Development of the Draft ESA EO Science Strategy

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on behalf of many contributors

Why an EO Science Strategy is important?

Open Calls for mission ideas and selection of ESA's future Research missions shall be guided by a Science Strategy

Proposed missions should respond to science questions and priorities outlined in a Science Strategy

The Science Strategy provides a framework to guide international partnerships with other Agencies

The Science Strategy shall guide priorities for investments in developing new technologies and observation sensing/platform capabilities required to implement new EO missions

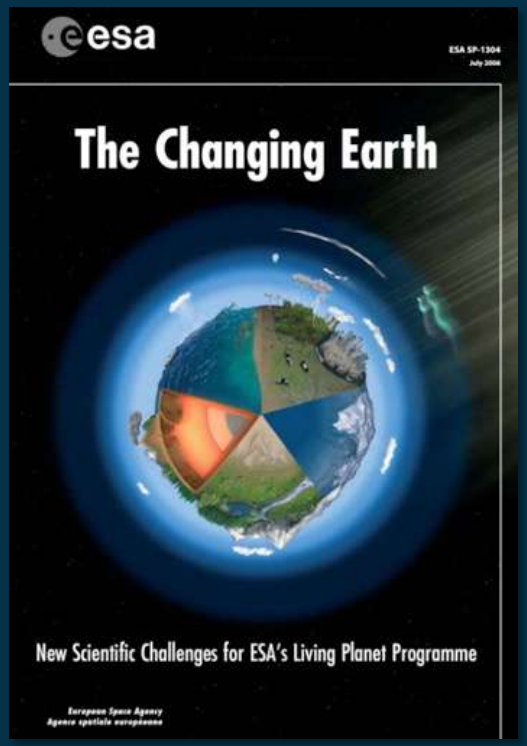
The science strategy will guide investments and priorities in ESA EO Programmes (e.g. R & D activities in ESA's FutureEO Programme)

The Science Strategy is a tool to communicate the vision, goals and ambition of ESA's EO Programmes, and provides a means to gauge progress and success, and to guide future programme implementation

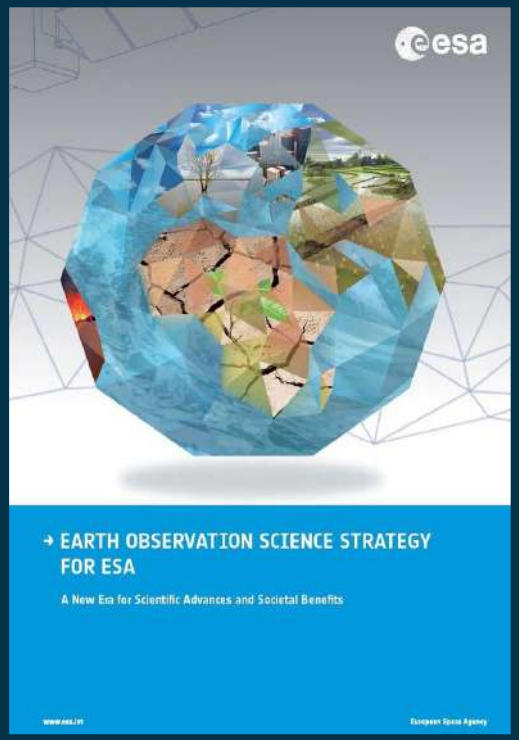
ESA EO Strategy Documents

1998

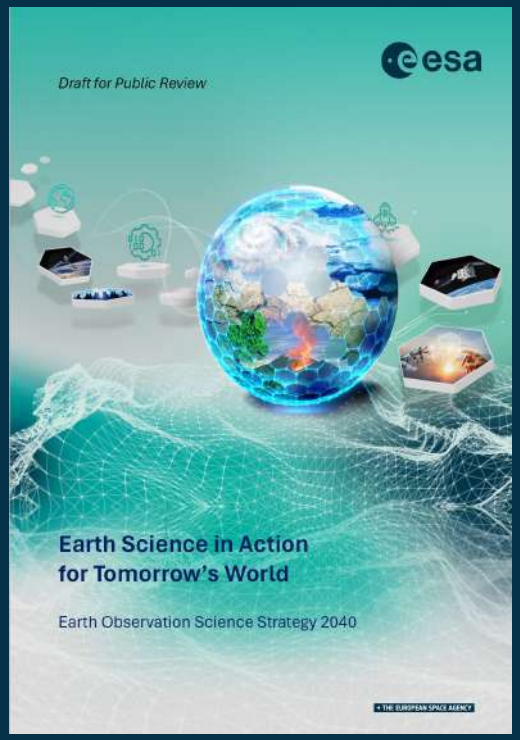
2006



2015



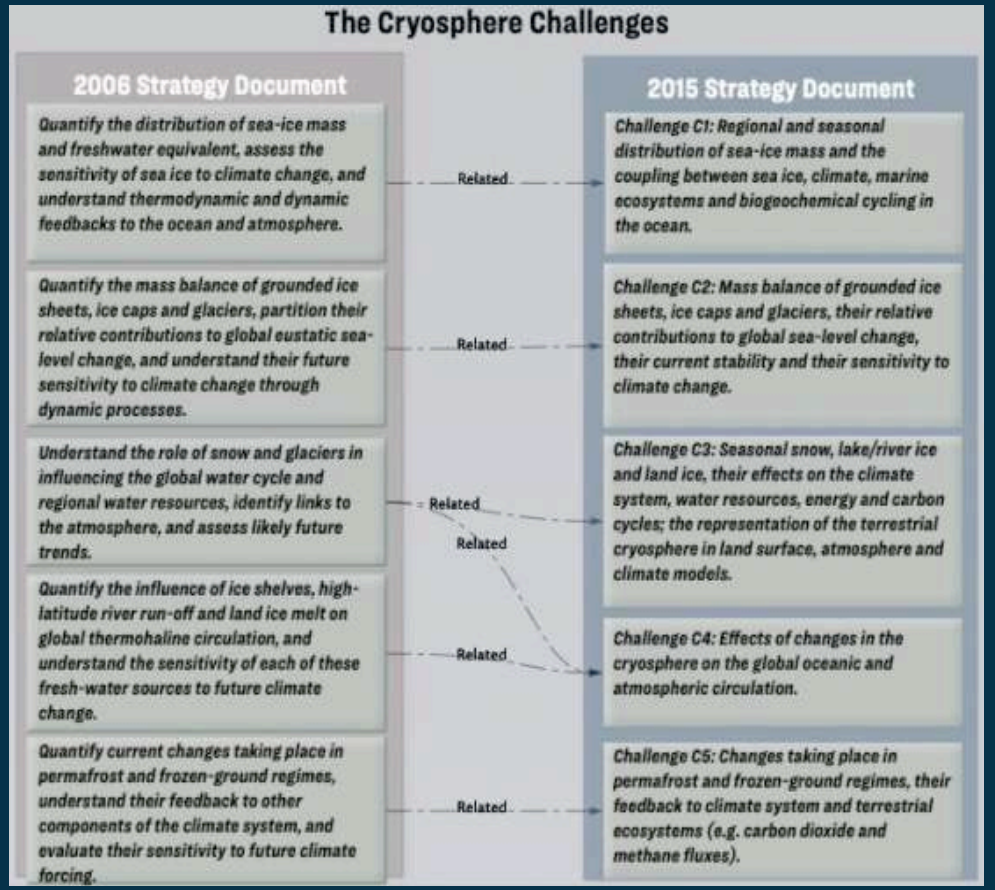
2024



Strategy updates approx. every 8 years

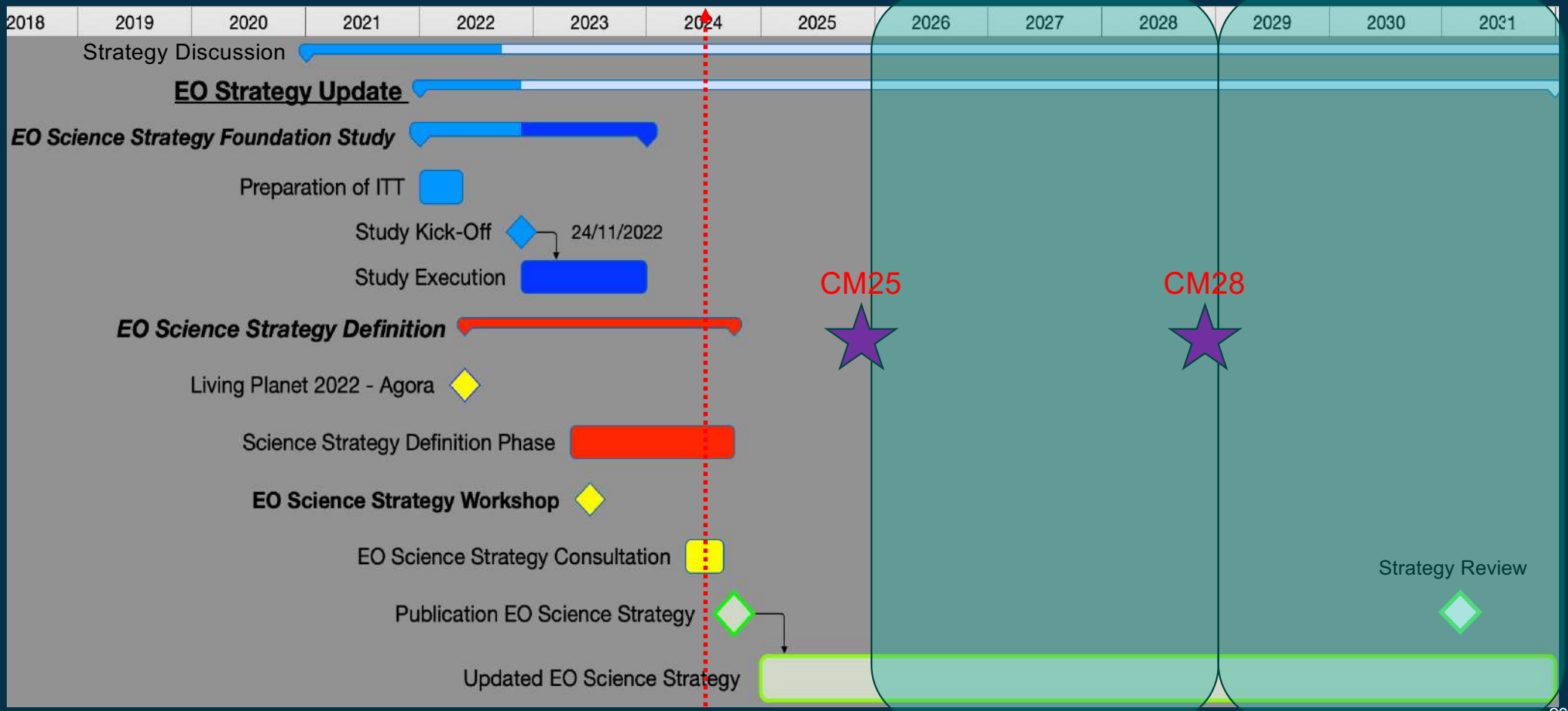
Strategy elaboration: Objectives

- Consult EO science community to review science questions and strategic objectives driving the Strategy
- Establish interdisciplinary science drivers cutting across traditional Earth system science domains
- Strengthen link between improved Earth System knowledge and delivery of societal benefits
- Emphasise timescales over which strategic actions are implemented and expected to deliver results
- Focus and reduce the number of science challenges in the strategy
- Review/adaptation of science priorities on a shorter 6 year timescale
- Include a short-term element spanning 6 year (2 x 3 yr programme cycles), and longer-term 2040 perspective.



Cryosphere challenges: minimal evolution 2006-2015

Science Strategy Timeline

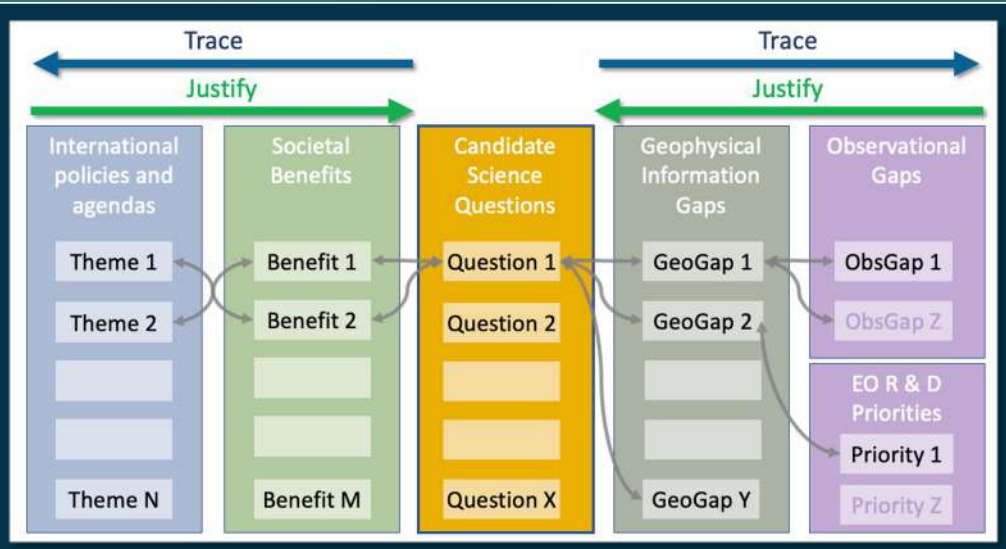


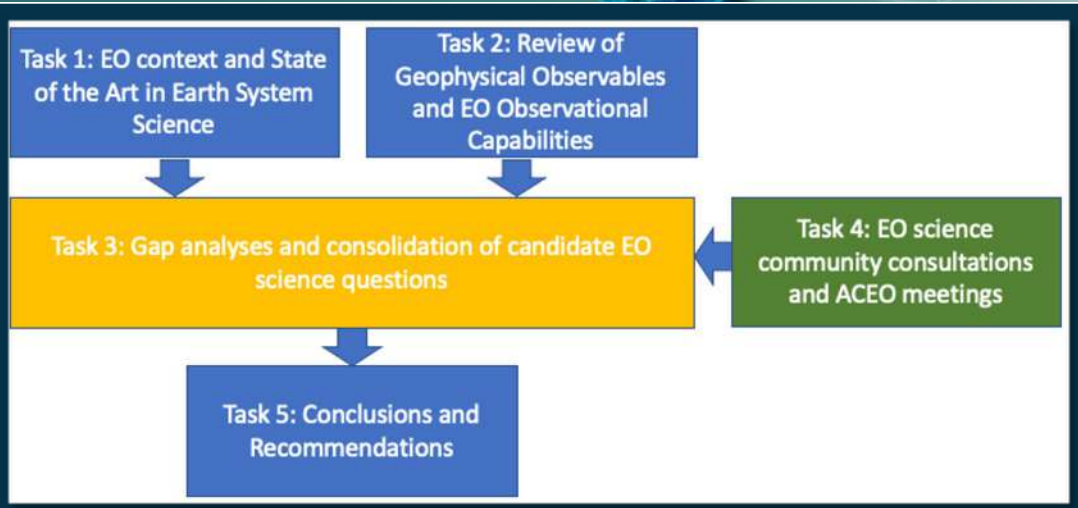
Initiating the Science Strategy Foundation Study

- EO science strategy update roadmap discussed with the EO community at LPS ’22 Strategy Agora
- EO Science Strategy Foundation Study (SSFS) concept endorsed by ACEO on 3 February 2022
    - Expand community involved in contributing to Future EO Strategy
    - Review the Living Planet Challenges and identify potential new scientific questions and gaps in scientific knowledge or EO observations
    - Research and propose updated candidate science questions
    - Document study results
- Statement of work (SoW) finalised with an Invitation to Tender (ITT) release in April 2022
- Strict requirement to assemble a cross-disciplinary, international science team
- Info session held in early May for all potential interested bidders

18 Month Study from Nov. 2022 – Apr. 2024

Science Strategy Foundation Study





- Broad horizon scan of scientific Grand Challenges, international research strategies, and state of the art in use of EO data in Earth science (Task 1)
- Gap analysis (Task 2) of EO mission geophysical products and observations (CEOS/OSCAR databases)
- Propose cross-disciplinary ("cross-cutting") Earth system Candidate Science Questions (CSQs) to inform and orient the EO science strategy
- Each candidate question traced to scientific objectives ("Knowledge Advancement Objectives" - KAOs) and to gaps in EO derived geophysical information and observational gaps.
- Traced and document links between candidate questions and societal benefits, international policies and agendas

Example CSQ: links to observations, benefits & policies

Question	Knowledge Advancement Objectives	Geophysical Observables [Links to MIM databases]	MIM Number	Measurement Specifications	Data sets, Methods, Tools & Models	Policies / Benefits
How has the ocean carbon cycle responded to anthropogenic CO2 and climate change?	A) Track changes in ocean uptake and removal of CO_2 associated with changes in atmospheric CO_2 concentration, sea surface temperature, ocean transport and biological productivity at 1°x1° or higher resolution over the globe?	**1. Critical Parameters** *Precise/accurate estimates of near-surface atmospheric CO2 and its spatial and temporal gradients*			Atmospheric GHG retrieval algorithms Atmospheric flux inverse models Global ocean biogeochemical models (GOBMs) Enhanced Cal/val	CC mitigation and adaptation policy
		Atmospheric CO_2 dry air mole fraction	CEOS-44	Precise/accurate (0.1 ppm) XCO_2 and XO_2 at a resolution of 1°x1° or higher at monthly intervals		
		Sea surface temperature (SST) and salinity				
		Sea Surface salinity	CEOS-152	SST, salinity at a spatial resolution of 1°x1° or higher at daily intervals		
		Sea surface temperature	CEOS-144			
		Surface vector winds				
		Wind speed over sea surface (horizontal)	CEOS-141	Ocean wind speed at a spatial resolution of 1°x1° or higher at daily intervals		
		Wind vector over sea surface (horizontal)	CEOS-143			
		Ocean colour				
		Ocean chlorophyll concentration	CEOS-149	Ocean colour at a spatial resolution of 1°x1° or higher at daily intervals		
		Ocean suspended sediment concentration	CEOS-150			
		Colour dissolved organic matter (CDOM)	CEOS-151			
		2. Supporting Parameters				
		Precipitation	CEOS-116	precipitation at a spatial resolution of 1°x1° or higher daily		

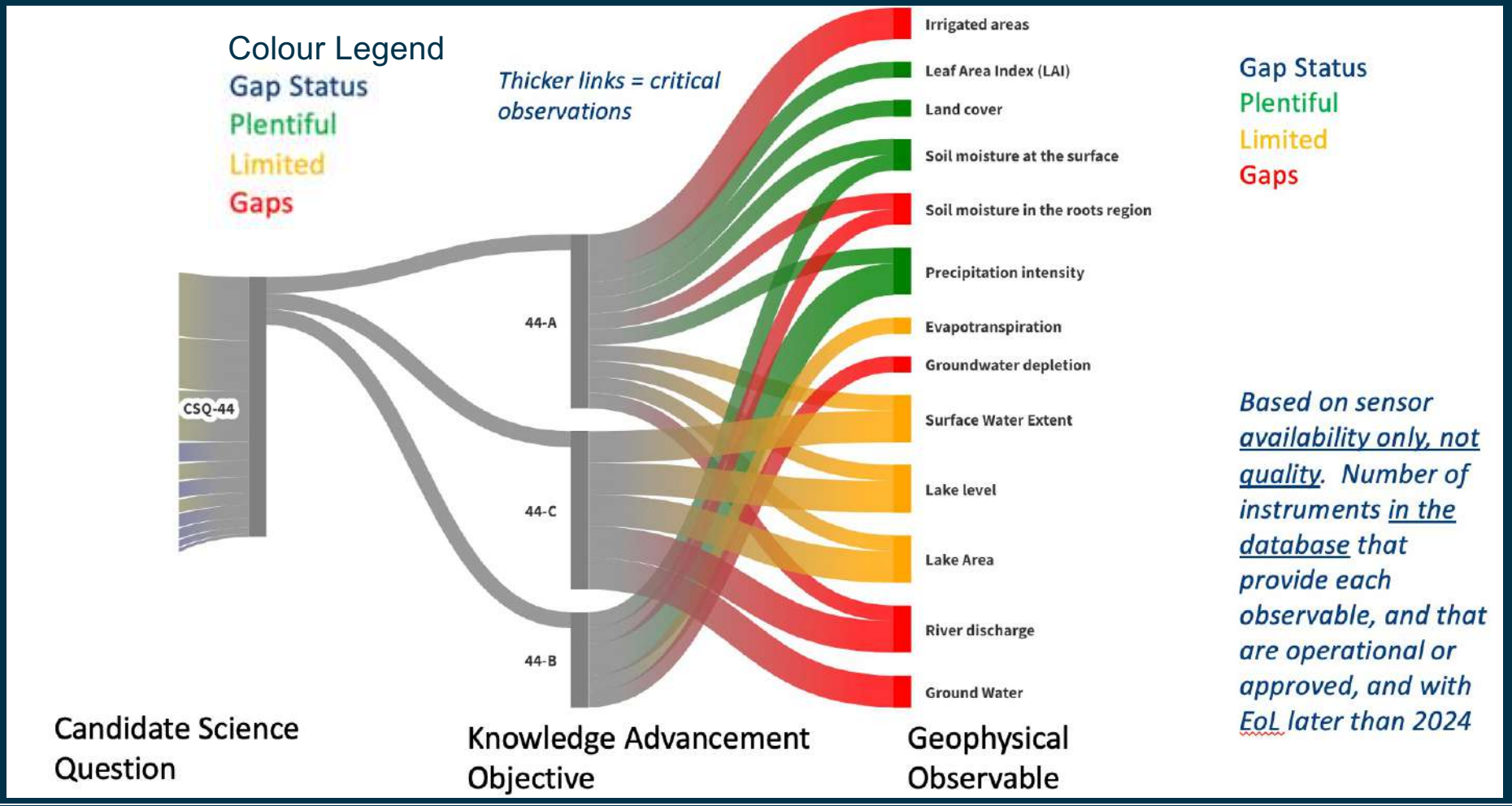
+ 3-4 page narrative for each CSQ detailing science need and rationale

EO Science Strategy Foundation Study- output

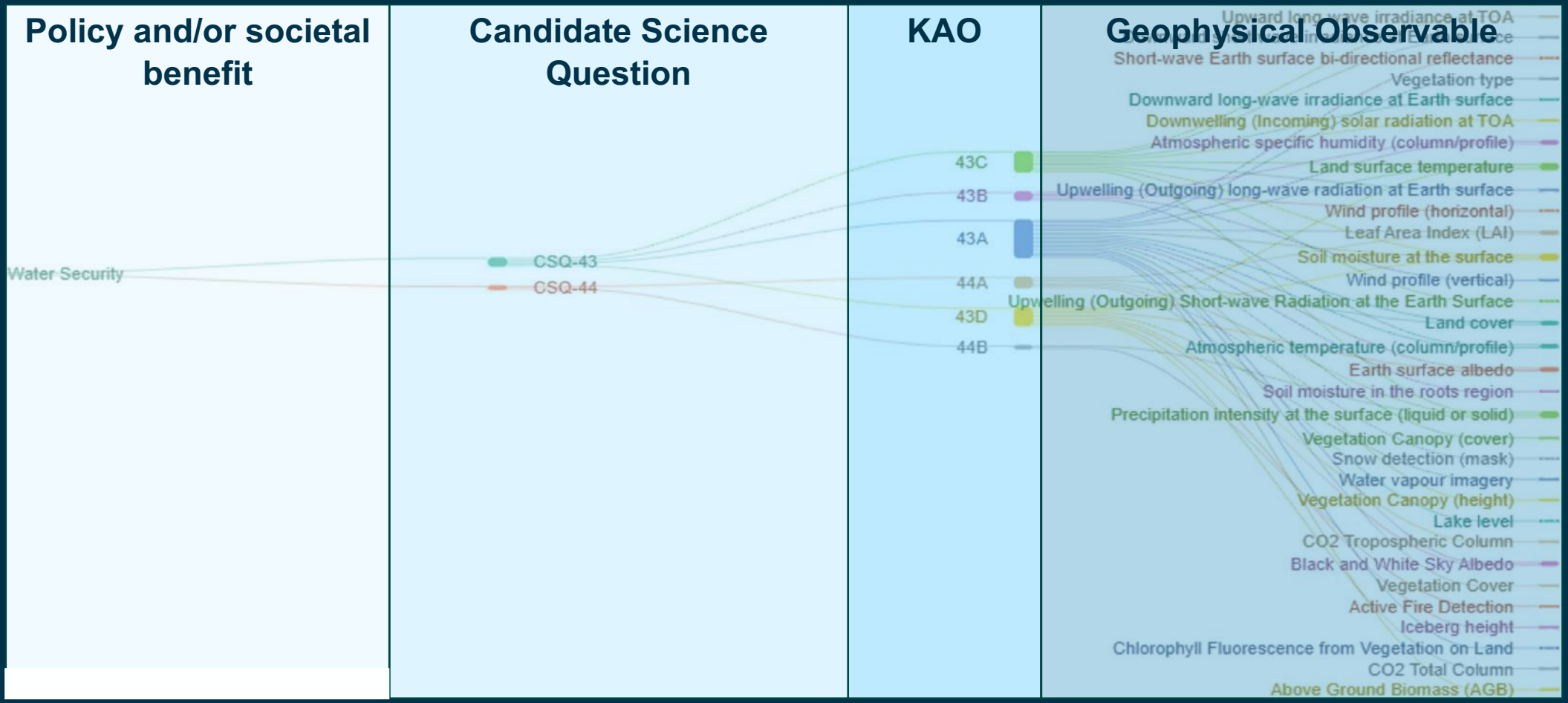
- 22 Community-vetted cross-domain priority Candidate Science Questions (CSQs) as candidate science drivers of the Science Strategy
- Justification and traceability between CSQs and
    1. Information needs and EO observation gaps
    2. International Policies/Societal Benefits

- Categorisation of each CSQ in terms of impact on 4 ESA programmatic drivers:
    1. Novelty and discovery science
    2. Policy relevance and benefits
    3. Scope to reduce knowledge gaps in 6 yrs
    4. Potential to fill critical observation gaps
- Tools (database, software) to prioritise science and knowledge advancement topics as a function of programatic priorities and content e.g. specific policies.

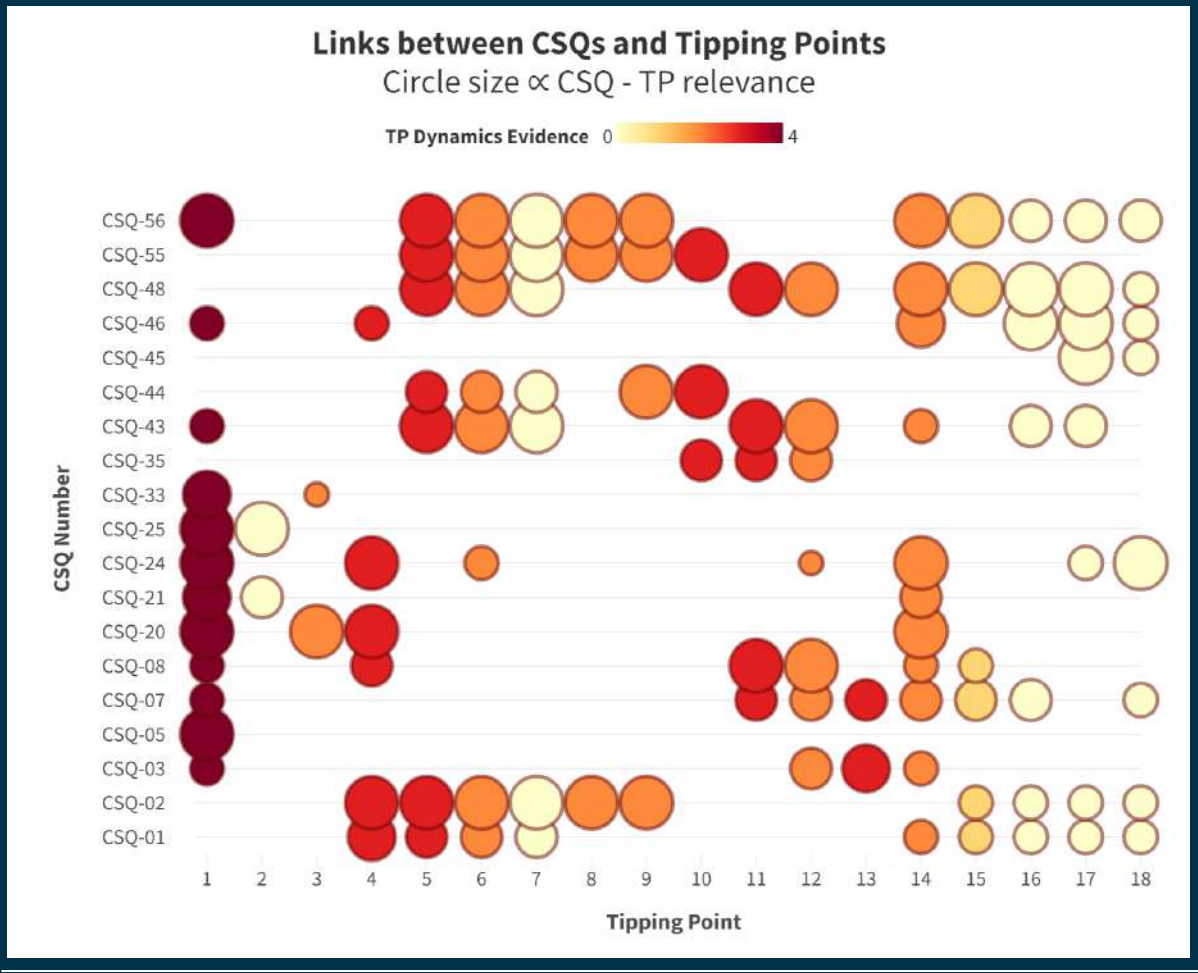
Example traceability between CSQ and observations



Example output: traceability for water security



CSQ Links to Tipping Points



TP-1	Cryosphere	Ice Sheets (collapse)
TP-2	Cryosphere	Sea Ice (loss)
TP-3	Cryosphere	Glaciers (retreat)
TP-4	Cryosphere	Permafrost (thaw)
TP-5	Biosphere	Tropical Forests (dieback)
TP-6	Biosphere	Boreal Forests (dieback / expansion)
TP-7	Biosphere	Temperate Forests (dieback)
TP-8	Biosphere	Savannas and Grasslands (regime shifts)
TP-9	Biosphere	Drylands (regime shifts)
TP-10	Biosphere	Freshwater / Lakes (regime shifts)
TP-11	Biosphere	Coastal - warm-water coral reefs (die-off)
TP-12	Biosphere	Coastal - mangroves and seagrass meadows (die-off)
TP-13	Biosphere	Marine ecosystems and environment (regime shifts)
TP-14	Ocean & Atmos	Ocean overturning (collapse)
TP-15	Ocean & Atmos	Monsoons (collapse / abrupt strengthening)
TP-16	Ocean & Atmos	Tropical clouds and circulation (reorganisation)
TP-17	Ocean & Atmos	ENSO (more extreme or permanent)
TP-18	Ocean & Atmos	Mid-latitude (shift to wavy-jet)

Strategic Areas of EO Action

A1: **Frontier Science and Discovery**

- innovative/blue-skies, novel discovery science
- groundbreaking/technologically challenging
- serving as a foundation for all areas of action
- harnesses science knowledge, technical know-how at European level through ESA

A2: **From Science to Benefits**

- contribution to areas of societal benefits in the domains of international and national policy
- science basis for development of green solutions
- science relevant to informing, assisting, enabling monitoring of compliance, and evaluate policy impact
- support to evidence-based policy implementation

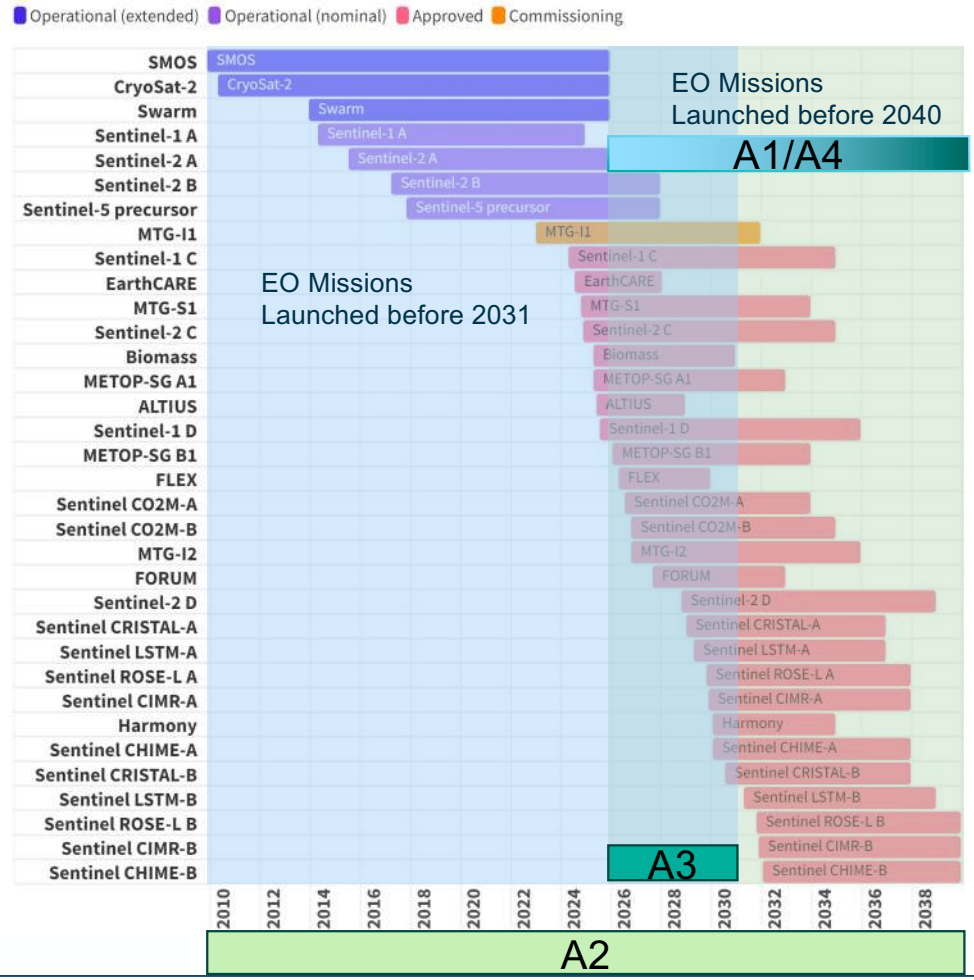
A3: **Reducing Critical Knowledge Gaps**

- uptake and contribution of existing/upcoming missions to science questions
- pursuit of multi-mission synergies
- agile Scout research missions for rapid return
- addressing high priority science through partnerships and institutional collaborations
- demonstrable progress made in 6 years

A4: **Filling Critical Observation Gaps**

- addressing crucial observation gaps with new technologies
- study and predevelopment of novel and improved observational capabilities
- requiring sustained science / technology development
- takes into account EO reference architecture

Short- and long-term ESA Mission Landscape



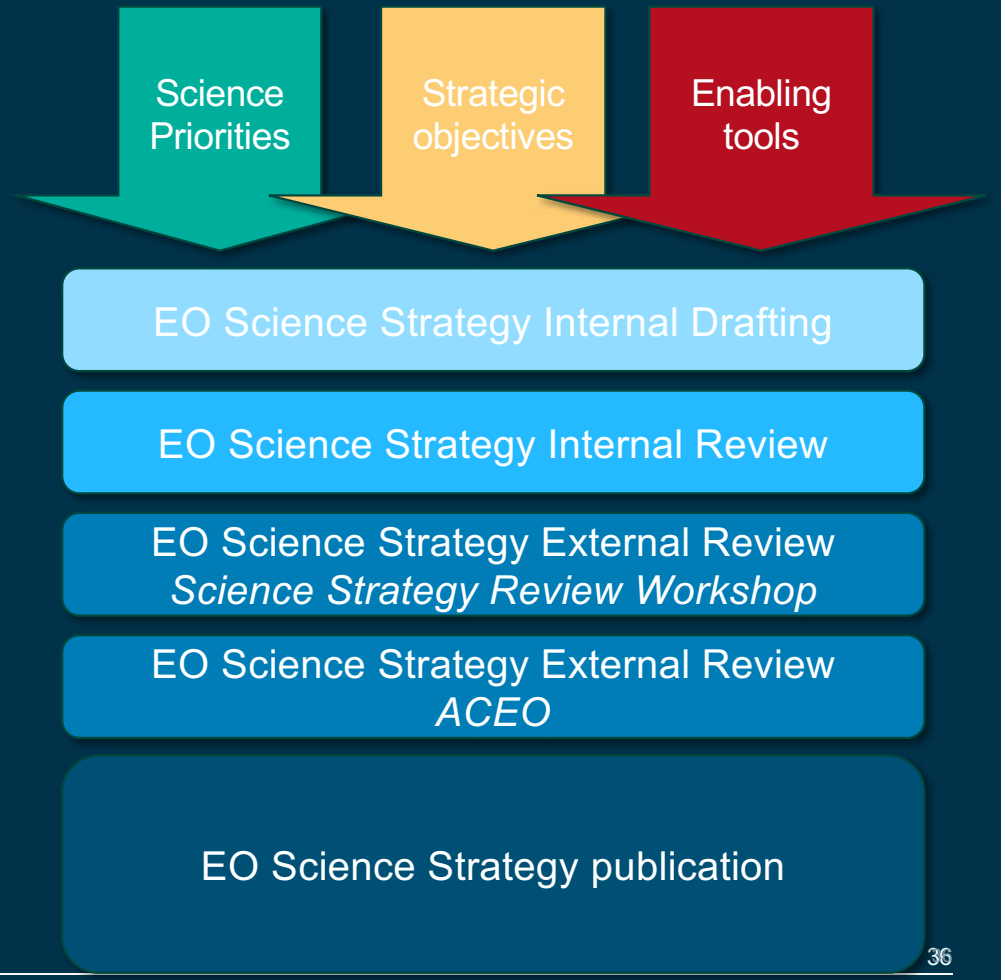
NB: As presented.
Figure to be Updated in Strategy Document

Key ingredients of the EO Science Strategy

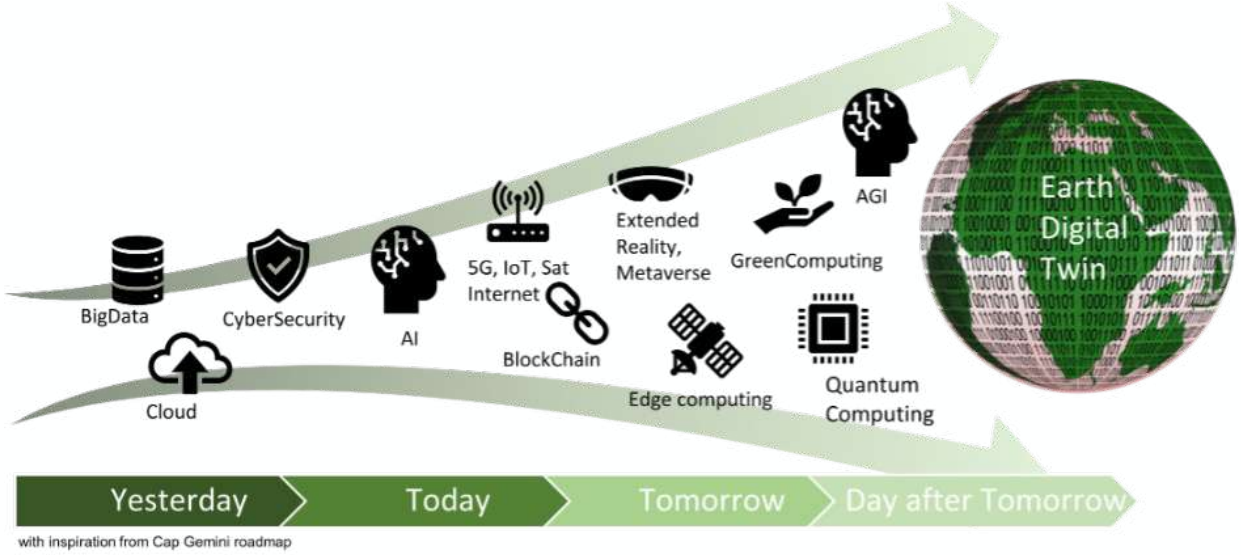
- Science priorities expressed through domain cross-cutting science questions (previously ‘challenges’), including:
  - Narrative (including background science references)
  - Potential actions (for advancing knowledge)
  - Supporting content (required geophysical variables, observation gaps, and methods)
- Areas of Action (A1, A2, A3, A4): aligned with ESA programme needs/programmatics, and enable high level mapping and prioritisation of the Science Questions into types programmatic implementation
- Identified Enabling Tools (i.e. the means to realise the Science Strategy)
- Strategic Objectives to summarise main actions.

Process & Status of the EO Science Strategy Document

- EO Science Strategy is a short concise document 15-20 pages long. Intent is to link to more extended background information on the CSQs
  - Science Priorities (currently CSQs) go into Appendix as reference
- Strategy document contains text and pop-up text boxes providing illustrations and/or examples of future science strategy implementation
- Draft Document structure:
  - Foreword (EO Director Message)
  - Vision
  - Prologue
  - Science Action Areas
    1. Frontier Science and Discovery: a strong foundation
    2. From Science to Benefits: meeting society's needs
    3. Reducing critical knowledge gaps: taking action now
    4. Filling critical observation gaps: preparing for tomorrow today
  - Enabling tools
  - Appendix



Enablers of Earth Action



- Building Partnerships and Cooperation
- Fostering a Community Approach to Science
- Building strong STEM Education, training and outreach
- Exploring EO science links with Commercial Space
- Harnessing Open Science through Digital Innovation

Science Strategy Consultation

Living Planet Symposium
Science Strategy Agora
Bonn (DE), May 2022

ACEO#10
May 2021
consultation on update of Living Planet Challenges

ACEO#11
Sept. 2021
Boost FutureEO plan presented

ACEO#15
Sept. 2022
Report on progress in Science Strategy Foundation Study

ACEO#17
June 2023
Bruges Workshop feedback and ACEO Advice on study focus for science priorities

ACEO#20
June 2024
Consultation on outcome of EO Science Strategy Review WS and final Review of the Strategy Document

Drafting of EO Programme Proposals (Sept '24 – June '25)

CM25

Start Science Strategy Foundation Study
Nov 2022

EO Strategy Workshop
Bruges (BE)
June 2023

End Science Strategy Foundation Study
April 2024

EO Strategy Review Workshop
ESA-ESRIN (IT)
May 2024

EO Strategy Publication
July 2024

In summary

- This second user consultation takes place at the end of the process to elaborate an updated draft EO Science Strategy
- The EO Science Strategy is an ESA document outlining scientific priorities and themes and approaches supporting implementation of EO Programmes
- The EO Science Strategy Foundation study supporting the strategy represents a new approach to establish candidate science questions their impact on the scientific knowledge and in terms of societal benefits and upon international programmes
- ESA will collect feedback from the science community at this Workshop and finalise the Strategy document in consultation with ACEO in June.
- The objective is to complete the new Strategy in Q3 2024 to guide the proposed Programme content (e.g. science priorities governing the EE13 Call) prior to CM25

EO Science Strategy Review Workshop

Background

- Climate change impacts are a present-day reality due to global warming and human pressures on the environment
- The Earth's systems are changing rapidly due to climate change and human influence, leading to new patterns in global water, carbon, and energy cycles with more frequent/intense extreme events
- There is a critical need to observe and understand these changes comprehensively to develop effective responses and adaptation measures
- Human activities must be integrated into Earth system studies to manage impacts globally and locally, which poses challenges for observation and modeling at unprecedented scales
- Interactions between nature, ecosystems, and socioeconomics require improved observing capabilities and interdisciplinary efforts to predict ecosystem evolution.

ESA’s Science Vision and the Earth Observation Science Strategy 2040 aims to address these challenges and needs along the full value chain from innovative missions through excellent science to societal benefits and applications

Outcome of Ministerial Council at Space Summit 2023

Strong political support for EO, climate and sustainability at summit 2023

Green & sustainable future is #1 of 3 priorities

> In pursuit of this vision, ESA must contribute future-defining initiatives, including development of ambitious missions, providing effective responses to urgent global challenges associated with the green transition towards carbon neutrality, as well as initiatives for greener space activities.

- The summit gave ESA the mandate to do more than build next gen. EO missions and systems
  - ESA EO should urgently provide (demonstrators of) solutions
- Policy based Green Deal and general geopolitical context strongly drives EO programme strategy and content
- ESA aims to realise the full potential of space solutions for society

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