Conferência CONCLIMA 12 de Setembro de 2013
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AEROCLIMA - Efeitos diretos e indiretos de aerossóis no clima da Amazônia e Pantanal

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

Amazonia: 3 different types of aerosols

Biogenic (primary and SOA)  Biomass Burning  Dust from Sahara

Each with VERY different properties and impacts
Aerosol Cycling in Amazonia

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

Pöschl, Angew Chem 2005
Aerosols, radiation, clouds and greenhouse gases in the global climate system

The major uncertainties in the climate system
Aerosol and cloud lifecycles
High sensitivity to Pollution in Pristine Regions

Amazon Basin:
- Low aerosol number concentrations +
- High water vapor concentration =
- Especially susceptible.
- Possibility of large changes in energy flows and rainfall patterns

Deforestation was reduced from 27,700 Km² in 2004 to 4,571 Km² in 2012.

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

What public policies are needed to sustain this reduction?
Yearly deforestation over the Brazilian Amazon region (INPE, 2010) compared to MODIS daily smoke optical depth and the daily number of hot pixels from NOAA-12 and NOAA-15. The results are shown according to the hydrological year, from August 1st of the previous year to July 31st of the years shown in the graph. The vertical lines indicate August 1st, which correspond to the onset of the burning season.
AOD 550 nm 1999-2012 in Porto Velho, Rondonia

- AERONET - 500nm
- MOD04-L2 (TERRA) - 550nm
- MYD04-L2 (AQUA) - 550nm

Southern Amazon
Aerosol composition in wet-season Amazonia

Fine Fraction
1.7 µg m\(^{-3}\)

Coarse Fraction
5.7 µg m\(^{-3}\)

Martin et al., 2010
Biological Particles & Molecules

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

DNA, AA, Proteins, Carbohydrates, etc.

phosphate -deoxyribose backbone

3' end

5' end

Adenine
Thymine
Guanine
Cytosine
## Natural biogenic particles

<table>
<thead>
<tr>
<th>Pol len/Spo re</th>
<th>$D_p , (\mu m)$</th>
<th>Day (m$^{-3}$)</th>
<th>Night (m$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fungal spores:</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Alternaria longissima</td>
<td>12-60</td>
<td>190</td>
<td>10</td>
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<tr>
<td>Ascospores</td>
<td>2-22</td>
<td>2,064</td>
<td>7,416</td>
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<tr>
<td>Aspergillus/ Penicillium</td>
<td>2-6</td>
<td>2,470</td>
<td>0</td>
</tr>
<tr>
<td>Basidiospores</td>
<td>12</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>Cladosporium</td>
<td>2-12</td>
<td>3,040</td>
<td>3,090</td>
</tr>
<tr>
<td>Dreschlera/ Exserohium</td>
<td>10-70</td>
<td>152</td>
<td>412</td>
</tr>
<tr>
<td>Myxomycete</td>
<td>8</td>
<td>10</td>
<td>2,060</td>
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<tr>
<td>Other</td>
<td>5-350</td>
<td>1,348</td>
<td>1,462</td>
</tr>
<tr>
<td>Periconia</td>
<td>10</td>
<td>57</td>
<td>309</td>
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<tr>
<td>Powdery Mildew</td>
<td>7-13</td>
<td>76</td>
<td>1,648</td>
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<tr>
<td>Rust</td>
<td>8-12</td>
<td>1,710</td>
<td>3,605</td>
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<tr>
<td>Smut</td>
<td>5-7</td>
<td>10</td>
<td>9,167</td>
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<tr>
<td>Yeast</td>
<td>2-10</td>
<td>12,255</td>
<td>203,528</td>
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<tr>
<td><strong>TOTAL FUNGAL</strong></td>
<td><strong>23,462</strong></td>
<td><strong>234,154</strong></td>
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<tr>
<td>Algae (unknown type)</td>
<td>8</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL ALGAE</strong></td>
<td><strong>20</strong></td>
<td><strong>0</strong></td>
<td></td>
</tr>
</tbody>
</table>

10 times higher at night !!!

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Source: MPIC, Mainz
Long term monitoring stations in Amazonia

Manaus and Porto Velho

Dry aerosol (RH<40%)
Site continuously operational since Feb 2008.
Porto Velho aerosol and trace gases sampling location
Centro de Pesquisas do Pantanal (CPP-SESC), Universidade Federal do Mato Grosso
Four flux towers with 85 meters already in operation at the ATTO site

Measurements at 6 levels for Ozone, CO, VOCs (PTR-MS), aerosol number size distribution, composition with ACSM, Light scattering (TSI Neph), light absorption using MAAP, Aethalometer, SP2), CO2, CH4, water vapor and others.
Instrumentation operational since February 2008

- MAAP - Multiangle Absorption Photometer: aerosol absorption at 637 nm
- Aethalometer absorption at 7 wavelengths.
- TSI Nephelometer: aerosol scattering at 450, 550, 700 nm
- CPC 3772: aerosol number concentration
- TSI SMPS: aerosol size distribution (10-500 nm)
- Stacked filter units: fine and coarse mode aerosol composition – trace elements by XRF and PIXE, BC, ions
- Quartz filter for EC/OC analysis (Sunset analyzer)
- Ozone monitor (Thermo Environment 42C)
- Picarro CO₂, CO.
- Raymetrics Raman Lidar with 3 wavelengths
- AERONET Cimel Sunphotometer and MFR radiometers
- Recently ACSM (Aerodyne Aerosol Chemical Speciation Monitor)
HYSPLIT air mass trajectories wet season 2008
Mass Concentration ($\mu g/m^3$)

Manaus TT34 ZF2 PM10, fine and coarse mode aerosol 2008-2012

- Fine
- Coarse

BCe Concentration (ng/m$^3$)

Manaus TT34 ZF2 equivalent black carbon fine and coarse mode aerosol 2008-2012

- Fine
- Coarse
Porto Velho aerosol mass concentration and black carbon from 1999 to 2012

Porto Velho fine and coarse mode aerosol mass 1999-2012

Mass Concentration (ug/m$^3$)

- **Fine**
- **Coarse**

Porto Velho Black Carbon 2009-2012 Fine and Coarse Mode

BC Concentration (ng/m$^3$)

- **Fine**
- **Coarse**
Seasonality of scattering and absorption

Particle scattering coefficients at 550nm between February 2008 and May 2011. Statistics were calculated for each 10 Julian days.

Aerosol absorption coefficients at 637nm between February 2008 and May 2011. Statistics were calculated for each 10 Julian days.
Scattering, absorption and SSA in Manaus and Porto Velho

Monthly statistics (2009 – 2012) for light scattering coefficient $\sigma_s$ at 637 nm and light absorption coefficient $\sigma_a$ 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
Manaus organic aerosol wet season measurements

Brito et al., 2013
Organic aerosol measurements in Rondónia

[Brito et al., 2013]

[Graph showing concentration of organic aerosol (Org/L0), NH4, SO4, NO3, and Chl over dates from 06/09/2012 to 30/09/2012. Pie charts indicate the percentage of each component with f60 values: 1.0% and 0.6%.]
No new particle formation observed at surface under pristine conditions in Amazon.

New particle formation: a two-step process:

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

Why no new particle formation?
- Low SO\textsubscript{2} concentration (20-30ppt) suggests the concentration of H\textsubscript{2}SO\textsubscript{4} is low
- Organic concentration may be low for the growth of stable clusters.

What is the impact of Manaus plume on NPF?
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.
Biogenic potassium salt particles as seeds for secondary organic aerosol in the Amazon

Our findings suggest that the primary emission of biogenic salt particles effectively regulates the number concentration of cloud condensation nuclei, directly influencing the microphysics and dynamics of cloud formation and precipitation over the rainforest.

STXM-NEXAFS measurements (Pöhlker et al., 2012)
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
SAMBA - South American Biomass Burning Analysis
Flight tracks of the BARCA aircraft campaigns (red: BARCA-A, black: BARCA-B.)
Comparisons of median vertical profiles for the Equatorial Transect east of Manaus ("E. Region"), N and S transects along 60W longitude, and near Manaus (excluding local pollution). Note the strong similarities between ABLE-2B and BARCA-B data taken more than 20 years apart. (Source of ABLE data: Harriss et al., 1990b).

Vertical profiles of CO mixing ratios (A) and CN number concentrations (B) during BARCA-A (excluding the smoky region) and BARCA-B.

Andreae et al., 2012
Rosenfeld D., et al., 2008: Flood or Drought: How Do Aerosols Affect Precipitation? Science, 321
Clouds and aerosols in Amazonia

Cloud top pressure ($P$) vs. AOD

Microphysics
absorption effects

Cloud fraction vs. AOD.

Koren et al., Science 2008
Correlation between aerosols and precipitation in Amazonia Region

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

Aerosols extending the duration of dry season

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

Bevan et al., JGR 2009
Relative roles of biogenic emissions and Saharan dust as ice nuclei in the Amazon basin

Anthony J. Prenni1*, Markus D. Petters1, Sonia M. Kreidenweis1, Colette L. Heald1, Scot T. Martin2, Paulo Artaxo3, Rebecca M. Garland4, Adam G. Wollny4 and Ulrich Pöschl4

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.
13:30 local-time map of rain rate ($R$) and the observed trend with aerosol loading in four selected regions. Period: July and August 2007. b, The average $R$ values are plotted for six aerosol-loading sets (blue, including zero $R$ grid squares; red, without zero $R$ grid squares). Note the $R$ intensification as a function of AOD in all cases. (Koren et al., Nature 2012)
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).
Average spatial distribution of the direct radiative forcing (DRF) of biomass burning aerosols in Amazonia during the dry season of 2010. CERES (Clouds and the Earth's Radiant Energy System) and MODIS.
Land-use change radiative forcing. Forested areas are selected in red and deforested areas are selected in yellow.

Mean Diurnal Radiative Forcing due to change in surface albedo in Rondonia:
- \(-7.3 \pm 0.9\) W/m\(^2\)

Mean Diurnal Aerosol Forcing Efficiency:
Forest: \(-22.5 \pm 1.4\) W/m\(^2\)
Cerrado: \(-16.6 \pm 1.7\) W/m\(^2\)

Water column difference by 6-10%

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

Sena et al., 2013
HOW MUCH CARBON DO PLANTS TAKE FROM THE ATMOSPHERE?

MODIS gross primary productivity (GPP) estimation from NDVI 2000-2010
Aerosol Effects on Net Plant Productivity

- **CO₂ Concentration**
- **Aerosol Concentration**
- **Temperature**
- **Photosynthesis**
- **BVOC emissions**

Boundary layer moistening and heating

- LE
- H
- Biogenic particles
- CO₂ uptake
- Photooxidation
- Terpenes

Kulmala et al., 2004
Strong aerosol effect on forest photosynthesis diffuse radiation have a large effect on CO2 fluxes

Amazonia Rondonia Forest site 2000-2001

Dry Season - NEE increase: 46 %

Wet Season - NEE increase: 24 %

Increase in aerosol loading
Aerosols effects on NEE – Manaus and Rondonia

K34 (Jul-Nov /1999-2009)

- NEE (max): ~ -20 µmol/m²s
- AOT: ~ 0.5

Manaus K34 tower

(Glauber Cirino, INPA, 2013)
Transport of Sahara dust and smoke from Africa to Amazonia
The dust-smoke interaction region (the dust is recognized by the strong backscattering signal relative to the smoke. The data was verified with MODIS image) (Yuval et. al, 2011).
Smoke and dust AOD for the 17 observation cases in 2008 indicating the advection of African aerosol toward Amazonia.

Baars et al., 2011
Raman Lidar: aerosols and water vapor up to 13 Km in Manaus

Henrique Barbosa, 2011
Efeitos do material particulado na saúde da população

- Efeitos diretos sobre o sistema respiratório e cardiovascular

Populações mais afetadas: crianças e idosos

Tempo de residência das partículas (Tr)

(Moda fina > Moda grossa)

Brônquios

Bronquiólos

Bronquiólos respiratórios

Alvéolos

Combustão de partículas, compostos orgânicos, etc

Cabelo humano

50-70 μm

< 2.5 μm

Areia fina de praia

PM2.5

PM10

(diâmetros em micrômetros)

Fonte: Valdir Soares, 2013
- Polycyclic Aromatic Hydrocarbons in intense and moderate biomass burning in the Amazon region

53% of identified PAHs are mutagenics
20% of identified PAHs are mutagenics and carcinogenics

Nilmara Alves et al., 2013
Mechanisms of action of PM$_{10}$ in lung cells

DNA damage → Human lung cells → Cell death

INCREASE THE LUNG CANCER RISK

Alves, Hacon et al., 2013
Amazonian Tall Tower Observatory
ATTO – 320 meters
Long term broad objectives observatory
ATTO site: Picture of the 85 meters tall tower at the left that is being used for aerosol and trace measurements and the proposed 320 tall tower under construction.
Experimento GoAmazon 2014
A expansão da agricultura e a variabilidade climática são agentes importantes nas alterações que estão ocorrendo no ecossistema amazônico. Em partes da região é possível observar sinais de transição para um regime dominado pelas alterações ambientais. Estes sinais incluem mudanças no balanço de energia e hidrológico na porção sul e este da Bacia Amazônica.

Interações entre mudanças globais, mudanças de uso do solo, queimadas, hidrologia, ecologia e dimensões humanas na Amazônia

Forçantes são indicadas por ovais vermelhos. Processos são as caixas verdes e consequências estão nas caixas azuis.
Processos físicos, químicos, biológicos e sociais na Amazônia formam um sistema fortemente acoplado.

Ainda temos muito a prender como funciona este sistema...

Obrigado pela atenção!!!