climate change initiative

→ CLIMATE MODELLING USER GROUP

D6.2 CMUG Slidedeck

CMUG Activities, Results & Scientific Highlights

V2.0: January – July 2024

cmug cci

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What is CMUG?

ESA has established the Climate Modelling User Group (CMUG) to place a climate system perspective at the centre of its Climate Change Initiative (CCI) programme. CMUG also provides a dedicated forum through which the Earth observation data community and the climate modelling and reanalysis community can work closely together. CMUG works with the Essential Climate Variable (ECV) CCI projects to achieve this goal.

CMUG is a consortium comprising: Met Office Hadley Centre, DLR, ECMWF, IPSL, Météo-France, SMHI, BSC, CMCC, DMI, NCEO (Uni Leicester and Uni Edinburgh), and UKRI-STFC.

Met Office

UNIVERSITY OF LEICESTER

DMI
Danish Meteorological Institute

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

ECMWF

METEO FRANCE

IPSL

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

SMHI

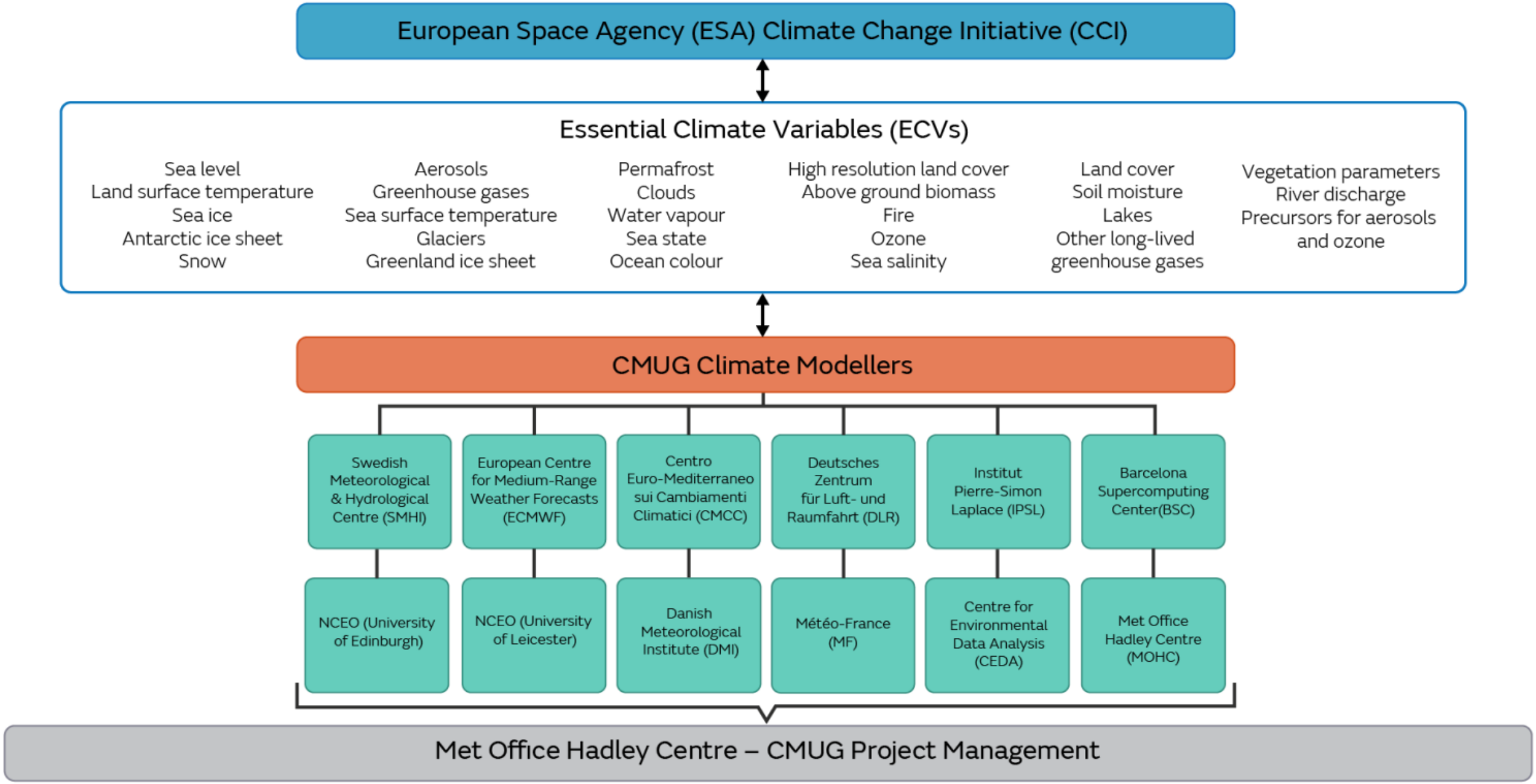
BSC Barcelona Supercomputing Center
Centro Nacional de Supercomputación

cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici

THE UNIVERSITY of EDINBURGH

UKRI Science and Technology Facilities Council
RAL Space

Met Office Climate Modelling User Group (CMUG) Project Structure



CMUG - Objectives

CMUG's objectives:

1. Support the integration within the CCI programme through:
   a) Requirements and user assessment from the Climate Modelling Community
   b) Feedback from a 'climate system' perspective
2. Foster the exploitation of Global Satellite Data Products within the Climate Modelling Community by:
   a) Promoting the use of CCI data sets to climate modellers
   b) Building partnerships and links with existing research organisations, networks and scientific bodies of the Climate Modelling Community
3. Assess quality and impact of individual/combined Global Satellite Data Products in Climate Model and Data Assimilation context by:
   a) Assessing suitability of products for climate applications (e.g., climate modelling, decadal prediction, reanalysis, etc.)
   b) Quantifying their incremental value on model performance in an objective manner

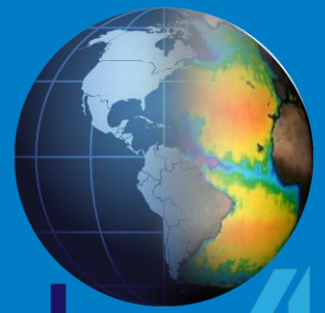
CMUG – Future Evolution of Obs4MIPs

A wide variety of observationally-based datasets are used for climate model evaluation. Obs4MIPs (Observations for Model Intercomparisons Project) refers to a limited collection of documented datasets that have been organised according to the Coupled Model Intercomparison Project (CMIP) model output requirements and made available on the Earth System Grid Federation (ESGF).

This effort was initiated with support from NASA and the U.S. Department of Energy (DOE) and has now expanded to include contributions from a broader community including ESA. Obs4MIPs underpins model evaluation in CMIP (and beyond) and thus makes a significant contribution to the assessment of and sustained improvement in model quality, e.g. as reported by IPCC. The CCI ECV projects contribute ECV data sets, which are decided to be of most interest to the CMIP community, to Obs4MIPs.
https://pcmdi.github.io/obs4MIPs/

Progress to date:

- CMUG held the kick off meeting for the obs4MIPS requirements deliverable (D5.7f) on 29th February 2024
- Interviews were agreed as the method to collate obs4MIPs requirements (D5.7f) and these were carried out with sign up from ESMO, CORDEX, and CMIP IPOs. The interviews will also be encouraged by CMUG partners and relevant Met Office colleagues. The findings will be collated into a report.



ESMO
Earth System Modelling and Observations

obs4MIPs
Observations for Model Intercomparisons Project

CMUG – ESMValTool

The Earth System Model Evaluation Tool (ESMValTool) is an open-source community-developed diagnostics and performance metrics tool for the evaluation and analysis of Earth System Models (ESMs). ESMValTool allows for a comparison of single or multiple models against predecessor versions and observations. The aim of the ESMValTool is to take model evaluation to the next level by facilitating analysis of many different ESM components, providing well-documented source code and scientific background of implemented diagnostics. CMUG's role is to enhance the ESMValTool with additional diagnostics and performance metrics enabling tailored analysis for the evaluation of models with ESA CCI and CCI+ data.
https://esmvaltool.org/

Progress to date:

- ESMValTool v2.10.0 released (January 2024)
- snow_cci v2.0 daily values of snow area fraction and snow water equivalent implemented (February 2024)
- permafrost_cci v3.0 yearly values of active layer thickness, permafrost extent and permafrost ground temperature implemented (March 2024)
- Work on evaluating cloud properties from reanalyses using cloud_cci presented at EGU 2024 (April 2024)
- ESMValTool Community Workshop held, Oberpfaffenhofen, Germany, 27-29 May 2024 (May 2024)
- Prototype for calculation of permafrost extent from CMIP models implemented (June 2024)
- ESMValTool 2.11.0 released (July 2024)
- Exploration of possibilities to take advantage of uncertainty information provided with CCI datasets for model evaluation using LST data (work in progress)

CMUG – Scientific Study WP5.1

Study WP5.1 Machine Learning to Advance Climate Model Evaluation and Process Understanding

- This study is led by Lisa Bock. Additional contributors to this Study are Axel Lauer and Veronika Eyring from DLR.
- The main CCI ECVs used in this Study are Cloud, Land Cover, Land Surface Temperature, Sea Surface Temperature, Water Vapour, Soil Moisture, Permafrost, and Snow.
- It is estimated that this Study will run from September 2023 until March 2025.

Description

This study comprises three parts. The first focuses on enhancing observational products for climate model evaluation with machine learning. This involved developing and applying a Machine Learning (ML)-based approach to derive cloud classes from high-resolution satellite data and coarse-resolution climate models; the application of NN to ESA CCI Cloud data leading to timeseries of labelled ESA CCI Cloud data; and the use of this dataset for an evaluation of clouds by cloud classes in climate models (here: ICON-A). The second focuses on causal model evaluation for cloud regimes and land cover types by calculating causal networks from the timeseries of several cloud variables of ESA CCI data to analyse and investigate the causal connections among the cloud properties and their controlling factors. Then causal networks are analysed for different cloud regimes and different land cover types. The same method is then applied to output from global climate models (here: ICON-A) and resulting causal networks are then compared to the ones obtained from the observations to evaluate the models. Thirdly, the evaluation of CMIP6 models with the ESMValTool will be undertaken. This involves CCI Snow and Permafrost datasets being implemented into ESMValTool and whenever possible, the CCI uncertainty estimates will be used to assess whether differences in the model simulations compared with the observations are significant.

Progress to date:

- Study kick-off at Integration (Nov 2023)
- Paper (Kaps et al., 2023) published (Jun 2024)
- Prepared poster for EGU24 on ‘Quantifying influence of cloud controlling factors with causal inference’ (Apr 2024)
- Initial assessment of the impact of Cloud Optical Depth (COD) and Aerosol Optical Depth (AOD) level 2 data on 4D-Var analysis both for air quality fields and for meteorological variables
- Initial assessment of the impact of coarse mode AOD to constrain desert dust simulations

Results and conclusions

Will be provided once ready.

CMUG – Scientific Study WP5.2

Study WP5.2 Impacts and Evaluation of Vegetation Phenology Changes on Observed and Modelled Land-Atmosphere Processes

- This Study is led by Daniele Peano from CMCC. Additional contributors to this Study are Debbie Hemming and Rob King from the Met Office.
- The main CCI ECVs used in this Study are Vegetation, Snow, Water Vapour, Land Surface Temperature, Biomass, Land Cover, and Soil Moisture.
- It is estimated that this Study will run from September 2023 until August 2025.

Description

This study comprises two parts. The first will occur during the development phase of the CCI Vegetation and, through interaction with the CMUG team, will provide testing and feedback on preliminary LAI (Leaf Area Index) and FAPAR (Fraction of Absorbed Photosynthetically Active Radiation) data. The second involves analysis of the relationships between phenology and land-atmosphere processes by defining a core set of phenology indicators at the global and habitat scale, quantifying the influence of phenology on land-atmosphere interactions, and comparisons with model and observed values.

Progress to date:

- Established a regular exchange of information between Vegetation CCI and the CMUG teams. These discussions brought about the development of spatial aggregation tool for Leaf Area Index data that will be employed within the WP5.2 future activities and will support tailoring of the data produced by the Vegetation CCI team.

Results and conclusions

Will be provided once ready.

CMUG – Scientific Study WP5.3

Study WP5.3 Impacts of Integrating CCI Land Cover Data in the ISBA Land Surface Model

- This Study is led by Jean-Christophe Calvet from Météo-France.
- The main CCI ECVs used in this Study are Land Cover, Land Surface Temperature, Soil Moisture, and Snow.
- It is estimated that this Study will run from September 2023 until August 2024.

Description

This study will assimilate CCI Snow Water Equivalent (SWE) in the ISBA land surface model of Meteo-France. CCI Soil Moisture and Land Surface Temperature products will be used as benchmarks to compare simulations with and without SWE assimilation. This comparison will be repeated twice, with and without using CCI Land Cover maps.

Progress to date:

- Tests and debugging of LDAS-Monde v9 of SURFEX completed (Feb 2024)
- Met with WP5.2 and Vegetation CCI team to support improvements to LAI product specifications
- 'Open-loop with pre-existing land cover' completed (Apr 2024)
- New open-loop simulation over Eurasia completed, including ESA-CCI land cover data (Jun 2024)

Results and conclusions

Will be provided once ready.

CMUG – Scientific Study WP5.4

Study WP5.4 Seasonal Predictability of Ocean Biogeochemistry and Potential Benefits of ESA CCI Data Assimilation

- This Study is led by David Ford from the Met Office. Additional contributors to this Study are Pablo Ortega and Joan Llort from BSC.
- The main CCI ECVs used in this Study are Sea Surface Temperature, Sea Surface Salinity, Sea Ice, Sea Level, and Ocean Colour.
- It is estimated that this Study will run from April 2024 until July 2025.

Description

The models EC-Earth3-CC and GloSea6/MEDUSA are used. This study has a tentative start date of April 2024 and comprises of two main parts with a third optional part. The first main part is the assimilation of ESA CCI variables to produce forced ocean/sea-ice reconstructions with EC-Earth3-CC and GloSea6/MEDUSA predictions systems. This includes the assimilation of physical variables: Sea Surface Temperature, Sea Ice Concentration and 3D ocean temperatures from EN4 below the ocean mixed layer. Then additional assimilation of Ocean Colour to determine the role of non-physical variables to BGC predictability and then additional assimilation of Sea Surface Salinity, Sea Surface Height and 3D ocean salinity from EN4 (GloSea6/MEDUSA). The second main part is exploring the impact of assimilation choices of these reconstructions on physical and biogeochemical properties such as evaluating physical properties of reconstructions and identifying a best strategy to reconstruct ocean biogeochemistry. The third, optional, part is to explore the impact of assimilation choices of these reconstructions on seasonal predictions.

Progress to date:

- WP5.4 kicked off in April 2024, and a kick-off meeting was held with ESA and ECV stakeholders.
- Over the summer 2024, technical work was ongoing at BSC and Met Office to set up the planned experiments, with the aim to run these in autumn 2024.
- The planned work was presented at ESA Salinity conference in May, an OceanPredict Task Team meeting in July, and will be presented at the OceanPredict ’24 Symposium in November 2024.

Results and conclusions

Will be provided once ready.

CMUG – Scientific Study WP5.5

Study WP5.5 Cloud and Aerosol Analysis

- This Study is led by Angela Benedetti and Kirsti Salonen from ECMWF. Additional contributors to this Study are Axel Lauer from DLR and Jeronimo Escribano from BSC.
- The main CCI ECVs used in this Study are Aerosol, Cloud, Soil Moisture, and Water Vapour.
- It is estimated that this Study will run from September 2023 to August 2024.

Description

This study comprises of three parts. The first part is undertaking dust aerosol analysis with the BSC system (Jeronimo Escribano, BSC). This would involve constraining global dust aerosol simulations from the BSC MONARCH model with CCI data to produce dust analyses during the extraordinary event of June 2020. The second part is to undertake Cloud / Aerosol analysis with the ECMWF system (Angela Benedetti and Kirsti Salonen, ECMWF). This would involve joint assimilation of Aerosol and Cloud ECVs in the ECMWF IFS during June 2020 and September 2021 with the IFS 4DVar scheme in CAMS configuration. The third part is to undertake the Cloud and Aerosol analysis validation Study (Angela Benedetti and Kirsti Salonen, ECMWF; Axel Lauer, DLR; and Jeronimo Escribano, BSC) involving evaluation using the ESMValTool and internal tools at BSC/ECMWF.

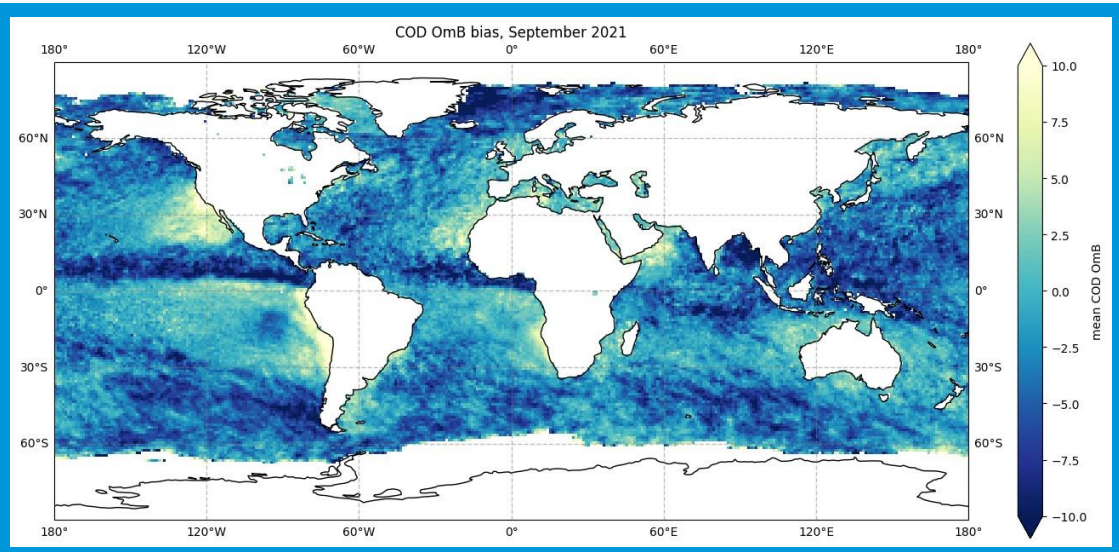
CMUG – Scientific Study WP5.5

Study WP5.5 Cloud and Aerosol Analysis

- This Study is led by Angela Benedetti and Kirsti Salonen from ECMWF. Additional contributors to this Study are Axel Lauer from DLR and Jeronimo Escribano from BSC.
- The main CCI ECVs used in this Study are Aerosol, Cloud, Soil Moisture, and Water Vapour.
- It is estimated that this Study will run from September 2023 to August 2024.

Results & Conclusions as of July 2024

Data sets for aerosol and cloud optical depth (AOD and COD) from Sea and Land Surface Temperature Radiometer (SLSTR) have been evaluated and tested for assimilation in the ECMWF 4DVar system. While AOD observations from other instruments are operationally used in the Copernicus Atmosphere Monitoring Service (CAMS) configuration, CODs are a new source of information and provide an interesting avenue for assimilation of cloud information into the system. Figure 1 (right) shows observation minus model background (OmB) mean difference from a passive monitoring experiment for CODs. The statistics indicate positive mean difference over regions where there is typically persistent marine stratus. Negative mean difference on the other hand is seen in the inter-tropical convergence zone. The results are in line with similar monitoring done for Ocean and Land Colour Instrument (OLCI) reflectances, indicating that the mean differences would originate from the lack of stratiform clouds in the model rather than an observational or retrieval problem. Monitoring of the CCI SLSTR AOD observations indicates good and homogeneous data quality over sea, except the regions where bias related to desert dust is present.



Impact studies have been performed in depleted observing system framework to emphasise the impact originating from the new data sources. The baseline experiment includes assimilation of conventional and gps observations and the AODs and CODs are added on top of the baseline experiment. Assimilation of the CCI AODs generally decreases the magnitude of the modified normalised mean bias as well as the fractional gross error with respect to independent AERONET AOD data. Experimenting with CODs indicates that strict quality screening of the observations is required and even so, some degradation is seen especially in the short-range temperature forecasts as verified using independent observations. The final experimentation with joint use of AODs and CODs is currently ongoing.

CMUG – Scientific Study WP5.6

Study WP5.6 Snow Dynamics Impacts on Temperature / High Latitude Climate

- This Study is led by Philippe Peylin and Catherine Ottle from IPSL.
- The main CCI ECVs used in this Study are Snow Cover, Land Cover, Land Surface Temperature, Fire, and Biomass.
- It is estimated that this Study will run from September 2023 until February 2025.

Description

This study's main objective is to improve our understanding and modeling of snow-vegetation-atmosphere feedback, with the IPSL climate model (LMDZORCHIDEE) and various CCI products (especially snow products). The Study comprises several parts. The first part involves data analysis including consistency check/analysis between Snow Cover (mass & extent), Land Cover and other CCI products (LST; Fire; Biomass; LAI) + Albedo with analysis of the differences between short and tall vegetation and Deciduous & Evergreen. The second part involves ORCHIDEE model evaluation with the evaluation of the simulated snow cover dynamics (mass and extent) and snow albedo using simulations with prescribed climate forcing (e.g., ERA5) and define a set of key “homogeneous points” for the identification of model biases. The third part involves model improvement with improved soil thermics (carbon impact on soil thermal properties; ongoing work) and SCF parameterizations and accounts for Shrubs and the representation of Snow - Vegetation dynamics. The fourth part involves Snow model parameter optimisation with model sensitivity experiments to identify critical parameters (Morris / Sobol approaches) and multi-site optimisation (local/global approaches, History Matching etc.) using Albedo, SCF and SWE data. The fifth, optional, part is to explore Coupled Model simulations with the use of the Coupled LMDZ -ORCHIDEE model (AMIP type simulation: fixed SST, SIC) and exploring historical simulations to analyse the impact of the “improved snow model” on surface-atmosphere feedbacks.

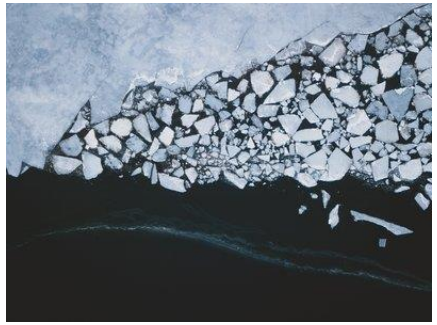
Progress to date:

- The work performed during this first year allowed to progress both, on the analysis of the CCI-Snow products (SCFV, SCFG and SWE) and on the assessment of their potential to improve the modelling of the snow cover fraction (SCF) and snow albedo in the ORCHIDEE Land Surface Model.
- A new calibration protocol was set up to revise the albedo and SCF parameterizations based on the assimilation of Albedo, SCF and SWE observations. The new Plant Functional Type maps derived from the CCI MRLC project by Harper et al., 2022 will be used in the next steps.

Results and conclusions

Will be provided once ready.

CMUG – Scientific Study WP5.7



Study WP5.7 Ice Sheets and Atmospheric Drivers

- This Study is led by Ulrika Willén from SMHI. Additional contributors to this Study are Ruth Mottram and Shuting Yang from DMI.
- The main CCI ECVs used in this Study are Land Surface Temperature, Total Column Water Vapour, Cloud, and Snow.
- It is estimated that this Study will run from February 2024 until August 2025.

Description

The scientific questions this Study aims to address include:

- Can regional/global climate models accurately represent the atmospheric and surface processes affecting the ice-sheets?
- Do the models capture the variability of the ECV's, and the albedo and emissivity feedbacks over the ice sheets?
- Where, when and why do the surface mass (energy) balance of the models' processes perform least and most well?
- Which ECV's show the most important biases affecting the surface mass budget estimates from regional/global climate models?
- Can the metrics be used for observational based model selection to reduce the spread of the ice sheet contributions to the future sea level rise?

Mottram et al. (2019) showed mass change time series for the entire Greenland Ice Sheet generated by DTU and TUDR and inter-comparison of mass change from GRACE (Greenland Ice Sheet CCI GMB product) and two regional climate models (HIRHAM5 and RACMO2.3) for different drainage basins and the entire Greenland Ice Sheet. This Study plans to repeat this type of inter-comparison for SMB and for the observed Surface Elevation Changes (SEC) for the whole basin and the sub-basins, comparing the observed variability with the regional models Surface Energy Balance (SEB) and the individual components (SWN, LWN, LE, and H) for Greenland and Antarctica.

Progress to date:

- Study kick-off Integration Meeting (Nov 2023)
- Attended EU Hybrid event (Jan 2024), presenting results from OCEAN ICE project
- Co-authored paper (Tian et al., 2024) (Mar 2024)
- PolarRES climate simulations ready (Apr 2024)
- PolarRES workshop (Jun 2024) where some ESA-CCI evaluations were made
- Greenland field campaign (Jun 2024)
- Water Vapour, Clouds, LST, Greenland Ice Sheet GMD and SEC, ECVs analysed at SMHI (Jun 2024)
- Analysis will be ongoing of new regional climate model simulations (Aug 2024)

Results and conclusions

Will be provided once ready.

CMUG – Scientific Study WP5.8

Study WP5.8 Using Machine-Learning to Evaluate and Understand our Capability to Model Tropical Wetland Methane Emissions

- This Study is led by Rob Parker and Cristina Ruiz Villena from NCEO (University of Leicester). Additional contributors to this Study are Nic Gedney from the Met Office and Paul Palmer from the University of Edinburgh.
- The main CCI ECVs used in this Study are Greenhouse Gas (methane), Land Surface Temperature, Soil Moisture, Land Cover, and possible Vegetation.
- It is estimated that this Study will run from January 2024 until July 2024.

Description

The models used are JULES (land surface) and GEOS-Chem (atmospheric). This study aims to develop an emulator for JULES wetland methane, use its explainability to show which factors matter in the model, drive the emulator with CCI Earth Observation data to generate wetland fluxes and compare those to a methane inversions performed on GOSAT/TROPOMI ESA CCI data. Current ensembles of JULES simulations with different driving data, temperature dependency, vegetation and wetland masks show massively different methane fluxes. This Study aims to address this.

Progress to date:

- Produced a large ensemble of JULES land surface model simulations with varying characteristics and configurations, aimed at sampling the key uncertainties in the processes leading to wetland methane production (such as the temperature sensitivity of the emissions).
- Taken those JULES simulations and begun developing machine-learning based emulators, first aiming to reproduce the simulated wetland extent and then ultimately the wetland methane emissions. This development work has consisted of exploring a range of possible configurations for the emulator that take different combinations of inputs and exploring which prove most capable in reproducing the simulations.

Results and conclusions

Will be provided once ready.