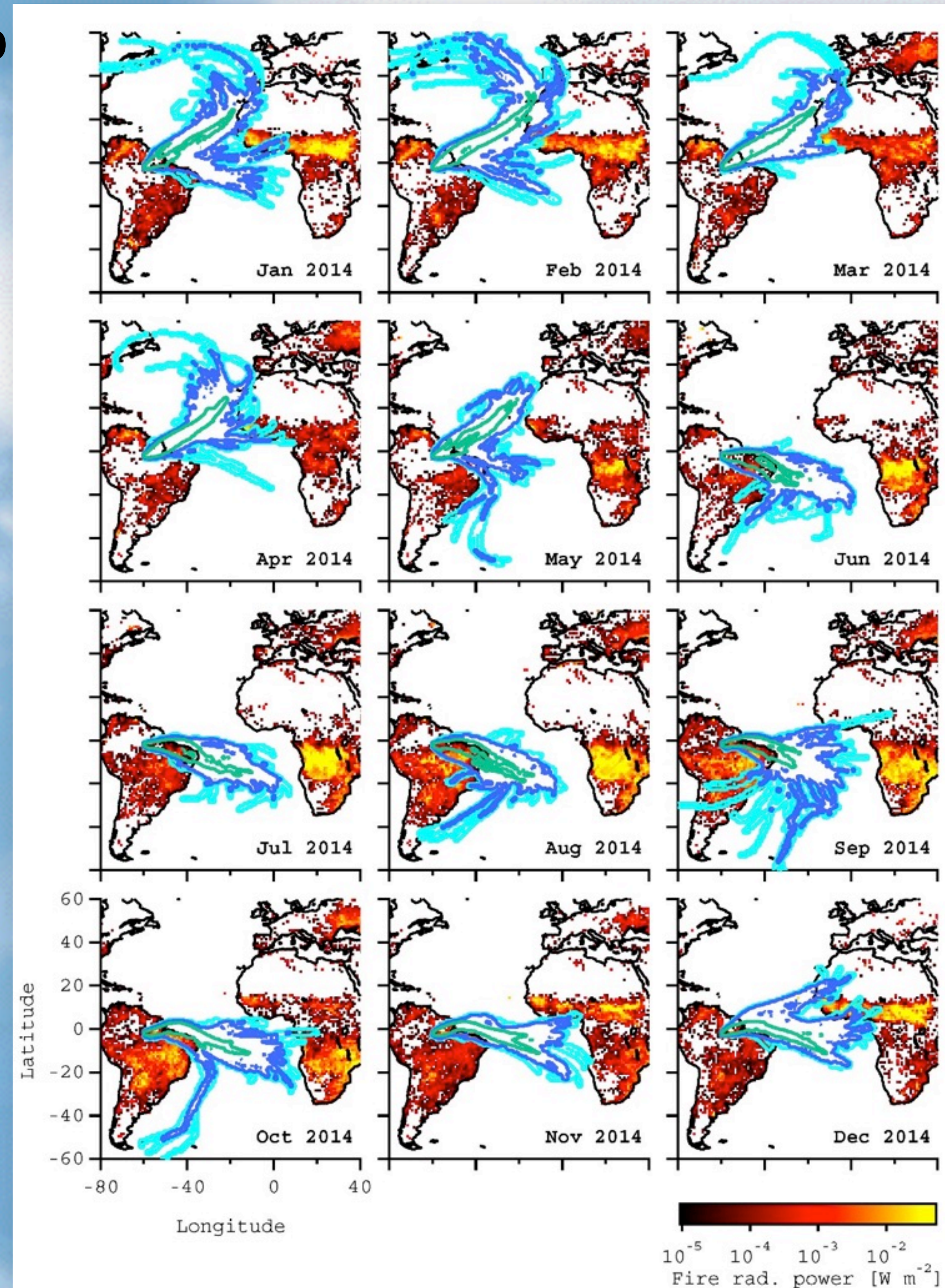
(Fernando Morais, Bruna , 2014)

Large scale back trajectories to T0a-ATTO

Note the change from wet to dry season

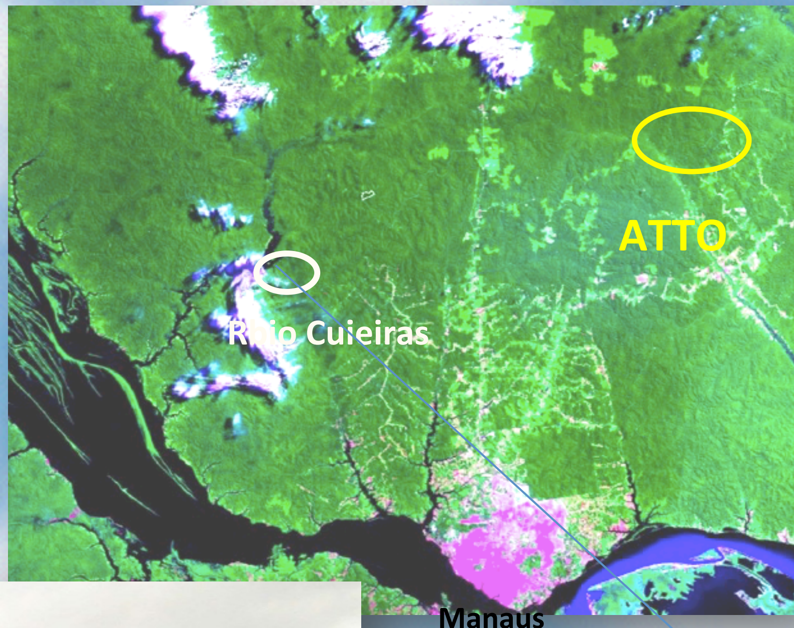
For the wet season AMAZE





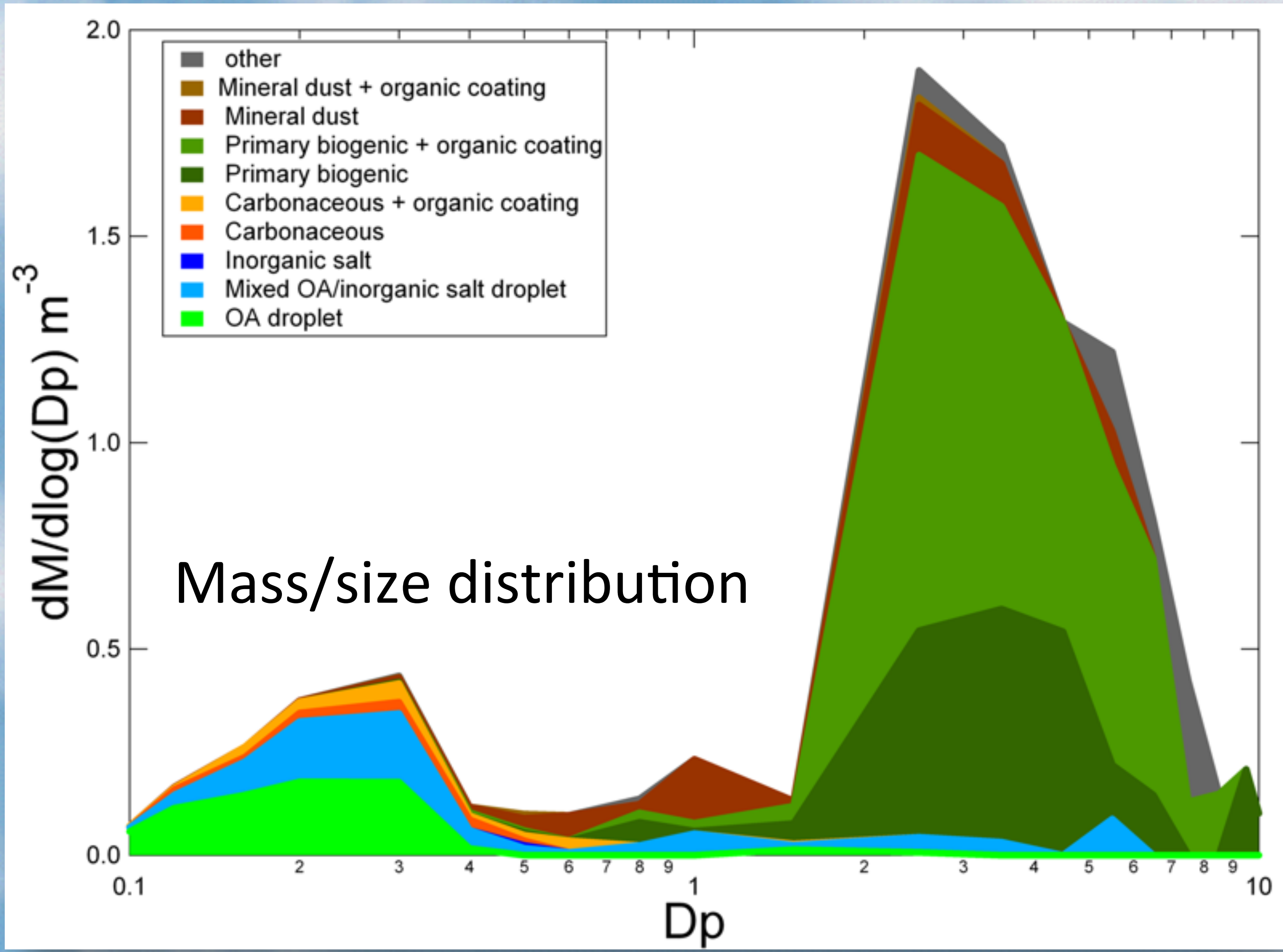
Martin et al., 2009, Andreae et al., 2015

Six measurement sites in Central Amazonia



Manaus ZF2 aerosol and trace gas measurements

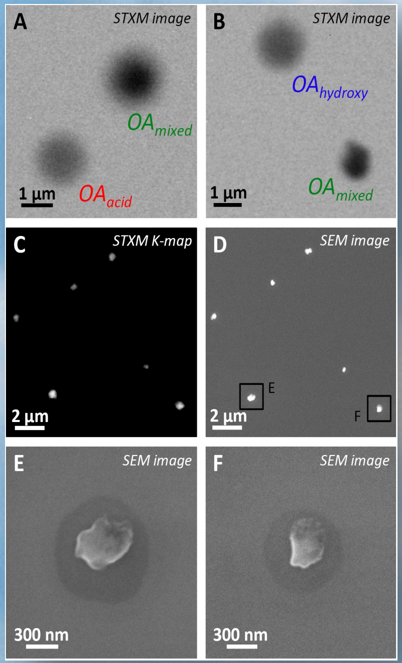
Particles in clean air over Amazon

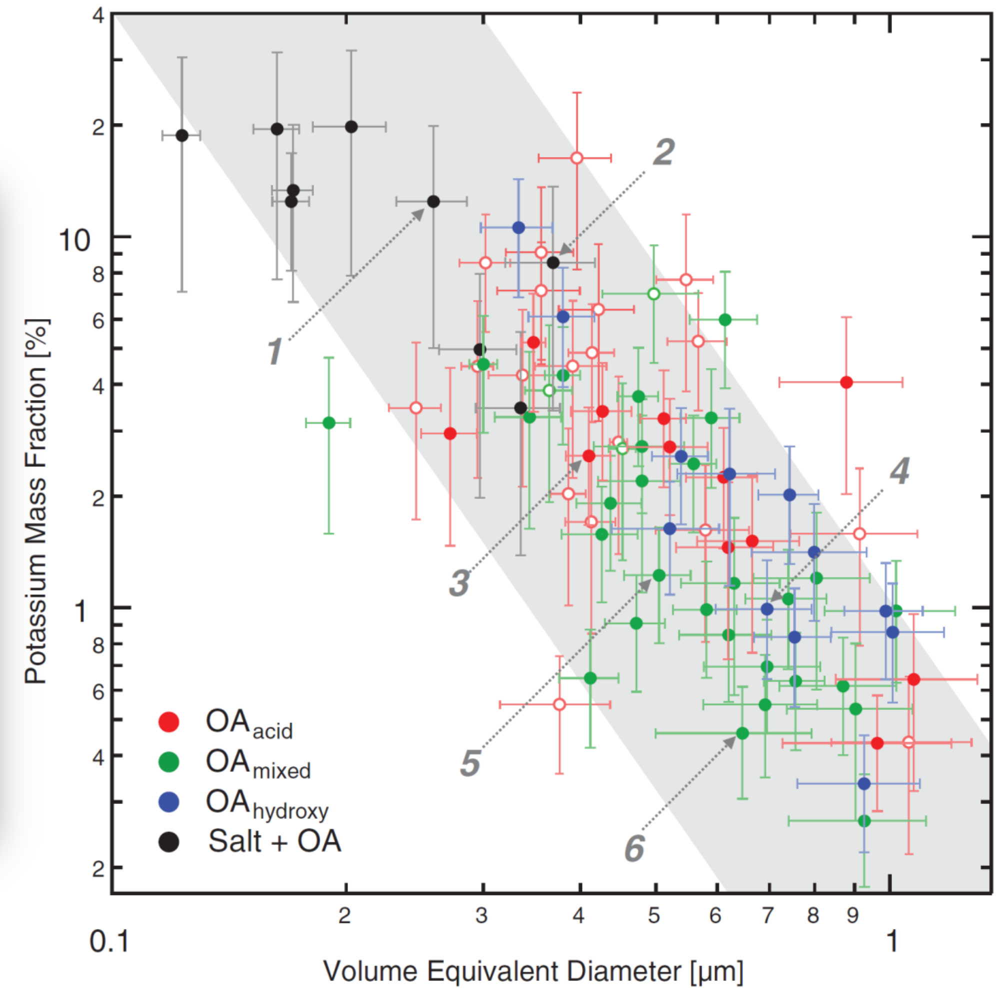


Biological, chemical, and physical processes over the Amazon form a closely coupled system

Martin et al., 2010, Pueschl et al., 2010

Size dependence of potassium mass fraction in Amazonian organic aerosol particles



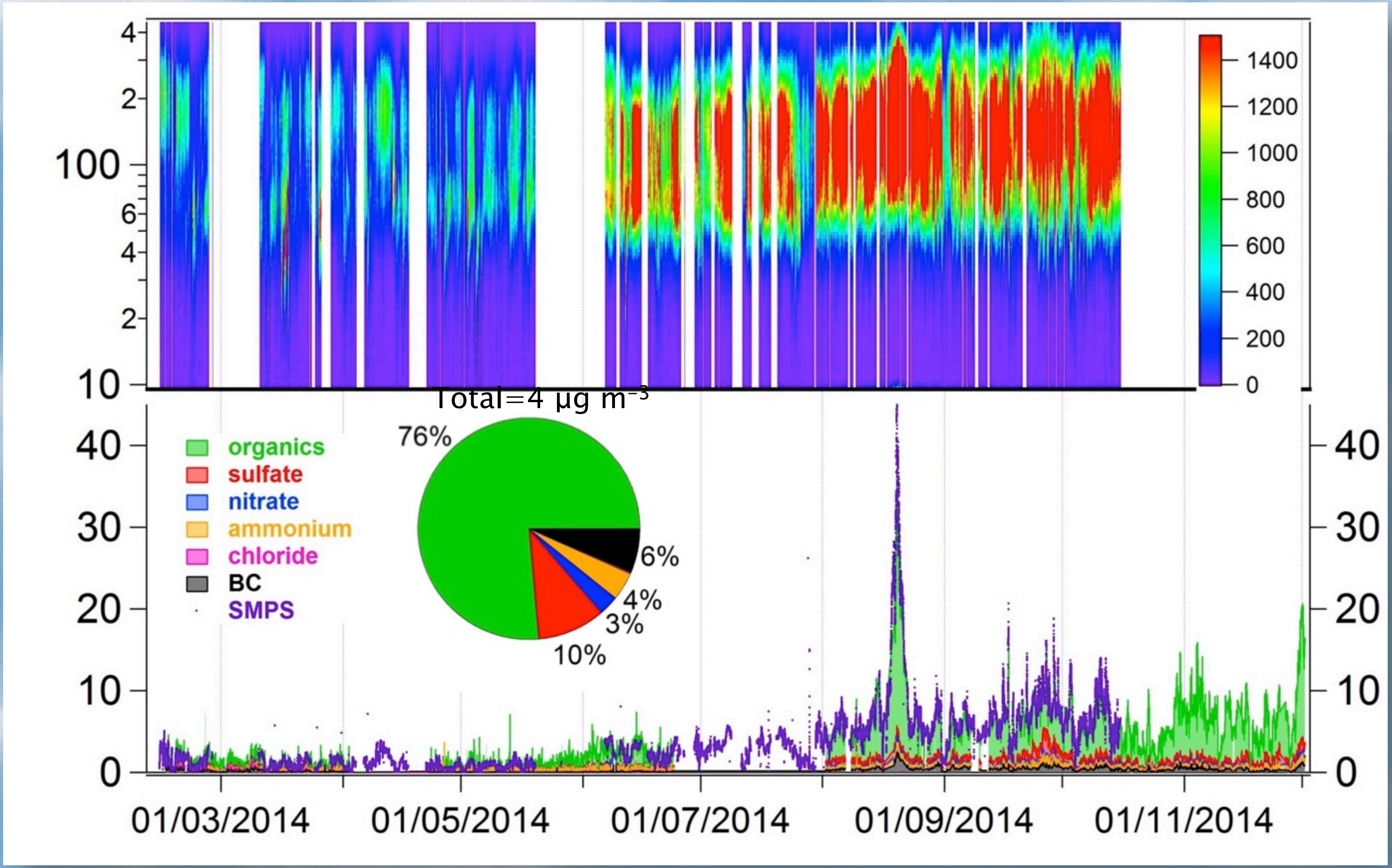


Chris Pöhlker et al., Science 2012

STXM-NEXAFS shows that 95% of particles contains K, even SOA with dp 20-40 nm

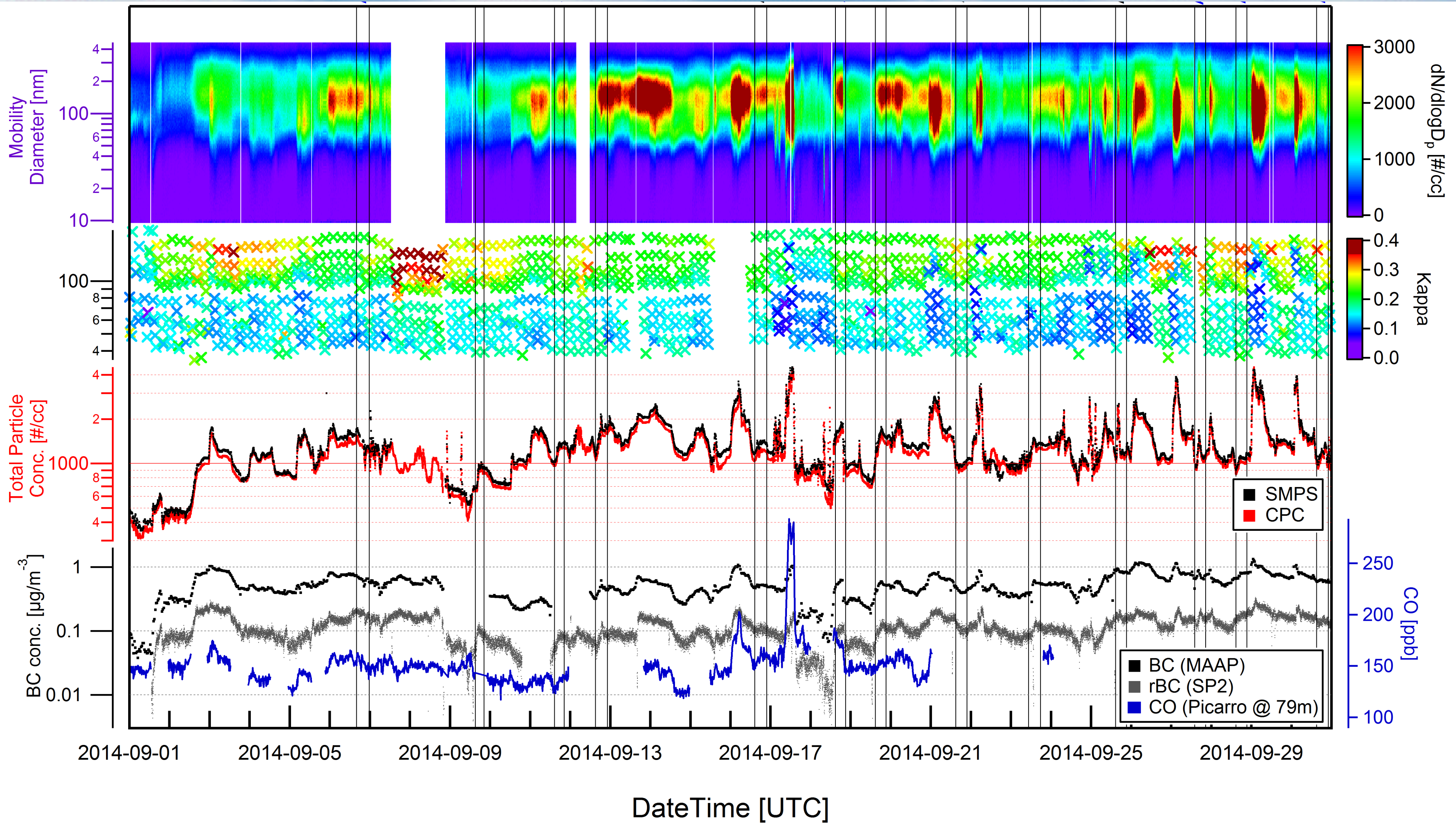
The growth of organic aerosol particles can be initiated by potassium-salt–rich particles emitted by biota in the rainforest

T0a – ATTO aerosol properties SMPS versus ACSM March to November 2014

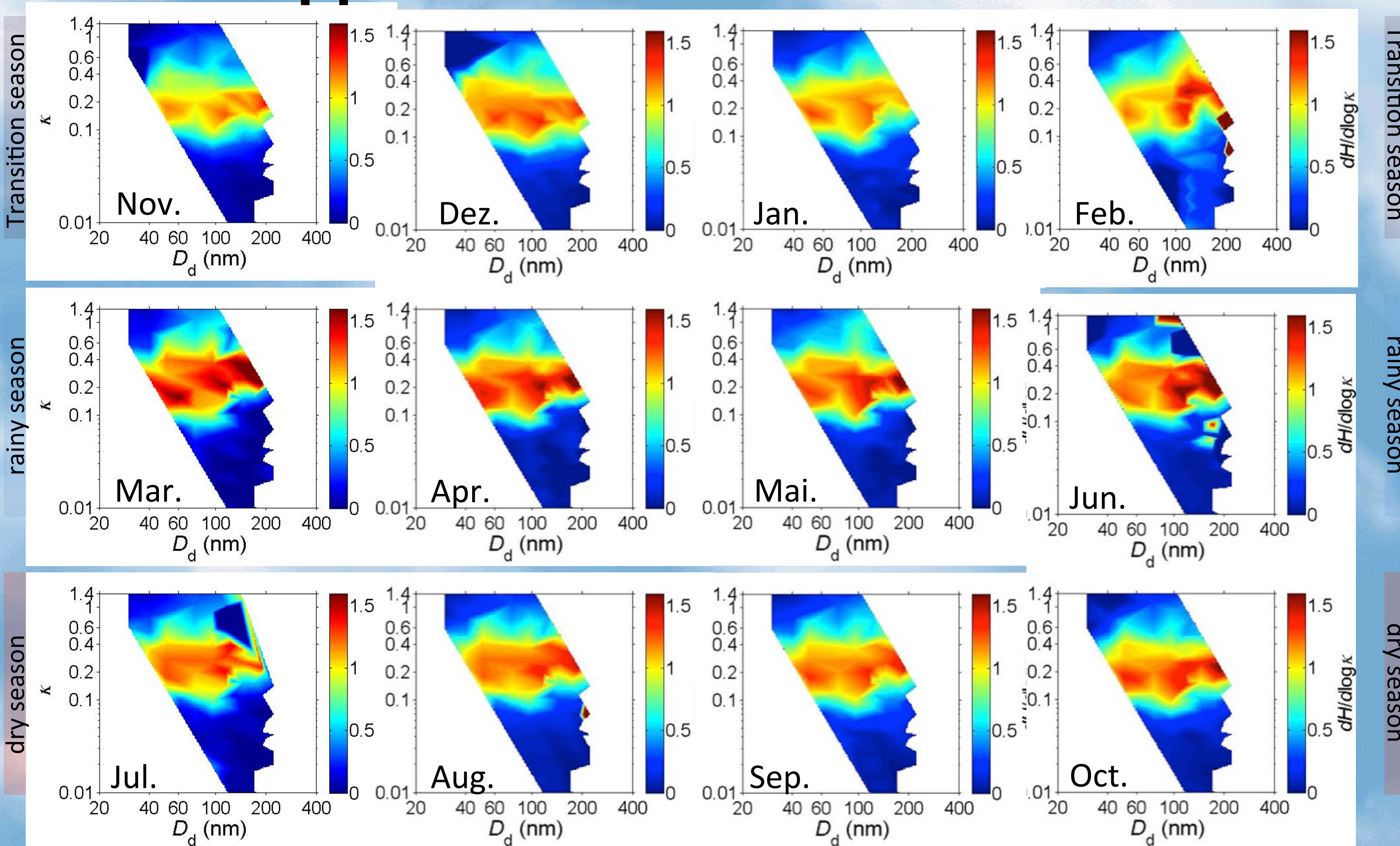


Samara Carbone, 2015

T0a - ATTO SMPS, CPC, BC, CO for September 2014



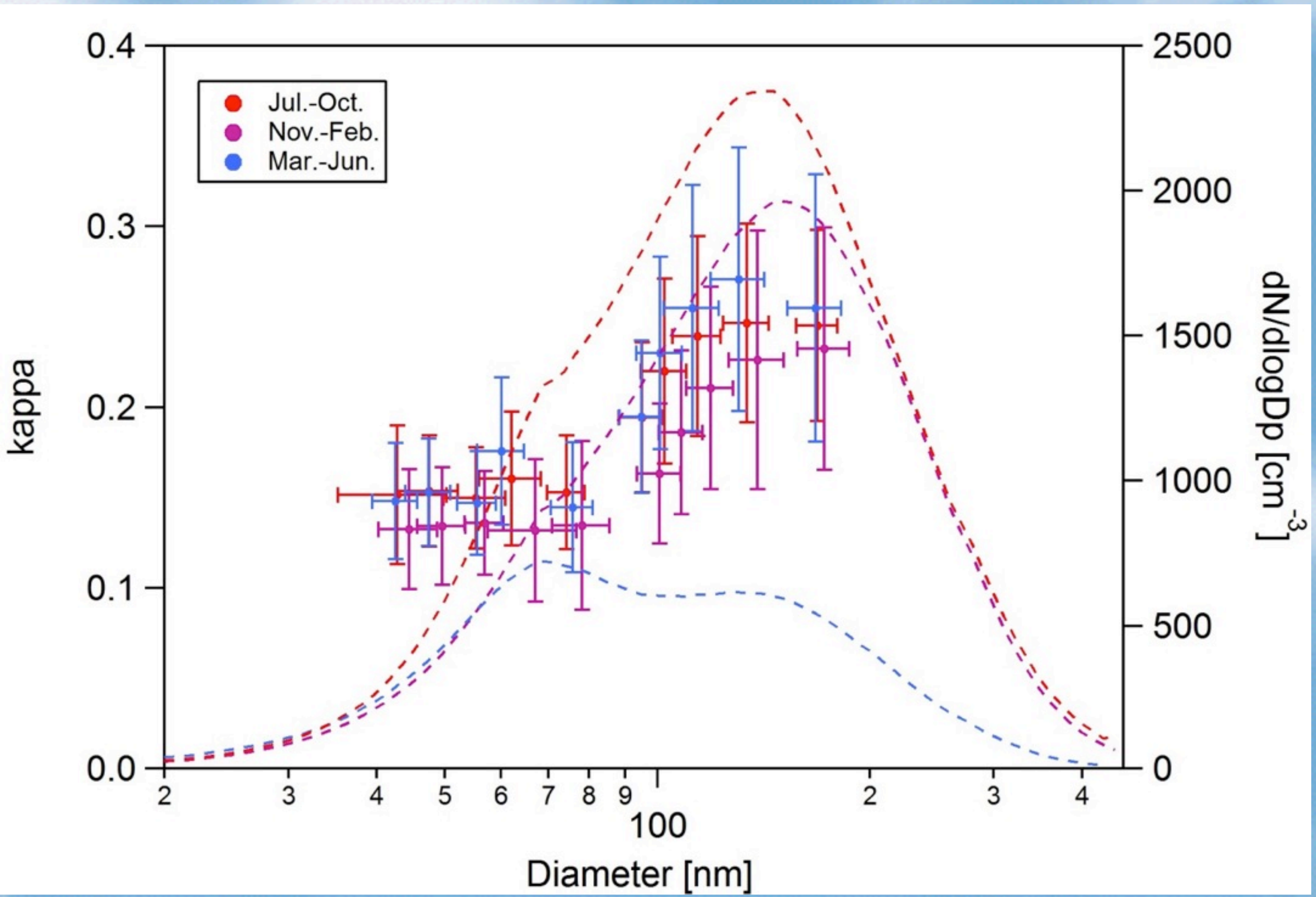
Kappa Distribution at ATTO Site



- enhanced values in the rainy season.
- the dominant kappa value is around 0.2, with larger values for larger diameters

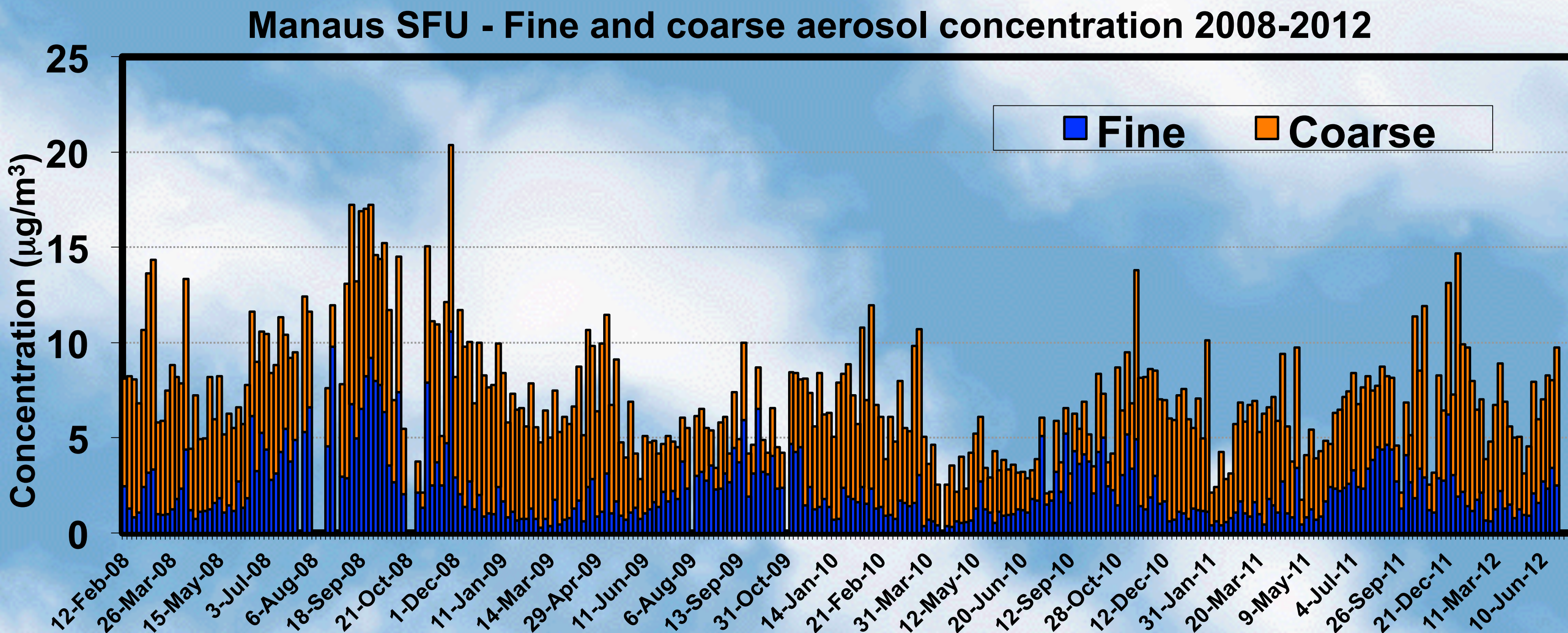
From Mira Kruger and H. Barbosa

kappa vs. midpoint activation diameter T0a - ATTO March 2014-Feb 2015

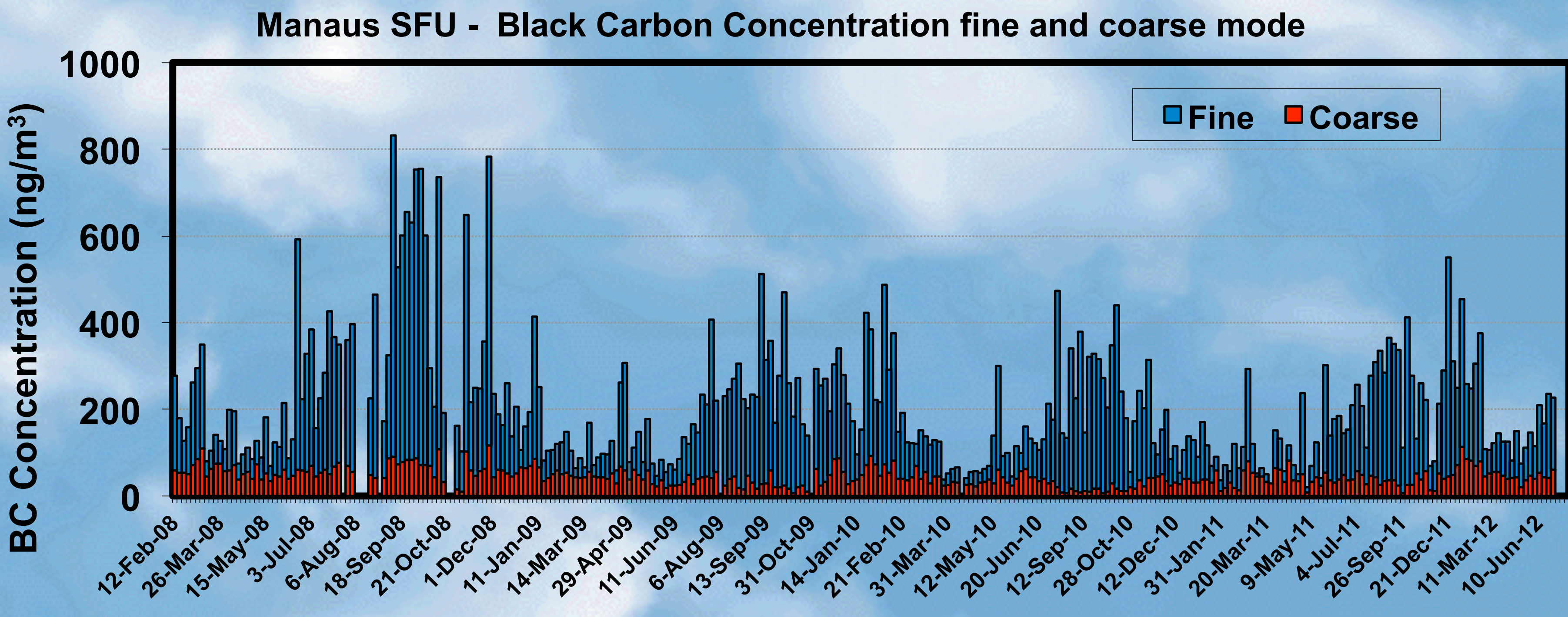


- highest kappa values and lowest particle in the rainy season
- the different kappa value between Aitken mode and accumulation mode results from different composition of the two modes.

From Mira Kruger and H. Barbosa

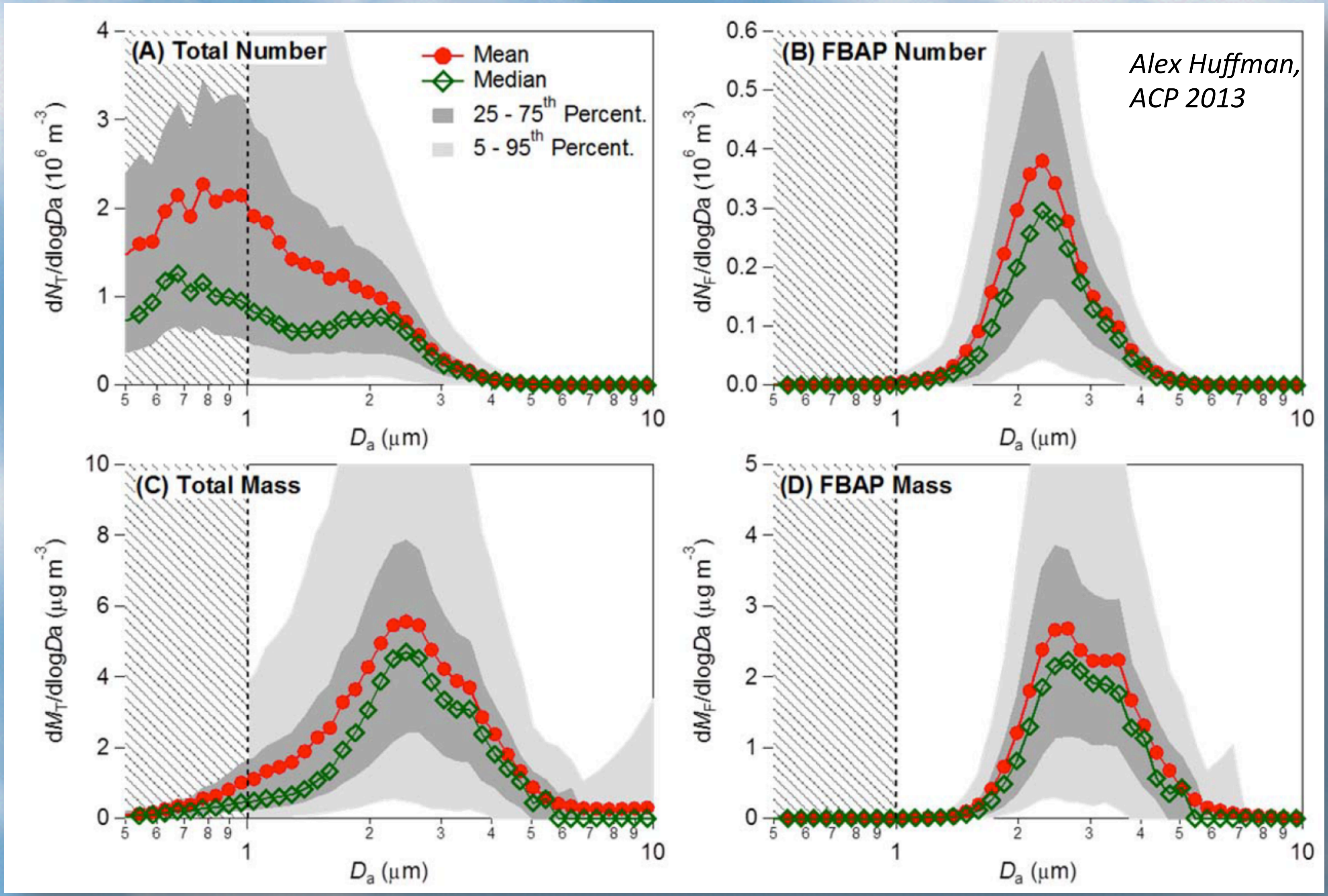


Manaus SFU - Fine and coarse aerosol concentration 2008-2012
Fine
Coarse
Concentration (μg/m³)
0
5
10
15
20
25
12-Feb-08
26-Mar-08
15-May-08
3-Jul-08
6-Aug-08
18-Sep-08
21-Oct-08
1-Dec-08
11-Jan-09
14-Mar-09
29-Apr-09
11-Jun-09
6-Aug-09
13-Sep-09
31-Oct-09
14-Jan-10
21-Feb-10
31-Mar-10
12-May-10
20-Jun-10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



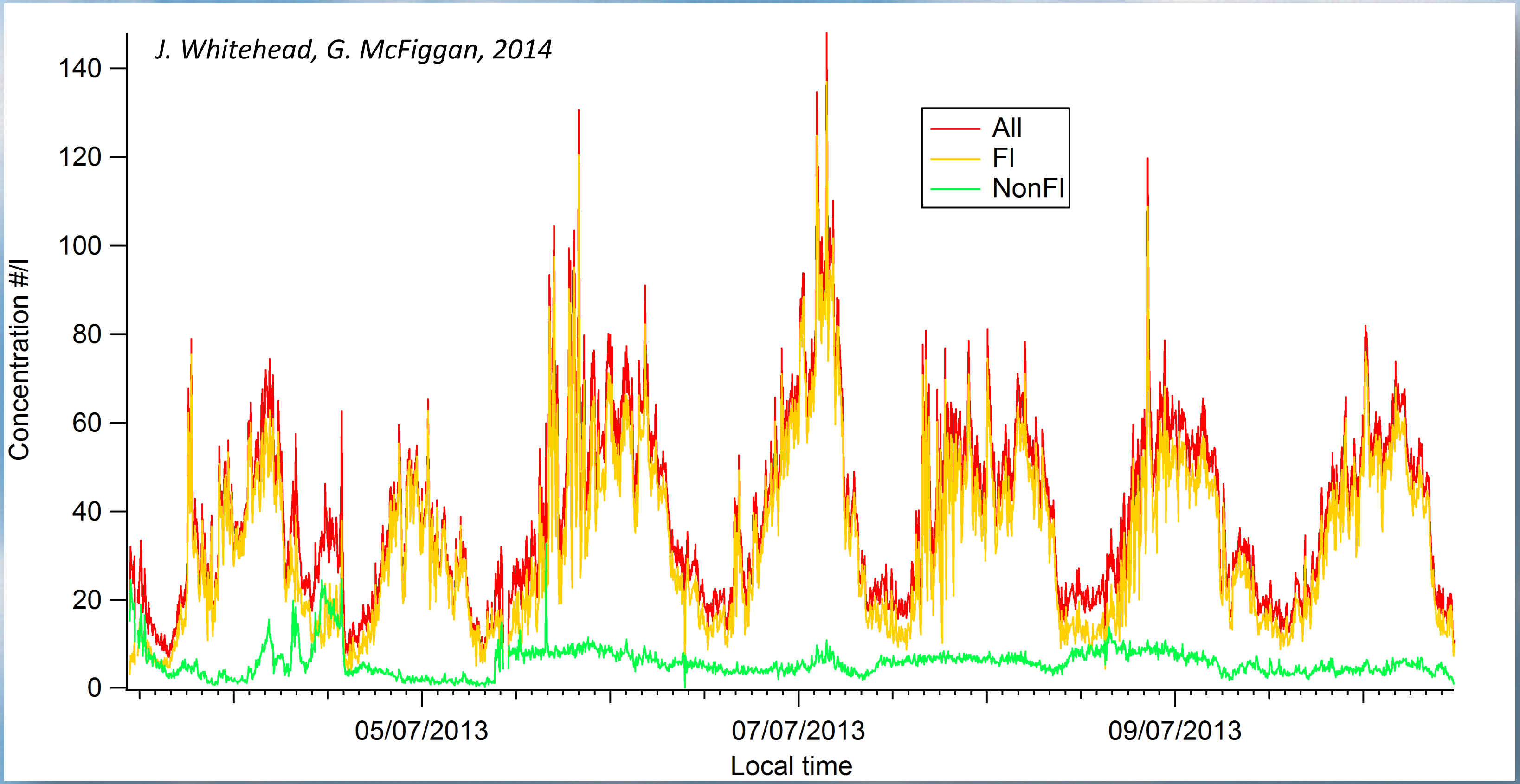
Manaus SFU - Black Carbon Concentration fine and coarse mode
Fine
Coarse
BC Concentration (ng/m³)
0
200
400
600
800
1000
12-Feb-08
26-Mar-08
15-May-08
3-Jul-08
6-Aug-08
18-Sep-08
21-Oct-08
1-Dec-08
11-Jan-09
14-Mar-09
29-Apr-09
11-Jun-09
6-Aug-09
13-Sep-09
31-Oct-09
14-Jan-10
21-Feb-10
31-Mar-10
12-May-10
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

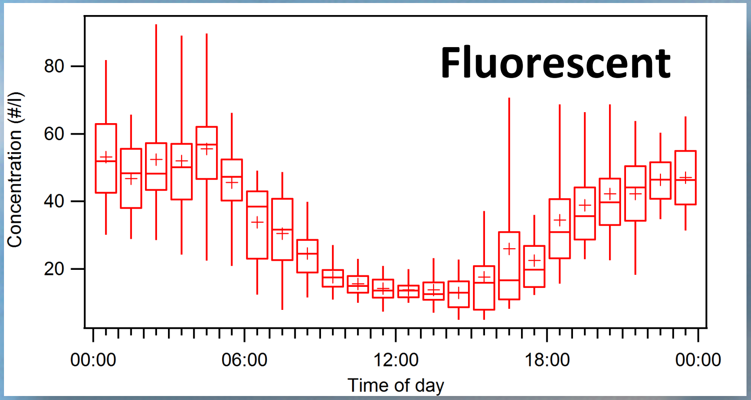
UV-APS Aerosol size distribution and UV fluorescence

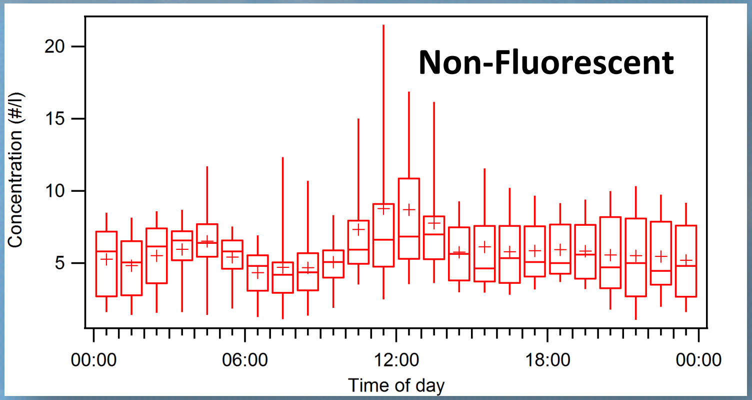


(A) total number (d*N*T/dlog*D*a), (B) FBAP number (d*N*T/dlog*D*a), (C) total mass (d*M*T/dlog*D*a), (D) FBAP mass (d*M*F/dlog*D*a).

Wide Issue Bioaerosol Sensor (WIBS-3)



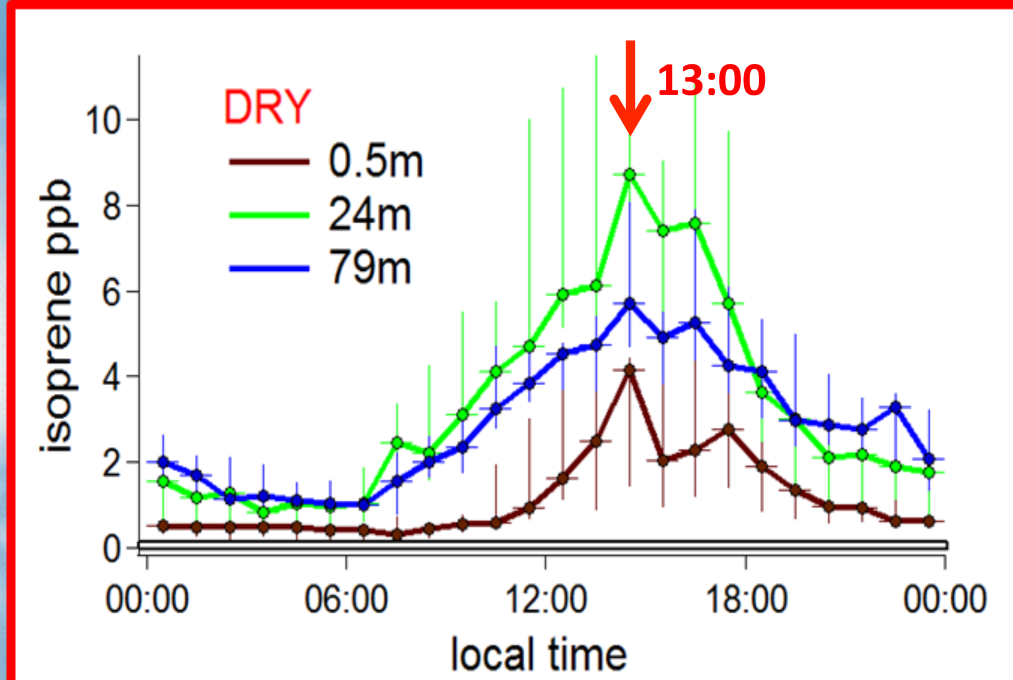


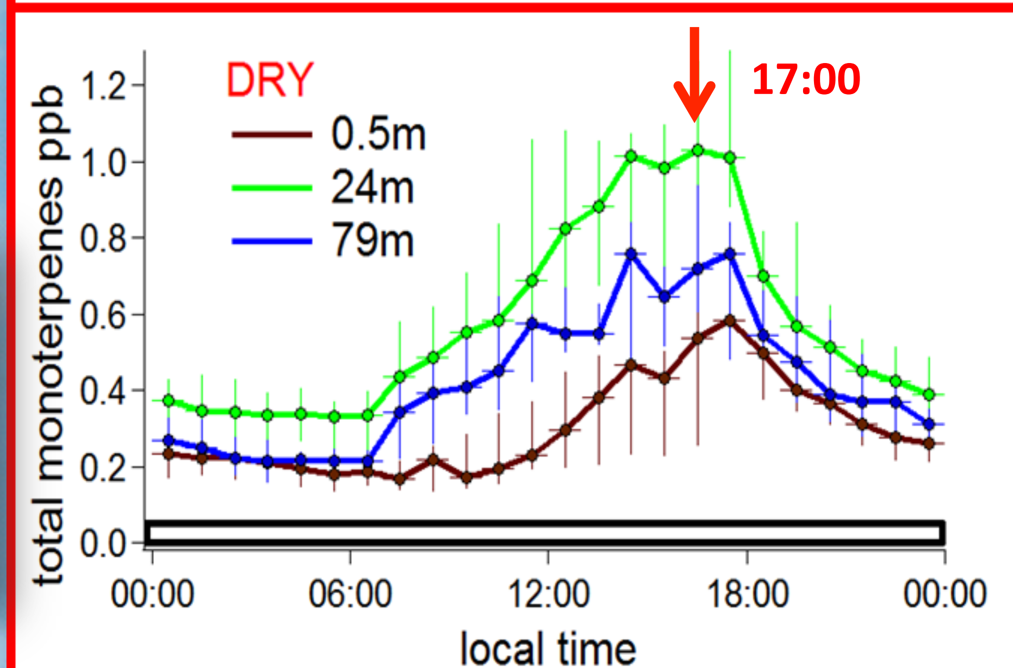


ATTO VOCs: Diurnal variability for isoprene and monoterpenes (dry season)

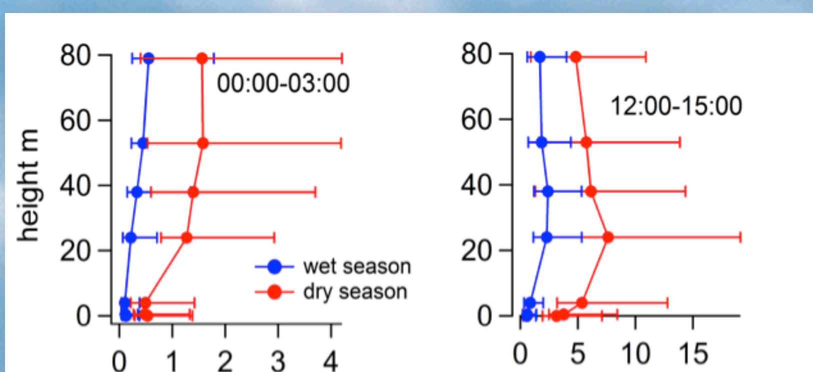
Isoprene has the highest mixing ratios at 13:00 coinciding with the radiation maximum.

Monoterpenes peaked around 17:00 and seem to follow temperature better than light.



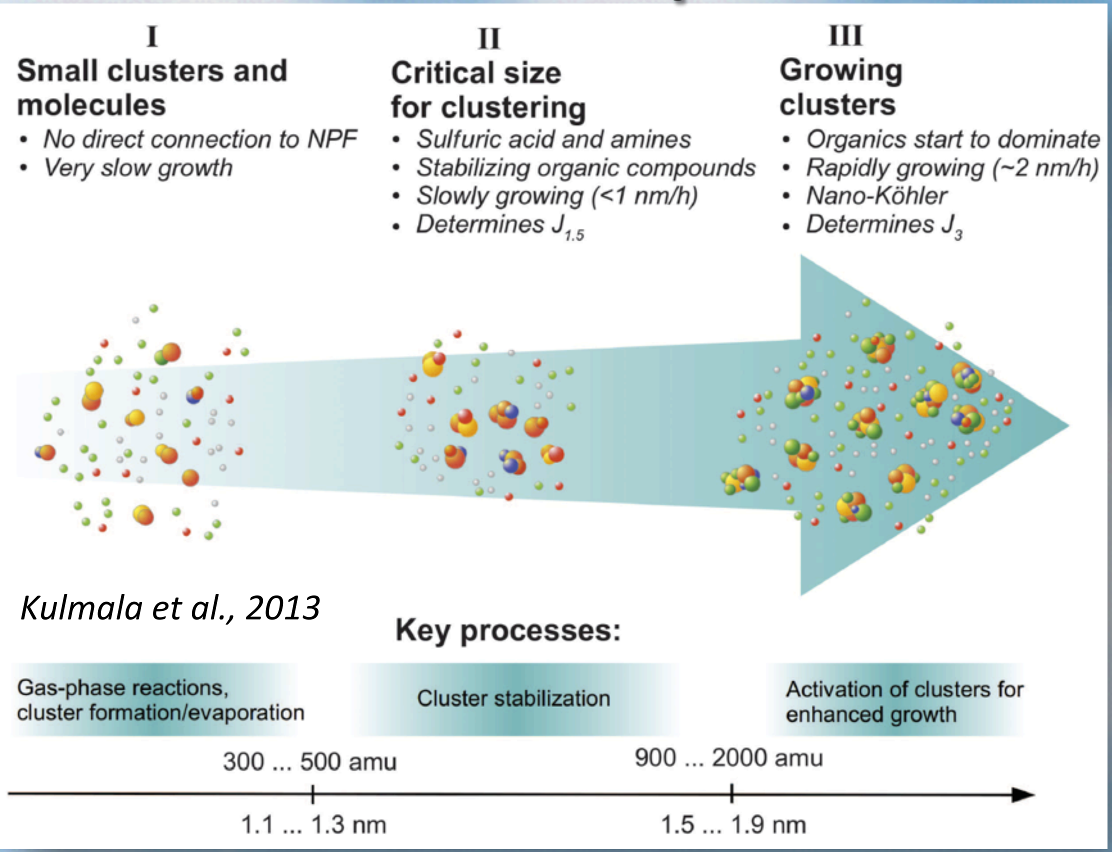


Higher isoprene concentrations during dry season for both night and day measurements



See Poster Ana Maria Yanez Serrano

No new aerosol particle formation observed at surface under pristine conditions in Amazon



Kulmala et al., 2013

New particle formation: a two-step process:

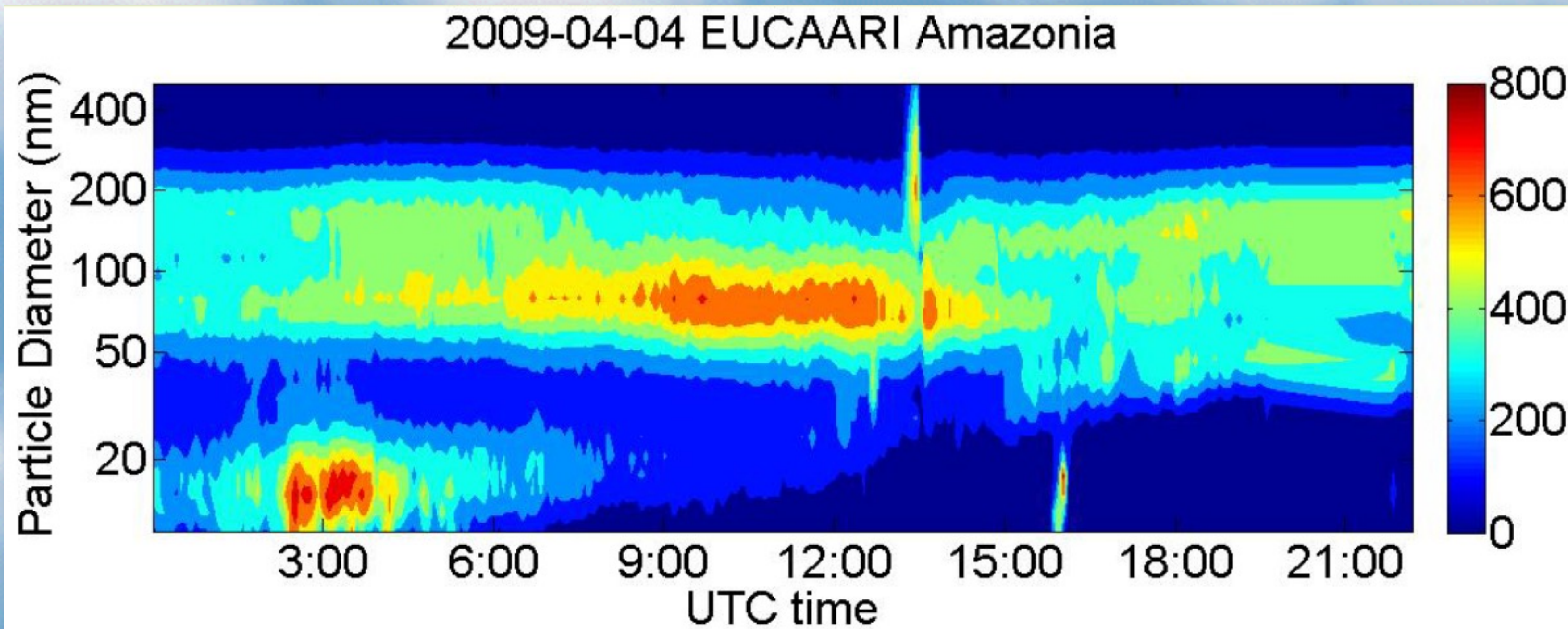
- **1st step: sulfuric acid and amines, ammonia, or organic vapor form stable clusters**
- **2nd step: organic vapor leads to enhance growth rate of the clusters to larger sizes.**

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.**

German HALO plane and DoE G1 also did not find NPF high into the atmosphere…

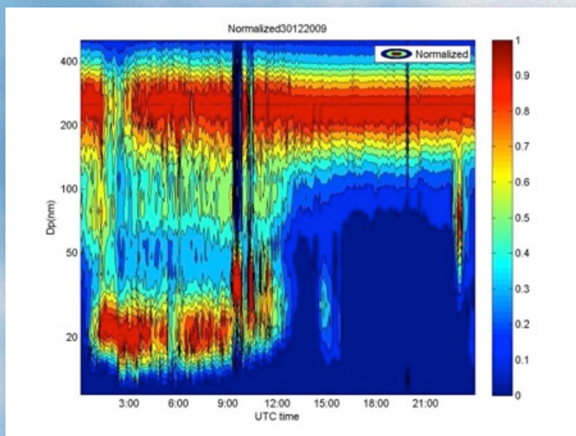
New particle formation? Bursts of particles $10<D_p<30$ nm.

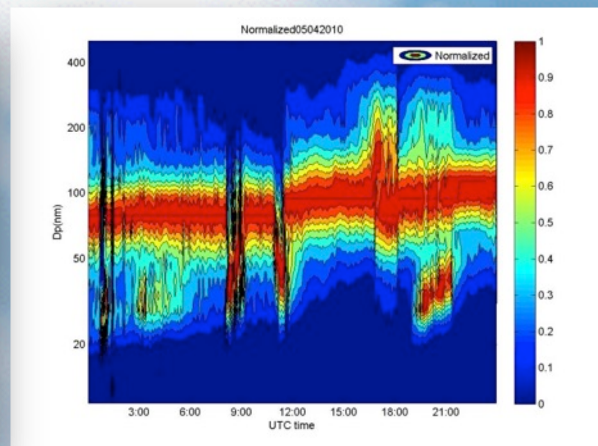


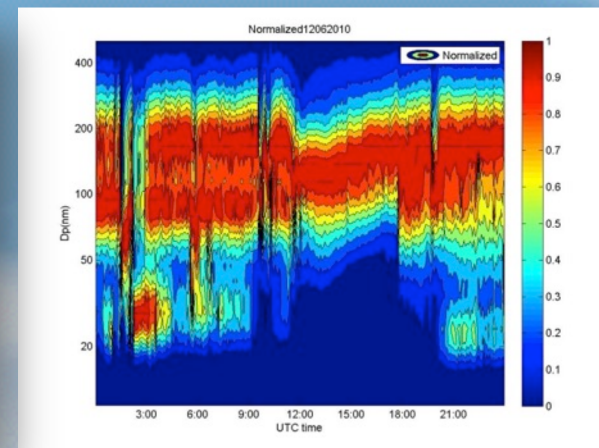
Aerosol size distributions measured in 2009 Apr 4th. There was a burst of ultrafine particles from 2:00 to 4:00 UTC time.

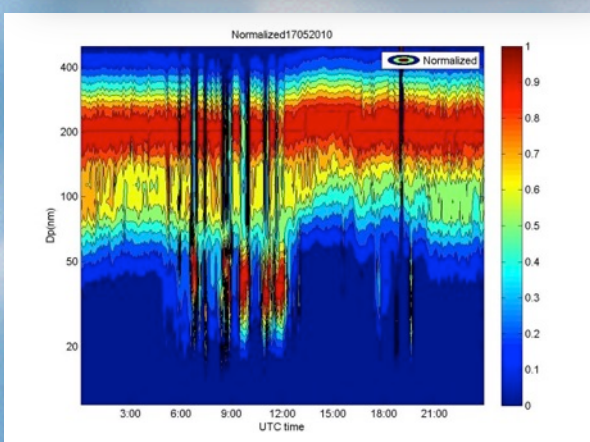
New particle formation and subsequent growth was seldom observed along two years of measurements. Nevertheless, in 70% of the days, bursts of particles with diameters in the range 10-40 nm were detected. The events usually lasted from 20 to 120min, and the subsequent growth to larger sizes was not always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

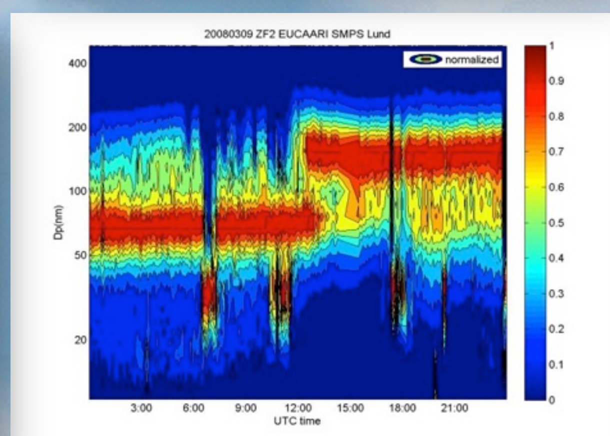
Particle bursts 20-30 nm at nighttime

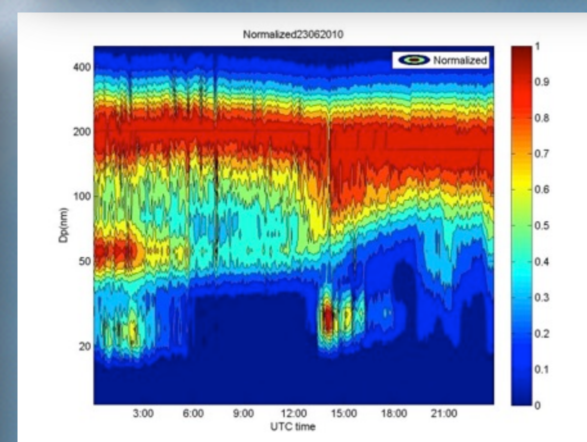




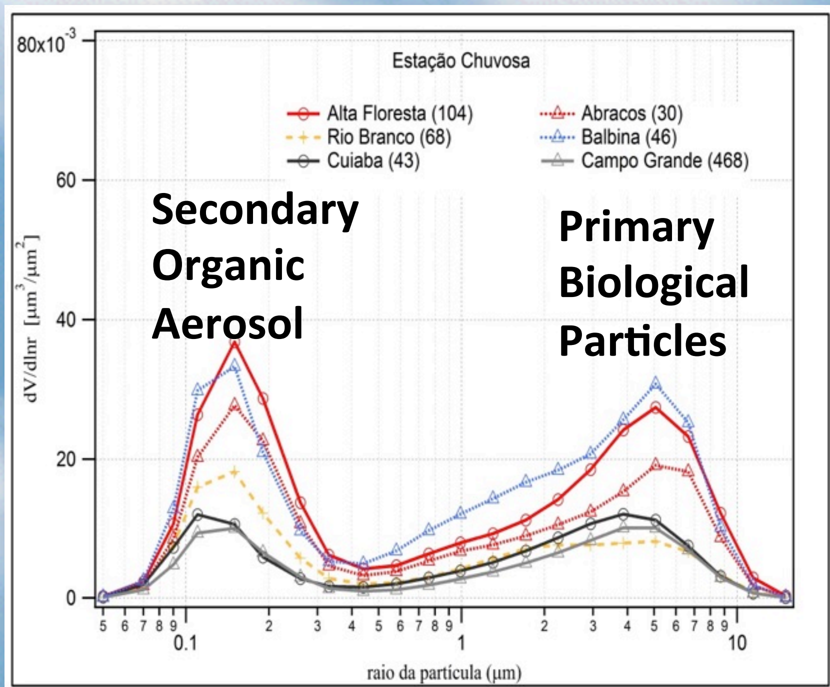




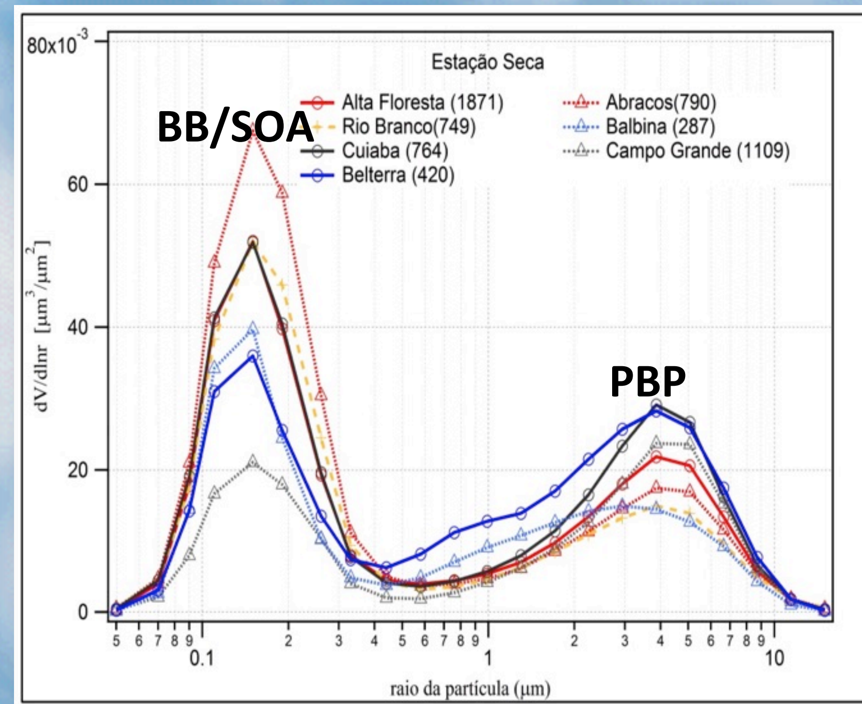




AERONET size distributions



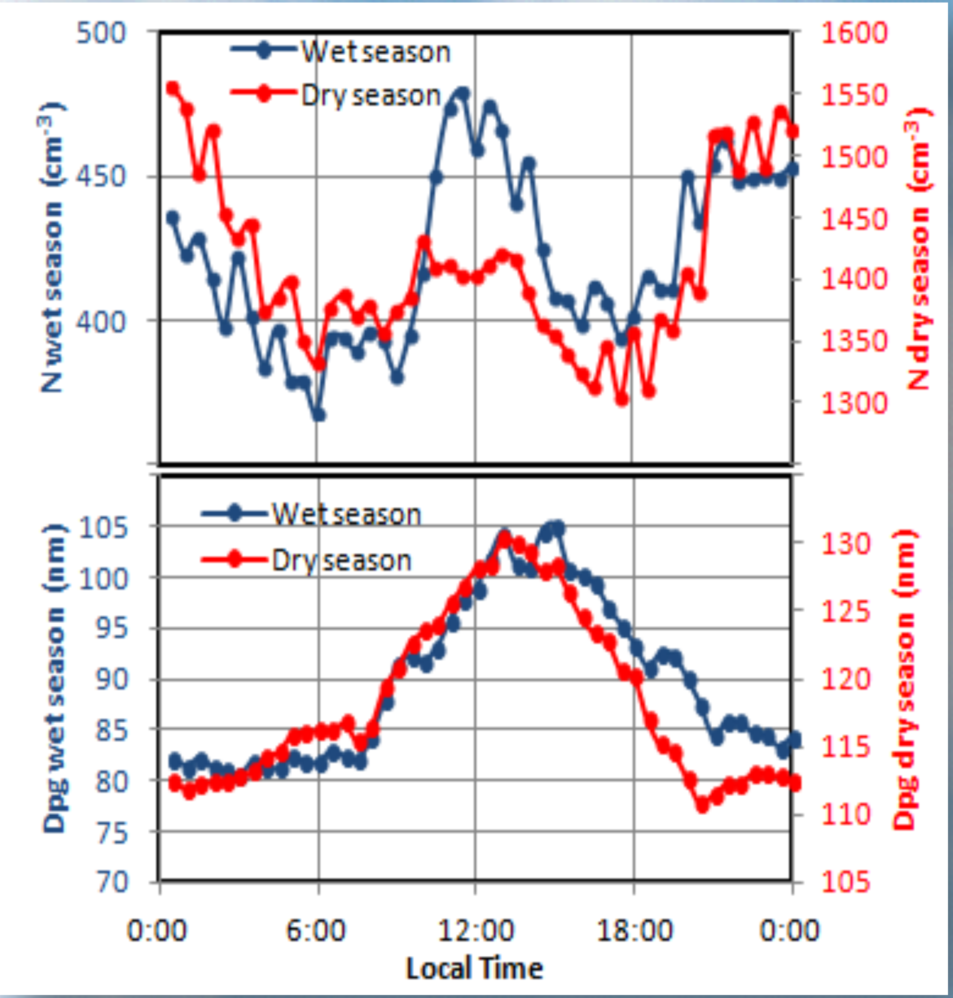
Size distribution Wet Season

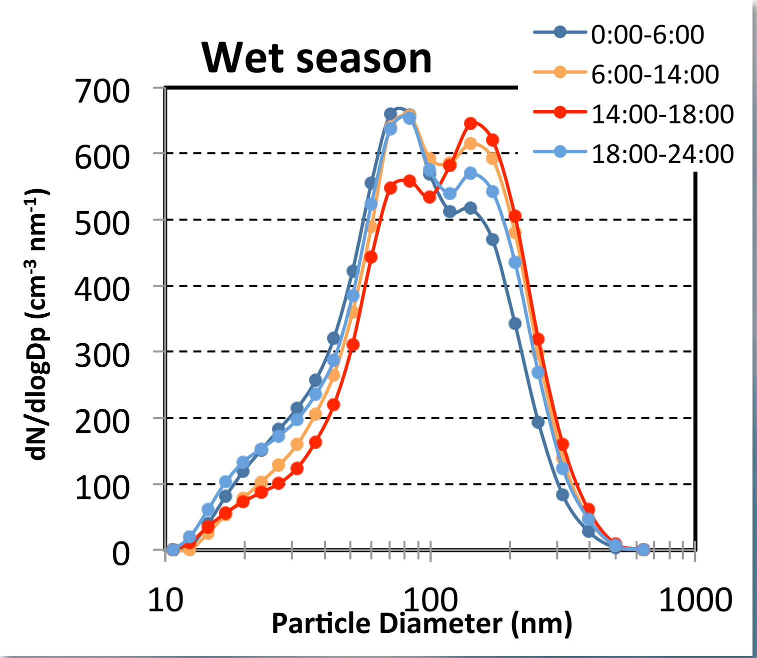


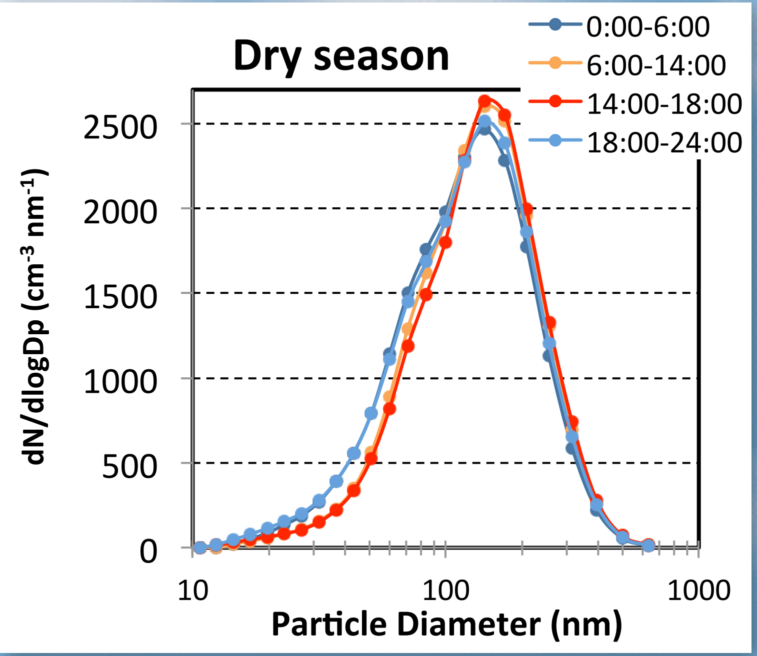
Dry Season

AERONET size distribution similar to ground based SMPS

Aerosol Size Distribution





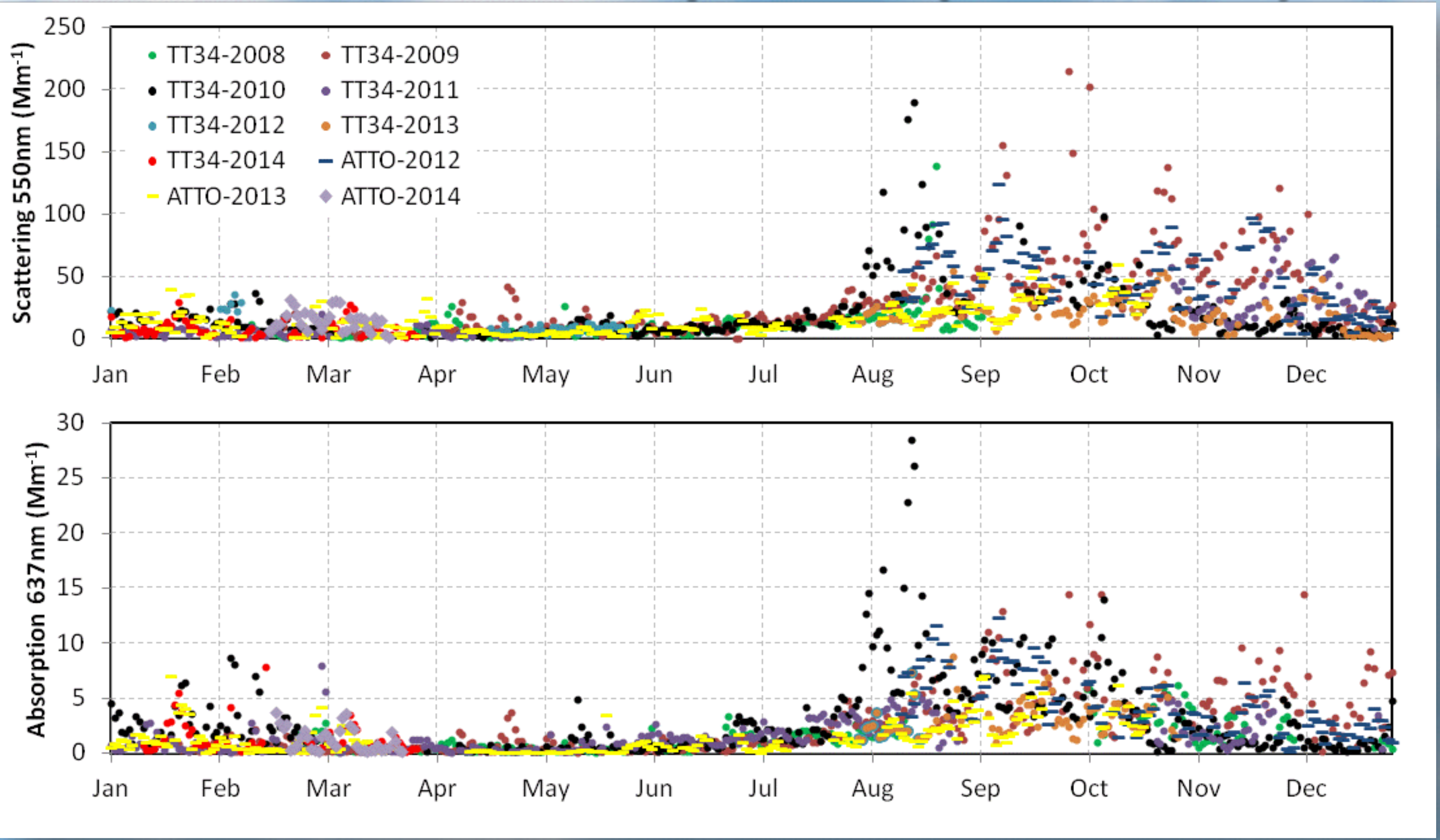


Median diurnal cycle for particle size distribution parameters

(120.000 size distributions from 2008 to 2014)

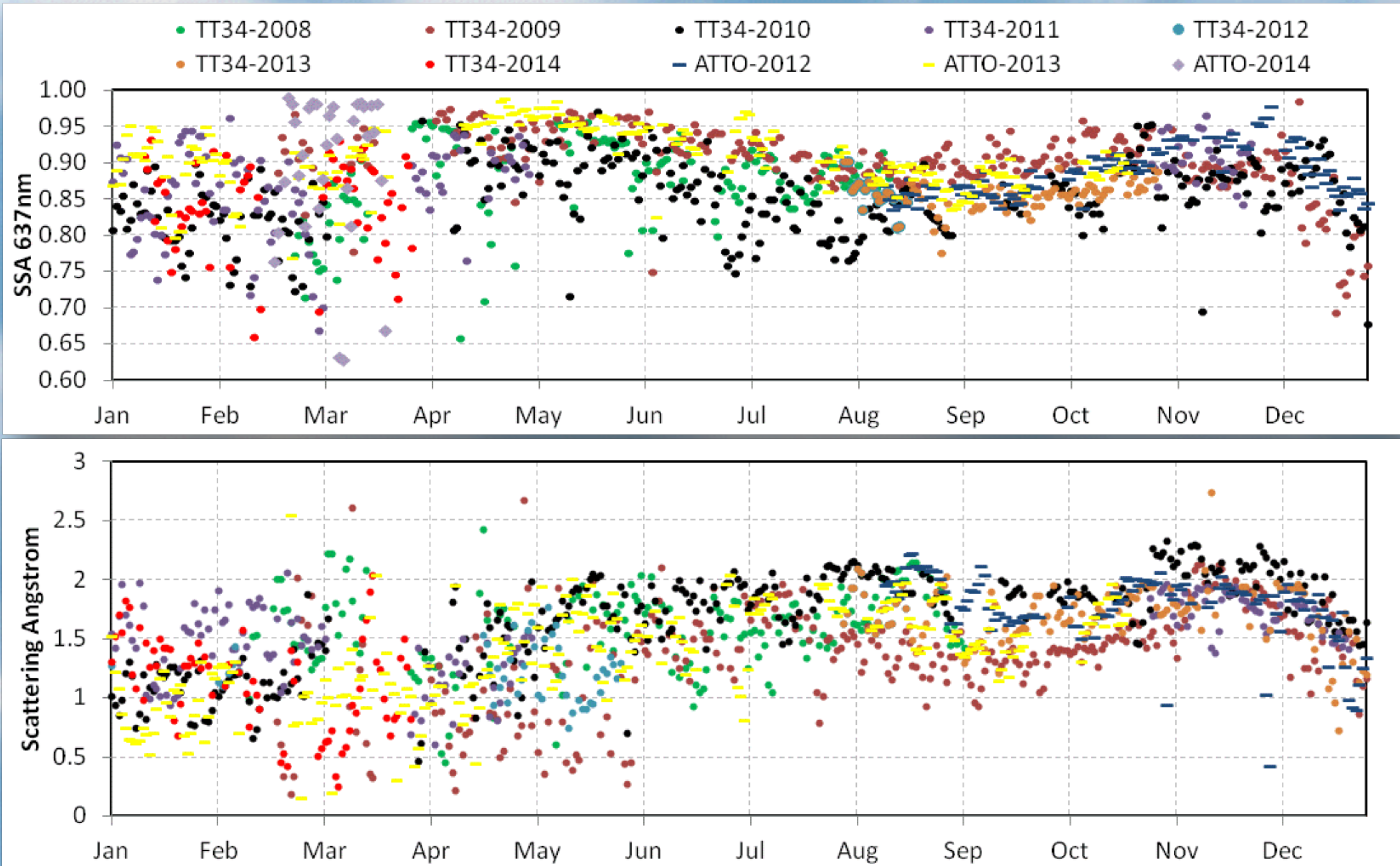
Luciana Rizzo compilation, 2015

Scattering and absorption daily median comparison (2008-2014)



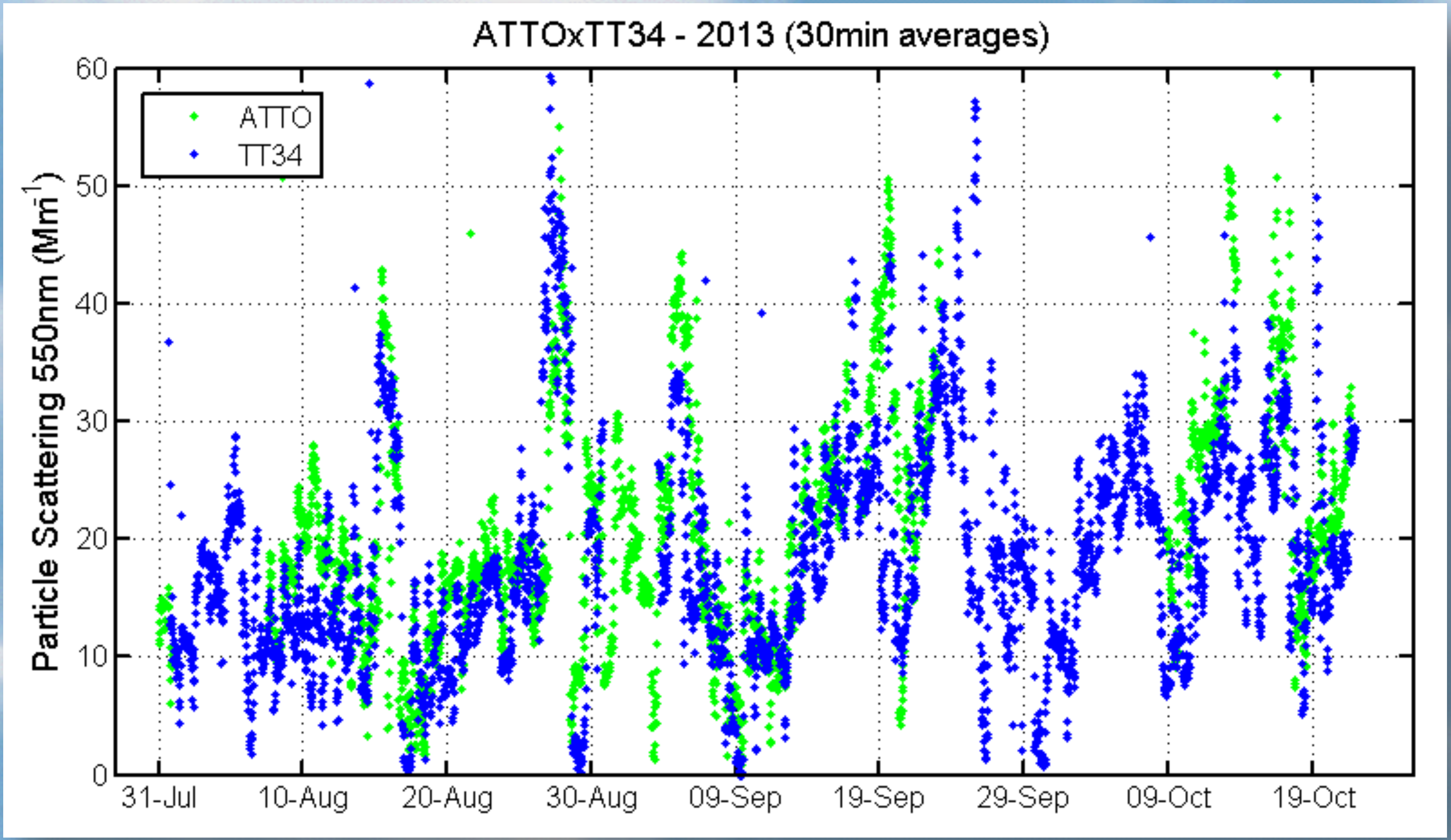
All data corrected for STP (1013 mbar, 0C).

Single scattering albedo and scattering angstrom daily median (2008-2014)



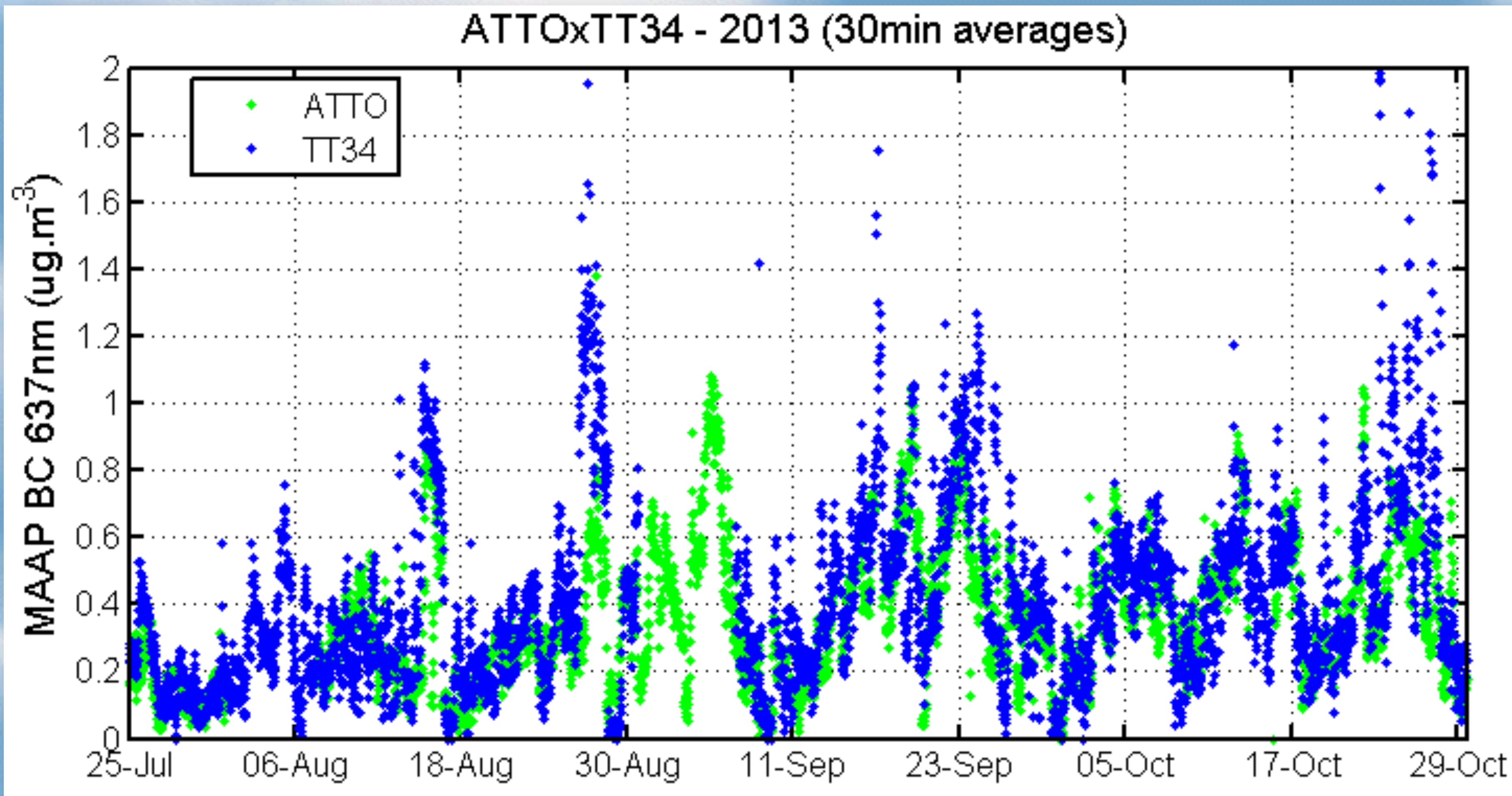
Joint analysis of two sites 100 Km apart

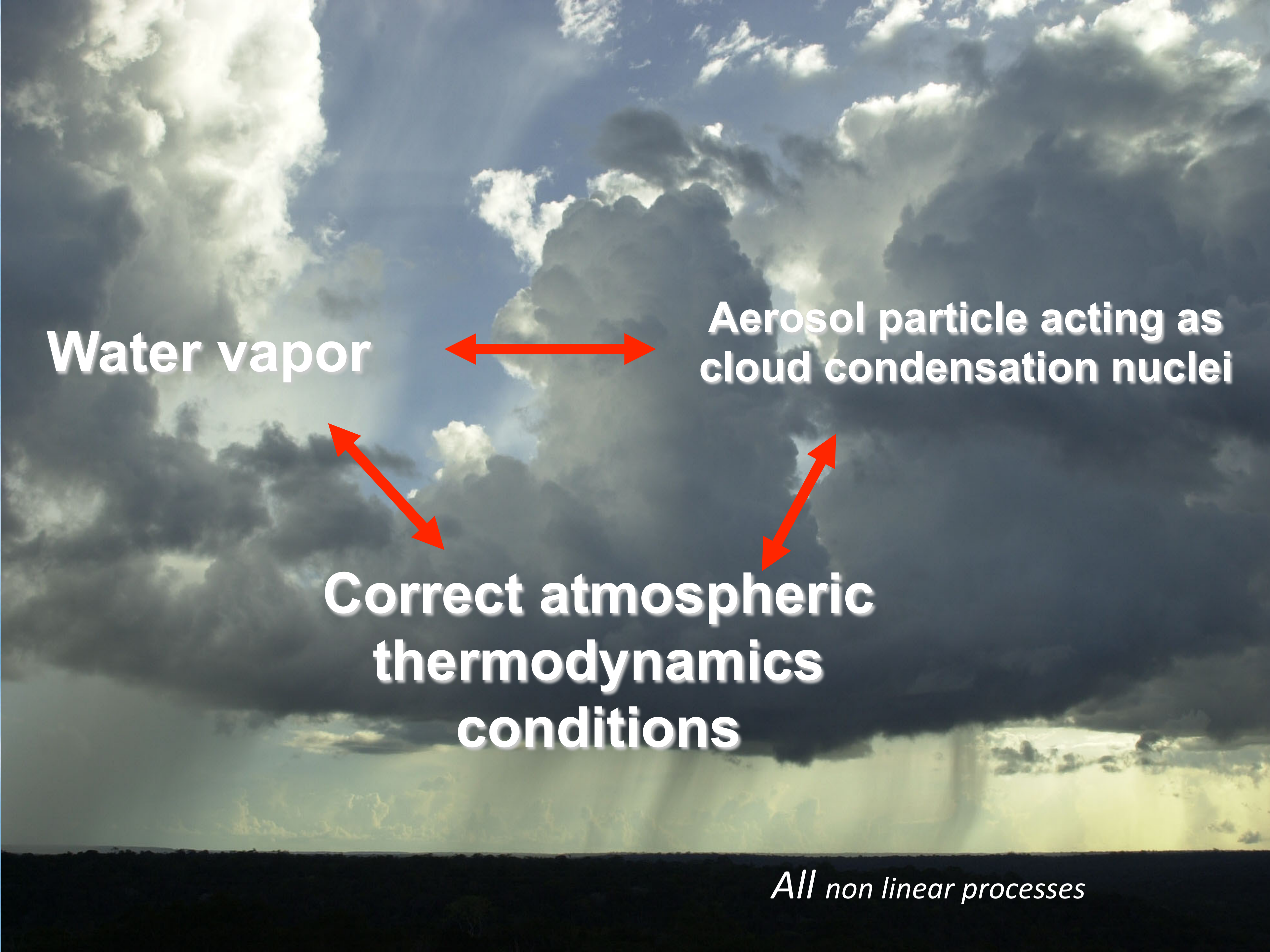
Light scattering



Joint analysis of two sites 100 Km apart

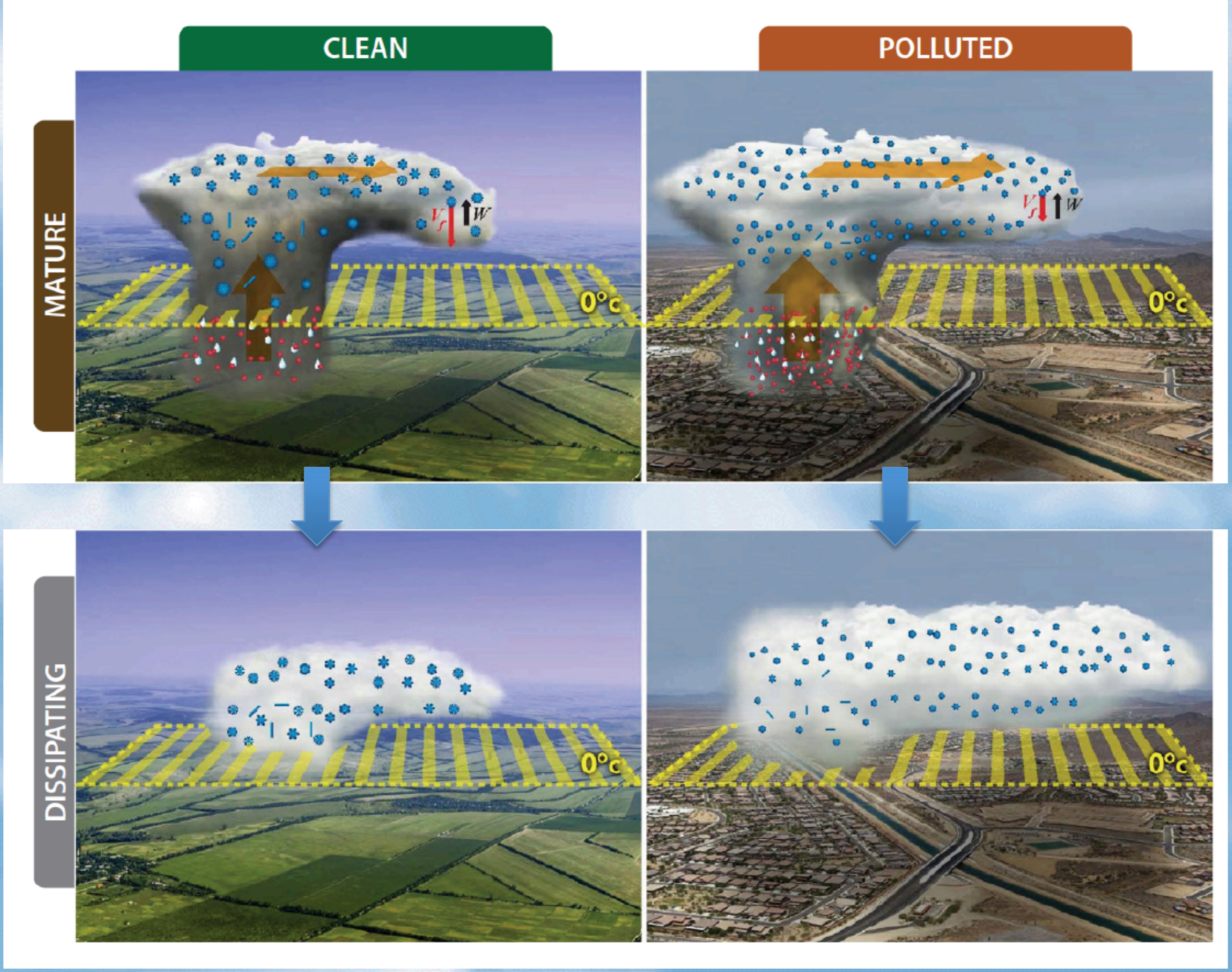
Black Carbon





Water vapor
Aerosol particle acting as cloud condensation nuclei
Correct atmospheric thermodynamics conditions
All non linear processes

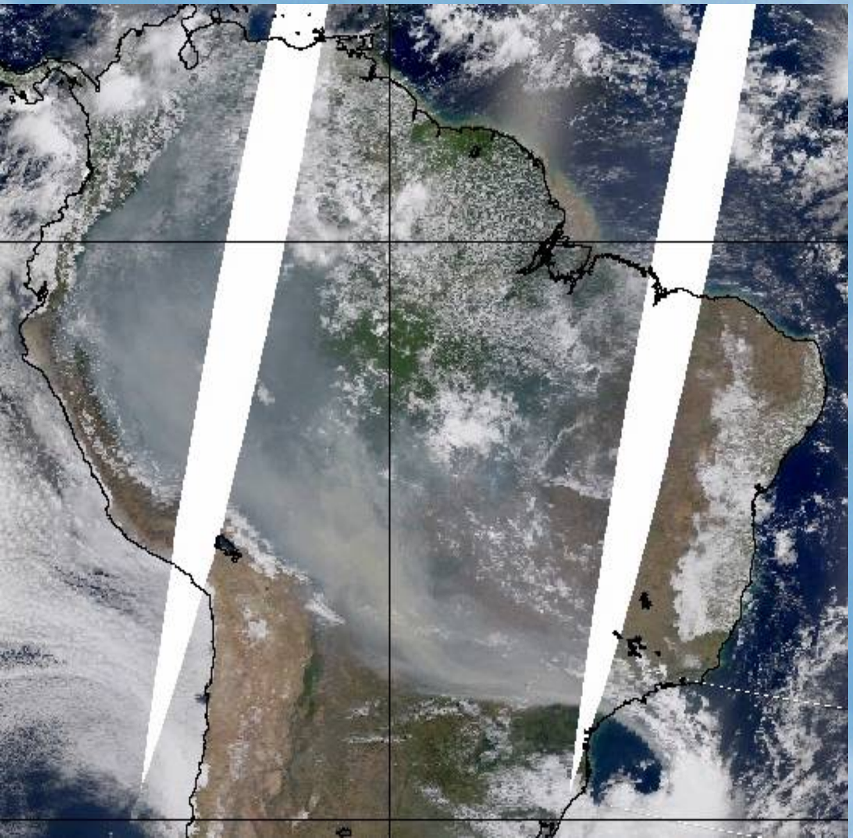
Effects of aerosols on clouds for clean and polluted condition

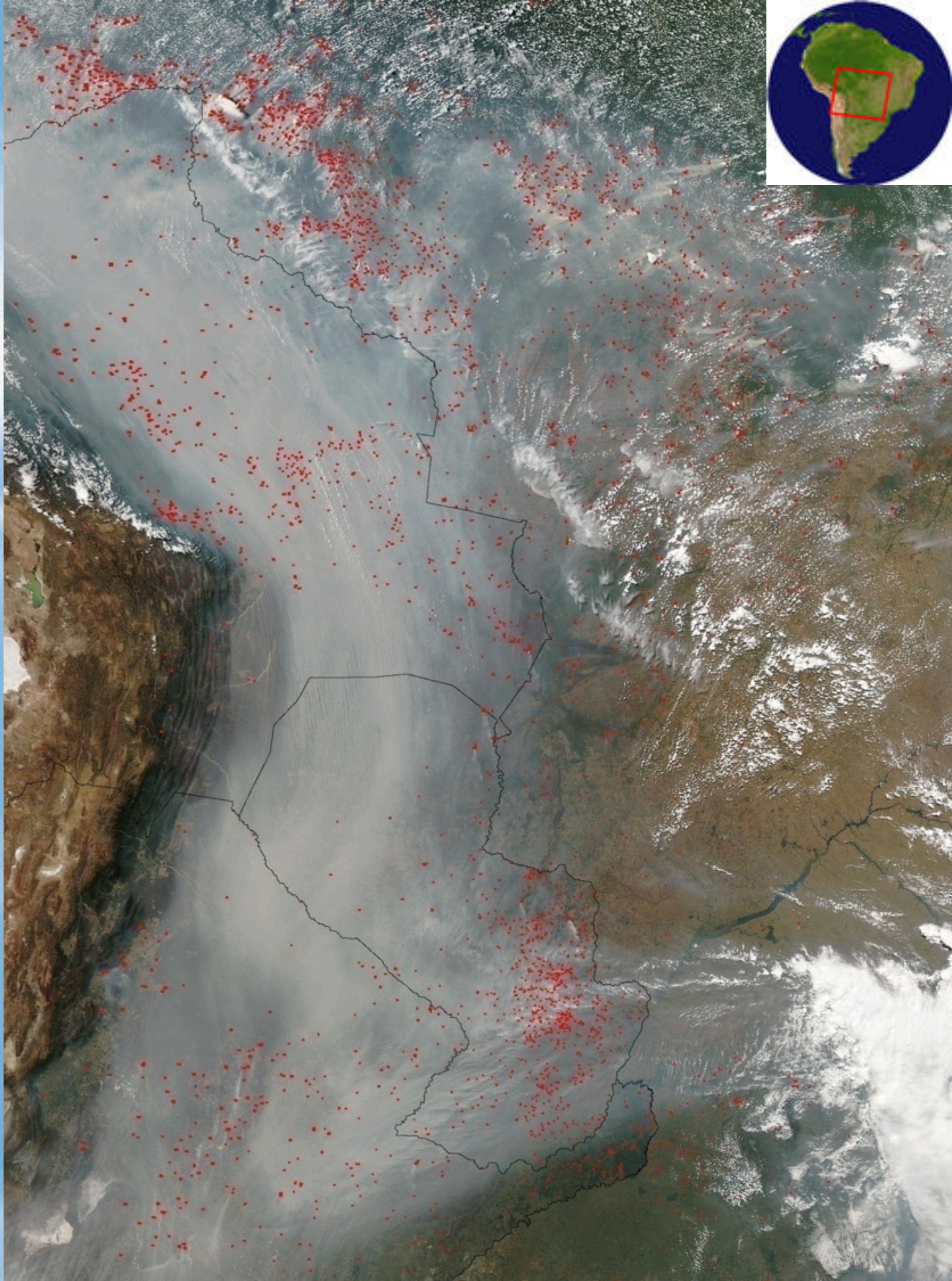


Amazonia is critically important for water vapor transport in South America

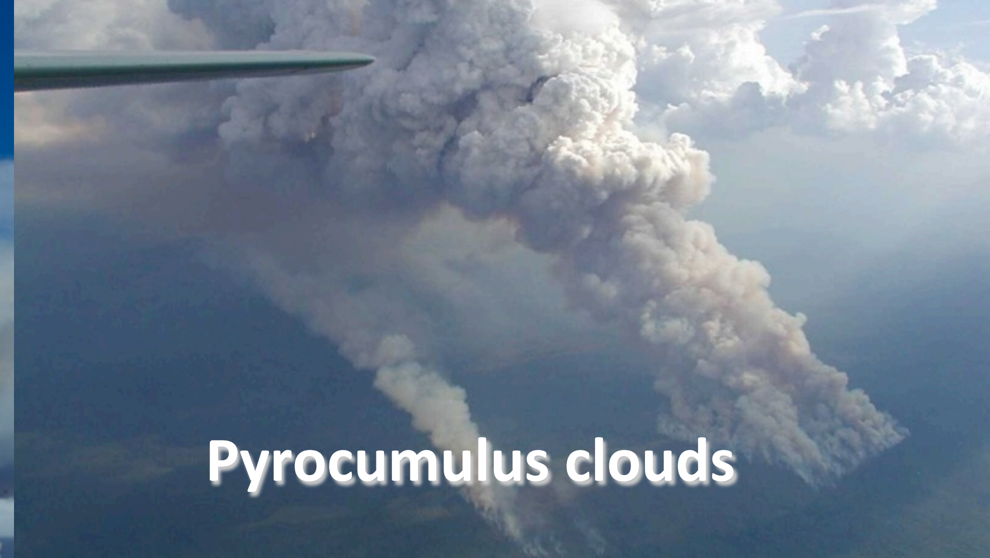
Large scale aerosol distribution in Amazonia

- 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





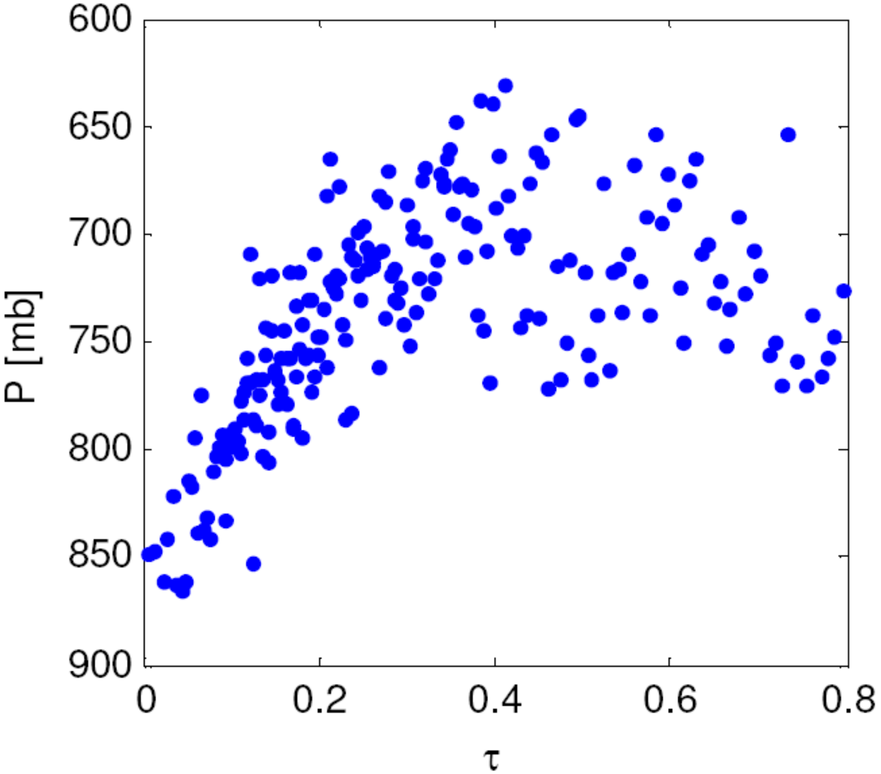
Hydrological cycle critical for Amazonia



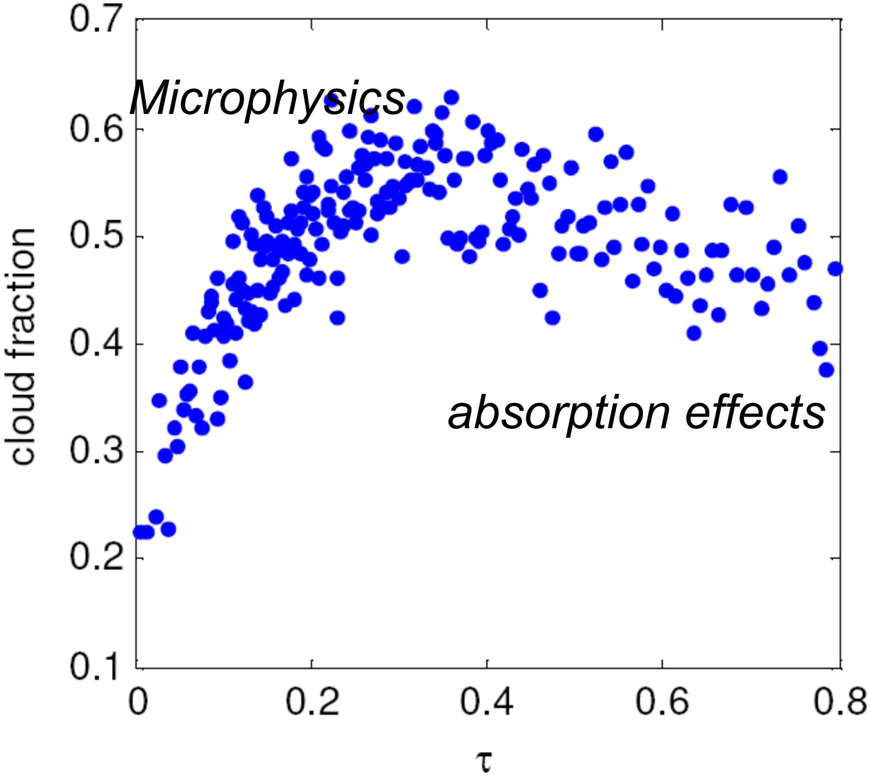
Pyrocumulus clouds

Natural clouds

Cloud fraction and height as a function of aerosols in Amazonia



Cloud top pressure (P) vs. AOD



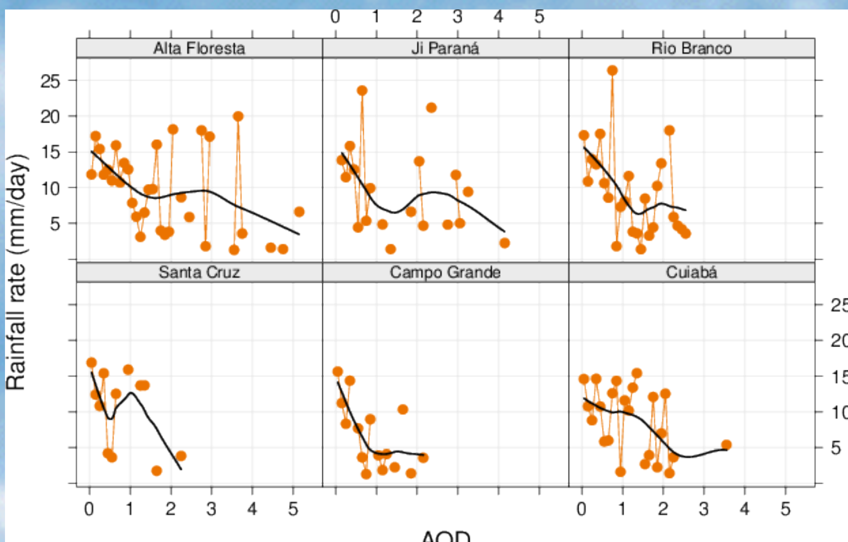
Cloud fraction vs. AOD.

Ilan Koren et al., Science 2008

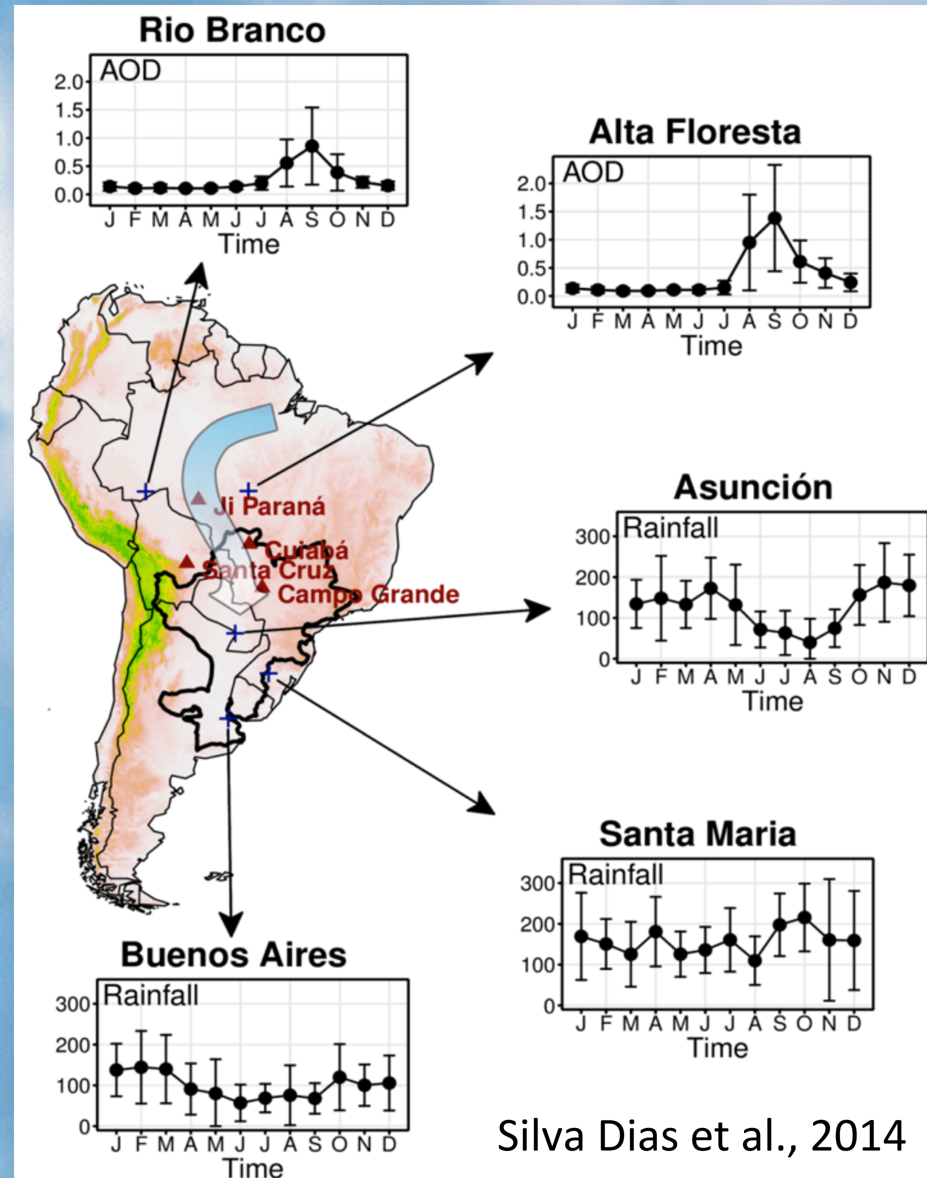
Relationship between aerosols and precipitation in the La Plata Basin

AERONET (Aerossols) + TRMM (Precipitation) + BRAMS (simulations)

Reduction in precipitation with increase in aerosols



BRAMS: Simulations with cloud microphysics confirm the measurements

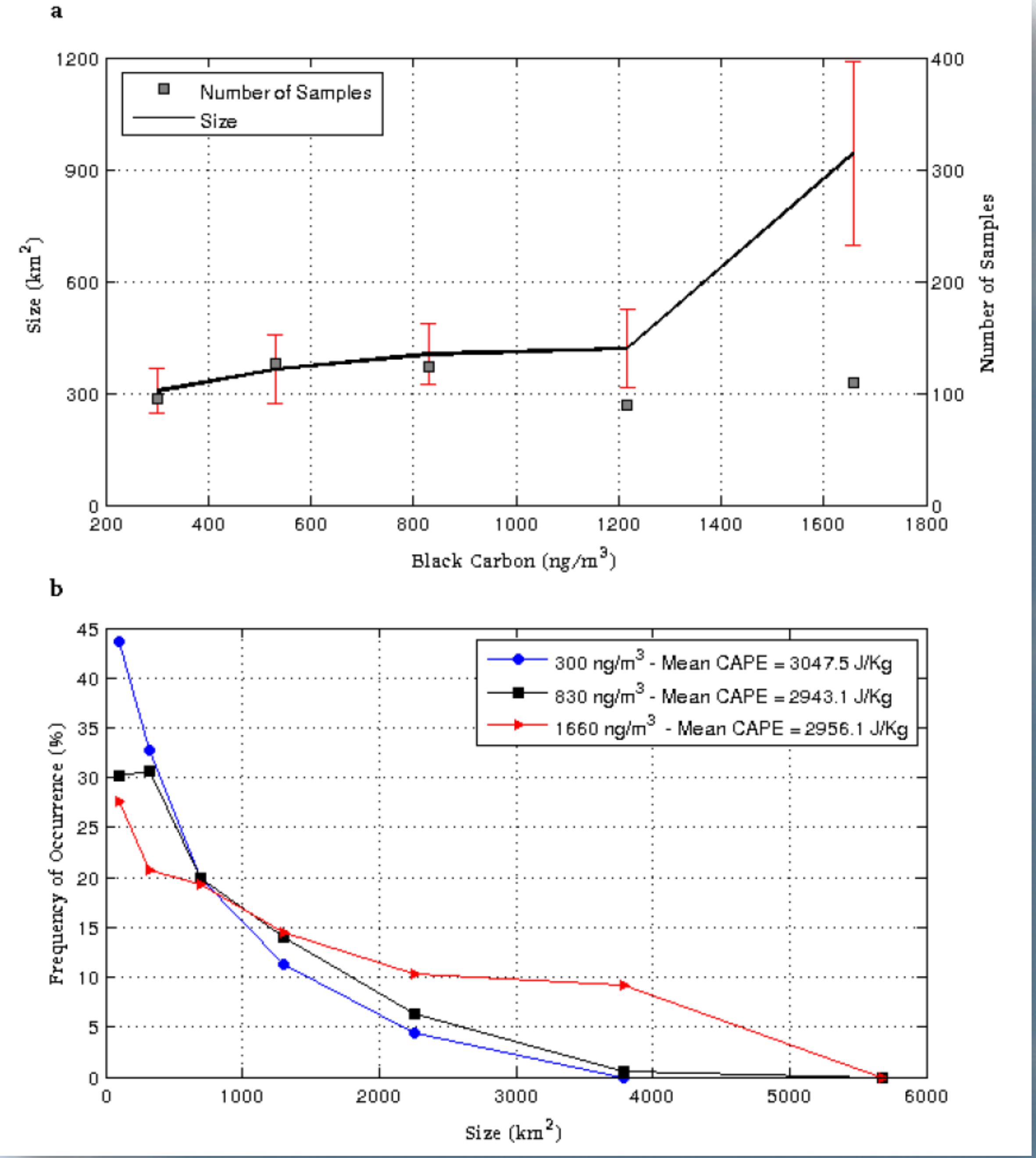


Silva Dias et al., 2014

Black Carbon effect on precipitation

Mean rain cells size (>100km²) for each black carbon bin for an unstable atmosphere

(b) Size frequency histograms for the three black carbon bins (inner panel).

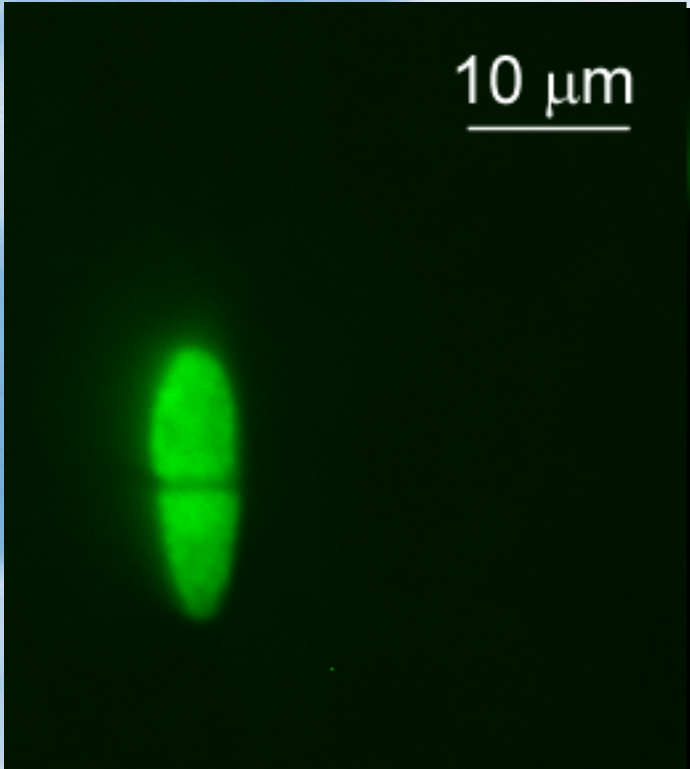


Machado et al., 2014

Species observed in cloud water.

Average Cloudy Air Conc.	Convective Cumulus	Fair Weather Cumulus	Stratus[a]
Ammonium (nmol m^{-3})	74 (± 23)	18 (± 8)	450
Nitrate (nmol m^{-3})	83 (± 30)	16 (± 5)	320
DON (nmol m^{-3})	21 (± 9)	9 (± 4)	110
Bacteria Concentration (no. m^{-3})	2.5×10^5 (± 1.3×10^5)	3.3×10^5 (± 9.9×10^4)	N/A
Bacteria N (nmol m^{-3})	2.9×10^{-11}	3.9×10^{-11}	N/A
Sulfate (nmol m^{-3})	41 (± 22)	7 (± 3)	140
Calcium (nmol m^{-3})	53 (± 31)	10 (± 8)	120

- Algae/ Protozoa observed in cloud water samples
- Protozoa were alive and moving



nature geoscience

LETTERS

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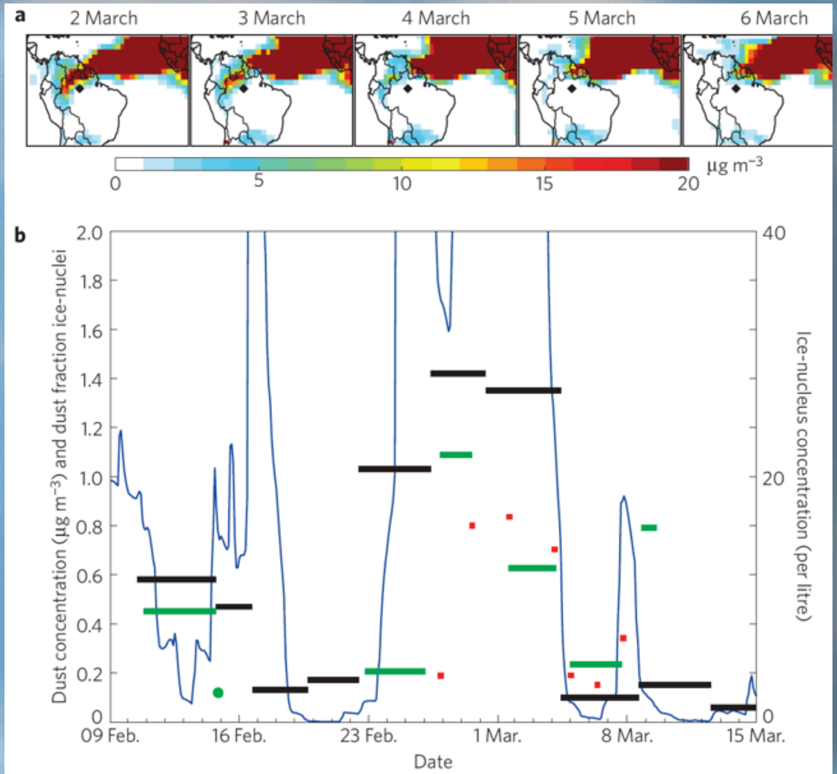
Relative roles of biogenic emissions and Saharan dust as ice nuclei in the Amazon basin

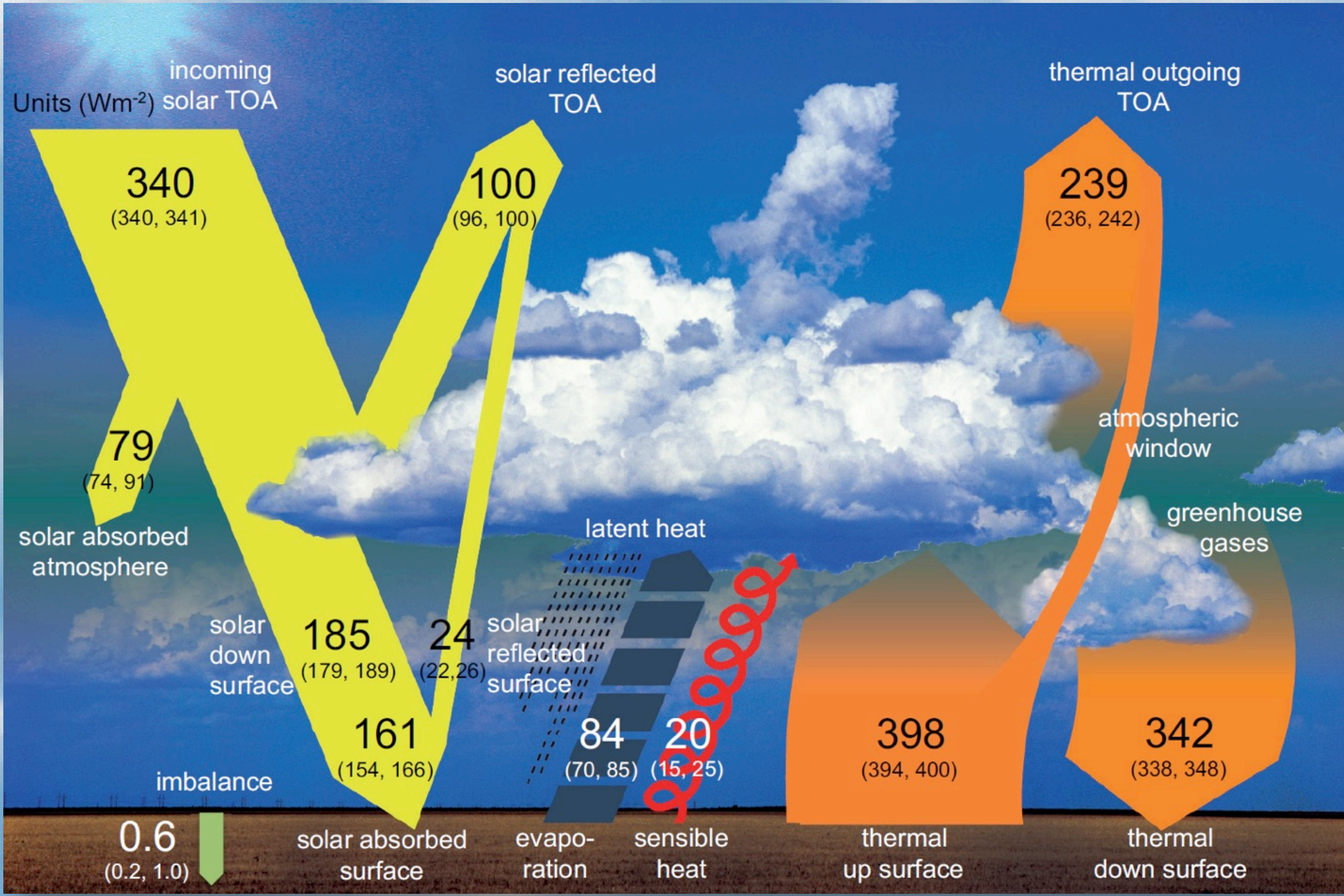
Anthony J. Prenni[1]*, Markus D. Petters[1], Sonia M. Kreidenweis[1], Colette L. Heald[1], Scot T. Martin[2], Paulo Artaxo[3], Rebecca M. Garland[4], Adam G. Wollny[4] and Ulrich Pöschl[4]

Ice nuclei from biogenic emissions and Sahara dust in Central Amazonia



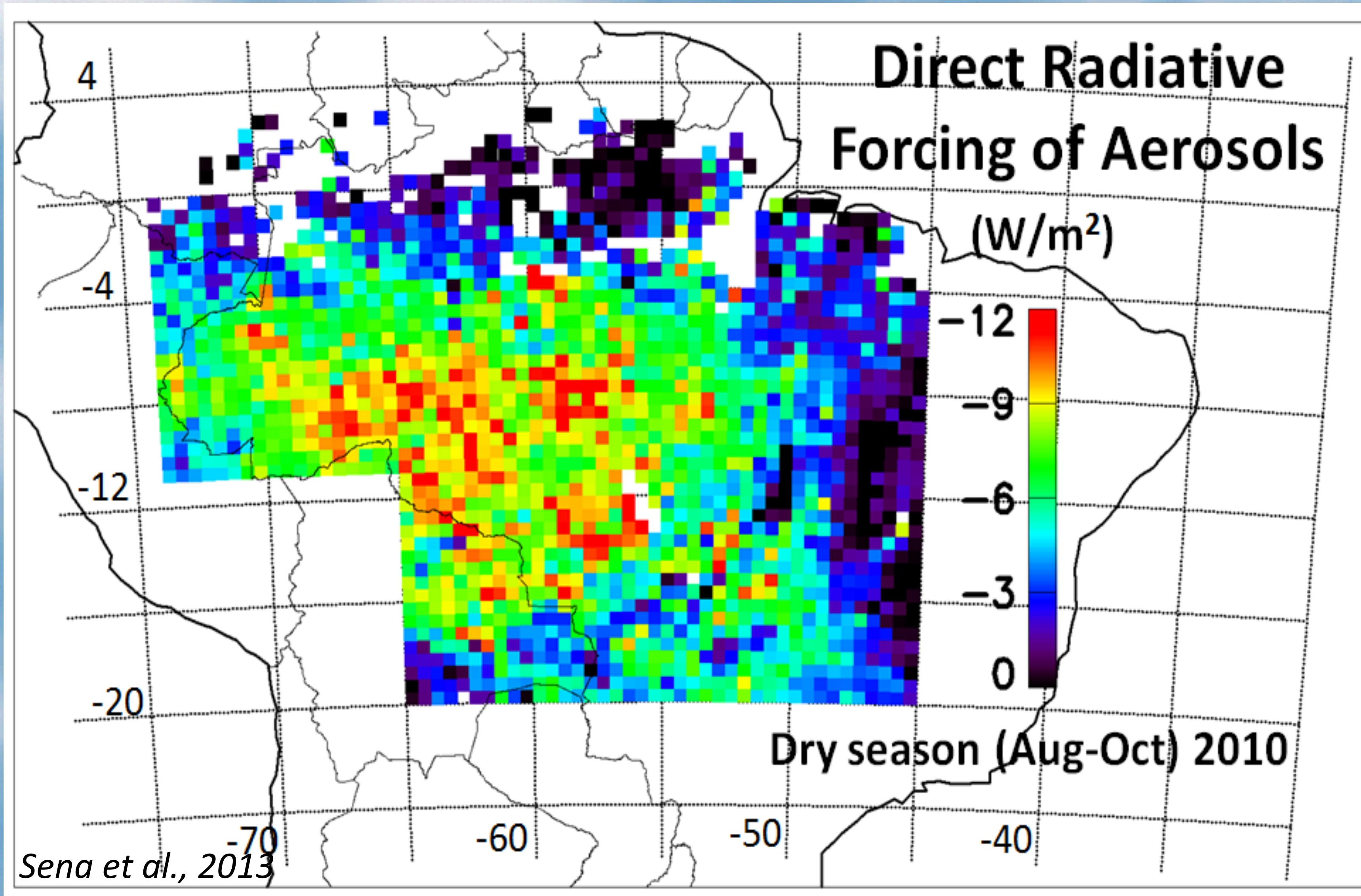
Dust relation to ice-nucleus measurements. Dust concentrations during AMAZE-08. a, GEOS-Chem simulated dust from 2–6 March at 18 UTC. The field site, shown as a black diamond, typically fell near the edge of the plumes. Fine-dust concentrations from PIXE measurements (black rectangles; μg/m³, dp<2μm.

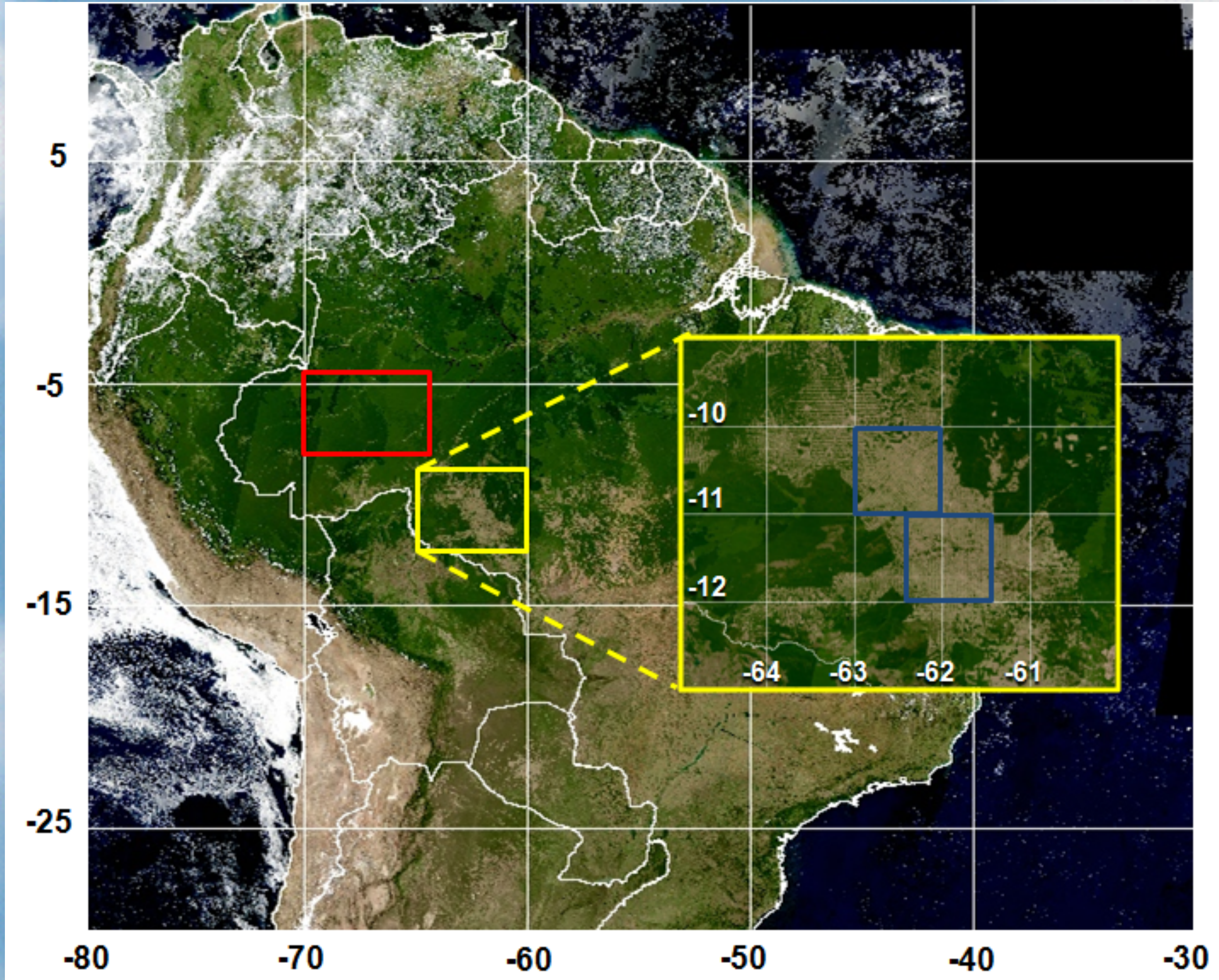
Regional and global energy balance



Average spatial distribution of the direct radiative forcing (DRF) of biomass burning aerosols in Amazonia during the dry season of 2010

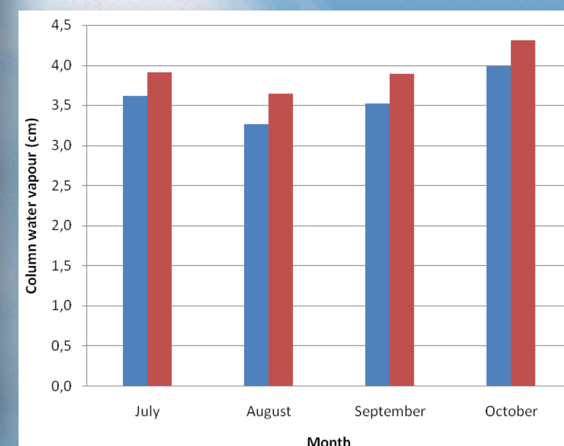
CERES *and MODIS*





Mean TOA Diurnal Radiative Forcing due to change in surface albedo in Rondonia: **-7.3 ± 0.9 W/m²**

Water vapor effects



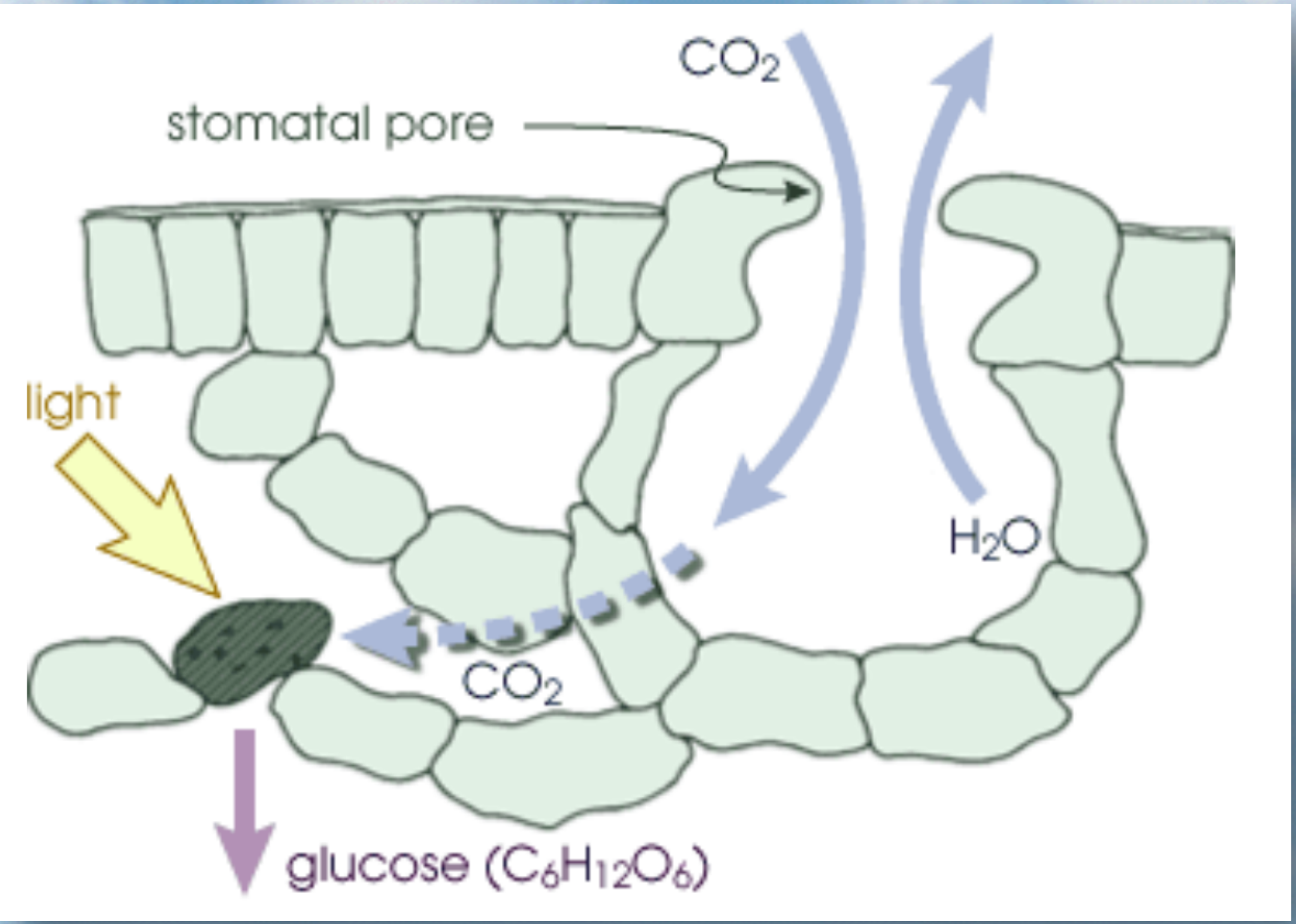
Land-use change radiative forcing. Forested areas are selected in red and deforested areas are selected in yellow.

Water column difference by 6-10%

Forcing of water vapor column: -0.4 to -1.2 W m^{-2}

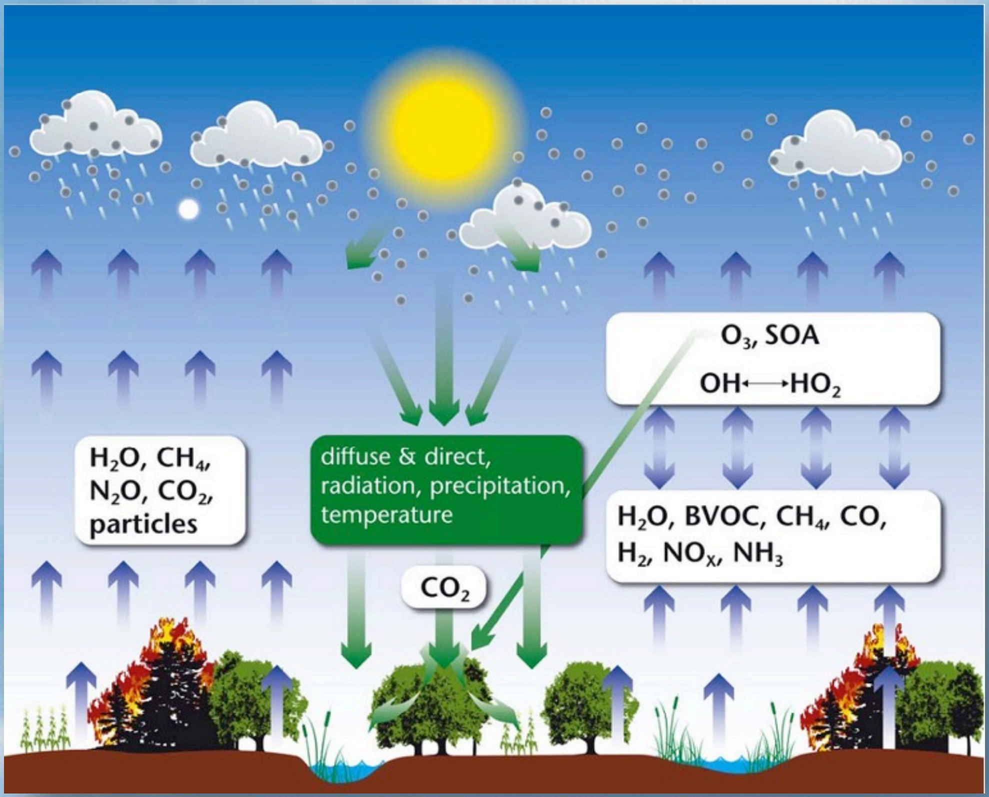
Sena and Artaxo, 2013, 2014

Photosynthesis: where radiation meets life

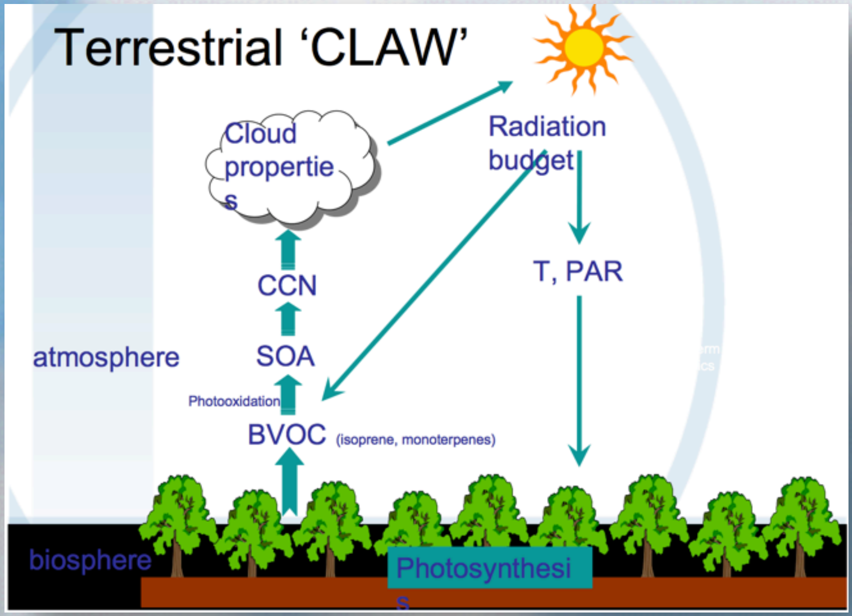


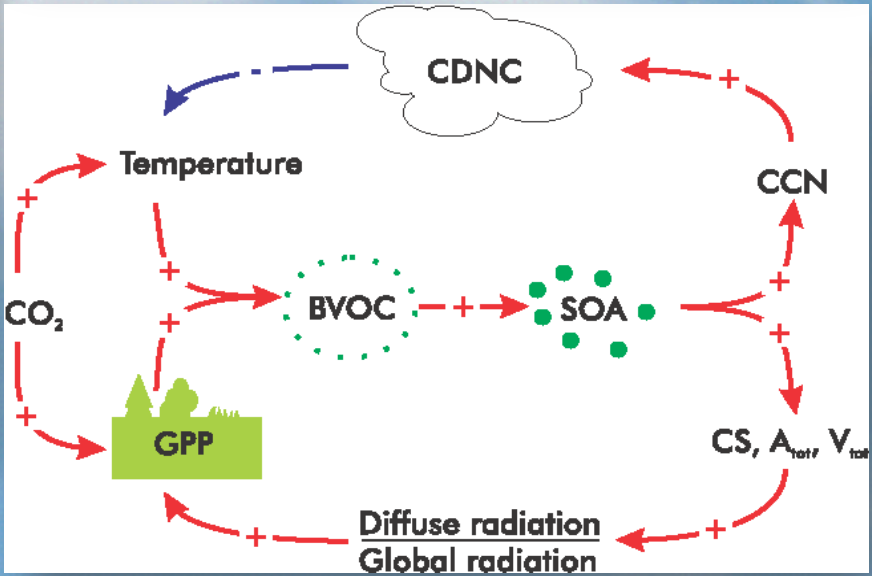
During photosynthesis, plants absorb carbon dioxide and sunlight to create fuel, glucose and other sugars for building plant structures. This process forms the foundation of the biological carbon cycle.

Conceptual overview of terrestrial carbon cycle – chemistry – climate interactions



Arneth et al., 2011

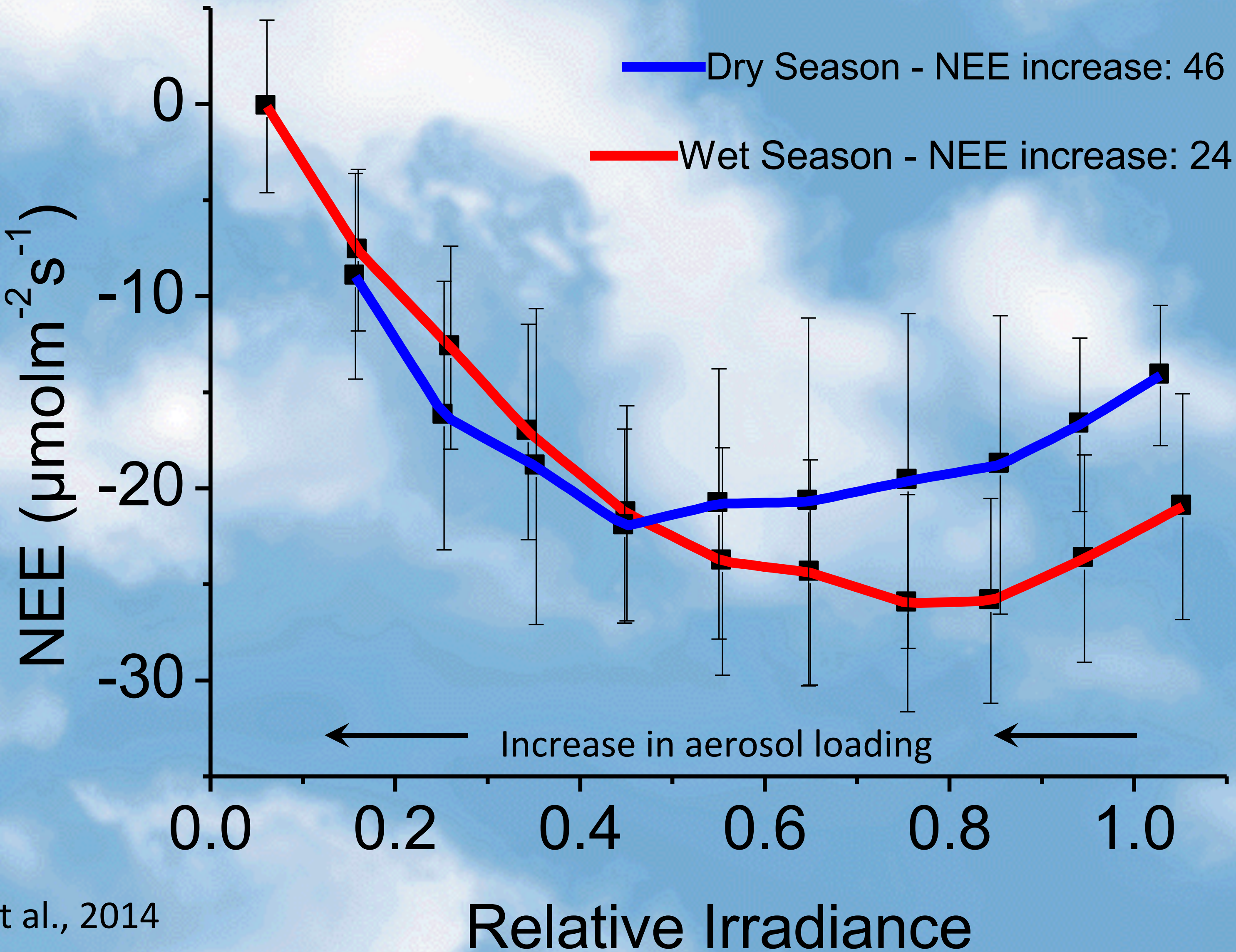




Kulmala et al, 2013

Strong effects of aerosols on carbon uptake in Amazonia

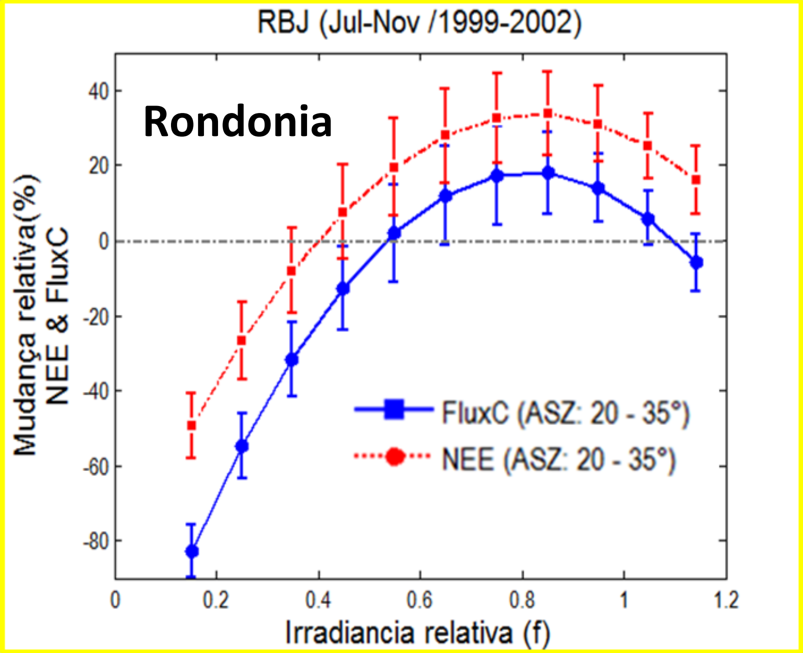
Amazonia Rondonia Forest site 2000-2001

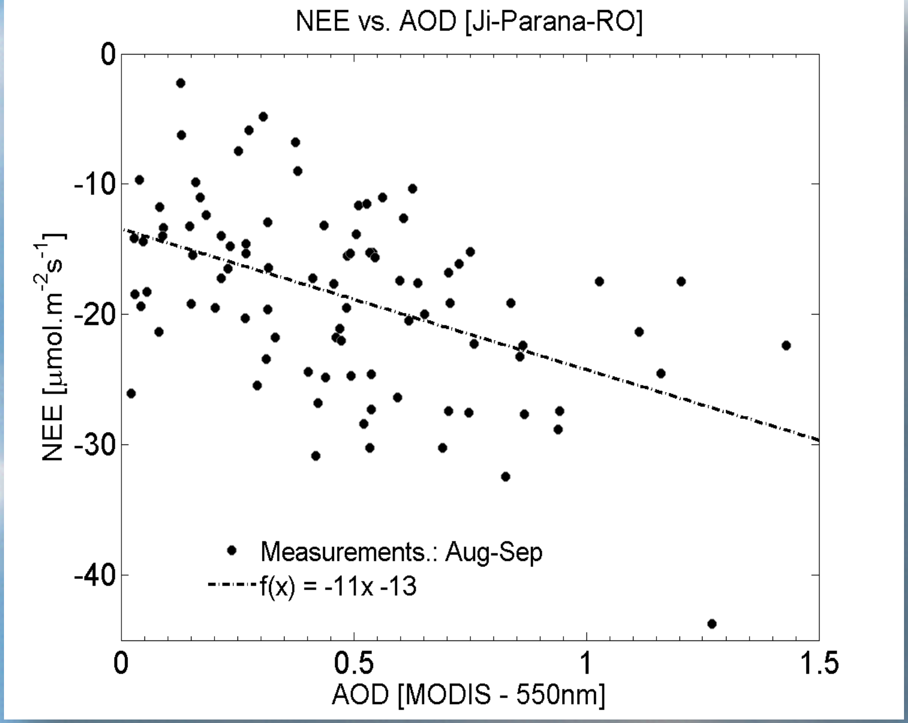


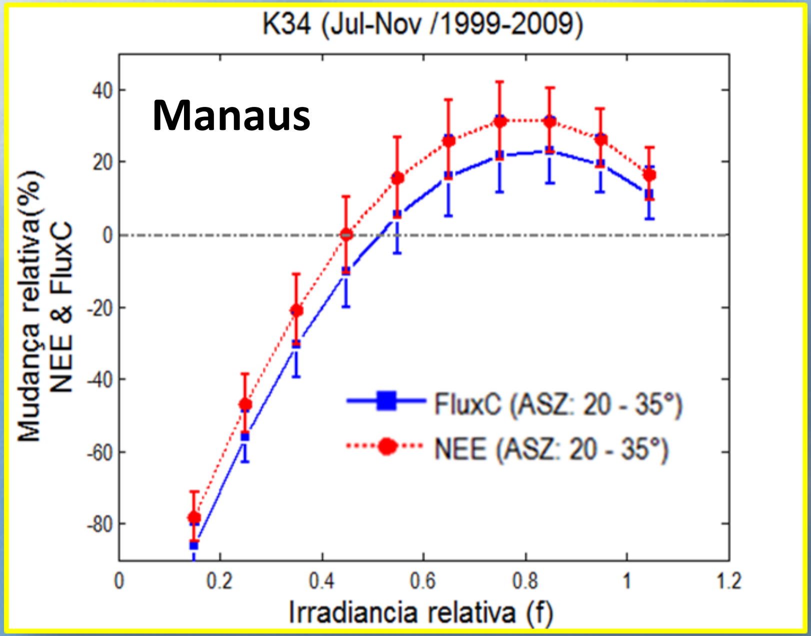
Cirino et al., 2014

Effects of aerosol particles on carbon uptake by the forest: Diffuse radiation plays a major role

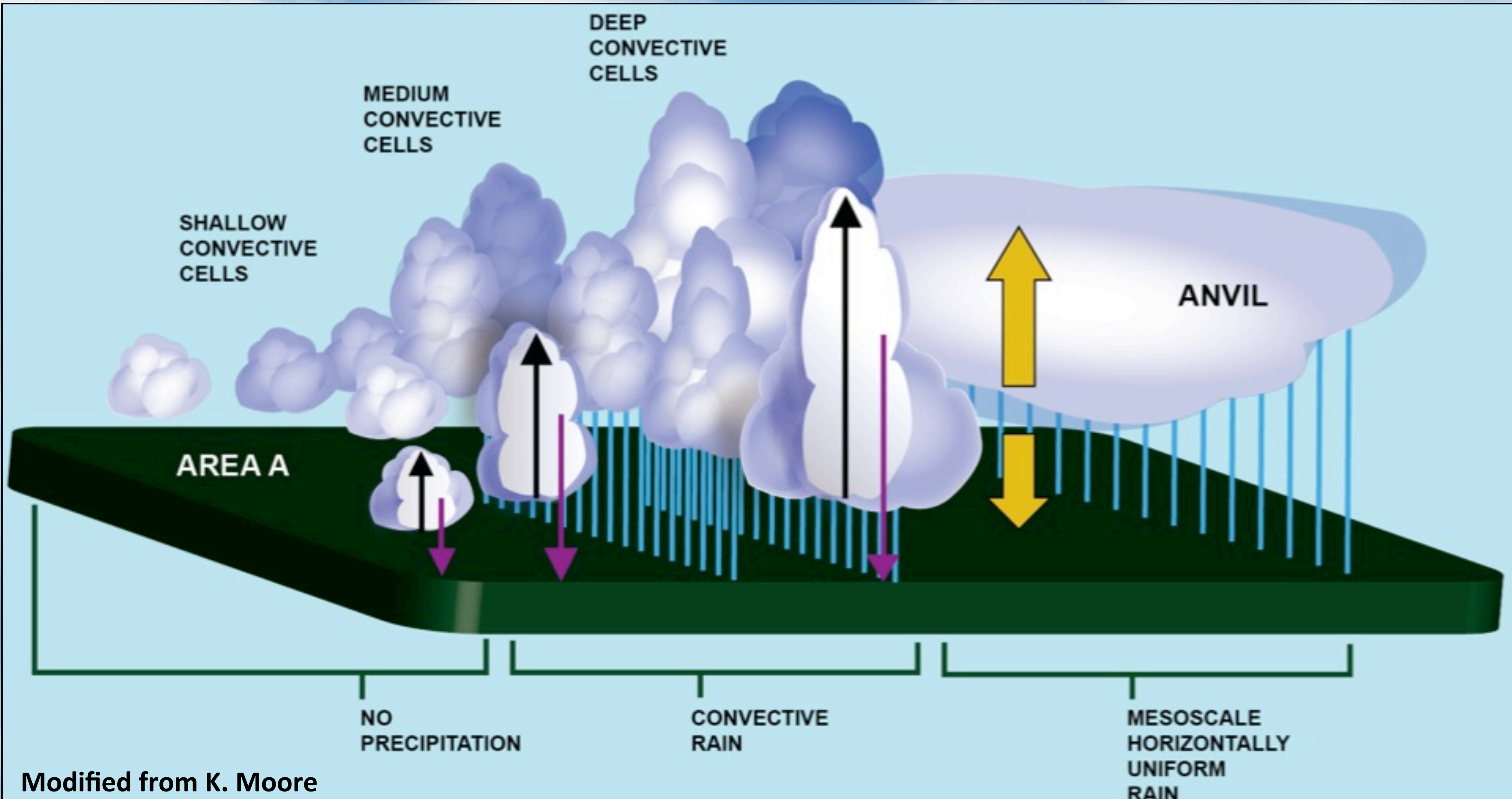
(Glauber Cirino, 2014)





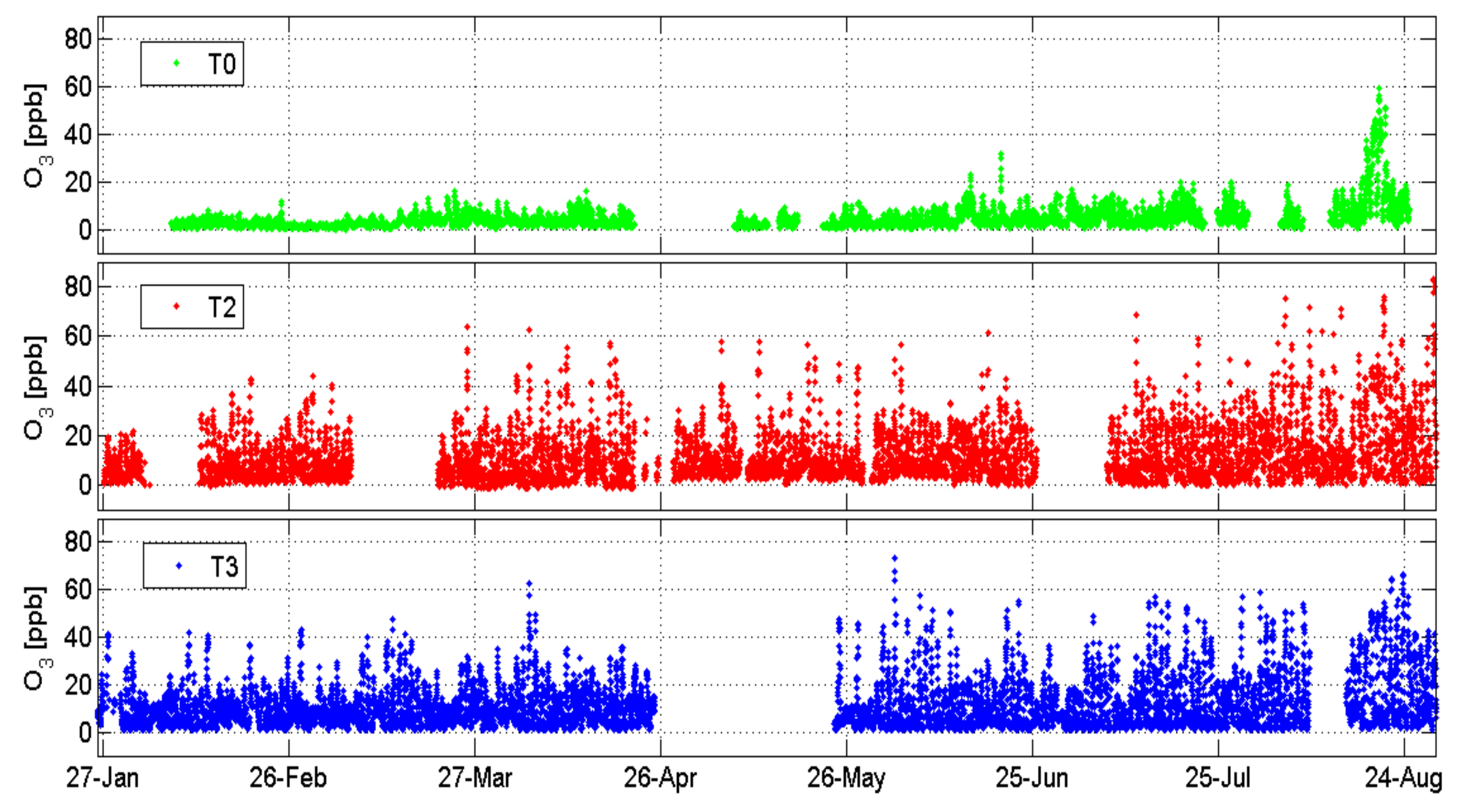


Squall lines and chemical transport

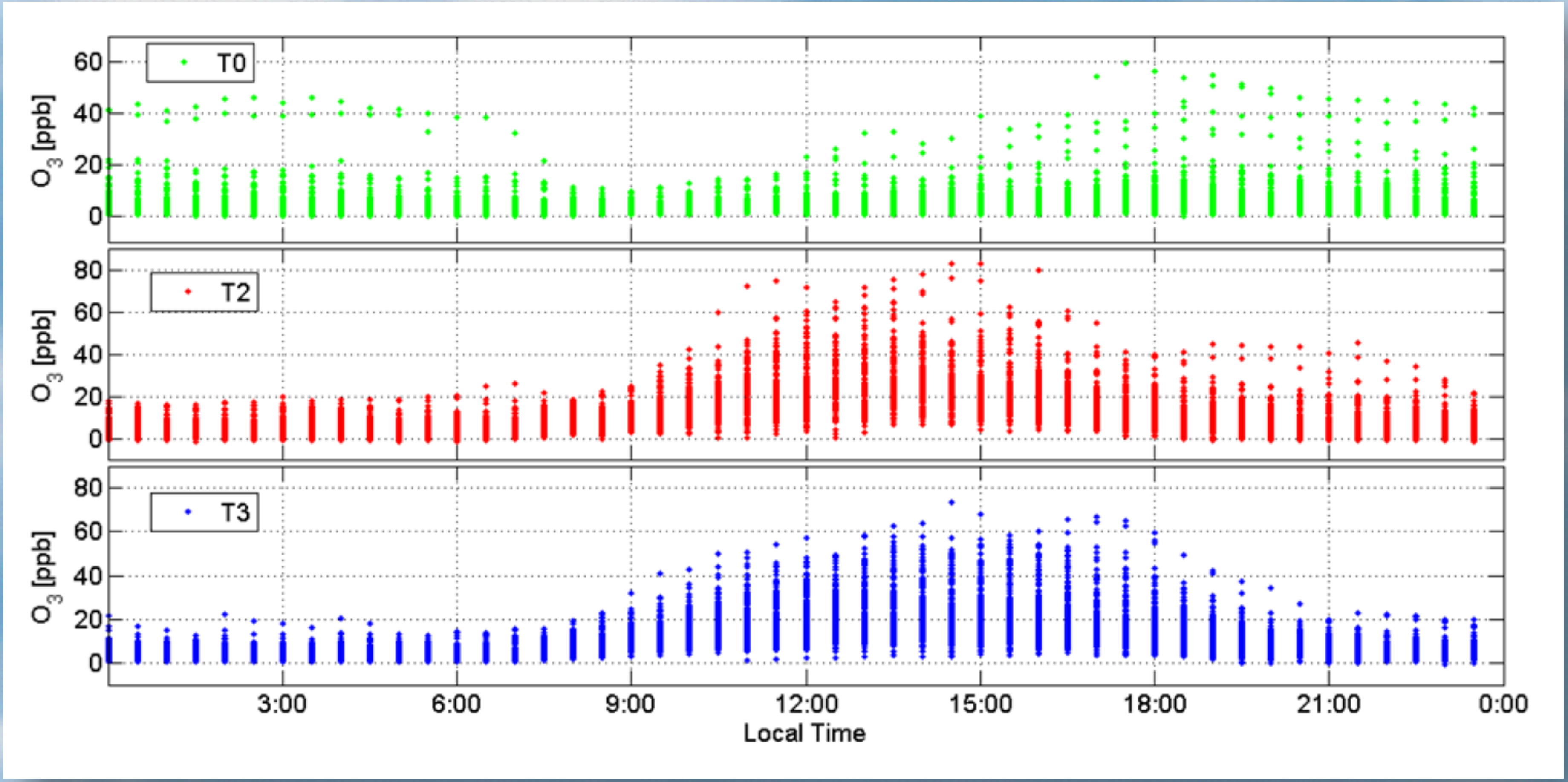


Squall lines downwardly transport ozone at different times within a day and the magnitude of ozone enhancement is a function of convective cells and strength of convection.

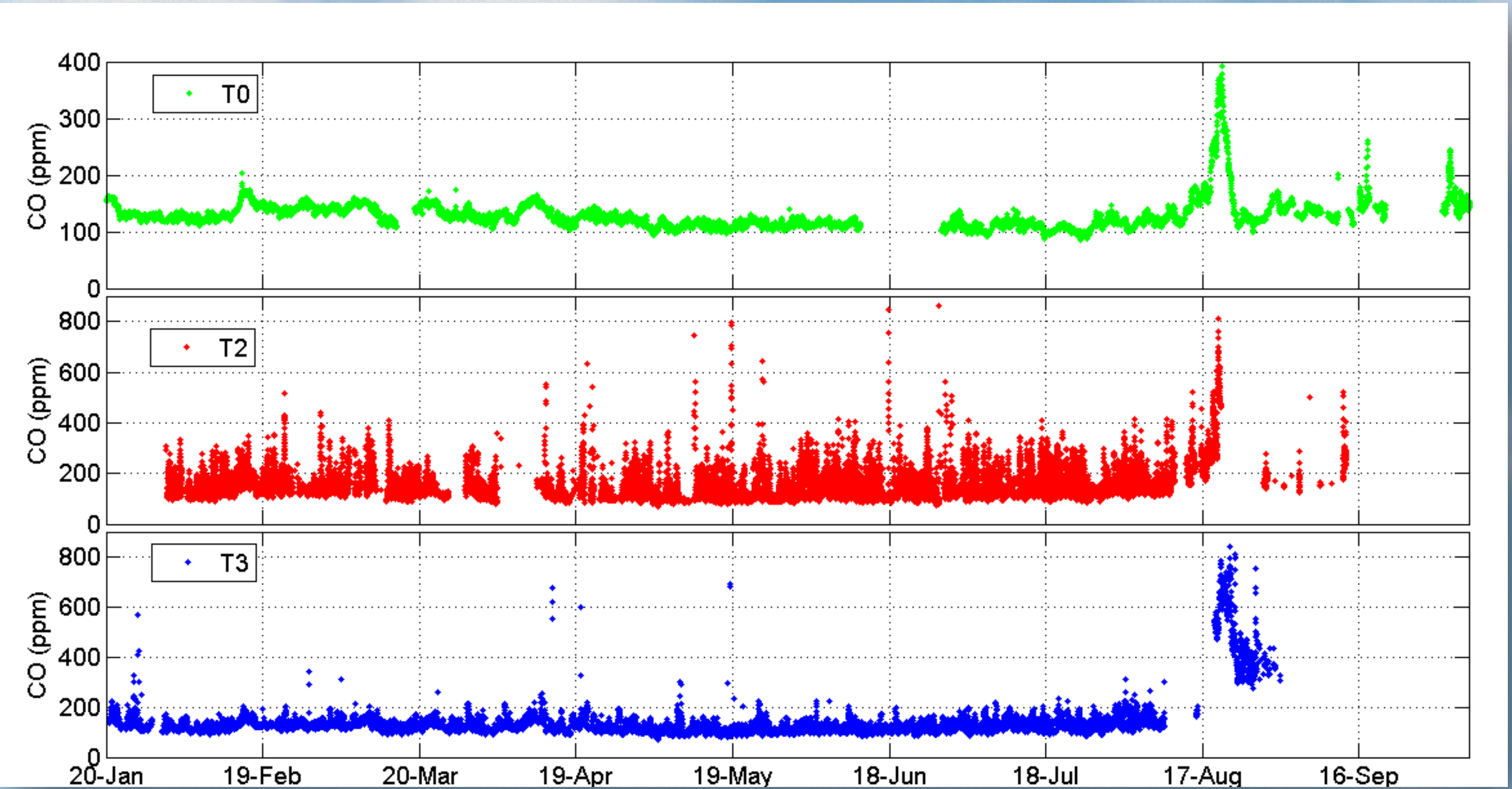
O_3 time series observed at T0z (ZF2), T2 and T3



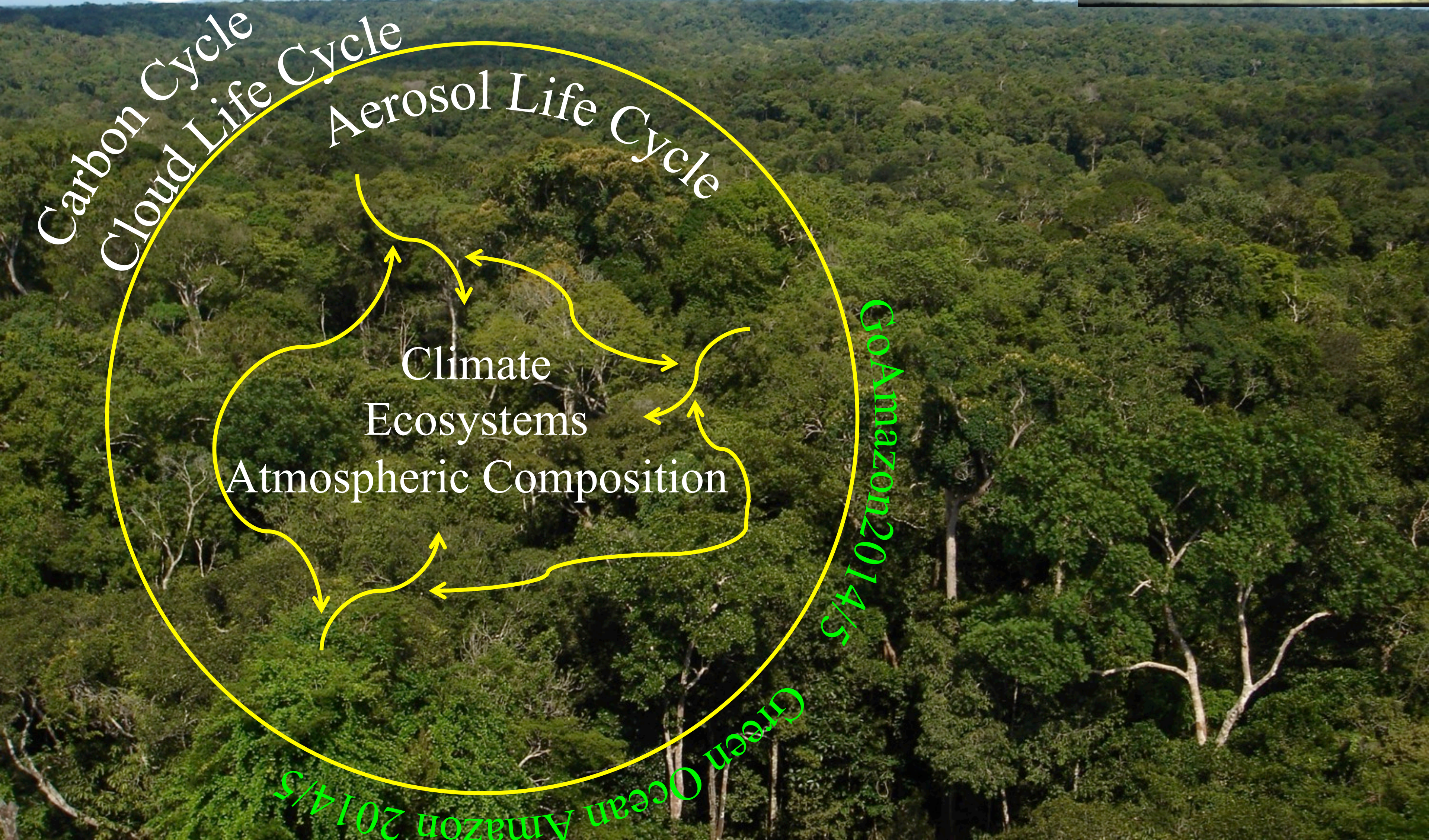
Ozone diurnal cycle for the 3 sites (T0, T2 and T3)



CO time series observed at T0z (ZF2), T2 and T3

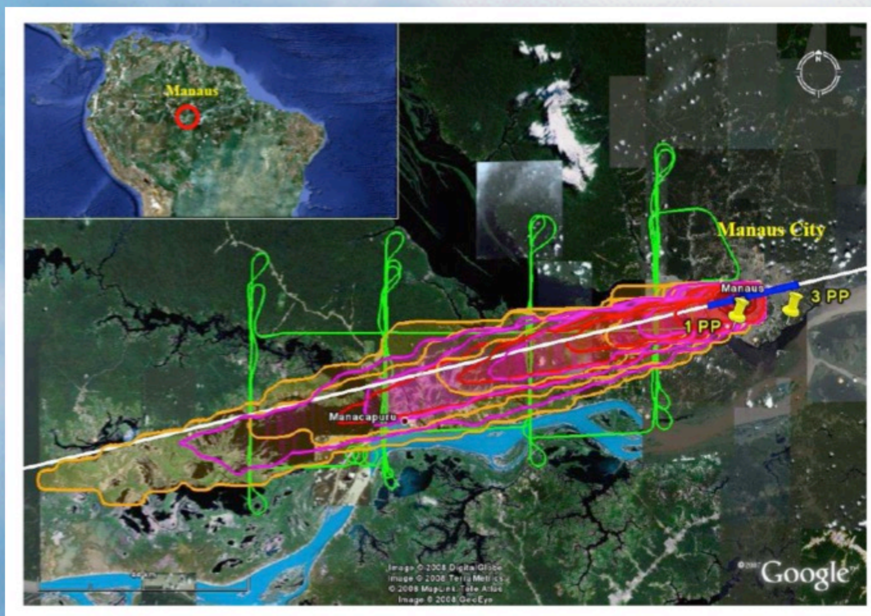


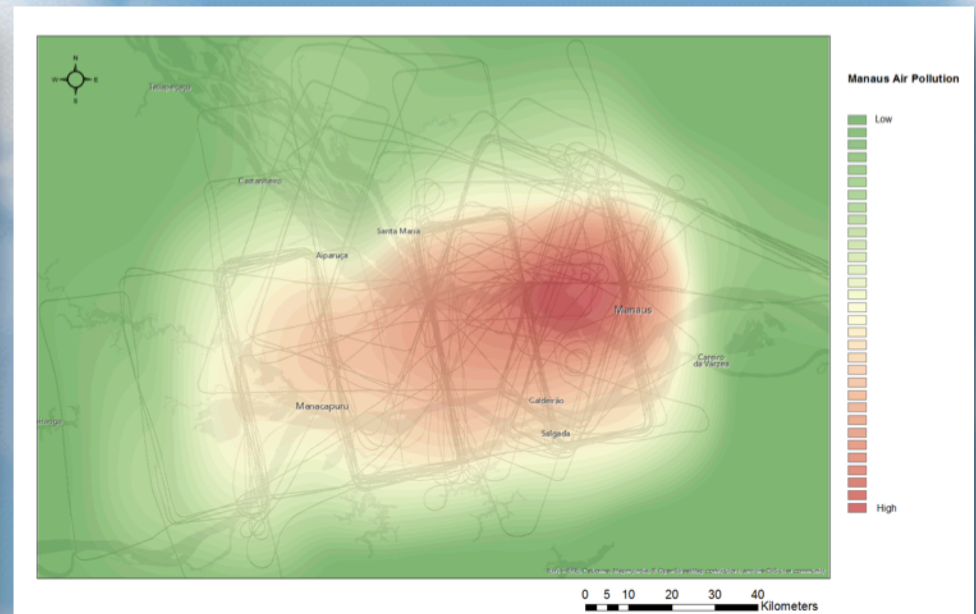
Observations and Modeling of the Green Ocean Amazon - GoAmazon2014/5



GoAmazon Experiment 2014-2015

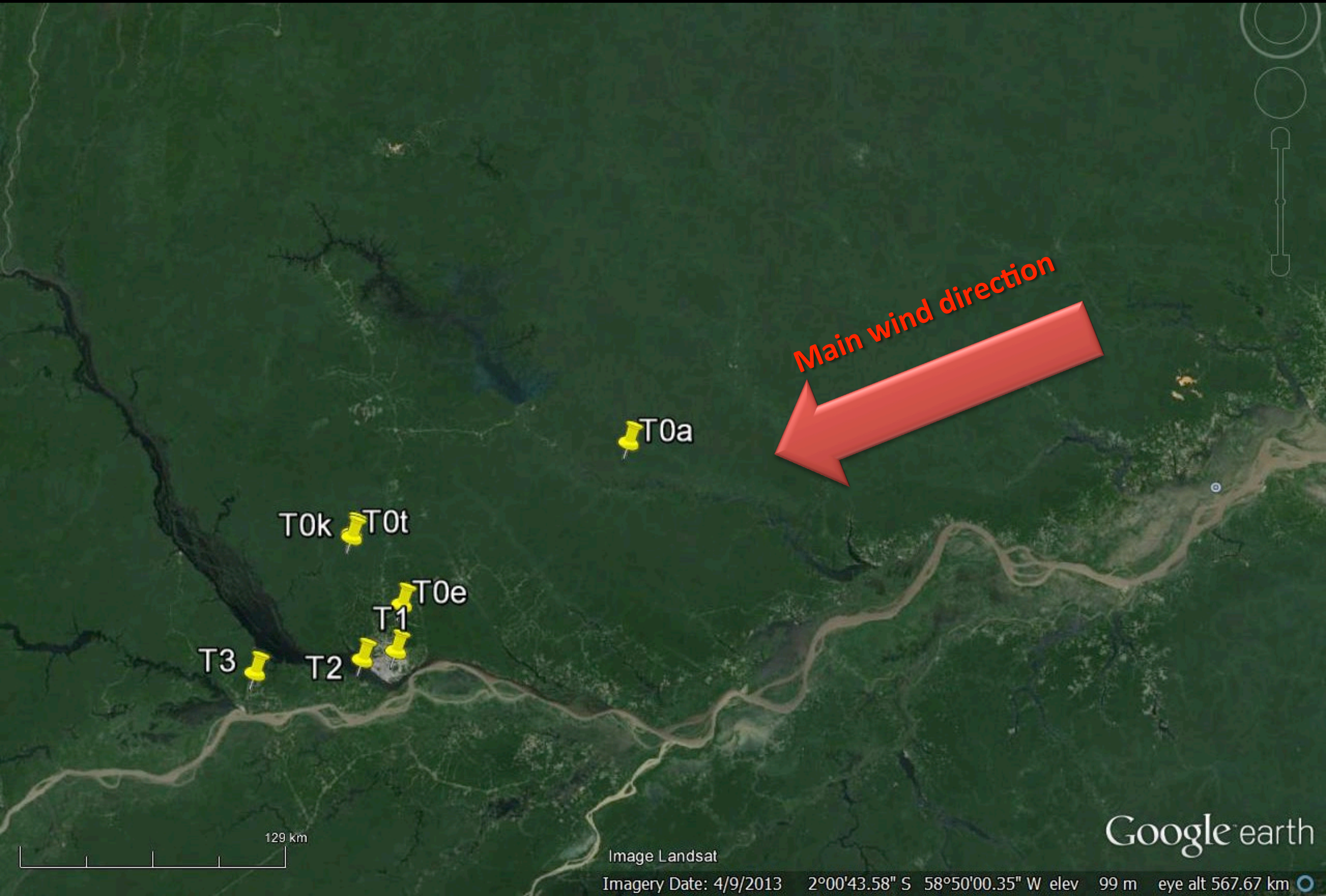
4 ground sites (before at and after Manaus plume)
DoE G1 plane and the German G5 HALO plane for large scale





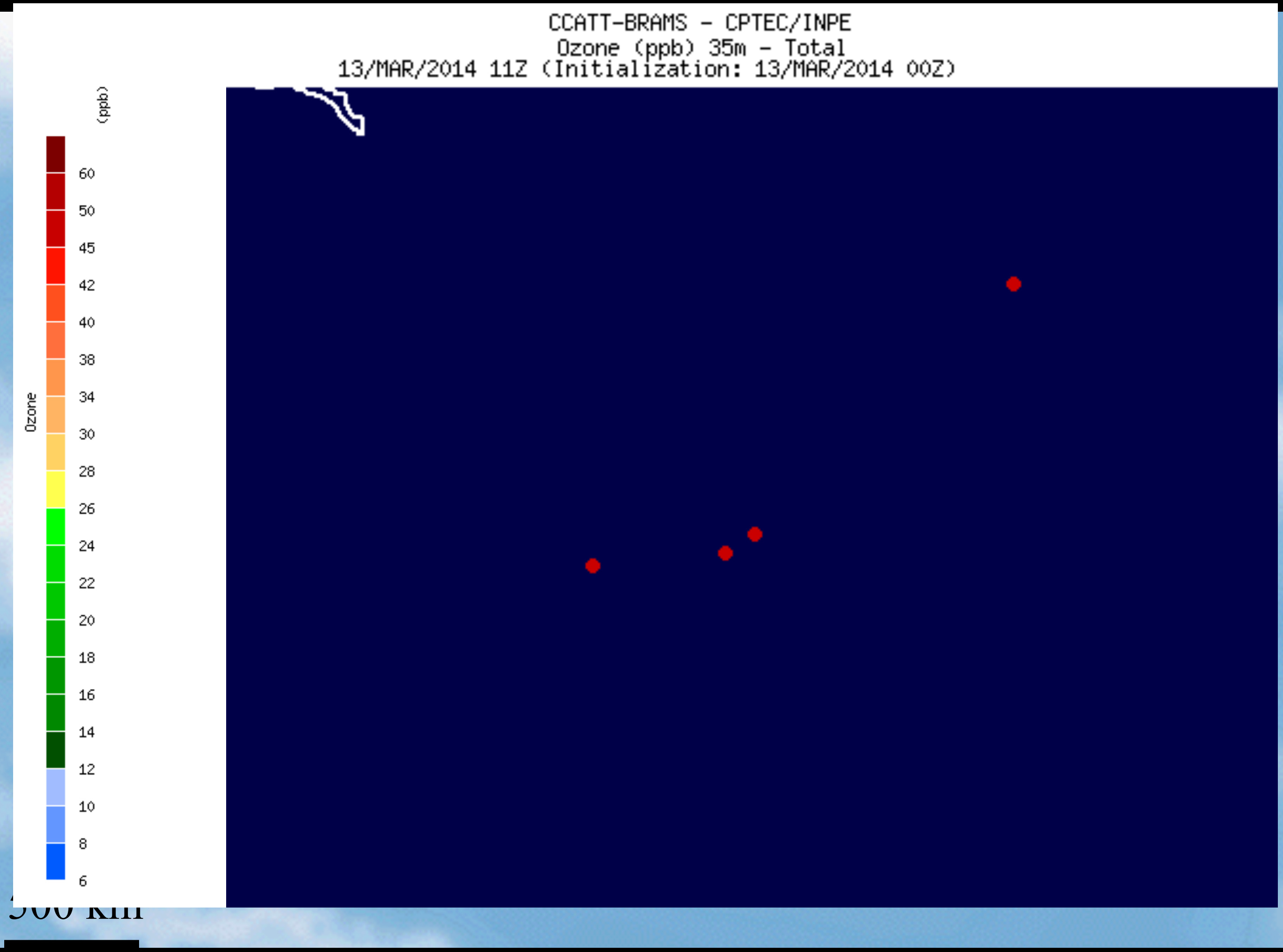
Study of the interactions of the urban plume of Manaus with the forest, producing secondary organic aerosols, ozone and others

Site Location



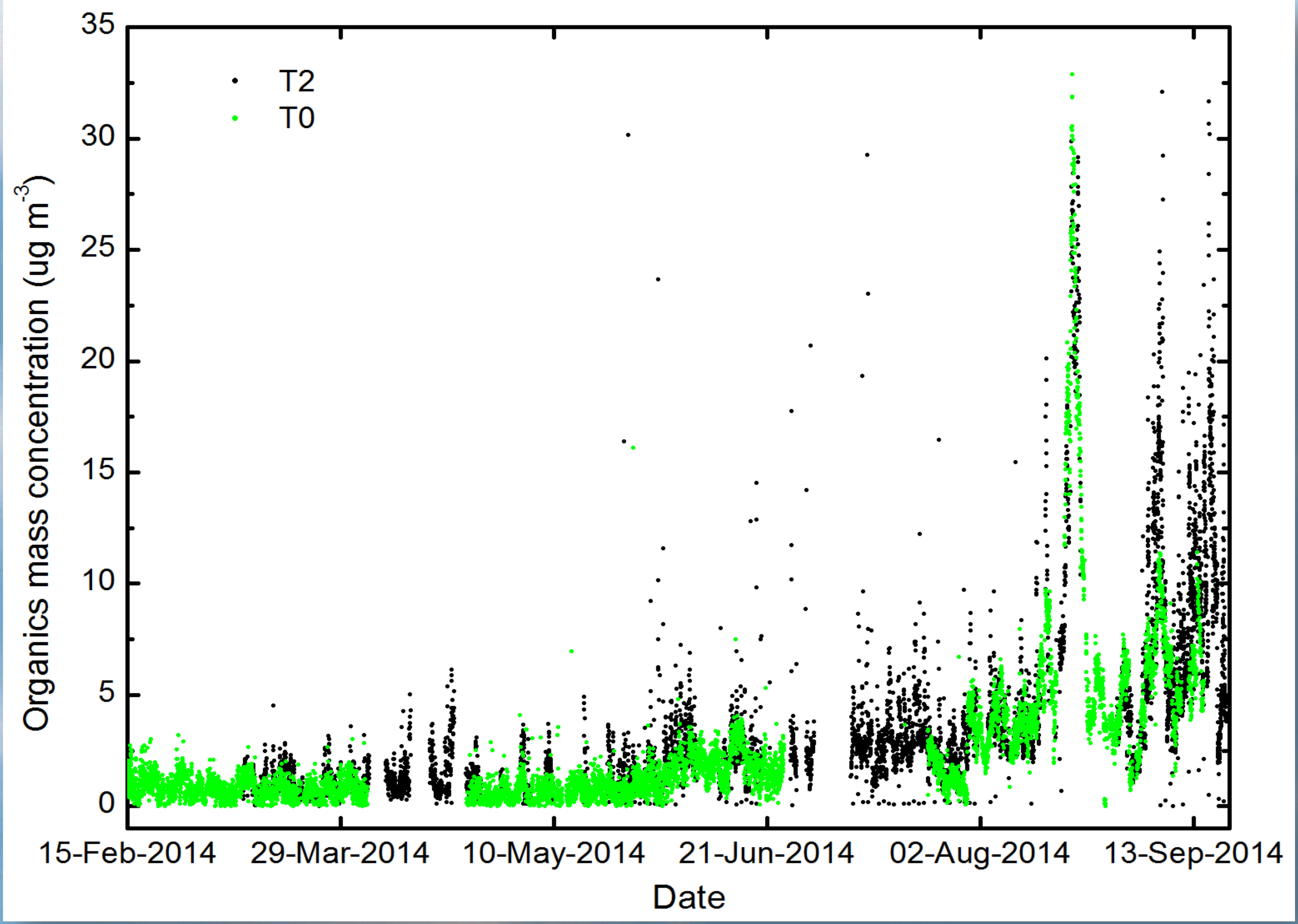
Plume Simulation by CCATT-BRAMS

Ozone, 13 March 2014

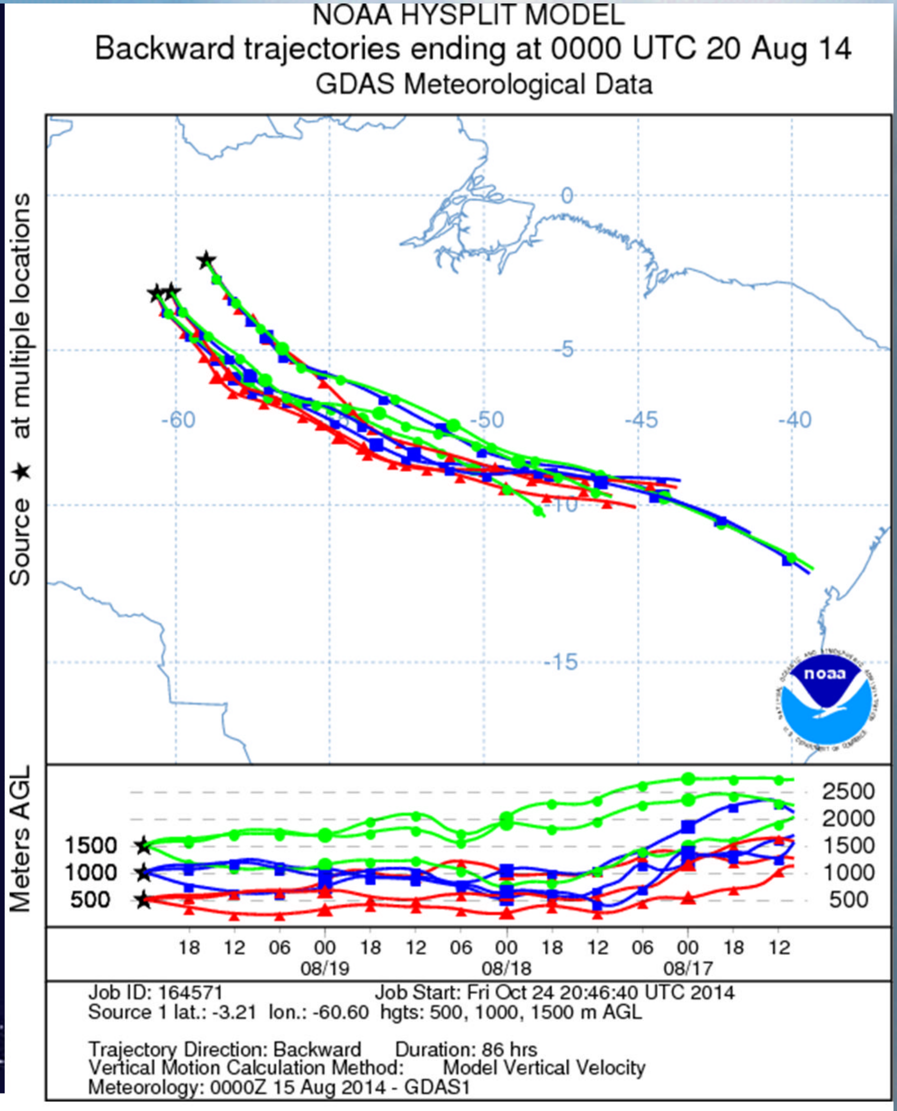


Credit: Karla Longo

ACSM – Organics at T0a (ATTO) and T2

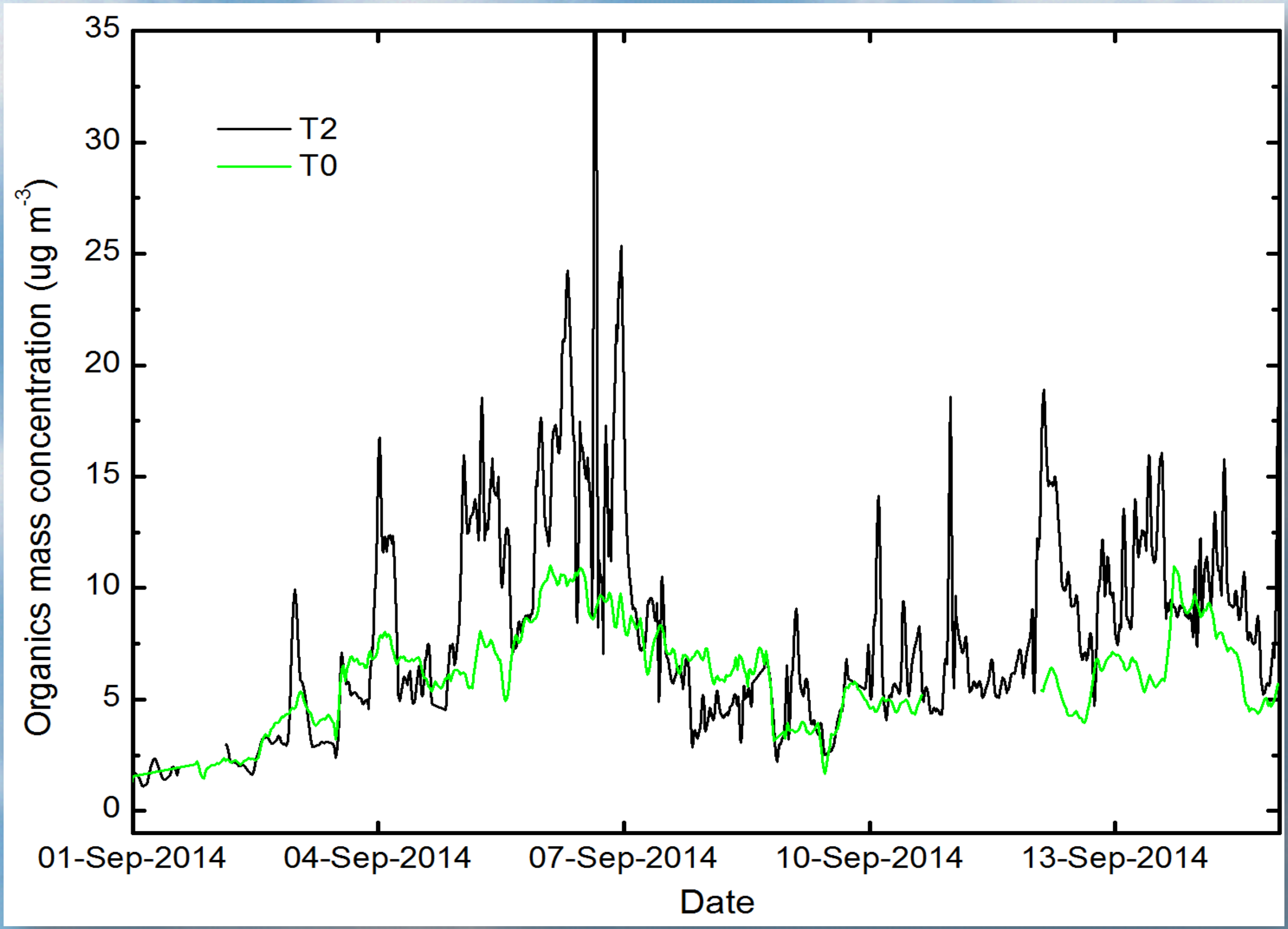


High biomass burning episode observed at the 3 sites

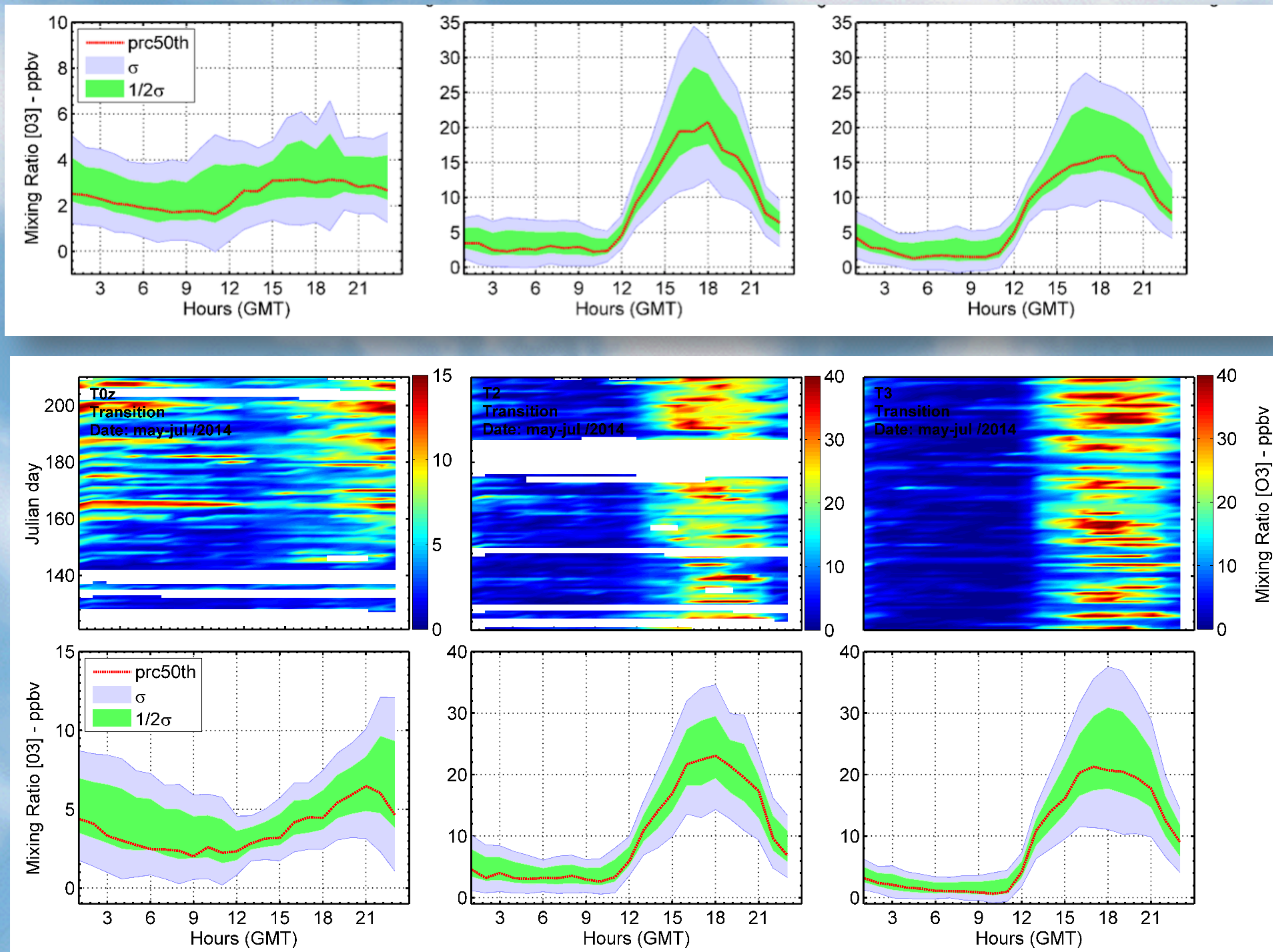


Fire counts for 19 to 28 August 2014. Backward mass trajectories for 86 hours finishing at August 20, 2014 at ATTO, Tiwa and Manacapuru.

Regional background under Manaus plume

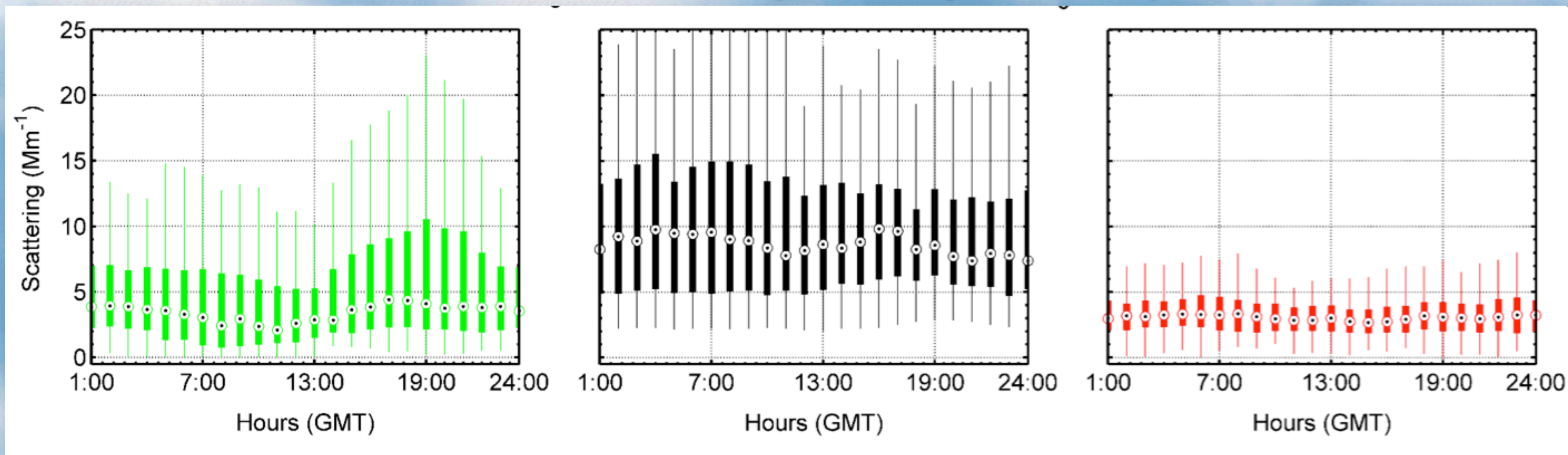


Ozone wet and transition seasons for the 3 GoAmazon sites T0z, T2 and T3

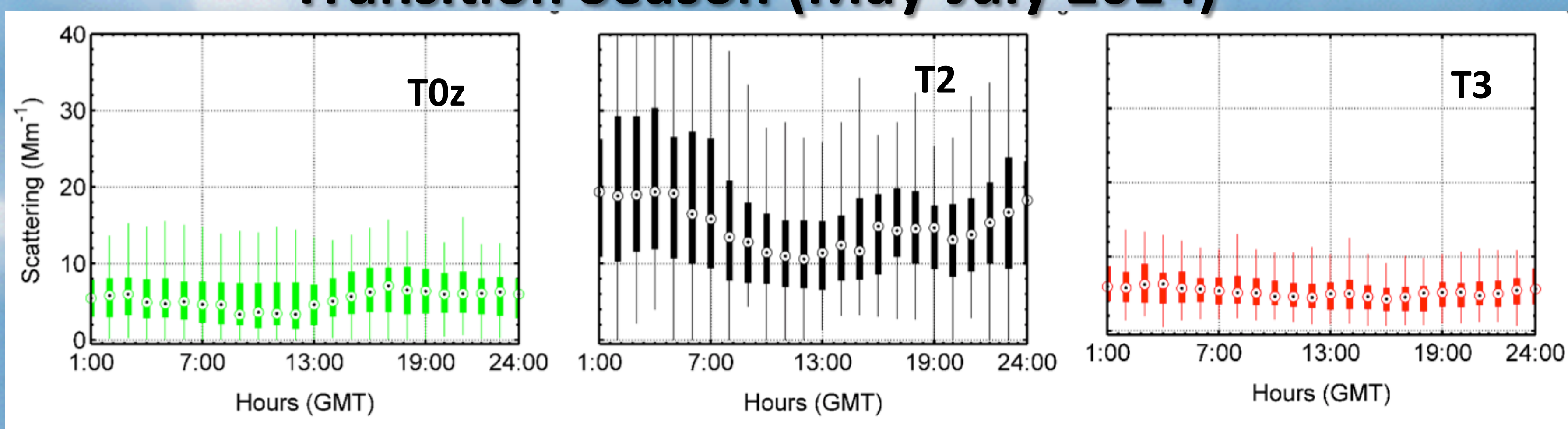


Light Scattering (Mm^{-1}) for T0z, T2 and T3

Wet Season (Feb-Apr 2014)

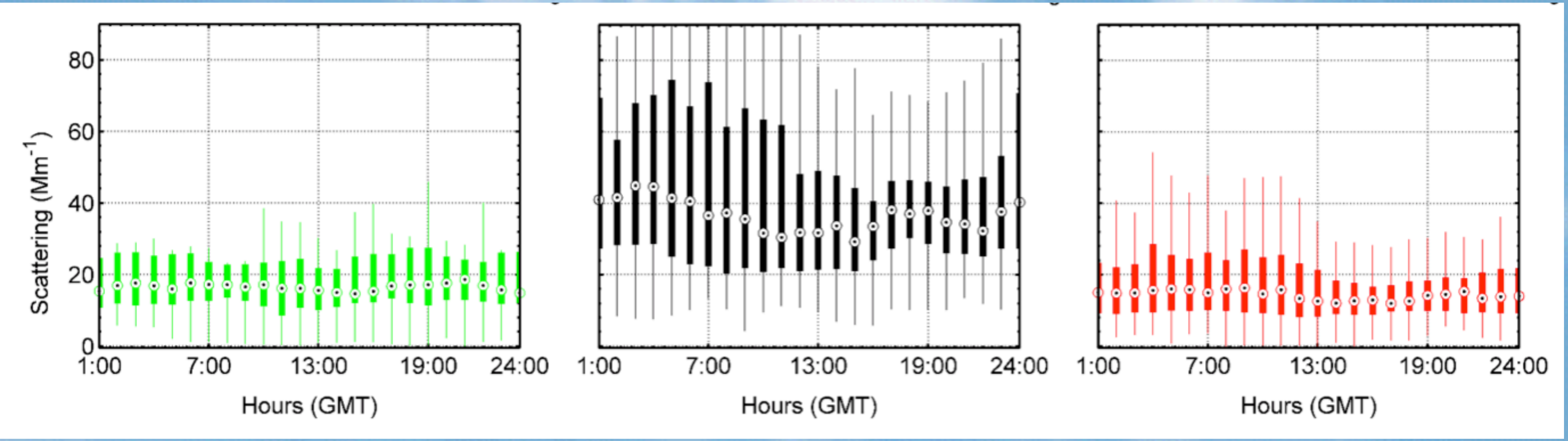


Transition Season (May-July 2014)



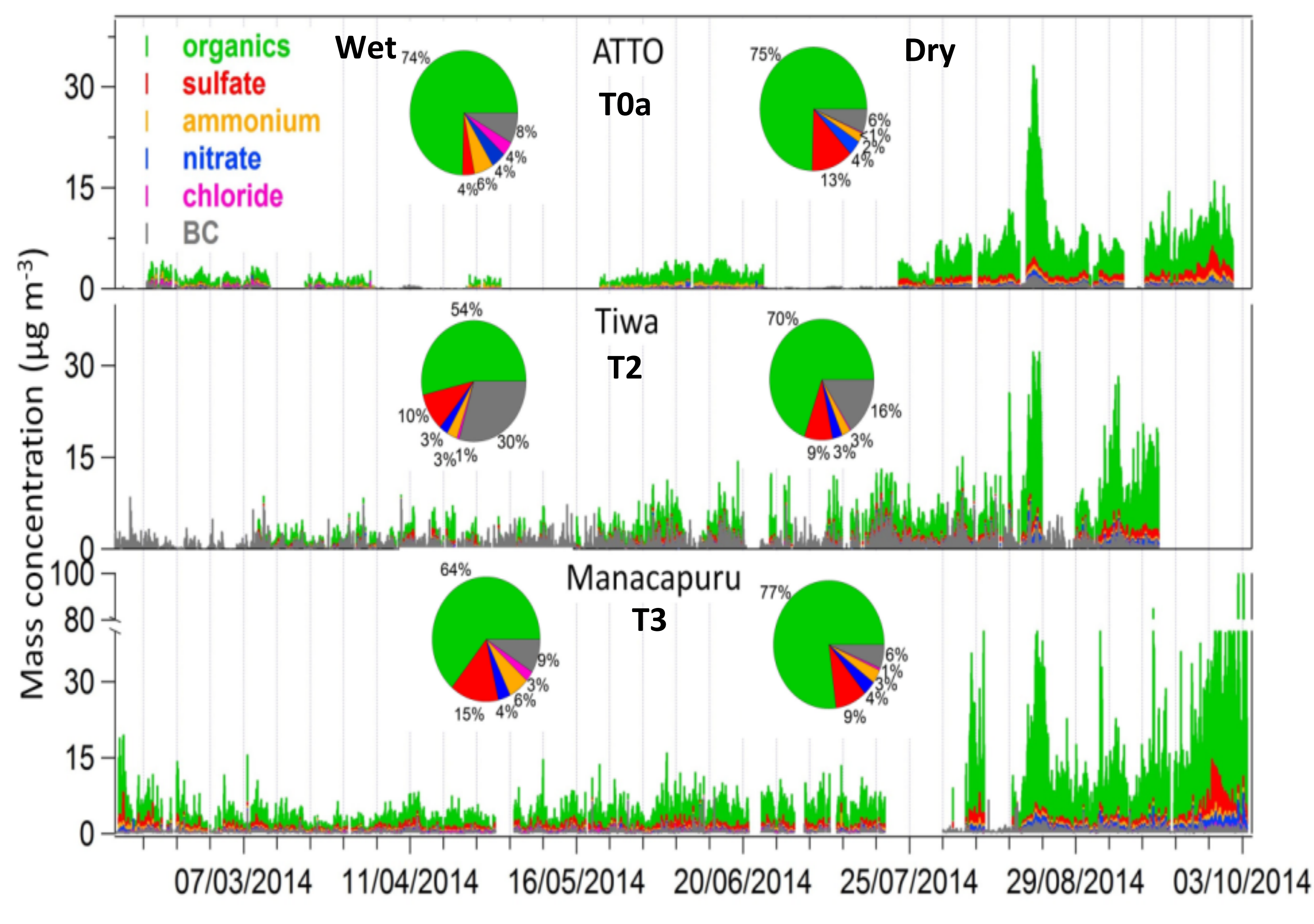
Light Scattering (Mm^{-1}) for T0z, T2 and T3

Dry season (August-October 2014)

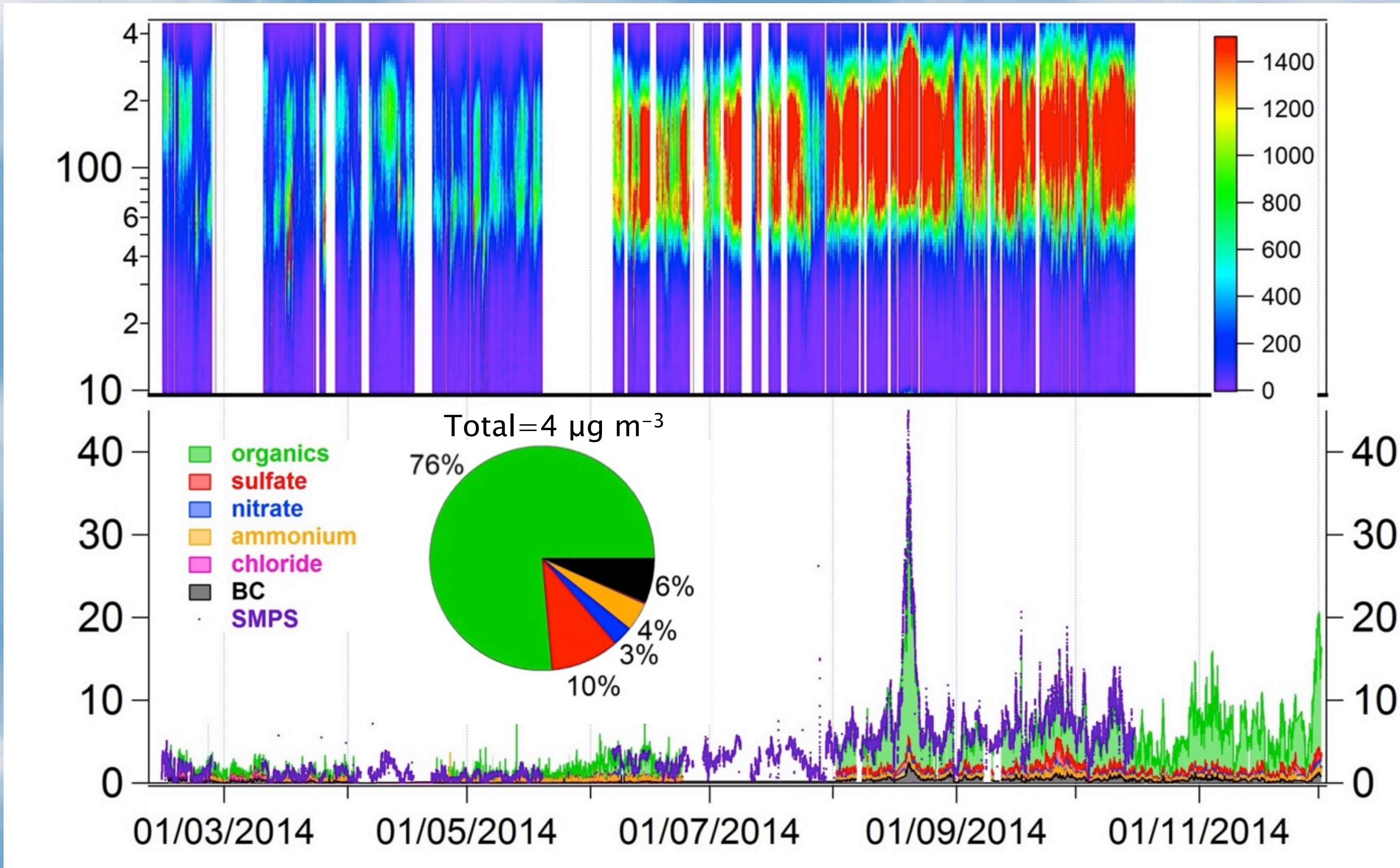


T0z = T3

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



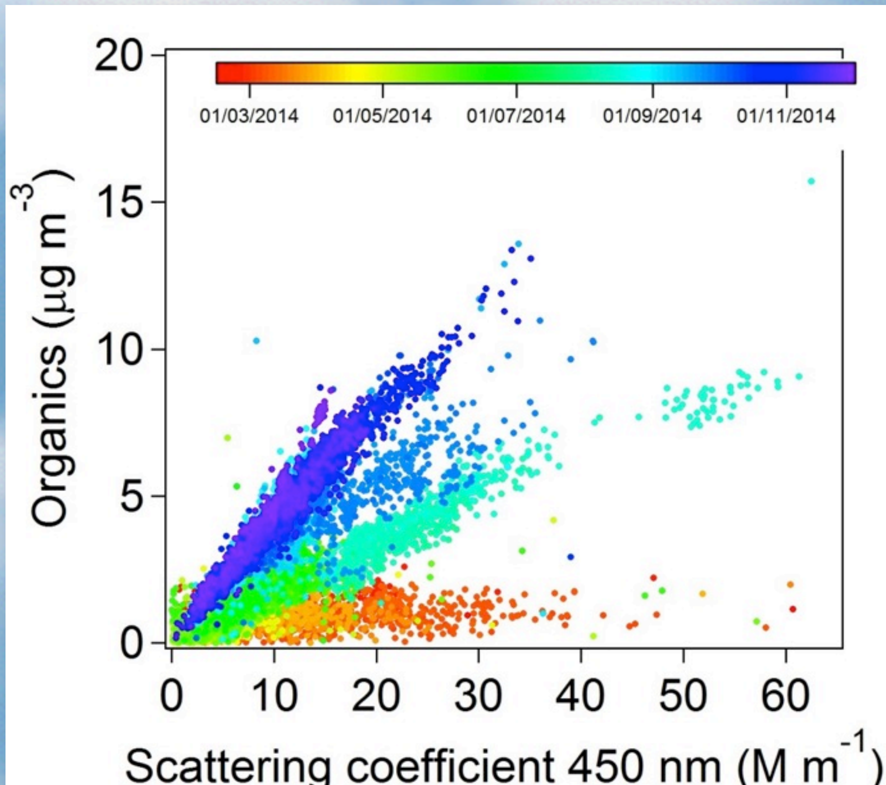
T0a – ATTO aerosol properties SMPS versus ACSM

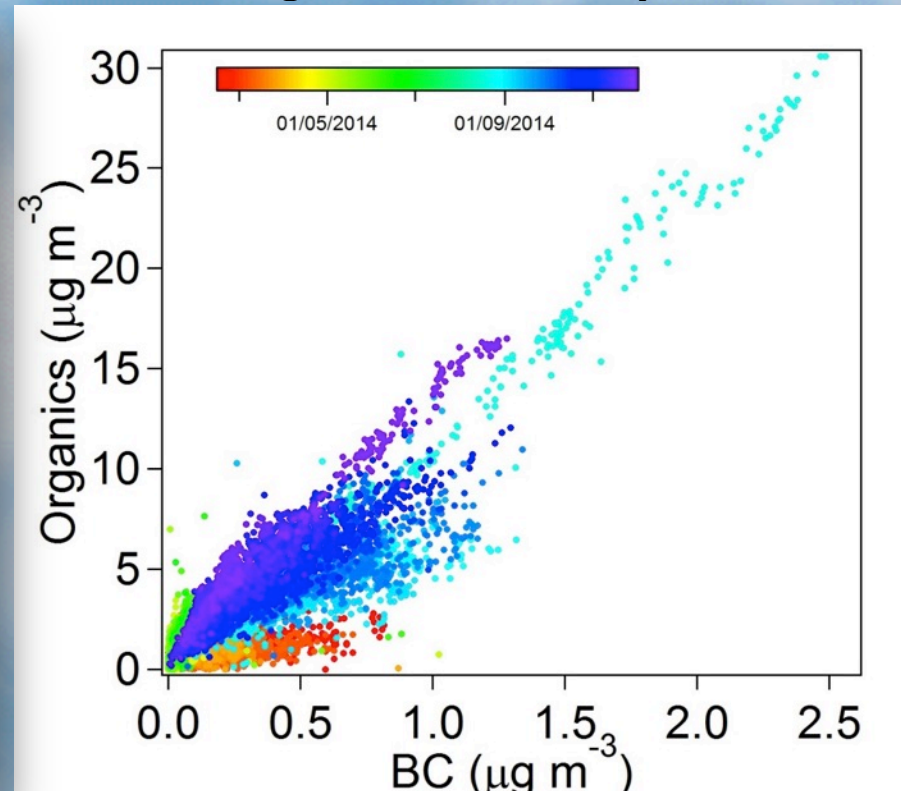


See poster from Samara Carbone

What drives light scattering and absorption for PM1?

T0a - Organics versus light scattering and absorption

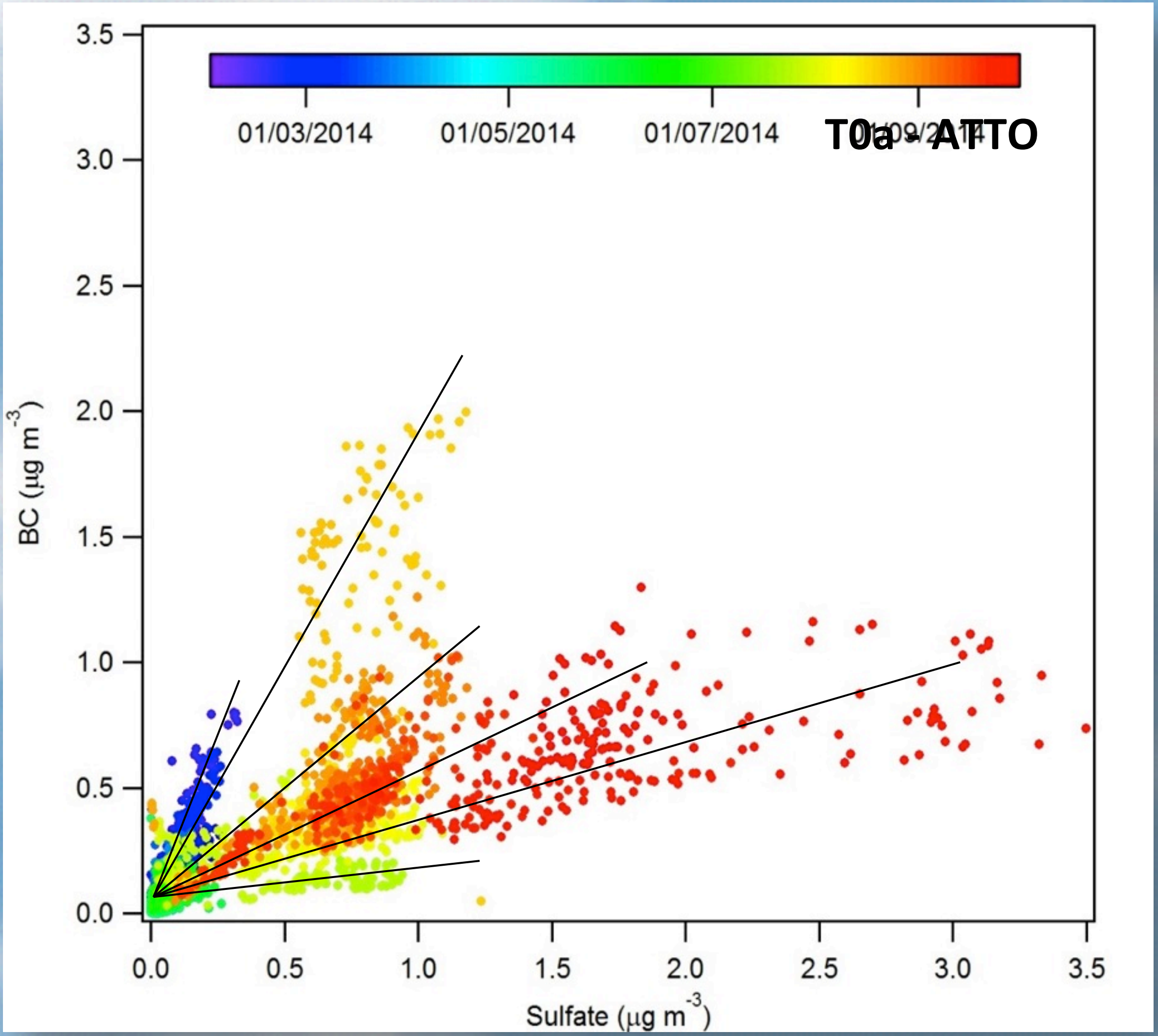




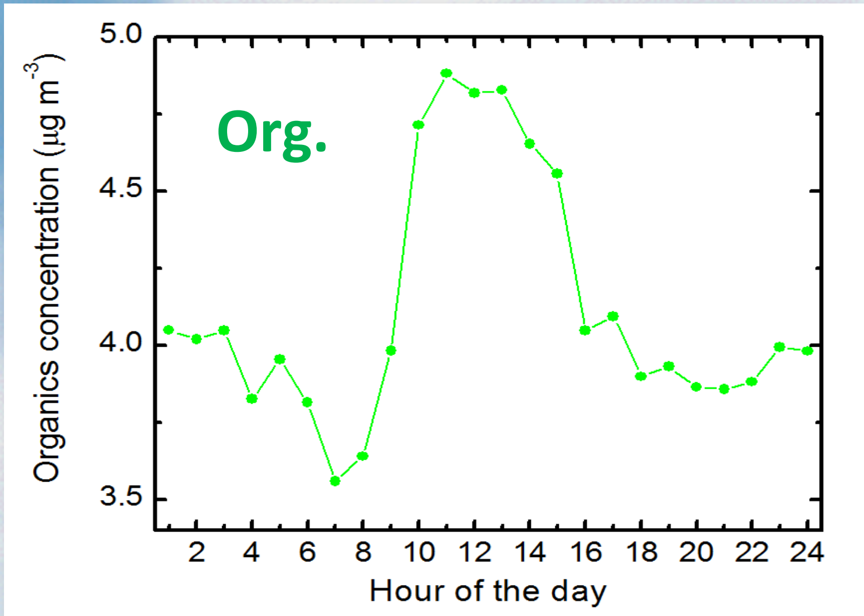
The organics made up to 76% of the fine particles and when investigated as a function of the scattering coefficient (σ_{450}) different patterns (with different slopes) were observed over time. BC also shows different patterns but less pronounced

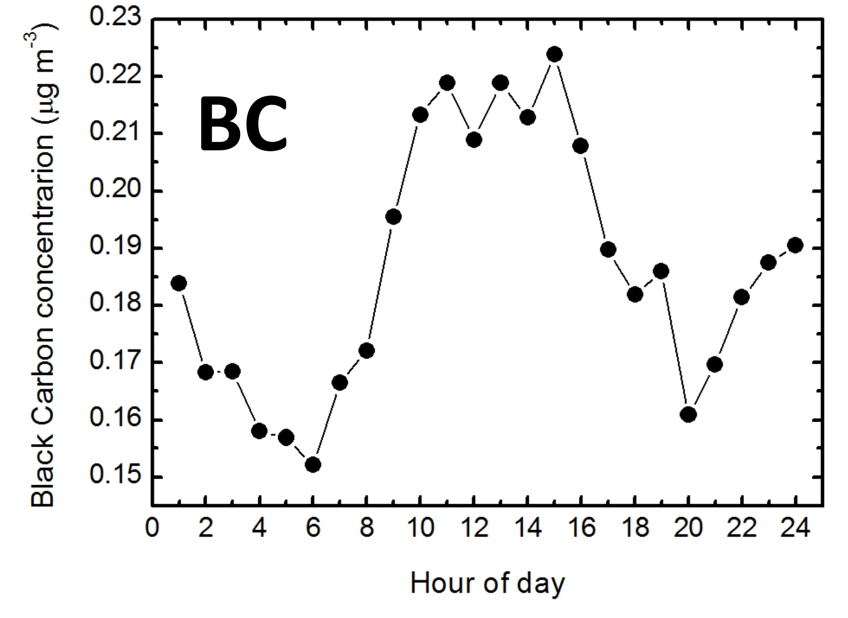
T0a Sulfate is related to BC, but with various ratios

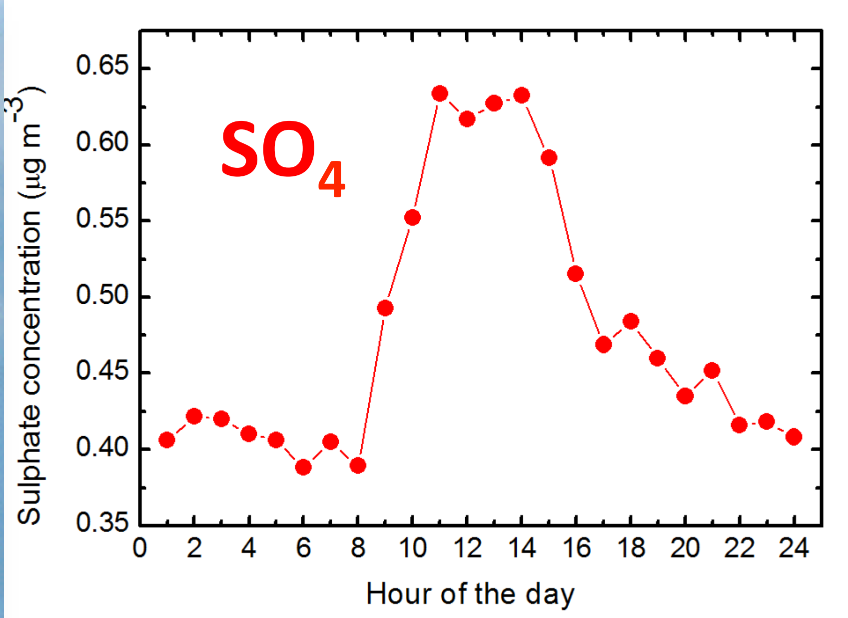
Different sources, modulated by different Long range transport processes



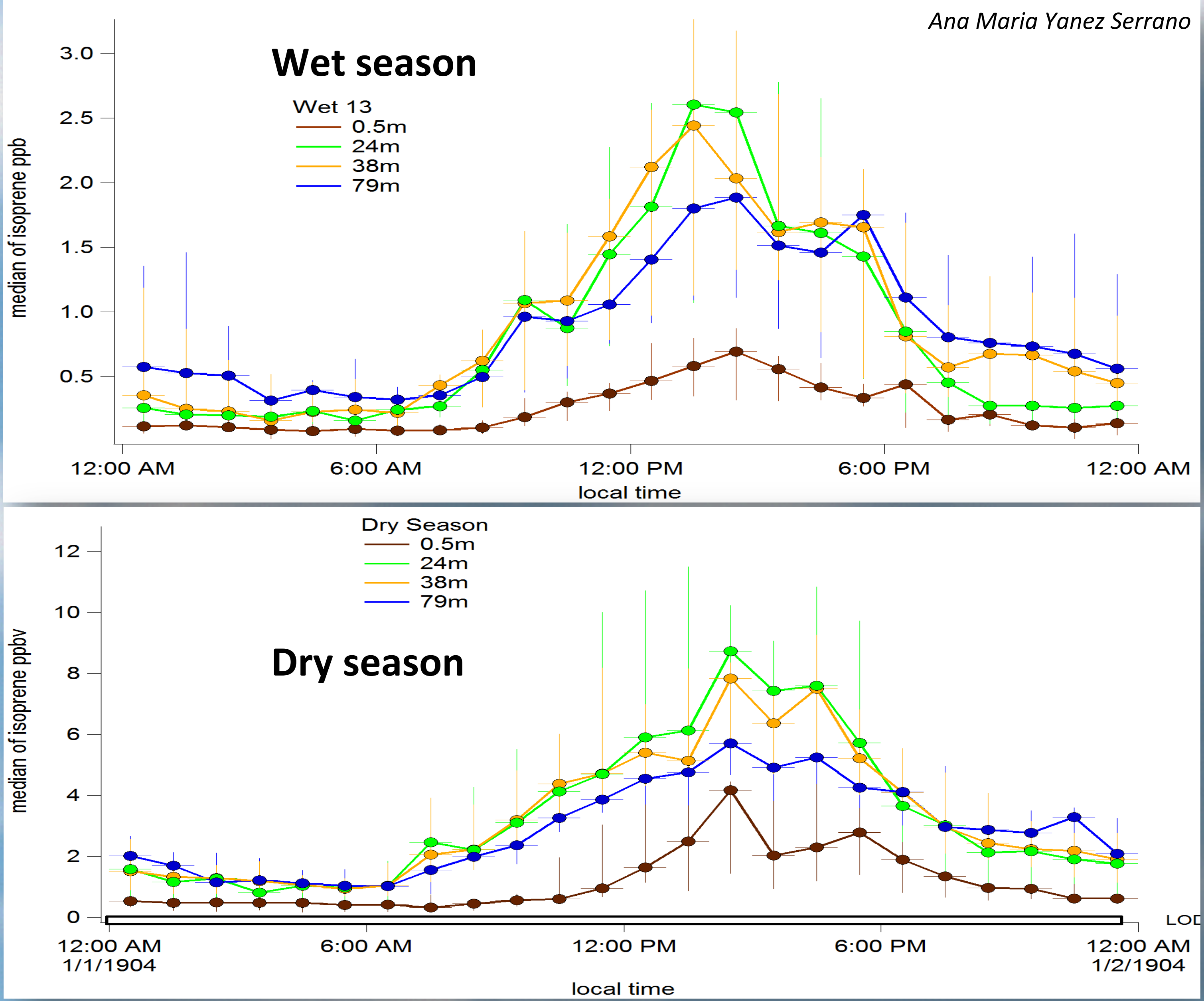
T0z – ZF2 diurnal variability of aerosol composition at the transition season





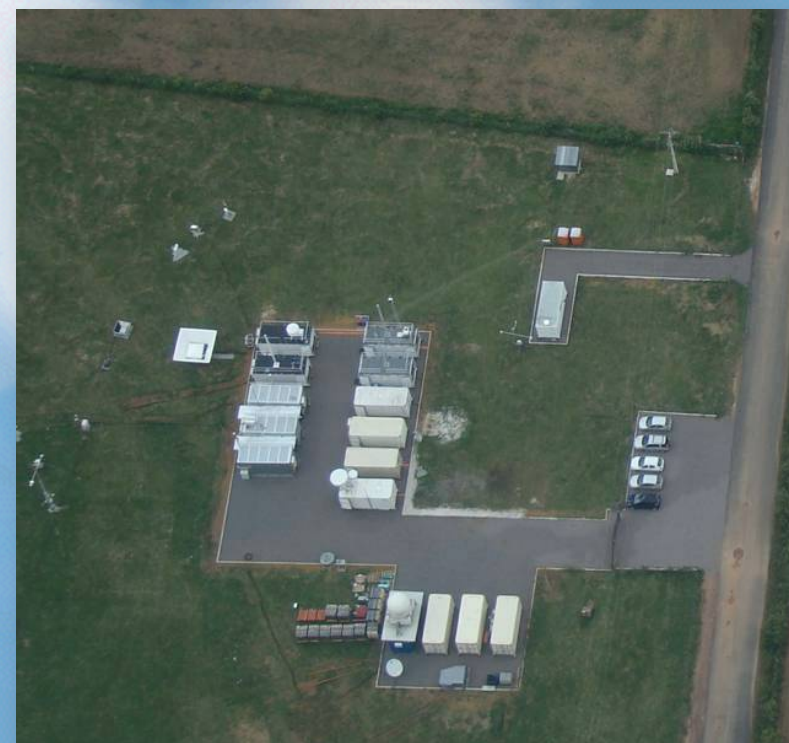


T0a-ATTO Diurnal variability of isoprene for wet and dry season



GoAmazon T2 site Tiwa Hotel

From T2-Tiwa to T3-Manacapuru

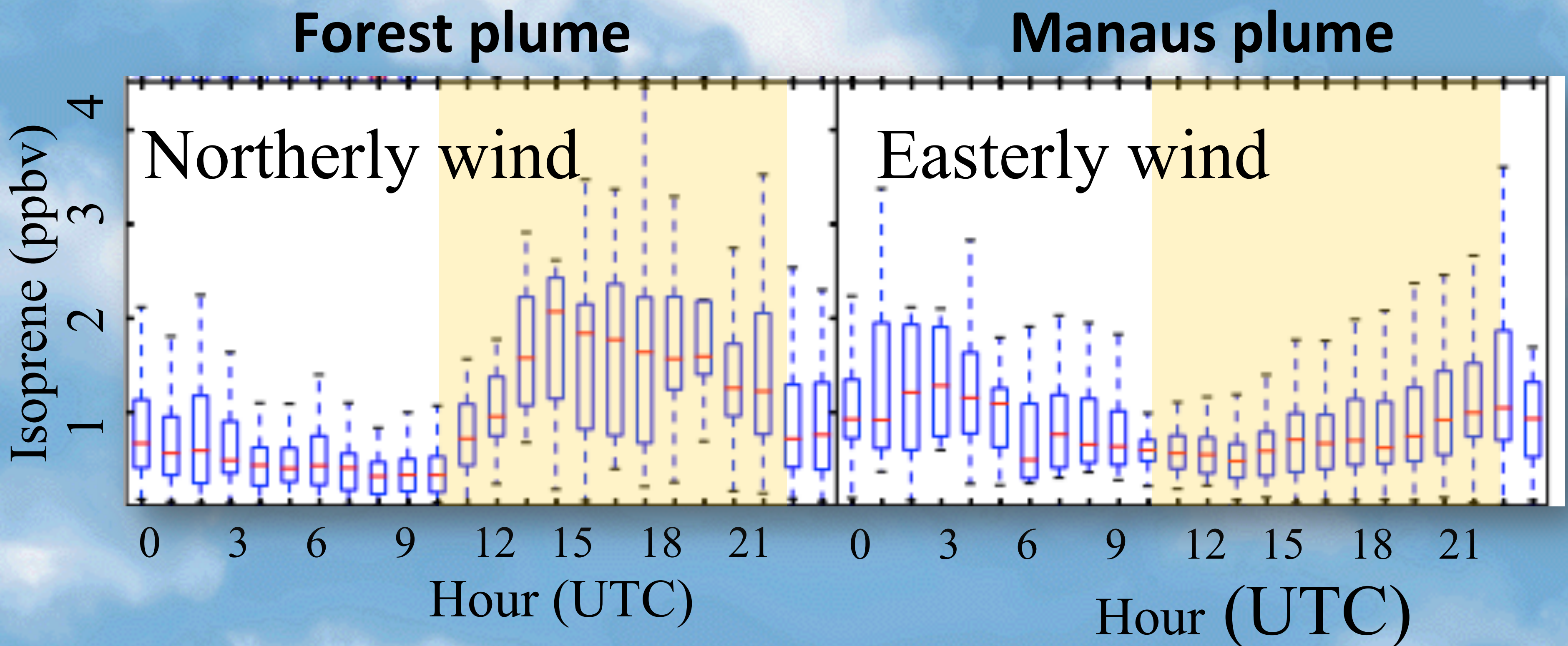


	Instrument	Analysis	Campaign	
			IOP 1 (Wet)	IOP 2 (Dry)
Gas Phase	PTR-Q-MS (Ionicon)	VOCs	X	X
Gas Phase	49i (Thermo)	Ozone	X	X
Gas Phase	43i (Thermo)	SO2 (trace level)	X	X
Gas Phase	CAPS (Aerodyne)	NO2		X
Gas Phase	Los Gatos Research	CO, N2O	X	X
Gas Phase	Los Gatos Research	CH4, CO2	X	
Aeorosol Phase	SMPS (TSI)	Aerosol Size Dist.	X	X
Aeorosol Phase	ACSM (Aerodyne)	PM1 NR Composition	X	X
Aeorosol Phase	Filters	Elem. Comp. & EC/OC	X	X
Aeorosol Phase	MAAP (Thermo) & AE33 (Magee)	Black Carbon	X	X
Aeorosol Phase	Nephelometer (Ecotech Aurora)	Light Scattering	X	X
Aeorosol Phase	TEOM (Thermo)	$PM_{2.5}$ & PM_{10}		X
Aeorosol Phase	CCNC (DMT)	Size-Resolved CCNC		X

ARM Mobile Facility (AMF1)
43 instruments

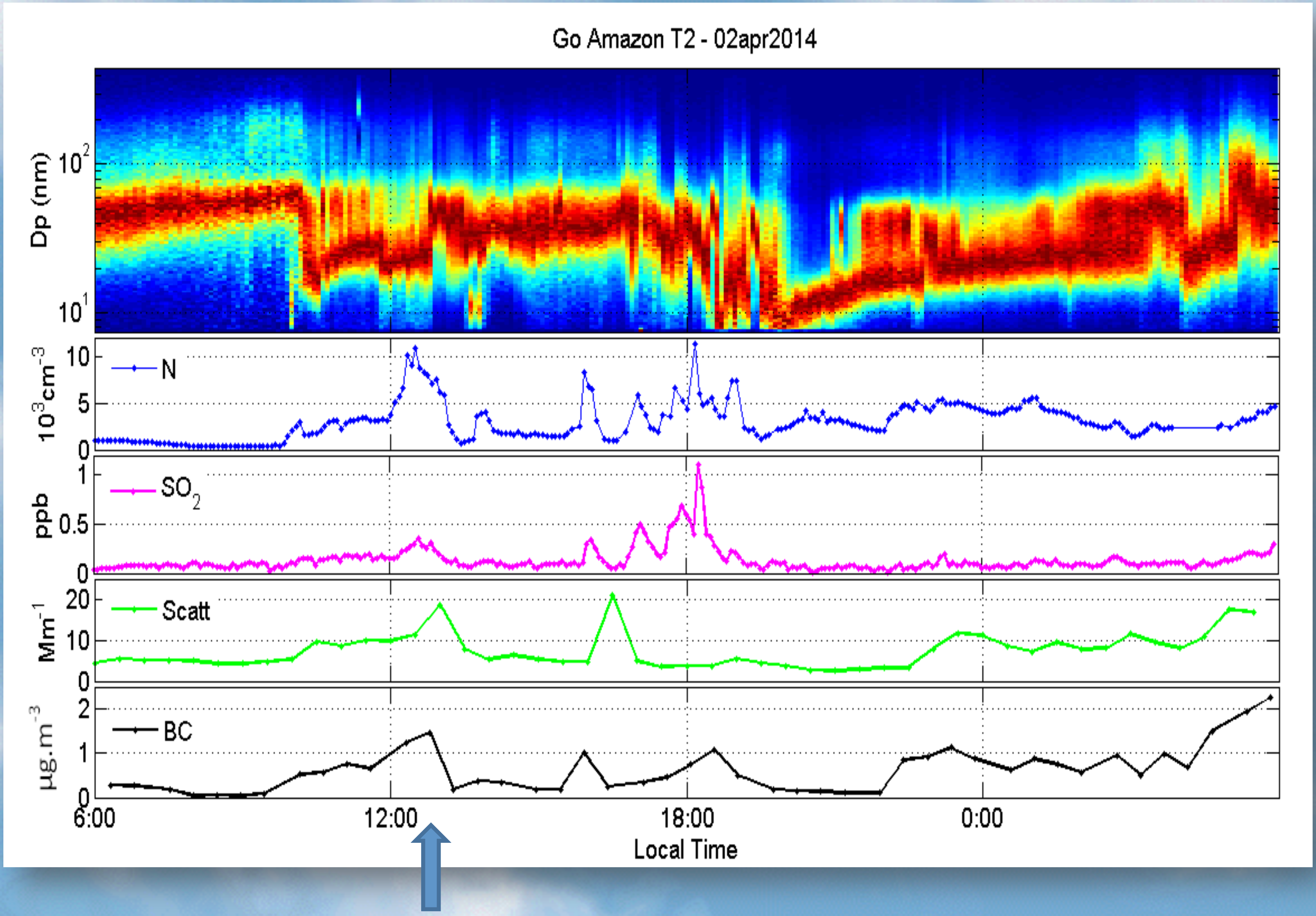
- **Aerosols (more in MAOS)**
  - Surface: CCN, CLAP, CPC, PSAP, Neph
  - Column: Sunphotometer
- **Atmospheric Profiling**
  - Microwave Radiometers (MWR): Profiler, high frequency, 3-channel
  - Balloon-borne Sounding System (SONDE)
- **Clouds**
  - Lidar: Micropulse and Doppler
  - Cloud Radars: Radar Wind Profiler, W-band, Scanning W-Band and Ka-Band
  - Narrow Field of View
  - Total Sky Imager
  - Ceilometer
- **Radiometers**
  - Atmospheric Emitted Radiance Interferometer, Infrared Thermometer, Multifilter Rotating Shadowband Radiometer, Upwelling Radiation, Multifilter Radiometer, Downwelling Radiation, Solar Array Spectrometer-Hemispheric, Solar Array Spectrometer-Zenith
- **Surface Meteorology**
  - Eddy Correlation Flux Measurement System, Surface Energy Balance System, Meteorological Instrumentation, Optical Rain Gauge, Tower Camera

T2 – Tiwa - Diel variation of isoprene mixing ratios depending on local wind direction

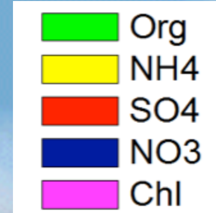


(Joel Brito results)

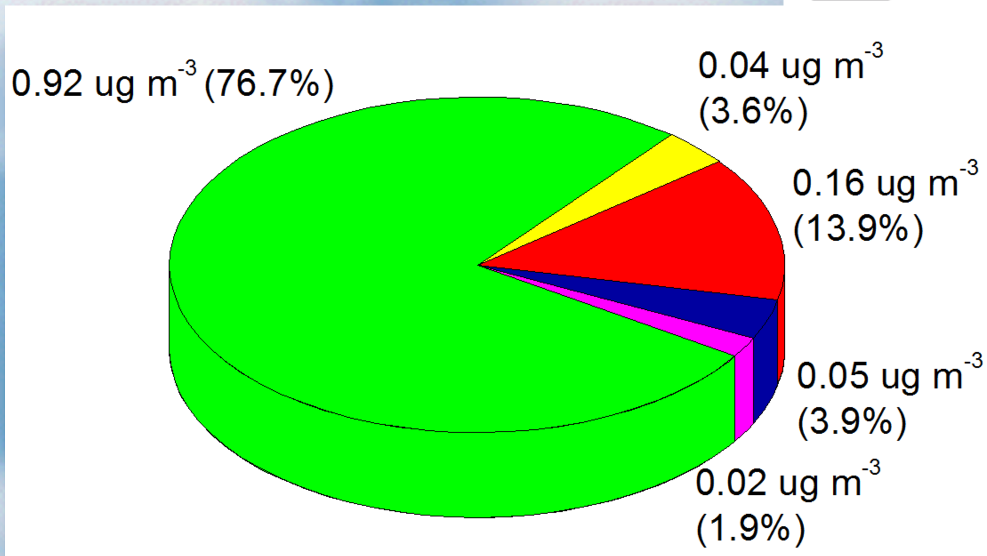
T2 - Size distribution, number, SO_2, light scattering and BC



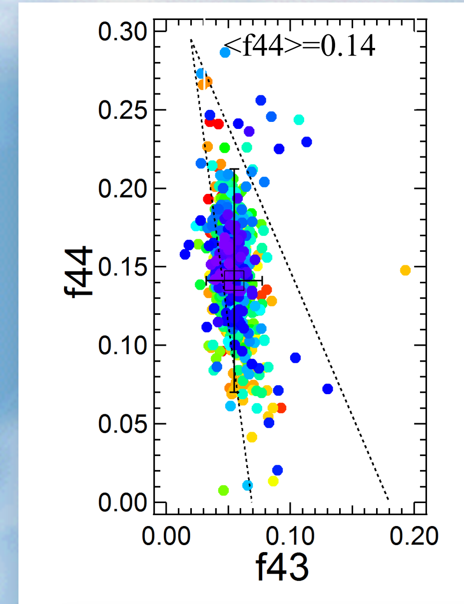
T2 – Tiwa Wet versus dry season

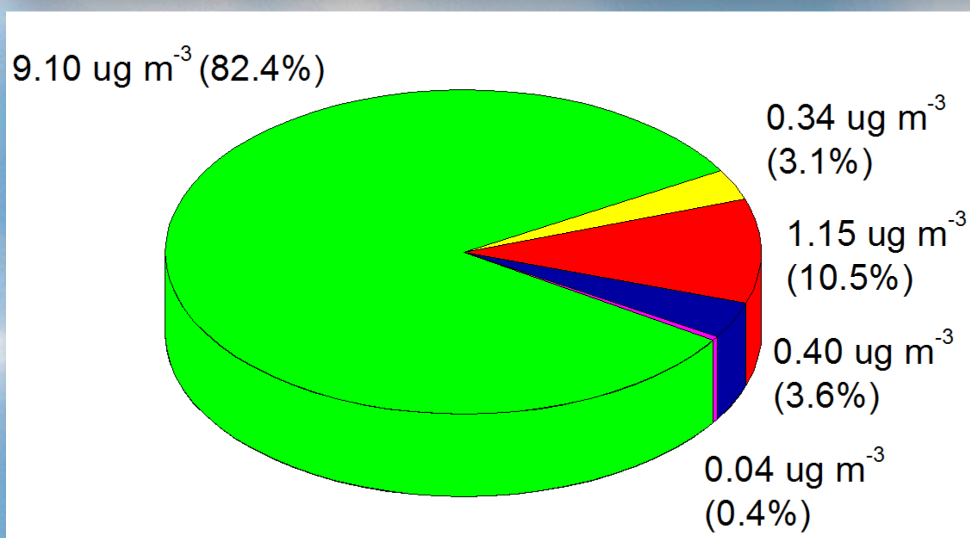


highly oxidized aerosols already at T2

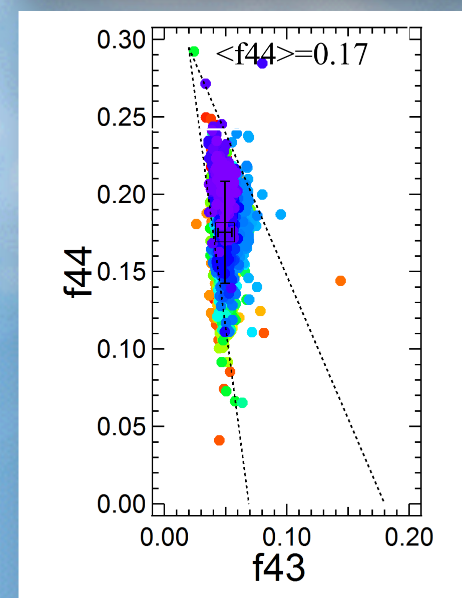


IOP1 - Wet season



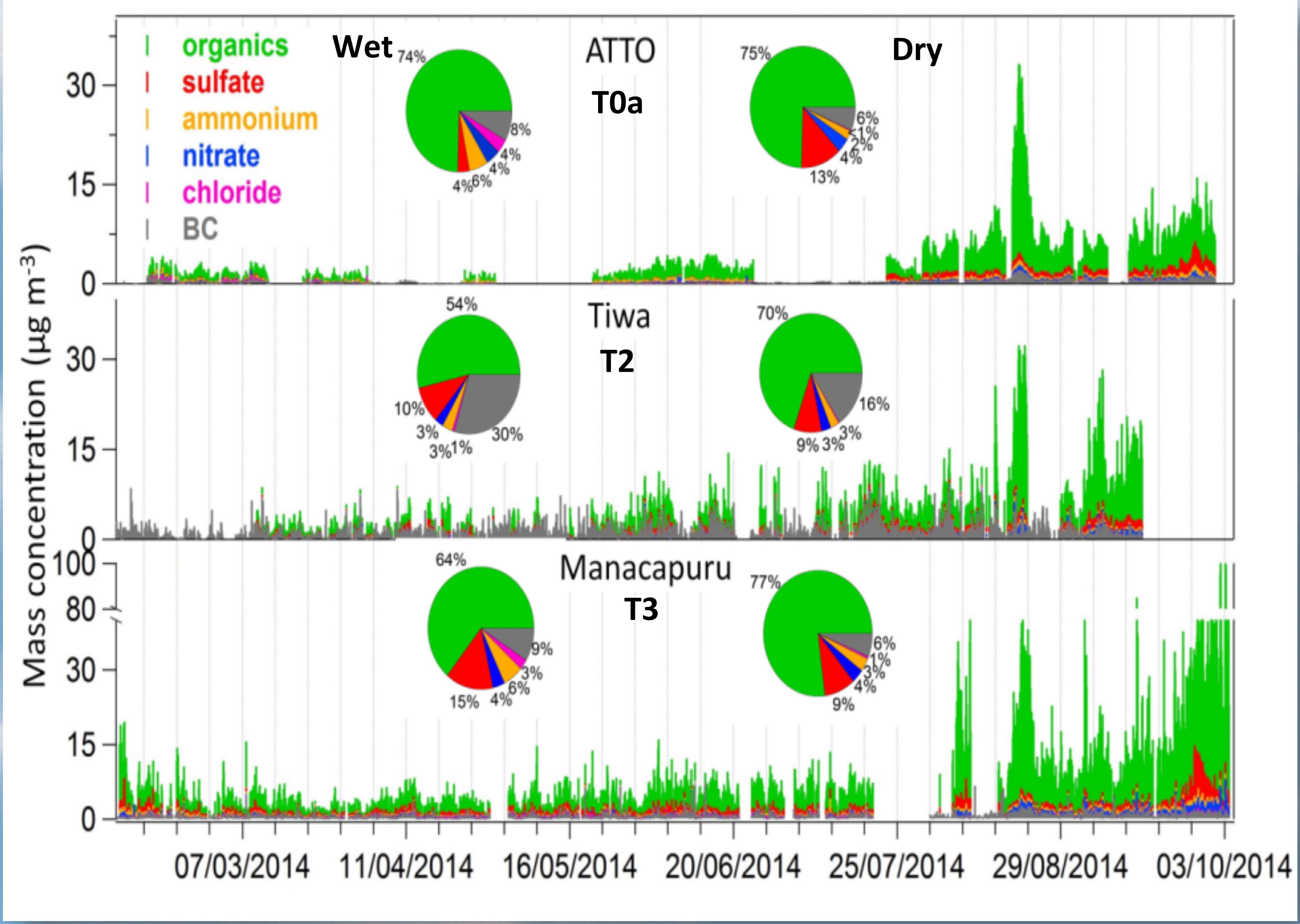


IOP2 - Dry season



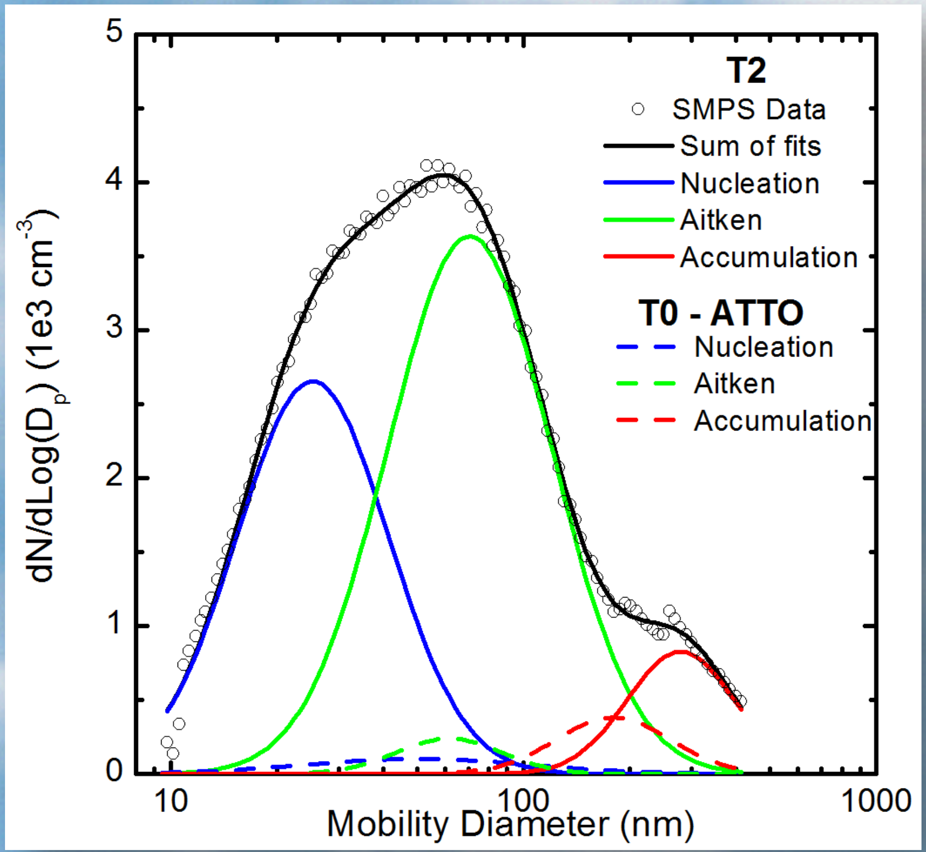
(See Joel Brito poster)

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

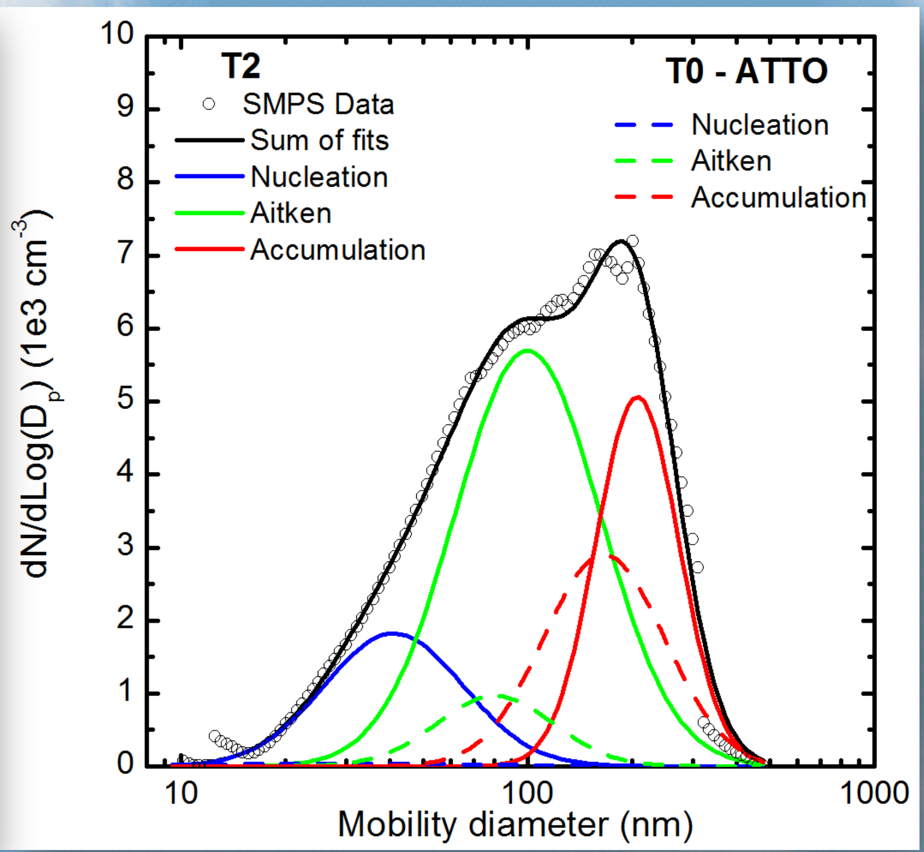


Aerosol size distribution T0a (ATTO) versus T2 (Tiwa)

Wet season

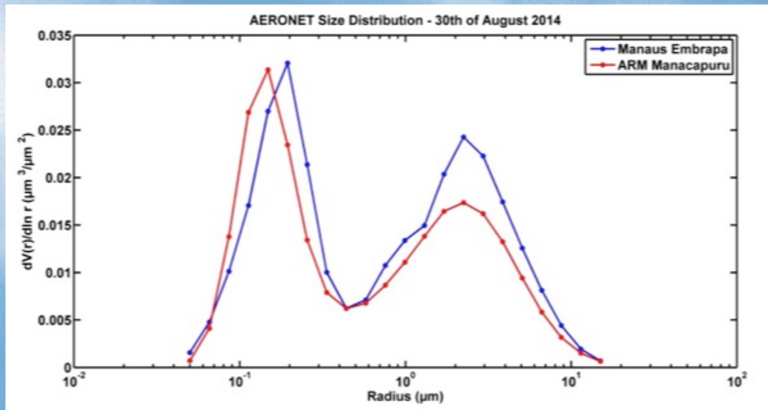


Dry season

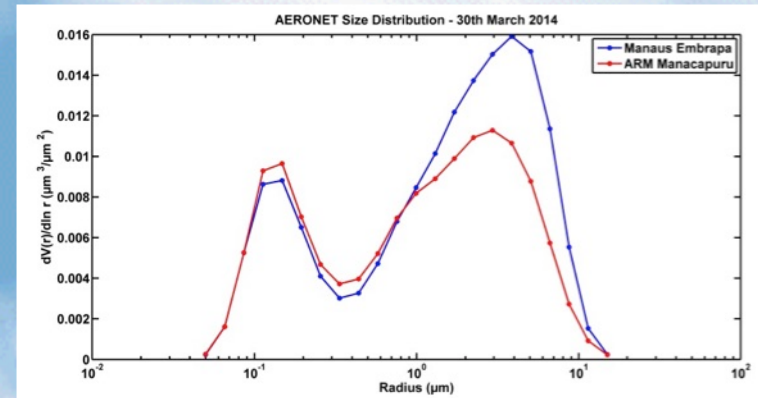


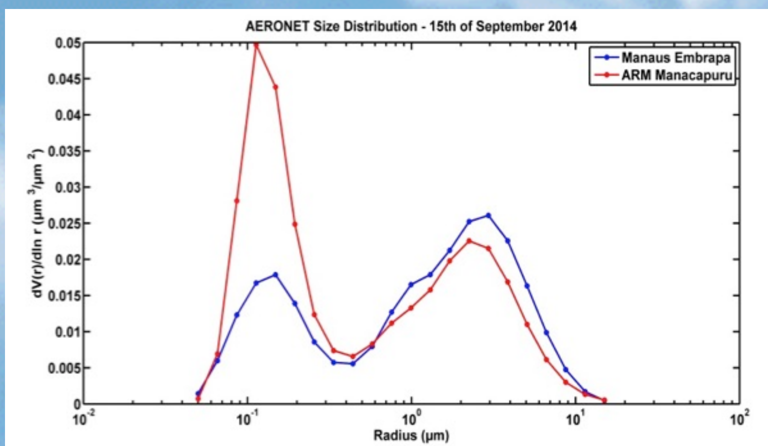
(Joel Brito results)

Aerosol Size Distribution AERONET - Embrapa versus Manacapuru

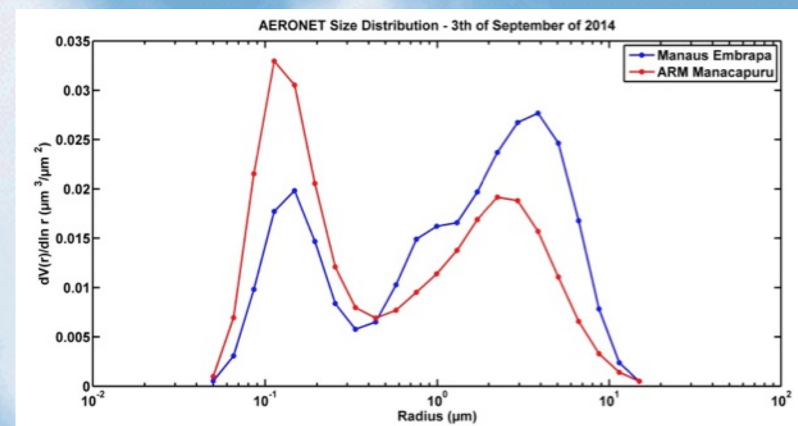


T0=T3



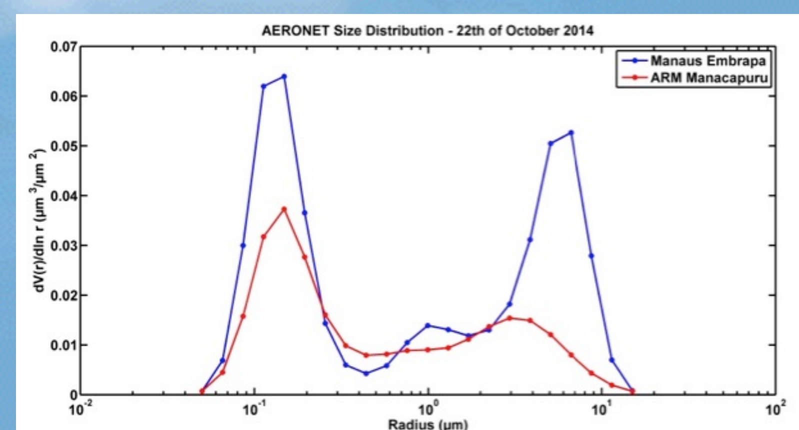


T0<T3

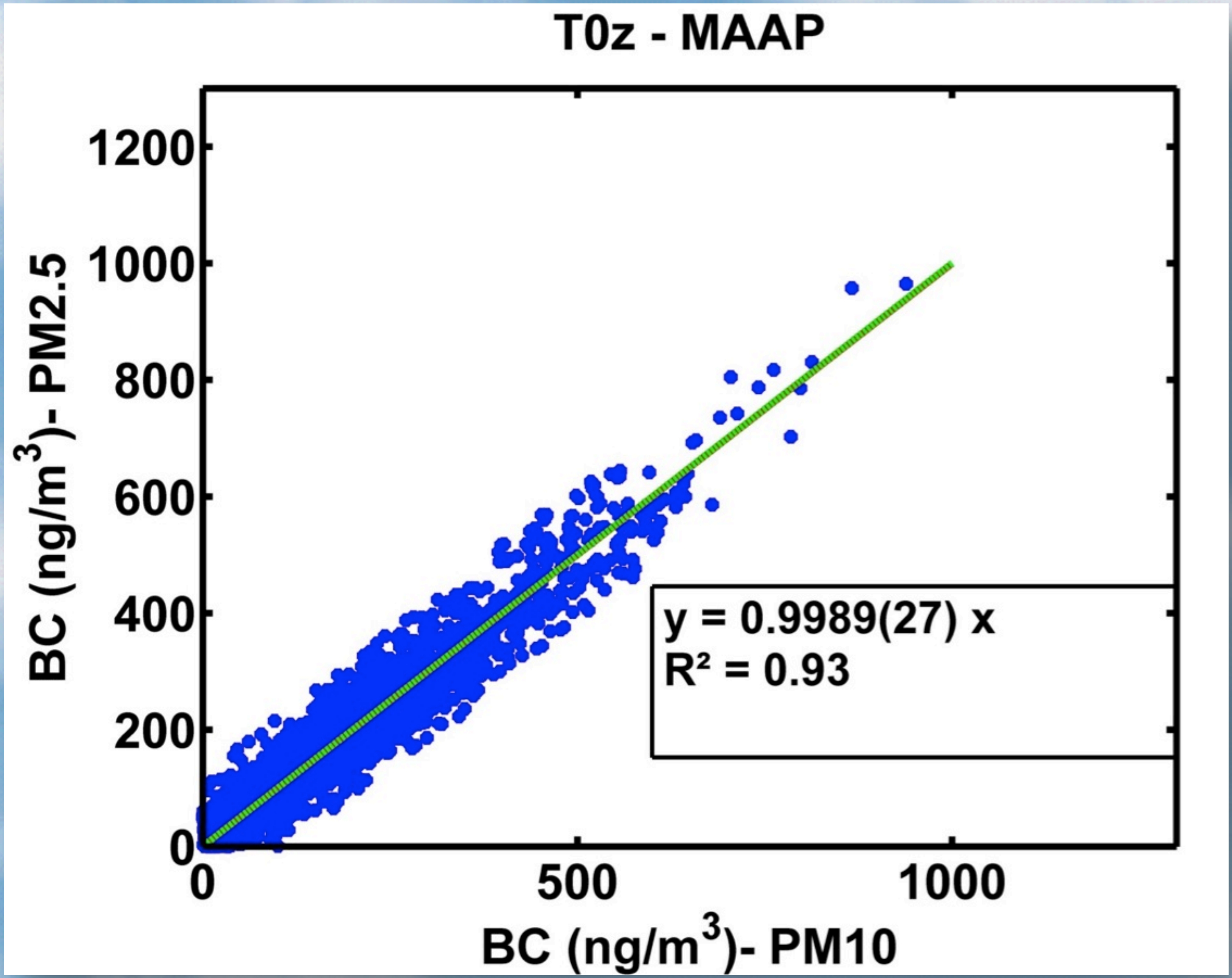


Very stable average diameters for both fine and coarse modes

T0>T3

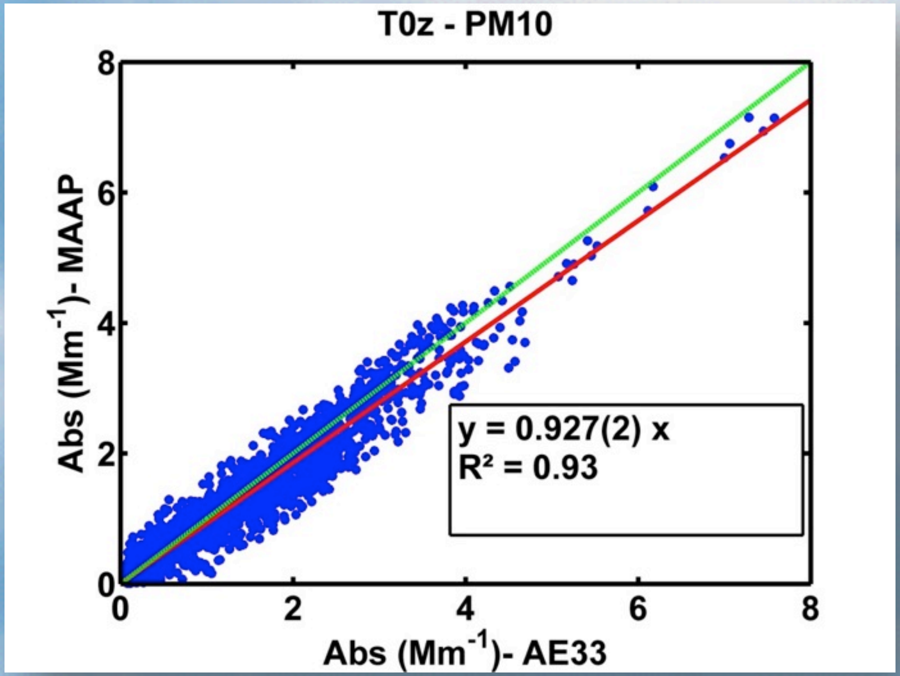


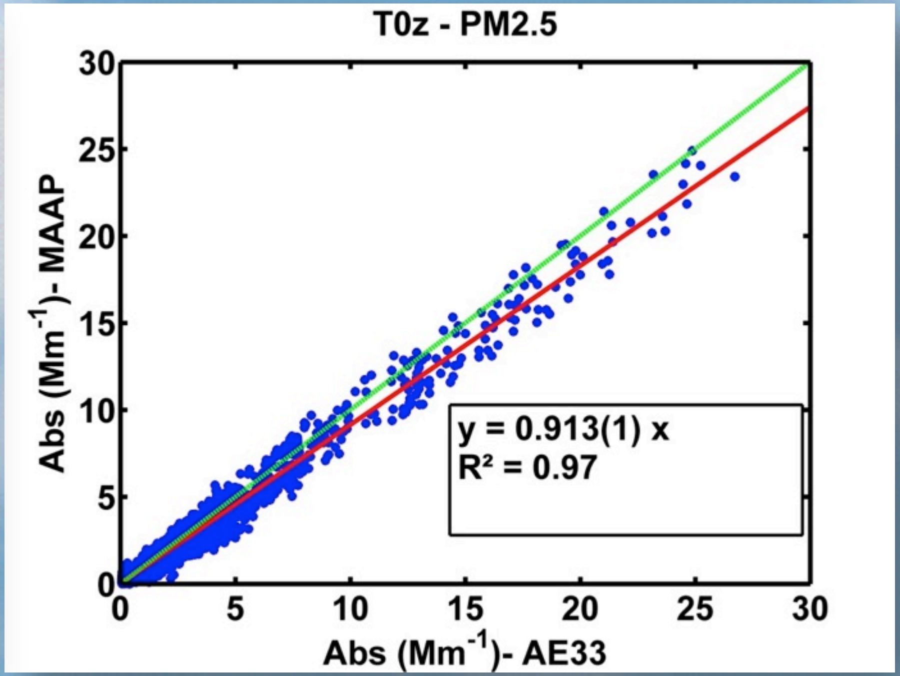
T0z - Absorption PM2.5 versus PM10 MAAP



Bruna Holanda data

T0z – ZF2 – MAAP versus AE33 Aethalometer for PM10 and PM2.5

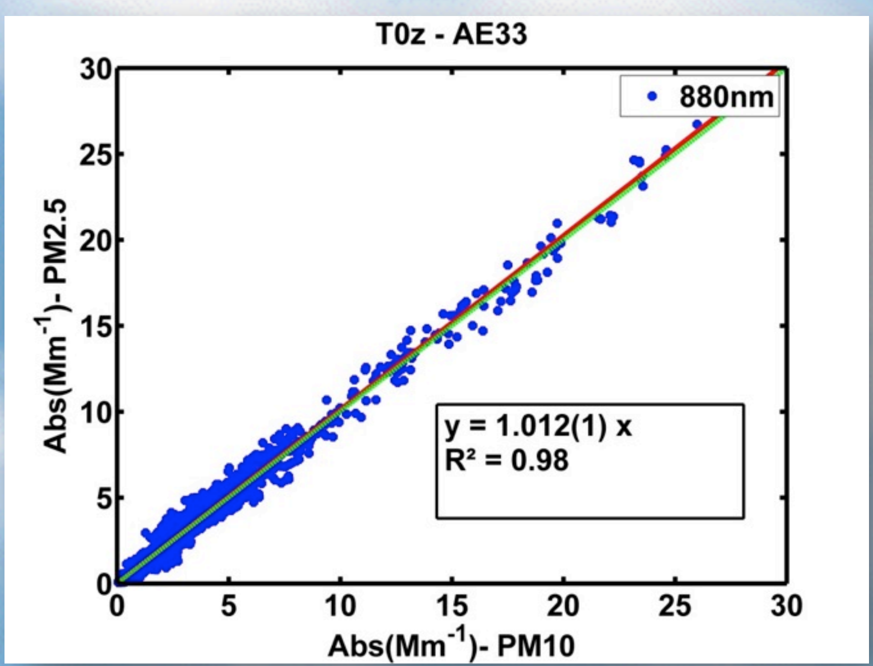




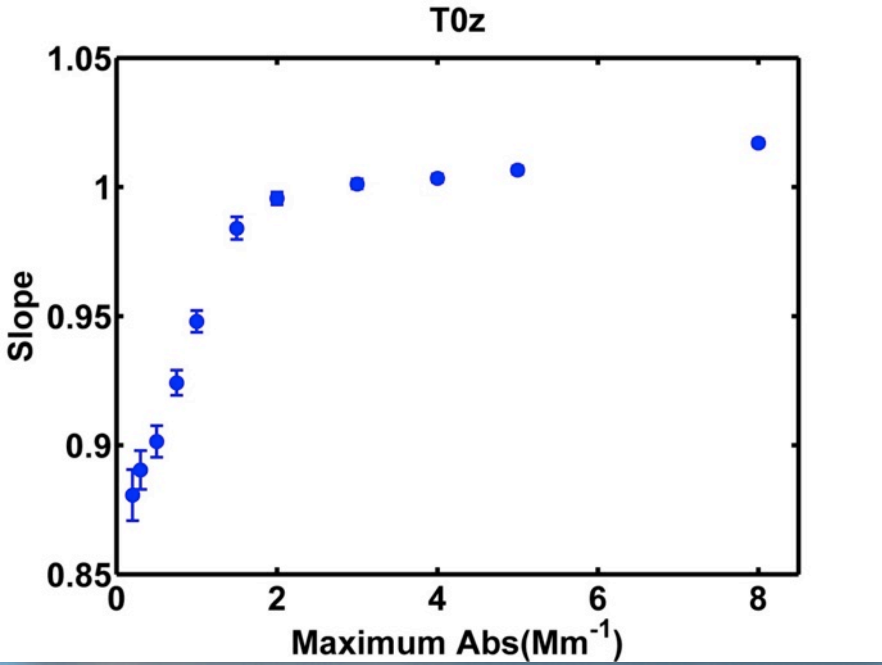
Comparison of the light absorption coefficients at 637nm between AE33 and MAAP with PM10 and PM2.5 inlets

Bruna Holanda data

T0z – PM10 versus PM2.5 absorption

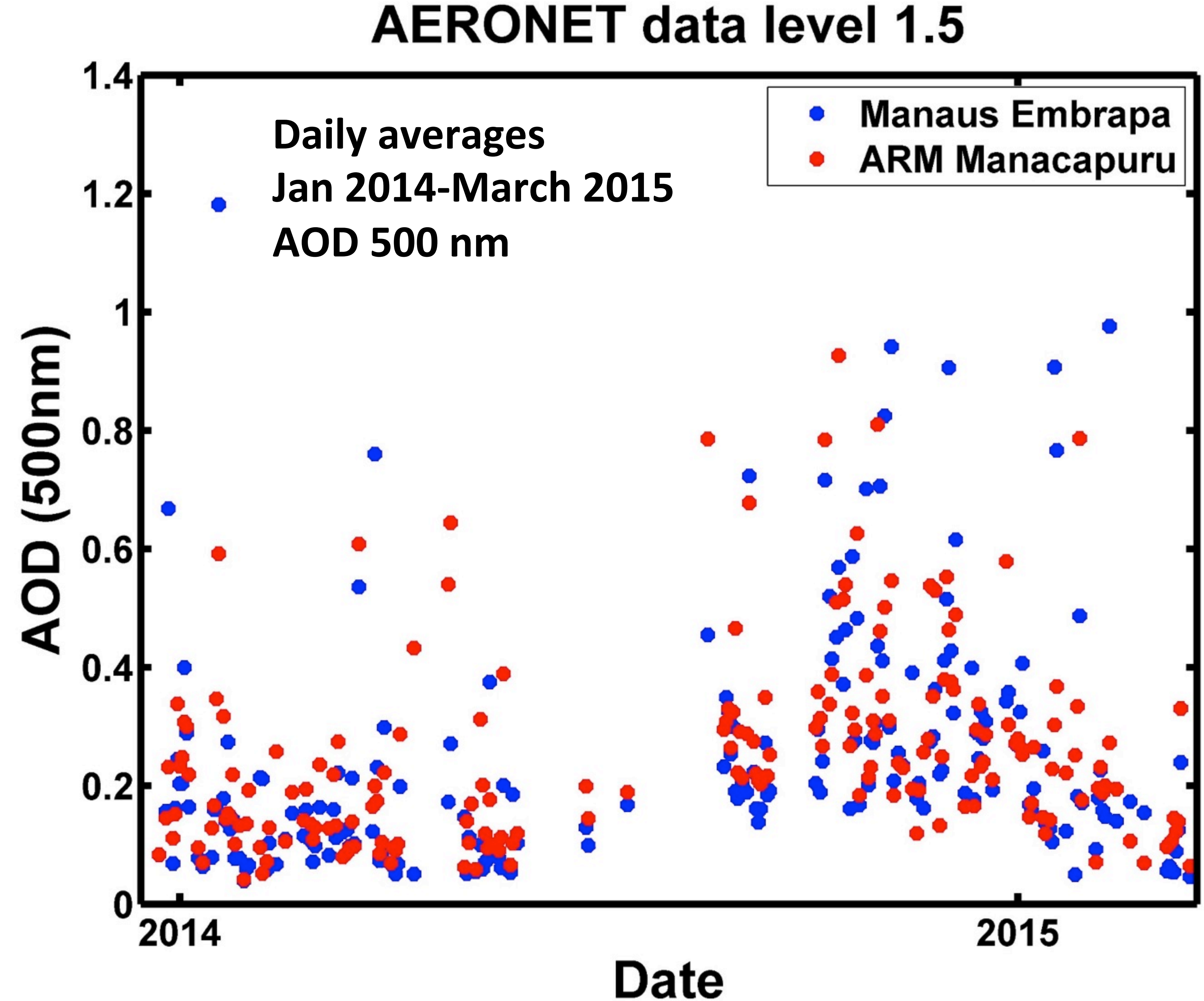


Comparison of the light absorption coefficients at 880nm between AE33 with PM10 and PM2.5 inlets, showing 30 min averages of data compensated for the loading effect and multiple scattering.

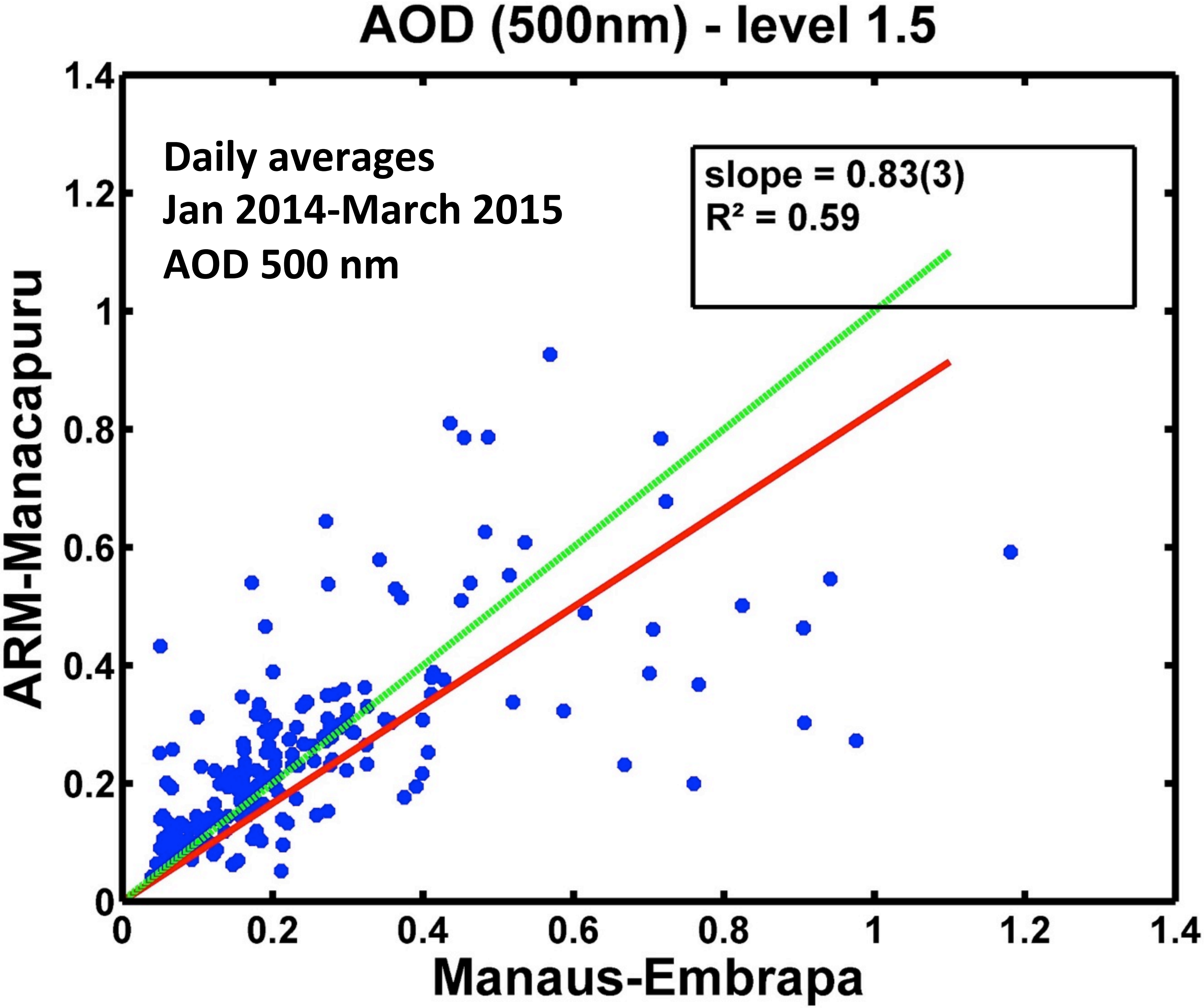


Slopes of the correlation between light absorption coefficients at 880nm measured by AE33 with PM10 and PM2.5 inlets, as a function of the maximum abs used in the regression.

Bruna Holanda data

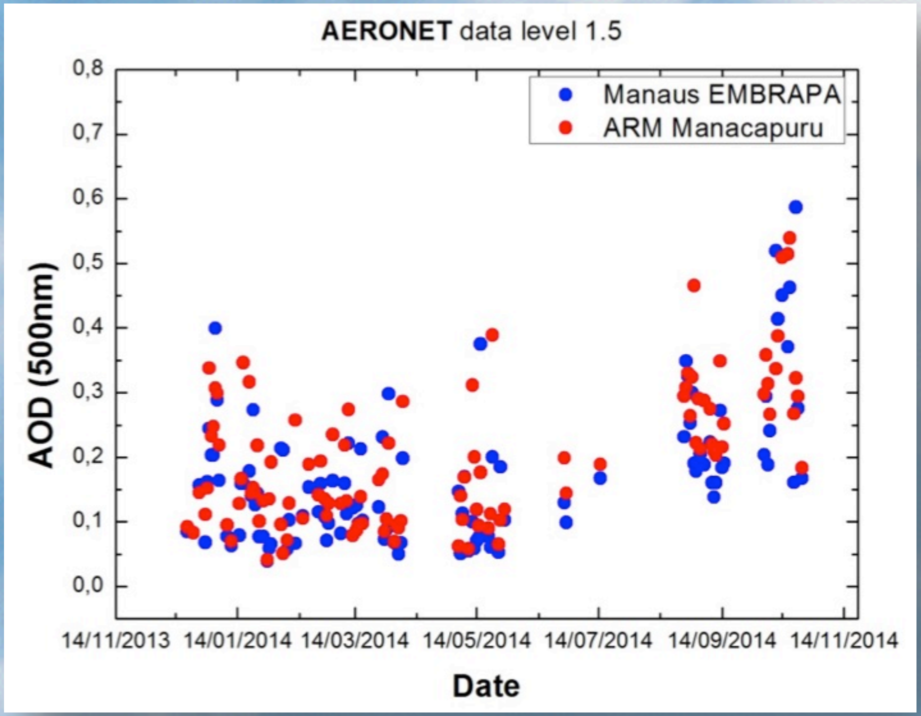


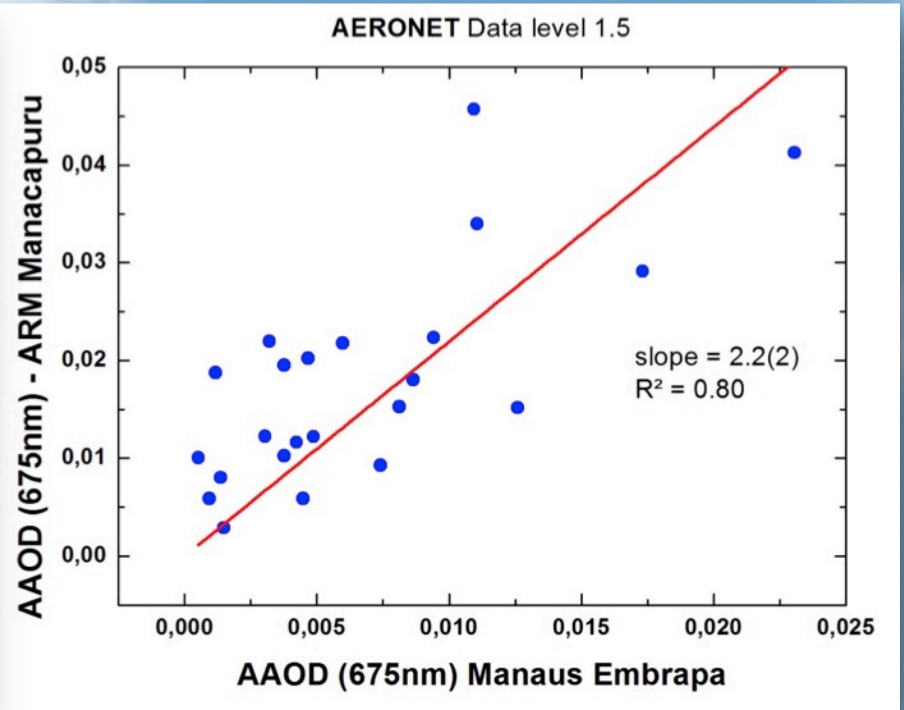
AERONET data level 1.5
Daily averages
Jan 2014-March 2015
AOD 500 nm
Manaus Embrapa
ARM Manacapuru
AOD (500nm)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2014
2015
Date



AOD (500nm) - level 1.5
Daily averages
Jan 2014-March 2015
AOD 500 nm
slope = 0.83(3)
R² = 0.59
ARM-Manacapuru
Manaus-Embrapa
0
0.2
0.4
0.6
0.8
1
1.2
1.4

Absorption aerosol optical thickness from AERONET T0e – Embrapa versus T3-Manacapuru





AOD similar at both sites (T0e and T3)

Absorption: Factor of 2 higher BC at T3 than T02

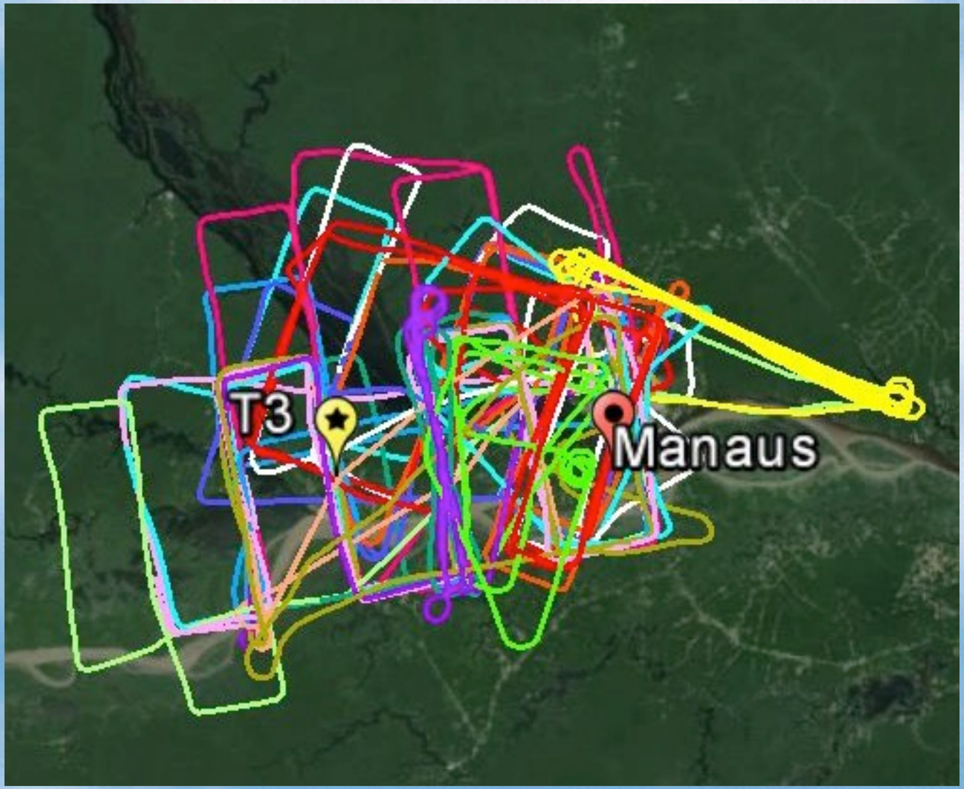
ACRIDICON - Aerosol, Cloud, Precipitation, and Radiation Interactions and Dynamics of CONvective Cloud Systems

"Intensive Airborne Research in Amazonia 2014" (IARA-2014)

South American Biomass Burning Analysis (SAMBBA) field experiment

G-1 Flight Paths during IARA

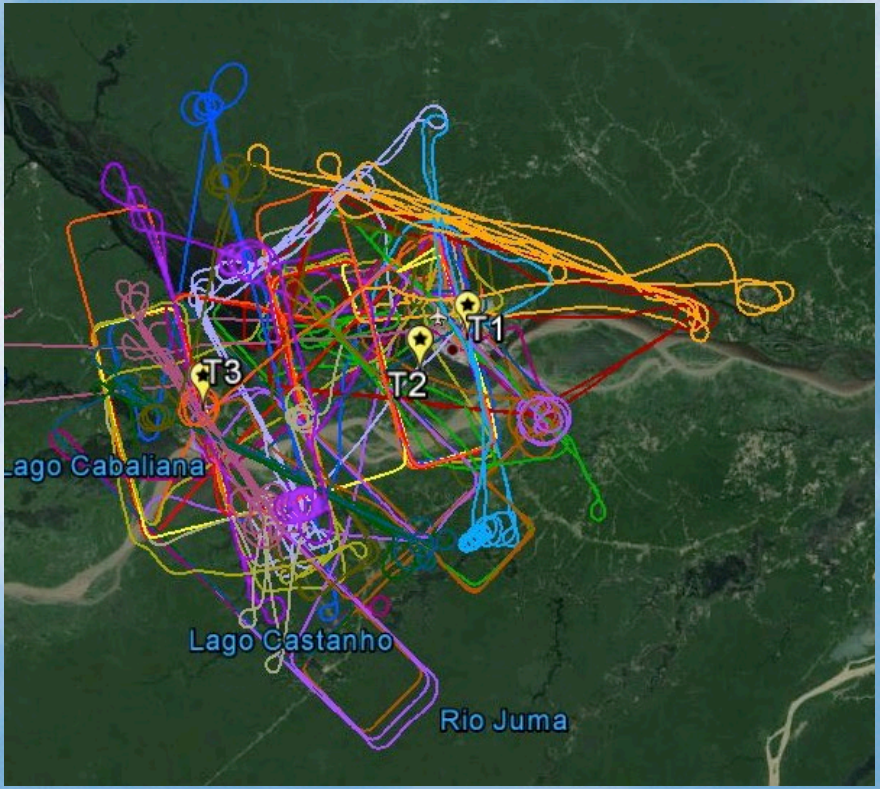
Phase 1 (Wet season)



16 flights – 42.8 hours

Feb 15th - March 26st , 2014

Phase 2 (dry season)

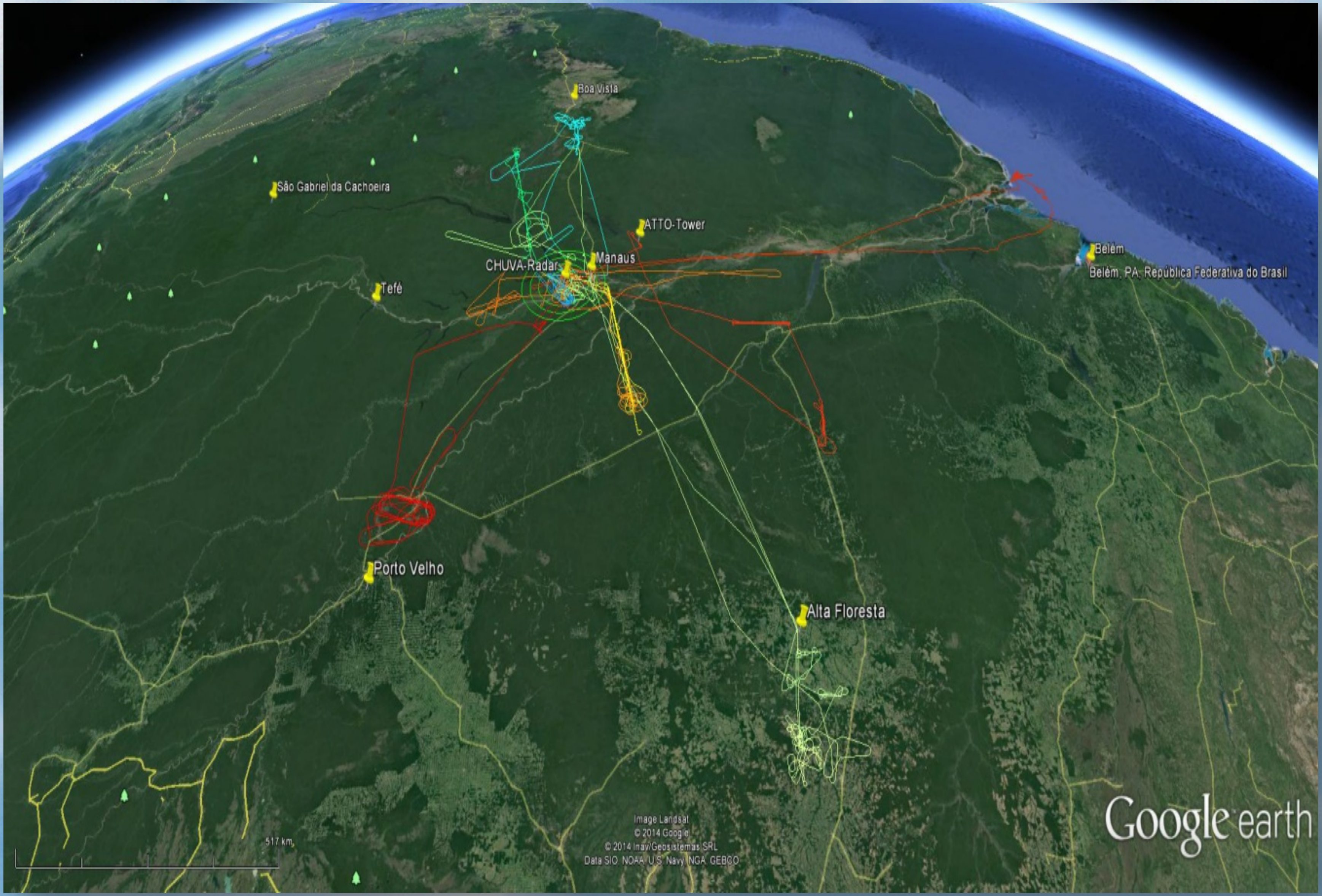


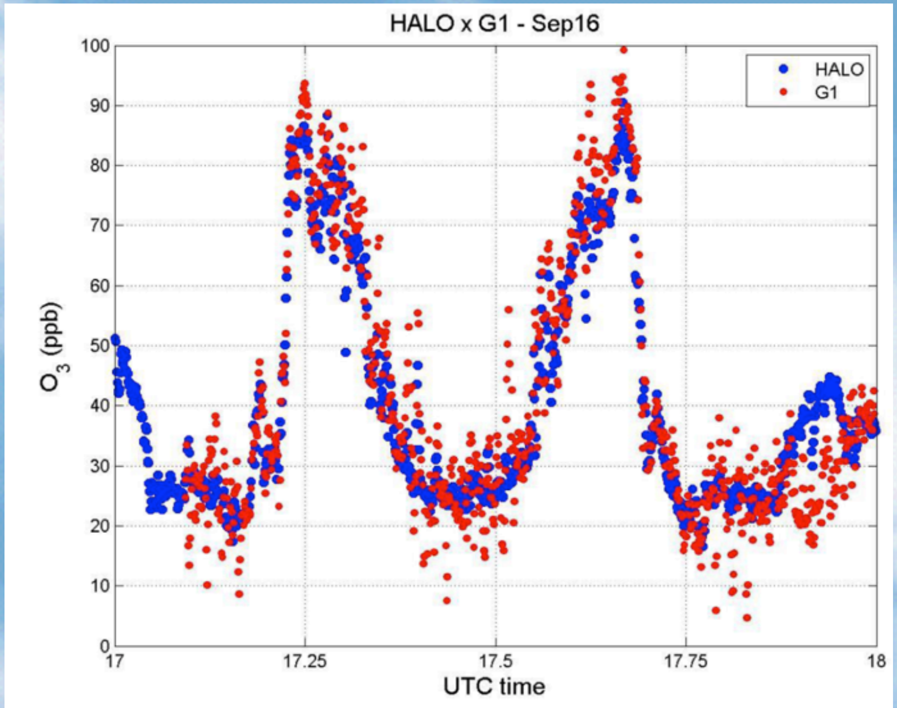
19 flights – 53.7 hours

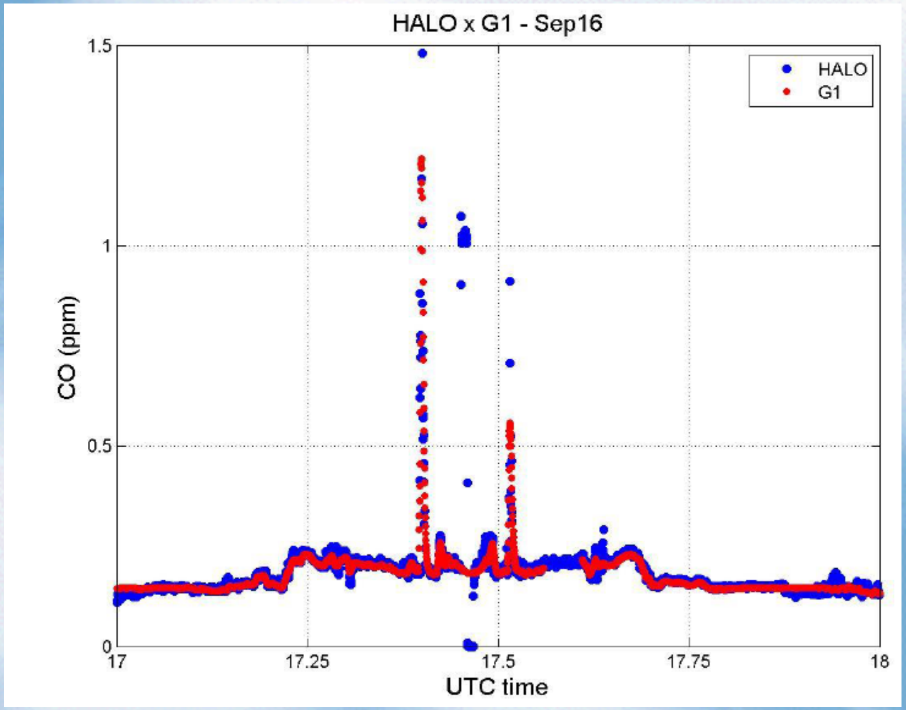
Sep 1st - Oct 10th , 2014

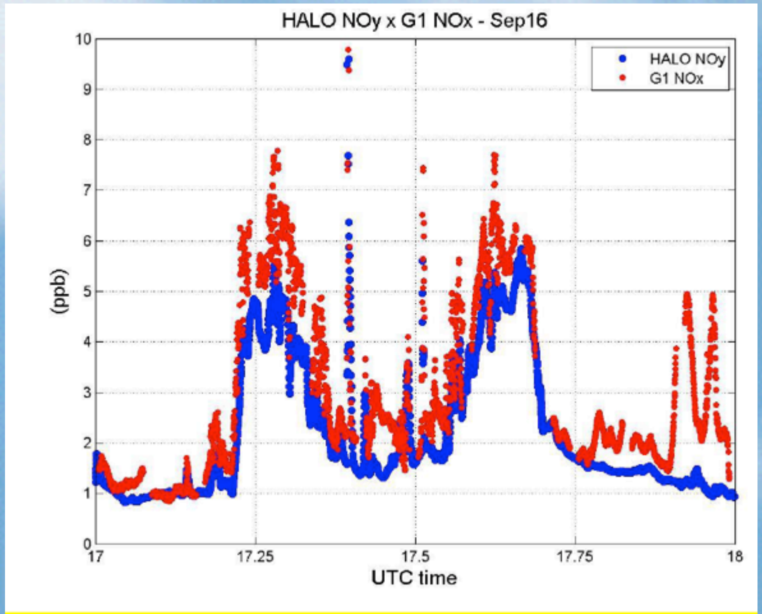
G5 HALO plane - “High Altitude and Long Range Research Aircraft” at the “ACRIDICON: Aerosol, Cloud, Precipitation, and Radiation Interactions and Dynamics of CONvective Cloud Systems”.

ACRIDICON Flights HALO plane dry season 2014



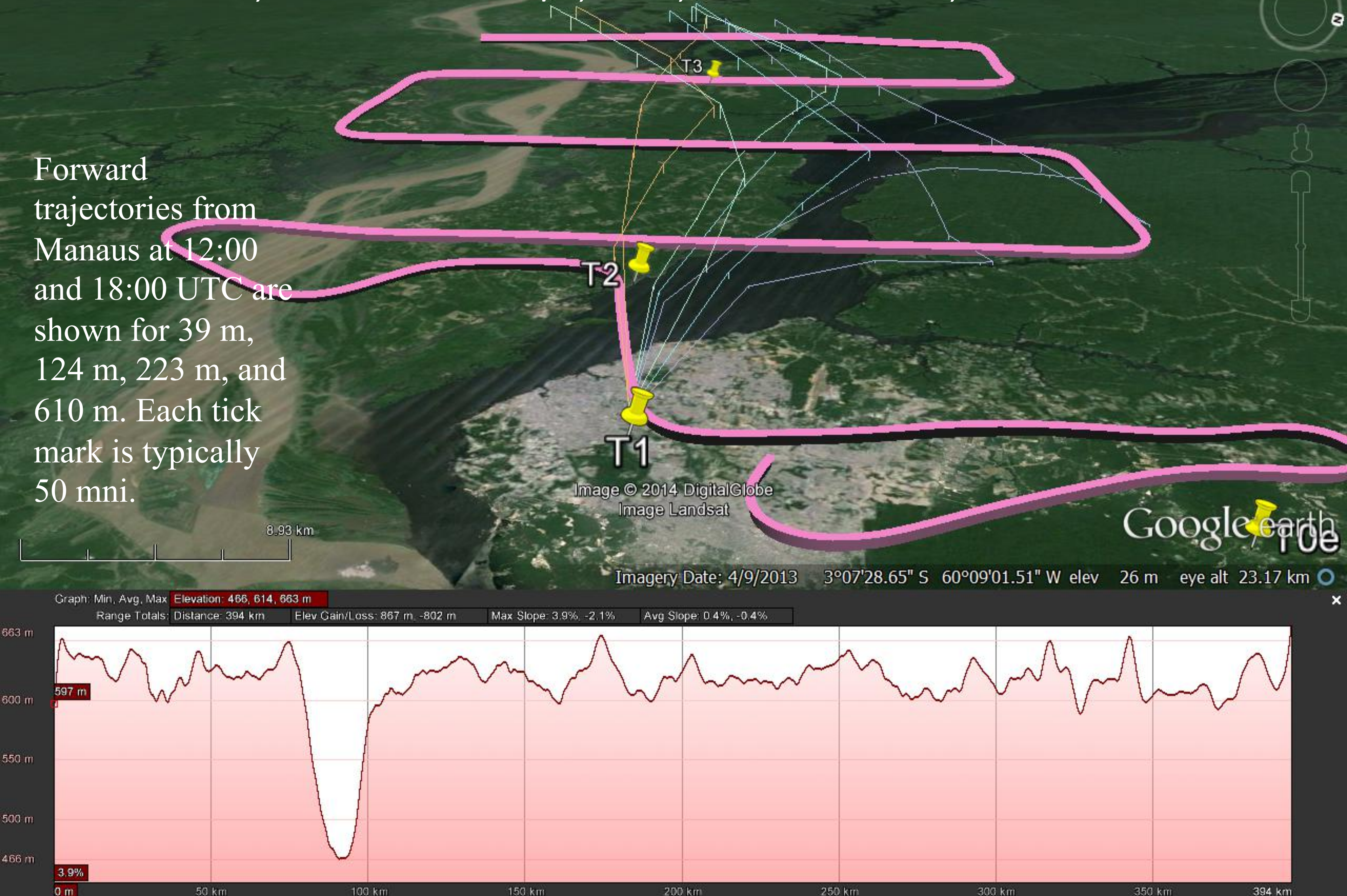






It was expected that HALO NOy > G1 NOx

FLIGHT TRACK, GoAmazon2014/5, IOP1, 17 March 2014, 16:24 to 17:31 UTC

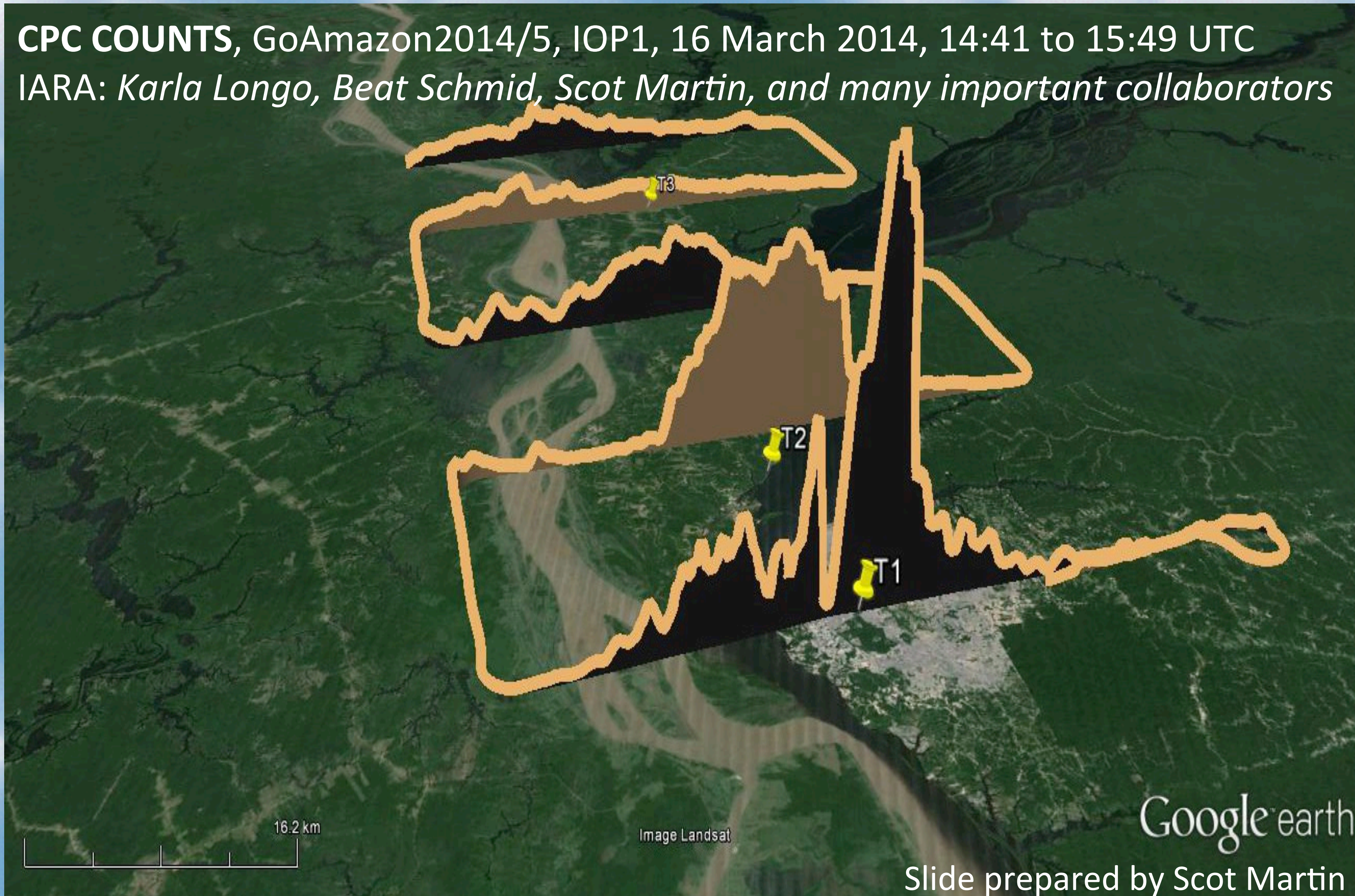


Forward trajectories from Manaus at 12:00 and 18:00 UTC are shown for 39 m, 124 m, 223 m, and 610 m. Each tick mark is typically 50 mni.

Slide prepared by Scot Martin

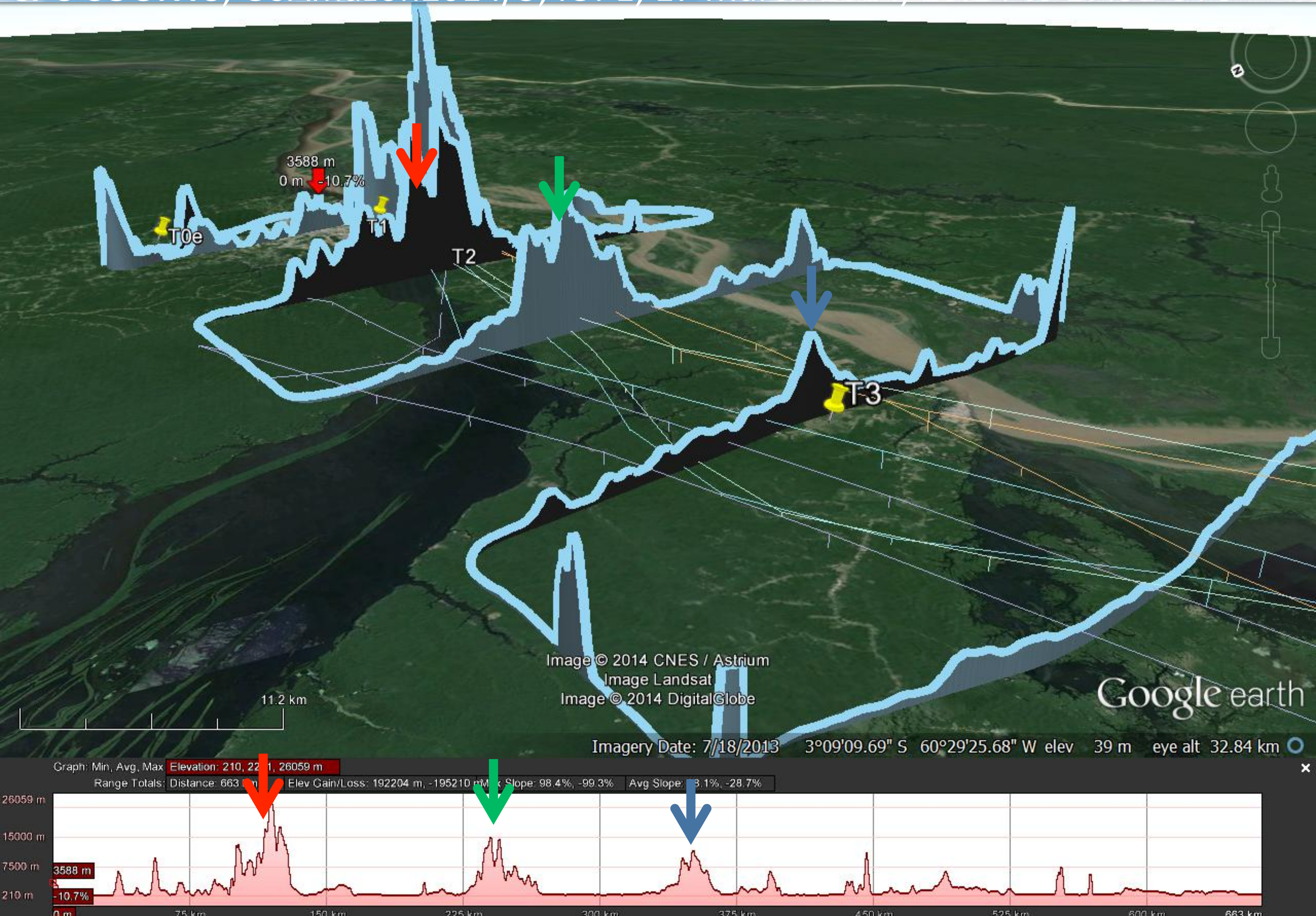
CPC COUNTS, GoAmazon2014/5, IOP1, 16 March 2014, 14:41 to 15:49 UTC

IARA: *Karla Longo, Beat Schmid, Scot Martin, and many important collaborators*

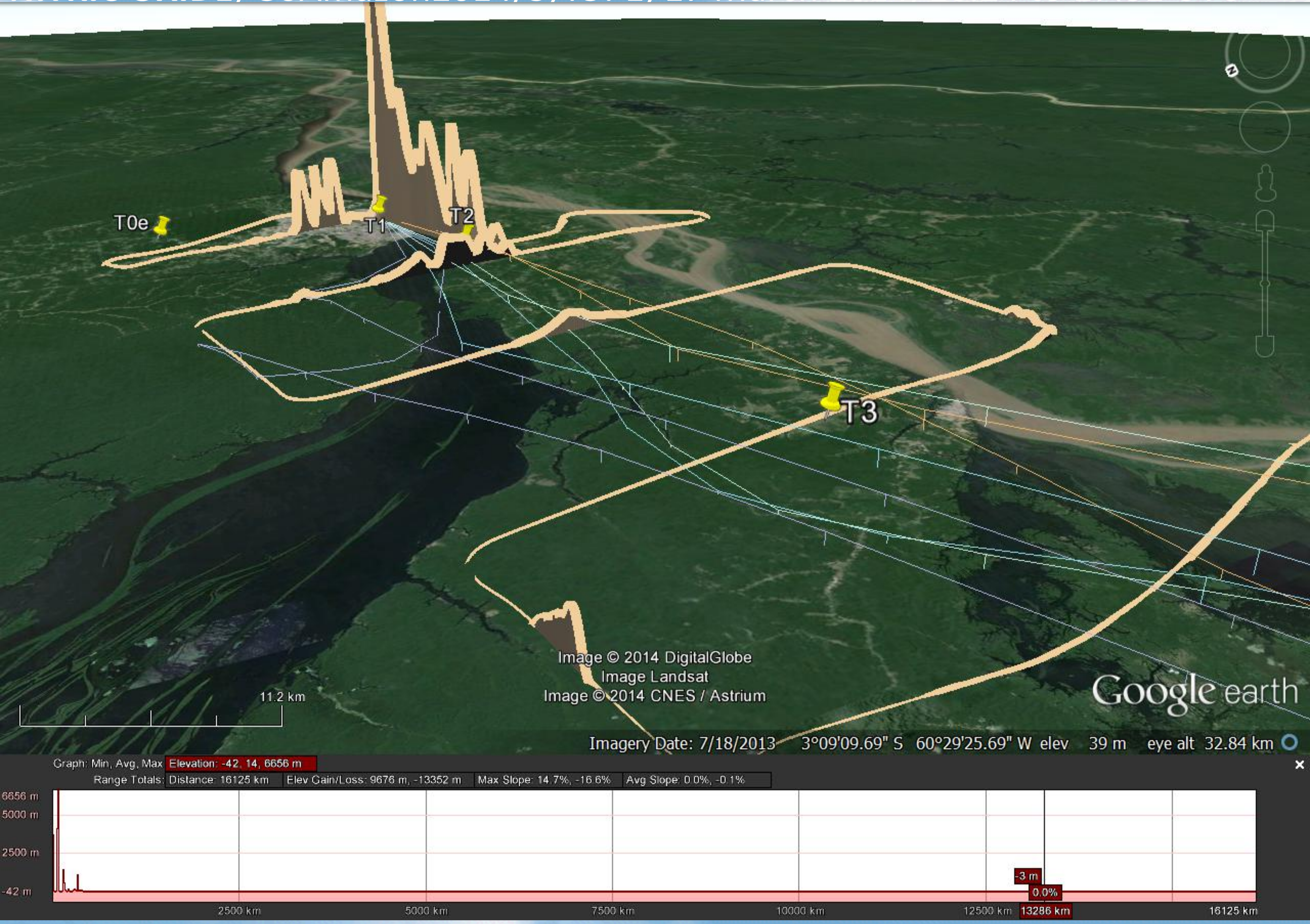


Slide prepared by Scot Martin

CPC COUNTS, GoAmazon2014/5, IOP1, 17 March 2014, 16:24 to 17:31 UTC

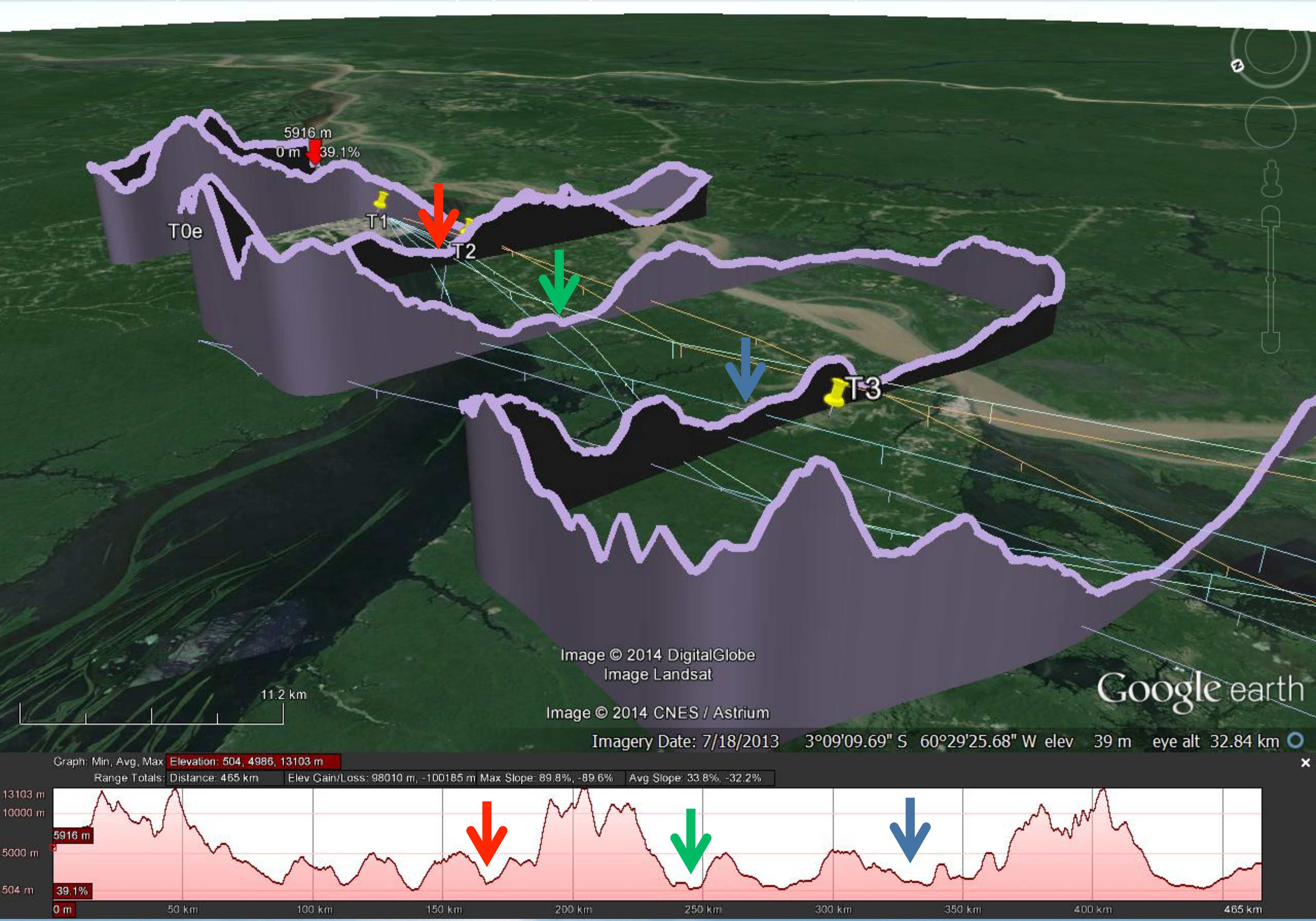


NITRIC OXIDE, GoAmazon2014/5, IOP1, 17 March 2014, 16:24 to 17:31 UTC



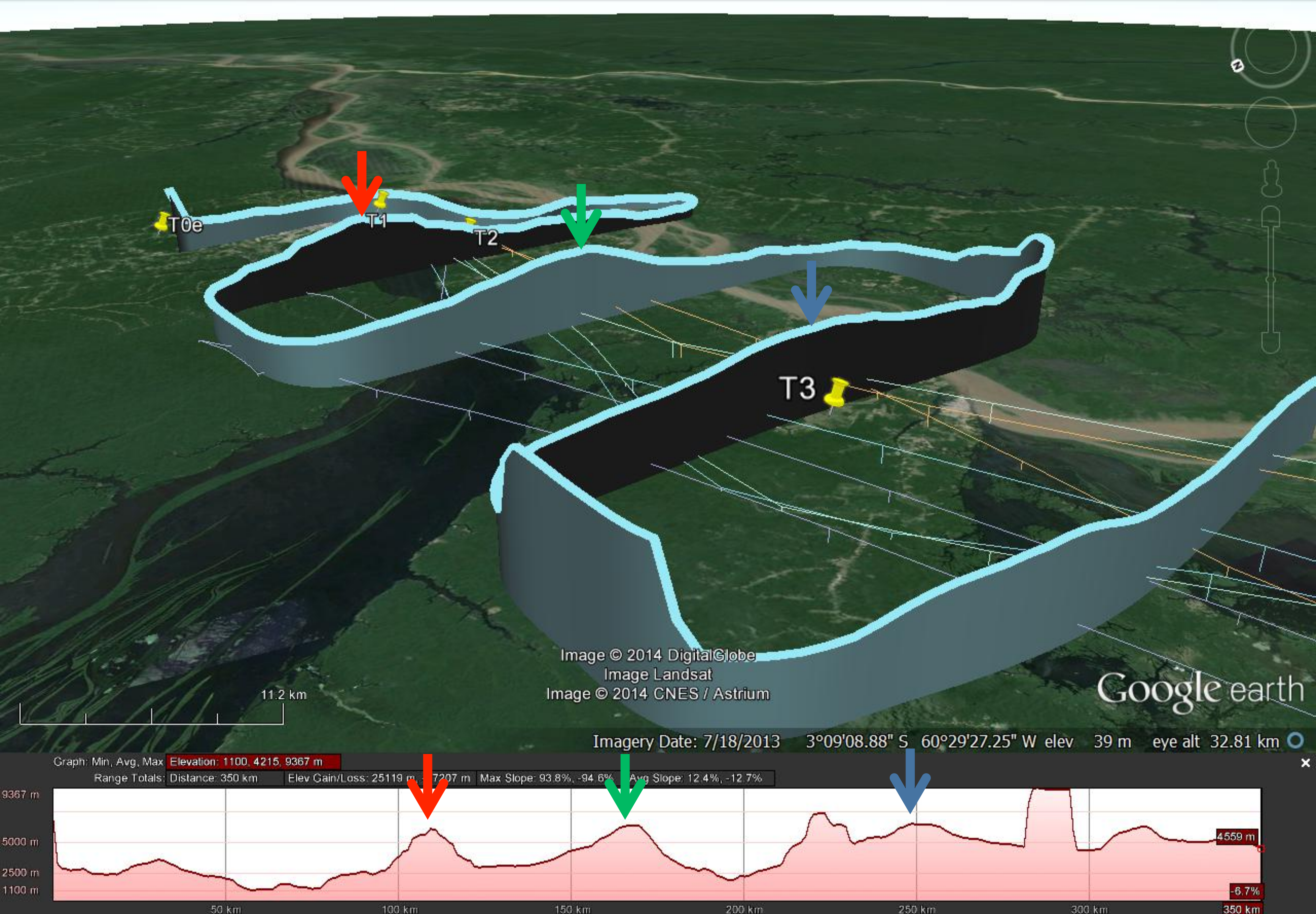
Slide prepared by Scot Martin

ISOPRENE, GoAmazon2014/5, IOP1, 17 March 2014, 16:24 to 17:31 UTC



Slide prepared by Scot Martin

PARTICLE ORGANIC, GoAmazon2014/5, IOP1, 17 March 2014, 16:24 to 17:31

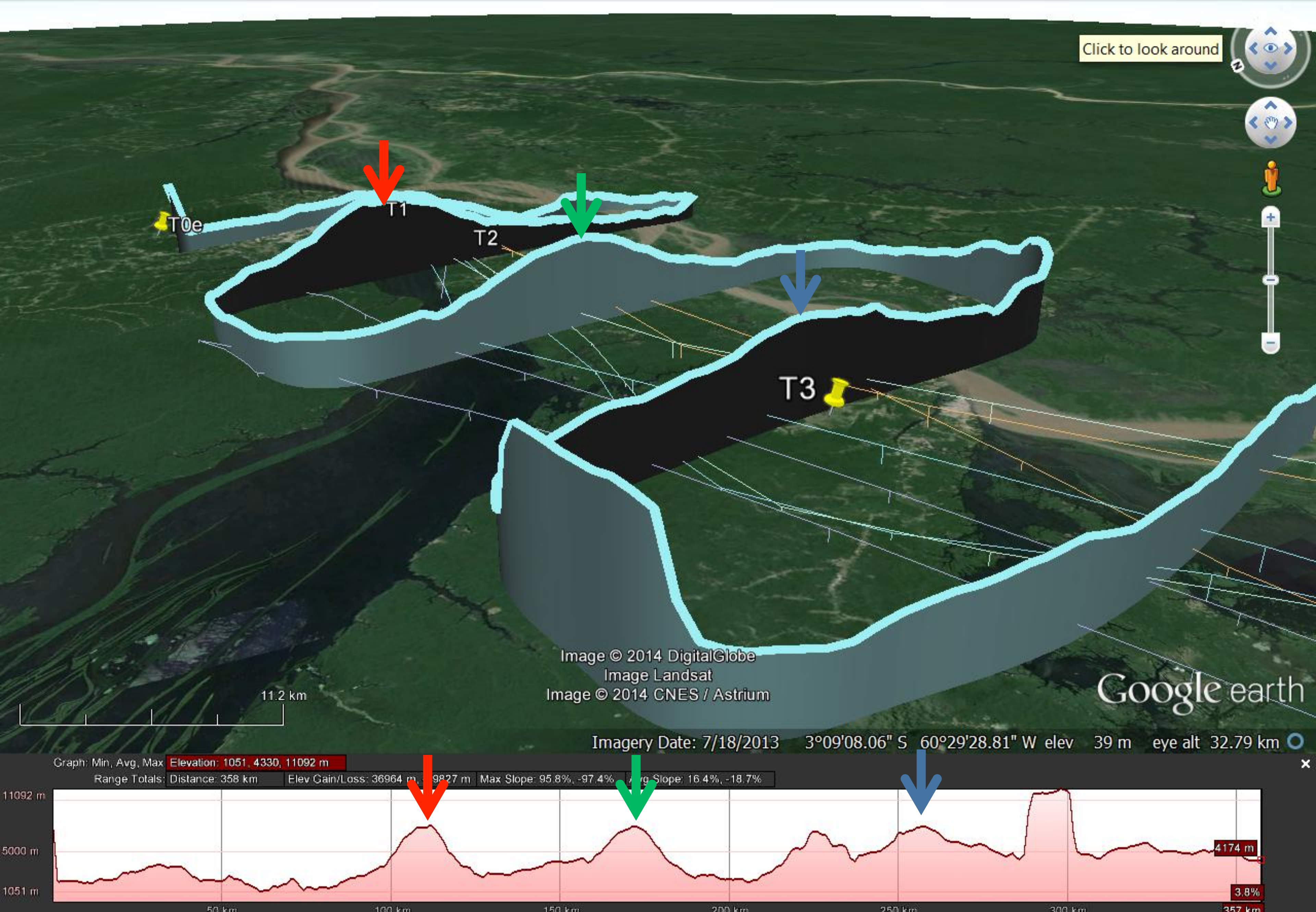


Slide prepared by Scot Martin

PARTICLE SULFATE, GoAmazon2014/5, IOP1, 17 March 2014, 16:24 to 17:31

Slide prepared by Scot Martin

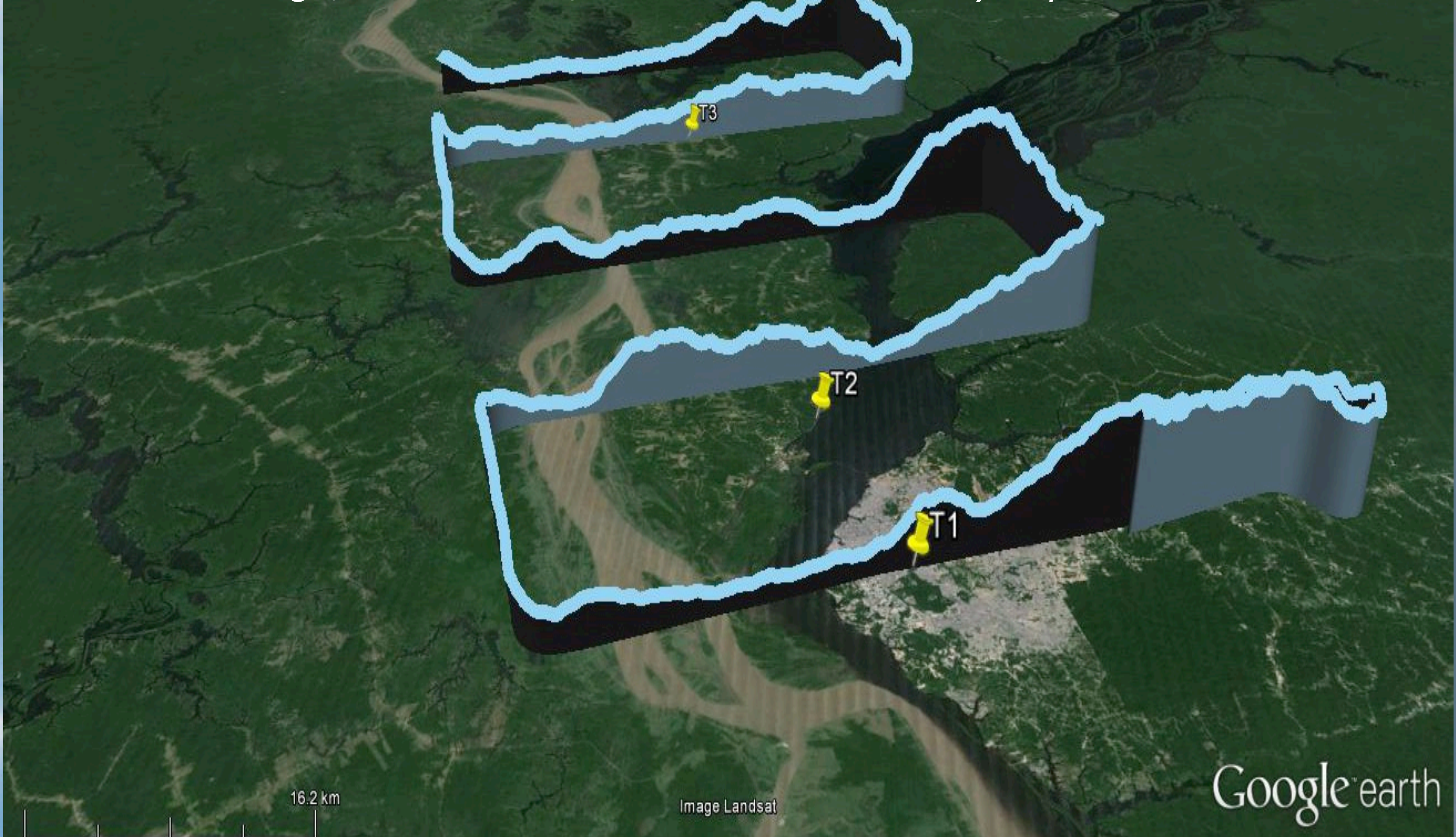
PARTICLE NITRATE, GoAmazon2014/5, IOP1, 17 March 2014, 16:24 to 17:31



Slide prepared by Scot Martin

ISOPRENE CONCENTRATIONS, GoAmazon2014/5, IOP1, 16 March 2014

IARA: *Karla Longo, Beat Schmid, Scot Martin, and many important collaborators*



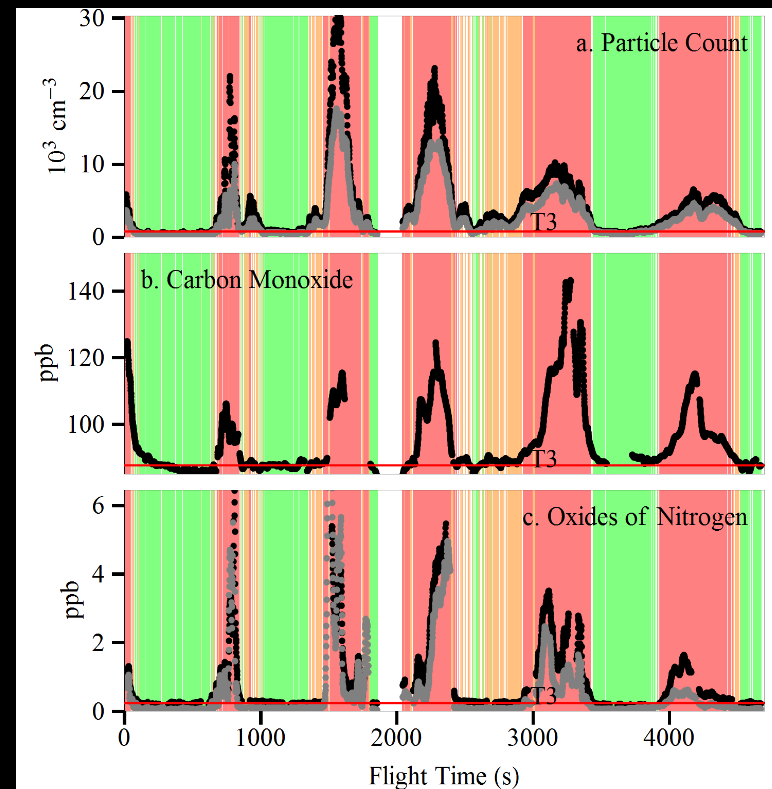
Slide prepared by Scot Martin

ISOPRENE CONC, GoAmazon2014/5, IOP1, 17 March 2014, 16:24 to 17:31 UTC

IARA: *Karla Longo, Beat Schmid, Scot Martin, and many important collaborators*

Slide prepared by Scot Martin

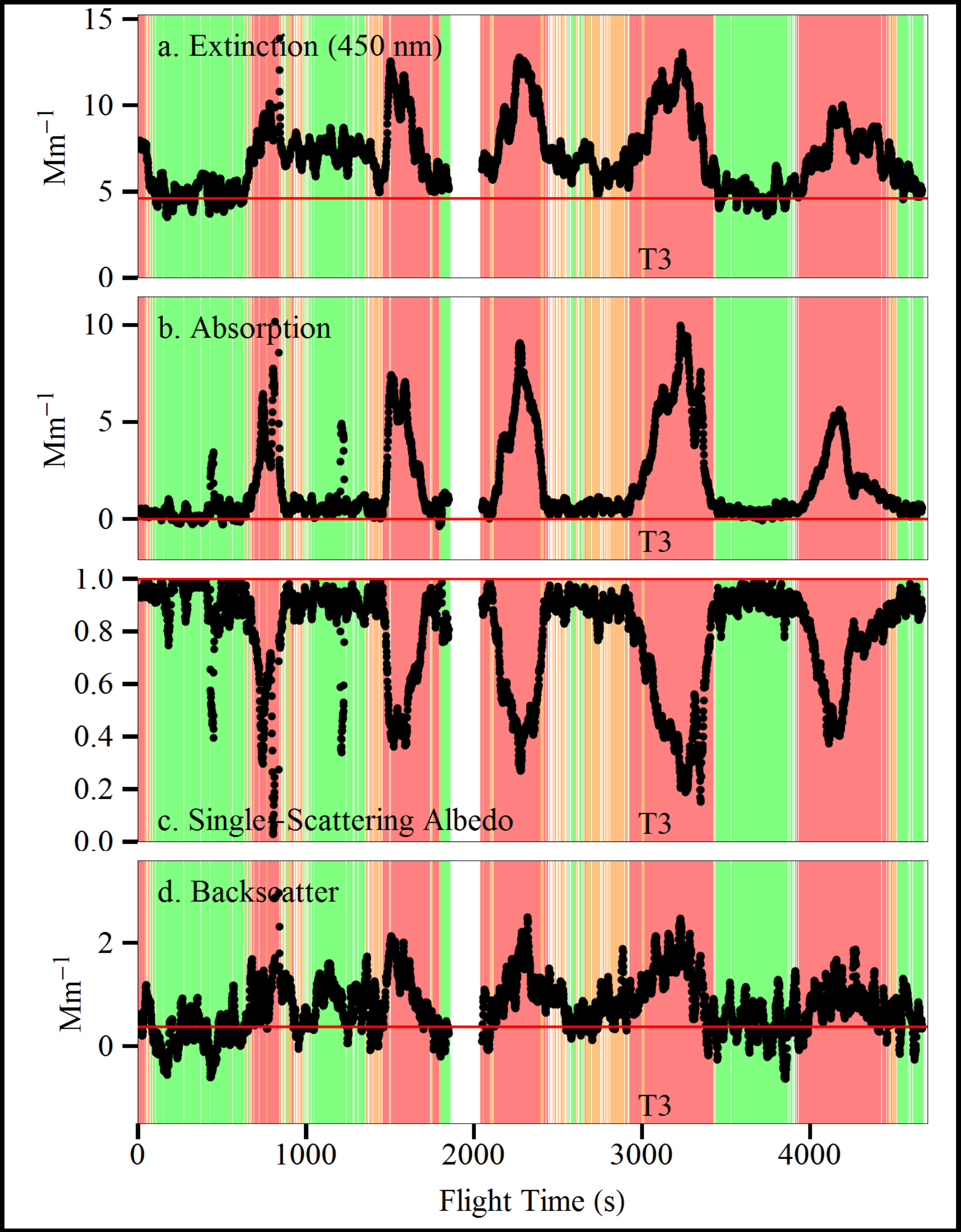
Transverse Transects of Urban Plume
500 m, 11 AM local, 13 March 2014



Data Source: Mei Fan, Stephen Springston, IARA Experiment, DOE AAF G1 Platform

Optical Properties

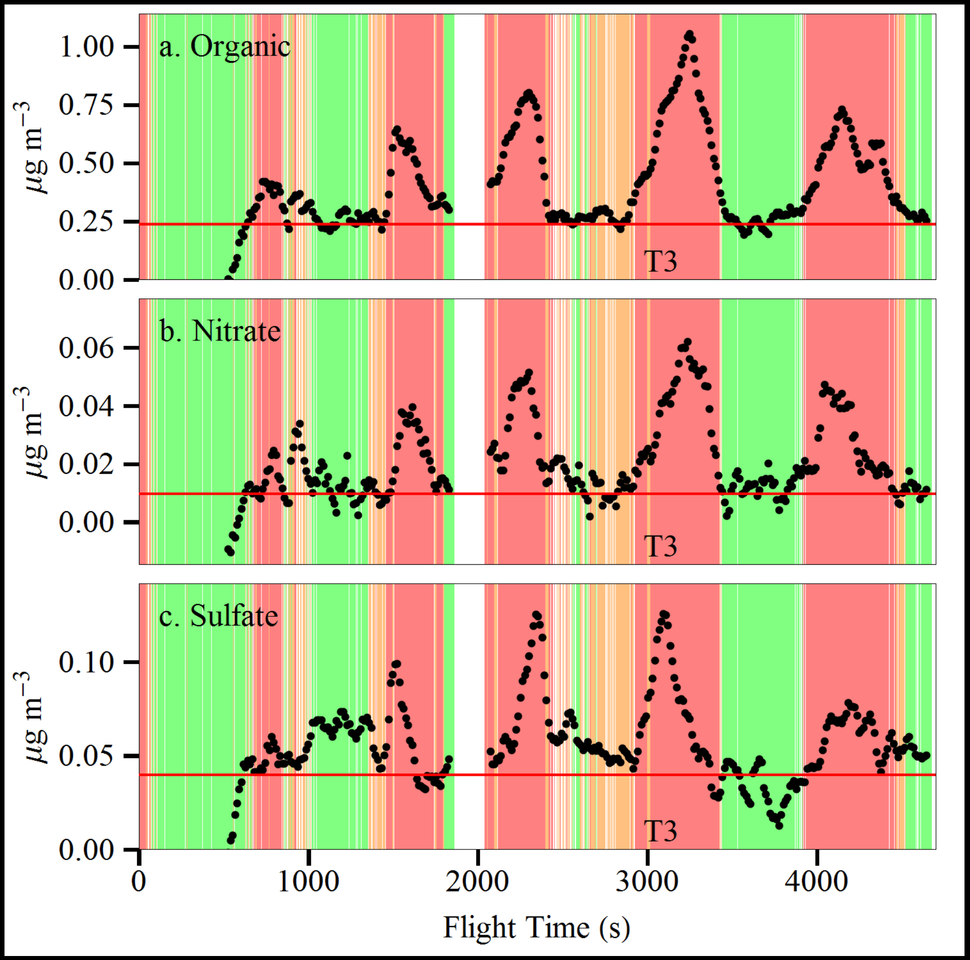
500 m, 11 AM local, 13 March 2014



Data Source: Duli Chand, IARA Experiment, DOE AAF G1 Platform

Organic, Nitrate, and Sulfate Mass Concentrations

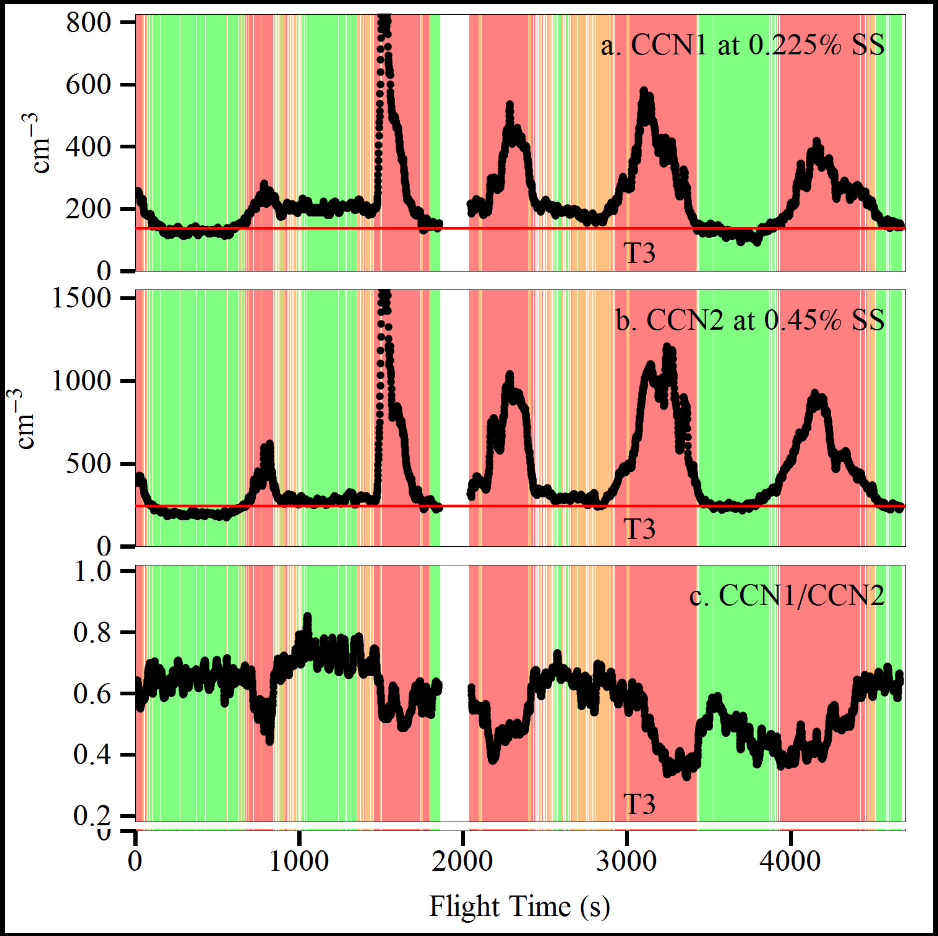
500 m, 11 AM local, 13 March 2014



Data Source: John Shilling, IARA Experiment, DOE AAF G1 Platform

CCN Concentrations

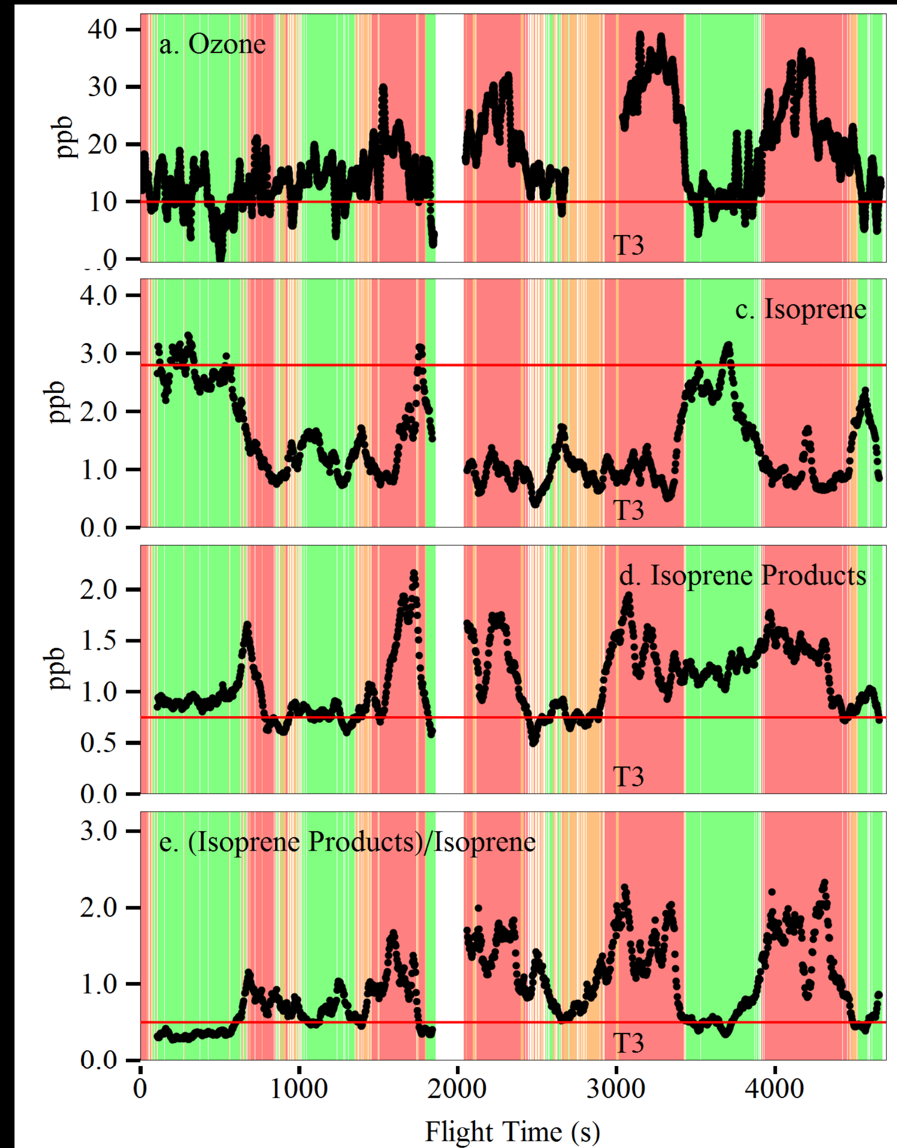
500 m, 11 AM local, 13 March 2014



Data Source: Mei Fan, IARA Experiment, DOE AAF G1 Platform

VOC Concentrations

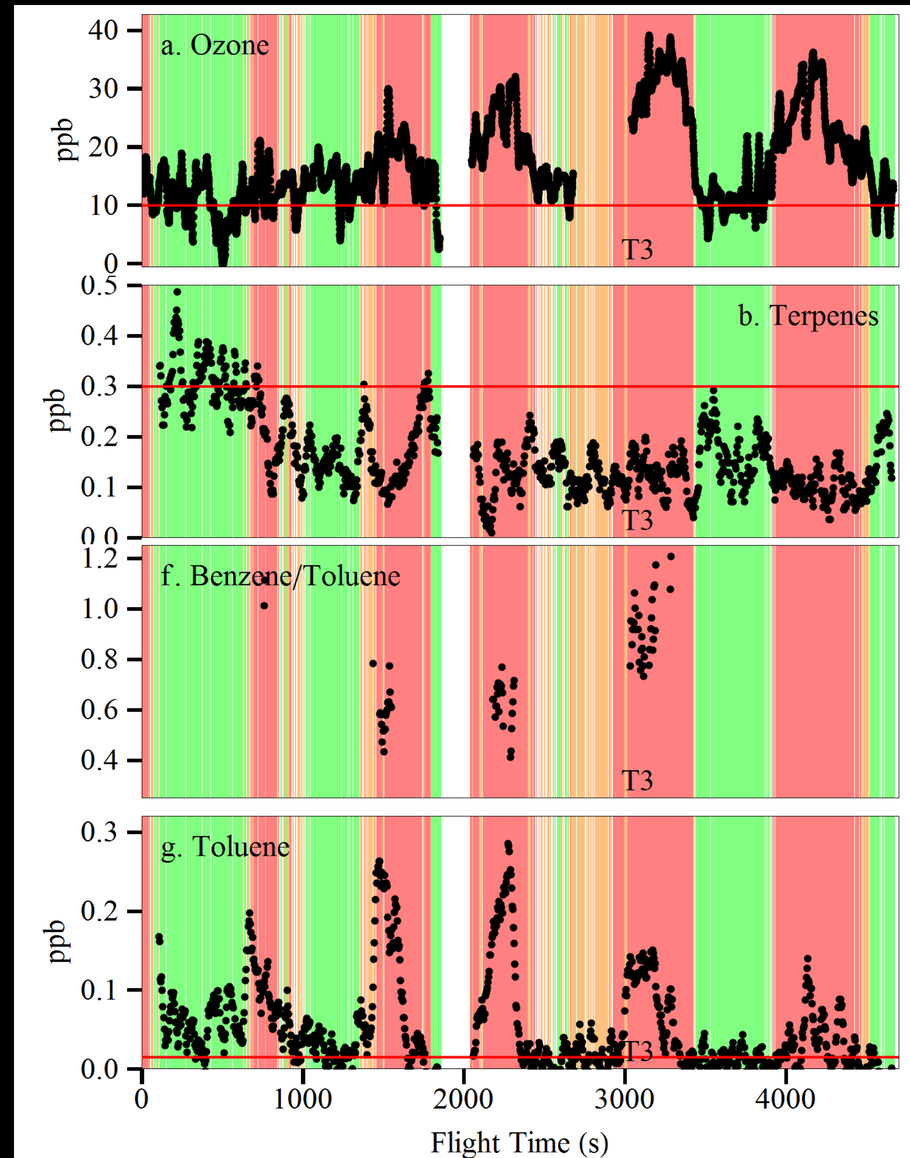
500 m, 11 AM local, 13 March 2014



Data Source: John Shilling, IARA Experiment, DOE AAF G1 Platform

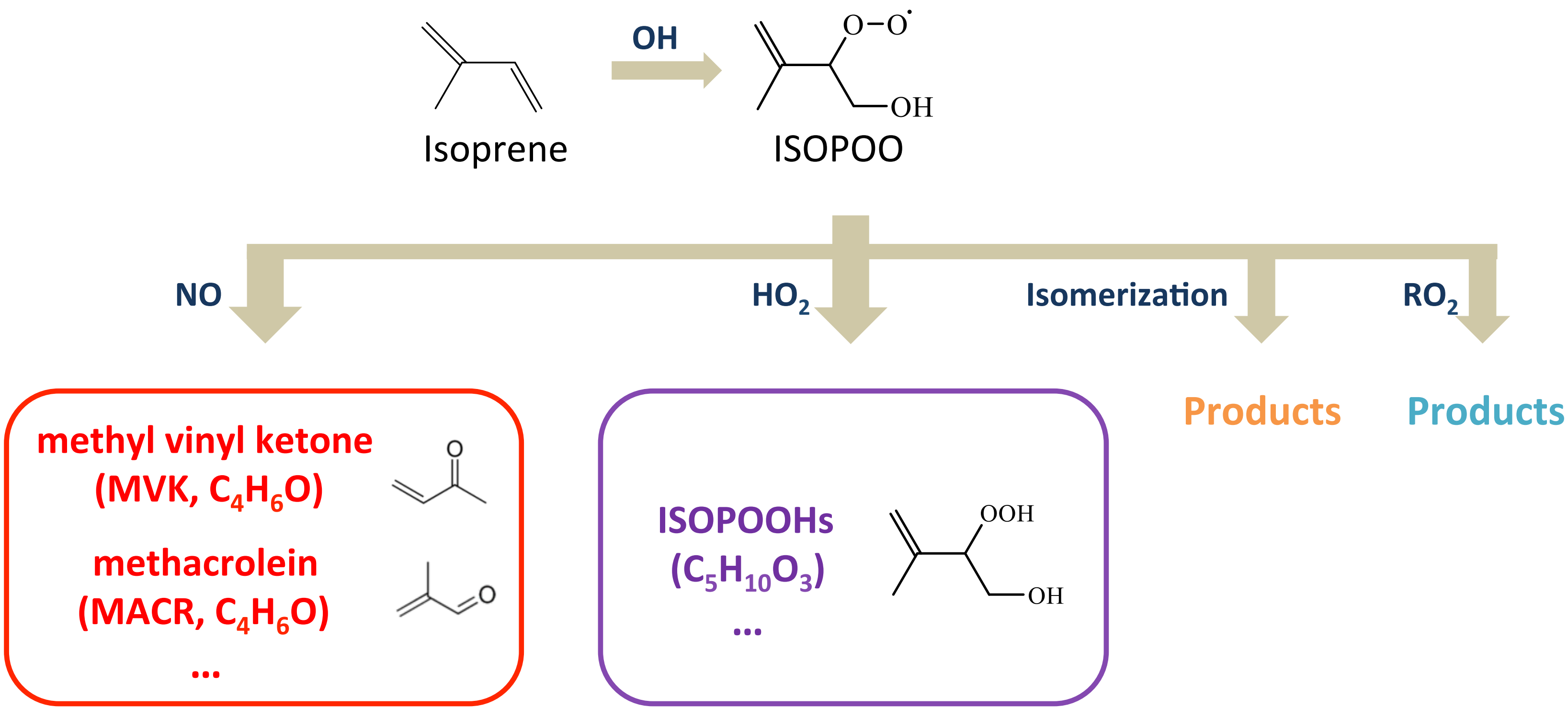
VOC Concentrations

500 m, 11 AM local, 13 March 2014



Data Source: John Shilling, IARA Experiment, DOE AAF G1 Platform

Isoprene Photochemistry in Transition?

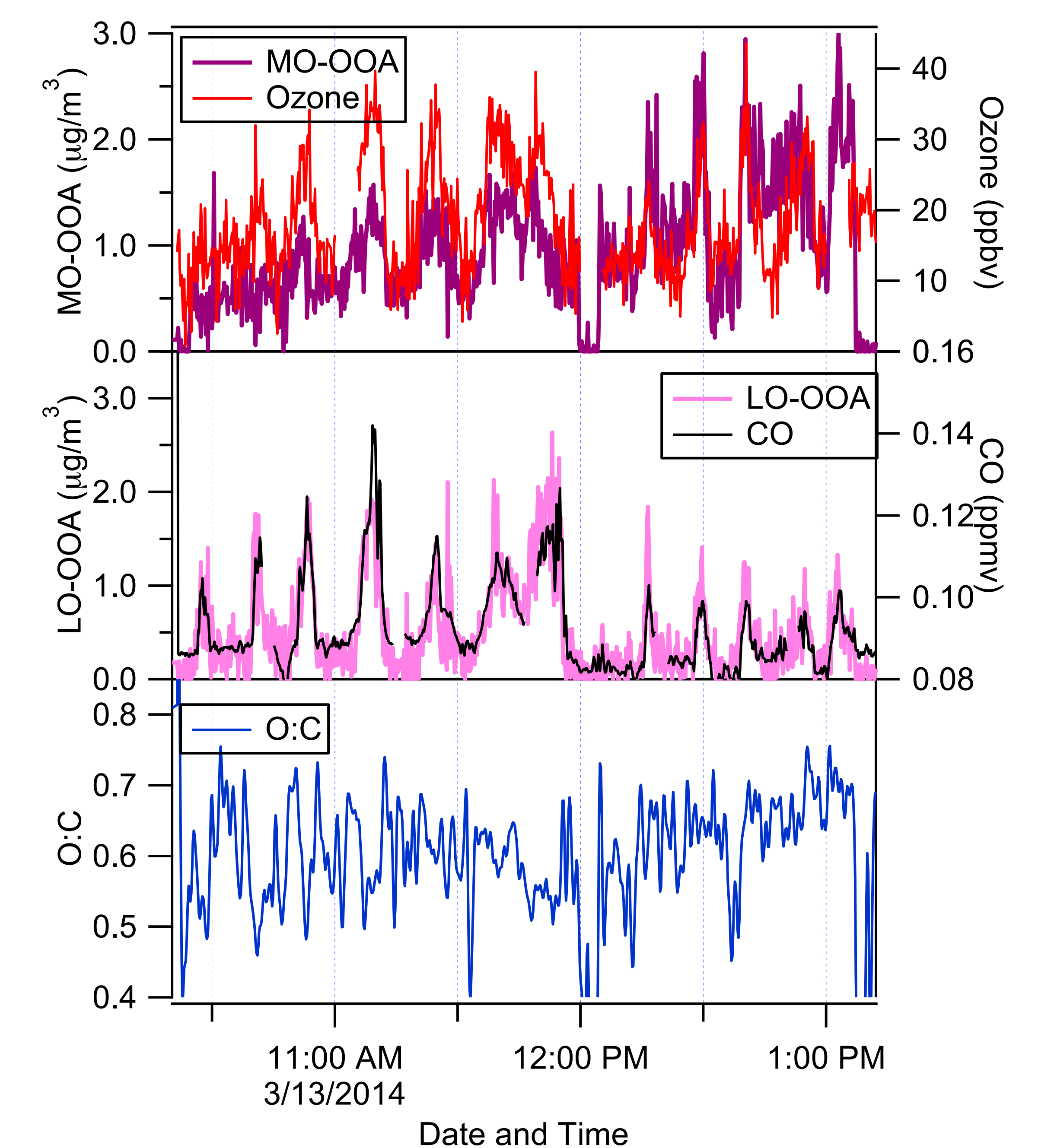


(Tuazon et al., 1990; Paulot et al., 2009; Surratt et al., 2010; Crounse et al., 2011, Peeters et al., 2009; 2010; 2014; Fuchs et al., 2013…)

PMF of OA

Aerosol Evolution in Manaus Plume – March 13th 2014

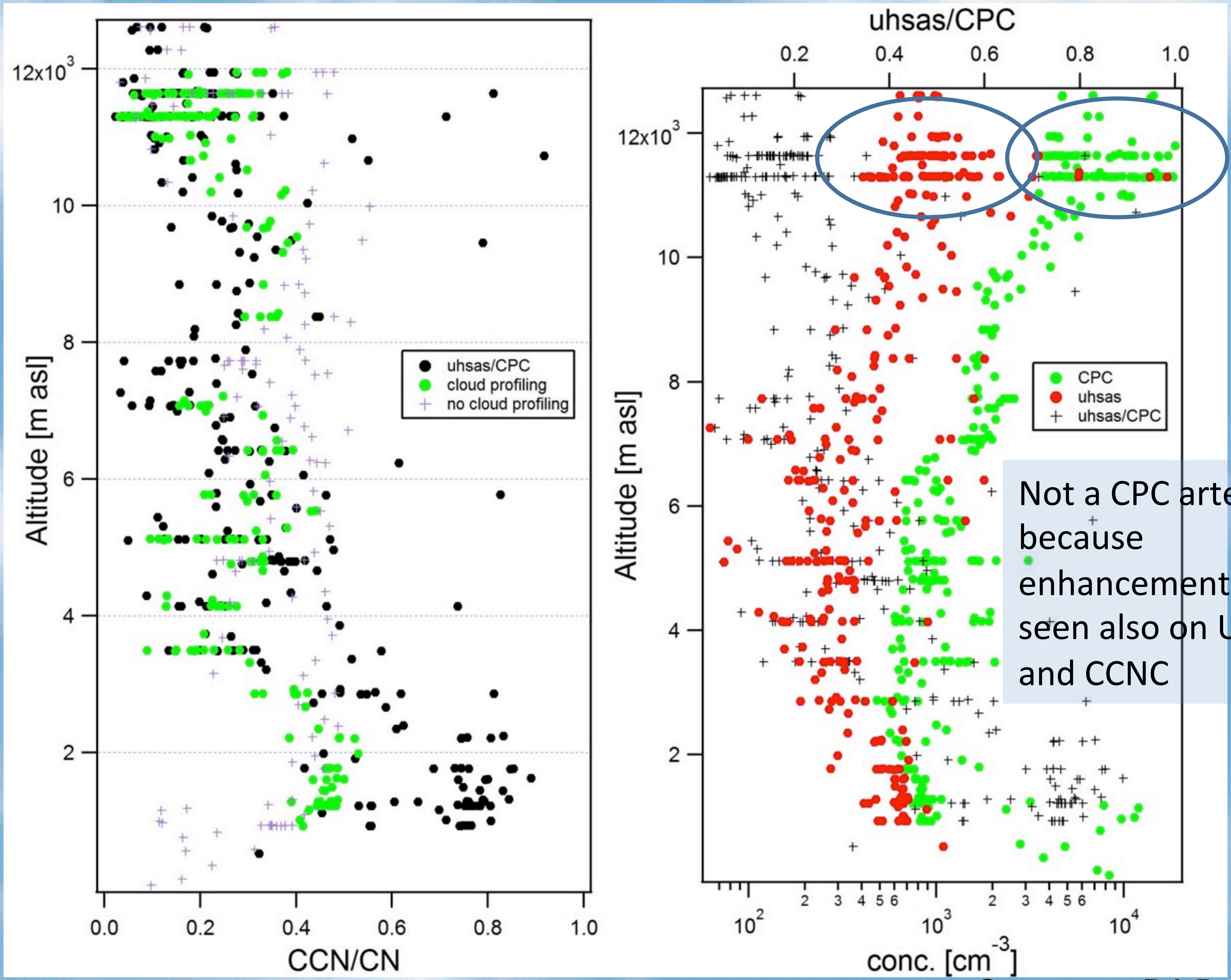
- LO-OOA dominates aerosol composition early in flight and correlates with CO.
- MO-OOA increases later in flight and correlates with ozone and aerosol SO_4.
- Organic O:C lower in the fresh plume.
- Observations are consistent with aging of plume downwind of Manaus.



John Shilling, 2015

HALO ACRIDICON-CHUVA campaign Sep. 2014

AC09

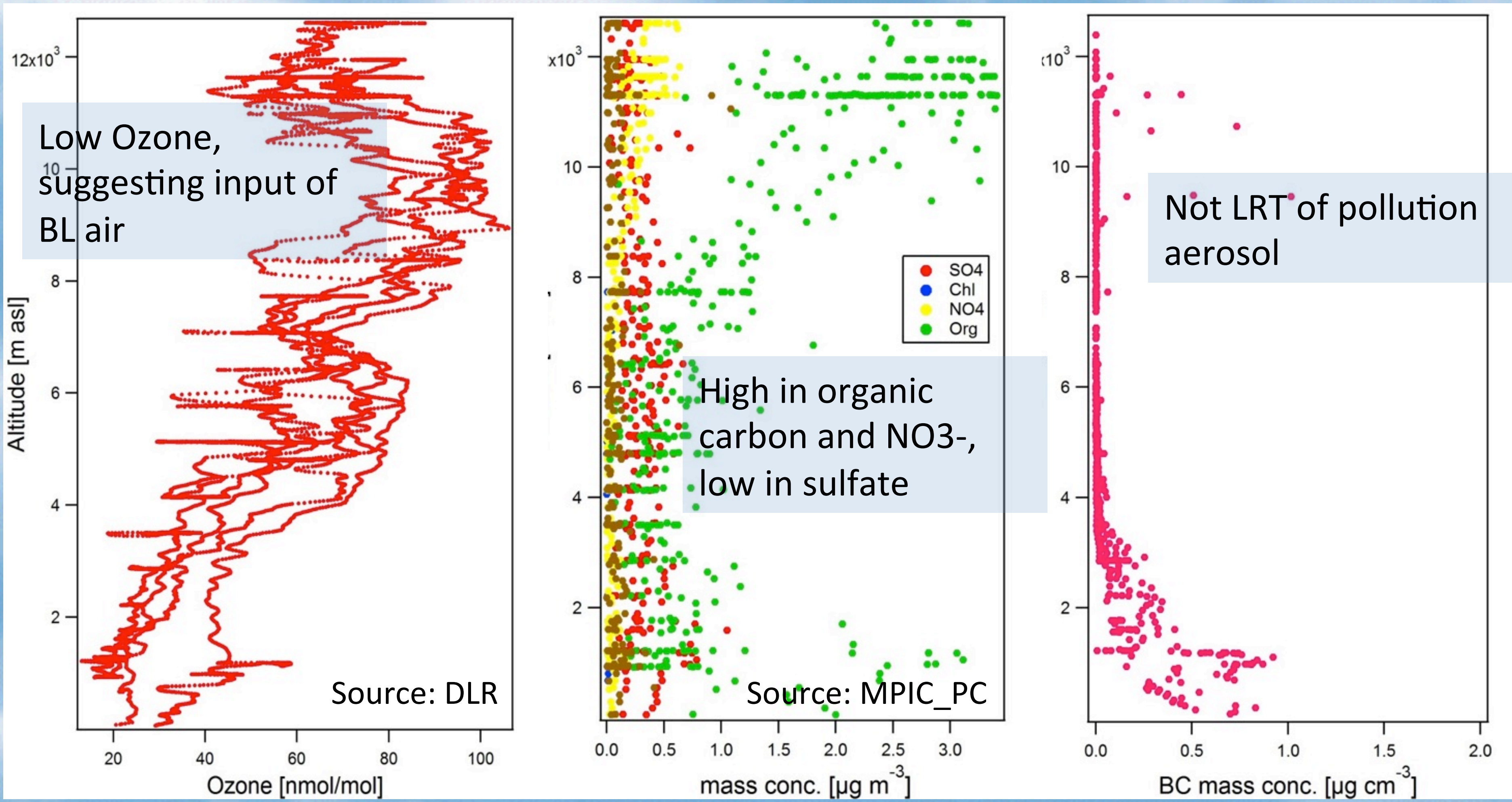


Not a CPC artefact, because enhancements are seen also on UHSAS and CCNC

Source: DLR, LMU

HALO ACRIDICON-CHUVA campaign Sep. 2014

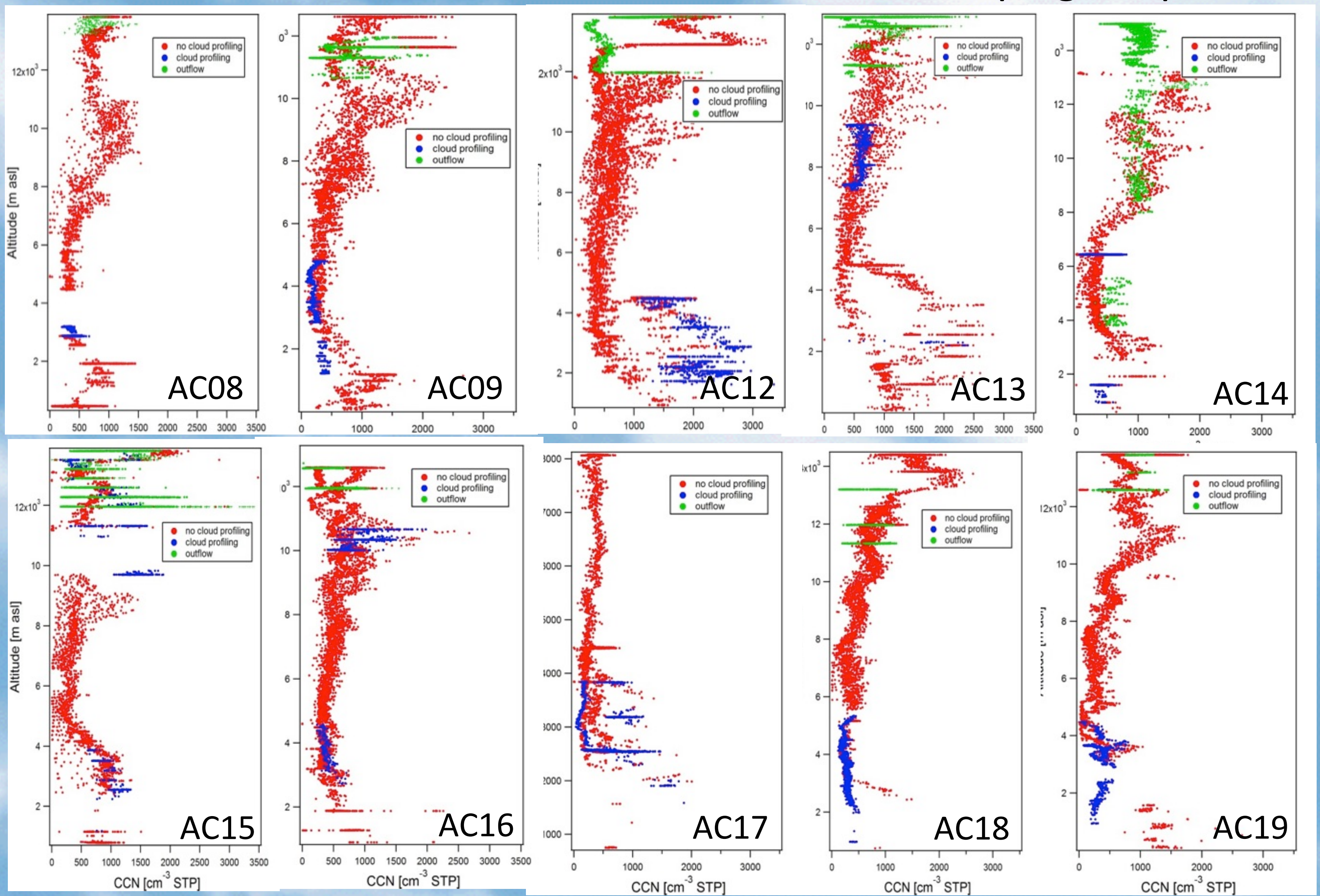
AC09



- BC from SP-2 and AMS at the HASI Inlet

Slide from Andi Andreae

CCN vertical Profiles HALO ACRIDICON-CHUVA campaign Sep. 2014



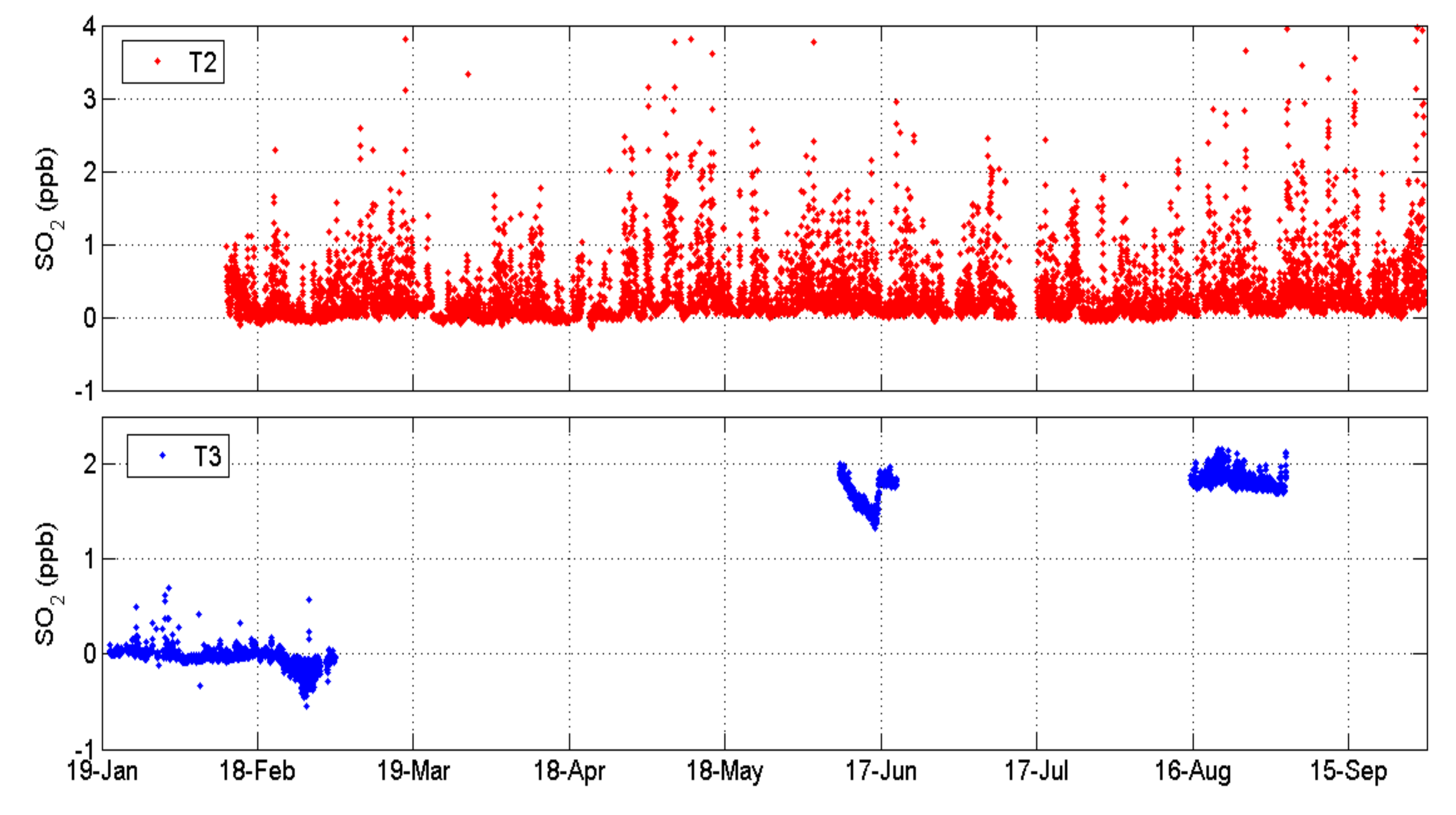
- enhanced CCN conc. at high altitude is observed in most of the flights (S~0.5%)

Slide from Andi Andreae Mira Kruger

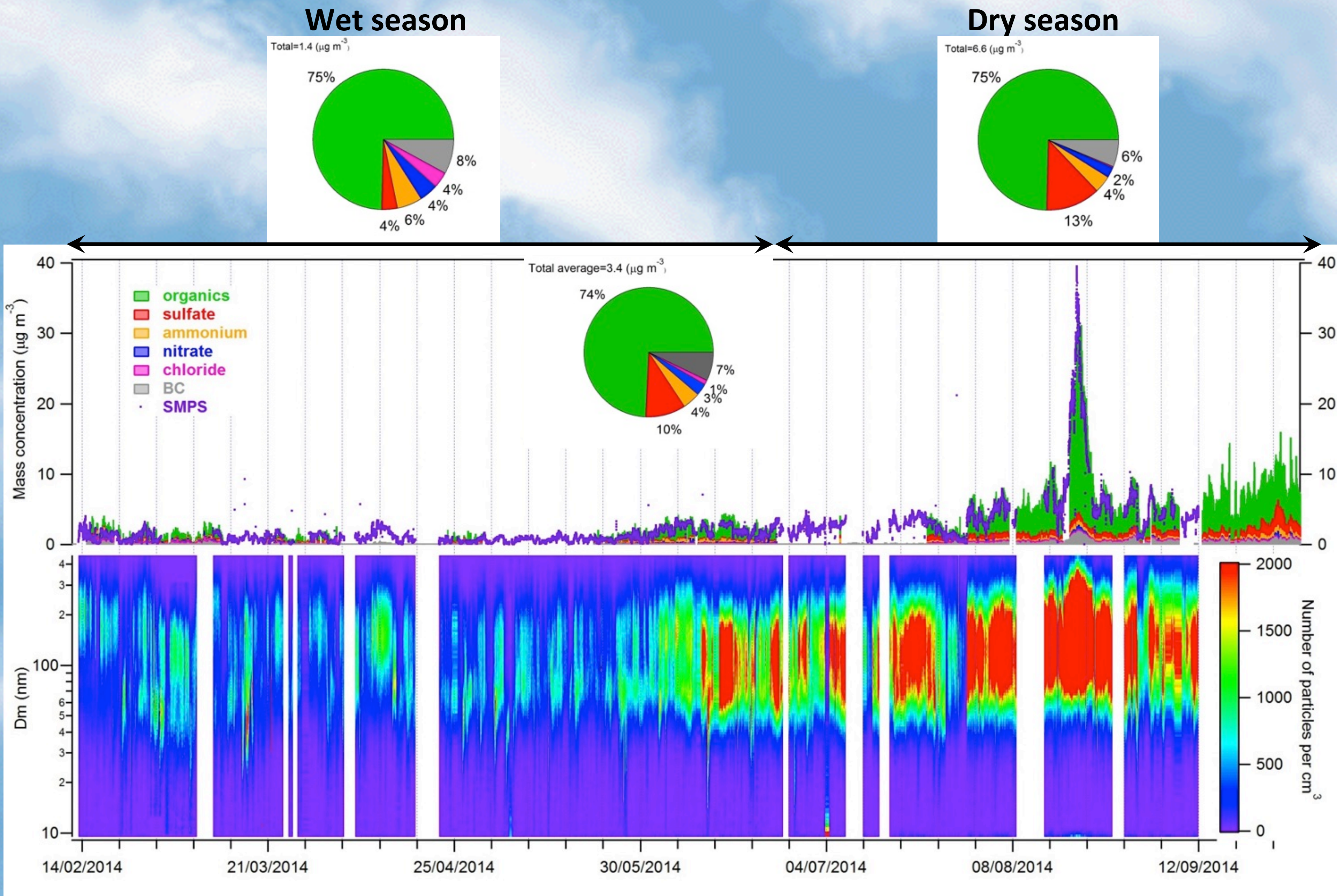
Torre ATTO
Observatório
Amazônico a
325 metros
de altura


A very nice natural laboratory
is waiting to be studied
The human induced changes
is essential to be considered…
Thanks for the attention!!

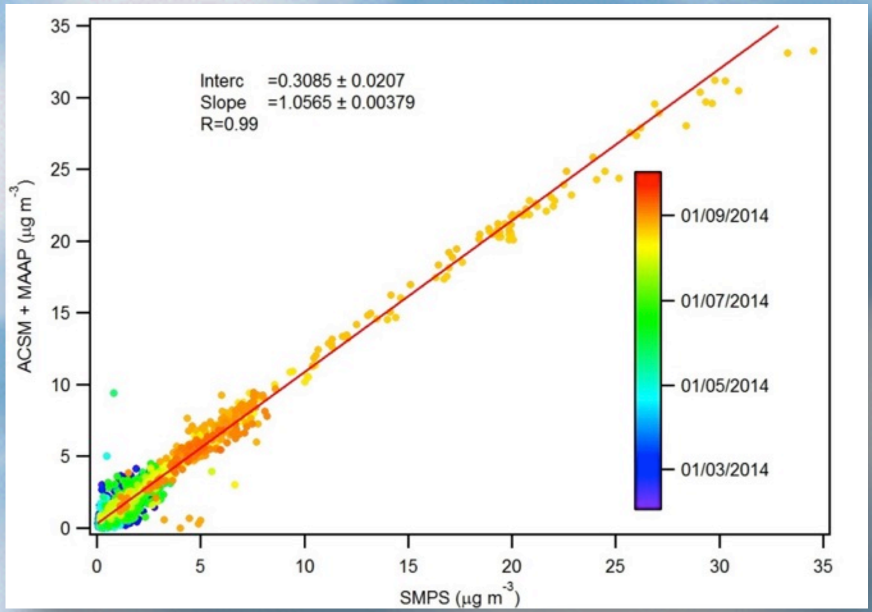
SO2 time series at T2 and T3

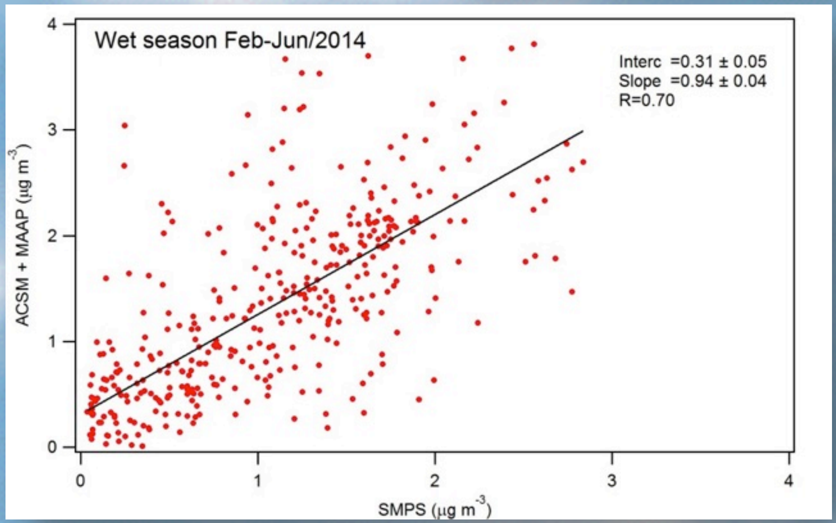


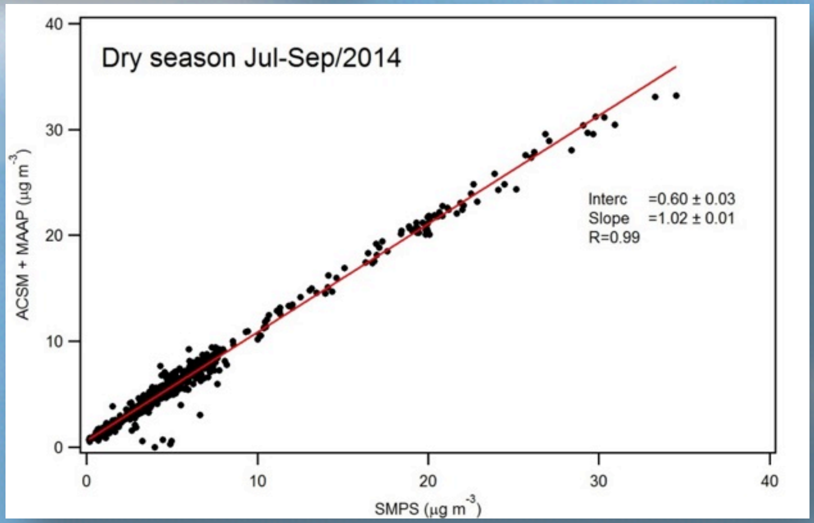
T0a-ATTO: Mass closure and number of particles over the time



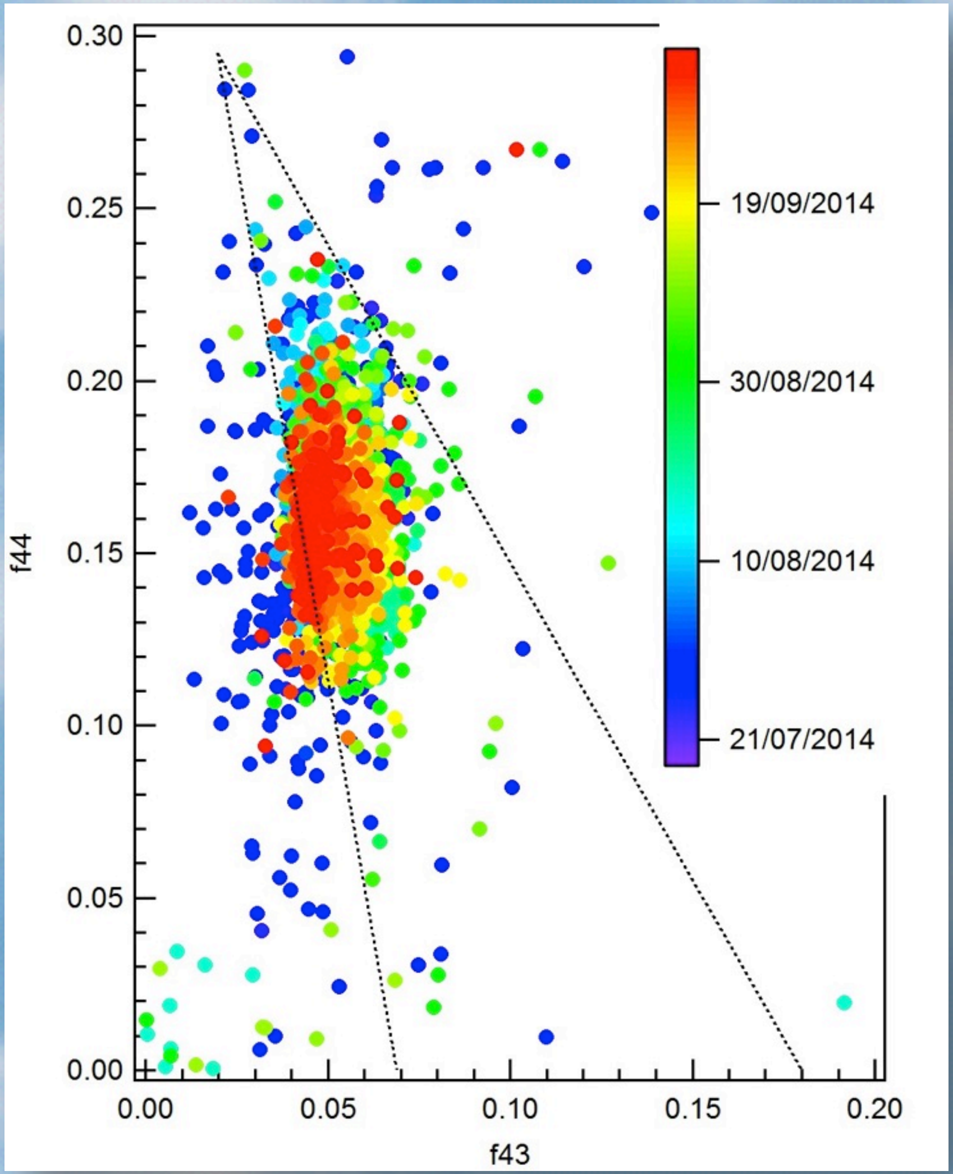
T0a – ATTO ACSM versus SMPS





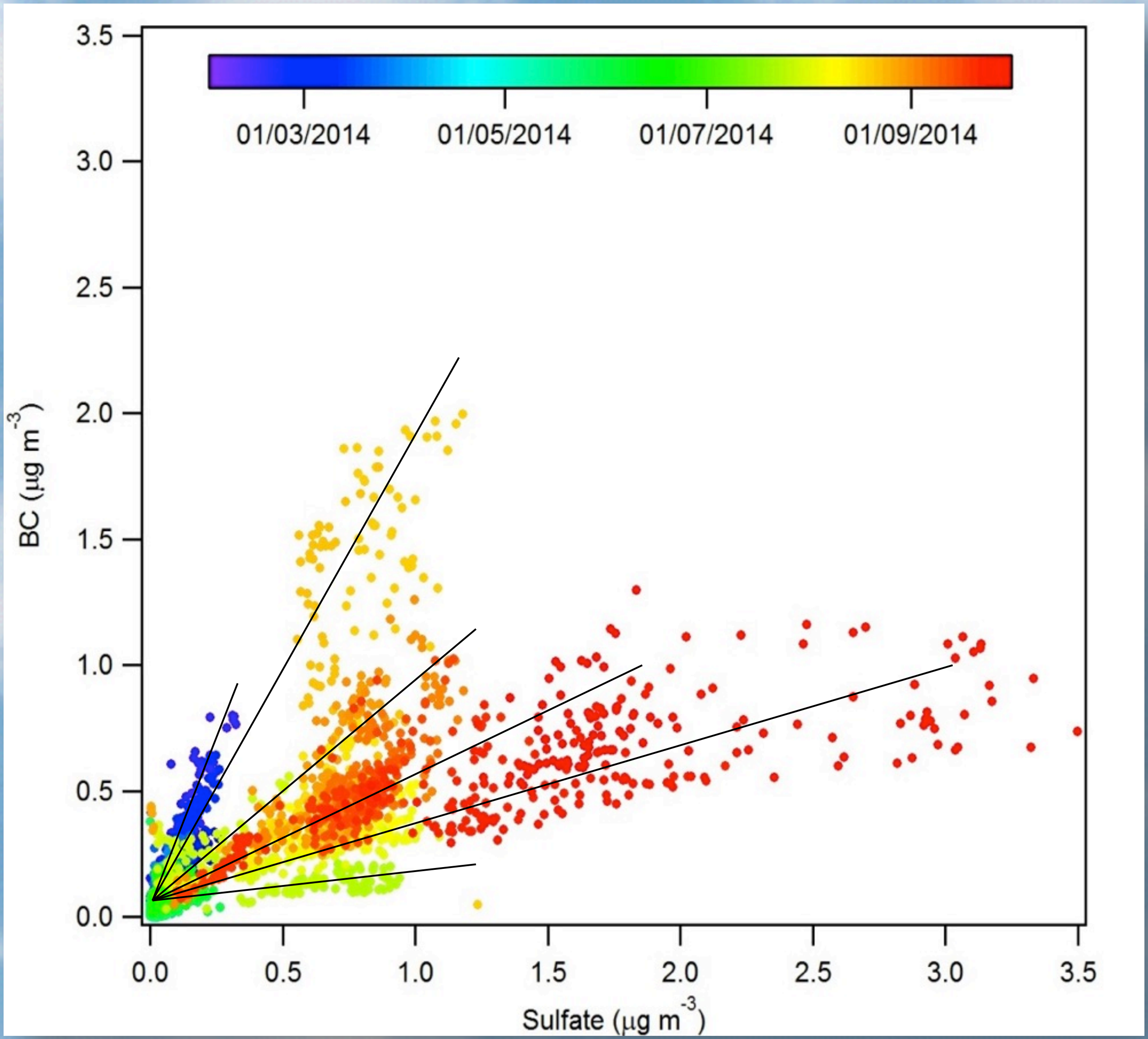


T0a-ATTO Aerosol particles presented moderate level of oxidation during the dry season

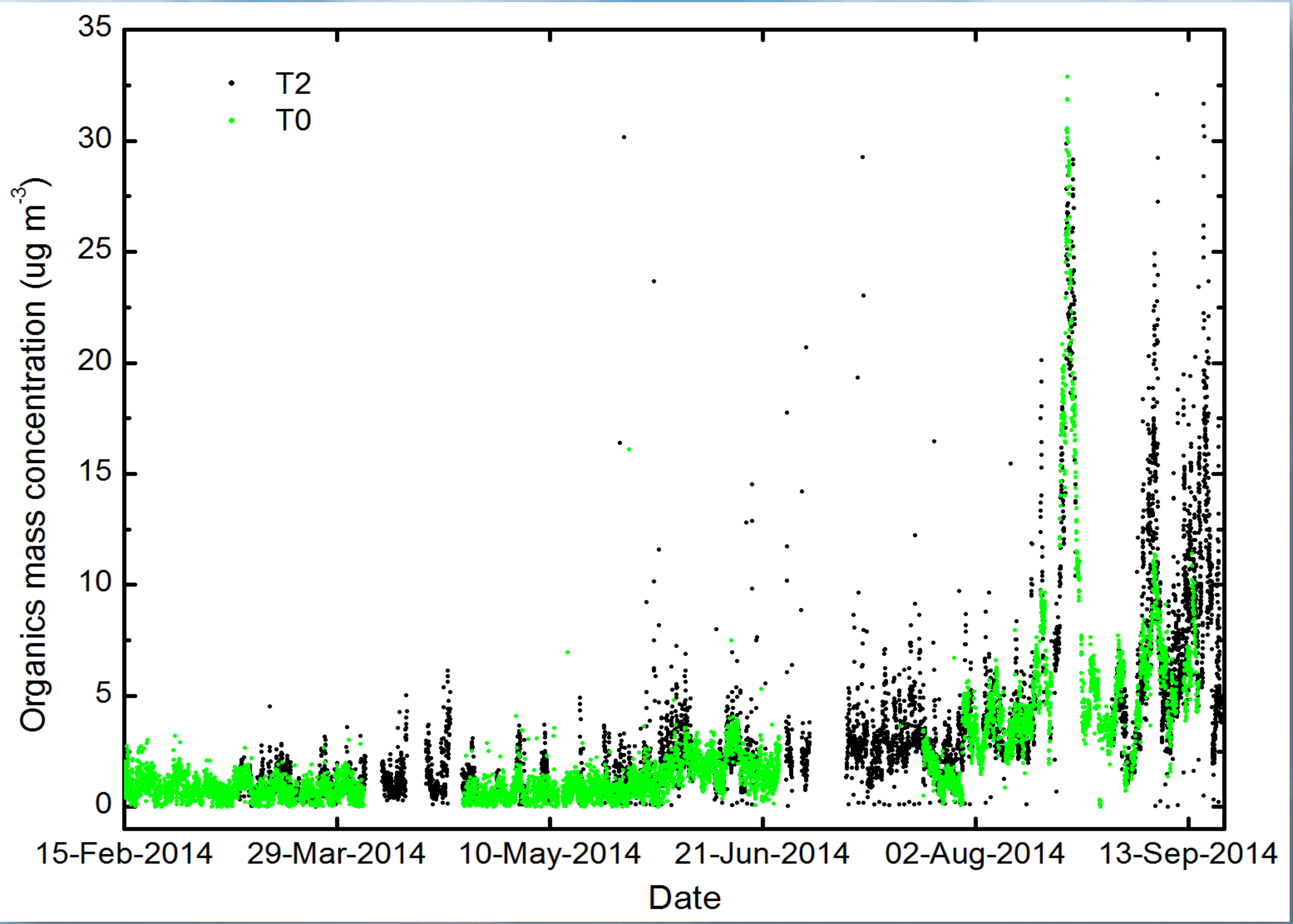


Sulfate is intimately related to BC, but with variou s ratios

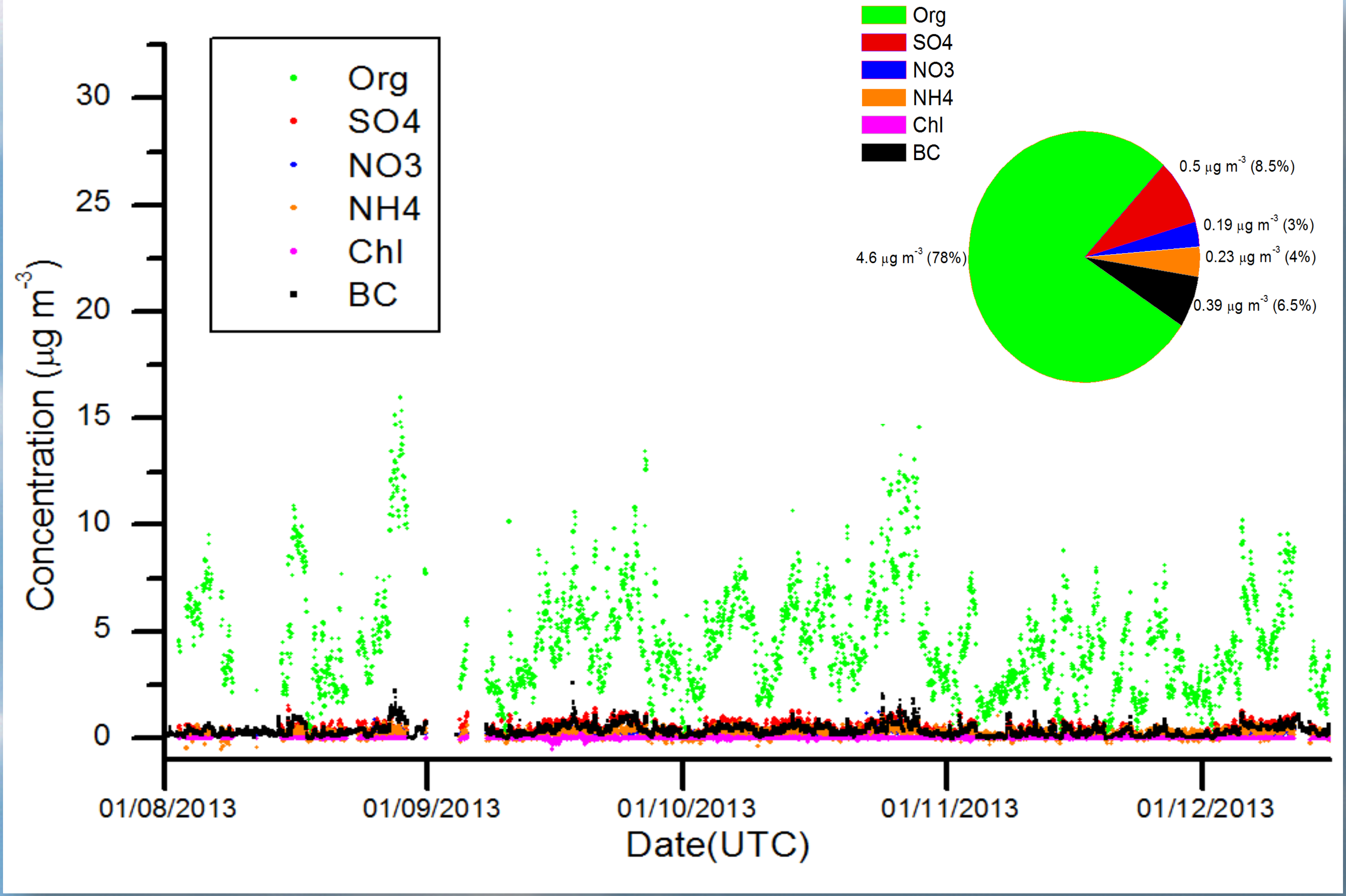
The different slopes likely represent episodes of LRT pollution



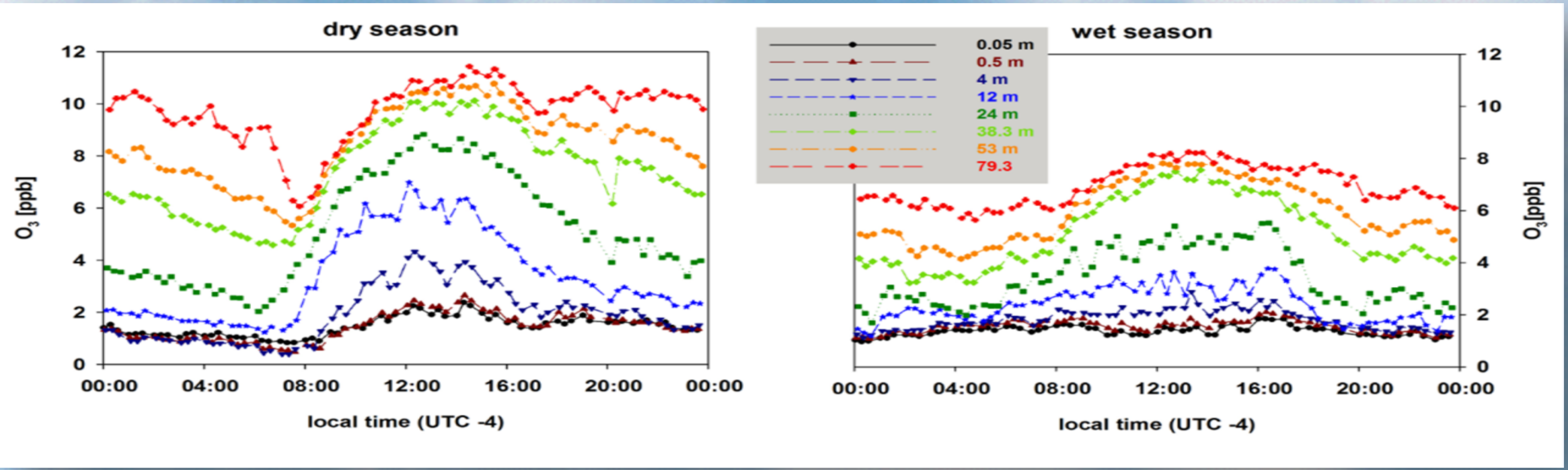
ACSM – Organics at T0a (ATTO) and T2



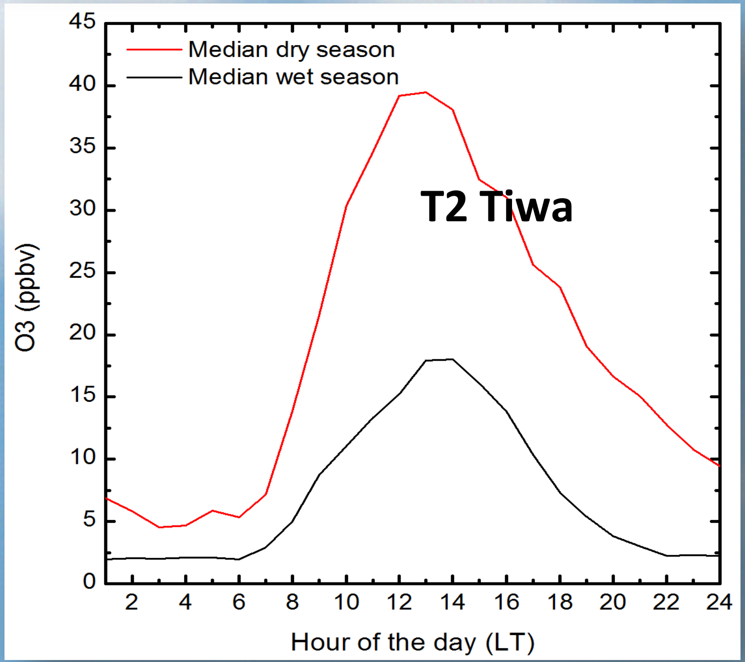
T0z-ZF2 aerosol composition dry season



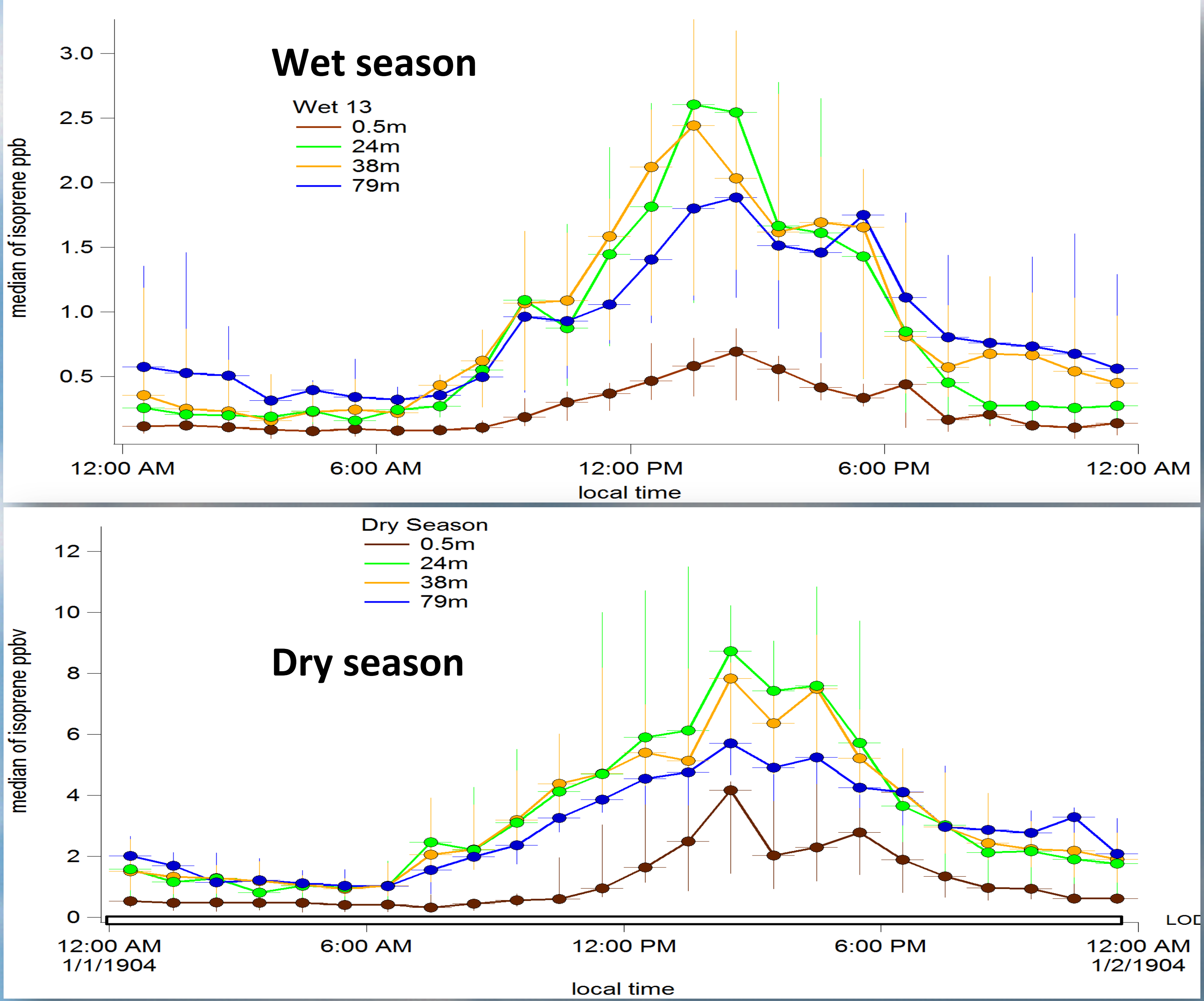
Ozone diurnal variability at T0a-ATTO and at T2-Tiwa



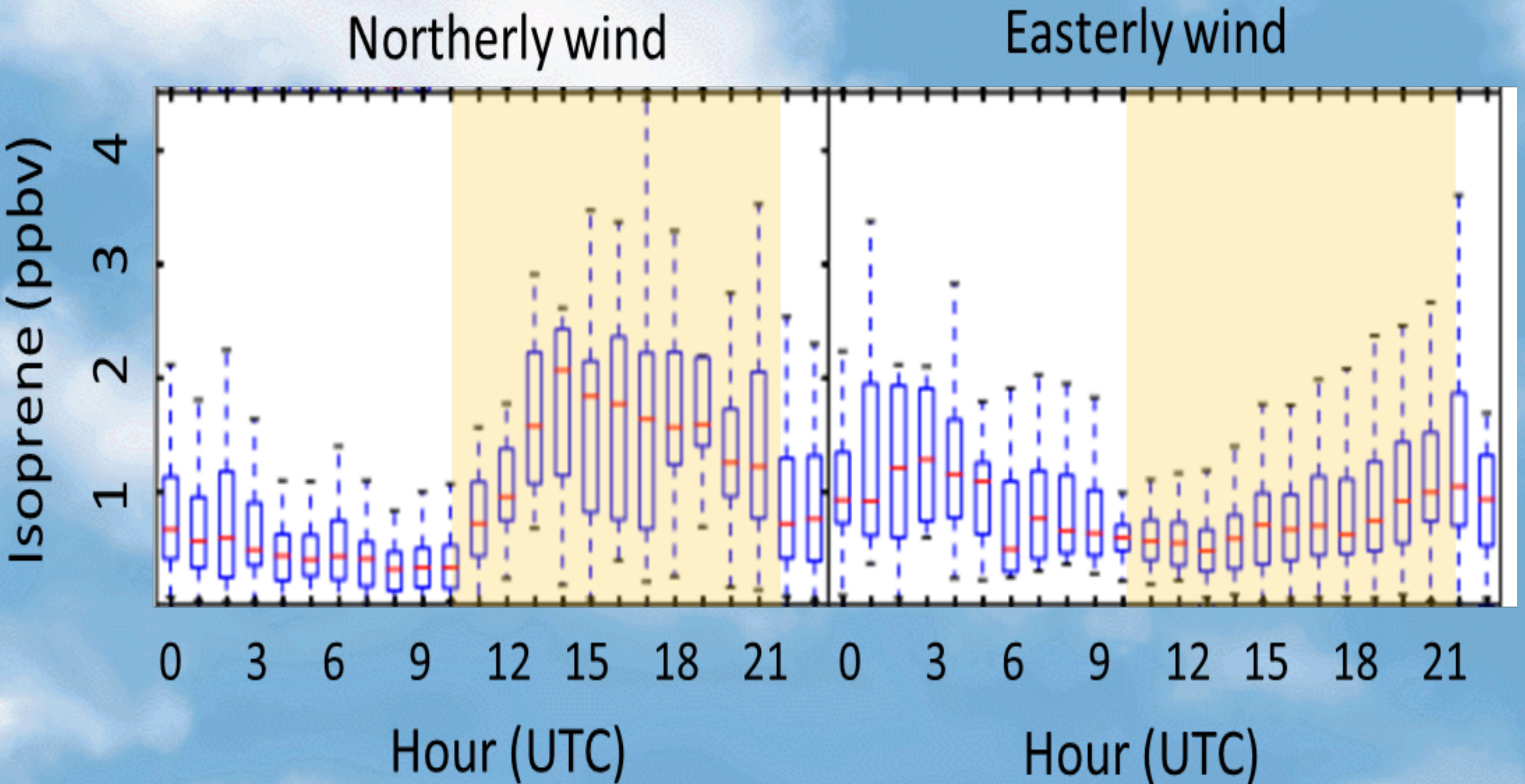
At Tiwa, from 15 to 40 ppb ozone from wet to dry season



T0a-ATTO Diurnal variability of isoprene for wet and dry season



Isoprene at T2-Tiwa: strong wind direction variability



TOLUENE CONC. (March 17, 2014)

Slide prepared by Scot Martin

ACETONE CONC. (March 17, 2014)

Slide prepared by Scot Martin

MVK+MACR CONC. (March 17, 2014)

Slide prepared by Scot Martin

Present and future dams in Amazonia

What energy options will dominate in the next 10-30 years in Latin America?

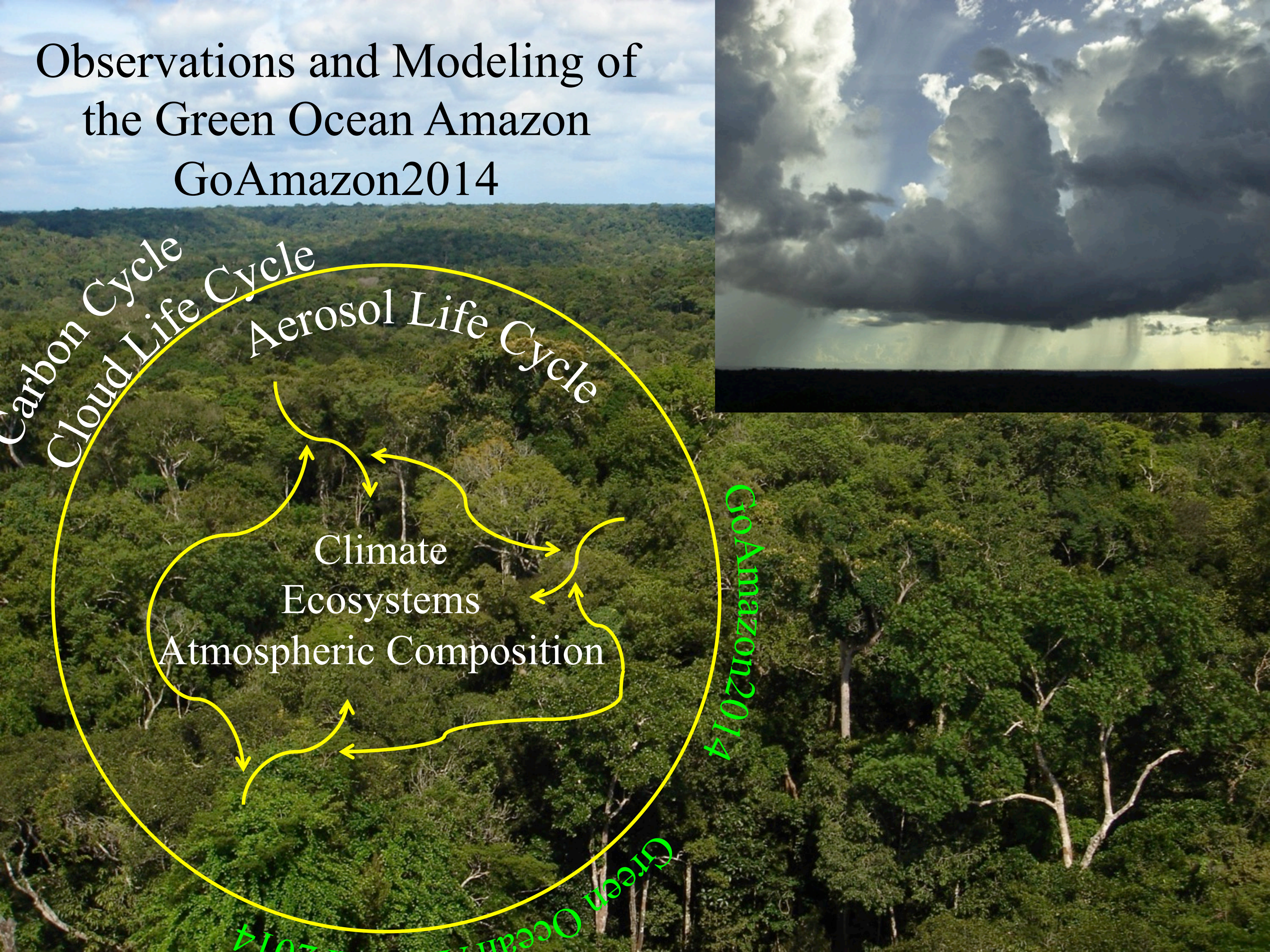
Dams in operation in the Amazon

Proposed dams for the Amazon Basin

http://dams-info.org/en

Tundisi et al., 2014

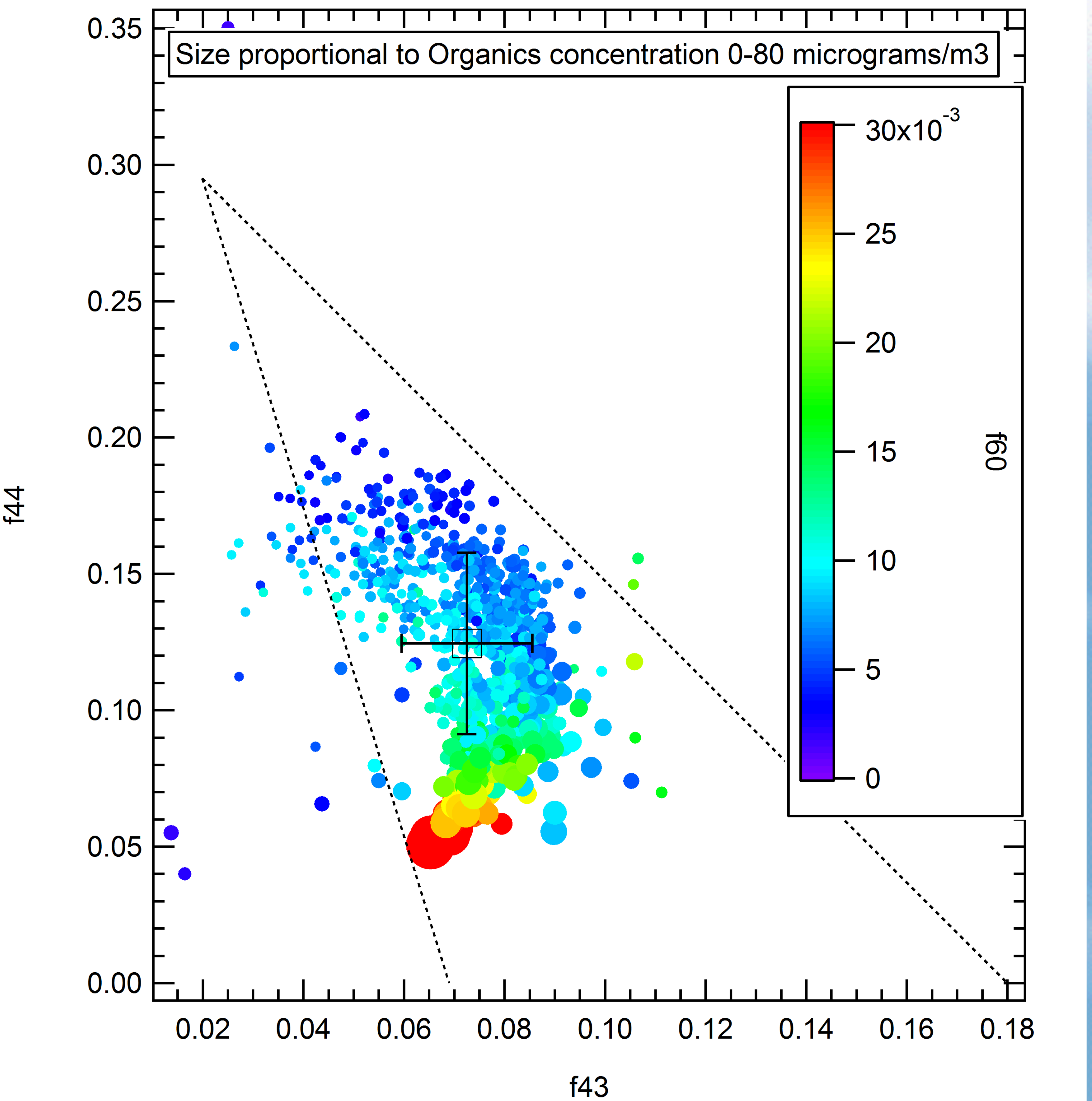

FLIGHT TRACK, GoAmazon2014/5, IOP1, 17 March 2014, 16:24 to 17:31 UTC
IARA: *Karla Longo, Beat Schmid, Scot Martin, and many important collaborators*
T1
T2
T3
33 km
Image Landsat
Google earth
Slide prepared by Scot Martin


Observations and Modeling of
the Green Ocean Amazon
GoAmazon2014
Carbon Cycle
Cloud Life Cycle
Aerosol Life Cycle
Climate
Ecosystems
Atmospheric Composition
GoAmazon2014
Green Ocean

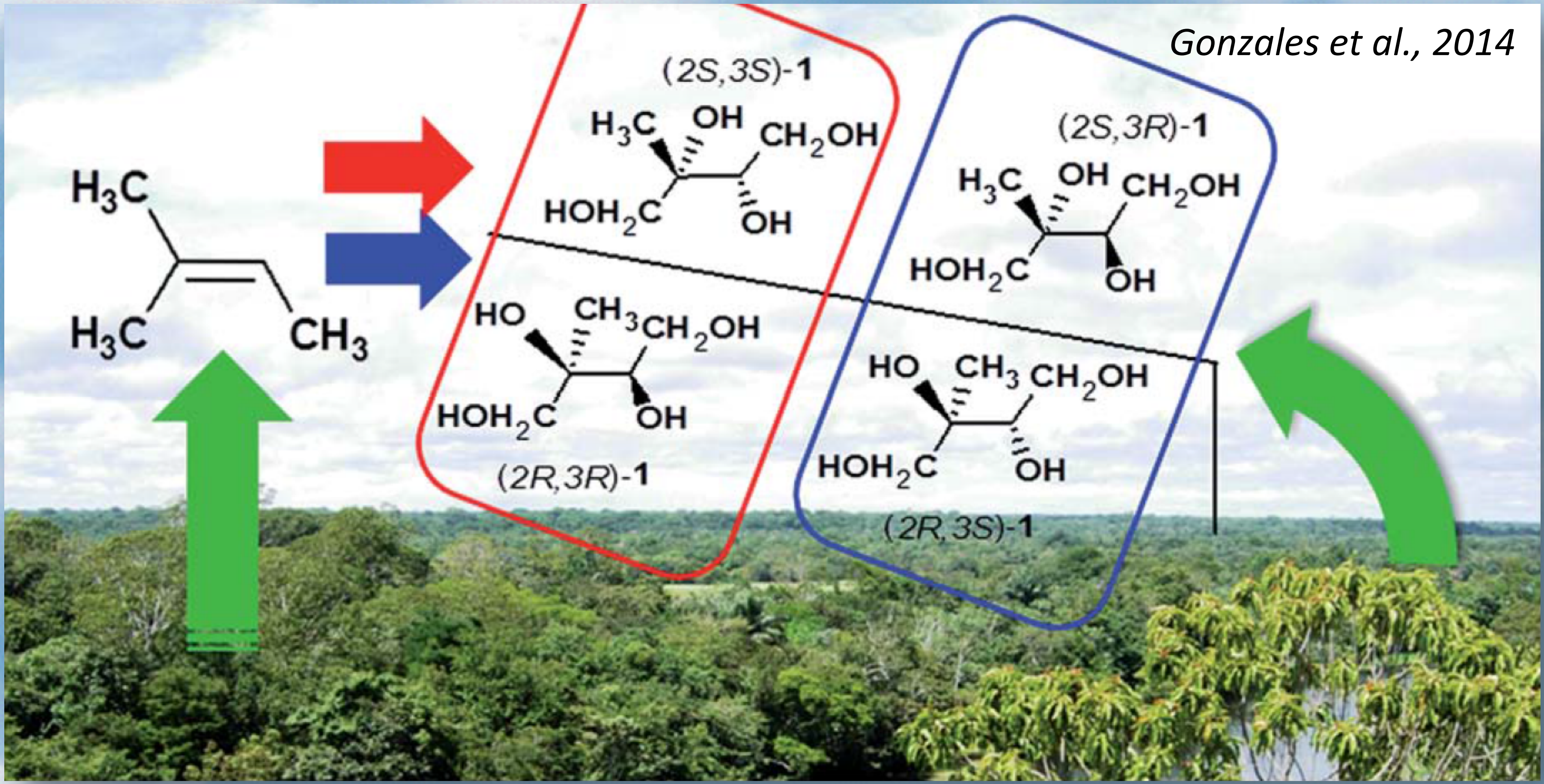
SAMBBA Biomass Burning f44/ f43 plot ACSM

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

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



Chiral analysis of 2- methyltetraols



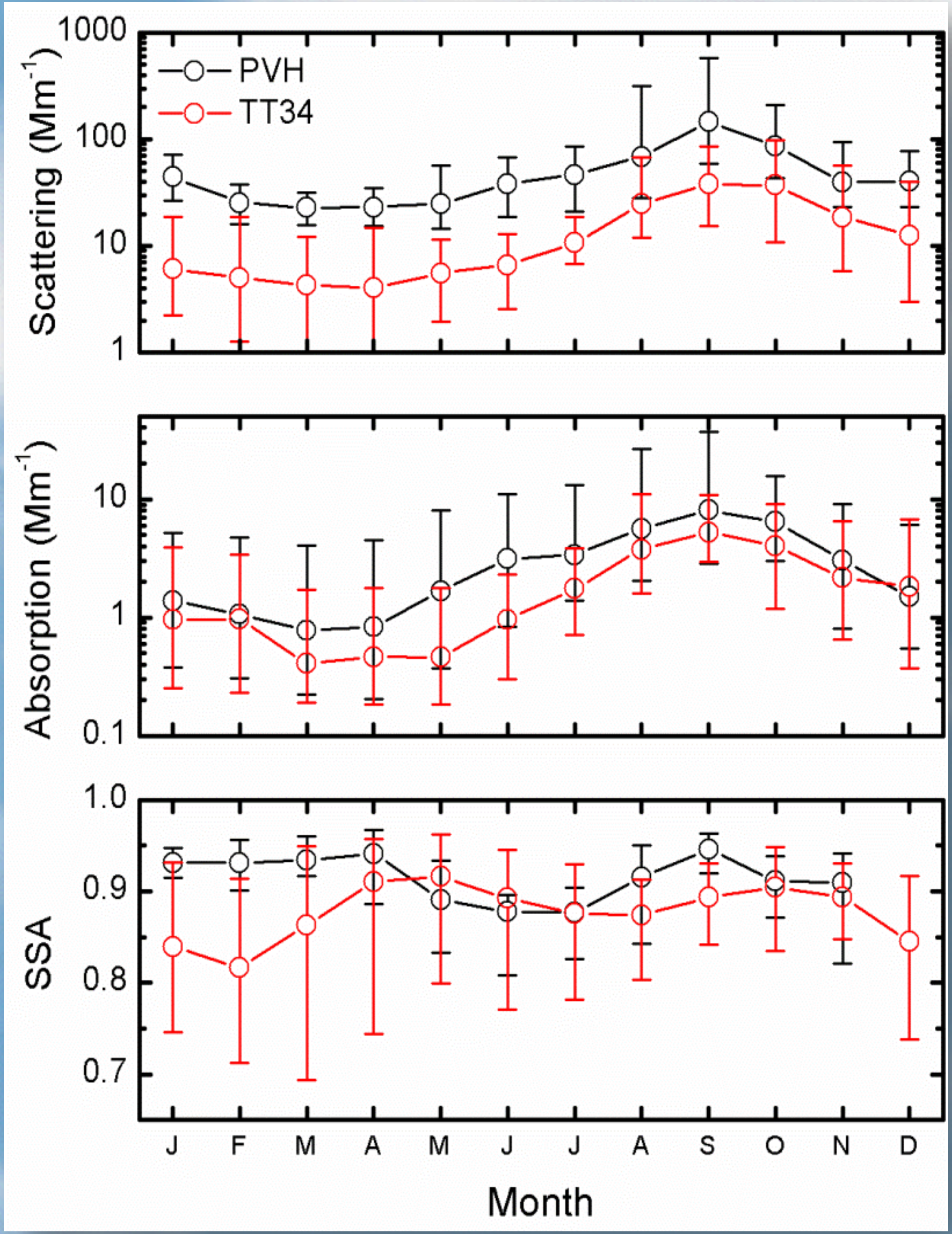
Chiral and isomeric analysis can be used to distinguish between atmospheric chemistry process or primary biological origin

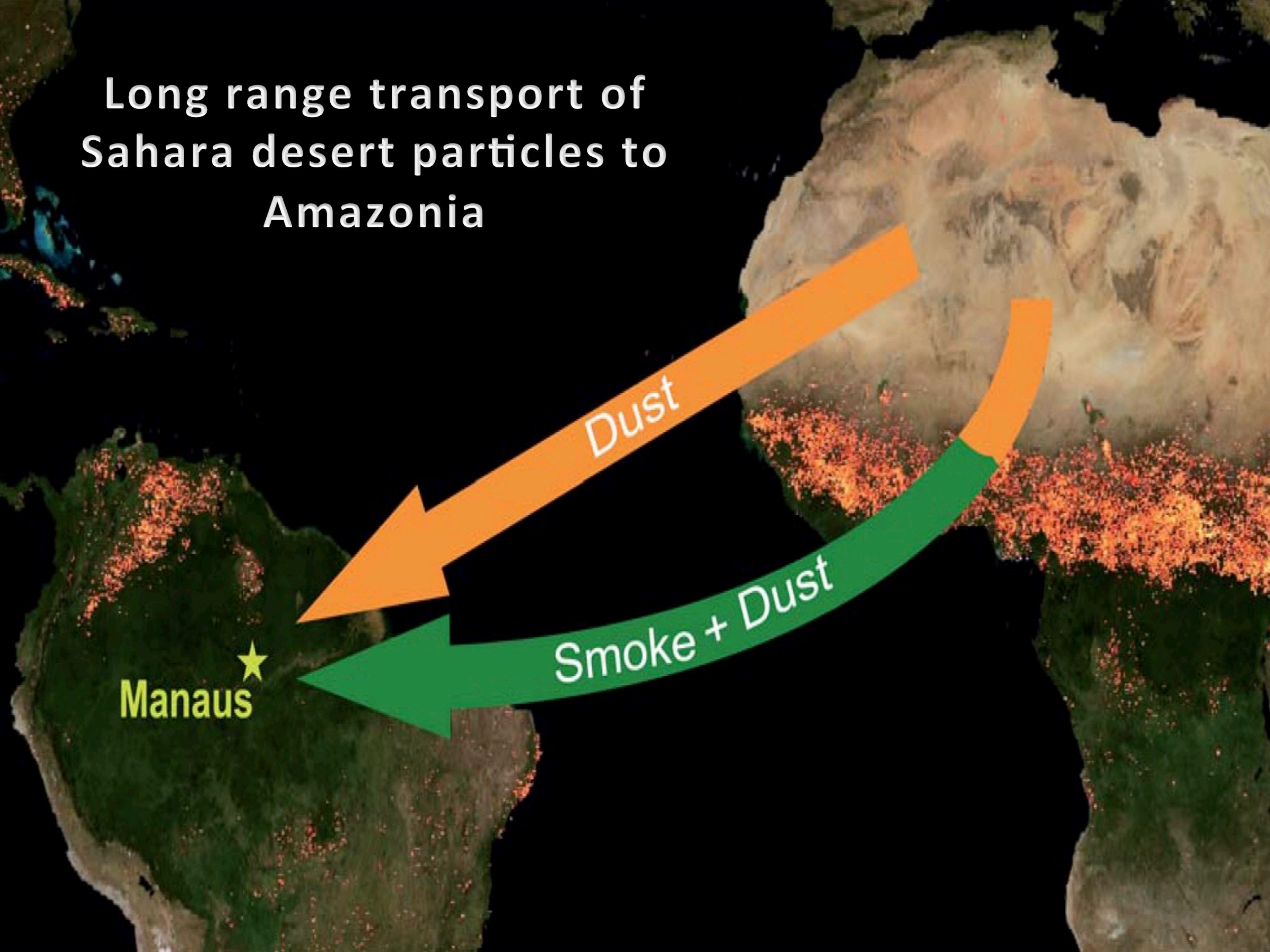
Scattering, absorption and SSA in Manaus and Porto Velho

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).

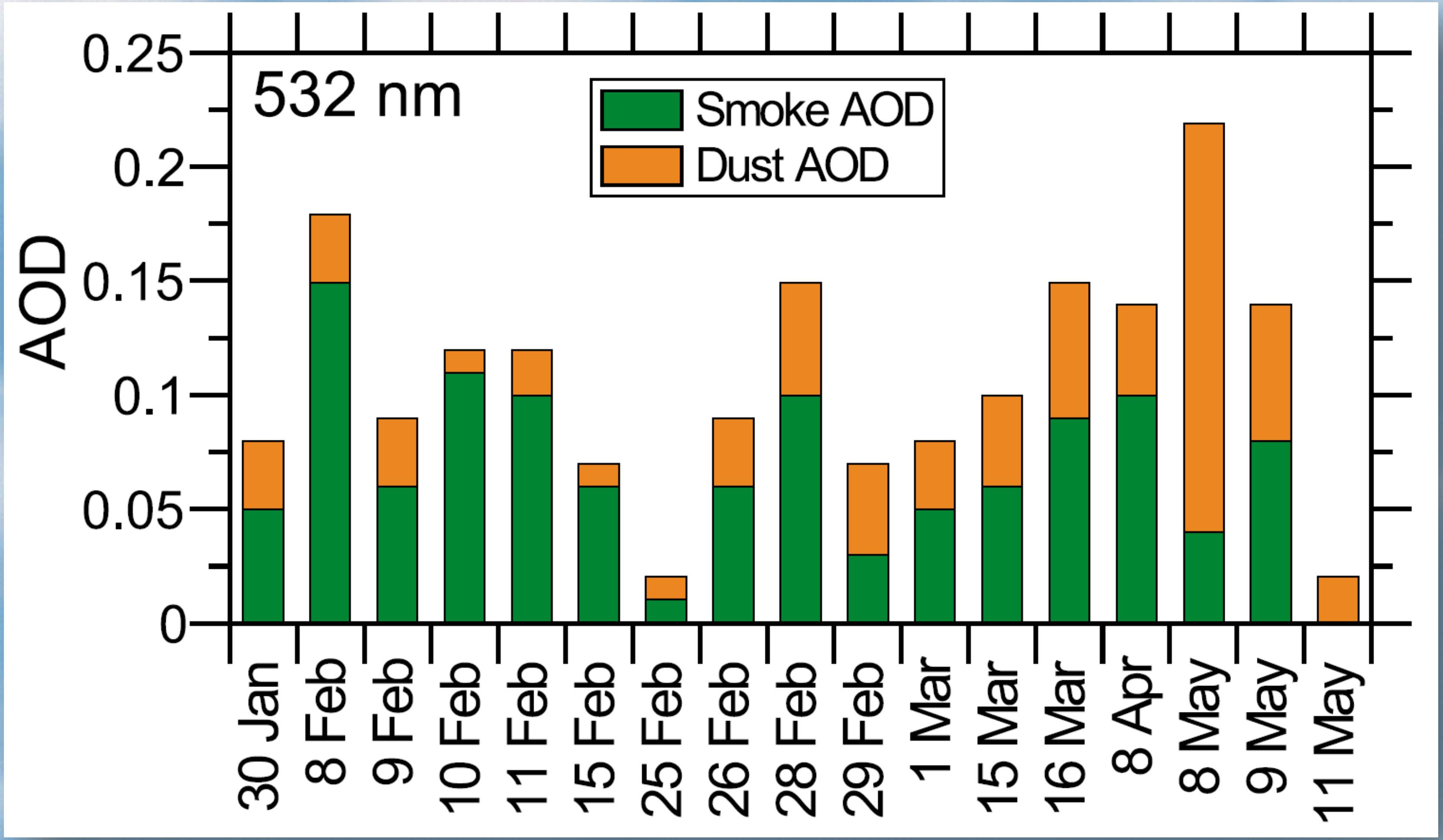
Single Scattering Albedo Lower at the pristine site

Artaxo et al., 2013



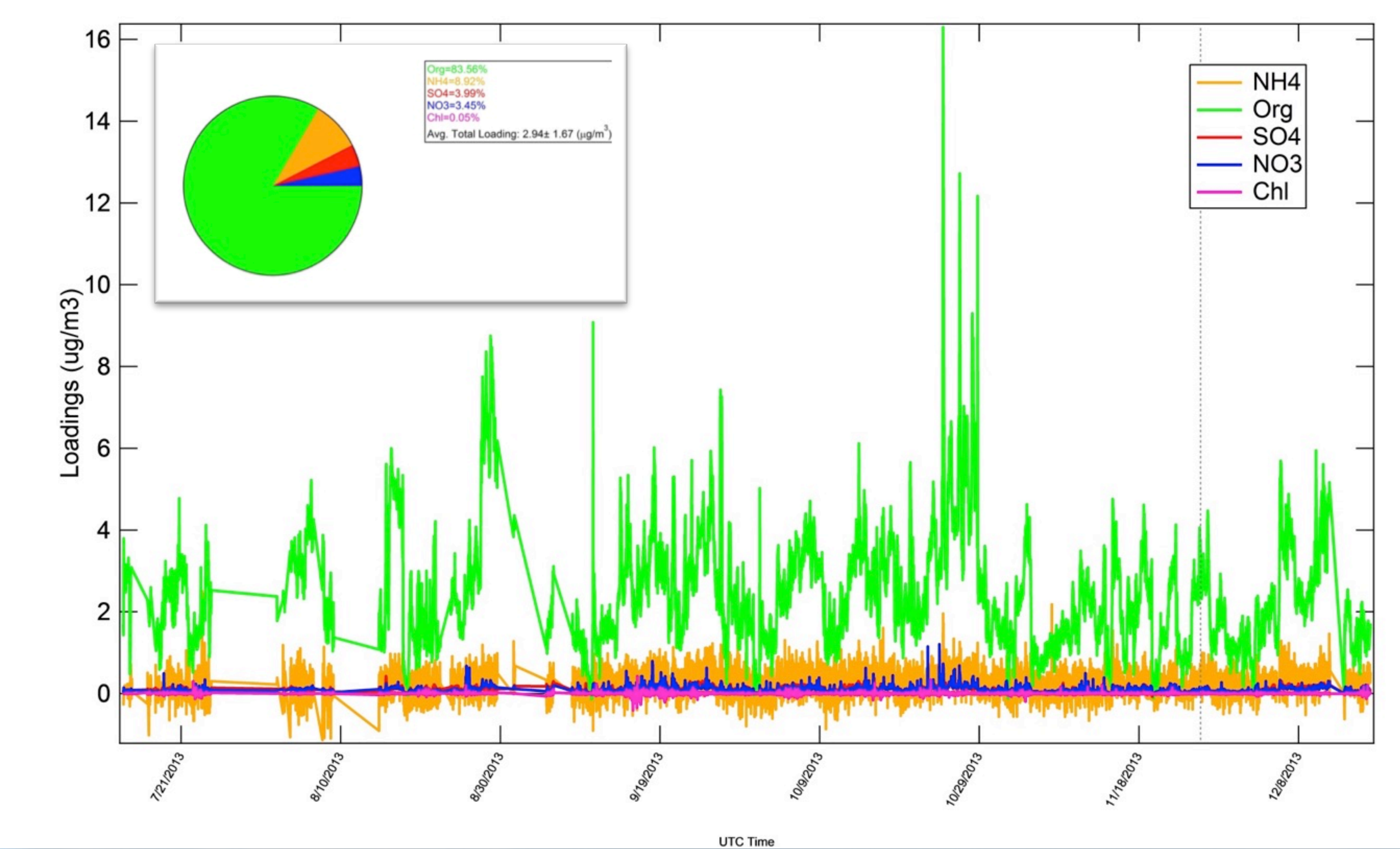

Long range transport of
Sahara desert particles to
Amazonia
Dust
Smoke + Dust
Manaus

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).

ACSM at ZF2 Dry season July-Dec 2013



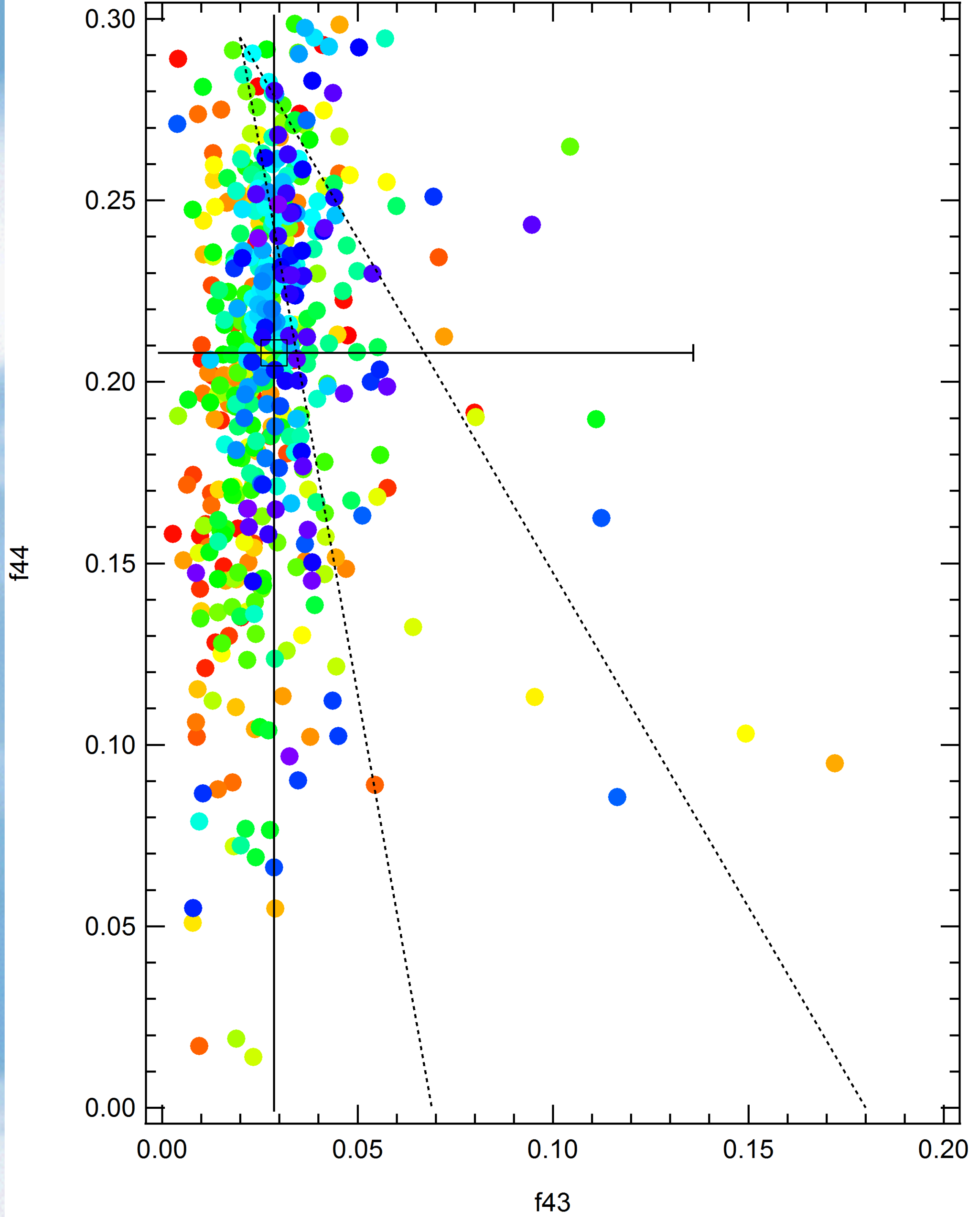
Brito et al., 2013

GoAmazon site in Manacapuru

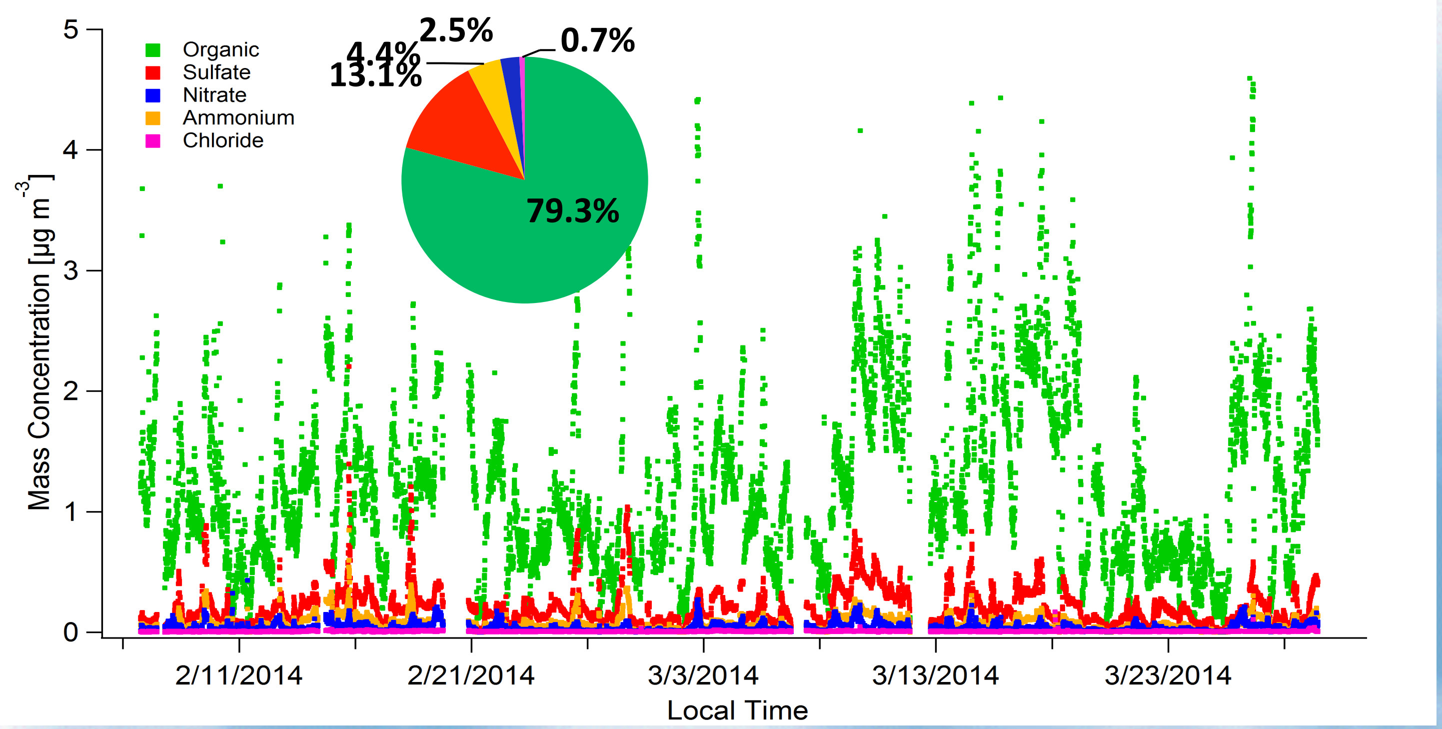
Aug, 18 - Sept 1, 2013

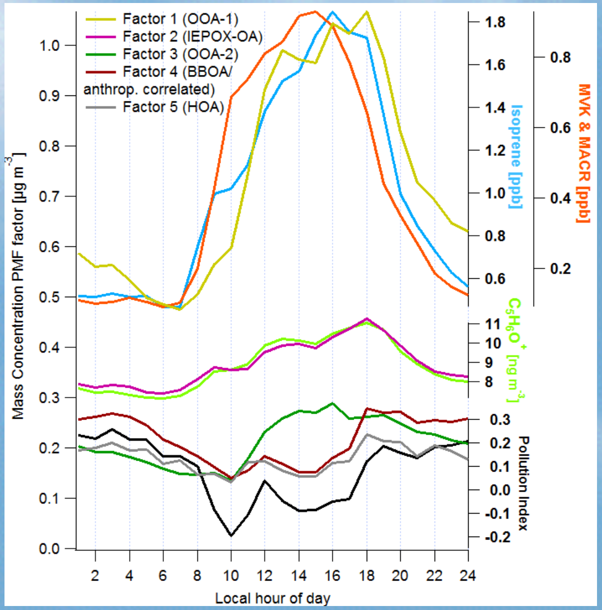
f44 = mainly CO_2^{+}, an indicator of highly oxidized species

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



GoAmazon Wet season T3 site





See Suzane Sá Poster