



CCST
Centro de Ciência
do Sistema Terrestre



SAEMC project

Meeting of the Americas of the American Geosciences Union

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Improving the Representation of Aerosols over South America in an Atmospheric Chemistry Model by Three Dimensional Variational Data Assimilation

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OBJECTIVES OF CHEMICAL DATA ASSIMILATION

- ◉ Bring together chemical measurements and CTM's to provide optimal spatio-temporal reconstructions of air quality parameters
- ◉ Better estimate variability, sources, sinks, and concentration trends
- ◉ Provide better air quality predictions
- ◉ Act as a decision support system for protection measures (Which emissions are most critical?)
- ◉ Reconstruct past changes
- ◉ Lay a basis to provide realistic chemical scenarios for future decades



SPECIAL CHALLENGES OF TROPOSPHERIC CHEMISTRY DATA ASSIMILATION

- ◉ Strong influence of manifold processes including emissions and deposition
- ◉ Spatially highly variable chemical regimes
- ◉ Chemical state observability (=analyseability) hampered by manifold hydrocarbon species and conversion of aerosols
- ◉ (In-?)Consistency of heterogeneous data sources: satellite and ground based remote sensing data, in-situ observations, etc.
- ◉ Limited information on vertical distribution
- ◉ Assumptions on aerosol properties



MODELING TOOL:

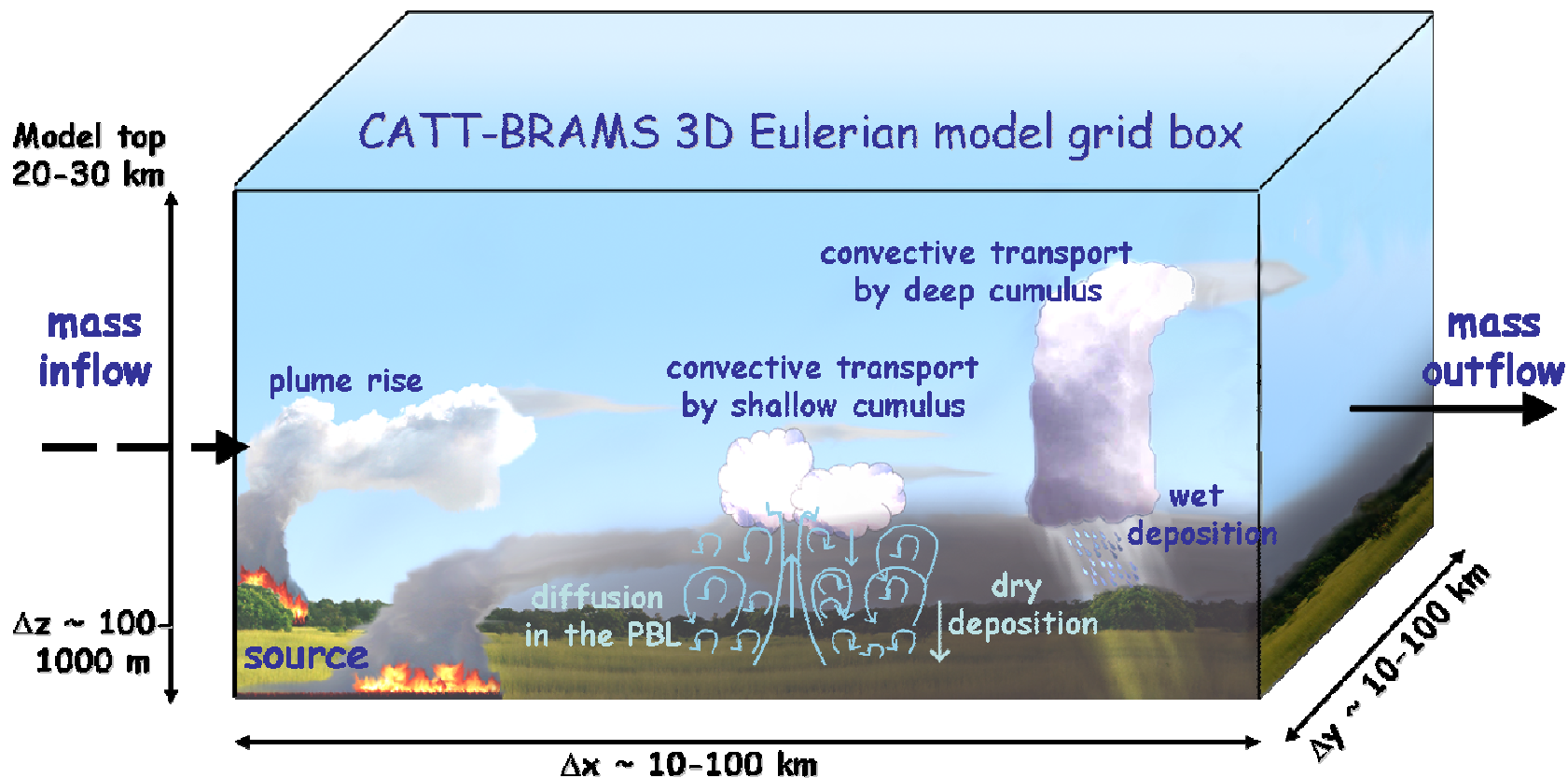
CCATT-BRAMS

THE COUPLED CHEMISTRY-AEROSOL-TRACER TRANSPORT MODEL TO THE BRAZILIAN DEVELOPMENTS ON THE REGIONAL ATMOSPHERIC MODELING SYSTEM

... is a numerical model developed for simulations of transport and processes related to biomass burning and other emissions on a regional to hemispheric scale

$$\frac{\partial \bar{s}}{\partial t} = \left(\frac{\partial \bar{s}}{\partial t} \right)_{adv} + \left(\frac{\partial \bar{s}}{\partial t} \right)_{PBL\ turb} + \left(\frac{\partial \bar{s}}{\partial t} \right)_{deep\ conv} + \left(\frac{\partial \bar{s}}{\partial t} \right)_{shallow\ conv} + W_{PM2.5} + R +$$
$$+ Q_{plume\ rise} + \left(\frac{\partial \bar{s}}{\partial t} \right)_{chemical\ reactions} + \left(\frac{\partial \bar{s}}{\partial t} \right)_{4dda}$$

Some sub-grid processes involved at gases/aerosols transport and simulated by CCATT-BRAMS



Model: Freitas et al., *Atmos. Chem. Phys.*, Vol. 9, p. 2843-2861, 2009
 Plume-rise: Freitas et al., *Geophys. Res. Lett.*, 33, L17808, 2006 &
 Freitas et al., *Atmos. Chem. Phys.*, v. 7, p. 3385-3398, 2007

SOUTH AMERICAN EMISSIONS

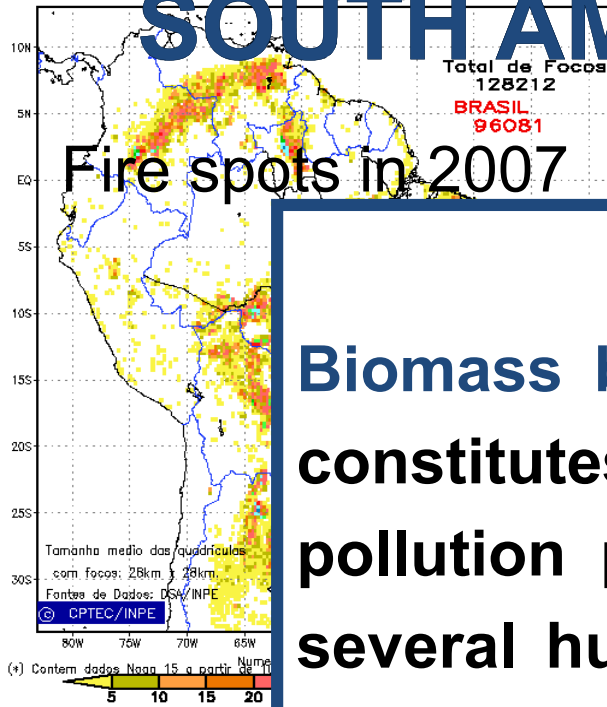
Sources:

Charcoal production, Agricult.
waste burning, Urban-industrial
(transport, biofuels), Biogenic
emissions

IAI Project: **SAEMC** - South
American Emissions,
Megacities and Climate



SOUTH AMERICAN EMISSIONS



Fire spots in 2007

Charcoal production, Agricult.

al

Biomass burning over South America constitutes a continental scale air pollution problem. The occurrence of several hundred of thousands of fires generates a regional smoke plume of about 4-5 Mio. km² every year.

Fire em

- regular
- ecosys
- (~Brazil
- and pasture land

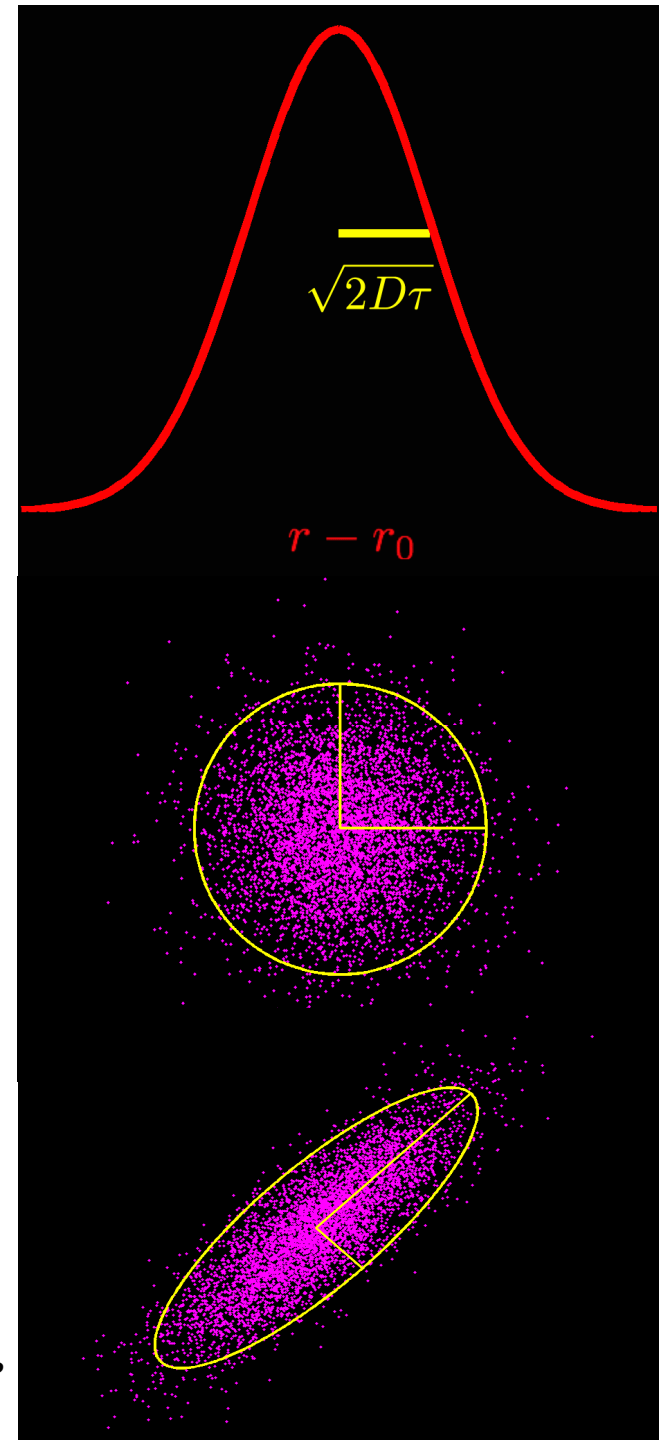
- fire causes: deforestation and savanna and pasture land maintenance



ASSIMILATION CODE:

- ⊙ 3D-VAR --> assimilating tropospheric mass concentration or Aerosol Optical Depth (AOD), from ground and satellite remote sensing and direct measurements from aircraft campaigns, code source: RIU/Univ. of Cologne, Germany
- ⊙ Diffusion approach for BECM-Matrix, following paper by Weaver and Courtier, Q.J. R. Meteorol. Soc., 2001

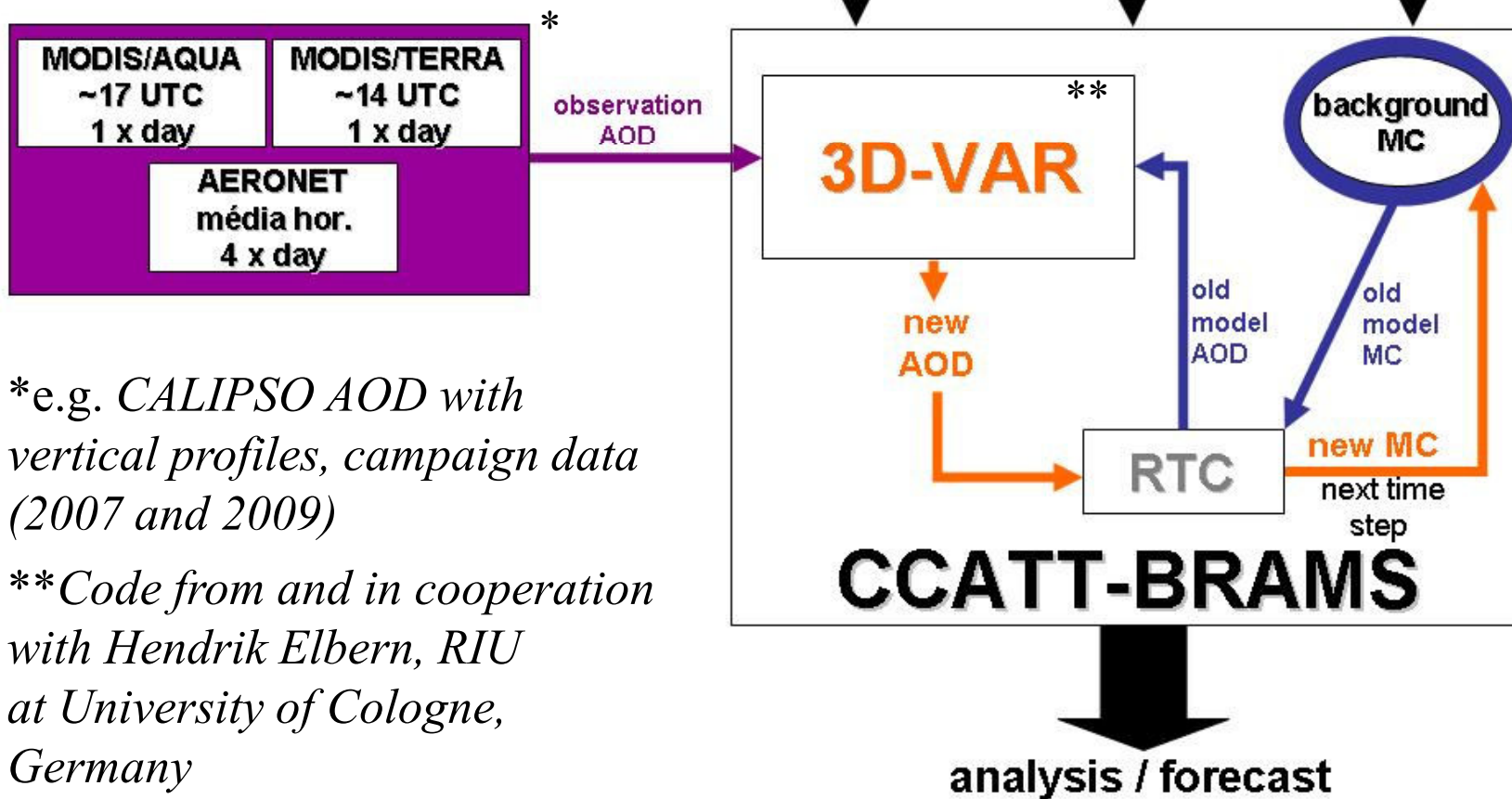
from: www.fmrrib.ox.ac.uk/fslcourse/lectures/fdt/all.htm



WHY THE DIFFUSION APPROACH?

- ◉ Why? - background correlations have similar behavior
- ◉ B^{-1} does not need to be calculated, stored and inverted (= expensive). B is converted into an operator. Only $B^{1/2}B^T/2$. In traditional 3D-VAR, B^{-1} is explicitly calculated.
- ◉ The diffusion approach allows an estimate of B without needing all dimensions [normally: $(N \times M, N \times M)$ for each species and vertical level]

CHEMICAL DATA ASSIMILATION WITH CCATT-BRAMS: A 3D-VAR ASSIMILATION SYSTEM



*e.g. CALIPSO AOD with vertical profiles, campaign data (2007 and 2009)

**Code from and in cooperation with Hendrik Elbern, RIU at University of Cologne, Germany

CLAIM - CLOUD-AEROSOL INTERACTION MEASUREMENTS CAMPAIGN

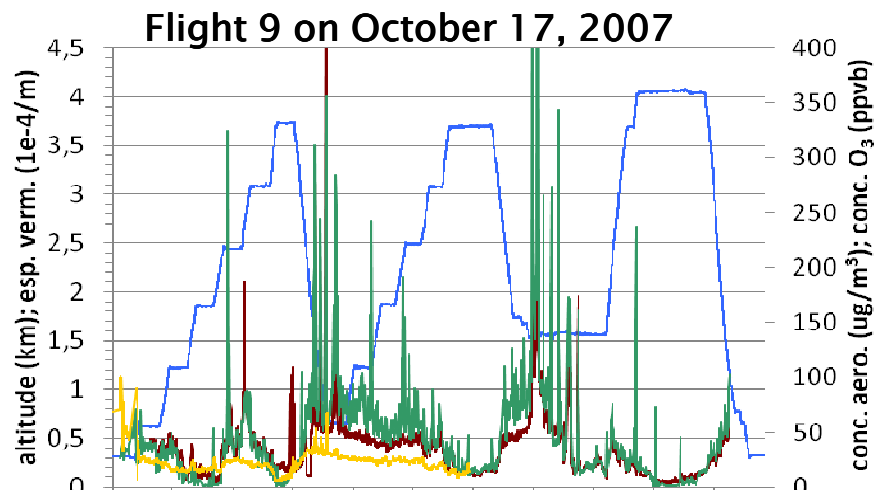


Fonte: <http://maps.google.com.br/>

Air Plane Flight Paths

When: October 9-22, 2007,
during burning season.

Data: Aerosol mass concentration,
measured by a DATARAM
instrument, 14 flights in total



**Munchow et al., Poster session, A41B-04, exhibited on Thursday in
Room Expocenter II-III,
AGU Meeting of the Americas, Foz do Iguaçu, 2010**

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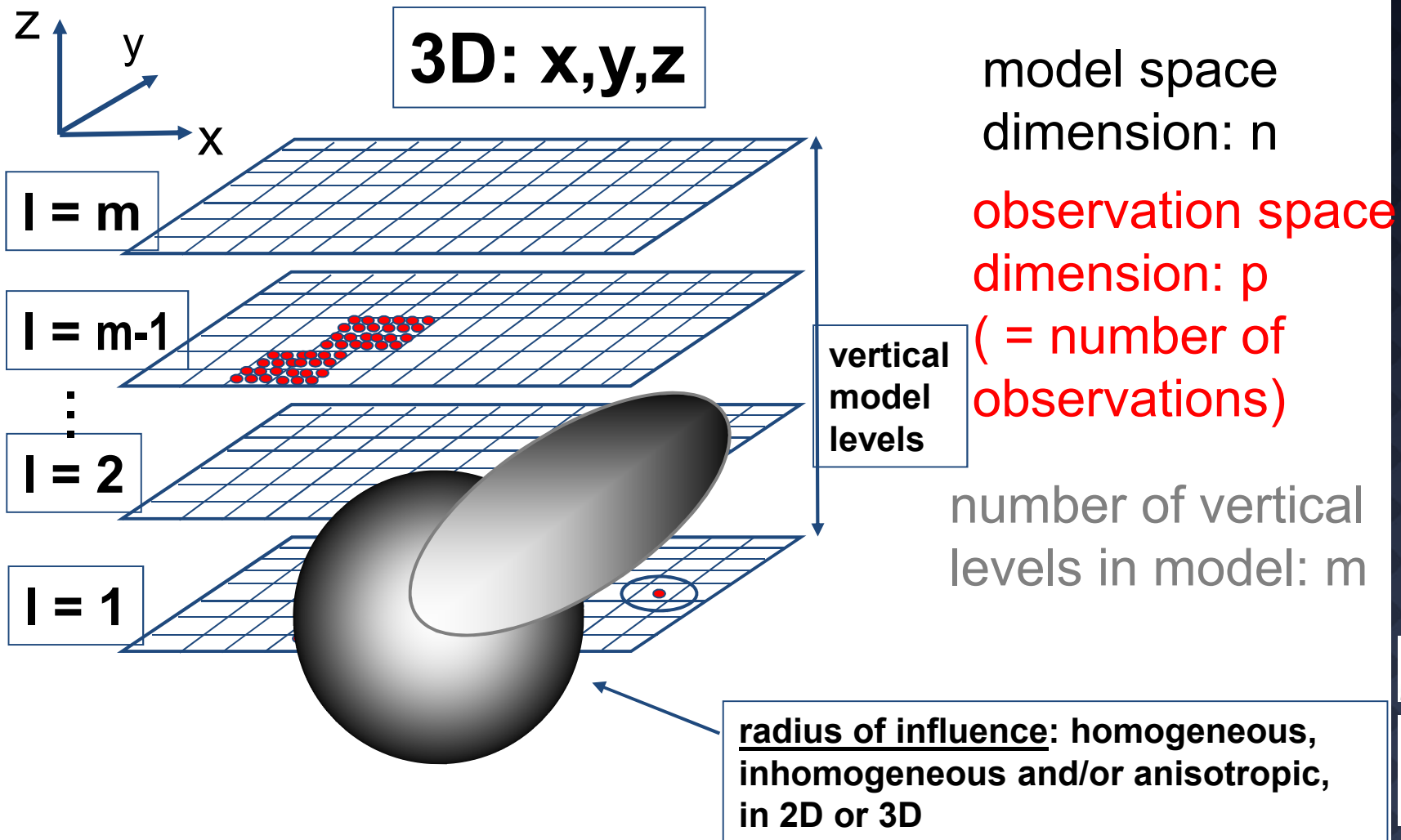
Supervisors: J. Hoelzemann, K. Longo, D. Herdies



MODIS AND AERONET AOD INTERCOMPARISON

- Understand the inter-comparability of observational data of different sources
- Make best use of sparse AERONET data
- Define inhomogeneous and anisotropic radii of influence for AERONET sites, that can be used for the Background Error Covariance Matrix in the assimilation process

RADII OF INFLUENCE IN DATA ASSIMILATION:



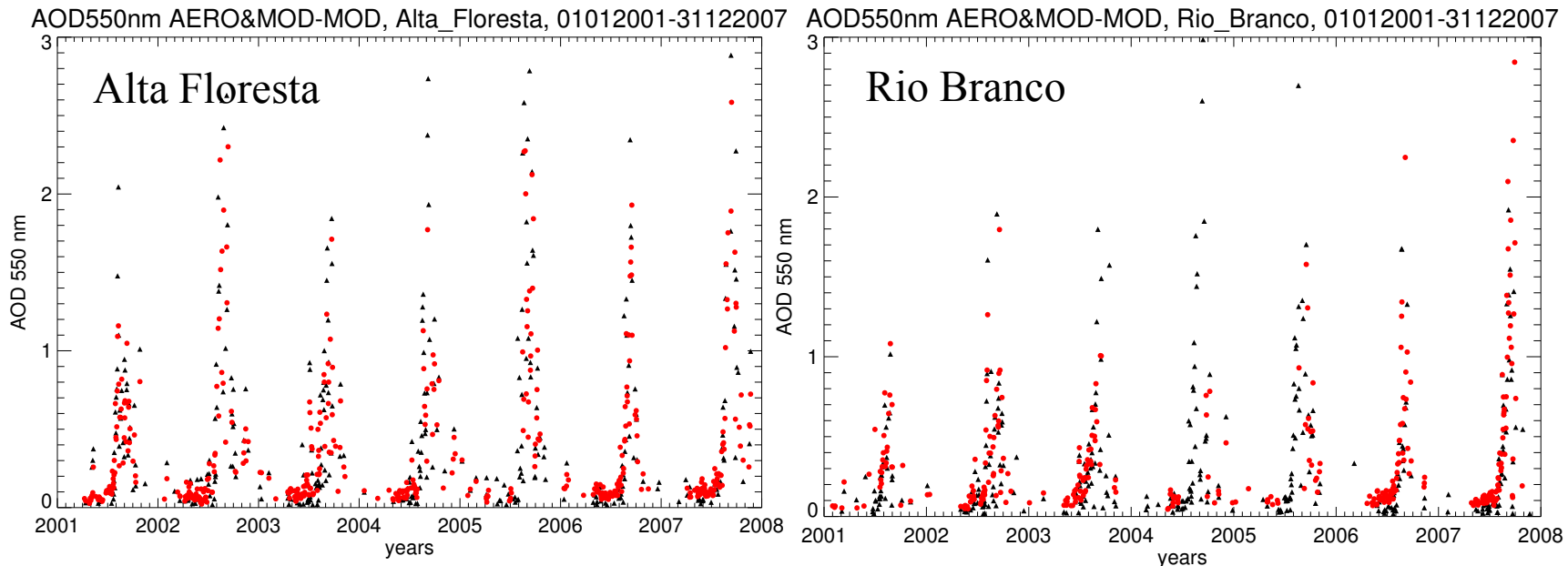
AERONET SITES



Location of AERONET 12 sites in South America with AOD measurements during the period 2001-2007 and for at least 3 years. Map source: Google Maps



TIME SERIES OF AERONET AND MODIS AOD FROM 2001 - 2007



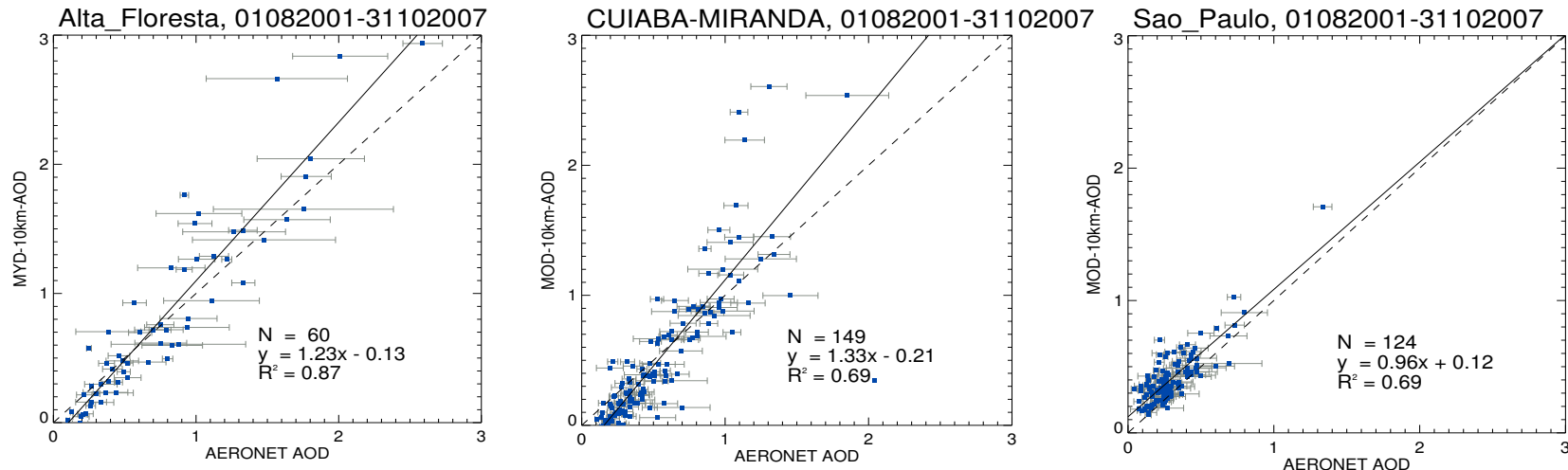
AOD-550nm - MODIS/TERRA (black)

AOD-550nm- AERONET hourly means (red) centered at TERRA overpass time

Figure source: Hoelzemann et al., JGR, 2009

Biomass burning influenced sites show distinct AOD signal during burning seasons, with maxima >3

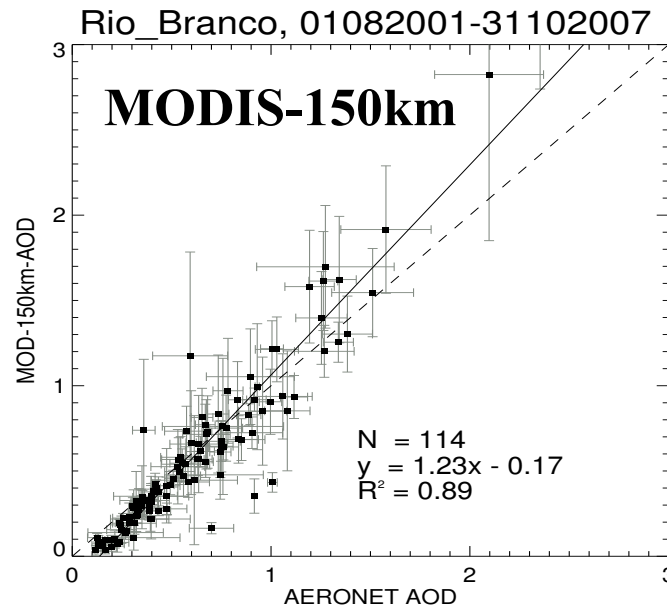
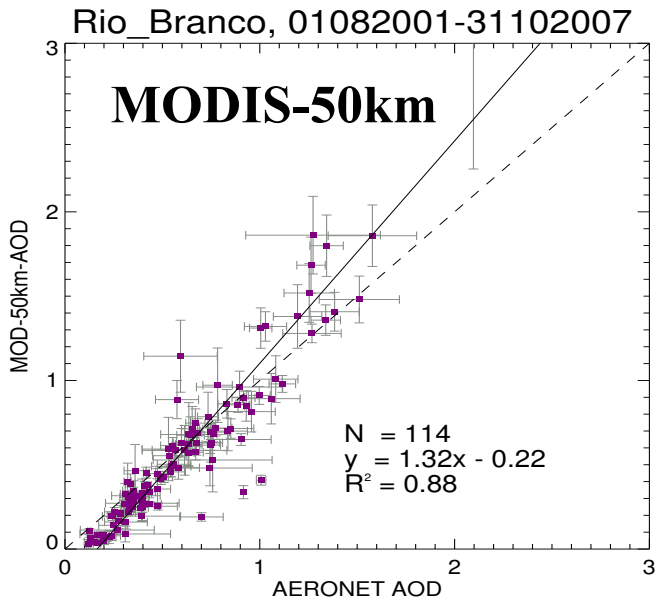
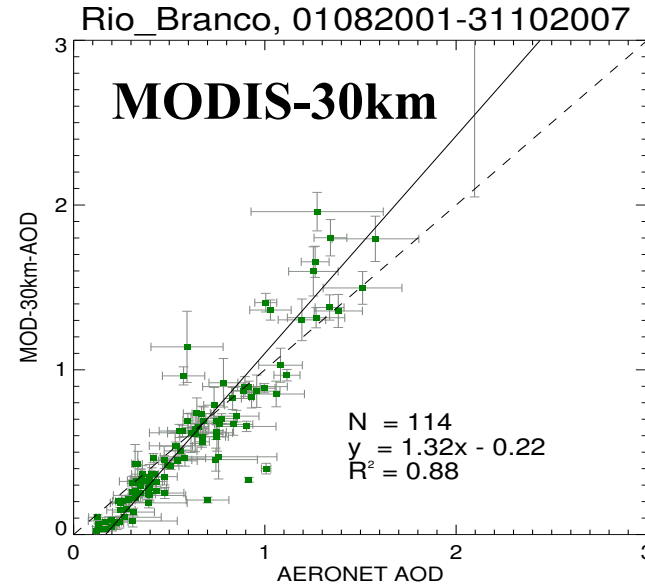
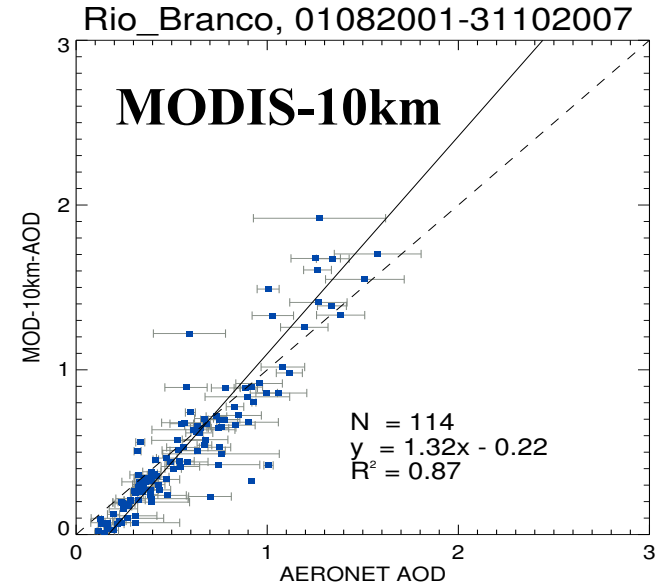
INTERCOMPARISON OF MODIS AND AERONET AOD



Scatterplots of MODIS and AERONET AOD at 550 nm integrated from August-October 2001-2007 at AERONET sites Alta Floresta, Cuiabá-Miranda, and São Paulo

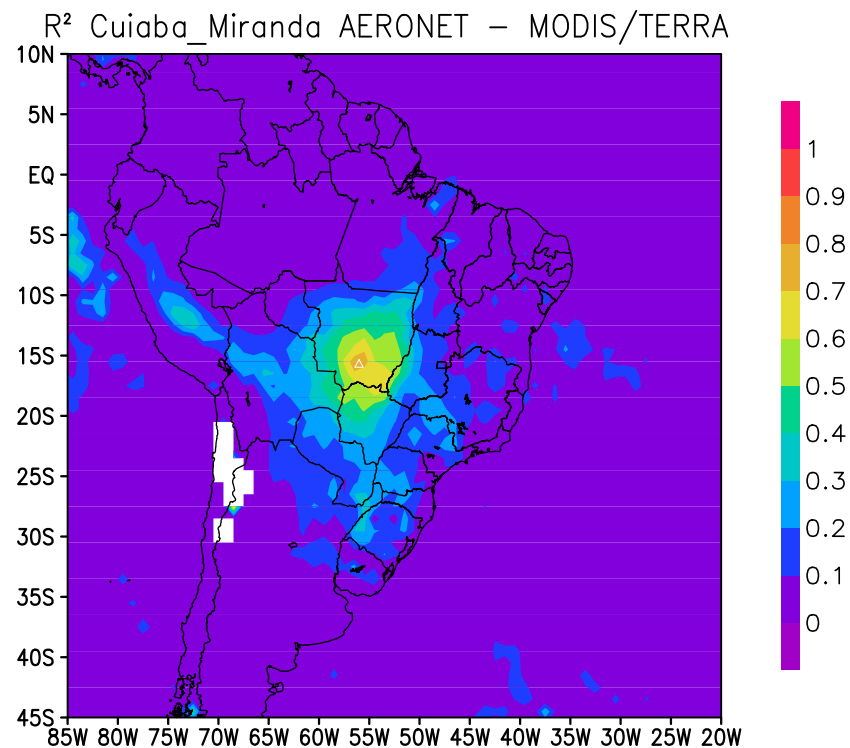
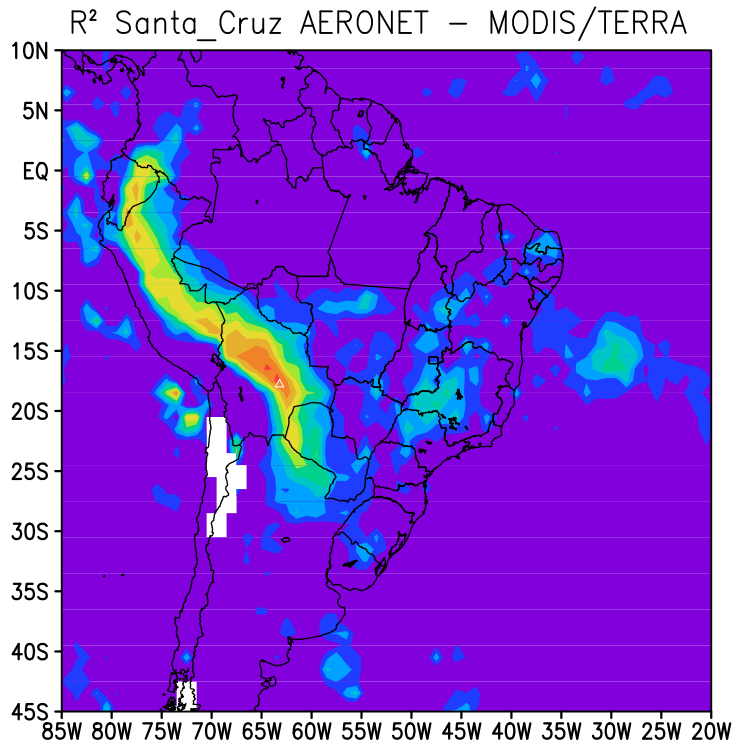
- Separate study for TERRA and AQUA, no large statistical differences
- AERONET and MODIS data correlate generally well ($R^2 > 0.7$), slope > 1
- Systematic bias: $AOD_{MOD} < AOD_{AERO}$ for small values and $AOD_{MOD} > AOD_{AERO}$ for high values
- No inter-annual trend of correlation / slope

ISOTROPIC RADII OF INFLUENCE



MODIS 10km, 30 km, 50 km, 150 km spatial average around each AERONET site

ANISOTROPIC AND INHOMOGENEOUS AREAS OF INFLUENCE

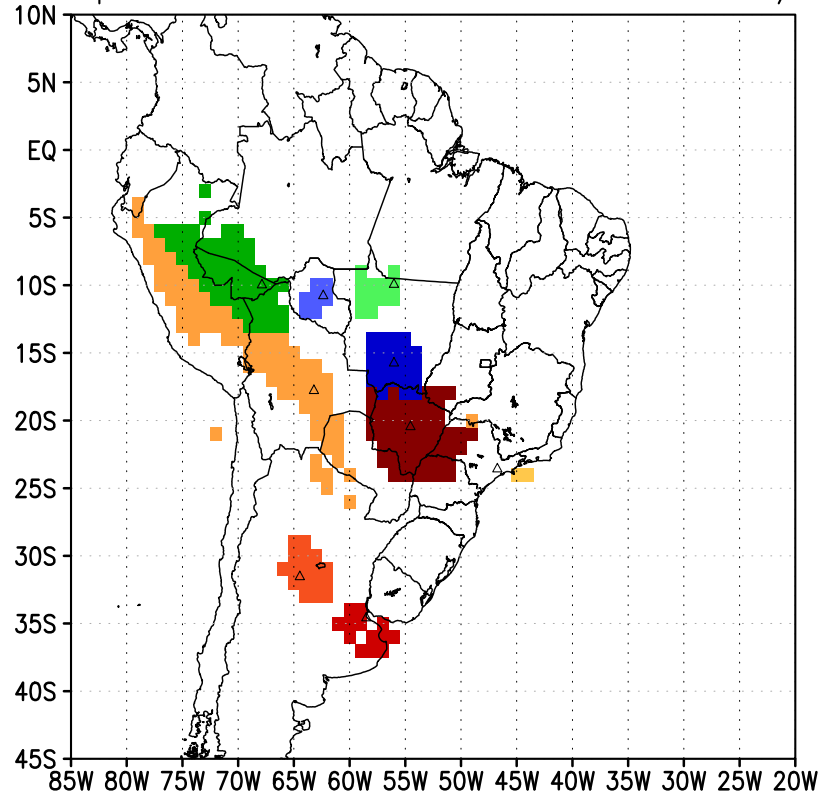


Gridded correlations of Santa Cruz and Cuiabá-Miranda AERONET sites calculated by correlation studies of AERONET and MODIS/TERRA (MOVAS 1 x 1) AOD at 550 nm for the burning seasons (AUG-OCT) from 2001 – 2007

Source: Hoelzemann et al., 2009

AERONET AREAS OF INFLUENCE IN SOUTH AMERICA

Anisotropic radii of influence AERONET – MODIS/AQUA



Anisotropic areas of influence of AERONET sites in South America for data assimilation purposes, calculated by correlation studies of AERONET and MODIS (MOVAS $1^\circ \times 1^\circ$) TERRA AOD at 550 nm.

Plotted AERONET sites:
Abracos Hill (1), Cuiabá-Miranda (2), Rio Branco (3), Alta Floresta (4), Campo Grande Sonda (5), Ceilap-BA (6), Cordoba-CETT (7), Santa Cruz (8), and São Paulo (9)



PERSPECTIVES

- ◉ Inclusion of inhomogeneous and anisotropic areas of influence as of Hoelzemann et al. (2009) in BECM of CCATT-BRAMS 3D-var system
- ◉ Include aerosol assimilation scheme in Brazilian chemical weather forecast system with CCATT-BRAMS model
- ◉ Trace gas assimilation such as CO, Ozone
- ◉ Intercomparison of current assimilation technique with others → LEKF in cooperation with DA group at CPTEC / INPE

PERSPECTIVES

- ◉ 10 year-reanalysis study of the atmospheric composition over South America with assimilation of best available observations
 - New data base that best represents chemical composition of region for reference and application e.g. in human health studies (Ignotti et al., 2010)
 - Preparation of chemistry module on climate time scale for integration in the Brazilian Earth System Model that is currently under development





**INPE - National Institute for Space Research,
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<http://meioambiente.cptec.inpe.br/>

Thank you

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