“Towards a 10 years reanalysis of tropospheric and lower-stratospheric ozone with the assimilation of IASI and MLS observations”

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4th IASI International Conference, Antibes Juan-les-Pins, France, april 2016

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INTRODUCTION

- **Monitoring the behavior of the atmospheric trace gases is key to understand the present climate and apprehend future climate changes.**
- **Long-term measurements of these gases are necessary to study :**
  - the evolution of their abundance at global and regional scales
  - changing sources and sinks

- **O3 is the third most important greenhouse gas contributing to global warming.**
- **As a reactive trace gas present simultaneously in the troposphere and in the stratosphere, O3 plays a significant role in radiative forcing atmospheric chemistry and air quality .**

- **Tropospheric O3 production is mainly driven by** emissions of primary pollutants (NOx, VOCs, ...), followed by photolysis and nonlinear chemistry reactions (Seinfeld and Pandis, 1998)
- **Since it has an average lifetime of about 2 weeks, it can be efficiently transported for several thousands of kilometers in the free troposphere (Zhang et al., 2008)**

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INTRODUCTION

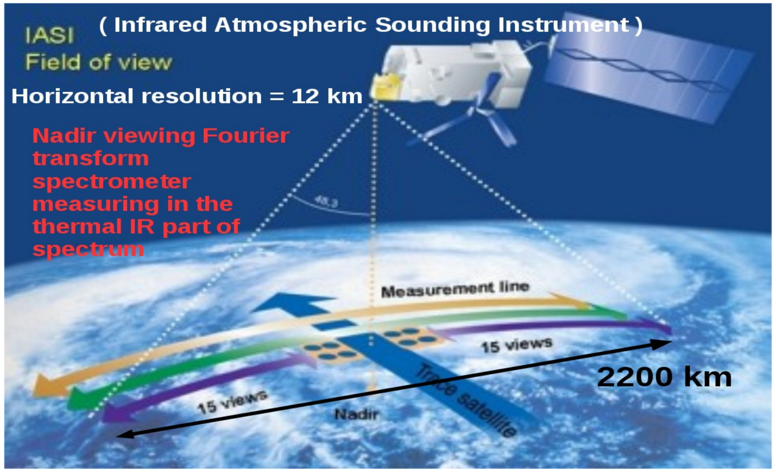
- **An accurate characterization of tropospheric and lower stratospheric ozone is important to quantify the impact of tropospheric O3 transport.**
- **The latest generation of thermal infrared spectrometers, on board Low Earth Orbit (LEO) satellites, is able to capture the tropospheric O3 signature (Eremenko et al., 2008).**

- **The combined assimilation of accurate MLS profiles in the stratosphere and IASI tropospheric columns is supposed to better constrain the ozone gradients at the tropopause and the ozone exchanges between the 2 layers (Emili et al., 2014).**
- **Several studies assimilated IASI data (L2) in Chemical Transport Models (CTM) during short time series (Massart et al., 2010 ; Emili et al., 2014).**

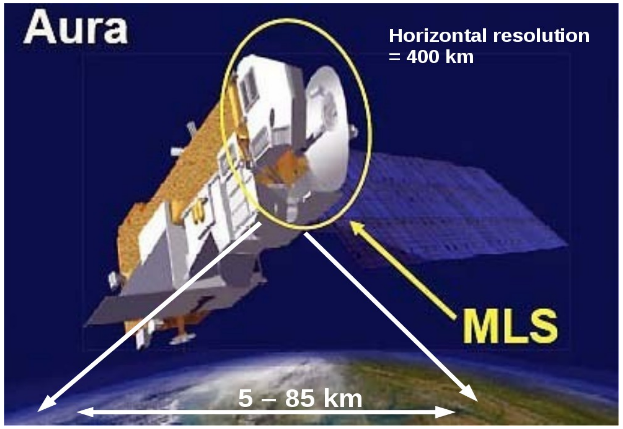
→AIM OF THIS STUDY :

- **Construct a multiyear time-series of global O3 fields at hourly resolution**
- **Validate its accuracy against ozonesondes**
- **Analyze the global O3 variability in the UTLS during the period 2008-2013**

1. Assimilated data



IASI	
Platform	METOP-A
Instrument type	Michelson Interferometer
O3 products	•SOFRID (Software for a Fast Retrieval of IASI Data (Barret et al.,2011, LA-OMP)) •AVK used •1000hPa-350hPa •Tropospheric data



MLS	
Platform	AURA (NASA)
Instrument type	Thermal-emission Microwave Limb Sounder
O3 products	•Version 4.2 •Data for pressures above 215hPa •Stratospheric data

2. Chemical transport model and data assimilation algorithm

Chemistry Transport model MOCAGE (developed at Météo France)

- 60 vertical levels (1015hPa – 0.1 hPa)
- Horizontal resolution = 2°x2° (Global)
- ERA-Interim forcing (ECMWF global reanalysis) ↔ frequency for the meteorological forcing = 6h
- Parametrization of Ozone = linear scheme CARIOLLE (Cariolle et al.,2007) -> surface emissions not used and a relaxation term to a climatological field is dominant in the troposphere

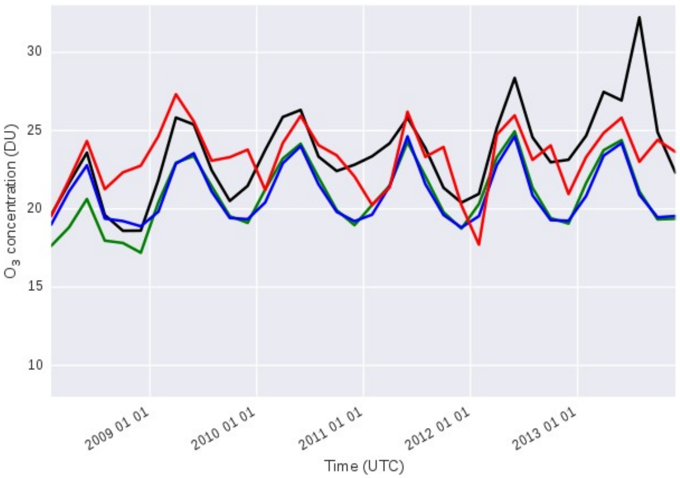
IASI and MLS analysis

- 4D-VAR data assimilation algorithm in MOCAGE allows a better exploitation of the spatio-temporal fingerprint of satellite observations
- Assimilation windows = 12h
- Background error covariance : 15% in troposphere and 5% in stratosphere
- **Two analyses produced :**
  - **MLS analysis :** MLS stratospheric data (2004-2014).
  - **IASI combined with MLS :** MLS stratospheric data + IASI-SOFRID tropospheric retrievals (2008-2013).

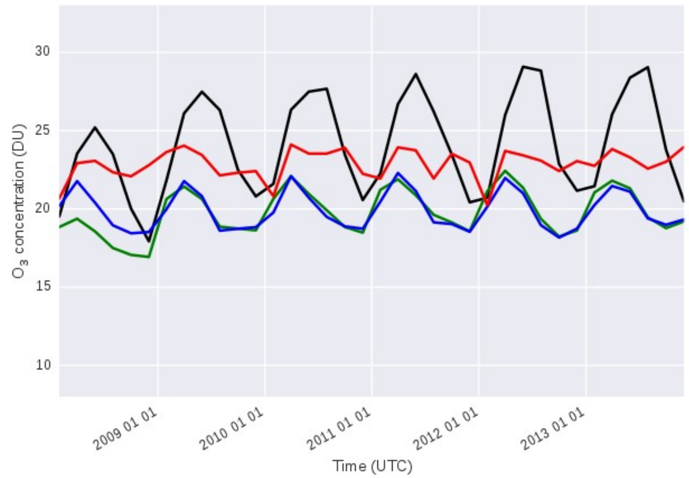
3. Validation

◆ **O3 tropospheric column in DU (350-1000hPa)**

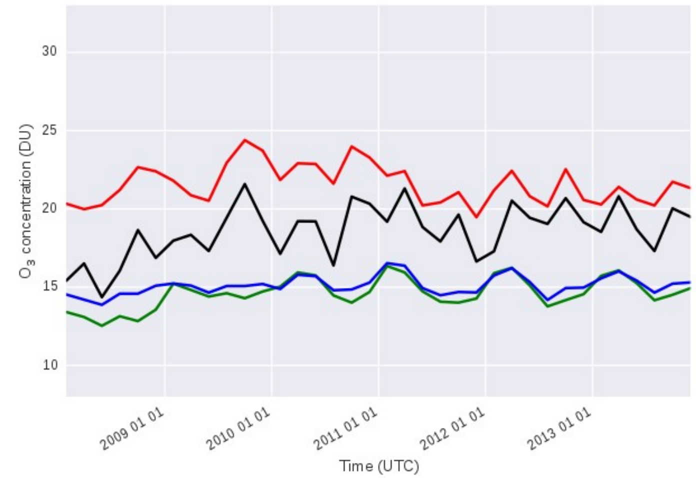
60°N-90°N



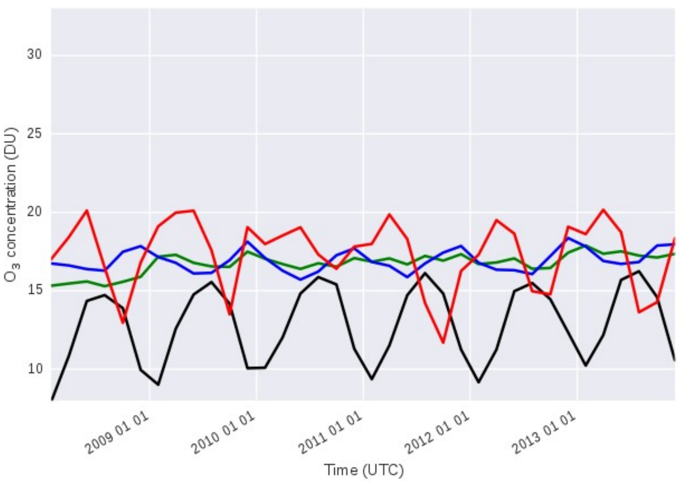
30°N-60°N



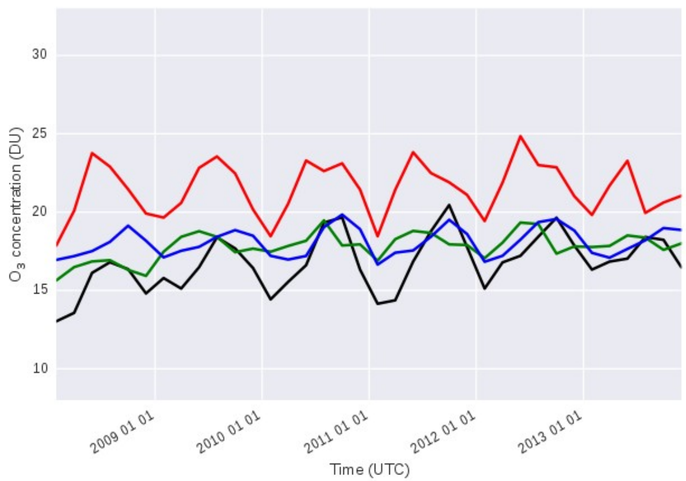
30°S-30°N



90°S-60°S



60°S-30°S



Ozonesonde

IASI/MLS analysis

MLS analysis

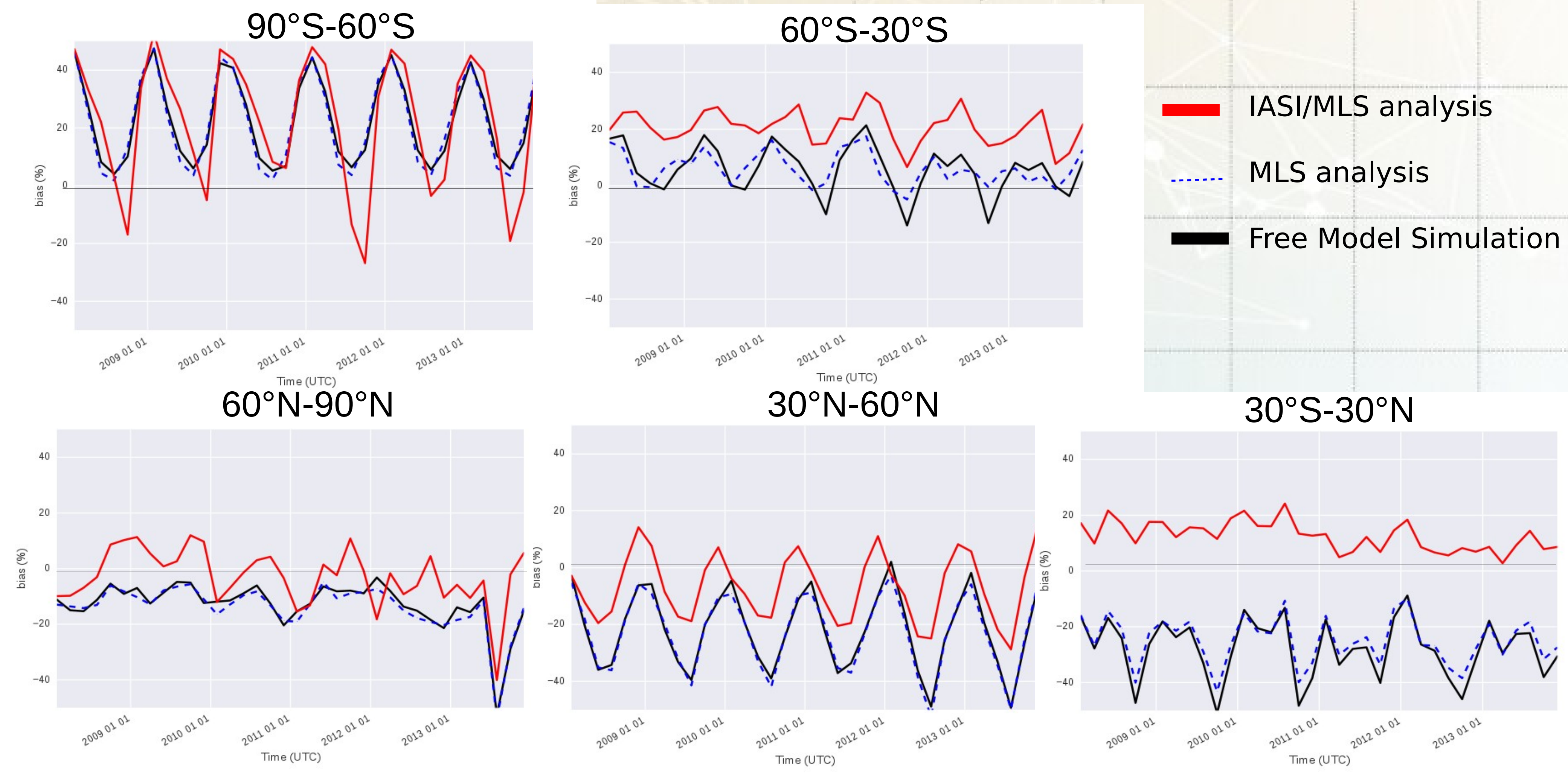
Free Model Simulation

149 stations of Ozonesondes (WOUDC database)

- Good monthly correlation in tropics between IASI/MLS analysis and Ozonesondes
- **Tropics and southern hemisphere (SH) :** Model variability increases in general → increased seasonal variability

3. Validation

◆ **Bias (%) of O3 tropospheric column (350-1000hPa) between analysis and ozonesondes**

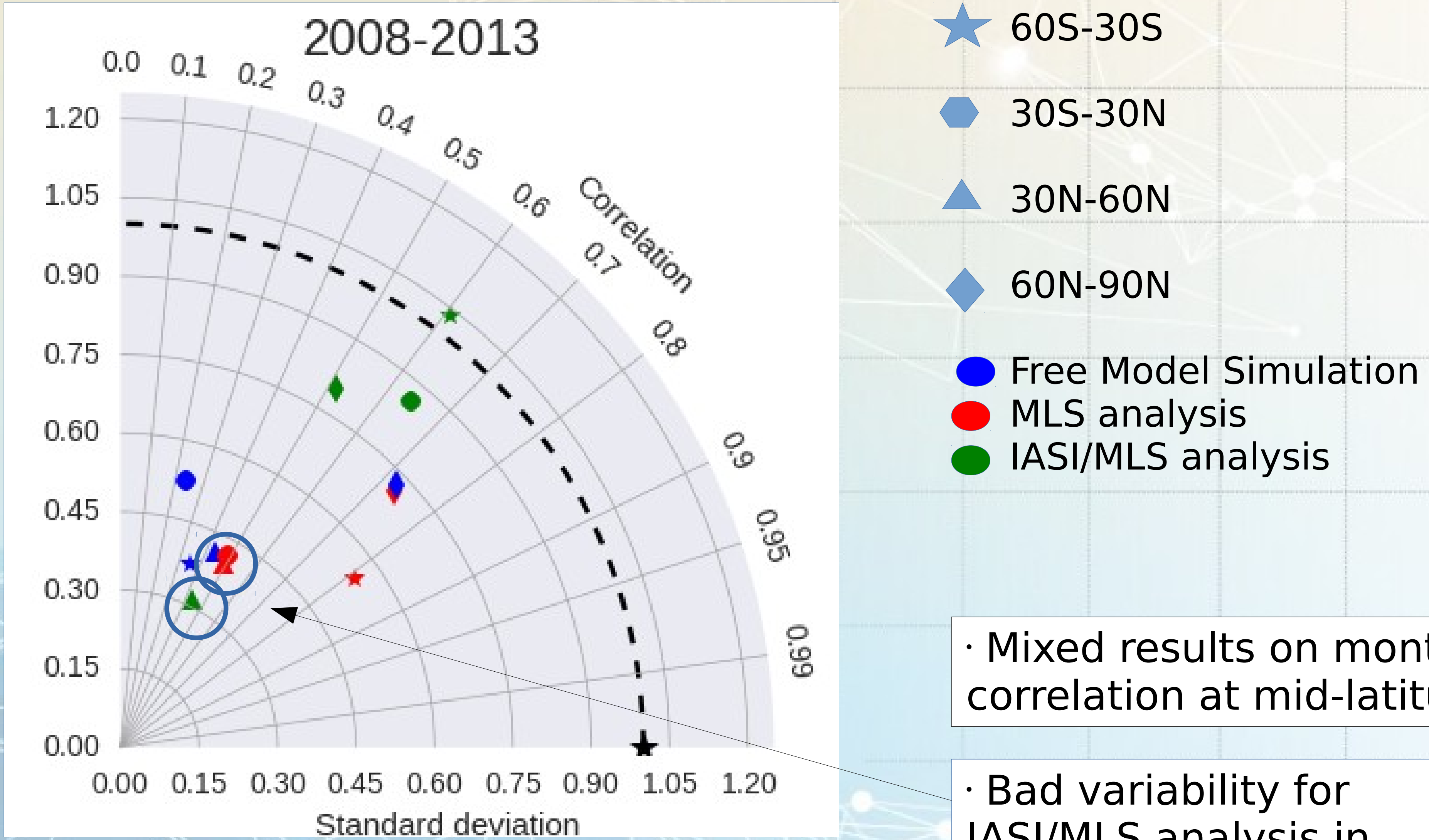


- Northern Hemisphere : Improvements brought by IASI/MLS analysis (bias ~ 0)
- Tropics and SH : IASI/MLS analysis over-estimate O_3 concentrations (10%-20%)

3. Validation

◆ **O3 tropospheric column (350-1000hPa)**

Taylor Diagram



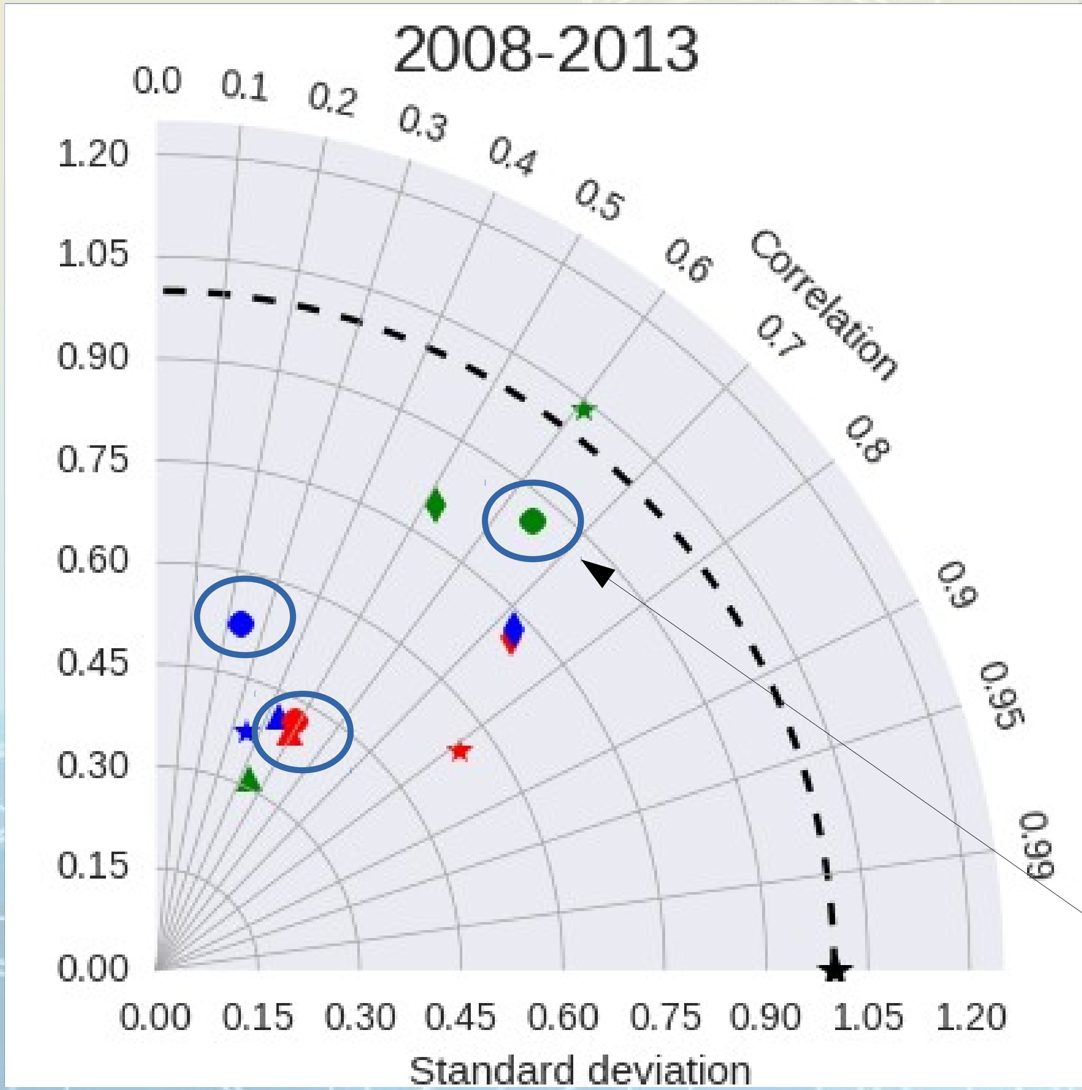
· Mixed results on monthly correlation at mid-latitudes

· Bad variability for IASI/MLS analysis in mid-latitudes North Hemisphere.

3. Validation

◆ **O3 tropospheric column (350-1000hPa)**

Taylor Diagram



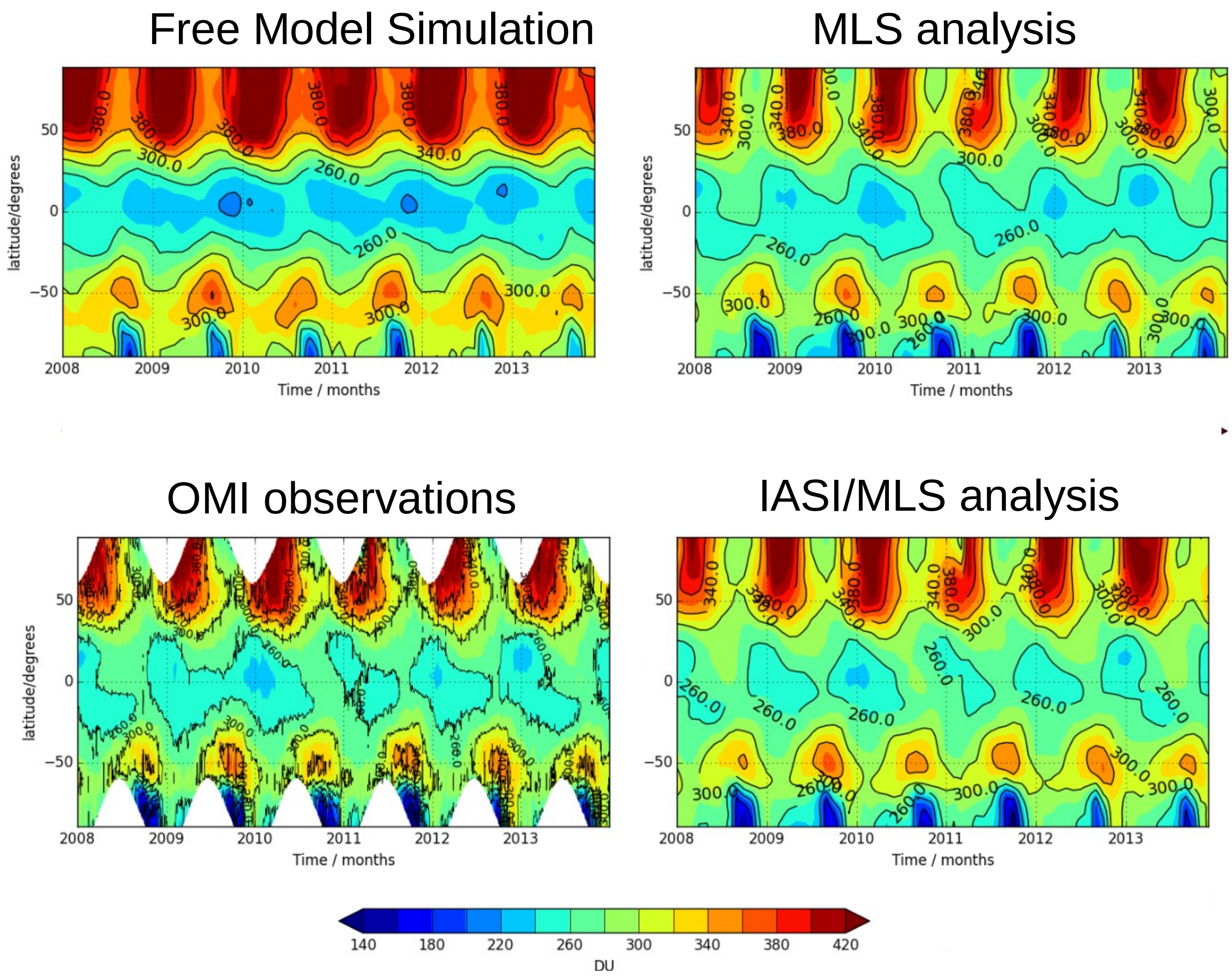
- 60S-30S
- 30S-30N
- 30N-60N
- 60N-90N

- Free Model Simulation
- MLS analysis
- IASI/MLS analysis

· Better variability for IASI/MLS analysis in tropics.

3. Validation

Hovmöller – total ozone column

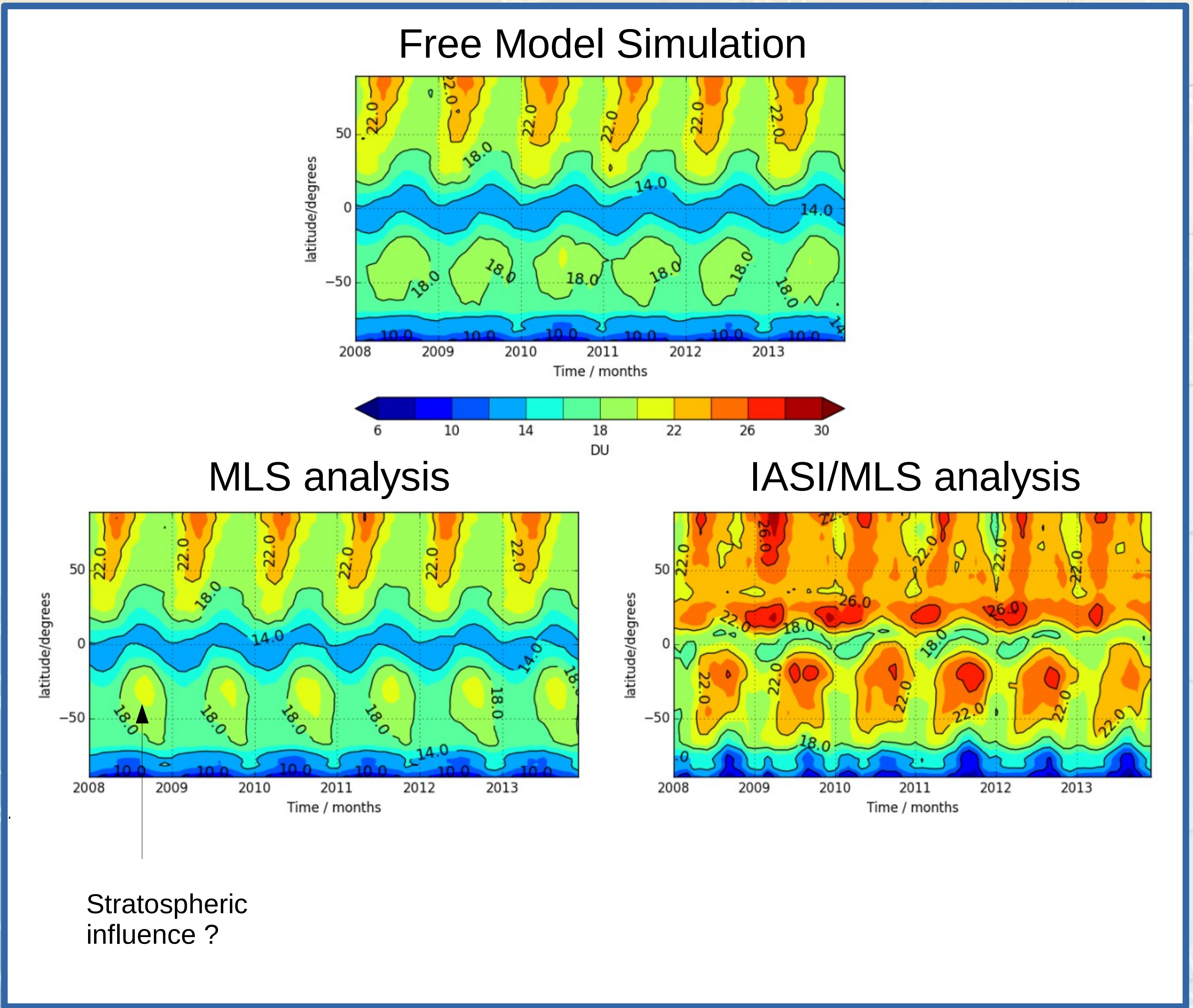


Time series of total O3 column zonal average for the period 2008 to 2013 for OMI observations, IASI with MLS reanalysis, Free Model Simulation and MLS analysis.

- **Seasonal variability :**
  - North Hemisphere: High values during boreal winter and spring due to Brewer-Dobson circulation(Ziemke et al, 2011).
  - Tropics : Lower values (slow large-scale ascent)
  - Southern Hemisphere :
    low values = Antarctic ozone hole
    higher values = belt around Antarctic

4. Tropospheric Ozone variability

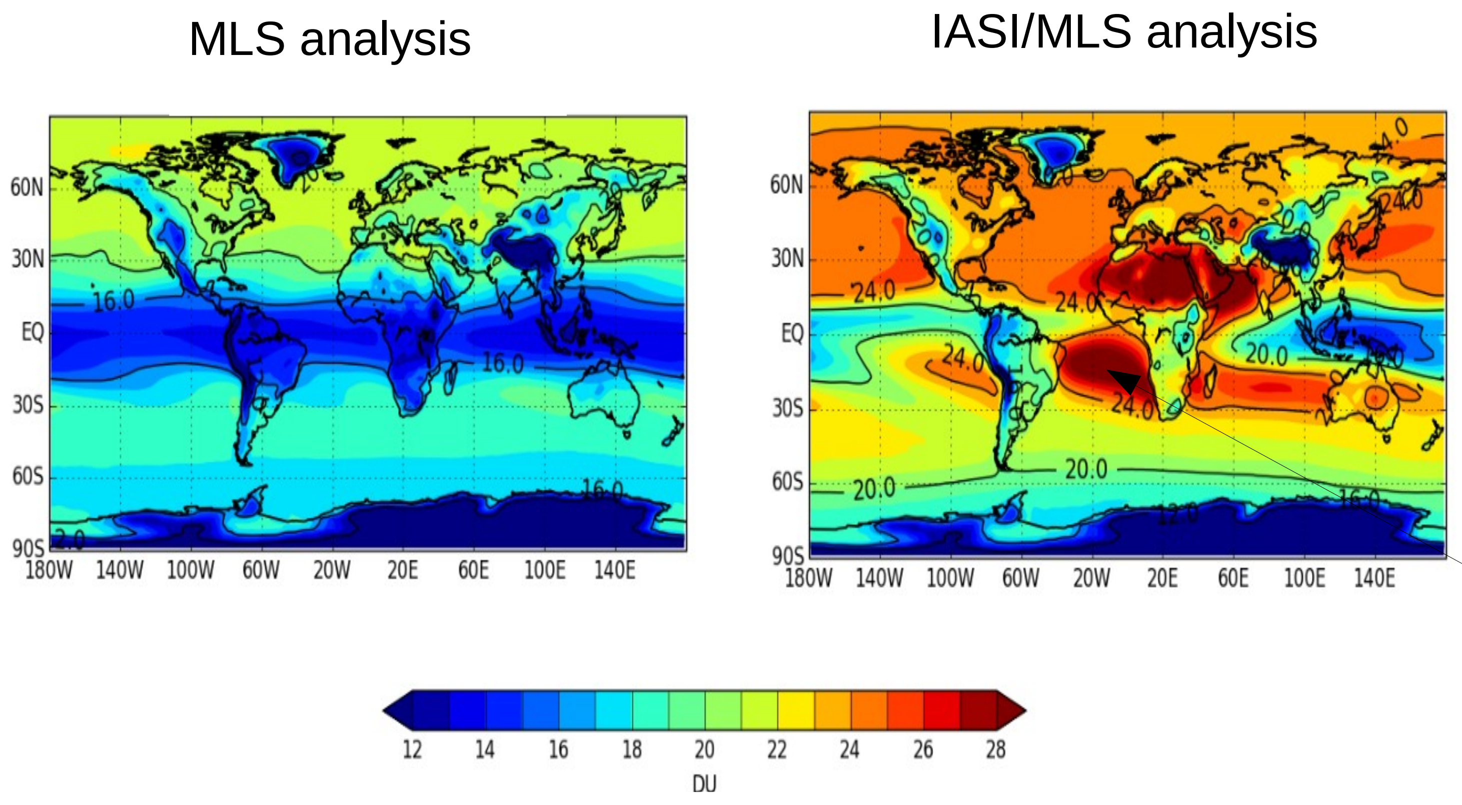
Hovmoller – zonal tropospheric column (1000hPa – 350hPa)



- Significant impact of IASI/MLS analysis for the tropospheric column

4. Tropospheric Ozone variability

Tropospheric column

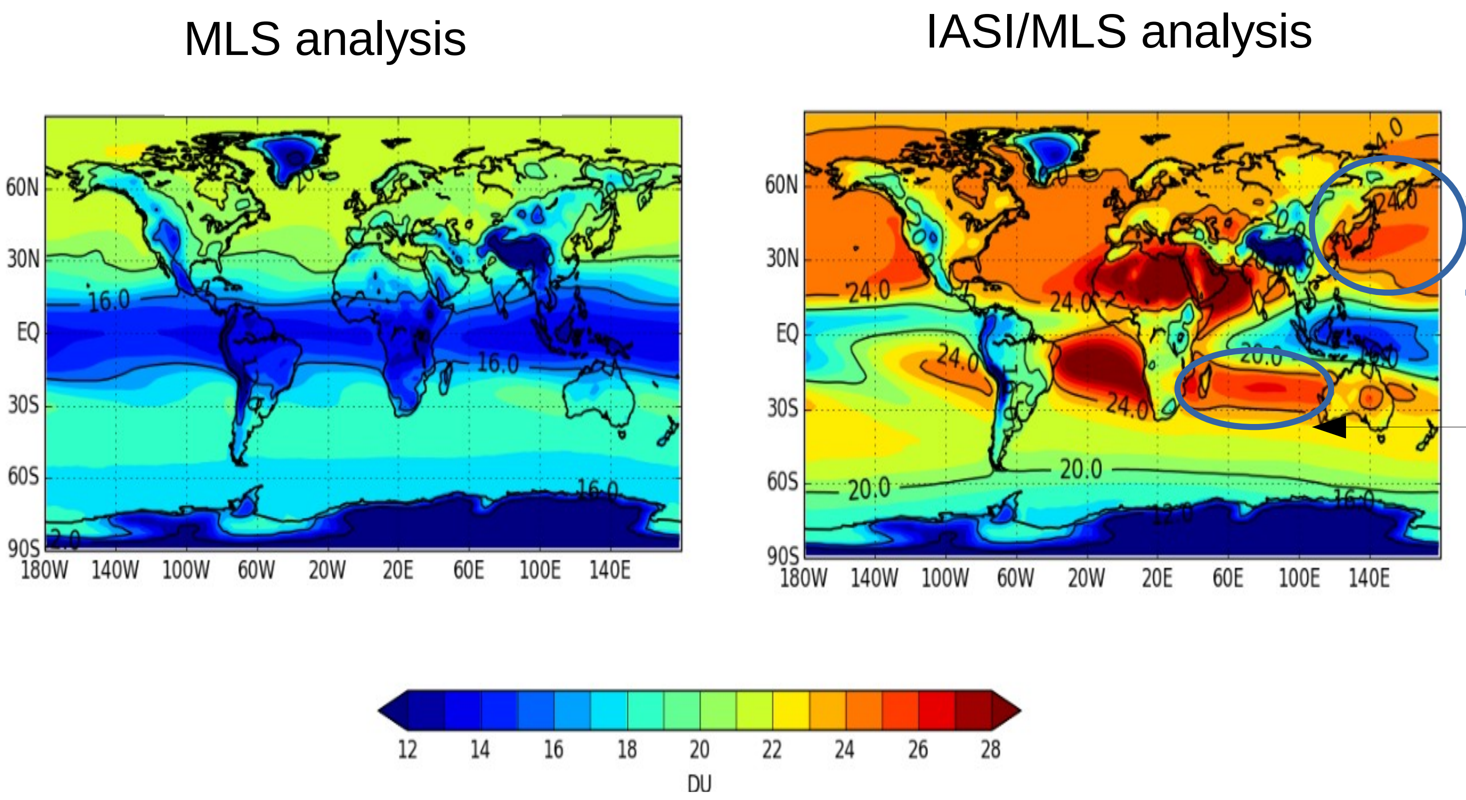


Time series of tropospheric O3 column (1000hPa – 350hPa) for the period 2008 to 2013 for MLS analysis and IASI/MLS analysis.

- Walker circulation transports LiNOx and Biomass burning (Martin et al., 2002)

4. Tropospheric Ozone variability

Tropospheric column



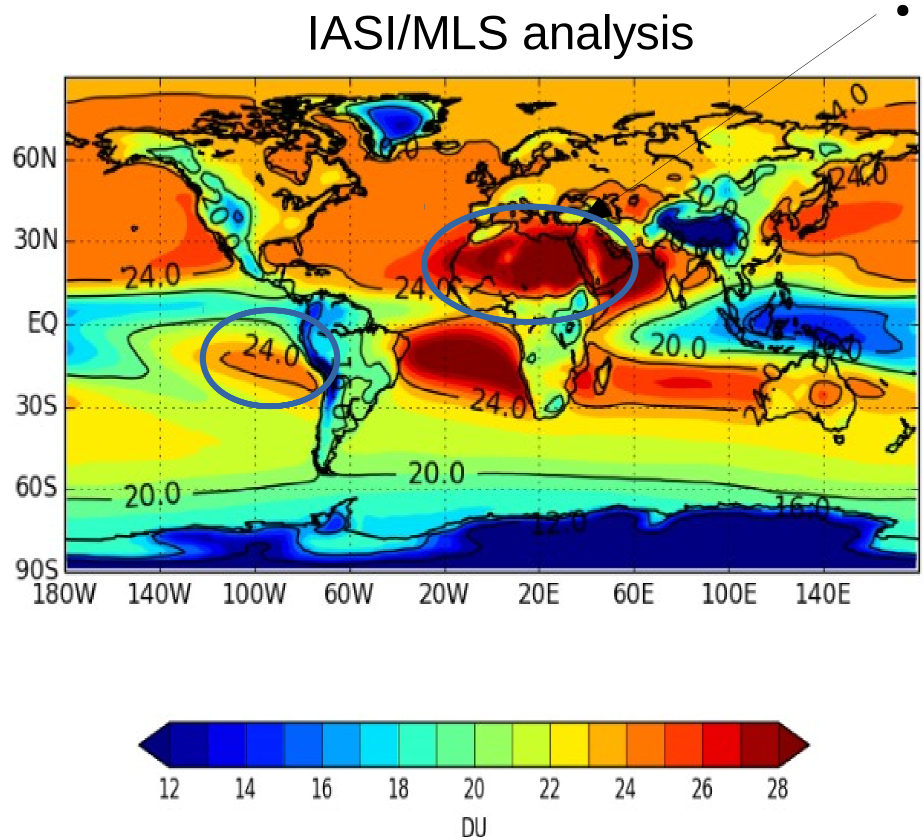
Eastern Asia continent pollution (Ziemke et al., 2011)

Biomass burning transport (Wai et al., 2014)

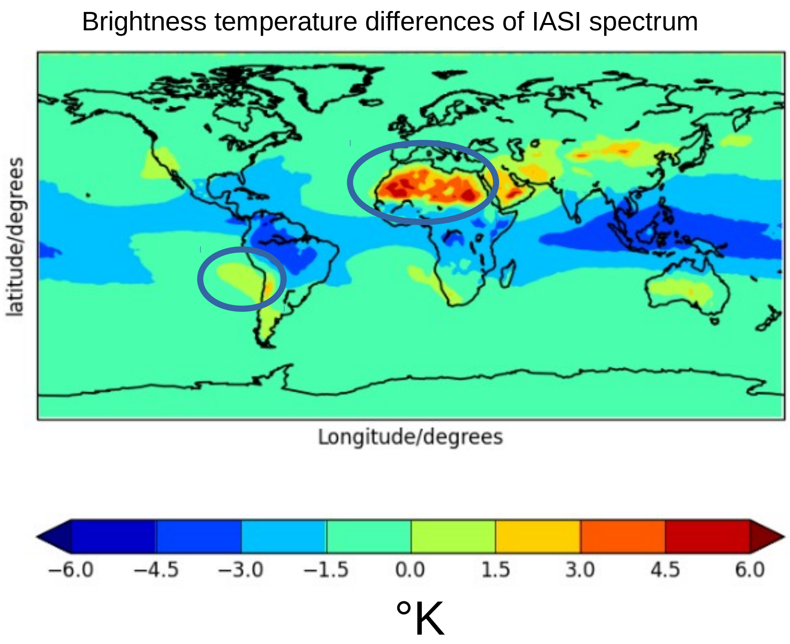
Time series of tropospheric ozone column (1000hPa – 350hPa) for the period 2008 to 2013 for MLS analysis and IASI/MLS analysis.

4. Tropospheric Ozone variability

Tropospheric column

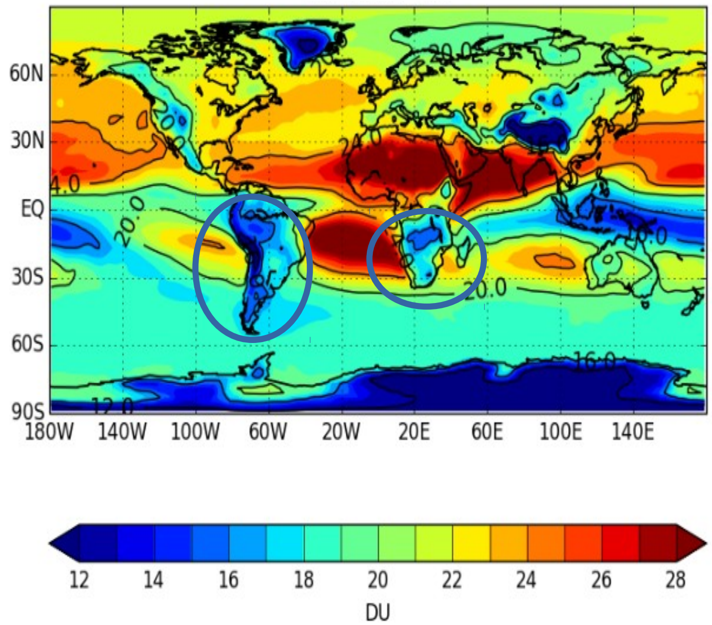


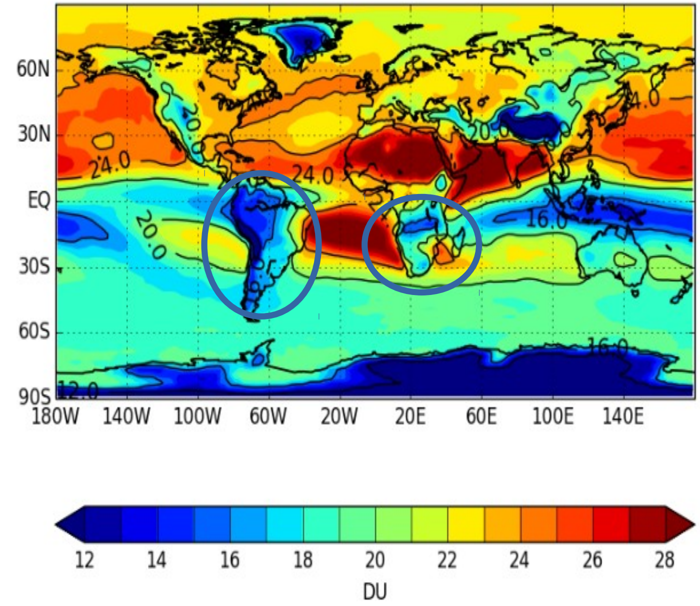
- Desert emissivity and dust aerosols = introduce biases in O3 retrievals

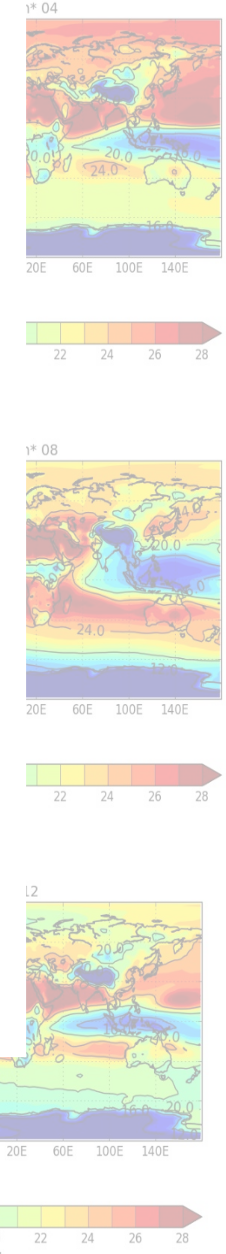


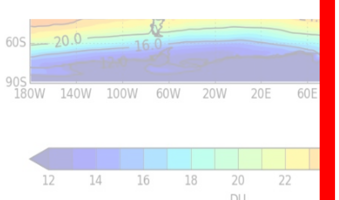
Time series of tropospheric ozone column (1000hPa – 350hPa) for the period 2008 to 2013 for MLS analysis and IASI/MLS analysis.

DBTsand = [BT(736)-BT(1310)]+[BT(2230)-BT(1804)]









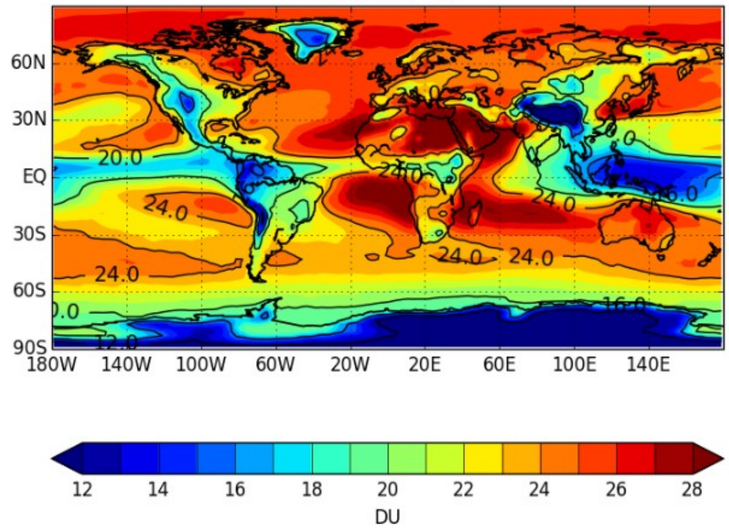
January and February:

smallest TOC in South Hemisphere high latitudes (<20 DU)

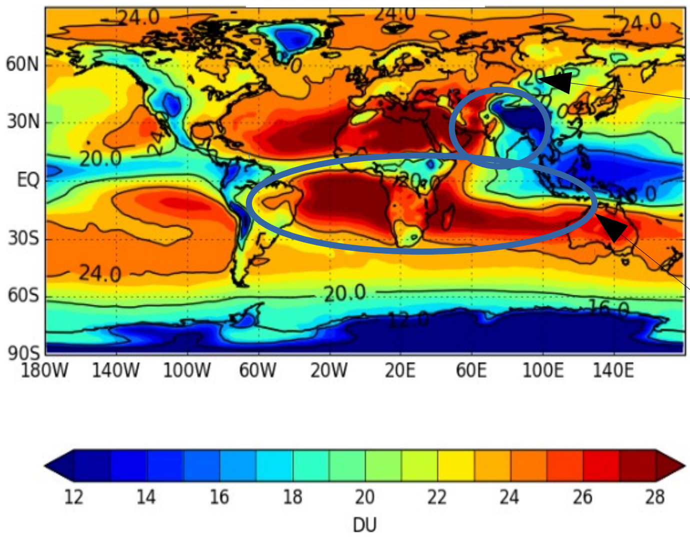
Lowest biomass burning (Ziemke et al., 2011)

Tropospheric ozone column (TOC in DU) derived from IASI/MLS reanalysis.
The time record for this monthly climatology is January 2008 through December 2013.

June



July

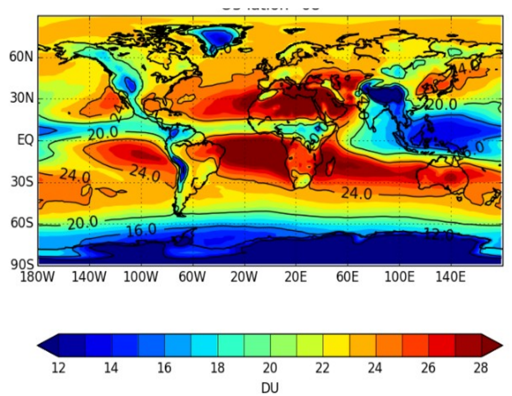


Indian Monsoon (Barret et al.,

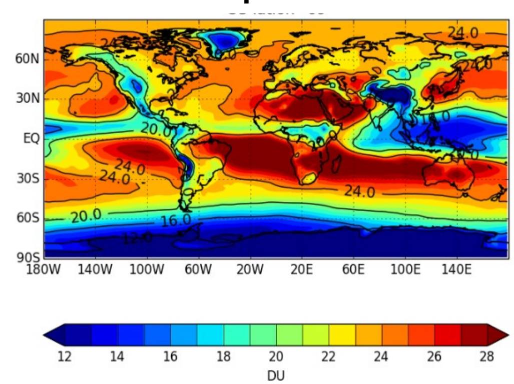
Biomass burning (Ziemke et al., 2011)

<u>June – July :</u>
largest columns in North Hemisphere
(Mediterranean and eastern Asia continent)

August

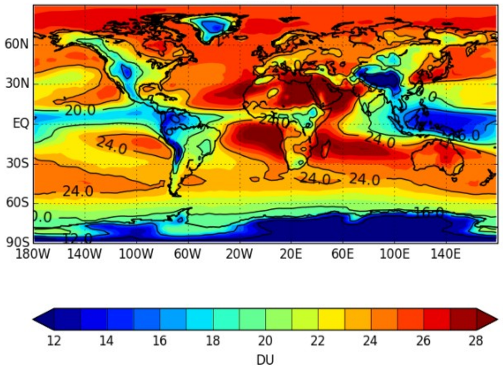


September

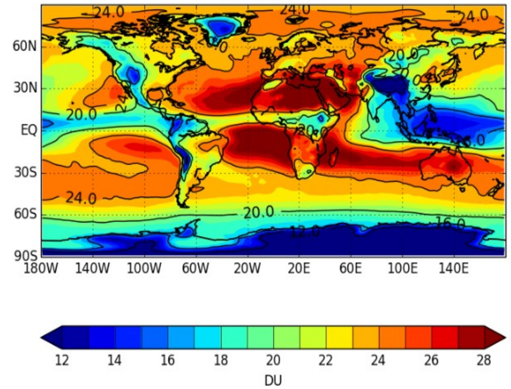


Tropospheric ozone column (DU) derived from IASI/MLS reanalysis.
The time record for this monthly climatology is January 2008 through December 2013.

June

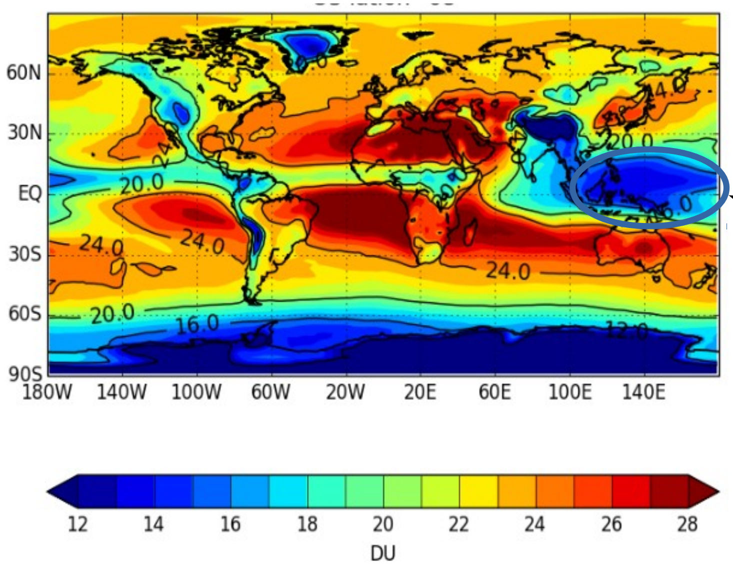


July



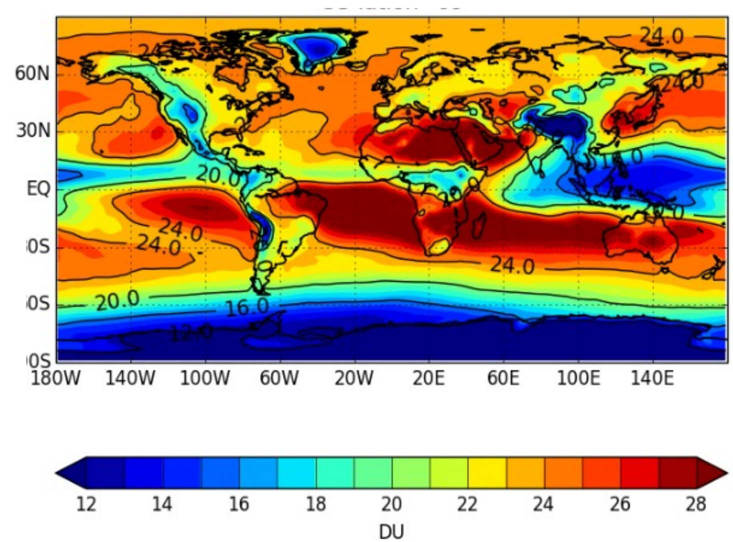
July – September :
lowest TOC in Tropical Pacific because of deep convection and vertical injection tropospheric ozone into the middle/upper troposphere (Ziemke et al., 2011)

August



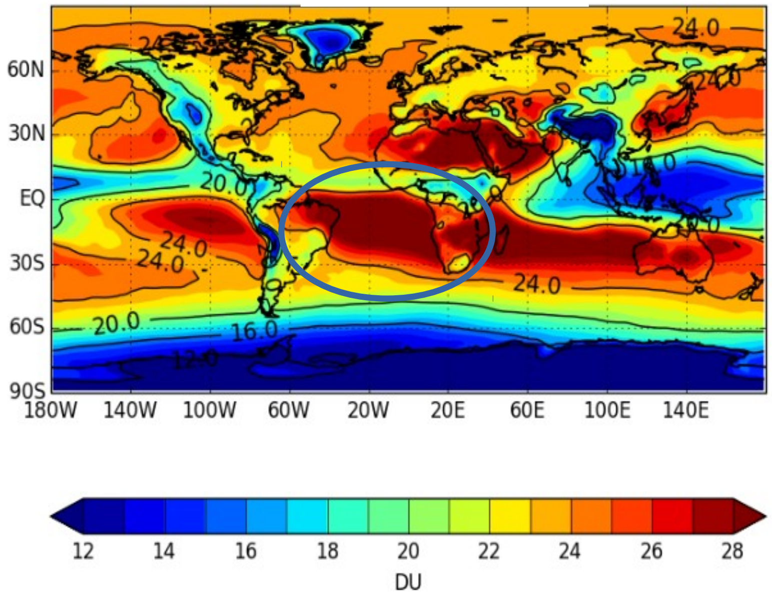
Warm Pool => South Pacific Convergence Zone (Vincent, 1994)

September

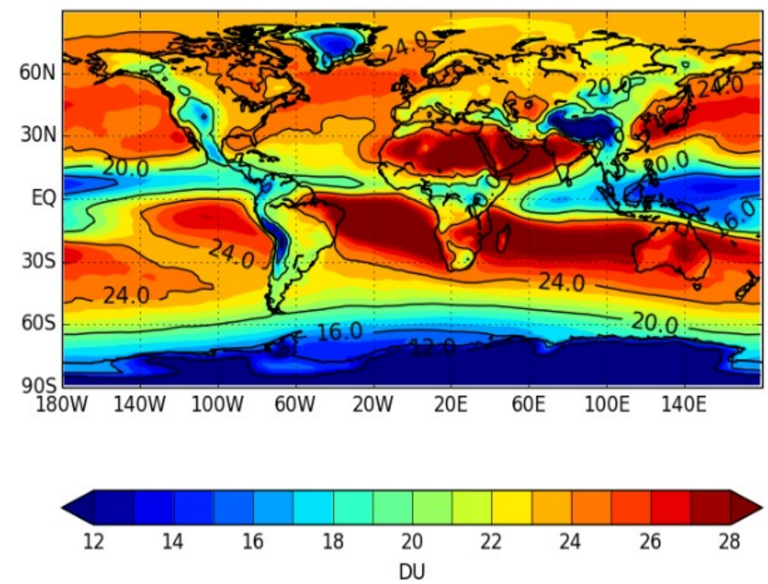


Tropospheric ozone column (DU) derived from IASI/MLS reanalysis. The time record for this monthly climatology is January 2008 through December 2013.

September



October



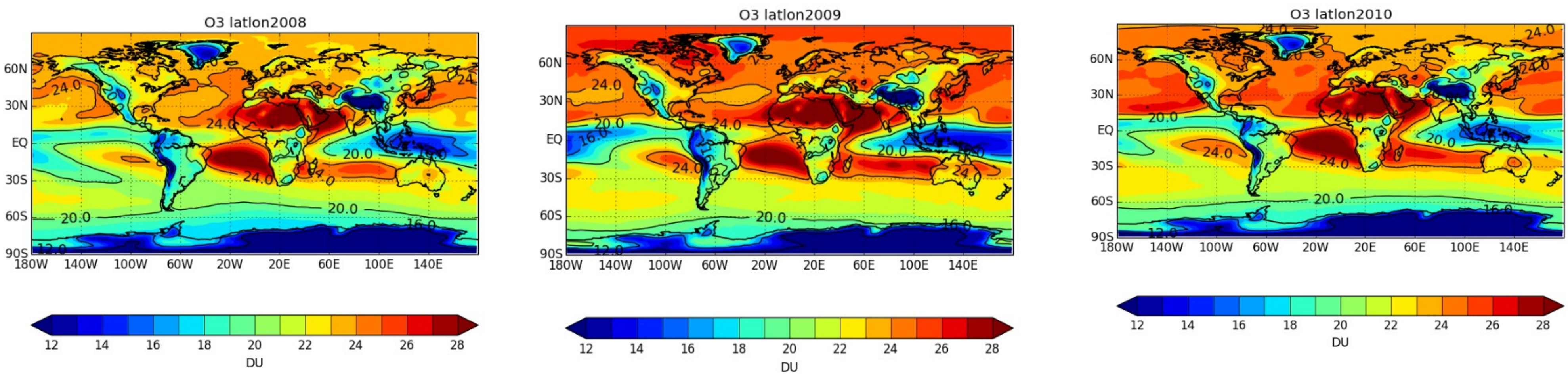
<u>Sept – oct :</u>

largest TOC in Tropical South Atlantic due to :

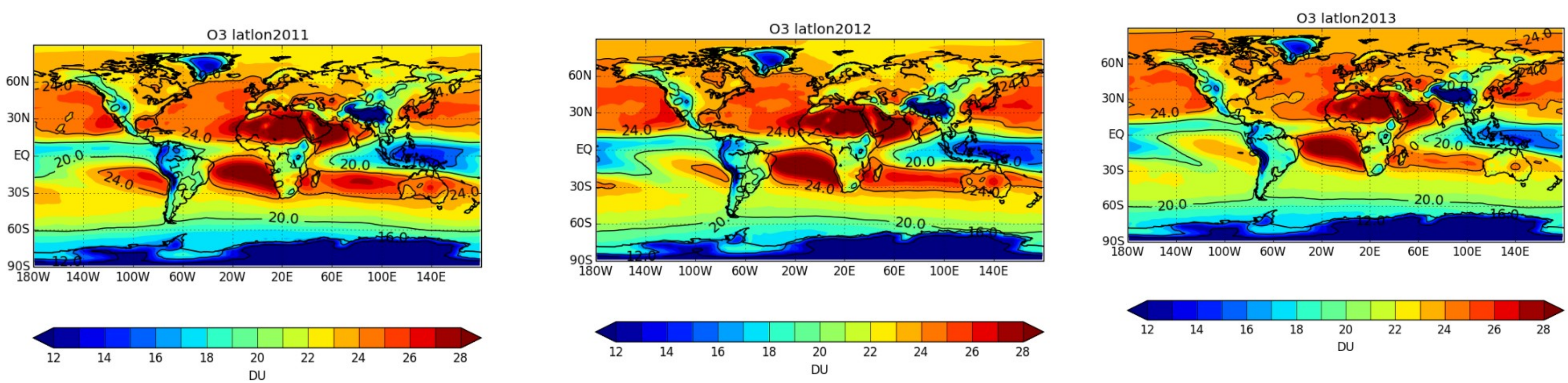
- Walker circulation (Wang et al., 2006)
- Biomass burning (Wai et al., 2014)
- Lightning (Sauvage et al., 2007)

Tropospheric ozone column (DU) derived from IASI/MLS reanalysis.
The time record for this monthly climatology is January 2008 through December 2013.

Tropospheric ozone column (1000hPa – 350hPa, DU) for the period 2008 -2013
Derived from IASI/MLS analysis.
<u>Annual average</u>



- Largest TOC in North Hemisphere, particularly in 2009
- Wave-one between Pacific and Atlantic (Thompson et al., 2003)



Conclusions and Perspectives

- **In tropics : IASI-SOFRID** ozone analysis **corrects biases** and **variability**
- **Inter-annual and monthly variability** of IASI-SOFRID/MLS **validated** against ozonesondes
- The assimilation of IASI tropospheric column introduces **strong ozone variability** in the model, coherent with previous studies, but more validation with other instruments needed.

- Filter IASI retrievals affected by dust and sand
- Correct biases in IASI-SOFRID retrievals particularly seen in south hemisphere and then re-evaluate global tropospheric budget using such long term reanalysis
- Episodes analysis
- Validate variability with other instruments

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