The Changing Earth Science Network: Projects 2009–2011

Diego Fernández-Prieto, Roberto Sabia and Steffen Dransfeld

Abstract To better understand the various processes and interactions that govern the Earth system and to determine whether recent human-induced changes could ultimately de-stabilise its dynamics, both natural system variability and the consequences of human activities have to be observed and quantified. In this context, the European Space Agency (ESA) published in 2006 the document "The Changing Earth: New Scientific Challenges for ESA's Living Planet Programme" as the main driver of ESA's new Earth Observation (EO) science strategy. The document outlines 25 major scientific challenges covering all the different aspects of the Earth system, where EO technology and ESA missions may provide a key contribution. In this framework, and aiming at enhancing the ESA scientific support towards the achievement of "The Challenges", the Agency has launched the "Changing Earth Science Network", an important programmatic component of the new Support To Science Element (STSE) of the Earth Observation Envelope Programme (EOEP). In this foreword, the objectives of this initiative are summarized and the list of the projects selected in the first call, and recently completed, is provided. An in-depth overview of such projects will be provided in the following book chapters.

Keywords Earth observation · ESA · Living planet · Support to science element

D. Fernández-Prieto (✉) · R. Sabia · S. Dransfeld
European Space Agency, ESA-ESRIN, EOP Directorate,
Via GalileoGalilei s/n Frascati 00044 Rome, Italy
e-mail: diego.fernandez@esa.int

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1 ESA EO Science Strategy and the Support To Science Element (STSE)

Since their advent, satellite missions have become central in the Earth monitoring and understanding, resulting in significant progresses in a broad range of scientific areas. Although the Earth has undergone significant changes in the past, there is mounting evidence that those occurring during the last 150 years are affecting the various interactions and processes among the different components of the Earth system. Understanding those changes, their impacts on human lives and how anthropogenic activities affect the Earth system and its climate represent a major scientific endeavour where EO technology is already playing a key role.

In the mid-1990s, ESA set up its Living Planet Programme (LPP) working in close cooperation with the international scientific community to define, develop and operate focused satellite missions addressing some of the key questions at the core of Earth system science.

Moreover, realising the importance of further understanding the Earth and its response to these recent changes, the European Space Agency published "The Changing Earth: New Scientific Challenges for ESA's Living Planet Programme" as the main driver of ESA's new EO science strategy. The document outlines 25 major scientific challenges faced today covering all the different aspects of the Earth System and climate (Oceans, Atmosphere, Cryosphere, Land Surface, Solid Earth), where EO technology and ESA missions may provide a key contribution, namely:

The Challenges of the Oceans

1. Quantify the interaction between variability in ocean dynamics, thermohaline circulation, sea level, and climate.
2. Understand physical and bio-chemical air/sea interaction processes.
3. Understand internal waves and the mesoscale in the ocean, its relevance for heat and energy transport and its influence on primary productivity.
4. Quantify marine-ecosystem variability, and its natural and anthropogenic physical, biological and geochemical forcing.
5. Understand land/ocean interactions in terms of natural and anthropogenic forcing.
6. Provide reliable model- and data-based assessments and predictions of the past, present and future state of the ocean.

The Challenges of the Atmosphere

1. Understand and quantify the natural variability and the human-induced changes in the Earth's climate system.
2. Understand, model and forecast atmospheric composition and air quality on adequate temporaland spatial scales, using ground-based and satellite data.
3. Better quantify the physical processes determining the life cycle of aerosols and their interaction with clouds.

4. Observe, monitor and understand the chemistry-dynamics coupling of the stratospheric and upper tropospheric circulations, and the apparent changes in these circulations.
5. Contribute to sustainable development through interdisciplinary research on climate circulation patterns and extreme events.

The Challenges of the Cryosphere

1. Quantify the distribution of sea-ice mass and freshwater equivalent, assess the sensitivity of sea ice to climate change, and understand thermodynamic and dynamic feedbacks to the ocean and atmosphere.
2. Quantify the mass balance of grounded ice sheets, ice caps and glaciers, partition their relative contributions to global eustatic sea-level change, and understand their future sensitivity to climate change through dynamic processes.
3. Understand the role of snow and glaciers in influencing the global water cycle and regional water resources, identify links to the atmosphere, and assess likely future trends.
4. Quantify the influence of ice shelves, high-latitude river run-off and land ice melt on global thermohaline circulation, and understand the sensitivity of each of these fresh-water sources to future climate change.
5. Quantify current changes taking place in permafrost and frozen-ground regimes, understand their feedback to other components of the climate system, and evaluate their sensitivity to future climate forcing.

The Challenges of the Land Surface

1. Understand the role of terrestrial ecosystems and their interaction with other components of the Earth System for the exchange of water, carbon and energy, including the quantification of the ecological, atmospheric, chemical and anthropogenic processes that control these biochemical fluxes.
2. Understand the interactions between biological diversity, climate variability and key ecosystem characteristics and processes, such as productivity, structure, nutrient cycling, water redistribution and vulnerability.
3. Understand the pressure caused by anthropogenic dynamics on land surfaces (use of natural resources, and land-use and land-cover change) and their impact on the functioning of terrestrial ecosystems.
4. Understand the effect of land-surface status on the terrestrial carbon cycle and its dynamics by quantifying their control and feedback mechanisms for determining future trends.

The Challenges of the Solid Earth

1. Identification and quantification of physical signatures associated with volcanic and earthquake processes—from terrestrial and space-based observations.
2. Improved knowledge of physical properties and geodynamic processes in the deep interior, and their relationship to Earth-surface changes.

3. Improved understanding of mass transport and mass distribution in the other Earth System components, which will allow the separation of the individual contributions and a clearer picture of the signal due to solid-Earth processes.
4. An extended understanding of core processes based on complementary sources of information and the impact of core processes on Earth System science.
5. The role of magnetic-field changes in affecting the distribution of ionised particles in the atmosphere and their possible effects on climate.

To reinforce this strategy, in 2008 it was established the Support to Science Elements (STSE) (www.esa.int/stse), to provide scientific support for both future and on-going missions, by taking a pro-active role in the formulation of new mission concepts and products, by offering support to the scientific use of ESA EO multi-mission data and promoting the achieved results.

In this context, STSE main pillars aim at:

- Developing novel mission concepts in preparation for the next generation of European scientific missions;
- Developing advanced algorithms and innovative products that exploit the increasing ESA multi-mission capacity;
- Reinforcing ESA collaboration with the major international scientific programmes and initiatives in Earth system sciences;
- Support the Next Generation of Earth System European Scientists (The Changing Earth Science Network).

2 The Changing Earth Science Network

As one of the main programmatic components of the STSE, ESA launched in 2008 a new initiative—the Changing Earth Science Network—to support young scientists to undertake leading-edge research activities contributing to achieve the 25 scientific challenges of the LPP by maximising the use of ESA data.

The initiative is implemented through a number of research projects proposed and led by early-stage scientists at post-doctoral level for a period of 2 years. Projects undertake innovative research activities furthering into the most pressing issues of the Earth system, while exploiting ESA missions data with special attention to the ESA data archives and the new Earth Explorer missions.

Specifically, the initiative aims at:

- Contributing to the scientific advancement in Member States towards the achievement of the new 25 strategic challenges of the Living Planet Programme;
- Fostering the use of ESA EO data by the Earth Science community maximising the scientific return (in terms of scientific results and publications) of ESA EO missions;
- Contributing to consolidate a critical mass of young scientists in Europe with a good scientific and operative knowledge of ESA EO missions, assets and programmes;

Fig. 1 Distribution of the participants at the Changing Earth Science Network

- Promoting the development of a dynamic research network in ESA Member States addressing key areas of relevance for ESA missions and the ESA science strategy;
- Enhancing interactions, exchanging know-how and allowing cross fertilisation between ESA and Earth science laboratories, research centres and universities.

The first call for proposals, issued in 2008 and implemented in 2009, resulted in the selection of 11 post-doctoral scientists from the Agency's Member States based on the scientific merit of the individual projects. The final results of this call, discussed in the following chapters, include several important advances and insights in the use of ESA EO data to address some of the key current Earth science open points. A second call for proposals was issued in early 2010 to be implemented between 2011 and 2013, resulting in a further selection of 10 leading-edge research activities, which are currently on-going. A new call is in preparation and will be issued in early 2012. The map below shows the geographic distribution of the individual researchers' institutes (Fig. 1).

This volume collects some of the results obtained by the first set of projects started in 2009 and completed in 2011 (table below provide a complete list of these projects). They describe research activities exploiting data coming from several remote sensors onboard a wide suite of ESA (ERS-1/2 and Envisat), EUMETSAT, NASA and JAXA satellites (among others). The authors remarked the envisaged enhanced capabilities that will be offered in the near future with the launch of the Sentinel satellites of the GMES programme.

Acronym	Full project title	Researcher	Institute
ASSOCO	Assimilation of ocean colour satellite data to monitor the biogeochemical state of oceans and estimate its variability	Maeva Doron	Laboratoire des Ecoulements Géophysiques et Industriels, MEOM-LEGI, Grenoble, France
CARBONGASES	Retrieval and analysis of CARBON dioxide and methane greenhouse GAses from SCIAMACHY on Envisat	Oliver Schneising	Institute of Environmental Physics (IUP), University of Bremen, Bremen, Germany
CHOCOLATE	CH_4, H_2O and CO from Limb middle-ATmospher Emissions	Maya García-Comas	Instituto de Astrofísica de Andalucía (CSIC), Granada, Spain
CLARIFI	CLouds and Aerosol Radiative Interaction and Forcing Investigation: the semi-direct effect	Martin de Graaf	Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands
DECPHY	Global ocean analysis of decadal covariability in phytoplankton and physical forcings through satellite remote sensing, in situ measurements and upper ocean modelling	Elodie Martinez	Laboratoire d'Océanographie de Villefranche (LOV-OOV), Villefranche sur Mer, France
DIMITRI	DIagnostics of MIxing and TRansport in atmospheric Interfaces	Elisa Palazzi	Istituto di Scienze dell'Atmosferae del Clima (ISAC-CNR), Bologna, Italy
FEMM	Fire Effects Modelling and Mapping	Patricia Oliva-Pavón	Department of Geography, University of Alcalá, Alcalá de Henares, Spain
INCUSAR	INverting consistent surface CUrrent fields from SAR	Knut-Frode Dagestad	Nansen Environmental and Remote Sensing Center, Bergen, Norway
ISMER	InSAR Survey of the Magmatic Effects on Rift development	Juliet Biggs	University of Bristol, Bristol, UK
OCCUR	Study of the chemistry-climate coupling in the UTLS region with satellite measurements	Enzo Papandrea	Department of Physics and Inorganic Chemistry, University of Bologna, Bologna, Italy
OC-FLUX	Open ocean and Coastal CO2 fluxes from Envisat and Sentinel-3 in support of global carbon cycle monitoring	Jamie Shutler	Plymouth Marine Laboratory, Plymouth, UK

In summary, the projects described in the following provide cutting-edge advanced exploitation of satellite data relevant to a broad range of scientific applications, towards an improved monitoring of the integrated Earth system.

3 Project List

The previous table provides a complete list of the projects.

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