



Climate Change

# Climate Change Service

Status and Plans on snow and ice monitoring

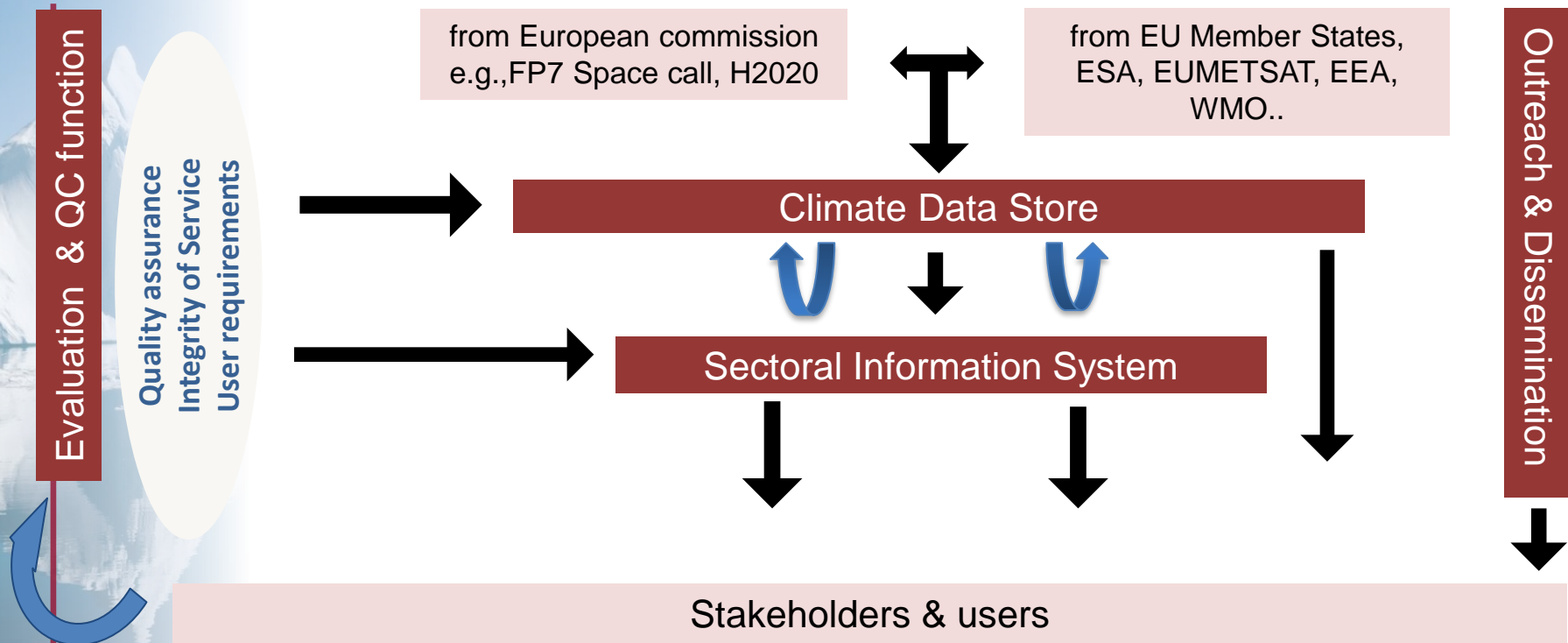
Joaquín Muñoz Sabater - ECMWF





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# C3S in a nutshell





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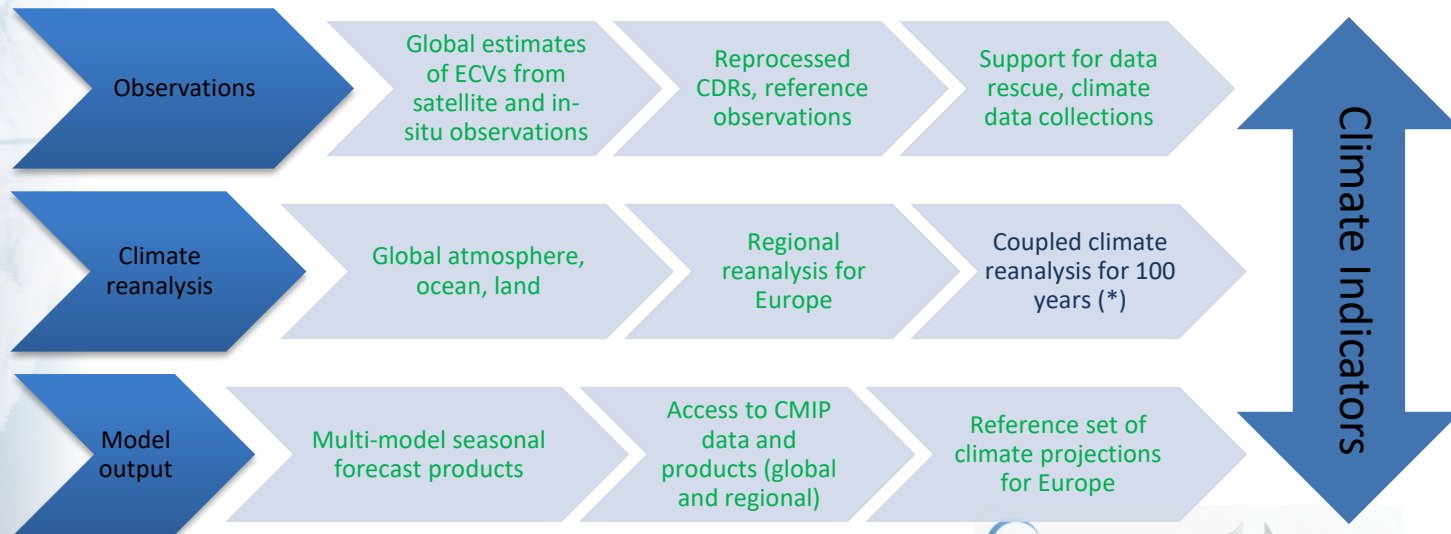
# Climate Data Store content (January 2018)



## Scientific basis:

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

■ Action engaged  
■ In progress  
■ Not started



(\*): CERA\_20C accessible via the CDS





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# ECV products based on Earth Observations

		C3S_312a		C3S_312b			
		GCOS	2017	2018	2019	2020	2021
<b>Atmospheric physics</b>							
Precipitation	4.3.5						
Surface Radiation Budget	4.3.6						
Water Vapour	4.5.3						
Cloud Properties	4.5.4						
Earth Radiation Budget	4.5.5						
<b>Atmospheric composition</b>							
Carbon Dioxide	4.7.1	Lot 6					
Methane	4.7.2	Lot 6					
Ozone	4.7.4	Lot 4					
Aerosol	4.7.5	Lot 5					
<b>Ocean</b>							
Sea Surface Temperature	5.3.1	Lot 3					
Sea Level	5.3.3	Lot 2					
Sea ice	5.3.5	Lot 1					
Ocean Colour	5.3.7						
<b>Land hydrology &amp; cryosphere</b>							
Lakes	6.3.4						
Glaciers	6.3.6	Lot 8					
Ice sheets and ice shelves	6.3.7						
Soil moisture	6.3.16	Lot 7					
<b>Land biosphere</b>							
Albedo	6.3.9	Lot 9					
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

## C3S\_312a:

- 12 ECVs in 9 Lots

## C3S\_312b:

- 22 ECVs in 5 Lots
- Continuity of service

## Heritage/coordination:

- ESA CCI
- EUMETSAT SAFs
- Other Copernicus Services
- etc..

- Snow as ECV is currently not part of this list, but covered in reanalysis

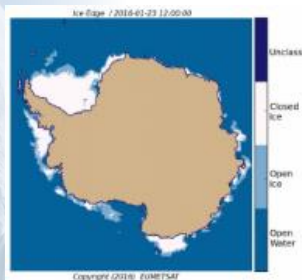


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# Sea Ice Production Service (DMI)

## Complementary with EUMETSAT OSI SAF & ESA CCI

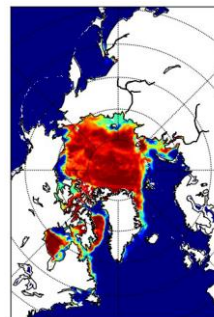
### Sea Ice Edge:



Distinguish between Open water, Open Ice and Closed Ice  
Global coverage  
10 km resolution

**CDR: 1979 – 2016**  
**ICDR: 2016 – onwards**

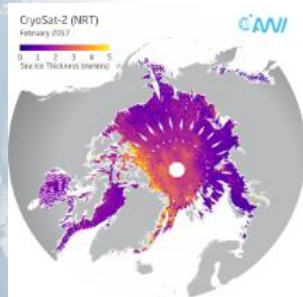
### Sea Ice concentration:



OSI SAF CDR (OSI-409) and ICDR (OSI-430)  
Global coverage  
10 km resolution  
Includes uncertainty estimates

**CDR: 10.1978 – 04.2015**  
**ICDR: 05.2015 - onwards**

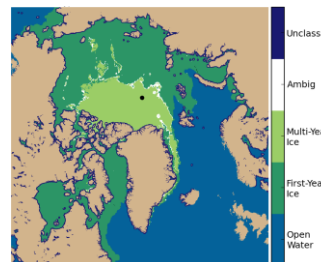
### Sea Ice Thickness:



Northern Hemisphere  
25 km resolution  
Includes uncertainty estimates

**ICDR: 2010 – onwards**

### Sea Ice Type:



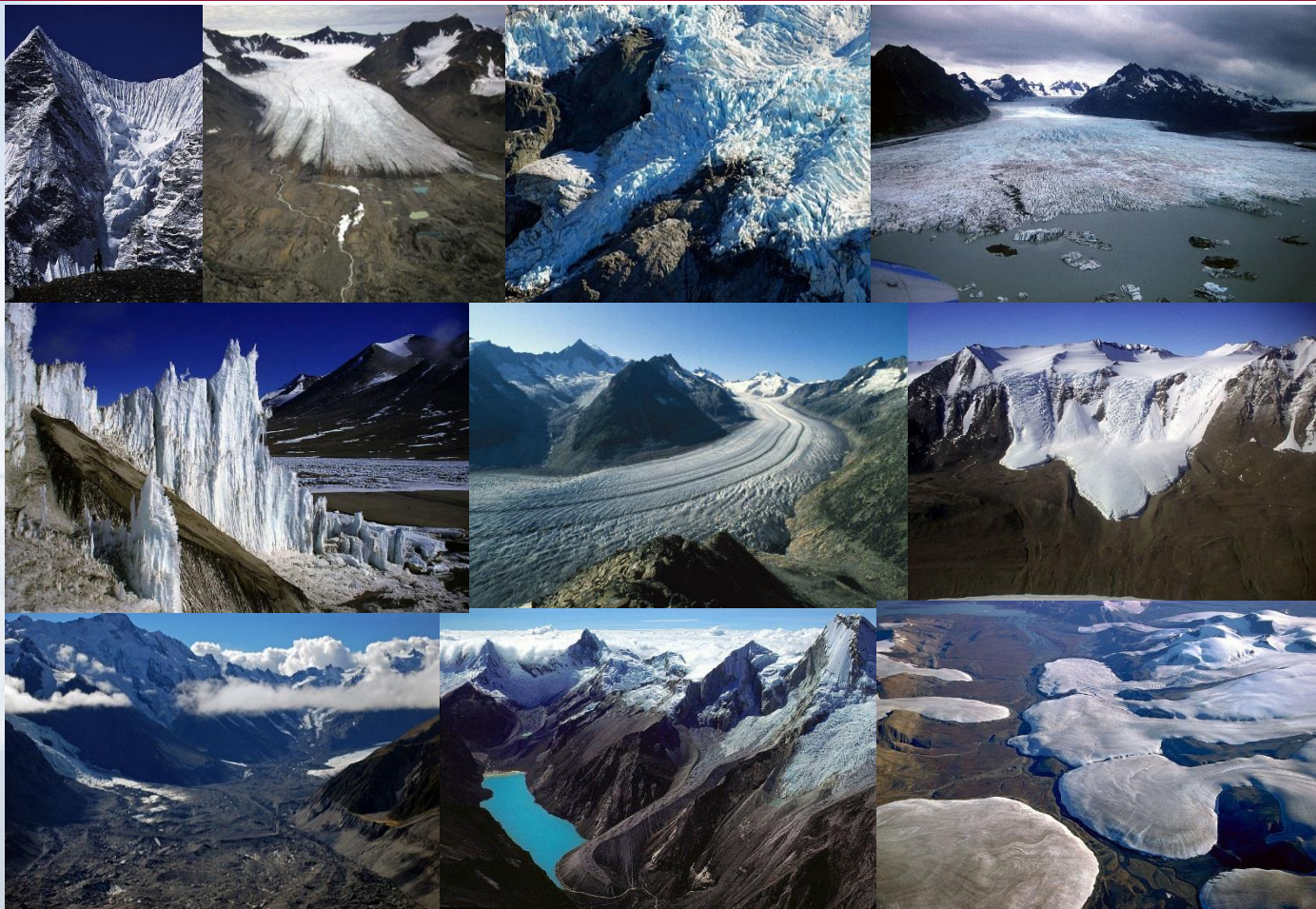
Distinguish between First-Year Ice and Multi-year Ice  
Northern Hemisphere  
10 km resolution

**CDR: 1979 – 2016**  
**ICDR: 2016 – onwards**



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# Glaciers & Ice Caps Services (Univ. Zurich)





- **A globally distributed ECV and monitoring concept**

- Glaciers occur globally and have a wide range of surface/dynamic characteristics
- Their monitoring is based on a global network of observers and has a >100 yr tradition
- RS data processing is also globally distributed (GLIMS) & based on scene-by-scene analysis
- GCOS accuracy reqs. can only be met when manual editing is applied (debris, clouds)

- **The Glacier Distribution and Change Service in C3S is based on**

- Glacier mapping & change assessm. with optical satellite data (L8/S2) in key regions
- Utilizing latest DEMs (TanDEM-X, Arctic DEM) to obtain glacier-specific elevation changes
- Enriching and improving pre-existing datasets (GLIMS/RGI & WGMS database)
- Collecting and integrating already published data from the community (reach out)

- **Developing of adaptors for integration of glacier data in the CDS**

- Step 1: Adaptor 1 & 2 brings existing RGI (inventory) & FoG (WGMS) databases into the CDS
- Step 2: Updating the CDS with new datasets (new, enriched, and collected products)
- Step 3: Adaptor 3 merges extents & elevation changes for improved calculation of sea level



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# Climate Data Store: Reanalyses

## ERA5 global reanalysis:

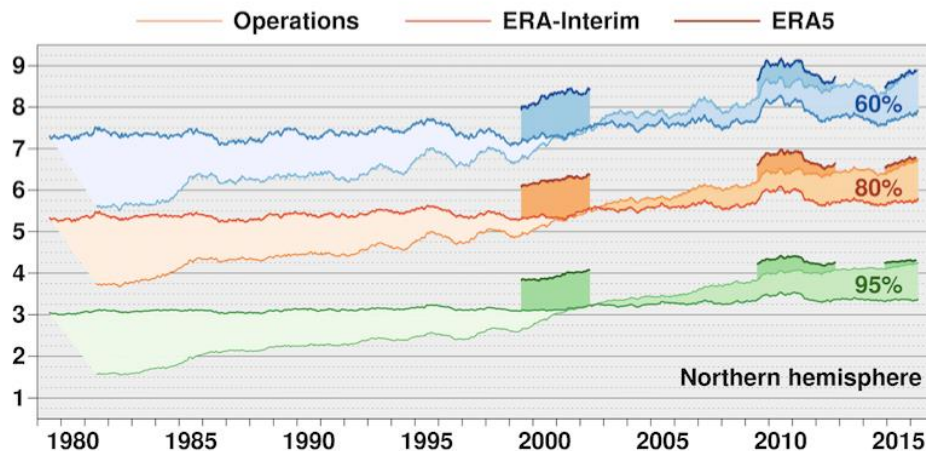
- Atmosphere/land/wave parameters
- 31 km global resolution, 137 levels
- Hourly output from 1979 onward
- Using improved input observations
- Ensemble data assimilation
- Providing uncertainty estimates

## However, need to

- provide better regional estimates of surface parameters by using improved model representations of surface fluxes;
- assimilate observations that are not used well (or not at all) in global reanalyses;
- improve the representation of extreme values and extreme events.

→ **Regional reanalysis (European + Arctic domains)**

Range (days) when 365-day mean 500hPa height AC (%) falls below threshold







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## C3S\_322 Lot 2: Regional reanalysis for the Arctic

- Warming in the Arctic (observational records and future scenarios) roughly twice as high as global average
- Need for understanding and management of change processes
- Increased economic activity in the region

*(Animated gif: NASA)*



Coverage in two domains, main areas of interest in the European sector of the Arctic

High resolution (2,5 km) adds value to global products

Extensive use of satellite data

Use of local surface observation datasets available in the partner countries

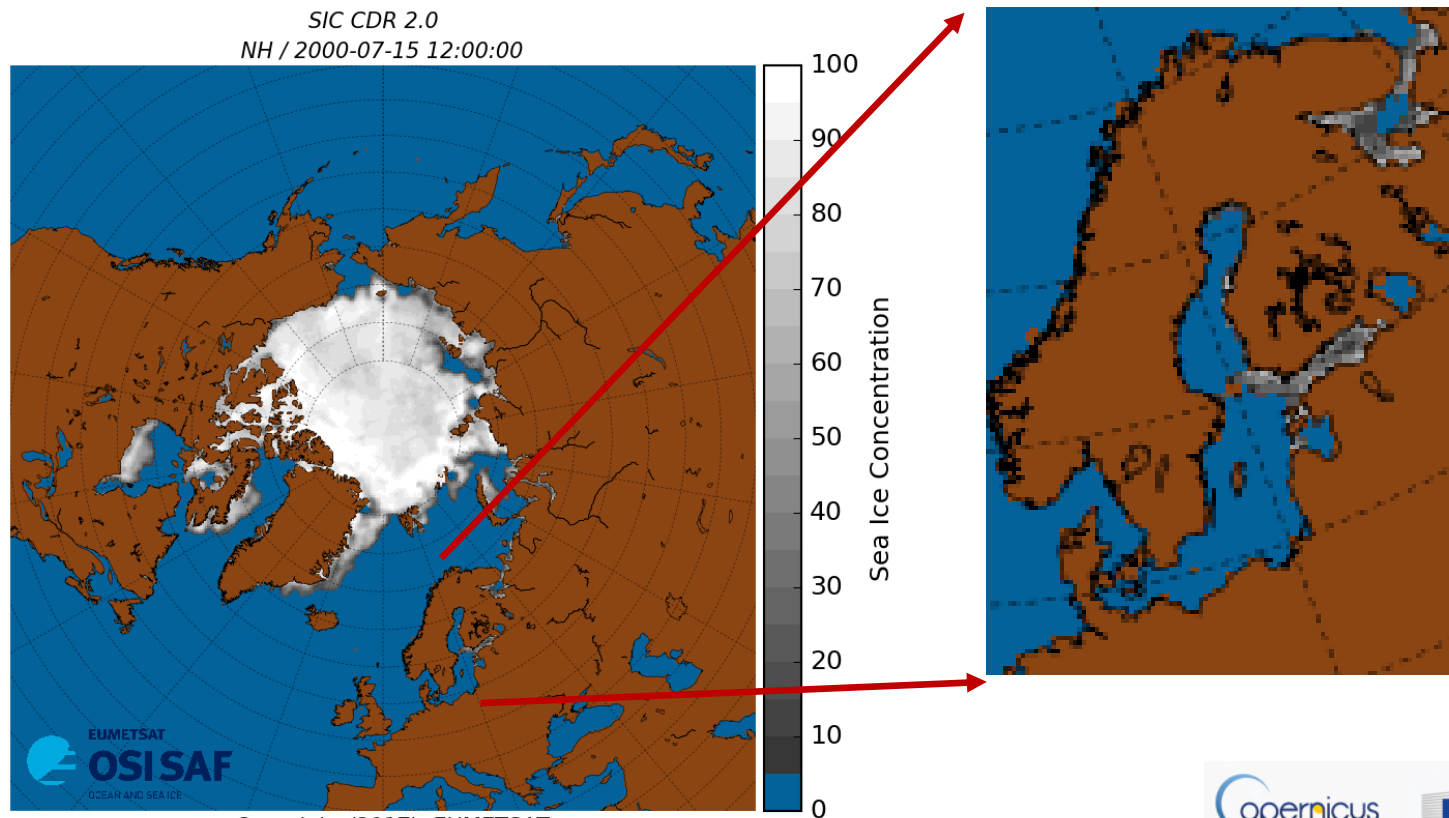
Special emphasis on NWP schemes and observations for the handling of “cold surfaces”: Snow, sea ice, glaciers



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# Sea-ice monitoring

- Spurious sea ice in the Baltic Sea.

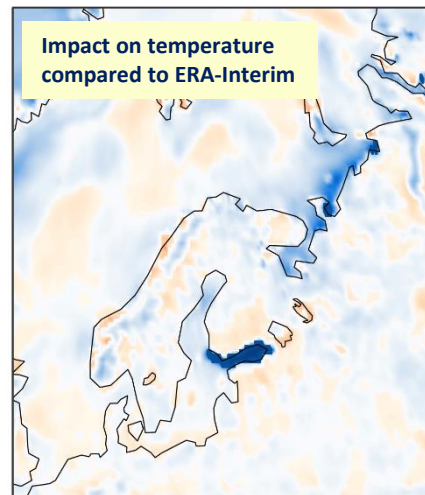
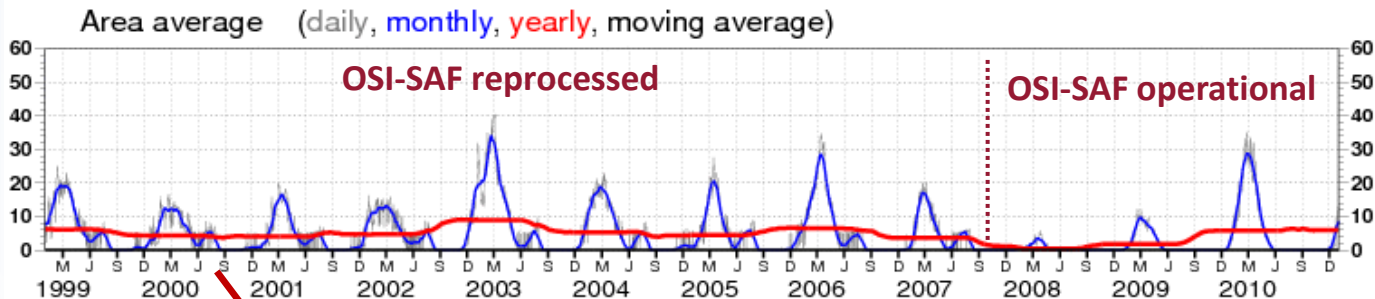




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# Frequency and impact

Occurs each year (from 1979 - 2007)  
Has detrimental effect on atmosphere and waves



Courtesy of H.  
Hersbach



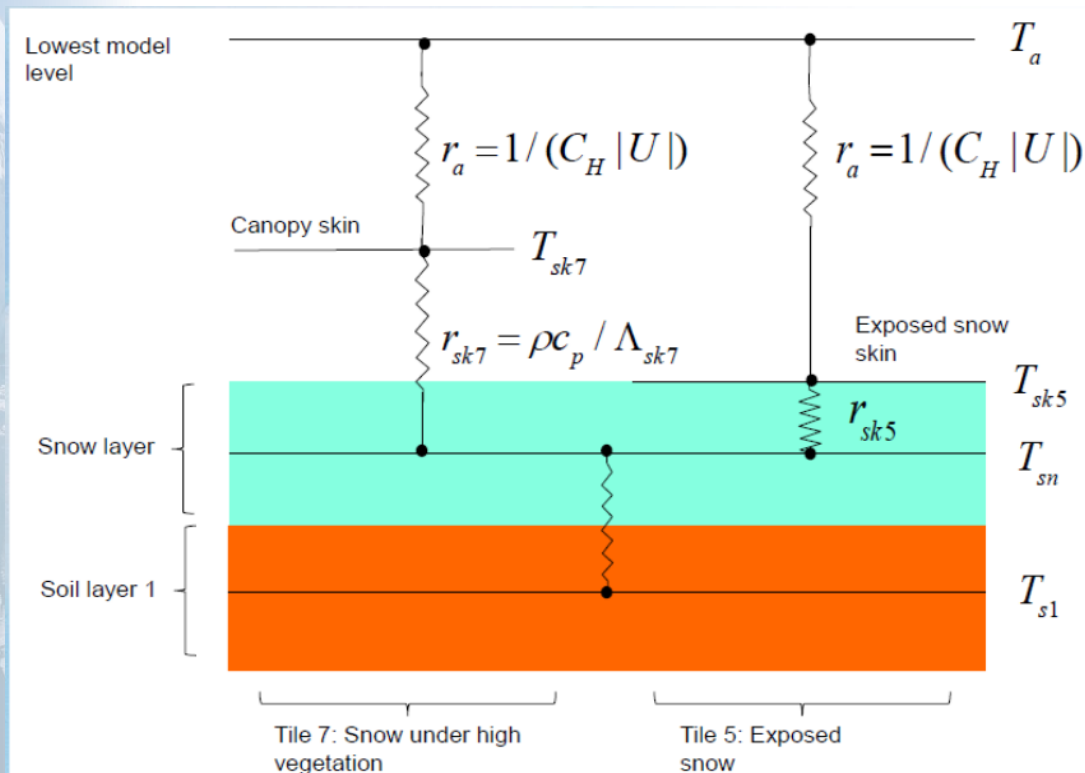
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## Snow products in ERA5 & relevance for NWP

- These products benefit from **modelling & data assimilation activities at ECMWF**
- In the past few years major development in the ECMWF modelling and data assimilation (DA) system affecting forecasts and analyses at Polar regions
- Snow DA assimilation crucial for NWP
  - Significant improvement of near-surface meteorology
  - In the absence of satellite dedicated missions, in-situ snow depth observations is by far the most relevant information for snow DA.
  - GAPS, in snow reports availability in the GTS
    - Some areas with poor reporting (Iceland)
    - Areas with seasonal reporting because they only report on snow covered areas
    - For some countries the data exist and is available in NRT → need to include it in the GTS network (decisions, resources)
    - For other countries (Finland) data policy issues
    - For all areas with gaps awareness is necessary



- **Global and regional reanalysis benefit from advances in modelling and data assimilation activities. Observations (truth) are needed.**



## Two tiles:

- 1) Exposed snow;
- 2) Snow under high vegetation

## Single snow-pack evolution

## Prognostic evolution:

- 1) Snow mass
- 2) Snow density
- 3) Snow temperature
- 4) Snow Albedo

## Diagnostics:

- 1) Snow depth
- 2) Snow cover fraction
- 3) Liquid water content



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# Snow data assimilation at ECMWF

## Snow depth

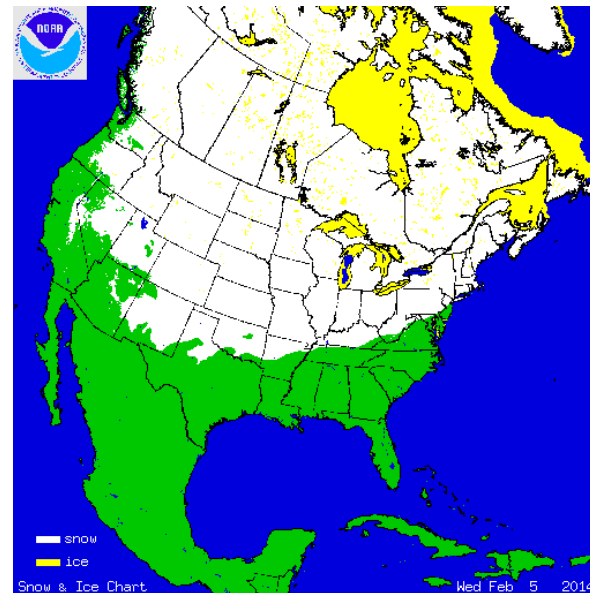
**Methods:** Cressman for ERA-Interim, 2D Optimal Interpolation (OI) for NWP & ERA5

**Conventional observations:** *in situ* snow depth (SYNOP & additional National data)

**Satellite data:** NOAA/NESDIS IMS Snow Cover Extent (daily product).

## Soil Temperature and Snow Temperature

1D-OI using analysed T2m as observation (NWP, ERA-Interim, ERA5)

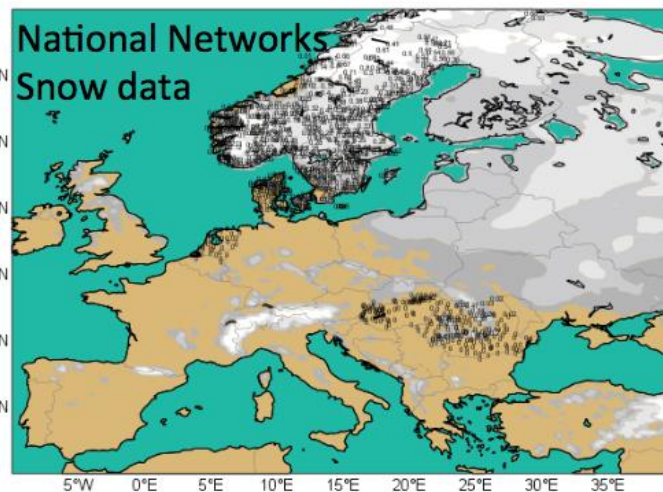
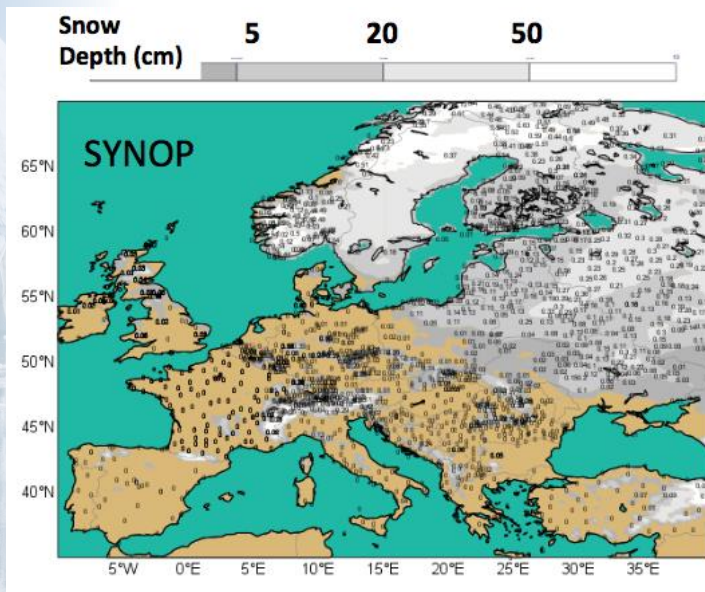
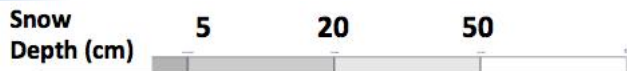




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## Available in the global GTS

*January 2017*

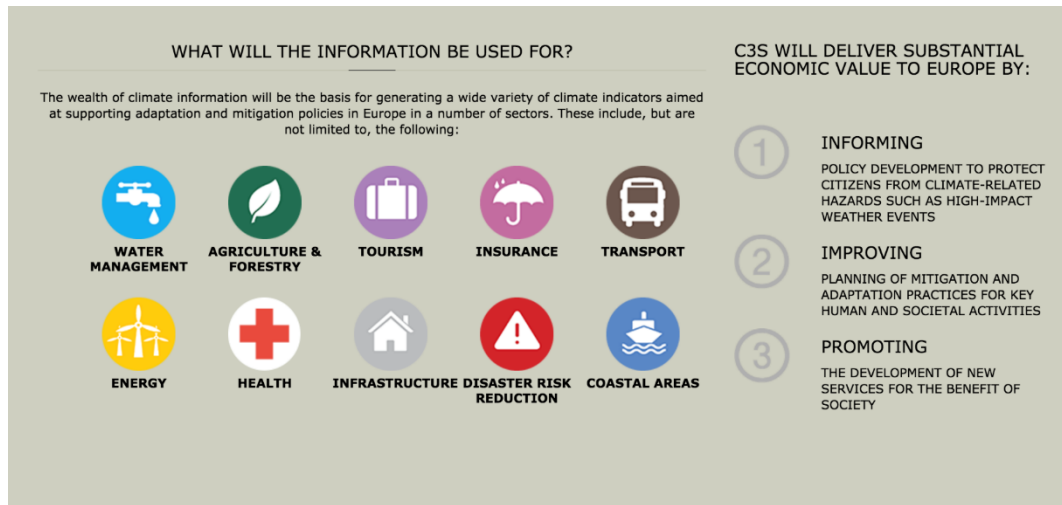




# Sectoral Information System

## Proof-of-concepts of climate services: Demonstration of the value chain with several 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 and indicators, good practices, tools and by supporting compelling use cases.





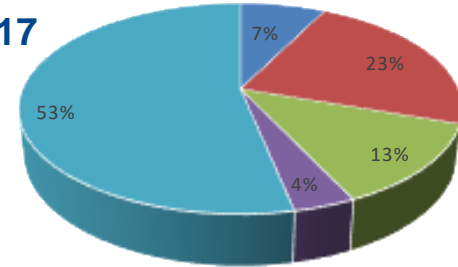


	Title	Start	End	Key deliverables
<b>C3S_51 Lot 2</b>	Quality Assurance for ECV Products Derived from Observations	01/10/16	31/12/18	<ul style="list-style-type: none"> <li>• <b>User requirements for climate data</b></li> <li>• Inventories of existing climate datasets</li> <li>• Scientific assessments and gap analysis for a selection of datasets</li> <li>• Recommendations for further development of the CDS</li> <li>• Recommendations for further development of the EQC function</li> </ul>
<b>C3S_51 Lot 3</b>	Quality Assurance for Multi-Model Seasonal Forecast Products	01/07/16	30/09/18	
<b>C3S_51 Lot 4</b>	Quality Assurance for Multi-Model Climate Projections	01/08/16	31/10/18	
<b>C3S_511</b>	Quality Assessment of ECV Products	01/11/17	30/06/21	<ul style="list-style-type: none"> <li>• Quality assessments for individual ECV products (appr. 100 datasets)</li> <li>• Multi-product assessments for each ECV (appr. 39 ECVs)</li> <li>• Thematic assessments for sets of related ECVs (appr. 6 themes)</li> </ul>

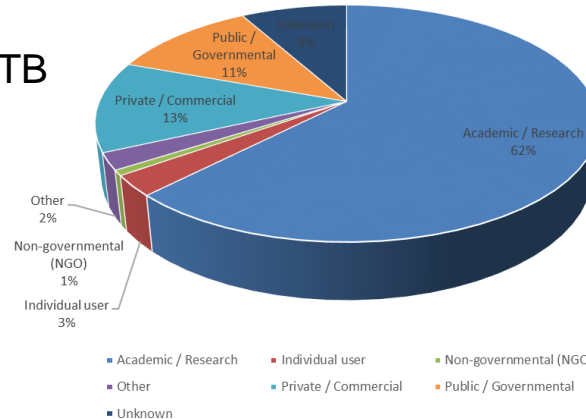


- Active users:
  - Global reanalysis: 7,362
    - ERA-Interim: 7,089
    - ERA5: 579
  - Seasonal forecast: 879 (web users)
  - SIS: 4,565 (web users)
- Data delivery
  - Global reanalysis
    - ERA-Interim: 333 TB
    - ERA5: 491 TB

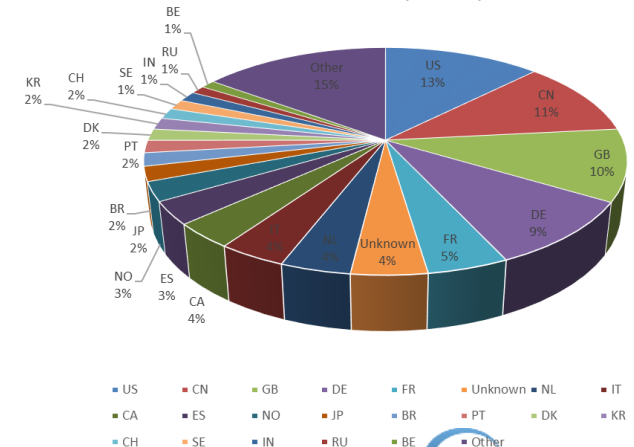
### Overall C3S usage in Q3 2017



ERA5: users by sector



ERA5: users by country





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## Summary

- C3S provides an increasing volume of climate information relevant for ice and snow covered areas, based on a combination of satellite and in-situ observations using the latest methods and tools.
- The Climate Data Store will offer a “one-stop-shop” access to this information
  - Data (including sectoral information)
  - Tools (data accessible and discoverable)
  - Best practices
- The Copernicus data policy is “full-free-open” → This will foster uptake by downstream services (national, local, private and public) and therefore support market development for EO and climate services in Europe.



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# Future

## ECVs

Snow and permafrost part of ESA CCI+ → once maturity possibly part of the C3S ECV portfolio

## Reanalysis

Regional reanalysis in the Arctic will continue developing. Antarctic?

Snow & ice modelling and DA still integral part of ECMWF activities

Agreements with other countries to access national network of snow observations

## User driven service

The C3S service driven by user requirements and user needs → EQC

Snow & Ice monitoring essential for SIS and impact on socio-economical sectors



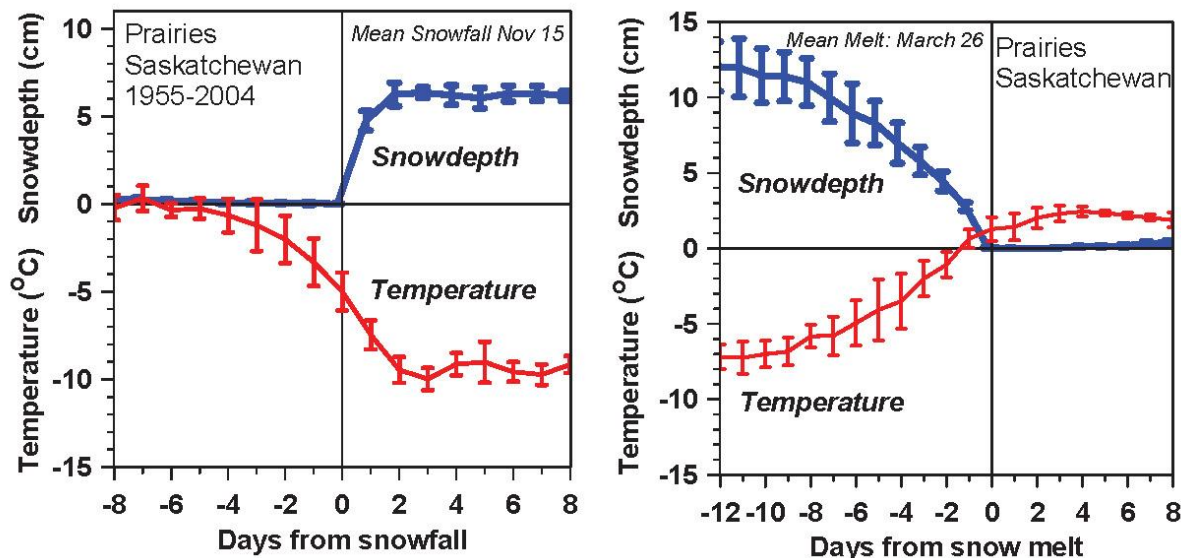
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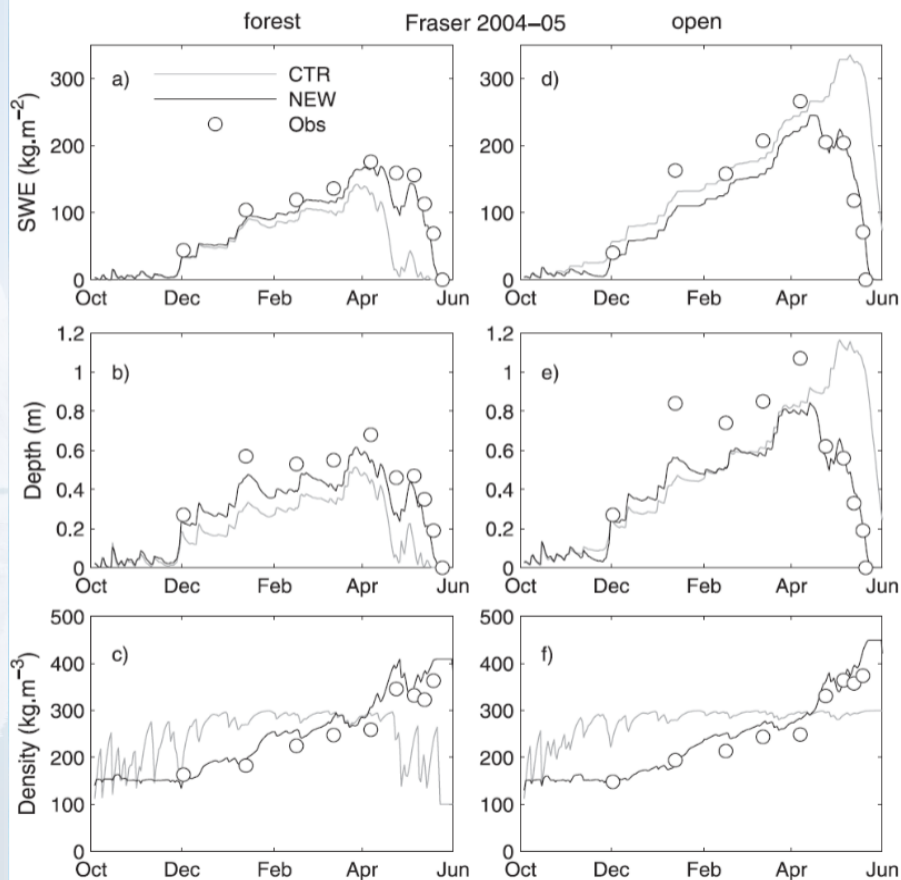
## Earth surface role, observational evidence (snow)

- **Global and regional reanalysis benefit from advances in modelling and data assimilation activities. Observations (truth) are needed.**



- **Temperature falls/rises about 10K with first snowfall/snowmelt**
- ***Snow reflects sunlight; shift to cold stable BL***
  - *Local climate switch between warm and cold seasons*
  - *Winter comes fast with snow*

*Betts et al. 2014*



**Point simulations (offline) in a forest and open areas nearby**  
**CTR (gray) : model before 2009**  
**NEW (black) : current model**

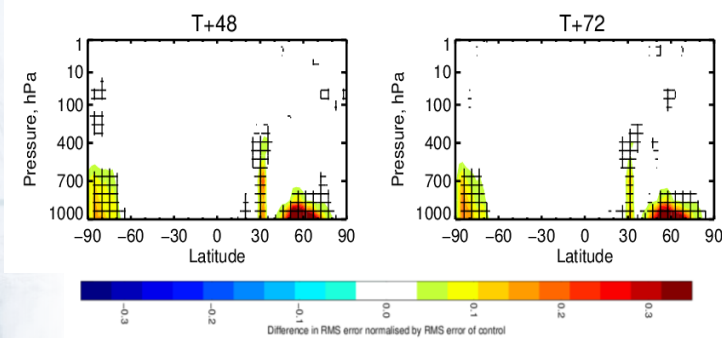
- **Better simulations of snow mass**
  - **Albedo changes**
  - **Liquid water representation**
- **Improved snow density**
  - **Before – exponential increase**
  - **Snow follows closely observations. Still some problems during melting**



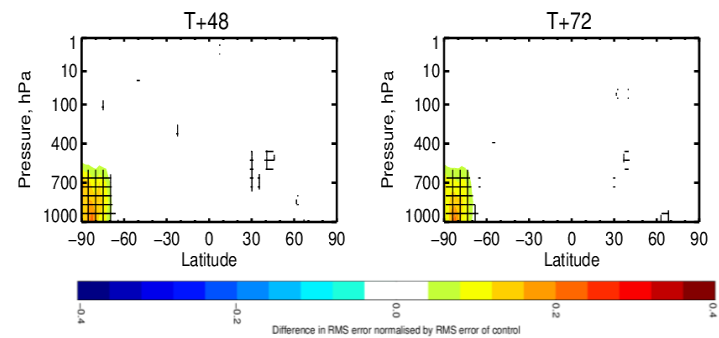
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# Relative Soil & Snow forecast impact

## Snow processes (winter 2015-16)



## Snow processes (summer 2015)



- Snow has both NH/SH impact (20-30% winter, 10-20% summer) lower troposphere