A New Era for Open Science and Earth Observation

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Planet Earth today is experiencing such environmental pressure that the life for humans is severely threatened by our past 200-year *abuse* of Earth's non-sustainable resources. Climate change, geohazards (both natural and anthropogenic), the food-water-energy nexus and population growth, with 9 billion forecasted by 2050, pose an existential challenge we must face immediately. Science together with political will are essential to finding solutions.

Never before have we had in our hands such powerful tools for monitoring, modelling and forecasting Earth phenomena. We need to synergistically leverage the different scientific pieces of the puzzle and combine them in a way to make life better for ***all*** humanity. This is the purpose of this session, to merge different aspect of Earth Observation Open Science to be more accessible to the challenge ahead.

The Digital Earth vision is a concept started in 1998 that has being implemented not only in the scientific realm but also in our daily life. It is a digital revolution, whose full effects were only able to imagine up until now. Earth Observation not only plays a key role for understanding the effects of our behavior but is the keystone that will provide us with a new era for scientific discovery. Productive Earth observation requires continuous availability of worldwide open data from all the Earth observing sensors. Access to this critical information monitoring Earth's vital signs is needed for use in multipurpose applications serving the science of climate change, atmospheric conditions, ocean status, land coverage, the rapidly disappearing cryosphere (our air conditioner) and ultimately our ability to maintain a sustainable planet and survive our more aggressive instincts.

The Internet of Everything (IoE) is emerging as the medium for this 'open' Earth observation. In the past twenty years internet connectivity has gone from less than 2% to now almost 50% at 3 billion and continues to increase. The Internet of Everything has four components (things (objects), data, processes and people), only the first one, things, has partially found its conceptualization as the Internet of Things (IoT). For the other three we are still at the very beginning of IoE. Big data and Earth System Data Cubes, open/linked/machine readable data, Citizen Science, geo-crowdsourcing and Volunteered Geographic Information (VGI) are like "children" taking their first steps. With hope for a beautifully meaningful Internet of Everything, this open information access and sharing can allow for faster and more intelligent decision-making guided by social media access combined with the results of a more collaborative international scientific community.

Meanwhile, the rise of cloud computing is changing the way we access and exploit data. Cloud-based platforms are being built which can drive innovation and growth in user applications, moving users (from scientists to citizen scientists) closer to the data. Privacy and citizen access, even researcher access, to these resources, and even access to the data remain major obstacles.

As a consequence of these activities, the Earth Observation Open Science is evolving in its modus operandi of doing research and organizing science for Society, toward openness, participation and sharing, thus towards its new true 2.0 for all status.

This session is a collection of relevant contributions in these extraordinarily innovative fields.

Alan O'Neill key note (Open EO Science and Innovation. Join the (R)evolution? by Alan O'Neill, Pierre Philippe Mathieu, Yves Louis Desnos and Michael Rast) focuses on Science 2.0 concepts and challenges, identifying the rapid and systematic changes involved in doing Research and organizing Science driven by the advances in ICT and digital technologies, especially when combined with a growing demand to do Science for Society (actionable research) and in Society

(co-design of knowledge). The talk gives a brief overview of EO activities aiming to facilitate the exploitation of large amount of data from EO missions in a collaborative, cross-disciplinary, and open way, going from the science to applications, and involving education and public outreach.

Edward Anderson and Mark Iliffe from World Bank present their activities in Dar Es Salaam (Tanzania) for managing flooding and for helping people creating resilient cities against such events that very often in poor countries turn out to become major catastrophes (Using Satellite, UAV and Citizen Data for Flood Management in Dar es Salaam Tanzania). Despite the increasing citizens' involvement, a fundamental role is still played by EO products and this requires a more flexible, intuitive and user-orientated access to data.

The ESA platform for new EO data is the subject of next presentation (SNAP the sentinel application platform by Carsten Brockmann and Norman Fomferra). SNAP (ESA SeNtinel Application Platform) allows the synergistic use of various EO data with common and specific advanced tools. It is fully open source, GPL 3 licensed. Sentinel (and other products) come with new features, like per pixel uncertainty, multiresolution and very flexible file format. The platform manages and publishes very large raster sets of Sentinel Products (40.000 x 40.000 pixels and larger) and Big Data Volumes (Sentinels 1+2+3 data correspond to Terabytes per day and Petabytes per mission). In order to deal with this big and complex data, the general approach followed is that of processing the data at its source instead of moving the data to other locations for processing.

Another relevant application is that presented by Constantinos Cartalis (EO information as a service to citizens regarding the quality of life in cities). An aggregate quality of life (QoL) index based on physical characteristics deduced from EO information and on attributes of the economic and social environment as obtained for census data. The theme is of critical relevance considering the large level of urbanization in Europe (90 % of population live in cities and the urbanization trend is increasing). The data to be considered for the index computation brings us immediately to big geo-data in terms of volume, velocity, variety and veracity.

First, all this data needs to be visualized. Traditional 2D web viewers have been surpassed in recent years by virtual globes, which provide a more immersive navigation of imagery and maps. The Java and Web versions of NASA WorldWind, presented by Maria A. Brovelli, open up new exciting possibilities for virtual globe applications. The use-cases include social media type activity as well as more sophisticated urban infrastructure management, climate research, disaster response and all types of navigation, from personal directions to industrial supply chain, to aeronautics and satellite tracking. (NASA Web WorldWind: welcome to the new era of virtual globes by Maria A. Brovelli, Patrick Hogan, David Collins, Tom Gaskin and Giorgio Zamboni).

Conor O'Sullivan in his presentation examines the changing landscape of EO technologies and markets starting from existing publications and from the knowledge of experts, gathered from workshops and interviews. (Earth observation for the 21st century). He emphasizes the importance of providing flexible, intuitive and user-orientated access to data to stimulate the interest of new non- traditional EO users. His conclusion is that ESA and industry share an important role in evangelizing and creating new opportunities for the European EO sector.

A relevant example of the analysis proposed by O'Sullivan is that presented by Duncan Watson-Parris in his "The Community Intercomparison Suite (CIS): an open-source toolbox" (by Duncan Watson-Parris, Nick Schutgens, Zak Kipling, Philip Stier, Philip Kershaw, Bryan Lawrence, Nick Cook). CIS is a flexible tool, which allows the straight-forward quantitative analysis, intercomparison and visualisation of remote sensing, in-situ and model data and many other data sources 'out-of-the-box', such as ESA Aerosol and Cloud CCI product, MODIS, Cloud CCI, Cloudsat, AERONET. The choice of an open-source, community developed tool opens up a huge amount of data, which would previously have been inaccessible to many users. Moreover, it is important to

provide replicable, repeatable analysis, which scientists and policy-makers alike can trust and understand.

Opening data and removing barriers to sharing of that data is a necessary first step to enable access and use of the Earth Observation data, but this is not enough. Data resources need to be well signposted, easily accessible and well meta-tagged. MYGEOSS project, presented by Elena Roglia (From Free and Open Earth Observation Data to Innovative Applications: the MYGEOSS Approach by Elena Roglia, Max Craglia and Sven Schade), aims to raise awareness of the opportunities offered by using Open Earth Observation data through open calls for the development of innovative web and mobile Apps.

Some recommendations and lessons learnt can be synthetized as outcome of the session:

1) The concepts of sharing, collaboration, openness and inter-disciplinarity are fundamental for EO Science 2.0 and for innovation.
2) Open data and open tools are strictly related. They are key driving elements in a robust economy.
3) The involvement of citizen (and of communities) requires facing big challenges, but this also creates big opportunities. Eliciting citizens' involvement and actions is also a way to educate them to better understand the world they live in and hopefully stimulate a stronger sense of responsibility for it.
4) ESA and industry share the important role in evangelizing and creating new opportunities for the European EO sector, namely involving new actors external to the traditional EO communities.
5) If we want to maximize innovation in the areas of spatial data management and scientific research for both government and private industry, we need a highly sophisticated open source web platform for visualizing and delivering data that all of us can share equally, whether for commercial use or free and open. This allows information to be exchanged in ways that facilitate maximum scientific awareness while also encouraging unlimited innovation, by academia, government research and private industry.
6) Looking at processes, for instance the climate system, there are many tools available to simply peruse specific satellite products, but there is a gap in available tools for analysing satellite data, e.g. comparison or modelling of data with other in-situ measurements. If ESA wants to get maximum value from their data, it needs to be more accessible to combine it with the vast amount of other data available today.
7) Opening data and removing barriers to its sharing is a necessary first step to enable access and use of the data but is not enough. Data resources need to be well signposted, easily accessible and well meta-tagged. This generic good practice is not easy to apply in the case of Earth Observation data where the scientific datasets are often large and complex and it is not possible to adopt the Linked Data approach and five-star rating of many open data initiatives, which largely deal with documents or relatively small datasets. The ways in which datasets are provided may suit the specialist user who is already familiar with the types of data and the approach to data delivery. But, unless this data is available via standard protocol, such as OGC's WMS et al, this same data would probably require a significant degree of data preparation and pre-processing to satisfy the needs of non-specialist users. This is a limitation but also a potential opportunity for the private sector, including SMEs, to act as intermediaries and create information products more suitable to generic users. It is also reminder of the opportunity for all data to comply with OGC standards.

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