Splinter Session B - Summary

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EO Candidate Science Questions Review Splinter (Room Vives – Blue Badge)

CSQ13. Would it be of value to develop a system of systems while combining different types of satellites under different orbit constellations to advance monitoring capacities (e.g., diurnal cycle, higher resolution)?

CSQ09. What are the characteristics of the processes related to climate extremes and the hazards related to them?

CSQ02. How has the land biosphere responded to human activity and climate change?

CSQ10. How can we improve the characterization and preparedness for risks related to compound climate extremes?

CSQ14. What are the main issues with calibration-validation, absolute calibration, long-term monitoring?

CSQ15. Which specific observations are needed: polar / tropical regions, new measurement techniques vs long-term series of observation, large-scale field experiments?

CSQ01. What anthropogenic and natural processes are driving the global carbon cycle?

(Missing) This relatively broad question includes stratospheric chemistry (ozone destruction etc.), the breaking and dissipation of atmospheric gravity in the mesosphere and lower thermosphere, and the energy budget of the thermosphere

(Missing) How can we improve our understanding of Transient Luminous Events (TLEs) and Terrestrial Gamma rayFlashes (TGFs),

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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?

CSQ13. Would it be of value to develop a system of systems while combining different types of satellites under different orbit constellations to advance monitoring capacities (e.g., diurnal cycle, higher resolution)?

- Not a science question, rephrase to ask what temporal sampling of Earth systems are required to study processes?
- We can observe different processes if finer temporal sampling available – but we don't want o sacrifice spatial resolution
  - Many observations become more valuable when obtained several times per day.
- Diurnal Cycle needed:
  - Diurnal observations of sea ice in Arctic are needed
  - Snow and ice has strong day-night variability (e.g. surface melt)
  - Vegetation cycle (transpiration and photosynthesis) is needed, also diurnal processes.
  - Atmospheric circulation is a priority measurement
  - Atmospheric composition, air pollution, atmospheric chemistry: all change throughout the day, mission sampling needs to capture that routinely, globally
  - Diurnal variability of CO2 and methane
  - Water dynamic processes (eg related to vegetation) has a clear diurnal cycle
  - Lightening and atmospheric electricity isn't routinely measured
  - Atmosphere – ionosphere coupling isn't sampled
  - Middle atmosphere circulation important to monitor diurnally
  - Dynamics in the ocean, ocean colour
  - For extreme events diurnal observations are important

CSQ09. What are the characteristics of the processes related to climate extremes and the hazards related to them?

- How do we observe extremes -> important understand what the processes driving the extremes. Enables us to work towards building predictive system.
- Process models required beyond 2-3 signa accuracy, which is where the extremes occur.
  - Current data-assimilation system need to be improved, include temporal and spatial components.
  - Think about heavy tailed distributions of events, difficult to observe as may only occur every 20 years
  - Important to consider impact of extreme events on Earth system/across thematic applications (e.g atmosphere impact on land)
    - Topic with high societal relevance, different regions more vulnerable
- Climate extreme priorities:
  - Need to include tsunamis, volcanic eruptions, etc
  - Atmospheric circulation should be studied – make use of meteorological satellites
  - Electromagnetic observations are needed (e.g. lightening in polar regions)

CSQ02. How has the land biosphere responded to human activity and climate change?

- This is an important question, and everything is linked…
- Carbon cycle question relevant to this question
- Land-use change is important to improve our understanding
- Have we fully identified all the observations that are needed to answer the question?
- Can we understand the interlink between patterns and trends

CSQ10. How can we improve the characterization and preparedness for risks related to compound climate extremes?

- Very relevant science question
- We have limited knowledge of extreme event processes, this needs to be improved
- There were more details on this in the summary text – see 245 page document!

- Specifically:
  - Large scale atmospheric circulation is really important
  - Coupling between different atmospheric layers is missing/needs to be improved (Swarm mission partially addresses this)
  - Aerosols influence extreme events – not well enough understood
  - Need to understand impact of extreme events on agriculture
  - Water cycle is important for forests and vegetation
  - Snow melt on land and ice sheets more extreme now than previously – impact on water cycle
  - Societal benefit of understanding how atmosphere responds to solar events

CSQ14. What are the main issues with calibration-validation, absolute calibration, long-term monitoring?

- Cal/Val is incredibly important – generated a lot of discussion.
- Overall, important to cal/val science as well as mission specifications
- Important to have long-term science cal val campaigns, maybe prioritised to most rapidly changing regions, e.g. amazon forest, polar regions, arctic sea ice, methane. (re-prosessing of old data important)
- Cal-val should also validate across Earth systems (e.g ocean-ice, land-atmosphere), rather than just being domain specific
- We must validate uncertainties of the satellite measurement as well as the bias – need to improve knowledge of error
- Instrument /mission overlap important for validation, networks of measurements required
- Easy access to CAL-VAL data required - homogenized, harmonized
- Standards – Best practice required, references need to be considered & metadata – Reference observations needed

- Cal/Val Gaps:
  - Winter months calibration missing
  - Several products not properly validated: snowfall, permafrost,
  - Carbon-based networks: land-ocean imbalance
  - Intersensory calibration needed, different resolutions
  - TRUTHS important: SITSATS –CEOS approach; science involved in this
  - System-of-Systems : atmospheric correcting right for land parameters, albedo helping us, emissivity of the surface – missing calibration, vegetation Atmosphere: full satellite pixels covered and vertical profiles needed.

CSQ15. Which specific observations are needed: polar / tropical regions, new measurement techniques vs long-term series of observation, large-scale field experiments?

- Data gaps exist in the critical zones: land-ocean coastline, ice-ocean edge, atmosphere-land boundary where almost all life is contained
- Specifically:
  - Ocean: dynamics, ocean currents, long time series needed, high spatial resolution, stability of the observations is needed
  - Important to monitor water vapour linking from surface to higher altitudes, for process understanding.
  - Beyond single system observation, beyond the surface
  - Land-atmosphere interfaces change region not well monitored
  - Cities missed, human activity (77% live in cities) - urbanization, field experiments also important! Modelling of cities, surface, temp, greenness, transpiration, albedo, increasing Urban areas!
  - High resolution modelling also important and is being developed
  - Sea ice sampling using e.g. ARGO-system – field experiment would be important
  - Aerosols and clouds / also difficult to validate, altitude information e.g. in experiments
  - Processes important, AI one tool
  - SAR imagery already 20 yrs. We don't' understand the signal properly –welcome improvements for understanding electromagnetic affects the surface properties
    - utilize several bands and polarizations, multifrequency
  - EU: has e.g. methane observation focus also for validating satellites. Collaboration needs communications.
  - Large-scale field ex: linking with existing campaigns and efforts
  - Soil moisture links to water cycle

SQ01. What anthropogenic and natural processes are driving the global carbon cycle?

- Overall, this is a top priority science topic
- Emission sources are important
- Fires are important
- Separate CO2 and CH4, consider both land and atmosphere processes
- Methane :
  - Methane pledge from Cop 26: we don't understand methane. Increasing rapidly
  - Atmospheric chemistry and OH, challenge (methane sinks), wetlands important
- What data do we need for accurate global stock takes?
- What data do we need for net-zero verification – both different but important
- Understanding of CO2 from volcanos need to be improved
- Links ocean, wetlands, peatlands – very important
- Links both physical processes on Earth and human impact

Missing big picture topics

- Mountain glaciers are there but under represented
- Urban regions are missing and require fine spatial resolution
- Impacts of space weather on the upper atmosphere and Earth system including strong ground induced currents
- Coupling of middle and upper atmosphere layers important in a system science approach, need to better understand the boundaries

- **New CSQ required**: Sampling of atmospheric boundary layer to Space is completely missing, plus knowledge of processes is minimal
  - Neutral plasma interactions
  - Energy budget of the thermosphere important. How it expands etc., input from above important also for weather and climate, and can help improve orbit determination (and prevent sudden deorbiting) of the thousands of satellites in low LEO
  - Ties also to 13: integral part of the entire system, both coupling from below and above, how are the layers coupled through collational electrodynamics, dynamics and circulation
  - Very few measurements in the region coupling the neutral atmosphere to the space plasma (“ignorosphere”)- lacking knowledge of fundamental processes and hence big uncertainties in atmospheric models (MSIS etc)