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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[illegible]tment of Earth and Pla[illegible] [illegible]d University, USA

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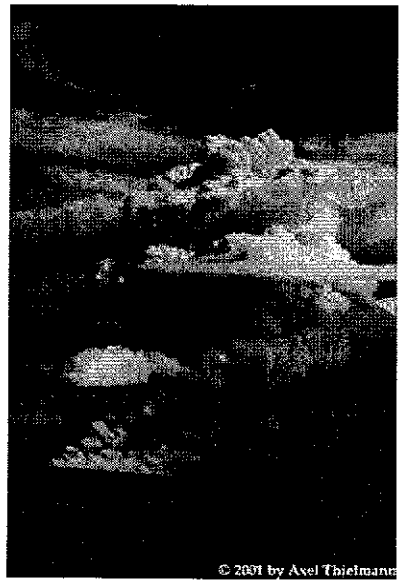
Motivation

Air chemistry regimes in the Amazon

Land-use effects



Clean vs. biomass burning conditions

Wet

Dry

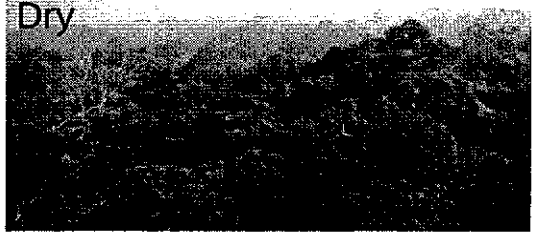
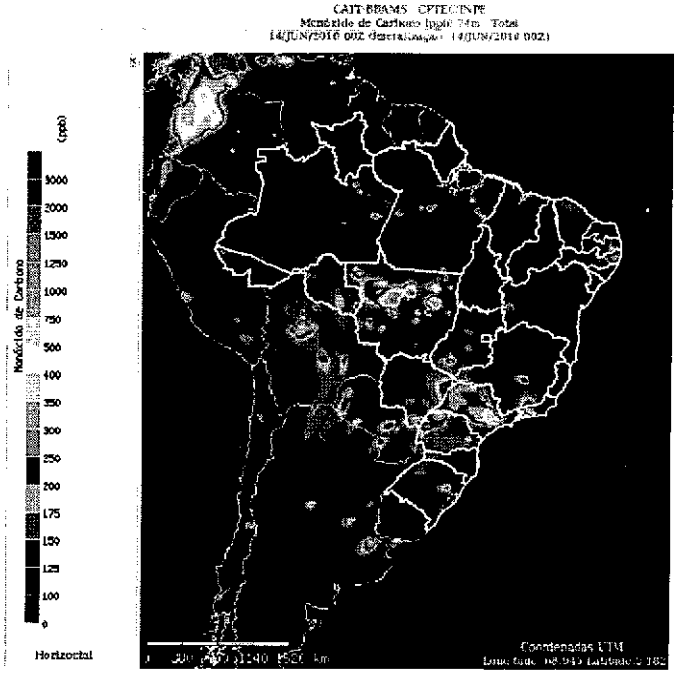


Image: Paulo Artaxo

S. America air quality forecast



Deep/shallow convection

Near Belém do Pará

Anthropogenic and biomass burning emissions

Central São Paulo

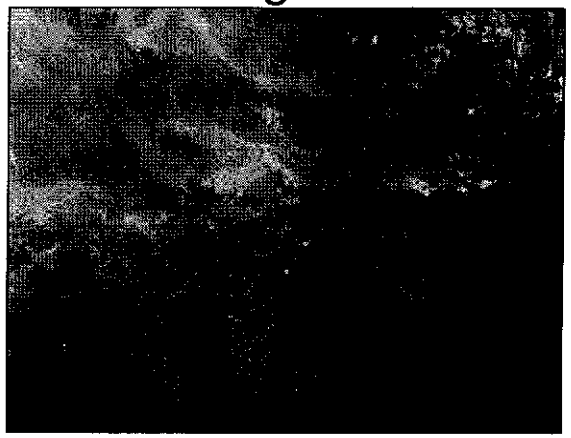
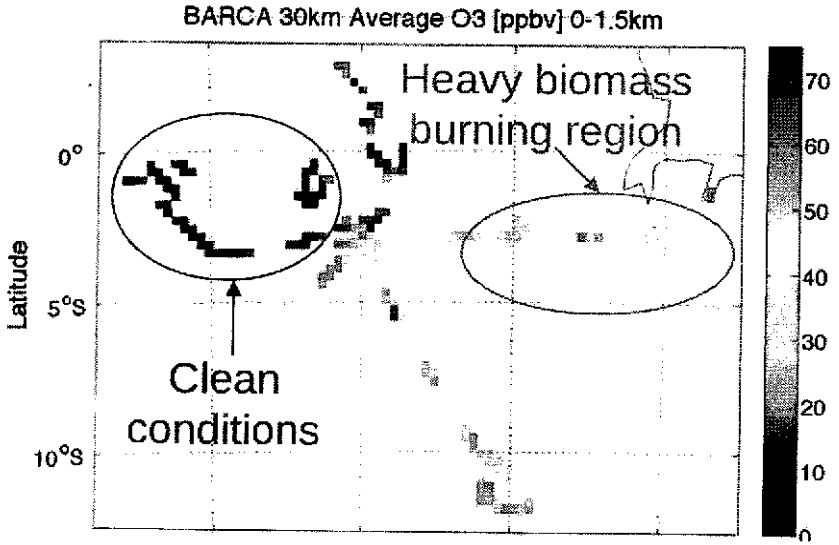


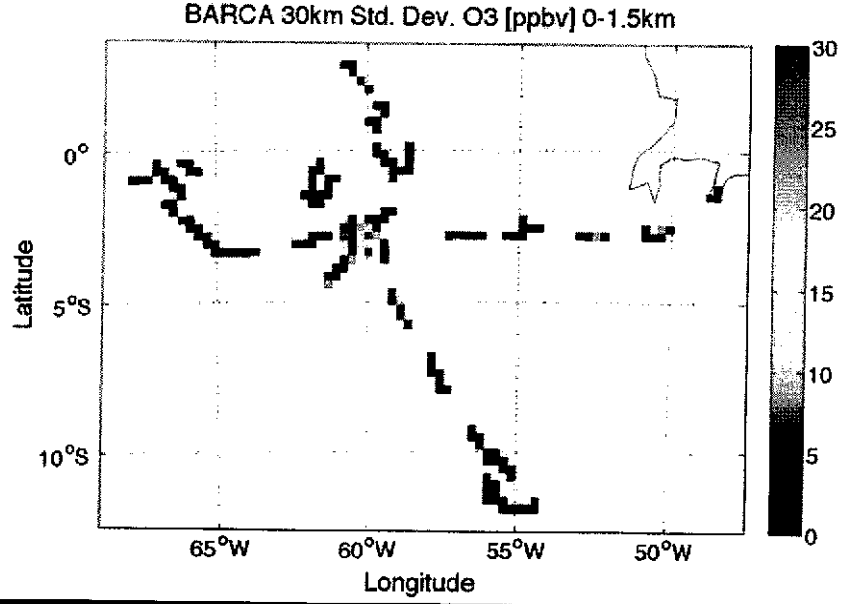
Image: MODIS 1-18-2002

Ozone WRF Meteorology WRF Chemistry Emissions

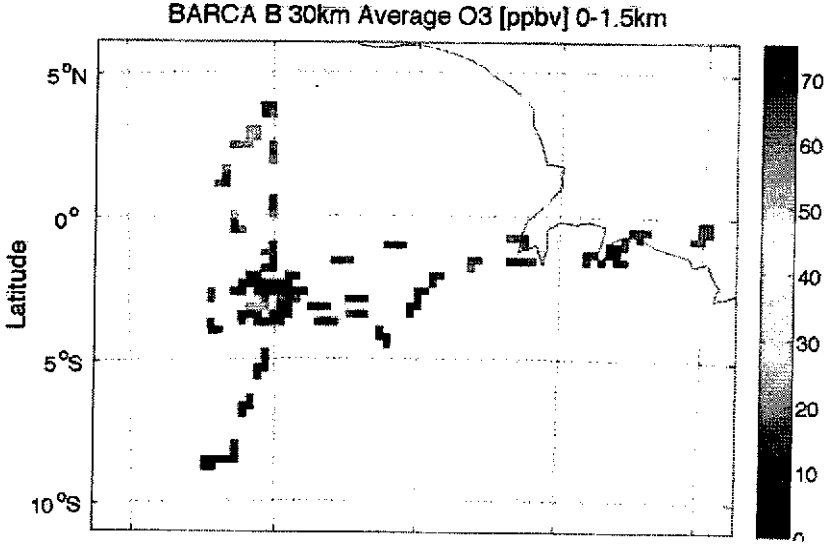
BARCA Regional O_3 Distribution (0-1.5 km)

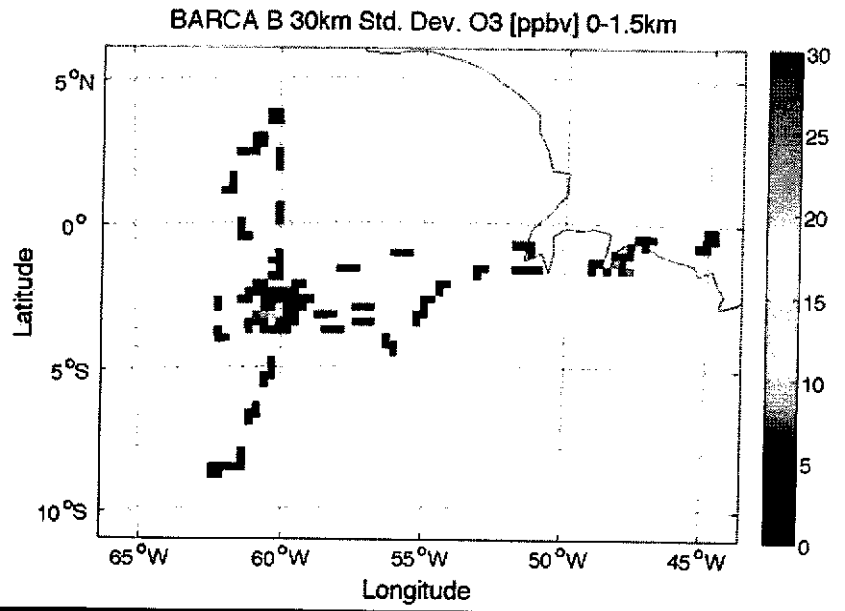
BARCA A 14 Nov - 2 Dec 2008





BARCA B 15-28 May 2009

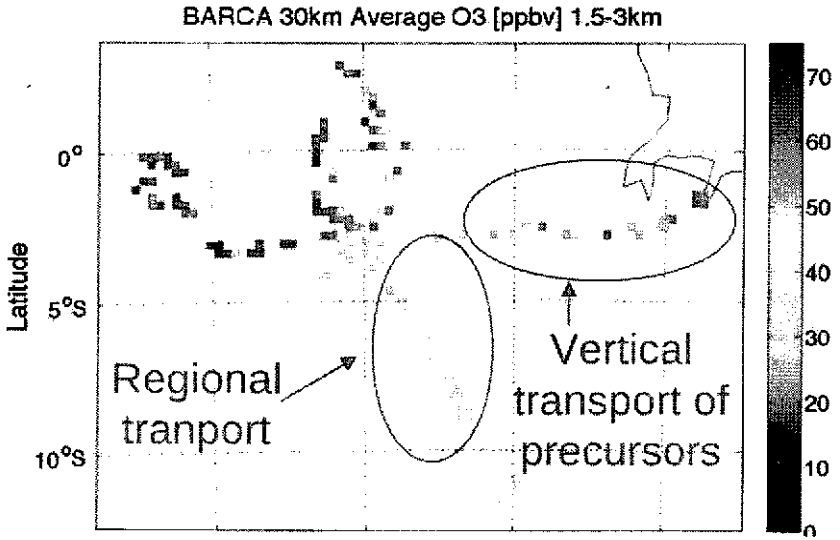


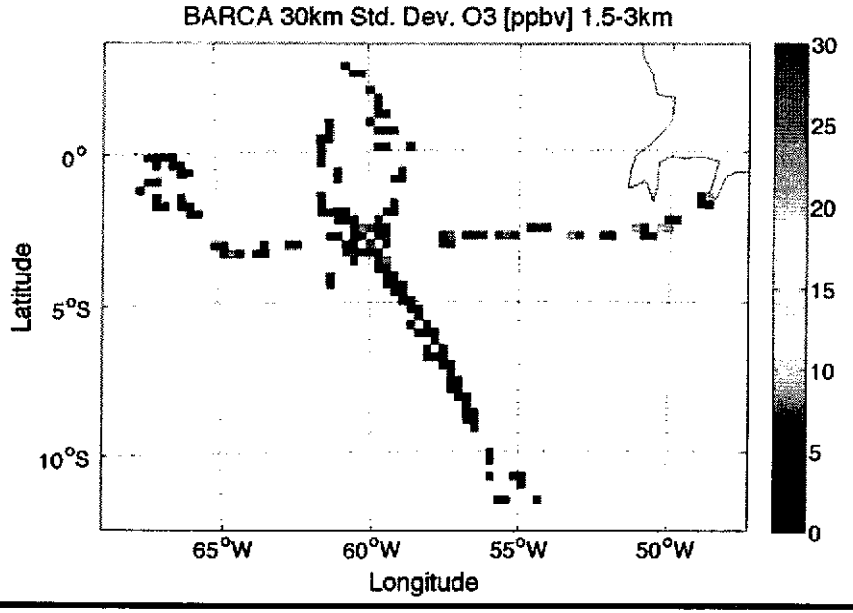


Ozone WRF Meteorology WRF Chemistry Emissions

BARCA Regional O_3 Distribution (1.5 – 3 km)

BARCA A 14 Nov - 2 Dec 2008





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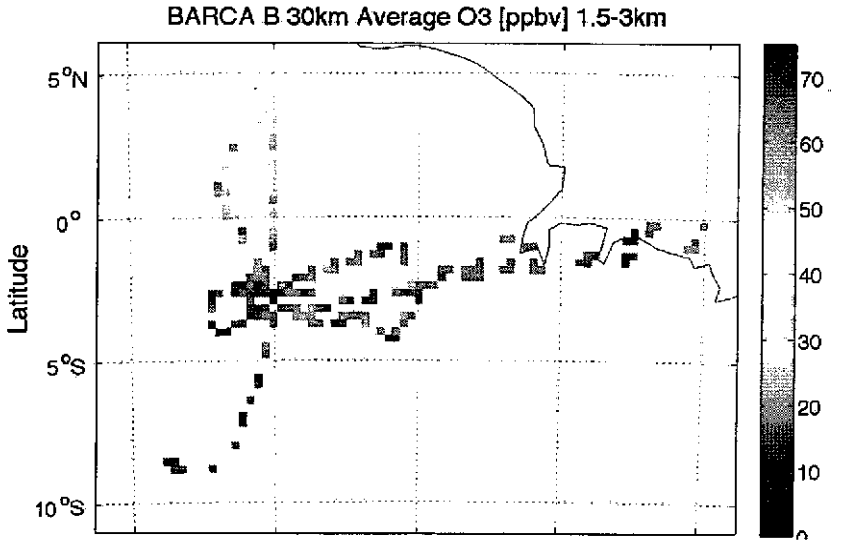

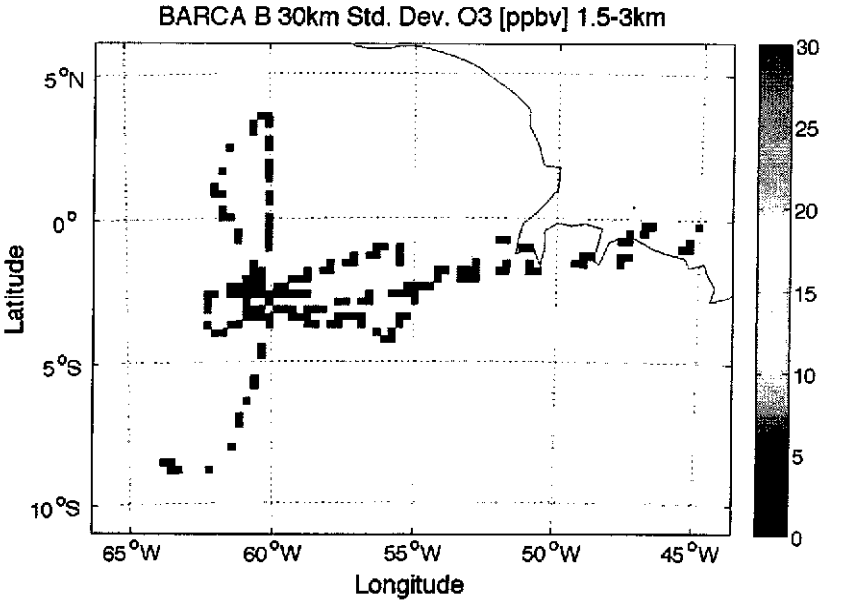

Ozone WRF Meteorology WRF Chemistry Emissions

BARCA Regional O_3 Distribution (3 – 4.5 km)

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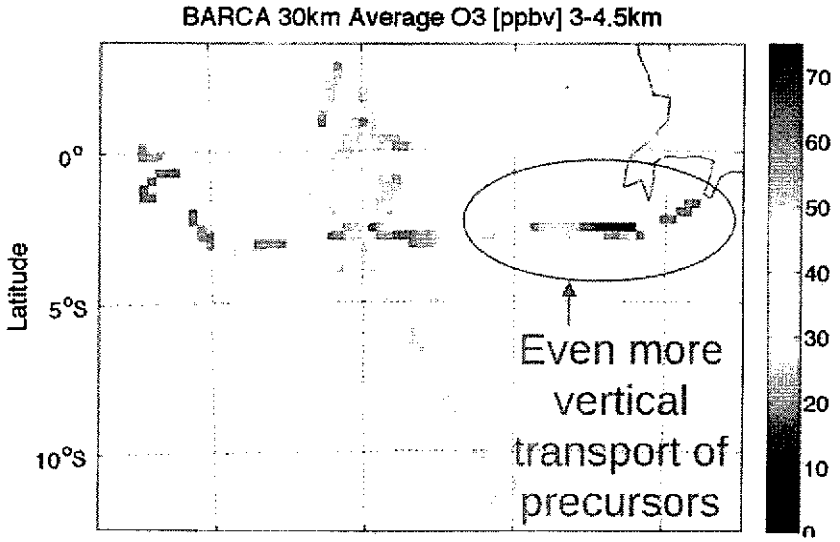

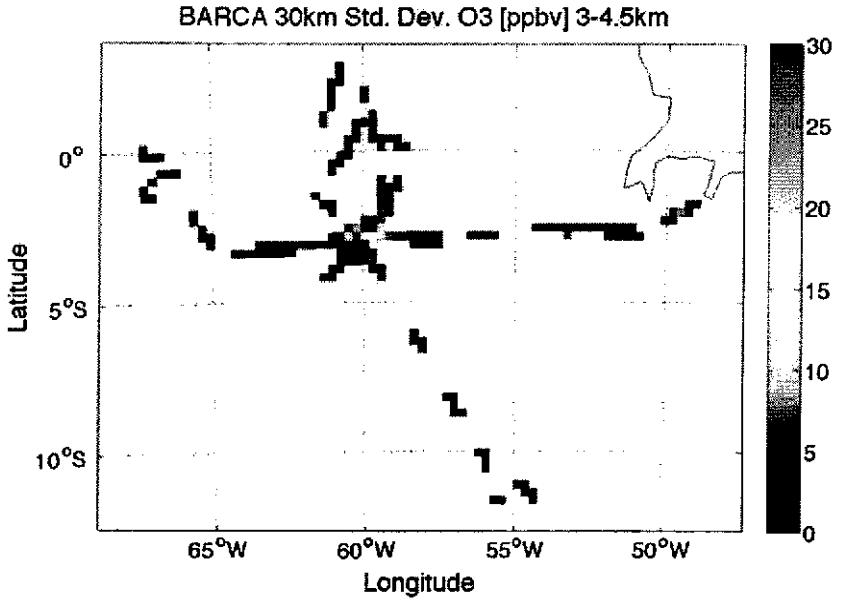

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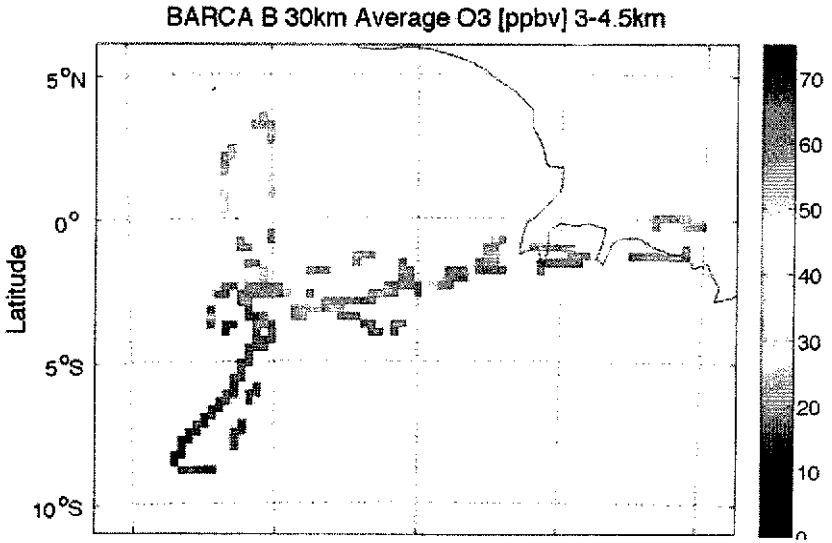
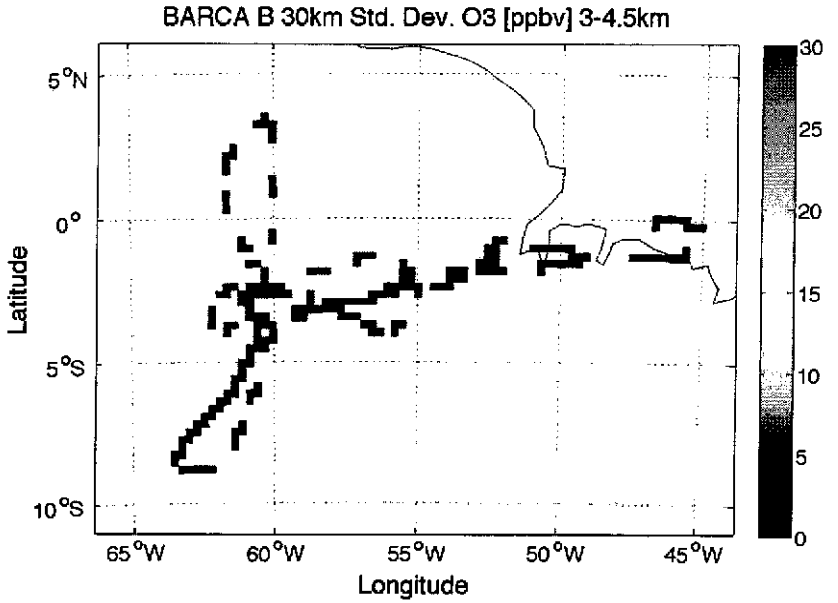




Ozone WRF Meteorology WRF Chemistry Emissions

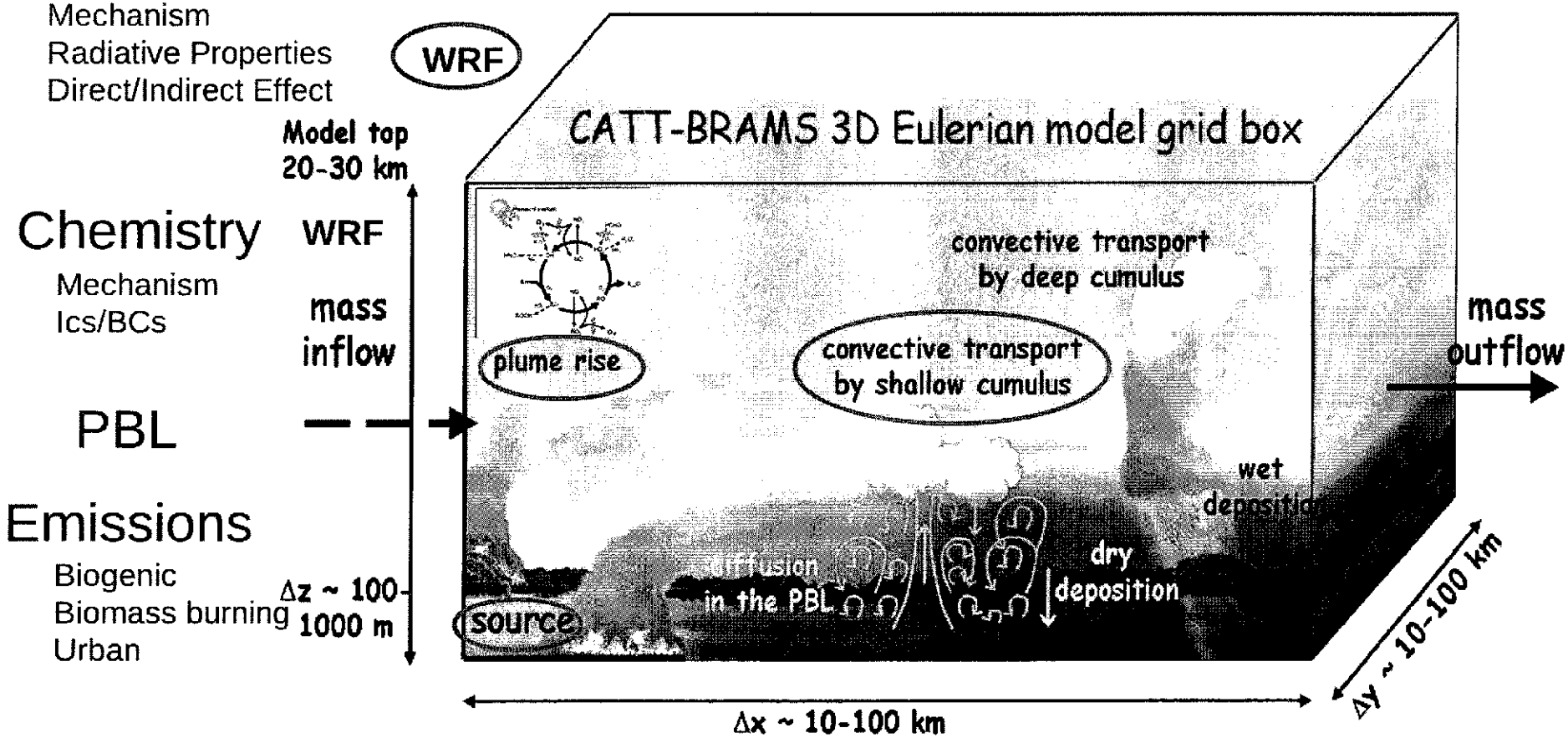
It's Complicated

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

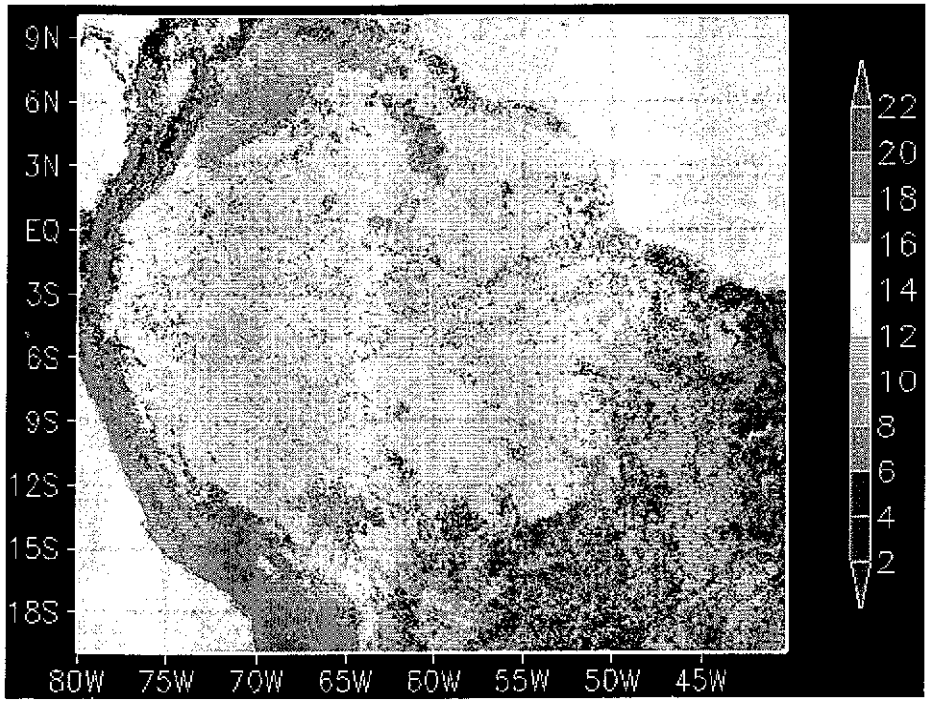


Land Surface Model

Land Surface Data
Vegetation Parameters
Soil Moisture Initialization

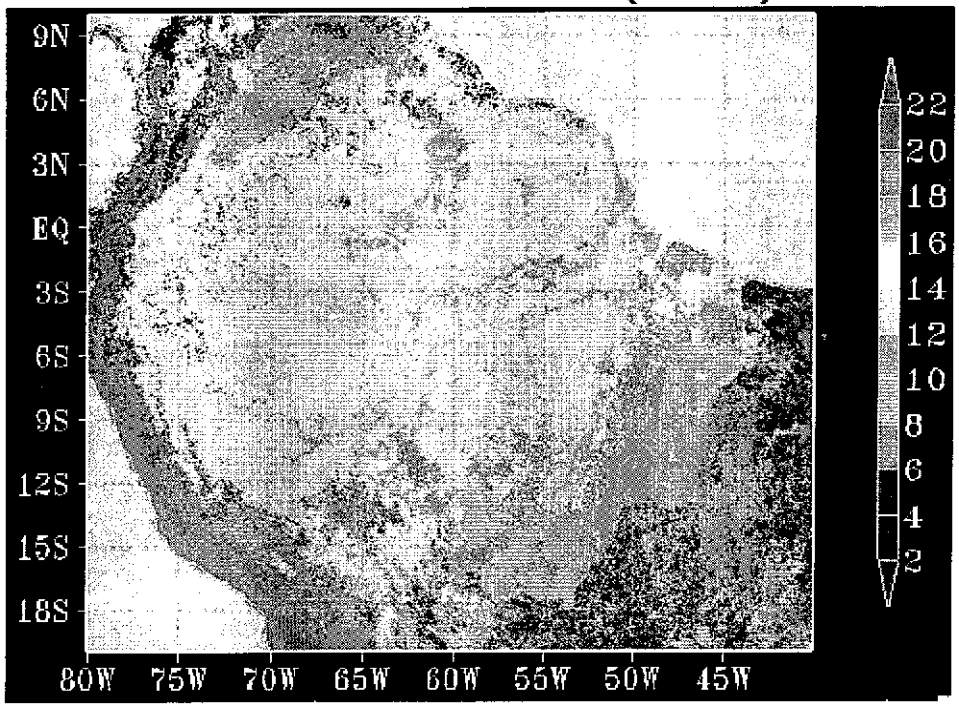
Updated Amazon Land Use Data

USGS Land Cover V.2



Global 1km AVHRR 1992-93

USGS + PROVEG (INPE)



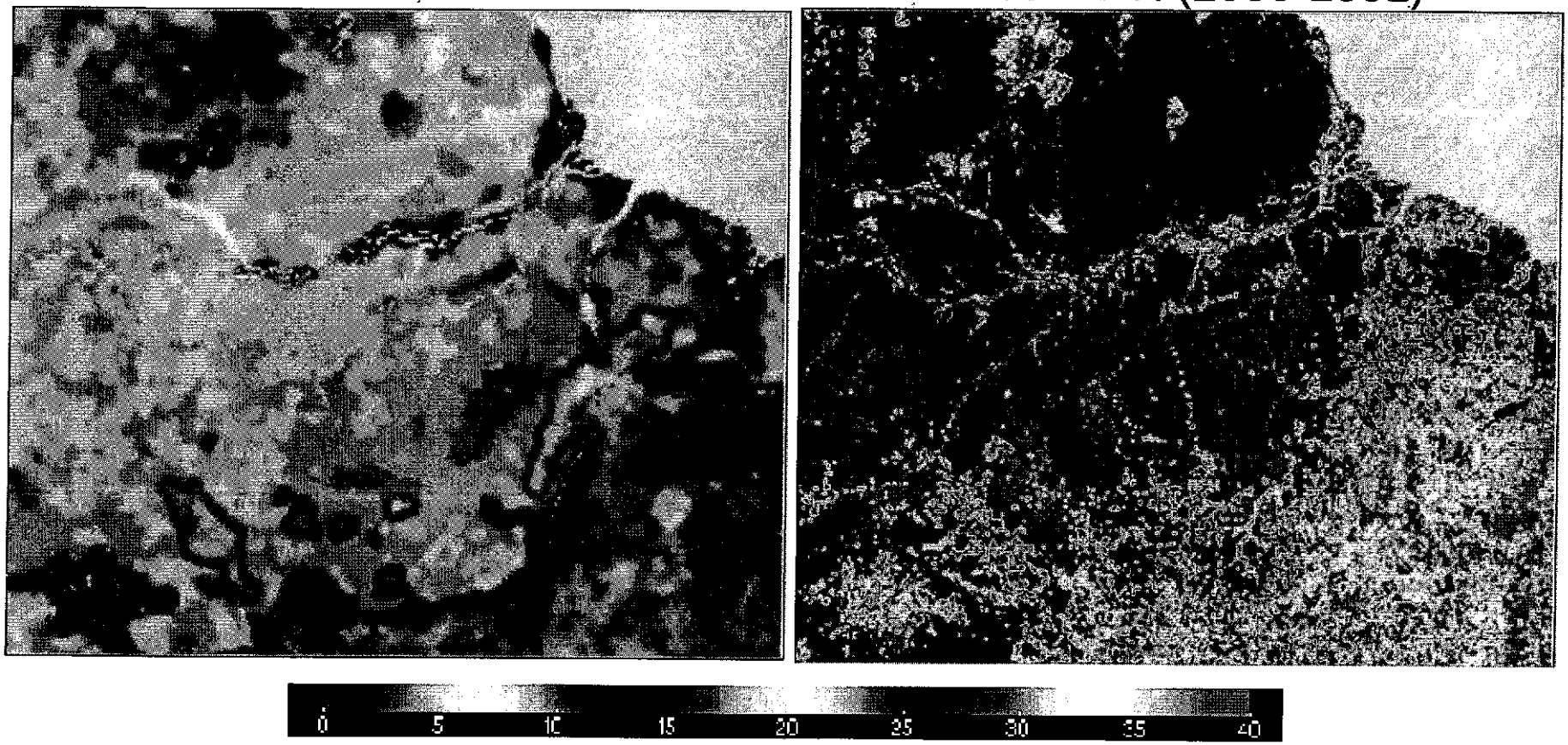
Amazon updated with 1km PROVEG from Landsat 2000-2001 (proveg.cptec.inpe.br)

grassland/pasture savanna

Updated Albedo (November)

NCEP 0.144º (1985-1993)

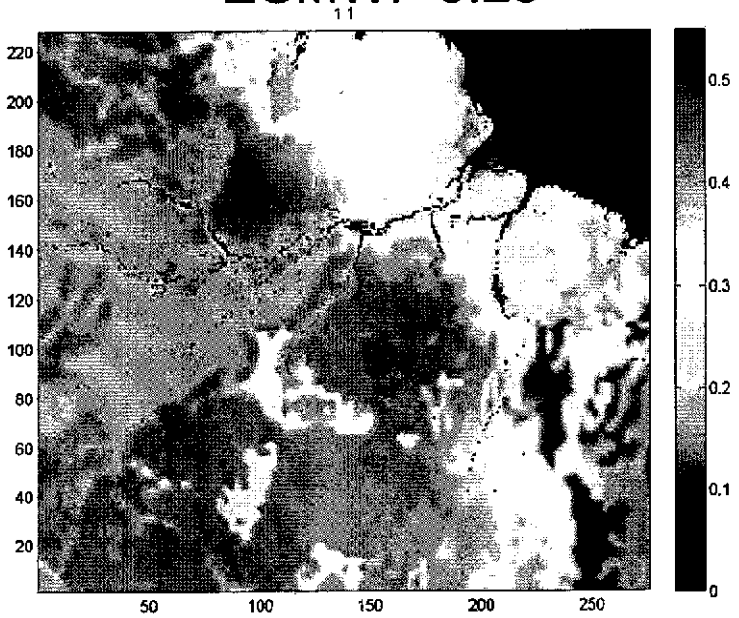
Estimated from 1km PROVEG and MODIS 30s NDVI (2000-2001)

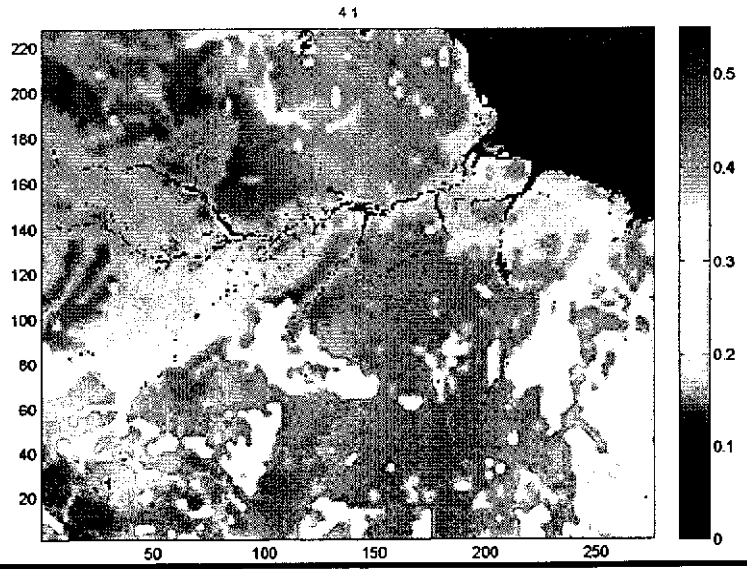


Observed (von Randow et al., 2004)
forest: 10-15
pasture/savanna: 18-22

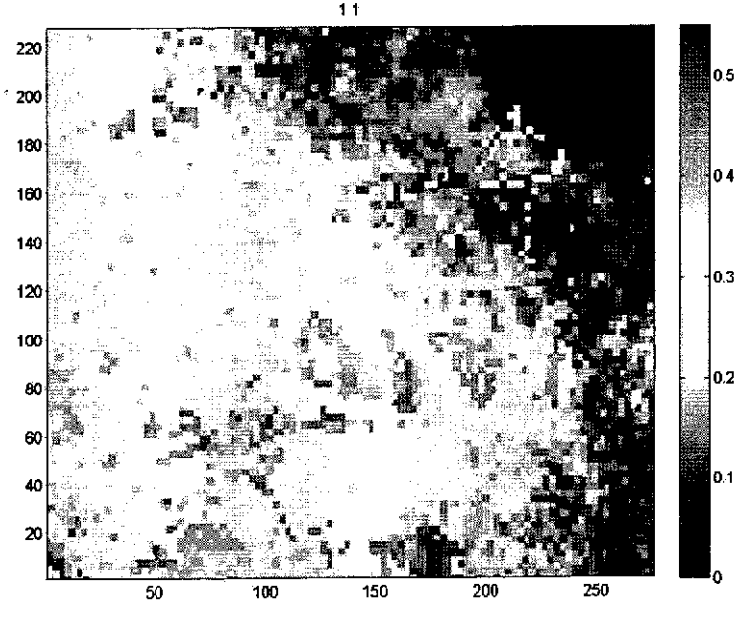
Soil Moisture Initialization – 1 Nov. 2008

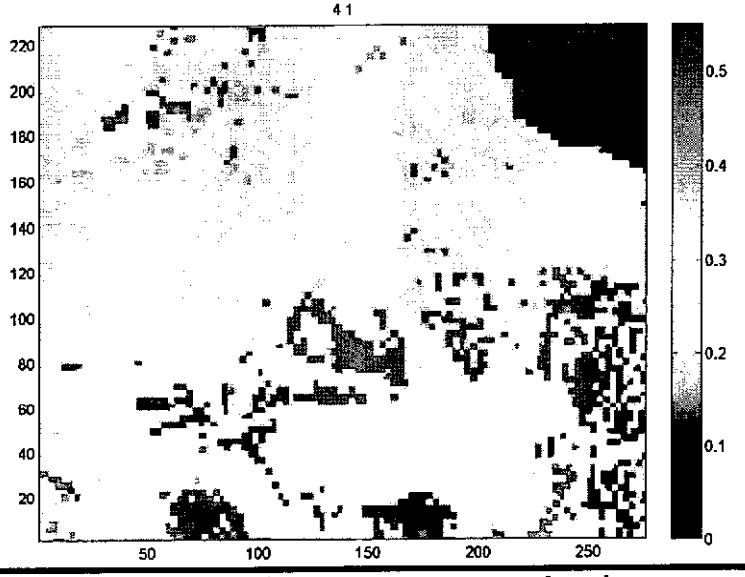
ECMWF 0.25°





GPNR 0.25°

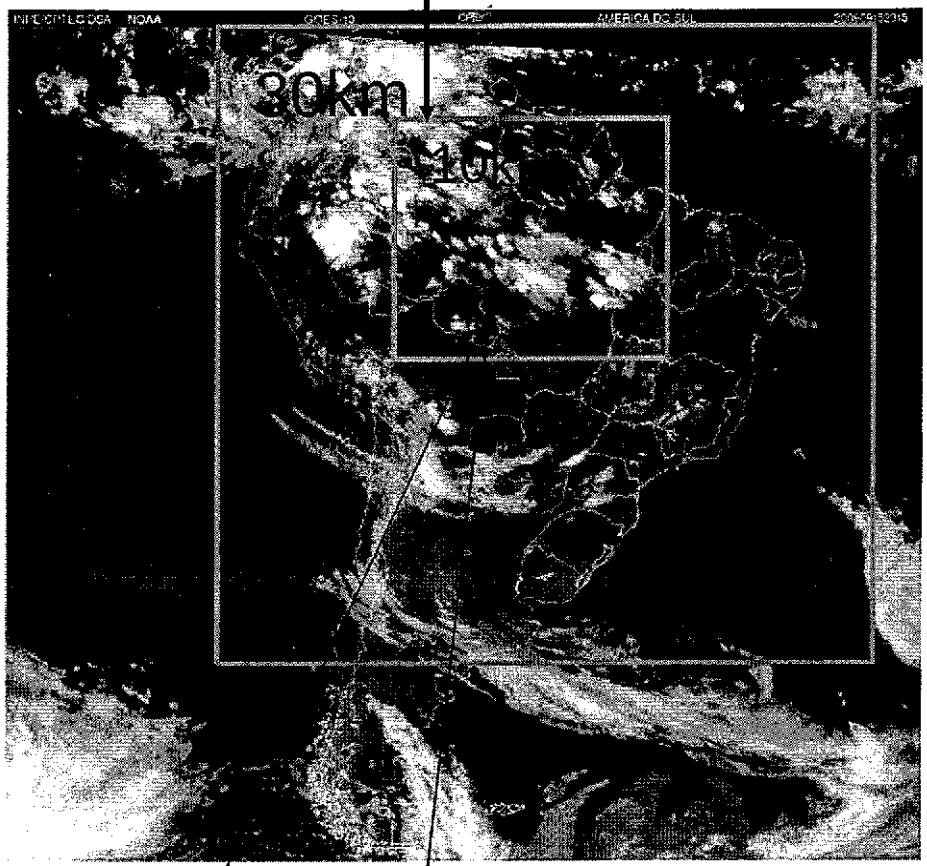




Ozone WRF Meteorology WRF Chemistry Emissions

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

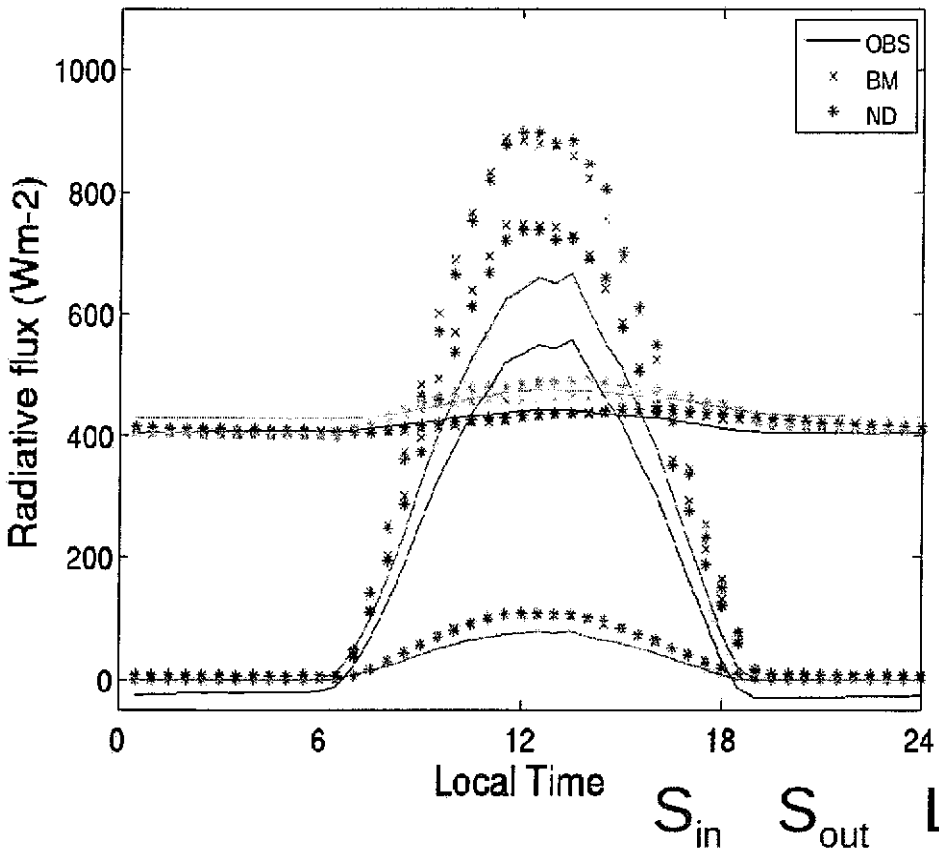
Observations:
LBA Flux Towers (30 min H, LH, R_n)
TRMM (0.25° 3hr accumulated precip)

Radiation Diurnal Cycle

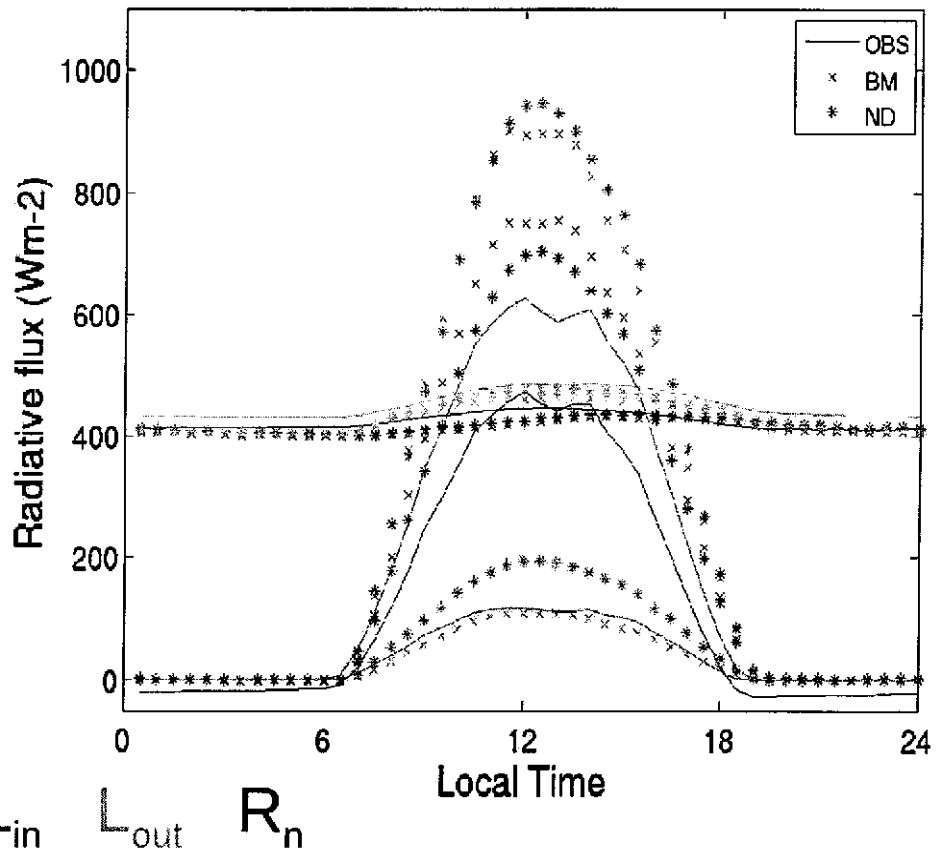
S_{in} too high -> R_n too high (missing cloud/aerosol effects?)

Everything else reasonable

Rebio Jarú (Forest)



FNS (Pasture)



S_{in} S_{out} L_{in} L_{out} R_n

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

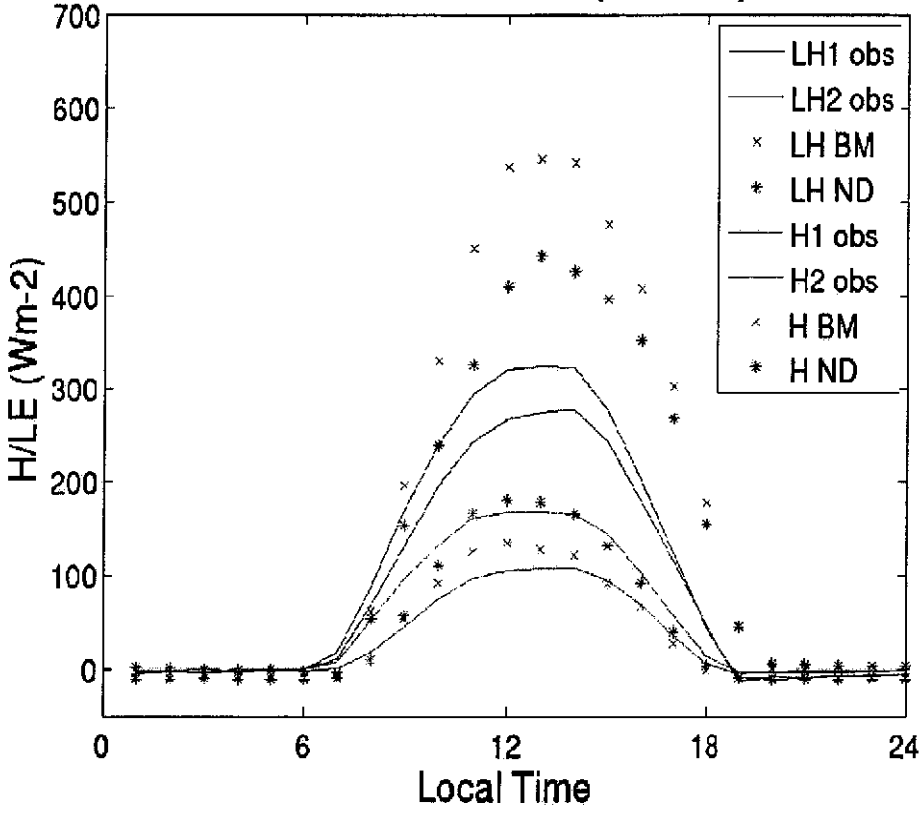
Simulated: A Very Wet Dry-to-Wet Transition (Nov-Dec 2008)

Heat Flux Diurnal Cycle

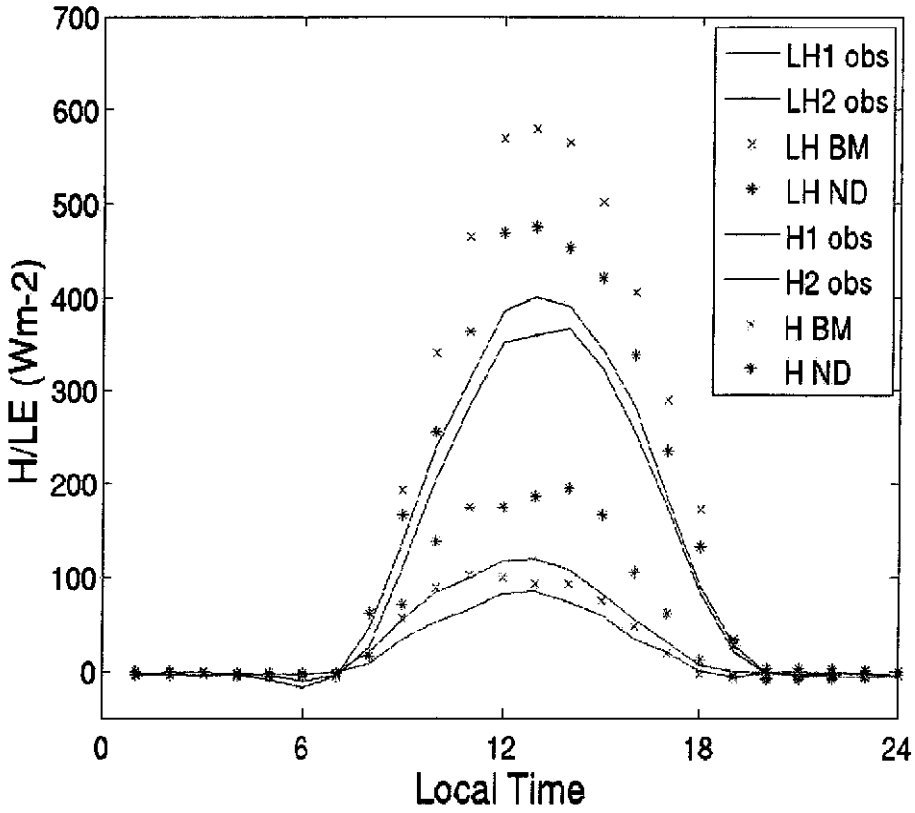
H reasonable, LH too high

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

Rebio Jarú (Forest)



FNS (Pasture)



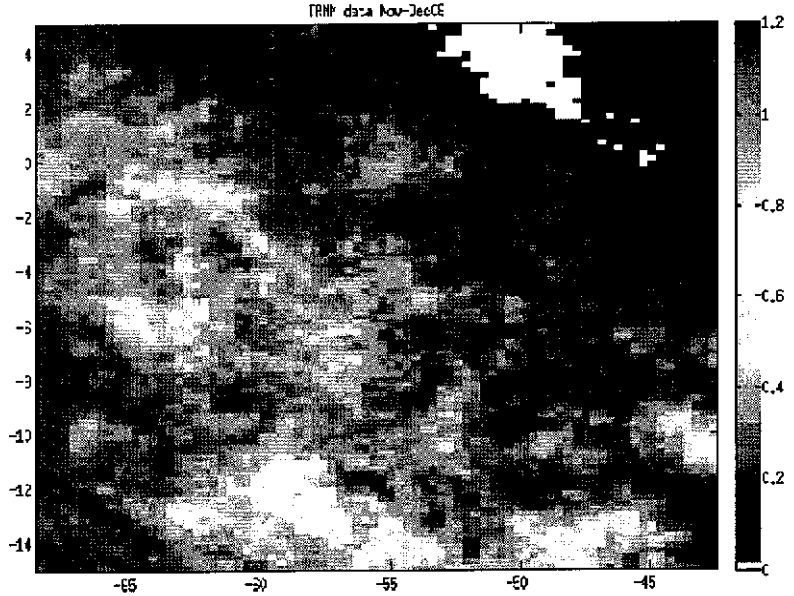
Observed: Wet Season (Jan-Mar 1999-2000)

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

Average Hourly Precipitation (mm hr^{-1})

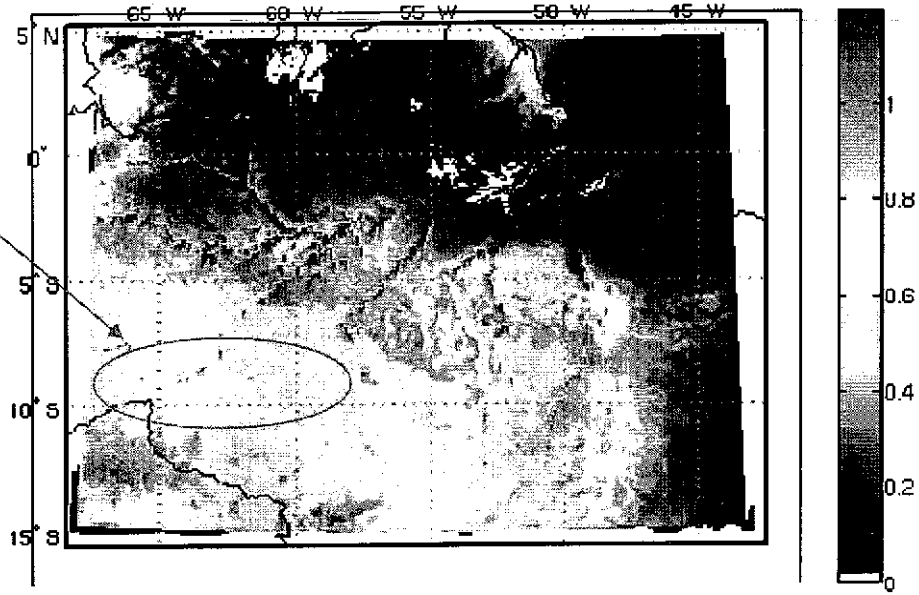
Nov-Dec 2008

TRMM 3B42 V6

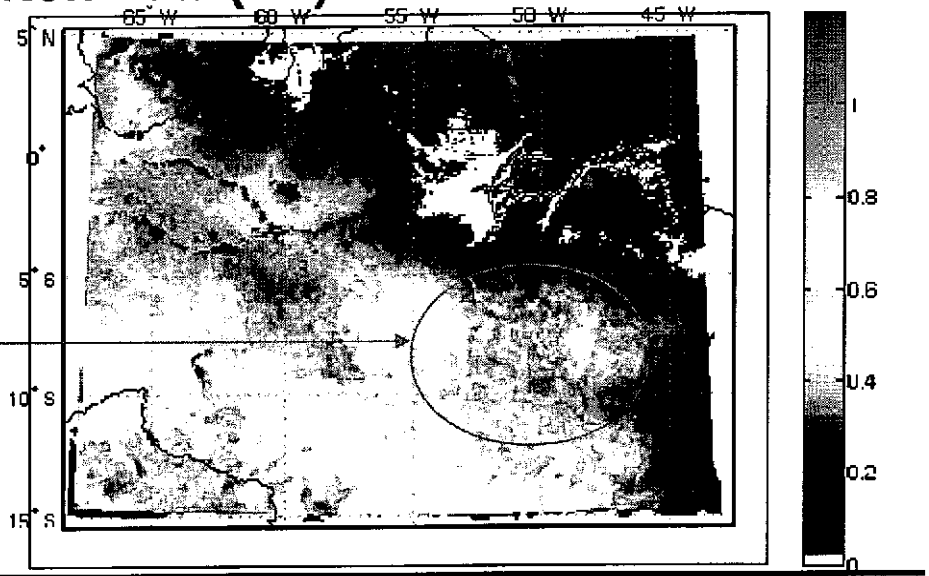


Excessive precip primarily in SW Amazon

Benchmark (BM)



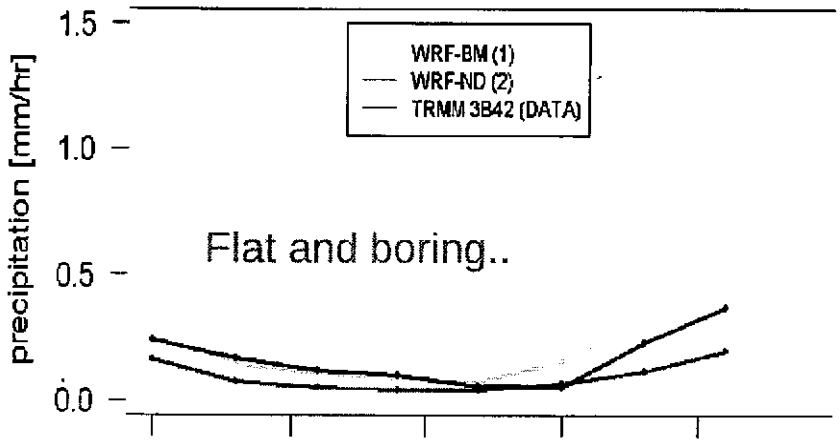
New Data (ND)



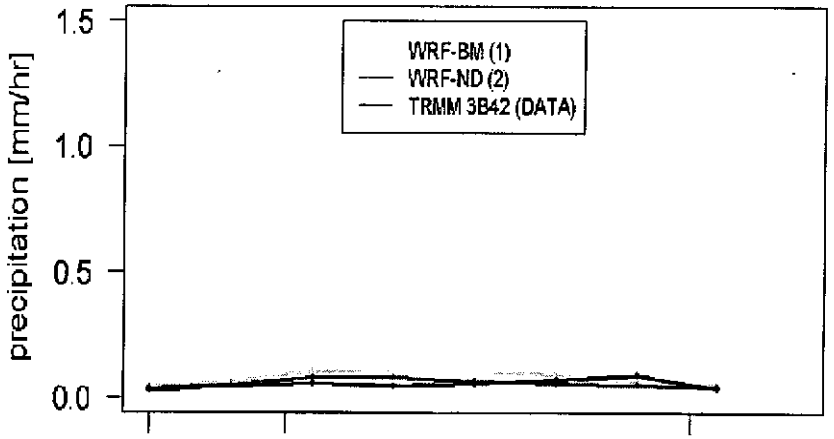
Reductions in SE with new land data

Precipitation Diurnal Cycle - NE

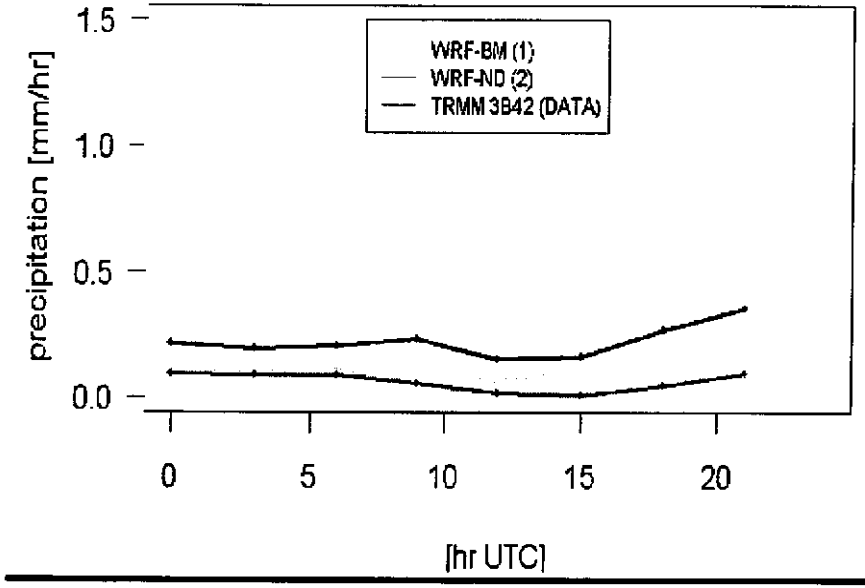
RAINC+RAINNC (WRF) vs. TRMM Box 3



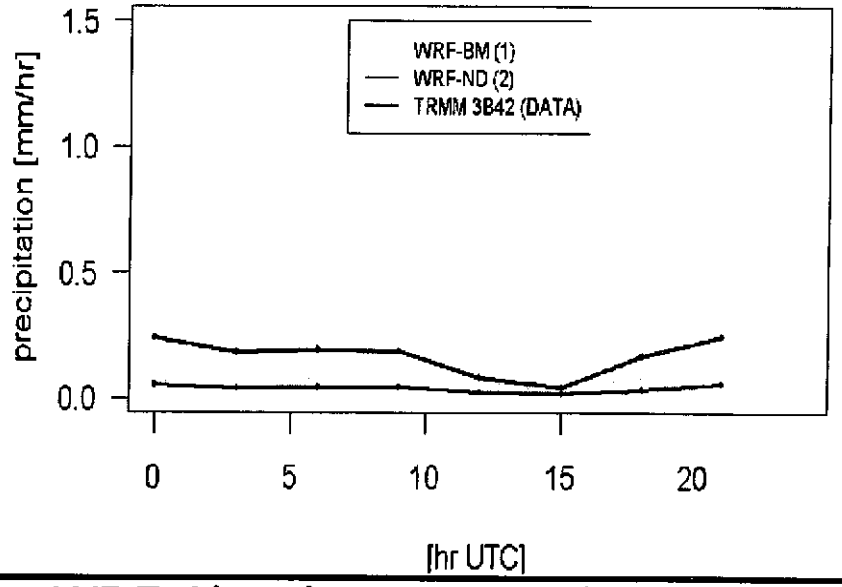
RAINC+RAINNC (WRF) vs. TRMM Box 4



RAINC+RAINNC (WRF) vs. TRMM Box 7

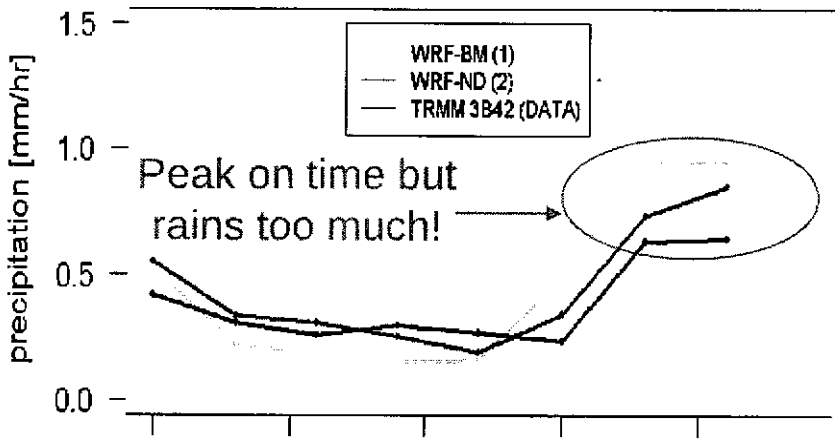


RAINC+RAINNC (WRF) vs. TRMM Box 8

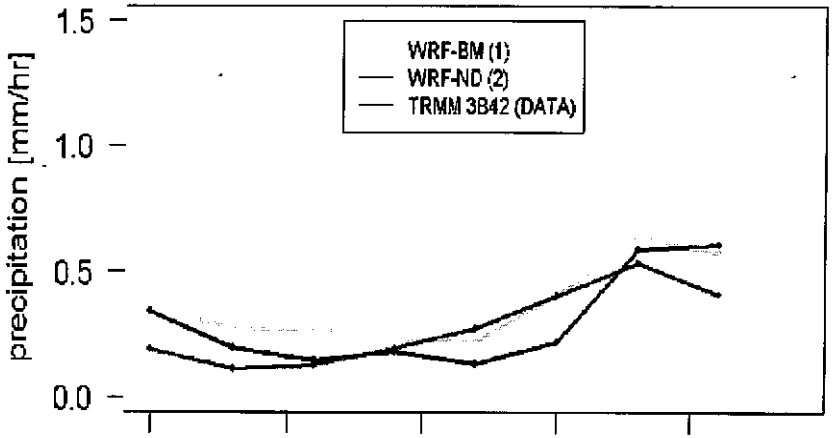


Precipitation Diurnal Cycle - SE

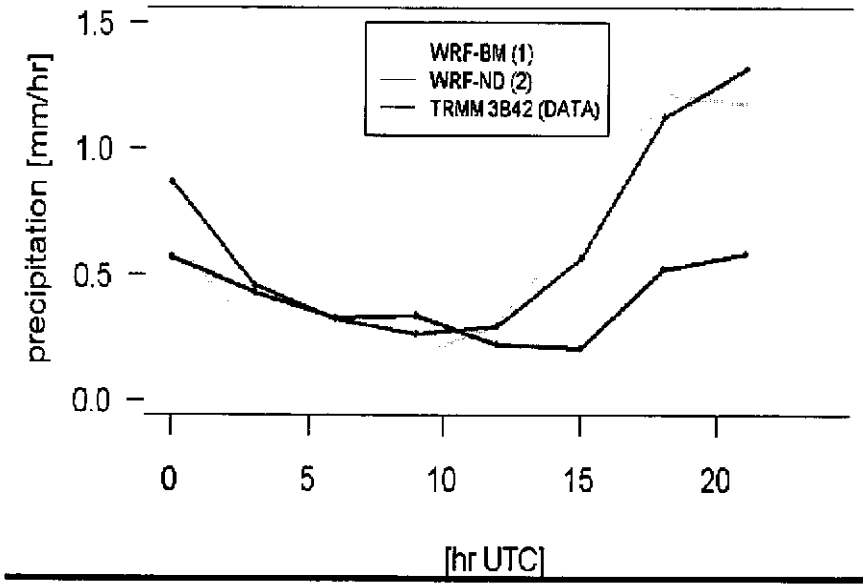
RAINC+RAINNC (WRF) vs. TRMM Box 11



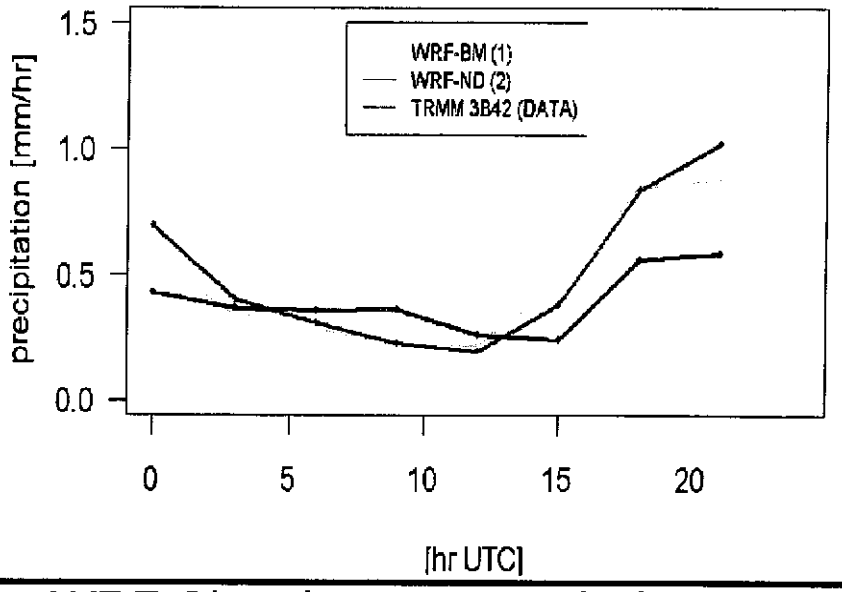
RAINC+RAINNC (WRF) vs. TRMM Box 12



RAINC+RAINNC (WRF) vs. TRMM Box 15

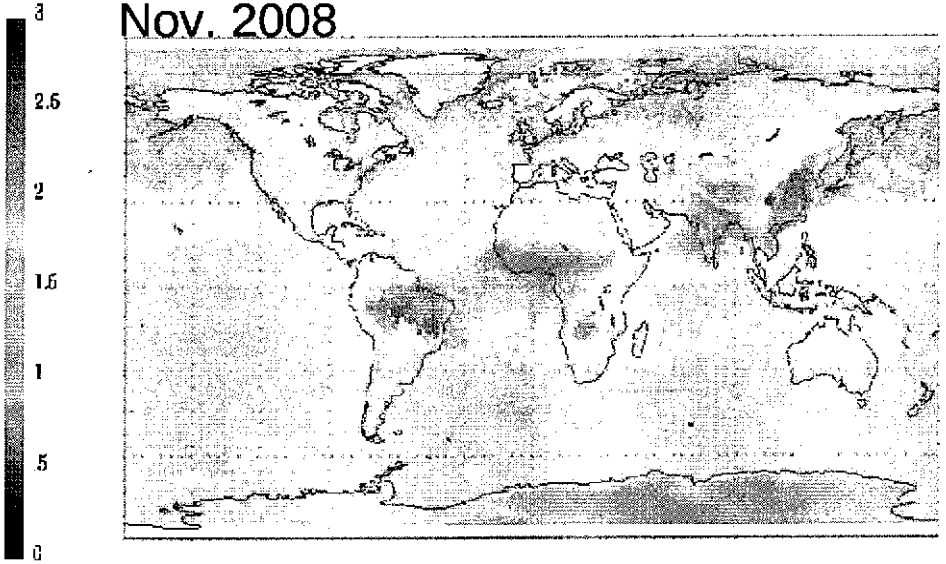


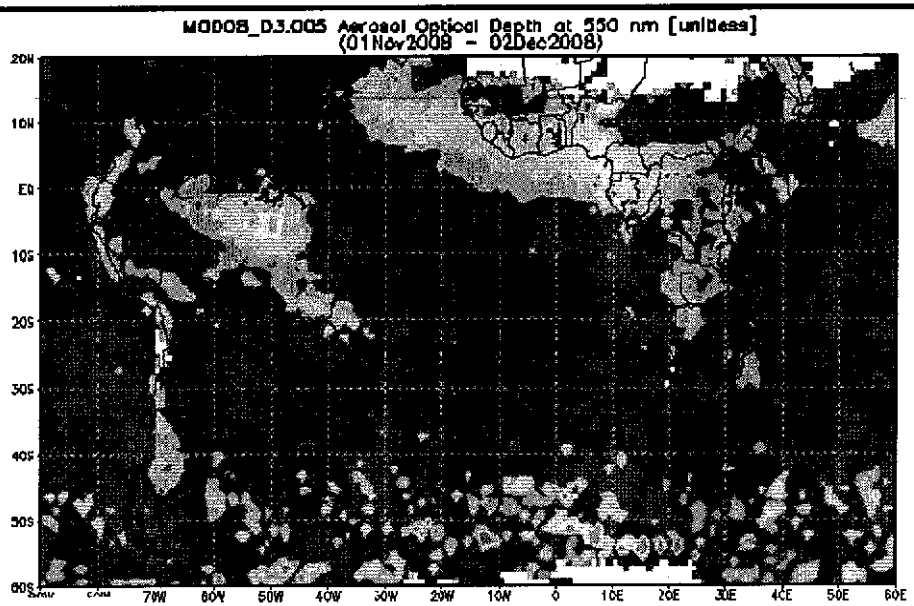
RAINC+RAINNC (WRF) vs. TRMM Box 16



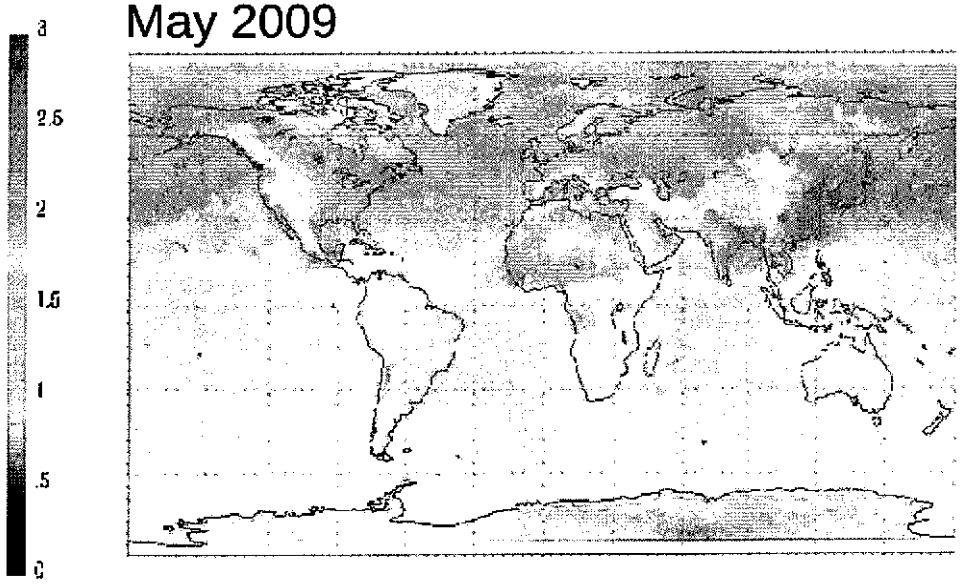
CO and AOD Satellite Data

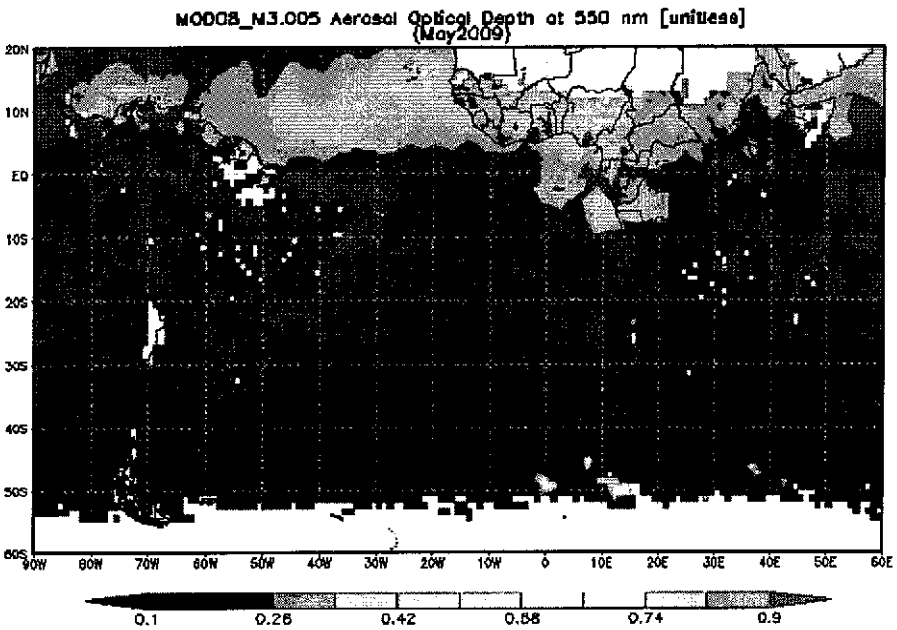
Nov. 2008





May 2009

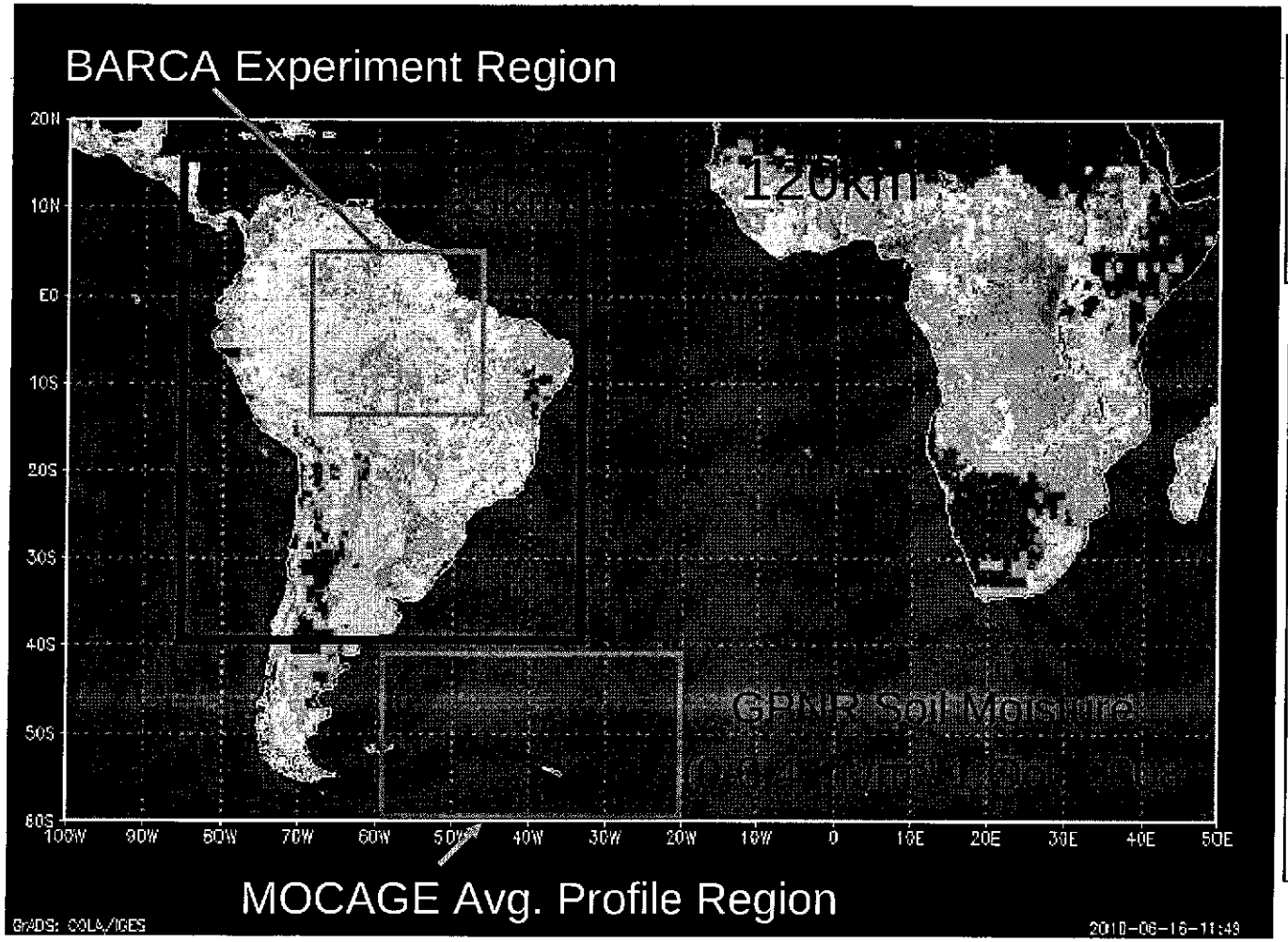




MOPITT CO Total Column (10^18 mol/cm^2)

Ozone WRF Meteorology WRF Chemistry Emissions

BARCA A WRF-Chem Simulations



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

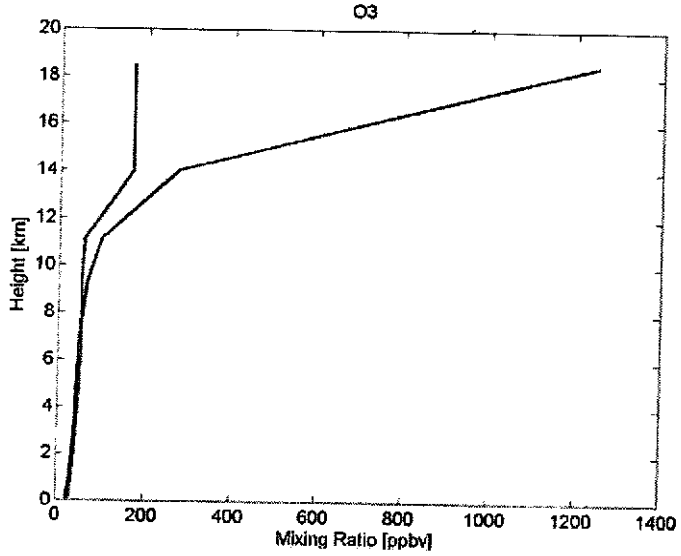
Chemistry: RACM-KPP
Aerosol: GOCART
Ics/BCs: GFS, MOCAGE clean average profiles

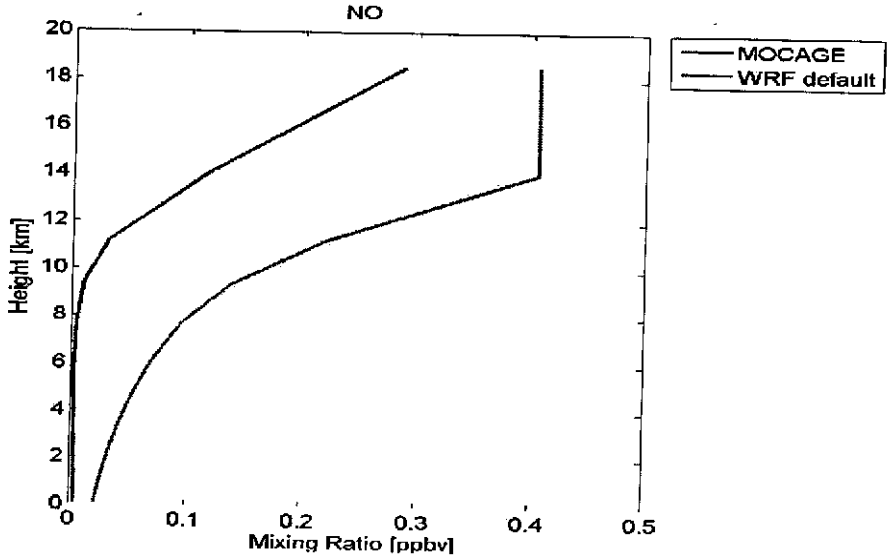
Observations:
In-situ: O_3, CO flight data
Satellite: OMI/MLS total tropospheric O_3,MOPITT 500hPa/total column CO, MODIS AOD

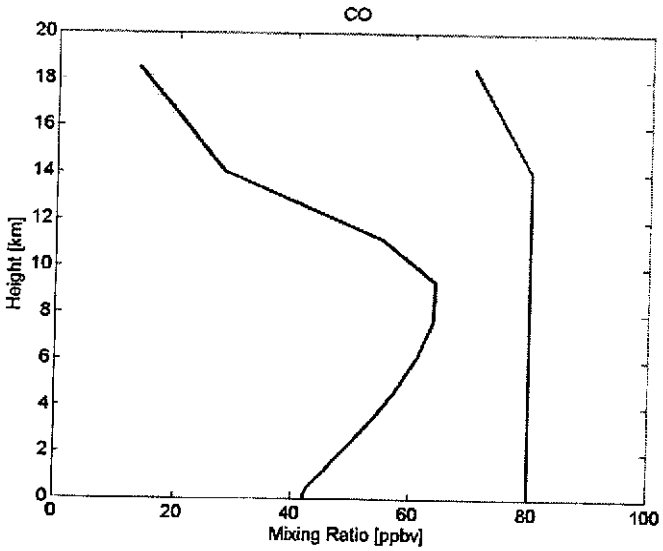
Ozone WRF Meteorology WRF Chemistry Emissions

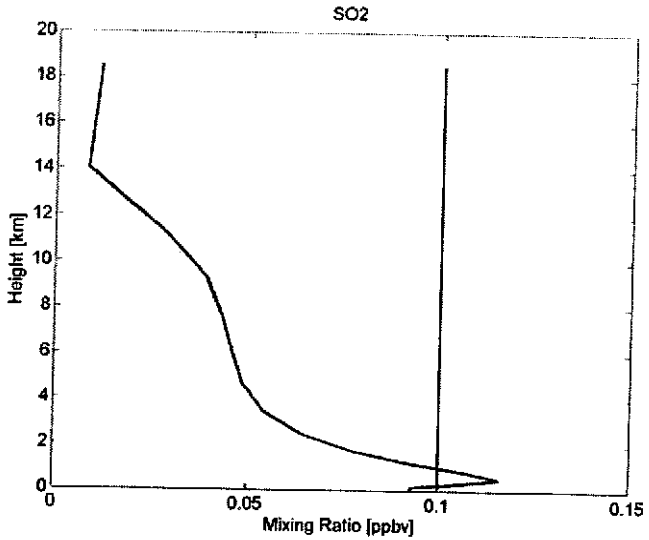
Chemistry Initial/Boundary Conditions

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





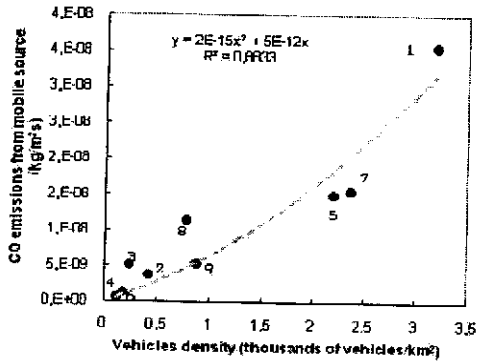


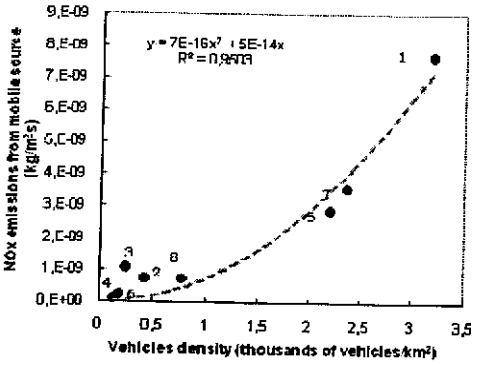


Ozone WRF Meteorology WRF Chemistry Emissions

Updated S. American Anthropogenic Emissions

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





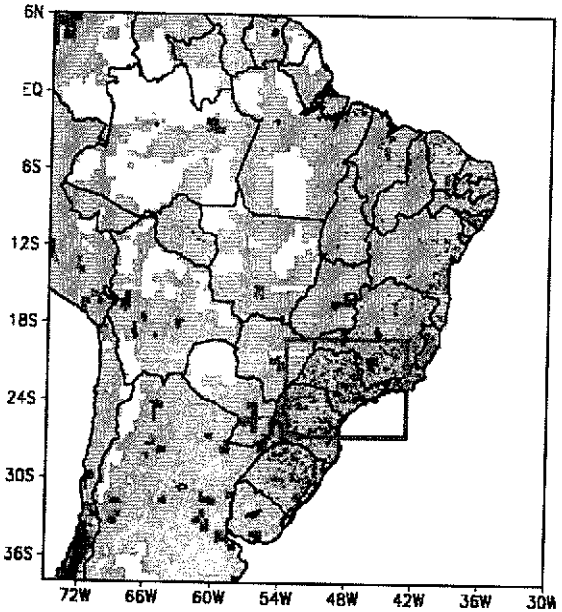
Brazil
1. Sao Paulo
2. Sorocaba
3. Campinas
4. Sao Jose dos Campos
5. Rio de Janeiro
6. Porto Alegre

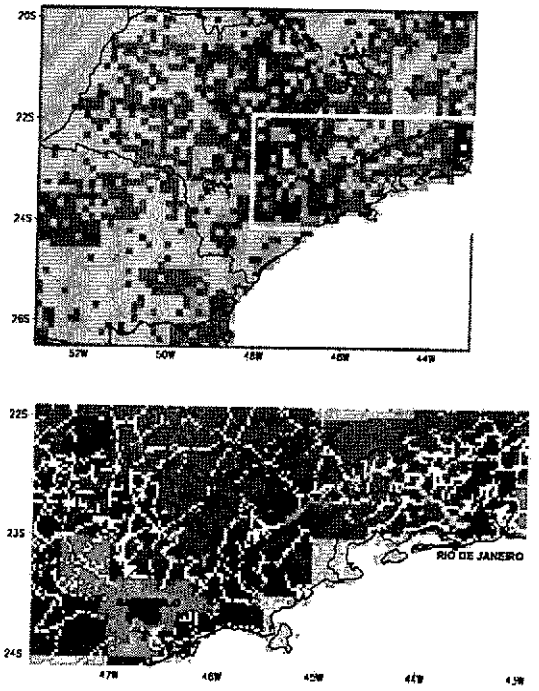
Chile
7. Santiago

8. Bogota

Argentina
9. Buenos Aires

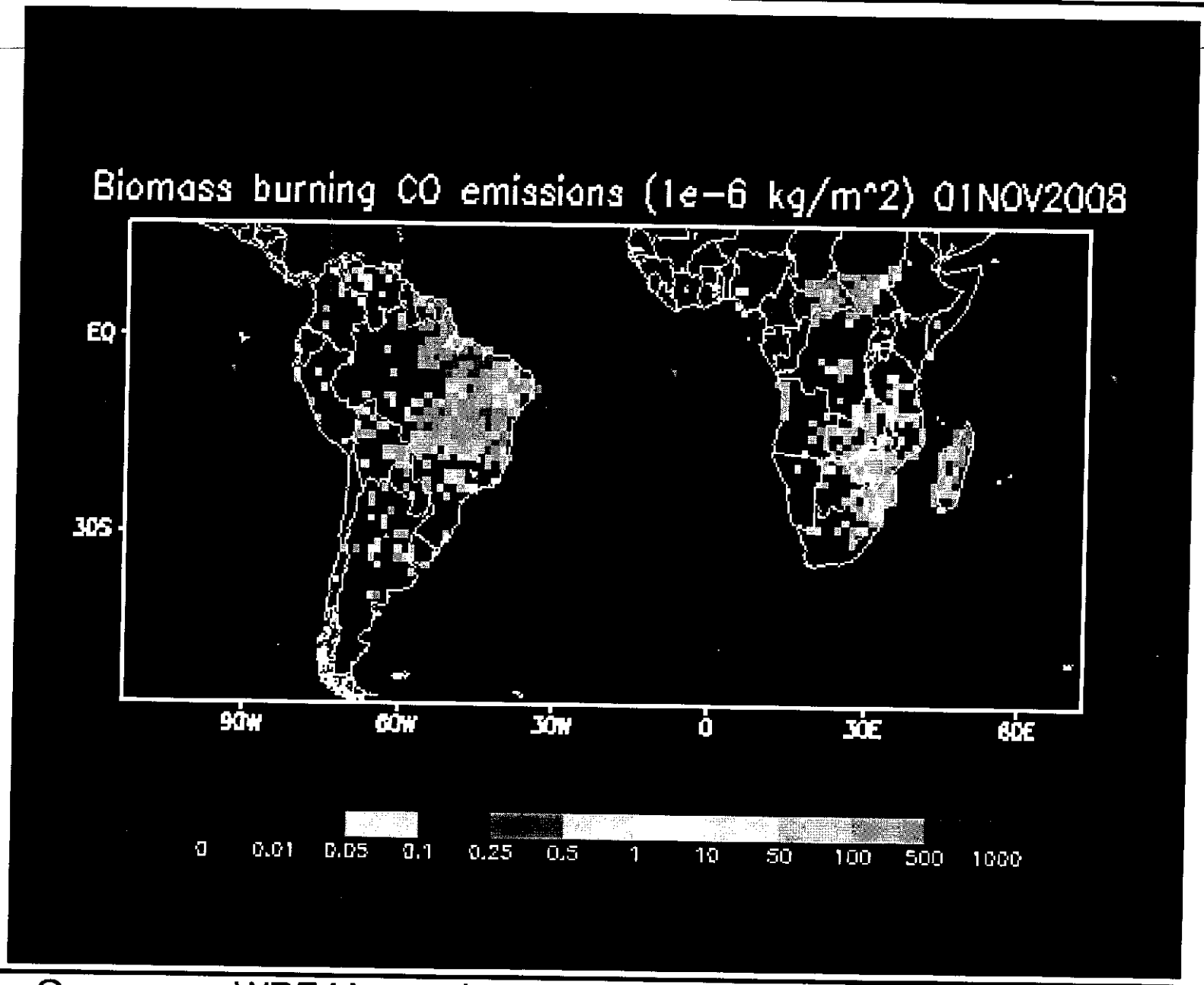
Updated CO emissions for São Paulo – Rio de Janeiro region on 5 km grid with addition of highway emissions





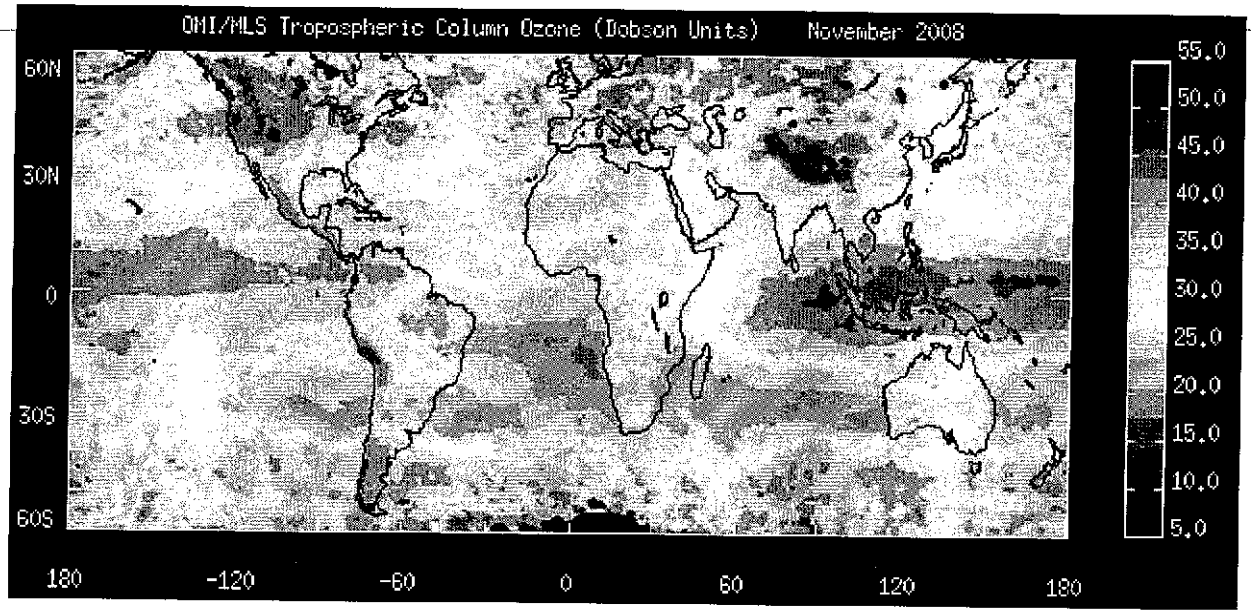
ALONSO, M. F.; LONGO, K.; FREITAS, S.; FONSECA R.; MARÉCAL V.; PIRRE M.; KLENNER L. An urban emissions inventory for South America and its application in numerical modeling of atmospheric chemical composition at local and regional scales. Atmos. Environm. Under review.

BARCA A Biomass Burning Emissions



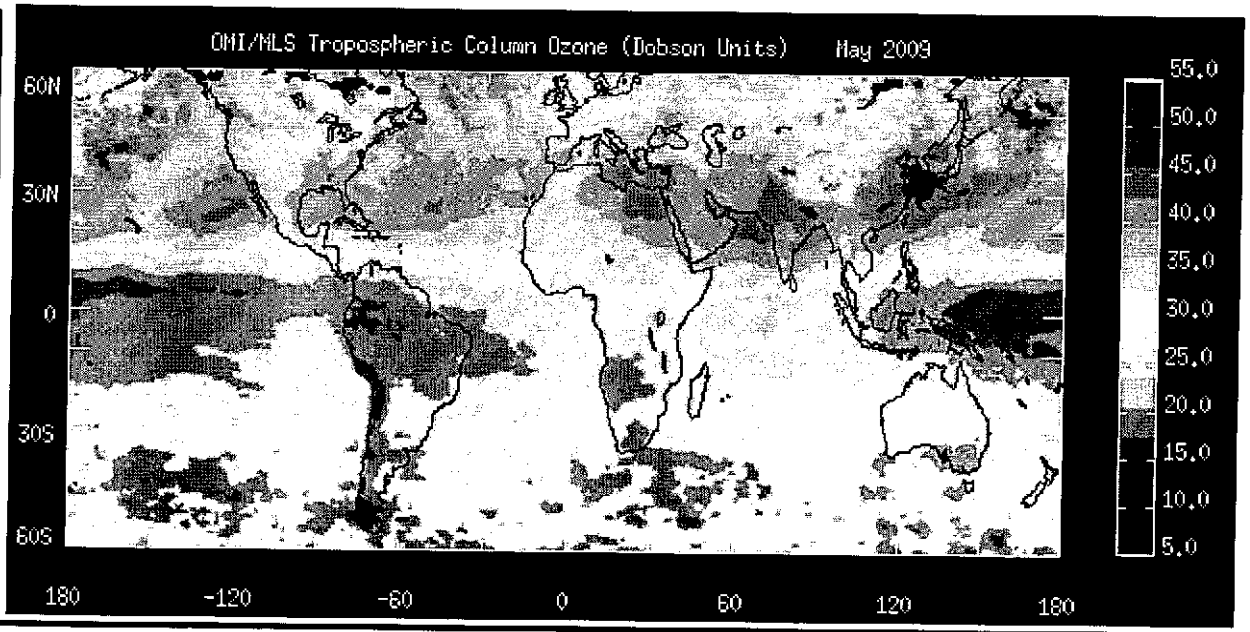
Ozone WRF Meteorology WRF Chemistry Emissions

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)



Ozone WRF Meteorology WRF Chemistry Emissions