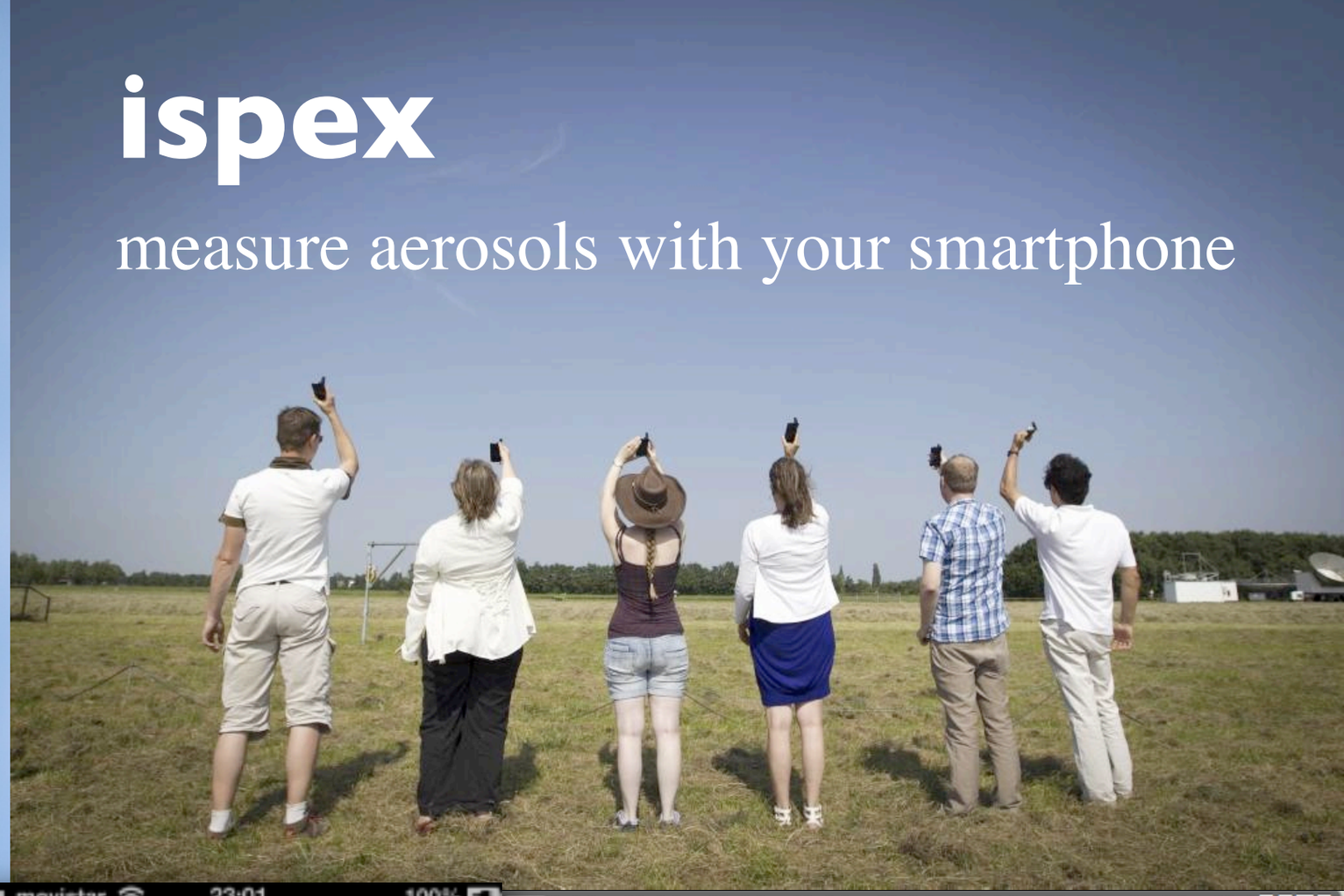
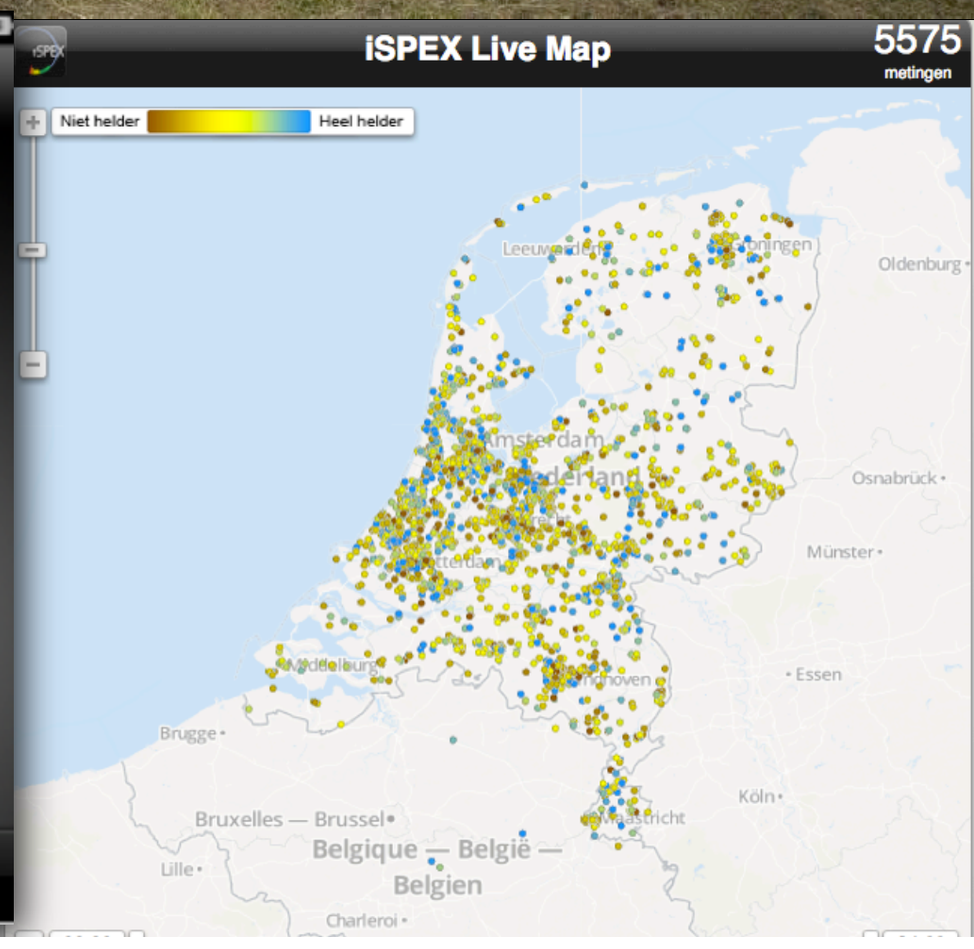
ispex.nl/en/ispex

ispex

measure aerosols with your smartphone





Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment

Status of TROPOMI on Sentinel 5 Precursor

Pepijn Veefkind
veefkind@knmi.nl

KNMI | TU-Delft

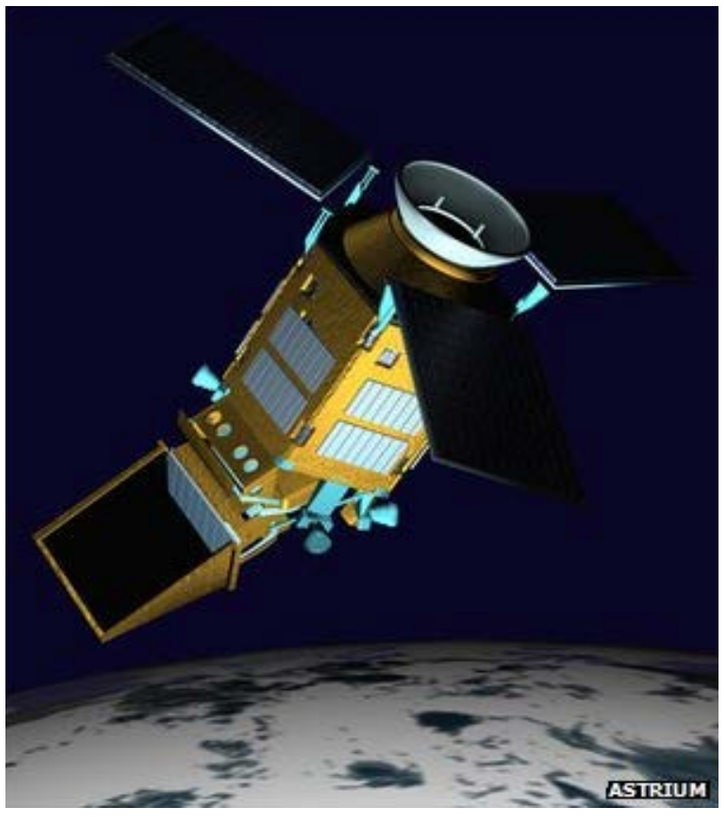
sentinel-5 precursor

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: 7x7km^2
- Global daily coverage at 13:30 local solar time.



CONTRIBUTION TO GMES

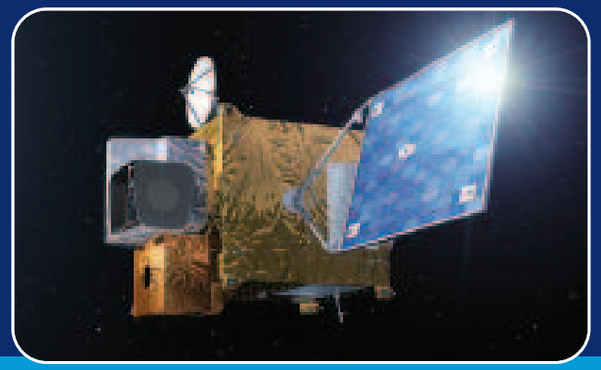
- Total column O_3, NO_2, CO, SO_2,CH_4, CH_2O,H_2O,BrO
- Tropospheric column O_3, NO_2
- O_3 profile
- Aerosol absorbing index, type, optical depth

sentinel-5 precursor

→ GMES LOW EARTH ORBIT ATMOSPHERE MISSION

2015-2022
daily global coverage

2019 - ~2030
hourly over Europe



sentinel-4

→ GMES GEOSTATIONARY ATMOSPHERIC MISSION

gems | tempo

KARI | NASA

2017 - ...
hourly over SE - ASIA

2017 - ...
hourly over N-America

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

TROPOMI

The TROPOMI Measurement Principle

Across track (swath)

Wavelengths

Flight direction

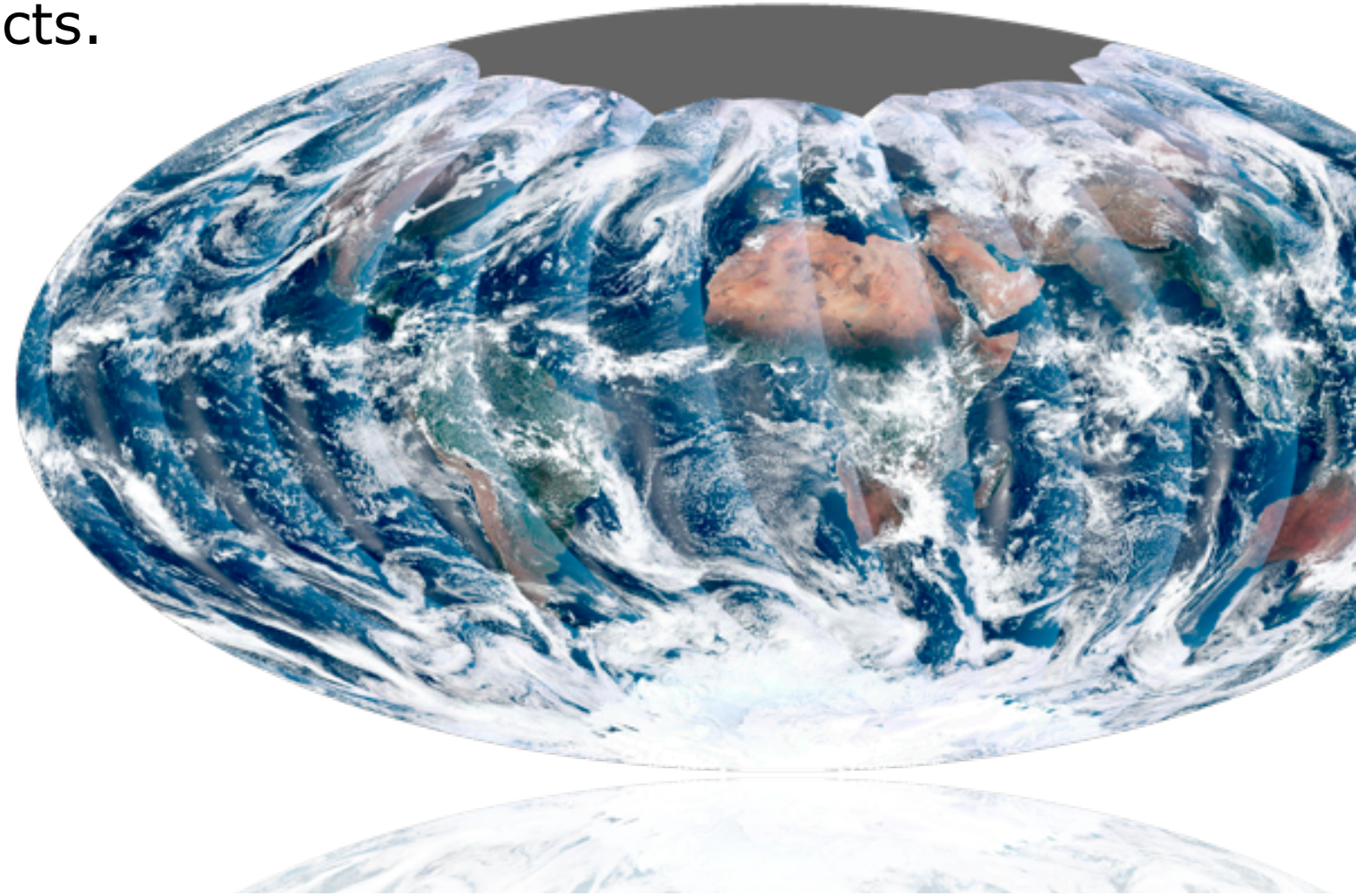
~ 7 km
(1s flight)

~2600 km

Courtesy of Pepijn Veefkind, KNMI, The Netherlands

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.



TROPOMI

Principal Investigator
KNMI (PI), SRON (co-PI)

Validation
KNMI, SRON, ESA, ...

Level 1-2
KNMI, SRON, DLR, IUP
BIRA-IASB, MPI Mainz, RAL

Level 0-1B
KNMI

Ground Segment
DLR

Operations
KNMI, ESOC

Calibration
KNMI / SRON
Dutch Space

Instrument
prime Dutch Space

TROPOMI Status

- I-CDR successfully completed
- Modules are being assembled
- Start of calibration: June 2014
- Instrument delivery: September 2014
- Planned launch date: September 2015

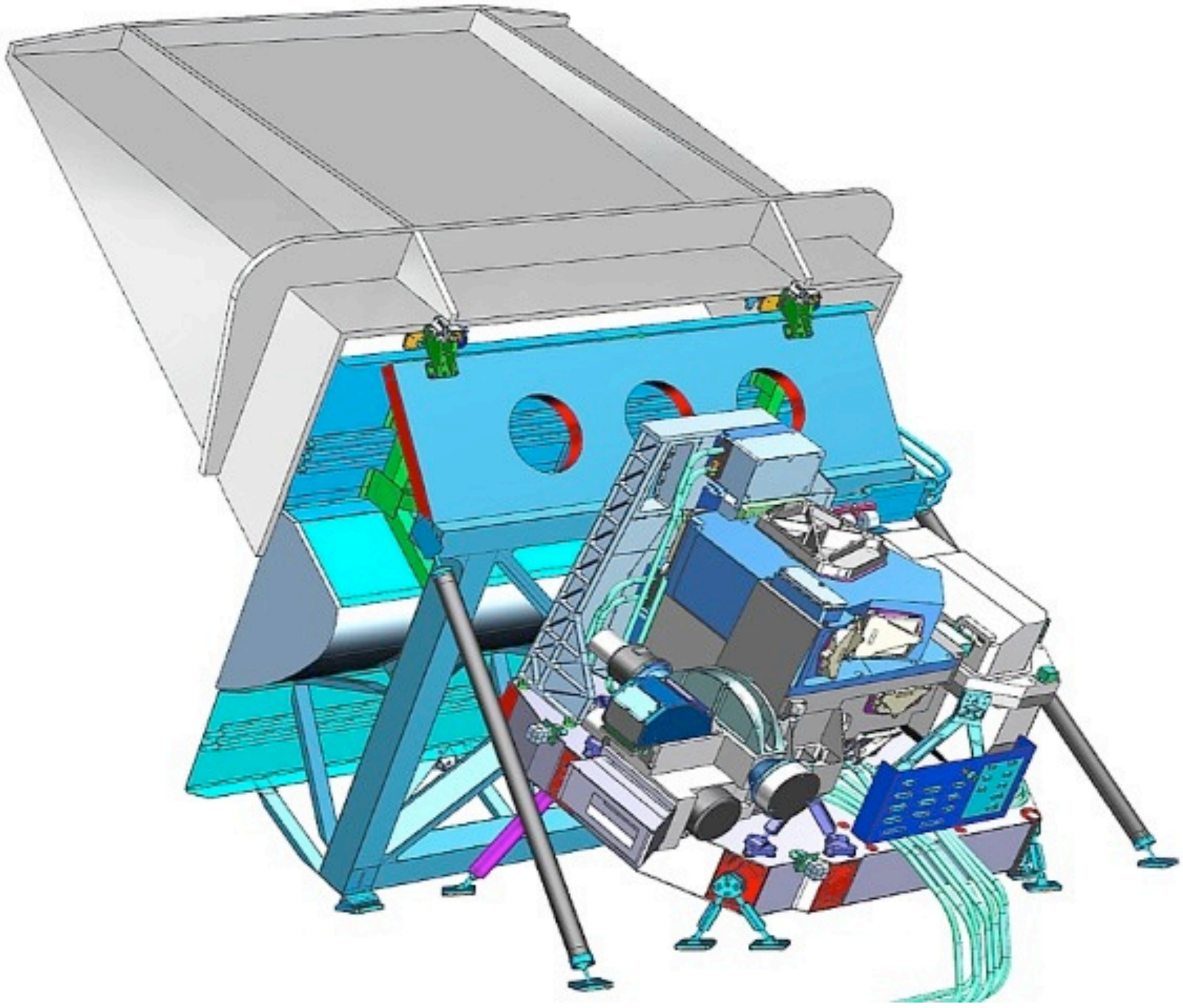
TROPOMI Data Products

Product	Accuracy :: Precision
Ozone total column profile (incl. troposphere) trop. column	 3% :: 1% 10% :: 5% 25% :: 10%
NO_2 total column trop. column	 $1 \cdot 10^{15}$ mol/cm^2 10% :: $1 \cdot 10^{15}$ mol/cm^2
CO total column	 15% :: 10%
CH_4 total column	 2% :: 1%
SO_2 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
CH_2O total column	 TBD
CHO-CHO total column	 TBD
BrO total column	 TBD
HDO total column	 TBD
H_2O total column	 20% :: 10%
OClO 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

TROPOMI



TNO innovation for life

Dutch Space
an EADS Astrium company

Wednesday, 24 July 2013

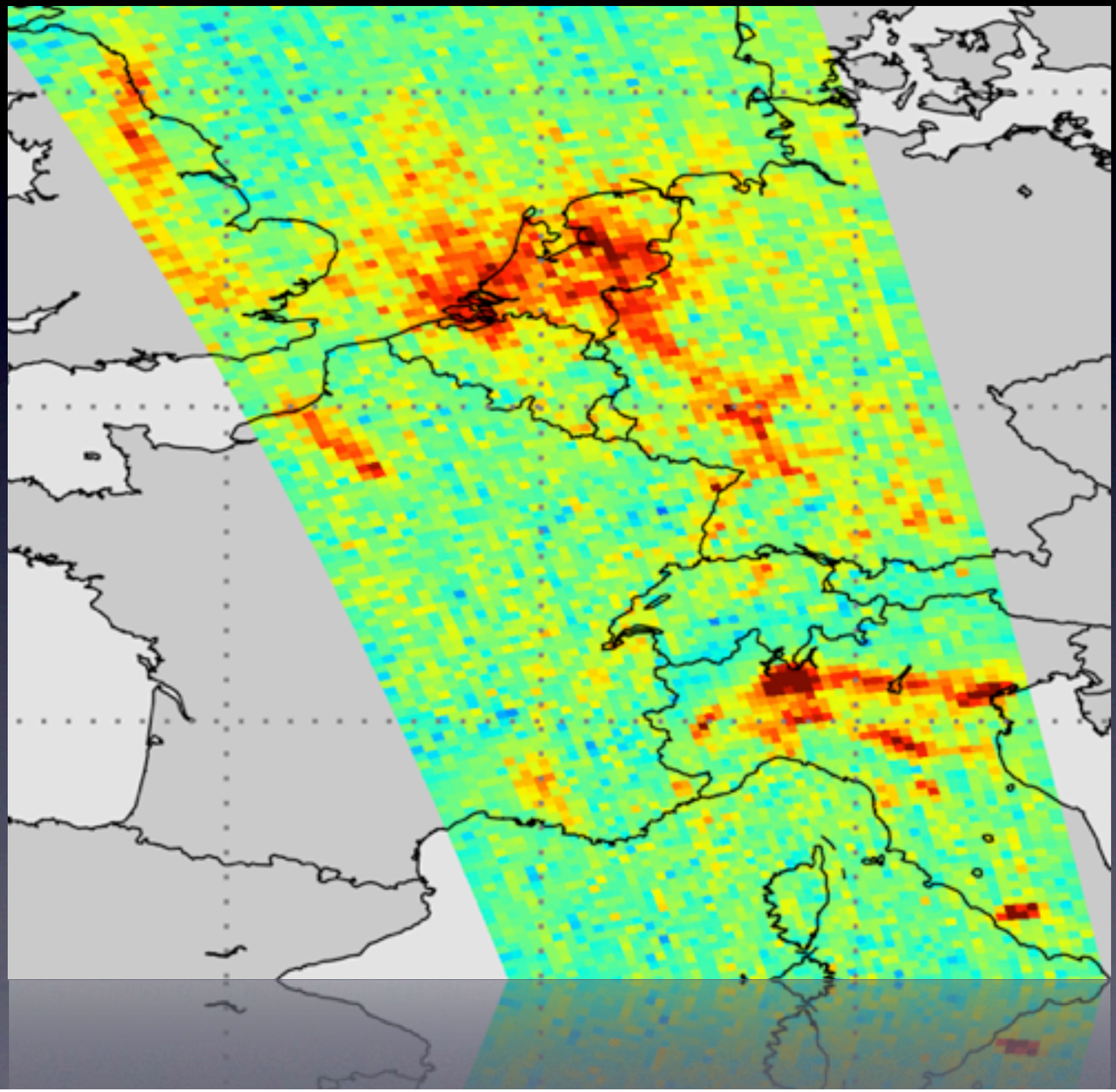
Performance Overview

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 FWHM[nm]	0.48	0.49	0.54	0.54	0.38	0.38	0.25	0.25
Spectral Sampling [nm]	0.071	0.073	0.22	0.22	0.14	0.14	0.10	0.10
Spectral Sampling Ratio[1]	6.8	6.7	2.5	2.5	2.8	2.8	2.5	2.5
Slit Width (µm)	560	560	280	280	280	280	560	560
Spectral magnification	0.327	0.319	0.231	0.231	0.263	0.263	TBD	TBD
Spatial Sampling at nadir [km^2]	28x7	7x7	7x7		7x7	3.5x7	7x7	
Required Signal-to-noise	100-800[2,3]	90-700[2]	800-1000[2]		100-500[2,4]		100-120[5]	

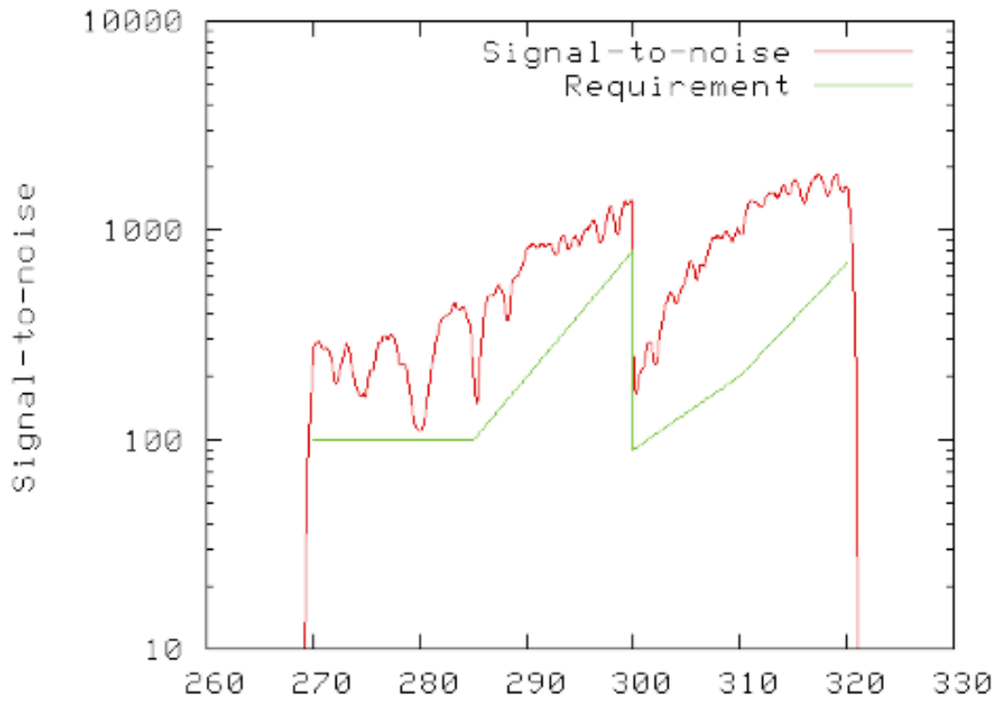
OMI Zoom

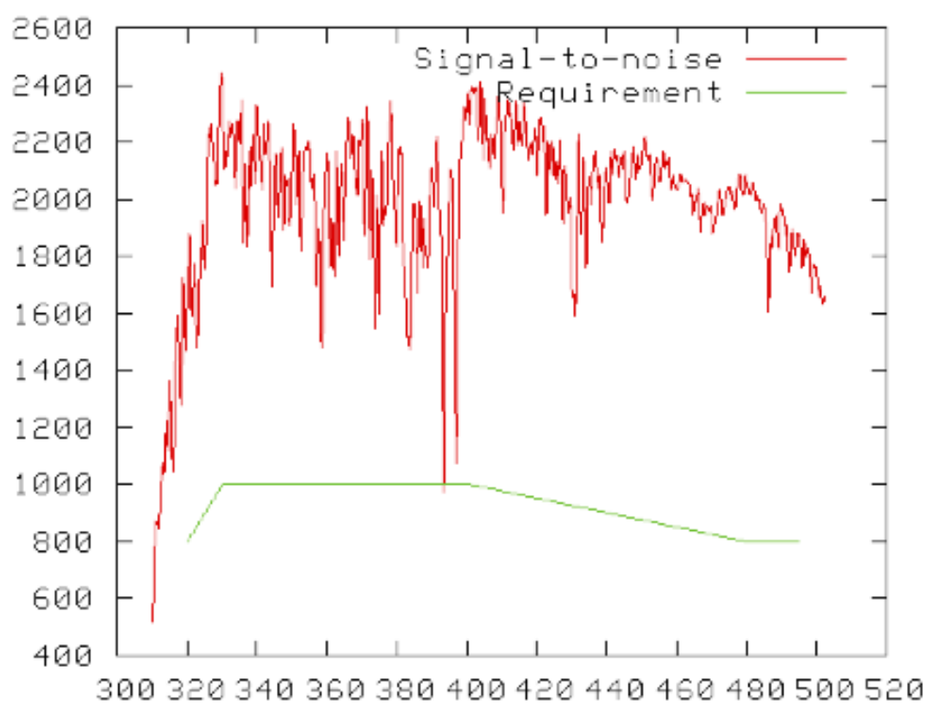
~13x12 km^2 Sampling

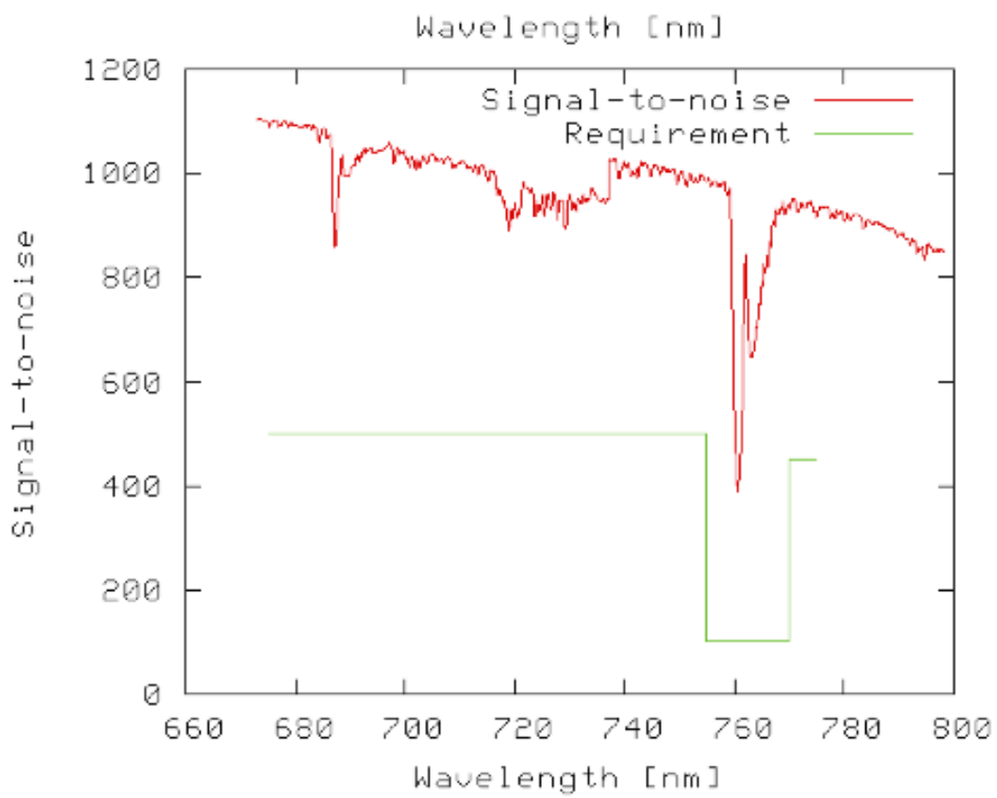
12 September 2006



SNR - CDR Status

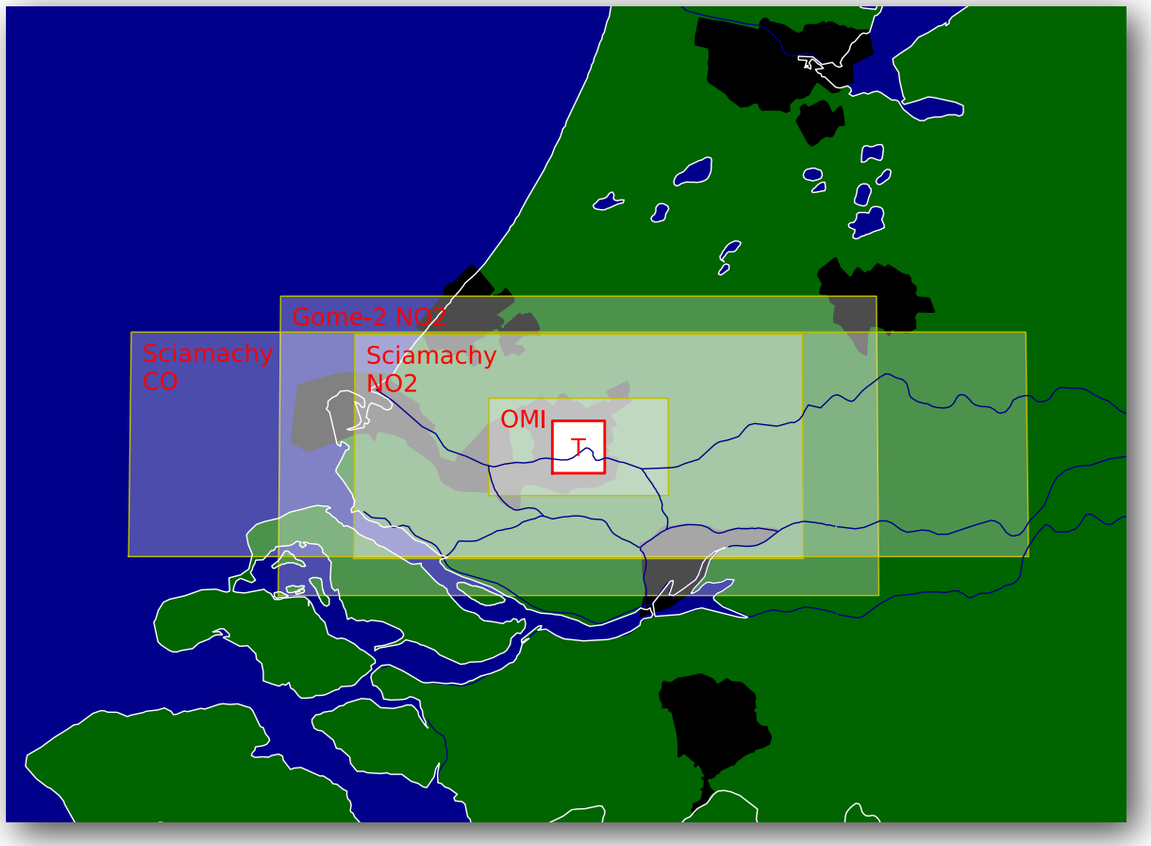


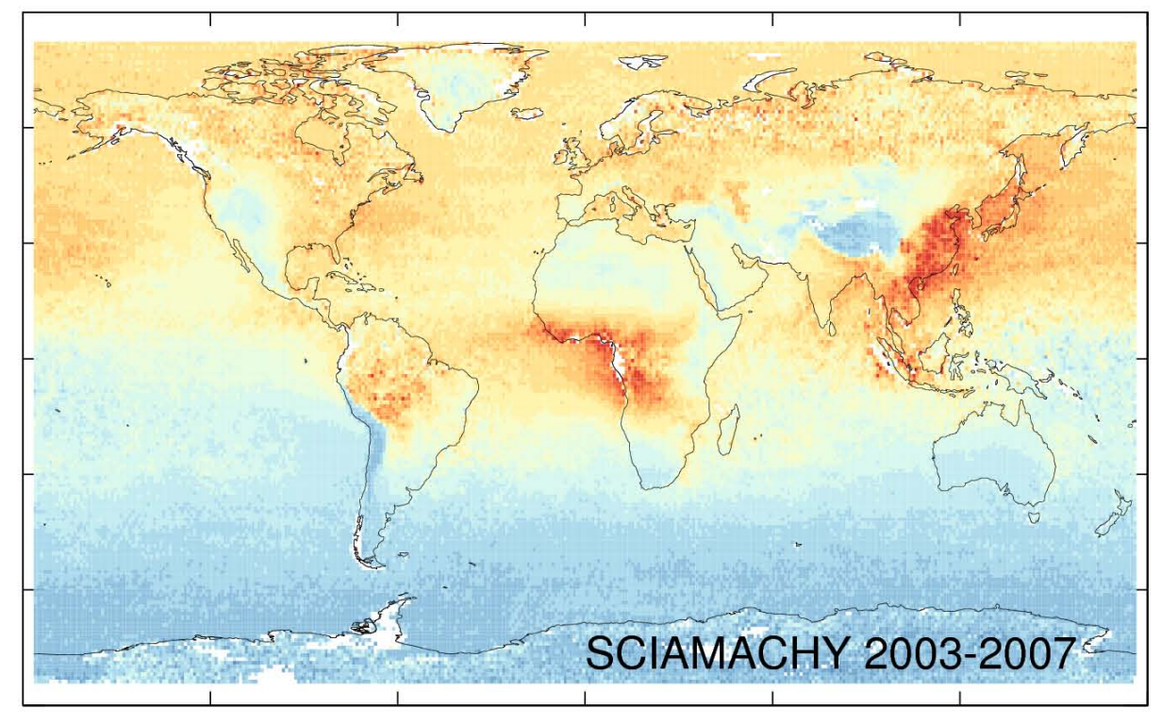




From OMI to TROPOMI

- **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+B bands
- **CO and CH_4 observations** from the SWIR band
- **Data rate ~20x OMI**



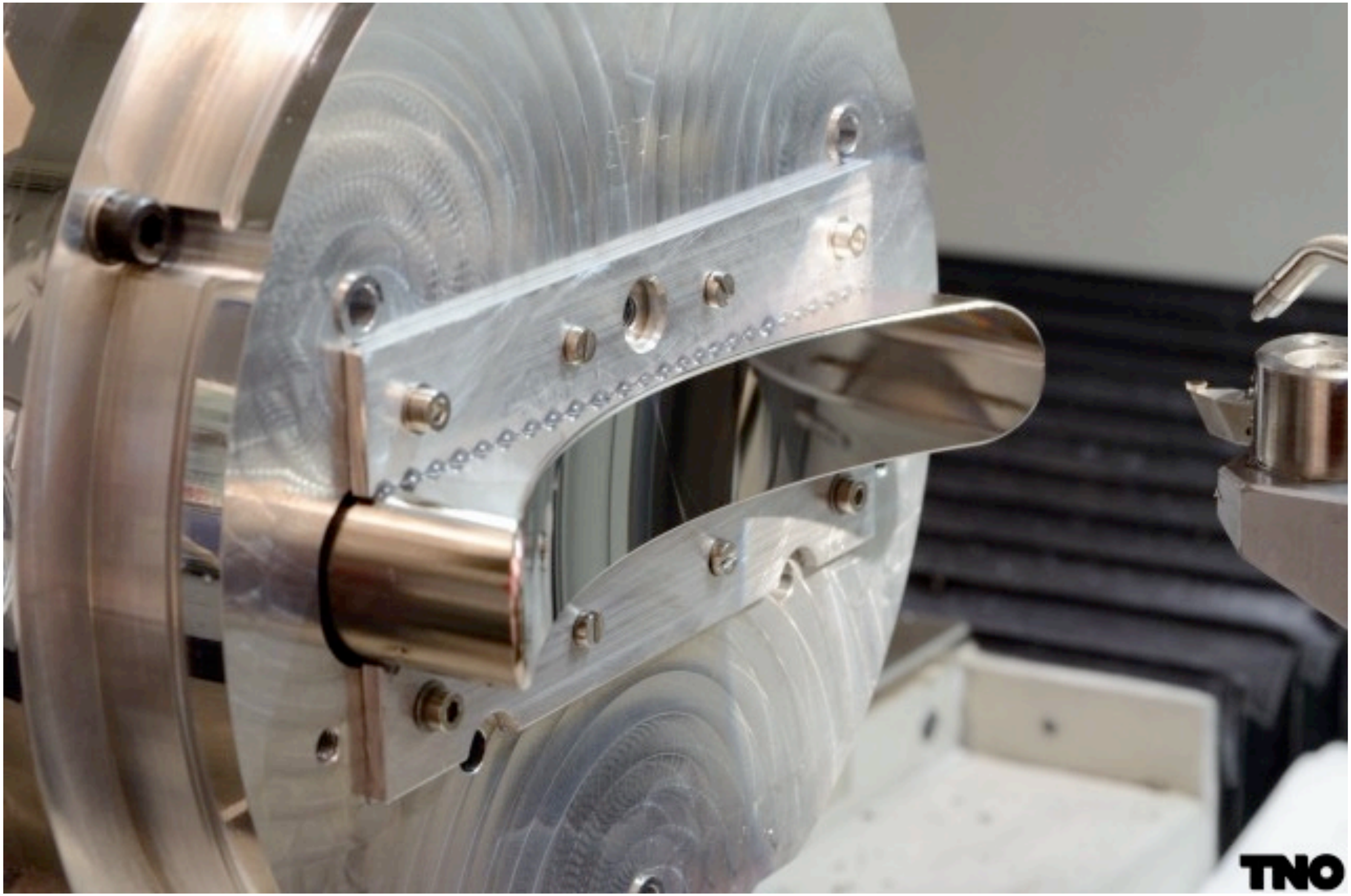


Gloudemans et al., SCIAMACHY CO over land and oceans: 2003–2007 interannual variability, ACP, 2009

OMI Lessons Learned

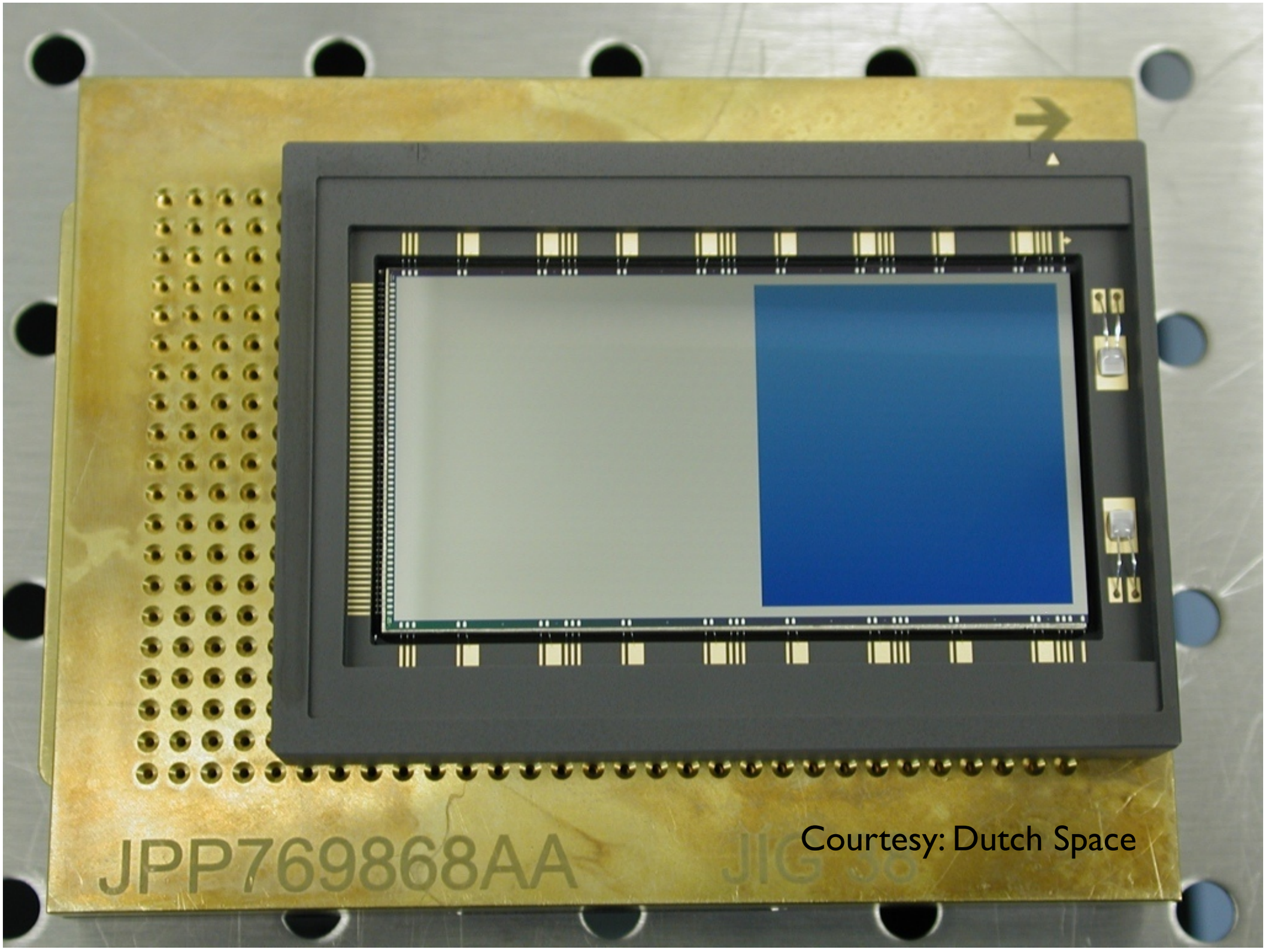
- CCD in NIMO mode and at ~220K because of random telegraph signals (RTS).
- No MLI close to the primary mirror field of view [row anomaly].
- Improve the image quality of the polarization scrambler (Req. pol. sens. 0.5%)
- Two identical QVD solar diffusers measuring over the first mirror.
- No channel breaks around 300 nm.
- Optical bench temperature stabilized.
- One-team approach to L01b, on-ground calibration and in-flight calibration.
- *- many more -*

Telescope First Mirror



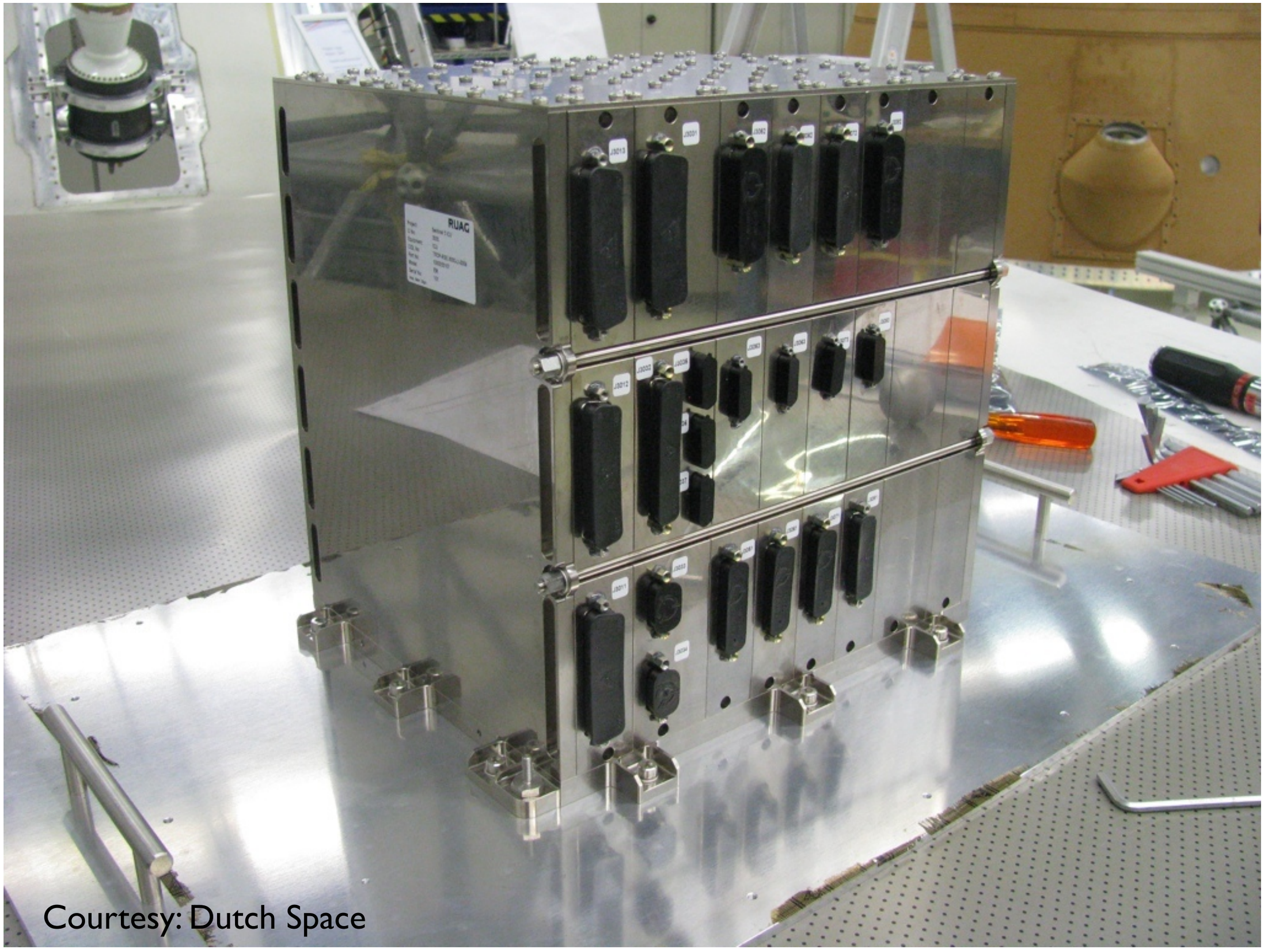
Courtesy: Dutch Space

CCD UVIS Spectrometer



Courtesy: Dutch Space

Instrument Control Unit



Courtesy: Dutch Space

esa | Netherlands Space Office | DLR | belspo

TROPOMI L2 PRODUCTS

L2 Working Group

PROTOTYPE

VERIFICATION

OPERATIONAL SW

GOME-SCIAMACHY-OMI

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

Level 1-2 Algorithm Challenges

- Data rate (300 spectra/s) in combination with NRT requirements requires multi-threading processing.
- Surface albedo / clouds / aerosol are linked. Spatial variations have to be taken into account in the trace gas retrievals.
- Provide realistic diagnostic information and user-friendly product.

The Role of TROPOMI in the GEO Constellation

- Open data policy, including L1B data.
- Harmonize L1B and L2 formats to easily exchange data.
- Use similar on-ground calibration standards and exchange in-flight CAL/VAL procedures.
- Harmonize L1-2 algorithms as far as practically possible (e.g. cross sections, DEM, AMF LUTs)

Summary & Outlook

veefkind@knmi.nl

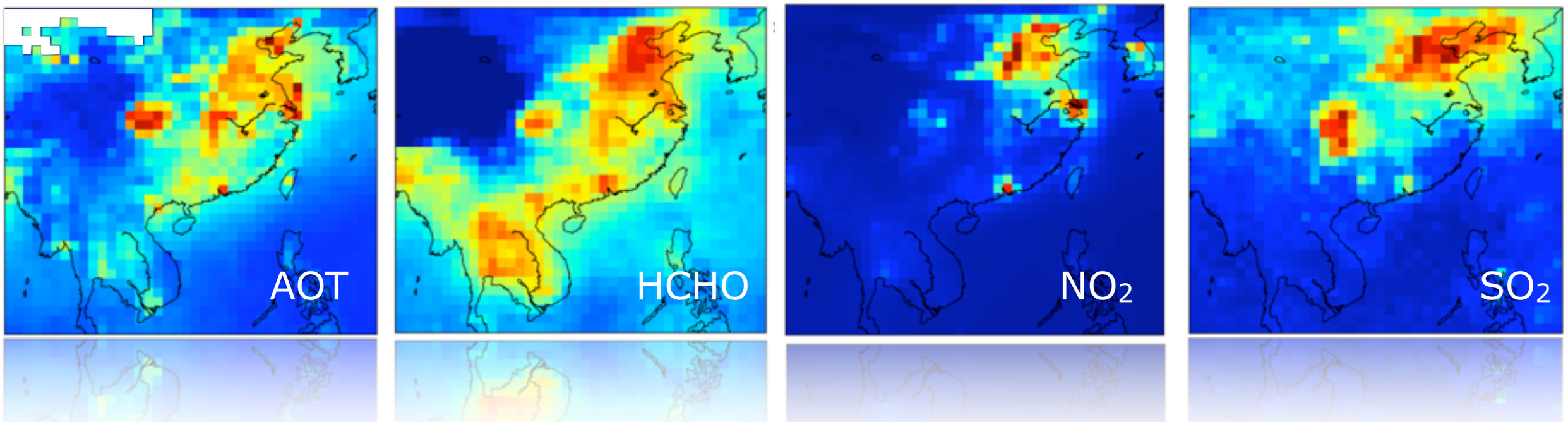
www.tropomi.eu

www.temis.nl

www.knmi.nl/omi

http://www.esa.int/esaLP

- TROPOMI will be a major step forward for atmospheric composition observations due to improved spatial resolution & sensitivity.
- The high spatial resolution provides new opportunities, while at the same time being challenging for the Level 2 product development.
- Sentinel 5 Precursor will connect to the geostationary missions providing in-flight CAL/ VAL opportunities.



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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

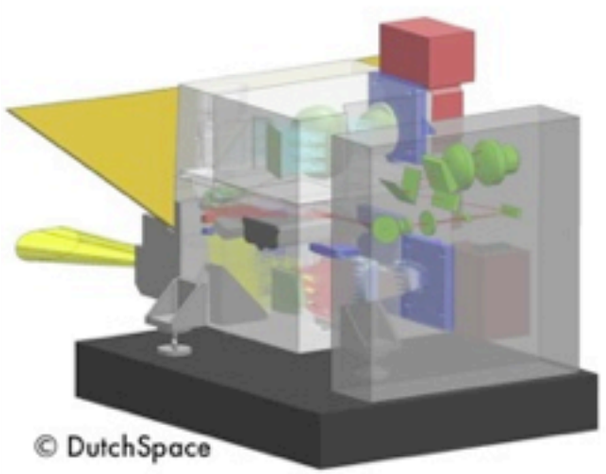
www.tropomi.eu

TROPOspheric Monitoring Instrument

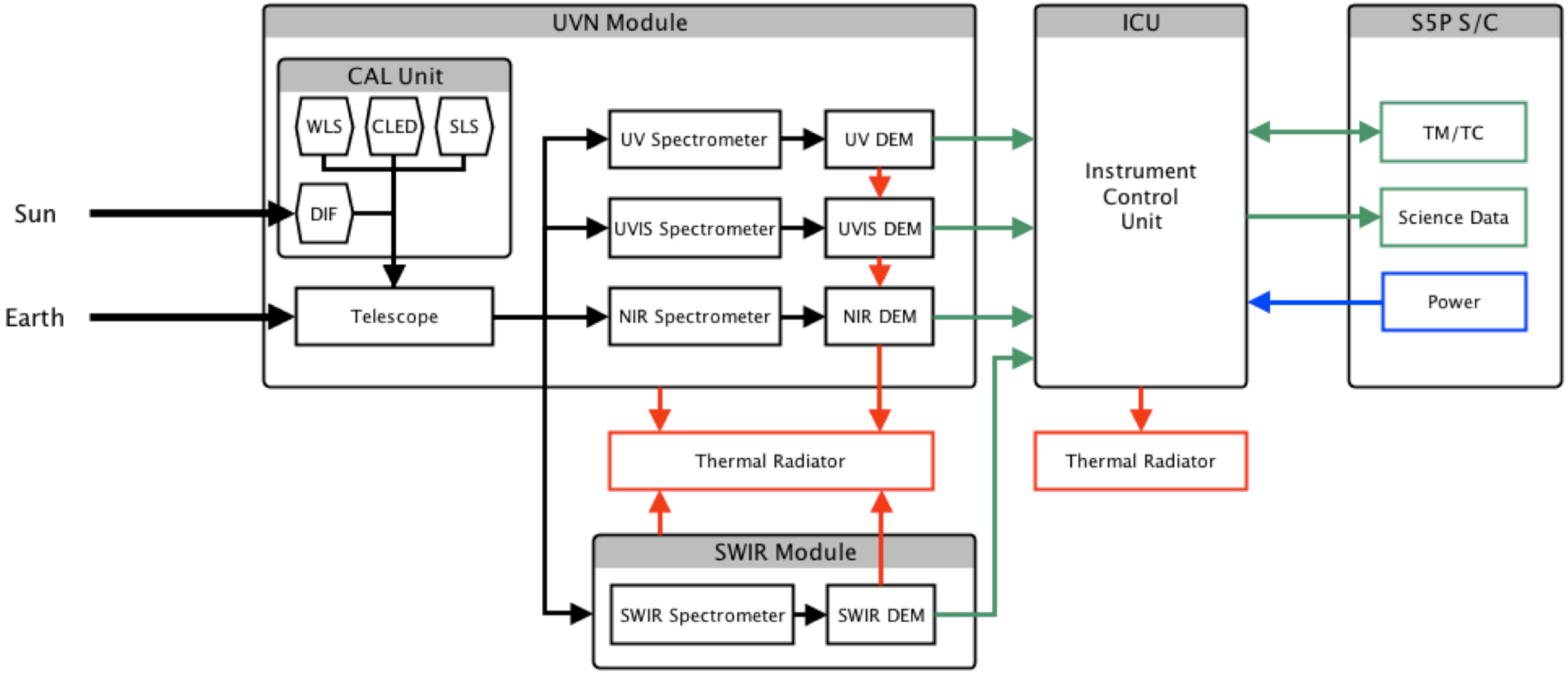
Home Instrument Data Doc Contact

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 extent 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

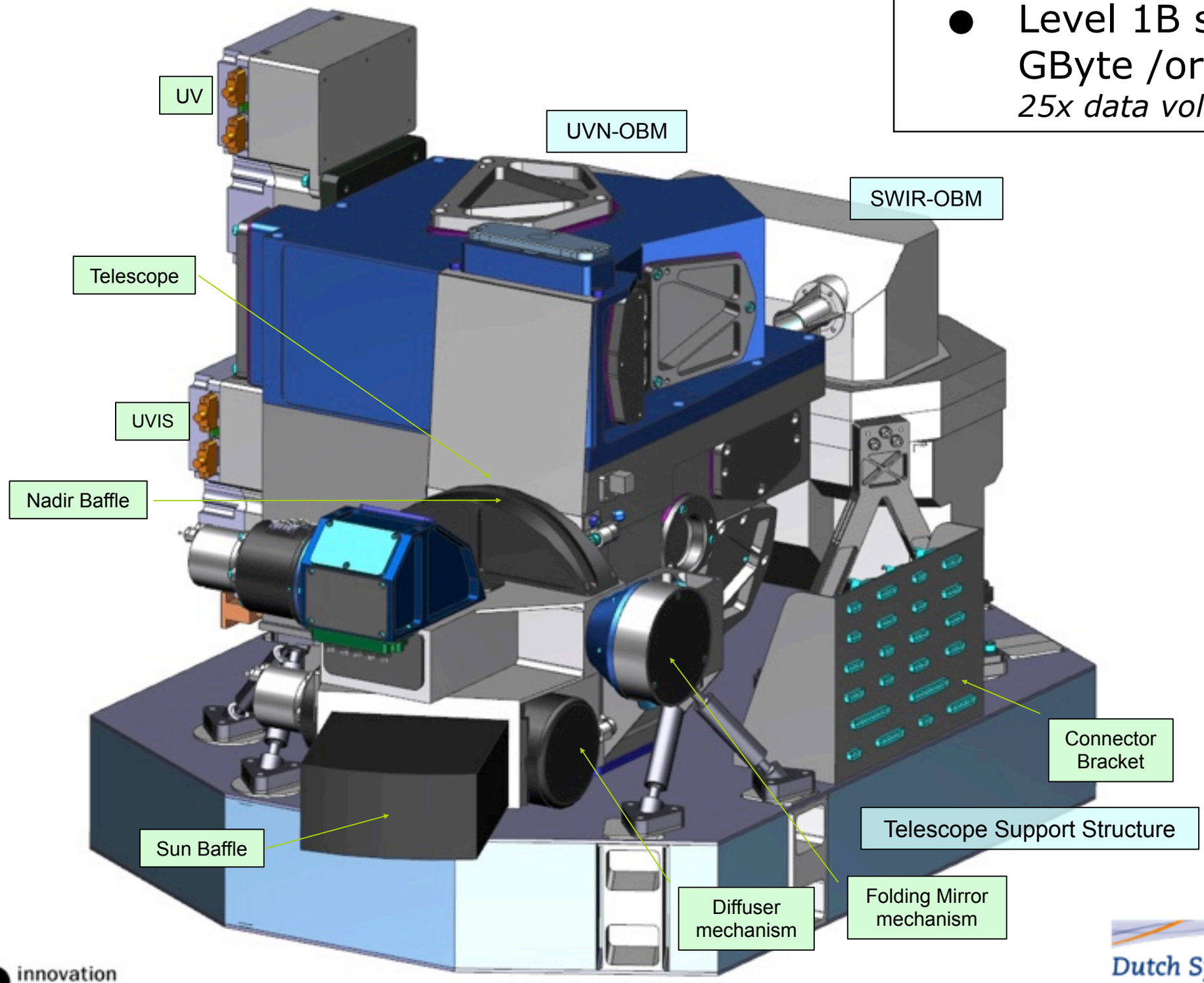


Functional Diagram



TROPOMI

- Mass ~200 kg
- Average power ~150W
- Level 1B size is approx. 20 GByte /orbit:
  25x data volume of OMI



TNO innovation for life

Dutch Space
an EADS Astrium company

Lessons learned incorporated in TROPOMI (1)

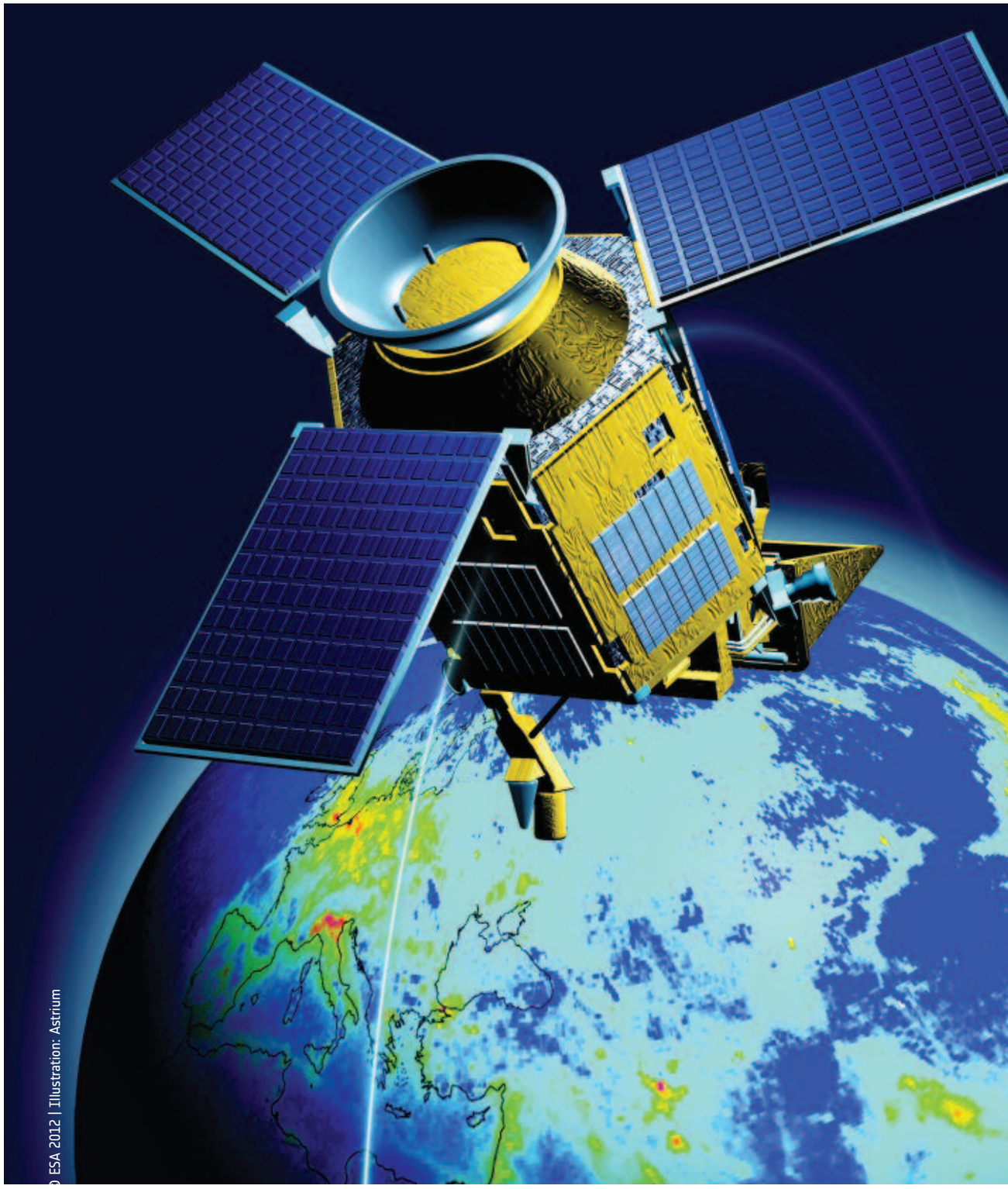
- better heater control
- OBM thermal stabilized
- no MLI in front of primary mirror field of view [row anomaly]
- close interaction between operations, L01b, OCAL, ICAL calibration and L2 people
- CCD used in NIMO to prevent RTS due to radiation damage
- no ALU diffusers, 2 identical QVD diffusers
- WLS and LED in calibration unit [alternative for WLS]
- LED’s for all detectors [better short term stability]
- Laser diodes for ISRF monitoring in SWIR [ice layer]
- operations baseline seasonal independent and optimized for trend monitoring
- aluminum platform [water vapour]

Lessons learned incorporated in TROPOMI (2)

- verification of onground calibration
- validation of accuracy of calibration vs requirements
- tools to monitor the calibration process
- calibration rehearsal
- formal error propagation
- CKD errors not taken into account
- L01b data processor not used during OGC
- flight representative conditions
- calibration definition by PI institute, execution under industry responsibility
- One-team approach to l01b / onground calibration and inflight calibration
- 2 axis turn – tilt cradle in vacuum facility
- No vacuum breaks during calibration [only 1]

Sentinel 5 Precursor Platform

- ASTRIUM
  Astrobus L 250 M
- 3-axis stabilized with yaw steering
- Launch mass 900 kg, including 80 kg fuel
- Data storage 230 Gbit.



Gome-2 NO2

Sciamachy CO

Sciamachy NO2

OMI

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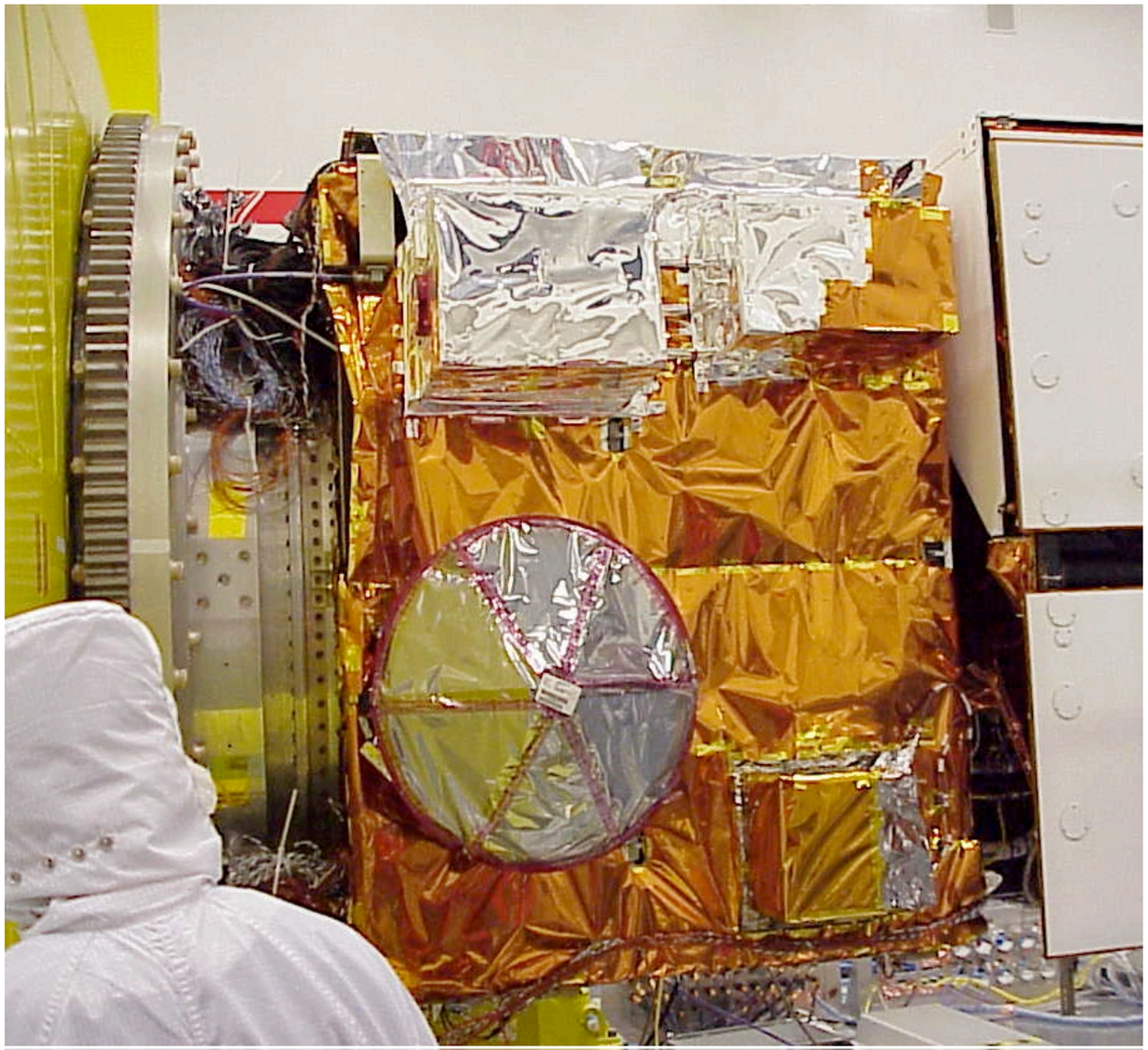
Wednesday, 24 July 2013

Ozone Monitoring Instrument



Ozone Monitoring Instrument

Instrument	Imaging spectrometer
Spectral Range	270 - 500 nm
Spectral Resolution	0.45 - 0.63 nm
Spectral Sampling	0.15 - 0.30 nm
Spatial Resolution	13x24 km^2 (nadir)
Swath Width	2600 km
Mass	65 kg
Size	50 cm × 40 cm × 35 cm
Power	66 W
Data rate	0.8 Mbps (average)
Spacecraft	NASA EOS-Aura
Launch Date	15 July 2004
Orbit	Sun synchronous, 13:30 hr
Altitude	705 km
Agencies	NSO (NIVR), FMI
PI Institutes	KNMI, FMI

OMI is the Dutch-Finnish contribution to the NASA EOS-Aura Mission and is developed by an international consortium led by Dutch Space and TNO.