Impact of tropical fires on the diurnal cycle of the tropospheric CO_2 concentration as seen from NOAA-10

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March 2006

Biomass burning emissions

Biomass burning is a key component of the global budgets of many radiatively and chemically active gases : CO_2, CH_4, N_2O, tropospheric O_3, and aerosols

Carbon emissions in Gt C / year	
Fossil fuel	**Tropical fires**
5.6	**2.0 to 3.2***

Estimates vary but biomass burning contributes up to: 40% of gross atmospheric CO_2 (IPCC, 2001), 38% of tropospheric O_3, 10 % of CH_4

CO_2 emissions resulting from burning forests converted to nonforests areas are largely net fluxes. Burning of savanna is largely balanced by the re-growth

Recent studies suggest that biomass burning could be a key contributor of the CO_2 interannual variability (*Schimel and Baker*, 2002; *Langenfelds et al.*, 2002; *Rodenbeck et al.*, 2003)

***van der Werf et al. (2005)**

Biomass Burning in the Tropics : Main Cycles

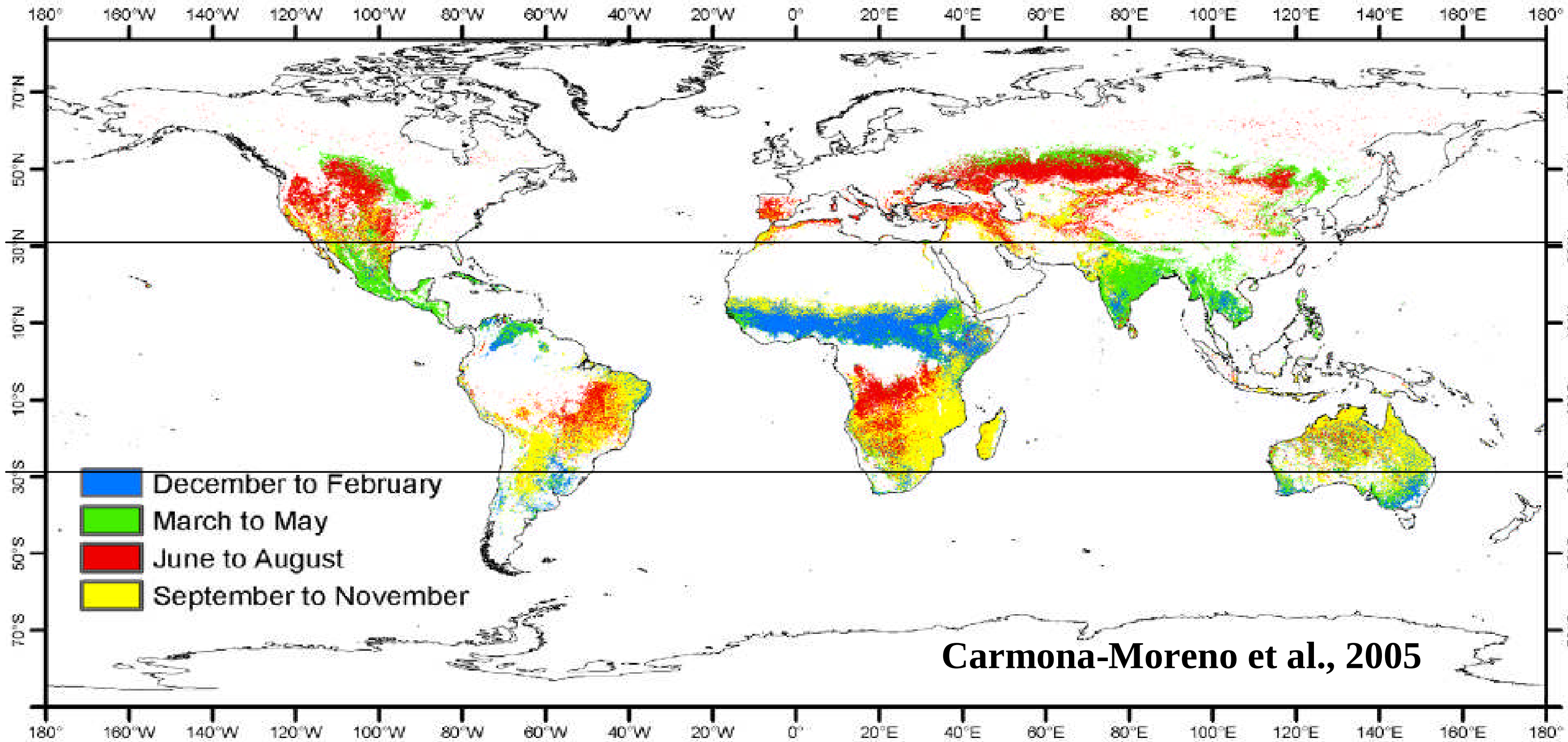
Biomass burning activity is seasonal :

- Occurs in the winter of each hemisphere (dry season)

- Lasts approximately 3 - 4 months ; longer in the southern hemisphere

- Peaks in December (NH) and ~in July (SH)

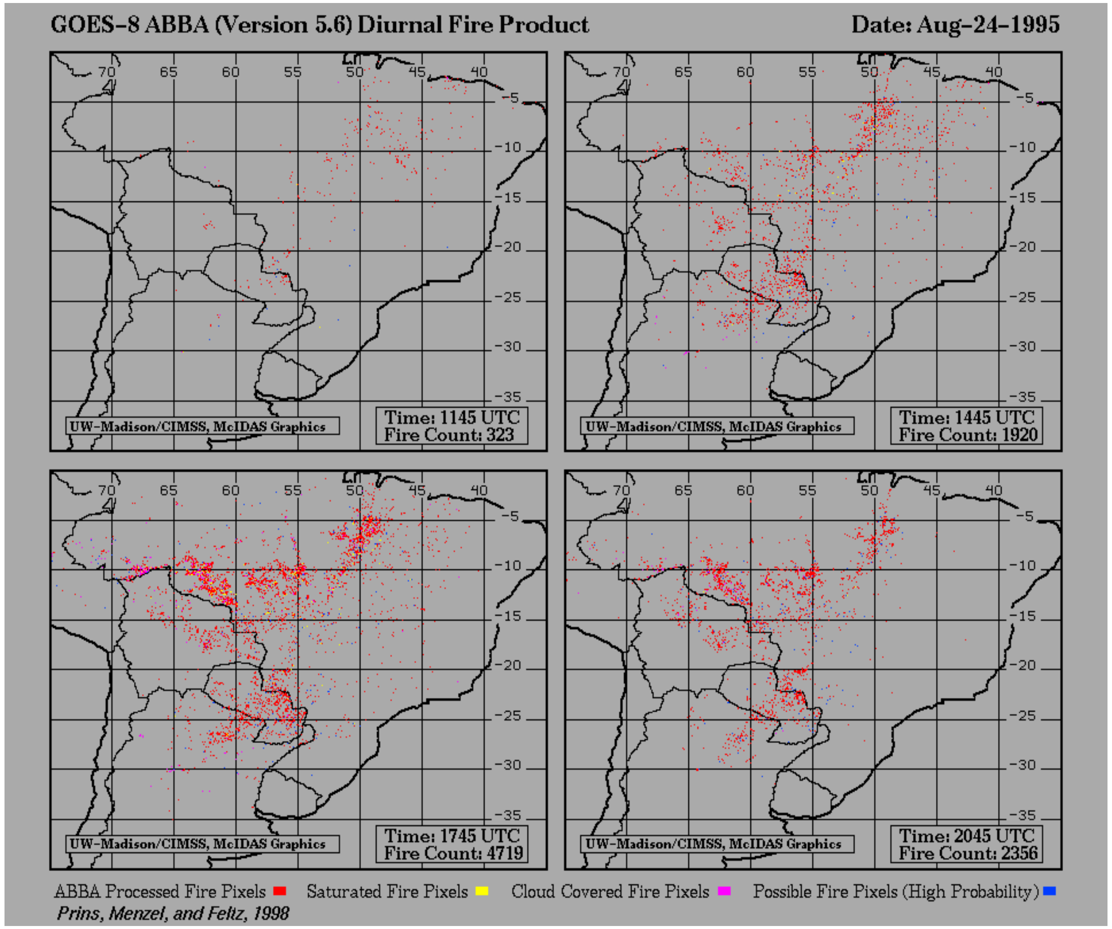
Global fire (burn scars) activity seasonal cycle (1982-1999)



Biomass Burning in the Tropics : Main Cycles

Diurnal variability of the number of fire pixels detected (ex: 1995 burning season): strong peak at ~ 14-16 h (LT)

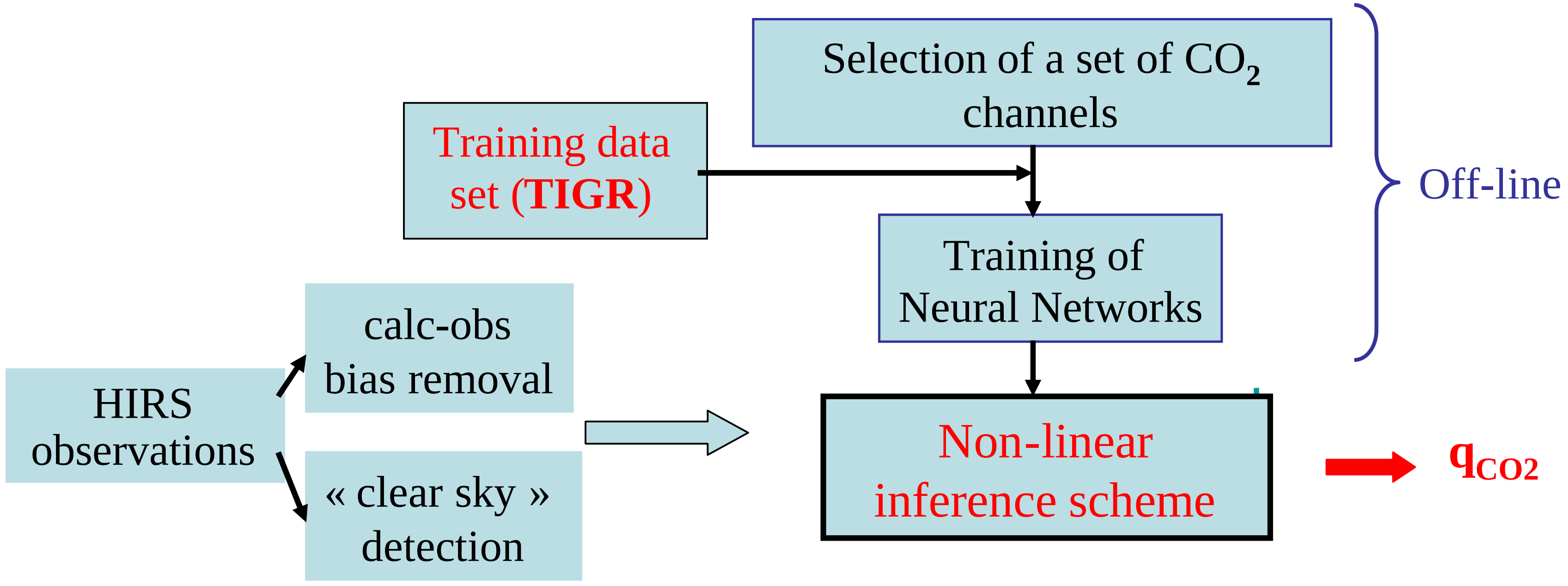
The number of fires detected at ~14h30 (LT) is from 3 to 4 times larger than 3h after or before and about 20 times larger than the number of fires detected 6h before



Prins et al., JGR, 1998

Good match with NOAA « morning » platforms
- **observation of a polluted troposphere at 19h30 (LT)**
- **observation of a clean troposphere at 7h30 (LT)**

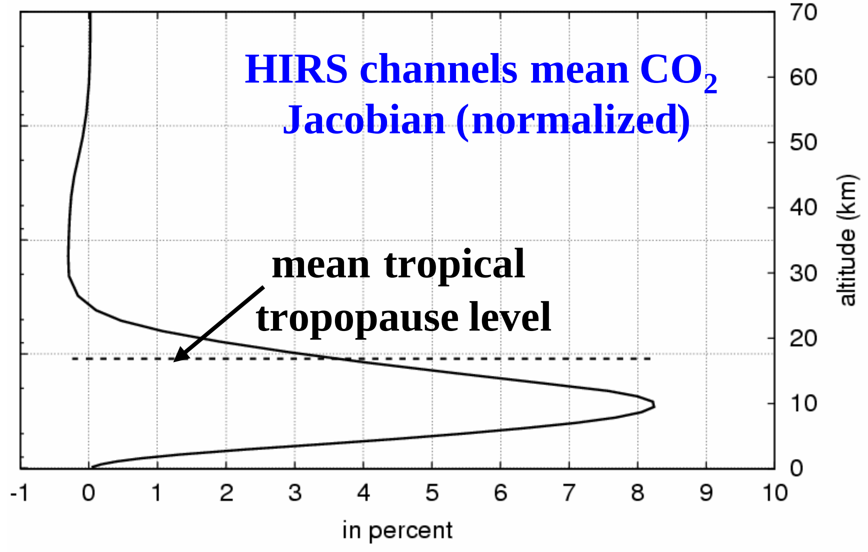
General features of the CO_2 column retrieval scheme : non-linear regressions



About five years of NOAA-10 observations analyzed (1987-1991)

The « Night minus Day Difference (N-DD) » product

1. HIRS channels are sensitive to variations of CO_2 in the mean to upper troposphere

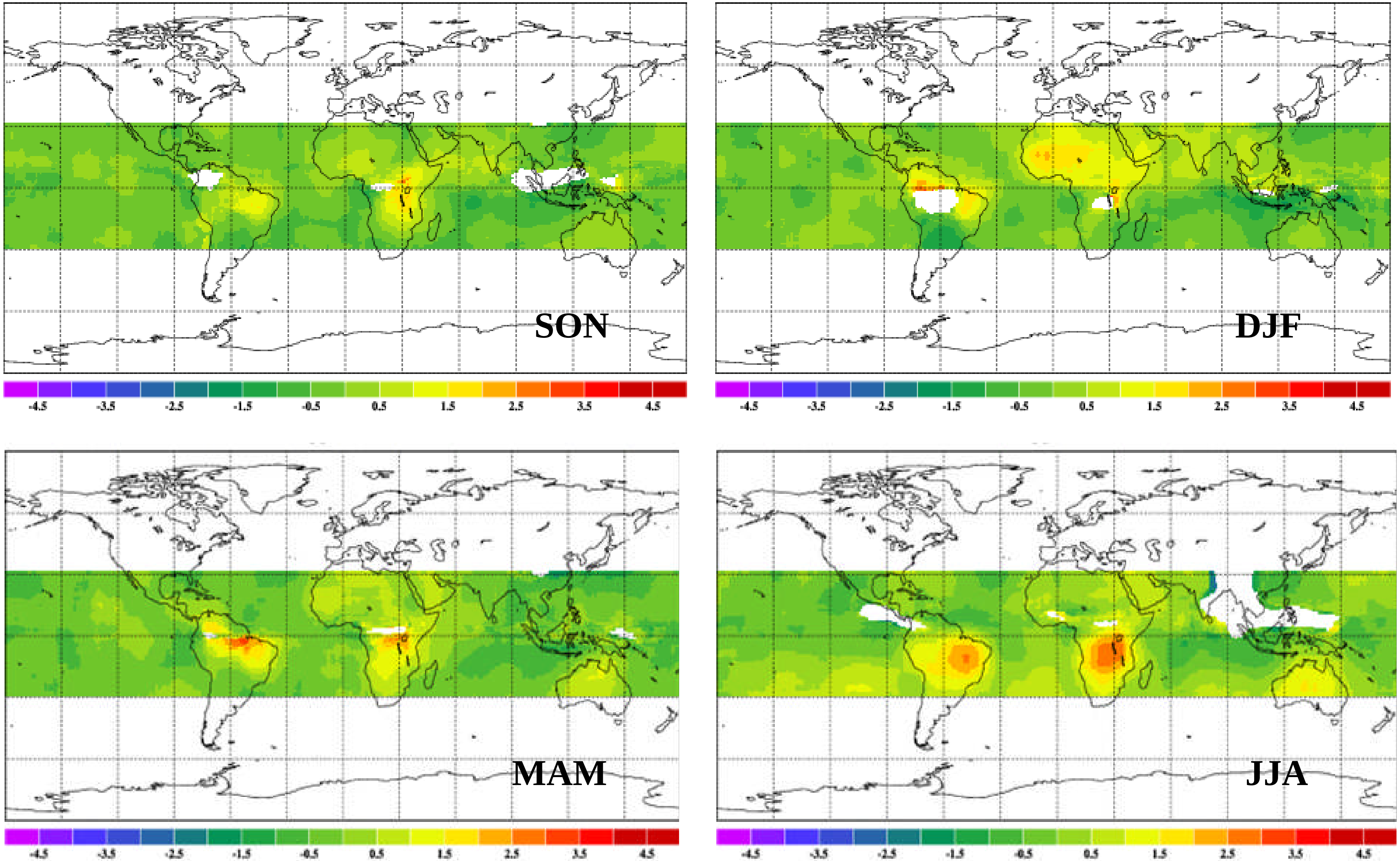


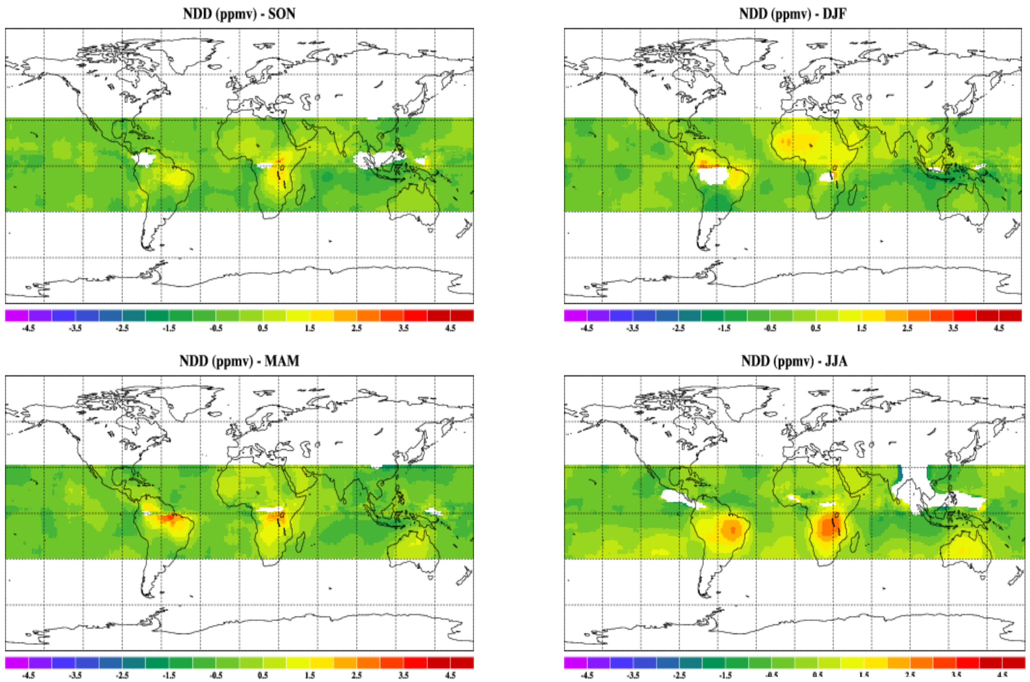
2. From NOAA-10, CO_2 columns may be retrieved at 0730 (day) and 1930 (night), local time

Here, we analyze the difference between nighttime and daytime retrievals (N-DD) over the period January 1987-August 1991

4-year seasonal mean N-DD (7.30 pm minus 7.30 am LT) over the tropics (20N-20S) January 1987-December 1991 retrieved from NOAA-10

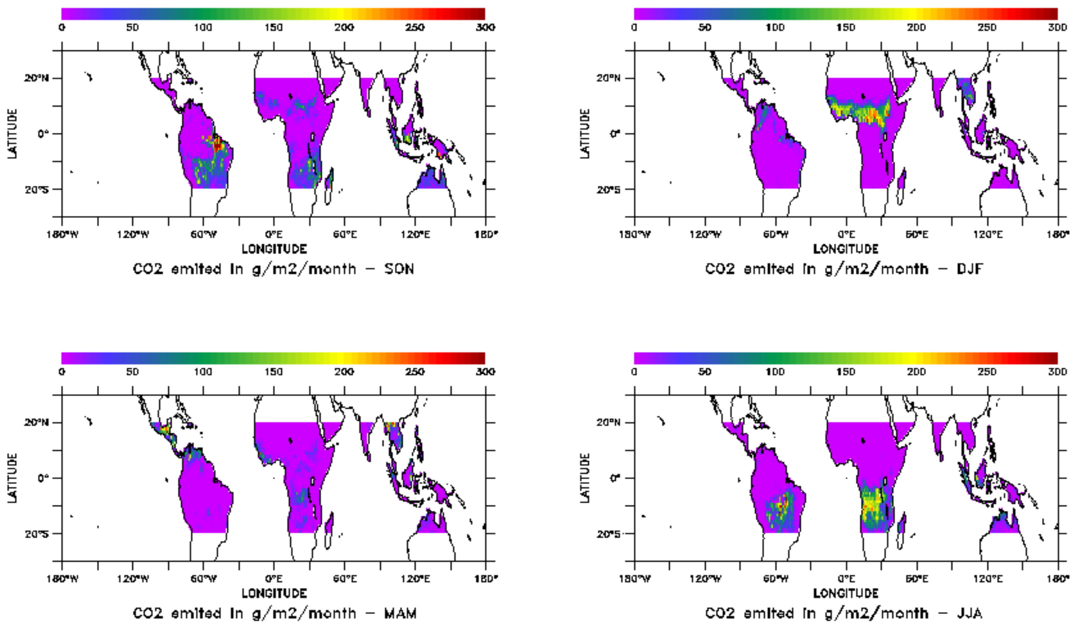
Spatial resolution: 15°x15°, 1° by 1° moving average (ppm)



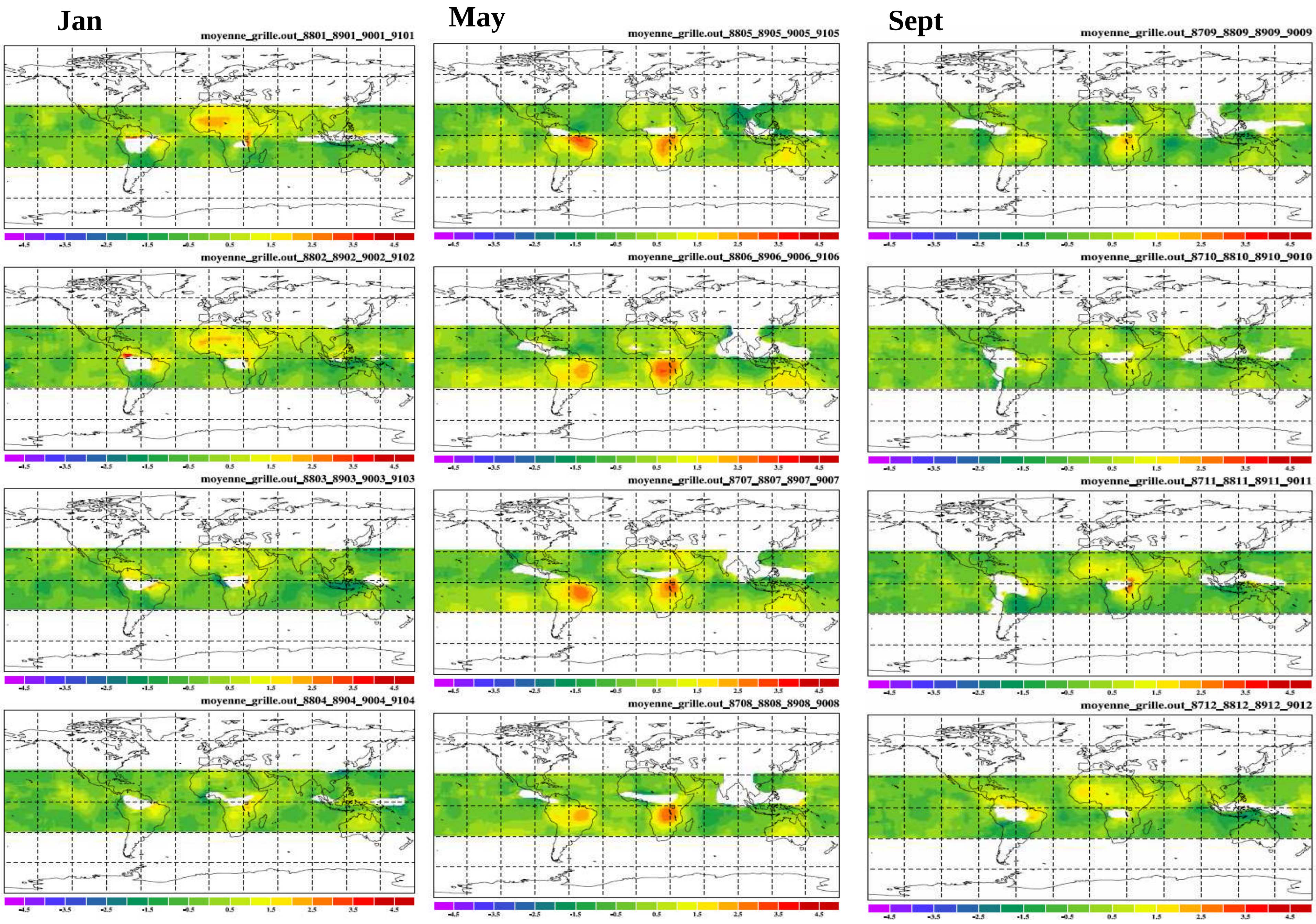


Seasonal mean N-DD
(July 1987-June 1991)
15°x15°
1° by 1° moving average

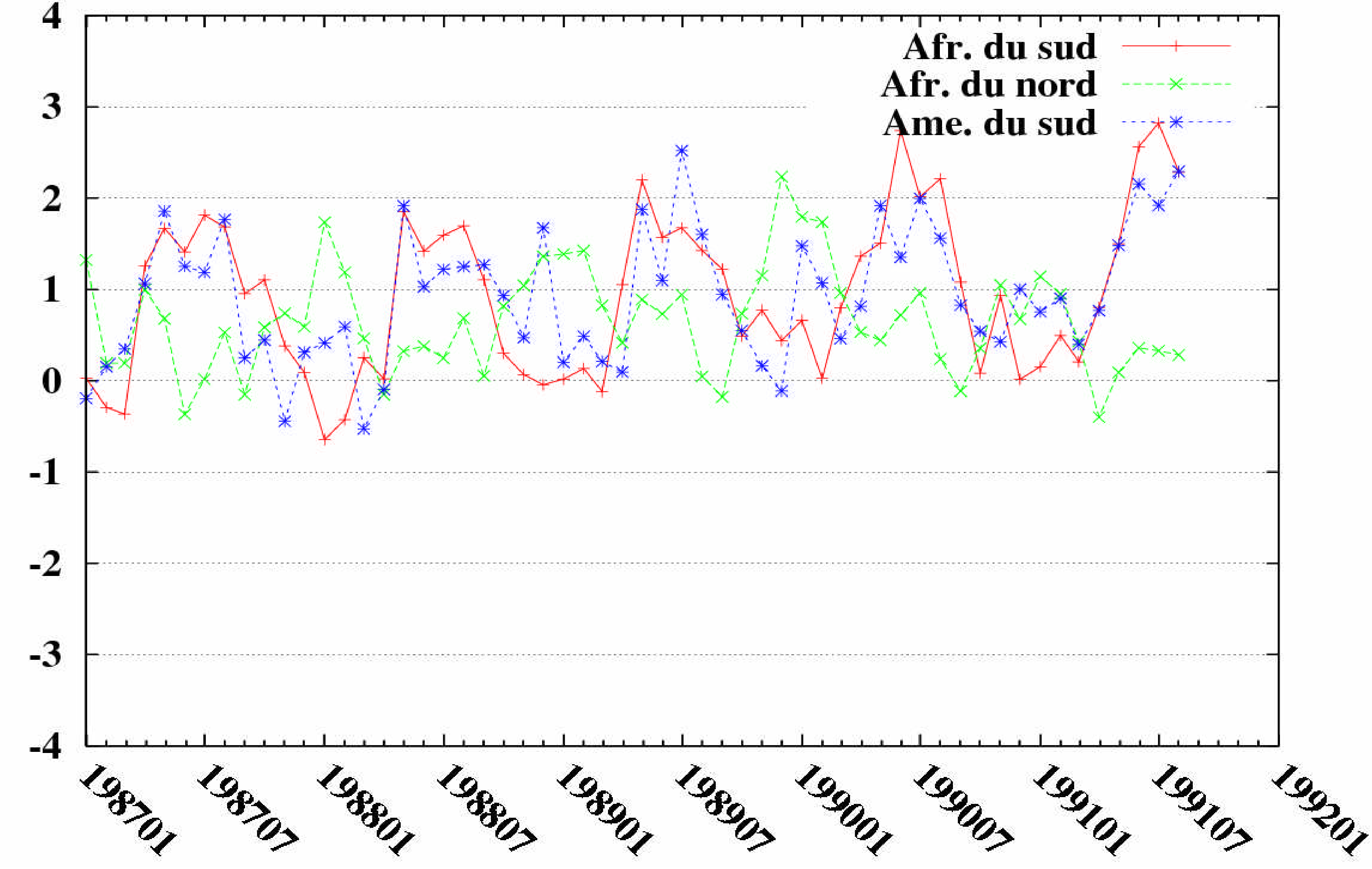
Seasonal mean fire emissions of carbon dioxide (g/m2/month) averaged over the period 1997-2002 (van der Werf et al., 2003)



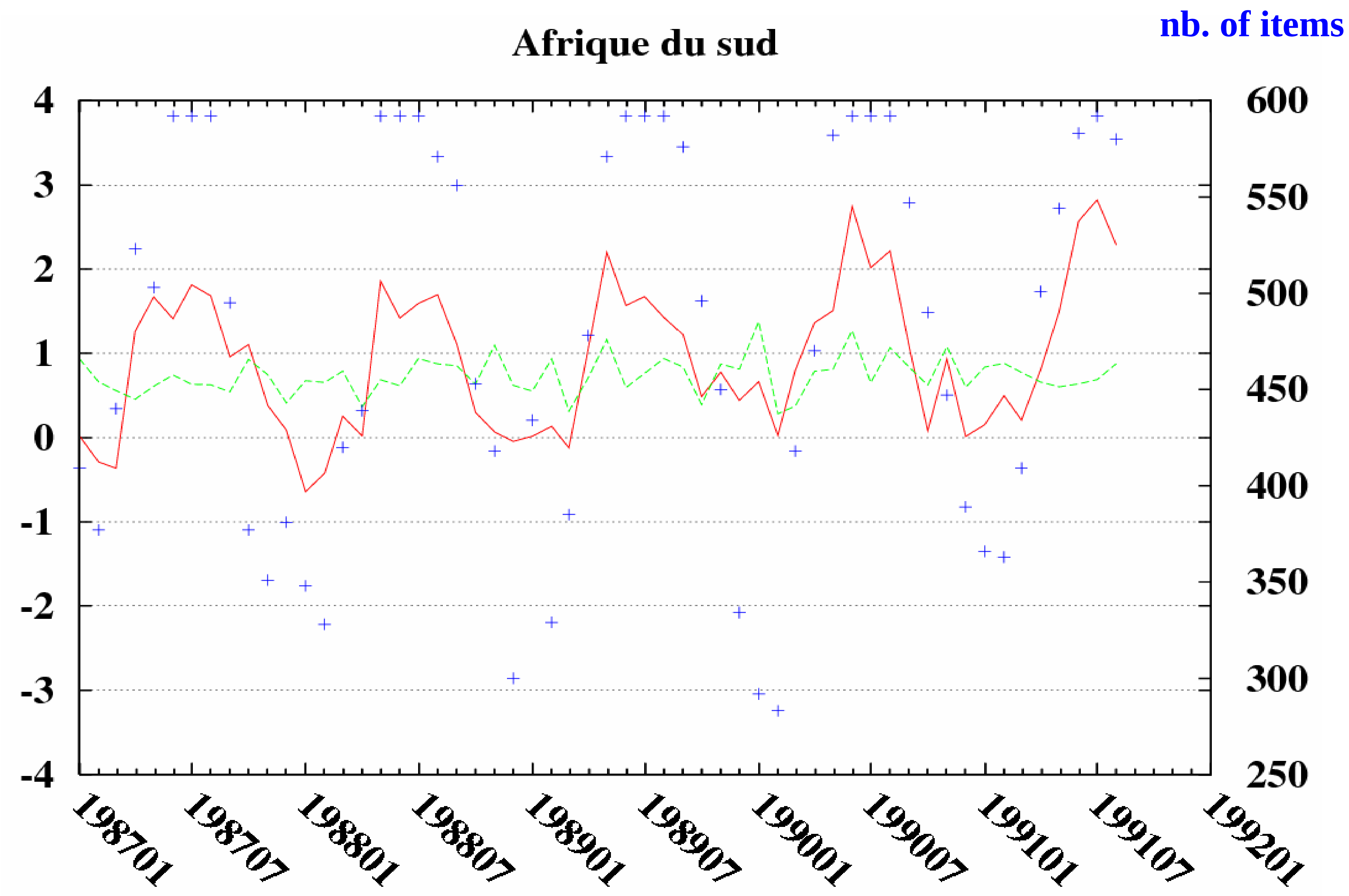
NDD 4-year monthly climatology



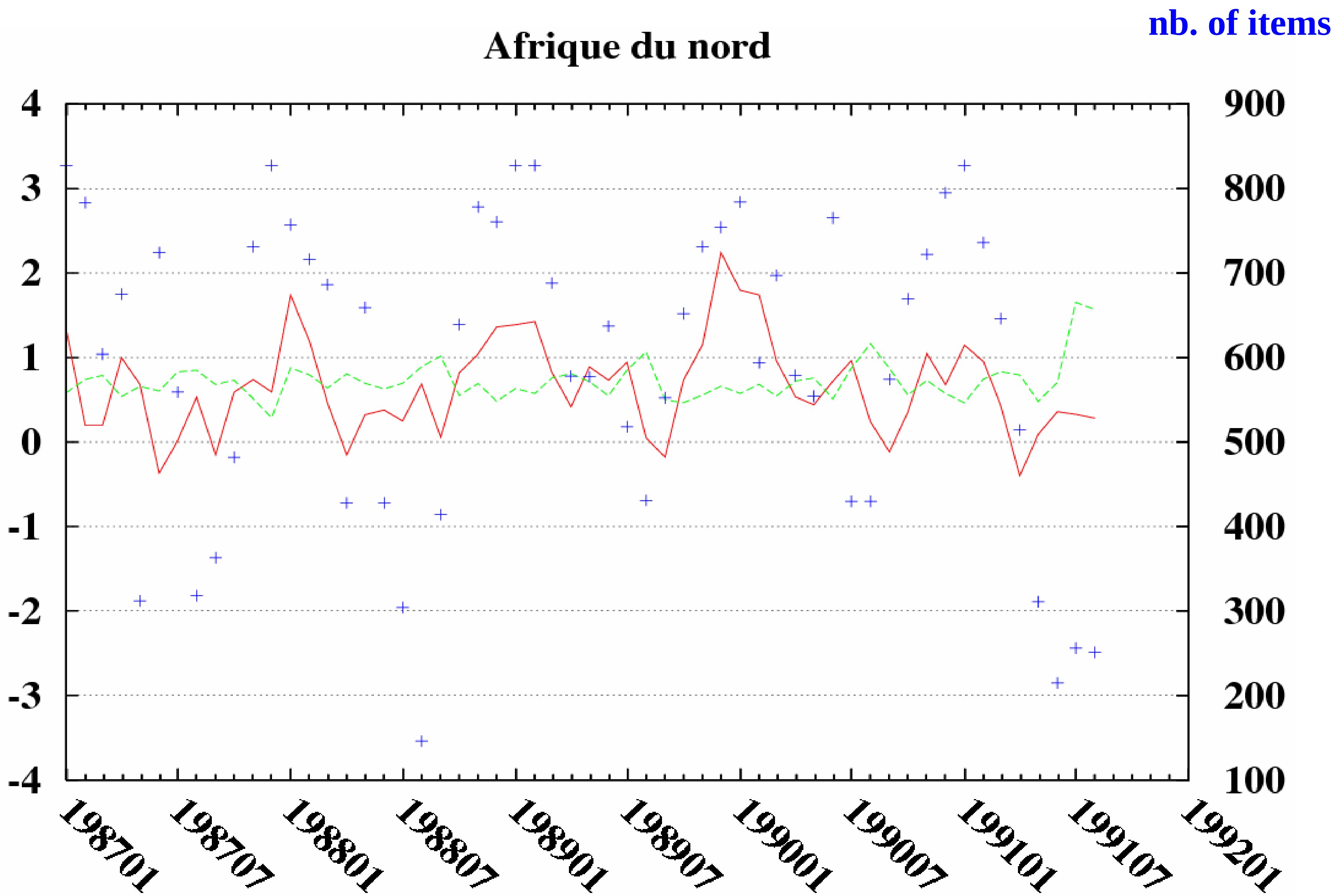
N-DD time series for three geographical areas : south Afr (red), north Afr (green), south Amer (blue); in ppm



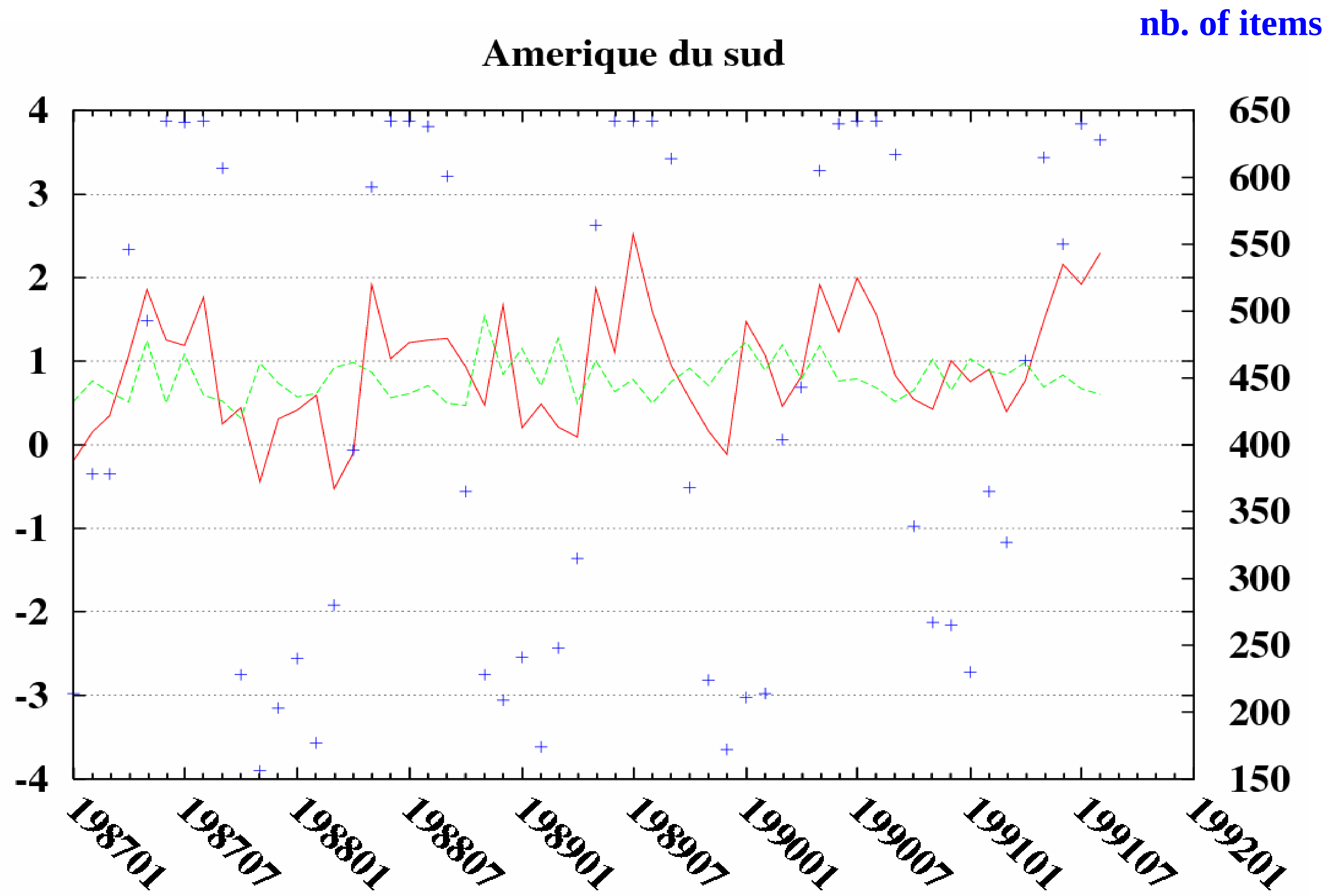
N-DD time series for south Afr (red) and its standard deviation (green); in ppm



N-DD time series for northern Afr (red) and its standard deviation (green); in ppm



N-DD time series for south Amer (red) and its standard deviation (green); in ppm



Interpretation of the N-DD signal

The N-DD signal results from the convolution of fire emissions and transport

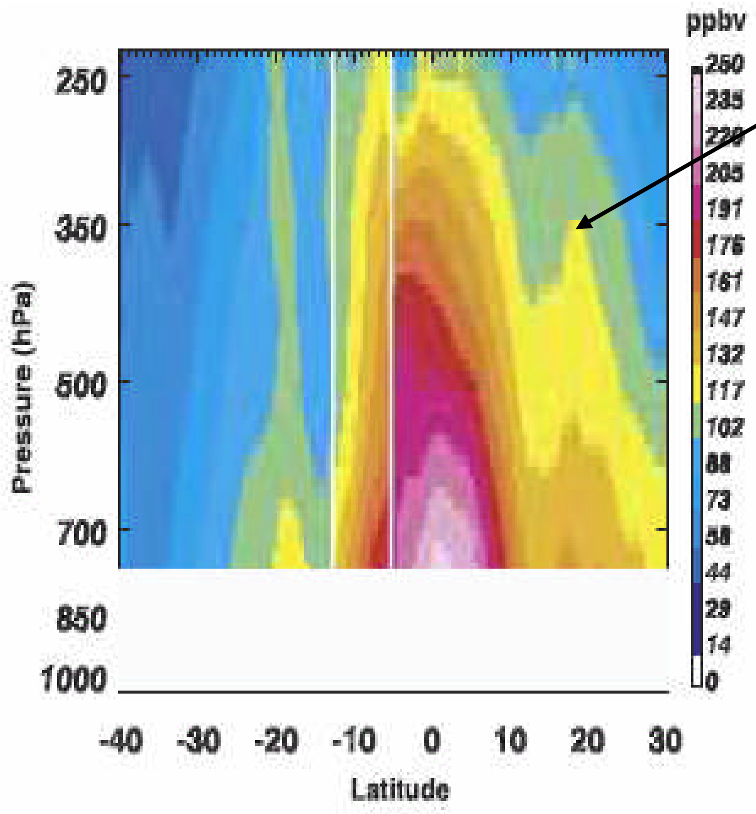
Two rapid transport mechanisms affect the CO_2 emitted by the fires:

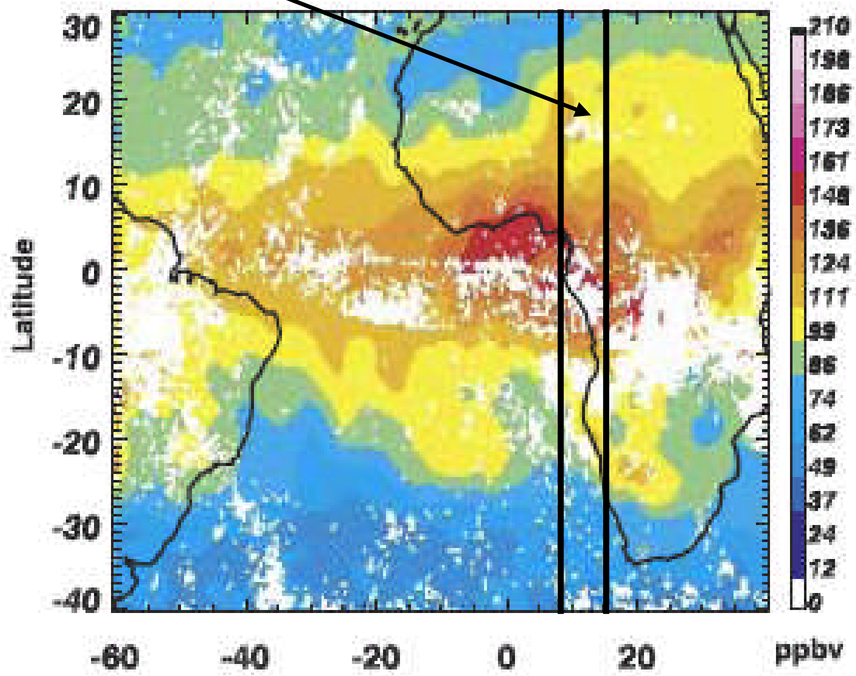
1. **vigorous fire-enhanced convective uplift of CO_2 plumes to the middle-upper troposphere occurring between morning and late afternoon, detected by the satellite at 7.30 pm (LT), (mechanism suggested by *Andreae et al*, 2004)**

2. **rapid dispersal of the burning emission-laden air in altitude by the prevailing upper tropospheric flow during the night, before the next satellite pass in the morning, *Krishnamurti et al.* (1996), *Freitas et al.* (2004)**

Recent observations of CO from MOPITT support this interpretation (1)

High values in altitude and north of the fires



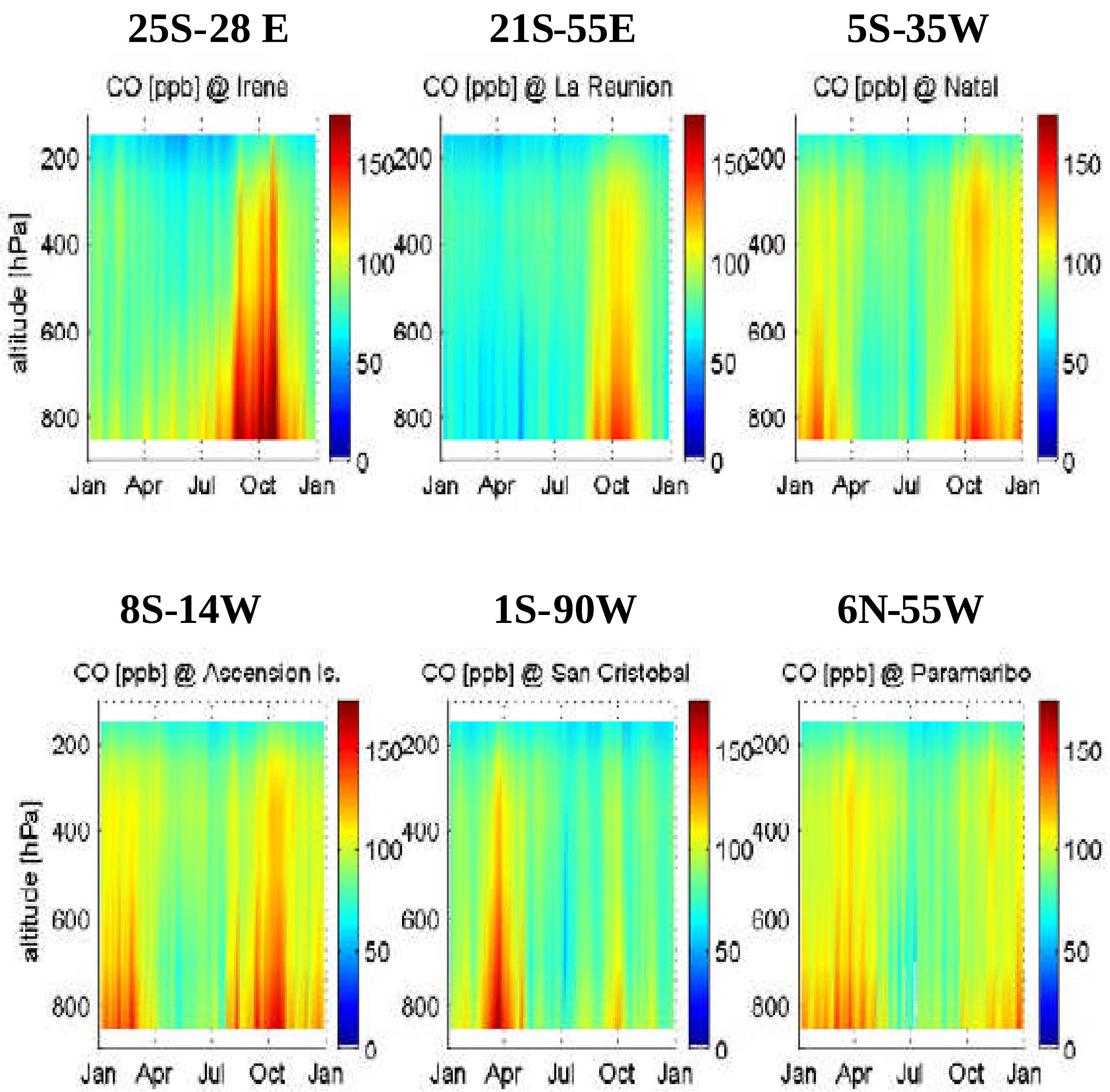


MOPITT latitudinal CO cross section
Average over longitudes 1OE-14E
last week of January 2001

MOPITT CO distribution [at 350 hPa]
for the last week of January 2001

From Edwards et al., JGR, 2003

Recent observations of CO from MOPITT support this interpretation (2)



MOPITT retrieved time-altitude cross sections for CO mixing ratios at 6 tropical locations (March 2000 to March 2003 climatology, binned in 5 days cells)

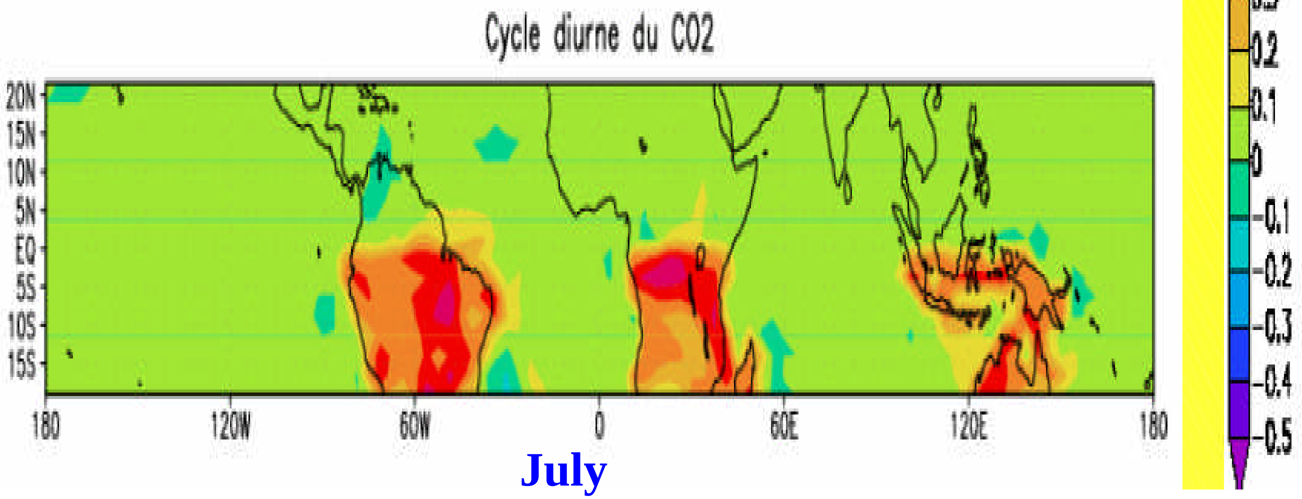
Show CO enhancements due to biomass burning up to high altitudes

From Bremer et al., JGR, 2004

Modeled monthly mean (July) diurnal cycle of N-DD (using LMD-z) support this interpretation (3)

Assumptions: - CO_2 injected over the continents (0-20S)
- uniformly between surface and 14 km
- according to the diurnal cycle of fires
- according to van der Werf et al., 2003

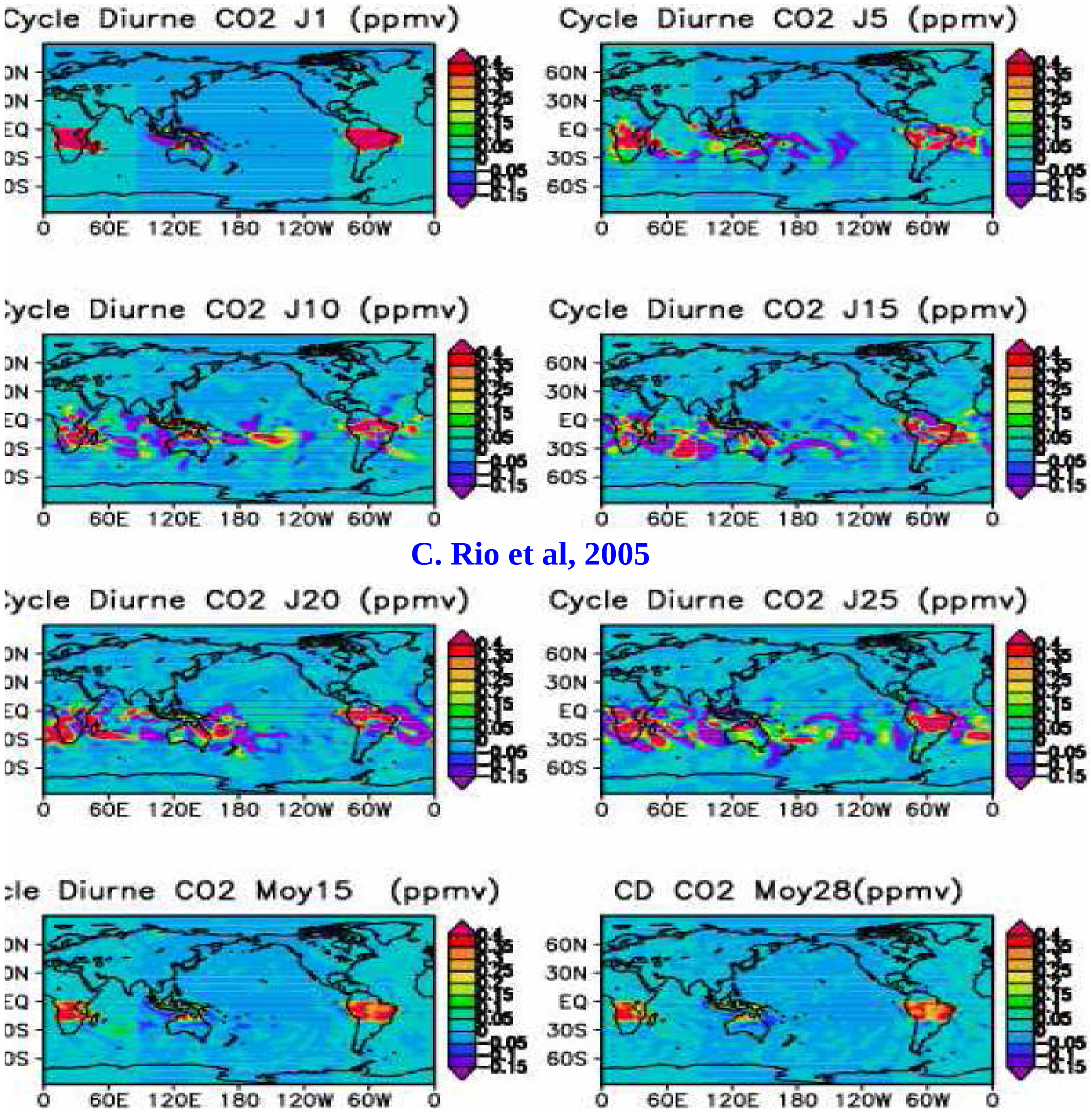
Strong signal persisting only over the continents



July

Problem : the amplitude of the signal strongly depends on the vertical distribution of the injection (quite poorly known : depends on fire power, meteorology, etc)

C. Rio et al., LMD, Dec. 2004



C. Rio et al, 2005

Modeled daily diurnal cycle : signatures seen far from the sources (from LMD-z)

Modeled mean diurnal cycle averaged over 15 or 28 days ~no signatures far from the sources

Modeled diurnal cycle : main features and consequences for the NDD

- model signatures (positive and negative) are seen far from the sources (over the oceans) on a daily basis : this is due to the transport

- model signatures are seen over or close to the sources when averaging over a sufficient number of days (for example, after 15 days) : « randomness » of the transport compared to the persistent character of the source emissions

- within a month, because of the presence of clouds, the retrieved NDD signal may result from the averaging of a number of days significantly smaller than the number of days in the month (during the cloud « season », for example)

- as a consequence, for such cases, retrieved NDD signatures (positive or negative) are expected to be seen far from the sources (ex: over the oceans)

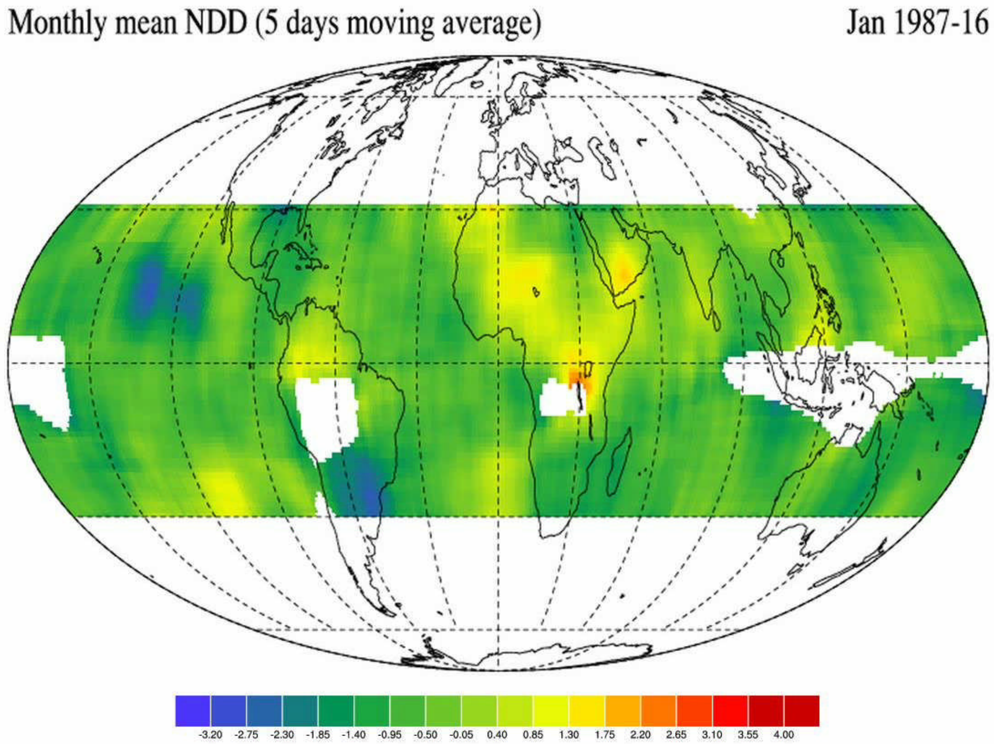
Potential contaminations of the N-DD signal

- the **differential** character of the N-DD signal makes it ***robust*** with respect to non diurnal sources of contamination which may affect TOVS-retrieved CO_2 columns

- major potential sources of contamination analyzed in Chédin et al, JGR, (2005) : **fire-induced ozone and aerosols** remain as potential contributors

  Ex 1: doubling of **tropospheric ozone** (from 50 ppb to 100 ppb, from the surface to 130 hPa) leads to a N-DD **contribution of 1 ppm**

  Ex 2: an **aerosol layer** of AOD=0.05 at 10 µm (about 0.7 at 0.55 µm, quite large), at a mean altitude of 5 km (quite high), leads to a N-DD **contribution of 1.2 ppm**



Monthly mean NDD (5 days moving average)
Jan 1987-16
-3.20 -2.75 -2.30 -1.85 -1.40 -0.95 -0.50 -0.05 0.40 0.85 1.30 1.75 2.20 2.65 3.10 3.55 4.00

Comments on the NDD movie

- blanck areas are essentially due to persistent cloudiness

- as for Mopitt and CO over northern Africa in winter (Edwards et al, 2003), signatures are seen northward the fire edge (15 N)

- as expected, signatures are seen far from the sources, and in particular over the oceans, and often over main known transport pathways (Africa / south America, for example)

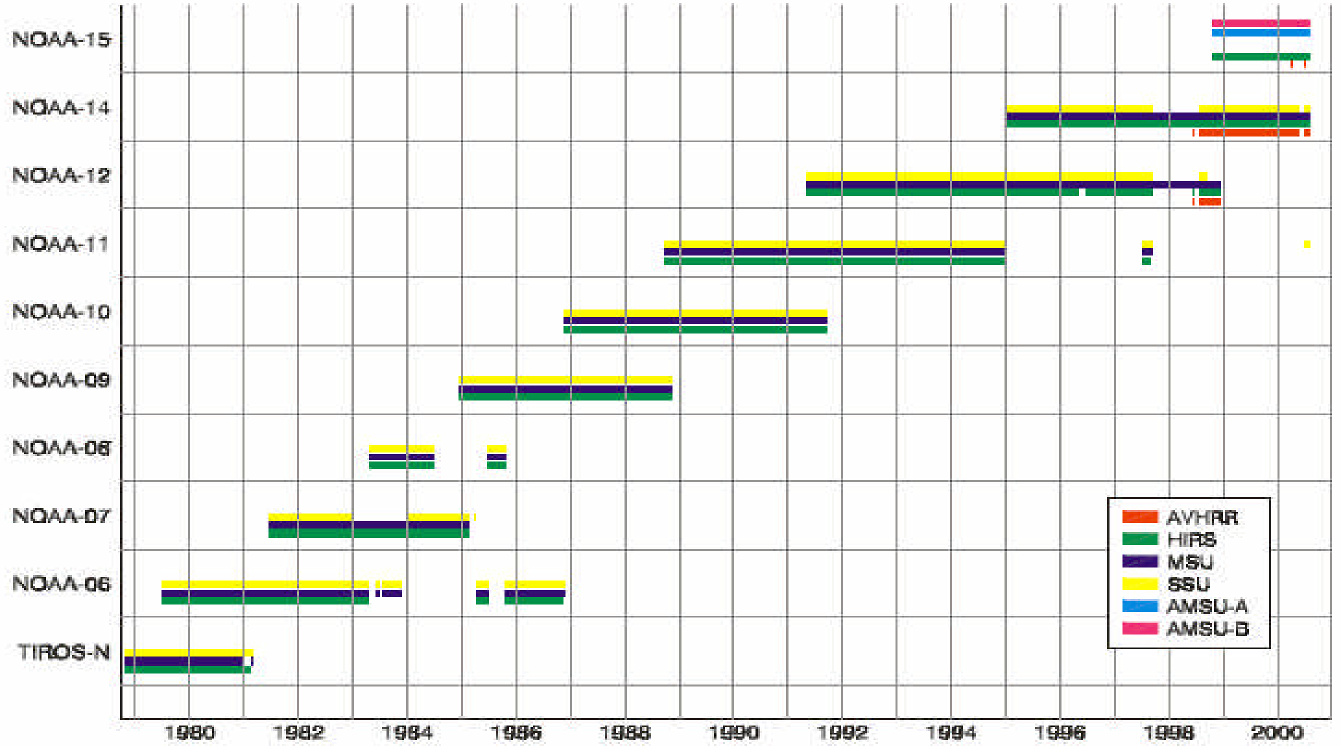
- the strongest signatures are seen in the summer of 1990 over south Africa, in agreement with several authors (Barbosa et al, 1999, for example)

- the end of the period is marked by the eruption of Mt Pinatubo (mid-June 1991) with a preferential initial dispersion in the southern hemisphere (McCormick et al, 1995). The N-DD signal is severely contaminated

Perspectives : extension of the analysis period

Just started:

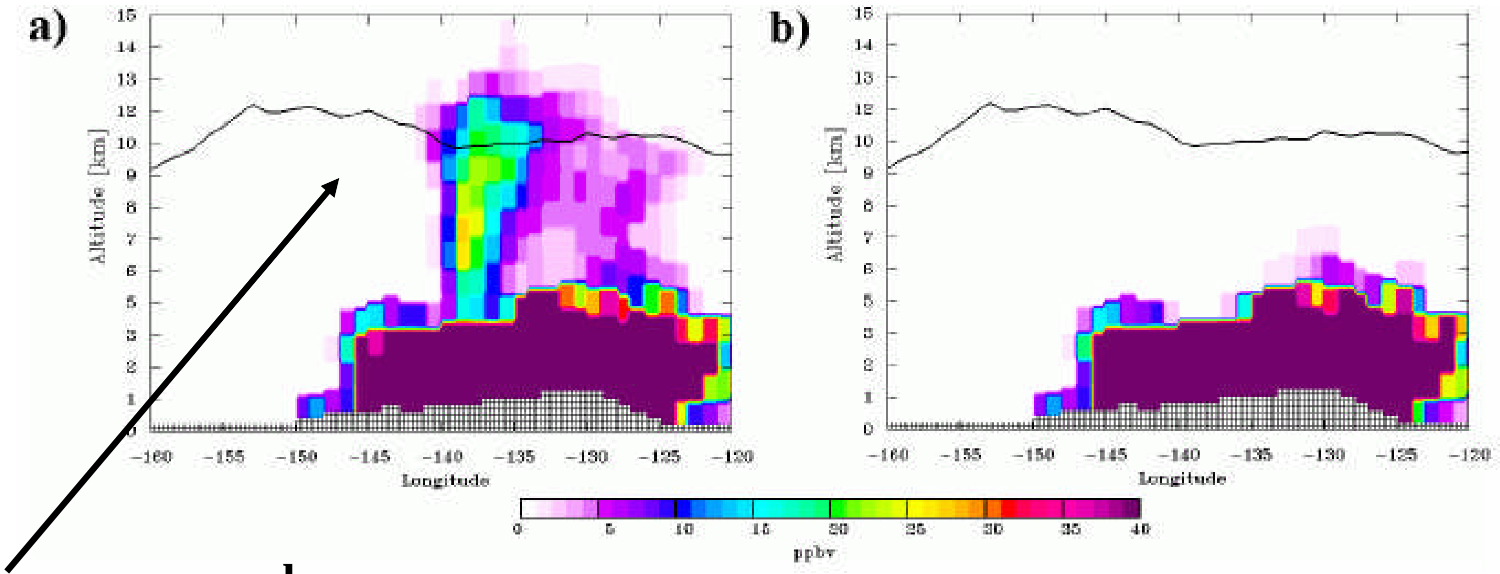
Reanalysis of the 25 years of TOVS archive in terms of N-DD signal. Morning satellites (7h30) are better suited to the fire diurnal cycle than afternoon satellites (13h30). However, both almost cover the whole period



Available (A)TOVS Level 1b data from NOAA polar orbiting satellites TIROS-N to NOAA 15.

Perspectives : improvement of the modeling of fire plumes : example of the impact of a convection scheme accounting for ***sub grid-scale*** convective transport

Vertical cross section of CO (at 64 N), on 24 June 2004, 12 TU, over strong forest fire enhancing convection



dynamical tropopause

scheme « on » (agreement with observations)

scheme « off »

From Damoah et al., ACP, 2006