The Sentinel-4 Mission and its Atmospheric Composition Products

Ben Veihelmann, Yasjka Meijer, Jörg Langen, Paul Ingmann, Rob Koopman, Norrie Wright, Grégory Bazalgette Courrèges-Lacoste, Giorgio Bagnasco

ESA / ESTEC

ATMOS 2015 Conference, 8-12 June 2015
Heraklion, Crete, Greece

Sentinel-4 Mission Objective

Sentinel-4 is designed to provide

- Tropospheric composition measurements
- With fast revisit time
- At high spatial resolution over Europe
- Operationally over at least 15 years
- For the Copernicus Atmosphere Monitoring Services

Copernicus Atmosphere Monitoring Service

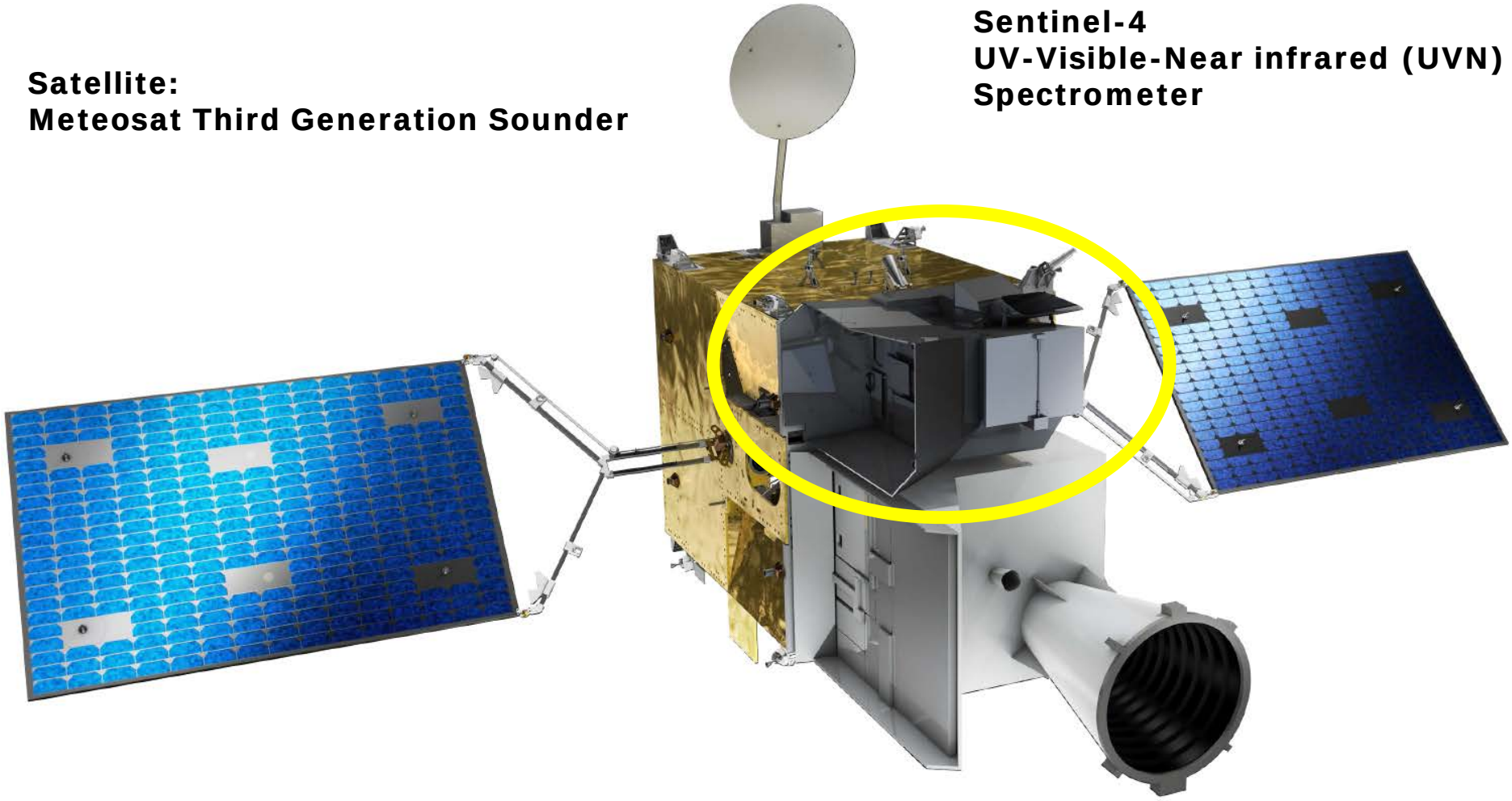
- Operational information services for policy makers, …, citizens
- Protocol compliance monitoring: ozone layer (Montreal, …), air quality (Göteborg, …), climate (Kyoto, …), emission verification
- Near-real-time services: Local air quality, health warning, aviation routing
- Assessments: Improve understanding of processes, validate chemical transport models, ground measurement networks
- Pre-operational: MACC, **http://atmosphere.copernicus.eu**
- Uses observations from current satellites,
  in the future also from **Sentinel-4, -5, -5P**, …

Monitoring atmospheric composition & climate – II

Sentinel-4/UVN Instrument

Satellite:
Meteosat Third Generation Sounder

Sentinel-4
UV-Visible-Near infrared (UVN)
Spectrometer



Infrared Sounder

Image courtesy Airbus Defence & Space

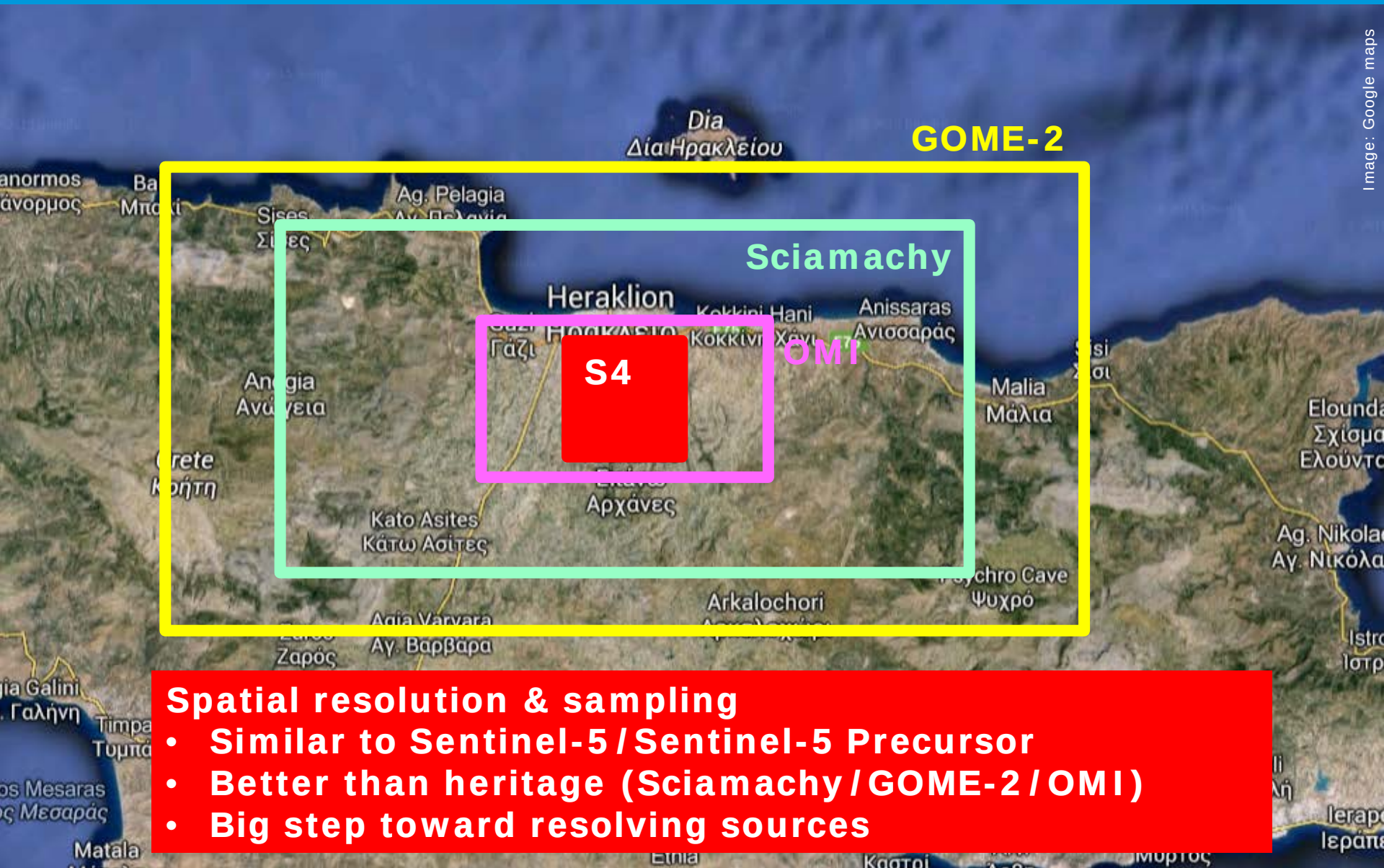
Copernicus

European Space Agency

Sentinel-4/UVN Instrument

Revisit time	1h
Geographic coverage	Europe + part of Atlantic + part of Sahara, FoV = 4° N/S, 11°-14° E/W
Spatial sampling	8 km at 45°N, 530 x 570 spatial samples
Spatial resolution	8.9 km N/S, 11.7 km E/W at 45°N
Spectral range	UV-VIS: 305-500 nm, NIR: 750-775 nm
Spectral resolution	UV-VIS ≤ 0.5 nm, NIR ≤ 0.12 nm
Spectral sampling ratio	>3
Envelope	1000 x 1000 x 1500 mm^3
Mass	200 kg
Power	180 W
Data rate (nominal operation)	30 Mbps

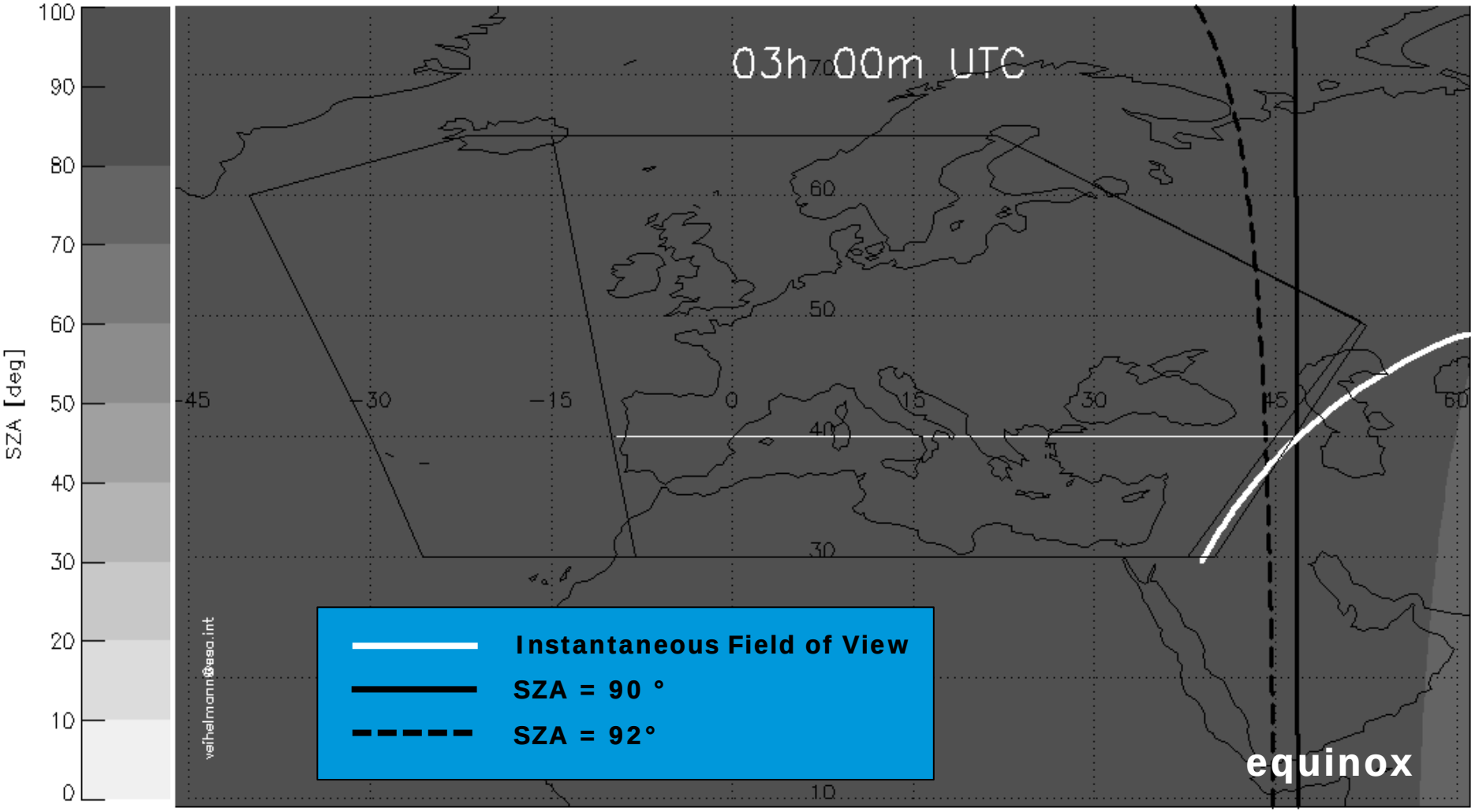
Sentinel-4 Spatial Footprint



Spatial resolution & sampling

- **Similar to Sentinel-5 / Sentinel-5 Precursor**
- **Better than heritage (Sciamachy / GOME-2 / OMI)**
- **Big step toward resolving sources**

Sentinel-4/UVN Instrument



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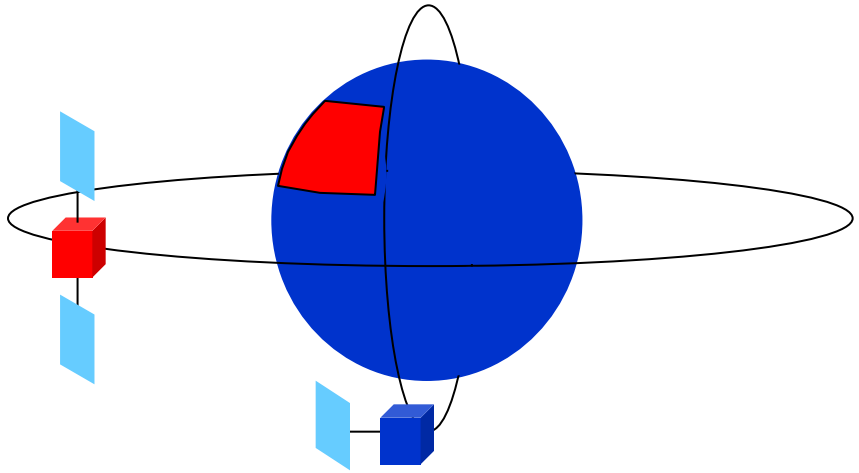
Sentinel-4 Level-2 Target Performances

Species	Uncertainty better than	Conditions (#)
O_3 total column	3% (goal) / 4% (threshold)	all cloud conditions
O_3 tropospheric column	25% (goal) / 40% (threshold)	cloud fraction < 20%
NO_2 tropospheric column	$1.5*10^{15}$ molec/cm² or 30% (goal) / 50% (threshold)	cloud fraction < 20%
HCHO total column	$1.5*10^{16}$ molec/cm² or 50% (goal) / 100% (threshold)	cloud fraction < 20%
SO_2 total column	$1.0*10^{16}$ molec/cm² or 80% (goal) / 100% (threshold)	cloud fraction < 20%, pollution cases
CHOCHO total column	$7.0*10^{14}$ molec/cm² or 50%	total col > $5.0*10^{14}$ molec/cm², cloud fraction < 20%
Aerosol Optical Depth	0.05 (from surface product)	cloud-free
Aerosol Layer Height	1 km	AOD > 0.3 at 760 nm, layer height > 1.5 km
Aerosol Index	0.3 (goal) / 0.5 (threshold)	all cloud conditions
Surface	first BRF parameter 0.01	cloud-free
Clouds	TBD by L2 developers	

(#) For all species: solar zenith angle and viewing zenith angle < 60°

GEO + LEO



GEOstationary (GEO)

- Hourly revisit time over Europe
- Mainly air quality
- Diurnal cycle of tropospheric composition

→ **Sentinel-4**

Low Earth Orbit (LEO)

- Daily revisit time global coverage
- Climate, air quality, ozone & UV
- Tropospheric & stratospheric composition

→ **Sentinel-5**

→ **Sentinel-5 Precursor**

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Sentinel-5 P																
Sentinel-4 – 1																
Sentinel-5 – 1																
Sentinel-4 – 2																
Sentinel-5 – 2																
Sentinel-5 – 3																

GEO + LEO

Mission	Instrument	Utilization of data from		
		Imager	Infrared sounder	Other
Sentinel-4	UVN spectrometer (1)	FCI (2)	IRS (1)	LI (2,*)
Sentinel-5	UVNS spectrometer (3)	VII (3)	IAS (3)	3MI (3)
Sentinel-5 Precursor	UVNS spectrometer TROPOMI (4)	VIIRS (5)	CRIS (5,*)	OMPS (5,*)

(1) on MTG sounder (GEO)
(2) on MTG imager (GEO)
(3) on MetOp-SG (LEO)
(4) on dedicated platform (LEO)
(5) on SNPP/JPSS (LEO)
(*) synergy on higher data level

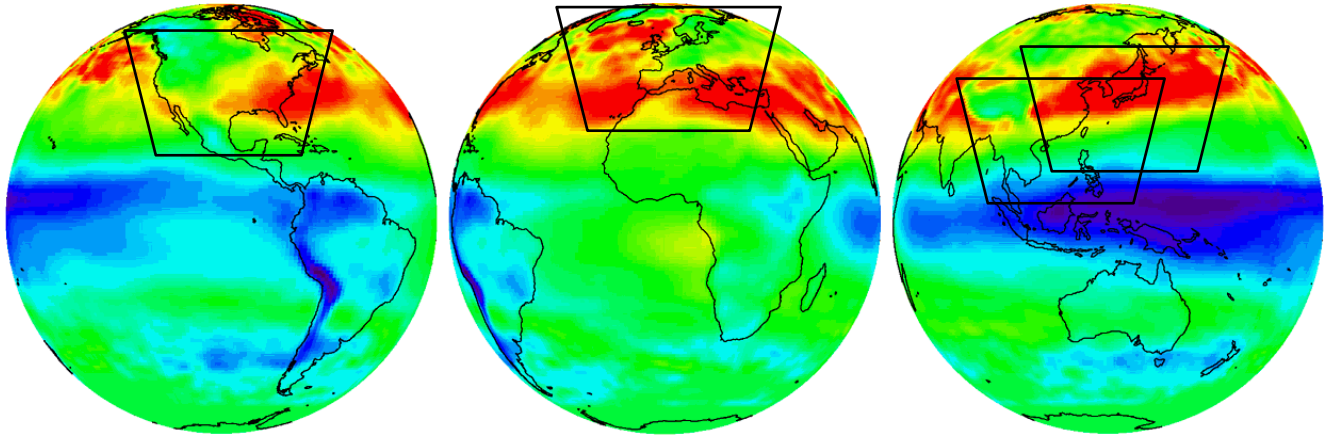
MTG = Meteosat Third Generation
MetOp-SG = MetOp-Second Generation
SNPP = Suomi National Polar-orbiting Partnership
JPSS = Joint Polar Satellite System

UVN = Ultraviolet + Visible + Near infrared
FCI = Flexible Combined Imager
IRS = InfraRed Sounder
LI = Lightning Imager

UVNS = UVN + Short wave infrared
VII = Visible/Infrared Imager (MetImage)
IAS = Infrared Atmospheric Sounder (IASI-NG)
3MI = Multi-viewing, -channel, -polarisation Imager

TROPOMI = TROPOspheric Monitoring Instrument
VIIRS = Visible Infrared Imaging Radiometer Suite
CrIS = Cross-track Infrared Sounder
OMPS = Ozone Mapping Profiler Suite

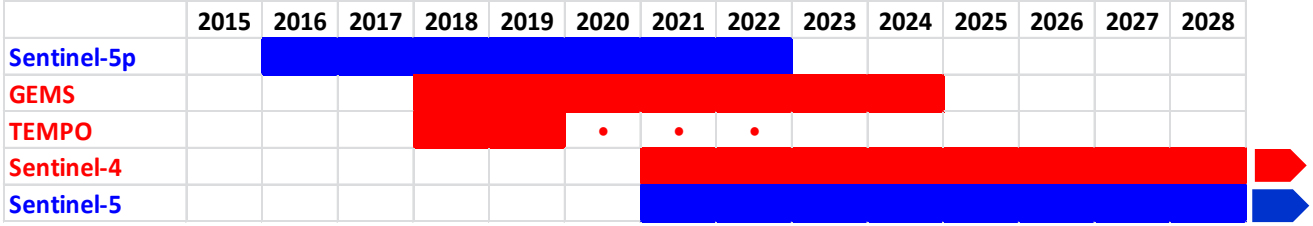
GEO + GEO + GEO + LEO



NASA TEMPO | ESA Sentinel-4 | KARI GEMS / JAXA GMAP-ASIA

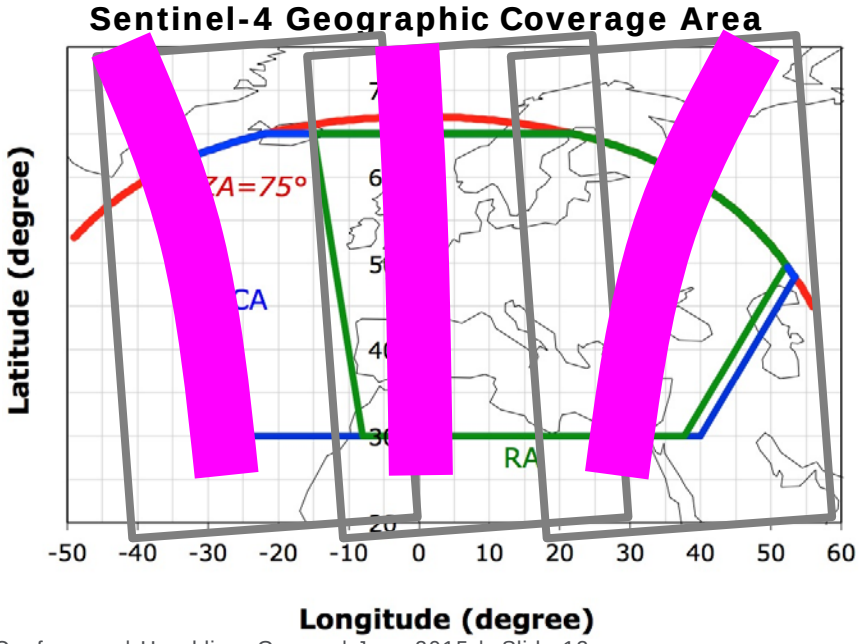
- **GEO** dedicated air quality missions: GEMS, Sentinel-4, TEMPO, …
- **LEO** missions with strong air quality assets: Sentinel-5 Precursor, Sentinel-5, …
- CEOS Atmospheric Composition Virtual Constellation

  www.ceos.org/images/ACC/AC_Geo_Position_Paper_v4.pdf



GEO + LEO

- Perfect co-location daily on several stripes
  - L1b inter-calibration
  - L2 consistency as pre-requisite for data assimilation
- Higher level synergy eg in CAMS



LEO orbits

Co-location within +/-5 min

Sentinel-4 Mission Implementation Status

- S4/UVN instrument & Level-1b Prototype Processor developed by ESA with Airbus Defence & Space as prime
  - Preliminary Design Review completed
  - Intermediate Instrument Performance Review end 2015
  - Critical Design Review mid 2016
  - Flight Acceptance Review early 2021
- Level-1b geometric processing developed on platform level
- Level-2 Operational Processor developed by ESA with DLR as prime
  - Kick-off 2 June 2015
  - Prototype and Operational Processor
  - System Integration & Verification, support to Commissioning
- EUMETSAT will operate the instrument and process the mission data up to Level-2

EUMETSAT

Copernicus

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Thanks for listening!

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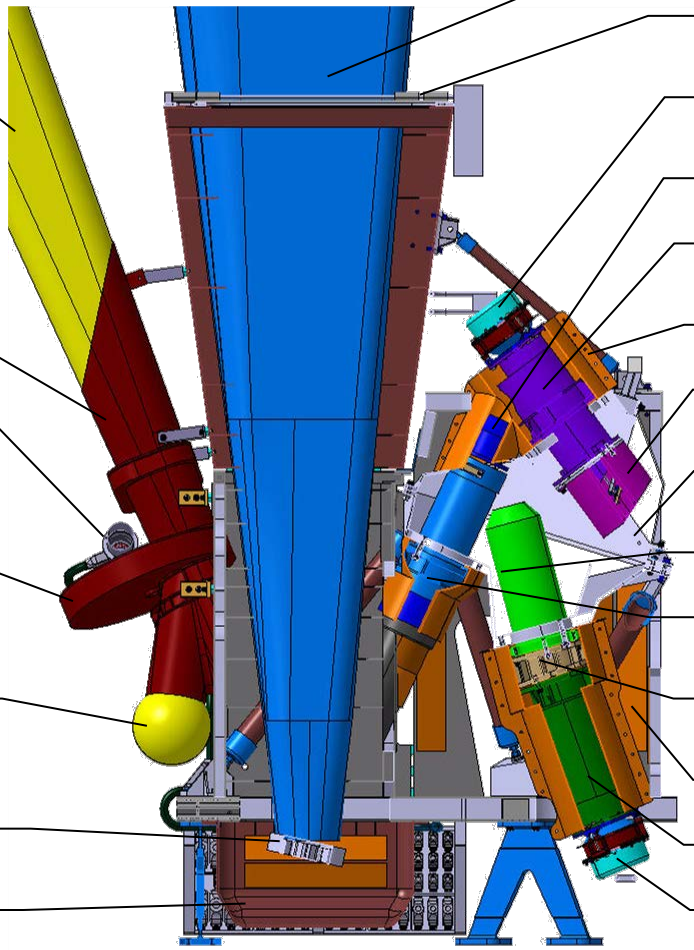
Sentinel-4 UVN Instrument

Optical Instrument Module



Optical Path Sun calibration
Sun Baffle
Diffuser Wheel Drive
Diffuser Wheel
White Light Source
Scan Mirror
Scanner Cover

Summer FoV
Aperture Cover
NIR FPA
Beam Splitter Assembly
NIR Spectrometer OA
Thermal Heat Shields
Grating
TSA Structure
UV-VIS Collimator
Telescope
GRISM Assembly
Heater Envelope
UV-VIS Camera
UV-VIS FPA

Z_{UVN}
Y_{UVN}
X_{UVN}

GEO + LEO

- Revisit time
  - GEO: hourly → Several phases of diurnal cycle, → More clear sky observations / day
  - LEO: daily at equator, several at high latitudes
- Geographic Coverage Area
  - GEO: Europe + part of Sahara + part of Atlantic
  - LEO: global
- Target Species
  - GEO: O_3, NO_2, HCHO, SO_2, aerosol, (CHOCHO) → Air Quality
  - LEO: CO, CH_4, ...
- Target vertical range
  - GEO: spectral range starts at 305 nm → tropospheric ozone
  - LEO: stratospheric ozone profile