OBSERVING
OUR FUTURE

TROPOMI on the Copernicus Sentinel 5 Precursor:
Ready for Launch

Pepijn Veefkind & the TROPOMI Team

Netherlands Space Office | esa | AIRBUS DEFENCE & SPACE | TNO innovation for life | SRON Netherlands Institute for Space Research | Koninklijk Nederlands Meteorologisch Instituut, Ministerie van Infrastructuur en Milieu

TROPOMI

Sentinel 5 precursor

COPERNICUS ATMOSPHERE MISSION IN POLAR ORBIT

TROPOMI

- The ESA Sentinel-5 Precursor (S-5P) is a pre-operational mission focusing on global observations of the atmospheric composition for air quality and climate.
- The TROPOspheric Monitoring Instrument (**TROPOMI**) is the payload of the S-5P mission and is jointly developed by The Netherlands and ESA.
- The planned launch date for S-5P is 2017 with a 7 year design lifetime.

TROPOMI

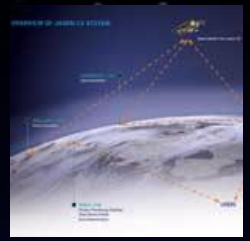
- UV-VIS-NIR-SWIR nadir view grating spectrometer.
- Spectral range: 270-500, 675-775, 2305-2385 nm
- Spectral Resolution: 0.25-0.5 nm
- Spatial Resolution: 7x7km2
- Global daily coverage at 13:30 local solar time.

Contribution to Copernicus

- Total column O_3, NO_2, CO, SO_2,CH_4, HCHO
- Tropospheric column O_3, NO_2
- O_3 profile
- UV Aerosol Index & Aerosol layer height
- Clouds

EU Copernicus Sentinels

Sentinel 5



Sentinel 6

Sentinel 1

Sentinel 2

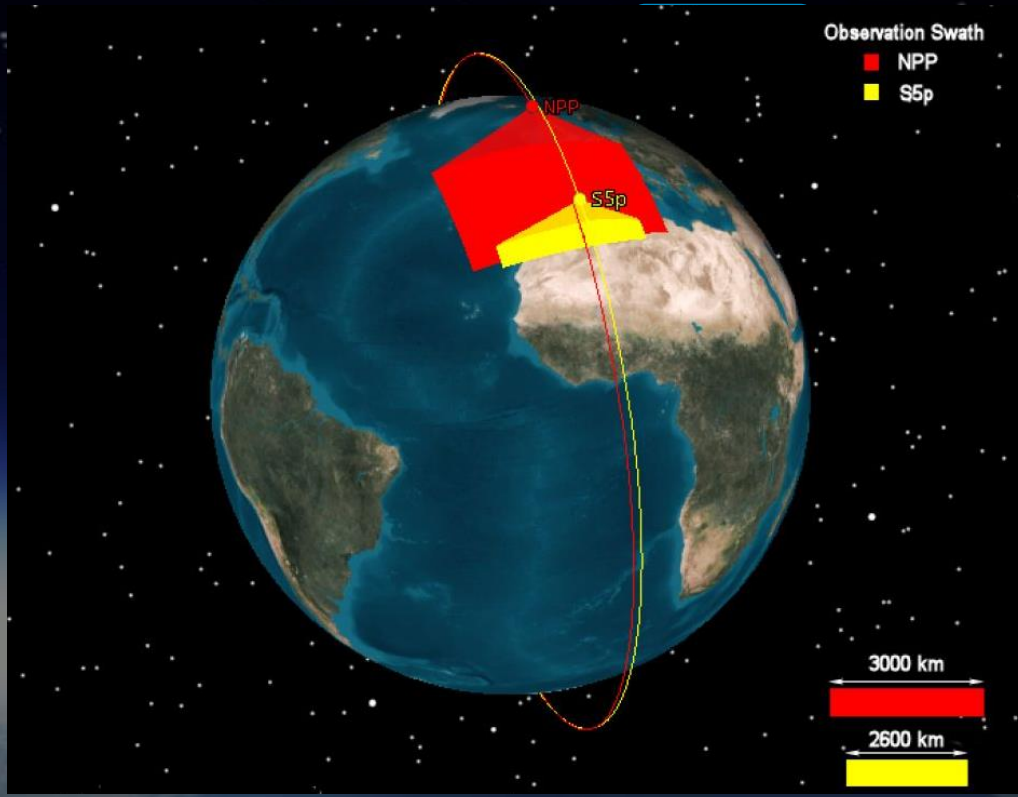
Sentinel 4

Sentinel 5P

Sentinel 3

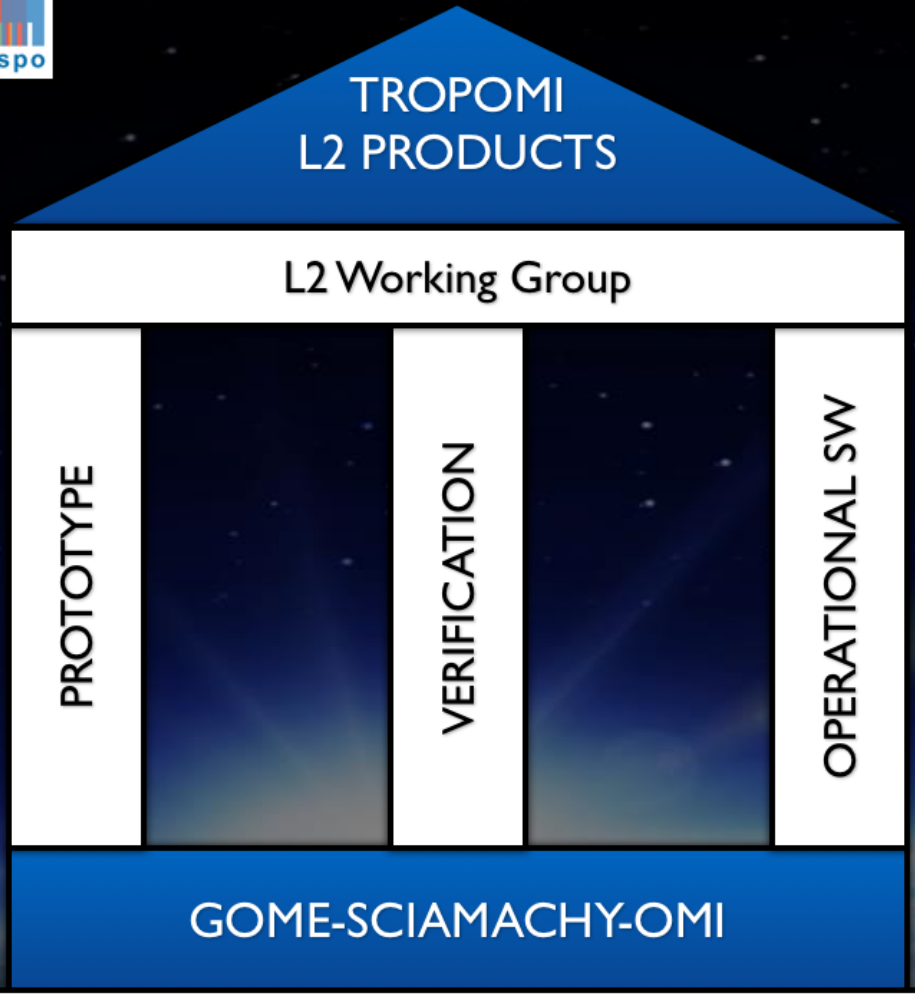
International Co-operation

- TROPOMI/S5P is part of the CEOS AQ Constellation
  - TROPOMI provides the global coverage
  - Act as a “travelling standard” between the GEOs
- S5P will fly in loose formation with Suomi NPP
  - Primary objective is to use the VIIRS data for cloud clearing



Level 2 Data Products

Product	Application
Ozone column	Ozone layer monitoring
Ozone profile, incl. troposphere	Ozone layer, Climate and Air quality monitoring
Ozone tropospheric column	Climate and Air quality monitoring
Nitrogen Dioxide	Air quality forecast / Emission monitoring
Formaldehyde	Air quality forecast / Emission monitoring
Sulphur Dioxide	Volcanic plume warnings / Emission monitoring
Methane	Climate and Air quality monitoring / Emission monitoring
Aerosol	Volcanic ash warnings / Climate monitoring
Carbon Monoxide	Air quality forecast / Emission monitoring
Cloud	Climate Monitoring
Surface UV index	UV Forecast
Solar irradiance	Climate monitoring

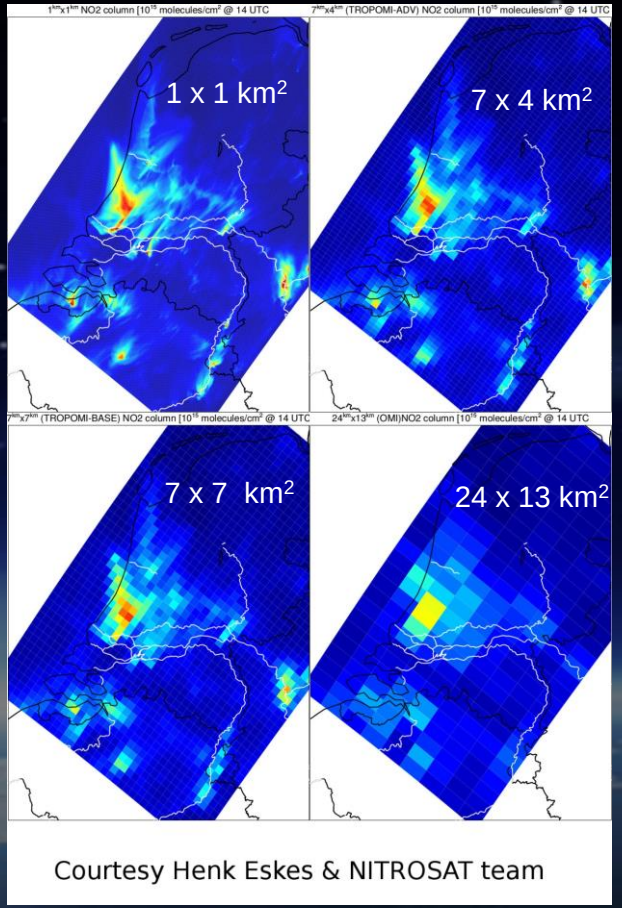


KNMI | DLR | IUP-Bremen | BIRA | SRON | MPIC | RAL | FMI

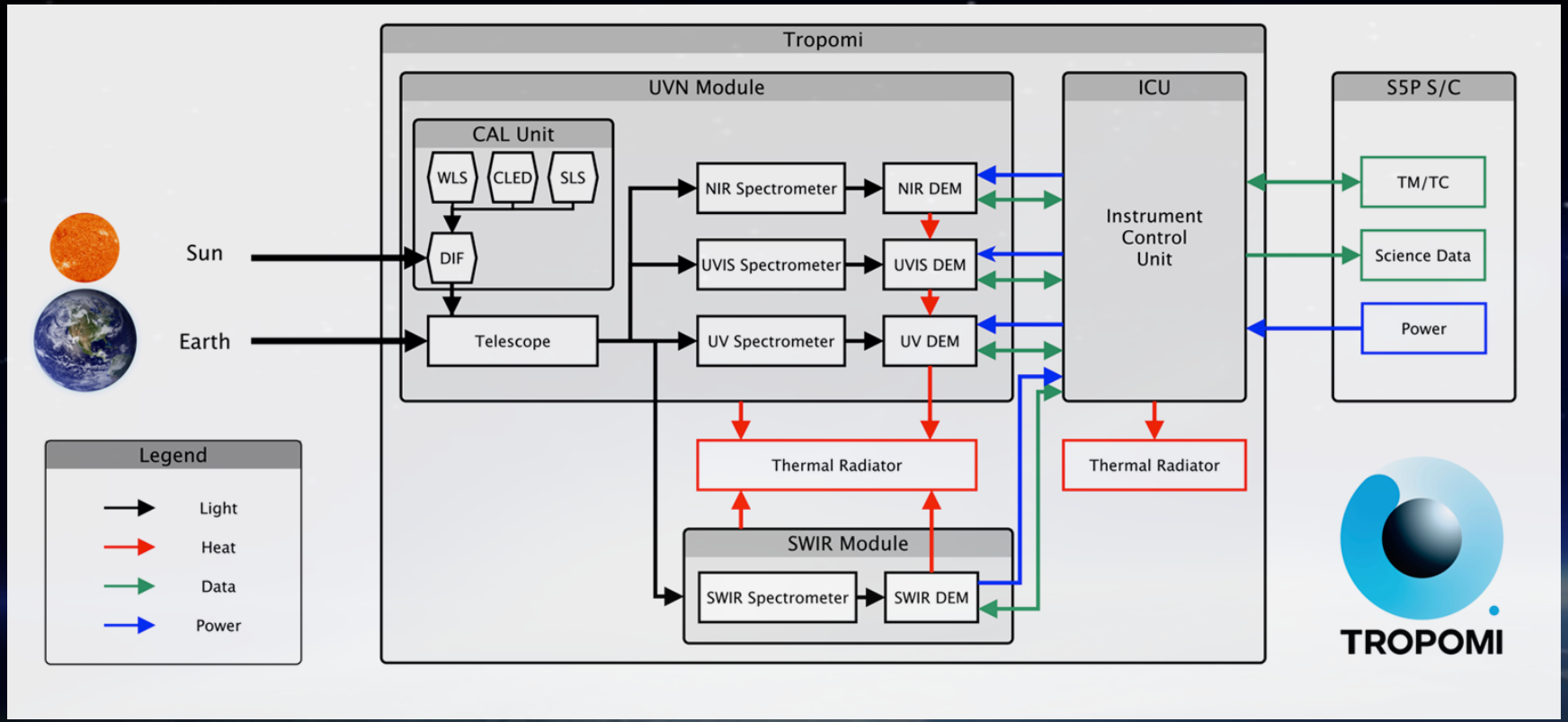
From OMI to TROPOMI

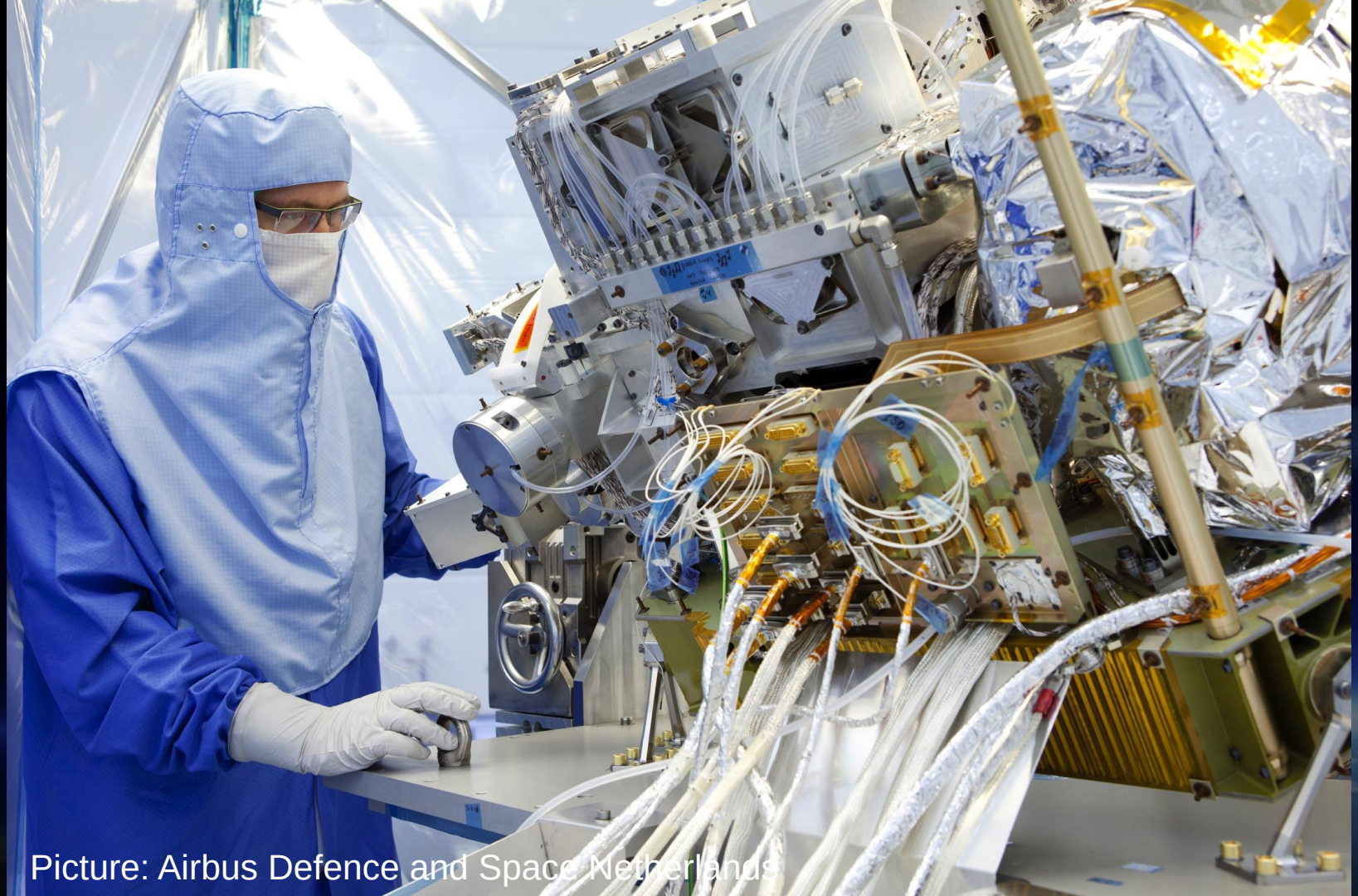
- **6x higher spatial resolution**
  7x7 km^2 vs. 13x24 km^2
- **1-5x higher signal-to-noise**
  per ground pixel
- **SWIR Band**
  CO and Methane
- **Better cloud information**
  oxygen A band added

- *Many lessons learned from 11 years of OMI data*



TROPOMI Functional Diagram





Picture: Airbus Defence and Space Netherlands

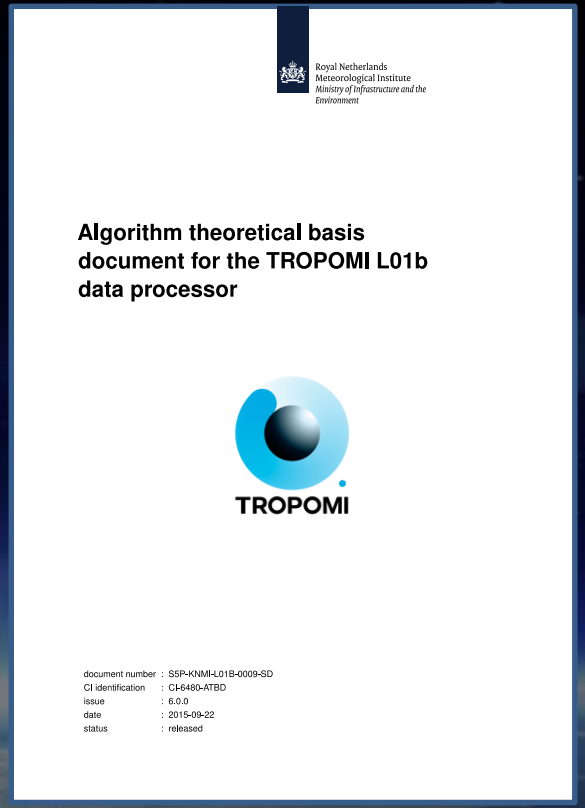
TROPOMI

TROPOMI	UV		UVIS		NIR		SWIR	
Band	1	2	3	4	5	6	7	8
Spectral coverage [nm]	270 – 320		320 – 495		675 - 775		2305 – 2385	
Full spectral coverage [nm]	267 - 332		303 - 499		660 - 784		2299 - 2390	
Spectral resolution [nm]	0.49		0.54		0.38		0.25	
Spectral sampling ratio	6.7		2.5		2.8		2.5	
Spatial sampling [km^2]	7 x 28	**7 x 3.5**					7 x 7	

TROPOMI

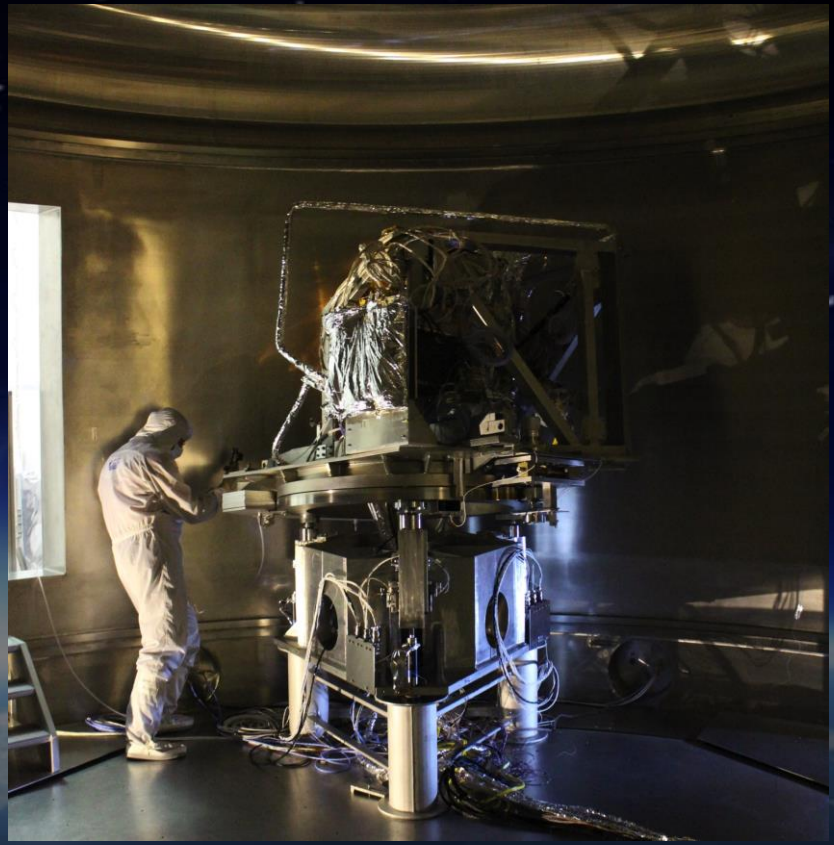
Level 0-1B Processor

- Multi-threading
- Multi-pass
- Algorithms are pluggable at run-time
- Full error propagation: noise + systematic errors
- L1B product ~35 Gbyte / 100 min
- S/W design can be re-used
- Level 0-1B Processor was used for the analysis of the on-ground calibration data



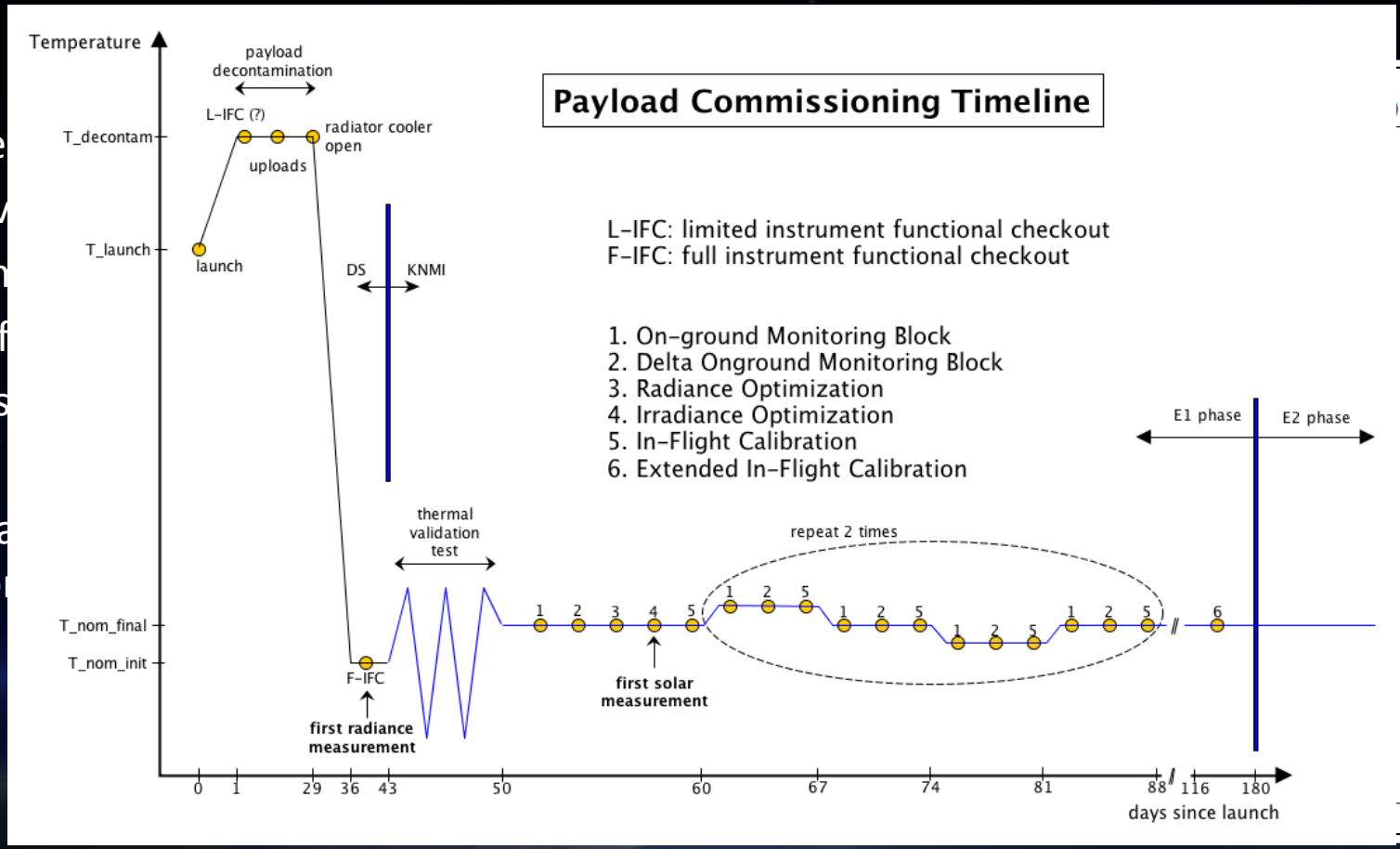
On-Ground Calibration

- All analyses finalized and key-data delivered.
- Delta investigations:
  - Re-calibration of OGSE for absolute radiometry
  - Investigations on out-of-spectral band stray light in the NIR spectrometer



Phase E1 Planning

- All the
  - Sev
  - Ten
  - In-f
  - Firs
- L2 E1 a
  the co



Scheduled (orbits/days)
45 / 3
390 / 26
0 / 0
0 / 0
30 / 2
90 / 6
30 / 2
0 / 0
0 / 0
0 / 0
0 / 0
0 / 0
0 / 0
0 / 0
0 / 0
0 / 0
405 / 27
150 / 10
405 / 27
14 / 0.933
0 / 0
45 / 3
0 / 0
15 / 1
3 / 0.2
1622 / 108

User Services

- Data dissemination
  - Near-Real-Time
  - offline data stream
- Data volume
  - Develop higher Level products (e.g. CAMS, GlobEmission)
  - Reliable and fast data access
  - Big data analyses and Cloud solutions
- Data Quality
  - Provide up-to-data information on the web
  - Routinely compare with ground based observations
- Standard data format
  - works with existing tools
  - ready for Sentinel 4 and 5

450	Per second
1,350,000	Per Orbit
19,575,000	Per day

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

Validation

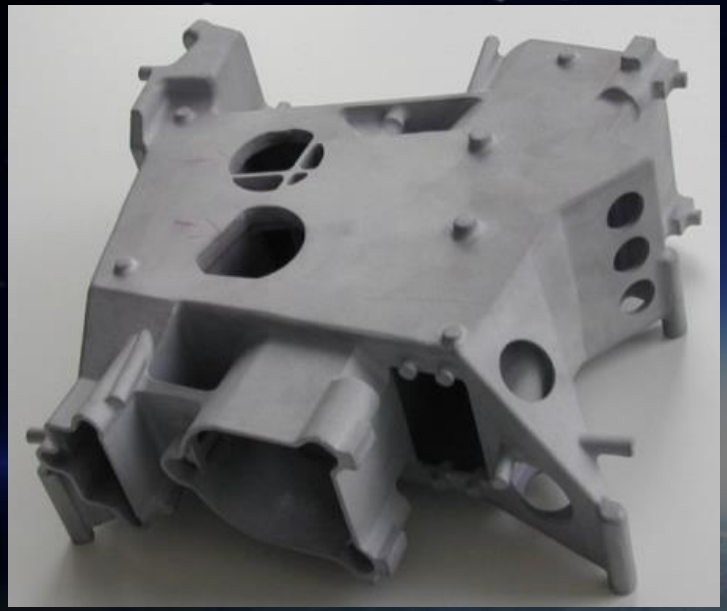
- The pre-launch CINDI-2 campaign organized in Cabauw, The Netherlands in September 2016, was very successful.
- ESA has organized 3 pre-launch campaigns in Romania and Germany.
- The community is involved in validation through the ESA Announcement of Opportunity.
- The preparation for the routine validation has started.

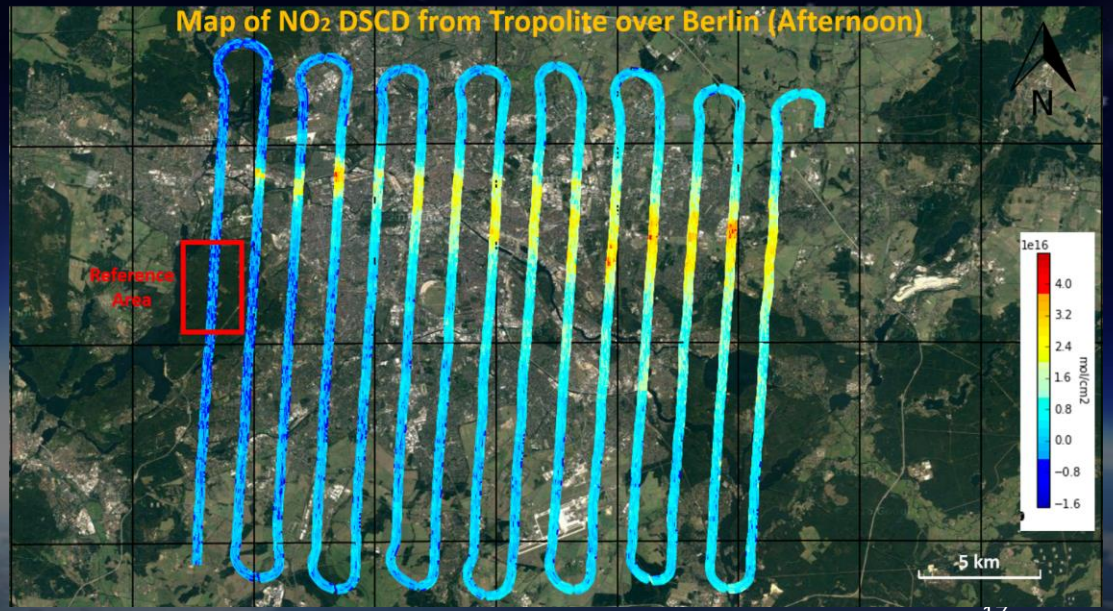
Arnoud Apituley, RIVM
Michel Van Roozendael, BIRA
Andreas Richter, IUP Bremen
Thomas Wagner, MPIC

4 Feb. 2016

Spectrolite | Tropolite

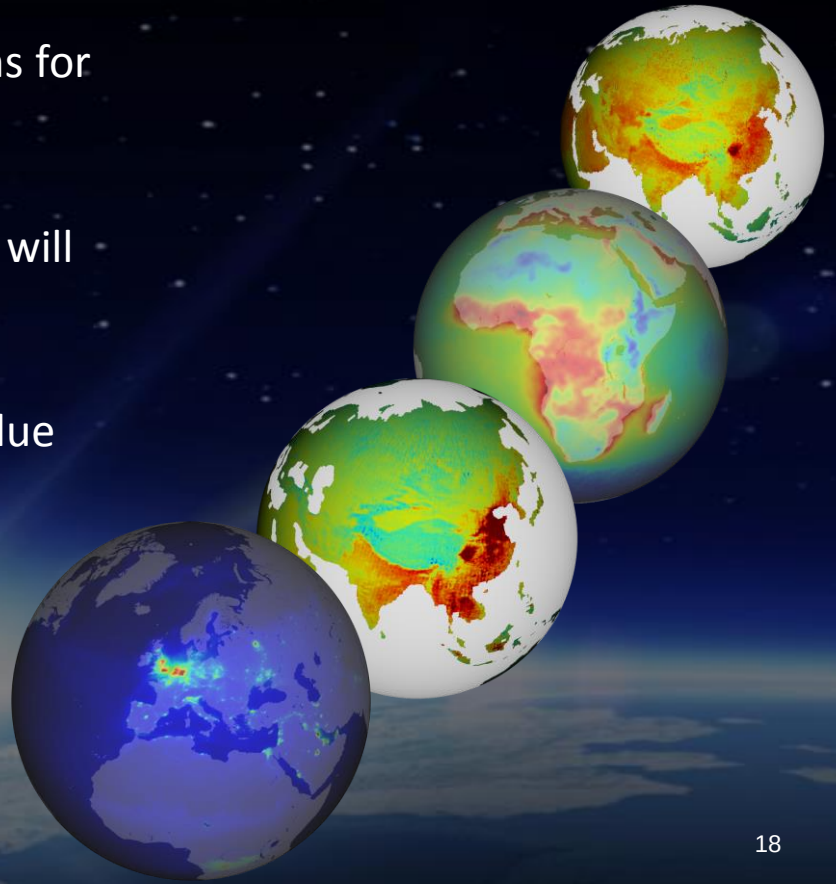
- Ambition: develop a instrument for micro or cubesat that can observe trace gases with a resolution of 1x1 km^2.



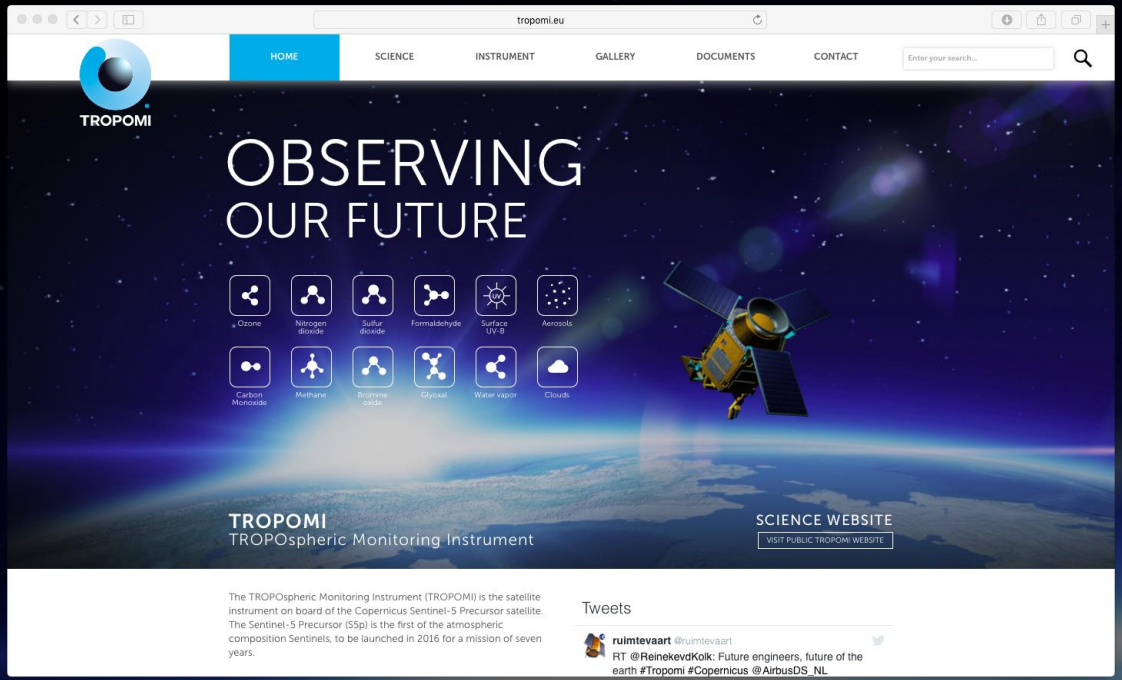


Summary & Conclusion

- TROPOMI data will contribute to applications for societal challenges on climate change, air quality and the ozone layer.
- Sentinel 5P operational: we expect that this will attract new users.
- TROPOMI will be a major step forward for atmospheric composition observations due to improved spatial resolution & sensitivity.
- The large data volumes are challenging for users and data providers.
- *We are counting down for a launch in 2017!*



More information



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www.tropomi.eu

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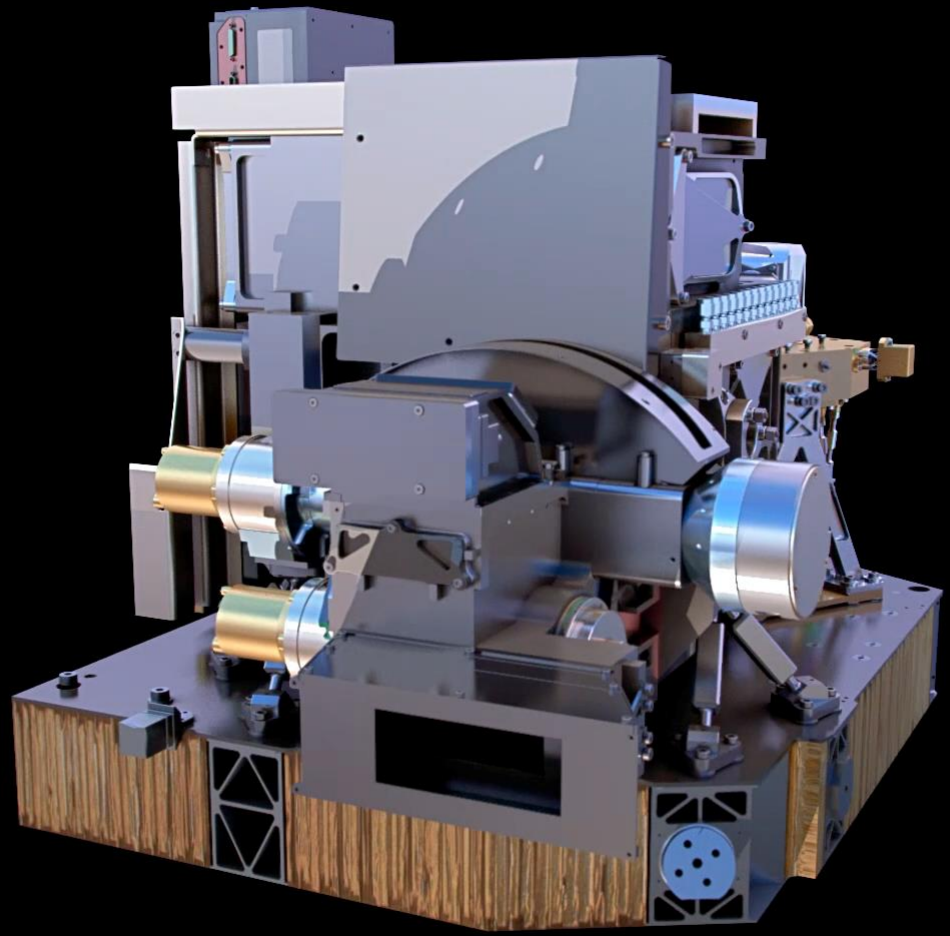
www.knmi.nl/omi

sentinel.esa.int/s5p

#tropomi_science



TROPOMI

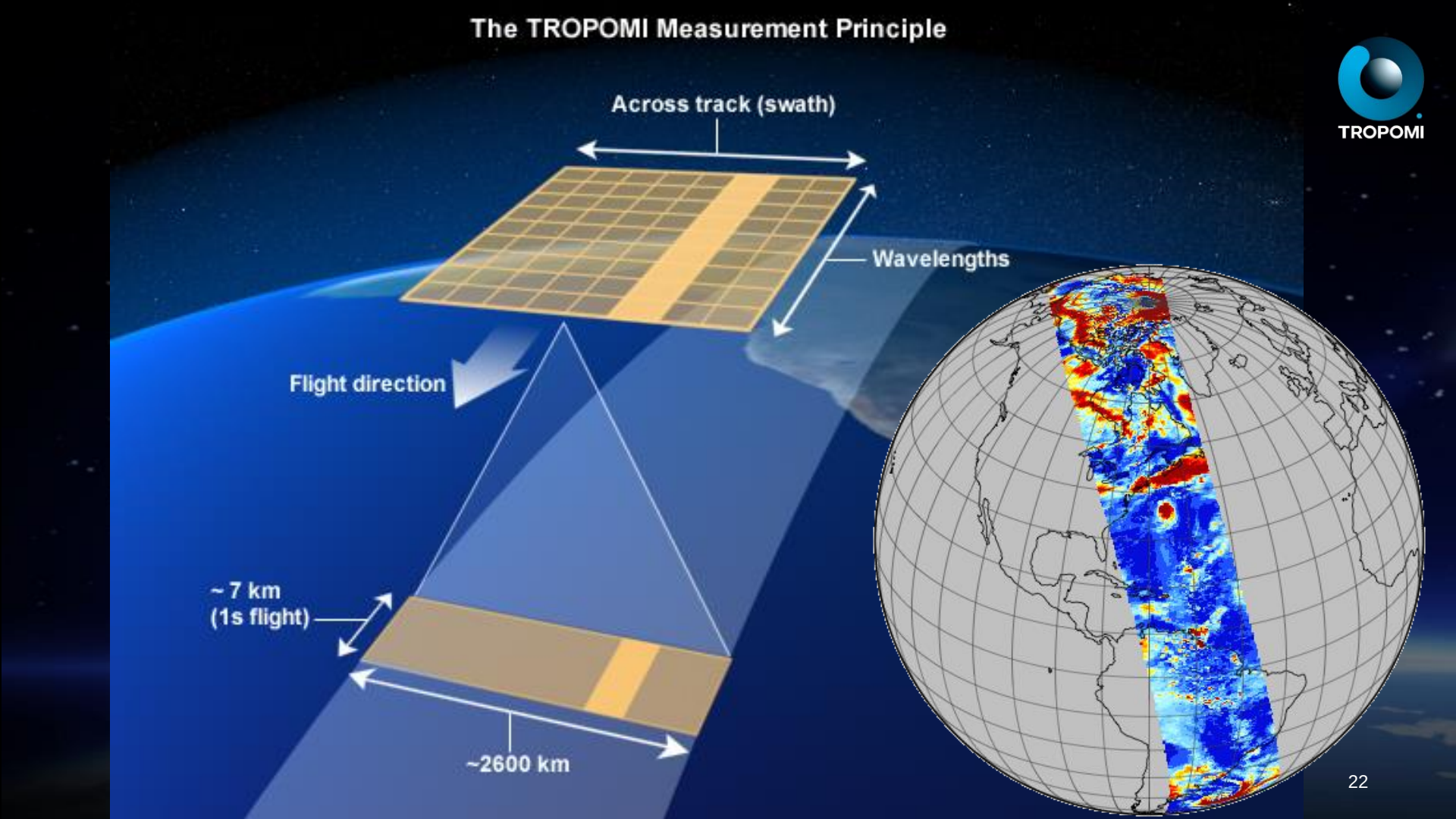
Netherlands Space Office

esa

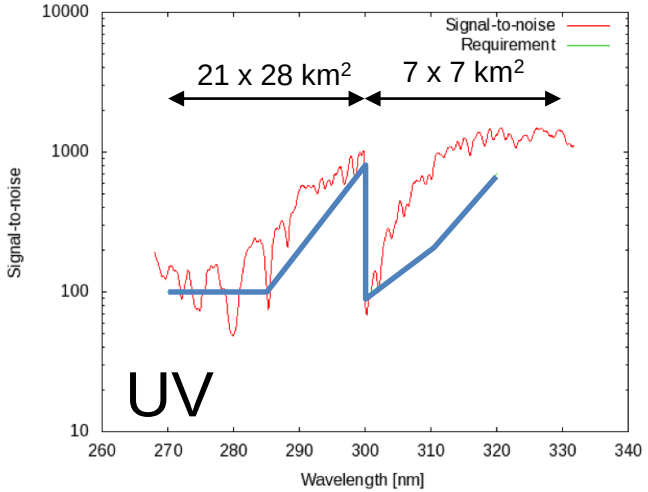
S5P Mission Performance Centre

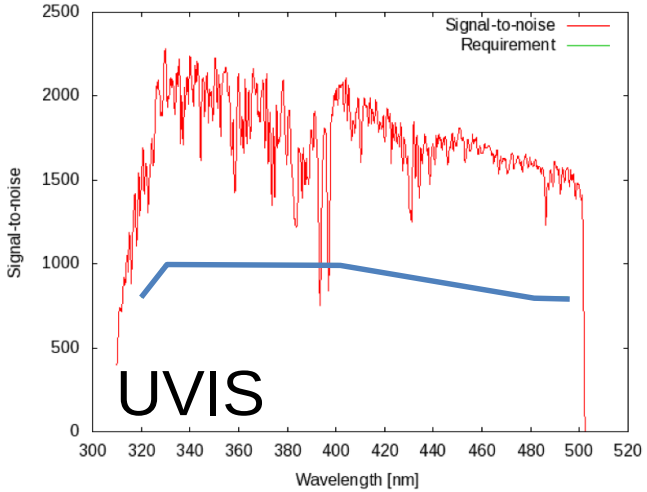
- S5P-MPC : is an operational service that includes
  - Quality control of L1B and L2 data products
  - In-orbit calibration of L1B data
  - Routine validation against operational networks
  - Algorithm evolutions and processor maintenance
  - User support

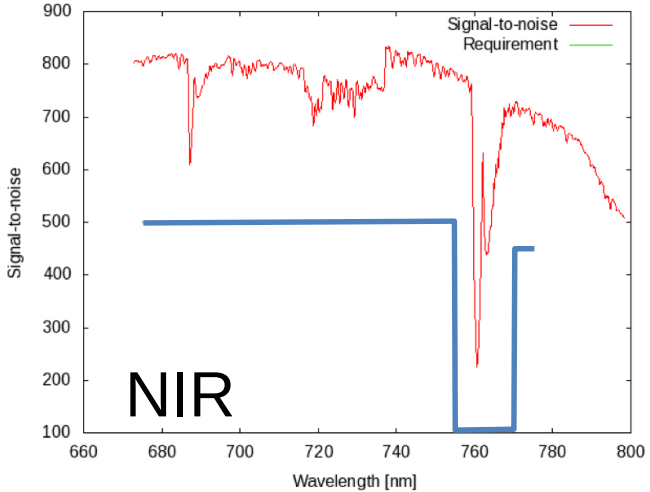
The TROPOMI Measurement Principle

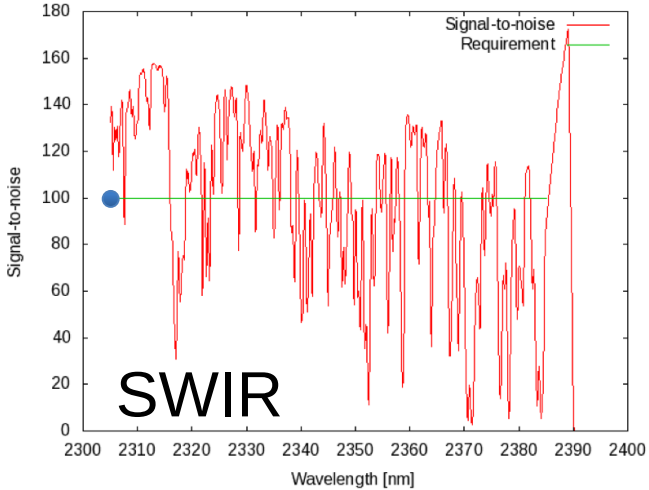


CAMS IN A NUTSHELL


Signal-to-noise
Requirement
21 x 28 km2
7 x 7 km2
UV
Signal-to-noise
Wavelength [nm]


Signal-to-noise
Requirement
UVIS
Signal-to-noise
Wavelength [nm]

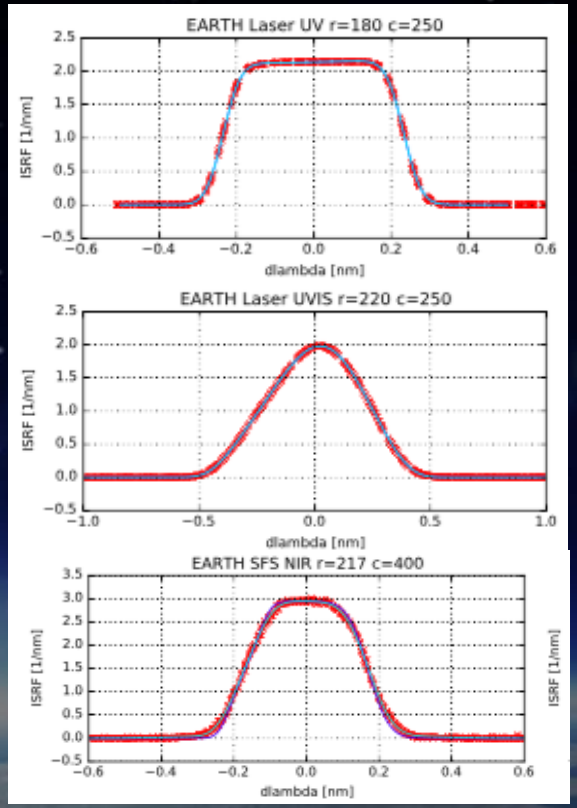

Signal-to-noise
Requirement
NIR
Signal-to-noise
Wavelength [nm]


Signal-to-noise
Requirement
SWIR
Signal-to-noise
Wavelength [nm]

TROPOMI

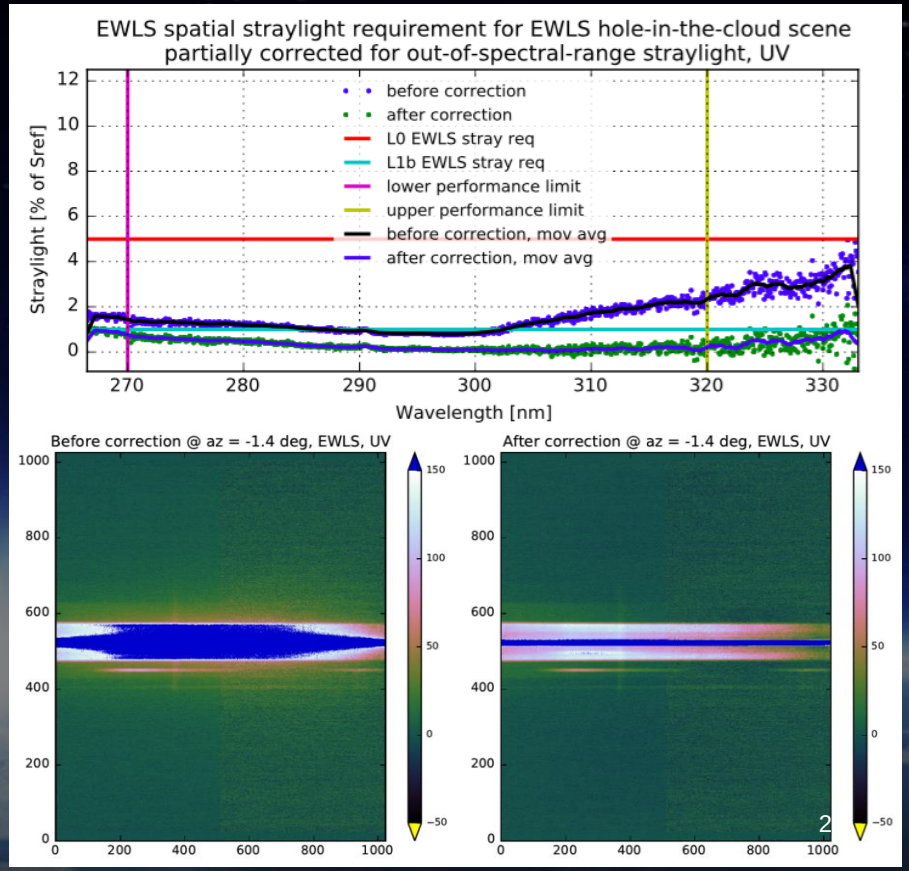
Instrument Spectral Response Function

- Measured with tunable lasers and slit-function stimulus
- Different ISRF shapes due to the optical design of the instrument
- Parametrized as function of swath angle and wavelength



UVN Stray Light

- New stray light correction algorithm has been implemented.
- Good performance after stray light correction is applied.
- NIR out-of-band stray light is further investigated.



Dark Current

Dark currents in Bands 1-6 lower than 2 e/s

band	dc e/s
1	1.622
2	1.477
3	1.593
4	1.579
5	1.759
6	1.849