Updating the Scientific Challenges of ESA's Living Planet Programme - Science Strategy

- A Proposal by the ESA Earth Science Advisory Committee

26 August 2013

European Space Agency
Agence spatiale européenne

Executive Summary

To address the major Challenges for our understanding of the Earth System for areas where satellites will make a major contribution, the European Space Agency (ESA) published the report 'The Changing Earth – New Scientific Challenges for ESA's Living Planet Programme". This document at the time set out a science strategy whereby ESA could assess the most important Earth-science questions to be addressed in the years to come. A recommendation of a Science Review in 2011 was to update periodically the Science Strategy with its scientific Challenges. Together with a number of well-known experts representing the different scientific Earth Observation disciplines, ESA's Earth Science Advisory Committee (ESAC) has now reviewed these Scientific Challenges and in this report proposes a set of new/updated Challenges.

An overview of this new set of Challenges together with some overarching science Challenges encompassing the different Earth Science disciplines will be presented at the Living Planet Symposium in Edinburgh on 9-13 September 2013. This gives the wider EO science community a possibility to respond and help ESA to further consolidate and confirm these new science Challenges. The new Challenges will become the core of the new Living Planet Programme (LPP) Science strategy, which will be used to guide the Call and Mission Selection of the next generation of ESA's Earth Explorer missions.

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1 Changes in the context of the Living Planet Programme

The European Space Agency (ESA) published the report 'The Changing Earth – New scientific Challenges for ESA's Living Planet Programme' (ESA SP-1304, http://esamultimedia.esa.int/docs/SP-1304.pdf) in July 2006. The advances in Earth system science, in Earth observation remote sensing and the information obtained from Earth Explorer satellites launched over the recent years had significant impacts on ESA's Earth Observation programmes and suggest a review and update of the Living Planet Challenges (LPCs).

Three Earth Explorers are in space

CryoSat-2 was launched in April 2010. CryoSat-2 carries a sophisticated radar altimeter to meet two principal challenges. The first is to acquire accurate measurements of the thickness of floating sea ice so that annual variations can be detected. The second is to survey the surface of ice sheets accurately enough to detect small changes.

GOCE was launched in March 2009. GOCE carries a highly sensitive gravity gradiometer which detects fine gravity field anomalies with unprecedented accuracy and resolution. GOCE provides the most accurate model of the geoid ever produced with applications in dynamic topography and circulation patterns of the oceans.

SMOS was launched in November 2009. SMOS measures microwave radiation emitted from Earth's surface using an interferometric radiometer. The principal goal of SMOS is to measure and monitor soil moisture and ocean salinity.

These three missions have now reached their main mission objectives – GOCE already extending its mission lifetime. The missions have addressed a number of the challenges laid out in the Living Planet Programme. The three Earth Explorers have enabled cross-cutting science, leading to a number of significant discoveries and a diversity of potential applications.

Four Earth Explorers waiting to be launched

Four Earth Explorer missions (ADM-Aeolus, EarthCARE, Swarm and Biomass) are under preparation.

ADM-Aeolus will provide direct global measurements of 3D wind fields, which will lead to improvements in numerical weather predictions and climate models.

EarthCARE will quantify cloud-aerosol-radiation interactions, improving their representation in climate- and numerical weather forecasting models.

Swarm will measure the geomagnetic field by acquiring magnetic signals from Earth's core, mantle, crust, oceans, ionosphere and magnetosphere.

Biomass, the seventh Earth Explorer, will determine the distribution of above-ground biomass in the world's forests and annual changes in this carbon stock.

Operational observation capabilities are in development

ESA is developing five new missions called Sentinels specifically for the operational needs of the Copernicus programme. The Sentinels will be launched from 2014 onwards. These missions carry a range of technologies, such as radar and multi-spectral imaging instruments for land, ocean and atmospheric monitoring. This accurate, timely and easily accessible information will improve the management of the environment, support to understand and mitigate the effects of climate change and help ensure civil security.

These missions will ensure continuity and build on ESA's successful past missions ERS-1, ERS-2, and Envisat. However, the Sentinels will also be of great benefit to science, providing long-term data, and thus making the missions highly valuable to gain a deeper insight into the processes and interactions that make up the Earth system and its changes.

ESA is further developing the MTG series, which will provide significant improvements over the current Meteosat satellite observations and take weather forecasting to the next level.

The European contribution through the Eumetsat Polar System (EPS) is providing precise observations to improve weather and climate forecasts through MetOp-A

launched in 2006, MetOp-B, launched in 2012, to be followed by MetOp-C in 2016. This guarantees the continuous delivery of high-quality data for medium- and long-range weather forecasting and for climate monitoring until at least 2020. As of 2020 the second generation of MetOp satellites will succeed the current series with enhanced capabilities for climatology and atmospheric chemistry.

Processes are complex and evolving

At the 5-year Programmatic Review of the Earth Observation Envelope Programme (ESA's user-driven programmatic approach to meet the Living Planet Science Challenges) in 2011, one of the recommendations brought forward by the Science Review Panel was that the 'Changing Earth' strategy be reviewed and updated periodically. This stems from the observation that processes related to global change, climate and environment – and their associated social impacts - are complex and evolving. It is thus necessary to periodically assess achievements and progress made and to reflect whether the identified Challenges, their priority and context are still valid.

2 Review of the Living Planet Programme Challenges

In order to ensure that a review of the 25 Living Planet Challenges (LPCs) laid out in the report "The Changing Earth" is performed in a sustained manner with a broad scientific community support, two steps were performed which are described below.

ESA consults scientists to review the Living Planet Challenges

ESA consulted over 50 scientists from different fields to review and assess the Living Planet Challenges (LPCs) in May/June 2013. Over 70% of all contacted scientists responded to the request and provided valuable input on the Challenges, provided records (journal articles, books, relevant new products etc.) and an assessment of the progress made since its publication in 2006. Many scientists suggested that the 25 Challenges remain either valid (i.e. have not been met) or need updates. It is worth mentioning that the scientists have also stressed the increasing importance of addressing the value of future missions for societal benefit areas and hence suggested a number of changes of the Challenges that would address these. They further identified gaps with respect to observational needs. None of the Challenges were considered to be fully met or completely obsolete.

ESAC concludes that an update of the Living Planet Challenges is needed

ESAC carefully reviewed and analysed the comments from the scientists. Furthermore, ESAC analysed the additional suggestions and noted the positive comments of several scientists suggesting the success of the programme through the achievements against the Living Planet Challenges as these have over a decade guided Earth Science Missions and contributed to the increased understanding of the Earth System. ESAC also noted several comments suggesting an overarching element that would describe interactions and interdependencies between disciplines/themes and would better respond to societal and economic Challenges and needs.

ESAC concluded that an update of the Challenges is necessary together with an overarching goal for the programme and a set of overarching Challenges. The goal, outlined below, is to be presented and discussed with the broad scientific community at the Living Planet Symposium in Edinburgh, UK, September 9-13.

3 Update of the Living Planet Programme Challenges

ESAC proposed the following approach:

- define an overarching and cross-cutting goal for science
- advise on implementation of the goal
- provide the context of the programme
- define and update challenges

These four elements are further elaborated below.

ESAC defines overall goal for science

ESAC has expressed the following overall scientific goal for the LPP:

> **The overall scientific goal for ESA's Living Planet Programme is to deliver science for society.**

In line with the responses of the community scientists, ESAC agreed on the need of addressing overarching/cross-cutting topics, which encompass the science themes of the Living Planet Programme. These cross-cutting topics include, through provision of global, quality-assured Earth Observations from space:

- coupling of water-, geo-biochemical- and energy cycles, heat and mass transport
- geospheric processes and natural and anthropogenic hazards
- global food, health and water security

This expresses the fact that the scientific benefits and the EO observations extend beyond the scientific community to a wide range of decision makers in public policy, environmental and natural resource managers, natural disaster, risk manager etc. This includes characterising and predicting the evolution of the Earth/climate system in response to urgent societal needs and embraces scientific exploitation and innovative applications from current and future Earth Explorer missions, long-term space observations from Earth Watch and GMES Sentinel missions.

ESAC advises on implementation of the goal

ESA's role in the implementation of this goal is to develop and expand capabilities for European science and industry. ESA should

- advance Earth sciences supported by new remote sensing technology developments
- on the basis of scientific understanding, develop application driven and operational missions, based on science and technology advances
- further strengthen international cooperation leading towards a globally integrated observing system

The complexity and interdisciplinary nature of future Challenges requires even more innovative technologies and observational methodologies in the next decade and ESA needs to continue to strive for excellence in developing science and leading-edge technology missions. Furthermore, application driven and operational missions should be developed when science and technology advances and a better scientific understanding necessitates it.

ESAC puts approach into context

The Living Planet Programme update is defined on the basis of inputs of the scientific community. In addition, it should recognise the *9 Research challenge questions* of "Future Earth" (RD3), the 5 WCRP Grand challenges for climate research (RD4) and apply the 5 ICSU Grand Challenge – "actions": Forecasting, Observing, Confining, Responding, Innovating (RD5).

ESAC defines challenges for action

ESAC has formulated 25 new scientific challenges. These Challenges place conditions on the ESA Member States, in that the ambitious programme to which Europe and Canada aspire needs sustained and adequate funding. They will guide ESA's efforts in providing essential Earth-observation information to all relevant user communities, in close cooperation with international partners.

The Challenges of the Atmosphere

Improve understanding and quantification of:

Challenge A1	the sensitivity of the evolving climate system to atmosphere changes during the anthropocene in order to improve prediction at all-time scales
Challenge A2	surface-atmosphere coupled systems and natural and anthropogenic feedback processes for carbon, water, energy and atmospheric chemistry
Challenge A3	cloud, aerosol and radiation processes and the consequences of their interactions in the atmosphere for energy and hydrological cycles
Challenge A4	the interactions between climate and atmospheric composition on fine to broad scales, and in critical regions of environmental change
Challenge A5	the influence and impact of changes in general atmospheric circulation patterns on regional weather and climate

The Challenges of the Cryosphere

Improve understanding and quantification of:

Challenge C1	regional and seasonal distribution of sea-ice mass and the coupling between sea ice, climate, marine ecosystems, and biogeochemical cycling in the ocean
Challenge C2	mass balance of grounded ice sheets, ice caps and glaciers, partition their relative contributions to global sea-level change; assess their current stability and sensitivity to climate change

Challenge C3	seasonal snow, lake/river ice and land ice, assess their effect to changes in climate system, water resources, energy and carbon cycles; improve the representation of the terrestrial cryosphere in land surface, atmosphere and climate models
Challenge C4	influence of ice shelves, ice sheet melt, sea ice formation and river run-off on thermohaline circulation, ocean stratification, marine productivity, and determine the response of the global oceanic and atmospheric circulation
Challenge C5	current changes taking place in permafrost and frozen-ground regimes, understand their feedback to climate system (e.g. CO_2 and CH_4 balances)

The Challenges of the Land Surface

Improve understanding and quantification of:

Challenge L1	natural processes and human activities and their interactions on the land surface
Challenge L2	interactions and feedbacks between global change drivers and biogeochemical and water cycles as well as biodiversity, structure and productivity of natural and managed ecosystems
Challenge L3	structural and functional characteristics of land use systems to manage sustainably food, water and energy supplies
Challenge L4	land resource utilization and resource conflicts between urbanization, food- and energy production and ecosystem services
Challenge L5	how limiting factors (e.g. freshwater scarcity, phosphorus) affect processes on the land surface and how this can adequately be represented in prediction models

The Challenges of the Ocean

Improve understanding and quantification of:

Challenge O1	evolution of coastal systems (including ocean/land interactions) in response to natural and human-induced environmental perturbations
Challenge O2	mesoscale and submesoscale circulation (including their interactions with internal and surface waves) on energy transport and biogeochemical cycles (through the vertical ocean pump)
Challenge O3	marine ecosystem variability in response to natural and anthropogenic changes, physical (e.g. temperature, mixing, stratification) and biogeochemical (e.g. acidification, de-oxygenation)
Challenge O4	physical and biogeochemical air/sea interaction processes at different spatio-temporal scales(including the role of extremes) and the fundamental role of the ocean on our weather and climate
Challenge O5	sea level changes from global to coastal scales and from days (e.g. storm surges) to centuries (climate change)

The Challenges of the Solid Earth

Improve understanding and quantification of:

Challenge G1	physical processes associated with volcanoes, earthquakes, tsunamis and landslides from in situ and satellite observations in order to better assess the natural hazards
Challenge G2	individual sources of mass transport in the Earth system at various spatio-temporal scales
Challenge G3	geology of the Earth crust and its relation with natural resources
Challenge G4	the physical properties in the deep interior, and their relationship to deep and shallow geodynamic processes
Challenge G5	different components of the Earth magnetic field and their relation to the dynamics of the charged particles in the outer atmosphere and ionosphere for Space Weather research

4 Schedule for finalisation

The schedule to further discuss, update and finalise the Living Planet Challenges is given below:

- 10 + 11 September 2013. Side event sessions on the Living Planet Challenges update at the Living Planet Symposium (LPS) from 17:30 to 18:30 each day, introduced and moderated by ESAC Chair, supported by ESAC members attending the Symposium
- October 2013. ESAC meeting agreeing on final version of the Living Planet Challenges, incorporating Living Planet Symposium participants comments
- November 2013. Submission of the Living Planet Challenges to ESA's Programme Board for Earth Observation
- During the course of 2014, establishment of the new Living Planet science strategy that will contain the new Science Challenges and additional narrative, and that will succeed the ESA publication "The Changing Earth"(ESA, 2006)

References

RD1 ESA (2006). The Changing Earth. New scientific challenges for ESA's Living Planet Programme. July 2006. ESA SP-1304

RD2 ESA (2011). The European Space Agency Earth Observation Envelope Programme. Science Review Report. Geneva Switzerland, May 2011

RD3 Future Earth Research Challenge Questions: http://www.sciencedirect.com/science/article/pii/S1877343513000808

RD4 WCRP Grand Challenges: http://www.wcrp-climate.org/index.php/grand-challenges

RD5 ICSU Grand Challenges: http://www.icsu.org/publications/reports-and-reviews/grand-challenges