ESA Climate Change Initiative
Programme Extension Phase 1

Climate Modelling User Group

Proposal of work

Technical

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1 Introduction

As part of the ESA Climate Change Initiative (CCI) Phases 1 and 2, the Climate Modelling Users Group (CMUG) has worked for seven years on defining user requirements, assessing precursor and CCI climate datasets, and promoting the CCI datasets to the climate research and modelling community. To date, CMUG has achieved success over this period leading to an increasing awareness of the CCI and CMUG activities in the international satellite observations and climate modelling and research communities. As a result, the ESA Climate Science Advisory Body has strongly endorsed the continuation of the CMUG into CCI+ to build on its success in Phases 1 and 2.

CMUG is a unique group that helps reduce the gaps between the modelling and observational communities – something realized by the World Climate Research Programme (WCRP) as one of the impediments to progress in climate research. CMUG ensures that the CCI data products are developed and provided in a form most useful for climate analysis and modelling work and that they are widely promoted within the climate research community.

This proposal is in response to the ESA statement of work CCI-PRGM-EOPS-SW-17-0053 for CMUG in CCI+.

1.1 Understanding of the requirements

The main goals and activities of the CMUG Phase 2 proposal are described in this section.

1. To carry out a more extensive (than was possible in Phases 1 and 2) ***independent* assessment of the CCI datasets.** This includes comparisons with precursors, impacts in coupled climate modelling through specification of boundary conditions, assimilations in atmospheric, land or ocean models and reanalyses, evaluations against existing reference data and benchmarking of Earth System Models (ESMs) etc. Independently assessing the Climate Data Records (CDRs) generated by the CCI teams is judged to be a valuable activity as it may be not all the problems associated with the datasets are identified by the CCI teams themselves. In some cases the CMUG has access to more ways of assessing CDRs than is available within the teams. The CMUG will continue to provide **feedback to CCI teams** on how to improve their datasets for climate model users in terms of the fidelity of their own datasets (parameters and uncertainty estimates) and their cross-ECV consistency.

2. **CMUG will perform two main assessments**. One in Years 1 and 2, based on the CCI products available at that time, and one at the end of Year 3 on the newly available CCI+ products available at that time. By conducting new, more rigorous studies on updated versions of existing CCI datasets CMUG will comprehensively quantify, (i) firstly the quality and value of CCI products with respect to current the state of the art datasets, and (ii) the additional improvements made by CCI phase 2 projects with regard to the performance and quality at the end of CCI phase 2. The assessments fall broadly into one of two categories (a) understanding ECV quality and consistency through applications with models and reanalyses, and (b) studies using available Coupled Model Intercomparison Project (CMIP) data.

3. **Benchmarking models with ESA CCI data in the era of CMIP6**: This activity will engage with international Model Intercomparison Projects (MIPs), other projects (e.g. the EU project CRESCENDO), and Obs4MIPs to foster the use of ESA CCI data in the routine evaluation and benchmarking of Earth System Models (ESMs). Specific tools will be developed for ease of exploitation of CCI datasets for climate model benchmarking purposes. By doing so we aim to demonstrate the merit of CCI datasets for CMIP model benchmarking and provide a way forward to make CCI datasets used in the frame of CMIP6 and other MIPs. This activity will also engage with the Program for Climate Model Diagnosis &

Intercomparison (PCMDI) and NASA JPL to encourage the CCI teams to host appropriate CCI datasets on the Obs4MIPS site to promote their use to climate modellers. However, it is expected that the preparation of the individual ESA CCI datasets in CMIP compliant format for Obs4MIPs as well as the corresponding technical notes for Obs4MIPs are created and submitted by the individual ESA CCI teams. The ESMVal tool being further developed by CMUG will be used for some of the assessments proposed.

4. Climate services are now being implemented nationally, regionally (e.g. Copernicus) and globally (under the WMO's Global Framework for Climate Services, GFCS). The **interface** of the CCI satellite datasets to these global and regional climate services will be defined as these services are now being operationally implemented. The CMUG activity for understanding user requirements will be driven in part by the needs of Copernicus Climate Change Service (C3S) users, who are a diverse group but with clear requirements for climate data and information.

5. To document how **the uncertainties** provided with the ECV datasets are used in the various applications demonstrated by CMUG and to assess if they are useful for climate modelling purposes. Recommendations on the use of the uncertainty information provided within the CCI datasets will be provided to the modelling community. The uncertainty information provided in the data can be used in a number of different ways:

- Provide values to use in data assimilation applications both for reanalyses and earth system models
- Provide bounds to compare with model simulations to determine if differences are significant. Metrics developed within ESMVal will make use of the uncertainties
- To provide an ensemble of realistic values for input to an ensemble of climate model simulations
- To assess if any long term trends seen in datasets are genuine

6. **Outreach and coordination** is an important element of the CMUG work once the CCI datasets become available. Links to coordinate/collaborate with other programmes/organisations (e.g. C3S, ERA5, CRESCENDO, EUSTACE, FIDUCEO, EUMETSAT and CMSAF) and promoting the work to other bodies (CEOS Climate WG, WCRP-DAC (WDAC), CMIP6, IPCC, GCOS, WCRP, GEWEX, NOAA, NASA, etc.) and to the Climate Modelling Communities will be maintained. One element will be to contribute to the ESA CCI web portal by providing the climate modelling perspective and advice on its development. (See section 3.6). Another element will be to act as a coordinating facilitator for the Climate Science Working Group of CCI+ including organising **workshops** for the CCI CRG (Climate Research Group) teams and small focused workshops for climate modellers outside the CCI along specific themes, especially if aligned to a larger scientific goal or research theme. Coordination with other CCI teams will be met by CMUG including the Data Portal, and Data Toolbox projects as well as other CCI working groups such as the SEWG and DSWG.

The work is summarised along with relevant information (ECVs covered, Deliverables, etc.) in Section 3 of this document.

1.2 CMUG organisation

The current CMUG partners (Met Office, ECMWF, MétéoFrance, MPI-M, DLR, SMHI, BSC, IPSL) all confirm willingness to continue working in CMUG.

CMUG will maintain its expertise in climate model benchmarking and its link to international climate model intercomparison projects (e.g., CMIP6) through DLR. The lead in DLR is Dr Veronika Eyring, who is Chair of the CMIP Panel and a member of the WGNE/WGCM Climate Model Metrics Panel, the

WCRP Data Advisory Council's (WDAC) Observations for Model Evaluation Task Team, and the Scientific Steering Committee of the IGAC/SPARC Chemistry-Climate Initiative (CCMI).

SMHI brings its expertise on cloud, radiation and land surface modelling and climate analysis into CMUG. SMHI has strong links to the regional climate modelling community via the WCRP CORDEX (Coordinated Regional Downscaling Experiment) programme and will perform regional simulations with and comparisons to CCI data.

IPSL will join as one of the main climate modelling centres in Europe with leading expertise in the fields of biogeochemical cycle modelling and observation, past and future climate studies, isotopic markers in the environment, atmospheric measurements, and modelling of atmospheric processes in the Earth's hydrological cycle.

The **Met Office** proposes to continue to lead the CMUG and provide the project management support as in Phases 1 and 2. It also works in the area of Climate Services and development of such services.

BSC will bring its expertise on seasonal forecasting, model initialisation and uncertainty representation to the WPs.

MPI-M has experience in climate modelling activities and will provide inputs to many of the work packages related to climate modelling and assessment of uncertainty of the CDRs produced by the ECV consortia.

Météo France has a long experience in climate modelling activities at the global and at the regional scale with a wide range of expertise to participate to dedicated assessments using the CCI datasets.

ECMWF provides an important role in both providing datasets for use by the ECV consortia and assessing the suitability of the CDRs produced for global atmospheric and oceanic reanalyses. ECMWF, through its work on the CMF (Climate Monitoring Facility) and partnerships with EUMETSAT, ESA, the EU and the European Science base, has the right links to promote CCI ECVs.

The expertise contracted within each partner has necessarily changed to better optimise the coverage of the ECVs. An analysis of the expertise in each group is presented in Figure 1 as indicated by the models each partner runs.

Institute	Model name	Model components					
		ATM	OCEAN	LAND	CARBON BUDGET	CHEM	CMIP5?
Hadley Centre	HadGEM2-ES	◆	◆		◆	◆	Yes
	UKESM-1	◆	◆		◇	◇	
	GLOSEA		◆				
	JULES			◆	◆		
	HadSST		◆				
MPI-M	MPI-ESM, JSBACH			◆	◆		Yes
	MPI-ESM, MPIOM		◆				
	MPI-ESM, HAMOCC		◆		◆		
	MPI-ESM, ECHAM	◆					
MétéoFrance	MOCAGE	◆				◆	
	ALADIN-CLIMAT-V5	◆					
	NEMO						
	CNRM-CM3.3	◆	◆	◆			Yes
IPSL	ORCHIDEE			◆	◆		
	ISPSL-CM5	◆	◆	◆	◆	◆	Yes
DLR	EMAC	◆	◆			◆	
SMHI	EC-Earth	◆	◆	◆		◇	Yes
	RCA	◆	(◆)	◆			
	HARMONIE	◆		◆			
ECMWF	ERA	◆	◆	◆		◆	
	MACC-II					◆	
	ORA		◆				

Figure 1: Models run by each CMUG partner.

2 Activities

2.1 Task 1: Meeting the evolving needs of the climate community

Responsible partners: All to contribute, Met Office to co-ordinate [5.4 PM]

During previous CMUG work the requirements of the climate modellers were sought and a document was prepared. This provided input to the CCI teams who subsequently had to develop their own requirements.

For this proposal the requirements of the modellers will be revisited to ensure they reflect the latest status and the phase 1 document will be updated. In particular regional modelling and its coordination (e.g. through Euro-CORDEX) has developed and its requirements need clearly defining. Current and planned EU projects (FIDUCEO, IS-ENES3, etc.) will also have an impact on the requirements and the interface of the CCI datasets to the Copernicus Climate Change Service will also dictate certain requirements that need to be documented, which could be done through their precursor projects. Another European programme with a climate research need is the EEA's ClimateADAPT and this should also be canvassed. It would also be useful to learn about the requirements of other international initiatives and programmes outside of the EU such as CORDEX and SOOS. The report will be input to the GCOS and CEOS teams who own the requirements for climate datasets.

A side meeting with the CEOS-WG on climate will be organised to provide input to a report on the needs of climate research for Earth Observations. It will provide input to a document on the current state of the infrastructure for climate models to exploit satellite data and how it might be improved.

One of the needs of the climate research community stated previously by CMUG was provision of the data in a standard format (NetCDF version 4.1 or higher) although exceptions were recognised (for example the glacier mapping community who do not routinely use this format). This proposal is contingent on the CCI data being made available in NetCDF format and also meeting other requirements, such as with Obs4MIPS compatibility. This is to allow ready access by CMUG and other climate researchers to the data.

The work is summarised along with relevant information (ECVs covered, Deliverables, etc.) in Section 3 of this document as WPs 1.1 and 1.2.

2.2 Task 2: Providing integrated view and feedback to ESA and CCI teams

Responsible partners: All to contribute, Met Office to co-ordinate [8.4 PM]

This task will provide **independent** feedback to both ESA and the CCI teams on the assessments of the CCI datasets and the associated documentation in the form of reports and presentations at the collocation meetings.

Firstly a scientific impact report of the achievement of phase 2 including the impact of the datasets available at the end of phase 2, where assessed by CMUG.

Secondly the CMUG data forum, for providers and users, will continue to gain feedback on applications of ESA CCI data products providing valuable insights to ESA and the CCI teams. This will be

complementary to the information on data sets and their use that is collected by the CCI Data Portal and CCI Tool Box projects.

Thirdly a report on the technical aspects of the CCI datasets as they become available will be provided. This will provide a critique of data formats, documentation, processing chain, provision of uncertainties, validation practices, etc.

The work is summarised along with relevant information (ECVs covered, Deliverables, etc.) in Section 3 of this document as WPs 2.1, 2.2 and 2.3.

2.3 Task 3: Assessing consistency and quality of CCI products across ECVs

Responsible partners: Met Office, ECMWF, Meteo France, DLR, BSC, and IPSL to contribute, Met Office to co-ordinate [62 PM]

Tasks 3, 4 and 5 are the three major scientific research and assessment tasks for CMUG, which are addressed in this proposal by WPs 3, 4 and 5. Together WPs 3 and 4 comprise over 50% of the budget and research time. WP3 directly addresses the requirement to assess the consistency and quality of CCI products across ECVs, and it does this through the use of climate and reanalyses modelling studies in a variety of experiment designs and model configurations. The majority of existing ECVs are covered and the new CCI+ ECVs are included except for Lakes and Permafrost, both of which are included in the Optional Extras. An overview of the key features of WP3 is given in Table 1.

WPs 3.1 to 3.6 cover the Terrestrial domain with a combination of current and new ECVs in four experiment types (reanalysis, benchmarking, statistical analysis, process analysis) involving six terrestrial CCI and CCI+ ECVs. These involve a set of carefully designed individual investigations, using a range of techniques, which complement each other and will provide a clear assessment of the consistency of multiple land-surface ECVs. WP3.4 which includes work on observational uncertainty at climate model scales will aim for those results to feed in to the other WP3 experiments where appropriate.

WPs 7 to 9 focus on the ocean domain and include a range of experiment types (reanalysis, hindcasts, assimilation, process study) covering six oceanic CCI and CCI+ ECVs. The first two will provide an assessment of the importance of CCI+ ECVs in improving observations of sea-ice and the subsequent impact on seasonal to decadal climate predictions. WP3.9 extends this by assimilating ocean colour ECV data to assess its ability to constrain important biophysical processes and the implications for ocean heat uptake and also enabling an assessment of the consistency of the other ECVs used.

WPs 3.10 to 3.12 focus on the atmosphere domain and include a range of experiment types (reanalysis, assimilation, process study, statistical analysis) covering two CCI and CCI+ ECVs. The CCI data is used to both constrain dust simulation in a model, and in the other experiment the CCI data is assimilated at a regional scale. The research in WP3.12 is unique as it aims to include CCI aerosol data in to reanalyses over a longer time span than is currently available. To achieve this the WP was allocated more than the maximum of 4 stated in the RfQ.

The work is summarised along with relevant information (ECVs covered, Deliverables, etc.) in Section 3 of this document as WPs 3.1 to 3.12.

WP 3						
3.1	Consistency between CCI LST, SM product and LAI products	Météo France	Reanalysis, benchmarking	4	LST, SM	C3S LAI
3.2	Consistency between CCI Snow, SM product and LAI products	Météo France	Reanalysis, benchmarking	4	Snow, SM	C3S LAI
3.3	Assess the added value of HRLC in the SM and LAI representation and analysis	Météo France	Reanalysis, benchmarking	4	HRLC, SM	C3S LAI
3.4	Propagation of CCI(+) observational uncertainties to climate models scales	BSC	Statistical analysis	4	SM, Fire, LST	
3.5	Document SM-atmosphere feedbacks in transition regions (temperature and ppts)	IPSL	Process analysis	4	SM,LST	turbulent fluxes, radiation, air temp. Precipitations
3.6	Better constrain evapotranspiration at the scale of climate model	IPSL	Process analysis	4	SM, Snow, LST, HRLC	LAI , flux, radiation, air temp
3.7	Production and evaluation of a high-resolution sea-ice reanalysis	BSC	Reanalysis	8	SI conc, SI thick, Salinity, SST	
3.8	Evaluation of the impact on skill of HiRES-SIR on seasonal prediction	BSC	Hindcast	4	SI conc, SI thick, Salinity, SST	
3.9	Biophysical feedbacks in the global ocean	Met Office	Assim, reanalyses, process	3	OC, SST, SI, Sea level, Salinity	Temp, salinity, carbon dioxide, ocean heat content
3.10	CCI/CCI+ data to constrain mineral dust simulations	BSC	Assimilation, stat. analysis	4	Aerosol dust, HRLC	
3.11	Dust reanalysis at the regional scale	BSC	Assimilation, stat. analysis	4	Aerosol dust, HRLC	
3.12	17-year long Global Aerosol Reanalysis	ECMWF	Reanalysis	11	Aerosol	

Table 1: Main features of WP3 on assessing consistency and quality of CCI products across ECVs.

2.4 Task 4: Exploiting CCI products in MIP experiments

Responsible partners: Met Office, BSC, MPI-M and IPSL to contribute, Met Office to co-ordinate [32 PM]

Task 4 is concerned with exploiting CCI products in MIP experiments, with eleven experiments (WPs 4.1 to 4.11) proposed by four CMUG partners. These are all focused studies which mostly rely on existing model output for the research instead of conducting new model runs. Many of the current CCI ECVs are included and five of the new CCI+ ECVs are planned for use, except for Lakes and Permafrost which are included in the Optional Extras. An overview of the key features for WP4 is given in Table 2.

WPs 4.1 to 4.6 are statistical analyses that evaluate facets of model behaviour in representing climate. They carefully target individual elements of uncertainty derived either from the climate system (e.g. internal variability, system memory) or the observations (e.g. levels of processing or scales of averaging) and then provide a framework for combining these. There is an emphasis on characterising and understanding uncertainty in these experiments with the aim of informing the work in WP5 on the ESMValTool to include uncertainty in its evaluation process for the metrics of the ECVs in these experiments.

WP 4.7 addresses the important issue relevant to the component of CMIP6 focusing on decadal prediction by applying multiple CCI/CCI+ atmospheric and marine ECVs to generate an assessment of the skill in decadal forecasting systems. WPs 4.8 to 4.10 focus on the application of CCI/CCI+ terrestrial ECVs to evaluate the physical basis of representation of biophysical land surface processes and assess their simulation in earth system model components. They will use data from the CMIP5 archive (also CORDEX where relevant and CMIP6 if available in time) to understand plant climate interactions, their representation in climate models and to evaluate model performance and suggest areas for future model development. Use of multiple ECVs and other products will also facilitate an assessment of the consistency of CCI products with other satellite data.

WP 4.11 will build on the process analysis undertaken in Task 3 and will apply several ECVs and other datasets to identify the drivers of biases in the state of the terrestrial surface and the fluxes generated by its interaction with the atmosphere. This will provide an assessment of the value of combining multiple ECVs with other data sources to assess the quality and identify areas for improvement in the atmospheric model component of CMIP.

The work is summarised along with relevant information (ECVs covered, Deliverables, etc.) in Section 3 of this document as WPs 4.1 to 4.11.

WP4	EXPLOITING CCI PRODUCTS IN MIP EXPERIMENTS					
4.1	Evaluation of modeled system memory	MPI-M	Statistical analysis	3	Salinity, Snow, LST, SST, SI	
4.2	Evaluation of model results considering observational uncertainty	MPI-M	Statistical analysis	3	Salinity, Snow, LST, SST, SI	
4.3	Evaluation of model results considering the abstraction level of observt'l products	MPI-M	Statistical analysis	3	Salinity, Snow, LST, SST, SI	
4.4	Optimal spatial and temporal scales for model evaluation	MPI-M	Statistical analysis	3	Salinity, Snow, LST, SST, SI	
4.5	Evaluation of model results considering internal variability	MPI-M	Statistical analysis	3	Salinity, Snow, LST, SST, SI	
4.6	Evaluation of model results considering a combination of sources of uncertainties	MPI-M	Statistical analysis	3	Salinity, Snow, LST, SST, SI	
4.7	Skill assessment of the DCPP decadal predictions	BSC	Skill analysis	4	Sea Level, SST, Clouds	
4.8	Thresholds in LST to vegetation type, productivity and moisture stress	Met Office	MIP process analysis	3	AGBiomass, LST, SM, LC	Temperature, Precipitation, FAPAR, LAI
4.9	Use CCI+ LST to evaluate model LST versus near surface temperature relationships	Met Office	MIP process analysis	3	LST, AGBiomass, HRLC	Temperature
4.10	Comparison of CCI data in vegetation study with other satellite data and LS models	Met Office	MIP process analysis	3	AGBiomass, LST, SM, LC	Temperature, Precipitation, FAPAR, LAI
4.11	Land-surface interaction related biases in AMIP	IPSL	MIP process analysis	4	LST , Snow, SM	Air temp, turb. fluxes (Jung, Gleam,) meteo analysis, MODIS data, CERES rad. fluxes, SM (SMOS, Gleam)

Table 2: Main features of WP4 on exploiting CCI products in MIP experiments.

2.5 Task 5: Adaptation of community climate evaluation tools for CCI needs

Responsible partners: DLR 13 PM, BSC 4 PM, MetO 4 PM, SMHI 3 PM, ECMWF 4 PM [Total 28 PM]

Task 5 is addressed by CMUG WP5 which is in two parts: the first part (WPs 5.1 to 5.5) incorporates CCI ECV datasets in to the ESMVal Tool, and then uses that tool to evaluate climate models; and WP5.6 which develops the CMF at ECMWF by incorporating CCI ECV data sets in to it.

2.5.1 ESMValTool

Note: The description of ESMValTool work includes Optional Extras, see WP Description (Section 3.5) for more details.

The aim of WP 5.1 is to fully exploit ESA CCI and CCI+ data in the context of Earth system model (ESM) evaluation. The ESMValTool is a standardized community based evaluation and benchmarking tool that will be used for CMIP6 model evaluation and analysis. The goal 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.

In WP 5.1 we will release the enhanced version of the ESMValTool from the project including full documentation of the code for users and developers. This task will also align work in ESA CMUG with that in other projects that support the ESMValTool development in order to fully exploit synergies. In WP 5.2O (optional) we will integrate methods developed in Task 3 on observational uncertainty and internal climate variability into the ESMValTool to ensure that these methods are available for the evaluation of CMIP6 models in Task 5.4. WP 5.3 / WP 5.3O will integrate new versions of ESA CCI/CCI+ data into the tool and will develop new tailored diagnostics and performance metrics. WP 5.4 / WP 5.4O will then use the implemented diagnostics to evaluate new simulations from the CMIP6 ensemble with ESA CCI and CCI+ data. WP 5.5O will enhance the ESMValTool so that it can be applied to regional models and will evaluate CORDEX simulations.

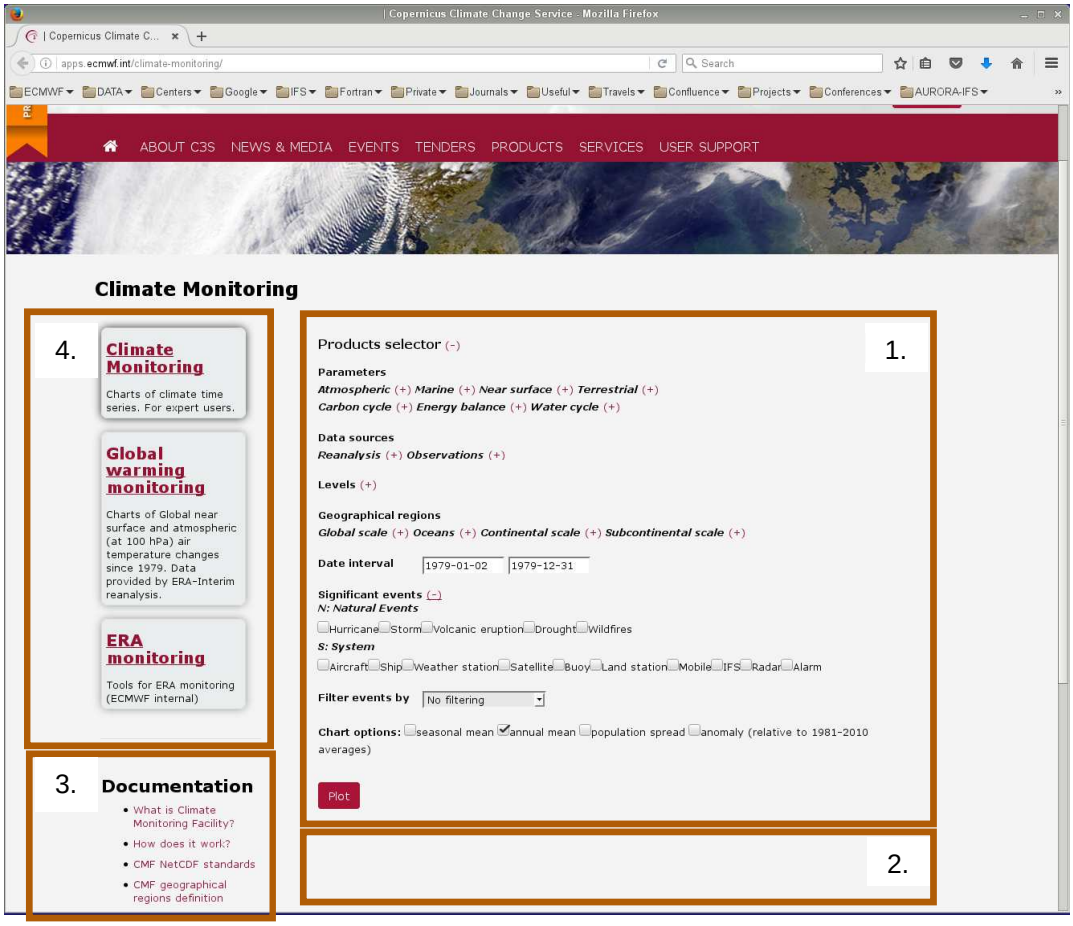
The results of WP 5 will lead to an enhanced use of ESA CCI/CCI+ data for climate model evaluation in CMIP and aim to make a substantial contribution to the analysis of CMIP6 data and to IPCC AR6.

Note: It is required that the ESA CCI and CCI+ datasets will be provided by the ESA CCI teams as best estimate plus uncertainty information in a format compliant with Obs4MIPs/CMIP standards ideally accompanied with a technical note similar to the Obs4MIPs descriptions.

2.5.2 Adaptation of the CMF and CMF database

As part of the CCI/CMUG contract and in collaboration with the Copernicus Climate Change Service (C3S), ECMWF has developed a monitoring tool, the Climate Monitoring Facility (CMF), to compare a variety of ECVs from observations and reanalysis products. The tool is designed to monitor the low-frequency temporal variability of those fields as provided through, for example, their monthly mean over a large selection of available areas and regions. To efficiently render an image with a response time of the order of a second, an ad-hoc data-base (here referred to as the CMFDb) was designed and populated with a large number of variables (>100) from reanalyses and available equivalent ECVs derived from CCI. Care has been taken in defining the metadata associated with each data record so that users can distinguish between sources and, for a given source, between different versions of the same product. The CMFDb also includes observational uncertainties that can be compared with field anomalies to identify systematic bias in the observations. The front end of the CMF is available on-line at the following link: http://apps.ecmwf.int/climate-monitoring/.

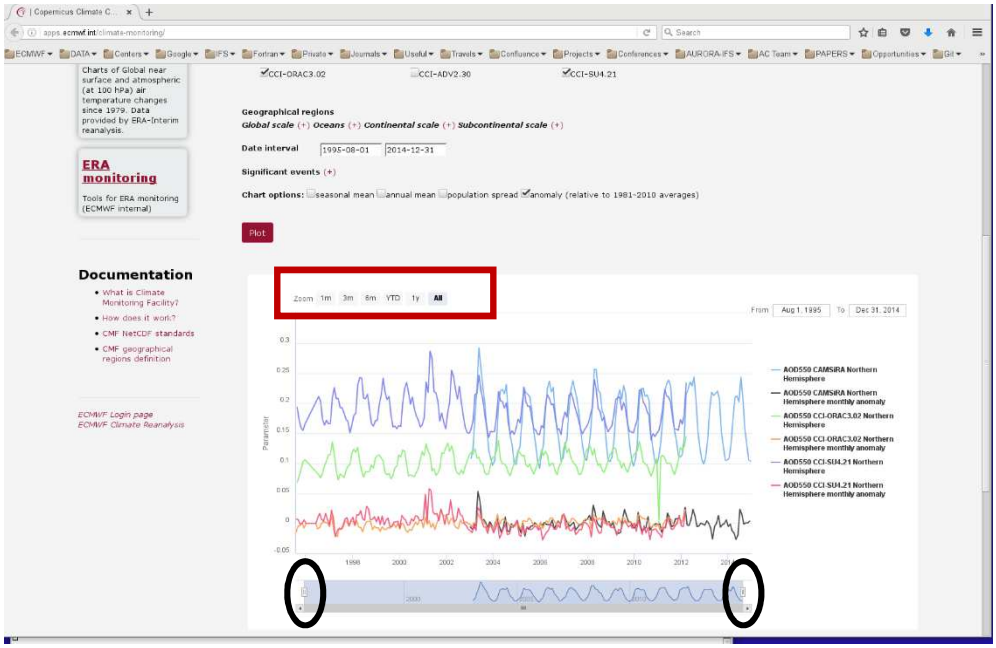
The proof of concept front end is now linked under the C3S web-page and appears to users as an easy to navigate user interface:



The user interface includes four areas (referring to the numbered boxes):

1. Selection panel: here users can choose the parameter(s) they are interested in (to facilitate the search these are grouped per domain and also per biogeochemical cycle), the source (reanalysis and observations), the vertical levels (available for 3D fields only), the geographical regions (also grouped for easy search), and the temporal coverage. The CMF is linked to a significant event database that can also be added in the selection. Additional statistics (annual or seasonal means, anomalies, etc.) can also be selected at this stage to be over plotted to the standard timeseries.
2. Plot area: this is where the plot is rendered.
3. Documentation area: it includes a user guide to explain what the CMF is and works, a summary of the data standards, and the definition of the geographical areas.
4. C3S link area: this area lists additional monitoring page of C3S.

The following figure shows, as an example, the time series of AOD at 550nm and their anomalies from the CAMS Interim Reanalysis and two CCI algorithms.



From the plot area, it is also possible to change period, clicking on one selection in the red box or by shifting the cursors (in the black ovals) with the mouse.

During CCI+, work is envisaged to maintain and extend the CMF Db to the new ECVs and the corresponding reanalysis fields as appropriate, and complete the existing datasets where their temporal coverage has been extended or new reprocessed versions become available. The following activities are needed:

- Download the original CCI and reanalysis datasets not available in the CMFDb for both the old and new ECVs as appropriate.
- Write software to process the new ECVs in a suitable form (both observations and reanalyses).
- Define database metadata for new ECVs (both observations and reanalyses).
- Data processing, and quality control.

2.6 Task 6: Coordination and outreach

Responsible partners: Met Office, ECMWF, MPI-M, Météo France, IPSL, SMHI, BSC
[All partners = 8.9 PM]

2.6.1 CMUG workshops and events

A vital exchange of ideas and experiences in the various climate research groups is the CCI is essential for a successful exploitation of the different CCI ECV datasets. **It is proposed to continue the Integration meetings hosted by CMUG annually** (as in Phase 2) with the aim of integrating more of the Climate Science Working Group activities. These have proven to be useful meetings to exchange experiences in the use of and generation of the CCI datasets during phase 2.

A dedicated **user event to engage climate modellers across Europe**. The user event will be open for all potential users of CCI datasets. CMUG aims at organizing such an event in the middle of phase-2 when mature phase 1 datasets are available.

The objectives of the event would be

- Bring together data experts (ECV data producers) and data users to better understand the characteristics of the datasets, their limitations and potentials as well as their potential usage

- Foster a scientific exchange about the ECV itself and different perspectives on the topic (observation <-> modelling)
- Provide a forum for the development of ideas for new, joint (cross ECV) studies

The workshop should also involve the wider climate research community and not only groups directly involved in the CCI and so will be organized as a side event within a conference (e.g. EGU, EUMETSAT conference, ECAC) or meetings of H2020 projects like IS-ENES3. One possibility is for a side event at EGU 2019.

A workshop in the third year of CMUG phase 2 is also proposed to develop a strategy with GCOS and CEOS on the observational needs for climate monitoring and how to exploit the new datasets coming from the Sentinel series of satellites. This will build on experience gained in the CCI phase 1 and 2 activities. A Foresight document will result from the participants of the workshop.

2.6.2 Publications

CMUG will publish the results of its work on CCI datasets, providing peer reviewed validation of the work upon which the integrity of the datasets is based and exposure of the CCI within the climate research community.

CMUG will encourage CRGs to contribute to a **CCI special issue**, focusing on the exploitation of CCI data products. This special issue will be initiated by CMUG members. Members of the editorial board shall consist of CSWG scientists, CMUG scientists as well as ESA. The special issue might be published approximately a year after the first CRG workshop has taken place. An open access online journal will be the preferential choice for such a publication due to the possibility of incremental special issues, which avoid large delays caused by single papers. Publications should be mindful of the IPCC WG1 deadline which is (approximately) January 2020.

2.6.3 Coordination with other activities

CMUG will ensure it works alongside related activities from the EC, EUMETSAT, GCOS or other international initiatives and research projects. The consortium represents the major climate modelling centres in Europe and are linked into all of the major networks of climate modelling activity, both in Europe and worldwide.

CMUG will work with the CCI Knowledge exchange team (and the experts it employs such as Planetary Visions) to ensure effective communications and synergies with special events (e.g. Living Planet, EGU) to avoid gaps and duplication of effort.

CMUG will also continue to engage with European funded research projects, including those which work in the area of Climate Services, and would participate in C3S meetings as appropriate (for example the C3S GA in September 2018, Berlin). The timing and interaction of some meetings is given in the Management section of this Proposal.

Obs4MIPS is creating a one stop shop for satellite climate datasets and the continued inclusion of the CCI datasets relevant to climate modelling should be a high priority for the CMUG. Some promotion on this has already started in phase 1.

A list of the organisations and projects with potential for CMUG collaboration are given in Table 3. Many of these activities were started in CMUG phase 1 of the CCI.

NAME	DESCRIPTION	CMUG COORDINATION ACTIVITY
ACTRIS	Aerosols, Clouds, and Trace gases Research InfraStructure Network	CMUG will continue contact with this group.
CEOS	Committee of Earth Observation Satellites	Continue liaison established by CMUG in Phase 1
CFMIP	Cloud Feedback Model Intercomparison Project	Continue link established by CMUG in Phase 1 IPSL and SMHI have involvement in this project.
CIRCLE-2	Climate Impact Research response Coordination for a Large Europe	CMUG will initiate contact with this group.
Climate-ADAPT	Climate information and data portal for the EEA and EC	Met Office works on the EEA ETC which has a WP supporting ClimateADAPT
CLIVAR	Variability and predictability of the ocean-atmosphere system	ECMWF participates to this project. Météo-France participates to the MedCLIVAR SSG.
CCMI	Chemistry-Climate Model Initiative	DLR is contributing model output and is represented in the SOC. Météo-France contributes to model results in this project.
CMIP	Coupled Model Inter-comparison Project	DLR CMUG member is Chair of the CMIP Panel. Met Office, MPI-M, IPSL, SMHI and Météo-France have all contributed model results to this project.
CORDEX	Coordinated Regional climate Downscaling Experiment	SMHI coordinates the regional modelling activities. Partners include IPSL, Météo-France contributes to model results in this projects and coordinates Med-CORDEX.
CRESCENDO	H2020 project for improving climate model processes	Met Office, SMHI, IPSL and MPI-M are partners
Cryoland	Copernicus Service Snow and Land Ice	CMUG will continue contact with this group.
EC-EARTH	European climate model development project	Continue links established by CMUG in Phase 1. SMHI is a partner in this project.
ECA&D	European Climate Assessment & Dataset project	Météo-France provides datasets for this project.
ECOMS	European Climate Observations, Modelling & Services	CMUG will continue contact with this group.
ESGF	Earth System Grid Federation	Continue link established by CMUG in Phase 1
EUCP	European Climate Projections for Climate Services	Met Office is lead partner in this project.
EUMETSAT CMSAF	European Meteorological Satellite climate monitorinf satellite application facility	Met Office is a partner of the CMSAF.
Ex-Arch	G8 initiative for Exa scale data archives	DLR collaborates with GFDL for the ESMValTool development. IPSL has involvement in this project.
EUSTACE	European project for surface temperature	Met Office is the lead partner in this project.
FIDUCEO	EC project for quality in FCDRs	Met Office is a partner

NAME	DESCRIPTION	CMUG COORDINATION ACTIVITY
GCOS	Global Climate Observing System	R. Saunders represents CCI at AOPC.
GCPC	Global Precipitation Climatology Project	CMUG will initiate contact with this group.
GEOSS	Group on Earth Observations	CMUG will initiate contact with this group.
GEWEX	Global Energy & Water Exchanges Project	Interactions with the GEWEX project team at various meetings. SMHI will contribute to GVAP
IPCC	Intergovernmental Panel on Climate Change	Met Office, DLR, MPI-M, SMHI, BSC, IPSL are involved in this initiative
IS-ENES3	Infrastructure for the European Network of Earth System Modelling	Continue link established by CMUG. Met Office, IPSL, Meteo France, DLR and SMHI are partners
JPI Climate	Joint Programming Initiative on Climate	Continue link established by CMUG in Phase 2.
JRA	Japanese Reanalysis Project	ECMWF and JRA have long working relationships that include a visiting scientist programme.
KIC	Knowledge Innovation Communities	IPSL is a partner in this project. Météo-France is partner in the KIC-Climate.
MIKLIP	German model system for decadal forecasts on climate and weather, including extreme events	MPI-M is leading the MIKLIP coordinating the MIKLIP consortium. MPI-M and DLR CMUG scientist are also directly involved in MIKLIP.
Obs4MIPs	Observations for Model Intercomparison Project	DLR is part of the WCRP Data Advisory Council's (WDAC) Observations for Model Evaluation Task.
PRIMAVERA	H2020 project for high resolution global modelling	Met Office, SMHI, IPSL and MPI-M are partners
PROVIA	UNEP initiative for Programme Research on Climate Change Vulnerability, Impact and Adaptation	CMUG will maintain contact with this group.
RCMES	Regional Climate Model Evaluation System	CMUG will maintain contact with this group.
REDDAF	Reducing Emissions from Deforestation and Degradation in Africa	CMUG will maintain contact with this group.
PROVIA	UNEP Programme on Research on Climate Change Vulnerability, Impacts and Adaptation	CMUG will maintain contact with this group.
SEIS	Shared Environmental Information System	CMUG will maintain contact with this group.
SOOS	Southern Ocean Observing System	Continue link established by CMUG in Phase 1
WCRP	World Climate Research Programme	Continue link established by CMUG in Phase 1
WGCM	Working Group on Coupled Modelling	DLR CMUG member is on WGCM IPSL is a partner in this project.

Table 3. List of projects and organisations with potential for CMUG coordination activity.

2.6.4 Climate Data Forum

In addition to the CMUG website developed under Phase 1, the climate data portal and forum website will be maintained (WP2.2). The aim of this continues to be to engage with the widest possible community of climate data users and providers to promote the CCI datasets. Other experts will be engaged to maximise for users of the site the accessibility and usability of information about the data. The outreach part of CMUG will also be used to promote this to the wider user community which includes Copernicus related projects, other stakeholders (EEA, JRC) and commercial users of climate data. It will be aligned with the data projects and activities in the CCI

Web statistics, and surveys (if needed) will be collected to record the nature and volume of activity on the site, and then allow analysis to guide the future direction and content of the site. A science comms expert would attend some CCI meetings to (a) stay informed of programme developments, and (b) discuss communications objectives with ESA.

2.7 Task 7: Interface with Climate Services

Responsible partners: Met Office, ECMWF, MPI-M, MétéoFrance, IPSL, BSC, SMHI [4.8 PM]

In addition to operating within a research context, it is recognised that the CCI is also creating climate information of value to society in general, and to organisations charged with providing security and benefit to society, who will exploit the climate information which the CCI produces. The added value of CMUG is that it can provide not only high quality CCI data integrated with other climate data in a user-accessible format, such as reanalysis and the CMF, but also projections from climate models evaluated with the CCI observation datasets.

Environmental monitoring in Europe, known as Copernicus and funded by the EC and ESA, is currently being implemented through several services with an operational mandate. Notably the climate element is the Copernicus Climate Change Service (C3S), which is coordinated by ECMWF. Other services with which there is scope for CMUG to interact include the Copernicus Atmospheric Monitoring Service (CAMS) also led by ECMWF, the Copernicus Marine Environment Monitoring Service (CMES), the Copernicus Land Monitoring Service (CLMS), and the Copernicus Emergency Management Service.

These services had several precursor projects that have involved research in direct collaboration with CCI teams and CMUG members. CMUG currently has good links with all the Copernicus Services ensuring that CCI data sets are fully exploited, particularly in the context of the climate change service C3S. The programmes, projects and bodies which CMUG will need to reach to support this interface are a subset of those given in Table 3.

CMUG will liaise with relevant parties in the international and European sphere of Climate Services to ensure that the research of CMUG and the CCI is applied to best possible effect. Through effective coordination with key European bodies (EC DGs: Research, Climate Action, Adaptation, and JRC; the EEA including Climate ADAPT[1], and EUMETSAT) CMUG will demonstrate how CCI/CMUG research supports their goals.

The structure for delivering European Climate Services is now established. It is envisaged that CMUG will closely collaborate with the services in the following capacity:

- Conducting joint research with one or more of the Copernicus services so that the CCI / CMUG climate research is embedded in their work for supporting climate services.
- Advocacy to the climate modelling community who are producing climate services, about the CCI datasets.
- Consultancy or workshops for climate service users demonstrating the strength and advantages of CCI data / CMUG modelling results, and the potential for their application in climate services or other research.

[1] http://climate-adapt.eea.europa.eu/

- Using the Climate Data Forum being developed in Task 2, Deliverable 2.2 to promote the utility and application of CCI data sets to users of climate services.

Coordination with providers and users of climate services to ensure the 'joined up' perspective of observations and modelling (CCI datasets and CMUG modelling) will be realised.

It is also noted that some of the CMUG research activities (e.g. wild fires) might link or be of interest to the fire component of the Copernicus Emergency Service, operated by JRC. CMUG will be mindful to establish contact about this in the context of this WP.

The focus in WP7 is almost exclusively on the Copernicus Services. It should be noted that there are activities in relation to, for example, CEOS (Committee on Earth Observation Satellites), and GCOS (Global Climate Observing System)? In particular, CEOS has a Working Group on Climate, in charge of implementing the global architecture for climate monitoring from space. CMUG will interact with these groups as appropriate.

3 Work packages

3.1 WP1 Meeting the evolving needs of the Climate Community

WP: 1.1		Start / end	M1	M4
Title: Meeting the Needs of the Climate Community - Requirements				

CMUG participant	DLR	ECMWF	SMHI	IPSL	MeteoFrance	MetOffice	MPI-M	BSC
PM	0.25	0.5	0.15	0.25	0.05	0.5	0.5	0.5

Sum: **2.6**

Key personnel	Richard Jones, Paul van der Linden, Jean-Christophe Calvet, Veronika Eyring, Jean-Louis Dufresne, Ulrika Willén, Rossana Dragani, Francisco Doblas-Reyes, Dirk Notz

CCI+ ECVs	WV	Salin	S-State	Lakes	Snow	PF	LST	HRLC	AGB				
	X	X	X	X	X	X	X	X	X				
ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS	Gla
	X	X	X	X	X	X	X	X	X	X	X	X	X

Objectives
The aim is to gather the latest requirements from climate modellers, impact modellers, GCOS, other users and for the interface to climate services and to build on the requirements gathered previously

Scientific questions to be addressed:
1. What are the requirements for satellite CDRs for global and regional climate modeling applications 2. What are the requirements for interface to Copernicus climate services
Tasks to be performed
1. Gather feedback by various means (on-line forms, phone interviews, etc) 2. Update user requirements document from phase 1 and add regional modelling requirements and climate services requirements 3. Publish summary on CMUG web pages,
Output / Deliverables
• Report D1.1 on updated requirements • Update CMUG web pages of user requirements

WP: 1.2		Start / end	M24	M28
Title: Meeting the Needs of the Climate Community – EO for climate foresight report				

CMUG participant	DLR	ECMWF	SMHI	IPSL	MeteoFrance	MetOffice	MPI-M	BSC
PM	0.25	0.5	0.15	0.25	0.05	0.5	0.5	0.5

Sum: **2.6**

Key personnel	Richard Jones, Paul van der Linden, Jean-Christophe Calvet, Veronika Eyring, Jean-Louis Dufresne, Ulrika Willén, Rossana Dragani, Francisco Doblas-Reyes, Dirk Notz

CCI+ ECVs	WV	Salin	S-State	Lakes	Snow	PF	LST	HRLC	AGB				
	X	X	X	X	X	X	X	X	X				
ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS	Gla
	X	X	X	X	X	X	X	X	X	X	X	X	X

Objectives

To provide a foresight report for use of EO data for climate applications (e.g. monitoring, model validation, reanalysis)

Scientific questions to be addressed:

1. What is the best framework to provide satellite climate data to the user community
2. Do the ESGF and Obs4MIPs comprise the best solution?

Tasks to be performed

1. Prepare draft report for input at workshop
2. Host workshop adjacent to a relevant meeting
1. Complete report D1.2 and publish

Output / Deliverables

1. Workshop hosted with relevant experts
2. Foresight Report D1.2

3.2 WP2 Providing an integrated view and feedback to ESA and the CCI Teams

WP: 2.1		**Start / end**	M1	M4
Title: Scientific Impact report				

CMUG participant	DLR	ECMWF	SMHI	IPSL	MeteoFrance	MetOffice	MPI-M	BSC
PM	0.15	0.7	0.1	0.15	0.03	1	0.7	0.3

Sum: **2.8**

Key personnel	Richard Jones, Paul van der Linden, Jean-Christophe Calvet, Veronika Eyring, Jean-Louis Dufresne, Ulrika Willén, Rossana Dragani, Francisco Doblas-Reyes, Dirk Notz

CCI+ ECVs	WV	Salin	S-State	Lakes	Snow	PF	LST	HRLC	AGB				
ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS	Gla
	X	X	X	X	X	X	X	X	X	X	X	X	X

Objectives
The aim is to document the scientific impact of the CCI on the climate research community at the end of CMUG phase 2.

Scientific questions to be addressed:
What is the scientific impact of the CCI data on the climate research community
Tasks to be performed
1. Gather input for report mainly as papers and presentations by climate scientists 2. Compile report 3. Get feedback from CCI team CRGs
Output / Deliverables
• Report D2.1 in M4

WP: 2.2		Start / end	M1	M33
Title: Climate Data Forum				

CMUG participant	DLR	ECMWF	SMHI	IPSL	MeteoFrance	MetOffice	MPI-M	BSC
PM	0.15	0.7	0.1	0.15	0.03	1	0.7	0.3

Sum: **2.8**

Key personnel	Richard Jones, Paul van der Linden, Jean-Christophe Calvet, Veronika Eyring, Jean-Louis Dufresne, Ulrika Willén, Rossana Dragani, Francisco Doblas-Reyes, Dirk Notz

CCI+ ECVs	WV	Salin	S-State	Lakes	Snow	PF	LST	HRLC	AGB				
	X	X	X	X	X	X	X	X	X				
ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS	Gla
	X	X	X	X	X	X	X	X	X	X	X	X	X

Objectives

Develop climate data forum web pages and be one-stop shop for information on satellite climate datasets. The forum will support the following:

1. Blogging about CCI data (scientists must register to do this)
2. Discussion groups on CCI data (scientists must register to do this)
3. Links to CCI (and allied) data sets
4. Links to supporting information on datasets (potentially this could be from the IS-ENES3, Obs4MIPS or other projects)
5. Liaise with CCI Knowledge Exchange team

This WP will support also the outreach WP in achieving its objectives.

Scientific questions to be addressed:

N/A

Tasks to be performed

1. Gather information
2. maintain forum site and seek comments (news, discussion, blog)
3. Promote the forum to the wider climate science community to secure their participation and engagement.
4. Update frequently during the project

Output / Deliverables

Web pages
Interaction with climate modeling, research and reanalysis community
Significant updates at Months 6, 16 and 33.

WP: 2.3		Start / end	M1	M30
Title: **Technical Note on Product Assessment**				

CMUG participant	DLR	ECMWF	SMHI	IPSL	MeteoFrance	MetOffice	MPI-M	BSC
PM	0.15	0.7	0.1	0.15	0.03	1	0.7	0.3

Sum: **2.8**

Key personnel	Richard Jones, Paul van der Linden, Jean-Christophe Calvet, Veronika Eyring, Jean-Louis Dufresne, Ulrika Willén, Rossana Dragani, Francisco Doblas-Reyes, Dirk Notz

CCI+ ECVs	WV	Salin	S-State	Lakes	Snow	PF	LST	HRLC	AGB				
	X	X	X	X	X	X	X	X	X				
ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS	Gla
	X	X	X	X	X	X	X	X	X	X	X	X	X

Objectives
Provide feedback to ESA and CCI teams on their plans for product assessments.

Scientific questions to be addressed:
Ascertain fidelity of CCI datasets for climate research
Tasks to be performed
1. Gather CCI documents for ECVs as they become available 2. Review reports 3. Draft initial report 4. Update report during phase 2 as more plans become available The timing of the reports will depend on the availability of the reports from the CCI teams.
Output / Deliverables
• Report D2.3v1, v2 and v3

3.3 WP3: Quality assessment of CCI products

WP3.1 consistency between CCI LST, SM product and LAI products
Leader and associated partners: Meteo-France: Jean-Christophe Calvet
Resources (man month/partner): 4
Type of assessment: reanalysis
Model used (e.g. Earth System model, individual components): ISBA land surface model in the SURFEX open-source modelling platform LDAS-Monde open-source data assimilation system
ECVs involved, CCI products involved: LST, SM, C3S LAI product and/or equivalent products (e.g. AVH15C1)
Aim of the experiments: Assess the consistency between CCI LST, SM product and LAI products
Scientific question addressed: 1. How can land ECVs consistency can be verified ? 2. Are land ECVs represented well in climate and land surface models ? 3. Can EO data improve land reanalyses ? 4. Can EO data improve representation of extreme events (e.g. droughts) ?
Rationale (why important for the community): LST is a key land ECV for surface energy budget, water resource assessment, crop production, fire risk monitoring, etc.; related to LAI and SM
Use of the uncertainty information: assessment of the usefulness/consistency of the product through time
Value of the assessment and complementarity with CCI experiments: LDAS-Monde has the unique capability of sequentially assimilating vegetation and SM products, jointly.
Coverage in space/ time: daily (daytime, night time), global, 1°x1°
Metrics to analyse the performances/impact: Correlation Coefficient, Bias, Standard Deviation of Differences, Root Mean Square Difference for LST (with and without assimilation of SM and LAI)
Tasks to be performed (e.g. re-formatting, analysis): Passive monitoring of LST associated to the assimilation of both SM and LAI. Assessment of model and analysis departures from the observations before and after the assimilation through time (seasonal and interannual variability, trends).
References: Albergel, C., et al.: Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8.0: LDAS-Monde assessment over the Euro-Mediterranean area, Geosci. Model Dev., Geosci. Model Dev., 10, 3889–3912, https://doi.org/10.5194/gmd-10-3889-2017, 2017.
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

WP3.2 consistency between CCI Snow, SM product and LAI products
Leader and associated partners: Meteo-France: Jean-Christophe Calvet
Resources (man month/partner): 4
Type of assessment: reanalysis
Model used (e.g. Earth System model, individual components): ISBA land surface model in the SURFEX open-source modelling platform LDAS-Monde open-source data assimilation system
ECVs involved, CCI products involved: Snow, SM, C3S LAI product and/or equivalent products (e.g. AVH15C1)
Aim of the experiments: Assess the consistency between CCI Snow, SM product and LAI products
Scientific question addressed: 1. How can land ECVs consistency can be verified ? 2. Are land ECVs represented well in climate and land surface models ? 3. Can EO data improve land reanalyses ? 4. Can EO data improve representation of extreme events (e.g. droughts) ?
Rationale (why important for the community): Snow is a key land ECV for water resource assessment, surface energy budget, etc.; related to SM and LAI through initial soil temperature profile conditions, and during and after melting
Use of the uncertainty information: assessment of the usefulness/consistency of the product through time
Value of the assessment and complementarity with CCI experiments: LDAS-Monde has the unique capability of sequentially assimilating vegetation and SM products, jointly.
Coverage in space/ time: daily, global, 1°x1°
Metrics to analyse the performances/impact: Correlation Coefficient, Bias, Standard Deviation of Differences, Root Mean Square Difference for snow depth (if feasible to derive) Correlation Coefficient, Bias, Standard Deviation of Differences, Root Mean Square Difference for SWE Differences in areas covered by snow (after and before the assimilation of SM and LAI) (with and without assimilation of SM and LAI)
Tasks to be performed (e.g. re-formatting, analysis): Active monitoring of the SWE snow product associated to the assimilation of both SM and LAI. Assessment of model and analysis departures from the observations before and after the assimilation through time (seasonal and interannual variability, trends).
References: Albergel, C., et al.: Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8.0: LDAS-Monde assessment over the Euro-Mediterranean area, Geosci. Model Dev., Geosci. Model Dev., 10, 3889–3912, https://doi.org/10.5194/gmd-10-3889-2017, 2017.
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

WP3.3 Assess the added value of HRLC in the SM and LAI representation and analysis
Leader and associated partners: Meteo-France: Jean-Christophe Calvet
Resources (man month/partner): 4
Type of assessment: reanalysis
Model used (e.g. Earth System model, individual components): ISBA land surface model in the SURFEX open-source modelling platform LDAS-Monde open-source data assimilation system
ECVs involved, CCI products involved: HRLC, SM, C3S LAI product and/or equivalent products (e.g. AVH15C1)
Aim of the experiments: Assess the added value of HRLC in the SM and LAI representation and analysis
Scientific question addressed: 1. How can land ECVs consistency can be verified ? 2. Are land ECVs represented well in climate and land surface models ? 3. Can EO data improve land reanalyses ? 4. Can EO data improve representation of extreme events (e.g. droughts) ?
Rationale (why important for the community): HRLC can enhance the representation of individual vegetation types in land surface models
Use of the uncertainty information: assessment of the added value of the product through time
Value of the assessment and complementarity with CCI experiments: LDAS-Monde has the unique capability of sequentially assimilating vegetation and SM products, jointly.
Coverage in space/ time: 5-yr period, continent TbD (e.g. Europe, Western Africa, ...), 0.25°x0.25°
Metrics to analyse the performances/impact: Correlation Coefficient, Bias, Standard Deviation of Differences, Root Mean Square Difference for SM Correlation Coefficient, Bias, Standard Deviation of Differences, Root Mean Square Difference for SM for LAI
Tasks to be performed (e.g. re-formatting, analysis): Assimilation of both SM and LAI. Assessment of model and analysis departures from the observations before and after the assimilation through time (seasonal and interannual variability, trends). Comparison with the ECOCLIMAP-SG geographical information contained in the SURFEX modelling platform.
References: Albergel, C., et al.: Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8.0: LDAS-Monde assessment over the Euro-Mediterranean area, Geosci. Model Dev., Geosci. Model Dev., 10, 3889–3912, https://doi.org/10.5194/gmd-10-3889-2017, 2017.
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

WP3.4 Propagation of CCI(+) observational uncertainties to climate models scales
Leader and associated partner: BSC: Louis-Philippe Caron
Resources (man month/partner): 4PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Statistical analysis
Model used (e.g. Earth System model, individual components): Coupled historical simulations Initialized seasonal prediction hindcasts
ECVs involved, CCI products involved: Old ECVs: soil moisture, fire (burned area) New ECVs: Land Surface Temperature
Aim of the experiments: Observational uncertainties originate from a cascade of errors in the retrieval process, structural uncertainties in the algorithms, and statistical uncertainties in the spatio-temporal projections (Merchant et al., 2017). These errors are correlated in space and time, due to mesoscale systems, for instance, that impact satellite retrieval on a given spatio-temporal scale. Observational uncertainties cannot therefore be averaged and scaled by the square root of the number of independent samples as for uncorrelated errors, but require the consideration of the correlation of errors in space and time. A novel approach how to achieve this has been presented in Bellprat et al. (2018) and applied to the CCI sea-surface temperature (SST) dataset. This task will aim at expanding this effort to other CCI ECVs (all relevant to the study of wild fires) in order to disseminate propagated observational uncertainties at daily, monthly, decadal, climatological scales as well as for different grid resolutions, regions, hemispheric and global averages.
Scientific question addressed: How can the observational uncertainty estimates provided by CCI(+) reference datasets be translated into different spatiotemporal scales to compare to climate model simulations? Are there important differences relative to the nature of the products?
Rationale (why important for the community): Uncertainties in climate models and observational references have been assessed thoroughly in the past. However, it has remained difficult to integrate these because of the lack of formal concepts that characterize uncertainties at common scales represented by both the models and the observations. Furthermore, methods of model evaluation and verification currently lack the ability to include observational uncertainties in metrics and statistical tests. The objective of this WP is to develop these missing concepts in order to use the observational uncertainty information developed in CCI(+) for CMUG and other future modelling users. This work is linked to the work in the FIDUCEO project.

Use of the uncertainty information:

The central outcome of the WP will be to demonstrate the value of observational uncertainty assessment in CCI(+) and to illustrate the relevance of observational uncertainties in comparison to climate model uncertainties (structural and internal), revisiting the paradigm that model uncertainties exceed those from observations.

Value of the assessment and complementarity with CCI experiments:

This WP will operate as a communication node between the uncertainty work carried out in the CCI(+) teams and the different CMUG partners, ensuring that observational uncertainties are propagated adequately to the required scales of analysis. This effort will be central for all CMUG partners and other users aiming at climate model–observation comparison using the CCI data (Massonnet et al., 2016). Finally, this task will act as bridge between CMUG and CCI teams on matters of model and observational uncertainty.

Coverage in space/ time:

Period covered by ESA CCI ECVs

Metrics to analyse the performances/impact:

Seasonal forecast skill will be computed using the Pearson correlation of the ensemble mean prediction with the observations. Probabilistic properties that could be derived from the ensemble will be omitted

Tasks to be performed (e.g. re-formatting, analysis):

1) Apply method developed in Bellprat et al. (2018) to investigate how observational uncertainties propagate to space-time means.

2) Compare the propagated observational uncertainties from the ECV CCI product to that derived from differences in different observational products.

This task will require interaction with each of the CCI ECV teams to determine the best currently available knowledge of error correlation scales in space and in time for the different ECVs.

References:

Merchant, C. J., Paul, F., Popp, T., Ablain, M., Bontemps, S., Defourny, P., Hollmann, R., Lavergne, T., Laeng, A., de Leeuw, G., Mittaz, J., Poulsen, C., Povey, A. C., Reuter, M., Sathyendranath, S., Sandven, S., Sofeiva, V. F., and Wagner, W. (2017). Uncertainty information in climate data records from Earth observation, Earth Syst. Sci. Data Discuss., 9, 511-527.

Bellprat, O., Massonnet, F., Siegert, S., Prodhomme C., Macias-Gomez, D., Guemas, V., Doblas-Reyes, F. (2018). Uncertainty propagation in observational references to climate model scales. Remote Sensing of the Environment, 203, 101-108.

Massonnet, F., Bellprat, O., Guemas, V., Doblas-Reyes, F. (2016) Using climate models to estimate the quality of global observational data sets, Science, 6311, 452-455.

Deliverables:

Report on propagation of observational uncertainty for the D3.1 quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

WP3.5: Document SM-atmosphere feedbacks in transition regions
Leader and associated partners: IPSL: F. Cheruy, J.L. Dufresne, A. Ducharne
Resources (man month/partner): 4
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Process oriented evaluation
Model used (e.g. Earth System model, individual components): Coupled Atmosphere-Land surface components of the IPSL-CM - nudged with winds
ECVs involved, CCI products involved: LST, SM, turbulent fluxes, radiation , air temperature , precipitation
Aim of the experiments: Can CCI(+) data be used to detect on observations the soil moisture /surface temperature feedback related to soil thermal inertia.
Scientific question addressed: Can the co-variations of SM, LST and precipitation be used to document the soil moisture - temperature feedback (intra-daily time scale)
Rationale (why important for the community): Improve processes related to the land-atmosphere coupling in climate models.
Use of the uncertainty information: Construct the same diagnostics with other available products, use instrumented site information.
Value of the assessment and complementarity with CCI experiments: Try to detect with observational analysis a new SM related temperature feedback
Coverage in space/ time: Global analysis done at regional scales, multi-year
Metrics to analyse the performances/impact: Comparison of the diagnostics done with satellite derived products and instrumented site observations.
Tasks to be performed (e.g. re-formatting, analysis): Process oriented diagnostics

References:

Cheruy F. , J.L. Dufresne, S. Ait Mesbah, JY Grandpeix, F Wang. Role of Soil Thermal Inertia in Surface Temperature and Soil Moisture-Temperature Feedback, 2017, JAMES; 9,8, 2906,2919 doi = {10.1002/2017MS001036}

Seneviratne S. I., M. Wilhelm, T. Stanelle, B. Hurk, S. Hagemann, A. Berg, F. Cheruy, M. E. Higgins, A. Meier, V. Brovkin, M. Claussen, A. Ducharne, J.-L. Dufresne, K. L. Findell, J. Ghattas, D. M. Lawrence, S. Malyshev, M. Rummukainen, and B. Smith. Impact of soil moisture-climate feedbacks on CMIP5 projections: First results from the GLACE-CMIP5 experiment. Geophysical Research Letters, 40:5212--5217, October 2013

Deliverables:

A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

Scientific paper if the results are suitable.

WP3.6: Constraining the evapotranspiration at the scale of climate model grid-cell
Leader and associated partners: IPSL: F. Cheruy, J.L. Dufresne, A. Ducharne
Resources (man month/partner): 4
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Process oriented evaluation
Model used (e.g. Earth System model, individual components): Coupled Atmosphere-Land surface components of the IPSL-CM - nudged with winds
ECVs involved, CCI products involved: LST, SM, snow = CCI ECV data Turbulent fluxes, radiation , air temperature, precipitation = non-ECV data
Aim of the experiments: Our main goal is to explore the potential of multiple satellite derived products to better understand the land surface processes and land-atmosphere coupling, at the scale of climate model grid-cells. We will mostly focus on the water and energy budgets over land, and try to identify relationships between presumably related variables, including new ECs as snow cover and LST.
Scientific question addressed: Can we better constrain the controls of evapotranspiration (ET) at the scale of climate model grid-cells? Do the corresponding stress functions (for soil moisture, incoming energy, atmospheric humidity, temperature) take a different form at the point and grid-cell scale? Can large-scale differences between LST and air temperature provide additional information to document the behavior important parameterization for the near surface climate such as turbulence, heat conduction into the soil (Ait-Mesbah et al., 2015, Wang et al., 2016)) snow dynamics?
Rationale (why important for the community): Improve processes related to the land-atmosphere coupling in climate models.
Use of the uncertainty information: Construct the same diagnostics with other available products, use instrumented site information.
Value of the assessment and complementarity with CCI experiments: Try to relate differences between air-temperature and LST to turbulence, heat conduction or snow dynamics parameterizations. Try to constrain the controls of evaporation at the scale of the model
Coverage in space/ time: Global analysis done at regional scales, multi-year
Metrics to analyse the performances/impact: Comparison of the diagnostics done with satellite derived products and instrumented site observations.

Tasks to be performed (e.g. re-formatting,analysis):

Prepare relevant process oriented diagnostics (based on energy fluxes and ECV states) for the analysis (e.g. Cheruy et al. 2017, Cheruy et al. 2013)

References:

F. Cheruy, A. Campoy**,** J.-C. Dupont, A. Ducharne, F. Hourdin, M. Haeffelin, M. Chiriaco, and A. Idelkadi. Combined influence of atmospheric physics and soil hydrology on the simulated meteorology at the SIRTA atmospheric observatory. Climate Dynamics, 40:2251--2269, May 2013.

Cheruy F, Dufresne JL, Ducharne A, Passy P, Magand C, Ghattas J (2017). Diagnostics of the soil moisture / atmosphere coupling in numerical simulations and in global datasets derived from in situ or satellite passive and active remote sensing. Report to the ESA CCI CMUG project, 15 pages

Ait-Mesbah,S. F. Cheruy , J.L. Dufresne F. Hourdin, On the representation of surface temperature in semi-arid and arid regions, Geophys. Res. Lett., 42(18), pp. 7572–7580, 2015, doi:10.1002/2015GL065553

Wang,F., Cheruy F., Vuichard N., Hourdin, F., 2016 The impact of heat roughness length on surface meteorology in IPSL - CM model , AMA (Ateliers de Modélisation Atmosphérique), Toulouse, 18-22 Jan. 2016

Deliverables:

A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

Scientific paper if the results are suitable.

WP3.7: Production and evaluation of a high-resolution sea-ice reanalysis (HiRes-SIR)
Leader and associated partners: BSC, Pablo Ortega
Resources (man month/partner): 8* person months *The production of this high-resolution reanalysis is computationally costly, and will extend over several months. Some additional months will be later required to perform its evaluation
Type of assessment: Reanalysis of Sea Ice Concentrations (based on assimilation with Ensemble Kalman Filter)
Model used (e.g. Earth System model, individual components): High-resolution (0.25°) version of the Coupled ocean (NEMO3.6) and sea-ice (LIM3) model
ECVs involved, CCI products involved: CCI/CCI+ ECVs: SIC (sea ice concentrations), ocean salinity, SST and SIT (sea ice thickness)
Aim of the experiments: We will generate a new sea ice reanalysis using the Ensemble Kalman Filter applied to NEMO3.6-LIM3, the ocean-sea ice components of EC-Earth3.2, to assimilate CCI sea ice concentration (SIC). This reanalysis will be generated using the ORCA025 configuration of NEMO3.6-LIM3, i.e. a horizontal resolution of about 0.25° with tropical refinement.
Scientific question addressed: · Can the highly resolved CCI SIC data improve the next generation of reanalyses? · Are the other CCI ocean products (SST, SSS, SIT) consistent with this HiRes-SIR reanalysis?
Rationale (why important for the community): Up until now, the use of a Kalman filter to assimilate sea ice information has only been applied at a typical resolution of about 1°. However, resolving mesoscale ocean eddies would allow for more realistic representation of the ice drift and deformation and, consequently, of the Arctic open water percentage (Gent et al, 2010). A better representation of the ocean circulation and associated heat transport toward the Arctic at high resolution as well as a better representation of the western boundary currents/frontal areas through their impact on the generation of storms which break the Arctic sea ice and lead to its melting, can produce a more realistic representation of Arctic sea ice processes (Delworth et al. 2012). This reanalysis will thus provide improved ICs for the seasonal and decadal predictions. It's effect on seasonal prediction will be tested in WP3.9. If time allows, a comparison with C3S reanalyses of the same ECVs would be useful.
Use of the uncertainty information: Uncertainty will be addressed by comparing the reanalysis with other Sea Ice products not directly used for the assimilation
Value of the assessment and complementarity with CCI experiments: This HiRes-SIR reanalysis will be compared with a previous one generated within the framework of previous ESA CMUG project, which was run at lower resolution and assimilating only SIC.

Coverage in space/time:

Global (with 50 km grid spacing or higher), daily resolution in the period 1993-2014.

Metrics to analyse the performances/impact:

Clustering techniques (k-means)/statistical analyses (EOFs) to identify the major regimes of sea ice variability in the reanalyses

Tasks to be performed (e.g. re-formatting,analysis):

- Producing a single-member spin-up experiment started from the EN4 and an ocean at rest with a sea ice thickness of 1m in the Antarctic and 3m in the Arctic.
- Generation of a 25-member sea ice reanalysis assimilating sea ice concentrations
- Evaluation of the consistency between the HiRes-SIR outputs and the other CCI products (SIT, SST, Ocean salinity when available). The added value of increasing the resolution will be evaluated by comparing also with an equivalent sea ice reanalysis performed in low resolution within the previous CMIG-CCI project.
- Sea ice modes of variability in SIC will be extracted from both HiRes-SIR and LowRes-SIR reanalyses using classification techniques previously applied at BSC (Fuckar et al, 2015) and compared with those in the CCI SIC dataset.

References:

Delworth, Thomas L, and Coauthors (2012) J. Clim, 25, 2755–2781.

Gent, PR, SG Yeager, RB Neale, S Levis and DA Bailey (2010) Clim Dyn, 34, 819–833, doi:10.1007/s00382-009-0614-8

Fuckar N S, Guemas V, Johnson N C, Massonnet F, Doblas-Reyes F J, 2015, Clusters of interannual sea ice variability in the Northern Hemisphere. Climate Dynamics, 45, 1-17, doi:10.1007/s00382-015-2917-2.

Deliverables:

A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

Scientific paper if the results are suitable.

WP3.8: Evaluation of the impact on skill of HiRES-SIR on seasonal prediction
Leader and associated partners: BSC, Pablo Ortega
Resources (man month/partner): 4 person months
Type of assessment: Seasonal hindcasts with sea ice conditions from the HiRes-SIR developed in WP3.8
Model used (e.g. Earth System model, individual components): EC-Earth v.3 under the same coupled configuration used for DCPP (Decadal Climate Prediction Project)
ECVs involved, CCI products involved: CCI/CCI+ ECVs: SIC, SST and SIT (and potentially salinity)
Aim of the experiments: To quantify the impact on forecast skill due to a better initialization of sea ice concentration (as expected from the HiRes-SIR reanalysis produced in WP xx).
Scientific question addressed: · What is the added-value of Initial Conditions from reanalyzed CCI+ sea ice data on the seasonal to decadal climate forecast quality? · Are there any teleconnections/dynamical processes improving the skill in other regions than the Arctic?
Rationale (why important for the community): Numerous studies have reported important impacts of sea ice on climate variability over remote regions (e.g. North Atlantic, Tropical Pacific, California, Mediterranean Sea), via diverse teleconnection mechanisms (e.g. Deser et al 2010, Grassi et al 2013, Cvijanovic et al 2017). Therefore, an improved initialization of sea ice on the seasonal-to-decadal forecast systems can have a beneficial impact on the skill of the climate predictions on large areas of the world.
Use of the uncertainty information: Uncertainty will be addressed by comparing the reanalysis with other Sea Ice products not directly used for the assimilation
Value of the assessment and complementarity with CCI experiments: Several seasonal forecast systems with the same model, but not initialized from HiRes-SIR (which assimilates CCI SIC data) will be additionally analysed to determine the impact on skill, and evaluated with other CCI products (such as SST and SIT) to test the cross-consistency across the ECVs (and in particular if skill is improved when information of CCI SIT data is included in the ICs).
Coverage in space/time: Global (with 50 km grid spacing or higher), daily resolution in the period 1993-2014

Metrics to analyse the performances/impact:

Forecast verification metrics in terms of bias and probabilistic (e.g. root- mean-square error skill and Rank Probability Skill Scores) and deterministic skill (e.g. Root mean Square Error, Anomaly Correlation Coefficient), and significance tests to attribute skill enhancements.

Tasks to be performed (e.g. re-formatting,analysis):

Evaluating the impact of using the HiRes-SIR on seasonal prediction skill in:

1. Sea Ice changes across the Arctic and their linkages/impacts on mid-latitudes (e.g. precipitation in the Mediterranean Sea)

2. The North Atlantic ocean circulation, in particular its response to recent freshening of the Labrador sea and its subsequent impacts on the subpolar gyre (characterized by an unprecedented cooling)

3. The NAO, ENSO and their teleconnections

References:

Cvijanovic I, B Santer, C Bonfils, DD Lucas, JCH Chiang, S Zimmerman (2017) Nat Comms 8, 1947.

Deser C, Tomas R, Alexander M, Lawrence D (2010) The seasonal atmospheric response to projected Arctic sea ice loss in the late twenty-first century. J Climate 23: 333-351

Grassi, B., G. Redaelli, and G. Visconti, 2013: Arctic sea ice reduction and extreme climate events over the Mediterranean region. *J. Climate*, **26**(24), 10101–10110.

Deliverables:

A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

Scientific paper if the results are suitable.

WP3.9: Biophysical feedbacks in the global ocean
Leader and associated partners: Met Office, David Ford.
Resources (man month/partner): 3
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Assimilation, reanalyses
Model used (e.g. Earth System model, individual components): NEMO physics, MEDUSA biogeochemistry, and CICE sea ice models, which together form the ocean components of the state-of-the-art UKESM1 Earth system model, which will be used for experiments to be submitted to CMIP6. Data assimilation will be performed using the variational NEMOVAR system, used for operational ocean forecasting and reanalysis at the Met Office and ECMWF.
ECVs involved, CCI products involved: CCI ECVs: OC, SST, SI, Sea level, sea surface salinity Other ECVs: temperature, salinity, carbon dioxide, and ocean heat content
Aim of the experiments: The distribution of chlorophyll in the ocean has an impact on light attenuation and therefore ocean heat uptake, changing the ocean physics and sea ice. However, this biophysical feedback is not yet commonly included in climate models or reanalyses. This activity will assess the suitability of CCI ocean colour products to constrain this process when assimilated into coupled physical-biogeochemical ocean reanalyses. Assimilating ocean colour data has been demonstrated to improve the accuracy of 3D model chlorophyll, and it is expected that this will lead to more accurate simulation of light attenuation and ocean heat uptake in reanalyses, when biophysical feedback processes are included. This should then improve consistency with other ECVs.
Scientific question addressed: Two equivalent reanalyses will be performed with NEMO-CICE-MEDUSA, assimilating CCI ocean colour products, and spanning a period of variability in the El Niño Southern Oscillation (ENSO), in which biophysical feedbacks are known to play a role. The first reanalysis will have no feedback from biology to physics, as in standard climate models. The second reanalysis will include the process. The two runs will then be assessed against CCI sea surface temperature (SST), sea level and sea ice products (sea surface salinity could also be used if available), as well as in situ observations of temperature, salinity, carbon dioxide, and ocean heat content. This will assess the impact of including biophysical feedbacks, driven by assimilation of CCI ocean colour data, on the model representation of the physical ocean and cryosphere ECVs, the consistency of features between ECVs and processes, and the carbon cycle.
Rationale (why important for the community): The WP will deliver an assessment of the suitability of CCI ocean colour products for constraining this process in the ocean, and the resulting interactions and consistency between multiple ECVs. The impacts on sea ice and the carbon cycle each relate the results to WCRP Grand Challenges, as well as advancing understanding of how climate models and reanalyses can deliver improved representations of climate processes. Furthermore, the results will provide an initial indication of the potential importance of the feedbacks for seasonal and decadal forecasting, relating to the WCRP Grand Challenge of Near-term Climate Prediction. This will build on prior work performed as part of the EC FP7 MyOcean2 project, the pre-operational phase of the Copernicus Marine Environment Monitoring Service (CMEMS).

Use of the uncertainty information: The uncertainty information provided with the CCI ocean colour products will be used both in the quality control of the observations, and in the error covariances used in the data assimilation, in order to provide the best possible error estimates for the data assimilation. If possible, will producing joint statements on uncertainty with other WPs working on the same ECVs.
Value of the assessment and complementarity with CCI experiments: Will coordinate activity with WPs 3.7 and 3.8 to include any uncertainty information on SI developed there in this work.
Coverage in space/ time: Global Ocean, time span for CCI data.
Metrics to analyse the performances/impact: Statistical comparison of model fields to ECVs, time series analysis of ocean heat content and other climate indicators, consistency of spatial and temporal features in model fields compared with ECVs.
Tasks to be performed (e.g. re-formatting, analysis): Two equivalent reanalyses will be performed with the NEMO-CICE-MEDUSA, ocean model, assimilating CCI ocean colour products, and spanning a period of variability in the El Niño Southern Oscillation (ENSO), in which biophysical feedbacks are known to play a role. The two runs will then be assessed against CCI sea surface temperature (SST), sea level and sea ice products (sea surface salinity could also be used if available), as well as in situ observations of temperature, salinity, carbon dioxide, and ocean heat content.
References: Builds upon earlier CMUG paper: Ford D. and Barciela R., Global marine biogeochemical reanalyses assimilating two different sets of merged ocean colour products, Remote Sensing of Environment, 2017, https://doi.org/10.1016/j.rse.2017.03.040. Builds upon earlier EC FP7 MyOcean2 report: Ford D. and Barciela R., Biophysical feedbacks in a coupled physical-biogeochemical ocean model, Forecasting Research Technical Report 608, Met Office, Exeter, UK, 2015.
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

WP3.10: Assessment of the potential of CCI/CCI+ data to constrain mineral dust simulations at the regional scale.
Leader and associated partners: C. Pérez García-Pando, E. Di Tomaso (BSC)
Resources (man month/partner): 4 PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): The assessment will consist of a statistical analysis of the CCI/CCI+ data before model integration, and of the evaluation of the impact of assimilating the data with an ensemble-based Kalman filter method over a regional domain. Development and testing of the assimilation of CCI IASI dust data will be performed at the regional scale and at high spatial resolution. Additionally, once CCI+ high resolution land cover data will become available, simulations will be run also with enhanced information on land use type.
Model used (e.g. Earth System model, individual components), Data assimilation experiments of mineral dust will be run with the NMMB-MONARCH model (Pérez et al. 2011) which uses of a LETKF DA scheme (Di Tomaso et al. 2017).
ECVs involved, CCI products involved: The work will consider the following CCI/CCI+ ECVs: Aerosol dust and High Res LC. CCI IASI dust data will be assimilated in model simulations, while CCI+ high resolution land cover data (once data will become available) will be used to enhance the NMMB-MONARCH's land use type, with a consequent impact on dust emissions.
Aim of the experiments: This contribution aims at demonstrating the use of CCI/CCI+ data to produce dust analyses at the regional scale. Part of its findings will set the basis for the assessment activity 11 on the production of a pilot dust reanalysis, where the impact on dust cycles at different temporal scales will be evaluated. It also aims at assessing the synergy of CCI aerosol data (in particular when constraining atmospheric concentrations over dust source areas) with CCI+ land cover data (used for an enhanced characterization of dust emissions), with the goal to provide feedback on these ECVs to the ESA CCI/CCI+ teams.
Scientific question addressed: · Are CCI (pixel-level) uncertainties realistic? · Which is the added value of assimilating thermal infrared retrievals? · Which is the impact of IASI data assimilation at the regional scale in high resolution simulations? · Does enhanced land type information improve the first-guess of mineral dust tracers, and consequently dust analyses? · Are the used CCI/CCI+ ECVs consistent?

Rationale (why important for the community):

Current aerosol (and dust) data assimilation is mainly based on retrievals in the visible part of the electromagnetic spectrum, and with no information on aerosol speciation. These retrievals have limitations over highly-reflective surfaces and rely on solar irradiance. CCI IASI retrievals in the thermal infrared have the potential to constrain dust simulations thanks to their sensitivity to silicate-based, large-size absorbers during both day and night, and over different surface types (both ocean and land, including deserts).

Use of the uncertainty information:

CCI pixel-level uncertainties will be taken into account to characterize the observation error statistics used by the data assimilation scheme.

Value of the assessment and complementarity with CCI experiments:

A data assimilation/modelling assessment of CCI/CCI+ data will be of added value to the standard CCI experiments as it will provide a different perspective to the evaluation efforts, and will allow to assess ECVs for cross-consistency.

Coverage in space/ time:

Data assimilation experiments will be run on a regional domain covering Northern Africa, Europe and the Middle East for specific dust events (usually lasting 1 to 10 days) during the active dust season.

Metrics to analyse the performances/impact:

The impact of ECVs will be assessed through data assimilation diagnostics based on first-guess and analysis departures, and through analysis validation with independent observations.

Tasks to be performed (e.g. re-formatting,analysis):

· processing IASI dust aerosol data to follow the assimilation cycles

· implementation of an observation operator for the thermal infrared

· identifying optimal assimilation settings for observation error statistics, observations' density and covariance localization

· implementation of the use of CCI+ high resolution land cover to characterize the model land type

· assessment of the impact of assimilating the data during relevant dust events and validation with independent observations

References:

Pérez, C., Haustein, K., Janjic, Z., Jorba, O., Huneeus, N., Baldasano, J. M., Black, T., Basart, S., Nickovic, S., Miller, R. L., Perlwitz, J. P., Schulz, M., and Thomson, M.: Atmospheric dust modeling from meso to global scales with the online NMMB/BSC-Dust model – Part 1: Model description, annual simulations and evaluation, Atmos. Chem. Phys., 11, 13001–13027, doi:10.5194/acp-11-13001-2011, 2011.

Di Tomaso, E., Schutgens, N. A. J., Jorba, O., and Pérez García-Pando, C. (2017): Assimilation of MODIS Dark Target and Deep Blue observations in the dust aerosol component of NMMB-MONARCH version 1.0, Geosci. Model Dev., 10, 1107-1129, doi:10.5194/gmd-10-1107-2017.

Deliverables:

Report on Assessment of dust assimilation at the regional scale, contributing to D3.1 Quality Report [BSC, month 35]

WP3.11: Production of a pilot dust reanalysis at the regional scale
Leader and associated partner: C. Pérez García-Pando, E. Di Tomaso (BSC)
Resources (man month/partner): 3 PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): The assessment will consistent of the production and evaluation of a pilot dust reanalysis, with special emphasis on assessing the characterization of diurnal and seasonal cycles. The production of a pilot dust reanalysis based on CCI/CCI+ ECVs will be performed during a 1 year period, and thoroughly validated with independent observations and other reanalyses. The experiment will capitalize on some of the results of the assessment activity 10 on the optimal configuration for an assimilation system for the ECVs considered.
Model used (e.g. Earth System model, individual components): The dust reanalysis will be produced with simulations from the NMMB-MONARCH model (Pérez et al. 2011) coupled to a LETKF DA scheme (Di Tomaso et al. 2017).
ECVs involved, CCI products involved: The work will consider the following CCI/CCI+ ECVs: Aerosol dust and High Res LC. CCI IASI dust data will be assimilated in model simulations for the reanalysis period. Simulations will make use also of CCI+ high resolution land cover data, once these will become available, in order to enhance the NMMB-MONARCH's land use type.
Aim of the experiments: This contribution aims at producing a pilot dust reanalysis based on CCI/CCI+ data, and at assessing whether their integration in model simulations can improve the monitoring of mineral dust and the characterization of dust cycles.
Scientific question addressed: Can CCI/CCI+ data improve aerosol reanalysis? Can CCI/CCI+ data improve in particular the characterization of dust cycles? How well does the regional dust reanalysis compare to global reanalyses?
Rationale (why important for the community): Aerosol (and dust) reanalyses provide valuable information to a range of different users, information which is also fed into aerosol-related climate services. A regional reanalysis with a dedicated focus on dust can aim at describing the fine spatio-temporal scales that meet the requirements of policy makers and stakeholders in sectors such as transport, energy and air quality.
Use of the uncertainty information: CCI uncertainty information will be used to "weigh" in an optimal way the observations in the estimation of the reanalysis.

Value of the assessment and complementarity with CCI experiments:

A reanalysis assessment is able to showcase the potential of CCI/CCI+ data to contribute to the formulation of management and mitigation plans of different socio-economic sectors. A dust reanalysis in particular can be used to provide resources for studying the impact of dust on health, weather and climate.

BSC's strong links to specific user communities through its WMO SDS-WAS activities can guarantee the visibility of such potential for the data considered.

Coverage in space/ time:

The dust reanalysis will be produced for a regional domain covering Northern Africa, Europe and the Middle East over a 1 year period.

Metrics to analyse the performances/impact:

Statistical analysis based on innovations will be used to detect systematic (spatial and temporal) patterns of data impacts on the dust analysis. Dust reanalysis mean values, uncertainty and characterization of diurnal and seasonal cycles will be analysed through comparison with independent observations.

Tasks to be performed (e.g. re-formatting,analysis):

- production of a pilot reanalysis over the course of a specific year characterized by relevant dust events
- statistical analysis of innovations throughout dust cycles at different temporal scales
- reanalysis validation with independent observations
- comparison of the dust reanalysis with other reanalyses

References:

Pérez, C., Haustein, K., Janjic, Z., Jorba, O., Huneeus, N., Baldasano, J. M., Black, T., Basart, S., Nickovic, S., Miller, R. L., Perlwitz, J. P., Schulz, M., and Thomson, M.: Atmospheric dust modeling from meso to global scales with the online NMMB/BSC-Dust model – Part 1: Model description, annual simulations and evaluation, Atmos. Chem. Phys., 11, 13001–13027, doi:10.5194/acp-11-13001-2011, 2011.

Di Tomaso, E., Schutgens, N. A. J., Jorba, O., and Pérez García-Pando, C. (2017): Assimilation of MODIS Dark Target and Deep Blue observations in the dust aerosol component of NMMB-MONARCH version 1.0, Geosci. Model Dev., 10, 1107-1129, doi:10.5194/gmd-10-1107-2017.

Deliverables:

Report on Assessment of the pilot regional dust reanalysis, contributing to D3.1 Quality Report [BSC, month 35]

WP3.12: A 17-year long Global Aerosol Reanalysis
Leader and associated partners: ECMWF: A. Benedetti, R. Dragani, J. Letertre-Danczak
Resources (man month/partner): 11 PM (see cost per individual task below)
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Reanalysis
Model used (e.g. Earth System model, individual components): The ECMWF IFS with enhanced chemistry
ECVs involved, CCI products involved: ATSR aerosol products
Aim of the experiments: The Aerosol-CCI has produced a 17-year long record of AOD retrieved from ATSR-2 and AATSR that starts in the mid-90s. This CCI data record will be used to produce a new global aerosol reanalysis for different aerosol species (namely dust, organic matter, black carbon, sulphate, and sea salt). This will extend further back in time the availability of current MACC and CAMS Interim aerosol reanalyses (currently starting in 2003; Inness et al, 2013; Fleming et al, 2017) and provide feedback and a test case for the future CAMS reanalysis to run over a longer period. Comparisons with existing Aerosol reanalyses and independent observations will be performed over the overlapping period and/or for specific event of interest to assess the quality and data consistency.
Scientific question addressed: 1. Suitability of the CCI ATSR2 and AATSR records to constrain a long aerosol reanalysis 2. Appropriateness of the observation uncertainty via the data assimilation system 3. Consistency between the two CCI data records and with independent observations 4. Consistency of the produced reanalysis with existing global reanalyses, i.e. CAMS reanalyses constrained by MODIS and MERRA-2 reanalysis constrained with AVHRR data 5. Assessment of the ability of ATSR-type vs. AVHRR-type instruments to produce accurate aerosol output.
Rationale (why important for the community): Reanalyses are widely use and for many reasons. The global aerosol reanalyses provided by the CAMS does not cover the period prior 2003, so this experiment will provide a scout reanalysis that could prompt future longer operational reanalyses by CAMS. Among others, having longer reanalysis products is crucial for having longer climate records, and for initializing forecast predictions from sub-seasonal to seasonal range as well as for calibrating the long-range forecasts.
Use of the uncertainty information: The use of the uncertainty is an integral part of the data assimilation process, and will be communicated to other WPs and the CCI teams

Value of the assessment and complementarity with CCI experiments:

There is no equivalent CCI experiment envisaged within CCI, but links to other CCI teams where there will be links (Fire, Clouds) will be maintained to ensure knowledge exchange, consistency and discussion of research and results

Coverage in space/ time:
Global / entire CCI data record (1995-2012).

Metrics to analyse the performances/impact:

Spatial and temporal comparisons with independent observations and existing global aerosol reanalyses will be performed and assessed in terms of e.g. mean and standard deviation of the differences, and RMSE.

Tasks to be performed (e.g. re-formatting,analysis):

1. Pre-process the CCI aerosol products in BUFR to be ingested in IFS, including any adaptation/change to the BUFR converter software [1.5PM]

2. Identify adequate aerosol emission datasets for the years 1997-2002. Write the software to prepare the datasets in GRIB format at different resolutions for use into the IFS system (using the CAMS reanalysis configuration) and pre-process the data. [2.5PM]

3. Assess the need for a bias correction of the CCI data and the consistency between the ATRS-2 and AATSR datasets during the overlapping period. [2PM]

4. Execute assimilation experiments in parallel streams covering overlapping periods and verification that the different streams are consistent one another. [2PM]

5. Assess the quality of the reanalysis via comparison with independent observations (e.g. the AERONET network), and existing reanalysis (CAMSIRA, and MERRA-2) [2PM]

6. Report to ESA and the CCI community, and feedback to the CAMS team. [1PM]

References:

1. Flemming, J., et al (2017): The CAMS interim Reanalysis of Carbon Monoxide, Ozone and Aerosol for 2003–2015, Atmos. Chem. Phys., 17, 1945-1983, doi:10.5194/acp-17-1945-2017, 2017.

2. Inness, A., et al (2013): The MACC reanalysis: an 8 yr data set of atmospheric composition, Atmos. Chem. Phys., 13, 4073-4109, doi:10.5194/acp-13-4073-2013.

Deliverables:

Report on the suitability of the CCI ATSR aerosol products to produce a long, global aerosol reanalysis in the D3.1 Quality Report

3.4 WP4: Exploiting CCI products in MIP experiments

WP4.1 Evaluation of modeled system memory
Leader and associated partners: MPI-M, Dirk Notz
Resources (man month/partner): 4 PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Statistical analysis
Model used (e.g. Earth System model, individual components): MPI-ESM, CMIP6 archive
ECVs involved, CCI products involved: Use of CCI+ variables depends on respective progress, but might include sea surface salinity, snow, LST For CCI variables, we will focus on SST and SI for this exploratory study. Routine evaluation will then be possible based on the framework developed within this study. (which links to WP 5)
Aim of the experiments: To develop and apply a framework that allows one to evaluate the simulated memory (temporal correlation) of ECVs in a model-evaluation processing chain
Scientific question addressed: How can we evaluate the memory of climate variables as simulated by large-scale model simulations?
Rationale (why important for the community): Model evaluation studies are usually concerned with the evaluation of individual snapshots, which usually are averaged over time. However, a key requirement for example for realistic seasonal prediction studies relates to the evaluation of the modeled memory of the system. Errors in realistically simulating the memory of a system can for example give misleading results in the potential seasonal predictability as obtained in so-called perfect-model studies.
Use of the uncertainty information: The uncertainty information will be used to assess the robustness of the obtained estimate of system memory
Value of the assessment and complementarity with CCI experiments: This assessment will allow us to evaluate the memory of a given ECV in climate-simulation assessments
Coverage in space/ time: as long and as global as possible for individual ECVs
Metrics to analyse the performances/impact: Differences in analysed model quality with and without consideration of memory allows one to assess the importance of internal variability for model evaluation, including an assessment of statistical robustness given the possibly limited sample sizes involved

Tasks to be performed (e.g. re-formatting,analysis): 1. Transfer and further develop knowledge on the evaluation on temporal correlation during model evaluation 2. Develop processing chain to routinely consider temporal correlation 3. Link with task 5 to implement processing chain into standard benchmarking tools
References:
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place) describing a possible processing chain, and highlighting examples of the evaluation of the temporal correlation

WP4.2 Evaluation of model results considering observational uncertainty
Leader and associated partners: MPI-M, Dirk Notz
Resources (man month/partner): 4 PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Statistical analysis
Model used (e.g. Earth System model, individual components): MPI-ESM, CMIP6 archive, possibly CORDEX
ECVs involved, CCI products involved: Use of CCI+ variables depends on respective progress, but might include sea surface salinity, snow, LST For CCI variables, we will focus on SST and SI for this exploratory study. Routine evaluation will then be possible based on the framework developed within this study. (which links to WP 5)
Aim of the experiments: To develop and apply a framework that allows one to include observational uncertainty information into a model-evaluation processing chain
Scientific question addressed: How can we take observational uncertainty into account when evaluating large-scale model simulations?
Rationale (why important for the community): The primary reason why observational uncertainties remain weakly explored in the climate modeling community is that the uncertainties are thought to be orders of magnitudes smaller than those of the models. This paradigm holds arguably for many ECVs and for older generations of climate models. Along with heavy climate model development during the past decades and increased horizontal model resolution thanks to more powerful high-performance computing systems, this paradigm has been put in question (Massonnet et al., 2016). The minor role attributed to the uncertainty of observational references should be particularly questioned for new ECVs that are strongly depending on complex retrieval algorithms as for instance used for sea-ice thickness.

Use of the uncertainty information: The uncertainty information will form the central part of this assessment
Value of the assessment and complementarity with CCI experiments: This assessment will allow us to consider observational uncertainty information for climate-simulation assessments
Coverage in space/ time: as long and as global as possible for individual ECVs
Metrics to analyse the performances/impact: Differences in analysed model quality with and without consideration of observational uncertainties allows one to assess the importance of the observational uncertainties for model evaluation
Tasks to be performed (e.g. re-formatting,analysis): 1. Transfer and further develop knowledge on the use of observational uncertainty for model evaluation 2. Develop processing chain to routinely consider observational uncertainty for model evaluation 3. Link with task 5 to implement processing chain into standard benchmarking tools
References: Massonnet et al., 2016: Using climate models to estimate the quality of global observational data sets, Science, 354, 452-455. Notz D. 2015 How well must climate models agree with observations? Phil. Trans. R. Soc. A 373: 20140164. http://dx.doi.org/10.1098/rsta.2014.0164
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place) describing a possible processing chain, and highlighting examples of the impact of observational uncertainty for model evaluation

WP4.3 Evaluation of model results considering the abstraction level of observational products
Leader and associated partners: MPI-M, Dirk Notz
Resources (man month/partner): 4 PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Statistical analysis
Model used (e.g. Earth System model, individual components): MPI-ESM, CMIP6 archive, possibly CORDEX

ECVs involved, CCI products involved: Use of CCI+ variables depends on respective progress, but might include sea surface salinity, snow, LST For CCI variables, we will focus on SST and SI for this exploratory study. Routine evaluation will then be possible based on the framework developed within this study. (which links to WP 5)
Aim of the experiments: To develop and apply a framework that allows one to estimate the ideal abstraction level at which a model evaluation should be carried out
Scientific question addressed: At which observational abstraction level should we evaluate large-scale model simulations?
Rationale (why important for the community): The retrieval algorithms of any ECV consists of various abstraction levels to convert the raw satellite data to the geophysical quantity of interest. At the various steps of the processing chain, assumptions are made which increase the observational uncertainty from one level to the next. This can cause substantial observational uncertainty in the highest-level product, which hence might not be the ideal choice for model evaluation. In this WP, we will examine procedures to define the ideal abstraction level for large-scale model simulations. We will for example examine how one can assess up to which level an instrument simulator in an ESM allows one to meaningfully reduce the impact of observational uncertainty. Links to the FIDUCEO project.
Use of the uncertainty information: The uncertainty information will form the central part of this assessment. Links to the FIDUCEO project.
Value of the assessment and complementarity with CCI experiments: This assessment will allow us to reduce the impact observational uncertainty information for climate-simulation assessments
Coverage in space/ time: as long and as global as possible for individual ECVs
Metrics to analyse the performances/impact: Differences in analysed model quality with and without consideration of the ideal abstraction level allows one to assess the importance of the observational uncertainties for model evaluation
Tasks to be performed (e.g. re-formatting,analysis): 1. Develop an overarching framework to define the ideal abstraction level for model evaluation 2. Develop processing chain to include various abstraction levels during model evaluation 3. Link with task 5 to implement processing chain into standard benchmarking tools
References: None
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place) describing a possible processing chain, and highlighting examples of the impact of different abstraction levels for model evaluation

WP4.4 Optimal spatial and temporal scales for model evaluation
Leader and associated partners: MPI-M, Dirk Notz
Resources (man month/partner): 4 PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Statistical analysis
Model used (e.g. Earth System model, individual components): MPI-ESM, CMIP6 archive, possibly CORDEX
ECVs involved, CCI products involved: Use of CCI+ variables depends on respective progress, but might include sea surface salinity, snow, LST For CCI variables, we will focus on SST and SI for this exploratory study. Routine evaluation will then be possible based on the framework developed within this study. (which links to WP 5)
Aim of the experiments: To develop and apply a framework that allows one to estimate the ideal spatial and temporal time horizon at which a model evaluation should be carried out to minimize the impact of observational uncertainty
Scientific question addressed: At which time and space scale should we evaluate large-scale model simulations?
Rationale (why important for the community): A point-wise examination of observational uncertainty fails short in taking the often considerable temporal and spatial correlation of the uncertainty into account. Hence, a point-wise consideration of observational uncertainty might give misleading results regarding model quality in a model-assessment study. In this WP, we will develop and use a framework to identify the ideal spatial and temporal scale at which a climate-model evaluation should be carried out.
Use of the uncertainty information: The uncertainty information will form the central part of this assessment
Value of the assessment and complementarity with CCI experiments: This assessment will allow us to reduce the impact of observational uncertainty information for climate-simulation assessments
Coverage in space/ time: as long and as global as possible for individual ECVs
Metrics to analyse the performances/impact: Differences in analysed model quality with and without consideration of the ideal temporal and spatial scale allows one to assess the importance of these scales for model evaluation

Tasks to be performed (e.g. re-formatting,analysis): 1. Develop an overarching framework to define the ideal spatial and temporal scale for model evaluation 2. Develop processing chain to consider various spatial and temporal scales during model evaluation 3. Link with task 5 to implement processing chain into standard benchmarking tools
References:
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place) describing a possible processing chain, and highlighting examples of the impact of different spatial and temporal scales for model evaluation

WP4.5 Evaluation of model results considering internal variability
Leader and associated partners: MPI-M, Dirk Notz
Resources (man month/partner): 4 PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Statistical analysis
Model used (e.g. Earth System model, individual components): MPI-ESM, CMIP6 archive, possibly CORDEX
ECVs involved, CCI products involved: Use of CCI+ variables depends on respective progress, but might include sea surface salinity, snow, LST For CCI variables, we will focus on SST and SI for this exploratory study. Routine evaluation will then be possible based on the framework developed within this study. (which links to WP 5)
Aim of the experiments: To develop and apply a framework that allows one to consider the impact of internal variability into a model-evaluation processing chain
Scientific question addressed: How can we take internal variability into account when evaluating large-scale model simulations?

Rationale (why important for the community): Often, much of the difference between model simulations and any given observational record is explicable by internal variability, which describes the chaotic fluctuation of the observational record around the long term mean that is determined by the external forcing of the climate system (Notz, 2015). Hence, internal variability often hinders possible improvements in our observational capabilities to directly increase the fidelity (or lack thereof) of our model simulations. However, a systematic assessment of the role of internal variability for model evaluation is largely lacking. In addition, we lack a systematic analysis of observational records to obtain estimates of internal variability that can be used for detection and attribution studies, for example. Hence, these are usually based on estimates of internal variability as determined from large model ensembles. In this task, we will in close collaboration with CCI teams attempt to determine internal variability of existing and new ECVs directly from the observational record. These will then be compared to model-derived estimates. This allows us to more robustly quantify the relative role of internal variability versus anthropogenic drivers for explaining changes in observables related to the changing climate of our planet.
Use of the uncertainty information: The uncertainty information will be used to assess the robustness of the obtained estimate of internal variability
Value of the assessment and complementarity with CCI experiments: This assessment will allow us to consider internal variability for climate-simulation assessments
Coverage in space/ time: as long and as global as possible for individual ECVs
Metrics to analyse the performances/impact: Differences in analysed model quality with and without consideration of internal variability allows one to assess the importance of internal variability for model evaluation
Tasks to be performed (e.g. re-formatting,analysis): 1. Transfer and further develop knowledge on the use of internal variability for model evaluation 2. Develop processing chain to routinely consider internal variability 3. Link with task 5 to implement processing chain into standard benchmarking tools
References: Notz D. 2015 How well must climate models agree with observations? Phil. Trans. R. Soc. A 373: 20140164. http://dx.doi.org/10.1098/rsta.2014.0164 Olonscheck, D. & Notz, D. (2017). Consistently estimating internal climate variability from climate model simulations. *Journal of Climate*, *30*, 9555-9573 , doi:10.1175/JCLI-D-16-0428.1
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place) describing a possible processing chain, and highlighting examples of the impact of internal variability for model evaluation

WP4.6 Evaluation of model results considering a combination of sources of uncertainties
Leader and associated partners: MPI-M, Dirk Notz
Resources (man month/partner): 4 PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Statistical analysis
Model used (e.g. Earth System model, individual components): MPI-ESM, CMIP6 archive, possibly CORDEX
ECVs involved, CCI products involved: Use of CCI+ variables depends on respective progress, but might include sea surface salinity, snow, LST For CCI variables, we will focus on SST and SI for this exploratory study. Routine evaluation will then be possible based on the framework developed within this study. (→Task 5)
Aim of the experiments: To develop and apply a framework that allows one to include both observational uncertainty and uncertainty arising from internal variability into a model-evaluation processing chain
Scientific question addressed: How can we take observational uncertainty and internal variability into account when evaluating large-scale model simulations?
Rationale (why important for the community): Any assessment of model quality based on a simple comparison of a model simulation with a given observational product is compromised both by uncertainties in the observations and uncertainties arising from internal variability. In this WP, we will combine the insights from parts 1 to 4 of this analysis into a joint framework, which then allows one to carry out a robust evaluation of model quality, taking observational uncertainty, internal variability, the ideal abstraction level and the ideal temporal and spatial scale into account.
Use of the uncertainty information: The uncertainty information will form the central part of this assessment
Value of the assessment and complementarity with CCI experiments: This assessment will allow us to consider observational uncertainty and internal variability for climate-simulation assessments
Coverage in space/ time: as long and as global as possible for individual ECVs
Metrics to analyse the performances/impact: Differences in analysed model quality with and without consideration of observational uncertainties and internal variability allows one to assess the importance of both sources of uncertainty for model evaluation

Tasks to be performed (e.g. re-formatting,analysis): 1. Develop a theoretical understanding for how best to combine the insights gained in parts 1 to 4 of this analysis. 2. Develop a processing chain to routinely consider observational uncertainty and internal variability 3. Link with task 5 to implement processing chain into standard benchmarking tools
References: Notz D. 2015 How well must climate models agree with observations? Phil. Trans. R. Soc. A 373: 20140164. http://dx.doi.org/10.1098/rsta.2014.0164
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place) describing a possible processing chain, and highlighting examples of the combined impact of observational uncertainty and internal variability for model evaluation

WP4.7 Skill assessment of the DCPP decadal predictions
Leader and associated partners: BSC, Louis Philippe Caron
Resources (man month/partner): 4 man months
Type of assessment: Evaluation of probabilistic and deterministic skill in decadal predictions
Model used (e.g. Earth System model, individual components): Decadal predictions based on global Earth system models
ECVs involved, CCI products involved: CCI ECVs: Sea Level, SST and Clouds (Only products more than 20 years long are considered, to be able to assess with some confidence the skill at decadal timescales)
Aim of the experiments: To produce an extensive model skill assessment of the decadal hindcasts done within DCPP (Boer et al 2016; and thus contributing to CMIP6 initiative) using the longest CCI products as an independent source for validation, thus testing at the same time the consistency of CCI data with the reference datasets used for their initialization
Scientific question addressed: · Which are the regions/variables with more skill for decadal prediction across climate models? · Can CCI/CCI+ data help to identify if these are robust across datasets? · Does skill arise for different variables over the same region? · Can this help to identify the processes behind the skill?
Rationale (why important for the community): The combined analysis of several state-of-the-art decadal climate prediction systems will help to constrain which climate variables and regions have robust skill, covering timescales from seasons to decades, and thus provide robust valuable climate information for the development of climate services

Use of the uncertainty information: Uncertainties in the predictions will be illustrated through the use of probabilistic skill metrics, and by evaluating them against different reference datasets
Value of the assessment and complementarity with CCI experiments: This comprehensive assessment can be considered as a complementary way of contrasting the CCI data with other observational/reanalysed products, in this case by testing to what extent prediction skill is sensitive to the reference observational dataset.
Coverage in space/time: Global,1982-2015
Metrics to analyse the performances/impact: Forecast verification metrics in terms of bias and probabilistic and deterministic skill, and to attribute significant differences in skill
Tasks to be performed (e.g. re-formatting,analysis): - Compilation of different observational products (CCI and non-CCI produced) to assess the skill of the variables of interest - Extraction and preparation of the pertinent climate fields from the EUCP dataset - Evaluation of the skill across the different models, variables and observational datasets - Synthesis of the main results
References: Boer J and Coauthors (2016), The Decadal Climate Prediction Project (DCPP) contribution to CMIP6, Geosci. Model Dev., 9, 3751–377.
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

WP4.8 Use LST products to understand sensitivities and thresholds in LST versus Temperature (near surface) related to vegetation type, productivity and moisture stress.
Leader and associated partners: MO, Rob King, Debbie Hemming
Resources (man month/partner): 3 months (MO)
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Statistical analyses / process study
Model used (e.g. Earth System model, individual components): JULES land surface model, UKESM1 model runs, other CMIP5 and (where available) CMIP6 runs
ECVs involved, CCI products involved: CCI: LST, AGBiomass, SM, LC Others: Temperature (near surface), Precipitation, FAPAR, LAI,
Aim of the experiments: - Use the differences between LST and Temperature (near surface) to assess spatial and temporal variations in vegetation moisture stress across biomes. SM will also be used to examine the vegetation moisture stress. The biomes will be characterised by AGBiomas and LC. - Understand relationships between LST and Temperature in the context of vegetation carbon exchanges across biomes and regions - Assess the potential for using LST versus Temperature relationships as a large-scale monitor of vegetation moisture stress
Scientific question addressed: Can LST versus Temperature relationships be used to monitor large-scale vegetation moisture stress across different biomes and regions? What quality information can be learned from the ancillary ECVs used in this study?
Rationale (why important for the community): This Activity will describe the temporal/spatial relationship between surface temperatures and biomes, allowing a better development of CCI+ LST for meeting user needs This research links with EUSTACE project to pull in and build on results from there.
Use of the uncertainty information: Spatial and temporal uncertainties in the LST and Temperature products will be characterized and used to estimate uncertainties in the proposed vegetation moisture stress indicator.
Value of the assessment and complementarity with CCI experiments: Links to WP4.10 and to other CMUG experiments on AGB, SM and LST.
Coverage in space/ time: Global at 5km / daily, currently available at: https://land.copernicus.eu/global/products/lst
Metrics to analyse the performances/impact: Average differences by biome and region in the LST versus Temperature relationship, Standard Deviation in the relationship spatially and temporally (intra and inter annual).

Tasks to be performed (e.g. re-formatting,analysis):

- Identify temporal and spatial relationships between LST and Temperature for different vegetation types and moisture regimes (using SM, LC and AGB)
- Assess relationships between LST vs Temperature and large-scale water and carbon flux observations over the range of vegetation types
- Derive metrics (including uncertainties) that could be used to monitor large-scale vegetation moisture stress and its implications for vegetation productivity

References:
None

Deliverables:
Results will contribute to D3.1 Quality Assessment Report in Month 36
Benchmark of current LST vs Temperature relationships and methodologies to assess these using ESA CCI LST, as input to WP2.

WP4.9 Use CCI+ products to evaluate model LST versus near surface temperature relationships to help understand biome interactions with climate

Leader and associated partners:
MO, Rob King Debbie Hemming

Resources (man month/partner):
3 months (MO)

Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis):
Statistical analyses, use of available hindcast model data.

Model used (e.g. Earth System model, individual components):
JULES land surface model, UKESM1 model runs, other CMIP5 and (where available) CMIP6 runs

ECVs involved, CCI products involved:
CCI: LST, AGBiomass, SM, HRLC
Other: Temperature (near surface),

Aim of the experiments:

- Evaluate how well the observed relationships between LST and Temperature across different vegetation types and moisture regimes are captured by the JULES land surface model, UKESM1 and other CMIP5 and 6 (where available) Earth System Models.

Scientific question addressed:
Can models capture the LST versus Temperature (near surface) relationships observed with satellite products across different vegetation types and moisture regimes?

Rationale (why important for the community): This Activity will describe the temporal/spatial relationship between LST CCI and biomes, allowing a better understanding of the product for meeting user needs Links with EUSTACE project to pull in and build on results from there. This WP can also include some treatment of CORDEX data (which could simplify some of the analyses as these are driven by reanalyses) so can be compared more directly with the ECVs as they will share much of the same intra-interannual variability
Use of the uncertainty information: Spatial and temporal uncertainties in the LST and Temperature products and the range of models used in this assessment will be characterized and compared
Value of the assessment and complementarity with CCI experiments: Links to WP4.9 and to other CMUG experiments on AGB, SM and LST.
Coverage in space/ time: Global at 5km / daily (will use what CCI LST produce)
Metrics to analyse the performances/impact: Average differences by biome and region in the LST versus Temperature relationship between satellite and model data, Standard Deviation in the relationship spatially and temporally (intra and inter annual).
Tasks to be performed (e.g. re-formatting,analysis): - Derive relationships between LST and Temperature (near surface) for historic model runs of JULES, UKESM1 and other CMIP5 and 6 (where available) models - Evaluate the model LST vs Temperature relationships across different vegetation types and moisture regimes against observed relationships - Summarise results by model, vegetation type, region and moisture regime, identifying key areas where models differ significantly from observations and possible reasons for these differences
References: None
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place) including statement on quality of ESA CCI LST and implications for model development.

WP4.10 Comparison of CCI products for studying vegetation variations with other satellite products and land surface models
Leader and associated partners: MO, Debbie Hemming
Resources (man month/partner): 3 months (MO)
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Statistical analyses, cross-comparison, model evaluation metric development
Model used (e.g. Earth System model, individual components): JULES land surface model, UKESM1 model runs, other CMIP5 and (where available) CMIP6 runs
ECVs involved, CCI products involved: AGBiomass, LST, SM, LC, Temperature (near surface), Precipitation, FAPAR, LAI
Aim of the experiments: - Compare the seasonal timing and magnitude of vegetation-relevant CCI products with other satellite products (inc MODIS) and vegetation variables from existing historic model runs (of JULES, UKESM1, CMIP5/6). - Identify significant differences in the timing, location and vegetation types between CCI products and other satellite and model data. - Suggest key areas for model development to improve vegetation seasonality. - Contribute results to a multi-model evaluation conducted in the CRESCENDO project.
Scientific question addressed: Can the large-scale CCI ECV satellite products be used to improve representation of sensitivities and thresholds between vegetation productivity (and other carbon cycle processes) and climate in land surface/Earth System Models?
Rationale (why important for the community): This work will allow a better understanding of how the CCI+ products meet user needs Links with model evaluation work under the CRESCENDO project
Use of the uncertainty information: Spatial and temporal uncertainties in the CCI ECVs will be characterized and compared with a range of model estimates.
Value of the assessment and complementarity with CCI experiments: There is very good potential for
Coverage in space/ time: Global at 5km / daily

Metrics to analyse the performances/impact: Phenology metrics – Start of Season, Peak of Season, End of Season, Length of Season. Timing and value of base data (i.e. LAI) for each metric, Standard Deviation of timing and value across key biomes and regions.
Tasks to be performed (e.g. re-formatting,analysis): Analysis, cross-comparison, time series analysis,
References: None
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place) Paper on evaluation of model seasonality in vegetation.

WP4.11 Assess the land-surface interaction related biases in AMIP simulations with CCI and other products.
Leader and associated partners: IPSL: Frederique Cheruy, Jean Louis Dufresne, A. Ducharne
Resources (man month/partner): 4
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): process oriented evaluation
Model used (e.g. Earth System model, individual components): Atmosphere-Land surface component of IPSL-CM
ECVs involved, CCI products involved: LST, snow , other : air temperature, turbulent fluxes(Jung, Gleam,) , meteorological analysis, MODIS data, CERES radiation fluxes, SM (CCI, SMOS, Gleam...)
Aim of the experiments: Identify biases in the surface state and surface fluxes in AMIP simulations and understanding the origin of these biases in present day simulations (temperature, albedo, fluxes)
Scientific question addressed: Our main goal is to explore the potential of multiple satellite derived products to try to relate existing and identified biases (surface state and surface fluxes) to missing or incorrectly represented processes, thus offering solutions for model improvement by revisiting the process representation.
Rationale (why important for the community): Biases in present-day simulations cast doubts on the reliability of the future climate projections, and question the use of near-surface variables produced by numerical climate models for climate change impact studies.
Use of the uncertainty information: check for consistency for the same diagnostics done with various data sources for ECV

Value of the assessment and complementarity with CCI experiments:
This experiment will take advantage of the experiments (and their results) in WP 3 where sensitivity studies using the nudging approach will be conducted on short time periods consistent with time period of the observations.

Coverage in space/ time:
Global/Multi-year and regional focus

Metrics to analyse the performances/impact:
AMIP Multi-model analysis of the near surface temperature biases will be performed, temperature biases will be evaluated with respect CCI observed variables (snow, SM, LST) and additional observed variables (Radiation budget, turbulent fluxes).

Tasks to be performed (e.g. re-formatting,analysis):
Correlation, surface energy budget analysis (Cheruy et al. 2014)

References:

Bellprat O, Kotlarski S, Lüthi D, Schär C (2013) Physical constraints for temperature biases in climate models. Geophys Res Lett 40:4042–4047. doi: 10.1002/grl.50737

F. Cheruy, J. L. Dufresne, F. Hourdin, and A. Ducharne. Role of clouds and land-atmosphere coupling in midlatitude continental summer warm biases and climate change amplification in CMIP5 simulations. Geophysical Research Letters, 41:6493--6500, September 2014

Jung T, Doblas-Reyes FJ, Goessling H, Guemas V, Bitz C, Buontempo C, Caballero R, Jokobsen E, Karcher M, Koenigk T, Matei D, Overland J, Spengler T, Yang S, 2015, Polar-lower latitude linkages and their role in weather and climate prediction. Bull. Amer. Meteor. Soc., 96, ES197-ES200, doi:10.1175/BAMS-D-15-00121.1.

Vogel, M.M., R. Orth, F. Cheruy, S. Hagemann, R. Lorenz, B.J.J.M. Hurk, and S.I. Seneviratne, 2017: Regional amplification of projected changes in extreme temperatures strongly controlled by soil moisture□temperature feedbacks. Geophysical Research Letters, 44(3), 1511-1519.

Deliverables:
A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place) and contribution to scientific paper if enough results

3.5 WP5 Adaptation of community climate evaluation tools for CCI needs

WP: 5.1 - 5.5		Start / end	1	36
ESMValTool				

NOTE: Text in red in WP5.1-5.5 is OPTIONAL EXTRA and not part of the baseline proposal

Lead Partner	Axel Lauer, Veronika Eyring, Birgit Hassler, Sabrina Zechlau (DLR)
Other CMUG partners	Javier Vegas, Kim Serradell (BSC) Debbie Hemming, Rob King (Met Office) Ulrika Willén, Klaus Zimmermann (SMHI) Dirk Notz (MPI-M) (optional) Frank Pattyn (ULB) (optional) Philippe Huybrechts (VUB) (optional)

Model(s)	CMIP5 and CMIP6 models, Regional Models (CORDEX)
Experiment type	Historical simulations according to the CMIP protocol with fully coupled Earth System Models; regional model simulations
Period for experiment	Observational period for each ECV provided by CCI

NEW ECVs	Sea Salinity	Sea State	AG Biom	LST	Snow	Lakes	Hi-res LC	Water Vap.	Per ma-frost					
	X		O	X	O		O	X	O					
OLD ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS – Arct	IS – Ant.	Gla
	X		O					X				O	O	

Other data	Other observational data for comparison where available

Objectives
The aim of **WP 5** is to fully exploit ESA CCI and CCI+ data in the context of Earth system model (ESM) evaluation. The ESMValTool is a standardized community based evaluation and benchmarking tool that will be used for CMIP6 model evaluation and analysis. The goal is to enhance the ESMValTool with additional diagnostics and performance metrics that as tailored analysis for the evaluation of models with ESA CCI and CCI+ data. In **WP 5.1** we will release the enhanced version of the ESMValTool from the project including proper documentation of the code for users and developers. This task will also ensure that the work in ESA CMUG is well aligned with the work in other projects that support the ESMValTool

development in order to fully exploit synergies. In **WP 5.2O (optional)** we will integrate methods developed in Task 3 on observational uncertainty and internal climate variability into the ESMValTool to ensure that these methods are available for the evaluation of CMIP6 models in Task 5.4. **WP 5.3 / WP 5.3O** will integrate new versions of ESA CCI/CCI+ data into the tool and will develop new tailored diagnostics and performance metrics. **WP 5.4 / WP 5.4O** will then use the implemented diagnostics to evaluate new simulations from the CMIP6 ensemble with ESA CCI and CCI+ data. In **WP 5.5O** will enhance the ESMValTool so that it can be applied to regional models and will evaluate CORDEX simulations.

The results of **WP 5** will lead to an enhanced use of ESA CCI/CCI+ data for climate model evaluation in CMIP and aim to make a substantial contribution to the analysis of CMIP6 data and to IPCC AR6.

Note: It is required that the ESA CCI and CCI+ datasets will be provided by the ESA CCI teams as best estimate plus uncertainty information in a format compliant with Obs4MIPs/CMIP standards ideally accompanied with a technical note similar to the Obs4MIPs descriptions.

Scientific questions to be addressed

1. How well can state-of-the-art Earth system models simulate climatological mean, variability and trends in the selected ECVs?
2. What is the progress that has been achieved in CMIP6 compared with CMIP5 in the selected ECVs?
3. Are the new observational time series of the ESA CCI complementing and changing global and regional model evaluation and benchmarking assessment of the models in comparison to other observations provided for example by obs4MIPs?
4. How can observational uncertainties and natural internal variability be integrated into the evaluation of climate models? (link to Task 3) OPTIONAL
5. What is the performance of global Earth system models for ESA CCI/CCI^{+} data compared to regional models? OPTIONAL

Tasks to be performed

Task 5.1 Coordination, support and documentation of ESMValTool CMUG activities

[DLR 2 PM; TOTAL 2 PM]

This Task ensures that the ESMValTool activities are well coordinated with other projects and releases the enhanced project version of the tool as open source software.

- Pull requests of new ESA CMUG contributions to the ESMValTool at the GitHub repository will be quality controlled.
- Tags will be included so that provenance is ensured in the final results and plots according to the ESMValTool standard. This will include information on e.g. input data, metadata, diagnostics, tool version, and doi's in the output files.
- Maximize synergies with other relevant projects, in particular with obs4MIPs, ESGF, CMIP, Copernicus projects like C3S-MAGIC and C3S-511, and EU projects like APPLICATE, CRESCENDO and PRIMAVERA.
- Release the enhanced ESMValTool and user's guide at the end of the project as open source software.

Task 5.2O (optional) Priority 1 Enhancement of ESMValTool with improved baseline diagnostics and methods for ESA CCI/ CCI+ ECVs

[MetO 4 PM, DLR 4 PM, MPI-M 4 PM; TOTAL 12 PM]

In this task we will develop an ESMValTool namelist that can form the basis for ECV assessments in Task 1.3. This namelist that can then be extended for specific ECVs in Task 1.3 will include basic measures such as mean, variability, and trends that can be calculated both for models and ESA CCI data. It will include the definition of pre-processors so that a common masking of the model data to actual observations and common regridding procedures are ensured. It will also provide additional information for a quick comparison of the datasets for example by providing the minimum and maximum dates in time series overall and per unit, the longest gapless streak in the ESA CCI data, a map of % completeness of time series overall and per unit [MetO, DLR].

In addition, we will include methods to improve the consideration of observational uncertainty and internal climate variability in model evaluation as they are developed by BSC and MPI-M, respectively, in Task 3 into the ESMValTool [MetO, MPI-M].

The resulting basic ESMValTool namelist will be delivered to Task 5.3 and expanded with ECV specific diagnostics and performance metrics.

Task 5.3 Implementation of CCI and CCI+ products into the ESMValTool

[DLR 7 PM, BSC 3 PM, MetO 3 PM, SMHI 2 PM; TOTAL 15 PM]

In this task we will integrate new CCI+ data as well CCI data that have not yet been implemented (e.g. methane) into the ESMValTool. The starting point will be the generic namelist developed in Task 5.2 which will be enhanced by the CMUG partners who lead the implementation of a specific ECV with ECV specific diagnostics. Within the ESA CCI programme, the ESMValTool will be available to the Climate Research Groups for their work.

Specifically, the following CCI/CCI+ data will be included by the partners listed in parenthesis:

- Land surface temperature [MetO 3 PM]
- Long-lived GHGs (CH_4), water vapour [DLR 6 PM]
- Sea surface salinity [BSC 3 PM]
- Ocean colour [SMHI 2 PM]

Each partner will follow the ESMValTool coding rules and will submit a pull request upon finalization of the implementation of the ECV at the ESMValTool GitHub repository. The contributions will be combined into a project specific ESMValTool namelist similar to https://github.com/ESMValGroup/ESMValTool/blob/master/nml/namelist_lauer17rse.xml. [DLR 1 PM].

Task 5.3O (optional) Priority 2 Implementation of CCI and CCI+ products into the ESMValTool

[DLR 11 PM, MetO 6 PM, ULB 3 PM, VUB 3 PM; TOTAL 23 PM]

Same as Task 5.3, but for the following ECVs:

- Above ground biomass [MetO 3 PM]
- Hi-res land cover [MetO 3 PM]
- Ice sheets (Arctic and Antarctic) [VUB 3 PM, ULB 3 PM]
- Snow cover [DLR 3 PM]
- Permafrost [DLR 3 PM]
- Sea surface height [DLR 3 PM]

Each partner will follow the ESMValTool coding rules and will submit a pull request upon finalization of the implementation of the ECV at the ESMValTool GitHub repository. The contributions will be combined into a project specific ESMValTool namelist similar to https://github.com/ESMValGroup/ESMValTool/blob/master/nml/namelist_lauer17rse.xml. In

addition, existing ESMValTool namelists such as the performance metrics namelist will be expanded to include the new CCI+ and CCI variables [DLR 2 PM].

Task 5.4 Evaluating the CMIP6 ensemble with ESA CCI and CCI+ data using the ESMValTool

[DLR 3 PM, MetO 1 PM, BSC 1 PM, SMHI 1 PM; TOTAL 6 PM]

In this Task we will run the enhanced version of the ESMValTool with ESA CCI / CCI+ data on the CMIP5 and CMIP6 ensembles for ECVs defined in **Task 5.3**. This enhanced version will also include new methods to assess observational uncertainty and internal variability from Task 3 **should Task 5.2O be funded**. Uncertainty provided for each ECVs will be used in the analyses of the results within the benchmarking framework. Total uncertainties on ECVs products on mean values (at a given location and at given spatial and temporal scales) will be considered in performance metrics and diagnostics. These uncertainties will provide bounds to compare with model simulations to determine if model errors are significant. A peer-reviewed publication will be written with the goal to submit it in time for the IPCC AR6 WG I cut-off date for paper submission (31 Jan 2020). This will ensure that the results of this WP can make a significant contribution to IPCC AR6.

Task 5.4.1 Evaluating the CMIP6 ensemble with ESA CCI and CCI+ data

- Application of the ESMValTool to CMIP6 model results
- Assessment of CMIP6 model performance with a focus on the newly implemented variables from **Task 5.3**, taking into account observational uncertainties and internal variability **should Task 5.2O be funded**

Task 5.4.2 Assessment of progress in CMIP6

- Application of the ESMValTool to CMIP5 model results and comparison with CMIP6
- Evaluation of CMIP6 progress in comparison to CMIP5

Task 5.4O (optional) Priority 2 Evaluating the CMIP6 ensemble with ESA CCI and CCI+ data using the ESMValTool

[DLR 5 PM, MetO 2 PM, ULB 1 PM, VUB 1 PM; TOTAL 10 PM]

Same as **Task 5.4**, but for the ECVs defined in **Task 5.3O.**

Task 5.5O (optional) Priority 3 Enhancement of ESMValTool for Regional Model Evaluation

[MetO 6 PM; DLR 2 PM; TOTAL 8 PM]

In this WP we will enhance the ESMValTool so that the namelists that are developed in WP1.3 can also be applied to regional models. A comparison of the performance of the global versus regional models and the added value of ESA CCI/CCI+ data for regional model evaluation will be performed.

Output / Deliverables

- D5.1 v1: Release of enhanced version of the ESMValTool and user guide released to wider community [DLR, month 36]
- D5.3.v1: Pull requests at the ESMValTool GitHub repository for specific ECVs of Task 5.3 [ECV leads of Task 5.3, month 24]
- D5.3.v2: Combined project specific ESMValTool namelist for global model evaluation released at GitHub for ECVs of Task 5.3 [DLR, month 28]
- D5.4.v1: Report on CMIP6 global model evaluation with ESA CCI/CCI+ data from Task 5.3 and improvements compared to CMIP5 in support of IPCC AR6 [DLR, BSC, MetO,

SMHI, month 36]

OPTIONAL

- D5.2O.v1: Enhanced ESMValTool namelist released for use in Task 5.3 that considers observational uncertainty and internal variability as developed in Task 3 [MetO, MPI-M, month 24]
- D5.3O.v1: Pull requests at the ESMValTool GitHub repository for specific ECVs of Task 5.3O [ECV leads of Task 5.3O, month 24]
- D5.3O.v2: Combined project specific ESMValTool namelist for global model evaluation released at GitHub for ECVs of Task 5.3O [DLR, month 28]
- D5.4O.v1: Report on CMIP6 global model evaluation with ESA CCI/CCI+ data from Task 5.3O and improvements compared to CMIP5 in support of IPCC AR6 [DLR, MetO, VUB, ULB, month 36]
- D5.5O.v1: Combined project specific ESMValTool namelist for regional model evaluation released at GitHub [MetO, month 32]
- D5.5O.v2: Report on CMIP6 regional model evaluation with ESA CCI/CCI+ data and improvements compared to CMIP5 in support of IPCC AR6 [MetO, month 36]

WP: 5.6		Start / end	1	36
Title: Adaptation of the CMF and CMF database				

CMUG participant	DLR	ECMWF	SMHI	IPSL	MeteoFrance	MetOffice	MPI-M	BSC
PM		4						

Sum:4

Key personnel	Rossana Dragani, Angela Bendetti
Model(s)	• Climate Monitoring Facility (CMF) and CMF database
Experiment type	• Development of the operational CMF tool
Notes	http://apps.ecmwf.int/climate-monitoring/.

CCI+ ECVs	
	During CCI+, work is envisaged to maintain and extend the CMF Db to the new ECVs and the corresponding reanalysis fields as appropriate
Period for experiment	• As available

CCI data products	• Statistics computed from L3 SST, SSH, SI, Cloud, GHG, O3, SM, Aerosol, (possibly) OC
Other data	• **Statistics computed from available recent reanalyses and other available observations**

Objectives
To complete the existing datasets where their temporal coverage has been extended or new reprocessed versions become available.
Use of the Uncertainty information
The UI will make use of data ingested in a database that includes the CCI L3 (merged) uncertainties processed in area averaged statistics.

Scientific questions to be addressed:
Not Applicable

Tasks to be performed
The following activities are needed: 1. Download the original CCI and reanalysis datasets not available in the CMFDb for both the old and new ECVs as appropriate. 2. Write software to process the new ECVs in a suitable form (both observations and reanalyses). 3. Definition of metadata database for new ECVs (both observations and reanalyses). 4. Data processing, and quality control.
Complementarity with CCI experiments
Not applicable

Output / Deliverables
• Updated CMFDb with additional CCI ECVs and corresponding reanalysis products as appropriate. Month 24

3.6 WP6 Coordination and Outreach

WP: 6.1		Start / end	M1	M36
Title: **Scientific exploitation report**				

CMUG participant	DLR	ECMWF	SMHI	IPSL	MeteoFranc	MetOffice	MPI-M	BSC
PM	0.0	0.7	0.1	0.1	0.1	2	1	0.4

Sum: **4.4**

Key personnel	Richard Jones, Paul van der Linden, Jean-Christophe Calvet, Jean-Louis Dufresne, Ulrika Willén, Rossana Dragani, Francisco Doblas-Reyes, Dirk Notz

CCI+ ECVs	WV	Salin	S-State	Lakes	Snow	PF	LST	HRLC	AGE				
	X	X	X	X	X	X	X	X	X				
ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS	Gla
	X	X	X	X	X	X	X	X	X	X	X	X	X

Objectives
The aim is to summarise the use of the CCI datasets through outcomes of integration meetings and results presented in other relevant conferences.

Scientific questions to be addressed:
How are the CCI datasets impacting on the latest climate research, in the following areas: 1. scientific research funded by the EC 2. scientific research funded at national level 3. through CCI uptake in other initiatives (Obs4MIPs, CMIP) 4. Other uptake (EEA, JRC) 3. applied or commercial research
Tasks to be performed
1. Gather feedback on the uses of CCI data 2. Compile reports from integration meetings
Output / Deliverables
Report D6.1 V1 in Month 7, v2 in month 18, v3 in month 36

WP: 6.2		Start / end	M1	M32
Title: **Promotion Package**				

CMUG participant	DLR	ECMWF	SMHI	IPSL	MeteoFranc	MetOffice	MPI-M	BSC
PM	0.0	0.7	0.1	0.1	0.1	2	1	0.4

Sum: **4.4**

Key personnel	Richard Jones, Paul van der Linden, Jean-Christophe Calvet, Jean-Louis Dufresne, Ulrika Willén, Rossana Dragani, Francisco Doblas-Reyes, Dirk Notz

CCI+ ECVs	WV	Salin	S-Stat e	Lakes	Sno w	PF	LS T	HRL C	AGE				
	X	X	X	X	X	X	X	X	X				
ECVs	OC	SS T	S S H	SI	SM	Fir e	LC	GH G	O 3	Cld	Aer	IS	Gla
	X	X	X	X	X	X	X	X	X	X	X	X	X

Objectives
Promote CCI datasets and CMUG results to the climate modelling and reanalysis community, to the Copernicus programme, international bodies and climate researchers.

Scientific questions to be addressed:
Liaise with CCI Knowledge Exchange team
Tasks to be performed
Prepare material for promotion of CCI products which include: - Newsletters (twice yearly, paper and email) - Flyers / posters / presentations at conferences, workshops and meetings - Website (kept up to date and relevant, with results and material promoting the CCI) - Use the web forum (WP2.2) as a comms tool to increase profile of the CCI - Journal papers illustrating the use of some of the CCI datasets - Maintain an email group of interested researchers/research groups - Horizon scanning for outreach opportunities - Maintain within the project plan a section on communications and outreach - Respond to ad-hoc requests for outreach activities
Output / Deliverables
Newsletters/Web pages/Flyers/Posters/Presentations/Journal Papers/Links with Web forum Outputs at Months 8, 20, 32

3.7 WP7: Interface of CCI data to climate services

WP: 7.1		Start / end	M1	M30
Title: **Interface of CCI data to climate services**				

CMUG participant	DLR	ECMWF	SMHI	IPSL	MeteoFrance	MetOffice	MPI-M	
PM	0	1	0.2	0.2	0.2	1	0.3	

Sum: **2.9**

Key personnel	Richard Jones, Paul van der Linden, Rossana Dragani Jean-Noel Thepaut at ECMWF and Chris Hewitt (Met Office) will provide input to CMUG on this topic when needed. Jean-Christophe Calvet, Jean-Louis Dufresne, Ulrika Willén, Rossana Dragani, Francisco Doblas-Reyes, Dirk Notz

ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS	Gla
	X	X	X	X	X	X	X	X	X	X	X	X	X

Objectives

Define interface of CCI data to climate services (i.e. Copernicus for Climate Change)

Scientific questions to be addressed:

N/A

Tasks to be performed

1. Meet with Copernicus Climate Change Service co-ordinators, other national climate services and key stakeholders (ECMWF, EEA, JRC)
2. Refer to requirements obtained in D1.1
3. Prepare report based on their inputs. The report will provide information on how CCI data can support the aims and objectives of Copernicus. The information will cover relevant scientific features of the data, some technical aspects, and the process links needed at organizational level.

Output / Deliverables

- Report D7.1

3.8 WP8: Project Management

WP: 8		Start / end	M1	M36
Title: **Project management**				

CMUG participant	DLR	ECMWF	SMHI	IPSL	MeteoFrance	MetOffice	MPI-M	
PM	0	0	0	0	0	4	0	

Sum: **4**

Key personnel	Paul VanderLinden, Richard Jones, Emilie Vanvyve

ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS	Gla
	X	X	X	X	X	X	X	X	X	X	X	X	X

Objectives

Manage the CMUG project

Scientific questions to be addressed:

N/A

Tasks to be performed

1. Project manage the CMUG phase 2 project
2. Scientifically manage project
3. Liaise with project team
4. Be main point of contact between CMUG and ESA
5. Provide quarterly and monthly reports on project
6. Maintain risk register
7. Ensure deliverables fulfill their objectives and are delivered on time
8. Ensure maximum effectiveness for communications and outreach
9. Organize annual CMUG integration meetings
10. Act as point of contact in CMUG for DSWG and SEWG
11. Coordinate CSWG
12. Work with ESA on annual progress meetings

Output / Deliverables

Monthly reports
Quarterly reports
Workshop reports

4 Background Intellectual Property

CMUG research will use modelling software created by researchers in the partner institutes (and other research organisations) which receive national and EC funding and support (such as access to supercomputing and data storage facilities). This funding is provided so the results are made publicly available for the benefit of society and the environment. As such the work is published in peer reviewed journals and the data made available on open access servers. Further, some of the models and tools that will be used by CMUG are open source, and come under open source licencing agreements.

5 Statement of compliance

5.1 Cardinal Requirements and SoW

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
CR-1	The team shall address the following new GCOS ECVs, also in the context of the other ECVs addressed by CCI since the beginning of the programme: Water Vapour, Sea Surface Salinity, Sea State, Lakes, Snow, Permafrost, Land Surface Temperature, High Resolution Land Cover, Above-Ground Biomass	No	Lakes and Permafrost are not covered in this proposal, but are covered in Optional extras.
CR-2	Within CCI+, CMUG shall pursue its original role of integration to: • Bridge the gap with the climate modelling and reanalysis community, • Reinforce the climate perspective view through quantitative assessment of CCI products across-ECVs, • Provide independent feedback on all CCI products and documents to ESA and the CCI teams. • Address a new set of ECVs and assess their quality, also in the context of previous ECVs	Yes	
CR-3	A strong focus shall be on new initiatives at European level, such as the Joint Programming Initiative on Climate (JPI), and at International level, such as Obs4MIPS, CEOS Working Group on Climate, WCRP Data Advisory Council (WDAC), and most importantly the CMIP6 exercise.	Yes	
CR-3	One particular focus of CMUG shall be the Climate Services in general and the Copernicus Climate Change Service (C3S) in particular, which will address the operational generation of CDRs	Yes	
CR-4	The integrated assessment performed by CMUG shall include a series of model-based assessment exercises aiming to (i) assess quality and consistency across ECVs, and (ii) support the CMIP exercise. These assessments shall use different methodologies and techniques, ranging from simple sensitivity tests up to more sophisticated Observing System Experiments (OSEs) and climate prediction simulations (only if anticipated to have a significant impact).	Yes	
CR-4	The approach shall be quantitative using a series of metrics, in line with the work of the WCRP metric panel.	Yes	

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
CR-4	The assessments shall be designed to complement the assessment performed by individual CCI teams, in particular by addressing multiple ECVs and their cross-consistency.	Yes	In as far as those proposals are currently known
CR-4	The CMUG team shall liaise with the CCI teams to ensure that complementarity (and avoid any duplication) is achieved with the work performed, in particular as part of the Climate Science Working Group (CSWG) to be coordinated by CMUG.	Yes	
CR-4	It is important to stress that all ECVs addressed by the CCI shall be within the scope of the contract. It is however recognised that individual ECVs will have different use, relevance and importance for modelling owing to the complexity and realism of the current generation of coupled climate models and their ability to handle observations of specific ECVs.	Yes	Acknowledged
CR-4	If some ECVs are not currently routinely used within climate simulations, CMUG shall explain the reasons thereof (e.g. poor realism of models), and provide recommendations on how to foster their uptake.	Yes	Acknowledged
CR-5	**Focus on regional modelling** A new specific focus shall be on developing strong links with the CMC operating at the regional scale within the framework of the Coordinated Regional Climate Downscaling Experiment (CORDEX). The current coarse resolution of climate models (e.g. typically at about 100km) is not adequate for a wide variety of climate applications, in particular regarding study of climate change adaptation, impact assessment and extreme events. CORDEX tries to address this need by exploiting regional modelling, nested models, and downscaling techniques to deliver climate information at a higher resolution (e.g. 10km today, towards km scale by the end of the decade) in various regions of the world. For example, the Data and Downscaling Portal will allow end-users to automatically downscale global simulations to their local sites. CMUG shall aim to better assess the impact of all CCI products at the regional scale (e.g. Land Cover), by performing relevant assessment activities within the framework of Regional Climate Model Evaluation System (RCMES). It is expected that the focus on the regional scale will bring additional value of the CCI data sets.	Yes Yes	Regional models and dynamical downscaling have their own set of structural issues (that use of the CCI datasets cannot address) and are not seen as “the answer” Another approach is high resolution GCM modelling, see the High ResMIP protocol.
CR-6	**Focus on climate services**	Yes	

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
	Also another key focus of CMUG shall be related to the rapid emergence of “climate services”, which aim to enable society to better manage the risks and opportunities arising from climate variability and change by exploiting science-based climate information. A portfolio of climate services is currently being developed across the world within the Global Framework for Climate Services (GFCS) of the World Meteorological Organisation (WMO) relying on the following pillars: a User Interface Platform, Climate Services Information System, Observations and monitoring, Research, modelling and prediction and capacity building activities. Europe has set up an operational Copernicus Climate Change Service (C3S) supporting climate adaptation, attribution, seasonal-to-decadal forecasting, CDR re-processing and climate re-analysis. In this context, CMUG shall capitalize on these new developments to explore new opportunities to sustain reprocessing of EO data within a rapidly evolving European framework. In particular CMUG shall explore ways how to evolve CCI products into products suitable for climate services, and how the re-processing system of all CCI products, or some parts of it, could be progressively migrated towards the Climate Service environment, and in particular the Climate Data Store, containing observed, analysed and simulated ECVs and derived set of indicators. This new focus on climate services is also in line with the focus on regional modelling, which is closer to needs supporting adaptation.	Yes	
CR-7	**Focus on cross-ECV quality and consistency assessment** Since 2010 CMUG has assessed all of the ECVs in CCI so far and a large effort has been provided to look at their cross-consistency, in particular for the terrestrial variables. This cross-ECV effort shall be continued in the CCI+ and expanded to cover all the ECV already started and the 9 new ECVs. There will be a strong focus on quality and consistency assessment of all CCI products, across ECVs in the context of other climate data sets from observations and model data. The cross-ECV assessments shall be performed on a systematic basis, and be shown to complement CCI assessments by each CRG and not duplicate efforts. Assessments should not be seen as a beauty contest but as an analysis of the individual strengths and limitations of the	Yes	

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
	data sets (e.g. NCAR Climate Data Guide). A series of assessments shall be performed, ranging from simple comparison with other products to detection studies, up to more sophisticated Data Assimilation (DA) experiments. It is important that CMUG liaises with the CCI teams to discuss in detail the results of their assessments.		
CR-8	**Focus on CMIP experiments and benchmarking activities** Specific attention shall be given to maximize the use of all CCI products in the experiments planned by CMIP6, for both constraining the simulations (e.g. initial condition, boundary condition) and to evaluate their quality.	Yes	
CR-8	**Focus on CMIP experiments and benchmarking activities** Also, specific efforts shall also be dedicated to exploit the potential of the huge CMIP5 archive for comparison with CCI products.	Yes	
CR-8	**Focus on CMIP experiments and benchmarking activities** CMUG shall also contribute to the global “benchmarking” community effort to evaluate the quality of coupled Earth System Models (ESMs) making full use of the CMIP archive. This effort is led by the WGNE/WGCM Climate Model Metrics Panel, which has been established to define model performance metrics for model-data inter-comparison and analyse various aspects of ESM simulations with a multitude of observational datasets.	Yes	
CR-8	**Focus on CMIP experiments and benchmarking activities** CMUG shall contribute to establish a standardized model benchmarking approach for the CCI in close collaboration with the CMIP, WGNE/WGCM Climate Model Metrics Panel, and the CEOS WG on Climate.	Yes	
CR-8	**Focus on CMIP experiments and benchmarking activities** In order to facilitate the inter-comparison of model and data, and the benchmarking of CMIP-type simulations, CMUG shall adapt the following tools to make use of CCI products: • The community Earth System Model Validation Tool (ESMValTool), which is a flexible and extensible open source package developed by an international European Consortium coordinated by DLR to facilitate the quantitative assessment of ESM	Yes	

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
	performances against pre-defined metrics, • The Climate Monitoring Facility (CMF) developed by ECMWF to enable users to easily assess the homogeneity of products by comparison with reference pre-computed diagnostics from re-analysis. The CMF is currently internal to ECMWF but will be made a public community tool.		
CR-8	**Focus on CMIP experiments and benchmarking activities** In addition, CMUG shall develop an user-friendly web-based interface to easily visualize the results of these tools to display inter-comparison of model and data. The idea is to work towards a standardized community based benchmarking toolkit, capitalizing also on the CCI Toolbox, that includes ESA CCI products and that could be used routinely for CMIP analysis.	Yes	Subject to discussion with ESA as to what there expectation is and how it fits in with CCI toolbox etc
CR-9	**Focus on exploitation of uncertainty information** Specific attention will be given to the exploitation of uncertainty information within a model context. CMUG has mainly focused on the assessment of quality of data, validating the products. One additional focus will be on “how” the error bar of CCI products can be properly used in climate models, “how” to reconcile different types of uncertainty (e.g. to address a scientific question, like energy budget or attribution issue), and “how” the error propagates across ECVs (e.g. how error in fire products translate into error on aerosol concentration.). Use of DA experiments to quantify the propagation of error is foreseen to address the complex questions.	Yes	
2.1	Some of the CCI+ documents shall be reviewed by CMUG, which will provide technical notes to ESA and the CCI teams as done in previous Phases. The feedback to the CCI teams shall be performed through D2.3 which will be the main vehicle for the independent view provided by CMUG. Several updates of this document are expected to enable flexible and rapid feedback due to the different schedules of the CCI teams.	Yes	
2.2	CMUG shall liaise with the Knowledge Exchange team in order to produce and update relevant outreach material and tools, and identify opportunities for wider promotion. CMUG shall provide input to, and	Yes	

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
	review content developed for, the CCI knowledge exchange activities, which includes communication to the wider scientific community, the public, decision makers, and educational audiences		
2.5	To take advantage of the latest research results, to avoid duplication, and achieve wider outreach of CCI products, CMUG shall actively pursue dialogue and collaboration with CCI teams but also with other on-going climate related activities.	Yes	
2.5	The Contractor shall ensure effective collaboration with these and other such relevant activities so that CMUG builds on existing capacity and past developments as much as possible. Duplication of existing activities is not acceptable.	Yes	
2.6	The project shall be carried out within 36 months from the Kick-Off (KO) with strong interactions with the scientific community and CCI teams.	Yes	
2.6	Each assessment WPs shall include more than one ECV to assess cross-consistency, quality and impact.	Yes	
2.6	The bulk of CMUG activities shall be related to the assessment of the CCI products.	Yes	Over half the cost is applied to WPs 3 and 4
2.6	Tasks 3 and 4 shall include a variety of assessment WPs, each of which is not expected to take more than 3-4 Man Months.	Yes	There are two notable exceptions
2.6	Each assessment WP shall address “clusters” of ECVs to get more insight into the interactions between different ECVs, both within and across the ocean, land, atmosphere, cryosphere and biosphere (e.g. cluster of marine ECVs, cluster of atmospheric ECVs, cluster of land-atmosphere-ice ECVs, cluster of ocean-land ECVs, etc.).	Yes	There are some issues with this approach
2.6	The project shall be carried out in 36 months with a review at the end of each year.	Yes	
2.6	By redoing several times the same assessment on different versions of the CCI products, CMUG shall comprehensively quantify, (i) firstly the quality and value of CCI products with respect to the state of the art prior to the start of the CCI programme, and (ii) secondly the additional improvements made by CCI.	Yes	
2.7	To achieve the objectives, CMUG shall undertake a number of linked and largely parallel tasks.	Yes	
2.7.1	**Task 1: Meeting the evolving needs of the climate community**	Yes	

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
	The task shall: • Update the requirements of the CMC identified in previous work, taking account of the new ECVs addressed as part of this phase, the new developments in model capability (e.g. regional focus of CORDEX), additional needs related to meta-data documentation, quality indicators, and climate research needs and challenges. This also includes new additional requirements for hosting CCI data in various temporal and spatial aggregation levels to be used within the ESMValTool, • Critically assess the proposed CCI data standards for the CMC, • Identify the main user groups and networks representing the Climate Service Community (e.g. C3S, framework for global climate service) and identify their needs, • Conduct interviews / surveys with key stakeholders (including members of the CSWG) to ensure that requirements reflect the view of the whole community (and not only CMUG), and maintain a data base of the users consulted for the survey, • Explore the future needs for satellite monitoring for climate (not limited to CCI ECVs) in partnership with the CCI teams and key actors, such as CEOS WG on Climate and the wider research community. The study shall ideally use a methodology to go quantitatively from the needs to the requirements. It shall provide recommendations to GCOS on requirements for existing and new ECVs to address, and to ESA on priorities for existing and potential new ECVs to include within CCI, • Provide GCOS and CEOS with new input following the update of requirements, and climate monitoring architecture.		
2.7.2	**Task 2: Providing integrated view and feedback to ESA and CCI teams** This task shall contribute to the overall integrated approach of the CCI by building appropriate two-ways interfaces with CCI Projects, and provide an integrated view of the portfolio and impact of CCI.	Yes	
2.7.2	**Task 2: Providing integrated view and feedback to ESA and CCI teams**	Yes	

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
	The task shall: • Provide feedback to ESA and CCI Projects at various levels including independent assessment of the quality and suitability of CCI data sets and algorithms, • Assess the scientific impact of CCI as a whole, synthesizing the work performed by CCI teams and CMUG, • Coordinate the CSWG, • Generate content for the Climate Data Discussion Forum (D2.2 here after) for all CCI and other climate products providing users with a well-informed perspective on climate data records in general, and the whole CCI portfolio in particular discussing their essential features, strengths, limitations, and utility, addressing questions such as, "What are the typical research applications of this data set? What are the most common mistakes that users encounter when processing or interpreting these data? What are some comparable data sets, if any? How is uncertainty characterized in these data? How do I best compare these data with model output? This content shall be integrated into the main CCI website, including the CCI Open Data Portal, • Solicit comments / feedback from both data set developers and experienced users for the data guide, • Assess how the CCI products meet the new and additional needs identified, and if not "fit-for-purpose" identify the additional products be developed,		
2.7.3	**Task 3: Assessing consistency and quality of CCI products across ECVs** The Contractor shall perform a series of assessment activities, which involve multiple ECVs, in order to explore interactions and cross-consistency.	Yes	
2.7.3	**Task 3: Assessing consistency and quality of CCI products across ECVs** Each assessment activity shall be described as an individual WP.	Yes	
2.7.4	**Task 4: Exploiting CCI products in MIP experiments** CMUG shall perform a comprehensive model evaluation with observations using multiple CCI products, which are important to initialise or constrain seasonal to decadal predictions and MIP type experiments.	Yes	

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
2.7.4	**Task 4: Exploiting CCI products in MIP experiments** The task shall: • Make full use of the CMIP archive to perform inter-comparison, • Perform a rigorous model skill assessment in CMIP with the help of diagnostics and observationally-based performance metrics, making optimal use of the community evaluation tools ESMValTool and the CMF, • Identify and prepare (if need be or requested by model groups such as EC-Earth) the reference data sets based on CCI products needed to initialise and constrain a variety of large coupled climate models, including non CMUG partners, • Test the impact of CCI products in a series of MIP simulations, focusing on the representation of the climatological mean state, variability, trends, extreme events, as well as spatial and temporal patterns. The idea is to capitalize on other initiatives, which are already funded to perform seasonal-to-decadal predictions and CMIP-type experiments, and foster the use of CCI products in these experiments.	Yes	It's a big archive, so not feasible to use every applicable dataset in it.
2.7.5	**Task 5: Adaptation of community climate evaluation tools for CCI needs** CMUG shall adapt the ESMValTool and the CMF to CCI needs, enabling scientists to use CCI products to perform rapid comparison and benchmarking with other data sets, from reanalysis, and CMIP simulations.	Yes	
2.7.5	**Task 5: Adaptation of community climate evaluation tools for CCI needs** In adapting these tools, CMUG shall maximise synergies with other relevant projects, and CCI teams, including for example (but not restricted to): • Available Observing Simulator Packages developed to enable users to perform direct and consistent comparison of satellite products (e.g. raw data or retrievals) with model outputs, • Available Climate Data Operators to enable climate analytics with big data, • The ESGF and Obs4MIPS data repositories, • CCI Open Data Portal • CCI Toolbox	Yes	

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
2.7.5	**Task 5: Adaptation of community climate evaluation tools for CCI needs** The Task shall: • Contribute to the tailoring of the CMF tool to CCI products, • Assess the value of the CCI toolbox for cross-ECV quality assessment, • Contribute to the tailoring for the ESMValTool for CCI products, • Develop / consolidate a web-based interface to visualize the results of these tools enabling, • Develop tutorials and test-cases to promote the use of the community tools (e.g. development of jupyter notebooks designed for climate modeller).	Yes	Some of these will need to be discussed with ESA, as for their specifics.
2.7.6	**Task 6: Coordination and Outreach** CMUG shall design and implement mechanisms to link with the CCI teams, and the whole Climate Modelling Community and Climate Services communities.	Yes	
2.7.6	**Task 6: Coordination and Outreach** This task shall: • Implement mechanisms to link with the CCI teams, • Link with European activities, a plan shall be established in the proposal to link with these activities, • Promote the use of CCI, and its products across a wide community, including the CMC and the climate impact and service community. The importance of linking primary climate data, with impact model data and other relevant information has been acknowledged by the climate impact community, • Organise workshops/side-events with key representatives of the international climate community, • Generate promotional material, and in particular a series of vital slides presenting CMUG results to a non-technical audience, highlighting impact of CCI products, and their interactions across ECVs, • Publish in scientific literature, and produce a CCI special issue in collaboration with CCI teams.	Yes	
2.7.7	**Task 7: Interface with Climate Services** The task shall: • Identify which part of the CCI production system could be progressively migrated towards a	Yes	

SOW REF.	DESCRIPTION	COMPLIANT	COMMENTS
	more operational environment. The analysis shall be made on a case by case basis per ECV, acknowledging that some ECV are more mature for transition than others, • Identify the requirements for a Climate Service system, and the architecture needed to retain a dual research & operation interactions and feedback loop, • Analyse to which extent the current CCI system and products are fit-for-purpose to meet these needs (also using the analysis of requirements made in D1.1), • Provide recommendations and a roadmap on things that need to be done to enable progressive transition (e.g. evolution of CCI system in terms of system readiness, automation, stability, re-processing frequency), but also to capture the needs of the wider climate service community		

Table 4. Compliance matrix with cardinal requirements and SOW requirements as measured against SoW [CCI-PRGM-EOPS-SW-17-0053].

5.2 Deliverables

NO.	DESCRIPTION		CMUG DATE	ESA DATE	COMPLIANT	COMMENTS
D1.1	Requirement document		KO+4	KO+3	**NO**	CMUG needs sufficient time to gather inputs from users
D1.2	EO for climate foresight report		KO+28	KO+28	**YES**	
D2.1	CCI scientific impact report		KO+4	KO+4	**YES**	
D2.2	Climate Data Forum	v1 v2 v3	KO+6 KO+16 KO+33	KO+6 KO+16 KO+33	**YES** **YES** **YES**	
D2.3	Tech'l note on product and assessment	v1 v2 v3	KO+6 KO+15 KO+30	KO+6 KO+15 KO+30	**YES** **YES** **YES**	
D3.1	Quality assessment report	v1 v2 v3	KO+12 KO+24 KO+35	KO+12 KO+24 KO+35	**YES** **YES** **YES**	
D4.1	Report on MIP impact assessment and bench marking of CMIP5 models	v1 v2 v3	KO+12 KO+24 KO+35	KO+3 KO+11 KO+23	**YES** **YES** **YES**	
D5.1	ESMValTool for CCI products and models eval'n	v1 v2 v3	KO+24 KO+28 KO+36	KO+8 KO+20 KO+32	**NO** **NO** **NO**	Development of the ESMValTool is tied to the CMIP6 timeline, thus a deliverable in the first 18 months is not feasible.
D5.2	CMF for CCI products and models evaluation		KO+24	NA		New deliverable
D6.1	Scientific exploitation report	v1 v2 v3	KO+8 KO+20 KO+32	KO+7 KO+18 KO+36	**NO** **NO** **NO**	CMUG suggests these timings are better aligned to data availability and user uptake
D6.2	Promotion package	v1 v2 v3	KO+8 KO+20 KO+32	KO+12 KO+24 KO+36	**NO** **NO** **NO**	CMUG suggests these timings are better aligned to user activities
D7.1	Climate Service Interface Reqm't & R'map	v1 v2	KO+10 KO+30	KO+10 KO+30	**YES** **YES**	
D8.1	Quarterly progress reports		Every quarter	Quarterly	**YES**	
D8.2	Maintenance of CMUG web pages		Ongoing	Ongoing	**YES**	

Table 5. Compliance matrix of CMUG deliverables measured against SoW [CCI-PRGM-EOPS-SW-17-0053]. A 'Yes' in the column indicates full compliance with the requested elements in that document.

6 Optional work

Here are the descriptions for WPs that are not included in the Baseline Proposal. These are the Options for extra work requested by ESA, and are complementary to the science WPs (WPs 3, 4 and 5) and support the communications and outreach WP in this proposal. It should be pointed out that extra scientific research also involves extra work in the Management, Coordination and Outreach WPs which needs to be taken in to account should any be selected.

Please note that in Sections 2.5.1 and 3.5, both of which concern the ESMValTool, there is Option work proposed. It is included there as it is an integrated part of the work and needs to be shown to understand the scope and ambition of that work, however, it is reproduced on the next page for completeness.

There are nine Optional WP proposals for WP3, one for WP4, and 3 for WP5. The ordering reflects the importance placed upon them by CMUG.

WP: 5.2O, 5.3O, 5.4O	Start / end	1	36
ESMValTool			
Lead Partner	Axel Lauer, Veronika Eyring, Birgit Hassler, Sabrina Zechlau (DLR)		
Other CMUG partners	Javier Vegas, Kim Serradell (BSC) Debbie Hemming, Rob King (Met Office) Ulrika Willén, Klaus Zimmermann (SMHI) Dirk Notz (MPI-M) (optional) Frank Pattyn (ULB) (optional) Philippe Huybrechts (VUB) (optional)		

Model(s)	CMIP5 and CMIP6 models, Regional Models (CORDEX)
Experiment type	Historical simulations according to the CMIP protocol with fully coupled Earth System Models; regional model simulations
Period for experiment	Observational period for each ECV provided by CCI

NEW ECVs	Sea Salinity	Sea State	AG Biom	LST	Snow	Lakes	Hi-res LC	Water Vap.	Permafrost					
	X		O	X	O		O	X	O					
OLD ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS – Arct	IS – Ant.	Gla
	X		O					X				O	O	

Other data	Other observational data for comparison where available

Objectives

In **WP 5.1** we will release the enhanced version of the ESMValTool from the project including proper documentation of the code for users and developers. This task will also ensure that the work in ESA CMUG is well aligned with the work in other projects that support the ESMValTool development in order to fully exploit synergies. In **WP 5.2O (optional)** we will integrate methods developed in Task 3 on observational uncertainty and internal climate variability into the ESMValTool to ensure that these methods are available for the evaluation of CMIP6 models in Task 5.4. **WP 5.3 / WP 5.3O** will integrate new versions of ESA CCI/CCI+ data into the tool and will develop new tailored diagnostics and performance metrics. **WP 5.4 / WP 5.4O** will then use the implemented diagnostics to evaluate new simulations from the CMIP6 ensemble with ESA CCI and CCI+ data. In **WP 5.5O** will enhance the ESMValTool so that it can be applied to regional models and will evaluate CORDEX simulations.

Scientific questions to be addressed

1. How well can state-of-the-art Earth system models simulate climatological mean, variability and trends in the selected ECVs?
2. What is the progress that has been achieved in CMIP6 compared with CMIP5 in the selected ECVs?

3. Are the new observational time series of the ESA CCI complementing and changing global and regional model evaluation and benchmarking assessment of the models in comparison to other observations provided for example by obs4MIPs?
4. How can observational uncertainties and natural internal variability be integrated into the evaluation of climate models? (link to Task 3) OPTIONAL
5. What is the performance of global Earth system models for ESA CCI/CCI+ data compared to regional models? OPTIONAL

Tasks to be performed

Task 5.2O (optional) Priority 1 Enhancement of ESMValTool with improved baseline diagnostics and methods for ESA CCI/ CCI+ ECVs

[MetO 4 PM, DLR 4 PM, MPI-M 4 PM; TOTAL 12 PM]

In this task we will develop an ESMValTool namelist that can form the basis for ECV assessments in Task 1.3. This namelist that can then be extended for specific ECVs in Task 1.3 will include basic measures such as mean, variability, and trends that can be calculated both for models and ESA CCI data. It will include the definition of pre-processors so that a common masking of the model data to actual observations and common regridding procedures are ensured. It will also provide additional information for a quick comparison of the datasets for example by providing the minimum and maximum dates in time series overall and per unit, the longest gapless streak in the ESA CCI data, a map of % completeness of time series overall and per unit [MetO, DLR].

In addition, we will include methods to improve the consideration of observational uncertainty and internal climate variability in model evaluation as they are developed by BSC and MPI-M, respectively, in Task 3 into the ESMValTool [MetO, MPI-M].

The resulting basic ESMValTool namelist will be delivered to Task 5.3 and expanded with ECV specific diagnostics and performance metrics.

Task 5.3O (optional) Priority 2 Implementation of CCI and CCI+ products into the ESMValTool

[DLR 11 PM, MetO 6 PM, ULB 3 PM, VUB 3 PM; TOTAL 23 PM]

Same as Task 5.3, but for the following ECVs:

- Above ground biomass [MetO 3 PM]
- Hi-res land cover [MetO 3 PM]
- Ice sheets (Arctic and Antarctic) [VUB 3 PM, ULB 3 PM]
- Snow cover [DLR 3 PM]
- Permafrost [DLR 3 PM]
- Sea surface height [DLR 3 PM]

Each partner will follow the ESMValTool coding rules and will submit a pull request upon finalization of the implementation of the ECV at the ESMValTool GitHub repository. The contributions will be combined into a project specific ESMValTool namelist similar to https://github.com/ESMValGroup/ESMValTool/blob/master/nml/namelist_lauer17rse.xml. In addition, existing ESMValTool namelists such as the performance metrics namelist will be expanded to include the new CCI+ and CCI variables [DLR 2 PM].

Task 5.4 Evaluating the CMIP6 ensemble with ESA CCI and CCI+ data using the ESMValTool

[DLR 3 PM, MetO 1 PM, BSC 1 PM, SMHI 1 PM; TOTAL 6 PM]

In this Task we will run the enhanced version of the ESMValTool with ESA CCI / CCI+ data on the CMIP5 and CMIP6 ensembles for ECVs defined in **Task 5.3**. This enhanced version will also include new methods to assess observational uncertainty and internal variability from Task 3 **should Task 5.2O be funded**. Uncertainty provided for each ECVs will be used in the analyses of the results within the benchmarking framework. Total uncertainties on ECVs products on

mean values (at a given location and at given spatial and temporal scales) will be considered in performance metrics and diagnostics. These uncertainties will provide bounds to compare with model simulations to determine if model errors are significant. A peer-reviewed publication will be written with the goal to submit it in time for the IPCC AR6 WG I cut-off date for paper submission (31 Jan 2020). This will ensure that the results of this WP can make a significant contribution to IPCC AR6.

Task 5.4.1 Evaluating the CMIP6 ensemble with ESA CCI and CCI+ data

- Application of the ESMValTool to CMIP6 model results
- Assessment of CMIP6 model performance with a focus on the newly implemented variables from **Task 5.3**, taking into account observational uncertainties and internal variability **should Task 5.2O be funded**

Task 5.4.2 Assessment of progress in CMIP6

- Application of the ESMValTool to CMIP5 model results and comparison with CMIP6
- Evaluation of CMIP6 progress in comparison to CMIP5

Task 5.4O (optional) Priority 2 Evaluating the CMIP6 ensemble with ESA CCI and CCI+ data using the ESMValTool

[DLR 5 PM, MetO 2 PM, ULB 1 PM, VUB 1 PM; TOTAL 10 PM]

Same as **Task 5.4**, but for the ECVs defined in **Task 5.3O.**

Task 5.5O (optional) Priority 3 Enhancement of ESMValTool for Regional Model Evaluation

[MetO 6 PM; DLR 2 PM; TOTAL 8 PM]

In this WP we will enhance the ESMValTool so that the namelists that are developed in WP1.3 can also be applied to regional models. A comparison of the performance of the global versus regional models and the added value of ESA CCI/CCI+ data for regional model evaluation will be performed.

Output / Deliverables

OPTIONAL

- D5.2O.v1: Enhanced ESMValTool namelist released for use in Task 5.3 that considers observational uncertainty and internal variability as developed in Task 3 [MetO, MPI-M, month 24]
- D5.3O.v1: Pull requests at the ESMValTool GitHub repository for specific ECVs of Task 5.3O [ECV leads of Task 5.3O, month 24]
- D5.3O.v2: Combined project specific ESMValTool namelist for global model evaluation released at GitHub for ECVs of Task 5.3O [DLR, month 28]
- D5.4O.v1: Report on CMIP6 global model evaluation with ESA CCI/CCI+ data from Task 5.3O and improvements compared to CMIP5 in support of IPCC AR6 [DLR, MetO, VUB, ULB, month 36]
- D5.5O.v1: Combined project specific ESMValTool namelist for regional model evaluation released at GitHub [MetO, month 32]
- D5.5O.v2: Report on CMIP6 regional model evaluation with ESA CCI/CCI+ data and improvements compared to CMIP5 in support of IPCC AR6 [MetO, month 36]

3.13O Generation of new ensembles of initial conditions for the Antarctic ice sheet
Leader and associated partners: ULB (associate partner)
Resources (man month/partner): 4 PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): assimilation, hindcast
Model used (e.g. Earth System model, individual components): BISICLES, f.ETISh
ECVs involved, CCI products involved: new ECVs: Sea Salinity; old ECVs: IS Antarctica (SEC, IV), SST **Aim of the experiments:** Generating new ensembles of initial conditions for the Antarctic ice sheet and analyzing its use for hindcast and decadal prediction. **Scientific question addressed:** What is the added-value of CCI ice sheets as sources of initial conditions on the seasonal to decadal climate forecast quality?
Rationale (why important for the community): Improving predictions/projections of future sea-level rise
Use of the uncertainty information:
Value of the assessment and complementarity with CCI experiments: **Coverage in space/ time:** 2007-2017, Antarctica (60°S)
Metrics to analyse the performances/impact: ensemble analysis
Tasks to be performed (e.g. re-formatting,analysis): Generation of new ensembles of initial conditions New ensembles of initial conditions will be generated for ice sheets using different models (BISICLES and f.ETISh). We will produce new initial conditions for the Antarctic ice sheet as follows: Two ensembles of ice sheet initial conditions will be produced: Transient simulations starting from the 2007-2009 initial state in order to assess SEC, GMB over the period 2007 to 2017 (hindcast) and transient simulations starting from the two initial states over the next century (ULB) will be carried out to check the influence of initial states obtained from IV on transient behaviour (comparison of model results with SEC) . The parameterization of sub-shelf melting using SST and Sea Salinity will be implemented and a comparison with model results for selected basins (to be precised as a function of data availability) will be conducted. Climate predictions Seasonal to decadal climate predictions will be initialized from these new initial conditions and compared with previous datasets. The comparison will provide a measure of the added value of these CCI and CCI+ data for f.ETISH/BISICLES forecast systems over timescales ranging from a few months ahead to a few decades. This will be carried out in another project (PARAMOUR-FNRS), but results will be useful for CCI+. **References:** **Deliverables:** Report on the added-value of CCI / CCI+ data as source of initial conditions for ie sheets

3.14O: Generation of new ensembles of initial conditions for the Greenland ice sheet
Leader and associated partners: VUB
Resources (man month/partner): 4 PM
Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): assimilation, hindcast
Model used (e.g. Earth System model, individual components): GISM-VUB **ECVs involved, CCI products involved:** IS Greenland (SEC, IV, GMB)
Aim of the experiments: Generating new ensembles of initial conditions for the Greenland ice sheet and analyzing its use for hindcast and decadal prediction. **Scientific question addressed:** What is the added value of assimilating CCI Greenland products to produce better initial conditions for decadal predictions.
Rationale (why important for the community): Improving predictions/projections of the Greenland ice sheet component to future sea-level rise. Contribution to ISMIP6/CMIP6/IPCC AR6.
Use of the uncertainty information: Uncertainty assessments of Greenland ice sheet ECVs are yet to be released. **Value of the assessment and complementarity with CCI experiments:** **Coverage in space/ time:** Greenland ice sheet and surrounding ocean. Initialization will use data from 2014-2017 (IV) and 1992-2017 (SEC) or longer if available. **Metrics to analyse the performances/impact:** Comparison of surface velocity, surface elevation, and surface elevation change with the ECVs using the ESMValTool.
Tasks to be performed (e.g. re-formatting,analysis): • **Assimilate IV, SEC, GMB in GISM-VUB using nudging methods to produce new ensembles of initial conditions for decadal predictions and century time-scale projections** • **Perform hindcast experiments on the 1992-2017 time scale and compare the model results with the ECVs** • **Perform predictions/projections on the decadal/century time scale** • **Perform sensitivity experiments to assess the added value of using CCI products** **References:** **Deliverables: Report on the added values of CCI products as source of initial conditions for the Greenland ice sheet.**

WP3.15O	
Title: Alpine glacier response to climate change	
Lead Partner	Antonello Provenzale, Carlo Baroni (CNR)
Model(s)	Minimal Glacier model, empirical glacier models, CMIP5-Euro-CORDEX models, CMIP6 runs.
Experiment type	Empirical modelling using CCI ECV datasets for validation; process study; inter-comparison
Period for experiment	historical: 1980-2016 projections: 2020-2080

NEW ECVs	Sea Salinity	Sea State	AG Biom	LST	Snow	Lakes	Hi-res LC	Water Vap.	Perma-frost					
				X	**X**		**X**	**X**	**X**					
OLD ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS – Arctic	IS – Ant.	Gla
					X		**X**			**X**				**X**

Other data	Alpine-scale in-situ and aerial data on glacier topography, shape; historical data on glacier mass balance and snout fluctuations.

Objectives

- To implement modelling frameworks for ensemble glacier dynamics, based on extensions of the process-based Minimal Glacier Models and/or of empirical models relating mass balance and glacier length to meteo-climatic data, and estimate the response of southern Alpine glaciers to climate change. Estimate the ability of current models (CMIP5-EuroCORDEX and CMIP6) to reproduce glacier response in mountains.

Scientific questions to be addressed

- Implement a suite of simplified models for mountain glacier dynamics, which can incorporate information on the geographical characteristics of the glaciers and relevant meteo-climatic variables. Estimate whether current models (high-resolution CMIP6 and CMIP5-EuroCORDEX) are able to reproduce glacier response and how ECVs can help improving the representation of glacier response.

Tasks to be performed

Glacier modelling [CNR 8 PM]

Mountain glaciers are retreating worldwide, with a corresponding reduction of the freshwater resources they contain. Currently, glacier models can be very complex and include several dynamical and thermodynamical processes. However, such models are appropriate for the detailed description of individual glaciers and require a large number of local information. In many instances, the interest is instead on the ensemble response of the glaciers in a given mountain range, in order to quantify the availability and evolution of cryospheric resources. In such cases, simplified models, such as process-based Minimal Glacier Models and/or empirical regressive models, are better suited to the goal.

Here, we intend to implement a suite of simplified models for mountain glacier dynamics, able to incorporate the information on the geographical characteristics of the glaciers and the relevant

meteo-climatic variables. ECVs such as glaciers, surface temperature, clouds and permafrost are essential to this goal. The models will be tuned and calibrated on existing ground observations on glacier length fluctuations and glacier mass balance, now available for the whole southern Alpine area, and a modelling framework for wider mountain areas will be developed and used for estimating the state of glaciers in the coming decades. Task 1: Develop/implement simplified models for the dynamics of mountain glaciers in selected mountain regions where ground information is available. Task 2: Validate the models on specific mountain ranges Task 3: Formulate future scenarios on the evolution of mountain glaciers in specific mountain ranges, based on suitably downscaled climate change scenarios.
Output / Deliverables
● D3.1A: Quality report on suite of simplified glacier models, able to incorporate the information from remotely-sensed ECVs [CNR, month 20] ● D3.1B: Quality report on estimates of future conditions of ensembles of mountain glaciers for various mountain ranges in different climate change scenarios [CNR, month 34]

WP3.16O Carbon fluxes and Earth Critical Zone dynamics in mountain areas	
Reference Partner	Antonello Provenzale, Elisa Palazzi, Ilaria Baneschi (CNR)
Model(s)	MetOffice JULES model, simplified soil-vegetation-atmosphere models, Euro-CORDEX models driven by CMIP5 GCMs, high-res CMIP6 runs from the PRIMAVERA H2020 project.
Experiment type	Task 3: Process studies; Land-vegetation-atmosphere modelling using ECVs as drivers and for validation; Use of ECVs in mountain environments.
Period for experiment	Test period: 2010-2016 projections: 2020-2050

NEW ECVs (only year 3)	Sea Salinity	Sea State	AG Biom	LST	Snow	Lakes	Hi-res LC	Water Vap.	Perma-frost					
			X	**X**	**X**		**X**		**X**					
OLD ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS – Arctic	IS – Ant.	Gla
					X		**X**							**X**

Other data	In-situ data (existing and collected during the project) on soil chemistry and physics, water and carbon fluxes by eddy covariance and accumulation chamber measurements, weathering, vegetation, geology and geomorphology in two study sites. Data from the H2020 ECOPOTENTIAL project.

Objectives
● To assess the reliability of the simulation of surface energy and water fluxes in the mountain Earth Critical Zone using Euro-CORDEX and high-res CMIP6 drivers. ● To analyse and model the dynamics of the Earth Critical Zone (ECZ) in mountain areas, developing and implementing appropriate numerical representations of ECZ processes and fluxes and their potential feedbacks to the climate system.
Scientific questions to be addressed
The high level questions for WP3.16O are as follows: ● How can CCI data be used for an assessment of the surface energy and water fluxes at high temporal and spatial resolutions and their representation in Euro-CORDEX models? ● How does uncertainty information of ESA CCI data translate into uncertainties of surface energy and water flux estimates? What are the key processes in ECZs affected by climate change, how well do models represent them, and how robust are modelling projections made for ECZs?
Tasks to be performed
WP 6.3.X Carbon fluxes and Earth Critical Zone dynamics in mountain areas [CNR 8 PM] To analyse and model the dynamics of the Earth Critical Zone (ECZ) in mountain areas and the associated soil-vegetation-atmosphere carbon fluxes developing and implementing appropriate numerical representations of the ECZ processes and fluxes. The models will use ECVs from Remote Sensing both as initial conditions and as validation data, and will make best use of the cross-scale, spatially extended information provided by remote sensing. Field data will be provided by two validation/study sites in the northwestern Italian Alps, namely the Nivolet Critical Zone Observatory at the Gran Paradiso National Park and the Torgnon instrumented site managed by the Aosta Valley Environmental Protection Agency. Remote Sensing of Essential Variables will be a starting point for a larger-scale characterization of the processes taking place in the mountain ECZ and of the ECZ evolution in time and space. The scientific challenge to be addressed is thus to develop appropriate models of some of the main processes in the ECZ (water and carbon fluxes, soil chemical evolution, weathering, vegetation dynamics), using the information provided by the Essential Climate Variables measured through Remote Sensing. Subtask 1: Develop/implement models for the dynamics of the mountain ECZ, based on existing modelling frameworks (JULES, ad-hoc simplified models) and able to incorporate information from ECVs. Subtask 2: Validate the models on specific study sites (Nivolet and Torgnon) Subtask 3: Formulate future scenarios on the evolution of the mountain ECZ, based on suitably downscaled climate change scenarios from CMIP5-EuroCORDEX runs and high-resolution CMIP6 simulations.
Output / Deliverables
● D6.3.1A: Quality report on suite of models, based on modifications of existing modelling frameworks and able to incorporate the information from remotely-sensed ECVs, for the dynamics of specific processes in the mountain Earth Critical Zone [CNR, months 24, 30] ● D63.1B: Quality report on estimates of future conditions of the mountain ECZ in different climate change scenarios [CNR, month 34]

WP3.17O consistency between CCI SM, PERMAFROST, and LAI products
Leader and associated partners: Meteo-France: Jean-Christophe Calvet
Resources (man month/partner): 4
Type of assessment: reanalysis, benchmarking
Model used (e.g. Earth System model, individual components): ISBA land surface model in the SURFEX open-source modelling platform LDAS-Monde open-source data assimilation system
ECVs involved, CCI products involved: SM, Permafrost, C3S LAI product and/or equivalent products (e.g. AVH15C1)
Aim of the experiments: Assess the consistency between CCI SM product, Permafrost, and LAI products
Scientific question addressed: 1. How can land ECVs consistency can be verified ? 2. Are land ECVs represented well in climate and land surface models ? 3. Can EO data improve land reanalyses ? 4. Can EO data improve representation of extreme events (e.g. droughts) ?
Rationale (why important for the community): SM is a key land ECV for hydrology, water resource assessment, crop production, fire risk monitoring, etc. Permafrost is related to SM and LAI through initial soil temperature profile conditions, and during and after melting
Use of the uncertainty information: specification of errors in the LDAS; assessment of the usefulness/consistency of the product through time
Value of the assessment and complementarity with CCI experiments: LDAS-Monde has the unique capability of sequentially assimilating vegetation and SM products, jointly.
Coverage in space/ time: daily, global, 1°x1°
Metrics to analyse the performances/impact: Correlation Coefficient on both volumetric and anomaly time-series, Bias, Standard Deviation of Differences, Root Mean Square Difference, Normalized Information Contribution for SM Correlation Coefficient, Bias, Standard Deviation of Differences, Root Mean Square Difference, Normalized Information Contribution for LAI Differences in areas affected by soil freezing (after and before the assimilation of SM and LAI) (with and without assimilation of SM and LAI) SM and LAI analysis Increments

Tasks to be performed (e.g. re-formatting,analysis): Active monitoring of soil moisture through the assimilation of both SM and LAI. Passive monitoring of the permafrost product associated to the assimilation of both SM and LAI. Assessment of model and analysis departures from the observations before and after the assimilation through time (seasonal and interannual variability, trends). Analysis of trends in river discharge, evapotranspiration and carbon flux variables (GPP, NEE, NPP, autotrophic and heterotrophic respiration terms).
References: Albergel, C., et al.: Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8.0: LDAS-Monde assessment over the Euro-Mediterranean area, Geosci. Model Dev., Geosci. Model Dev., 10, 3889–3912, https://doi.org/10.5194/gmd-10-3889-2017, 2017.
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)

WP3.18O Constraining future climate projections with ESA CCI Data OPTION	
Lead Partner	Veronika Eyring, Birgit Hassler, Axel Lauer, Mattia Righi, Sabrina Zechlau (DLR)
Other CMUG partners	Virginie Guemas (BSC), Javier Garcia-Serrano (BSC), Valentina Sicardi (BSC), Raffaele Bernardello (BSC) Dirk Notz (MPI)
Model(s)	CMIP5 and CMIP6 (including APPLICATE and PRIMAVERA simulations)
Experiment type	Historical + future climate projections (standard and high-resolution)
Period for experiment	1850-2100

NEW ECVs	Sea Salinity	Sea State	AG Biom	LST	Snow	lakes	Hi-res LC	Water Vap.	Perma-frost					
				X	X			X						
OLD ECVs	OC	SST	SSH	SI	SM	Fire	LC	GHG	O3	Cld	Aer	IS – Arctic	IS-Ant.	Gla
	X	X		X				X		X				

Other data	

Objectives
An emergent constraint refers to the use of observations to constrain a simulated future Earth system feedback. It is referred to as emergent, because a relationship between such a feedback and an observable element of climate variability emerges from an ensemble of ESM projections, providing a constraint on the future feedback. If physically plausible relationships can be found between, for example, changes occurring on seasonal or interannual time scales and changes found in anthropogenically-forced climate change, then an observational constraint of multi-model projections might be possible. The aim of this WP is to use ESA CCI and ESA CCI+ data to identify new or confirm existing emergent constraints. All emergent constraint diagnostics will be implemented into the ESMValTool in order to advance this discipline and make the results useable by the wider community. Emergent constraints help guiding model development onto processes crucial to the magnitude and spread of future climate change and to guide future observational priorities.

Scientific questions to be addressed:
• Can emergent constraints help to reduce the inter-model spread and uncertainties in climate projections? • Can ESA CCI data be used to identify new or confirm existing emergent constraints? • Are the ESA CCI derived emergent constraints robust when observational uncertainty is considered? • Are the ESA CCI derived emergent constraints robust across different ensembles of models? • Do the ESA CCI derived emergent constraints show similar short-term variability and response as alternative observational records? •
Tasks to be performed
In each task below, we will test the ESA CCI derived emergent constraints with other observational data if available and also consider alternate observational datasets that are provided by ESA CCI in addition to the best estimate. The robustness of the obtained emergent constraints results will be related to the uncertainty of the ESA CCI observational records. This will allow quantifying the confidence intervals for the emergent constraints themselves. In addition, each emergent constraint study will be tested for different model ensembles (e.g. CMIP5 versus CMIP6). All emergent constraint diagnostics will be implemented into the ESMValTool. **WP 18.1 Terrestrial carbon cycle feedbacks** [DLR 4 PM] Emergent constraints on carbon cycle feedbacks have been published in the last years with CMIP5 (Wenzel et al., 2014; 2016). For example, ESMs simulate a wide spread in tropical land carbon storage for the quadrupling of atmospheric CO_2, which is in the order of 252 ± 112 GtC when carbon climate feedbacks are enabled. Consequently, the spread in the long-term sensitivity of land carbon storage to future climate change (γ_{LT}) is large (-49 ± 40 GtC/K) and thus remains one of the key uncertainties in current ESM projections. A tight correlation in CMIP5 ESMs has been found between γ_{LT} and the short-term sensitivity of atmospheric CO_2 to inter annual variability in tropical temperature (γ_{IAV}), which enables the projections to be constrained with observations. The observed γ_{IAV} (-4.9 ± 0.9 GtC/yr/K) constrains the carbon cycle-climate feedback γ_{LT} to -44 ± 14 GtC/K (Wenzel et al., 2014). Emergent constraints of this type help to understand some of the underlying processes controlling future projection sensitivity and offer a promising approach to reduce uncertainty in Earth system projections. However, the emergent constraints on the carbon cycle so far used ground-based measurements and are restricted to specific regions. Here we will expand this work by using ESA CCI satellite data.

WP 18.2 Water vapor feedbacks [DLR 4 PM]

The increase in atmospheric water vapor as a response to global warming can act as a large positive climate feedback. Because of the magnitude of this feedback, even small errors can lead to large uncertainties in projections of future climate change. Previous estimates of the water vapor feedback based on the relationship between the short and long term water vapor feedback range between 1.9 and 2.8 $Wm^{-2}K^{-1}$. A critical limiting factor to accurately estimate the water vapor feedback is the length of the observational record (Gordon et al., 2013). High quality ESA CCI data will be used to update current estimates of the water vapor feedback and can contribute to reducing the uncertainty in climate projections.

WP 18.3 Cloud feedbacks [DLR 4 PM]

Cloud feedbacks are a leading contributor to the large inter-model spread in equilibrium climate sensitivity (ECS) (Stocker et al., 2013). In recent years, a number of new potential emergent constraints for cloud feedbacks have been proposed in the literature. A plausible physical explaining for the empirical relationship between predictor and predictand is seen as an important criterion for the reliability of an emergent constraint (Klein and Hall, 2015). Emergent constraints for the cloud feedback that are particularly promising in this respect such as the sensitivity of extra-tropical low-level cloud optical depth to temperature (Gordon and Klein, 2014) or the sensitivity of subtropical marine low-level cloud cover to sea surface temperature (Qu et al., 2014). They will be investigated using ESA CCI datasets.

WP 18.4 Snow albedo feedback [DLR 4 PM]

Spatial and temporal variability of snow cover maps are of great importance for various weather, climate and hydrological applications [Muñoz et al., 2013]. Emergent constraints for snow were first introduced by Hall and Qu (2006), showing that the seasonal cycle in snow albedo can be used to constrain the estimated temperature change in ESM's. The approach was further refined by Qu and Hall (2007). The ESA CCI snow and land surface temperature datasets provide new opportunities to quantify the snow albedo feedback. We will therefore expand the work from Qu & Hall (2006) using the ESA CCI datasets and implement a novel diagnostic within the ESMValTool.

WP18.5 Sea ice, Arctic amplification and linkages with the mid-latitudes [BSC 6 PM, MPI 6 PM]

A summer Arctic ice-free is currently not predictable by CMIP-class models with less than 100 years of uncertainties (Jahn et al, 2016). Relating simulated present-day sea ice characteristics with the rate of sea ice melting in CMIP5 database has allowed in the past to provide a refined estimate of the time window (2041-2060) for a summer Arctic ice free (Massonnet et al 2012). Here we will develop new diagnostics to weight sea ice projections with ESA CCI data. To which extent the Arctic changes described and constraint in Task 2.1.4 will impact the mid-latitude climate is still at a preconsensus stage (Cohen et al, 2014). We will relate the amplitude of the Arctic climate change and its linkages with the mid-latitudes to the climate mean state and variability, through the analysis of wide multi-model ensemble of PRIMAVERA/HighResMIP high-resolution climate change experiments, APPLICATE climate predictions and projections and CMIP6 historical simulations and scenarios as well as sensitivity experiments at both high and low resolution to the Arctic conditions. Such statistical relationships will allow to refine the estimates of Arctic amplification and Arctic-mid-latitude linkages based on CCI estimates of present day mean state and variability.

References:

Cohen J. et al, 2014, Recent Arctic amplification and extreme mid-latitude weather, Nat. Geosciences, 7, 627-637, doi:10.1038/ngeo2234.

Gordon, N. D., A. K. Jonko, P. M. Forster, and K. M. Shell: An observationally based constraint on the water-vapor feedback, J. Geophys. Res. Atmos., 118, 12,435-12,443, doi: 10.1002/2013JD020184, 2013.

Gordon, N. D., Klein, S. A.: Low-cloud optical depth feedback in climate models. J Geophys Res Atmos., 119, 6052-65, 2014.

Hall, A., and X. Qu (2006), Using the current seasonal cycle to constrain snow albedo feedback in future climate change, Geophys. Res. Lett., 33, L03502, doi:10.1029/2005GL025127.

Jahn A, J E Kay, M M Holland, D M Hall: How predictable is the timing of a summer ice-free Arctic? Geophys. Res. Lett., 43, 9113, 9120, doi: 10.1002/2016GL070067.

Kessler A. and J. Tjiputra The Southern Ocean as a constraint to reduce uncertainty in future ocean carbon sinks. Earth Syst. Dynam., 7, 295-312, 2016

Massonnet, F, T. Fichefet, H. Goosse, C. M. Bitz, G. Philippon-Berthier, M. M. Holland, P. -Y. Barriat, 2012, Constraining projections of summer Arctic sea ice, The Cryosphere, 6 1383-1394.

Muñoz, J., Infante, J., Lakhankar, T., Khanbilvardi, R., Romanov, P., Krakauer, N., & Powell, A. (2013). Synergistic Use of Remote Sensing for Snow Cover and Snow Water Equivalent Estimation. British Journal of Environment and Climate Change, 3(4), 612.

Qu, X. and A. Hall, 2007: What Controls the Strength of Snow-Albedo Feedback?. J. Climate, 20, 3971–3981, doi: 10.1175/JCLI4186.1.

Qu X., Hall, A., Klein, S. A., Caldwell, P. M.: On the spread of changes in marine low cloud cover in climate model simulations of the 21st century. Clim Dyn., 42, 2603-26, doi: 10.1007/s00382-013-1945-z, 2014.

Stocker, T. F., Qin, D., Plattner, G.-K., et al.: Technical summary. In: Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M., editors. Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge: Cambridge University; 2013. p. 33-115.

Wenzel, S., Cox, P. M., Eyring, V., and Friedlingstein, P.: Projected land photosynthesis constrained by changes in the seasonal cycle of atmospheric CO2, Nature, doi: 10.1038/nature19772, 2016.

Wenzel, S., P. M. Cox, V. Eyring, and P. Friedlingstein, Emergent Constraints on Climate Carbon Cycle Feedbacks in the CMIP5 Earth System Models, JGR Biogeoscience, 119(5): 2013JG002591, 2014.

Output / Deliverables

- D2.1 v1: Emergent constraints implemented into the ESMValTool [BSC, DLR, MPI, month 24]
- D2.1. v2 Report on the application of the selected emergent constraints and ESA CCI / CCI+ data [BSC, DLR, MPI, month 30]

3.19O Biophysical feedbacks in shelf seas

Leader and associated partners: Met Office

Resources (man month/partner): 4

Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Assimilation, reanalyses

Model used (e.g. Earth System model, individual components): The model used will be NEMO-ERSEM, which is used as part of CMEMS for operational forecasting and reanalysis of the North-West European Shelf Seas, and is also used for regional climate studies. The assimilation system will be NEMOVAR, and will make use of the uncertainty estimates provided with the CCI products. Data assimilation will be performed using the variational NEMOVAR system, used for operational ocean forecasting and reanalysis at the Met Office and ECMWF.

ECVs involved, CCI products involved:

CCI ECVs: OC, SST, Sea level, sea surface salinity could (if available)

Other ECVs: temperature, salinity, carbon dioxide, and ocean heat content

Aim of the experiments:

This activity follows on from Activity 2, but with a focus on the North-West European Shelf Seas, a highly productive and economically important region, identified as being vulnerable to climate change.

This activity will perform additional experiments to complement those performed in Activity 2, in order to assess the relative suitability of current CCI ocean colour products for constraining model reanalyses of case 1 and case 2 waters.

The distribution of chlorophyll in the ocean has an impact on light attenuation and therefore ocean heat uptake, changing the ocean physics and sea temperature. However, this biophysical feedback is not yet commonly included in climate models or reanalyses. This activity will assess the suitability of CCI ocean colour products to constrain this process when assimilated into coupled physical-biogeochemical ocean reanalyses. Assimilating ocean colour data has been demonstrated to improve the accuracy of 3D model chlorophyll, and it is expected that this will lead to more accurate simulation of light attenuation and ocean heat uptake in reanalyses, when biophysical feedback processes are included.

Furthermore, the relative ability of the CCI ocean colour products to constrain model biogeochemistry in overlapping case 1 and case 2 regions in the global NEMO-MEDUSA and regional NEMO-ERSEM models will be assessed.

Scientific question addressed:

This will assess the impact of including biophysical feedbacks, driven by assimilation of CCI ocean colour data, on the model representation of the physical ocean ECVs, the consistency of features between ECVs and processes, and the carbon cycle.

This activity will provide an assessment of how much further development may be required for CCI products to be as suitable for reanalysis in the coastal as the global ocean. It will also provide an indication of the consequences of this for estimates of shelf sea carbon budgets, an important uncertainty in the future global carbon cycle.

Rationale (why important for the community):

During CCI, ocean colour products were developed with a particular focus on case 1 (clear, open ocean) waters, but with case 2 (complex, coastal) water algorithms included in the V3.0 product release. Nonetheless, the suitability of CCI ocean colour products for use in case 2 waters, which cover the majority of the world's fisheries, has been identified as a key requirement for further development.

This WP will deliver an assessment of the relative suitability of CCI ocean colour products for constraining ocean biogeochemistry and physics in the global and coastal oceans, and recommendations for improvements required for CCI products to be better suited to highly productive and economically important coastal waters. This relates to the WCRP Grand Challenges on Carbon Feedbacks and Near-term Climate Prediction, as well as to the UN Sustainable Development Goal 14 on Life Below Water.

This will build on prior work performed as part of the EC FP7 MyOcean2 project, the pre-operational phase of the Copernicus Marine Environment Monitoring Service (CMEMS).

Use of the uncertainty information:

The uncertainty information provided with the CCI ocean colour products will be used both in the quality control of the observations, and in the error covariances used in the data assimilation, in order to provide the best possible error estimates for the data assimilation. This will also allow the experiments to account for known increases in uncertainty in Case 2 waters, as calculated by the CCI team.

Value of the assessment and complementarity with CCI experiments:

Complements the work in Activity 2

Coverage in space/ time: North-West European Shelf Seas, time span for CCI data.

Metrics to analyse the performances/impact:

Statistical comparison of model fields to ECVs, time series analysis of ocean heat content and other climate indicators, consistency of spatial and temporal features in model fields compared with ECVs.

Tasks to be performed (e.g. re-formatting, analysis):

Two equivalent reanalyses will be performed, assimilating CCI ocean colour products. The first reanalysis will have no feedback from biology to physics, as in standard climate models. The second reanalysis will include the process. The two runs will then be assessed against CCI sea surface temperature (SST), sea level products (sea surface salinity could also be used if available), as well as in situ observations of temperature, salinity, carbon dioxide, and ocean heat content.

References: Builds upon earlier CMUG paper: Ford D. and Barciela R., Global marine biogeochemical reanalyses assimilating two different sets of merged ocean colour products, Remote Sensing of Environment, 2017, https://doi.org/10.1016/j.rse.2017.03.040.

Builds upon earlier EC FP7 MyOcean2 report: Ford D. and Barciela R., Biophysical feedbacks in a coupled physical-biogeochemical ocean model, Forecasting Research Technical Report 608, Met Office, Exeter, UK, 2015.

Deliverables: Contribution to CMUG D3.1 Quality Assessment Report, Journal paper on results

3.20O The effect of Lakes on local temperatures

Leader and associated partners: Met Office

Resources (man month/partner): 4

Type of assessment (e.g. statistical analysis, detection, attribution, assimilation, prediction, hindcast, budget analysis, reanalysis): Assimilation, process understanding

Model used (e.g. Earth System model, individual components): PRECIS Met Office Regional Climate Model

ECVs involved, CCI products involved:

CCI ECVs: Lakes, LST,

Other ECVs: Lake surface water temperature

Aim of the experiment:

This activity aims to identify and describe the interactions and relationships between lakes and their surrounding land areas. Typically this would be around large lakes (e.g. Victoria, Great Lakes)

Scientific question addressed:

What are the interactions between lakes and the surrounding land areas?

What effect does lake temperature (or other parameter) have on the surrounding LST?

Rationale (why important for the community):

A key use for LST data is as a driver for regional models in small scale processes. This work will validate the LST by using it to understand and estimate the effects of lake surface water temperature.

Use of the uncertainty information:

As provided in the ECV data and model.

Value of the assessment and complementarity with CCI experiments:

This work complements the LST work in WPs 3.1, 3.4 and 3.5. It should be able to include the work on uncertainty from WP4.

Coverage in space/ time: 12km resolution, time span for CCI data.

Metrics to analyse the performances/impact:

Comparison of model fields to ECVs, time series analysis for processes involved and climate indicators, consistency of spatial and temporal features in model fields compared with ECVs.

Tasks to be performed (e.g. re-formatting, analysis):

Run a simulation of Lake Surface water Temperature dependence on surface air temperature using satellite-era LSWT observations for about 4 major lakes and LST over that period. Testing the correlation of observations and simulation on a variety of timescales, and assess the degree of temporal consistency of observed and simulated mean and variability statistics. Interpret the usefulness of the results.

References: None, but has links to EUSTACE project

Deliverables: Contribution to CMUG D3.1 Quality Assessment Report.

3.21O: LDAS-Monde_PERMAFROST

Leader and associated partners: Meteo-France

Resources (man month/partner): 4 / Meteo-France

Type of assessment: reanalysis

Model used (e.g. Earth System model, individual components):
ISBA land surface model in the SURFEX open-source modelling platform
LDAS-Monde open-source data assimilation system

ECVs involved, CCI products involved: Permafrost, SM, C3S LAI product and/or equivalent products (e.g. AVH15C1)

Aim of the experiments: Assess the consistency between CCI Permafrost, SM product and LAI products

Scientific question addressed:
1. How can land ECVs consistency can be verified ?
2. Are land ECVs represented well in climate and land surface models ?
3. Can EO data improve land reanalyses ?
4. Can EO data improve representation of extreme events (e.g. droughts) ?

Rationale (why important for the community):
Permafrost is related to SM and LAI through initial soil temperature profile conditions, and during and after melting

Use of the uncertainty information:
Assessment of the usefulness/consistency of the product through time

Value of the assessment and complementarity with CCI experiments:
LDAS-Monde has the unique capability of sequentially assimilating vegetation and SM products, jointly.

Coverage in space/ time: daily, boreal areas, 0.25°x0.25°

Metrics to analyse the performances/impact:
Differences in areas affected by soil freezing (after and before the assimilation of SM and LAI)
(with and without assimilation of SM and LAI)

Tasks to be performed (e.g. re-formatting,analysis):
Passive monitoring of the permafrost product associated to the assimilation of both SM and LAI. Assessment of model and analysis departures from the observations before and after the assimilation through time (seasonal and interannual variability, trends).

References:
Albergel, C., et al.: Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8.0: LDAS-Monde assessment over the Euro-Mediterranean area, Geosci. Model Dev., Geosci. Model Dev., 10, 3889–3912, https://doi.org/10.5194/gmd-10-3889-2017, 2017.

Deliverables:
A quality assessment report

3.22O: LDAS-France_SM_SNOW

Leader and associated partners: Meteo-France

Resources (man month/partner): 4/Meteo-France

Type of assessment: reanalysis

Model used (e.g. Earth System model, individual components):

ISBA land surface model in the SURFEX open-source modelling platform

LDAS-Monde open-source data assimilation system

ECVs involved, CCI products involved: SM, SNOW, LST, C3S LAI product and/or equivalent products (e.g. AVH15C1)

Aim of the experiments: Assess the consistency between SNOW, LST, SM CCI products and LAI products

Scientific question addressed:

1. How can land ECVs consistency can be verified ?
2. Are land ECVs represented well in climate and land surface models ?
3. Can EO data improve land reanalyses ?
4. Can EO data improve representation of extreme events (e.g. droughts) ?

Rationale (why important for the community):

SM is a key land ECV for hydrology, water resource assessment, crop production, fire risk monitoring, etc.

Use of the uncertainty information:

specification of errors in the LDAS ; assessment of the usefulness/consistency of the product through time

Value of the assessment and complementarity with CCI experiments:

LDAS-Monde has the unique capability of sequentially assimilating vegetation and SM products, jointly.

Coverage in space/ time: daily (daytime, night-time for LST), metropolitan France, 8 km x 8 km

Metrics to analyse the performances/impact:

Correlation Coefficient on both volumetric and anomaly time-series, Bias, Standard Deviation of Differences, Root Mean Square Difference, Normalized Information Contribution for SM

Correlation Coefficient, Bias, Standard Deviation of Differences, Root Mean Square Difference, Normalized Information Contribution for LAI

Correlation Coefficient, Bias, Standard Deviation of Differences, Root Mean Square Difference for LST

(with and without assimilation of SM and LAI)

Correlation Coefficient, Bias, Standard Deviation of Differences, Root Mean Square Difference for snow depth

Correlation Coefficient, Bias, Standard Deviation of Differences, Root Mean Square Difference for SWE

Differences in areas covered by snow (after and before the assimilation of SM and LAI)

SM and LAI analysis Increments

Tasks to be performed (e.g. re-formatting,analysis):

Active monitoring of soil moisture and SWE through the assimilation of SWE, SM and LAI.

Passive monitoring of LST associated to the assimilation of SWE, SM and LAI.

Assessment of model and analysis departures from the observations before and after the assimilation through time (seasonal and interannual variability, trends). Analysis of trends in river discharge, evapotranspiration and carbon flux variables (GPP, NEE, NPP, autotrophic and heterotrophic respiration terms).

References:

Albergel, C., et al.: Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8.0: LDAS-Monde assessment over the Euro-Mediterranean area, Geosci. Model Dev., Geosci. Model Dev., 10, 3889–3912, https://doi.org/10.5194/gmd-10-3889-2017, 2017.

Deliverables:

A quality assessment report

WP4.12O Improving the representation of sea ice variability and mean state in EC-Earth
Leader and associated partners: BSC, Pablo Ortega
Resources (man month/partner): 4 man months
Type of assessment: Analysis of the consistency of sea ice CCI products with different alternative configurations of LIM3 (sea-ice model in EC-Earth)
Model used (e.g. Earth System model, individual components): DFS atmospheric forced NEMO3.6-LIM3 (Madec 2008; Vancopenolle et al 2009) model (the ocean and sea ice components in the CMIP6 version of EC-Earth).
ECVs involved, CCI products involved: CCI/CCI+ ECVs: Sea Ice Concentrations (SIC) and Thickness (SIT)
Aim of the experiments: To identify the best performing configuration of the NEMO3.6-LIM3 regarding the representation of Arctic Sea Ice, to be used in later developments of the EC-Earth model (thus impacting future CMIPs). These experiments will be performed within the context of the H2020 projects PRIMAVERA and APPLICATE.
Scientific question addressed: · What sea ice rheology scheme (Maxwell elasto-brittle or anisotropic) leads to a better representation of sea ice in the model? · Can we improve this representation by increasing/decreasing the default number of sea ice categories in the model (i.e. 5)? · Does the inclusion of a melting pond scheme improve the realism of the model? · How do these different model configurations impact the representation of the sea ice mean state and variability, and the occurrence of extreme events? · Are the improvements consistent for both sea ice concentration and thickness?
Rationale (why important for the community): Fine-tuning the global Earth System models is always an arduous task, as it requires to find a balanced representation of many different climate processes at different timescales and across all the different components. In these exercises, it's usually difficult to isolate and investigate the impact of specific configuration choices to the representation of specific processes. The analysis herein envisaged will allow to constrain the optimal setup to improve the representation of sea-ice processes in the NEMO3.6-LIM3 stand-alone configuration, to be later tested in its coupled ocean-atmosphere version, and provide a guideline for other climate models.
Use of the uncertainty information:
Value of the assessment and complementarity with CCI experiments: The parallel assessment of the coherence between the different model configurations and both the SIC and SIT datasets will serve as an additional cross-consistency test between both CCI products, and also individually between them and other independent observational datasets.

Coverage in space/time: Pan-Arctic region, 1978-Apr 2015
Metrics to analyse the performances/impact: Spatial and temporal correlations, Empirical Orthogonal Functions, Histograms
Tasks to be performed (e.g. re-formatting,analysis): - Compilation of different observational products (CCI and non-CCI produced) to be compared with the model outputs - Estimation of the biases (in mean state and variability) across the different model configurations - EOF analysis of the major modes of sea ice variability in the observational and model data - Histograms of the occurrence of extreme events between and within the observational and model datasets - Synthesis of the main results
References: Madec G (2008) NEMO ocean engine, Technical Note, IPSL Vancopenolle, M, T Fichefet, H Goosse, S Bouillon, G Madec and MAM Maqueda (2009) Ocean Modelling, 27(1):33–53.
Deliverables: A quality assessment report at M12, M24 and/or 36 for D3.1 (depends on CCI data availability and when the CMUG research takes place)