



Status of the Sentinel-5 Precursor Mission and Cal/Val lessons learned

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This presentation includes modified Copernicus data (2017-2019)

Sentinel-5 Precursor mission operations → in operations since April 2018 and in routine operations since March 2019

Methane (CH_4) – 01 March 2019

Tropospheric Ozone Column (trop. O_3)

Sulfur Dioxide (SO_2)

Formaldehyde (OCHO)

Total Columns of Ozone (O_3)

Nitrogen Dioxide (NO_2)

Carbon Monoxide (CO)

Cloud information

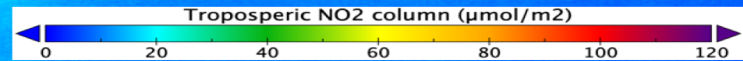
Aerosol information

Radiances/Irradiances – 10 July 2018

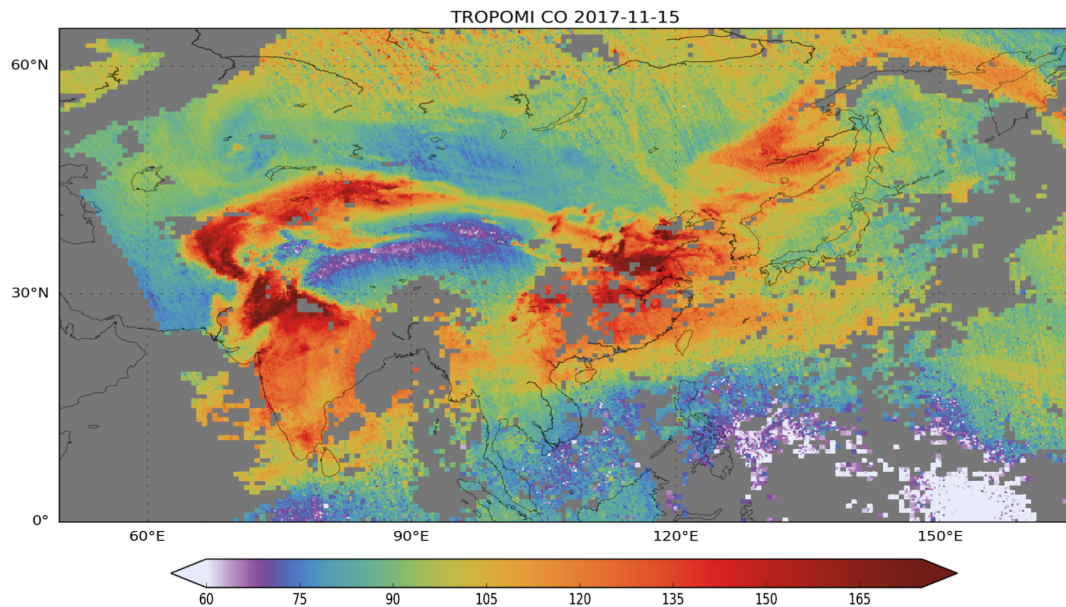
Sentinel-5P TROPOMI

first yearly average NO_2 map
April 2018 – April 2019

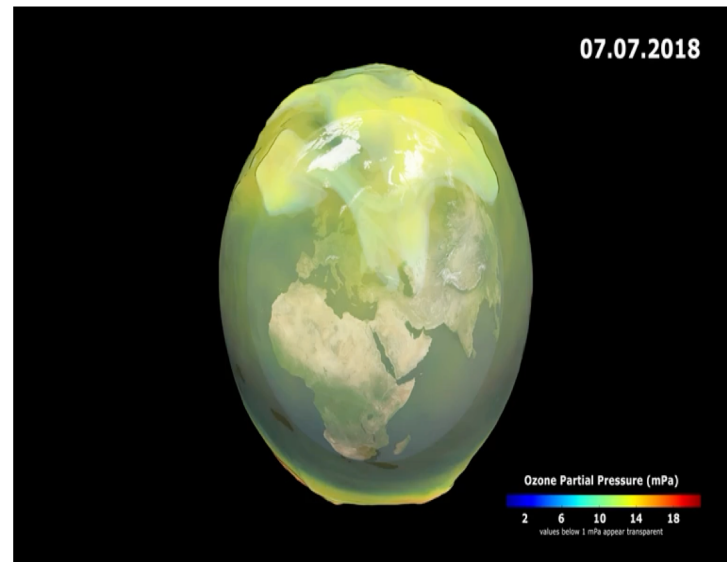
Copyright: Contains modified Copernicus Sentinel data (2018-2019) / processed by KNMI



http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-5P/Copernicus_Sentinel-5P_releases_first_data

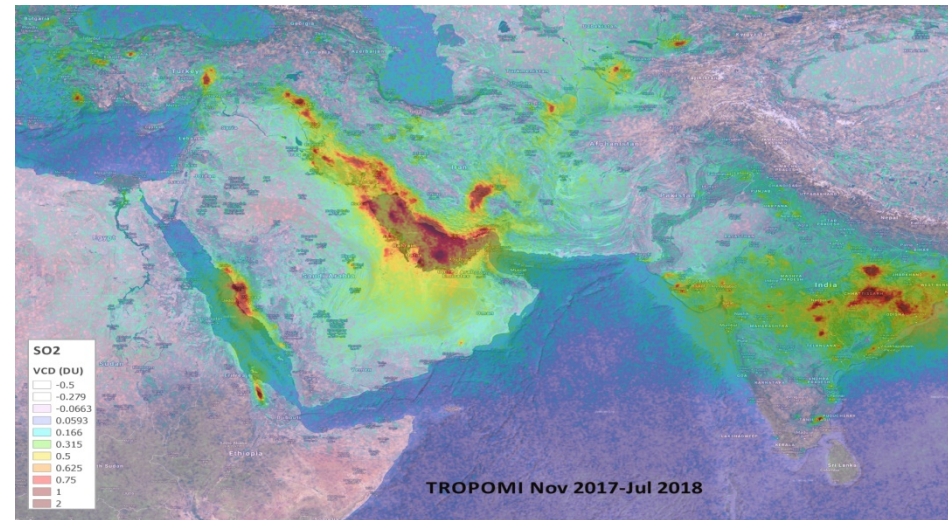
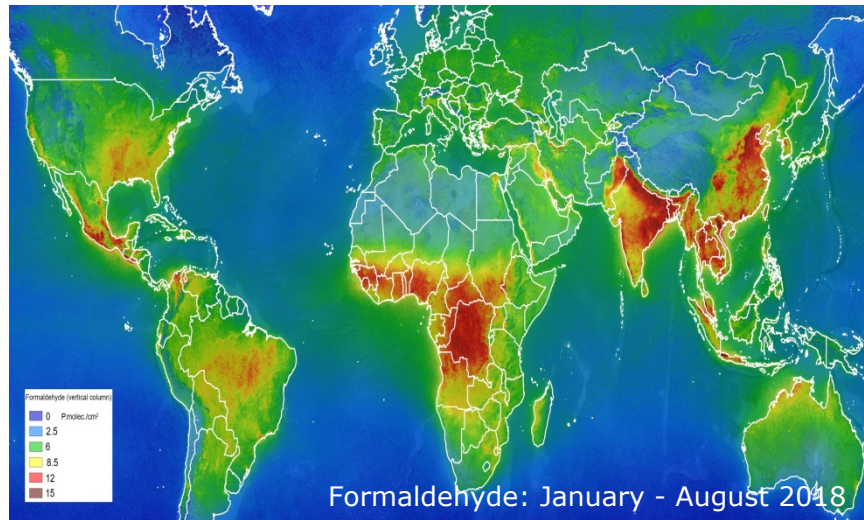


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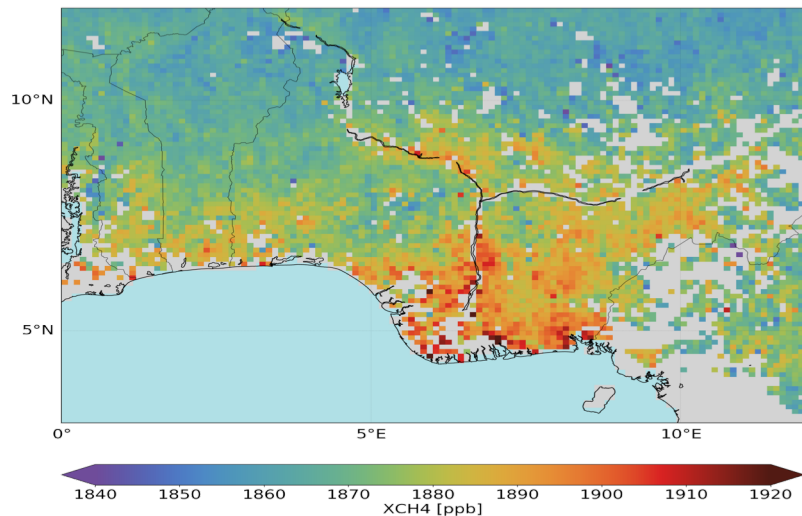


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http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-5P/Copernicus_Sentinel-5P_reveals_new_nasties

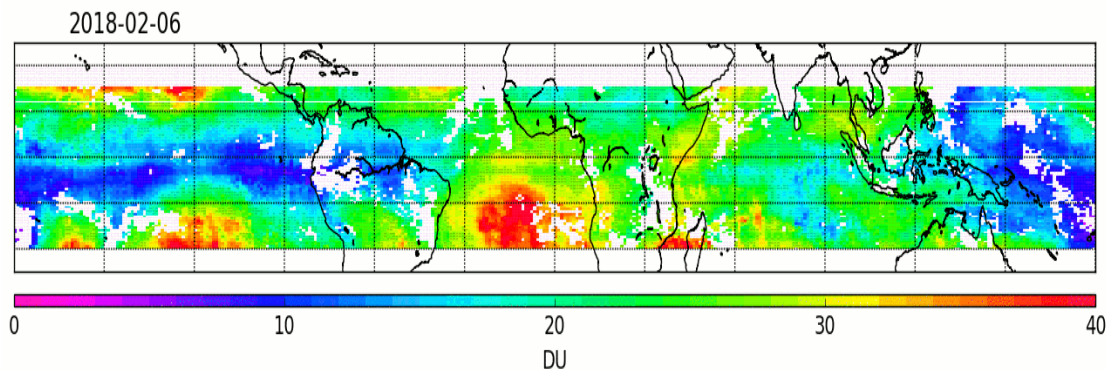


http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-5P/Methane_and_ozone_data_products_from_Copernicus_Sentinel-5P



Methane over wetlands in Nigeria between November 2018 and February 2019

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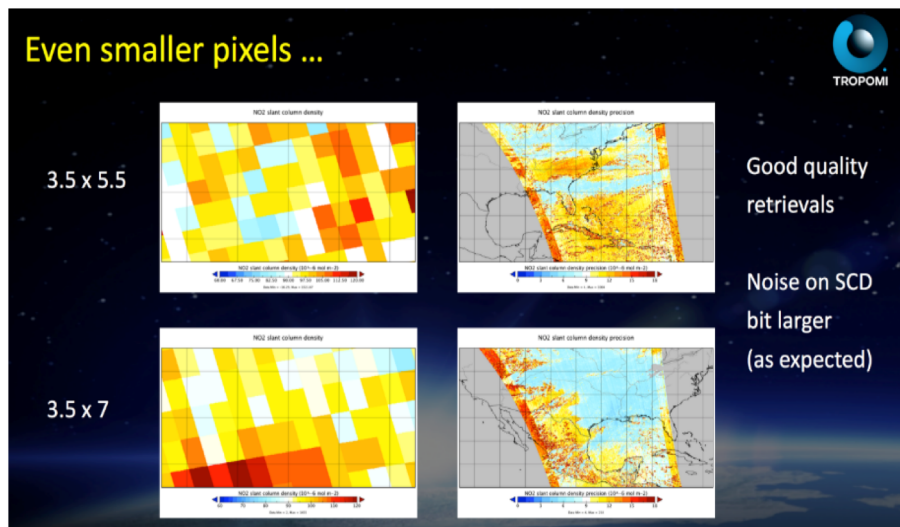


Tropospheric Ozone Columns

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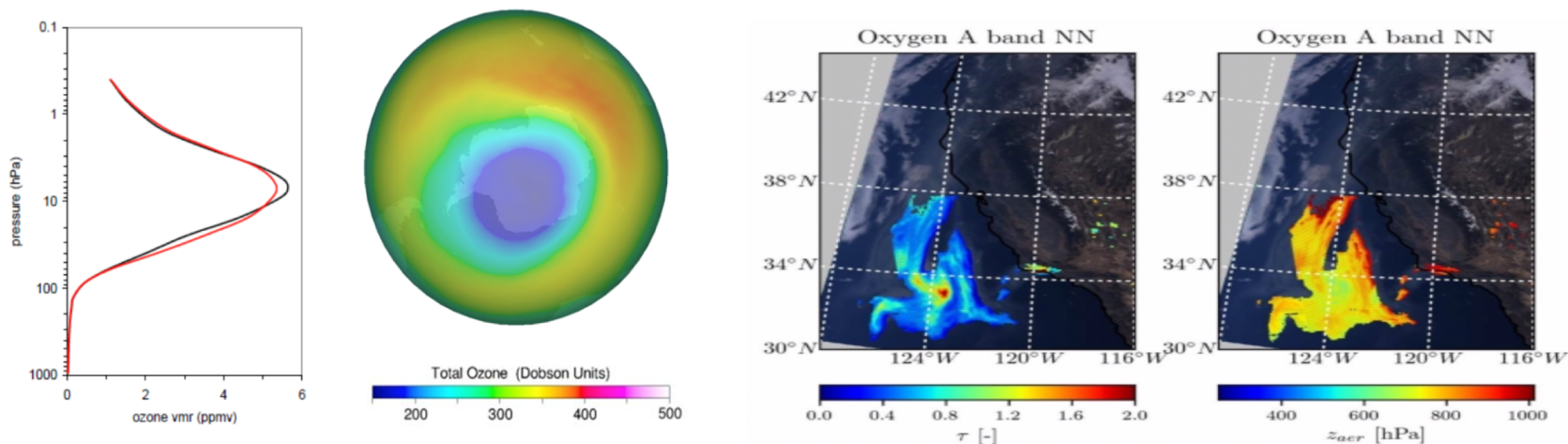
- **Towards an improved spatial sampling:**

- ✓ Change of TROPOMI operations for reduced along-track spatial sampling (5.5 km instead of 7 km) during mid 2019 to reduce occurrences of saturated pixels over the tropics for high clouds in the VIS and NIR wavelength range.
- ✓ Planned mid July 2019



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Ozone Profiles (end 2019) and Aerosol Layer Height (mid 2019)

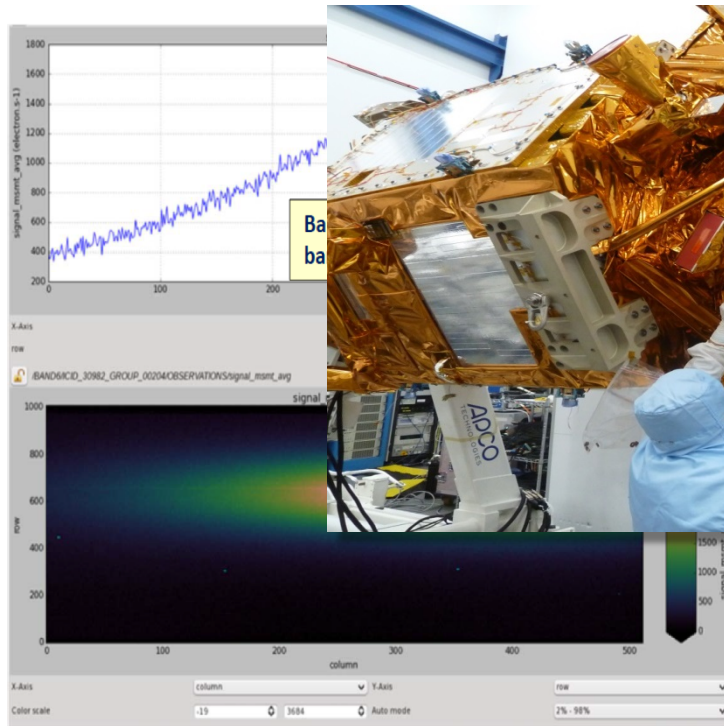


The Ozone Profiles release can only be done after an L1 product change

- Most products have been provided to the public (2 missing)
- The Aerosol Layer Height product to be released during this summer
- The Ozone Profile product to be released by the end of this year/early next year
- Overall product quality is already good but improvements are planned (e.g. use better surface reflectance (ozone NRT products), bias in SO₂ slant columns)
- First TROPOMI operations change is planned early August (improved spatial resolution – 20% more science data) – original Requirement: 7 x 7 km² – 5.5 x 3.5 km²
- Prototype development on 10 new possible products is starting (e.g. H₂O, BrO, SIF, AOD)

Importance of the pre-flight calibration campaign!

- unexpected response observed in pre-launch calibration measurements;
→ NIR channel (661 – 786 nm)
- origin & magnitude of effect initially unclear
- analyses of spectral filters & light sources revealed signals originated by emissions at wavelengths > 800 nm



Pre-flight calibration problem (straylight in the NIR) solved during time period of the launch delay – Dec. 16/Jan. 17 at Airbus D&S / UK

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Funding: EC/ESA + national NL/NSO, D/DLR, BE/BELSP0



Norsk institutt for luftforskning
Norwegian Institute for Air Research



Objectives + Responsibilities

Routine Quality Control

Level 1 and Level 2

Long-Term Monitoring

TROPOMI instrument sensor and ageing

In-flight calibration

TROPOMI instrument on-board S5P – meet product quality requirements

Geophysical Validation of Products

Using external and independent data sets on a routine basis

Maintenance and evolution

Manage the updates of:

- Calibration algorithms and tools
- L1 and L2 Processor algorithms
- Quality control tools
- Validation algorithms

Communication

S5P/TROPOMI status and products

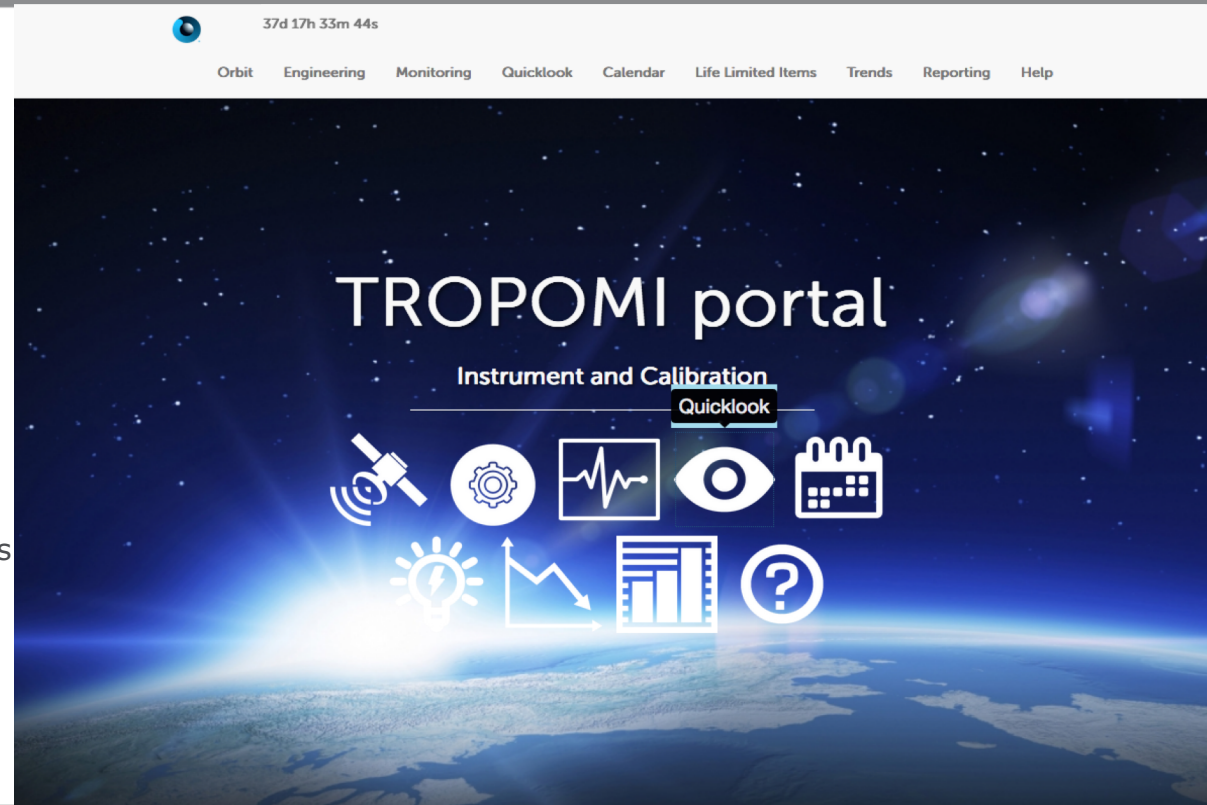
Mission Performance Centre: operational Cal/Val









Dedicated web portal

<http://www.tropomi.eu>

- Automated extraction of L1 + L2 and calibration information
- Orbital information
- Engineering data information
- Calendar – events/anomalies/
- Measurement calendar/processing statistics
- Weekly/monthly reporting
- etc ...

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Parameter	Data Product	Vertical Resolution	Accuracy	Precision
Ozone 	Ozone Profile	6 km	10-30%	10%
	Total Ozone	total column	3.5-5%	1.6-2.5%
	Tropospheric Ozone	trop column	25%	25%
NO ₂ 	Stratospheric NO ₂	strat column	<10%	0.5e15
	Tropospheric NO ₂	trop column	25-50%	0.7e15
SO ₂ 	SO ₂ enhanced	total column	30%	0.15-0.3 (0.06-0.12) DU
	Total SO ₂	total column	30-50%	1-3 (0.4-1.2) DU
Formaldehyde 	Total HCHO	total column	40-80%	1.2e16 (4e15)
CO 	Total CO	total column	15%	<10%
Methane 	Total CH ₄	total column	1.5%	1%
Cloud 	Cloud Fraction	total column	<20%	0.05
	Albedo (Optical Thickness)	total column	<20%	0.05 (10)
	Cloud Height (Pressure)	total column	<20%	<0.5 km (<30hPa)
	SNPP VIIRS Cloud data			
Aerosol 	Aerosol Layer Height	total column	<100hPa	<50hPa
	Aerosol Type	total column	~1 AAI	<0.1 AAI
Surface UV	Provided by FMI in frame of the Finnish Sentinel Collaborative Ground Segment			

SENTINEL VALIDATION TEAM : The validation team complete the MPC activities by providing independent validation measurements or independent analysis. The team members are selected through an open call process. The intention of this call is to create scientific validation teams to provide structured coordination of international activities that contribute to Sentinel validation across the entire mission (i.e. Phase E1 and E2).

The Mission Performance Center

The Mission Performance Center is in charge of the **operational** and **overall validation** providing the synthesis of the results.

MPC S1, MPC S2, MPC S3, MPC S5P
have been set up.

**Quality Working
Group
QWG**

**ESA Data
Quality
Manager**

The information is then discussed, further processed in the **Quality Working Groups** which provide synthetic results to the **Mission Managers**, used for improving the products quality and the products knowledge.

The Sentinel Validation Teams (SVT):

The validation team complete the MPC activities by providing independent validation measurements or independent analysis.

S2VT, S3VT, S5PVT have been set up.

Fiducial Reference Measurements providers

Specific activities need to be put in place for providing mandatory FRMs (e.g. for **atmospheric FRMs**: PANDONIA/PGN, FRM4DOAS, FRM4GHG)

User Community and international forum:

The validation program benefits from the feedback from:

- Workshops/conferences (ESA or international)
- Bilateral relation (NASA, NOAA, CNES, DLR, UKSA, JRC, EUMETSAT etc.)
- Coordination within **CEOS WGCV** and **CEOS VCs**

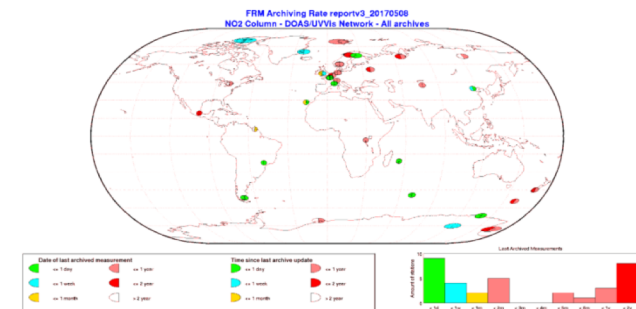
S5P Mission Performance Center: Routine Operations Geophysical Validation

-> Validation Data Analysis Facility (VDAF)
tool specifically developed within the MPC for S5P
<http://mpc-vdaf.tropomi.eu>

- Based on Fiducial Reference Measurements (FRMs)
- Extract overpass information from Level 2 products
- Ingest the overpass files and FRMs into validation database
(→ S5P MPC, VDAF)
- Tools act on VDAF database to generate quality information:
 - Tables, plots
 - User queries and automated jobs
 - Dashboards and reports

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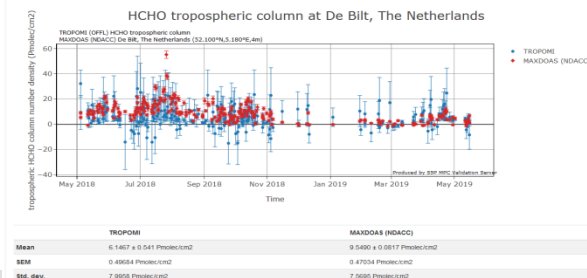
Monitoring of FRM streams



Traceable, automated comparisons

Comparison

Preliminary and unverified validation results, please visit the main S5P MPC validation website for consolidated results



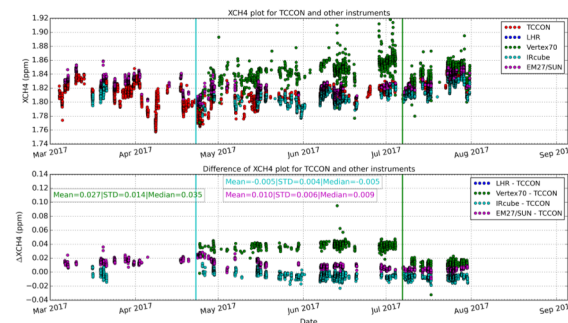
S5P Fiducial Reference Measurements

Required as input data sets for the MPC routine validation:

- ✓ FRM4DOAS <http://frm4doas.aeronomie.be>
 - Harmonization of retrievals from UV-Vis ground based spectrometers (e.g. MAXDOAS) and development of centralised processing system
 - Adopt FRMs standards for: tropospheric & stratospheric NO₂ vertical profiles, total O₃, & tropospheric formaldehyde profiles. The system can be extended for additional species (SO₂, CHOCHO, HONO, H₂O)
- ✓ FRM4GHG <http://frm4ghg.aeronomie.be>
 - Inter-comparison of ground based transportable FTIR systems with reference to TCCON as standard system
 - characterisation and harmonization of products of FTIR systems
 - Campaign in Sodankylä (Lapland) March – October 2017
 - Target Products: CO, CH₄



Source: BIRA

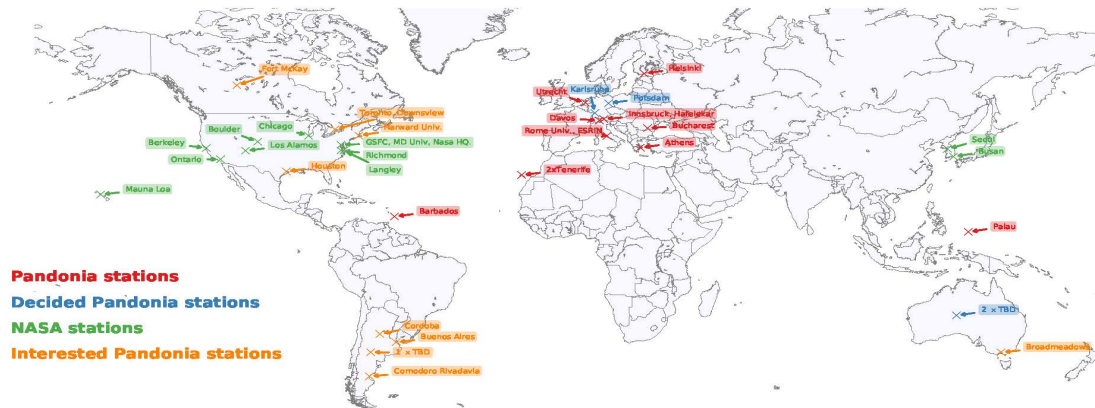


S5P Fiducial Reference Measurements

- ✓ Pandonia FRM <http://pandonia.net>
 - Ground-based remote sensing network using Pandora-2S and Pandora spectrometers
 - Target products, total & tropospheric column: O_3 , NO_2 ;
additional possible products: SO_2 , $HCHO$, H_2O ,
Spectral Aerosol Optical Depth (AOD),



Pandora/Pandonia Sites



Sentinel Validation Team - S5PVT:

AO call during fall 2014, to engage international experts for the Calibration & Validation of S5P:

- ✓ 55 Projects accepted
- ✓ S5P AO Call summaries of current proposals available:
<https://earth.esa.int/aos/S5PVT>
- ✓ S5PVT workshop planned during 11-14 Nov. 2019

**The AO call for
The Sentinel-5 Precursor
Validation Team is
permanently open**

<https://earth.esa.int/aos/S5PVT>

Official ESA repository for validation and campaign datasets, including FRMs
S5P MPC to access FRM and other validation data sets via the EVDC
S5PVT to upload AO validation data sets to the EVDC
New portal <https://evdc.esa.int> since August 2017 including new features:

- Overpass predictor and Orbit Tool;
- Satellite data sub-setting:
 - S5P, ADM-Aeolus
 - EarthCare in the future



- S5P **MPC** responsible for **operational calibration and geophysical validation**
- Fiducial Reference Measurements (**FRMs**) - FRM4DOAS, FRM4GHG, and Pandonia projects provide the basis for operational validation
- **EVDC** – ESA Atmospheric Composition Validation Data Center
- The independent S5P Validation Team **S5PVT** including the international community complements the MPC (science, products fit for purpose?)