ECV Inventory Gap Analysis

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1 Introduction

1.1 Purpose

This document provides (i) a definition of *gap* (§2), (ii) a preliminary exploration of the activities involved in *gap analysis* (§3). This provision is in response to the objective of the CEOS ECV Gap Definition Action Group, commissioned to define an approach to CMRS-2 in support of the 2014-2016 Work Plan [RD-3]. In particular, the approach defined herein

- *Focuses on CDR Pillar* of the Climate Architecture
- *Capitalises* on the Climate Architecture [RD-2] via a proposed link with the ECV Inventory
- *Complements* the work undertaken by the other CMRS action groups,
- *Derives* directly from the CEOS WG Climate Terms of Reference [RD-1].
- *Systematically* identifies and treats gaps.

1.2 References

[RD-1] CEOS WG Climate Terms of Reference, 24th October 2013.

[RD-2] Strategy Towards an Architecture for Climate Monitoring from Space, CEOS paper.

[RD-3] CEOS 2014 - 2016 Work Plan, June 2014

[RD-4] ECSS Standard ECSS-M-ST-10C Rev.1, 6 March 2009. Space Project Management.

1.3 Terminology

Mission

The CEOS WGClimate Terms of Reference refer to *future* and *current* missions in context to the objectives of the working group. In order to perform a gap analysis, we have found it useful to adopt a finer grained definition of these terms, particularly for those missions which have yet to launch. To that end, a definition of Past Missions, Current Missions, Future Planned Missions and Future Unplanned Missions are provided, based on the phases of a typical mission lifecycle [RD-4] as illustrated in Figure 1.

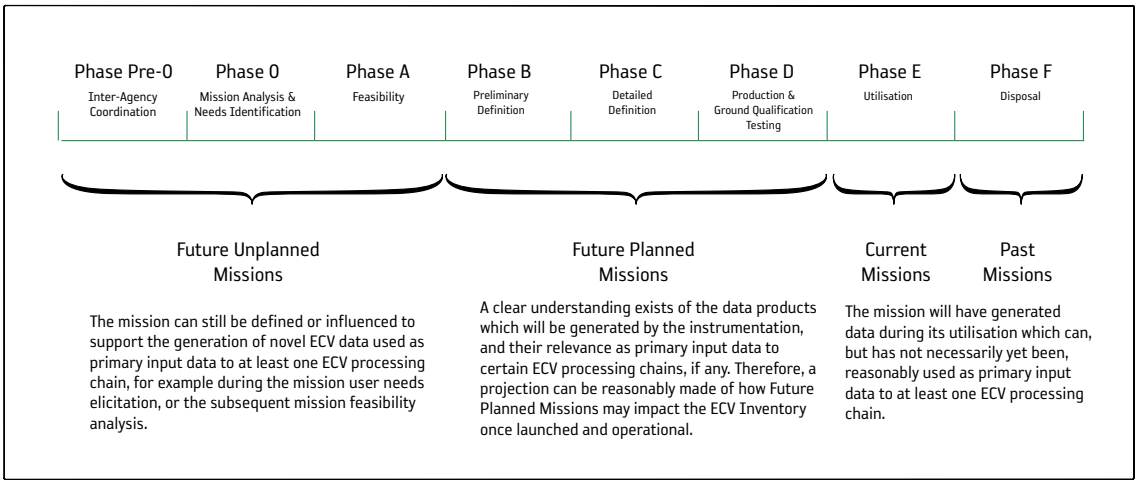

Figure 1 : Mission categories based on mission phases and their influence on the ECV Inventory

Past Mission

A mission which has completed its utilisation (Phase E), and has since been withdrawn from service (Phase F). The mission will have generated data during its utilization which can, but has not necessarily yet been, reasonably used as primary input data to at least one ECV processing chain.

Current Mission
A mission which is currently being utilised (Phase E). The mission is currently generating data which can, but has not necessarily yet been, reasonably used as primary input data to at least one ECV processing chain.

Future Planned Mission
A mission which is planned to be utilised in future. The mission is being either preliminarily defined (Phase B), defined in detail (Phase C), or its Space and Ground Segment assets being produced (Phase D). The satellite instrumentation has been defined to such a degree that no significant modification to instrumentation design or build may be made prior to launch which will impact ECV data products. A clear understanding exists of the data products which will be generated by the instrumentation, and their relevance as primary input data to certain ECV processing chains, if any. Therefore, a projection can be reasonably made of how Future Planned Missions may impact the ECV Inventory once launched and operational.

Future Unplanned Mission
A potential future mission being discussed only conceptually (Phase Pre-0), undergoing a user needs activity (Phase 0), or having feasibility assessed (Phase A). A mission may still be defined to support the generation of novel ECV data used as primary input data to at least one ECV processing chain.

GCOS Requirement Type
The complete group of types of GCOS Requirement referred to herein are constrained to Horizontal Resolution, Vertical Resolution, Temporal Resolution, Accuracy and Stability, as defined in GCOS-154.

GCOS Requirement Status
For a given GCOS Parameter of a given GCOS ECV, the status of a given ECV data product in meeting a given GCOS Requirement Type is one and only one of the following :

- *Fully Met*. The ECV data product fully meets the GCOS requirement
- *Partially Met*. The ECV data product only partially meets the GCOS requirement
- *Empty*. An ECV data product does not exist to address the GCOS requirement.
- *Not Applicable*. The type of GCOS requirement is not applicable to the GCOS parameter.
- *Unspecified*. The type of GCOS requirement is unspecified for the GCOS parameter.
- *Unknown*. An ECV data product exists but its status to the GCOS parameter is unknown.

2 Gap

The definition of *gap* is drawn from, and fully supportive to, the three main objectives of the WGClimate Terms of References (Figure 2).

Interpreting these main objectives from the perspective of a gap analysis, the first objective denotes the provision of an ECV Inventory representing the current snapshot of ECV data products across the CEOS partners. These records will meet, to a certain extent, the requirements defined for their associated ECVs in GCOS-154. The data associated with this objective is derived from Past Missions and Current Missions.

The second objective aims to identify the conditions required to fulfill GCOS requirements not yet met from the current snapshot of ECV data products, and make best use of the currently available assets to meet these conditions. Such assets come not only in the form of data, but may also be in the form of computing infrastructure, funding, and personnel. Moreover, such assets may be shared across agencies to fulfill such unmet conditions. The data associated with this objective is derived from Past Missions and Current Missions.

The over-arching goal of the CEOS/CGMS Working Group on Climate (WG Climate) will be to improve the systematic availability of Climate Data Records through the coordinated implementation, and further development of the architecture for climate monitoring from space.

More specifically, the coordination shall be designed to achieve three main objectives:

- Provision of a structured, comprehensive and accessible view as to what Climate Data Records are currently available from satellite missions of CEOS and CGMS members or their combination;
- Creation of the conditions for delivering further Climate Data Records, including multi-mission Climate Date Records, through best use of available data to fulfil GCOS requirements (e.g. by identifying and targetting cross-calibration or re-processing gaps/shortfalls);
- Optimisation of the planning of future satellite missions and constellations to expand existing and planned Climate Data Records, both in terms of coverage and record length, and to address possible gaps with respect to GCOS requirements.

Figure 2 : The WG Climate Main Objectives [RD-1]

The third objective looks towards sustainability and the long term, relating to Future Unplanned Missions and Future Planned Missions, from which data may be used to derive future records for the ECV Inventory. Given their maturity of specification, a projection can be reasonably made of how Future Planned Missions may impact the ECV Inventory once launched and operational. In contrast, the specification of Future Unplanned Missions can still be shaped to influence their impact on the ECV Inventory.

In addition to catering for Future Planned Missions and Future Unplanned Missions, the third objective also relates to undertaking a continuous alignment of the ECV Inventory to the GCOS requirements as those requirements naturally evolve over time.

2.1 Definition of Gap

The three WGClimate objectives lead to our definition of gap :

> A Gap is a deficit in any condition necessary to fulfill the GCOS requirements.

Figure 1 provides a simple example for illustrative purposes only. A data product for GCOS ECV <e> parameter <p> meets the relevant GCOS requirement for Horizontal Resolution. All conditions necessary to fulfill the GCOS requirement, namely Conditions #1, #2, #3 and #4, are successfully met.

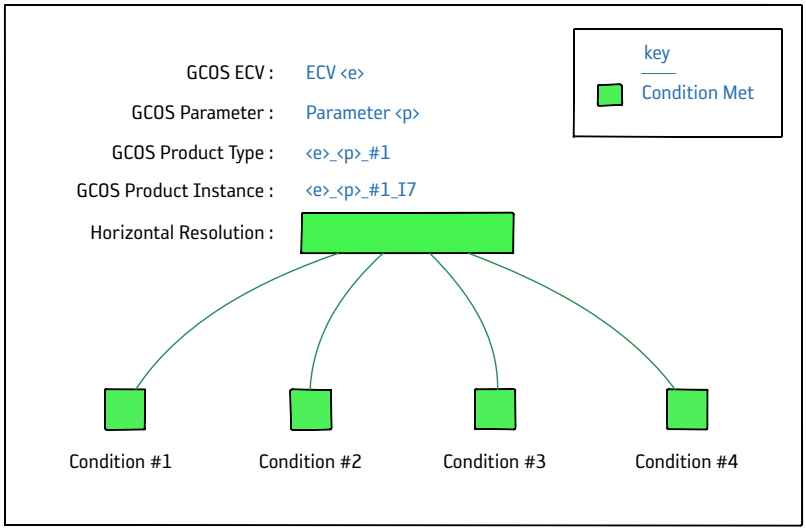

Figure 3 : Example GCOS requirement where all necessary conditions are fully met.

In contrast, Figure 2 portrays all conditions necessary to fulfill the GCOS requirement for Horizontal Resolution are met by the data product, with the exception of Condition #1 which has only been partially met; given that all logically necessary conditions must be met for the fulfillment of the GCOS requirement, the Horizontal resolution requirement fails. Therefore, a gap exists., The weakest form of logical satisfaction across the conditions is propagated upwards to deduce the extent to which the GCOS requirement has been satisfied, i.e. *Partially Met*.

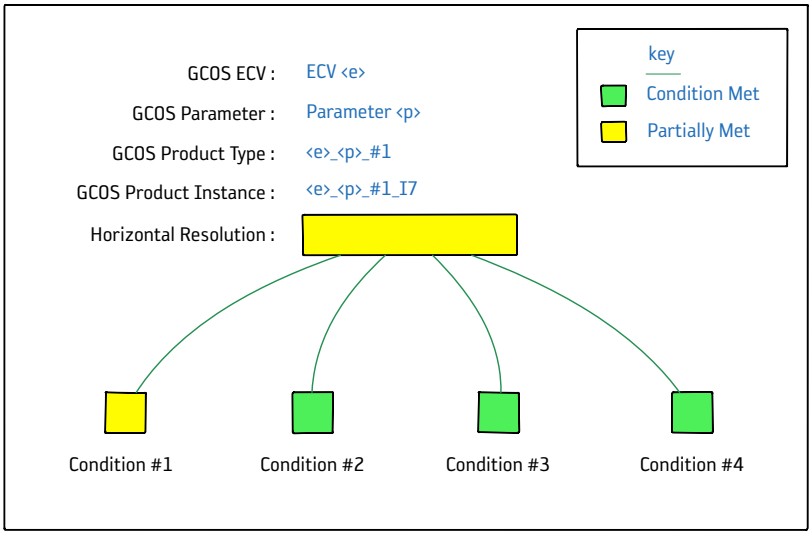

Figure 4 : Example GCOS requirement where all conditions are not fully met.

Similarly, in Figure 5 a gap exists given that a condition has entirely failed in being satisfied. Condition #2, in this case, has no asset to satisfy the condition, and consequently there now appear two gaps in meeting the necessary conditions for the GCOS requirement. Given the relative severity of condition #2, its status propagates upwards towards a fairly represented GCOS requirement status.

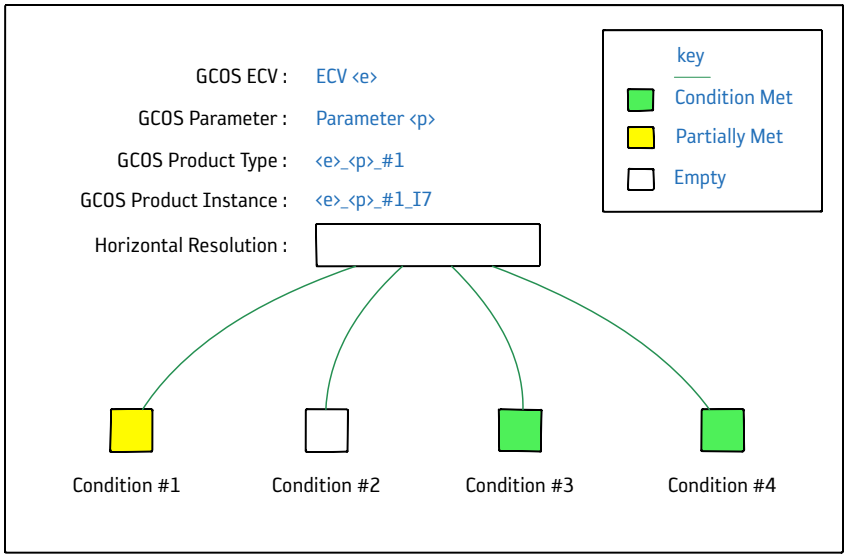

Figure 5 : Example GCOS requirement where all conditions are not fully met

In the context of CMRS#2 activities, the conditions necessary to fulfill GCOS requirements of any GCOS ECV by a data product are **conditions on information within pillars of the Climate Architecture**, as illustrated by Figure 6. To fulfill a GCOS requirement, therefore, means meeting necessary conditions for that requirement across the Climate Architecture. The conditions on each of the pillars are defined in the next section.

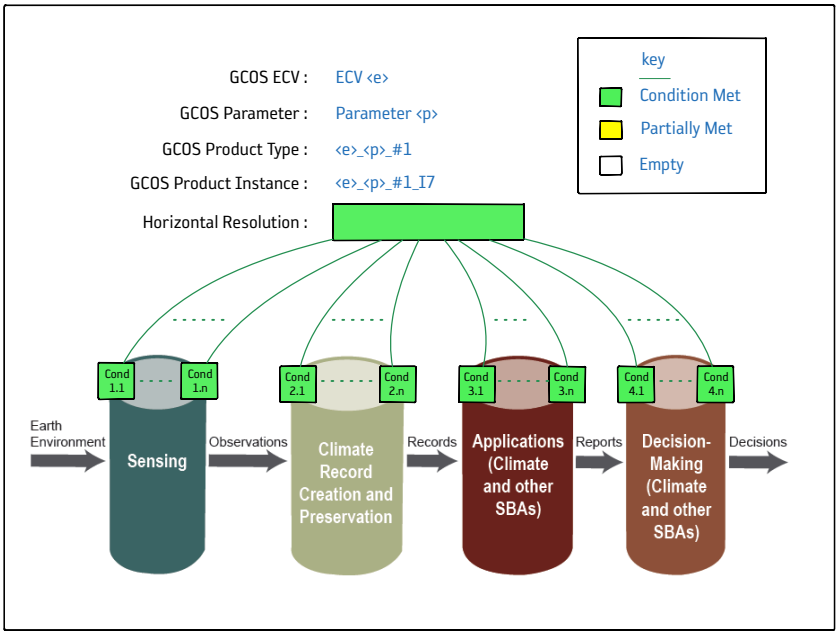

Figure 6 : Conditions necessary to fulfill GCOS requirements span the Climate Architecture

2.2 Types of Gap

The types of gap, i.e. the types of deficit in conditions necessary to fulfill the GCOS requirements, differ considerably across the Climate Architecture. The characteristics of each pillar of the Climate Architecture have a unique bearing on conditions placed on fulfilling GCOS requirements.

Therefore, we propose four main types of gap, each uniquely associated with a pillar of the Climate Architecture. A Sensing Gap (Type 1) is the type of gap associated with the Sensing pillar of the Climate Architecture, i.e. a Sensing Gap is a sensing deficit in any condition necessary to fulfill the GCOS requirements. Similarly, the Climate Record Creation & Preservation Gap, Applications Gap and

Decision-Making Gap are associated with the Climate Record Creation & Preservation pillar, Applications pillar and Decision-Making pillar, respectively.

The entry point for Gap Analysis (§3) is the second pillar of the Climate Architecture – Climate Record Creation & Preservation pillar. The ECV Inventory furnishes this pillar. Given the current activities of this pillar for CMRS#2, the preliminary definition of gap types across the Climate Architecture begins with the Climate Record and Preservation pillar (§2.2.1) below, followed by Sensing (§2.2.2), Applications (§2.2.3) and Decision Making (§2.2.4).

2.2.1 Climate Record Creation & Preservation Gap

The definition of gap related to the second pillar of the Climate Architecture is as follows :

> A Climate Record Creation & Preservation Gap is a deficit in any condition on the Climate Record Creation & Preservation pillar of the Climate Architecture necessary to fulfill a given GCOS requirement.

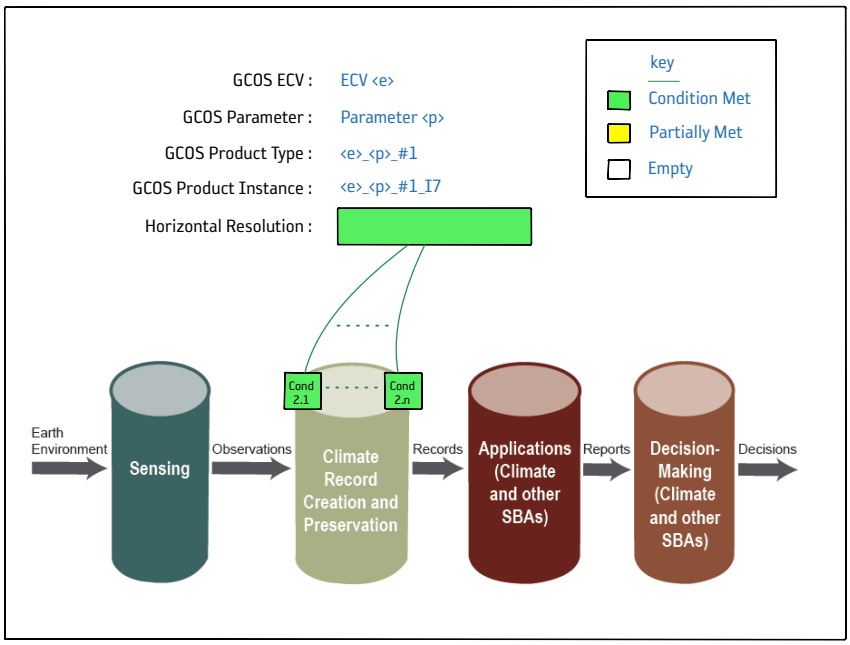

Figure 7 : Climate Record & Creation conditions necessary to fulfill GCOS requirements.

The following conditions on the Climate Record Creation & Preservation pillar of the Climate Architecture must be fully met to fulfill a given GCOS requirement. **Failure to satisfy any one of these conditions will deem there to be a Climate Record Creation & Preservation Gap** (Type 2) :

- *Condition 2.1* : *Funding Resources for Product Generation*. Assuming that data fully exists for production of a given ECV data product, the undertaking of that production is conditional on the their being funding available for the activity.
- *Condition 2.2* : *Infrastructure Resources for Product Generation*. The processing of available data for the production of an ECV data product requires appropriate computing infrastructure. Given the considerable, and accelerating, computational demands of climate data processing, the generating of ECV data products is conditional on adequate computing infrastructure being available. This condition on ECV data production is significantly different, albeit not distinct, from required funding resource.
- *Condition 2.3* : *Human Resources for Product Generation*. Similarly to funding and computing infrastructure, the generation of ECV data products is conditional on adequate staffing of the production. This includes, most importantly, science personnel to undertake, for example, the

climate science research, definition of associated algorithms for data production, and performance of the validation required for the processing of ECV data products.

- *Condition 2.4* : *Cal / Val Resourcing*. The integrity of an ECV data product in meeting GCOS requirements is conditional on the quality and homogeneity of the data product [Need-4][1]

- *Condition 2.5* : *Sustainability.* The sustainability of ECV data production to be sustainable for the long term in meeting GCOS requirements, a number of dependencies apply. A full description of the steps taken in the data production should be maintained including algorithms and validation [Need-1] with the same care as the data [GCMP-3], as should information on the scientific review process [Need-5].

- *Condition 2.6* : *Adequate Analysis* . Towards optimally meeting GCOS requirements, it is imperative that the ECV data processing system include a statement of expected accuracy, stability and resolution of the product, to therefore enable a comparison with the GCOS requirements [Need-3]. Similarly, long term stability should be assessed in a manner allowing comparison to GCOS requirements [Need-4].

- *Condition 2.6* : *Operationalisation.* To satisfy the UNFCCC need for *systematic* climate observation, systemisation of the processing chains in the production of ECV data products is required. Failure to meet this condition, renders limited integrity in the meeting of the requirements. This includes version management [Need 7], provision of access to the data products and documentation for climate users [Need 8, GCMP-10, GCMP-17][2], and recognition of long term system requirements [GCMP-8]. Moreover, operational production of priority climate products should be sustained [GCMP-16].

- *Condition 2.7* : *User Consultation.* The meeting of GCOS requirements by ECV data products is conditional on attaining user feedback, for instance in the prioritisation of resources towards optimally tackling the GCOS requirements (GCMP-7), and in usefulness of the generated data products. A facility to enable user feedback is required, [Need-9] as is a timeliness of release of ECV data products which is synchronised with their usage [Need-10]. Moreover, consideration of needs for environmental and climate-monitoring products and assessment are required [GCMP-5].

- *Condition 2.8* : *Maturity*. A qualitative and quantitative assessment of the maturity of an ECV data product provides an invaluable indicator of the integrity of the product in its meeting GCOS requirements [Need-11]. The integrity of the data product is conditional on its maturity, and therefore any failure to meet this condition renders a gap.

2.2.2 Sensing Gap

The definition of gap related to the first pillar of the Climate Architecture is as follows :

> A Sensing Gap is a deficit in any condition on the Sensing pillar of the Climate Architecture necessary to fulfill a given GCOS requirement.

The Sensing pillar is an integral and fundamental aspect of the end-to-end architecture, especially as it requires a long-term perspective given the long (decadal) lead-time for mission planning. There are two high priority challenges to be overcome in this broader perspective, which must be taken into account for the definition of conditions on the Sensing pillar and therefore WGClimate gap analysis activities :

1. *Operational & R&D Missions* have different requirements across agencies in long-term planning and coordination, despite a number of R&D missions being successfully sustained for over a decade.
2. *Climate View of Broader EO Architecture*. At mission level, given that sensors may support several applications, it follows that climate should not be regarded in isolation from other

[1] The references [Need *x*] have been used throughout this document to index the GCOS-143 needs which the GCOS Steering Committee recommend data producers pay particular attention to. See Annex A.

[2] The references [GCMP *x*] index the GCOS-143 Climate Monitoring Principles. See Annex B.

applications. Therefore, the first pillar should be interpreted as a *Climate View* onto a wider EO architecture, with its own requirements and its own processes ensuring that the wider architecture meets climate requirements.

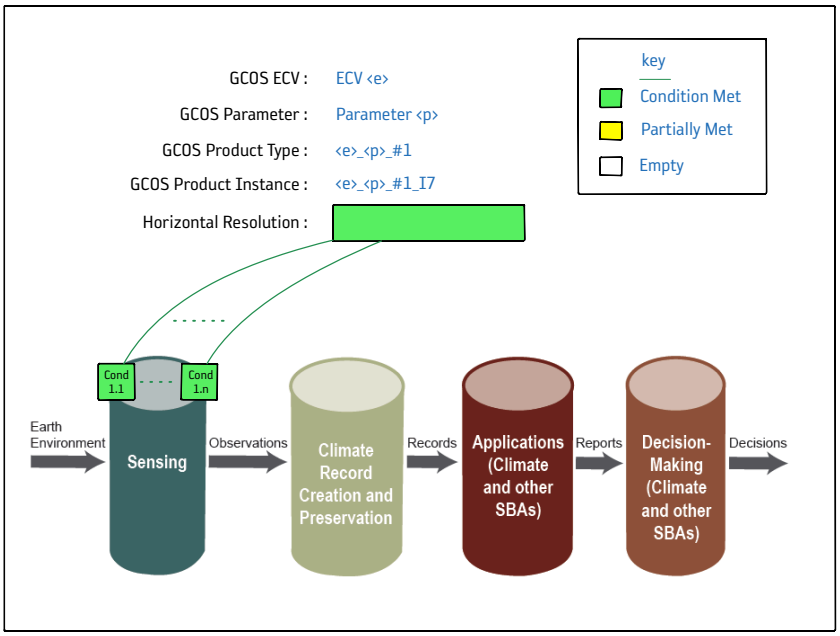

Figure 8 : Sensing conditions necessary to fulfill GCOS requirements.

The following conditions on the Sensing pillar of the Climate Architecture must be fully met to fulfill a given GCOS requirement. **Failure to satisfy any one of these conditions will deem there to be a Sensing Gap** (Type 1) :

- *Condition 1.1* : *Absolute Sensor Instrumentation & Associated Risk*. For the GCOS-154 requirements of a given GCOS ECV variable to be met, the required EO sensing instrumentation must exist providing input to the production of the ECV data product. Any failure in meeting this condition necessary to meet the GCOS requirements denotes a gap in sensor information. This includes the condition that sensor instrumentation provide the coverage required by the GCOS requirement [Need 6].

  An inherent risk exists in meeting this condition, such as an unstable plan for launch of the instrument, or a launch date shift. For example, a current risk exists in the gap between NPP and JPSS. This risk does not necessarily materialize as a concrete gap, and therefore the resolving of this gap is a question of risk management.

- *Condition 1.2* : *Relative Sensor Instrumentation*. For the GCOS-154 requirements of a given GCOS ECV variable to be met, the required EO sensing instrumentation, which in this case exists, must be capable of serving ECV data production to fully meet the GCOS requirement.

- *Condition 1.3* : *Sensor Quality*. The quality of an ECV data product is predicated on (i) the calibration and validation of the sensor instrumentation [Need 2], including its Level 0 data, providing input data to the production of the ECV data product, and (ii) the availability of other EO sensor instrumentation to enable an independent validation of the quality of the ECV data product once generated. A number of ancillary factors come to bear in identifying deficits in these two conditions.

  - Regular assessment of the quality and homogeneity of sensor data should be regularly assessed as part of operations. [GCMP-4]

  - A suitable period of overlap is required across old and new satellite systems to ensure determination of inter-satellite biases [GCMP-12]. Such an overlap is the safest and most convenient situation especially when a new system is directly comparable to an old system in a series. However, as discusses at the 2011 Climate Workshop, a more open strategy could be considered – ideally, a stable calibration reference is required across

overlapping missions, with each mission calibrating to the reference. GCICS is currently working to this approach.

- Rigorous pre-launch instrument characterisation and calibration. [GCMP-14]
- On-board calibration adequate for climate observation [GCMP-15]. Moreover, this is also a question of sharing best practices and calibration references across missions towards supporting consistency and traceability, so building on WGCV and GSICS.
- Maintenance of sensing instrumentation [GCMP-18]
- Identification of random errors and time-dependent biases in sensing instrumentation. [GCMP-20]

- *Condition 1.4* : *Long-term Sensor Availability*. To ensure continued integrity of an ECV data product into the long term, the continuity of the required satellite instruments should be ensured [GCMP-13]. Similarly, research observing systems which have provided input to ECV data production are require progression or conversion to longer-term missions [GCMP-9].

  This in principle requires long-term coordination and planning commitment across CEOS agencies, with the associated depth of commitment predicated on how long-term the mission planning should ensue. The depth of commitment also depends on the uniqueness of a mission, the level of redundancy required, and their agency-specific framework for long term planning.

  The CGMS baseline if an early attempt in this direction, though not limited to climate. Within WGClimate, there is yet to be an elaboration to find the reasonable level of detail for such a planning exercise, and to define a process for reviewing, managing risk and mitigating risk. This activity would build on a permanent inventory of sensors able to provide the data suitable to feed FCDRs. Further discussion is required within WGClimate to ascertain the appetite for this long term coordination for sensor availability.

- *Condition 1.5* : *Ground Segment Infrastructure*. Processing of an ECV data product requires a ground segment capable of processing, and providing reliable access to [GCMP-10], its necessary sensor data. Consequently, maintenance of the ground segment is required [GCMP-6].

- *Condition 1.6* : *Mission Consultation*. The optimisation in integrity of ECV data products is conditional on the consultation of space agencies and their climate science partners as part of mission definition and planning. Prioritisation in climate science needs facilitates and optimises the usage of resources to future missions.

2.2.3 Applications Gap

The definition of gap related to the third pillar of the Climate Architecture is as follows :

> An Applications Gap is a deficit in any condition on the Applications pillar of the Climate Architecture necessary to fulfill an Application-specific requirement.

The nature of a gap, i.e. a deficit in any condition required to meet a requirement, applies to the Applications pillar quite differently than the first two pillars. A number of considerations must be made prior to defining the sub-types of gap for the Applications pillar, comprising :

1. Each application has its own mapping to the GCOS variables. There is no one-size-fits-all mapping from applications to relevant GCOS variables.
2. Each application will in principle have its own perspective on whether the values described in GCOS-154 requirements per variable sufficient for the application. An application will not necessarily require the same horizontal resolution, etc., as demanded in GCOS-154.
3. The ECV data product requirements for an application can only come about following thorough consultation with the application users. Moreover, this consultation is non-trivial given that the expertise of the application user will not necessarily match an understanding of ECVs, and therefore specialised skill is required to map the needs of the user to ECV requirements. The

identified gaps have a delta to the GCOS requirements which is important to know, resource prioritisation

4. This is the realm of the WMO and other authorities who have the expertise and background to identify, and map to, the applications to be focused on.

5. It is impractical to have a bespoke flavour of ECV product per application. There are two means to resolve this challenge. The first is to rely on an untailored ECV data product, which has been produced explicitly to satisfy GCOS requirements rather than any particular applications, for all applications which require it; in such a case, it is advantageous to recognise the delta between the application expectations of an ECV data product and the GCOS requirement equivalent. The second is to provide a service, such as the Copernicus Climate Change Service being developed by the European Commission.

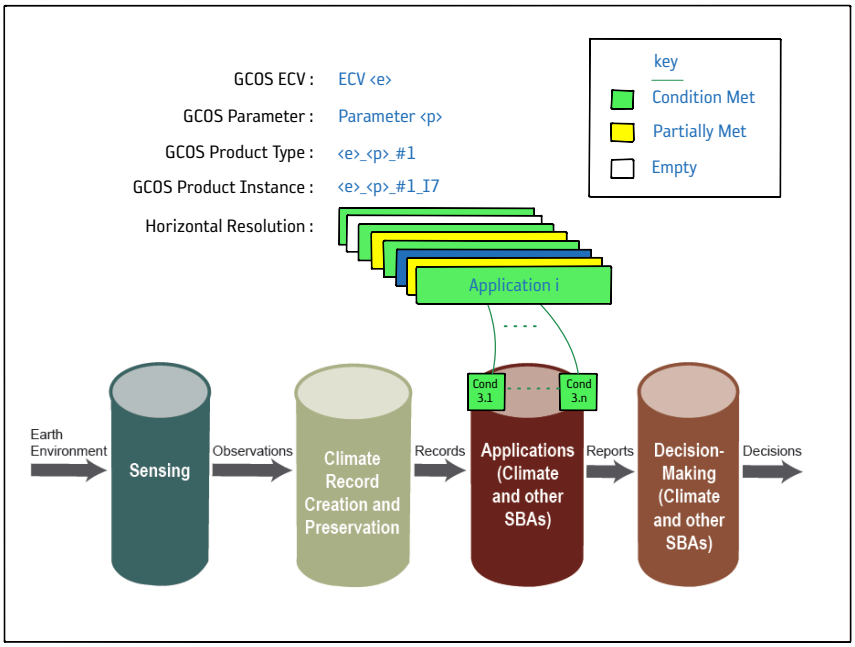

Figure 9 : Application-specific conditions necessary to fulfill Application requirements.

Given the above considerations, the sub-types of the Application Gap (Type 3) comprise the following :

- *Condition 3.1 : GCOS-Mapping Conditions*. Given an application-specific mapping from Application to its required GCOS Variables, this gap is the delta between the application-specific requirements on the ECV and the GCOS requirements. This gap provides a valuable quantitative indication of the difference between the GCOS-specific demands and the application-specific demands of the same ECV. This gap will provide information to facilitate prioritisation of resources and assess feasibility, for example, dependent on how far away the applications demands are from the GCOS equivalent expectations.

- *Condition 3.2 : ECV-Mapping Conditions*. Given an application-specific mapping from Application to its required GCOS Variables, this gap is the delta between the application-specific requirements on the ECV and the corresponding values of ECVs striving to meet those GCOS requirements. This gap provides an indication on how currently feasible it is to undertake the application given the existing data products.

2.2.4 Decision-Making Gap

Decision-making Gaps (Type 4) are yet to be fully defined.

3 Gap Analysis

3.1 Approach

The ECV Inventory and the second pillar of the Climate Architecture are key to the gap analysis :

- *ECV Inventory residency*. The Climate Record Creation & Preservation pillar houses the ECV Inventory. The climate data record denotes the extent to which the GCOS requirements are met, and where they are not met then the opportunities for identification, coordination and planning of resources to meet such requirements.
- *GCOS Requirement Status*. The ECV Inventory marks the GCOS requirement status across all CEOS ECV data sets.
- *GCOS-143 needs*. The ECV Inventory has been specifically structured to respond to the GCOS-143 needs for generation and update of ECV data products. The inventory, therefore, reflects the GCOS-143 conditions for production of data products to meet GCOS-154 requirements.
- *Basis for gap analysis*. More broadly, the ECV Inventory provides the primary material with which to assess the status of all conditions earlier defined. For those GCOS requirements where the status is not satisfactory, the inventory provides the source information to deduce why a requirement has not been met, i.e. identification of those conditions which have failed and therefore invoked the gap.
- *Gap & condition prioritisation*. The approach allows for **variety in the degree of compliance to satisfaction of GCOS requirements**, rather than taking a 'binary' interpretation of gap. A gap is defined by the full context of conditions, with the status of those conditions, in meeting a GCOS requirement, and not by a simple yes/no as to whether a GCOS requirement has been satisfied. This approach also lends itself to prioritisation of those conditions in the exercise of gap analysis.
- *Risk mitigation*. The ECV Inventory and its association with the Climate Architecture provide a useful framework to qualitatively and quantitatively identify, assess and manage risk posed to the ECV Inventory by Future Planned Missions and Future Unplanned Missions.

3.2 Process

The proposed steps for Gap Analysis comprise [3]:

1. *Definition of complete types of gap*, as has been largely undertaken herein (§2). It is important to define the types, or classes, of gap rather than solely the particular cases, or instances, of gap for a number of reasons : (i) each class of gap will tend to have similar solutions, allowing for opportunities in the systemisation of gap identification and gap filling, (ii) there may be types of gap which can be identified but that do not yet have any instances currently, but which can be noted now for the benefit of future gap analysis iterations, (iii) a classification of gaps will enable a more efficient and systematic sweep of the ECV Inventory.
2. Per CMRS cycle or CEOS Work Plan cycle :
    a. *Selection and prioritisation of gap types*. Given the resource intensive nature of this exercise, it is advised that the exercise be undertaken following a prioritisation of the types of gap. For example, gap type 2.2 is likely to have greater direct impact, and perhaps be easier to immediately achieve, than gap type 2.8 on maturity.
    b. *Selection and prioritisation of GCOS ECVs*. This activity serves a number of purposes. Scheduling risk is mitigating by allowing the selection of mature entries of the ECV Inventory. Additionally, observing only a subset of ECV entries per iteration provides the opportunity for quicker turnarounds of cycles, providing a number of advantages, for example the speedier capture of Best Practice and its filtration into the following cycles.

[3] These steps assume a completed ECV Inventory (CMRS#1).

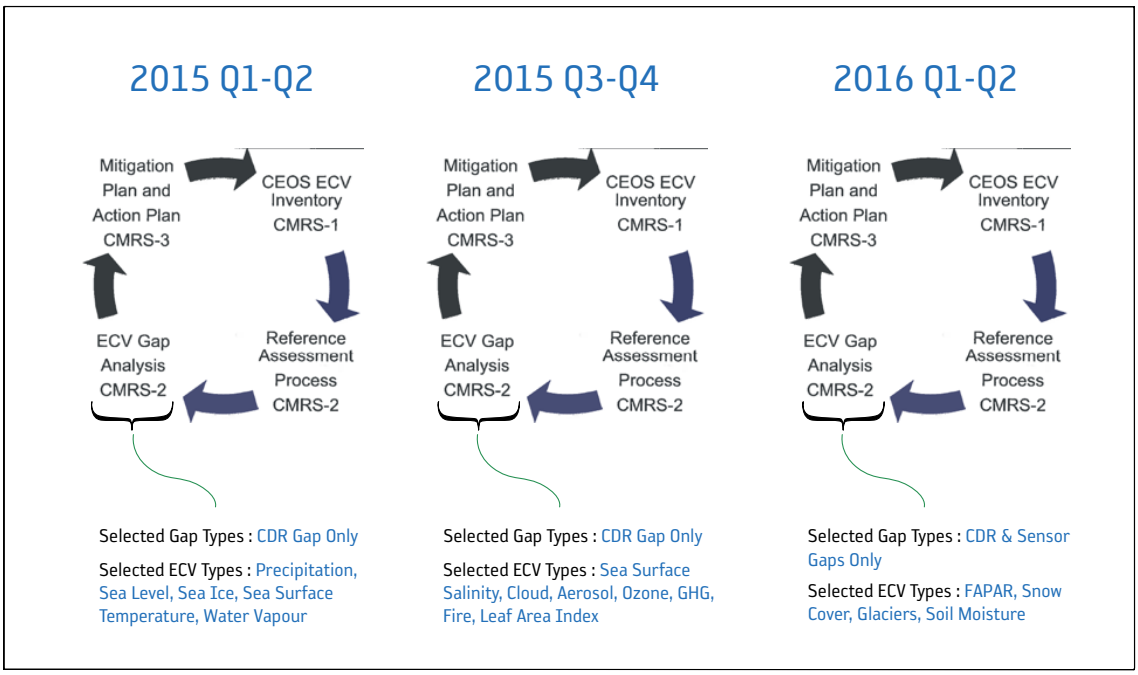

Figure 10 : An illustration of Gap & ECV prioritization & selection per gap analysis cycle

c. *Definition of gap-filling strategies per type of selected gap or condition*. It is envisaged that actual gaps that fit into the same type, or classification, of gap can be filled with significantly similar approaches. Moreover, this will provide a more systematic and efficient means of tackling the filling of each gap, particularly so given that several actual gaps may be tackled together.

   As an example, a strategy to resolve Gap type 2.2 (Gap in Infrastructure Resources for Product Generation) may be to first identify the infrastructure needs specific to the gap, followed by an overlap analysis of those needs with the available infrastructure resourcing available across CEOS members, followed by coordination amongst those parties to plan the sharing of their infrastructure to conduct the processing. To facilitate such an undertaking, it may be wise for each CEOS participant to volunteer information on their available infrastructure for sharing, from which not only one gap strategy exercise could apply but many.

d. *Identification of condition deficits per type of gap chosen*. This activity centres on usage of the ECV Inventory for capturing deficit conditions. In principle, the ECV Inventory houses the information required to determine condition status.

e. *Recommendations* are compiled for the adjoining CMRS action groups.

Annex A : GCOS-143 Needs

The GCOS Steering Committee recommends that data producers pay particular attention to the following 12 needs, towards ensuring full documentation, transparency and scientific stewardship in the generation and update of FCDRs and ECV data products. The GCOS-143 expression of these needs are here stated verbatim :

1. Full description of all steps taken in the generation of FCDRs and ECV products, including algorithms used, specific FCDRs used, and characteristics and outcomes of validation activities
2. Application of appropriate calibration/validation activities
3. Statement of expected accuracy, stability and resolution (time, space) of the product, including, where possible, a comparison with the GCOS requirements
4. Assessment of long-term stability and homogeneity of the product
5. Information on the scientific review process related to FCDR/product construction (including algorithm selection), FCDR/product quality and applications
6. Global coverage of FCDRs and products where possible
7. Version management of FCDRs and products, particularly in connection with improved algorithms and reprocessing
8. Arrangements for access to the FCDRs, products and all documentation
9. Timeliness of data release to the user community to enable monitoring activities
10. Facility for user feedback
11. Application of a quantitative maturity index if possible
12. Publication of a summary (a webpage or a peer-reviewed article) documenting point-by-point the extent to which this guideline has been followed

Annex B : GCOS-143 Climate Monitoring Principles

GCOS-143 states that effective monitoring systems for climate should adhere to the following principles, here stated verbatim :

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems is required.
3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.
4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.
5. Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
6. Operation of historically-uninterrupted stations and observing systems should be maintained.
7. High priority for additional observations should be focused on data-poor regions, poorly-observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.
8. Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
9. The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.
10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

Furthermore, operators of satellite systems for monitoring climate need to:

(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system; and

(b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term interannual) changes can be resolved.

Thus satellite systems for climate monitoring should adhere to the following specific principles:

11. Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained.
12. A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations.
13. Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.
14. Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.
15. On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.
16. Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.
17. Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.
18. Use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when these exist on de-commissioned satellites.
19. Complementary *in situ* baseline observations for satellite measurements should be maintained through appropriate activities and cooperation.

20. Random errors and time-dependent biases in satellite observations and derived products should be identified.