ESA Earth Observation & Climate

Simon Pinnock, ESA Climate Office

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Image credit: Shane Sutton

ESA Vision for EO

Taking the Pulse of our Planet

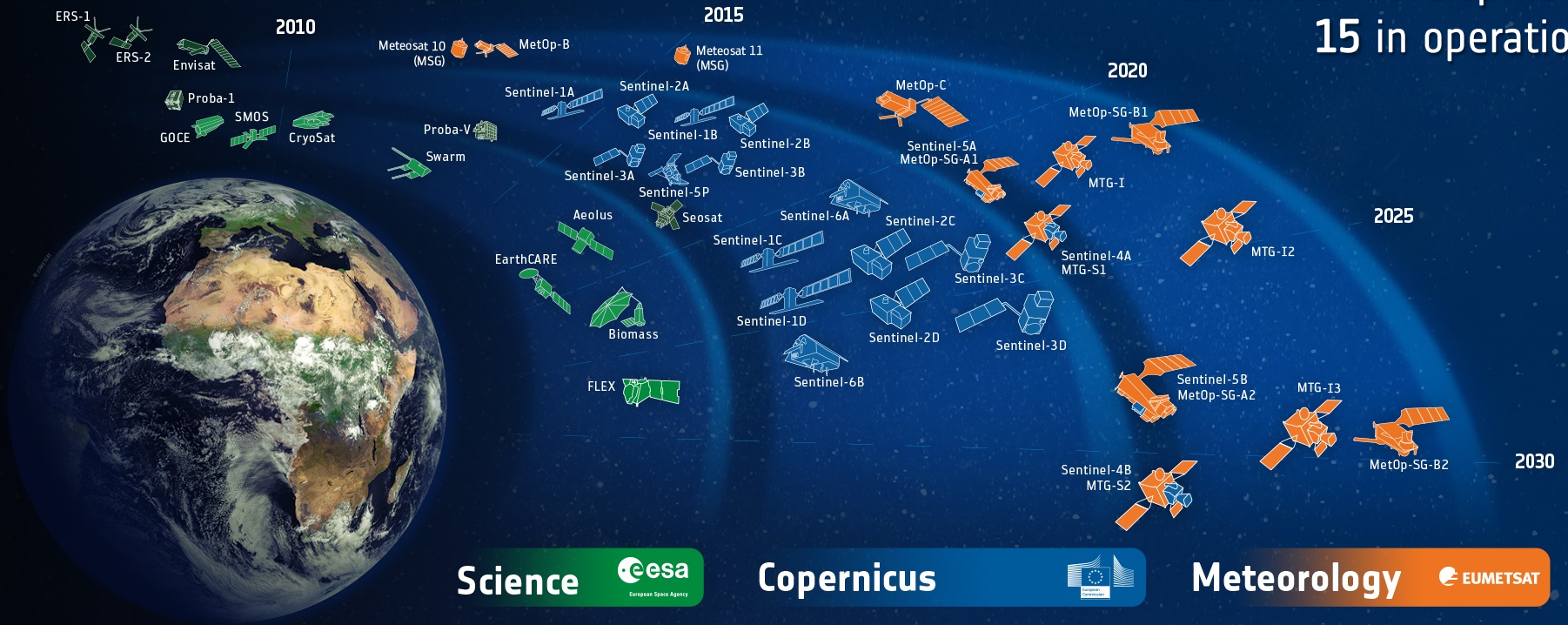
ESA-Developed Earth Observation Missions

esa

Satellites

25 under development

15 in operation



Science esa European Space Agency | **Copernicus** | **Meteorology** EUMETSAT

Aeolus Launch

Kourou
22 August 2018

Sentinel-3B Launch

Plesetzk
25 April 2018

MetOp-C Launch

Kourou
6 November 2018

ESA-Developed Earth Observation Missions

esa

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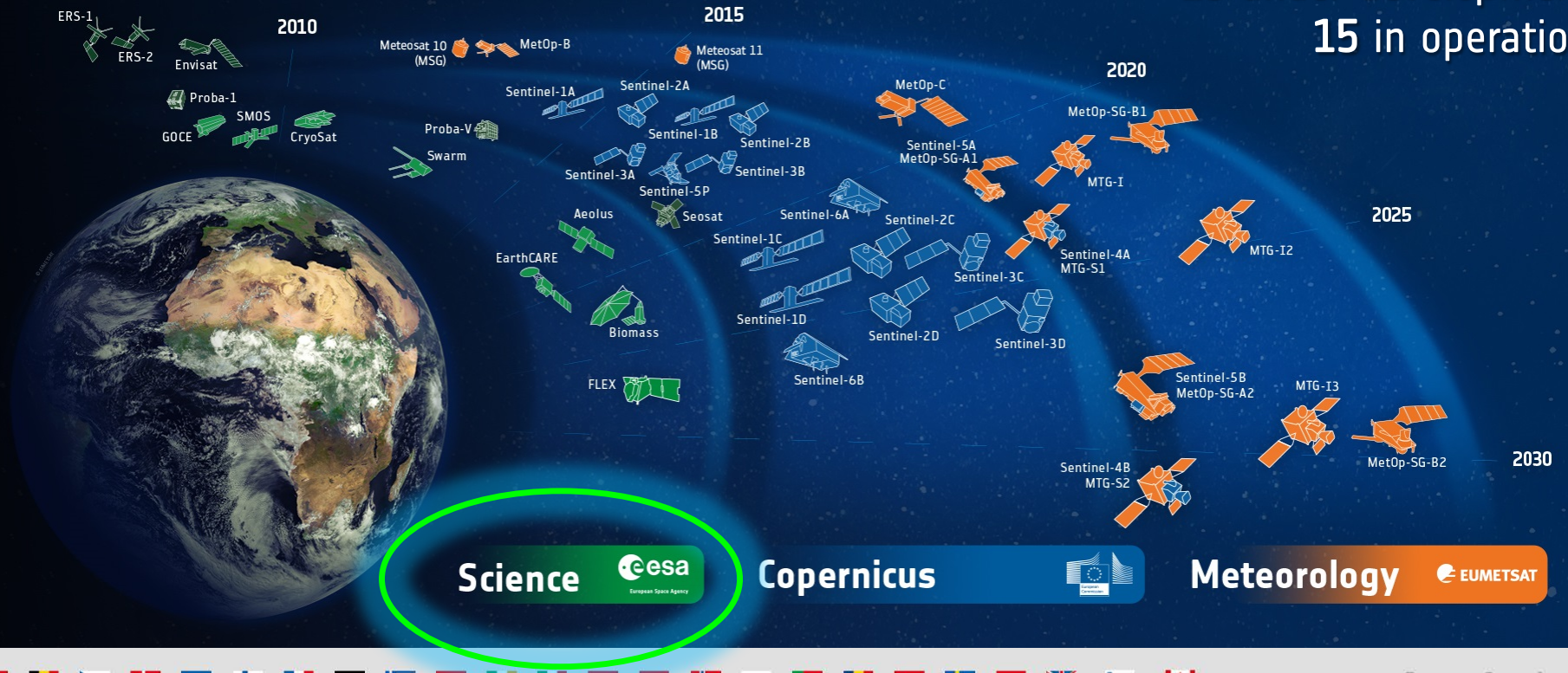


Science: Earth Explorers

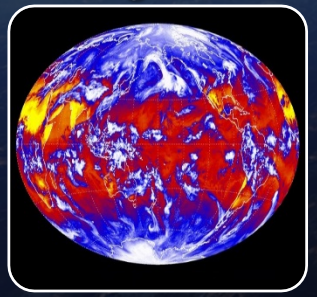
GOCE, SMOS, CRYOSAT, SWARM, AEOLUS, EARTHCARE [credit:ESA/AEOS Medialab] | BIOMASS Credits:Airbus | FLEX Credits: Thales Alenia

Earth Explorer 9 – Two Candidates

Mission selection 2019; launch around 2025

FORUM

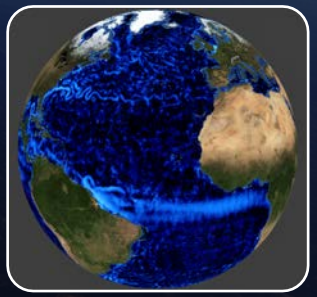
Far-infrared Outgoing Radiation Understanding and Monitoring



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

SKIM

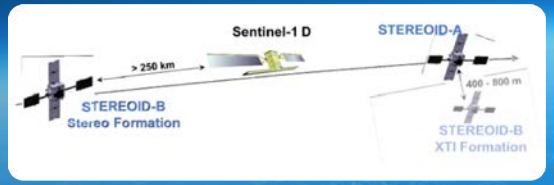
Sea-surface Kinematics Multiscale monitoring



Will carry novel wide-swath scanning multibeam radar altimeter to measure ocean-surface currents with Doppler technique

Earth Explorer 10 – Three Candidates

STEREOID

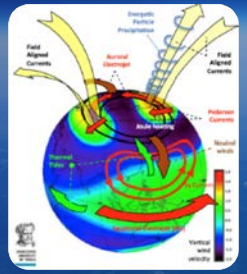


Bistatic SAR as passive followers of Sentinel-1
Two <500kg spacecraft

Applications

- Cryosphere
- Oceanography
- Geosphere

Daedalus



Explore mesosphere, lower thermosphere & 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

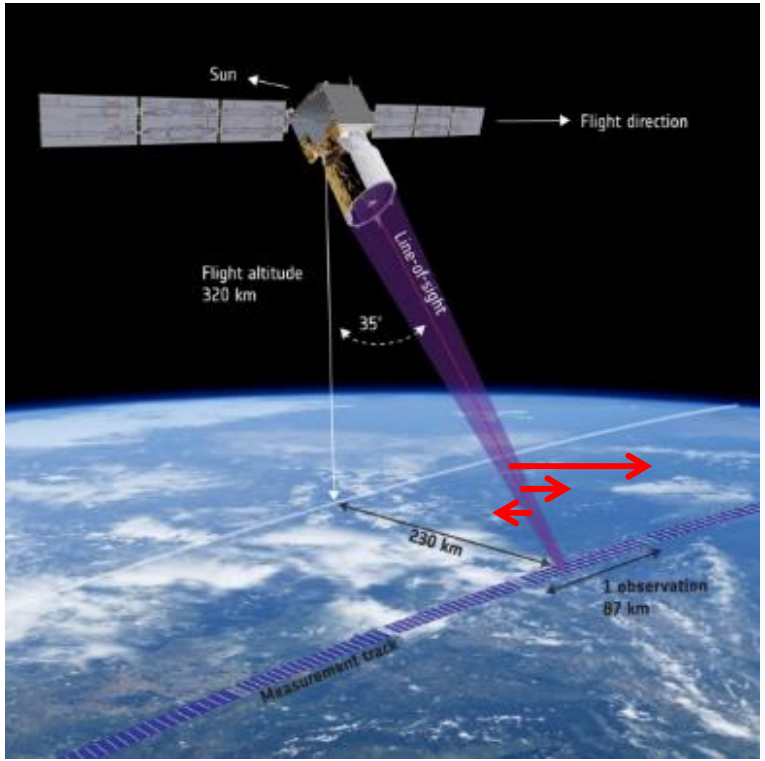
Products:

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



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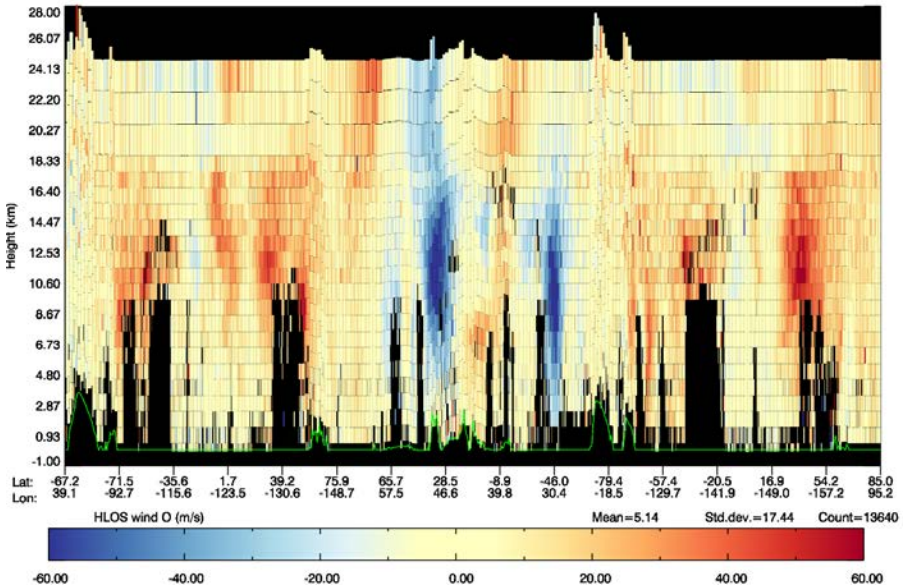
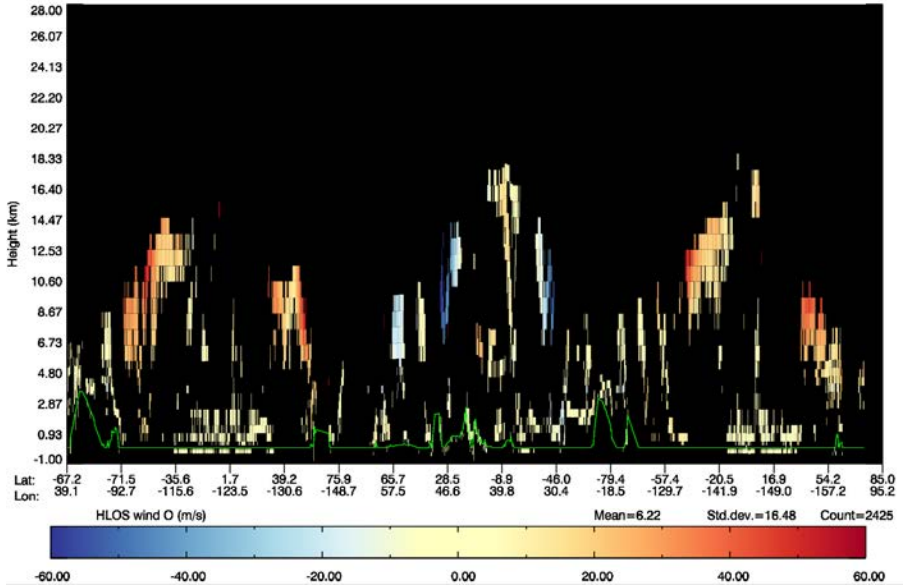
Aeolus observed molecular (left) and particle/cloud (right) Level 2B winds





Courtesy Michael Rennie, ECMWF

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ESA-Developed Earth Observation Missions

esa

Satellites
25 under development
15 in operation

2010
ERS-1
ERS-2
Envisat
Proba-1
SMOS
GOCE
CryoSat

2015
Meteosat 10 (MSG)
MetOp-B
Meteosat 11 (MSG)
Sentinel-1A
Sentinel-2A
Sentinel-1B
Sentinel-2B
Proba-V
Swarm
Sentinel-3A
Sentinel-3B
Sentinel-5P
Aeolus
Seosat
Sentinel-6A
Sentinel-2C
Sentinel-1C
EarthCARE
Sentinel-3C
Biomass
Sentinel-1D
Sentinel-2D
Sentinel-3D
Sentinel-6B
FLEX

2020
MetOp-C
MetOp-SG-B1
Sentinel-5A
MetOp-SG-A1
MTG-I
Sentinel-4A
MTG-S1

2025
MTG-I2
Sentinel-5B
MetOp-SG-A2
MTG-I3
MetOp-SG-B2

2030
Sentinel-4B
MTG-S2

Science esa European Space Agency
Copernicus
Meteorology EUMETSAT

Copernicus – Sentinel Status

S-1

Radar

A	3 Apr. 2014
B	25 Apr. 2016
C	2022/23
D	> 2022/23

S-2

High Res. Optical

A	23 Jun. 2015
B	6 Mar. 2017
C	2022/23
D	> 2022/23

S-3

Medium Res. Optical & Altimetry

A	16 Feb. 2016
B	25 Apr. 2018
C	2023
D	> 2023

S-4

Atmospheric Chemistry (GEO)

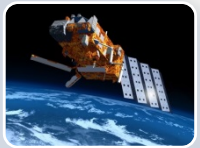
A	2022
B	2027

S-5P

Atmospheric Chemistry (LEO)

A	13 Oct. 2017

S-5



Atmospheric Chemistry (LEO)

A	2021
B	2027
C	> 2027

S-6

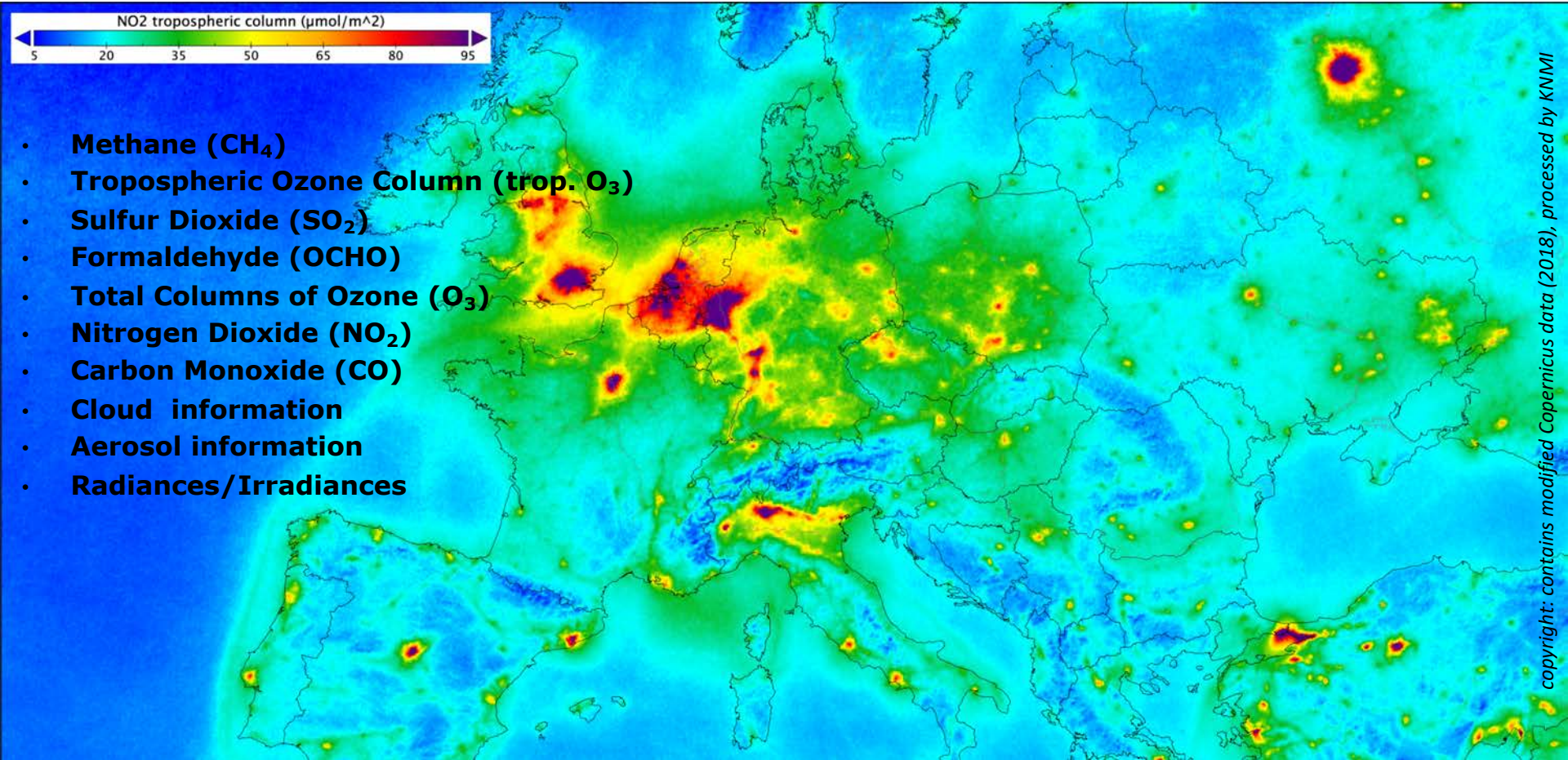
Altimetry

A	2020
B	2025

Copernicus Sentinel-5P

Launch:	13 Oct 2017
Lifetime:	7 years
Swath:	2600km
Resolution:	3.5 x 7 km
Coverage:	daily, global

Copernicus Sentinel-5P

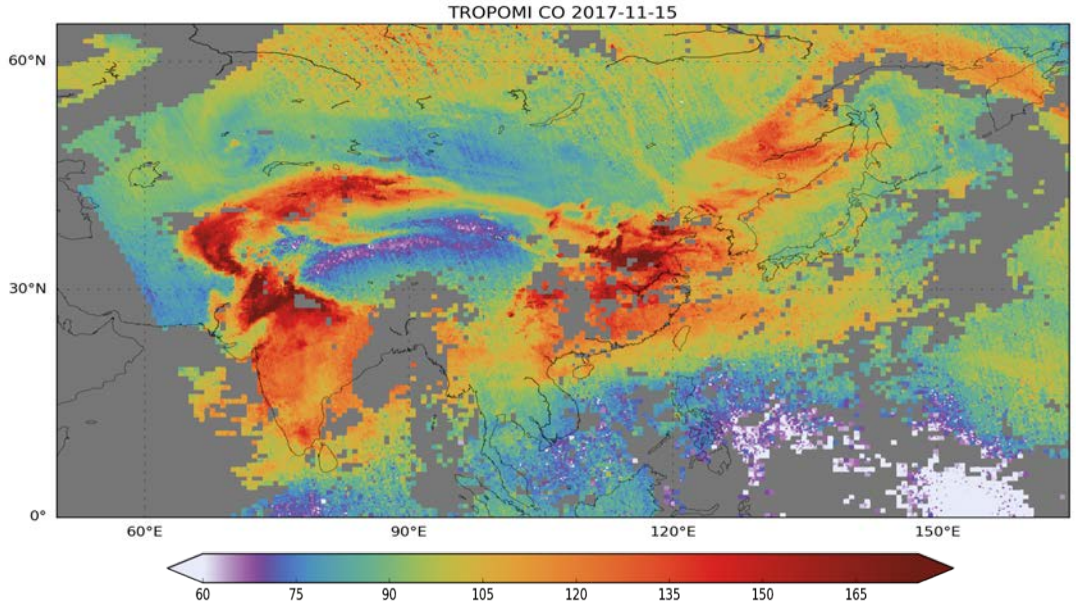


- **Methane (CH_4)**
- **Tropospheric Ozone Column (trop. O_3)**
- **Sulfur Dioxide (SO_2)**
- **Formaldehyde (OCHO)**
- **Total Columns of Ozone (O_3)**
- **Nitrogen Dioxide (NO_2)**
- **Carbon Monoxide (CO)**
- **Cloud information**
- **Aerosol information**
- **Radiances/Irradiances**

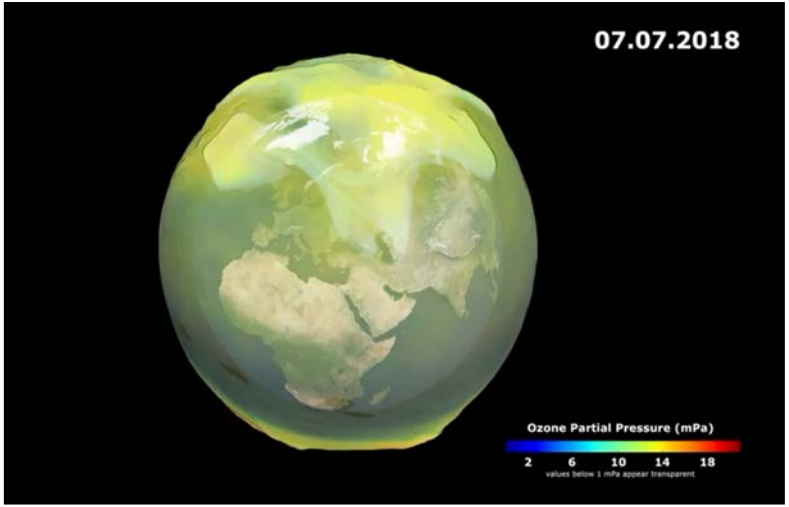
copyright: contains modified Copernicus data (2018), processed by KNMI

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

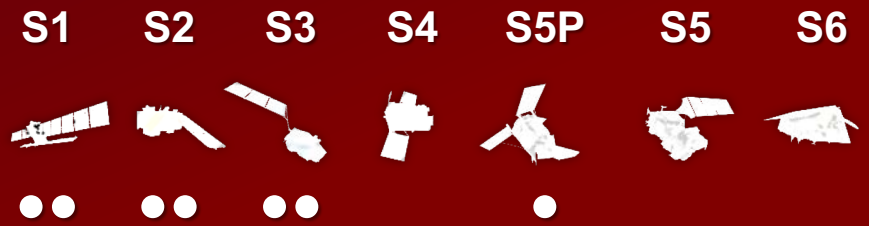
> 215.000
registered users
= tip of the iceberg

6 operational services

250 TB satellite data distributed per day

full, free & open data policy

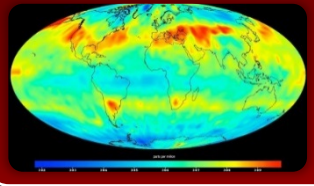
7 satellites flying



preparing Copernicus 2.0

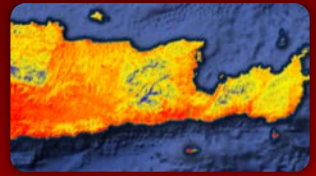
Copernicus 2.0 – New Monitoring Missions

Anthropogenic CO_2 Mon. Mission



Causes of
Climate Change

Land Surface Temperature Mission

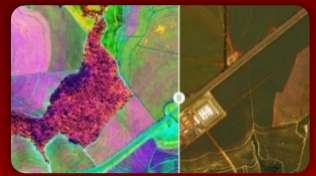


Agriculture & Water
Productivity

CRISTAL – Polar Ice & Snow Topography

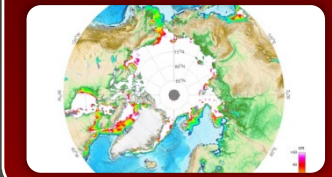
Effects of
Climate Change

CHIME – Hyperspectral Imaging Mission



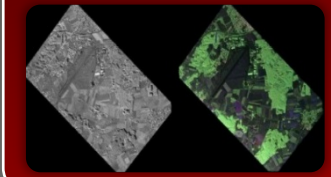
Food Security, Soil,
Biodiversity

CIMR – Passive Microwave Radiometer



Sea: Surface Temp.
& Ice Concentration

L-band SAR Mission



Vegetation & Ground
Motion & Moisture

Essential Climate Variables (ECVs)

United Nations
Framework Convention on Climate Change

Measurement domain	Essential Climate Variables
Atmospheric	Surface: air temperature, wind speed and direction, water vapour, pressure, precipitation, surface radiation budget Upper-air: temperature, wind speed and direction, water vapour, cloud properties, Earth radiation budget, lightning Composition: carbon dioxide (CO2), methane (CH4), other long-lived greenhouse gases, ozone, aerosol, precursors for aerosol and ozone
Oceanic	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 Biogeochemistry: inorganic carbon, oxygen, nutrients, transient tracers, nitrous oxide (N_2O), ocean colour Biology/ecosystems: plankton, marine habitat properties
Terrestrial	Hydrology: river discharge, groundwater, lakes, soil moisture Cryosphere: snow, glaciers, Ice sheets and Ice shelves, permafrost Biosphere: albedo, land cover, fraction of absorbed photosynthetically active radiation, leaf area index, above-ground biomass, soil carbon, fire, land surface temperature Human use of natural resources: water use, greenhouse gas fluxes

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- Established 2010
- €160M
- 21 ECVs in total

- Operational production of 13 CCI ECVs has been transferred to C3S

esa

Oceanic

- sea ice
- sea level
- sea state
- sea surface salinity
- ocean colour
- sst

Terrestrial

- antarctic ice sheet
- greenland ice sheet
- glaciers
- snow
- permafrost
- lakes
- soil moisture
- fire
- land surface temperature
- biomass
- land cover

Atmospheric

- aerosol
- cloud
- ozone
- water vapour
- ghg

climate change initiative

cmug cci

open data portal cci

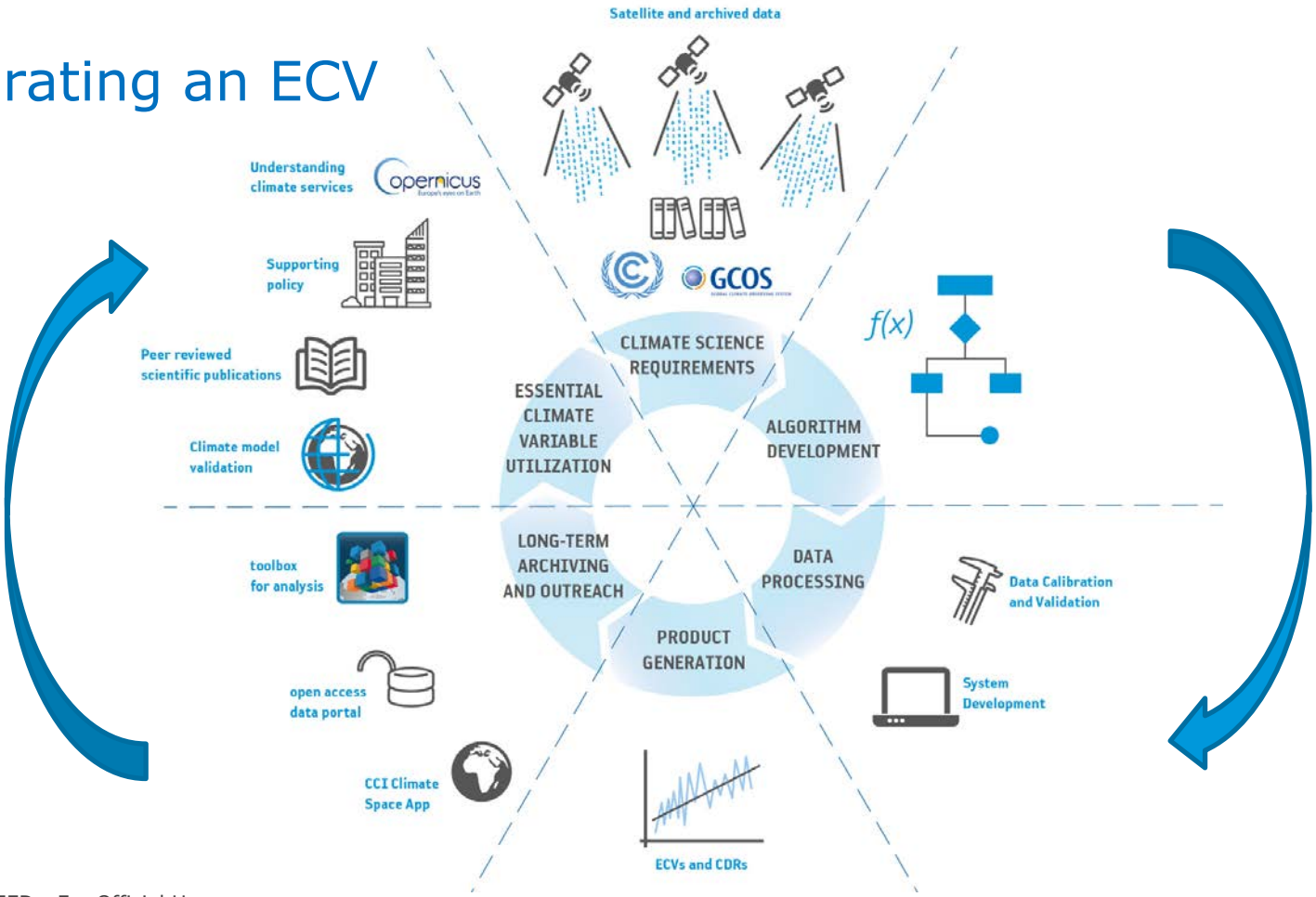
toolbox cci

Sea Level Budget

reccap-2 cci

European Space Agency

Generating an ECV



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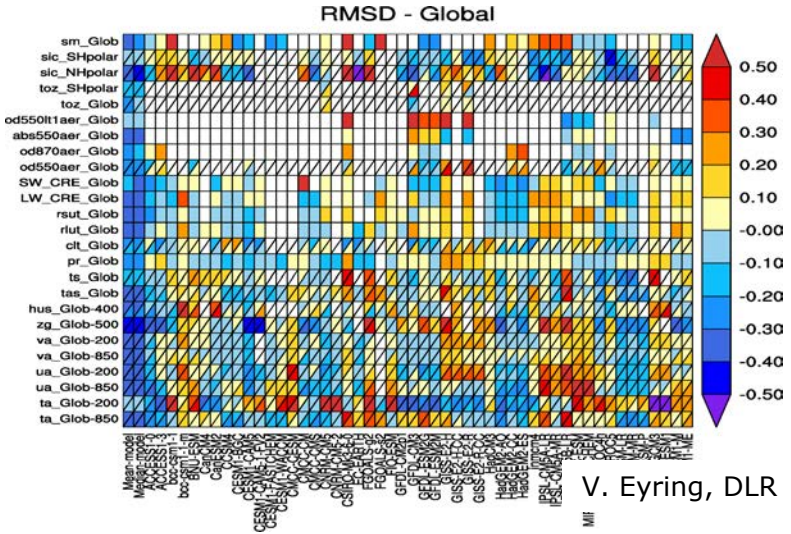
Climate Modelling User Group (CMUG)

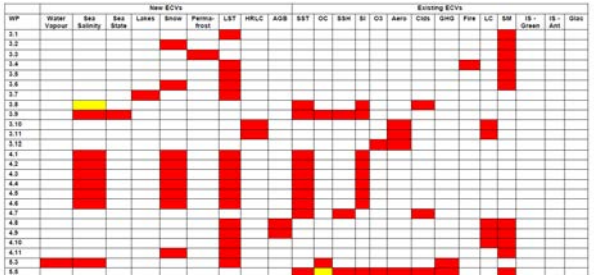
Hadley Centre, DLR, ECMWF, BSC,
Meteo France, MPI-Met, IPSL, SMHI

Provides feedback to CCI projects on:

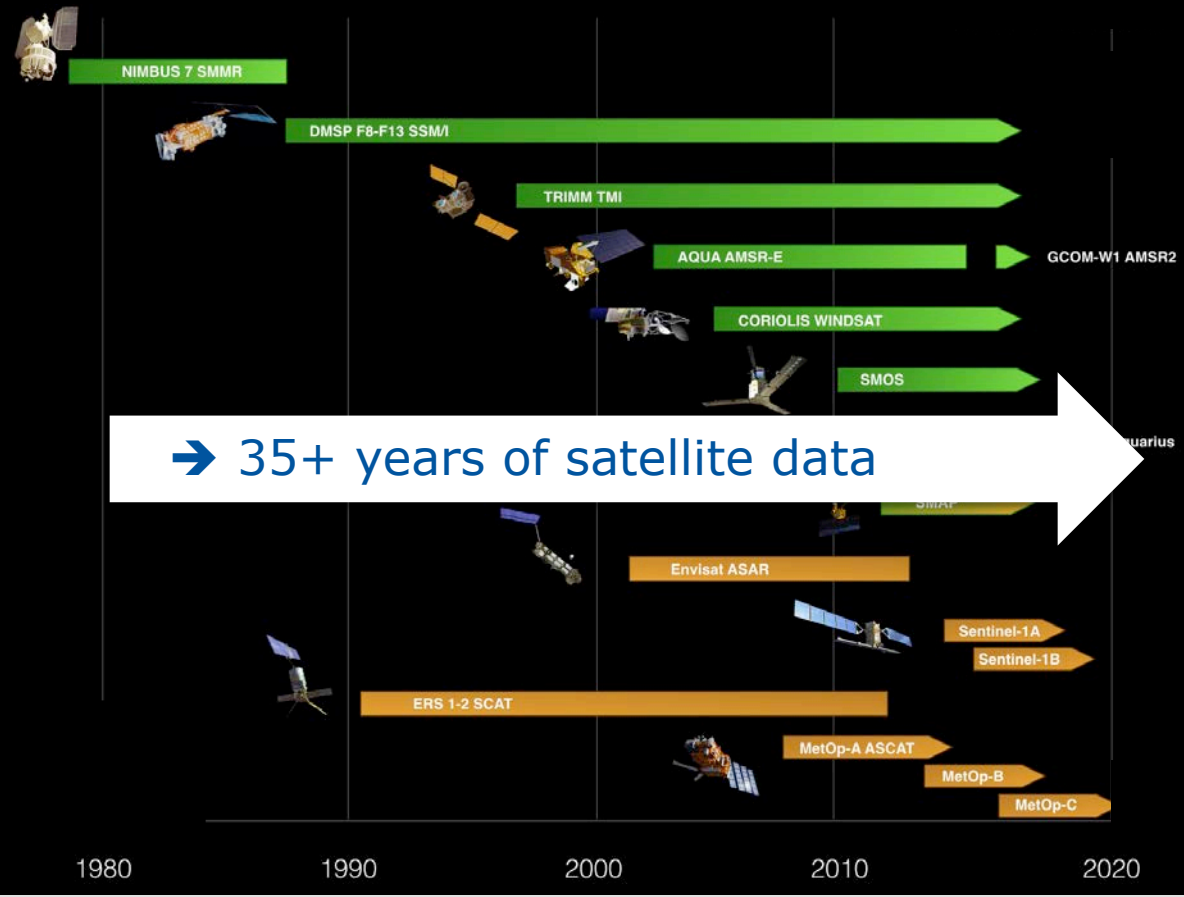
- Climate science user requirements
- ECV product specification
  e.g. product uncertainties
- Independent assessments of using CCI data in modelling studies: verification, assimilation, etc.
- Cross-ECV consistency



V. Eyring, DLR

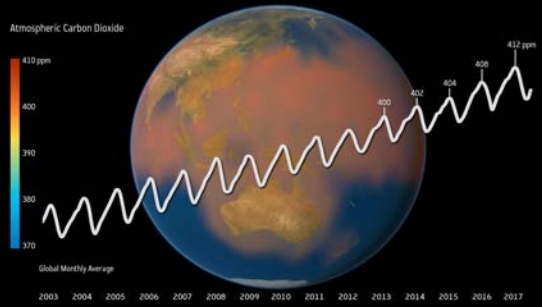


Exploiting the satellite archive – Soil Moisture ECV



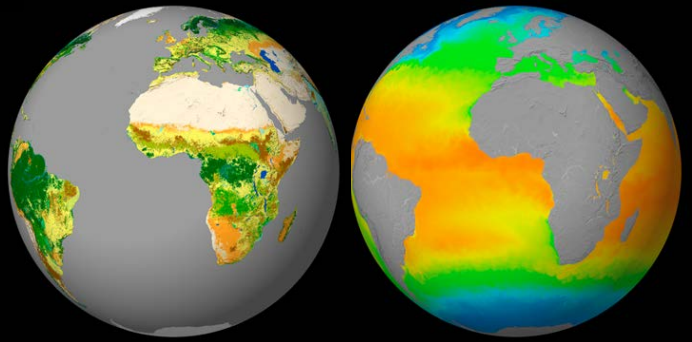
Climate Change Initiative

Atmospheric Carbon Dioxide (ppm)



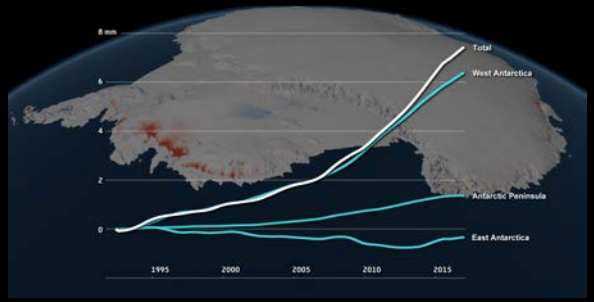
Sea Ice Concentration

Land Cover & Sea Surface Temperature time series

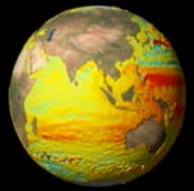


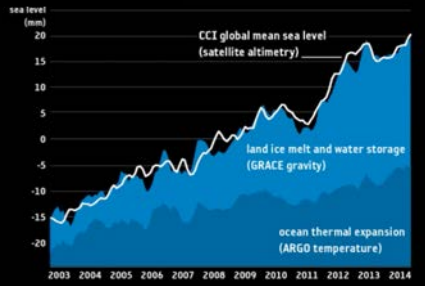
9,000 Gt glacier ice loss since 1961

Antarctic Ice Sheet Contribution to Global Sea Level



Global Mean Sea Level Budget





CCI achievements to date

450
European scientists

178
Institutions

22
ECVs

13 ECVs transferred to Copernicus

Open data

133
terabytes

100+
datasets

4.2
million files

640
Peer-reviewed articles

IPCC AR5

28 Contributing authors

15 Papers, cited 60 times

Thank You!

Oceanic

- sea ice
- sea level
- sea state
- sea surface salinity
- ocean colour
- sst

Terrestrial

- antarctic ice sheet
- greenland ice sheet
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climate change initiative

cmug cci

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toolbox cci