

3rd GEOSS Science and Technology Stakeholder Workshop
NAVIGATING SUSTAINABILITY ON A CHANGING
PLANET
March 23-25, 2015, Norfolk, VA, USA

WORKSHOP REPORT



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Acronyms

DAB	Discovery and Access Broker
EOV	Essential Ocean Variable
GCI	GEOSS Common Infrastructure
GSTS	GEOSS Science and Technology Stakeholder
GTSN	GEOSS Science and Technology Stakeholder Network
OGC	Open Geospatial Consortium
RRR	Rolling Repository of Requirements
SBA	Societal Benefit Area
SOSH	Safe Operating Space for Humanity
WPS	Web Processing Service

1 Goals and Objectives of the Workshop

Informing Sustainability: 2015 is a year of important decisions preparing humanity's Road to Dignity. Our leaders need comprehensive information about the state and trends of the planet, including our global society, to make progress on this road to sustainability and dignity. The workshop linked societal goals to essential variables needed to measure progress towards these goals and discuss research innovations in support of sustainable development.

Our planet is rapidly changing and moving out of the Holocene. Navigating and managing the changes and maintaining a sustainable development is complex. We need to have goals and targets related to sustainable development, understand the limits of what is a safe and sustainable development, know the ongoing changes, and have foresight about the impact of our actions on the planet. The workshop brought together the science that links our goals with the "navigation tools," that is, the indicators of change, and the Earth observations required to quantify these indicators.

A main outcome of the United Nations Conference on Sustainable Development (Rio+20), held in June 2012 in Rio de Janeiro, was the agreement by Member States to initiate a process to develop a set of "Sustainable Development Goals" (SDGs). Motivated by the partial success during the decade from 2005 to 2015 of achieving the "Millennium Development Goals" (MDGs), the SDGs would serve as the driver for progress towards the decade from 2015 to 2025. Since RIO+20, a number of groups have been active in developing the set of goals, with the Open Working Group on Sustainable Development (OWG) being central in the process. In July 2014, the OWG published its proposal for the SDGs (see the Outcome Documents of the 13th Session of the OWG), and in December 2014, the Secretary General added a synthesis report detailing The Road to Dignity. Both, for MDGs and SDGs, metrics that can measure progress towards the goals are important. The OWG has identified a set of indicators for the SDGs, which aim for consistency with the indicators used for the MDGs. These indicators are currently refined by technical teams. Many of these indicators are environment-related and require comprehensive Earth observations for a reliable quantification.

The concept of a safe operating space for humanity (SOSH) is central to sustainability. The global boundaries of the SOSH are partly known quantitatively, and partly blurred, with potential thresholds still unknown. A better quantification of the boundaries and a monitoring of the state of the planet with respect to these boundaries depend on comprehensive Earth observations.

Major scientific organizations have identified grand research challenges that need to be addressed in order to provide the knowledge needed to make progress towards global sustainability. The required research also depends on a comprehensive and accessible Earth observation database. Research innovations are needed at many scales to address the grand challenges and to make progress towards the societal goals.

The Group on Earth Observations (GEO) is implemented the Global Earth Observation System of Systems (GEOSS) with the goal to improve access to, and the use of, Earth observations for a broad range of stakeholders. The 10 Year Implementation Plan for GEOSS endorsed by a Ministerial Summit in 2005 states "GEOSS was a step toward addressing the challenges articulated by United Nations Millennium Declaration and the 2002 World Summit on Sustainable Development, including the achievement of the Millennium Development Goals. GEOSS will also further the implementation of international environmental treaty obligations." The Ministerial Summit on Earth Observation held in January 2014 in Geneva (see meeting documents) underlined the importance of the SDGs and of GEO focusing the development of GEOSS on the information needs that arise from humanity's quest for the SDGs.

The Implementation Plan Working Group (IPWG) initiated during the Ministerial Summit in 2014 with

the mandate to draft the next 10 Year Implementation Plan for GEOSS provided in March 2015 a first report summarizing the first “reflective phase” of the IPWG and laying out the scheme for the further development of GEOSS. At the XI GEO Plenary, the IPWG provided a draft Strategic Plan. The workshop built on these reports and discussed the science and metric needed to achieve the goals indicated in these report.

With this in mind, the 3rd *GEOSS Science and Technology Stakeholder (GSTS) Workshop* focused on the knowledge needs of the global and national decision makers to enable progress towards global sustainability on a changing planet. The workshop used the priorities of the discussion on the SGDs, the preliminary indicators, the grand challenges identified by ICSU and the Belmont Forum, and the global boundaries of the SOSH as a starting point in the discussion of the science of sustainability indicators with the goal to make progress towards a comprehensive sustainability metrics. The workshop addressed to what extent the current and planned Earth observation systems would allow a quantification of the indicators comprising this metrics.

Outcomes of the workshop include recommendations for the future focus of GEO and GEOSS on grand challenges and the societal goals addressing these challenges. It is recommended that GEO is opening to a broader community including the private sector and that GEOSS utilizes new observation types. It was emphasized that there is a need to evolve both GEO and GEOSS with the changing view on what is needed and a changing technological environment.

Scientists and researchers engaged in environmental research supporting the previous MDGs and the current SDGs and addressing the grand challenges are key stakeholders of GEOSS. Aligning the governing strategy for the implementation of GEOSS to the needs of these stakeholders should have a high priority for GEO. The workshop reviewed the support of GEOSS for research on global sustainability and provided guidance on how to improve this support.

2 Summary of Workshop Findings and Recommendations

The 3nd and 4th GEOSS Science and Technology Stakeholder Workshops held in Norfolk, VA, USA on March 23-26, 2015 reviewed two key aspects of the future development of GEOSS, that is, the alignment of the efforts to the grand challenges associated with humanity’s quest for a sustainable development on a changing planet and the opportunities arising from new concepts and for future earth observation and information systems serving the needs of growing user communities.

The workshops were organized by the *GEOSS Science and Technology Stakeholder Network (GSTSN)* together with a total of 20 international research organizations, United Nations agencies, funding agencies, and research projects funded by the European Commission.

The workshop participants noted the many efforts made by the international community to make progress towards a more sustainable world, identified “big issues” that need to be addressed in this quest, emphasized the need for a focused research effort to support decision makers, policy makers and the public in making progress towards increased sustainability and resilience, elaborated on the many opportunities arising from new technologies and new concepts for data collection, information and knowledge creation and dissemination, introduced new user groups for earth observations and GEOSS, and urged the Member Countries and Participating Organizations of GEO to make an effort to utilize these opportunities to provide the data and infrastructure needed to create and access information and knowledge derived from Earth observations.

Addressing the global challenges, the Workshop participants emphasized that

- Climate change and the grossing of global boundaries of the safe operating space for humanity poses threat to sustainable development;
- Adaptation to the changes in the polar regions is challenging security;
- Food and water security are at risk due to increasing droughts, floods, and heat waves at the same time as demand for food is growing;
- Population growth and escalating migration are an increasing threat to international stability and a challenge for both the developing and developed world;
- Disaster risk management and developing resilient communities is an urgent matter considering that growing populations are exposed to hazards and mega cities are sprawling into hazardous areas;
- Tipping points in the coupled socio-economic and environmental system may be crossed due to global and climate change and social and economic development;

With respect to the international activities, it was underlined that

- The international community has made progress towards new frameworks for sustainable development, disaster risk management, climate change mitigation and adaptation, and a global financial system aligned to the needs of sustainable development;
- All these efforts require indicators that provide the metrics to measure progress towards the articulated goals and targets and support the planning of actions and development of policies in support of implementation;
- Most of the indicators considered require significant Earth observations integrated with socio-economic data;
- There is a high economic costs associated with the uncertainties resulting from insufficient or incomplete observing systems;
- There is a need to have a planetary dashboard providing timely warnings in cases where tipping points might be crossed;

The workshop deliberation acknowledged the efforts made by GEO to

- Stimulate global and regional initiatives for the coordination of Earth observation networks and the development of existing and new observing systems;
- Identify the essential variables in each of the Societal Benefit Areas with particular focus on those required to quantify the indicators and to improve predictive capabilities;

Based on these considerations, the participants identified the needs that the Strategic Plan of GEO:

- Defines GEOSS as a knowledge hub that directly serves countries and international efforts at the highest political level to enhance policy formulation and impact of policy implementation to achieve tangible benefits of societal development;
- Addresses the information needs of decision and policy makers at international and national levels;

- Emphasizes the mandate of GEOSS and its global role to provide the science and observation base for making development policies and decision-making relevant at the level of the commonwealth of nations worldwide including high-level capacity building;
- Underlines the need for co-design of the GEO agenda and co-creation of knowledge and anticipates the incorporation of decision and policy makers from beginning of GEO activities to the tailored delivery of the results;
- Outlines a governance structure that provides structure and processes bringing together the different implementation elements into a coherent effort where the whole is significant larger than the sum of the individual efforts;
- Clarifies the role of, and requirements for the composition of, GEO Initiatives and Flagships;
- Acknowledges the importance of the development of a GEO Knowledge Base which documents the societal information needs linked to observational requirements and includes best practices and compelling examples that showcase how data, technology and communities move from basic to applied research and support for policy and decision-making;
- Elaborates on the need for a gap analysis across all societal issues based on a fully populated GEO Knowledge Base with the goal to inform prioritization of efforts in Earth observations;

Concerning the future community coordinating GEOSS implementation, they recommended to make provisions for the future GEOSS to

- Facilitate new data and big data integration and to address relevant policies and issues, including privacy, anonymization, processes to control use, legal interoperability, and quality labeling and trust processes.;
- Increase accountability, traceability, and attributability through data citation and a consistent digital object identification system;
- Develop an e-infrastructure that supports open access, legal interoperability, education, and changing data culture;
- Strengthen cooperation through and open source environment that supports coordination, sharing of infrastructure and data, and allows for extensive community contributions;
- Serve as a forum for airing issues and problems that is complementary to other efforts;

With respect to the opening of GEO for the private sector, the participants asked the GEO community to work with the private sector to

- Shape GEO to involve a bigger constituency;
- Open GEO for Participating Organization originating in the private sector.

2.1 Workshop Minutes

Plenary Session 1: Assessing and Managing the Changes: The Metrics

Co-Chairs: Hans-Peter Plag, Stefano Nativi

This session set the stage for the workshop by summarized the knowledge about indicators for the state and trends in the Earth system, including the social component of this system and by introducing recent developments in GEO. The Workshop was opened by a welcoming note delivered by Douglas Cripe, GEO Secretariat, and Hans-Peter Plag linking the present workshop to the previous two workshops. Douglas Cripe introduced the participants to the strategic work in GEO in preparation of the post-2015 period. Tim Lenton emphasized the need to anticipate tipping points that could hamper sustainable development.

Breakout Sessions Block 1: Designing the Metrics

In the first block of breakout sessions, themes focused on specific goal sets and the indicators used in relation to these goals. The sessions reviewed to what extent the indicators are linked to essential variables of the Earth system. The objective was to discuss and draft sets of essential variables for each of the goal sets.

Breakout Session 1.1: Sustainable Development Goals, Global Boundaries, and Safe Operating Space for Humanity

Chairs: Hans-Peter Plag; Rapporteur: Senay Habtezion

Hans-Peter Plag introduced the topic and referred to the GEO Ministerial summit on EOs (Jan 2014), which emphasized the importance of SDGs and asked GEO to focus in the development of GEOSS on the information and knowledge needs for SDGs. There is a need for a framework for defining and documenting observations and comprehensive sustainability metrics. EOs play a key role in this, but they need to be combined with socio-economic data and merged with data.

In the discussion, the question of how can we measure progress towards achievement of the SDGs was raised. It was clarified that the indicators are a management tool and a report card for progress toward the SDG targets. Another question raised was whether GEO could contribute to a refinement of the indicators or just focus on the EVs for the pre-defined indicators. A role for GEOSS could be to develop a sustainability information framework allowing pulling out relevant information from GEOSS. A role for GEO could be to serve as a forum to others not necessarily represented within the UN process, for example, businesses.

It was recommended that the declaration for the upcoming Ministerial Summit in 2015 would include a commitment of the GEO Member Countries to use GEOSS.

Concerning the SDGs that were proposed, it was commented that in light of broad nature of the proposed goals and targets, GEO may need to prioritize and focus on key SDG targets that contribute most to sustainability.

Breakout Session 1.2: GEO Societal Benefit Areas

Chairs: Antonio Bombelli; Rapporteur: Mark Bourassa

Antonio Bombelli introduced the questions to be addressed, i.e., (1) What process and criteria could be used to develop indicators that can serve as a management tool to support planning and a report tool

to support assessments of progress? and (2) How developed are indicators in a given area of societal goals? He used the example of CO₂ to illustrate the importance of understanding the information needs associated with a given variable.

The discussion around the questions resulted in a number of comments. Deciding on which societal goals to focus is a difficult task because the scope is large. The process of looking at the possible goals was like peeling an onion – always more layers. The GEO *Societal Benefit Areas (SBAs)*, impacts, science issues and variables are separate issues but related and it is difficult to determine where to start. There needs to be a strategy to engage stakeholders and other groups already invest in these topics. Different indicators are needed for political applications than those used in scientific applications, and the understanding of requirements for different applications needs to be improved. Indicators of warnings (i.e., increased risk) could come from production, logistics, population dynamics as well as environmental variables.

It was emphasized that models are needed for forecasts, and data are needed as input for these models and for model development. Developing predictive capabilities and understanding the processes requires observations with much better temporal and spatial resolution than those needed to identify changes in the climate system. For the latter, knowing the short-term fluctuations and extremes is important. The science metrics (quantitative) must be linked to risk and the GEO SBAs. An indicator example considered was the ratio of magnitude of earthquakes to loss of lives (risk) modulated by local preparations. The quantitative indicators should be linked to risk. Disasters in one location are linked to changes in demand in other areas. There is a need to link the SBAs to scientific goals and these in turn to required observations.

The types of indicators discussed included:

- measurement of physical change;
- measurement of progress on science objectives;
- measurement of impact (use as well as real impact).

It was concluded that GEO should act as a forum to bring together groups with a vested interest in the topic. For communications purposes, the need for observations and modeling needs to be linked to the SBAs.

Plenary Session 2: Assessment of the Metrics

Chair: Jay Pearlman

The session was opened by Jay Pearlman introducing the rapporteurs of the previous breakout sessions and the two keynote speakers of the session. The breakout session reports (see above for details) were presented by Senay Habtezion and Mark Bourassa, respectively.

Ben Hamlington gave a summary of the knowledge about past and current sea level changes. He emphasized that sea level is an essential climate variable that provides important insight into the state of the climate. Changes in sea level reflect both thermal expansion from rising ocean temperatures as well as well as mass-change due to increased run-off from ice sheet and glacier melt. Changes in sea level also pose a direct and serious societal and economic risk. In the past two decades, satellite measurements have improved our understanding of sea level, and a number of studies on the driving processes have led to closure of the sea level budget. There is a need to continue the satellite-measured sea level record into the future. There are still many questions to be answered with regards to future sea level. There is a

growing need to communicate uncertainties more clearly. He pointed out that there is a possibility that the “likely” range of future sea level rise is underestimating the full range.

Thorsten Tanhua reviewed the efforts in the ocean observing community to identify *Essential Ocean Variables (EOVs)*. He underlined that feasibility of observations has a high weight in defining the EVs and most of the efforts are focused on the upper right corner of the impact versus feasibility diagram, i.e. high feasibility and high impact. The connection to societal goals takes place after the EVs have been identified. The procedure is fully expert-based.

Based on the previous plenary and breakout sessions, an assessment of the available metrics in terms of completeness, applicability, and decision support was attempted. There was considerable discussion about the role of GEO in defining and quantifying metrics. There was a consensus that GEO had an important convening function and that the focus of GEO should be on providing the EVs for the quantification of indicators that compose the metrics.

Breakout Sessions Block 2: Quantifying the Metrics

Based on the outcome of the breakout session of the first day, the breakout sessions will consider the sets of essential variables for several goal sets (SDGs, SBAs, SOSH) and discuss availability and applicability of data for these essential variables that would allow quantification of these goal-related indicators.

Breakout Session 2.1: Essential Variables for Sustainable Development Goals, Global Boundaries and Safe Operating Space for Humanity

Chair: Hans-Peter Plag, Rapporteur: Senay Habtezion

The session addressed four key questions related to EVs:

- WHAT: Definition of EV
- WHY: Why should GEOs provide description of indicators?
- HOW: What process is desirable and feasible to provide description of EVs?
- WHO: Who would use a template for description of EVs (communities of practice)

Several of the proposed SDG indicators were used as examples to discuss the status to which EVs are identified for these indicators. Most of the discussion focused on a template for the description of an EV. It was agreed that for the goal-based approach, the template should include the following fields:

- Describe the societal goal(s) that have a linkage to the EV
- Describe the societal target(s) or equivalent entities that are linked to the indicators
- Describe the indicator(s) that depend on the EV
- Describe the system relevance of the EV, where system is the coupled human-natural system.
- Provide details on the system components for which the EV is essential
- Describe operational, forecasting, and discipline-specific relevance of the EV
- Describe the underlying data organization/management for the EV

- Describe the benefits of having the EV available

Concerning the definition of EVs, there was agreement that a process of how to identify an EV should be promoted. It was suggested that the use of models and empirical studies should be part of the process. Importantly, the expert-based approach starts a observational capabilities and progresses to societal benefits, while the goal- and target-based approach starts at the societal benefits and progressed to the EVs.

There was considerable discussion about the definition of EVs. The preliminary definition stated: “Variables that determine the system’s state and developments, are crucial for predicting system developments, and allow us to define metrics that measure the trajectory of the system. Limited knowledge of essential variables implies limited predictive capabilities and limited means to measure where the system is heading.”

It was pointed out that there may be a need to rephrase the suggested definition such that there are two parts: one addressing the technical aspects of EV and the second dealing with Societal relevance.

In terms of societal relevance, it was pointed out that EVs should be crucial for the creation of practice-relevant knowledge. EVs are closer to knowledge than others.

There was consensus that EVs are domain specific. Different communities of practice have different approaches and are likely to characterize their variables their way. The role of GEO should be to recommend one or more processes for determining EVs but not to prescribe domain-specific variables. The question of how we can facilitate a coordinated deliberation of EVs in GEO was touched upon but remained open.

Breakout Session 2.2: Essential Variables for GEO Societal Benefit Areas

Chair: Antonio Bombelli, Rapporteur: Kathy Fontaine

Several of the GEO SBAs have started processes towards the identification of EVs. The breakout session will review the status of these initiatives and their approaches to linking these EVs to metrics. The goal is to give recommendations how a consistent process could be developed to be used in all SBA areas.

The session was opened by stating that taking stock of the previous sessions the follow point should be addressed in the session:

- Analyze the sets of essential variables (EVs) identified for the different GEO SBA.
- Assess their completeness, applicability and usefulness in decision support.
- Address the issues that can limit their use: uncertainty, resolution, accuracy, cost-effectiveness and inadequacy of the current observing systems.
- Consider existing initiatives to identify EVs for different GEO SBAs.

The questions to be addressed included:

- To ensure that the indicators can be quantified, essential variables need to be identified and observed. What process and criteria could be used to identify EVs and link indicators to them?
- Is a top-down approach available and used to link indicators to EVs in your area of societal goals?

The question why EVs are needed was discussed and it was concluded that they are needed to:

- Understand natural and anthropogenic processes;
- Monitor state and trends in the Earth system;
- Detect and attribute changes;
- Assess the impacts of these changes;
- Identify tolerable limits of these changes (sustainable development).

Core criteria to select EVs were identified:

- Useful to a wide range of users, particularly decision makers;
- Cross-cutting several GEO SBAs;
- Credibility, Feasibility, Cost-effectiveness (GCOS criteria).

The discussion touched upon several aspects of EVs. EVs should be observable and useful at the same time. The usefulness of a variable potentially “essential” can be limited by uncertainty, resolution and accuracy. Therefore, in addition to them being essential for describing states and trends the EVs have to meet in practice the user needs. Could different EVs be used in different contexts according to different user categories, or should focus mainly be on “universal” EVs, cross-cutting different users and SBAs? This relates to the question who the main target users are for GEO, and the groups that were mentioned are policy makers and other high-level decision makers. A question that should be address at the ConnectinGEO workshop on Essential Variables was that of what the current gaps are and the main requirements to set up operational monitoring networks.

Summarizing the main points of the discussion,

- EVs are currently probably more closely linked with the science community, while indicators are more relevant to the policy arena.
- EVs have been developed by various communities (IGOS, GCOS, Communities of Practice, GEO tasks, etc.).
- UN process has developed indicators to monitor progress toward the targets associated with the SDGs.
- Challenge is to connect all the dots in a more complete picture of how GEO can support SDGs.

For the path forward, the following points were noted:

- Gather the EVs from their respective arenas, including from organizations that have no previous connection to GEO.
- Look at the SBAs and identify the major geophysical processes within each SBA.
- Map the variables to the geophysical processes; map the variables also to the indicators for the SDGs; see where the gaps are.
- Use the GCOS criteria for EVs [credible, feasible, cost-effective] by way of assigning weighting/priorities/urgency

Plenary Session 3: Monitoring and Foreseeing the Changes: The Role of Earth Observations

Co-Chairs: Paola Campus, Andiswa Mlisa

The session started with reports from the two previous breakout sessions delivered by Senay Habtezion and Kathy Fontaine, respectively. See the previous sections for details.

Paola Campus discussed aspects of monitoring change. She pointed out that the increase of world-wide communications in the last decades has increased the level of information about the threats associated to Global Change and asked whether this really has increased awareness and resilience. A crucial step towards the development of an effective plan for increasing resilience and supporting sustainable development is based on the adoption of a comprehensive and interconnected monitoring of all the phenomena and parameters which might help issue early warnings associated with significant environmental changes. Basic components for robust monitoring include synergetic technologies and networks recording in real-time all the areas at risk on our Planet; simultaneous data transmission to operational centers in near-real time; optimized data analysis to rapidly identify a risk increase; and data sharing. She emphasized the role of GEO and GEOSS in ensuring these aspects.

Roberto Azzolini used the example of monitoring the polar regions to analyze the need for monitoring and the role GEO and GEOSS could play. He stated that deep Changes are affecting the Polar Regions much faster than other regions. They can have widespread effects on environment and socio-economic activities on hemisphere scale. The fast environmental changes could affect the human society at a rate that could not be properly recovered. However, they may also create new opportunities for societal development that must be managed properly.

Understanding and predicting changes is crucial for managing appropriate mitigation measures. Polar regions show in advance and with a greater clearness the climate changes happening on the Planet. Several authoritative Arctic and Antarctic Organizations, representing wide sectors of science, are working to provide scientific priorities and guidelines. The IASC ICARP III and the SCAR Horizon Scan initiatives must be mentioned in this framework. However, these organizations mainly focus on regional issues.

A huge asset of well equipped scientific infrastructure and technologies to face Polar issues is already available along with a top-level scientific community. However, despite the increasing number of international networks and programs, many observations are still carried out at a national or regional scale. A rather high rate of fragmentation, duplication of efforts, not optimized use of infrastructures, scarcely coordinated national agendas and plans must still be faced.

In order to improve the efficiency of the system, a common effort to strengthen cooperation supported by coordination, sharing infrastructure and data is needed. GEO should take into consideration the Polar Regions because of their vulnerability to changes and, at the same time, their crucial contribution to shape the Earth Climate and its changes. GEOSS may play a crucial role in integrating Polar observations at Regional and global scale and streamlining data sharing, interoperability and quality control.

He summarized that in close contact with polar organizations, programs and stakeholders GEO may help:

- Prioritize observation targets (EVs);
- Avoid fragmentation/duplication;
- Facilitate International Cooperation;
- Data Policy and Quality control.

Plenary Session 4: Setting Priorities

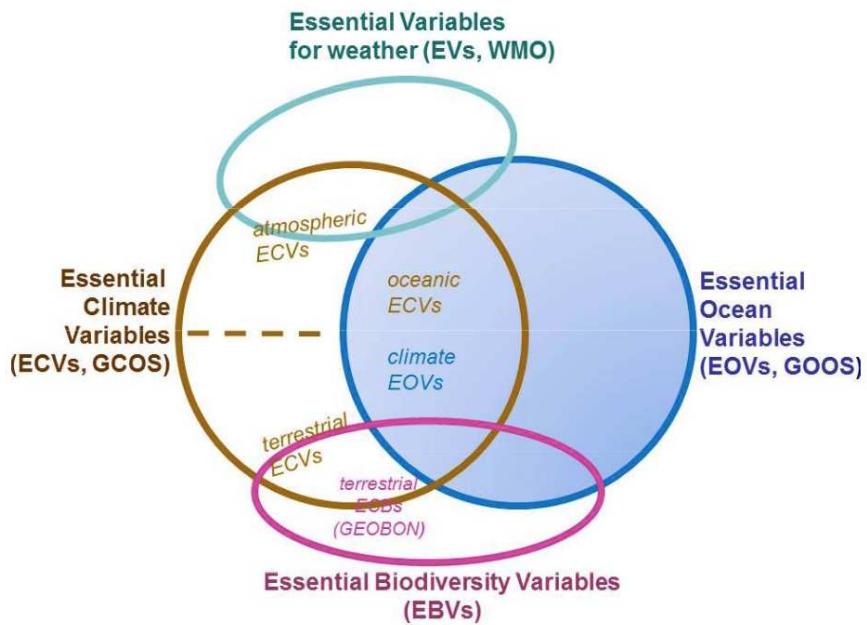


Figure 1. EVs for Different Domains and Their Overlap.

From Bourassa (2015), presentation at the workshop.

Chair: Wolfgang Grabs

The session was opened with a presentation by David Arctur on the GEOSS Water Services and their role in federating regional and national water data. He presented the activities in several AIP projects of the GEO Water SBA.

Mark Bourassa used the example of the oceans to discuss the community approach to EOVS. He pointed out that 93% of global warming is going into the oceans, and underlined that the oceans are an important sink for CO₂. They are also the dominant source of variability on time scales from weeks to centuries. He showed that there is significant overlap between EVs for different domains (Fig. 1. In the climate and ocean communities, EVs have the following characteristics:

- Relevance: Important for monitoring the variability of the ocean or the climate system;
- Feasible: Technically able to measure at sufficient accuracy;
- Cost Effective: able to support the cost of the observations

Feasibility and Cost Effectiveness are also critical to get “buy in” from funders of the observing system (not just Relevance). He raised the question of who “owns” the EVs:

- Integrated Ocean Observing System (IOOS) Physical Variables:
 - salinity, temperature, bathymetry, sea level, surface waves, surface (vector) currents, ice concentration, surface heat flux, bottom characteristics
 - IOOS Meteorological variables are covered by GCOS
- Global Ocean Observing System (GOOS) Physical Variables:

- Based on Global Climate Observing System (GCOS) Ocean variables
- Related GCOS Ocean Variables:
 - Surface: Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton.
 - Subsurface: Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers

Another question considered by the speaker was “How do we define accuracy requirements?”

- One approach is to take requirements for different applications:
 - Example, the *Rolling Repository of Requirements (RRR)* available at <https://www.wmo.int/pages/prog/www/OSY/RRR-DB.html>
 - However, there are many applications and conflicting input:
 - * Operations?
 - * Science?
- Alternatively, requirements can be determined for processes:
 - Estimate the accuracy needs. Sampling based on time scale
 - Perhaps 10 times the sampling is needed to understand
 - Allows quantitative assessment of fitness for purpose for each purpose
 - Provides researchers with information about what can be achieved with the existing and historical observation systems

Mark Bourassa summarized the talk with the following points:

- There are multiple sets of EOVs depending on the organization that states what is essential. ECVs are defined by one group (GCOS)
- We are trying to better articulate the links between SBAs, science issues, observational requirements and EVCs
- The Framework for Ocean Observations (FOO) and Strategic Mapping provides a mechanism for feedback between SBAs and ECVs, and feedback to modify the requirements and ECVs
- Goals for the observing system fit well into this context
- One of the great lapses is sustaining observations

Joint Plenary Session A: Changing Science for a Changing Planet

Co-Chair: Hans-Peter Plag, James Syvitski

Dork Sahagian opened the session with a keynote addressing the relationship of science and society, asking whether it is symbiotic or askew. He pointed out that science was initially developed to address societal needs and developed to serve an evolving society. In the 20th century, scientists started to serve industry. In the 21st century, scientists face greater challenges due to a rapid global change, and they have to evolve into planetary physicians (Fig. 2). He identified four types of questions that science needs to address:

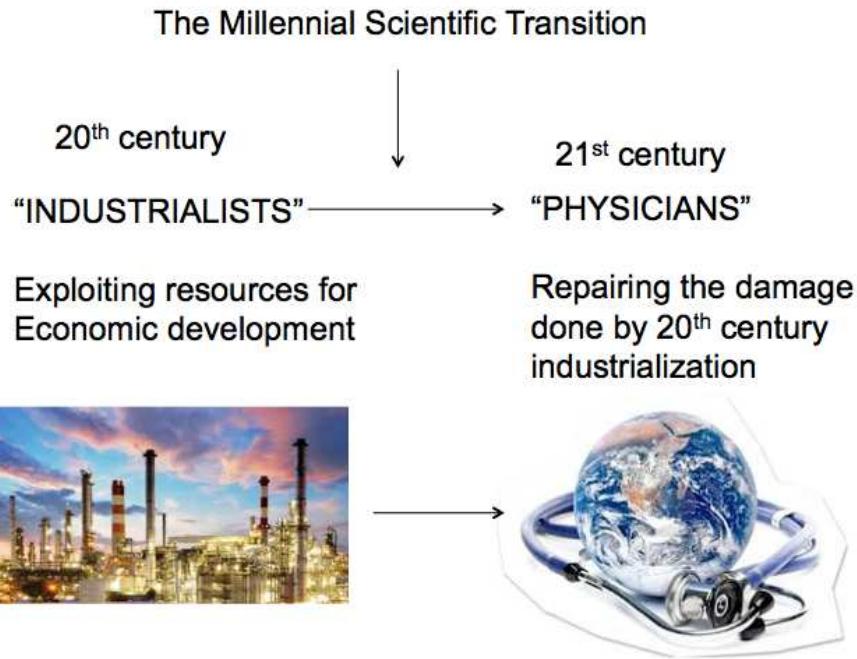


Figure 2. The Millennial Scientific Transition.

In the 20th century, scientists played a crucial role in supporting the industrial development that was based on exploiting resources for economic development. In the 21st century, the role of scientists has to transition to that of planetary “physicians” engaged in repairing the damage done in the 20th century.

- Analytical questions: What do we need to know about the basic science issues?
- Operational questions: How should we proceed with adaptation and mitigation?
- Normative questions: What do we want?
- Strategic questions: How do we get what we want?

He pointed out that IGBP/GAIN had identified a total of 23 questions in the categories that need to be addressed by the science of the 21st century. He identified contradictions between individual goals (e.g., the contraction between “eradicate poverty” and “halt climate change”). Emphasizing that science cannot solve the problem and that only people can do this, he added a few questions to be considered in the deliberations:

- What kind of natural, social, and economic environments do we want for ourselves and our great-grandchildren?
- What equity principles should be used for resource allocation?
- Who should assume the risk (and cost) for known hazards?
- Who should control policy decisions? What role should science (and scientists) play?

Sketching the way forward, he emphasized the importance of organizing and articulating societal goals; strengthening the scientific community; promoting short and long-term research; and couching scientific

results in societal terms. He concluded that the role of science has changed in the 21st century, because humanity must learn to “live off the interest” provided by the global ecosystem. In order to achieve this societal goals must be clarified and science must address them. Moreover, scientists must speak the language of society (not vice-versa), and society needs to acknowledge that science is a critical part of society, not an adversary.

Dennis Oijma summarized the scope and objectives of “Future Earth.” He identified the complex challenges in the Anthropocene as:

- Feeding nine billion people within planetary boundaries
- Understanding ocean and coastal transitioning under changing climate and biodiversity conditions
- Adapting to a warmer and more urban world
- Reducing disaster risks
- Valuing and protecting nature, ecosystem services and biodiversity
- Providing income and innovation opportunities through transformations to global sustainability
- Improving equity
- Estimating wealth and well-being, not GDP
- Aligning governance with stewardship

Future Earth is assisting with research in support decision making for UN Conventions (UNFCCC, CBD, UNCCD) and SDGs by supporting discovery and innovation to address the demands and requirements of evidenced based decisions. In a vision for 2015, he identified the challenges:

- Nexus of Sustainable water, energy, and food systems
- Low carbon socio-economic systems
- Safeguard the terrestrial, freshwater and marine natural assets
- Build healthy, resilient and productive cities
- Promote sustainable rural futures
- Improve human health by understanding complex environmental interactions
- Encourage sustainable consumption and production patterns
- Increase social resilience to future natural threats

Stefano Nativi discussed the next technological revolution for the *GEOSS Common Infrastructure (GCI)*. He acknowledged that in the past 10 years, GEO has done valuable work in building GEOSS. By recognizing and embracing significant technological revolutions, GEOSS has increased the discoverability and accessibility of data and services. Flexibility and openness are important to assure further evolution. He predicted that the next revolution will require to develop a cloud-based software ecosystem, and a social ecosystem to create and share a knowledge base.

Hans-Peter Plag reviewed the challenges for humanity resulting from the transition into the Post-Holocene. The changes introduced to the Planet in terms of energy usage, land use, population growth, biodiversity loss, and climate change are pushing the coupled natural and socio-economic system out of the *Safe Operating Space for Humanity (SOSH)* that the Holocene has provided to humanity. In this transition, it will be important to detect any approach to major thresholds as early as possible. He showed that the climate system is outside the normal range defined by the variability during the last 800,000 years, and the prognosis is putting the system far away from that normal range. Referring to Tim Lenton's earlier presentation, he emphasized the importance of thresholds and crossing these might change the system substantially. He asked whether a science that is more focused on avoiding Type 1 errors (basically false alarms) that Type 2 errors (basically missed alarms) can provide the knowledge that decision makers need to understand the scale of the challenge this transition has and the timely warnings needed to avoid global disasters in the course of the transition.

James Syvitski started with the statement that in the 21st century, the three pillars of environmental cyber-infrastructure are: 1) satellite observations, 2) field observations, and 3) model simulations. His presentation focused on the last of these, and he used three examples to illustrate the power of model simulation:

- Application of nested and coupled models used to assess the role of hurricanes on offshore infrastructure.
- Using coastal deltas, where surface elevation change is complex, involving crustal motion, climate and runoff, vegetation dynamics, sedimentation, sediment compaction, and sediment transport, by waves, tides and currents, he demonstrated the use of models to assess the importance of environmental processes and parameters.
- Use of models to assess the risk and predict river floods.

The comparison of model simulations and predictions to in situ and remote sensing observations highlighted the importance of all three pillars of 21st century environmental cyber-infrastructure.

The discussion at the end of the session emphasized the challenges for both science and society that results from global and climate change. The role of GEO and GEOSS within the three pillars of environmental intelligence discussed by James Syvitski was underlined.

Joint Breakout Sessions: Creating the practice-relevant knowledge to cope with global change

The breakout sessions reviewed methods for knowledge creation related to key areas of global change and consider the possibilities of rapid changes that might challenge the traditional scientific approach.

Joint Breakout Session 1: Intelligent use of data quantity vs focusing on data quality

Chair: Stefano Nativi; Rapporteur: Bart de Lathouwer

The new Web 2.0 environment has impacted economy with what is termed “wikinomics” by Don Tapscott and Anthony Williams and shifted the basis to four principles: openness, peering, sharing and acting globally. Stefano Nativi introduced the questions to be addressed in the session: How is the Web 2.0 impacting the generation and use of data and knowledge? How can, and how should, classical Earth observation with a focus on data quality make use of the new technologies where the data quantity provides for new ways of extracting information and knowledge from the huge amount of data available

now? How can new approaches of co-design of research agendas for problem solutions and co-creation of knowledge help make use of data quantity?

Bart De Lathouwer introduced the *Open Geospatial Consortium (OGC) Web Processing Service (WPS)* as a tool that functions as a filter for the web, similar to the “Unix filter”. It allows definition of web work flows for complex analyses. It also provides the utility to upload the processing into the cloud and down-load the result instead of down-loading all data that is stored in the cloud for local processing.

Jonas Eberle discussed requirements for intelligent use of large data quantity and identified automation in data access, easy to use clients, and the utility to create and publish new information as core ingredients. Important goals of using the data include the detection and attribution of change. For that, the scientific algorithms have to be linked to automated data access. For an “Earth Change Monitor” he stated the objectives as:

- Detect areas based on environmental change events in high density time series data (MODIS);
- Provide high resolution images (Landsat) of the pre- and after change events;
- Add further datasets to distinguish between different types of change;
- Provide simple tools for users and developers with web services and web interfaces.

The Earth Change Monitor makes use of a wide variety of available data (data quantity) to create new information, which is used to build up a reference database. He concluded that crowd-sourced initiatives can help scientists to better test their algorithms for information extraction and benefit from the input of users. He emphasized the need for simple web services for data access linked with web services for algorithm execution registered in GEOSS.

Palma Blonda discussed the role of expert knowledge for the integration of in situ and remote sensing data using the example of habitat and ecosystem monitoring. Multi-source data integration plays a crucial role for the monitoring. A knowledge-based world model (in a specific domain) consists of concepts (objects) and spatial and temporal relationships between these objects. Ontologies play a core role in describing the relationships.

Joint Breakout Session 2: Shifting from disciplinary to problem and solution focused science

Chair: Kathy Fontaine; Rapporteur: Andiswa Mlisa

The complexity of global change, climate change, and sustainability requires a transition from a bottom-up, discipline-based approach that often addresses complexity by simplification, to a top-down approach starting at the problem and recognizing the full scale of complexity. Kathy Fontaine opened the session by reminding that research generally categorized into “basic (pure)” and “applied” research. The basic research can be broken into theoretical and experimental/practical, and seeks to add to the general body of knowledge. The applied research seeks to solve a specific problem. While basic research is generally funded by a governmental institution for the public good, applied research is generally funded by private Research and Development entities. However, lately there is a tendency for governmental institutions seeking to prove return on investment by funding more applied-type research in support of solving policy problems. Given the trend to use basic research results for applied research problems, and given that GEO focuses on providing the results of basic research for use in the applied sciences, she asked the session participants to consider the following questions:

- What recommendations can we make to facilitate the reuse of basic research data in support of SDGs, SBA goals, etc.?

- What might the implications be for modeling, reproducibility, ethics, and other research data sharing and reuse concerns?
- Are there any communities that have models we can study (for instance, the clinical trial model)?

In the discussion, it was underlined that there is a need to start with end users, incorporate the decision makers from the beginning of the projects, and tailor the delivery of science into the application. This should be a requirement for the composition of the GEO Flagships and Initiatives. These components need to understand how decisions are made and the data and information needs to be packages to be fit for the purpose.

The Research community was identified as a user community. There needs to be a balance between the needs of the research community and operational requirement resulting from other user groups. GEO also needs to address the issue of trust in applications from the various communities. A question to consider is how to shape GEO so that it involves a bigger constituency, and also involves this community in the Flagships and even the Ministerial Summits.

It was recommended that national GEO representatives engage with the statistical agencies with respect to the EO contribution to the indicators for the SDGs. This would also help to ensure inclusion of environmental data for the monitoring of the SDG targets. GEO should consider a role in setting targets and defining indicators.

It was suggested that best practices are developed for showcasing how data, technology and communities move from basic to applied research. This would support the dialogues with users. Considering a recipe or blue print for a good case study would allow reusing it for other applications. Points to consider include:

- Provenance, work flow, transformational algorithms, political issues
- Impact on the decision with or without the EO information

The GEOSS Knowledge Base could be a place to store this information and GEO should maintain the information as part of a Foundational Tasks.

There was considerable discussion on what openness means in the various communities and within GEO:

- Open access to data and interoperability;
- Data integrity; traceability of what happens to data;
- Open access and sharing of the data could mean not everything is open at the back end;
- What are the implications of processing the data in cloud or by the *Discovery and Access Broker (DAB)*, can the provided softwares be trusted?
- Linkage between access to data and time frames for decision making (e.g., climate change happens so quickly that we need the research data to be freely available)

Joint Plenary Session B: Linking Societal Goals, Science, Metrics, and Observation Systems

Co-Chairs: Stefano Nativi, Hans-Peter Plag

In the final session, the rapporteurs of the previous two breakout sessions presented their report (see previous sections for details).

35 Years Later ...

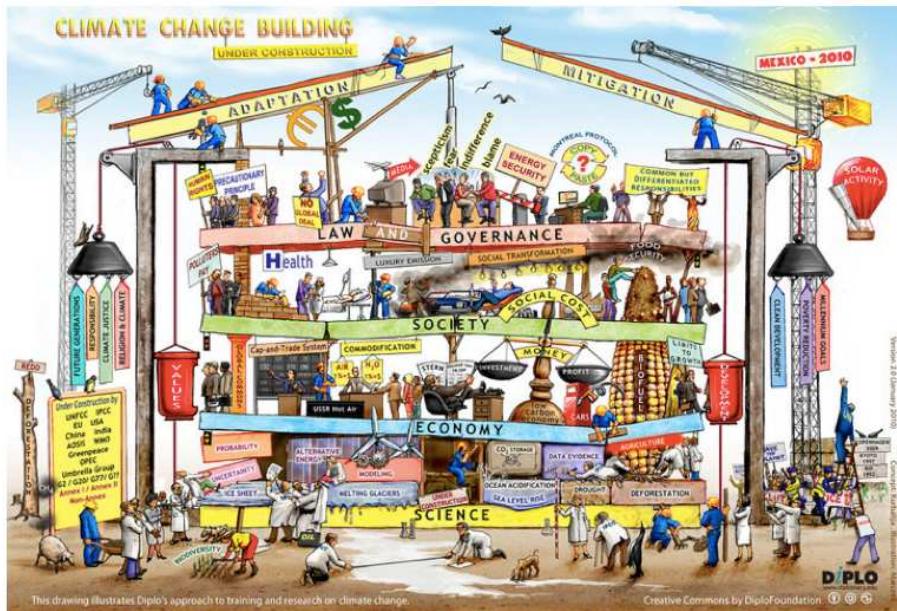


Figure 3. The Climate Change Building.

Thirty five years after it was acknowledge that monitoring and understanding anthropogenic climate change is an important task for humanity and at a time when it is clear that this is even more urgent, the “climate change building” is still in a poor shape. From Bruce Wielicki’s presentation.

The final presentation was given by Bruce Wielicki who started by pointing out that there is no climate observing system. The meteorological observing system is a weather observing system, which does not provide the very accurate climate data. Based on an extensive model study, he concluded that climate requires ten time the amount of data and a ten time higher accuracy than weather. Because of the lack of a climate observing system, knowledge about climate change is uncertain, and this uncertainty leads to inaction. Although the necessity of monitoring and understanding anthropogenic climate change was acknowledge in the late 1970-ties, thirty five years later the “climate change building” is still in a poor shape (Fig. 3).

The climate modeling community is struggling to get sufficient resources for the modeling. As a result, science questions related to climate change are typically qualitative not quantitative, focusing more on the understanding and exploring than the rigorous testing of hypothesis. The resulting uncertainty in climate change leads to inaction, which has a high cost in the future. The cost of business as usual was estimated to be on the order of 0.5 to 5% of the global GDP in the 2050 to 2100 window. He asked the question, “What is the right amount to invest in climate science?” Answering this question requires the linking of science to economics and a thinking outside narrow disciplines. Based on thousands of model runs, the economic assessment showed that even investing an additional \$10 B/year over the next 30 years for a climate observing system would lead to a large return of investment. He criticized the absence of long-term commitment for climate observations (Fig. 4).

He recommended a transition to quantitative science questions focusing on rigorous hypothesis testing and the conduction of observing system simulation experiments to improve the observation requirements for these systems. He pointed out that at current pace, its seems unlikely that climate change will be much better understood even after another 35 years. Underlining that we cannot go back in time and

Climate Observations: No Long Term Plan

- Global Satellite Observations without long term commitments
 - Radiation Budget (e.g. CERES)
 - Gravity (ice sheet mass) (e.g. GRACE)
 - Ice Sheet Elevation (e.g. ICESAT/Cryosat)
 - Sea Level Altimetry (e.g. JASON)
 - Sea surface Salinity (e.g. Aquarius)
 - Cloud and Aerosol Profiles (e.g. CALIPSO/Cloudsat, EarthCARE)
 - Precipitation (e.g. GPM, CloudSat/EarthCARE)
 - Soil Moisture (e.g. SMAP)
 - Ocean surface winds (e.g. QuickSCAT)
 - Carbon Source/Sinks (e.g. OCO)
 - Methane/Carbon Monoxide (MOPPIT)
 - In orbit Calibration References (e.g. CLARREO)
- Surface and In-situ observations have similar issues



Figure 4. The Lack of Long Term Commitment for Climate Observing Satellites.

For many satellites that are crucial part of the climate observing system, a long-term commitment is lacking. Similarly, surface and near-surface observations face similar issues. From Bruce Wielicki's presentation.

measure what we failed to observe, he ended by stating that it is time to invest in an advanced climate observing system.

The final discussion focused on the importance of a comprehensive observations system that can produce the environmental intelligence required by the global governments to ensure a sustainable development and progress towards the SDG targets. The roles of GEO in this effort included an convening role linking the users of EO with the providers in an effort to better capture the societal information needs and to meet these needs with users focused data and information products.

3 Additional Material

3.1 Workshop Organizers

Program Committee

- GEOSS Science and Technology Stakeholder Network: *Hans-Peter Plag, Stefano Nativi*
- Group on Earth Observations: *Douglas Cripe*
- GEO Institutional Development Implementation Board *Stuart Marsh*
- GEO Societal Benefits Implementation Board: *Rick Lawford/Khondar Rifat Hossain*
- GEO Water Cycle Community of Practice: *Rick Lawford*
- World Health Organization: *Khondkar Rifat Hossain*
- Belmont Forum: *Maria Uhle*
- European Science Foundation: *Paola Campus*
- Earth Science Information Partnership: *Erin Robinson*
- European Commission: *Michel Schouppe*
- ConnectinGEO: *Joan Maso*
- World Data System: *Mustapha Mokrane*
- CODATA: *Alex Sherbenin/Bob Chen*
- IEEE/OES: *Hans-Peter Plag, Jay Pearlman*
- IGBP: *James Syvitski*
- ISSC: *Heide Hackmann/Sarah Moore*
- IUGG: *Peter Fox*
- START: *Hassan Virji, Senay Habtezion*
- UNU-EHS: *Jörg Szarzynski*

Local Organizing Committee (hosted by Old Dominion University, Norfolk, VA, USA):

- Hans-Peter Plag
- Chris Campbell
- Yongcun Cheng
- Judy Hinch
- Shelley Jules-Plag
- Elizabeth Smith



Figure 5. Geographical Distribution of the Participants.

3.2 Workshop Participants

The Workshop was open to all GEOSS Science and Technology Stakeholders. Participants represented science communities engaged in research related to sustainability indicators, SDGs, global boundaries, and/or Future-Earth topics, United Nations' agencies involved in SGDs related processes; or communities involved in the provision of Earth observations and the implementation of GEOSS.

3.2.1 Statistics

The geographical distribution of the participants is shown in Fig. 5. The participants were more or less equally distributed in North America and Europe, with very little participation from outside these regions. Most participants participated in both workshops (Fig. 6).



Figure 6. Geographical Distribution of the Participants.

3.2.2 List of Participants

R: Remote participation; WS3: 3rd Workshop; WS4: 4th Workshop.

Last Name	First Name	Affiliation	Country	R	WS3	WS4
Arctur	David	University of Texas	US		x	x
Azzolini	Roberto	CNR	Italy		x	
Bigagli	Lorenzo	Consiglio Nazionale delle Ricerche	Italy			x
Blonda	Palma Nicoletta	CNR-ISSIA	Italy		x	x
Bohn	Robert	NIST	US			x
Bombelli	Antonio	CMCC-Euro-Mediterranean	Italy		x	
Bourassa	Mark	Florida State University	US		x	
Browdy	Steven	OMS Tech	US		x	x
Budai	Jeffery	National Centers for Environmental Information	US		x	x
Bye	Bente Lilja	BLB	Norway			x
Callihan	Heather	ESRI	US			x
Campus	Paolo	European Science Foundation	France		x	
Chen	Robert	Columbia University	US			x
Cripe	Douglas	GEO Secretariat	Switzerland		x	x
De Lathouwer	Bart	Open Geospatial Consortium				x
Dettmann	Carsten	Ministry of Transport and Digital Infrastructure	Germany		x	x
Druckenmiller	Matthew	US Agency for International Development	US		x	
Eberle	Jonas	University of Jena, Germany	Germany		x	x
Favors	Jamie	NASA DEVELOP National Programs	US			x
Fontaine	Kathleen	RPI	US		x	x
Grabs	Wolfgang	BFG	Germany			x
Habtezion	Senay	START - global Change SysTem for Analysis, Research and Training	US		x	x
Haklay	Muki	University College London	US	X		x
Hamlington	Ben	Old Dominion University	US		x	
Johnson	Shawana	Global Marketing Insights, Inc.	US		x	x
Jones	Dave	Stormcenter	US			x
Jules-Plag	Shelley	ODU	US		x	
Katz	Daniel S.	University of Chicago	US			x
Kerr	Thomas	Global Marketing Insights, Inc.	US		x	x

Last Name	First Name	Affiliation	Country	R	WS3	WS4
Lee	Hyunrok	APEC Climate Center	Korea		x	x
Lee	Craig	The Aerospace Corporation	US			x
Lenton	Tim	University of Exeter	U.K.	X	x	
Lovison-Golob	Lucia	Afriterra Foundation	USA			x
Maso	Joan	Universitat Autonoma de Barcelona	Spain		x	
Mazzetti	Paolo	Consiglio Nazionale delle Ricerche	Italy		x	x
Mlisa	Andiswa	GEO	Switzerland		x	x
Nativi	Stefano	Consiglio Nazionale delle Ricerche	Italy		x	x
Nesje	Oystein	Climate and Environment, Norway	Norway		x	x
Ochiai	Osamu	Group on Earth Observations	Switzerland		x	
Ojima	Dennis	CNU/Future Earth	US			x
Pearlman	Francoise	IEEE Committee on Earth Observations	US		x	x
Pearlman	Jay	IEEE Committee on Earth Observations	US		x	x
Plag	Bombeli	Old Dominion University	US		x	x
Remetey	Gabor	Hungarian Association for Geo-Information	Hungary			x
Saad	Merna	NASA DEVELOP Program	US		x	
Sahagian	Dork	Lehigh University	US		x	
Schouuppe	Michel	European Commission - DG RTD	Belgium			x
Shanley	Lea	NASA Headquarters	US	X		x
Shrestha	Ranjay	Center for Spatial Information Science and Systems	US		x	x
Syvitski	James	University of Colorado	US		x	x
Tanhua	Toste	GEOMAR	US	X	x	
Turner	Andrew	Esri	US			x
Wee	Brian	NEON, Inc.	US			x
Wielicki	Bruce	NASA Langley Research Center	US		x	
Yetman	Greg	Columbia University	US			x
Yu	Eugene	George Mason University	US			x

3.3 Session Overview

The program included plenary session that featured invited high-level presentations to introduce core themes. Subsequent breakout sessions focused on sub-themes and consisted of short presentations, panels, and discussions. After each breakout sessions, a plenary session summarized the outcomes of the breakout sessions and provided input for subsequent sessions.

The following sessions were conducted (text is pre-workshop version):

Plenary Session 1: Assessing and Managing the Changes: The Metrics

This session will summarize the knowledge about indicators for the state and trends in the Earth system, including the social component of this system. Particular focus will be on indicators related to the SDGs, the SOSH, and sustainable development in general. The science behind the indicators will be the starting point for presentations.

Breakout Sessions Block 1: Designing the Metrics

In the first block of breakout sessions, the focus will be on specific sets of indicators and the extent to which the indicators are linked to essential variables of the earth system.

Plenary Session 2: Assessment of the Metrics

Based on the previous plenary and breakout sessions, an assessment of the available metrics in terms of completeness, applicability, and decision support will be considered.

Breakout Sessions Block 2: Quantifying the Metrics

Based on the outcome of the previous breakout sessions, the sessions will consider the sets of essential variables for several goal sets (SDGs, SBAs, SOSH) and discuss availability and applicability of data for these essential variables that would allow quantification of these goal-related indicators.

Plenary Session 3: Monitoring and Foreseeing the Changes

The Role of Earth Observations Quantification of the indicators — the metrics — requires observations of the essential variables used to generate the indicators. This session will compare the available and anticipated observations of essential variables to the needs arising from the task, which is navigating sustainable development on a rapidly changing, dynamic planet.

Plenary Session 4: Setting Priorities

Based on the previous sessions, priorities for Earth observations will be discussed and translated into recommendations.

Joint Plenary Session A (Jointly organized with Workshop 4): Changing Science for a Changing Planet

The rapid changes in key variables of the planet (for example, biodiversity, atmospheric chemistry, ocean heat content, water cycle and sediment transport, ocean acidity, land cover, ice sheets, sea level) that are

already taking place and expected to increase can lead to major challenges for humanity. We need to ask whether the current approach to science will be able to identify these challenges in a timely manner and provide the practice-relevant knowledge needed to address them, or whether a new approach to rapid knowledge creation is needed.

Joint Breakout Sessions Block (Jointly organized with Workshop 4): Creating the practice-relevant knowledge to cope with global change

The breakout sessions will review methods for knowledge creation related to key areas of global change while considering the potential for rapid changes that might challenge the traditional scientific approach.

Joint Plenary Session B (Jointly organized with Workshop 4): Linking Science, Metrics, and Observation Systems

In this session, we will aim to bring together science and goal-based metrics in order to better understand the requirements of future observing systems which will provide the data required to quantify the metrics and enable applications for societal benefits.

3.4 Workshop Program

Monday, March 23, 2015

0800 - 0900:	<i>Registration</i>
0900 - 1030:	Plenary Session 1: Assessing and Managing the Changes: The Metrics Co-Chairs: <i>Hans-Peter Plag, Stefano Nativi</i>
0900 - 0910	<i>Douglas Cripe, Geo Secretariat</i> : Welcoming Address
0910 - 0920	<i>Hans-Peter Plag, Stefano Nativi</i> : Workshop Organization and Goals
0920 - 0950	<i>Douglas Cripe</i> : The GEO Strategic Plan for 2015-2025
0950 - 1020	<i>Tim Lenton</i> : Keynote Presentation: Measuring Global Changes and Detecting Tipping Points
1020 - 1030	<i>Workshop Chairs</i> : Mission for Breakout Sessions
1030 - 1100:	<i>Coffee Break</i>
1100 - 1230:	Breakout Sessions Block 1: Designing the Metrics Breakout Session 1.1: Sustainable Development Goals, Global Boundaries, and Safe Operating Space for Humanity Chair: <i>Hans-Peter Plag</i> ; Rapporteur: <i>Senay Habtezion</i>
1100 - 1120	<i>Hans-Peter Plag</i> : Introduction to the session
1120 - 1220	<i>All</i> : Discussion
1220 - 1230	<i>Hans-Peter Plag, Senay Habtezion</i> : Session Summary Breakout Session 1.2: GEO Societal Benefit Areas Chair: <i>Antonio Bombelli</i> ; Rapporteur: <i>Mark Bourassa</i>
1100 - 1115	<i>Antonio Bombelli</i> : Introduction to the session
1115 - 1220	<i>All</i> : Discussion
1220 - 1230	<i>Antonio Bombelli, Mark Bourassa</i> : Session Summary
1230 - 1400:	<i>Lunch</i>
1400 - 1530:	Plenary Session 2: Assessment of the Metrics Chair: <i>Jay Pearlman</i>
1400 - 1405	<i>Jay Pearlman</i> : Introduction to Session
1405 - 1415	<i>Senay Habtezion</i> : Report of Breakout session 1.1
1415 - 1425	<i>Mark Bourassa</i> : Report of Breakout session 1.2
1425 - 1500	<i>Ben Hamlington</i> : Keynote: What we know and don't know about sea level
1500 - 1530	<i>Toste Tanhua</i> : Keynote: Indicators and Essential Variables
1530 - 1535	<i>Workshop Chairs</i> : Mission for breakout sessions
1535 - 1600:	<i>Coffee Break</i>
1600 - 1730:	Breakout Sessions Block 2: Quantifying the Metrics Breakout Session 2.1: Essential Variables for Sustainable Development Goals, Global Boundaries and Safe Operating Space for Humanity Chair: <i>Hans-Peter Plag</i> ; Rapporteur: <i>Senay Habtezion</i>
1600 - 1615	<i>Hans-Peter Plag</i> : Introduction to the session
1615 - 1720	<i>All</i> : Discussion
1615 - 1730	<i>Hans-Peter Plag</i> : Session Summary Breakout Session 2.2: Essential Variables for GEO Societal Benefit Areas Chair: <i>Antonio Bombelli</i> ; Rapporteur: <i>Kathy Fontaine</i>
1600 - 1615	<i>Antonio Bombelli</i> : Introduction to the session
1615 - 1630	<i>Douglas Cripe</i> : Essential Variables in the Water SBA
1630 - 1730	<i>All</i> : Discussion

Tuesday, March 24, 2015

0800 - 0900: *Registration*

0900 - 1030: Plenary Session 3: Monitoring and Foreseeing the Changes: The Role of Earth Observations
Co-Chairs: *Paola Campus, Andiswa Mlisa*

0900 - 0910 *Senay Habtezion*: Report of breakout session 2.1

0910 - 0920 *Kathy Fontaine*: Report of breakout session 2.2

0920 - 0940 *Paola Campus*: Introduction to Monitoring of Changes

0940 - 1010 *Roberto Azzolini*: Keynote: Monitoring the polar regions

1010 - 1030 *All*: Discussion

1030 - 1100: *Coffee Break*

1100 - 1230: Plenary Session 4: Setting Priorities

Chair: *Wolfgang Grabs*

1100 - 1130 *David Arctur*: Keynote: GEOSS Water Services: Federating Regional and National Water Data

1130 - 1200 *Mark Bourassa*: Keynote: Key essential variables: The example of the oceans

1200 - 1230 *All*: Discussing the priorities

1230 - 1400: *Lunch*

1400 - 1730: Joint Plenary Session A: Changing Science for a Changing Planet

Co-Chair: *Hans-Peter Plag, James Syvitski*

1400 - 1430 *Dork Sahagian*: Keynote: Science and Society: Symbiotic or Askew?

1430 - 1500 *Dennis Oijma*: Keynote: Future Earth Research Challenges

1500 - 1530 *Stefano Nativi*: Keynote: The Next Revolution for the GEOSS Common Infrastructure

1530 - 1600: *iCoffee Break*

1600 - 1630 *Hans-Peter Plag*: Keynote: The Need For A New Science to Guide Humanity's Transition Into The Post-Holocene

1630 - 1700 *James Syvitski*: Keynote: Use of Surface-Dynamic Models for Identifying Environmental Indicators and Processes

1700 - 1725 *All*: Discussion

1725 - 1730 *Session Chairs*: Mission for the breakout sessions

Wednesday, March 25, 2015

0900 - 1030:	Joint Breakout Sessions: Creating the practice-relevant knowledge to cope with global change
	Joint Breakout Session 1: Intelligent use of data quantity vs focusing on data quality
	Chair: <i>Stefano Nativi</i> ; Rapporteur: <i>Bart de Lathouwer</i>
0900 - 0905	<i>Stefano Nativi</i> : Introduction to the breakout session
0905 - 0920	<i>Andreas Matheus</i> : The COB-WEB Project
0920 - 0935	<i>Bart De Lathouwer</i> : Use of WPS (and other web services) for Earth Observation
0935 - 0950	<i>Jonas Eberle, Christian Hüttich, Christiane Schmullius</i> : Automatization of information extraction to build up a crowd-sourced reference database for vegetation changes
0950 - 1005	<i>Palma Blonda, C. Marangi, A. Adamo, C. Tarantino, F. Lovergne</i> : Integration of EO and in-situ data through expert knowledge for habitats and ecosystems monitoring
1005 - 1020	<i>Dave Jones</i> : The Challenge of accessing and Sharing “Big Data” in Real-Time – Connecting GEO Nations Now
1020 - 1030	<i>Stefano Nativi, Bart de Lathouwer</i> : Session Summary
	Joint Breakout Session 2: Shifting from disciplinary to problem and solution focused science
	Chair: <i>Kathy Fontaine</i> ; Rapporteur: <i>Andiswa Mlisa</i>
0900 - 0915	<i>Kathy Fontaine</i> : Introductions to the breakout session
0915 - 1020	<i>All</i> : Discussion
1015 - 1030	<i>Kathy Fontaine, Andiswa Mlisa</i> : Session Summary
1030 - 1100:	<i>Coffee Break</i>
1100 - 1230:	Joint Plenary Session B: Linking Societal Goals, Science, Metrics, and Observing System
	Co-Chairs: Stefano Nativi, Hans-Peter Plag
1100 - 1115	<i>Bart de Lathouwer</i> : Report from joint breakout session 1
1115 - 1130	<i>Andiswa Mlisa</i> : Report from joint breakout session 2
1130 - 1200	<i>Bruce Wielicki</i> : Keynote: Climate Change Accuracy: Observing Requirements and Economic Value
1200 - 1230	<i>All</i> : Discussion

3.5 Abstracts

GEOSS Water Services: Federating Regional and National Water Data

David Arctur, University of Texas at Austin

Since 2012, the Water SBA team for the GEOSS Architecture Implementation Pilot (AIP) has helped water data agencies in several countries to implement and publish standards-based water resource information. The following water data providers and research centers have developed a consistent implementation of this framework, which are or will soon be searchable in GEOSS:

- CUAHSI Water Data Center - collecting water data from over a hundred data providers
- Canadian Rainfall Monitoring Network - precipitation
- Flemish Water Portal (Belgium) - streamflow
- French Geological Survey (BRGM) Groundwater Level Monitoring Network
- Italian National Water Agency (ISPRA) - streamflow
- New Zealand National Water Agency (NIWA) - streamflow, temperature, and 9 water quality variables
- Taiwan Monitoring Network - streamflow
- USGS National Water Information System (NWIS) - streamflow
- NASA Land Data Assimilation System (LDAS) - model-based time series (“data rods”) for global precipitation, runoff, soil moisture, evapotranspiration, and other land surface dynamics variables.

Continued development and expansion of this network will bring within reach the ability to study and understand water data across and among whole continents, on demand.

The emphasis in the upcoming 2015 cycle will be the application of this GEOSS Water Services framework for flood monitoring, prediction, and mitigation.

Integration of EO and in-situ data through expert knowledge for habitats and ecosystems monitoring

P. Blonda, C. Marangi, A. Adamo, C. Tarantino, F. Lovergne

Expert knowledge can be used to develop a descriptive scheme, based on ontologies, of habitats (as proxies for species), ecosystems, ecosystem services and their interactions/functions and related Indicators and variables such as Essential Biodiversity Variables (EBV), Essential Ecosystem Variables (EEV).

The main objective is to design and develop a pre-operational cost-effective environmental monitoring system able to integrate EO and in-situ data, based on the elicitation of such knowledge. The system should provide as outputs series of thematic maps (LCLU and habitats, ecosystems, with these based on MAES report definition) and extract indicators and essential variables (EV) to be used as inputs to change detection and modelling tools. The experience developed in the FP7 BIO_SOS project will be described as basis for future research within the Horizon2020 Ecopotential project.

Essential Observations for the Oceans

Mark A. Bourassa, Center for Ocean-Atmosphere Prediction Studies, Florida State University, Tallahassee, FL Co-chair Ocean Observation Panel for Climate

The ocean observations that are deemed (by national and international organizations) as important and feasible to observe with sufficient accuracy as Essential Climate Variables (ECVs) or as Essential Ocean Variables (EOVs). These variables have been well established for physical oceanography, and some have been established for the biogeochemistry. The biological community is working towards suggesting EOVs to the national and international organizations that are charged with selecting these variables and setting the observational goals. Decades ago, the physical oceanography, atmospheric, and terrestrial ECVs were determined with the goal of addressing climate variability in the context of societal issues and related science questions. The Essential Ocean Variables were developed later, with goals beyond climate: weather forecasting, transport, recreation and others. They are similar to the ECVs, but also address issues such as the delay between observations being taken and being made available, as well as the differences in quality between near real-time data and delayed mode data (which often has more rigorous quality control and adjustments to improve accuracy). A short overview of ECVs and EOVs will be given, with a short explanation of some of the differences. Efforts are ongoing to better select and explain the need for ECVs and EOVs. Therefore this is a time when outreach and interaction will have their maximum benefit.

A question that is currently being pondered is how to take advantage of established components of the observing system (typically physical variables) to more rapidly develop and deploy less mature components of the observing system (chemical and biological variables). Key issues are structural compatibility and changes in cost, operational life time, and infrastructure needs. For example, the cost and availability of ship time influences the goals for operational lifetime. The sampling needs and the advantage of collocated variables is another critical consideration. For example, the usefulness of many biogeochemical variables is greatly enhanced by collocation with physical variables, and vice versa. Another factor in considering how these observations should be combined is the links to societal and science drivers, which are in turn linked to global conventions and mandates. New efforts to describe these links will be described and demonstrated. The approach shown highlights the different applications to which the observations apply.

Automatization of information extraction to build up a crowd-sourced reference database for vegetation changes

Jonas Eberle, Christian Hüttich, Christiane Schmullius; Friedrich-Schiller-University Jena, Institute for Geography, Department for Earth Observation, Jena, Germany

Scientists can benefit from the wide range of data quantity if their algorithms are made available to the public in an easy-to-use manner. Automated data access in combination with the follow-up execution of algorithms can help to test algorithms in different regions around the world and lead to new information based on the knowledge of local users. In the example of vegetation change analysis based on Earth Observation time-series data, we can provide lots of data for the validation of changes detected by scientific algorithms, e.g., true/false color images, fire data, weather data. Based on these input users can validate the algorithm in their study areas. Furthermore, they can build up a database with change areas that can be used as reference databases on other analysis tools (e.g., change classifications).

Based on the bfast (Breaks For Additive Season and Trend) algorithm we can detect vegetation changes in time-series data. For the validation of a detected “break” we will search automatically for other datasets at the detected date of break and provide these data in an easy-to-use web portal. So users can execute the algorithm for change detection and validate the detected changes. A crowd-sourced reference database

can be build up on areas where change occurred and this change was validated by users.

Such a crowd-sourced initiative can help scientists to better understand algorithms for information extraction. The authors of an algorithm can benefit from the input of users that are testing the algorithm. The Web 2.0 leads us to a new way of how algorithms can be tested and how we can build up reference databases with areas around the world. Thus, Earth Observation time-series data are better useable and lead to new knowledge to further improve algorithms and validated reference information.

In this presentation the author will describe the developments made for automated data access in combination with automated data analysis based on Earth Observation vegetation time-series data with no need to process any data by the users.

What We Know and What We Don't Know About Sea Level

Benjamin Hamlington, Center for Coastal Physical Oceanography, Old Dominion University, Norfolk, VA, USA

The change of sea level in response to the warming of our planet is of great interest for both scientific and socio-economic reasons. Sea level change has enormous socio-economic implications for the planet as coastal populations become more susceptible to storm surges and eventually inundation from the oceans. In addition, sea level is an essential climate variable and critical indicator of how our planet is responding to climate change. Sea level, when averaged globally, responds primarily to the amount of heat absorbed by the oceans, and the melting of land ice. Thus, many groups—climate scientists, politicians, economists, insurance companies, public utilities, coastal property owners, civil engineers, and other “stakeholders”—have a need for accurate and reliable projections of future sea level change and its regional variations.

Projecting sea level change begins with improving our understanding of past sea level change and the factors contributing to it. On a local level, the sea level problem is complex due to its multi-faceted and coupled nature, involving essentially all Earth System components, and including multiple feedbacks. In the past decade, the network of observing systems has grown to be able to measure more of the factors contributing to sea level than ever before. This has led to significant advances in our understanding of sea level change in the past, present and future, while also aiding model efforts to project future regional sea level rise. Despite this, significant gaps in our understanding remain that have important implications for our ability to prepare for climate change in the coming years. In this presentation, we take stock of what we currently know and what needs to be understood better regarding sea level rise on global and regional scales. Although the focus is on sea level, the discussion here can be similarly extended to other areas, underscoring the need for improved understanding of all essential climate variables.

Anticipating tipping points

Tim Lenton, Earth System Science, University of Exeter, Exeter, U.K.

A tipping point occurs when a small change in forcing triggers a strongly non-linear response in the internal dynamics of a system, qualitatively changing its future state. Large-scale tipping elements have been identified in the Earth's climate system that may pass a tipping point under human-induced global change this century (Lenton et al. (2008) PNAS 105: 1786-1793). Such abrupt, non-linear changes are likely to have large impacts, but our capacity to forecast them has historically been poor. Recently, much excitement has been generated by the possibility that approaching tipping points carry generic early warning signals (Scheffer et al. (2009) Nature 461: 53-59; Lenton (2011) Nature Climate Change 1: 201-209). I will introduce the theory and prospects for gaining early warning of approaching climate tipping points.

Promising methods are based on detecting critical slowing down in the rate a system recovers from small perturbations, and on characteristic changes in the statistical distribution of its behaviour (e.g. increasing variability). Early warning signals have been found in paleo-climate data approaching past abrupt transitions, in models being gradually forced past tipping points, and in analysis of recent Arctic climate data. I will discuss the outstanding challenge of how to design a tipping point early warning system and how to identify the essential variables to monitor in specific target systems.

The Next Revolution for the GEOSS Common Infrastructure

Stefano Nativi, Institute of Atmospheric Pollution Research of the National Research Council of Italy (CNR-IIA), Sesto Fiorentino, Italy

GCI has faced some important (technological) revolutions in the past 10 years. Entering in its next decade, GEOSS and the GCI are going to face a new important revolution, including Pico satellites and Internet of Things, Big Data Analytics and Knowledge generation, Citizen Observatories and Consumerization. This presentation will introduce the present GCI architecture, discussing its flexibility and introducing its possible extension to address the next challenges.

Future Earth Research Challenges

Dennis Ojima, Colorado State University, US Global Hub of the Future Earth Executive Secretariat, School of Global Environmental Sustainability, Fort Collins, CO, USA

The primary mission of Future Earth is to align the global change research community with decision makers and innovators of change to co-develop pathways for sustainable development and transformation to sustainability. Future Earth provides a platform to analysis and development of strategies to enhance resilience and preparedness to global change in regions and ecosystems across the globe. Future Earth has enhanced trans-disciplinary research and engagement activities across a suite of issues (e.g., food security, energy, public health, water, biodiversity loss) and public and private sector partners related to development, risk reduction, and strategies to more sustainable use of ecosystem services and natural capital.

Regional to global research across multiple sectors will require greater integrated observations platforms and analysis tools. Inter-operability across and between earth system parameters and societal information will be needed to provide decision makers in the public and private sector the knowledge needed to make science based decisions on assets being managed. Current global tools provide aggregate analysis of certain aspects of the earth system, however greater granularity of integration and analysis will be necessary for management decisions by regional to local decisions makers.

Social-ecological systems which bring together observations and analysis of multiple capital ranging from natural capitals to social, physical, and institutional capitals will provide an integration platform of information and knowledge. Developing this information for decision making will need to provide the information at the scale and metrics used currently by decision makers. The translation of observations and analysis will need to be co-designed with various sectors and end-users. Further research and innovation will be needed to finalize the co-production of information useful to these end-users.

Future Earth will focus on the societal challenges identified in the 2015 Vision report and utilize these to aggregate the various SDG indicators across these 8 different domains of interest to Future Earth. The eight Challenges are to:

- Deliver water, energy, and food for all, and manage the synergies and trade-offs among them, by understanding how these interactions are shaped by environmental, economic, social and political

changes.

- Decarbonise socio-economic systems to stabilise the climate by promoting the technological, economic, social, political and behavioural changes enabling transformations, while building knowledge about the impacts of climate change and adaptation responses for people and ecosystems.
- Safeguard the terrestrial, freshwater and marine natural assets underpinning human well-being by understanding relationships between biodiversity, ecosystem functioning and services, and developing effective valuation and governance approaches.
- Build healthy, resilient and productive cities by identifying and shaping innovations that combine better urban environments and lives with declining resource footprints, and provide efficient services and infrastructures that are robust to disasters.
- Promote sustainable rural futures to feed rising and more affluent populations amidst changes in biodiversity, resources and climate by analysing alternative land uses, food systems and ecosystem options, and identifying institutional and governance needs.
- Improve human health by elucidating, and finding responses to, the complex interactions among environmental change, pollution, pathogens, disease vectors, ecosystem services, and peoples livelihoods, nutrition and well-being.
- Encourage sustainable consumption and production patterns that are equitable by understanding the social and environmental impacts of consumption of all resources, opportunities for decoupling resource use from growth in well-being, and options for sustainable development pathways and related changes in human behaviour.
- Increase social resilience to future threats by building adaptive governance systems, developing early warning of global and connected thresholds and risks, and testing effective, accountable and transparent institutions that promote transformations to sustainability.

The Need For A New Science to Guide Humanity's Transition Into The Post-Holocene

Hans-Peter Plag, Mitigation and Adaptation Research Institute, Old Dominion University, Norfolk, VA, USA; Shelley Jules-Plag, Tiwah, USA

Humanity has left the Holocene and the “safe operating space for humanity” it provided to us. The Holocene, the last geological epoch that began about 11,700 years ago, had an exceptionally stable climate that allowed human beings to settle in one place for a long time and to learn agriculture. With 6,000 years of a stable sea level humans were able to build long-term settlements in river deltas and benefit from the rich ecosystem services and logistical advantages of being at a river and the coast.

During the last hundred years, many things have changed very rapidly: we grew in numbers several hundred times faster than ever before, our energy usage grew 1,600 times faster, and inequality among humans grew 100 times faster. These rapid changes led to an increase of atmospheric carbon dioxide about 600 times faster than during the Holocene, temperature changed more than 100 times faster, and extinction rates of at-risk species increased dramatically. While we have seen many environmental factors changing rapidly, others are lagging behind and will soon exhibit accelerated changes. Sea level in particular has the potential to rise rapidly and threaten our global society.

We have replaced the time of stability by a time of rapid change, making the future for our children very uncertain. The planet is on a trajectory that is rapidly moving us away from the safe operating space. We discover thresholds normally (with a few exception) by crossing them. The rapid degradation of

the Earth's life support system resembles the situation of a patient in the emergency room with rapidly degrading organs. The best news out of the emergency room is that the patient is stable, and the on-going changes within humanity and in the Earth's life-support system do not signal that this is the news about humanity in the emergency room.

Safeguarding the future requires a major paradigm shift in which we work towards slowing down these rapid changes so that we can reach a new equilibrium with the planet and its life-support system. Our economy needs to safeguard the Earth's life-support systems on which we and all future generations depend, instead of aiming for more wealth for a few. Our goal needs to be equity among humans both in time and space.

Current science is not explicitly focusing on the knowledge needs that arise from this existential challenge to reach equilibrium and restore stability. If such knowledge emerges, it is a bi-product. We do not have a science adapted to being in the emergency room, and while there are emerging research activities that aim to find ways for humanity to thrive without degrading the Earth's life support systems, there is no strategic science framework that would bring these initiatives coherently into a major effort of humanity to generate the knowledge we need to meet the challenge. There is also a need for a coupled tactical science that could respond to rapidly developing new threats, which we should expect as a consequence of the rapid changes we are enforcing on the system that supports our life. With such a framework, science could generate the knowledge to be integrated into decision making for a safe journey into the uncertain future of the Post-Holocene. Like in the emergency room, having the observing system that provides comprehensive information about the states and trends of both humanity and the life-support systems is crucial for global governance to make informed decisions how to react to rapid changes and new developments.

Science and Society: Symbiotic or Askew?

Dork Sahagian, Earth and Environmental Sciences, Lehigh University, Bethlehem, PA, USA

Science has a long history of serving society, from the harnessing of fire, to development of tools and technology for commerce and war, and now to addressing global issues. In long-term symbiosis, science provided social systems with the knowledge required for development and security, while society ensured that the scientific community had the resources and support needed to function most effectively. In modern times, 20th century scientists were viewed like "industrialists," working to exploit natural resources for growing economies in an "open world" in which consumption and disposal were accommodated by the physical, chemical, and biological processes throughout the global ecosystem. In the 21st century, however, society is increasingly treating scientists as "physicians," turning to the scientific community to find ways to repair damage caused by overexploitation of the very resources that enabled rapid economic development, and that are now in jeopardy. As societies begin to understand that their economies and long-term well-being depend on the rate at which the global and local environment provide a broad spectrum of goods and services, and that this rate is rapidly declining due to overexploitation, science is in a position to provide the knowledge necessary to restore the rate of provision of these goods and services. In effect, we are "living off the interest" that the stock within the global ecosystem provides, but in recent decades, we have rapidly "eaten into the principal" thus reducing the "interest," just when we need to increase it due to the burgeoning human populations demand for energy, food, and material goods. Although the modern scientific community has been aware of this unsustainable situation, communication between science and society has fallen to all-time lows in many areas, rendering science and society askew in that they are operating toward different goals, and the gulf widens. As a result, political decisions are often made that exacerbate the reduction of ecosystem goods and services, while the scientific community is marginalized in its influence on the political process.

In 2000, at the turn of the century, the International Geosphere Biosphere Programme followed on the approach of the 19th century mathematician, David Gilbert, and challenged 21st century scientists with 23 difficult questions, the answers to which could provide the guidance needed to restore and sustain the rate of provision of environmental goods and services that would support future societies. Some of these questions pertain to the operation of the Earth system, while others are more strategic, relating to societal goals. One of the most difficult of these was the question “What kind of nature do societies want?” This kind of normative question is not subject to scientific analysis, but relies on an organized vision regarding the future of each society’s relation with the natural environment and what it provides.

While society needs from science the answers to such questions and many others, science needs the support of society to make any progress at all toward answering them. As the gulf between the scientific and political communities widens, global environmental issues are often politicized and support is reduced for the very scientific community that could help ease the transition into a sustainable relation with the global ecosystem. For example, the U.N. Millennium Goals include the eradication of poverty, and the Post-2015 Agenda involves stabilization of global climate. Yet, research on climate change is being stifled in some key societies. Aggressive policies based on the best scientific insights available at this point will be necessary in order for these two U.N. goals not to be in direct conflict.

As scientific techniques, models and results become more complex, the distancing from mainstream society is exacerbated by numerous misconceptions and miscommunications. These include concepts such as truth, objectivity, uncertainty, and underlying motivations. Miscommunication is sometimes caused by drastically different vernacular in scientific and lay circles. Scientists have become notorious for speaking in terms that make sense strictly in a scientific context, but not in a social or political context, in vain attempts toward “turning them all into scientists.” While we would like to think that the entire citizenry should become scientifically astute, this approach is clearly untenable. Yet, only an informed populace can appreciate and thus benefit from the role of science in decision-making. So a critical question becomes “How can we most effectively provide scientific results and understanding to the general population in the face of rampant misinformation promoted by those in whose short-term interest it is to prevent decision-making based on science?”

The way forward necessarily involves a scientific community that understands and works within the value system of the society that depends on it (and that it depends on). This requires “speaking their language” not only in words, but in context. As such, outreach and education efforts on the part of scientists need to be both re-oriented and intensified. While decisions regarding resource consumption and distribution, human population, and the logical basis for decision-making may appear obvious to scientists, understanding that the world-view of much of the population is quite different will enable the scientific community to more effectively provide the needed insights in the service of society.

Use of Surface-Dynamic Models for Identifying Environmental Indicators and Processes

JP Syvitski, Community Surface Dynamics Modeling System — CSDMS, University of Colorado, Boulder, CO, USA

The three pillars of 21st century environmental cyber-infrastructure are: 1) satellite observations, 2) field observations, and 3) model simulations. While our 20th century efforts using this combination are legion, we now recognize the effort to develop effective state-of-the-art operational workflows. Each of the three pillars, on their own, contains substantive bias and error. Field observations also tend to be expensive and seldom offer the same spatial coverage as satellite systems or numerical models. Satellite systems have both spatial and temporal restrictions, based on the nature of the orbit, data transfer limitations, and other environmental restrictions (e.g. cloud cover, atmospheric moisture). Model simulations offer great

temporal and spatial resolution, but are labor-intensive, and affected by model simplicity, computational resources, and efficiency of the code itself. However when combined, these cyber-infrastructure pillars offer greatly reduced bias and error. Three examples highlight the role of model simulations in 21st century environmental cyber-infrastructure.

The first example highlights the application of nested and coupled models used to assess the role of hurricanes on offshore infrastructure. The Gulf of Mexico is a mature offshore petroleum production area generating more than 1.7 mb of oil per day, through more than 3,500 oil platforms, connected by 28,000 miles of underwater pipes, all exposed to different types of structural damage associated with extreme oceanic and atmospheric events. About 5% of broken or damaged underwater pipes are by sudden and violent sediment flows. Short-lived hurricanes can generate 10m waves during their passage and both liquefy and re-suspend seafloor sediment, and thereby induce turbidity currents. The U.S. Bureau of Ocean Energy Management has overseen the development of a complex array of nested and coupled numerical models for determining the locations most likely impacted by turbidity currents, and the factors that precondition or trigger such flows. The workflow includes: 1) modeling the flux of water and sediment from rivers into the Gulf, augmented by field data; 2) ingesting outer boundary conditions from more regional oceanographic models, and seabed sediment textures; 3) employing a high resolution (10 km) wave action model and 4) a lower resolution (1 km) ocean circulation model, to support 5) a wave-driven sediment-suspension model, and 6) a gravity flow setup model to determine the location and duration of areas of potential turbidity current generation. A Navier-Stokes Reynolds Averaged version is then used to route the sediment flows down canyons, providing estimates of bottom shear stress needed for ascertaining possible damage to offshore infrastructure.

The second example highlights how models are used to assess the importance of environmental processes and parameters. In coastal deltas, surface elevation change is complex, involving: crustal motion, climate and runoff, vegetation dynamics, sedimentation, sediment compaction, and sediment transport by waves, tides and currents. Few existing instruments can measure the impact of all of these processes, and none resolve elevation changes across all pertinent spatial and temporal scales. No numerical model fully captures these terrestrial and subaqueous dynamics, although recent versions of Delft3D capture many of the morphodynamic impacts. When applied to the Louisiana coast, both cold fronts and hurricanes are shown to cause erosion of the Mississippi delta. Although a single hurricane can move more sediment, cold fronts are more critical for delta evolution as they transport much more sediment away from the coast due to their higher frequency nature. Waves intensify sediment erosion, and aboveground vegetation reduces the amount of erosion. Models can capture the impact of plausible scenarios, such as how the order or frequency of weather events influences delta stability. Combined with observing systems, model applications offer guidance to stakeholders needing information on our disappearing deltas.

Measurements of river discharge and watershed runoff are essential to water resources management, efficient hydropower generation, accurate flood prediction and control, and improved understanding of the global water cycle. Our third example focuses on river floods. Optical (near-infrared) and SAR satellite systems are great for mapping flood inundation but cannot on their own detect cause. As the number of large and devastating floods have increased over the last couple of decades, it remains important to ascribe a cause to these floods, such as from the intensification of the hydrological cycle or changing weather patterns either due to climate change, or from infrastructure failure of levees, barrages and diversions. Orbital (advanced) microwave sensors can measure river discharge variation in a manner closely analogous to its measurement at ground stations. For international measurements, hydrological modeling provides the needed calibration of sensor data to discharge. Comparison with gauging station data commonly indicates a need of small positive bias removal for both the modeled discharge and the satellite-observed runoff, highlighting the importance of all three pillars of 21st century environmental

cyber-infrastructure.

Essential Ocean Variables for Biogeochemistry, towards indicators and indices

Toste Tanhua, GEOMAR, Germany

The Global Ocean Observing System (GOOS) is working towards defining essential ocean variables, development of targets for the observing networks and defining observing system metrics and the assessment of risk to the observing system. GOOS is essentially focusing the work around a framework known as FOO — Framework for Ocean Observing — an outcome of the OceanObs conference in 2009 that was driven by a strong will to work collectively among ocean observing groups. The FOO is organized around the concept of essential ocean variables (EOVs), rather than around observing platforms. GOOS aims at delivering an observing system that is fit for purpose and is driven by scientific inquiry and societal issues. While the FOO balances research with the need for sustained observations, it defines a system that is based on requirements, observations, and data and information. The concept of readiness level is important for the FOO and is based on assessment of feasibility, capacity and impact.

This talk will focus on the efforts of the biogeochemical panel of GOOS in formulating societal requirements and defining EOVS for biogeochemistry, and point to a way toward defining indicators and indices of the observing system and ocean “biogeochemistry state”, feeding back to the societal requirements that motivate the EOVs.