The Copernicus Sentinel-4 Mission

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Project team at ESA: G. Bagnasco, N. Wright, G. Bazalgette Courrèges Lacoste, ...
Level-2 consortium: D. Loyola (DLR), R. Siddans (RAL), T. Wagner (MPIC), ...
Industrial consortium: lead by Airbus Defence and Space

AC-VC-15, hosted by JAXA, 10-13 June 2019, Nakano, Tokyo, Japan
• European system for monitoring land, marine, atmosphere, climate change, emergency management, security
• Observations from satellites, ground-based, air-borne sensors
• Information service for policymakers, public authorities, ..., citizens
• Space Component: Sentinel missions by European Space Agency

Copernicus Atmosphere Monitoring Services

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

Sentinel missions dedicated to atmospheric composition
Copernicus Missions for Atmospheric Composition

**Sentinel-4**
- Focus: Short lived species in troposphere
- Driving Application: Air quality
- Orbit: Geostationary
- Coverage: Hourly over Europe + parts of Atlantic and North Africa

**Sentinel-5 Precursor**
- UVN on dedicated platform
- Focus: Short and long lived species in troposphere and stratosphere
- Driving Application: Air quality, climate, ozone, ...
- Orbit: Low Earth orbit
- Coverage: Daily global

**Sentinel-5**
- UVNS on MetOp-SG A

Image: ESA
Copernicus Sentinel-4 Mission

- Built under the responsibility of ESA
  - Instruments and Level-1b prototype processor by a consortium led by ADS
  - Level-2 operational processor by a consortium led by DLR
- Will be operated by EUMETSAT
- Geostationary
- Embarked on Meteosat Third Generation-Sounder (MTG-S)
- Synergy with FCI and LI on MTG-I, IRS on MTG-S
- Two S4/UVN in sequence → mission lifetime of 15 years
- Flight Acceptance Review planned 2022 (MTG-S1)
- Launch expected 2023
## Copernicus Sentinel-4 UV-Vis-NIR (UVN) Imaging Spectrometer

<table>
<thead>
<tr>
<th></th>
<th>Spectral Range [nm]</th>
<th>Spectral Resolution [nm]</th>
<th>Spectral Oversampling</th>
<th>Signal to Noise Ratio of radiance (SZA~65°, albedo=0.05/0.05/0.15)</th>
<th>Radiometric Accuracy</th>
<th>Polarisation Sensitivity</th>
<th>Spectral Features</th>
<th>Revisit Time</th>
<th>Coverage</th>
<th>Spatial Sampling / Resolution [km²]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spectral Range [nm]</strong></td>
<td>305-400</td>
<td>400-500</td>
<td>750 – 775</td>
<td>300 @ 310 nm</td>
<td>2-3%</td>
<td>1%</td>
<td>0.05%</td>
<td>hourly</td>
<td>Europe + part of Sahara and Atlantic</td>
<td>8×8 / 8.9×11.7 (N/S×E/W @ 45°N)</td>
</tr>
<tr>
<td><strong>Spectral Resolution [nm]</strong></td>
<td>0.5</td>
<td>0.5</td>
<td>0.12</td>
<td>1800 @ 450 nm</td>
<td>2-3%</td>
<td>1%</td>
<td>0.05%</td>
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<tr>
<td><strong>Spectral Oversampling</strong></td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>600 (continuum)</td>
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Sentinel-4/UVN Instrument Concept

Light sources
- Sun
- Earth
- White light source

Optical elements
- Solar diffuser
- Scan mirror
- Telescope
- Polarization scrambler
- Beam splitter
- Slit
- UV-Vis
- LED
- Data Processing Electronics
- NIR
- LED
- Spectrometers with FPA and FEE

Electronics
- LED
- Data Processing Electronics

Sentinel-4/UVN Instrument Concept
Sentinel-4/UVN Schematic View

- Earth Port
- NIR Spectrometer
  - Telescope, Scrambler, Beam-splitter, Slits
- UV-Vis Spectrometer
- Calibration Assembly
- Solar Port
- Scan Mirror
Sentinel-4/UVN Structural Thermal Model (STM)

• Environmental testing successfully completed
• Delivered to MTG early 2017
Sentinel-4/UVN Enhanced Engineering Model (e-EM)

- Microvibration and EMC Tests successfully completed mid 2018
- TB/TV & pre-calibration test completed early 2019
Sentinel-4/UVN Flight Model Status

- Delivered: telescope, collimator, structure, harness, calibration assembly mechanism, aperture cover mechanisms
- Telescope-beamsplitter-scrambler assembly and spectrometers mid 2019
- Proto Flight Model (PFM) and FM2 planned 2021 and 2022
Tropospheric Ozone (O₃)
Total ozone column (O₃)
Nitrogen dioxide (NO₂)
Sulphur dioxide (SO₂)
Formaldehyde (HCHO)
Glyoxal (CHOCHO)
UV Aerosol Index
Aerosol Layer Height
Cloud Height and Fraction
Surface Reflectance and AOD

Copernicus Sentinel-4 Spectral Bands and Fit Windows
## Copernicus Sentinel-4 Level-2 Performances

<table>
<thead>
<tr>
<th></th>
<th>Current Performance Estimate</th>
<th>Target Up to SZA&lt;60°, VZA&lt;60°</th>
<th>GeoAQ Consistency Target</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>O$_3$ total</strong></td>
<td>1.6% random, 3.5% systematic</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>O$_3$ tropospheric</strong></td>
<td>0-6 km 40% random</td>
<td>25%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>NO$_2$ tropospheric</strong></td>
<td>0.5-1.5×10$^{15}$ molec/cm$^2$, AMF: 42% (poll.), 31% (unpoll.)</td>
<td>1.5×10$^{15}$ molec/cm$^2$ or 30%</td>
<td>1×10$^{15}$ molec/cm$^2$</td>
</tr>
<tr>
<td><strong>SO$_2$ total</strong></td>
<td>40% random, 60% systematic (polluted, SZA&amp;VZA=30°)</td>
<td>3×10$^{16}$ molec/cm$^2$ or 60%</td>
<td>1×10$^{16}$ molec/cm$^2$</td>
</tr>
<tr>
<td><strong>HCHO total</strong></td>
<td>70% random, 30% systematic (1×10$^{16}$ molec/cm$^2$)</td>
<td>1×10$^{16}$ molec/cm$^2$ or 80%</td>
<td>1×10$^{16}$ molec/cm$^2$</td>
</tr>
<tr>
<td><strong>CHOCHO total</strong></td>
<td>TBD</td>
<td>7×10$^{14}$ molec/cm$^2$ or 50%</td>
<td>4×10$^{14}$ molec/cm$^2$</td>
</tr>
<tr>
<td><strong>Aerosol Optical Depth</strong></td>
<td>Target met for homogeneous cases</td>
<td>0.05</td>
<td>0.05 @ 440 nm</td>
</tr>
<tr>
<td><strong>Aerosol Layer Height</strong></td>
<td>0.5 km (ocean), 1.5 km (land)</td>
<td>1 km (&gt;1.5 km, AOD$_{760}&gt;0.3$)</td>
<td>-</td>
</tr>
<tr>
<td><strong>UV Aerosol Index</strong></td>
<td>0.3 to 0.5</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td><strong>Surface</strong></td>
<td>Target met for homogeneous cases</td>
<td>First BRF parameter 0.01</td>
<td>-</td>
</tr>
</tbody>
</table>
Copernicus Sentinel-4 Level-2 Processing

L1b Earth radiance
L1b Solar irradiance
CAMS forecast composition
ECMWF forecast meteo
Cloud Imager scene & cloud
Background map
S4 surface & aerosol

Data-Driven L2 processor
L2 products

Copernicus Services
- Atmosphere (CAMS)
- Climate (CDI)

Other services
- Operational & pre-operational
- Global, regional, local
- Commercial, non-commercial

Scientific Users

Other Users

Data-Driven L2 processor
Daily background processor
Daily S4 surface & aerosol

ESA UNCLASSIFIED - For Official Use
Copernicus Sentinel-4 and Sentinel-5 Data

- **Free, full, and open access**
  - Copernicus Sentinel Data Policy & EU Regulations
- Processed up to L2 in EUMETSAT’s MTG and EPS-SG ground segments
- Dissemination of L2 products in NRT via EumetCast
- Access to L1b and L2 via **EUMETSAT Data Centre**
  - L1b and L2 via rolling archive (limited time horizon and bandwidth)
  - L1b and L2 via archive
- Cloud-based access to data and processing tools
  - **DIAS**: Copernicus Data and Information Access Services, funded by EC
  - Enable users to build applications and process large datasets easily
- **Copernicus Services benefitting from the atmospheric Sentinels**
  - **CAMS**: Copernicus Atmosphere Monitoring Service
  - **C3S**: Copernicus Climate Change Service
Copernicus Sentinel-4 Mission Implementation Status

• Instruments and Level-1b prototype processor
  o Critical Design Review completed
  o STM and e-EM and tests completed
  o On-ground C&C planned for 2021
  o PFM delivery to MTG planned for 2021
  o Flight Acceptance Review planned 2022 (MTG-S1)

• Level-2 operational processor by a consortium led by DLR
  o Algorithm breadboarding
  o Independent Verification
  o Critical Design Review completed
  o Deliveries v1 end 2019, v2 after C&C, v3 after launch

• Launch expected 2023
Thank you
Copernicus Atmosphere Monitoring Service (CAMS)

Provides

- Air pollution over Europe monitoring and forecast: near-surface NO$_2$, SO$_2$, O$_3$, PM
- Atmospheric composition global analyses, forecasts, re-analyses
- Emission inventories for SO$_2$, NO$_x$, VOC, NMVOC, PM2.5, CH$_4$
- Essential Climate Variables monitoring of CH$_4$, O$_3$, aerosol, precursors
- Radiative forcing estimates
- Constrain atmospheric oxidizing capacity, improve process understanding and models
- Volcanic emission events monitoring
- Stratospheric ozone events monitoring
- Down-welling irradiance and erythemal dose rates

- Implemented by ECMWF
- https://atmosphere.copernicus.eu
Copernicus Climate Change Service (C3S)

Provides

• Authoritative climate information to enable mitigation and adaptation strategies by policy makers and businesses
• Essential Climate Variable records via Climate Data Store (CDS)
• Tools and expert guidance to transform data into visual products
• Essential Climate Variable assessment reports

• Implemented by ECMWF
• https://climate.copernicus.eu
Air Quality Constellation

Sentinel-4

Sentinel-5, GOME-2

TEMPO

Sentinel-5P, OMPS, EMI

GEMS