CMUG CCI+ Deliverable

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Climate Modelling User Group

Deliverable 3.1

Quality Assessment Report

Centres providing input: Met Office, MPI-M, ECMWF, MétéoFrance, IPSL, BSC

Revision nr.	Date	Status
0.1	26 July 2019	Agreed outline and scope of content with ESA
0.2	9 Sept. 2019	First input from partners of activity and results, Met Office, IPSL, BSC
1.0	24 Sept 2019	Input from all WP3 partners, submission to ESA
1.1	21 Feb 2020	Address comments from ESA
1.2	March 2020	Accepted by ESA
1.3	August 2020	Typo corrected

CMUG CCI+ Deliverable 3.1

Quality Assessment Report

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Technical report on quality assessment

1. Purpose and scope of this report

This document is the first technical Report on the Quality Assessment of CCI ECVs in the CCI+ phase of the initiative. Its purpose is to assess the quality of the available versions of CCI products and update feedback to ESA and the CCI teams. This assessment is being conducted by the climate modelling and reanalysis centres in the CMUG consortium using CCI Phase 2 data and includes a wide range of data and model interactions (assimilation, boundary conditions, optimisation, reanalysis, sensitivity studies etc.). This evaluation continues to examine the following top level questions:

- Are the CCI data products of 'climate quality' i.e. is their quality adequate for use in climate modelling, reanalysis and for wider research applications?
- Are the error characteristics provided by CCI products adequate?
- Do the products meet the Global Climate Observing System (GCOS) quality requirements for satellite for Essential Climate Variables (ECV)?
- Is the quality of the products sufficient for climate service applications?

2. CMUG approach for assessing quality in CCI products

This report describes the results in the first year of CMUG CCI+ Task 3 "Assessing consistency and quality of CCI products". The work is spread across twelve Work Packages (WP) listed in Table 1, which includes the CCI product being assessed, and the type of climate modeling experiment.

The CMUG results presented here provide information on the accuracy, consistency and usefulness of the CCI data sets available to CMUG up to July 2019. The analysis assesses the suitability of the CCI datasets for coupled climate model and reanalysis applications and evaluates the impact of the data products on model based studies, including quantification of the uncertainties associated with both the models and the observations. This information is aimed at the CCI teams producing the data but is also of use to other modelling centres which will use CCI data in the future.

The modeling experiments are described in the following sections of this report and cover the following topics: assimilation of CCI data into climate models; cross assessments of CCI data (those which have physical links/interactions); benchmarking of models against observations; applications for reanalysis; statistical analysis; hindcasting; and Earth system process studies. The CMUG work reported here was conducted with the CCI data available at the time, which is the final Phase 2 Climate Record Data Packages produced by the CCI projects but owing to the early stage of the "new" CCI+ projects, no data was available from them. Where the results are not yet available, the section is marked accordingly. A planned update of this report in the Autumn of 2020 will include assessments missing from this version.

CMUG WP 3: Quality Assessment of CCI products		Lead	Experiment type	CCI ECVs	Other ECVs
3.1	Consistency between CCI LST, SM product and LAI products	Météo France	Reanalysis, benchmarking	LST, SM	C3S LAI
3.2	Consistency between CCI Snow, SM product and LAI products	Météo France	Reanalysis, benchmarking	Snow, SM	C3S LAI
3.3	Consistency between CCI SM, PERMAFROST, and LAI products	Météo France	Reanalysis, benchmarking	Permafrost, SM	C3S LAI
3.4	Propagation of CCI(+) observational uncertainties to climate models scales	BSC	Statistical analysis	SM, Fire, LST	
3.5	Document SM-atmosphere feedbacks in transition regions (temperature and precipitation)	IPSL	Process analysis	SM,LST	turbulent fluxes, radiation, air temp. Precipitations
3.6	Better constrain evapotranspiration at the scale of climate model	IPSL	Process analysis	SM, Snow, LST	LAI , flux, radiation, air temp
3.7	The effect of Lakes on local temperatures	Met Office	Assimilation, process understanding	Lakes, LST	Lake surface temp datasets
3.8	Evaluation of the impact on skill of HiRES-SIR on seasonal prediction	BSC	Hindcast	SI conc, SI thick, Salinity, SST	
3.9	Biophysical feedbacks in the global ocean	Met Office	Assimilation, reanalyses, process study	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	Aerosol dust, HRLC/LC	
3.11	Dust reanalysis at the regional scale	BSC	Assimilation, stat. analysis	Aerosol dust, HRLC/LC	
3.12	Integrated assimilation of the CCI+ Sentinel 3 AOD and Sentinel 5P ozone retrievals in the IFS	ECMWF	Reanalysis	Aerosol and Ozone	

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

3. CMUG Quality Assessment Results

3.1 Consistency between CCI LST, SM product and LAI products

Lead partner: Météo France
Author: Jean-Christophe Calvet

Aim

The aim of this research is to assess the consistency between CCI LST, SM product and LAI products. It will address the following scientific questions:

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) ?

Summary of Work

With CCI LST data not being available, work could not proceed in this WP.

Publications

None so far, but the interest in the results leading to a journal or conference publication will be described in the next version of this report.

Interactions with the ECVs used in this experiment

In the first 12 months of this phase of CMUG work there have been interactions with the SM and LST CCI ECV teams at the quarterly CSWG meetings and the Integration meetings. Contact outside that has been only to check on the continuation of the SM project, and to learn about the beta data that LST released in late 2019.

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

This experiment is dependent on CCI LST data and now that a beta dataset is available the work can start, however,contrary to other ECV products, the LST-CCI portfolio contains many independent products instead of a single merged CDR. Integrating all of them in our application would be difficult. We may concentrate on year 2008 since all products should be available for this year, including the merged product using all-weather microwave observations. It must be noted that a number of independent products are already available to CMUG but that they are still under validation by the LST team.

3.2 Consistency between CCI Snow, SM product and LAI products

Lead partner: Météo France
Author: Jean-Christophe Calvet

Aim

The aim of this research is to assess the consistency between CCI Snow, SM product and LAI products. It will address the following scientific questions:

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)?

Summary of Work

With CCI LST and CCI Snow data not being available, work did proceed in this WP. The Snow products are still under validation by the Snow team. The NOAA IMS product has been used as a proxy for the CCI product in the first tests of the assimilation of Snow Cover Fraction into the ISBA land surface model.

Publications

None so far, but the interest in the results leading to a journal or conference publication will be described in the next version of this report.

Interactions with the ECVs used in this experiment

In the first 12 months of this phase of CMUG work there have been interactions with the SM and Snow CCI ECV teams at the quarterly CSWG meetings and the Integration meetings. Contact outside that has been only to check on the continuation of the SM project, and to learn about the beta data that LST released in late 2019.

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

This experiment is dependent on CCI LST data and now that a beta dataset is available the work can start. The plan is to use the Snow Cover Fraction product.

3.3 Consistency between CCI SM, PERMAFROST, and LAI products

Lead partner: Météo France
Author: Jean-Christophe Calvet

Aim

The aim of this research is to assess the consistency between CCI SM, CCI Permafrost and LAI products. It is noted that the CCI Permafrost data will be produced in a permafrost model forced with CCI SM data (amongst other data inputs) thus comparisons will be made with and without CCI SM. It will address the following scientific questions:

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) ?

Summary of Work

With CCI_Permafrost data not being available, work could not proceed in this WP.

Publications

None so far, but the interest in the results leading to a journal or conference publication will be described in the next version of this report.

Interactions with the ECVs used in this experiment

In the first 12 months of this phase of CMUG work there have been interactions with the SM and Permafrost CCI ECV teams at the quarterly CSWG meetings and the Integration meetings. Contact outside that has been only to check on the continuation of the SM project.

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

This experiment is dependent on CCI Permafrost and CCI Snow ECV data and will proceed when they are available. The permafrost products are now being uploaded by the team and should be available later in 2020, in which case the CMUG work will proceed as planned in the description of work.

3.4 Propagation of CCI(+) observational uncertainties to climate model scales

Lead partner: BSC
Authors: Aude Carreric, Markus Donat, Pablo Ortega and Etienne Tourigny

Aim

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. It will address the following scientific questions:

1. How can the observational uncertainty estimates provided by CCI(+) reference datasets be translated into different spatiotemporal scales to compare to climate model simulations?
2. Are there important differences relative to the nature of the products?

Key Outcomes of CMUG Research

1. Preliminary results suggest that observational uncertainty on Arctic SICs can have a strong impact on the assessment of seasonal forecasts, larger than the uncertainty related to ensemble size and the length of the records.
2. An interesting region to study the effect of the propagation of errors for the fire ECV (burnt area) is North Australia.

Summary of Results

The analysis on the propagation of errors started in the 1st July 2019, after the hiring of Aude Carreric (who is performing the analysis), and will finally be centered on two ECVs: fires (i.e. burnt area) as initially planned, and sea ice (i.e. sea ice concentrations; SIC) in substitution of the originally envisaged soil moisture, for which only trajectory based L2 datasets are currently available through the CCI data portal, thus complicating the propagation into the model scales, which are gridded in space[1]. We believe that sea ice concentrations are an excellent alternative of greater utility for our ongoing activities, in which sea ice plays a central role, and the propagated errors will be more easily exploitable, as for example in the evaluation of the

[1] CMUG acknowledge that more datasets are available than are published on the CCI data portal and CMUG always contact the ECV teams to check if such datasets are available.

forecasts with the enhanced sea ice reanalysis performed in Work Package 3.8. The new ECV Land Surface Temperature has not been considered yet as the data was not available at the time the analysis started.

The analysis of SICs was initially focused on the Barents and Kara Seas in September and October (red area in Figure 3.4.1), a region and a season in which sea ice variations have been linked with other remote impacts, including on the North Atlantic Oscillation (e.g. Ruggieri et al 2016) and the occurrence of extremes over Europe (e.g. Acosta-Navarro et al 2019).

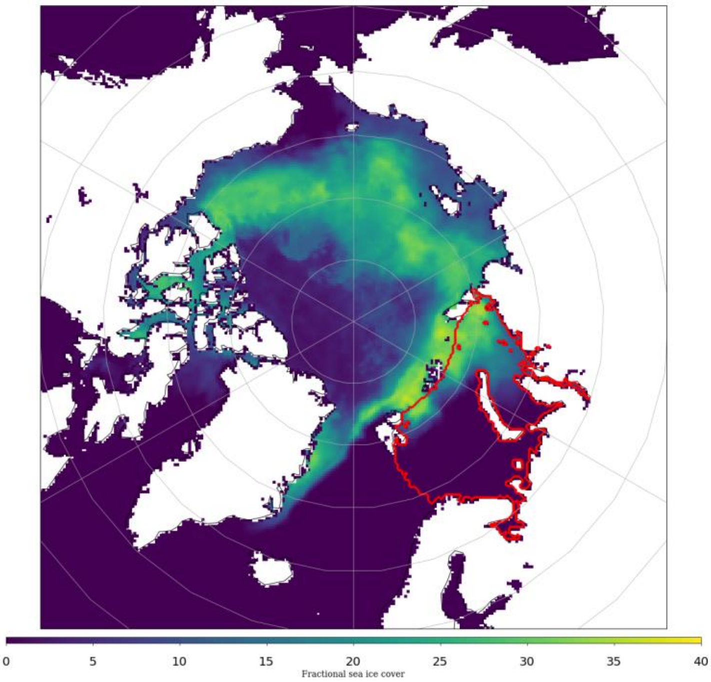


***Figure 3.4.1**: Interannual standard deviation of the observed SICs (in colours) from the in August and September over the period 2003-2016. The red line encloses the Barents and Kara Seas. ESA observational data from SIC climate data record from the AMSR-E and AMSR-2 instruments at 50km grid spacing, version 2.1.*

We followed the methodology and equations in Bellprat et al. (2017) to propagate the uncertainties of SICs (from the Sea Ice Concentration climate data record from the AMSR-E and AMSR-2 instruments at 50km grid spacing, version 2.1) into the model scales, in this case for EC-Earth 3.2 in its standard resolution (approximately 1° in the ocean). As a first example, we concentrated on the average of SICs over the Barents and Kara Sea. Uncertainties are propagated to investigate their impact in the evaluation of skill for a seasonal prediction forecast with EC-Earth 3.2 initialized every 1st May for the period 1993-2014. Their effect is compared with that of the uncertainty related to the ensemble size and the length of the forecast period (see Bellprat et al 2017 for further details).

Figure 3.4.2 shows that the observational uncertainties have indeed a strong impact on the skill, especially for the longer lead times. In August, for example, anomaly correlation coefficients range from 0.7 (which would correspond to good performance) to negative values close to -0.4 (suggestive of really poor performance). This effect is comparable to the combined effect of the ensemble size and hindcast length uncertainty. Such results thus highlight that the skill over this area is particularly uncertain, at least for the seasonal forecasts with EC-Earth 3.2. It is therefore important to identify other regions and seasons for which the skill remains high and is less sensitive to all these uncertainty sources.

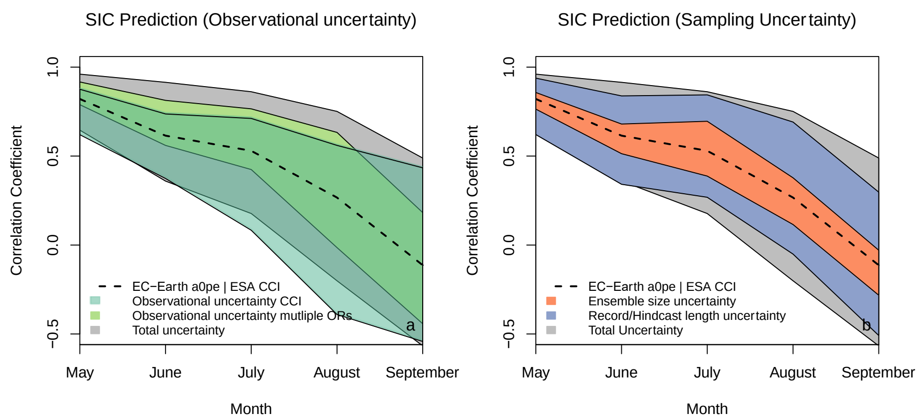


Figure 3.4.2: *Sub-seasonal to seasonal forecast skill of EC-Earth3.2 (10 members) with respect to ESA-CCI SIC (dashed line) in predicting the average sea ice concentration in the Barents and Kara Seas in a seasonal forecast system initialised on the 1st May. The areas show the 5-95% percentile range of the bootstrapped (10^6) uncertainty sources around the sample correlation skill for (left) the uncertainty in the ESA-CCI SIC observations once propagated into the model scales (blue) and the uncertainties as derived from the comparison of three other SIC products (green; NSIDC51, NSDC79 and an earlier version of ESA-CCI SIC) and (right) the sample uncertainty due to a limited ensemble size and record length of the ESA-CCI SIC product. The grey area shows the total uncertainty obtained by resampling all sources at the same time.*

Publications

None so far, but the builds upon the methodology developed by Bellprat et al. (2017) in the previous phase of CMUG.

Interactions with the ECVs used in this experiment

In the first 12 months of this phase of CMUG work there have been interactions with the SI and Fire CCI ECV teams at the quarterly CSWG meetings and the Integration meetings.

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

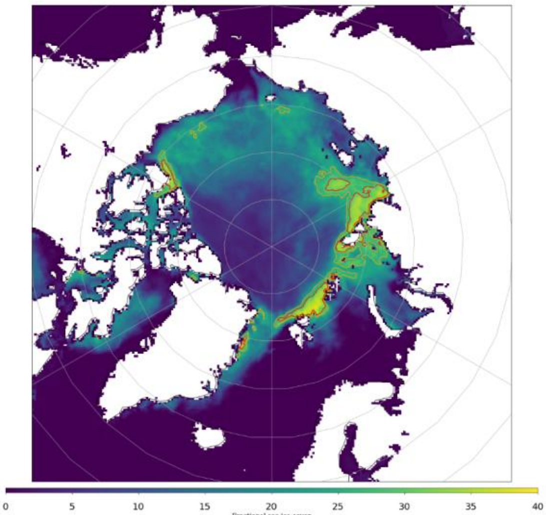
Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

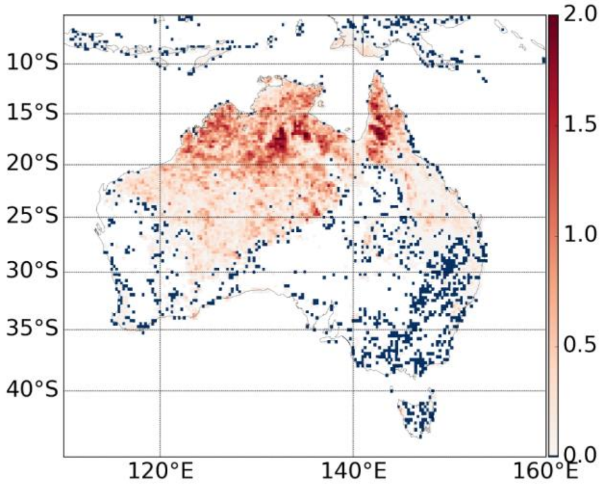
In the following two months, with which we will cover the 4 PMs allocated for this task, Aude Carreric will extend the analysis to a wider region over the Arctic, also of interest for seasonal forecasting. Predicting successfully the summer Arctic sea ice extent is of great interest for different socio-economic sectors, from fishing to shipping and even oil extraction. Our new area will cover the areas with higher interannual variability in SIC in the months of July and August (See Figure 4.3.3). These expand from the northeast tip of Greenland all the way to the Laptev Sea. Finally, a grid-point wise analysis of the effect of these uncertainties will also be done, covering the whole pan-Arctic region.

If time allows, we will also perform a similar analysis focused on the predictability of burned area (ECV-CCI fires) over Australia (Figure 3.4.4). This is a region with high interannual variability in wild fires, and where their occurrence is mostly natural (instead of human induced). It's important to notice that only wild fires of natural origin, or with a strong natural component, are predictable.



served SICs (in colours) in July and ·ed lines enclose the regions where ctively. ESA observational data from ·2 instruments at 50km grid spacing,

Figure 3.4.4: *Interannual standard deviation of total burned area in September-October-November over the period 2001-2018. Observational ESA data from MODIS fire_cci burned area grid product, version 5.1.*



3.5 Document SM-atmosphere feedbacks in transition regions (temperature and precipitation)

Lead partner: IPSL
Authors: Frederique Cheruy, Agnes Ducharne, Y. Zhao

Aim

The aim of this research is to examine if CCI(+) data be used to detect on observations the soil moisture/surface temperature feedback related to soil thermal inertia. It will address the following scientific question:

1. Can the co-variations of SM, LST and precipitation be used to document the soil moisture - temperature feedback (intra-daily time scale)?

Summary of Work

With LST data not being available, work did not proceed in this WP. The LST test beta data became available at the end of 2019, and it is suitable for use in this work.

Publications

None so far, but the interest in the results leading to a journal or conference publication will be described in the next version of this report.

Interactions with the ECVs used in this experiment

In the first 12 months of this phase of CMUG work there have been interactions with the SM and LST CCI ECV teams at the quarterly CSWG meetings and the Integration meetings.

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

Y. Zhao was hired on a CMUG contract starting 1st of October 2019. She has been in contact with the LST team in the person of D. Ghent. The various datasets available for the analysis have been identified. They include LST, Soil Moisture and are listed below:

LST CCI data sets
* SEVIRI Level-3 0.05deg hourly (2008-2010) – clear-sky only, Europe, Africa and parts of S. America
* Harmonized ATSR-2/AATSR multi-sensor product 0.05deg daily (day and night) (1995-2012) – clear-sky only, global
* Terra-MODIS/Aqua-MODIS Level-3 0.05deg daily (day and night) (2000-2018) – clear-sky only, global
* SSMI and SSMIS Level 3 0.25deg daily (day and night) (1995-2017) – all-sky, global SM CCI data sets:
* CCI SM v04.5 COMBINED product 0.25deg daily (day and night) (1987-2018) – global

The next step will be to combine these data at regional scale and verify that the statistics is sufficient to sample the soil-moisture and diurnal amplitude of the LST relationship in transition regions such as the Sahel. We will try to use precipitation observations to get information on the time occurrence of the precipitating events since the LST are only clear sky products. The data planned to be used are the TRRM products, we will also check the possibility of using the SM2RAIN-Ascat soil product.

Commented [DA1]: TRMM?

3.6 Constraining the evapotranspiration at the scale of climate model grid-cell

Lead partner: IPSL
Authors: Frederique Cheruy, Agnes Ducharne, Y. Zhao

Aim

The aim of this research 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. It will mostly focus on the water and energy budgets over land, and try to identify relationships between presumably related variables, including new ECVs as snow cover and LST. It will address the following scientific questions:

1. Can we better constrain the controls of evapotranspiration (ET) at the scale of climate model grid-cells?
2. Do the corresponding stress functions (for soil moisture, incoming energy, atmospheric humidity, temperature) take a different form at the point and grid-cell scale?
3. Can large-scale differences between LST and air temperature provide additional information to document the behaviour 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?

Summary of Work

We have shown that the evapotranspiration is better constrained with a multi-layer hydrology scheme than with a *Choisnel* type scheme, however the atmospheric forcing (in coupled mode) is decisive in terms of realisms for the regional distribution of the evapotranspiration (figure 3.6.1). Concerning the snow, analysis have been done with Interactive Multisensor Snow and Ice Mapping System and Satellite processing NOAA since the CCI data where not yet available. A strong overestimation of the snow cover inducing a marked cold bias in winter has been diagnosed on complex terrain such as the Tibetan plateau. This bias involves albedo-snow feedbacks and probably defects in modelling the snow cover on complex terrain (Cheruy et al. 2020). More detailed regional analyses will be undertaken quickly. They will be able to use the CCI product.

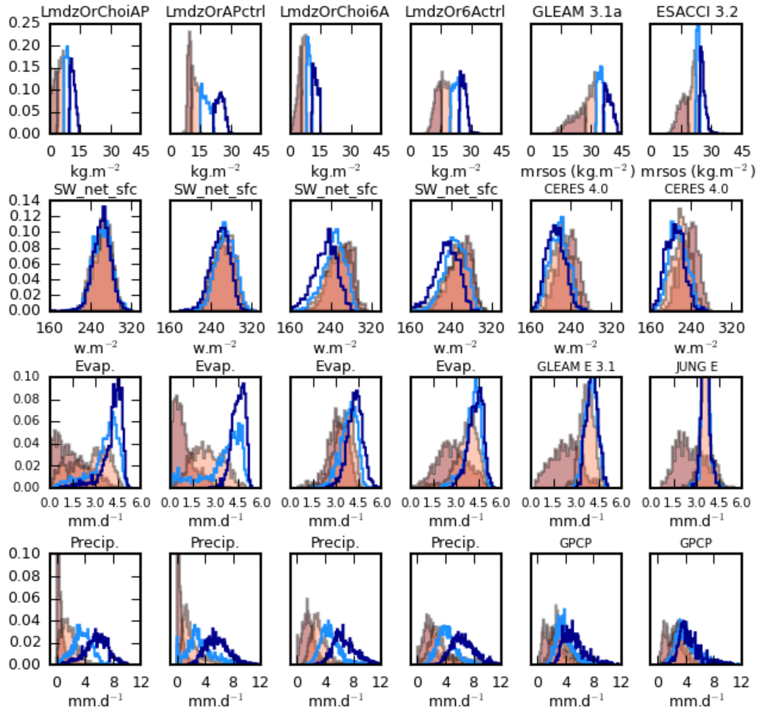


Figure 3.6.1: *Regional distribution of evapotranspiration variables, modelled and observations.*

Regional histograms computed on the monthly value of the individual grid points corresponding to the Southern Great Plains region (delimited with the Koeppen-Geiger climate classification) in JJA. Each row is dedicated to a particular variable relying on the coupling: superficial soil moisture (first row), net SW radiation at the surface (second row), evaporation (third row), and precipitation (fourth row). The first four columns correspond to the 4 reference experiments with different version of the GCM and land-surface model of IPSL. The first column corresponds to the configuration used for CMIP5 the last one to the configuration used for CMIP6, and the last two columns to the different sets of observations (indicated above the corresponding histograms). The colors depict the PDF from the minimum to first quartile (dark pink shade) from first quartile to the median (pale pink shade), from median to third quartile (cyan line) and from the third quartile to the maximum (blue line). (Cheruy et al., 2020, Submitted to JAMES).

Publications

None so far, but Cheruy et al., (submitted) describes the methodology developed for this work.

Interactions with the ECVs used in this experiment

In the first 12 months of this phase of CMUG work there have been interactions with the Snow, SM and LST CCI ECV teams at the quarterly CSWG meetings and the Integration meetings. This was to be informed data suitability for the work and data availability (direct from the CCI ECV teams or from the CCI Open Data Portal).

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

With CCI LST and CCI Snow data now becoming available, the work should proceed in 2020.

3.7 The effect of Lakes on local temperatures

Lead partner: Met Office
Authors: Richard Jones

Aim

The aim of this research is 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). It will address the following scientific questions:

1. What are the interactions between lakes and the surrounding land areas?
2. What effect does lake temperature (or other parameter) have on the surrounding LST?

Summary of Work

With LST data not being available, work did not proceed in this WP.

Publications

None so far, but the interest in the results leading to a journal or conference publication will be described in the next version of this report.

Interactions with the ECVs used in this experiment

None reported, as the researcher who will conduct this modelling experiment has yet to be recruited at the Met Office.

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

This experiment is dependent on CCI LST and CCI Lakes ECV data and will proceed when they are available. Any use of CCI beta data would need to be agreed between ESA, CCI Lakes, CCI LST and CMUG.

3.8 Evaluation of the impact of an enhanced ESA Sea Ice reanalysis (EnESA-SIR) on initialization of seasonal prediction

Lead partner: BSC
Authors: Juan Camilo Acosta-Navarro, Rubén Cruz-García, Vladimir Lapin, Yohan Ruprich-Roberts, Valentina Sicardi, Pablo Ortega.

Aim

The aim of this research is to quantify the benefits on forecast skill related to an enhanced initialization of sea ice (based on a reanalysis that includes both assimilation of Sea Ice concentrations from ESA and nudging of SSTs). This is an improved strategy to the one previously used in CMUG2, which only included assimilation of sea ice concentrations. This approach produced a strong initial shock in the predictions due to inconsistencies with the initial conditions used for the ocean and the atmosphere. The EnESA-SIR should minimise the initial shock, and thus is expected to improve the prediction skill. It will address the following scientific questions:

1. What is the added-value of Initial Conditions from EnESA-SIR on the seasonal climate forecast quality?
2. Are there any teleconnections/dynamical processes improving the skill in other regions than the Arctic?

Key Outcomes of CMUG Research

1. The model capabilities allowing the assimilation of sea ice concentrations and ocean sea surface temperatures have been finally implemented in the CMIP6 version of the Earth System Model EC-Earth.

Summary of Results

This research required from some preliminary technical work to enable the necessary model features to perform the enhanced Sea Ice reanalysis. The nudging capability for ocean temperature and salinity was introduced in the CMIP6 version of EC-Earth at the beginning of the year by Valentina Sicardi and Yohan Ruprich-Robert. Just recently, Vladimir Lapin was able to implement in the model an additional nudging routine to assimilate sea ice concentrations and sea ice thickness. This module is currently being tested, with encouraging results. Figure 3.8.1 (top row) shows that, for a nudging experiment with EC-Earth 3.3 that assimilates the sea ice concentrations in June-July-August from the future Arctic/Antarctica scenario in PAMIP (Smith et al 2019), the model constrains quite accurately the target fields. Indeed, when computing the difference between the simulations and the target fields, values are always below the 10% for all seasons, and are particularly small in JAS in the Arctic, with errors in the order of 2%.

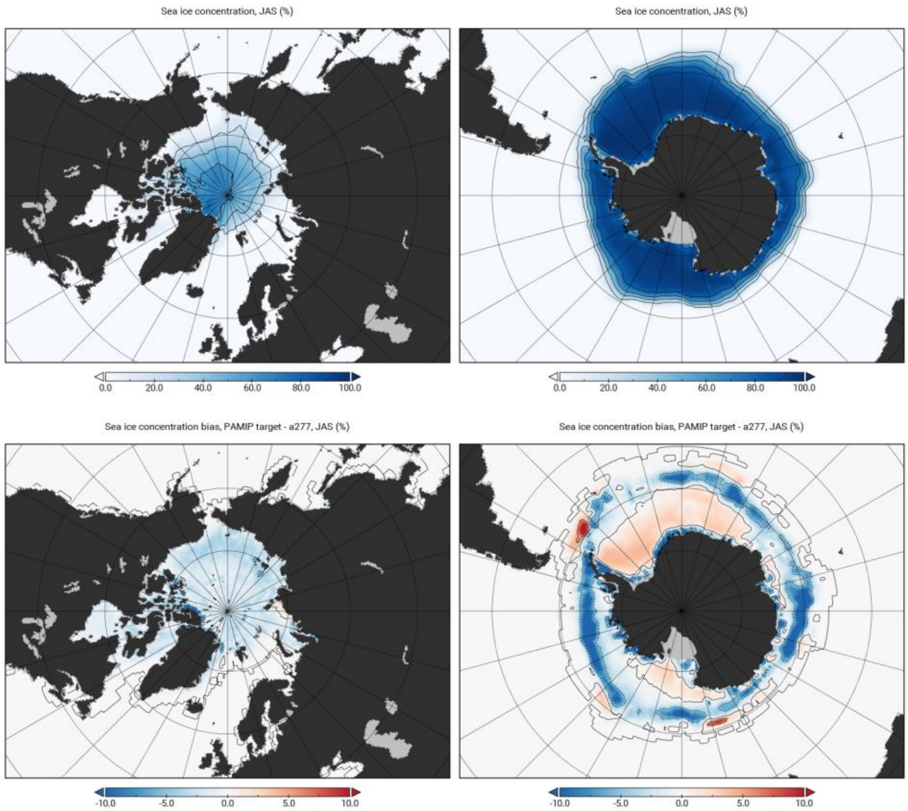


Figure 3.8.1: *(top) Average of JAS sea ice concentrations (shaded in %) in a simulation with EC-Earth3.3 that assimilates the sea ice of the future Arctic/Antarctic scenario in PAMIP (Smith et al 2019; contours in increments of 20%), respectively. (bottom) Difference in JAS sea ice concentrations (in %) between the EC-Earth nudged experiment and the reference PAMIP future Arctic/Antarctic sea ice concentrations, respectively.*

Publications

None so far, but the interest in the results leading to a journal or conference publication will be described in the next version of this report.

Interactions with the ECVs used in this experiment

There have been good interactions with the CCI ECV teams whose data are being used in this CMUG WP.

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

Once the sea ice nudging routine is thoroughly validated, we will start the production of the enhanced sea ice reanalysis, assimilating ESA data (SICs and SSTs). This reanalysis will then be used to initialize our enhanced seasonal forecast system, which we expect to perform and analyze for the next Assessment Report. For the analysis, the specific diagnostics are being currently designed by Juan Acosta, and used to evaluate a previous version of the seasonal forecast system only assimilating ocean temperature and salinity.

3.9 Biophysical feedbacks in the global ocean

Lead partner: Met Office
Authors: David Ford

Aim

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. Furthermore, air-sea CO_2 flux parameterisations typically used in climate models do not use sea surface state as an input, even though this is known to play a role. A further experiment will assess the impact on air-sea gas exchange of including sea state data as an input in the flux parameterisation. It will address the following scientific questions:

1. 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.
2. The two runs will then be assessed against CCI sea surface temperature (SST), sea level, sea surface salinity, and sea ice products, 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.
3. A further model run will include level 4 sea surface state data as an input to the model air-sea CO_2 flux parameterisation, and investigate the impact on the ocean carbon cycle compared with the standard parameterisation which just uses wind speed.

Key Outcomes of CMUG Research

1. Contact has been made with all marine ECV teams to discuss CMUG requirements, the details of these experiments, and which product releases will be most appropriate to use.
2. Ocean colour data for assimilation has been downloaded and prepared, and precursor work has been performed which will directly inform these experiments.

Summary of Results

The assimilation of chlorophyll from CCI ocean colour products to constrain the light attenuation and ocean physics builds on work previously performed with precursor GlobColour data, and during the previous phase of CMUG. A paper describing results assessing multivariate consistency of ocean CCI products, from experiments performed during the previous phase of CMUG, has recently been submitted to a peer-review journal (Ford, in review, "Assessing the role and consistency of satellite observation products in global physical-biogeochemical ocean reanalysis", https://www.ocean-sci-discuss.net/os-2019-118/).

A key result from this paper, which will directly inform the work performed in WP3.9, is shown in Fig. 3.9.1. Previous studies have suggested a direct correlation between the timing of the initiation of the spring bloom and that of the annual switch from negative to positive air-sea heat fluxes. Other studies have reached contrasting or mixed conclusions. This may in part be due to some studies looking at chlorophyll concentration, and others at phytoplankton biomass. The reanalyses produced as part of CMUG provided an opportunity to look at this relationship in a long model time series, and the impact of data assimilation. In the free-running model, there was a strong positive correlation between phytoplankton biomass and net air-sea heat flux across much of the ocean, whereas for chlorophyll concentration the correlation with net air-sea heat flux was weaker, and often negative at low latitudes. This suggests that seasonal variations in carbon-to-chlorophyll ratio play an important role, and that studies of phytoplankton bloom initiation based solely on chlorophyll data may not provide a full understanding of the underlying processes.

In WP3.9, chlorophyll derived from ocean colour will be assimilated, constraining the model chlorophyll, and with the addition of a feedback on the light attenuation, which will then affect the air-sea heat fluxes. This will provide the opportunity to study the two-way coupling between air-sea heat fluxes and timing of phytoplankton blooms, and it is envisaged that this will lead to a publication in a peer-reviewed journal.

The latest version of the CCI ocean colour data (v4) was released in May 2019, and this has been downloaded and prepared for use in these experiments. CMUG has also had interactions via email about user requirements with the marine ECV teams, as well as discussing the work with all relevant teams at the 2018 integration meeting, and reviewing the latest technical documents produced by the ocean colour, SST and sea level teams.

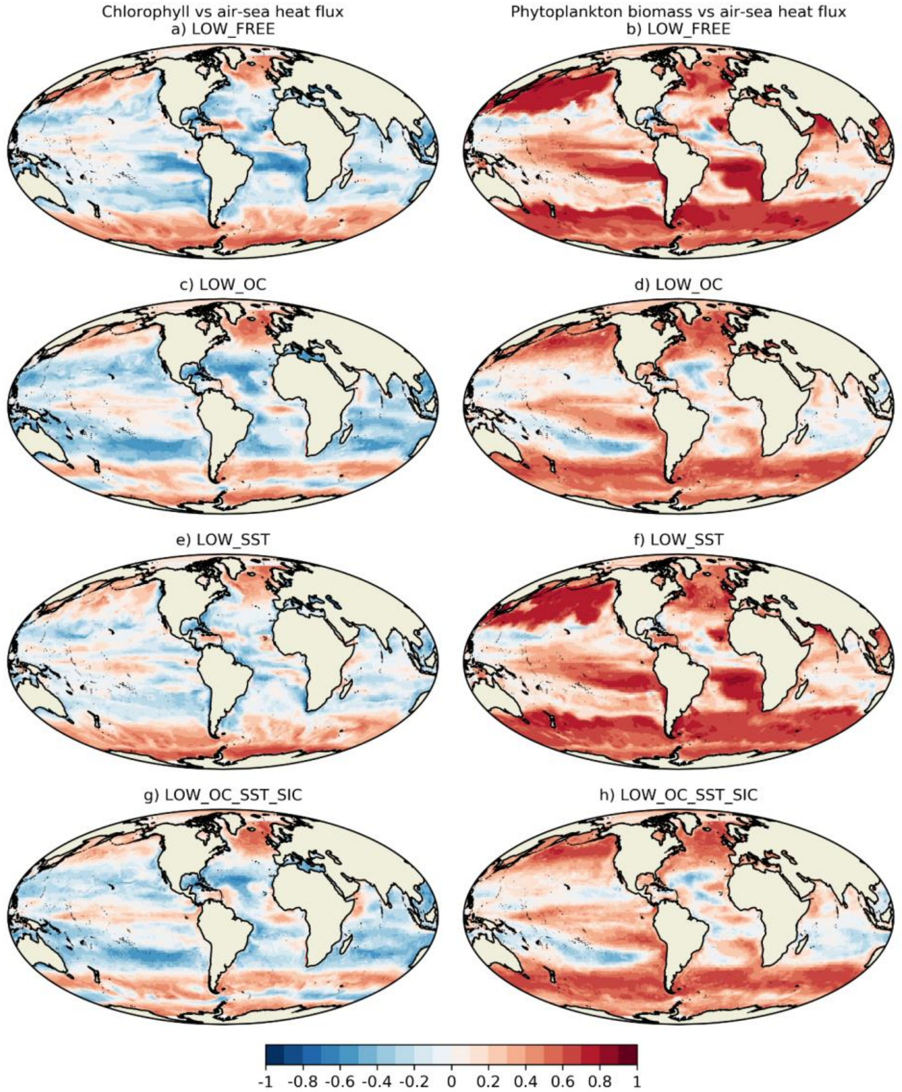


Figure 3.9.1. Maps of correlation between surface chlorophyll and net air-sea heat flux (left column) and surface phytoplankton biomass and net air-sea heat flux (right column), covering 1998 - 2010 for model runs with (a-b) no data assimilation, (c-d) assimilation of CCI ocean colour, (e-f) assimilation of CCI SST, (g-h) assimilation of CCI ocean colour, SST and sea ice. Taken from Ford (in review.).

Publications

A journal paper is in review.

Interactions with the ECVs used in this experiment

There have been good interactions with the CCI ECV teams whose data are being used in this CMUG WP.

Consistency between data products

In addition to relevant results described above, a record of any inconsistencies found between ECV products will be completed in this section in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

During Year 2, the biophysical feedback process will be coded in the model, and thoroughly tested with and without data assimilation. The model runs assimilating ocean colour data will be performed, and assessment of results will begin, including download and processing of relevant CCI data sets for validation, once these are available.

Following discussion with the ECV teams, it is planned to use the v4 ocean colour release for assimilation, and the v2.1 SST, v1.8 salinity, and v2.0 sea level products for validation. For sea ice concentration, it is aimed to use (a preview release of) v3 if this is available at the time the experiments are performed, or v2 otherwise.

For the experiments using sea state, the recent v1.1 release will be most appropriate, as future releases are likely to be released after the CMUG experiments will be performed. The experiments described here require level 4 significant wave height data. Ideally for the experiments this would be at daily or sub-daily resolution, to match reanalysis wind inputs, but it is recognised that this is not a common requirement. The v1.1 products include level 4 significant wave height data at monthly resolution, as this meets the needs of most climate users, with higher resolution level 2 and level 3 data. Monthly data can still be used for these experiments, but will just allow for a sensitivity test to assess the potential impact on future reanalyses. This can then inform whether higher temporal resolution level 4 products are likely to be a future requirement or not, as this is currently unclear – it may be more appropriate to assimilate level 2 or level 3 products, or it may be that the impact on the model is small.

3.10 Assessment of the potential of CCI/CCI+ data to constrain mineral dust simulations at the regional scale

Lead partner: BSC
Authors: Enza Di Tomaso, Jeronimo Escribano, Carlos Pérez García-Pando

Aim

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.

Key Outcomes of CMUG Research

Work done in Year 1 for this assessment activity aimed to prepare experiments to address the following scientific questions:

1. Are CCI (pixel-level) uncertainties realistic?
2. Which is the added value of assimilating thermal infrared retrievals?
3. Which is the impact of IASI data assimilation at the regional scale in high resolution simulations?
4. Does enhanced land type information improve the first-guess of mineral dust tracers, and consequently dust analyses?
5. Are the used CCI/CCI+ ECVs consistent?

Summary of Results

The work done in Year 1 focused on the preparation of CCI aerosol data for the assimilation system according to the first two tasks planned in the proposal:

- processing IASI dust aerosol data to follow the assimilation cycles;
- implementation of an observation operator for the thermal infrared.

Compared to a previous case study performed within the phase 2 of the aerosol_cci project, a more advanced assimilation of dust aerosol data is envisaged in this assessment activity with the aim to better demonstrating the use of CCI/CCI+ data to produce dust analyses at the regional scale. In particular the following novel aspects are introduced:

- Experiments will be run on a regional scale to allow for high resolution simulations better representing the smaller features of dust events;
- Dust retrievals will be assimilated at Level 2 resolution (circa 10 km) rather than Level 3 (1 degree) to avoid the propagation of observation uncertainties difficult to describe in a Level 3 product;
- Retrievals will be assimilated at the original retrieval wavelength in the thermal infrared (10 µm) in order to avoid the introduction of errors due to the conversion to a different wavelength (e.g. in the visible part of the electromagnetic spectrum).

The preparation of the observations and of the assimilation system has involved three main tasks which have seen the contact with the Université Libre de Brussels's (ULB) retrieval team:

- IASI dust optical depth from Metop-A have been downloaded for the summer period of 2016. The period has been selected following the recommendation of the data providers: the most recent years of the IASI dust retrieval benefit of higher quality of the EUMETSAT ancillary data used in the retrieval algorithm.

- Retrievals have been filters using the two flags provided (pre_quality_flag=1 and post_quality_flag=1). The pre-quality flag is set depending on cloud coverage (only cloud free data are processed), while the post-quality flag removes unreliable retrievals.

- The observation operator has been built for dust aerosol optical depth at 10 um. The operator consists in calculating the model equivalent of the observations, i.e. to map model background state vector into the observation space. Hence it has two components: the horizontal interpolation component (model tracers are interpolated at the observation location), followed by the calculation of a total column extinction from a model mass concentration profile. The simulated extinction for wavelength λ is calculated at a given observation location according to the following linear operator:

$$\mathrm{ext}_{\lambda} = \sum \frac{3\,\mathrm{qext}_{b\lambda}\, c_b}{4\, r_b \rho_b}$$

where ρ_b [kg m−3] is the particle mass density, r_b [m] is the effective radius, c_b [kg m−3] is the dust mass concentration for each dust bin, and qextλ is the extinction efficiency factor.

Since the assimilated observations are an infrared product, the dust aerosol optical depth is mostly the coarse mode. Therefore only model dust coarse bins are used in the observation operator. The extinction efficiency factors for 10 µm have been calculated using the Mie scattering theory assuming dust spherical, non-soluble particles for the 4 model coarse size bins, and, within a bin, a lognormal distribution for dust with geometric radius of 0.2986 µm and standard deviation of 2.0. Information on refractive indices has been extracted from the OPAC database.

The setting of the first high resolution assimilation experiments over a regional domain is currently ongoing.

Publications

None so far, but the interest in the results leading to a journal or conference publication will be described in the next version of this report.

Interactions with the ECVs used in this experiment

In the first 12 months of this phase of CMUG work there have been interactions with the Aerosol, LC and HRLC CCI ECV teams at the quarterly CSWG meetings and the Integration meetings and by personal contact and email.

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

Plans for Year 2 involve investigating: (a) whether the pixel level uncertainty for dust aerosol retrievals are meaningful, (b) which is the impact of IASI data assimilation at the regional scale in high resolution simulations, and (c) which is the added value of assimilating thermal infrared retrievals. Initial preparation work to use CCI/CCI+ Land Cover information is also envisaged.

The following tasks will be performed:

- Run assimilation experiments specifically targeting the representation of observation uncertainty;
- Identifying optimal assimilation settings for observation error statistics and covariance localization
- Perform assimilation simulations on a regional domain for specific dust events (usually lasting 1 to 10 days) during the active dust season;
- Assess the impact of assimilating the data during relevant dust events through the validation with independent observations: the AERONET aerosol optical depth product with the application of a dust filter, as well as the AERONET SDA coarse mode product.
- Initial formatting of CCI/CCI+ Land Cover data to follow the dust model requirements.

3.11 Production of a pilot dust reanalysis at the regional scale

Lead partner: BSC
Authors: Enza Di Tomaso, Jeronimo Escribano, Carlos Pérez García-Pando

Aim

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.

Key Outcomes of CMUG Research

Work done in Year 1 for this assessment activity aimed to prepare experiments to address the following scientific questions:

1. Can CCI/CCI+ data improve aerosol reanalysis?
2. Can CCI/CCI+ data improve in particular the characterization of dust cycles?
3. How well does the regional dust reanalysis compare to other reanalyses?

Summary of Results

This assessment activity is subject to the accomplishment of some of the tasks of assessment activity 3.10 on the potential of CCI/CCI+ data to constrain mineral dust simulations at the regional scale. However preparatory technical work was necessary on the refinement of the BSC technical infrastructure for high resolution (computationally demanding) IASI assimilation experiments to be run over a regional domain and over the longer (1 year) period of the pilot dust reanalysis, compared to what it is planned for selected dust events in 3.10. During this first year advances have been made in the BSC simulation workflow manager in order to improve the automatization of experiments and to optimize the storage of simulations' outputs.

Publications

None so far, but the interest in the results leading to a journal or conference publication will be described in the next version of this report.

Interactions with the ECVs used in this experiment

There have been interactions with the Aerosol, LC and HRLC CCI ECV teams at the quarterly CSWG meetings and the Integration meetings about the potential use of their products in the WP.

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

Plans for Year 2 will involve the preparation of assimilation experiments capitalizing on some of the results that will be obtained in the assessment activity 3.10. CCI IASI dust data will be assimilated in model simulations for a first month of the reanalysis period on a regional domain covering Northern Africa, Europe and the Middle East before the final production of the pilot dust reanalysis is performed. Results will be evaluation against independent observation and compared to a MODIS dust reanalysis of comparable spatial resolution.

3.12 Integrated assimilation of the CCI+ Sentinel 3 AOD and Sentinel 5P ozone retrievals in the IFS

Lead partner: ECMWF
Authors: Rossana Dragani, Angela Benedetti

Aim

The aim of this research is to assess the impact of assimilating the CCI+ ozone retrievals from Sentinel 5P and Aerosol Optical Depth (AOD) from the Sentinel 3 measurements to feed back to the Copernicus Climate Change Service (C3S) and Copernicus Atmosphere Monitoring Service (CAMS) reanalyses.. It will address the following scientific questions:

1. Suitability of the CCI+ ozone and aerosol data to constrain a global reanalysis
2. Appropriateness of the observation uncertainty via the data assimilation system
3. Consistency between the two CCI data records via a data assimilation system and with independent observations
4. Consistency of the produced reanalysis with existing global reanalyses.

Summary of Work

With CCI+ ozone ~~LST~~ data not being available, work did not proceed in this WP.

Publications

None so far, but the interest in the results leading to a journal or conference publication will be described in the next version of this report.

Interactions with the ECVs used in this experiment

In the first 12 months of this phase of CMUG work there have been interactions with the Aerosol and Ozone CCI ECV teams at the quarterly CSWG meetings and the Integration meetings and by personal contact, attendance at an ECV project meeting, and email.

Consistency between data products

This section will provide a record of any inconsistencies found between ECV products, and will be completed in the next version of this report.

Recommendations to the CCI ECV teams

To be completed in next version of this report.

Plan for Year 2

This experiment is dependent on CCI+ Ozone data and can only proceed when they are available. Any use of CCI+ beta data would need to be agreed between ESA, CCI Ozone and CMUG.

For the aerosol activities, which are funded under the CCI+ AER contract, the data from Sentinel-3 will start being available in March 2020 and the activities will start then. The following datasets will be provided by the AER team:

SLSTR and AATSR, 2 algorithms (Swansea, Rayference CISAR)

Type of data: Aerosol Optical Depth (AOD) and FineMode AOD
Timeline:
03/2020: 4 months 2018, 2002, 2003 (S3A-SLSTR, S3B-SLSTR, ATSR-2, AATSR)
12/2020: 4 months 2018, 2002, 2003 (S3A-SLSTR, S3B-SLSTR, ATSR-2, AATSR)
12/2021: 12 months 2018, 2002, 2003 (S3A-SLSTR, S3B-SLSTR, ATSR-2, AATSR)

Level: lv2 (10x10km2), lv3 daily (1 degree), lv3 monthly (1 degree)
Uncertainty information: lv2 propagated pixel-level; lv3: averaged (equals the worst case of fully correlated uncertainties).

Envisaged AOD assimilation experiments:
1. Control experiment with no assimilated aerosol observations
2. Experiment S3A-SLSTR & S3B-SLSTR AOD data only (Swansea), for 2 months in 2018 (selected from the available 4 months).
3. Experiment with CAMS operational configuration for the same period in 2018 (MODIS and PMAP AOD)
4. Experiment with CAMS operational configuration plus S3A-SLSTR & S3B-SLSTR AOD data for the same period in 2018.

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