



Royal Netherlands
Meteorological Institute
*Ministry of Infrastructure and the
Environment*

Sentinel 5 Precursor

Pepijn Veeffkind



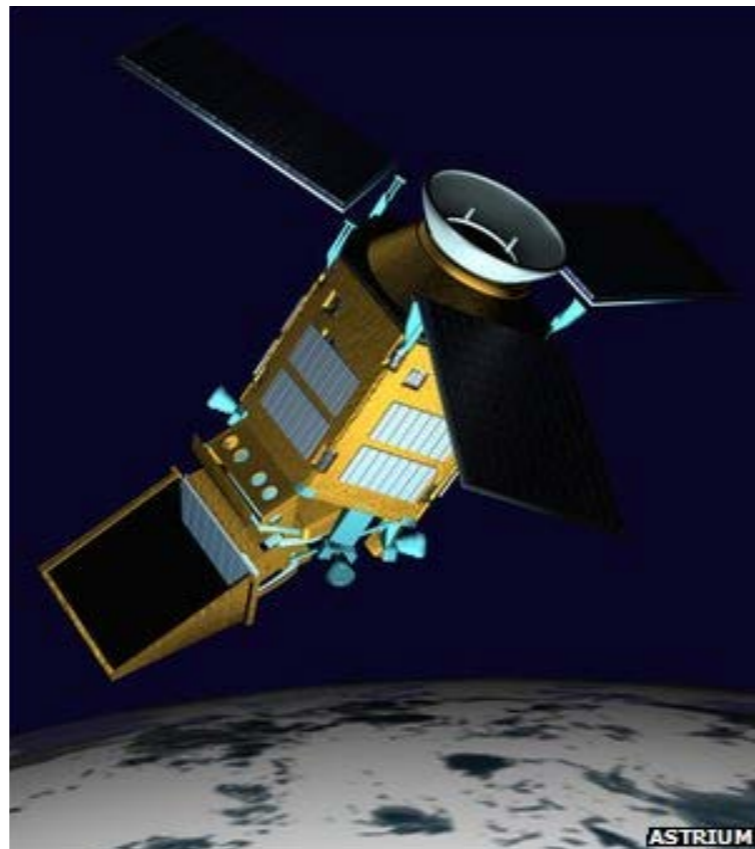
sentinel-5 precursor

GMES ATMOSPHERE MISSION IN POLAR ORBIT

- The ESA Sentinel-5 Precursor (S-5P) is a pre-operational mission focussing 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 2015 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: 0.25-1.1 nm
- ▶ Spatial Resolution: 7x7km²
- ▶ Global daily coverage at 13:30 local solar time.



CONTRIBUTION TO GMES

- ▶ Total column
O₃, NO₂, CO, SO₂, CH₄,
CH₂O, H₂O, BrO
- ▶ Tropospheric column
O₃, NO₂
- ▶ O₃ profile
- ▶ Aerosol absorbing index,
type, optical depth

TROPOMI Science Objectives

- To better **constrain** the strength, evolution, and spatiotemporal variability of **the sources of trace gases and aerosols** impacting air quality and climate.
- To **improve upon the attribution of climate forcing** by a better understanding of the processes controlling the lifetime and distribution of methane, tropospheric ozone, and aerosols.
- To better estimate **long-term trends** in the troposphere related to air quality and climate from the regional to the global scale.
- To **develop and improve air quality model processes and data assimilation** in support of operational services including air quality forecasting and protocol monitoring.



TROPOMI Data Products

| Product | Accuracy :: Precision |
|---|---|
| Ozone total column profile (incl. troposphere) trop. column | 3% :: 1% 10% :: 5% 25% :: 10% |
| NO₂ total column trop. column | $1 \cdot 10^{15}$ mol/cm ² 10% :: $1 \cdot 10^{15}$ mol/cm ² |
| CO total column | 15% :: 10% |
| CH₄ total column | 2% :: 1% |
| SO₂ volcanic plume top. column | 2 DU :: 1 DU 1 DU :: 0.5 DU |
| Aerosol AAI aerosol layer height* aerosol optical thickness single scattering albedo | n/a :: 0.25 1 km :: 0.5 km 0.1 (20%) :: 0.05 (10%) 0.05 :: 0.01 |
| Cloud radiance fraction pressure mask Regridded VIIRS | 0.05 :: 0.02 50 hPa :: 20 hPa |

| Product | Accuracy :: Precision |
|---|-----------------------|
| CH₂O total column | TBD |
| CHO-CHO total column | TBD |
| BrO total column | TBD |
| HDO total column | TBD |
| H₂O total column | 20% :: 10% |
| OCIO total column | TBD |
| UV surface flux | 10% :: 5% |
| Surface Reflectance monthly climatology | 3% :: 1% |

**The operational data products will be developed by a collaboration of European institutes.
 KNMI/DLR-IMF/IUP/BIRA-IASB/SRON/MPIC/RAL/FMI**



sentinel-5 precursor

→ GMES LOW EARTH ORBIT ATMOSPHERE MISSION

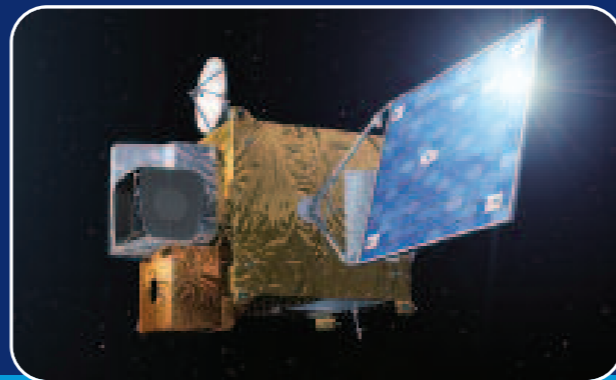
→ GMES LOW EARTH ORBIT ATMOSPHERE MISSION

2015-2022
daily global coverage



EUMETSAT Polar System

2019 - ~2030
hourly over Europe



sentinel-4

→ GMES GEOSTATIONARY ATMOSPHERIC MISSION

→ GMES GEOSTATIONARY ATMOSPHERIC MISSION

2017 - ...
hourly over SE - ASIA

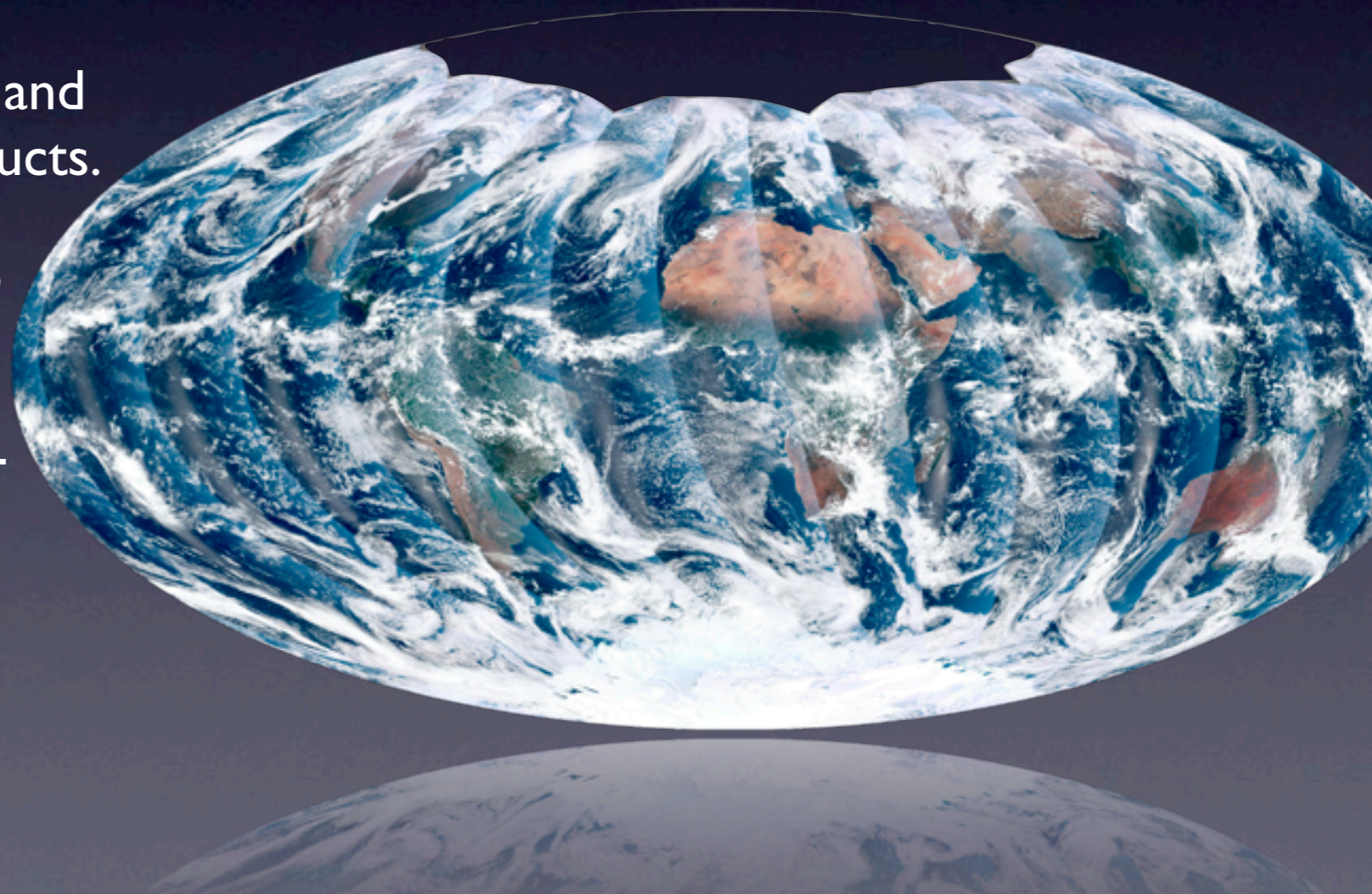
gems | tempo

KARI | NASA

2017 - ...
hourly over N-America

Suomi-NPP - S5P formation Flying

- S-5P is planned to observe within 5 min. of Suomi-NPP.
- Primary goal is to use VIIRS cloud mask for S-5P methane observations.
- Other opportunities:
 - ▶ TROPOMI-VIIRS cloud and aerosol combined products.
 - ▶ TROPOMI-OMPS-CRIS ozone profiles.
 - ▶ TROPOMI-OMPS inter-calibration.



S5P Satellite



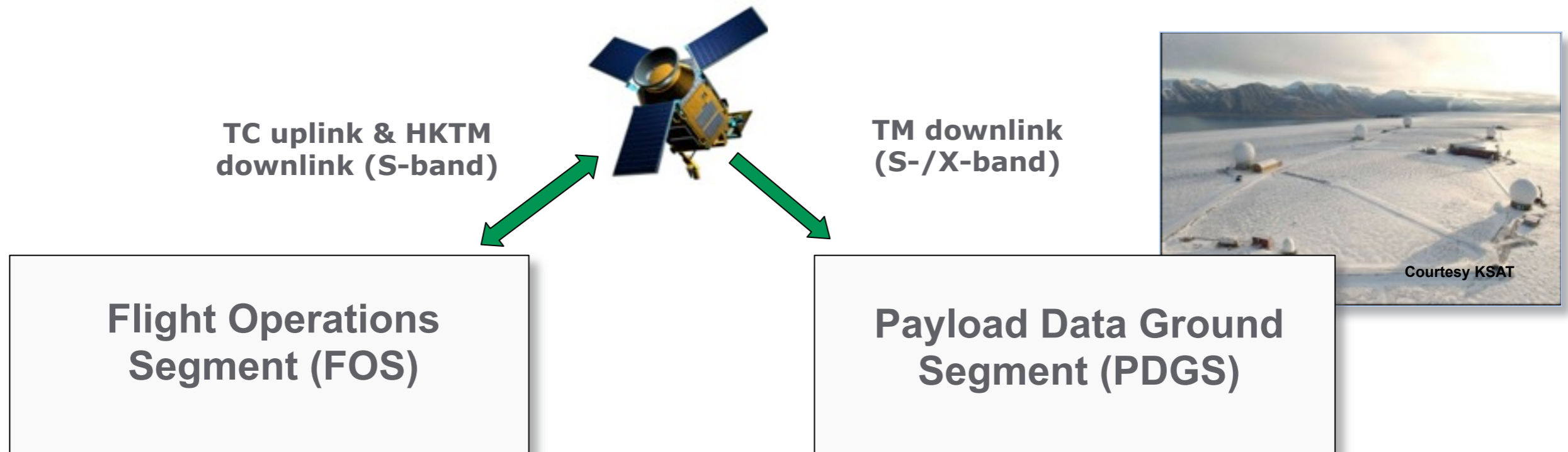
Orbit

- *Near polar, sun-synchronous*
- *mean orbit height: 835 km*
- *LTAN: 13:35 h*
- *Repeat cycle: 241 orbits / 17 days*

Spacecraft

- *Mass: ~ 980 kg (incl. TROPOMI ~220 kg)*
- *Solar Array: fixed panels ~1500 W peak*
- *Mass Memory: 480 / 230 Gbit ((BOL / EOL)*
- *TT&C S-band: 64 kbps up / < 1Mbps down*
- *X-band downlink: 310 Mbps*
- *data volume (X-band): 168.4 Gbits / orbit*
-> *required dump time ~ 543 s / orbit*

S5P Ground Segment



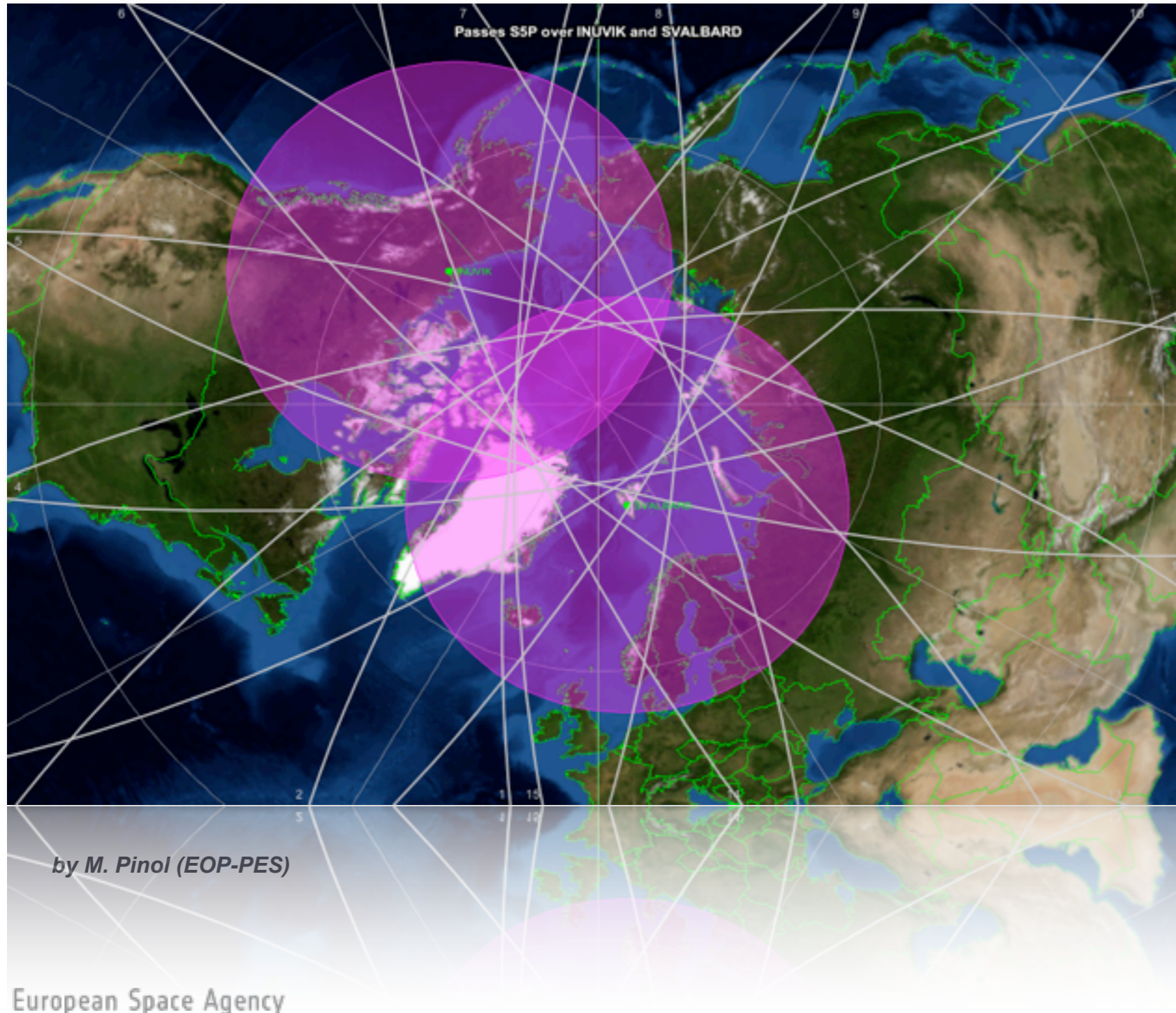
Tasks:

- acquisition of S-band telemetry (RT)
- platform & instrument monitoring
- orbit maintenance
- downlink scheduling
- **TROPOMI planning tasks**
- TC uplink: on-board parameters & schedule

Tasks:

- downlink planning & acquisition of S-/X-band data (except Kiruna TT&C)
- Level 0 ⇔ L1B ⇔ L2 processing
- TROPOMI in-flight calibration & trend monitoring
- archiving & dissemination

Ground Station Selection



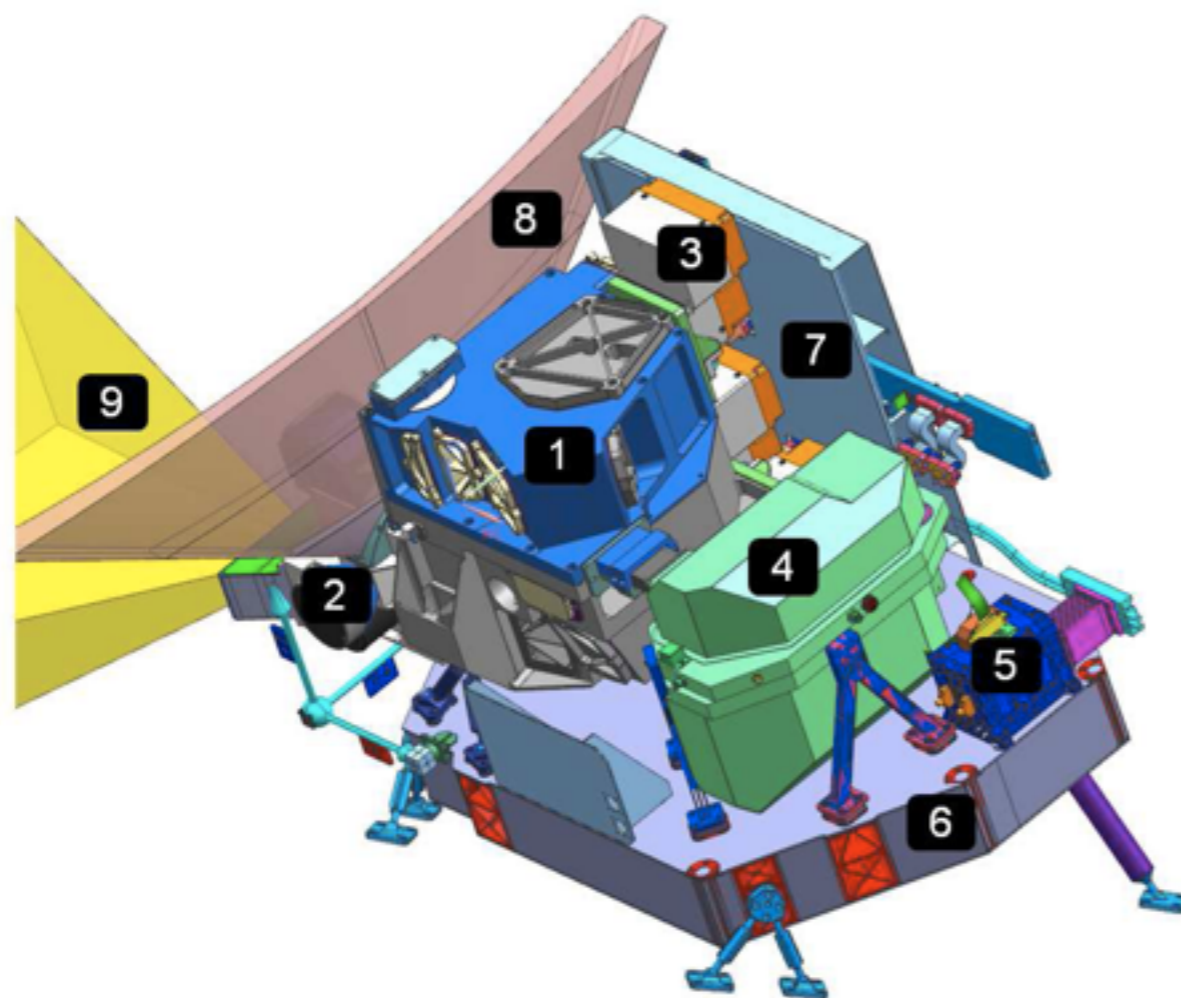
Visibility zones for
Svalbard (N) and
Inuvik (Ca)

Slide



Sentinel 5 Precursor Mission

TROPOMI Instrument Status

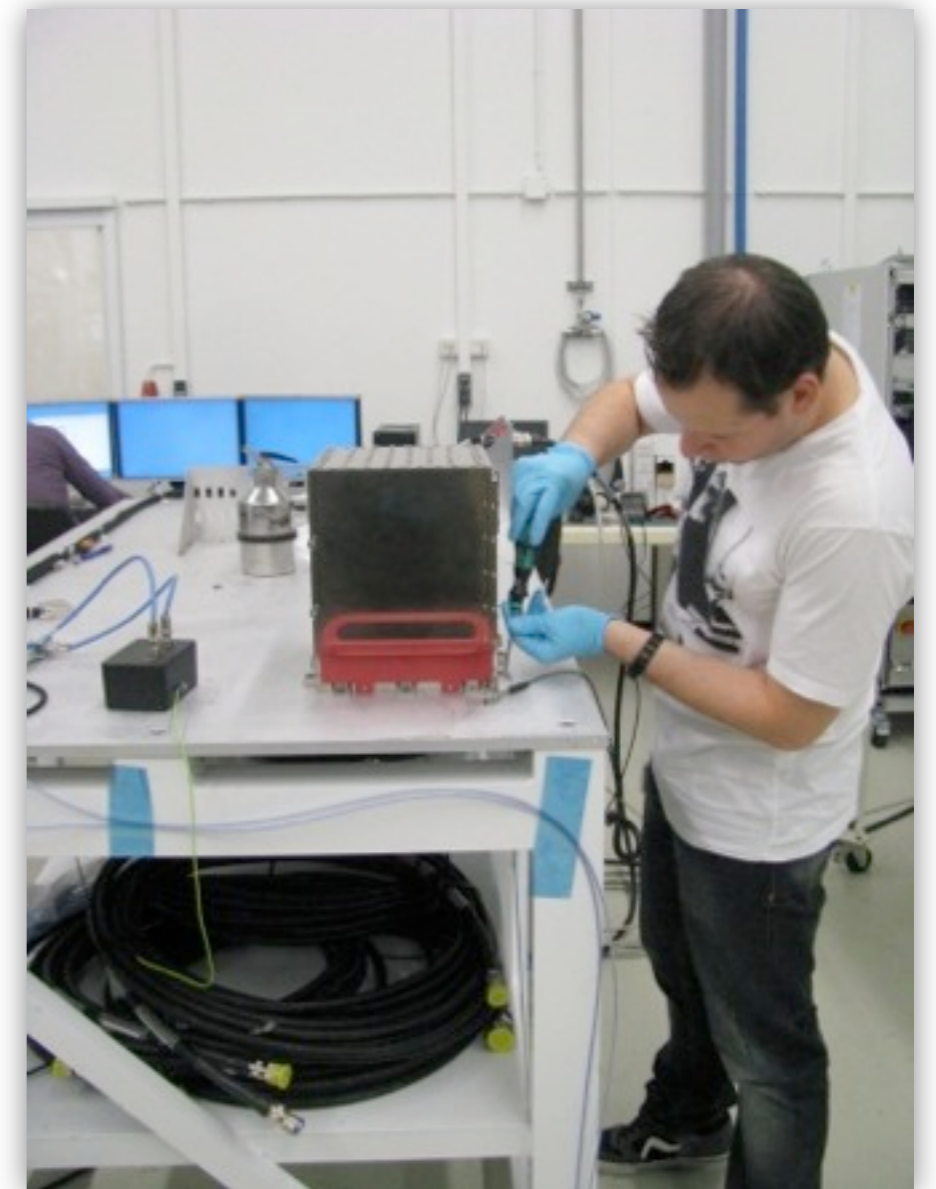


- 1 – UVN Module (TNO)
- 2 – Calibration Unit (TNO)
- 3 – UVN Detector Module (RUAG)
- 4 – SWIR Module (SSTL)
- 5 – SWIR Front End Electronics (SRON)
- 6 – Telescope Support Structure (EADS)
- 7 – Thermal Bus Unit (EADS)
- 8 – Nadir Field of View
- 9 – Solar Field of View

Achievements

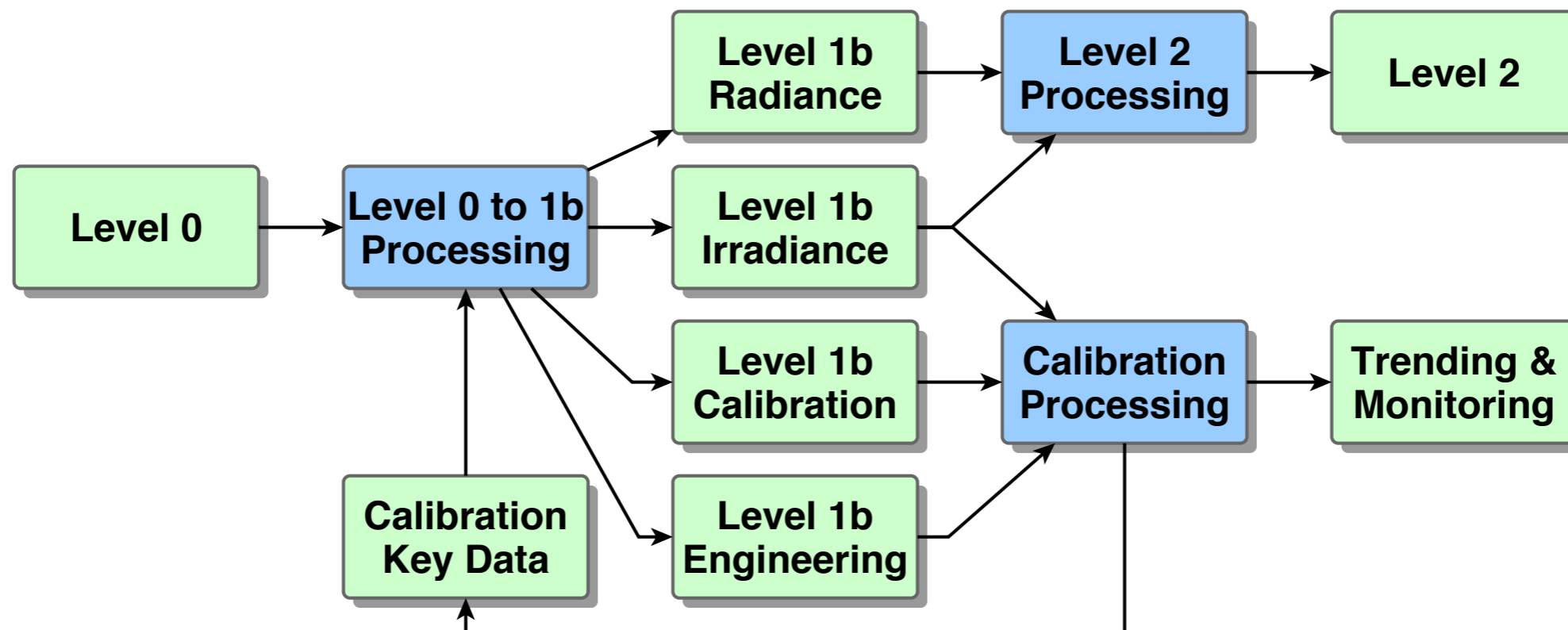


- ✓ First phase of electrical tests started at DS (EM-ICU, EFM-EGSE)
- ✓ Unit CDR's all but one (SWIR) successfully concluded
- ✓ Instrument CDR well underway

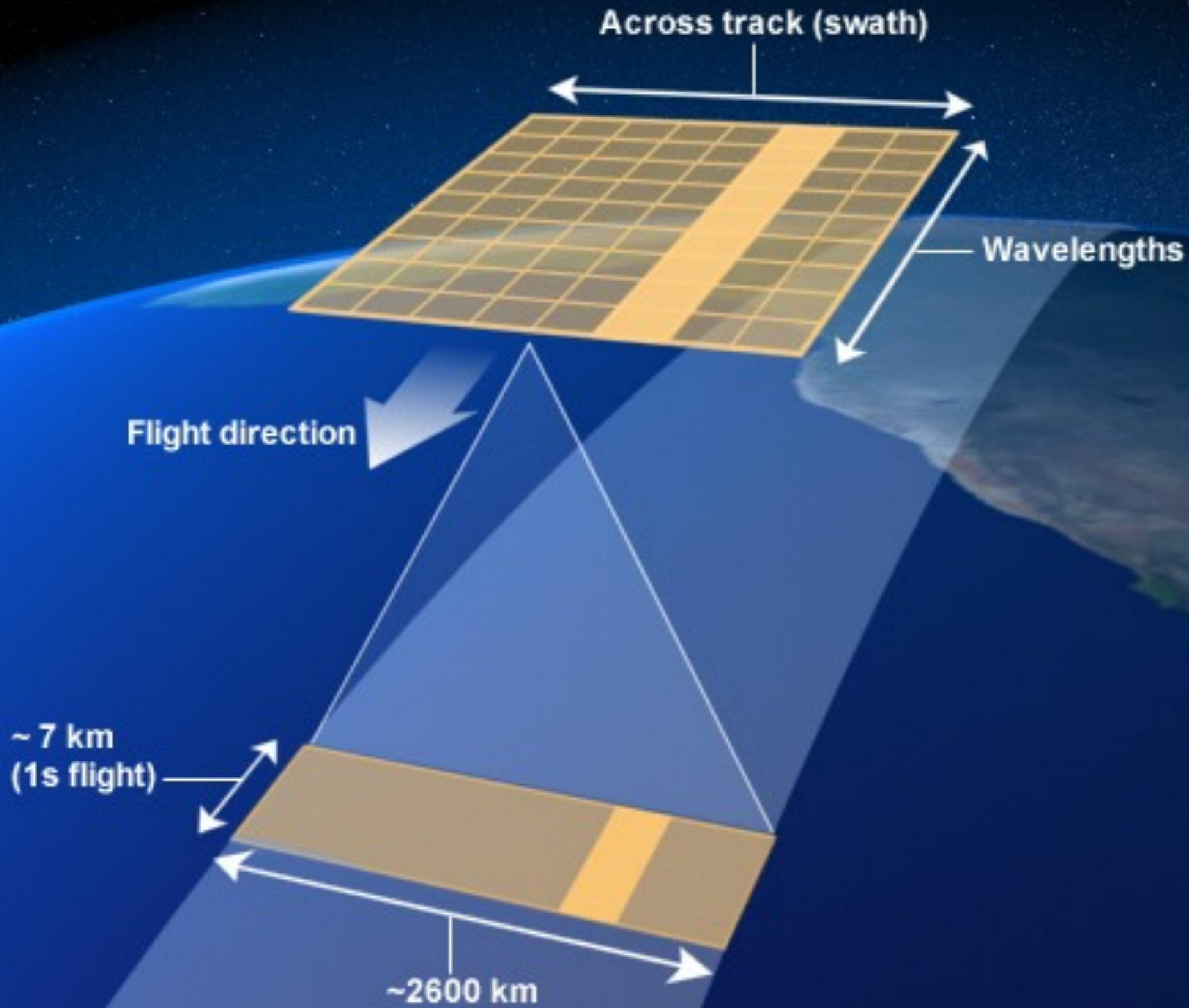


L0-1B and Calibration

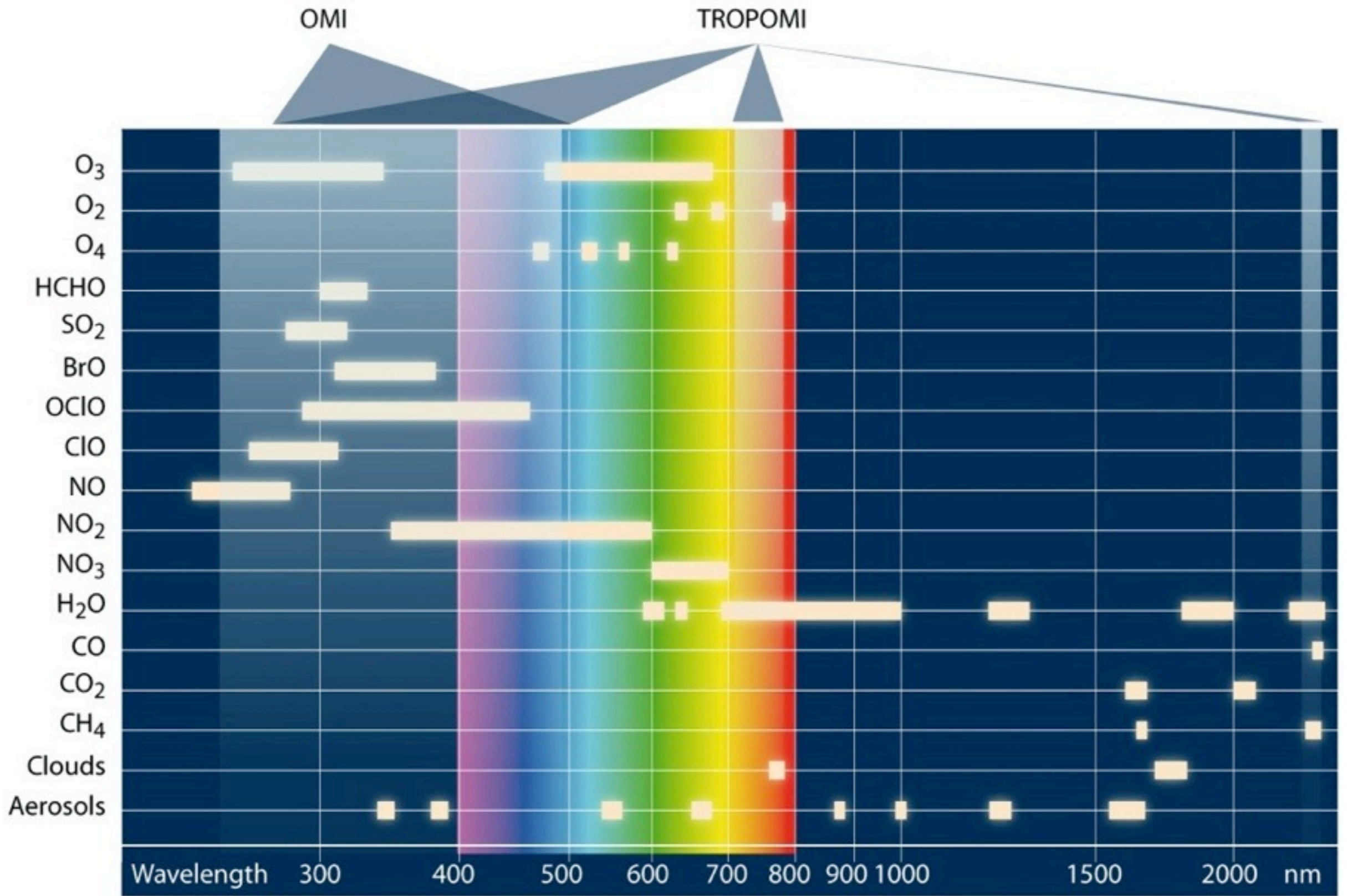
- KNMI develops the L0-1B processor.
- KNMI/SRON are responsible for the calibration requirements.
- The L0-1B processor will be used for data reduction and to perform close loop tests during on-ground calibration, verification and tests.



The TROPOMI Measurement Principle



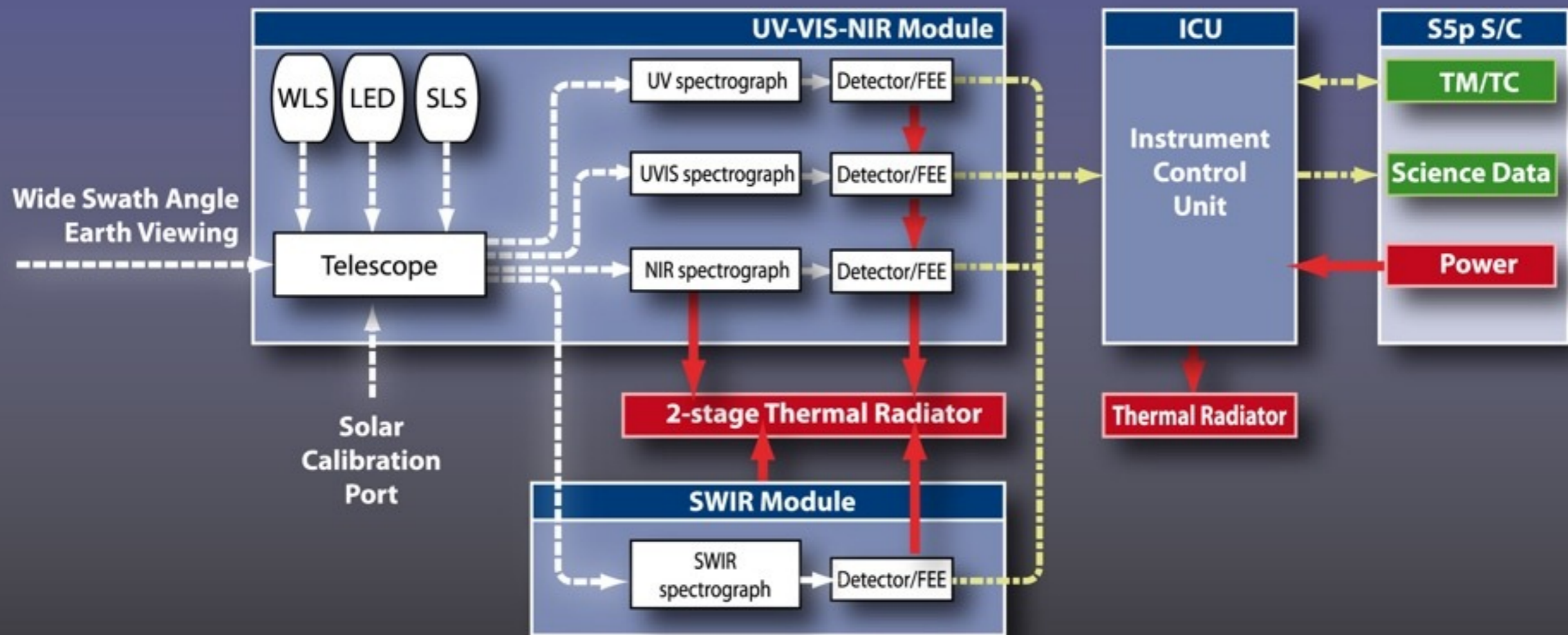
Courtesy of Pepijn Veeffkind, KNMI, The Netherlands



GOME

SCIAMACHY

FUNCTIONAL DIAGRAM



Courtesy of DutchSpace

Radiant Cooler

Nadir FOV

Telescope Support Structure

SUN Calibration FOV

TROPOMI Spectral Bands

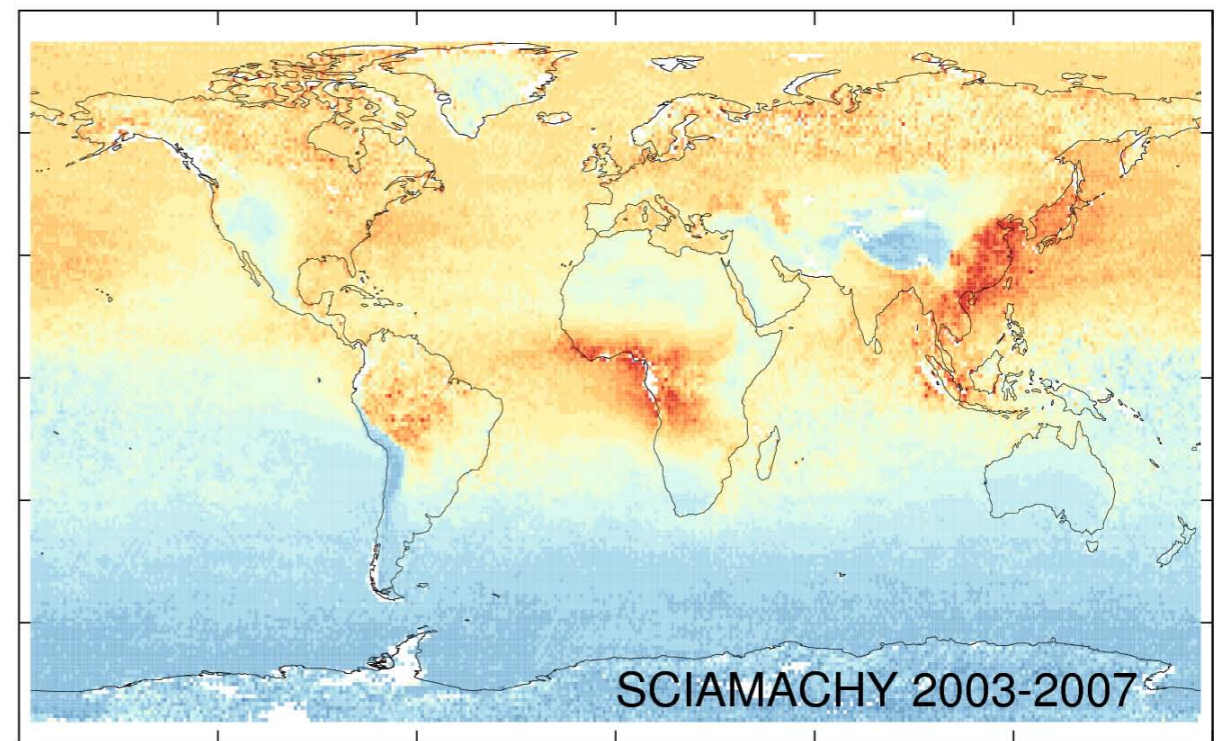
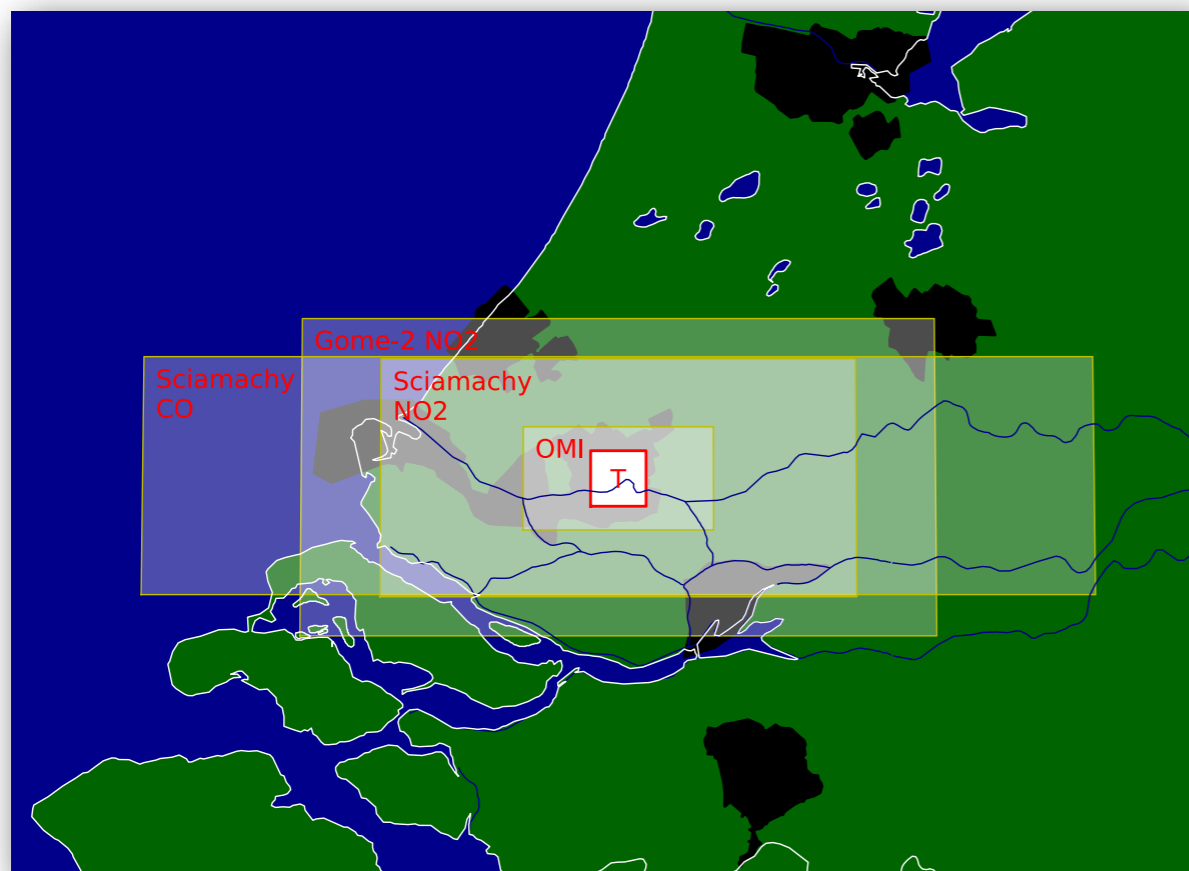
| Spectrometer | UV | | UVIS | | NIR | | SWIR | |
|-------------------------------------|-----------|----------|-----------|---------|-----------|---------|-------------|-----------|
| Band ID | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Full Range [nm] | 270 - 320 | | 310 - 495 | | 675 - 775 | | 2305 - 2385 | |
| Performance range [nm] | 270-300 | 300-320 | 320-405 | 405-495 | 675-725 | 725-775 | 2305-2345 | 2345-2385 |
| Spectral Resolution [nm] | 0.48 | 0.49 | 0.54 | 0.54 | 0.38 | 0.38 | 0.25 | 0.25 |
| Spectral Sampling Ratio | 6.8 | 6.7 | 2.5 | 2.5 | 2.8 | 2.8 | 2.5 | 2.5 |
| Signal-to-noise | 100 | 100-1000 | 1000-1500 | 1500 | 500 | 100-500 | 100-120 | 100-120 |
| Spatial Sampling [km ²] | 7x28 | 7x7 | 7x7 | 7x7 | 7x7 | 7x3.5 | 7x7 | 7x7 |



Tropospheric Monitoring Instrument

From OMI to TROPOMI

- **6x higher spatial resolution**
7x7 km² vs. 13x24 km²
- **1-5x higher signal-to-noise**
- **Variable binning scheme**
- **better cloud information**
from the oxygen A band
- **CO and CH₄ observations**
from the SWIR band
- **Data rate ~20x OMI**



0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 9.9
CO column [10^{18} molecules/cm²]

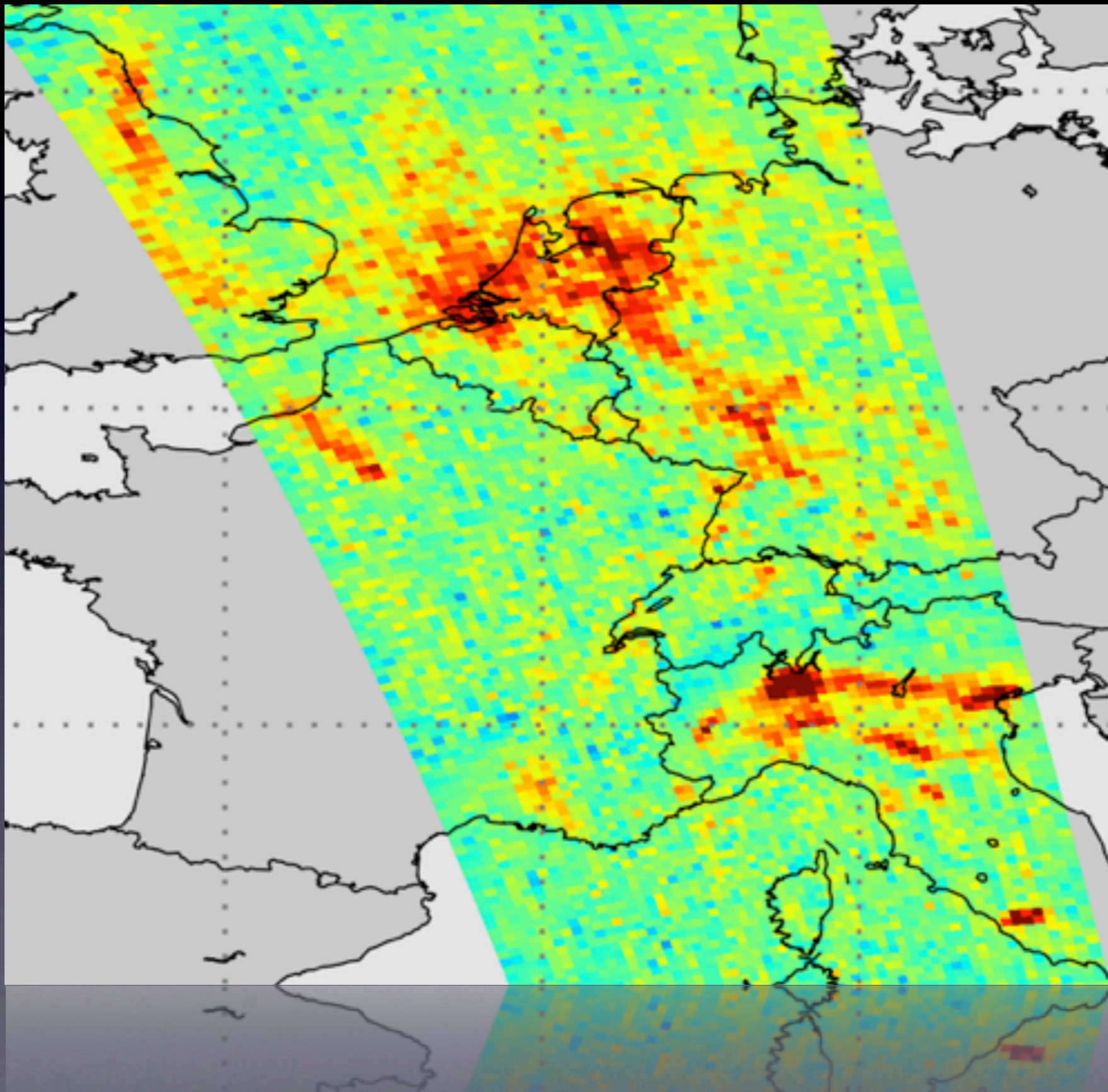
Gloudemans et al., SCIAMACHY CO over land and oceans: 2003–2007 interannual variability, ACP, 2009



OMI Zoom

~13x12 km² Sampling

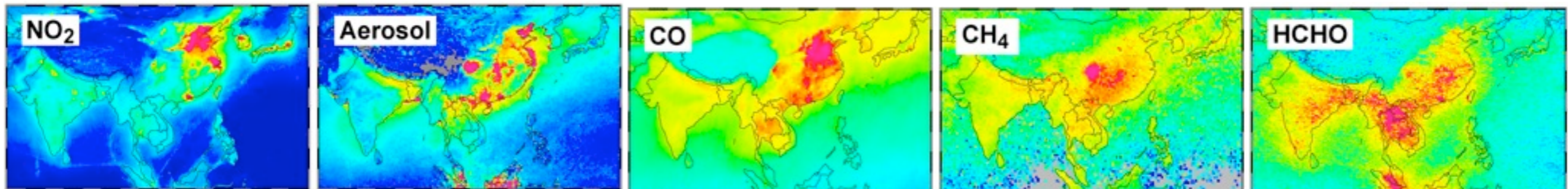
12 September 2006



TROPOMI Data Product Development

Goal: To develop operational TROPOMI data products that

- ▶ meet the user requirements
- ▶ are state-of-science
- ▶ have reliable and well-described quality
- ▶ have open access and are easy to use
- ▶ contribute to long-term data records
- ▶ are continuously evaluated and improved
- ▶ are of reasonable quality within 3 (tbc) months after commissioning



TROPOMI L2 PRODUCTS

L2 Working Group

PROTOTYPE

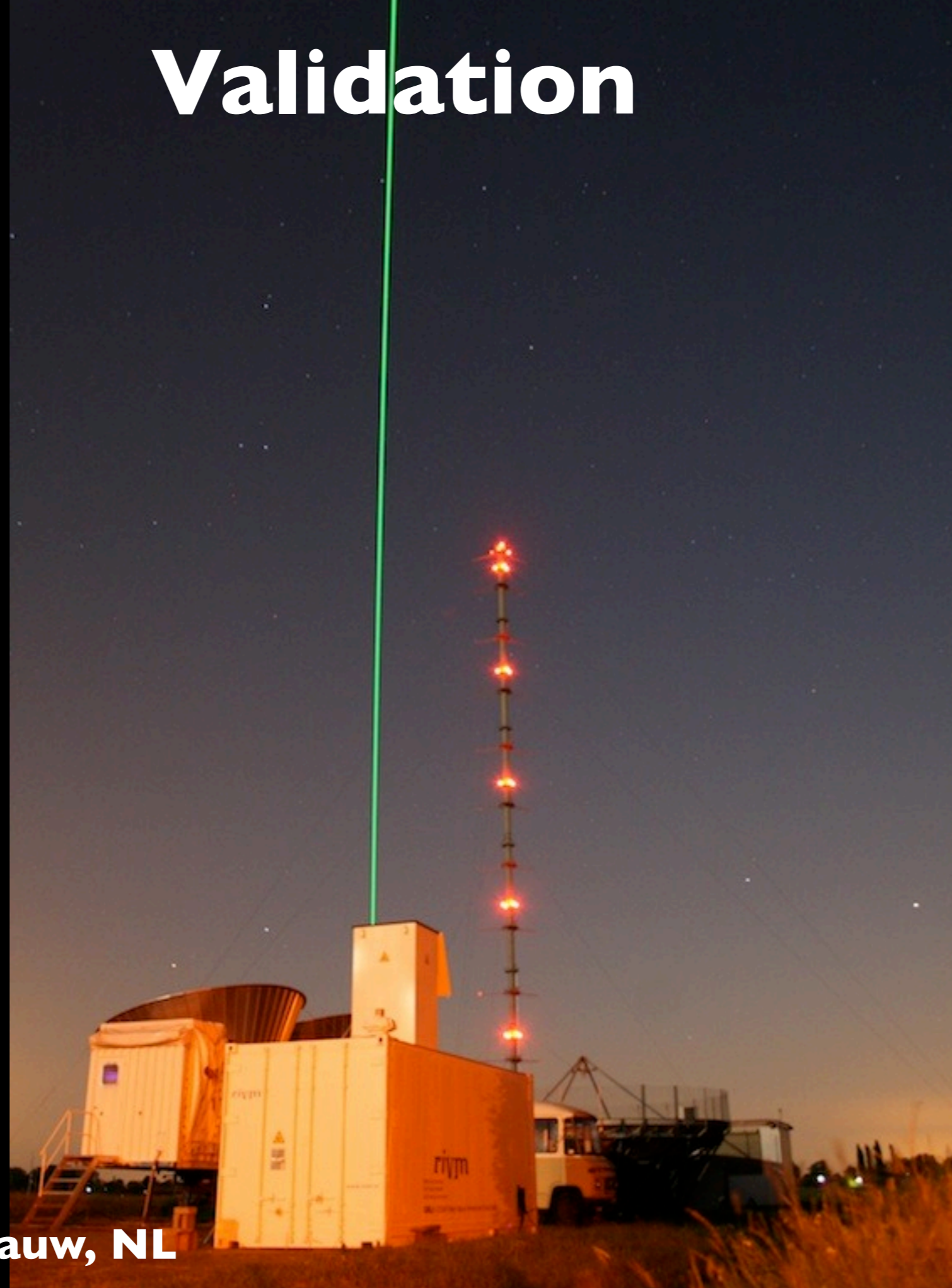
VERIFICATION

OPERATIONAL SW

GOME-SCIAMACHY-OMI

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

Validation



Caeli LIDAR, Cabauw, NL

Validation

- Shift the focus to more challenging conditions:
 - ▶ partly cloudy
 - ▶ spatial gradients
 - ▶ inhomogeneous terrain
 - ▶ high aerosol loadings
- Super sites are essential (cloud, aerosol, trace gas observations)



Caeli LIDAR, Cabauw, NL



Tropospheric Monitoring Instrument

Summary & Outlook



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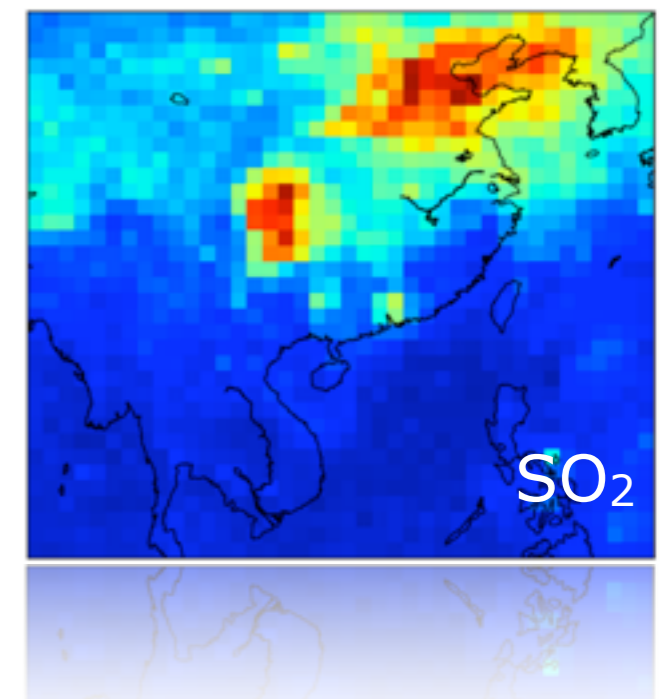
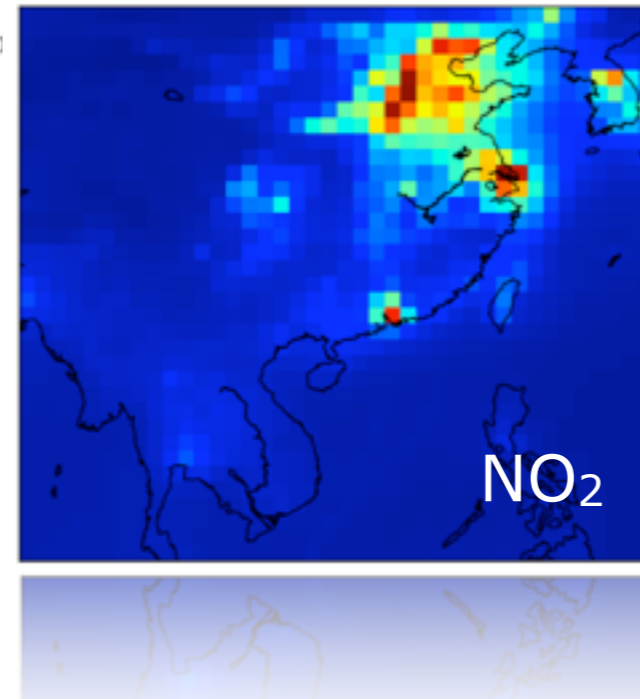
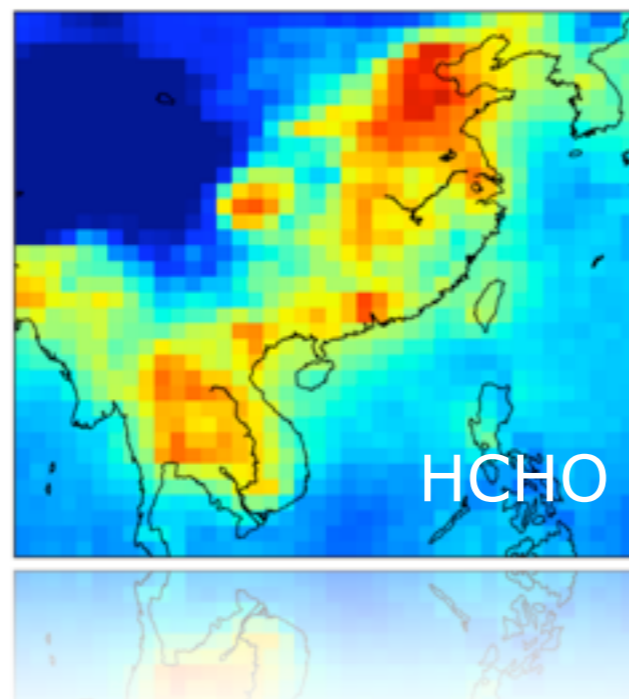
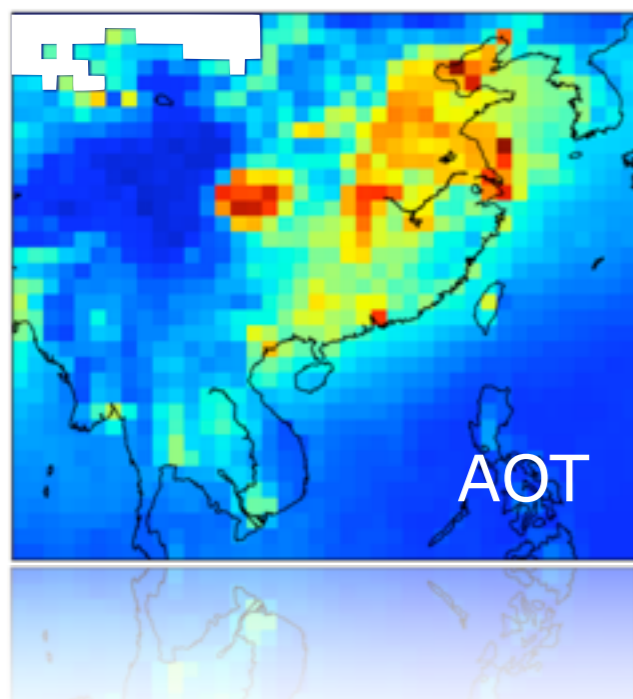
www.tropomi.eu

www.temis.nl

www.knmi.nl/omi

<http://www.esa.int/esaLP>

- S5P TROPOMI will be a major step forward for atmospheric composition observations due to improved spatial resolution & sensitivity.
- S5P will connect the geostationary UVN mission: Sentinel-4, GEMS and TEMPO.
- The Level 2 products are developed by an experienced team of European institutes.
- For the validation of the L2 products campaigns are needed that focus on challenging conditions.





Contents lists available at SciVerse ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse



TROPOMI on the ESA Sentinel-5 Precursor: A GMES mission for global observations of the atmospheric composition for climate, air quality and ozone layer applications

J.P. Veefkind^{a,g,*}, I. Aben^b, K. McMullan^c, H. Förster^d, J. de Vries^e, G. Otter^f, J. Claas^a, H.J. Eskes^a, J.F. de Haan^a, Q. Kleipool^a, M. van Weele^a, O. Hasekamp^b, R. Hoogeveen^b, J. Landgraf^b, R. Snel^b, P. Tol^b, P. Ingmann^c, R. Voors^e, B. Kruizinga^f, R. Vink^f, H. Visser^f, P.F. Levelt^{a,g}

<http://dx.doi.org/10.1016/j.rse.2011.09.027>

TROPOMI

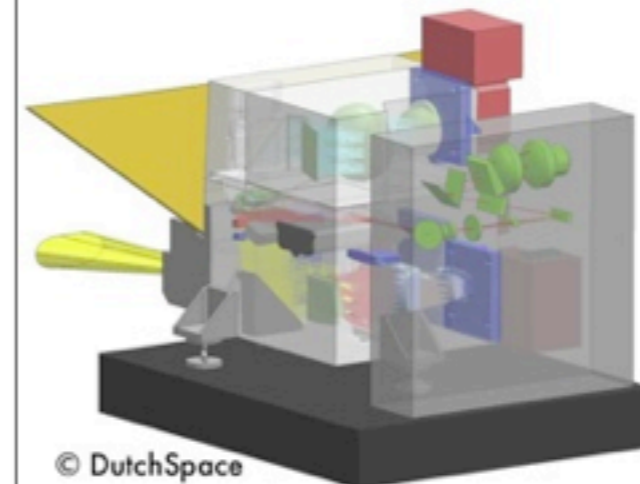
TROPOspheric Monitoring Instrument

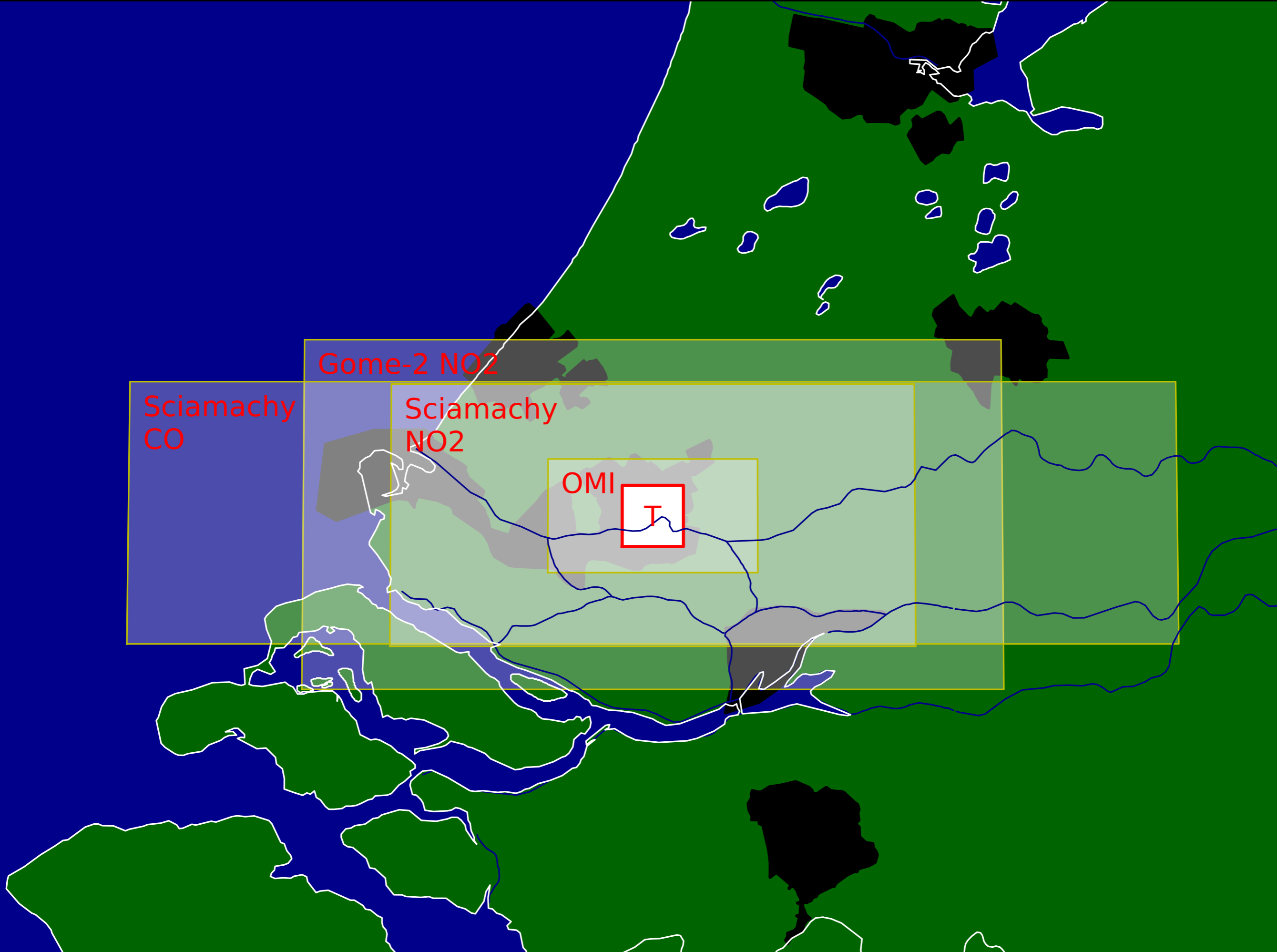
www.tropomi.eu

[Home](#) [Instrument](#) [Data](#) [Doc](#) [Contact](#)

The TROPOspheric Monitoring Instrument (TROPOMI) is a spaceborne nadir viewing spectrometer with bands in the ultraviolet, the visible, the near infrared and the shortwave infrared. TROPOMI is the payload for the ESA/GMES Sentinel 5 Precursor mission, planned for launch in 2014 with 7 years design lifetime. The objective of the mission is to provide high-quality and timely information on the global atmospheric composition for climate and air quality applications. TROPOMI will make daily global observations of key atmospheric constituents, including ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, methane, formaldehyde and aerosol properties. The Sentinel-5 Precursor mission will extend the current data records from OMI (Ozone Monitoring Instrument) on NASA EOS Aura and SCIAMACHY (SCanning Imaging Absorption spectrometer for Atmospheric Cartography) on ESA Envisat and is the link between the current scientific missions and the operational Sentinel-4/-5 missions.

TROPOMI is an initiative from the Netherlands and is developed in cooperation





Gome-2 NO2

Sciamachy
CO

Sciamachy
NO2

OMI

T

