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TAKING THE PULSE OF OUR PLANET FROM SPACE

The Climate Modelling User Group evaluation and promotion of ESA CCI ECVs

Amy Doherty, Met Office

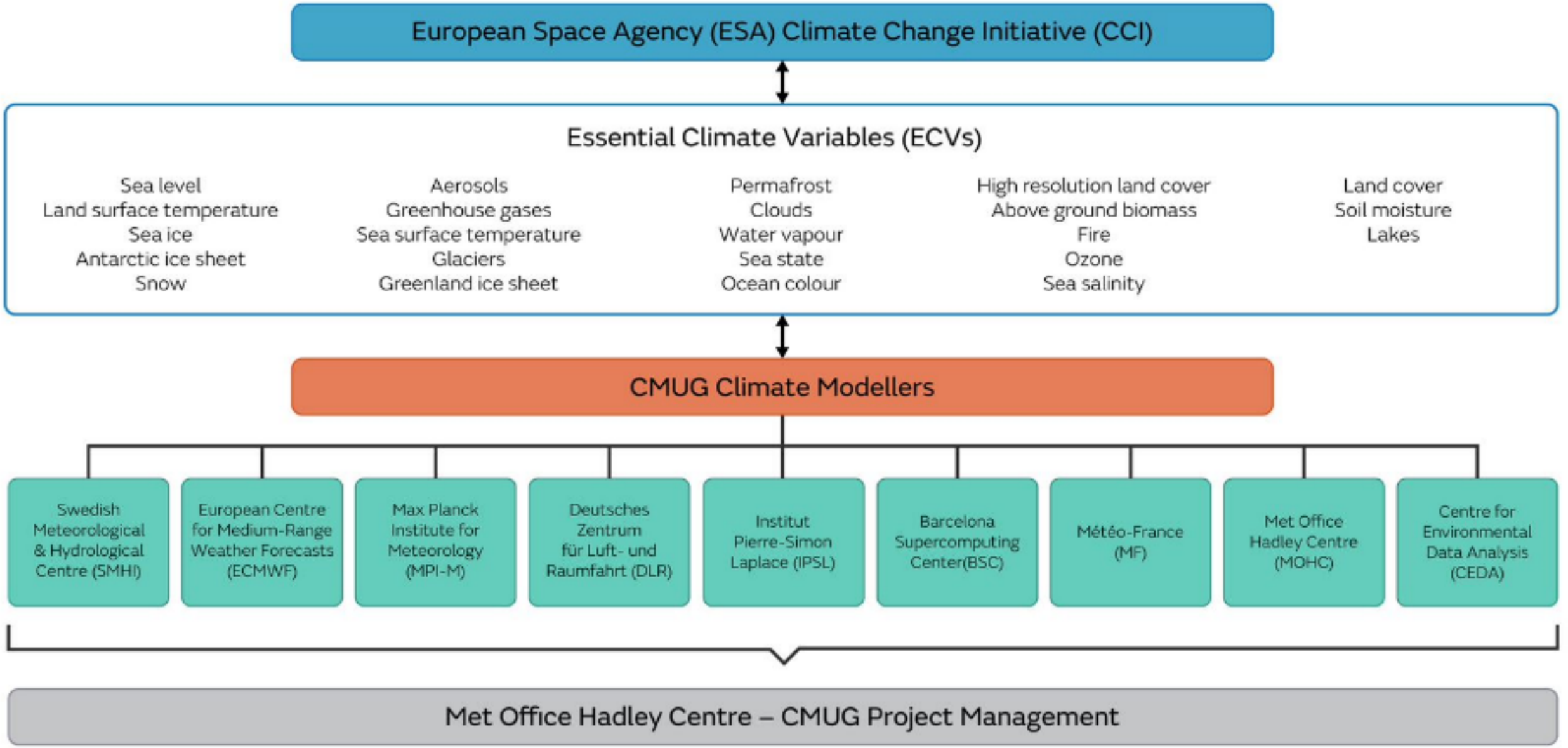
27 May 2022

CMUG – Climate Modelling User Group

"CMUG brings a climate system perspective to the CCI programme and provides a dedicated forum in which the **Earth observation** community, **climate modelling** community and **climate research** community work together."

The overarching aim of CMUG is to ensure state of the art climate datasets developed by ESA are accessible to and applied in the climate modelling and research community with the broadest possible range of applications

Met Office Climate Modelling User Group (CMUG) Project Structure



CMUG objectives

1. Support integration within the CCI programme	• Through requirements and user assessment from data users • Through feedback from a "climate system" perspective
2. Foster the exploitation of satellite-derived Essential Climate Variables (ECVs)	• By promoting the use of CCI datasets to climate modellers • By building partnership and links with the climate modelling community • By working to include CCI data in standard databases and tools
3. Assess quality and impact of individual/combined CCI ECVs in climate research and data assimilation contexts	• By assessing suitability of products for climate applications (e.g. climate modelling, decadal prediction, reanalysis, etc) • By quantifying their added value on model performance in an objective manner

Main CMUG activities

Refine scientific requirements of Earth observations for climate modellers and climate researchers

Provide technical and scientific feedback to CCI projects

Assess the global satellite climate data records produced by the Essential Climate Variable (ECV) projects

Promote and report on the application of CCI datasets for climate modelling, research, services and reanalysis

Look at consistencies and uncertainties across ECVs from a user viewpoint

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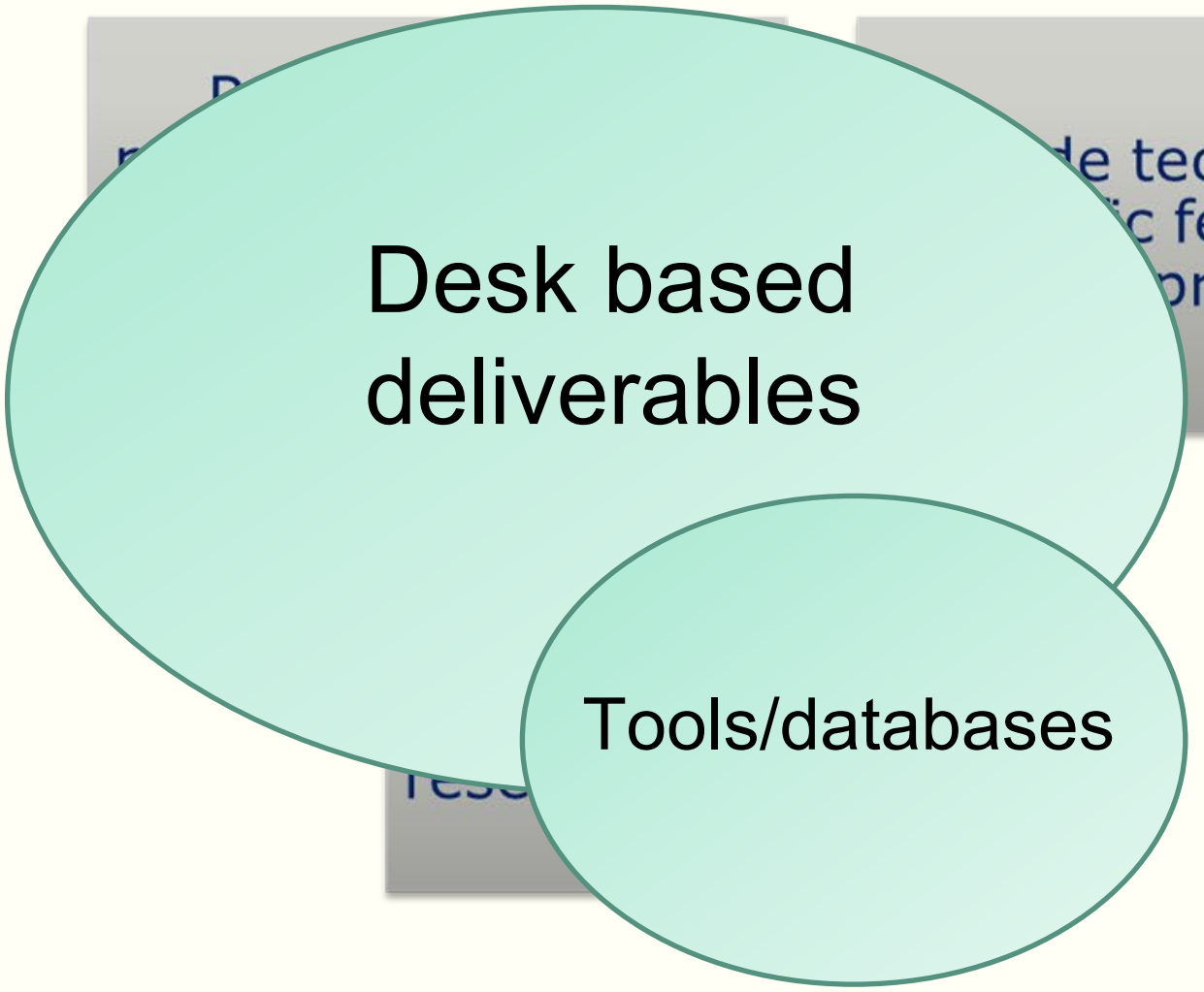

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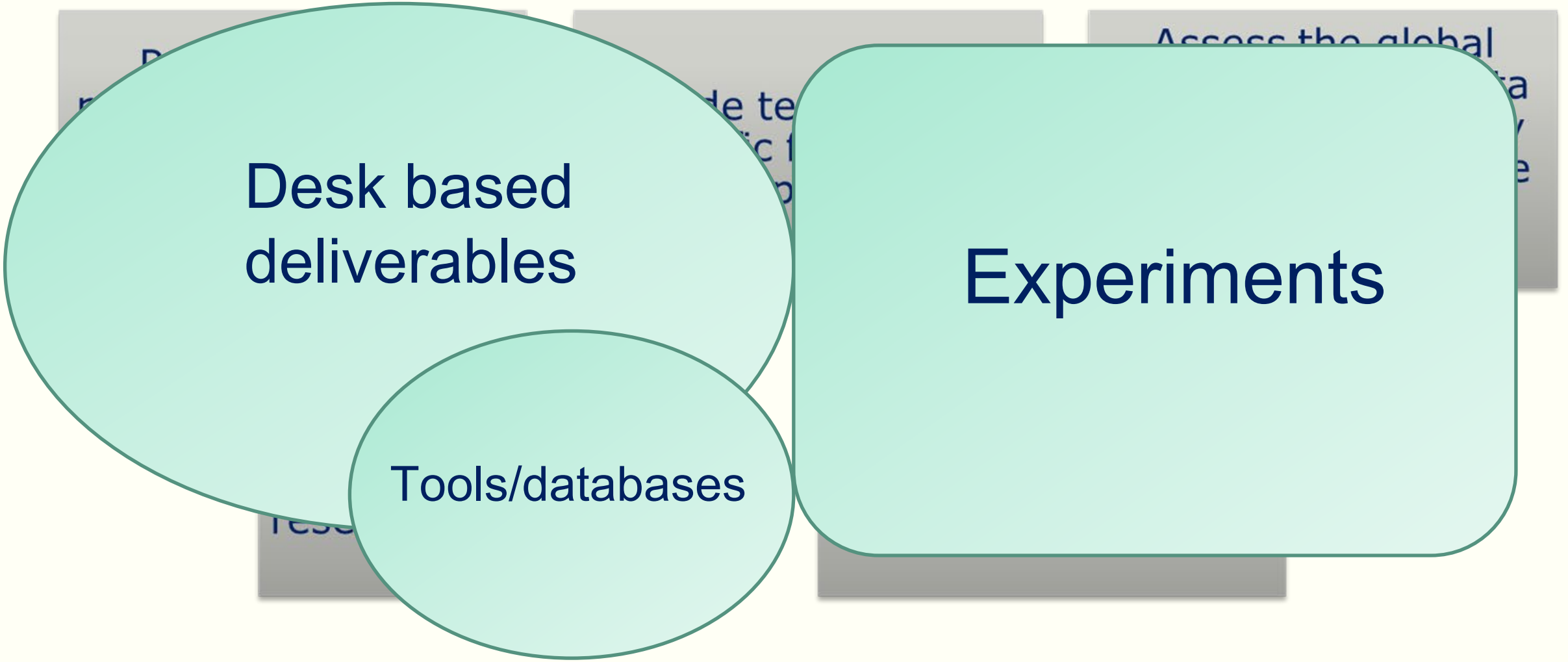


Desk based deliverables

- Foresight report
- User requirements document
- Scientific exploitation report
- Promotion package
- Climate services interface
- Suitability of CCI ECVs for climate science and services

European Space Agency (ESA) Climate Change Initiative (CCI) Sea Surface Temperature (SST), Sea Level, Sea Ice and Ocean Colour in Reanalysis

Experiments carried out by the Climate Modelling User Group, David Ford, Met Office

Data

Four marine ESA CCI Essential Climate Variables (ECVs) produced from satellite data were used

- *Sea surface temperature (SST),*
- *Sea level,*
- *Ocean colour (chlorophyll) and*
- *Sea ice*

Plus *in situ* measurements of temperature and salinity

Method

For a set of case studies, a physical–biogeochemical ocean model assimilated different combinations of the ESA CCI ECVs

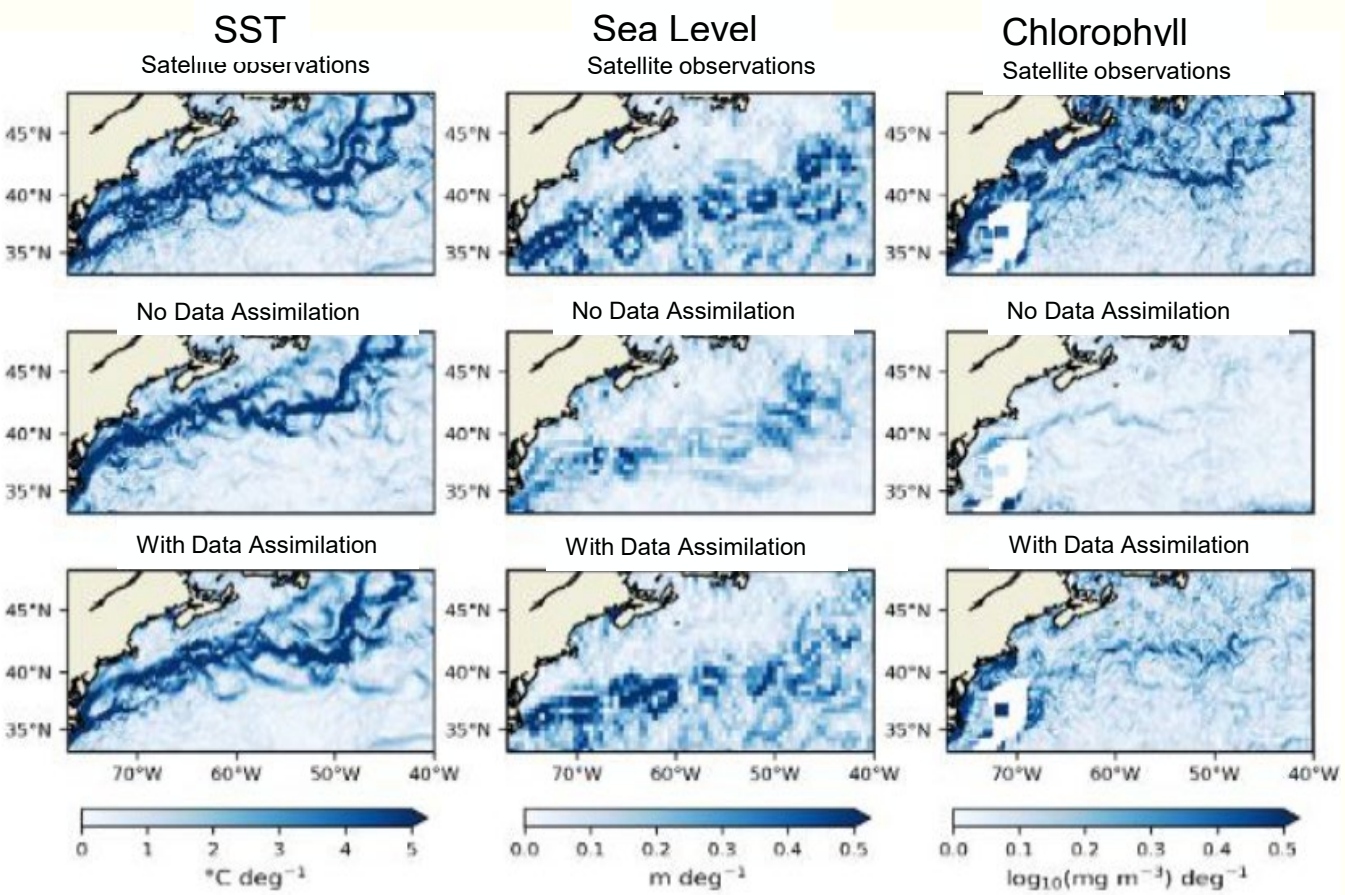
The aims of the study were to assess:

- Whether the ESA CCI datasets are consistent with each other
- The consistency of physical–biogeochemical relationships in reanalyses assimilating different combinations of data
- The impact of assimilating the ESA CCI datasets on the marine carbon cycle

Results

- The 4 marine ECVs assessed were found to be consistent
- This consistency transferred through the data assimilation, resulting in an improved reanalysis when the ECVs were assimilated together
- a strong positive correlation between phytoplankton biomass and net air–sea heat flux was found

This suggests that seasonal variations in the carbon-to-chlorophyll ratio are important, and phytoplankton bloom is dependent on other variables in addition to chlorophyll.



The figure shows horizontal gradients of temperature (left column), sea level (middle column), and chlorophyll [CCI OC dataset] (right column) in the Gulf Stream region during December 2010, from satellite observations (top), a model with no data assimilation (middle), and assimilating SST, sea level, ocean colour, and sea ice (bottom). Reproduced from Ford (2020)[1] It is clear that assimilating the ESA CCI datasets gives results closer to observations for this case study and similar results were seen for other case studies.

[1] *https://os.copernicus.org/articles/16/875/2020/*

Assimilating ESA CCI snow water equivalent to improve river discharge modelling

Jean-Christophe Calvet, Météo France

Key Findings

- Using ESA CCI Snow Water Equivalent improved river flow (Figure 1: red represents an improvement in river flow modelling and blue a deterioration)
- The significant area of improvement are the Elbe river basin in the Czech Republic/Germany and the Rhône river basin in France/Switzerland.
- It is interesting that this large improvement is seen in areas which are already well modelled (Gelati et al., 2018)

Context

- River discharge modelling is important for flood and drought forecasting and water system management
- Snow melt is an important contribution to river flow
- Modelling depends on reliable observations of snow pack

Data and methodology

Snow water equivalent (SWE) is the amount of water present in the snowpack. The ESA CCI product used is available over the N. Hemisphere from 1979-2018 for the winter period (Oct-May)

For verification an independent dataset of river discharge was used from the Global Runoff Data Centre (GRDC, 2021)

A land surface model for Europe was coupled to a river discharge model and the results for 2008-2018 were examined with and without the assimilation of the SWE product.

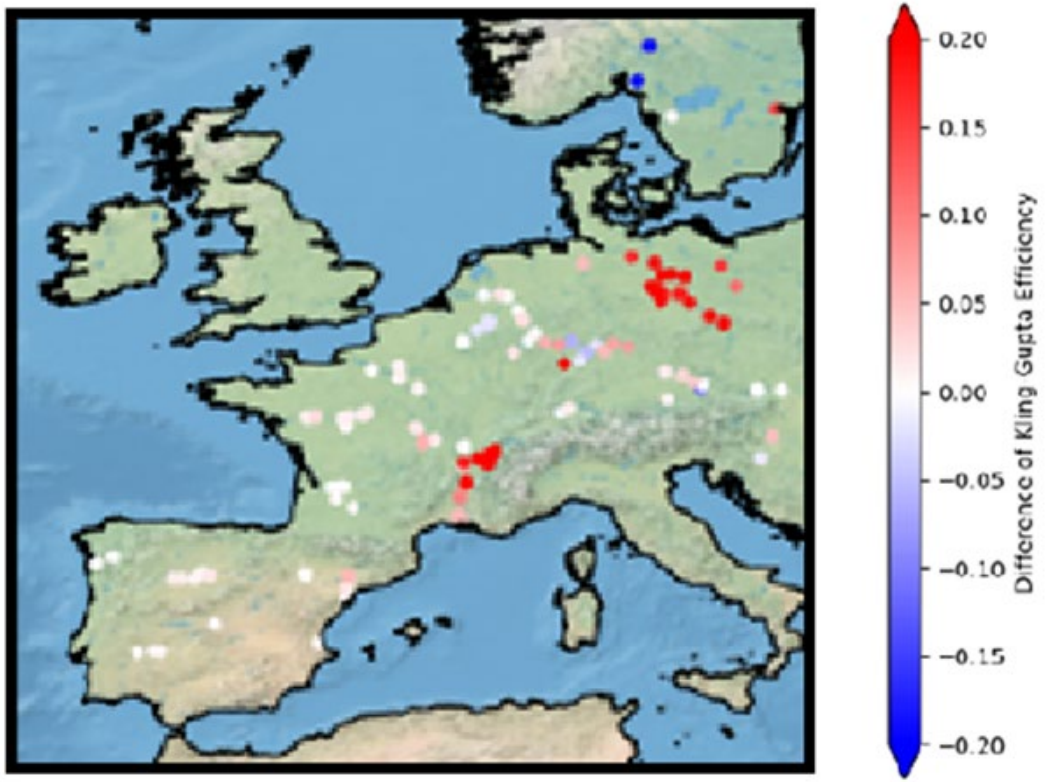


Figure 1: Impact on river discharge in Western Europe of assimilating SWE, using the Kling-Gupta Efficiency verification metric (Gupta et al., 2009). The Rhône and Elba river basins are particularly improved (clusters of red dots)

References

Gelati et al. (2018) Hydrological assessment of atmospheric forcing uncertainty in the Euro-Mediterranean area using a land surface model, Hydrol. Earth Syst. Sci., 22, 2091–2115, https://doi.org/10.5194/hess-22-2091-2018

GRDC: Global Runoff Data Centre, Federal Institute of Hydrology, Koblenz, Germany, http://www.bafg.de/GRDC/EN/Home/homepage_node.html, last access: November 2021

Assimilating ESA CCI sea ice observations to improve summer predictions in the Arctic and beyond

Pablo Ortega (BSC)

- The Arctic is a key region for understanding climate change. Enhanced warming and sea ice loss are linked through feedbacks.
- Major long-term changes in the Arctic can also impact the climate of the mid-latitudes, via teleconnection mechanisms.
- This experiment was designed to answer two questions. (1) Do shorter-term changes in Arctic sea ice also influence the climate in remote regions? (2) Can this be used to improve predictions?

Assimilating sea ice concentrations improves sea ice prediction …

Assimilating sea ice concentration (SIC) provides better forecasts of Arctic sea ice extent than the predictions without SIC, from May to July (see Figure below). The improvements are even greater in the Atlantic than the Arctic (Figure 1).

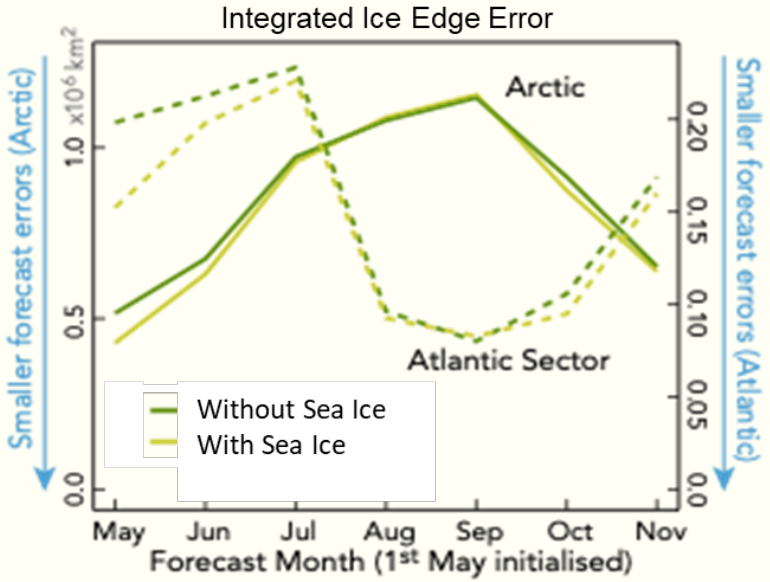


Figure 1: Improvement in ice edge forecast when assimilating SIC, from Acosta Navarro et al. submitted

… and improves climate prediction in Eurasia

In the Atlantic, Sea Surface Temperature (SST) forecasts are improved by using the SIC data, through a more realistic connection with ice in the Labrador sea.

The improved SSTs lead to better prediction of the large-scale atmospheric circulation (Figure 2) which leads to improvements in the prediction of surface temperature and precipitation in Eurasia.

From: Acosta Navarro J., V. Lapin, P. Ortega, J. García-Serrano "Added value of Arctic sea ice concentration assimilation for seasonal climate forecasts" (Submitted to Environmental Research Letters)

Difference in Skill (for July-September)

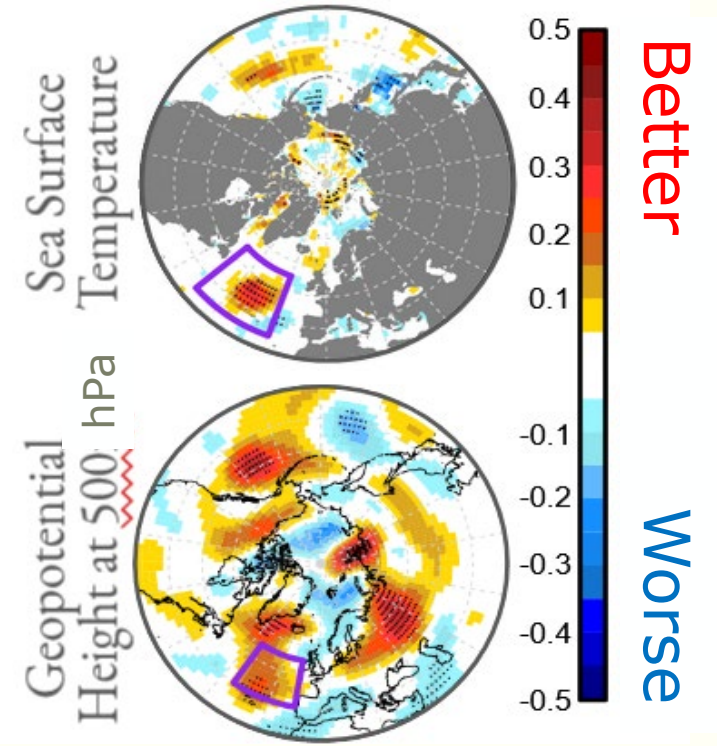


Figure 2: Improvement in SST and geopotential height when using SIC from Acosta Navarro et al. in prep

ESA CCI Soil Moisture product demonstrates improvement in a CMIP6 atmosphere-land surface model

Frederique Cheruy, Agnes Ducharne, Yanfeng Zhao, IPSL

Coupled Modelling and CMIP6

- Interaction between surface and atmosphere drive key aspects of the climate system.
- Development of atmospheric-land surface models which simulate this interaction is crucial for improving our understanding of the Earth System and climate change.
- The sixth phase of the Climate Model Intercomparison Project (CMIP6) provides important tools to measure the progress of coupled modeling and identify areas for future evolution.

This Experiment

The ESA CCI Climate Modelling User Group (CMUG) (Frederique Cheruy at IPSL) evaluated the latest version of, and improvements in, their land-atmosphere climate model (IPSL-CM6) by comparison with the ESA CCI soil moisture dataset and the previous version. The dataset is created from satellite observations using combined active and passive microwave retrievals of surface soil moisture (Dorigo et al., 2017).

Results

- Significant improvement between the CMIP5 and CMIP6 IPSL models.
- The CMIP6 model is better match to observations (Figure 1)
- Progress is due to developments in atmosphere and land surface process modelling (Cheruy et al., 2020)

Future Work: The assessment highlighted areas for future model development such as convection schemes, turbulence in the boundary layer and representation of the surface layer.

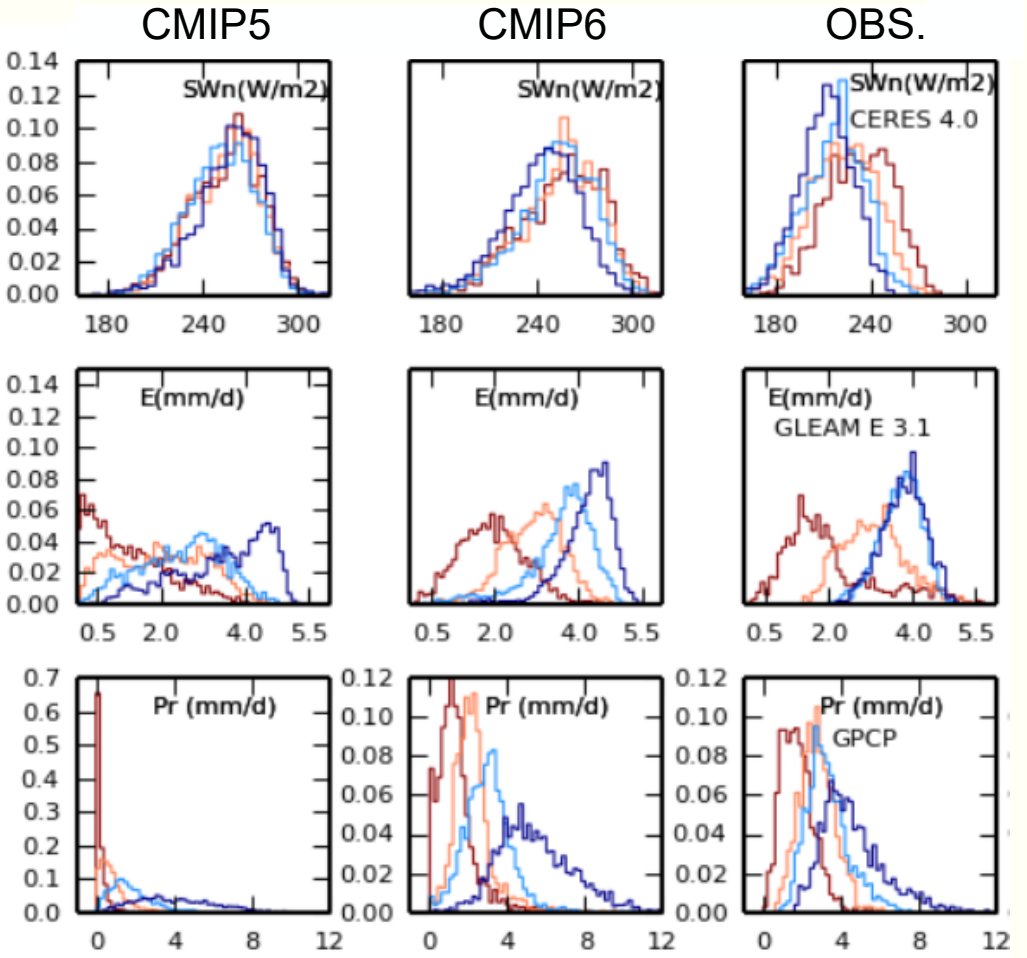


Figure 1: Results for Central North America in June-August for 10 years. Rows: Top - Solar flux; Middle - Evaporation; Bottom - Precipitation. Columns: Left - CMIP5 model; Middle - CMIP6 model; Right – Observations. Colours depict probability distributions of the variable for ranges of CCI soil moisture: dark red being for the driest values through pale orange and cyan to blue which depicts the distribution for the wettest values.

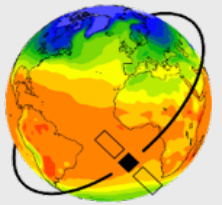
References: Cheruy et al 2020, Improved near surface continental climate in IPSL-CM6A-LR by combined evolutions of atmospheric and land surface physics. Journal of Advances in Modeling Earth System, 12, e2019MS002005, https://doi.org/10.1029/2019MS002005
Dorigo et al 2017, ESA CCI Soil Moisture for improved Earth system understanding: State-of-the art and future directions. Remote Sensing of Environment.

ESA CCI datasets for evaluating CMIP6 models using ESMValTool

ESA CCI ECV observational datasets[1] are vital for 1) model development, highlighting areas where improvement is needed in future model versions; and 2) assessment of model skill in reproducing observations, which informs the interpretation of model future projections.

ESMValTool[2]: a tool for fast and easy evaluation and analysis of Earth system models

- Traceable and reproducible
- Model performance assessment and quality control
- Publicly available, international community effort



ESMValTool
Earth System Model Evaluation Tool

CMUG is expanding ESMValTool to use the ESA CCI satellite datasets, making these invaluable data available for evaluation of CMIP6 models.

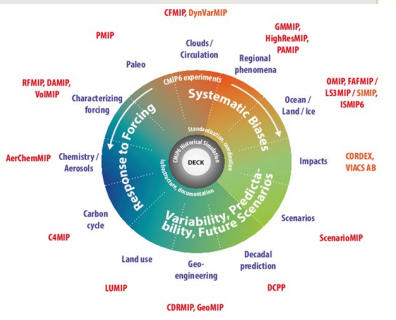
The objective of **CMIP**[3] is to better understand climate changes and make the multi-model output publicly available in a standardized format

CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

CCI data were used in the recently released **IPCC AR6** report[4]. Increasing the number of CCI datasets available through ESMValTool provides additional lines of evidence for future IPCC and other such reports advising on policy changes.

ESA CCI Essential Climate Variables datasets:

- Satellite derived datasets
- Good spatial and temporal resolution
- Long time series of consistent data
- Include uncertainty characteristics
- Open access



Eyring et al., Geosci. Model Dev., 2016

References
[1] https://climate.esa.int/en/odp/#/dashboard
[2] https://www.esmvaltool.org/
[3] https://www.wcrp-climate.org/wgcm-cmip
[4] https://www.ipcc.ch/assessment-report/ar6/

Working with Obs4MIPs to make ESA CCI products available for model intercomparison projects (MIPs)

Obs4MIPs (Observations for Model Intercomparison Projects) is a climate model community initiative to encourage widespread uptake of satellite observations for climate model verification and development.

ESA's Climate Modelling Working Group (CMUG) is working with the ESA CCI projects to include as many CCI ECV datasets as possible on Obs4MIPs to enable their use by a wide variety of research.

To date the following CCI products are included:

- Aerosol
- GHG (CO2 and Methane)
- SST
- Cloud

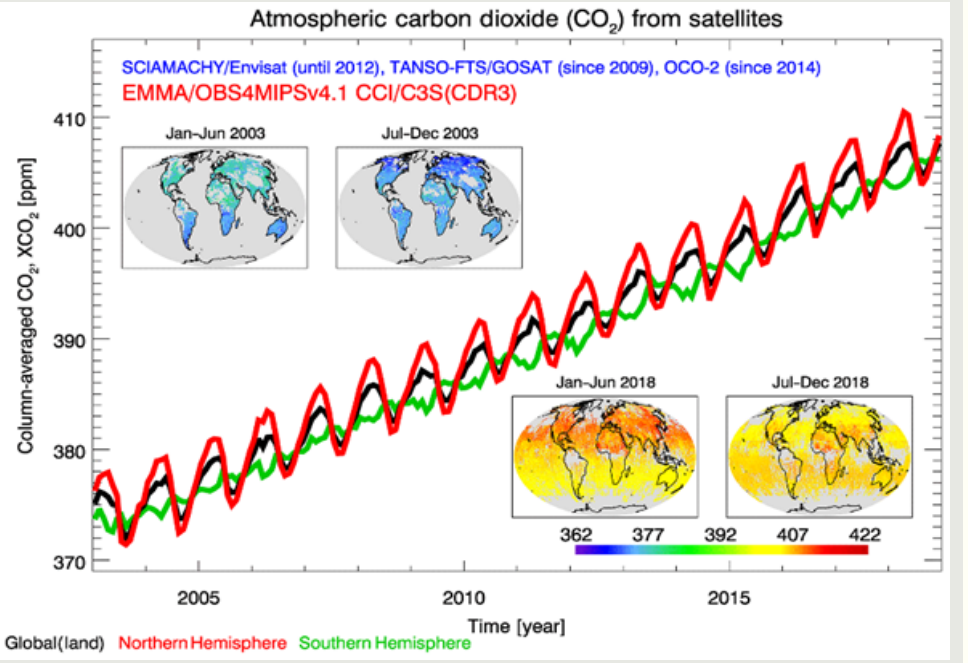


Figure 1: Overview of the XCO2 CCI_GHG data set from obs4MIPs. Shown are the time series over land for three latitude bands (global, black line; Northern Hemisphere, red; Southern Hemisphere, green) and global maps (half-yeary averages at 1° x 1° obtained by gridding (averaging) the merged Level 2, i.e., EMMA, product). From Reuter et al. (2020).

These data can now be easily compared to CMIP6 data and to other obs4MIPs datasets facilitating their use in high profile publications such as IPCC reports which draw heavily on results from CMIP in their assessments.

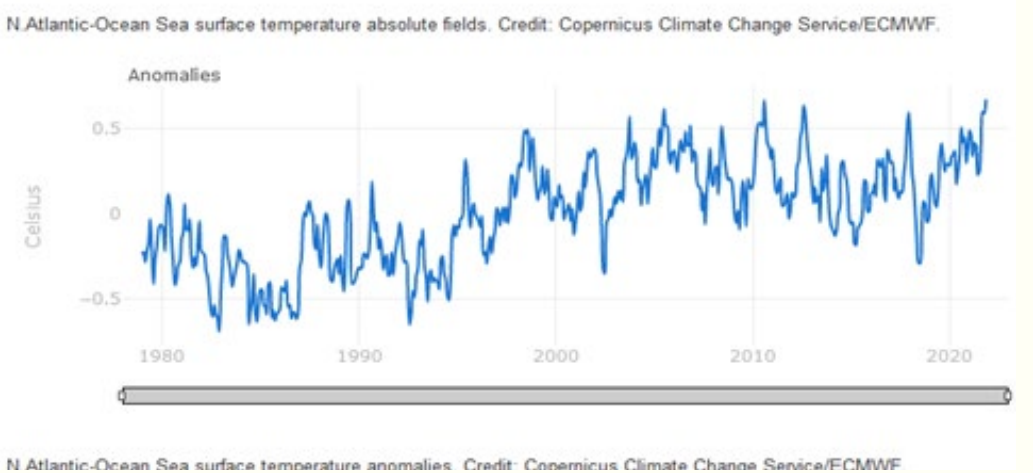
Reference: Reuter, M., Buchwitz, M., Schneising, O., Noël, S., Bovensmann, H., Burrows, J. P., Boesch, H., Di Noia, A., Anand, J., Parker, R. J., Somkuti, P., Wu, L., Hasekamp, O. P., Aben, I., Kuze, A., Suto, H., Shiomi, K., Yoshida, Y., Morino, I., Crisp, D., O'Dell, C. W., Notholt, J., Petri, C., Warneke, T., Velazco, V. A., Deutscher, N. M., Griffith, D. W. T., Kivi, R., Pollard, D. F., Hase, F., Sussmann, R., Té, Y. V., Strong, K., Roche, S., Sha, M. K., De Mazière, M., Feist, D. G., Iraci, L. T., Roehl, C. M., Retscher, C., and Schepers, D. (2020): Ensemble-based satellite-derived carbon dioxide and methane column-averaged dry-air mole fraction data sets (2003–2018) for carbon and climate applications, Atmos. Meas. Tech., 13, 789–819, https://doi.org/10.5194/amt-13-789-2020.

Including ESA CCI ECVs in the C3S Toolbox

Iryna Rozum (ECMWF)

The Climate Monitoring Facility:

- a web based application
- integrated with the Toolbox of the Copernicus Climate Change Service (C3S)
- Can access all datasets in the Climate Data Store (CDS)



CCI ECVs included in prototype:

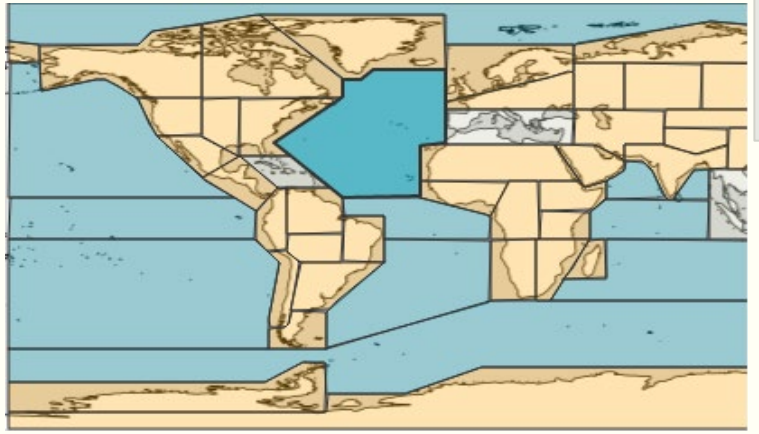
- Sea Surface Temperature (N Atlantic example shown)
- Soil Moisture

Additional CCI ECVs in CDS:

- OC
- Sea Ice
- Sea Level
- Ozone
- Aerosols

Geographical regions have been re-defined, now including:

- regions used in the C3S monthly climate bulletins
- NUTS regions (country sub-divisions for statistics)
- areas defined in the UN Intergovernmental Panel on Climate Change 6th Assessment Report (IPCC AR6)



Climate Change Service

Inclusion of CCI ECV datasets in the CMF offers the opportunity for them to reach a wider range of users

Find the CMF prototype at:
https://cds.climate.copernicus.eu/cdsapp#!/software/app-climate-monitoring-cci?tab=app

Foresight report conclusions

Focus areas identified:

- New observations
- Continuity in and improvement of existing observations
- Modelling and climate science
- System studies
- Modelling and in-situ observations for applications
- Building capability

ECV opportunities:

- Precipitation,
- Rivers and wetlands
- GHGs and the global carbon cycle
- Surface temperature
- Maintain continuity in satellite measurements
- Uncertainties
- Inter-ECV consistency

Conclusions

CMUG is demonstrating and encouraging use of CCI datasets for many climate modelling applications

Combining ECV data with modelling allows a more complete characterisation of the state and evolution of the Earth System

Common data formats and easy to use tools are vital

CMUG Phase 4 will start in October 2022

Thank you

https://climate.esa.int/en/projects/cmug/