

Newsletter

Integrated Land Ecosystem - Atmosphere Process Study

Special issue on Environmental Research Infrastructures

Special guest editors

Ketil Koop-Jakobsen
COOPEUS project

Yannick Legré
ENVRI project





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Erik Palmenin aukio
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Executive Editor

Tanja Suni

Guest editors

Ketil Koop-Jakobsen and Yannick Legré
kjakobsen@marum.de / yannick.legre@egi.eu

Newsletter Coordinator

Magdalena Brus

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News and Science Highlights

European research infrastructures for excellent science: open calls of Horizon 2020

The main objective of the action is to endow Europe with world-class research infrastructures, which are accessible to all researchers in Europe and beyond and fully exploit their potential for scientific advancement and innovation.

Four calls are open with a budget of 277 million € for 2014:

- Developing new world-class research infrastructures
- Integrating and opening RIs of European interest
- Development, deployment and operation of ICT based e-Infrastructures
- Fostering the innovation potential of RIs and their human resources, support to policy and international cooperation.

All information on the action, work programme and how to apply is available on the H2020 website: <http://ec.europa.eu/programmes/horizon2020/en/area/research-infrastructures>

Principles of data management and sharing at European Research Infrastructures

Under the umbrella of BioMedBridges, the biomedical sciences research infrastructures involved in the project plus AnaEE, ISBE and MIRRI as well as LifeWatch developed a document on the Principles of data management and sharing at European Research Infrastructures. The document makes key recommendations on how data management and sharing via the research infrastructures can be supported and encouraged.

The detailed recommendations and the background and context for data management and sharing at the Research Infrastructures are described in the full version of the document, which can be downloaded here:

<http://zenodo.org/record/8304#.U3NLAk2SyAU>

Transformations to Sustainability Programme

The International Social Science Council (ISSC) is pleased to announce the launch of a new global research funding programme on transformations to sustainability. The programme will promote research on the fundamental and innovative processes of social transformations needed to secure effective, equitable and durable solutions to some of today's most urgent challenges of global change and sustainability.

A minimum of three Transformative Knowledge Networks will be funded. Selected Transformative Knowledge Networks will each receive up to €300,000.00 per year over a three-year period.

Issue of call: End of October 2014

Submission deadline: Mid-January 2015

First Copernicus satellite, Sentinel 1A was launched successfully!

The ability of European citizens, policymakers and service providers to access key environmental data on a routine basis will take a major step forward following the launch of ESA's Sentinel-1A satellite. Sentinel 1A is the first satellite of the first of six families of dedicated satellite missions, which will be launched between 2014 and 2021.

The launch can be viewed here: www.youtube.com/arianespace

Dr. habil. Werner Kutsch appointed as ICOS Director General

In December 2013 ICOS Stakeholder Interim Council appointed Dr. habil. Werner Kutsch as ICOS Director General. Director General will lead the ICOS RI Head Office. The office is hosted by Finland with the secondary node in France.

GEO Appathon - Unleash the power of Earth Observation data to allow us all to make smarter decisions

The GEO Appathon is a global App development competition open to any non-commercial individual, team or entity (students, scientists and developers) with a passion for unleashing the power of Earth Observations (EO) to allow us all to make smarter decisions about the planet.

The Appathon kicks off on 7 May 2014 and runs until 31 August 2014. Visit the GEO Appathon website (www.geoappathon.org) for more rules, details of how to register and information about how you can help us unleash the power of Earth observation data.

The 5th PEEEX Workshop and The 1st Open Pan-Eurasian Experiment (PEEX) Science Conference 2015

PEEX "Pan-Eurasian Experiment" study is a multidisciplinary climate change, air quality, environment and research infrastructure program focused on the Northern Eurasian particularly arctic and boreal regions.

The Science Conference and Workshop will take place from Tuesday 10 February to Friday 13 February 2015, in Helsinki, Finland. The goal of the conference is to bring professional and scientific experts together under PEEEX research themes related to atmosphere, land ecosystems, aquatic, anthropogenic activities, and Northern societies in the Northern Pan-Eurasian region. The Workshop aim is to take next steps for PEEEX implementation. Deadline for abstract submission: 1. December 2014. More information in www.atm.helsinki.fi/peex/



Wouter Los¹ and Christoph Waldmann².

¹ENVRI coordinator

²COOPEUS coordinator

Research Infrastructure collaboration improves services for environmental scientists



When we read about the grand challenges, as identified by national governments and the European Union, it is obvious that their concerns are about the well-being of our society and our environment. These are interconnected challenges since a sustainable development of our society heavily relies on an intact environment. This is increasingly the basis of frontier research directed at understanding the interaction of different environmental systems. The core of the Earth and the solar radiation are the driving forces of the planet surface and marine systems, as well as the atmospheric system. The living environment – biodiversity and ecosystems – is buffering these abiotic systems providing services with relatively stable atmospheric gas composition and temperature.

Many scientific efforts are now directed at understanding these system interactions meaning that we are in a phase of developing a more holistic approach to environmental sciences. But these efforts are seriously handicapped by a lack of data with sufficient temporal and spatial coverage. Rather than only focusing on small-scale controlled experiments, scientists are currently facing the challenge of developing models for each system and on interacting system processes. Obviously these challenges can only be met by an integrated, international effort where expert groups from different disciplines are working closely together.

Research infrastructures play a key role in these efforts providing the capabilities and services to produce, collect and archive key data and to serve these data to the scientific community, and to offer functionalities to integrate and process big data from various scientific disciplines with targeted computational capacity. This iLEAPS issue is presenting a number of existing and emerging international research infrastructures with a mission to fulfill this role of providing new services in order to support frontier research and promote global integration of the research efforts on the world's grand environmental challenges. These stories tell how scientists and engineers are working closely together to construct and operate the larger facilities that single institutes and projects cannot afford.

The Research Infrastructure facilities are becoming a major part of the international research landscape. Their interactions with the scientific user communities are contributing to paving the way to a better understanding of environmental systems. It is essential that they capitalize on their joint potential to ensure that the international scientific community derives full value from the investments in these large-scale environmental projects, and will keep environmental scientists at the forefront of global research. To this end, a few EU-funded projects are fostering this joint potential.

One of the EU-funded projects is ENVRI, focusing on common operations of the Environmental Research Infrastructures¹. The project is developing common e-science components and services for their facilities with support from experts on information and communication technology. The results are speeding up the construction of the infrastructures and allow scientists to use the data and software from each facility to enable multi-disciplinary science. The ENVRI project is aiming to minimize the heterogeneity among environmental data infrastructures to offer common best practices and to provide technical tools to help them to better fulfill their scientific mission.

The COOPEUS project is focusing on improving the interoperability of European environmental research infrastructures and their US counterparts. Research infrastructures from five different domains of environmental research have been brought together to improve cross-disciplinary collaboration across the Atlantic, to learn from each other's experience and finally to improve access to data and information across discipline boundaries. The project is guided by the needs of the individual domains; in the current phase it is now focusing on demonstrating the benefits of merging the information coming from the domain specific data endpoints. Use-cases play a central role in this exercise. Both COOPEUS and ENVRI are also paving the ground for future efforts like activities planned within the Belmont Forum framework and they will act as supporting platforms for international initiatives like GEOSS and the Research Data Alliance.

For specific domains, there are also other global cooperative projects, for example Creative-B. This project brings together global infrastructures for biodiversity and ecosystem research across continents to identify common priorities with infrastructure interoperability, together with attention for legal and governance implications.

¹<http://envri.eu>

Emina Mamaca

Head of Euro-Argo Project Office, IFREMER Centre de Brest, Plouzané, France

Euro-Argo: A New European Research Infrastructure. A sustained contribution to a global ocean observing system



Euro-Argo
Research infrastructure for ocean science and observations

Mission
To allow active coordination and strengthening of the European contribution to the international Argo programme

Timeline
Start of construction: 2001
Start of operation: 2011

Estimated Costs
Preparation costs: 3.0 M€;
Construction Phase: not applicable
Operation Phase: 8.4 M€/year

Number of Partners
15

Coordinator
Dr. Pierre Yves Le Traon

Head of Project office
Dr. Emina Mamaca

Set up of ERIC (The legal framework for a European Research Infrastructure Consortium)
May 2014

Website
www.euro-argo.eu

The science of climate dynamics and climate change is one of the most pressing issues of our century. Understanding and predicting changes in both the atmosphere and ocean are needed to guide international actions, to optimize governments' policies and to shape industrial strategies. This understanding requires global data sets of the highest quality. The Argo float is an autonomous instrument deployed worldwide which measures the temperature and salinity in the heart of the oceans.

Currently the international Argo programme has over 3,600 profiling floats. These floats measure temperature and salinity throughout the deep global oceans, down to 2,000 metres and deliver data in real time for operational users such as GMES-Copernicus Marine Core Services, MyOcean and researchers. This is the first-ever global,

in-situ ocean-observing network in the history of oceanography, providing an essential complement to satellite systems. One of Argo's most important contributions so far is a huge improvement in estimations of heat stored by the oceans - a key factor to gauge global warming and gain a better understanding of the mechanisms behind rising mean sea level. Argo has also brought remarkable advances in ocean forecasting and seasonal climate predictions. Maintaining the array's size and global coverage in the coming decades is the next challenge for Argo. At least 800 new floats will be required each year to maintain the 3,600 float array.

Euro-Argo will develop and progressively consolidate the European

Figure 1. Active Argo floats by country

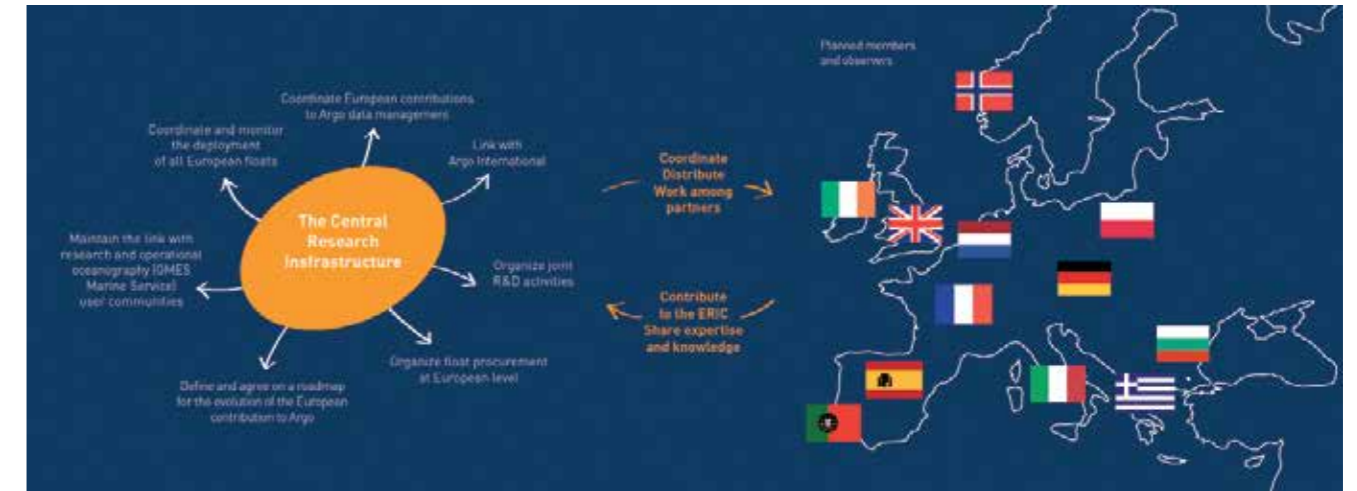


Figure 2. Central Research Infrastructure and distributed national facilities

component of the global network. Specific European interests also require increased sampling in some regional seas. Overall, the Euro-Argo infrastructure should comprise 800 floats in operation at any given time. The maintenance of such an array would require Europe to deploy about 250 floats per year.

Euro-Argo will optimize the European contributions to Argo and establish a high level cooperation between European partners. This will lead to an improved efficiency in all implementation aspects: operation at sea, array monitoring and evolution, technological and scientific developments, improving data access for research and operational oceanography users. A well-organized European research infrastructure will be highly beneficial for the Copernicus Marine Core Service and will strengthen European excellence and expertise in climate research.

Euro-Argo is one of the 35 new European research infrastructures selected by the European Strategy Forum on Research Infrastructures (ESFRI) in its first roadmap in 2006. Euro-Argo started a preparatory phase (15 partners, 12 countries) funded through the EU 7th Framework Research Programme to undertake the work needed to ensure that, by 2014, Europe will be able to provide, deploy and operate an array of 800 floats and to provide a world-class service to the ocean and climate research and operational oceanogra-

phy (GMES Marine Core Service) communities. The long-term structure for Euro-Argo is at the final step of its implementation. Its legal form follows the new EU legal framework for European Research Infrastructure Consortium (ERIC) which has been designed to facilitate the joint establishment and operation of research facilities of European interest.

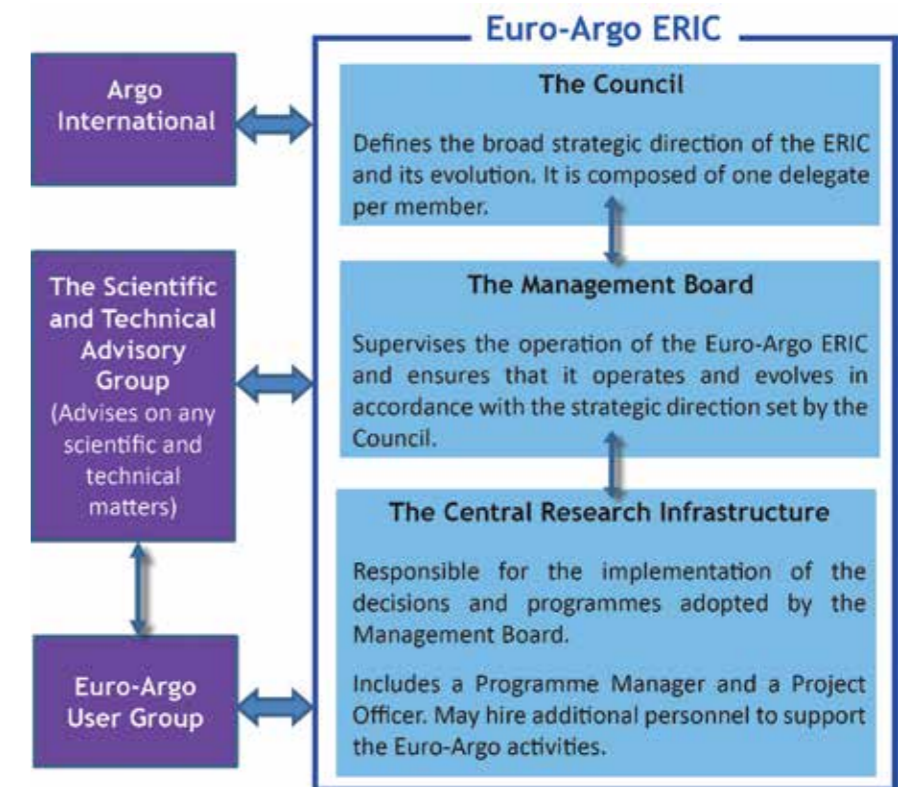
The Euro-Argo Long Term Research Infrastructure

The structure will include a central facility (Central Research Infrastructure) and distributed national facilities. The central Research infrastructure will

have a European legal structure to receive EC and national (member states) funding, to procure floats (includes logistics and test facilities) and to provide funding to the international structure.

After signature at ministerial level by different countries (Members are France, Germany, United Kingdom, Italy, Netherlands, Finland, Bulgaria, Greece and observers are Poland, Norway), the Euro-Argo ERIC is now validated at European level and will be formally in place (after publication in the Official Journal of EU) in the beginning of April 2014. The hosting institu-

Figure 3. The Euro-Argo ERIC Governance



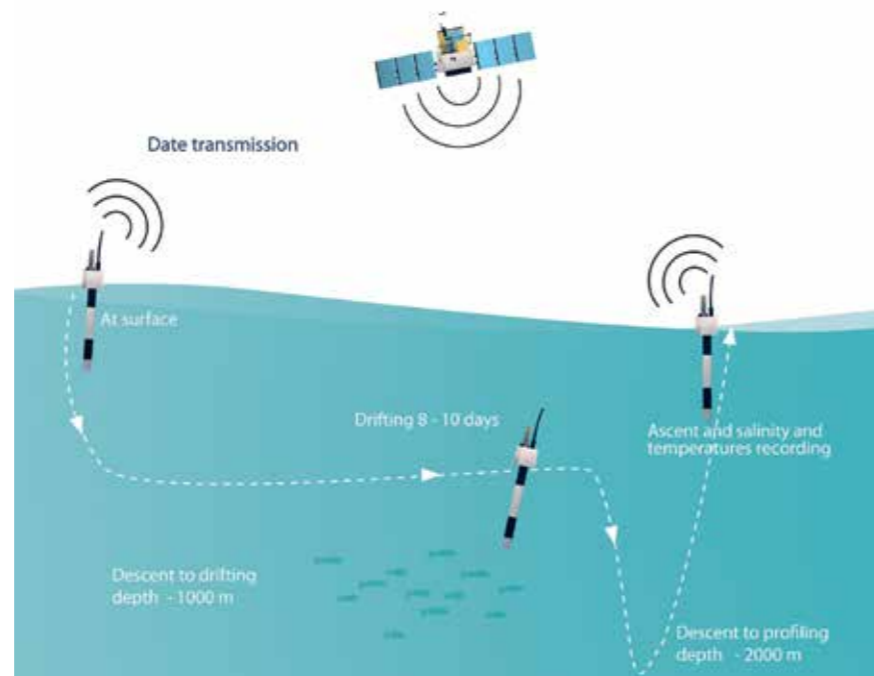
tion for the Euro-Argo ERIC is Ifremer (France) for the first 5 years.

A governance model for the structure has been defined (council, board, scientific and technical advisory group) and its main characteristics are agreed by all partners. ■

Emina.Mamaca@ifremer.fr

The international ARGO programme (for more details, see www.argo.ucsd.edu/) was initiated in 1999 as a pilot project endorsed by the Climate Research Programme of the World Meteorological Organisation, GOOS, and the Intergovernmental Oceanographic Commission.

The Argo network is a global array of autonomous instruments, deployed over the world ocean, reporting subsurface ocean properties to a wide range of users via satellite transmission links to data centres.



Autonomous profiling floats are the basic technology on which the Argo observing array is based. The Argo float is an autonomous subsurface instrument that measures the temperature and salinity in the heart of the oceans. The float is programmed and deployed from research vessels or ships of opportunity (deployments from plane are also possible). The floats operate on 10-day cycles over several years until their energy is depleted. Each cycle consists of a descent to the programmed depth (up to 1000m) and then a drift with the current and ends with a final descent to 2000m and ascent to the surface where it transmits the collected data.

B Research Infrastructures

Ingrid Mann, Anders Tjulin, Ingemar Häggström and Carl-Fredrik Enell

EISCAT Scientific Association, Kiruna, Sweden

EISCAT and EISCAT 3D: How is the Earth's atmosphere coupled to space?



EISCAT 3-D

The next generation European incoherent scatter radar system

Mission

To observe the arctic atmosphere from the northern Scandinavian Peninsula in order to investigate how the Earth's atmosphere is coupled to space

Timeline

Start of construction: 2015/2016

Start of operation: 2019/2022

Estimated Costs

Preparatory Phase: 4.5 M€

Construction Phase: 125 M€ (1142 MSEK Full EISCAT_3D) / 76 M€ (689 MSEK EISCAT_3D

Stage 1)

Operation Phase:

8 M€/year (78 MSEK/year Full EISCAT_3D)

/ 6.2 M€/year

Number of Partners

9 (6 Associates and 3 Affiliates)

Website

www.eiscat3d.se

EISCAT and the future EISCAT_3D system are radar instruments dedicated to observations of the Earth's polar atmosphere in order to study how the atmosphere is coupled to space. The polar regions are of special interest for this coupling that leads to a number of different physical processes and becomes apparent for instance in the Northern Lights (or Aurora Borealis). Many of the induced physical processes due to coupling occur in the ionosphere, the 85-600 km altitude region of the Earth atmosphere that is ionized by solar radiation. This is an altitude range of typical EISCAT observations. The Earth is shielded against the solar wind and other cosmic particles of high energy by its magnetic field, but charged particles interact at the boundary structure between the ionosphere and the surrounding interplanetary space and the convergence of magnetic field lines toward the poles causes charged particles with high energy to flow into the high latitude ionosphere. These fluxes are highly variable and are linked to solar activity. Space weather is the term used for these phenomena and a larger group of variable environmental conditions in the space near Earth. The polar region is also very interesting for middle atmospheric studies below 85 km where ionization is less and chemistry and dynamics within the atmosphere connect the upper and lower atmosphere layers. Here, the EISCAT observations cover the atmospheric region

that has the very lowest temperatures on Earth. The minimum temperatures of around 130 K are observed in the summer mesosphere and cause noctilucent clouds (NLC) as well as specific radar echoes (Polar Mesospheric Summer Echoes, PMSE) discussed below.

EISCAT is an existing international research infrastructure at a unique location for research into the polar atmosphere in the northernmost region of Europe. The EISCAT radars are located on Svalbard and on the northern Scandinavian peninsula. This latter location is where the new EISCAT_3D system [1] will be located. The region offers an infrastructure of research and university institutions that is unique within the Arctic. It hosts a dense and versatile network of instruments for active and passive observations of the atmosphere, like other types of radars and radio instrumentation, lidars, magnetometers, and optical imagers.

Two permanent launch facilities for sounding rockets are also located on the northern Scandinavian peninsula: Andoya rocket range close to Andenes in Norway and Esrange close to Kiruna in Sweden. The site configuration for EISCAT_3D is planned to facilitate joint observation campaigns with rocket flights launched from both facilities.

EISCAT_3D will transmit radio-waves (radar pulses) into the atmosphere and measure the back-scattered signal within a bandwidth up to 30 MHz around the transmitted 233 MHz

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frequency. The radar pulses are transmitted from a core site and the pulses of back-scattered signals are measured at the core site and at four different remote sites within 250 km of the core. Each site will consist of a large number of simple antennas whose individual signals are digitally controlled and combined to permit complex antenna pattern control. With this phased array technique the radar beams are formed by electronic signal processing instead of the mechanical steering of the large antenna dishes used in earlier systems. Further improvements in performance are achieved by digitizing the antenna signals at an early stage so that signal processing can be done flexibly by software as opposed to the hardware-based processing of analogue signals. As sketched in (Fig. 1), the measurements will be coordinated from an operation centre and the data will be ar-

chived and made available for easy user access at a data centre. The operation centre will be located close to the transmitting radar site and the data centre will be located at one or several of the existing high performance computing centres in the Nordic countries. A mirror site will possibly be located in another geographical region.

EISCAT_3D will give improvements of more than an order of magnitude in the temporal and spatial resolution of ionospheric observations compared to the present system. In addition it will be the first system of its kind that offers 3-D imaging capability from the upper atmosphere over a wide range of altitudes in the ionosphere. (Fig. 2) illustrates how rapid beam scanning with phased array radars can provide measurements of a volume in space within a comparatively short time. The new system can be operated continuously and

special observation modes triggered automatically, e.g. in response to aurora or other space weather events.

The incoherent scatter technique used with EISCAT probes the charged components of the atmosphere. It is based on transmitting a high-power radio wave and detecting the signal which is backscattered from free electrons. The motions of the electrons and ions in the ionosphere are controlled by ion-acoustic and other plasma waves. In order to keep the balance of positive and negative charges, the electrons follow the ions, so that electrons and ions form similar spatial structures. The spectrum of the back-scattered radio waves contains information on the characteristics of the atmospheric electron, ion and neutral densities and line-of-sight ion velocity over a wide range of altitudes [2]. Other radio scattering objects such as meteor trails, small solar system objects and mesospheric echoes are detected at the same time. Incoherent scatter observations explore in particular the altitude above the range of aircraft and balloon measurements and below the range of most satellite measurements. Another advantage of the method is that observations can be carried out independent of cloud coverage, weather conditions and space weather events. The EISCAT_3D multistatic configuration also permits us to derive vector parameters and to study atmospheric winds.

(Fig. 3) shows an example of EISCAT measurements during a summer day. The figure displays results obtained from EISCAT measurements by real-time analysis based on the assumption that incoherent scatter is the predominant scatter process. This is typically the case at altitudes above 100 km, and often also below. In the absence of other effects, the overall electron densities above 100 km nicely reflect how the ionization varies during the day because the ultraviolet illumination of the atmosphere changes with solar elevation. Thin wavy layers of enhanced electron density are observed above 100 km (sporadic E layers). These are caused by metallic ions that are deposited into the ionosphere during the entry of small solid extraterrestrial objects (cosmic dust and mete-

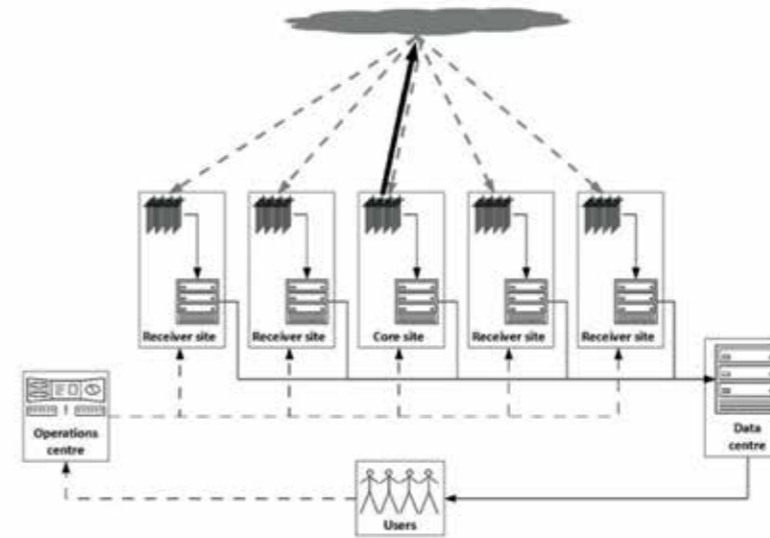
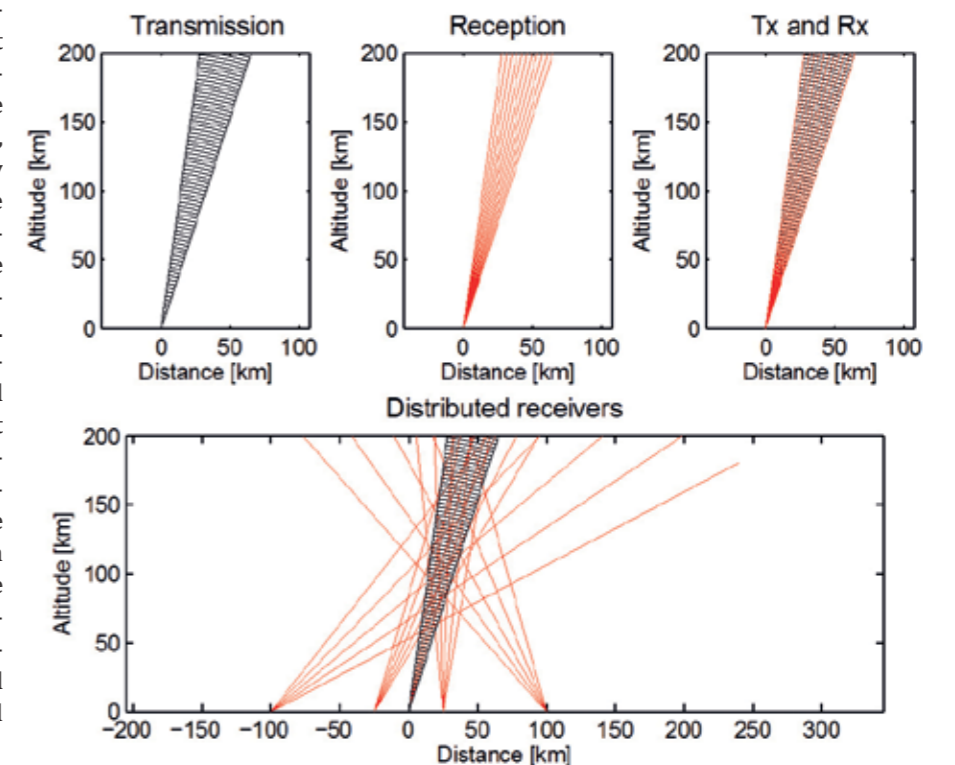


Figure 1: The overall structure of the future EISCAT_3D system comprises a radar core site for transmission and reception of radio waves, remote receiver sites, an operation centre and a data centre, which will most likely be distributed among existing high-performance computing facilities.

rites). Wind shears and electric fields accumulate these meteoric ions into wavy layers. The electrons, in turn follow the spatial distribution of the ions. The vertical structures seen around 13:00 UT, around 16:00 UT and after 21:00 UT are caused by particle precipitation events where particles that enter the ionosphere with high energy collide with other particles. These in turn gain energy and collide again, forming an avalanche of high energy particles and thereby generating the observed increase of the electron density over several 10 km of altitude. The frequency distribution of the back-scattered radiowaves is not seen in (Fig. 3). It is however important since it is characteristic of the scattering process and helps to distinguish the incoherent scatter signal from other radar scattering. During the summer distinct radar echoes are often observed from the mesopause region (the patches seen around 80 to 90 km in Fig. 3); these are called Polar Mesospheric Summer Echoes (PMSE). They are caused by irregularities in the electron distribution and are linked to the presence of charged

ice particles that form when the atmospheric temperature reaches its minimum. The PMSE hence result from complex dusty plasma interactions and are at the same time linked to the temperature and the formation of ice particles in the mesosphere [3]. Some horizontal structures seen at low altitudes are caused by radar reflections at the ground ("ground clutter").

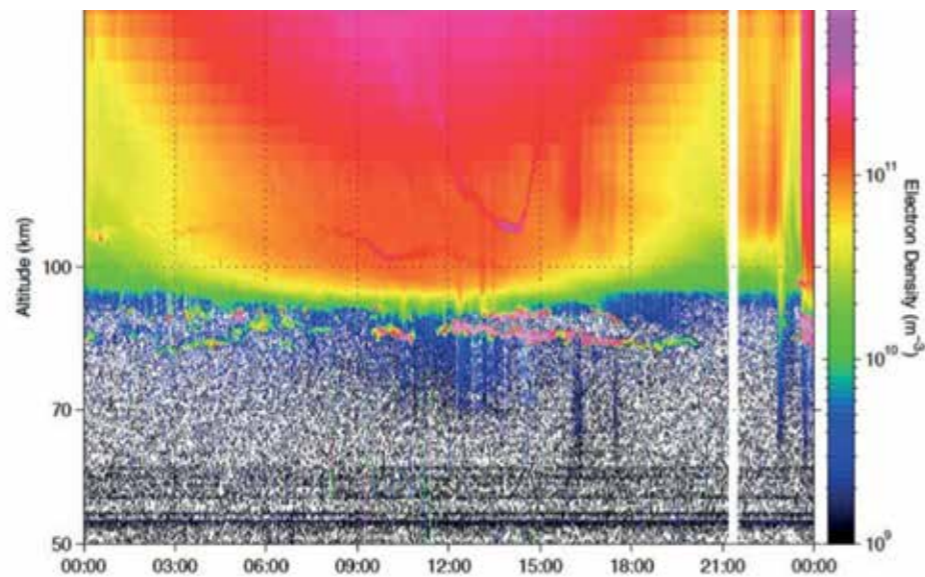
The future EISCAT_3D will also contribute to long-term monitoring of changes in the Arctic atmosphere. EISCAT_3D will make a set of basic



ionospheric parameters as function of time (as displayed in Fig. 3 for one day) available for every day of the year and over a larger altitude range. This offers a novel type of data monitoring products to modellers, with the purpose of extending conventional weather model databases beyond the current range (60 km) up to higher altitudes. Since EISCAT_3D will greatly increase the amount of raw data produced, it is also especially important to plan how to reduce the data, what type of data products to offer to the users and what fraction of data products to store. Improving the documentation is also of particular importance for reaching a broader community of climate and atmospheric researchers who are not yet familiar with the incoherent scatter technique or with radar technology in

Figure 2: Volumetric imaging with EISCAT_3D. The transmitted radar signal (Tx) is modulated so that atmospheric layers at different altitude (distance from the transmitter) are subsequently illuminated. Receiving (Rx) in narrow beams provides the backscattered signal from different angles. Combining the transmitted and received data (Tx and Rx) provides the back-scattered signal together with height and radial information hence from well-defined volumes in space ("voxels").

Figure 3: EISCAT observations during a summer day. These data are generated in real-time analysis based on the assumption that the incoherent scatter process is predominant. Above 80 km the colour scale is a true representation of electron densities. In the range of the PMSE explained in the text it shows an amplitude proportional to the back-scattered power. (EISCAT uncalibrated quick-look data, not for further analysis.)



general. The new system will also offer more flexibility to collaborate with atmospheric radars around the globe.

At present 15 radar systems world-wide are used for incoherent scatter measurements. These cooperate closely on dedicated observation campaigns and use a common database. Data from different instruments world-wide can be accessed directly through the Madrigal upper atmospheric science database. Data at each Madrigal site is locally controlled and can be updated at any time, but metadata is shared between Madrigal sites. This permits the user to search all Madrigal sites at once from any Madrigal site.

There are three typical levels of incoherent scatter data format that are commonly used and the specific measurement question determines what format is best to use.

*Raw signal data represent the signal on the level of voltages captured by a single digital receiver channel, after downconversion or sometimes directly at the radio frequency.

*Correlation product data represent the RF signal data after pairwise auto- and/or cross-correlation has been applied,

in space and/or time, often with some temporal and/or spatial averaging.

*Fitted plasma parameter data contain electron density, electron and ion temperatures, and line-of-sight plasma flow, with estimates of the uncertainty. An example of fitted plasma parameter data are the derived electron density profiles presented in Fig. 2, and the PMSE in the same observation are an example where correlation product data are used for detailed analysis.

While the international incoherent scatter community is using similar standards and descriptions for these three levels of data products, there is still a broad variety in the data formats used for all three levels. Within the COPEUS project, EISCAT works together with US institutions that operate incoherent scatter radar facilities

to further harmonize the data strategies. ■

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3. Hartquist T *et al.* 2009. Exploring Polar Mesospheric Summer Echoes, *Astron. Geophys*, 50, 1.08-1.14.

B Research Infrastructures

Laura Beranzoli^{1,2} on behalf of the EMSO consortium

1 Istituto Nazionale di Geofisica e Vulcanologia, Rome, ITALY

2 EMSO Interim Office, Rome, ITALY

The European Multidisciplinary Seafloor and water-column Observatory (EMSO)– A New Tool in Defense of the Marine Environment



EMSO

European Multidisciplinary Seafloor and water-column Observatory

Mission

Long-term multidisciplinary monitoring of the ocean margin environment around Europe

Timeline

Start of construction: 2007

Start of operation:

9 sites out of 12 operating starting from 2007

Estimated Costs

Preparatory phase: 75 M€ (2008-2011, including 5,8M€ from EC funding of Preparatory Phase project) Construction Phase: 120,6 M€ (in-kind contribution from partners, 2012-2014), 300 M€ (2012-2020) Operation Phase: 40 M€/year

Number of Partners

13

Set up of ERIC (The legal framework for a European Research Infrastructure Consortium)

late 2014

Website

www.emso-eu.org

“The advent of hi-tech deep ocean observatories like EMSO heralds a new era for marine exploration and scientific research with profound economic and social benefits, perhaps nowhere as urgent and timely as in the Mediterranean” - Paolo Favali, Coordinator, EMSO.

Abstract

Climate change, pollution, the loss of biodiversity, the energy crunch and recent severe natural and man-made hazards are giving new impetus and urgency to the study of the world's oceans which represent more than 70% of the Earth's surface. The European continental margins and the Mediterranean are a case in point, where a rapidly deteriorating marine environment poses a mounting threat particularly to overcrowded coastal populations.

European policy makers have big issues to grapple with: not only climate change but also marine geo-hazards, food resources in the sea, human health, and a loss of economic momentum resulting from the financial crisis. The seas and oceans, with their vast resources, can provide a sustainable supply of food; energy from wind, wave and tide; new drugs through marine biotechnology; valuable raw materials from the ocean floor; and much more. According to the European Commission Communication on Blue Growth, the EU blue economy delivers a gross

added value of €500 billion per year and supports 5.4 million jobs. There is a clear recognition that to make maritime activities sustainable and realize their potential will require significant investments in collaborative and cross disciplinary marine research including new advanced tools such as the next generation of ocean observation infrastructure.

In response to these challenges, European scientists are increasingly coming together and joining forces in seeking to apply sophisticated new marine research and monitoring technologies to better understand how to interpret the ocean. One of the most important joint efforts is the European Multidisciplinary Seafloor and water-column Observatory (EMSO), www.emso-eu.org/management/ a ground-breaking project to develop a pan-Mediterranean network and test-bed of underwater observatories sponsored by the Commission. EMSO is included in the Roadmap of the European Strategy Forum on Research Infrastructures (ES-FRI) established in 2002 by the European Commission and Member States to set a common vision and joint strategy for developing and integrating Research Infrastructures of pan-European relevance.

Once fully operational, EMSO will greatly increase insight from diverse disciplines into the many poorly understood environmental occurrences



Figure 1. EMSO – a network of fixed-point deep ocean observatories reaching from the Arctic to the Black Sea passing through the Mediterranean Sea (yellow labels) and shallow water sites (white labels) for equipment testing. Stars mark presently operating EMSO nodes.

and hazards affecting the deterioration of the European seas. It also will bring significant social economic benefits to participating partner countries in the project in the form of new marine high-tech research and development jobs, new advanced educational aides and content and strengthened competitiveness of innovating ocean technology SMEs.

What is EMSO?

EMSO is a pan-European network of fixed-point deep ocean observatories

and platforms with the basic scientific objective of long-term monitoring, also in real-time, of environmental processes related to the interaction between the geo-sphere, biosphere, and hydrosphere, with a strong focus also on natural hazards. This network of linked, geographically distributed deep-sea floor observatories is being deployed on specific sites in European waters, reaching from the Arctic to the Black Sea passing through the Mediterranean Sea, thus forming a widely distributed European scale infrastructure. These sites were originally selected with-

in European Community projects in 2002-2004 and the European Seas Observatory Network (ESONET-- Network of Excellence, 2007-2011).

EMSO will provide information on climate change, marine ecosystem modifications, natural hazards and a basis for sustainable management of the European Seas. Most importantly, it will constitute the European sub-sea segment for in-situ measurements of GEOSS (Global Earth Observation System of Systems), a global approach and strategy regarding the Earth System observations being developed by Group on Earth Observations (GEO) established by the G8 in 2002 and currently sponsored by the EU Commission and 88 member countries.

The establishment of the EMSO network of seafloor observatories represents an exciting change of direction in Ocean Science research - considering that over 70% of Earth's surface is

Figure 2. Flow chart of EMSO research objectives and expected scientific, social, economic benefits.

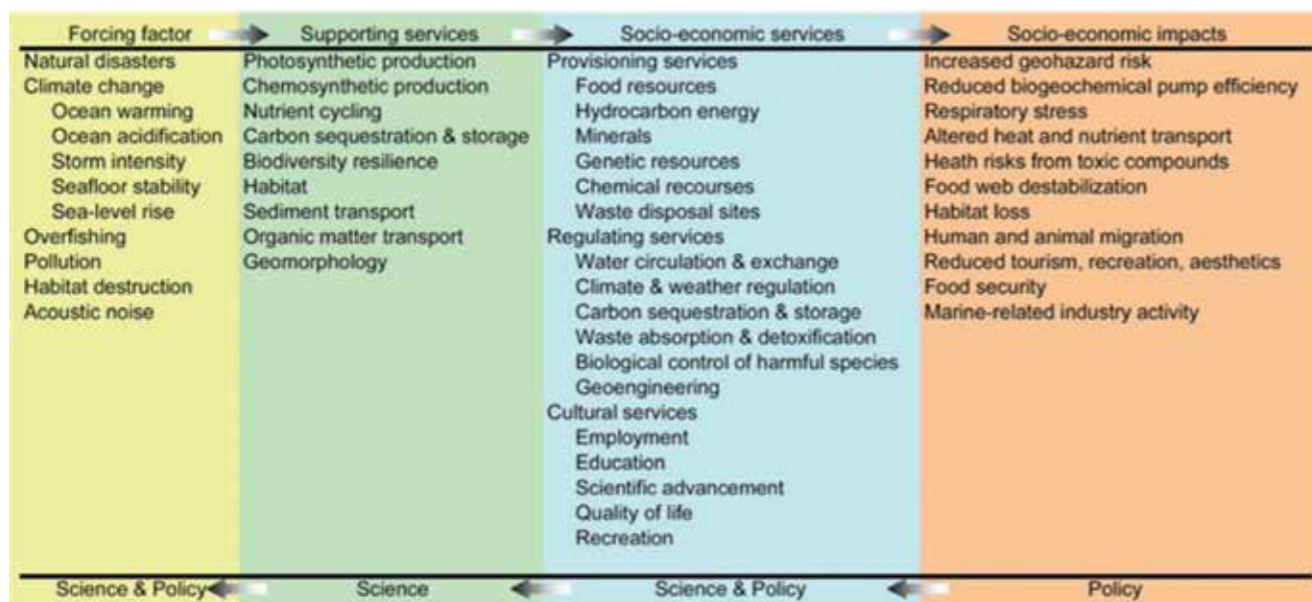


Figure 3. Major International Research infrastructure Programs addressing ocean observations: Northern America: Ocean Network Canada (ONC) and Ocean Observation Initiative (OOI); Eastern Asia: Dense Ocean-floor Network system for Earthquakes and Tsunamis (DONET), Marine Cable Hosted Observatory (MACHO), East China Sea Seafloor Observation System (ECSOS); Australia: Integrated Marine Observing System (IMOS).

its main focus is real-time monitoring for seismic and tsunami warning.

In Taiwan, MACHO (Marine Cable Hosted Observatory) is a project recently established to build a sub-sea cabled observatory offshore off the eastern part of the island to provide early warning of earthquakes and tsunamis, and to monitor submarine volcanic activity.

Moreover, in 2012 China began building its own large scale observatory infrastructure called ECSOS (East China Sea Seafloor Observation System) in the East China Sea while Australia continues to extend its IMOS (Integrated Marine Observing System) established in 2007.

EMSO implementation - Next Steps

In September 2012, EMSO successfully concluded its Preparatory Phase. It is now poised to become a concrete reality. In October 2012, 10 Countries - Italy, United Kingdom, Ireland, the Netherlands, Portugal, Greece, France, Germany, Spain and Romania – signed an MoU committing to establishing the EMSO-ERIC (European Research Infrastructure Consortium) as a legal entity with its statutory seat in Italy to oversee and

covered by oceans - to provide truly global geophysical and oceanographic coverage. The EMSO infrastructure will enhance our understanding of processes that require long time series data appropriate to the scale of the phenomena. The new frontier of multidisciplinary understanding of ocean interior, deep-sea biology and chemistry and ocean margin processes will finally be addressed efficiently by permanent monitoring of key areas around Europe.

Linkages between EMSO and other European research infrastructure programs such as KM3NET, SIOS, Fix03 and Euro-Argo will further enhance reciprocal scientific and technological benefits. Moreover, close synergy between the EMSO scientific community and industry will also spur marine technological innovation and will strengthen European capabilities and competitiveness in this key sector vis a vis leading marine RI initiatives in other countries.

Marine Research Infrastructure Initiatives in Other Countries

Large-scale projects to establish permanent seafloor networks are in various stages of development internationally with hopes of one day uniting them into a single, globally-linked network. In addition to EMSO in Europe, currently also Canada, USA, Japan, Taiwan, China, and Australia have major research infrastructure programs leading the way to the realization of this ground-

breaking global system.

Ocean Networks Canada (ONC)'s NEPTUNE (North East Pacific Time-series Underwater Networked Experiments) and VENUS (Victoria Experimental Network Under the Sea) observatories off the coast of British Columbia were the first large scale undersea research infrastructure projects to be operational.

In the United States the OOI (Ocean Observatories Initiative), a NSF (National Science Foundation) Division of Ocean Sciences program has launched the RSN (Regional-Scale Nodes). OOI and EMSO are working closely together in CoopEUS, <http://www.coopeus.eu/> an EU-US initiative to connect large research infrastructures on the two sides of the Atlantic (see article on CoopEUS 31).

Japan's most important large cabled seafloor observatory project for scientific use was started in 1978. Called DONET - Dense Oceanfloor Network system for Earthquakes and Tsunamis,

Main Milestones:

- September 2012: end of EMSO Preparatory Phase
- End 2012 -Early 2013: signature of EMSO-ERIC MoU by partner countries
- Early 2013: completion of MoU signatures
- September 2013: establishment of the EMSO-ERIC Interim Office in Rome
- November 2013: EMSO Symposium in Rome

- December 2013: Presentation of EMSO-ERIC application to European Commission
- Mid 2014: review of application
- Fall 2014: Approval of the EMSO-ERIC
- Fall 2014: establishment of the EMSO-ERIC Central Management Office in Rome
- January 2015: funding and launch of construction and deployment phase
- September 2017: 3-Year Review.

further develop the EMSO infrastructure and network. In December 2013, the Italian government submitted the formal application to the European Commission to constitute the EMSO-ERIC with headquarters in Rome. ■

Figure 3. EMSO funding as of January 2014

SECURED FUNDING			
	available in-cash contribution (M€)	Explanatory notes	EXPECTED PARTICIPATION IN THE ERIC
ITALY	6.0	Dedicated Funds to EMSO from Research Ministry for the 2012-2013 period	Full Member
FRANCE	2.7/y	Yearly dedicated funds from Research Ministry to IFREMER and CNRS for the Large Research Infrastructure EMSO	Full Member
GERMANY	1.5/y as in kind contribution	Ship time, ROV and AUV deployments, and deep sea drilling missions where current spending is about 1.5 M/y for Hausgarten and Svalbard science missions	Full Member
GREECE	3.7	a) 3.7M€. Implementation of EMSO-Hellenic (2012-2015) b) 0.125 M€. Scoping study of EMSO-Hellas (2010-2011) Indirect funding to EMSO: 0.5 ME€ for maintenance and annual servicing Poseidon system (including ship time) (2009-2012)	Full Member
UK	1.8/y	Current spending for PAP-SO is 1.8M€/year. As much as 17 M€ for CAPEX will be requested when ERIC is formed	Full Member
ROMANIA	6.7	MARINE GEO-HAZARD Project	First Observer Then Full Member
SPAIN	4.5/y	Canary Island (PLOCAN consortium - Plataforma Oceánica de Canarias) Yearly budget	Full Member
IRELAND	-	There is no dedicated ERIC funding for any of the ESFRI projects available at national level. However, national funding calls are issued on a periodic basis and will be targeted when membership of the EMSO ERIC is sought.	Observer
TURKEY	1.5	"Marmara Sea Bottom Observatory (MSBO) project of KOERI" funded by Turkish Telecom	Observer
THE NETHERLAND	-	NIOZ is active with in-house money and due to COST Action PERGAMON offshore Svalbard	Observer
NORWAY	-	The project COSMOS is planned to be re-submitted to the Norwegian Research Council. If accepted, Norwegian commitment might therefore change from observer to full member	Observer or Full Member
PORTUGAL	-	Funding will likely come from a new institute being created now called "Instituto Portugues do Mar e da Atmosfera" that will manage everything related with Geophysics Meteorology and Marine research	If funding to the institute is confirmed full member
SWEDEN	-	-	Small national community. Decision will be postponed

2nd International Ocean Research Conference

Barcelona (Spain), 17-21 November 2014

An online application form is available at:
www.iocunesco-oneplanetoneocean.fnob.org

Online broadcast access

Yin Chen, Alex Hardisty

School of Computer Science and Informatics, Cardiff University

A Common Reference Model for Environmental Research Infrastructures



ENVRI

Common Operations of Environmental Research infrastructures

Mission

To enable environmental scientists to access, study and correlate data from multiple domains for "system level" research

Timeline

Start date: 01/11/2011

Duration: 36 months

Funding Scheme

European 7th Framework Programme

Requested EU contribution: 3,7 M€

Number of Partners

16 partners from 8 countries

Website

www.envri.eu

The project Common Operations of Environmental Research Infrastructures (ENVRI) is a collaboration conducted within the European Strategy Forum on Research Infrastructures (ESFRI) Environmental Cluster. ENVRI gathers six ESFRI environmental research infrastructures (ICOS, EURO-Argo, EISCAT-3D, LifeWatch, EPOS, and EMSO), aiming to minimise the heterogeneity among these environmental data infrastructures in order to promote common best practices and to provide technical tools to help them better fulfil their scientific mission. The results will speed up the construction of these infrastructures and will allow scientists to use the data and software from each facility to enable multidisciplinary science.

Started in October 2011, the 3-year project has so far investigated the common requirements of environmental ESFRI projects, focusing on information architectures, metadata frameworks, data discovery, visualisation and curation issues. It then proposed guidelines for meeting these requirements, including a Reference Model and associated standards.

The ENVRI Reference Model provides a common ontological framework for the description and characterisation of computational and storage infrastructures. It serves as a community standard to help the ENVRI research infrastructures achieve greater interoperability between their hetero-

geneous resources. Fundamentally the model serves as a uniform framework onto which an infrastructure's components can be classified and compared. This can help to identify common solutions to similar problems.

There is an urgent need to create such a model, as we are at the beginning of a new era. The advances in automation, communication, sensing and computation result in the generation of data and digital objects at unprecedented speeds and volumes. Many infrastructures are starting to be built to exploit the growing wealth of scientific data and enable multi-disciplinary knowledge sharing. In the case of ENVRI, most investigated research infrastructures are in their planning/construction phase. Only by adopting a good reference model can the research infrastructure community secure interoperability between infrastructures, enable reuse of computational solutions, share resources and experiences, and avoid unnecessary duplication of effort.

The ENVRI Reference Model

The ENVRI Reference Model is developed based on the experience gathered by the participating research infrastructures. By analysing the common requirements of ENVRI research infrastructures, five common subsystems have been identified: Data Acquisition,

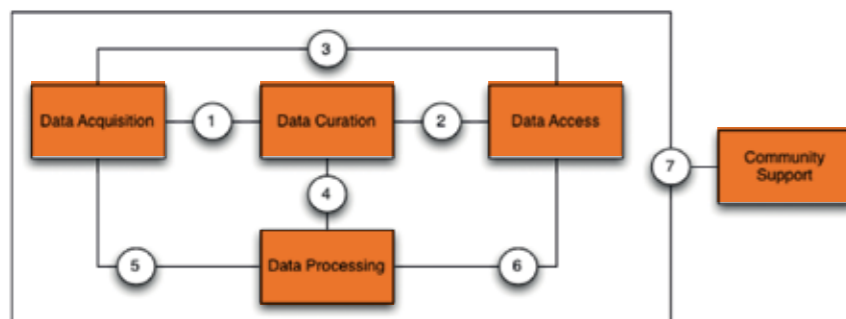


Figure 1: The five ENVRI common subsystems and their relationships

Data Curation, Data Access, Data Processing and Community Support. Their definition are as follows:

- The Data Acquisition subsystem collects raw data from sensor arrays, various instruments, or human observers, and brings the measurements (data streams) into the system.
- The Data Curation subsystem facilitates quality control and preservation of scientific data. It is typically operated at a data centre.
- The Data Access subsystem enables discovery and retrieval of data housed in data resources managed by a data curation subsystem.
- The Data Processing subsystem aggregates the data from various resources and provides computational capabilities and capacities for conducting data analysis and scientific experiments.
- The Community Support subsystem manages, controls and tracks users' activities and supports users to conduct their roles in communities.

The five ENVRI common subsystems are specified using the Open Distributed Processing (ODP) framework, an international standard published by ISO/IEC (ISO/IEC 10746-1, 1998). Using the ODP viewpoint approach, the Reference Model defines an 'archetypical' environmental research infrastructure from three different perspectives: Science, Information and Computation.

- The Science Viewpoint provides concepts and model elements for capturing the requirements for an environmental research infrastructure from

the perspective of the people who perform their tasks and achieve their goals as mediated by the infrastructure.

- The Information Viewpoint specifies information objects to be handled by an infrastructure data lifecycles.
- The Computational Viewpoint specifies the major computational objects expected within an environmental research infrastructure and the interfaces by which they interact.

Examples of Usage

Since the first version released in May 2013, the Reference Model has started to be adopted by the ENVRI research infrastructures.

The European Plate Observing System (EPOS), www.epos-eu.org/, is the European integrated solid earth sciences research infrastructure; a long-term plan to integrate existing national research infrastructures for seismology, volcanology, geodesy and other solid earth sciences. The design challenge of EPOS is to provide a lightweight service layer that can be placed over the existing heterogeneous and distributed national solid earth science infrastructures, in order to provide seamless data access and processing. The ENVRI Reference Model is able to contribute to the design of the EPOS Core Services by simplifying the design problem, breaking it down by subsystem and demonstrating necessary dependencies between science, data and computation. Using the Reference Model, a research infrastructure such as EPOS, can benefit from a uniform framework with well-defined subsystems of compo-

nents specified from different complementary viewpoints (Science, Information and Computation), which promotes structural thinking in the construction of system architectures, enabling designers to deliver a practical architecture that leads to concrete implementations.

The European research infrastructure EMSO, www.emso-eu.org/, is a European network of fixed-point, deep-seafloor and water column observatories deployed in key sites of the European Continental margin and the Arctic. The EMSO data architecture is currently adapted to the ENVRI Reference Model including the five ENVRI common subsystems. Concepts and terms defined in the ENVRI Reference Model are used to illustrate the currently practiced common data management strategies for real time as well as archived data within the EMSO distributed data management system. The Reference Model serves architects and designers of EMSO with a set of ready-to-use terminology with a publicly-accessible reference base, which can be used to describe requirements and architectural features of an infrastructure, providing a common language in documentation and communication.

The Reference Model can also be used as a guide to inform the implementation of common services. To demonstrate the feasibility of the design specifications of the reference model, model components have been selected to implement a data access subsystem. A data portal is developed which allows data products from different environmental research infrastructures (including measurements of deep sea, upper space, volcano and seismology, open sea, atmosphere, and biodiversity) to be retrieved through a single data access interface. Scientists can use this new resource to study environmental problems that were not previously possible. For example, two studies are currently being investigated: the study of the climate impacts caused by the eruptions of Iceland volcano in 2010 that caused enormous disruption of air travel, and the invasive species phenomenon around the island of Sicily.

Current Status and Future Developments

The ENVRI Reference Model is published at www.envri.eu/rm. Training videos and materials are provided (at the same website) to assist users wanting to get hands on experience with the Reference Model and to explore various ways of using it. Currently, our target users are the ENVRI research infrastructure community. In future work, we will promote the Reference Model as the basis for common understanding, dialogue, and interoperability between disciplines in a wider scope.

We will continue to improve the Reference Model. Further refactoring of individual components and further development of individual elements is to be expected in later versions. Further development of the presentation of the model is also essential, in order to both

improve clarity to readers and in order to promote a coherent position. ■

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ISO/IEC 10746-1 (1998): Information technology—Open Distributed Processing – Reference Model: Overview, ISO/IEC standard.

References

1. ICOS, www.icos-infrastructure.eu/, is a European distributed infrastructure dedicated to the monitoring of greenhouse gases (GHG) through its atmospheric, ecosystem and ocean networks.
2. EURO-Argo, www.euro-argo.eu/, is the European contribution to Argo, which is a global ocean observing system.
3. EISCAT-3D, www.eiscat3d.se/, is a European new-generation incoherent-scatter research radar for upper atmospheric science.
4. LifeWatch, www.lifewatch.eu/, is an e-science Infrastructure for biodiversity and ecosystem research.
5. EPOS, www.epos-eu.org/, is a European Research Infrastructure on earthquakes, volca-

noes, surface dynamics and tectonics
6. EMSO, www.emso-eu.org/, is a European network of seafloor observatories for the long-term monitoring of environmental processes related to ecosystems, climate change and geo-hazards.

Meeting highlights

Joint Nordic Focus on Research Infrastructures - Looking to the Future

The conference spanned a wide range of topics, all related to planned and existing large-scale research facilities in the Nordic countries. Among the participants were both policy makers and research leaders in the area of research infrastructure.

The focus of the conference was the joint efforts involved in these infrastructures, and how to facilitate and improve the modes of collaboration for them. The themes were material and molecules, climate and environment, health and welfare, education and training as well as e-science and e-infrastructure.

The conference was arranged in November 2013 by the Nordic Council of Ministers, the Swedish Ministry of Education and Research, NordForsk and the Swedish Research Council.

The conference was filmed and streamed live. You can find links to the webcast material here: www.vr.se/NordicInfra2013

European - Australian collaboration

Collaboration between Europe and Australia in research infrastructures, including infrastructure to support the exploitation of large and complex research datasets, was advanced at two events hosted by the Australian Government Department of Education in Canberra and Melbourne. See the joint Communiqué following the Visit by a European Union Delegation on Research Infrastructure to Australia on 4-8 November 2013:

<http://ec.europa.eu/research/infrastructures/pdf/Third%20European%20Australian%20Workshop%20on%20Research%20Infrastructure%20Communique.pdf#view=fit&pagemode=none>

Marjut Kaukolehto and Timo Vesala

ICOS Head Office
Department of Physics, University of Helsinki

From carbon-nitrogen research to standardization of greenhouse gas measurements



ICOS

Integrated Carbon Observation System

Mission

To enable research to understand the greenhouse gas budgets and perturbations.

Timeline

Preparatory Project Phase: 2008-2013

Start of construction: 2011

Start of operation: 2014

Estimated Costs

Construction Phase: 170M€

Operation Phase: 50M€/year

Number of Partners

10+

Set up of ERIC

(The legal framework for a European Research Infrastructure Consortium)
Autumn 2014

Autumn 2014

Website

www.icos-infrastructure.eu/

Introduction

In the 2000's several EU funded projects on carbon and nitrogen cycles were in operation. The research-orientated work and the bottom-up approach has led to the harmonization and standardization of greenhouse gas measurement techniques together with data processing and archiving. These are among the core activities in Integrated Carbon Observation System ICOS. A year ago we reported in iLEAPS Newsletter (Issue No. 12 September, 2012) about the developments of ICOS Research Infrastructure (ICOS RI). A lot has happened during one year on many aspects related to organisational, technical, national and European developments. Construction and upgrading of the national measurement station networks and central facilities have continued. Considerable developments in data acquisition processes and protocols have taken place. Individual Countries have committed the resources necessary to join the ICOS ERIC (European Research Infrastructure Consortium, legal entity to coordinate and integrate the research infrastructure). Negotiations between 16 countries on legal and financial issues related to the legal entity have advanced to the application level. Involvement of so many countries has resulted in lengthy negotiation process, but on the other hand, in strong commitment and common interest to build and set up a European ICOS research infrastructure.

Mission, structure and users

The mission of ICOS RI is to enable research to understand the greenhouse gas (GHG) budgets and perturbations by providing long-term observations required to understand the present state and predict future behavior of the global carbon cycle and greenhouse gas emissions. The three tier ICOS RI structure includes: 1) Organized ICOS National Networks; 2) ICOS Central Facilities including Atmospheric Thematic Centre (ATC), Ecosystem Thematic Centre (ETC), Ocean Thematic Centre (OTC) and Central Analytical Laboratory (CAL); and 3) European legal entity, ICOS ERIC, including the Head Office (HO) and Carbon Portal (CP). Observations are carried out by the distributed National Networks of atmospheric and ecosystem measurement towers and oceanic measurement points. The measurement technique, calibration and data processing are standardised and organised by Central Facilities. The Carbon Portal distributes various levels of data products. Greenhouse gas researchers are the main users of the data provided by ICOS, but the overall user group potentially interested in the ICOS products and services belong to a wide variety of entities, ranging from science to policy, from public to the private sector and from mass media to operational monitoring agencies. The following categories of potential users can be



Figure 1. Hyytiälä tall tower for atmospheric greenhouse gas concentration measurements. (Photo: Timjami Kauristie)

tion and to continue the work done in the preparatory project were immediately set up. The leader of ICOS before the Director General was recruited by Professor Timo Vesala at the University of Helsinki. In 5 December 2013 ICOS Stakeholders' Interim Council (ISIC) appointed Dr. habil. Werner Kutsch as ICOS Director General for the forthcoming five years. He began work at the Head Office in March 2014. The Interim Research Infrastructure Committee is the steering body of ICOS helping the director in scientific strategic planning, coordination of the implementation of ICOS RI, and enabling and strengthening the communication between the ICOS Central Facilities, ICOS National Networks and the ICOS RI transition phase governance bodies.

The Transitional Head Office was officially established in Helsinki. A Team was appointed to manage the ICOS ERIC preparation and application process, and to establish the management methods and physical Head Office for the ICOS ERIC. The ISIC continues as the highest decision-making body for country representatives to discuss and approve strategic issues such as legal, governance and financial implementation, and site selection. When ICOS ERIC is established the ISIC becomes the General Assembly of ICOS ERIC. The interim scientific advisory board (ISAB) was established. The scope of the ISAB includes advising on how to best achieve the overall science objectives of ICOS RI, assuring that ICOS's scientific grand challenges can be addressed by the research infrastructure, and following the progress in achieving these goals, and helping develop strategies that will advance the progress of ICOS RI.

ISIC agreed on the ICOS ERIC statutes and the five year financial plan in May 2013, together with internal financial rules and the data policy document. ICOS ERIC statutes were submitted by the Finland's permanent representation to the European Commission for ERIC step 1 evaluation in June 2013. EC

distinguished: I) National and international scientific programmes and environmental agencies that monitor C-cycle or relevant data; II) Operational and pre-operational service providers about carbon fluxes (Copernicus projects such as MACC-II); III) Regional authorities representing towns and municipalities; IV) Protocol verification bodies for companies that report their emissions to major climate registries and programs, and any entities that need external independent verification of their carbon footprint; V) Scientific communities devoted to research

and monitoring of nitrogen cycle, other trace gases, aerosol particles and weather forecasting; VI) Remote sensing communities; VII) Private sector; VIII) Educational organizations.

Recent progress

The ICOS preparatory project, coordinated by France and funded by the European Commission, ended in March 2013. ICOS entered a transitional phase until ICOS receives ERIC status in 2014. Several interim bodies to support the ICOS implementation and coordina-

Figure 2. Eddy covariance measurement set-up for methane and carbon dioxide at Siikaneva bog wetland in Finland (Photo: Timo Vesala)



checks the compliance of the statutes against the ERIC Regulation after which the step 2 of the ICOS ERIC process can start. Then the countries will give their binding signatures for becoming ICOS ERIC members or observers for at least the next five years. Step 2 is expected to start early 2014 and ICOS ERIC established by summer 2014.

In May 2013 ISIC decided that the Carbon Portal will be coordinated and hosted by Sweden together with The Netherlands. The planning phase of the Carbon Portal has started in September 2013 and will continue until end of December. Then after that the construction phase will begin and continue over a year. Carbon Portal will be fully operational in 2015. The recruitment process for the Director of the Carbon Portal has started.

Construction and operative phase

ICOS construction phase will continue over 2014 including defining the major deliverables and products of the RI, and concluding organizational arrangements of the ICOS RI. During 2015, the core activities of ICOS RI, such as data collection from the ecosystem and atmospheric stations, data processing, quality control, calibration and the station support by the ATC and ETC, and ICOS data discovery and access through

Carbon Portal, will be fully operational. The first few years in ICOS operational phase will show the extension and strengthening of the ICOS National Networks and development of protocols and new methods.

The environmental sciences are rapidly taking more space in the European research infrastructure landscape. Advanced analytical and modelling software is needed, in addition to sufficient computational capacity to run demanding workflows on the huge data sets that are provided by the observations and measurements of the various components of the environmental system. ICOS is seeking for synergies and integration of operations from the group of RIs in environmental domains

and deepening the collaboration in RIs on aerosols, cloud observations, other trace gases, ecosystem and atmospheric experiments and ocean observations. The RIs would benefit from the co-location of the measurements (e.g. ACTRIS, ANAEE), on the joint measurement strategies (e.g. IAGOS, EURO-ARGO) and on the joint e-infra interoperability (e.g. LifeWatch and other ESFRIs) to help the researchers in gaining a comprehensive understanding of the complex Earth System. The leading position of ICOS RI will favour the development of a consistent global ground-based environmental system with a capacity of detecting environmental signals and impacts at multiple temporal and spatial scales. ■

Michael SanClements; Stefan Metzger; Hongyan Luo; Natchaya Pingintha-Durden; Rommel Zulueta; Henry Loescher

National Ecological Observatory Network, (NEON)

The National Ecological Observatory Network (NEON): Providing free long-term ecological data on a continental scale



NEON
The National Ecological Observatory Network
Mission
To enable a Better Understanding of Continental-Scale Ecology
Timeline
Start of construction: 2012
Start of operation: 2017 -2047
Estimated Costs
Construction Phase: 434 M\$
Operation Phase: Not Applicable
Number of Partners
NEON is solely funded by the US National Science Foundation
Website
www.neoninc.org

The National Ecological Observatory Network (NEON) is a multi-decadal and continental-scale observatory providing freely available data, educational resources and infrastructure to facilitate ecological research on the impacts of climate change, land use change and invasive species. NEON includes 60 terrestrial and 46 aquatic sites distributed across the United States (Lat. 18–71°N; Lon. 72–156°W). Data collected at these sites will enable scientists, educators, planners and policy makers to improve their understanding of ecological change.

A unique component of NEON is the ability to address key questions of ecological change over multiple scales, from individual plots to a continent, and from seconds to decades. Standardized traceable methods driven by a centralized top-down management structure help ensure valid data comparisons across sites and through time. The ability to make such comparisons expands our capacity to predict the effects of human activities on ecosystem processes and services across the continent.

Tower and Soil Based Sensors

Each NEON terrestrial site contains a suite of tower- and soil-based automated sensors, (co-located with sample based observations) (Fig. 1) to quantify environmental drivers and corre-

sponding ecosystem responses. Tower and soil sensor observations include:

- Atmospheric pressure, precipitation, throughfall, incoming and reflected shortwave and longwave radiation, and vertical profiles of wind, temperature, humidity, CO₂, CH₄ (potentially at limited sites) and photosynthetic active radiation; Surface-atmosphere exchange of momentum, heat, H₂O, CO₂, O₃, NO and NO₂;
- Wet deposition, dust/dry deposition, ¹³C in CO₂, and ¹⁸O and ²H in H₂O;
- Phenology of canopy and roots;
- Soil surface temperature, soil heat flux and soil CO₂ flux, and profiles of soil temperature, soil water content and soil CO₂

NEON tower locations are determined based on local wind patterns. The exact tower position is chosen to minimize the effects of complex terrain, and to be highly representative of a target ecosystem (≥80% flux footprint climatology). The NEON tower design is standardized to ensure that the tower structure can withstand 30 years of operation with minimum deflection and harmonic motion that could impact data quality. Tower height and orientation are site-specific, depending on the local canopy height and structure [1]. All instruments are mounted on stable horizontal boom arms at a minimum distance of 4 m away from the

“ After several years of preparatory work, the Euro-Argo research infrastructure is now established as an ERIC since May 12, 2014

This is great news and a major step forward the new scientific challenges regarding ocean observation and forecasting.

The main celebration event took place on July 17 in Brussels!”



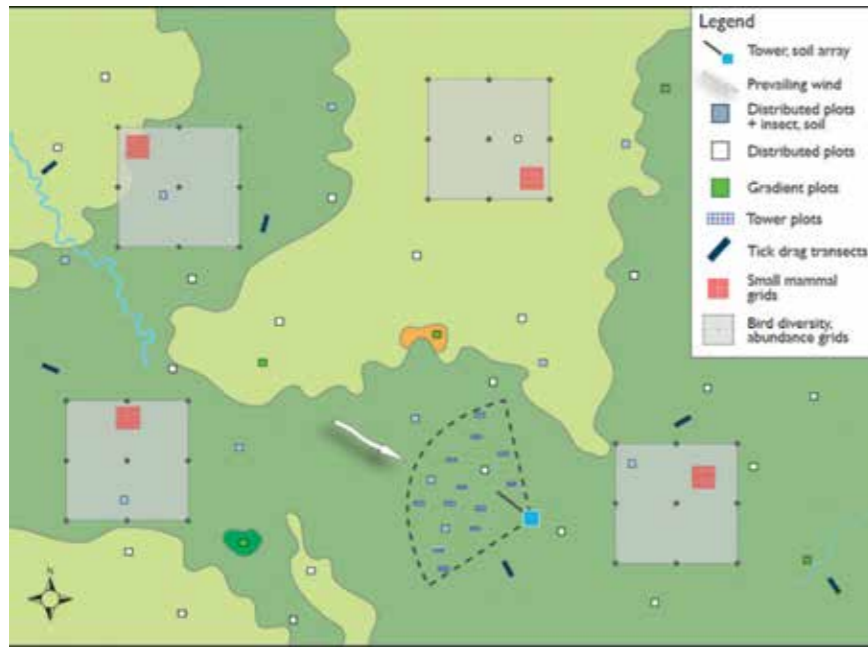


Figure 1. Left panel: Depiction of a NEON site showing the co-location of the NEON tower infrastructure and soil sensors with other NEON plot based sampling for biogeochemistry and organisms. Right panel: Construction at NEON sites is ongoing - here instrumentation is being deployed at the Ordway-Swisher site.

tower structure to minimize the impact flow-distortions and thermally induced chimney effects.

Five soil plots (collectively named the soil array) are located inside the tower flux footprint to enable the interpretation of soil-plant-atmosphere linkages. To ensure that soil plots account for spatial heterogeneity, NEON uses distributed soil temperature and moisture measurements in combination with geostatistical approaches to determine the optimal spacing between soil plots [2].

Wet and dry deposition collectors gather samples to provide chemical inputs to the ecosystem and the isotopic signatures in precipitation, while soil samples to a maximum depth of 3 m assist in calibration of soil sensors. Subsets of these samples will be archived by NEON and are available per request. It's important to note that the soil and water samples collected at the tower and soil pit locations for use in calibrations comprise only a small fraction of the soil, water and biological samples collected under the broader scope of NEON (for more information visit

www.neoninc.org/). (Fig.1) (left panel) depicts the tower and soil array locations in relation to other field sampling plots for regular intensive collection of numerous biogeochemical and organismal data. Aquatic sampling occurs at separate, but often co-located sites.

Calibration and validation are essential for monitoring sensor performance, calculating uncertainties, and for establishing confidence in reported data products. The central Calibration, Validation and Audit Laboratory (CVAL) at NEON headquarters performs baseline calibrations for new sensors and periodical recalibration after deployment. These calibrations are standardized for all sensors across NEON sites, and are traceable to internationally recognized standards such as those defined by the National Institute of Standards and Technology (NIST) or the World Meteorological Organization (WMO). Due to the high demand for gas and liquid working standards, NEON has developed in-house standards for CO_2 , ^{18}O , and ^{13}C that are calibrated according to International Atomic Energy Agency guidelines and are subject to round-robin tests and inspection by auditors.

Each sensor deployed in the field is equipped with a memory chip to store sensor-specific information, such as sensor type, serial number, calibration coefficients, etc. During operation, these sensor-specific data, along with



all measurement data, are transmitted from the sites to NEON headquarters in real-time by an in-house smart data acquisition system (Grouped Remote Analog Peripheral Equipment, GRAPE). A dynamic dataflow combined with bi-weekly site maintenance intervals allows collecting data, and efficiently monitoring and restoring the health of sensors at remote sites.

Scaling tower data across diverse ecosystems

All NEON observations at terrestrial sites are designed in a spatio-temporal hierarchy that informs a similar hierarchy of model representations (Fig. 2):

- Human-based inventories of biota, soil properties and other biophysical state variables on the plot scale ($\approx 10^1$ - $3km^2$);
- Tower, soil and aquatic instrumentation systems, providing automated micrometeorological, bioclimatic, and biogeochemical observations on landscape and watershed scales ($\approx 10^0$ km^2);
- Airborne observations, providing three-dimensional, high-resolution (≈ 1 m) remote sensing observations on the regional scale ($\approx 10^2$ km^2).

To allow scaling in space and time, novel tools for quantitative extraction of relationships among observations

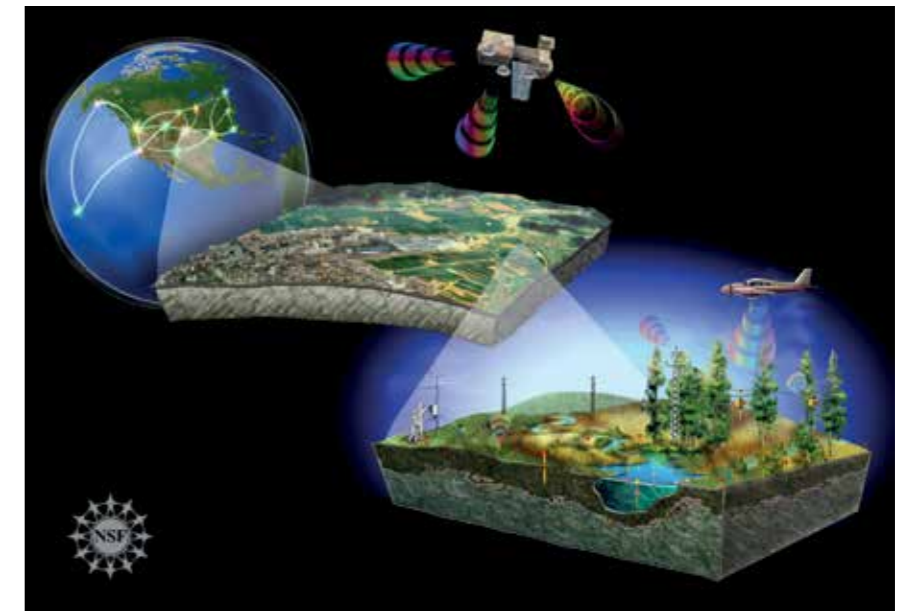
Figure 2. NEON observations are designed in a spatio-temporal hierarchy that informs a similar hierarchy of model representations.

will be used. For example, key relationships between environmental responses measured by the tower based instrumentation and related drivers measured by high-resolution airborne remote sensing will be extracted. The resulting environmental response function [e.g. 3] has the predictive power to fill gaps in space or time where only partial information is available. The surface-atmosphere exchange over the entire airborne sampling domain ($\approx 10^2$ km^2) will be determined from measurements at a single tower location ($\approx 10^0$ km^2). In this way, the expected value, as well as spatial variability over a target domain, can be quantified to within $\approx 20\%$ accuracy. The resulting spatio-temporal continuous grids can then bridge the scale-gap to process-based land surface models, which usually operate at spatial resolutions of 10^2 - 10^4 km^2 .

Broader Context

The NEON design observes both terrestrial and aquatic ecosystems distributed across twenty 20 eco-climatic domains as defined by multivariate clustering of national data sets [4,5]. NEON's 60 terrestrial sites are classified as either 'core' or 'relocatable', with each domain containing one core and two relocatable sites (see "Organizational biography"). Core sites represent the dominant wildland ecosystem within each eco-climatic domain and will remain in place collecting data for thirty years. Relocatable sites were selected to enable specific question driven gradient or comparison studies and will move every 5-10 years to address new ecological phenomena as defined by a community driven process.

Data generated by NEON are provided on a free and open access basis to scientists, students, educators, planners, policymakers and the general public via <http://www.neoninc.org>. All available data sets are subjected to rigorous quality assessment and quality control [e.g. 6], and are accompanied



by transparent data quality information [7]

In addition to accessing data, a range of opportunities exist for collaboration between other agencies and individuals to conduct research at NEON sites, or to utilize NEON infrastructure and samples through a formal request process. These include NEON's third aircraft for remote sensing, several Mobile Deployment Platforms (mobile instrumentation and laboratories for PI led research), the NEON tower structure, the calibration and validation library and NEON's archive of physical samples.

NEON also provides information infrastructure to the science community. NEON's focus on the standardiza-

tion of measurements and scaling can help provide a framework for the future of interoperability in ecological re-

The National Ecological Observatory Network (NEON) is funded solely by the United States National Science Foundation. Its purpose is to enable understanding and forecasting of the impacts of climate change, land use change and invasive species on continental scale ecology. This is achieved by providing infrastructure and consistent methodologies to support research and education in these areas. NEON successfully completed the planning and design phases and entered the construction phase in Spring 2012. NEON expects to be in full operation by approximately 2017. Data from these sites will be collected for 30 years. Visit www.neoninc.org for more information.

Organizational biography



search. For example, an interoperability framework called CoopEUS is jointly funded by the European Union Framework Project 7 and the U.S. National Science Foundation, and is currently being implemented. The framework already comprises several partnerships (e.g., ICOS, Lifewatch, CzechGlobe and NEON). Network interoperability promotes collaboration and data synthesis by tracing measurements and observations to known standards and best community practices. Essential to achieving interoperability are high-quality and freely available data.

As a platform to facilitate ecological research and education, NEON will provide high quality and freely available data for decades into the future. These data and associated NEON infrastruc-

ture will support research and collaborative opportunities to address critical ecological questions across much of North America and beyond. ■

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Professor Stuart Phinn¹, Dr Bek Christensen²

1. Associate Science Director TERN – Terrestrial Ecosystem Research Network - The University of Queensland
2. Communication and engagement manager TERN – Terrestrial Ecosystem Research Network - The University of Queensland

Australia's terrestrial ecosystem research ecosystem



TERN

Australia's Terrestrial Ecosystem Research Network

Mission

To advance science and contribute to effective management and sustainable use of our ecosystems

Timeline

Planning and Construction Phase 1: 2008-2010 Construction Phase 2 and Operation: 2010-2014

Operation and Revision: 2014

Estimated Costs

Planning and Construction Phase 1: 20 M\$ (NCRIS) + in kind 100 M\$ of past infrastructure investment

Construction Phase 2 and Operation: 25 M\$ (EIF) + 100 M\$ of past infrastructure investment Operation Phase: Estimated annual operating budget 12 M\$

Number of Partners

All major Australia universities, Commonwealth and State Government Environmental Monitoring and Management Agencies, Research Institutions

Website

www.tern.org.au

Australia's Terrestrial Ecosystem Research Network (TERN) connects ecosystem scientists and enables them to collect, contribute, store, share and integrate data across disciplines.

By delivering critical research infrastructure and supporting networks of scientists, environmental managers and other stakeholders, TERN is increasing the capacity of the Australian ecosystem science community to advance science and contribute to effective management and sustainable use of ecosystems.

At establishment, TERN's main objectives were to:

- provide a national institutional infrastructure network for terrestrial ecosystem research and management
- coordinate national observational networks to provide valuable information about terrestrial ecosystems and to encourage research collaboration and cooperation nationally
- facilitate improved access, including by electronic means, for researchers to quality assured observational data so questions about our environment can be answered
- identify future needs, by involving the terrestrial ecosystem research community, for research and strengthen the capability of the terrestrial ecosystem community across Australia so we are better able to respond to questions of national significance.¹

In concert with these objectives, a range of key science questions were identified as key drivers for the design of TERN's infrastructure during its scoping and building phase:

- How are the spatial distribution and abundance of key Australian environmental assets (e.g. plant and animal species, carbon stocks, and in some cases water) changing?
- How are ecosystems and ecosystem processes changing, and what are the key processes driving change?
- How are introduced plant and animal species affecting native ecosystems?
- How can we better monitor ecosystems?
- How can we better manage ecosystems?
- What is the impact of management interventions on Australian ecosystems and ecosystem processes?
- How can we get maximum value out of hard-won ecosystem science data by sharing it more efficiently and effectively?

Partnering with existing research groups and infrastructure providers was a fundamental component of TERN's establishment. TERN has been built with the direct involvement of 17 university partners, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and more than 25 other research organisations,

Meeting highlights

The International Conference on Research Infrastructures

The International Conference on Research Infrastructures, ICRI 2014, took place in Athens, Greece April 2-4. This was the Eighth Conference on Research Infrastructures.

The ambition of ICRI 2014 was to highlight how global research infrastructures can respond to the grand challenges that the world is facing today, what lessons have been learned from the past, and what the priorities and directions are for the future.

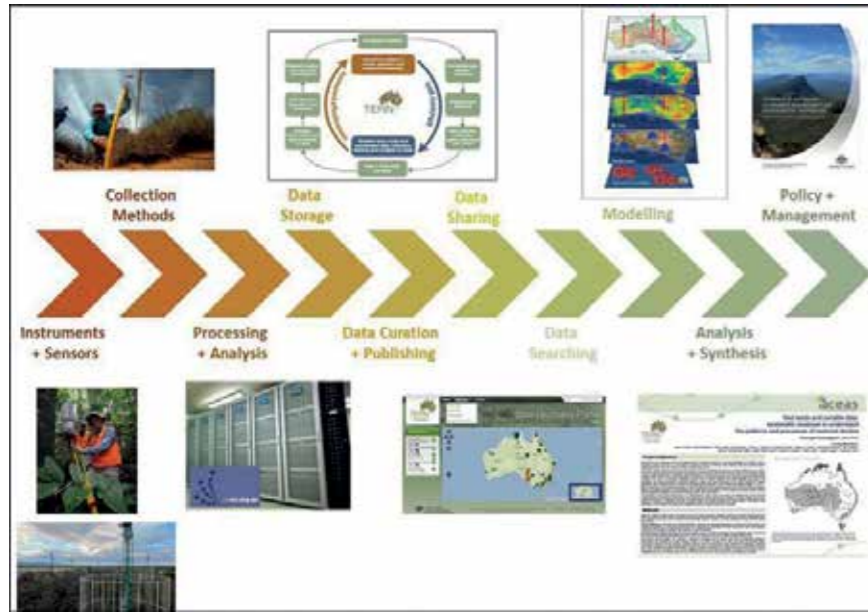
During the two-day event, issues such as decision making processes, funding, management, use-dissemination-exploitation (including data access) of research infrastructures were discussed in depth. More than 600 experts, scientists and stakeholders attended the event and spoke about how global research infrastructures can tackle the so-called Grand Challenges, more specifically in the fields of health, environment and energy.

The Conference made specific recommendations on how international cooperation on research infrastructures can be more effective in the future. All presentations of ICRI 2014 are now available on the conference site: www.icri2014.eu/programme

The EGI (European Grid Infrastructure) Forum 2014

The EGI Community Forum 2014 was held at the Helsinki University, Finland in May 19-23, 2014. The event was hosted by EGI.eu in partnership with the University of Helsinki and CSC - IT Center for Science Ltd. The leading theme for the meeting was "Advancing excellent science" and the conference programme included a set of user-orientated tracks designed to give new and existing user communities an opportunity to present their requirements, report on success stories, get support in porting applications and network with technical providers and other partners.

More information on the outcomes of this event can be found here: <http://cf2014.egi.eu/>



Australian, state and territory government agencies, non-government organisations, and others.

As a result, TERN has been able to rapidly implement comprehensive, national, ecosystem data infrastructure that supports researchers throughout all stages of the ecosystem research data lifecycle (Fig. 1). In addition to the conventional 'hard' data collection and storage infrastructure (e.g. flux towers, transects and plot networks, real-time ecosystem sensors of all kinds), TERN delivers equally important, unmappable 'soft' infrastructure such as nationally standardised methods; new ways of collecting, managing and discovering data; and new multidisciplinary collaborations and capacities for synthesis. Through this comprehensive approach, TERN is enabling coordinated collection of bio-geophysical data (surface energy balance and flux, satellite image based biophysical products), ecological data (flora and fauna surveys), along with integration, analysis and synthesis for transforming science for environmental management.

How Does TERN Work?

TERN operates as a network of facilities each with a specific focus, that when combined enable the achievement of TERN's greater goals (Fig. 2):

- TERN Central – providing overall

coordination of TERN and management of the TERN Data Discovery Portal, which provides access to all TERN data and data contributed by other researchers

- AusCover – producing nationally consistent, long time series of satellite images, satellite-based biophysical map products, next generation remote sensing research data, and product validation for Australian conditions
- AusPlots - establishing and maintaining a national network of plots undertaking baseline assessments of ecosystems across the country
- Australian Supersite Network (ASN) - a national network of multidisciplinary ecosystem observatories collecting detailed data on flora, fauna and biophysical processes to improve understanding of how key ecosystems respond to environmental change
- Australian Transect Network - informing predictions about possible future ecosystem changes by studying ecological and genetic structure and processes, patterns and trends, along multiple sub-continental transects
- Australian Centre for Ecological Analysis and Synthesis (ACEAS) – enabling multidisciplinary analysis and synthesis among ecosystem scientists and ecosystem managers, essential for planning sustainable management of Australia's environment into the future
- Australian Coastal Ecosystem Facility (ACEF) – producing an accessible time

series of research data on field surveys, spatial data, and satellite/airborne image data sets, covering flora, fauna and biophysical properties of Australia's coastal ecosystems

- Eco-Informatics – enabling storage, sharing, integration and visualisation of ecological plot data through the Australian Ecological Knowledge and Observation System (ÆKOS) and other products

- Ecosystem Modelling and Scaling Infrastructure (eMAST) – enabling the collection, integration and scaling of site/plot, flux tower, remote sensing and eco-informatics data for use in developing, benchmarking and applying ecosystem models

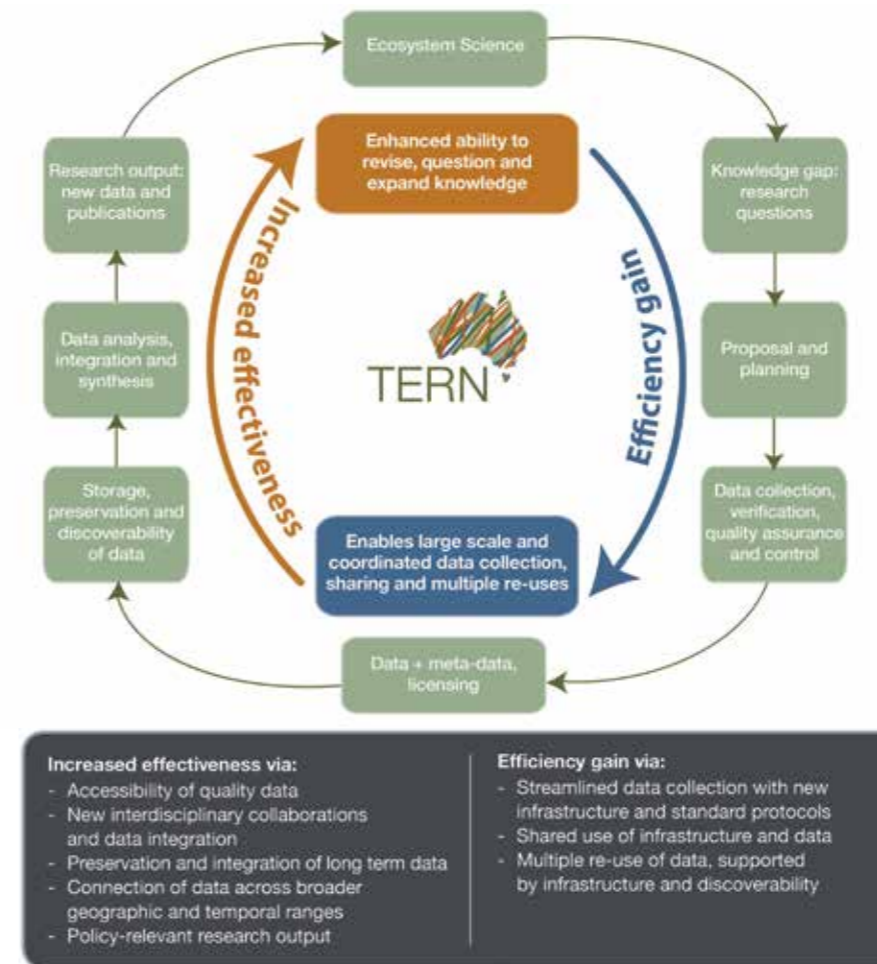
- Long-Term Ecological Research Network (LTERN) - linking twelve existing long-term ecological plot-based monitoring programs across a range of Australian ecosystems, collecting detailed information about vegetation, soils, fauna, genetics and phenology to better understand environmental change

- OzFlux – measuring key energy, water and carbon dioxide fluxes and making the data available for multiple ecosystem science and modelling applications

- Soil and Landscape Grid of Australia – producing a high-spatial resolution soils grid for Australia and a network for collaboration and sharing of field and spatial data sets, models, and analytic approaches on soil landscapes and dynamics.

The approaches developed in TERN are wide ranging, and extend beyond those normally associated with an ecological observatory to include:

- coordinated data collection at a range of spatial and temporal scales;
- collection of data relevant to key science and management questions, e.g. essential climate or ecosystem variables, using techniques that have been assessed and verified across each discipline area to meet national and international standards;
- standards for data collection, checking and storage formats;
- flexible, and standardised meta-data that is fit for purpose;
- appropriate data licensing that is: fit



for the purpose of data use, appropriate to the context of data production, and appropriate for individual and institutional Intellectual Property;

- data publishing procedures and formats to Australian and international standards, enabling data, meta-data and licences to be published in a discoverable form with appropriate referencing for citation and citation tracking (Digital-Object-Identifiers, DOIs);
- discipline-based databases using appropriate data formats and context rich meta-data;
- discipline- or application-based code and model libraries;
- capability for multi- and inter-disciplinary integration and synthesis activities to address complex problems; and
- a capacity for translating the results of science so that they are relevant, useful, and have maximum impact for policy and management.

Achievements and impact

Good research infrastructure provides a neutral collaborative framework that

is the nucleus around which previously fragmented activities and communities can coalesce. In surprisingly short periods of time, leaps forward become feasible on fronts that were not only previously inaccessible, but unanticipated.

It is clear that TERN is fulfilling this catalytic role for the Australian ecosystem science community, and has transformed it from a situation in which effort was fragmented, inefficient and short-term, to one in which effort is national, networked and delivering for Australia's future. TERN has brought this transformation about by connecting ecosystem scientists and managers, and enabling them to collect, contribute, store, share and integrate data across disciplines.

In only four years TERN has built upon previously disconnected discipline-specific efforts across the ecosystem science landscape, giving rise to a new, effective, interdisciplinary national network of infrastructure and people. TERN's unique approach to overcoming barriers to sharing and collaboration has permitted significant

Figure 1: The ecosystem data lifecycle and TERN's role

extension of previously-existing activities, infrastructure and data across multiple groups within the ecosystem science community.

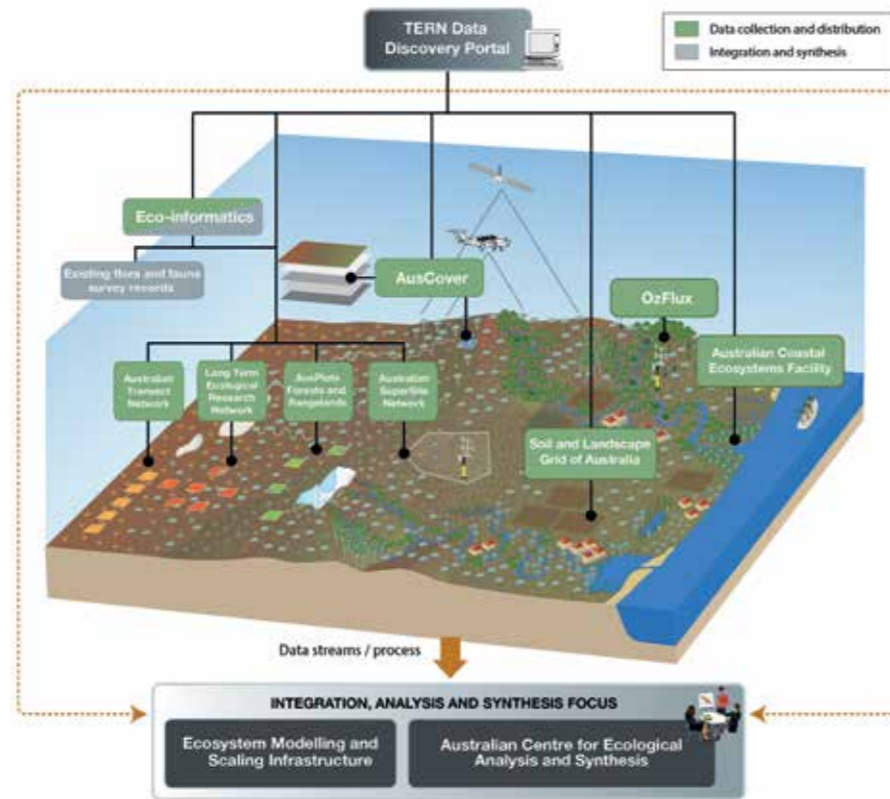
One of TERN's major achievements has been the initiation of a profound cultural shift in the way Australian ecosystem scientists and managers deal with data and advance environmental knowledge, by delivering the national ecosystem data infrastructure they need. TERN now offers a comprehensive solution for consistent data collection, storage, discovery, publishing, licensing and citation, all of which is freely available to scientists and managers anywhere in the country.

This new capacity to move efficiently through the ecosystem data management lifecycle is already helping to reduce duplication of effort, increase scope for collaboration, and thereby deliver better returns on investment in Australian environmental science and management. It also puts Australian scientists and managers in a stronger position to rapidly and safely realise the benefits of the global movement towards open data and data publishing in the context of complex domestic environmental problems.

Notable examples of TERN-facilitated improvements in the management or protection of Australia's environment include:

- Remotely-sensed determination of carbon emissions from the first savanna-burning project approved under the national Carbon Farming Initiative (www.tern.org.au/Newsletter-2012-Nov-SavannaCarbonEmissions-pg24310.html);
- Improvements to the tool used by the federal environment department to identify and prioritise areas important for biodiversity, thereby enhancing the quality of biodiversity information available for natural heritage and conservation assessments (<http://tern.org.au/Newsletter-2012-June-ACEAS-Laity-workshop-pg22198.html>);
- Development and adoption of nation-

Figure 2: How TERN fits together?



ally-accepted methods for monitoring trend and condition in Australia's rangeland and forest ecosystems, enabling continental-scale assessments (www.tern.org.au/ausplotsrange-landsmanual);

- Better capability to inform Australian fire behaviour models and fire danger rating systems in near-real-time through collaborative work with the Australian Bureau of Meteorology and Bushfires Cooperative Research Centre (<http://www.tern.org.au/Newsletter-2012-Nov-MapFireSeveritySavanna-pg24309.html>, <http://www.slideshare.net/TERNCOMMS/ian-grantgrassland-curing-derived-from-nearrealtime-modis-satellite-data-to-support-bush-fire-management>);

- Collaborative combinations of datasets to deliver continental-scale assessments of ecosystem condition for federal agencies, for example the Australian Bureau of Agricultural and Resource Economics and Sciences' Ground cover monitoring for Australia project (<http://www.tern.org.au/Newsletter-2012-Aug-ABARES-pg23191.html>); and

- Imminent publication of Australian guidelines for field-based measurement standards, calibration, measurement and validation protocols for remote sensing data and derived products.

Moving Forward – Collaborative Ecosystem Science

A critical part of TERN's success to date, has been its capacity to recognise existing efforts and programs, cooperate effectively with these, and build upon them to advance ecosystem science. This principle will underpin the continued development of TERN and its application to ecosystem science, along with recognition of existing discipline-based approaches to data collection. TERN's approach will also enable new and continuing collaborations to develop nationally consistent methods for data collection within and across disciplines and jurisdictions that also build on existing approaches. ■

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Acknowledgements

TERN is supported by the Australian Government through the National Collaborative Research Infrastructure Strategy and the Super Science Initiative. We are grateful to all of our partners and contributors for their role in building TERN and enabling the continuation of this important research infrastructure. A full list of partners can be found at: <http://www.tern.org.au/Partners-pg17725.html>

B Research Infrastructures

Ketil Koop-Jakobsen¹, Henry W. Loescher², Lindsay Powers², Robert Huber¹ and Christoph Waldmann¹

¹Center for Marine Environmental Sciences (MARUM), University of Bremen, Bremen, Germany

²National Ecological Observatory Network Inc. (NEON Inc.), Boulder CO, USA

COOPEUS – Building the framework for information exchange between the US and EU Environmental Research Infrastructures



COOPEUS

Strengthening the cooperation between the US and the EU in the field of environmental research infrastructures

Mission

To bring together environmental research infrastructures from different science disciplines from both sides of the Atlantic in order to promote efficient access and open sharing of data

Timeline

Start date: 01/09/2012

Duration: 36 months

Funding Scheme

European 7th Framework Programme

2 M€

Partners

15 partners from EU and US

Website

www.coopeus.eu

Environmental research today is addressing large-scale challenges in basic research as well as providing understanding for societal benefit. Due to the scale and complexity of these challenges, information is required on a very diverse set of data types from different scientific fields that range over ecosystem production, carbon budgets, biodiversity, geodesy and seismology, and ocean and atmospheric circulation (1,2,3).

The COOPEUS project, funded under the European Commission's 7th Framework Programme and in part by the National Science Foundation's (NSF) Science Across Virtual Institutes (SAVI), is building a framework to facilitate transatlantic interdisciplinary collaboration and interoperability among environmental Research Infrastructures (RIs). COOPEUS brings together RI projects and networks from the EU and US, such as European Incoherent Scatter Scientific Association (EISCAT), European Plate Observing System (EPOS), European e-Science infrastructure for biodiversity and ecosystem research (LifeWatch), European Multidisciplinary Seafloor and Water Column Observatory (EMSO), and Integrated Carbon Observing System (ICOS) in Europe and their US counterparts in Advanced Modular Incoherent Scatter Radar (AMISR), Incorporated Research Institutions for Seismology (IRIS), UNAVCO, EarthScope, Data Observation Network for

Earth (DataONE), Ocean Observatories Initiative (OOI) and National Ecological Observatory Network (NEON). This diverse suite of RIs from the EU and the US comprise 5 scientific work packages, namely Carbon Observations, Ocean Observatories, Space Weather, Solid Earth Dynamics and Biodiversity (Fig. 1). Additionally, COOPEUS has two work packages focused on building a roadmap for cross-disciplinary data interoperability facilitating exchange of data among RIs. The COOPEUS project will serve as a model for the integration of data standards and the implementation of collaborative data and information policies for environmental RIs.

Development of large scale, world-class RIs for collection of consistent, traceable environmental data over decadal timescales has been prioritized in recent years to improve environmental research and science-based decision making on environmental issues [1, 2]. RIs are typically designed for specific scientific fields or specific environments. To address large-scale environmental challenges, however, requires a cross-disciplinary approach that spans multiple RI domains [4, 5, 6]. This requires means to integrate data and information from a diversity of RIs and networks across scientific disciplines, international borders and continents. Challenges to this integration include harmonizing policies for data accessibility, intellectual property rights, standards for data and metadata, se-



Figure 1: COOPEUS aims to improve the transatlantic collaboration among environmental research infrastructures working with Carbon Observations, Ocean Observatories, Space Weather, Solid Earth Dynamics and Biodiversity.

mantics and controlled vocabularies, and quality control among RIs and contributing institutions.

The primary goal of COOPEUS is to establish a working framework to improve international data and information exchange among environmental RIs across scientific and national borders. Towards this effort, COOPEUS has identified numerous actionable tasks that include, 1) identifying imminent challenges for transatlantic and cross disciplinary data-exchange, 2) defining and assessing the current state of interoperability, 3) creating a roadmap for harmonization of data policies and 4) establishing a data policy for COOPEUS RIs. In this way, COOPEUS works towards building a framework to foster the exchange of data among environmental RIs, and will provide a working model to further interlink other infrastructures on a global scale.

We recognize that COOPEUS is not the only organization with the goals of international data interoperability, and as such, we are collaborating closely with other complimentary programs and projects to jointly define the future interoperability among environmental RIs. Key among them are; EU's Common Operations of Environmental Research Infrastructures (ENVRI) US NSF's EarthCube (www.nsf.gov/geo/earthcube), Research Data Alliance (www.rd-alliance.org), Data Observation Network for Earth (Data-

ONE, www.dataone.org), International Council for Science's Future Earth initiative (www.icsu.org/future-earth), the G8 multilateral initiative called the Belmont Forum, and the activities of the Group on Earth Observations (GEO, www.earthobservations.org/index.shtml) and GEO System of Systems (GEOSS, www.earthobservations.org/geoss.shtml).

COOPEUS has built its collaborations among research infrastructures with a diversity of maturity in their science and governance structures and experience in data collection, processing and distribution. In this way, the more mature RIs can provide guidance and insight to those still in development. COOPEUS aims to improve research infrastructure collaboration between the EU and US through a bottom-up process, where experience of the individual RIs can be beneficial to all involved RIs.

In the initial phase (first year), COOPEUS focused on finding commonalities and differences in data policies, standards and access among the involved RIs, and COOPEUS activities were designed to address data interoperability and standardization issues; some of these activities are presented below:

Questionnaires: Questionnaires were used to assess the current use of standards for data and metadata, data formats, accessibility of data, and identifi-

cation of workflow among all of the RIs. Results from the first questionnaires revealed that although most of the COOPEUS RIs provide significant access to data through web services, currently many RIs still restrict full open access. Additionally, although there has been significant international collaboration to develop metadata standards, standardized interfaces are not yet implemented and available at many RIs.

Workshops: Through two workshops, COOPEUS in collaboration with ENVRI and EUDAT (European Data Infrastructure) engaged the broader scientific community to discuss 1) the issues that limit the harmonization of data sharing and 2) the use of Persistent Identifiers (PIDs) as they relate to open time series data. Open time series data presents a unique suite of challenges in assigning PIDs due to the dynamic nature of data collection and the need to periodically update the PID and its attribution. These workshop activities are continuing and aim to define the requirements needed to advance/implement the standardization of dynamic PIDs and data citation through broad community and stakeholder engagement.

Use-cases. As much as workshops, gap analyses, and community engagement can inform the process to harmonize data, we cannot comprehend the unique informatics-, and implementation-related issues, unless we test the exchange of data between RIs in practice. Therefore, COOPEUS is also developing cross-disciplinary use cases involving multiple RIs from different scientific disciplines.

Building Blocks. There is no clear pathway to advance the construction of interoperable datasets and how users can access them. In partnership with Earth Cube and GEOSS, COOPEUS participates in building block activi-

ties such as the GEOSS Standards and Interoperability Forum, web brokering, semantic discovery, and development of user tools to facilitate integration of data from different RIs.

COOPEUS will continue to conduct workshops and develop use cases to further define procedures for data collection, processing and distribution that are accepted by the broader user community. For example, in September 2014, the Carbon Observation work package will conduct a workshop to engage early career scientists in the use of atmospheric and ecosystem greenhouse gas data from large observational networks. The Biodiversity, Carbon Observation and Ocean Observation work packages are collaborating on a use case to identify scientific questions addressing global carbon biogeochemistry, which can be tractably answered through cross-disciplinary efforts. Through activities like these, COOPEUS advances comprehensive issues facing all RIs.

Cross-disciplinary collaborations can be difficult in and of themselves due to differences in shared vocabular-

ies, metadata standards, QA/QC standards etc. Adding to these collaborative challenges are the cultural, language and policy differences among countries. Although virtual collaborations are an important goal in this effort, it is also necessary for collaborators to sit together to work through these challenges, especially early in the process. Interoperability requires human and programmatic commitment, effective communication and trust that is best facilitated by in-person interactions.

Outside COOPEUS, there are also many efforts to establish means to foster international and cross disciplinary (or even discipline specific) interoperability of data, but so far no clear path has emerged. Therefore, COOPEUS strives to create the forum, where diverse user communities can test new ideas, methodologies and philosophies for implementation of international data interoperability initiatives. As such, COOPEUS will provide a framework for discussion, discovery, engagement, adoption and implementation of new informatics to foster the open and widespread sharing of data. We envision these collaborative efforts to become the norm in the future

and result in a global framework for interoperable data for all environmental Research infrastructures and other observatory networks. ■

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Creative-B
www.creative-b.eu

On 26 September 2014 in Brussels will be presented a global Roadmap of biodiversity data research infrastructures, focusing on common priorities and infrastructure engagement, enhancing infrastructure interoperability, and the legal and governance implications.

Registration for this open event from 09:00 – 14:00 is possible after registration at: www.creative-b-2014.sciencesconf.org/.

Location: Palais des academies – Salles du Trone, 1 rue Ducale, Brussels, Belgium.

Uta Moderow¹, Christian Bernhofer¹

1. Technische Universität Dresden, Faculty of Environmental Sciences, Institute of Hydrology and Meteorology, Germany

Cluster of the Technische Universität Dresden for greenhouse gas and water fluxes

Reliable information is needed on the exchange of greenhouse gases (CO₂, CH₄, N₂O and others) between different ecosystems and the atmosphere to fully understand the change in concentrations in the atmosphere. In turn, this enables us to better understand global climate change, which is mainly caused by increased anthropogenic emissions of greenhouse gases into the atmosphere. Knowledge about the relevant exchange processes is a precondition for defining appropriate mitigation strategies as a part of land use management (e.g. how to best sustain and enhance carbon sinks). Here, long-term studies are essential. They enable us to study the exchange processes under a wide variety of meteorological and hydrological conditions thus broadening our understanding for these processes. Furthermore, long-term studies are important to identify differences caused by climate variability including extremes and in parallel to learn about potential changes under conditions of climate change. To provide such information is a core mission of the cluster of the Technische Universität Dresden (TUD-cluster) for greenhouse gas and water fluxes.

TU Dresden's continuous meteorological and hydrological measurements at the Tharandter Wald trace back to the second half of the last century with meteorological measurements (since the 1950') and hydrological measure-

ments at the catchment Wernersbach (since 1968), continuing through today. The first continuous measurements of CO₂ flux by eddy covariance were made at the Anchor Station Tharandter Wald (ASTW, spruce) in 1996. Today, the TUD-cluster includes eight flux measurement sites (Fig. 1, Table 1) from varying land use types (coniferous and deciduous forest, grassland, agricultural crop rotation, and wetland). Most of the cluster's measurement sites are situated in or close to the forest Tharandter Wald (60 km²) about 25 km southwest of Dresden, Germany (Fig.1).

Since the start of the first flux measurements at Anchor Station Tharandter Wald, the sites of the TUD-cluster have contributed to international research frameworks such as EUROFLUX CARBOEUROPE-FLUX, CARBOEUROPE-IP, and it is now part of ICOS-D (Integrated Carbon Observation System), the German contribution to ICOS Europe. The value and high quality of data from Anchor Station Tharandter Wald is documented by more than 200 publications (e.g. [1-5]). Together with the other greenhouse gas flux observatories of TU Dresden: Grillenburg (grassland), Klingenberg (crop rotation) and Spreewald (wetland), which have been operational since 2002, 2004 and 2010 respectively. Anchor Station Tharandter Wald forms the backbone of the TUD-cluster (Table 1 and Fig. 1).

All sites are subject to a similar cli-

mate, most of them even to very similar weather conditions. This allows investigations of land-use induced effects on greenhouse gas exchanges with the atmosphere under similar climatic conditions. However, mean annual precipitation and mean annual temperature differ a bit among the sites mainly due to their different altitudes (Table 1). Mean annual precipitation (uncorrected for wind loss) ranges between 570 mm and 900 mm and mean annual temperature between 9.4°C and 7.8°C reflecting the altitudinal gradient between the lowland wetland sites and Klingenberg at 480 m above mean sea level. Oberbärenburg at 730 m above mean sea level is somewhat colder and wetter (5.5 °C and 1000 mm, respectively). We are aware that these regional climate differences have an effect on the greenhouse gas exchanges in addition to the land-use effect.

Understanding the exchange processes between the earth surface and the atmosphere requires the assessment of meteorological data as well as the important characteristics of the investigated ecosystem. Consequently, measurements are not constrained to flux measurements of trace gases (CO₂, H₂O, selectively also CH₄, NO_x and NH₃), momentum and energy fluxes by means of eddy covariance. Additional measurements include radiation, air temperature, humidity and precipitation as well as soil heat flux. At selected

sites, profiles of soil moisture, soil temperature, air temperature and humidity are measured, and soil respiration is measured by automatic chambers. Tree transpiration via sap flow as well as phenological phases are recorded.

By end of 2013, the time series of the Anchor Station Tharandter Wald, which is the site of the TUD-cluster with the longest record, covered almost 18 years of flux measurements with a broad range of annual precipitation (2003: 501 mm, 2002: 1098 mm). Net ecosystem productivity (NEP) was lowest in 2003 (400 g C m⁻²) whereas the highest NEP was recorded in 1999

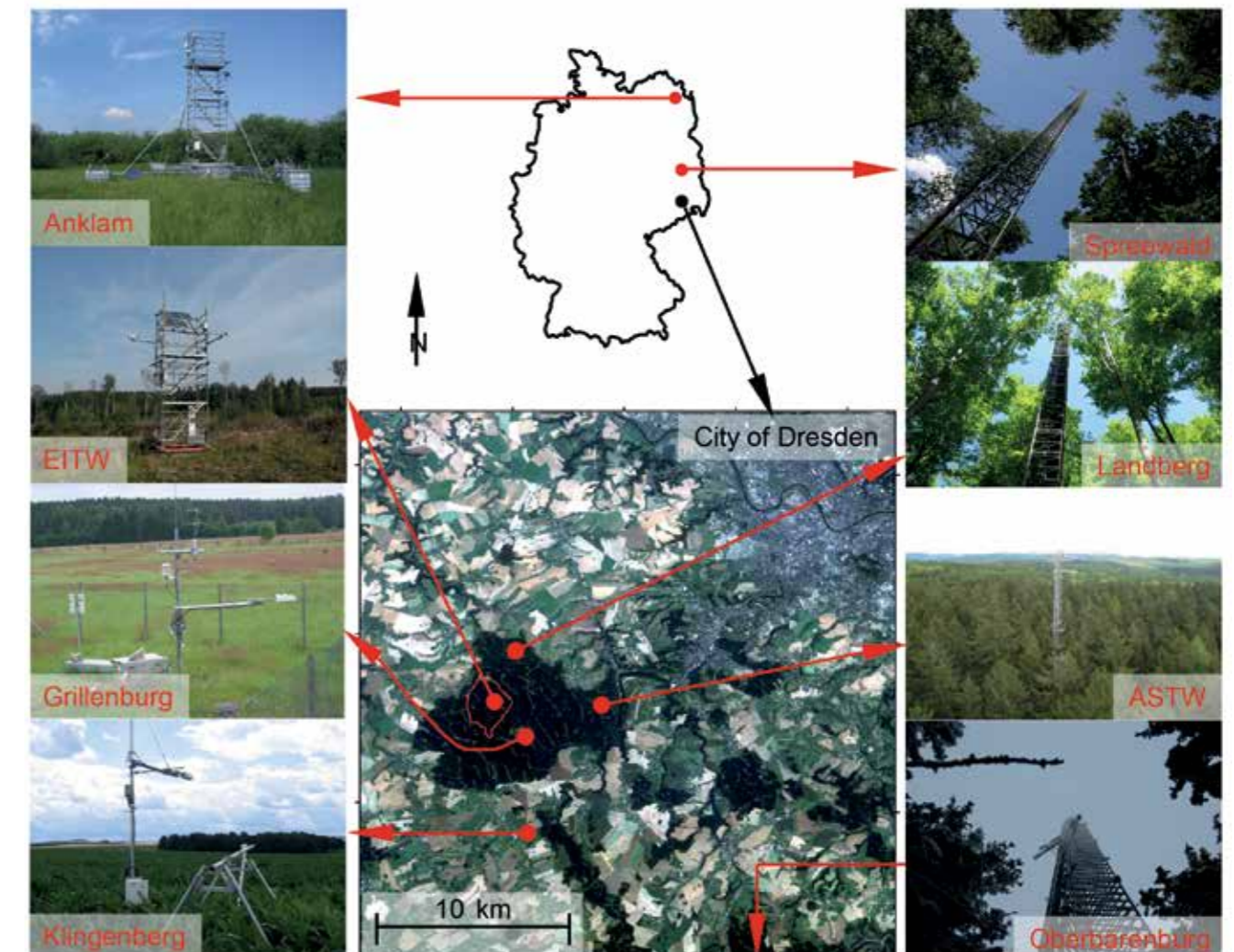
(700 g C m⁻²) - a year with precipitation similar to the long-term mean but somewhat warmer. (Fig. 2) shows results from 1997 through 2012 for most of the sites. Highest cumulative NEP rates occur at Anchor Station Tharandter Wald whereas the other spruce site Oberbärenburg shows lower cumulative NEP rates due to the cooler climate. The cumulative NEP of the agricultural sites exhibits strong inter-annual variations. Grassland's NEP as a continuous cover shows a smaller variability. Results for the two wetlands are also shown but no conclusion can be drawn yet about the inter-annual variation.

These results illustrate that annual NEP can considerably differ for an individual site (e.g. Anchor Station Tharandter) with respect to the meteorological conditions of each year. Such findings are only possible on the basis of long-term studies which capture

both average and extreme conditions. Furthermore, the different carbon flux of the different land uses is apparent. For the agricultural site, NEP not only differs in dependence of abiotic factors but also of the cultivated crop. The influences of a different climate (e.g. cooler due to the higher altitude) on NEP of the same species are evident in the results for Anchor Station Tharandter and Oberbärenburg, which do not differ largely in species and soil composition. We expect that spruce stands under the current regional climate, NEP will likely decrease with altitude and decreasing temperature.

However, specific aspects of the exchange processes between the earth surface and the atmosphere are still not well understood. Some of these aspects were investigated in intensive measurement campaigns at Anchor Station Tharandter Wald, which aimed at

Figure 1: Measurement sites of TUD-cluster. Upper centre denotes Germany. Red arrows and points refer to measurement sites. Black arrow and point are for geographical guidance, satellite picture of the region of Tharandter Wald from Landsat TM.



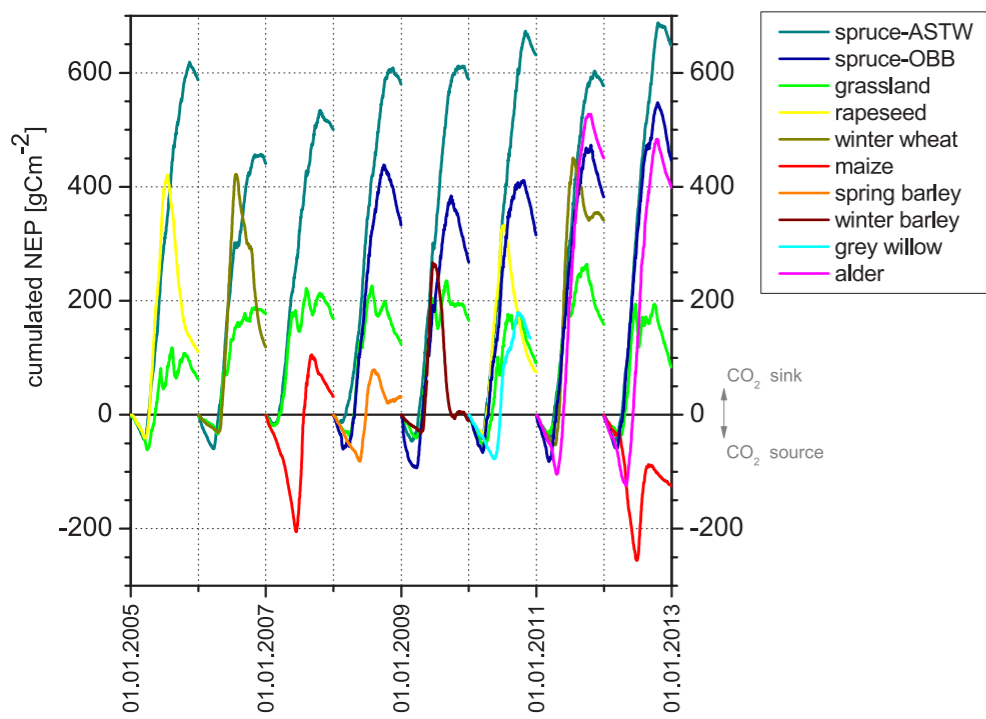


Figure 2: Net ecosystem productivity from TUD-cluster's sites. OBB refers to Oberbärenburg. Klingenberg is represented by different agricultural crops. Grey willow refers to the wetland site Anklam and alder to the wetland site Spreewald.

quantifying advection (MORE I [6] and MORE II [7]) and verifying footprint models (Traceflux [8]). Another recent measurement campaign (TurbEFA, which lasted a year) studied the effect of heterogeneity on the turbulent atmospheric flow in the lower part of the atmospheric boundary layer by means of 4 large towers, more than 20 ultrasonic anemometers and a tethered bal-

loon. Results of TurbEFA were combined with terrestrial laser scanning data of the forest in a novel approach to improve the parameterisation in numerical models for unresolved (small scale) turbulent exchange caused by heterogeneity [9].

The TUD-cluster not only aims to make substantial contribution to the understanding of greenhouse gas exchanges, energy fluxes and water fluxes between the earth surface and the atmosphere but also to facilitate experiments designed for special research questions. We hope that the TUD-cluster will continue to provide reliable long-term data of the regional climate system in a changing world and to al-

low monitoring based research on process understanding at TUD and elsewhere. ■

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Acknowledgement

Operation and maintenance of these sites as well as associated scientific work would not have been possible without the contribution and engagement of numerous people. Special thanks go to Uwe Eichelmann, Thomas Grünwald, Horst Hebenanz, Barbara Köstner, Udo Postel, Heiko Prasse, Ronald Queck and Uwe Spank (all TU Dresden, Faculty of Environmental Sciences, Institute of Hydrology and Meteorology, Chair of Meteorology, Germany).

Table 1: Basic characteristics of TUD-cluster sites

Site	Dominating land use	Latitude/ Longitude	Altitude (m)	Mean canopy height (m)	Maximum leaf/plant area index (m ² m ⁻²)	Start of flux measurements (year)
ASTW*	Spruce forest (<i>Picea abies</i>)	50°58' N, 13°34' E	380	26.5 ⁽¹⁹⁹⁹⁾ 31 ⁽²⁰⁰⁸⁾	7-8	1996
Grillenburg	Grassland	50°57' N, 13°31' E	385	0.5/0.09 [§]	1-3	2002
Klingenberg	Crop rotation [#]	50°54' N, 13°31' E	480	variable	variable	2004
Spreewald	Wetland (<i>Alnus glutinosa</i>)	51°53' N, 14°02' E	61	28 ⁽²⁰¹⁰⁾	3-4	2010
Landberg	Beech forest (<i>Fagus sylvatica</i>)	50°59' N, 13°29' E	400	30 ⁽²⁰⁰⁸⁾	4	2005
EITW**	Young oak plantation (<i>Quercus rubra</i> , <i>Quercus robur</i>)	50°57' N, 13°29' E	395	variable	&	2010
Oberbärenburg	Spruce forest (<i>Picea abies</i>)	50°47' N, 13°43' E	735	16 ⁽¹⁹⁹⁸⁾ 22 ⁽²⁰¹³⁾	4-5	2008 [§]
Anklam	Wetland (<i>Salix cinerea</i> ^{§§})	53°51' N, 13°41' E	-1	1-5	spatially variable	2009

*ASTW stands for Anchor station Tharandter Wald

** EITW stands for Oak site Tharandter Wald (Eichenstandort Tharandter Wald)

§ mean value before and after cut, average over 9 years; 2-3 cuts per year

rapeseed, winter wheat, maize, spring barley, winter barley

& LAI of oaks was small in 2013 (planting in 2008 and 2010) but LAI of total plant cover was about 2 m² m⁻².

§§ Sensible heat flux has been measured since 1994. Measurements of latent heat flux and CO₂-flux started in 2008.

§§§ mosaic pattern of *Salix cinerea*, *Carex spec.*, and *Phragmites*

PEEX – Pan-Eurasian Experiment.

www.atm.helsinki.fi/peex/



Alex Vermeulen
Chair of TTorch RNP

TTorch: When the flow starts the program ends... Experiences with the TTorch ESF Research Networking Programme



TTORCH
Tall Tower and surface observation Research Network for verification of Climate relevant emissions of Human origin in Europe.

Mission
Torch is a European Science Foundation (ESF) Research Networking Program (RNP), supported by 11 ESF member organisations that focuses on measurements and modelling of non-CO₂ greenhouse gases and related tracers. The main purpose of TTORCH is to support and help improve the European network of observations of greenhouse gases through communication, workshops, grants for exchange visits and summer schools.

TTORCH will work, by capacity building, towards extension of the measurement network in poorly covered areas, like Eastern Europe. The Programme will also contribute to strengthening the connection between measurement and modelling scientists by organising joint workshops and publications.

Timeline
March 2009 – October 2014

Estimated Costs
354000 €

Website
www.ttorch.org

The European Research Arena is one of the biggest success stories of the European Union. The Commission's R&D Framework Programmes (FP), now in its 8th edition called Horizon2020, bring together scientists from all EU member states and associated countries to join their efforts in projects that would otherwise be less successful or even possible at all. Formerly, the European Science Foundation promoted cooperation between European scientists through programs like the Research Networking Programme (RNP).

With the end of the 5th European Framework Programme, a funding gap evolved as projects like CHIOTTO, CarboEurope-IP and related projects ended. In order to keep the network of scientists involved in the development of the European observational capacity for greenhouse gas fluxes and concentrations alive, the TTorch RNP project was initiated.

The project was selected in 2007 and started in February 2009 with the initial Support of 8 and later 9 ESF member countries. TTorch (Tall Tower and surface Research Network for verification of Climate relevant emissions of Human origin in Europe), chaired by ECN in the Netherlands, is designed to provide five major activities: a database supporting the exchange of the observational data, support international workshops, exchange of young scientists, dissemination of research, and

the organization of summer schools for training young scientists and finally coordination of all these activities. TTorch will formally end in October 2014. The total budget for the TTorch actions is relatively modest: € 430 000, of which about € 75 000 is used by the ESF administration.

TTorch (www.ttorch.org) a permanently open call for proposals. Where young students can apply for support for either short term or long term visits to institutes. The grants cover travel costs and per-diem expenses, for work relevant to the TTorch research area. In addition, a permanent open call exists for support for scientific meetings and workshops. The proposals are evaluated by the TTorch Steering Committee (SC), existing of representatives of the 9 supporting member countries. The evaluation usually takes place within 2 weeks after application, after which the applicant will receive from the ESF administration an advance payment just before the visit or meeting, and the remainder after submittal and approval by the SC of the report on the visit or meeting.

Results

The TTorch database activity resulted in an intermediate database that has been applied in the FP6 NitroEurope-IP project in its very successful inverse

modelling workpackage for methane and nitrous oxide [1, 2]. Furthermore the network led to the setup of the InGOS Integrated Activity in FP7 that started in 2012 and will end in October 2015. This project has taken over the TTorch database activity.

The 2011 TTorch midterm report noted a substantial underspending. The first half of the project only supported a few visiting students and one summer school. In the second half of the TTorch lifetime, now almost complete, this trend has shown a magnificent acceleration, as shown in table 1, which shows the result score of the TTorch RNP thus far.

The TTorch summer schools in Hyytiälä (Finland), organised in the early autumns of 2011 and 2013, were a big success and proved to fulfill a big demand for training of young scientists in the working field of GHGEurope, ICOS, InGOS and related projects. The feedback from the students informed us that especially the provision of training in field work, theory and modelling in one course in a stimulating environment was highly appreciated, as well as the much appreciated provision of relaxation and fun in the afterhours.

At the final annual meeting of the TTorch Steering Committee, March 2014 in Amsterdam, we noted the following lessons learned:

- Starting a network is a slow process
- ESF administration has grown to be very expensive
- Asking for even a small proposal text means a big, but necessary hurdle for applicants
- Spending money can be difficult, but we learned how to do it

- Short visits are extremely useful and serve a strong need of young scientists
- Long visits are excellent CV boosters
- Summer schools are extremely useful
- When a network is finally rolling smoothly, it stops!

The future

Based on these conclusions the SC decided to strive for continuation of the network and its activities after the end of the RNP later this year. The first try will be to initiate a TTorch COST action. Furthermore it was decided to continue the successful two-yearly TTorch Summer Schools in Hyytiälä, with a third edition in 2015, using support from ICOS Finland, InGOS and other projects.

The still upcoming planned activities supported by TTorch in 2014 are:

- 2nd FLEXPART modelling training course: Vienna May 2014
- TransCOM workshop: Groningen 22-26 June 2014
- ICOS Monitoring Stations Assembly Atmosphere: Amsterdam 23-26 June 2014
- ICOS Carbon Portal/Transcom Networking Design Workshop: Amsterdam 27 June 2014
- Hyytiälä lake GHG workshop for the future: Advancing the science of gas exchange between fresh waters and the atmosphere, 16-19 September 2014
- Summer School on Data Assimilation Techniques in BioGeoChemical Sciences: Trieste 20-27 September 2014
- ICOS Scientific Conference, Brussels 23-26 September 2014 ■

alex@torch.org

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Acronyms

- COST:** A European framework supporting cooperation between scientists <http://www.cost.eu>
- CHIOTTO:** European research project for setting up 8 tall towers for Greenhouse gas observations (2004-2007)
- CarboEurope-IP:** EU Integrated research project on the carbon balance of Europe, 2004-2008
- GHGEurope:** EU Integrated research project on the Greenhouse Gas balance of Europe, 2009-2013
- ICOS:** EU Research Infrastructure spanning currently 15 member states and projected to run for the next 20 years: Integrated Carbon Observing System, <http://www.icos-infrastructure.eu>
- InGOS:** EU FP7 integrating activity 2011-2015: Integrated non-CO2 Observing System, <http://www.ingos-infrastructure.eu>

Table 1. Results delivered by the TTorch RNP, besides to the website and dissemination leaflets.

	1st Period 1	2nd Period	Total (incl. planned)
Short visits	10	13	26
Long visits	1	4	6
Science meetings	2	8	10
Summer Schools	1	1	3
Courses	-	2	2
SC meetings	3	3	6

Ilkka Klang¹, Ari J. Asmi², Antti Pursula³

1. Science editor, Finland.
2. University of Helsinki, Div. of Atmospheric Sciences, Dept. of Physics, Finland.
3. CSC – IT Center for Science, Finland.

Risto Makkonen, Tea Thum, Antti Pursula

Connecting research infrastructures for integrated research on the atmosphere

Introduction

With constantly increasing interest in predictive long-term climate modelling among policy-makers and the general public, atmospheric research is one of the more visible areas in modern science. Climate science, and by extension atmospheric science, deals with highly complex systems in many different scales ranging from global extent, such as ocean currents, to molecular scales as in formation of aerosols. Moreover, studying the different scales and systems involves knowledge from various scientific disciplines. Such a gigantic

scope increases the difficulty of performing atmospheric research since no single scientist can be a specialist in all of the involved fields.

There exists a long tradition to collect observations of the natural phenomena surrounding us, and thus extensive time series of, for example, weather and climate parameters have been preserved. Currently, the observations have extended to producing extremely large amounts of data by automated instruments on a highly diverse set of variables, from satellite images to greenhouse gas concentrations and to ocean temperatures at different depths.

Specialized research infrastructures have been established to develop and operate the measurement stations and instruments. Atmospheric science is an example of a multi-disciplinary field for which the research infrastructures are promising to offer novel opportunities by making more and more diversified research data available for scientific analysis.

Consequently atmospheric research benefits significantly from inputs of interdisciplinary initiatives such as ENVRI (Common Operations of Environmental Research Infrastructures). ENVRI is a collaborative project



Antti Pursula is a project director in Research Infrastructure unit at CSC – IT Center for Science Ltd. working with development and support of e-infrastructure solutions for research communities.



Tea Thum is a research scientist at Finnish Meteorological Institute, FMI, working with the carbon cycle in the land surface models. (Photo by Kristina Luus)



Risto Makkonen is a postdoctoral researcher at University of Helsinki working with Earth System Models, especially with aerosol-climate interactions. (Photo by Ella-Maria Kyrö)



Atmospheric measurements in Hyytiälä station, Finland

model is computed. The complexity stems from a wide array of challenges, ranging from the problem of calculating fluid motions of air masses just on a physical level, to correctly identifying on a theoretical level the numerous interdependent interactions within the chaotic system that is Earth's atmosphere. For example, the chemical dynamics of the atmosphere are still not completely understood.

Climate models are computationally intensive in addition to requiring and generating vast amounts of input and output data, respectively. More complex models may use more detailed data sources or denser grid units, further increasing the computational load. Research organizations and universities that develop the models may have their own powerful computers from which they can allocate CPU time. It is also common to use resources from external computing centers for running the simulations. In Finland, the national service is provided by CSC – IT Center for Science.

A model can only be as accurate as its algorithms and data inputs allow; accurate measurements are essential for model accuracy as well as for verifying the validity of a model. The source data is gathered by various research teams, universities and other organizations around the world, and while their data is usually available through one of the current research infrastructures, that is by no means certain. The lack of established conventions and aggregate databases are seen as slight problems that require creative solutions, such as gathering lists of measurement stations from previously released papers.

Data discovery in practice

"Obtaining data is very much dependent on finding the right person to ask", answers Risto Makkonen, research scientist working at University of Helsinki, currently working on global aerosol-climate models. "In Helsinki, we fortunately have plenty of people with good professional networks, but that approach has its limits. There are cas-

of a number of environmental research infrastructures that have been listed on ESFRI (European Strategy Forum on Research Infrastructures) roadmaps. The main benefit of interdisciplinary collaboration in this area is to enable the use of observational data across disciplines. It is also critical to make this data discoverable and usable to scientists also outside the community providing these observations.

We continue to make progress toward the numerous challenges to data sharing. Common challenges include data discovery (i.e. discovering that data exists and how it can be accessed), data harmonisation (i.e. how to make different de-facto standards compatible with each other), and practices of data sharing (who can give permission to access the data, under which conditions, and how is the source of the data

acknowledged). In this paper we set out to review the current research data related impediments for conducting interdisciplinary atmospheric research in practice by conducting interviews with scientist who face this problem in their daily work. Ilkka Klang, a science editor conducted the interviews and wrote the main part of the article. Ari Asmi, Dr. and research coordinator at Division of Atmospheric Sciences at Helsinki University, and Antti Pursula, project director at CSC – IT Center for Science, provided their expertise and co-authored the article.

Global models

Global climate models are complex simulations where the lower portion of Earth's atmosphere is divided into a three-dimensional grid on which the

es where a team somewhere has taken measurements from a site for ten years and is now practically sitting on all that data unless you find a way to contact one of their researchers. We're running a huge Earth System model that aims to simulate all known processes in the atmosphere, ocean and land. The model is a complex one, and while we can make good estimates on what data we need to gather and use for it, I'm nevertheless certain that there are input data sources somewhere in the world that would be useful for us, but we're not even aware of them."

Similar thoughts are echoed by Tea Thum, research scientist for greenhouse gas modeling at Finnish Meteorological Institute: "There are lots of data banks. I've personally used data from FLUXNET, but when we need more sources, there are other data banks and remnants of old projects. The problem is just finding them. When the data exists, obtaining the permission to use it is usually not an issue. We have a positive enough atmosphere in the research community so that people are willing to share the data in the interests of science. However, as the number of people and measurement stations grows, the sense of community is diminishing. People no longer know each other and the unwritten practices are no longer as well agreed upon. Generally, people are very willing to share the data but there are differences whether they require co-authorship in your paper or if just crediting them is enough."

The challenge of discovering and accessing various data sources is an identified theme within the environmental science communities. "Developing data discovery and access tools and piloting these solutions is one of the focus points of the ENVRI project", tells Antti Pursula, who is responsible for the ENVRI project participation at CSC. "The project aims to enhance interdisciplinary research in environmental science by making measurement data from different research infrastructures available for all relevant users". The approach of ENVRI includes production of a searchable metadata catalogue, meaning that a researcher can perform queries on availability of data from distributed data collections, and a common

reference model to enhance interoperability of the infrastructures. Once in larger use, the effort of contacting different research teams in order to find data sources can be greatly simplified. University of Helsinki and CSC are the Finnish participants to ENVRI project.

Data sharing practices

The issue of authorship is one that comes up on occasion. The incentive structures in academia create a world where authorship and acknowledgements in papers and articles have effectively become a valuable currency that affects researchers' prestige and job prospects. Combined with the general lack of conventions and interdisciplinary oversight, this has resulted in a situation where there are no clear guidelines on how a team performing the measurements should be academically compensated for making their findings available to public use.

Both sides, data producers and users, have their own priorities. A research team's funding may be dependent upon the number of citations it receives, or a government may forbid publishing of data unless it is listed as a co-author. The end users want to avoid a situation where any publication that uses data from a larger pool of sources would end up as being 'authored' by tens of people, some of whom only have a tangential relation to the paper.

"There are some conflicts of interest. When measurers gather high quality data, they usually prefer to see it used in other researchers' work as well, and would also prefer to get publications under their own name as co-authors," describes Makkonen. "On the other hand, leveraging a decade-long time series of measurements to a growing stream of co-authorships is a bit disproportionate from a modeler's or a theoretician's point of view, so we'd need some mutually agreed guidelines that take all sides' needs into account."

Research bottlenecks

Many organizations have their own computing clusters these days, but large-scale atmospheric models still require some extra computing consider-

ations. For example, Makkonen's model is run at supercomputing systems provided by CSC Finland, and its bottleneck is not found on the usual CPU cycles, but on the amount of data processed:

"Storing the results we get is actually a bigger issue than running the simulations. The amount of data generated quickly becomes staggering so we rarely store it in full. This may cause problems for evaluating the validity of our models if the outputs we have generated are less granular than the measurement data from the real world we're comparing them with," outlines Makkonen. "CSC are doing a good job finding solutions for us but usually the pressure to increase the detail level of a model increases in sync with increases in available disk space or CPU capacity so the storage problem never really goes away."

Another challenge is in the uneven distribution of measurements for atmospheric research. Generally, data and measurements range from adequate to abundant in the EU area, thanks to numerous university and governmental programs supporting it. But for global climate modeling, one continent is no more than a decent start. So what about the rest of the world? Unfortunately, the situation is not as rosy, as Makkonen describes: "Since most climate models have to be global, we need to have global measurements as well. Outside Europe and North America, this becomes tricky, at least for particle measurements, which is an important parameter for atmospheric models. Compared to Europe, the spatial coverage of such observations in South America and Africa is very limited." In addition, work is being done to strengthen connections to research infrastructures in Asia.

Future outlook

Natural sciences have a long tradition of ingenious researchers inventing and constructing their own equipment as they go, and while that spirit of discovery in many ways have advanced various research field, a well-established field such as atmospheric research in its current state tends to benefit more from standardized equipment and con-

ventions, as the researchers' statements in this article imply. One example of a standardizing initiative is the ICOS (Integrated Carbon Observation System) research infrastructure that seeks to tackle the inconsistency of data by standardizing the measuring equipment, and by providing a portable laboratory system for its members. ICOS is also one of the infrastructures participating to ENVRI project.

But sometimes the equipment is the least of the problem. The lack of standard conventions also plagues data formatting, which can lead to issues in utilizing the data: "There are no conventions for formatting of data. Some of it is in text files, some in spreadsheets," outlines Tea Thum. "The quality of metadata also varies a lot, sometimes it even doesn't exist. On the other hand, if you focus on a certain area or source, you can get a lot of information by contacting the researchers. Of

course, if you need to gather data from a broader list of sources, that course of action isn't that realistic - I haven't been personally involved with ICOS, but I approve of the core idea. For example, flux readings in my field with can be done with open-path or closed-path analysers, and the difference between them causes occasional confusion. The more consistent our measuring devices, the less we have to deal with additional uncertainty."

Risto Makkonen found similar up-sides on his recently used data bank: "For our project, we used the EBAS database that is operated by Norwegian Institute for Air Research (NILU). I'm not aware of how exactly the data was gathered and collected there, and from a researcher's viewpoint, it is not essential to know what organizations, projects or individuals have been involved in it. It's more about actually having access to both the data and rel-

evant information about the data such as measuring equipment used."

The atmosphere modeler's ideal scenario is a grid of reliable observation stations covering the earth, producing standardized data, which is made easily accessible in global data-banks. In this way, advanced climate models could be built. Whereas this scenario may never become reality, there are slight advances on many fronts; more models are being theorized and tested which create demand for new measuring stations and better data, which in turn becomes more easily available and providing fuel for the next generation of climate models. ■

1st ICOS science Conference

Greenhouse Gases and Biogeochemical Cycles
Brussels 23-25 September 2014



The ICOS Science Conference topics:

- Atmospheric GHG concentrations and anthropogenic sources
 - ICOS data and global biogeochemical modelling
 - Biogeochemical cycles of forests, grasslands, wetlands and agricultural ecosystems
 - Ocean GHG observations and fluxes
 - Regional integration studies
 - Different GHG species
- Contributions on freshwaters and urban environments are also welcome.

Important dates:

- May, registration opens
- 26 June 2014, abstract submission deadline
- 4 July 2014, notice on abstract acceptance
- 11 August 2014, registration deadline
- 23-25 September 2014, 1st ICOS Science Conference
- 26 September 2014, ICOS RI stakeholder meetings

www.icos-infrastructure.eu/scienceconference

Magdalena Brus

Division of Atmospheric Sciences, Department of Physics,
University of Helsinki, Helsinki, Finland

Environmental research infrastructures in the context of Science and Society

Magdalena Brus presents three interviews with international experts specializing on policy-making, collaboration and harmonized development of research infrastructures in the field of environmental sciences. They are discussing the specific role of environmental research infrastructures in advancement of science and technology, especially in relation to grand challenges the society is facing. The interviewees also present their views on perhaps less recognized impacts of the research infrastructures on European economy and the society in general. Last but not least, they talk about the policy-making on research infrastructures and importance of systematic approach and interdisciplinary collaboration in the process of their construction.

Firstly, could you explain where you see the scientific impact of environmental research infrastructures in relation with societal grand challenges, such as climate change, air quality, water availability, food supply and others?

Actually all the challenges you are mentioning here are closely related to environmental science. If we want to work on solutions that will reduce environmental risks and impacts of these challenges, we first need to understand the Earth system and its functioning and this is exactly the aim of the environmental research; environmental research infrastructures (RIs) play an indispensable role here as they provide the knowledge needed for sustainable management of the natural and human

environment and the resources of our planet. In addition, decision-making should be always based on the up-to-date scientific knowledge and RIs, by providing the world-class research environments and research data, enable such a high-quality science.

However, we should bear in minds that the societal challenges are interlinked and decisions made on one environmental issue also affects other environmental challenges. For example, previous European Union decisions on increasing the proportion of biofuels in car tanks was followed by conversion of South-East Asian peatlands for bio-fuel production. The actual conversion, however, had profound implications for global greenhouse gas emissions. The use of biofuels thus resulted in similar or even more negative impacts

European research infrastructures are being built in order to overcome the limitations and fragmentations of national efforts in different scientific fields and thus reach the critical mass necessary for scientific excellence and cutting-edge research. They represent the fundamental component laying the foundation for new knowledge, skills and developments turning into innovations, which is one of the key drivers for implementation and maximizing the impact of Europe 2020 strategy.

Dr. Sanna Sorvari is a key collaborator in ICOS research infrastructure. In ENVRI and COOPEUS projects, she is coordinating the work towards common vision, strategies and improved interoperability of the environmental research infrastructures. In this interview, Sanna explains, why she considers research infrastructures to be very important not only for advancement of science, but also for education, society and European economy.



on climate than use of fossil fuels they replaced. It is therefore obvious, that solving the environmental challenges is not possible without multicomponent assessments and truly systematic approaches. Environmental RIs, if developed together into interoperable system, play a crucial role in this.

Most economists agree that research and innovation are the main motors for European economy to be more productive and competitive as well as sustainable. Could you explain where you see the social and economic impact of the environmental research infrastructures, including innovation potential and possible cooperation with industry?

Environmental RIs can be seen as centers of competence, where the actors of basic research (academia), applied science (mainly research institutes) and industry as well as the private sector will work together. Such environments naturally foster the innovation capacity. Currently, environmental RIs have been set up to serve certain science fields, such as EPOS for seismology, ICOS for greenhouse gas observations, LifeWatch for biodiversity, and therefore, each of the research infrastructures has specific societal and economic impacts and innovation potentials. However, at the general level, all environmental RIs enhance the development of new methods, techniques and services. These technological innovations can be naturally translated into successful market applications.

Research infrastructures are often said to be at the center of the knowledge triangle of research, education and innovation. Where do you see the added value of research infrastructures for education?

As mentioned earlier, RIs offer world-class research environments that attract scientists and talented students from different countries. This creates an excellent teaching environment, not only to train students to use the research infrastructure or its data, but also for senior scientists and professors to update their skills and knowledge.

RIs also provide a natural environment for intensive training courses, such as summer and winter schools. The RIs are as well part of the paradigm shift towards “big data”, which calls for more organized RIs with more coordinated production, management and use of research data. All these changes require a new kind of data scientists with very specific set of skills. So, the future challenge is to educate a new generation of environmental and data scientists able to meet these requirements.

Could you describe the role of ESFRI and its Strategic Working Groups in the development of European research infrastructures?

Firstly, I would like to point out that RIs are a key component of the European Research Area (ERA), as they bring together a wide variety of stakeholders to search for solutions to the scientific problems being faced by society today. RIs offer unique research opportunities for users from different countries and from different disciplines; they attract young scientists and help to shape sci-

entific communities. Last but not least, RIs play an increasingly important role in the advancement of knowledge and the development of technology to help Europe compete in an increasingly globalized knowledge economy.

Considering the importance of RIs, the EU Council recommended to set-up a specific forum, ESFRI, to support the development and policy-making on RIs. After a comprehensive assessment, the ESFRI also ensures the follow-up of implementation of already on-going ESFRI projects, as well as the prioritization of the infrastructure projects listed in the ESFRI roadmap.

To perform its tasks, the Forum has decided to set up Strategic Working Groups (SWGs). They all proved instrumental in monitoring the scientific developments and emerging research challenges in the domain of its competence, as well as addressing the issue of socio-economic impact, while taking innovation aspect into account. The SWGs also contribute to dissemination activities, sharing of the best practices among the RIs and promoting the use and the development of e-infrastructures. The groups also advise ESFRI in

European Strategy Forum on Research Infrastructures (ESFRI) was established to support a coherent and strategy-led approach to policy-making on research infrastructures in Europe and to facilitate multilateral initiatives leading to better use and development of research infrastructures. In 2006, the ESFRI published its first roadmap, which identified new research infrastructures of pan-European interest corresponding to the long-term needs of the European research communities.

To perform its tasks, the Forum has decided to set up Strategic Working Groups for assistance in the different domains: Energy, Environmental Sciences and Climate Change, Health and Food, Social and Cultural Innovation, Physical Sciences and Engineering.

Dr. Gelsomina Pappalardo, chair of ESFRI Strategy Working Group for Environmental Sciences, describes the main mission of ESFRI and its working groups and explains, why it is necessary to explore the synergies within as well as among the different domains, not only for scientific but also for socio-economic reasons.



areas where coordinated actions are necessary, i.e. for example, in developing ties with industry and in interacting with stakeholders to work together on strategies.

Speaking of the working group for Environmental sciences, there is no specific goal for this group different from the goals of other SWGs, as we are trying to work on the same line with the other domains. The only specification of the environmental domain is perhaps the distributed approach of its RIs, as we need to study certain aspects in different conditions.

However, what I consider very important is that we also work on the specific demands for the link among the different domains. Meaning that for the Environmental group, we should for example also explore the synergies with the Energy or Health and Food domains.

Where you, as a chair of ESFRI Strategic Working Group for Environmental Sciences, see the social and economic impact of the environmental research infrastructures?

It is important to mention that we have not yet developed a quantitative way of assessing socio-economic impacts of RIs, as we first need a complete landscape analysis. Nevertheless, considering the knowledge they provide and innovation potential they have, we can expect that their impact on both social and economic development will be significant. New knowledge produced by the RIs will not only impact science itself, but we can also expect a potential socio-economic impact. New knowledge generate new ideas and new ideas boost innovation, which is yet another key aspect. New tools, prototypes, techniques and instruments developed by the RIs are innovative products potentially having a huge impact on European market and industry as well as on environmental solutions.

Another important point is the training of new generation of scientists, which is not only important for future development of science and green development of the future, but also for the

socio-economic impacts for the hosting region, because it helps to create new jobs.

Another aspect we should not forget is that RIs are here to serve the public. Environmental RIs are especially well positioned to serve the citizens by providing information and solutions related to environmental challenges. Moreover, RIs can also transfer their knowledge and services to other, non-scientific communities, including national and regional environmental agencies, policy makers and others.

What is in your opinion the added value of interdisciplinary collaboration among research infrastructures in the environmental sciences?

In my opinion, enforcing the cooperation and exploring the synergies among the RIs is crucial and will be even more important in future. Exploring the synergies can reduce the costs, improve the efficiency as well as enhance the impact of the RIs. For example, systems or expertise developed by one RI can serve and be used by the other.

We cannot forget that interdisciplinary collaboration is even more important within the environmental domain, where there are no clear limits or borders among the disciplines. The Earth system is highly interlinked and different components cannot be studied in the isolation. For example, oceans are tightly coupled with the atmosphere, and land properties are relevant as well, so they cannot be studied in separation. RI projects are currently focusing mainly on their implementation, but in future, they should increasingly focus on their integration and interdisciplinary collaboration.

Are there any crucial components of the Earth system still missing from the ESFRI roadmap?

Sure, there are still important components missing from the observing system. And it is a role of SWG to perform a complete landscape analysis as well as to use the feedback from existing RIs before the update of the ESFRI

roadmap.

In my opinion, it is important to identify those missing components, which could be linked to already existing RIs. Aerosol and clouds are not yet included within the atmospheric domain, and different environments, such as lakes, rivers and urban regions, are not yet well covered by the ecosystem measurements, just to name a few examples. In general, RIs should not stagnate but explore their possibilities for natural expansion in future, especially with respect to its innovation capabilities.

Other aspects we should, in my opinion, explore better in the future are the missing components in the strategic vision of an Integrated Global Observing System, adaptation to and mitigation of climate change, resource analysis and resource management. Last but not least, regional aspects should be also considered in the landscape, as Arctic or Mediterranean are good examples of very important regions with the specific needs, possibly serving as natural laboratories to study the interactions among different domains.

What do you consider to be the added value of the interdisciplinary collaboration among the environmental research infrastructures? Can you mention an example, where lack of data interoperability noticeably limited our ability to understand certain phenomena?

Earth is a big planet, where tremendous amount of feedbacks and processes connect the different phases together. No single research infrastructure or discipline can manage all connections, and any subset will still be dependent on the feedbacks from other parts of the system. For example, understanding climate is not just understanding the atmospheric processes, we also need information on human activities, biosphere and oceans to get even close to a realistic picture what is happening. Environmental sciences are cluttered with examples of how one can

Environmental research is continuously evolving in response to environmental challenges facing human society and increasingly relies on global-scale data delivery with analyses from observations, experiments and modelling. Given the scale and complexity of the environmental challenges, it is necessary to collect an extensive amount of very diverse and interdisciplinary data across the fields of environmental science. This, however, requires new approaches for example for data discovery, access, standardization and data harmonization.

Dr. Ari Asmi is currently leading a development of the long-term strategy for environmental research infrastructures. In ENVRI and COOPEUS projects, he is mainly focusing on strategic planning and improved data collaboration of the environmental research infrastructures. In this interview, Ari describes the challenges behind the harmonization of heterogeneous datasets and computation across research infrastructures to serve an increasingly multidisciplinary scientific community.



get a completely wrong view if just assuming that things happen in isolation, ignoring the feedbacks and processes happening in other regions or outside of the studied discipline. Therefore, collaborative work between disciplines is crucial to all environmental studies. In the sense of added value, I think that collaboration creates the majority of value from the RIs in the future. Without collaboration, we are just observing aspects of a complex picture, never getting to the actual understanding of the Earth system.

Naturally, it is hard to give an example of research, which has not happened. However, it is clear that we could have been much earlier in finding out several key feedbacks e.g. between biosphere and atmosphere, if we would have had more direct and easier ways to share datasets and understanding between disciplines. Another issue is that we need to develop the interoperability between RIs for purposes that might not yet be apparent. An archetypical example demonstrating the need for cross-disciplinary data-collection is the Eyjafjallajökull volcano eruption in 2010, which caused enormous disruption to air travel over the Europe. Suddenly, there was an urgent need to integrate measurements available both from national and international networks with a wide variety of data sharing policies and data sharing cultures, data availability and documen-

tation. Even finding out what actually was available in the sense of measurements was difficult.

What are the most crucial cross-disciplinary challenges in the current landscape of environmental research infrastructures?

Currently, I think that we are already moving forward in good speed in Europe, although a lot needs to be done. So far, RIs have mostly concentrated on providing services for their own disciplines and stakeholders, which is only natural as that is why they have been constructed in the first place. However, we need to build a research culture, where we automatically position the infrastructures and Earth system research towards holistic understanding of the whole planet. The other key issues, such as data openness, access, discovery, and documentation will follow from accepting the need of the holistic understanding.

This kind of lofty goal for understanding the planet will of course need a huge amount of work. We need a way to share our information in understandable, easy ways between the disciplines. We need a way to trust that the shared information is used and cited properly. Similarly we need trust on the originator of the datasets and on the validity of the measurements and documentation. In addition, there is a

huge amount of purely technical issues as well, such as data storage capacities, discovery processes, and standardization needs.

Could you suggest any possible actions that would improve current situation?

I think that we should really start by building trust and improving communication. Not just between the RIs, which has already been initiated in the ENVRI and COOPEUS projects, but also between the data user groups, scientists and the public. The key issue is still lack of communication between the disciplines, and I think that the RIs can form a good long-term way to facilitate this communication. Standardization of terminology and building together a common research culture are examples, although admittedly vague ones. If we get the communication between the RIs to work in a sustainable way, then the trust and culture can be built. Hopefully that would then generate the way to tackle the technical challenges as well. ■

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Markus Reichstein, Biogeochemical Model-Data Integration Group, Max Planck Institute for Biogeochemistry, Jena, Germany

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Nathalie de Noblet-Ducoudré, Laboratoire des Sciences du Climat et de l'Environnement (LSCE), Gif-sur-Yvette cedex, France

Daniel Rosenfeld, Institute of Earth Sciences, Hebrew University, Israel

ILEAPS-ENDORSED PROJECTS AND RESEARCH INITIATIVES

ACPC

Aerosols, Clouds, Precipitation and Climate Research Program

AMMA

African Monsoon Multidisciplinary Analyses

BRIDGING THE GAP BETWEEN ILEAPS AND GEWEX LAND-SURFACE MODELLING

EEE

Extreme Events and Environments

EMISSION, EXCHANGE, AND PROCESSES OF REACTIVE COMPOUNDS

FLUXNET

International Network Measuring Terrestrial Carbon, Water and Energy Fluxes

HENVI Forests and Climate Change

GEIA

Global Emissions Initiative

GLACE -CMIPS

Global Land-Atmosphere Coupling Experiment

IBBI

Interdisciplinary Biomass Burning Initiative

IMECS

Interactions among Managed Ecosystems, Climate, and Societies

LUCID

Land-Use and Climate, Identification of robust impacts
Methane Loss From The Arctic

NEESPI

Northern Eurasia Earth Science Partnership Initiative

PEEX

Pan-Eurasian Experiment

TAITA

Multidisciplinary Research Station in Kenya

WELGEGUND

Observation Platform in South Africa