Sentinel-4 and Sentinel-5 Mission Overview and Implementation Status

Ben Veihelmann, ESA/ESTEC, Sentinel-4 and -5 Mission Scientist, AC-VC co-chair

The Sentinel-4 and Sentinel-5 teams at ESA, at industry, and within the science community
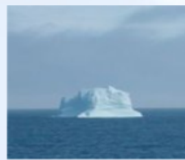
European Space Agency

- European system for monitoring land, marine, atmosphere, climate change, emergency management, security

- Observations from satellites, ground-based, air-borne sensors

- Space Component: Sentinel missions by European Space Agency

- For policymakers, public authorities, …, citizens

Copernicus Atmosphere Monitoring Services

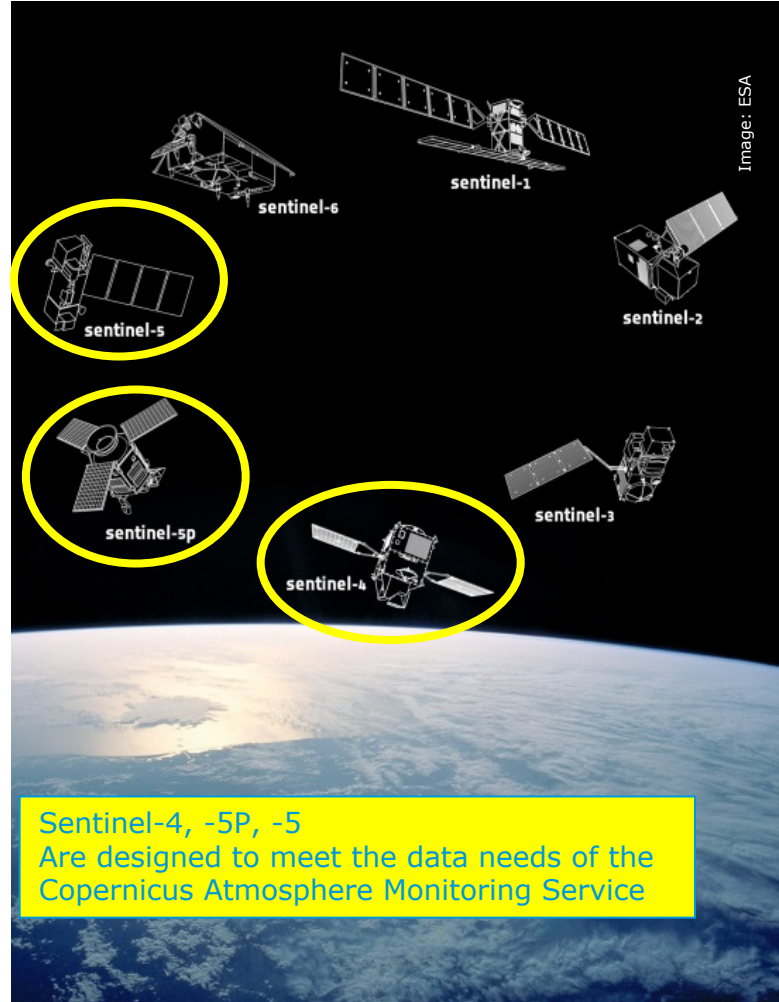Air Quality and Atmospheric Composition | Climate Forcing | Ozone Layer & UV | Solar Radiation | Emissions and Surface Fluxes
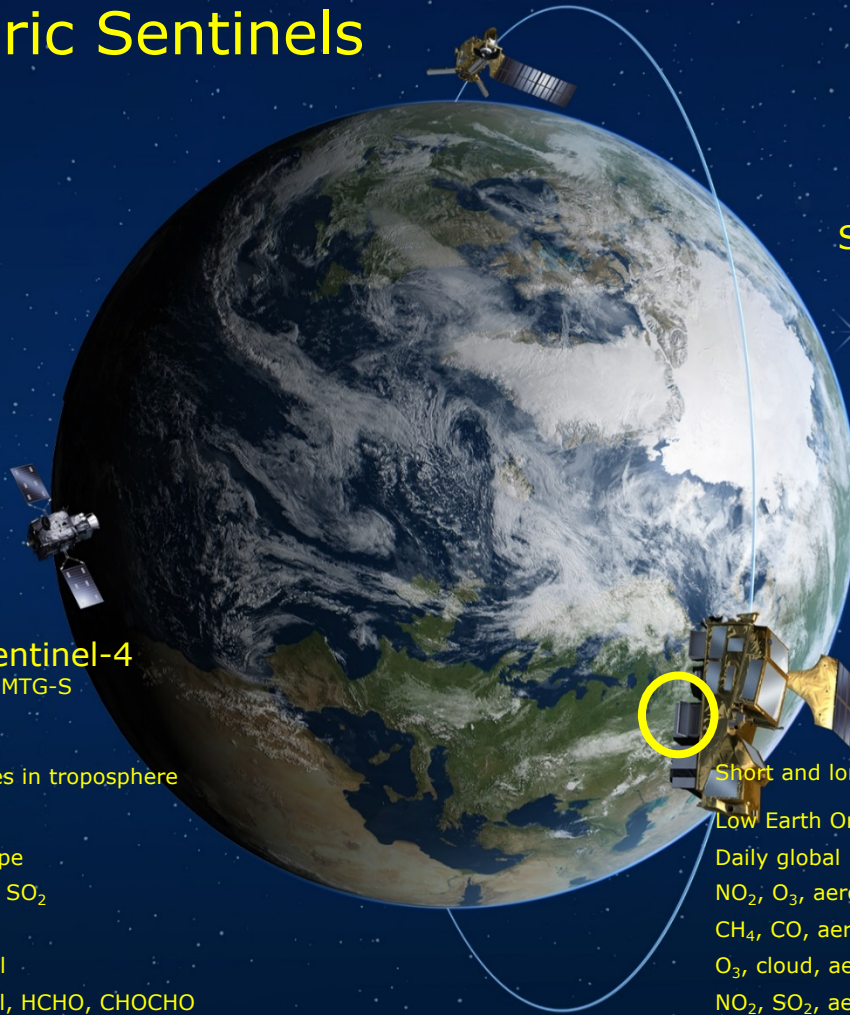
Image: ESA

sentinel-6
sentinel-1
sentinel-5
sentinel-2
sentinel-5p
sentinel-3
sentinel-4

Sentinel-4, -5P, -5
Are designed to meet the data needs of the Copernicus Atmosphere Monitoring Service

European Space Agency

The Atmospheric Sentinels

Sentinel-5 Precursor

Sentinel-4
on MTG-S

Sentinel-5
on MetOp-SG

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Focus	short lived species in troposphere	Short and long lived species in troposphere and stratosphere
Orbit	Geostationary	Low Earth Orbit
Sampling	Hourly over Europe	Daily global
Air Quality	NO_2, O_3, aerosol, SO_2	NO_2, O_3, aerosol, SO_2, CO
Climate	aerosol, O_3	CH_4, CO, aerosol, O_3
Ozone & UV	O_3, cloud, aerosol	O_3, cloud, aerosol
Emissions	NO_2, SO_2, aerosol, HCHO, CHOCHO	NO_2, SO_2, aerosol, HCHO, CO, CH_4

Sentinel-4

- UV - Vis - Near infrared imaging spectrometer (S4/UVN)

- Embarked on Meteosat Third Generation-Sounder (MTG-S) satellite

- Built under responsibility of ESA
  - Instruments and Level-1b prototype processor by a consortium led by Airbus Defence and Space
  - Level-2 operational processor by a consortium led by DLR

- Proto Flight Model integration start in Q3 2018

- Flight Acceptance Review of first MTG-S satellite expected in 2022

- Two S4/UVN instruments in sequence spanning a mission lifetime of 15 years

- Will be operated by Eumetsat

European Space Agency

Sentinel-4

Spectral Ranges [nm]	305-400	400-500	750 – 775
Resolution [nm]	0.5	0.5	0.12
oversampling	3	3	3
Signal to Noise of radiance (SZA ~65°, albedo= 0.05/0.05/0.15)	300 @ 310 nm	1800 @ 450 nm	600 (continuum)
Radiometric Accuracy	2-3%	2-3%	2-3%
Polarisation Sensitivity	1%	1%	1%
Spectral Features	0.05%	0.05%	0.05%

Revisit Time	Coverage Area	Spatial Sampling Distance
hourly	Europe + part of Sahara and Atlantic	8 km @ 40°N
Mass	Power (Obs.)	Data Rate
≈ 200 kg	≈ 180 W (average)	≈ 30 Mb/s (average)

Enhanced Engineering Model of the Sentinel-4 Optical Instrument Module
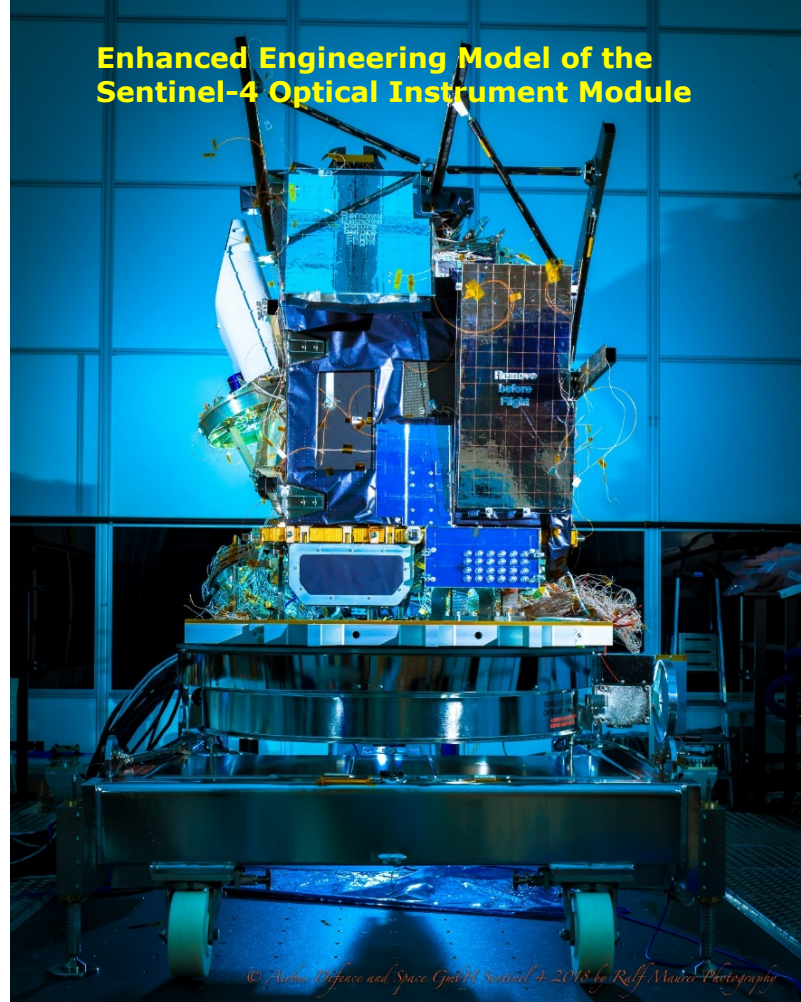
© Airbus Defence and Space GmbH Sentinel 4 2018 by Ralf Mauro Photography

Sentinel-5

- UV - Vis - Near infrared – Short wave infrared imaging spectrometer (S5/UVNS)

- Embarked on MetOp – Second Generation (MetOP-SG) satellite A platform

- Built under responsibility of ESA

  o Instruments and Level-1b prototype processor by a consortium led by Airbus Defence and Space

  o Level-2 prototype processor by a consortium led by S&T

- Engineering Model integration ongoing

- Flight Acceptance Review of the first Metop-SG is expected in 2021

- Three S5/UVNS instruments in sequence spanning a mission lifetime of 21 years

- Will be operated by Eumetsat

European Space Agency

Sentinel-5

Spectral Ranges [nm]	270 - 310	300 – 400	685 - 710	755 – 773	1595 - 1675	2305 - 2385
Resolution [nm]	1	0.5	0.4	0.4	0.25	0.25
Oversampling	3	3	3	3	2.5	2.5
Signal to Noise of radiance (SZA=75/70°, alb=0.02/0.05 in UVN/SWIR)	100 @ 270 nm	1500 @ 420 nm	500 @ 710 nm	500 @ 755 nm	~220 (cont.)	~100 (cont.)
Radiometric Accuracy	3%	3%	3%	3%	6%	3.5%
Polarisation Sensitivity	0.5%	0.5%	0.5%	0.5 / 0.7%	20%	20%
Spectral Features	0.25% and constrained by L2 impact					

Mock-up of the Sentinel-5 Instrument
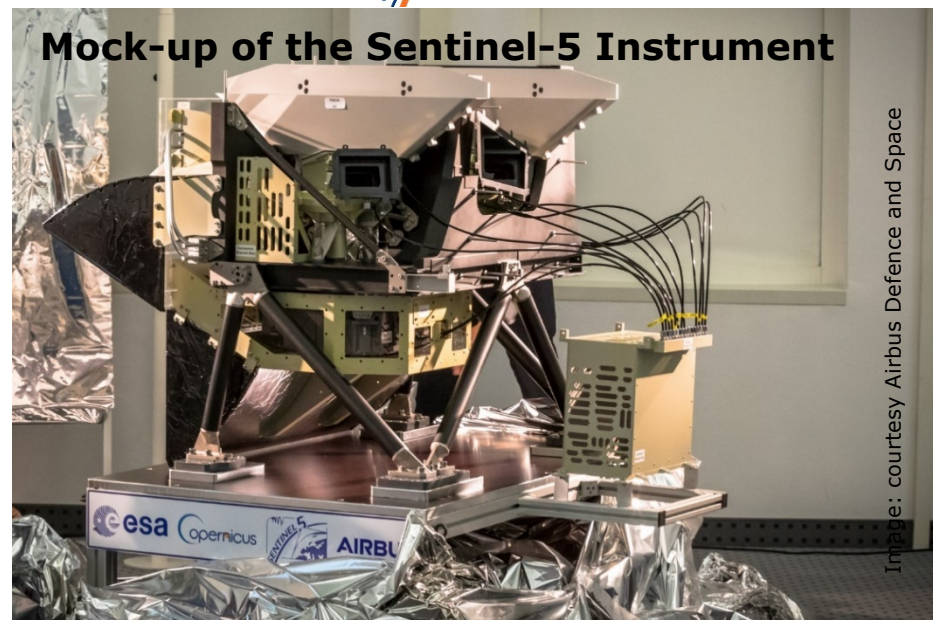
Image: courtesy Airbus Defence and Space

Revisit time	Coverage	Spatial Sampling	Mass	Power (Obs.)	Data Rate
Daily (more often at higher latitudes)	global	7.5 km @ nadir	295 kg	300 W (average)	≈ 20 Mb/s (average)

European Space Agency

Level-2 Algorithms	Sentinel-4	Sentinel-5
O_3 total column	DOAS, iterative AMF computation, cloud as scattering layer, DLR/BIRA	DOAS, iterative AMF computation, cloud as scattering layer, BIRA
O3 profile	Optimal Estimation using Hartley (stratosphere) and Huggins (troposphere) bands, RAL	Optimal Estimation using Hartley (stratosphere) and Huggins (troposphere) bands, RAL
NO_2	DOAS, stratospheric correction based on forecast or spatial filtering, background correction, IUP Bremen, KNMI	DOAS, stratospheric correction based on forecast, background correction using reference sector, KNMI
SO_2	DOAS reference solar irradiance of earth radiance, multiple fit windows, background correction, BIRA	DOAS reference solar irradiance of earth radiance, multiple fit windows, background correction using reference sector, layer height retrieval for SCA>25 DU, BIRA
HCHO	DOAS reference earth radiance, background correction, BIRA	DOAS reference earth radiance, background correction using reference sector, BIRA
CHOCHO	TBD, IUP-Bremen	DOAS reference earth radiance, background correction using reference sector, BIRA
CH_4	-	RemoTec: proxy and full physics retrieval of CH_4, H_2O, CO_2, O_2, using up to 3 bands, SRON
CO	-	SICOR: full physics retrieval of CH_4 and H_2O, using SWIR-3 band, SRON

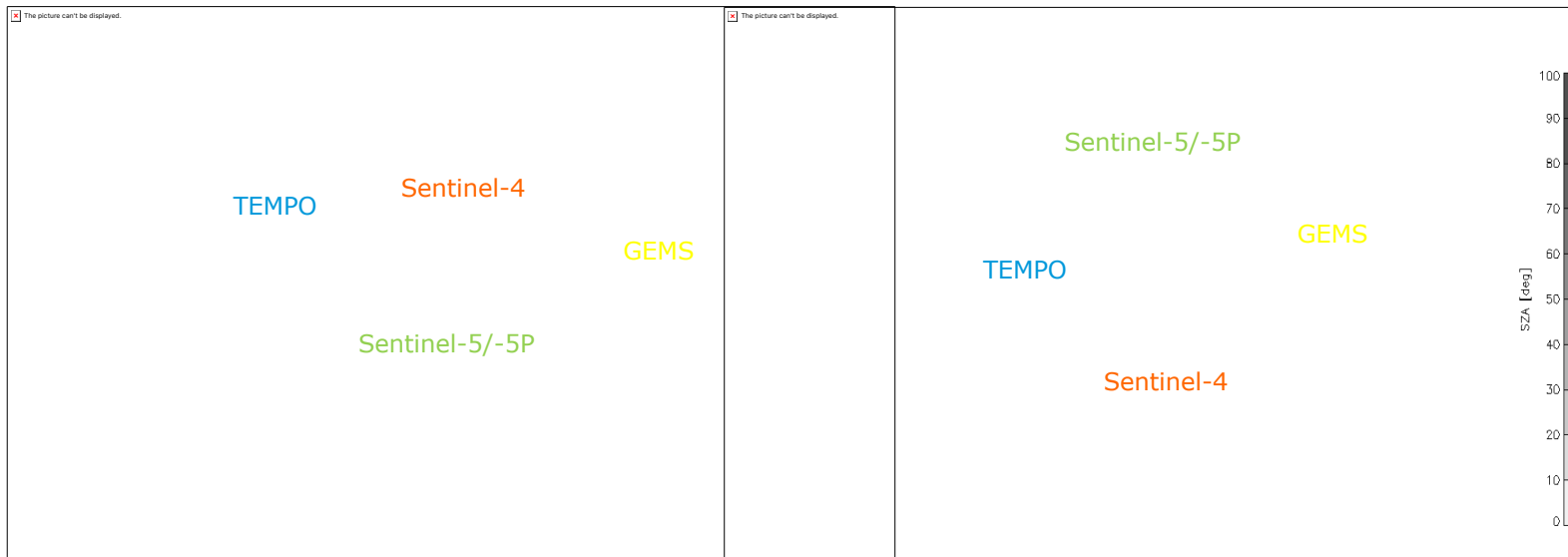| Level-2 Algorithms	Sentinel-4	Sentinel-5
Aerosol	Simultaneously retrieved with surface parameters	AOD from UV-vis (OMAREO extended to visible), KNMI, Omar Torres
Aerosol Layer Height	Optimal Estimation, O_2A-band, pre-filtering, KNMI	Optimal Estimation, O_2A- or O_2B-band, pre-filtering, KNMI
Aerosol Index	Radiometric residual, 3 wavelength pairs, KNMI	Radiometric residual, 3 wavelength pairs, KNMI
Cloud	Cloud fraction from visible (OCRA), top pressure from O_2A-band (ROCINN), DLR	Effective cloud fraction and top height from O_2A- or O_2B- band using LUT based, Fresco, KNMI
Cloud Support	Scene data from FCI for enhanced cloud flagging and processing, spatial co-registration and heterogeneity processing, RAL	Scene data from VII/Metimage for enhanced cloud flagging and processing, spatial co-registration and heterogeneity processing, RAL
Surface	Simultaneous retrieval of LER albedo, BRF, and aerosol optical depth from aggregated data over several days, daily product with hourly time resolution, LOA/Catalysts	LER climatology
Surface UV	-	Erythemal & vitamin-D dose from downwelling near surface irradiance spectrum computed from cloud and aerosol data, FMI

Copernicus Atmosphere Monitoring Service

- Near-real-time analyses and forecasts, re-analyses

- For policy: mitigation impact assessments, air quality reports

- Solar and UV radiation products

- Greenhouse gas surface flux inversions

- Climate forcings

- Anthropogenic emissions

- Uses observations from current satellites, in the future also from Sentinel-4, Sentinel-5, Sentinel-5 Precursor, …

- Operational ➜ **http://atmosphere.copernicus.eu**

See presentation by Richard Engelen Thu afternoon

Sentinel-4 and Sentinel-5 in the AC-VC and GeoAQ constellation

	USA TEMPO	Europe Sentinel-4	Korea GEMS	Sentinel-5/-5P
Orbit	Geostationary	Geostationary	Geostationary	LEO
Domain	North America	Europe and surrounding	Asia-Pacific	global
Revisit [h]	1 hour	1 hour	1 hour	Daily, more @ higher lat
Spectral ranges	UV-Vis	UV-Vis-NIR	UV-Vis	UV-Vis-NIR-SWIR
Key products	O_3, NO_2, SO_2, HCHO, CHOCHO, aerosol	O_3, NO_2, SO_2, HCHO, CHOCHO, aerosol	O_3, NO_2, SO_2, HCHO, CHOCHO, aerosol	O_3, NO_2, SO_2, HCHO, CHOCHO, aerosol, CH_4, CO, ...
Spatial res. [km²]	9 x 5 at 35°N	8 x 8 at 40°N	8 x 7, 8 x 3.5 at 38°N	7 x 7 at nadir