Toward Policymaking Support Based on Remote Sensing Data

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ABSTRACT

Environmental policies often strongly depend on environmental monitoring data, yet these increasing datasets are not always used effectively in enacting and implementing public policy. We propose a science-policy process that defines the conditions that facilitate the use of remote sensing data for a policy. One of the most complex challenges that scientific and policy-making communities are facing in is that it involves knowledge sharing and exchanges among a wide range of disciplines and actors. So a relationship between scientists and policymakers enables translation of data into knowledge useful for public policy. This paper suggests the way to work scientists and policymakers more efficiently together to use remote sensing data in environment. As a result, we concludes the understanding of different perspectives on the concept of data quality between scientists and policymakers, and the collaboration of scientists and policymakers to transform and exchange the data increase the likelihood of it being used for decision making. As a concrete example, we propose the applicability of satellite-derived data in oil spill assessment in the view point of scientific aspects.

Keywords: remote sensing data, policymaking, knowledge sharing, complexity, consensus

1. INTRODUCTION

Scientific observations are the basis for monitoring, understanding, and predicting the Earth system processes and changes. These observational data provide the framework for creation of useful products and services for decision makers and society at large. Complex, changing interactions of the global dynamics of the atmosphere, land and ocean are only beginning to be understood. Space-based remote sensing platforms provide a unique perspective on these interactions on a global scale, and are the essential elements for discovery when complemented by air-borne and *in situ* observational data. Remote sensing data from NASA's Earth Observing System (EOS) satellites are valuable for understanding the global change, particularly at decadal time scales. The EOS program consists of satellites such as Landsat 7, Terra, Aqua, and Aura, which are designed to continuously collect measurements of the earth's land surface, atmosphere, and the oceans to understand the earth system science [1][2]. Even though EOS data were designed primarily to collect global change research measurements, these data could be potentially used to develop various applications that are relevant to policymakers. To explore the use of remote sensing data collected by the EOS satellites for the development of applications that are relevant to state, local and tribal agencies as well as individual users, the Synergy program was started in 2000 [3]. In October 1999, two working groups of the International Society for Photogrammetry and Remote Sensing (ISPRS) joined with the University of Michigan to convene discussions on how remote sensing technology could contribute to the information needs required for the implementation of the Kyoto Protocol and compliance with its terms [4]. Furthermore, remote sensing technology in support of the European union (EU) water frame work directive (WFD) has been suggested [5]. Integration and interoperability of observational data and information from independent sources are the requisites for enabling the Earth system scientific research, creating highly accurate predictive capabilities, and creation of information tools and products to directly benefit society [6]. However, we should also consider that environmental issues underscore a need for the exchange information between remote sensing scientists and policymakers. In view of this, this study addresses to find the capability of remote sensing technology to policymaking. Emphasis is placed on to suggest the way to work scientists and policymakers more efficiently together to use remote sensing data in environment.

2. PROCESS FROM OBSERVATION TO DECISION SUPPORT

We first define the science-policy process in the use of scientific data derived from satellite remote sensing and the use of those data in policy. The researchers and scientific experts convert raw data from monitoring networks into scientific information. They translate this information into scientific knowledge for the policymaker, who then translates it into policy-relevant knowledge. The translation is not linear, but iterative, with input throughout the process. As the information provided to policymakers such as political appointees and elected officials, they use this information as one factor among many others in their decision making. It is important to note that scientific data is only one source of information that a strong science-based component. The science-policy process represents a path for scientific data to reach the policymaker in a form that increases the likelihood that it will be used appropriately.

Environmental monitoring data sources have rapidly expanded in the last decade but their use in environmental policy still requires translation into a form useful for policymakers. This part of the process can be simplified to:

Monitoring data → information → knowledge → policymaking support.

The conversion from information to knowledge that can be used for policy is the crux of the science-policy process, requiring the synthesis of scientific information into a clear messages and facts that can be incorporated into policy decisions.

The science-policy process defines the conditions for use of monitoring data in environmental policy, specially a partnership between scientists and policymakers to translate environmental data into policy-relevant information. We applied this process in two case studies based on the literature:

- Water Framework Directive (WFD) in the European Union (EU)
- Kyoto Protocol

2.1 Case 1: Water Framework Directive (WFD) in the European Union (EU)

For the most people in EU, access to clean water in abundant quantities is taken for granted. It is not realized, however, that many human activities put a burden on water quality and quantity. All polluted waters, whether originating from households, industry or agriculture, return, one way another, to the environment and may cause damage to it or to human health. An increasing demand by citizens and environmental organizations for cleaner rivers and lakes, groundwater and coastal beaches made WFD. So WFD aims to get polluted water clean again, and to ensure that clean waters are kept clean [7].

The monitoring of water quality using remote sensing started in the 1970's (e.g. [8][9]) using earth resources technology satellite, later renamed Landsat-1 (ERTS-1) launched in August 1972. Since then, the digital evaluation of remotely sensed data has been widely used to estimate water quality characteristics of surface waters. Remote sensing technology is a valuable tool for obtaining information on the processes taking place in the surface waters. A major advantage of remote sensing observations is the provision of both spatial and temporal data relating to surface water characteristics [10]. Since new and more advanced sensors are often being replaced by equivalents to ensure continuity of the data recorded, remote sensing and image analysis techniques can provide access to spatial information about the Earth's surface on different scales [11]. With this enormous data resource, there seems to a potential for remote sensing to assist EU member states and candidates in meeting their obligations under the WFD. Up to the present, the digital evaluation of optical sensors in the visible and near-infrared (VNIR) regions has been used to monitor water quality problems. Modern advanced satellite sensors such as MODIS (Moderate Resolution Imaging Spectrometer) and MERIS (Medium resolution Imaging Spectrometer) can provide a better understanding of water quality monitoring, since they are able to measure the radiance leaving surface water in six or more bands in the VNIR region. Satellite sensors can also provide relatively low-cost, simultaneous information on surface water conditions in many of the lakes, river estuaries and coastal areas situated within a large geographic area [10].

In order to support implementation of the WFD, five major areas have been identified in which remote sensing technology could be applied to monitor surface water status [5]:

(1) the provision of systematic observations of relevant surface water areas;
(2) support for the establishment of river basin management plans;
(3) the detection and spatial distribution of changes in surface water areas;
(4) the quantification of chlorophyll-*a* concentrations and associated changes therein;
(5) the mapping and monitoring of certain sources of e.g. pollution by nitrates, total nitrogen and total phosphorus.

When reviewing this case in terms of the science-policy process, there are still limitations to the practical use of the data within the field of the water policy. A thematic product derived from remotely sensed data, e.g. a classification of surface water status, water quality estimation and a simple map of chlorophyll-*a* concentrations, has no value or credibility unless its accuracy can be reliably assessed and quantified. So *in situ* data are required for the application to develop algorithms and models for the monitoring of surface water status and the validation of derived products.

2.2 Case 2: Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) contains quantified and legally binding commitments to limit or reduce greenhouse gas emissions to 1990 levels. The protocol allows sinks associated with vegetation growth and expansion to be included to offset carbon emissions, which in turn raises debate about the adequacy of existing methods for establishing reliable estimates of 1990 carbon stocks/sinks levels and for measuring and monitoring current and future carbon stocks/sinks. In October 1999, two working groups of the International Society for Photogrammetry and Remote Sensing (ISPRS) joined with the University of Michigan (MI, USA) to convene discussions on how remote sensing technology could contribute to the information needs required for the implementation of the Kyoto Protocol and compliance with its term [4].

Over the past half century, a range of airborne and space-borne sensors has acquired remote sensing data, with the number of sensors and their diversity of capability increasing over time. Today a large number of satellite sensors observe the Earth at wavelengths ranging from visible to microwave, at spatial resolutions ranging from sub-meter to kilometers and temporal frequencies ranging from 30 min to weeks or months. Given this enormous resource, there seems potential for remote sensing to assist countries in meeting their obligations under the Kyoto Protocol.

Five major areas have been identified where remote sensing technology could be applied to support implementation of the treaty [4]:

(1) provision of systematic observation of relevant land cover;
(2) support to the establishment of a 1990 carbon stock baseline;
(3) detection and spatial quantification of change in land cover;
(4) quantification of above-ground vegetation biomass stocks and associated changes therein;
(5) mapping and monitoring of certain sources of anthropogenic CH_4.

As we did for case 1, this case can be viewed under the science-policy process. The obstacles to apply remote sensing data to the treaty are the intricacies and inaccessibility of numeric models, the primary tool for investigating large-scale, complex systems. Science uses a combination of data, theory, and models depending on the particular problem at hand. There is less confidence in understanding large-scale, complex systems than confined experimental systems described by simple mechanistic hypothesis. Issues such as the global change that involves large-scale, complex systems are more uncertain.

3. PERSPECTIVES ON DATA QUALITY

Conflict and indecision are hallmarks of environmental policy formulation [12]. One of the most difficult aspects of translating science into policy is scientific uncertainty. As the uncertainty information varies by users, the responsibility to provide this information also lies on different actors. The concept of uncertainty in providing information on environmental issues is closely linked to the concept of data and model quality. The appreciation of data quality on its turn is dependent on the final application and use of the data. The independent use is relevant for any analysis of this concept with respect to environmental data and models.

There are two different perspectives on the concept of data quality [13].

- The scientist is looking for the truth by trying to find weak spots in theory and data and by falsification. The data quality will be high if the data or predictions based on them are confirmed by independent estimates. If falsification occurs, the scientist will work on it until he or she understands the reasons and derives better data or a better theory.
- A policymaker is looking for agreement and will therefore be more inclined towards reaching consensus and compromise. In many cases a policymaker does not have enough time to wait until all scientific problems are solved: a company might have asked for a permit for a new activity, and regulations prescribe a decision to be made within given period of time; or a country has to report its emissions according to a protocol before a certain fixed data. The policymaker will have to decide, although a number of uncertainties are still present and a number of phenomena might not be fully understood.

These perspectives on data quality applied for air pollution emission inventory, but we believe that it also can be applied to any other cases using remote sensing data. Common grounds of data between scientists and policymakers provide a structure to request and receive relevant, timely data from a trusted source. It provides the policymaker sufficient information to make comparisons and small changes, using the scientists as a means to process large amounts of data. The common grounds of data improve the scientific capability to study the environment and human impact. The collaboration of scientists and policymakers to transform and exchange the data increases the likelihood of it being used for decision making.

Figure 1 shows the “science-policy gap” as the difference in levels of confidence for a given scientific finding expressed by the scientific community and society [12]. This relationship is portrayed as linear for the scientific community where the confidence level tracks the rate of confirmation. In contrast, the degree and rate at which social confidence and consensus develops for a given scientific finding may lag behind that of the science community due to a complex of social factors. In reality, the shape of this function will vary with individual scientific findings. The level of confidence by the scientific community increases with the level of scientific confirmation (i.e., scientific activities that cumulatively corroborate the theory's hypotheses). As evidence accumulates to support the underlying hypotheses, confidence in its representations increases. In time, a model achieves greater standing as inferences concerning its representations are disseminated and debated in scientific literature and other forums. At some threshold of accord within the scientific community, consensus emerges. However, the emergence of the so-called scientific consensus does not necessarily guarantee the level of certainty demanded by most policymakers [13]. In the case of large-scale simulation models, constants and parameters contain assumptions and uncertainties that propagate in uncertain ways to produce uncertain output. Such uncertainty is usual for scientists, but it may not for society and decision makers.

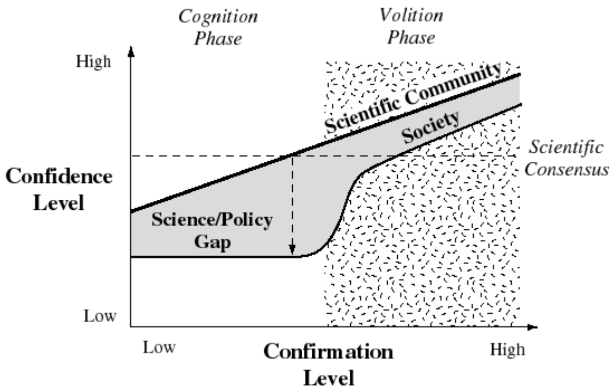

Figure 1. Schematically, the science-policy gap is defined as the difference in levels of confidence for a given scientific finding expressed by the scientific community and society [12].

Although scientists are familiar with uncertainty and complexity, policymakers and the public often seek certainty and deterministic results. There are three general approaches for bridging the “science-policy gap.” These are: (1) increasing the rate of scientific confirmation; (2) to help the public and policymakers understand risk and uncertainty as scientists do; (3) increasing communication, especially through meaningful collaboration.

4. CONCRETE EXAMPLE

With respect to consensus building, it is necessary to integrate knowledge not only from scientific aspects but also from social aspects and desires what the society expects. As a concrete example, we propose the applicability of satellite-derived data in oil spill assessment in the view point of scientific aspects [14]. The consideration on other aspects will be left for further research.

Basically, risk assessment process is consists of four steps: hazard identification, frequency assessment, consequence assessment and risk evaluation. In three of those steps, satellite-derived data can be used:

- For detection and real-time monitoring at hazard identification:
  A very important aspect of remote sensing is the production of data so that operations people can quickly and directly use it. An operational space-borne system for risk assessment, should guarantee the following aspects [15]: (1) the revisit-time (the maximum period between two consecutive acquisitions on a given site) shall be compatible with the delay allowed for product generation in the case of an emergency, (2) the resolution and the coverage of images shall be appropriate for the required application.
- For database at frequency analysis:
  A database would have many potential applications ranging from Environmental Impact Assessment of proposed developments to zoning for land use planning or monitoring of ecosystem and Environmental Sensitivity Index mapping for rapid oil spill response. Also, the database could usefully contain socio-economic datasets or at least links to such data.
- For simulation at consequence analysis:
  The use of modeling, spatial analysis and near real-time system can assist decision-makers to make better-informed judgments that will affect the governance and management of the sea environment during oil spillage. Remote sensing and GIS are to mitigate the age-old problems of

information availability and timeliness, data management.

Also satellite-derived data can be used as an environmental indicator at posterior survey:

- Mapping and understanding in ocean color can assist in the management of fish stocks and other aquatic life, help define harvest quotas, monitor the water quality and allow for the identification of human and natural water pollution such as oil or algal blooms, which are dangerous to fish farms and other shell fish industries.

5. CONCLUSION

The role of remote sensing is under scrutiny given its potential capacity for systematic observations at scales ranging from local to global and for the provision of data archives extending back over several decades. Many environmental issues also underscore a need for the exchange of knowledge between scientists and policymakers. One of the conversions to make a policy is the different perspectives of data quality between scientists and policymakers. Scientists search for weaknesses and errors in the data, and the data quality is high if it produces predictions that are confirmed. On the other hand, policymakers search for consensus and agreement, and the data quality is high if everybody involved agrees. The understanding of this difference and the collaboration of scientists and policymakers to transform and exchange the data increases the likelihood of it being used for decision making.

REFERENCES

[1]. Asrar, G., Kaye, J.A. and Morel, P. (2001): NASA research strategy for earth system science: climate component. Bulletin of the American Meteorological Society, vol.82 No.7, pp.1309-1329.

[2]. King, M.D. (1999): EOS Science Plan: The State of Science in the EOS Program. NASA, Greenbelt, Maryland, 307p.

[3]. Kalluri, S., Gilruth, P.and Bergman, R. (2003): The potential of remote sensing data for decision makers at the state, local and tribal level: experiences from NASA's Synergy program. Environmental Science & Policy, vol.6, pp.487-500.

[4]. Rosenqvist, A., Milne, A., Lucas, R., Imhoff M. and Dobson, C. (2003): A review of remote sensing technology in support of the Kyoto Protocol. Environmental Science and Policy, vol.6, pp.441-455.

[5]. Chen, Q., Zhang, Y., Ekroos, A. and Hallikainen, M. (2004): The role of remote sensing technology in the EU water framework directive (WFD). Environmental Science & Policy, vol.7, pp.267-276.

[6]. McCuistion, J.D. and Birk, R. (2005): From observations to decision support: the new paradigm for satellite data. Acta Astronautica, vol.56, pp.5-8.

[7]. http://europa.eu.int/comm/environment/water/water-framework/overview.html

[8]. Strong, A.E. (1974): Remote sensing of algal blooms by aircraft and satellite in Lake Erie and Utah Lake. Remote Sensing Environment, vol.3, pp.99-107.

[9]. Klemas, V., Bartlett, D., Philpot, W. and Roger, R. (1974): Coastal and estuarine studies with ERTS-1 and Skylab. Remote Sensing Environment, vol.3, pp.153-177.

[10]. Lindell, T., Pierson, D., Premazzi, G. and Zilioli, E. (1999): Manual for monitoring European lakes using remote sensing techniques. Official Publication of the European Communities, Luxembourg, p.161.

[11]. Ehlers, M. and Edwards, G. (1989): Integration of remote sensing with Geographic Information Systems: A necessary evolution. Photogram. Engineering of Remote Sensing, vol.55, pp.1619-1628.

[12]. Bradshaw, G. A. and Borchers, J.G. (2000): Uncertainty as information: Narrowing the science-policy gap. Conservation Ecology, vol.4 no.1: 7.

[13]. Pulles, M.P.J. and Heslinga D. (2003): On the variability of Air Pollutant Emissions from Gas Fired Industrial Combustion Plants, TNO/MEP, Netherlands.

[14]. Miyashita, M., Makowski, M. and Nakamori, Y. (2004): Applicability of Satellite-Derived Data to Oil Spill Assessment, the 5th International Symposium on Knowledge and Systems Sciences, (KSS2004), pp.258-262

[15]. Sarti, F., Inglada, J., Landry, R. and Pultz, T. (2003): Risk management using Remote Sensing data: moving from scientific to operational applications, the tenth of Brazilian Symposium of Remote Sensing , http://www.treemail.nl/download/