# Course Remote Sensing and Climate

## Summer 2026
## University of Frankfurt

**2. Day (R. Hollmann)**

- → Content and Structure of Course
- → Motivation and background
- → A short introduction in Physics
- → Radiative Transport and retrieval basics
- → Satellite orbits and instruments
- → **Climatologies based on satellite instrument and usage**

## Notes to PDF-Version

**This PDF is based on the presentation given in the summer term 2025 of University Frankfurt as part of the course „remote sensing and climate".**

**It is meant to recall the content the content of the lecture and is for the personal use of the participants of the course and <u>not</u> for a wider audience.**

**Parts in this document have been taken from other lectures, books, publications, the internet or other sources. These parts are not always have a correct acknowledgment or a proper citation.**

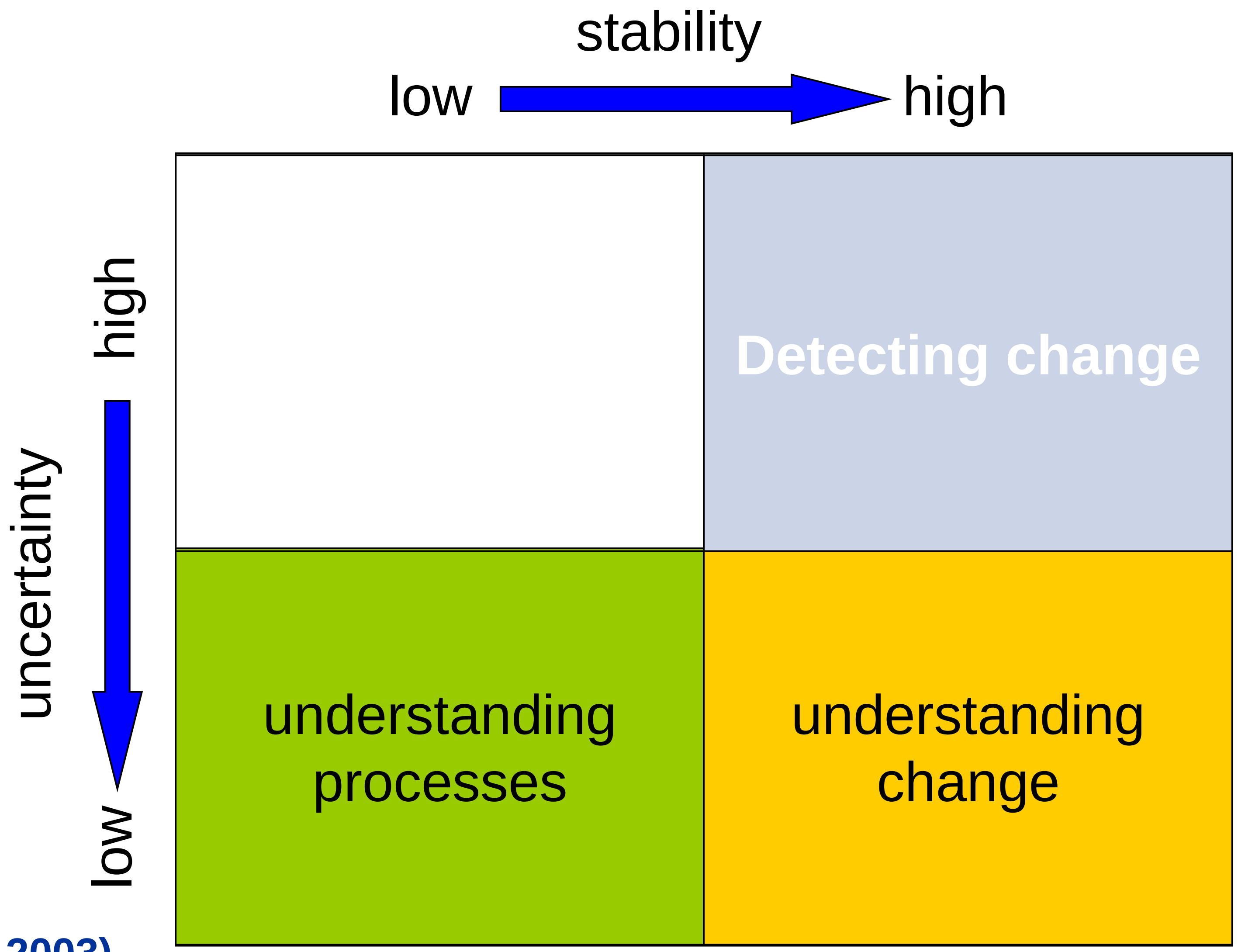
**Thus, please contact me (rainer.hollmann@dwd.de) in case you would like to cite from this pdf.**

# Climatologies based on satellite instrument and usage

- **Definition of a Climate data record (CDR)**
  - what is needed to generate a CDR?

- Climate related Satellite Activities in Europe
  - Development in recent years
  - Use of satellite data in Reanalyse
  - ESA CCI
  - Copernicus C3S
  - EUMETSAT CM SAF

# Desired characteristics of a climate observing system




(Stephens, 2003)

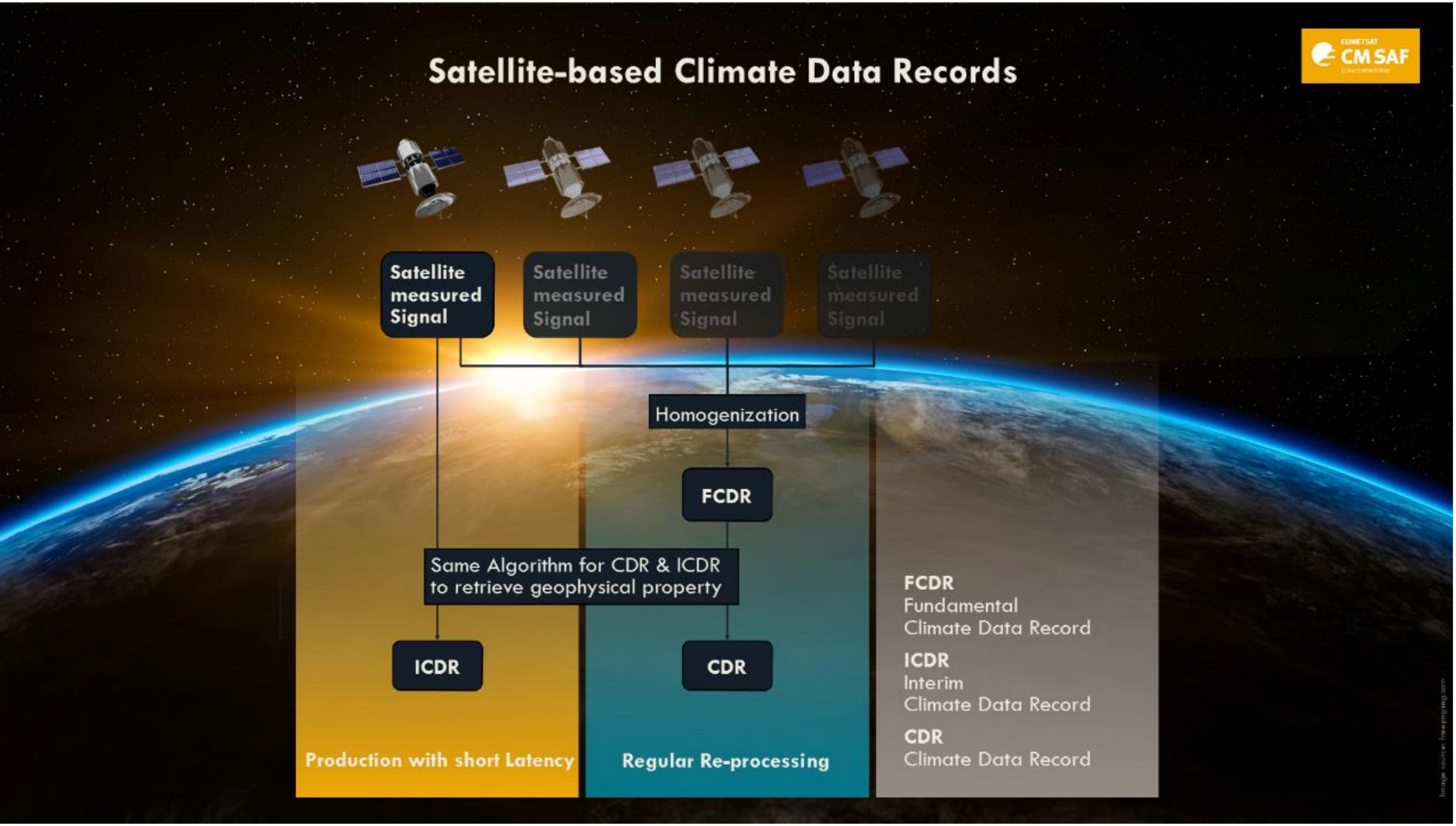
# Terminology

"**Climate Data Record":** A Climate Data Record (CDR) is a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change. It goes together with the requirement to base any thematic climate data records on fundamental climate data records.

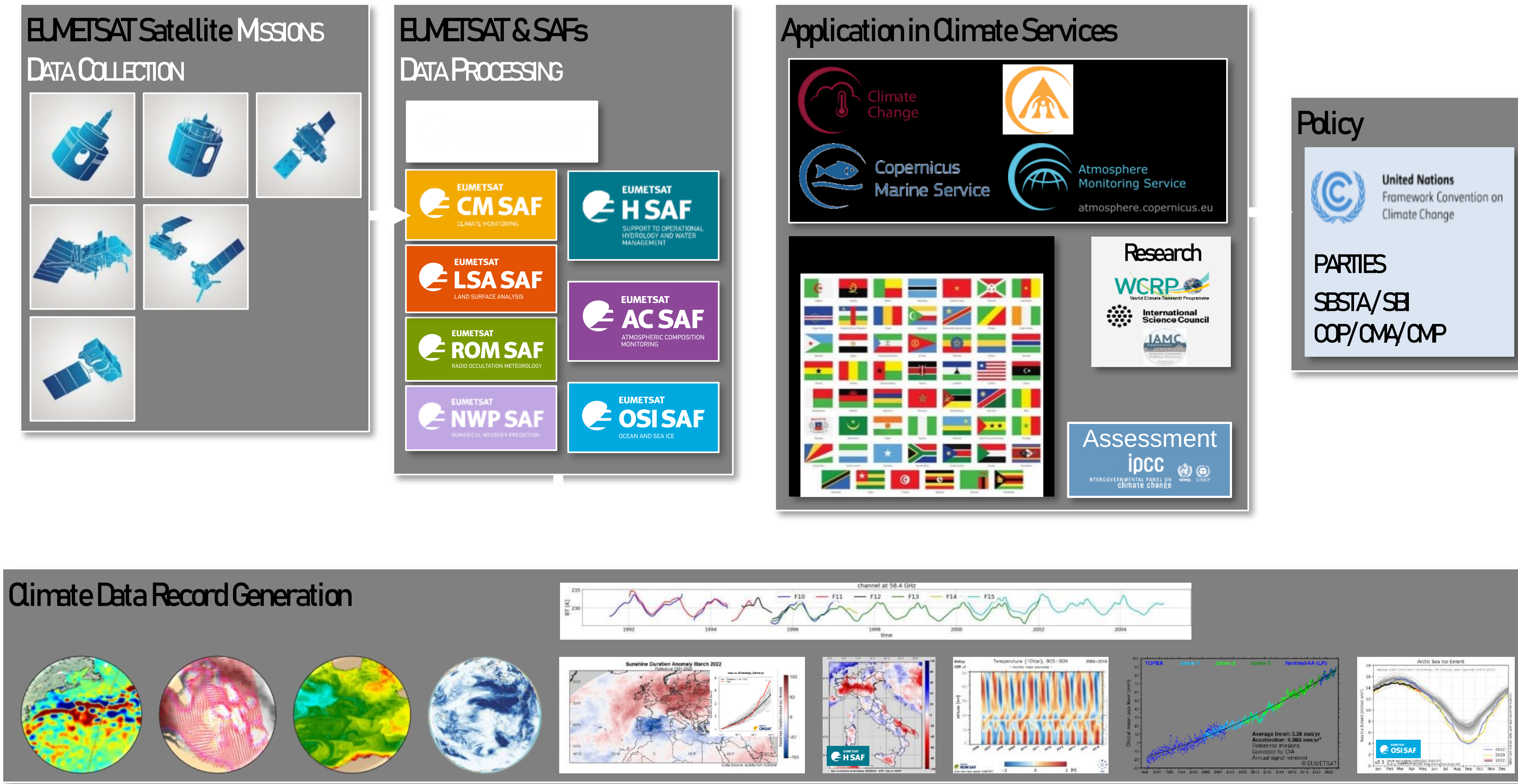
**"Interim Climate Data record":** An Interim Climate Data Records (ICDR) denotes a regularly updated TCDR in shorter time latency with an algorithm and processing system as consistent as possible to the generation of reference TCDR. An ICDR is usually based on the latest available inter-calibration and requires a different validation approach.

**"Environmental data record":** Environmental Data Records (EDRs) are time-tagged earth-located geophysical parameters produced from the sensor data. Often EDR's are derived in low to medium latency to satellite sensor data, not fulfilling highest climate requirements.

# Satellite-based climate data Records



# Operational value adding chain




Credit: EUMETSAT

# Global Climate Observing System (GCOS)

- Established in 1992 to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users
- Outcome of the Second World Climate Conference
- GCOS is co-sponsered by:
  - World Meteorological Organization (WMO)
  - Intergovernmental Oceanographic Commission (IOC) of UNESCO
  - United Nations Environment Programme (UNEP)
  - International Council for Science (ICSU)
- GCOS regularly reports on the adequacy of the current climate observing system to the United Nations Framework Convention on Climate Change (UNFCCC),
  and thereby identifies the needs of the current climate observing system
- www.gcos.wmo.int

# Global Climate Observing System (GCOS) (II)

GCOS is the **authoritative global source of information** and advice for planning and development of the Global Climate Observing System, its networks and data management. It is the authoritative source reference for formulating **requirements for space and in situ climate observations**.

→ **GCOS does not directly make observations nor generation of data products**

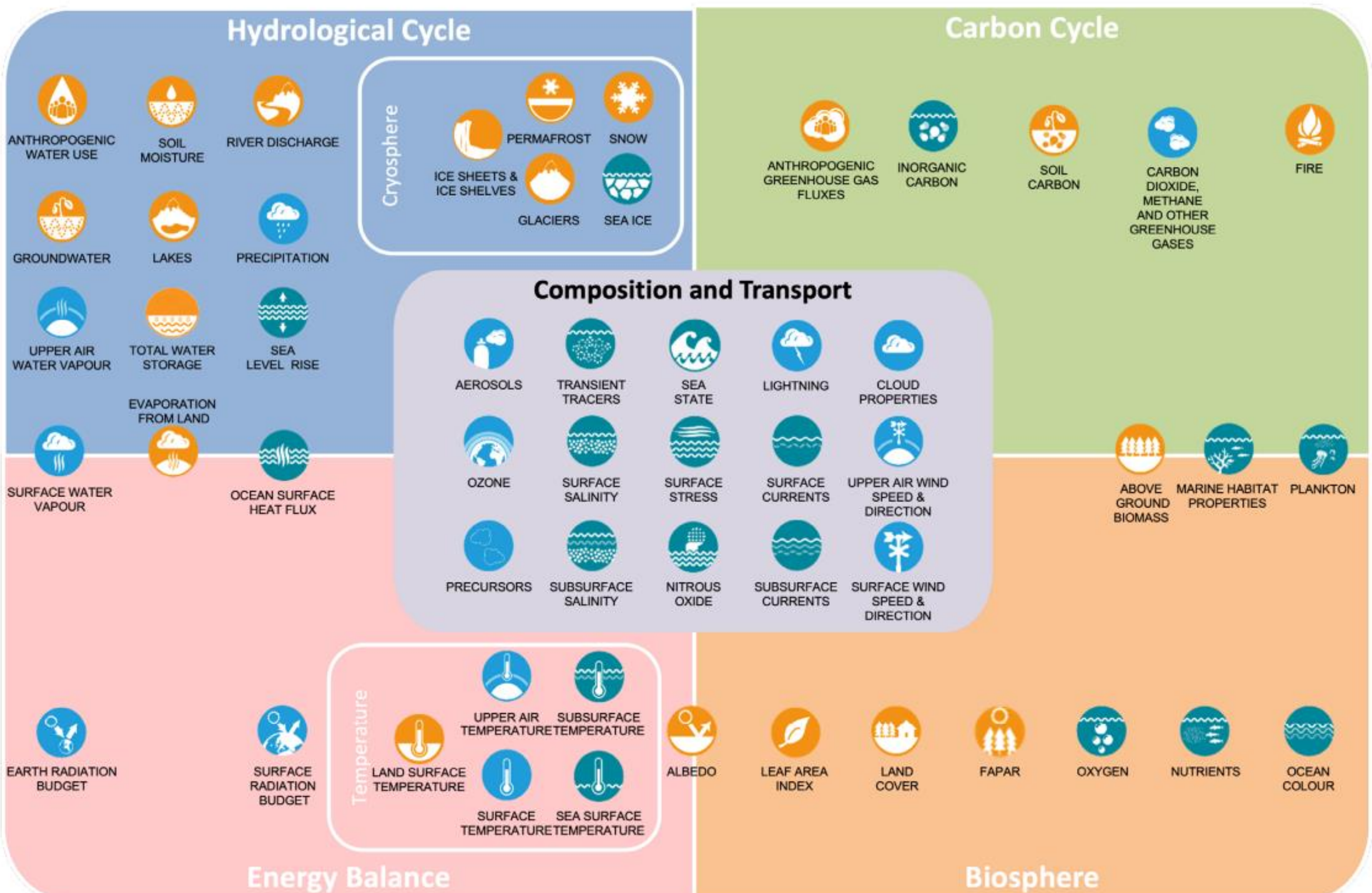
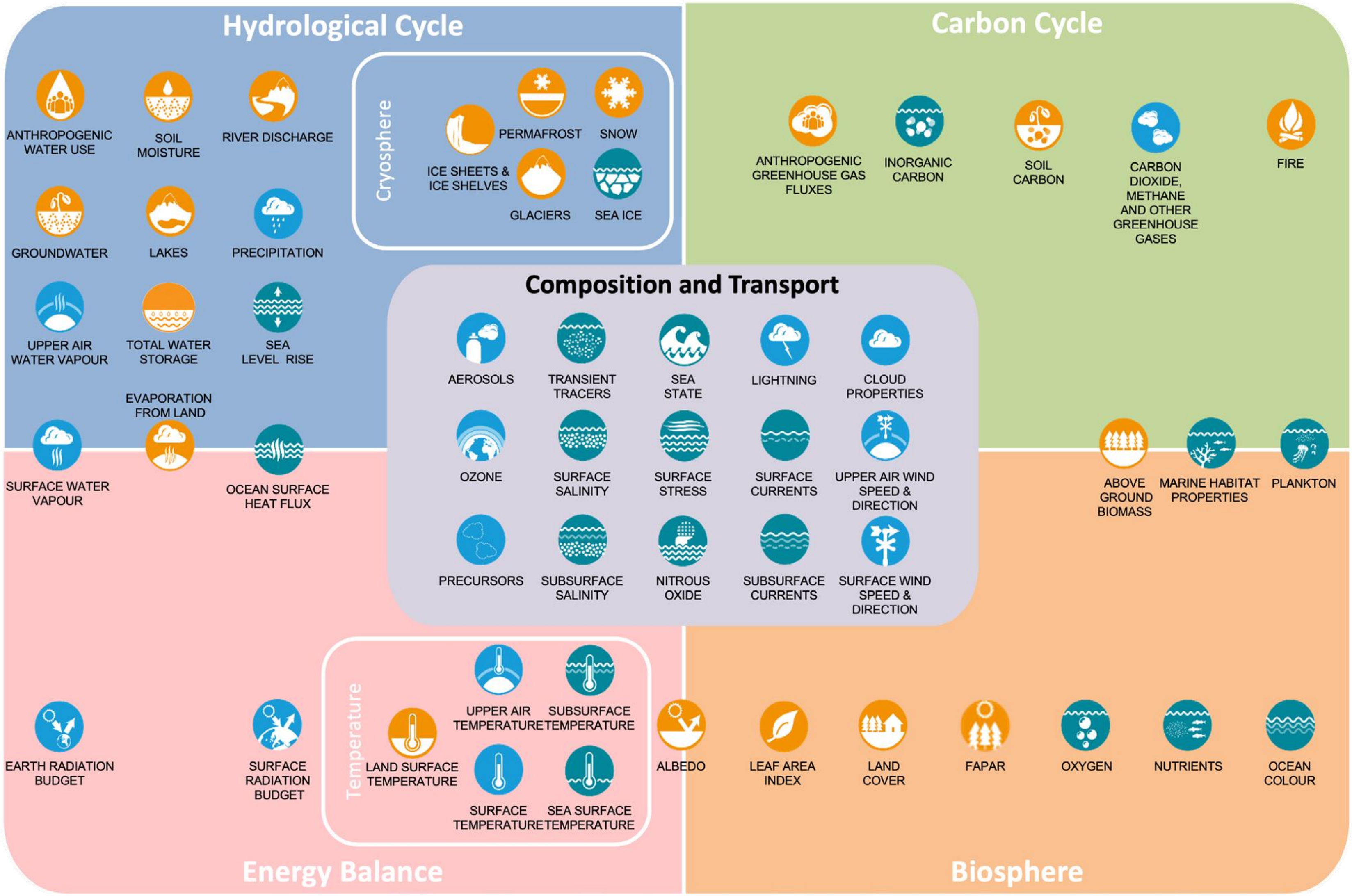



*Fig.2 from* GCOS IP-2022

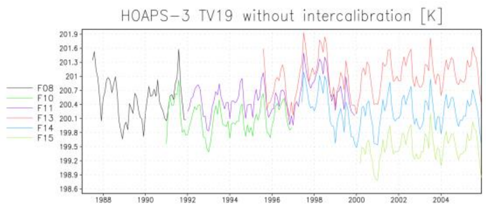
# Essential Climate Variables ~ 50

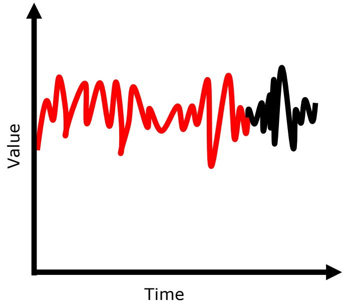


# Climate Data Record: GCOS-Requirements

1. Full description of all steps in the generation of data sets and products, including algorithms used, specific FCDRs used, and characteristics and outcomes of validation activities
2. Information on publications in peer-reviewed journals, covering both the description and the application of data sets and products
3. Statement of expected accuracy, stability and resolution (time, space) of the product, including, where possible, a comparison with the requirements stated in the Satellite Supplement (or any subsequent revision)
4. Arrangements for access to the data sets, products and all documentation
5. Version management of data sets and products, particularly in connection with improved algorithms and reprocessing
6. Long-term stability and homogeneity of the product
7. Full application of all appropriate calibration/validation activities that would enhance product quality
8. Global coverage where appropriate
9. Timeliness of data release to the user community to enable monitoring activities
10. Facility for user feedback
11. Application of a quantitative maturity index if possible
12. Publication of a summary (preferably on-line) documenting point-by-point the extent to which this guideline has been followed

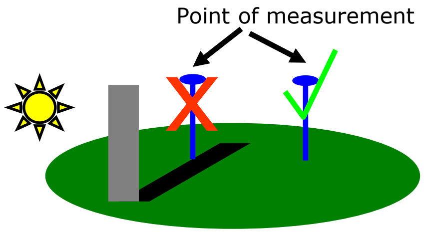
# What are the requirements for a Climate Data Record?



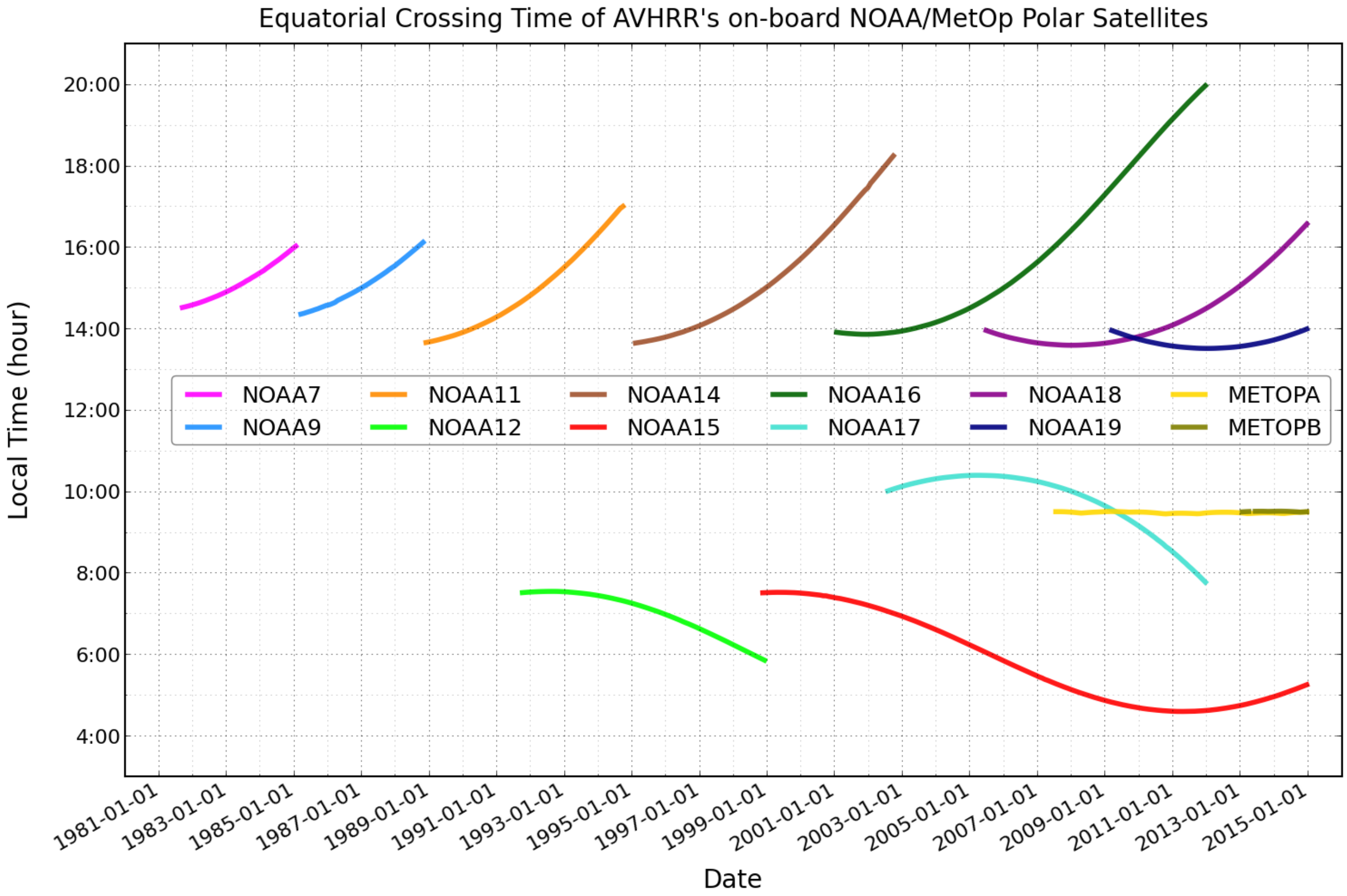

**Sufficient long timeseries**

**Calibration**



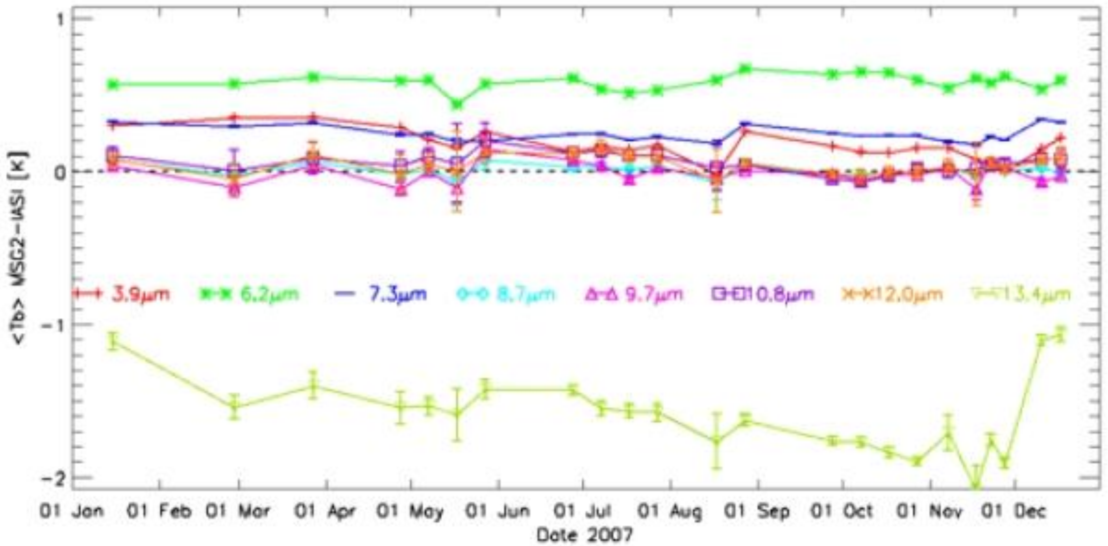

**Representativeness**

# calibration and stability (I)



# calibration and stability (II)

- GSICS – Global Satellite Inter-calibration System (NOAA, EUMETSAT,…)




GSICS News, T. Hewison, EUMETSAT

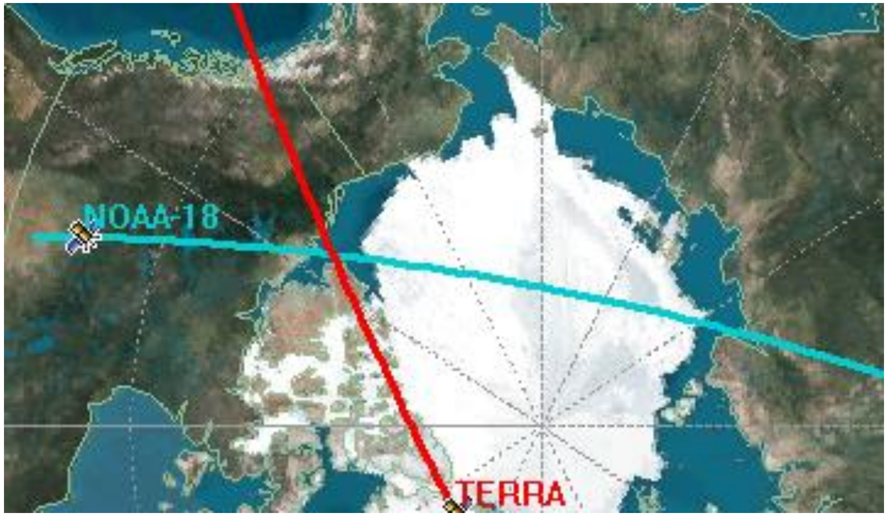
- Satellite nadir/conical over-passing (NOAA, GSICS,…)

- Homogenisation (PDF-matching during overlap in time, CMSAF)

Courtesy L. Schüller, 2010

# CDR: Interkalibration
## Global Space-based Inter-calibration System  (GSICS)

*POLAR- POLAR intercalibration*

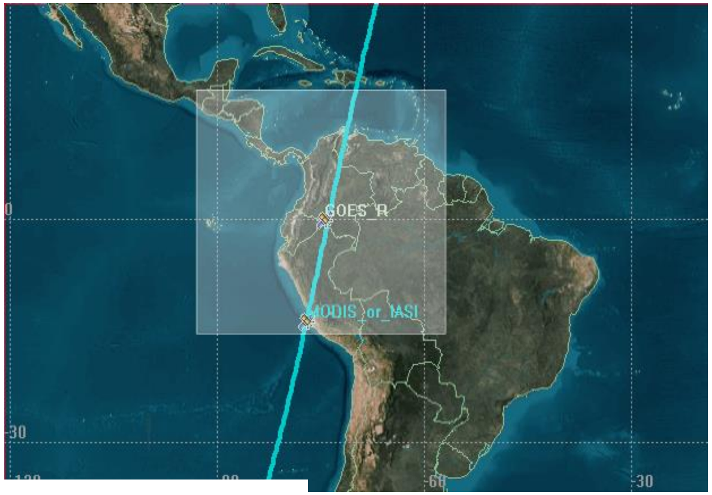



**Simultaneous Nadir Overpass (SNO) inter-calibration method**

Images courtesy of NOAA

- To ensure consistency of datasets from different missions and operators
- 8 Organizations currently contributing (+WMO)

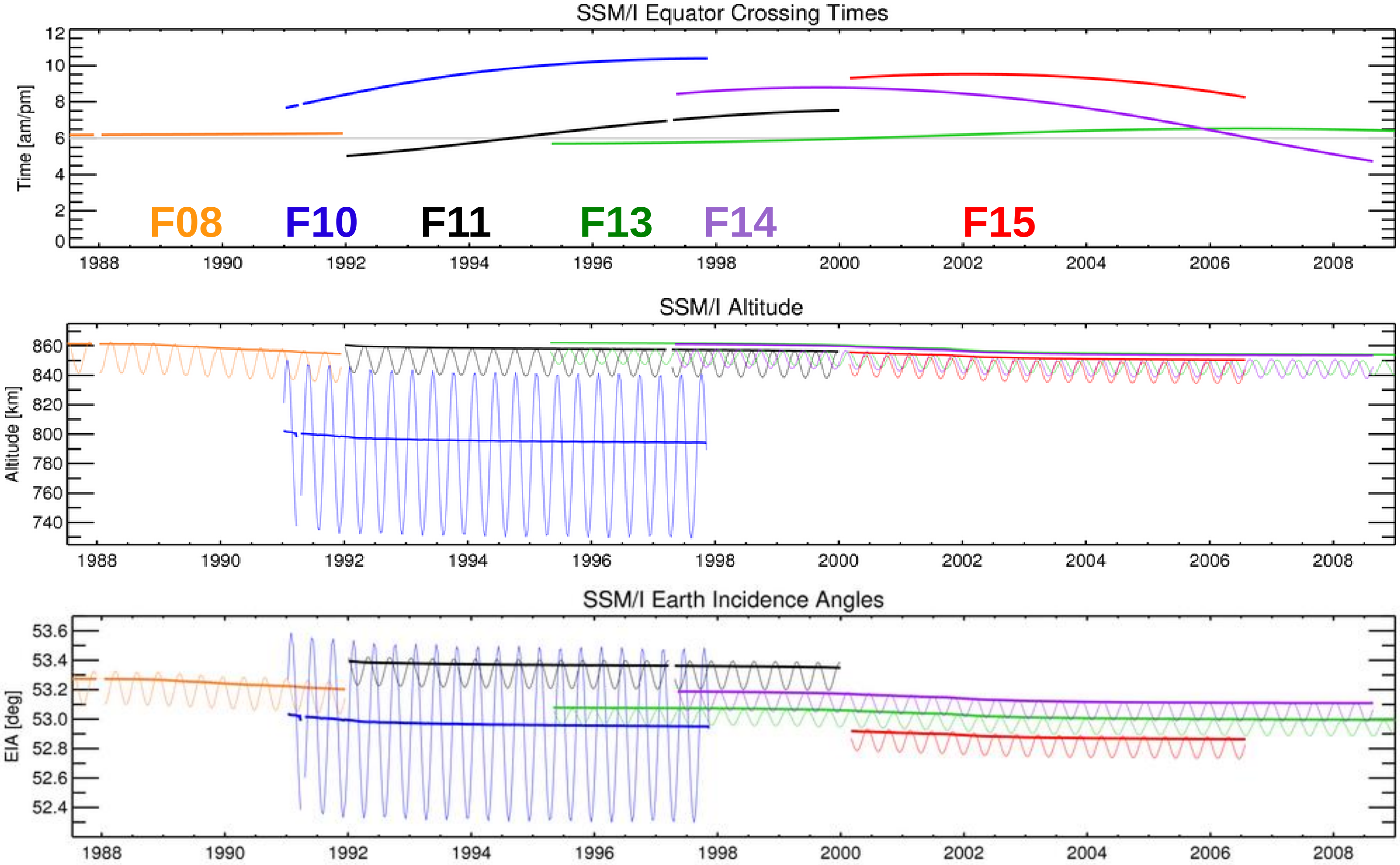
*GEO versus Polar-orbiting*




Courtesy L. Schüller, 2010

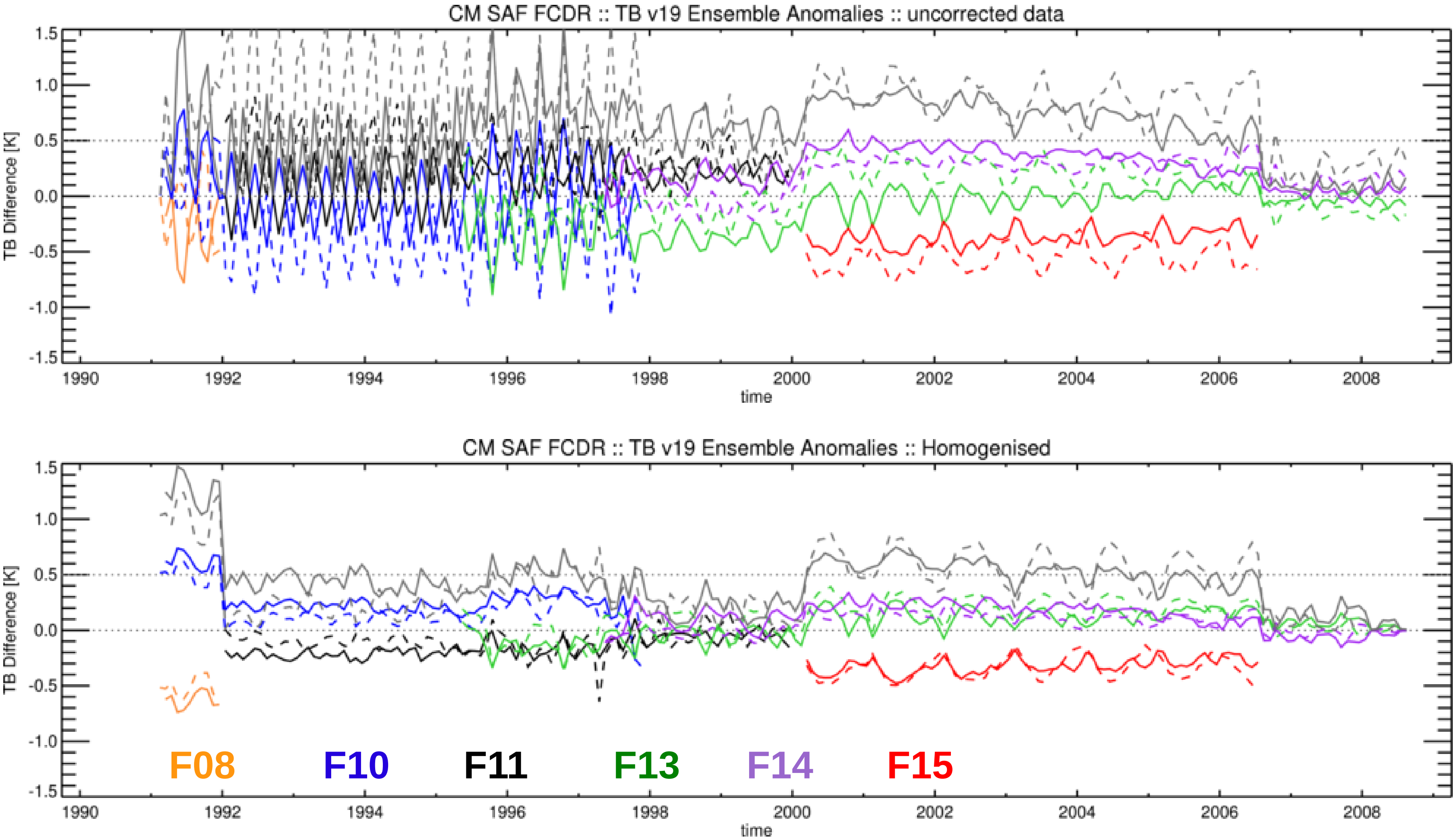
# calibration (I)

## Platform stability -> calibration impact



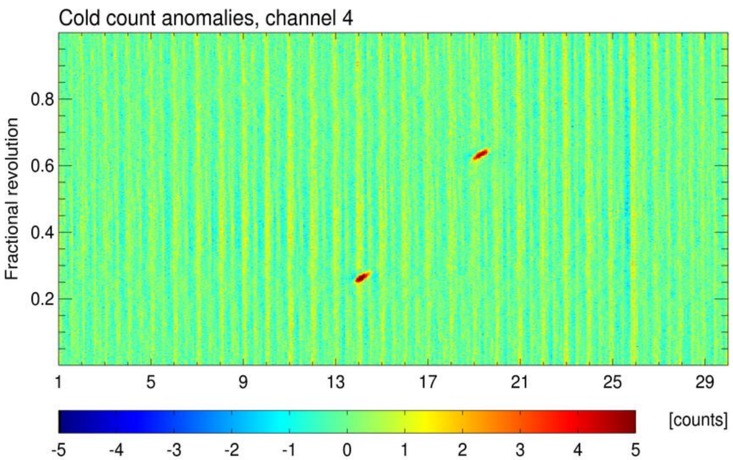
# calibration (II)

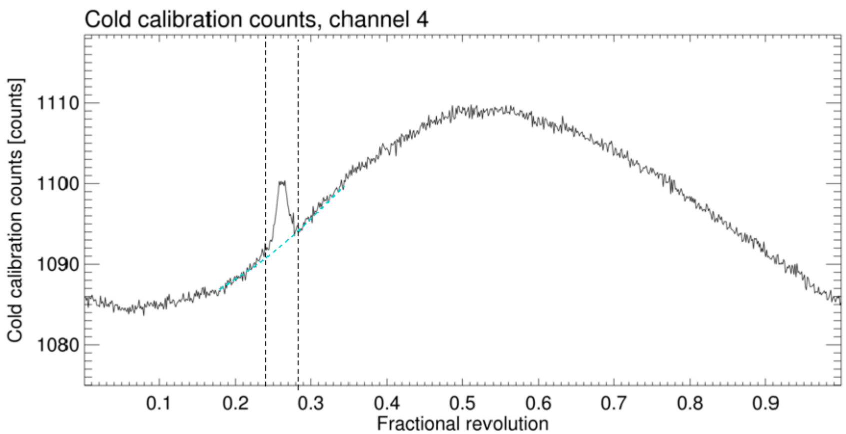
## Evaluation TB v19 Normalization



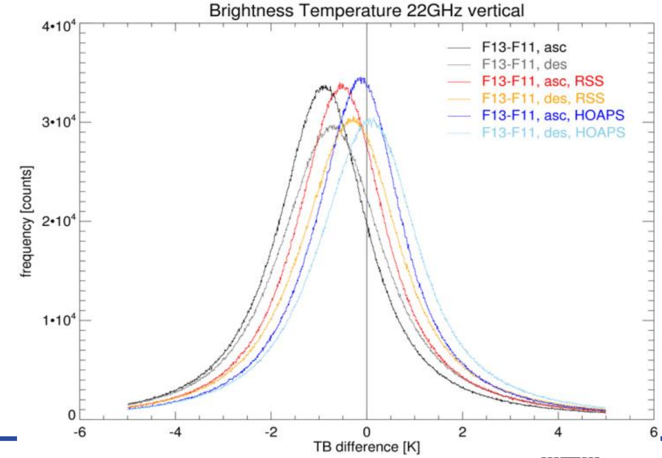
# calibration (III): Example SSMI

Exemplary raw data correction:
Moon is visible in the cold view, depending on the orbit parameters about twice per month. Intrusions are detected and removed.




Typical offsets are in the order of 1K before and less than 0.2K after intercalibration (relative to F11).

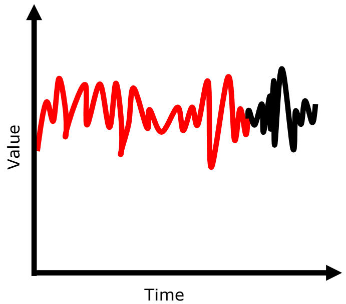


# calibration (IV)

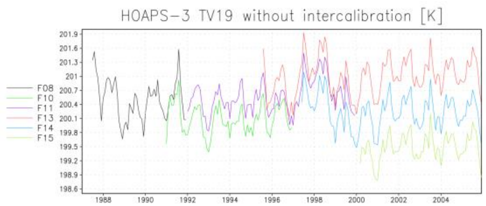
**A few international initiatives related to Calibration/Validation**

- **GSICS**
- **CEOS Working Group on Calibration and Validation**
- **GEO-QA4EO**: specification of quality indicators within EO products (standardization effort)
- **Europe:**
  - **ESA**: CAL/VAL activities, ESA-CCI
  - ***EU**: FIDUCEO, GAIA-CLIM (Project-based)*
  - **EUMETSAT**: Satellite Application Facilities (SAF), Central Facility

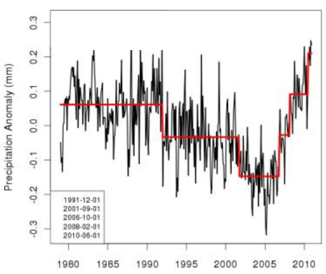
# What are requirements for a Climate Data Record?



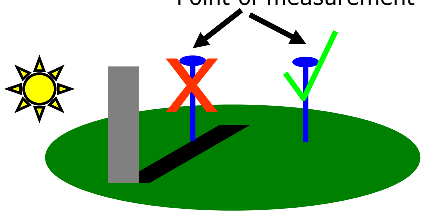

**Sufficient long timeseries**




**Calibration**

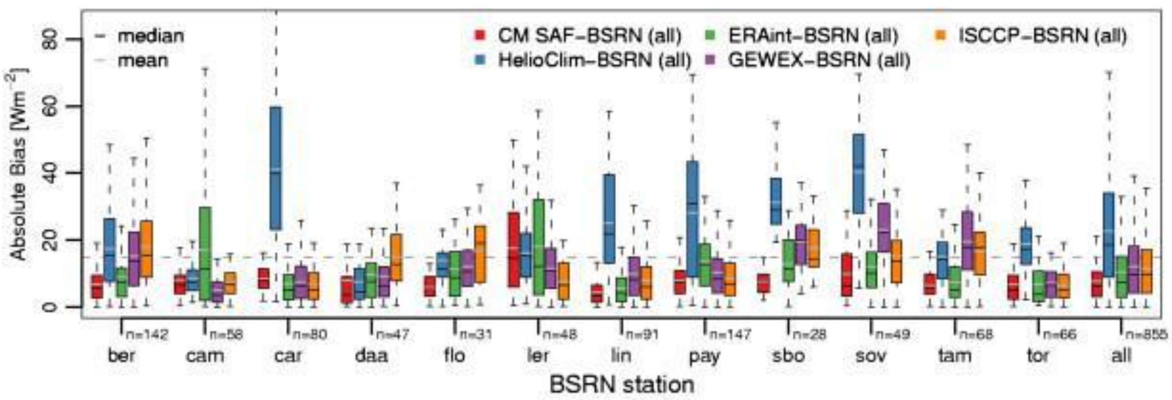



**Homogeneity**



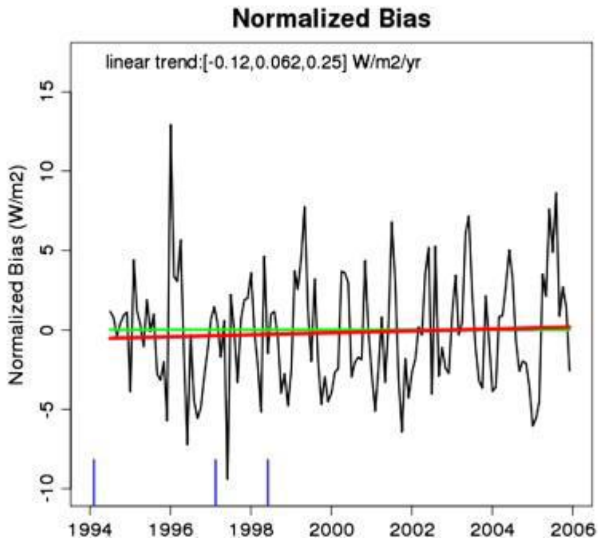

**Representativeness**

# Homogeneity:
# CM SAF vs BSRN (1994-2005)



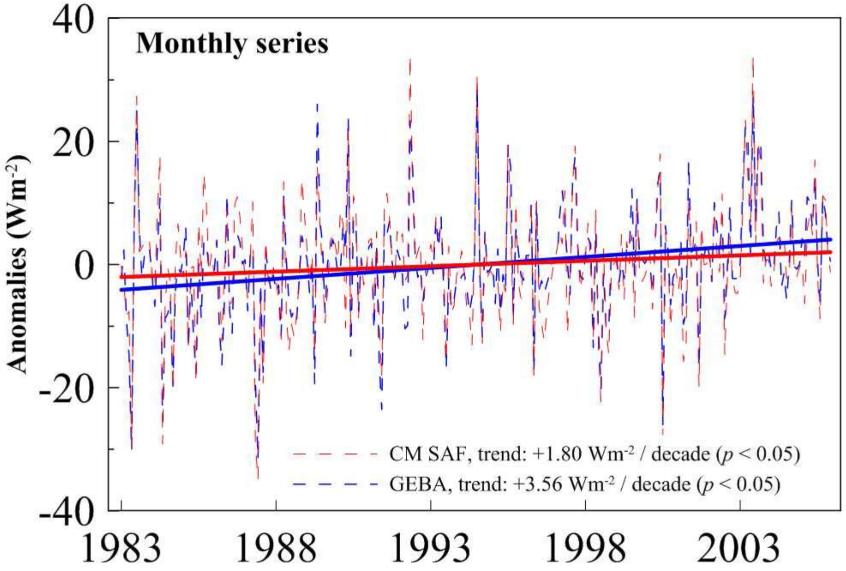

The mean absolute bias (r) of the monthly SSR is +4.40 W m-2 (0.89),
well below the target accuracy of 10 W m-2 defined by the CM SAF

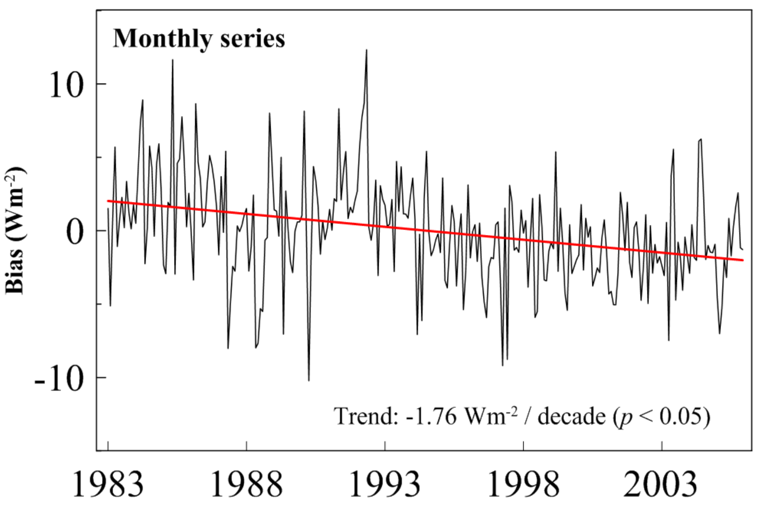
No detectable trend in the temporal evolution of the normalized bias between the CM SAF data set and the BSRN, which proves the homogeneity of the CM SAF data for the analyzed time period




Posselt et al. (2012), Sanchez-Lorenzo (2013)

# CDR Homogeneity



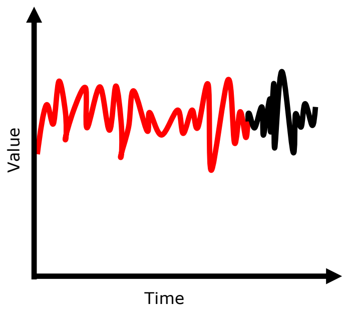




Mean monthly Radiation series (dashed lines) of the CM SAF (red) and GEBA datasets (blue) over Europe (1983-2005).

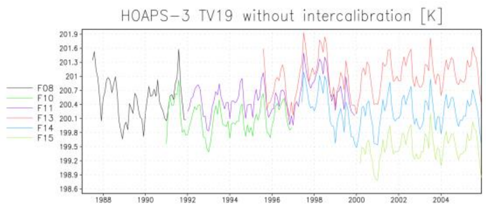
Differences of the CM SAF - GEBA mean monthly series with the linear regression line.

Sanchez-Lorenzo et al. (2014)

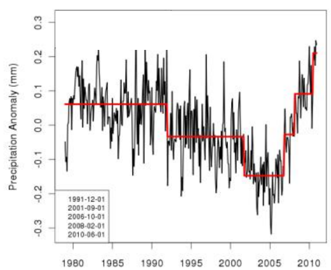
# What are requirements for a Climate Data Record?



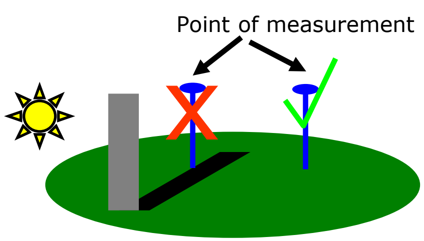

**Sufficient long timeseries**



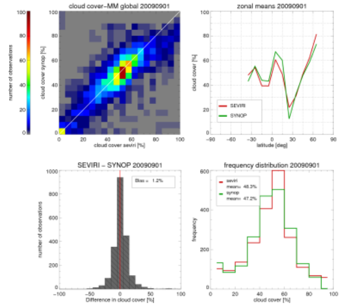

**Calibration**

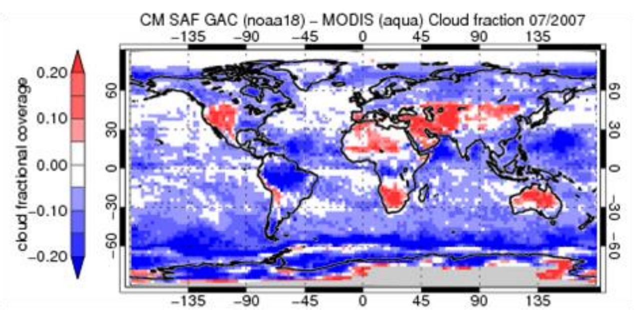



**Homogeneity**




**Representativeness**

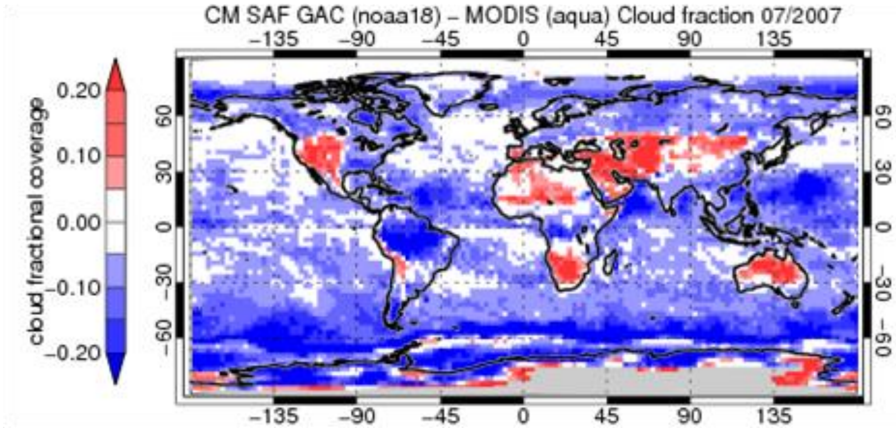




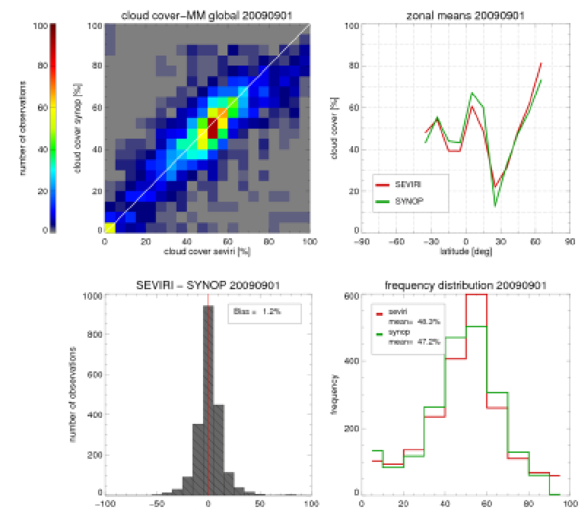

**Quality control**

# Quality control and details on retrievals

- Usually done with reference systems
- Either surface-based or satellite-based
- Through international assessments
- Publications & papers



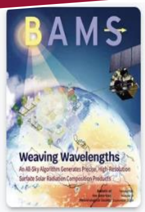

- For Cloud properties
- For Radiation
- For Water vapour
- For precipitation
- See examples and lectures yesterday



# C3S – Evaluation and Quality (i)

## A user-oriented Evaluation and Quality Control function

**EQC Vision Paper published**




BAMS Article

**Are Our Climate Data Fit for Your Purpose?**

Dick Dee,[a] André Obregon,[b] and Carlo Buontempo[b]

*"Which dataset meets my specific requirements?"*

*"If there are alternatives, how do I select the most suitable?"*

*"Are there other use cases similar to mine, and what can I learn from them?"*

**Redesigned, more user-oriented EQC framework**


**Quality assurance**
Independent verification of C3S technical requirements imposed on CDS data, addressing data management, data content, metadata and documentation.

**Quality assessments**
- Real use cases, real questions
- Informed by published research
- Shareable Jupyter notebooks
- Outcomes address usability, strengths and limitations

**Fitness for purpose**
- How well does this dataset meet my specific requirements?
- Have all technical attributes been verified?
- Has data quality been assessed in relevant contexts?

https://doi.org/10.1175/BAMS-D-23-0295.1

Source: C3S, J. Munoz-Sabatier

PROGRAMME OF THE EUROPEAN UNION

# C3S – Evaluation and Quality (ii)

## A user-oriented Evaluation and Quality Control function

# Climatologies based on satellite instrument and usage

- ➔ Definition of a Climate data record (CDR)
  - ➔ what is needed to generate a CDR?

- ➔ **Climate related Satellite Activities in Europe**
  - ➔ **Development in recent years**
  - ➔ Use of satellite data in Reanalyse
  - ➔ ESA CCI
  - ➔ Copernicus C3S
  - ➔ EUMETSAT CM SAF

# Development of Strategy for Climate Monitoring 2013

Strategy Towards an Architecture for Climate Monitoring from Space


Established the CEOS/CGMS Working Group on Climate (WG Climate) to

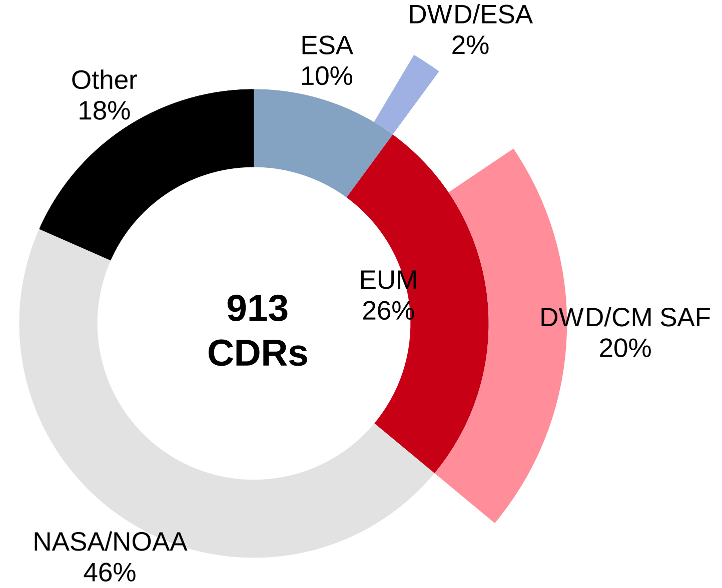
- ➔ **improve the systematic availability of Climate Data Records from space through coordinated implementation**
- ➔ **Provision of a structured, comprehensive and accessible view**
- ➔ **Creation of the conditions for delivering further Climate Data Records**
- ➔ **Optimisation of the planning of future satellite missions and constellations to expand existing and planned Climate Data Records**.

# ECV inventory – Task of CEOS /CGMS WG climate

## CEOS & CGMS WG Climate ECV Inventory

- **available since 2017**

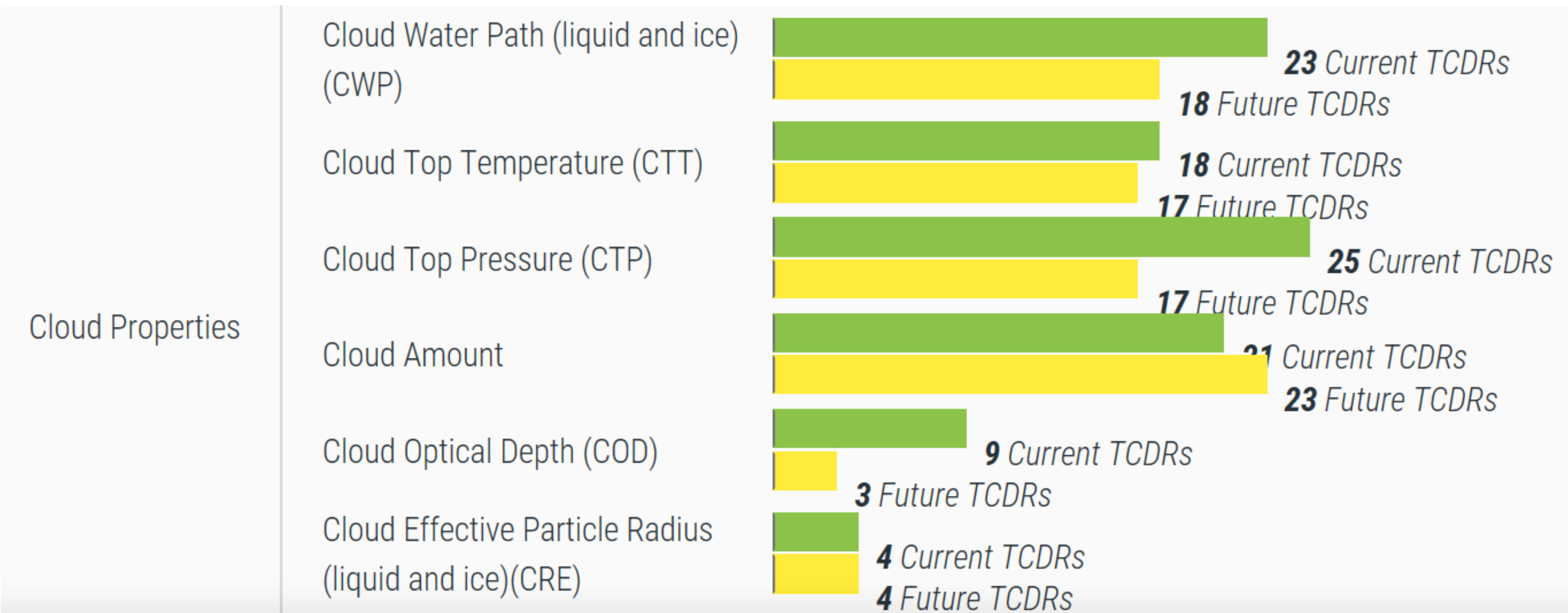
**Relative contributions by organisation**




GCOS Essential Climate Variables

http://climatemonitoring.info/ecvinventory

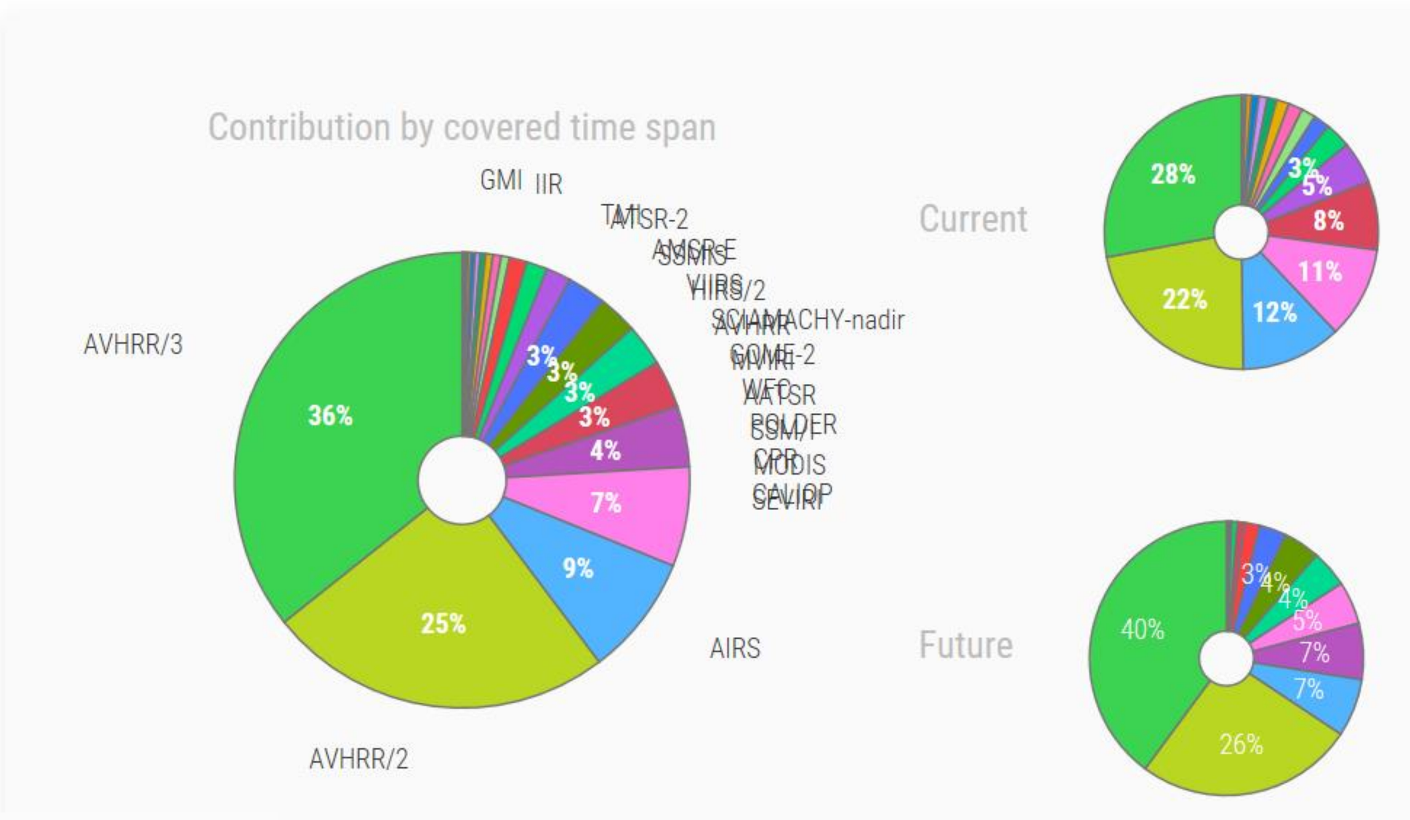
# ECV inventory: Cloud Climatologies – How many?




WGClimate CEOS CGMS

# ECV inventory: Clouds – Based on which instruments?

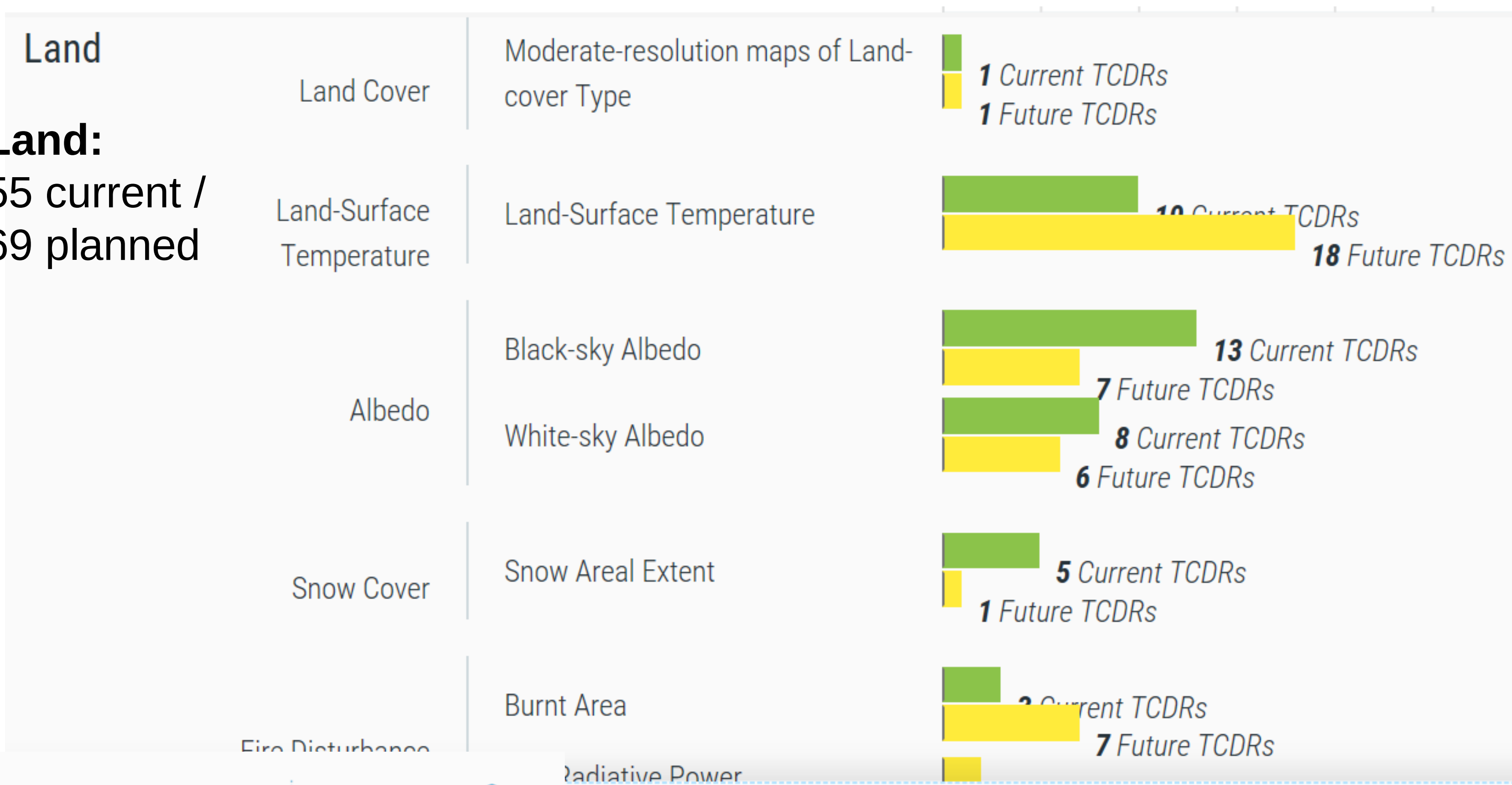
Relative Satellite/Instrument contributions




WGClimate CEOS CGMS

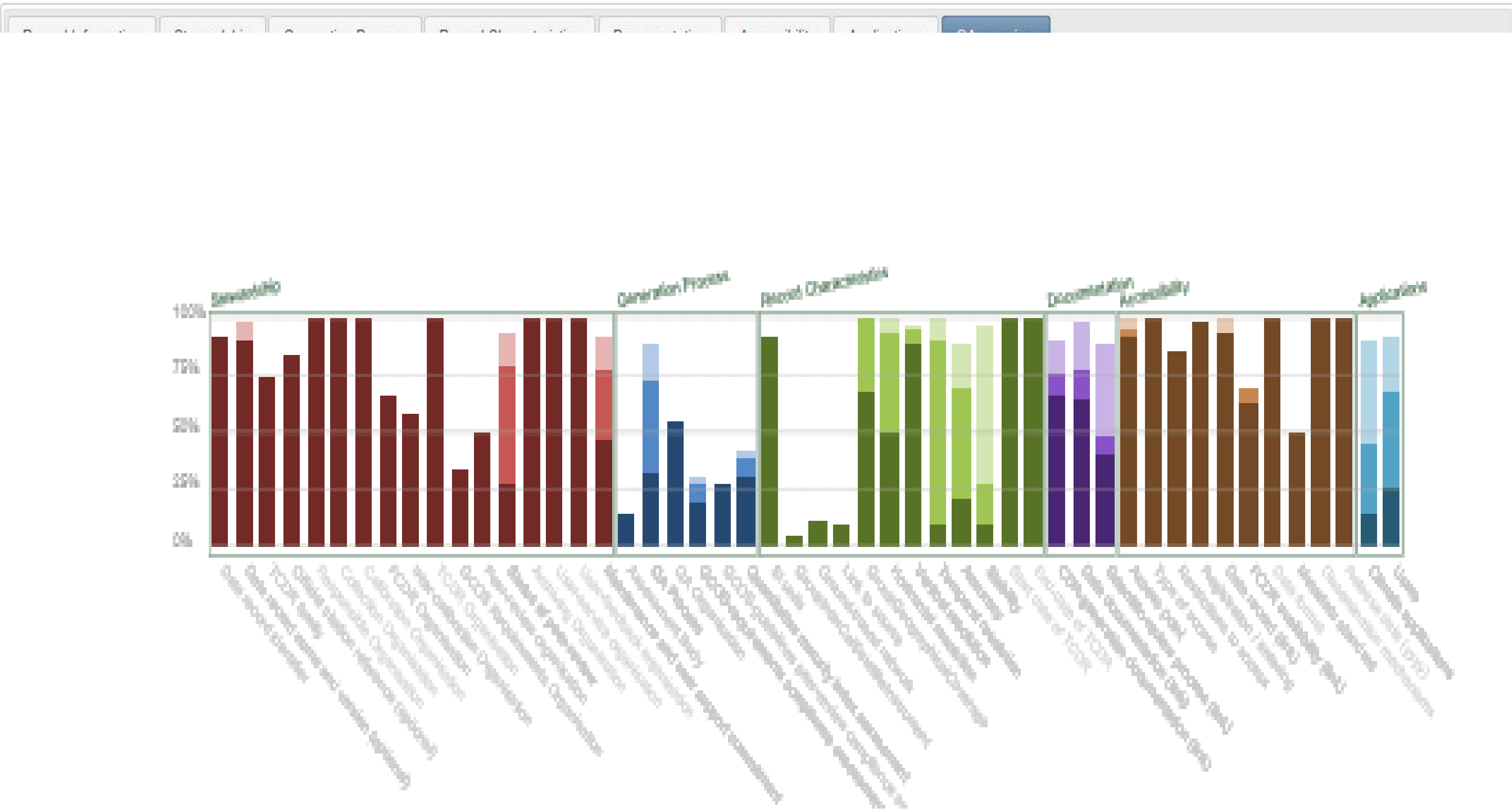
# ECV-Inventory: How many ECV CDR‘s are available?

**Land:**
55 current /
69 planned




Cf. Atmosphere CDRs: 681 entries, total 913;

# ECV-Inventory: Assessment…



# Climatologies based on satellite instrument and usage

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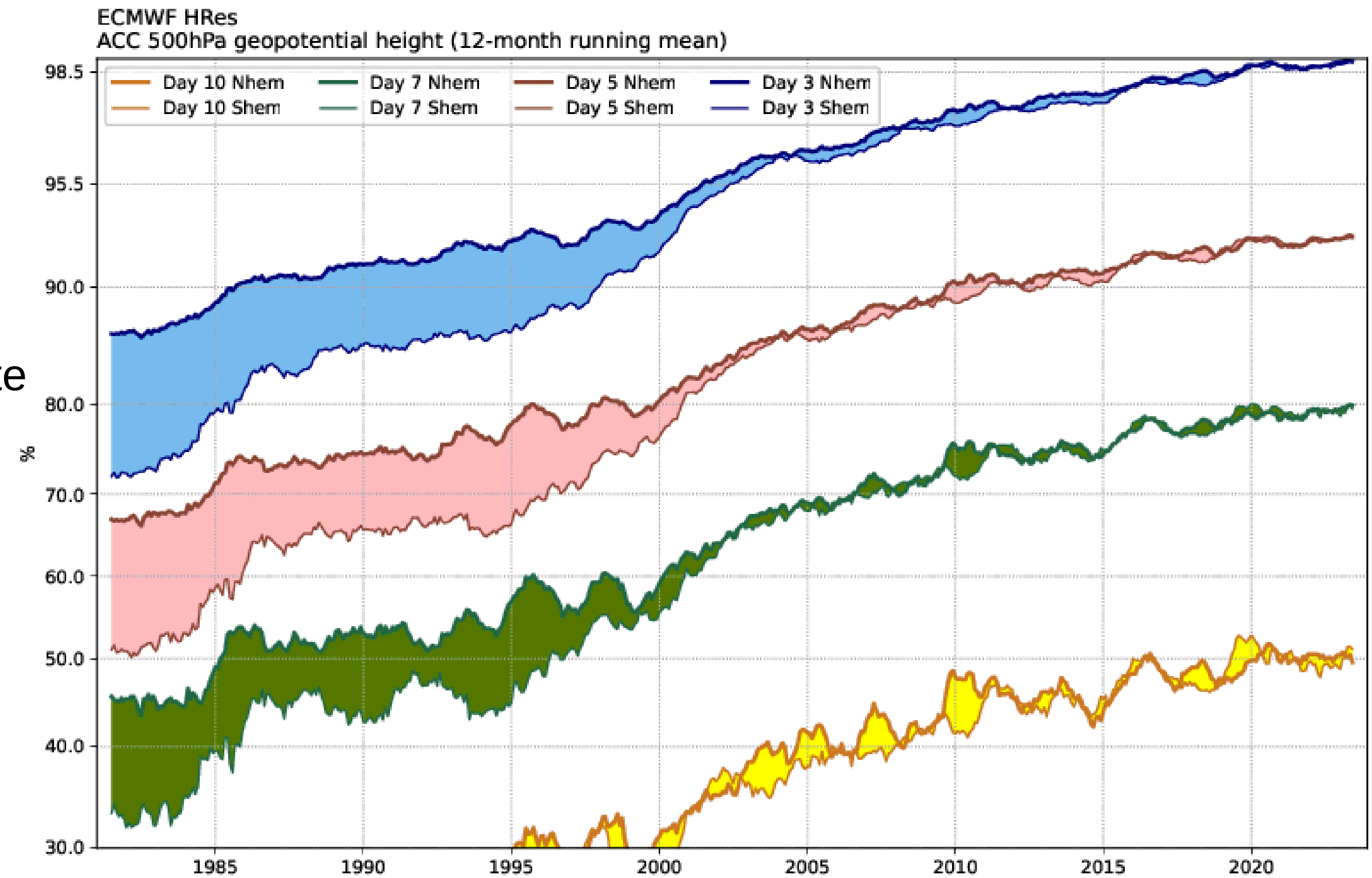
# Progress in analysis accuracy:  forecast skill (I)

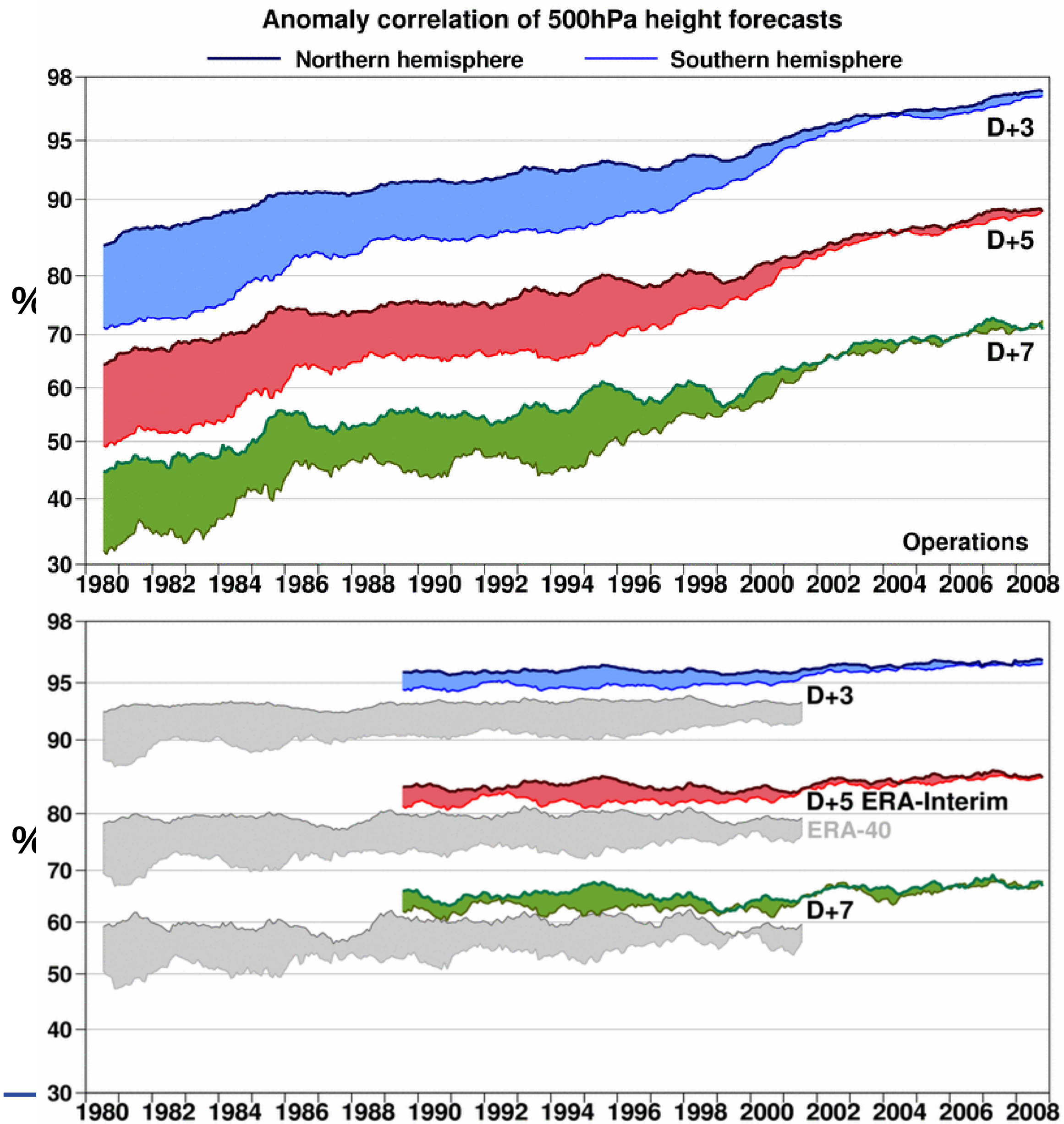
Highly accurate

useful




EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

# Progress in analysis accuracy:  forecast skill (II)




**Updated from Simmons & Hollingsworth (2002)**

Quality of reanalyses

# Climatologies based on satellite instrument and usage

- ➔ Definition of a Climate data record (CDR)
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  - ➔ CM SAF

# ESA‘s Climate Change Initative

## Climate Change Initiative - Objectives

*Realize the full potential of the long-term global EO archives that ESA, together with its Member states, has established over the last thirty years.....*

*..... as a significant and timely contribution to the ECV databases required by the United Nations Framework Convention on Climate Change*

| 7 Years / 93 Meuro | 7 Years / 85 Meuro |
|---|---|
| + 6 Years / 100 Meuro | Hollmann et al. (2013), BAMS |

# Climate Change Initiative from ESA

- The objective of Climate Change Initiative is to **realize the full potential of the long-term** global Earth Observation archives that ESA together with its Member states have established over the last thirty years, as a significant and timely contribution to the ECV databases required by UNFCCC.

- It will ensure that full capital is derived from ongoing and planned ESA missions for climate purposes, including ERS, ENVISAT, the Earth Explorer missions, relevant ESA-managed archives of Third-Party Mission data and, in due course, the GMES Space Component.

- [www.esa-cci.org](http://www.esa-cci.org)

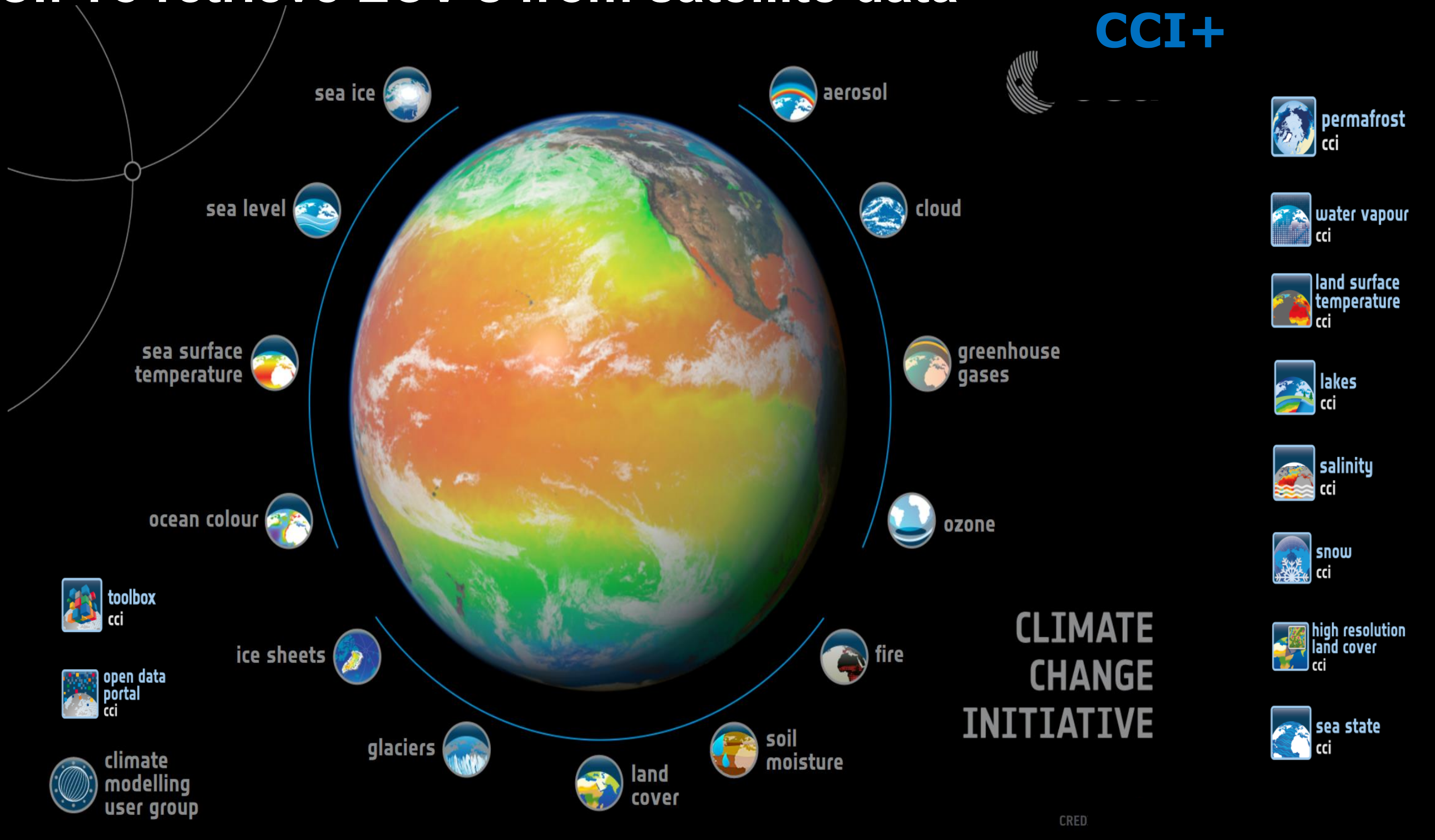
- Hollmann et al. (2013), BAMS

# Climate Change Initiative from ESA (II)

- Based on this analysis the following five main activities will be implemented to achieve the overall objective:
  - **Gathering, collating and preserving** the long-term time series in ESA's distributed archives.
  - **(Re-)Processing periodically** the basic EO-data sets from each individual mission and applying the most up-to-date algorithms and cal/val corrections.
  - **Integrating the calibrated data sets** derived from individual contributing EO mission and sensors to constitute the most comprehensive and well-characterized global long term records possible for each ECV.
  - **Assessing the trends and consistency** of the ECV records in the context of climate models and assimilation schemes.
  - **Developing improved algorithms** and data models for production of the required variables from emerging data sources, consistent with the long term record

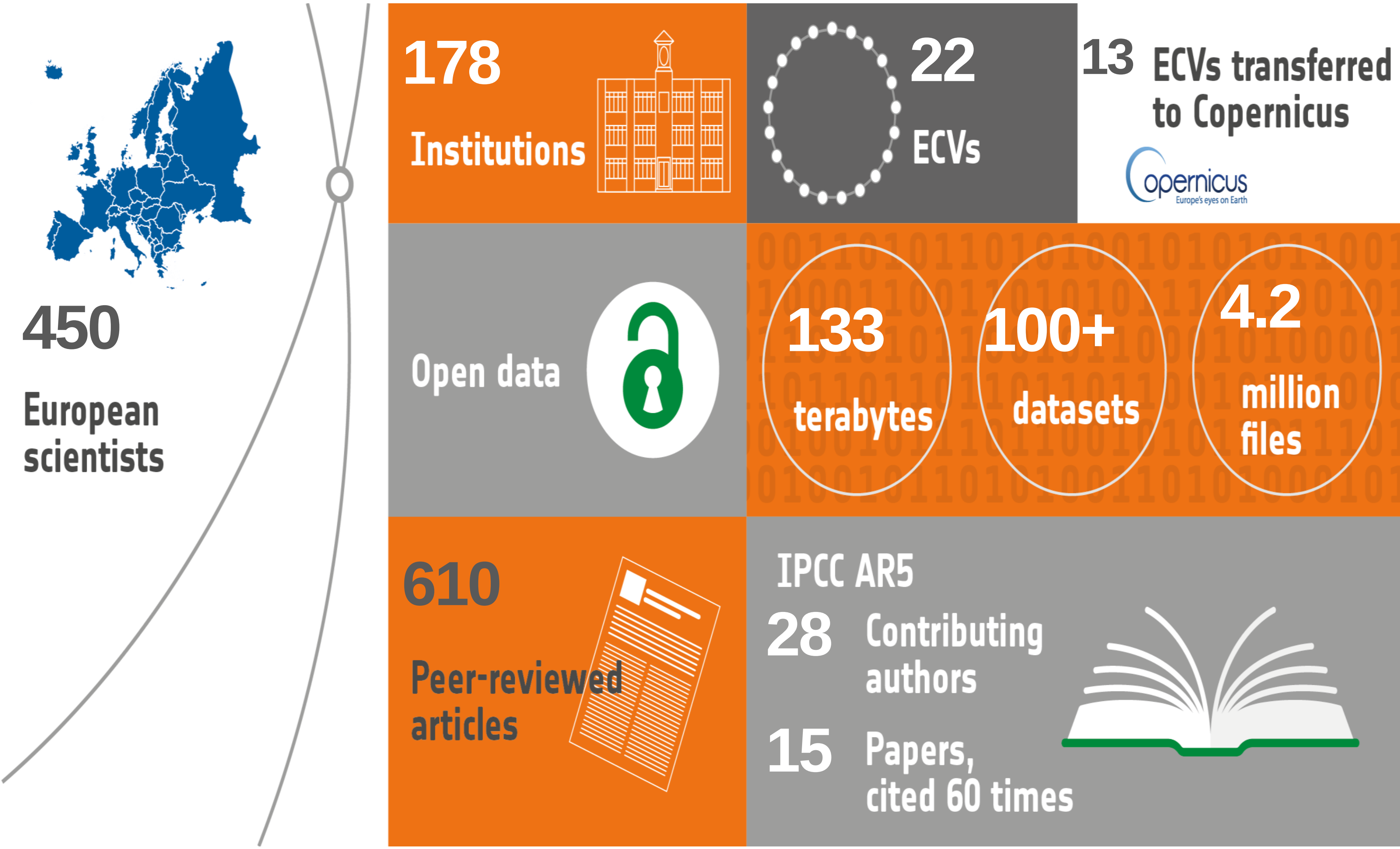
# CCI: To retrieve ECV's from satellite data

CCI+

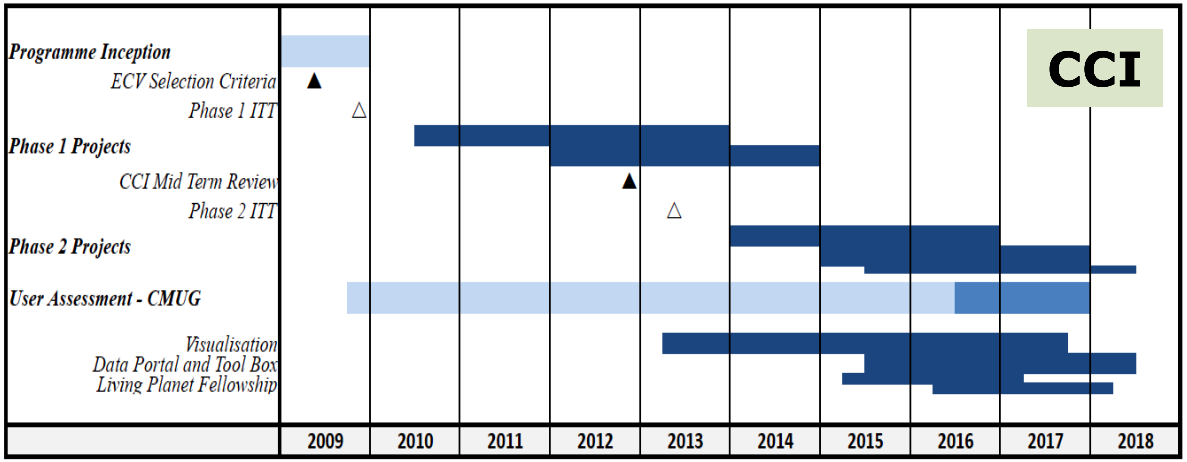



## CCI: 1st Phase ECV Projects

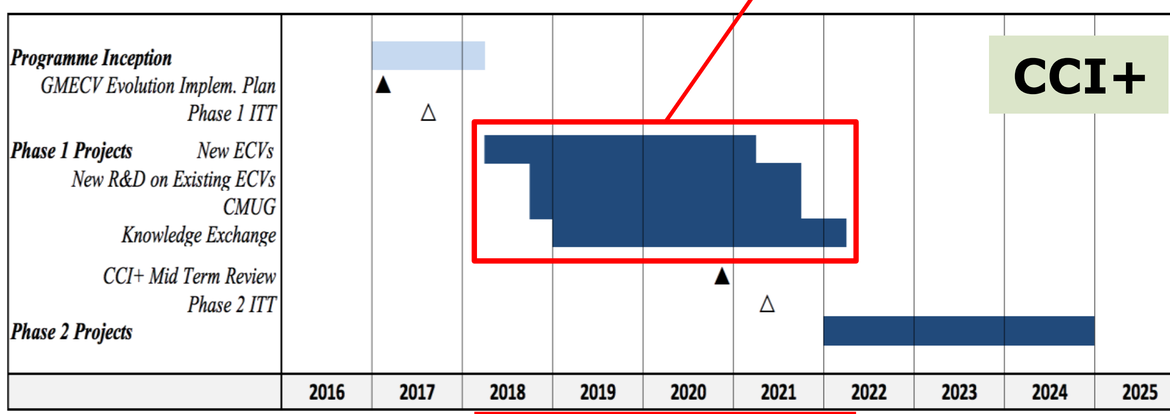
# CCI achievements to date (Status 2019)



# ESA Climate Change Initiative – Phases




CCI+:
i) New ECV projects
ii) R&D on existing ECVs
iii) Cross-ECV exploitation
iv) Knowledge Exchange



# Webinar Series: Monitoring climate change from space

https://climate.esa.int/en/climate-change-initiative-training/webinars/

## Webinar Series: Monitoring climate change from space

Join our latest monthly webinar series showcasing the latest climate science from the ESA-CCI ECV projects

### This month's webinar:

**Permafrost and Climate Change: Insights from CCI data**

**Date: 22 April 2026**

**Time: 16:00 - 17:00 CEST**

Annett Bartsch, b-geos

Join Annett Bartsch on April 22nd for an insightful webinar on how satellite data can be used to monitor permafrost from space. Annett is Managing Director of b.geos as well as the Science Lead for ESA's Climate Change Initiative (CCI) Permafrost project.

This webinar will focus on the ESA CCI Permafrost project providing an overview on the type and magnitude of changes related to permafrost thaw and how these are quantified.

The webinar will:

- Explain how permafrost thaw can be identified from space
- Discuss the differences between Arctic lowlands and mountain areas
- Highlight where the hotspots of permafrost thaw are located
- Explore the different Earth observation approaches that are needed to capture changes in lowland and mountain areas.

Register for the Webinar here

The ESA CCI is a major research effort that generates global, decades-long satellite data records to track and understand key aspects of the Earth's climate system, known as Essential Climate Variables (ECVs).

## Webinar Series: Monitoring climate change from space

**Next webinar:**

Date: 20th May 2026
Time: 16:00 - 17:00 CET

Speaker: Christiaan van der Tol, University of Twente (CCI Vegetation Parameters)

This webinar will present a 21-year, high-resolution satellite dataset measuring foliage density and leaf light absorption - key climate variables affecting the carbon budget. Learn how to access the data and apply it in research and environmental monitoring.

Sign up details coming soon!

https://climate.esa.int/en/climate-change-initiative-training/webinars/

# Climatologies based on satellite instrument and usage

- ➔ Definition of a Climate data record (CDR)
  - ➔ what is needed to generate a CDR?

- ➔ **Climate related Satellite Activities in Europe**
  - ➔ Development in recent years
  - ➔ Use of satellite data in Reanalyse
  - ➔ ESA CCI
  - ➔ **Copernicus C3S**
  - ➔ EUMETSAT CM SAF

# EU - Copernicus Programme


Space Components – „Sentinels“ + 6 dedicated Services

# Copernicus C3S

# C3S Components

C3S components

European Commission

**Copernicus Climate Change Service**

| Climate Data Store | **Sectoral Information System** | Evaluation and Quality Control | Outreach and Dissemination |
|---|---|---|---|

**Climate Data Store**

- ECVs past, present and future
- Observed, reanalysed and simulated
- Derived climate indicators
- Tools to support adaptation and mitigation at global and European level

**Sectoral Information System**

**Evaluation and Quality Control**

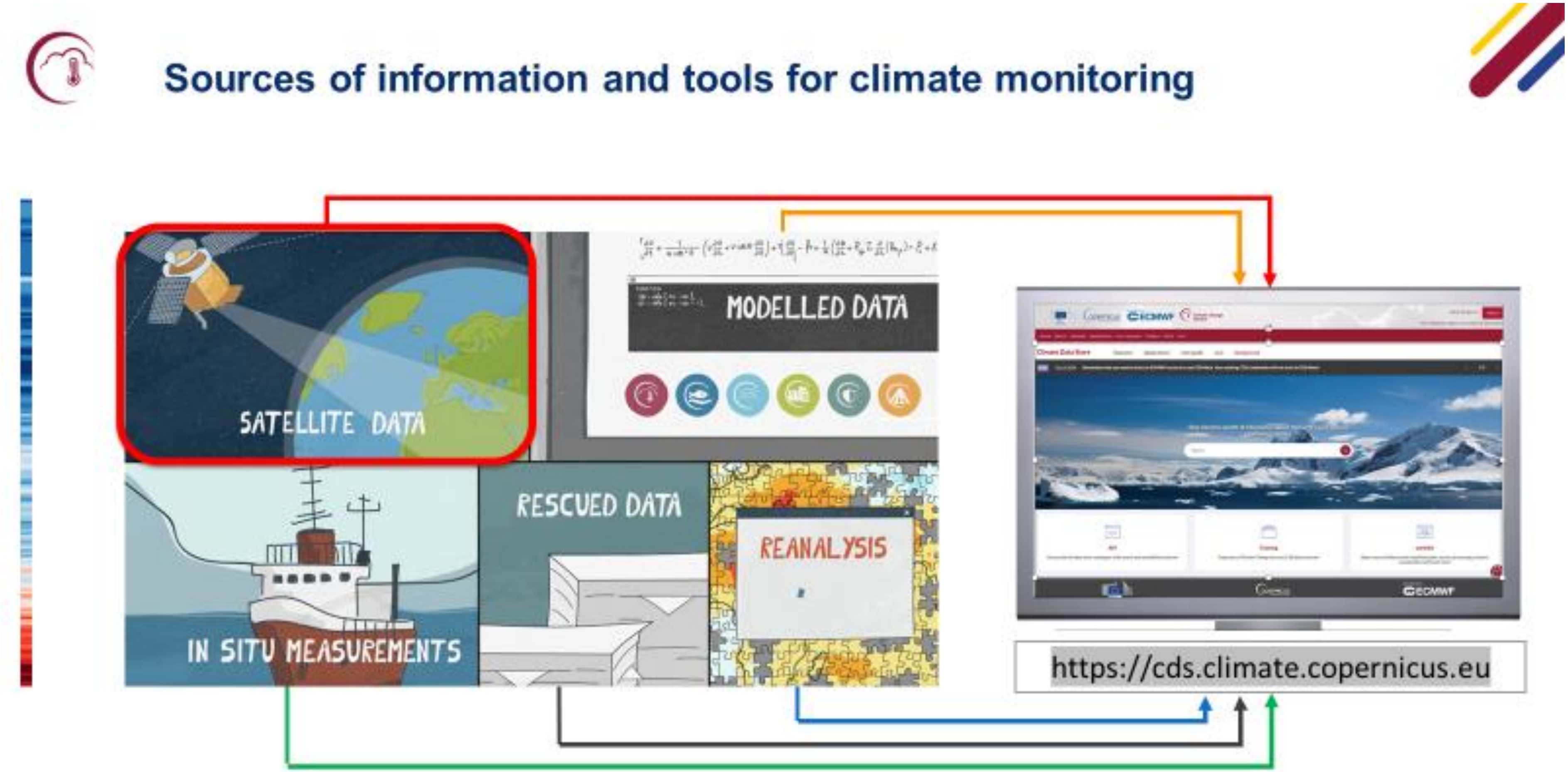
- Monitors quality of C3S products and services
- Ensures C3S delivers state-of-the-art climate information to end-users
- Identifies gaps in service provision
- Bridges Copernicus with the research agenda in Europe (e.g. H2020, national research projects)

**Outreach and Dissemination**

- Web content
- Public outreach
- Coordination with national outreach
- Liaison with public authorities
- Conferences, seminars
- Training and education

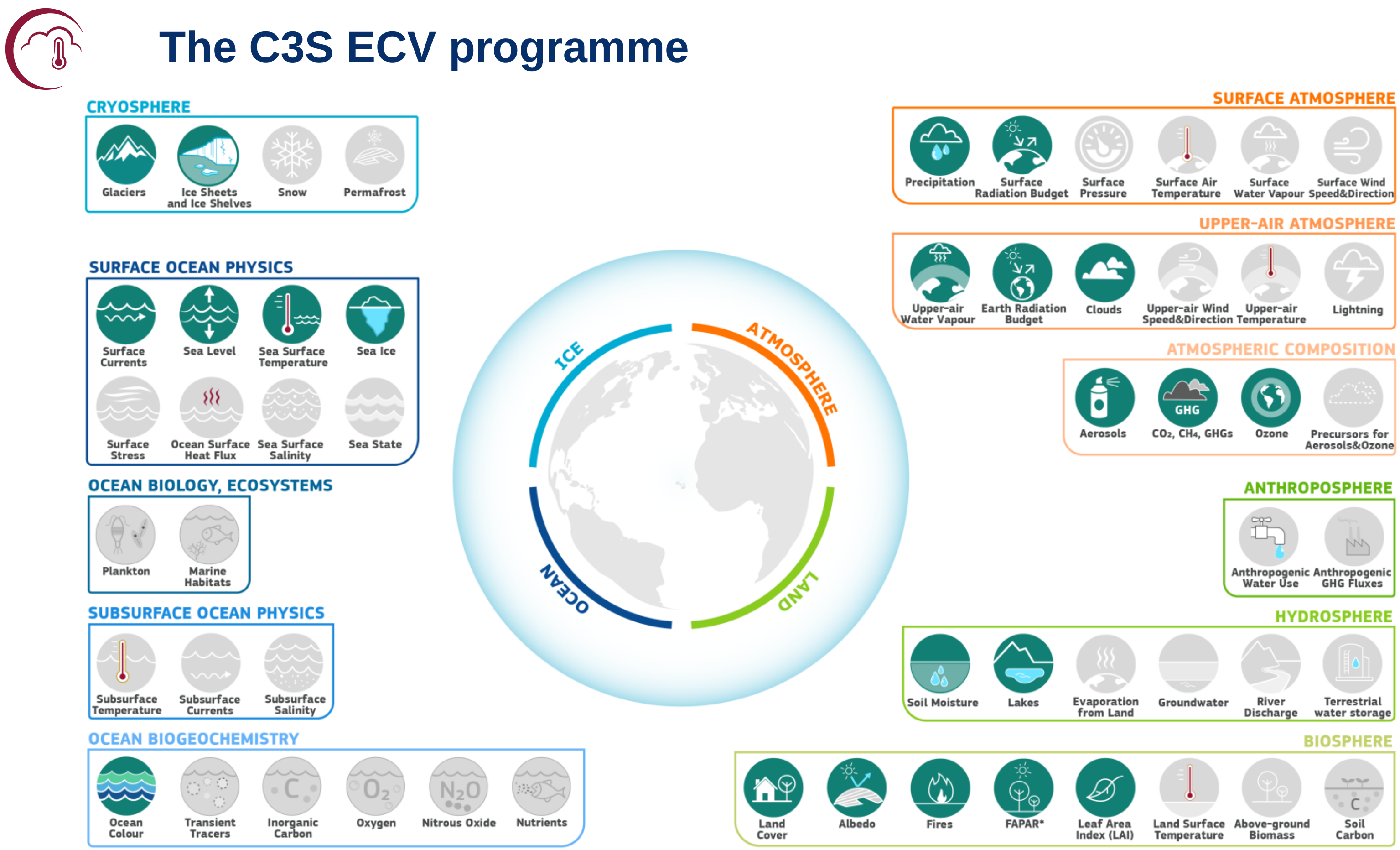
Copernicus
Europe's eyes on Earth

# C3S Climate Data Store




Source: C3S, J. Munoz-Sabatier

# The C3S ECV programme




Source: C3S, J. Munoz-Sabatier

In total GCOS defines 55 ECVs (GCOS 2022 Implementation Plan)

Three main domains:

- Atmospheric
- Oceanic
- Terrestrial

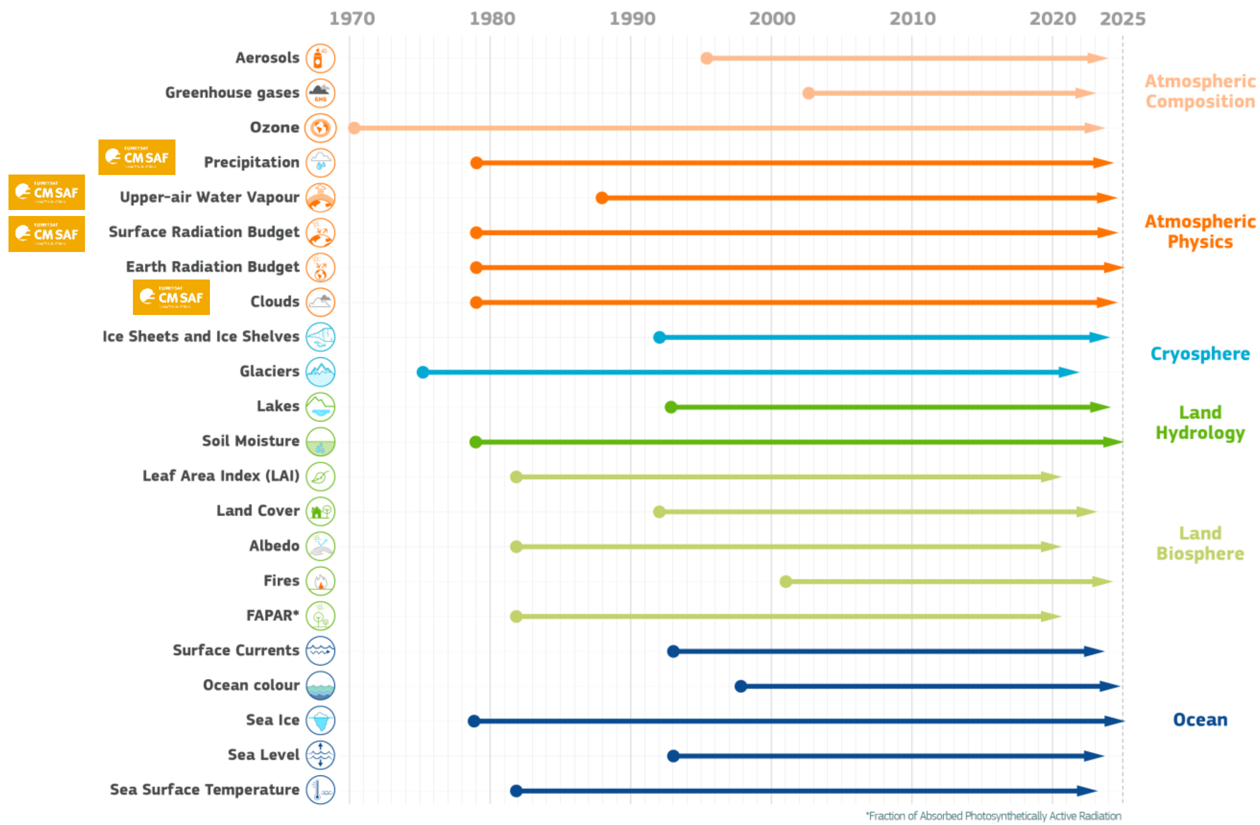
# C3S ECV Portfolio

## Climate Data Records of Essential Climate Variables – current offer

*Based on satellite data, they monitor trends and variability*

*Involve close coordination and collaboration with major providers (ESA, EUMETSAT) and Copernicus Services*

*Their production require the expertise of many public and private entities in Europe*




Source: C3S, J. Munoz-Sabatier

PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

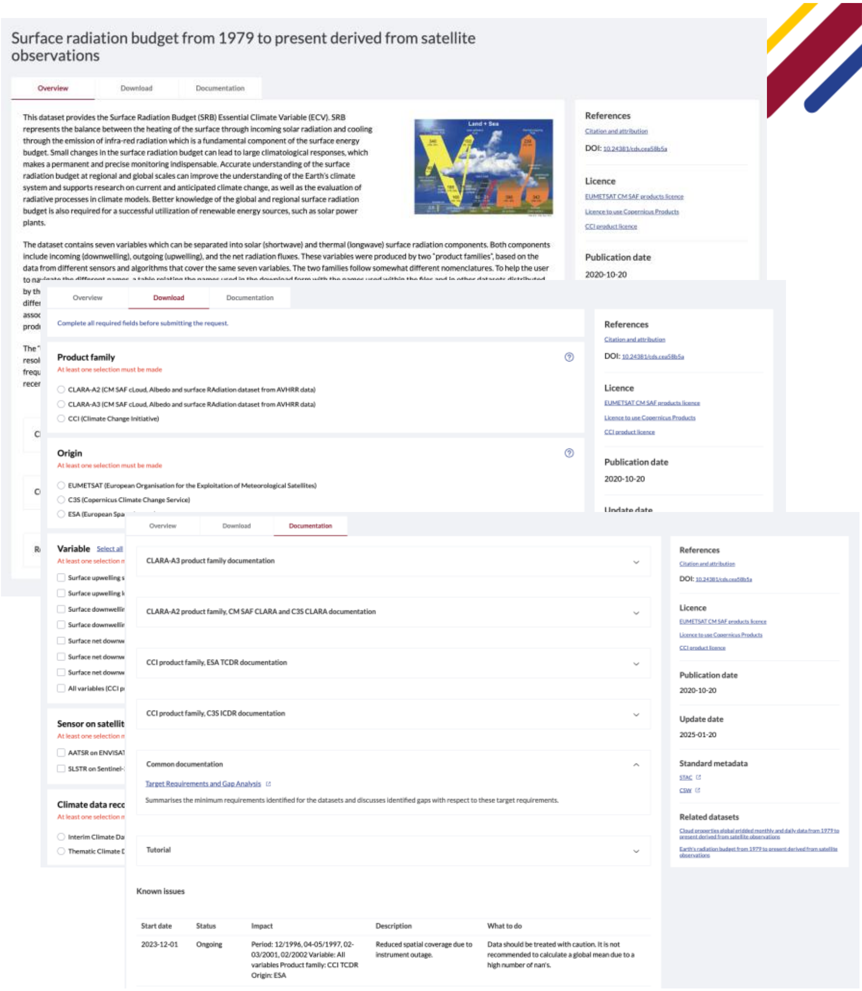
Climate Change Service climate.copernicus.eu

# C3S ECV Services (i)

## C3S ECV services

**Access to ECV products** through a harmonized look-and-feel interface (CDS), which are:

- State of the art (coordination with ESA, EUMETSAT, Copernicus Services)
- Long-term, consistent, complete (CDR) [multi-sensor approach]
- Regularly extended in time (ICDR)
- Gridded, aggregated (meeting climate requirements)
- Accessible & Traceable
  - Access through the Climate Data Store
  - Comprehensive documentation




Source: C3S, J. Munoz-Sabatier

PROGRAMME OF THE EUROPEAN UNION

# C3S ECV Services (ii)

## C3S ECV services

Independent **Evaluation and Quality Control**

Specialised **User Support**

**Training** material

**Use cases**

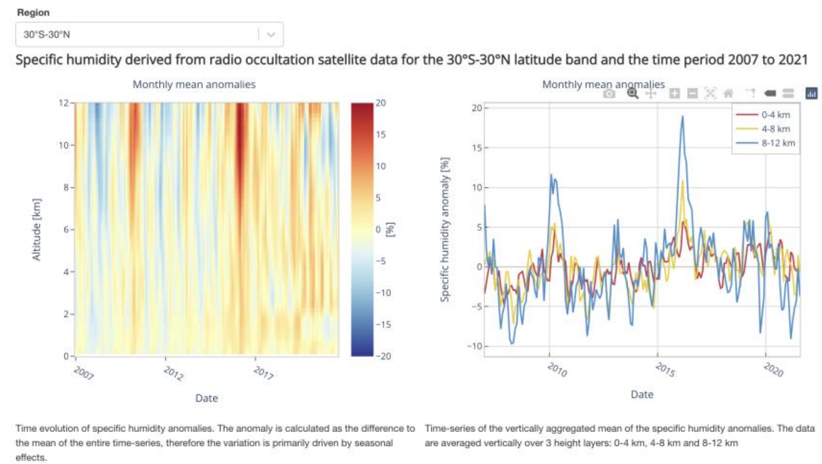
Data **visualisation**

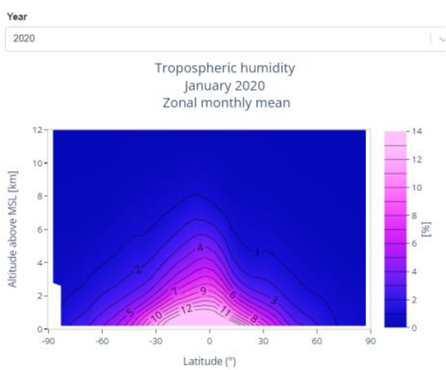
Licenses, references, doi

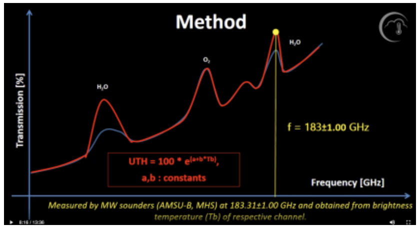
**Applications** tailored to different sectors

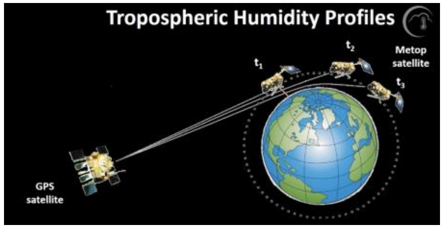
Climate Intelligence derived **products**

...



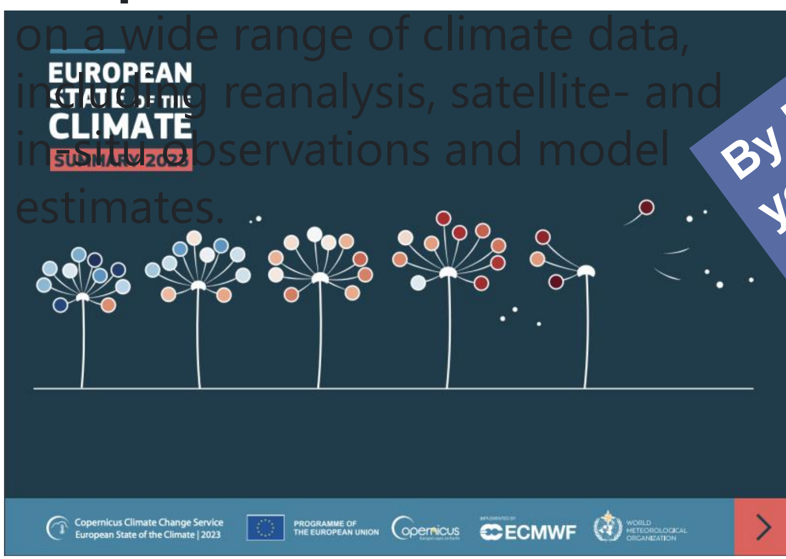

Source: C3S, J. Munoz-Sabatier

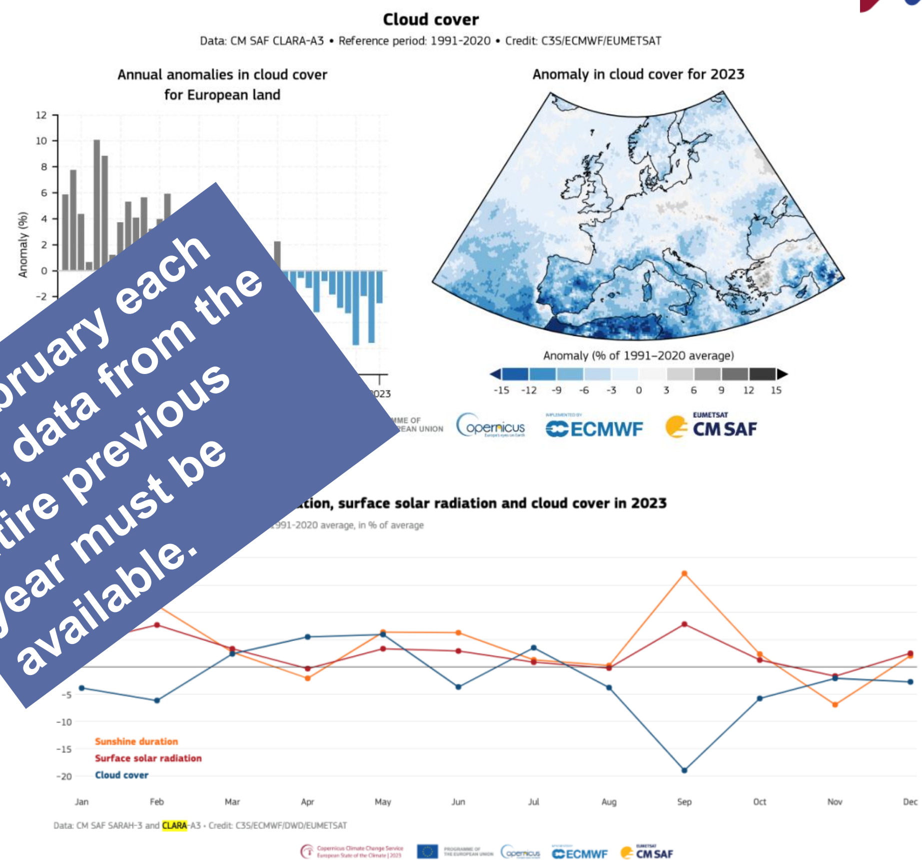
PROGRAMME OF THE EUROPEAN UNION

# C3S ECV Services (iii)

## The European State of the Climate

Typically published in April of the following year, **the ESOTC provides information about the climate conditions of the *previous year* for Europe and the Arctic**. It is based on a wide range of climate data, including reanalysis, satellite- and in-situ observations and model estimates.




**By February each year, data from the entire previous year must be available.**

Source: C3S, J. Munoz-Sabatier — PROGRAMME OF THE EUROPEAN UNION — opernicus, Europe's eyes on Earth — IMPLEMENTED BY ECMWF — Climate Change Service, climate.copernicus.eu

# Copernicus – continue global leadership in EO

esa

**> 200.000**

registered users
= tip of the iceberg

**6 operational services**

Land | Atmosphere | Ocean | Climate | Disaster | Security

**150 TB** satellite data distributed per day

**full, free & open** data policy

**7 satellites flying**

S1 ● ●
S2 ● ●
S3 ● ●
S4
S5P ●
S5
S6

**preparing Copernicus 2.0**

# Climatologies based on satellite instrument and usage

- ➔ Definition of a Climate data record (CDR)
  - ➔ what is needed to generate a CDR?

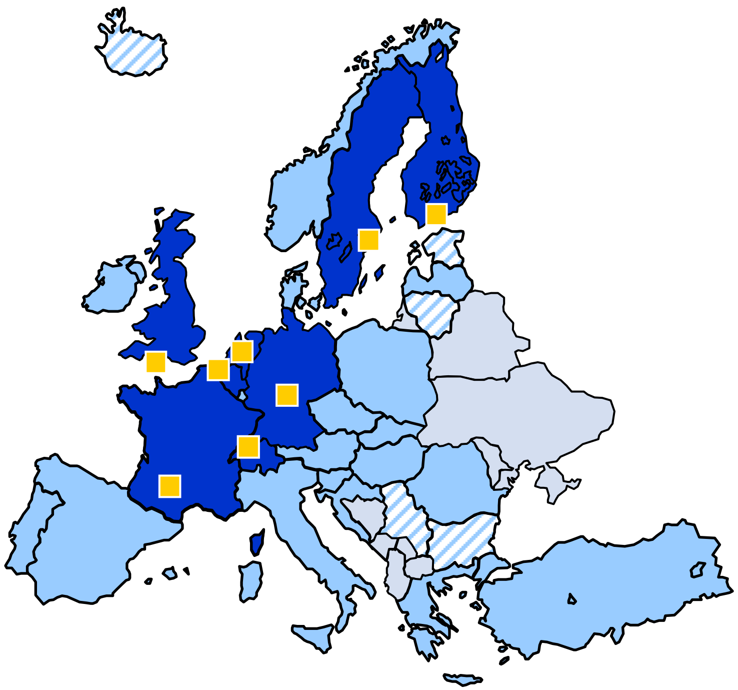
- ➔ **Climate related Satellite Activities in Europe**
  - ➔ Development in recent years
  - ➔ Use of satellite data in Reanalyse
  - ➔ ESA CCI
  - ➔ Copernicus C3S
  - ➔ **EUMETSAT CM SAF**

# The EUMETSAT SAF Network

- Established in 1999 as decentralised part of the operational ground segment
- Using the expertise from Member States – capacity building in Member States
- Definition of dedicated application areas
- Each SAF is lead by a NMHS and involves further Met. Services / other partner organisations

EUMETSAT CM SAF CLIMATE MONITORING

# CM SAF Partners



- *EUMETSAT Member States*
- *EUMETSAT Cooperating States*
- *CM SAF Member States*
- *Location of Partner NMHSs*

*Deutscher Wetterdienst*

*Swedish Meteorological and Hydrological Institute*

Koninklijk Nederlands
Meteorologisch Instituut
*Ministerie van Verkeer en Waterstaat*

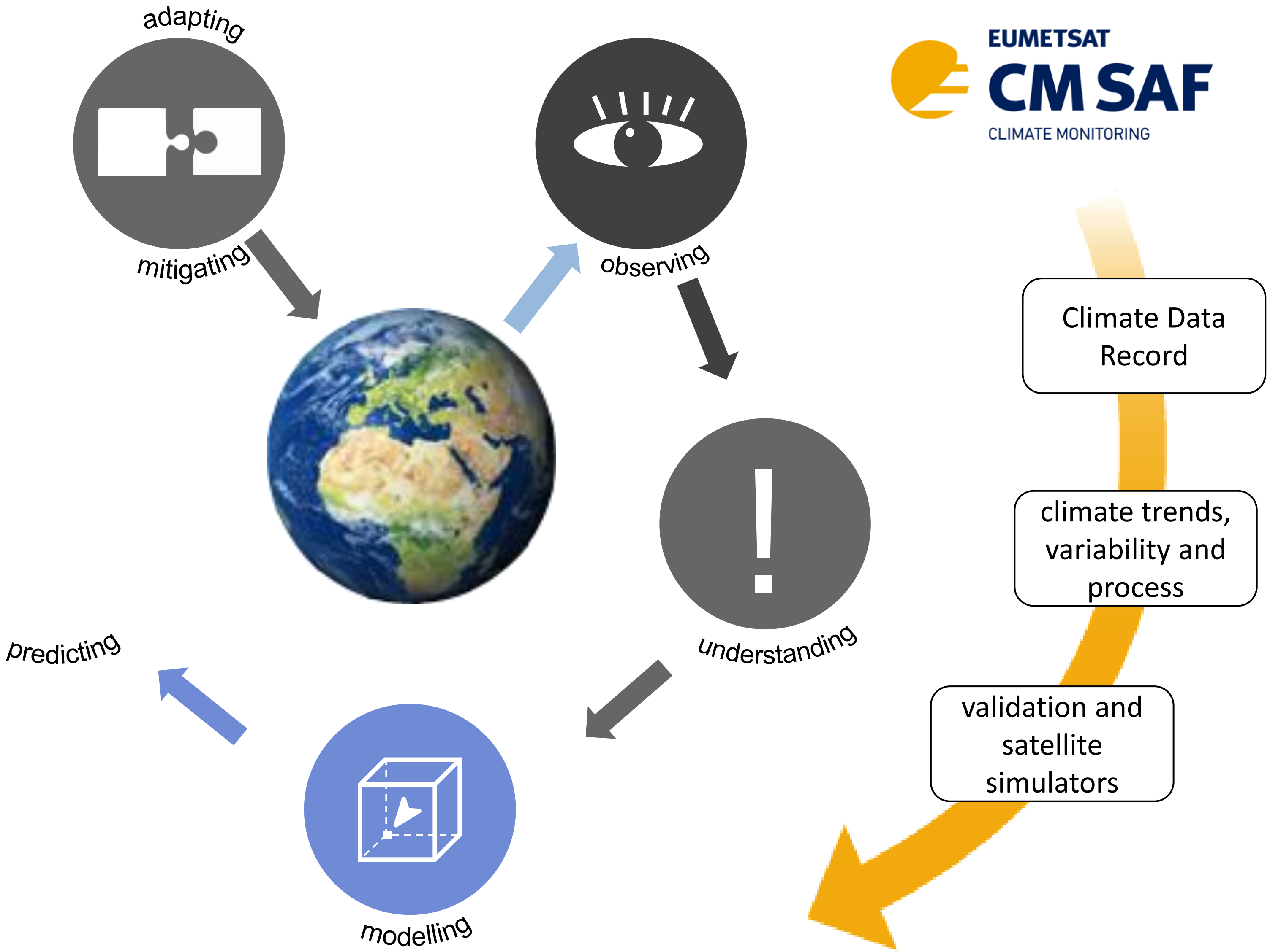
*Royal Meteorological Institute of Belgium*

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
**Federal Office of Meteorology and Climatology**
**MeteoSwiss**

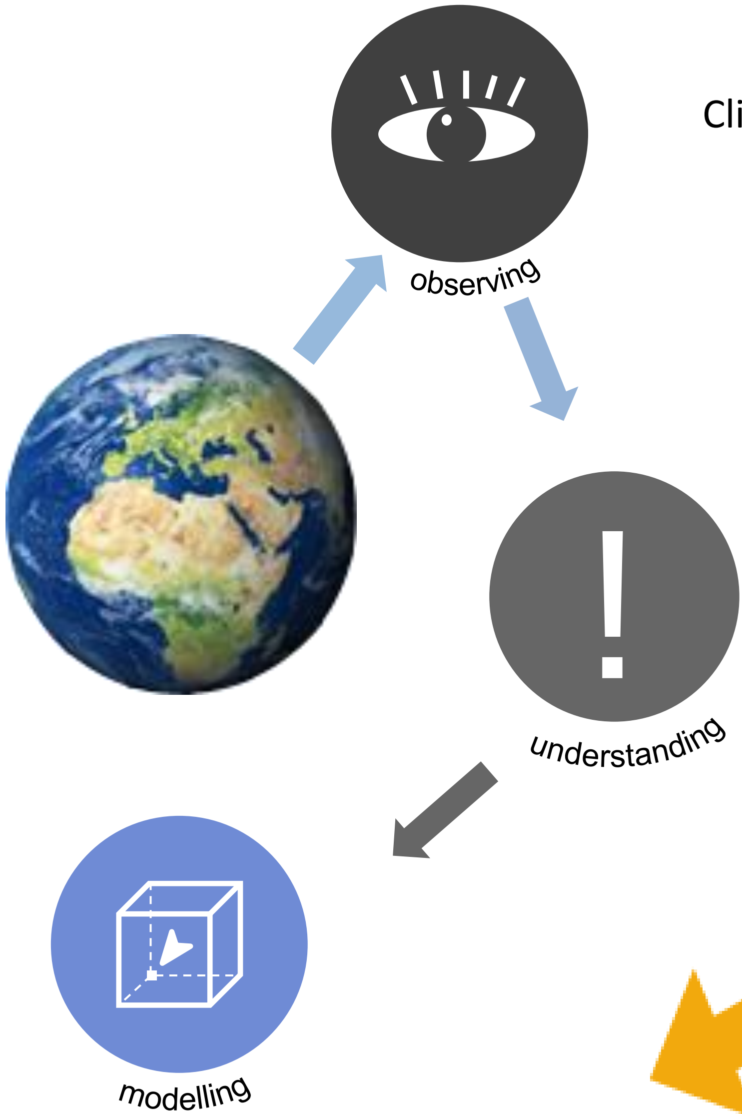
*Finnish Meteorological Institute*

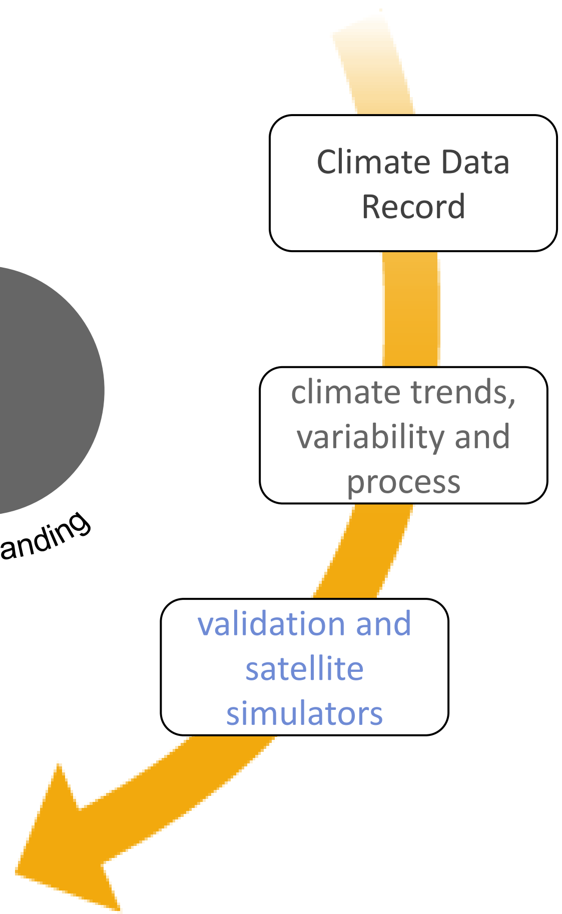
*Met Office, United Kingdom*

Centre National de la recherche scientifique


adapting
mitigating
observing
understanding
modelling
predicting
Climate Data Record
climate trends, variability and process
validation and satellite simulators

# Climate Monitoring based on Satellites @ DWD




**We provide**
- Essential Climate Variables
    - Thematic Climate Data Records
    - Interim Climate Data Records
- Fundamental Climate Data Records

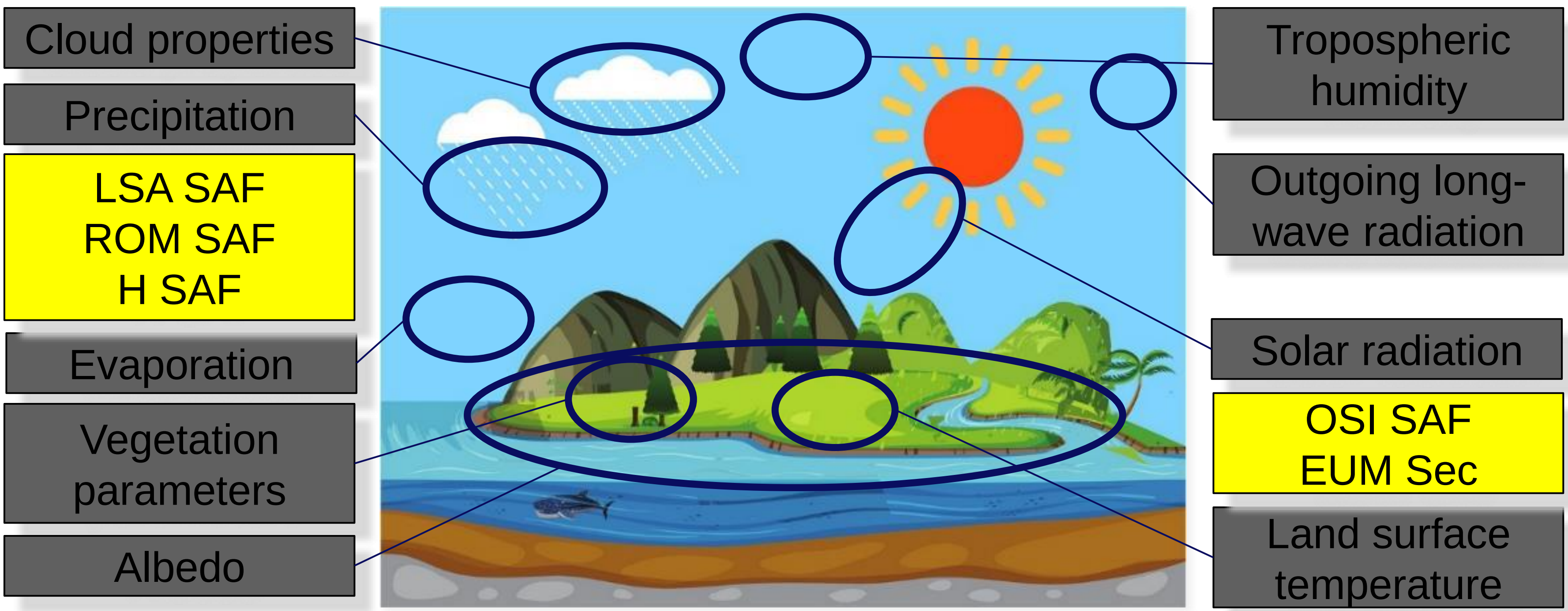
**We provide**
- Training & capacity building
- toolbox
- Application examples

**We support**
- Process analysis
- Statistical analysis
- Climate assessments

**We provide**
- Validation data (Obs4MIPs compatible)
- Satellite simulators

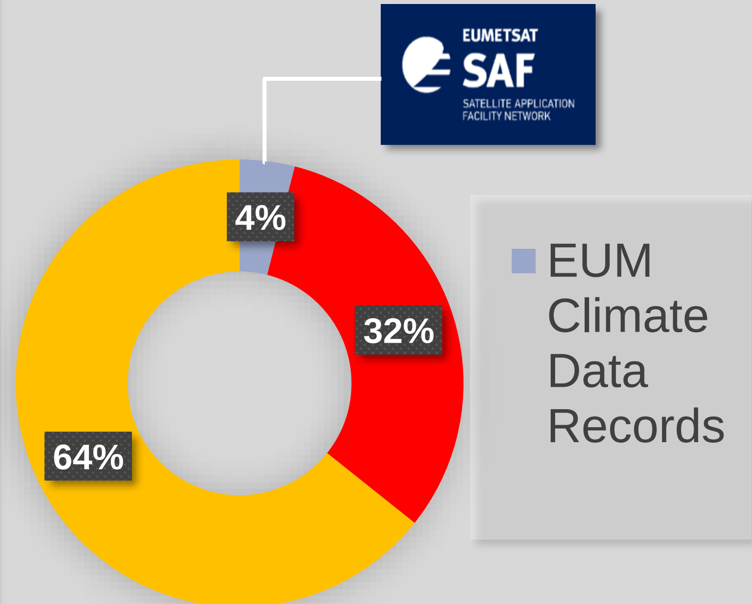
# EUMETSAT Climate Product Portfolio

| PP | IOP | CDOP-1 | CDOP-2 | CDOP-3 | CDOP-4 | CDOP-5 | CDOP-6 |
|---|---|---|---|---|---|---|---|
| 1999-2004 | 2004-2007 | 2007-2012 | 2012-2017 | 2017-2022 | 2022-2027 | 2027-2032 | beyond 2032 |

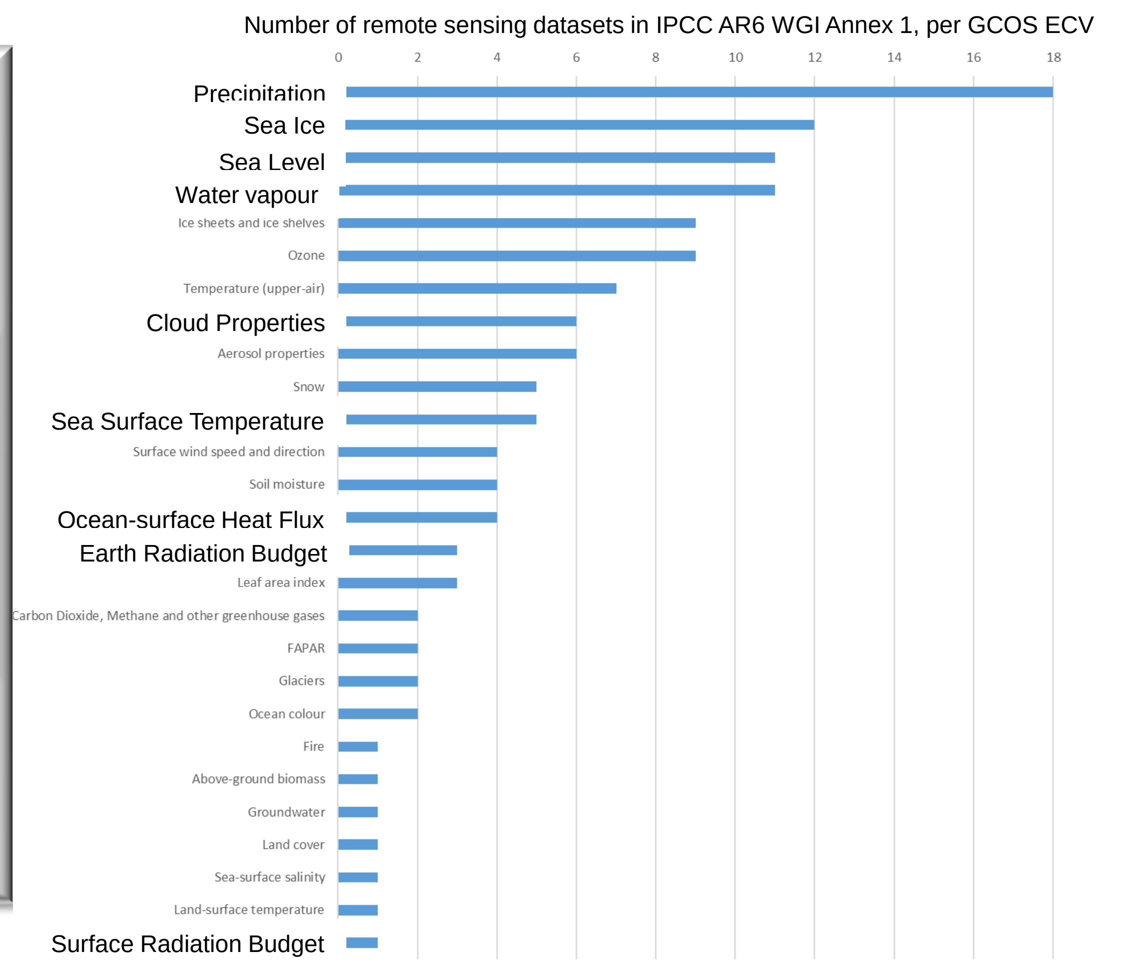


# IPCC WG-1 AR6 (2021) – EUMETSAT contribution

## IPCC Data USAGE




Pie Chart corresponds to 126 (45% of total number) data sets labelled as remote sensing and reanalysis or combinations

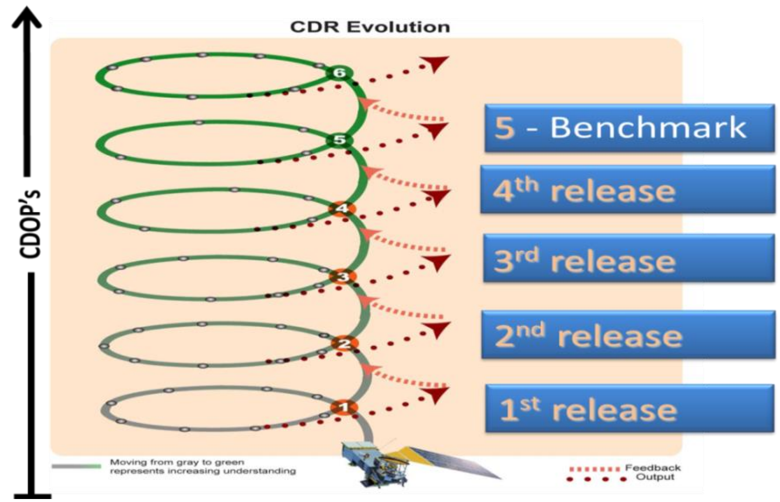


PP 1999-2004 | IOP 2004-2007 | CDOP-1 2007-2012 | CDOP-2 2012-2017 | CDOP-3 2017-2022 | CDOP-4 2022-2027 | CDOP-5 2027-2032 | CDOP-6 beyond 2032

# CM SAF concept and design

➔ **Focus** on generation and provision of climate data records to support climate monitoring

- ➔ Cyclic reprocessing of data
- ➔ Agile framework using opportunities and chances
- ➔ Access to high performance IT infrastructure (e.g. ECMWF, EWC, DWD)
- ➔ All data record are quality controlled
- ➔ Strong collaboration with Sec. & SAF network



# Overall portfolio of climate data records - global

| Sensor, Satellite resp. | Parameter | CDR Period | Coverage |
|---|---|---|---|
| **F**undamental **C**limate **D**ata **R**ecord (FCDR) | | | |
| **SMMR, SSM/I, SSMIS** | **Microwave Radiances** | 1979 – 2022 | global |
| **C**limate **D**ata **R**ecord (CDR) | | | |
| **AVHRR GAC** | **Cloud parameters, surface radiation parameters, incl. albedo, TOA radiation (CLARA*)** | 1982 – 2020 | Global |
| **SSM/I, SSMIS** | **HOAPS (precip, evap, hum., wind, ...) (ice-free ocean )** | 1987 – 2014 | |
| **ATOVS** | **Water vapour and temperature profiles** | 1999 – 2012 | |
| **Microwave imagers + sounders, Geo-ring** | **Global precipitation (GIRAFE)** | 2002 – 2020 | |
| **MSU, AMSU, SSM/T2, MHS** | **Upper troposphere humidity** | 1994 – 2018 | |
| **Microwave+NIR imagers** | **Total column water vapour with ESA WV_cci** | 2002 – 2017 | |

* ICDR service, data available until present time

| PP | IOP | CDOP-1 | CDOP-2 | CDOP-3 | CDOP-4 | CDOP-5 | CDOP-6 |
|---|---|---|---|---|---|---|---|
| 1999-2004 | 2004-2007 | 2007-2012 | 2012-2017 | 2017-2022 | 2022-2027 | 2027-2032 | beyond 2032 |

# Available CDRs – Regional (Focus on Europe/Africa)

| Sensor, Satellite resp. | Parameter | CDR Period | Coverage |
|---|---|---|---|
| **C**limate **D**ata **R**ecord (CDR) | | | |
| **SEVIRI** | **Cloud parameters (frac., height, opt. dep., phase, eff. rad., LWP, IWP), AOD (-2012) (CLAAS*)** | 2004 – 2012<br>2004 – 2017<br>2004 – 2020* | Regional |
| **GERB/SEVIRI** | **Top of atmosphere radiative fluxes** | 2004 – 2015 | |
| **MVIRI/SEVIRI** | **Cloud frac. (COMET), Land Surface Temperature (SUMET), surface radiation budget**<br>**Latent + sensible heat flux (land)**<br>**Free tropospheric humidity**<br>**Surface radiation (SARAH*)** | 1983 – 2020<br><br>1983 – 2020<br>1983 – 2009<br>1983 – 2020* | |

* ICDR service, data available until present time

# More Climate data records to come…

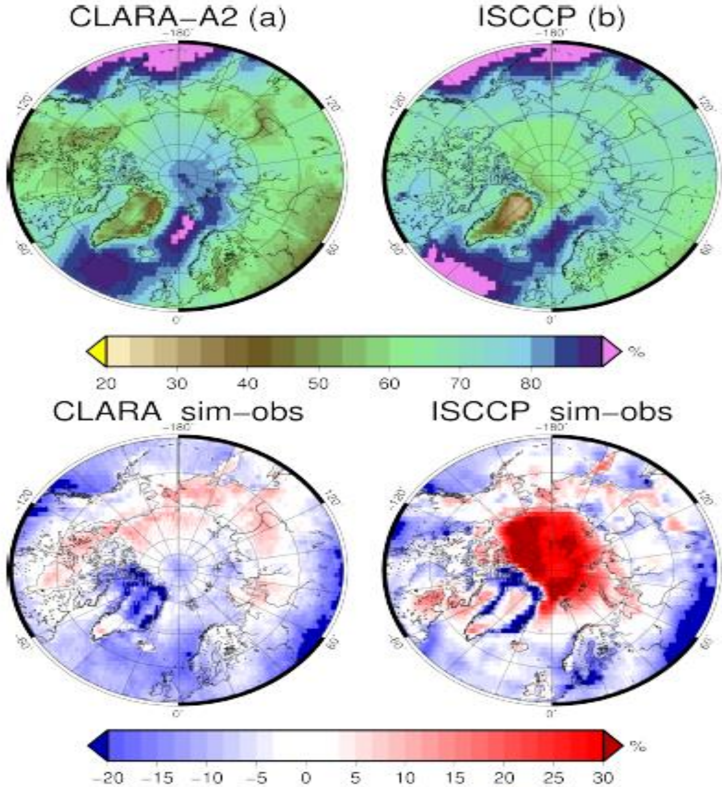
| Sensor, Satellite resp. | Parameter | CDR Period | Coverage |
|---|---|---|---|
| **Climate Data Record (CDR)** | | | |
| **SEVIRI** | **Cloud parameters (CLAAS-4*)** | 2004 – 2024* | Regional |
| **Geo-ring** | **Land surface temp., latent+sensible heat flux, SRB** | CDOP 5 | Global |
| **Geo-ring** | **Cloud products, TOA radiation** | ***ISCCP-NG demo*** | |
| **Microwave imagers+sounders, Geo-ring** | **Global precipitation (GIRAFE) *** | 2002 – 2020 (2024)* | Global |
| **AVHRR GAC** | **(CLARA-A3.5*)** | 1979 – 2024* | Global |
| **SSM/I, SSMIS, TMI, GMI, AMSR-E, AMSR2** | **HOAPS 5 (precip, evap, hum., wind, ..)** | 1987 – 2022) | |
| **Geo-ring** | **Surface radiation (SARAH*-GEO)** | 1983 – 2025* | |
| **MSU, AMSU, SSM/T2, MHS**<br><br>**Microwave+NIR imagers** | **Upper troposphere humidity**<br><br>**Total column water vapour (from ESA WV_cci)** | 1994 – 2023<br><br>2000 – 2022 | |

* Continued/new ICDR service

# Example Application of CM SAF data…

## CLARA cloud simulator

- CLARA and CLAAS CDRs have associated satellite simulators to enable better model to observations comparisions
- Simulators adjust model cloud cloudiness to emulate cloud detection capabilies of CDR.
- Figure shows CLARA-A2 and ISCCP CDRs (obs) with respective simulators (sim) based on EC Earth climate model. July 1983 to June 2015.
- CLARA simulator takes into account limitations of cloud detection in the Arctic.

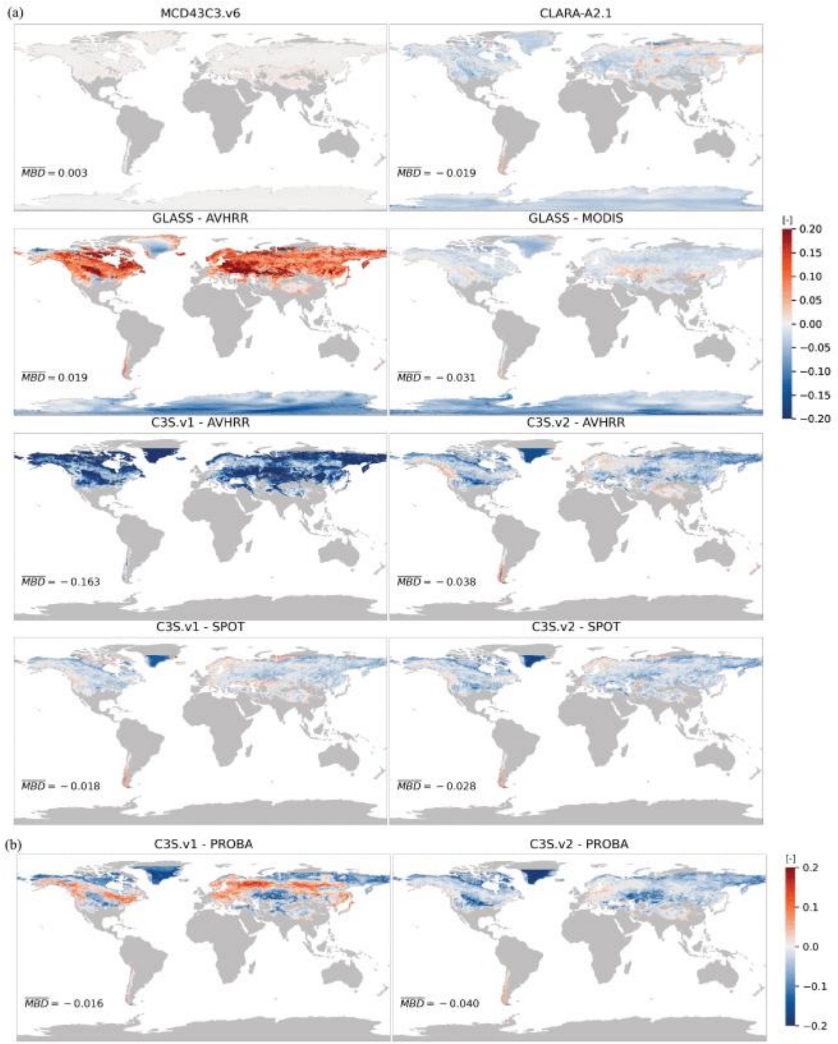



Eliasson et. al., 2020

# Example Application of CM SAF data…

## Comparison of snow albedo data records

- Bias assessment (right) suggests that CLARA-A2.1 had the closest agreement with MODIS (MCD43C3 ed 6.1) among the evaluated data records.
- But some drift in CLARA albedo since 2015 was apparent due to AVHRR radiometric calibration drifts.
- The independent validation results confirm the validity of the CLARA approach to snow and ice albedo estimation:
- ”Only CLARA-A2.1 is able to produce acceptable estimations in terms of bias, while all the products face stability issues”

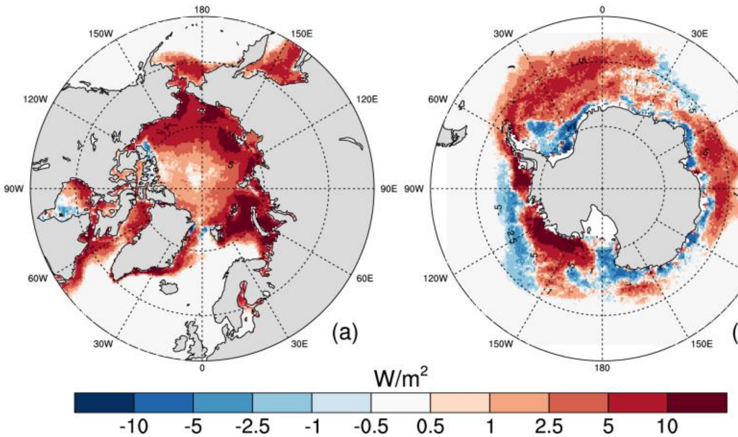



Urraca, R., Lanconelli, C., Cappucci, F., & Gobron, N. (2023). Assessing the fitness of satellite albedo products for monitoring snow albedo trends. *IEEE Transactions on Geoscience and Remote Sensing*, *61*, 1-17.

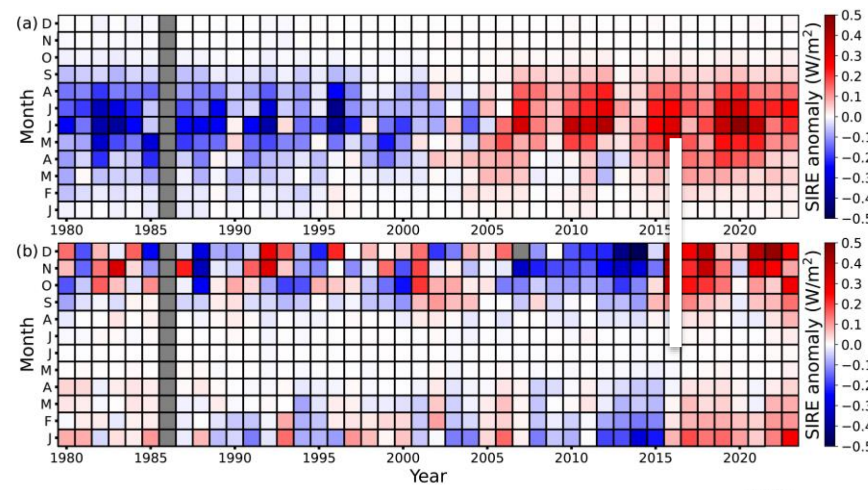
# Example Application of CM SAF data…

## Decadal changes in polar sea ice radiative effect (SIRE) from CLARA-A3 surface albedo and radiative transfer simulations

(2016-2023) – (1980-1988) SIRE




Monthly SIRE anomalies in the Arctic (top) and Antarctic (bottom)



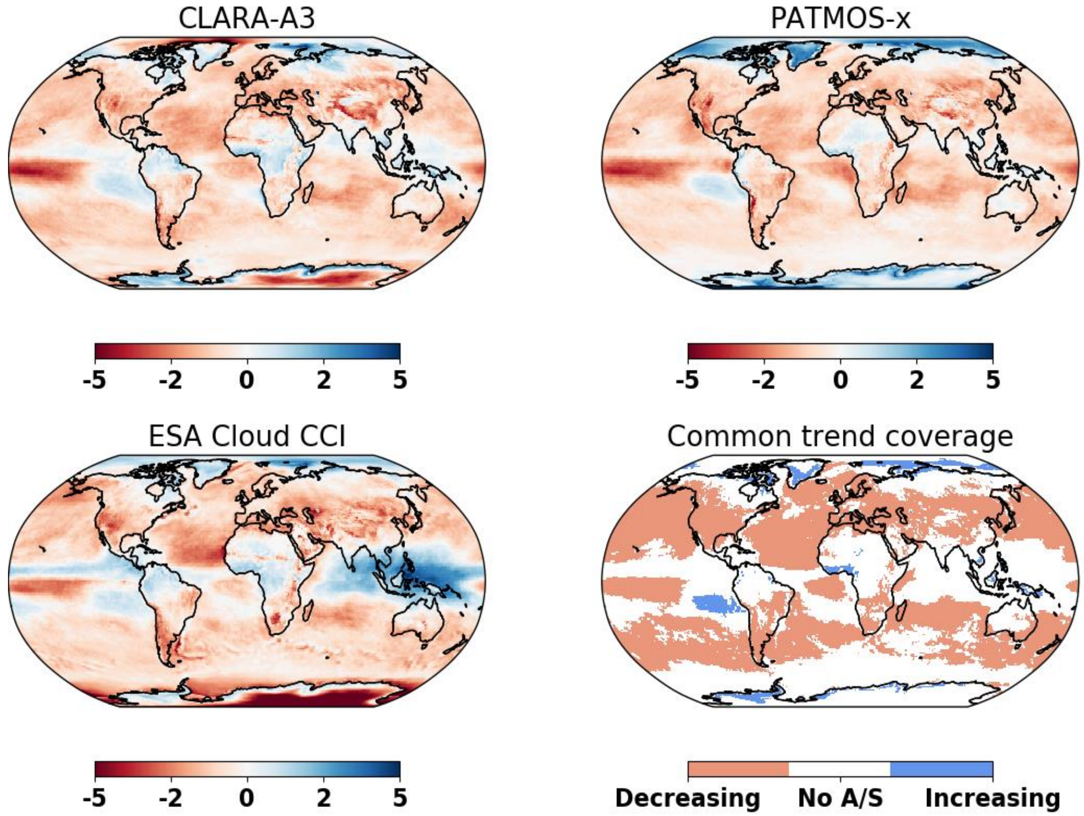

- The 'cooling power' of Arctic sea ice has reduced by 20% (0.16 W/m²) compared to the 1980s
- Corresponding reduction for Antarctic sea ice is 12% (0.10 W/m²)
- The implied sea ice albedo feedback is 0.24–0.38 W/m²/K
  - Upper end of that simulated by CMIP5 models (*Donohoe et al*., 2020)


Duspayev, A., Flanner, M. G., & Riihelä, A. (2024). Earth's sea ice radiative effect from 1980 to 2023. *Geophysical Research Letters*, *51*(14), e2024GL109608.

# Where on Earth are clouds changing most?

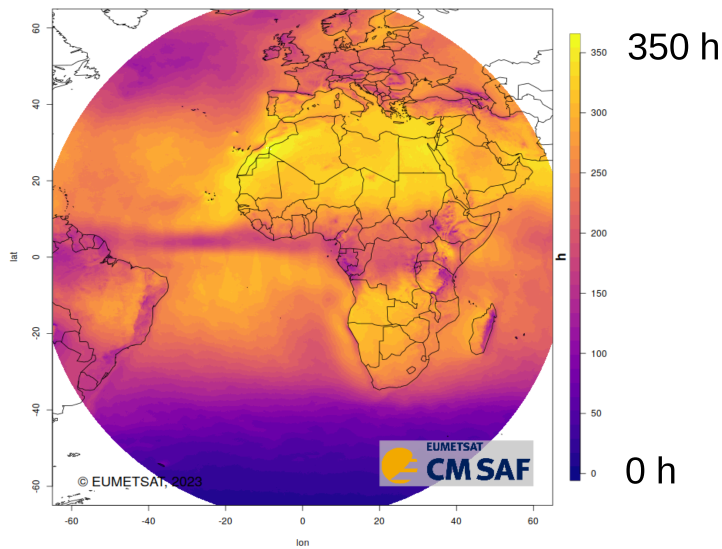
Trends in total cloud amount
(in % per decade)

Reference: 2004-2020

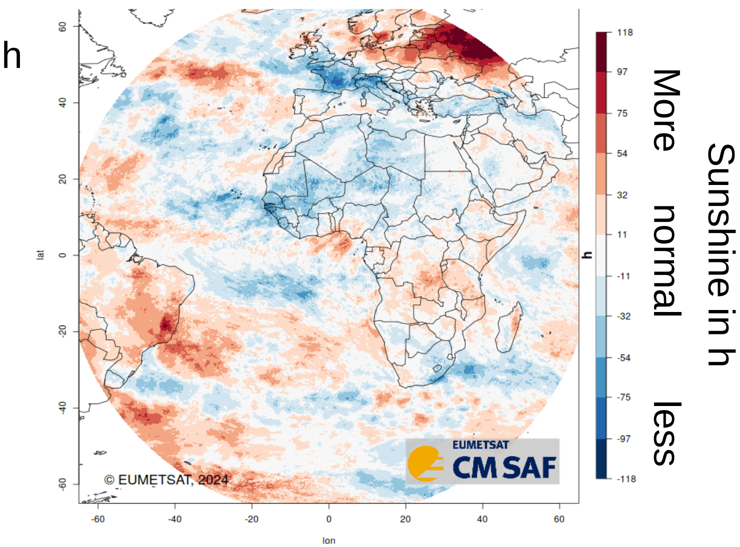


- ➔ WMO Reference Period 1991 – 2020 is now covered
- ➔ Operational retrieval of Anomalies (e.g. for Sunshine duration) based on the Climate Normal and latest actual data

## Climate Normal, 1991-2020




## Monthly anomaly, Sep. 24

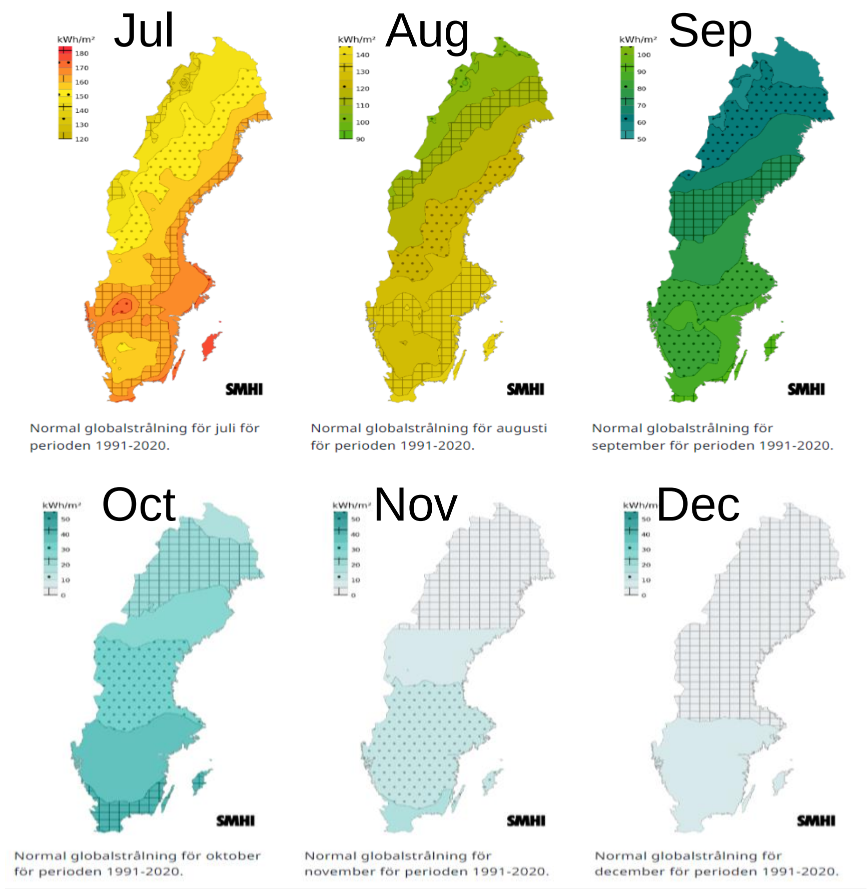



**Example: Anomaly of Sunshine duration**

# Monthly climate normals of surface incoming solar radiation (SIS) over Sweden based on CLARA-A3

- ➔ Following the WMO guidelines, covering 1991 – 2020 reference period
- ➔ Started with a research project.
- ➔ Operational use of CM SAF anomalies is in preparation

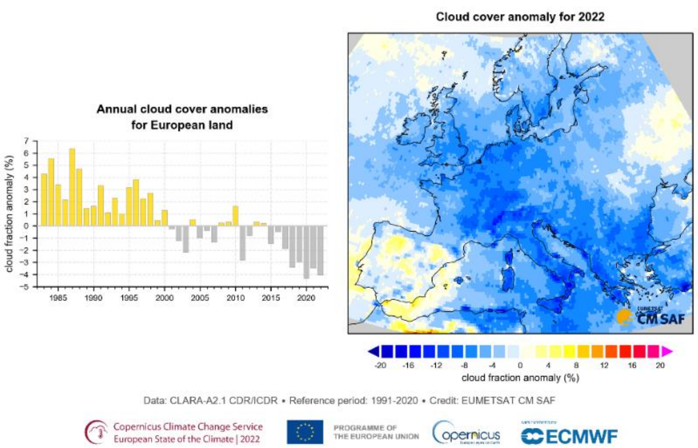
SMHI

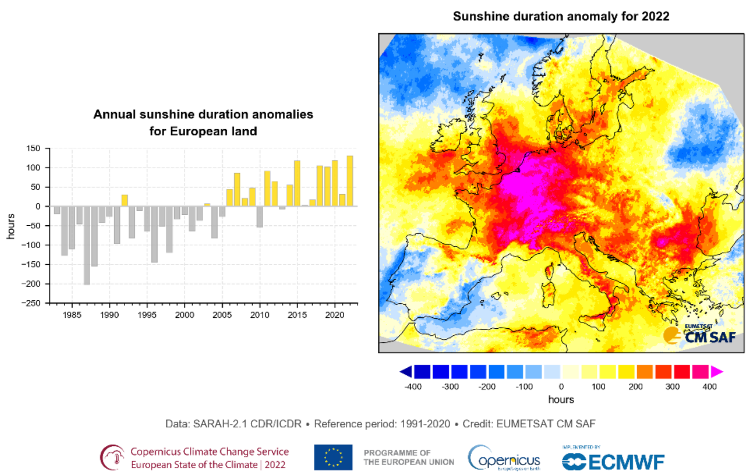



Devasthale, A.; Karlsson, K.-G.; Andersson, S.; Engström, E. Difference between WMO Climate Normal and Climatology: Insights from a Satellite-Based Global Cloud and Radiation Climate Data Record. *Remote Sens.* **2023**, *15*, 5598. https://doi.org/10.3390/rs15235598

https://www.smhi.se/data/meteorologi/kartor/normal/normal-manadsglobalstralning

# In 2022, Europe recorded the highest sunshine duration and second-lowest cloud cover of all time



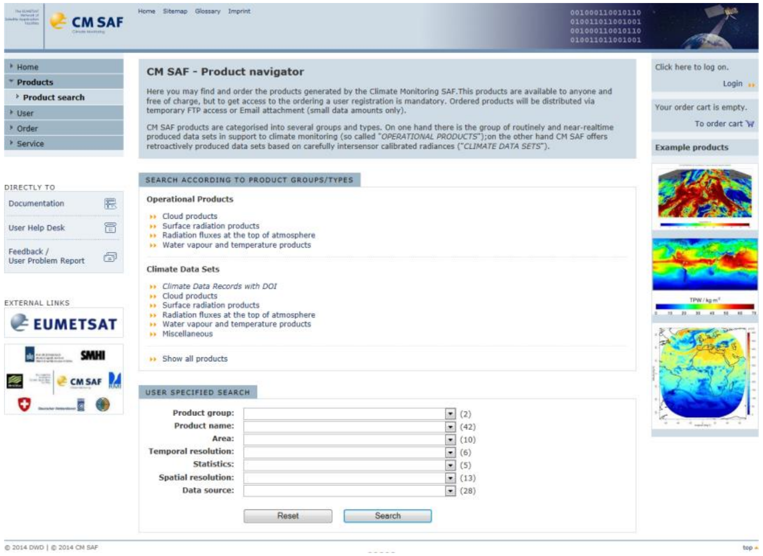




Source: European State of Climate 2022, https://climate.copernicus.eu/esotc/2022/clouds-and-sunshine-duration

Anomalies are being used in European State of Climate report

# Data access

- **Web User Interface**
  - Simple selection and ordering process
  - Standing orders
  - Postprocessing:
    - Spatial, temporal
    - Data format (netcdf, hdf)
    - Pre-defined regions (e.g.CORDEX Gebiete)
  - ftp or E-Mail
  - Free



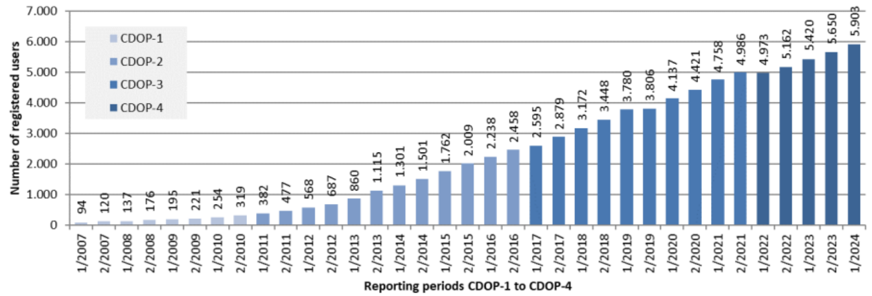

**https://wui.cmsaf.eu**

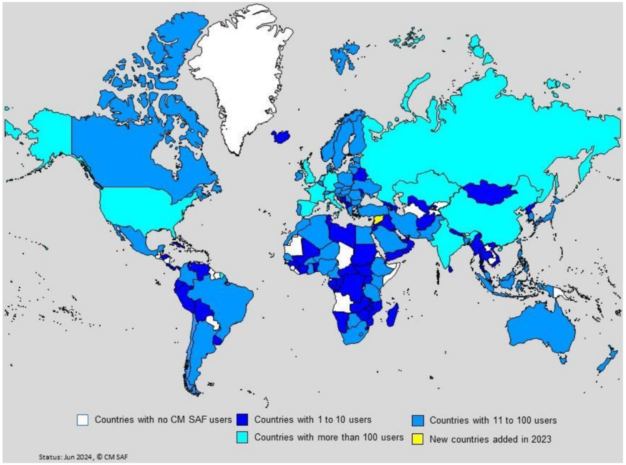
# Training

- Trainings-Workshops in Co-operation with EUMETSAT
- Hand-on training with CM SAF Data
- Content of course available here: http://training.eumetsat.org
- R-Toolbox for an easy use, analyses and visualisation of CM SAF data: www.cmsaf.eu/tools

# CM SAF users worldwide

- ➔ CM SAF has ~6000 users in **146 different countries** at the end of June 2024
- ➔ Users from **all 30 EUMETSAT** member states
- ➔ New user in first half of 2024 from here:
- Syrian Arab Republic
- Cuba




*Caveat: voluntary information during registration