Copernicus Climate Change Service (C3S)

Climate Change

European Contribution to the Monitoring of Essential Climate Variables from Space

Jean-Noël Thépaut, ECMWF

Copernicus Europe's eyes on Earth

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Copernicus: Earth observations and information services

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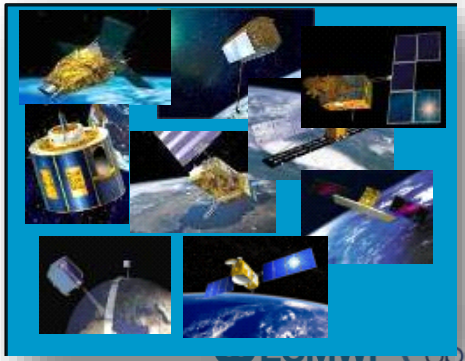
Contributing missions and insitu component

Copernicus services rely on data from in situ monitoring networks (maps, ground based weather stations, ocean buoys and air quality monitoring networks) to provide robust integrated information and to calibrate and validate the data from satellites.

Copernicus services rely on data from many other missions. The Copernicus Climate Change Service (C3S) benefits from historical datasets from space and in situ



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Goals for the Climate Change Service

To support European adaptation and mitigation policies by:

- Providing consistent and authoritative information about climate
- Building on existing capabilities and infrastructures
- Stimulating the market for climate services in Europe

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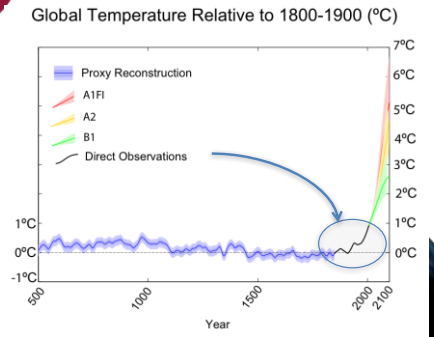
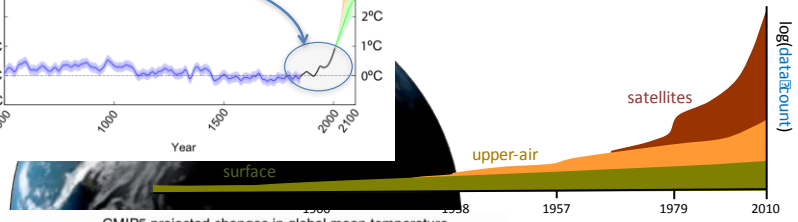
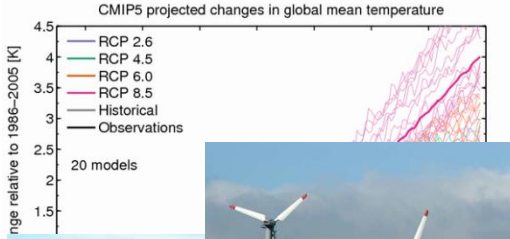
Climate Change Service: Solutions

Climate Change







- How is the climate changing?
- How will it change in future?
- How will it impact society?

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Climate Change

C3S portfolio

Scientific basis:

- **Essential Climate Variables** as defined by **GCOS**
- **GCOS** Status Report and Implementation Plan
- IPCC, CMIP

Observations	Global estimates of ECVs from satellite and in-situ observations	Reprocessed CDRs, reference observations	Support for data rescue, climate data collections	Climate Indicators
Climate reanalysis	Global atmosphere, ocean, land	Regional reanalysis for Europe	Coupled climate reanalysis for 100 years	
Model output	Multi-model seasonal forecast products	Access to CMIP data and products (global and regional)	Reference set of climate projections for Europe	

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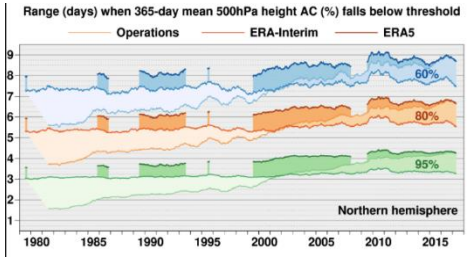
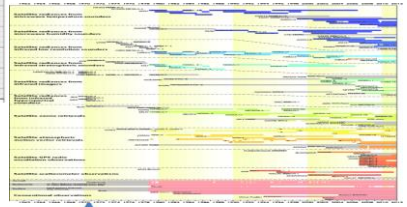
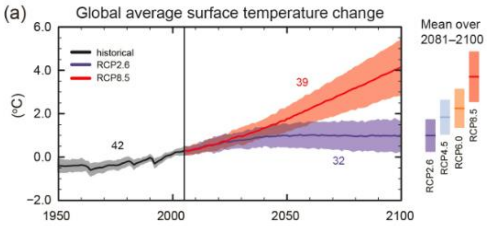
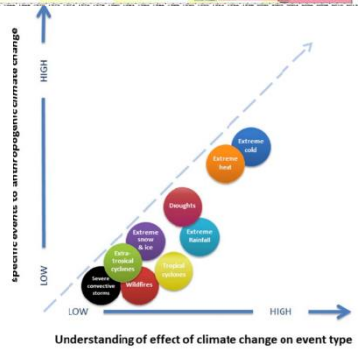
Overarching Principle: Building Upon National and European Investments

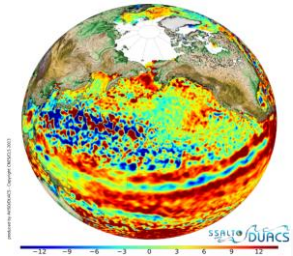
National investments: Modeling capabilities, in-situ observations, seasonal forecasts, …

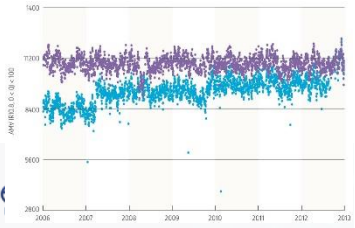






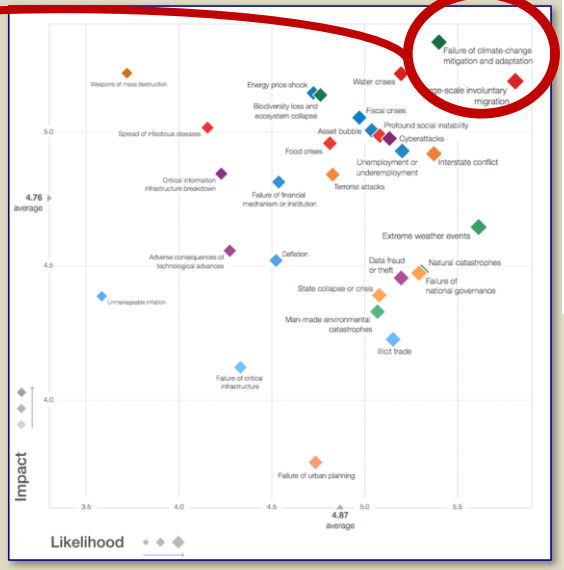






Global Risks Landscape 2016

Failure of climate-change mitigation and adaptation

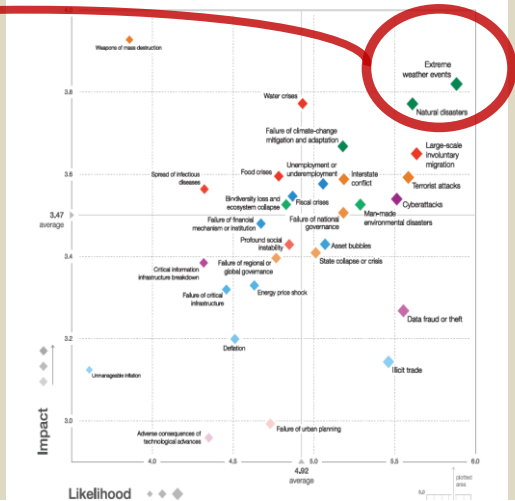


Source World Economic Forum
Global Risks Report 2016
Copyright World Economic Forum 2016
http://www.weforum.org/reports/the-global-risks-report-2016

Credit: C. Richter, S. Briggs, GCOS

Global Risks Landscape 2017

Extreme Weather & Natural Disasters



Source World Economic Forum
Global Risks Report 2017
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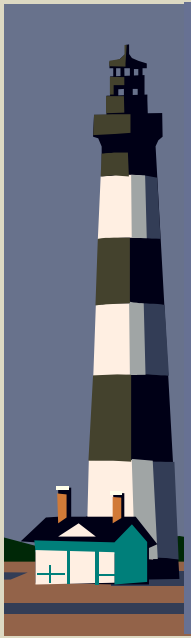
Improved observations lead to significant benefits



GCOS produces ECV Requirements, Adequacy Reports, Plans

…. which lead to observations, products, open data

…. which inform science, assessments, policy

…..which are needed by climate services, risk assessments, early warning &disaster risk reduction policies

…..which lead to successful adaptation and mitigation, reduced climate risks, enhanced livelihoods, and food &water security.

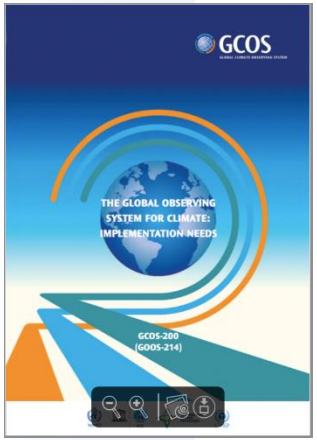
Credit: C. Richter, S. Briggs, GCOS

From the GCOS website

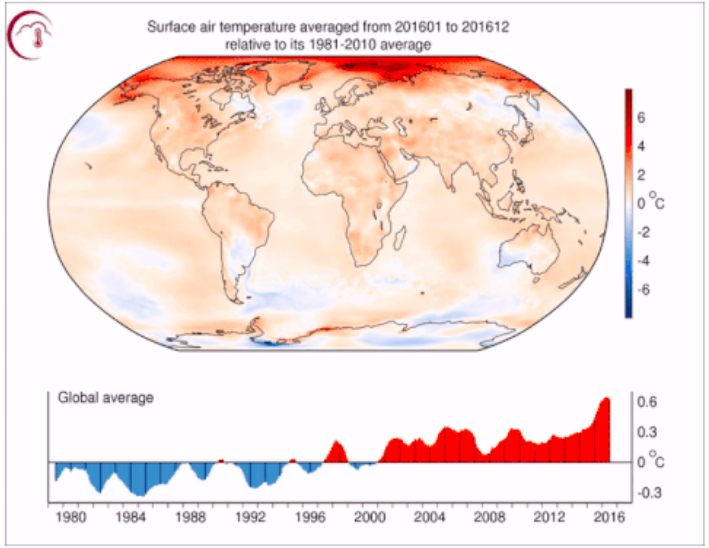
Working towards a world where everyone has access to the climate observations and the information they need to address climate-related concerns

The vision of Global Climate Observing System (GCOS) is for all users to have access to the climate observations, data records and information they need to address pressing climate-related concerns. GCOS users include individuals, national and international organizations, institutions and agencies. GCOS works with partners to ensure the sustained provision of reliable physical, chemical and biological observations and data records for the total climate system – across the atmospheric, oceanic and terrestrial domains, including hydrological and carbon cycles and the cryosphere.

GCOS specifies 54 Essential Climate Variables (ECVs) that are key for sustainable climate observations.

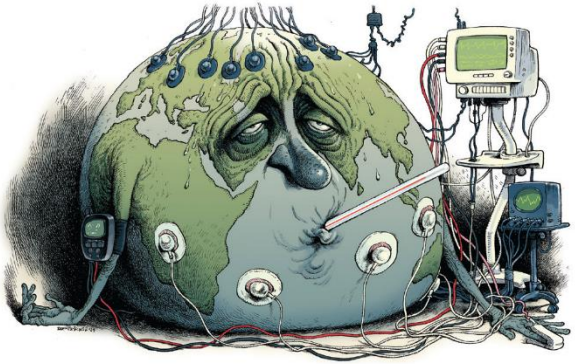


New: Implementation plan



Measurements of air temperature, a GCOS ECV, provided by the Copernicus Climate Change Service (C3S), implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF).

.. Of the importance of climate observations…



Credit: Victor & Kennel, Nature Climate Change, 2014.

GCOS ECVs grouped by measurement domain and area covered.
The groups show how observations across all the measurement domains are needed to capture specific phenomena or issues.

	Atmosphere	Terrestrial	Ocean
Energy & Temperature	Surface Radiation Budget, Earth Radiation Budget, Surface Temperature, Upper Air Temperature, Surface and Upper Air Wind Speed	Albedo, *Latent and Sensible Heat* fluxes, Land Surface Temperature	Ocean Surface Heat Flux, Sea Surface Temperature, Subsurface Temperature
Other Physical Properties	Surface Wind, Upper Air Wind, Pressure, Lightning, Aerosol Properties		Surface Currents, Subsurface Currents, Ocean Surface Stress, Sea State, Transient Traces
Carbon Cycle and other GHGs	Carbon Dioxide, Methane, Other long-lived GHG, Ozone, Precursors for Aerosol and Ozone	Soil Carbon, Above-ground Biomass	Inorganic Carbon, Nitrous Oxide
Hydrosphere	Precipitation, Cloud Properties, Water Vapour (Surface), Water Vapour (Upper Air), Surface Temperature,	Soil Moisture, River Discharge, Lakes, Groundwater,	Sea Surface Salinity, Subsurface Salinity, Sea Level, Sea Surface Temperature
Snow & Ice		Glaciers, Ice Sheets and ice shelves, Permafrost, Snow	Sea Ice
Biosphere		Land Cover, Leaf Area Index (LAI), Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), Fire	Plankton, Oxygen, Nutrients, Ocean Colour, Marine Habitat Properties
Human Use of Natural Resources		Water Use, Greenhouse Gases (GHG) Fluxes	Marine Habitat Properties

Credit: C. Richter, S. Briggs, GCOS

GCOS
GLOBAL CLIMATE OBSERVING SYSTEM

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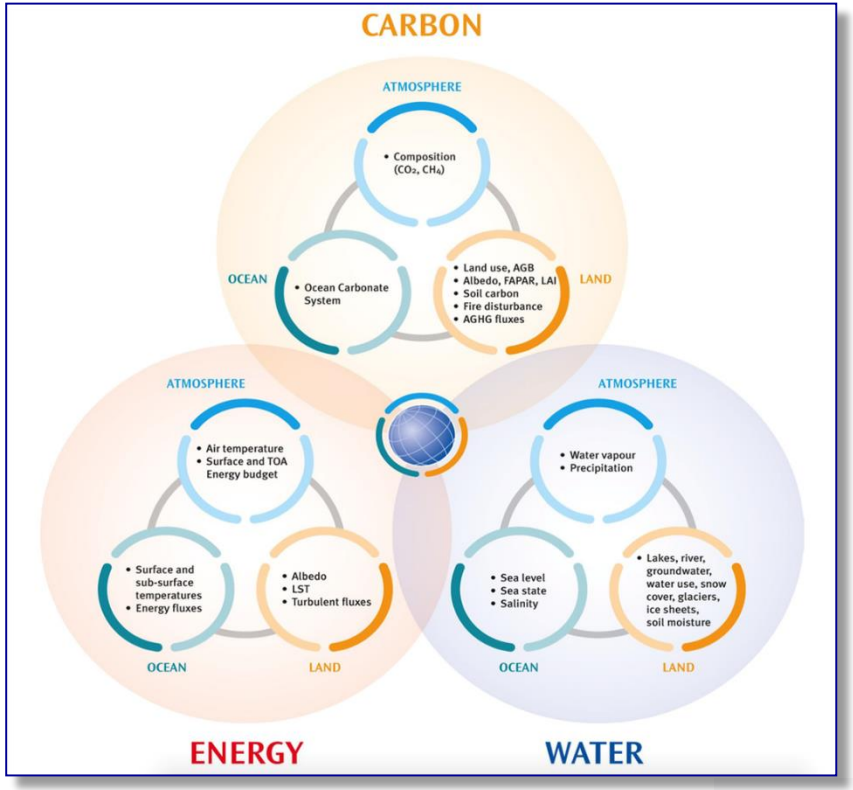
Consistent observations across the Earth System Cycles



Credit: C. Richter, S. Briggs, GCOS

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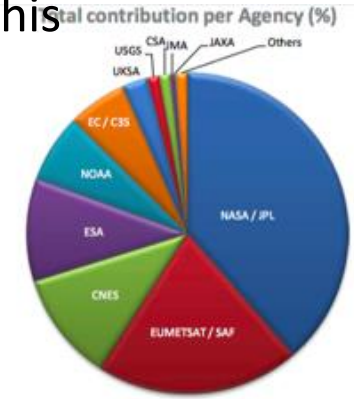
Who actions the GCOS implementation plan?

Climate Change

- GCOS's role is to set requirements
- Various agencies and organizations implement and produce this set of ECVs
  - CEOS (Committee of Earth Observation Satellites)
  - CGMS (Coordination Group for Meteorological Satellites (CGMS)
  - Copernicus



			C3S_312a				
				C3S_312b			
		GCOS	2017	2018	2019	2020	2021
Atmospheric physics							
	Precipitation	4.3.5		Lot 1			
	Surface Radiation Budget	4.3.6					
	Water Vapour	4.5.3					
	Cloud Properties	4.5.4					
	Earth Radiation Budget	4.5.5					
Atmospheric composition							
	Carbon Dioxide	4.7.1	Lot 6		Lot 2		
	Methane	4.7.2	Lot 6				
	Ozone	4.7.4	Lot 4				
	Aerosol	4.7.5	Lot 5				
Ocean							
	Sea Surface Temperature	5.3.1	Lot 3		Lot 3		
	Sea Level	5.3.3	Lot 2				
	Sea ice	5.3.5	Lot 1				
	Ocean Colour	5.3.7					
Land hydrology & cryosphere							
	Lakes	6.3.4			Lot 4		
	Glaciers	6.3.6	Lot 8				
	Ice sheets and ice shelves	6.3.7					
	Soil moisture	6.3.16	Lot 7				
Land biosphere							
	Albedo	6.3.9	Lot 9		Lot 5		
	Land Cover	6.3.10					
	Fraction of Absorbed Photosyntheti	6.3.11	Lot 9				
	Leaf Area Index	6.3.12	Lot 9				
	Fire	6.3.15					
			2017	2018	2019	2020	2021

...

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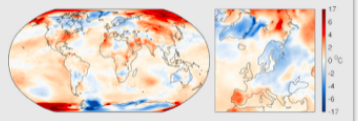
C3S Response: Monthly State of Climate

Climate Change

ABOUT C3S | NEWS & MEDIA | EVENTS | TENDERS | PRODUCTS | SERVICES | HELP & SUPPORT

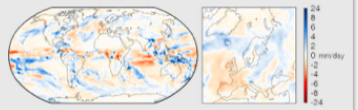
Monthly Maps and Charts

home



Surface air temperature

Sea-ice



Hydrological climate variables

more to come...

- AVERAGE SURFACE AIR TEMPERATURE MONTHLY MAPS
- MONTHLY SEA-ICE MAPS
- HYDROLOGICAL CLIMATE VARIABLES
- CLIMATE REANALYSIS
- SEASONAL FORECASTS

NEWS

03 Nov 2017
Copernicus services help tackle global climate change issues

27 Oct 2017
Meeting the world's science journalists at WCSJ2017

26 Oct 2017
ECMWF Copernicus Services at GEO Week 2017

26 Oct 2017
Alpha testing of the Climate Data Store (CDS) Toolbox

18 Oct 2017
C3S Attribution workshop organised in Prague

More News

EVENTS

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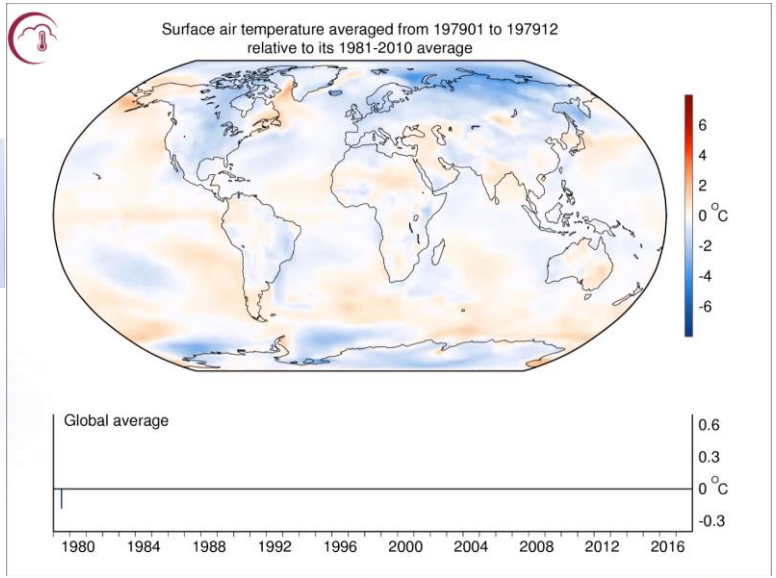
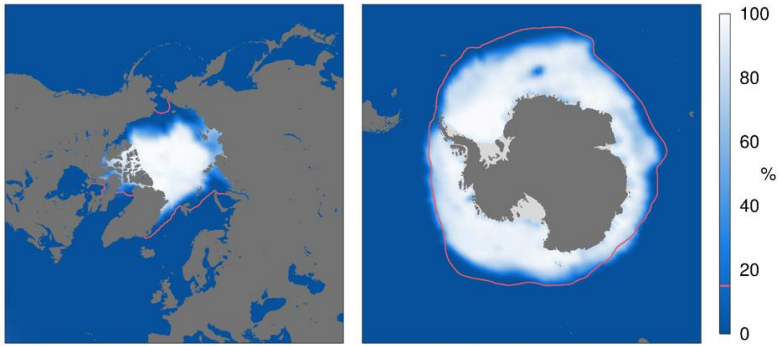
C3S Response: Monthly State of Climate

Climate Change

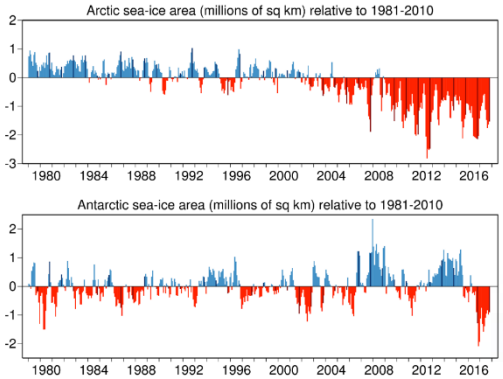
Air temperature anomaly evolution



Sea-ice cover October 2017



WMO Press Release 2017/11/06



Sea-ice cover anomaly time series

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ECMWF

Reanalyses combine models and observations

Climat
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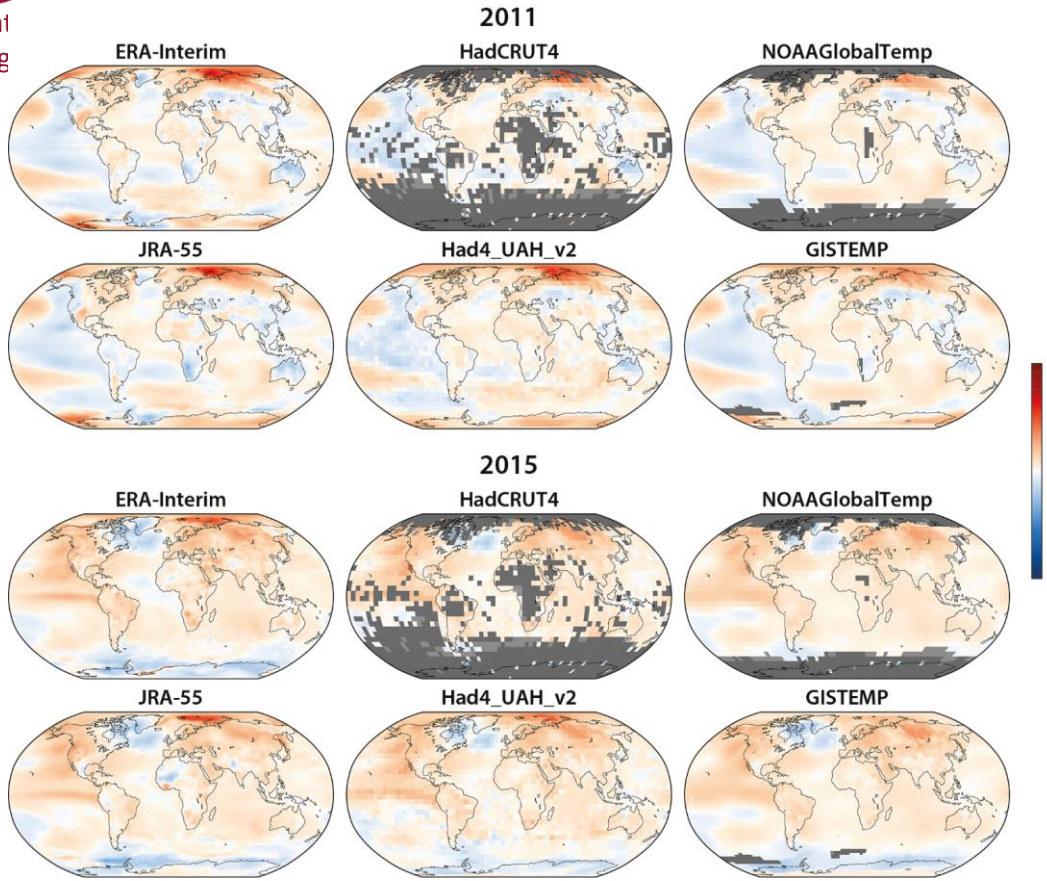

Combing observations and numerical models allow delivering 4D representation of the earth system (“maps with no gaps”)

Critical importance of reprocessing

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What is new in ERA5?

	ERA-Interim	ERA5
Period	1979 – present	Initially 1979 – present, later addition 1950-1978
Streams	1979-1989, 1989-present	Parallel streams, one/two per decade
Assimilation system	2006, 4D-Var	2016 ECMWF model cycle (41r2), 4D-Var
Model input (radiation and surface)	As in operations, *(inconsistent sea surface temperature)*	***Appropriate for climate***, e.g., evolution greenhouse gases, volcanic eruptions, sea surface temperature and sea ice
Spatial resolution	79 km globally 60 levels to 10 Pa	***31 km globally*** 137 levels to 1 Pa
Uncertainty estimate		Based on a 10-member ***4D-Var ensemble*** at 62 km
Land Component	79km	ERA5L, 9km (separate, forced by ERA5)
Output frequency	6-hourly Analysis fields	***Hourly*** (three-hourly for the ensemble), ***Extended list of parameters*** ***~ 9 Peta Byte (1950 - timely updates)***
Extra Observations	Mostly ERA-40, GTS	Various ***reprocessed CDRs***, ***latest instruments***
Variational Bias correction	Satellite radiances, radiosondes predetermined	Also ozone, aircraft, surface pressure, newly predetermined for radiosondes.

Credit: H. Hersbach, ECMWF

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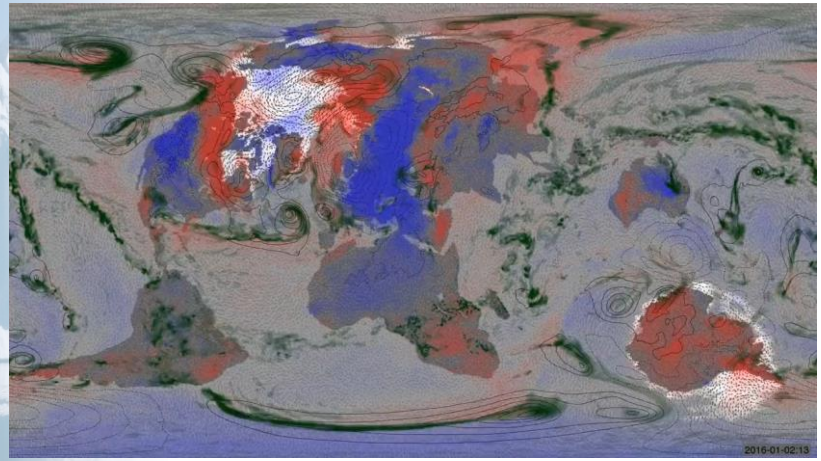
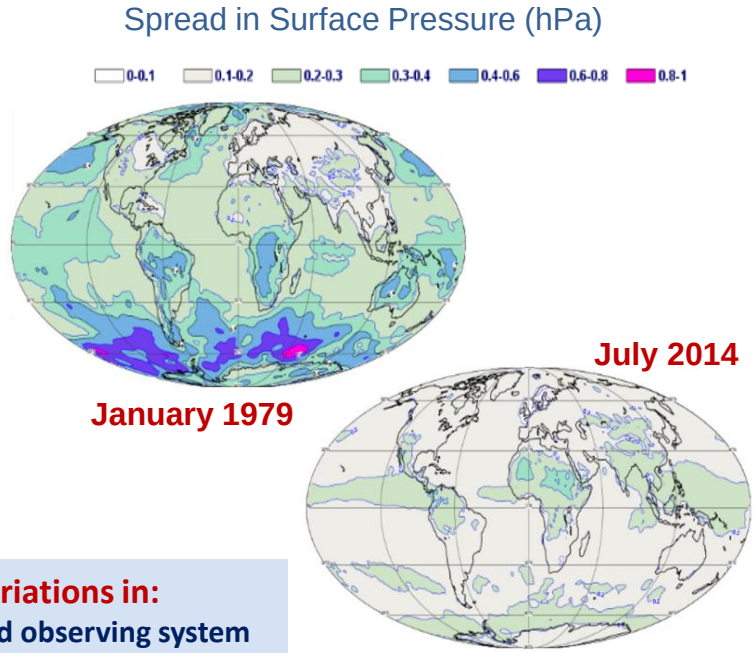
What is new in ERA5?

Hourly data and more parameters



Courtesy: Philip Brohan

Uncertainty estimate



Reflects variations in:

- ingested observing system
- flow-dependent sensitivity

Credit: H. Hersbach, ECMWF

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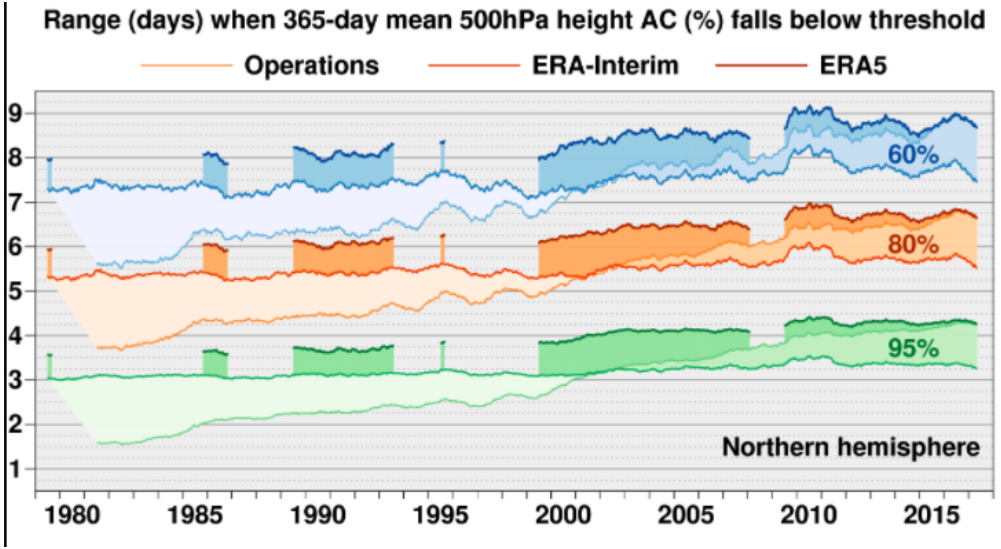
Climate Data Store: Reanalyses

Climate Change

ERA5 global reanalysis:

- First release of 2010-2016 dataset



Regional reanalyses will also be produced as part of C3S:

- European +Arctic
- Higher resolution

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Earth Observation based ECVs in C3S

			C3S_312a				
				C3S_312b			
		GCOS	2017	2018	2019	2020	2021
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			2017	2018	2019	2020	2021

Heritage/coordination:

- ESA CCI(+)
- EUMETSAT SAFs
- Other Copernicus Services
- etc..

- Multiple datasets
- Provision of uncertainty estimates
- Focus on stability and consistency
- ..

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C3S 312a Lot1 Sea Ice production service

Climate Change

Contractor:

Danish Meteorological Institute (DMI)

Sub-contractors:

Norwegian Meteorological Institute (MET Norway)

Alfred Wegener Institute (AWI)

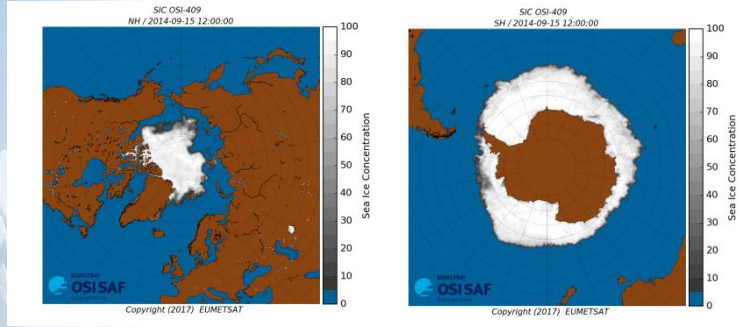
Nansen Environmental and Remote Sensing Center (NERSC)

Will deliver following Essential Climate Variables:

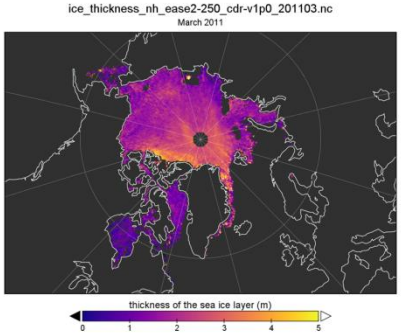
- Sea Ice Concentration CDR and ICDR (brokered from OSI SAF)
- Sea Ice Edge CDR
- Sea Ice Thickness CDR
- Sea Ice Type CDR

C3S 312a Lot1 Sea Ice production service

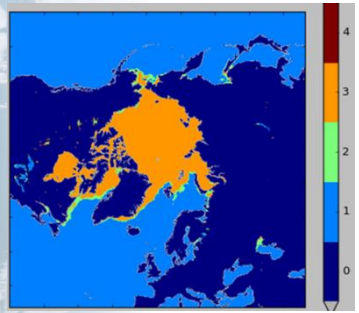
Climate Change

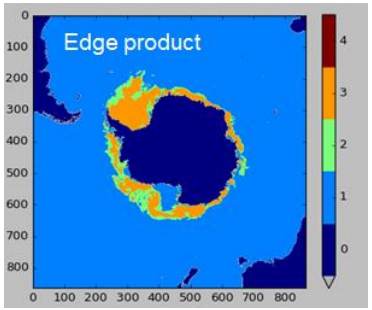


Sea Ice concentration



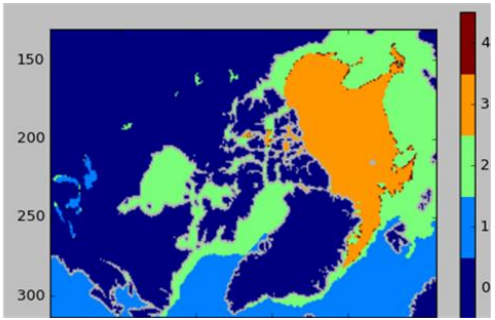
Sea Ice Thickness





Sea Ice Edge

Closed Ice
Open Ice
Open Water



Sea Ice Type

Ambiguous
Multi-year Ice
First-year Ice
Open Water

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C3S 312a Lot2 Sea Level production service

- The **Sea Level ECV** produced within the C3S (312a_Lot2) is derived from **satellite altimetry**.
- The service is ensured by **CLS and LEGOS** (France)
- **Gridded daily maps** of **sea level anomalies** and **velocities** are provided in delayed-time in the **global ocean**, **Mediterranean** and **Black seas** during 1993-2017.
- **Users** are interested in **sea level changes**, **ocean dynamics**, **data assimilation for climate projections**, **model validation**, …

- Strong **interaction and complementarity** with the **Copernicus Marine Service (CMEMS):**
  - **C3S**: retrieval of **long-term variability** and
    focus on the **Mean Sea Level stability**
    with a stable altimeter constellation in time.
  - **CMEMS**: focus on the **mesoscale estimation** with
    all satellites missions available to provide the best sampling.

- Strong **interaction** is required with **Copernicus space component** and **space agencies:**
  - To **manage satellite databases** and
  - To phase the production with R&D activities (ESA CCI+…)

CLS COLLECTE LOCALISATION SATELLITES

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C3S 312a Lot2 Sea Level production service

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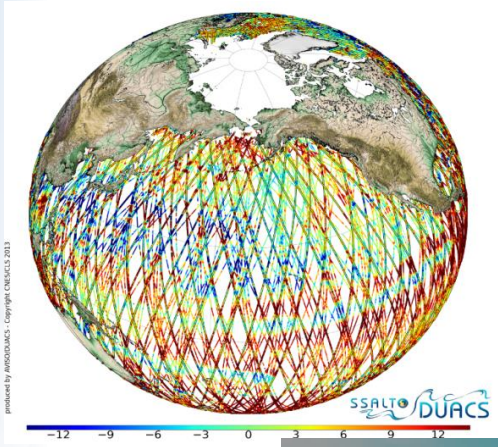
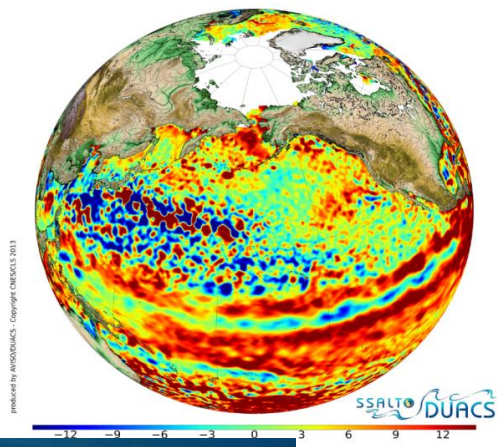
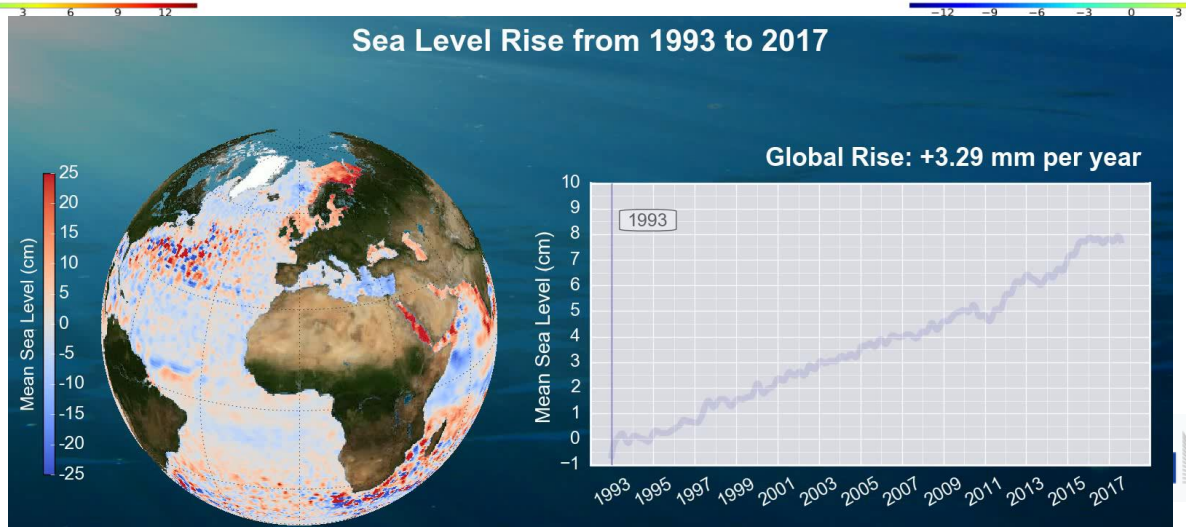


From satellite **along-track** measurements…

… to **sea level gridded maps**…



… to derive Ocean Monitoring Indicators



European Commission

Climate Change

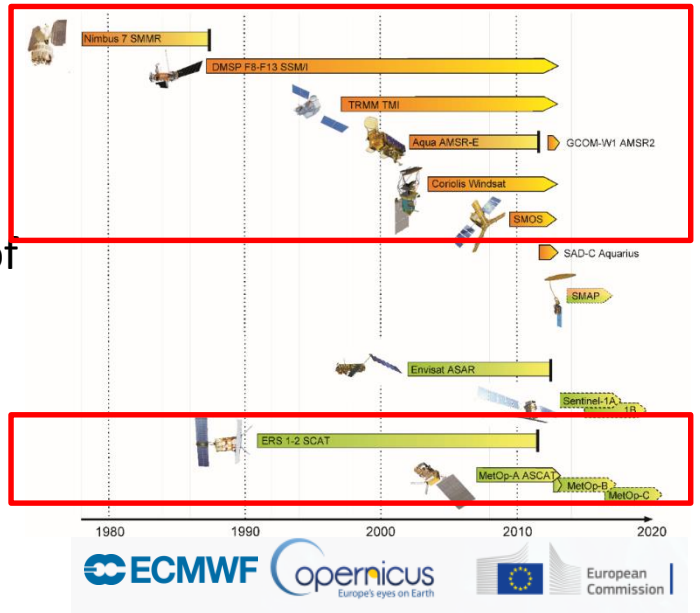
Soil Moisture Production Service

Service Aims:

- **Maximize** the **temporal/spatial sampling**, **accuracy**, **stability** and **length** of the TCDR based on available observations and state-of-the-art capability and algorithms
- **Extend** the **scope** of the ESA CCI SM processor towards fuller operational capacity
- **Implement** a Climate Data Record Production System (**CPS**)

Product Overview:

- Product **derived** from **active** and **passive** satellite systems
- **Volumetric Surface Soil Moisture** (m3/m3, % of saturation for active merged product)
- **25km** Resolution, **Global** Coverage
- **Daily** Images, 10 day **Update**
- **Building** on the legacy of **ESA's CCI SM** project
- **Extending** current **37 year**, global, TCDR



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Past, Present, Future ECVs

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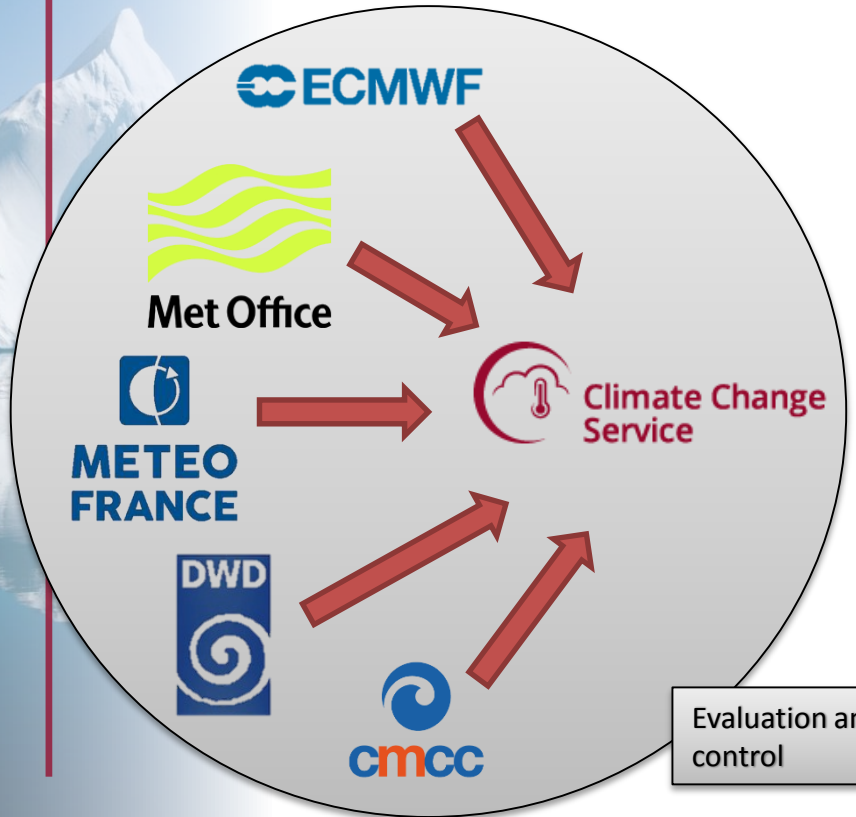
C3S seasonal forecasts

Aim: to generate seasonal forecast products based on the best information available, to an operational schedule, and make them publicly available.



Horizontal grid: global 1deg x 1deg
Ensemble size:

- Forecasts: ~50 members
- Hindcasts: ~25 members x 24 years (1993-2016)

Variables

- Surface
  - 7 variables every 6h
  - +30 variables every 24h
- Pressure (11 levels, from 925 hPa to 10 hPa)
  - 8 variables every 12 h

Agreed netCDF specification (based on CF)

Evaluation and quality control

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Seasonal forecasts- current contents

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Variables:

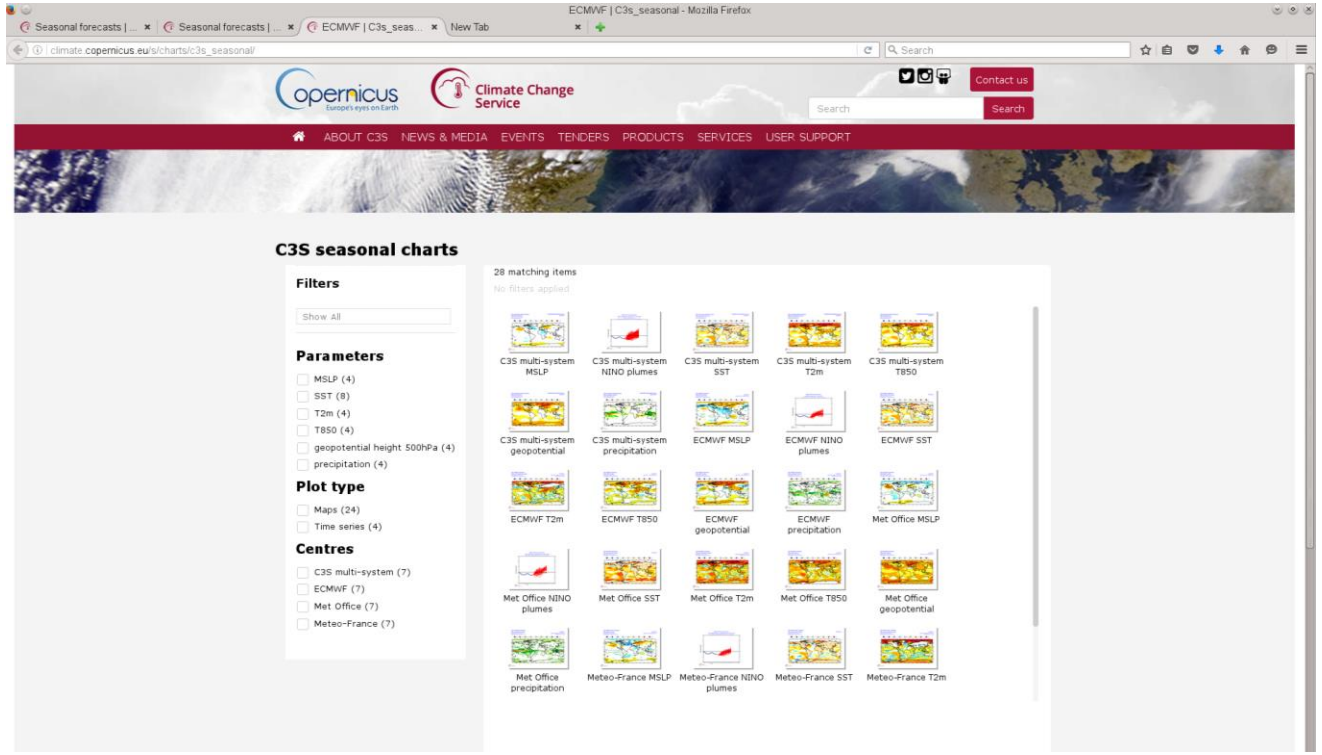
- sea-level pressure
- geopotential height
- precipitation
- air temperature

Type of plots:

- maps:
  - global
  - pre-defined regions
- time series

Publication schedule:

- monthly updates
- published on each 15th



http://climate.copernicus.eu/seasonal-forecasts

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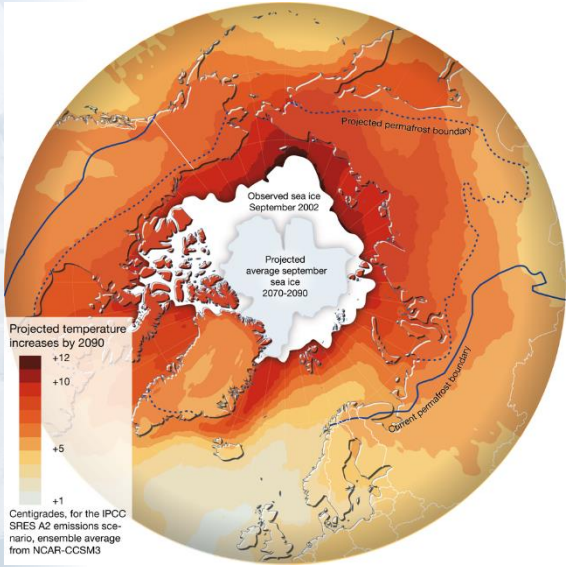
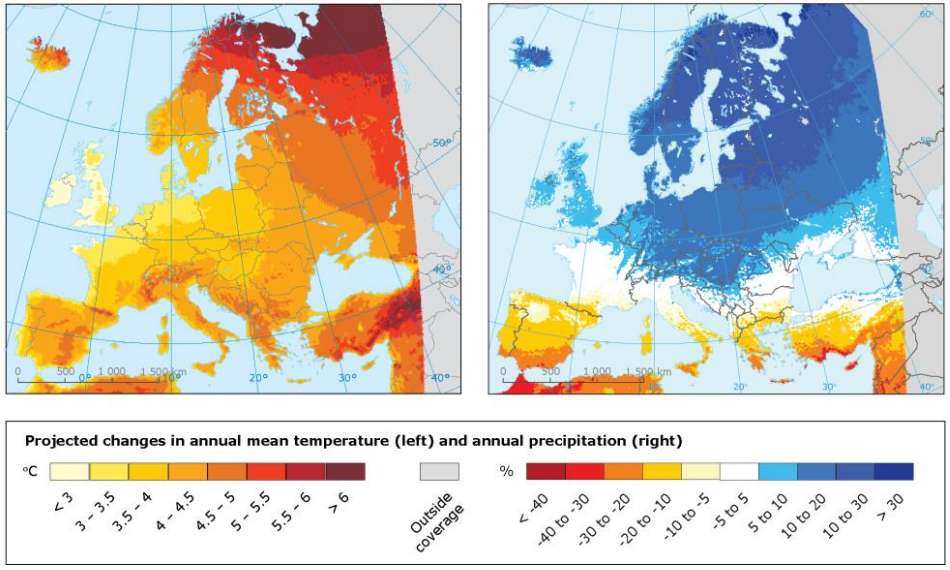
Climate Change

Climate projections

Service: Providing users with timely access to climate change scenarios produced with state-of-the-art climate models (CMIP, CORDEX)





Climate Change

Climate projections

Service: Providing users with timely access to climate change scenarios produced with state-of-the-art climate models (CMIP, CORDEX)

How:

Global climate projections:

- Access to ESGF via the Climate Data Store
- Multi-model global product generation
- Reference set of climate projections for Europe

Regional climate projections:

- Access to CORDEX simulations for the European domain
- Production of additional climate projections for Europe

Climate Change

Climate Data Store

Infrastructure and toolbox

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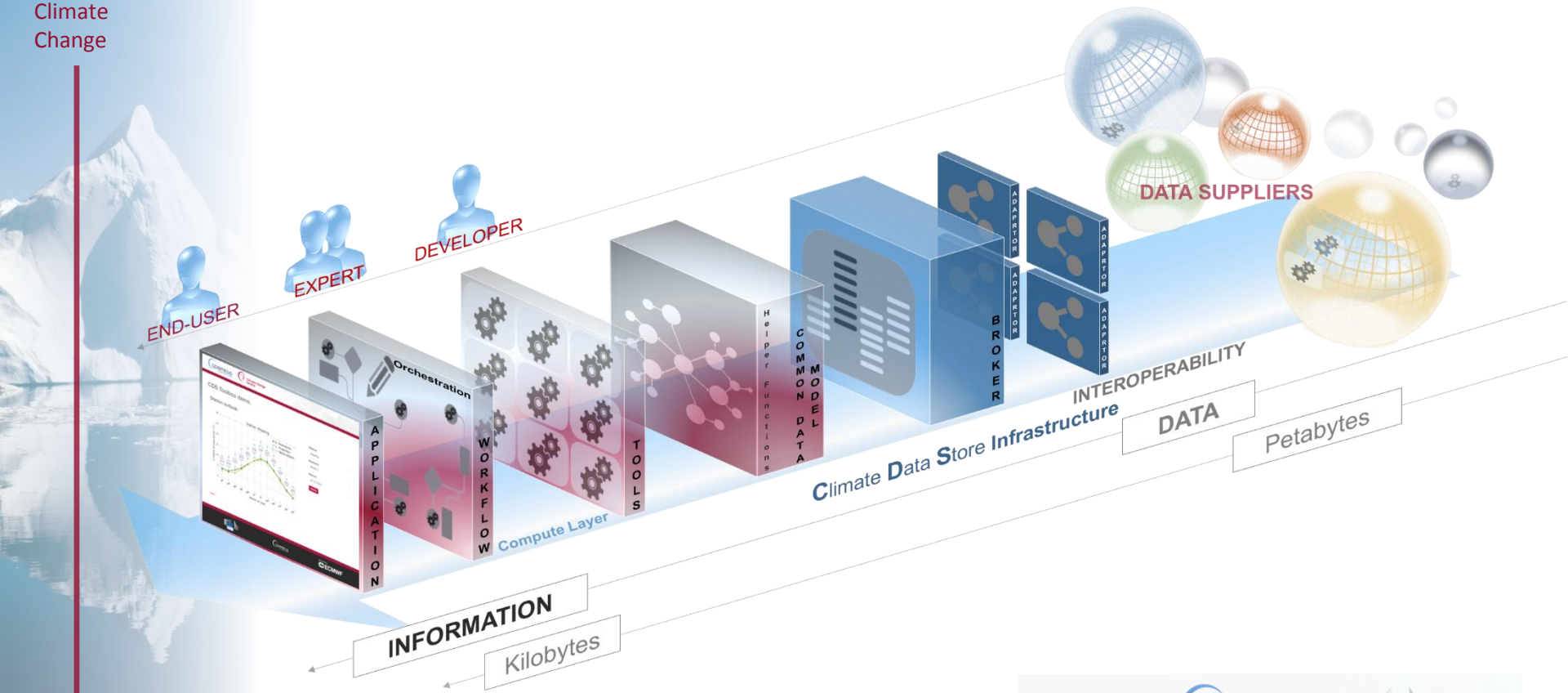
CDS infrastructure and toolbox

Climate Change



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Sectoral Information System

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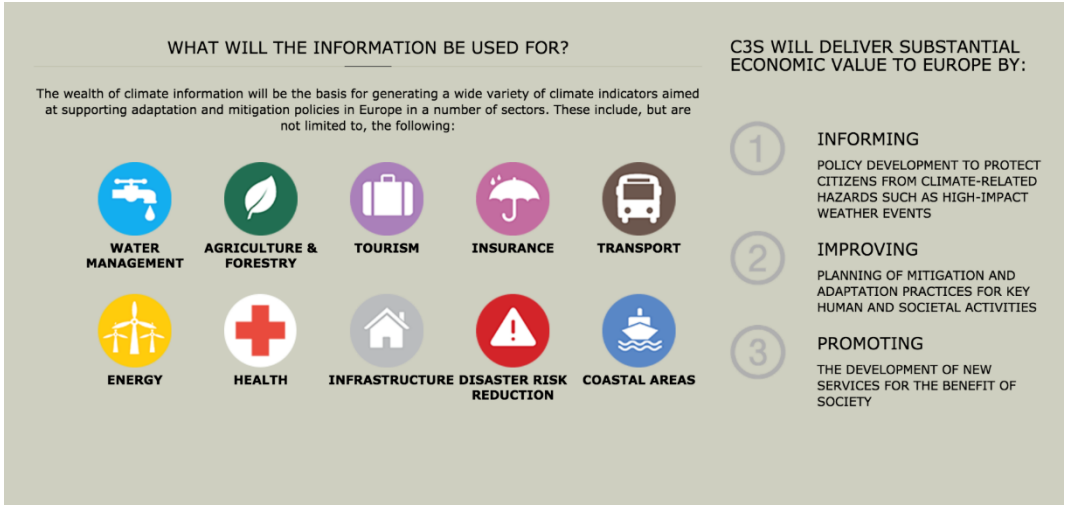
Proof-of-concepts of climate services: Demonstration of the value chain with end-to-end demonstrators

As an operational Service, C3S ambitions to become an enabler of downstream climate services, by providing or brokering high quality and sector relevant climate data, good practices, tools and compelling use cases.



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COPERNICUS EVOLUTION

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Police Needs and stated priorities: Space Strategy for Europe

- Stability of the programme and long term committment
  - (Enhanced) continuity of current data and services;
  - Continuity of full, open and free data policy for the environmental domain;

- Additional services will be considered to meet emerging needs
  - Climate change and sustainable development;
  - Monitoring CO2 and other greenhouse gas emissions;
  - Land use and forestry;
  - Changes in the Arctic;
  - Security and Defence: Improving the EU's capacity (border controls and maritime surveillance);

Space Component: Resulting Observation Priorities

The (enhanced) continuity of existing observation capacity is the overarching priority;

Conclusions on major gaps :

- CO_2 measurements to estimate anthropogenic emissions
- High-Resolution Thermal observations
- SAR L-band observations
- Monitoring of sea ice and ice sheets in the polar region (PMR Imaging, Altimeter)
- Hyper-spectral measurements

The results of these planned six studies will serve as input to iterate further the LTS but do not present any commitment of the Commission at this stage.

The next Copernicus Regulation will frame the implementation of the Copernicus Space Component in the next programme period and spell out the missions to be part of the future programme.

The context:

- Consolidation elements (will have been operational only for 2 years)
  - For ECMWF: reanalyses, seasonal forecasts
    - Capitalizing on latest ECMWF model/DA developments
- New service elements based on user demand
  - Decadal, Attribution
- **Build upon Sentinels for CDRs and ECV generation**
- Mid-term review, surveys & economic impact analysis (PwC…)
  - Management of expectations with new Service
- CO2 mission “sentinel 7” (previous slides)

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What is new?

- Contribution to CO2 Observatory (in support to UNFCCC) – *mutualized with CAMS*
- Attribution Service
- Decadal Prediction Service (including verification)
- Fast track response Service

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Climate Change Service

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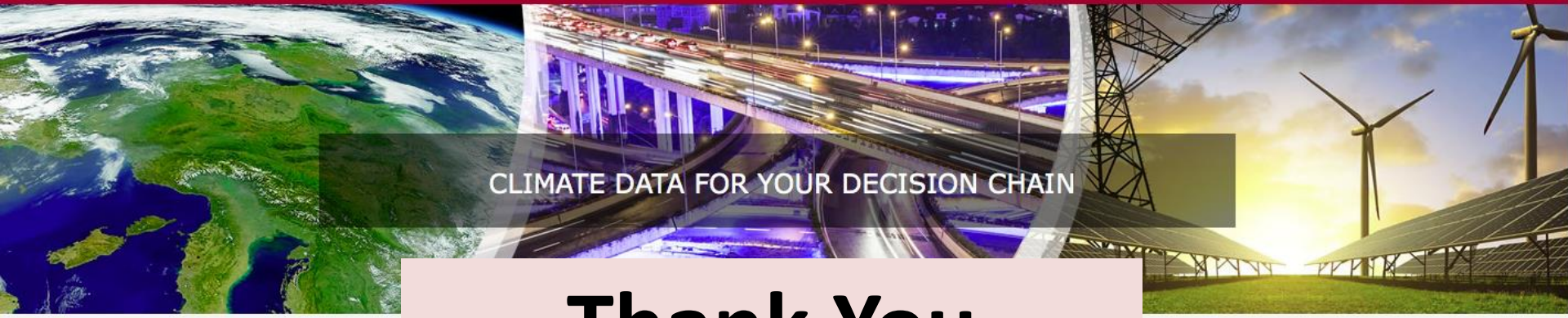
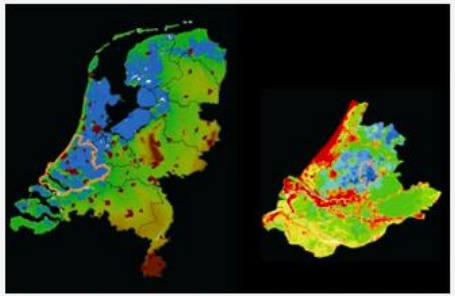


Thank You

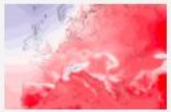
IN FOCUS



"Brewing a better world" with help from Copernicus

17 Aug 2017

Monthly maps and charts of essential climate variables



16 Jul 2017
C3S releases powerful new climate change "encyclopaedia" for public use

03 Mar 2017
#OpenDataHack @ECMWF - explore creative uses of open data

03 Mar 2017
C3S holds its inaugural General Assembly