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Climate Modelling User Group

Deliverable 1.2

Requirement Baseline Document

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2.0	17 Dec 2012	Updated to include new ECVs (IS,SM)

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Contents

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Purpose, scope and construction of the Requirement Baseline Document

The purpose of this document is to assist the CCI projects by focussing on the needs of the Climate Modelling Community (CMC). It aims to the following:

1) to present an analysis of the satellite climate observation data requirements of the CMC. The requirements were captured by CMUG through a workshop, questionnaire and interviews with 35 key members of the CMC, and is representative of the full range of models and their applications operated by these modellers.

2) to cover both the requirements for the 13 ECVs in terms of parameters, resolution and errors/uncertainties and also where appropriate cover the requirement for observation operators for each of the ECVs.

3) to cover overarching technical requirements on the datasets produced for the CMC. Version (V1.5) of the document was written based on the earlier (V1.3) draft using the outcomes from the first colocation meeting of the ECV teams in September 2010 and then updated with comments from the different ECV projects, the updated GCOS requirements and the CMUG integration meeting in Reading in March 2011. Version 1.6 has also at least included mention of the new ECVs soil moisture and ice sheets although a user requirement exercise was not done for these.

It is also recognised that the climate observation data needs of the CMC are evolving and will change over time, therefore CMUG will present further updated versions of this document to keep CCI informed with up to date information about the needs of the CMC.

1. Introduction

Our climate system is continuously changing, so climate researchers need to measure its changes globally and regionally, and to model the system to understand the causes of the changes. Given their global and temporal coverage and spatial resolution, satellite data, which now span up to 30 years, can potentially be used for both climate monitoring, and model initialisation and evaluation provided certain requirements can be met.

The uncertainties of the satellite datasets must be understood and quantified; otherwise no confidence can be placed in the derived climate data records. Because most of the measurements were not taken with climate applications in mind, the data need careful preparation for climate monitoring. Also, satellites do not make localised 'conventional' *in situ* measurements of e.g. temperature or moisture as represented by climate models, but measurements of indirect parameters e.g. upwelling radiance or GPS signal refraction angles. Climate models can deal with this by including 'observation operators' to compute the variable measured by the satellite from the model fields, thus avoiding the uncertainties in the retrieval of conventional variables from satellite data. However it is important that these simulations can be interpreted in terms of standard geophysical variables, or physical properties such as humidity, cloud drop size or crystal shape, as model parameterisations are often framed in terms of these physical quantities.

Climate researchers need to confront models with observations with the following aims:

- To interpret the observations and explain the causes of observed variability and change
- To develop, constrain and validate climate models, thus gaining confidence in their projections of future change
- To initialise models for reanalyses, seasonal and decadal timescale predictability (data assimilation) and to provide representative initial conditions for climate model simulations
- To prescribe boundary conditions of quantities that are not prognostic variables in climate models

Accordingly, the generic requirements for satellite data are:

- to provide long term monitoring datasets of particular parameters with or without *in situ* data to ascertain decadal and longer-term changes (e.g. Rayner et al. (2003) for sea surface temperature and sea ice extent). Models can then be used to attribute the observed variations to natural and anthropogenic forcings and internal variability (IPCC 4th Assessment, Chapter 9; Stott et al., 2000);
- to compare measured parameters, or combinations of observed and/or reanalysed parameters, with model equivalents on hourly up to decadal timescales, to assess the processes and biases in the models and if necessary to constrain, the processes.
- to initialise seasonal forecasting models with, for example, realistic estimates of soil moisture and sea surface temperature (Douville, 2004).

- to help evaluate the skill of seasonal (Folland et al., 2006) to decadal forecasts (Smith et al, 2007).
- to interpret short term variations of the climate in the long term context, as in recent reports on the impact and character of the 2007-8 La Niña.
- to help identify biases in the current and past *in situ* observing network (e.g. using AATSR: Kennedy, 2008). Comparisons of Microwave Sounding Unit (MSU) retrievals to “families” of radiosondes (Christy and Norris, 2006, Christy et al., 2007) have identified shortcomings both in the raw radiosonde data and the satellite datasets.
- to provide homogeneous data, with good estimates of random errors and bias-correction uncertainties, for reanalyses. Existing reanalyses are already very useful for model validation, especially in combination with independent satellite data; but the next generation of reanalyses also needs to be sufficiently homogeneous to allow the estimation of long-term trends (Bengtsson et. al., 2007).

Now that satellite climate data records are reaching 30 years in length they are becoming an important source of data for these applications. Hence the CMC need to make best strategic use of the emerging opportunities provided by satellite data.

Section 2 identifies in more detail those generic application areas where satellite datasets are required for climate modelling. Section 3 outlines the specific requirements for the satellite CDRs for the 11 ESA ECVs and section 4 lists cross-ECV requirements. Section 5 gives the requirements for observation operators and other tools required by climate modellers to exploit the datasets. Section 6 outlines the technical requirements for data formats, projection, access etc. A list of acronyms and definition of various terms is in section 9. Finally Annex A gives a definition of the error characteristics and Annex B the datasheets which were used as input to this requirements analysis.

2. Generic requirements for climate applications

Table 1 summarises the generic requirements for the 11 ESA CCI ECVs from a recent survey of the applications by the CMUG of climate modelling centres. It also lists in the bottom row the responses from the CMUG questionnaire as to what the CCI CDRs will be used for. All application areas are mentioned but the comparison with models for model validation and development dominated the uses. Surprisingly not many users questioned are engaged in long term climate monitoring and attribution studies.

An important requirement for all the CDRs is to include their associated errors for each observation where possible. For many applications it is crucial to have an associated precision for each observation. Also the error correlations between variables are important to consider.

2.1 Climate monitoring and attribution

Satellite datasets need to span at least several decades in order to monitor climate change. Some satellite datasets already approach 30 years in length, but many are shorter than 20 years although continually expanding.

Climate monitoring implies the most stringent requirements for satellite data both in terms of stability of the measurement and in the minimum time period of the dataset. For temperature trends it has been shown that a minimum of 15 years is required in order to measure any meaningful trend with ‘perfect observations’. In addition significant overlap periods between successive sensors as recommended by the GCOS monitoring principles (See annex 2 of GCOS, 2010) is also a crucial requirement to ensure the fidelity of the time series.

GCOS ECV	Model Initialisation	Prescribe Boundary Conditions	Re-analyses	Data Assimilation	Model Development and Validation	Climate Monitoring/ Attribution	Q/C in situ data
Atmospheric							
Cloud properties			X		X	X	
Ozone	X	X	X	X	X	X	X
Greenhouse gases	X	X	X	X	X	X	X
Aerosols	X	X	X	X	X	X	X
Oceanic							
SST	X	X	X	X	X	X	X
Sea level	X	X	X	X	X	X	X
Sea-ice	X	X	X		X	X	X
Ocean colour				X	X	X	
Terrestrial							
Glaciers and ice caps	X	X			X	X	
Ice sheets	X	X			X	X	
Land cover (inc veg)	X	X	X		X	X	
Fire	X	X			X	X	
Soil Moisture	X	X	X	X	X	X	X
Users responses							
Declared uses	6	6	2	6	22	2	1

Table 1. Use of CCI ECVs for different climate applications

For the atmosphere the atmospheric temperature from the surface to the upper stratosphere is a primary variable of interest and trends need to be known to better than 0.05K/decade (satellite supplement to GCOS (2004)) which is very challenging for satellite data. This is not directly addressed by the ESA CCI projects but indirectly the ESA CCI atmospheric variables should benefit the temperature analyses and predictions through being able to better represent the radiative effects of the gases and aerosol concentrations and hence the atmospheric heating/cooling profile.

Time series of greenhouse gas, ozone and aerosol concentration profiles and total column amounts are important for trend analyses to assess if there are significant increases or decreases in these atmospheric variables which will affect the atmospheric radiative heat balance. The global coverage allows regional and/or temporal variations to be investigated and potentially attribute them to natural or anthropogenic causes.

For the ocean ECVs sea level, sea-ice coverage and thickness are critical parameters that must be monitored as key indicators of climate change. Sea surface temperature similarly is an ECV which has been monitored by in-situ observations since the mid 1800's and so is an excellent indicator of climate change. The complication with satellite measurements of SST is that they measure the skin not the bulk SST and so a "correction" has to be made to the satellite CDRs of SST to obtain a "bulk" SST as would be measured by ships and buoys. This is an example of the need for an observation operator (see sec. 5). The record for ocean colour measurements is relatively short but when the length of the time series reaches > 20 years this will provide another important indicator of climate change.

For the land surface, fires are important to help monitor and understand the carbon cycle. Records of fire numbers and burnt area help to show the amount of deforestation occurring in the last 2 decades. The extent of ice sheets, glaciers and ice caps is also an important indicator of climate change and the satellite data can complement the ground based observations. Land cover type is an ECV required as a model surface field as it can affect the local radiation and provide sources and sinks of various atmospheric variables (e.g. aerosols, CO_2, CH_4 etc). All NWP and climate models use land cover to initialise their land surface models.

A new area of concern in climate monitoring is the assessment of rapid climate changes which requires confidence in the prediction of the thermohaline circulation and carbon cycle/sea ice tipping points. Close monitoring of greenhouse gas concentrations and sea-ice coverage/thickness from satellites is important to provide early warning of any sudden changes. Fire and vegetation changes are also examples of variables that can change rapidly and have significant impacts.

Finally there are some satellite derived metrics, which are not ECVs as defined by GCOS, but nevertheless are of interest. Severe weather events such as the annual number of tropical cyclones in each ocean basin, frequency of intense extra tropical storms, severe drought episodes and heat waves are all of interest for climate change and applications studies and can be inferred from satellite data with some effort. There is a need from policy makers and other users for a better understanding of the risk of current extreme weather events and the extent to which this risk has changed as a result of human influence. Some of the ESA ECVs may contribute to these metrics and the requirements will need to reflect this.

The requirements for climate monitoring measurements are stringent. For example a US survey in 2007 lists the decadal trends in various atmospheric variables, listed in Table 2, and the resultant stability required of the satellite CDRs measuring these variables has to be a small fraction of these values (e.g. SST <0.05K). It is important to distinguish between stability and accuracy here. For climate trends the measurements have to be stable over long time periods and any changes must be understood and be able to be accurately modelled. Requirements on the bias (accuracy) can be less stringent so long as there are other complementary measurements to compare with. The GSICS project is putting in place an infrastructure to provide these measurements to estimate and monitor biases in different sensors. Therefore one of the requirements on some of the ECVs is that they make use of the GSICS measurements to ensure their accuracy can be traced back to International Standards as addressed by the WMO QA4EO project[1]. The GSICS initiative[2] is crucial to improve the quality of the global satellite datasets.

Solar Irradiance	0.3 W/m^2
Reflected solar radiation	1.5 W/m^2
Outgoing longwave radiation	1.0 W/m^2
Atmospheric temperature	0.2 ^{0}C
Sea surface temperature	0.2 ^{0}C
Water vapor	1.3 %
Precipitation	0.015 mm/hr
Cloud amount	0.015

Table 2. Climate measurement requirements: expected decadal trends[3]

2.2 Model initialisation and definition of boundary conditions

A major requirement for satellite data to date has been to help define the initial state of the atmosphere/surface for NWP models along with conventional *in situ* data. The ECMWF Reanalyses are important examples of this. An example of this is shown in Figure 1 from the ECMWF ERA-40 reanalysis where the link between total column water vapour and sea surface temperature becomes closer once satellite data are available (from 1972 onwards).
1. initialisation of 'present-day' coupled climate control experiments.

For initialisation of 'present-day' coupled climate control experiments the atmospheric state (provided the latter is in reasonable balance) is not so crucial as in principle, the model should equilibrate to its own climate state no matter what the initial state is, but it is still preferable to start from accurate initial conditions in order to avoid big adjustments that take a lot of computational time to settle down, and to be able to judge the growth of errors without massive drifts.

Some of the 13 ESA CCI ECVs have potential for model initialisation (see Table 1) primarily through improving the representation of the surface fields.

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[1] Quality Assurance Framework for Earth Observation (QA4EO) [http://www.qa4eo.org/]

[2] http://www.star.nesdis.noaa.gov/smcd/spb/calibration/icvs/GSICS/

[3] From G. Ohring, Summary of ASIC3 workshop, CLARREO Workshop, July 2007, see: http://www.map.nasa.gov/documents/CLARREO/7_07_presentations/Ohring_CLARREO.pdf

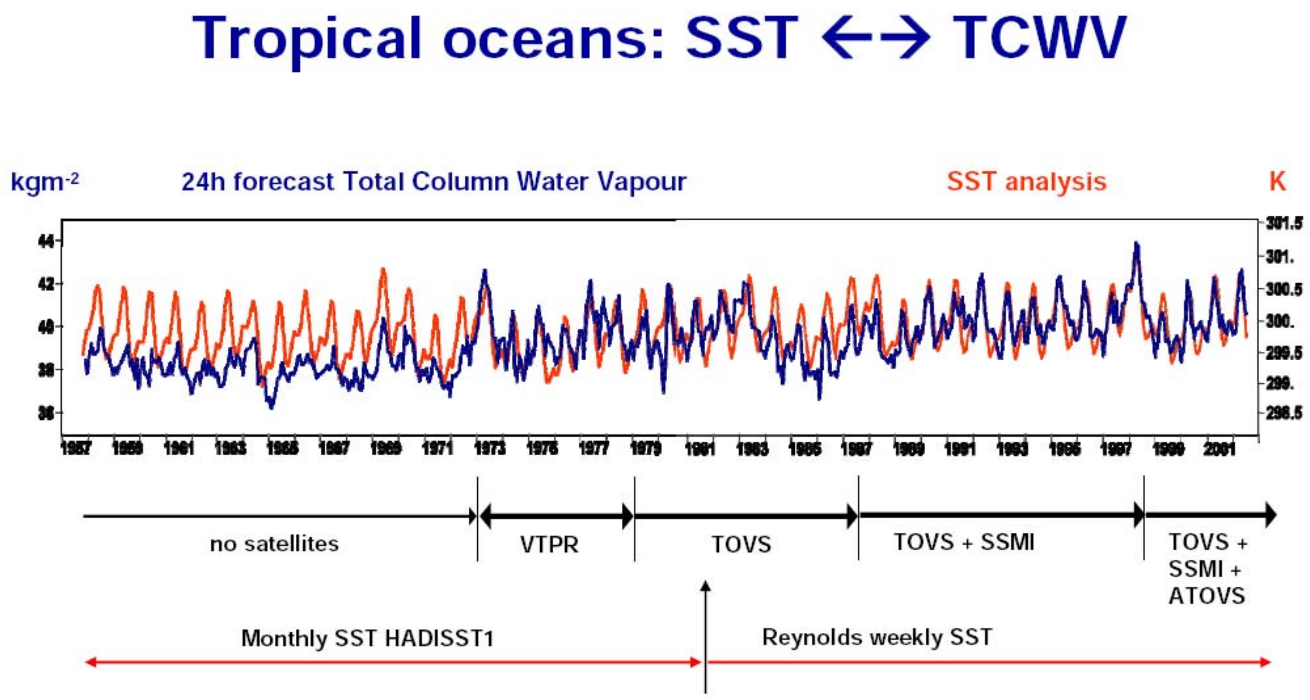

Figure 1. Correlation between total column water vapour and SST in ERA-40 before and after satellite data were introduced.

The stability and accuracy requirements for initialisation are more relaxed than for climate monitoring as the initial uncertainties in the model fields without the observations are often far greater than the measurement uncertainty. Ozone is a good example of an ECV where the model uncertainty easily exceeds the measurement uncertainty.

2.3 Model Development and Evaluation

Satellite observations should be a key part of the model development process for testing the ability of a model to simulate the climatology, annual cycle etc, e.g. of sea ice as part of the development cycle of the sea ice model. Banks et al. (2008) present assessment criteria for the Hadley Centre model, HadGEM3. Particular attention should be paid to areas where the components of HadGEM3 were found to be sensitive to atmospheric and ocean fluxes, e.g. land surface temperature (particularly northern continental summer temperature), rainfall over land (particularly Indian sub-continental rainfall in northern summer), soil moisture, and dust concentrations over both land and ocean (Banks et al (2008)).

Coupling the various components is a priority. For instance, the coupling between atmospheric chemistry (air quality, oxidation, stratosphere-troposphere processes, ozone hole, etc) and climate is important. Indeed, according to Brasseur et al, (2007), although the current generation of tropospheric ozone models is generally successful in describing the principal features of the present-day global ozone distribution, there is much less confidence in the ability to reproduce the changes in ozone associated with perturbations of emissions or climate. There are major discrepancies with observed long-term trends in ozone concentrations over the 20th century (Hauglustaine and Brasseur, 2001; Mickley et al., 2001; Shindell and Favulegi, 2002; Shindell et al., 2003; Lamarque et al., 2005), including after 1970 when the reliability of observed ozone trends is high (Fusco and Logan, 2003). Resolving these discrepancies is needed to establish confidence in the models. Consistency between the processes described in the models has to be checked. The observations of the various ECVs should allow to check this consistency and if appropriate help to improve the bio-physical-chemical schemes used in the models.

Long term vertically resolved data sets of constituent observations are required to assess Chemistry Climate Models (CCM). This includes ozone, but also other species that are used to diagnose processes involved in CCM: transport, chemistry, radiation, and dynamics. Such observations are required by CCM validation exercises like CCMVal-2 (see overall recommendations in executive summary, http://www.atmosp.physics.utoronto.ca/SPARC/CCMVAL_FINAL/index.php).

For the ESA ECVs clouds, aerosols and trace gas concentrations are important to validate the model fields. For example the accurate representation of clouds in climate models is important to reduce the range of uncertainty in climate sensitivity studies. Datasets of cloud properties (i.e. fractional cover, top height, phase, microphysical properties etc) provide an important constraint for climate models. Cloud droplet size and drop number concentration are also variables of specific interest. Regional estimates of all these parameters will be important for detection/attribution studies. In addition instantaneous estimates of cloudiness are also important to monitor the diurnal to annual cycles of cloud. In order to compare satellite clouds (e.g. from ISCCP or CloudSat) with model clouds a cloud simulator (sec 5) is desirable. The MOHC has developed the COSP (CFMIP Observational Simulator Package; http://cfmip.metoffice.com/COSP.html) to enable such comparisons.

The requirements on accuracy for model evaluation are less stringent. It depends on the magnitude of the model error but in all cases the requirement should be more relaxed than for climate monitoring.

2.4 Input to reanalyses

Global and regional atmospheric and ocean reanalyses are now being undertaken in a number of centres to provide a consistent analysis of the atmosphere over a long time period, typically 40-100 years using an NWP model as a constraint for the variables. Increasingly these reanalysis datasets are being used for climate applications. A key requirement for the data to be assimilated into these reanalyses is that they are uniformly processed without the discontinuities often seen in operational real time processed datasets caused by changes to operational real time processing of the instrument data.

Accordingly, satellite climate data records are well suited for reanalyses provided they come from a stable processing environment and provide associated error estimates. For the recent ECMWF reanalysis (ERA-40) satellite agencies did make an effort to provide some homogenous datasets for example the atmospheric motion wind vectors provided by EUMETSAT where the products from the early years were much improved with reprocessing.

In general, re-analysis applications require single-sensor products rather than merged products. Furthermore, these applications often ingest Level-1 satellite data rather than Level-2 retrievals and thus there is a strong interest in uniformly processed fundamental climate data records. Should such records be generated during the ECV projects, it would be desirable to make them available to the user community as well.

It is worth noting that comprehensive multi-decadal reanalyses are substantial computational projects with demanding production schedules. Uptake of CCI ECV products would be increased if the ECV production timelines can be coordinated with such activities, and CMUG is in a position to keep the ECV projects informed of relevant ECMWF plans.

2.5 Data assimilation for seasonal and decadal forecasts

Recently the need for better initialisation of seasonal and decadal hindcast or forecast models in the operational forecasting centres has become apparent. The oceanic variables with sufficient inertia to act as forcing for seasonal time scales include sea surface temperature, salinity and sea-ice thickness and concentration. Proper initialisation of land surface temperature, soil moisture, snow cover and depth especially over Siberia, and aerosol concentration can also increase prediction skill. Vegetation type will also be of interest particularly if coupled with a vegetation model though a good high resolution dataset of recent vegetation is valuable in its own right.

Interactions between the polar stratosphere and the mid-latitude troposphere occur on the timescale of a few weeks, and the initialisation of the former could aid the prediction of the latter especially in the first few weeks of seasonal forecasts (Scaife et al, 2005). Stratospheric temperature, winds and gas concentrations are therefore of interest to define in the model initial state. These parameters can now be measured by satellites to a reasonable degree of accuracy. The experience at operational NWP centres of satellite data assimilation, which now provides the major impact on forecast skill, can be applied to these longer range model initialisation problems. In current models the atmosphere is represented by at least 70 levels from the surface to 0.1hPa with a horizontal grid size approaching 60km. Only satellite data can provide truly global coverage at this horizontal scale although radiosondes still have better vertical resolution.

The experience of satellite data assimilation at NWP centres, which now provides the major impact on forecast skill, can be applied to these longer range model initialisation problems in particular from seasonal to decadal forecasts. The atmosphere is now represented by at least 70 levels from the surface to 0.1hPa with a horizontal grid size approaching 50km. Only satellite data can provide truly global coverage at this horizontal scale although radiosondes will still have better vertical resolution. In contrast for reanalyses the satellite climate data records are assimilated to affect the short range forecasts. In order for models to be able to assimilate a particular ECV it must be represented within the model as a prognostic variable. Table 1 shows those variables where data assimilation will be a possibility in the next 5 years.

2.6 Quality control of in-situ data

Satellite data can be used to validate in-situ measurements by using the large scale attributes of the satellite data if it can be assumed that any bias is stable over large spatial (>1000km) and temporal (>1hr) scales. The requirement is for the stability of the satellite CDR to be more stable than the in situ measurement errors being validated and so this depends on a case by case basis. If the in situ measurements are accurate and only have small drifts then the accuracy (stability and bias) requirements on the satellite data can be high

An example of this might be the use of AATSR brightness temperatures to validate drifting buoy sea surface temperature measurements. The latter can often be in error by several degrees and so an accuracy requirement on AATSR for this application need only be 0.5K to still show useful results. This is a much lower accuracy than the requirement for climate monitoring.

3. Synthesis of requirements for CCI ECVs

The CMUG has undertaken a review of the requirements for the 11 original CCI ECVs through direct interactions with users, input from a workshop and responses to a questionnaire. The respondents to the latter and their comments are given in the CMUG report on *Profile and main needs of the climate modelling community*[4]. This report presents an analysis of their input together with the GCOS requirements which was the starting point although noting that the GCOS requirements themselves are under review. It is hoped this report will inform the GCOS requirements review process. The 2 ECV projects which were funded later in phase 1 (Soil moisture and Ice sheets) were not included in the requirements gathering exercise as they have their own URDs. The recent report commissioned by the European Union (Wilson et. al. 2010) also attempts to summarise the user requirements for the ECVs and checks were made for consistency with this document.

The intention ultimately is to match the requirements from the CMC given here with those from the CCI projects which are not yet available. An underlying assumption in this requirements definition process is that the CCI datasets produced will be *better* than any existing satellite CDRs, The complete datasheets containing the CMC requirements are given in Annex-B but a summary table for each ECV are listed in the sub-sections below. Note that it is difficult to be too prescriptive for accuracies as this depends on the horizontal scale chosen to represent the parameters so for example a SST at a 50km scale may be more accurate than at a 1km scale.

At the colocation meeting in September 2010 it was agreed to update the user requirements to ensure the rationale and traceability of the requirements could be ensured. Also these ECV CDRs will be peer reviewed allowing a reference to be given. The requirements for the CRC summarised in the Tables in this section have been translated into the new ESA template for requirements and provided as Annex B to this document.

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[4] http://www.cci-cmug.org/ click on Project Resources

The CMUG have set up a WIKI page at: http://esacci.pbworks.com/ where the latest versions of the requirements tables are presented and users can change the tables listed below for each ECV and add comments on the requirements. This will be a tool to continually update the requirements of the CMC.

In addition to the consistent presentation of the requirements a consistent description of the errors also needs to be used. This is outlined in Annex A of this document. There are different requirements for errors for different applications. Table 3 gives those type of errors which are considered here.

Types of error
Single sensor uncertainty estimates for every observation (SSEOB)
Single sensor accuracy estimates for every observation (SSAOB)
Single sensor uncertainty estimates for TCDR (SSECDR)
Single sensor accuracy estimates for TCDR (SSACDR)
Error covariance matrix for TCDR (ERRCOV)
L3 merged product accuracy (ERRMERG)

Table 3. Types of errors for inclusion with TCDR datasets. The acronyms are used in the tables below.

3.1 Sea surface temperature – status

Sea surface temperature (SST) is an important variable to monitor over many timescales as a key indicator of climate change. Satellite SST data are crucial to obtaining globally complete SST analyses and in particular the high temporal and spatial resolution that appears to be increasingly needed for understanding processes such as ENSO, NAO etc.

The IPCC AR4 report states "*But satellite SST data alone have not been used as a major resource for estimating climate change because of their strong time-varying biases which are hard to completely remove, for example, as shown in Reynolds et al. (2002) for the Pathfinder polar orbiting satellite SST data set (Kilpatrick et al., 2001). Figures 3.9 and 3.10 (Section 3.2.2.7) do, however, make use of spatial relationships based on adjusted satellite SST estimates after November 1981 to provide nearer-to-global coverage for the 1979 to 2005 period, and O'Carroll et al. (2006) have developed an analysis based on Along-Track Scanning Radiometers (ATSRs) with potential for the future. However, satellite data are unable to fill in estimates of surface temperature over or near sea ice areas.*" and so removal of the biases is clearly a critical need for climate monitoring. It is also an important problem for climate change to monitor the SSTs over the Arctic Ocean which has become ice-free during the summer months. The warming of the ocean here governs how quickly the ice returns in the winter.

The OSTIA SST analysis is used by the Met Office and other NWP centres for operational forecasting (NWP and Ocean) and plans are in place within the GHRSST project to do an OSTIA reanalysis. This will be a valuable complement to the HadISST climate data analysis already produced in the MOHC which makes use of the SST climate data records. These high resolution analyses are linked to the longer term climate record of SST. The intention is to use the HadISST analysis for the next ECMWF reanalysis ERA-CLIM which uses satellite data (AVHRR and ATSR) from 1979 onwards.

The requirements for satellite SST are given in Table 4 for a number of applications related to climate modelling. An important consideration is whether sea surface skin temperature or sea surface subskin temperature (also known as a foundation temperature) is required (the latter requires an observation operator). The requirements are the same for both. For long term trend monitoring both parameters are of interest with foundation temperature used more in the past but for the satellite era skin temperature could be used. Long term trend monitoring and attribution is the most challenging application with high demands on the accuracy and stability of the product.

There are a number of requirements for initialising the initial state of seasonal, decadal and coupled climate model runs which all have similar requirements on accuracy. The deep ocean temperatures are more important for these longer range forecasts. For reanalysis the requirement is to provide a 3 hourly update to the SST field as a boundary condition for the assimilation of the atmospheric and other oceanic variables.

Application	Horizontal resolution	Temporal sampling	Precision	Accuracy	Stability	Error Type (see Table 3)
trend monitoring	10km	1 month	0.05K	0.1K	0.05K/ decade	SSAOB
Seasonal f/c	100km	24h	0.1K	0.1K	0.1K/ decade	SSEOB
Decadal f/c	50km	1 month	0.1K	0.1K	0.1K/ decade	SSEOB
Climate quality analysis	50km	1 month	0.1K	0.1K	0.1K/ decade	SSEOB
Reanalysis	1km	3h	0.2K	0.2K	0.1K/ decade	SSEOB

Table 4. Requirements for satellite SST observations

3.2 Ocean Colour – status

The impact of climate change on marine ecosystems and the ocean carbon cycle, from global to regional scales, can only be quantified by using long-term data sets, including satellite ocean colour. Synoptic fields of ocean colour (derived chlorophyll pigment), are used as an index for phytoplankton biomass, which is the single most important property of the marine ecosystem. Ocean colour is also the basis to infer primary production (CO_2 uptake by algae) and is currently the only source of observational data offering complete global coverage. This offers a wide scope of ocean colour CDRs applications, which include:

- initialisation and verification of coupled ocean-biogeochemical models and potentially ocean-atmosphere-biogeochemical models.
- data assimilation for state, as well as parameter estimation in ocean forecasting models.

The patterns of ocean phytoplankton concentration provided by the ocean colour data, combined with models, are an important source of information to physical-biogeochemical process studies, such as primary production, respiration and interactions at the air-sea interface.

Parameter	**Application**	**Horizontal Resolution**	**Observing Cycle**	**Precision**	**Accuracy**	**Stability**	**Error Type (see Table 3)**
Derived chlorophyll *a*	Trend monitoring	4km	1month	30%	30%	2%/decade	SSAOB
	Decadal forecasting	50km	1 month	30%	30%	2%/decade	SSEOB
	Assimilation	4km	1 day	30%	30%	N/A	SSEOB

Table 5. Requirements for satellite ocean colour observations

The CMC requirements for satellite ocean colour observations are given in Table 5. Compared to the GCOS requirements these are close to the goals of GCOS in terms of resolution and observing cycle. The accuracy and precision requirements are well below the GCOS requirements not even approaching the threshold value of 25% (which calls in to question the GCOS value though for 100km grid scale it may be realistic) but modellers input stated that even 30% accuracies in derived chlorophyll alpha would provide some benefits. The requirements could also be sub-divided into CASE-1, CASE-2 and coastal waters where the first is the easiest case to achieve the stated requirements. There are a range of other possible products which could be considered for example in carbon budget assessments but modellers to date have not expressed any firm requirements for these.

3.3 Sea level – status

Sea level increase is one of the clearer indirect impacts of global warming and its potential effects justify a careful study of the sea level trends at the global and regional scales. It is also a key parameter to monitor some important features of climate variability such as the ENSO. Satellite observations with altimetry from the early 90's has demonstrated their great potential for monitoring sea level at scales extending from global to the mid-latitude ocean eddies. They have also provided an incentive to the development of ocean data assimilation schemes through the constraint they bring to ocean dynamics and thus to the initialization of seasonal, decadal and climate prediction models.

For the CMC the interest is to run historical realisations of the climate and to compare the modelled regional variability of sea level with that observed. Getting models to match the observed variability should improve the value of their predictions. It is also important to ensure the overall sea level rise due to rising temperatures and melting of ice sheets that is modelled is consistent with the observations.

The CMC requirements for satellite sea level observations are given in Table 6. For CMUG, goal values for revisit and stability can be kept but it suggested to give as a target breakthrough values of 0.2 cm/decade and 2 days and 0.5 cm/decade and 5 days for threshold.

Parameter	Application	Horizontal Resolution	Observing Cycle	Accuracy	Stability	Types of error
Ocean dynamic topography	Model Development and Evaluation	50 km	30 d	1 cm	2mm/ decade	SSEOB
	Seasonal and decadal forecast model initialisation	50km	30d	1 cm	2mm/ decade	SSEOB
	Ocean reanalyses	25km	2d	1 cm	2mm/ decade	SSEOB
	Long Term Trend Monitoring and Attribution	25 km	2 d	1 cm	2mm/ decade	SSEOB
Coastal sea level change	Model Development and Evaluation	12km	10 d	1 cm	2mm/ decade	SSEOB
	Long Term Trend Monitoring and Attribution	12km	2 d	1 cm	2mm/ decade	SSEOB

Table 6. Requirements for satellite sea level observations note all global datasets should go to the ice edge and not be limited to a latitude of 66S.

3.4 Sea-Ice – status

Important characteristics of sea ice for climate include: its concentration (that fraction of the ocean covered by ice); its extent (the area enclosed by the ice edge – operationally defined as the 15% concentration contour); the total area of ice within its extent (i.e., extent weighted by concentration); the area of multi-year ice within the total extent; its thickness (and the thickness of the snow cover on it); its velocity; and its growth and melt rates (and hence salt or freshwater flux into the ocean). In addition melt ponds on the ice are important to monitor due to their effect on the surface albedo and climate change signal.

Ice extent is the only sea ice variable for which observations are available for more than a few decades and so a clear requirement on the stability of the observations is crucial. The IPCC AR4 report states there is a significant decreasing trend in Arctic sea ice extent of $-33 \pm 7.4 \times 10^3\ \mathrm{km}^2\ \mathrm{yr}^{-1}$ (equivalent to –2.7% ± 0.6% per decade), whereas the Antarctic results show a small positive trend of $5.6 \pm 9.2 \times 10^3\ \mathrm{km}^2\ \mathrm{yr}^{-1}$ (0.47% ± 0.8% per decade), which is not statistically significant. The uncertainties represent the 90% confidence interval around the trend estimate and the percentages are based on the 1978 to 2005 mean. The decrease in Arctic sea-ice extent has accelerated in recent years and this was not predicted by the models. The requirements for measuring sea-ice cover for global climate models are listed in Table 7.

The GCOS requirement for stability of 5%/decade is considered to be too large and a figure of closer to 1% is what is required. Sea-ice thickness is important for models to represent but to date continuous global measurements have not been available. It is hoped the new satellite sensors just being launched will provide these measurements and the modellers requirements are given in Table 7. The GCOS accuracy requirements for sea-ice thickness (0.2cm) seem to be unrealistic. The accuracy values of 10cm or 10% of the thickness, whichever is the smaller, are required.

Parameter	Application	Horizontal Resolution	Observing Cycle	Precision	Accuracy	Stability	Types of error
Sea-ice cover (first year & multi-year ice)	trend monitoring	12.5km	1 day	5%	5%	1%/decade	SSAOB
	decadal f/c	50km	1 month	5%	5%	1%/decade	SSEOB
	Initialise	5km	1 day	5%	5%	1%/decade	SSEOB
	Reanalysis	12.5km	1 day	5%	5%	1%/decade	SSEOB
Sea-ice thickness	trend monitoring	20km	1 day	10cm or 10%	10cm or 10%	2 mm/decade	SSAOB
	decadal f/c	50km	1 month	10cm or 10%	10cm or 10%	2 mm/decade	SSEOB
	Initialise	20km	1 day	10cm or 10%	10cm or 10%	2 mm/decade	SSEOB
	Reanalysis	20km	1 day	10cm or 10%	10cm or 10%	2 mm/decade	SSEOB
Sea-ice drift	trend monitoring	12.5km	1-2-7 dy	0.01 m/s	0.01 m/s	0.01 m/s/decade	SSAOB
	Initialise	5km	1 day	0.01 m/s	0.01 m/s		SSEOB
	Reanalysis	12.5km	1 day	0.01 m/s	0.01 m/s		SSEOB
Melt pond fraction	trend monitoring	12.5km	1-2-7 dy	2%	5%	1%/decade	SSAOB
	Initialise	5km	1 day	2%	5%		SSEOB
	Reanalysis	12.5km	1 day	2%	5%		SSEOB

Table 7. Requirements for satellite observations of sea-ice

3.5 Clouds – status

The latest IPCC AR4 report highlighted cloud feedbacks (in particular those related to changes in boundary layer clouds) as the largest contributor to uncertainties in global climate sensitivity and this can be addressed by improving the representation of clouds in the climate model.

It also summarised the status of cloud observations from space as: *"In summary, while there is some consistency between different satellite datasets (ISCCP, ERBS, SAGE II) and surface observations of a reduction in high cloud cover during the 1990s relative to the 1980s, there are substantial uncertainties in decadal trends in all data sets and at present there is no clear consensus"* suggesting that at least for trend analysis, work remains to be done on quantifying the uncertainties in decadal trends of cloud parameters. For process studies there is also a strong requirement for satellite observations to improve the representation of clouds in climate models and here the long term stability is not an important requirement as the data are used to investigate changes on timescales of hours to seasons. As a result the CMUG are recommending that the cloud ECV datasets are designed with validating cloud model processes in mind rather than building long term monitoring datasets.

Table 8 summarizes the climate modelling requirements based on their use for detailed process studies (horizontal and vertical resolution, observing cycle). The precise requirements need to take into account how the data are to be used. Dealing with these three criteria in turn:

Horizontal resolution

Current global climate models are moving towards horizontal resolutions of around 50 km, with developments over the next 5 years or so taking this down to around 25 km. For detailed process studies it is desirable to have information at sub-grid scales, hence the specification of 10 km. For more general evaluation studies, e.g. comparison of monthly mean geographical distributions, this could be relaxed considerably and horizontal resolutions of around 100 km might still be useful.

Vertical resolution

The distribution of the vertical levels in atmospheric models is highly non-linear with respect to altitude – the layers are typically much more tightly spaced in the boundary compared to the free troposphere, for example. Current models have vertical resolutions of around 200 m in the boundary layer (with even this not being entirely satisfactory to represent stratocumulus cloud), increasing to around 500 m in the middle troposphere – the specification of 100 m is thus again based on the requirement for process studies. This could also be relaxed for other evaluation work and a vertical resolution of 500 m (or more) might be useful, depending on the information content of the particular observations. As part of CFMIP (Cloud Feedback Model Intercomparison Project; http://cfmip.metoffice.com) data sets using CloudSat and CALIPSO observations specifically designed for model evaluation have been produced (see http://climserv.ipsl.polytechnique.fr/cfmip-obs.html); these have vertical resolutions of around 500 m and 2 km respectively.

Observing cycle

In common with many related processes (e.g. rainfall, convection) the diurnal cycle of cloud remains a common weakness in the majority of current models. Examples of cloud systems with large diurnal cycles are tropical convection over land and marine stratocumulus cloud. Ideally, data with a temporal resolution comparable to the typical model time step (15-30 minutes) would be desirable. Again, however, much useful information could be obtained with 1-hourly data, with the upper limit on utility probably being 3 hours.

There are various products of interest which range from fields of cloud cover and top pressure/temperature to profiles of water and ice cloud concentration. The CMUG initial proposal to the CCI clouds project will be to produce histograms of cloud parameters related to other cloud parameters and, for example, aerosols. The CCI datasets will need to be readily incorporated into the COSP simulator by the CMUG in the same way as the ISCCP, CloudSat and CALIPSO data sets are currently exploited. The utility of the ISCCP data stems from the fact that statistical summaries (e.g. optical depth vs cloud top pressure histograms) when employing the COSP simulator, can be compared to climate model output in a very straightforward manner. This has been recognised by the observational community and

ISCCP-like histograms are now produced using both MODIS and MISR data. This approach has several advantages:

- It puts the CCI data into a format that is already familiar to modellers.
- It allows the CCI data to be easily compared to other cloud data sets.
- It allows the CCI data to be easily integrated into pre-existing and tested methods for exploiting satellite cloud data for model evaluation.

Parameter	**Application**	**Horizontal Resolution**	**Vertical resolution**	**Observing Cycle**	**Precision**	**Accuracy**	**Stability**	**Types of error**
Cloud cover	model development	10km	N/A	1h	10%	5%	1%/year	SSEOB
	trend monitoring	30km	N/A	3h	10%	5%	1%/decade	SSAOB
Cloud top height	model development	10km	N/A	1h	0.1km	0.1km	0.1km/ year	SSEOB
	data assimilation	5km	N/A	1h	0.1km	0.1km	N/A	ERRCOV
	trend monitoring	30km	N/A	3h	0.2km	0.2km	0.1km/ decade	SSAOB
Cloud top temp	model development	10km	N/A	1h		0.25K		SSEOB
	trend monitoring	30km	N/A	3h	0.25K	0.25K	0.25K/decade	SSAOB
Cloud ice profile	model development	10km	0.2km	1h				SSEOB
Cloud water profile (> 100 µm)	model development	10km	0.2km	1h				SSEOB
Cloud water profile (< 100 µm)	model development	10km	0.2km	1h				SSEOB
Cloud effective radius?	model development	10km	0.2km	1h	1um	1um	1um	SSEOB

Table 8. Requirements for satellite cloud observations

The requirements for trend detection are somewhat more difficult to ascertain. Firstly, there is currently no clear indication from presently-available observations about cloud trends and secondly this may well be too stringent a test for current models, given the known uncertainties in the representation of cloud processes. It certainly the case that the cloud modelling and cloud feedback community is currently much more focused on process studies than on long-term trends. That said, a new data set that was able to determine trends in cloud amount, for example, with the specified level of accuracy/stability would be a major advance and would undoubtedly be of great interest to climate modellers.

The GCOS requirements for the cloud ECV are somewhat relaxed in terms of observing cycle (3-6hr) compared to the CMC requirements which may reflect the needs in terms of long term trend monitoring rather than model process studies. Also the GCOS accuracies for cloud cover and cloud top height are more relaxed than those required for model processes.

Finally, another consideration is that the generation of merged products from quite different sensors will be difficult to interpret for most applications. Such merged products are difficult to use: indeed, the rationale behind the simulator approach is precisely to avoid such difficulties by generating model equivalents of single-sensor products. It is thus unlikely that such products will be attractive to modellers.

3.6 Ozone – status

The ozone concentration in the atmosphere (mainly the total ozone column) has been measured for several decades after the discovery of the impact of human activities on the upper stratosphere and lower stratosphere chemical processes, resulting in the high latitude ozone holes. Monitoring the trends of ozone content remains a key issue for the study of the recovery of stratospheric ozone and also for monitoring human induced greenhouse gases as far as tropospheric ozone is concerned. It is also essential to study stratospheric-tropospheric exchange processes and to give a better representation of the dynamics, chemical, transport and radiative processes. Ozone data assimilation is of primary importance for environmental studies including the initialization of air quality prediction (interactions between air quality and climate are deemed increasingly important). Some studies have also revealed the potential of ozone observations in constraining the atmospheric dynamics through data assimilation. Considering available observations, those from satellites are crucial in providing information on the ozone content of the atmospheric column but also, through the development of new sensors, to provide valuable information on partial columns and also the ozone profile.

The requirements for the ozone ECV are given in Table 9. The CMUG initial proposal to the CCI project for ozone is to have different specifications according to the altitude range. CMUG would prefer the same threshold specifications on vertical resolution for higher troposphere and lower stratosphere (2km) for a better validation of chemical-transport models.

Parameter	**Application**	**Horizontal Resolution (km)**	**Vertical Resolution (km)**	**Observing Cycle (h)**	**Precision (%)**	**Accuracy (%)**	**Stability (%)**	**Types of error**
Ozone profile								
Higher stratosphere & mesosphere (HS & M)	Model Development and Evaluation	500	3	48	15	15%	3.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	100	1	6	5	5%	1.0 %/decade	SSEOB
Lower stratosphere (LS)	Model Development and Evaluation	100	2	72	15	15%	3.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	75	1	6	5	5%	1.0 %/decade	SSEOB
Higher troposphere (HT)	Model Development and Evaluation	100	2	72	20	20%	3.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	20	1	6	5	5%	1.0 %/decade	SSEOB
Lower troposphere (LT)	Model Development and Evaluation	50	2	72	20	20%	3.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	10	1	3	10	10%	1.0 %/decade	SSEOB
Ozone column								

Troposphere column	Model Development and Evaluation	50		72	15	15	5.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	10		3	5	5	3.0 %/decade	SSEOB
Total column	Model Development and Evaluation	50		72	15	15	5.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	10		6	5	5	3.0 %/decade	SSEOB

Table 9. Requirements for satellite observation of ozone.

For lower troposphere and tropospheric column, CMUG prefer more stringent requirements on the observing cycle to better constrain O_3 pollution episodes. However, even if the final goal is to allow the link between air quality (which needs a short cycle and very high accuracy in the boundary layer) and climate, with a 2 to 3 day observing cycle these episodes can be detected and their impacts on a monthly mean correctly taken into account.

As far as ozone assimilation is concerned, in particular within the context of successors to the MACC re-analysis, products from single sensors would be preferred to merged products. Merged products if they are all obtained with the same technique and over a along period span (like the SBUV sensors over 30 years) are useful in a model validation context like CCMVal, aiming at evaluating each process separately. This implies to provide these different products as separate datasets. The CCI requirements are similar to those from CMUG.

Depending on the specific satellite products and periods eventually chosen for re-processing by the CCI-ozone project, further suggestions for improvements to data quality may be provided based on existing experience within the data assimilation community of existing/related data products.

3.7 Greenhouse Gases – status

A comprehensive understanding of greenhouse gases is crucial for informing societal response to climate change. Applications with a need for observations of greenhouse gases such as CO_2 and CH_4 include Model Development, Decadal Forecasting and Regional Source/Sink Determination. As shown in Table 10, each application has somewhat different observational requirements reflecting the particular aspect of greenhouse gases under consideration.

To elaborate on the GHG observational requirements for Regional Source/Sink Determination, the tabulated values are based on the activities undertaken within the frame of the MACC sub-project on greenhouse gases. The principal products from that sub-project are:

- 4-dimensional gridded fields of CO_2 and CH_4 produced in near-real-time (based on data assimilation of near-real-time data products, typically from operational satellites),
- 4-dimensional gridded fields of CO_2 and CH_4 produced in “delayed mode” (6 months delay, to allow data assimilation of research-mode satellite data products),
- 3-dimensional gridded fluxes of CO_2 and CH_4 produced in “delayed mode”,

- Re-analysed concentration and flux fields of CO_2 and CH_4 for the period 2003-2010.

Flux fields are an important factor for decision-makers at several levels, and need to be estimated with confidence. The fidelity of flux estimates is strongly influenced by accuracy and stability of the observations that are used as input to the data assimilation and re-analysis systems. This drives the requirements given in Table 10 for some of the required parameters. The requirements for full GHG concentration profiles are given in Annex B.

Horizontal Resolution and Observing Cycle requirements are consistent with GCOS, and reflect the spatial and temporal variability of important classes of regional sources and sinks. The need for good flux estimates makes the current requirements for accuracy and stability more demanding than previous GCOS requirements.

Parameter	Application	Horizontal Resolution	Vertical Resolution	Observing Cycle	Precision	Accuracy	Stability	Types of error
Trace gas profile CH_4 - Troposphere column	Regional source/sink determination	10/20/50 km	N/A	3/4/6 h	2/4/10% 20/40/100 ppb	0.5/0.7/1.0% 5/7/10 ppb	0.5/0.7/1.0 %/yr 5/7/10 ppb/yr	SSEOB
Trace gas profile CH_4 - Total column	model development	25km	N/A	1 day	10%	10%	N/A	SSEOB
	decadal f/c	500km	N/A	1 year	2/4/10% 20/40/100 ppb	0.5/0.7/1.0% 5/7/10 ppb	0.5/0.7/1.0 %/yr 5/7/10 ppb/yr	SSAOB
	Regional source/sink determination	10/50/250 km	N/A	3/4/6 h	2/4/10% 20/40/100 ppb	0.5/0.7/1.0% 5/7/10 ppb	0.5/0.7/1.0 %/yr 5/7/10 ppb/yr	SSEOB
Trace gas profile CO_2 - Total column	model development	100km		monthly	0.5/1ppm	0.5/1ppm	N/A	SSEOB
	decadal f/c	500km	N/A	1 year	1/1.3/2% 3/4/6 ppm	0.15/0.2/0.3% 0.5/0.7/1.0 ppm	0.15/0.2/0.3 %/yr 0.5/0.7/1.0 ppm/yr	SSAOB
	Regional source/sink determination	50/100/500 km	N/A	3/4/6 h	1/1.3/2% 3/4/6 ppm	0.15/0.2/0.3% 0.5/0.7/1.0 ppm	0.15/0.2/0.3 %/yr 0.5/0.7/1.0 ppm/yr	SSEOB
Trace gas profile CO_2 - Troposphere column	Regional source/sink determination	10/50/500 km	N/A	3/4/6 h	1/1.3/2% 3/4/6 ppm	0.15/0.2/0.3% 0.5/0.7/1.0 ppm	0.15/0.2/0.3 %/yr 0.5/0.7/1.0 ppm/yr	SSEOB

Table 10. Requirements for satellite observation of greenhouse gases

The requirements are given for tropospheric and total column only, in recognition that requirements for profile data would be very demanding for existing satellite data. In the event that data providers consider it feasible to provide profile data approaching GCOS requirements, then more refined user requirements could be given in a future update of this document. The user community increasingly asks for horizontal and vertical resolution in the

Lower Stratosphere to be the same as that for the Higher Troposphere, in contrast to previous GCOS requirements. As mentioned above, other applications of greenhouse gas observations may have different sets of requirements. For example, the detection of CH_4 emissions from pipelines or similar small sources would require higher horizontal resolution and vertical resolution in the lower troposphere.

Similar to the ozone section above, it would be important to provide not only merged GHG products but also products from single sensors as separate datasets.

Turning now to the GHG observation requirements for decadal forecasting, it is principally the distribution of the trace gases at the start of the forecast that can be important to help define the atmospheric fields. Long period averages are sufficient for this purpose.

3.8 Aerosols – status

The impact of aerosols on climate is often cited as one of the most uncertain factors governing climate change. Aerosols have offset part of the warming expected from anthropogenic emissions of greenhouse gases. It is very important to decrease the uncertainties on the aerosol forcing because this will contribute to better constrain the climate sensitivity from current observational climate records. As a result measurements of atmospheric aerosols (both tropospheric and stratospheric) are required. There is a further arbitrary split at 3km height to obtain aerosol products below and above the lower troposphere.

Aside from the direct radiative effect it is in particular impact of indirect radiative effects (mainly through clouds) which needs to be better understood to better estimate the climate sensitivity to aerosols in climate models. Thus, there are two aspects that need to be addressed. Relatively high resolution data with associated environmental data (e.g. clouds) for a better process understanding, as well as long-term monitoring on global scales to address trends in aerosol properties.

The current aerosol climatologies within global models are usually extremely basic and essentially consist of time-invariant two-dimensional fields an aerosol amount. Thus datasets of aerosol properties considering both spatial and temporal as well as compositional variations will be a step forward. The parameters required are listed in Table 11. It includes the aerosol extinction optical depth (AOD) (at the modelling reference wavelength at 550nm) for both the total atmospheric column as well as stratified over four atmospheric altitude sections to distinguish between stratosphere (important after major volcanic eruptions) and tropospheric layers linked to high-, mid- and low level clouds. Upper tropospheric aerosol have enhanced capabilities for long range transport, while lower tropospheric aerosols remain more local and influence the near surface meteorology (e.g. visibility, air quality). In addition to total extinction optical depth (absorption + scattering) the absorption optical depth is also an important parameter to measure and has more stringent accuracy requirements being only part of the total extinction.

Aside from aerosol amount also the aerosol composition is of interest. A very useful property in that sense are data for AOD at different wavelengths. These different AOD data provide information on aerosol size. AODs at two different wavelengths already define the Angstrom parameter, which a more general size-indicator. Even better is the AOD fine mode fraction, which requires AOD data at least four different wavelengths in the visible and the near-IR. Then via the Angstrom parameter spectral dependence the total AODs can be stratified into fractions associated with smaller (radii <0.5um) and larger sizes (radii >0.5um). Thus, aside from the AOD retrieval at 0.55um, additional AOD retrievals at one or even better at three other wavelengths in the visible or near-IR are desirable (e.g. 443nm, 670nm, 870nm). Other useful elements to characterize aerosol type are data on polarization and absorption. Polarization provides information on aerosol shape (e.g. mainly to discriminate dust from other aerosol type). In most retrievals a-priori assumptions on aerosol absorption are made.

One CMC requirement is defined by the assessment of aerosol processes in climate models which requires data on associated environmental properties. Thus such process understanding of processes involves especially the potential interactions with clouds. Thus, data on clouds (from the cloud ECV) are required which match in terms of spatial and temporal) resolution, observing period and if possible satellite platform. The other CMC requirement is the establishment of long time-series for aerosol properties.

The GCOS requirements for aerosol optical depth match those of the CMUG in terms of horizontal resolution but the observing cycle of 6hr for monitoring and 1hr for process studies is more frequent than the GCOS goal of 1 day.

Depending on the specific satellite products and periods eventually chosen for re-processing by the CCI-aerosol project, further suggestions for improvements to data quality may be provided based on existing experience within the data assimilation community of existing and related data products.

Parameter	Application	Horizontal Resolution	Observing cycle	Precision	Accuracy	Stability	Types of error
Total extinction optical depth (at 4 VIS + IR wavelengths)	model development	1km	1hr	0.02	0.02	N/A	SSEOB
	assimilation	20km	1hr	0.02	0.02	N/A	SSEOB
	decadal f/c	50km	1 month	0.02	0.02	.01/decade	SSEOB
	trend monitoring	25km	6hr	0.005/ 0.01	0.01/ 0.02	.01/decade	SSAOB
Total aerosol absorption optical depth at 0.55um	model development	1km	1hr	0.01	0.01	N/A	SSEOB
	trend monitoring	25km	6hr	0.002/ 0.01	0.004/ 0.02	.002/ decade	SSAOB
Aerosol optical depth in stratosphere (at 4 VIS + IR wavelengths)	model development	1km	1hr	0.02	0.02	N/A	SSEOB
	trend monitoring	25km	6hr	0.02	0.02	.01/decade	SSAOB

Aerosol optical depth in troposphere (at 4 VIS + IR wavelengths)	model development	1km	1hr	0.02	0.02	N/A	SSEOB
	trend monitoring	25km	6hr	0.02	0.02	.01/decade	SSAOB
Aerosol optical depth above ~3km (680hPa) (at 4 VIS + IR wavelengths)	model development	1km	1hr	0.02	0.02	N/A	SSEOB
	trend monitoring	25km	6hr	0.02	0.02	.01/decade	SSAOB
Aerosol optical depth below ~3km (680hPa) (at 4 VIS + IR wavelengths)	model development	1km	1hr	0.02	0.02	N/A	SSEOB
	trend monitoring	25km	6hr	0.02	0.02	.01/decade	SSAOB
Aerosol depolarisaton ratio (VIS)	model development	1km	1hr	?	?	N/A	SSEOB
	trend monitoring	25km	6hr	?	?	?	SSAOB

Table 11. Requirements for satellite aerosol datasets

3.9 Glaciers and Ice caps – status

Glaciers and ice caps provide one of the most visible indications of the effects of climate change. The mass balance at the surface of a glacier (the gain or loss of snow and ice over a hydrological cycle) is determined by the climate. The current extent of glaciers and icecaps is given in Table 12 as documented by the IPCC in the AR4 report. The changes with time are what is important to measure and also how well climate models can represent or implement glaciers and icecaps.

Source	Area $(10^3 km^2)$	Volume $(10^3 km^3)$	Sea level equivalent (m) [f]
Raper and Braithwaite 2005[a,c]	522±42	87±10	0.24±0.03
Ohmura 2004[a,d]	512	51	0.15
Dyergerov and Meier 2005[a,e]	546±30	133±20	0.37±0.06
Dyergerov and Meier 2005[b,e]	785±100	260±65	0.72±0.2
IPCC 2001[b]	680	180±40	0.5±0.1

Table 12. Extents of glaciers and ice caps as given by different authors (from IPCC AR-4)

Notes:
a glaciers and ice caps surrounding Greenland and Antarctic Ice Sheets are excluded.
b glaciers and ice caps surrounding Greenland and West Antarctic Ice Sheets are included.
c volume derived from hypsometry and volume/area scaling within 1° × 1° grid cells.
d volume derived from a statistical relationship between glacier volume and area, calibrated with 61 glacier volumes derived from radio-echo-sounding measurements.
e volume derived from a statistical relationship between glacier volume and area, calibrated with 144 glacier volumes derived from radio-echo-sounding measurements.
f calculated for the ocean surface area of 362 × 106 km^2.

According to the tiered strategy of global glacier monitoring in the Global Terrestrial Network for Glaciers (GTN-G), the basic application of satellite data is the generation of repeat glacier inventories at decadal time scales using cost-efficient semi-automatic classification techniques and data processing in Geographic Information Systems (e.g. Paul et al. 2007). This is in line with Product T.2.1 from GCOS (2006) that ultimately requests to obtain a globally complete map of glaciers and icecaps. With the now free availability of all Landsat data from the USGS archive and global DEMs (SRTM, GDEM), this goal has become feasible and considerable progress in regard to this ambitious goal has been made in the recent past (Paul, 2010). The final global map of glaciers and icecaps would serve several fields of application, including further ECVs:

- improved modelling of global sea-level rise (e.g. Hock et al., 2009; Hirabayashi et al., 2010),
- a sound basis for change assessment (e.g. Bolch et al., 2010),
- an important input for hydrological (e.g. Viviroli et al., 2009) and glaciological modeling (e.g. Oerlemans et al., 1998).
- a possibility to validate output from RCMs (e.g. Ghan et al., 2006), and
- a data set to initialise the land ice fields in RCMs (Kotlarski et al., 2010).

Apart from the glacier extent, satellite data are used widely to derive further glaciological parameters including snow facies, velocity fields and elevation changes (e.g. Paul et al., 2009). All these products do strongly vary in terms of sensors (resolution), observing period and cycle, or required precision and accuracy. The related list of satellite based observatonal requirements and capabilities was compiled by IGOS (2007). We have used this list (table B.6) as a base for Table 13 below. The long term stability of the measurements is crucial for this ECV as it is an indicator of climate change.

Parameter	**Application**	**Horizontal Resolution**	**Observing Cycle**	**Precision**	**Accuracy**	**Stability**	**Types of error**
Glacier Area	Initialisation	30 m	1 year	0.01km^2	<5%		SSEOB
	trend monitoring	30 m	5 years	0.01km^2	<5%	0.01km^2/ decade	SSAOB
Glacier Topography	Initialisation	<100 m	1 year	1 m	5 m		SSEOB
	trend monitoring	<100 m	5-10 years	1 m	5 m	1 m/ decade	SSAOB
Velocity	Initialisation	30 m	1-12 months	1 m/yr	10 m/yr		SSEOB
	trend monitoring	30 m	1 year	1 m/yr	10 m/yr	1 m/ decade	SSAOB
Snowline	Initialisation	30 m	1 year	30 m	100 m		SSEOB
	trend monitoring	30 m	1 week / 1 year	30 m	100 m	30 m / decade	SSAOB

Table 13. Requirements for glacier and ice caps

The two main requirements for the glacier and ice cap datasets for the CMC are trend monitoring and providing initial conditions for climate models. The datasets can also be used for validation of land surface process in climate model predictions which have the same requirements for accuracy as the trend monitoring.

3.10 Land Cover – status

Detailed information about global land cover and land cover dynamics is an important variable for global and regional climate modelling over many timescales. Land cover information is used in climate models for the initialization as well as a boundary condition. The land cover information is hereby translated into surface parameters (e.g. albedo, LAI, fractional vegetation cover) which provide the lower boundary condition for the atmospheric models. On the other hand, detailed regional land cover information provides a very valuable information for process studies like e.g. the assessment of the impact of fires.

Thus, even though land cover data provides essential spatial patterns of different land cover types, the land cover classes need to be translated into model relevant surface parameters that can be used in the model equations. The mapping of land cover information into model parameters is performed using literature data (Hagemann, 2002) or remote sensing based climatologies like e.g. ECOCLIMAP (Champeaux et al., 2005).

A variety of different global land cover products exist (e.g. GLOBCOVER, MODIS) for limited time periods, while there is a lack for a consistent long-term land cover data product at the global scale that could be used as a boundary condition in models at decadal time scales.

The combination of land cover information with observed variability of land surface characteristics is essential to improve the description of land surface dynamics in climate models as advised by the CSAB (ESA/PB-EO(2009)69, Annex-1). While methods have been developed to retrieve consistent land surface parameters from satellite data (Pinty et al., 2006; Clerici et al., 2010), these have not yet been combined with high resolution land cover information to generate a consistent, remote sensing based, land surface parameter data set which can be used as a boundary condition in climate models.

Parameter	Application	Horizontal Resolution	Observing Cycle	Precision	Accuracy	Stability	Types of error
Land cover type	model development	300m - 1km	2-5 years	not applicable	5-10%	<10%	ERRMERG
Land cover change	trend monitoring	300m - 1km	2-5 years	not applicable	5-10%	<10%	ERRMERG

Table 14. Requirement for satellite land cover parameters

The requirements for land cover are given in Table 14. Compared to GCOS requirements, the CMUG figures are very similar in all respects. The Land cover CCI should aim at delivering a product meeting these requirements with a possible extension of the approach to longer timescales and an appropriate error characterization.

3.11 Fire – status

Fire disturbances alter vegetation dynamics and impact climate. Climate models that account dynamically for climate induced changes in vegetation simulate fire disturbance within process based fire sub-models. The development and evaluation of such sub-models depend on the availability and quality of satellites based fire disturbance products. Such complex Earth System models are crucial to assess fire climate interactions and the impact of fire on the global carbon cycle.

In addition, global vegetation models can be utilized to diagnostically simulate fire emissions by combining information on burned area, available fuel load and burning conditions. Satellite based burned area products can thereby serve as prescribed boundary conditions. Besides uncertainties in burned area estimates, such an approach is limited by an uncertain quantification of available fuel loads and burning conditions (e.g. combustion completeness, mortality rates, emission factors). Fire disturbance products will therefore be best exploited in models when consistently derived ancillary data products, such as land cover classification or biomass availability, are provided that help to constrain specific burning conditions.

The assessment of fire emissions will be one important application of fire disturbance products. Fire emissions serve as boundary conditions for atmospheric aerosol and chemistry models used to assess air quality. An operational usage of atmospheric composition models will require near real-time availability of the fire disturbance ECV.

The strong interannual variability of fire activity vegetation models will require data products that cover a multiyear timespan (5-10 years) for the development and evaluation of process based fire models as well as for the application of satellite observed burned area products as boundary condition.

The specific requirements for the fire disturbance ECV are listed in Table 15. In terms of spatial resolution and observing cycle these are close to the GCOS requirements.

Parameter	Application	Horizontal Resolution	Observing Cycle	Accuracy	Stability
Burned fire area	trend monitoring	0.25/1.0/5.0 km	1/1.5/3 d	30/20/10 %(MAX)	5.00%
	Prescribe model boundary condition	0.25/1.0/5.0 km	1/1.5/3 d	30/20/10 %(MAX)	5.00%

Table 15. Requirements for satellite burned area fire parameters

No fire radiative product is planned by the fire CCI project and this is not strictly an ECV although it is a requirement of climate modellers. This issue will need to be raised at least with the CCI project and to make this more explicit within the GCOS parameter list.

3.12 Ice Sheets

Climate modellers, are interested in modelling ice sheets because of their interactions with other components of the climate system (e.g. freshwater fluxes from ice sheets to modify sea-level on orographic forcing of wind patterns). The ice sheets ECV project was created over a year after the original draft of this document and so no user requirement exercise was done. However the ice sheets team did do a user requirement summary and it can be found at: http://esa-icesheets-cci.org/sites/default/files/documents/public/ST-DTU-ESA-ISCCI-URD-001%20User%20Requirements%20Document%20v1.5.pdf although relatively few climate modellers participated in the survey partly because to date satellite data of ice sheets has not been exploited in models. In summary Table 16 is derived from this document for the modelling applications.

Parameter	Application	Horizontal Resolution	Observing Cycle	Accuracy	Stability	Types of error
Surface elevation change	Initialisation	<5km	All year	0.1m/yr		SSEOB
	trend monitoring	<500 m	5-10 years	<0.1m/yr	<0.1 m/ decade	SSAOB
Ice Velocity	Initialisation	<5km	All year	30 m/yr		SSEOB
	trend monitoring	50m	5-10 years	<30m/yr	<30m/yr	SSAOB

Table 16. Requirements for ice sheets for modelling applications

One important requirement for climate modellers is to include both the Greenland and Antarctic sheets in any satellite dataset that is produced.

3.13 Soil Moisture

Soil moisture is an important variable for all models from NWP to climate time scales. As for ice sheets this project started late and so was not included in the original draft of this document. The URD for this ECV is still in preparation. For reference the GCOS requirements are given in Table 17 below along with those assumed in NWP data assimilation systems.

Parameter	Application	Horizontal Resolution	Observing Cycle	Accuracy	Stability	Types of error
Volumetric soil moisture (up to 5cm depth)	Initialisation	50km	Daily	$0.035m^3/m^3$		SSEOB
	trend monitoring	50km	Daily	$0.04m^3/m^3$	$0.01m^3/m^3/$ yr	SSAOB

Table 17. GCOS and modelling requirements for soil moisture

Soil moisture is beginning to be used widely to initialise surface fields in models. There is strong need for consistency in this ECV with other ECVs for example temperature, surface humidity, albedo, vegetation and precipitation.

4. Across-ECV requirements

To ensure consistency between ECV datasets which is important for climate modelling and reanalyses there are a number of considerations that should be respected for the CCI projects. Also to facilitate common practices the CCI should converge on terminology as this can be different for each ECV project and will enhance communication across the project.

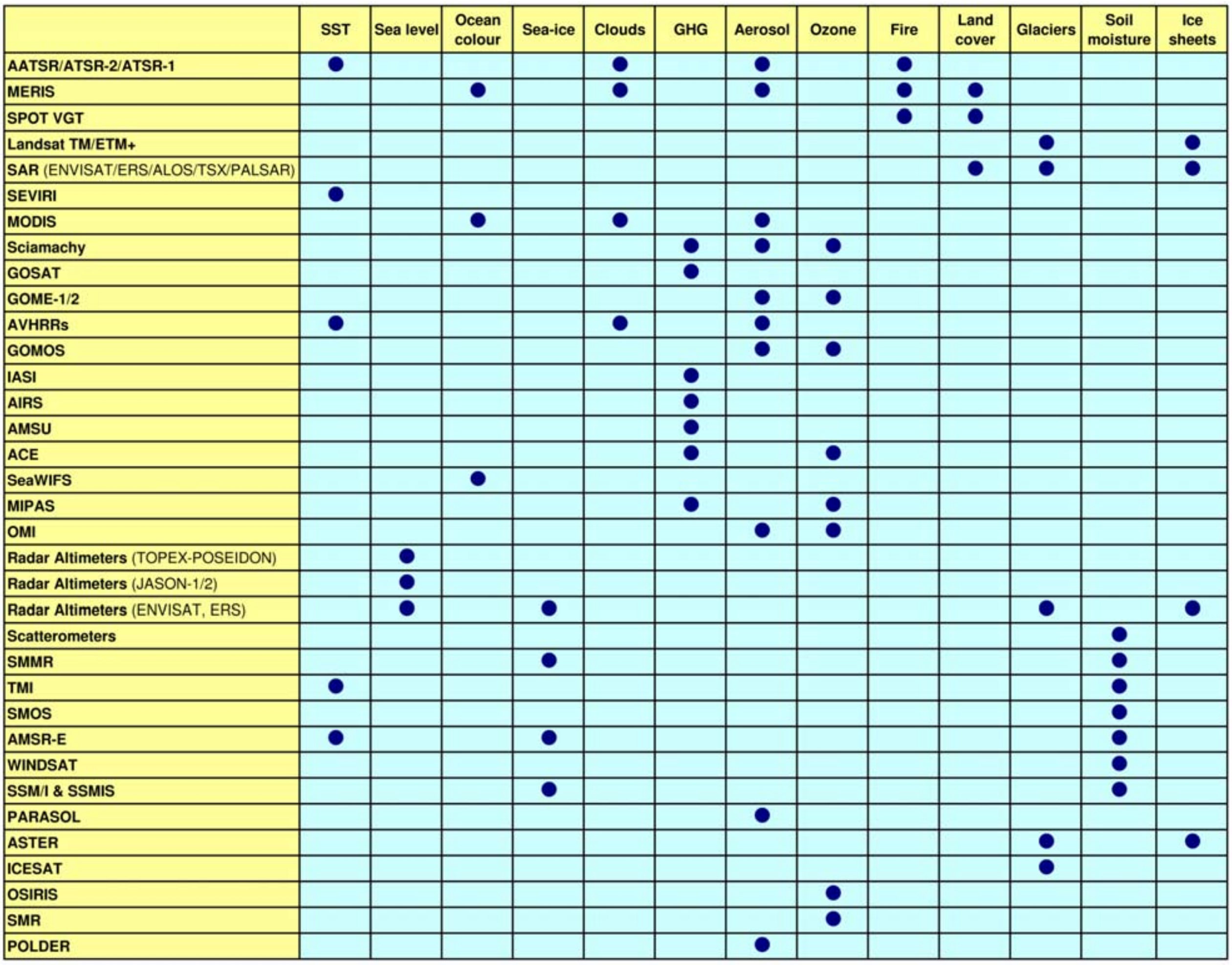
Firstly the ECV projects should all use the same level 1 (or level 2) datasets as input to their level 2 (or level 3) processing. Some of the ESA FCDRs (e.g. MODIS and AATSR) are in the processing of being regenerated with improved calibration, geolocation etc. and there needs to be a clear steer from ESA at least for ESA satellites what are the recommended level 1&2 datasets to use. Table 18 shows which sensors are common to which ECVs.

Secondly some ECVs will benefit from access to other ECVs being generated from within the CCI project to explore synergies and also where one ECV's retrieval can benefit from another. Table 19 attempts to identify where these cross-linkages are between ECVs.

Thirdly the use of common ancillary fields will be important. ERA-Interim will be a good source of atmospheric fields from 1980 onwards with ERA-40 available before that. This would ensure a consistent assumption about the atmospheric state for all ECV datasets. The next reanalysis will be ERA-CLIM with improvements to the model and observational datasets. This however will not be ready in time for the CCI projects at least in phase 1. For surface fields an agreed SINGLE source for surface albedo, vegetation (LAI, FAPAR), emissivity, ice caps and glacier climatology, sea ice, SST etc should be defined and agreed by the CCI projects. If this is not done inevitable inconsistencies will be seen in the products which will be only due to different representations of the atmosphere/surface being assumed. A common land/sea/lake mask also needs to be adopted by all ECV projects.

The horizontal grids should be common to level 3 products to enable easy comparisons and processing of data from different ECV CDRs. Similarly the definition of atmospheric layering should be common across ECVs (e.g. aerosol and clouds) for level 2 and 3 products.

Finally the specification of error characteristics should be provided in a consistent way and where appropriate separated into precision, accuracy and stability. The errors should also be specified, where possible, for each individual measurement.



	SST	Sea level	Ocean colour	Sea-ice	Clouds	GHG	Aerosol	Ozone	Fire	Land cover	Glaciers	Soil moisture	Ice sheets
AATSR/ATSR-2/ATSR-1	●				●		●		●				
MERIS			●		●		●		●	●			
SPOT VGT									●	●			
Landsat TM/ETM+											●		●
SAR (ENVISAT/ERS/ALOS/TSX/PALSAR)										●	●		●
SEVIRI	●												
MODIS			●		●		●						
Sciamachy						●	●	●					
GOSAT						●							
GOME-1/2							●	●					
AVHRRs	●				●		●						
GOMOS							●	●					
IASI						●							
AIRS						●							
AMSU						●							
ACE						●		●					
SeaWIFS			●										
MIPAS						●		●					
OMI							●	●					
Radar Altimeters (TOPEX-POSEIDON)		●											
Radar Altimeters (JASON-1/2)		●											
Radar Altimeters (ENVISAT, ERS)		●		●							●		●
Scatterometers												●	
SMMR				●								●	
TMI	●											●	
SMOS												●	
AMSR-E	●			●								●	
WINDSAT												●	
SSM/I & SSMIS				●								●	
PARASOL							●						
ASTER											●		●
ICESAT											●		
OSIRIS								●					
SMR								●					
POLDER							●						

Table 18. Primary sensors for each ECV project as given in the DARDs

	SST	**Sea level**	**Clouds**	**Sea ice**	**Ocean colour**	**Aerosol**	**GHG**	**Landcover**	**Fire**	**Ozone**	**Glaciers**	**Ice Sheets**	**Soil Moisture**
SST		x	x	X	X	x				x			
Sea level	x			x								x	
Clouds	x			x	X	x	x	X	x	X			
Sea ice	x	x	x		X					x	x		
Ocean colour	X		x	x		x							
Aerosol			x		X			X	x	X	x		
GHG			x			x			x	X			
Landcover			x			x			x		x		x
Fire			x			x	x	X		x			x
Ozone			x			x	X						
Glaciers				x				X				x	
Ice Sheets											x		
Soil moisture													

Table 19. An analysis of cross linkages between ECVs indicating where comparisons need to made to ensure consistency. The left hand column is the project with the identified need, the top horizontal row is the provider. The larger crosses indicate where the CDRs generated by that ECV project would potentially be of use in the retrieval of the ECV listed on the left side.

5. Requirements for observation operators and other software tools

5.1 Observation operators

Climate modellers not only require the satellite CDRs from the CCI projects for all 11 ECVs but also for some of the CDRs observation operators or satellite simulators to convert the model state variables to the satellite measured variable are required. These operators are normally in the form of a generic software package that can be “plugged” into any climate model and interfaced with the model variables. The COSP package is a good example of this and contains a list of observation operators for many different satellite datasets, including ISCCP, CloudSat, CALIPSO, HIRS and SSM/I.

The requirements for operators for each of the 11 ECVs will need to be considered. Currently it is envisaged that the observation operators listed in Table 20 will be required for the CCI datasets where the model variables are converted to a satellite observed quantity.

ECV	Model variable	Satellite variable to simulate
Atmospheric		
Cloud properties	Liquid/Ice concn profile	Cloud amount/top pressure
	Fractional cloud cover	Equivalent cloud cover
Ozone	Ozone concn profile	Total column ozone
Greenhouse gases	CO_2 and CH_4 profiles	Total column CO_2 and CH_4
Aerosols	Aerosol concn profile	Aerosol optical depth
Oceanic		
SST	Sea surface bulk temp	Sea surface skin temp
Sea level	N/A	N/A
Sea-ice	Sea-ice thickness	Area mean freeboard
	Sea-ice concentration	MW br. temps
Ocean colour	Phytoplankton concn	Derived chlorophyll alpha
Terrestrial		
Glaciers and ice caps	N/A	N/A
Land cover (inc veg)	N/A	N/A
Fire	N/A	N/A
Ice Sheets	N/A	N/A
Soil Moisture	Soil moisture	Surface wetness

Table 20. Observation operators required for CCI datasets

5.2 Routines and documentation to ingest CDRs

It is vital that climate modellers are able to easily ingest the CCI datasets into their model environments. The aim will be to make the format as familiar to users as possible (see next section) so they probably have the tools they need already but nevertheless the option of tools to read in the data should be provided. One way to ensure easy to use datasets is to impose a consistent naming convention across the ECV projects and beyond.

To make reading the datasets as easy as possible a small software package consisting of source code, documentation, build scripts, and installation tests (sample input data and expected output from test programs in order to verify correct installation) is envisaged as an effective solution by climate modellers.

5.3 Metadata

There are various metadata required to be made available with the satellite CDRs. This also should be documented. Examples include a timeline of both satellite and instrument related anomalies, documentation on version of level 1 processing, what ancillary datasets have been used in the level 2 processing etc.

5.4 Map projections

Geospatial datasets have to be stored in a specific projection and this can cause problems in the analysis of the datasets (e.g. data day definition). The important thing is to provide simple tools to translate between any projection and a basic lat/lon grid. The CCI datasets should all share a common projection where possible to facilitate the joint analysis of different datasets from different ECVs. Land/Sea/Lake masks are also important to be common between the ECV projects otherwise inconsistencies will be seen due to the use of different masks.

5.5 Co-location software and data

For most of the CDRs they should be accompanied by colocation software with datasets of in-situ measurements (e.g. buoys for SST) to assist a wide range of users in the validation of the datasets. Tools for the spatial interpolation of the data to allow for a resampling of the observational data would be useful. Up and downscaling resampling may also need to be done. Common interpolation tools should be adopted across projects and ECMWF offered the CDO tool as a possible candidate.

6. Requirements for data formats and data access

6.1 Naming conventions and documentation

In order to make life simple for users the naming conventions for files, datasets and variables must be commonly agreed between users and data producers. A recommended naming convention for individual variables for the CDRs can be accessed here:
http://cf-pcmdi.llnl.gov/documents/cf-standard-names/standard-name-table/15/cf-standard-name-table.html
together with guidance on what the convention is:
http://cf-pcmdi.llnl.gov/documents/cf-standard-names/guidelines

For example we have *sea surface skin temperature* and *sea surface subskin temperature* for the SST ECV. There are some variables that will still need to be defined as this list does not cover all variables in the CCI ECV list. A data reference syntax is being defined as part of CMIP5 and should be followed for the CCI datasets also, see:
http://pcmdi-cmip.llnl.gov/cmip5/output_req.html#req_format

There is also a recommended way for CCI projects to add new variable names which can be adopted by the CMC.

A short technical note for climate scientists with no knowledge of satellite datasets is recommended for each ECV. It should highlight the advantages of each datasets and its main characteristics. An example is given here from the NASA project: http://oodt.jpl.nasa.gov/wiki/display/CLIMATE which includes the following guidelines for a technical note:

- *The target audience is the analysis community that will evaluate the climate model experiments in CMIP5, who have little experience with NASA datasets.*
- *The technical note should be written at the graduate student level.*
- *The note must be specific to one particular satellite observation dataset, which must contain a single variable.*
- *The note should summarize essential information for comparing the dataset to model output.*
- *Anything of interest only to experts should be referenced, but not include in the main body of the note.*
- *An appropriate length for the note (from Section 1 to 6 in the template) is 3-5 pages, excluding tables and figures.*

The template begins on the next page. Some instruments or projects will provide datasets for multiple variables. The CMIP requirements state that each variable must be contained in a separate file. The guidance is to provide a technical note for each variable, even if it means substantial duplication of text across the notes.

6.2 Data formats

The users were asked for their preferred format for the CDRs and 88% replied NetCDF with the remainder happy with any standard format. One respondent replied HDF5 as their preferred format and one stated he preferred a simple format such as ASCII. 28% of respondents specifically asked for a CF compliant NetCDF dataset. Specifically for NetCDF CF, additional attributes in the file should be provided to ensure it is easily identifiable by man and machine. A good example of the use of additional attributes is provided by the PCMDI CMOR (Climate Model Output Re-writer) package, which is used to standardise climate model output from the CMIP5 project. The convention for NetCDF files for climate datasets are published here: `http://cf-pcmdi.llnl.gov/documents/cf-conventions/1.4` The use of swath based data (levels 1 and 2)) in NetCDF is still under development but remains the preferred option.

The file format should be chosen so that the data can be delivered through the same range of services as the climate model output it is intended to validate. For the metadata: An XML document with a well defined schema which clearly defines the instrument, its measurement technique and the analysis method used to retrieve the data record. It would be extremely helpful if the schema could, at the top level at least, share some of the structure which has been developed by the EU FP7 project METAFOR to describe climate models and their output. For example, descriptions of institutions could use the same schema elements.

6.3 Data access

For getting access to the data 84% of the respondents specifically requested FTP access and 40% requested web access via a browser. There is a need to be able to subset in time and space the datasets in a convenient way such as OpenDAP. Other physical media such as DVD were not generally supported. Access from recognised data centres such as NASA DAAC, PMCDI and EUMETSAT UMARF were also stated as a requirement reflecting the support they can provide to users.

As far as the location of the datasets is concerned they should be hosted on a node of the Earth System Grid so that users will have the same interface for European, US and other climate datasets. They need to be hosted on the Earth System Grid "data nodes" which publish to "gateway nodes" see http://esg-pcmdi.llnl.gov/ for more details. The BADC is currently connected to the Grid and would provide a suitable host for CCI datasets.

6.4 Level of processing

The user community was asked which level of processing they required for their applications and the results are summarised in Table 21 which shows a fairly even split between level 1 and level 2 processed products. Other products refer to gridded products at monthly resolution, variable-variable correlations, ability to filter in space and time for multiple variables.

Processing Level	No. of users	Percentage of users
Level 1	16	47.1 %
Level 2	21	61.8 %
Other products	3	8.8 %
Total	34	100.0 %

Table 21. Feedback from users on required level of processing

Another property of the data CMUG sought views on from the users was whether for level 3 products single sensor datasets or merged datasets would be required. The results in Table 22 suggest a fairly equal split between merged and single sensor products. This also will be very dependent on the ECV. The disadvantage of merged products is that the error characteristics are more complex and so for reanalyses single sensor products are preferred at level 1 or level 2. The 'other' category referred to the following option: Intelligently searchable multivariate databases - e.g. the ozone and cloud properties associated with an ensemble of North Atlantic storms (calculated directly via the interface rather than after you have download all of the data yourself).

Single sensor datasets	18	52.9 %
Merged product datasets	20	58.8 %
Other	2	5.9 %
Total	34	100.0 %

Table 22. Feedback from users on single sensor vs merged products

7. Summary

The CMUG has carried out a survey of the climate modelling community and presented an initial analysis here. One important finding is that the majority of modellers want to use the CCI datasets for model validation and development and only a few are engaged in climate monitoring.

An analysis of the individual requirements for climate modelling for the 11 CCI ECVs has been carried out with the following inputs:

- GCOS requirements
- Inputs from CMUG consultations (including workshop at EGU, on-line questionnaire and direct consultation of experts)
- Comments and analysis from the CMUG integration meeting at Reading in March 2011

This has enabled the CMUG to undertake an analysis of how well the current GCOS requirements meet the needs of climate modellers and how the initial thoughts of the CMC match these requirements. This can be used as input to the CCI requirements specification as it evolves and is a good basis for discussions.

Comments on the technical details of the proposed CCI datasets were also sought on format and data access in order to gain an overview of the preferred formats for the climate modelling community. The majority view was for CF compliant NetCDF format with access via FTP or browser interfaces ideally through the Earth System Grid which is the same interface climate modellers are using.

CMUG believes the CCI will meet the requirements of GCOS for most but not all ECVs, and the exceptions are due to limitations of the observational datasets. It is recognised that the climate observation data needs of the CMC are often variable and will change over time, hence the need to re-consult at future dates with the CMC and revise this document accordingly.

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9. Glossary

Terms	
Data assimilation	Observations directly influence the model initial state taking into account their error characteristics during every cycle of a model. This is used for reanalysis, NWP which includes seasonal and decadal forecasting.
Model validation	Observations are compared with equivalent model fields to assess the accuracy of the model. This can be on short time scales for process studies or long time scales for climate trends.
Climate monitoring	This describes the use of a satellite only dataset to monitor a particular atmospheric or surface variable over a period > 15yrs to investigate whether there is a trend due to climate change.
Initialisation	To initialise prognostic quantities of the model with reasonable values at the beginning of the simulation but do not continuously update.
Prescribe boundary conditions	Prescribe boundary conditions for a model run for variable that are not prognostic (e.g. land cover, ice caps etc)
Accuracy	Accuracy is the measure of the non-random, systematic error, or bias, that defines the offset between the measured value and the true value that constitutes the SI absolute standard
Stability	Stability is a term often invoked with respect to long-term records when no absolute standard is available to quantitatively establish the systematic error – the bias defining the time-dependent (or instrument-dependent) difference between the observed quantity and the true value.
Precision	Precision is the measure of reproducibility or repeatability of the measurement without reference to an international standard so that precision is a measure of the random and not the systematic error. Suitable averaging of the random error can improve the precision of the measurement but does not establish the systematic error of the observation.
Acronyms	
(A)ATSR	(Advanced) Along Track Scanning Radiometer on ERS -1&2 and ENVISAT
AVHRR	Advanced Very High Resolution Radiometer
BADC	British Atmospheric Data Centre
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite
CCI	Climate Change Initiative
CCMVAL	Chemistry-Climate Model Validation Activity
CMC	Climate Modelling Community
CMIP5	Climate Model Intercomparison Project-5
CMUG	Climate Modelling Users Group
COSP	CMIP5 Observation Simulator Package
CSAB	Climate Scientific Advisory Board
DAAC	Distributed Active Archive Centres
ECV	Essential Climate Variable
EGU	European Geophysical Union
ENSO	El Nino- Southern Oscillation
ERA	ECMWF Reanalysis
ERBS	Earth Radiation Budget Satellite
ERRMERG	Error of merged dataset
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FOAM	The Fast Ocean Atmosphere Model
GCOS	Global Climate Observing System
GPS	Global Positioning System

GSICS	GCOS Satellite InterCalibration System
HIRS	High resolution Infrared Radiation Sounder
IGOS	Integrated Global Observing Strategy
IPCC	International Panel for Climate Change
ISCCP	International Satellite Cloud Climatology Project
LAI	Leaf Area Index
MACC	Monitoring Atmospheric Composition and Climate
METAFOR	Common Metadata for Climate Modelling Digital Repositories
NAO	North Atlantic Oscillation
NWP	Numerical Weather Prediction
OSTIA	Operational Sea Surface Temperature and Sea Ice Analysis
PCMDI	Program for Climate Model Diagnosis and Intercomparison
SAGE	Stratospheric Aerosol and Gas Experiment
SSAOB	Single sensor accuracy for each observation
SSEOB	Single sensor error for each observation
SSM/I	Special Sensor Microwave Imager
SST	Sea Surface Temperature
UMARF	Unified Meteorological Archive and Retrieval Facility

Annex A: A Consistent Definition of Error Characteristics

For climate data records it is important to have a consistent definition of error characteristics of these datasets. Depending on the application there are several aspects of the measurements where the uncertainty needs to be defined. A recent meeting[5] between meteorologists and metrologists attempted to define these different aspects of the errors which are given below. It is recommended the CCI projects adopt a consistent definition for error characteristics and a first iteration is given below. Figure A1 is a graphical example of the different types of error. A more complete description is given on page 16 of the *Strategy Towards an Architecture for Climate Monitoring from Space, WMO Space Programme.*

Accuracy is the measure of the non-random, systematic error, or bias, that defines the offset between the measured value and the true value that constitutes the SI absolute standard

Precision is the measure of reproducibility or repeatability of a measurement without reference to an international standard so it is a measure of the random and not the systematic error. Suitable averaging of the random error can improve the precision of the measurement but does not establish the systematic error of the observation. Note that in satellite measurements precision also refers to the number of bits a raw measurement is stored in.

Stability is a term often invoked with respect to long-term records when no absolute standard is available to quantitatively establish the systematic error - the bias defining the time-dependent (or instrument-dependent) difference between the observed quantity and the true value.

Representativity is important when comparing with or assimilating in models. Measurements are typically averaged over different horizontal and vertical scales compared to model fields. If the measurements are smaller scale than the model it is important. The sampling strategy can also affect this term.

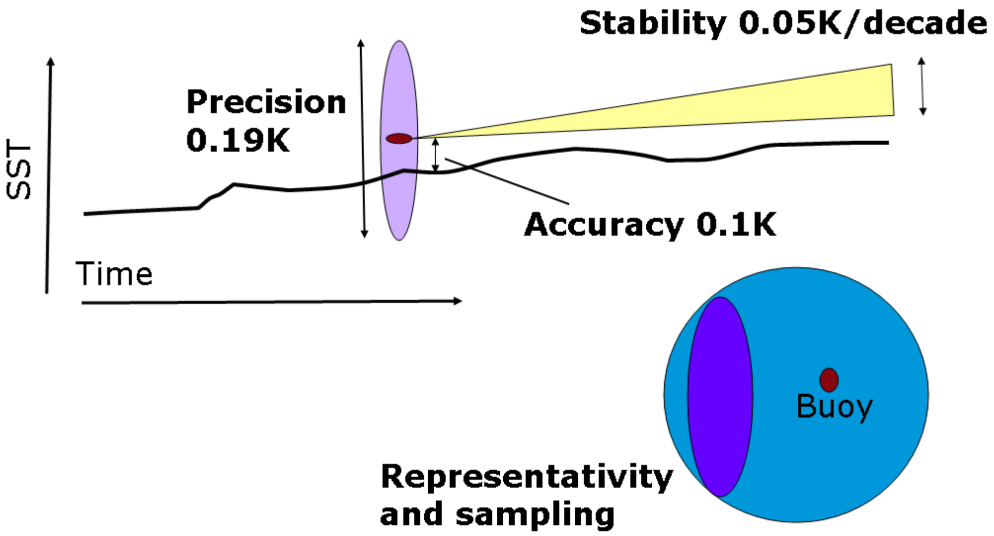

Figure A1. Plot showing different kinds of errors which may need to be defined for satellite CDR.

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[5] http://www.bipm.org/en/events/wmo-bipm_workshop/