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MONITORING GREENHOUSE GASES FROM SPACE AND THE KYOTO PROTOCOL

Masami Onoda
Research Fellow, Japan Society for the Promotion of Science;
PhD. Candidate, Graduate School of Global Environmental Studies, Kyoto University
Kyoto, Japan
masami.naito@gakushikai.jp

ABSTRACT

As the 1997 Protocol to the Framework Convention on Climate Change has become an increasingly significant political agenda, space agencies have initiated satellite programs to respond to the international demands for scientific information. Satellite Earth observation can improve the observation gaps of current carbon observation networks needed as the basis for scientific understanding as required by the UNFCCC and its Kyoto Protocol, a response by Parties to the general and loose obligation to cooperate in systematic observation. For the reporting and reviewing procedures, however, satellite data is not directly applicable at the present stage, since it is difficult to identify anthropogenic emissions or land use changes. Thus, there seems to be little it can do for "compliance monitoring" in the field of climate change. To pursue this kind of a role by satellite Earth observation in the future, it is necessary to alter the present procedures through intensive interaction between policy, science and technology. Further, there is a possibility that satellite data may provide options for the next steps, by providing means to "validate" or "verify" the state of accomplishment of the treaty objectives and to assess the workability of the treaty regime, in the arena of scientific research as the basis for future decision-making.

1. Introduction

International framework based on treaty often constitutes a rationale to promote a national or international activity related to its implementation. On one hand, this could be understood as a positive effect of the treaty, but on the other hand, it could be dangerous to rely on such rationale without careful determination of the specific treaty objectives and obligations in relation to the individual implementation efforts. Correct understanding of the treaty obligations in relation to the surrounding implementation efforts is essential for effective management of such projects and achievement of treaty objectives.

In this regard, the adoption and enter into force of the Protocol to the Framework

Convention on Climate Change (Kyoto Protocol) [1] has accelerated the race between the U.S. and Japan to be the first to launch a greenhouse gases measuring mission. Japan is developing the Greenhouse gases Observing SATellite (GOSAT) [2] and the U.S. is developing the Orbiting Carbon Observatory (OCO)[3]. While these two major space-faring countries are confronted over their policies towards the Protocol, the fact that they have both initiated satellite programs with the aim to observing greenhouse gases from space is highly interesting. GOSAT mission is linked to the "implementation" of the Kyoto Protocol[4], while OCO is mainly scientific.

Some point out, in relation to the Kyoto Protocol, that satellite Earth observation may permit closer monitoring of information that is self-reported by parties and supply information for adjudicating disputes, a Global Earth Observation System of Systems[5] figuring prominently as a means of "monitoring compliance" [6]. Would this prospect still stand, when we look into specific technologies and the role they can play in the present international framework? What are the specific obligations of the Kyoto Protocol that greenhouse gases observation by satellite is relevant to? What are the significances and obstacles of satellite observation in the process of implementation of the Kyoto Protocol? What can we expect as possible developments in this area, in the near future?

To answer these questions, this paper will attempt to provide a case study as to the legal and policy aspects of greenhouse gases monitoring by satellites in relation to the Kyoto Protocol. There are technical limits to the information from satellites as well as programmatic obstacles that prevent the efforts from providing certain information. By considering such limits in light of the specific supervisory techniques required by the legal framework, it should be possible to provide an initial analysis of the legal status of satellite Earth observation in the framework of the Protocol.

The paper will consider existing studies on Kyoto Protocol requirements and possible satellite observation technologies to establish a comprehensive understanding of the issue. Then the significance of the planned two greenhouse gases observing satellites will be examined, in light of their relation to the climate change regime. Through such considerations, we will try to identify, if any, specific obligations to which satellite greenhouse gases monitoring relates to, and the range of compliance or cooperation issues concerned. Based on such considerations, the paper will discuss the potential of satellite observation in international cooperation.

2. The Role of Satellite Observation in Greenhouse Gases Monitoring

"Satellite Earth observation" encompasses a variety of observations performed from space, in parameters observed, technology involved and application. Historically, space-faring nations have launched various Earth observation satellites for land observation, resources monitoring, disaster monitoring, and environmental monitoring. We can start from examining how these existing satellite data have been, or could be applied to international cooperation in the field of climate change.

2.1 Land Observation

A cross-disciplinary study on existing satellite data identifies the following areas where remote sensing[7] technology (land observation) could be applied to the requirements of the Kyoto Protocol (The greenhouse gases considered relevant in the context of remote sensing are CO_2 and CH_4) [8]:

Relevant Provisions in Kyoto Protocol	Corresponding Remote Sensing Technology
Provision of systematic observations of relevant land cover (Articles 5 and 10)	Presently provided at a global level by coarse and medium resolution sensors including NOAA, Landsat, SPOT, Terra, and ADEOS-II sensors
Support to the establishment of a 1990 carbon stock baseline (Article 3)	Historical Landsat, SPOT and JERS-1 SAR
Detection and spatial quantification of change in land cover (Articles 3 and 12)	A the local or regional level, finer resolution data such as Landsat and SPOT required. Space-borne SAR is useful in areas of persistent cloud cover.
Quantification of above-ground vegetation biomass stocks and associated changes therein (Articles 3 and 12)	Airborne LIDAR, polarimetric SAR and VHF band radar for biomass estimation.
Mapping and monitoring of certain sources of anthropogenic CH4 (Articles 3, 5 and 10)	Space-borne SAR and optical data.

Table 1: Kyoto Protocol Requirements and Corresponding Remote Sensing Measurements[9]

The study concludes that, as the Kyoto Protocol requires quantification of afforestation, reforestation and deforestation (ARD)[10], revegetation and land use management[11], and to establish a baseline of carbon stocks for 1990[12], existing and historical remote sensing data could play an important role in supporting the establishment these information.

2.2 Carbon Cycle

On a broader issue of global carbon cycle observation, the report[13] of the Integrated Global Observing Strategy[14] Carbon Theme sets forth a strategy to realize a coordinated system of integrated global carbon cycle observations. The objectives are to provide the long-term observations required to improve understanding of the present state and future behavior of the global carbon cycle, particularly the factors that control the global atmospheric CO_2 level; and to monitor and assess the effectiveness of carbon sequestration and/or emission reduction activities on global atmospheric CO_2 levels, including attribution of sources and sinks by region and sector[15]. It identifies the global observation required, corresponding existing space instruments and potential new missions[16]. Among groundbased observations at monitoring stations, aircraft, ship and other observation networks, satellite observation provides parameters relevant to terrestrial carbon (land cover, land cover changes induced by land use practices, vegetation phenology and bio physical properties, fires, radiation); ocean carbon (surface winds, sea surface temperature, ocean color). Space-based measurement of atmospheric CO_2 using existing long-wave infrared measurements on NOAA[17] satellites and retrieval of CO_2 by short-wave infrared signal from an Envisat[18] sensor are identified as existing possibilities, though these satellite instruments are not launched with the measurement of atmospheric CO_2 concentration as their focus. As the next generation atmospheric CO_2 observation, the report identifies the Orbiting Carbon Observatory (OCO), and the Greenhouse Gases Observing SATellite (GOSAT), using measurements of reflected sunlight in the short-wave infrared or thermal infrared to provide global, high-precision measurements of CO_2. This new development will be discussed in the following.

2.3 Atmospheric Greenhouse Gases Observation

The Greenhouse gases Observing SATellite (GOSAT), planned for launch in August 2008, will monitor CO_2 globally from orbit. It is a joint project of the Japan Aerospace Exploration Agency (JAXA) and the Ministry of Environment (MOE), and the National Institute for Environmental Studies (NIES). It is a satellite to monitor CO_2 and CH_4 globally from orbit, and aims to contribute to the international efforts to prevent global warming, such as the Kyoto Protocol[19].
The mission targets are (i) to observe CO_2 and CH_4 column density at 100-1000km spatial scale, with 1% relative accuracy for CO_2 and 2% for CH_4, during the Kyoto Protocol's first commitment period; and (ii) to reduce sub-continental scale CO_2 annual flux estimation errors by half[20].

This challenging mission certainly has many technical issues to overcome, but scientifically, there would be an important

value of global repetitive data collected over a continuing period. Currently, the profile of greenhouse gas concentration is mapped by some 300 ground and airborne observations, while GOSAT will be capable of providing 56,000 observation points. Such measurement by satellite is expected to significantly enhance the current observation network capability.

Another mission to observe atmospheric greenhouse gas from space is the Orbiting Carbon Observatory (OCO) [21] , a mission of the Earth System Science Pathfinder Project (ESSP) of the National Aeronautics and Space Administration, designed to make precise, time-dependent global measurements of atmospheric CO_2. Using a space-based platform, OCO will collect a far greater number of high resolution measurements which in turn will provide the distribution of CO_2 over the entire globe. OCO will acquire the space-based data needed to identify CO_2 sources and sinks and quantify their variability over the seasonal cycle. The Approach is to: Collect spectra of CO_2 and O_2 absorption in reflected sunlight; Use these data to resolve variations in the column averaged CO_2 dry air mole fraction over the sunlit hemisphere, and to validate measurements to ensure its accuracies of 1-2 ppm (0.3-0.5%) on regional scales at monthly intervals[22]. These measurements will be combined with data from the ground-based network to provide scientists with the information that they will need to better understand the processes that regulate atmospheric CO_2 and its role in the carbon cycle. This enhanced understanding is essential to improve predictions of future atmospheric CO_2 increases and their impact on the climate. This information could help policy makers and business leaders make better decisions to ensure climate stability and, at the same time, retain our quality of life.

The OCO and GOSAT share the same objective of space-based column measurements of greenhouse gases, which will complement the existing surface measurement network. GOSAT measures CO_2, CH_4, O_2, O_3 and H_2O, while OCO measures CO_2 and O_2. GOSAT is a medium size satellite with total mass of 1750kg, carrying two sensors, while OCO is a much smaller satellite of 440kg mass, dedicated to a single spectrometer. Both are in the sun-synchronous orbit, GOSAT's revisit time being 3 days and OCO 16 days. Both satellites are planned for launch in August – September 2008. With such similar missions, the OCO highlights its contribution to climate change research, and GOSAT emphasizes its contribution to international efforts such as the Kyoto Protocol.

3. Relative Obligations in the UNFCCC and Kyoto Protocol

3.1 Kyoto Protocol's Monitoring Procedures

There is a growing need to enhance information for environmental treaties. Provisions for the gathering and dissemination of information appear with great regularity in major multilateral agreements[23]. The modern international agreements build a system of regulation based on "supervisory techniques" [24] to ensure implementation of and compliance to the international obligations. Such supervisory techniques are designed to gather information on the general situation of the field and to create a continuing flow of information on parties' performance of treaty obligations. Most treaty regimes rely on self-reporting by parties, rather than creating a centralized data gathering organization, as a means to ensure this data flow. Incidence of reporting requirements are so high that they seem to be included almost pro forma in many agreements, with little concern about cost or implementing capacity[25].

The Kyoto Protocol also adopts a methodology of information gathering, primarily by way of self-reporting. It is recognized that its effectiveness will depend upon two critical factors: whether Parties follow the Protocol's rulebook and comply with their commitments; and whether the emissions data used to assess compliance is reliable[26]. The Kyoto Protocol and Marrakesh Accords[27] adopted by the first meeting of the

Parties to the Kyoto Protocol (COP/MOP1), include a set of monitoring and compliance procedures to enforce the Protocol's rules, address and compliance problems and avoid any error in calculating emissions data and accounting for transactions under the three Kyoto mechanisms. In the following, such rules will be examined in detail.

The Protocol's monitoring procedures are based on existing reporting and review procedures under the 1992 United Nations Framework Convention on Climate Change (UNFCCC)[28]. Articles 5,7 and 8 of the Kyoto Protocol address reporting and review of information by Parties listed in Annex I of the UNFCCC (Annex I Parties) [29] under the Protocol, as well as national systems and methodologies for the preparation of greenhouse gas inventories.

1) Article 5 commits Annex I Parties to having in place, no later than 2007, national systems for the estimation of greenhouse gas emissions by sources and removals by sinks[30]. Article 7 requires Annex I Parties to submit annual greenhouse gas inventories, as well as national communications, at regular intervals, both including supplementary information to demonstrate compliance with the Protocol.
2) Article 8 establishes that expert review teams will review the inventories, and national communications submitted by Annex I Parties.
3) Article 10 calls for cooperation of the Parties in research and to promote systematic observation systems and development of data archives.

For the purpose of the discussion of this paper, we will examine specifically two methodologies of the Kyoto Protocol monitoring procedures: reporting and review (1 and 2 above), and systematic observation (3 above).

3.2 Reporting and Review

While environmental treaties require constant information to ensure the treaty implementation as well as for further decision-making, the question is how to collect such constant and reliable data. Particularly, with the sensitivity to sovereignty in the international arena, international treaty regimes often rely on self-reporting by the parties[31], the UNFCCC and Kyoto Protocol not being an exception. In this process, reporting is coupled with review, which may lead to appropriate action taken by the Conference of Parties.

The UNFCCC requires that all Parties shall develop, periodically update, publish and make available national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases; and communicate information related to implementation.

The Kyoto Protocol provides that each Annex I Party shall incorporate in its annual inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases the necessary supplementary information for the purposes of ensuring compliance.[32]

Thus, the information to be reported by Parties under these provisions is quite comprehensive and widespread. It includes not only a "national inventory" of anthropogenic emissions by sources and removals by sinks of all greenhouse gases, but also general description of steps taken or envisaged by the Party to implement the Convention, and any other information that the Party considers relevant to the achievement of the objective of the Convention[33], together with information on anthropogenic greenhouse gas emissions by sources and removals by sinks from land use, land-use change and forestry activities under Article 3. 3 of the Kyoto Protocol, and other supplementary information according to Kyoto Protocol Article 7.1. As they will be more detailed, these annual inventories will supersede those currently required under UNFCCC.

The Kyoto Protocol also requires in the "communications" to be included a detailed description of the policies and measures, and

specific estimate of the effects that such policies and measures will have on anthropogenic emissions by its sources and removals by its sinks of greenhouse gasses, together with supplementary information according to Kyoto Protocol Article 7.2. These will be merged with national communications submitted under UNFCCC.

The comprehensiveness and detail of requirements for information under the UNFCCC and Kyoto Protocol indicates the understanding of the significance of reporting requirements, which needs to be matched by the seriousness of purpose and adequacy of resources to implement them[34].

The UNFCCC requires that the information communicated by the Parties shall be reviewed by the Conference of the Parties. The Conference of the Parties shall take appropriate action, which may include adoption of amendments to the required commitments[35]. The Kyoto Protocol specifically requires that the submitted information shall be reviewed by expert review teams, as part of the annual compilation and accounting of emissions inventories and assigned amounts, and of the review of communications. The review process is to provide a thorough and comprehensive technical assessment of all aspects of the implementation by a Party. The expert review teams are to prepare a report to the Conference of Parties, assessing the implementation of the commitments of the Party and identifying any potential problems in, and factors influencing, the fulfillment of commitments[36].

The annual inventory review will be conducted as a desk or centralized review and in addition, each Annex I Party will be subject to at least one in-country visit during the commitment period. If any problems are found, the expert review team may recommend adjusting the data to make sure that emissions during any year of the commitment period are not underestimated. If there is disagreement between a Party and the expert review team about the data adjustment that should be made, the Compliance Committee may intervene. Aside from recommending data adjustments, the expert review team has the mandate to raise any apparent implementation problems with the Compliance Committee. Once the expert review team is satisfied with a Party's annual inventory, the compilation and accounting database will be updated with a record of the Party's emissions for that year[37].

Each national communication submitted under the Protocol will be subject to an in-depth review by an expert review team as well, performed as an in-country visit. The expert review team will prepare a report on its review, including any identified potential implementation problems[38].

3.3 Systematic Observation

The term "systematic observations" [39] first appears in a multilateral treaty in the 1985 Vienna Convention for the Protection of the Ozone Layer (Vienna Convention) [40]. In the Vienna Convention, Parties have agreed to undertake, "in accordance with the means at their disposal and their capabilities" to "Co-operate by means of systematic observations, research and information exchange"[41]. This includes satellite observations and research using satellite data, instrument development and the establishment of an operational observing system integrated with groundbased systems.[42]

The UNFCCC provides that all Parties shall "Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives ..."[43] It also requires that Parties shall support and further develop international and intergovernmental programs and networks or organizations, taking into account the need to minimize duplication of effort[44].

The Kyoto Protocol[45] requires that "Parties shall cooperate in scientific and technical research and promote the maintenance and the development of systematic observation systems and development of data archives... and promote the development and strengthening of endogenous capacities and

capabilities to participate in international and intergovernmental efforts, programs and networks on research an systematic observation, taking into account Article 5 of the Convention".

The Convention's Subsidiary Body for Scientific and Technological Advice (SBSTA) [46] has discussed regularly the item of Systematic Observation. The Conference of Parties (COP) has adopted reporting guidelines[47] on global climate observing systems and invited Parties to provide detailed reports on systematic observation as part of their national communications (on a voluntary basis, in the case of non-Annex I Parties[48]). COP 9 (Milan, December 2003) adopted a decision on global observing systems for climate[49]. This decision calls for the preparation of an implementation plan for global climate observations to be coordinated by GCOS in collaboration with the Group on Earth Observations (GEO)[50]. The implementation plan was submitted to and endorsed by COP 10 (Buenos Aires, December, 2004)[51]. SBSTA 22 (Bonn, May 2005) welcomed the endorsement of the 10-year Implementation Plan at the third Earth Observation Summit in February 2005 which establishes the Global Earth Observation System of Systems (GEOSS) as an important development in systematic observation to contribute to the enhancement of climate change research[52].

The above considerations on monitoring procedures of the Kyoto Protocol, and the UNFCCC which provides the basis for it, indicates that the specific flow of information is designed in two ways. One flow starts with the Parties' self-reporting, going through a review process and providing feedback to Conference of Parties for their decisions on further measures to be taken. According to such decisions, Parties will provide future reports, thus consisting a continuing flow of information. This is a procedure of monitoring of national performances.

The other monitoring procedure is that of international cooperation. Article 4 of the UNFCCC provides that the Parties are committed to "promote and cooperate" in systematic observation to "further the understanding and to reduce or eliminate the remaining uncertainties regarding the causes, effects, magnitude and timing of climate change". In Article 3.3. , it should be understood that systematic observation is intended to provide general information to support Parties' decisions to take precautionary policies and measures to deal with climate change in a cost-effective manner. The Kyoto Protocol essentially repeats the commitments of UNFCCC for systematic observation. Parties are to communicate their activities on systematic observation in their national communications.

4. Present Role, Potential and Implications

The OCO mission is focused on science, which is understandable from the background of U.S. climate change policy[53]. The GOSAT mission, on the other hand, has a certain political focus. In the Long Term Plan of Space Development[54] issued by Space Activities Commission in September 2003, it is stated that Japan shall develop, operate and advance, in cooperation with related institutions, a satellite observation system to observe the global distribution of greenhouse gas concentration, in order to *clarify* the stabilization concentration of CO_2 and other greenhouse gases, and to *verify* the reduction status of greenhouse gases by combination with in-situ data and models etc. For this, the Plan says that Japan shall develop a sensor that will observe the global distribution of greenhouse gas concentration, and by its operation, establish the effectiveness of greenhouse gas observation method by a satellite observation system. It also states that further, so as to enable continuing *monitoring*, Japan will establish a technology basis by which national emissions and removals can be *estimated*[55].

The Mid-Term Plan[56] of JAXA states that GOSAT will be developed with the aim to contribute to administration including *verification* of the statues of greenhouse gases reduction in the first commitment period (2008-2012) of the Kyoto Protocol, in

preparation for global observation of concentration distribution at sub-continental level (relative accuracy approximately 1%).

The Ministry of Environment (MOE) has decided, as some countries did not ratify the Kyoto Protocol to UNFCCC saying that the scientific understanding is not enough, to promote greenhouse gas observation for *validating* national emission inventories and to *understand* the carbon cycle, and to *predict* the future climate including feedback process[57]. It is the belief of the Ministry of Environment and NIES that parallel efforts to reduce the greenhouse gas emission and to *understand* the carbon cycle are very urgent targets of science and technology[58].

In these usages of terms in the political rationale of the GOSAT satellite mission, there seems to be a mixture of focus in "validating (verifying)" "understanding (clarifying, estimating)" and "predicting". Though Kyoto Protocol is silent about "verification" or "validation", this could be understood as part of the review process. "Understanding" and "predicting" are part of the information that is the basis for decisions of Parties, which would be an effort of research and systematic observation.

The role satellite Earth observation can play in the Kyoto Protocol procedures is, however, still limited at the present stage. There are two reasons for this: firstly, most satellite programs are not designed nor operated particularly for use in an international treaty framework. They are aimed to collect data primarily for scientific purposes, or in some cases, operational purposes such as meteorology, which limits their capacity in continuity and adequacy in relation to a specific objective such as that of the Kyoto Protocol. Secondly, the methodology of the Kyoto Protocol is to ensure that "their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases... do not exceed their assigned amount". As discussed in the previous sections of this paper, Parties are to demonstrate and promote compliance to this obligation by submitting and communicating information on their performances as to the treaty obligations. The measurements by Earth observation satellites in themselves do not coincide with such requirements of the Protocol, as it does not provide, for example, "land use" data, but "land cover" data, nor does it distinguish between "human induced" deforestation and otherwise. Such information is only acquired by in-situ information. What can be said at most seems to be that remote sensing would be able to support quantification of the observations required in the Kyoto Protocol procedures.

The estimation guidelines for establishing national inventories are based on calculations of CO_2 equivalence of anthropogenic emissions using global warming potentials as accepted by Intergovernmental Panel on Climate Change[59] and agreed upon by the Conference of Parties. On the other hand, satellite data is not capable of distinguishing between natural or anthropogenic emissions. Even for a satellite mission such as GOSAT that is developed with a certain political focus, this requirement is not easily matched. The first of the GOSAT series is expected to achieve sub-continental estimation of CO2 emissions and removals. National-level estimation is only planned to be achieved by the follow-on missions of GOSAT.

Therefore, it is not realistic to expect satellite data to be able to contribute directly in the reporting and review process of national inventories, or to replace such data in this process in the Kyoto Protocol, as long as the calculating guidelines remain to be based on human-induced CO_2 emissions.

Thus, the role at present and in the foreseeable future of greenhouse gases observations by satellite is, in the context of implementation of Kyoto Protocol obligations, that they can provide an integral part of systematic observation on greenhouse gases (CO_2 and CH_4). This would enhance the quality of information and understanding on the long-term and general status of climate change, thus reducing the uncertainty of the scientific basis of the treaty.

5. Conclusion

Scientifically, satellite Earth observation can improve the observation gaps of current carbon observation networks needed as the basis for scientific understanding as required by the UNFCCC and its Kyoto Protocol. Thus, satellite observation is a response by Parties to the general and loose obligation to cooperate in systematic observation. For the reporting and reviewing procedures, however, satellite data is not directly applicable at the present stage, since it is difficult to distinguish anthropogenic emissions or land use changes induced by human activities from the net value using satellite data. As the UNFCCC and Kyoto Protocol build upon the rights and obligations of States, it is certainly difficult to combine the process with scientific data acquired from space.

Therefore, if we understand "compliance" as the degree of implementation by a Party of obligations of the Kyoto Protocol, that is, in essence, the commitment to reduce anthropogenic emissions of greenhouse gases, there seems to be little that satellite Earth observation can do for "compliance monitoring" in the field of climate change at the present stage. To pursue this kind of a role by satellite Earth observation in the future, it is necessary to alter the present procedures through intensive interaction between policy, science and technology.

However, it is possible only from space to acquire continuous, repetitive and independent data with global coverage by a centralized and standardized system. The role of these upcoming satellites would be to offer systematic observation, enhancing understanding of the present and future situation of greenhouse gases. Further, there is a possibility that satellite data may provide options for the next steps, by providing means to "validate" or "verify" the state of accomplishment of the treaty objectives and to assess the workability of the treaty regime. This would be in the arena of scientific research as the basis for future decision-making.

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4 Japan Aerospace Exploration Agency (JAXA), Plan to Achieve the Mid-term Goal of the Japan Aerospace Exploration Agency, at 11, *available (only in Japanese) at* http://www.jaxa.jp/missions/plan/pdf/mid-term_plan.pdf (last visited Sept. 20, 2006) ; National Institute for Environmental Studies (NIES) Center for Global Environmental Research, GOSAT *brochure, available at* http://www-cger.nies.go.jp/cger-e/e_pub/e_pamph/pamph_index-e.html (last visited Sept. 14, 2006).

5 See generally, Group on Earth Observations, *Homepage, at* http://earthobservations.org/ (last visited Sept. 11, 2005).

6 Molly K Macouley, *Is the Vision of Earth Observation Summit Realizable?*, 21 SPACE POLICY, 29-39 (2005).

7 In this paper, the meaning of "remote sensing" is almost equivalent to "Earth observation". The former could have a broader meaning of detection from a distance regardless the object to be sensed, while the latter focuses on the object of observation, which is the Earth.

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16 *Id.*, at 40-43.

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24 PATRICIA BIRNIE & ALAN BOYLE, INTERNATIONAL LAW & THE ENVIRONMENT 206-211 (2d ed., 2002).

25 CHAYES, *supra* note 5, at 154.

26 *Methodological Issues, Reporting and Review under the Kyoto Protocol, at* http://unfccc.int/national_reports/accounting_reporting_and_review_under_the_kyoto_protocol/items/1029.php (last visited Sept. 14, 2005).

27 Conference of the Parties, Marrakesh, Oct. 29-Nov. 10, 2001, Report of the Conference of the Parties on its Seventh Session, Addendum, Part II: Action Taken by the Conference of Parties, Volume II, at FCCC/CP/2001/13/Add.2 (Jan. 21, 2002).

28 United Nations Framework Convention on Climate Change, May 9, 1992, 1771 U.N.T.S. 107 [hereinafter UNFCCC].

29 *Id.*, at Annex I; Annex I countries include the industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States.

30 Kyoto Protocol, *supra* note 1, at art 5.1.

31 CHAYES, *supra* note 23, at 154.

32 Kyoto Protocol, *supra* note 1, at art 7. 1.

33 UNFCCC, *supra* note 28.

34 CHAYES, *supra* note 23 at 173.

35 UNFCCC, *supra* note 28, at art 4.1. (d).

36 Kyoto Protocol, *supra* note 1, at art 8.1.

37 UNFCCC *Homepage, Reporting and Review, at* http://unfccc.int/national_reports/accounting_reporting_and_review_under_the_kyoto_protocol/items/1113.php (last visited Sept. 18, 2006)

38 *Id.*

39 See Masami Onoda, *Satellite Earth Observation As Systematic Observation in Multilateral Environmental Treaties*, 31 Journal of Space Law 339-411 (2005).

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41 *Id.*, at art. 2.

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43 *Id.*, at art. 4.1. (g).

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55 *Id.* at 10.

56 JAXA, *supra* note 4.

57 NIES, *supra* note 4 at 2.

58 *Id.*, at 3.

59 Intergovernmental Panel on Climate Change, *Revised 1996 Guidelines for National Greenhouse Gas Inventories, available at* http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm (last visited Sept. 30, 2006).