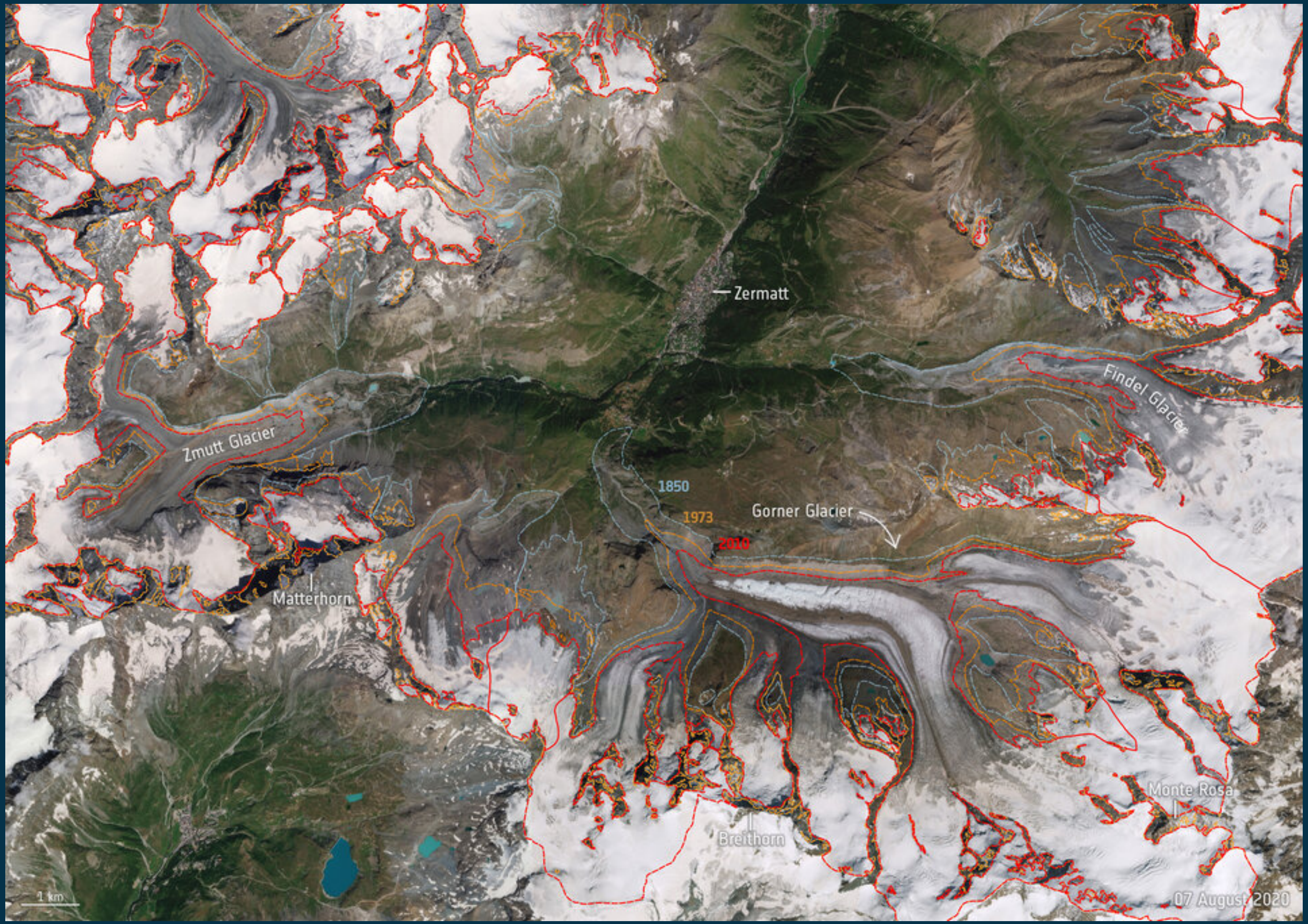
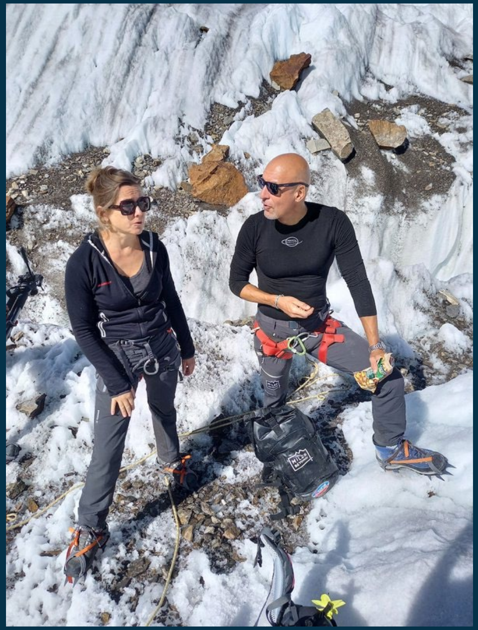
Observations from space and metrology: how to best use them in our quest to tackle climate change

Susanne Mecklenburg
European Space Agency, Head of Climate Office
Harwell Campus, Didcot, UK

Measurements for Climate Action| 14 October 2021

THE STATE OF THE CLIMATE & CHALLENGES





The retreating Gorner Glacier Zermatt, Switzerland, August 2021

What we see from space and what is there in reality

Intergovernmental Panel of Climate Change (IPCC)

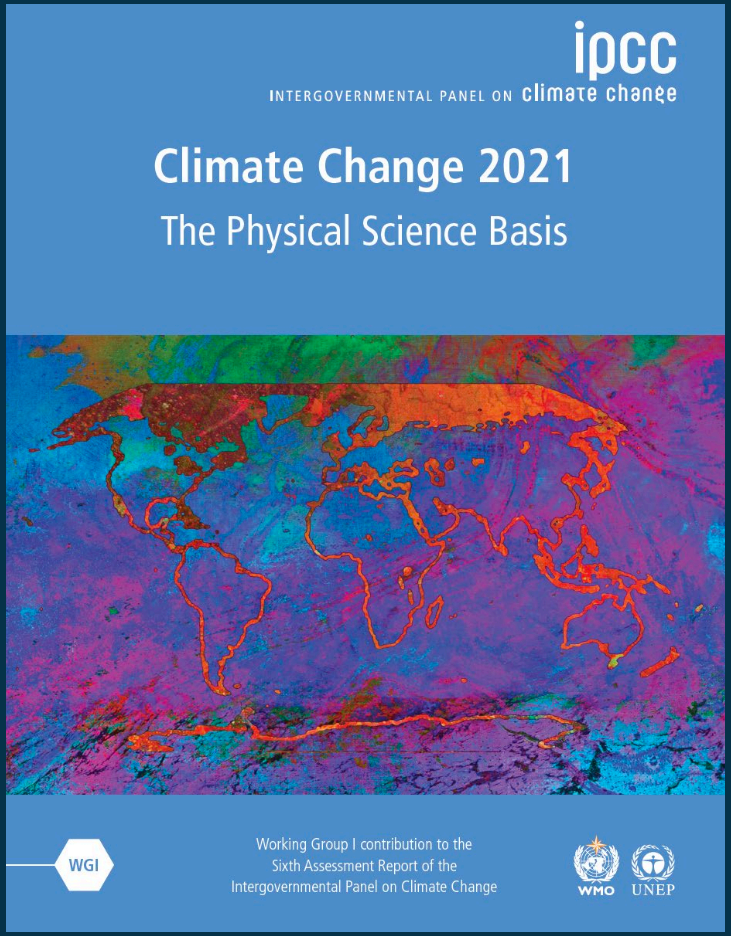
Assessment Report from WG I , August 2021

*"It is unequivocal that **human influence has warmed the atmosphere, ocean and land**. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred."*

Warming accelerates: Each of the last four decades has been successively warmer than any decade that preceded it since 1850.

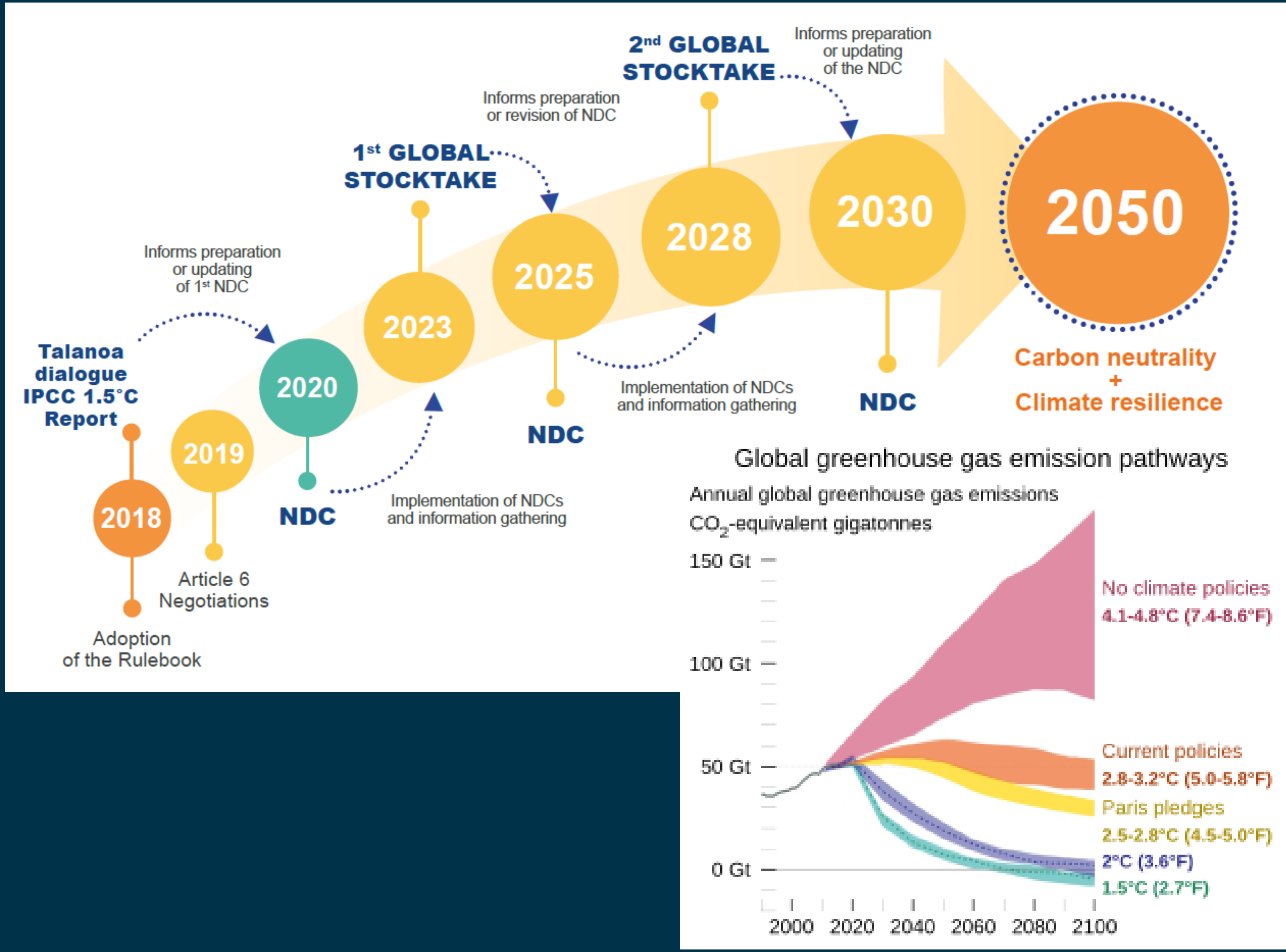
2001-2020: 0.99 [0.84 to 1.10] °C

2011–2020: 1.09 [0.95 to 1.20] °C



"Methodological advances and new datasets contributed approximately 0.1ºC to the updated estimate of warming in AR6."

United Nations Framework Convention on Climate Change



Paris Agreement 2015

Article 2a) … *Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change …*

The challenge: Think “globally local”

Policy

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

Provide scientific evidence to support evolution of policy

Support to and guidelines for *regional* implementation

Support European climate services in providing information for adaptation and mitigation measures

National implementation and reporting

Data for assessing National Determined Contributions, national emission reporting, adaptation and mitigation measures

Global → **Regional** → **National**

OBSERVING THE EARTH FROM SPACE

long-term | continuous | timely | global | collocated

For climate – what do we want to observe? …

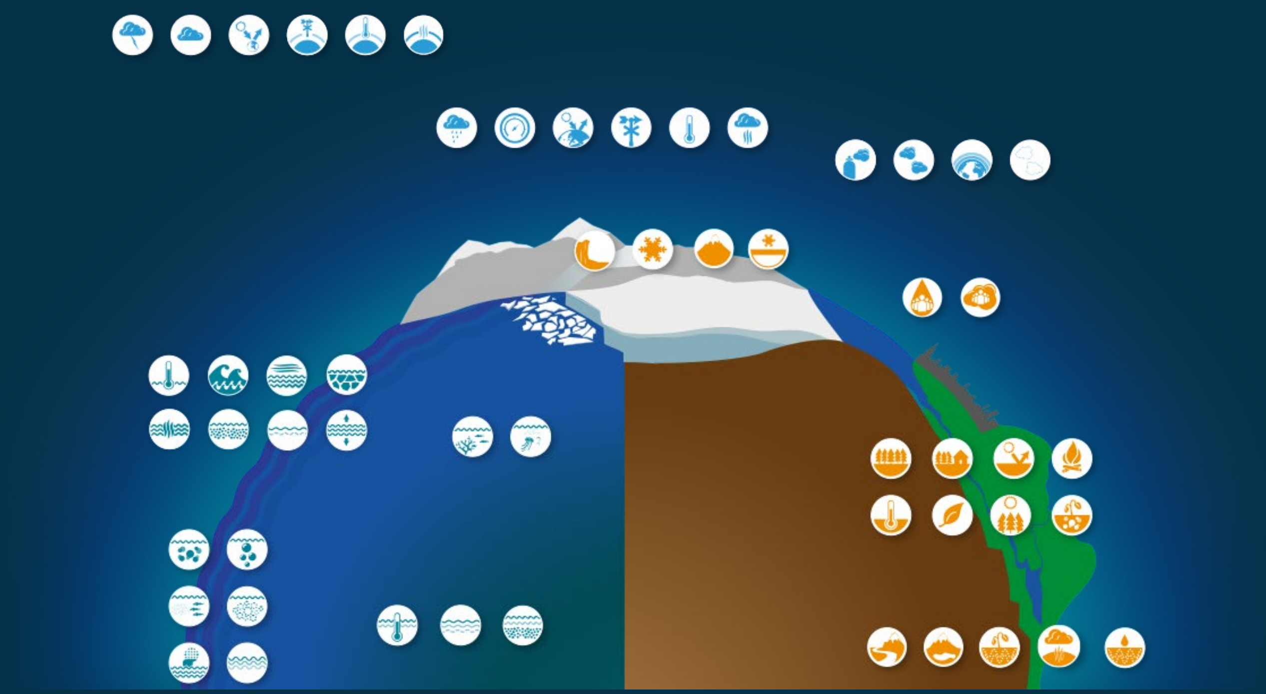
Essential Climate Variable

(GCOS Implementation Plan, 2016)

Relevance: The variable is critical for characterizing the climate system and its changes.

Feasibility: Observing or deriving the variable on a global scale is technically feasible using proven, scientifically understood methods.

Cost effectiveness: Generating and archiving data on the variable is affordable, mainly relying on coordinated observing systems using proven technology, taking advantage where possible of historical datasets.

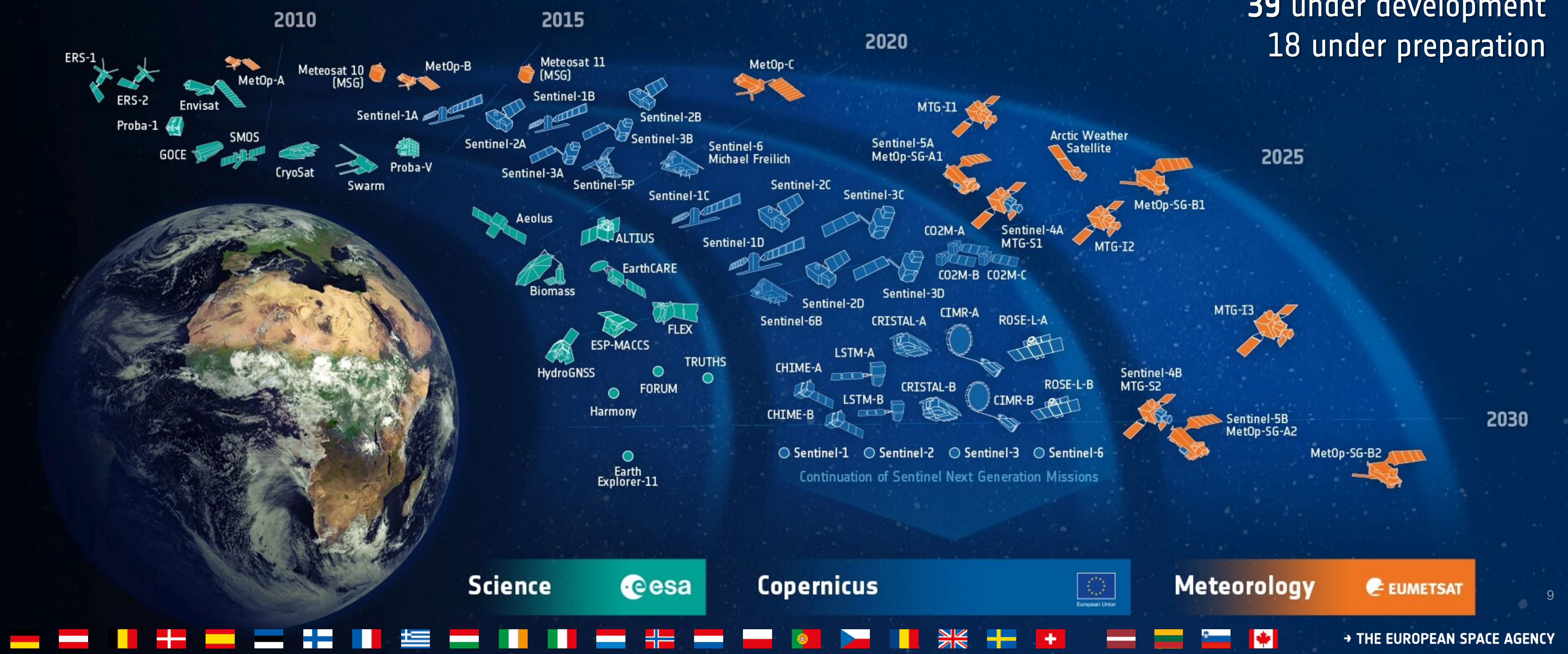


… observed according to the GCOS Climate Monitoring Principles for consistency, traceable calibration and for climate-relevant (diurnal, seasonal, and long-term interannual) changes to be resolved.

ESA-Developed Earth Observation Missions

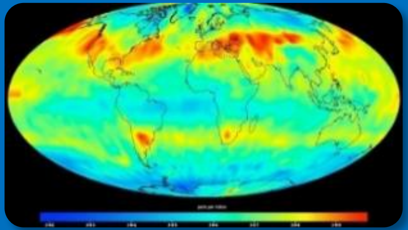
Satellites

15 in operation
39 under development
18 under preparation



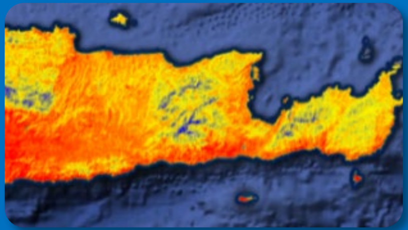
Sentinel Expansion Missions – the Future

CO2M - Anthropogenic CO_2 Monitoring



Causes of Climate Change

LST – Land Surface Temperature Mission



Agriculture & Urban Management

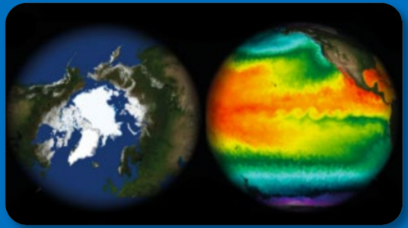
CRISTAL – Polar Ice & Snow Topography

Effects of Climate Change

CHIME – Hyperspectral Imaging Mission

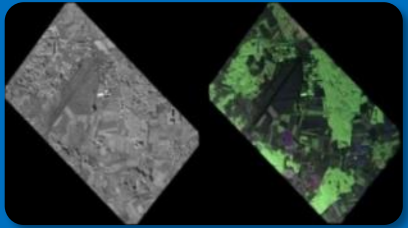
Food Security, Soil, Minerals, Biodiversity

CIMR – Passive Microwave Radiometer



Sea: Surface Temp. & Ice Concentration

ROSE-L – L-band SAR Mission



Vegetation & Ground Motion & Moisture

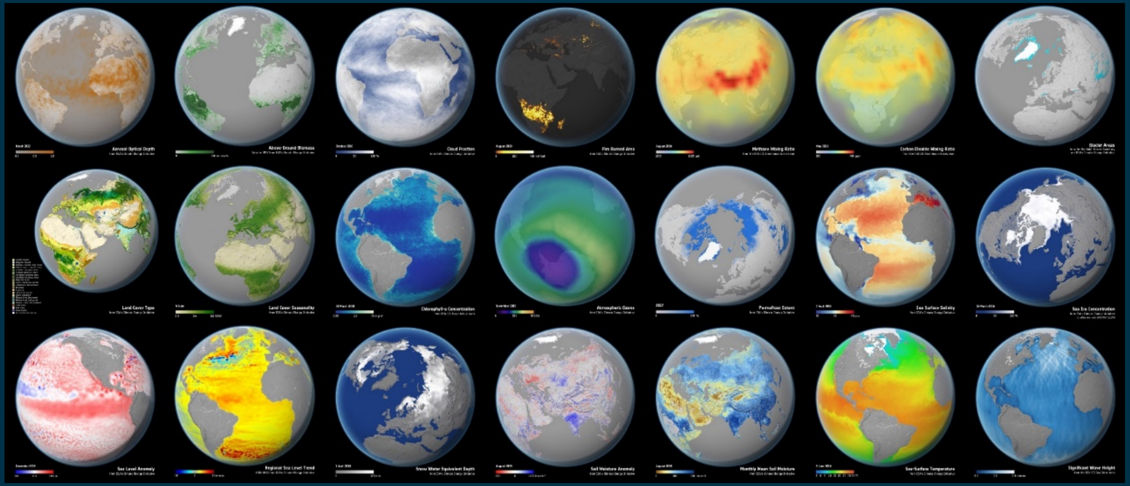
All contracts were signed in 2020

ESA Climate Office

- ✓ Implement the Climate Change Initiative (CCI) Programme – our flagship programme
- ✓ Working on international (policy) level with EU, Copernicus Services, ECMWF, EUMETSAT, UNFCCC, IPCC, GCOS, CEOS, CGMS, WCRP, WMO, Future Earth, SCO etc
- ✓ Observer at IPCC and UNFCCC

Climate Change Initiative

WMO defined **54** Essential Climate Variables
36 benefit from space observations
21 generated by ESA Climate Change Initiative



climate modelling user group cci

sea level budget closure cci

reccap-2 cci

www.climate.esa.int

ESA's Climate Change Initiative contributing to IPCC

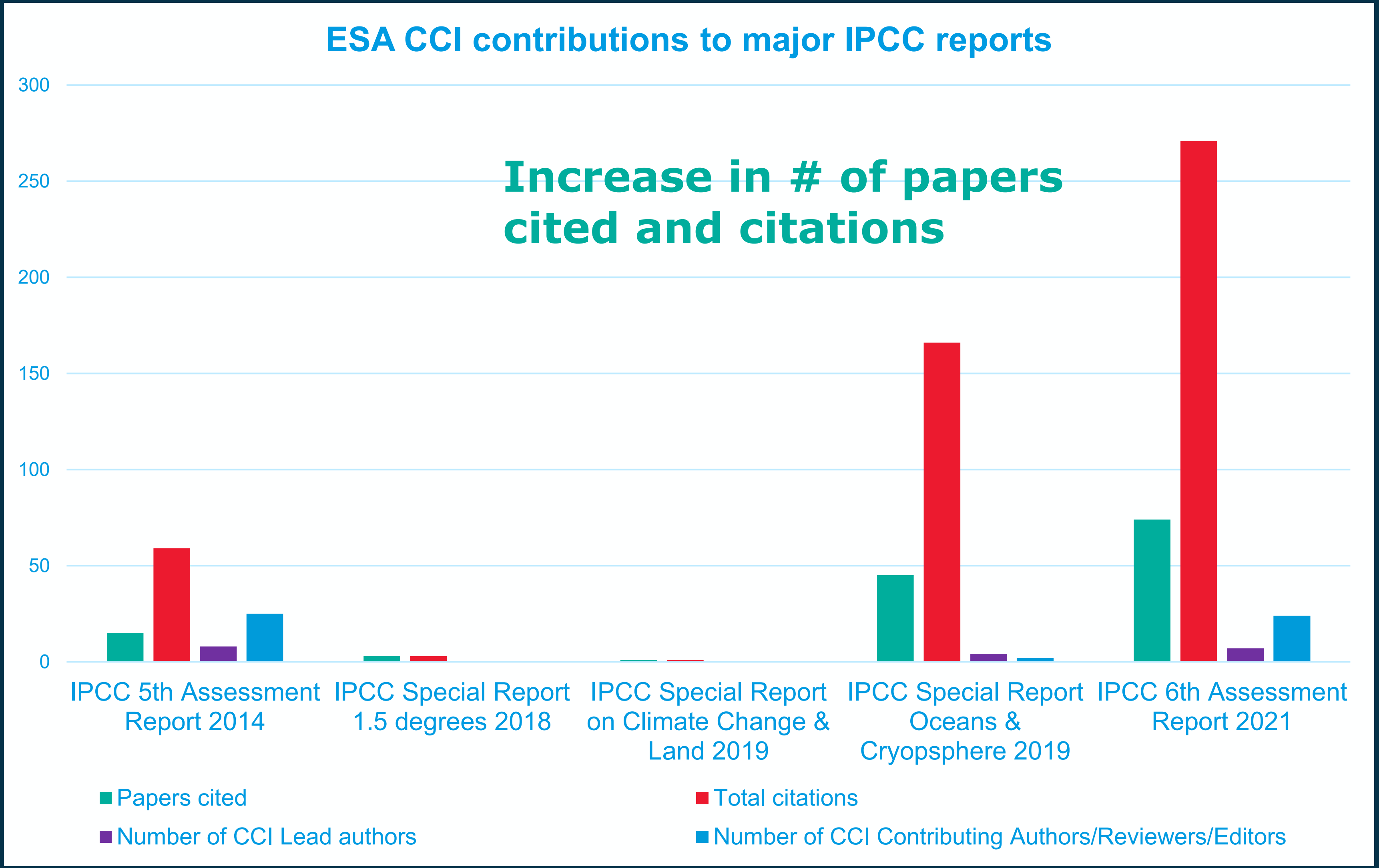
AR6 WG1 report:
7 lead/coordinating authors

14 contributing authors

~10 expert reviewers

~75 papers cited

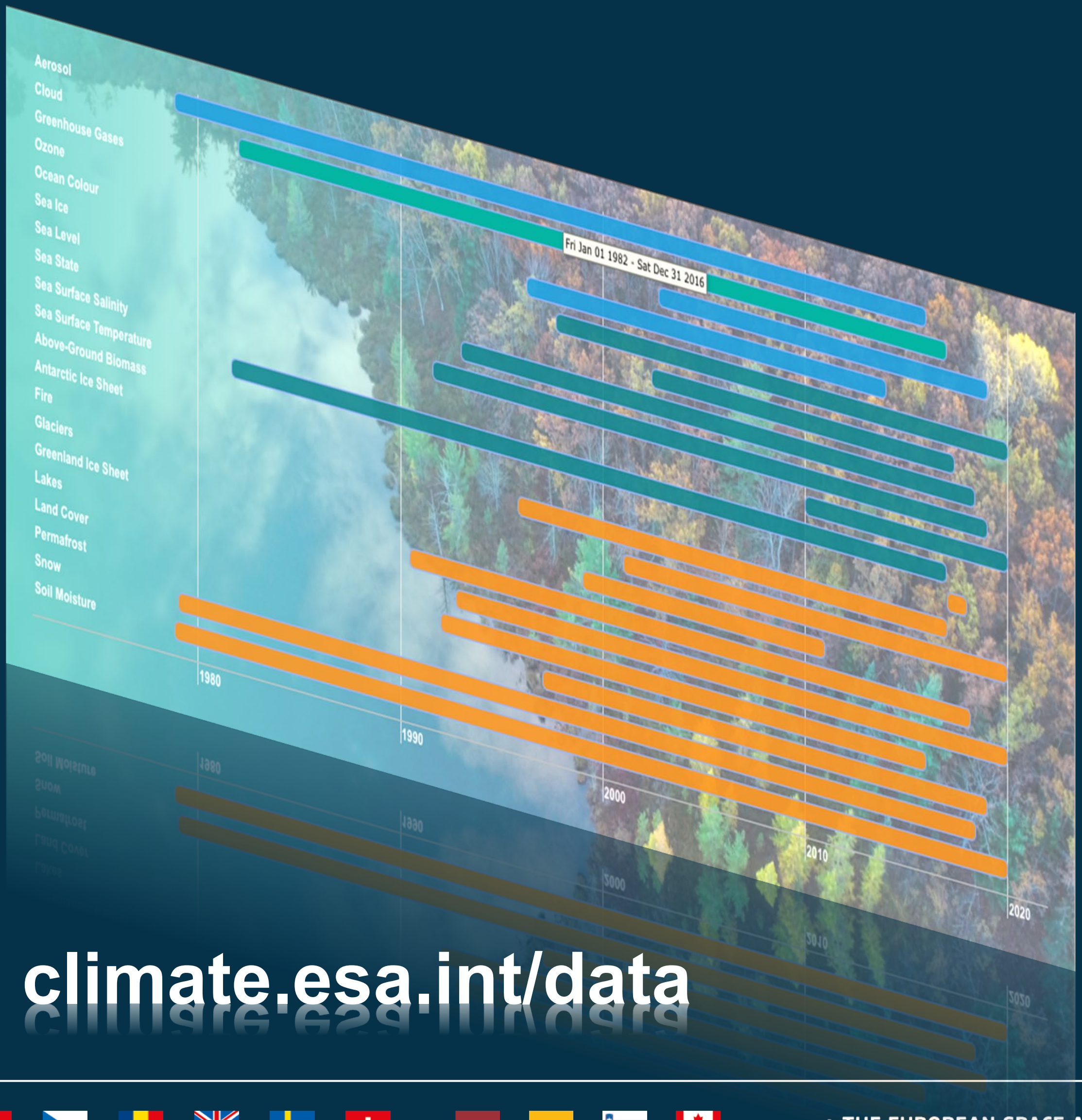
+270 in-text citations



ECV DATA ACCESS – *CCI OPEN DATA PORTAL*

Hosted and managed by CEDA on JASMIN

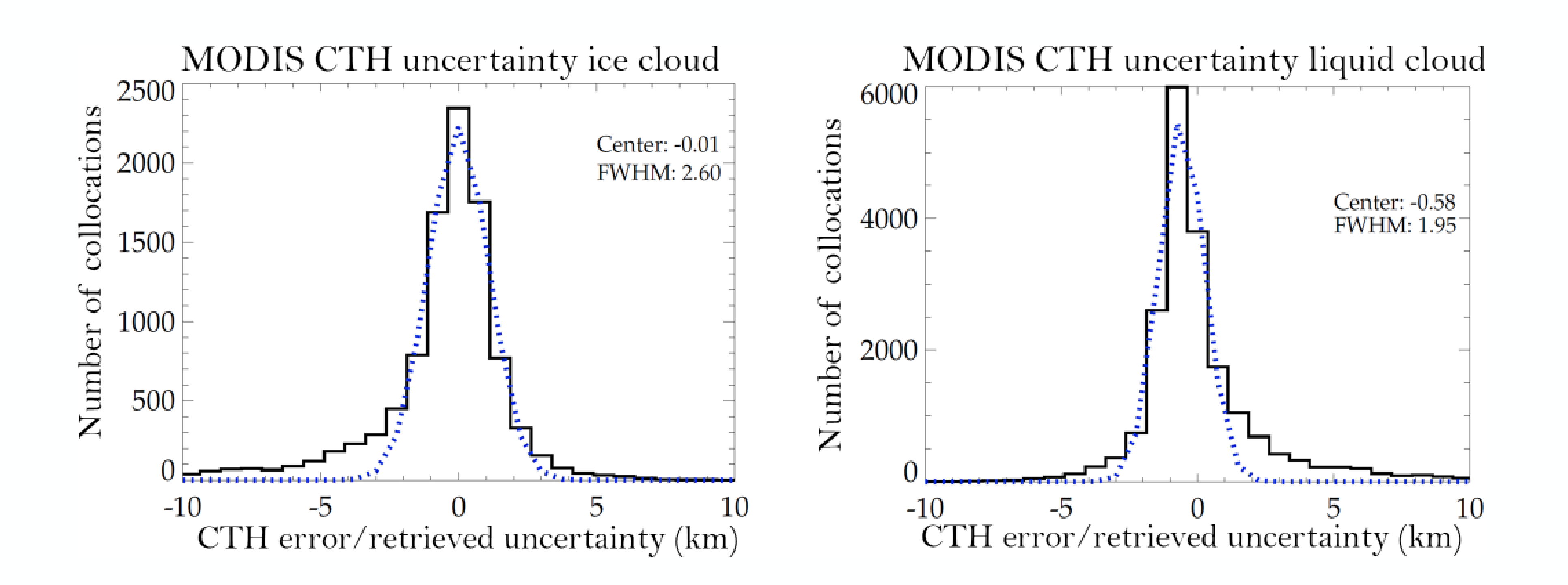
- ✓ **20 ECV products, 350TB across 180 datasets**
- ✓ **Free and Open Access**
- ✓ **Global** coverage (where applicable)
- ✓ Long timeseries (20-30 years)
- ✓ **Gridded** (at a usable resolution e.g. ¼ degree)
- ✓ **Validated** (by in situ observations) and tested
- ✓ **Bias corrected** (e.g. between different satellites)
- ✓ **Uncertainty characterisation** (per pixel, correlated…)
- ✓ Useful temporal resolution (**daily, monthly**…)
- ✓ Can be sourced back to algorithm choice
- ✓ Level 1, 2 or 3
- ✓ **Consistency** between CCI_ECV datasets
- ✓ Full documentation & version control
- ✓ Available on CCI Data Portal and Copernicus Services
- ✓ Supporting information, e.g. cloud masks



climate.esa.int/data

UNCERTAINTY QUANTIFICATION

Uncertainty in Climate Data Records from Earth Observation, C. J. Merchant et al., 2017, (10.5194/essd-9-511-2017) - best practice across 11 CCI ECV projects (18 authors; land, atmos, ocean, cryosphere)

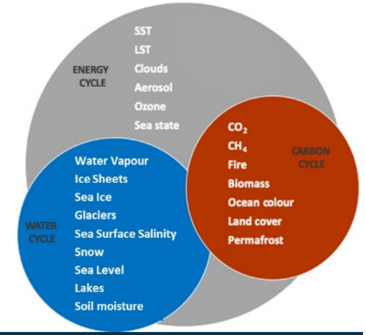


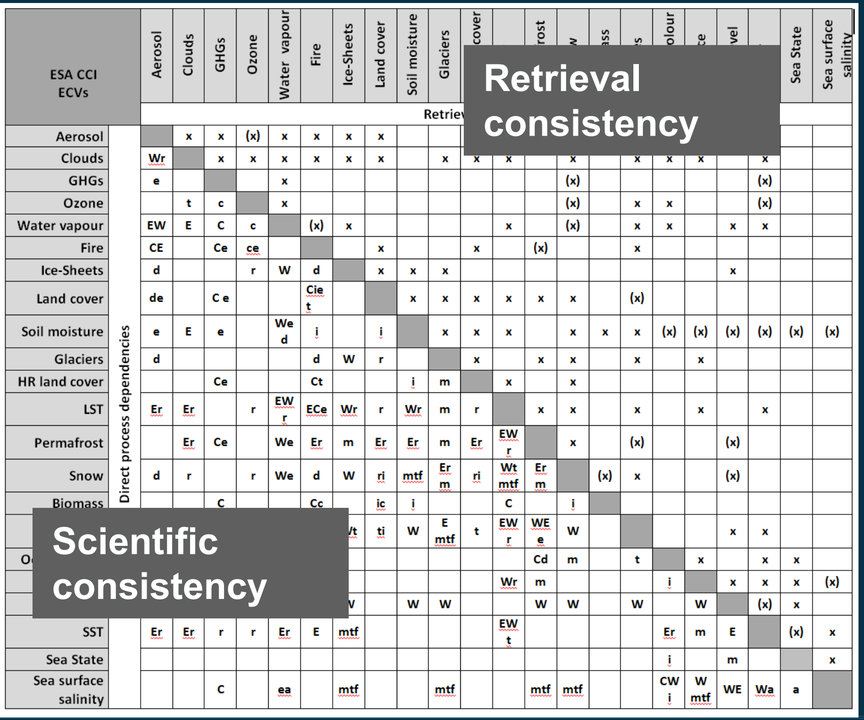
Uncertainty validation using the distribution of differences between matched cloud top heights measured by Cloud_cci and CALIPSO. A correct estimation of the retrieval uncertainty should reproduce the dashed blue curve, with a FWHM of 2.35.

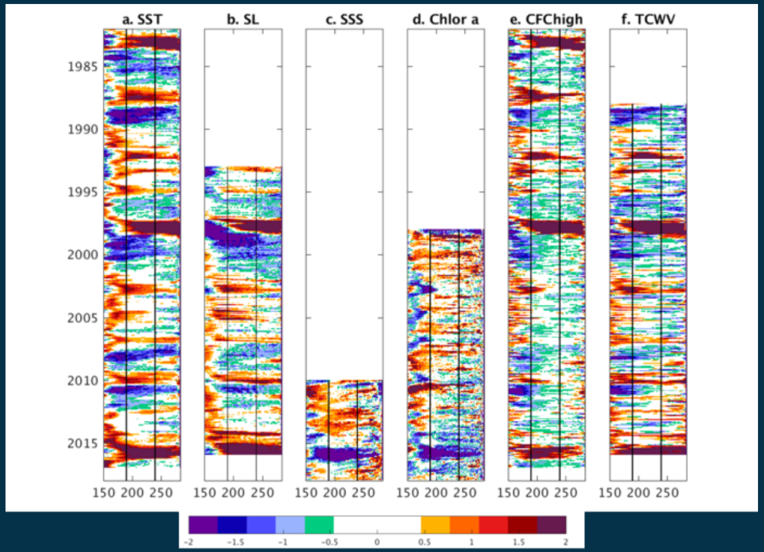
Cross-ECV Consistency

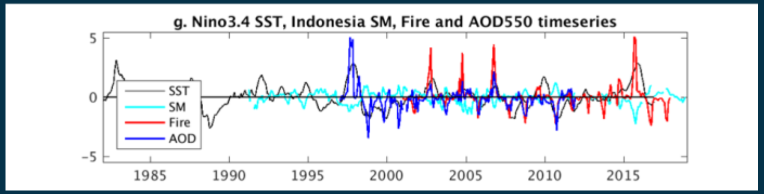
Consistency of satellite climate data records for Earth system monitoring, T. Popp et al., BAMS, 2020. https://doi.org/10.1175/BAMS-D-19-0127.1

Establish and define the concept of (technical, retrieval, scientific) cross-ECV consistency - 22 CCI co-authors, with 8 detailed examples from across the CCI, identifying also status of research into cross-consistencies









Example above shows co-variation between multiple ECVs: El-Nino region SST, sea level, sea surface salinity, chlorophyll-α, cloud fraction, water vapor, soil moisture, aerosol optical depth (credit: U. Willen, SMHI)

SOME THOUGHTS ON
METROLOGY & CLIMATE OBSERVATIONS AND DATA

Working with the metrology community

Sources of input

- Experience and expertise from ESA Climate Office / CCI (e.g. combining different sensors, L1 versus L2)
- Joint Workshop on Representation Uncertainty in the Earth Sciences was held in March 2021, sponsored by the National Centre for Earth Observation
- Interaction with WCRP's CMIP panel
- (SI-Traceable Space-based Climate Observing System (SITSCOS), A CEOS and GSICS International Workshop held at the National Physical Laboratory, London, UK, September 9-11, 2019)

cci_soil moisture: combining passive & active sensors

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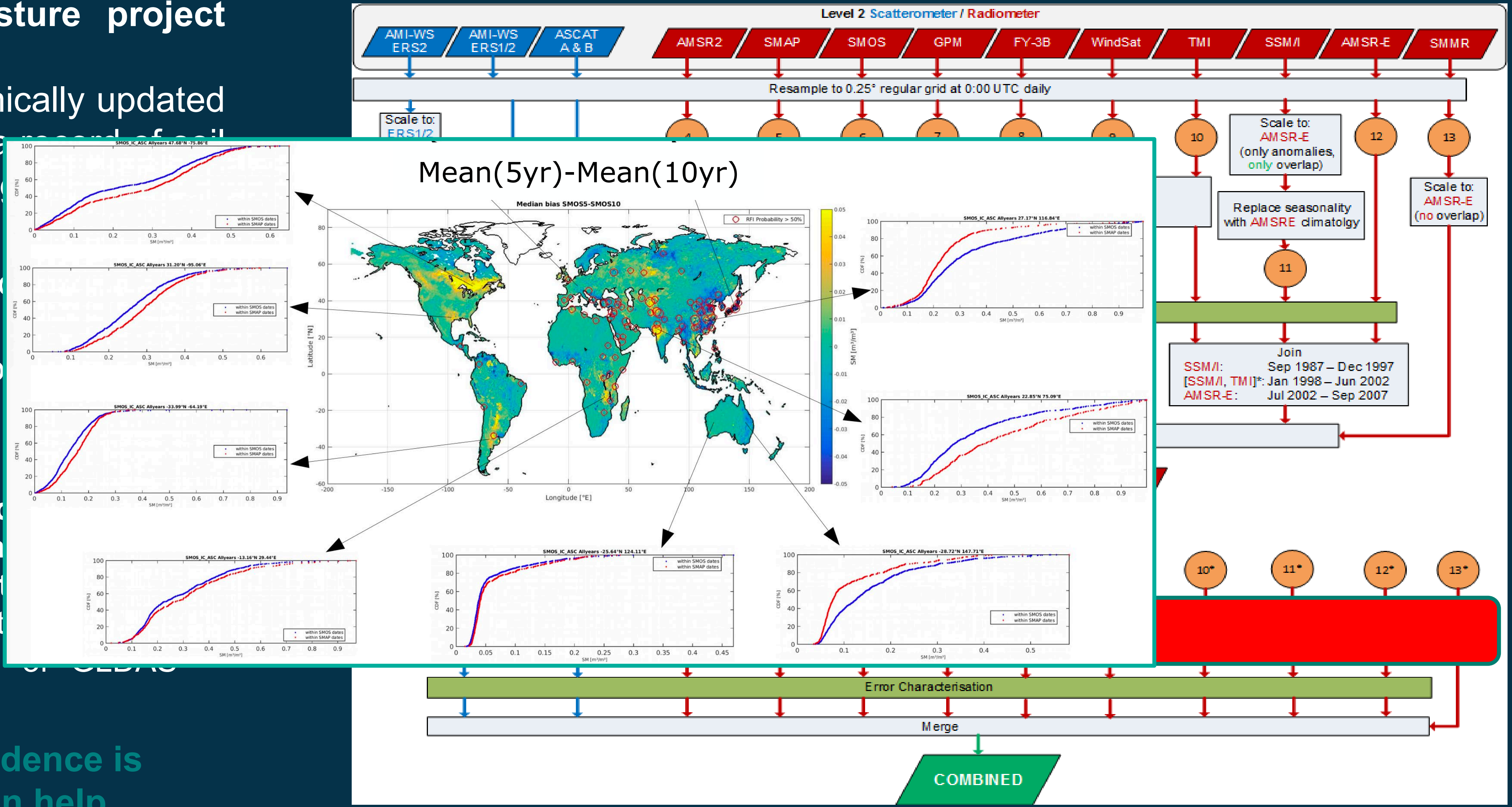
The CCI Soil Moisture project produces:

- Annually algorithmically updated global climate data record of soil moisture spanning more than 40 years
- 3 separate soil moisture products derived from active, passive and combined (active + passive) sensors

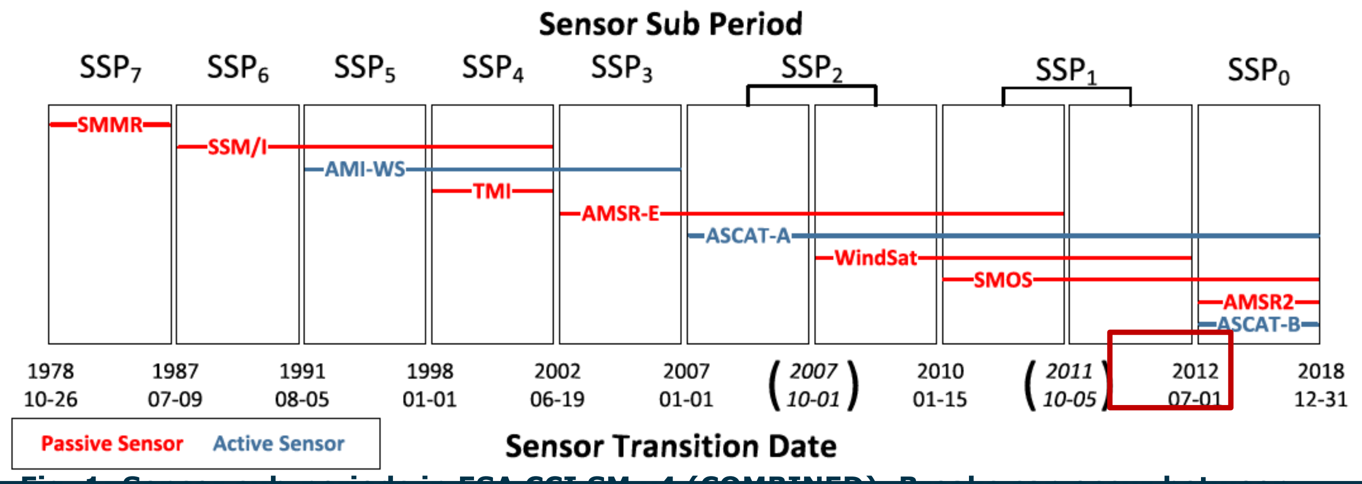
For the Combined product, NASA's GLDAS Noah model is currently used as the reference : Observations are scaled in the value domain of GLDAS Noah SM

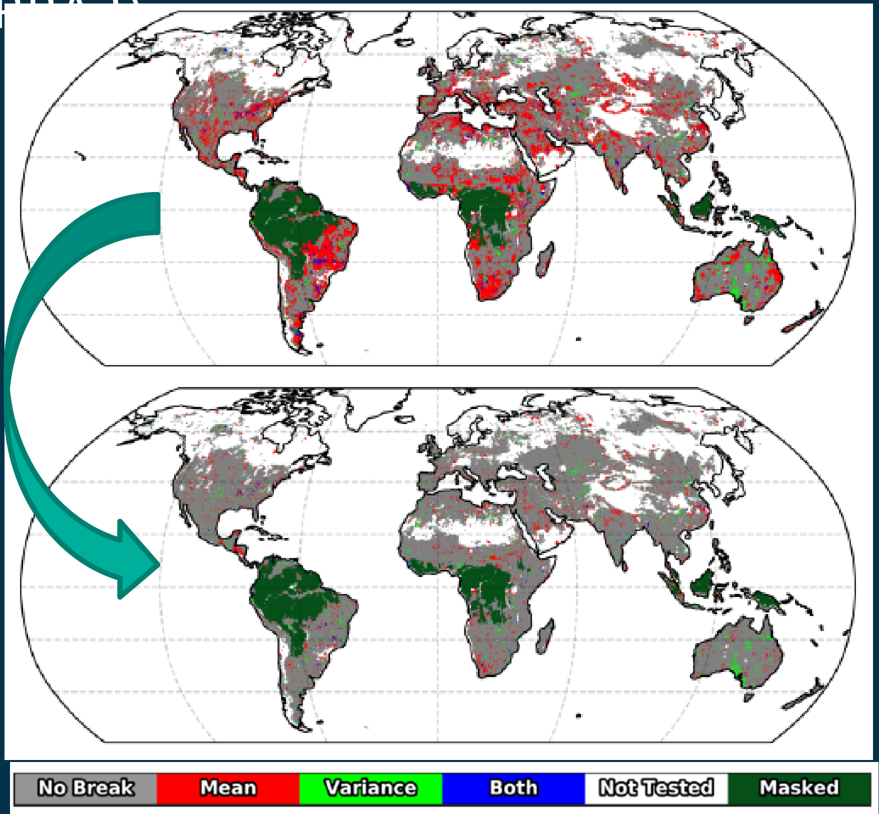
➔ Model independence is needed, SMOS can help



Break Detection / Corrections in multi sensors CDR

- Detection of inhomogeneities (breaks in <u>mean</u> and <u>variance</u>) of a (merged) sensor time series
  - Assumption: Breaks occur between sensor sub periods / at sensor transition dates (*Fig. 1*)
  - Statistical (non-parametric) tests to identify significant differences in mean/variance between two adjacent sub-periods (*Fig. 2*) – following: *Su et al., 2016*[1]
    - Relative to (assumed) homogenous reference (e.g. MER
    - Wilcoxon rank sums test (break in **mean**)
    - Fligner-Killeen test (break in **variance**)

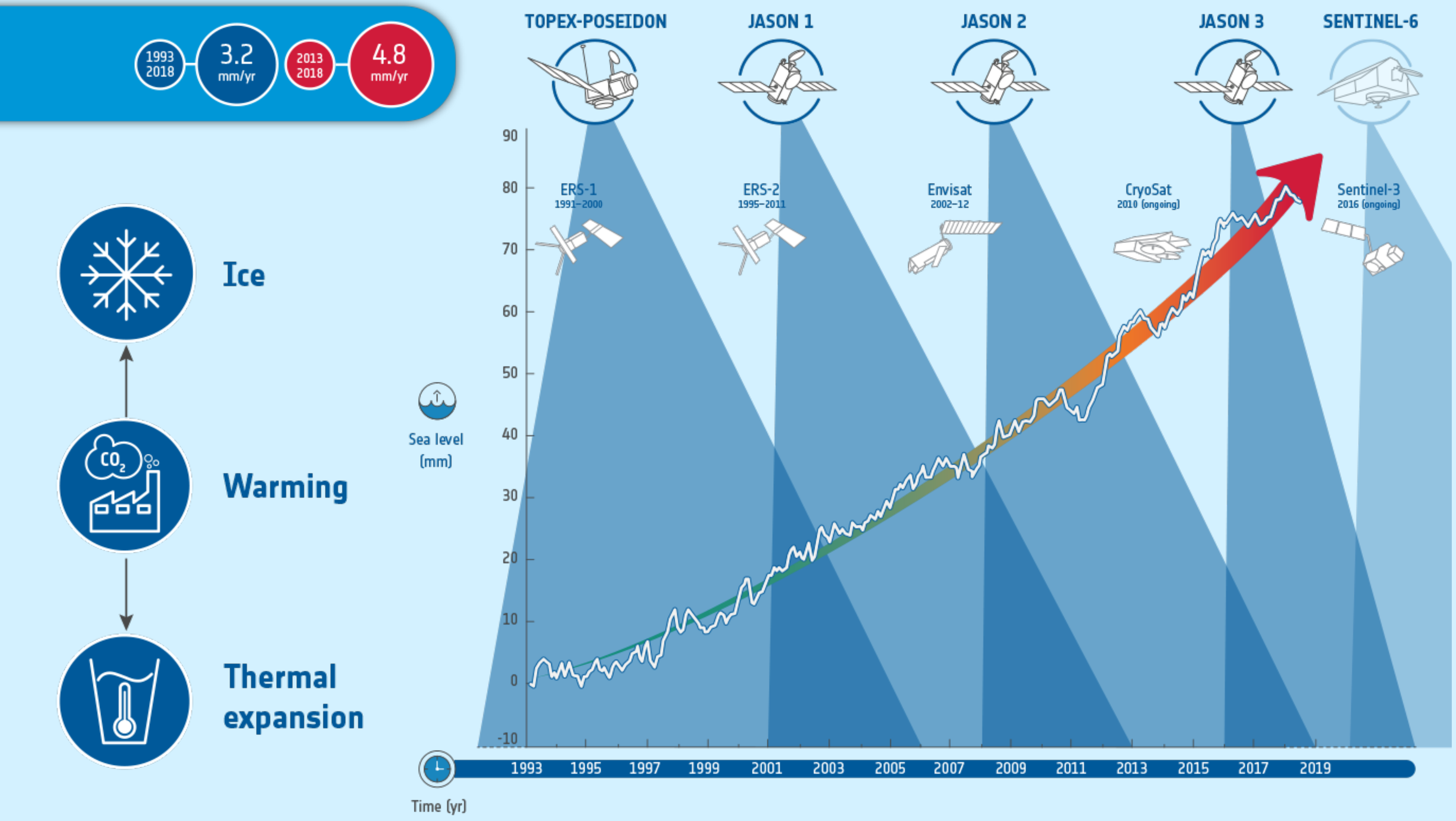




- Quantile Category Matching (QCM) adjustment

[1] https://doi.org/10.1002/2016GL070458

Sea Level Rise: combining altimeter sensors



IPCC AR WG I, 2021

A4.3 Heating of the climate system has caused global mean sea level rise through ice loss on land and thermal expansion from ocean warming. **Thermal expansion explained 50% of sea level rise during 1971– 2018, while ice loss from glaciers contributed 22%, ice sheets 20% and changes in land water storage 8%. …** Together, ice sheet and glacier mass loss were the dominant contributors to global mean sea level rise during 2006-2018.

A1.7 Acceleration of SLR

1.3 mm/year 1901-1971

1.9 mm/year 1971 -2006

3.7 mm/year 2006-2018

Impact of satellite data resolution

Importance of small fires and their carbon emission

➔ Over Africa 90% more small fires (<100 ha) were detected with Sentinel 2 than with MODIS in 2016

➔ *Contribute to 2.02 million km² of the 4.89 million km² total burned area detected*

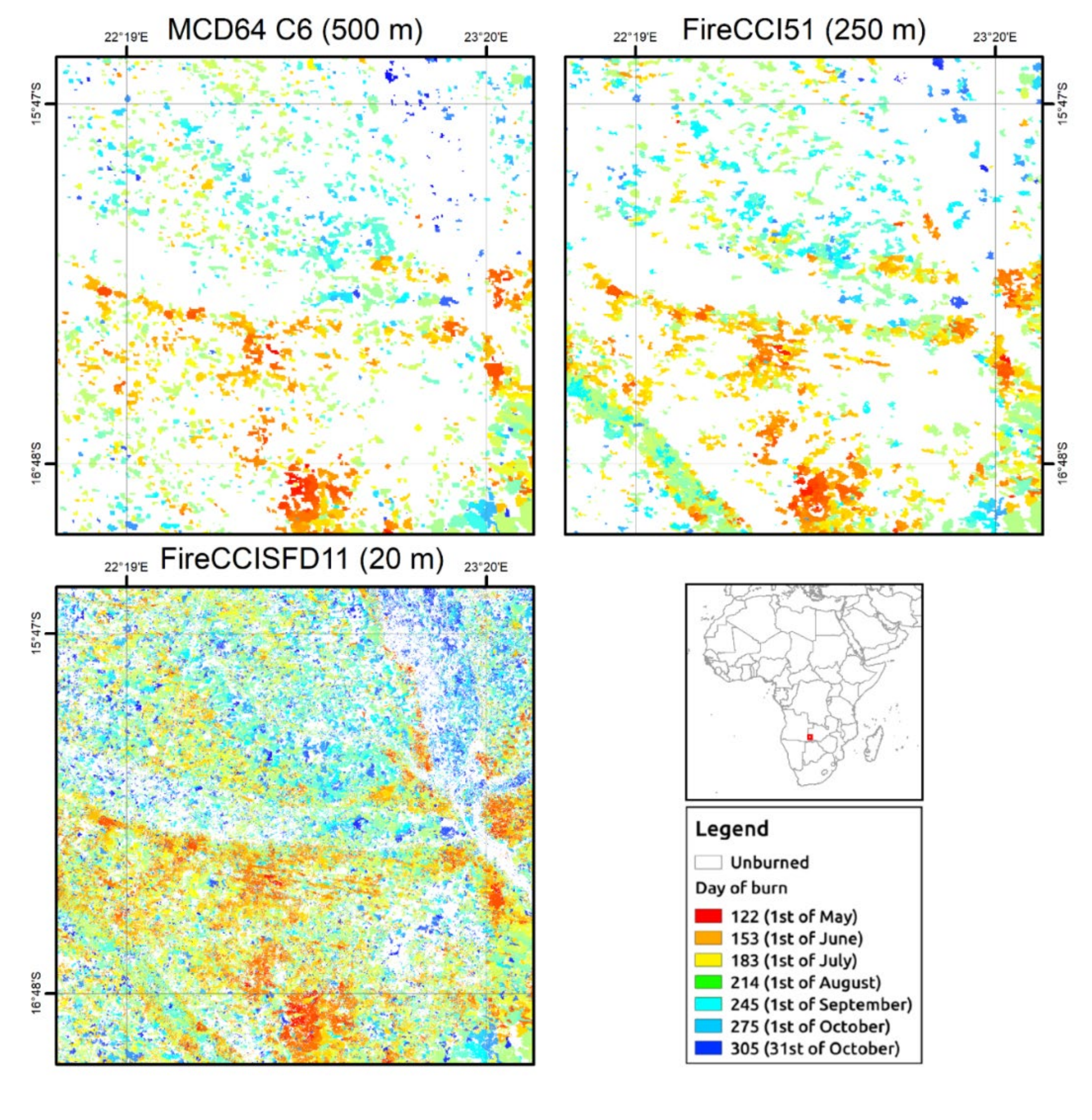
Corresponding Fire C emission estimated are 1.44 PgC

➔ *31-101% higher that previously thought*

➔ *14% of global C emission from FF burning*

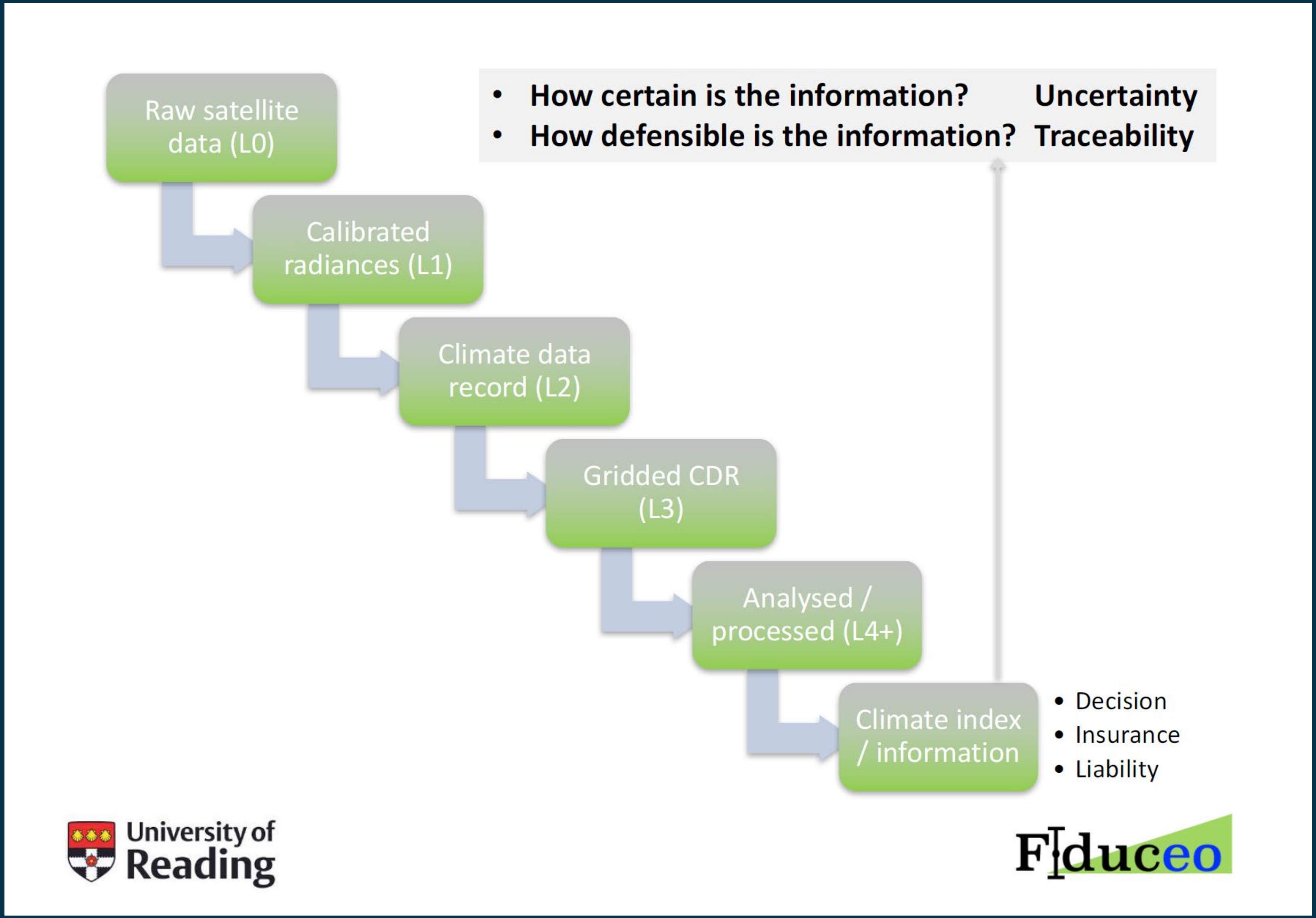
Critical driver of BA in Sub-Saharan Africa

➔ *Raises the contribution of biomass burning to global GHG and aerosols*

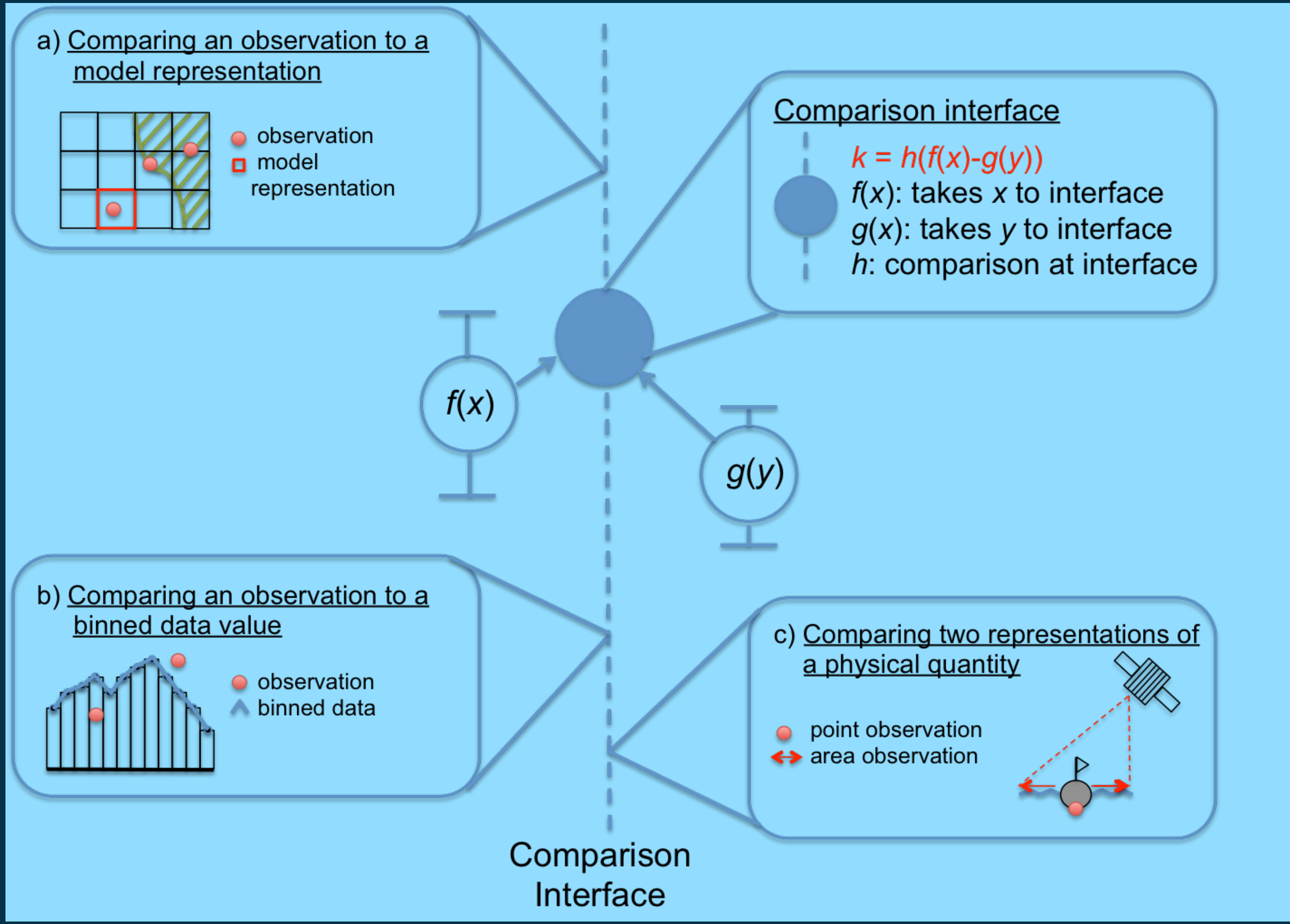


Ramo, R., et al: ***African burned area and fire carbon emissions are strongly impacted by small fires undetected by coarse resolution satellite data***, Proceedings of the National Academy of Sciences Mar 2021, 118 (9) e2011160118; DOI: 10.1073/pnas.2011160118

Applying metrological principles to EO



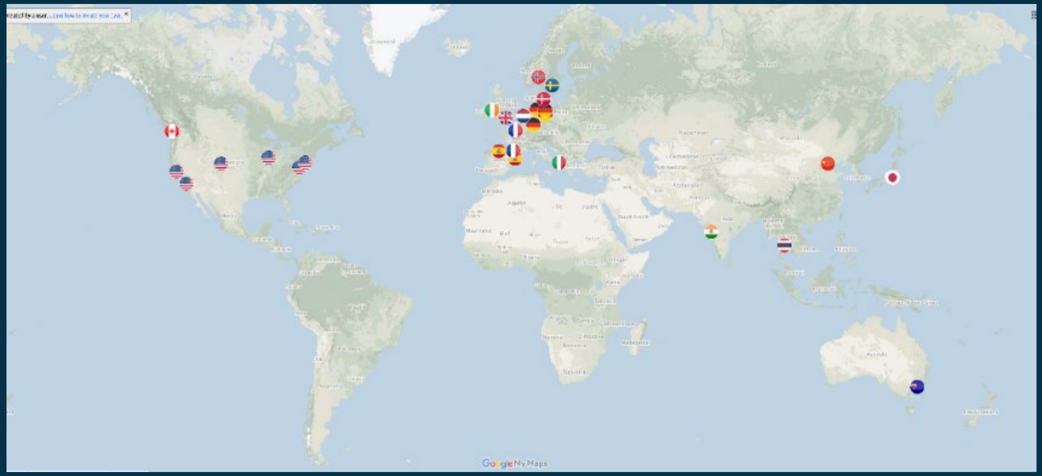
Representation uncertainty



- Workshop on representation uncertainty in the Earth Sciences, Reading, March 2021
- ‘The intrinsic uncertainty at the interface of comparing two quantities, A and B, that also have an associated uncertainty.’
- ‘This contribution to the uncertainty is generated only at this interface’
- Communication is key! Even within communities, different terms have been used to describe “representation uncertainty”

Climate observation and modelling community

- ESA hosts WCRP's CMIP-IPO from 2021 onwards
- WCRP **flagship** programme, established in 1995 under WMO
- **Focal point** for the leading national and international entities in **climate modelling worldwide**



CMIP-6 Modelling Groups 16 out of 28 in Europe; currently in its 7th cycle

Main topics from CMIP

- **Cross-calibration (Truths):** critical because it also enables the calibration of long-term measurements, which is key for climate change analysis and modelling.
- **Quality control of CMIP data**: knowing methods (statistics or other) that is used to identify when data are outside acceptable range.

Outlook

- ESA Ministerial Council in 2022
- New climate programme – COMPASS - to be presented to ESA member states in 2022 with focus on
    - Maintaining and expanding the portfolio of high-quality Essential Climate Variables, and
    - Responding to the UNFCCC Paris Agreement
- Linking climate observations and modelling: ESA will host the WCRP CMIP Project Office at ECSAY, Harwell Campus
- Extend our collaboration with operational climate services

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