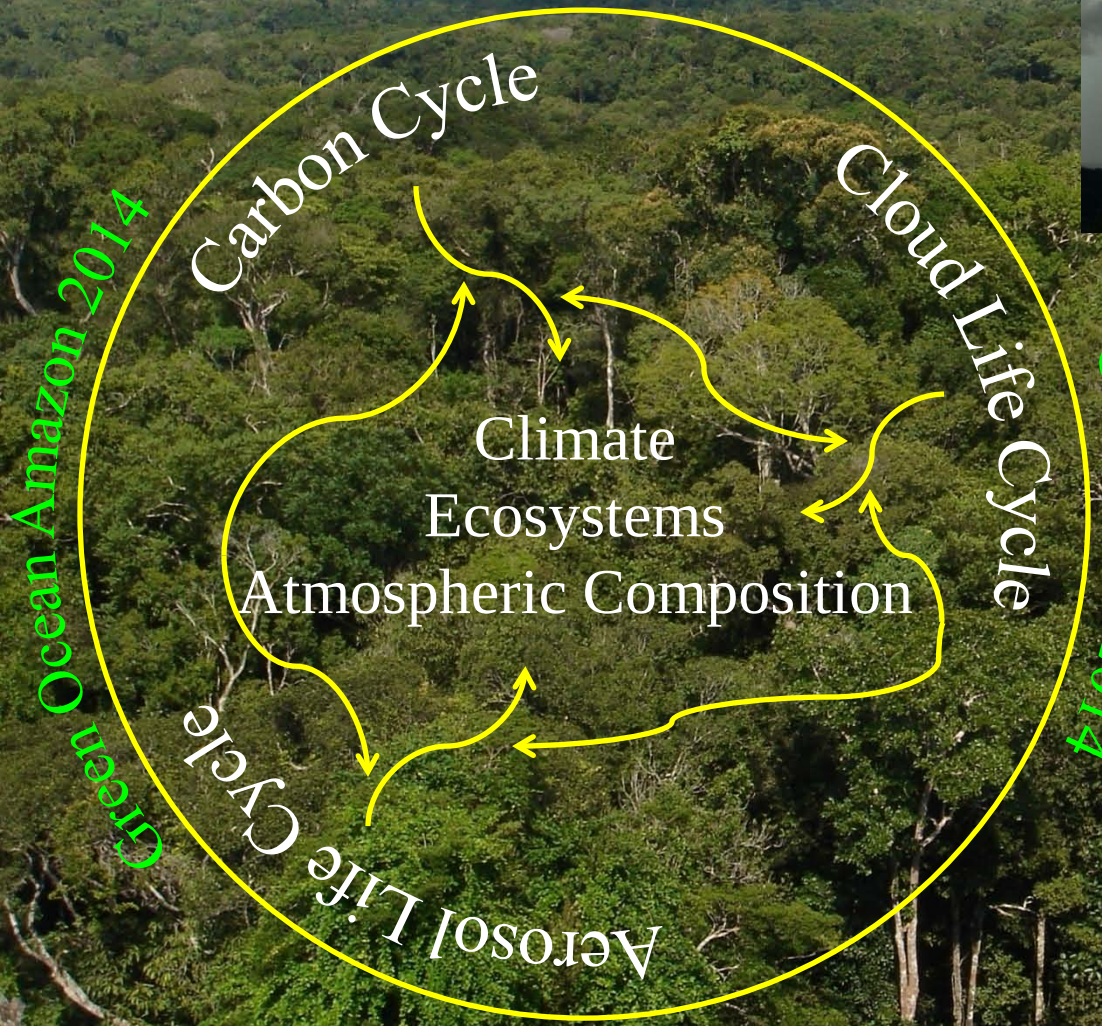
Observations and Modeling of the Green Ocean Amazon



Presented by Scot Martin at DOE Workshop, 26-27 July 2011, Washington, D.C.

Outline of Presentation

- WHY this experiment?
- WHERE will this experiment take place?
- WHEN will this experiment take place?
- WHAT instrumentation and facilities are part of experiment?
- HOW is the experiment organized?

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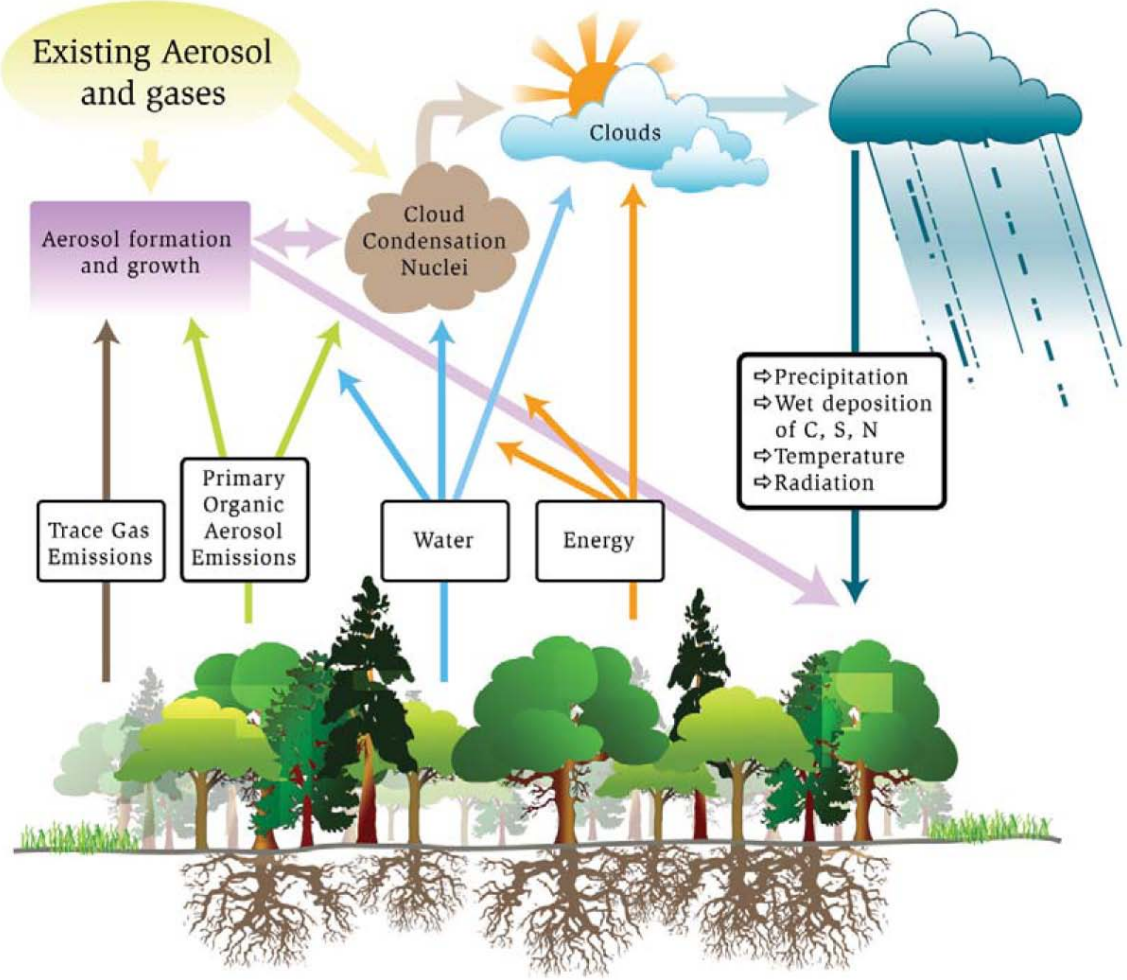
Amazon Basin has strong coupling between terrestrial ecosystem and the hydrologic cycle: The linkages among carbon cycle, aerosol life cycle, and cloud life cycle need to be understood and quantified.

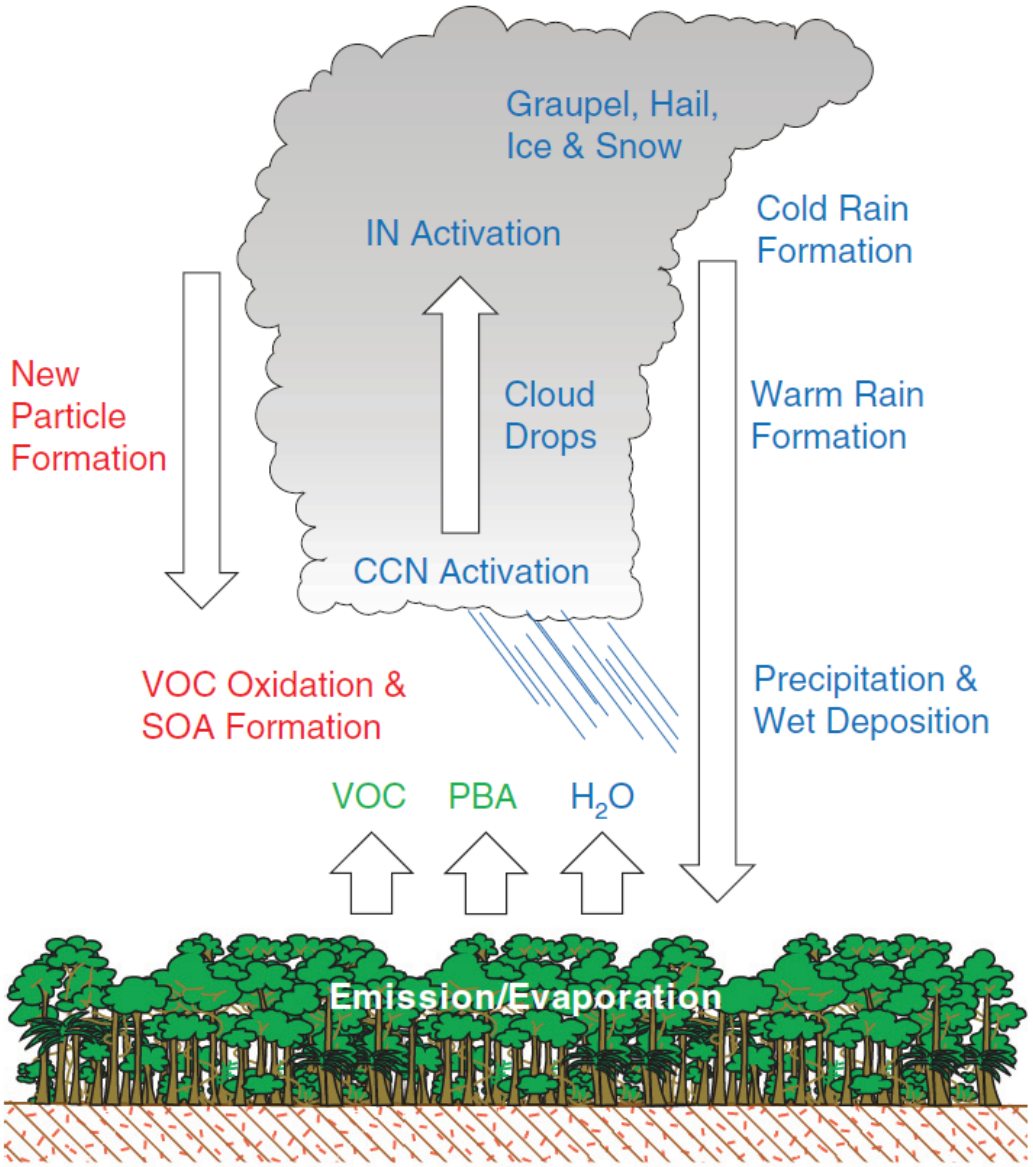


Source: Barth et al., "Coupling between Land Ecosystems and the Atmospheric Hydrologic Cycle through Biogenic Aerosol Particles," *BAMS*, *86*, 1738-1742, 2005.

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

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

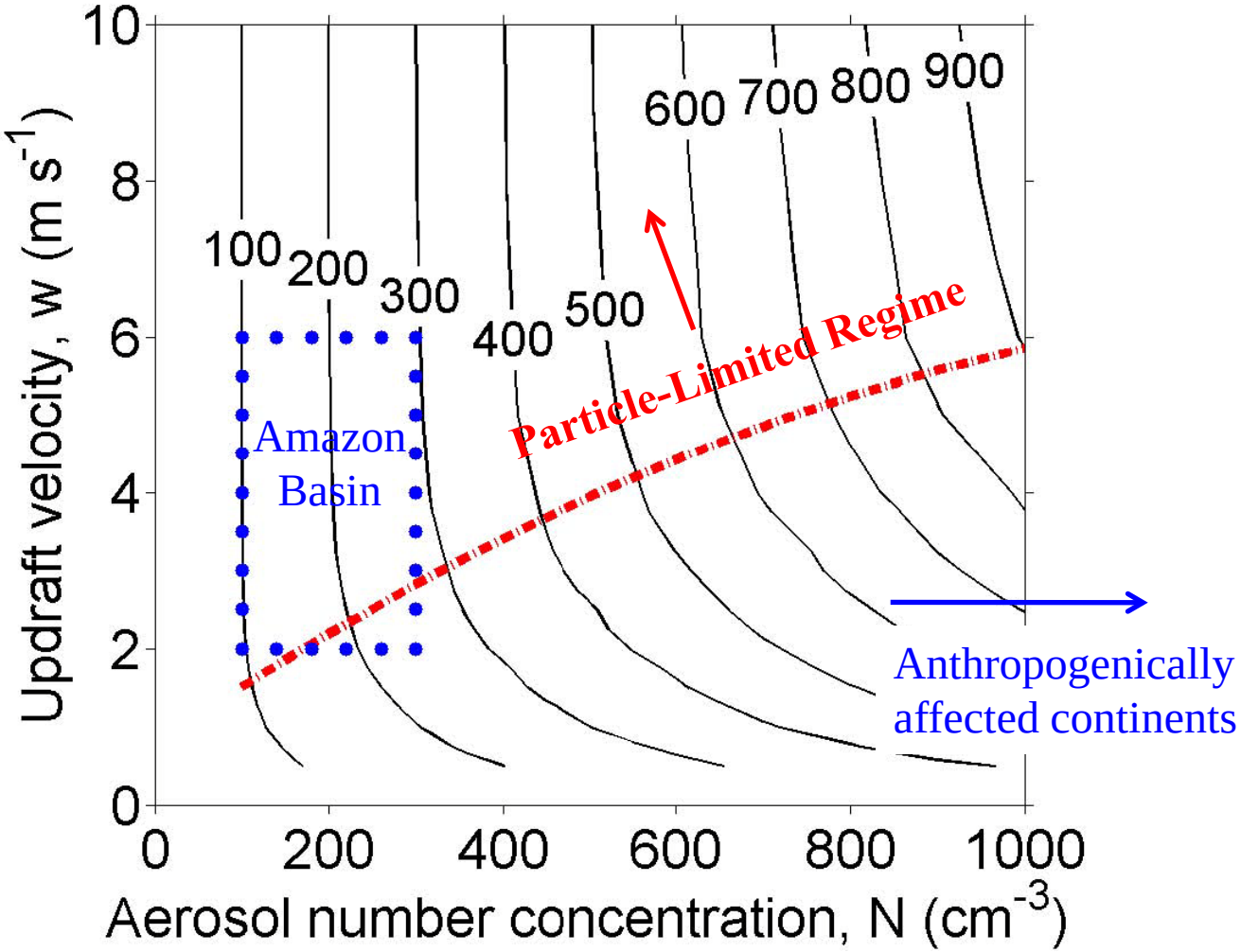
GoAmazon2014: What is the effect of pollution on these cycles and the coupling among them?



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.

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

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

Scientific Questions for GoAmazon2014

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

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

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

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

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

Scientific Questions for GoAmazon2014

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

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

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

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

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

Scientific Questions for GoAmazon2014

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

The theme uniting these objectives is the development of a data-driven knowledge base for predicting how the present-day functioning of energy, carbon, and chemical flows in the Basin might change, both due to external forcing on the Basin from global climate change and internal forcing from past and projected demographic changes in the Basin.

The ultimate goal is to estimate future changes in direct and indirect radiative forcing, energy distributions, regional climate, ecosystem functioning, and feedbacks to global climate.

In this regard, the presented objectives are representative, and further definition and broadening can be expected as the science team spins up prior to deployment.

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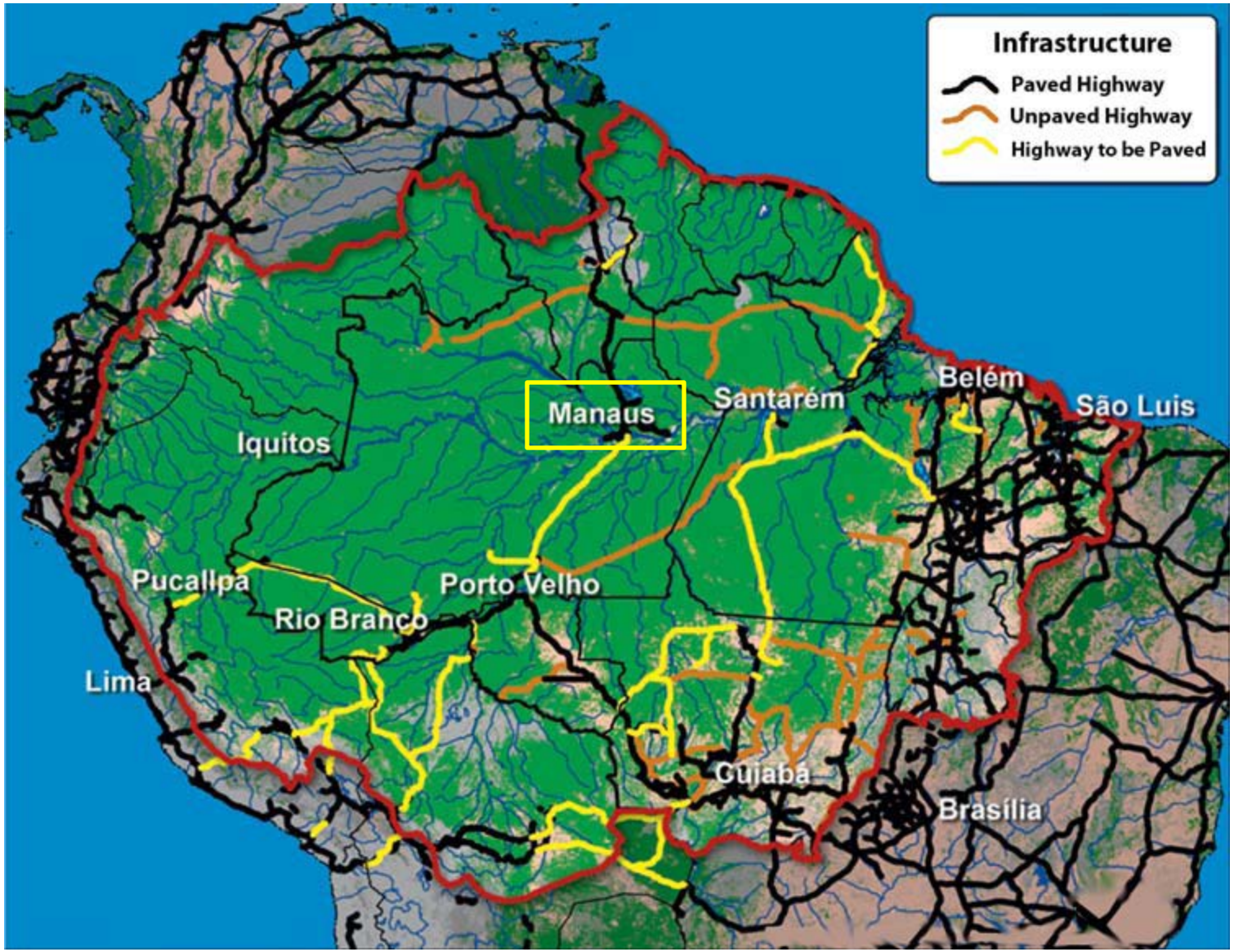
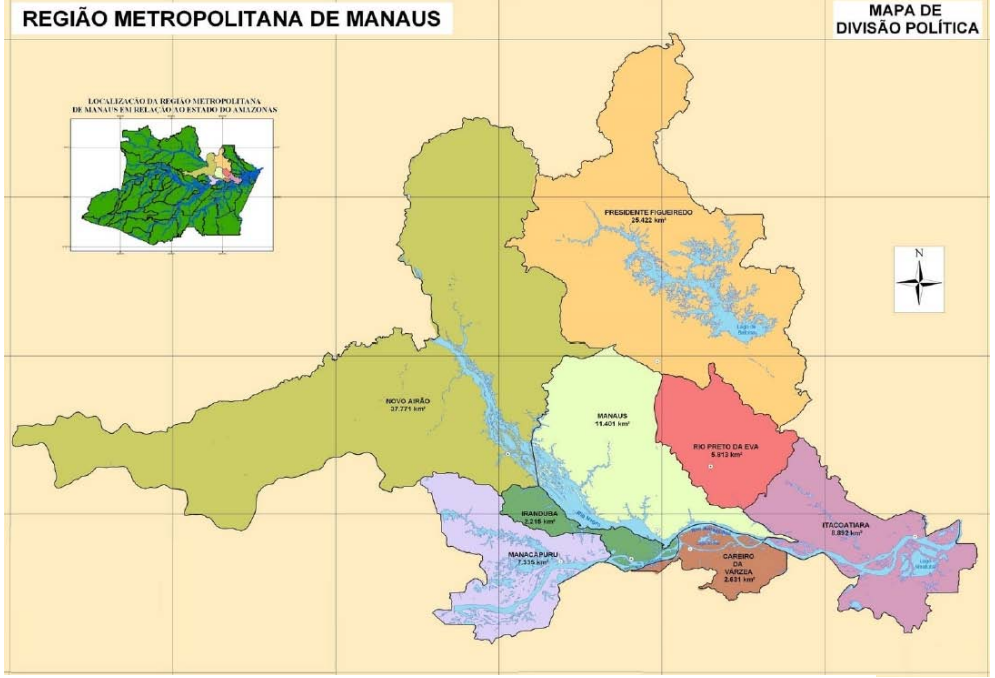
Site Location



Manaus

Population for the metropolitan region of Manaus: 2002/2009



POPULAÇÃO PARA A REGIÃO METROPOLITANA DE MANAUS - 2002 / 2009

Municípios	2002	2003	2004	2005	2006	2007	2008	2009
MANAUS	1.488.805	1.527.314	1.592.555	1.644.690	1.688.524	1.646.602	1.709.010	1.738.641
CAREIRO DA VÁRZEA	17.079	16.992	16.844	16.725	16.626	23.023	24.030	24.704
IRANDUBA	35.128	36.439	38.661	40.436	42.812	32.869	33.834	33.884
ITACOATIARA	74.914	76.217	78.425	80.190	81.674	84.676	87.896	89.440
MANACAPURU	77.171	78.785	81.518	83.703	84.656	82.309	85.279	86.472
NOVO AIRÃO	8.731	8.304	7.580	7.002	6.516	14.630	15.343	15.915
PRESIDENTE FIGUEIREDO	19.562	20.569	22.273	23.636	24.781	24.360	25.474	26.282
RIO PRETO DA EVA	19.910	20.990	22.820	24.283	25.513	24.858	26.004	26.847
REGIÃO METROPOLITANA	**1.741.300**	**1.785.610**	**1.860.676**	**1.920.665**	**1.971.102**	**1.933.327**	**2.006.870**	**2.042.185**

FONTE: IBGE

Acknowledgments: Rodrigo Souza, UEA

Manaus: Vehicle Fleet 2010

Frota de Veículos -

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

Fonte: DETRAN/AM

FUEL MIX:

-tractor, truck and bus: almost 100% diesel

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

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

Acknowledgments: Rodrigo Souza, UEA

Manaus: Power Plant 2009: Fuel Oil

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

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

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

Hydropower

Oils of different grades

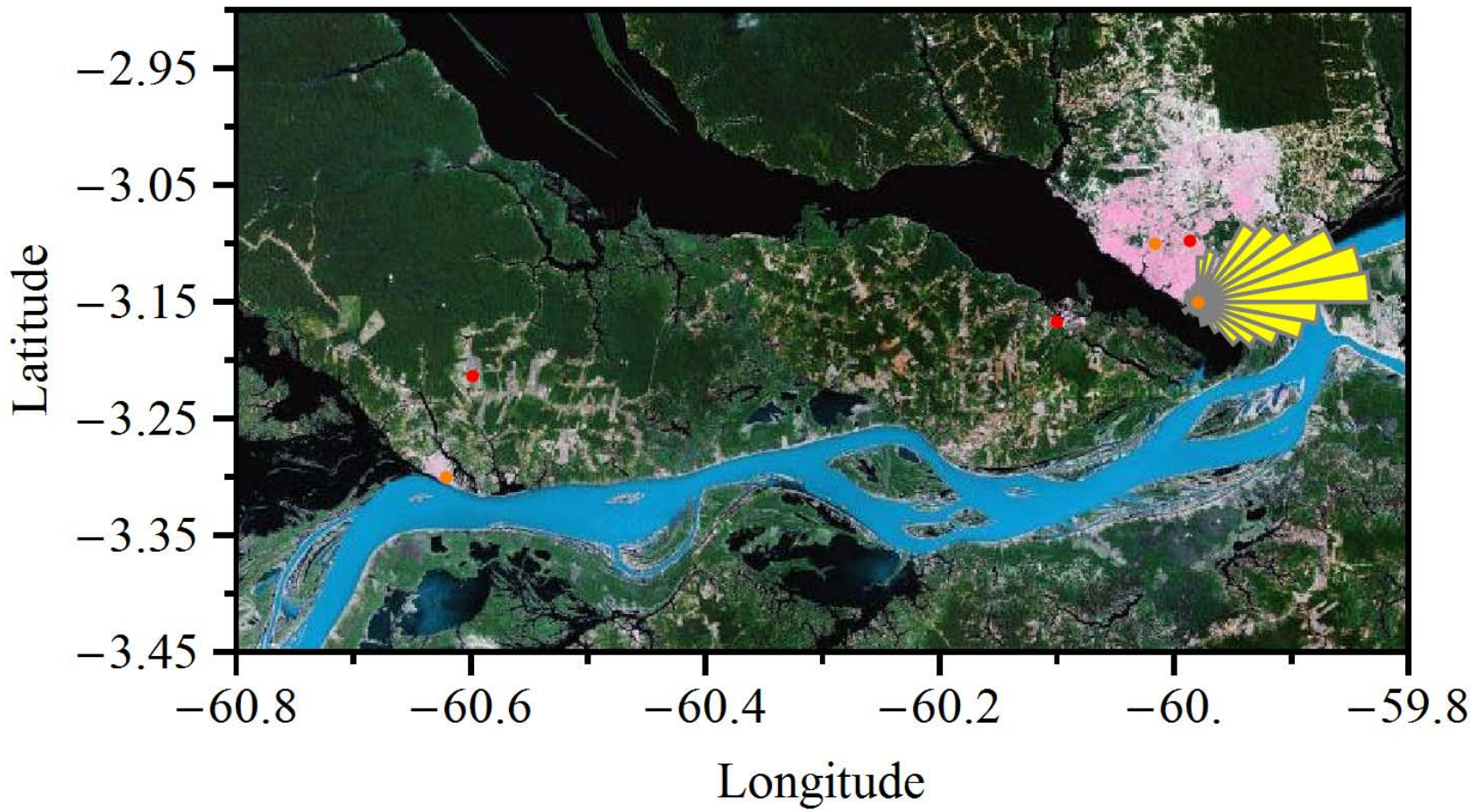
PTE - óleo leve "Para Turbina Elétrica"

PGE - óleo combustível "Para Gerador Elétrico"

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

Acknowledgments: Rodrigo Souza, UEA

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.

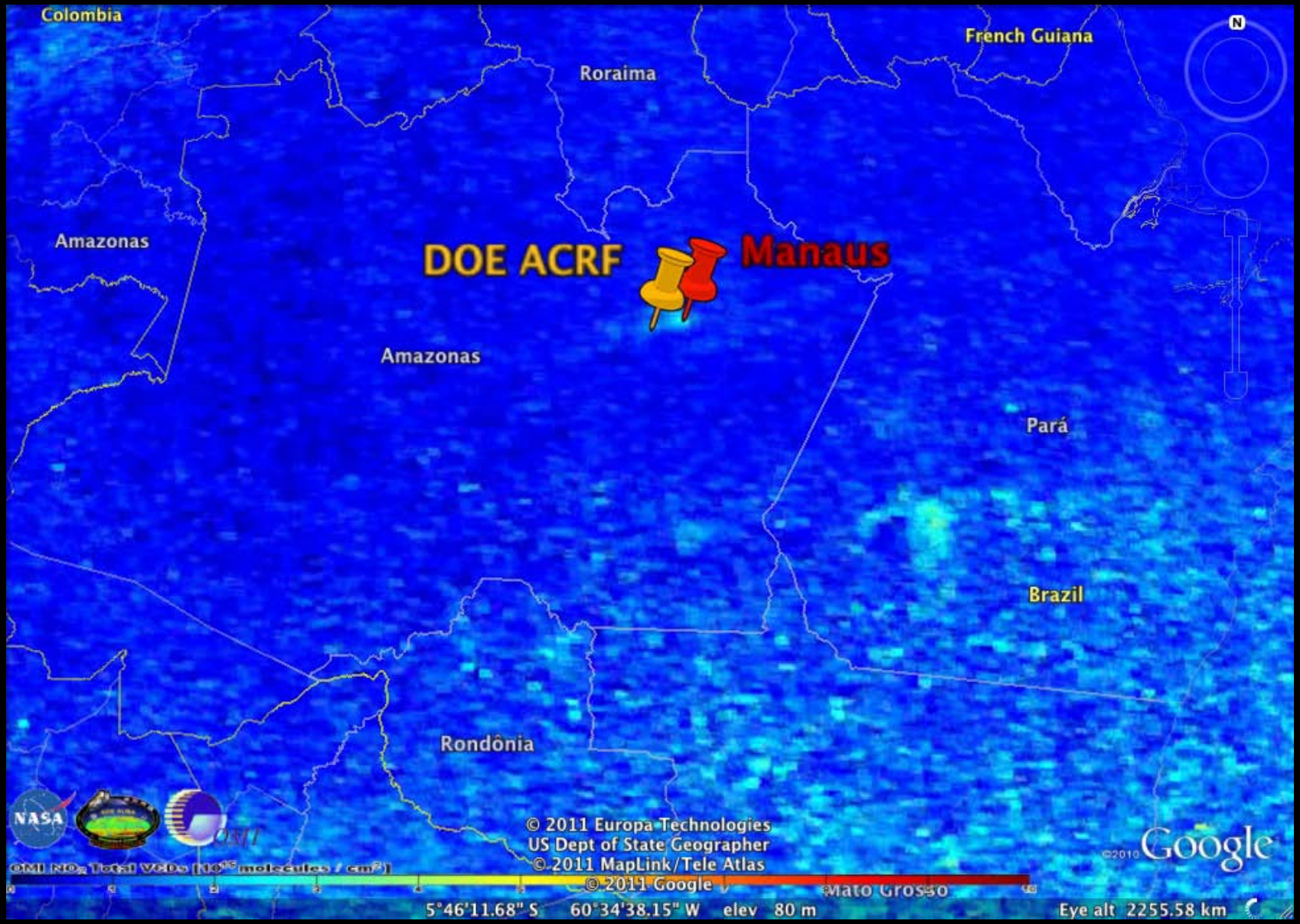
Downwind of Manaus

The deployment site is situated such that it experiences the extremes of:

(i) a pristine atmosphere when the Manaus pollution plume meanders; and

(ii) heavy pollution and the interactions of that pollution with the natural environment when the plume regularly intersects the site.

NO_2 Outflow from Manaus in Aug 2010 observed by OMI



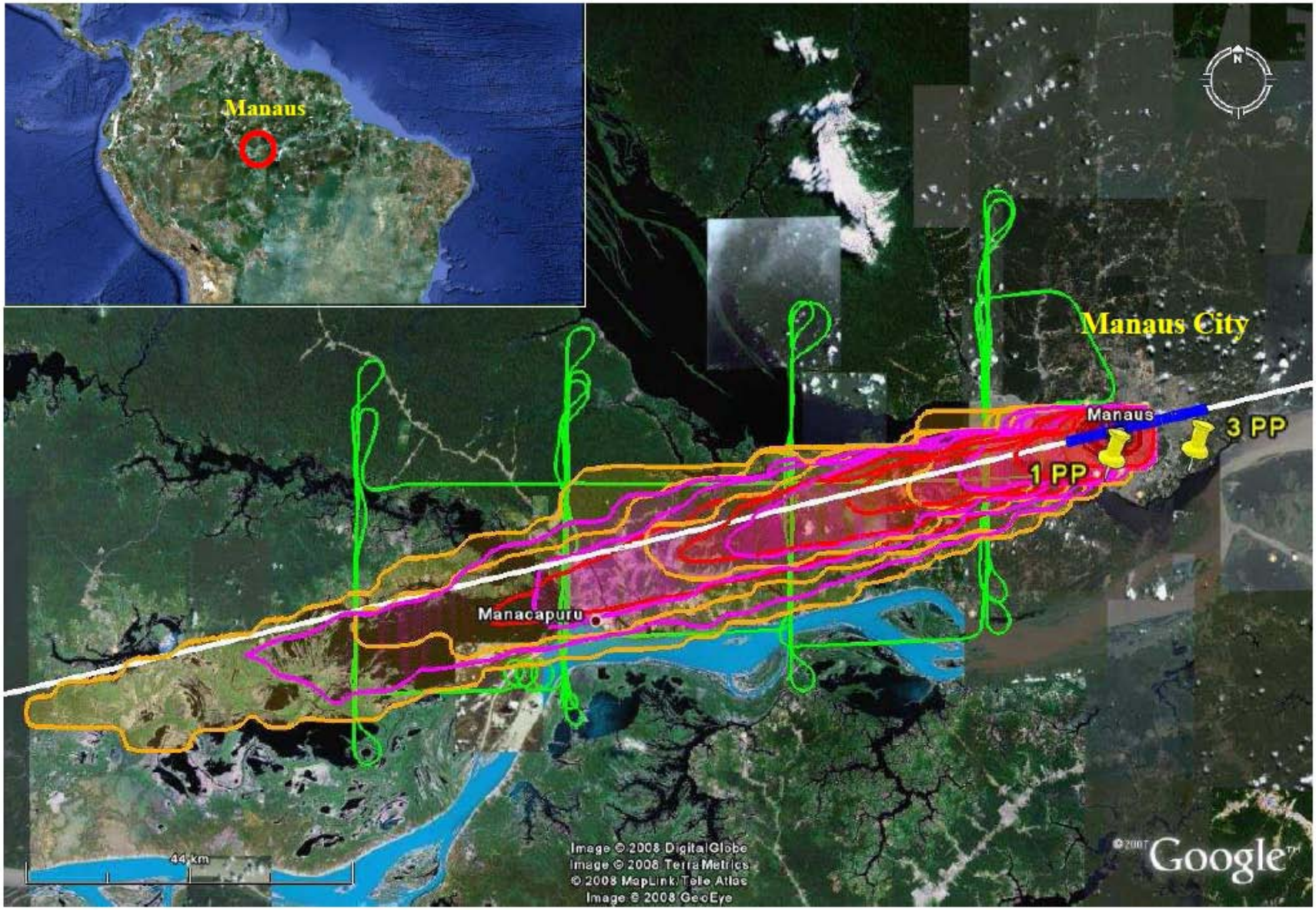
Acknowledgments: Jun Wang, Univ. Nebraska

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

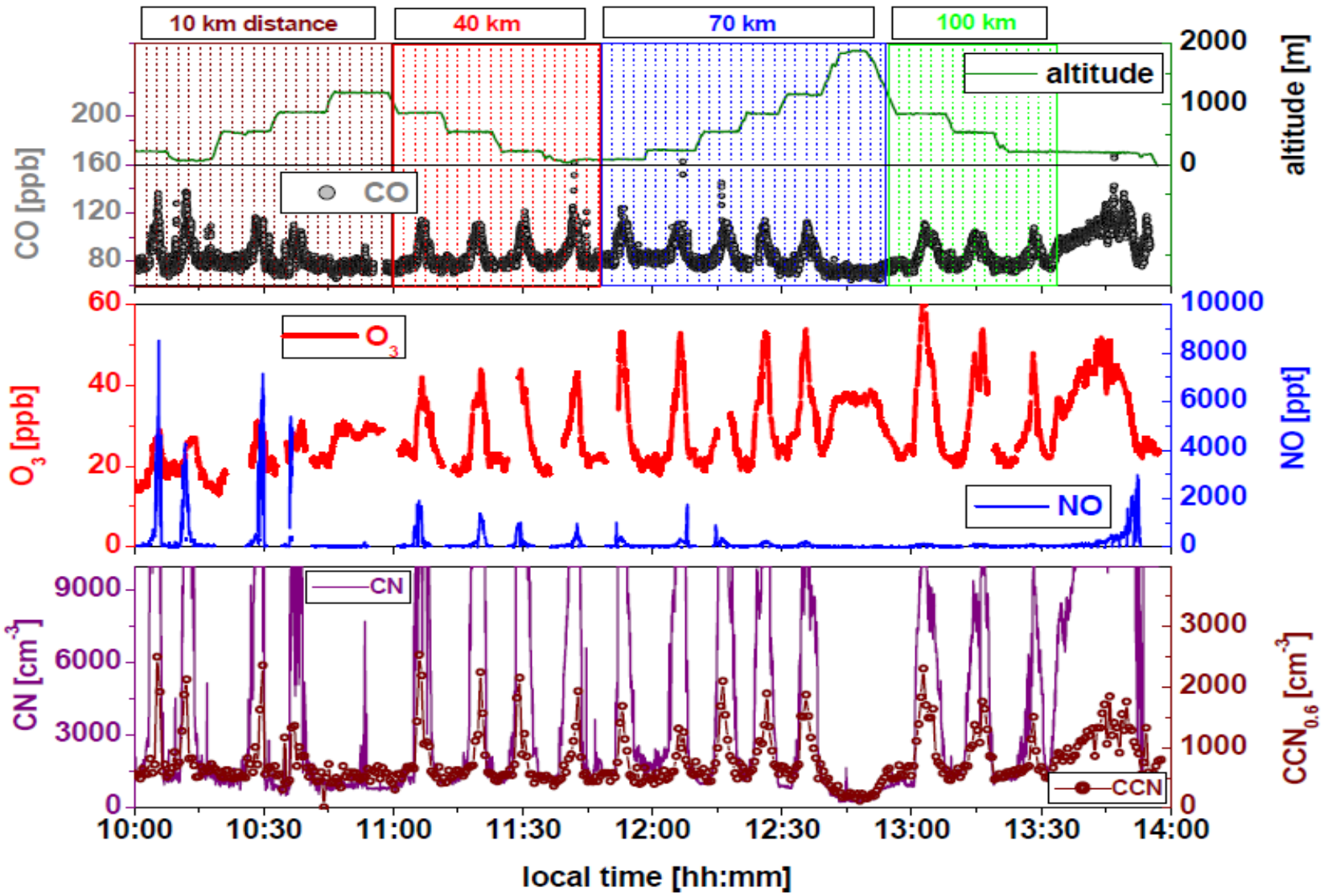
Outflow from Manaus first Crosses River: 2 to 10 km wide

Manaus Outflow Continues Across 60 km Forest

Arrival at AAA Large Pasture Site:
Location of ACRF Deployment

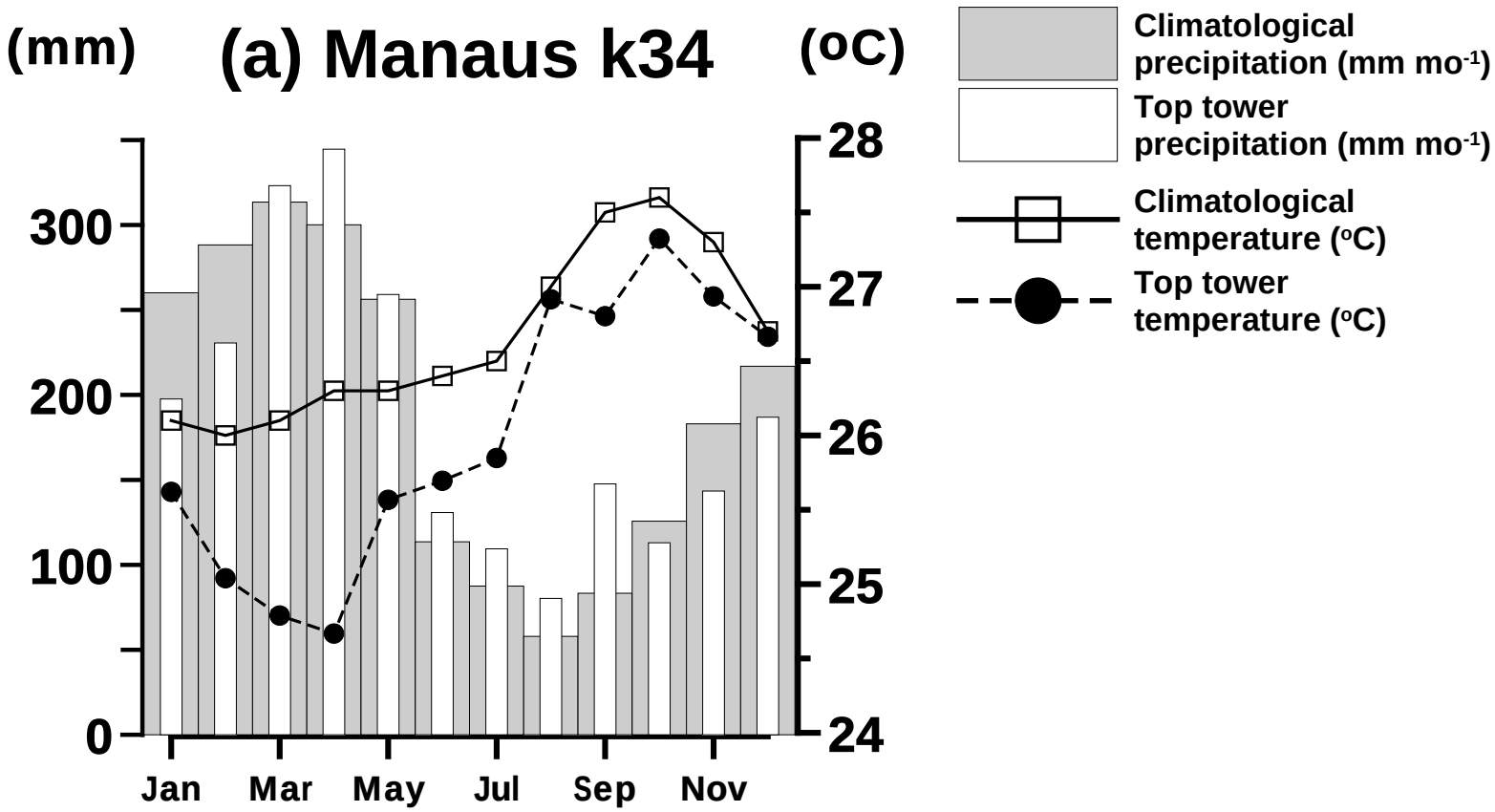


Reference: Kuhn, U.; Ganzeveld, L.; Thielmann, A.; Dindorf, T.; Welling, M.; Sciare, J.; Roberts, G.; Meixner, F. X.; Kesselmeier, J.; Lelieveld, J.; Ciccioli, P.; Kolle, O.; Lloyd, J.; Trentmann, J.; Artaxo, P.; Andreae, M. O., "Impact of Manaus City on the Amazon Green Ocean atmosphere: Ozone production,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



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

Seasonal Variability of Rainfall in Region

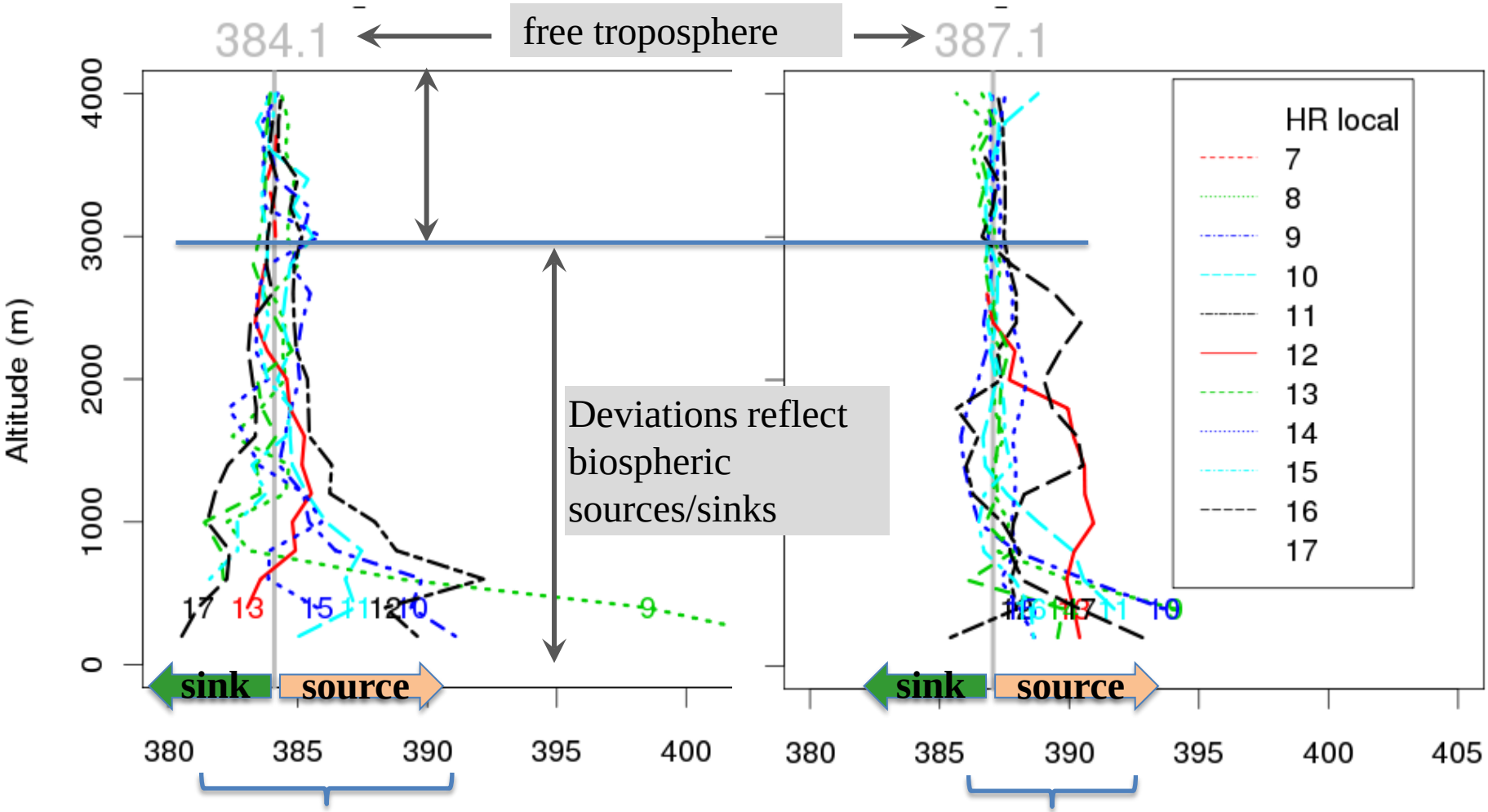


Source: Rocha et al. 2009 (JGR), 2010 (LBA book)

CO_2 Profiles in Manaus Region (BARCA)

A. Dry-season (16-22 November 2008)

B. Wet-season (15-27 May 2009)



Deviations show biosphere to be neutral or a weak CO_2 source (dry season)

Deviations show biosphere to be a strong CO_2 source (wet season)

Source: Saleska, Wofsy, et al. (personal communication)

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Dates of GoAmazon2014

AMF Operations (T3 ground site)

- 1 January until 31 December 2014
- Primaries
  - Brazil-side: INPA/LBA Office program manager (TBD)
  - USA side: Kim Nitschke (DOE LANL)
  - Scientific License: Rodrigo Souza (UEA) and Paulo Artaxo (USP)

Dates of GoAmazon2014

AAF Operations (aircraft)

- 40 flight days in period of 15 February until 31 March 2014
- 40 flight days in period of 1 September until 15 October 2014
- Primaries
  - Brazil-side: Karla Longo (INPE), Luiz Machado (INPE), and Gilberto Fisch (CTA)
  - USA side: Beat Schmid (DOE PNNL)
  - Scientific License: Karla Longo (INPE)

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ARM – Brazil Ground Site Operations Overview

Kim Nitschke
Field Instrument Deployments and Operations (FIDO) Office
Los Alamos National Laboratory

LAUR 072442

ARM Mobile Facility One - Typical Deployment

Van Cluster

- AMF1-A1
- AMF1-S4 (Workshop/spares & tools storage)
- AMF1-A3 (GENSET)
- AMF1-A2
- Ka-W SACR
- MAOS-A
- MAOS-C

Instrument Field

- SKYRAD
- TSI/MFRSR Stand
- RWP
- BBSS Launcher
- MWR
- MWRP
- MWR-HF
- ECOR
- MET/GNDRAD Tower

Revised March 2011

AMF1

AMF1 – 7 x 20' sea containers
1 full-time on-site technician

- Precision Spectral Pyranometer (PSP) x 2
- Precision Infrared Radiometer (PIR) x 2
- Shaded Black & White Pyranometer (B/W)
- Shaded Precision Infrared Pyrgeometer (PIR)
- Normal Incidence Pyrhiliometer (NIP)
- Infrared Thermometer (IRT) x 2
- Multi-Filter Rotating Shadowband Radiometer (MFRSR)
- Narrow Field of View Zenith Radiometer (NFOV)
- Optical Rain Gauge (ORG)
- Anemometers (WND)
- Temperature/Relative Humidity Sensor (T/RH)
- Barometer (BAR)
- Present Weather Detector (PWD)
- Eddy Correlation Flux Measurement System (ECOR)
- Shortwave Array Spectrometer (SAS-He, SAS-Ze)

- Microwave Radiometer (MWR)
- Microwave Radiometer Profiler (MWRP)
- Microwave Radiometer 90/150 (MWR-HF)
- Doppler Lidar (DL)
- Ceilometer (CEIL)
- Balloon Borne Sounding System (BBSS)
- W-band ARM Cloud Radar - 95GHz (WACR)
- Ka-W Scanning ARM Cloud Radar (SACR)
- Atmospheric Emitted Radiance Interferometer (AERI)
- Total Sky Imager (TSI)
- Aerosol Observation System (AOS)
  - CCNC
  - PSAP
  - Nephelometers X 2
- Radar Wind Profiler – 1290MHz (RWP)
- Cimel Sunphotometer (CSPHOT)

LANL Solar Fourier Transform Spectrophotometer (FTS) (Dubey) (OCO-2 validation)

MAOS

Mobile Aerosol Observing System (MAOS) – 2 x 20' sea containers (MAOS-A & MAOS-C)

2 x full time post-docs (supplied by ARM)

Guest operational personnel (approx. 5)

- SOnic Detection And Ranging (SODAR) System (1000 to 4000 Hz)
- Ultra-High Sensitivity Aerosol Spectrometer (enhanced)
- Dual Column Cloud Condensation Nuclei Counter (CCN)
- Single Particle Soot Photometer (SP2)
- Scanning Mobility Particle Sizer (SMPS)
- Photo-Acoustic Soot Spectrometer (PASS), 3 Wavelength
- Humidigraph (3 Relative Humidities with 3 single wavelength nephelometers)
- Humidigraph (Scanning Relative Humidity with 3 single wavelength nephelometers)
- Trace Gas Instrument System (Research-Grade)
- Particle Into Liquid Sampler-Ion Chromatography-Water Soluble Organic Carbon (PILS-IC-WSOC)
- Particle Soot Absorption Photometer (PSAP), 3 Wavelength
- Nephelometer, 3 Wavelength
- Condensation Particle Counter (CPC), 10 nm to >3000 nm particle size range
- Condensation Particle Counter (CPC), 2.5 nm to >3000 nm particle size range
- Hygroscopic Tandem Differential Mobility Analyzer (HTDMA)
- Proton Transfer Mass Spectrometer (PTRMS)
- 7-Wavelength Aethelometer
- Weather Transmitter (WXT-520)
- Aerosol Chemistry Speciation Monitor (ACSM)

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

The ARM Aerial Facility (AAF) in Brazil

IARA-2014: AAF G1 Payload

Platform Position/Velocity/Altitude			
Instrument	**Trimble DSM**	**Trimble TANS 10 Hz**	
Measurement	position/velocity at 10 Hz	pitch/roll/azimuth	
Atmospheric State			
Instrument	**Rosemont 102 probe**	**Rosemount 1201F1**	**Rosemont 1221F2 (3)**
Measurement	temperature	static pressure	differential pressure (dynamic, alpha, beta)
Instrument	**GE-1011B chilled-mirror hygrometer**	**AIMMS-20**	
Measurement	dew-point temperature	5-port air motion sensing: true air speed, altitude, angle-of-attack, side-slip, temperature, relative humidity	
Aerosol Measurements			
Instrument	**TSI 3025 ultrafine condensation particle counter (UCPC)**	**TSI 3010 condensation particle counter (CPC)**	**fast integrated mobility spectrometer (FIMS)**
Measurement	total particle concentration (>3 nm)	total particle concentration (>10 nm)	aerosol particle size distribution (30 to 100 nm)
Instrument	**passive cavity aerosol spectrometer probe (PCASP)**	**particle/soot absorption photometer (PSAP)**	**TSI Nephelometer**
Measurement	aerosol particle size distribution (100 to 3000 nm)	aerosol particle light absorption at 3 wavelengths	aerosol particle light scattering at 3 wavelengths
Instrument	**Aerodyne HR-ToF-AMS**	**DMT Dual Cloud Condensation Nuclei Counter (CCNC)**	**isokinetic inlet (heated)**
Measurement	size-resolved particle composition	CCN concentrations at two supersaturations	sample stream of dry aerosol, sizes < 2.5 µm
Gas Measurements			
Instrument	**Ionicon Quadrupole PTR-MS**	**carbon monoxide analyzer**	**oxides of nitrogen instrument**
Measurement	real-time VOCs	CO	NO, NO_2, NO_y
Instrument	**Thermo environmental model 49i**	**Picarro cavity ringdown spectrometer**	
Measurement	O_3	CO_2, CH_4, H_2O	

IARA-2014: AAF G1 Payload

Cloud Measurements			
Instrument	**HVPS-3**	**2DS**	**Fast-CDP**
Measurement	cloud droplet size distribution (400 to 50000 µm)	cloud droplet size distribution (10 to 3000 µm)	cloud droplet size distribution (2 to 50 µm)
Instrument	**CIP**	**SEA WCM-2000**	
Measurement	images of cloud particles (2 to 1000 µm)	liquid water content and total water content	
Radiation			
Instrument	**SPN-1 unshaded**	**SPN-1 unshaded**	
Measurement	downwelling shortwave radiation	Upwelling shortwave radiation	
Other Measurements			
Instrument	**SEA M300**	**weather radar**	**TCAS**
Measurement	central data acquisition/ display system	cockpit display of precipitation returns	traffic collision and avoidance system
Instrument	**TAWS**		
Measurement	terrain awareness and warning system		

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Brazil-Side Organizations

- LBA - Large-Scale Biosphere Atmosphere Experiment, http://lba.inpa.gov.br/lba/
- INPA - National Institute for Research in the Amazon, http://www.inpa.gov.br/
- INPE - National Institute for Space Research, http://www.inpe.br/ingles/index.php
- CTA - Department of Science and Aerospace Technology, http://www.cta.br/
- UEA - University of the State of Amazonas, http://www1.uea.edu.br/
- USP - University of São Paulo, http://www.thefullwiki.org/University_of_Sao_Paulo, http://web.if.usp.br/ifusp/, http://www.master.iag.usp.br/index.php?pi=N
- Links to GPM-CHUVA (http://chuvaproject.cptec.inpe.br/portal/en/index.html), SAMBBA (http://www.ncas.ac.uk/fgam/index.php?option=com_content&task=view&id=194&Itemid=1), Andes-Amazon Initiative (http://www.moore.org/andes-amazon.aspx), Amazon-PIRE (http://www.amazonpire.org/)

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

Main research foci:

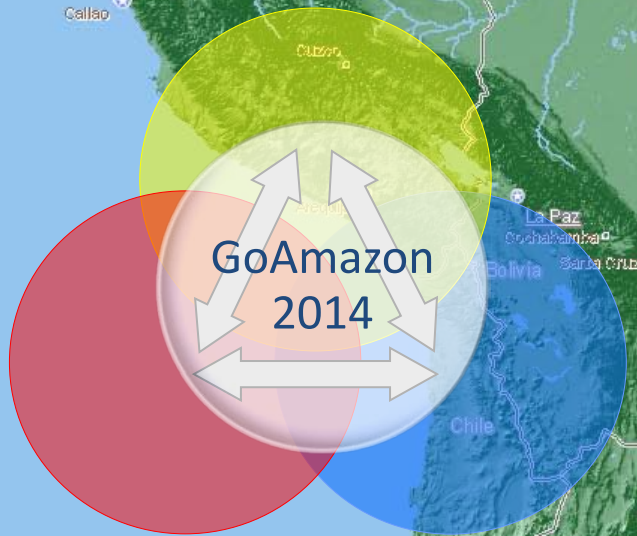
- The changing environment of Amazonia
- Environmental sustainability and the sustainability of current terrestrial and aquatic production systems
- Variability and changes in climatic and hydrologic systems – feedback, adaptation and mitigation

Integrated and interdisciplinary investigations:

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

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

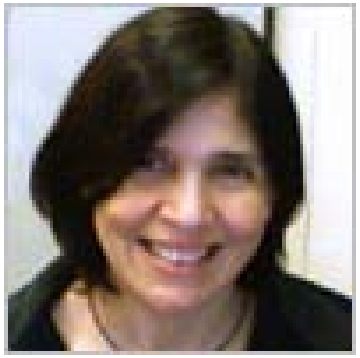
Blue: the social dimensions of environmental change and the dynamics of land cover change



Acknowledgments: Laszlo Nagy, INPA/LBA

Brazil-Side Scientific Steering Committee

Gilberto Fisch (CTA)
Boundary Layer Studies
http://buscatextual.cnpq.br/buscatextual/visualizacv.jsp?id=K4780139T4

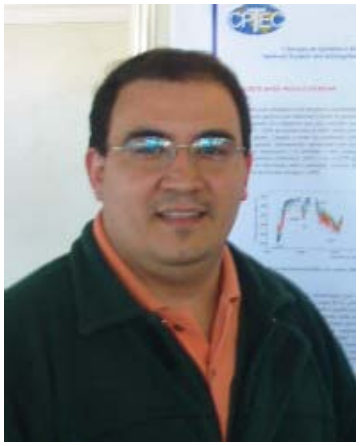


Karla Longo (INPE)
Atmos. Modeling: Chemistry
http://meioambiente.cptec.inpe.br/gmai/index.php

Luiz Machado (INPE)
Convection/Cloud Dynamics
http://buscatextual.cnpq.br/buscatextual/visualizacv.jsp?id=K4789453E1

M.A. Silva Dias (USP)
Atmos.Models: Energy Flows
http://www.proficiencia.org.br/article.php3?id_article=88

Paulo Artaxo (USP)
Aerosol Life Cycle & Climate
http://www.csixxxvii.org/index.php?pag=invited



Rodrigo Souza (UEA)
Satellite Observations
http://buscatextual.cnpq.br/buscatextual/visualizacv.jsp?id=K4768578Y1

GoAmazon2014: Known and Planned Activities

Cloud Life Cycle Project
GPM-CHUVA
Leader: Luiz Machado

IARA-2014
DOE AAF Deployment

NASA Satellite Science
Coordinators: Loretta Mickley and Jun Wang

iLEAPS IGAC ACPC
Point of contact: Meinrat Andreae

DOE AMF Deployment

Aerosol-Cloud-Precipitation Interactions
Aeroclima
Leader: Paulo Artaxo

Aerosol Life Cycle Project
BEACHON
Leader: Alex Guenther

An Aerosol Life Cycle Project
T2 → T3 Lagrangian experiment accompanying IARA-2014
Coordinator: Jian Wang

Cloud Life Cycle Project
NSF Facilities S-POL
Leader: Courtney Schumacher

More activities expected (some DOE, some not DOE):
Cloud Life Cycle, Aerosol-Cloud-Precipitation Interactions, Carbon Cycle, international partners, …

Outline of Presentation

- WHY this experiment?
- WHERE will this experiment take place?
- WHEN will this experiment take place?
- WHAT instrumentation and facilities are part of experiment?
- HOW is the experiment organized?

Google Group:

http://groups.google.com/group/GoAmazon2014

Websites:

DOE maintained: http://campaign.arm.gov/goamazon2014/

PI maintained: http://www.seas.harvard.edu/environmental-chemistry/GoAmazon2014/