International Environmental Agreements and Remote Sensing Technologies

Karen Kline and Kal Raustiala*

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Center for International Earth Science Information Network
Columbia University
P.O. Box 1000
Palisades, NY 10964 USA
Tel. +1-845-365-8988, Fax +1-845-365-8922

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* Remote Sensing Research Unit, University of California-Santa Barbara, and Law School, University of California-Los Angeles, respectively.

EXECUTIVE SUMMARY

Remote sensing (RS) refers to the collection of atmospheric, terrestrial, marine, or social data from a platform located above the surface of the earth, including satellites, airplanes (manned and unmanned), the Space Shuttle, and soon the International Space Station. Advances in RS technologies permit the gathering of a wide array of hitherto-unavailable data that are relevant to international environmental policy, and the number and variety of RS instruments in the sky at any given time keeps increasing. Similarly, in recent decades multilateral environmental agreements (MEAs) have grown in number, scope, and complexity. Many of these MEAs contain provisions for monitoring, reporting, and assessing both environmental and behavioral data (See Annex 1). This paper brings these two developments together and explores what roles RS data might play in international environmental policy.

RS data has several attractive qualities. It is generally accurate and objective; it can have globally-consistent coverage; it can be tuned to ecological regions of widely-varying scales; and because it is sensed from space, it can present a wide range of relevant data synoptically and without legally infringing national sovereignty. RS data also has limitations. It must be interpreted by people with sufficient technical expertise, the process of interpretation is still subject to subjective biases, it is expensive to obtain, and will not eliminate core political obstacles to environmental protection. On balance, however, RS data has many positive features in the context of agreements, such as MEAs, that require data about both human behavior and environmental change.

The areas of potential beneficial use of RS technology in environmental policymaking suggested in this paper fall under five headings:

- *MEA Negotiation*
  RS data may provide an impetus for MEA negotiation by identifying new or underappreciated aspects of transboundary or shared problems, such as changes in rates of deforestation. It may help guide the adjustment of MEA regulations over time.

- *Implementation review*
  Many MEAs employ some form of implementation review, in which the performance of governments in implementing their commitments is evaluated. MEAs typically require national reports by governments on implementation. RS data can enhance reporting and review processes at the national level, and can link national level data to more aggregate regional or global data. RS technology may also permit the corroboration of data in national reports.

- *Compliance and dispute resolution*
  RS data can promote compliance with MEA obligations by increasing the transparency of behavior and assuring participants that others are complying. Through the use of RS, behavior that was previously unobservable, such as high seas dumping, may become observable and thus effectively regulated. RS data may promote voluntary compliance efforts and build capacity, whether on the part of governments or regulated private actors such as firms. The existence of RS data may also act as a potent deterrent to non-compliance and could aid in formal dispute resolution proceedings and non-compliance mechanisms.

- *The broader political process*
  Increasingly RS data will be available to and used by private actors. Both firms interested in assuring compliance with MEA rules by their competitors and public interest organizations interested in pressuring governments toward environmental action may employ RS data fruitfully. Images, such as that of the Antarctic "ozone hole," are particularly salient to the public and thus RS technology may help enhance popular understanding and concern with global and regional environmental degradation.

- *Environmental assessment*
  As environmental transformations become more numerous, and their scope is increasingly global, scientific assessments have assumed growing importance. Examples include the Intergovernmental Panel on Climate Change and the Millenium Ecosystem Assessment, just getting underway. RS data can transform the assessment process by expanding the range and detail of data. Environmental assessments rely on data more than any other aspect of international environmental cooperation, and may ultimately represent the single most important utilization of RS technology for bolstering MEAs.

Abbreviations

Basel Convention	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989)
CBD	Convention on Biological Diversity (1992)
CCD	Convention to Combat Desertification (1994)
CIESIN	Center for International Earth Science Information Network of Columbia University
CITES	Convention on International Trade in Endangered Species (1973)
CMS	Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) (1983)
FCCC	United Nations Framework Convention on Climate Change (1992)
LRTAP	Convention on Long Range Transboundary Air Pollution (1979)
MARPOL	International Convention for the Prevention of Pollution from Ships (1973/78)
MEA	Multilateral Environmental Agreement
Montreal Protocol	Montreal Protocol on Substances that Deplete the Ozone Layer (1987)
NAFO	Convention on Future Multilateral Co-operation in the Northwest Atlantic Fisheries (1978)
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic (1992)
Ramsar Convention	Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat (1971)
RS	Remote sensing
UNCLOS	United Nations Convention on Law of the Sea (1994)
UNEP/GRID	United Nations Environment Programme/Global Resource Information Database
Vienna Convention	Vienna Convention on the Protection of the Ozone Layer (1985)
World Heritage Convention	Convention Concerning the Protection of the World Cultural and Natural Heritage

I. Introduction

There is a growing interest in the application of remote sensing technologies to the protection of the global environment. Remote sensing (RS) refers to the collection of atmospheric, terrestrial, marine, or social data from a platform located above the surface of the earth, including satellites, airplanes (manned and unmanned), the Space Shuttle, and soon the International Space Station. Recent advances in RS technologies permit the gathering of a wide array of hitherto-unavailable data that are relevant to environmental policy. In addition, there has been tremendous growth in recent years in the suite of observational data products, both from long-running US and European programs and from more recent programs developed by Japan, China, Brazil, and even private vendors. Some analysts predict that by 2003 eleven or more private companies will be offering satellite data.[1] For its part, international environmental policy is typically cast in the form of bilateral or multilateral environmental agreements (MEAs), which are agreements forged between governments to collectively address an environmental problem. As with RS technologies, the number and range of these MEAs is growing rapidly.

This paper is intended to provide a background for an examination of the potential of RS technologies to influence the development, operation, and effectiveness of MEAs. Many observers have noted the importance of RS technology to international environmental cooperation. Participants at a United Nations meeting in 1999 on synergies among MEAs called for harmonization of methodologies for data gathering and analysis, and identified RS technology as "an underutilized resource that should be focused more explicitly on MEA monitoring and implementation."[2] Similarly, a recent report commissioned by the European Union called for "greater dialogue between suppliers of [RS] data and [MEA parties]...in order to make parties to treaties more aware of the detailed and tailored capabilities of satellite data and inform suppliers' of users requirements."[3] Most MEAs contain provisions that call for the monitoring, reporting or assessment of data on environmental parameters, human behavior, and/or specific sites such as wetlands. RS technology may provide significant new types of data, as well as simply more or better quality data, but linking RS data to policy is not straightforward. This paper provides a basic overview of the possibilities for international environmental cooperation presented by RS data. Yet the difficulties and limits to use that exist are not trivial.

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[1] Yahya A. Dehqanzada and Ann M. Florini (2000), *Secrets for Sale: How Commercial Satellite Imagery Will Change the World*, Carnegie Endowment for International Peace.

[2] UN University (1999), *Interlinkages: Synergies and Coordination between Multilateral Environmental Agreements*, report of a conference, Tokyo, Japan, July 14-16, 1999.

[3] Smith System Engineering *et al*, (1995) *Final Report on a Study to Assess the Use of Satellite EO Data to Increase the Effectiveness of International Environmental Treaties*, a report to DG-XXII of the European Commission. See also Paul F. Uhlir (1995), ">From Spacecraft to Statecraft: The role of earth observation satellites in the development of international environmental protection agreements," *GIS Law* Vol. 2, No. 3.

Part II of this paper presents an overview of the international policy process and the theories of cooperation developed by social scientists and lawyers. Part III discusses two central concerns in the study of MEAs--compliance and effectiveness--and the relevant variables that have been identified to analyze them. Part IV presents a brief review of the development of remote sensing and some of the issues to keep in mind when evaluating the potential of remotely sensed imagery. Part V considers the various roles remote sensing technologies may play in enhancing international environmental cooperation.

II. MEAs and the international policy process: a basic overview

International environmental agreements date back at least a century. In the last 30 years, however, MEAs have proliferated as environmental protection has become a major issue worldwide.[4] The 1992 Rio Conference (UNCED), and the 1972 Stockholm Conference (UNCHE) before it, reflected the rise of concern for the global environment and each was a catalyst for the creation of new accords. MEAs currently address a wide range of environmental phenomena, both regional and global in nature. Newer MEAs address increasingly complex issues of pollution, land-use, and conservation. A sampling of existing agreements illustrates the diversity:

- The International Convention for the Regulation of Whaling (1946)
- The Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat (1971)
- The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters (1972)
- The Convention on International Trade In Endangered Species (CITES) (1973)
- The Convention for the Protection of the Rhine against Chemical Pollution (1976)
- The Convention on Long-Range Transboundary Air Pollution (LRTAP) (1979) and the First Sulfur Protocol (1985), the Nitrous Oxides Protocol (1988), the Volatile Organic Compounds Protocol (1991), and the Second Sulfur Protocol (1994).
- The Vienna Convention on the Protection of the Ozone Layer (1985) and the Montreal Protocol on Substances That Deplete the Ozone Layer (1987)
- The Convention on Biological Diversity (1992)
- The Framework Convention on Climate Change (1992) and the Kyoto Protocol (1997).
- The Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa (1994).

[4] Interesting data on the exponential post-World War II rise of environmental concern, MEAs, and organizations can be found in John W. Meyer, et al. (1997), "A World Environmental Regime, 1870-1990" *International Organization* Vol 51, No. 4.

The negotiation of agreements

MEAs are negotiated through a diplomatic process that can last for years. Part of the cause of such slow negotiation is the political necessity for consensus among the governments involved. Consensus is an important component of international decision-making because of the existence of state sovereignty. Sovereignty is a complex concept, but the essential idea is that a sovereign state is one over whom no other state has legitimate control. Sovereignty is closely tied to territory; a state is sovereign over a territory, and that territory includes the airspace above it and, if it is coastal, the portion of the ocean immediately adjacent to the coast. (In a formal, legal sense remote sensing technologies do not violate sovereignty, but as a political matter they may be perceived to do so.) All states are formally equal and sovereign – though their power in fact varies widely – and thus no state can be bound to cooperative efforts without its consent. For this reason the international system is considered anarchic, or un-governed. Even when a state consents to a particular action or policy there are few effective levers over governments comparable to police and courts in domestic settings, and hence there is no reliable and legitimate way to ensure that it will abide by its commitment. But because the number of states is small and their interactions frequent and dense, in practice cooperation among states is common and international law not an oxymoron. States are constantly negotiating often complex agreements amongst themselves. For reasons that are discussed below, they generally comply with the commitments they negotiate.

This cooperation is often quite "shallow," however. Because MEAs are negotiated agreements they frequently reflect a lowest-common-denominator dynamic, in which the state or states that seek to do the least influence the terms of the accord disproportionately. While consensus around a lowest-common denominator makes agreement and cooperation possible it also means that the commitments embodied in MEAs are often surprisingly minimal. The Ramsar Convention on wetlands, for example, merely obliges states to list wetlands of importance that fall within their territory and to use them wisely, but it does not commit states to regulate or protect them in any specific way. Nor does anything happen in practice if they fail to list or wisely use their wetlands. The minimal nature of most environmental commitments is one of the primary reasons there are moderately high levels of compliance. In some cases, however, governments fail to comply with even minimal commitments.

In practice each MEA forms the core of a larger social institution, known in international relations theory as a regime. Much of the literature on international cooperation employs the terminology of regimes or its counterpart, international institutions.[5] A regime is a persistent set of rules (formal and informal) that prescribes behavioral roles, constrains activity, and shapes expectations.[6] Unlike an MEA, which

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[5] An institution in this sense is distinguished from an organization, which is a physical entity, typically with staff, buildings, letterhead, etc.

[6] Robert O. Keohane (1989), *International Institutions and State Power: Essays in International Relations Theory*, Boulder, CO: Westview Press.

is a textual accord that can be read, a regime is a social concept and the identification of a regime or the delimitation of its parameters is not clear-cut. These terms are used interchangeably for the most part, but the concept of regime is important because it links a given MEA to the array of surrounding norms and constraints. Regimes themselves are often linked to one another and to broader political processes. The desire to ease the tensions of the Cold War encouraged East-West environmental cooperation in the 1970s, leading to the negotiation of the Long-Range Transboundary Air Pollution agreement. Regimes for international trade, development, human rights, and the oceans all interact with various treaties and with one another. The result is a complex set of agreements and institutions that generally reinforce one another, though at times they work at cross-purposes. The depth of this policy interdependence among states creates many incentives to negotiate and renegotiate accords and to comply with those accords, and these incentives in practice dampen the fundamentally anarchic nature of the international system.

All international agreements are commitments by governments to one another--though non-governmental organizations sometimes play important roles--and thus the proximate focus of international commitments is government behavior. But one very important aspect of MEAs is that in almost all cases the ultimate regulatory targets are private actors: individuals driving cars, power-plant operators, leather-goods importers, shipping companies. In many other international agreements, such as arms control negotiations, the government that negotiates the accords also takes the actions necessary to comply with the accord and to achieve its goals. In those cases the behavior of governments is the proximate focus of the commitments as well as the ultimate target of those commitments. For most MEAs, conversely, the ultimate regulatory targets are individuals, firms, and so forth. This has two important implications.

First, it means that the regulatory structure created at the international level--the commitments and institutions of the MEA--typically must mesh or interact with a regulatory structure within the states that are parties to the MEA. For example, many states have some sort of domestic legislation governing pollution into marine areas, and often this legislation is very detailed. International commitments to reduce land-based marine pollution interact with the laws and actions already undertaken domestically, complicating the implementation process and complicating any analysis of the impact of MEAs on state behavior. Second, the focus of MEAs on private actors creates distinct data needs. Analysts of MEAs not only need to know about government behavior, such as whether the US passed new legislation or regulation addressing the protection of fish stocks. They also need to know if in fact this process altered the behavior of fishers or the population dynamics of the fish stocks, and in addition they need data about other variables that may have produced the same outcomes. Data needs can be high in any international agreement, but the societal causes of many environmental problems and the societal focus of many MEAs mean that data needs are likely to be very high.

In summary, although legal language and formal, contractual terms give an appearance of law to environmental cooperation, the process is quite different from legislation or regulation in a domestic setting. The political, social, and economic context of international cooperation matter enormously. For many governments, particularly the advanced industrial democracies, the political incentives and disincentives associated with negotiating and implementing new MEAs are complex and can lead to the rejection of agreements that had been painstakingly negotiated (as the US government did with the Convention on Biological Diversity), or the drafting of commitments that are purposefully ambiguous (as is the case with the Framework Convention on Climate Change (FCCC), where the commitment to reduce carbon dioxide emissions was drafted in a way that was artfully vague--and in fact almost no state will meet that commitment strictly construed). At other times, the political context furthers cooperation and promotes actions that states would not otherwise have done, as was the case with Long-Range Transboundary Air Pollution Regime. There, the Cold War helped produce the initial agreement, and then the political salience of environmental protection in many European states during the 1980s produced a competitive dynamic in which governments tried to appear "green" to their populaces. The central point is that while scientific data and theory about the environment are critical inputs into MEAs, politics determines when and how these data and theories play a role.

The Structure of MEAs

MEAs are typically brief and formal documents that describe the problem being addressed, the commitments of the governments involved, and the institutional infrastructure to be created. They are commonly cast in the form of binding international treaties, though some are non-binding statements of principles or aspirations. In practice, because of the weaknesses of the international legal system discussed above, the difference between binding and non-binding agreements is not great. Most MEAs create a series of international organizations to administer the agreement, such as secretariats and technical and scientific committees, and invest the power to alter and amend the treaty in a Conference of the Parties, which acts by consensus in almost all cases. As a result MEAs not only embody commitments among states, they also create new institutions and organizations that structure future cooperation.

MEAs often contain a very general set of commitments which create a framework for the negotiation of more specialized accords known as protocols. This is known as the “framework-protocol” format.[7] The Vienna Convention on the protection of the ozone layer, for example, created a general process for cooperation on stratospheric ozone depletion while the Montreal Protocol and its subsequent amendments laid out detailed commitments relating to the production and consumption of specific ozone-depleting chemicals. Similarly, the Long-Range Transboundary Air Pollution

[7] The governments that negotiate and are parties to each protocol are usually a subset of those party to the initial agreement.

convention created a general process of cooperation and scientific data collection that then spawned four specialized agreements on specific categories of pollutants. Sometimes subsequent agreements are cast in a non-binding form even if the framework is a binding treaty, as for example has been the case with the North Sea marine pollution regime and with Rhine River cooperation.

Parties typically report on national measures undertaken and progress related to an MEA commitments. This self-reporting process is common to most environmental regimes, and often the reports are annual. The existence of self-reporting systems is illustrative of the weaknesses of the international legal system: states report on their own actions, rather than being monitored by others, and even under these favorable conditions such reports are often not filed on time or at all. Many MEAs also contain provisions that require or encourage research, the monitoring of environmental parameters, the monitoring of environmentally-relevant behavior (such as fishing), and/or the monitoring of specific sites of interest, such as protected wetlands. A survey of such provisions, culled from 12 MEAs, is contained in Annex 1 of this paper. These provisions indicate the wide range of data needs that have been identified, many of which can be addressed, perhaps quite well, through RS technology. These provisions also illustrate the varying approaches of MEAs and the wide range of legal obligations they contain.

MEAs are evolutionary documents, intended to initiate a long-lasting cooperative process. This is part of the impetus behind the framework-protocol format: the framework provides the groundrules and procedures for the creation of new, more substantive agreements. It is anticipated that commitments will be periodically revised as new scientific data becomes available and as the political stances of various states shift. The Rhine convention, for example, creates a initial framework within which specific threshold levels for pollutants are developed. The climate change convention (which is also a framework convention) has already produced one protocol on greenhouse gas emissions and is linked in practice to the work of the Intergovernmental Panel on Climate Change, which comprises some 2000 scientists from around the world with a mandate to assess and synthesize research on the causes and impacts of climate change. While not formally connected to the treaty, the findings of the Panel are closely watched and influence the path of the regime.

The interaction between changes in scientific data and theory and changes in environmental policy is not seamless. The international whaling regime is undergoing severe stress because the current ban on whaling, while popular with non-whaling states and many conservation organizations, is in tension with scientific data demonstrating that many species of whales are flourishing. The African Elephant was moved in the late 1980s from the threatened to endangered list under the Convention on International Trade in Endangered Species despite evidence that many herds were well-managed and that the ban would actually lead to more poaching of elephants. Some also see a disconnect between the development of climate science and of climate policy. As with all data, interpretation determines influence. Nonetheless, the important practical role for data in most MEAs means that effective and novel data gathering techniques, such as remote sensing, have great potential as inputs into the policymaking process.

III. Analyzing Compliance and Effectiveness

MEAs are only important if they achieve or produce outcomes that would not have otherwise occurred. That is, international agreements are important if they are effective, and to be effective they must alter relevant behavior from what it would be in the absence of the agreement. Contemporary research on MEAs focuses on several core questions:

- How should effectiveness be defined and measured?
- What explains variation in compliance and effectiveness?
- How can causal factors associated with MEAs be separated from other factors that may also influence government behavior or produce specific environmental outcomes?
- How can compliance and effectiveness be improved?

Effectiveness is the central concern in this line of research, though compliance is a very important variable in its own right and as an intervening factor that influences effectiveness. There are many definitions of effectiveness. Effectiveness has been variously defined as the degree to which a given regime induces changes in behavior that further the goals of the regime; the degree that a regime improves the state of the underlying environmental problem it addresses; the degree that a regime achieves its policy objective.[8] Compliance is a less-debated legal concept that refers to a state of conformity or identity between an actor's behavior and a specified rule. Compliance is measured by reference to the standards set down in an agreement, but it says nothing about the wisdom or applicability of those standards.

While effectiveness and compliance are closely linked, they are not the same. Compliance is not an end in itself, but rather an important means to effectiveness. An MEA can be effective even if compliance is low: the MEA may induce significant change in behavior that furthers the aims of the MEA or improves the underlying environmental problem even if that change in behavior does not comply with the legal standard set in the accord. And while high levels of compliance can indicate high levels of effectiveness, they can also indicate low, readily-met and ineffective standards.

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[8] For definitions of effectiveness see Oran R. Young (1997), "The Effectiveness of International Environmental Regimes: A Mid-Term Report" *International Environmental Affairs*; Oran R. Young (1994), *International Governance*, Cornell University Press, in particular Chapter 6; Peter M. Haas, Robert Keohane, and Marc A. Levy, eds. (1993), *Institutions for the Earth,* MIT Press; David G. Victor, Kal Raustiala, and Eugene B. Skolnikoff, eds. (1998), *The Implementation and Effectiveness of International Environmental Commitments*, MIT Press; Arild Underdal (forthcoming), "One Question, Two Answers" Chapter 1 in E. Miles, ed. *Explaining Regime Effectiveness: Confronting Theory with Evidence*. Cambridge, MA: MIT Press.

Many international agreements reflect a lowest-common-denominator dynamic that makes compliance easy but influence on behavior negligible. The early years of the international whaling regime, for example, exhibited relative high levels of compliance but low effectiveness because the catch quotas of whales were set to roughly match then-current practice. Compliance was high, but there was little effect on behavior or on the underlying problem: the changes observed correlated with but were not caused by the MEA itself. All else equal, from an effectiveness perspective more compliance is better, and compliance is a major focus of research on MEAs. But regimes with significant non-compliance may still be effective. Thus there is neither a necessary nor a sufficient connection between compliance with international commitments and the effectiveness of those commitments.

Implementation, a concept related to both compliance and effectiveness, refers to the process of putting international commitments into practice. Implementation occurs at the international level through the establishment of organizations like secretariats and the holding of regularized meetings of the parties to an MEA. Implementation occurs domestically through the passage of legislation, promulgation of regulations, and enforcement of rules. Implementation is what transforms an MEA from a legal document to a functioning regime. Implementation is typically a critical step toward compliance, but compliance can occur without implementation; that is, without any effort or action by a government or regulated entity. If the international commitments in an MEA match current practice in a given state implementation is unnecessary, compliance is automatic, and the effectiveness of the MEA is basically zero. Compliance can also occur for reasons entirely exogenous to the treaty process: economic collapse in the former Soviet Union, for example, has produced perfect, but coincidental, compliance with many MEAs. Implementation of MEAs is therefore neither necessary nor sufficient for compliance with MEAs. However, implementation is generally necessary, but not sufficient, for effectiveness. While it is conceivable that the sheer existence of a set of international rules may alter the behavior of actors, in almost all cases rules need to be put in practice in order to influence behavior.

Relevant Causal Variables

The preceding section suggested that compliance with and the effectiveness of international commitments can have many sources. Distinguishing the causal impact of a regime from other causal factors that may have influenced human behavior is a major challenge. But only by understanding the full range of causal variables that may influence behavior can compliance with and the effectiveness of agreements be explained and improved. This section focuses on four major classes of variables identified by social scientists studying regimes:

- the nature of the problem addressed;
- the domestic structure of the states involved;
- the qualities of the international system;
- and the design features of the agreement itself.

In addition, two different assumptions about state behavior are presented: that states carefully weigh the costs and benefits of compliance in each instance and that states have a general propensity to comply with international rules.[9] These two assumptions are central to debates over compliance and effectiveness and can be thought of as cutting across the four classes of variables. The significance of the variables in the four core groups depends in part on which assumption about state behavior is embraced. In particular, these assumptions are relevant to the design of MEAs. Much of the contemporary discussion about how best to design environmental agreements revolves around these assumptions and the theories that flow from them.

The first assumption, that states have no propensity to comply with international rules but instead carefully weigh the costs and benefits of compliance grows out of microeconomic theories of behavior. Governments are treated for purposes of analysis as utility-maximizers, whose behavior responds to incentives and disincentives. The second assumption, that states have a propensity to comply, flows from several sources. Because collectively states determine the content of rules, an assumption of rational behavior leads to a prediction that the rules negotiated are desired and that states have an interest in compliance with them. Compliance is also efficient from an internal perspective because repeated calculation of costs and benefits is itself costly. Finally, norms of respect for law induce a sense of obligation in states.

Regardless of whether the first or the second assumption about state behavior is used or which is in fact more valid and fruitful, the following categories of causal variables are likely to be significant for explaining state behavior and the success of MEAs.

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[9] The two assumptions roughly correspond to those employed, respectively, in George W. Downs, David M. Rocke, and Peter N. Barsoom (1996), "Is the Good News about Compliance Good News about Coopertion?" *International Organization*, and Abram Chayes and Antonia Handler Chayes (1995), *The New Sovereignty*, Cambridge, MA: Harvard University Press.

• Problem structure
This set of causal variables encompasses variables of strategic interaction and of the nature of the underlying substantive problem. For example, non-cooperative game theory illustrates that the incentives to cooperate in "collaboration games" differ markedly from those in "coordination games."[10] In a coordination game the parties seek to agree upon a uniform rule to coordinate their actions, such as driving on the right-side of the road. Incentives to deviate from such a rule are very low; all else equal compliance will be high. In collaboration games each party would prefer to have every party comply with the rules except itself. Incentives to deviate are high and compliance likely to be low. Climate change presents a classic collaboration game: almost every state would prefer a world in which all other states took costly preventative action, but it did not.

Other aspects of problem structure can affect behavior similarly. Environmental problems that involve small numbers of states may eliminate or dampen the public goods nature of enforcement efforts and thus enjoy higher levels of compliance and be more effective than comparable multilateral or global agreements. The regulatory scope and complexity of the underlying problem can overburden administrative and bureaucratic capacity and hence the likelihood of lasting changes in behavior. Some actions are intrinsically more transparent to other actors, and hence more monitorible, than others, and again all else equal compliance should be higher. For example, deforestation patterns are more transparent than are biodiversity losses, which cannot be readily assessed by others through RS technology. There are many aspects to structure of a problem; the central point is that some problems are more difficult to solve than others. This difficulty, which can be intrinsic to the problem but, as the examples above indicate, can also be altered through strategic choices, ultimately affects the success of the regime.

• Domestic structure
Behavior may also vary depending on the nature of the states involved. Governments vary in many ways. Some are democracies, some autocracies; some have strong environment ministries. Some are broadly "liberal," meaning that they embody the rule of law and the protection of civil and minority rights. Empirical research suggests that liberal states are in fact more likely than illiberal states to agree to create international institutions for regularized and domestically-intrusive implementation review, institutions that often enhance the effectiveness of international commitments.[11] Because one common facet of liberal societies is the "rule of law", liberal or democratic states may also agree to and comply with decisions by international institutions more readily than illiberal and non-democractic states. Feedback from an MEA may also create changes in the preferences of domestic actors that lead to greater incentives for compliance. For example, manufacturers of waste-water treatment equipment may have a stake in and promote compliance with riparian

[10] A basic overview is found in Arthur Stein (1990), *Why Nations Cooperate*, Ithaca, NY: Cornell University Press.

[11] Kal Raustiala and David G. Victor (1998), "Conclusions" in Victor, Raustiala, and Skolnikoff, op. cit.

pollution standards. Shifts in the preferences of societal actors as well as their political impact vary based on domestic structure.

• The international system
The level of international interdependence and institutionalization, and the presence or absence of an overarchingly powerful state--or hegemonic state--are major explanatory variables in international relations theory. By generally influencing state behavior, systemic or international structural variables may alter government choices in specific cases. For example, highly institutionalized international systems with extensive networks of international agreements may create positive spirals of behavior by embedding states in regularized processes of cooperation that are mutually reinforcing and that make them concerned about their reputation. Contemporary Europe may be an example of such a virtuous cycle of cooperation. The existence of a hegemonic state with strong interests in specific areas of environmental protection may produce compliance in other states through coercion or the use of market power. The US regularly plays this role in regard to several fisheries agreements, and there is evidence that this has in fact improved overall compliance levels.[12]

Developments and variations in the role and nature of what is often termed international civil society--the non-governmental groups that are increasingly active in international affairs--may also influence MEAs. Scientists themselves, when loosely connected into communities of like-minded analysts (known as epistemic communities) can influence the formation of MEAs, as several studies have shown.[13] These communities may influence the implementation, compliance, and effectiveness of MEAs as well. These varied characteristics of the international system are relatively inchoate and typically not manipulable by policy in any reasonable timeframe. But they are bulwarks of international relations theories in other areas, and cannot be ignored in comparisons across environmental regimes.

• MEA design features
Most important from a policy perspective is the structure of the solution--the attributes of the accord itself. These attributes are the specific institutional design choices of the MEA, such as the nature and content of the primary rules of behavior, the employment of punitive measures, positive inducements, or capacity-building programs, or the use of regularized systems for the review and assessment of implementation. These design elements, of which there are many, can range from the details of substantive rules to broad principles of regime design.

Conduct rules, for example, can be more or less specific and more or less clear. Regime designers can chose to focus on more rather than less transparent aspects of a problem, transforming the "problem" from more to less difficult. The standards set

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[12] Steve Charnovitz (1994), "Encouraging Environmental Cooperation Through the Pelly Amendment" *Journal of Environment & Development*, Vol. 3, No. 1.

[13] Peter M. Haas, ed. (1992), "Knowledge, Power, and International Policy Coordination" (special issue), *International Organization* Vol. 46, No. 1.

can be challenging or they can merely codify existing behavior patterns. The power to take compliance decisions can be allocated to actors more or less likely to comply. The choice of regulatory rules can raise the costs of compliance or lower them, altering compliance rates: the choice of tradable pollution permits, for example, may lower aggregate compliance costs compared to discrete, national and non-transferable pollution targets, though doing so may make monitoring much more difficult. Indeed, there may be a tradeoff between the monitoring gains that RS technologies permit (such as observation of pollution plumes) given fixed allowable emission quantities and the costs gains associated with tradeable permit schemes.

Regime rules can also influence the provision of useful information. Collaborative scientific data-gathering and monitoring networks may create a dynamic that fosters learning and change in preferences toward environmental protection as it also enhances the effectiveness of later MEAs.[14] In some MEAs the provision of new data about underlying environmental problems has been critical to the success of the regime and to the expansion of the regime to new states, which may have disbelieved early data or considered their own ecosystems to be unaffected. The evolution of the European acid rain regime is a particularly salient example: Germany's views of the acid rain problem changed substantially as new data indicating German environmental degradation emerged from the collaborative data-gathering system that was created by the parties to the regime.[15] (RS technology may be particularly relevant here; by creating more and better data than can conventional ground methods, this learning and preference-shifting process may be accelerated substantially).

Perhaps most important for compliance is the structure of rules governing responses to instances of non-compliance: how information about non-compliance is gathered, who has the authority to respond to it, and what the nature of possible responses are. One important implication that flows from the assumption that states are utility maximizers is that deterrence is important for compliance. To be effective, deterrence relies on monitoring and enforcement, and thus an MEA must incorporate corresponding provisions that make non-compliance observable and costly. The alternative assumption, that states have a propensity to comply, suggests instead that non-compliance is largely inadvertent and hence compliance should be facilitated and fostered cooperatively rather than promoted through threats. While under either assumption RS technology may play a role, under the former RS can be particularly important, if the behavior governed by the regime is observable via satellite. Indeed, wide-scale use of RS technology may make previously unsuccessful regulatory strategies successful: in the intentional marine oil pollution regime, which focused on oil pollution from normal tanker operation and is discussed further below, the initial strategy of regulating ship discharges on the high seas largely failed. The discharges were unobservable with conventional technology and thus the rules were a weak deterrent. RS technology, however, could detect the oil slicks left behind in the ocean

[14] Marc A. Levy, "European Acid Rain: The Power of Tote-Board Diplomacy" in Haas, Keohane, and Levy, op. cit.
[15] Id.

and thus might make this regulatory strategy much more effective than it was in the 1960s.

Finally, the process by which the MEA or regime develops and implements rules may also influence state behavior. Process in this context encompasses the methods by which the substantive rules and decisions and/or the non-compliance procedures of the regime are developed, and the qualities of the processes by which the various institutions operate. The focus here is on normative concerns. The inclusivity, fairness, perceived legitimacy, coerciveness, etc. of the production of collective rules may influence the degree that states accept and internalize international rules. Theories of cooperation employing process variables of this type are largely found in the legal literature, and often focus on the allegedly special qualities of legal rules and norms that help to produce compliance with those rules.[16]

This brief summary of causal variables is not complete. State behavior vis-a-vis MEAs can be caused by many different events ranging from technological breakthroughs, to changes in relative prices,[17] to economic depressions brought on by political instability or war. The preceding categories of variables, however, constitute the core of most environmentally-relevant behavior.

Analyzing Effectiveness

Earlier it was noted that there are many definitions of effectiveness. For the sake of clarity in presenting the potential causes of state behavior the term effectiveness has been used in a general way. The more precise varying definitions of effectiveness lead to different analytical and methodological challenges and different data needs. The most intuitive, common-sense definition of effectiveness--solving the problem that led to the creation of the MEA--is also the most problematic in practice. The scope and definition of the problem that gave rise to the MEA is not always agreed upon. More significantly, the causal link between an MEA or regime and an underlying environmental problem is very hard to trace. As Oran Young has argued,

> The danger of ending up with spurious correlation is a constant threat to efforts to understand regime effectiveness construed as problem-solving. The disappearance or amelioration of a problem following the formation of a regime does not constitute proof that the regime was a causal agent in the process. Conversely, the failure of a problem to disappear following regime creation does not justify the conclusion that the regime had no effect at all; the problem could well have grown more severe in

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[16] E.g. Thomas M. Franck (1990), *The Power of Legitimacy Among States*, New York: Oxford University Press.

[17] For example, compliance with pollution standards for the Rhine was enhanced by the shift in value of heavy metals like cadmium, which had previously been discarded in wastewater. See Thomas Bernauer and Peter Moser (1996), "Reducing Pollution of the River Rhine: The Influence of International Cooperation," *Journal of Environment & Development*, Vol. 5, No. 4.

> the absence of the regime...the operation of a regime is typically only one of a suite of factors--both intended and unintended--that play some role in determining the course of international environmental problems.[18]

As a result of these complexities many analyses of the effectiveness of MEAs use some version of a behavioral definition of effectiveness. The analytic focus is the variance between observed behavior and the behavior likely to have occurred without the agreement. This approach necessarily involves counter-factual reasoning. To evaluate MEA effectiveness, and to identify the factors that influenced effectiveness, the analyst must estimate what the behavior of a given state or set of states would have been if the MEA had not existed, and then compare this hypothetical state of affairs to the empirically-observed state of affairs.

For example, in the marine oil pollution case mentioned above, Ronald Mitchell compared tanker behavior under two different rules.[19] Both rules had as their goal the elimination or reduction of oil pollution. The first rule regulated discharges on the high seas. The second rule mandated specific equipment that was built into the ship and that made discharges impossible. There was little evidence that the discharge standard had changed the behavior of tanker operators. As noted, the failure of the discharge standard to be effective was mainly due to data-gathering problems; it was very difficult to monitor the behavior of ships at sea and therefore little deterrence of non-compliance. The equipment standard, however, proved very effective. Once a ship was built to meet the standard, the ship complied with the rule as long as it was in operation because it was prevented from discharging any oil. In comparing the two rules and arguing that the equipment standard was ultimately more effective, Mitchell made assumptions about what would have happened had the equipment rule never been introduced: specifically, that the discharge rule would have continued to operate in the ineffective manner it had previously. Given this counterfactual argument--which is quite reasonable--the equipment standard was a marked improvement in compliance and effectiveness terms.

Most cases, however, do not present such a clear dichotomy between different sets of rules or such a clear cut case of behavioral change resulting from change in MEA attributes. Thus the counterfactual reasoning involved in most analyses of MEAs is typically more difficult and more contestable. Disentangling the roles of problem structure, domestic characteristics, qualities of the international system, and MEA design features is the major challenge, and one that involves a significant amount of interpretation by analysts. It is important to underscore that regime analysis and regime design are as much art as science; Young compares it to medical diagnosis, which requires expert knowledge deployed in conjunction with contextual interpretation rather than the development of law-like relations and clear recipes.

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[18] Young, 1997, op. cit.

[19] Ronald Mitchell (1994), *Intentional Oil Pollution at Sea: Environmental Policy and Treaty Compliance,* MIT Press. These rules grew out of the same regime, but the precise institutional and legal complexities are not significant here.

Assessments and the Evolution of Regimes

Regimes are dynamic institutions and their commitments evolve over time. One major input into the evaluation, appraisal, and adjustment of commitments are environmental assessments. In general terms, the role of such assessments is three-fold: to integrate disparate expert knowledge into answers to policy-related questions; to disseminate these answers to policymakers and other interested parties; and to identify gaps in understandings and avenues for future research. Perhaps the most well-known international environmental assessment process is the Intergovernmental Panel on Climate Change (IPCC), which draws upon the expertise of over a thousand individuals from around the world and from many disciplines.

In the narrowest sense assessments are reports on a given problem or issue. More broadly, assessment can be conceived as a social, communicative process by which expert knowledge, related to a specific policy problem, is organized, evaluated, integrated, and presented in discrete documents meant to inform policymakers or decisionmaking.[20] Environmental assessments are often scientific in nature, but they can and do also drawn upon disciplines such as economics, political science, engineering, law, and anthropology. The communication inherent in the process of assessment also need not be, and rarely is, confined to technical experts. Rather it is a process of communication among experts, decisionmakers, and advocates. Assessments do not monopolize debate on environmental issues; they interact with the myriad less formal communicative processes underway in any environmental issue, such as media attention, lobbying, and advocacy campaigns. Understood in this way, environmental assessments have a special role because of their high profile and technical credibility, but they compete with and interact with other less formal "assessments."

Environmental assessments vary on several dimensions. Some are focused on the evaluation of discrete policy options, others on canvassing the state of scientific knowledge. Some are international in nature, others national. Some are consensus documents while others record and reflect dissenting views. Some are more technically-credible. While all assessments have some political component, this component varies widely: in the context of LRTAP, for instance, participant selection, assessment design, and the involvement of non-governmental institutions such as the International Institute for Applied Systems Analysis (IIASA) and its RAINS (Regional Acification Information and Simulation) model of acidification reflected deliberate attempts by assessment participants to be perceived as broadly international and non-partisan.[21] The IPCC process is avowedly intergovernmental, reflecting the great

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[20] This is a modified presentation of the definitions used by the Global Environment Assessment project at Harvard University, led by Bill Clark *et al*. See http://www.environment.harvard.edu/gea

[21] VanDeveer, Stacy D. (1998) "European Politics with a Scientific Face: Transition Countries, International Environmental Assessment, and Long-Range Transboundary Air Pollution". ENRP Discussion Paper E-98-09, Kennedy School of Government, Harvard University.

importance that governments have placed on ongoing assessments of climate change and the concomitant desire of governments to channel and control the assessment process. While the IPCC's rules of operation (such as reliance on peer-reviewed literature) ensure its technical credibility, it is also subject to the political influences of an intergovernmental process.

Like the broader regimes and MEAs with which they interact and that they often inform, assessments can be more or less effective. Credibility is clearly an important attribute of an effective assessment. But credibility in a technical sense--credibility among the relevant expert community--is only one source of effective assessments, and credibility can be complex to achieve in practice. Technical expertise can be distrusted and hence incredible to some lay persons, for example. Widespread participation by many groups and stakeholders--those individuals and groups with an interest in the problem or its resolution--is as a result sometimes thought to be important to raising credibility with laypersons. Wider participation, however, may tradeoff technical credibility for legitimacy with the public. In addition to credibility, saliency and legitimacy are also important factors in effective assessments. Saliency is the degree to which the audience for an assessment values the issue and the assessment. Legitimacy is the perceived fairness and openness of the assessment process to a wide variety of interests. All these factors are non-technical, but they are often important politically.

Environmental assessments may provide one of the best points of entry into the policy process for remote sensing technologies, because the assessment process is capable of being highly influential and is also highly data-dependent. Recent research on assessments suggests that these three factors in conjunction correlate with effective assessments--with "effective" understood in roughly the same way as it was understood in the context of regime effectiveness: as promoting behavioral change and environmental problem-solving.[22]

Looking at assessment effectiveness more closely, several causal pathways can be identified.[23] First, assessments may influence the understandings that policymakers and the general public have about particular environmental issues by providing new data, analyses, and theories. Assessments may also highlight gaps in knowledge and identify the most pressing areas for further research. Second, assessments may increase public and elite concern about a given issue and therefore influence an issue's "placement" on international and national agendas. Third, by "framing" an issue or question in a particular way, or linking previously discrete problems, assessments may influence the terms of debate over a problem and its resolution. Because basic data and theories are an essential part of almost any claim about a given policy issue, the contours of that data and theory can have great influence. Fourth, by disseminating new knowledge and information, assessments may alter the political strategies of relevant actors toward specific problems, making certain strategies more attractive and

[22] GEA Project, op. cit.

[23] This draws on Barbara Connolly, et al. (1997-98), "Institutions Working Group Theme Paper: Information and Governance," GEA Project.

others less. Finally, assessments may, through all the preceding mechanisms, prompt policy responses and changes. (Though sometimes, as in the whaling convention, the direct implications of scientific assessments may be rejected for political reasons.) Overall, probably the most powerful mode of influence is in terms of framing problems and and highlighting knowledge/policy needs.

It is important to recognize that just as regimes themselves evolve over time, the communicative process that assessments embody also evolve over the lifetime of a given issue and/or regime. Nearly all policy issues demonstrate what is known as an "issue-attention cycle." This is the commonly-observed phenomenon of low attention to a particular problem rising to moderate or high attention--often for reasons that are not clear at the time or even in retrospect--and then dropping back after time to low attention. In the context of environmental assessment this cycle has certain implications. In the low attention phase assessment is typically an expert-driven process, in which scientists communicate primary with other scientists and with research funders. As the issue rises in the attention cycle policy-makers and advocates participate more. During its peak, the public and the media are increasingly involved.

The often cyclical nature of attention has important implications. Assessment effectiveness depends on tuning the assessment outputs and the resulting communicative process to the shifts in the issue-attention cycle and the corresponding shifts in the relevant actors. In short, those "listening" need to understand and be interested in what those who are "speaking" are saying if an assessment is to be effective.

IV. Remote sensing: products and sensors

This section of the background paper will provide a brief synopsis of the history of remote sensing, a review of the terminology related to remote sensing, and provide an overview of some important issues to consider in the use of data from remote sensing.

This is a very brief summary of over two hundred years of developments and history in the field of remote sensing. Today, the American Society for Photogrammetry and Remote Sensing defines remote sensing as:

> In the broadest sense, the measurement or acquisition of information of some property of an object or phenomena, by a recording device that is not in physical or intimate contact with the object or phenomenon under study; e.g. the utilization at a distance (as from aircraft, spacecraft, or ship) of any device and its attendant display for gathering information pertinent to the environment, such as measurements of force fields, electromagnetic radiation, or acoustic energy. The technique employs such devices as the camera, lasers, and radio

frequency receivers, radar systems, sonar, siesmographs, gravimeters, magnetometers, and scintillation counters.[24]

In this particular setting, remote sensing will be defined as the use of a sensor onboard a spacecraft to record data about the earth. Although there are many other sources of remotely sensed data, this paper will be limited only to space based platforms. Discussion will also be confined to sensors which record those portions of the electromagnetic spectrum found in the most common products used today, although a much wider portion of the spectrum is often used for a plethora of studies covering other topics of interest and other planets.

History

Remote sensing really begins with the invention of photography, with the first photographs taken in the early 1800s by Louis M. Daguerre and Joseph Nicephore Niepce. During the 1830s, inventions in photography included the daguerreotype, the negative/positive process known as "calotype," and the stereoscope. In 1858, the first known aerial photograph was taken by Gaspar Felix Tournachon Nadar from a captive balloon at an altitude of 1,200 feet over Paris. The middle of the 19th century saw the beginning of the color additive theory (white light = blue + green + red) for the production of color photographs. During the late 1870s, German foresters used aerial photography taken from balloons to map tree species. This is an example of the earliest known application of aerial photographic interpretation.[25]

The use of rockets to launch cameras first occurred in 1906 when Albert Maul launched a rocket propelled by compressed air. In 1909, Wilbur Wright took one of the first photographs from an airplane in Centrocelli, Italy. By 1915, cameras devoted to aerial photography were being produced. World War I saw an explosion in the use of aerial photographs. The first infrared sensed image taken from an airplane occurred in 1919.

Advances in film technology also occurred at this time. 1924 saw a patent issued to Mannes and Gadousky for multi-layer film, which led to Kodachrome (Kodak film product). The American Society for Photogrammetry was formed in 1934, and was one of the first formal organizations devoted to advocating the uses of aerial photography. The Society is now known as the American Society for Photogrammetry and Remote Sensing (ASPRS) and promotes remote sensing education as well as provides a forum for remote sensing specialists and photogrammetrists to exchange ideas.[26]

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[24] American Society of Photogrammetry and Remote Sensing, Manual of Remote Sensing, Vol. 2, pp. 2102

[25] Most of the historical information cited in this section was garnered from the Remote Sensing Core Curriculum web site, http://www.umbc.edu/rscc

[26] American Society for Photogrammetry and Remote Sensing, http://www.asprs.org

World War II led to developments in aerial photography, with a special interest in color infrared (camouflage detection) film and thermal infrared imagery for military applications. Kodak patented the first false color infrared sensitive film in 1946. The 1950s saw developments in technology that allowed multispectral imagery to be taken. The U2 spy plane was first flown in 1954, and the downing of a U2 in 1960 over the Soviet Union caused an international incident.

The era of satellite imagery began in 1960 with the launch of the TIROS 1 satellite for meteorological data collection. Intelligence photography was also collected by various systems, including the CORONA and KH programs. During the late 1960s, photographs were taken from the Gemini and Apollo manned space programs. The Earth Resources Technology Satellite (ERTS-1) was launched in July 1972 (and later renamed Landsat 1). The Landsat series has continued to this day, with the relatively recent launch of Landsat 7 in April 1999.[27] The Coastal Zone Color Scanner (CZCS) was launched in 1978 (Nimbus 7); this instrument was devoted to observing the color of the ocean.[28] The Advanced Very High Resolution Radiometer (AVHRR) sensor was first sent onboard the NOAA 6 satellite.[29] The data gathered from the AVHRR sensor is often used for monitoring vegetation across large regions.

A commercial company, EOSAT, was awarded the Landsat commercial contract in 1985, at which time the government turned control of the program to EOSAT. Over time it was determined that the rapid commercialization of the program was not producing optimal results. In 1992, the U.S. Land Remote Sensing Act brought the program back under the control of the U.S. government.

Other countries entered the space imaging arena with the launch of the French Systeme Probatoire de la Observation de la Terre (SPOT) satellite in 1986 and the Indian Remote Sensing Satellite in 1988. The European Radar Satellite (ERS-1) was launched in 1991, and was aimed primarily at oceanographic applications. In 1995, Canada launched Radarsat.[30]

Terminology

Remotely sensed data are collected in many regions of the electromagnetic spectrum (see Figure 1), ranging from radio waves through microwave (radar) to thermal infrared to visible, ultraviolet and x-ray portions of the spectrum. Data recorded from

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27 Landsat Program, http://geo.arc.nasa.gov/sge/landsat/landsat.html

28 Coastal Zone Color Scanner (CZCS), http://daac.gsfc.nasa.gov/SENSOR_DOCS/CZCS_Sensor.html

29 Advanced Very High Resolution Radiometer (AVHRR), http://edc.usgs.gov/glis/hyper/guide/avhrr

30 For more information on satellites and specifications for sensors, download Annex 3 from the remote sensing and treaties workshop web site at http://sedac.ciesin.columbia.edu/rs-treaties.

different parts of the electromagnetic spectrum can provide different information under different circumstances. For example, so-called “active” radar sensors emit microwaves which can penetrate clouds, thereby allowing scientists to record information about normally cloud covered areas such as the Amazon. They can also collect data at night. Passive sensors, on the other hand, generally collect data during daylight hours, though they are able to detect “lights at night” and infrared radiation from the earth at night. They collect electromagnetic radiation that is reflected, emitted or scattered from the earth's surface. Below is a general schematic showing the electromagnetic spectrum. The visible portion is relatively small, and represents only one portion of the spectrum that is of use to remote sensing scientists.

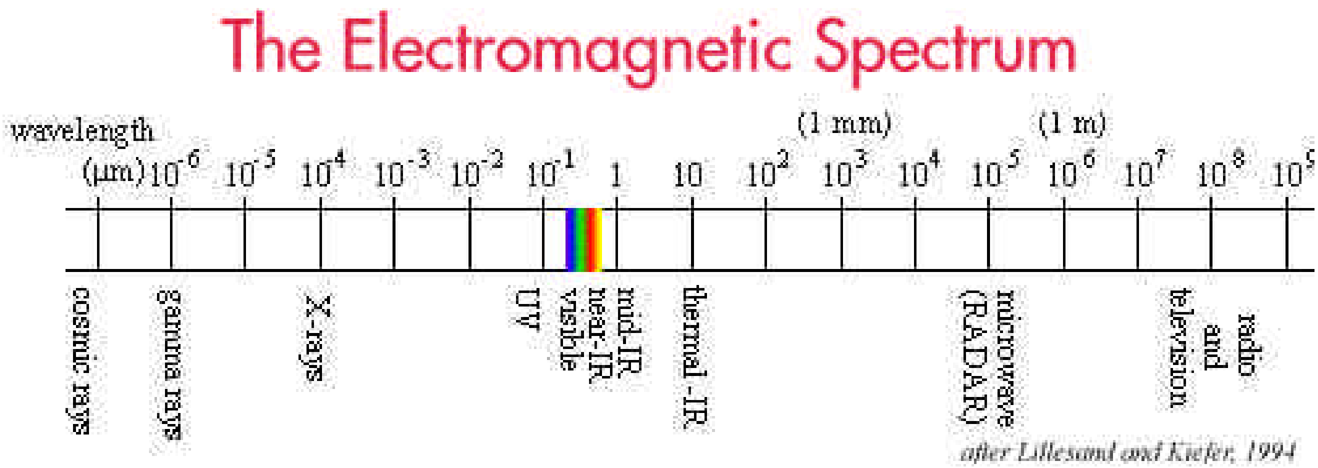

Figure 1[31]

The precise band-widths that a sensor is able to detect defines its *spectral resolution*. In addition, the *spatial* and *temporal resolutions* are very important in remotely sensed imagery. The spatial resolution is the size of the smallest area that can be seen by the sensor, which is known as a pixel, or picture element. Space borne sensors have a wide range of spatial resolutions from kilometers to centimeters, although the highest resolution imagery is generally classified. It is important to note that the spatial resolution will determine the smallest objects that can be clearly identified in the imagery. Imagery with a spatial resolution of 15 m x 15 m will allow users to determine objects that are 15 m x 15 m or larger. The temporal resolution refers to how often a sensor covers the same area. Some sensors have a repeat time of weeks while others have a repeat time of minutes. For ephemeral events, a sensor that has a high temporal frequency is more useful. For example, a satellite with a temporal resolution of 16 days means that every 16 days, the same point on the equator is sensed.[32]

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[31] See the Remote Sensing Core Curriculum, Volume 2, at http://www.research.umbc.edu/~tbenja1/

[32] For specifications of the major sensors, download Annex 3 from the remote sensing and treaties workshop web site at http://sedac.ciesin.columbia.edu/rs-treaties.

What the sensor provides is data. These data are then converted to information via processing. The data do not come "ready to use," they must be processed and transformed into information that can be used by software programs and viewed by users; and the information must be placed within context for it to be useful. The data alone are not enough to solve problems; they must be placed in models or geographic information systems and combined with other information from other sources to provide useful results. J. Lions, former president of the Centre National d'Etudes Spatiale (CNES), once said, "...a model without data has no predictive value... data without a model causes confusion."

As an example of the need for auxiliary information, see Figure 2. With no other information, the image cannot be placed in context, and therefore provides no information to us. Without locational information (i.e., latitude and longitude), or the spatial or spectral resolution, it is impossible to determine what is contained within this particular image.

Education of users of remotely sensed imagery is critical. Passing references have been made to the media's incorrect identification of objects within imagery during the Chernobyl crisis.[33] The main elements of image interpretation include tone or color, resolution, size and shape, texture and pattern, site and association, and height and shadows. All of these elements combine to provide the analyst with information to identify the objects in the image. It takes many years for an analyst to become proficient at interpreting these various elements.

Some important issues to keep in mind when using remotely sensed imagery include the need for validation of the data, matching the data to the purpose, and baseline data. When the data are delivered to the remote sensing specialist, they are simply a collection of numbers ranging in value from 0 to 255 (digital numbers). The first step is to change this collection of numbers into information, which is accomplished by classifying the image. Classification of the image can be done in one of two ways, supervised or unsupervised. Supervised classification entails telling the computer what a certain pixel is, such as chaparral, then having the computer classify every pixel similar to the known pixel as chaparral. Unsupervised classification essentially means telling the computer the number of classes desired and then letting the computer sort the numbers into classes. Both methods have their merits, but beyond this brief description, will not be covered further.

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33 Dehqanzada and Florini, *Secrets for Sale: How Commercial Satellite Imagery Will Change the World*, op. cit.

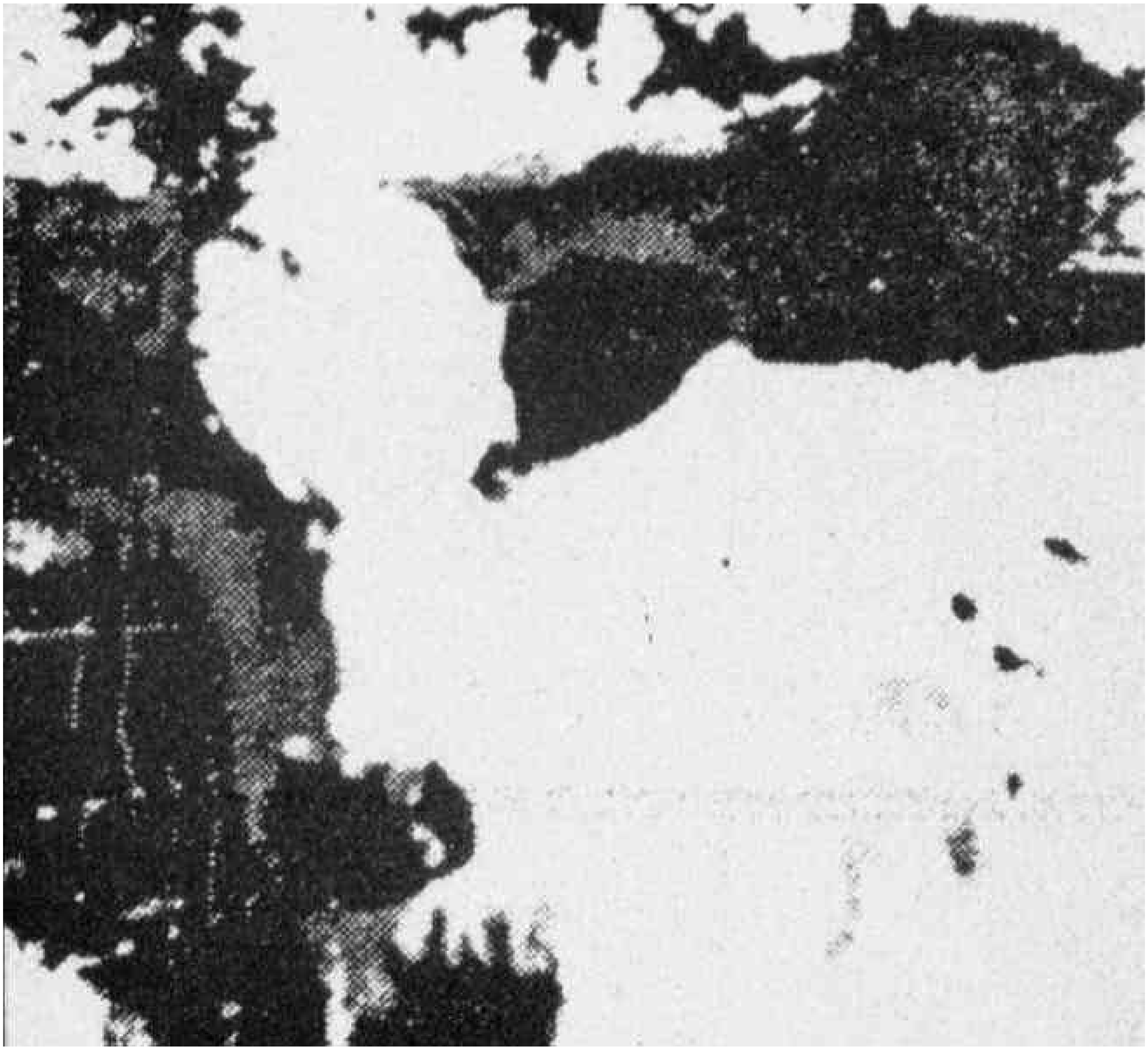

Figure 2[34]

Once the image is classified, it is necessary to tie what the image shows is there to what is really on the earth's surface at that point. This step is called validation, and is vital to determining how accurate the sensors and the classification systems used are. Determining what is on the ground is accomplished by either fieldwork where spectra and other measurements are taken of the groundcover at that point, or by comparing the classified image with previously existing maps or images of known accuracy. Statistical information can be derived from the classified imagery once the comparison

[34] Remote Sensing Core Curriculum, Volume 1, http://www.umbc.edu/rscc. This particular image is of a cow.

has been made, and is used to determine the accuracy of the imagery. This accuracy is important, since the data are often used as a basis for decision-making or other tasks.

In addition to validation, matching the data to the purpose is essential. When looking at phenomena on a spatial scale of meters, 1-kilometer data is not appropriate. The spectral, spatial, and temporal scales must be matched to the use to which the data will be put. It is an inappropriate use of time, money, and effort if the data are not suitable to the cause. The figures below indicate the vast differences between 1-kilometer imagery and 30 meter imagery. In the Landsat TM imagery (left), the Santa Barbara airport is visible in the upper right corner, with the UCSB campus lagoon in the lower right corner. If the location of the AVHRR imagery was not indicated, it would be almost impossible to determine what part of the earth's surface this represented (right).

30 meter Landsat Thematic Mapper (TM) imagery
University of California, Santa Barbara campus

1 kilometer Advanced Very High Resolution
Radiometer (AVHRR) imagery
University of California, Santa Barbara campus

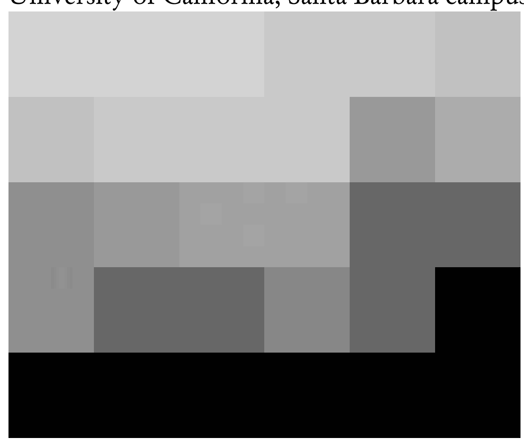

Figure 3: Comparison of 30 meter and 1 km imagery

For change detection, a baseline data set is essential. Change cannot be measured if there is nothing to which it can be compared. A series of images, taken at regular intervals, is integral to change detection.

Other items to keep in mind, particularly for land based remote sensing, is that seasonality can have an effect on an image. Imagery of a vegetated area will be different depending upon the season and its location. Imagery often taken during winter will have snow and no leaves, while summer will have full leaf. Depending upon the project's purpose, the difference between seasons can produce vastly different results.

Space borne remote sensing is a relatively new field, since it has only been operational and available to the public since the 1970s. The technological ability to image at better spectral, spatial and temporal resolutions is constantly increasing. And with more satellites and sensors being launched, more resources are becoming available to more people. Remotely sensed imagery can play a vital role that will only increase as the technology improves in international environmental agreements.

V. Remote sensing and the effectiveness of environmental regimes[35]

How can RS data make a difference in international environmental cooperation? RS data has many attractive features in the context of environmental regimes. It is generally accurate and objective; it can have globally-consistent coverage; it can be tuned to ecological regions of widely-varying scales; and because it is sensed from space it can present a wide range of relevant data synoptically and without infringing national sovereignty.[36] While international or collaborative monitoring of the environment is not currently central to most environmental regimes, to the degree monitoring does take place remote sensing is a promising method.

There is precedent for the greater use of RS data in conjunction with international policy; for example, the European Union uses RS data within its Common Agricultural Policy to determine crop usage patterns and to verify farmer's claims about crop plantings. The EU has also employed RS data in developing its CORINE Land Cover Database; about 70% of the CORINE data is remotely-sensed.[37] RS data has also been used in other quite varied environmental settings. Several United Nations organizations have utilized remotely sensed data to combat desertification, albeit not without challenges to overcome, such as the cost of procuring the data. The Food and Agriculture Organization has utilized remotely sensed data to create AFRICOVER, a 1:250,000 map of Africa to be used to assist in the fight against desertification.[38]

This section presents some preliminary ideas about the potential roles that remote sensing tools and data might play in making environmental agreements more effective. These ideas are meant to be suggestive and exploratory; undoubtedly there are many others to be generated. RS data is neither a panacea for many environmental problems nor is it likely to radically transform the process of international treaty-making.[39] On

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[35] For other treatments of this issue see John Estes, Karen Kline, and Beatrice Labonne, eds. (1996), “Proceedings of the Interregional Seminar of Global Mapping for the Implementation of Multinational Environmental Agreements,” report of a seminar, Santa Barbara, USA, November 13-16, 1996; and Smith System Engineering *et al*, 1995, op. cit.

[36] The view that remote sensing does not infringe on national sovereignity was not always held and probably still is not shared by many states. >From the late 1960s to the mid 1980s there was substantial opposition to the legality of remote sensing. But in 1986 RS proponents succeeded in this debate and the right to collect environmental data from space was affirmed (Uhlir, 1995).

[37] Smith System Engineering *et al*, 1995, op. cit.

[38] United Nations Food and Agriculture Organization, AFRICOVER, http://www.africover.org

[39] Indeed RS data, and particularly data available from commercial satellites, may and almost surely will be used to accelerate the exploitation of natural resources. For example, new marine oil fields can be discovered by measuring the surface movement of water, which is retarded by more viscous oil seeping

the one hand, there are limitations in the ability of remote sensing to accurately measure certain phenomena such as atmospheric air pollution, carbon emissions, and potential carbon sequestration through reforestation or afforestation, though with constantly improving technology the limitations may be overcome. On the other hand, there are political considerations, such as the acceptability of technological approaches to monitoring compliance, particularly among developing countries. RS data are not only costly, but they also require significant technical expertise to be properly interpreted.[40] Such expertise is generally scarce in the developing world, and therefore some countries may feel themselves at a disadvantage when it comes to utilizing "environmental intelligence" for negotiating treaties and protocols or producing national reports. Finally, data requires a receptive human context. RS data on stratospheric ozone depletion was ignored for years until a ground-based team indicated the existence of the depletion problem.[41]

The areas of potential RS use in policymaking are grouped under five headings below: negotiation; compliance and dispute resolution; implementation review; the broader political process; and environmental assessment. When considering these ideas, three dimensions of the question of greater RS data use are important: First, are the data currently available likely to be useful from a pure policy perspective? Second, are the benefits of RS data in a particular use likely to justify the cost of gathering and organizing such data? And third, are the data likely to be accepted and used politically?

• Negotiation

RS technologies may prove extremely beneficial in the creation of environmental commitments. Defining the scope and characteristics of an environmental problem with greater accuracy will help potential parties to an MEA better define necessary and feasible political responses. For example, future protocols to the UN Desertification Convention could benefit from better data about the extent and characteristics of desertification advances and patterns. Similarly, the negotiation of river pollution agreements could benefit from RS data about pollution point sources, and the negotiation of a forest treaty from better data about forest characteristics, such as deforestation and reforestation patterns and rates. In fact, in the 1990s Mexico and Guatemala created a 4-million acre biosphere reserve along their joint border in part due to evidence of tropical forest destruction gained through satellites.[42] RS data sometimes prove that initial assumptions about the state of an environmental problem were inaccurate: for example, satellite data about the fragmentation produced by

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to the surface (Dehqanzada and Florini, 2000). Thus in the race to preserve ecosystems and major environmental systems, the increasing availability and decreasing cost of RS data may or may not prove on balance to be a positive addition from an environmental perspective.

[40] E.g. Dehqanzada and Florini, 2000, op. cit.; David B. Sandalow,"Remote Sensing and Foreign Policy," remarks of the US Assistant Secretary of State, OES at GW University, June 6 2000, see http://www.state.gov/www/policy_remarks/2000/000606_sandalow_satellite.html

[41] Uhlir, 1995, op. cit.

[42] Id.

deforestation in the Amazon basin suggested that damage to biological diversity through habitat destruction was likely to be higher than previously anticipated.[43] In other cases, such as stratospheric ozone depletion, RS data was ultimately instrumental in shaping the negotiation process and subsequent revisions of the international agreement.

• Implementation review
There is evidence that comprehensive and well-functioning systems for the review of MEA implementation are a significant factor in producing effective environmental regimes. Many MEAs now require national reports on implementation, often annual, which feed into these review processes.[44] Annex 1 includes samples of some provisions for monitoring and review contained in the texts of major treaties. RS technology may be able to provide more accurate and rich data about implementation efforts and their environmental effects, as well as about extant environmental or social factors that interact with implementation efforts, such as land-use changes or population growth patterns. This data may help states to understand policy-environment interactions within their own territorial boundaries, and can help link up national level data with regional and global data. RS data can form the basis of more extensive national reports, and can improve national processes of implementation review. RS data may also assist international bodies, such as the many technical committees in the Montreal Protocol, to review and evaluate national reports, implementation efforts and the causes of implementation failures. While typically the international review of national reports is cursory and reported data is taken at face value, there is evidence that review is becoming more intensive in several MEAs, such as CITES and the FCCC.[45] If so, RS data may help international organization evaluate the veracity of national reports and correlate or "correct" reports with other data.

• Compliance and dispute resolution
RS data may foster compliance with MEA obligations in several ways. By bolstering the ability to monitor treaty-relevant behavior, remote sensing can identify instances of non-compliance and deter future non-compliance. For example, for fisheries treaties RS data can provide evidence of illegal fishing. RS data can also enable governments to come into compliance and improve their performance. When used in a cooperative spirit aimed at enhancing performance, acquired data on non-compliance can help outside experts, and officials from other states or from international bodies, assist the non-compliant state in evaluating the causes of non-compliance and in developing remedies to promote compliance. Lack of capacity is often a major source of non-compliance, and better environmental data may help states coordinate and strategically

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[43] David Skole and Compton Tucker (1993), "Tropical Deforestation and Habitat Fragmentation in the Amazon: Satellite Data from 1978 to 1988" *Science.*

[44] For an intensive review of such processes see Kal Raustiala (forthcoming), *Review Institutions in Multilateral Environmental Agreements*, UNEP.

[45] Id.

target their treaty-related expenditures, thus improving compliance. This use of RS data—as a tool to assist states in their efforts to implement MEA rules—is most likely to be accepted by parties to MEAs. If RS data is widely available to the private sector, as it is increasingly becoming, it may also assist private actors in voluntarily achieving compliance with the domestic-level regulations that frequently implement international commitments. The major oil multinational Texaco, for example, is already developing RS capability to help it pursue environmentally-sound internal policies and measures.[46]

Less likely compliance-related roles for RS data include deterrence and dispute resolution. Used as a deterrent form of monitoring, the existence of remote sensing capabilities may persuade states to comply out of fear of discovery. And while the formal dispute resolution procedures that appear in most MEAs are rarely or never used, should this change RS data could potentially perform a useful role in disputes in which environmental damage, transboundary harm, and the like are at issue. Similarly, while actual verification of party compliance with MEAs is not currently a part of any existing MEA, such verification is a part of other international agreements, for example in the area of arms control. Remote sensing could substantially facilitate any verification scheme that might be developed, as would likely attend, for example, the inauguration of joint implementation, emissions trading, the Clean Development Mechanism under the Kyoto Protocol, or for tradable fishing quotas in fisheries MEAs. To work effectively in these roles, however, RS data must appear fair, impartial, and accurate. Given that RS data is often subject to manipulation, processing, and interpretative disagreements, this may not be easy to achieve.[47]

• The broader political process

RS data need not be the exclusive property of governments and international organizations. Data can be useful to private sector actors, whether commercial entities with an interest in their own or competitors' treaty-relevant behavior or non-governmental organizations, such as Greenpeace, interested in using data for their own analyses or advocacy campaigns. Many analysts point to the "democratization" of RS technology as one of the most important impacts of the commercialization and evolution of RS.[48] Image-based data in particular may prove particularly salient and understandable to lay audiences and the general public. The concept of the Antarctic "ozone hole" had great impact on public opinion relating to stratospheric ozone depletion. Depiction of the hole graphically was likely a significant factor in creating this impact. By fostering greater understanding of particular environmental problems, RS data may feed into the broader political process by raising public concern, which is often one of the most critical factors in MEA effectiveness.[49] This impact might be felt in the negotiation phase of an environmental regime or later as new commitments

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[46] Dehqanzada and Florini, 2000, op. cit.

[47] Uhlir, 1995, op. cit.

[48] Dehqanzada and Florini, 2000, op. cit.

[49] See in particular Haas, Keohane and Levy, 1993, op cit.

are contemplated and developed. Greater availability and distribution of some forms of data can be fostered through web-based databases such as those at CIESIN or UNEP/GRID.

• Environmental assessment

Environmental assessments rely heavily on data, and improving the quality and scope of data may significantly improve the quality of assessments. While RS data is already an indirect input to many environmental assessments, making that input more direct could further improve assessment quality. For example, the developers of the VEGETATION sensor have offered to provide free data to the scientific community in support of the Millenium Ecosystem Assessment, a global and regional assessment of the health of key ecosystems. The assessment, in turn, is explicitly tied to several conventions such as the Convention on Biological Diversity, Desertification Convention and Ramsar. RS data can transform the assessment process by expanding the range and detail of environmental data. Assessment of regime impacts and particular projects, such as the pilot phase of joint implementation under the climate convention, may also be enhanced by greater use of RS data. The development of RS data-banks that can be freely accessed by all MEA parties can help parties assess national, regional, and global changes and thus improve their performance (and compliance). Because environmental assessments such as the IPCC are more closely linked to scientific data than any other aspect of international environmental cooperation, assessments may ultimately provide the single most important input for RS data.

ANNEX 1: SELECT MEA PROVISIONS REGARDING MONITORING, REPORTING, REVIEW, & RESEARCH

MEA	Select Provisions
Kyoto protocol to the United Nations framework convention on climate change	· Each party in Annex I shall have in place . . . a national system for the estimation of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by Montreal Protocol. The conference of the parties serving as the meeting of the parties to this protocol shall regularly review and, as appropriate, revise such methodologies and adjustments, taking into account any relevant decisions by the conference of the parties · The information submitted under…by each party included in annex I shall be reviewed by expert review teams… · All parties . . . shall formulate, implement, publish and regularly update national and where appropriate, regional programmes containing measures to mitigate climate change and measures to facilitate adequate adaptation to climate change
Convention on the long-range transboundary air pollution (LRTAP)	· Each contracting party undertakes to develop the best policies and strategies including air quality management systems and, as part of them, control measures compatible with balanced development, in particular by using the best available technology which is economically feasible and low- and non-waste technology · The contracting parties stress the need for the implementation of the existing "Cooperative programme for the monitoring and evaluation of the long-range transmission of air pollutants in Europe" (hereinafter referred to as EMEP) and, with regard to the further development of this programme, agree to emphasize: a) the desirability if the contracting parties joining in and fully implementing EMEP . . . b) the need to use comparable or standardized procedures for monitoring whenever possible . . . c) the desirability of basing the monitoring programme on the framework of both national and international programmes
Montreal Protocol on substances that deplete the ozone layer	· The parties shall assess the control measures…on the basis of available scientific, environmental, technical and economic information · Each party shall provide to the secretariat, within three months of becoming a party, statistical data on its production, imports and exports of each of the controlled substances · The parties at the first meeting shall: d) establish, where necessary, guidelines or procedures for reporting of information

MEA	Select Provisions
Convention on the prevention of marine pollution by dumping of wastes and other matter	· Each contracting party shall designate an appropriate authority or authorities to: c) keep records of the nature and quantities of all matter permitted to be dumped and the location, time and method of dumping . . . d) monitor individually, or in collaboration with other parties and competent international organizations, the condition of the seas for the purposes of this convention · The contracting parties undertake to develop procedures for the assessment of liability & the settlement of disputes regarding dumping
Convention on biological diversity	· Each contracting party shall . . . a) identify components of biological diversity important for its conservation and sustainable use having regard to the indicative list of categories set down . . . b) monitor, through sampling and other techniques, the components of biological diversity identified . . . c) identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity . . . d) maintain and organize, by any mechanism data, derived from identification and monitoring activities · Each contracting party shall, as far as possible and as appropriate . . . c) regulate or manage biological resources important for the conservation of biological diversity . .. g) establish or maintain means to regulate, manage or control the risks associated with the use and release of living modified organisms resulting from biotechnology which are likely to have adverse environmental impacts · Each contracting party...shall: c) promote, on the basis of reciprocity, notification, exchange of information and consultation on activities under their jurisdiction or control which are likely to significantly affect adversely the biological diversity of other states or areas beyond the limits of national jurisdiction · A subsidiary body for the provision of scientific, technical and technological advice is hereby established. . . this body shall: a) provide scientific and technical assessments of the status of biological diversity b) prepare scientific and technical assessments of the effects of types of measures taken in accordance with the provisions of this convention, c) identify innovative, efficient and state of the art technologies and know how relating to the conservation and sustainable use of biological diversity and advise on the ways and means of promoting development and/or transferring such technologies · Each contracting party shall...present...reports on measures which it has taken or the implementation of the provisions of this convention and their effectiveness in meeting the objectives of this convention

MEA	Select Provisions
Convention on wetlands of international importance especially as waterfowl habit (Ramsar)	· Each contracting party shall designate suitable wetlands within its territory for inclusion in a list of wetlands of international importance · Each contracting party shall arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the list has changed . . . information on such changes shall be passed without delay to the organization or government responsible for the continuing bureau duties · Each contracting party shall promote the conservation of wetlands and waterfowl by establishing nature reserves on wetlands, whether they are included in the list or not · The contracting parties shall encourage research and the exchange of data and publications regarding wetlands and their flora and fauna
Convention for the protection of the world heritage cultural and natural heritage (World Heritage)	· It is for each state party to this convention to identify and delineate the different properties situated on its territory · Each state party to this convention shall endeavor, in so far as possible, and as appropriate for each country: b) to set up within its territories, where such services do not exist, one or more services for the protection, conservation and presentation of the cultural and natural heritage . . . c) to develop scientific and technical studies and research and to work out such operating methods as will make the state capable of counteracting the dangers that threaten its cultural or natural heritage . . d) To take appropriate legal, scientific, technical, administrative and financial measures necessary for the identification, protection, conservation, presentation and rehabilitation of this heritage · Each state party...shall... submit to the world heritage committee an inventory of property forming part of the cultural heritage and natural heritage · The world heritage committee shall receive and study requests for international assistance . . . shall decide on the action to be taken . . . [and] shall determine an order of priorities for its operations

MEA	Select Provisions
Convention to combat desertification in those countries experiencing serious drought and/or desertification, particularly Africa	· Each party shall enhance national climatological, meteorological, and hydrological capabilities and the means to provide for drought early warning . . . require regular review of, and progress reports on, their implementation · The parties agree, according to their respective capabilities, to integrate and coordinate the collection, analysis and exchange of relevant short term and long term data and information to ensure systematic observation of land degradation in affected areas and to understand better and assess the process and effects of drought and desertification · The parties shall . . . a) contribute to increased knowledge of the processes leading to desertification and drought and the impact of, and distinction between, casual factors, both natural and human, with a view to combating desertification and mitigating the effects of drought, and achieving improved productivity as well as sustainable use and management resources
Convention on the conservation of migratory species of wild animals	· The parties: a) should promote, co-operate in and support research relating to migratory species, b) shall endeavor to provide immediate protection for migratory species · Each agreement should: b) describe the range and migration route of the migratory species . . . d) establish, if necessary, appropriate machinery to assist in carrying out the aims of the Agreement, to monitor its effectiveness, and to prepare reports for the conference of the parties · Each agreement should provide for but not limited to: a) periodic review of the conservation status of the migratory species concerned and the identification of the factors which may be harmful to that status... c) research into ecology and population dynamics of the migratory species concerned . . . d) the exchange of information on the migratory species concerned · At each of its meetings the conference of the parties shall review the implementation of this convention and may in particular: a) review and assess the conservation statutes of migratory species b) review the progress made towards the conservation of migratory species · The conference of the parties shall establish a scientific council...the functions of the scientific council...may include: a) providing scientific advice to the conference . . . recommending research and the co-ordination of research on migratory species, evaluating the results of such research in order to ascertain the conservation status of migratory species and reporting to the conference of the parties on such status and measures for improvement

MEA	Select Provisions
Draft agreement for the implementation of the provisions of the united Nations on the law of the sea of 10 December 1982 relating to the	· In order to conserve and manage straddling fish stocks and highly migratory fish stocks, coastal states and states fishing on the high seas shall: e) adopt, where necessary, conservation and management measures for species belonging to the same ecosystem or dependent on or associated with the target stock . . . j) collect and share, in a timely manner, complete and accurate data concerning fishing activities on, inter alia, vessel position, catch of target and non-target species and fishing effort · Develop data collection and research programmes to assess the impact of fishing on non-target and associated or dependent species and their environment · States shall enter into consultation... particularly where there is evidence that the straddling fish stocks and highly migratory fish stocks concerned may be under threat of over-exploitation or where a new fishery is being developed for such stock · States shall . . . collect and exchange scientific, technical and statistical data with respect to fisheries for straddling fish stocks and highly migratory fish stocks . . . b) ensure that data are collected in sufficient detail to facilitate effective stock assessment and are provided in a timely manner to fulfill the requirements of subregional or regional fisheries management organizations · Duties of a flag state include . . . g) monitoring, control and surveillance of such vessels, their fishing operations and related activities · A state shall ensure compliance by vessels flying its flag . . . a) enforce such measures irrespective of where violation occur, b) investigate immediately and fully any alleged violation of subregional or regional conservation and management measures · States shall assist each other in identifying vessels reported to have engaged in activities undermining the effectiveness of subregional, regional or global conservation and management measures
Convention on fishing and conservation of the living resources in the Baltic Sea and the Belts	· It shall be the duty of the Commission: a) to keep under review the living resources and the fisheries in the Convention area by collecting, aggregating, analyzing and disseminating statistical data . . . c) to prepare and submit recommendations based as far practicable on results of the scientific research and concerned measures... · The Commission shall draw the attention of any state which is not a party to this convention to such operations, undertaken by its national or vessels in the convention area, which might affect negatively the activities of the commission or the implementation of the purposes of this convention
Agreement for co-operation in dealing with pollution of the north sea by oil and other harmful substances	· Whenever a contracting party is aware of casualty or the presence of oil slicks in the North Sea area likely to constitute a serious threat to the coast or related interests of any other contracting party, it shall inform that other party without delay through its competent authority

ANNEX 2: EXISTING EFFORTS TO UTILIZE REMOTE SENSING FOR GLOBAL OR REGIONAL ENVIRONMENTAL ASSESSMENTS[50]

- Global Observation of Forest Cover (http://www.gofc.org/)
- Millenium Ecosystem Assessment (www.ma-secretariat.org)
- Global Vegetation Monitoring (Space Applications Institute, JRC; http://www.gvm.sai.jrc.it/) including Global Land Cover 2000 (http://www.gvm.sai.jrc.it/LandCover/defaultLandCover.htm), and Tropical Ecosystem Environment Observation by Satellite (TREES; http://www.gvm.sai.jrc.it/Forest/defaultForest.htm)
- Integrated Global Observing Strategy (IGOS; http://www.igospartners.org/)
- AFRICOVER (http://www.africover.org/)
- International Geosphere Biosphere Programme (IGBP; http://www.igbp.kva.se/index.html)

[50] For more information on these initiatives, see the remote sensing and environmental treaties workshop website, "related initiatives" section, at http://sedac.ciesin.columbia.edu/rs-treaties.