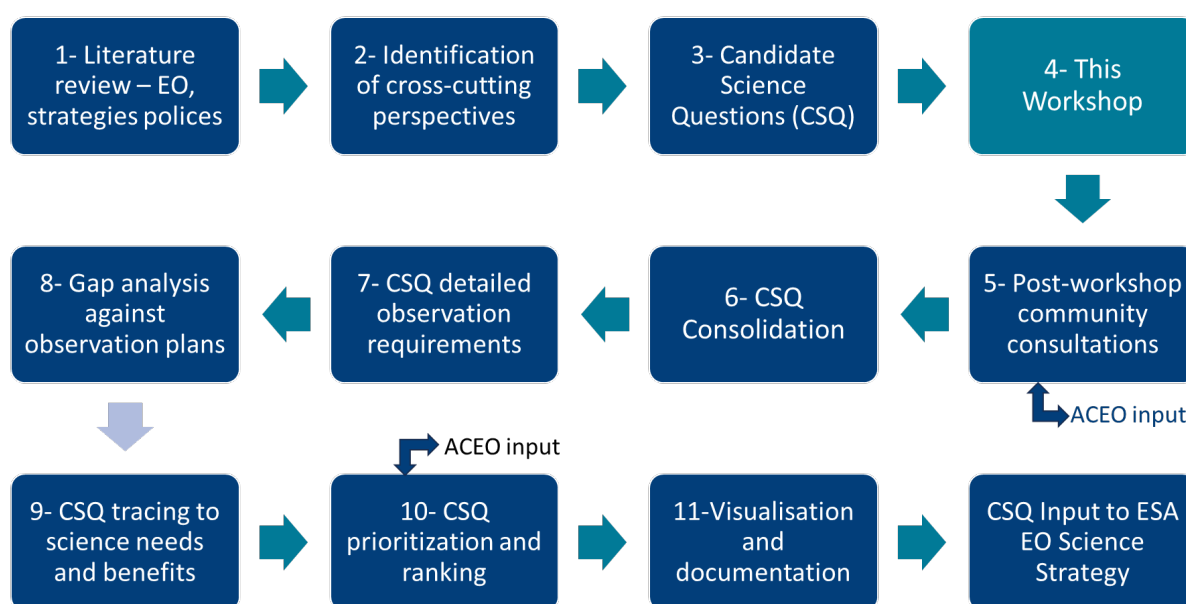


Introduction

The ESA EO Science Strategy Foundation Study (SSFS) is generating the evidence to underpin the next EO Science Strategy due to be released in 2024.

As part of this work the study team is generating a set of “Candidate Science Questions” (CSQs), that can be used by ESA and the ACEO to underpin the development of the new strategy. The CSQs are intended to encapsulate a series of pressing Earth system science issues that can be addressed using Earth observation data – either from existing and soon to be launched missions, or from future missions that need to be developed.

A working version of the CSQs was published in advance of the ESA Science Strategy Workshop in order to stimulate discussion, to help identify community priorities, and to guide future work of the study. The overall process used for the study is shown below.



Format of the CSQs

There were 59 CSQs prepared in advance of the workshop. Each of the CSQs was expressed as a summary table, with a supporting narrative. The summary table included the following elements:

1. A high-level summary of the question
2. A set of “Knowledge Advancement Objectives”: Specific objectives, for example for process understanding or reducing uncertainties, through which progress towards resolving the question could be measured
3. Geophysical Observables: Identification of the *main* geophysical variables needed to advance the science, noting that there will often be several other supporting datasets needed
4. Measurement Specifications: Initial view of the science requirements for datasets providing the geophysical observables. Note as above that many CSQs require other subsidiary datasets.
5. Tools and Models: Beyond EO derived observations, what else is needed. That could be new retrieval algorithms, new data-model assimilation techniques, calibration/validation facilities etc..

6. Policies & Benefits: A brief link to the key societal benefit and policy areas that the CSQ's service. This aspect will be elaborated on in more detail later in the study.

An index was provided that listed the CSQs, and each CSQ was contained in a separate PDF file, which was named with the CSQ number and the first few words of the question.

CSQ Discussion at the Workshop

To complement the plenary sessions at the workshop, a series of splinter sessions was organised to allow more focussed discussion of the CSQs. In advance of the workshop, participants were invited to select from the CSSQ those they were most interested in discussing and to provide comments on the CSQs and highlight potentially missing questions. As a result of these choices, the most commonly selected CSQs were divided amongst three groups of workshop participants for discussion. Each of the splinter groups was requested to discuss the following questions with respect to the set of CSQs they had been allocated:

1. How **complete** are the Candidate Science Questions (CSQs) in terms of description and supporting justification?

Within the scope of the current CSQs being discussed, is there anything important missing?

- Missing objectives? Or refinements needed?
- Missing CSQs?

2. What is the **expected Science Impact** of the current CSQs

- Which CSQs have the biggest impact on Earth system science and how is this impact expressed (e.g. improved understanding, reduced uncertainty, societal needs)?

3. What are the **timescales** associated with CSQs and knowledge advancement objectives?

a. Which CSQs can be advanced significantly in **medium term 5-6 year timescale** (typically supported by data from existing or soon-to-be available EO missions)?

b. Which CSQs will take much longer and might require new observations not available in the near future?

c. How can progress be measured for both medium and longer-term time scales?

4. Overall prioritization

a. Which CSQs can be advanced significantly in medium term, 5-6 year, timescale (typically supported by data from existing or soon-to-be available EO missions)?

b. Which CSQs will take much longer and might require new observations not available in the near future?

High Level Summary

The presentations prepared by the rapporteurs for each splinter group are provided at the end of this document. Those presentations provide a summary of the of the discussion on each of the CSQs allocated to the group. An overall synthesis of the main discussion points across the three splinter groups is provided below:

Nature of the science questions – processes vs methodology:

All three of the group discussions included assessment on the nature of some of the CSQs, and whether they qualified as "Science Questions". Several of the CSQs, as posed, reflected more methodological issues, or requirements for improved observations (long term monitoring, better spatial / temporal sampling), Cal /Val or other programmatic activities. There was a general consensus that these types of questions should be treated differently, as cross cutting issues, and the CSQs themselves should focus more closely on critical

questions of Earth system process understanding. That is not to say that the “methodological” questions are unimportant, but we are considering the EO *science* strategy here and some of the issues raised may fit better in other areas of ESA’s EO strategy.

Cross-cutting topics – extreme events and tipping points

There was a dichotomy of responses to these CSQs. On the one hand they generated a lot of interest in the community, recognising both their societal relevance and the scientific challenges in addressing them. However, it was also noted that the questions typically required improved temporal sampling either to detect extremes or to monitor progression towards tipping points and could thus be considered methodological questions. The participants suggested that if retained the questions should be rephrased to focus on the key processes that need better understanding. Alternatively, where these processes are covered in other CSQs, those questions could be flagged to highlight their relevance to extreme events/tipping points.

Inter-relatedness

Notwithstanding the fact that the approach to CSQ generation was already cross cutting, the inter-relatedness of several CSQs was noted – in many cases progress in one CSQ would depend upon progress in another. So the number of CSQs could be reduced by further consolidation into overarching questions with the proviso that such general questions could lead to more difficulty in focussing a future strategy.

Potential Missing Topics

Participants raised a few topics, or domains they felt were missing, or underrepresented in the initial list of CSQs:

Global Agricultural Monitoring: Given the societal significance of food production and security in the context of climate change participants argued that a dedicated question on Global Agriculture was justified. Discussion surrounded the role of ESA EO science compared to the long-term monitoring and derived information generation that could be accomplished within the Copernicus programme.

Response of Atmospheric Circulation to GHG and aerosol emissions: This is not explicitly covered in the CSQs but has potential high impact and the issue is not well described in current models. There is a need to better measure and understand the impacts on mean transport circulation.

Upper atmosphere and space weather: Discussion covered a number of sub-topics including the need for better understanding of the linkages between the atmosphere and space plasma, and the influence of lower atmospheric processes on space weather. This may require interaction between EO and other ESA programmes, not only for science but also for societal implications such as the protection of key infrastructures.

Mountain regions: The initial CSQs include regional foci on polar regions and coastal zones, but mountain regions are not explicitly included and they too are very sensitive to impacts of climate change, with significant consequences for society

Prioritization and timescales

Most of the time spent on discussion in the splinter groups was on specific CSQs, with little comment on the broader issues of the *basis* on which prioritisation of CSQs should be undertaken.