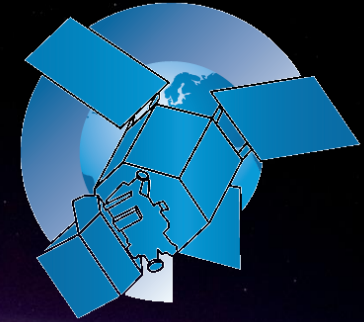


# TROPOMI tropical tropospheric ozone column data

Geophysical assessment and comparison  
to ozonesondes, GOME-2B and OMI



Daan Hubert, K.-P. Heue, J.-C. Lambert, T. Verhoelst, M. Allaart, S. Compemolle, P. Cullis, A. Dehn, C. Félix, B. Johnson, A. Keppens, D. Kollonige, C. Lerot, D. Loyola, M. Maata, S. Mitro, M. Mohamad, A. Pitters, F. Romahn, H. Selkirk, F.R. da Silva, R. Stauffer, A. Thompson, P. Veefkind, H. Vömel, J. Witte, and C. Zehner



# Two years of TROPOMI tropospheric ozone column data



processed at DLR with L2\_O3\_TCL OFFL processor v01.01.05-08

Atmos. Meas. Tech., 9, 5037–5051, 2016  
www.atmos-meas-tech.net/9/5037/2016/  
doi:10.5194/amt-9-5037-2016  
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Atmospheric  
Measurement  
Techniques  
EGU

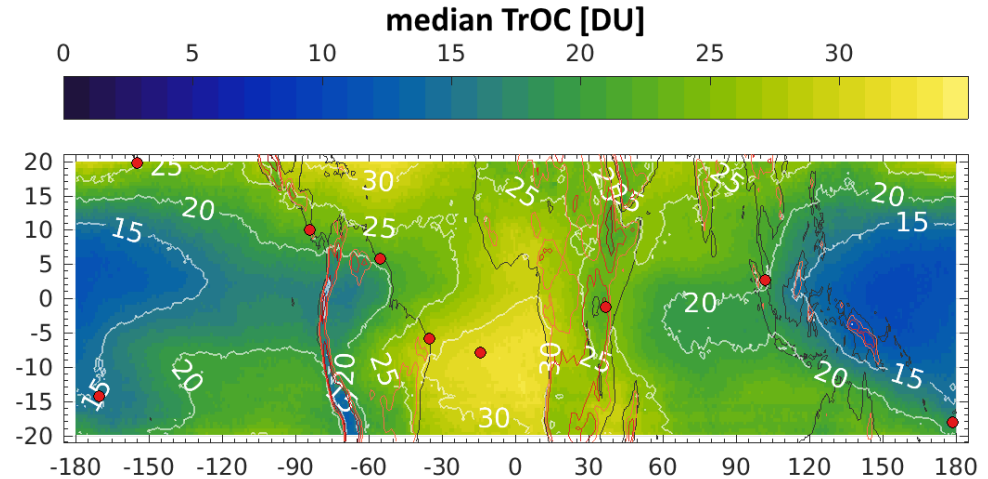
**Trends of tropical tropospheric ozone from 20 years of European satellite measurements and perspectives for the Sentinel-5 Precursor**

Klaus-Peter Heue<sup>1</sup>, Melanie Coldewey-Egbers<sup>1</sup>, Andy Delcloo<sup>2</sup>, Christophe Lerot<sup>3</sup>, Diego Loyola<sup>1</sup>, Pieter Valks<sup>1</sup>, and Michel van Roozendael<sup>3</sup>

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Revised: 22 September 2016 – Accepted: 23 September 2016 – Published: 13 October 2016



## Convective Cloud Differential (CCD) technique using

- TROPOMI total ozone column data (GODFIT v4)
- TROPOMI cloud data (OCRA/ROCINN\_CRB)
- GOME/SCIAMACHY/GOME-2/OMI heritage

## Represents

- (cloud-free) O<sub>3</sub> column surface-270 hPa
- daily sampled 3-day moving average
- 20°S-20°N, 0.5° lat. x 1° long.

Contains modified Copernicus S5P data post-processed at BIRA-IASB

S5P data available publicly since 30 Apr 2018 at <https://scihub.copernicus.eu>

CEOSAC-VC-16 teleconference - June 10, 2020

# Assessment of TROPOMI tropospheric ozone (CCD)



## Methodology

- Comparison to SHADOZ ozonesonde and to GOME-2 & OMI satellite data
- Estimates of bias & dispersion + analysis of space/time variations
- Reduction of random mismatch errors via analysis of co-located triplets
- Estimates of sampling errors (as gridded data product)
- Assessment of geophysical cycles and patterns: annual, biomass burning, MJO...

Hubert et al.: TROPOMI tropical tropospheric O<sub>3</sub> assessment

Submitted to AMT for the TROPOMI Special Issue

**TROPOMI tropospheric ozone column data : Geophysical assessment and comparison to ozonesondes, GOME-2B and OMI**

Daan Hubert<sup>1</sup>, Klaus-Peter Heue<sup>2</sup>, Jean-Christophe Lambert<sup>1</sup>, Tijl Verhoed<sup>1</sup>, Marc Allaert<sup>1</sup>, Steven Compernelle<sup>1</sup>, Patrick D. Cullis<sup>3</sup>, Angelika Dehn<sup>4</sup>, Christian Felix<sup>5</sup>, Bryan J. Johnson<sup>6</sup>, Arno Keppens<sup>1</sup>, Debra E. Kollonge<sup>1,4</sup>, Christophe Lerot<sup>7</sup>, Diego Loyola<sup>8</sup>, Matakite Maata<sup>9</sup>, Sukarni Mitro<sup>10</sup>, Mazrozan Mohamad<sup>11</sup>, Ankie Pliets<sup>1</sup>, Fabian Romahn<sup>1</sup>, Henry B. Selkirk<sup>12,13</sup>, Francisco R. da Silva<sup>14</sup>, Ryan M. Stauffer<sup>15,15</sup>, Anne M. Thompson<sup>16</sup>, J. Pepijn Veefkind<sup>1</sup>, Holger Vomal<sup>17</sup>, Jacques van C. Wille<sup>18</sup>, and Claus Zehner<sup>2</sup>

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<sup>4</sup>NOAA Global Monitoring Laboratory (NOAA/ESRL/GML), 1325 Broadway, Boulder 80305-3337, CO, USA  
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<sup>6</sup>Federal Office of Meteorology and Climatology, MeteoSwiss, Payerne, Switzerland  
<sup>7</sup>Science Systems and Applications, Inc., Lanham, MD, USA  
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<sup>11</sup>Atmospheric Science and Cloud Seeding Division, Malaysian Meteorological Department, Petaling Jaya, Selangor, Malaysia  
<sup>12</sup>Universities Space Research Association, Columbia, MD, USA  
<sup>13</sup>NASA Goddard Space Flight Center, Greenbelt, MD, USA  
<sup>14</sup>Laboratory of Environmental and Tropical Variables, Brazilian Institute of Space Research, Natal, Brazil  
<sup>15</sup>Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD, USA  
<sup>16</sup>National Center for Atmospheric Research, Boulder, CO, USA

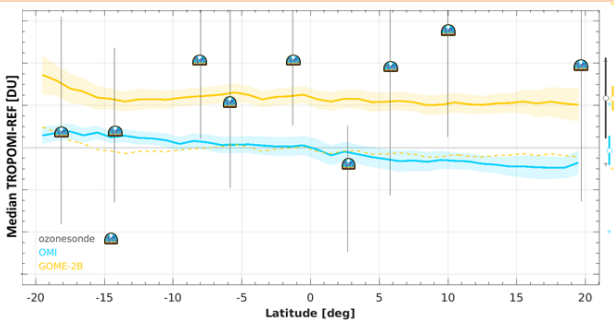
Correspondence: daan.hubert@aecronomic.be

**Abstract.** Ozone in the troposphere affects humans and ecosystems as a pollutant and as a greenhouse gas. Observing, understanding and modelling this dual role, as well as monitoring effects of international regulations on air quality and climate change, however, challenge measurement systems to operate at opposite ends of the spatio-temporal scale ladder. On board of the ESA/EU Copernicus Sentinel-5 Precursor (S5P) satellite launched in October 2017, TROPOMI (TROPospheric Monitoring Instrument) aspires to take the next leap forward by measuring ozone and its precursors at unprecedented horizontal resolutions until at least the mid 2020s. In this work, we assess the quality of TROPOMI's first release (V01.01.05-08) of tropical tropospheric ozone column data (TROCC). Derived with the Convective Cloud Differential (CCD) method, TROPOMI daily TROCC data represent the three-day moving mean ozone column between surface and 270 hPa under clear sky conditions gridded at 0.5° latitude by 1° longitude resolution. Comparisons to almost two years of co-located SHADOZ ozonesonde and satellite data (Aura OMI and MetOp-B GOME-2) conclude to TROPOMI biases between -0.1 and +2.3 DU (<+13%) when averaged over the tropical belt. The field of the bias is essentially uniform in space (deviations <1 DU) and stable in time at the 1.5–2.5 DU level. However, the record is still fairly short and continued monitoring will be key to clarify whether observed patterns and stability persist, alter behaviour or disappear. Biases are partially due to TROPOMI and the reference data records themselves, but they can also be linked to systematic effects of the non perfect co-locations. Random uncertainty due to co-location mismatch

# Quality Indicators for tropical tropospheric ozone from the Sentinels

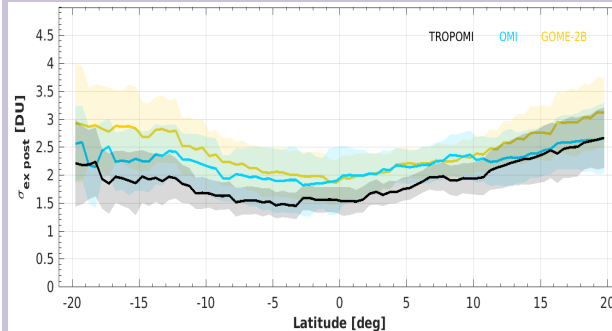
## Bias

- < 25% ? (systematic error mission requirement)
- Overall :
- Dependences SAT-to-SAT :
  - meridian :
  - zonal :
  - seasonal :



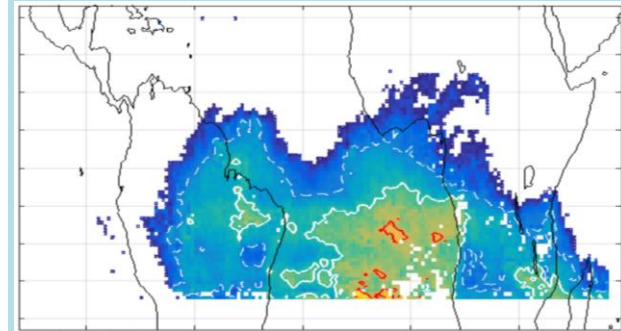
## Dispersion

- < 25 % ? (uncertainty mission requirement)
- From pairwise :
- From triplets :
- Dependences SAT-to-SAT:
  - meridian :
- Sampling error :



## Geophysical patterns & signals

- Zonal wave one ?
- Biomass burning season ?
- Annual + semi-annual cycles ?
- Madden-Julian Oscillation ?
- Other known features ?

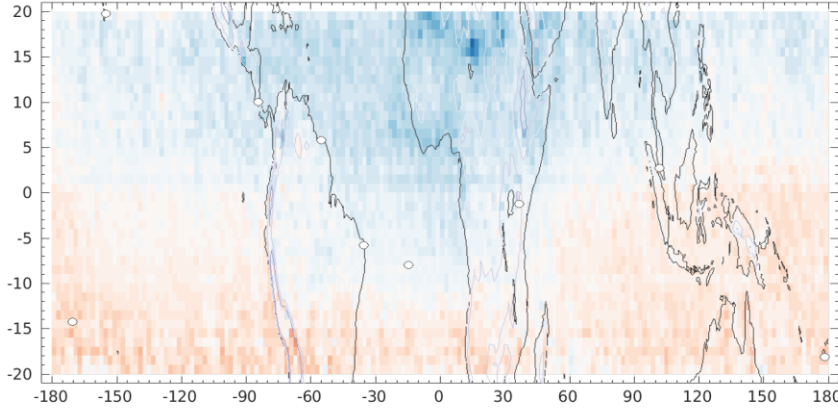


Bias vs sonde/satellite : 0.1-2.3 DU (<13%)

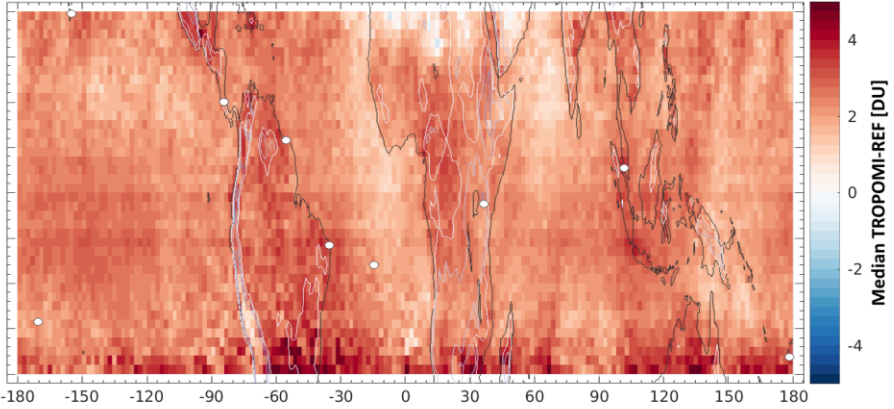
meets mission requirement (<25%)



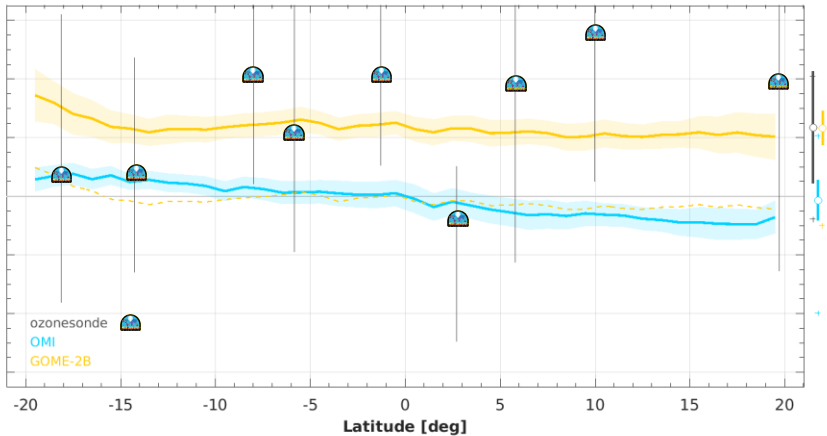
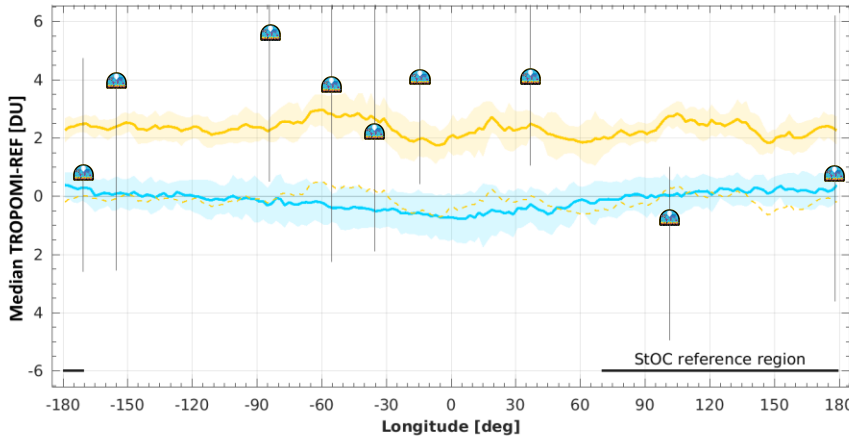
TROPOMI - OMI



TROPOMI - GOME-2B

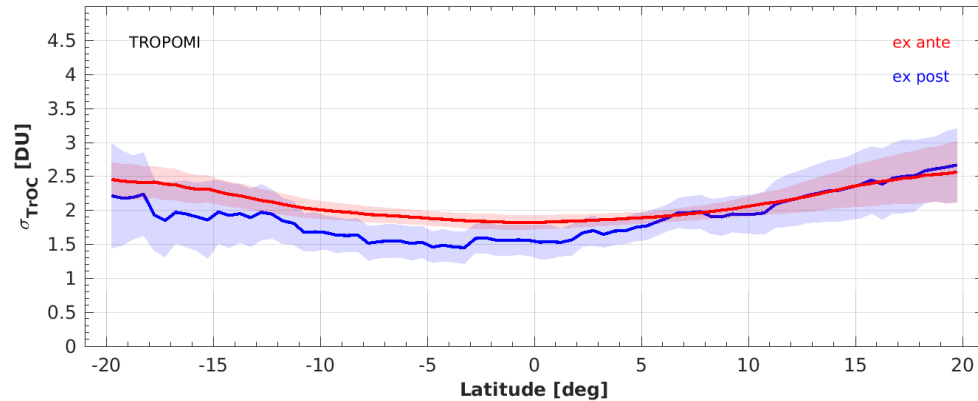
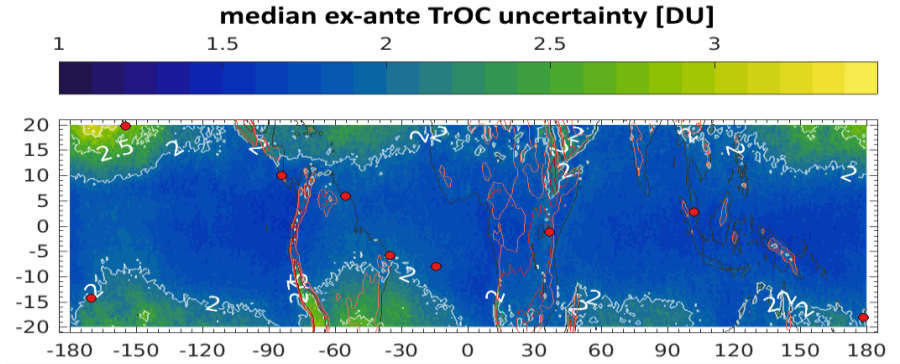
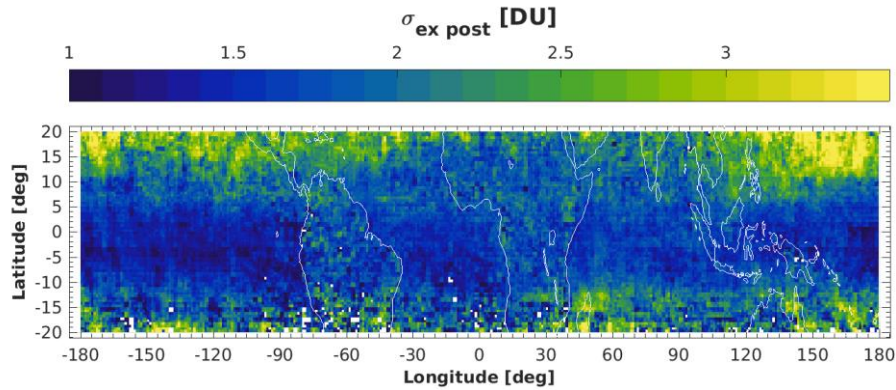


Median TROPOMI-REF [DU]

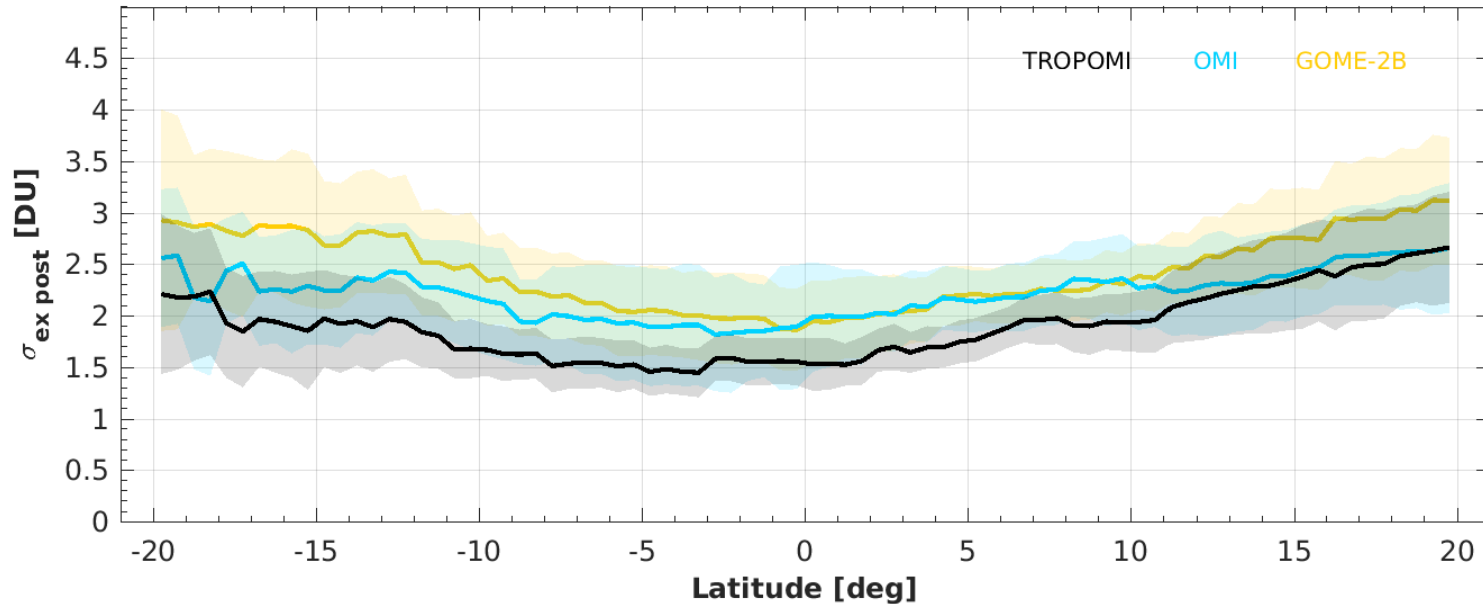


Uncertainty (dispersion): < 1.5-2.5 DU (8-13%)

meets mission requirement (<25%)



# Comparison to similar GOME-2B and OMI CCD data

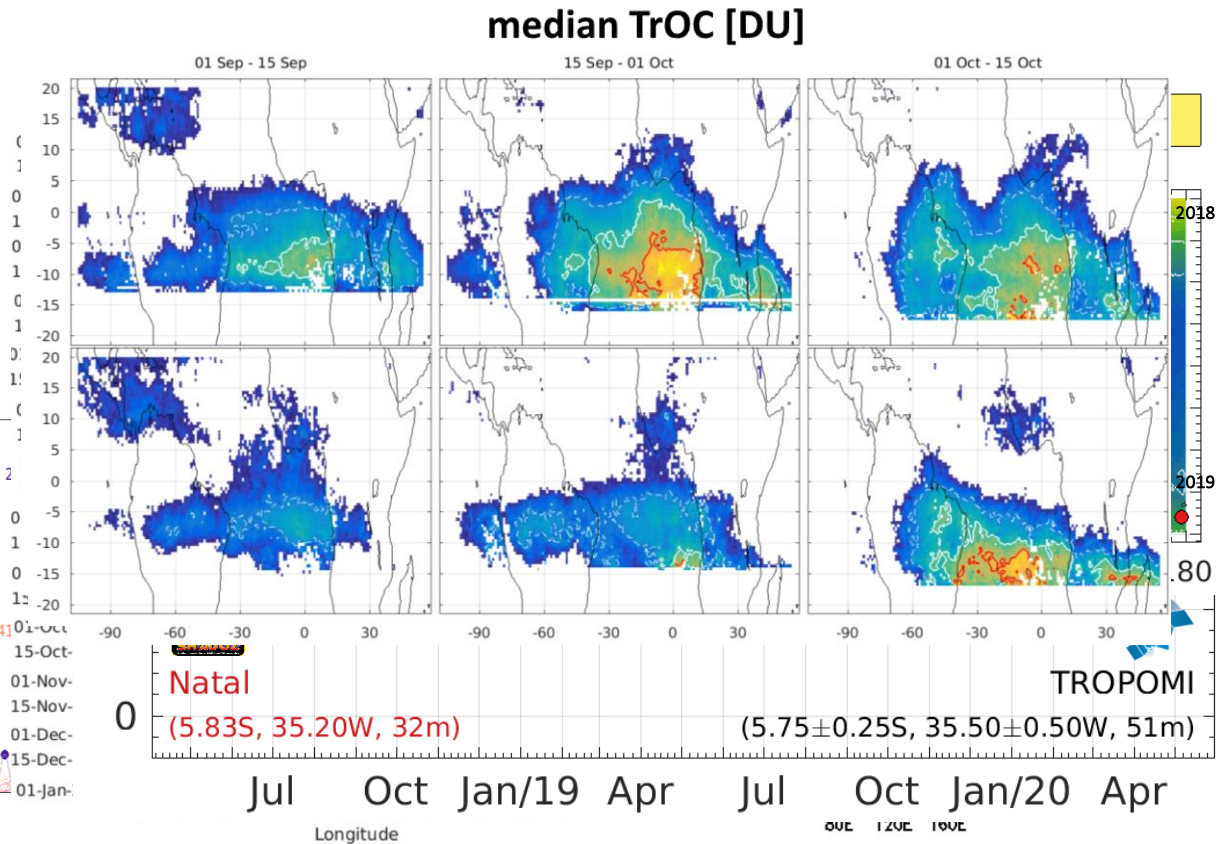
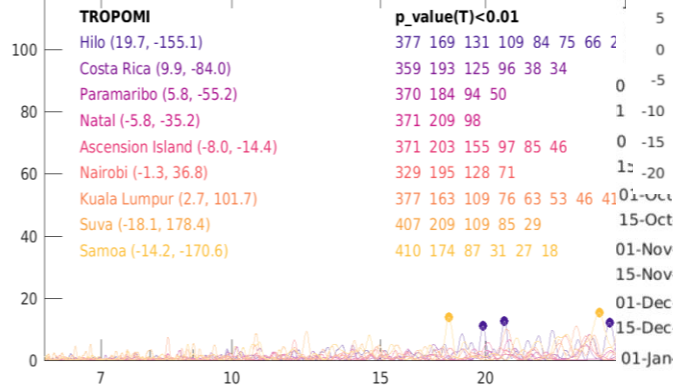


~20-25% better precision & 6x better sampling resolution

# How does TROPOMI capture known signals and patterns of tropical ozone ?



- ✓ Zonal wave one
- ✓ Biomass burning
- ✓ Annual & semi-annual cycles
- ✓ Madden-Julian Oscillation
- Higher-frequency signals reminiscent of Kelvin waves (?)



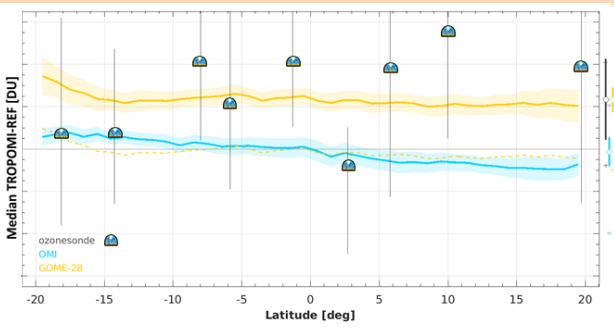


# Overview of S5P TROPOMI data quality

S5P data 2018/04-2020/04 processed at DLR with L2\_O3\_TCL OFFL processor v01.01.05-08

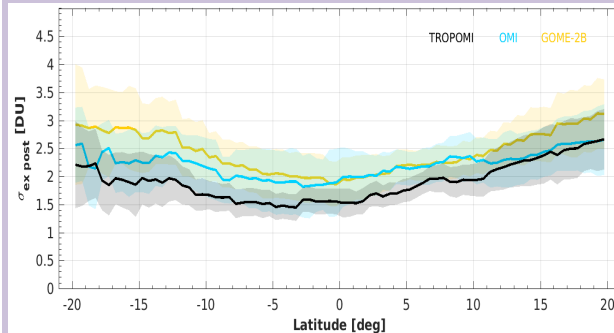
## Bias

- ✓ <25% (mission requirement on systematic error)
- Overall : -0.1 ... +2.3 DU or -0.3 ... +13 %
- Dependences SAT-to-SAT :
  - meridian : 0.3-1.1 DU
  - zonal : 0-1.0 DU
  - seasonal : 1.2-2.4 DU



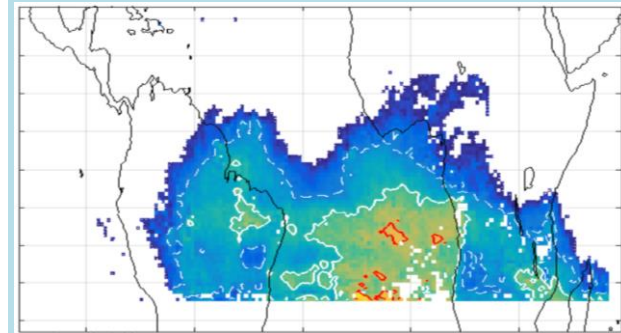
## Dispersion

- ✓ <25 % (mission requirement on uncertainty)
- From pairwise : 2.6-4.6 DU or 14-23 %
- From triplets : 1.5-2.5 DU or 8-13 %
- Dependences SAT-to-SAT:
  - meridian : 1.0 DU
- Sampling error : 1-5 DU



## Geophysical patterns & signals

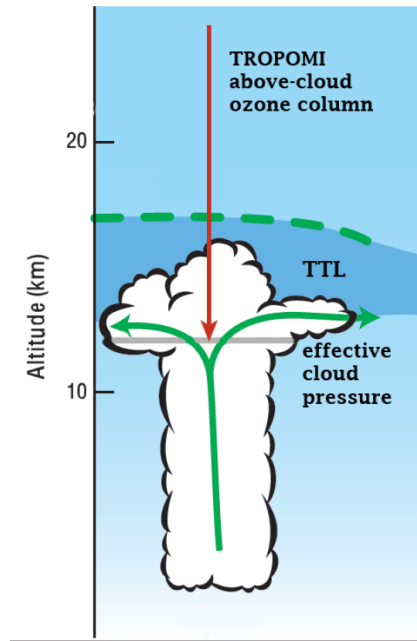
- ✓ Zonal wave one
- ✓ Biomass burning season
- ✓ Annual + semi-annual cycles
- ✓ Madden-Julian Oscillation
- ...



# Backup slides

# 5P TROPOMI tropical tropospheric ozone column product

- Convective Cloud Differential (CCD) technique using
  - TROPOMI total ozone column data (GODFIT v4)
  - TROPOMI cloud data (OCRA/ROCINN\_CRB)
- Represents
  - $O_3$  column surface-270 hPa
  - daily product,  $0.5^\circ \times 1^\circ$  between  $20^\circ S$ - $20^\circ N$
  - cloud-free 3-day moving average
- Processed at DLR with L2\_O3\_TCL OFFL processor v01.01.05-08
- Available operationally since 30 Apr 2018 on the Copernicus data hub: <https://scihub.copernicus.eu>



Atmos. Meas. Tech., 7, 2513–2526, 2014  
[www.atmos-meas-tech.net/2014/7/2513/](http://www.atmos-meas-tech.net/2014/7/2513/)  
 doi:10.5194/amt-7-2513-2014  
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Atmospheric Measurement Techniques

**Tropical tropospheric ozone column retrieval for GOME-2**  
 P. Valkó, N. Bal, A. Gansau Garcia, D. Loyola, M. Damiani, P. Richter, and A. Balogh<sup>1</sup>  
<sup>1</sup>Deutsches Zentrum für Luft- und Raumfahrt (DLR), German Aerospace Establishment, Oberpfaffenhofen, Germany  
<sup>2</sup>Centre for Global Ozone Monitoring (CGOM), Deutsche Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen, Germany  
<sup>3</sup>Royal Meteorological Institute of Belgium (RMI), Brussels, Belgium

Correspondence to: P. Valkó (peter.valko@dlr.de)

Received: 10 December 2013 / Published in Atmos. Meas. Tech. Discuss.: 28 January 2014  
 Revised: 15 June 2014 / Accepted: 17 June 2014 / Published: 14 August 2014

Abstract. This paper presents the operational retrieval of tropical tropospheric ozone column (TTCO) from the GOME-2 satellite. The retrieval is based on the CCD technique.

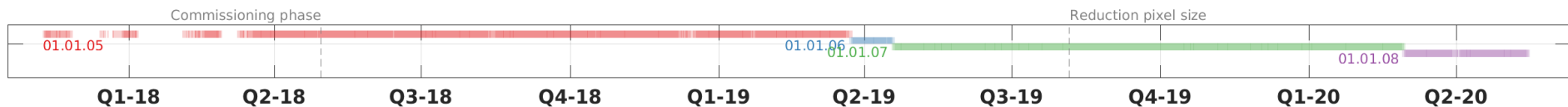
Atmos. Meas. Tech., 6, 5017–5041, 2016  
[www.atmos-meas-tech.net/2016/6/5017/](http://www.atmos-meas-tech.net/2016/6/5017/)  
 doi:10.5194/amt-6-5017-2016  
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Atmospheric Measurement Techniques

**Trends of tropical tropospheric ozone from 20 years of European satellite measurements and perspectives for the Sentinel-5 Precursor**  
 Klaus-Peter Han, Melissa Ockwazy-Egberts, Andy Delvaux, Christophe Leroy, Diego Loyola, Peter Valkó, and Michel Van Roozendael<sup>1</sup>  
<sup>1</sup>Deutsches Zentrum für Luft- und Raumfahrt, München, 80, 82234 Oberpfaffenhofen, Germany  
 Royal Meteorological Institute, Avenue Circulaire 1, 1180 Brussels, Belgium  
 Royal Belgian Institute for Space Aeronomy, Ringlaan 1, 1180 Brussels, Belgium

Correspondence to: Klaus-Peter Han (klaus.peter.han@dlr.de)

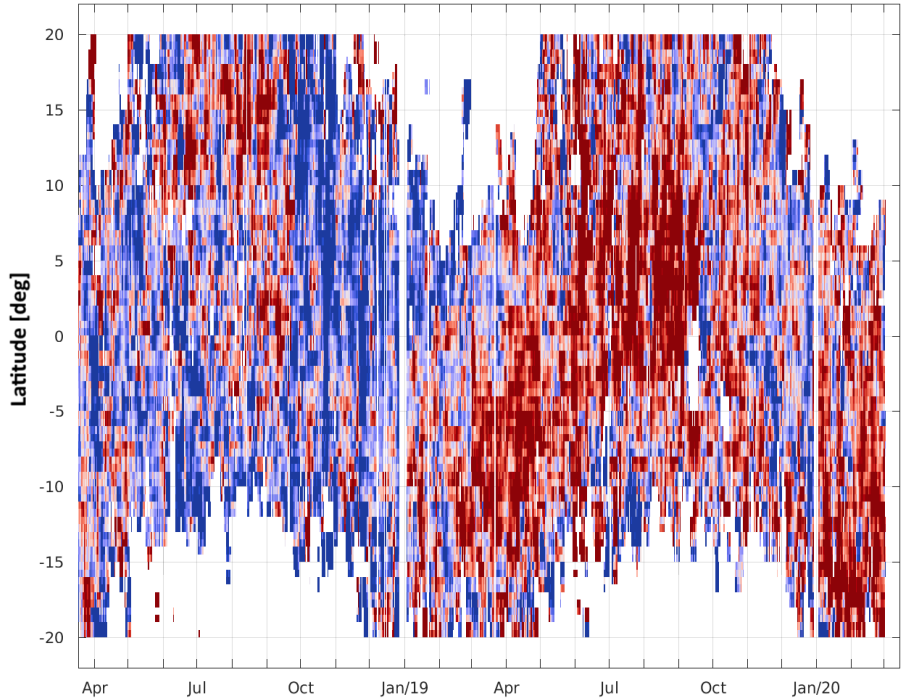
Received: 21 April 2016 / Published in Atmos. Meas. Tech. Discuss.: 3 June 2016  
 Revised: 22 September 2016 / Accepted: 23 September 2016 / Published: 13 October 2016



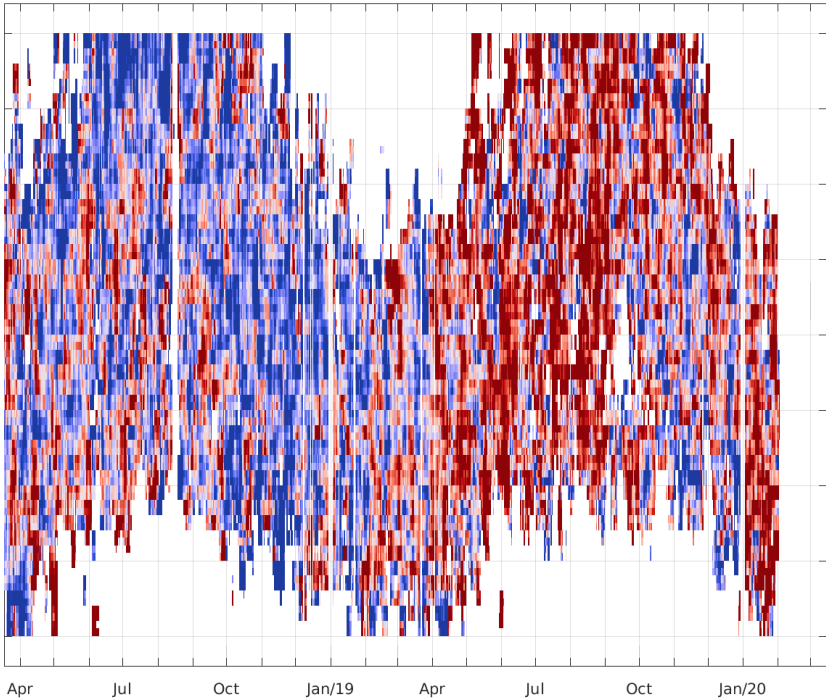
# Bias between satellites: Early signs of a seasonal pattern



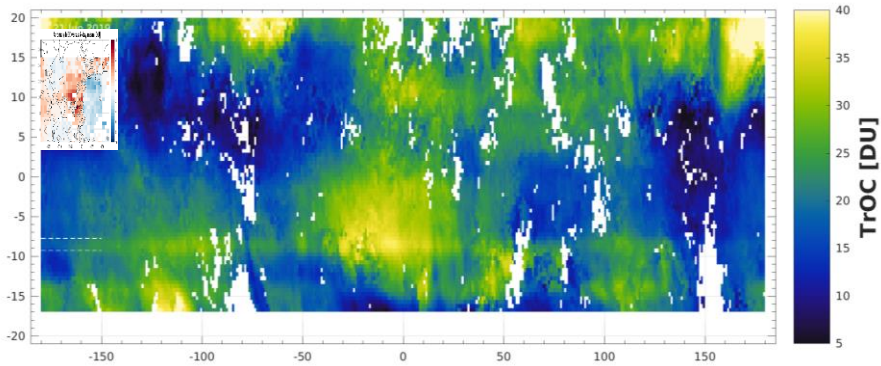
TROPOMI - OMI



TROPOMI - GOME2B



# Random sampling errors : 1-5 DU



1. Striping up to  $\sim 0.5$ -1 DU due to sampling error for stratospheric reference column

2. Correlated small-scale anomalies of up to 5 DU due to sampling error for total column

**Anomaly TrOC versus 7-day mean [DU]**

