Data to Decisions

Valuing the Societal Benefit of Geospatial Information

A Workshop organized by the

GEOValue Community in Collaboration with OECD, NASA, and USGS

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Final Report

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In Memory of

Molly Macauley

"What we're talking about is profound. Earth observing is like looking in the mirror."

March 11, 2016

Concept Definition

The workshop was organized to create a framework to identify and implement best practices for capturing the societal value of geospatial information for both public and private uses. The primary objective was to define case studies and use cases that trace the information flow end-to-end from earth observation and data acquisition systems to decisions by end users.

Observation systems are one or more sensing elements that collect observations of the Earth, measure environmental parameters, or survey biological or other earth resources. Observations from satellite systems, as well as airborne, terrestrial, and marine networks that intersect with the human dimension support better public and private decision-making.

The goal of the workshop was to provide opportunities for participants to demonstrate and compare approaches to valuation of geospatial information and forge a path forward for research that leads to standards of practice.

This two-day workshop focused on two societal impact areas: disasters and ecosystems.

- The disasters area focus was mitigation, response and resilience to natural disasters, extreme events that include earthquake, tsunami, drought, flooding and extreme weather
- The ecosystems area (terrestrial, freshwater, and ocean) focus was ecosystem-based management that recognizes and honors the land-water-energy nexus.

Disaster risk reduction and ecosystems management support the UN Sustainable Development Goals, are in the nine GEO Societal Benefit areas, and are included in the U.S. National Plan for Civil Earth Observations, and both the NASA Applied sciences and USGS Science strategy. In preparing their discussions for the workshop, participants were asked to consider how the work they were presenting could inform decisions and decision-making processes. How does the work address societal issues at a local or national level? What stakeholders and other constituencies are involved or affected?

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- The Organization for Economic Co-operation and Development (OECD)
- National Aeronautics and Space Administration (NASA)
- United States Geological Survey (USGS)
- The Group on Earth Observation (GEO)
- Euro SDR
- East Carolina University (ECU), North Carolina, U.S.

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the contributors and do not necessarily reflect the views of NASA, USGS, GEO, Euro SDR, or ECU.

The workshop included 77 participants coming from Europe, America, Africa, and Asia, representing international organizations, public and private sectors, non-government organizations, and academia. A list of participants is provided in Appendix 1. Disciplines covered included policy makers and analysts, economists, natural scientists, geospatial practitioners and other discipline experts. Brief biographies of the speakers, session chairs, and discussants and brief presentation and poster abstracts are provided in Appendix 2. A list of the posters presented is included in Appendix 3.

Pre-workshop Tutorial

A one-day Pre-Workshop Tutorial on Benefit Cost Analysis techniques and applications was held on March 9, 2016, at l'Ecole des Mines, 60 Boulevard Saint-Michel, 75006 Paris, France. The tutorial provided policy makers and geospatial specialists with information and activities designed to increase participants' understanding of the basic economic framework within which socioeconomic evaluations are conducted. The critical importance of effectively presenting evaluations and research results to policy makers and for business cases was also covered during the tutorial. A case study was presented to elucidate the concepts and principles that underpin cost–benefit analysis and illustrate approaches to applying this analysis in different geospatial contexts. The case study drew on the analysis of improved geological map information for mineral exploration undertaken in a joint study by the USGS and Geological Survey of Canada. Participants used the case study to evaluate tradeoffs by applying benefit-cost analysis to value economic (market) and ecosystem services (nonmarket) benefits.

In the second half of the tutorial, participants put the concepts into practice in an example developed from the case study. The following questions were addressed:

- Which methodology is appropriate to different circumstances?
- What strategies are effective to communicate the message?
- How are nonmarket considerations factored into the analysis?

The tutorial provided documentation to illustrate the application of the techniques for economic, social and environmental benefits and costs.

Workshop Introduction

The Data to Decision workshop brought together scholars and stakeholders to identify best practices for developing and implementing frameworks to capture the societal value of geospatial information for both public and private uses. The two-day workshop primarily focused on monitoring, mitigation, response, and resilience related to natural disasters—weather events including earthquake, tsunami, drought, flooding, and volatile weather; climate; and environmental concerns, such as water and ecosystem-based management that recognizes and honors the land–water–energy nexus.

The primary objectives were to discuss case studies and define use cases that trace the information flow end-to-end from earth observation and data acquisition systems to decisions by end users.

The goals of the workshop included:

- Demonstrating and comparing approaches to valuation of geospatial information,
- Identifying one or more case studies to further review as examples for a range of subsequent applications, and
- Forging a path forward for research that leads to standards of practice.

Societal benefit focus areas included:

- Disaster mitigation, response, and resilience
- Natural disasters, extreme events that include earthquake, tsunami, wildfire, drought, flooding and extreme weather
- Ecosystems (terrestrial, freshwater, and ocean) ecosystem based Management that recognizes and honors the land-water-energy nexus.

In preparing their discussions for the workshop, participants were asked to consider how the work they presented could contribute to decisions. How will that work address societal issues?

Questions framing the issues included:

- What is the task to be accomplished?
- What are the metrics for measuring success/value?
- Who are the actors? What is each actor's level of scientific expertise? Do they trust the data and analysis? What factors influence the decision (political will, trust, estimates of outcomes, risk)?
- What communication methods will make the information usable, enable trust, and are supportive of better decisions for the task?
- What statistical/analytic methods and decision support systems are available to summarize or reduce the complexity of the information?
- What geospatial data are available or should exist to support the task?
- What changes in fundamental measurement systems and standards are needed? Is there sufficient continuity to trust the availability of data?
- What evidence indicates that the information was used to effect a change?

Presentations included case studies of specific problems on local and global levels as well as general discussions of analytical frameworks, tools, and methodologies.

Disaster risk reduction and ecosystems support the UN Sustainable Development Goals are in the nine GEO Societal Benefit areas and are included in the U.S. National Plan for Civil Earth Observations, the NASA Applied Sciences program, and USGS Science strategy. The scope of applications presented was broader than the original focus however this enriched the dialogue with considerations of the broader issues and frameworks. Open discussion on data to decisions was encouraged and welcomed.

Background

Of particular interest is whether the full value of an Earth-observing system—including societal benefits beyond its designed uses—is accurately estimated. Is it possible to evaluate the effect that geospatial information has on decisions that affect the protection of life, property, and the environment? For example, what is the value of accurate and timely information about natural hazards that allows decision makers to evacuate or protect vulnerable populations and thereby minimize and avoid losses? To help answer these questions, an international community of social, economic, physical, natural, and management science researchers is developing rigorous methods for estimating the socioeconomic value of geospatial information that are transferable across disciplines and domains. Since data, analyses, and information products from geoscience research are often spatially referenced, these questions also address the value of research for society.

As geospatial information becomes more available and its utility potentially enhanced by big data applications, its value to decision makers may increase. It is important that value be measured accurately so governments estimate the return on their Earth observation investments. That was the topic of a recent workshop, Assessing the Socioeconomic Impacts and Value of "Open" Geospatial Information. Participants called for improved methods for quantifying the socioeconomic impact of geospatial data. Here we examine approaches to estimating the benefits of research and geospatial information derived from Earth observations.

Day One Agenda: Issues and Discussion

Welcome and Opening Remarks

Andrew Wyckoff, Director, OECD Science Technology and Innovation Directorate

Opening Keynotes

Dr. Suzette Kimball, Director of the U.S. Geological Survey (USGS), *"Societal Benefit of Geospatial Information: Scientific Basis and Research Needs."*

Dr. Kimball stressed the importance of openly sharing geospatial information and linking science to decisions. She referenced the prior socioeconomic workshop held in 2014 on the socioeconomic impact and value of open geospatial information, highlighting the importance of accessibility and participation in enhancing societal benefits, and the need for case studies to improve understanding and uses of geospatial data and methods for estimating benefits. She briefly discusses the USGS charge regarding a Science and

Decision center and the value of natural resources. USGS is responsible for providing non-advocacy scientific data that is important to policy makers. Science-driven geospatial data can help stakeholders make effective decisions about critical issues including ecosystem loss, climate change, and limits on resources and water. Addressing these challenges involves difficult choices for which people need timely, well-integrated information.

USGS focuses on predictive capabilities, on systems rather than disciplines, on looking beyond the geological to human impact. We need to develop better understanding of the uses of information, benefits of information, importance of open access to information, and assessment of impacts.

The Science and Decision center will provide focus by applying economics to evaluate social impacts, tradeoffs, and other related concerns. Researchers and stakeholders need to understand societal impacts and the best practices for collecting and assessing data. Results of the workshop will be important to governments and to taxpayers worldwide. Open sharing of geo-spatial and earth observation data that can inform decisions at all levels are particularly critical for decision making, particularly for communities and countries that don't have the capacity to collect and apply data to problems. In concert with other agencies, a USGS goal is to make information readily available.

Kimball identified critical challenges:

- Can we develop and apply methods that are methodologically appropriate and result in timely results?
- Can the community develop key standards that are common to societal benefit studies?
- Can we identify and develop policies that will advance efforts to enhance the use and value of scientific geospatial information including the understanding and measurement of societal benefits?
- Can we develop partnerships that span disciplines, the public, private, and academic sectors, and political boundaries?
- How can the science of using geospatial information best complement the science of obtaining new geospatial information?

Outcomes

"Achieving impacts is our challenge."

President Obama noted the importance of broader citizen participation in science and planned to enhance and build innovative approaches that involve citizens and communities. Such initiatives will increase the public's appreciation of science and help professionals understand community needs. NOAA, NASA and other agencies are coming together to develop strategies to meet these needs.

A key issue is balancing conflicting needs for timely and rigorous information. Another is the need to reduce uncertainty. The previous Washington workshop stressed the need for case-studies and proof-of-concept work. Case studies enable U.S. to explore interrelationships and tradeoffs. A focus on disaster and risk reduction is important because the issues are not specific to any nation.

Robert Mendelsohn, Yale, USA, *"Using Earth Observation in Economic Analysis"*

Dr. Mendelsohn's keynote focused on direct uses of earth observations by economists. Environmental management critically relies on "big" geospatial data. However, "Big Data" is not valuable unless it is carefully processed and analyzed. Economists depend on high frequency geospatial weather and climate data across space and time. High quality data describing extreme events informs development of strategies to protect people and economic activity. Dr. Mendelsohn gave a number of examples illustrating the use of geospatial data. One example on climate change, contrasted immediate versus long term trends, across space.

Geospatial data could be made more useful: many earth observations are not directly interpretable, requiring translation by remote sensing experts. Remote sensed observations need geo-referencing into cells, while economic data and decisions are organized by political units such as counties, states, and countries.

- Urban v. Rural—Cities are a focal point during extreme events because more people are affected. A research challenge is to identify the urban structures that support higher density without increasing risk. If, however, we measure damage/capita, that measure is much lower in cities than in rural areas leading to a conclusion that urbanizing populations makes people safer.
- Energy data is useful for measuring cause and effect between energy and pollution. Geospatial measurements of pollution concentrations have helped determine the consequence of different methods of energy production. The key to making an integrated assessment is capturing the information and creating models that link to consequences and back to specific emissions so that it is possible to target most harmful emissions.

Land use planning will become ever more important because people are competing for ever scarcer remaining land resources. In the future, better land use plans must be developed, such as restricting the expansion of cities, which is socially desirable. We need data for making these types of decisions.

Could geo-spatial data be more useful? Geospatial data are valuable but need to be analyzed to be useful.

- Many earth observations are not directly interpretable
- Economic data and decisions are organized by political units which do not conform to earth observation units of analysis
- Gov't agencies depend on private firms to process public data for public use. The privatization of processing can reduce public access and sidetrack an open data policy.
- The societal gain of an open data policy for providing valuable geospatial data however, if data are not analyzed and put in a usable form, data are not being used.

Introductions and Charge for the Day

Jamie Kruse, Director, Center for Natural Hazards Research; Professor of Economics, East Carolina University

Panel 1–Ecosystem Case Studies and Use cases

Richard Bernknopf, adjunct professor, University of New-Mexico, and panel moderator introduced the panelists: Leon Hauser; Yusuke Kuwayama; and Zhiliang Zhu.

Gordon Campbell, European Space Agency "ESA's use of satellite derived information for ecosystem service assessment"

Leon T. Hauser, Department of Sensing Technology, GIS & GPS; Space Technology Institute, Vietnam Academy of Science & Technology (VAST), Hanoi, Vietnam "The development and application of an open-access browser-based hyperspectral reflectance library for common mangrove forest species and land cover types in Southern Vietnam"

Dr. Hauser discussed using remote sensing for land use classification for monitoring mangrove forest changes. Data from satellite hyperspectral imagery and from data collected in the field are being used to create a catalog of mangrove vegetation that can be used for making environmental decisions.

Yusuke Kuwayama, Resources for the Future, Washington DC, U.S.A. "The Value of Information from a GRACE-Enhanced Drought Severity Index"

Yusuke Kuwayama discussed the use of GRACE-enhanced drought severity index for analyzing the cost effectiveness of policies for managing water resources including water used for agricultural purposes and ground water pollution. Various economic modeling alternatives result in different policy alternatives.

Zhiliang Zhu, USGS; assessing Carbon sequestration potential as an ecosystem service for publicly managed lands in the United States

Dr. Zhu described assessing carbon sequestration potential as an ecosystem service. Much of the carbon sequestration in the U.S. is on public land. Examples from three projects were provided to illustrate the use of Landsat remote sensing and field observations in collecting data. The geo-spatial data analysis demonstrates the potential and societal value of sequestration.

Panel 1 Discussion

How often do decisions include use of economic analysis? And how can we expand use of economic and geospatial analysis to support regulatory decisions? Transition from pure science to incorporation of socioeconomic perspectives is happening now. For example, USGS is investing in a science and decision center. The kinds of tools of interest are decision support tools, "what if" scenarios, and forecasting. Challenges are associated with the complexity of the system. A major issue is uncertainty; geospatial data may help to explain uncertainties. Metrics of evaluation need to be prioritized.

Delivery of useful information on a systematic basis is critical for management decisions. How can we provide information on the value of certain scientific products; how can we have more systemized approach to the value of information?

National investments are not always responding to national needs but are often driven by curiosity science questions.

Keynote

Jeffrey K. Lazo, National Center for Atmospheric Research, *"The Socioeconomic benefits of Hydro-Meteorological information"*

Dr. Lazo, presented the Weather Information Value Chain referring to several studies and commenting on the quality and availability of information used for "value chain" studies. He identified a fundamental need for studies to be policy-relevant, cost-appropriate, and high quality.

Dr. Lazo gave the example of an empirical study of the relationship between economic output and weather variability**.** All sectors and all states show significant economic sensitivity to weather variability. The U.S. GDP varies by up to $485 billion a year (2008)—about 3.4%—due to weather variability. When he discusses the value chain, the chain includes not just the "geo-spatial" information but the entire communication/decision-making value process—noting in particular that increasing accuracy of geo-spatial information does not translate necessarily into increased value. Why use economics? The focus of the study on economics allows for program evaluation and justification, determining the value relative to user goals, and prioritization or reallocation of resources. The study should highlight the methods and rigor. The need for high quality studies is related to need for studies that do a better job of tracing the information flow end-to-end from the geospatial data acquisition system to decisions by end users. The value of weather may include the economic impact of weather, the value of current weather information, the value of improved weather forecasts, the value of research to improve forecasts, and the value of improving dissemination, decisions, etc. For example, the value of current weather information is estimated at $236 (U.S.) per household per year, with a benefits-cost ration of 6.2 to 1. Dr. Lazo referenced a book on *Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services* by the World Meteorological Organization, World Bank Group, Global Facility for Disaster Reduction and Recovery, and United States Agency for International Development, WMO No. 1153, Geneva, Switzerland. These organizations have a strong interest in improving the quality, transparency, and usefulness of Socioeconomic Benefits studies.

Dr. Lazo described the weather information value chain as including observations, modeling, forecasting, dissemination, communication, interpretation, decisions, and outcomes. The decisions can be analyzed ex-ante, and the outcomes ex-post. It is the *potential to make different* decisions using geo-spatial information given the decision-maker's decision context (objectives, resources, and constraints) that generates economic value. There are a number of primary valuation methods such as non-market valuation, economic decision modeling, and avoided cost/damage assessment.

To answer the workshop objectives, Dr. Lazo described three use case examples respectively focused on end user value model, non-market valuation (extreme weather event), and an ex-post case study (wind shear warning). In conclusion, he recommends that all major investments or changes in hydro-met services should undertake economics analysis.

Recommendations

- All major investments in geospatial information infrastructure should require economic analysis.
- Evaluate contribution of behavioral economics to decision models
  Need primary valuation critical review and consolidation

Panel 2—Disaster Risk Reduction Case Studies and Use Cases

Jamie Kruse, East Carolina University (moderator). Dr. Kruse introduced the four panel participants, who each gave a short presentation:

Yazidhi Bamutaze, Makerere University, UGANDA.

Uganda is prone to natural disasters and people in Uganda want to use information but most don't have sufficient access.

Lessons

- Broken flow of geo-data in hierarchical structures causes problems. The capacity to process data is low nationally and regionally.
- Case studies that address these issues were presented on flood and landslide

Jacob Hochard, East Carolina University, Storm Protection of Mangroves on Economic Growth and Infant Mortality: A Global Geospatial Analysis.

Issues identified in this presentation include:

- Mangroves are being lost (1/3 in the last few years)
- Value of the forests to coastal communities not well understood
- Mangrove forests reduce damage from severe weather

The case study applied an autoregressive model to 110 countries over 38 years and determined that loss of mangroves is predicted to reduce income by 7% over next 20 years. Their study showed that tropical cyclones reduce economic growth in developing countries.

Benjamin M. Miller, RAND Corporation "The Not-so Marginal Value of Weather Warning Systems"

Have the benefits of the program changed over time? For example, for warning systems—should cell phone push messages replace sirens?

This study looked at weather radios—and asked, "How well would people fare without the system?"

Approach to the research included cross-sections and data from Predictions Center's National Tornedo archive, and county-by-year population from the Decennial Census. Transmitters were rolled out in the 1970s. The current work measures the value of the system to end users and considers:

- Changes to benefits from systems over time
- Measure of value to end users

Fanglin Sun, University of California, San Diego (UCSD), "Valuing the Storm Surge Mitigation Service of Coastal Wetland"

The case study focused on putting a dollar value on coastal storm surge mitigation. The introduction addressed: What is a cyclone? What is a wetland? The study used an econometric model of regional mapped difference to determine storm impact for each region. The data included:

- Coastal and wetland coverage
- Historical data
- Pricing information

Conclusions

- Consider wetland when creating coastal communities
- Optimize economic data in decision making

Panel 2 Discussion

Discussion following the panel focused on the response or lack thereof to early warning systems. If an event is coming, what does that mean to the individuals? The "cry wolf" effect was mentioned. A study on tornadoes showed that people did not know the difference between a watch and a warning. Communicators have switched to cell phone warning, which provides more information. These items are addressed in communications literature, risk communication, and behavioral economics. The importance of pets to individuals was given as an example.

Participants were also concerned with the impact of value of information studies, and what happens to the studies. There are many techniques for estimating the value of information. Communities of practice can offer those tools but need resources to develop and deploy them. The WMO book chapter on communications concluded that economists have to understand and communicate policy recommendations.

Issues and questions that emerged during discussion included:

- Developing a standard measure of willingness to pay.
- Establishing the parameters for benefits transfer and the value of meta-data
- Collecting existing literature and developing thorough literature reviews are needed.
- Conducting studies that address why people don't respond to threats of particular weather events with the aim of reducing fatalities
- Assessing the value of information studies
- Matching valuation methods to questions more effectively
- Developing communities of practice to focus on specific types of data and models
- Consolidating data and models and making them available in an archive, maybe a website or library-supported archive
- Developing strategies for communicating information to policy makers and stake holders that will encourage accurate interpretations of information
- Helping economists understand and use policy language.

Panel 3—Ecosystem Case Studies and Use Cases # 2

Andy Coote, ConsultingWhere (moderator)

Mr. Coote stressed the importance of communications with decision makers. When experts walk into a decision maker's office, they have only 2 minutes, to answer questions including: *what is the problem; why should I care; what do you want me to do about it.*

Elisabeth Haggquist, Economics Unit, Lulea University of Technology. "Valuation of health risk reductions in municipal drinking water."

This presentation addressed PFAS potential impact on public health with a case study looked at the risks of tap water. Considerations included:

- Willingness to pay for minimizing risks from microbial outbreaks
- A choice experiment with data collected in municipalities
- PFASs found everywhere and may get worse due to climate change
- Need to communicate long-term low level health risks of different magnitudes
- Value to end users depends on product properties and the user experience
- Choice Experiments capture subjective and objective consumer criteria and help with evaluating current water management strategies

Miriam Murambadoro, Sustainability Science and Resource Economics Research Group, Natural Resources and Environment, Johannesburg, South Africa "Enhancing the uptake of climate change information through participatory approaches for learning in South Africa".

The Group seeks to provide local decision makers with information. There is another step beyond the policy makers. Use of spatial planning tools and climate change information GAP and SARVA have been poor. The assumption is that if science is generated and disseminated, the targeted users will use the science. Considerations for improving provision and use of information include recognizing:

- Local government officials have tacit knowledge of situations and conditions
- Gaps exist between users and scientists' communication practices
- Importance of shifting approaches to include users in design and adaptation
- Stake-holder participation in the initial design of the problem and its solution space can improve outcomes
- Roles of the formal and informal social learning systems in climate change adaptation
- Role of participatory platforms such as networks and cycles of knowledge sharing in connecting scientists, policy- and decision-makers in promoting social learning

The study used an appreciative inquiry model in the case study. Data sources included the South African Risk and Vulnerability Atlas, Limpopo GAP, workshop participants' information, and LATS.

Conclusions of the study identified:

- Local government officials are essential to spatial planning and land-use/management
- Approaches based on the inclusion of these stakeholders

- Co-production of knowledge—tacit and explicit
- Ways interpretation of scientific and spatial data apply to different stakeholders
- Co-learning through sharing scientific and non-scientific knowledge can inform planning and decision making on climate change mitigation and adaptation

Carl Shapiro, USGS Survey Science and Decisions Center; Reston, VA. "The value of stream gage Information: A case study evaluating the use and value of stream gage data for culvert design and operations."

Shapiro discussed stream-gage network research. Information is readily available and has many applications. There are opportunities for benefits, and researchers need to move to hypotheses about the usefulness and benefits of the tool. Benefits might be applied to flood mitigation, culvert design, power, and boating. The value of benefits is being assessed using a bottom up approach.

A case study on culvert design was presented. Implications of the study include

- Need for water-flow information to identify and design culvert capacity
- More observations and stream gages will lead to optimization of capacity
- Not all information is equivalent
- Need for stream bank-full information
- Use of onsite stream-gage data
- Discussion of risks due to culvert design flaws

Lessons Learned

- Data was difficult to find
- Investigators like stream gages but need to identify and quantify data
- Data would be useful for culvert design

The next steps include looking at the value of hydro-gauges.

Panel 3 Discussion

Where do we go from here? First, it's important to understand rather than assume user needs. A multi-disciplinary approach is needed to understand what users need and the form in which they need it. This is where the GEOValue community comes in. Researchers and policy-makers need to build in time for incorporating feedback mechanisms in the decision process, to identify synergies, and to consider resource limitations. Valuing and using geo-spatial data in decision-making is an iterative process that aids in identifying problems, considering solutions, prioritizing, and achieving a balance among needs.

How can we make this truly multi-disciplinary and speed up the pace of change?

We can use a forum, include other stakeholder groups, and highlight successes showcased in case studies. With large acquisition programs, the funding decision is made ex-ante but the study should be redone every few years. We need to evaluate the use of information, outcomes, and policy changes to determine whether decisions are made using the information. We should be aware that scientific information could be cherry picked to provide credibility to pre-ordained decisions. However, the use of open data, open tools, and open policy describing scientific basis can bring transparency to the process of using

geo-spatial information for valuation. Is there value without users? We need to look across the whole value chain, improve communication to decision makers.

Open Discussion Day One Panels

Lawrence Friedl summarized the top five major issues discussed over the course of the day:

- **The community needs studies, studies, studies.** The participants commented over the course of the day that we don't have sufficient numbers of studies and that the quality of studies is critical. We need some shared standards for studies of geo-spatial data valuation, more cross-disciplinary work and publication s reporting on that work, and tracing of value chains.
- **The community needs to establish some shared terminology**. Although some terms are shared by both the economic community and the earth science community, others are unique to each or defined differently by each. Shared understanding of terms will aid in multi-disciplinary activities and improve cross-community discussion. We should be thinking about developing communities of practice to share conceptual understanding and development of shared terms and to enable engagement.
- **The community identified factors that affect the uptake of information**. We need to be able to show the value of information and data gathering activities. We should be considering standard operating procedures in decision-making contexts, for example, that decision makers can be risk averse or that in some cases decisions have been made before data is provided and stake holders want studies that back-up their decisions and actions.
- **The community needs to better communicate analysis and show the impacts that data can have**. Credibility of data and analysis is important. The effectiveness of options and trade-offs needs to be clearly presented to decision makes who must implement solutions.
- **The community needs to consider the human dimensions**. The earth observation community needs to connect with decision makers to determine the co-benefits to decision makers and earth system science. For example, land-use is a human dimension; the natural sciences can be drivers for change by linking land use to processes such as climate change. We need additional "language capacity," scientists with the flexibility to articulate science to influential audiences.

Observations

Participants commented on various issues, concerns, opportunities, challenges and approaches that emerged over the course of the conference. Notable points included the following.

- Working across disciplines is valuable but comes with complexities including differences in language, methods, and cultures that need to be negotiated.
- Open access to data and determining user requirements for access is critical to enhancing use value and reducing barriers to the use of data.
- Opportunities to enhance geo-value data development and analysis include participatory science, citizen science, crowd-sourcing, and similar strategies.

- Organizations, groups, and individuals not currently represented in the community should be encouraged to participate because they can address noticeable gaps in the community's skills and knowledge base.
- Use values and non-use values need further discussion; we need to improve on articulating these ideas.
- We could be more precise in describing analyses, decisions, and actions along the value chain. The lack of explanation is similar to "black boxing" how information is developed.
- The scale of studies varies from micro to macro.
- We should consider frameworks for methods, decision types, and analysis techniques that include data, assumptions, benefits, use and non-use values
- The U.N. Agenda 2030 includes sustainable development goals for earth observation and analysis that should be considered.

Day Two Agenda: Issues and Discussion

Welcome, Opening Remarks, and Charge for the Day

Jay Pearlman, J & F Enterprise, University of Colorado (Moderator)

Dr. Pearlman briefly summarized the highlights of the previous day. He then emphasized contribution to the Sustainable Development Goals (SDG), citing the 2030 agenda for the SDG, *Transforming our World: The 2030 Plan for Global Action*—Article 76: "We will promote transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including Earth observation and geo-spatial information". He concluded with the following points: consider collaboration and international opportunities (GEO, Future Earth, Belmont Forum, etc.); contribute case studies to the GEOValue Community, and think end to end—don't stop at the limits of your comfort level.

Lawrence Friedl, Director, Applied Sciences Program, NASA

Mr. Friedl described the upcoming decadal survey update, the objective being to "Develop prioritized list of top-level science and application objectives to guide space-based Earth obs. over a 10-year period." A request for information is posted, with focus on the following question: What additional items can this community do to advance its research and applications interests and priorities?

Opening Keynotes

Barbara Ryan, Executive Director of GEO Secretariat, *"Data to Decisions: Closing the Gap with the Group on Earth Observations (GEO)"*

The GEO vision is to realize a future wherein decisions and actions, for the benefit of humankind, are informed by coordinated, comprehensive and sustained Earth observations and information. GEOSS is clearly at the start of the Earth Observation supply chain. The challenge is to integrate all of the information.

There are still some gaps in GEO membership, which includes 102 member states and 92 participating organizations. The organizations highlighted either have a representative in the room or are related to disasters or biodiversity.

Over the last year, new Societal Benefit Areas (SBAs) were restructured around actions required. The resulting program initiatives are related to the case studies topics presented yesterday (ecosystem services, and disaster risk reduction). Ms. Ryan presented the list of GEO foundational tasks and highlighted Community Development task CD-03, which assesses the benefits from Earth Observations and of their socio-economic value.

There are several kinds of Earth Observations, such as land temperature, sea surface temperature, and vegetation for example. Earth observations and geospatial data can be combined, where for example, land temperature, total rainfall, and vegetation are environmental factors associated with Malaria transmission. The results are reflected in the Sustainable Development Goals (SDGs), The 2030 Plan for Global Action—Article 76: "We will promote transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including Earth observation and geo-spatial information, while ensuring national ownership in supporting and tracking progress." UN conventions, such as the one on biodiversity help closing the loop by inviting "Parties, indigenous and local communities

and other relevant stakeholders to collaborate with the Group on Earth Observations Biodiversity Observation Network and other relevant organizations that contribute to building observing systems and to biodiversity monitoring". Nations need support and encouragement to continue making investments. At the 2015 Sendai UN conference on disaster risk reduction, there was work on an international framework on EO. The Sendai Framework included language recognizing that Earth observations have a clear role in Disaster Risk Reduction. GEO and other partners proposed to establish a Synergy Framework for the Integration of Earth Observation Technologies into Disaster Risk Reduction.

Ms. Ryan emphasized a couple of points: open sharing of data, and what is being done with the downloaded data, with focus on annual economic benefits. For example, the University of Maryland has performed an analysis of forest data. Australia has developed a data cube (with every pixel rectified) and has performed flood risk analysis at pixel level. Open data is a precursor to bringing users to the table. The activities below were highlighted. The G20 agricultural ministers have engaged, leading to the GEOGLAM system, a crop information system for decision-making (The crops currently include maize, rice, wheat, soybeans). Another example has to do with visualizing the impact of public policy. Corn and soybeans used to be planted in rotations until the ethanol legislation resulted in corn being planted only. Barbara concluded by mentioning that "Countries have borders, Earth Observations do not".

Mark Pelling, King's College London, *"Risk Information to Action: integrating risk information into social research for policy impact"*

Mark Pelling is a human geographer who focuses on sustainable development from the perspective of identifying failures and increases in inequality. Mr. Pelling is on the steering committee of King's College Center for Integrated Research on Risk and Resilience (CIRRR) where he heads one working group (risk information to action), and works with the Belmont Forum.

Mr. Pelling has shifted from describing problems to opening solution spaces. Social science history reveals work at the grass root level and at very high levels; Mr. Pelling is looking at the possibility of operating in the middle space where GEO Data may be most important. This positioning raises two questions: Can GEO Data play a role in that framework? What is the empirical question to be solved, and what about governance?

Three projects Mr. Pelling described use GEO data for decision-making.

Story One: Urban risk management in Africa. This is a three-year project, in which seven countries are collaborating. The project faced problems including data scarcity (data is either not accessible or not affordable); fragmented land-use, which geospatial data may be able to help resolve; and polycentric planning regime involving many social actors. Can we bring GEO Data to enable discussions, recognizing for example, the importance of boundaries? GEO Data brings legitimacy to the project because it is seen as neutral, and involves a level of technical expertise suitable to open up the conversation. The solution space includes a database of sources available via online portal (for legitimacy), a focus on city infrastructure analysis with particular attention to boundaries, recognition of the importance of ground truth, and attention to hazard history and interactions.

Story Two: Metropole, urban resilience in UK, U.S., and Brazil. The problem space in this project includes data variability and an increasing gap between historic and

contemporary local sea-defense planning rights and powers. A challenge is not lack of risk awareness but the need to re-think how to approach risk management and data scarcity.

Strategic conversations were held within local governments—with local, regional and national stakeholders, and between local, regional and national stakeholders. Again, geospatial data projects are considered a safe science partner—political neutrality, technical—bespoke sea-level rise hazard assessment and adaptation cost-benefit analysis. Geospatial data is handed over to institutional analysis to explore solutions, such as the development of an Adaptive Capacity Index.

Mark gave the example of an Integrated Framework to analyze local decision-making and adaptive capacity to large-scale environmental change. He looked at a flood hazard risk model based on LIDAR risk data commenting that the data was very difficult to use.

The adaptive capacity index is designed to improve understanding of the barriers to adaptation planning:

- How values, demographics and cultural factors influence stakeholder receptivity to locally specific scientific and economic data and governance approaches
- What decision-making tradeoffs exist around costs, risk and public good for possible adaptation options, and local willingness to support action
- Regional adaptive capacity—institutional factors that support the ability of risk management actors to adapt and mobilize change.

Story Three: Transformation and resilience on urban coasts. This case focused on meeting the needs of mid-century flood risk and heat wave scenarios. Data accessibility across cities is a challenge. Problems include susceptibility, lack of coping capacity, and lack of adaptive capacity. Detailed policy analysis was undertaken; it took a year and a half to get modeling data out.

The three examples illustrate a combination of geospatial data modeling and social analysis and highlight the need for improved dissemination of data (including access and awareness). Sources available to organizations and community groups are essential to improve local decision making processes. Trust building and engagement through transparency and co-production is also important. The local recognition of potential impacts of disaster risk, including those associated with climate change, facilitates galvanizing local action with implications for wider urban governance.

Panel 4–Methodologies

Melissa Kenney, University of Maryland (Moderator) **"**Indicators: Are they valuable for decision-making?"

Dr. Kenney briefly introduced indicators, asking if they are valuable for decision-making. She defined an indicator as "a regularly updated representation of status, rates of change, or trends of a phenomenon using measured data, modeled data, or an index to assess or advance scientific understanding, to communicate, to inform decision-making, and/or to denote progress in achieving management objectives". She described a process to develop the national climate indicator system as a proof of concept to be iterated over time. Dr. Kenney gave some examples of visual information—annual heating and cooling degree days (as proxy for energy use), and an example addressing understandability.

Lesley Arnold, Research Fellow, Department of Spatial Sciences, Curtin University, Perth, Western Australia, Cooperative Research Centre for Spatial Information "Spatial Data Supply Chain and End User Frameworks: Towards an Ontology for Value Creation"

Dr. Arnold asked whether "we are delivering the right value to the consumers?" She emphasized a pull production approach, which delivers answers in the user context, in contrast to the more commonly used information push.

In the pull production approach, a specific query is addressed—for example, am I in danger from the flood; in a push approach, general information is pushed to the user and maintained. This was illustrated by the value proposition problem—a map contains general fire information, which does not necessary provide the desired value to the end user. The user is looking to make lives simpler and safer and to receive an answer to a question in a manner that is intuitive and seamless.

In the push approach, the end-user query is interpreted; ontologies are processed; the metadata is collected; the resulting information is ranked, and the results portrayed. Dr. Arnold provided a handout illustrating the transition from the supply chain to the value chain framework. The benefits framework showed the acquisition of knowledge, which is either used or not. Provenance is maintained through the decision-making process, including fit for purpose. When knowledge is used, a decision is made according to that information and either positive or negative benefits are accrued.

Emily Sylak-Glassman IDA Science and Technology Policy Institute, Washington DC) A method to estimate societal benefit derived from Earth observations (EO): An example from the United States' National Earth Observation Assessment"

Ms. Sylak-Glassman described methodology development in support of EO assessment, using a value tree Societal Benefits Area framework. The SBA value tree is a hierarchical model that establishes the connection from top-level societal benefits to the set of observing systems that contribute to the SBA. The goal is to make the connection between the Earth observations and the value they provide (societal benefit delivered). To assess the relative impact of each EO system on the provision of societal benefit, it is necessary to assign relative weights to each of the sub-areas, key objectives, and Key Products, Services and Outcomes (KPSOs). Each sub-area within an SBA is assigned a relative weight, such that the total weight of all subareas in that SBA is 100%. This initial weight is only the starting point for a discussion. The method of using votes to determine a rank, which determines an initial weight, ensures that the starting point for the discussion is based on the views of the team as a whole. The extent to which SBA team members adjusted the rank and weight of the key objectives from the initial values was examined. Analysis of the weighting results was performed, looking at the correlation between the initial and final weights for each SBA, and at the goodness of the fit of the line describing the final weight as a function of the initial weight.

Charles Wooldridge, Deputy Director, International and Interagency Affairs Division, NOAA. "Understanding and Assessing the Value of Improved Satellite Data for the Users of Operational Sea Ice Products and Information (CGMS SETT Case Study)"

The project is in its 4th year and has involved social scientists from the beginning of the study. It involves a case study of best practices/lessons learned for CGMS, the objective being assessment of the socioeconomic benefits of improved operational products resulting from enhanced satellite data. The scope was achievable within the time and resources available. The data on sea ice was obtained from remote sensing. A simplified value chain included: observations, modeling/forecasting, product dissemination, user interpretation, and decision making. The observations focused on sensors looking at the ice edge. Benefit assessment methodologies included counter factual and data denial studies. The activities considered included transportation and commercial fisheries.

The analysis showed that transportation could be cut from 55 days to 19 days using the northern route.

The following potential next steps were identified:

- Identification of resources available for the socio-economic benefits study:
- Operational analysis (in kind)
- Economic analysis (in kind or monetary)
- Conducting of the Socio-economic Benefits study
- Development of a plan for communicating the results
- Updating the Guidance Document.

"We have big data; we don't have big analysis."

Michael Papenfus, EPA, discussed using ocean color satellite data to estimate economic benefits associated with monitoring and preventing harmful algal blooms.

Mr. Papenfus raised the question of who is going to take action as a result of the study? Actions are constrained by money, time, and other considerations. These constraints should be identified at the inception of a project. The team should communicate these constraints as part of the objective of their research. When selecting the arctic, there is also a concern about a subject, which is political.

Networking Break and e-posters displays

Panel 5–GeoValue Policy

Claire Jolly, OECD (Moderator)

Important points from the presentations include that value of data is in the eye of the beholder, and that data needs to be coordinated over the local, regional, and national levels.

Jared Berenter, The Palladium Group, "The Effect of 'Pace of Onset' and 'Administrative Scale of Environmental Hazards' on the End-User Value of Satellite Data for Environmental Decision-Making: A Contextual Analysis Based on Fieldwork in Central America and the Himalayas"

Mr. Berenter discussed the SERVIR program sponsored by NASA and USAID that collaborates with many agencies in locations worldwide. This discussion focused on three case studies representing the agency's work. The cases studies present projects in three countries: Nepal, El Salvador, and Guatemala.

The SERVIR program has an international development agenda, driven by contextual issues globally, for example, data availability, lack of infrastructure for decision making, necessity of fees for transfer, and other challenges. SERVIR is primarily a regional visualization and monitoring system and began work with South America. The program is now in Africa and Central America as well.

SERVIR works with a variety of other agencies for mapping and resource development. Collaborations create "hubs" for how NASA and other agencies work.

A big question emerged from this work: Where is value derived and where does it have impacts for the hubs?

Geo-Value Policy Questions

Mr. Berenter described several case studies. In Nepal, the projects were post-disaster. They had a small administrative scale, limited use of data observed with no impact observed. The event was a localized, rapid incident that needed rapid response. Nepal already assessed problems. The administration was large and they didn't use available agricultural and ground vegetation data. SERVIR had impact on forest fire damage through hotspot mapping.

The El Salvador case study involved water quality related to algae blooms, a slow event. The best use of the data for identifying and mapping was used to determine areas for testing. The administration involved was large. Mr. Berenter described the effect of "pace of onset" and "administrative scale of environmental hazards" on the end-user value of satellite data for environmental decision making: a contextual analysis based on fieldwork in central America and the Himalayas". He reported on a three-year performance evaluation of SERVIR.

The program objective focused on the USAID/NASA collaborative initiative to provide geospatial data tools and resources to countries in Central America, Eastern and Southern Africa, and the Hindu Kush-Himalayan regions to inform environmental decision-making

and management of climate risks, natural resources, and natural disasters. The sectors addressed included hydrology, disaster management, Land use, biodiversity, and ecosystem management.

Findings were based on nine case studies, which dealt with eight products, and seven countries across three regions. Work was performed through hubs on the ground. Hubs currently include the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) in Panama City, Panama; the International Centre for Integrated Mountain Development (ICIMOD) in Kathmandu, Nepal; and the Regional Centre for Mapping of Resources for Development (RCMRD) in Nairobi, Kenya. New hubs are under development in Ghana and South East Asia. A set of evaluation questions addressed the uses of SERVIR data products and services for environmental decision-making are listed below:

- How are SERVIR products being used and what are the measurable impacts on the relevant societal benefit areas themselves?
- What are the impacts of SERVIR's capacity-building efforts on hubs to become stronger regional service providers?
- What is the value of SERVIR's capacity building, science applications, data sharing efforts and global network?

Determining the value of SERVIR geospatial data products and service was predicated on use, driven by the nine case studies. Three examples were given associated with the "pace of onset". A second group of examples focused on the Geographic Scale of the Decision-Making and associated context. Conclusions regarding the pace of onset and the scale are respectively stated below: for the pace of onset, product-specific and institutional barriers to product delivery, processing and use favor the monitoring function of geospatial data and thus render geospatial data more valuable for chronic or slow-onset events**.** Across the nine case studies, SERVIR's tools proved most useful where the administration of the response to an event spans a geographically large administrative unit.

In conclusion, Mr. Berenter summarized the finding regarding the value and impacts of SERVIR products according to several categories: the environmental impact was strongest in the forestry and land use sectors, where threats to ecosystems are slow to materialize; likewise, value to be gained from preservation or restoration of ecosystem services was also slow to materialize. The economic impact was most strongly visible in post-onset service delivery; areas highly affected by environmental calamity over a large geographic region with multiple administrative units were better served. Social impact was most visible through environmental sensitization or behavioral impact. In select cases, such as Guatemala, where geospatial data has effectively reduced risk, social value was gained through preservation of cultural and environmental heritage. Identifiable direct impact on public health was limited by low reporting and unverified diagnoses.

Administratively, geospatial data was being used to increase data confidence, complement other sources of information or more comprehensive monitoring system, and fill data gaps. These administrative gains improved accuracy and precision of monitoring and damage assessments and facilitated more cost-effective use of government resources.

Danny Vandenbroucke, University of Leuven; "Performance measurement of location enabled work processes: a use case-based approach"

Mr. Vandenbroucke addressed the integration of Spatial Data Infrastructures (SDI) components in e-Government Business Processes to support G2C, G2B and G2G

interactions. In Europe, there is a rich data infrastructure, due to INSPIRE, which consists of 99,606 spatial data sets and 45,276 spatial data services. However, the uptake of these components remains relatively weak. A use case-based approach is used to estimate and measure impact of the location enabled processes. The impact is assessed at the mezzo-level, using the business process as unit of analysis.

Mr. Vandenbroucke described the business processes as constituting of inputs, throughputs, outputs, and outcomes. Examples of the process included monitoring animal transport and animal diseases; traffic safety monitoring and policy; mapping flooding and flood areas; obtaining environmental permits. He defined a two-step approach, mapping and assessing the processes, based on a series of indicators. Two use cases illustrated the approach: one on traffic safety and one on floods. The value to the end user was measured, assessing performance, looking at occurrences of bottlenecks and bad quality, need for re-engineering, and any sub-optimal use of spatial data. The final step focused on assessment of the business process regarding time, cost, and quality and applying new technologies to enhance the process.

Ivan Hascic, OECD Environment Directorate, "Applying geospatial information with OECD Environmental and Green Growth indicators"

Mr. Hascic discussed production of internationally harmonized data, statistics and indicators as a core function of the OECD, which adopted the green growth strategy in 2009. Geospatial data offer opportunities to develop new or improved indicators across countries and regions, particularly in the domain of the environment and green growth because satellite and other geospatial data are often a unique source of relevant information. This approach offers a cost-efficient opportunity for the OECD to respond to the growing demands for better-targeted policy recommendations and a more granular and more policy-relevant information base.

The measurement framework focuses on the interface between environment and economy. It is natural-asset based; looking at environment resource productivity, the environmental dimension of quality of life, and economic opportunities and policy responses.

A traditional way to collect data has been based on a questionnaire requesting yearly inputs. There are however several issues with this approach such as lack of response; obtaining non-comparable inputs; and challenges with the level of aggregation (eg. air pollution data provided is averaged).

Recent progress and remaining challenges were discussed, notably concerning measuring population exposure to air pollution; land cover and land cover changes; and protected areas. Examples of indicator applications in OECD's country reviews and empirical policy analyses were also presented (e.g. environmental aspects of land use policy). Value added by geospatial data includes the ability to cover all countries in a harmonized manner, and to track changes over time. The next frontier is to combine the geospatial data with demographic data. Opportunities for future developments include those arising from demands to measure the environmental dimension of quality of life better, resilience to environmental risks, availability of natural assets and the use of environmental sinks.

Pierre Glynn, USGS, "The Value of Geospatial Data and Internet Communication Technology for Science/Policy Governance of Complex Systems"

Scientific method depends on independent observations. Geospatial information is "Big Data" that encompasses "us," "our" activities, and processes of entire ecosystems. It transcends political and cultural boundaries. We have little experience with geospatial data or knowledge of "event-chains," nor do we have much knowledge regarding its "value in use" beyond relatively short-term and local/regional applications.

Acquisition, structuring, use of geospatial information is influenced by our beliefs, biases, heuristics, and prioritization Values (BBHV). How can we intelligently use and therefore value geospatial data? Our BBHV are not necessarily well conditioned to the use or valuation of geospatial data.

The "Value of Information" (VOI) could be the combination of the information being used to initiate an "Event-Chain", and the impact of the Event-Chain. What are the "Reference Event-Chains"? And what is the ensemble of Event-Chains, and the net expected or realized value of that ensemble? Dr. Glynn argues that it is the "Value in Use" rather than VOI that matters.

Having "Open Data" is not enough. We need "Open, Traceable, Understandable, Accessible" tools for discovery, and analysis, models for synthesis, scenario building, and assessments and tools for stakeholder engagement (e.g. visualization, gaming). Internet Communication Technologies (ICT) can be a facilitator. For science-based decisions, we need records and honest, detailed, predictions of consequences.

For scientific evidence-based decisions, we need "Open, Traceable, Understandable, Accountable Policy." "Open Policy" is the essential counterpart to "Open Data." We require institutional and political follow-up, including monitoring of predicted outcomes. We need stakeholder engagement for the long-term, across disciplinary, cultural and political boundaries.

For achieving democratization of Science and Policy, public participation is essential. The public can greatly help, obtaining data, conducting image analyses and more. The greatest value of a fully engaged public are: to provide local and historical knowledge, elicit BBHV, avoid groupthink through diversity, and to facilitate enhancing Value-In-Use from information.

Possible applications include predicting and countering the spread of a zoonotic epidemic (e.g. Zika) as a function of climate and biophysical and ecological controls; creating other disaster mitigation and response plans; creating a water/energy/food management and land-use plan for a watershed or region; creating a land-use (and resource extraction) conservation plan, informed by climate-change scenarios, for a threatened species or biome; creating an urban or rural management plan that allows optimal allocation of our human, ecosystem, and infrastructure resources, in both time and space.

Open Discussion Day Two Panels

Dr. Kruse opened discussion by asking how products might be adjusted to increase use. One of the problems is that technical products and components are not meant for the public. Data needs to be analyzed. We need to look at what people use—what are the applications? What are the legitimate uses of information? What is the capacity of the data? What is the language used? What are peoples' cultural positioning?

One participant commented on the issue of trying to get data to various countries in a useable form. What are the distribution bottlenecks? How do we find ways that work?

Dr. Downs noted that the intended audiences for information or data—are not the only audiences. Other groups who were not recognized as audiences for the data are equally important. He asked whether the panelists find that to be the case. How do we find, measure, and report on the needs of multiple audiences? How could understanding this issue be used to improve things?

A number of points and suggestions were raised:

- In terms of audience, build recommendations from previously demonstrated cases.
- Ensure that information is provided to all stakeholders; assess needs before and measure uses after developing the products.
- Be aware that it takes time to create graphical representations.
- Consider that discovering potential users involves tracking needs; people may also approach researchers with needs.
- Find out about how people are thinking about using data (what is the scale? are layers needed? etc.)
- Identify champions and create user databases and hubs. Links to users get weaker as information moves farther out from the origin of data.
- Avoid being descriptive or prescriptive with users—countries can pick the data they think is most appropriate.
- Determine the form that users are most likely to use. Primary users may be interested in data that can be manipulated; others may be looking for reports and summaries of analyzed data.
- Track who is using data, network the usage, and use the information to facilitate data presentation.
- Model with stake holders.
- Have objectives but follow up with users. If someone starts out interested in mining data for a particular purpose, find out how tools are used for alternative purposes.
- Develop a database of use-cases and follow-up on results.
- Understand timescales of use and the needs for updating data.
- Look at what “regular people” are doing to collect data and how they’re doing it. Could we learn from that?

Charge for Breakout Sessions

Lawrence Friedl, NASA

Dr. Friedl led an activity to help participants consider the question: What can we do to enhance the development of studies on the social/economic needs for and impacts of data? How can we improve studies, community awareness, and brokering?

Small groups worked to identify two possibilities for studies to conduct on value of earth observation for analysis, decisions, or implementation actions.

Each group reviewed the use cases, which had been presented, and provided recommendations for a path forward. A representative for each group then presented the breakout team's conclusion to a 3-person jury, similar to the investors group portrayed in the Shark Tank reality television show. This TV program features aspiring entrepreneur-contestants that make business presentations to a panel of "shark" investors, who then choose whether or not to invest.

The groups were instructed to consider data and methods of analysis appropriate for their scenarios including:

- Analyses, decision, actions, methodology
- Value and impacts
- Data needed
- Counterfactual perspectives
- Output
- Description of each
- Rational and methodology

Closing Discussion—Strategies for Advancing the Science and Practice Standards

Carl Shapiro, USGS; **Molly Macauley**, RFF (Moderators)

The group discussed how to proceed based on issues and needs raised during the conference. Suggestions included the following:

- Collect case studies to determine what has been accomplished and how data have been used.
- Develop an inventory of methods from studies.
- Identify societal impact exemplars from studies.
- Develop a repository for new publications and presentations that will facilitate cross-disciplinary collaboration.
- Continue engagement between workshops. Investigate ways that other groups have accomplished on-going contact to sustain progress in building the community.
- Collect feedback on the workshops.
- Consider the possibilities of shared standards, frameworks, common terms, best practices for valuation.

Workshop organizers

Francoise Pearlman, Manager, J&F Enterprise, Community Outreach and Coordination.

Francoise Pearlman has 30 years of experience in engineering and management including system of systems engineering, software engineering and software/system integration and testing. For over 15 years, she has applied her management expertise to government programs with focus on development, integration, and field testing of digitization software/systems. Francoise has also participated in numerous technical reviews and proposals for a wide range of information systems and Command and Control programs. After a career in technical management for major aerospace corporations, she is currently co-owner of J&F Enterprise, a small technical services company operating in the global dimension. She is a senior member of IEEE.

Jay Pearlman, J & F Enterprise, University of Colorado

Dr. Pearlman has 40 years of experience in science, development, and systems activities. His background includes basic research, program management, and program development in systems, sensors, information technology, and the impacts of information on decision-making. Dr. Pearlman is technical director of J&F Enterprise and Professor (adjunct) at the University of Colorado. Jay focuses on research and applications in oceans and large-scale information systems. He is co-chair of the NSF EarthCube Technology and Architecture Committee and a member of the U.S. Committee for the Research Data Alliance, both addressing data interoperability on a national and international scale. Dr. Pearlman also continues his efforts in Earth observation and geospatial information.

Jamie Kruse, Director, Center for Natural Hazards Research; Distinguished Professor of Economics, East Carolina University; Senior Scientist, Institute for Coastal Science and Policy

Dr. Kruse is recognized for her research in economics and decision making under uncertainty especially as it relates to natural hazards. She completed her doctoral work at University of Arizona under dissertation advisor, Vernon Smith (2002 Nobel Laureate). Dr. Kruse has published over sixty refereed journal articles in addition to proceedings, abstracts, and reports. She has held faculty positions at the University of Colorado, Texas Tech University, East Carolina University, and a visiting position at Eidgenossische Technische Hochschule (ETH) in Zurich, Switzerland. Her work has been supported by National Aeronautics and Space Administration, National Science Foundation, U.S. Geological Survey, Department of Energy, National Institute of Standards and Technology, Federal Emergency Management Agency, Department of Homeland Security, Federal Deposit Insurance Corporation, Niagara Mohawk, State of Texas and the State of North Carolina. In 2010, she held the position of Chief Economist at National Oceanic and Atmospheric Administration.

Lawrence Friedl, Director, Applied Sciences Program, Earth Science Division, NASA. Washington, D.C.

Lawrence Friedl leads efforts to discover and demonstrate innovative and practical applications of Earth science by public and private organizations. He has been with the NASA Applied Sciences Program since 2002. Among his responsibilities, Lawrence is a Co-Chair of the interagency U.S. Group on Earth Observations (USGEO) and represents the United States on the international Group on Earth Observations (GEO). He is the NASA Principal for the interagency Civil Applications Committee. He also serves on the Award Committee for the National Space Club's Award for Innovative Uses of Earth Observation Satellite Data, the Program Organizing Committee for the American Meteorological Society 2014 meeting, and the International Committee for Remote Sensing of Environment.

Carl Shapiro, Director of the USGS Science and Decisions Center; Senior Economist, Energy & Minerals, and Environmental Health, USGS Survey Science & Decisions Center, Reston, VA.

SDC provides an interdisciplinary focus to enhance the use and value of scientific information emphasizing research and application in five science areas: (1) ecosystem services; (2) decision science; (3) resilience; (4) participatory science and innovation; and (5) natural resource economics. Before his work with SDC, Carl spent almost 20 years as the Principal Economist in the USGS Office of the Director, where he initiated, led, and participated in multidisciplinary studies. While in the Director's Office, Carl also served as Senior Advisor to the Director and Acting Chief, Office of Strategic Planning and Analysis. Carl has received the Department of the Interior's

Meritorious Service and Superior Service Awards. Carl is an adjunct associate professor of economics in the School of Public Affairs at American University in Washington, DC, where he has taught graduate courses in economics and public management.

Claire Jolly, Head, OECD Space Forum/Ocean Economy Group, Directorate for Science, Technology, and Innovation; Organization for Economic Co-operation and Development

Claire Jolly is a Senior Policy Analyst and Head of Unit in the Directorate for Science, Technology, and Innovation. In the Organisation for Economic Co-operation and Development (OECD). She heads the OECD Space Forum and the Ocean Economy Group. She joined the OECD in 2003, after providing policy and economic analysis to public and private organizations in aerospace and defense in Europe and North America. Her background is in international economics (Univ. Versailles and Cornell University) and aerospace engineering (ENSTA, Paris).

Appendix 1: Workshop participants

Name		Organization
Aldo	Aldama	Permanent delegation of Mexico to OECD
Lesley	Arnold	Curtin University, Perth, Australia
Yazidhi	Bamutaze	Makere University, Uganda
Karl	Benedict	University of New Mexico, USA
Jared	Berenter	The Palladium group
Rich	Bernknopf	University of New Mexico, USA
Gordon	Campbell	European Space Agency
Andrew	Coote	Consulting Where, UK
Joep	Crompvoets	KU Leuven Public Governance Institute, Belgium
Sytze	De Bruin	Wageningen University
Vincent	Dedieu	French Ministry of Defense
Robert	Downs	CIESIN, Columbia University, USA
Vanessa	Escobar	NASA, USA
Lawrence	Friedl	NASA, USA
Johanna	Frojdenlind	Lantmäteriet National Land Survey of Sweden
Jason	Gallo	Mission Applications Coordinator, IDA, USA
Anita	Gibson	OECD
Pierre	Glynn	USGS, USA
Johnathan	Gourley	NOAA, USA
Dillon	Green	US mission to UNESCO
Roswitha	Gruemann	DLR, Germany
Dominique	Guellec	OECD
Balan Alejandro	Gutiérrez Herrera	Agencia Espacial Mexicana, Mexico
Elisabeth	Haeggquist	Lulea University of Technology, Sweden
Ivan	Hascic	OECD
Leon	Hauser	Space technology institute, Hanoi, Vietnam
Einar-Arne	Herland	Norwegian Space Center, Norway
Jacob	Hochard	East Carolina University, USA
Claire	Jolly	OECD
Donna	Kain	East Carolina University, USA
Aleski	Kalenius	Permanent delegation of Finland to OECD
Melissa	Kenney	University of Maryland, USA
Nikolay	Khabarov	IAASA, Austria
Suzette	Kimball	USGS, USA
John Leslie	King	University of Michigan, USA
Calvin	Klatt	Natural Resources, Canada
Jamie	Kruse	East Carolina University, USA
Yusuke	Kuwayama	Resources for the Future, USA
Muriel	Lafaye	CNES National Centre for Space Studies, France

Name		Organization
Jeff	Lazo	National Center for Atmospheric Research, USA
William	Lecky	UK Space Agency
Steven	Lev	IDA, USA
Lucia	Lovinson-Golob	Afriterra Foundation,
Molly	Macauley	Resources for the Future, USA
Paida	Mangara	SANSA, South Africa
Tanaka	Masafumi	French Ministry of Economy, Industry and Digital Affairs
Robert	Mendelsohn	Yale University, USA
Laure	Ménétrier	French Ministry of Economy, Industry & Digital Affairs
Benjamin	Miller	RAND Corporation, USA
Stuart	Miller	Terragotech, Perth, Scotland
Douglas	Muchoney	USGS
Yusauke	Muraki	Japan Aerospace Exploration Agency, Japan
Miriam	Murambadoro	CSIR, South Africa
Mattia	Olivari	OECD
Michael	Papenfus	Environmental Protection Agency, USA
Jung Ho	Park	Korea Aerospace Research Institute
Francoise	Pearlman	J&F Enterprises, USA
Jay	Pearlman	J&F Enterprises, USA
Mark	Pelling	King's College, UK
Gilles	Ragain	CNES National Centre for Space Studies, France
Barbara	Richardson	UK Space Agency
Giovanni	Rum	GEO, Switzerland
Barbara	Ryan	GEO, Switzerland
Carl	Shapiro	USGS, USA
Alan	Smart	ACIL Allen Consulting, Australia
Fanglin	Sun	University of California at San Diego, USA
Anna	Svedlund	Lantmäteriet National Land Survey of Sweden
Emily	Sylak-Glassman	IDA, USA
Alicja	Tamiz Christiansen	Agency for Data Supply and Efficiency, Denmark
Jurkka	Tuokko	National Land Survey Finland
Marit	Undseth	OECD
Glenn	Vancauwenberghe	KU Leuven Spatial Applications Division, Belgium
Danny	Vandenbroucke	KU Leuven Spatial Applications Division, Belgium
Ingrid	Verstaeten	USGS, USA
Stéphanie	Willekens	European Space Agency
Charles	Wooldridge	NOAA Satellite and Information Service, USA
Andrew	Wyckoff	OECD
Zhiliang	Zhu	USGS, USA

Appendix 2: Speaker Bios and Presentation Abstracts

Andrew W. Wyckoff, Director, OECD Science Technology and Innovation Directorate

Andrew Wyckoff oversees OECD's work on innovation, business dynamics, science and technology, information and communication technology policy as well as the statistical work associated with each of these areas. Mr. Wyckoff was previously Head of the Information, Computer, and Communications Policy (ICCP) division at the OECD, which supports the organization's work on information society and consumer policy. Before heading ICCP, he was head of STI's Economic Analysis and Statistics Division. His experience prior to the OECD includes being a program an economist at the U.S. National Science Foundation (NSF) and a programmer at The Brookings Institution.

Suzette Kimball, Director of the U.S. Geological Survey (USGS)

Dr. Kimball leads the largest water, earth, and biological science, and civilian mapping agency in the US. Dr. Kimball was the USGS Deputy Director. In 2008, she became the Acting Associate Director for Geology; prior to that, she was Director of the USGS Eastern Region, starting in 2004. She joined USGS as Eastern Regional Executive for Biology and built many partnerships, helped shape programs, and led the establishment of the USGS Florida Integrated Science Center. She serves on executive boards and many State and national committees, including the Consortium for Coastal Restoration through Science & Technology, the Council of Examiners of the National Association of State Boards of Geology, and the DOI Senior Executive Service Advisory Council.

OPENING KEYNOTE: Dr. Suzette Kimball

Robert Mendelsohn, Yale University, School of Forestry and Environmental Studies

Professor Mendelsohn has written over one hundred peer-reviewed articles and edited six books. The focus of his research has been the valuation of the environment, and he has developed methods to value natural ecosystems including coral reefs, old-growth forests, non-timber forest products, ecotourism, and outdoor recreation. He has also developed methods to value pollution including emissions of criteria pollutants and hazardous waste sites. His most recent work values the impacts of greenhouse gases, including the effects of climate change on agriculture, forests, water resources, energy, and coasts.

KEYNOTE: Robert Mendelsohn. "Using Earth Observations in Economic Analysis"

Geospatial data is critical to measuring and understanding many natural science phenomena and so are indirectly parts of many economic analyses involving environmental management. Economists directly use earth observations for everyday measurements of the environment as well as observations of extreme events. For example, weather measurements have been invaluable for many climate related studies in economics. Geospatial observations are also critical for managing the land-water-energy nexus. For example, pollution and weather monitors help connect production of energy to the environmental consequences of emissions. Water monitors measure the supply of fresh water in each and every watershed which then must be allocated across multiple demands such as hydropower, food, drinking water, industry and aquatic ecosystems. Land use measurements help resolve how to utilize the available land resources on earth for food, shelter, production, conservation, and biomass energy. As the global economy continues to grow, the pressure to manage all these limited resources more carefully will only increase.

Richard Bernknopf, Research Professor, Department of Economics, University of New Mexico

Dr. Bernknopf's research focuses on the value to society of scientific data, including earth observation, and the translation of that information into a form compatible with decision-making processes. Currently he is associated with the Science Impact Laboratory for Policy and Economics at the University of New Mexico and the Wharton Geospatial Initiative at the University of Pennsylvania. Previously, Dr. Bernknopf was an economist with the United States Geological Survey for more than 38 years. During his tenure at USGS, he was a consulting professor and co-director of the Center for Earth Science Information Research at Stanford University, and co-director of the Spatial Integration Laboratory for Urban Systems at the University of Pennsylvania.

Leon T. Hauser, Department of Sensing Technology, GIS & GPS; Space Technology Institute, Vietnam Academy of Science & Technology (VAST), Hanoi, Vietnam

Leon Hauser is an environmental research officer for Vietnam's Space Technology Institute (STI) involved in increasing national capacity to monitor and research environmental changes through remote sensing resources including Vietnam's own Earth Observation Satellite, the VN-RedSat1. His current research focuses on monitoring coastal forests in Vietnam with hyper- and multispectral- remote sensing data looking at degradation hotspots and vegetation distributions. Prior to work for STI, he explored understanding the interplay of agricultural production, biodiversity conservation, and land policies in rural landscapes in Western Europe using agricultural censi and aerial imagery. He has collaborated with the Dutch Ministry of Economic Affairs to conduct research on invasive aquatic species in West-Africa.

"From Spectral Signatures to Ecosystem Management Decisions; the Value of a Hyperspectral Reflectance Library for Common Mangrove Species Mapping in Southern Vietnam"

Leon T. Hauser, Vietnam Academy of Science; Nguyễn Vũ Giang, Vietnam Academy of Science; Nguyễn Minh Hiếu, Vietnam Academy of Science; Phạm Việt Hò, Vietnam Academy of Science

Hyperspectral sensors for earth observation offer unprecedented detail in recording subtle spectral differences for detailed land surface classification purposes. Through statistical analysis, this paper shows that the hyperspectral reflectance signatures of the canopies of common mangrove species in Southern Vietnam possess significant separability within the Visible and Near-Infrared regions of the electromagnetic spectrum—despite the challenges paired with in-situ field measurements of vegetation. In anticipation of wider availability of satellite hyperspectral imagery, the development of a spectral library consistent of common mangrove species in Ca Mau peninsula offers potential to support more accurate and detailed mapping products for mangrove ecosystem monitoring and thereby support ecosystem management decisions. This paper explores the discussion on how to assess the potential value of the spectral library for enhanced ecosystem management decisions.

Yusuke Kuwayama Resources for the Future, Washington DC, U.S.A.

Yusuke Kuwayama's research focuses on the economics of environmental regulation, with an emphasis on water resources and ecosystems. Using theoretical and numerical modeling, he analyzes whether accounting for the complexity of environmental processes in economic optimization problems yields policy recommendations that are different from those currently offered in the literature, and whether management practices that reflect these differences will lead to better economic and environmental outcomes. His recent work analyzes the cost effectiveness of policies to manage spatially heterogeneous externalities from agricultural water use the, implications of time lags and uncertainty on the optimal design of tradable permit systems, and the potential for hydrologic models to inform the choice of strategies to control groundwater pollution.

"The Value of Information from a GRACE-Enhanced Drought Severity Index"

Zhilian Zhu, U.S. Geological Survey.

Zhiliang Zhu is a program chief for the U.S. Geological Survey (USGS) with responsibilities for leading assessment and research of greenhouse gas fluxes and carbon sequestration capacities by ecosystems. Prior to the current assignment, he was a research scientist with the U.S. federal government (since 1990) studying wildfires, forest monitoring, and remote sensing. He obtained master and PhD degrees from the University of Michigan, and bachelor degree from Nanjing Forestry University, all in 1980s.

"Assessing Carbon Sequestration Potential as an Ecosystem Service For Publicly Managed Lands in the United States."

Carbon sequestration is an ecosystem service because the process stores carbon in its pools for a long term and helps mitigate the negative effects of climate change. Approximately one third of the United States lands and waters are managed as public lands. These lands are national parks, forests, grasslands, and wetlands. Among the many ecosystem services provided by public lands, such as recreation and clean water, is ecosystem carbon sequestration. A recent study by the U.S. Geological Survey (USGS) shows that public lands represented 23% and 82% of the ecosystem carbon sink in the conterminous 48 states and the state of Alaska respectively. The carbon stored

in various pools is a long-term ecosystem service. For example, using the USGS study results including Landsat remote sensing of land use and land cover (LULC) change, the amount of carbon stored in national parks in the conterminous U.S. provides a total societal value estimated at 583 million dollars per year (Richardson and others 2015). Applications of remote sensing methods with field observations and processes, as well as simulation models are useful tools for such studies at the national as well as landscape scales. At the landscape scale, different and more of a variety of remote sensing platforms and methods such as LIDAR tend to be used to derive targeted biophysical variables. I illustrate the applications of geospatial data products to derive societal benefits in the United States by discussing two separate but related studies we have conducted in evaluating ecosystem carbon sequestration as a societal benefit.

Jeffery K. Lazo, Director of the Societal Impacts Program (SIP) at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado

Dr. Lazo has extensive expertise in non-market valuation of hydro-meteorological information. His work focuses on the communication, use, and value of weather information and the economic impact of severe weather events, including developing economic metrics for evaluation of the benefits of improved forecasting for solar energy, developing expert elicitation approaches for benefit estimates of improved hydrometeorological services in developing countries, and benefit cost analysis of programs to enhance weather forecasting. As part of World Bank projects, Jeff currently leads the benefit-cost analysis of national hydro-meteorological services in Mozambique and Bangladesh. He is working with The World Bank, the World Meteorological Organization (WMO), and USAID,

"Economic Assessment of Hydro-Met Services and Products: A Value Chain Approach"

Every year weather related hazards such as typhoons, floods, heat waves, droughts, and tornadoes cause billions of dollars of damage and affect millions worldwide in both developed and developing countries. Guha et al (2015) report that between 2004 and 2013 an annual average of 127 meteorological, 32 climatological, and 192 hydrological disasters affected an average of 191 million people each year, and caused an average annual $122 Billion dollars of damages (Guha, 2015.). "Day-to-day" events (not considered "disasters") likely have an even larger aggregate impact on society and affect virtually everyone on the planet in some manner every year. While not all (or perhaps even most) of the impacts can be avoided or mitigated, with appropriate information systems and processes there are undoubtedly significant societal benefits of geo-spatial information on weather, water, and climate. In this paper I present an overview of economic assessment of the benefits of hydrological, meteorological, and climatological (aka hydromet) services and products. While the emphasis is on meteorological information, hydrological and climate information generally follows from the same or similar observation networks, modeling, and communication approaches and the applications and methods discussed are largely applicable for hydrological and climate information in addition to meteorological information. After providing background information on some prior work and resources on economic valuation of hydromet services, I discuss the concept of a "Weather Information Value Chain" as a tool for understanding the creation of value from hydromet information as well as explicating the difficulties of valuation and opportunities for value enhancement

Yazidhi Bamutaze, Senior Lecturer and Head at the Department of Geography, Geo-Informatics, and Climatic Sciences at Makerere University, Uganda

Dr. Yazidhi Bamutaze has over 15 years of proven research and academic experience especially in Africa. His areas of professional expertise and teaching include GIS, remote sensing, natural hazards, disaster management, and geomorphology. His research spans a wide range of issues including hazard and disaster studies in coupled environments, natural resource degradation analysis and modeling, surface process analysis covering erosion and sediment loading, land use, land cover transformations, and climate change adaptation. He also has a keen interest in the application of geospatial techniques in research and teaching.

"Evaluation of Geospatial Data Utilization for Disaster Governance in Uganda"

The need for spatially explicit information for disaster management in Uganda has gained elevated momentum over the last 10 years. A spatial inspection (Figure 1) reveals a myriad of recurring disaster inducing hazards, which are omnipresent across the country. The prominence of these hazards underpin the importance of harnessing geospatial data and its governance in order to protect the societies in a better way and obviate the economic impacts often linked to disaster

events. Visibly, a significant concern in Uganda is directed toward landslides and flood hazards that are relatively fast and relatively complex to predict. The government of Uganda (GoU) has had a paradigm shift in disaster governance with a redirection from "firefighting" (response) to disaster risk reduction. The paradigm shift largely culminates from three processes: (i) the engagement of the Hyogo Framework of Actions (HFA) 2005-2015, which stipulated certain activities and processes; (ii) the recognition that managing risk is more economically and socially profitable than disaster response; (iii) the stress emanating from increasing disastrous events, notably the landslide of 2010, which killed over 300 people, and the Kasese floods of 2013, which massively destroyed properties including loss of lives. Consequently, there has been an increased need to utilize geospatial data and information in governance for early warning activities, as well as in disaster risk reduction planning. Recognition of the importance of geospatial information in disaster governance has subsequently grown in Uganda, but its utility remains suboptimal. It is therefore imperative to distill some of the intricacies underpinning geospatial data and information utility in disaster governance in Uganda, as reflected in case study presented herein albeit premised largely on qualitative analysis and synthesis**.**

Jacob Hochard, Assistant Professor, Department of Economics, Assistant Scientist, Institute for Coastal Science and Policy, East Carolina University

Dr. Jacob Hochard's primary areas of research include ecosystem services from coastal wetlands and barrier islands, natural capital accounting, ecosystem services from wildlife populations, land use change in developing countries and health externalities from upstream water pollution. He has published in Natural Resource Modeling and Environmental and Resource Economics and a book chapter in the Elgar Handbook for Alternative Theories of Economic Development. Hochard has also served as a referee for the Journal of Economic Behavior and Organization, Environmental and Resource Economics, Marine and Resource Economics, Resource and Energy Economics and Ecological Economics and is a member of the following organizations: American Economic Association, Associated of Environmental and Resource Economists, Agricultural and Applied Economics Association, Northeast Agricultural and Resource Economics Association, and the Southern Economic Association.

"Storm Protection of Mangroves on Economic Growth and Infant Mortality: A Global Geospatial Analysis"

Edward B. Barbier, University of Wyoming, Stuart E. Hamilton, Salisbury University, Jacob P. Hochard, East Carolina University

Mangrove forests reduce the damaging effects of cyclones through their ability to attenuate storm surge waves and buffer winds. An emerging literature has sought to quantify the coastal effects of cyclone exposure on economic activity but has not captured if these adverse effects are attenuated by the presence of coastal wetlands. We examine mangrove storm protection services by synthesizing global geospatial datasets on economic development, cyclones paths, topography and mangrove forests. We exploit sub-provincial and time-varying data to identify a causal link between cyclone exposure and economic growth. Cyclone-exposed areas receive a subsequent 2.2% growth reduction without evidence of returning to trend. Consistent with a growing literature on optimal adaptation theory, historically cyclone-prone areas appear better able to endure exposure. Higher elevation and increased width of mangrove forests attenuate adverse growth effects. Post-disaster growth is stimulated by 0.1% for every 10 meters of elevation and 0.4% for every kilometer of seaward mangrove forests. We estimate that mangrove forests continue to recede annually by approximately 0.28 meters per km width in cyclone years and 1.06 meters per km width in non-cyclone years. Suspected storm disruption of mangrove-conversion activities curtailed mangrove losses by an estimated 12.7 percentage points or 86,000 ha. Policy interventions may consider targeting mangrove conservation in particularly low-lying areas without a natural topographic protection from tropical cyclones. A silver lining from our analysis is that climate change predictions of increased storm frequency may mitigate mangrove deforestation by disrupting conversion activities in cyclone years.

Benjamin M. Miller, Associate Economist, RAND Corporation

Dr. Benjamin Miller's research spans a variety of applied microeconomics topics including public, environmental, development, agricultural, health, and labor issues. Consistent across his diverse work is a focus on policy implications and causal identification. A variety of work at the intersection of weather and economics includes an econometric assessment of how weather predictability

impacts methodologies which use rainfall variation for identifying variation in income as well as an impact evaluation of the extent to which the NOAA's Weather Radio All Hazards transmitters reduce fatalities and injuries. His current research includes improving the resilience of energy systems, blood supplies, and physical infrastructure against environmental or market-based shocks.

"The Not-so Marginal Value of Weather Warning Systems"

Estimates of the causal impact of programs are important for determining the optimal levels of investment. Yet estimates of the causal impacts of weather warning systems are sparse, perhaps because there is often no clear counter-factual of how individuals would have fared without a particular warning system. This paper enriches the literature and informs policy decisions by using conditional variation in the initial broadcast dates of the National Oceanic and Atmospheric Administration's Weather Radio All Hazards (NWR) transmitters to produce both cross sectional and fixed effects estimates of the causal impact of NWR transmitters. Results suggest the presence of a NWR transmitter causally reduces injuries by almost 40% and fatalities by as much as 50%.

Fanglin Sun, Ph.D. student, Department of Economics, University of California, San Diego

Fanglin (Lynn) Sun's research focuses on environmental and resource economics, energy markets, and public economics. She takes an interdisciplinary approach to studying non-market valuation of natural resources. Her current project is on valuing the storm-surge mitigation service of coastal wetlands through analyzing satellite data on land cover. She is also interested in examining the effects of energy policies and exploring the adoption process of renewable energy technologies in developing countries. She is currently investigating household electricity consumption responses to climate change.

"Valuing the Storm Surge Mitigation Service of Coastal Wetland"

Storm surge presents a severe threat to life and property along the coast. Coastal wetlands provide a natural levee for storms by attenuating waves and creating a buffer zone between the landfall location of the storm and highly populated regions. This paper uses an econometric model to investigate the contribution of coastal wetland vegetation to hurricane storm surge protection. I analyzed 27 hurricane disasters that have hit the U.S. since 1996, and constructed a county-level storm surge damage and coastal wetland distribution dataset using geo-spatial data on land cover across the United States. The main result of the paper is that for coastal communities suffering from economic loss caused by a storm surge disaster, a loss of one square kilometer of coastal wetland is associated with 0.1% increase in property and crop damage, controlling for specific storm and county characteristics, and the average marginal value of coastal wetland for protecting properties and crops from a storm surge disaster in the U.S. is $338,000perkm.

Andy Coote, ConsultingWhere

Andrew has over thirty years' experience in development and use of information systems, specializing in the management of location-enabled applications. He has held senior management positions in the public and private sector working in various countries. Since founding the independent IT consultancy ConsultingWhere in 2008, he has undertaken strategic and business consultancy assignments for both commercial and public sector customers in Europe, North America, the Middle East, Russia, Australia and New Zealand. He has been involved in the development of GIS and spatial data infrastructures (SDI) since leading work for Ordnance Survey on the redesign of their National Topographic Databases in the early 1990s. He has more recently undertaken Internationally significant geospatial assignments for the European Union, as part of the INSPIRE initiative.

Elisabeth Haggquist, PhD Student, Economics, Lulea University of Technology.

Elisabeth Häggquist's current project is funded by Swedish Geological Survey and her thesis focus on the societal value of geological information. She is currently the chairperson of the PhD Student Association, the PhD representative in the Faculty Board of Humanities and Social Sciences, as well as a member of the University board of Luleå University of Technology. As a consultant, she contributed to the forthcoming 3rd edition of Open Data Barometer.

"Valuation of health risk reductions in municipal drinking water."

Prioritization of policy measures concerning health risks is required in modern water management. In this project, we elicit individuals' willingness to pay (WTP) for health risk reduction through a

choice experiment based on users of the municipal drinking water. The commodity tap water is descried as a bundle of attributes, each describing some valuable characteristics. We are looking at the public's preferences with respect to reducing water-soluble perfluorinated alkylate substances (PFASs) in their tap water. PFASs have been used in commercial products such as fire-fighting foams and paints, yet is mostly known as a main ingredient in Scotchgard and Teflon. PFASs are interesting environmental risks to study since they are emerging persistent organic pollutions that bioaccumulate in humans and nature. Moreover, high exposure of PFASs are connected to an increased risk of infertility. To our knowledge, this paper is the first effort to elicit willingness to pay (WTP) for health risk reductions from PFASs, focusing of the trade-offs between infertility and microbial risks.

Miriam Murambadoro, sustainability Science and Resource Economics Research Group, Natural Resources and Environment, Johannesburg, South Africa

Miriam is a Social Science researcher at the Council for Scientific and Industrial Research in South Africa. Her work is centered on stakeholder engagement and capacity building of different stakeholder groups on topics such as decision making for sustainability, climate change adaptation and enhancing South Africa's transition to a green economy. Added to her experience, she has research interests that lie at the human and nature interface in areas such as poverty and development, sustainable livelihoods, disaster risk reduction and management as well monitoring and evaluation.

"Enhancing the uptake of climate change information through participatory approaches for learning in South Africa"

Climate change is projected to increase the frequency and magnitude of extreme weather events of which, without measures to reduce vulnerability, the risk of disasters will also increase and this has the potential to magnify the uneven distribution of risk between the poor and those with wealth (IPCC, 2012; CDKN, 2012). The total cost of weather-related disasters in South Africa was estimated to be approximately R 9.2 billion in the period between 2000 and 2009 (DEA, 2013; DEA, 2015). There is a strong relationship between climate change and development given that climate change will impact on all aspects of society and has the potential to derail social and economic development. Socio-economic development priorities can on the other spectrum be used to mainstream climate change response and ensure the realization of development goals (IPCC, 2007; AMCEN, 2011). The South African National Planning Commission highlighted the need for improved understanding of the spatial and temporal dimensions to aid spatially equitable and sustainable development outcomes that also take into cognizance the risks posed by a changing climate. At national level, the South African government has committed to minimizing the impacts of climate change and achieving sustainable development. This has been done for example, by signing of the United Nations Framework Convention on Climate Change and the Kyoto Protocol as well as the development of the National Climate Change Policy in 2011.

Carl Shapiro, Director of the USGS Science and Decisions Center; Senior Economist, Energy & Minerals, and Environmental Health, USGS Survey Science & Decisions Center, Reston, VA.

SDC provides an interdisciplinary focus to enhance the use and value of scientific information emphasizing research and application in five science areas: (1) ecosystem services; (2) decision science; (3) resilience; (4) participatory science and innovation; and (5) natural resource economics. Before his work with SDC, Carl spent almost 20 years as the Principal Economist in the USGS Office of the Director, where he initiated, led, and participated in multidisciplinary studies. While in the Director's Office, Carl also served as Senior Advisor to the Director and Acting Chief, Office of Strategic Planning and Analysis. Carl has received the Department of the Interior's Meritorious Service and Superior Service Awards. Carl is an adjunct associate professor of economics in the School of Public Affairs at American University in Washington, DC, where he has taught graduate courses in economics and public management.

"The Value of Stream gage Information: A case study evaluating the use and value of stream gage data for culvert design and operations."

Gordon Campbell, Directorate of EO Programmes, European Space Agency

"ESA's use of satellite derived information for ecosystem service assessment"

There is an increasing level of interest in the potential use of satellite data to support the estimation of spatial and temporal changes in components of ecosystems (e.g. habitat structure, water quality)

within ecosystem service assessment. Traditionally, satellite Earth Observation has been used to derive basic geographic parameters (e.g. land cover classification, sediment concentration etc.) at relatively low sampling frequencies (e.g. annual or seasonal status for land cover, monthly p90 concentrations for coastal sediments etc.). Over the last 5 years, a range of step improvements have combined to change the extent to which satellite Earth Observation can contribute to ecosystem assessment. New observation techniques (e.g. long wavelength imaging radar, new spectral infra-red bands), radical improvements in sampling frequency (e.g. an image of the total Earth land surface every 5 days with Sentinel 2), new processing algorithms (e.g. polarimetric InSAR), and access to improved computing power are opening up new possibilities to make wider use of satellite EO derived information for characterizing ecosystems. This presentation will illustrate results to date and some of the capabilities and on-going initiatives where ESA is supporting wider use of EO derived information for characterizing the status of ecosystems with a view to improving methodologies for ecosystem service assessment, natural capital estimation and landscape valuation.

KEYNOTE: Barbara Ryan, Executive Director, Intergovernmental Group on Earth Observations (GEO), Geneva, Switzerland

Barbara J. Ryan leads the Secretariat in coordinating the activities of 100 Member States and 89 Participating Organizations who are striving to integrate Earth observations so that informed decisions can be made across nine Societal Benefit Areas including agriculture, biodiversity, climate, ecosystems, energy, disasters, health, water and weather. Before assuming this position, she was the Director of the World Meteorological Organization (WMO) Space Programme. She also served as the technical focal point for WMO's activities with GEO. Before joining WMO in October 2008, she was the Associate Director for Geography at the U.S. Geological Survey (USGS) in Reston, Virginia where she had responsibility for the Landsat, remote sensing, geography and civilian mapping programs of the agency. Under her leadership, implementation of the Landsat data policy was reformed to release all data over the internet at no additional cost to the user—an action that has resulted in the release of more than 25 million Landsat scenes to date.

KEYNOTE: Barbara Ryan. "From Data to Decisions: Closing the Gap with the Group on Earth Observations (GEO)"

Mark Pelling, Professor of Geography, King's College London. "Risk Information to Action: integrating risk information into social research for policy impact"

Mark Pelling's research expertise is in social and institutional aspects of climate change adaptation and disaster risk management with a particular focus on urban contexts. He has served as a lead author for the Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation and its Fifth Assessment Report. Mark sits on the Scientific Steering Committees for the International Council for Science (ICSU) programmes Integrated Research on Disaster Risk, with responsibility for its work programme on Risk Information to Action; and on Future Earth Coasts with responsibility for its work on urbanization, risk and the coast. Mark is the principal researcher in the Belmont Forum project Transformation and Resilience in Urban Coasts, which brings together heatwave and flood risk modelling with expert judgements and household surveys to assess the adaptive capacity of megacities and their scope to transition between adaptive frameworks.

KEYNOTE: Mark Pelling. "Risk Information to Action: integrating risk information into social research for policy impact"

Melissa A. Kenney, Assistant Research Professor in Environmental Decision Analysis at the University of Maryland, Earth System Science Interdisciplinary Center.

Dr. Kenney's research addresses how to integrate scientific knowledge and societal values into policy decision-making under uncertainty. She works closely with multiple U.S. Federal agencies on climate decision support systems, including leading an effort to develop a proof-of-concept indicator system recently implemented by the U.S. Global Change Research Program. She was also a lead author of the Decision Support Chapter of the 2014 U.S. National Climate Assessment. From 2010-2012, Dr. Kenney was a Research Assistant Scientist at The Johns Hopkins University and an AAAS Science and Technology Policy Fellow hosted by the National Oceanic and Atmospheric Administration.

"Understandability of Indicators for Non-Expert Audiences: Increasing Their Potential Value for Decision-making."
Melissa A. Kenney, University of Maryland; Michael D. Gerst, University of Maryland; Felix Wolfinger, University of Maryland

Indicators are regularly updated representations of the status, rates of change, or trends of a phenomenon. In order to be useful, tools within a decision-making context have to be understandable and relevant to the target audience. Through a series of online surveys we assessed the general public's understanding of the climate change indicators included in the U.S. Global Change Research Program prototype indicators system released in the Spring of 2015. We found that understanding varies significantly among indicators and that small modifications to indicator graphics can lead to improvements in understandability by non-expert audiences.

Lesley Arnold, Research Fellow, Department of Spatial Sciences, Curtin University, Perth, Western Australia, Cooperative Research Centre for Spatial Information

Lesley Arnold is currently pursuing next generation spatial data supply chains to accelerate data acquisition and create value for consumers. She is also Director and owner of consulting firm Geospatial Frameworks Pty Ltd. Lesley is for developing national strategies for spatial information reform and innovation within Australia and Asia. She also develops spatial policy to support open data initiatives, including working with Vietnam to develop a Decree for Data Sharing and a Data Release Policy for Main Roads WA (2015). Lesley is Vice Chair of the Surveying and Spatial Science Institute, Western Australia, and was an Executive Member on the Intergovernmental Governmental Committee for Surveying and Mapping, Australia. She also chaired the Permanent Committee on Topographic Mapping (Australia), and National Points of Interest Working Group.

"Spatial Data Supply Chain and End User Frameworks: Towards an Ontology for Value Creation"

Organizations that collect, manage and distribute spatial information currently do so without necessarily understanding the purpose for which the information will be used and the consequential value to end-users. Conversely, end users (businesses and individuals) know what knowledge they require but find it difficult to locate the information they need, when they need it, and in a format that is of value to them. The point of issue for data producers is "Are we delivering the right value?" Consumers today want to query at will data to meet their immediate need. For this to happen, a new approach to spatial data supply chains is required. This paper proposes a Pull Production Model that is based on an end-user query driven process that delivers knowledge to users just when it is needed. All data producers need to do is make their data openly available. The data producer and end-user perspectives are encapsulated in a Supply Chain Framework and End-user Value Chain Framework (respectively) and will be used to develop an Ontology for value creation.

Emily Sylak-Glassman IDA Science and Technology Policy Institute, Washington DC)

Dr. Sylak-Glassman *has expertise in physical chemistry and biophysics. At STPI, she focuses on Earth observations work with OSTP and the U.S. Group on Earth Observation Program, as well as work related to climate policy. Prior to joining STPI, her research focused on developing spectroscopic techniques to study energy quenching in plants for the purpose of improving photosynthetic efficiency. Dr. Sylak-Glassman holds a PhD in chemistry from the University of California, Berkeley.*

"A method to estimate societal benefit derived from Earth observations: An example from the United States' National Earth Observation Assessment"

Charles Wooldridge, Interim Director, International and Interagency Affairs Division (IIA) of NOAA's Satellite and Information Service

Charles (Chuck) Wooldridge has held a variety of positions during his 28-year NOAA career. He served as Deputy Director of IIA from 2010—2015. In addition, Chuck chairs the Coordination Group on Meteorological Satellites (CGMS) Socioeconomic Benefits Tiger Team, which CGMS established to develop credible methodology and common terminology for articulating the socioeconomic benefit of satellite observing systems, and explore the most effective ways to communicate this information to desired stakeholders. Before rejoining IIA, he was Chief of Staff for NESDI, head of NOAA's Commercial Remote Sensing Regulatory Program, analyst in the Office of

Policy and Strategic Planning, Senior International Relations Specialist for NESDIS, and Presidential Management Fellow at NOAA's Office of International Affairs and NASA.

Understanding and Assessing the Value of Improved Satellite Data for the Users of Operational Sea Ice Products and Information.
Charles Wooldridge, National Oceanic and Atmosphere Administration; Mary Ann Kutny, National Oceanic and Atmospheric Administration.

The importance of attributing socioeconomic benefits of the data collected by meteorological satellites—the value derived from the practical application the data and data products—is increasingly important to the Coordination Group for Meteorological Satellites (CGMS) members as they seek to defend public investments in existing and planned meteorological satellite programs. As a current priority, CGMS Socioeconomic Benefits Tiger Team (SETT) has initiated a pilot socioeconomic benefit study: Understanding and Assessing the Value of Improved Satellite Data for the Users of Operational Sea Ice Products and Information.

Jared Berenter, The Palladium Group, Isaac Morrison, Management Systems International

Jared Berenter is a public policy professional and social scientist with graduate-level training in quantitative and qualitative methods for international policy research and evaluation. He has applied a broad range of analytical methods for evaluation of socioeconomic and environmental programs worldwide. Currently coordinating and conducting evaluation activities for Palladium/MSI's USAID Bureau of Economic Growth, Education and Environment (E3) Analytics and Evaluation Team. His recent work is focused on a performance evaluation of NASA/USAID's Regional Visualization and Monitoring System (SERVIR), a program deploying remote sensing and earth observation data for environmental decision-making and disaster response in Central America, East Africa, and the Hindu Kush Himalaya regions.

"The Effect of "Pace of Onset" and "Administrative Scale of Environmental Hazards" on the End-User Value of Satellite Data for Environmental Decision-Making: A Contextual Analysis Based on Fieldwork in Central America, Africa, and the Himalayas."

The increased frequency, severity, and variability of natural disasters and other environmental hazards brought about by global climate change have created significant need for accurate and timely environmental monitoring systems. Where ground-level monitoring capabilities are constrained by resources or terrain, satellite imagery provides decision-makers with a valuable alternative source of monitoring information. The utility and value of satellite information for decision-making is itself constrained by product limitations, obstacles to data access, and institutional barriers in end-user networks. This paper examines two key parameters affecting the value of satellite data products for environmental decision-making: (1) pace of onset, and (2) administrative scale of the environmental threat in question. The paper posits that remote sensing data gains greater value when (a) event onset is slow or chronic, allowing time for information to move through the communications chain from processing to delivery to use; and (b) when the administrative scale of the event and decision-making context is large, outstripping capacity for ground-level data collection while increasing the need for observation of distant or remote areas. This paper's analysis of pace of onset and administrative scale is placed within the context of the Regional Visualization and Monitoring System (SERVIR), a USAID/NASA collaboration that provides geospatial data tools and resources to countries in Central America, Eastern and Southern Africa, and the Hindu Kush-Himalaya to help these countries better manage climate risks, natural resources, and natural disasters.

Danny Vandenbroucke, University of Leuven; performance measurement of location enabled work processes: a use case based approach

Danny Vandenbroucke focuses on the impact of the application of GI-standards on the performance of work processes, and on the assessment of Spatial Data Infrastructures (SDI). Over the past 25 years, he was involved as project manager and senior expert in more than 50 small and large GI and SDI projects at local, national, and international levels. He is involved in INSPIRE (Infrastructure for Spatial Information in Europe) developments since 2002: as co-chair of the INSPIRE Drafting Team for Monitoring and Reporting, and more recently as leader of a team contributing to the technical evaluation of INSPIRE implementation in the Member States. He is chair of the ISO/TC 211 and CEN/TC 287 Belgian mirror committee, and active member on behalf of KU Leuven in the Open Geospatial Consortium (OGC).

Pierre Glynn, Acting Associate Director for Energy and Minerals, and Environmental Health, U.S. Geological Survey

Pierre Glynn oversees research and assessment of location, quantity, and quality of mineral and energy resources, including the economic and environmental effects of resource extraction and use. He also leads the study of the interface between health and the environment. Pierre serves as Chief of the USGS National Research Program's Eastern Branch, which conducts hydrologic research on topics including: numerical modeling of water and solute transport, environmental isotope forensics, groundwater dating, water and sediment contamination, nutrient cycling, ecological habitats, geomorphology, and microbiology. His research interests have focused recently on the intersection of biogeosciences and behavioral sciences.

"The Value of Geospatial Data and Internet Communication Technology for Science/Policy Governance of Complex Systems"

Ivan Hascic, Senior Economist, Empirical Policy Analysis Unit, OECD Environment Directorate

Dr. Hascic has been primarily working on the effects of public policy on environmental innovation by firms (using patent data, but also business and financial micro-databases). He has also contributed to a project on the effects of environmental policy on household behavior (using survey data). He is working on the implications of behavioral economics for the design of environmental policy. Ivan obtained his PhD in Agricultural and Resource Economics from Oregon State University, and a MSc in Environmental and Development Economics at University of Oslo. His current research interests also include renewable energy and energy systems.

"Using geospatial information for OECD Environmental and Green Growth indicators"

Production of internationally harmonized data, statistics and indicators is a core function of the OECD. Geospatial data offer opportunities to develop new or improved indicators, particularly in the domain of the environment and green growth because satellite and other geospatial data are often a unique source of relevant information. Moreover, such data allow achieving a better commensurability of indicators across countries and regions. Geospatial data offer a cost-efficient opportunity for the OECD respond to the growing demands for better-targeted policy recommendations and a more granular and more policy-relevant information base.

Recent progress and remaining challenges will be discussed, notably concerning measuring population exposure to air pollution and land cover and land cover changes. Examples of indicator applications in OECD's country reviews and empirical policy analyses will also be presented (e.g. environmental aspects of land use policy). Opportunities for future developments include those arising from demands to better measure the environmental dimension of quality of life, resilience to environmental risks, availability of natural assets and the use of environmental sinks.

Appendix 3: E-poster Displays

Sytze de Bruin, Associate Professor, Geographical Information Science Wageningen University, Laboratory of GIS and Remote Sensing, Netherlands

Dr. de Bruin is interested in uncertainty analysis to assess fitness-for-purpose, data acquisition, including spatial and temporal sampling and sensing, spatio-temporal interpolation, and quantitative methods used in spatial and temporal analysis.. He has been involved in research projects with applications ranging from land degradation assessment to precision agriculture. He worked four years in Central America (Costa Rica and Nicaragua) as an applied soil scientist. His research and education focus on using sound methodology for transforming spatial data into useful geo-information. He has written over 45 papers published in peer-reviewed international journals, is associate editor of the International Journal of Geographical Information Science, and serves on the editorial board of Spatial Statistics.

"Fitness-for-Use of Geospatial Information Products: Uncertainty and Value"
Sytze de Bruin, Wageningen University
Arnold Bregt, Wageningen University
Martin Herold, Wageningen University
Rose Maria Roman Cuesta, Wageningen University
Nandin-Erdene Tsendbazar, Wageningen University

Spatial data quality has been a topic of research for several decades but the usefulness of spatial data quality parameters needs to be improved to enable valuation of geospatial information in real-world applications. In this paper, we list a variety of studies focusing on methodological aspects of fitness-for-purpose assessments as well as case studies in this research field. Relevant methods involve error modelling accounting for spatial correlation of map errors, propagation of input uncertainties through models, and the expected value of information (EVOI) for ex-ante assessment of the value of geospatial information products. We finish by underscoring the need for comprehensive and convincing studies on valuation of geospatial information for complex socioeconomic decision making.

Robert Downs, Senior Digital Archivist and Acting Head of Cyberinfrastructure, Center for International Earth Science Information Network (CIESIN), the Earth Institute, Columbia University.

"Spatial Information for Disaster Planning and the Reinsurance Industry"
Dr. Robert R. Downs is Vice-Chair of the Columbia University Morningside Institutional Review Board and holds the PhD in Information Management from the Stevens Institute of Technology. He is a member of the Board of Directors of the Foundation for Earth Science Information Partners (ESIP) and is a member of the Editorial Board of the CODATA Data Science Journal. He is a Senior Member of the Association for Computing Machinery (ACM) and is a member of the American Geophysical Union (AGU), the Association for Information Science and Technology (ASIS&T), and the International Association for Social Sciences Information Services and Technology (IASSIST).

Nikolay Khabarov, Research Scholar, International Institute for Applied Systems Analysis (IIASA), Ecosystems Services and Management Program (ESM)

Dr. Khabarov has been a principal investigator and contributor to a range of IIASA's research projects with a particular focus on benefits of improved Earth observations; crop growth modeling; economics of adaptation; assessment of disasters, climate change impacts, and adaptation options; estimation of the value of information; and modeling of carbon market and regulatory risks and their reduction through innovative financial tools. His expertise is mathematical modeling and optimization under uncertainty with a rich set of applications including natural disasters (e.g. forest fires and related GHG emissions) and risk-optimal portfolios (e.g. technological portfolios for power generation. He has been involved in more than 15 international research projects.

"Valuing Weather Observation Systems for Forest Fire Management"
Nikolay Khabarov, International Institute for Applied System Analysis
Elena Moltchanova, University of Canterbury
Michael Obersteiner, International Institute for Applied System Analysis

Weather information is an integral part of modern fire management systems. In this paper, we investigate, by means of modeling, how improvements in the weather observation systems help to reduce burned area by targeting and monitoring places ripe fires are likely to occur. In our model, air patrolling is used for fire detection. The patrolling schedule is determined by the Nesterov fire danger index, which is calculated from observed weather data. We use two weather data sets based on "rough" and "fine" grids. The reduction of the total burned area, associated with an air patrolling schedule based on the "fine" grid, indicates the benefits of using better weather observations. We explore the sensitivity of the model with respect to the quality of input data and find the largest marginal improvement from the rough grid results when observation is refined in most critical areas.

John Leslie King, Bishop Professor of Information, University of Michigan

John Leslie King is former Dean of the School of Information and former Vice Provost at the University of Michigan. He came to Michigan in 2000 after twenty years on the faculty of the University of California at Irvine. He has published widely on the relationship between changes in information technology and changes in organizations, institutions, and markets. He has been a senior editor of many journals, a member of the Computing Research Association (CRA) Board and the Council of the Computing Community Consortium, and on numerous National Science Foundation advisory committees and National Research Council studies. He is a Fellow of the Association for Information Systems and a Fellow of the American Association for the Advancement of Science.

"Stakeholder Alignment Collaborative; Challenges to Societal Value From Geospatial Information"

Getting value from geospatial information requires sharing. A study of over 2,000 respondents from the EarthCube initiative shows that people like the idea of sharing, but challenges remain. These include ineffective markets due to traditions of monopsony and monopoly. The presentation concludes with what is required for success and pragmatic suggestions for speeding up the process of change.

Yusuke Muraki, Engineer, Japan Aerospace Exploration Agency (JAXA).

"Policy and Earth Observation Innovation Cycle (PEOIC) project"

Yusuke Kuwayama's research focuses on the economics of water resource and ecosystem management. After working in the International Space Station (ISS) program at JAXA for seven years, he is now seconded to Asian Development Bank (ADB), a regional development bank to support developing countries in Asia and the Pacific to achieve poverty reduction and economic growth. He has a leading role in introducing satellite applications to the new field of sustainable development of developing countries, as the first and only staff in charge of space technology. His recent work addresses groundwater use in the agricultural sector, the water resource impacts of oil and gas development, the societal value of hydrologic information, and the economics of wastewater treatment.

Michael Papenfus, U.S. EPA, Office of Research & Development

Michael Papenfus' research approach to the protecting the environment is informed by the integration of ideas from economics, microeconomics, ecology, and natural resource management so that all of these contribute to improving decisions that people make. His work focuses on estimating the value of environmental and resource services so that this information can be valuable part of the information and knowledge base that support environmental and resource management decisions and policy. He is currently working on valuation projects using both revealed and stated preference methods to value a wide range of ecological services including water quality, wild fish populations, and demand for outdoor recreation. He is also beginning to explore connections between environmental quality and human health outcomes.

"Using Ocean Color Satellite Data to Estimate Economics Benefits Associated with Monitoring and Preventing Harmful Algal Blooms"

This presentation describes proposed work that will use satellite data to detect and monitor harmful algal blooms (HABs) in freshwater lakes to support two types of economic analyses. In the first part of the analysis, we will identify the extent to which information from remote monitoring of HABS can act as a substitute for using traditional field-based monitoring programs. These cost savings can be used in any number of ways to improve programs aimed at minimizing the occurrence of HAB

events. In the second component of the analysis, we will use data derived from satellite imagery to characterize the frequency, duration, and spatial extent of HAB events across freshwater lakes. The information will then be used to construct realistic scenarios describing the state of HAB events in a particular region or set of waterbodies. The realistic scenarios will form the baseline scenario in a stated preference study to estimate the economic benefits associated with avoiding HAB events. This project is a joint effort between four U.S. agencies (EPA, NASA, NOAA, and USGS).

Lucia Lovison-Golob, Afriterra Foundation, Boston.

Lucia Lovison-Golob is AIP-GEOSS Capacity-Building Leader for GEOSS-AIP disaster management and risk reduction projects in Latin America (particularly in Chile), Africa, and Asia. She is Geospatial Director and Librarian, cataloguing metadata, and geospatial developer. She was project Director and Librarian for a project related to cartography and geography for the One Laptop per Child (OLPC), now available to schools around the world. She is also a member of the Digital Technologies in Cartographic Heritage Working Group of the International Cartographic Association (ICA-ACI) and served as Co-chair of the Open Data Access and Intellectual Property Rights for Cartography Working Group, International Cartographic Association.

"Data to Decisions: Valuing the Societal Benefit of Geospatial Information in case of Disasters such as Earthquakes and Tsunamis"

The issue of how to convert data to information and then to decision is applied it to Chilean application tool. Within the Architecture Implementation Pilot (AIP) project, Capacity Building Working Group (CB WG) that I'm coordinating, we have selected seven test pilot areas related to earthquakes, tsunamis, volcanic eruptions and fires. We are applying a service oriented architecture (SOA) that allows each agency (national of international) to manage its own data silos; however each agency agrees to make the metadata of those data available through web services according to a GEO Common Infrastructure (GCI) platform that is interoperable according to OGC (Open Geospatial Consortium) and ISO (International Standard Organization) geospatial standards. We look to capture the geographic diversity and increase Chile's resilience to disasters by developing a model for evaluating the socio-economic impact of web services, in order to allow emergency personnel, regional authorities and others, to optimize their decisions in relation to the characteristics of the disasters. In this paper, I plan to consider initially earthquakes and tsunamis to promote feedback and possible collaboration between the communities stricken by a disasters and the decision makers.

Appendix 4: Evaluation of Participant Satisfaction

Following the workshop, the organizers surveyed participants about their satisfaction with the event. Results will inform planning for future meetings. Participants were invited to respond to an online survey, and 14 people responded to the invitation.

Summary of Survey Results

- About 85% of respondents rated presentations overall mostly or extremely valuable; 92% rated the Opening Keynote, "Societal Benefit of Geospatial Information," mostly or extremely valuable; 92% rated Panel 4: Methodologies mostly or extremely valuable, and 92% rated Panel 5: GeoValue Policy mostly or extremely valuable.
- About 93% of respondents would like to devote more time to networking (50%) and to break out sessions (43%)
- When asked what topics respondents would have devoted more time to, they indicated Melissa Kenney's talk, "Indicators: Are they valuable for decision-making;" and discussions about disaster risk reduction, misallocation of funding from the drought monitor before GRACE, and ways to influence the policy process.
- When asked in what ways respondents expect to apply information and concepts gained from the workshop, the most frequent choices included that 43% would conduct academic research/scholarship, and 21% would assess the value of the geo-spatial information for decisions, projects, or publications.
- From a list of professional development activities related to geospatial data that respondents were asked to prioritize, 25% identified workshops as their top choice and 58% as their second choice; 25% listed conferences/symposia as their top choice and 25% as a second choice. Several participants listed "other" for their top choice and specified research and funding opportunities. The most frequently cited reason for participants' top choices was community building.
- Key ideas respondents reported taking away from the workshop focused on methodologies including the importance of case studies, multiple methods for measuring the value of geospatial information, and testing integrated methods/frameworks; the complexity of cross discipline work; the state of geospatial data valuation research, and the need for funding.
- When asked what they would do differently as a result of attending the workshop, respondents commented that they would:
  - think in new ways about delivering value to end users
  - apply methodologies discussed to measure values and impacts
  - work with people they met at the conference and with others in the geovalue community
  - frame questions and valuation differently
  - consider entire value chains, and investigate institutional issues related to geospatial information
- Respondents were asked to identify their primary areas of interest. The most reported were disaster resilience (42.9%); biodiversity and ecosystem sustainability (14.3%) infrastructure and transportation management (14.3%), and water resources management (14.3%).

- Respondents recommend that organizations that providing earth-observation data focus more on:
  - recognizing that the value of information exists when it answers the users' question
  - considering sufficiently society preferences in ranking projects in addition to advice from scientists
  - providing a list of available data, funding both research and applications along value chains
  - conducting multiple studies to assess the value of geospatial information, providing clear, easy to use and consistent documentation for users
  - facilitating connections within the community of people doing this work.
- Respondents prioritized professional development activities they would like USGS to provide: 77% ranked workshops as their first and second choices, 55% Conferences & Symposia as their first and second choices. Nine respondents chose "other," and 89% of them identified "other" as funding.
- Most respondents, 93%, would support holding future workshops at the OECD.