Several decades of observation of mid-tropospheric CO_2 from ATOVS, AIRS and IASI

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TropFire
project Blanc 2010

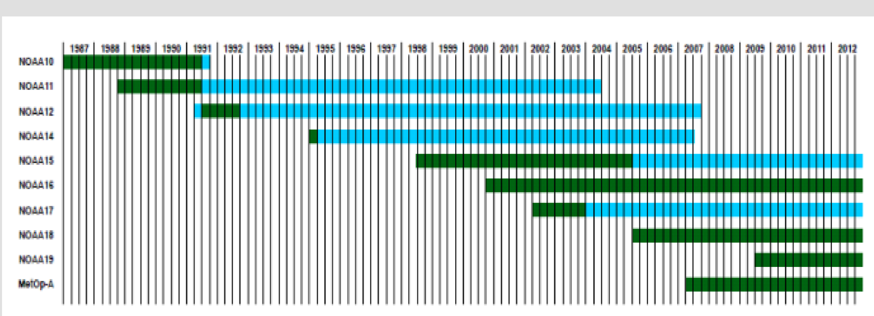
Introduction

Since the first retrieval of mid-tropospheric CO_2 from NOAA-10/TOVS observations made by Chédin et al. (2003), the non linear inference scheme based on neural networks has been adapted to process observations from several TOVS and ATOVS instruments, and then from the hyperspectral instruments AIRS onboard Aqua and IASI onboard Metop-A. Several decades of observation can now be used to follow the long-term evolution of CO_2, seasonality and growth rate.

The instruments

Several decades of observation are available from IR and WV sounders onboard the NOAA, Aqua and Metop platforms.
Over the years, the characteristics of the instruments have evolved (see Table) and need to be taken into account in the retrieval process.

Instruments	IR sounder	MW sounder	Satellites
TOVS	HIRS	MSU	NOAA10 to NOAA 14
ATOVS	HIRS	AMSU	NOAA15 to NOAA19
ATOVS	HIRS/4	AMSU	MetOp-A and B
	IASI	AMSU	MetOp-A and B

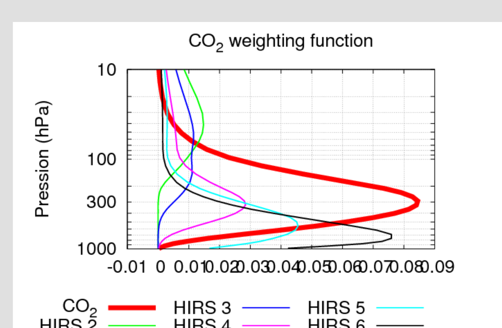


However, even if some observations are available for many years for each platforms (blue), the retrieval of CO_2 can only be performed for the years (green) when all the required channels are available.

Here, we use observations from NOAA10, NOAA11, NOAA15, Metop-A HIRS/4 and Metop-A/IASI

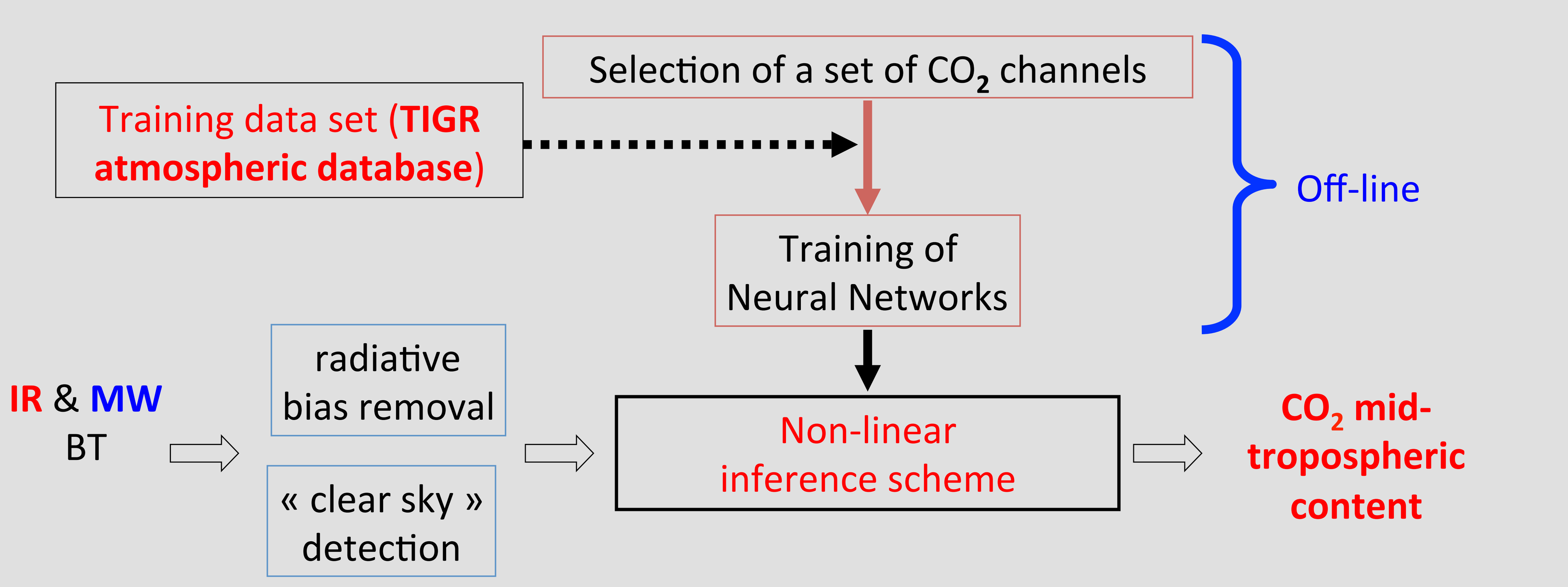
Selected channels

Sensitivities of CO_2 channels after a -1% variation of CO_2 concentration computed over the tropical TIGR atmospheres using 4A/OP (Scott et al., 1981) and GEISA-2009 (Jacquinet et al.,2011)					
HIRS/4 channels	2	3	4	5	6
ΔT (K)	-0.05	0.00	0.09	0.12	0.12
Noise (K)	0.74	0.56	0.32	0.18	0.18
IASI channels*	133	70	224	323	377
ΔT (K)	-0.05	-0.03	0.08	0.13	0.12
Noise (K)	0.34	0.38	0.27	0.22	0.20



The retrieval method

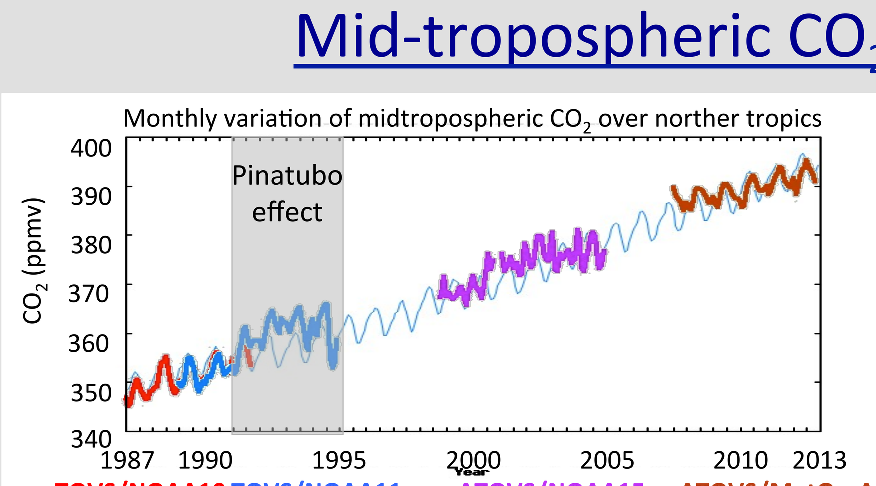
Use is made of a non linear inference scheme based on neural networks(Chédin et al., 2003).



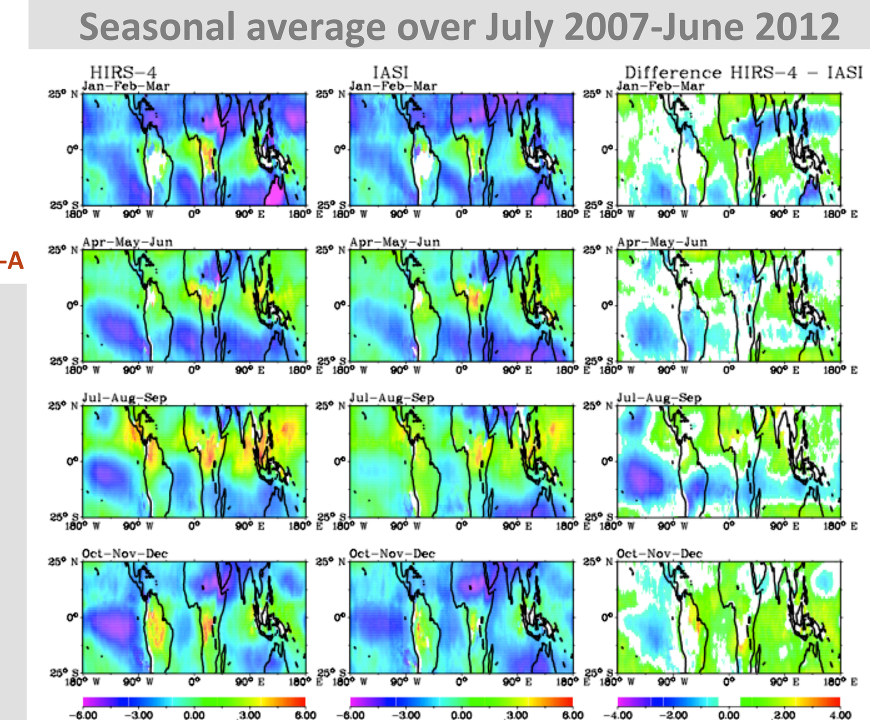
•Simultaneous use of IR channels sensitive to T and CO_2 and of MW channels only sensitive to T allows to decorrelate T/CO_2.

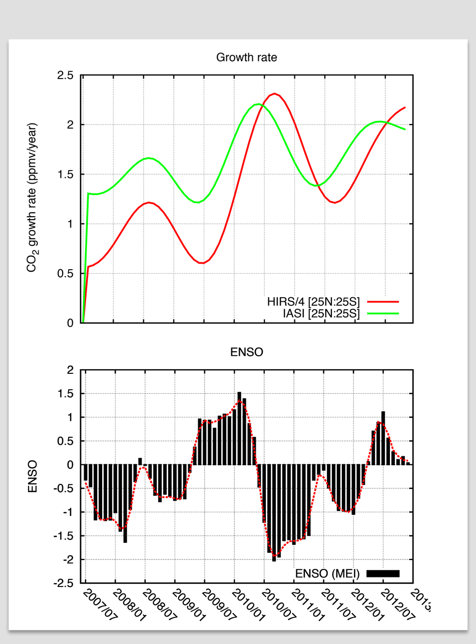
•The processing of TOVS, ATOVS, AIRS and IASI observations has required adapting each of the retrieval step to the characteristics of each instrument.

Mid-tropospheric CO_2 from 5 instruments



Geographical distribution of CO_2 from HIRS/4 and IASI both onboard Metop-A
Seasonal average over July 2007-June 2012





The CO_2 growth rate derived from IASI and HIRS/4 onboard Metop-A agrees well with the climate index ENSO (increase in El Niño years and decrease in La Niña years). The 3 month-lag stems from the fact that IR sounders are mostly sensitive to mid-troposphere.

Chédin et al. (2005), Impact of tropical biomass burning emissions on the diurnal cycle of upper tropospheric CO2 retrieved from NOAA-10 satellite observations, *J.Geophys. Res., 110,* D11309 **Chédin et al. (2008)**, A quantitative link between CO2 emissions from tropical vegetation fires and the daily tropospheric excess (DTE) of CO2 seen by NOAA-10 (1987-1991), *J. Geophys. Res., 113,* D05302 **Giglio, L. (2007)**, Characterization of the tropical diurnal fire cycle using VIRS and MODIS observations, *Remote Sens. Environ.*, doi:110.16/j.rse.2006.11.018 **Jacquinet-Husson et al. (2011)** The 2009 edition of the GEISA spectroscopic database, *J. Quant. Spectrosc. Radiat. Transfer*, doi:10.1016/j.jqsrt.2011.06.004 **Rio et al. (2010)**, Numerical simulation of atmospheric injection of biomass burning products by pyro-thermal plumes, *Atmos. Chem. Phys*., 10, 3463-3478 **Roy et al. (2008)**, The Collection 5 MODIS Burned Area Product – Global Evaluation by Comparison with the MODIS Active Fire Product. *Remote Sens. of Environ.*, 112, 3690-3707 **Scott and Chédin (1981)** A fast line-by-line method for atmospheric absorption computations: The Automatized Atmospheric Absorption Atlas, *J. Appl. Meteor*., 20(7), 802-812. **van der Werf et al. (2010)**, Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009), *Atmos. Chem. Phys*., 10, 11707-11735.

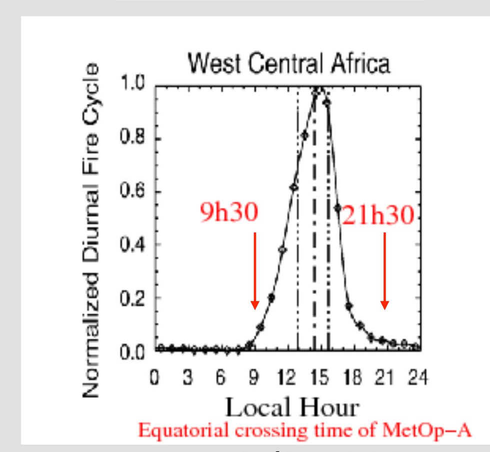
Definition of Daily Tropospheric Excess (DTE)

Infrared sounders onboard polar satellites overpass every point twice a day. TOVS/ATOVS, AIRS and IASI onboard NOAA, Aqua and Metop platforms, observe CO_2 by day and by night, allowing to study the night minus day difference of retrieved CO_2. We call this difference the ***Daily Tropospheric Excess (DTE) of CO_2***. Chédin et al. (2005, 2008) have shown for NOAA10 observations that DTE is qualitatively related to fire emissions.

The 2 origins of the observation of DTE

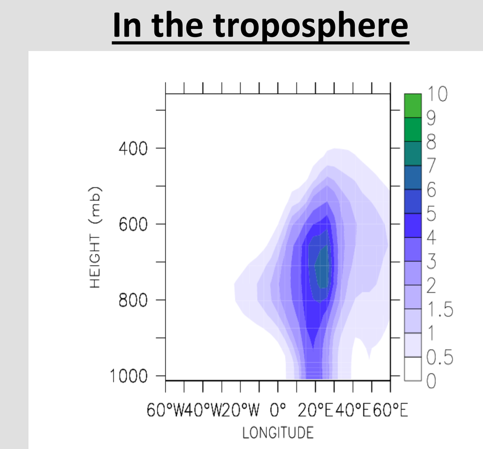
The physical mechanism linking DTE with fire emissions comes from the diurnal cycle of fire emissions associated with enhanced convection: hot convective fire plumes injects CO_2 into the troposphere during the afternoon peak of fire activity, which is seen by the satellite evening passing; it is then diluted by large scale atmospheric transport, before the next satellite morning passing. This mechanism has been validated by *Rio et al. (2010)* using a thermal plume parametrization in the LMDz atmospheric transport model.

Diurnal cycle of fire

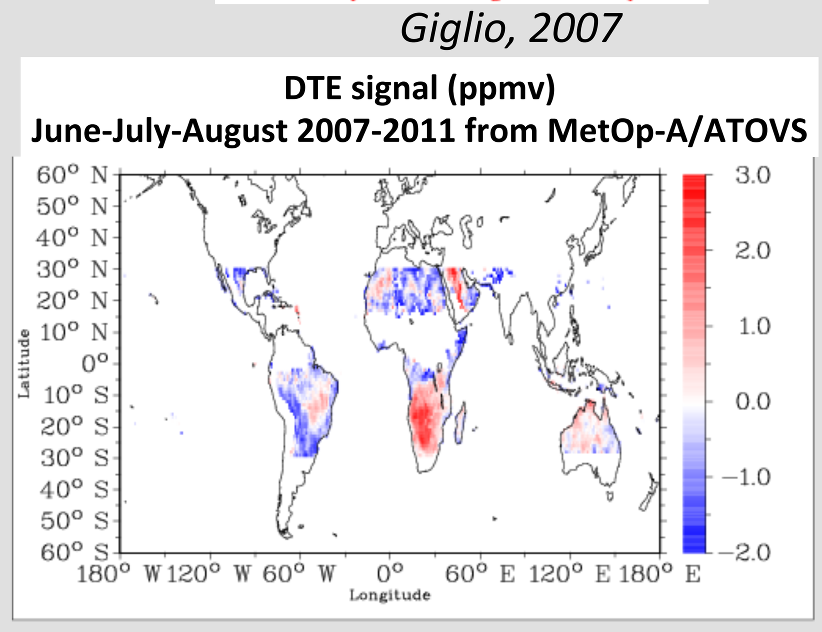


Giglio, 2007

Convection of fire emssions In the troposphere

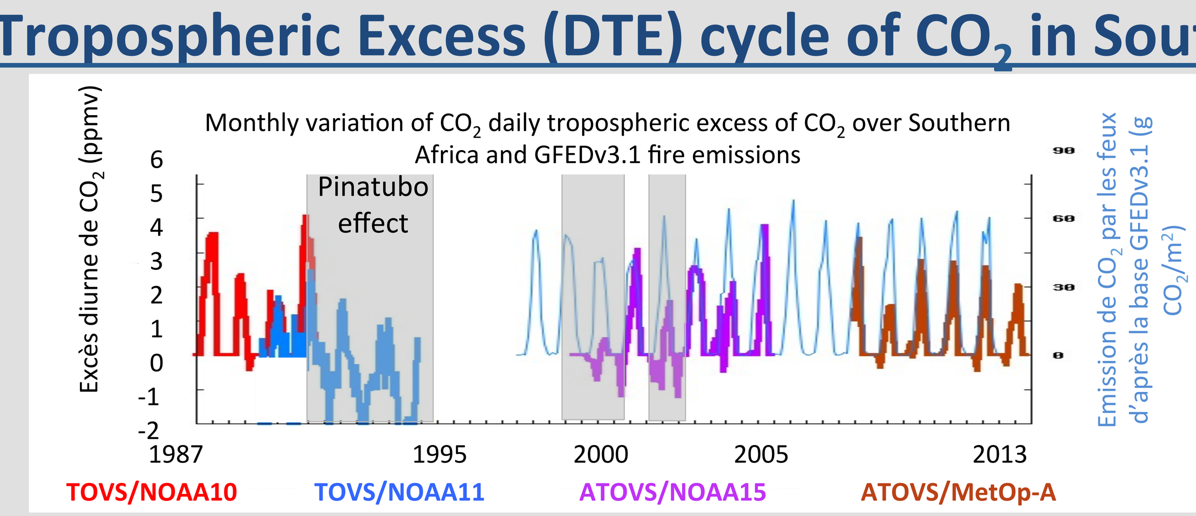


Rio et al., 2010

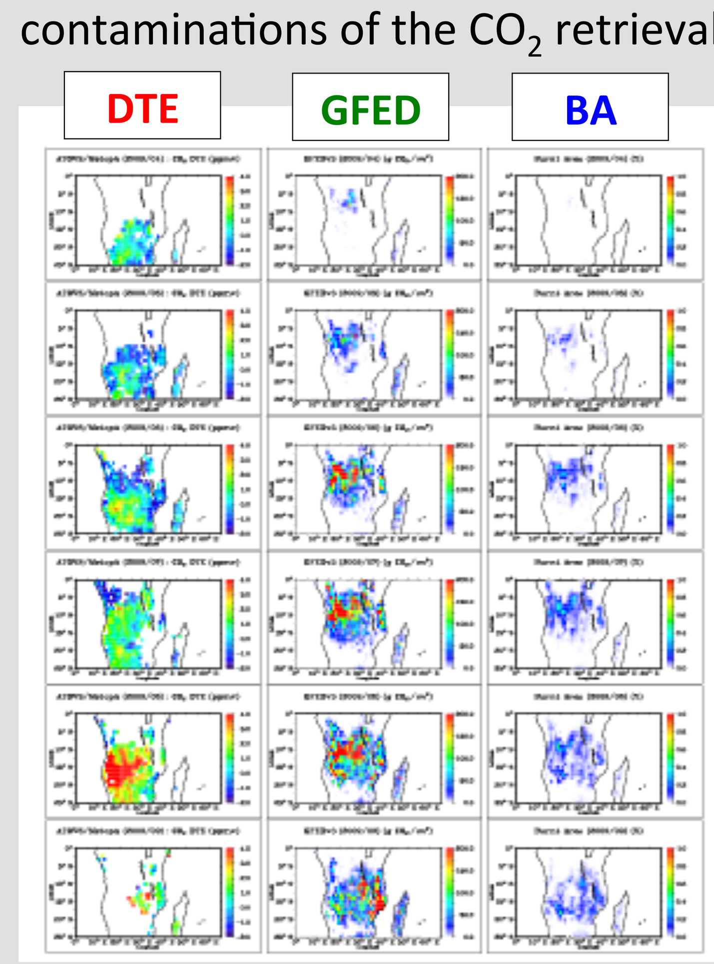


The difference between night and day CO_2 retrievals (DTE) seen by IR/MW sounders is linked to CO_2 fire emissions. This signal, about 1.5-4 ppmv, is low and spatially very localized.

Daily Tropospheric Excess (DTE) cycle of CO_2 in Southern Africa



The Daily Tropospheric Excess (DTE) obtained from the 5 instruments used here increases up to several ppm over regions affected by biomass fires, confirming the results obtained from NOAA10 TOVS observations over 1987-1991. This signal is quite robust based on its differential nature, which helps eliminating potential contaminations of the CO_2 retrievals (platform drifts, potential trends, etc.).



The **CO_2 DTE** shows monthly, seasonal and annual spatial patterns similar to fire products, such as **CO_2 emissions** from the Global Fire Emission Database (GFEDv3) and burned areas from the MODIS instrument.

Conclusion

We conclude that infrared sounders can play a fundamental role in the monitoring of CO_2 and associated emissions. In particular, the DTE signal can be very useful as a quantitative proxy to constrain the analysis of current fire emissions, as well as to help reconstructing their patterns before the MODIS period by using TOVS and ATOVS instruments flying onboard the NOAA platforms since 1979.

With the launch of two other successive IASI-like instruments in 2012 and 2018, more than 20 years of observations of mid-tropospheric CO_2 will be available to complement the NOAA time series for climate studies.