Climate Change

Precipitation

In the context of European Climate Services

Joaquín Muñoz-Sabater

Climate Change

Outline

- The W(H)-questions [What/When/How/Why]
- Requirements
- Climate Services – what can we do for you? (C3S),
  - The Copernicus Climate Change Service (C3S)
  - C3S offer for precipitation
- Gap analysis & uncertainty
- Summary

Precipitation: What


“In meteorology, precipitation is any product of the condensation of atmospheric water vapor that falls from clouds due to gravitational pull.” (*Glosary of Meteorology, AMS, 2019*)



What’s relevant?

Not only **amount**, but **type**, **frequency**, **intensity** and **duration.**


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Precipitation: When

→ Precipitation has been a **subject of investigation for thousands of years** as people seek to understand its impact, such as its correlation with agricultural yields.

Qualitative records:

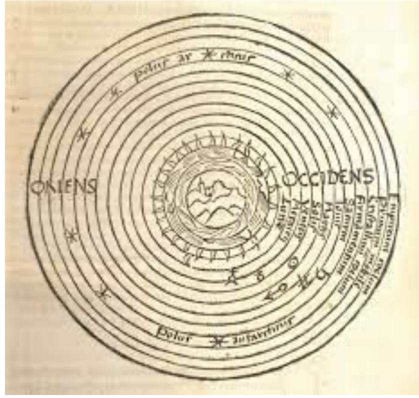
- **Greece**: around 500 BCE (texts like **Aristotle's "Meteorology"** discuss the concept of rain gauges and reference observing different types of precipitation (rain, snow, hail)).
- **India**: around 400 BCE (The **Arthashastra** text from India references rainfall patterns and their connection to expected crop yields, hinting at some form of observation or measurement.)
- **Palestine**: around 100 AD (Jewish texts like the **Mishnah** mention a possible rain gauge used in agricultural practices)

Quantitative measurements: Development of rain gauges

- **Palestine**: 100 AD
- **Korea**: 14th Century (the Myeongnyeongsil)

Arthashastra

Aristotle's meteorology



Systematic recording:

- **Europe**: 17th century (R. Hooke in London)
- **US**: 18th century

Modern era:

- Standardized networks of rain gauges
- Remote Sensing

References:

- *"A history of rainfall measurements" J.C. Willmott et al. (2003) in the Int. J. Climat.*
- *"The evolution of rain gauges and their use in the measurement of precipitation" by G.J. Young (1994) in Weather*
- *"Isaac Newton and the problem of Gravity", J. Gleick.*

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Precipitation: How

- **In-situ** rain-gauges cannot create a gap-free, long-term precipitation dataset since almost entirely available over land only, and density is variable. Local topographic features influence gauge measurements, and they are affected by wind on the gauge catch, particularly for snow and light rain.

- **Satellite measurements** have a better spatial coverage globally. Temporal coverage is limited though, mostly since the 1990s. Only measurements of instantaneous rate can be made, and the algorithms converting radiometric measurements (radar, microwave, infrared) into precipitation rates in surface also carry uncertainties.

→ Different measurement techniques between ground and satellite measurements, means relative large variability between precipitation datasets

- **Reanalysis** can be used as an alternative to observational datasets, for instance ERA5, which assimilate satellite, precipitation radar and gauge measurements. Globally complete, long coverage, but biases are a problem, for instance due to unresolved processes relevant to microphysics (clouds) or uncertainties in the parameterisation or initial conditions used.

  → Main problems encountered in tropical oceans, in complex mountain areas, high-latitude regions or areas with sparse network of observations

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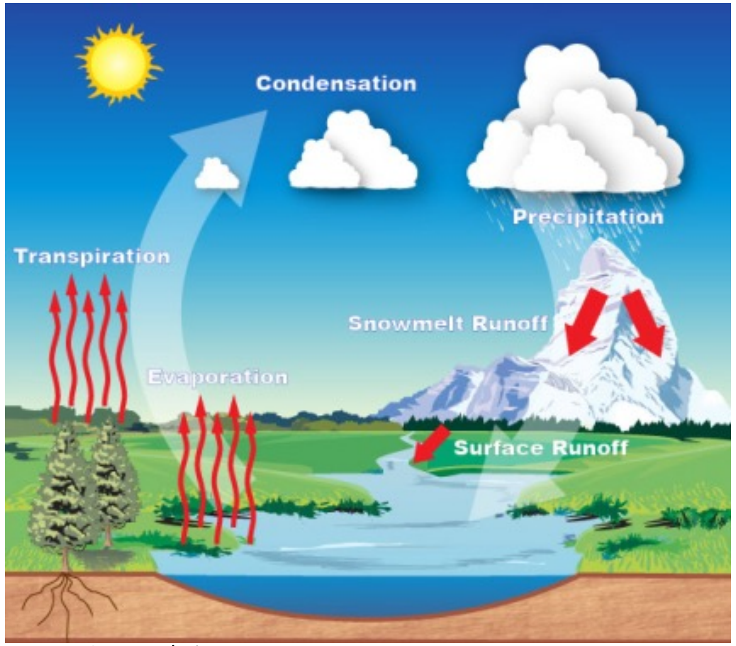
Precipitation: Why

- Changes in climate are not only on temperature, but also affect atmospheric moisture and precipitation (among others)
- One of the main components of the water cycle
- It is an important variable relevant for climate monitoring, climate analysis, model evaluation, general research, agriculture, water resources management, food security, disaster risk reduction, health, tourism, etc
- Arguably the most important variable directly affecting humans.



From NOAA website

- What do scientists need to understand Earth's weather patterns in relation to climate change?

 and

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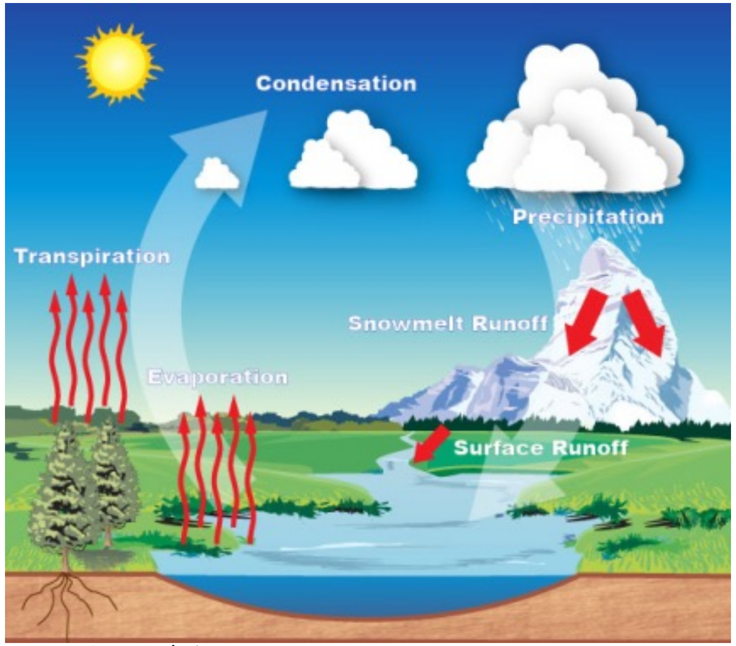

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  Precipitation, ______ and ______

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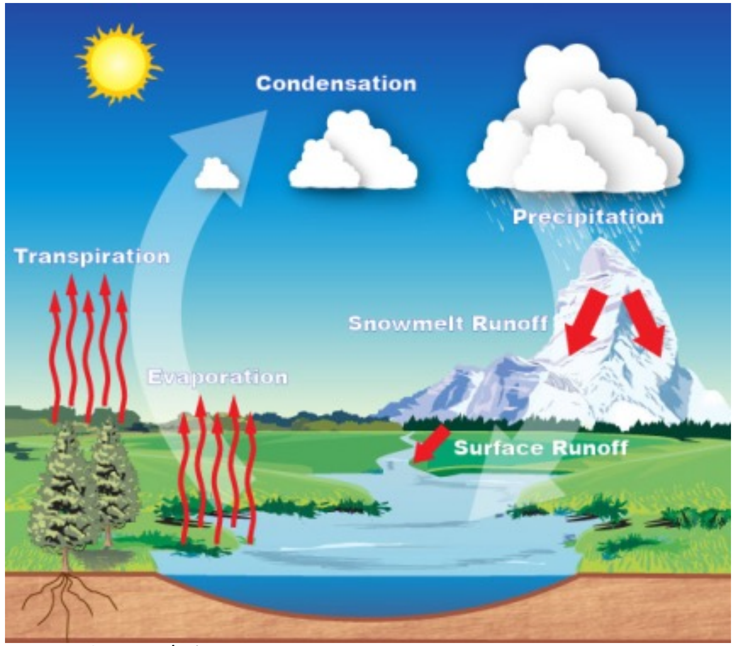

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Climate Change

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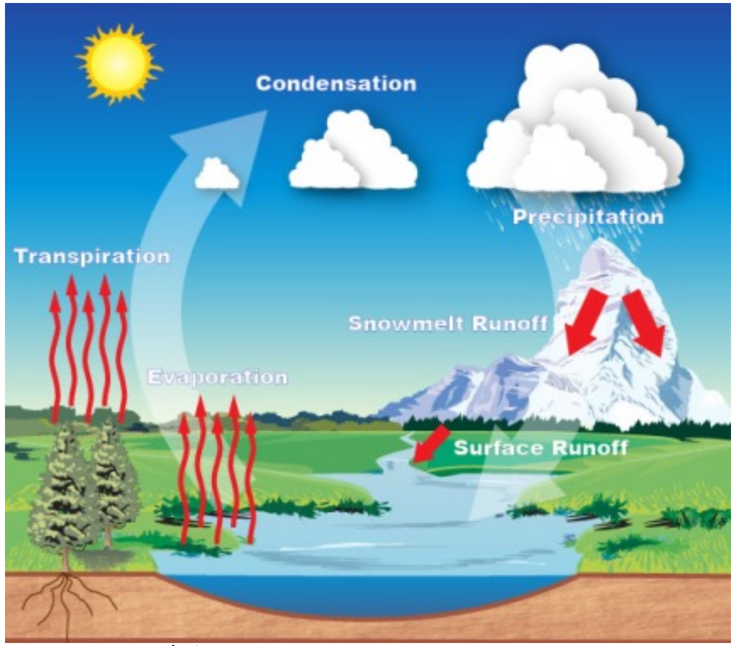

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  Precipitation, precipitation and precipitation

Precipitation as an Essential Climate Variable

The crucial role of Precipitation in climate is acknowledged by designating it as an Essential Climate Variable

- Relevant
- Feasible
- Cost-effective

→ Influences supply of water, causes risks to life and livelihoods when associated with floods, landslides and droughts, affect infrastructure planning, leisure activities, etc.

→ Related to cloud properties, ocean surface salinity, soil moisture, and others, participates in the release of latent heat within the energy cycle and at the heart of the hydrological cycle.

From GCOS Implementation Plan - 2022

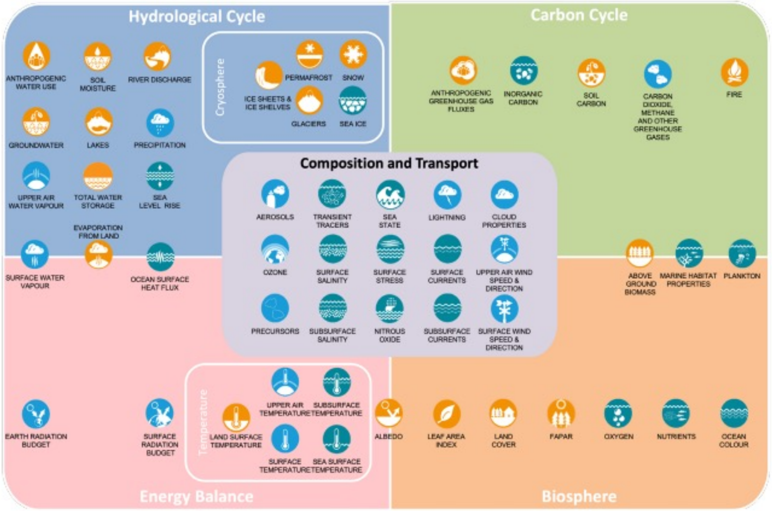

Figure 2. Essential Climate Variables and the climate cycles (See section 2.4). Many ECV contribute to understanding several different cycles – this only indicates the main links.

ECVs belong to three panel domains: ● Atmosphere ECVs (AOPC); ● Ocean ECVs (OOPC); ● Terrestrial ECVs (TOPC)

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Requirements on precipitation

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Precipitation requirements ensure that climate services for precipitation are comprehensive, accurate, and actionable for a wide range of users and applications.

- **Real-Time Monitoring:** High spatial and temporal resolution data (e.g., hourly, daily) is needed to track storms, droughts, and other short-term events. This allows for real-time monitoring and early warnings.
- **Climate Monitoring:** Long-term, consistent and stable datasets
- **Future Predictions:** Climate models require comprehensive information about past and present precipitation patterns to generate reliable forecasts. This allows for projections of future precipitation scenarios.

GCOS-2016

Atmospheric ECV product requirements								
ECV	Product	Frequency	Resolution	Required measurement uncertainty	Stability (per decade)	Standards/ references	Entity (see Part II, section 2.2)[93]	
							Satellite	In situ
Precipitation	Estimates of liquid and solid precipitation	Monthly (resolving diurnal cycles and with statistics of three-hour values)	25 km/NA	0.5 mm/h	0.02 mm/decade	CMSAF requirements related to the HOAPS release 4.0 (CM-12611)	WGClimate	WIGOS

GCOS-2022

Name	Accumulated precipitation				
Definition	Integration of solid and liquid precipitation rate reaching the ground over a time period defined in the metadata.				
Unit	mm				
Note	This ECV is designed to monitor the amount of precipitation globally in order to investigate the impact on the hydrological cycle, agriculture, drinking water supply or droughts. It is driven to support studies on a continental to global scale. This implies, that it is not designed to monitor extremes globally on a local to regional scale in space and time, as the requirements are different to answer both scientific questions.				
Requirements					
Item needed	**Unit**	**Metric**	**[1]**	**Value**	**Notes**
Horizontal Resolution	km		G	50	
			B	125	
			T	250	
Vertical Resolution			G	-	N/A
			B	-	
			T	-	
Temporal Resolution	d		G	1	Daily aggregation over period which defines the upper limit of temporal sampling
			B	30	Monthly aggregation over period which defines the upper limit of temporal sampling
			T	365	Annual aggregation over period which defines the upper limit of temporal sampling
Timeliness	d		G	1	
			B	7	
			T	30	
Required Measurement Uncertainty (2-sigma)	mm		G	1	
			B	2	
			T	5	
Stability	mm/decade		G	0.02	
			B	0.05	
			T	0.1	
Standards and References					

ean
ission

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Requirements on precipitation

Applications:

- **Agriculture:** Information about total precipitation might not be sufficient. Also need types of precipitation (e.g., rain, snow) and its timing to optimize planting and irrigation decisions.
- **Water management:** Need information on total precipitation over specific watersheds to manage water resources effectively. Understanding spatial distribution of precipitation is crucial.
- **Public safety:** Need real-time data on heavy rainfall or snowfall to issue warnings and prepare for potential flooding or avalanches. Timely data access is critical.

Other requirements:

- **Accessibility:** The data should be readily available in a usable format for the service's users. **Ease of access is crucial for timely decision-making**.
- **User-Friendly Platforms:** Accessible and user-friendly platforms or tools for stakeholders to easily interpret and use precipitation information.
- **Interoperability:** Ideally, the data should be compatible with other datasets used by the service for integrated analysis. Combining data from different sources can provide a more comprehensive picture.
- **Uncertainty:** Information about the uncertainty associated with the data is important for interpreting results. Uncertainty helps users understand the reliability of the data.
- **Cost:** The cost of accessing and processing the data should be taken into account. This depends on data source and desired features.
- Tailored **communication strategies** to effectively convey precipitation-related information to different user groups.

- **Research and Development:** Ongoing research and development to improve precipitation measurement techniques, models, and forecasting capabilities.
- **Collaboration and Stakeholder Engagement:** Collaboration with relevant stakeholders, including government agencies, industries, and local communities, to understand their specific needs and tailor services accordingly.

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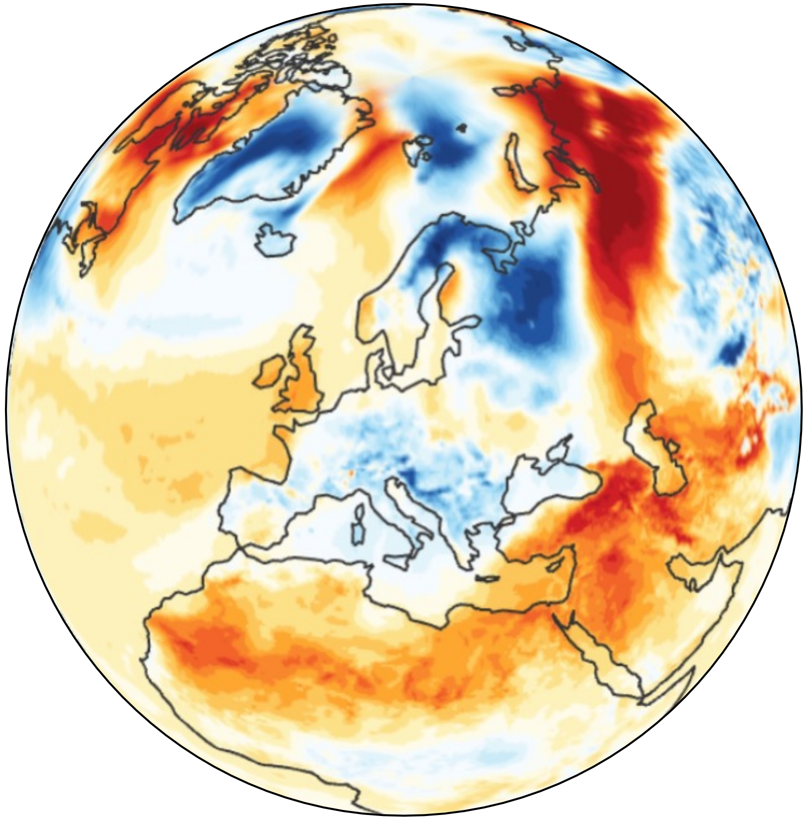
Climate services – what can we do for you?

"Climate services are the provision and use of climate data, information and knowledge to assist decision-making. Climate services require appropriate engagement between the recipient of the service and its provider, along with an effective access mechanism to enable timely action (*WMO, GFCS*)"

C3S Key achievements:

- recognised global voice on climate; informing EU institutions, the IPCC and UN institutions.
- truly pan-European effort with offices in three countries and contracts/agreements/MOUs with all EU Member States and Copernicus contributing countries.
- informing the global discourse on climate through products that have become a common resource for many international media outlets.
- trusted, authoritative and operational, source of information on climate for European (and global) citizens



The European Vision

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2014
C3S launch

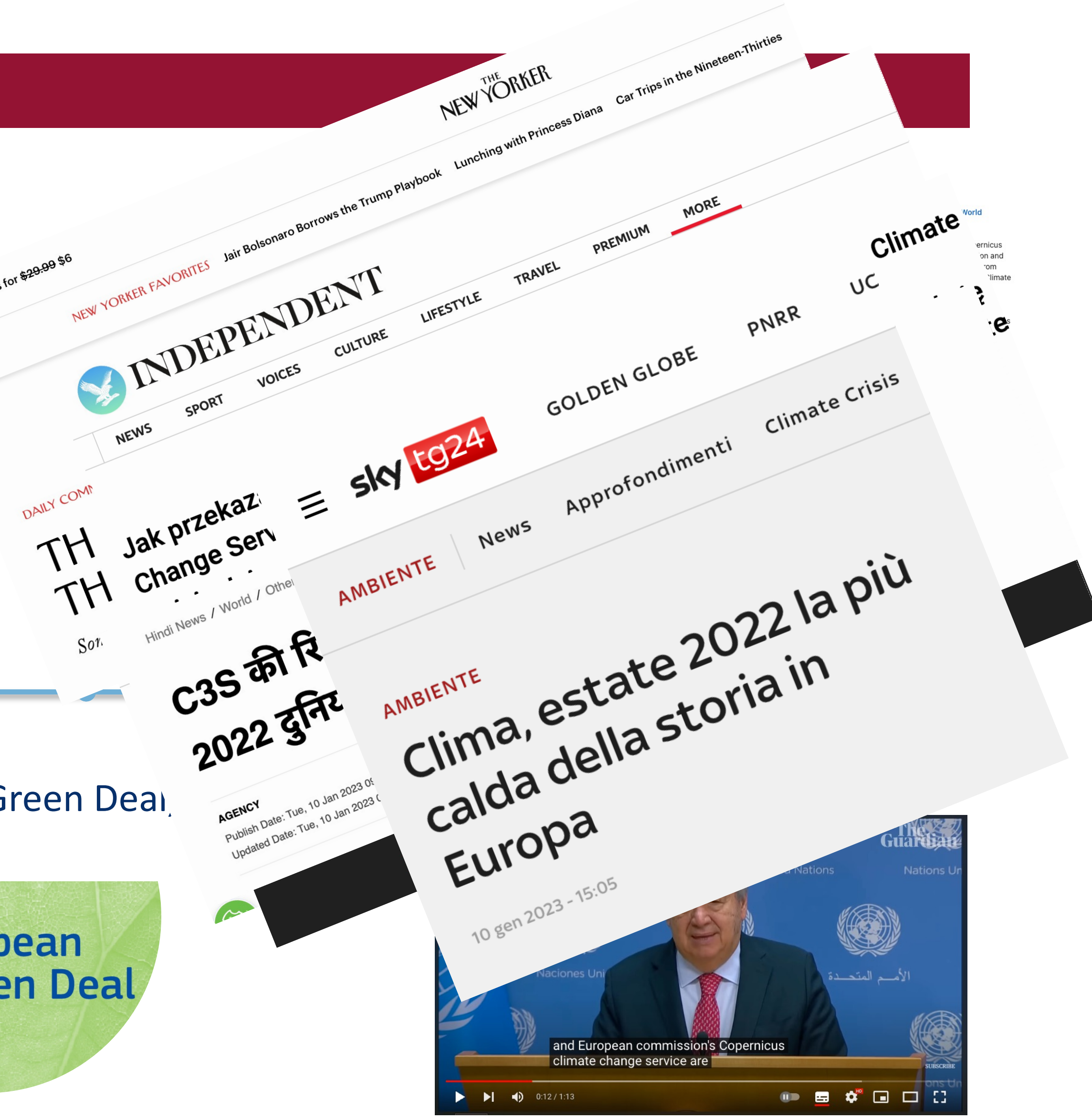
2015
Sentinel 2A,
Paris agreement

2016
Sentinel 1B & 3A

2017
Sentinel 2B & 5P

2018
CDS becomes operational,
Sentinal 3B

2020
European Green Deal
Sentinel 6



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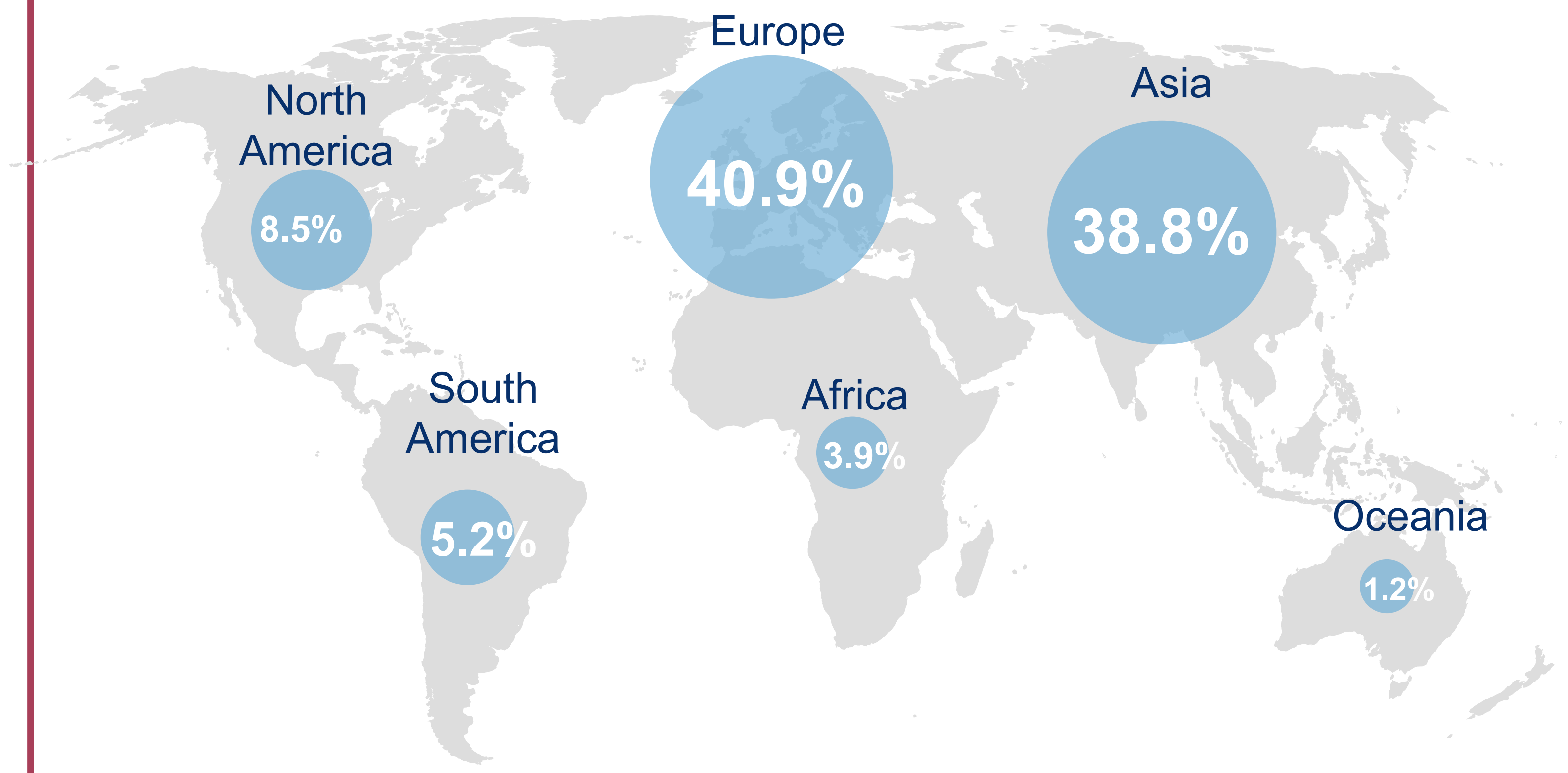
C3S – the numbers

Worldwide users

Open climate data has never been more important



Registered users
>285,000

External users
Several millions

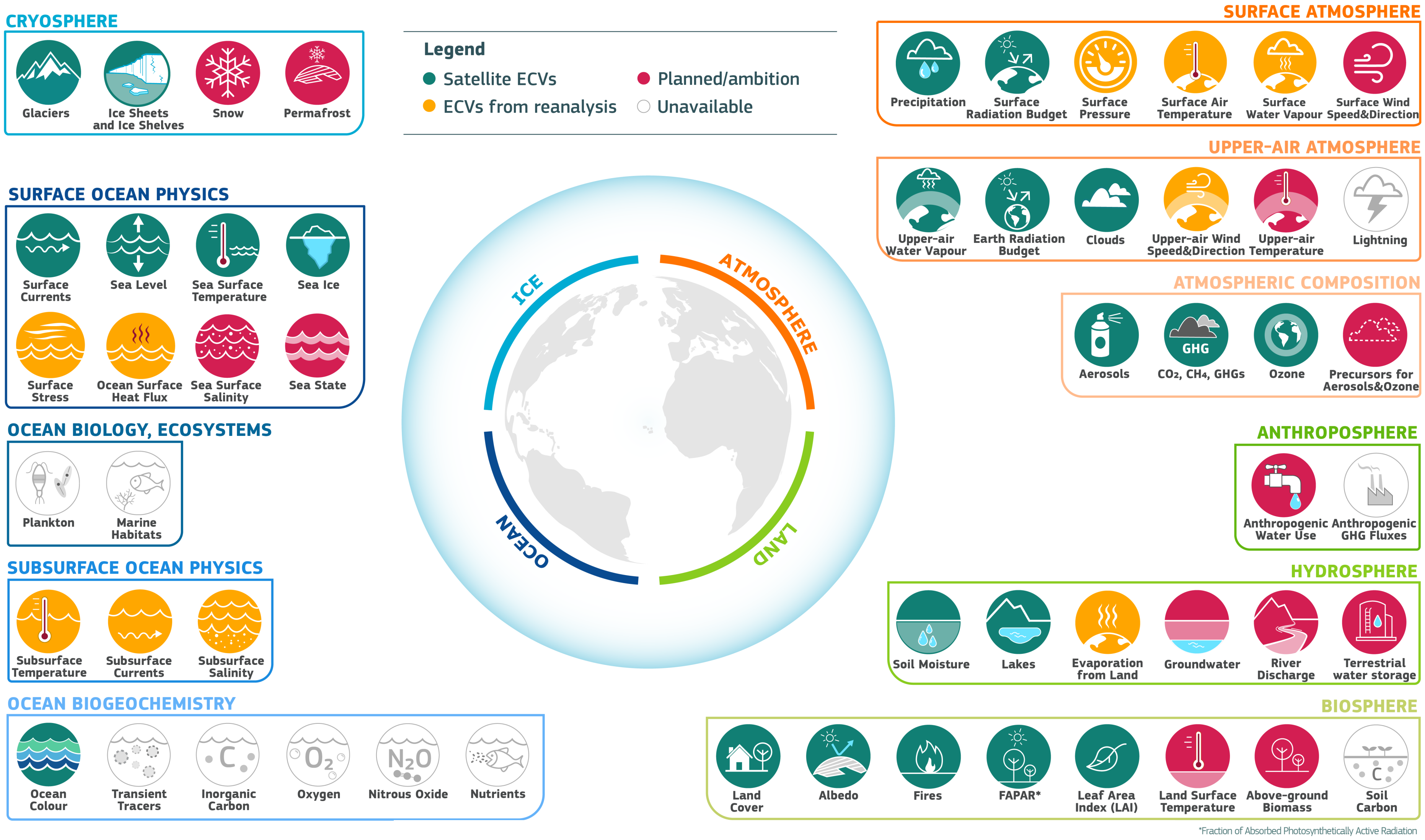
Requests
800 million

Data downloaded
166 PB

Top 5 dataset groups
ERA5, ERA5 land, seasonal forecast, CORDEX, CARRA, CERRA, ORAS5, ECVs

Essential Climate Variables in C3S

Clima
Chan



Crucial to understand changes in our climate.

C3S responds to GCOS and UNFCCC implementation needs.

ECV – Climate Data Records

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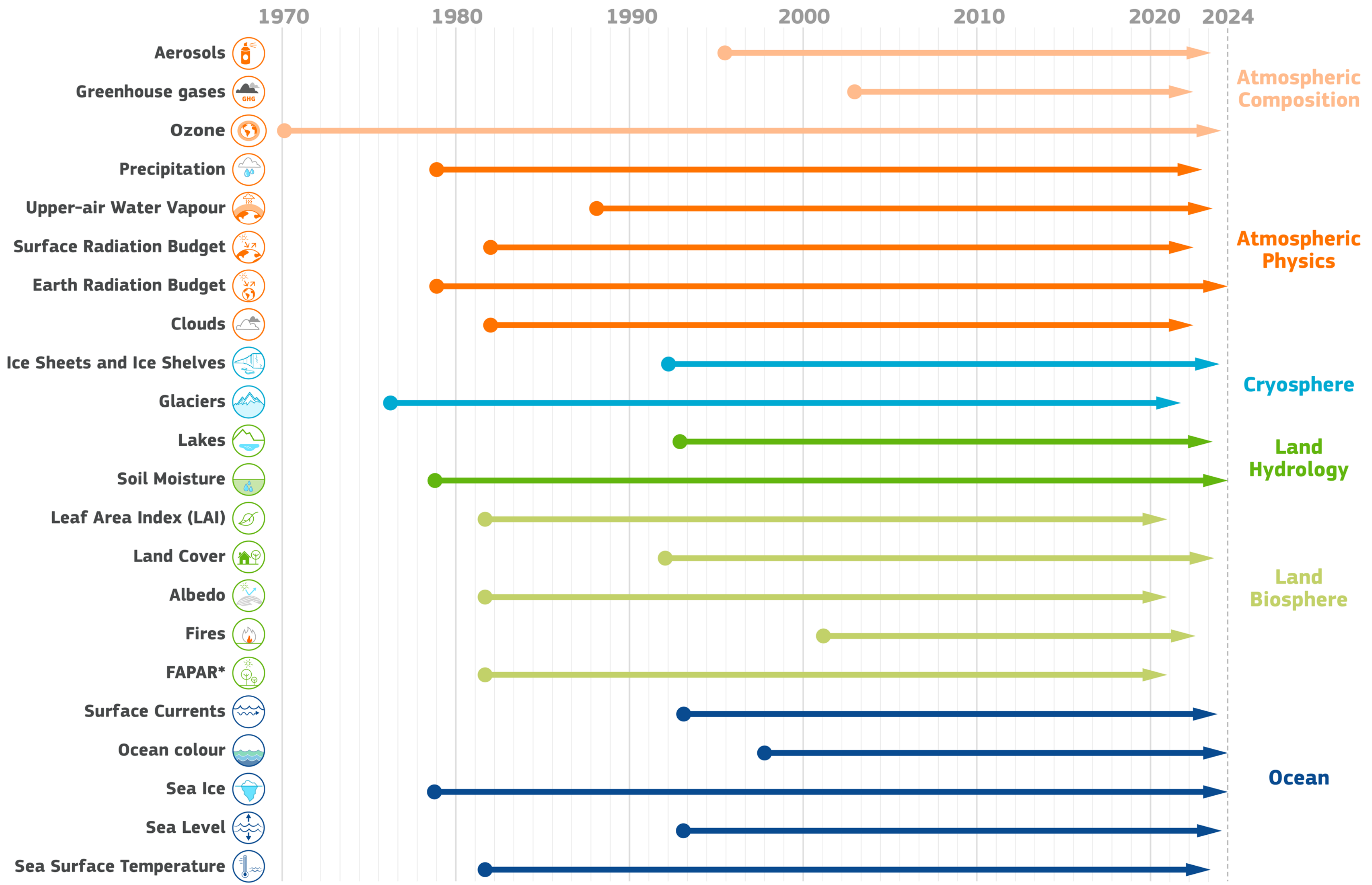
Based on satellite data, they monitor trends and variability

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



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C3S offer for precipitation

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- Provide access to the precipitation data through a harmonized look-and-feel interface
- Comprehensive Documentation
- Quality Assurance
- Specialised User Support
- Training material
- Use cases
- Data visualisation
- Licenses, references, doi
- Climate Intellligence

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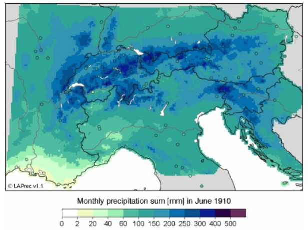
Access to in-situ, regional gridded precipitation datasets

Alpine gridded monthly precipitation data since 1871 derived from in-situ observations

Dataset | Europe | Atmosphere (surface) | In-situ observations

This dataset, also known as the Long-term Alpine Precipitation Reconstruction (LAPrec), provides gridded fields of monthly precipitation for the Alpine region (eight countries). The dataset is derived from station observations and is provided in two issues: LAPrec1871 starts in 1871 and is based on data from 85 input series; LAPrec1901 starts in 1901 and is based on data from 165 input series. ...



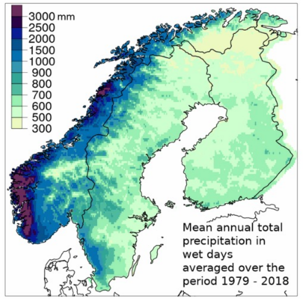
- Long-term Alpine precipitation Reconstruction dataset.
- LAPrec was constructed to satisfy high climatological standards, such as temporal consistency and the realistic reproduction of spatial patterns in complex terrain.
- 1871-2020, 5 km

Nordic gridded temperature and precipitation data from 1971 to present derived from in-situ observations

Dataset | Atmosphere (surface) | In-situ observations

The Nordic Gridded Climate Dataset (NGCD) is a high resolution, observational, gridded dataset of daily minimum, maximum and mean temperatures and daily precipitation totals, covering Finland, Sweden and Norway. The time period covered begins in January 1971 and continues to the present. The dataset is regularly updated every 6 months, in March and in September. In addition, there are daily, provi...

Updated 2024-02-25

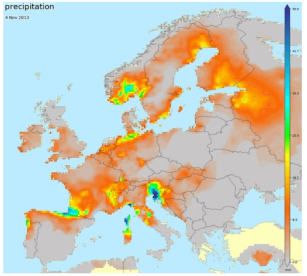


- Nordic Gridded Climate dataset.
- Finland, Sweden & Norway
- 1971-present
- 1x1 km

E-OBS daily gridded meteorological data for Europe from 1950 to present derived from in-situ observations

Dataset | Europe | Atmosphere (surface) | In-situ observations

E-OBS is a daily gridded land-only observational dataset over Europe. The blended time series from the station network of the European Climate Assessment & Dataset (ECA&D) project form the basis for the E-OBS gridded dataset. All station data are sourced directly from the European National Meteorological and Hydrological Services (NMHSs) or other data holding institutions. For a considerable numbe...



- 24h time steps of precipitation dataset.
- Data sources from NHMSs or other national data holders.
- Main applications: validations and climate monitoring [assessment of the magnitude and frequency of daily extremes].

In situ observations of meteorological and soil variables from the US Climate Reference Network near the surface from 2006 to present

Dataset | In-situ observations | Atmosphere (surface) | Global

This catalogue entry provides access to a continuous series of near-surface climate observations collected in-situ at United States Climate Reference Network (USCRN) stations. There are over 130 USCRN stations over the conterminous United States (U.S.), Alaska, and Hawaii. The USCRN stations are managed and maintained by the U.S. National Oceanic and Atmospheric Administration (NOAA). The USCRN...

- 130 reference stations with confidence provided in the form of detailed uncertainties.
- Monthly values of accumulated precipitation
- 2006-2022

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Access to remote sensed based gridded precipitation datasets

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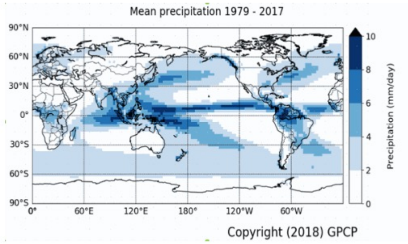
Precipitation monthly and daily gridded data from 1979 to present derived from satellite measurements

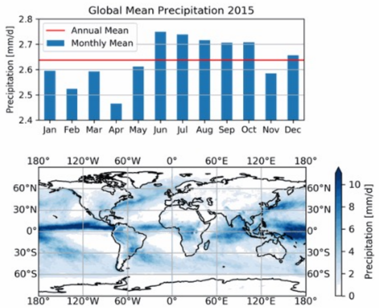


Dataset | Satellite observations | Global | Land (hydrology) | Atmosphere (surface)

The analysis of the Global Precipitation Climatology Project (GPCP) provides global estimates of precipitation as monthly means since 1979 (GPCP monthly v2.3) and as daily means since 1996 (GPCP daily v1.3), based on estimates using microwave imagers on polar-orbiting satellites and infrared imagers on geostationary satellites. The monthly product also includes information from rain-gauge observat...

- Monthly means (since 1979) & daily means (since 1996)
- Microwave imagers on polar-orbiter satellites and infrared imagers on geostationary satellites. Rain gauges observations also blended in the monthly product.

Precipitation monthly and daily gridded data from 2000 to 2017 derived from satellite microwave observations



Dataset | Satellite observations | Global | Land (hydrology) | Atmosphere (surface)

This dataset provides global estimates of daily accumulated and monthly means of precipitation. The precipitation estimates are based on a merge of passive microwave observations from two different radiometer classes operating on multiple Low Earth Orbit (LEO) satellites. Spaceborne passive microwave (MW) provides the most effective measurements for the remote sensing of precipitation because the ...

Updated 2022-08-19

- Global estimates of daily accumulated and monthly means.
- Based on passive microwave observations from radiometers

Precipitation in context (15 Feb 2024)

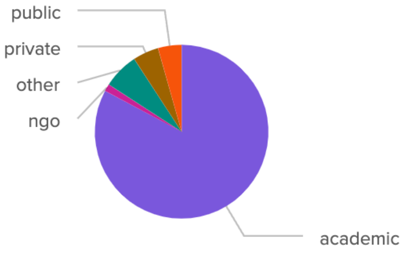
Climate Change

RESEARCH

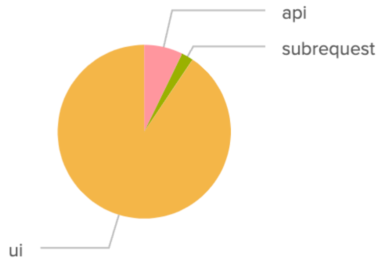
Total active users

3,851

Distribution by sector



Distribution by origin of request

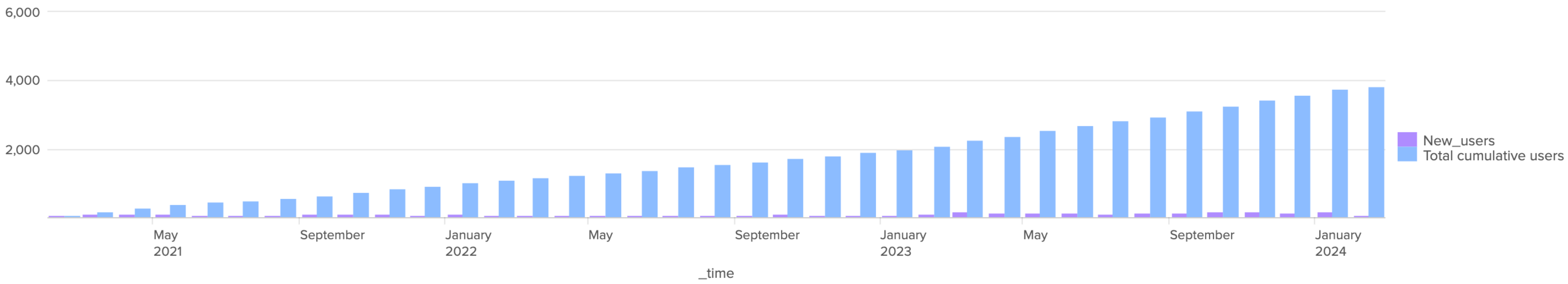


20m ago

Detailed info by products

resource_geonetworkid	users
eu.copernicus.climate.satellite-precipitation	3513
eu.copernicus.climate.satellite-precipitation-microwave	527

User uptake



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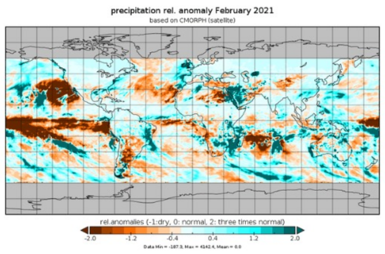
Blended in-situ and remote-sensed precipitation datasets

Temperature and precipitation gridded data for global and regional domains derived from in-situ and satellite observations

Dataset | Global | Atmosphere (surface) | In-situ observations | Satellite observations

This dataset provides high-resolution gridded temperature and precipitation observations from a selection of sources. Additionally the dataset contains daily global average near-surface temperature anomalies. All fields are defined on either daily or monthly frequency. The datasets are regularly updated to incorporate recent observations. The included data sources are commonly known as GISTEMP, B...

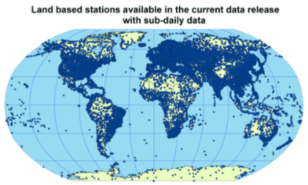


- High-res gridded precipitation from a collection of sources. Used to study weather extremes and climate trends.
- CHIRPS: Africa [gridded rainfall using in-situ & satellite → for trend analysis and seasonal drought monitoring
- CPC: CONUS
- CPC, GPCC, IMERG: Global
- CMORPH: Quasi-global [main source is low orbiting satellite microwave observations]

Global land surface atmospheric variables from 1755 to 2020 from comprehensive in-situ observations

Dataset | In-situ observations | Global | Atmosphere (surface)

This set of data holdings provides access to data collected from land surface meteorological observations across the globe. Data are available at the observational level and also at daily and monthly aggregations. Data have been collated and harmonised and quality control checks have been performed, but no attempt has been made to assess for potential biases. Data are provided for a range of commo...



- Data collated, reconciled and harmonised.
- Users with new sources can contribute by uploading data, via the data deposition service.

Precipitation estimates from Reanalysis

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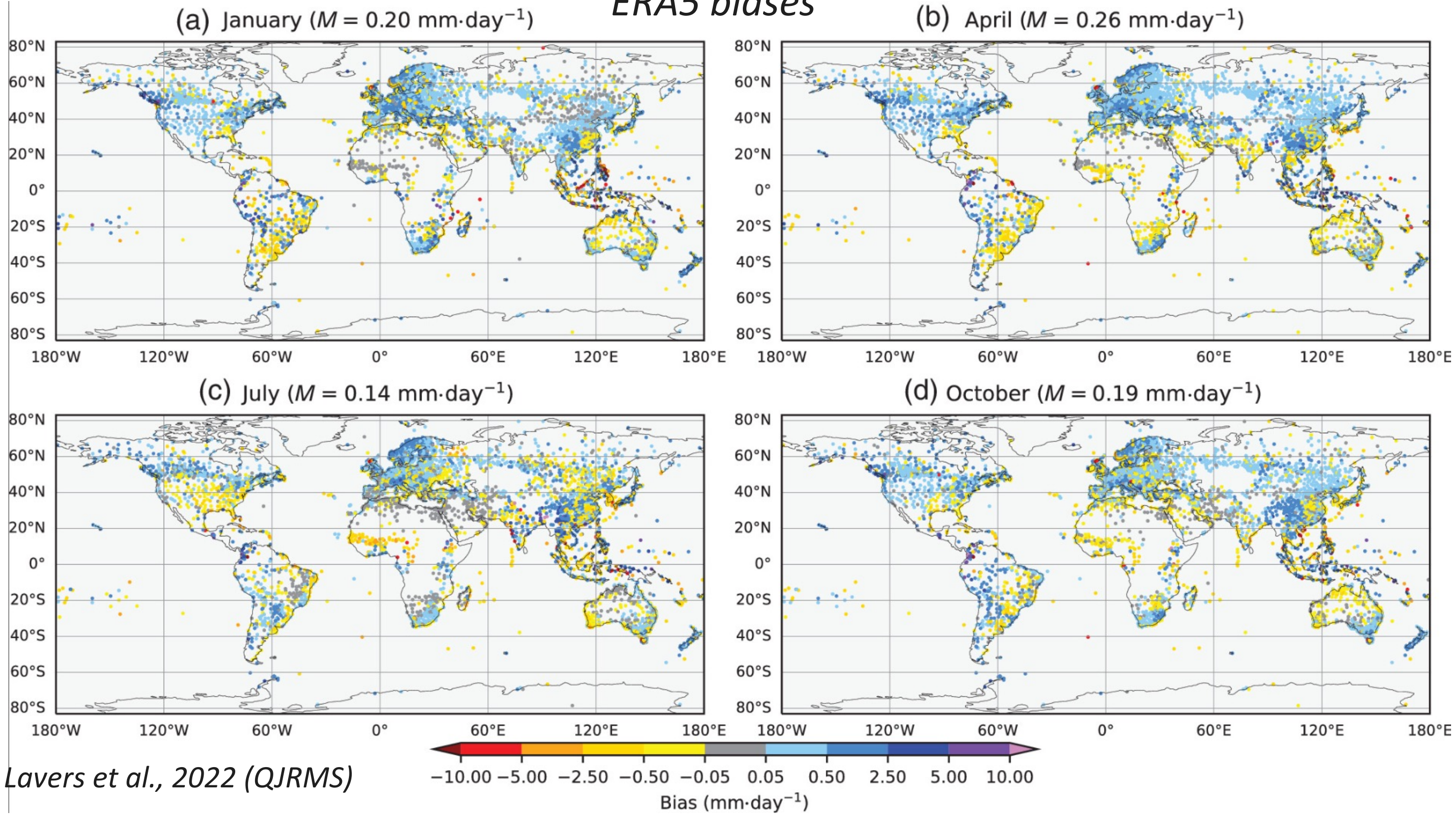
Global reanalysis

- **ERA5** atmospheric reanalysis
- 31 Km
- 1940-present

Regional reanalysis

- European Arctic **CARRA** reanalysis, 1990-present, 2.5 km
- European **CERRA** reanalysis 1984-2021, 5.5 km

ERA5 biases



Lavers et al., 2022 (QJRMS)

- Larger errors are found in the Tropics.
- The errors grow in the summer Extratropics.
- the errors in the Tropics move with the intertropical convergence zone.
- users can have confidence in ERA5 precipitation in extratropical regions.
- it is recommended that ERA5 is mostly used for extratropical precipitation monitoring.

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Precipitation in context

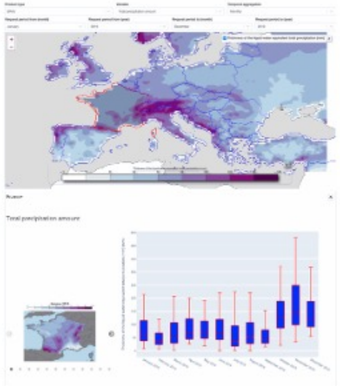
Climate Change

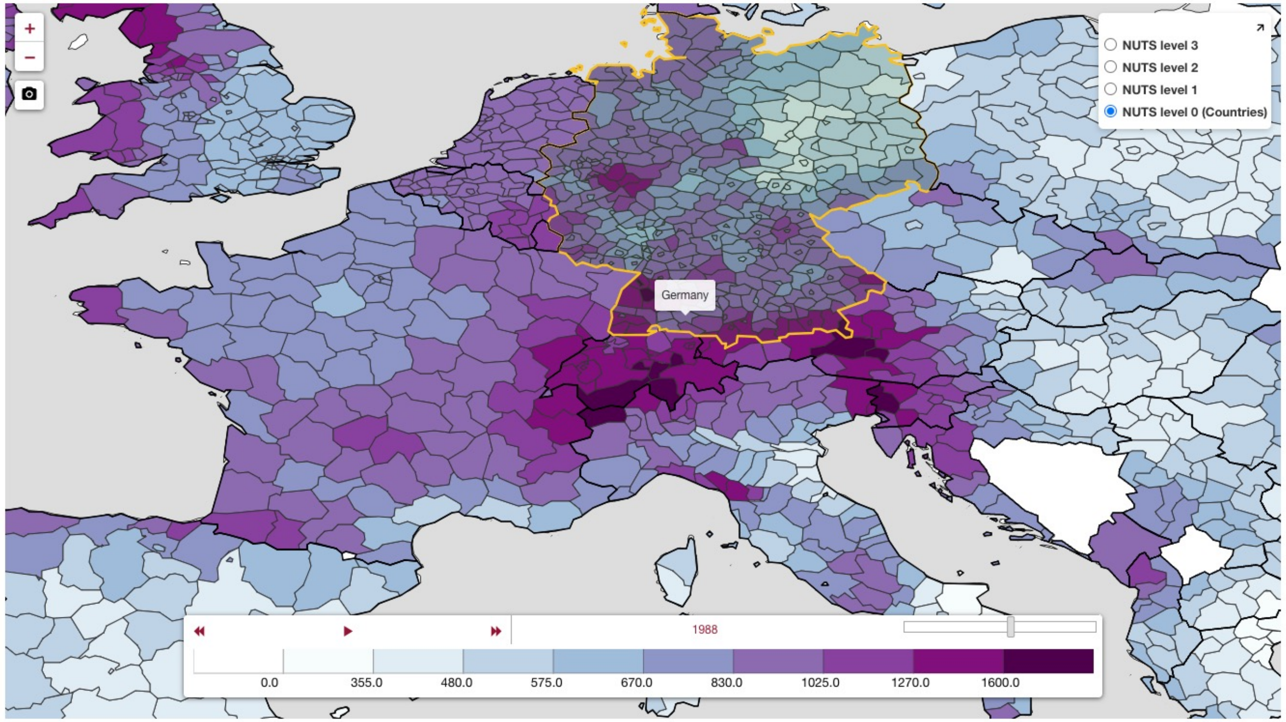
Extreme precipitation statistics for Europe

Extreme precipitation statistics for Europe

Application

This application allows users to access, analyse and compare extreme precipitation indicators within the Extreme precipitation indicators for Europe and European cities from 1950 to 2019 dataset available in the CDS catalogue. These indicators include: (i) a sub-set of ETCCDI (Expert Team on Climate Change Detection and Indices) indicators with fixed and percentile thresholds and indicators for th...





Source datasets:

- ERA5
- E-obs

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Climate Change

Precipitation in context

White, white, wet: when might we have our last Christmas?

Extreme precipitation statistics for Europe

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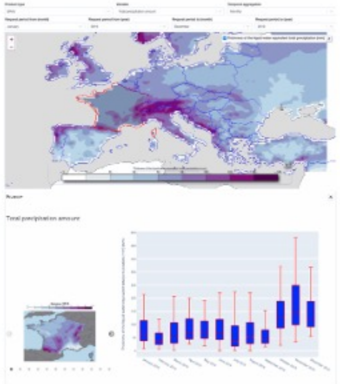

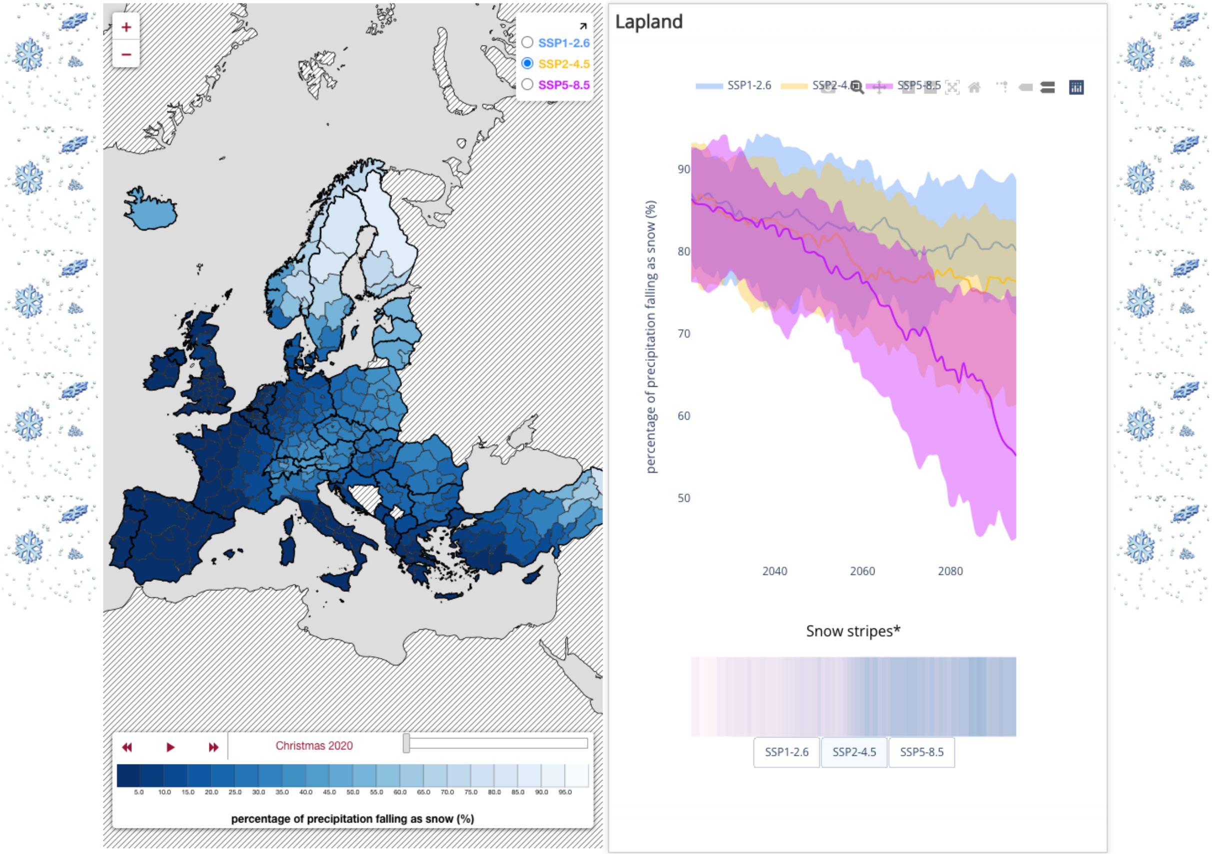

- Explores how the percentage of winter precipitation that falls as snow might change over the coming decades.
- Data source: CMIP6

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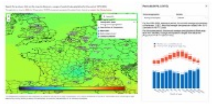
Climate Change

Precipitation in context

ERA5 explorer

Application | Global | Reanalysis

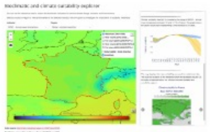
. The available options are global average temperatures, wind speeds and **precipitation** totals



Bioclimatic indicator and climate suitability explorer

Application | Biodiversity | Global | Land (biosphere)

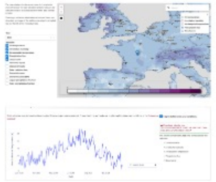
warmest quarter, BIO11 - Mean temperature of coldest quarter, BIO12 - Annual **precipitation** , BIO13



Agrometeorological indicators explorer and data extractor

Application | Agriculture | Reanalysis | Global | Land (biosphere)

elements cover temperature, **precipitation** , snow depth, humidity, cloud cover and radiation. These variables



Agroclimatic indicators explorer for Europe from 1970 to 2100

Application | Global | Land (biosphere) | Reanalysis | Climate projections | Agriculture

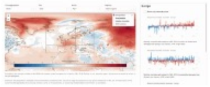
and minimum temperatures as well as accumulated **precipitation** . ERA5-Land reanalysis was used to cover

C3S monthly climate bulletin explorer

Application | Global | Reanalysis | Atmosphere (surface) | Land (hydrology) | Ocean (physics)

one out of temperature, **precipitation** , humidity and soil moisture anomalies with respect to a

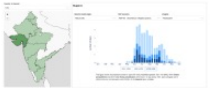
Updated 2021-11-05



Climate change and global cotton growing conditions

Application | Agriculture

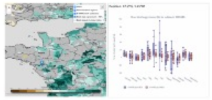
cotton. Variables in the dataset/application are: Growing season length, Heavy **precipitation** days



European hydrology and climate data explorer

Application | Water management | Europe

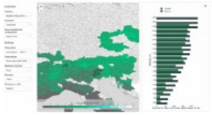
temperature, Aridity actual, Aridity potential, Flood recurrence, Highest 5-day **precipitation** amount, Longest



Mountain tourism meteorological and snow indicators for Europe from 1986 to 2100 derived from reanalysis and climate projections

Application | Tourism | Europe

, Total **precipitation** from November to April, Total snow **precipitation** from November to April

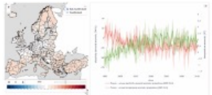


European energy and climate data explorer

Application | Energy | Reanalysis | Europe

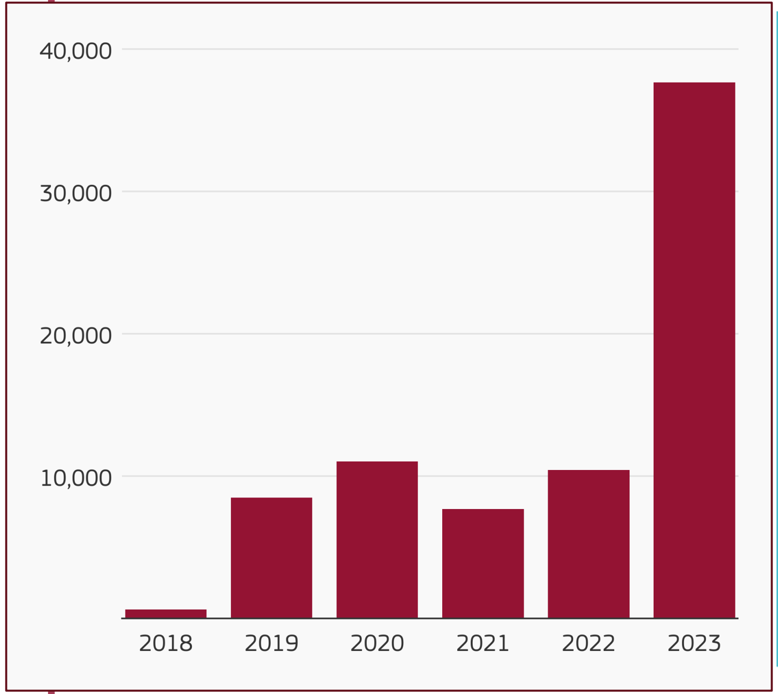
photovoltaic power generation, Surface downwelling shortwave radiation, Total **precipitation** , Wind power

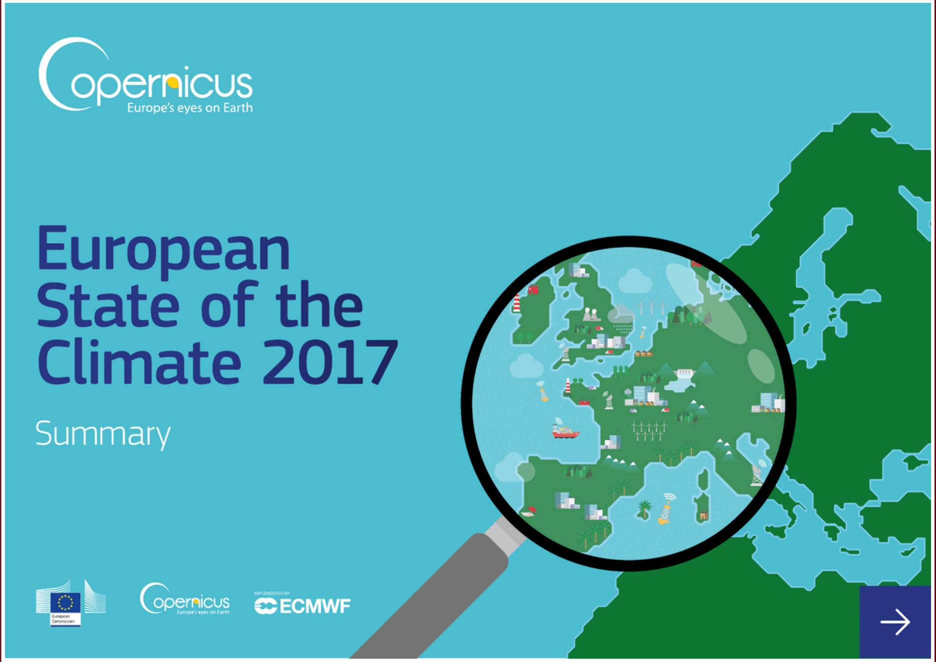
Updated 2022-12-21



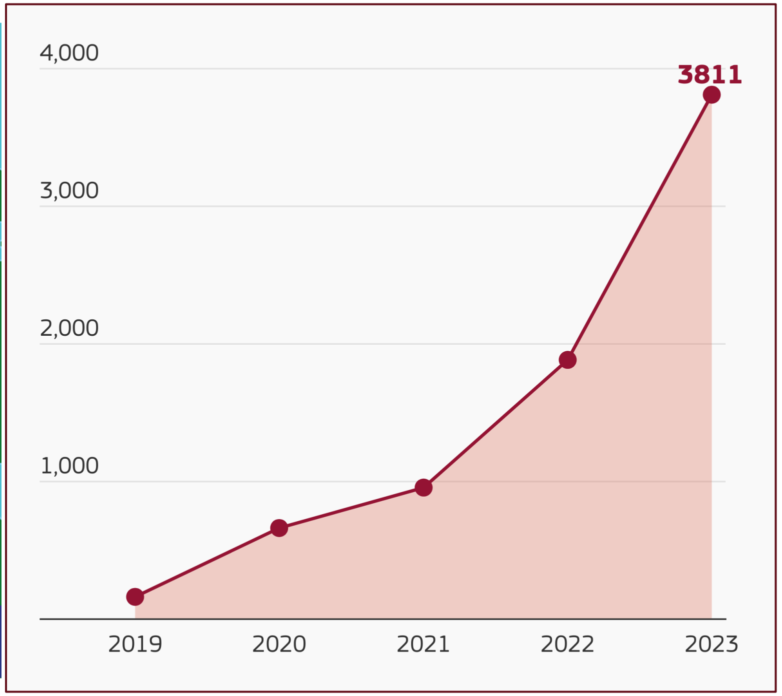
Media impact

EVOLUTION OF MEDIA COVERAG





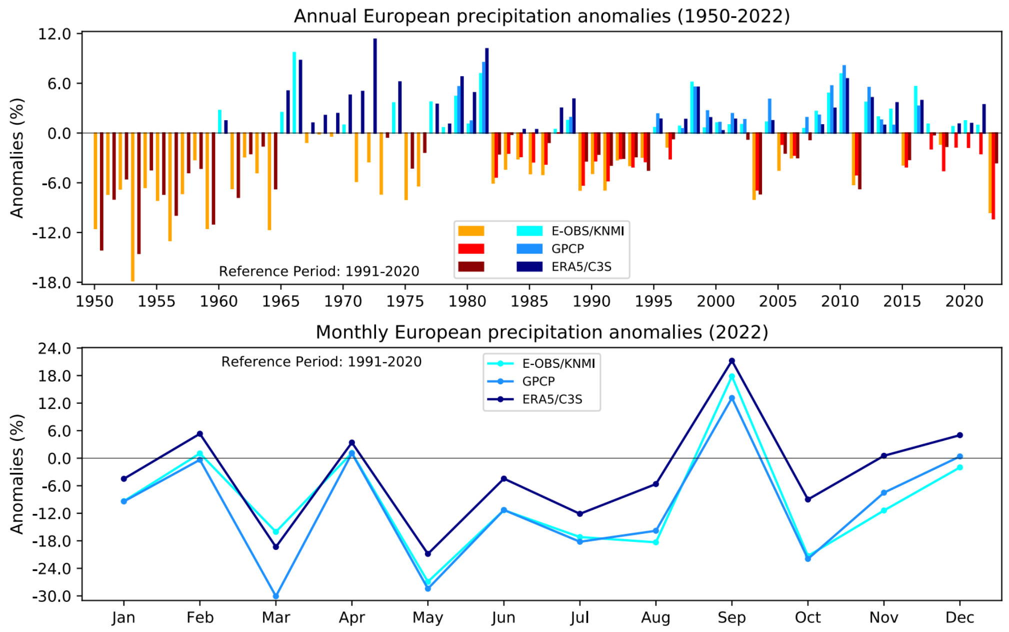
ESOTC MEDIA MENTIONS



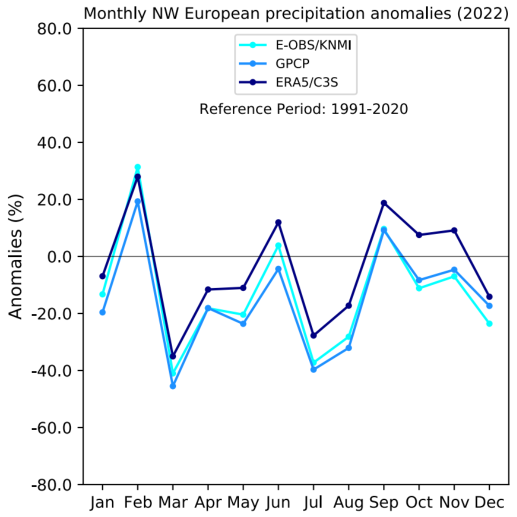
Climate Change

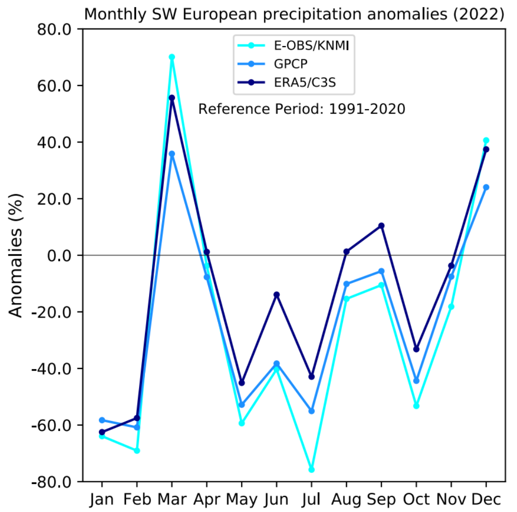
European State of The Climate (ESoTC)

The ESOTC report includes a snapshot of the **global context** during the year, a more comprehensive overview of **conditions in Europe**, and a **focus on the Arctic**. It provides a detailed analysis, with descriptions of climate conditions and events, and explores the associated variations in key climate variables from across all parts of the Earth system.



Copernicus Climate Change Service
European State of the Climate | 2022
PROGRAMME OF THE EUROPEAN UNION





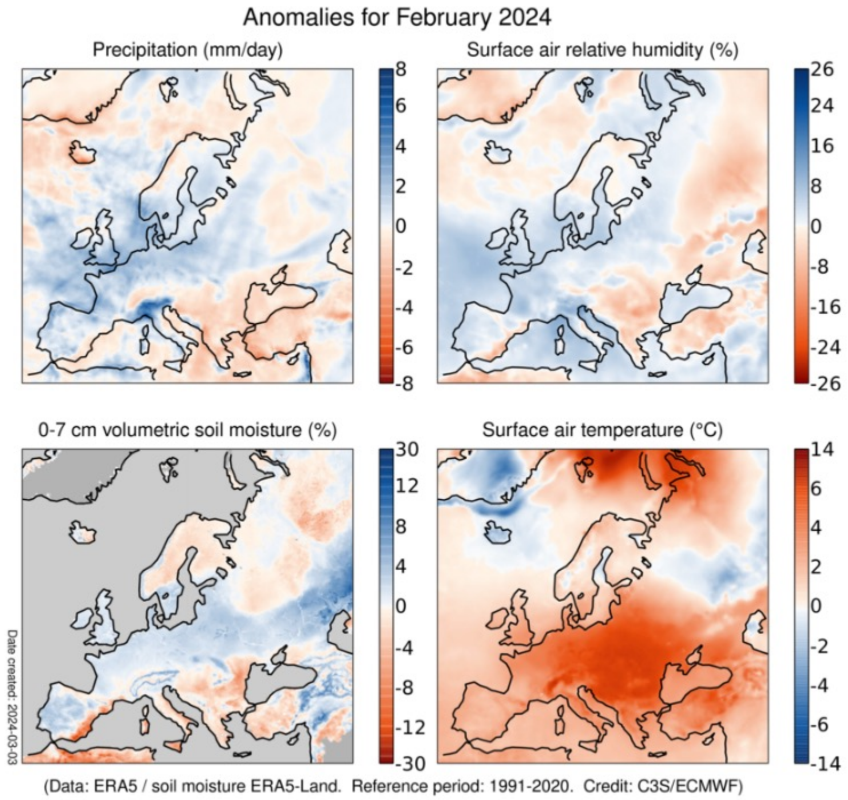
PROGRAMME OF THE EUROPEAN UNION

Climate Change

Climate Bulletins

Europe - February 2024

1991-2020 | 1981-2010



PROGRAMME OF THE EUROPEAN UNION Copernicus ECMWF Climate Change Service

Anomalies in precipitation, the relative humidity of surface air, the volumetric moisture content of the top 7 cm of soil and surface air temperature for February 2024 with respect to February averages for the period 1991-2020. The darker grey shading denotes where soil moisture is not shown due to ice cover or climatologically low precipitation. Data source: ERA5 Credit: Copernicus Climate Change Service/ECMWF.

- Presentation of the current condition of the climate using key climate change indicators, as well as analysis of the maps and guidance on how they are produced.
- Data sources: ERA5 and ERA5-Land

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Climate Change

Summary: What can climate services do for you?

The C3S approach for precipitation:

- Provide **access to the precipitation data** through a harmonized look-and-feel interface
- Comprehensive **Documentation**
- Independent **Evaluation and Quality Control**
- Specialised **User Support**
- **Training** material
- **Use cases**
- Data **visualisation**
- Licenses, references, doi
- Climate Intelligence derived **products**
- **Applications** tailored to different sectors
- …

Climate Change

Outline

- The W(H)-questions [What/When/How/Why]
- Requirements
- Climate Services – what can we do for you? (C3S),
  - The Copernicus Climate Change Service (C3S)
  - C3S offer for precipitation
- Gap analysis & uncertainty
- Summary

Precipitation Gap Analysis - EO missions

- Using WMO OSCAR/Space:
  - Precipitation (liquid or solid)
  - Precipitation intensity at surface
  - Accumulated precipitation over 24h

- Using the “evaluation of measurements”
  - 1-5 scale indicates relevance of an instrument to observe a given geophysical variable

Climate Change

Precipitation (liquid or solid)

- 3D field of the vertical flux of precipitating water mass (precipitation intensity)

Instrument	NRT?	Relevance	Satellite	ECT/Lon	Orbit	DLR	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
DPR	Yes	1 - primary	GPM Core Observato	65 °	DRIFT		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								
PMR (FY-3)		1 - primary	FY-3G	50 °	DRIFT									X	X	X	X	X	X	X									
PMR (FY-3)		1 - primary	FY-3I	50 °	DRIFT												X	X	X	X	X	X	X						
AOS Doppler Radar		3 - high	AOS-PMM	55 °	DRIFT															X	X	X	X	X	X				
PR		3 - high	TRMM	35 °	DRIFT																								
INCUS-radar		4 - fair	INCUS-1		DRIFT												X	X	X										
INCUS-radar		4 - fair	INCUS-2		DRIFT												X	X	X										
INCUS-radar		4 - fair	INCUS-3		DRIFT												X	X	X										
RainCube		4 - fair	ISS RainCube	51.6 °	DRIFT				X	X	X																		
AOS-Sky radar		5 - marginal	AOS-Sky	13:30	SunSync																	X	X	X	X	X	X		
CPR (CloudSat)		5 - marginal	CloudSat	13:30 asc	SunSync		X	X	X	X	X	X	X	X															
CPR (Earth-CARE)		5 - marginal	EarthCARE	14:00 desc	SunSync										X	X	X	X											

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European Commission

Climate Change

Precipitation intensity at surface (liquid or solid)

- Intensity of precipitation reaching the ground - Physical unit: [mm/h] (if solid, mm/h of liquid water after melting) - Accuracy unit: [mm/h]. Since accuracy changes with intensity, it is necessary to specify a reference intensity. Assumed rate: 5 mm/h.

Instrument	NRT?	Relevance	Satellite	ECT/Lon	Orbit	DLR	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
DPR	Yes	1 - primary	GPM Core Observato	65 °	DRIFT		X	X	X	X	X	X	X	X															
PMR (FY-3)		1 - primary	FY-3G	50 °	DRIFT		X	X	X	X	X	X	X																
PMR (FY-3)		1 - primary	FY-3I	50 °	DRIFT					X	X	X	X	X	X	X													
AOS Doppler Radar		2 - very high	AOS-PMM	55 °	DRIFT								X	X	X	X	X	X											
PR		2 - very high	TRMM	35 °	DRIFT																								
AMSR		2 - very high	ADEOS-2	10:30 desc	SunSync																								
AMSR-E	No	2 - very high	Aqua	13:30 asc	SunSync																								
AMSR3		2 - very high	GOSAT-GW	13:30 asc	SunSync			X	X	X	X	X	X	X	X														
TMI		2 - very high	TRMM	35 °	DRIFT																								
MTVZA-GY		3 - high	Meteor-M N2	09:30 asc	SunSync																								
MTVZA-GY		3 - high	Meteor-M N2-1	15:09 asc	SunSync																								
MTVZA-GY		3 - high	Meteor-M N2-2	15:15 asc	SunSync		X	X																					
MTVZA-GY		3 - high	Meteor-M N2-3	15:09 desc	SunSync		X	X	X	X	X	X																	
MTVZA-GY		3 - high	Meteor-M N2-4		SunSync			X	X	X	X	X	X																
MTVZA-GY		3 - high	Meteor-M N2-5	15:00 desc	SunSync				X	X	X	X	X	X															
MTVZA-GY		3 - high	Meteor-M N2-6	09:00 asc	SunSync					X	X	X	X	X	X														
MTVZA-GY		3 - high	Meteor-M N1	09:30 desc	SunSync																								
MTVZA-GY-MP		3 - high	Meteor-MP N1	15:30 asc	SunSync				X	X	X	X	X	X	X	X													
MTVZA-GY-MP		3 - high	Meteor-MP N2	09:30 desc	SunSync					X	X	X	X	X	X	X	X												
MTVZA-OK (MW)		3 - high	SICH-1M	82.5 °	DRIFT																								
MWI (MetOp-SG)		3 - high	Metop-SG-B1	09:30 desc	SunSync					X	X	X	X	X	X	X	X	X											
MWI (MetOp-SG)		3 - high	Metop-SG-B2	09:30 desc	SunSync												X	X	X	X	X	X	X	X	X				
MWI (MetOp-SG)		3 - high	Metop-SG-B3	09:30 desc	SunSync																			X	X	X	X	X	
MWRI-RM		3 - high	FY-3G	50 °	DRIFT		X	X	X	X	X	X	X																
MWRI-RM		3 - high	FY-3I	50 °	DRIFT					X	X	X	X	X	X	X													
MTVZA		3 - high	Meteor-3M	09:15 asc	SunSync																								
SSMIS	No	3 - high	DMSP-F16	06:20 desc	SunSync		X																						
SSMIS	No	3 - high	DMSP-F19	06:36 desc	SunSync																								
ABI	No	3 - high	GOES-17	104.7°W	GEO		X	X	X	X	X	X	X																
ABI		3 - high	GOES-U	75°W	GEO			X	X	X	X	X	X	X	X	X	X												
AGRI	Yes	3 - high	FY-4A	104.7°E	GEO		X	X																					
AGRI		3 - high	FY-4B	105°E	GEO		X	X	X	X	X	X																	
AGRI		3 - high	FY-4C		GEO				X	X	X	X	X	X	X	X													
AGRI		3 - high	FY-4D	105°E	GEO					X	X	X	X	X	X	X	X												
AGRI		3 - high	FY-4E	86.5°E	GEO						X	X	X	X	X	X	X	X											
AHI	No	3 - high	Himawari-8	140.7°E	GEO		X	X	X	X	X	X	X	X															
AMI	Yes	3 - high	GEO-KOMPSAT-2A	128.2°E	GEO		X	X	X	X	X	X	X																
FCI		3 - high	MTG-I1	3.5°W	GEO		X	X	X	X	X	X	X	X	X	X	X	X											
FCI		3 - high	MTG-I2	0°	GEO					X	X	X	X	X	X	X	X	X	X	X									
FCI		3 - high	MTG-I3	0°	GEO											X	X	X	X	X	X	X	X	X	X	X			
FCI		3 - high	MTG-I4	0°	GEO															X	X	X	X	X	X	X	X	X	
GHMI		3 - high	Himawari-10	140.7°E	GEO							X	X	X	X	X	X	X	X	X	X	X							
GXI		3 - high	GeoXO East	75°W	GEO											X	X	X	X	X	X	X	X	X	X	X	X	X	
GXI		3 - high	GeoXO West	137°W	GEO														X	X	X	X	X	X	X	X	X	X	
IMAGER (INSAT)	Yes	3 - high	INSAT-3D	82°E	GEO		X	X	X																				
IMAGER (INSAT)	Yes	3 - high	INSAT-3DR	74°E	GEO		X	X	X	X																			
IMAGER (INSAT)		3 - high	INSAT-3DS	82°E	GEO			X	X	X	X	X	X	X															
MSU-GSM		3 - high	Electro-M N1		GEO														X	X	X	X	X	X	X	X	X	X	
MSU-GSM		3 - high	Electro-M N2		GEO														X	X	X	X	X	X	X	X	X	X	
MSU-GSM		3 - high	Electro-M N3		GEO														X	X	X	X	X	X	X	X	X	X	

This tables shows all related requirements. For more operations/filtering, please consult the full list of Requirements
Note: In reading the values, goal is marked blue, breakthrough green, threshold orange
Application-dependent Technical Priority (ATP) Magenta and Relative priority of the attributes Red

Id	Variable	Layer	App Area	ATP	Uncertainty	Layer/s Quality	Coverage Quality	Stability / decade	Hor Res	Ver Res	Obs Cyc	Timeliness	Coverage	Conf Level	Val Date	Source	General Comment
45	Precipitation intensity at surface (liquid or solid)	Near Surface	2.9 Agricultural Meteorology						0.25 km 1 km 10 km		8 min 30 min 2 h		Global	tentative	2003-01-01	WMO TD No. 1052, SAT-26	Unknown
104	Precipitation intensity at surface (liquid or solid)	Near Surface	Climate-AOPC (deprecated)		0.1 mm/h 0.3 mm/h 2 mm/h				100 km 200 km 500 km		3 h 4 h 6 h	3 h 6 h 12 h	Global	firm	2007-07-19	AOPC	
289	Precipitation intensity at surface (liquid or solid)	Near Surface	2.1 Global Numerical Weather Prediction and Real-time Monitoring		0.1 mm/h 0.5 mm/h 1 mm/h				5 km 15 km 50 km		60 min 3 h 12 h	6 min 30 min 6 h	Global	reasonable	2009-02-10	John Eyre	
368	Precipitation intensity at surface (liquid or solid)	Near Surface	2.2 High-Resolution Numerical Weather Prediction		0.1 mm/h 0.2 mm/h 1 mm/h				0.5 km 2 km 10 km		15 min 30 min 2 h	15 min 30 min 2 h	Global	reasonable	2019-12-04	T Montmerle	
442	Precipitation intensity at surface (liquid or solid)	Near Surface	2.3 Nowcasting / Very Short-Range Forecasting		0.1 mm/h 0.3 mm/h 1 mm/h				1 km 5 km 30 km		5 min 10 min 60 min	5 min 10 min 30 min	Global	reasonable	2013-04-03	P. Ambrosetti	Over populated area and close to rivers requirements are more strict than elsewhere.
730	Precipitation intensity at surface (liquid or solid)	Near Surface	2.8 Aeronautical Meteorology		0.001 mm/h 0.01 mm/h 0.1 mm/h						30 min 60 min 2 h	5 min 10 min 30 min	Local	firm	2014-03-27	J van der Meulen	At the aerodrome Variable to be extended to layer LT
773	Precipitation intensity at surface (liquid or solid)	Near Surface	2.5 Atmospheric Climate Monitoring		0.5 mm/h			0.02 mm/h	25 km		30 d		Global	reasonable	2019-09-25	GCOS-200: The Global Observing System for Climate: Implementation Needs (Published 2016)	Requirements in the GCOS-200 IP, Annex A, are only specified at the goal level. Requirements for observing cycle are monthly (resolving diurnal cycles and with statistics of three-hour values)

Accumulated precipitation (over 24h)

Climate Change

- Integration of precipitation rate reaching the ground over several time intervals. The reference requirement referes to integration over 24 h.

Instrument	NRT?	Relevance	Satellite	ECT/Lon	Orbit	DLR	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	20
AMSR		2 - very high	ADEOS-2	10:30 desc	SunSync																								
AMSR-E	No	2 - very high	Aqua	13:30 asc	SunSync																								
AMSR3		2 - very high	GOSAT-GW	13:30 asc	SunSync								X	X	X	X	X	X	X	X									
TMI		2 - very high	TRMM	35 °	DRIFT																								
MTVZA-GY		3 - high	Meteor-M N1	09:30 desc	SunSync																								
MTVZA-GY		3 - high	Meteor-M N2	09:30 asc	SunSync																								
MTVZA-GY		3 - high	Meteor-M N2-1	15:09 asc	SunSync																								
MTVZA-GY		3 - high	Meteor-M N2-2	15:15 asc	SunSync			X	X	X	X	X	X																
MTVZA-GY		3 - high	Meteor-M N2-3	15:09 desc	SunSync							X	X	X	X	X	X												
MTVZA-GY		3 - high	Meteor-M N2-4		SunSync								X	X	X	X	X	X											
MTVZA-GY		3 - high	Meteor-M N2-5	15:00 desc	SunSync									X	X	X	X	X	X										
MTVZA-GY		3 - high	Meteor-M N2-6	09:00 asc	SunSync										X	X	X	X	X	X									
MTVZA-GY-MP		3 - high	Meteor-MP N1	15:30 asc	SunSync									X	X	X	X	X	X	X	X								
MTVZA-GY-MP		3 - high	Meteor-MP N2	09:30 desc	SunSync										X	X	X	X	X	X	X	X							
MTVZA-OK (MW)		3 - high	SICH-1M	82.5 °	DRIFT																								
MWI (MetOp-SG)		3 - high	Metop-SG-B1	09:30 desc	SunSync										X	X	X	X	X	X	X	X	X						
MWI (MetOp-SG)		3 - high	Metop-SG-B2	09:30 desc	SunSync																	X	X	X	X	X	X	X	
MWI (MetOp-SG)		3 - high	Metop-SG-B3	09:30 desc	SunSync																								
MWRI-RM		3 - high	FY-3G	50 °	DRIFT							X	X	X	X	X	X	X											
MWRI-RM		3 - high	FY-3I	50 °	DRIFT										X	X	X	X	X	X	X								
MTVZA		3 - high	Meteor-3M	09:15 asc	SunSync																								
SSMIS	No	3 - high	DMSP-F16	06:20 desc	SunSync		X	X	X	X	X	X																	
SSMIS	No	3 - high	DMSP-F19	06:36 desc	SunSync																								
ABI	No	3 - high	GOES-17	104.7°W	GEO		X	X	X	X	X	X	X	X	X	X	X	X											
ABI		3 - high	GOES-U	75°W	GEO								X	X	X	X	X	X	X	X	X	X							
AGRI	Yes	3 - high	FY-4A	104.7°E	GEO		X	X	X	X	X	X	X																
AGRI		3 - high	FY-4B	105°E	GEO					X	X	X	X	X	X	X	X												
AGRI		3 - high	FY-4C		GEO									X	X	X	X	X	X	X	X								
AGRI		3 - high	FY-4D	105°E	GEO										X	X	X	X	X	X	X	X							
AGRI		3 - high	FY-4E	86.5°E	GEO											X	X	X	X	X	X	X	X						
AHI	No	3 - high	Himawari-8	140.7°E	GEO		X	X	X	X	X	X	X	X	X	X	X	X	X										
AMI	Yes	3 - high	GEO-KOMPSAT-2A	128.2°E	GEO		X	X	X	X	X	X	X	X	X	X	X	X											
FCI		3 - high	MTG-I1	3.5°W	GEO						X	X	X	X	X	X	X	X	X	X	X	X	X						
FCI		3 - high	MTG-I2	0°	GEO										X	X	X	X	X	X	X	X	X	X	X				
FCI		3 - high	MTG-I3	0°	GEO																X	X	X	X	X	X	X	X	
FCI		3 - high	MTG-I4	0°	GEO																				X	X	X	X	
GHMI		3 - high	Himawari-10	140.7°E	GEO												X	X	X	X	X	X	X	X	X	X	X		
GXI		3 - high	GeoXO East	75°W	GEO																X	X	X	X	X	X	X	X	
GXI		3 - high	GeoXO West	137°W	GEO																			X	X	X	X	X	
IMAGER (INSAT)	Yes	3 - high	INSAT-3D	82°E	GEO		X	X	X	X	X	X	X	X															
IMAGER (INSAT)	Yes	3 - high	INSAT-3DR	74°E	GEO		X	X	X	X	X	X	X	X	X														
IMAGER (INSAT)		3 - high	INSAT-3DS	82°E	GEO								X	X	X	X	X	X	X										
MSU-GSM		3 - high	Electro-M N1		GEO																			X	X	X	X	X	
MSU-GSM		3 - high	Electro-M N2		GEO																			X	X	X	X	X	
MSU-GSM		3 - high	Electro-M N3		GEO																			X	X	X	X	X	
SEVIRI		3 - high	Meteosat-8	3.7°E	GEO																								
SEVIRI		3 - high	Meteosat-9	3.5°E	GEO		X	X	X	X	X																		
SEVIRI		3 - high	Meteosat-8 (IODC)	41.5°E	GEO		X	X	X	X	X																		
SEVIRI	Yes	3 - high	Meteosat-9 (IODC)	45.5°E	GEO						X	X	X	X	X	X													
MX-LWIR		3 - high	GISAT-1R	83°E	GEO						X	X	X	X	X	X	X	X											

This tables shows all related requirements. For more operations/filtering, please consult the full list of Requirements

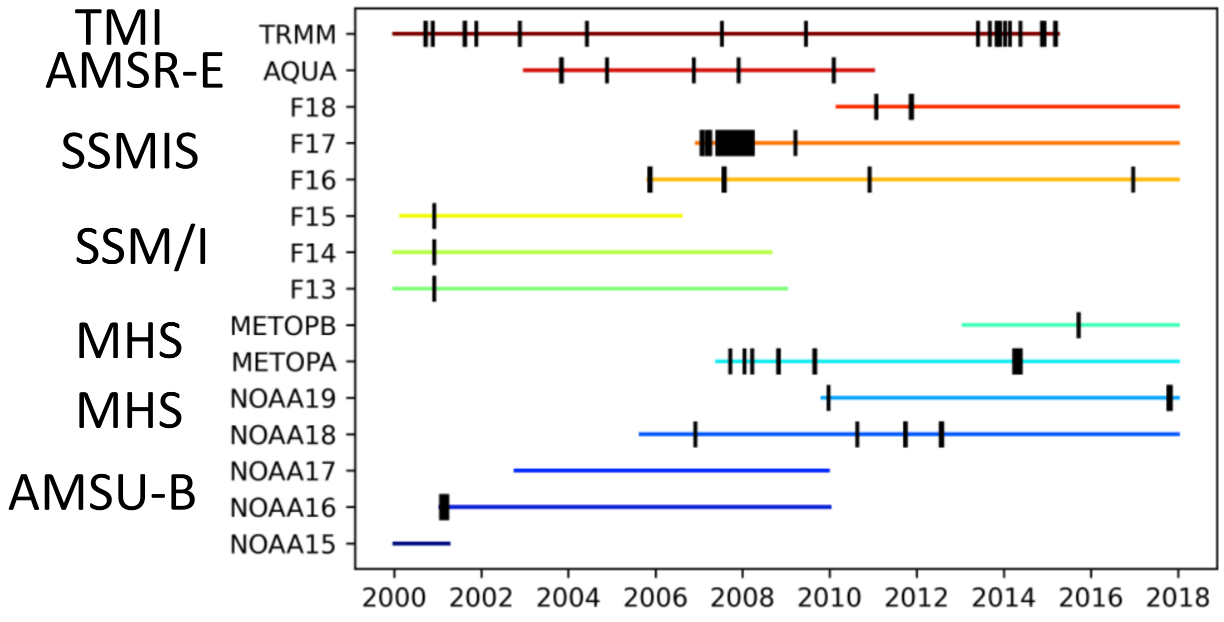
Note: In reading the values, goal is marked blue, breakthrough green, threshold orange

Application-dependent Technical Priority (ATP) Magenta and Relative priority of the attributes Red

Id	Variable	Layer	App Area	ATP	Uncertainty	Layer/s Quality	Coverage Quality	Stability / decade	Hor Res	Ver Res	Obs Cyc	Timeliness	Coverage	Conf Level	Val Date	Source	General Comment	Applicati Area Commen
31	Accumulated precipitation (over 24 h)	Near Surface	2.9 Agricultural Meteorology		2 mm 5 mm 10 mm				0.25 km 20 km 50 km		24 h 36 h 3 d	24 h 30 h 2 d	Global	reasonable	2003-10-20	ET ODRRGOS	Evaluation of soil moisture and avail to plants	
54	Accumulated precipitation (over 24 h)	Near Surface	Climate-AOPC (deprecated)		1 mm 1.3 mm 2 mm				100 km 200 km 500 km		12 h 16 h 24 h	24 h 3 d 12 d	Global	firm	2007-07-19	AOPC		
204	Accumulated precipitation (over 24 h)	Near Surface	GEWEX (deprecated)		0.5 mm 1 mm 5 mm				50 km 100 km 250 km		60 min 3 h 12 h	30 d 45 d 60 d	Global	reasonable	1998-10-29	WCRP		
244	Accumulated precipitation (over 24 h)	Near Surface	2.1 Global Numerical Weather Prediction and Real-time Monitoring		0.5 mm 2 mm 5 mm				10 km 30 km 100 km		60 min 3 h 12 h	24 h 5 d 30 d	Global	firm	2009-02-10	John Eyre		
334	Accumulated precipitation (over 24 h)	Near Surface	2.2 High-Resolution Numerical Weather Prediction		0.5 mm 2 mm 5 mm				0.5 km 2 km 10 km		30 min 2 h 6 h	6 h 9 h 24 h	Global	firm	2011-08-04	T Montmerle		
1003	Accumulated precipitation (over 24 h)	Near Surface	2.5 Atmospheric Climate Monitoring	0.5	1 mm 2 mm 5 mm 0.5			0.02 mm 0.05 mm 0.1 mm 0.5	50 km 125 km 250 km 0.5		24 h 30 d 1 y 0.5	24 h 7 d 30 d 0.5	Global	firm	2023-05-02	GCOS-245: The 2022 ECVs Requirements (GCOS-245)	Requirements for uncertainty are specified at 2-sigma.	

Copernicus micrOwave-based gloBal pRecipitAtion dataset (COBRA)

- Global daily and monthly precipitation rates [mm/d]
- 2000-2017
- 1° × 1°
- PNPR-CLIM (MHS & AMSU-B) & HOAPS v4(SSM/I, SSMIS, AMSR-E, TMI) algorithms



Climate Change

COBRA target requirements

Daily mean precipitation (reference is GPCP v1.3 daily)

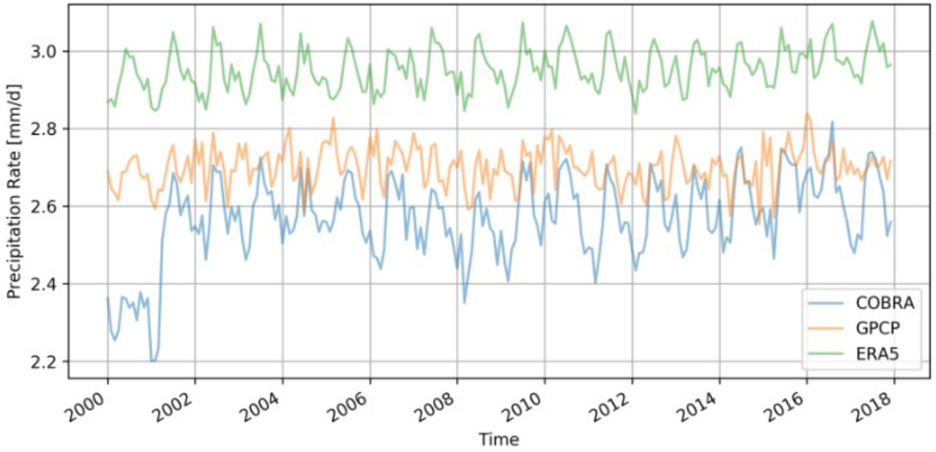
Dataset property	Global	|Lat|<30°	30°≤|Lat|<60°	60°≤|Lat|
Systematic error	1.532 mm/d	1.408 mm/d	1.908 mm/d	2.134 mm/d
Random error	5.757 mm/d	6.411 mm/d	5.209 mm/d	1.972 mm/d

	Achieved		Target requirement
	Global	|Lat|<60°	
Accuracy	87.5% achieved	91.8% achieved	0.3 mm/d
Stability	0.018 mm/d/dec	0.033 mm/d/dec	0.034 mm/d/dec

Monthly mean precipitation (reference is GPCP v2.3 monthly)

Dataset property	Global	|Lat|<30°	30°≤|Lat|<60°	60°≤|Lat|
Random error	1.561 mm/d	1.721 mm/d	1.321 mm/d	0.841 mm/d
Systematic error	0.140 mm/d	0.266 mm/d	0.461 mm/d	0.946 mm/d

	Achieved		Target requirement
	Global	|Lat|<60°	
Accuracy	98.5% achieved	100% achieved	0.3 mm/d
Stability	0.034 mm/d/dec	0.051 mm/d/dec	0.034 mm/d/dec



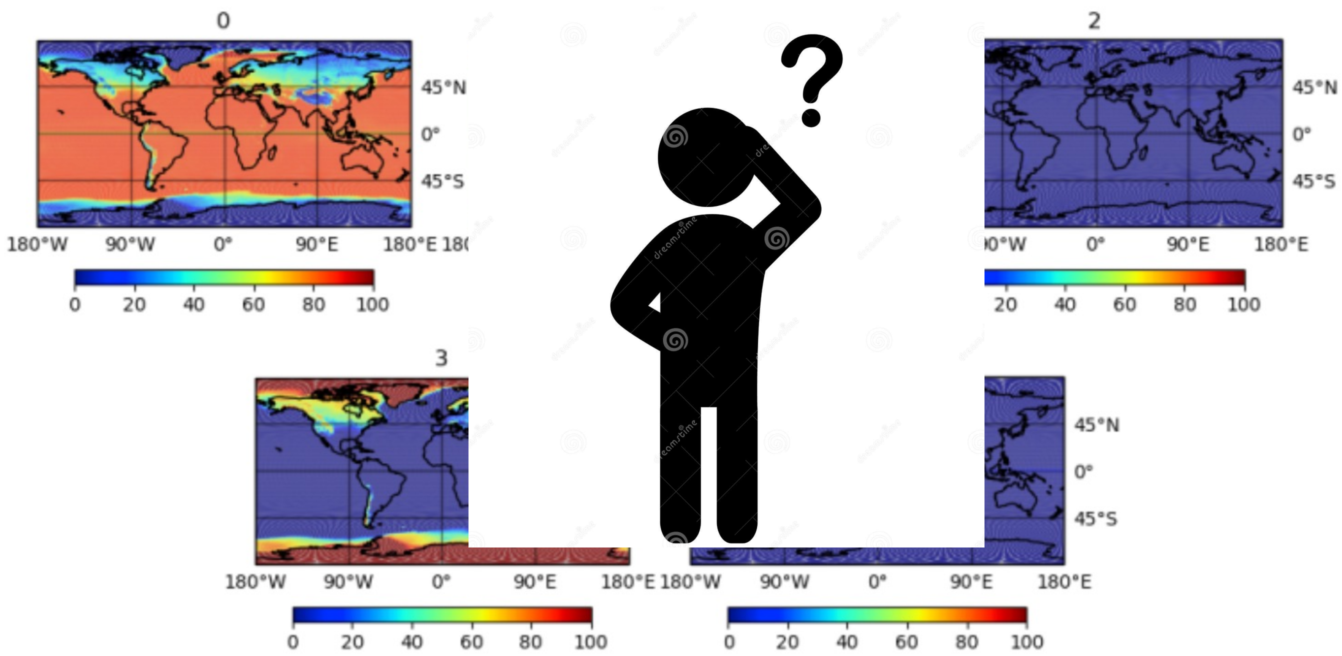
Uncertainty

Requirement: All datasets should incorporate meaningful estimates of uncertainty.

COBRA:

- *Precipitation stdv: monthly mean of intra-platform standard deviation derived from hourly values*
- *Quality flag Index; from 0 (high quality) to 3 (poor quality) → product quality and reliability*

Year 2017



Climate Change

Outline

- The W(H)-questions [What/When/How/Why]
- Requirements
- Climate Services – what can we do for you? (C3S),
  - The Copernicus Climate Change Service (C3S)
  - C3S offer for precipitation
- Gap analysis & uncertainty
- Summary

Climate Change

Take home messages

- Climate services bridge the scientific climate knowledge with end user requirements.
- User requirements may vary widely depending on the objective and the application.
- The current C3S offer for precipitation is very extensive, including multi-decadal in-situ and satellite-based data records, reanalysis, projections and user applications.
- Based on WMO OSCAR/Space, the basis to continue producing a European-based microwave precipitation climate data record is guaranteed
- While precipitation datasets come associated with some form of uncertainty, determining the optimal utilization remains an ongoing challenge.

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Some further questions

- There are dozens of precipitation datasets available. Are we satisfied with the current options?
- Have we considered factors such as accessibility, cost, and sustainability?
- What specific gaps do we aim to address?
- Which applications are in need of improvement?
- Where should our focus lie?
- Are emerging applications demanding new resolutions?
- What breakthroughs are we targeting?