The *Ultimate Earth Project* as an FET Flagship

About us

We (Prof. John Ludden, executive Director British Geological Survey, UK, and Prof. Philippe Gillet, Earth and Planetary Science Laboratory, École Polytechnique Fédérale de Lausanne, Switzerland) represent a consortium of leading earth and environmental scientists, and informatics experts who are part of the Earth and environmental sciences community working on the Earth system's envelopes, from its core to the outer atmosphere and external forces impacting on it. The consortium comprises scientists who lead institutions, infrastructure projects major science initiatives and are linked to global earth and environmental programmes. Our intention is to harmonise and integrate decades of data collection by the national research and government agencies and through European projects into an interoperable and open reference frame for the Earth.

The European Earth and Environment community

Infrastructures

- ICES (http://www.icesfoundation.org/)
- EPOS (http://www.epos-eu.org/)
- IPBES (http://www.iucn.org)
- ICOS (https://www.icos-ri.eu/)
- ENVRI+ (http://www.envriplus.eu/)

The thematic communities and initiatives

- National meteorological survey and ECMWF
- Climate modelling institutes and research centres
- Internal Earth research community: gravity, seismic, magnetic, volcanoes, geochemistry
- Solar Earth interaction research centres
- National Oceanographic Institutions
- National surveys and EuroGeoSurveys (http://www.eurogeosurveys.org/)
- Biodiversity research centres and organisations
- EEA
- ESA and national space agencies
- Copernicus
- Global initiatives: GEO, Future Earth, OneGeology

We, the proposers, have engaged with communities that cover the spectrum from the core of the Earth to the outer atmosphere, including the external solar forcing and have strong buy in to the Ultimate Earth approach. As would be expected some groups are sceptical of the scale of our ambition, some very open and realising that a FET initiative would introduce the step change that would result in European global leadership in this area.

This paper is an informal contribution that has been elaborated through a virtual dialogue and a meeting in Geneva on the 15th April 2016, organised by the EPFL, Switzerland and BGS, UK. Others consulted, attending the meeting and in support represent the following institutions: (Consortium Geo.8 - European Alliance for Earth Sciences: GFZ/Germany, INGV/Italy, ETHZ/Switzerland, Geoplanet/Poland, U. Utrecht/The Netherlands, CSIC-ICTJA/Spain, BGS/UK, IPG-Paris/France), INSU CNRS France, IPSL UPMC, France, ISE Poland, ICES Foundation, GEO Geneva, LAEO Portugal, CNES France, Univ. Aberdeen Scotland, Univ. Bremen/Germany, Satellite applications CoE, Univ of Leicester UK.

What is the challenge and the vision?

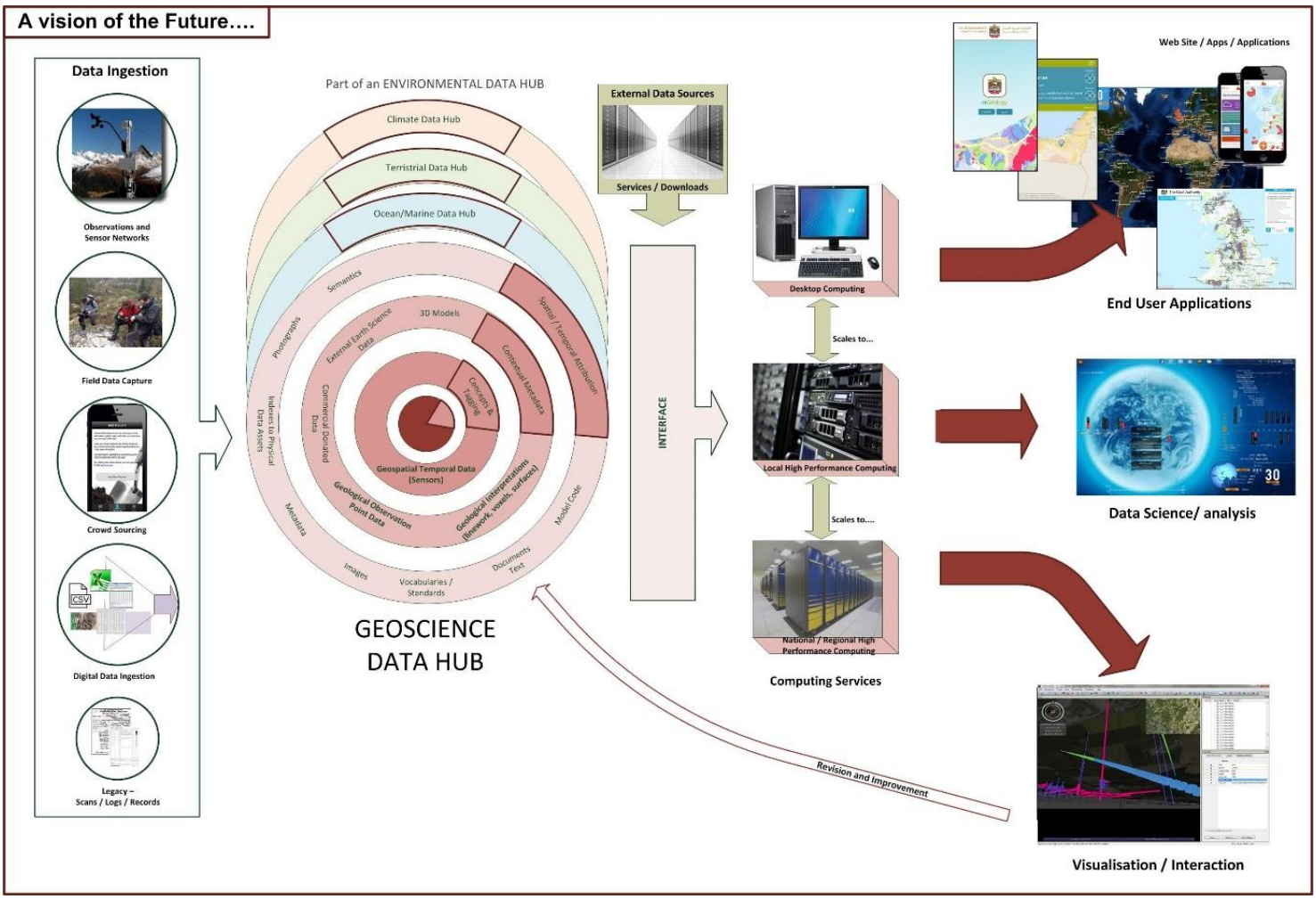
Living sustainably on the Earth as it changes requires us to develop a full understanding of the Earth system. As societal demands on the Earth increase, Policy makers and Industry must have the information necessary to make informed decisions to ensure society's safety, well-being and economic demands, from understanding and mitigating natural hazards, to anthropogenic effects on climate change and sustainable management of natural resources. Public perception, understanding and acceptance of how the Earth may change in their life-time or in future generations need to be addressed urgently. Research agencies, industry and government across Europe must engage and define a new approach to address this challenge. Underlying this is the need for data on the Earth system which can be accessed, openly communicated and, when appropriate, sourced by all stakeholders and the public to define realistic base-lines and models of the Earth. We believe that Europe, through a FET Flagship, can take global leadership in the "Ultimate Earth Project". This model will need to scale to accommodate discipline specific (climate, resources, health etc.) and national Earth, environment and socio-economic models that will develop in parallel.

Data on the Earth and its environment is currently held in disparate poorly connected and often undiscoverable archives, including both public (Government and research agencies) and private sector (Industry). Despite efforts in consolidating infrastructures (such as EPOS, ICOS, GEO), data sets will remain incomplete and in siloes of disciplinary fields or encumbered by national controls and thus not integrated enough to create comprehensive models for environmental baselines that are useful for predicting the future of the planet. This state of affairs will persist over the next decades unless we act now, on an appropriate scale and ambition. Furthermore, there is a vast wealth of new data being produced through satellites, Earth based observing systems and community sourced data systems (social media, connected devices), and a significant proportion of these data will continue to be lost or undiscoverable unless we open these archives and their associated models.

The idea to integrate the vast amount of data relevant to the Earth from a wide variety of sources is not new. The need for such an Ultimate Earth project (e.g. the Japanese Earth simulator) has been posed in past decades and attempts have met with partial success, with some sub-disciplines arguing that investment is better focussed on regional or disciplinary problems, as the science and socio-economic questions are more apparent. Notwithstanding this, and going back to the early 20th century Vernadsky, Taillard de Chardin, and more recently Lovelock and Margulis, the need to integrate the components of the Earth system has been apparent. We do not propose to reinvent existing programmes, but we believe that diverse information and observing systems and informatics are now poised to achieve the challenge of the Ultimate Earth Project and that European scientists through FET will liberate new paradigms for the Earth and create new ICT technology and associated commercial advantages and social well-being for Europe and society in general.

We need to assess now how we can **provide and then maintain a credible model for the Earth in all its states – physical, chemical and biological.** Our key challenges are to **understand** the current state of the earth (to create a reference model, baseline model), and then use this to understand how to it will develop. Ultimate Earth must have as a goal, to simulate the planet. This should enable us to understand and predict the **human drivers of change**, the implications for **global security and reduction of risk.** This should include understanding, predicting, and identifying the consequences of things such as sea level rise, loss of biodiversity and ecosystem services, ocean acidification, impacts of climate on agriculture, resource security, geohazards and geoengineering.

We, the proposers and the community we stand to represent, push for a community-driven project to transform the landscape of research on the planet and its impacts on society and economy. Researchers should be the main actors but stakeholders (governments, industry and the public) will engage in data collection delivery and validation. We feel that it is time to be ambitious and to bring together all the scientific communities that work on the Earth to invite them to share their data by provision of tools for handling and processing the data - integrating them into models of our planet and new data-based services. The approach must be transparent and inclusive to accelerate our ability to understand and predict the entire earth system.



Ultimate Earth plays directly into the EC Digital single market (http://ec.europa.eu/atwork/pdf/cwp_2016_en.pdf) in that it in itself will provide a connected single model (in reality a portfolio of models, e.g. the via the **EC Model Web**) that will break down barriers and connect silos (the earth's envelopes and external forcing on them) and provide a resource for social-economic development; both in quality of life and in economic development through new environmentally related digital technology. Ultimate Earth approach will be ambitious, provide a step change in the provision of e-infrastructure for the Earth and environmental science across all of the Earth system's envelopes. It must provide value for money in that Europe and the globe would get better predictions and hence decision making, by modelling the interconnected envelopes: a fully interconnected series of models being the "Ultimate Earth" objective, hence the use of this term. Ultimate Earth will:

- Provide a "**scaffolding**" for research data and development work - a way to organize and prioritize it;
- **Identify gaps** in data, science, and models;
- Support needed **developments in both science and technology.**

Why is it good for Europe?

Understanding in detail the functioning of the Earth in relation to human activity is one of the greatest challenges facing 21st century science. If we can rise to the challenge, we can gain profound insights into the mid- and long-term future of the planet and how we can use in a sustainable way resources (including minerals, water and biodiversity); face climate change and its impacts; anticipate and mitigate hazards; and set-up the boundaries for the energy revolution. Today, for the first time, modern ICT has brought these goals within sight and it is possible to build a world-leading federated ICT infrastructure for earth and environmental research, centred in Europe. Europe has taken the global lead in construction of Earth and environmental infrastructure, of note are EC and ESA initiatives (Cryosat, Envisat, Swarm, GRACE etc), but more specifically the Copernicus project with its Sentinel satellites and ground-based component, and distributed infrastructures EPOS, ICOS Earthwatch and associated integration programmes (ENVRI+). Europe has HPC power and will invest in the EU HPC Cloud (https://ec.europa.eu/digital-single-market/en/european-cloud-partnership). Furthermore, European nations have globally leading operational agencies (ESA, ECMWF, geological surveys, ocean- and eco-ecosystem research establishments) and in some nations, outperforms research in the USA, Japan and China.

Europe is strategically poised to lead a step-change in our ability to model the Earth and solve critical problems of relevance to the security of humankind. In the same way as the Human Brain project has spawned parallel initiatives in the USA and China, we anticipate these and other nations will accelerate their activities in e-infrastructure development around the Earth and its environment. We believe that Europe should and can lead this global challenge

What would it take to do it?

Ultimate Earth relies on the development of a cyberinfrastructure built to meet the current and future needs of Earth and environmental scientists. We must push for a community-driven project to transform the landscape of research on the planet and its impacts on society and economy. What we aim to foster finds its roots in several existing initiatives among which are the Earth simulator in Japan, the Earth Cube in the USA and the ICES Foundation initiative http://www.icesfoundation.org/. It follows on from what the neuroscientific community has launched for brain research through the FET Flagship “Human Brain Project”. This is not without its challenges, the foremost being a engendering a belief from the science silos that by building interlinked and interoperable models, they will create better and more impactful solutions and help solve UN sustainability objectives.

All the scientific fields involved in understanding the Earth must be engaged: Solid Earth, Atmosphere, Hydrosphere, Cryosphere, Biosphere, including extra-terrestrial forces, resource and social and economic sciences. Through, "The Ultimate Earth", individuals and institutions must create the scaffolding upon which data systems can be layered and models integrated and archived and through which we will be able to address and find answers for some of the fundamental questions which affect the security of humankind on this planet

European citizens are increasingly connected through mobile devices and the “Internet of Things”. We are already witnessing a step change in environmental awareness and are on the cusp of an environmental revolution where European citizens will hold governments accountable and force behavioural changes on industry. Industry must exploit this requirement for environmental knowledge and create products and wealth through environmental digital

technology, including new, faster and more connected sensor networks, requiring improvements particularly in data transfer and storage, thus promoting economic growth and prosperity in Europe.

The key steps are to:

Create and Develop an Earth Simulation Platform operated as a community resource. To generate a comprehensive 3D + time model/representation of the Earth including: the Solid Earth, Atmosphere, Hydrosphere, Cryosphere, Biosphere, and anthropogenic changes such as resource depletion. This must encompass appropriate timescales for different processes and systems: e.g. climate/weather systems, plate tectonics/geohazards, ocean circulation/tsunamis, erosion/landslides, vegetation/seasons, biosystem cycle and biodiversity as well as major geochemical cycles.

Use the Model Web to support comparisons between models based on different tools and approaches. Track missing key data from the outcomes of the models to ask for further data/samples key to the Ultimate Earth Project and appropriate for distributed and interactive models**.**

Liberate the data**:** Commitment to improving data transfer and storage and creation of recognised hubs with Core provision and distribution project as implied by the FET concept is critical. We must break down the silos of academia, to allow data integration, innovative transformation and commercialisation in the earth and environmental milieu.

Establish standards: Data types and formats are multiple: physical and chemistry of rocks, water and the atmosphere, species and biodiversity, geohazards, sea level rise, observations of the Earth from space (Copernicus) etc., and their use will require harmonisation and integration. We must therefore:

- Establish standard software for federated active data repositories with a focus on European data producing sites.
- Extend federated data repository networks to include key strategic sites worldwide.
- Develop continuous integration of datasets from remote repositories, automated feature extraction and initial data-driven ontologies. Develop additional curation workflows and tools to support new datatypes.
- Enhance data mining infrastructure to support new machine vision classifiers for additional datatypes and features.
- Deliver data management tools for the analysis, mining and tracking of data in globally distributed repositories.
- Provide a “cockpit interface” for data management and visualization.

Use social networks**:** We should also interact with the “new generation of data providers” and utilise social networks and data gathered by citizens (crowdsourcing), and develop ways of validating and using these data alongside traditionally sources scientific data (these could include temperature, biological records etc.)

Promote the “green/blue economy”**:** data generated at vast expense are frequently underused (e.g. space data). We should “liberate the data” to permit their use in the creation of new industry and benefit the economy and well-being of society.

Work with data providers to open access to the data and create economic growth.

Increase accountability in industry, in particular in resource and waste management this will require openness and accountability, the costs of which would be passed onto consumers, thus efficient interoperable systems and environmental data management systems will be essential.

Build community buy-in: Europe has built strong communities in the Earth and environmental data science fields. The leaders of the various thematic communities, from solid Earth to the outer atmosphere, nevertheless, must committed to the project and believe that their science and its impact will benefit from the integrated model we propose. Community buy-in is paramount to tackle the challenges of integration.