Taking the Pulse of our Planet
ESA-Developed Earth Observation Missions

Satellites

25 under development

15 in operation
ESA-Developed Earth Observation Missions

Satellites

25 under development
15 in operation

Science
Copernicus
Meteorology
Science: Earth Explorers

- **flex**
  - ESA’s Fluorescence Mission
  - 2023

- **goce**
  - ESA’s Gravity Mission
  - 2009–2013

- **biomass**
  - ESA’s Forest Mission
  - 2022

- **smos**
  - ESA’s Water Mission
  - 2009–present

- **earthcare**
  - ESA’s Cloud, Aerosol, and Radiation Mission
  - 2022

- **cryosat**
  - ESA’s Ice Mission
  - 2009–present

- **aeolus**
  - ESA’s Wind Mission
  - 2018–present

- **swarm**
  - ESA’s Magnetic Field Mission
  - 2013–present
Earth Explorer 9 – Two Candidates

Mission selection 2019; launch around 2025

**FORUM**

Far-infrared Outgoing Radiation Understanding and Monitoring

Benchmark measurements will improve our understanding of the greenhouse effect and contribute to climate change assessments accuracy

**SKIM**

Sea-surface Kinematics Multiscale monitoring

Will carry novel wide-swath scanning multibeam radar altimeter to measure ocean-surface currents with Doppler technique
Earth Explorer 10 – Three Candidates

**STEREOID**

- Bistatic SAR as passive followers of Sentinel-1
- Two <500kg spacecraft

**Applications**
- Cryosphere
- Oceanography
- Geosphere

**Daedalus**

- Explore mesosphere, lower thermosphere, and Ionosphere
- Four cubesats at 120 km altitude

- Focus on temperature, heating processes & composition structure

**G-CLASS**

- Science on daily water cycle
- Geostationary C-band SAR

- Benefits for weather forecasting, hydrology, mountain cryosphere
Doppler Wind Lidar:
- Operated in the UV, measuring winds in cloud free atmosphere, in optically thin cloud/aerosol layers, and on top of optically thick clouds

Orbit:
- Sun synchronous, 6 am/pm local time, 320 km altitude
- 7 day repeat cycle, 111 orbits per week

Products:
Level-2A: backscatter and extinction coeffs => cloud/aerosol vertical structure and properties
Level-2B: Profiles of single component wind vectors (~u)
- 24 layers: surface to 30km
- horiz. res. 85 km (Rayleigh) and 10 km (Mie)
Level-2C: ECMWF-assimilated wind vectors
Aeolus observed molecular (left) and particle/cloud (right) Level 2B winds

Courtesy Michael Rennie, ECMWF
ESA-Developed Earth Observation Missions

25 under development
15 in operation
## Copernicus – Sentinel Status

<table>
<thead>
<tr>
<th>S-1</th>
<th>S-2</th>
<th>S-3</th>
<th>S-4</th>
<th>S-5P</th>
<th>S-5</th>
<th>S-6</th>
</tr>
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<tbody>
<tr>
<td><strong>A</strong>&lt;br&gt;3 Apr. 2014</td>
<td><strong>A</strong>&lt;br&gt;23 Jun. 2015</td>
<td><strong>A</strong>&lt;br&gt;16 Feb. 2016</td>
<td><strong>A</strong>&lt;br&gt;2022</td>
<td><strong>A</strong>&lt;br&gt;13 Oct. 2017</td>
<td><strong>A</strong>&lt;br&gt;2021</td>
<td><strong>A</strong>&lt;br&gt;2020</td>
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<td><strong>B</strong>&lt;br&gt;25 Apr. 2016</td>
<td><strong>B</strong>&lt;br&gt;6 Mar. 2017</td>
<td><strong>B</strong>&lt;br&gt;25 Apr. 2018</td>
<td><strong>B</strong>&lt;br&gt;2027</td>
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Copernicus Sentinel-5P

Launch: 13 Oct 2017
Lifetime: 7 years
Swath: 2600km
Resolution: 3.5 x 7 km
Coverage: daily, global
- Methane (CH₄)
- Tropospheric Ozone Column (trop. O₃)
- Sulfur Dioxide (SO₂)
- Formaldehyde (OCHO)
- Total Columns of Ozone (O₃)
- Nitrogen Dioxide (NO₂)
- Carbon Monoxide (CO)
- Cloud information
- Aerosol information
- Radiances/Irradiances
Sentinel-5P results

Transboundary Carbon Monoxide

Total Ozone columns

Copyright: Contains modified Copernicus Sentinel data (2017-2019) / processed by SRON and KNMI
Copernicus: Global European Leadership in EO

> 215,000 registered users = tip of the iceberg

250 TB satellite data distributed per day

Full, free & open data policy

6 operational services

- Land
- Atmosphere
- Ocean
- Climate
- Disaster
- Security

7 satellites flying

- S1
- S2
- S3
- S4
- S5P
- S5
- S6

Preparing Copernicus 2.0
Copernicus 2.0 – New Monitoring Missions

Anthropogenic CO₂ Mon. Mission
- Causes of Climate Change

CRISTAL – Polar Ice & Snow Topography
- Effects of Climate Change

CIMR – Passive Microwave Radiometer
- Sea: Surface Temp. & Ice Concentration

Land Surface Temperature Mission
- Agriculture & Water Productivity

CHIME – Hyperspectral Imaging Mission
- Food Security, Soil, Biodiversity

L-band SAR Mission
- Vegetation & Ground Motion & Moisture

Causes of Climate Change
- Agriculture & Water Productivity

Effects of Climate Change
- Food Security, Soil, Biodiversity

Sea: Surface Temp. & Ice Concentration
- Vegetation & Ground Motion & Moisture
## Essential Climate Variables (ECVs)

<table>
<thead>
<tr>
<th>Measurement domain</th>
<th>Essential Climate Variables</th>
</tr>
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<tbody>
<tr>
<td><strong>Atmospheric</strong></td>
<td>Surface: air temperature, wind speed and direction, water vapour, pressure, precipitation, surface radiation budget &lt;br&gt;Upper-air: temperature, wind speed and direction, water vapour, cloud properties, Earth radiation budget, lightning &lt;br&gt;Composition: carbon dioxide (CO2), methane (CH4), other long-lived greenhouse gases, ozone, aerosol, precursors for aerosol and ozone</td>
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<tr>
<td><strong>Oceanic</strong></td>
<td>Physics: temperature; sea surface and subsurface; salinity; sea surface and subsurface; currents, surface currents, sea level, sea state, sea ice, ocean surface stress, ocean surface heat flux &lt;br&gt;Biogeochemistry: inorganic carbon, oxygen, nutrients, transient tracers, nitrous oxide (N₂O), ocean colour &lt;br&gt;Biology/ecosystems: plankton, marine habitat properties</td>
</tr>
<tr>
<td><strong>Terrestrial</strong></td>
<td>Hydrology: river discharge, groundwater, lakes, soil moisture &lt;br&gt;Cryosphere: snow, glaciers, Ice sheets and Ice shelves, permafrost &lt;br&gt;Biosphere: albedo, land cover, fraction of absorbed photosynthetically active radiation, leaf area index, above-ground biomass, soil carbon, fire, land surface temperature &lt;br&gt;Human use of natural resources: water use, greenhouse gas fluxes</td>
</tr>
</tbody>
</table>
• Established 2010
• €160M
• 21 ECVs in total

• Operational production of 13 CCI ECVs has been transferred to C3S
Generating an ECV

ESAs Climate Change Initiative (CCI) generates Europe's first-generation Climate Change Derived Products (CCDPs) – Climate Change Indicators (CCI-Indicators) – to provide rich, geospatially referenced, long-term datasets of climate variables. These datasets are based on satellite and archived data and provide a unique perspective on climate change. The diagram illustrates the process of generating an ECV (Climate Change Derived Product), which includes understanding climate services, supporting policy, peer-reviewed scientific publications, climate model validation, and developing a toolbox for analysis. The process also involves archiving and outreach, data processing, and product generation, leading to the creation of ECVs and CDRs.
Climate Modelling User Group (CMUG)

Hadley Centre, DLR, ECMWF, BSC, Meteo France, MPI-Met, IPSL, SMHI

Provides feedback to CCI projects on:

- Climate science user requirements
- ECV product specification  
  e.g. product uncertainties
- Independent assessments of using CCI data  
  in modelling studies: verification, assimilation, etc.
- Cross-ECV consistency
Exploiting the satellite archive – Soil Moisture ECV

35+ years of satellite data
Climate Change Initiative

Atmospheric Carbon Dioxide (ppm)

Sea Ice Concentration

Land Cover & Sea Surface Temperature time series

9,000 Gt glacier ice loss since 1961

Antarctic Ice Sheet Contribution to Global Sea Level

Global Mean Sea Level Budget
CCI achievements to date

- **178** Institutions
- **22** ECVs
- **13** ECVs transferred to Copernicus

- **450** European scientists
- **133** terabytes
- **100+** datasets
- **4.2** million files

- **640** Peer-reviewed articles
- **IPCC AR5**
  - **28** Contributing authors
  - **15** Papers, cited 60 times