Study on variability and trend of stratospheric ozone over the southern tropics and subtropics

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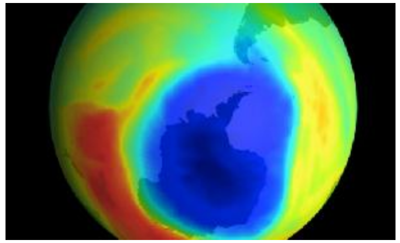
0 : INTRODUCTION

0-1 : MOTIVATION



- ❑ **Ozone layer protects human being against UV solar radiation.**

Variation of Ozone concentration depends:

- Ozone Depleting Substance ($C_xF_yCl_z$, C_xF_yBr, $C_xH_xCl_z$, …)
- Green house gases (CH4 , CO2 , CO …)
- dynamic forcing such QBO , ENSO
- Solar cycle activity
- Wave activity
- Seasonal variability of climate
- …

- ❑ **T CO decreases from the beginning of 19th century**
- ❑ **High surveillance since the ozone hole discovery in 1985.**
- ❑ **10 years after the Montreal protocol (1987) , Ozone is suspect to increase du to the reducing of ODS (ozone depleting substance) in the atmosphere**
- ❑ **need to create long term and consistence data record in order to study the current model of ozone variability and to estimates long terms trend especially after 1997.**
- ❑ **Validate models used to predict future evolution**

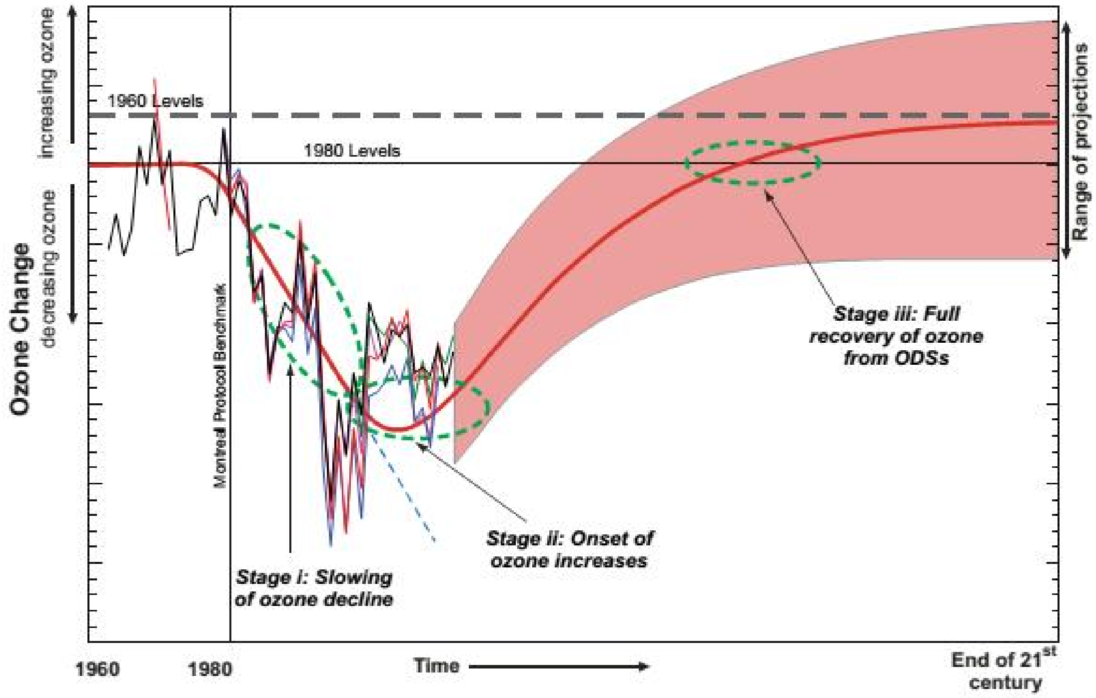
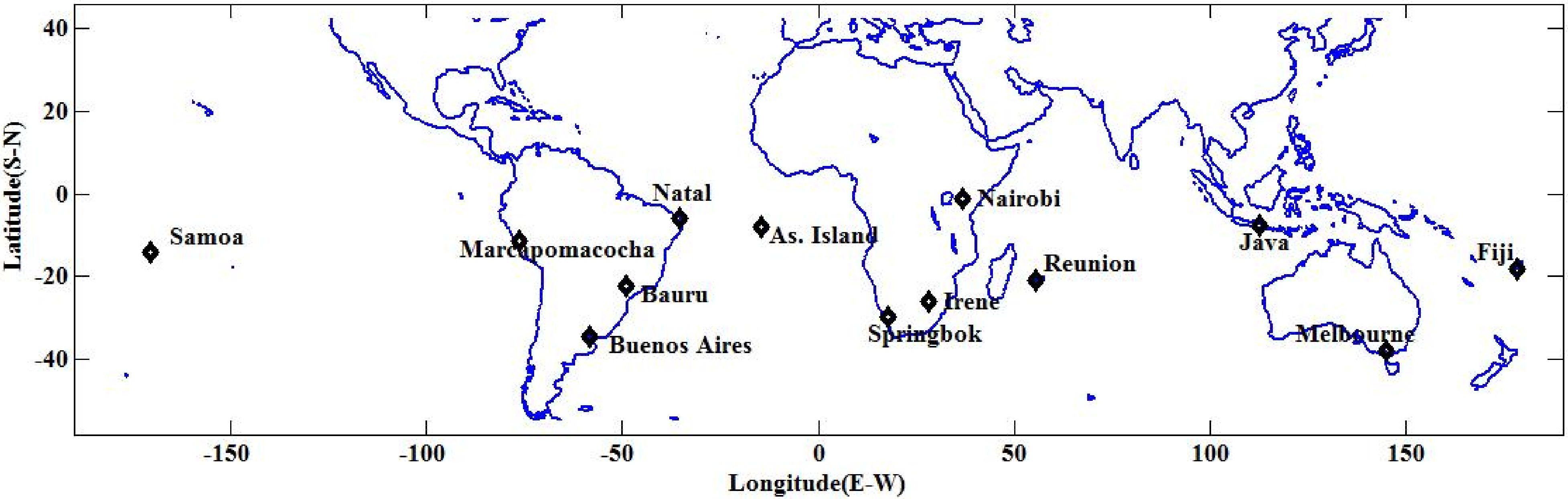


Diagram of Time evolution of TCO in the 60°N-60°S latitude band during the period 1960-2100 (MWO-UNEP, 2010)

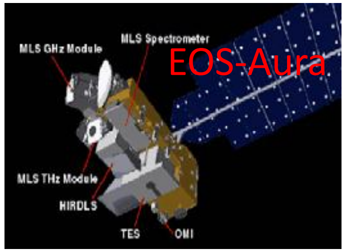
0-2 : OBJECTIVES

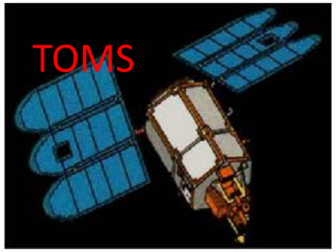
- I: Validation ozone measurements over the study sites and data set reconstruction
- II: Identification and Analysis of the basic modes of ozone variability
- III: Quantification of contribution and response of each mode of variability on total variability of ozone
- IV: Estimation trends over the study region from 1998



I : CONSTRUCTION OF LONG TERM AND RELIABLE OZONE DATASET

I-1 : DATA SOURCES





Stations	latitude	longitude	TOMS	Dobson/SAOZ	OMI & MLS	SHADOZ	IASI
Bauru	-22.34	-49.03	Jul.1996-nov.2005	Nov.1995-dec.2012	Oct.2004-dec.2012		Jun2008-dec.2012
Buenos Aires	-34.58	-58.48	Jul.1996-nov.2005	Jan.1990-dec.2012	Oct.2004-dec.2012		Jun2008-dec.2012
Irene	-25.91	28.21	Jul.1996-nov.2005	Jul.1990-dec.2012	Oct.2004-dec.2012	1998-2012	Jun2008-dec.2012
Marcapomacocha	-11.40	-76.32	Jul.1996-nov.2005	feb.2000-dec.2012	Oct.2004-dec.2012		Jun2008-dec.2012
Melbourne	-37.80	144.97	Jul.1996-nov.2005	Jan.1990-dec.2012	Oct.2004-dec.2012		Jun2008-dec.2012
Natal	-5.87	-35.2	Jul.1996-nov.2005	Jan.1990-sep.2006	Oct.2004-dec.2012	1998-2010	Jun2008-dec.2012
Reunion	-20.90	55.48	Jul.1996-nov.2005	Aug.1993-dec.2012	Oct.2004-dec.2012	1998-2012	Jun2008-dec.2012
Springbok	-26.7	17.9	Jul.1996-nov.2005	Mar.1995-dec.2012	Oct.2004-dec.2012		Jun2008-dec.2012
Ascension Island	-7.98	-14.42	Jul.1996-nov.2005		Oct.2004-dec.2012	1998-2010	Jun2008-dec.2012
Nairobi	-1.27	36.8	Jul.1996-nov.2005		Oct.2004-dec.2012	1998-2012	Jun2008-dec.2012
Samoa	-14.23	-170.56	Jul.1996-nov.2005		Oct.2004-dec.2012	1998-2012	Jun2008-dec.2012
Fiji	-18.13	178.40	Jul.1996-nov.2005		Oct.2004-dec.2012	1998-2011	Jun2008-dec.2012
Java	-7.65	112.65	Jul.1996-nov.2005		Oct.2004-dec.2012	1998-2012	Jun2008-dec.2012

I-2 : Data Validation Method

Comparison between measurements recorded over the site from different instruments.
Comparison index used are :

$$R = \frac{\sigma_{XY}}{\sigma_X \sigma_y}$$

R = Correlation coefficient between X and Y time series

$$RD_i = 100 \times \frac{X_i - Y_i}{Y_i}$$

RD = Relative difference between X and Y with respect to Y time series

$$B = \frac{1}{N} \sum_{i=1}^{N} RD_i$$

B = mean bias between X and Y with respect to Y time series

$$RMS_a = \sqrt{\frac{1}{N} \sum_{i=1}^{N} \left(X_i - Y_i\right)^2}$$

RMSa = absolute Root Mean Square between X and Y

$$PR = 100 \times \frac{\sigma}{\mu}$$

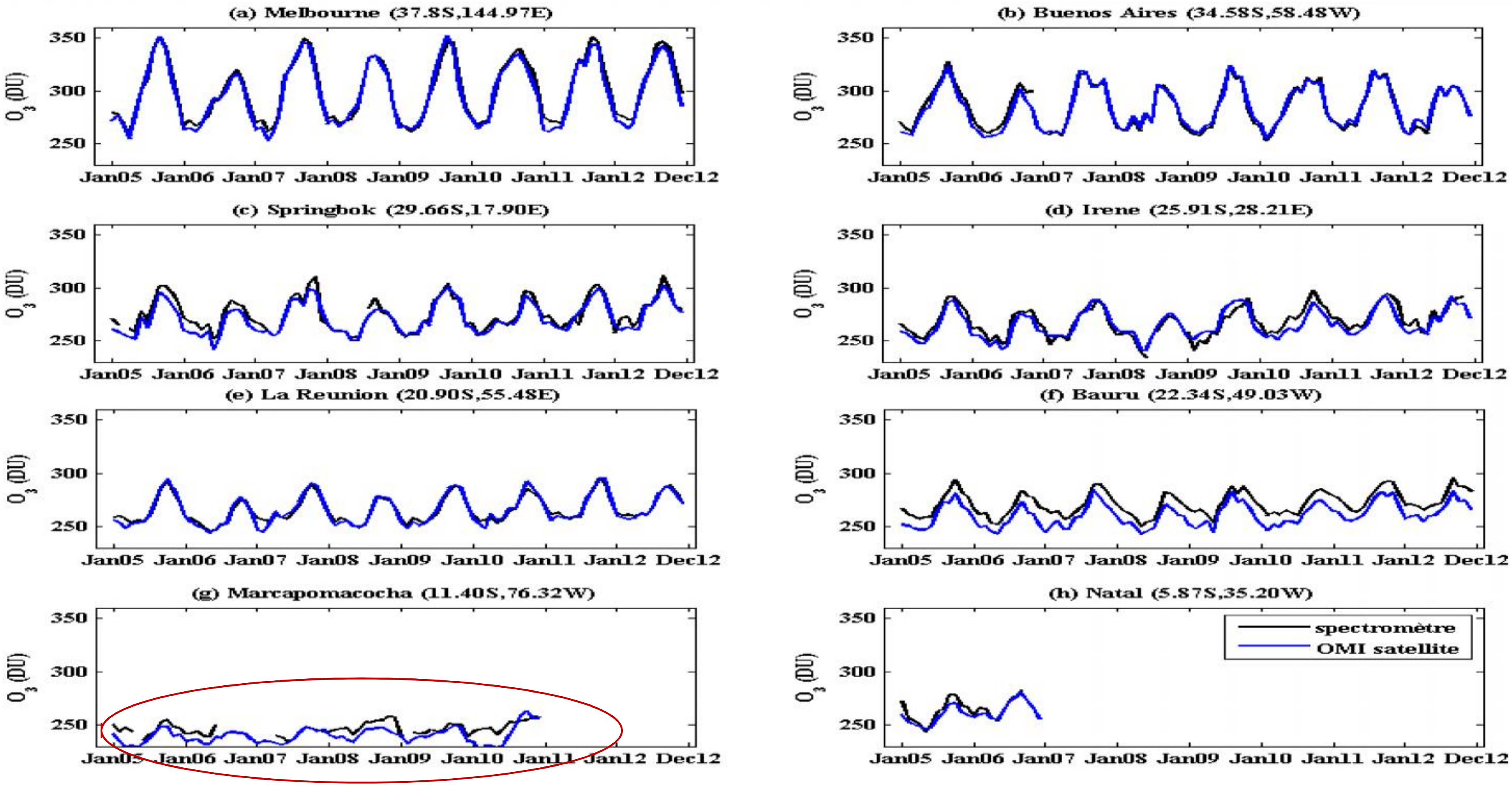
PR: Monthly precision/ variability

I-2 : DATA VALIDATION METHOD

OMI validation using ground based spectrometer (Dobson and SAOZ) over 8 stations where there is both satellite and ground based observation (Melbourne , Buenos Aires , Springbok , Irene , Bauru , Reunion, Marcapomacocha and Natal)

(**SASAS Proceeding paper Toihir et al. 2013**)

OMI fits well ground based observations



I-2 : Data Validation Method

OMI validation using ground based spectrometer (Dobson and SAOZ) over 8 stations where there is both satellite and ground based observation

(SASAS peer reviewed Proceeding paper Toihir et al. 2013)

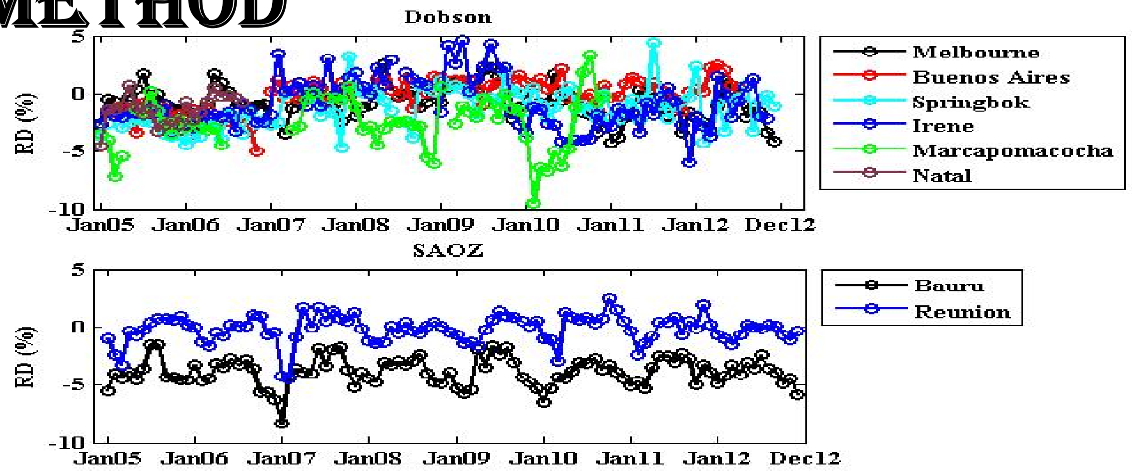


Tableau 2.5 : Biais, RMS, précision des mesures mensuelles, coefficient de corrélation entre OMI et les spectromètres SAOZ (Bauru et la Réunion) et Dobson (6 autres stations)

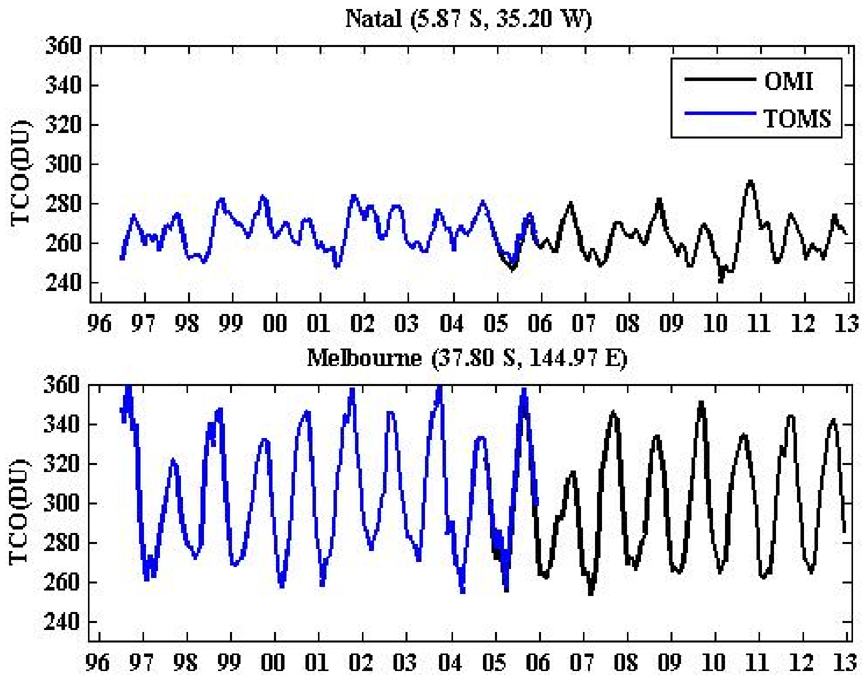
	Cordonnées			% biais	% variabilité mensuelle		%RMS	R
	Latitude	Longitude	Elévation		OMI	Spectromètre		
Melbourne	-37.80	144.97	128 m	-0.86	5.37	5.17	3.11	0,99
Buenos aires	-34.58	-58.48	25 m	-0.17	5.25	5.37	3.05	0,98
Springbok	-26.7	17.9	1003 m	-1.28	3.47	3.25	3.61	0,95
Irène	-25.91	28.21	1524 m	-0.90	2.80	2.82	4.49	0,91
Bauru	-22.34	-49.03	611 m	-3.87	2.75	2.34	5.44	0,95
Réunion	-20.90	55.48	24 m	-1.17	2.85	2.01	3.23	0,98
Marcapomacocha	-11.40	-76.32	4479 m	-2.85	2.56	1.76	5.68	0,64
Natal	-5.87	-35.2	32 m	-1.39	1.51	1.76	3.06	0,94

High correlation and low bias = good agreement between satellite and ground based observation

Lowest agreement

I-2 : DATA VALIDATION METHOD

Inter-comparison between OMI and TOMS



High correlation and low bias = good agreement between OMI and TOMS

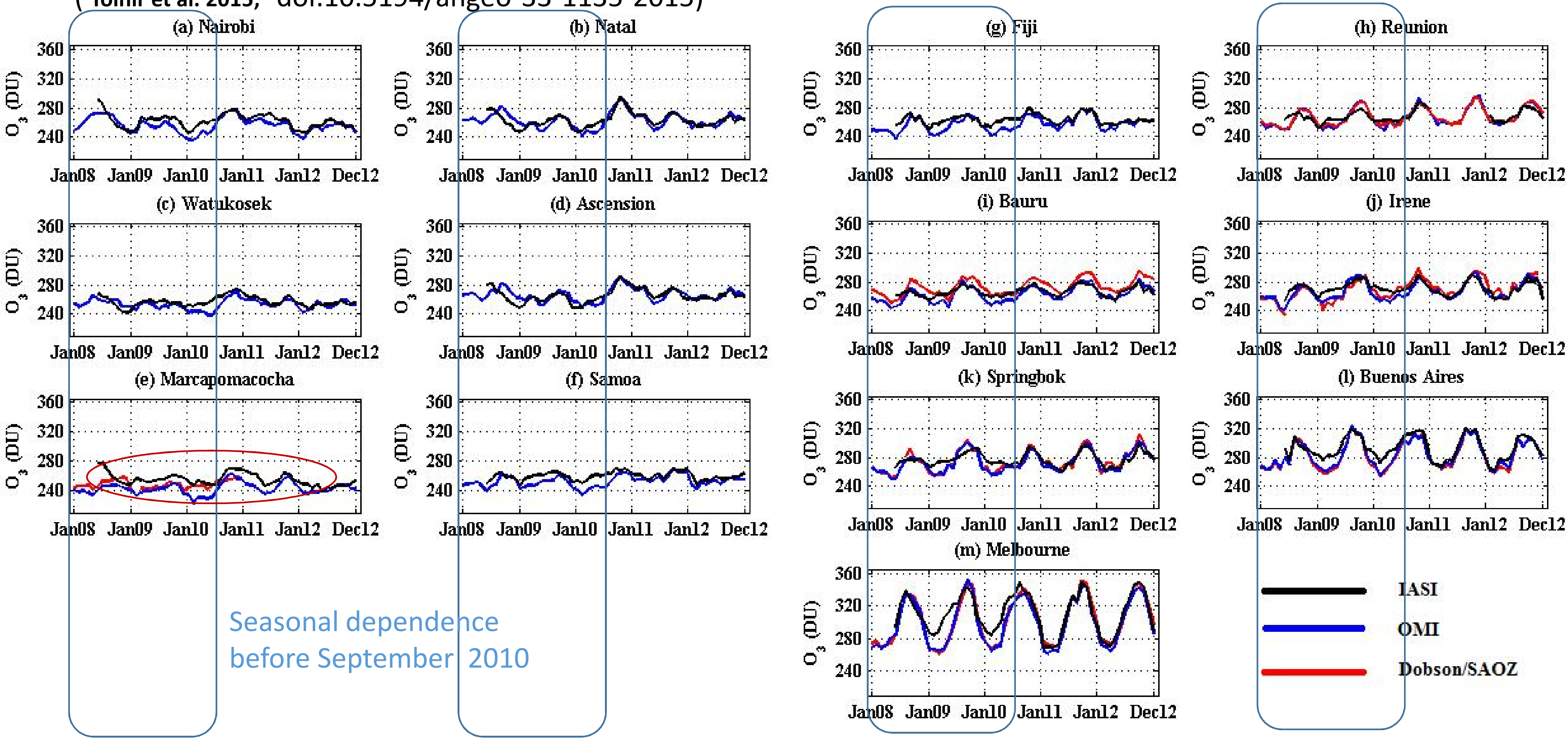
Biais, RMS, et coefficient de corrélation entre les mesures TCO obtenues par OMI et TOMS par rapport à OMI sur les 13 sites de l'étude.

Stations	Coordonnées			% biais (1σ)	RMS [DU]	R
	Latitude	Longitude	Elévation			
Melbourne	-37.80	144.97	128 m	1.74 (1.48)	6.16 (2.05%)	0,99
Buenos aires	-34.58	-58.48	25 m	1.61 (1.20)	4.85 (1.70%)	0.99
Springbok	-26.7	17.90	1003 m	1.78 (0.67)	5.30 (1.60%)	0.99
Irène	-25.91	28.21	1524 m	2.07 (0.78)	5.59 (2.11%)	0.99
Bauru	-22.34	-49.03	611 m	2.52 (0.55)	6.59 (2.52%)	0.99
Réunion	-20.90	55.48	24 m	1.60 (1.18)	4.46 (1.71%)	0.99
Fiji	-18.13	-178.40	6 m	1.58 (1.15)	3.47 (1.35%)	0.97
Samoa	-14.23	170.56	77 m	1.36 (0.62)	3.39 (1.36%)	0.96
Ascension	-7.98	14.42	91 m	1.60 (0.57)	4.23 (1.60%)	0.98
Java	-7.57	-112.65	50 m	1.57 (0.58)	4.22 (1.57%)	0.97
Marcapomacocha	-11.40	-76.32	4479 m	3.36 (0.70)	7.98 (3.33%)	0.97
Natal	-5.87	-35.2	32 m	1.13 (0.82)	3.08 (1.19%)	0.97
Nairobi	-1.27	36.80	1795 m	2.85 (1.09)	7.16 (2.85%)	0.96

I-2 : Data Validation Method

IASI validation using OMI and ground based (Dobson and SAOZ)

(**Toihir et al. 2015;** doi:10.5194/angeo-33-1135-2015)



I-2 : DATA VALIDATION METHOD

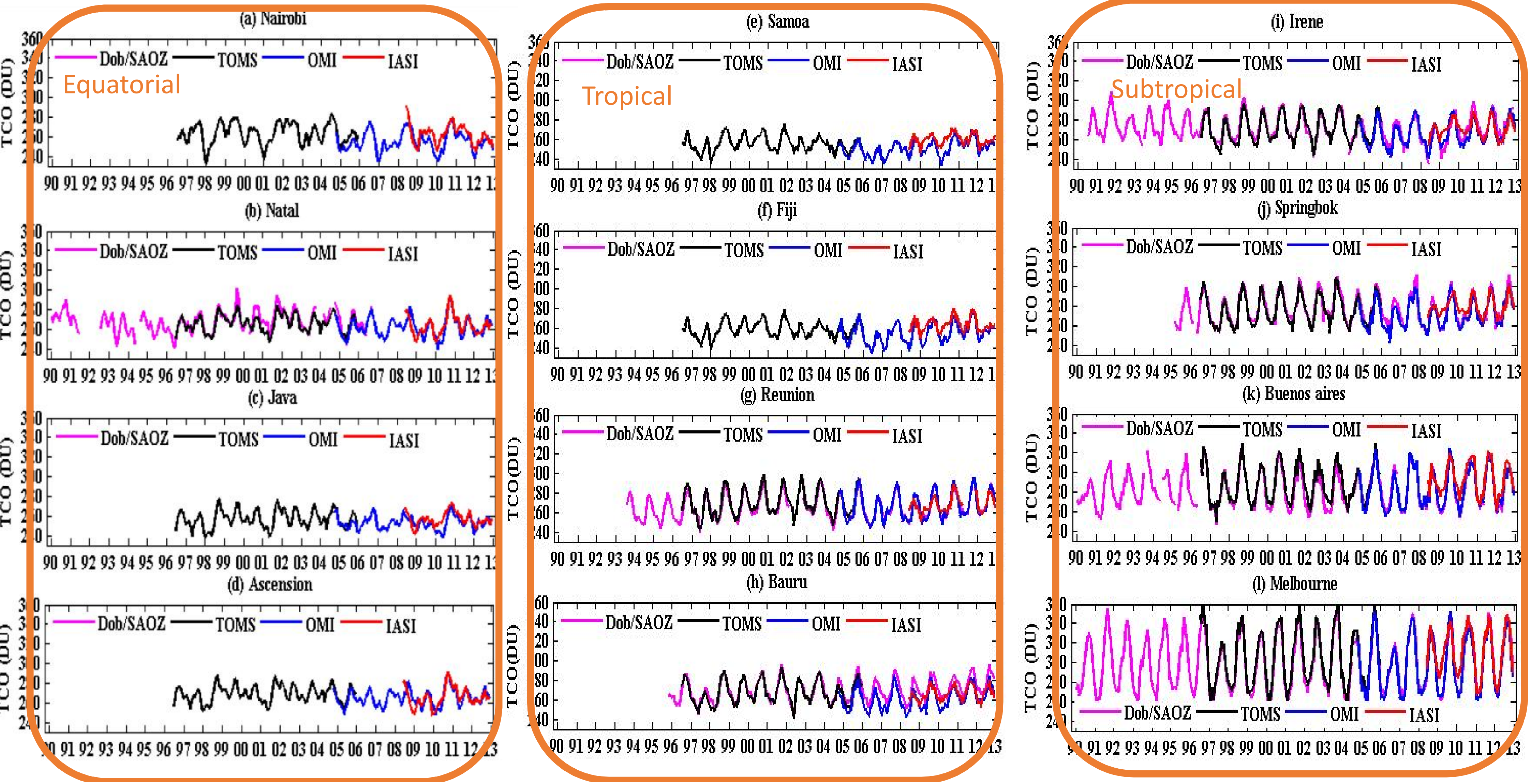
IASI validation using OMI and ground based (Dobson and SAOZ)

(**Toihir et al. 2015;** doi:10.5194/angeo-33-1135-2015)

Stations			IASI- OMI			IASI – Dobson (ou SAOZ)		
	Lat.	Long.	RMS (DU)	%biais (1σ)	R	RMS (DU)	%biais (1σ)	R
Nairobi	-1.27	36.80	6.93 (2.7%)	2.33 (2.4)	0.82			
Natal	-5.87	-35.2	5.27 (2.0%)	0.40 (2.6)	0.78			
Java	-7.57	112.65	5.58 (2.2%)	1.57 (2.3)	0.63			
Ascension	-7.98	-14.42	5.22 (1.9%)	-0.12 (2.5)	0.75			
Marcapomacocha	-11.40	-76.32	12.12 (5.0%)	4.99 (3.2)	0.57	9.93 (3.9%)	3.43 (3.3)	0.41
Samoa	-14.23	-170.50	7.24 (2.8%)	2.85 (2.2)	0.75			
Fiji	-18.13	178.40	6.27 (2.5%)	2.35 (2.5)	0.83			
La Réunion	-20.90	55.48	6.13 (2.3%)	0.25 (2.8)	0.84	5.66 (2.1%)	0.19 (2.6)	0.82
Bauru	-22.34	-49.03	5.29 (2.0%)	1.25 (2.2)	0.85	8.47 (3.0%)	-2.65 (2.5)	0.76
Irène	-25.91	28.21	5.78 (2.2%)	1.16 (2.5)	0.86	7.12 (2.6%)	0.26 (3.6)	0.75
Springbok	-26.7	17.9	6.46 (2.4%)	1,21 (2.8)	0.85	7.10 (2.5%)	0,43 (3.2)	0.83
Buenos Aires	-34.58	-58.48	7.74 (2.7%)	2.48 (3.5)	0.93	9.22 (3.5%)	3.12 (2.9)	0.93
Melbourne	-37.80	144.97	10.16 (3.5%)	3.09 (3.5)	0.94	9.51 (3.6%)	2.15 (4.2)	0.91

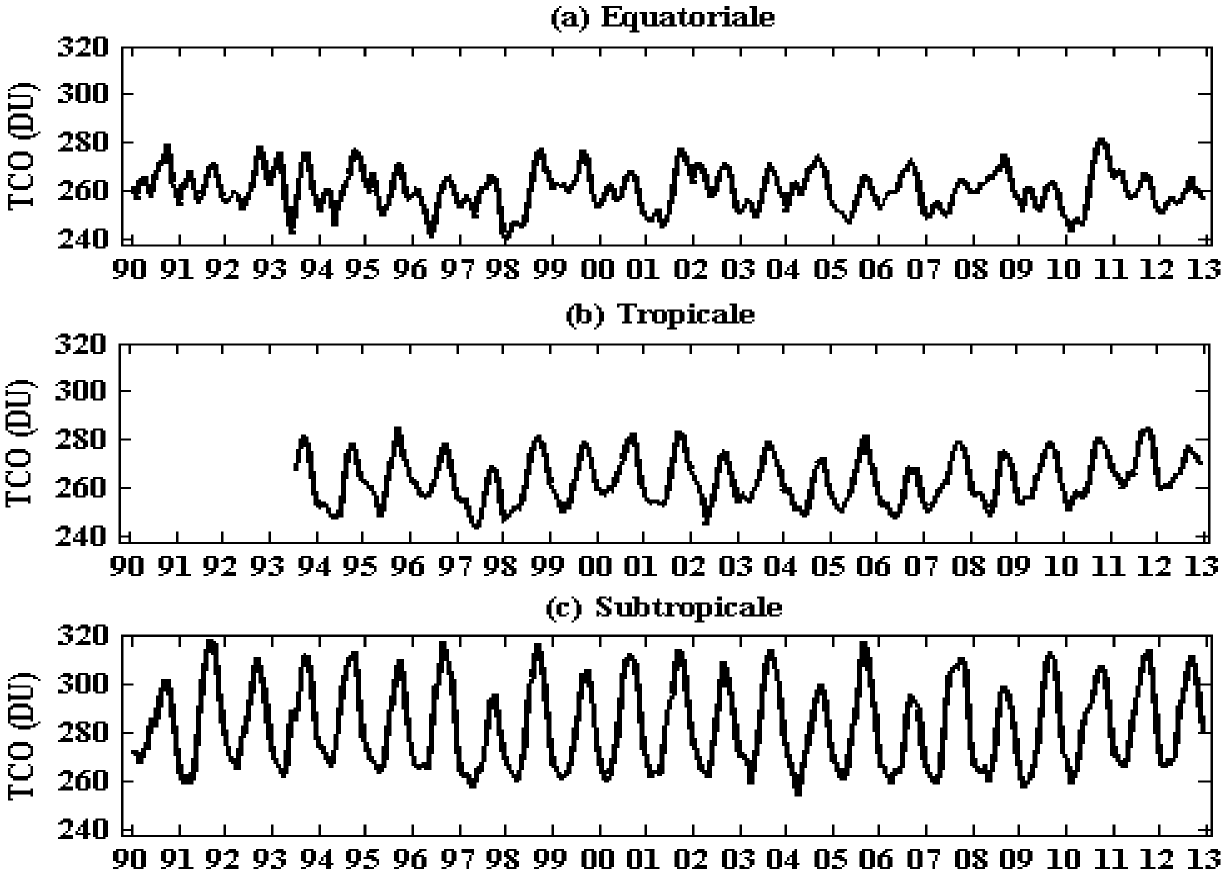
%biais (1 σ)	OMI		DOBSON		SAOZ	
Période	(2008-2012)	dès SEPT. 2010	(2008-2012)	dès SEPT. 2010	(2008-2012)	dès SEPT. 2010
DJF	2.47 (2.00)	1.98 (1.76)	1.14 (2.34)	-0.78 (2.03)	-1.10 (2.70)	-0.53 (1.97)
MAM	3.86 (1.87)	2.18 (1.58)	3.46 (2.31)	0.67 (1.80)	2.18 (2.40)	0.47 (1.12)
JJA	3.05 (1.71)	1.62 (1.59)	1.53 (2.16)	0.57 (1.73)	2.03 (3.80)	1,25 (0.90)
SON	0.66 (1.90)	0.52 (1.48)	-0.82 (1.90)	-1.4 (1.72)	-2.38 (3.37)	-1.56 (1.57)
Annuel	2.51 (1.87)	1.57 (1.60)	1.32 (2.17)	-0.23 (1.82)	0.73 (3.08)	-0.10 (1.39)

I-3 : DATA RECONSTRUCTION



I-3 : DATA RECONSTRUCTION

Time-series of TCO over each region



Evolution of the reconstructed total ozone time series over the three regions. Equatorial (a), tropical (b) and subtropical (c)

Natal , Nairobi , Java and Ascension island

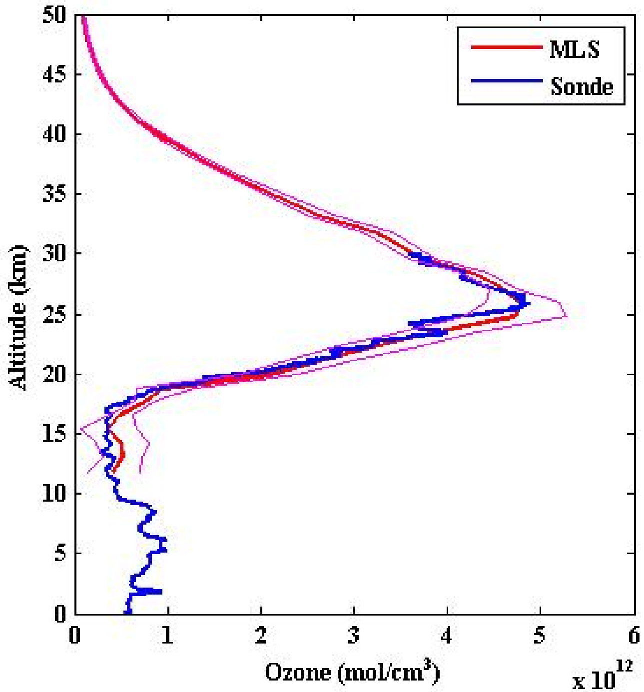
Samoa , Fiji, Reunion and Bauru

Irene Springbok, Buenos Aires and Melbourne

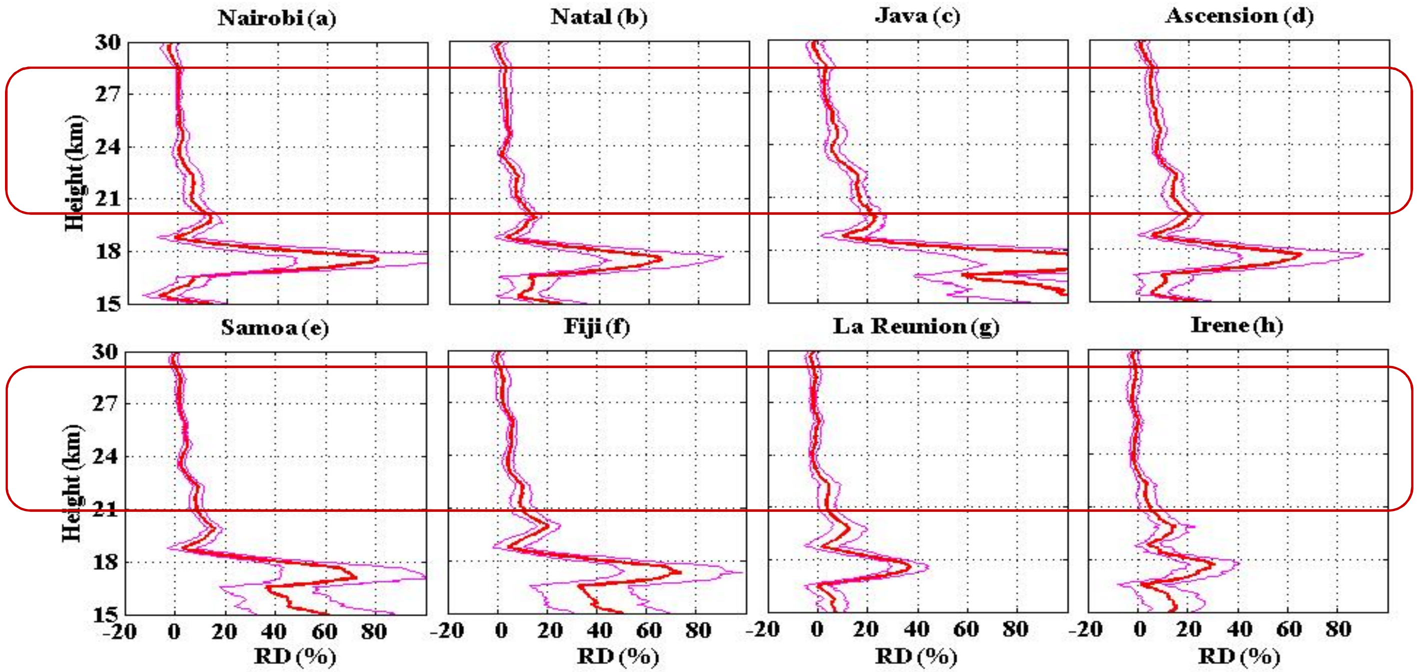
I-3 : DATA RECONSTRUCTION

Comparison and combination of ozone profiles from MLS satellite instrument and balloon sonde recorded over 8 sites

(**Eumetsat Proceeding paper Toihir et al. 2015**)



Profil journalier (rouge) de concentration d'ozone enregistré le 03 janvier 2008 par MLS au-dessus du site « Ascension Island ». Le profil journalier est la moyenne de 12 profils enregistrés autours du site lors du passage du satellite



Moyenne de la différence relative (rouge) et l'écart type associé (rose) entre MLS et SHADOZ sur chaque site. La liste des stations est numérotée de (a) à (h) est ordonnée en fonction de la latitude, dans le sens Equateur vers le Pôle sud.

Good agreement at 20-30 km altitude band

I-3 : DATA RECONSTRUCTION

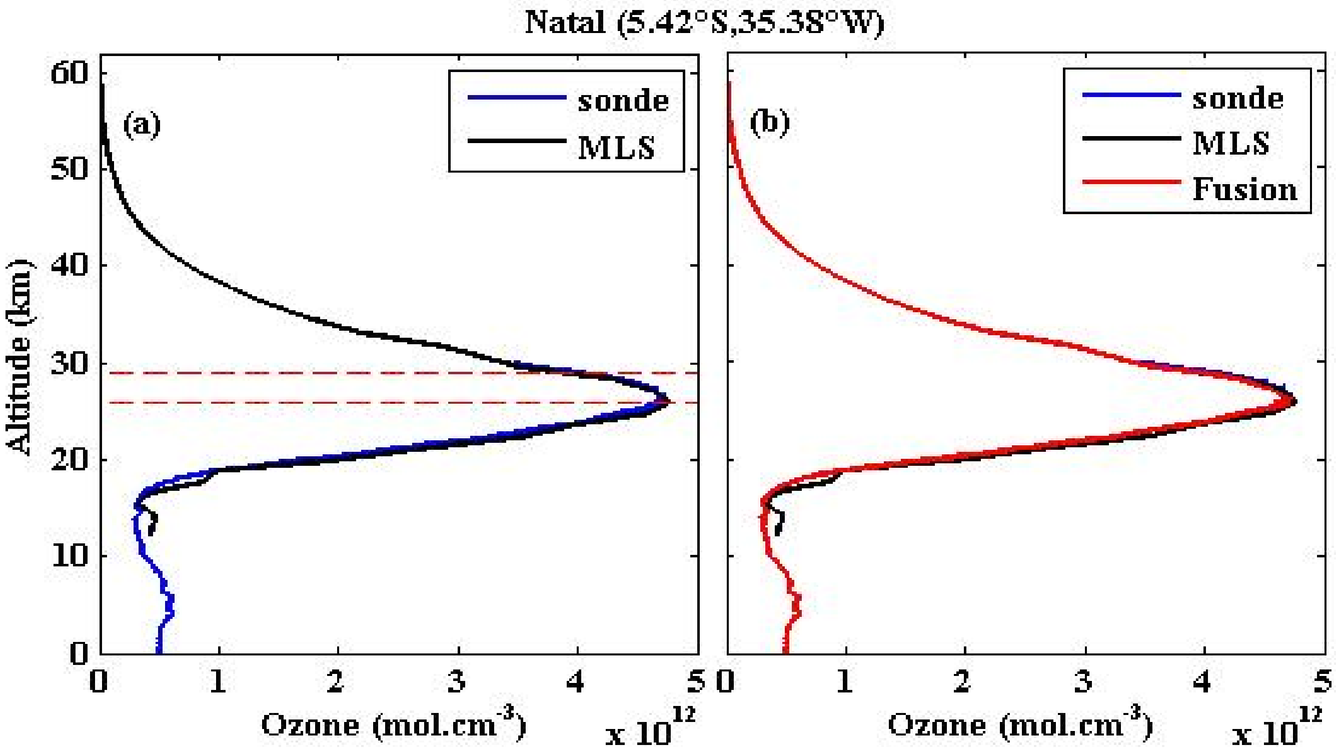


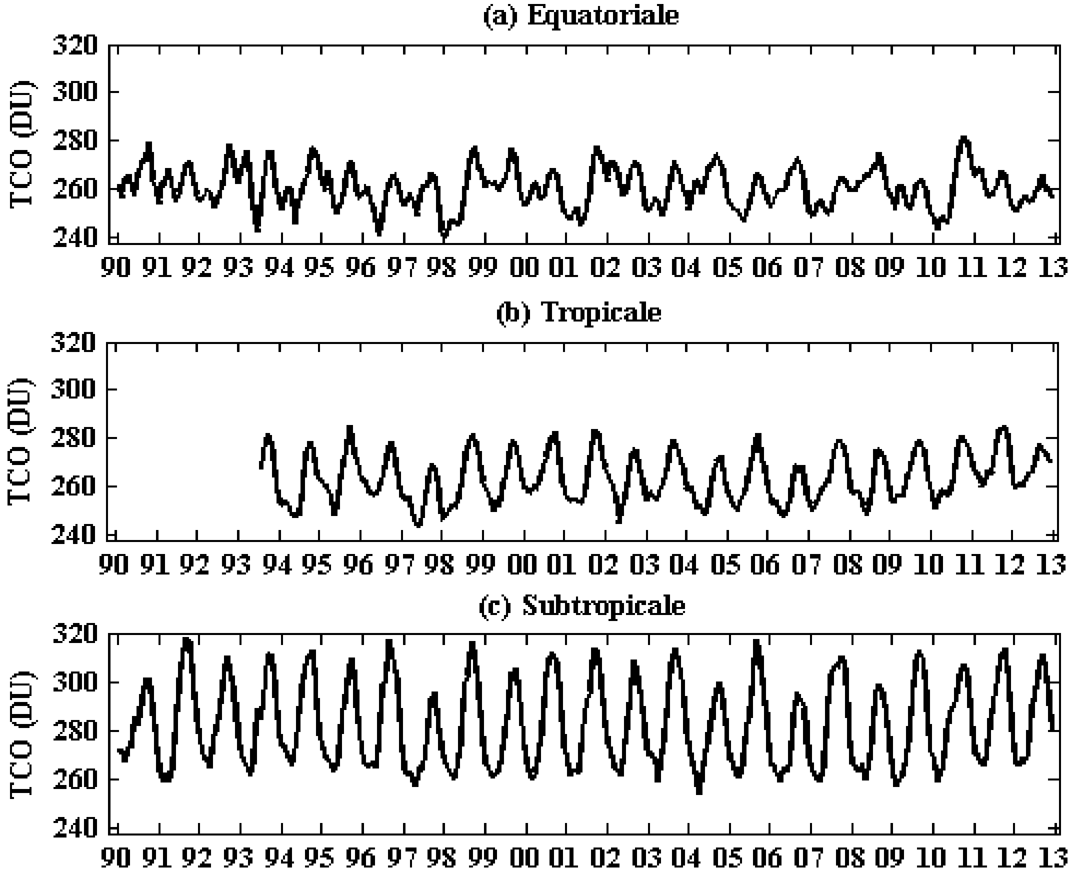
Figure 2.14 : une comparaison explicitant les profils moyens mensuels enregistrés le mois de juin par MLS (noir) et SHADOZ (bleu) pour créer la climatologie (rouge) de juin sur Natal. La tranche d'altitude où les deux profils sont fusionnés est cadrée par deux lignes rouges en point tillé

Monthly mean ozone profiles from MLS and Sonde are combined at 26-29 km in order to create height profiles which cover 0-50 km of altitude.

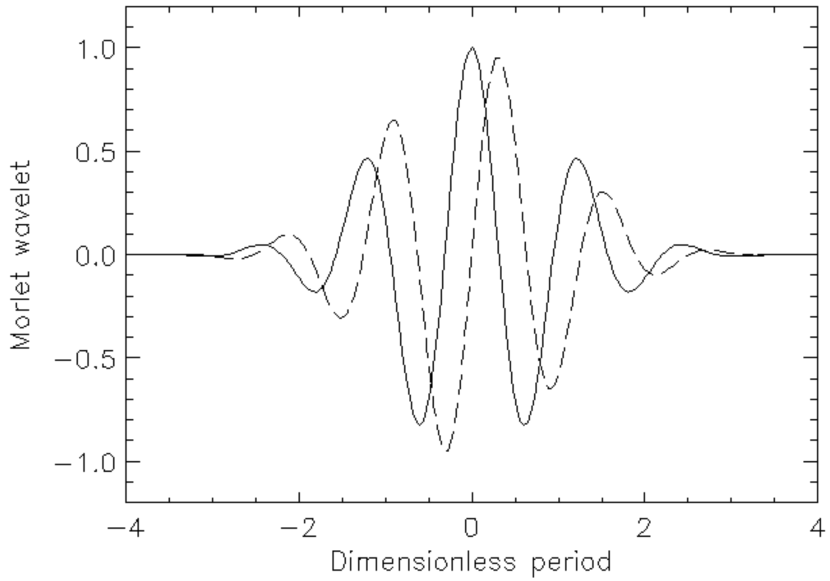
III : IDENTIFICATION AND ANALYSIS OF BASIC MODES OF OZONE VARIABILITY

II-1 : WAVELET TECHNIC

Xt = ozone time series



$$\varphi_0(t) = \pi^{-1/4} e^{i w_0 t} e^{-t^2/2}$$

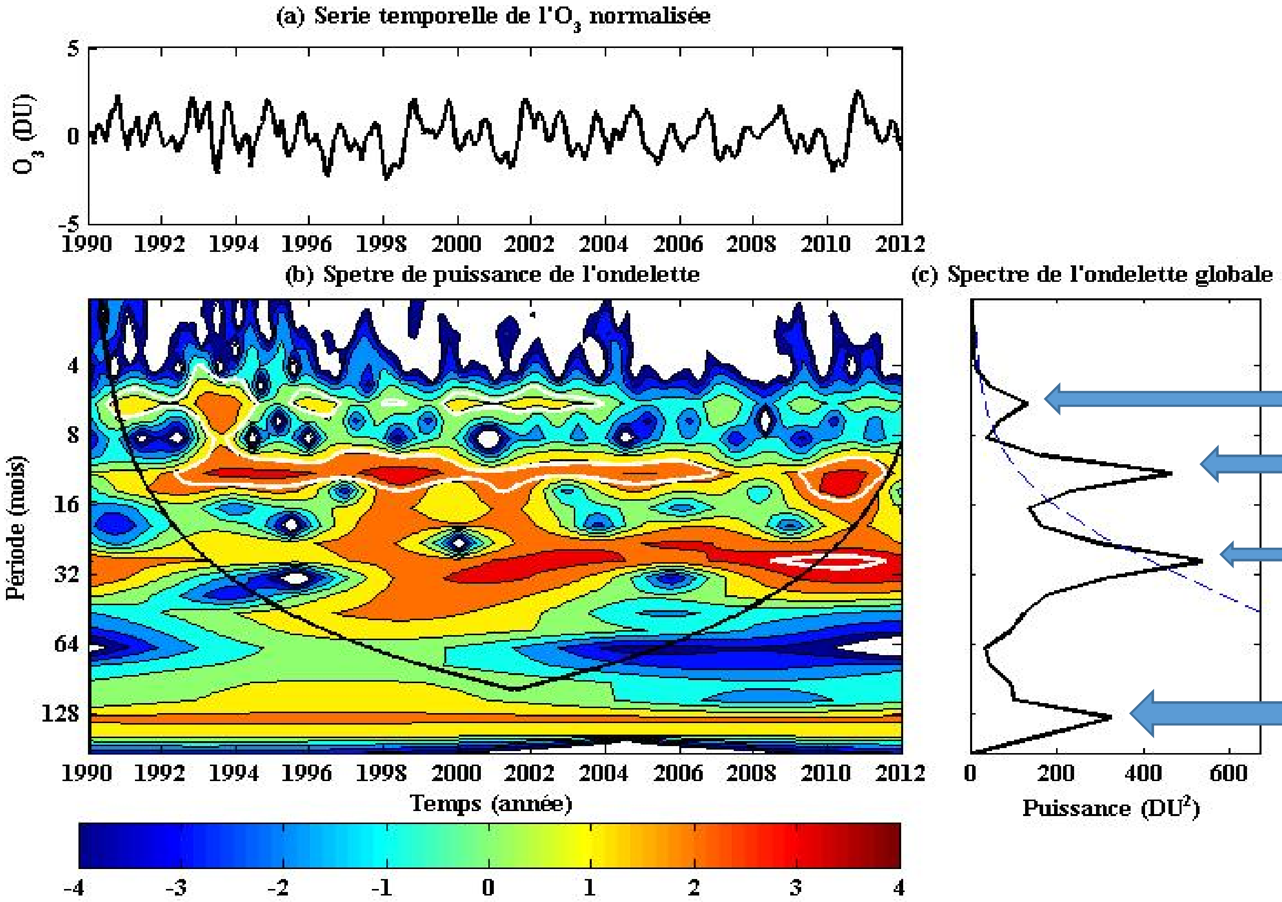


$$W_b(s) = \sum_{t=0}^{N-1} X_t \varphi * \left[\frac{(t-b)\delta t}{s} \right]$$ Wavelet transform

$$\overline{W}^2(S) = \frac{1}{N} \sum_{n=0}^{N-1} \left| W_n(S) \right|^2$$ Wavelet Power spectrum

II-2 : RESULTS

Equatorial region : analyse of the wavelet power spectrum



6 months linked to SAO

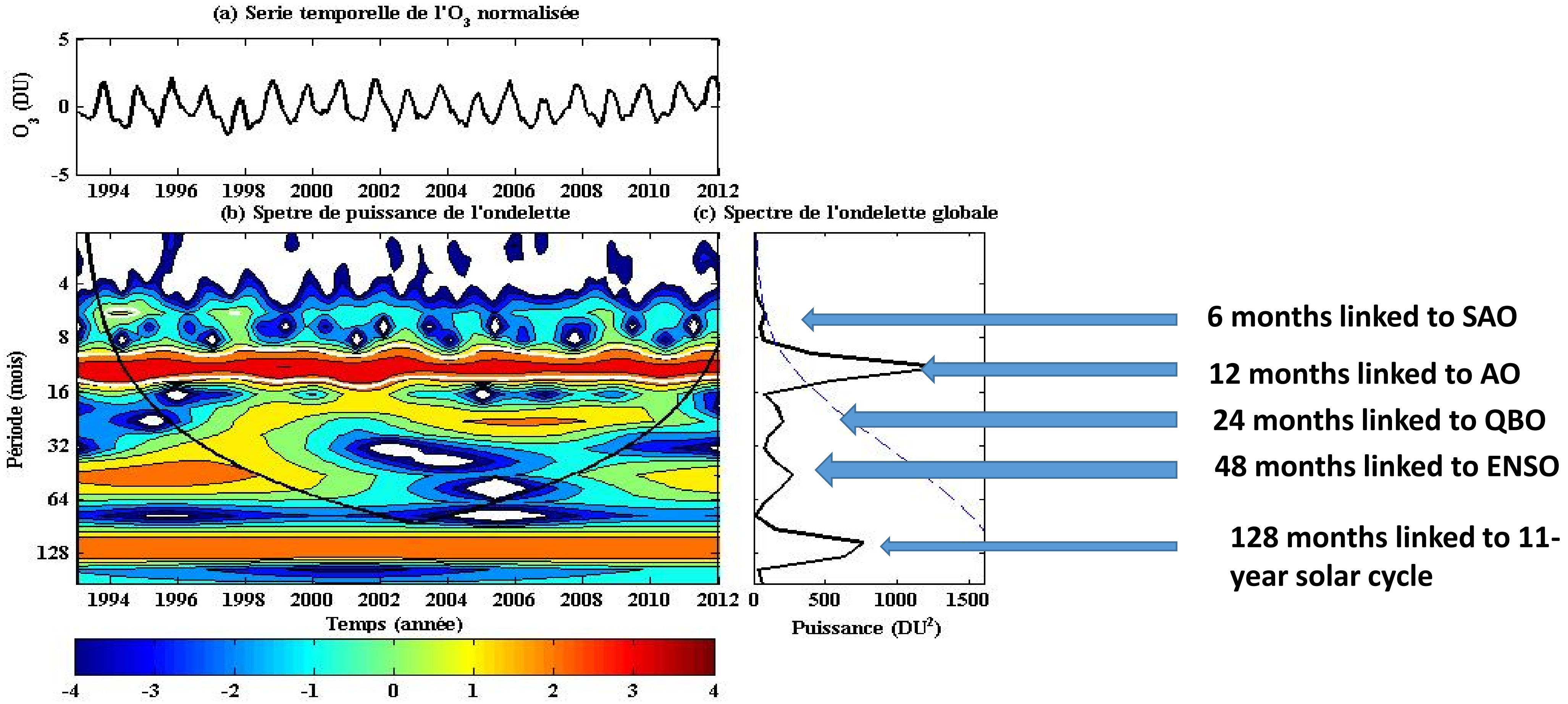
12 months linked to AO

28 months linked to QBO

132 month linked to 11- year solar cycle

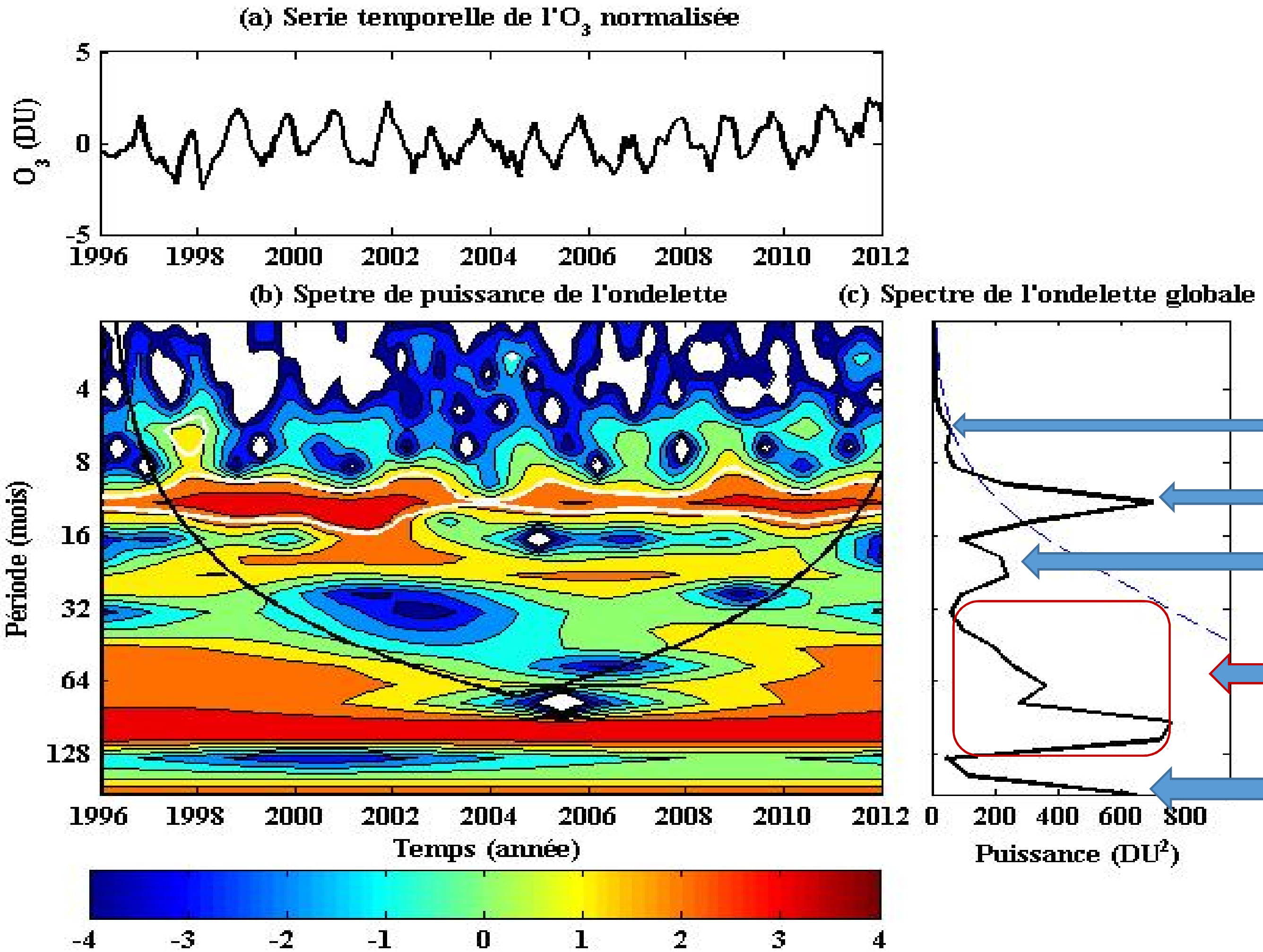
II-2 : RESULTS

Tropical region: analyse of the wavelet power spectrum



II-2 : RESULTS

Tropical region: analyse of the wavelet power spectrum : case of tropical pacific region



6 months linked to SAO

12 months linked to AO

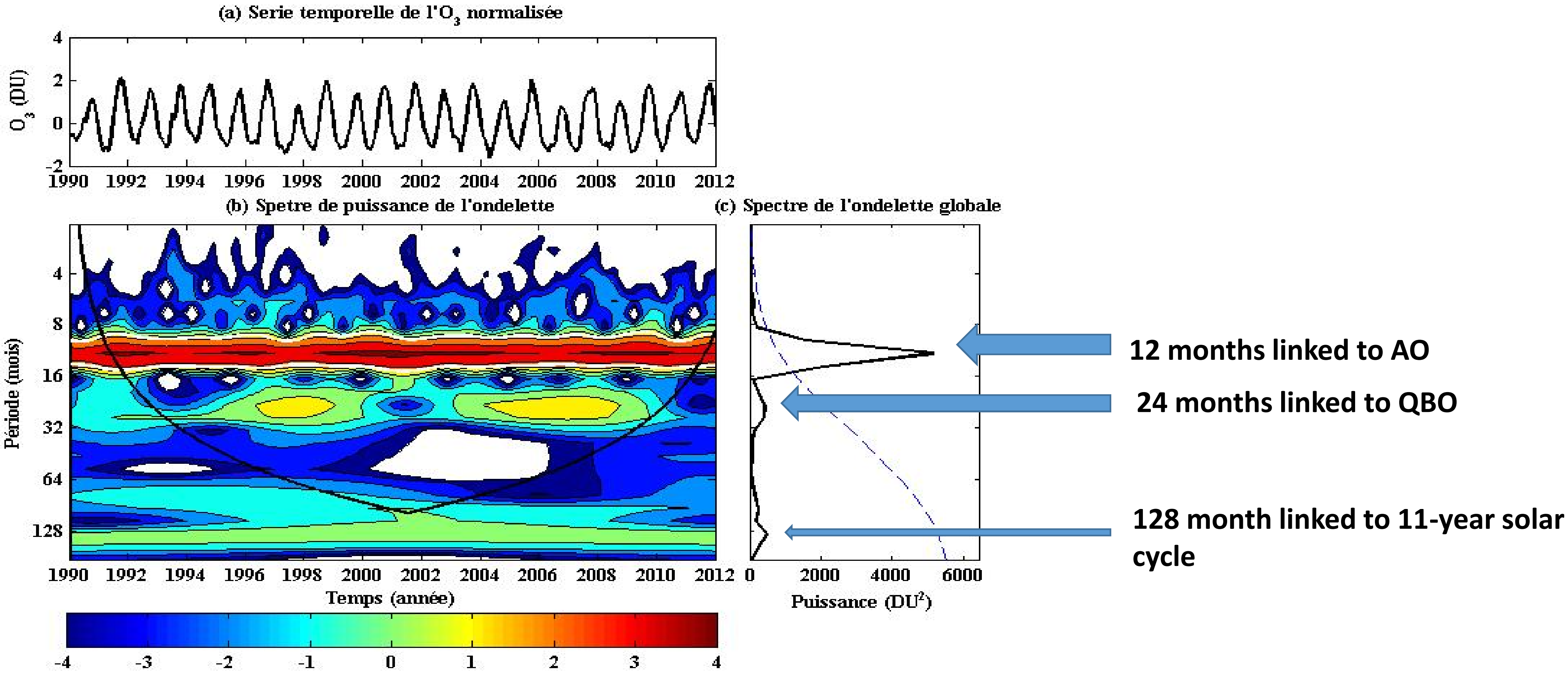
24 months linked to QBO

High variability of ENSO over this frequency band

132 month linked to 11- year solar cycle

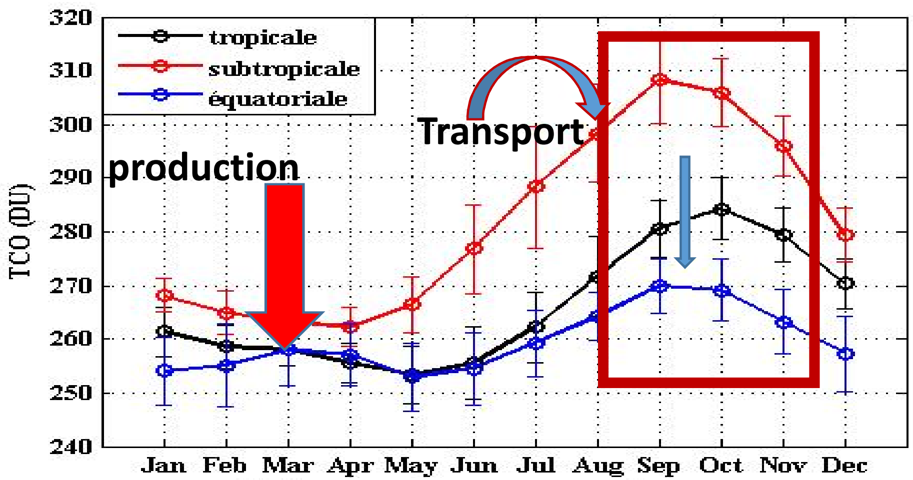
II-2 : RESULTS

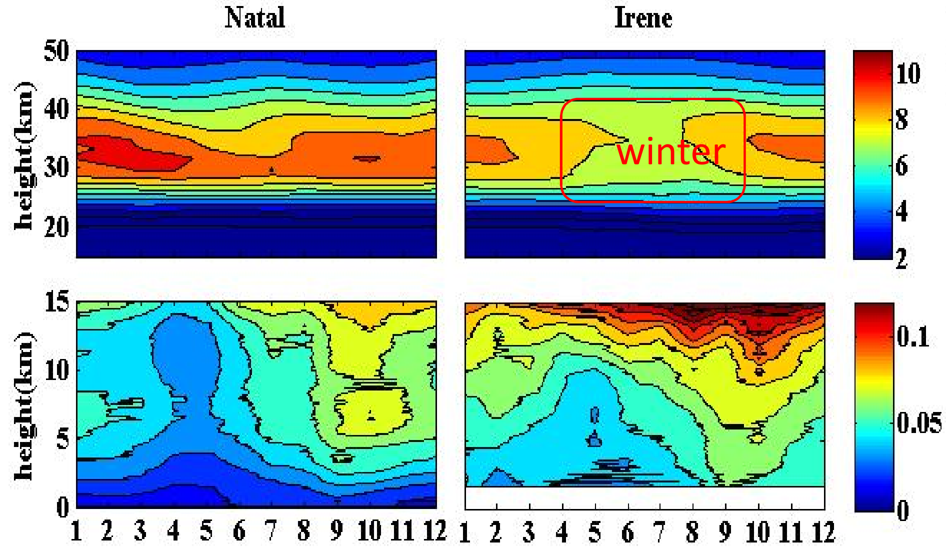
Subtropical region: analyse of the wavelet power spectrum

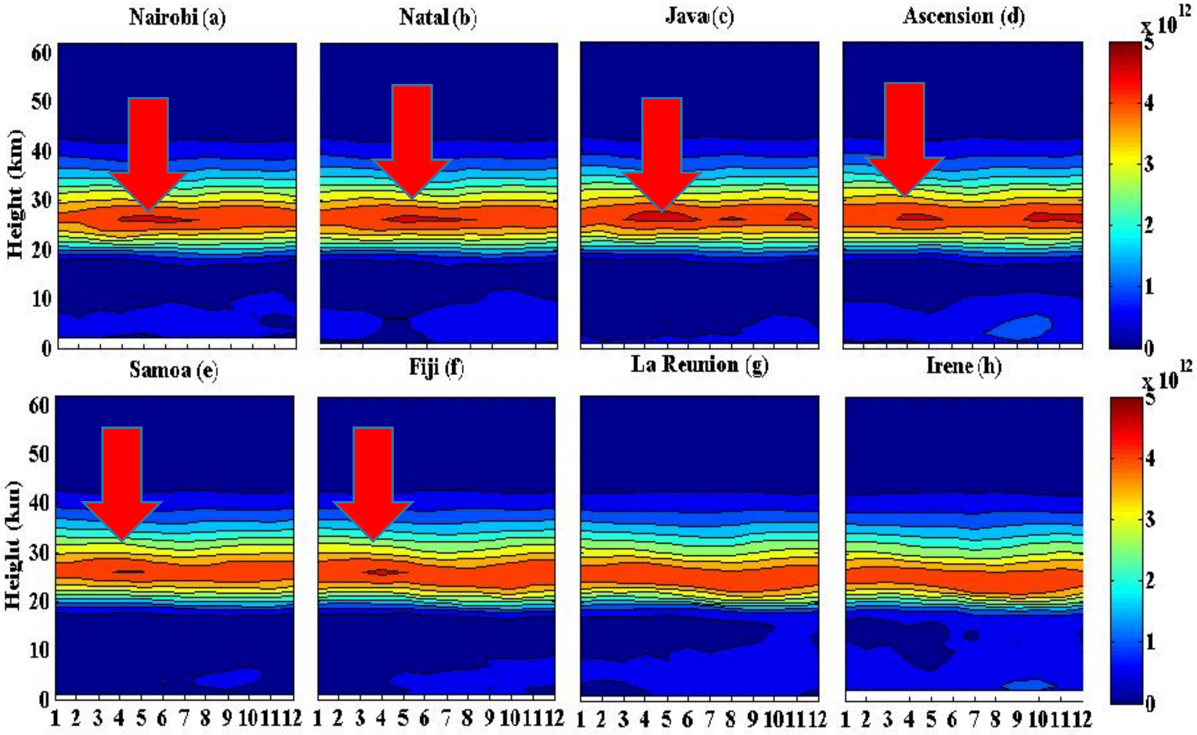


II-2 : RESULTS

Analysis of Annual and semi-annual oscillation (climatology)

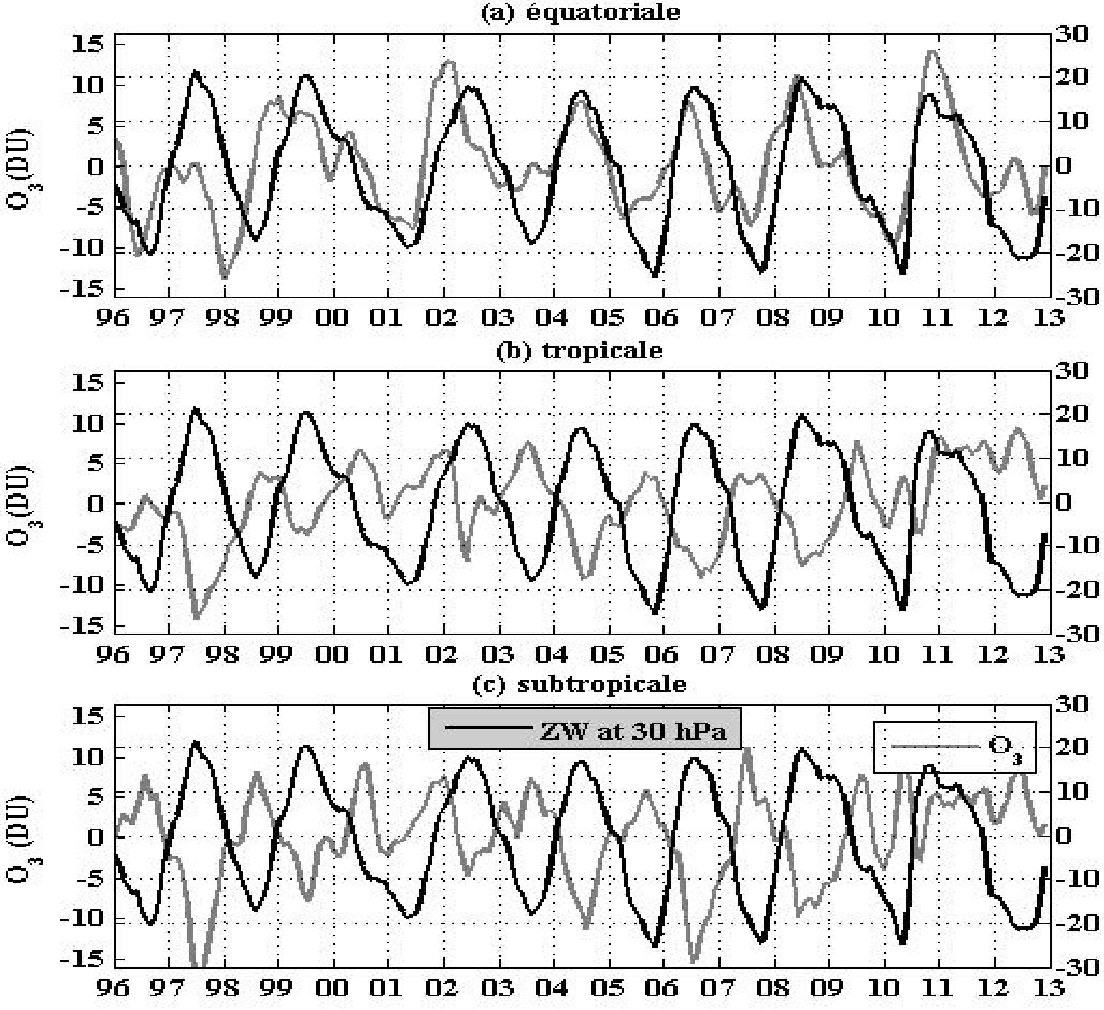




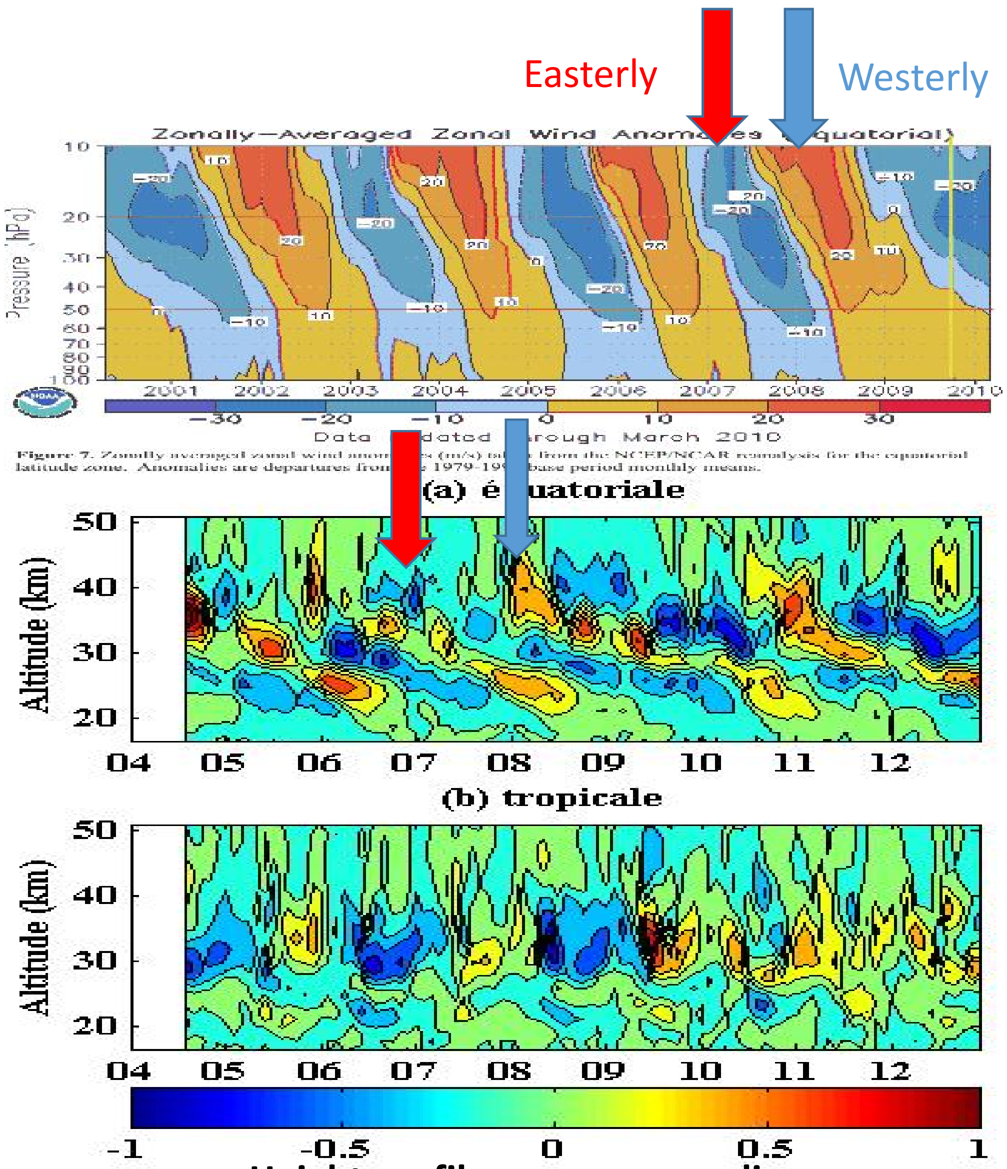


II-2 : RESULTS

Analysis of Quasi-biennale oscillations (QBO)



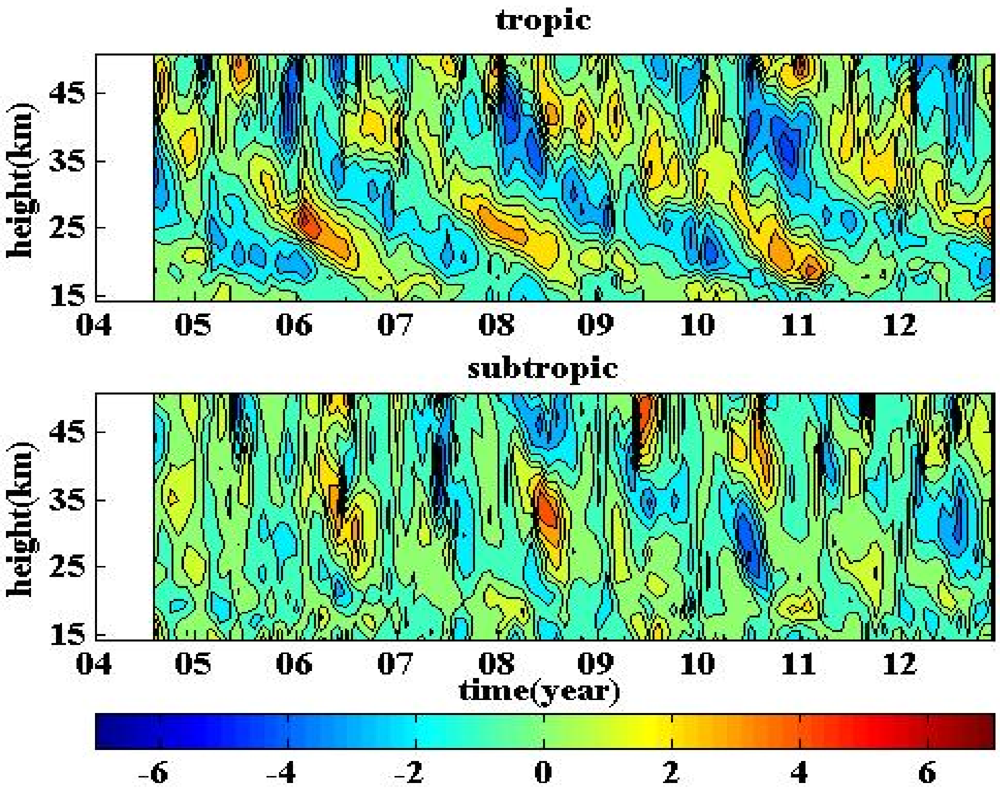
TCO anomalies with respect to the climatology



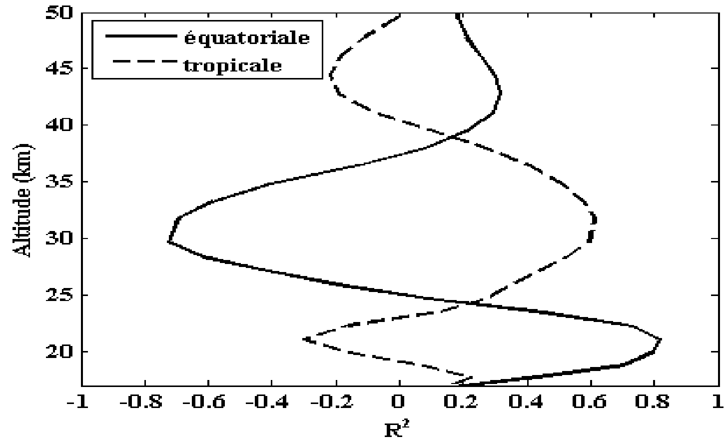
Height profile ozone anomalies

II-2 : RESULTS

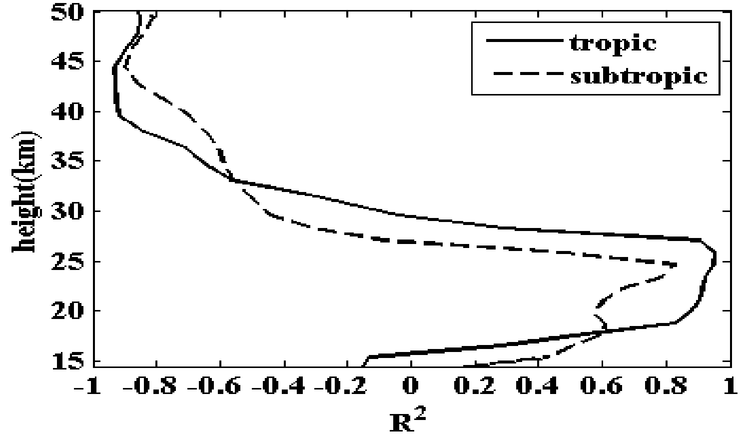
Analysis of Quasi-biennale oscillations (QBO): Proprieties



Height profile of temperature anomalies



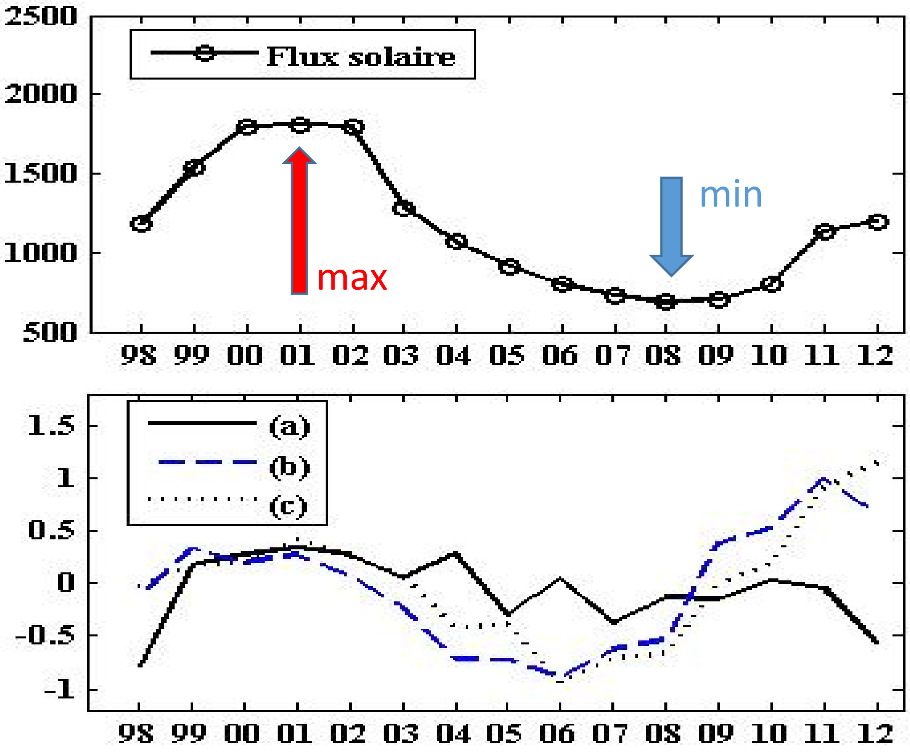
Correlation between equatorial and tropical ozone anomalies



Correlation between the ozone and temperature anomalies

II-2 : RESULTS

Analysis of 11- solar cycle



Time evolution of annual mean of ozone over the equatorial (a) tropical (b) ad subtropical region (c)

Solar flux is in phase with annual mean ozone variability.
High solar flux activity lead to positive anomaly of ozone and vice versa.

Total Ozone change between the year with maximum (2001) and minimum (2008) solar activity is evaluated to : 1.05%,1.52%, and 1.60% at equatorial (a), tropical (b) and extratropical (c) regions respectively

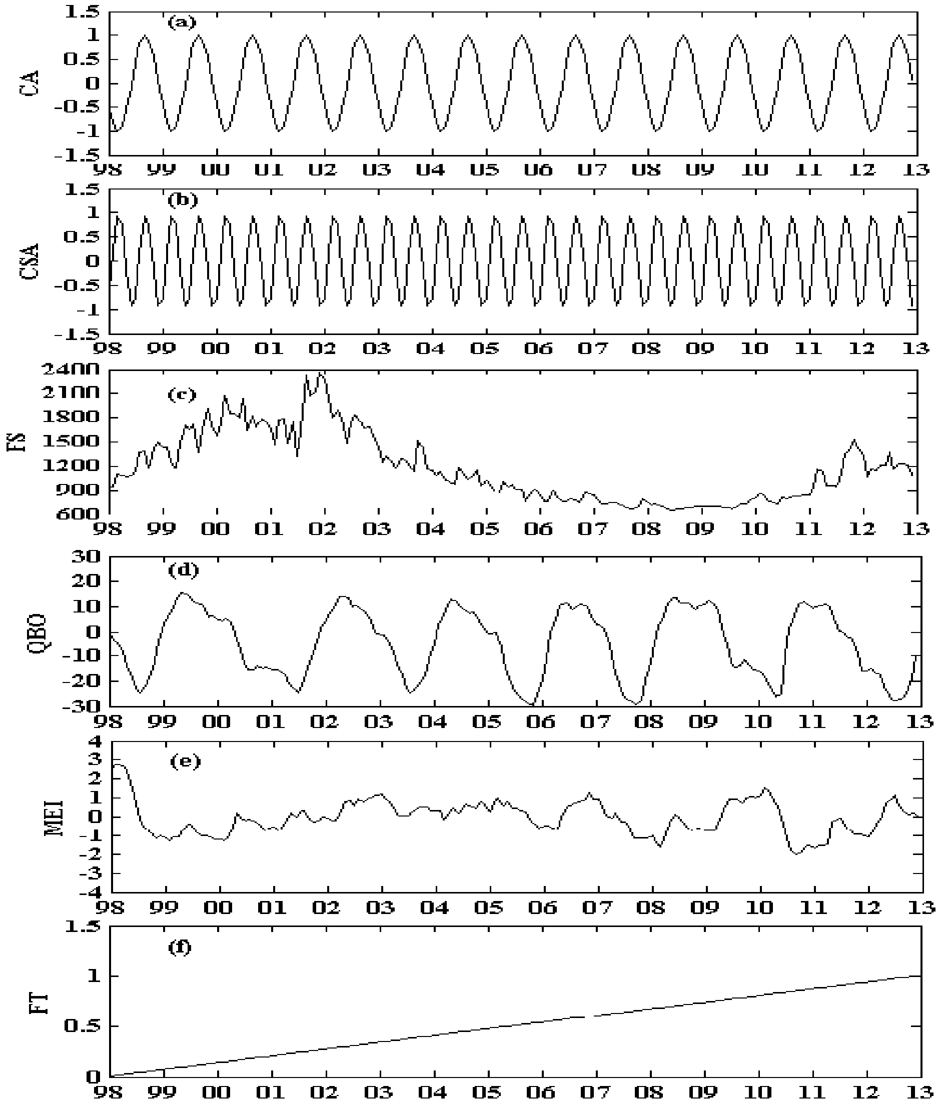
III :QUANTIFICATION OF OZONE VARIABILITY AND TREND ESTIMATE

III-1 : THE TREND RUN MODEL

Ozone variability and trend are analysis using the trend-Run Model

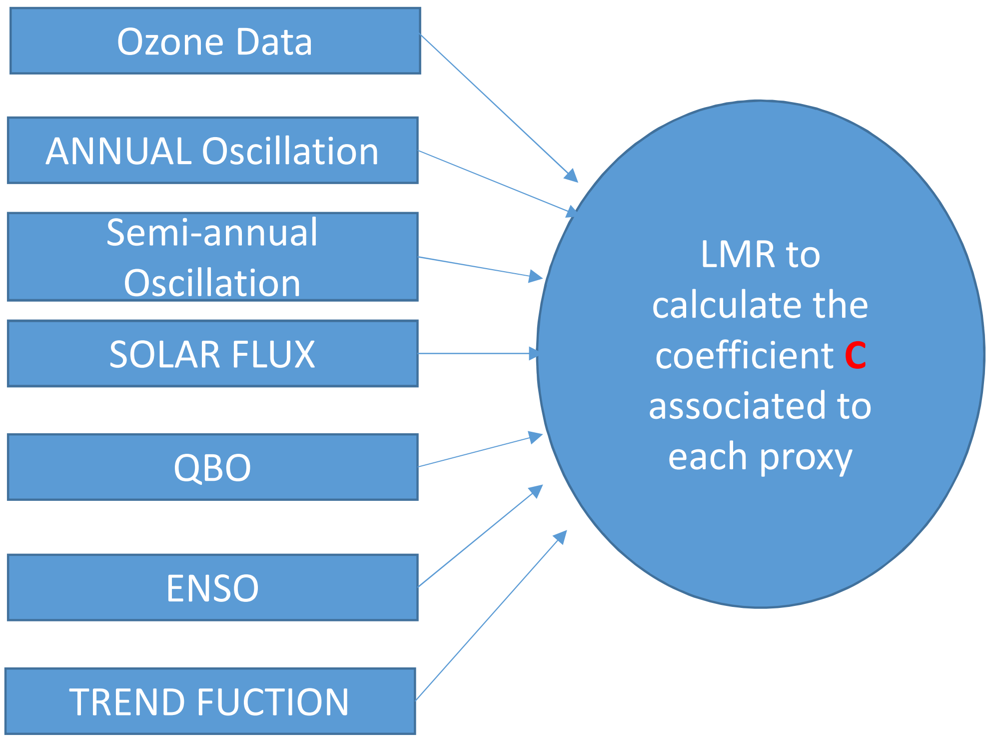
The Trend-Run is a multi-regression model based on the principle of breaking down the variations of ozone time-series into a sum of several forcings (seasonal cycles (AO ,SAO), QBO, ENSO, Solar cycles, ...) that explain most of its variability. The trend values are from the residual terms as a linear function

- **Input parameters are time-series of ozone monthly mean and monthly mean value of each proxy.**
- **output are : temporal ozone distribution as simulated by the Trend-Run model ; the contribution part of each proxy on ozone variability and the trend in percentage per decade as estimated by the model**



III-1 : THE TREND RUN MODEL

The time series of input proxies should be firstly parametrized and normalized.



$$Y(z,t) = C(z)_0 + C(z)_1 Y_{ao}(t) + C(z)_2 Y_{sao}(t) + C(z)_3 Y_{sf}(t) + C_4(z) Y_{qbo}(t) + C(z)_5 Y_{enso}(t) + C(z)_6 Y_{trend}(t) + \varepsilon(z,t)$$

$$O_3(z,t) - Y(z,t) = \varepsilon(z,t)$$

The regression coefficient are determined based on least-square method in order to minimize the sum of the residual squares.

The coefficient $C_{i(1\text{-}6)}$ uncertainty are assessed by taking into account the autocorrelation coefficient φ of the residual term and are formulated as follow:

$$\sigma_a^2 = v(k) \cdot \sigma_s^2 \cdot \frac{1+\varphi}{1-\varphi}$$

σ_s^2 = **Variance of residual term**

$v(k)$ = **covariance matrix of proxies**

III-1 : THE TREND RUN MODEL

The Trend value is calculated based on coefficient C associated to the Trend Function

The error associated to the trend is calculated based on the variance of residual term

A coefficient R^2 is used to quantify how well the fitting model describes the observed data . R^2 measures the proportion of the total variation in total ozone in time, explained by the model. When the model explain the most part of ozone variability, R^2 is close to unity and zero on the other hand

III-1 : THE TREND RUN MODEL

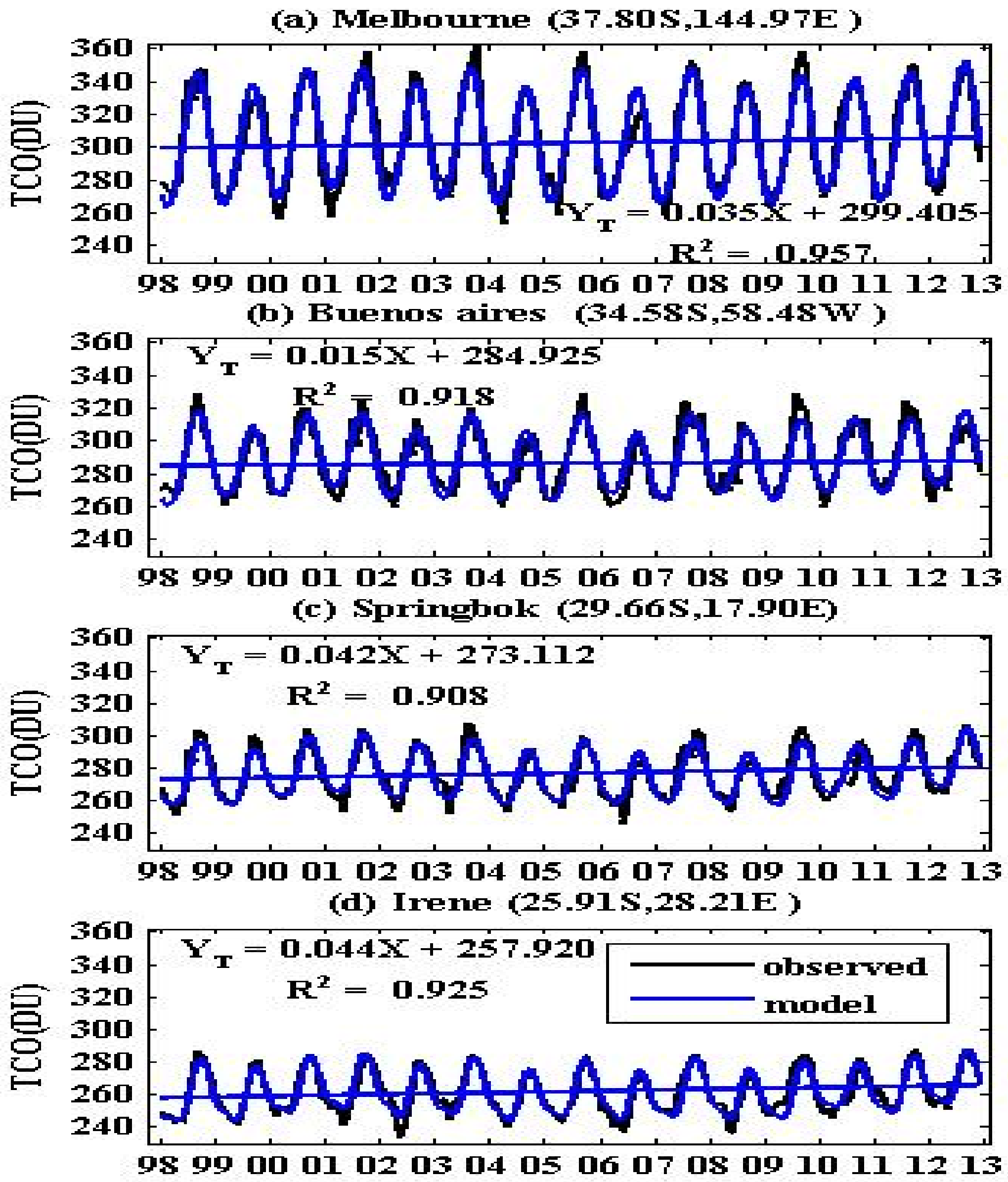
Model assessment: southern subtropics

Study on variability and trend of Total Column Ozone (TCO) obtained from combined satellite (TOMS and OMI) measurements over the southern subtropic
(SASAS peer reviewed Proceeding paper. Toihir et al. 2014)

Model explains about 82-92% of ozone total variability

Contribution part of AO, SAO SF , QBO and ENSO on Total variability of TCO and the decadal estimated trend (%)

	R^2	%AO	% SAO	%SF	% QBO	% ENSO	% Trend/ decade
Melbourne	0.92	84.07	0.86	0.70	1.93	0.10	1.38
Buenos Aires	0.84	72.45	0.94	0.41	3.48	0.77	0.62
Springbok	0.82	64.27	2.77	3.49	3.17	0.10	1.85
Irene	0.85	65.01	6.26	4.65	3.60	0.27	1.70

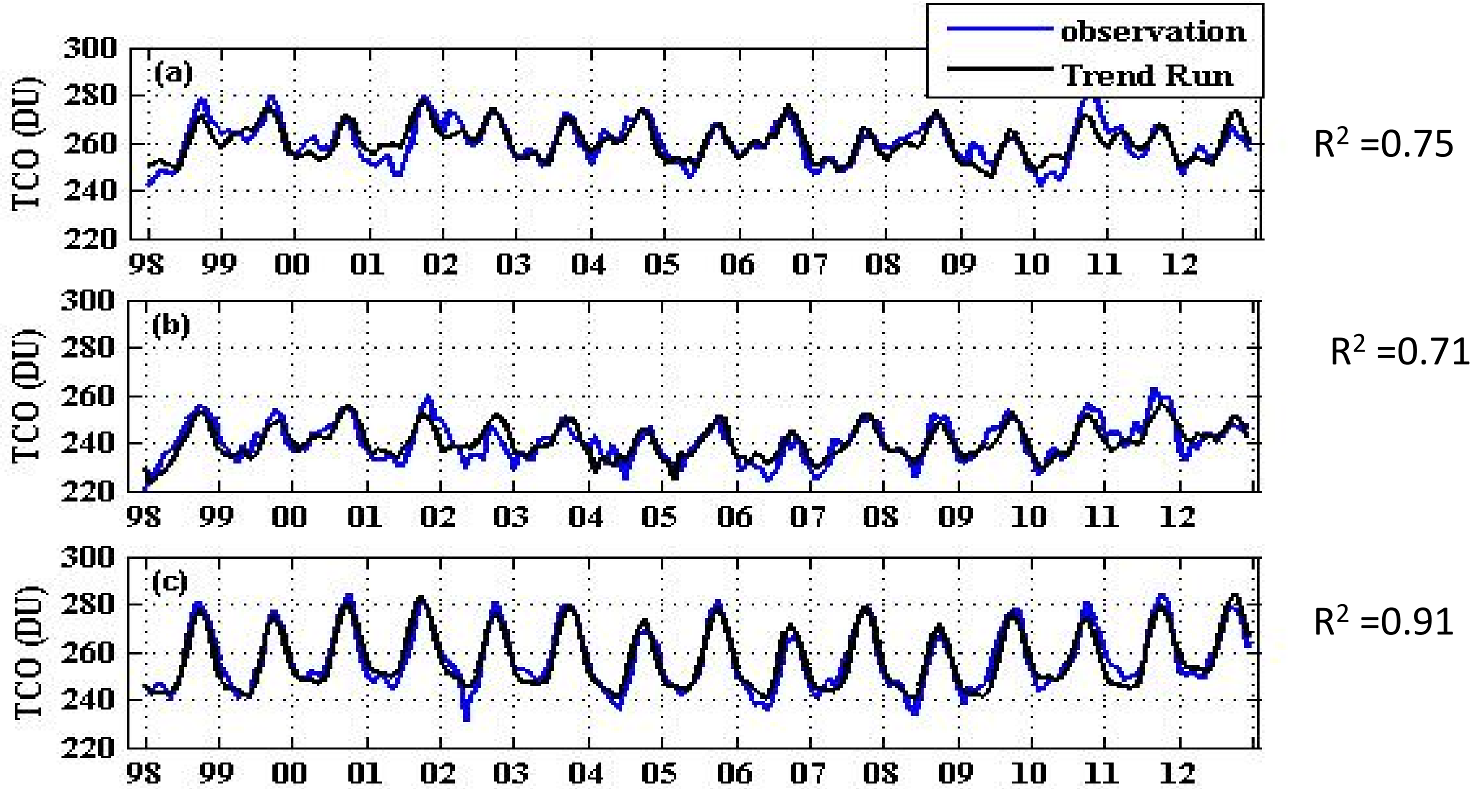


III-1 : THE TREND RUN MODEL

Model assessment : TCO over the equatorial, tropical and subtropical regions

Model fits well observation and explain about 71-91 % of total ozone variability

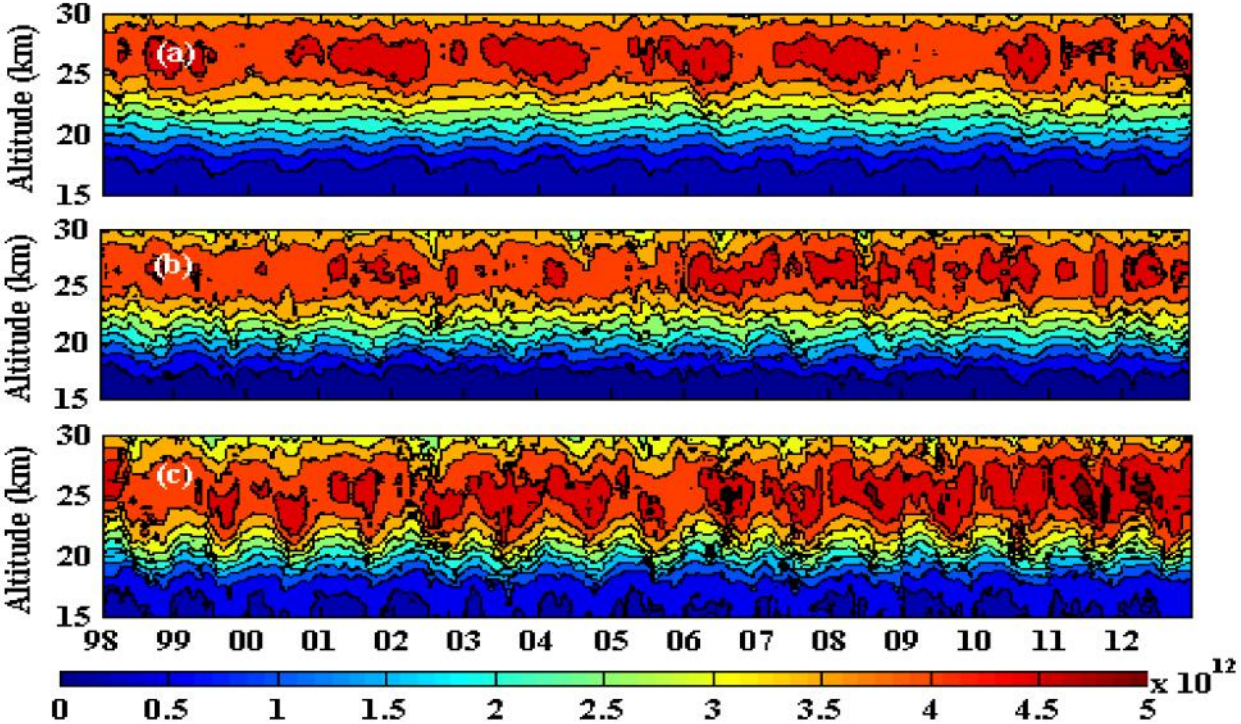
The best agreement is observed over the subtropic region



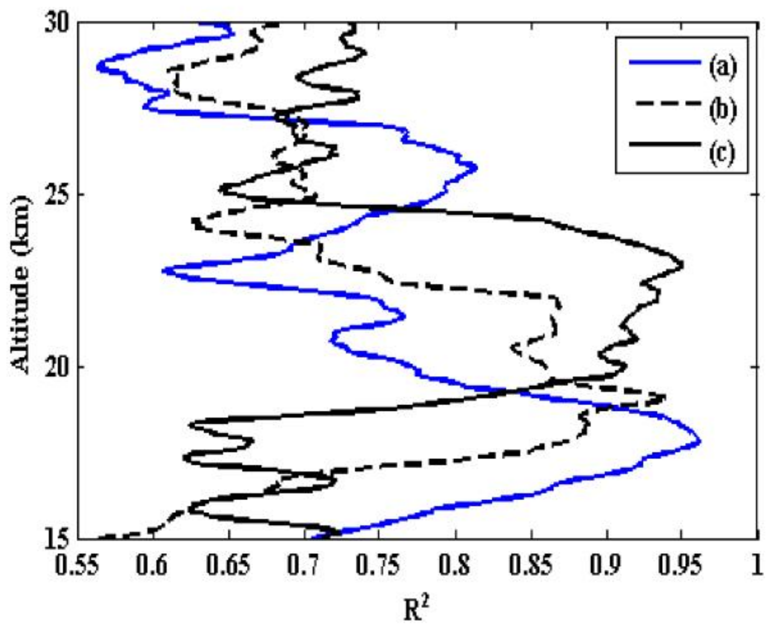
Time evolution of total ozone values (blue) records over the three regions. The superimposed black line represents total ozone value simulated by the Trend-Run model (tropical region is represented by Samoa and Fiji while the subtropics is presented by Reunion and Irene)

III-1 : THE TREND RUN MODEL

Model assessment : Height profile of ozone over the equatorial, tropical and subtropical regions



Time- height section of ozone concentration (mol.cm^{-3}) obtained by mean monthly profiles recorded over stations located between 0-10° S (a) , 10°- 20° S (b) and 20° S - 30° S (c) from January 1998 to December 2012.



Height profiles of R^2 (determination coefficient) calculated by the Trend-Run for the selected latitude band over the equatorial (a), tropical (b) and subtropical (c) regions.

III-2 : RESULTS

Contribution analysis : TCO over the equatorial, tropical and subtropical regions

Contribution part of AO, SAO SF , QBO and ENSO on Total variability of TCO over the three regions estimated trend (%)

	(a) equatorial	(b) tropical	(c) subtropical
Annual cycle	25.04± 1.60%	33.77 ± 2.05%	65.33 ± 3.97%
Semiannual cycle	12.13 ± 1.44%	8.19 ± 0.88%	6.19 ± 1.40%
Solar flux	9.57 ± 0.84%	8.41± 1.08%	5.66 ± 1.20%
QBO	13.0 ± 2.15%	7.82 ± 0.90%	3.95 ± 0.99%
ENSO	7.65 ± 0.68%	9.53 ± 1.74%	0.01 ± 0.03%

- **the QBO contribution on TCO variability is apparent over the three region and decrease with the increase of latitude poleward**
- **the variability is dominated by annual cycle. AO contribution is high over subtropic ad decrease with the decrease of latitude equatorward**
- **the semi-annual oscillation and solar flux contributions are present negative gradient from equatorial to poleward .**
- **the solar cycle is more apparent on tropical compared to the sites near middle latitude and equatorial**
- **Enso is mostly pronounced on tropical than equatorial region and no significant on subtropic**

III-2 : RESULTS

Response analysis : TCO over the equatorial, tropical and subtropical regions

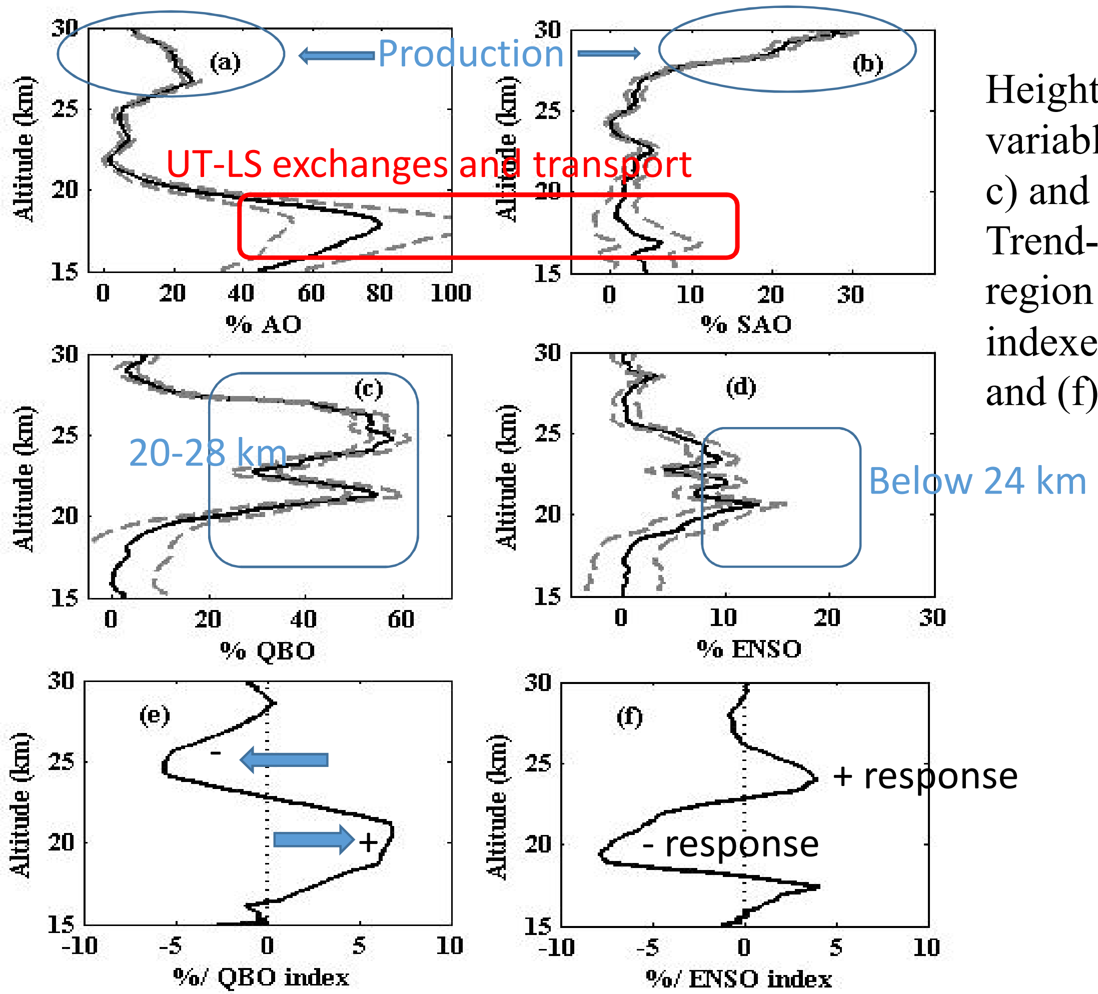
Response values of the chosen proxies (annual cycle, semiannual cycle, solar flux, QBO end ENSO) on total ozone variability for individual sites as obtained by the Trend-Run model. The response is given in percent by unit of the normalized proxy

station	AO	SAO	Solar flux	QBO	ENSO
Nairobi	1.66	1.52	1.60	3.04	2.15
Natal	1.96	1.73	1.59	2.95	-2.55
Java	1.87	1.90	1.88	2.55	2.87
As. Island	2.83	1.96	1.90	2.34	-3.08
Samoa	2.44	1.42	1.50	2.42	-3.47
Fiji	3.03	1.40	1.65	-1.44	-3.16
Reunion	5.56	1.27	1.26	-2.33	0.15
Irene	5.56	1.27	1.18	-2.46	0.04

- the QBO response is positive from Nairobi to Samoa and negative from Fiji to southward indicating that the border change between the opposite regime of QBO on ozone variability is around 15°
- AO , SAO and Soar flux response are positive indicting that those oscillation are in phase with the ozone time evolution
- the SAO and solar flux oscillations response are high over As. Island and decrease by moving away from this site to equatorial or poleward.
- ENSO response is negative in the west pacific , eastern Africa and Indian ocean sites indicating an increase of ozone in this region during ENSO warm event while TCO decreases over western Pacific, Atlantic and south American sites where negative ENSO response are recorded

III-2 : RESULTS

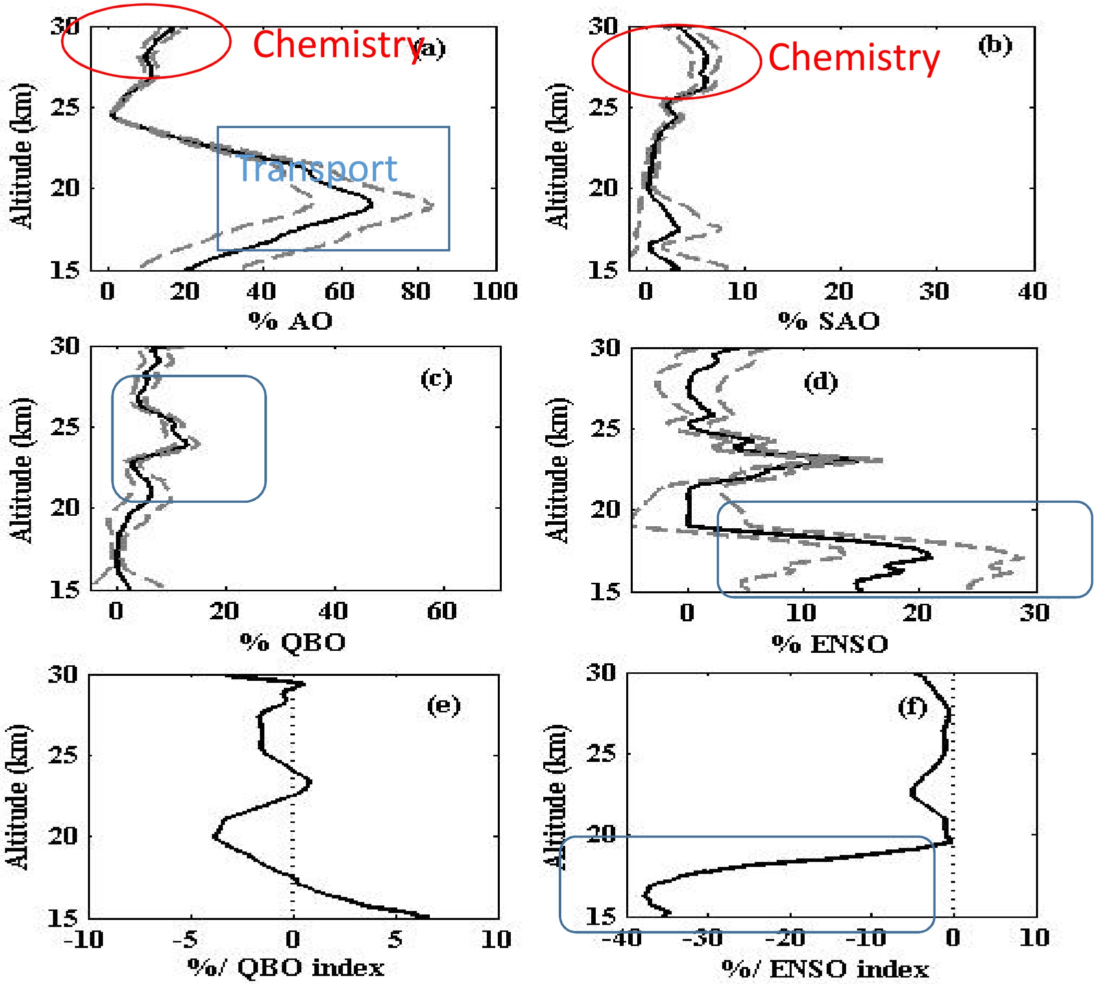
Contribution and response : Tropical : Ozone height profile analysis



Height profile of percentage of contribution of different variables (annual cycle (a), semiannual cycle (b) , QBO (c) and ENSO (d)) with standard deviation calculated by Trend-Run model from 15 km to 30 km over the equatorial region (0°- 10° S). The responses of QBO and ENSO indexes on ozone variability are plotted in the figure (e) and (f) respectively

III-2 : RESULTS

Contribution and response : Tropical: Ozone height profile analysis

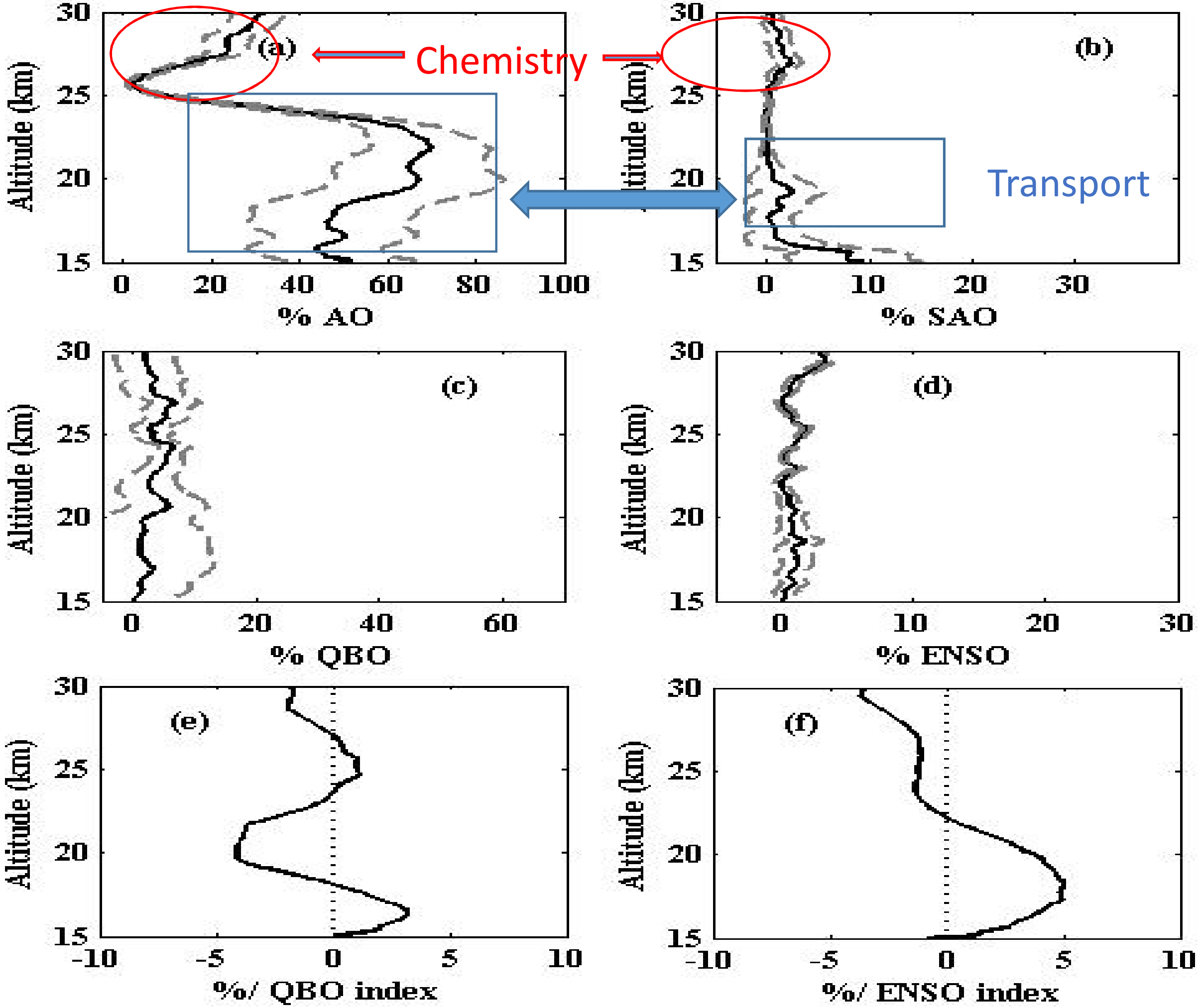


- QBO reduced with respect to equatorial region

- High ENSO contribution and negative response at UT-LS

III-2 : RESULTS

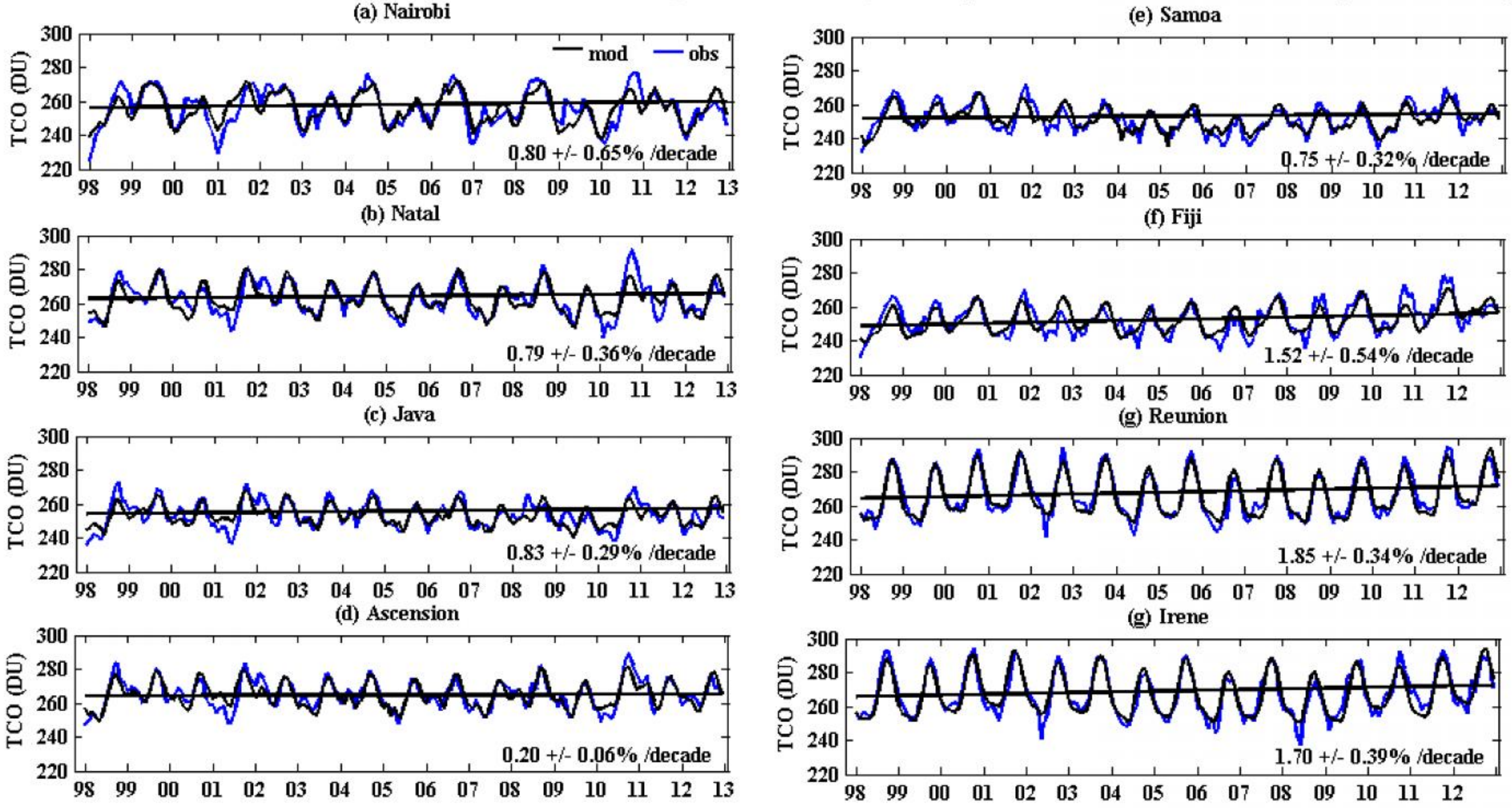
Contribution and response : Subtropical: Ozone height profile analysis



Seasonal oscillations are the most dominant modes of ozone variability over the subtropics

III-3 : TRENDS ESTIMATE

The trend of TCO over the equatorial, tropical and subtropical regions

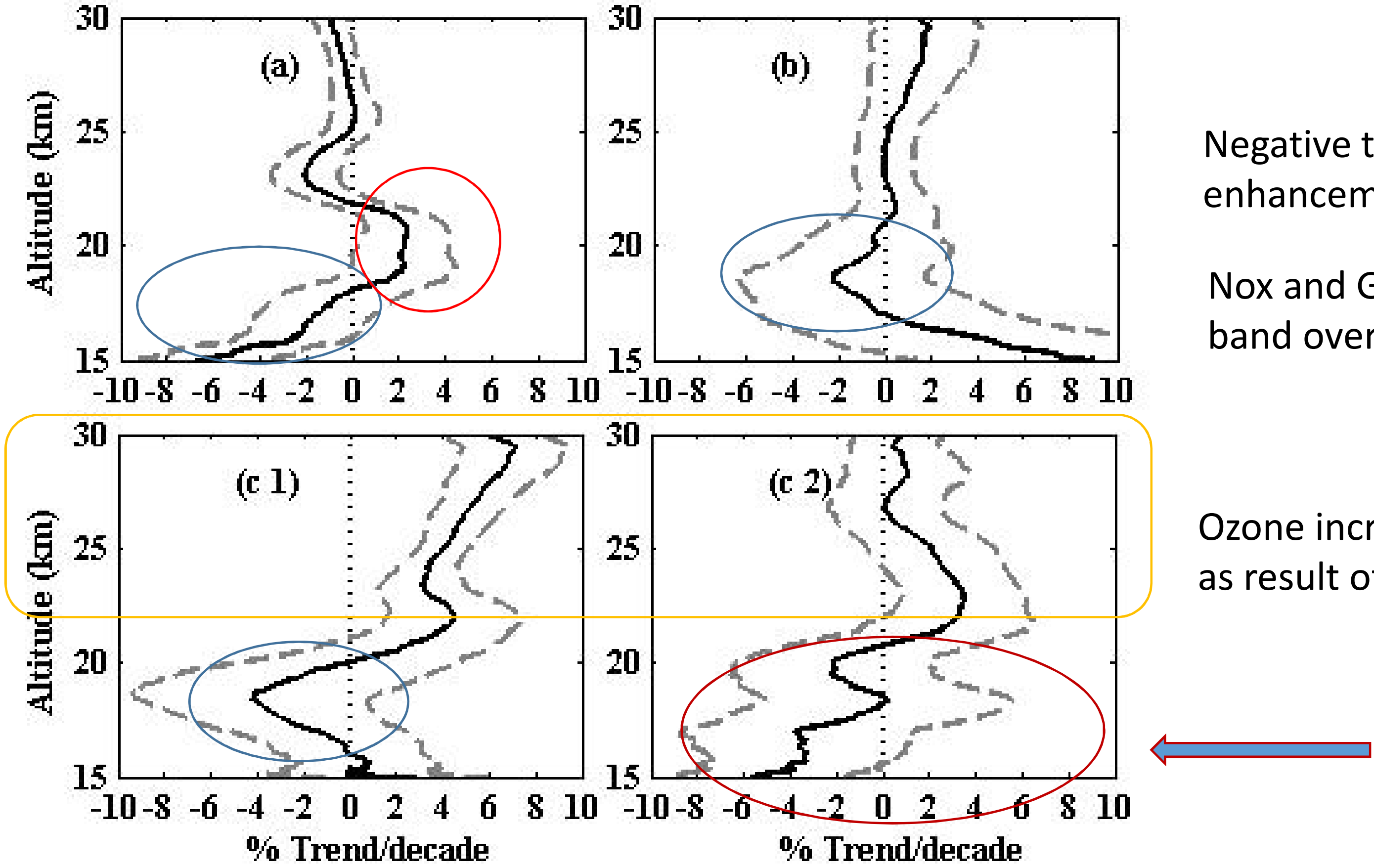


Positive trend over all study sites

Less than 1% from Nairobi to Samoa and more than 1.50% from Fiji to southward

Time evolution of monthly total ozone values (blue) observed on each site. For each site, the superimposed black line represents the time evolution of the TCO as modeled by the Trend-Run, while the straight black line illustrates the obtained decadal trend of value.

III-3 : TRENDS ESTIMATE



vertical profile of ozone decadal trends derived by the Trend-Run model from 15 km to 30 km at the equatorial (a), tropical (b), Reunion (c 1) and Irene (c 2). Irene and Reunion are separated for this present case due to the lack of ozone profile at Irene station from January 2008 to October 2012. Irene trend profile was calculated based on ozone profiles recorded from January 1998 to December 2007(10 years).

Negative trend at UT-LS due to BDC enhancement over the tropics

Nox and GHG increase at 20-23 km altitude band over the equatorial region

Ozone increase due to the decrease of ODS as result of Montreal protocol

Downward trend probably due to air pollution over Irene

Ngiyabonga ukulalela kwenu

Asante sana kwa kunisikiliza

misaotra naharirtra ny aino hatraminy farany

Marahaba ho stahamili muniyichiliye

Merci pour votre aimable attention

THANKS FOR YOUR ATTENTION