Tropospheric ozone anomalies during El Niño and CO_2 retrieval from high resolution NDACC spectra

Master Thesis and PhD

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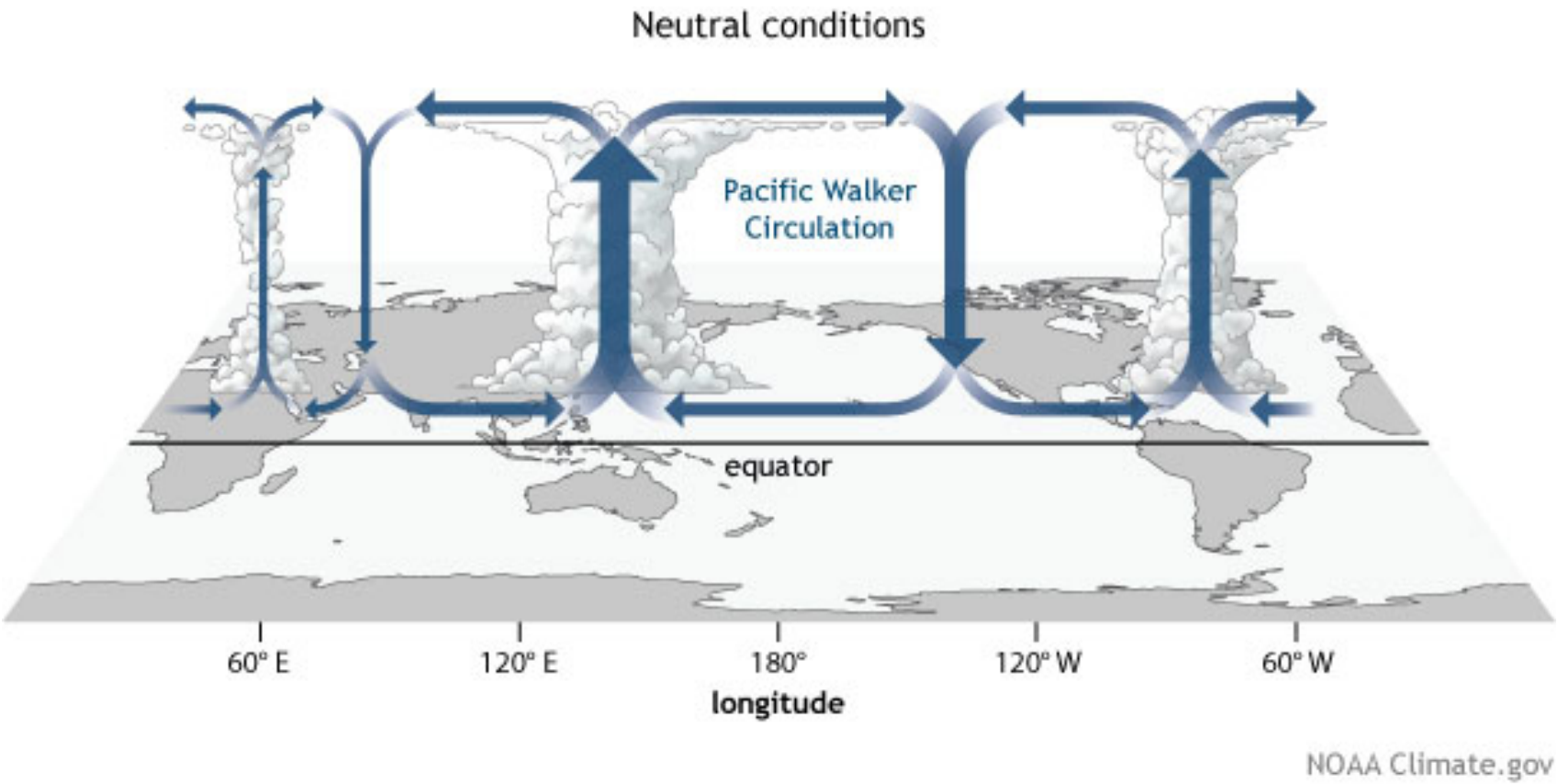
Outline

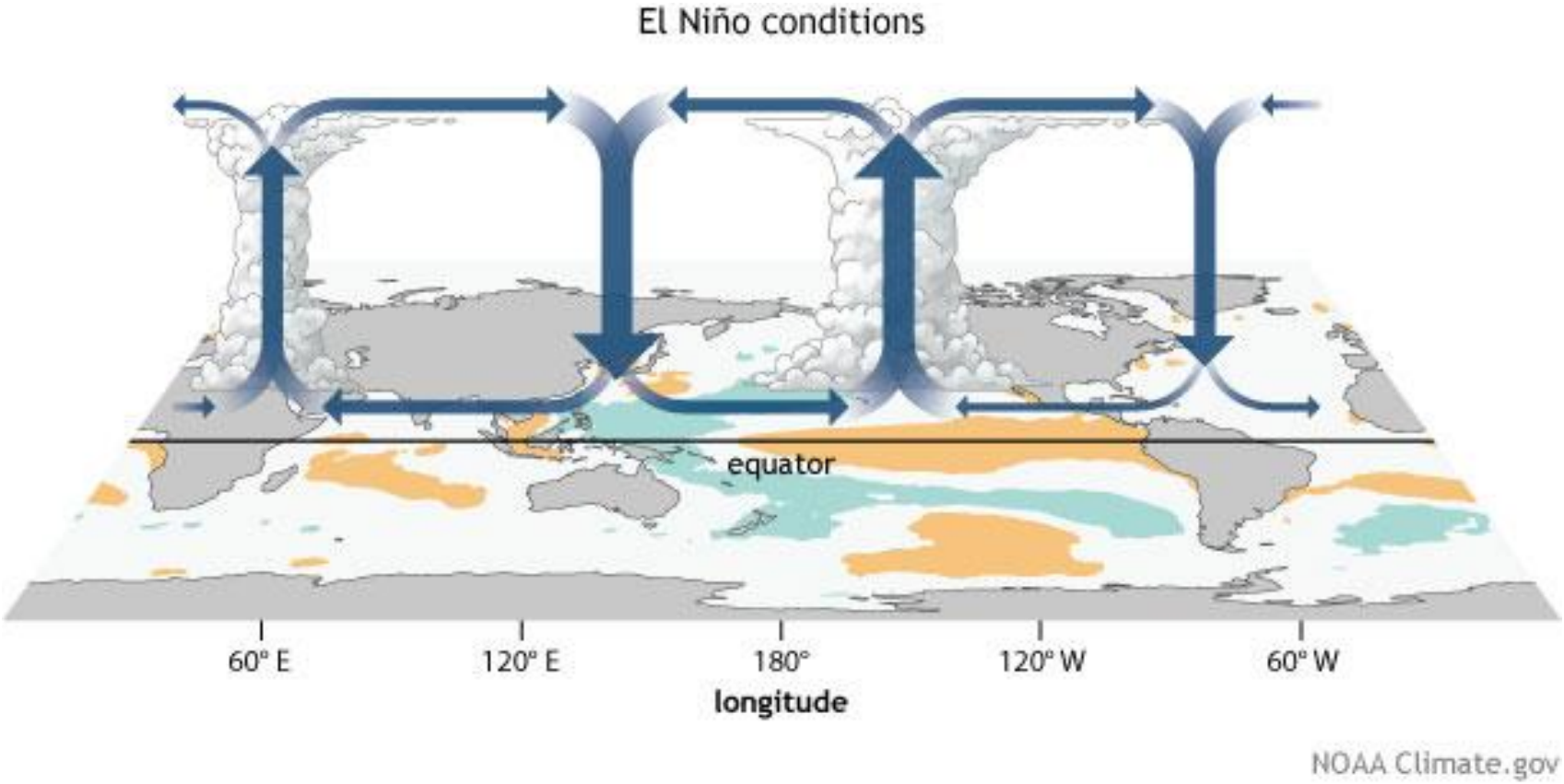
The Walker cell



Standard Walker Circulation for December-February during neutral conditions (Figure taken from NOAA: https://www.climate.gov/news-features/blogs/ enso/walker-circulation-ensos-atmospheric-buddy, drawing by Fiona Martin.)

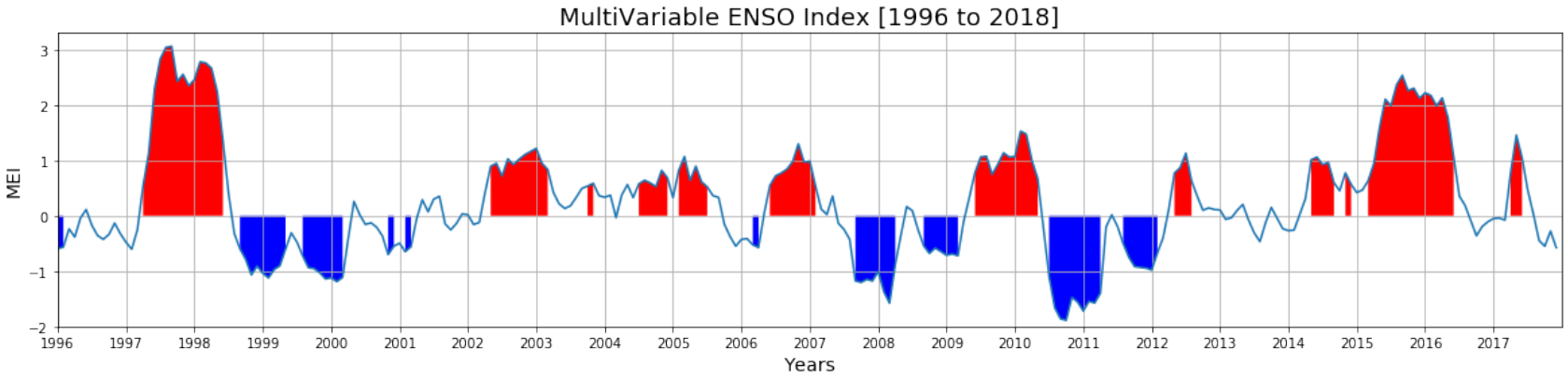
The Walker cell and El Niño

Sea Surface Temperature positive anomalies



Standard Walker Circulation for December-February during El Niño conditions (Figure taken from NOAA: https://www.climate.gov/news-features/blogs/ enso/walker-circulation-ensos-atmospheric-buddy, drawing by Fiona Martin.)

Effects of El Niño in the troposphere



Data from: https://www.esrl.noaa.gov/psd/enso/mei/

- Reverse of the Walker circulation, suppressed convection and drought over the Pacific warm pool [Ropelewski and Halpert, 1987].
- Higher count of wild fires on Oceania [Doherty et al., 2006].
- Increase of Tropical Tropospheric Column of Ozone (TTCO) in Pacific warm pool [Chandra et al., 1998], [Fujiwara and Kita, 2000], [Sudo and Takahashi, 2001], [Thompson, 2001].
- Other tropospheric chemistry changes [Sudo and Takahashi, 2001].

Tropical Tropospheric Ozone Column [Leventidou, 2017]

- GOME/ERS-2, SCIAMACHY/Envisat, GOME-2/MetOp-A,
- Available for 1996 to 2017 and 20°N and 20°S
- Convective Cloud Differential (CCD) [Ziemke et al., 1998]

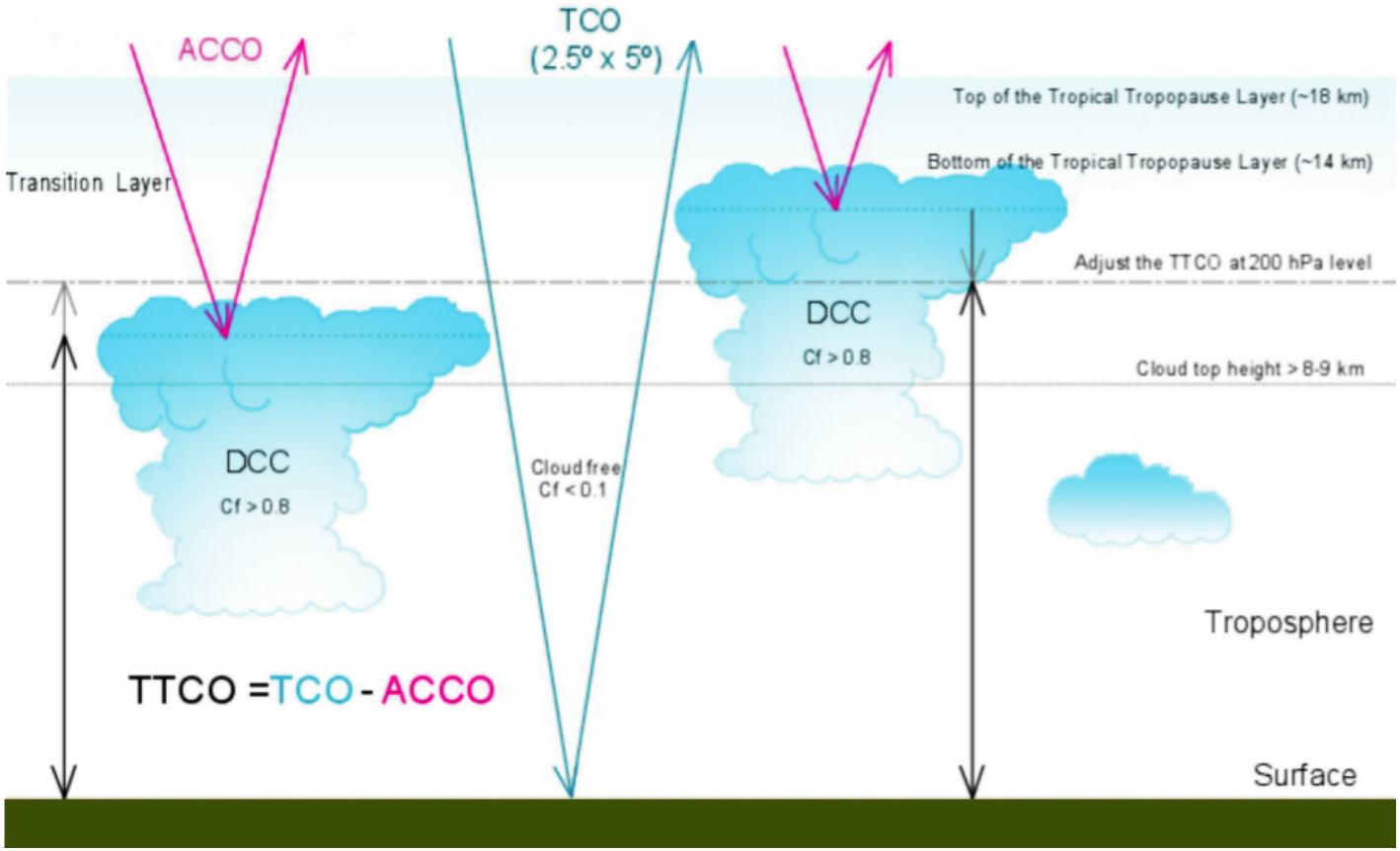


Figure taken from [Leventidou et al., 2016] and modified

Global Fire Emissions Databased (*GFED4*) [van der Werf et al., 2017]

- Derived from satellites measurements (VIRS, ATSR and MODIS).
- Months: August to January of 1997/1998 and 2015/2016.
- Resolution of 0.25° by 0.25°, [20°N, 20°S].

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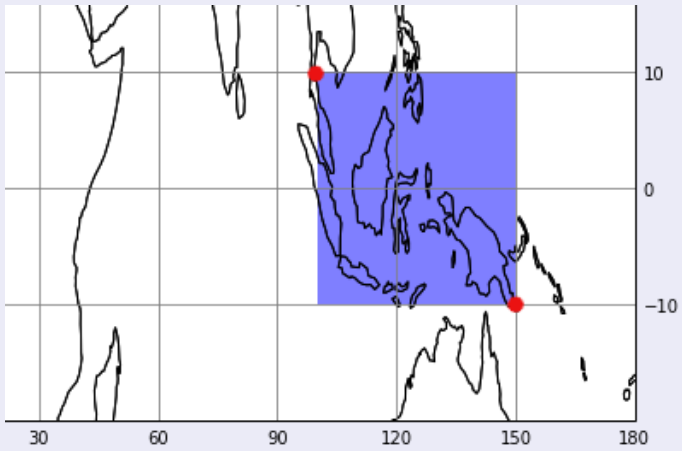
Particle transport & dispersion model FLEXPART [Stohl et al., 2005]

Lagrangian off-line model version 8.0. Meteorological fields from the European Center of Mid-range Weather Forecast (*ECMWF*)

- Forward simulation upper left corner [10°, 100°] lower right corner [-10°, 150°].
- Resolution: 1°x 1° , 20 layers of 1km
- Monthly emissions 2.0×10^6 particles

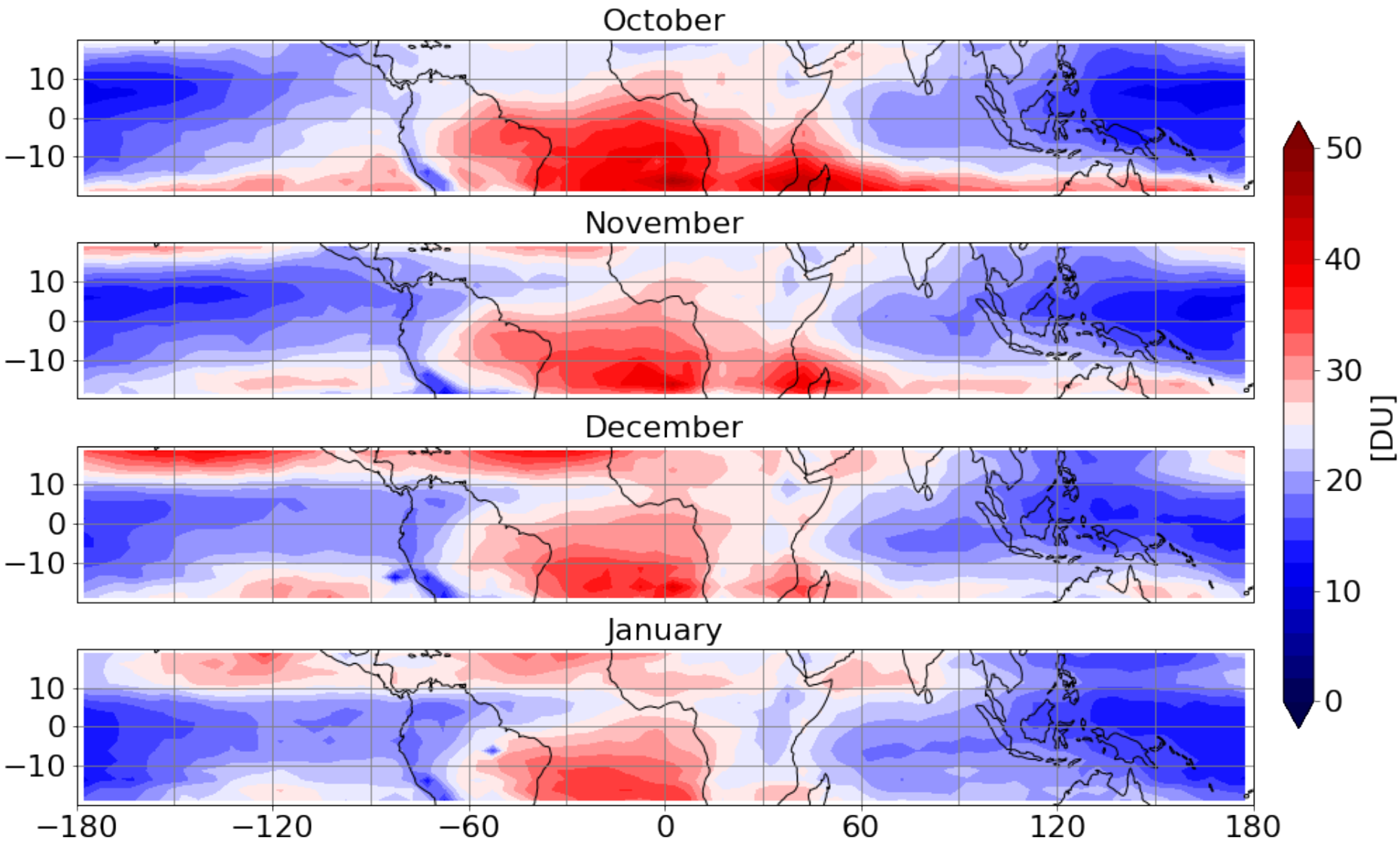


Global Chemistry and transport TM4-EPCL [Daskalakis et al., 2016]

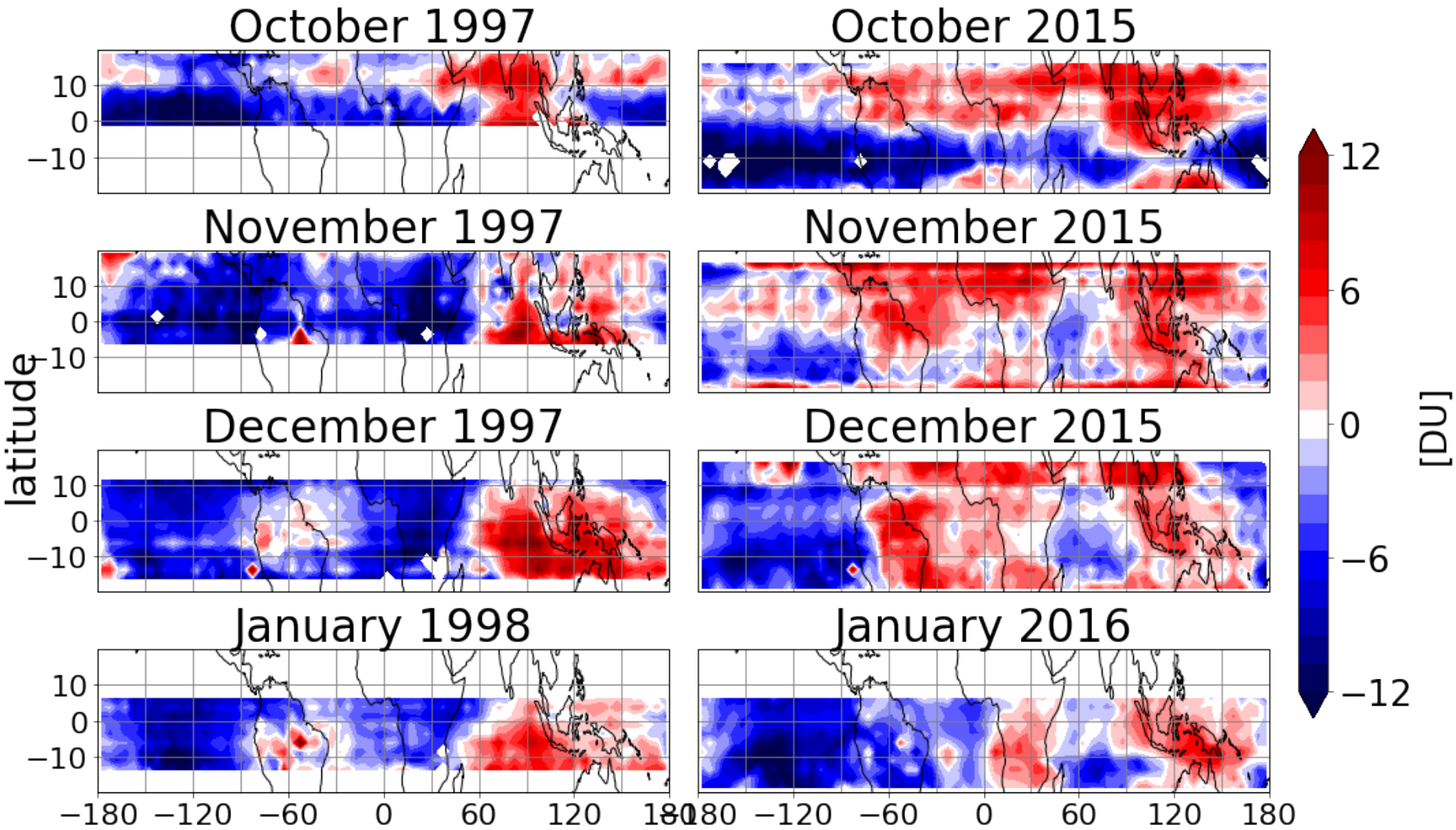
3D offline model. Meteorology from *ECMWF*, anthropogenic and biomass emissions from *ACCMP*, vegetation inventory from *MEGAN-MACC* and *POET2000* for soils and oceans.

- O_3, CO Fields
- Anthropogenic and Biomass Burning scenarios
- Resolution: 2° by 3° and 34 hybrid vertical layers
- Top of troposphere below 150 ppb of O_3 (23rd layer)

Observed ozone monthly mean for the 20 year period

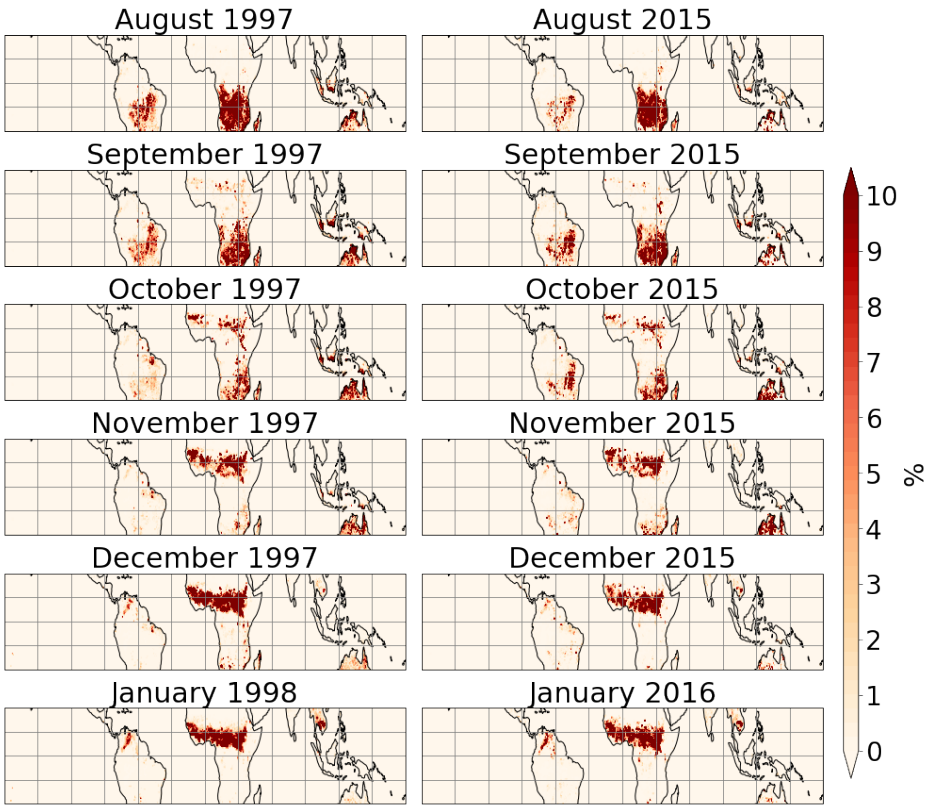


The observed tropospheric ozone anomalies

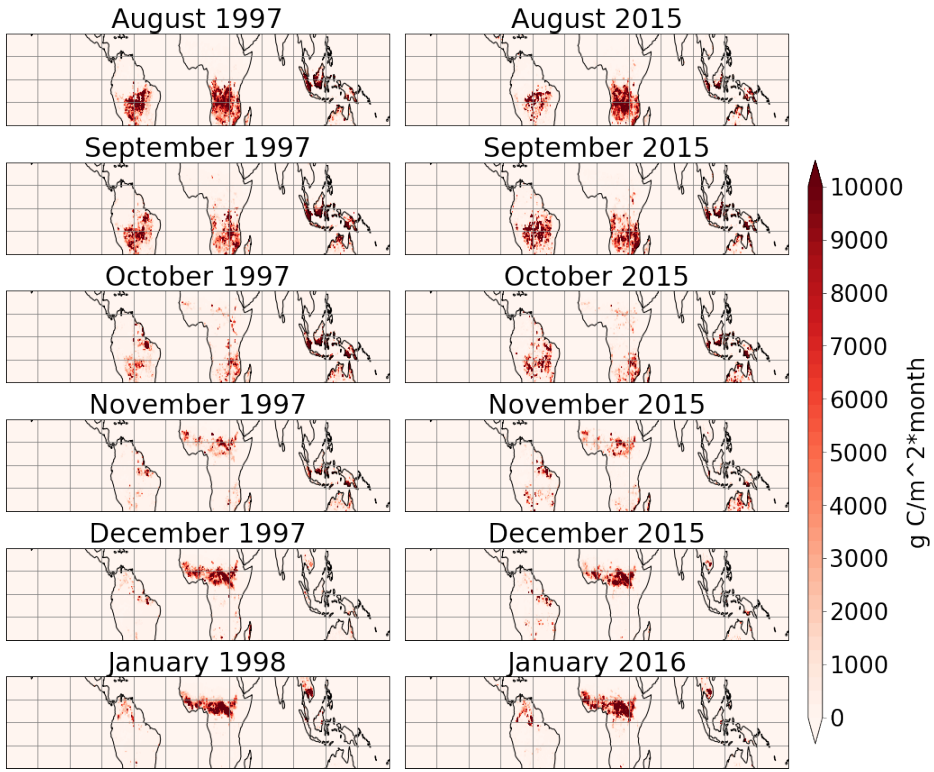


The GFED4 data

Monthly burned area fraction

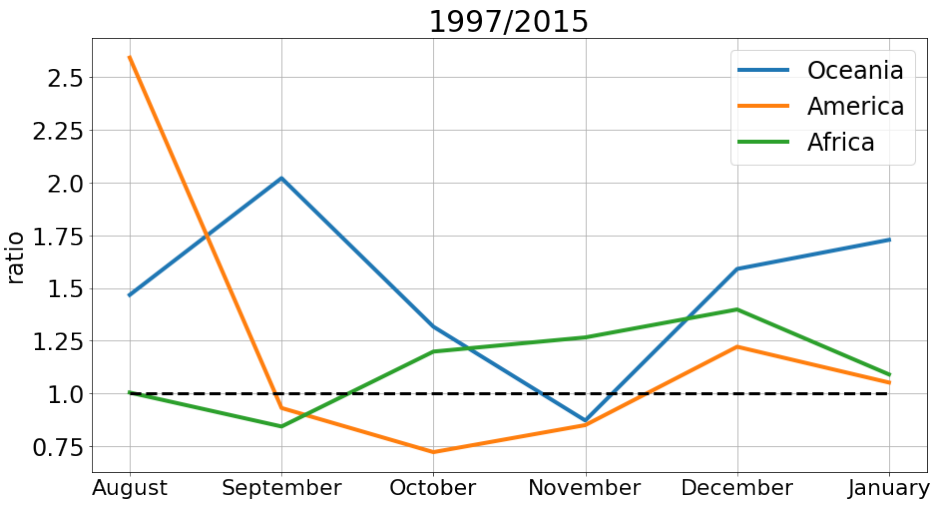


Monthly fire carbon emissions

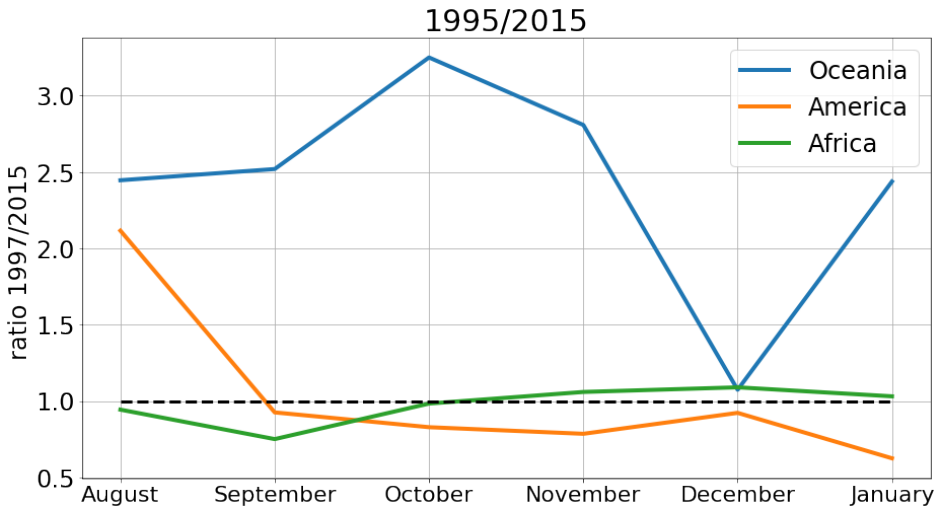


The ratios of GFED4 data

Ratios : 1997/1998 divided by 2015/2016.
Regions: Oceania [-90°, -160°], Africa [-20°, 50°], America [90°, 160°]

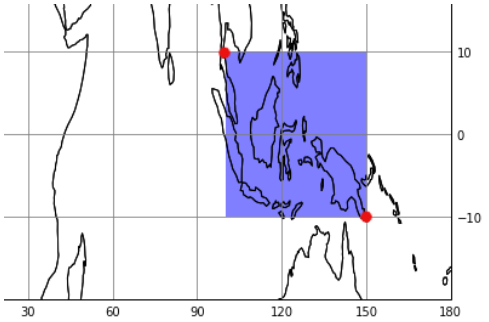


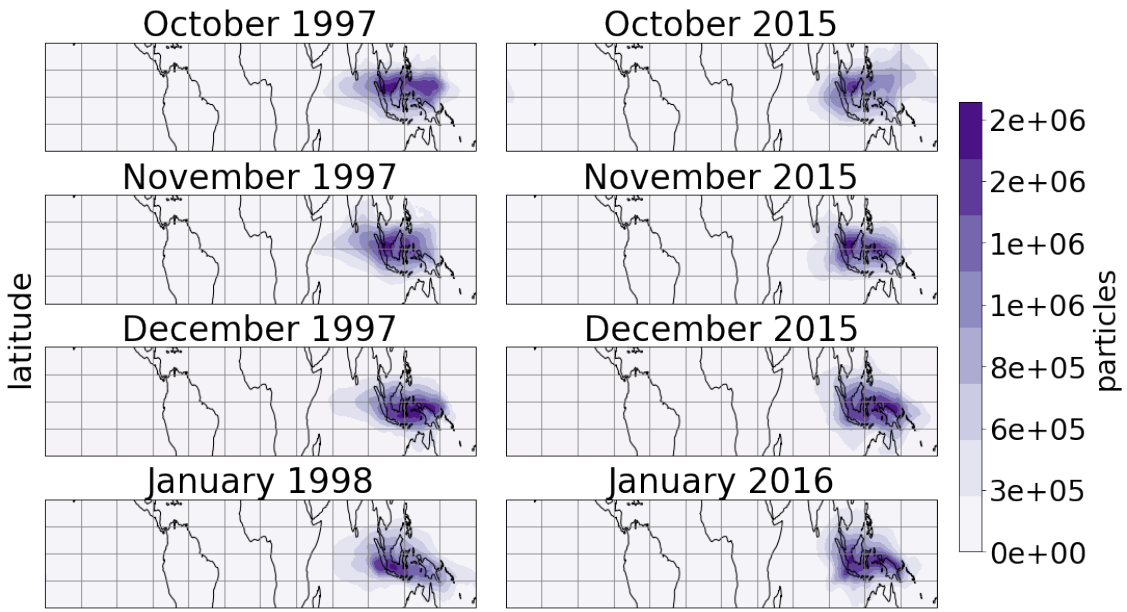
Burned fraction area



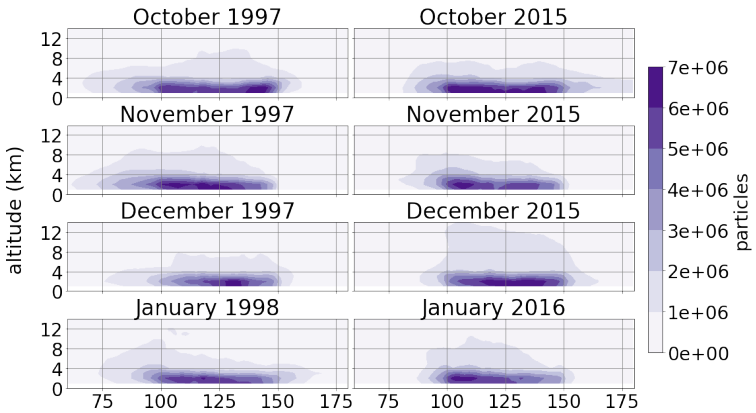
Fire carbon emissions

FLEXPART Transport of ozone





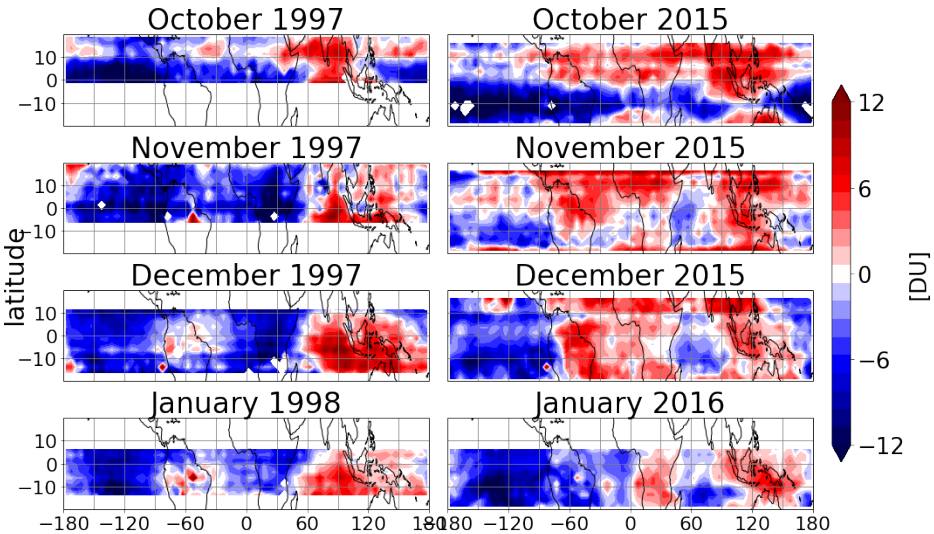
Monthly geographical transport



Monthly altitudinal profile

Observed TTCO and TM4-ECPL TTCO

Tropospheric Ozone anomalies



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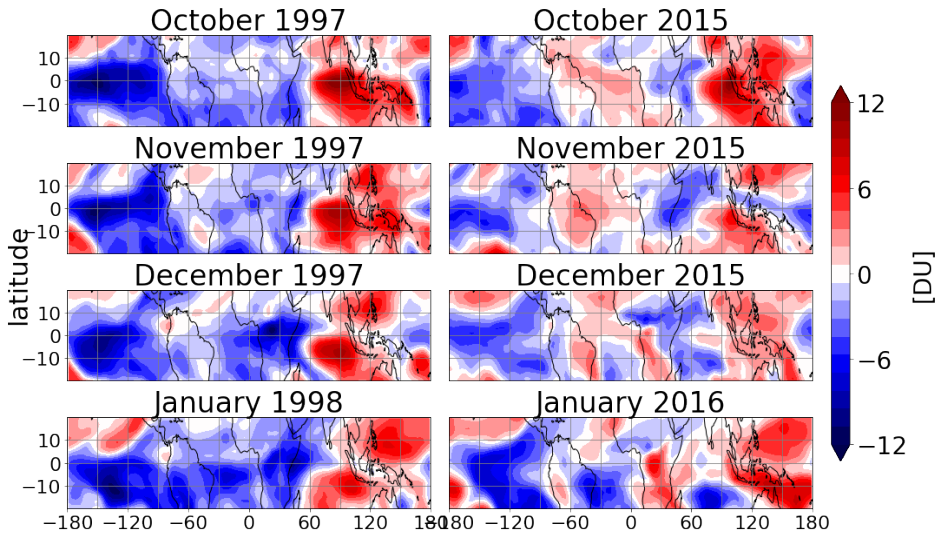
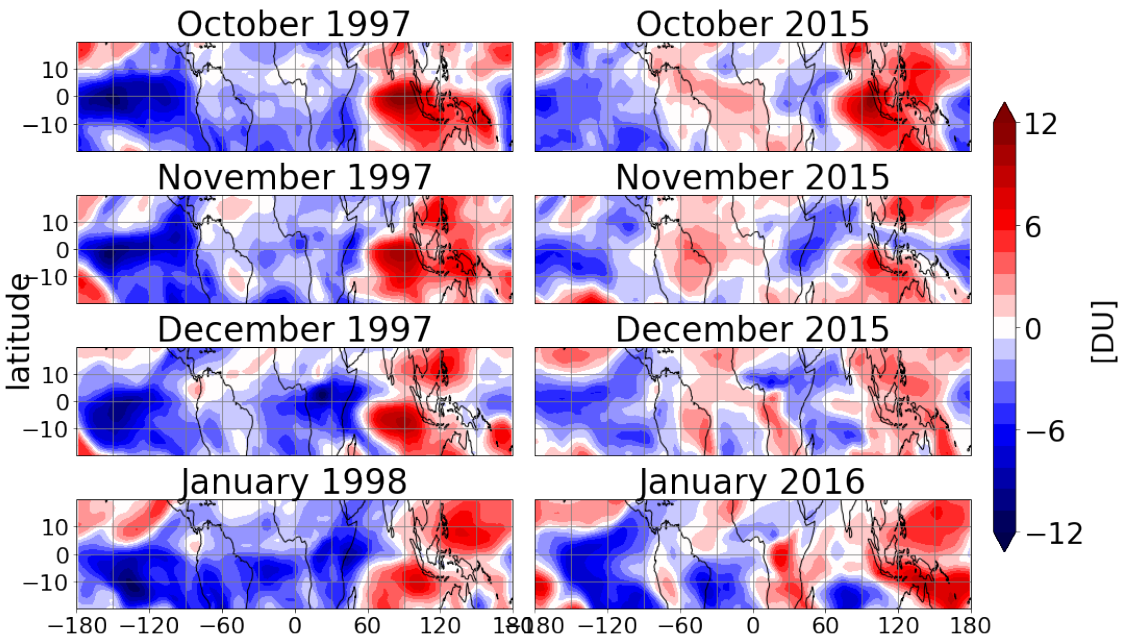


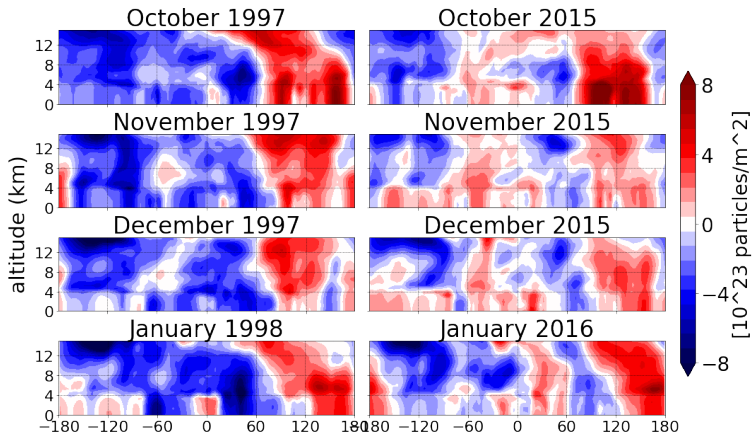
TM4-ECPL TTCO anomalies

TM4-ECPL Changes in the concentration of ozone and precursors

Tropospheric Ozone anomalies



TTCO anomalies



Ozone vertical profile anomalies

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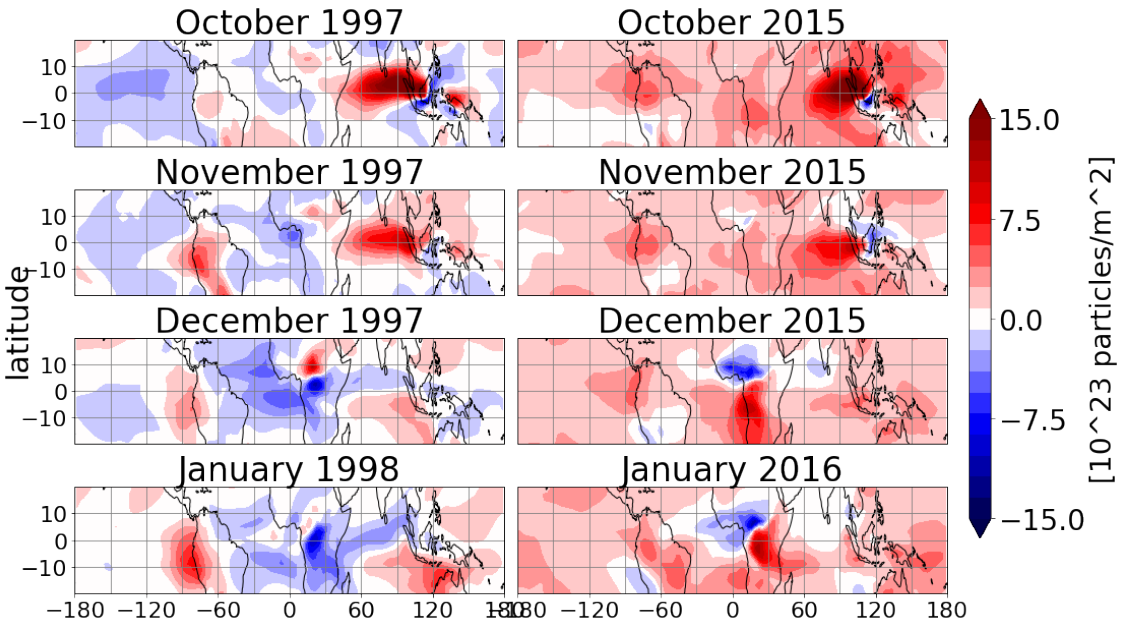
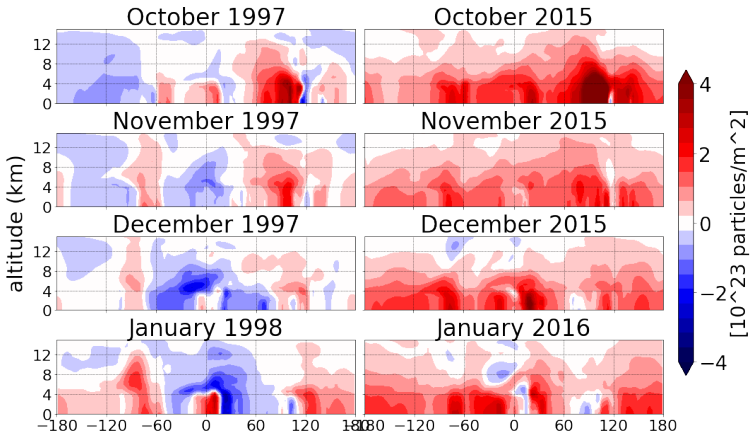


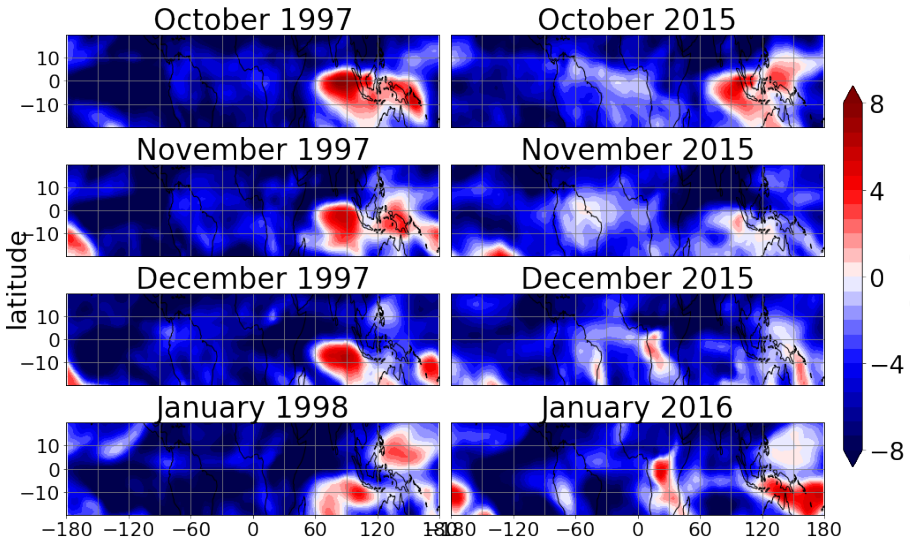
tropospheric carbon monoxide column anomalies



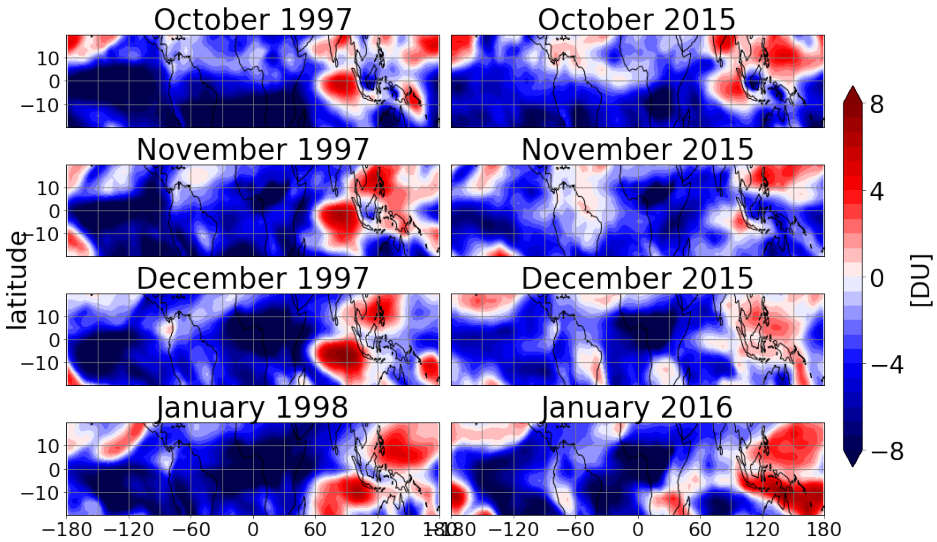
carbon monoxide vertical profile anomalies

TM4-ECPL Biomass Burning and Antropogenic emissions

Ozone anomalies



Biomass burning anomalies



Anthropogenic anomalies

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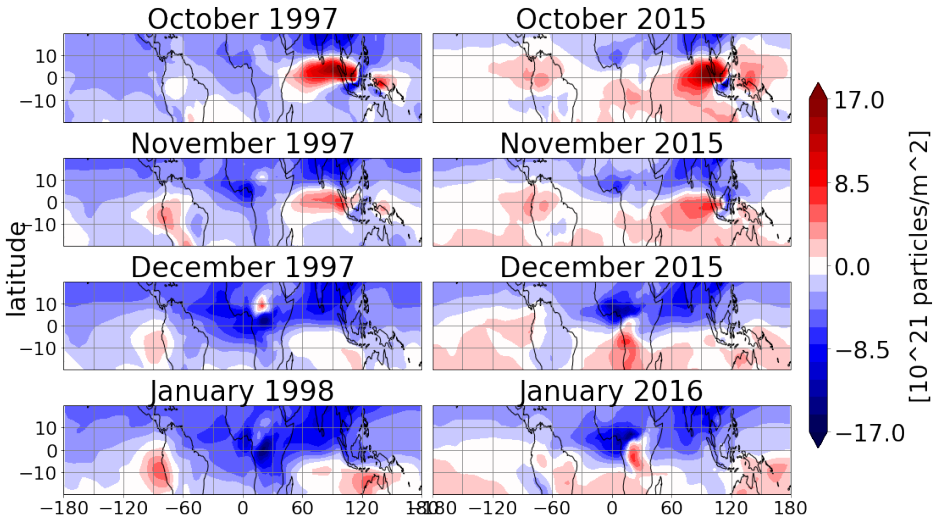
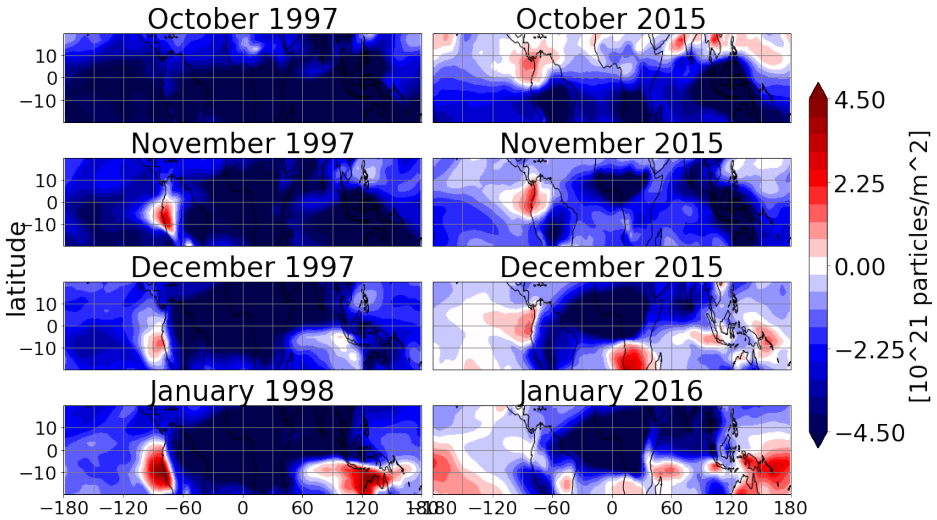


Biomass Burning anomalies



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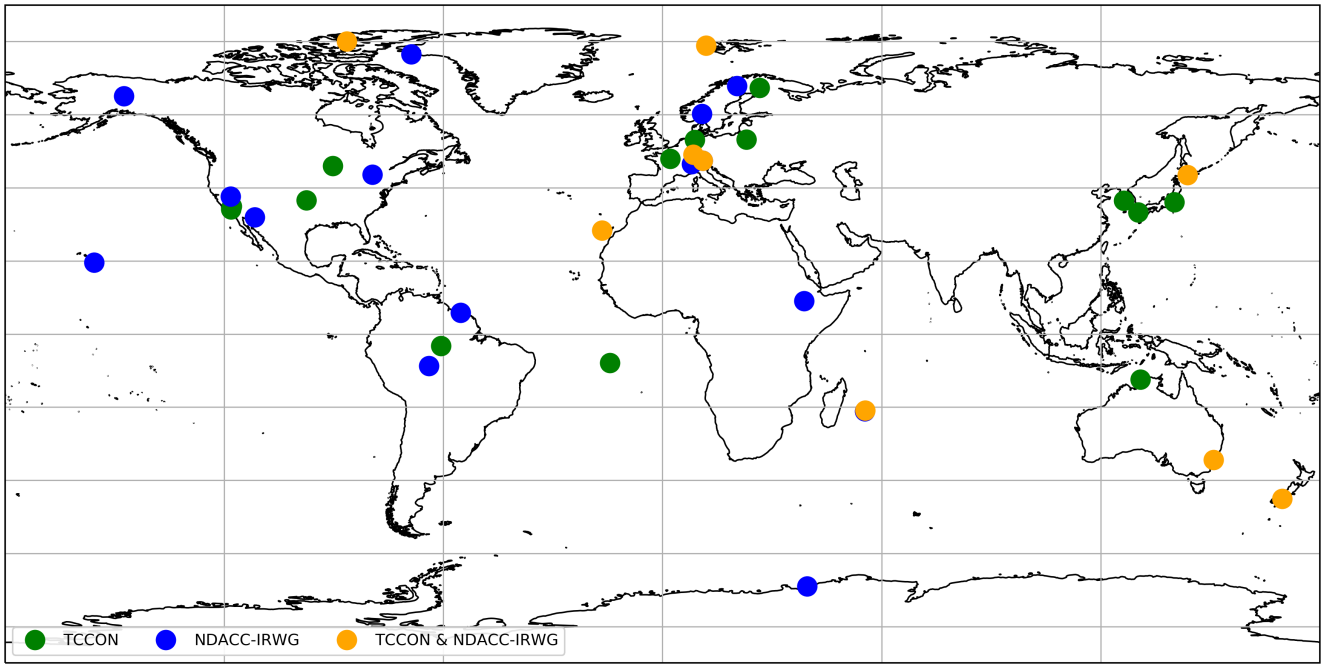
- Why the O_3 has the same values for biomass burning and athropogenic?

PhD: Towards a better understanding on carbon fluxes in the tropics

- We want to study CO_2 fluxes in the Amazon region
- There is little remote sensing measurements retrieving GHGs
- Establish a xCO_2 retrieval for NDACC measurements that are available in:



PhD so far

xCO_2 retrieval from high resolution NDACC measurements in the 4800 cm^{-1} region

Introduction

- TCCON operation started in 2004
- NDACC spectra are available in Ny-Ålesund since the early 1990s.
- Use the NDACC spectra for xCO_2 retrieval
- Selected the spectral window in the region between 4780 cm^{-1} and 4800 cm^{-1}
- Used the ggg2014 TCCON retrieval package
- The daily means of the xCO_2 NDACC compared to TCCON and *in situ* data.

Data and Methods

w90 : spectral window centered at 4790 cm^{-1} and 20 cm^{-1} width

From it xCO_2 is calculated:

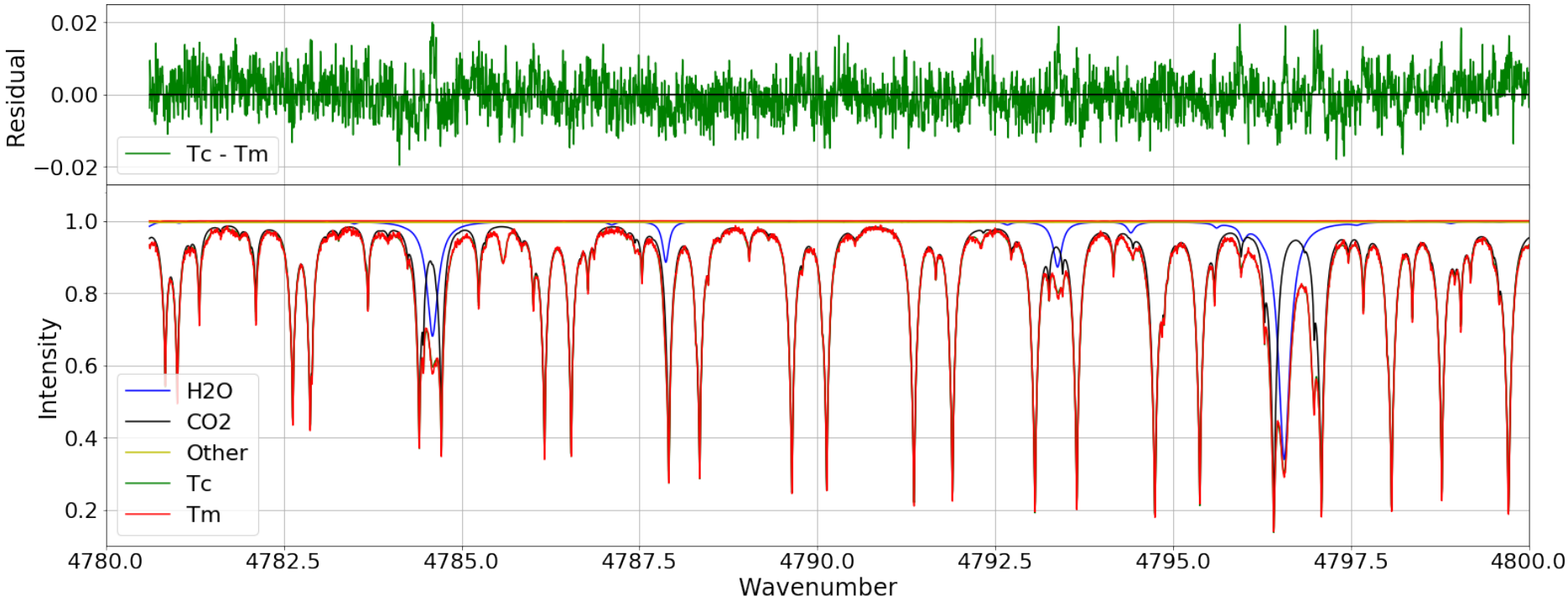
$$xCO_2 = \frac{VC_{CO_2}}{VC_{air}} = \frac{VC_{CO_2}}{\frac{P_s\, N_A}{m_{air}^{dry}\ \{g\}} - \frac{VC_{H_2O}\, m_{H_2O}}{m_{air}^{dry}}}$$

H_2O window at 4576.85 cm^{-1} and 1.90 cm^{-1} width.

Filter criteria: spectra with a SZA >83° and bad spectra.

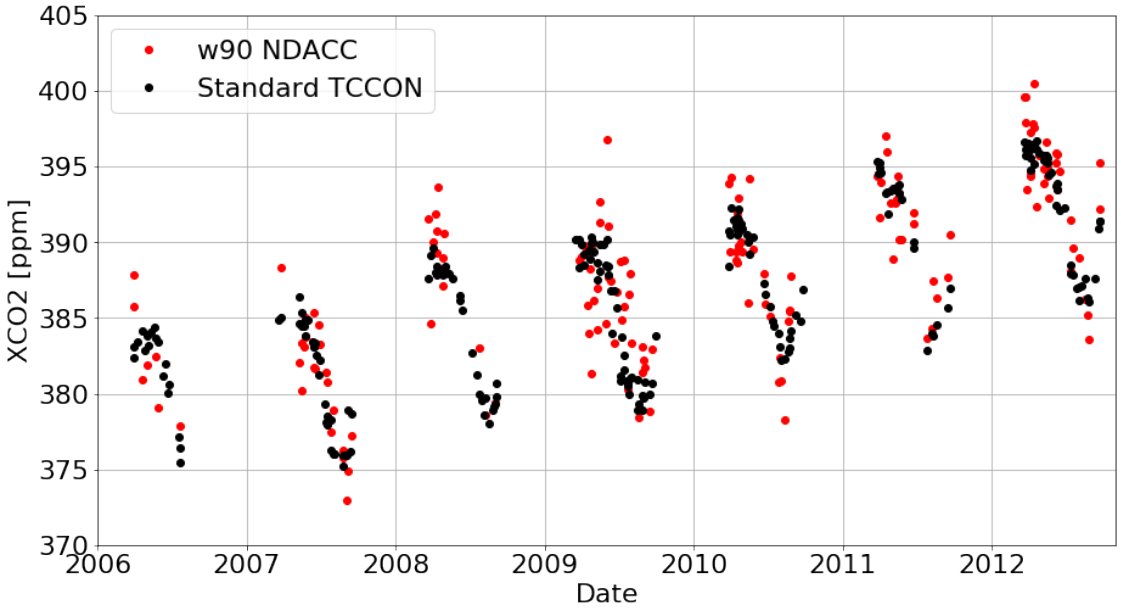
Lastly, daily means weighted with the error of the retrieval was calculated.

Fit and Residual

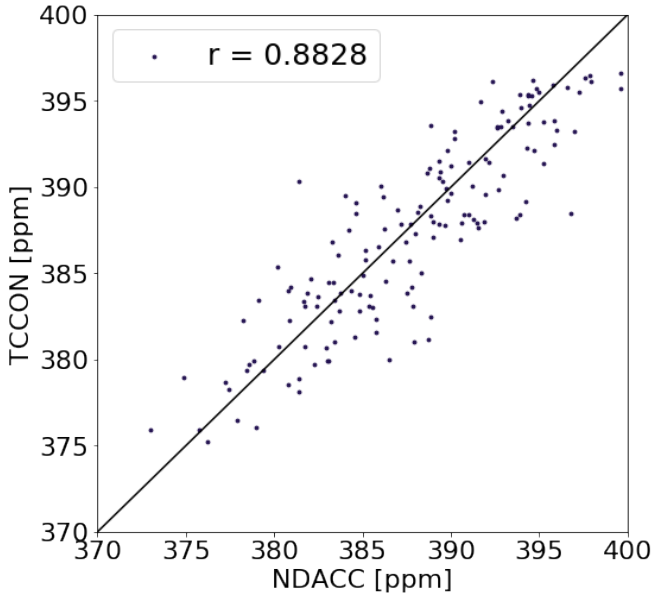


The fit of the calculated spectra and the residual (Tm-Tc) for a typical NDACC spectrum

NDACC and TCCON

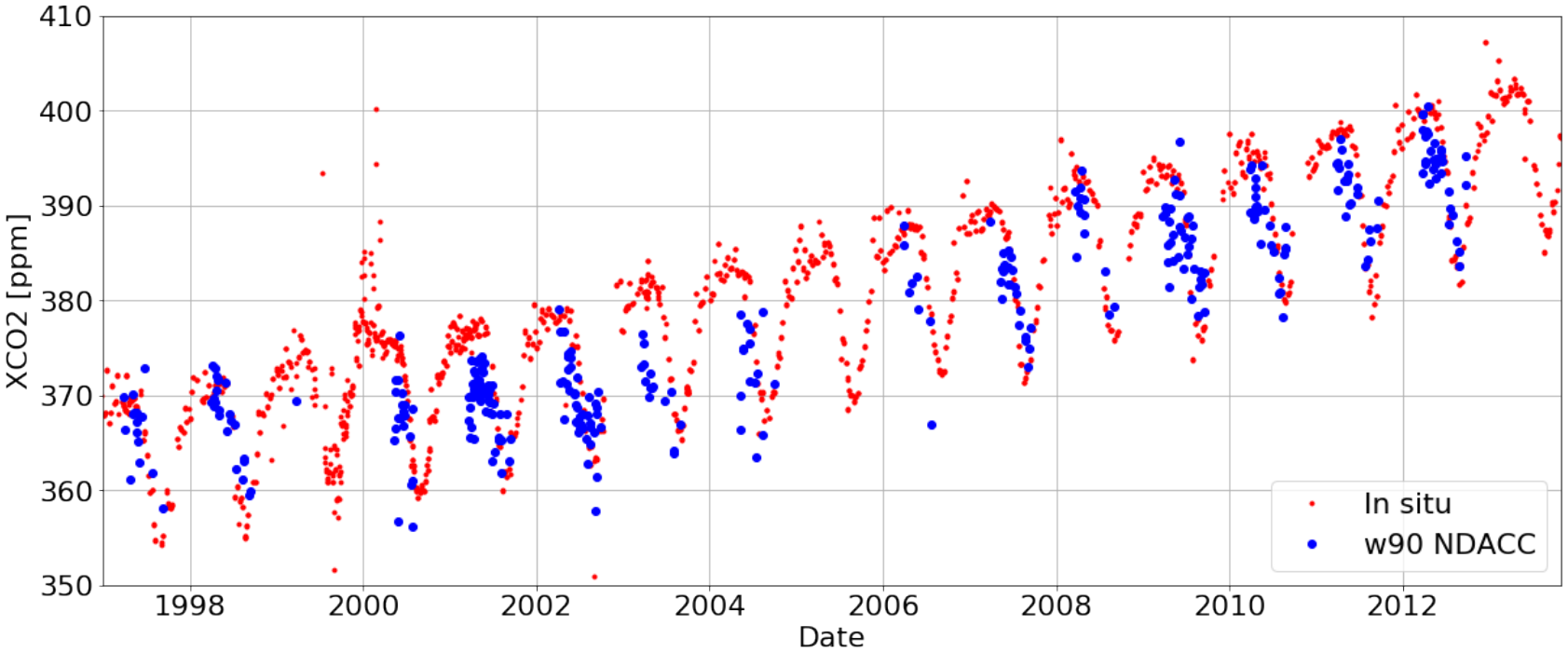


Daily means of xCO_2 of the TCCON and the weighted daily mean of xCO_2 NDACC



The correlation between TCCON and NDACC

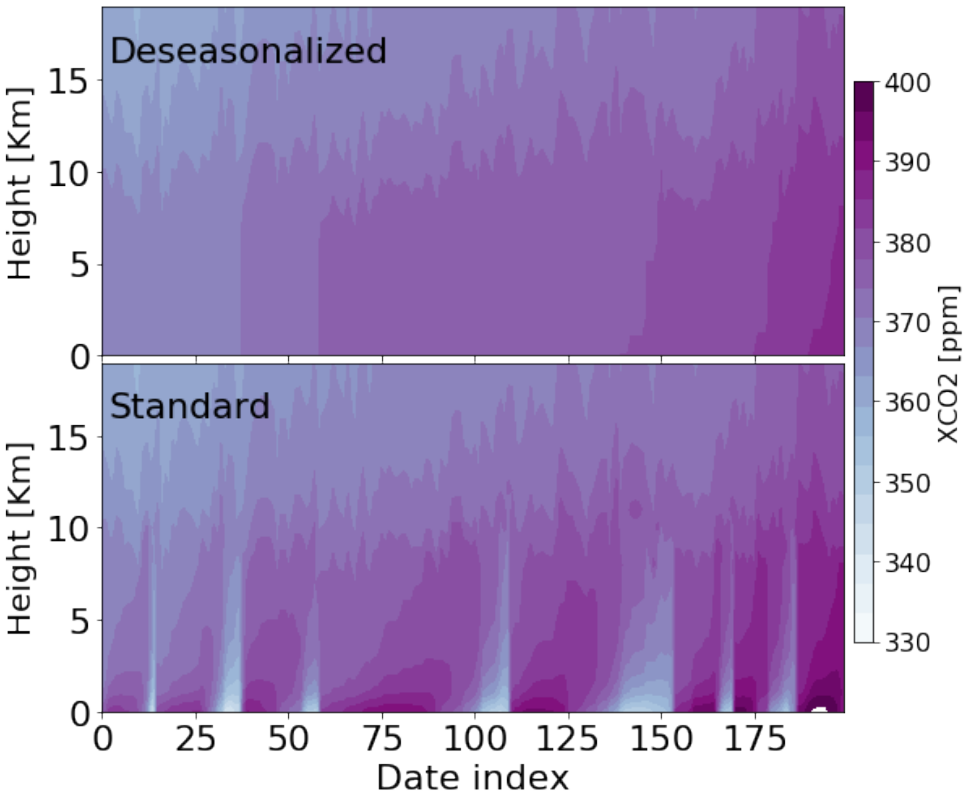
NDACC and *in situ*



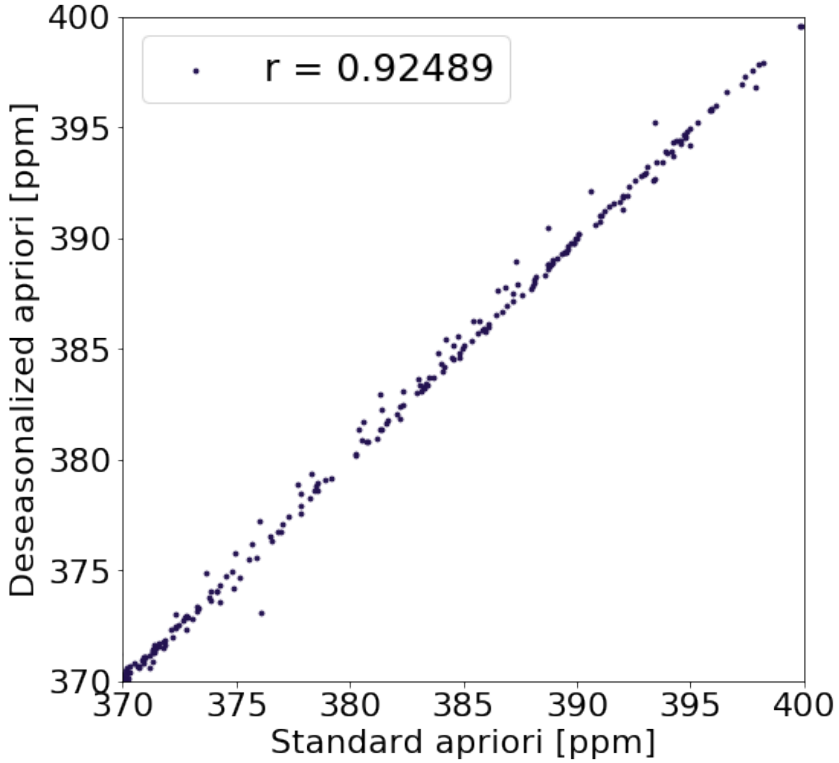
NDACC CO_2 comparison with *in situ* flask data ZEP

[Dlugokencky, E.J.] (*ftp://aftp.cmdl.noaa.gov/data/trace_gases/co2/flask/surface/*)

Sensitivity studies: *a Priori*

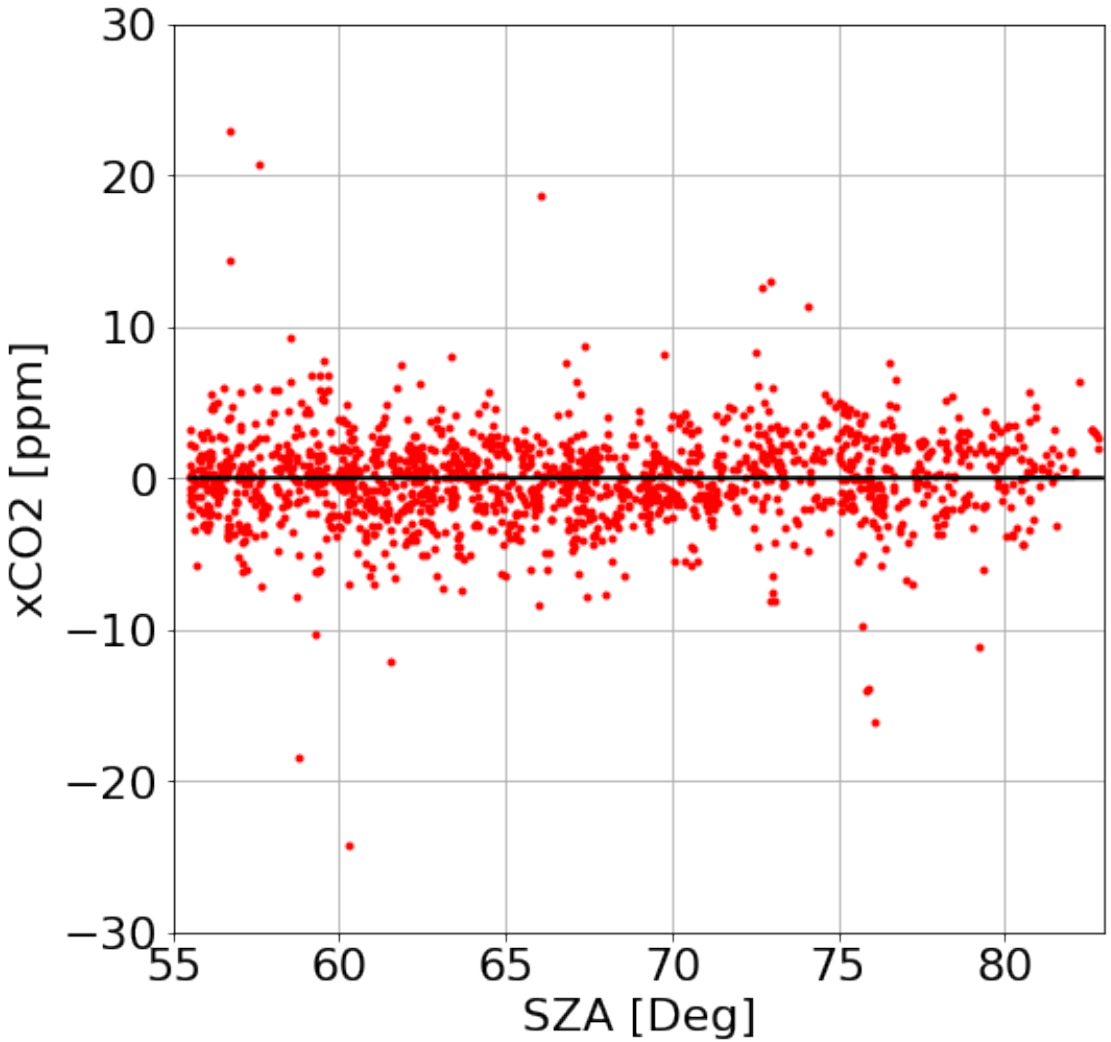


Standard and deseasonalized *a priori* profiles



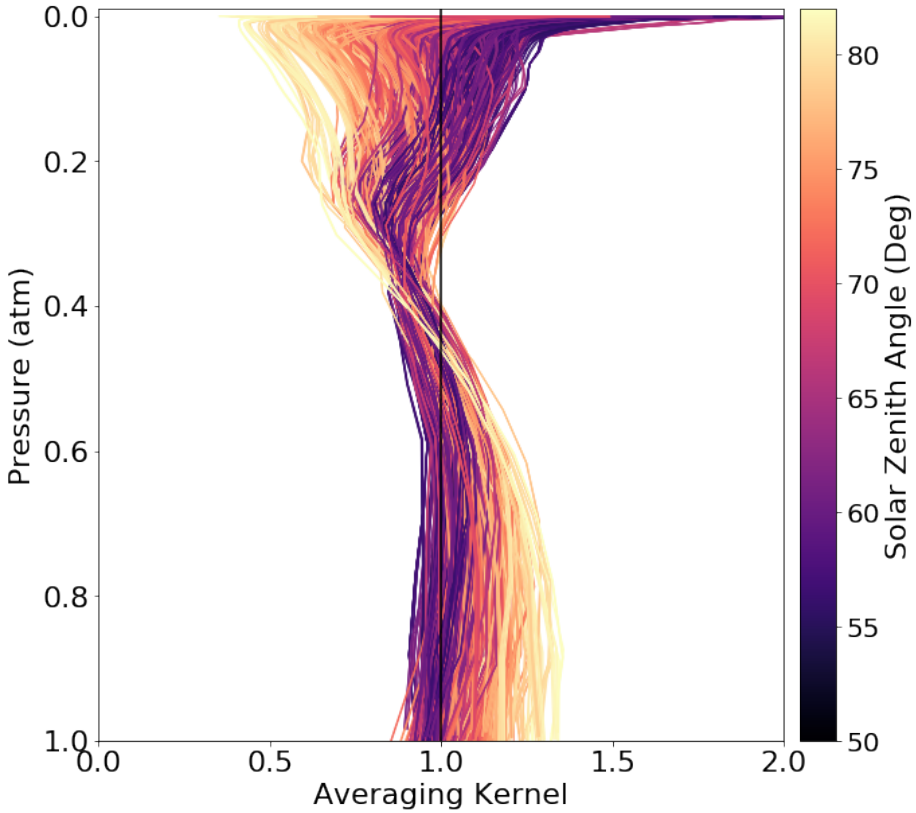
Correlation between xCO_2 with standard and deseasonalized *a priori*

Sensitivity studies: Solar Zenith Angle

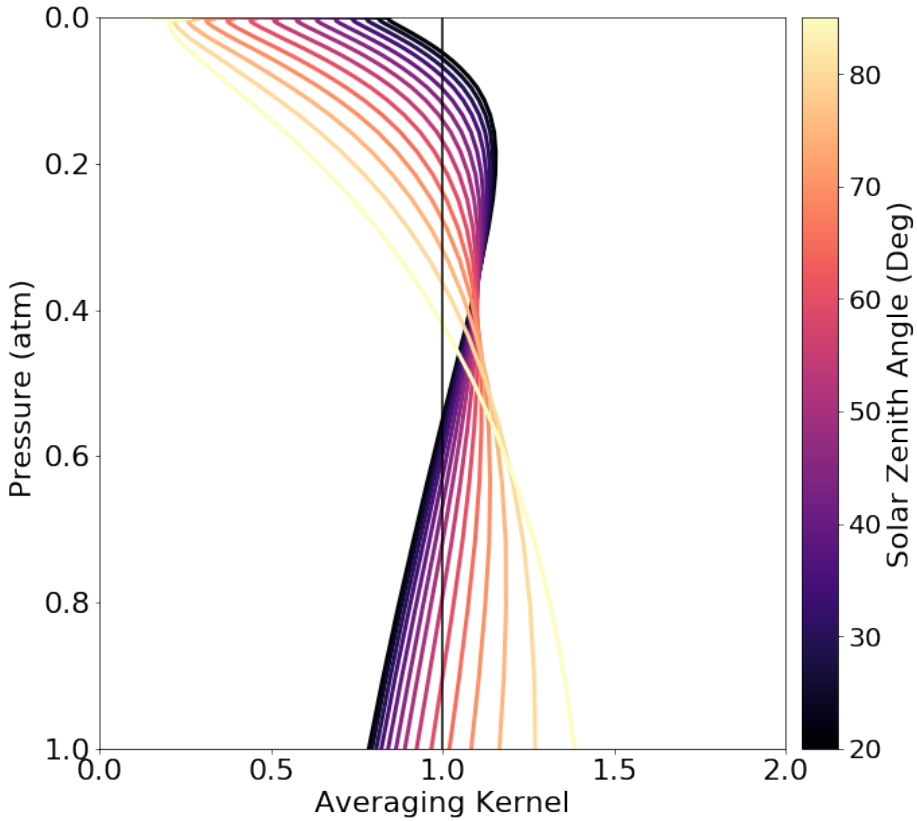


NDACC xCO_2 - monthly mean SZA dependance

Total column averaging kernels



W90 averaging kernels for all NDACC spectra



The averaging kernels for the standard TCCON xCO_2

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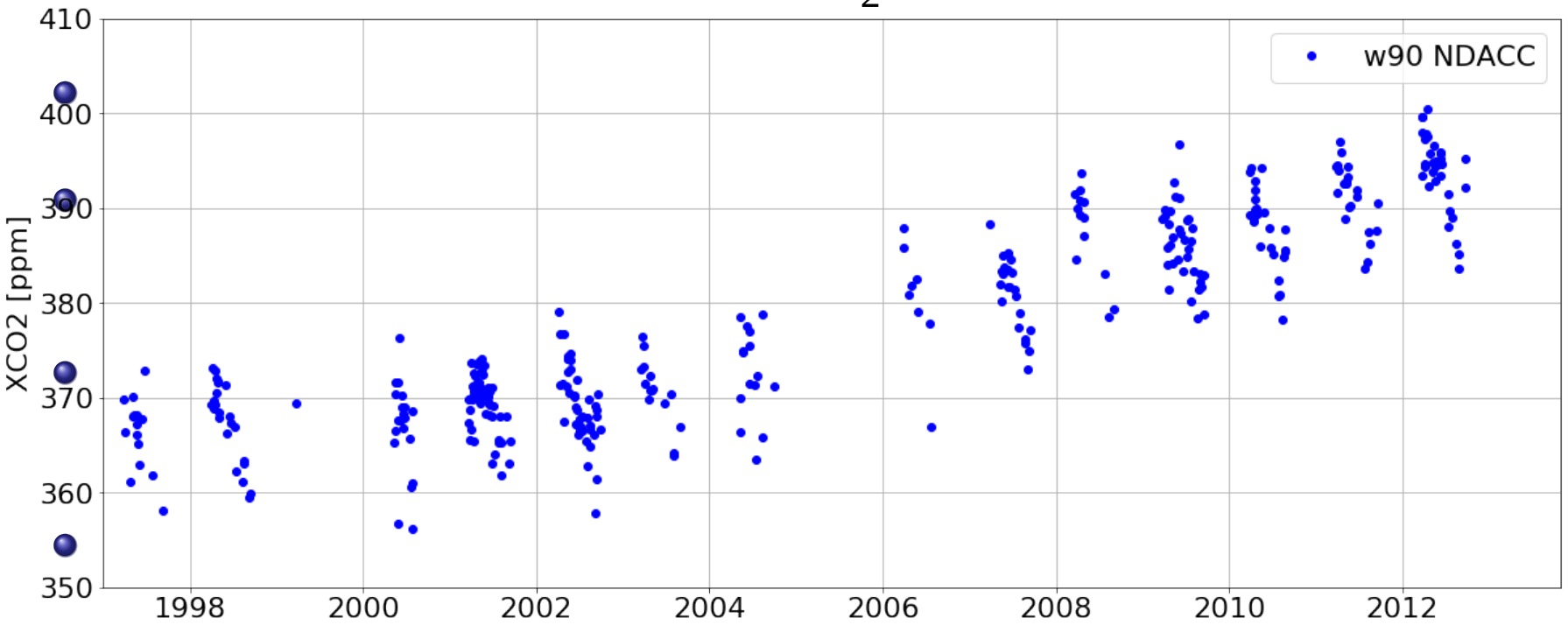

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- Compare the results with atmospheric and biospheric models
- Using future *in situ* measurements of carbon in rivers in the tropics.

Thank you

References

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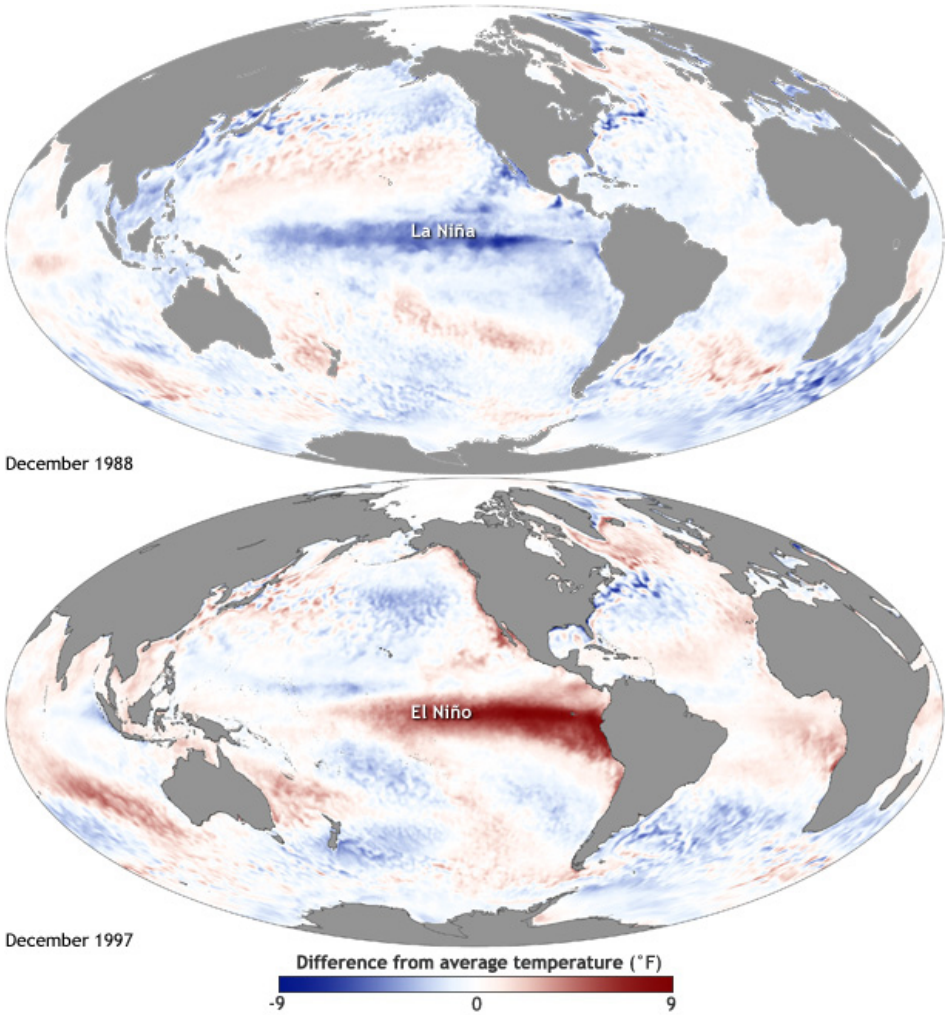
Region	Carbon emissions Tg C yr^{-1}		Contribution of vegetation type to the emissions (%)			
	Mean	Maximum	Savanna	Tropical Forest	Peat	Agriculture
Central America	38	177	45.5	36.7	0.0	15.9
Northern S.A	32	60	71.1	23	0.0	5.9
Southern S.A	291	561	49.3	45.1	0.0	3.2
Northern Africa	451	645	88.3	5.2	0.0	6.5
Southern Africa	669	774	92.4	4.8	0.0	2.7
Indonesia	173	1110	11.2	43.7	42.8	2.2
Australia	116	190	86.3	2.3	0.0	1.5

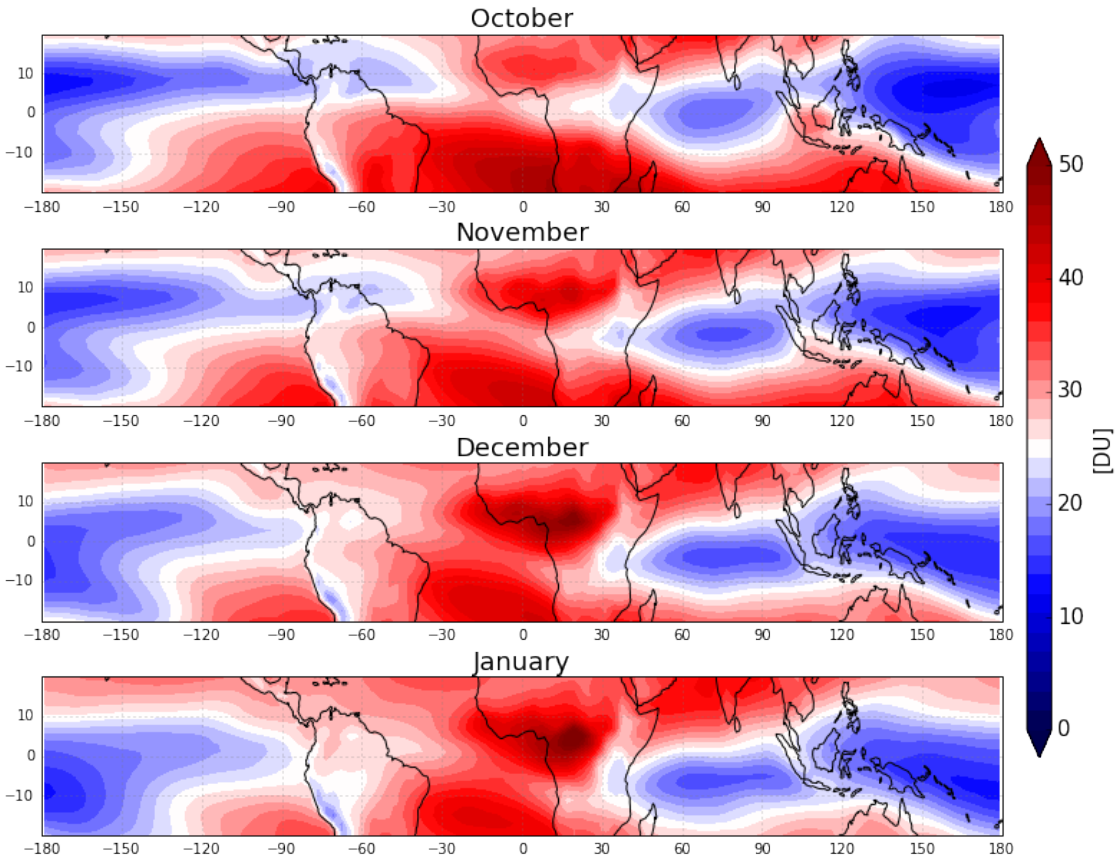
Carbon emissions estimates and the contribution of different fire categories over the 1996 to 2016 study period. Values, some regions, and some vegetation types selected from [van der Werf et al., 2017] page 711.



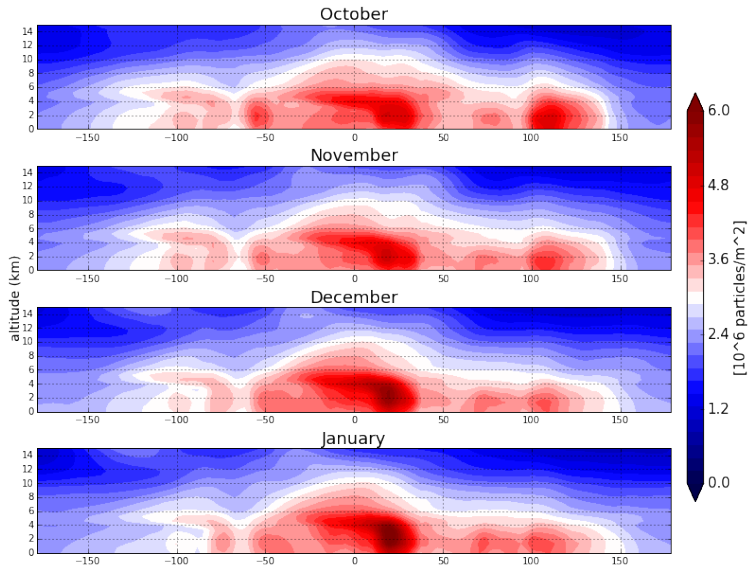
Maps of sea surface temperature anomaly in the Pacific Ocean during a strong La Niña (top, December 1988) and El Niño (bottom, December 1997). Maps by NOAA Climate.gov, based on data provided by NOAA

TM4-ECPL 20 year mean TTCO

Tropospheric Ozone MEAN of 20 years



TTCO MEAN



Ozone vertical profile

$$xCO_2 = \frac{VC_{CO_2}}{\frac{P_s\, N_A}{m_{air}^{dry}\,\{g\}} - \frac{VC_{H_2O}\, m_{H_2O}}{m_{air}^{dry}}}$$

VC_{CO_2} is the CO_2 vertical column from the ggg output from w90, VC_{H_2O} is the vertical column from the ggg output for the water window at 4576.85 cm^{-1} of 1.90 cm^{-1} width, P_s is the surface pressure in hPa, $Na = 6.0221415\ 10^{23}$ molecules/mole, the Avogadro number; $m_{air}^{dry} = 28.9644$ g/mole, mass of dry air; $m_{H_2O} = 18.01534$ g/mole, the mass water and $\{g\} = 9.81\frac{m}{s^2}$