Chapter 17

Conclusion

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17.1 Key Findings

In the previous chapters, experts have contributed examples of their work on the impacts of space-based Earth observation on society and policy and have provided insights on how these impacts can be quantitatively assessed. The case studies in Parts II-IV demonstrate how specific countries, organizations, or projects have attempted to link societal needs and global policy demands to the benefits of satellite Earth observations. Chapter 16 examines topics related to a future Earth Observation Regime Complex and a possible Earth Observation Environmental Data Forum.

The points of departure for the book were laid out in the key findings from the Policy and Earth Observation Innovation Cycle (PEOIC) Advisory Board workshop held in Tokyo in November 2015 (see Appendix C for the full text):

1. Earth observations provide a unique window and perspective on our world, serving the betterment of all humankind by supporting policies aimed at sustainably managing natural and societal resources on an ever more populous, affluent, and interconnected planet Earth.
2. Earth observations should be regarded as critical societal infrastructure. There is strong evidence that publicly open Earth observations are making positive, cost-effective contributions to solving a variety of high priority environmental and societal problems.
3. There is a need to develop appropriate institutions in the field of Earth observation through a process to ensure that the observations and prediction systems

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are comprehensively exploited for policy-making with full engagement of all stakeholders and end users.

4. Japan, together with its international partners, should identify and fill emerging gaps in next generation space missions to guarantee full realization of all societal benefits of Earth observations derived from long-term continuity.
5. There is a changing paradigm for Earth observations, with nongovernmental groups launching satellites and with the growing popularity of small satellites, drones and crowd-sourcing/citizen science campaigns, which are associated with the rapid development of data technology and applications.

Each author contribution builds on these statements and elaborates in detail lessons learned from their individual experiences. All contributions recognize the growing *impact of human action on the Earth system*, the efforts to *integrate natural and social sciences*, and the usefulness of space-based Earth observations that provide a unique viewpoint for understanding this interaction and *supporting decision-making by providing scientific evidence*. A key message from the contributions is the need to demonstrate the *value* or *ROI* of Earth observations. The importance of *open access to data* for increased societal benefit is also stressed. However, authors note the *challenge of quantitatively assessing* the societal and economic impacts of Earth observations, as well as the *need to select the right analytical technique* for the specific context in question. Finally, the impact of *new technologies* is recognized as an opportunity to extract actionable knowledge, as well as a challenge to the assessment of benefits, as they will combine space-based Earth observations with other sources of information.

17.2 Assessment Methodologies

The assessment methodologies introduced in this volume can be categorized largely into literature-based analysis and economic analysis.

17.2.1 Literature-Based Analysis

The PEOIC project of Japan (Chap. 2) takes a unique approach in combining literature analysis with data mining techniques to assess how satellite Earth observation data and information have been used in policy formation and implementation, based on an institutional approach featuring the case of the protection of the stratospheric ozone layer. Satellite Earth observations are a key monitoring tool for the regime, providing decision-makers with information on the status of the environment (i.e., systematic observations of the ozone layer). The study applies a text-mining technique to investigate the relationship between policy and satellite Earth observations by selecting literature that represent policy decisions and

scientific reports. The work is significant and unique as there has been no such analysis performed in the past. Constructing comparable literature databases proved challenging.

Presented in Chap. 14, Johnson et al. attempt an assessment of the quantity of Earth observation data used for Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+) implementation. Results show that Earth observation data *quality* (i.e., spatial resolution) was basically uniform among users, while data *quantity* (i.e., the number of maps produced, the length of historical timeframe for which data were used) varied considerably from country to country and project to project, while neither the data quality nor quantity explained the ways in which the countries or projects utilized the data.

Earlier work on the application of Landsat data (Macauley 2008) followed a similar but distinct approach. Further, the Group on Earth Observations (GEO) conducted an analysis to identify Earth observation priorities for different Societal Benefit Areas (SBAs) and then performed a cross-SBA analysis based on documents from the past 10 years (Group on Earth Observations 2010). As useful as these studies are in providing quantitative evidence of the benefits of Earth observations for addressing policy priorities, literature-based studies have limitations mainly due to the fact that outside the scientific domain, it is rare that a specific data source, satellite, or sensor name will be mentioned in policy literature. The challenge therefore is to identify a meaningful correlation between satellite data and policy decisions, given that satellite data are almost always combined with other data sources before they are processed into information useful to decision-makers. The PEOIC study does succeed in showing a quantifiable relationship between scientific assessments and policy decisions. By establishing the role of satellite data within the scientific assessments it attempts to identify the role of satellite Earth observation in decision-making. Evolving information technology will allow more progress to be made in this area.

17.2.2 *Economic Analysis*

Economic analysis is a method applied increasingly to measure, account for, and demonstrate the benefits of Earth observations in many societal settings. The need has been prompted in particular by growth of economic constraints in most major space programs. In Chap. 7, Lafaye notes that assessing benefits for public policies and the development of commercial space-based services is now part of the framework of French Earth observation programs.

For the U.S. perspective, Onoda presents Macauley's analysis of rationales and processes for investment in Earth observations to serve national needs (Chap. 3). Emphasis is given to the value of Earth observations in meeting national imperatives in the management of natural and environmental resources, including energy, water, forests, and air quality. The chapter presents an overview of legislation, interagency cooperation, and the Decadal Survey and national assessment processes

to inform Earth observation investment. The concept of Value of Information (VOI) is introduced, along with a summary of its applicability as a measure of the economic value of Earth-observing systems, referencing specific examples.

In Chap. 4, Friedl provides an introduction to NASA's Applied Earth Science Program and how missions and applications are linked to societal benefits and environmental policy. He introduces two specific examples—air quality and volcanic ash—for which NASA has conducted studies on the socioeconomic impacts of satellite missions and applications. The study on air quality estimated that satellite data represents a value of around 26 million USD. In the case of volcanic ash, it was estimated that the use of satellite Earth observation data for air traffic management following the 2010 Eyjafjallajökull volcanic eruption in Iceland saved 25–72 million USD. If data had been used from the beginning of the incident, costs estimated at an additional 132 million USD might have been avoided.

ESA's Earth observation strategy and the European Copernicus program are introduced by Aschbacher (Chap. 5). The Copernicus program included an extensive study in its mission-planning phase based on prospective (*ex ante*) costs and benefits. Independent studies for Copernicus have shown that, on average, 1 EUR invested in the Copernicus program leads to an economic benefit of approximately 10 EUR due to better decisions, more efficient policy implementation, and savings due to better preparedness in the case of natural disasters, combined with various other economic potentials such as in job creation and the use of imagery. He also notes that these benefits will only be realized if access to space-based Earth observation data and information is full, free, and open.

Lafaye, in Chap. 7, introduces two examples of collaboration between the French space agency (CNES) and Ministries through a master agreement with the French Ministry of Environment (MEDDE) and the Ministry of Overseas Territories (DGOM). In this frame, an analysis of public policies and the identification of satellite Earth observation contributions were conducted, in areas including the management of natural and environmental resources, as well as maritime environmental surveillance and security. CNES has also initiated studies to assess the economic impact of government investment in the downstream sector of satellite Earth observation. The article provides an informative set of lessons learned and perspectives.

In Chap. 15, Jolly introduces the activities of the OECD Space Forum and examines their methods (both macro- and micro-economic) for assessing socioeconomic benefits derived from space technologies. An important lesson is that existing methods provide useful insights into the socioeconomic benefits derived from space infrastructure, but with a range of caveats. There is a need for further refinement of quantitative analytical tools. She concludes that it remains essential to maintain the effort to build the international knowledge base, an effort that OECD is taking up with the major space-related organizations in OECD economies.

Obersteiner et al. contribute a visionary description of their work to develop methodologies and analytical tools to assess the societal benefits of investments in improving the Global Earth Observation System of Systems (GEOSS) across its nine SBAs (Chap. 12). The fundamental idea of this work is that costs incurred in

incrementally improving the observing system will result in benefits through information cost reduction or better-informed decisions. The assessment finds that in the majority of case studies, the societal benefits of improved and globally coordinated Earth observation systems were orders of magnitude higher than the investment costs. It concludes that GEOSS-informed Earth system science products and services must receive adequate support to guarantee a transition to more scientific and evidence-based decision-making.

17.3 Perspectives on the Benefits of Earth Observations for Society and Policy

Sir Martin Sweeting introduces a U.K. perspective in Chap. 6. Observations of the environment are of critical importance to the U.K., providing scientific evidence to support decision-making. There is a need for comprehensive, continuous, and fresh observation of a growing range of parameters to address the various challenges facing the country. Furthermore, he notes the opportunities from new technologies and the avalanche of data and actionable knowledge they will provide. Sustained contributions from all forms and sources—national and international—are needed and there is a clear need for stakeholder dialog in order to maximize the potential of environmental observations for decision-making.

China (Chap. 8) has developed a top-down policy approach with the Ten-year Plan for the China Integrated Earth Observation System (2007) and the Medium- and Long-Term Plan for Development of Science and Technology (2006–2020). Earth observation technologies are now recognized as major public goods that are urgently required in support of various areas. In this chapter, Fan introduces the key components of the Chinese Earth observation program—including the meteorological, oceanic, Earth resources, high-resolution, and environmental protection and Disaster Monitoring Constellation components—as well as the role of the private sector. The Chinese Earth observation program uses a system-of-systems approach and data are distributed free of charge in line with international practice.

Japan's Greenhouse gases Observing SATellite (GOSAT, 'Ibuki') is the world's first satellite dedicated to measuring atmospheric concentrations of carbon dioxide (CO₂) and methane (CH₄) from space. In Chap. 9, Yokota presents an overview of the GOSAT program, its instruments, the measurements it provides, and plans for its successor, GOSAT-2. He also discusses the potential of satellite measurements to support Measurement, Reporting, and Verification (MRV) for multilateral agreements, in particular for carbon inventory verification. Yokota concludes that free and open data and information exchange are essential to realize this potential.

Nakajima, in Chap. 10, introduces the Japanese satellite Earth observation program, and suggests that there will be a gap in Earth observation capacity after 2022. He urges Japan to reinforce its national satellite planning, advocating a bottom-up planning approach. The Dream Roadmap toward 2050, proposed by the

Science Council of Japan is introduced, along with many other requirements for sustained Earth system observations. Japan's Earth observation plans for missions and applications are discussed and the need to enhance Japan's national Earth observation program planning process is reiterated. He further points out the need to connect satellite Earth observation with advanced modeling and societal services.

GEO has established the new decadal strategy of the GEOSS (Chap. 11). Since 2005, GEO has had considerable success in developing GEOSS, advocating broad and open data sharing, initiating major global monitoring initiatives, strengthening these accomplishments, and recognizing the need for further collective effort to foster the use of Earth observation resources to their fullest extent. The GEO Strategic Plan 2016–2025 is introduced in Sect. 4.1. The Plan builds on the strong foundations of GEO, identifying improvements including strengthening the SBAs; engaging more broadly with stakeholders; establishing a robust, steady resourcing mechanism within the voluntary framework of GEO; and identifying new opportunities.

Highlighting a specific case of a Multilateral Environmental Agreement (MEA), Rosenqvist describes in Chap. 13 how Earth observation techniques are used to support the UNFCCC agreement on REDD+. The Global Forest Observations Initiative (GFOI) is presented, and outcomes and implementation challenges are discussed.

Finally, returning to the taxonomy provided in Chap. 1 on the roles that satellite Earth observations can play in addressing environmental concerns (i.e., inform on progress, assist prevention or mitigation, enhance compliance), the practical next steps may involve a project to map Earth observations against the taxonomy in Table 1.1 and to perform analyses of the extent that each role is being addressed, based on the various methodologies presented in the above contributions. Such analyses would help us understand, from an institutional point of view, the role and impact of satellite Earth observations on environmental policy. In Chap. 16, Stokke and Young explore this question in detail and ask whether these capabilities have progressed to the point where there is a compelling case to create an integrated Earth Observation Regime Complex, which will, if realized, complete the innovation cycle from science to policy. They conclude with a discussion of a future international Earth Observation Data Forum with a mandate to foster enhanced coordination between providers and the user community.

17.4 A Model of Earth Observation for Society and Policy, and Lessons for Japan

Based on the contributions to this volume and the 2-year study of the PEOIC project, we can describe a general model as shown in Fig. 17.1.

Starting with stakeholder dialog, the model starts with the identification of taxonomy, segments, actors, the value chain, and values associated with the societal

Fig. 17.1 A model of Earth observation for society and policy

or policy goals of the mission, as well as an *ex ante* (prospective) assessment of ROI. The optimal mission design can be established based on this assessment. The program then moves into the development and operation phases. The assessment guarantees that the mission provides comprehensive observations that are adapted to user needs and ensure continuity and sustainability. Sustained funding and stakeholder dialog are critical. Commercial capabilities and new technologies should be leveraged in a timely manner; these companies should be involved as stakeholders throughout the process. Finally, an international knowledge base, such as that of the OECD Space Forum, should be maintained so that experiences can be shared for subsequent missions. The model can be applied to various societal or scientific domains, targeted either to specific nations or international programs; it can also be combined with the concept of an Earth observation regime complex to effectively carry out the programs.

The lack of a systematic approach such as the one described above may have slowed the future planning of the Japanese Earth observation program. Now that Japan's space program has matured, and given the economic constraints Japan has been facing over the last two decades, it seems timely for Japan's space program to take concrete steps toward establishing such an effective scheme, together with international partners and stakeholders. It is time to realize that the focus of space-based Earth observations is no longer purely R&D or science; it must also serve the needs of those who finance it.

The PEOIC project started as an effort to look to the international community for guidance on the development of tools to assess the benefits of Earth observations. With the establishment of the International Advisory Board, the project evolved beyond its initial scope, enabling us not only to compile the latest achievements in the field but also to add a novel view on the future governance of Earth observation systems. This has given us a broader perspective on where we are heading with existing and newly emerging Earth observation technologies. The study was timely because today we are at the point where we have the technological capability to exploit the avalanche of new information and thus knowledge that are derived from Earth observations for improved decision-making. It is therefore our responsibility to use this opportunity well, to achieve a better future for human society and the Earth's environment.

References

- Group on Earth Observations (2010) GEO Task US-09-01a: critical Earth observation priorities, final report. https://sbageotask.larc.nasa.gov/Final_SBA_Report_US0901a_Apr2011.pdf. Accessed 8 Dec 2016
- Macauley MK (2008) Earth observations in social science research for management of natural resources and the environment: identifying the landsat contribution. *J Terr Obs* 1(2):31–51

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