

Production and Transport of Ozone in the Amazon: Evaluation of WRF-Chem Simulations with In-Situ Observations from the BARCA Campaign

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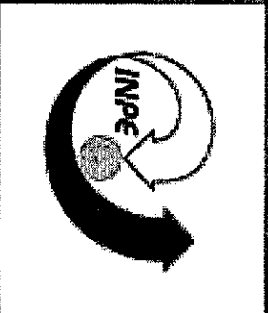
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³Max Planck Institute for Biogeochemistry, Jena, Germany

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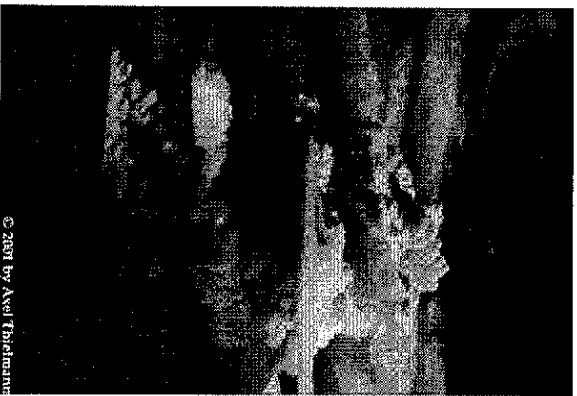
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Motivation

Air chemistry regimes in the Amazon S. America air quality forecast

Land-use effects



Clean vs. biomass burning conditions

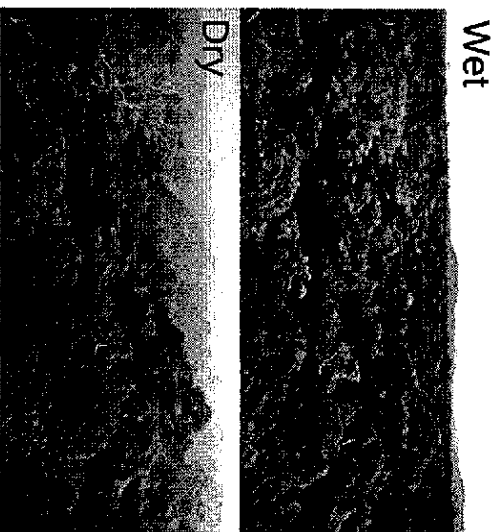


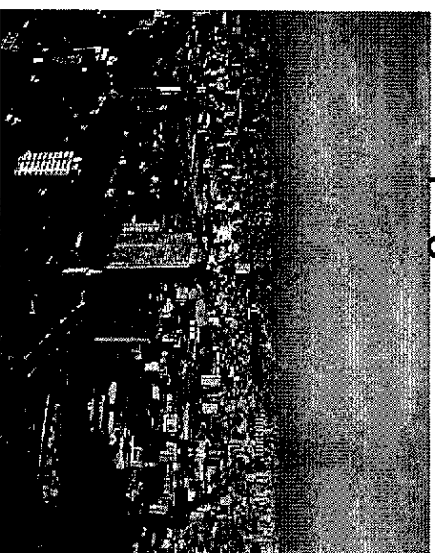
Image: Paulo Artaxo

Deep/shallow convection



Near Belém do Pará

Anthropogenic and biomass burning emissions



Central São Paulo

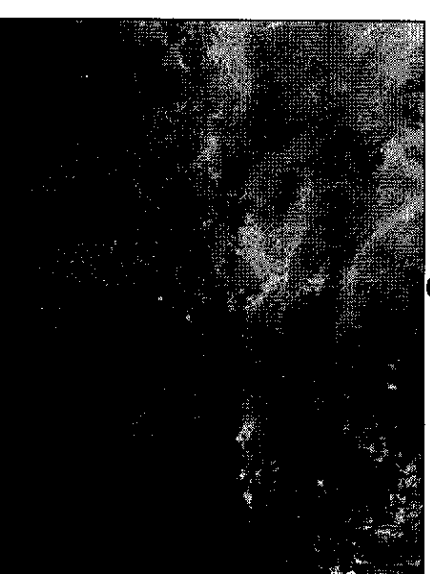
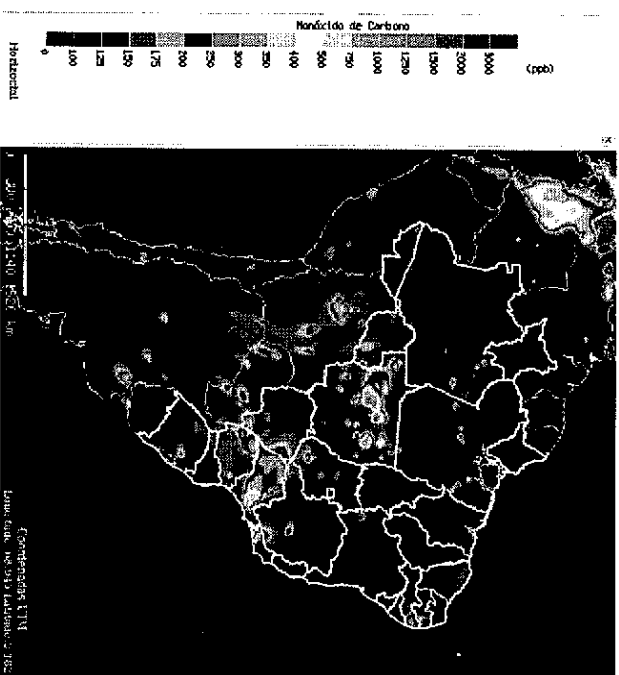
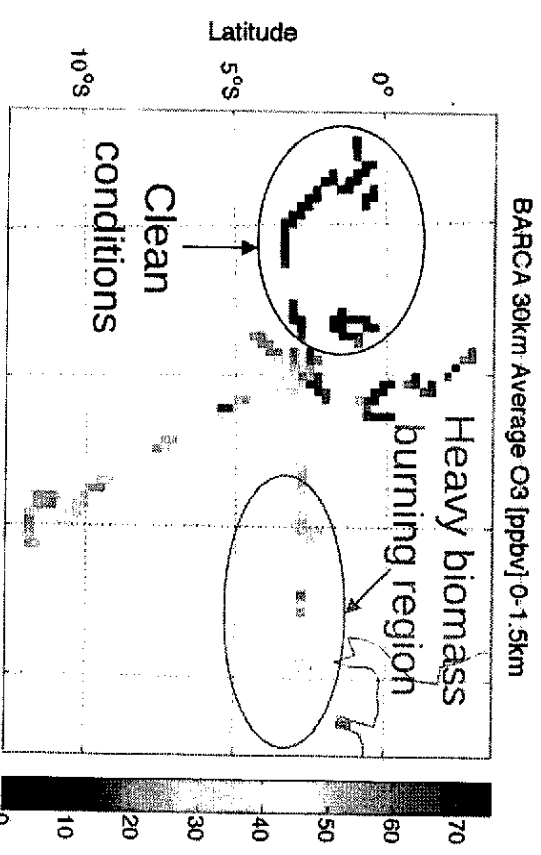


Image: MODIS 1-18-2002

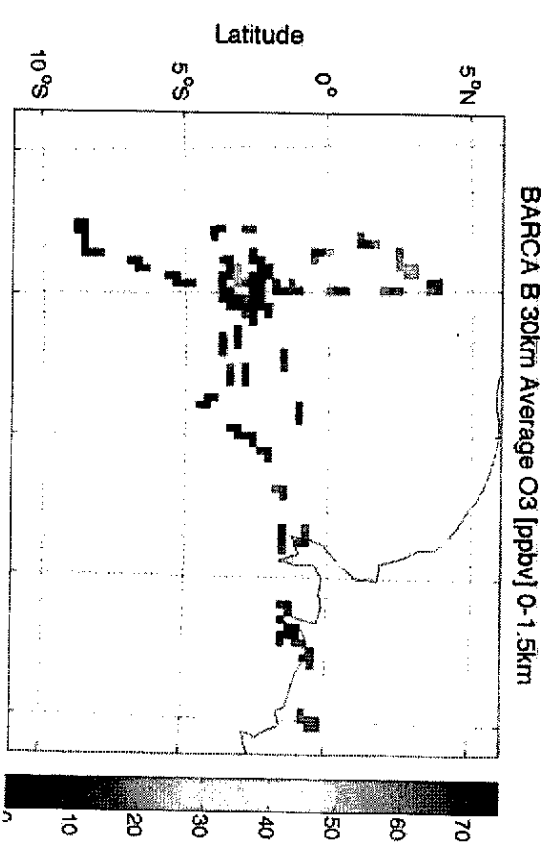
Ozone WRF Meteorology WRF Chemistry Emissions

BARCA Regional O₃ Distribution (0-1.5 km)

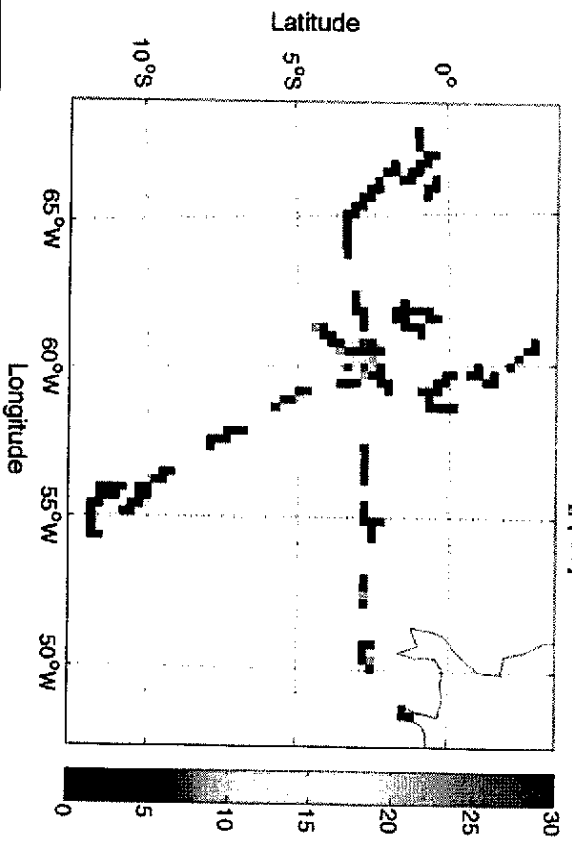
BARCA A 14 Nov - 2 Dec 2008



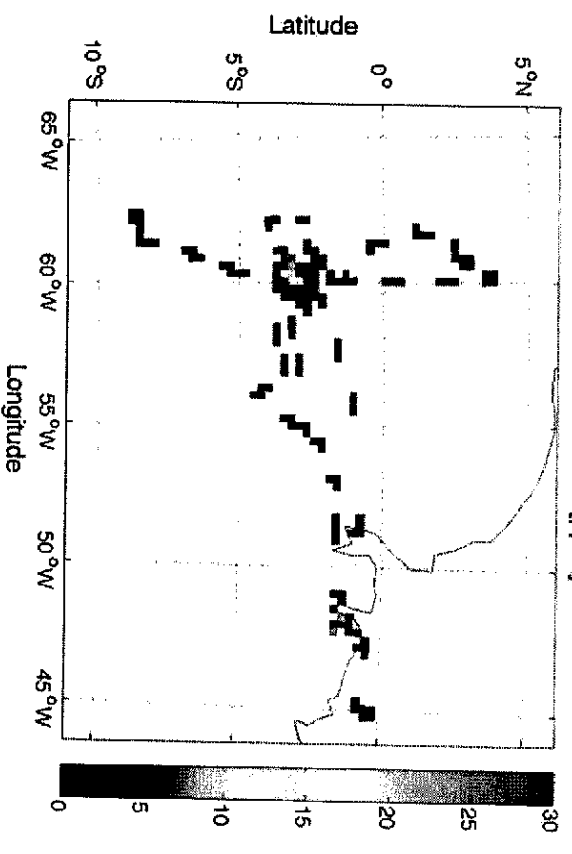
BARCA B 15-28 May 2009



BARCA 30km Std. Dev. O₃ [ppbv] 0-1.5km



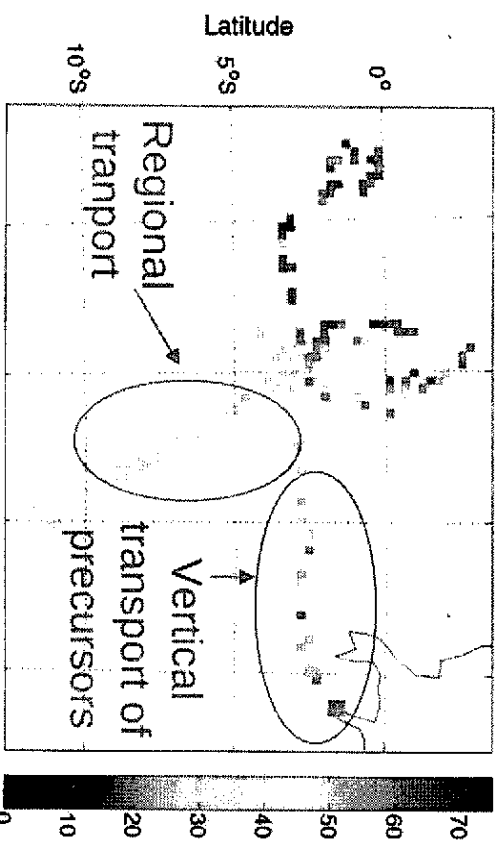
BARCA B 30km Std. Dev. O₃ [ppbv] 0-1.5km



BARCA Regional O₃ Distribution (1.5 – 3 km)

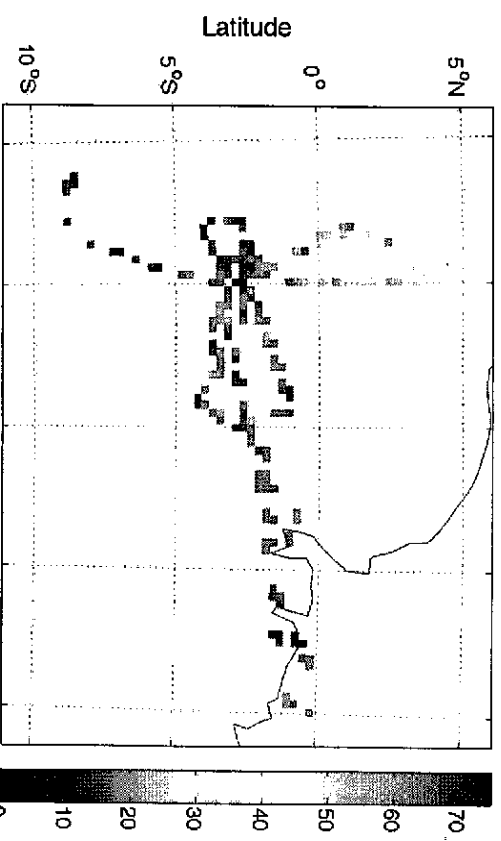
BARCA A 14 Nov - 2 Dec 2008

BARCA 30km Std. Dev. O₃ [ppbv] 1.5-3km

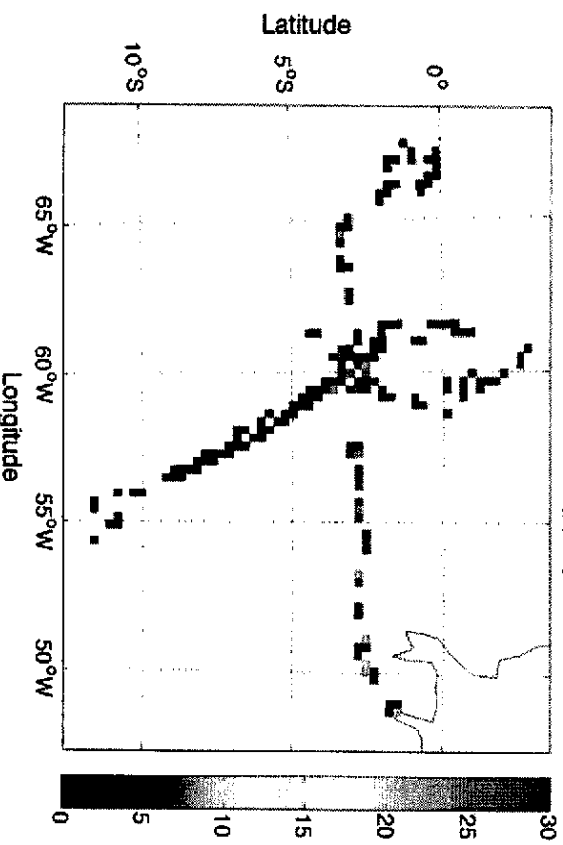


BARCA B 15-28 May 2009

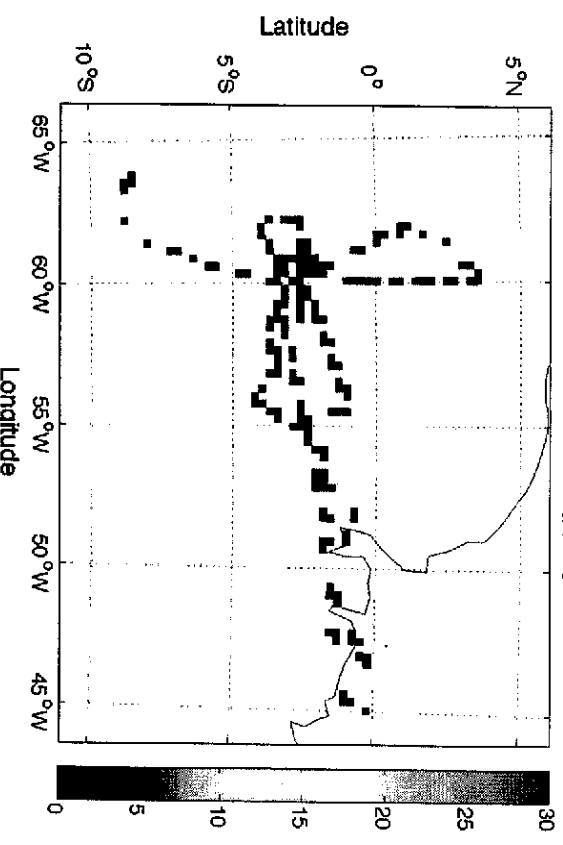
BARCA B 30km Average O₃ [ppbv] 1.5-3km



BARCA 30km Std. Dev. O₃ [ppbv] 1.5-3km



BARCA B 30km Std. Dev. O₃ [ppbv] 1.5-3km



Ozone

WRF Meteorology

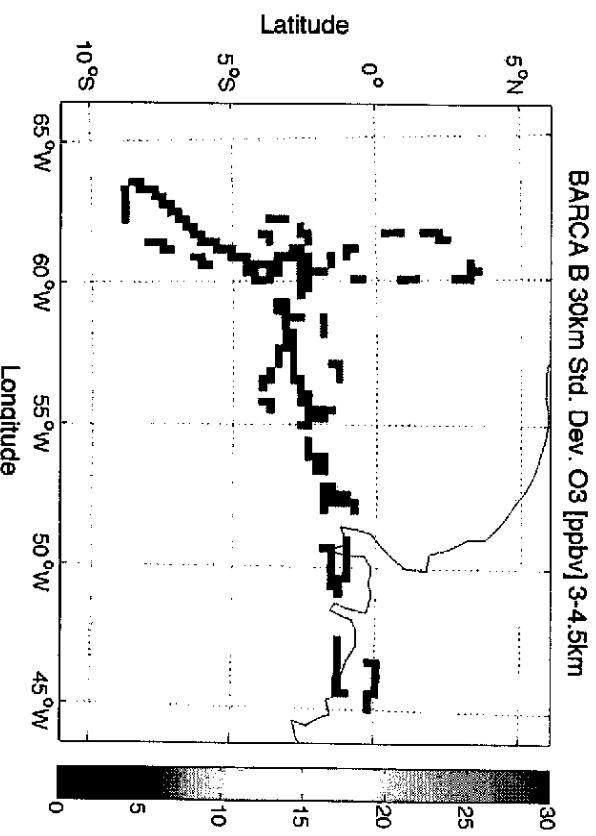
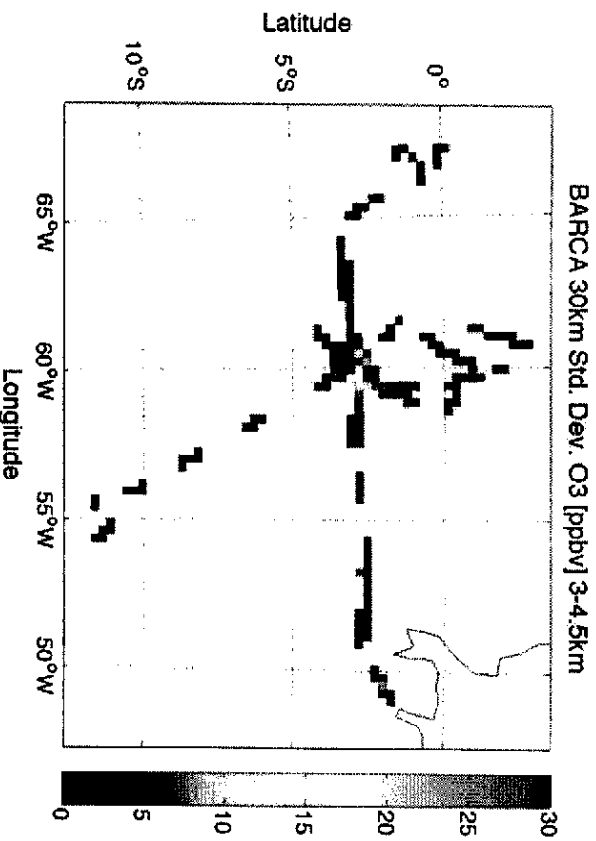
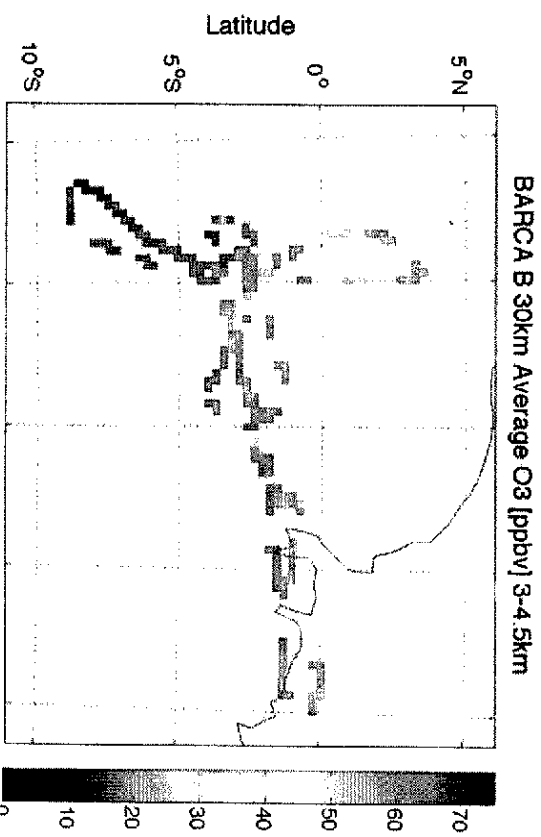
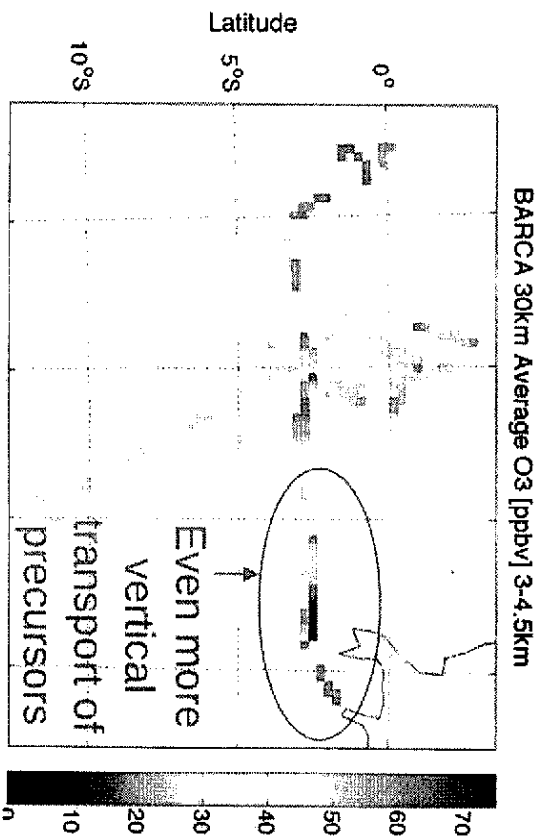
WRF Chemistry

Emissions

BARCA Regional O₃ Distribution (3 – 4.5 km)

BARCA A 14 Nov - 2 Dec 2008

BARCA B 15-28 May 2009



Ozone

WRF Meteorology

WRF Chemistry

Emissions

It's Complicated

How do different physical and chemical processes affect tropospheric ozone production and transport in the Amazon?

Aerosols Radiation Microphysics Shallow/Deep Convection

Mechanism
Radiative Properties
Direct/Indirect Effect

WRF

Model top
20-30 km

Chemistry

Mechanism
Ics/BCCs

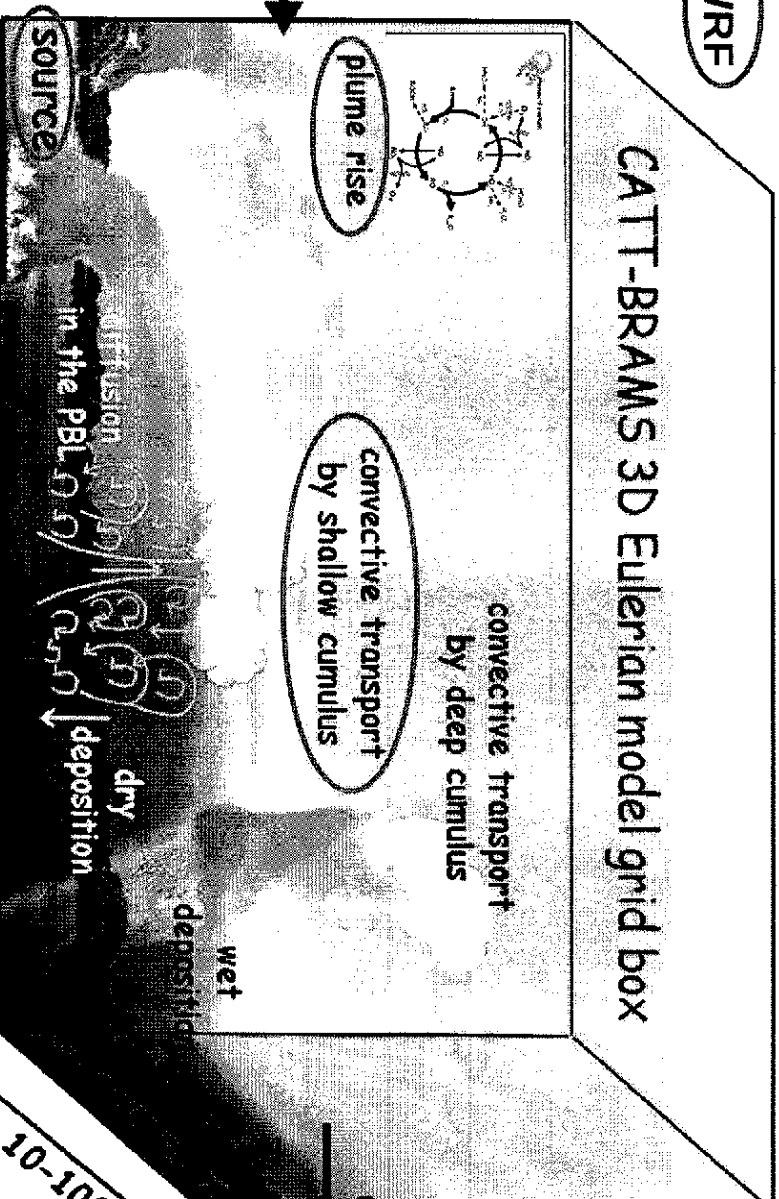
WRF

mass
inflow

PBL

Emissions

Biogenic
Biomass burning
Urban
Az ~ 100-1000 m



$\Delta x \sim 10-100$ km

$\Delta y \sim 10-100$ km

Land Surface Model

Land Surface Data
Vegetation Parameters
Soil Moisture Initialization

Ozone

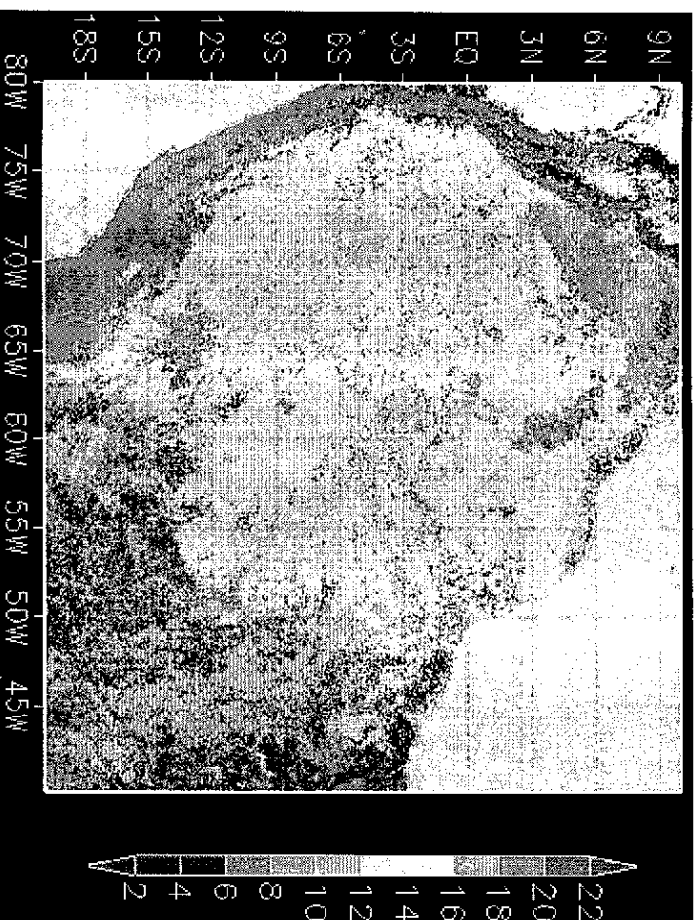
WRF Meteorology

WRF Chemistry

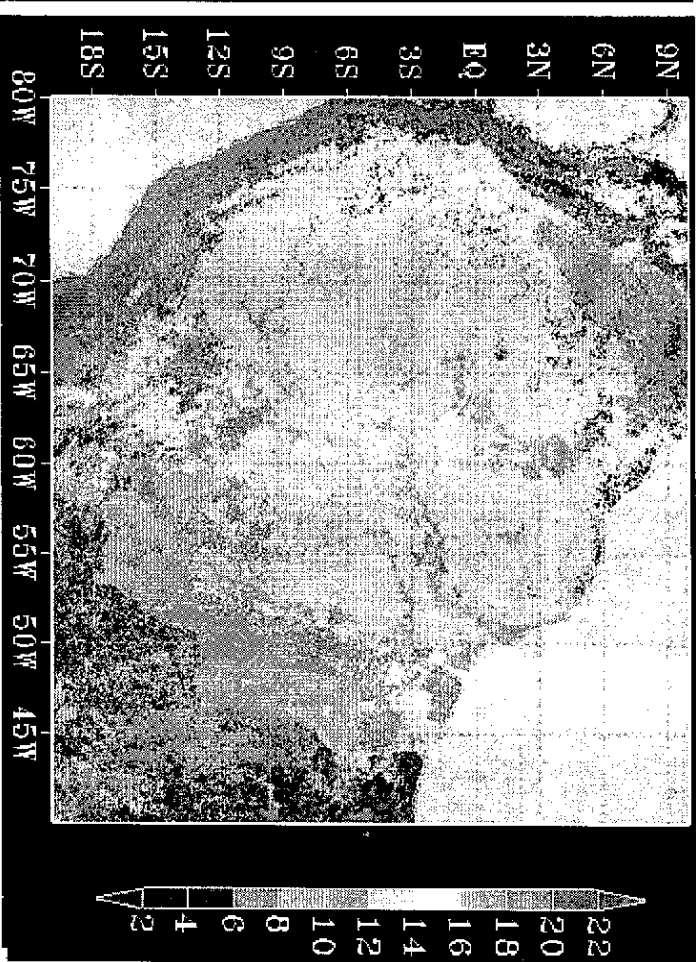
Emissions

Updated Amazon Land Use Data

USGS Land Cover V.2



USGS + PROVEG (INPE)



Global 1km AVHRR 1992-93

grassland/pasture savanna

Amazon updated with 1km PROVEG from
Landsat 2000-2001 (proveg.cptec.inpe.br)

Ozone

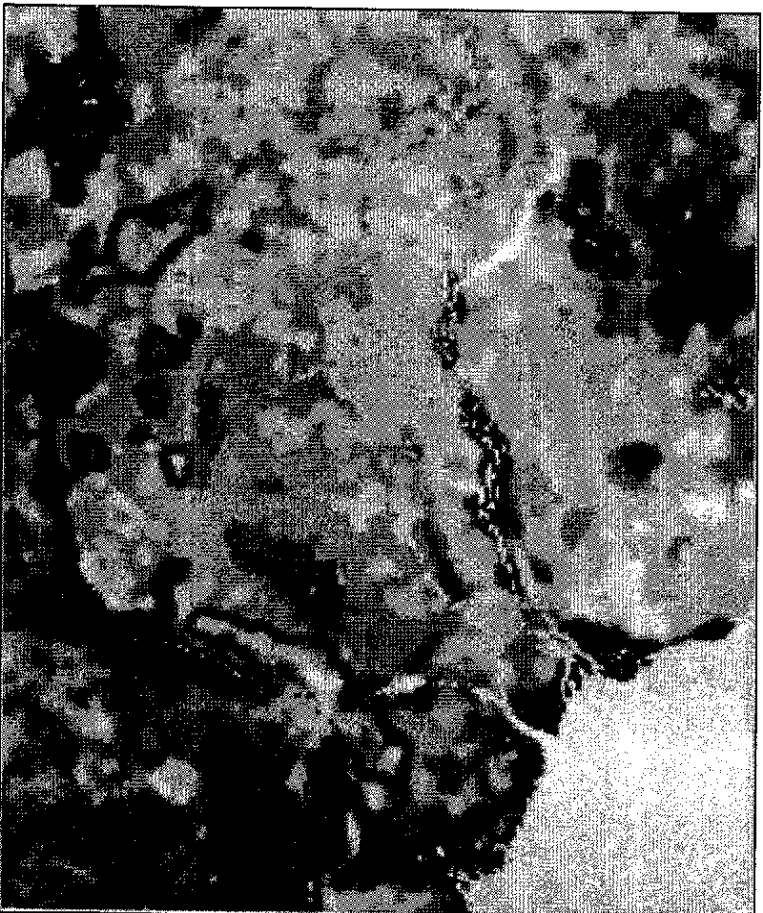
WRF Meteorology

WRF Chemistry

Emissions

Updated Albedo (November)

NCEP 0.144° (1985-1993)



Estimated from 1km PROVEG and
MODIS 30s NDVI (2000-2001)



Observed (von Randow et al., 2004)
forest: 10-15
pasture/savanna: 18-22

Ozone

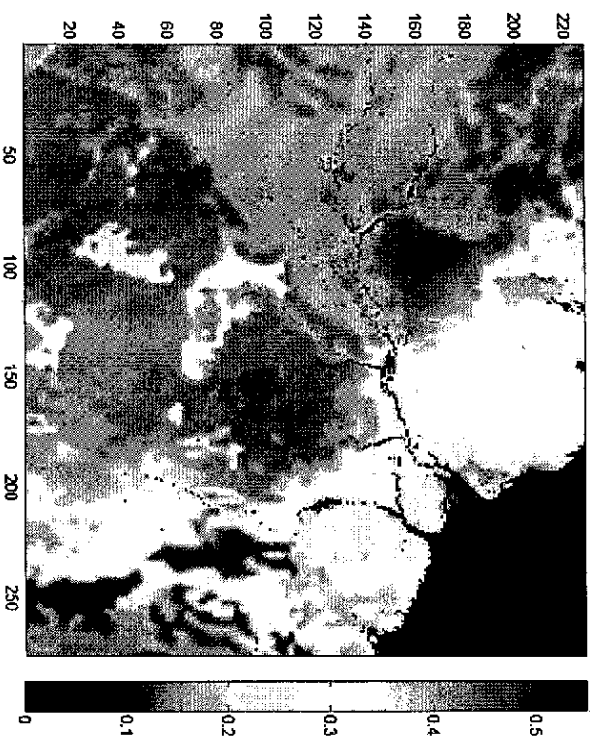
WRF Meteorology

WRF Chemistry

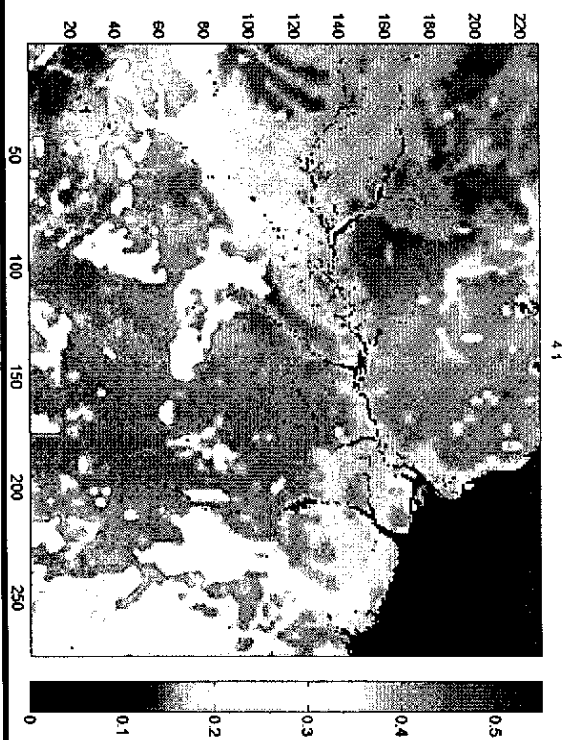
Emissions

Soil Moisture Initialization – 1 Nov. 2008

ECMWF 0.25°₁₁

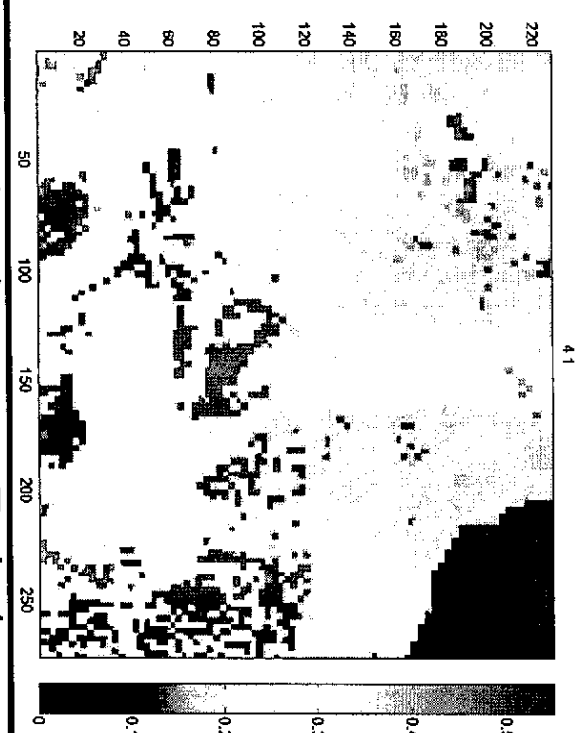


GPNR 0.25°₁₁



Ozone

WRF Meteorology

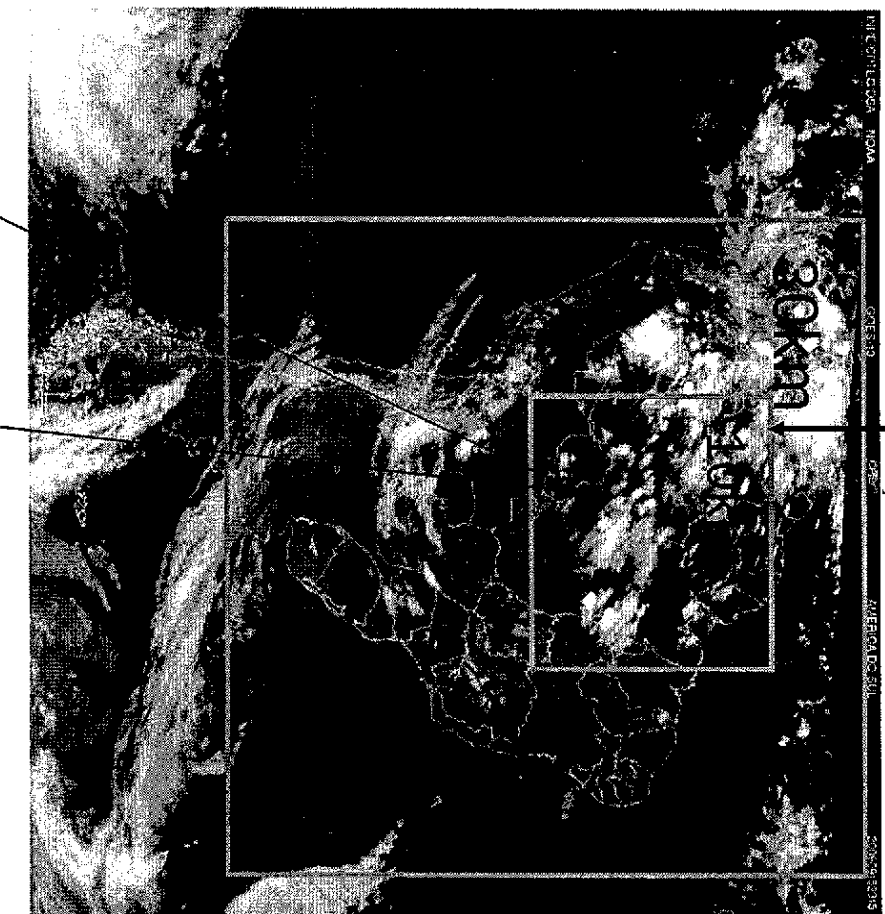


WRF Chemistry

Emissions

WRF Meteorology Evaluation for the Amazon

BARCA Experiment Region



Rebio Jarú (Forest) Fazenda Nossa Senhora (Pasture)

Runs (Nov. – Dec. 2008):

- (1) Benchmark
- (2) Updated surface data + GPNR soil moisture

Convection: Grell-Devenyi (30km),
Grell3 (10km)
(with radiative feedback)

Short/Longwave Radiation: RRTMG
Microphysics: WSM5
PBL: Mellor-Yamada-Janjic
LSM: Noah

Observations:

LBA Flux Towers (30 min H, LH, R_n)
TRMM (0.25° 3hr accumulated precip)

Ozone

WRF Meteorology

WRF Chemistry

Emissions

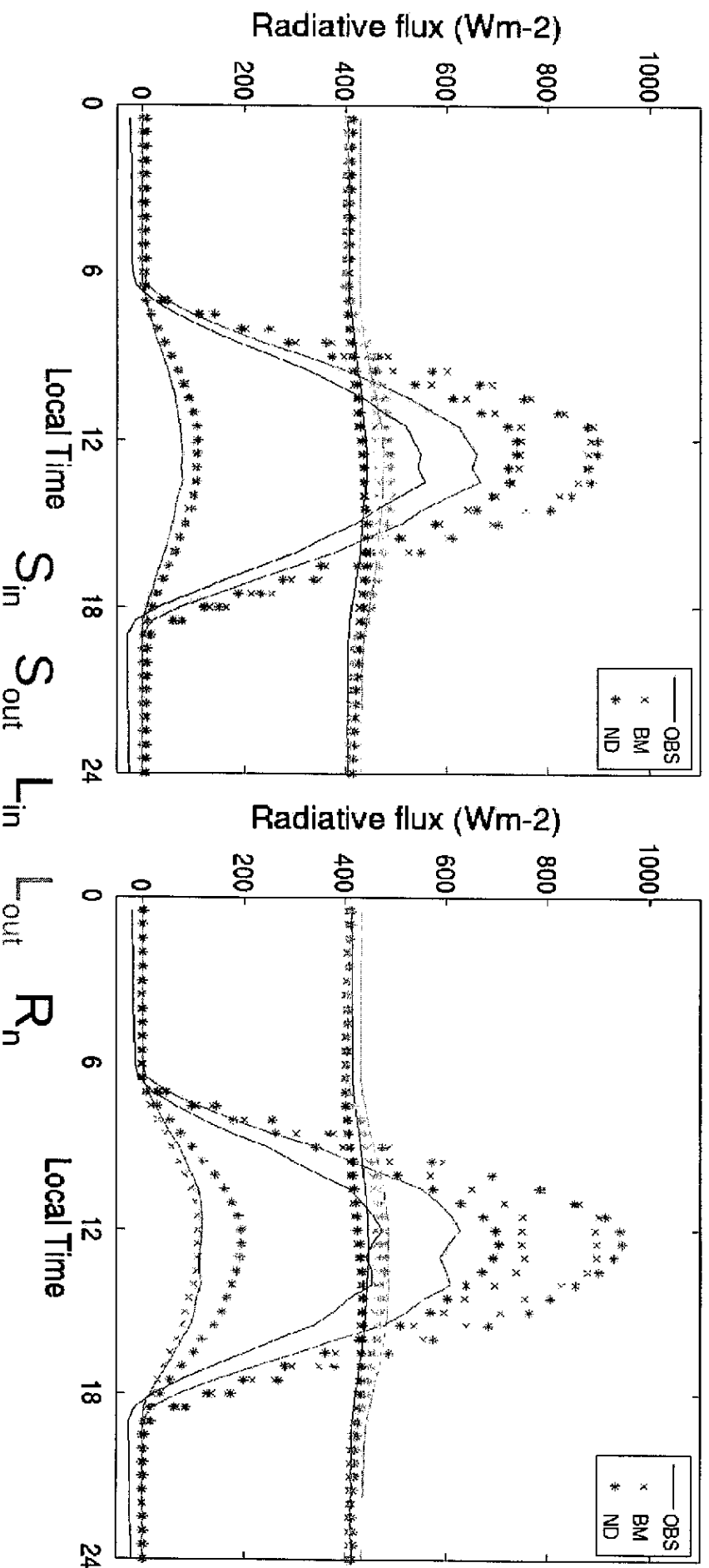
Radiation Diurnal Cycle

S_{in} too high \rightarrow R_n too high (missing cloud/aerosol effects?)

Everything else reasonable

Rebio Jarú (Forest)

FNS (Pasture)



Observed: Wet Season (Jan-Mar 1999-2000) (von Randow et al., 2004)

Simulated: A Very Wet Dry-to-Wet Transition (Nov-Dec 2008)

Ozone

WRF Meteorology

WRF Chemistry

Emissions

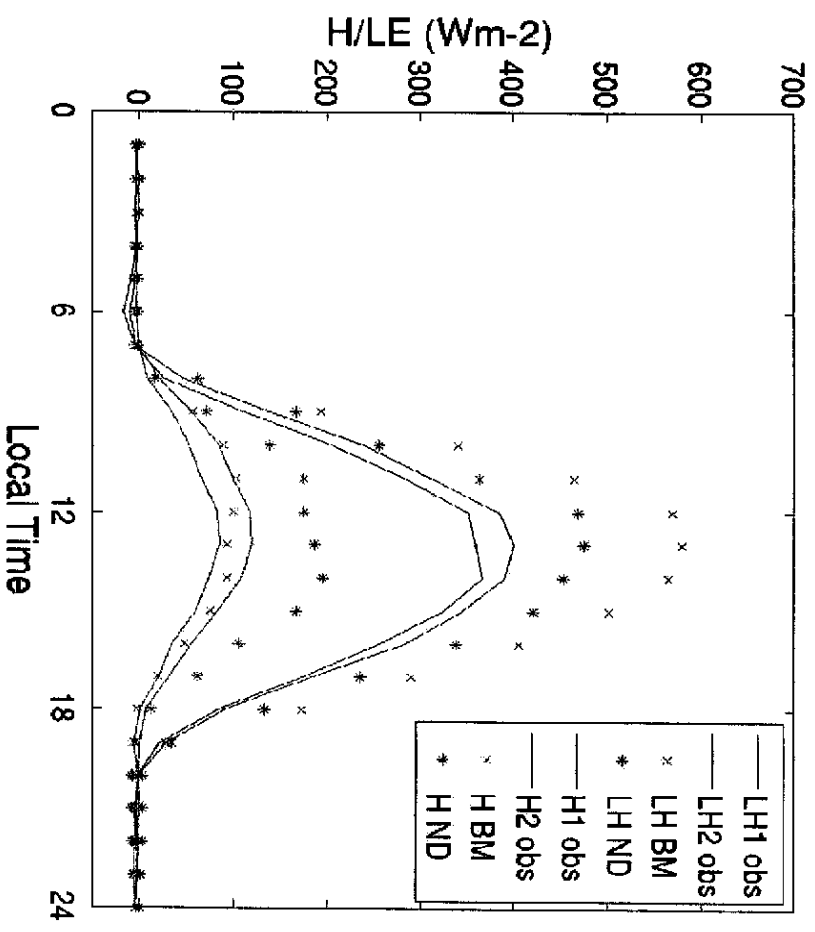
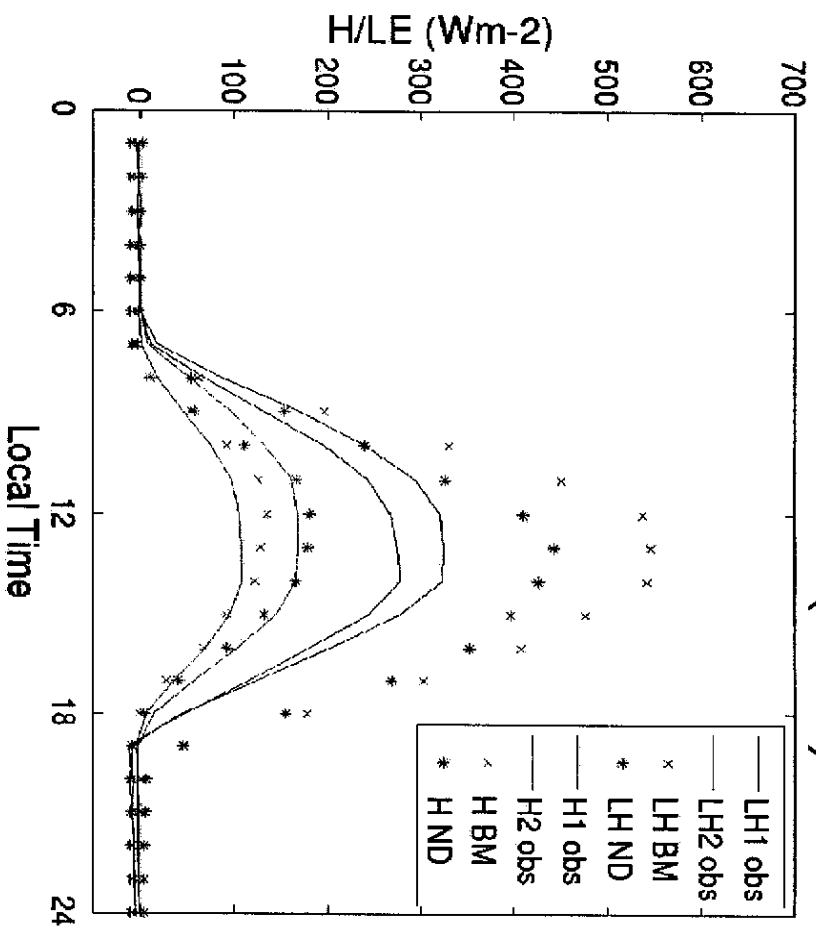
Heat Flux Diurnal Cycle

H reasonable, LH too high

(possible causes: high S_{in} , LSM)

Rebio Jarú (Forest)

FNS (Pasture)



Observed: Wet Season (Jan-Mar 1999-2000)

Simulated: A Very Wet Dry-to-Wet Transition (Nov-Dec 2008)

Ozone

WRF Meteorology

WRF Chemistry

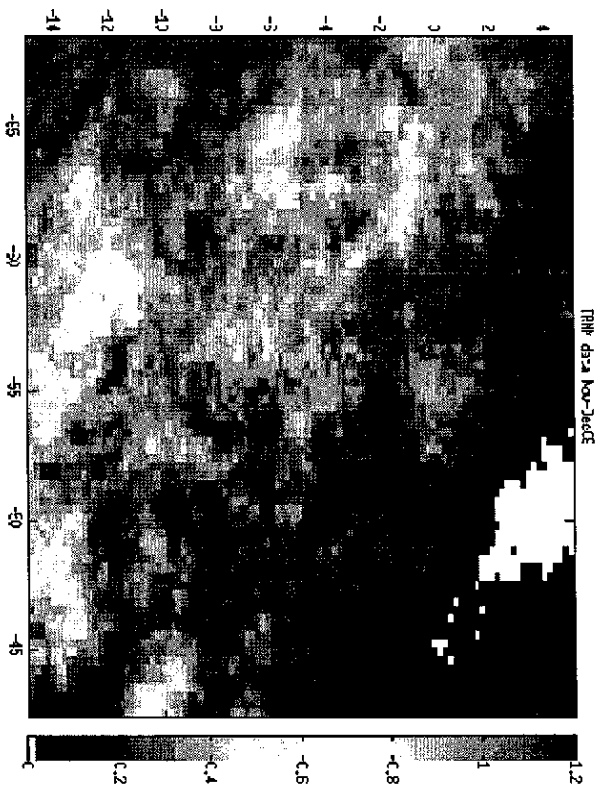
Emissions

Average Hourly Precipitation (mm hr⁻¹)

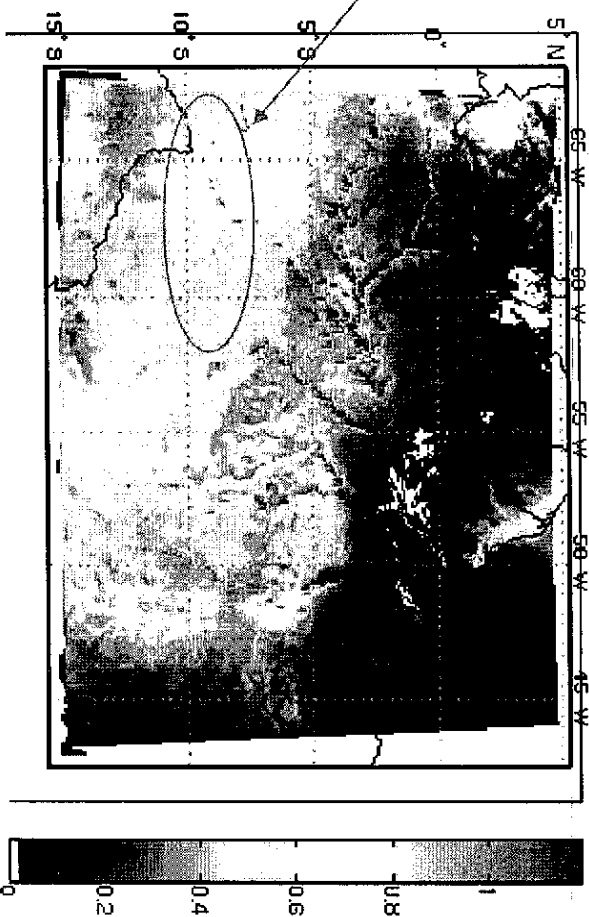
Nov-Dec 2008

Excessive precip primarily in SW Amazon

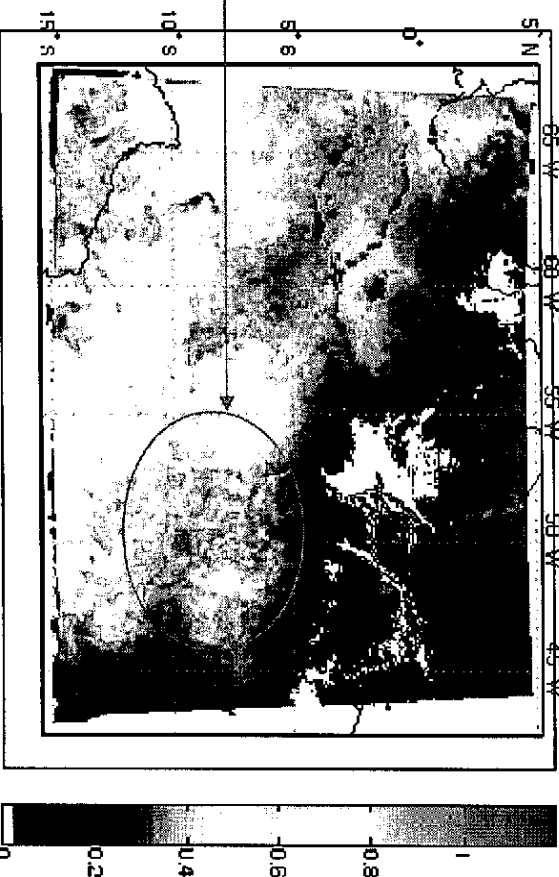
TRMM 3B42 V6



Benchmark (BM)



New Data (ND)



Reductions in SE with new land data

Ozone

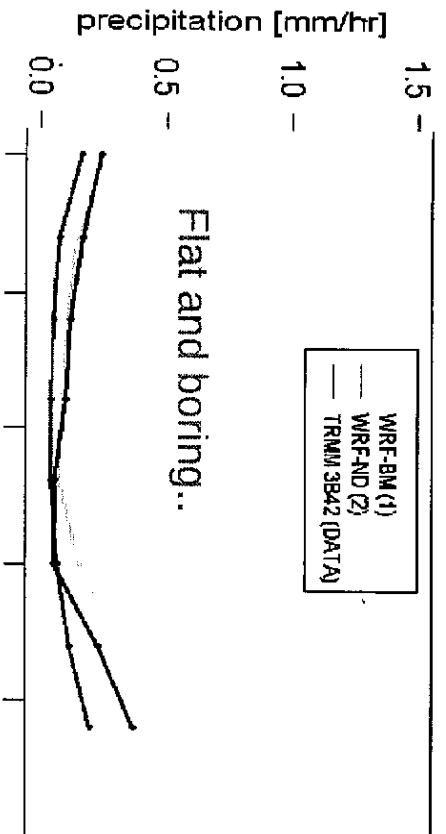
WRF Meteorology

WRF Chemistry

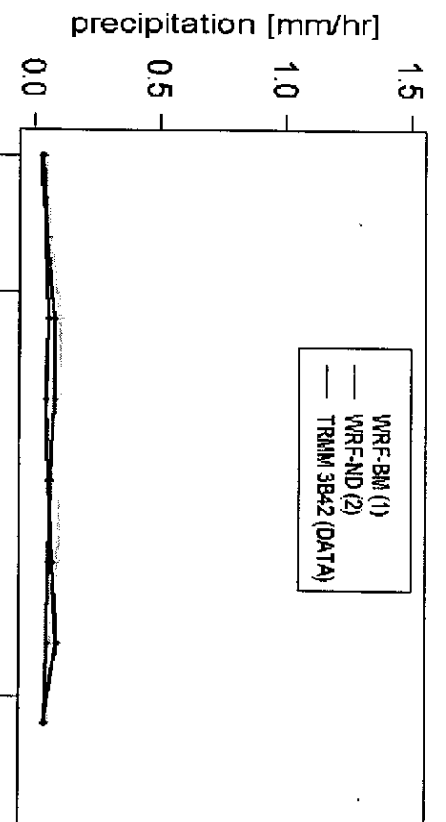
Emissions

Precipitation Diurnal Cycle - NE

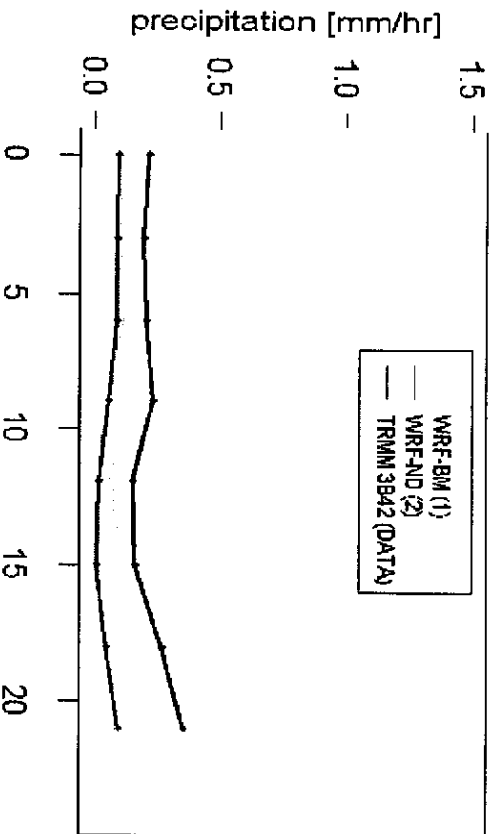
RAINNC+RAINNC (WRF) vs. TRMM Box 3



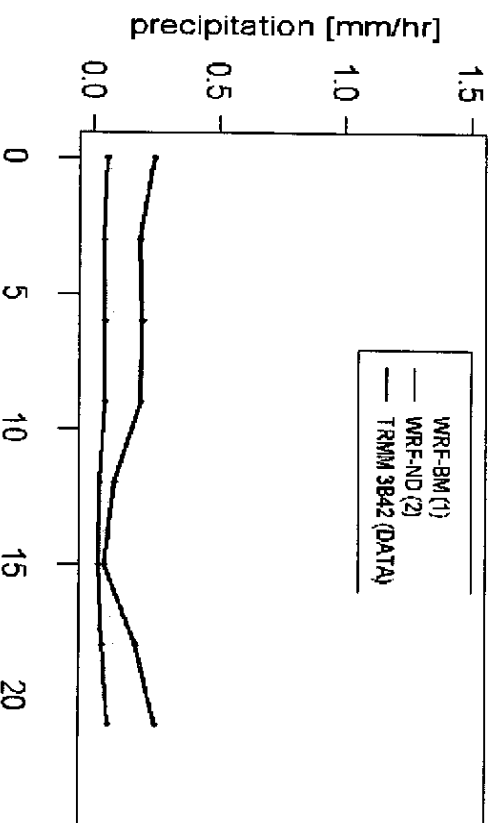
RAINNC+RAINNC (WRF) vs. TRMM Box 4



RAINNC+RAINNC (WRF) vs. TRMM Box 7

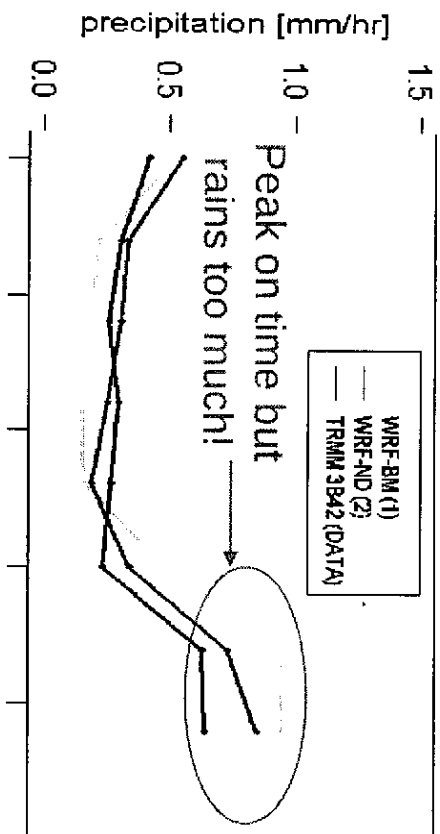


RAINNC+RAINNC (WRF) vs. TRMM Box 8

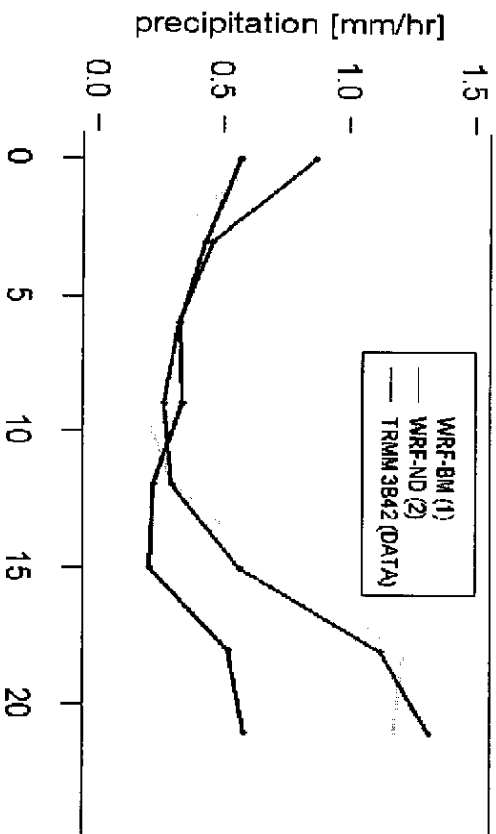


Precipitation Diurnal Cycle - SE

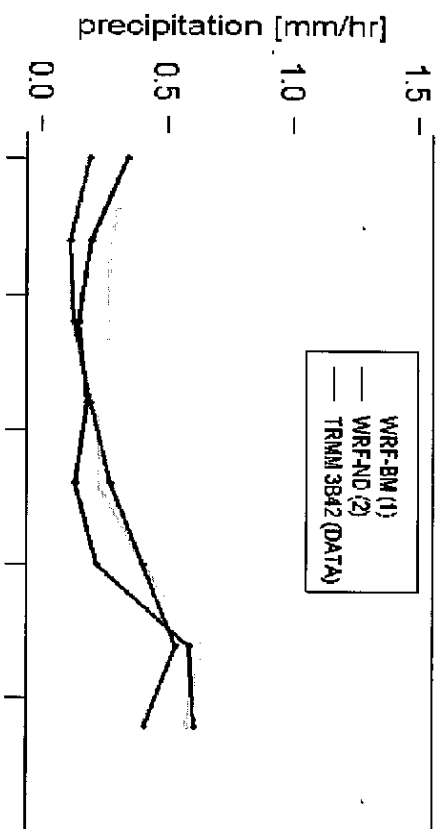
RAINCG+RAINNC (WRF) vs. TRMM Box 11



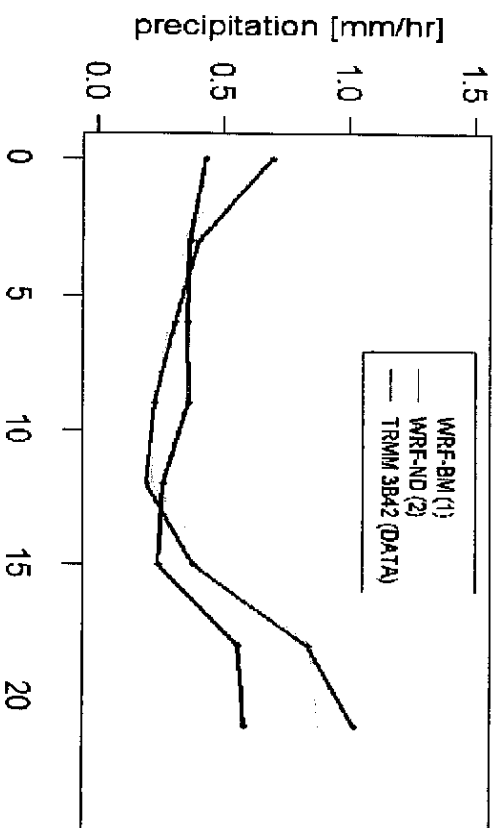
RAINCG+RAINNC (WRF) vs. TRMM Box 15



RAINCG+RAINNC (WRF) vs. TRMM Box 12



RAINCG+RAINNC (WRF) vs. TRMM Box 16



Ozone

WRF Meteorology

WRF Chemistry

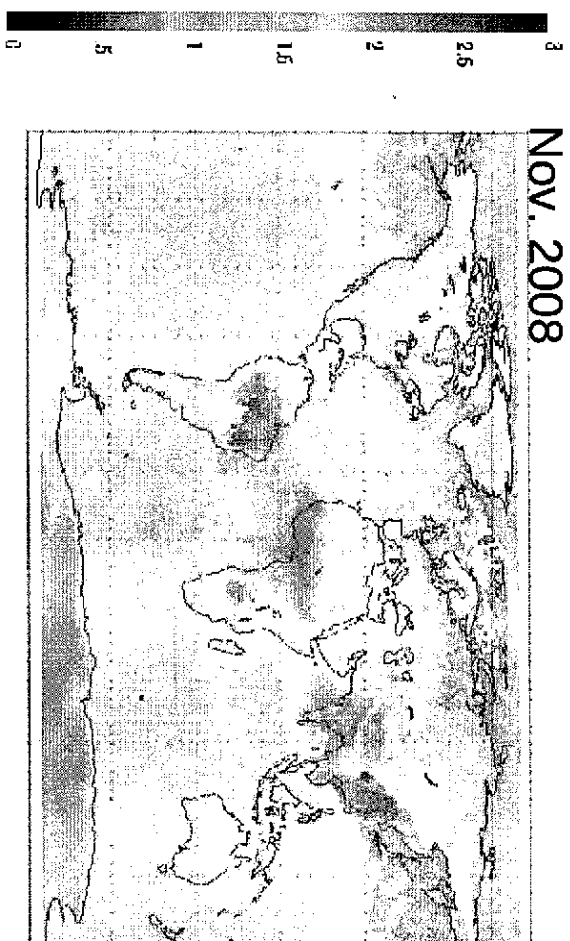
Emissions

[hr UTC]

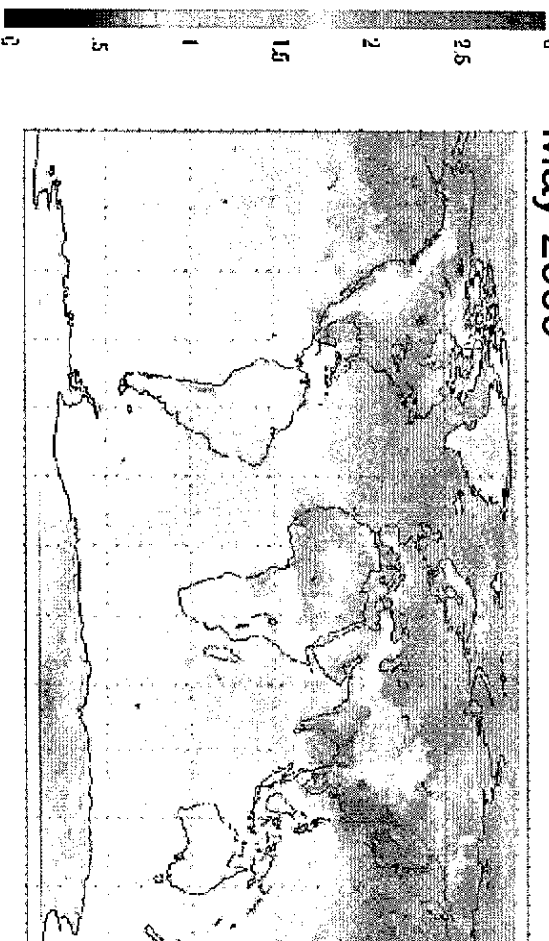
[hr UTC]

CO and AOD Satellite Data

Nov. 2008

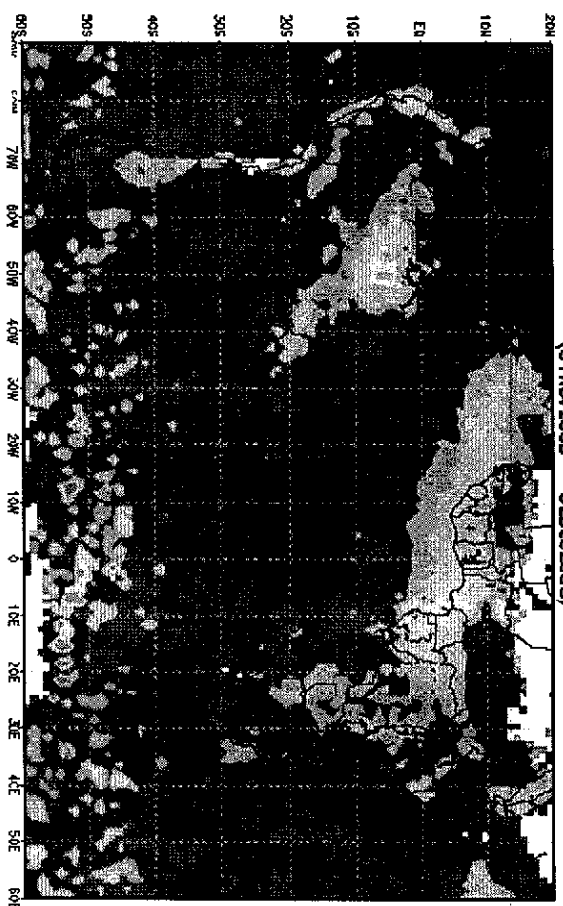


May 2009

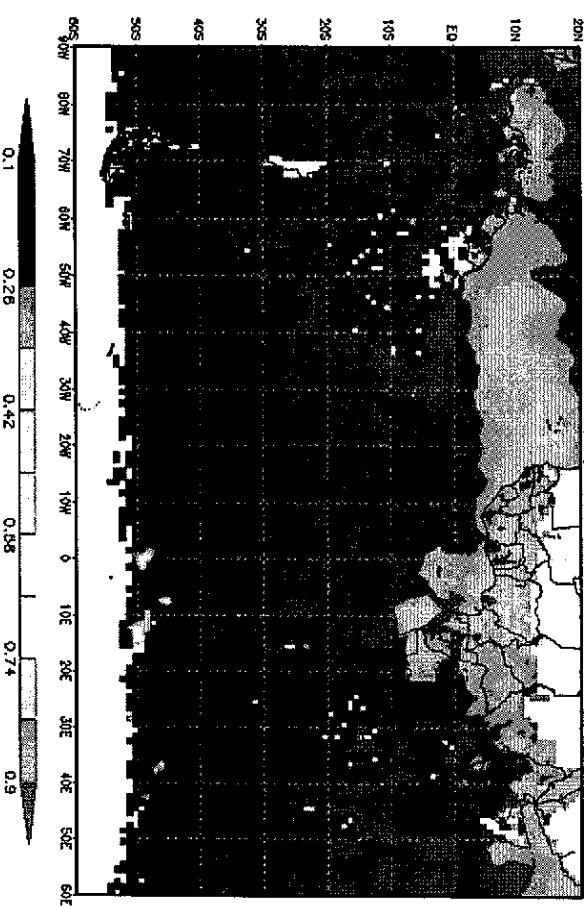


MOPITT CO Total Column (10^{18} mol/cm²)

MOD08_D3.A05 Aerosol Optical Depth at 550 nm [unitless]
(01 Nov 2008 - 02 Dec 2008)



MOD08_M3.A05 Aerosol Optical Depth at 550 nm [unitless]
(01 May 2009)



Ozone

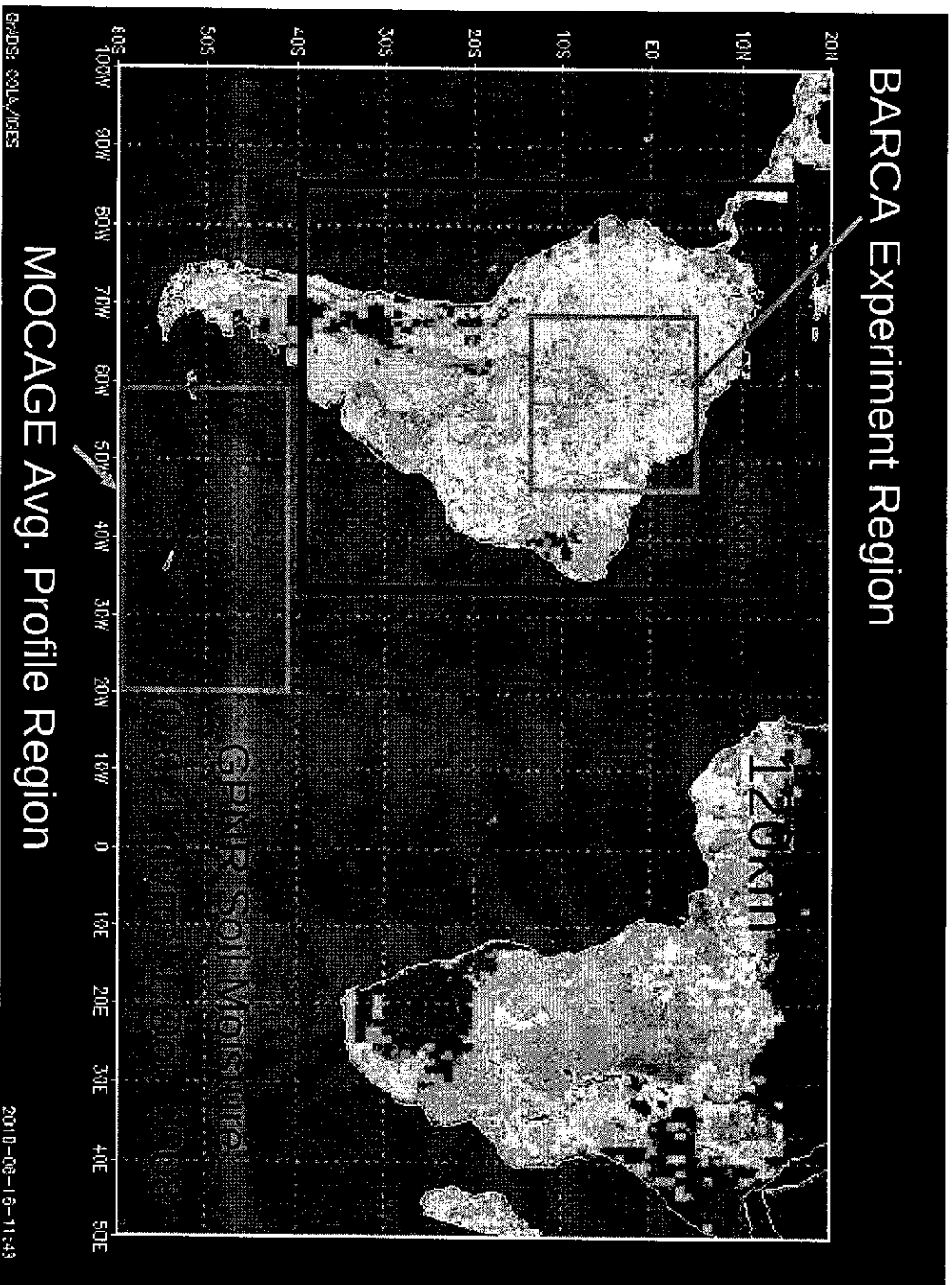
WRF Meteorology

WRF Chemistry

Emissions

BARCA A WRF-Chem Simulations

BARCA Experiment Region



Spinup:

Oct. 2008, 120km

Experiment:

Nov. 2008, 120/35km

Convection: Grell3

(radiative feedback)

Radiation: Goddard

SW, RRTM lw

Microphysics:

WSM5

PBL: Mellor-Yamada-

Janjic

LSM: Noah

Chemistry: RACM-KPP

Aerosol: GOCART

Ics/BCs: GFS, MOCAGE

clean average profiles

Observations:

In-situ: O₃, CO flight data

Satellite: OMI/MLS total tropospheric O₃, MOPITT

500hPa/total column CO₂, MODIS AOD

Ozone

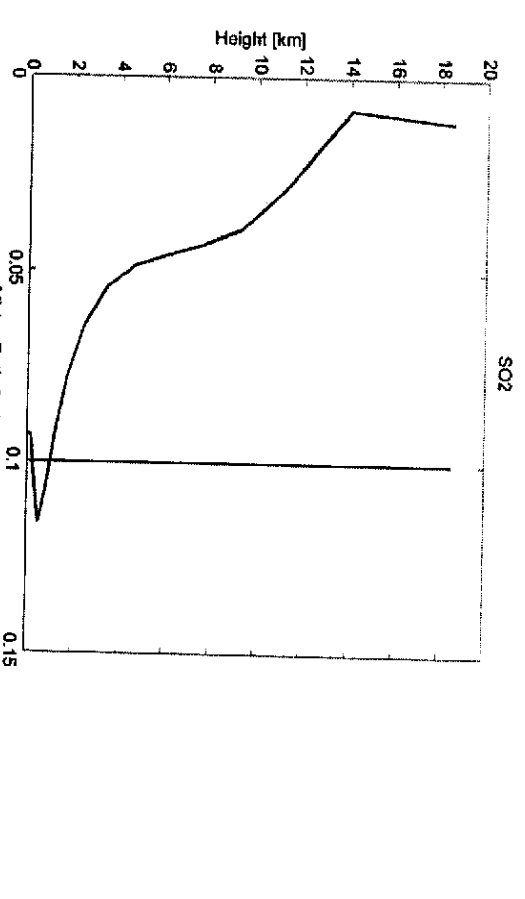
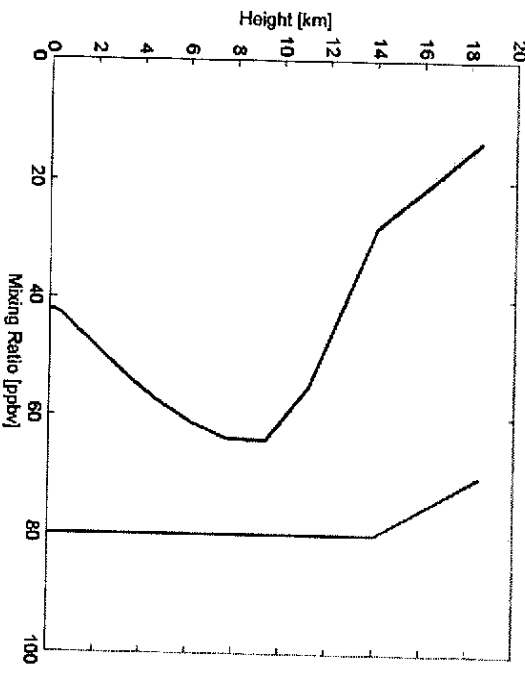
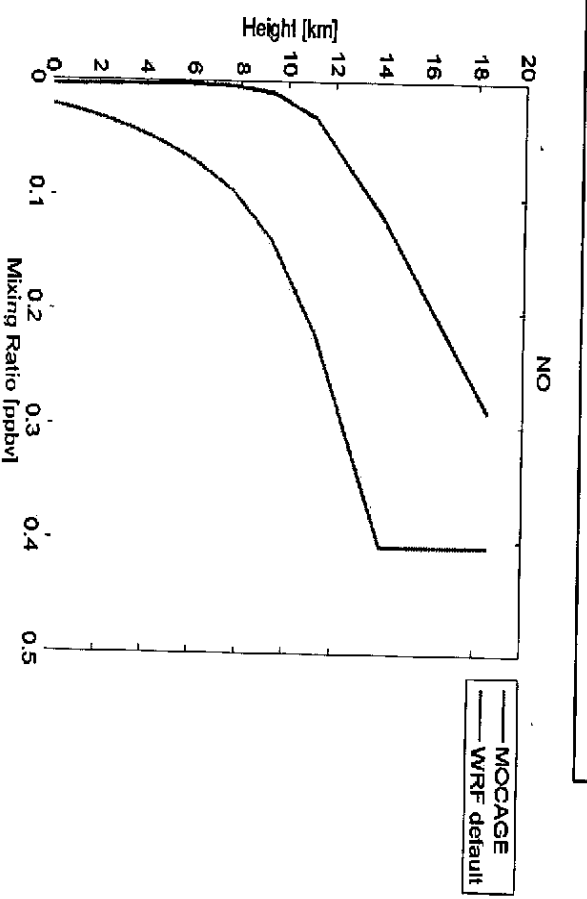
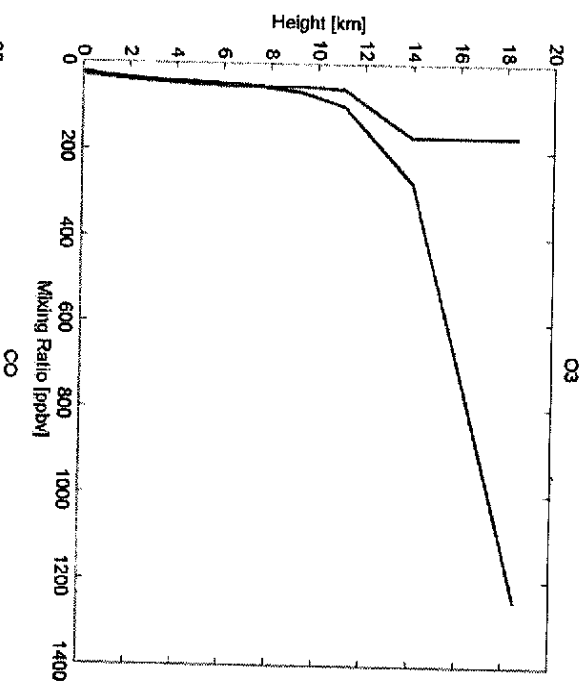
WRF Meteorology

WRF Chemistry

Emissions

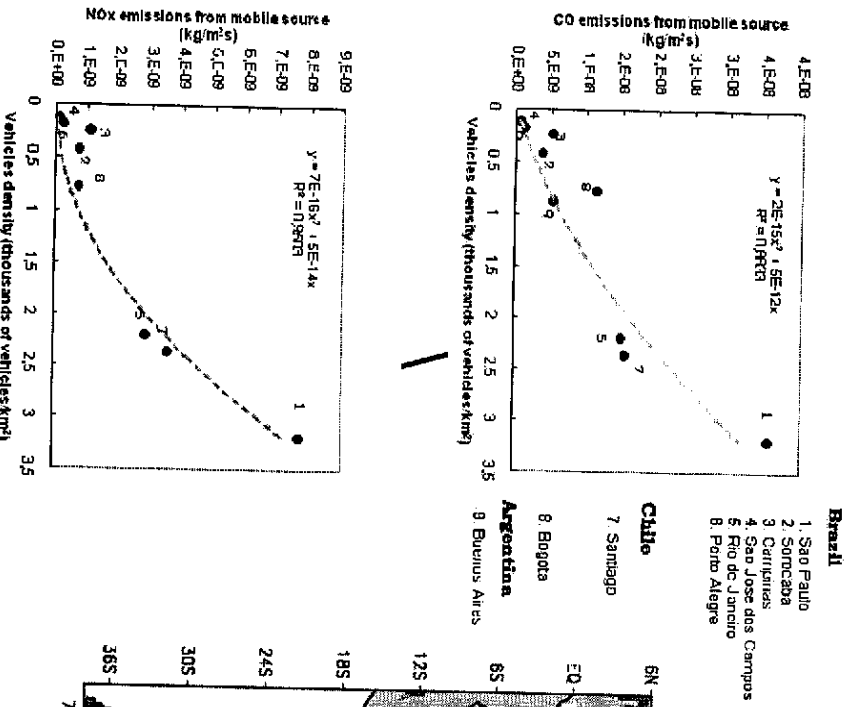
Chemistry Initial/Boundary Conditions

Default WRF-Chem profiles: mid-latitude N. Hemisphere, clean conditions
 MOCAGE mean profiles: 60°W – 20°W, 40°S – 60°S, 1 Oct – 2 Dec 2008

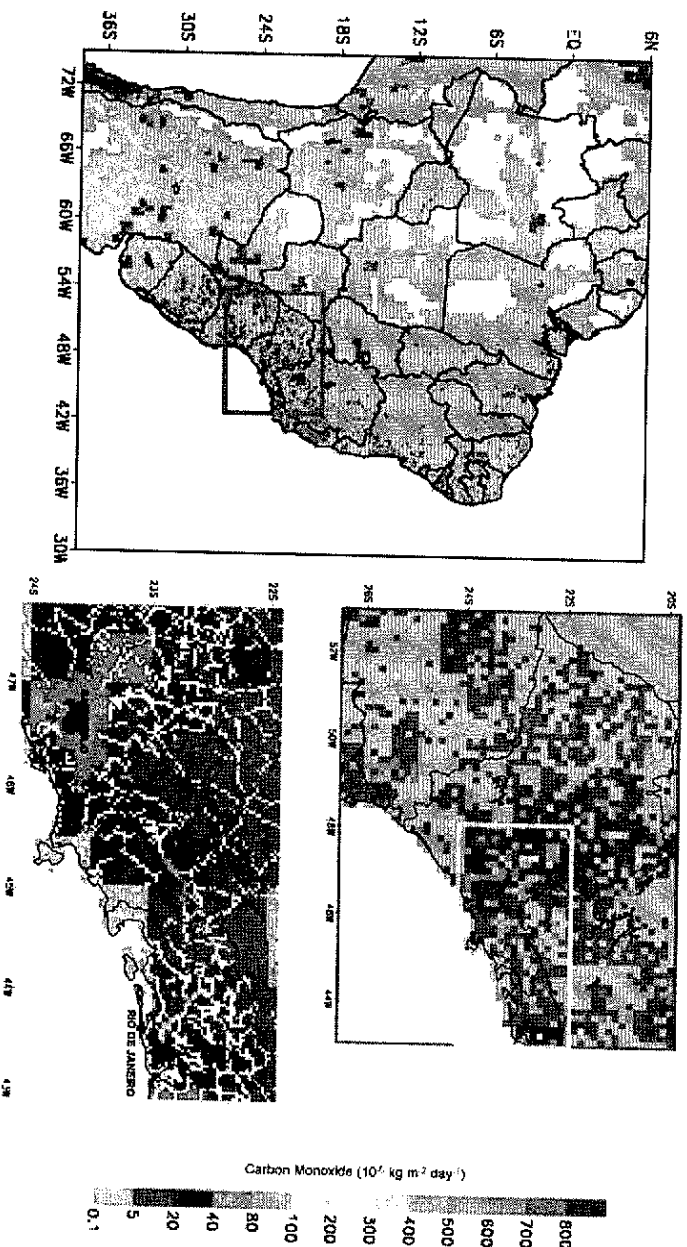


Updated S. American Anthropogenic Emissions

EDGAR/RETRO updated with local inventories or extrapolated from vehicle density
 Spatial redistribution of emissions on high-resolution grids



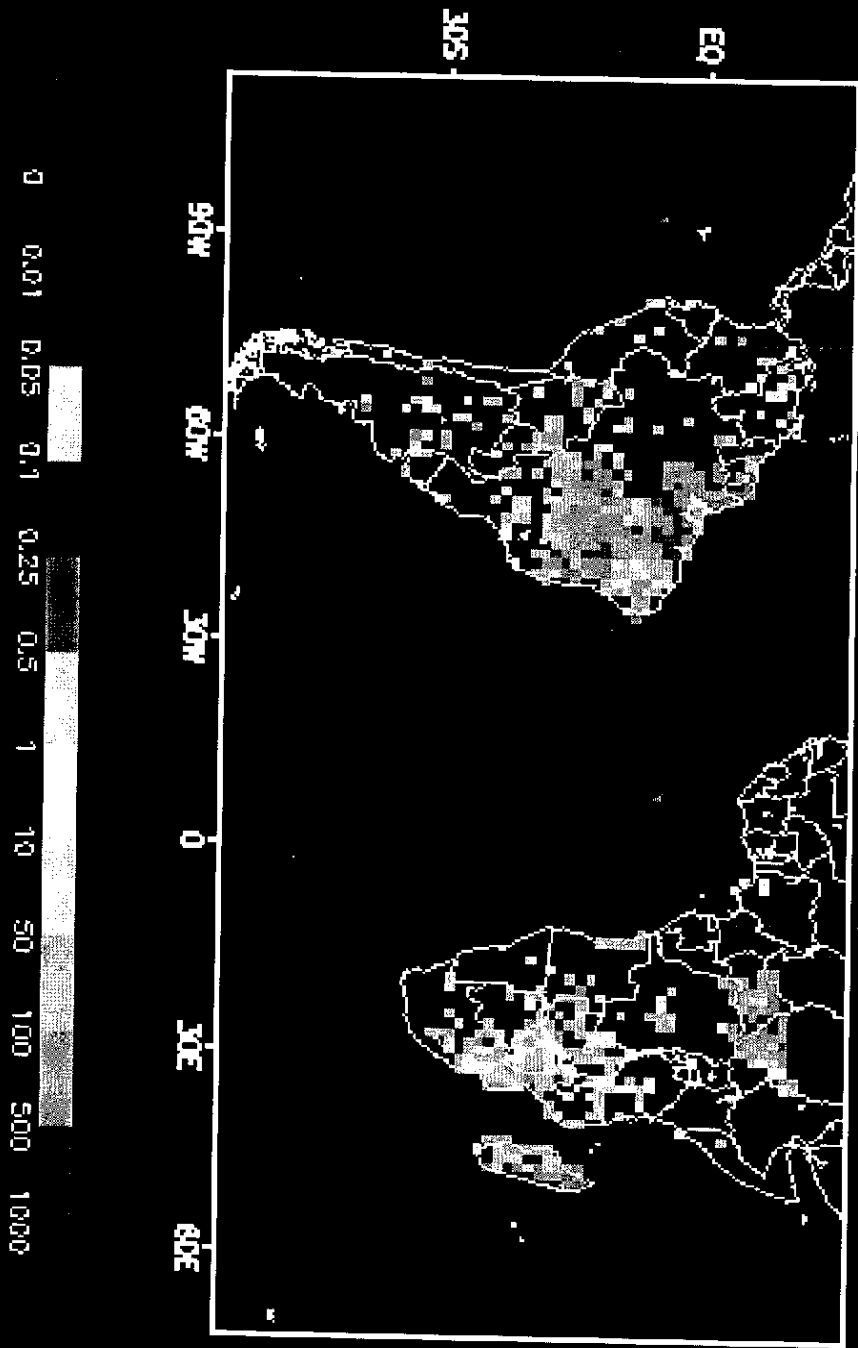
Updated CO emissions for São Paulo – Rio de Janeiro region on 5 km grid with addition of highway emissions



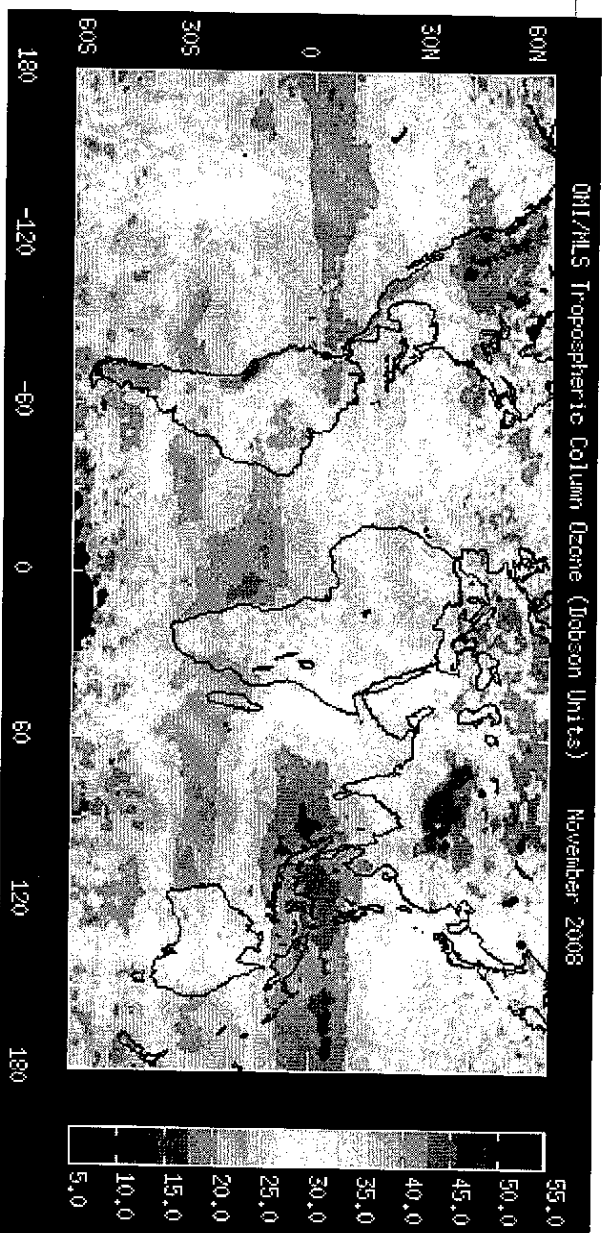
ALONSO, M. F.; LONGO, K.; FREITAS, S.; FONSECA R.; MARÉCAL V.; PIRRE M.; KLENNER L. An urban emissions inventory for South America and its application in numerical modeling of atmospheric chemical composition at local and regional scales. Atmos. Environm. Under review.

BARCA A Biomass Burning Emissions

Biomass burning CO emissions ($1e-6$ kg/m²) 01NOV2008



Next Steps



- Environmental wind effects on plume rise
 - Check aerosol optical properties
 - Aerosol feedbacks
 - Shallow convection

- Compare with regional distributions (flight+satellite data)
 - Compare flight data with high(er)-resolution “golden day” runs
 - Model intercomparison (meteorology+chemistry)

