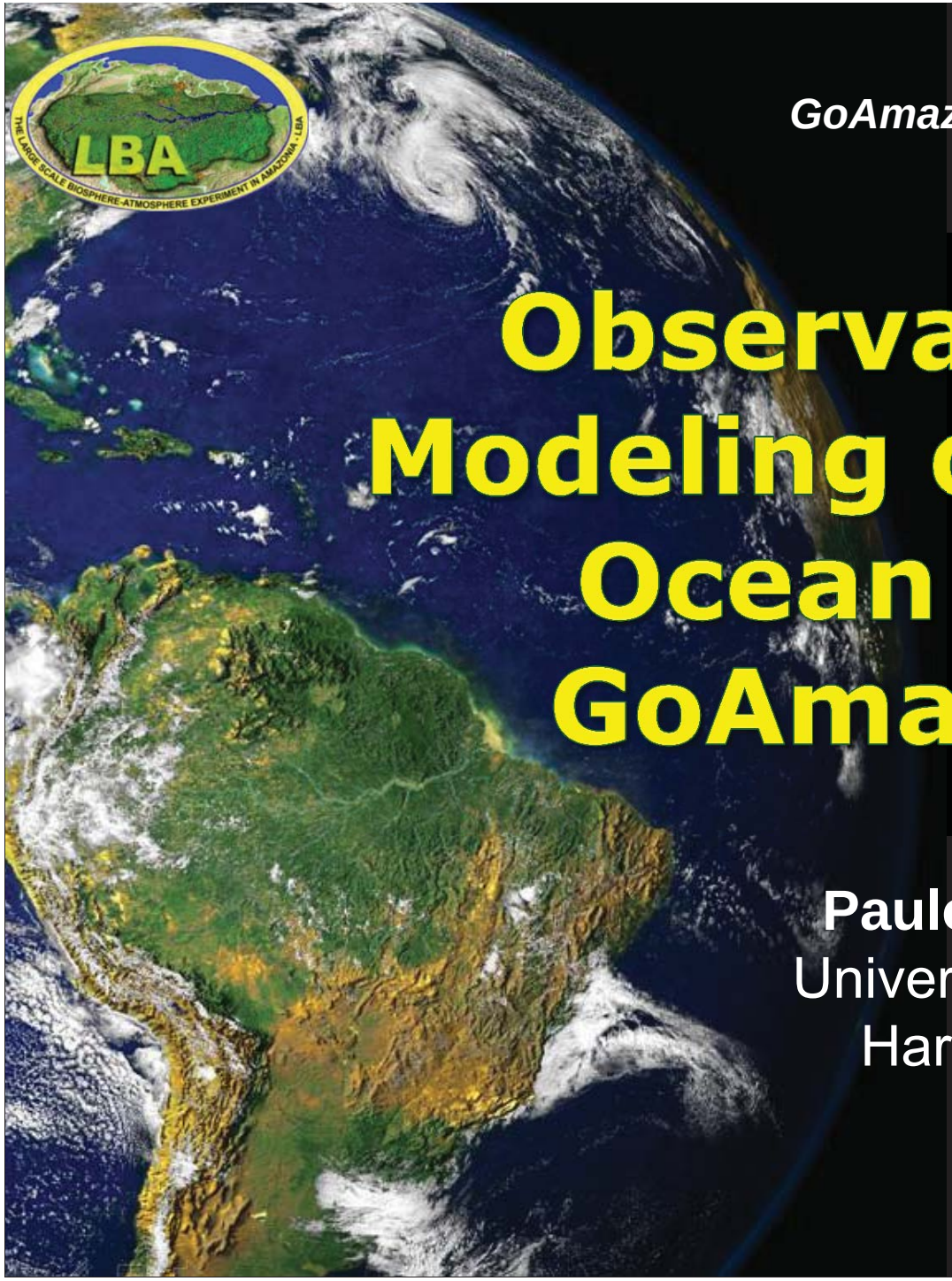


GoAmazon2014 , AGU 12 December 2011

Observations and Modeling of the Green Ocean Amazon GoAmazon2014

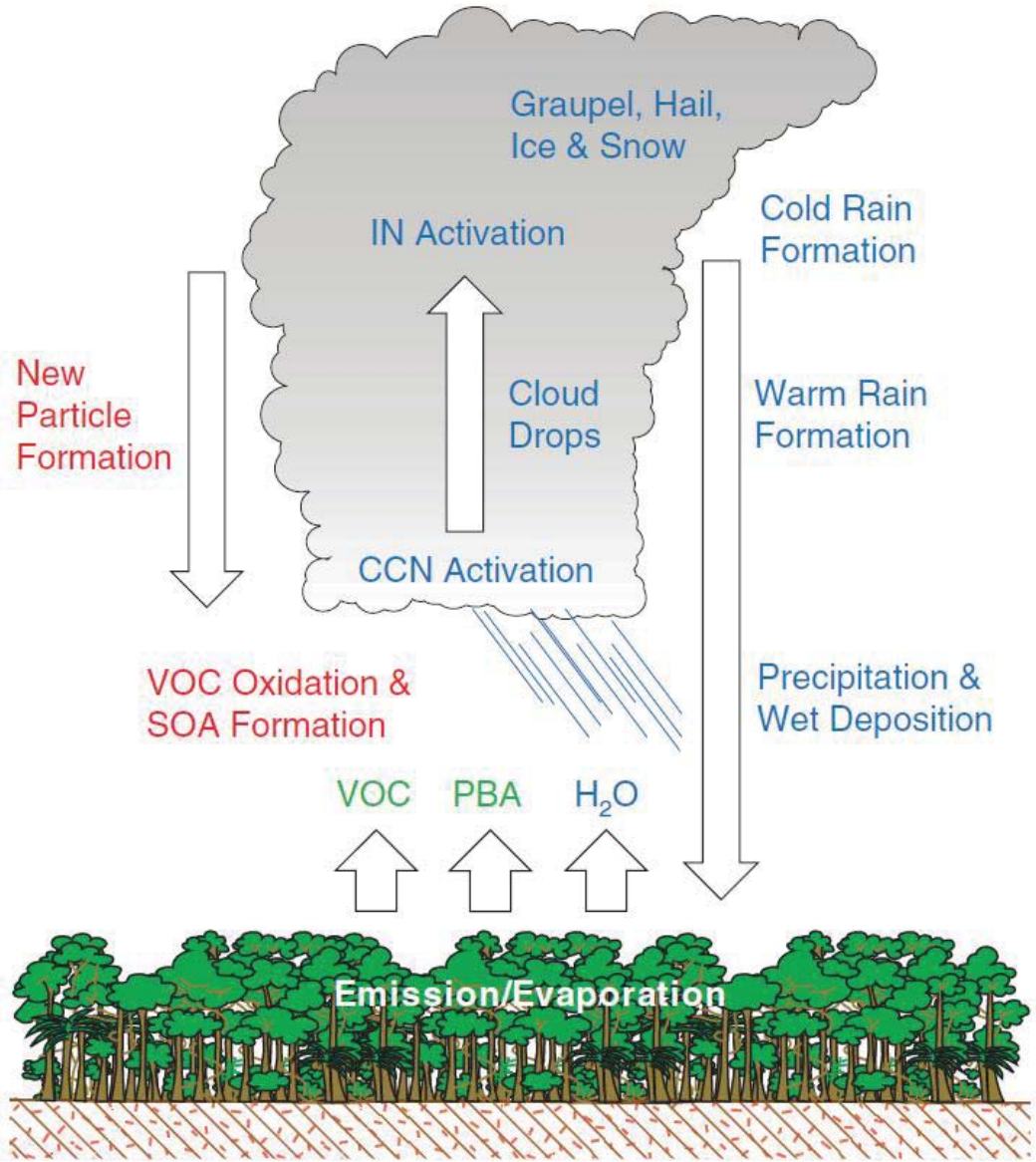
Paulo Artaxo, Scot Martin,
University of São Paulo, Brazil
Harvard University, USA.
artaxo@if.usp,br

Amazonia: some key scientific issues

- Amazonia holds ≈ 50 billion tons of carbon in the forest and ≈75 billion tons carbon in the soil
- The most vigorous hydrological cycle in any ecosystem
- Tropical convection: drivers, long distance effects
- Strong coupling between Forest-Atmosphere-Climate and Biology-Physics-Chemistry. Aerosol-clouds interactions and aerosol radiative forcing
- Tropical convection: Drivers, long distance effects
- Land Use Change and its effects, including carbon cycling, biomass burning emissions, modeling and social drivers.
- Role of disturbances (droughts of 2005 and 2010)
- Urbanization in Amazonia and its effects on regional chemistry, radiation balance and precipitation issues.
- Links between biology/ecosystem/chemistry/climate

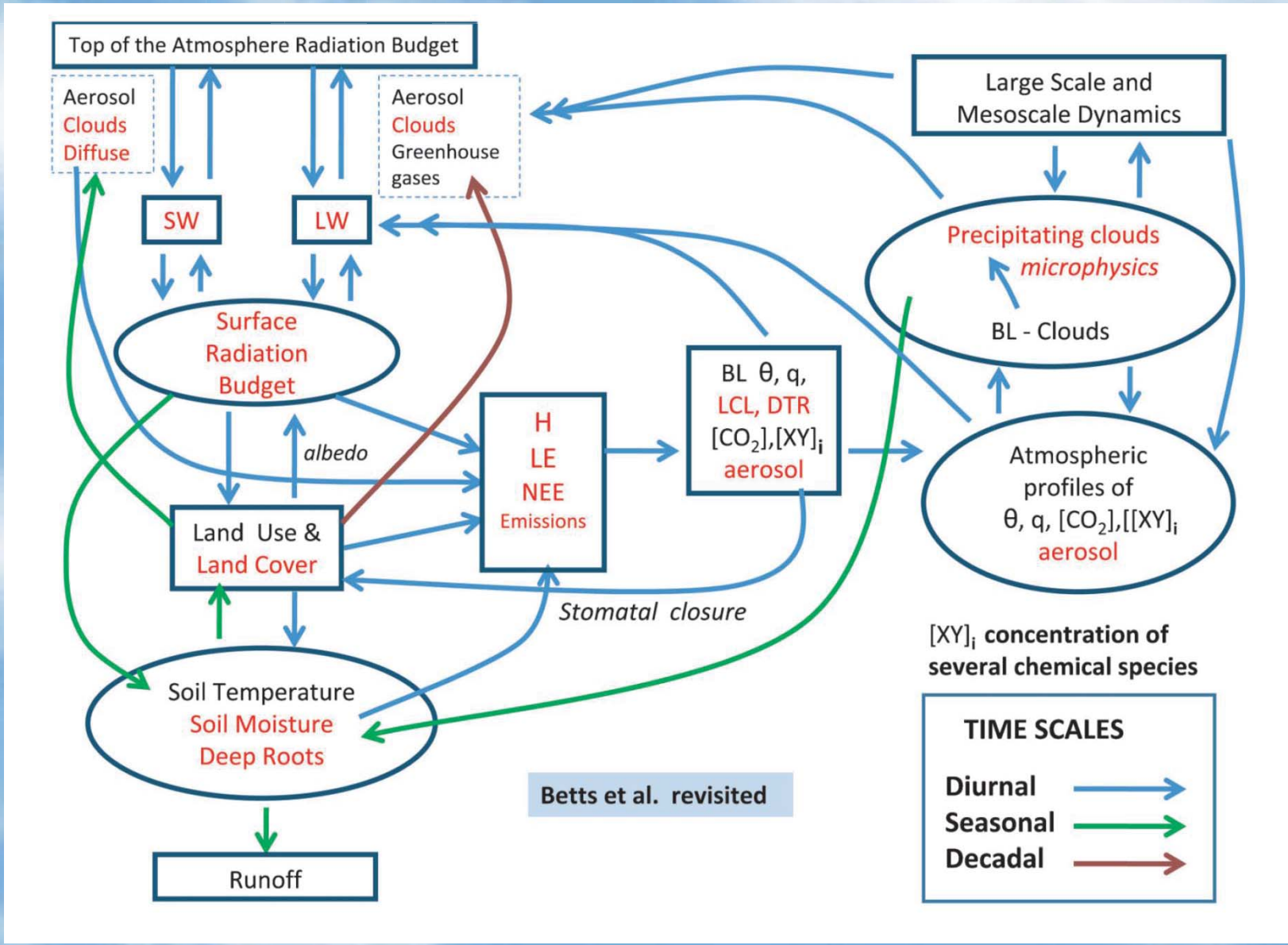
Cloud Life Cycle, Aerosol Life Cycle, Aerosol-Cloud-Precipitation Interactions, Carbon Cycle are all represented in this schematic.

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



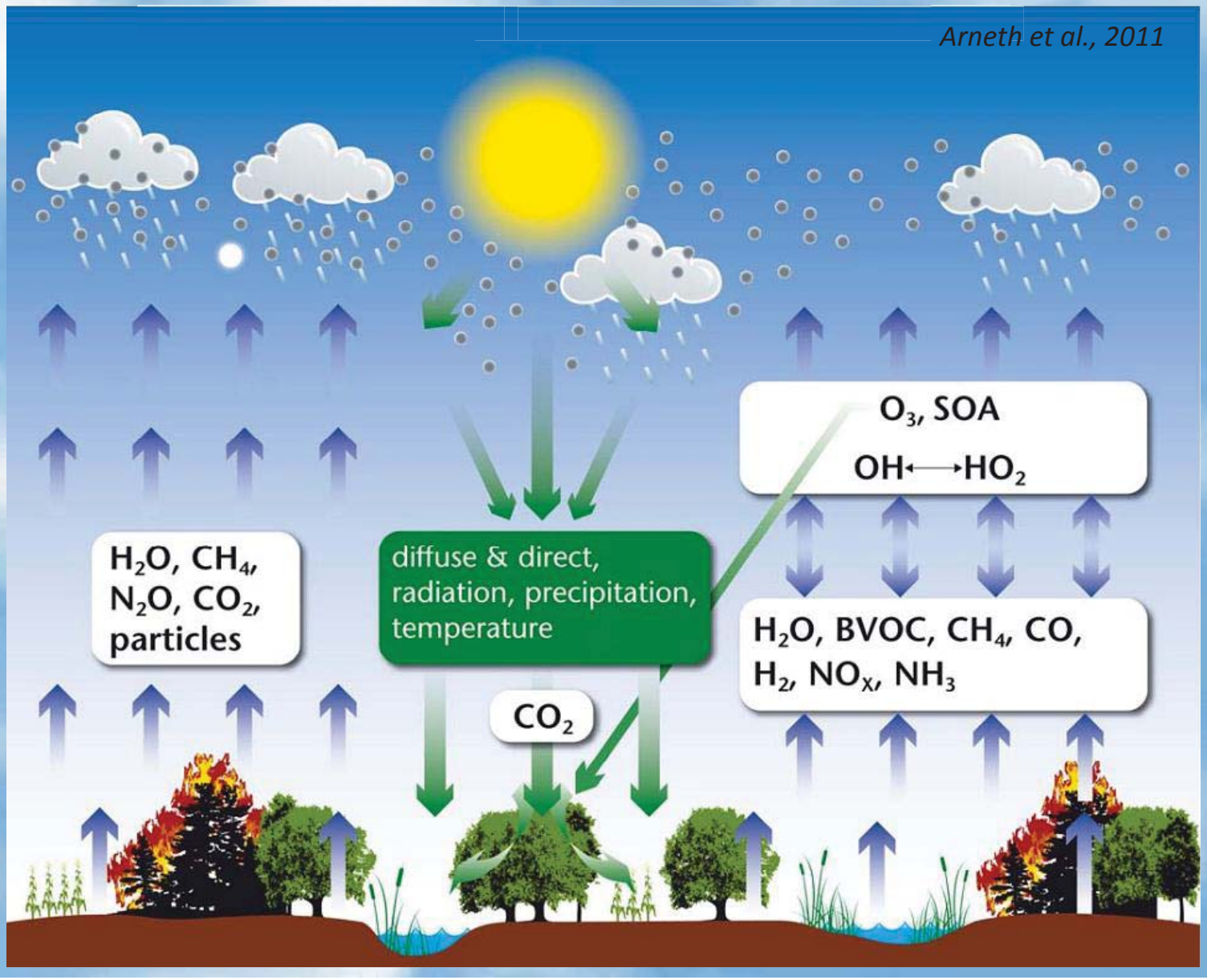
U. Pöschl, S.T. Martin, B. Sinha, Q. Chen, S.S. Gunthe, J.A. Huffman, S. Borrmann, D.K. Farmer, R.M. Garland, G. Helas, J.L. Jimenez, S.M. King, A. Manzi, E. Mikhailov, T. Pauliquevis, M.D. Petters, A.J. Prenni, P. Roldin, D. Rose, J. Schneider, H. Su, S.R. Zorn, P. Artaxo, M. O. Andreae, "Rainforest aerosols as biogenic nuclei of clouds and precipitation in the Amazon," *Science*, 2010, 329, 1513-1516.

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

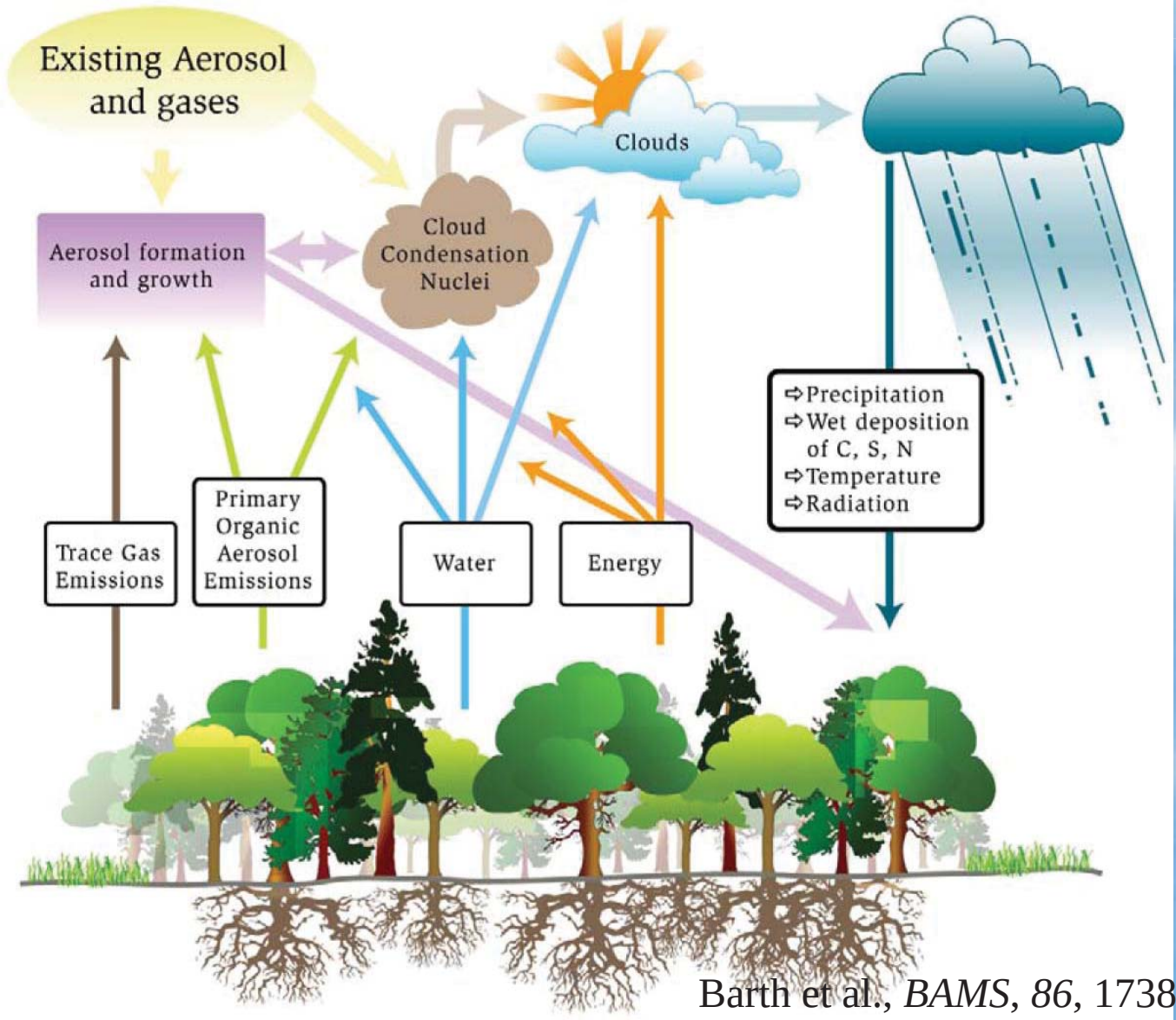


Meteorology, atmospheric chemistry, ecosystem function, radiation, etc. all very linked

Conceptual overview of terrestrial carbon cycle – chemistry – climate interactions



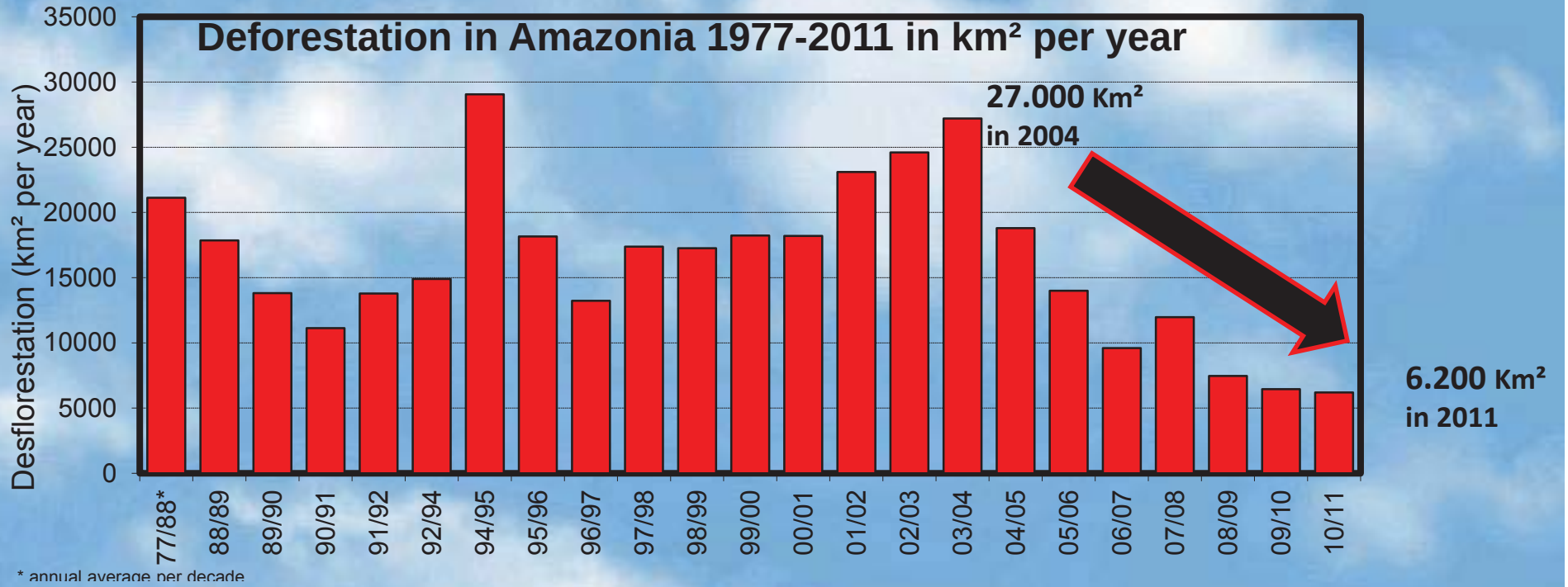
Aerosol Particles, energy and water vapor: Coupling of Terrestrial Ecosystems and the Hydrologic Cycle



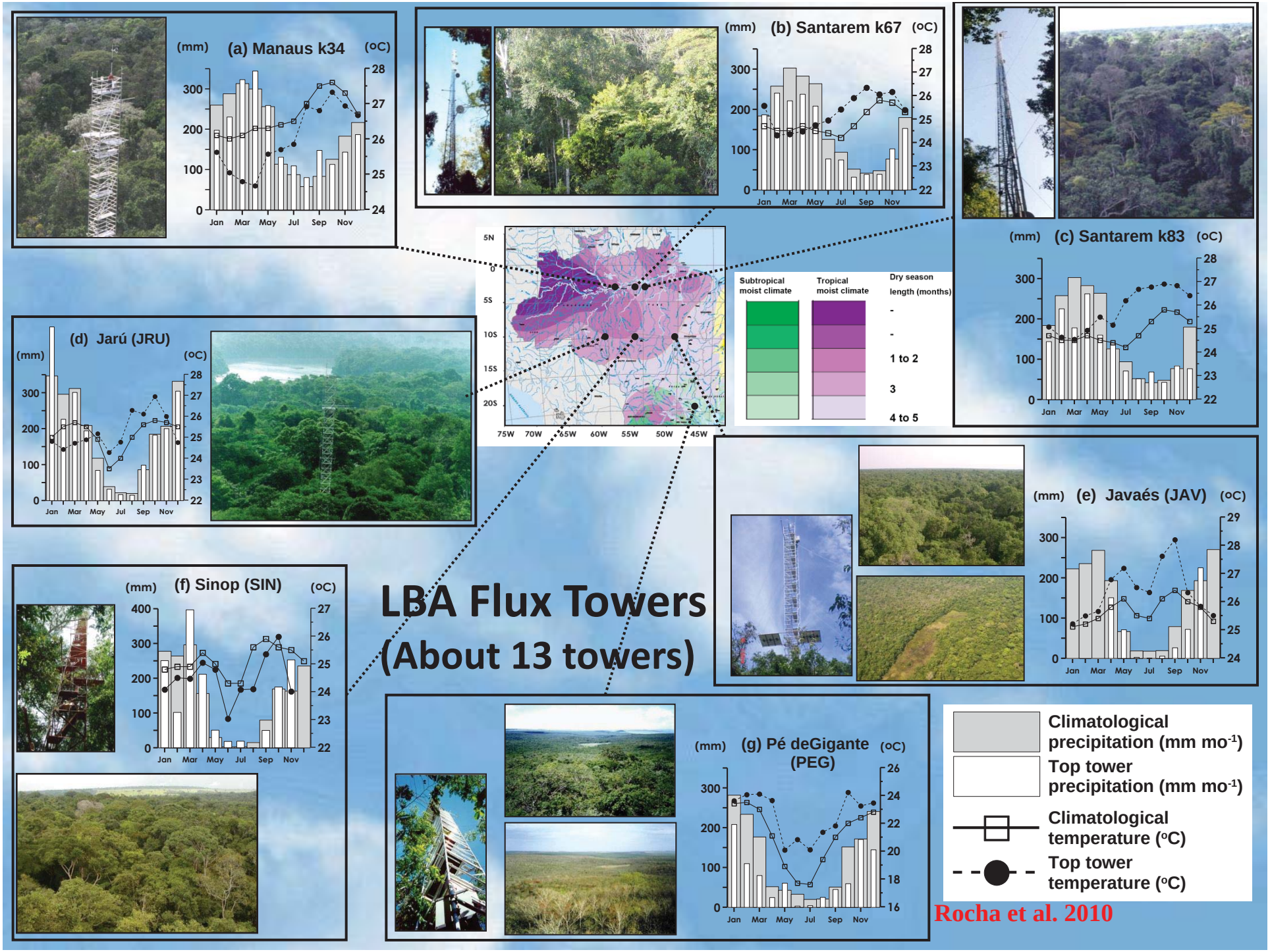
Barth et al., *BAMS*, *86*, 1738-1742, 2005.

Deforestation was reduced from 27,000 Km² in 2004 to 6,200 Km² in 2011.

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

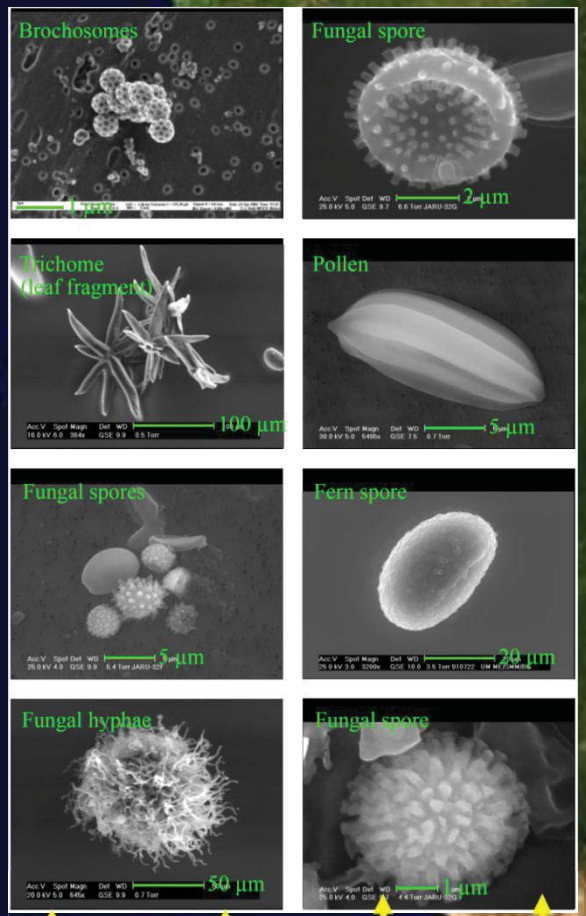


What public policies are needed to sustain this reduction?

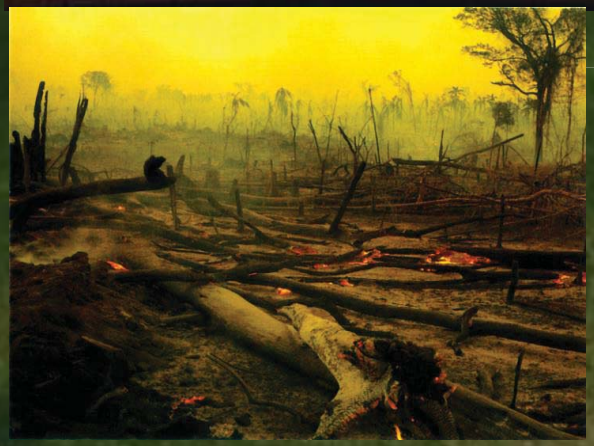

LBA Flux Towers
(About 13 towers)
(a) Manaus k34
(b) Santarem k67
(c) Santarem k83
(d) Jarú (JRU)
(e) Javaés (JAV)
(f) Sinop (SIN)
(g) Pé deGigante (PEG)
(mm)
(oC)
Jan Mar May Jul Sep Nov
Subtropical moist climate
Tropical moist climate
Dry season length (months)
1 to 2
3
4 to 5
Climatological precipitation (mm mo-1)
Top tower precipitation (mm mo-1)
Climatological temperature (oC)
Top tower temperature (oC)
Rocha et al. 2010

Amazonia: 3 different types of aerosols

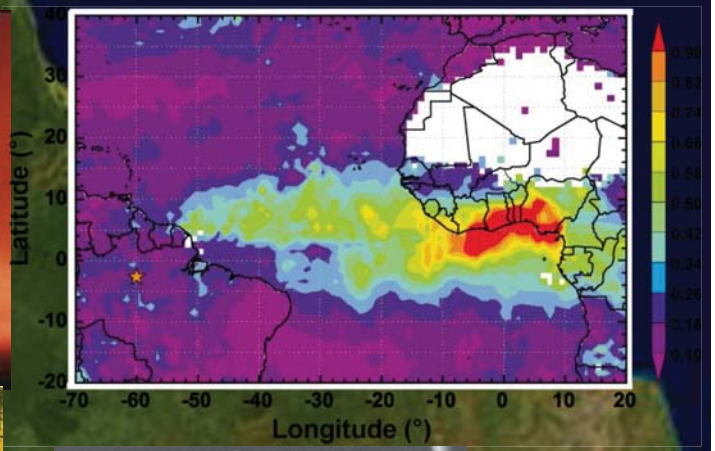
Biogenic (primary and SOA)

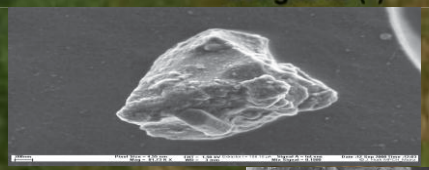


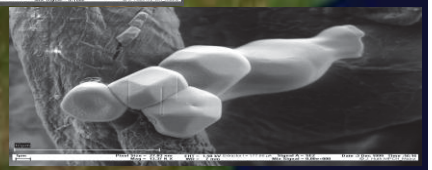
Biomass Burning



Dust from Sahara



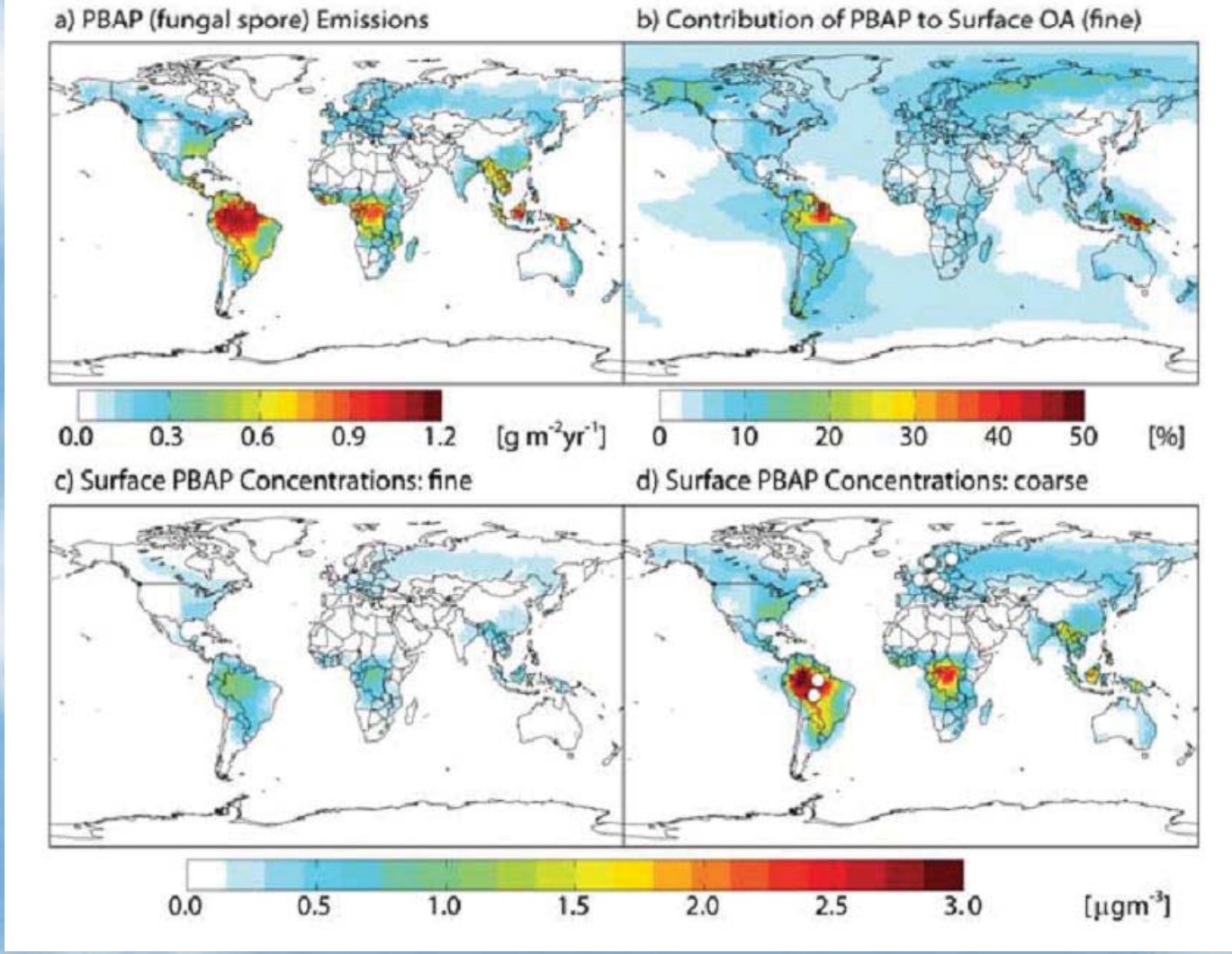




Each with VERY different properties and impacts
Size: from 1 nanometer to 10 micrometers

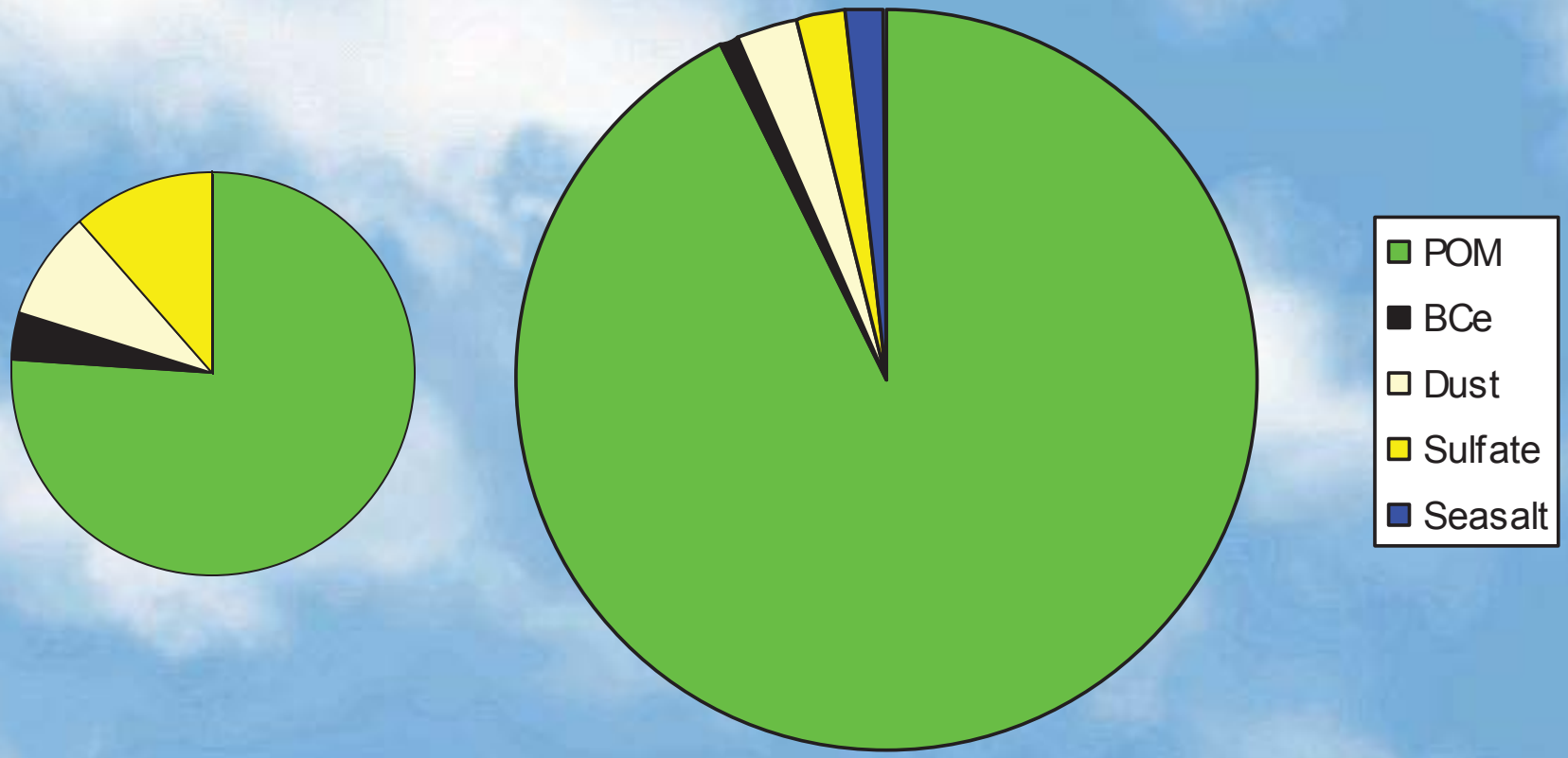
We live in a biological world: biology really matters

Atmospheric budget of primary biological aerosol particles from fungal spores



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

Aerosol composition in wet-season Amazonia

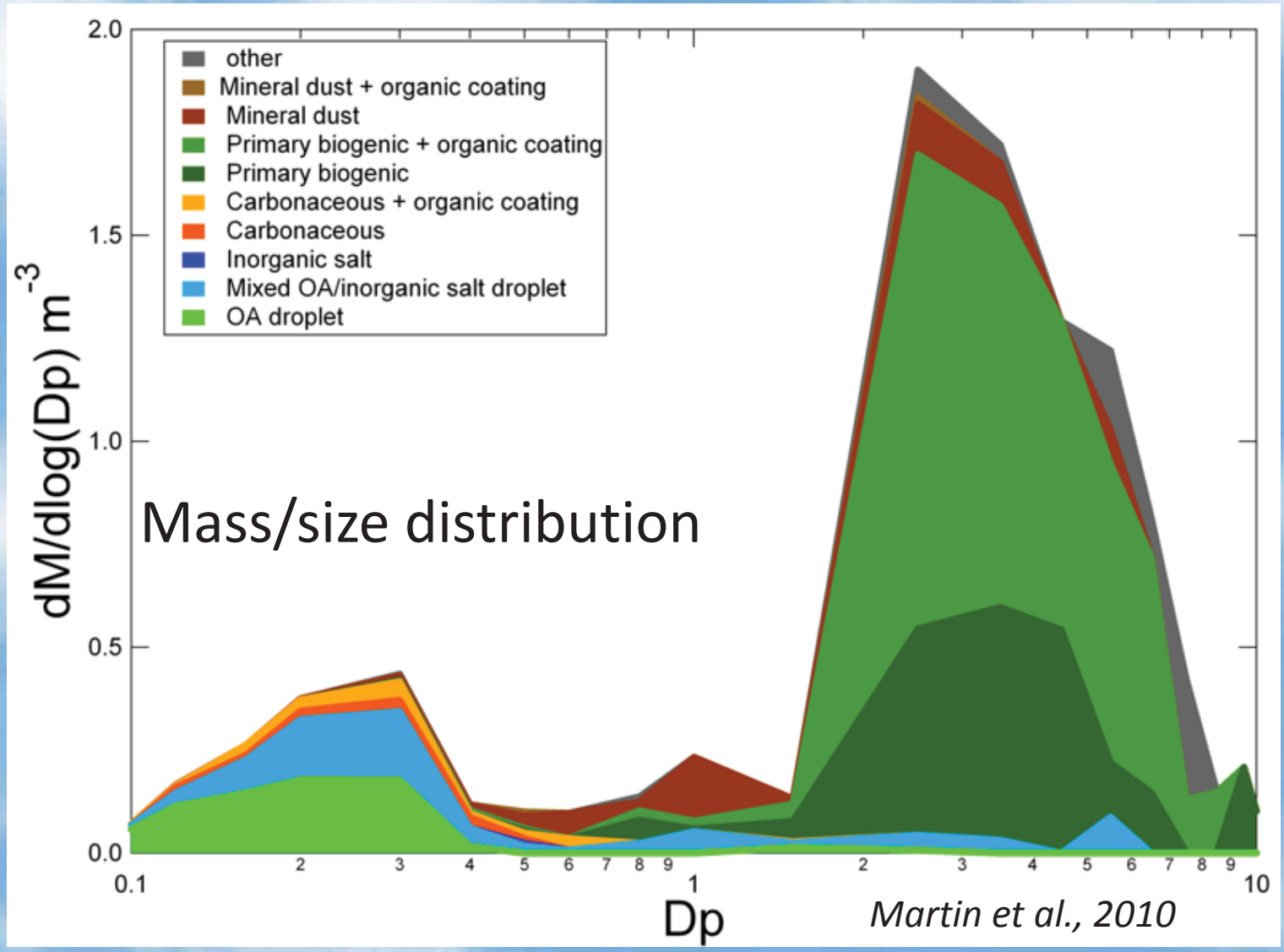


Fine Fraction
1.7 µg m^{-3}

Coarse Fraction
5.7 µg m^{-3}

Martin et al., 2010

Particles in clean air over Amazon



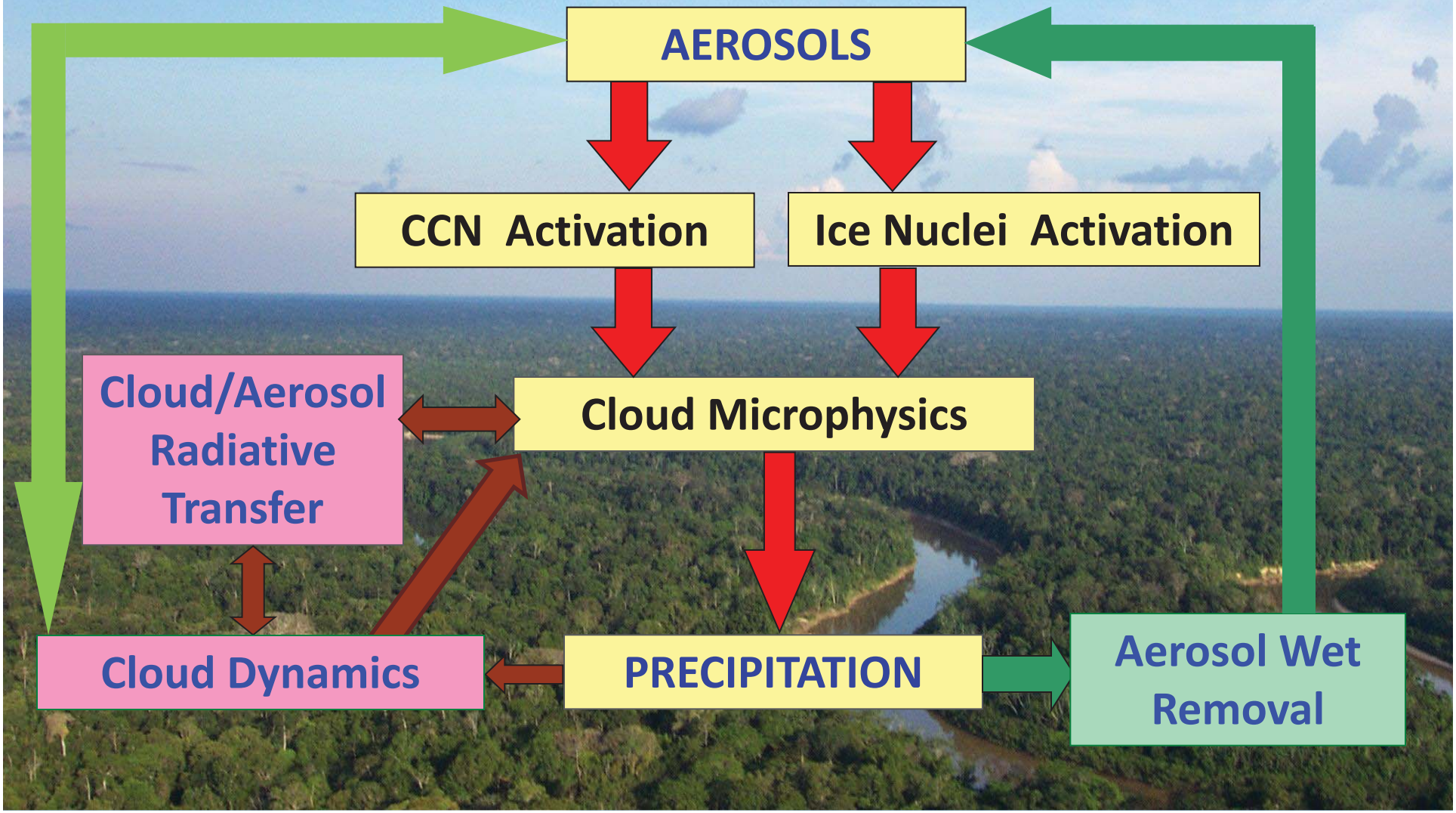
Biological, chemical, and physical processes over the Amazon form a closely coupled system

Aerosol-clouds interactions, tropical convection and aerosol radiative forcing

- Optical, physical properties and chemical composition of biomass burning and natural biogenic aerosols
- Cloud Condensation Nuclei (CCN) properties
- Ice Nuclei (IN) properties of biogenic and Sahara dust aerosols
- Long term measurements of ground, vertical distribution and column integrated optical properties
- Convective clouds physical properties and distribution coupled with cloud droplet microphysical properties.

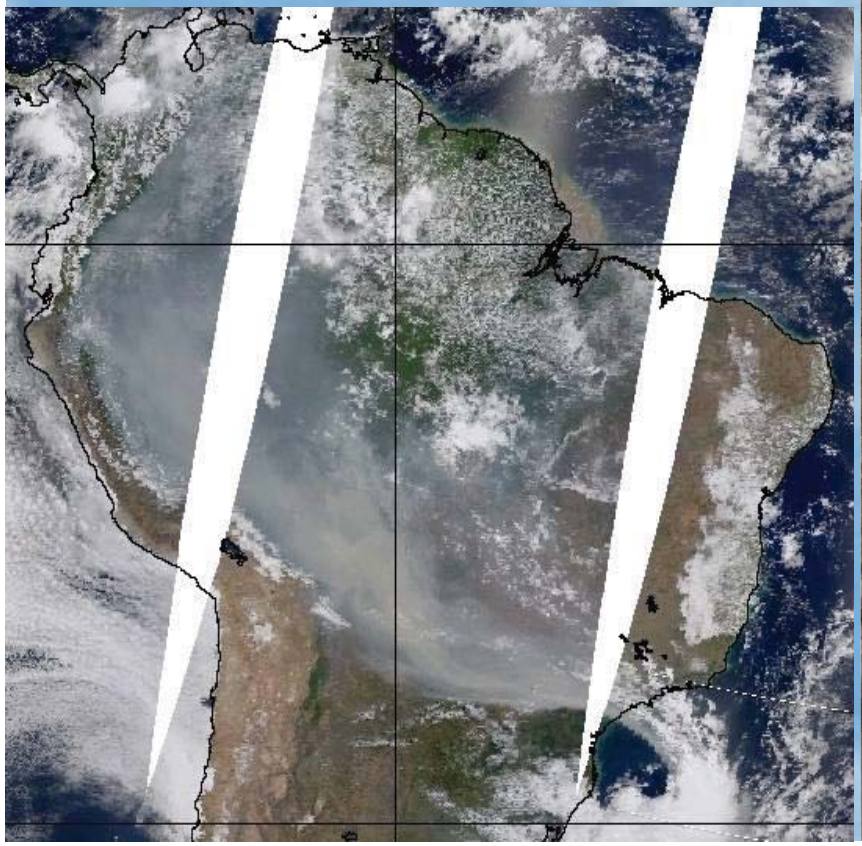
Aerosol-cloud-precipitation feedbacks

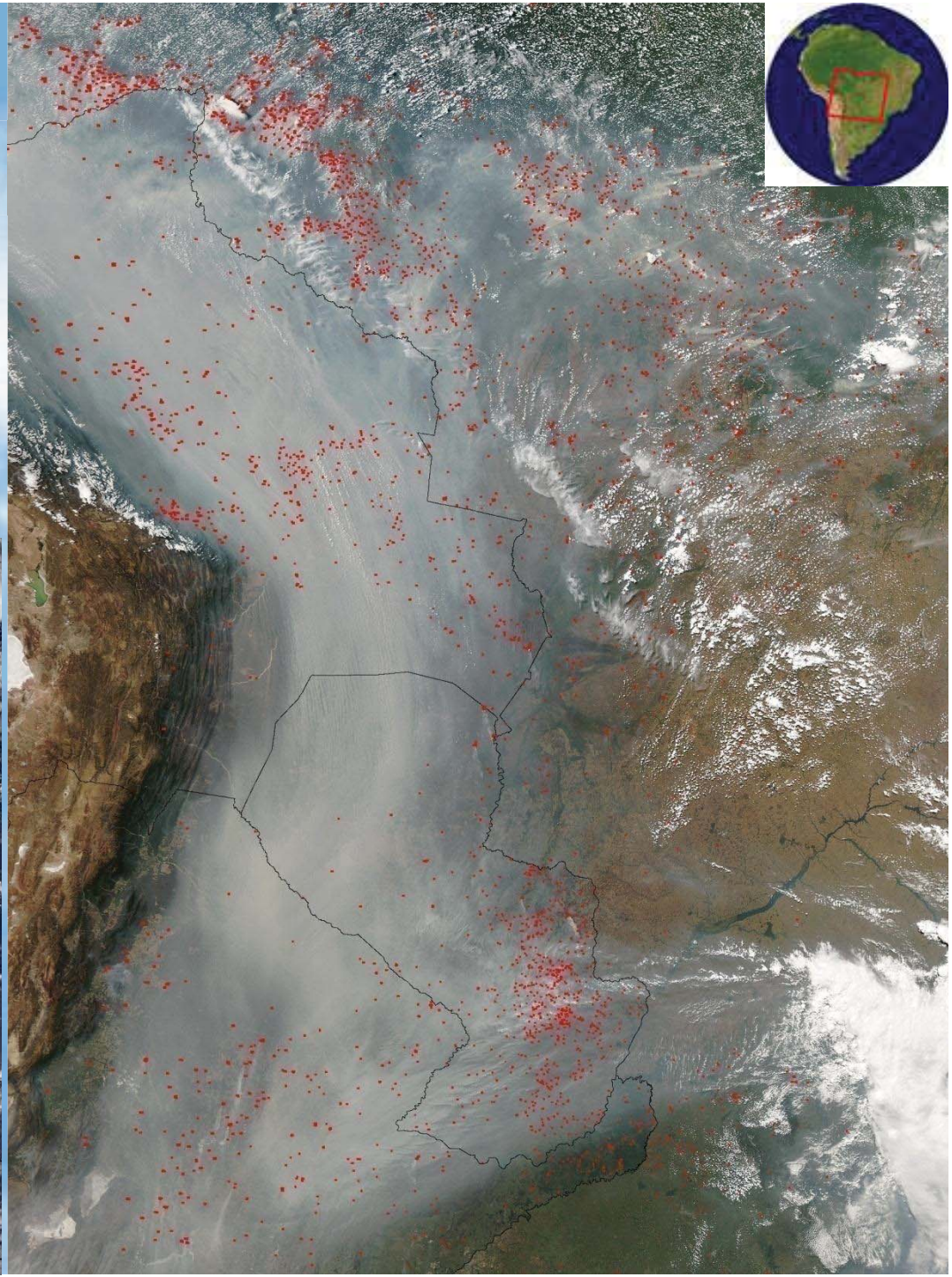
CCN = cloud condensation nuclei and IN = ice nuclei.



Large scale aerosol distribution in Amazonia

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





Amazonia - Average direct aerosol forcing clear sky

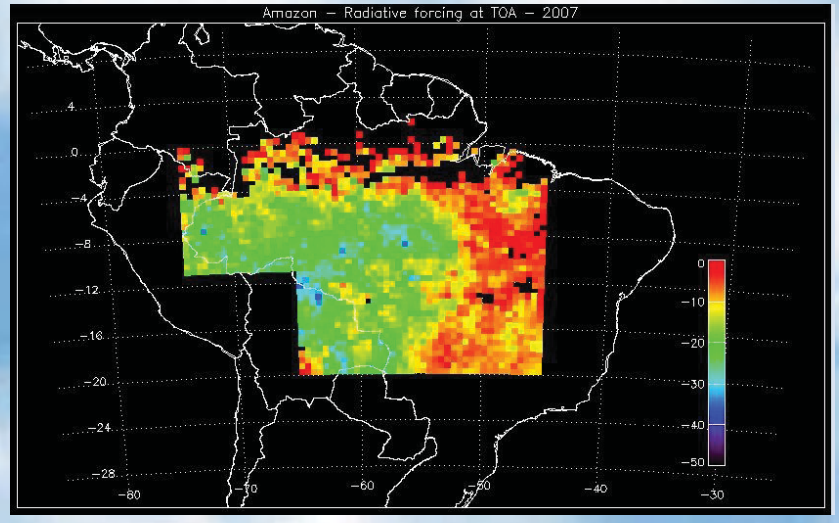
Top: - 10 w/m²

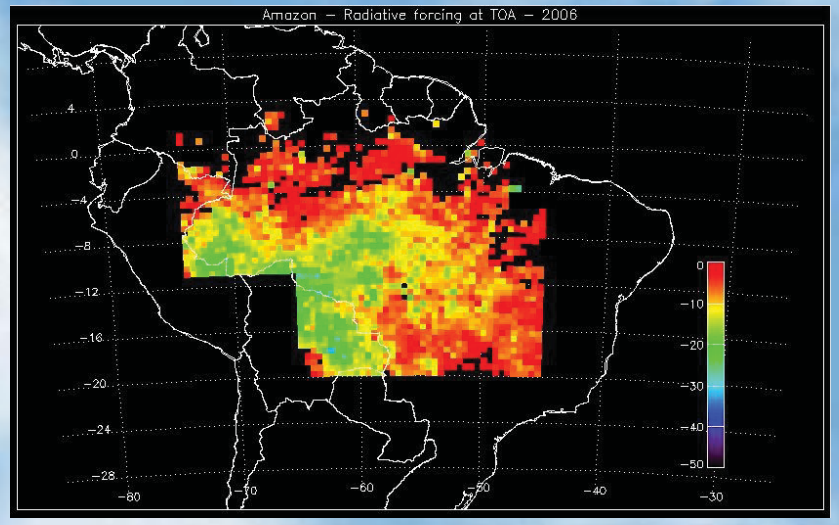
Surface: - 38 w/m²

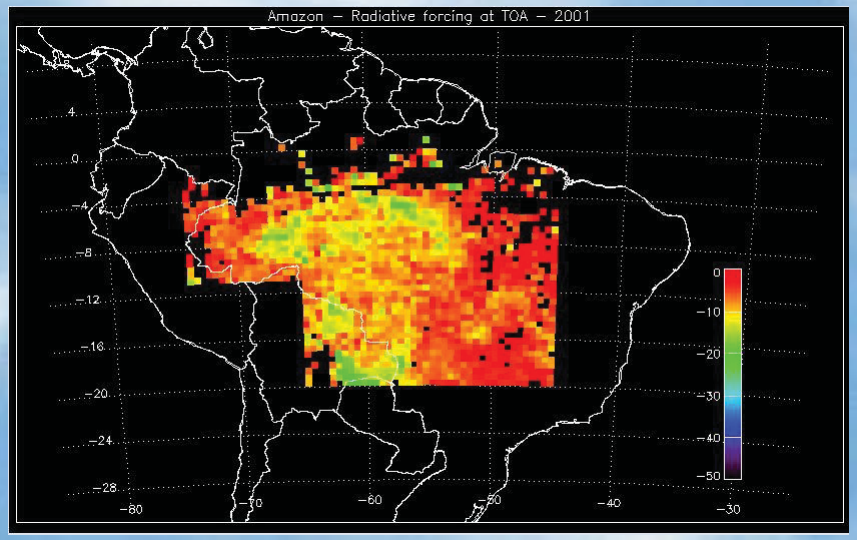
Conditions: surface: forest vegetation AOT (τ=0.95 at 500nm); 24 hour average
7 years (93-95, 99-02 dry season Aug-Oct)

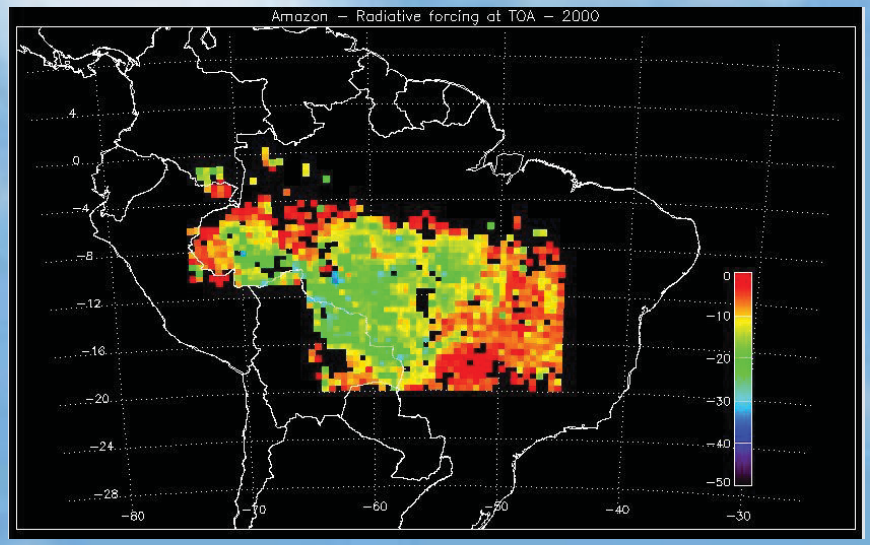
Large scale radiative forcing in Amazonia from 2000 to 2007

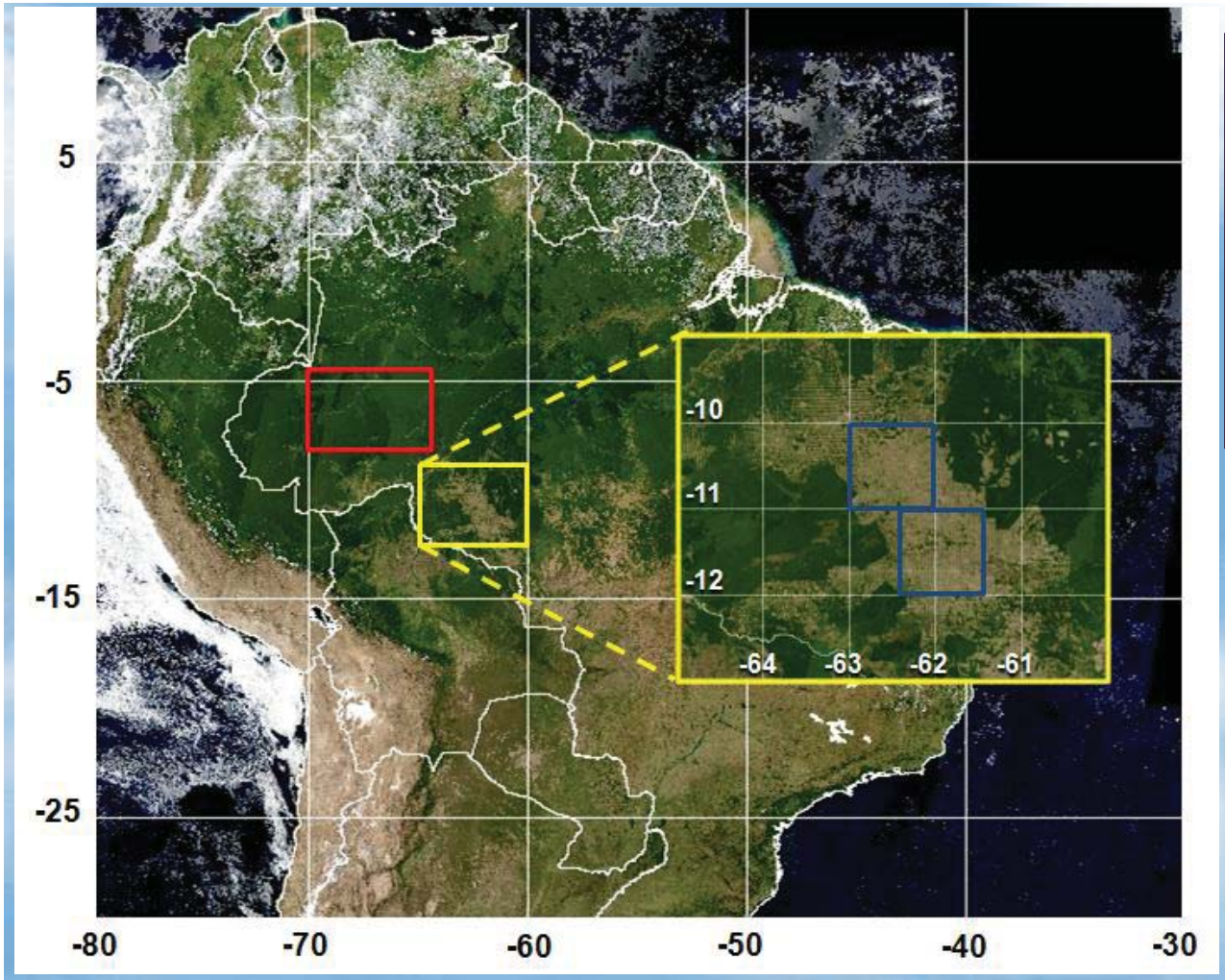
CERES *(Clouds and the Earth's Radiant Energy System) and MODIS*











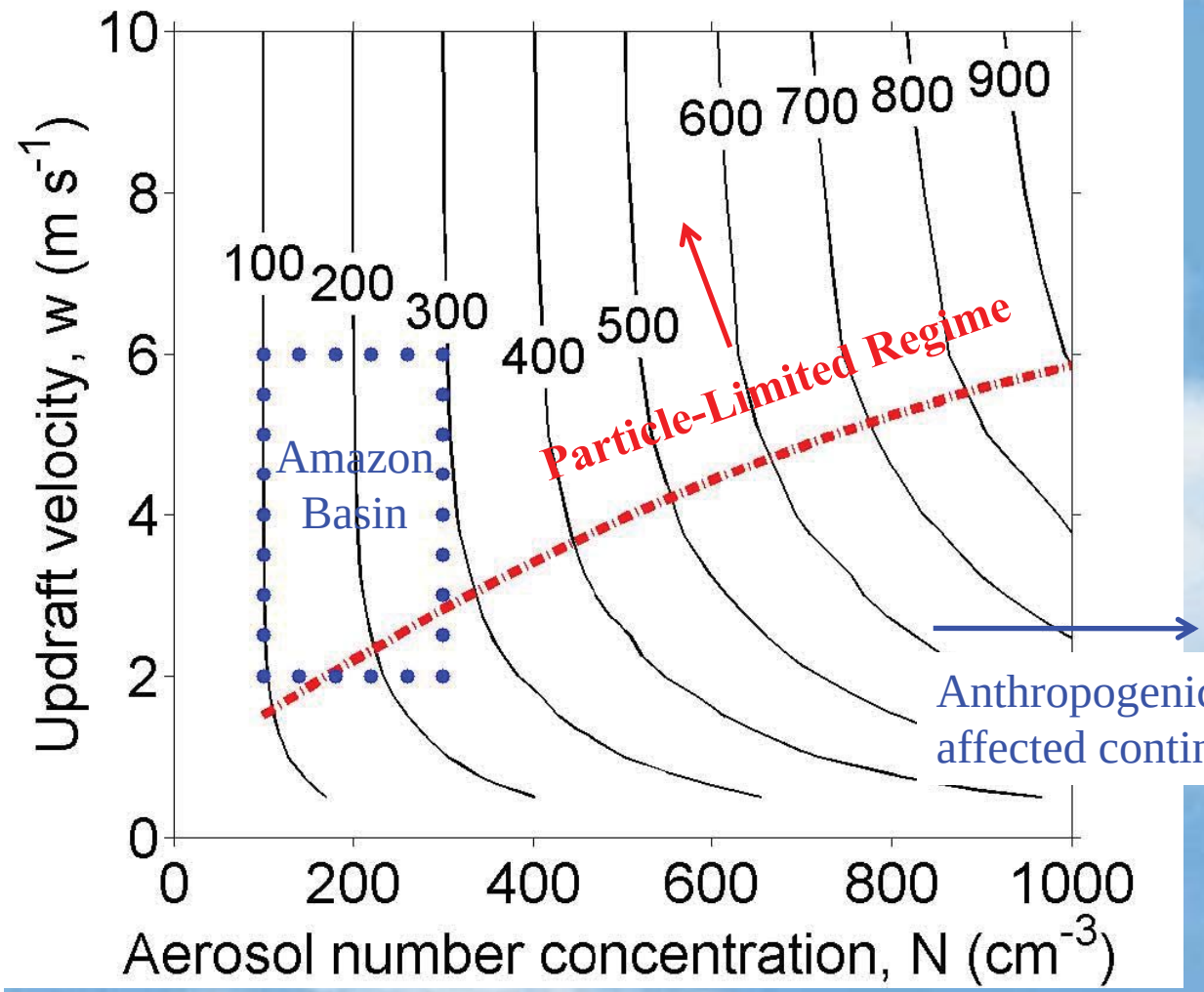
Land-use change radiative forcing. Forested areas are selected in red and deforested areas are selected in blue.

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

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

Cloud Droplet Number Concentration (CDNC):

Sensitivity to Pollution in Pristine Regions



Amazon Basin:

Low aerosol number concentrations +

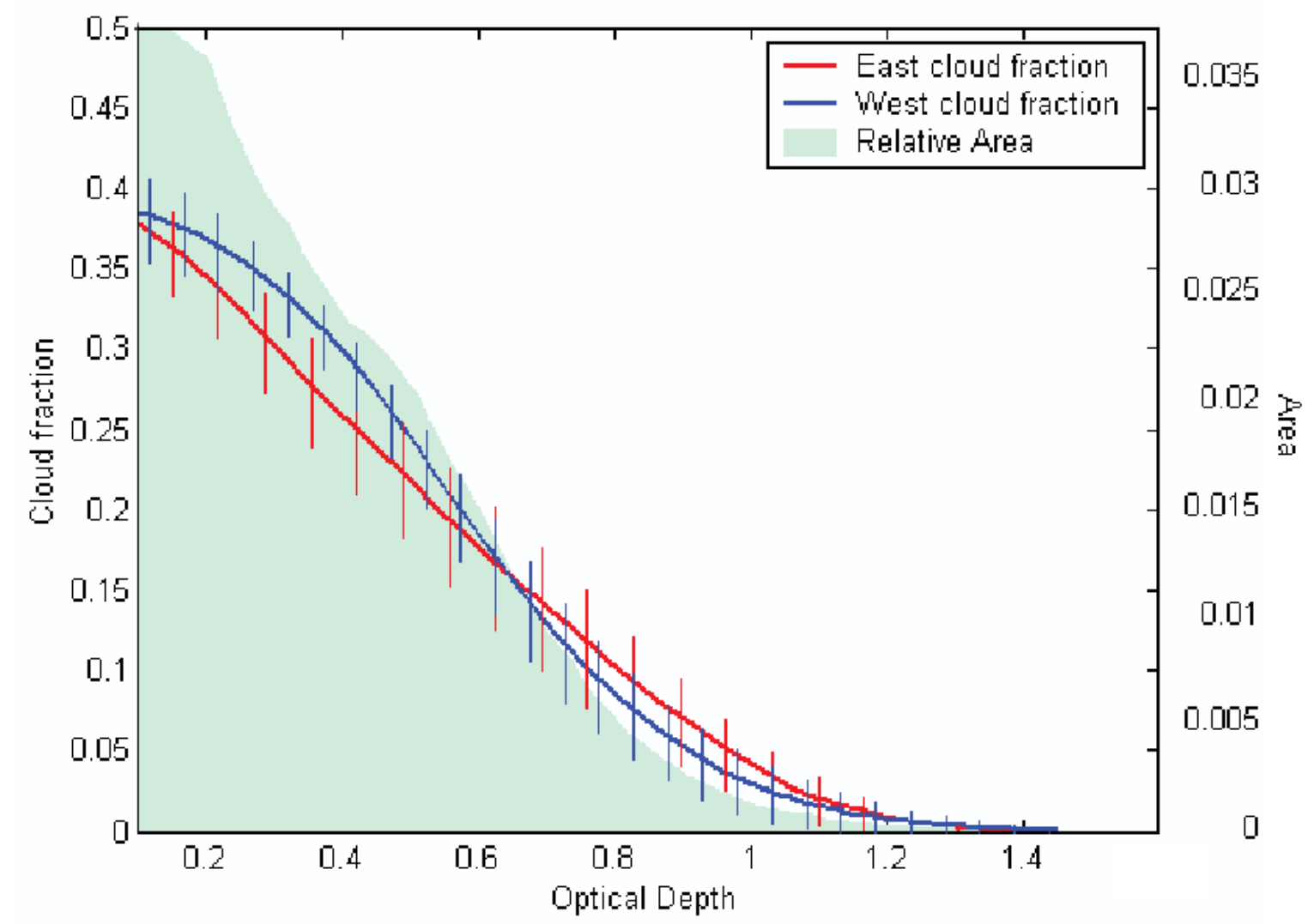
High water vapor concentration =

Especially susceptible.

Possibility of dramatic changes in energy flows and rainfall patterns

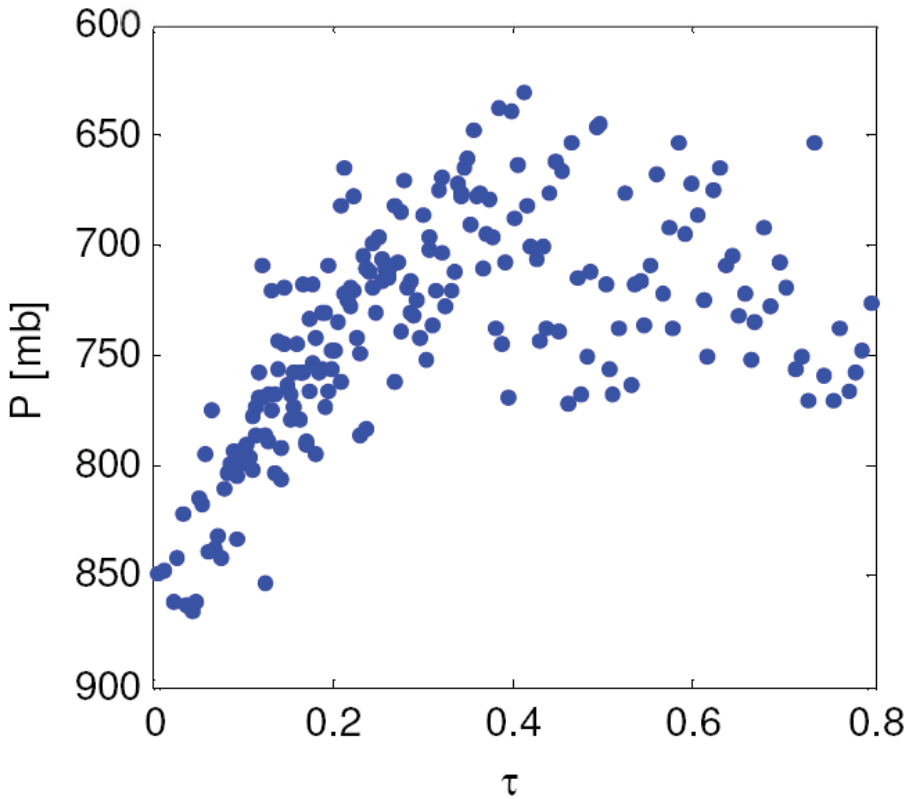
Pöschl et al., "Rainforest aerosols as biogenic nuclei of clouds and precipitation in the Amazon," *Science*, **2010**, *329*, 1513-1516.

Suppression of low cloud formation by aerosols in Amazonia

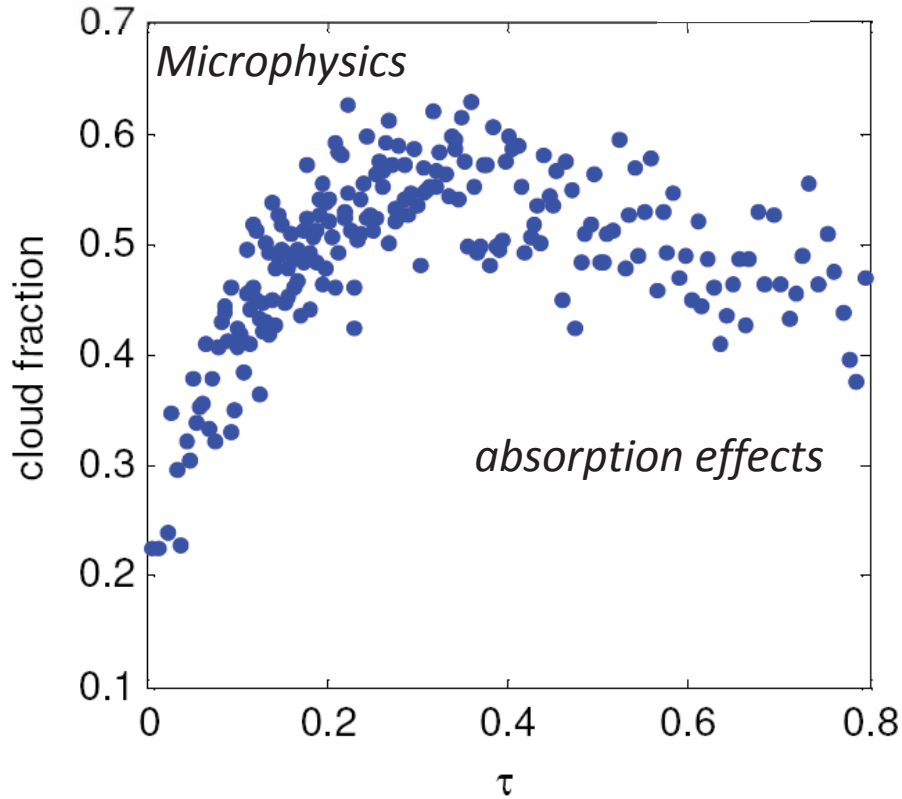


Cloud fraction as function of aerosol optical depth (OD). On average, the cloud fraction decreases to less than 1/8 of the cloud fraction in clean conditions when OD = 1. (Koren and Kaufman, 2003)

Relationships between cloud properties and aerosol loading in Amazonia



Cloud top pressure (P) vs. AOD



Cloud fraction vs. AOD.

Koren et al., Science 2008

nature geoscience

LETTERS

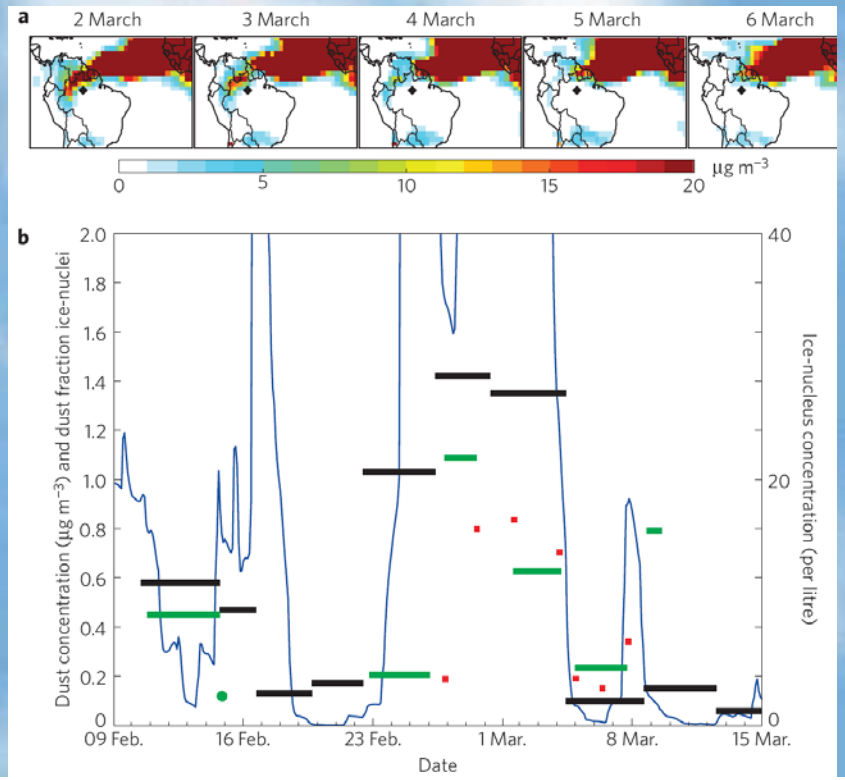
PUBLISHED ONLINE: 3 MAY 2009 | DOI: 10.1038/NGEO517

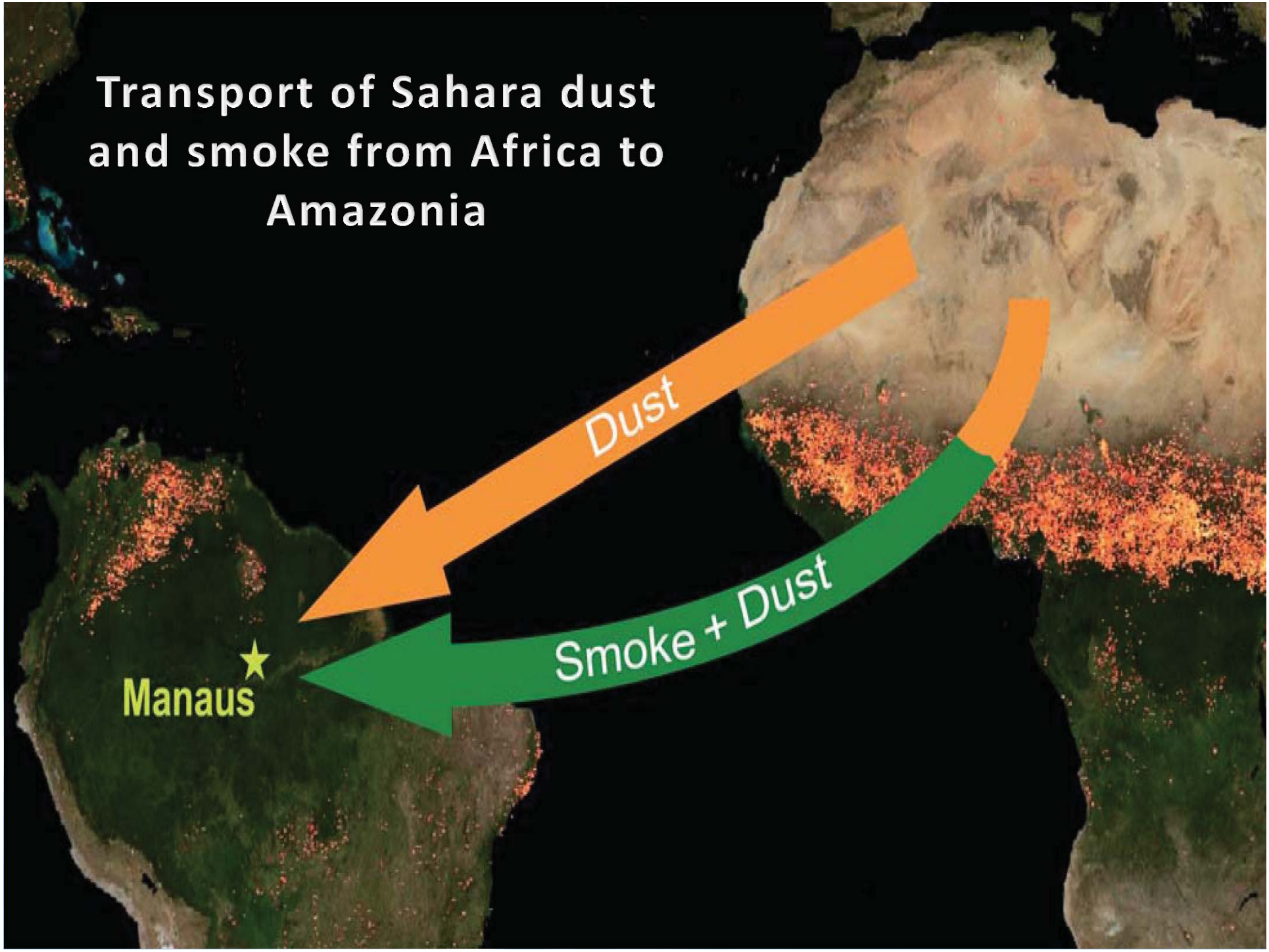
Relative roles of biogenic emissions and Saharan dust as ice nuclei in the Amazon basin

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.




Transport of Sahara dust and smoke from Africa to Amazonia
Dust
Smoke + Dust
Manaus

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

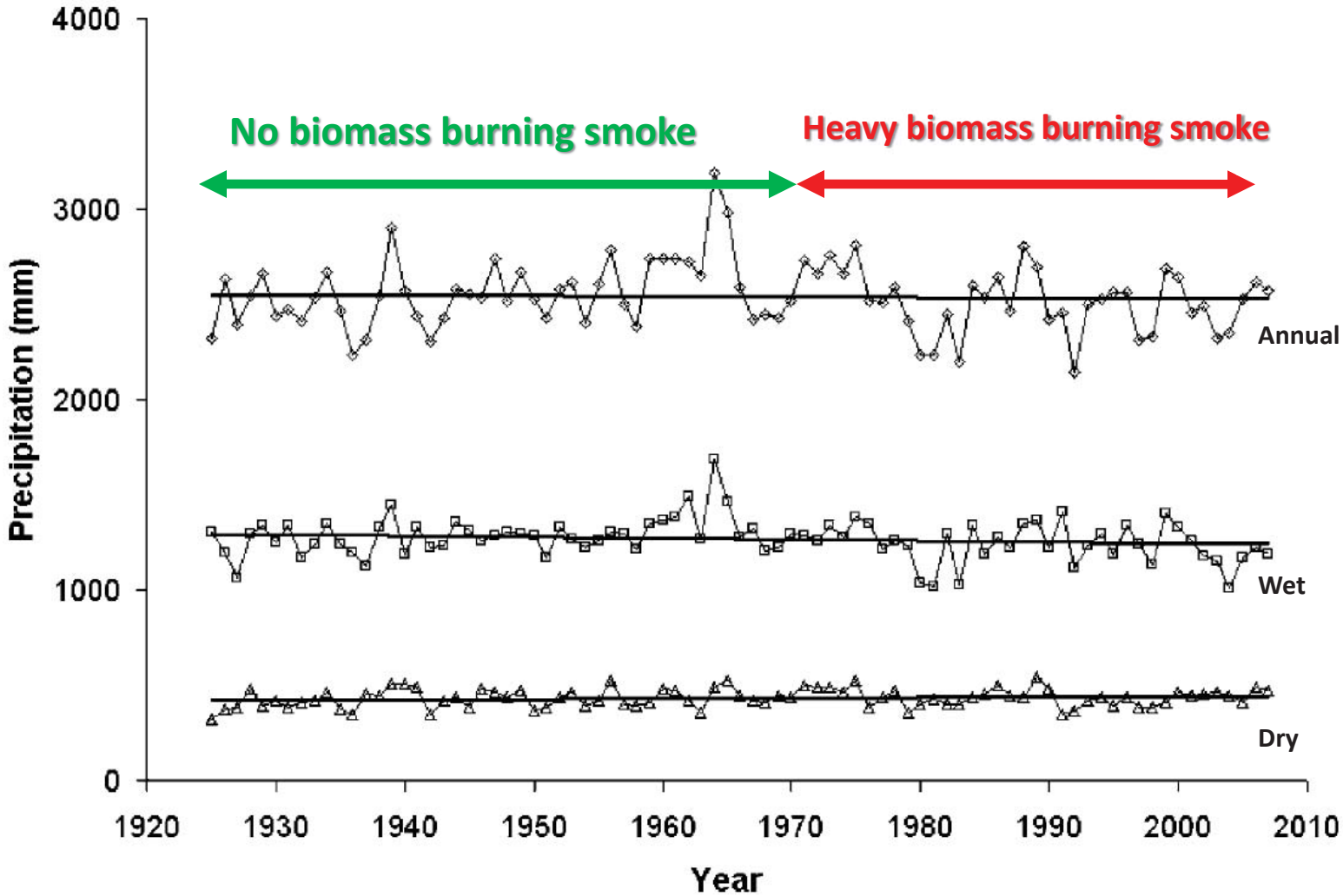
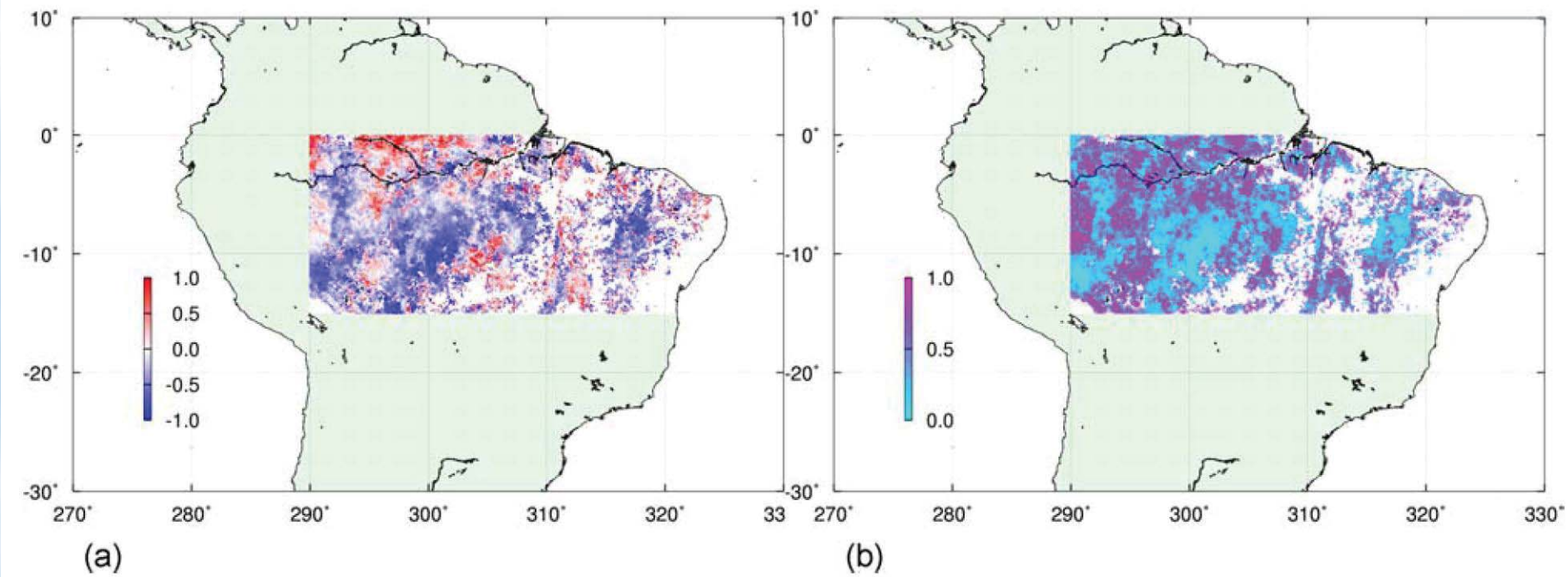


Fig. 4 Whole Region average annual and wet-season (JFMA) precipitation series and their linear-trend lines

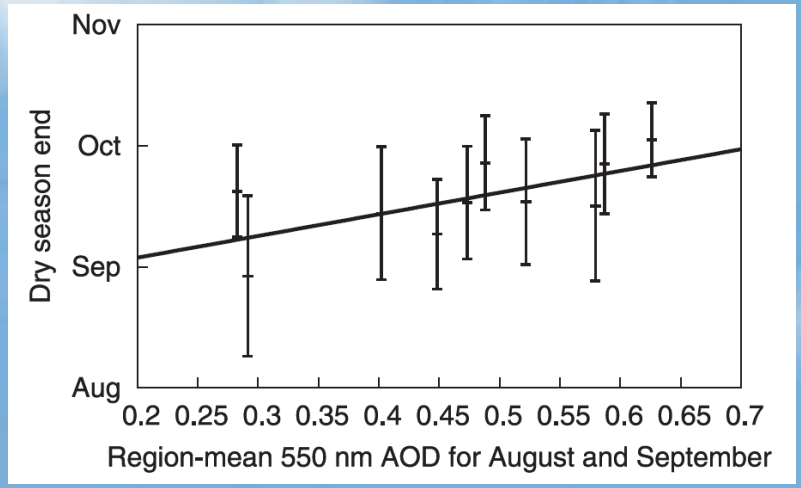
Satyamurty et al., 2010

Correlation between aerosols and precipitation in Amazonia



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

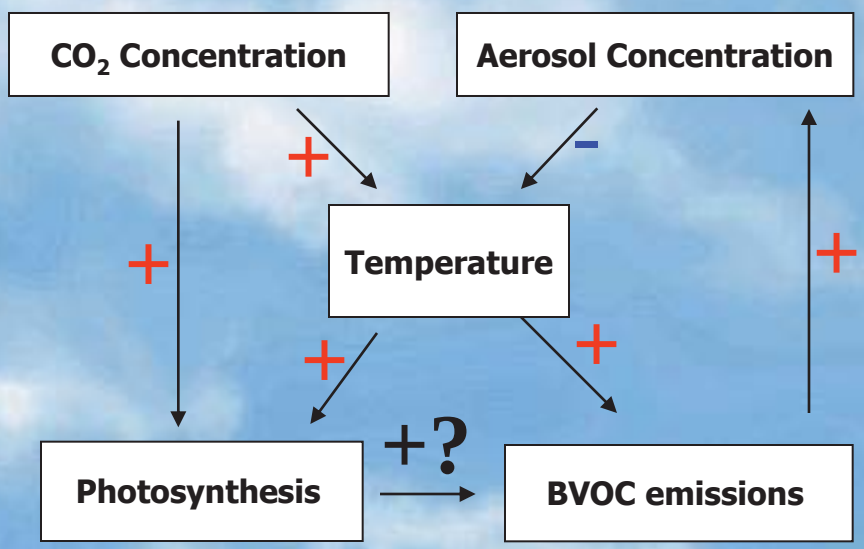
Aerosols extending duration of dry season



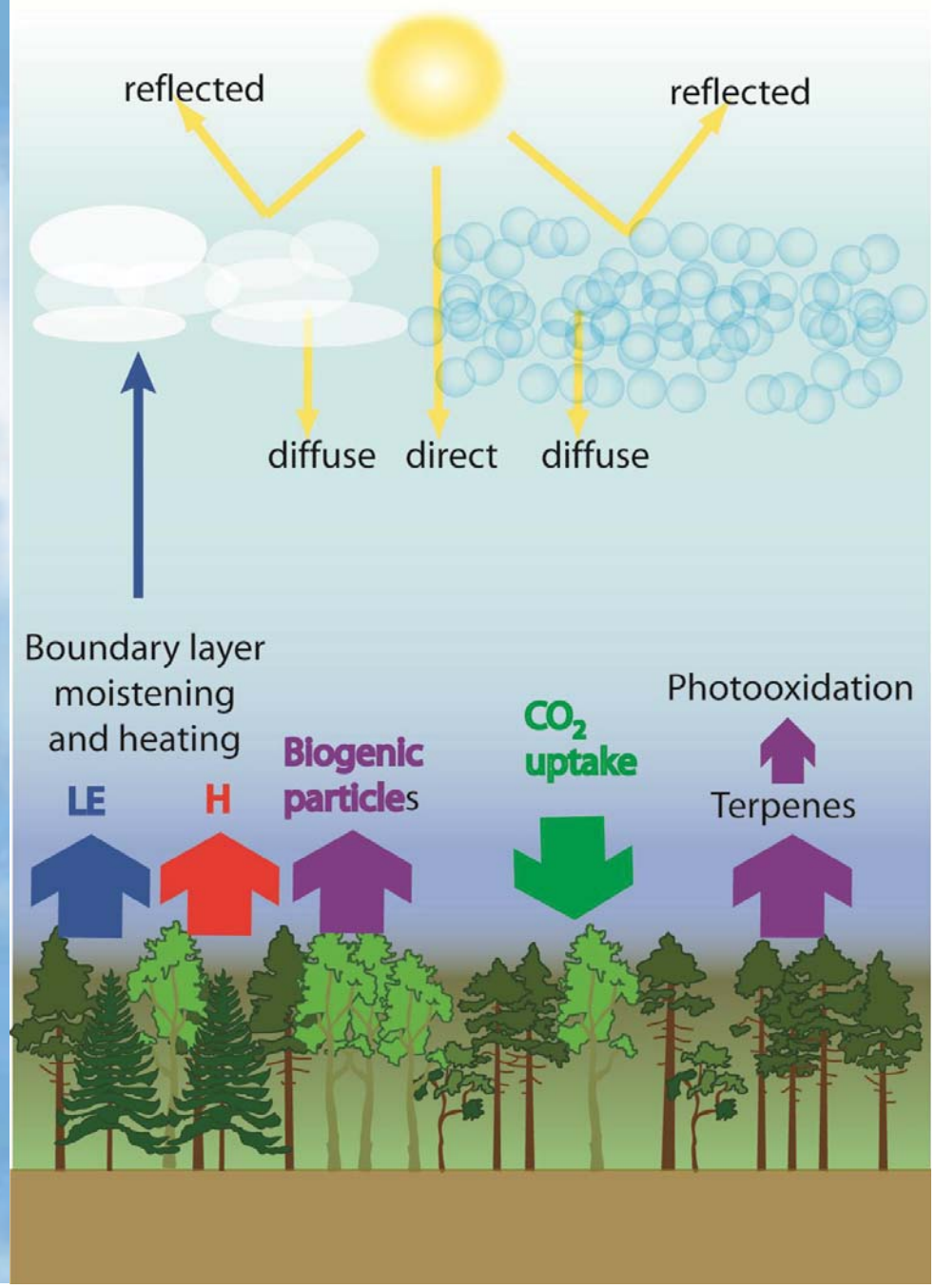
Region-mean end of dry season and corresponding 550-nm AOD.

Bevan et al., JGR May 2009

Aerosol effects on the Net Plant Productivity

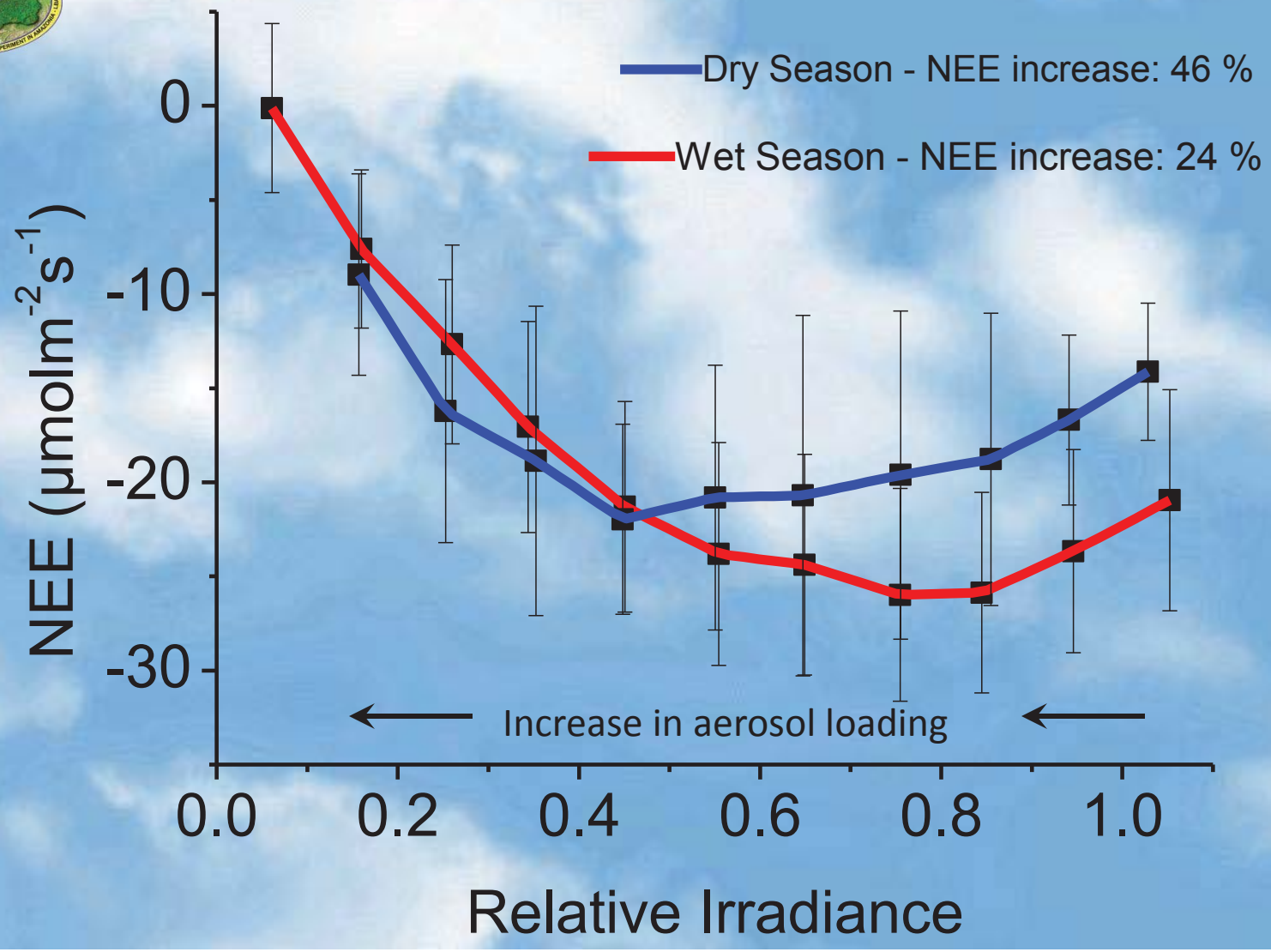


Kulmala et al., 2004



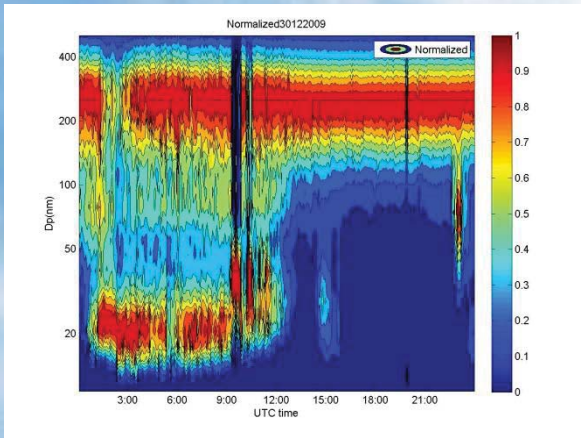
Strong aerosol effect on forest photosynthesis diffuse radiation have a large effect on CO2 fluxes

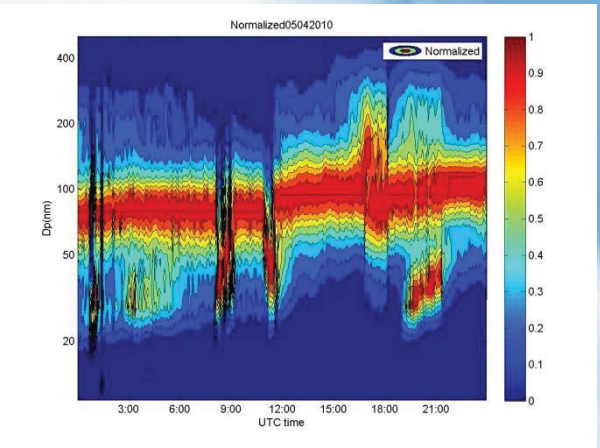
Amazonia Rondonia Forest site 2000-2001

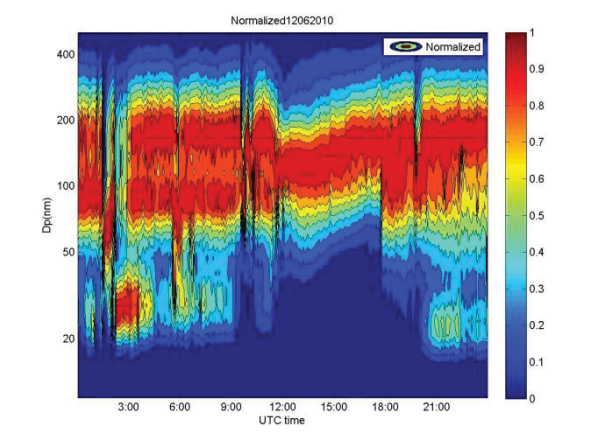


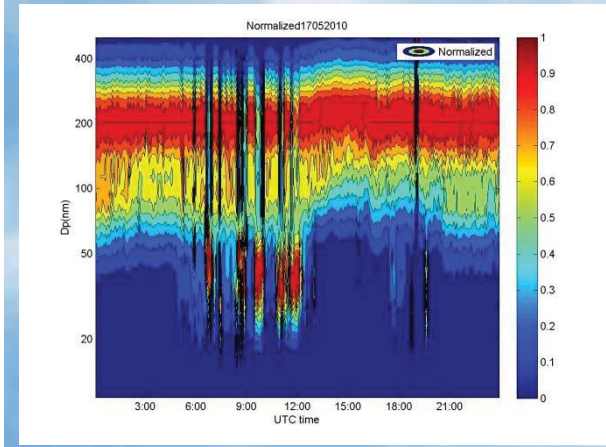
Particle production at about 20 nm

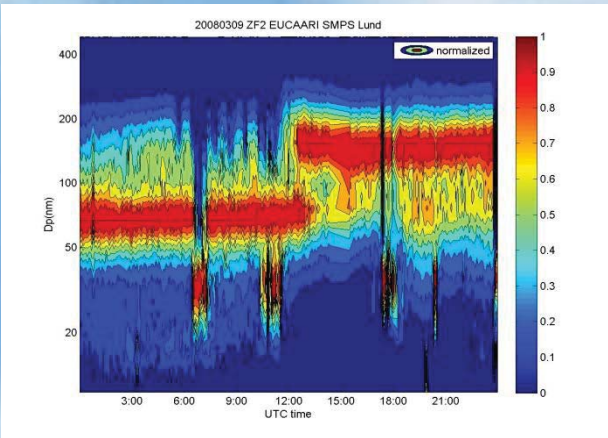
Which biological or atmospheric process is responsible for this new particle formation?

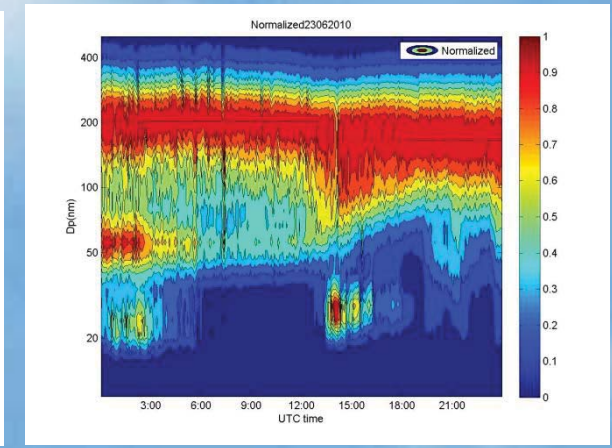






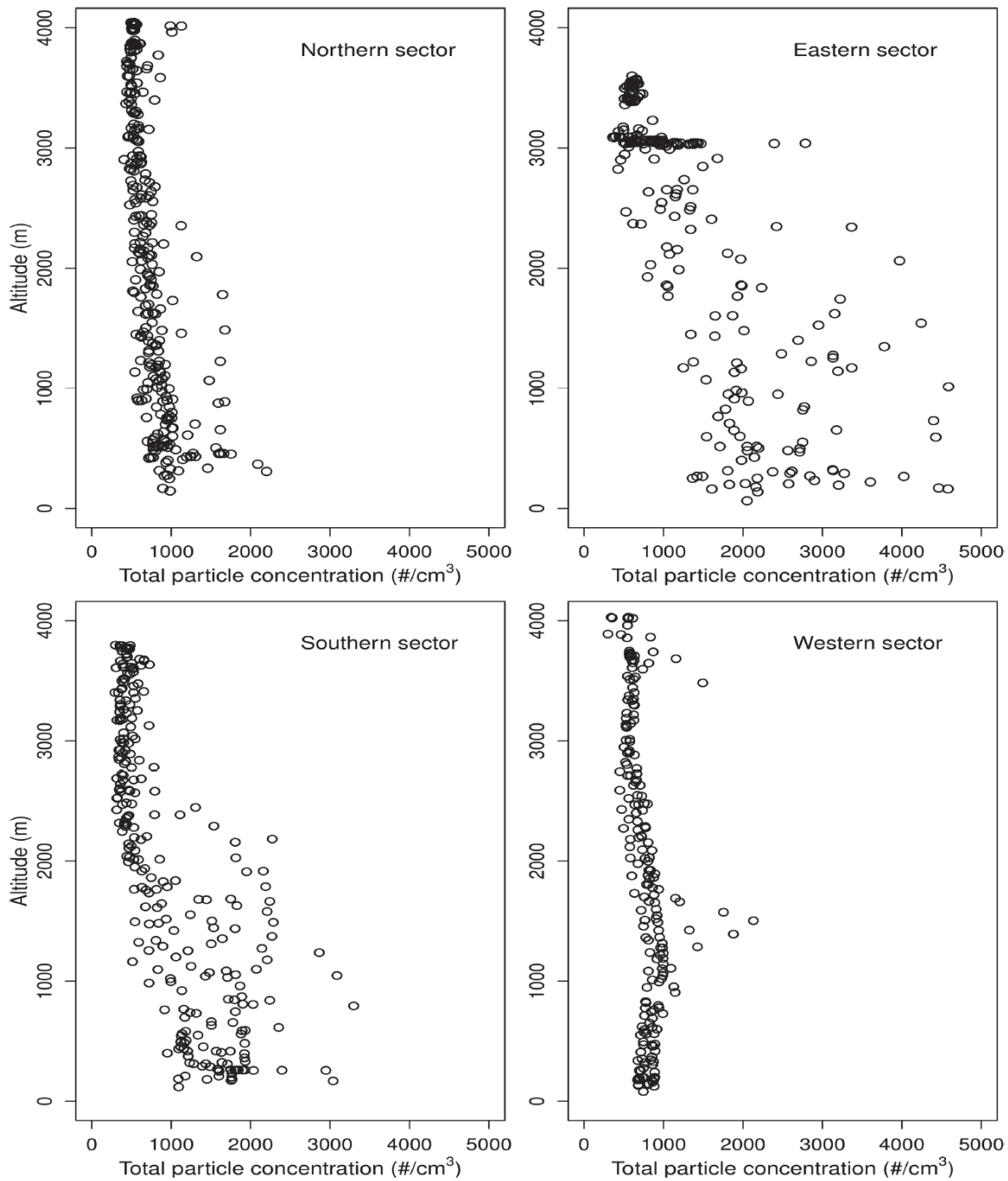






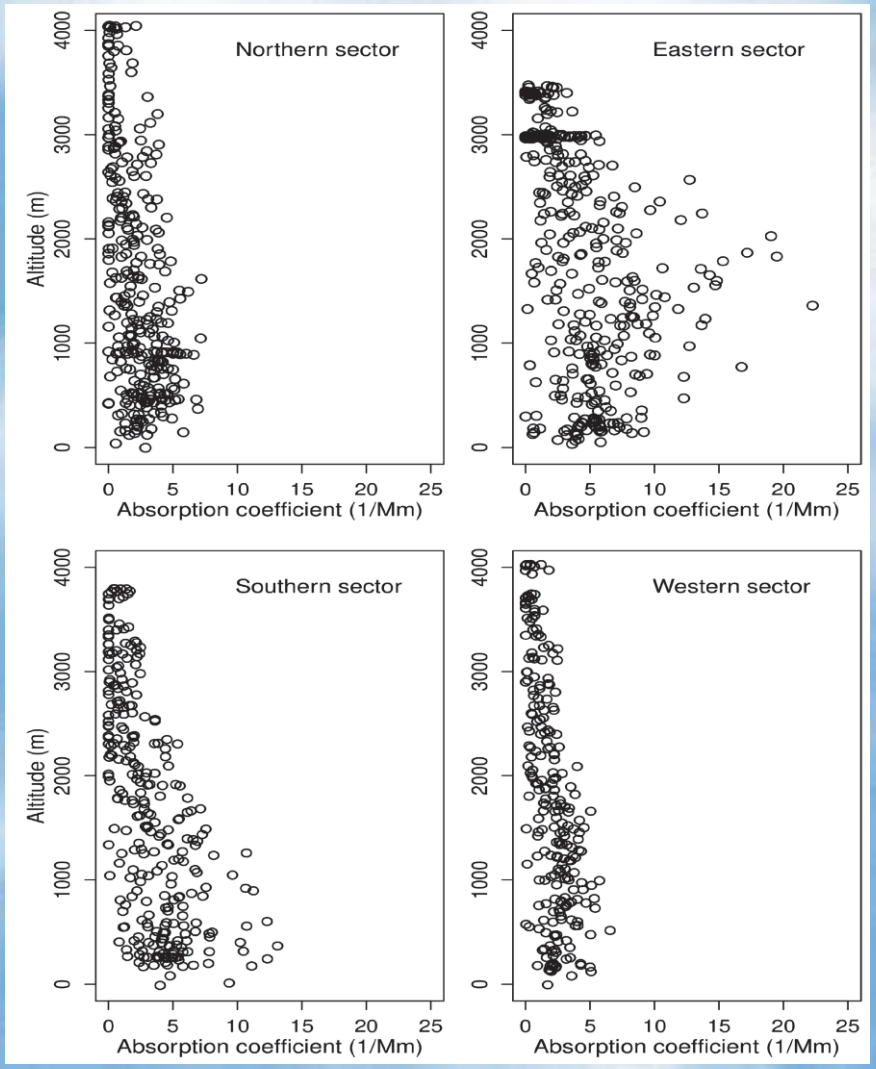
Vertical profile of CN particles (TSI 3010). Very good vertical mixing all the way to 4 Km.

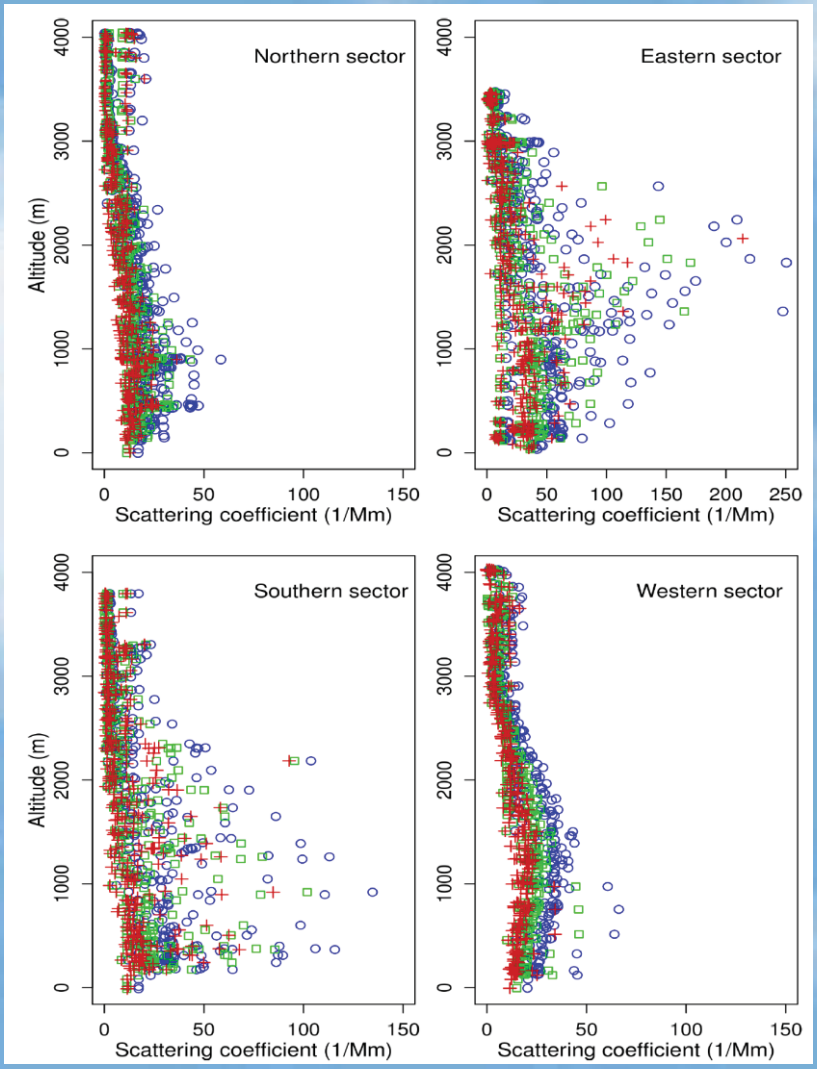
Measurements reported for four sectors around Manaus.



Wiedman et al., to be submitted

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

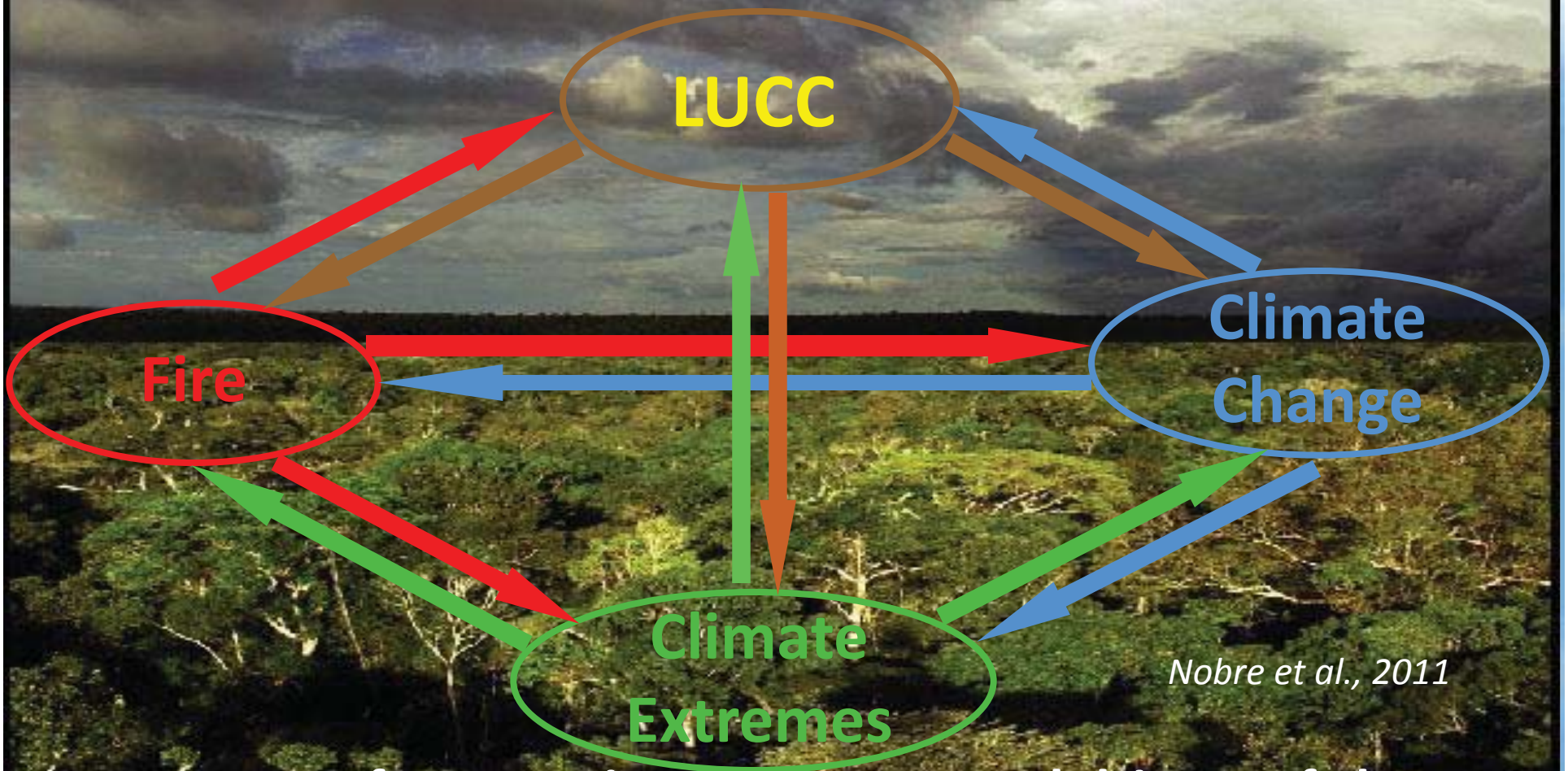




Kenia Wiedman et al., to be submitted

Effects of climate change in Amazonia

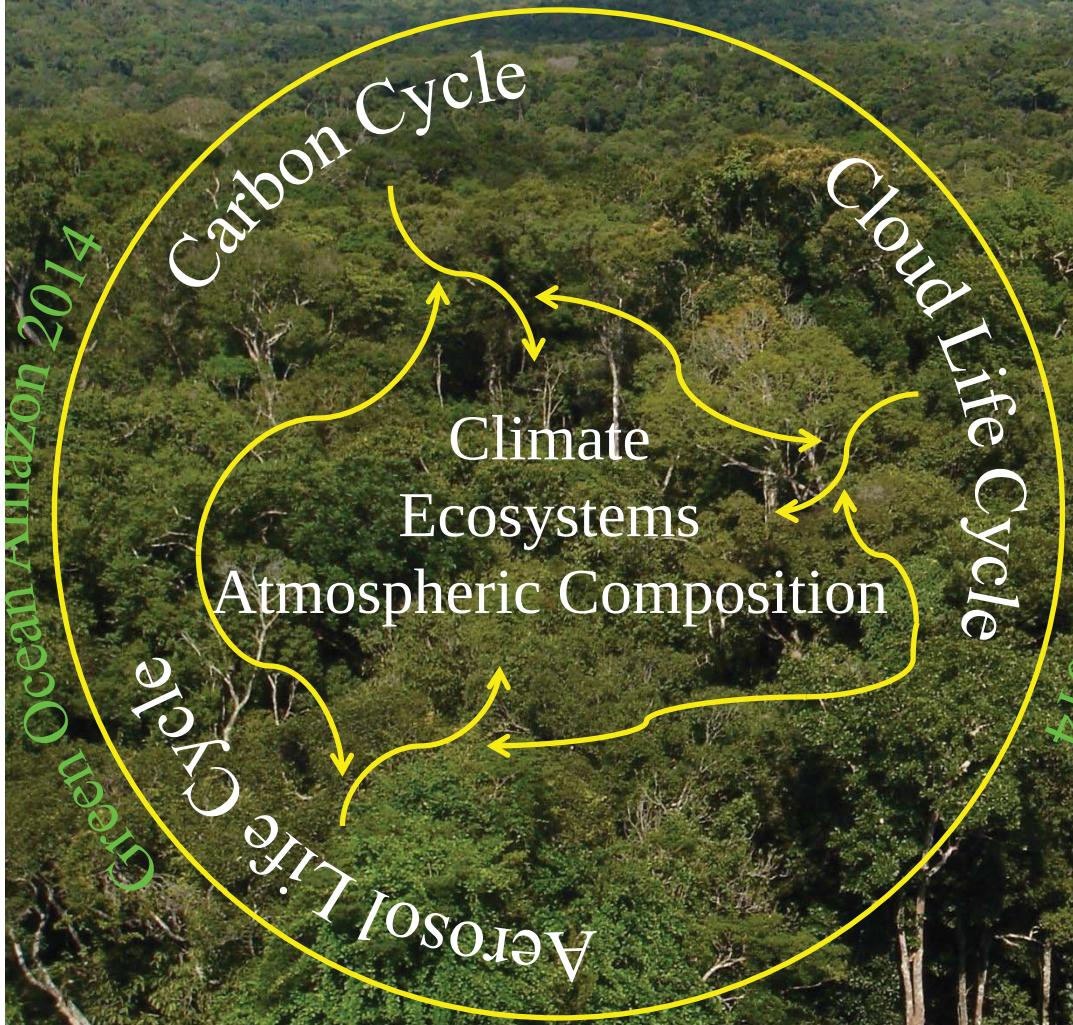
Complex Earth System Models are needed to study all these interacting and simultaneous drivers

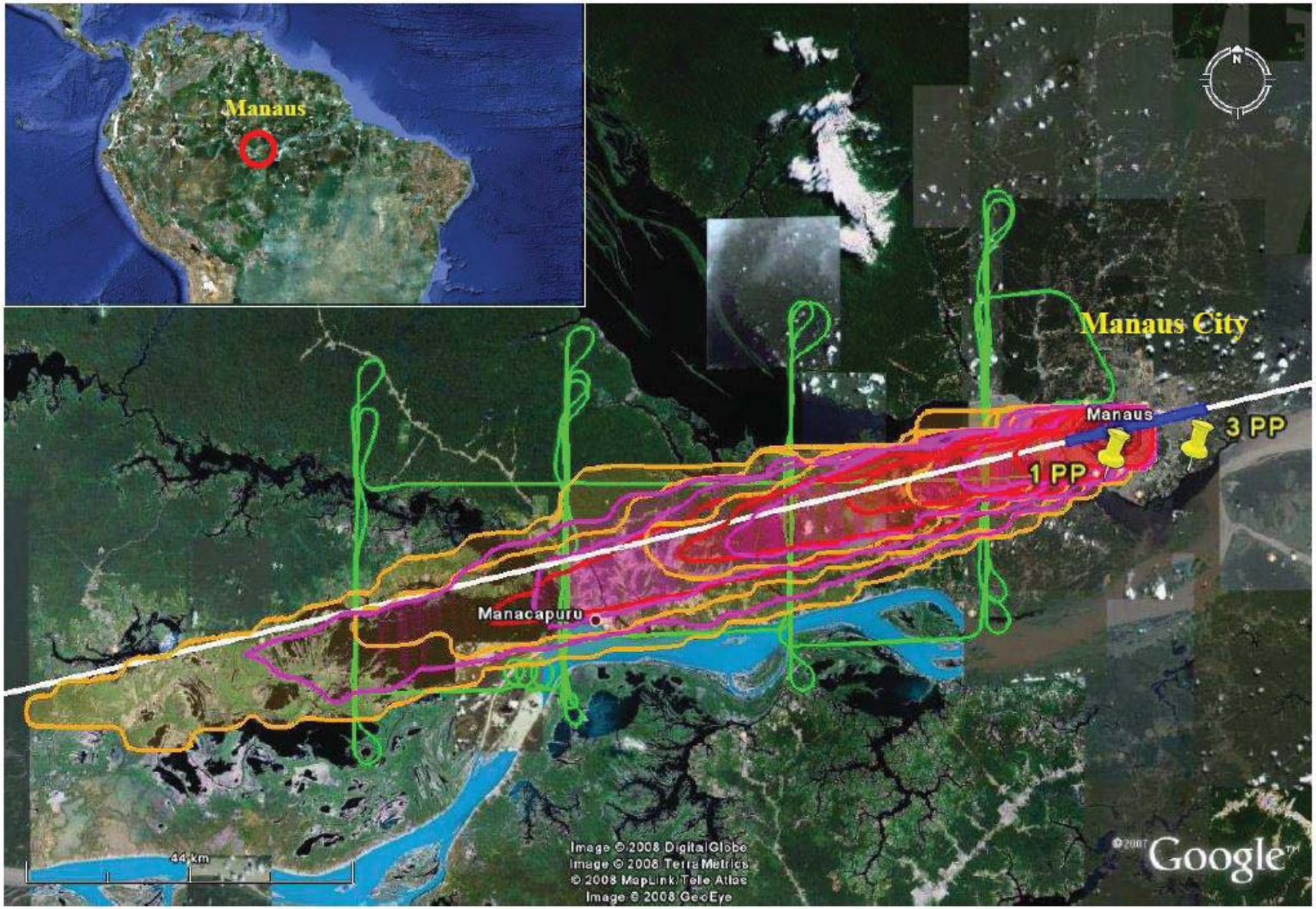


Nobre et al., 2011

Ecosystems of Amazonia - environmental drivers of change

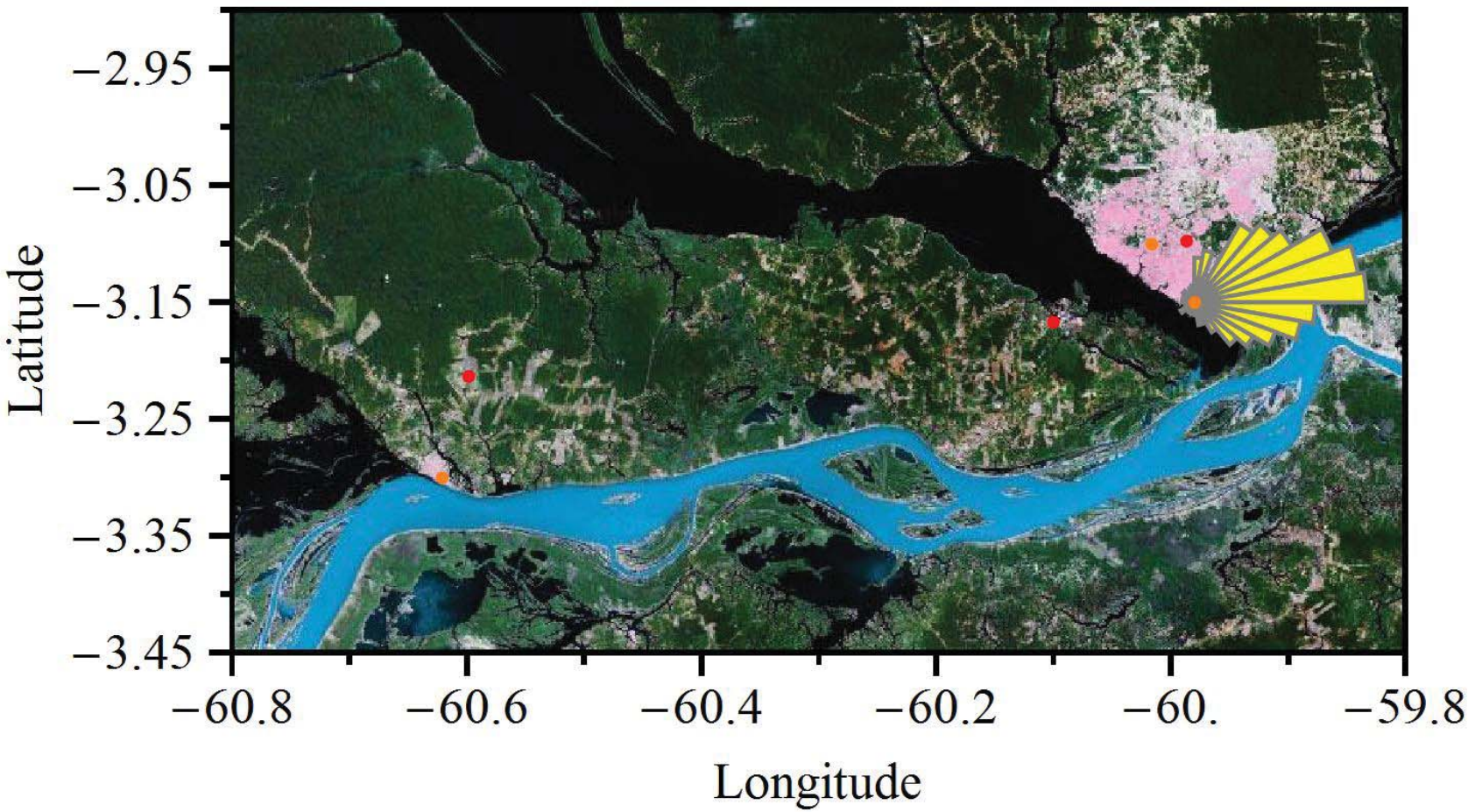
Observations and Modeling of the Green Ocean Amazon GoAmazon2014 (DoE)





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

Downwind of Manaus



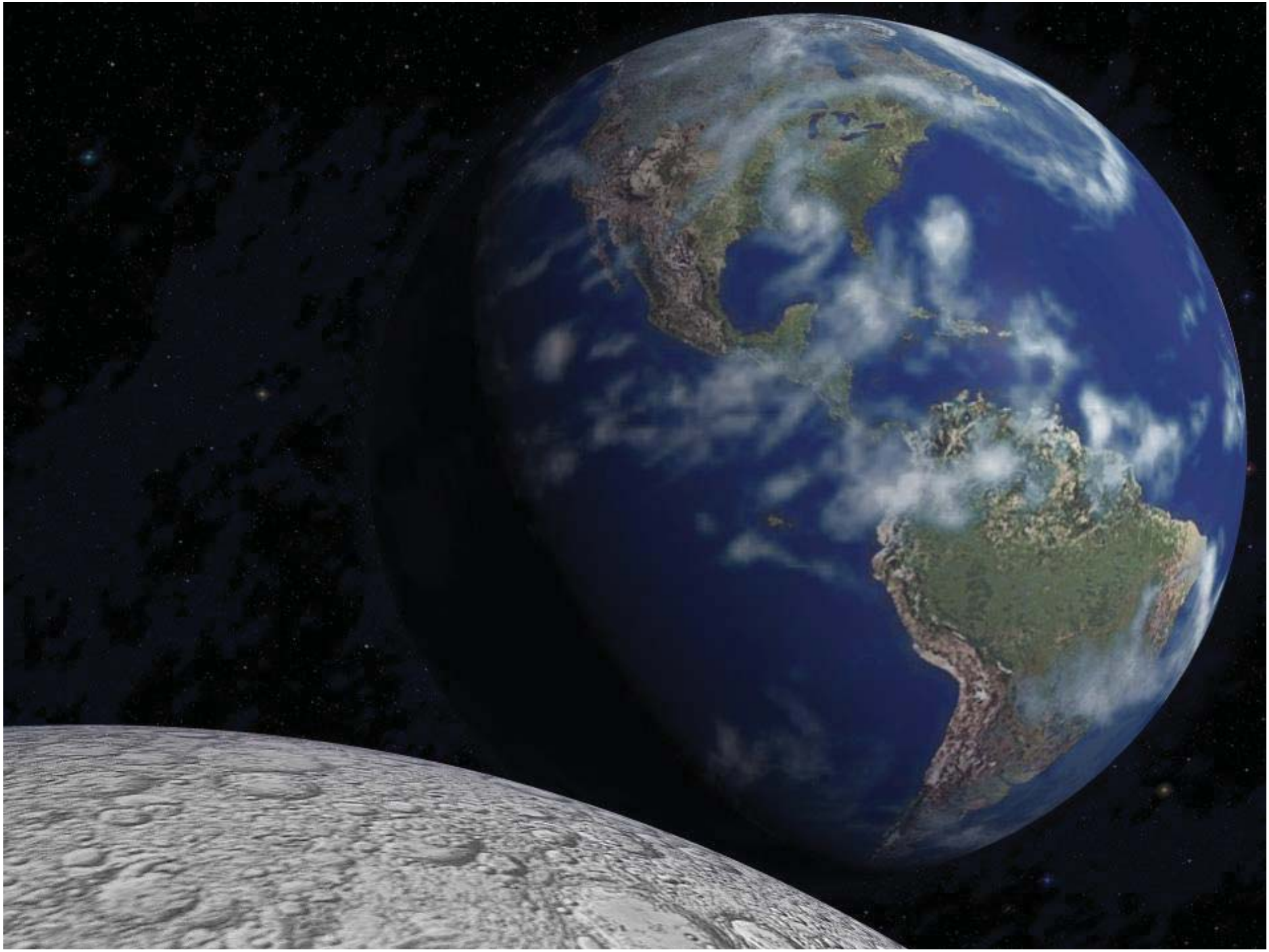
(−3.21328 ,	−60.5987)	DOE ARM ACRF	T3
(−3.16667 ,	−60.1)	TBD	T2
(−3.09722 ,	−59.9867)	INPA/UEA	T1
(−2.14663 ,	−59.005)	ATTO	T0
(−2.60908 ,	−60.2093)	K34	K34
(−2.59458 ,	−60.2093)	AMAZE08	TT34

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

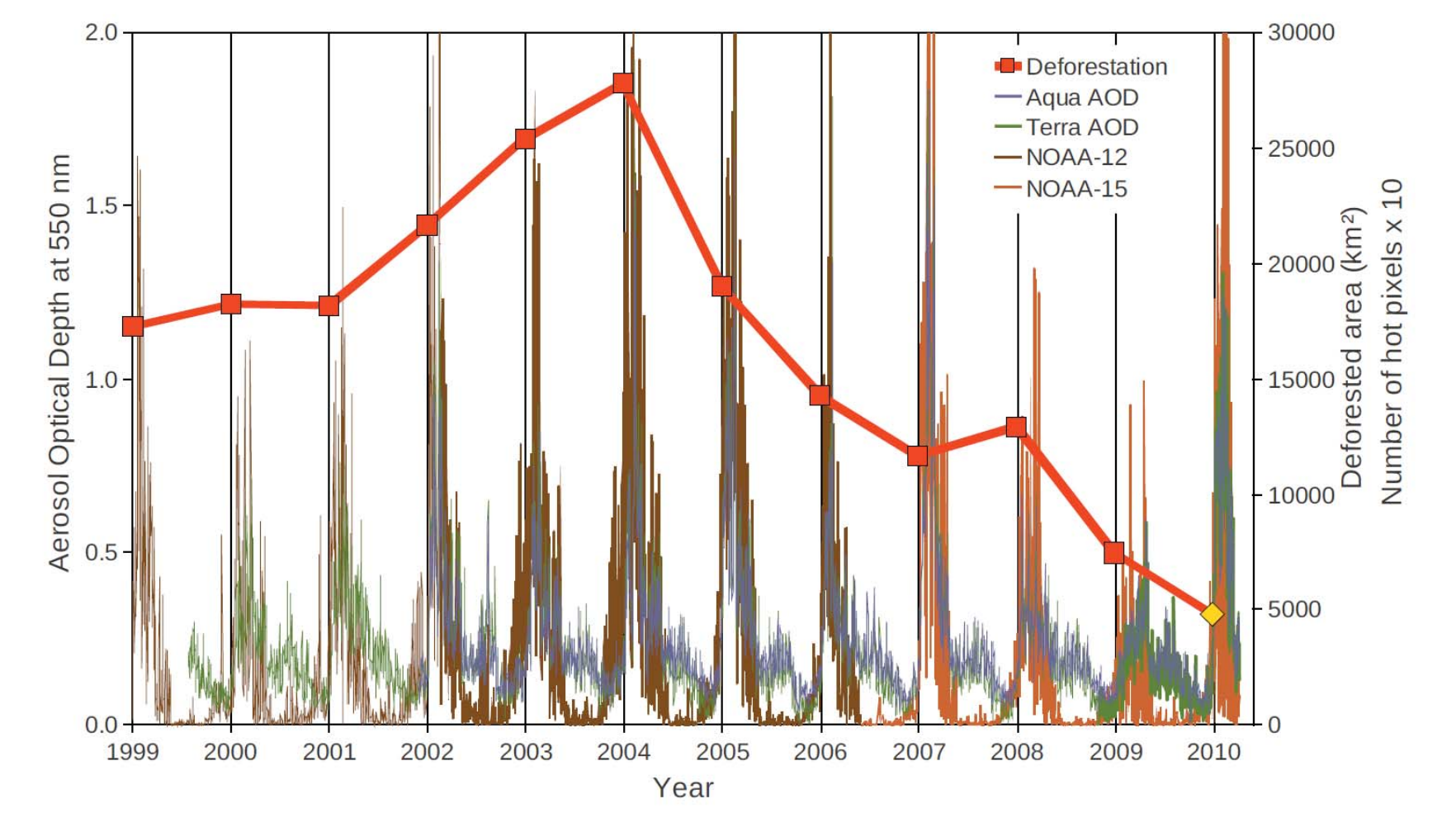
After LBA produced more than 1,400 papers and 14 Science and Nature papers,

Amazonia provides excellent opportunities for great and innovative science.

Thanks for the attention!!!

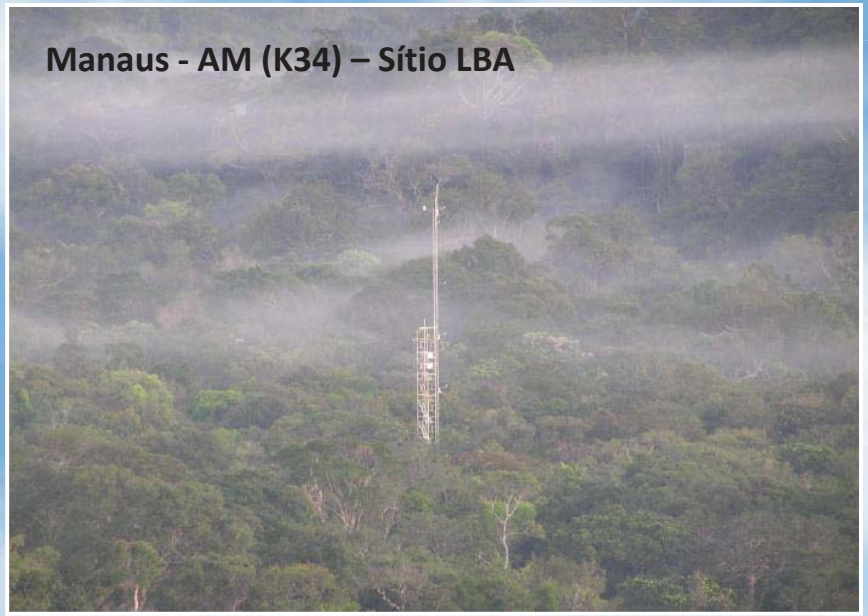


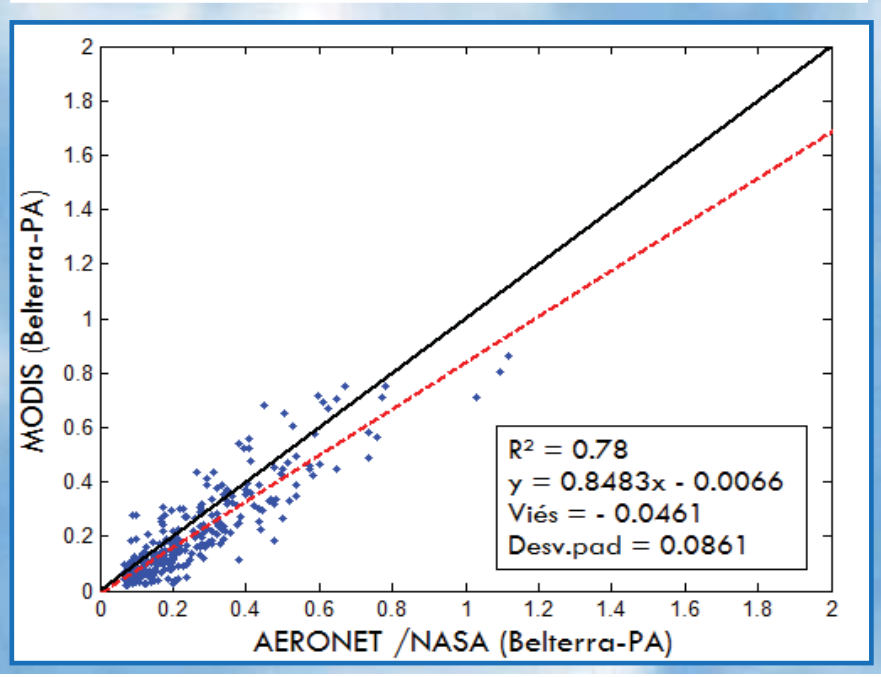
Yearly deforestation with MODIS AOD and hot pixels from NOAA-12/15

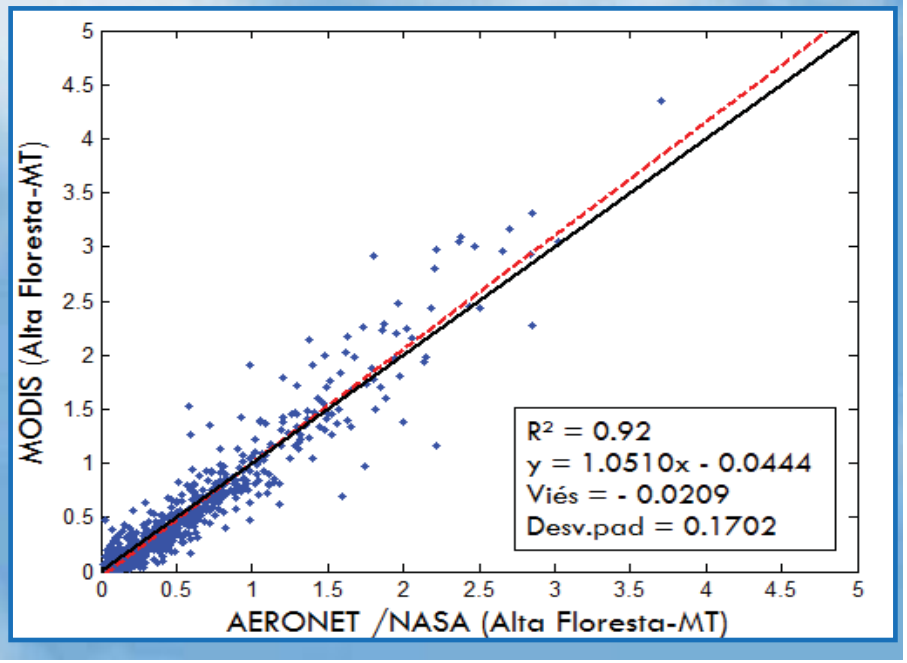


Yearly deforestation over the Brazilian Amazon region (INPE, 2010) compared to MODIS daily smoke optical depth and the daily number of hot pixels from NOAA-12 and NOAA-15. The results are shown according to the hydrological year, from August 1st of the previous year to July 31st of the years shown in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

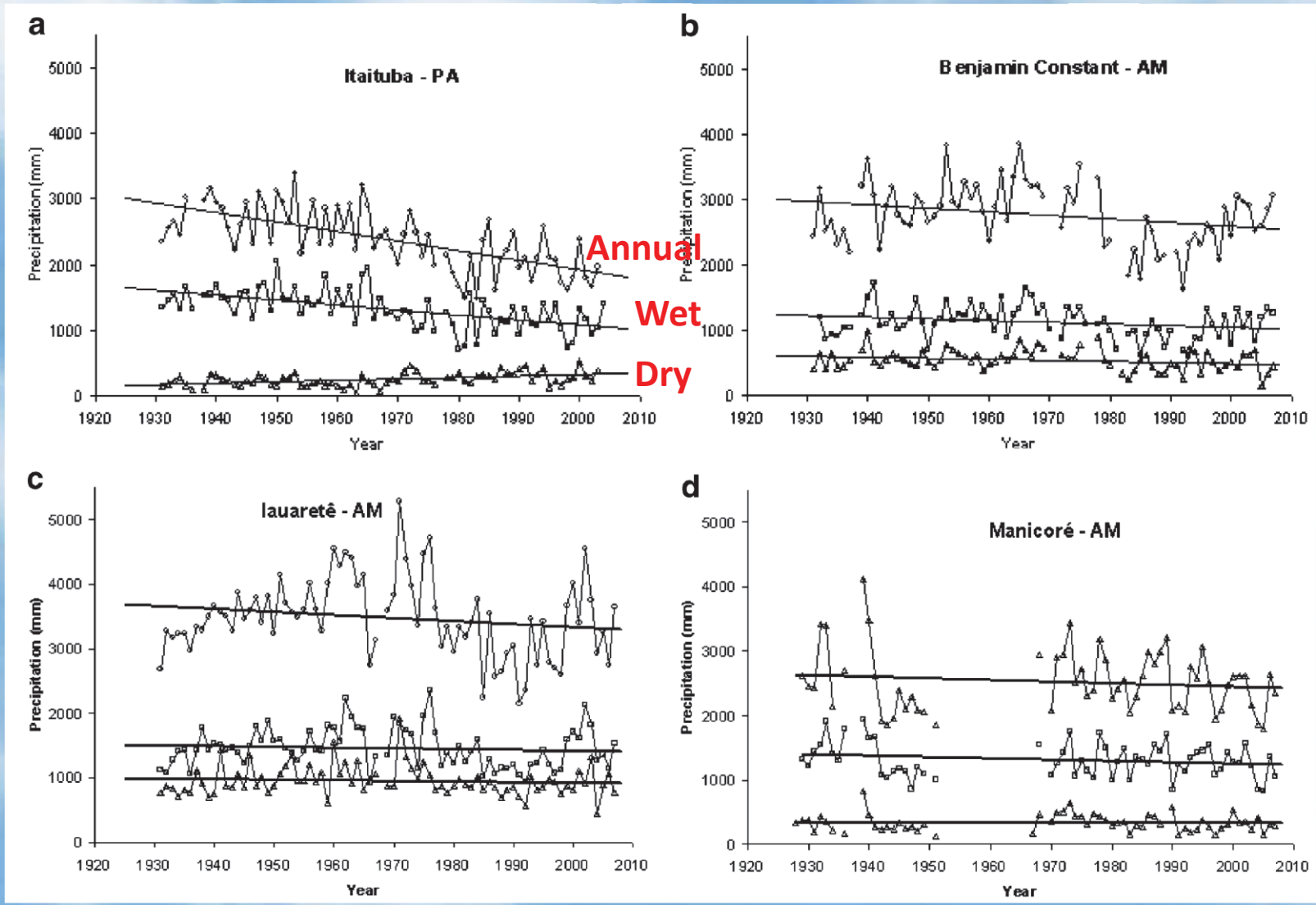
Carbon fluxes and aerosols with MODIS AOD





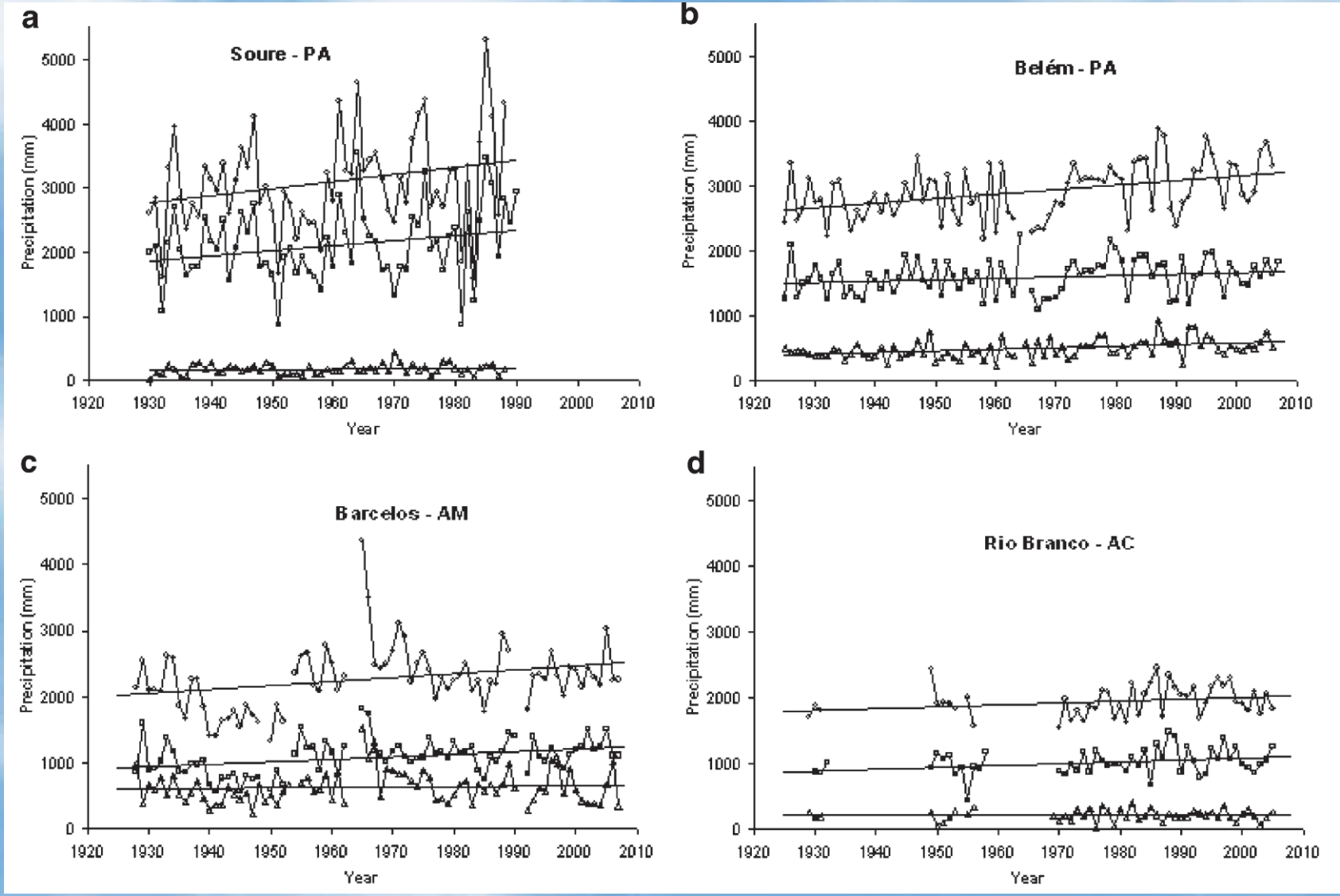


Rainfall trends in the Brazilian Amazon 1925-2008 (18 stations): Decreasing at Pará and Amazon states?



Satyamurty et al., 2010

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



Satyamurty et al., 2010