Comparison between MOPITT and OCO-2 Flux Inversions : Analyze of CO-CO_2 correlation

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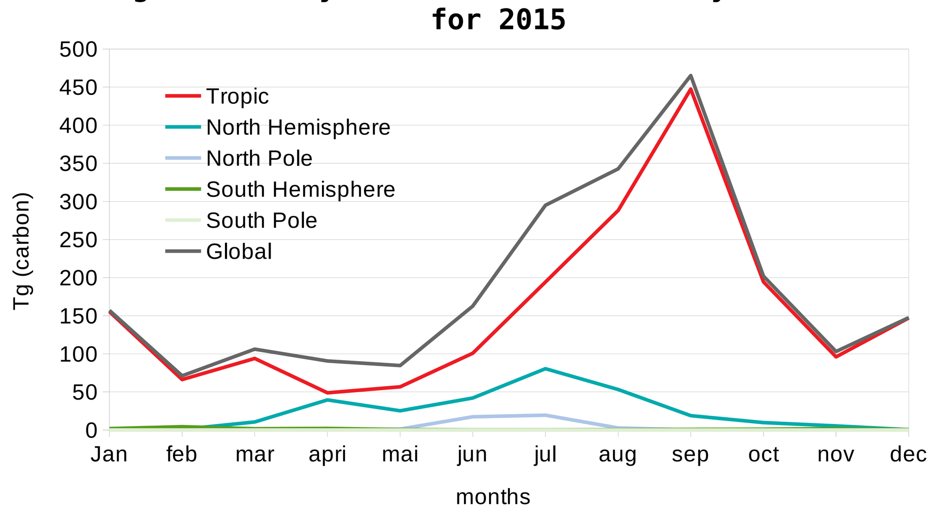
Introduction and motivation

Biomass burning in the tropics is the major source for the global carbon budgets of many trace gases (see fig.1) such as carbon dioxide (CO_2), Carbon monoxide (CO), methane (CH4) and other reduced gases in the troposphere (Crutzen et al., 1990).

As a product of inefficient combustion, CO has often been used as a CO_2 tracer from combustion (Potosnak et al., 1999, Turnbull et al., 2006).

The emission ratio of CO_2 to CO (CO_2:CO) varies with the efficiency of combustion (Andreae et Merlet, 2001). Hence, CO_2-CO correlation slopes provide useful constraints for identifying source types.

Fig 1. Monthly emissions of carbon by latitudes for 2015



Understanding and quantifying CO + CO_2 variability requires accurate data on the emissions of trace gases and the information of atmospheric dynamic from chemistry transport model. In this study, we analyze the correlation between CO inversion from MOPITT and CO_2 inversion from OCO-2 over the tropics during 2015. Four areas of study are analyze (see fig.2 - 3). CO_2 and CO data from OCO-2 and MOPITT have been used and validated in several studies (Basu et al., 2013, Crowell et al., 2019).

Fig 2. Monthly burned area for the four area of study over the tropics in 2015

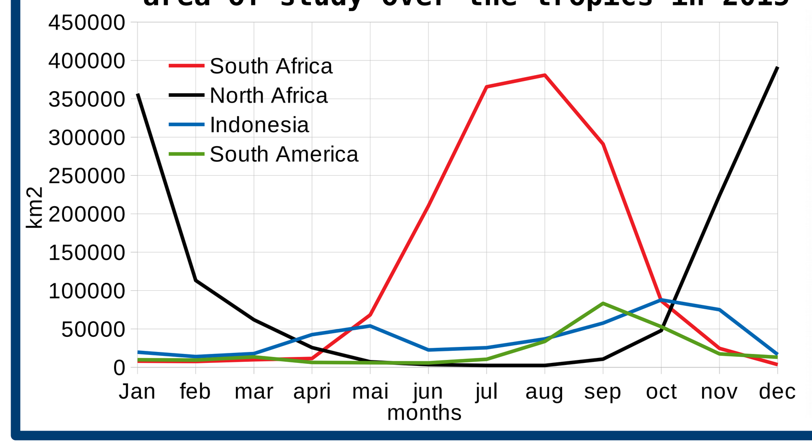
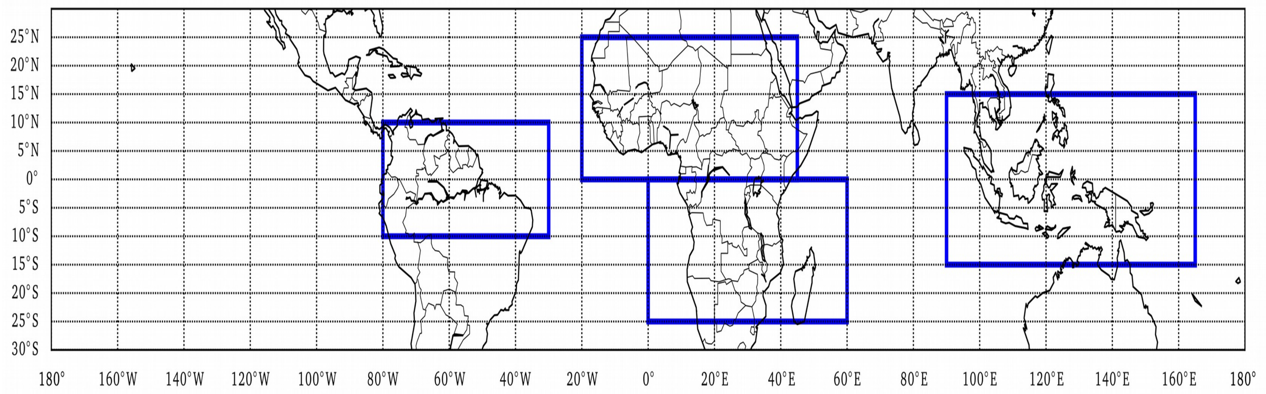
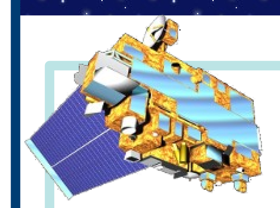


Fig 3. Map of the study regions (in blue) over the tropics.



Satellite Dataset

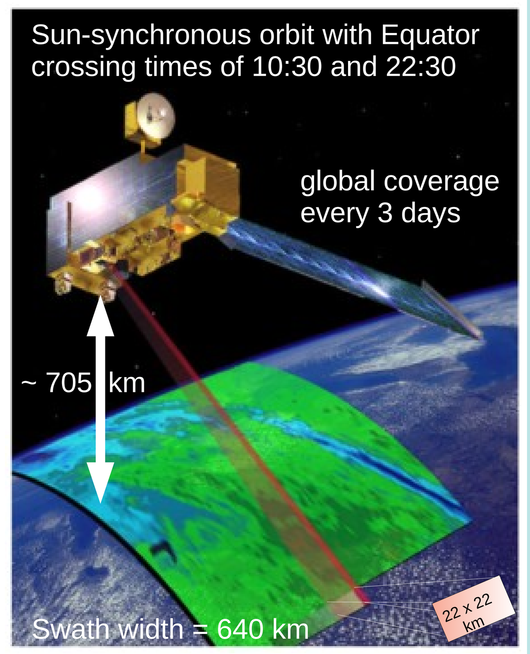


MOPITT (Measurements of Pollution in the Troposphere) retrievals v7 (Deeter et al., 2013)

- **Launch :** in December 1999 on board NASA's Terra satellite
- **Spectral bands :** MOPITT is a gas correlation nadir radiometer with 2 spectral channels for CO

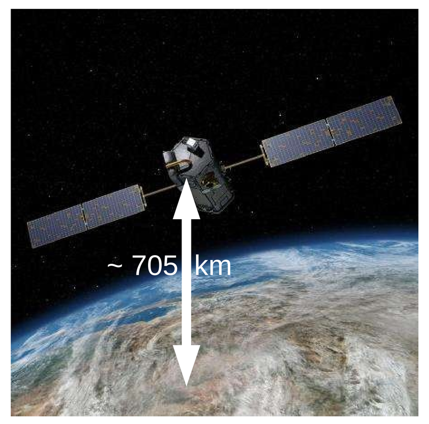
Thermal-infrared	Near-infrared
4.7 µm	2.3 µm using reflected solar radiation
offers the highest temporal stability during day/night, and over land/ocean	suited for the analysis of CO total columns, produced for daytime observations over land.

- **Benefits of the shortwave infrared sounders :** they are sensitive to the entire atmospheric column, including the boundary layer.
- **Accuracy :** 10 % for the CO profile and total column (Pan et al., 1995)
- **Software retrieval : MOPFAS** (The MOPITT Fast Forward Model, Edwards et al., 1999). Daily level 2 data with a 1x1 deg resolution grid
- **Biases** in the lower troposphere from -3.4 % to 2.8 % at the surface level (Deeter et al., 2017)



OCO-2 (Orbiting Carbon Observatory version 7, Crisp et al., 2014)

- **Launch :** in 2014 on board OCO-2 sun-synchronous orbit satellite with equator crossing times of 13:30.
- **Horizontal resolution :** 1.29 x 2.25 km at nadir mode
- **Swath width** = ~ 10.5 km, **global coverage** every 16 days
- **Spectral bands :** Three high-resolution grating spectrometers including Oxygen A band (~ 0.765 µm, NIR), a weak CO_2 band (~ 1.61 µm, SWIR) and a strong CO_2 band (~ 2.06 µm, SWIR).
- **CO_2 products : ACOS** (Atmospheric CO_2 Observations from Space, O'Dell et al., 2012; Crisp et al., 2017), land Nadir data + AVK used
- **Biases** in the troposphere and in the tropics are around 3 ppm (Crowell et al., 2019)



Methodology

Weekly mean prior CO_2 emissions for four categories :

- Anthropogenic (combustion of fossil + biofuels) from ODIAC (Open-source Data Inventory for Anthropogenic CO_2, Oda and Maksyutov, 2011). Dirunal cycle are imposed by the TIMES product (Nassar et al., 2013)
- Ocean fluxes= Takahashi et al., 2009
- Natural sources = 3 hourly terrestrial biosphere fluxes from NASA Ames Carnegie-Ames-Standford-Approach (CASA, Olsen and Randerson,2004)
- Fires : FINN emissions with GFED 4.1s

weekly mean prior CO emissions for three categories :

- Anthropogenic (combustion of fossil + biofuels) from the MACCity/CityZEN EU projects, Granier et al., 2011) database, total to 588 Tg CO in 2015.
- Optimized biomass burning (vegetation fires) from the Global Fire Emissions Database (GFED4.1) used with a total of 6995 Tg CO in 2015.
- Natural sources = direct emissions from plants and ocean amounting to 115 Tg CO/yr (Houweling et al., 1998) + contribution of NMVOC-CO (isoprene + monoterpenes) oxidation based on monthly 3D CO production fields from TM5 full chemistry version.

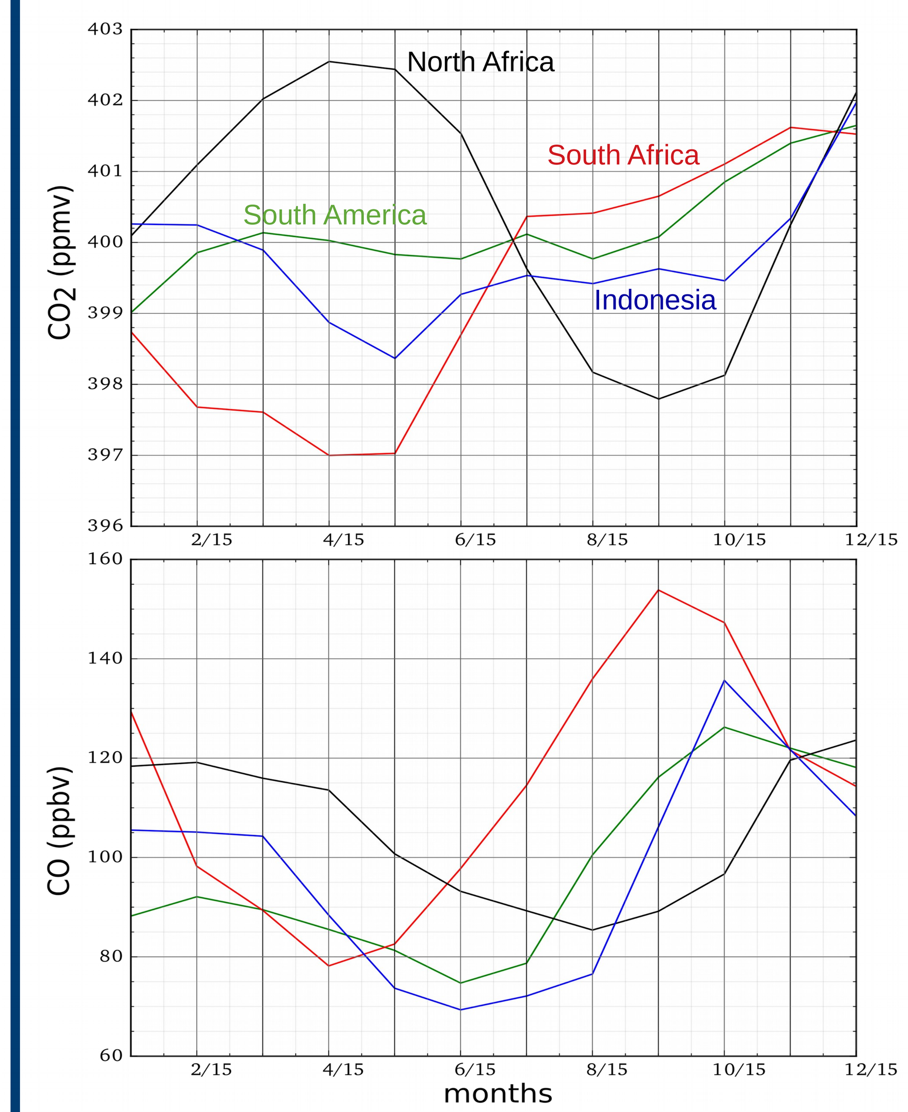
Climatological OH tropospheric fields parameterization (Spivakovsky et al., 2000), scaled with a factor 0.92 in order to keep the model linear (Huijnen et al., 2010).

Chemistry transport model TM5 (Krol et al., 2005)

- 6x4 horizontal grid resolution with 25 vertical levels
- Adjoint inversion technique used : derive optimized gas emissions on the CTM grid through an interactive approach used to minimize the mismatch between model and observations (Mulller and Stavrakou, 2005; Fortems-cheiney et al., 2009).
- Interactive minimizer used : M1QN3 (Gilbert and Lemarechal, 1989)
- Prior error covariance : spatial and temporal error correlations, Gaussian spatial correlation length of 1000 km used for all emission categories.
- **Meteorological fields** (ERA-Interim on a 3-hourly basis)

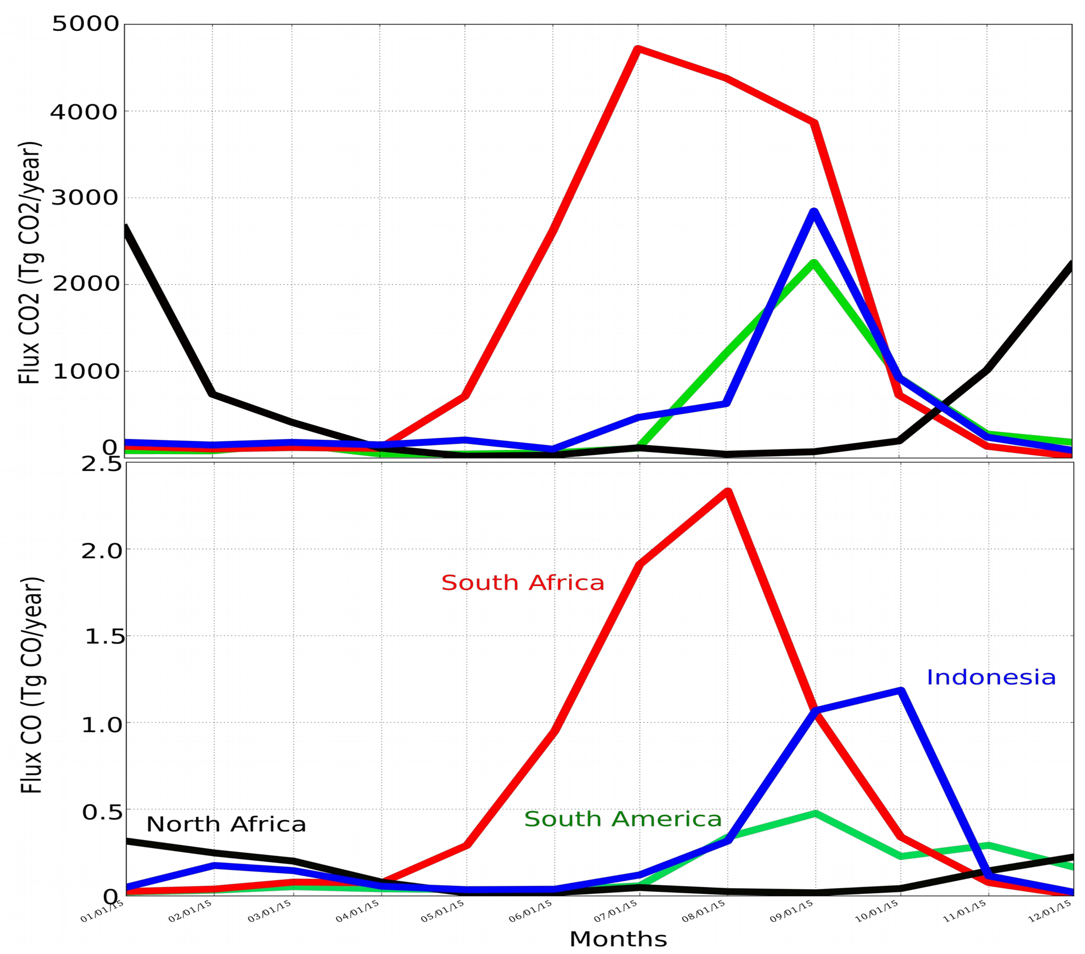
Results

I . Monthly mean CO_2 (top) and CO (bottom) mixing ratio for the tropics (Southern America, Southern Africa, Northern Africa and Indonesia) during 2015.



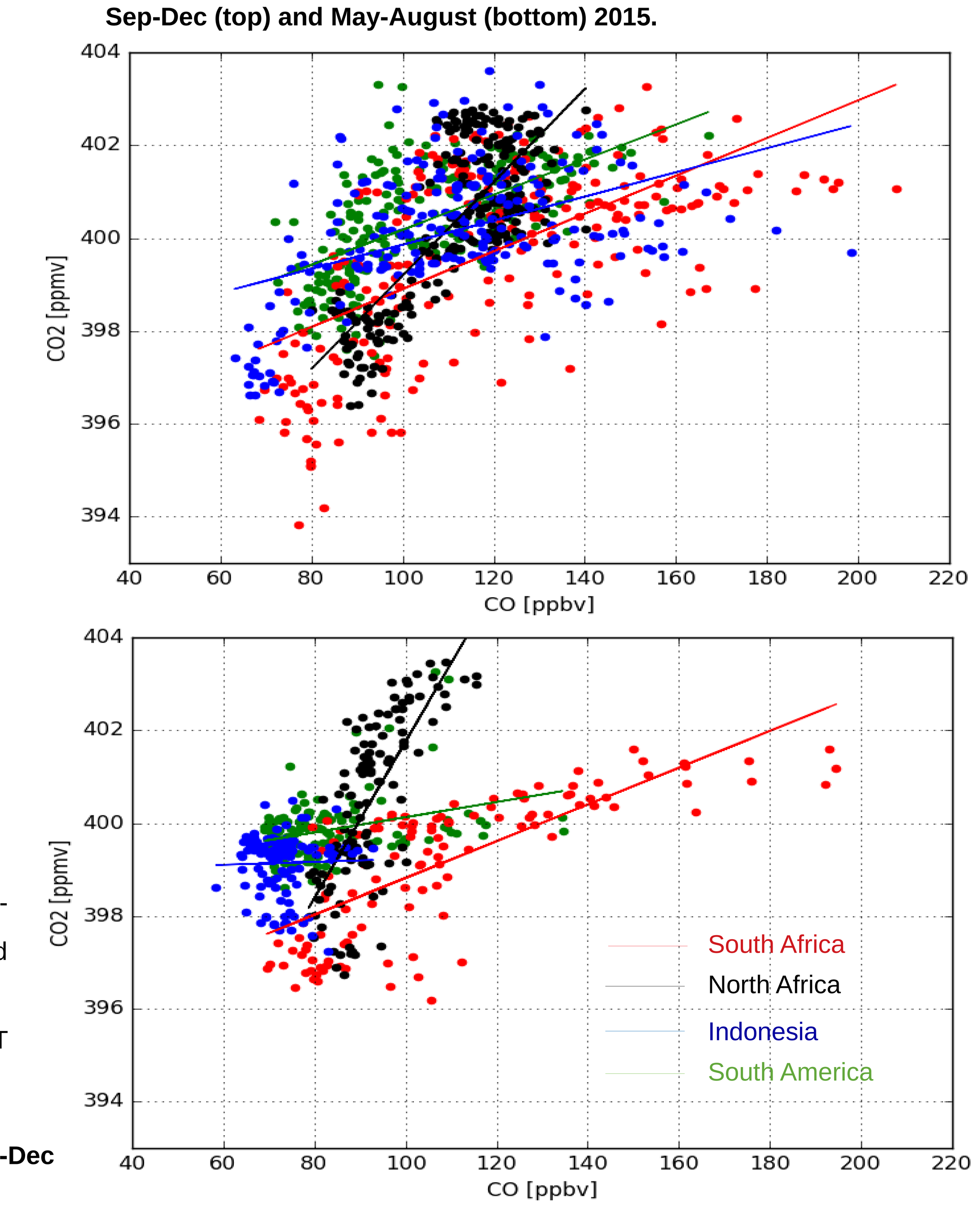
- South Africa has an opposite seasonality compared to the three others areas (CO_2,CO ↘ in January, ↗ in May). The winter in South Africa is during November through March while for the others areas is from June to October.
- Boreal/Austral Summer = photosynthesis > production of CO_2.
- CO_2 inversion from OCO-2 and CO inversion from MOPITT are seasonally correlated over the tropics

II . Monthly CO_2 (top) and CO (bottom) fire fluxes for the tropics (Southern America, Southern Africa, Northern Africa and Indonesia) during 2015.



- Observation of biomass burning season : maximum of CO_2 and CO fluxes during Jul-Aug for South Africa, Sep-Oct for Indonesia and South America (ENSO period), and Dec-Jan for North Africa.
- Strong correlation between CO and CO_2 fluxes obtained and optimized from MOPITT and OCO-2 inversions.

III . Daily CO_2-CO relationship observed for the tropics during Jan-Apr-Sep-Dec (top) and May-August (bottom) 2015.



IV . Slopes and coefficient correlation characterizing CO_2-CO correlation in Jan-Apr-Sep-Dec and May-Aug for the four areas of the study.

	Jan-Apr-Sep-Dec				May-Aug			
	Slopes (ppm/ppb)	Coefficient correlation	Standard deviation		Slopes (ppm/ppb)	Coefficient correlation	Standard deviation	
			CO	CO_2			CO	CO_2
North Africa	0.1	0.77	13.3	1.74	0.2	0.73	7.72	1.78
South Africa	0.04	0.61	30.2	2.02	0.04	0.74	28.2	1.50
South America	0.04	0.63	19.4	1.16	0.02	0.32	13.8	0.71
Indonesia	0.026	0.46	24.8	1.39	0.003	0.03	5.66	0.65

- In the area of study, only Southern America has opposite seasonality (winter in Jun-July) → Strong correlation in winter of NH and SH for the areas of study (see fig III, and table IV.) => strong influences of combustion emissions on CO_2.
- Correlation coefficient in boreal/austral summer < boreal/austral winter but correlation slopes similar (table IV.).
- Biospheric activity impact CO_2 but not CO (except from oxidation of biogenic hydrocarbons) => insignificant correlation in boreal/austral summer.

Conclusions and perspectives

- Strong correlation between CO inversions with MOPITT and CO_2 inversions with OCO-2 over the tropics particularly during winter of each hemisphere.
- Correlation of seasonality between the two inversions of CO MOPITT and CO_2 OCO-2 during 2015.
- During dry season and season of biomass burning, we observe better and strong correlation in winter compared to summer
- Perspectives : Coupling the CO and CO_2 inversions to better constraint the biospheric, anthropogenic and combustion emissions

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- The MOPITT data were obtained from the NASA Langley Research Center Atmospheric Science Data Center and OCO-2 data from JPL.