SAMBBA: The South American Biomass Burning Analysis

Jim Haywood, Ben Johnson, Hugh Coe , Karla Longo, Paulo Artaxo, Saulo Freitas

© Crown copyright Met Office

SAMBBA

- Who, what, where and when?
- Met Office perspective
- NERC perspective
- Brazilian perspective
- More detailed planning

SAMBBA: Who, what, where and when?

Who: The main partners in SAMBBA are from the Brazil/UK but with collaborative support from other nationalities. INPE, University of Sao Paulo, Met Office, UK Universities make up the scientific steering group

What: SAMBBA is an international measurement/modelling campaign investigating far-reaching aspects of South American biomass burning

Where and when: The main measurement component is centred on deployment of aircraft and surface instrumentation over the biomass burning season in 2012 (aircraft Sept 2012, based in Porto Velho, Rondonia)

The measurements underpin the modelling components which span a wide range of spatial and temporal scales from microphysical evolution of aerosols in plumes through to global scale weather and climate models

© Crown copyright Met Office

SAMBBA core partners & scientific steering group

MET OFFICE

Ben Johnson

Jim Haywood

INPE

Karla Longo

Saulo Freitas

NERC

Hugh Coe

USP

Paulo Artaxo

© Crown copyright Met Office

The Met Office Perspective: Why SAMMBA?

© Crown copyright Met Office

The Met Office Perspective: Why SAMMBA?

- Biomass burning aerosols exert significant radiative impacts through
  - Direct effects (scattering and absorption of radiation)
  - Semi-direct effects (absorption causes heating, changing atmospheric lapse rates)
  - Indirect effects (impacts on cloud microphysical properties, lifetime, height etc)
- The impacts via these mechanisms on the TOA/ atmospheric/surface energy budget
- These impacts are not just of interest for climate research – they impact global and regional NWP models.
- Following the success of AMMA in developing and implementing mineral dust models in climate and NWP models, a similar procedure can be used for biomass burning aerosols.
- By utilising and strengthening existing partnerships (e.g. MO/INPE MOU) and establishing new ones, maximum progress can be made.

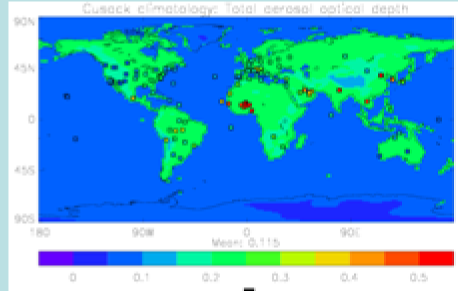
© Crown copyright Met Office

Global NWP:

Where we were:

2001-2008

Simple Land/Sea climatologies

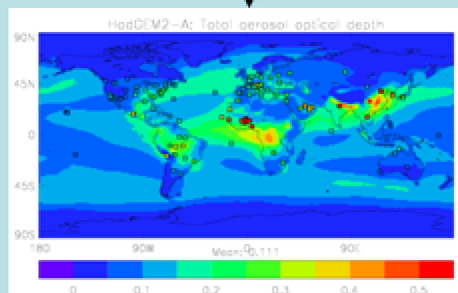


Little resemblance to reality

No cost

2008-2011

CLASSIC aerosol climatologies



Reasonable monthly means but no relation to meteorology

Cheap

Mid-term

Replacement of climatologies with prognostic schemes based on CLASSIC

- **Sea-salt**
- **Biomass burning**
- **Saharan dust**

Fully prognostic driven by meteorology

Moderate

Long-term upgrades

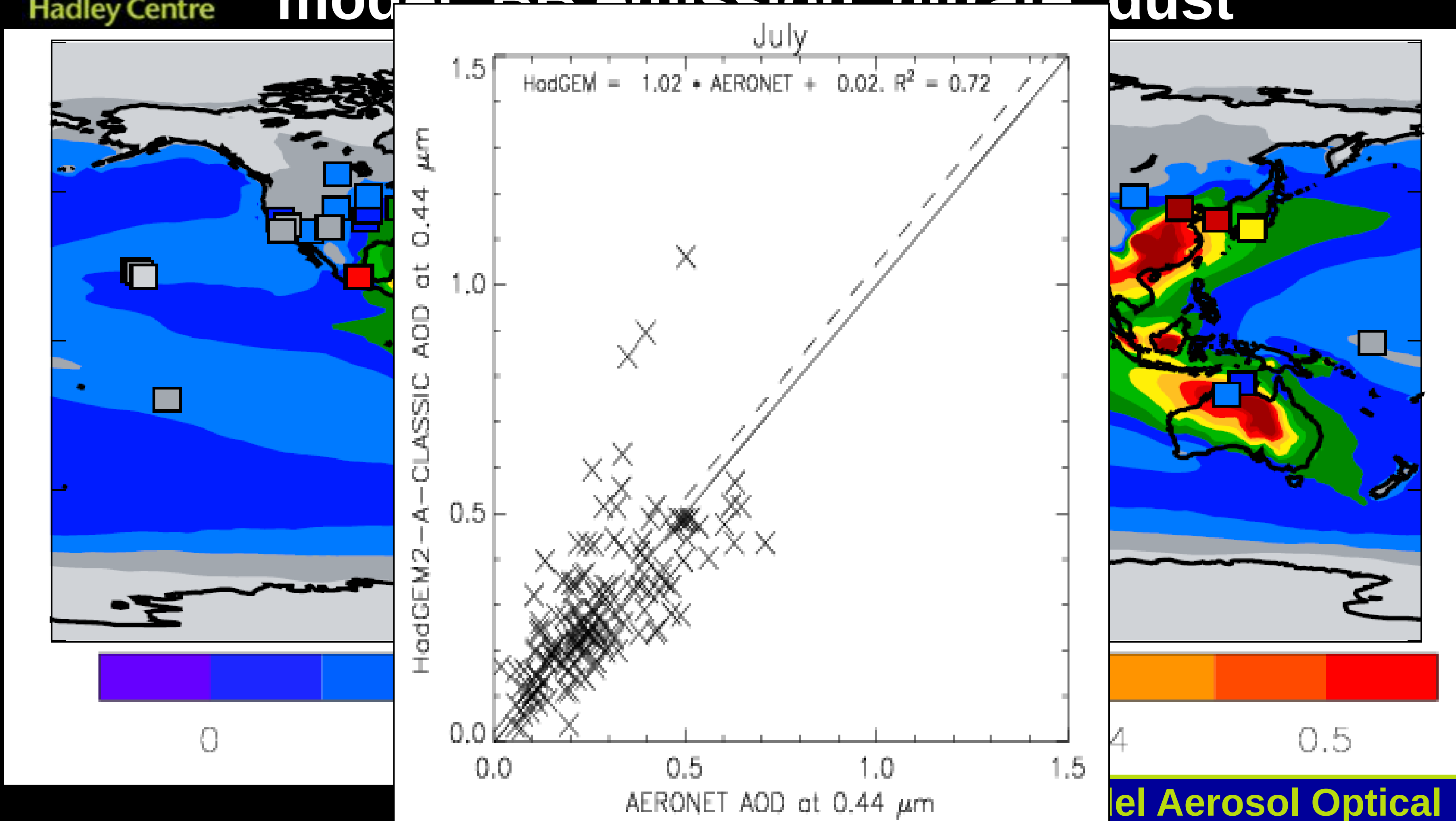
MACC/GEMS Assimilated aerosol for initial conditions

Prognostic UKCA-MODE upgrades for other aerosol species

DA of fires for biomass burning

Moderate/ expensive

Stage 1: Improvement of AODs in climate model for use in NWP model: BB emission, nitrate, dust

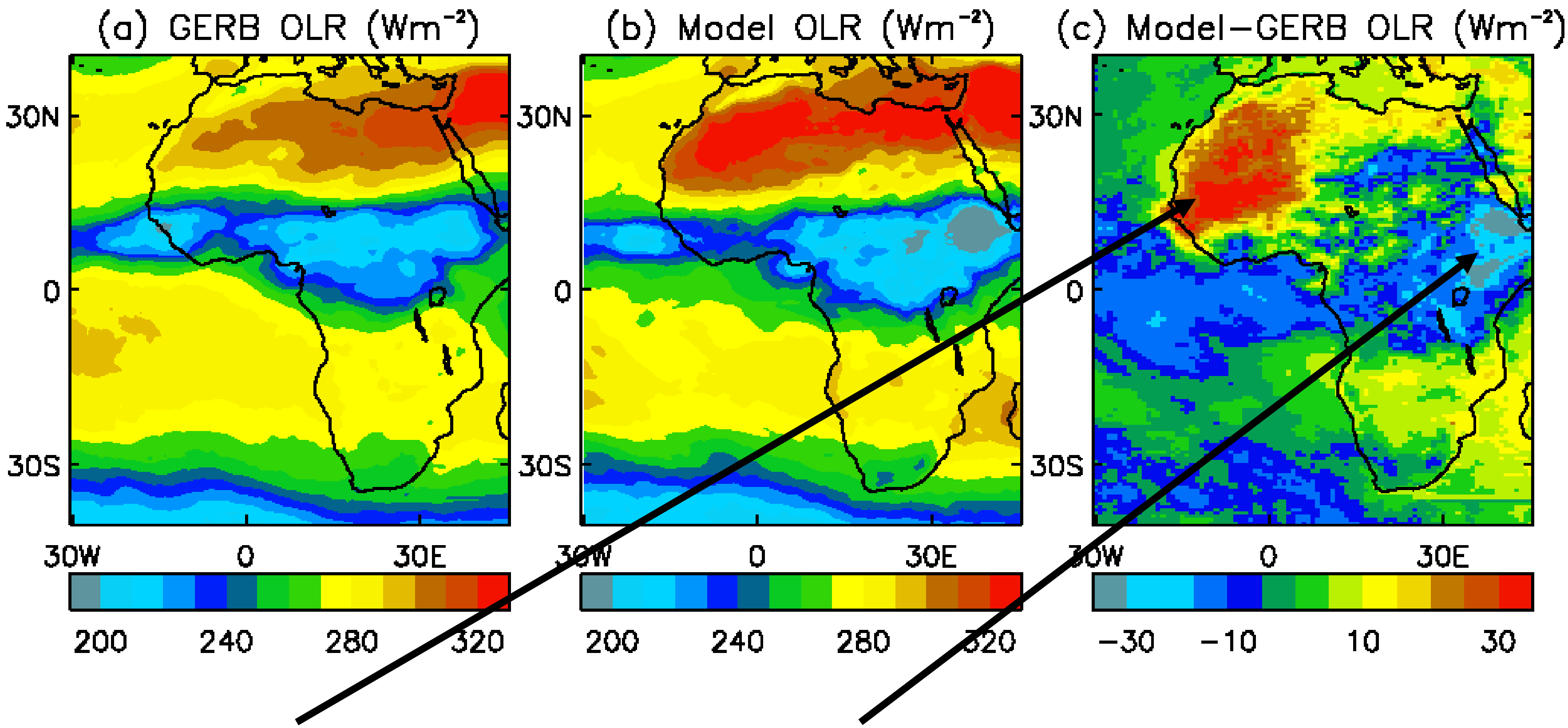


…del Aerosol Optical Depths compared against AERONET observations

© Crown copyright Met Office

An example of why aerosols (e.g. mineral dust) are important in NWP regional and global models

Data from SINERGEE project using 6Z, 12Z, 18Z, 24Z, July 2003

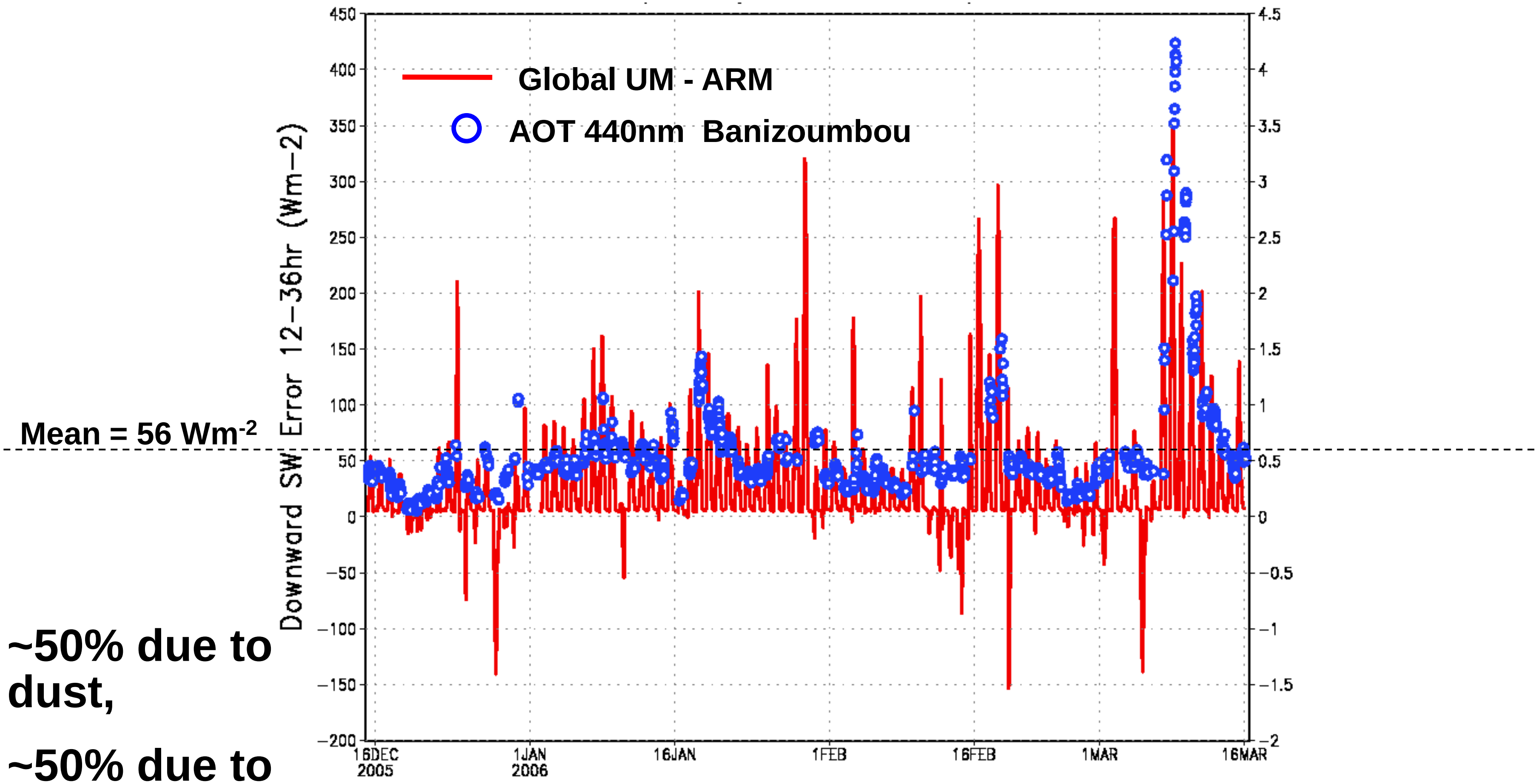


The +ve anomaly over desert is ~ -ve anolmaly over ITCZ clouds

Haywood et al., 2005

Why go from monthly mean climatologies to prognostic aerosols?

The aerosol optical depth and global NWP model bias in surface SW radiation in W Africa



~50% due to dust,

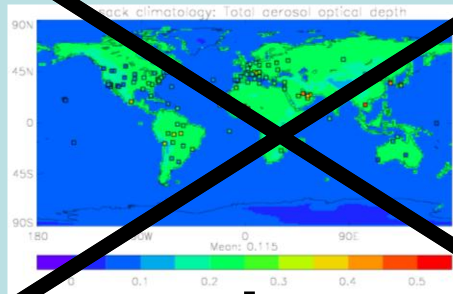
~50% due to smoke

Milton et al (2008)

Where we are now:

2001-2008

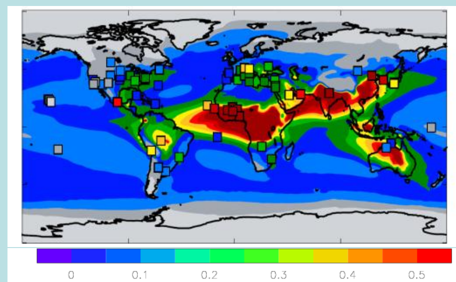
Simple Land/Sea climatologies



Little resemblance to reality

2008-2011

Improved CLASSIC aerosol climatologies



Reasonable monthly means but no relation to meteorology

Current

Replacement of climatologies with prognostic schemes based on CLASSIC

- **Saharan dust***
- **Sea-salt**
- **Biomass burning**

Fully prognostic driven by meteorology

Mid-Term Upgrades

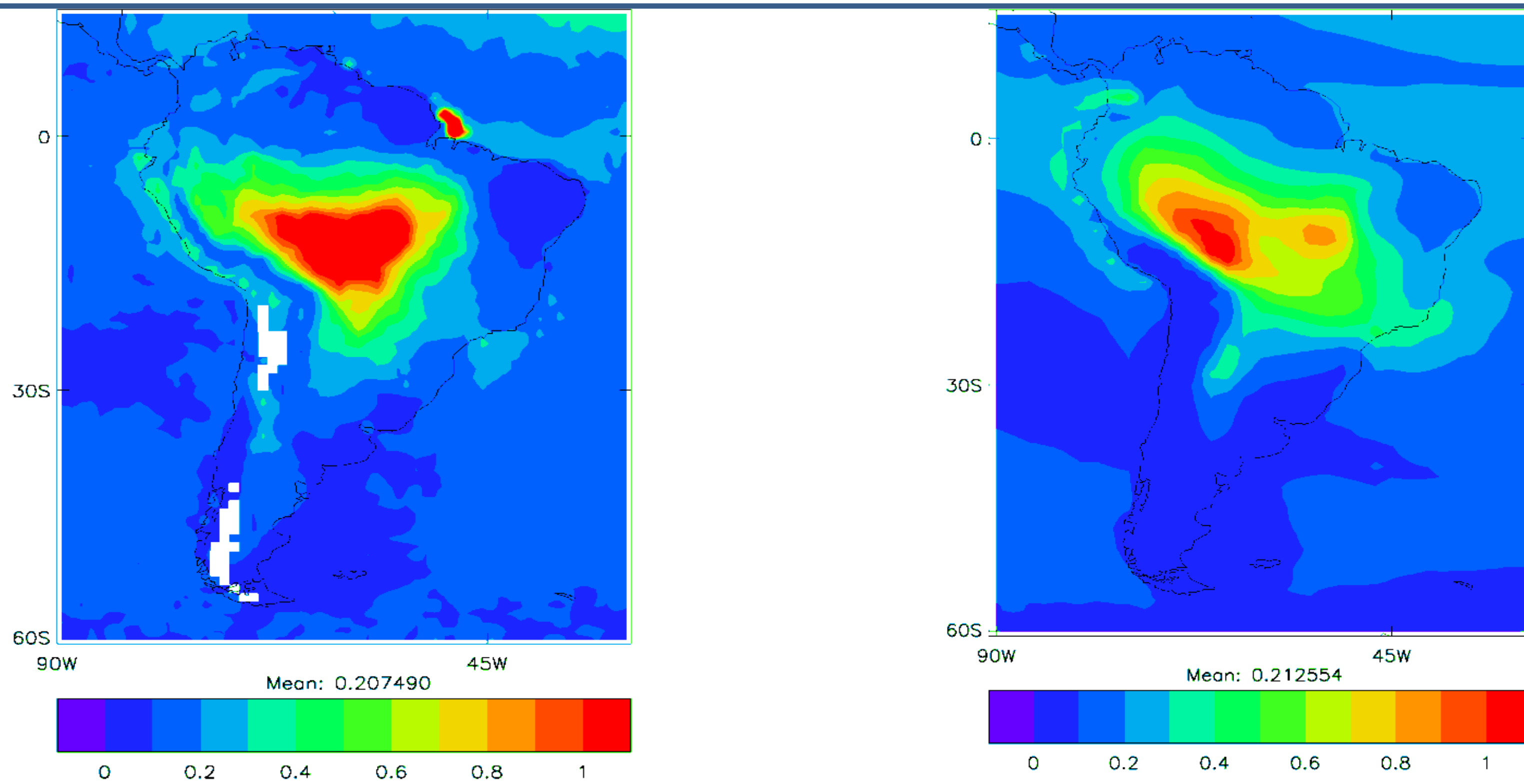
MACC/GEMS Assimilated aerosol for initial conditions

Prognostic UKCA-MODE upgrades for other aerosol species

DA of fires for biomass burning

The aerosol optical depths from biomass burning over S. America are very large

Q) Which is the model and which is the satellite observation?



The AOD simulations are reasonable but there are significant uncertainties in the aerosol absorption which significantly impacts the surface radiation.

The absorption is critical in determining the impact on surface fluxes, sensible and latent heat, photosynthesis etc.

The NERC Perspective: Why SAMMBA?

© Crown copyright Met Office

South American Biomass Burning Analysis (SAMBBA)

PI: Coe (Manchester)

Investigators

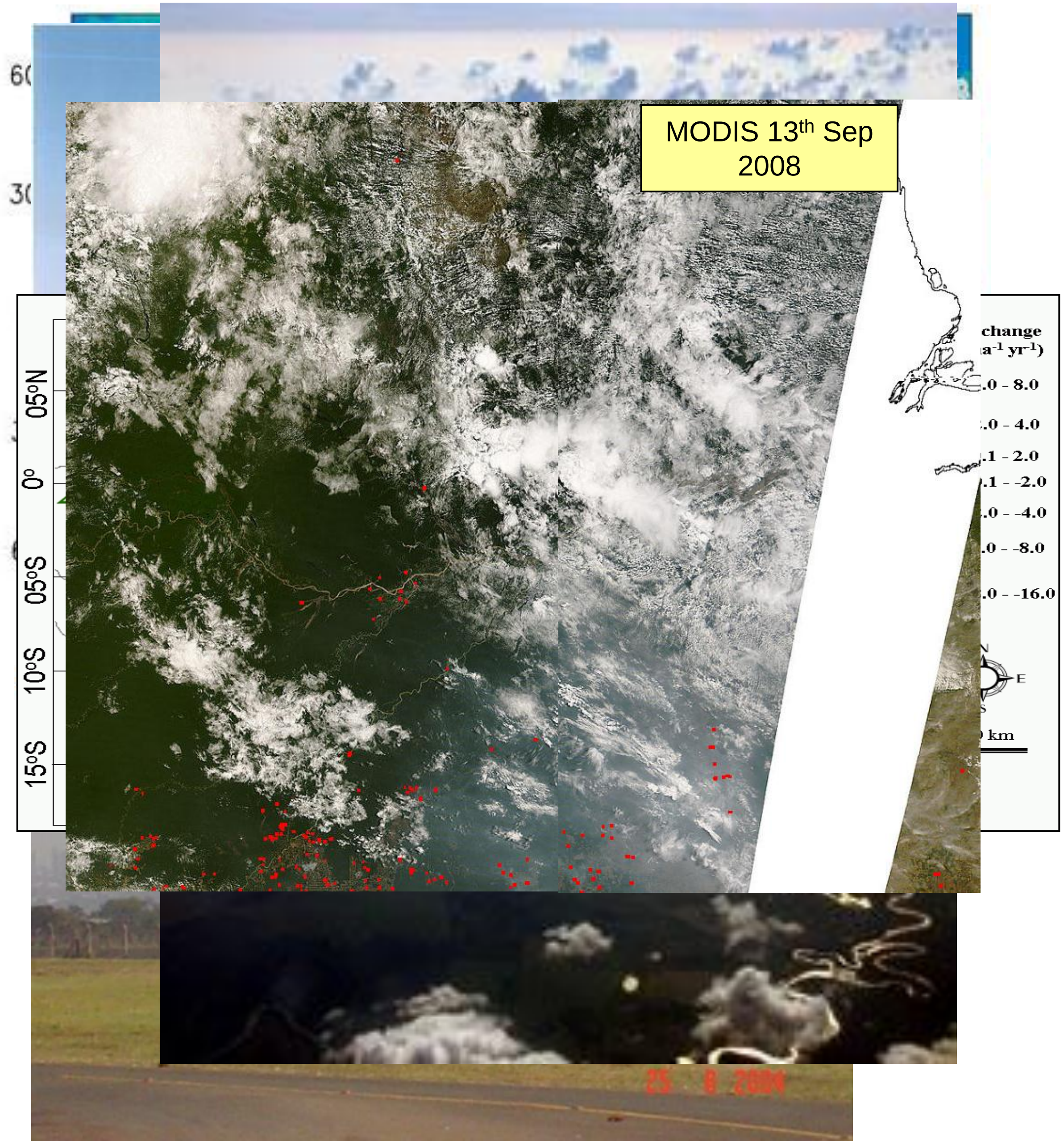
Exeter:	Jim Haywood; Peter Cox; Stephen Sitch; Lina Mercado
Kings:	Martin Wooster;
Leeds:	Spracklen; Carslaw; Mann; Marsham; McQuaid; Parker;
Manchester:	McFiggans; Connolly; Gallagher; Allan; Williams;
Reading:	Highwood; Shaffrey; Ryder;
UEA:	Oram; Mills;
York:	Lewis; Hopkins; Purvis

Partners (providing £1.3M of matched support):

Met Office:	Ben Johnson; Paul Field; Sean Milton; Chris Jones
INPE:	Karla Longo and Saulo Freitas
University of Sao Paolo	Paulo Artaxo
ECMWF:	Adrian Simmons and Johannes Kaiser
Harvard and DOE:	Scot Martin
Brookhaven	Arthur Sedlacek

The Scientific Drivers

- Regional climate
- Global Climate
- Biosphere-carbon cycle interactions
- Numerical Weather Prediction
- Air Quality



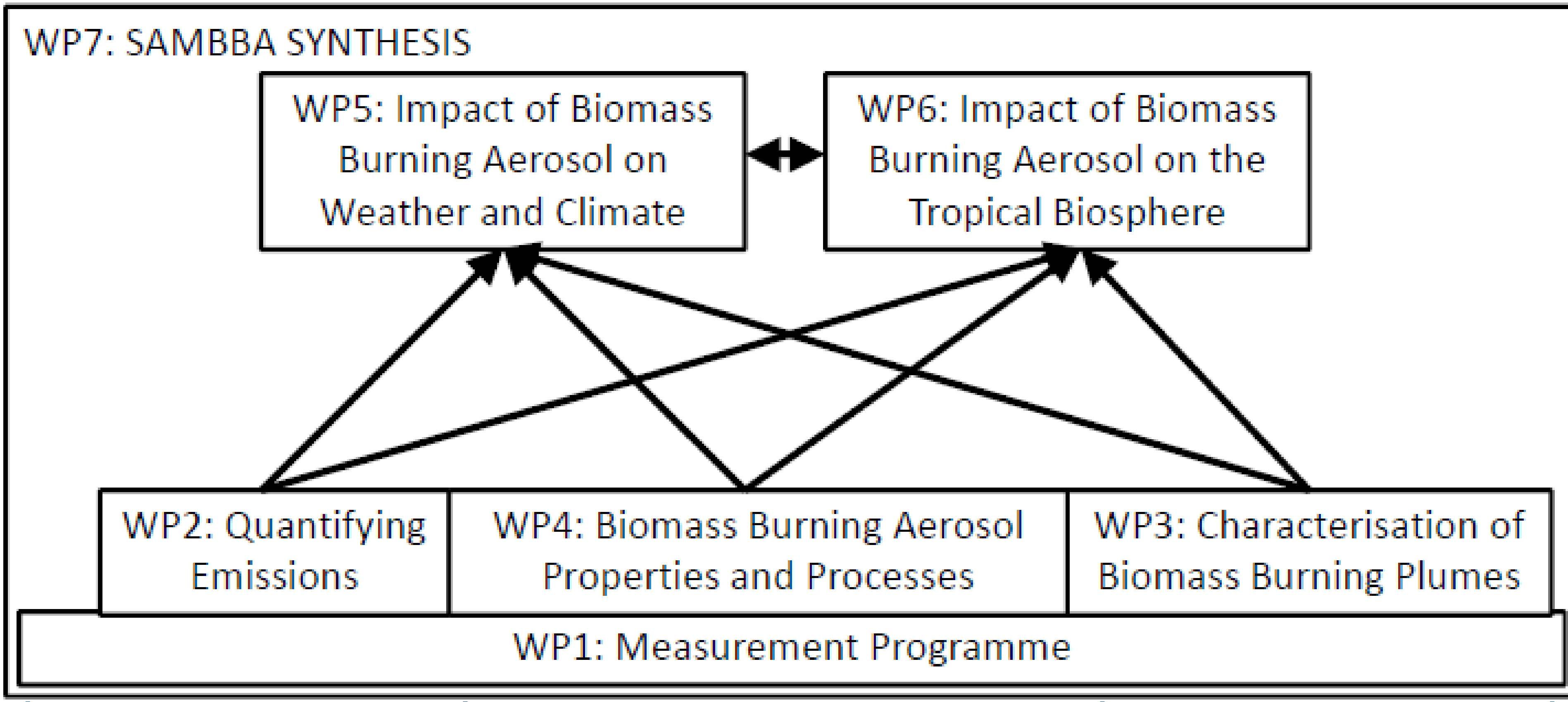
SAMBBA

Assessments

Emissions

Impacts

Regional climate

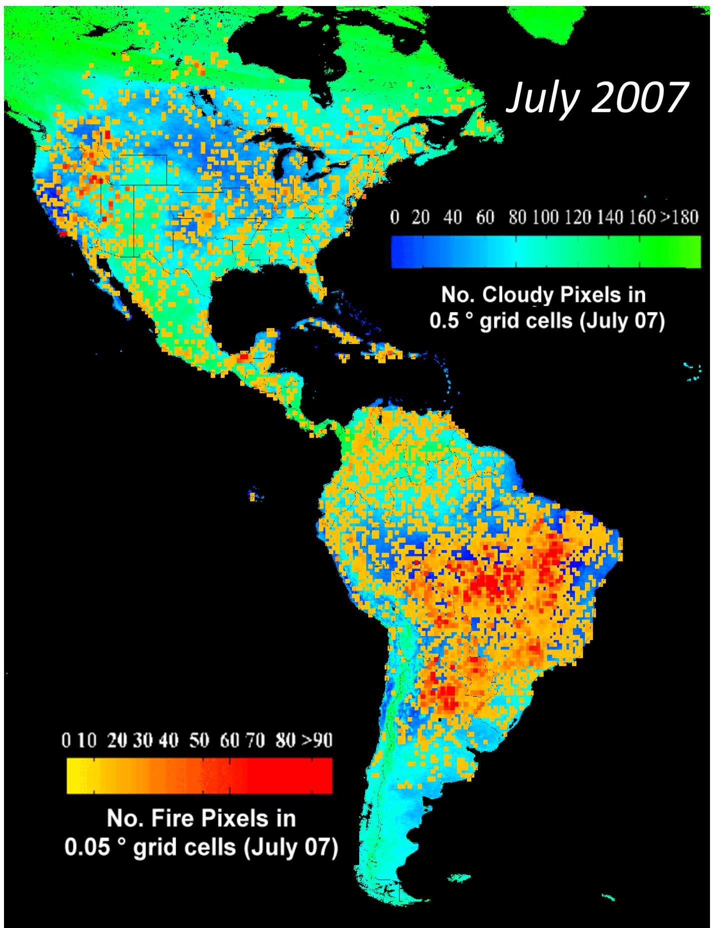


Air Quality

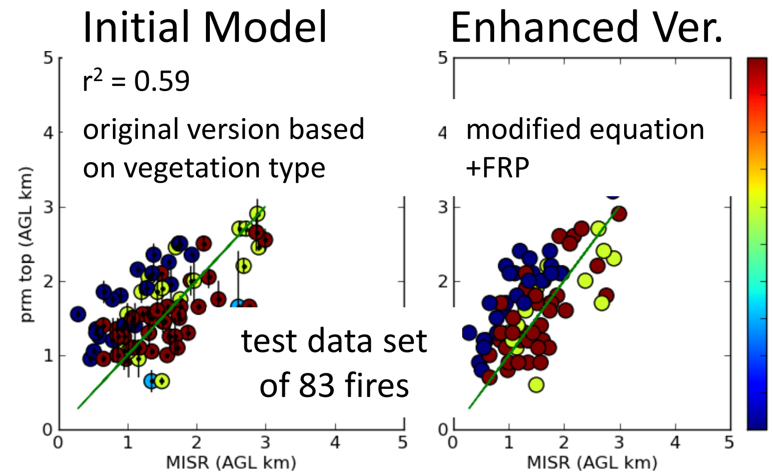
Assessing radiative balance

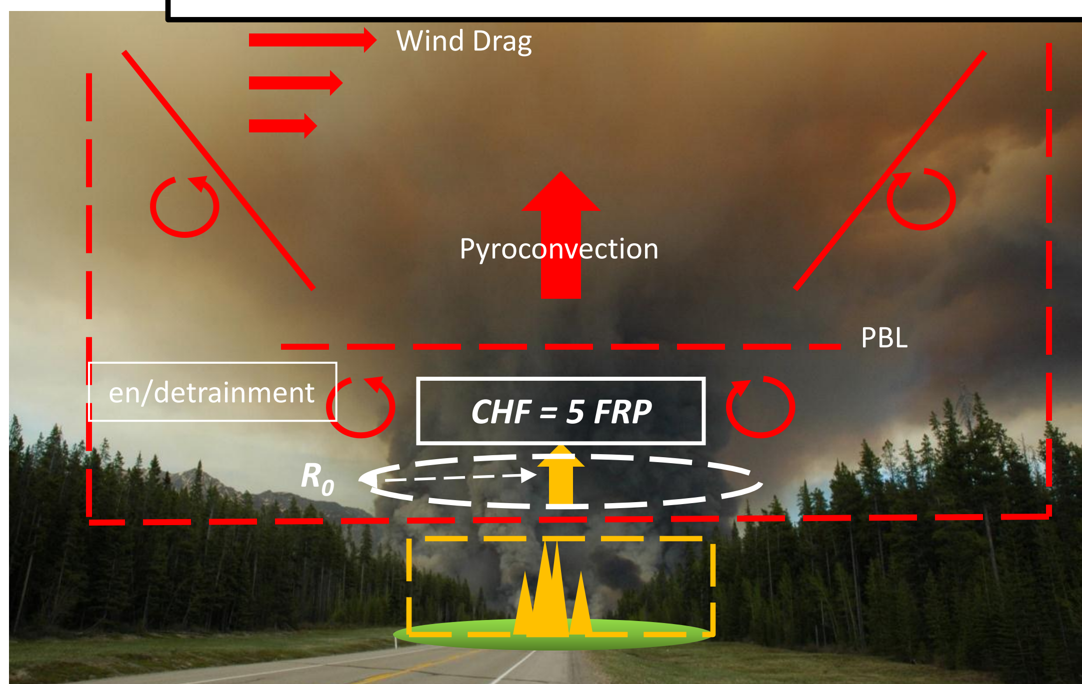
WP 2: Quantifying Emissions

- Fire Radiative Power as an approach to capturing fuel consumption
- Emissions ratio measurements (ground and air)
- Plume rise mode verification and testing



Plume Rise Model (Freitas *et al.*, 2007; 2010)





WP 3: Transformations in Plumes

- Assessment of transformation rates in plumes
- Determination of key processes in plumes

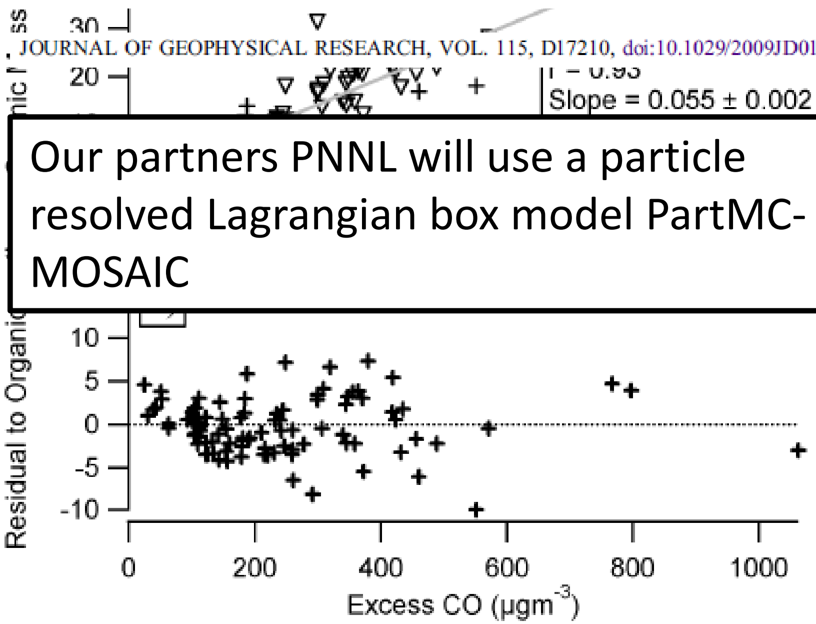
Aging of biomass burning aerosols over West Africa: Aircraft measurements of chemical composition, microphysical properties, and emission ratios

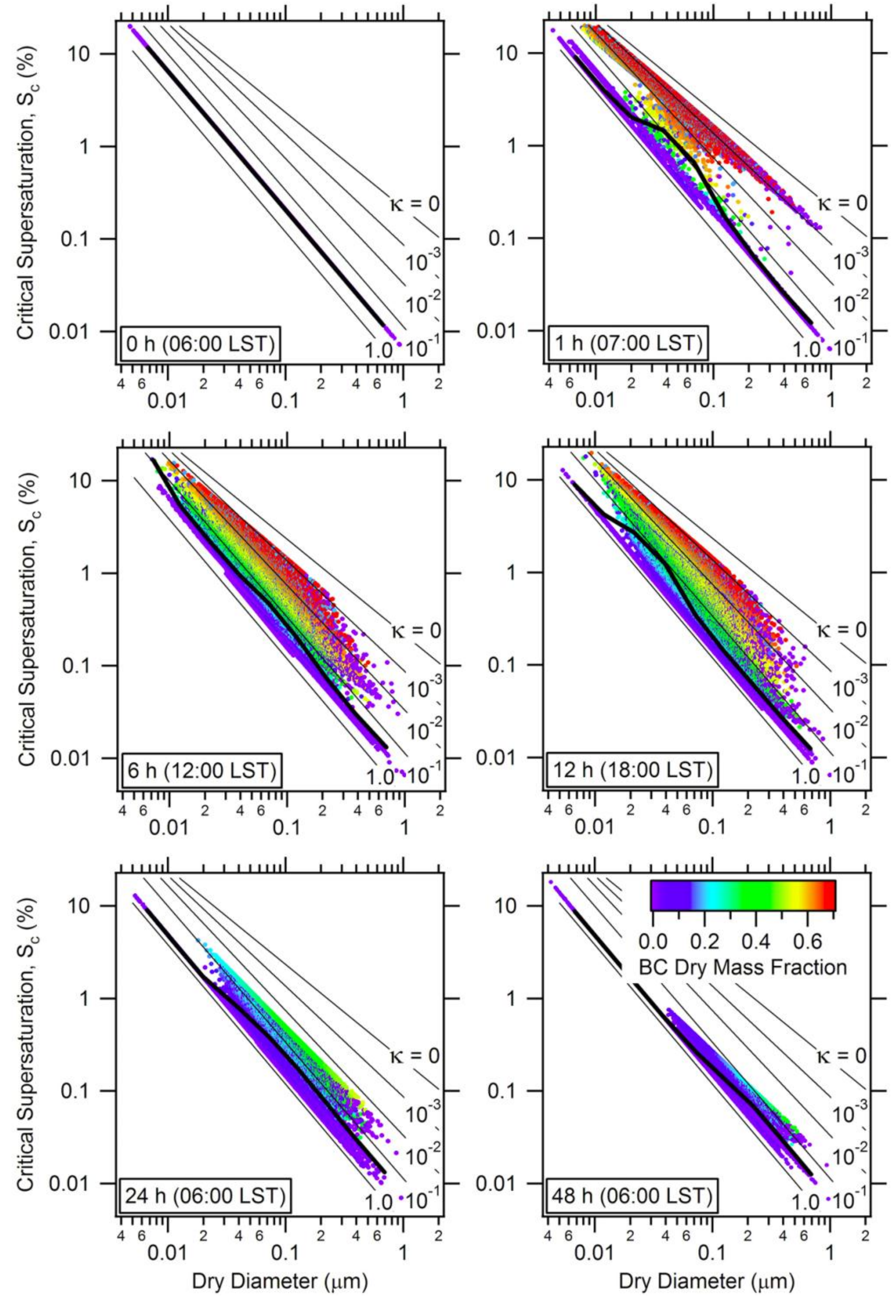
Particle-resolved simulation of aerosol size, composition, mixing state, and the associated optical and cloud condensation nuclei activation properties in an evolving urban plume

Rahul A. Zaveri,[1] James C. Barnard,[1] Richard C. Easter,[1] Nicole Riemer,[2] and Matthew West[3]

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, D17210, doi:10.1029/2009JD013616, 2010

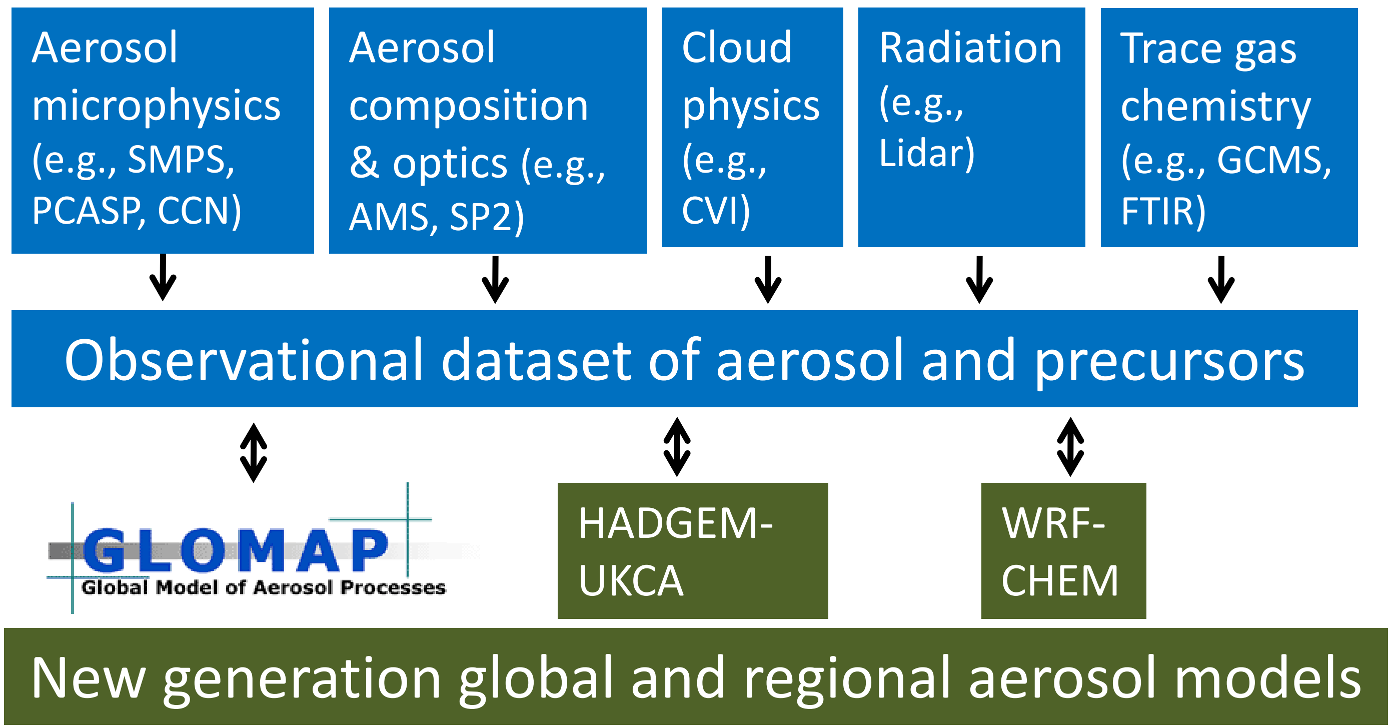
Our partners PNNL will use a particle resolved Lagrangian box model PartMC-MOSAIC





WP 4: BBA Properties and Processes

Quantifying impacts of BBA requires understanding of the physical, chemical and optical properties of the aerosol.



We will synthesise a detailed observational dataset of BBA to confront and test a new generation aerosol and climate models.

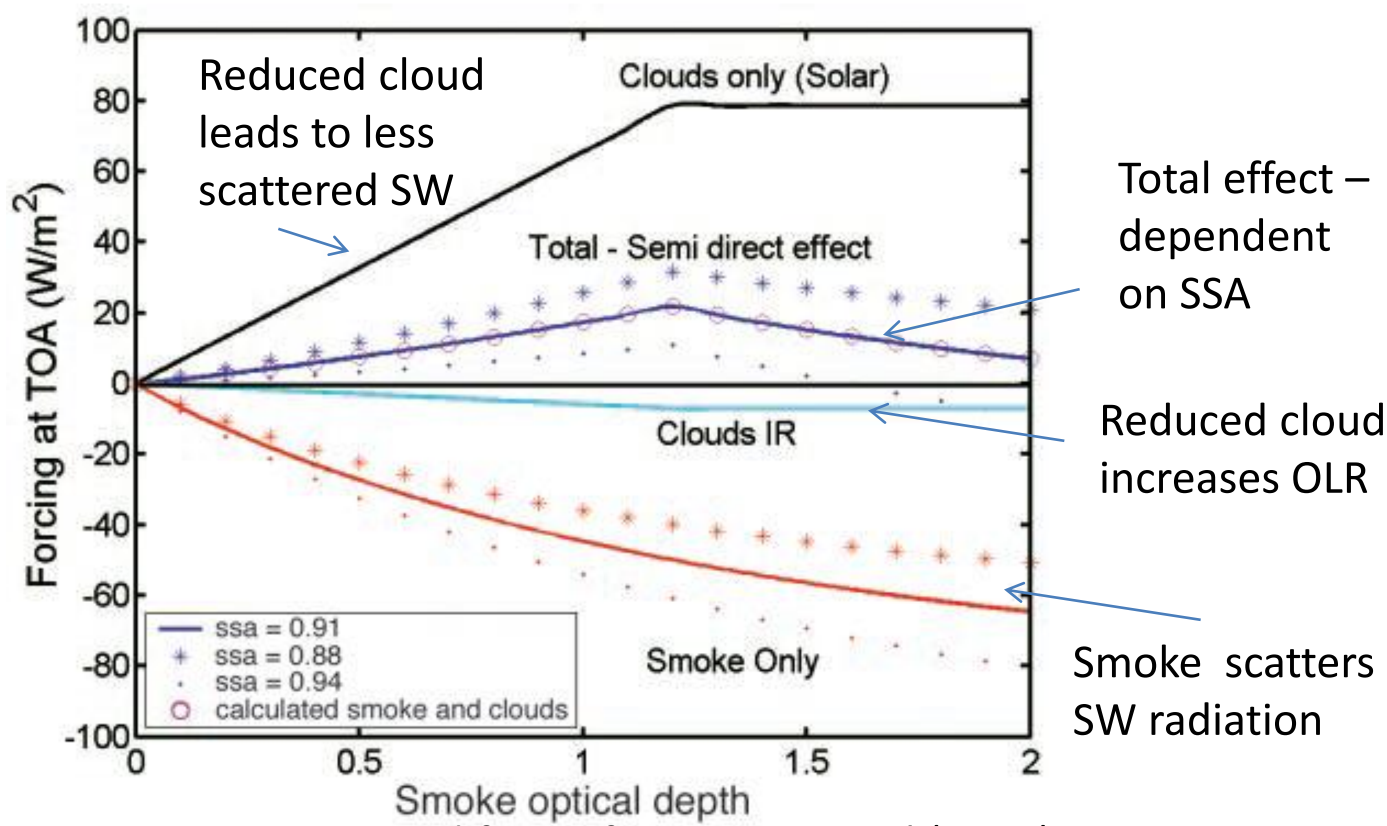
- D4.1 Detailed characterization of BB and background aerosol
- D4.2 Assess radiative closure
- D4.3 Quantify local impact of BBA on radiative budget and cloud

WP 5: Impacts on Weather and Climate

•**Quantify the direct, semi-direct and indirect effect of BBA from Amazonia** (e.g. inform future IPCC reports, characterise uncertainties in forcing)

•**Assess the sensitivity of BBA impacts on regional weather patterns to model resolution and complexity**

Hierarchy of models with a range of resolution and complexity, constrained and informed by measurements from WP1



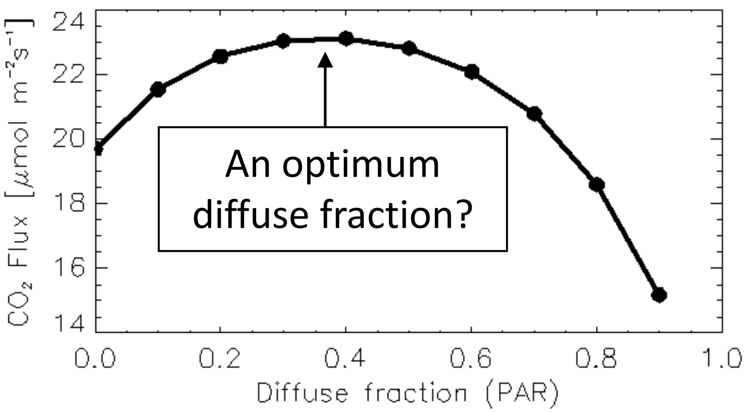
Annotated figure from Koren et al (2004) Science

WP 6: Impact of BA on the Biosphere

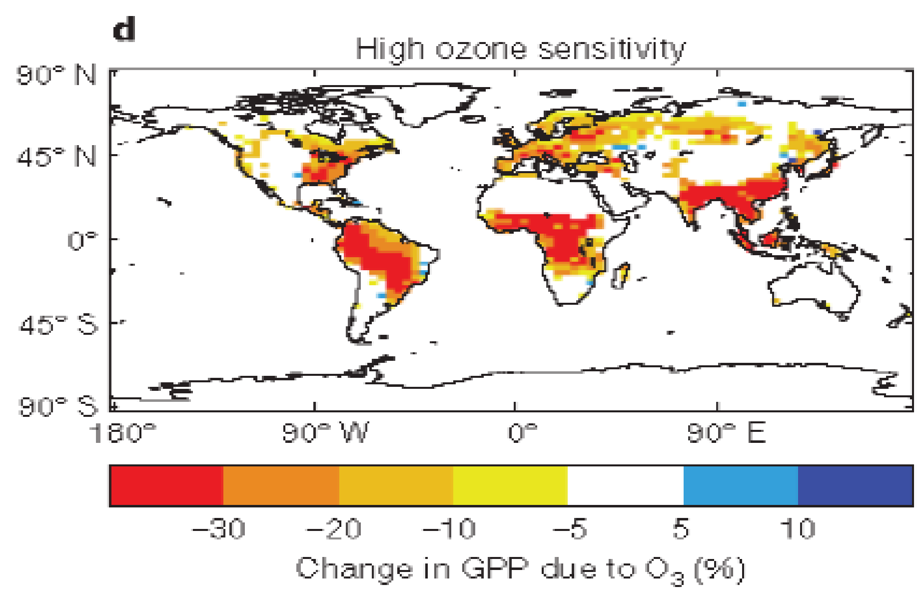
Climate feedback mechanisms, particularly the interaction with the terrestrial biosphere, are of fundamental importance in understanding future climate change scenarios and impacts on the health of the Amazonian rainforest.

WP6 will assess the impacts on the biosphere of:

- increased atmospheric CO_2 on the biosphere
- smoke on direct/diffuse radiation and photosynthesis
- ozone as a result of biomass burning



Mercado et al. 2009



Sitch et al Nature 2007

WP 7: Synthesis

- SAMBBA Database
- Synthesis of Amazonian aerosol composition and properties
- Quantification of relative importance of BC from BBA compared to that from other anthropogenic sources
- Assessment of impact of inclusion of biogeochemical feedbacks on climate metrics

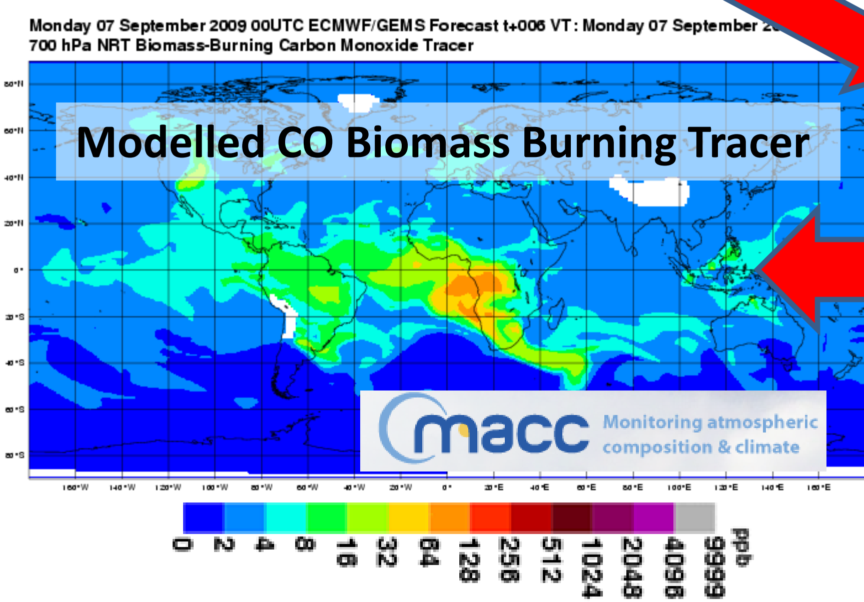
Pathways to Impact

Observations of Fire Locations & FRP

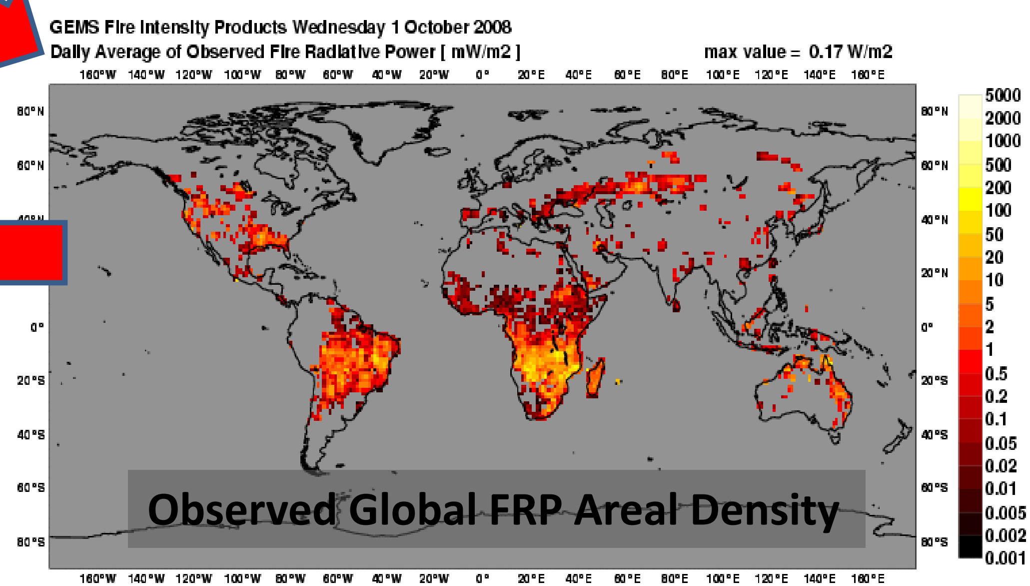
MACC system uses EO data on actively burning fires and their fire radiative power (FRP) to prescribe BB emissions to the atmosphere. It is the prototype GMES Atmospheric Core Service (http://www.gmes-atmosphere.eu/)

Currently uses polar-orbiter FRP, being tested with geostationary FRP of Africa. System will operate at higher resolution during SAMBBA – with new S. America geostationary inputs.

Modelled CO Biomass Burning Tracer



Observed Global FRP Areal Density



Brazilian Perspective

Why SAMBBA?

Modelling:

INPE-Met Office MOU underpins the model development of biomass burning emissions, plume rise, AQ, NWP and climate impacts for both institutions.

Met Office has provided INPE with HadGEM2, including CLASSIC aerosol scheme.

INPE has included the Freitas plume rise scheme incorporating CLASSIC in HadGEM2.

INPE has a host of operational tools for optimising the deployment of the aircraft, which in return can provide high quality validation data for e.g. Emissions, plume rise schemes, aerosol schemes etc.

Modelling: INPE models for optimising aircraft operations: Aircraft then provides synergistic validation of the models

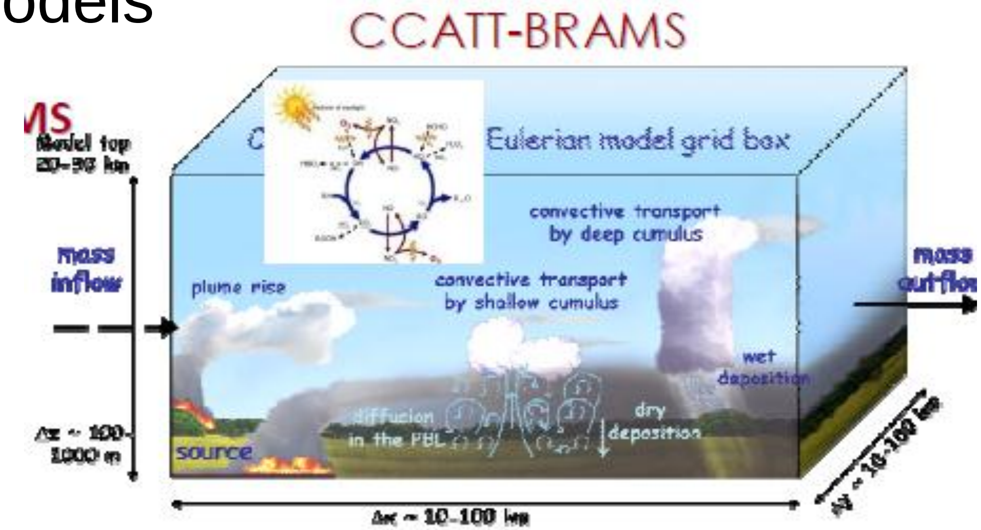
- CCATT-BRAMS (Coupled Aerosol and Tracer Transport model to the Brazilian developments on the Regional Atmospheric Modelling System)

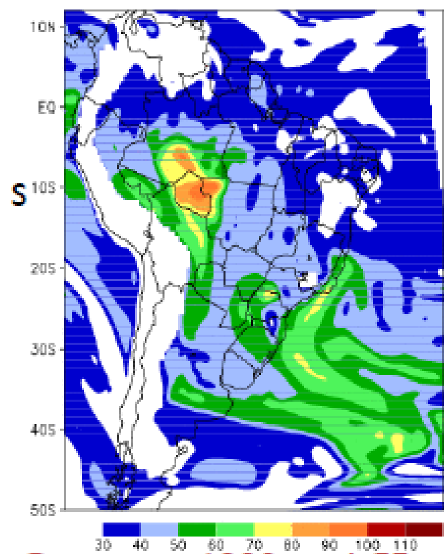
http://meioambiente.cptec.inpe.br

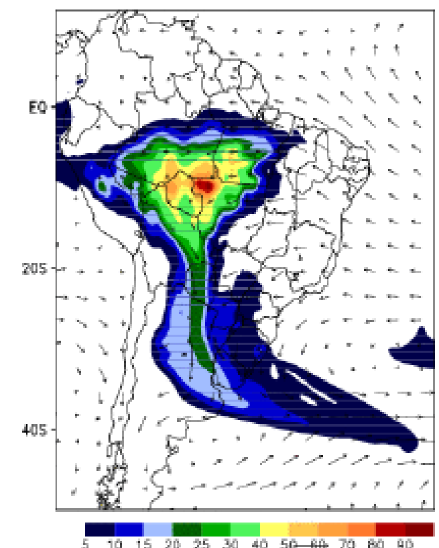
- Predicts concentrations of:

PM2.5, CO, O3, NOx, NMVOCs

- 4D data assimilation of met. and satellite fire detection




Ozone at 1000 m ASL

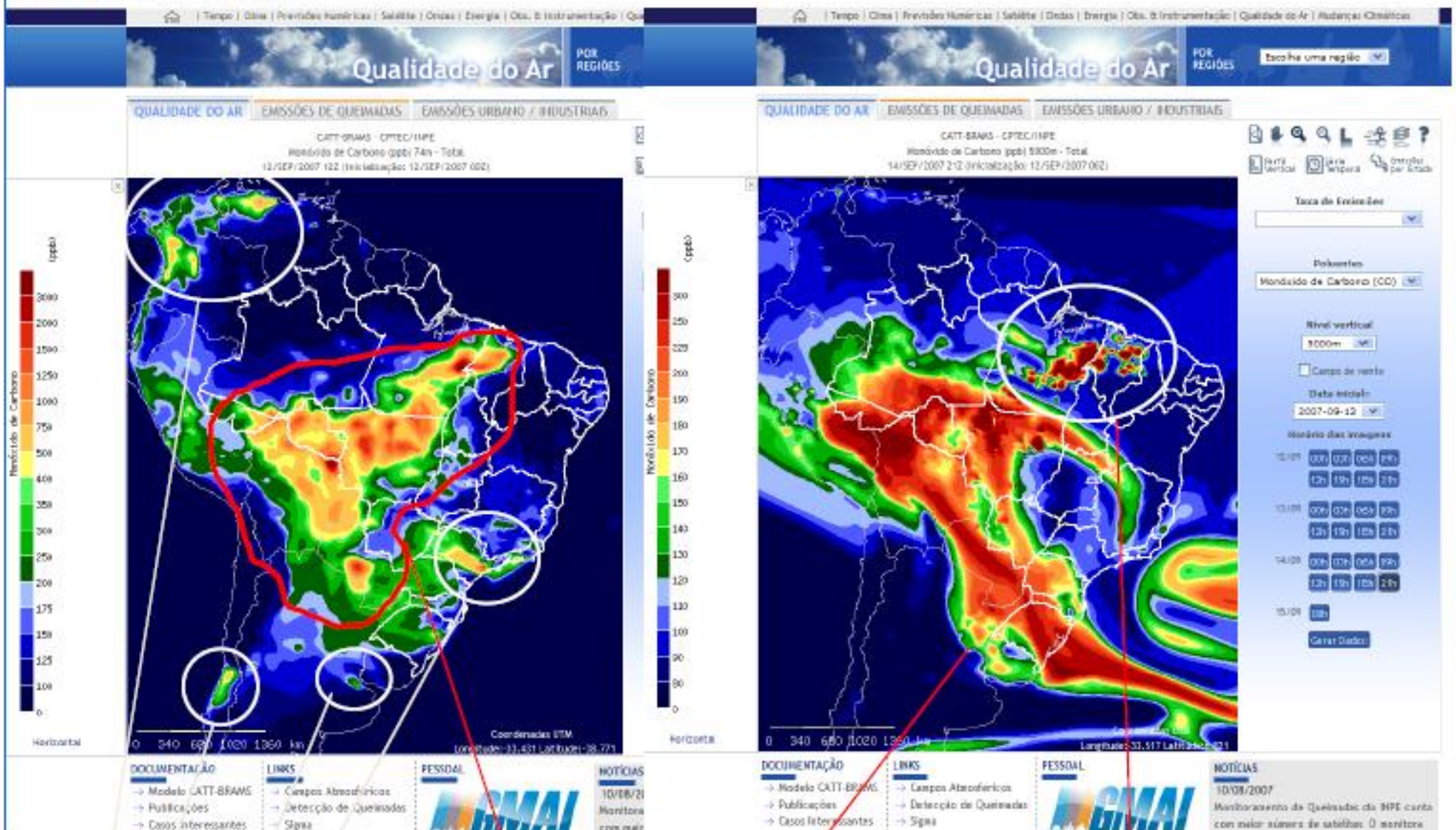

PM2.5 (bio. burn.) column

© Crown copyright Met Office

Air Quality forecast for South America:
http://meioambiente.cptec.inpe.br

Surface level CO (ppb)
12Z12SEP2007

500 hPa CO (ppb)



Mega Cities pollution

Biomass burning pollution

new fresh plume injected by pyrocumulus

BRAMS

Including plume rise sub-grid scale transport trough the *"super-parameterization"* concept

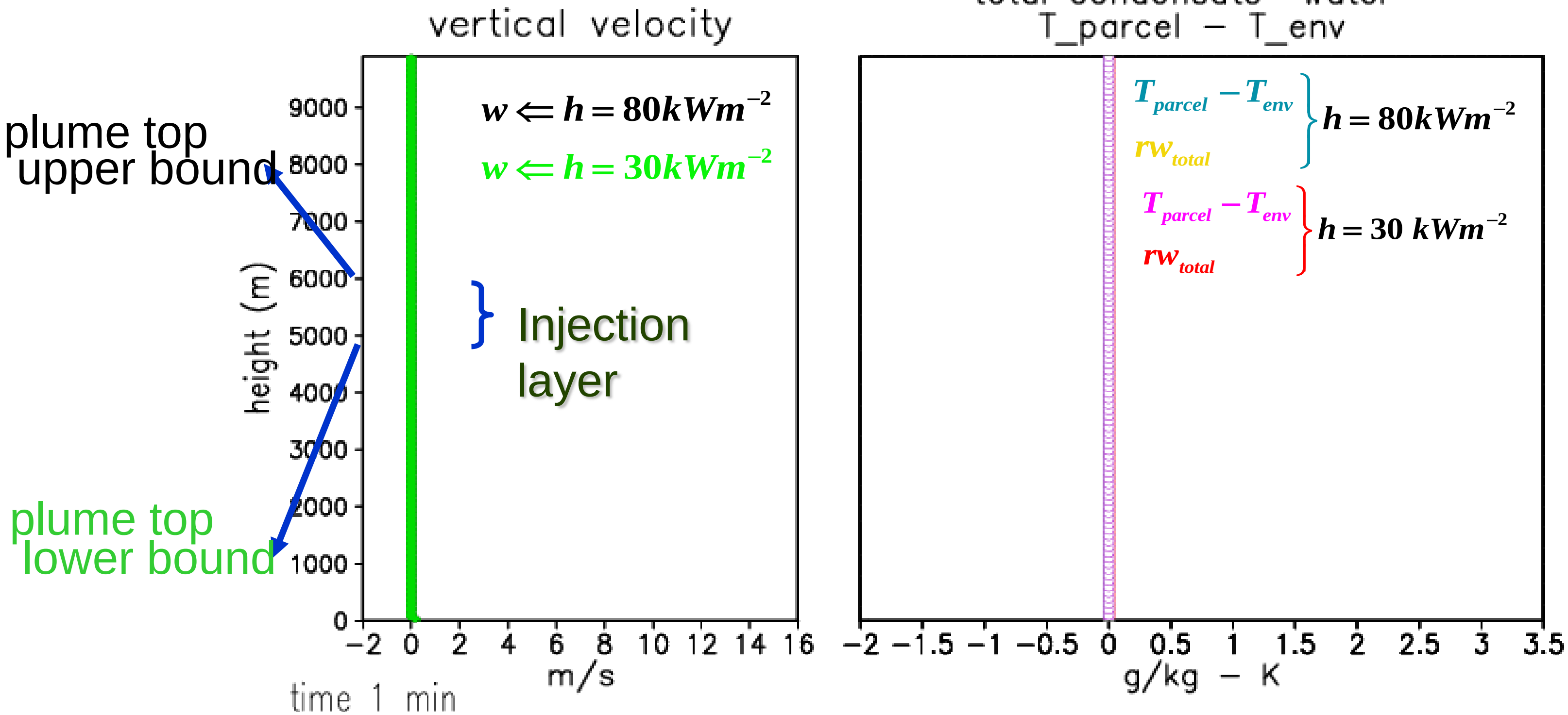
1D plume-rise model for vegetation fires

Biome: Forest

Time duration: 50 mn

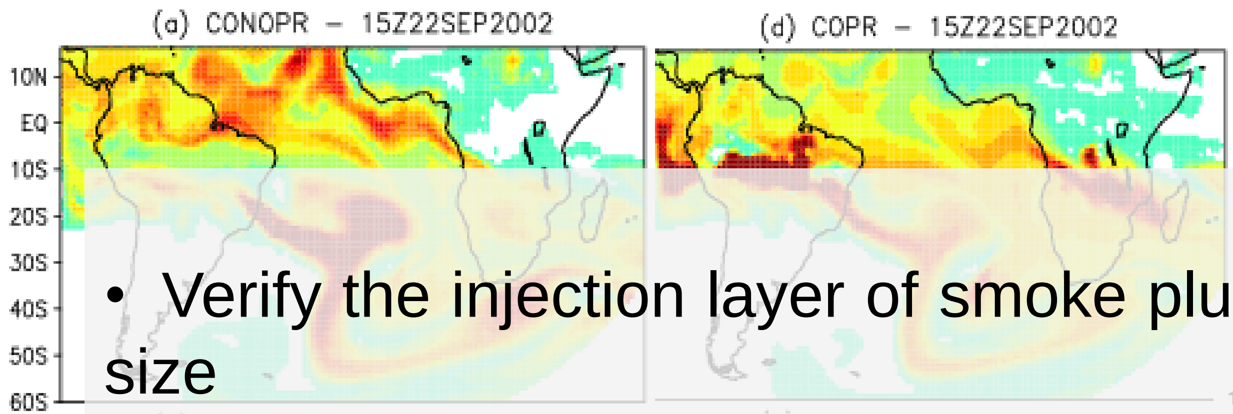
Fire size: 20 ha

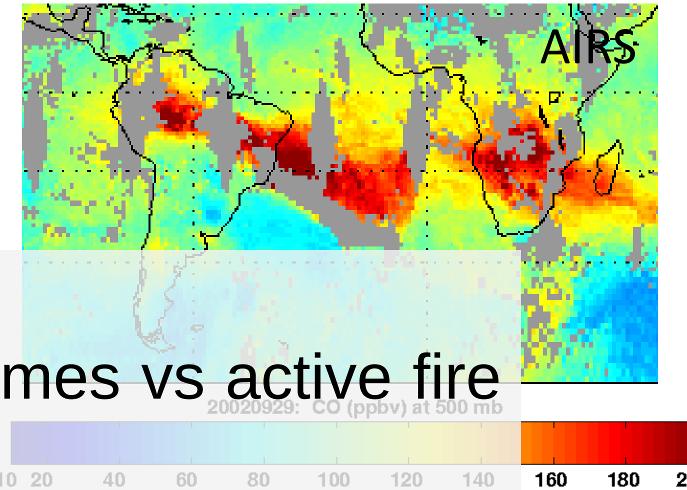
Heat flux: 80 kWm^{-2} / 30 kWm^{-2}



Melhores resultados

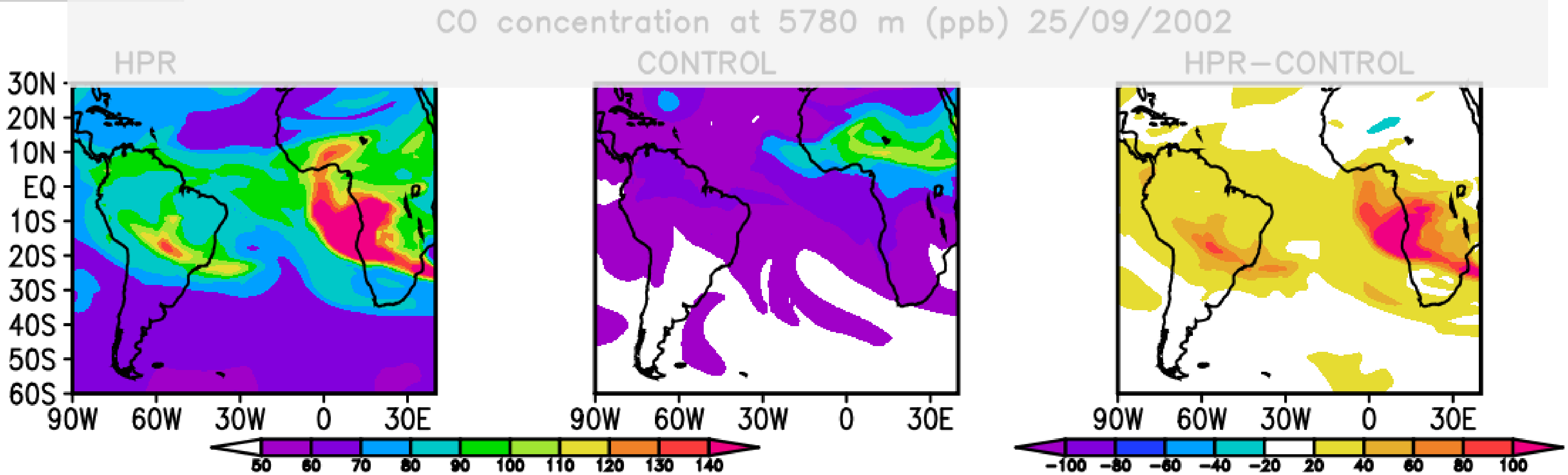
CCATT-BRAMS



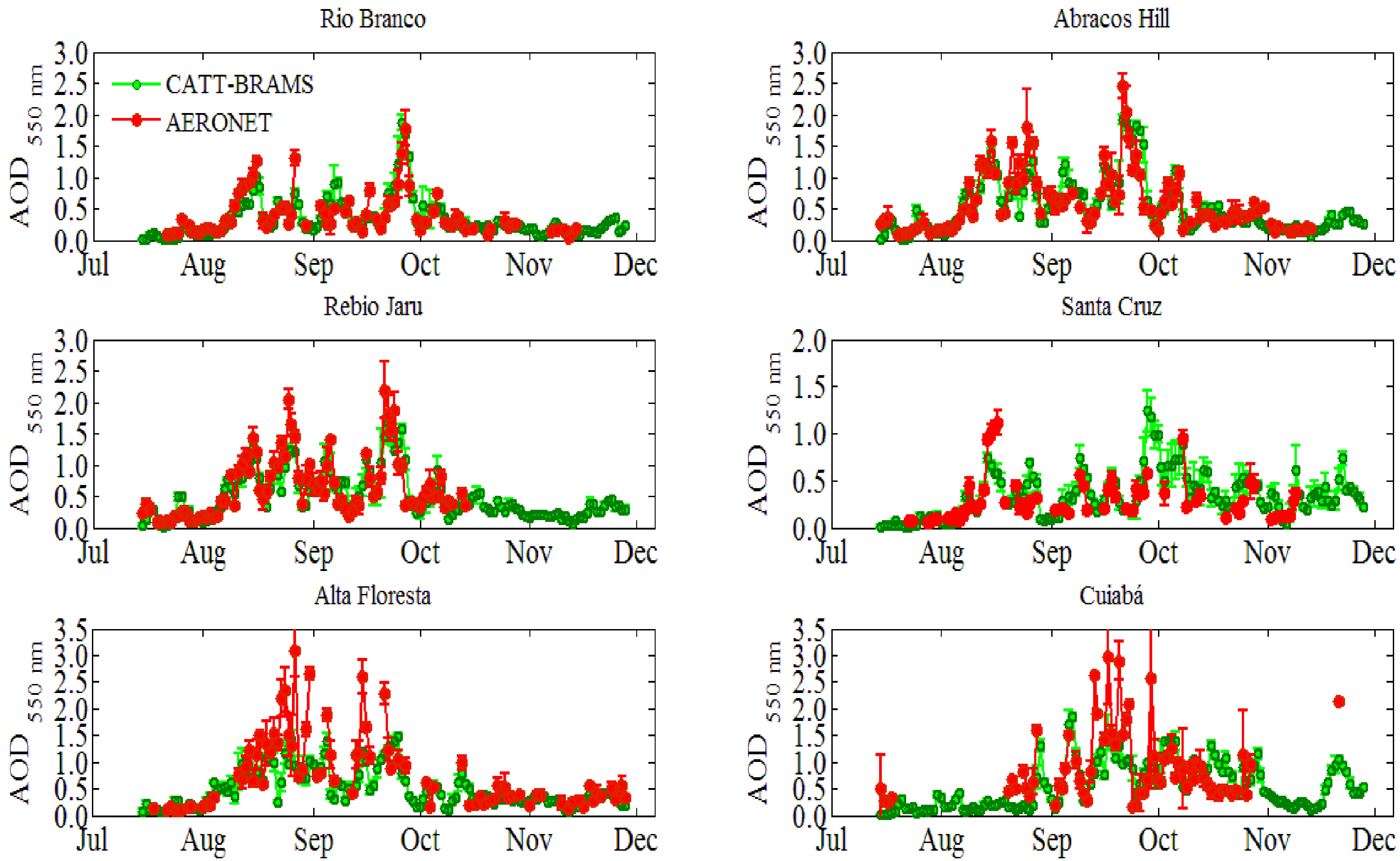


- Verify the injection layer of smoke plumes vs active fire size

HadGEM2-INPE



Aerosol optical thickness validation (model x AERONET)



PhD thesis: Rosário, N. E. , USP), 2011.

Ministério da Ciência e Tecnologia
BRASIL UM PAÍS DE TODOS
GOVERNO FEDERAL

Measurements:

The UK activities are mainly focussed on the aircraft instrumentation with only limited deployment of ground based instrumentation to Porto Velho: lidar, POM, BBRs. University of Sao Paulo plan to provide much more:

1) TSI and Ecotech 3 lambda nephelometers (dry aerosol)
2) TSI SMPS for dry size distribution measurements (10-450nm)
3) GRIMM OPC for aerosol size distributions 0.3-10 micrometers
4) MAAP for aerosol absorption
5) Aethalometer (7 lambdas) for spectral dependence of absorption
6) EC/OC measuremenst with a Sunset instrument
7) Ozone (Thermo Environment)
8) CO/CO2 using a Picarro Calibrated by NIST standards
9) SFU for aerosol composition for fine and coarse mode fractions.
10) nano-MOUDI for composition size distribution
11) Mini-AMS ACSM from Aerodyne.
12) DMT CCN counter.
13) CIMELS sunphotometer
14) MFR Radiometer
15) Kipp & Zonen radiometers

© Crown copyright Met Office

FAAM BAe146 aircraft
(Facility for Airborne Atmospheric Measurements)

© Crown copyright Met O

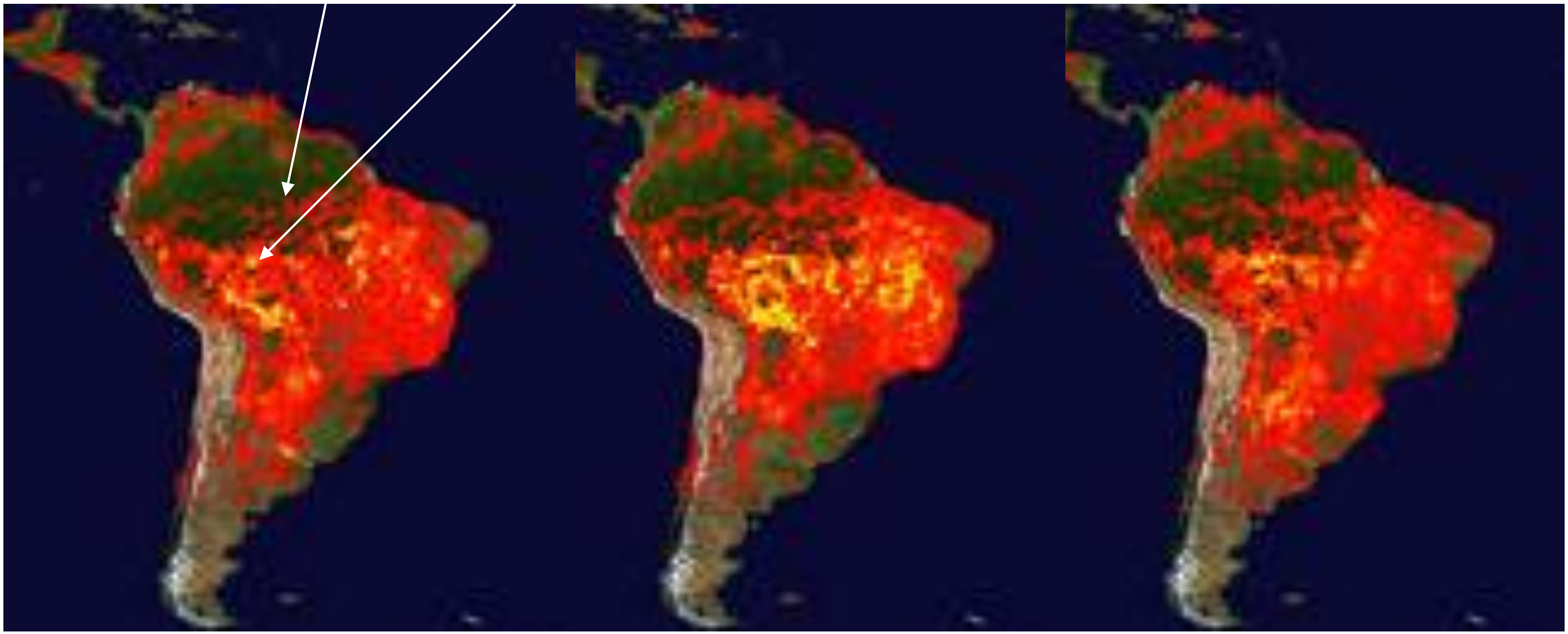
Key measurements

- Aerosol size distributions: Primarily fine particles (PCASP, CVI-PCASP, VAAC, AMS)
- Absorption / black carbon (PSAP, SP2)
- Aerosol chemistry (AMS, filters?, VAAC)
- Hygroscopicity (wet neph)
- Gaseous chemistry (core chem, NOx, PTRMS, Fast GHG, WAS, PAN, others…?)
- Liquid cloud properties (N(d), LWC)
- SW radiation (BBRs, SWS+SHIMS)
- LIDAR
- IR signature of fires? (ARIES, IR camera)

© Crown copyright Met Office

Biomass burning fires in S. America

Manaus Porto Velho

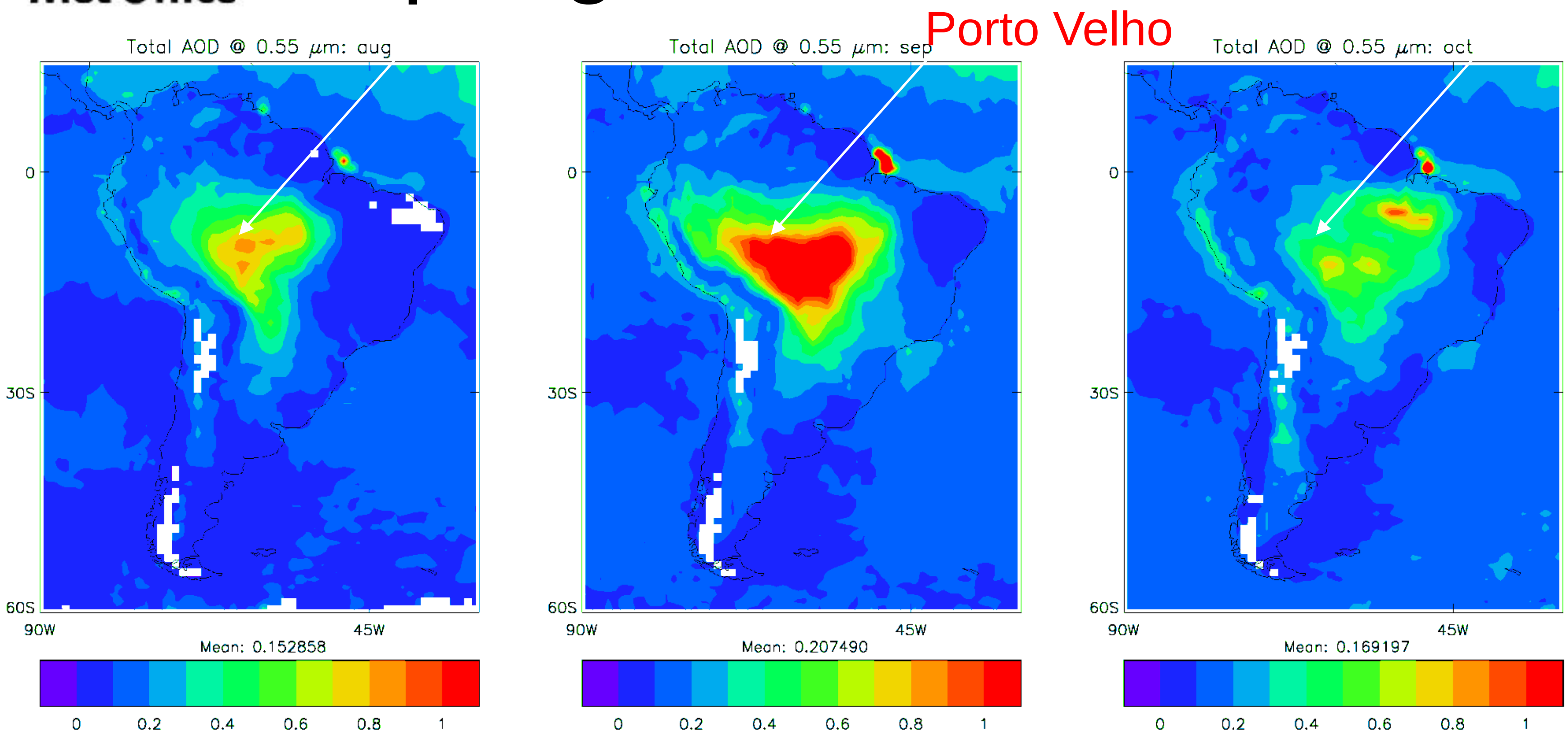


Mid-september Modis fire counts for years:

2008 2007 2006

© Crown copyright Met Office

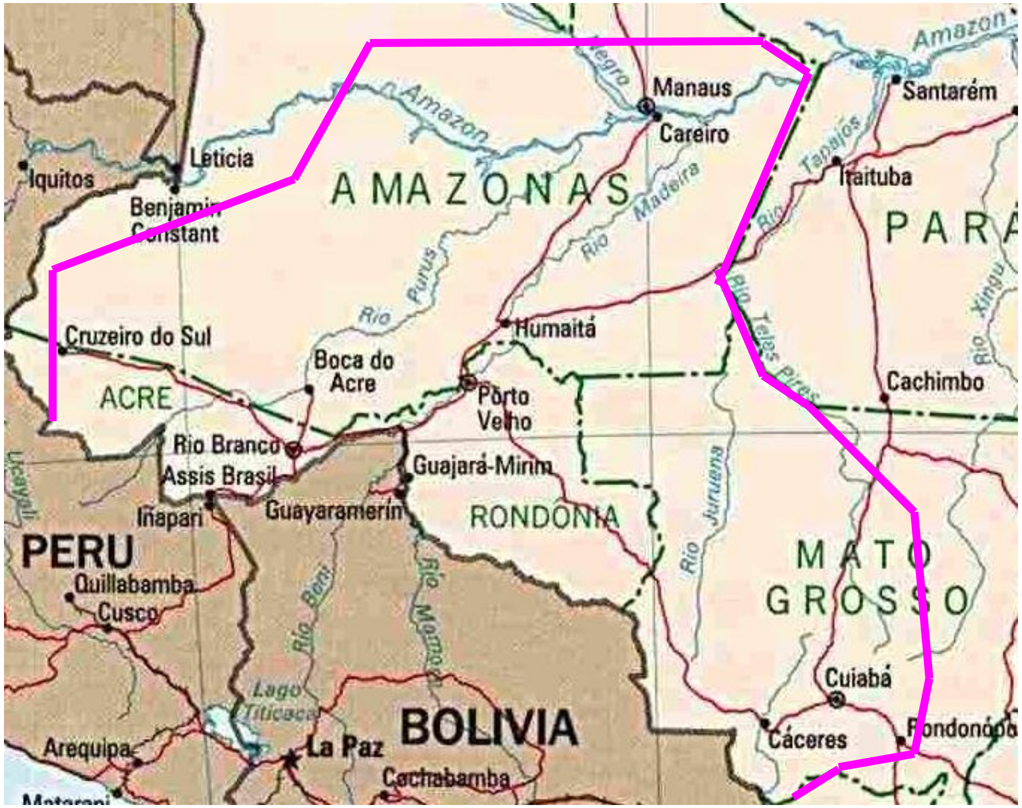
Where is the aerosol optical depth greatest?



Monthly mean aerosol optical depths at 0.55μm from MODIS Collection 5 for Aug, Sept, Oct

© Crown copyright Met Office

Where we want to fly



Proposed extent of BAe-146 operations (bounded by Brazilian border on SW side)

<u>Incorporates states of:</u>

Rondonia

Amazonas

Acre

Mato Grasso

© Crown copyright Met Office

Where and when does biomass burning occur?

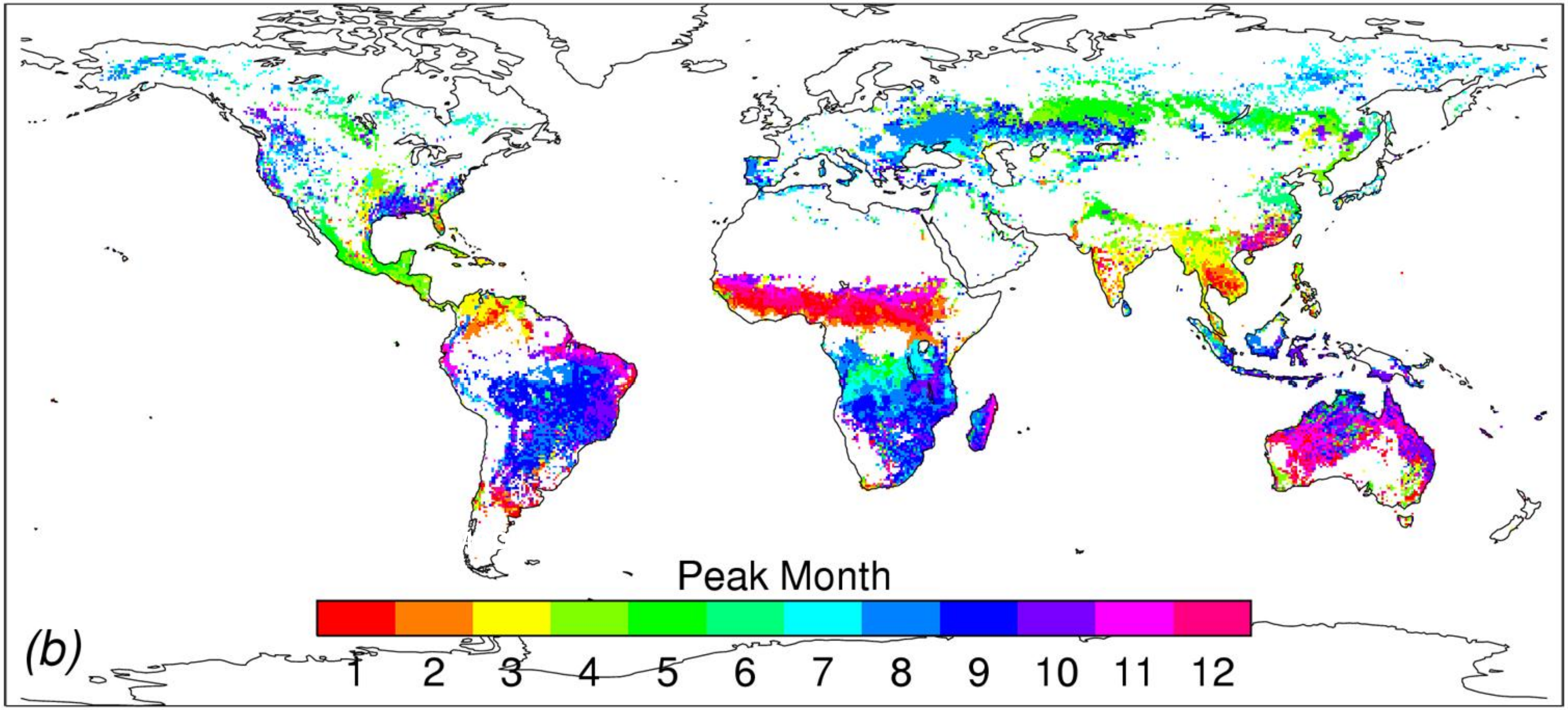
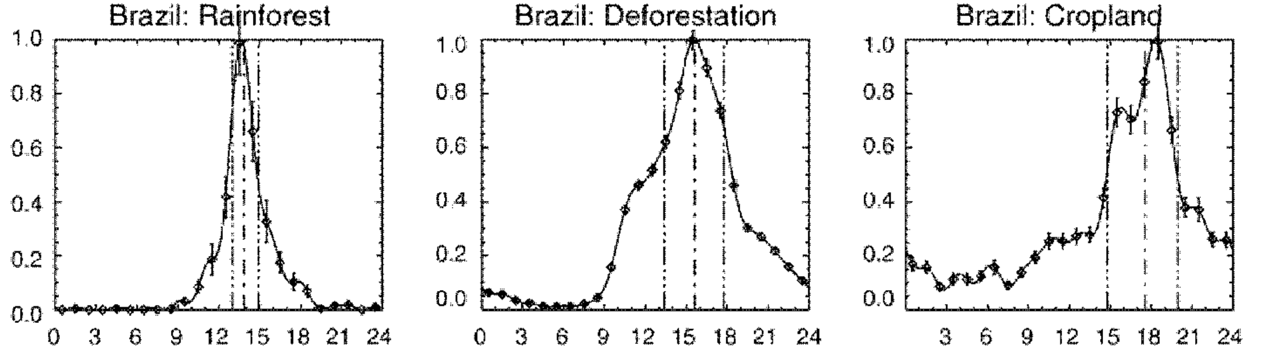


Figure 3. The seasonality of fires derived from MODIS by Giglio et al. (2006).

© Crown copyright Met Office

Time of day of fires in Brazil



The diurnal cycle of fire activity in Brazil. From Giglio (2007).

© Crown copyright Met Office

AIRCRAFT CAPABILITIES on SAMBBA

17 scientists and 3 crew.

Flight duration up to 4.5hrs (depending on airfield diversions, flight plans, and instrumentation load)

Altitude range (up to ~10km)

Science based at Brazil: 88 hrs

~20 science flights

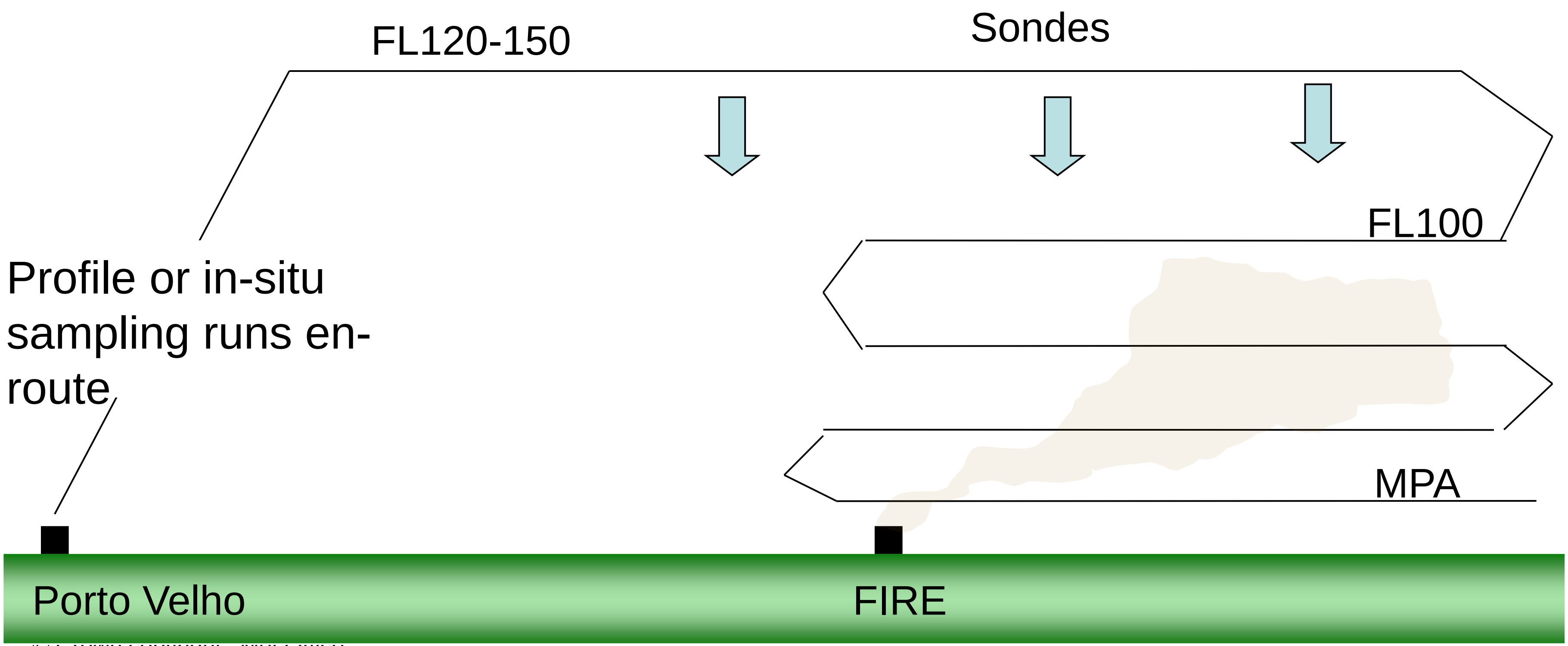
© Crown copyright Met Office

Typical sorties

1. Fire / smoke plume studies
2. Radiative closure studies
3. Manaus CLARE tower sorties
4. Aerosol-cloud interaction studies

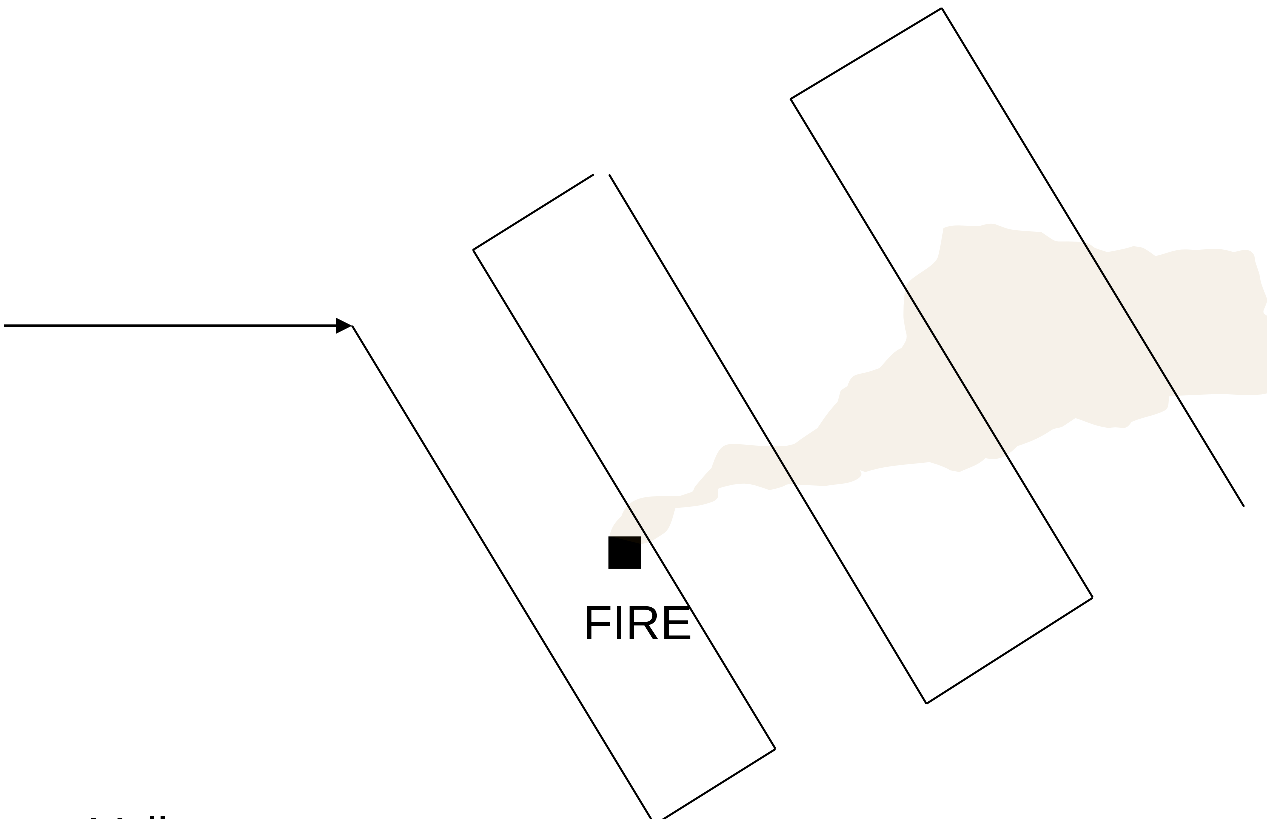
© Crown copyright   Met Office

Example of Smoke plume study



© Crown copyright Met Office

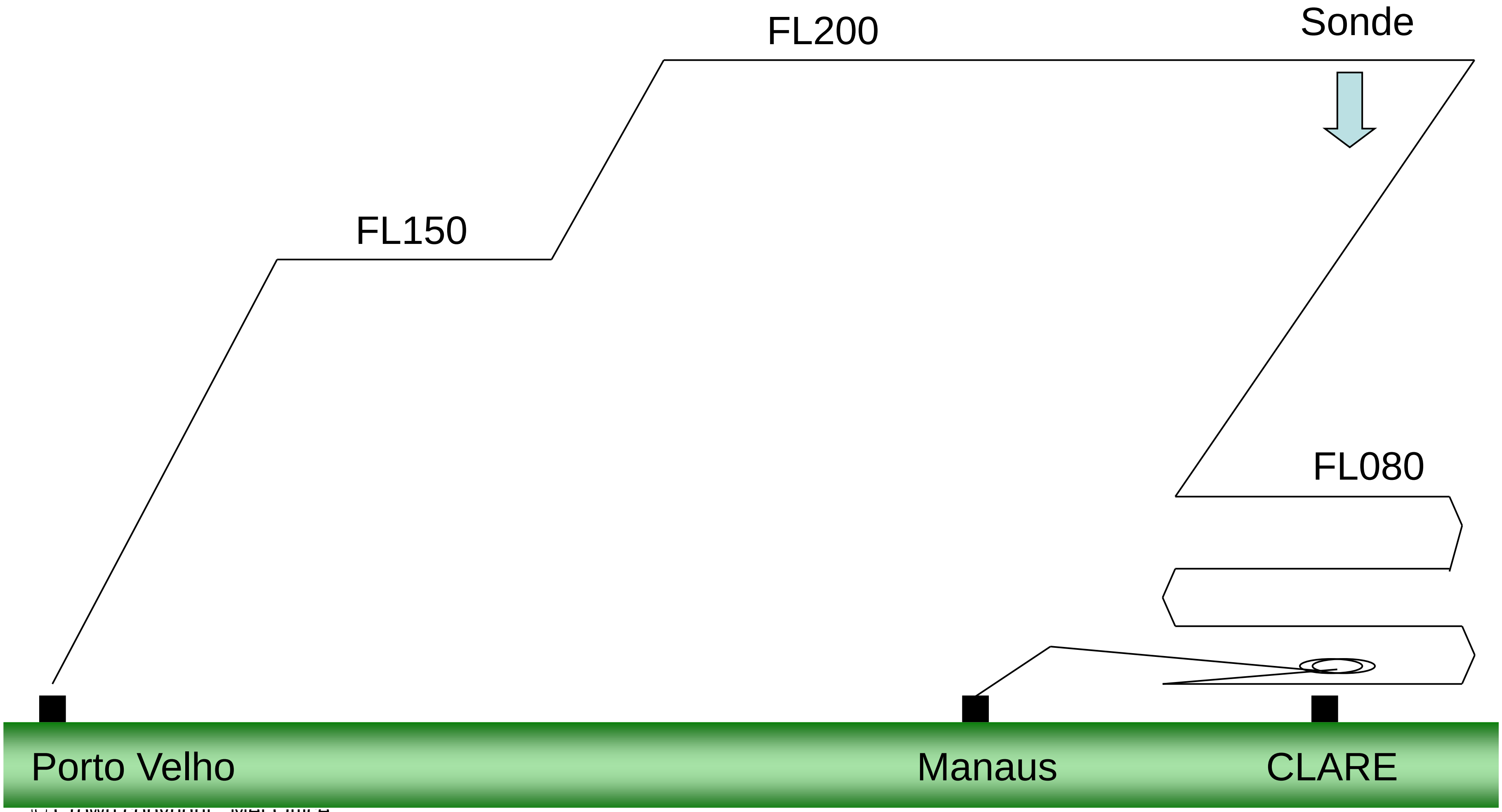
Ways of working smoke plumes (Overhead view)



Porto Velho

© Crown copyright Met Office

Example of Manaus sortie / radiative closure pattern



© Crown copyright   Met Office