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Satellites, Remote Sensing and Big Data
Legal Implications for Measuring Emissions

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About the Author

Timiebi Aganaba-Jeanty is a post-doctoral fellow with CIGI's International Law Research Program. While at CIGI, she is examining the governance structures addressing global commons environmental issues. Her research focuses on the role of technology solutions and analyzes the evolving legal principles that would be required to regulate the use of emerging and high technologies in the fight against climate change.

Timiebi holds a D.CL. and an LL.M. in aviation and space law from McGill University. Her doctoral thesis received the George S. and Ann K. Robinson Space Law Prize for exhibiting advanced research capabilities and original contribution to space jurisprudence. She has an M.Sc. in space management from the International Space University in Strasbourg, France, an LL.B. from the University of Leicester in the United Kingdom and is called to the Nigerian bar.

About the International Law Research Program

The International Law Research Program (ILRP) at CIGI is an integrated multidisciplinary research program that provides leading academics, government and private sector legal experts, as well as students from Canada and abroad, with the opportunity to contribute to advancements in international law.

The ILRP strives to be the world's leading international law research program, with recognized impact on how international law is brought to bear on significant global issues. The program's mission is to connect knowledge, policy and practice to build the international law framework — the globalized rule of law — to support international governance of the future. Its founding belief is that better international governance, including a strengthened international law framework, can improve the lives of people everywhere, increase prosperity, ensure global sustainability, address inequality, safeguard human rights and promote a more secure world.

The ILRP focuses on the areas of international law that are most important to global innovation, prosperity and sustainability: international economic law, international intellectual property law and international environmental law. In its research, the ILRP is attentive to the emerging interactions among international and transnational law, Indigenous law and constitutional law.

Acronyms and Abbreviations

CCS	carbon capture and storage
CH_4	methane
CNES	Centre National d'Etudes Spatiales
CO	carbon monoxide
CO_2	carbon dioxide
COP	Conference of the Parties
ECV	essential climate variables
ERT	expert review team
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FSA	Facilitative Sharing of Views
GCOS	Global Climate Observing System
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
GHG	greenhouse gas
GPM	Global Precipitation Measurement
IAR	International Assessment and Review
ICA	International Consultation and Analysis
IG3IS	Integrated Global Greenhouse Gas Information System
IPCC	Intergovernmental Panel on Climate Change
JAXA	Japanese Space Agency
MOUs	memoranda of understanding
MRV	monitoring, reporting and verification
NASA	National Aeronautics and Space Administration
NDCs	nationally determined contributions
NOAA	National Oceanic and Atmospheric Administration
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization

Executive Summary

Central to the new regime under the Paris Agreement on climate change is the need to build mutual trust and confidence to promote effective implementation of the agreement. To that end, an "enhanced transparency framework" for action and support is established under article 13(1). This paper poses two important questions: how is transparency enhanced by emerging monitoring technology and measurement techniques; and, are proposed new satellite-enabled approaches to monitoring greenhouse gas (GHG) emissions consistent with article 13(3) of the Paris Agreement, considering that remote sensing of territories and possible sharing of the data, without permission of the state being observed, could be seen as intrusive and contrary to national sovereignty?

This paper introduces evolving measurement techniques and technologies in the context of GHG inventory data collection and reporting and review processes. It assesses the international and national law applicable to emissions monitoring by satellite and how "non-intrusive" has been understood in climate change governance. The paper recommends that increased international cooperation is required to address concerns of new monitoring and measurement techniques, while encouraging access to the information collected. Because the New Delhi Declaration on climate change signals the intent of a group of 60 space agencies to develop an "international, independent system for estimating and curbing anthropogenic GHG emissions," initiators of the declaration should consider institutionalizing a process of work under the declaration and establish a forum in which a wider variety of stakeholders can discuss issues around monitoring emissions and the linkages with climate action. This could feed into the United Nations Framework Convention on Climate Change (UNFCCC) process and leverage other similar initiatives by the World Meteorological Organization (WMO) and the European Commission to support the transparency goals of the Paris Agreement.

Introduction

Decades of wavering political commitment to climate action eroded public confidence in finding a solution to the increasing effects of climate change, as well as to limit future temperature increases. That is, until the momentum and global show of support for the Paris Agreement of the UNFCCC, which entered into force on November 4, 2016, and has been ratified by 169 states parties.[1] The objective of the Paris Agreement, as laid out in its article 2, is to strengthen the global response to the threat of climate change, in part by holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the increase to 1.5°C; and by increasing the ability to adapt to adverse climate impacts and foster low levels of GHG emissions. Article 4(2) calls for the preparation and communication of nationally determined contributions (NDCs) that include mitigation actions that will show progression over time. While the agreement does not set specific, country-based targets, some parties have established their own targets in the NDCs. Climate actions of each party should be linked to measurable emissions reductions to reflect progress nationally and globally regarding the temperature goal. Accurate information on emissions is fundamental because it reveals trends and sets the baseline against which climate action can be marked. The process of determining emissions, as well as information on the implementation and achievement of NDCs, must therefore be transparent.

Transparency in international law is a broad concept that seeks to provide good governance and enhance the overall legitimacy and effectiveness of the international legal system.[2] According to Jutta Brunnee and Ellen Hey, in international environmental governance, "transparency mechanisms serve to foster input and output legitimacy by both promoting transparency *of* governance and using transparency instrumentally

1 United Nations Framework Convention on Climate Change, *Paris Agreement*, 12 December 2015 (entered into force 4 November 2016) [*Paris Agreement*], online: <http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf>.

2 Andrea Bianchi, "On Power and Illusion: The Concept of Transparency in International Law" in Andrea Bianchi & Anne Peters, eds, *Transparency in International Law* (New York: Cambridge University Press, 2013).

for governance."[3] It is focused in part on the degree to which activities and procedures are transparent and the use of instruments to influence conduct, through, for example, the open and participatory nature of deliberations, exchange of information, reporting and compliance.

From a technical standpoint, transparency has a slightly different meaning in the context of GHG emissions inventories. GHG emissions inventories usually contain the total emissions of specific GHGs, originating from all source categories and sinks in a certain geographical area and within a specified time span. Under the UNFCCC's reporting guidelines on annual inventories, transparency is defined to mean "that the assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported information."[4] Under the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, transparency means that "there is sufficient and clear documentation such that individuals or groups other than the inventory compilers can understand how the inventory was compiled and can assure themselves it meets the good practice requirements for national greenhouse gas emissions inventories."[5] From this technical standpoint, transparency therefore calls for the provision of methodologies, data and data sources, assumptions and quantifiable information, which should be clearly explained to facilitate *replication* and assessment of reported information.

Under the Paris Agreement, while developing an NDC is obligatory for each signatory country, there are few legally binding obligations. Central to the regime under the Paris Agreement is the need to build mutual trust and confidence to promote effective implementation of the agreement and, hence, its legitimacy. An "enhanced transparency framework" for action and support is established under article 13(1), the modalities, procedures and guidelines of which are under deliberation by the Ad Hoc Working Group on the Paris Agreement. The purpose of the framework for transparency of action as laid down in article 13(5) is to provide a clear understanding of climate change action, including clarity and tracking of progress toward achieving parties' individual NDCs and parties' adaptation actions under article 7, and informing the global stocktake under article 14.

Subject to "technical expert review" and "multilateral consideration of progress," article 13(7) requests mandatory submission to the UNFCCC Secretariat of a national inventory report, information "necessary to track progress" and of "support provided."[6] On a discretionary basis (as evidenced by the verb "should"), states are to provide information "related to climate change impacts and adaptation," and on "support needed and received." The provision, however, gives no guidance on what form some of this information will take, besides that "national communications, biennial reports and biennial update reports, international assessment and review and international consultation and analysis, shall form part of the experience drawn upon for the development of the modalities, procedures and guidelines" for the transparency framework. Proposals highlight possible structures of reporting guidelines for GHG inventories, information to track progress, technical expert review and multilateral consideration of progress.[7] The required "national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases, prepared using good practice methodologies accepted by the Intergovernmental Panel on Climate Change" is, however, the most concrete area where all states have guidance on a method for tracking the effects of climate action. This is because the information submitted by parties on progress made in implementing and achieving NDCs and the process for participation in a facilitative, multilateral

3 Jutta Brunnee & Ellen Hey, "Transparency and International Environment Institutions" in Andrea Bianchi & Anne Peters, eds, *Transparency in International Law* (New York: Cambridge University Press, 2013).

4 *Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual greenhouse gas inventories*, UNFCCC COPOR, 19th Sess, Annex, UN Doc FCCC/CP/2013/10/Add.3 (2014) at 4.

5 IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, in HS Eggleston et al, eds (Kanagawa, Japan: Institute for Global Environmental Strategies, 2006), online: <www.ipcc-nggip.iges.or.jp/public/2006gl/>.

6 *Paris Agreement, supra* note 1, art 13(12).

7 OECD, Environment Directorate, *Possible Structure of Mitigation Related Modalities, Procedures and Guidelines for the Enhanced Transparency Framework*, prepared by Gregory Briner & Sara Moarif, OECD/IEA Climate Change Expert Group Paper No 2016(5) (2016), online: <www.oecd-ilibrary.org/docserver/download/e070e176-en.pdf?expires=1507756594&id=id&accname=guest&checksum=BFA5ED91E7E4568B8DDE5D4FDA38E8DC>.

consideration of progress regarding achievement of NDCs for all parties are new requirements.[8]

These developments raise the first important question addressed by this paper: how can transparency be enhanced by emerging monitoring technology and measurement techniques? Another issue is whether emissions can be accurately determined as part of transparency efforts under the Paris Agreement. Failure to accurately determine emissions can not only erode trust but lead to a misinterpretation of the progress made in achieving targets, affecting processes such as the global stocktake under article 14, which seeks to assess collective progress toward the objectives of the agreement and to provide countries with the basis for strengthening their actions and submitting new national climate commitments.[9]

Today, a variety of systems exist for monitoring variables that are important to an understanding of the climate system. The Global Climate Observing System (GCOS)[10] defined the 54 atmospheric, oceanic and terrestrial variables known as essential climate variables (ECV).[11] Of the variables being monitored today, half — including rising sea level, water vapour and sea ice extent — largely depend on satellite measurements.[12] The 2016 GCOS Implementation Plan[13] describes a new ECV — anthropogenic GHG fluxes.[14] Actions related to this ECV seek to support national emissions inventories through atmospheric composition observations.[15] The plan also highlights the need for measurement of point-source fluxes from emission sources such as fossil fuel power plants. These measurements, made from space-borne platforms, seek to augment the bottom-up statistical approaches of the IPCC guidelines and allow improved integrated estimates of emissions. Plans have emerged independently from the WMO, the European Commission and a group of 60 space agencies through the New Delhi Declaration to develop such an integrated carbon monitoring system. The first global stocktaking in 2023, proposed under article 14 of the agreement, is expected to benefit from prototype systems that are projected to develop into a more operational system thereafter.

However, challenges to such top-down monitoring could raise concerns regarding parties' rights to provide their own information on emissions. Article 13(3) of the Paris Agreement calls for implementation of the transparency framework in a "facilitative, non-intrusive, non-punitive manner, respectful of national sovereignty." The second important question this paper addresses is whether proposed new satellite-enabled approaches to monitoring GHG emissions are consistent with article 13(3) of the Paris Agreement, considering that remote sensing of territories and possible sharing of the data, without permission of the state being observed, could be seen as intrusive and contrary to national sovereignty. This paper assesses governance instruments that, on the one hand, address concerns about using potentially invasive emerging technology by third parties to get information and, on the other hand, encourage access to this information to enhance transparency and legitimacy. The first part of the paper introduces the broader technologies and the emerging international frameworks to develop them. The second part identifies critical legal issues and suggests governance approaches for sharing the resulting data sets.

8 OECD, Environment Directorate, *Unpacking Provisions Related to Transparency of Mitigation and Support in the Paris Agreement*, prepared by Gregory Briner & Sara Moarif, OECD/IEA Climate Change Expert Group Paper No 2016(2) (2016), online: <www.oecd.org/environment/cc/Unpacking-transparency-provisions-Paris-Agreement-CCXG-May2016.pdf>.

9 Christian Holz & Xolisa Ngwadla, *The Global Stocktake Under the Paris Agreement: Opportunities and Challenges* (Oxford: European Capacity Building Initiative, 2016), online: <www.eurocapacity.org/downloads/GST_2016%5B1%5D.pdf>.

10 The GCOS is sponsored by the WMO, the Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization, the United Nations Environment Programme and the International Council for Science.

11 "Global Observing System", online: WMO <https://public.wmo.int/en/programmes/global-observing-system>.

12 "The Essential Climate Variables", *CEOS EO Handbook — The Important Role of Earth Observation*, online: CEOS <www.eohandbook.com/eohb2011/climate_variables.html>.

13 WMO, *The Global Observing System for Climate: Implementation Needs*, GCOS 2016 Implementation Plan (World Meteorological Organization, 2016) [WMO, *GCOS Implementation Needs*], online: <https://unfccc.int/files/science/workstreams/systematic_observation/application/pdf/gcos_ip_10oct2016.pdf>.

14 A flux is the rate of emission or removal of an atmospheric gas.

15 Stephen Hardwick & Heather Graven, "Satellite Observations to Support Monitoring of Greenhouse Gas Emissions" (2016) Grantham Institute Briefing Paper No 16.

GHG Emissions Monitoring Technologies

Current Methods for Determining Emissions

GHG emissions are reported by states in national inventory reports submitted to the UNFCCC Secretariat, with the data collected by states developed in accordance with IPCC guidance. There are three categories of approaches for determining emissions:[16]

- calculations using statistical information, especially for fossil fuel use;
- satellite measurements of land use through imagery; and
- tracer-transport inversion, a technique based on atmospheric and/or oceanic measurements of the gases and mathematical models of air and water flow.

Each approach developed independently; however, the statistical method for *calculating* emissions is the most widely adopted, because fossil fuel use is the dominant source of carbon dioxide (CO_2) in many developed countries.[17] The IPCC guidelines provide a flexible approach to GHG calculation and are based on a tiered system to consider parties' differing capacities to report. Usually three tiers are provided: Tier 1 is the basic method, Tier 2 intermediate and Tier 3 most demanding in terms of complexity and data requirements. Inventories of the developed countries are advanced because of already existing activity data collected for a variety of public policy reasons. Emissions data is derived from figures calculated using this activity data and emissions factors, especially in the energy sector. For example, in Canada, the combustion of natural gas in a boiler results in emissions of GHGs such as CO_2, carbon monoxide (CO), and nitrous oxide (N2O).[18] Each GHG has published emission factors that relate its emission rates to quantities of natural gas burned. To determine emissions, a facility would need to determine the total quantity of natural gas consumed during the calendar year (using billing records or meter readings) and multiply this quantity by the emission factor for each GHG.

Limitations of Inventories

While the prevailing view is that the quality and breadth of emissions inventories has generally been improving over time, with improvements in the quality of underlying data and emissions factors,[19] national inventories have several limitations in monitoring GHG emissions. As emissions are primarily calculated, and their accuracy depends on the availability of activity data or quality of emissions factors, the quality of inventories varies greatly between countries and contributes to the uncertainty in global estimates. The uncertainty of current regional emissions estimates varies, either by top-down or bottom-up approaches. Using atmospheric measurements, Levin et al showed that some emissions reported to the UNFCCC were underestimated by 70 to 80 percent, emphasizing the need for a further layer of reviewing emissions estimates.[20] Questions have recently been raised about the decreasing accuracy of these estimates at the global level for fossil fuel and industrial emissions, due to the increase in emissions from countries with less accurate statistics.[21] But, even in advanced countries, inventories also require revisions, especially for more heterogeneous and dispersed sources such as methane (CH_4) from waste management and pipeline transmission, which are more difficult to estimate. For example, German CH_4 emissions for 2001 reported to the UNFCCC were revised upward substantially, resulting in an increase of reported CH_4 emissions by approximately 70 percent for

16 National Research Council of the National Academies, *Verifying Greenhouse Gas Emissions: Methods to Support International Climate Agreement* (Washington, DC: The National Academies Press, 2010).

17 *Ibid*.

18 Environment and Climate Change Canada, "Technical Guidance on Reporting Greenhouse Gas Emissions", online: Government of Canada <www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=47B640C5-1&offset=5&toc=hide>.

19 OECD, Environment Directorate, *Identifying and Addressing Gaps in the UNFCCC Reporting Framework*, prepared by Jane Ellis & Sara Moarif, OECD/IEA Climate Change Expert Group Paper No 2015(7) (2015), online: <www.oecd-ilibrary.org/docserver/download/5jm56w6f918n-en.pdf?expires=1508767206&id=id&accname=guest&checksum=55A70C4F91F3D0B3C6F6EE5B312DBD93>.

20 I Levin et al, "The Global SF6 Source Inferred from Long-Term High Precision Atmospheric Measurements and its Comparison with Emission Inventories" (2010) 10:6 Atmospheric Chemistry & Physics 2655.

21 WMO, *GCOS Implementation Needs*, *supra* note 13.

the whole-time series 1990–2001.[22] While this may appear to be an isolated occurrence, according to Ray Weiss and Ronald Prinn, "the discrepancies are large enough to call into serious question the reliability of the emission factors that are used in bottom-up emissions accounting, the many significant digits with which these emissions are typically reported, and the viability of GHG emissions reduction legislation that depends solely on bottom-up reporting procedures."[23]

Inventories are generally trusted, but the issue of inflating emissions for the base year or understating emissions for a commitment period year is understudied. Based on 2010 data, Alexander Zahar assessed the general direction states moved under scrutiny by an expert review team (ERT) of emissions inventories under the Kyoto Protocol.[24] The findings were that dialogue between states and the ERT during the review led to voluntary revision of initial estimates. Of the 37 Annex B parties[25] whose base-year estimates were subject to review, 34 revised their estimates or had them adjusted during the review. Of the 34 cases, 23 (62 percent of the total) led to a reduction in the base-year estimate — they had advantageously initially over-reported emissions in the base year (30 percent under-reported). What is conclusive from this is that the review process is vital and that as more actors are required to report on emissions, there could be room for improvement in the monitoring approaches for all actors.

Could implementation of the Paris Agreement benefit from internationally accepted data or process to supplement current methods, not only to support states but also to facilitate international review? What new internationally agreed frameworks would be necessary to support the adoption of innovative technologies that could create an internationally accepted set of measurement data or techniques? Article 10(5) of the Paris Agreement places an emphasis on "accelerating, encouraging, and enabling innovation," which is "critical for an effective, long-term global response to climate change and promoting economic growth and sustainable development." The focus thus far has been on energy innovations in areas such as renewables, but climate action legislation often also calls for reduction targets requiring an objective understanding of baselines and industrial reporting programs, which both require continuous monitoring and verification. Toward the goal of transparency, the technique of atmospheric measurement would require additional investment in research and technologies, increasing the density of well-calibrated atmospheric GHG measurements and improving atmospheric transport modelling and data assimilation capabilities.[26] This could help improve application of the existing regulatory frameworks to support climate action by bringing to light the efficiency challenges of emissions reduction programs.

Emerging International Frameworks

"Systematic Observation" as a Global Endeavour

"Systematic observation" was adopted in article 4(1)(g) of the UNFCCC.[27] It calls for an approach of *integrated* data collection to gather crucial information for decision making by the international community. The ninth Conference of the Parties (COP 9) to the UNFCCC adopted a decision calling for the first implementation plan for global climate observations to be coordinated by the GCOS, leading to a decision on "research and systematic observation" at

22 P Bergamaschi et al, "Inverse Modelling of National and European CH_4 Emissions Using the Atmospheric Zoom Model TM5" (2005) 5 Atmospheric Chemistry & Physics 2431.

23 Ray F Weiss & Ronald G Prinn, "Quantifying Greenhouse-Gas Emissions from Atmospheric Measurements: A Critical Reality Check for Climate Legislation" (2011) 369 Philosophical Transactions: Mathematical, Physical & Engineering Sciences Volume 1925.

24 Alexander Zahar, "Does Self-Interest Skew State Reporting of Greenhouse Gas Emissions? A Preliminary Analysis Based on the First Verified Emissions Estimates Under the Kyoto Protocol" (2010) 1:2 Climate L 313; *Review of First Communications from the Parties included in Annex 1 to the Convention*, COP Dec 2/CP.1, UNFCCC COPOR, 1st Sess, UN Doc FCCC/CP/1995/7/Add.1 (1995) 7; *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, 10 December 1997, UN Doc FCCC/CP/1997/7/Add.1, 37 ILM 22 (entered into force 16 February 2005) [Kyoto Protocol].

25 Group of countries included in Annex B of the Kyoto Protocol that agreed to a target for their GHG emissions.

26 Phil DeCola & WMO Secretariat, "An Integrated Global Greenhouse Gas Information System (IG3IS)" (2017) 66:1 WMO Bulletin, online: <https://public.wmo.int/en/resources/bulletin/integrated-global-greenhouse-gas-information-system-ig3is>.

27 UNFCCC, *Report of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change on the work of the second part of its fifth session, held at New York from 30 April to 9 May 1992*, UN Doc A/AC.237/18 (Part II)/Add.1, 1771 UNTS 107, 31 ILM 849 (entered into force 21 March 1994).

COP 10.[28] The trend is now toward developing enhanced technical capabilities for these fully integrated information systems.

In June 2015, the seventeenth World Meteorological Congress passed a resolution initiating the development of an Integrated Global Greenhouse Gas Information System (IG3IS) to be an information source and framework that will join atmospheric GHG composition and flux measurements and other observations (the "top-down") with socio-economic emission inventory data (the "bottom-up").[29] Technically, atmospheric concentrations of CO_2 and CH_4 are in part determined by the transport and mixing of air. To estimate the spatial distribution and magnitude of CO_2 and CH_4 fluxes using atmospheric concentration measurements, models of atmospheric transport including wind speed and other meteorological data must be included. The WMO IG3IS project therefore sought to establish the methodological standard for how atmospheric transport inverse model analysis of atmospheric GHG concentration measurements can be combined with emissions inventory data to better inform and manage emissions reduction policies and measures.

As of 2017, the IG3IS project seeks the following objectives:

→ to reduce uncertainty of national emissions inventories reporting to UNFCCC;

→ to locate and quantify previously unknown emissions reduction opportunities such as fugitive methane emissions (i.e., emissions of gases or vapours from pressurized equipment due to leaks and other unintended or irregular releases of gases, mostly from industrial activities);

→ to provide subnational entities, such as large urban source regions (megacities), with timely and quantified information on the amounts, trends and attribution by sector of their GHG emissions to evaluate and guide progress toward emissions reduction goals; and

→ to support the Paris Agreement's global stocktake.[30]

The long-term WMO vision, based on its concept note, is for a GHG analysis and forecast system that will incorporate multiple coordinated satellites, aircraft, balloons and ground observations, together with inventory data in a system of systems.[31]

The WMO provides a road map that states can follow to reduce emissions inventory uncertainties and situational awareness, and it outlines new mitigation opportunities as part of the IG3IS project.[32] This effort will require partnerships with the national emissions inventory agencies for a priori emissions information and uptake of results, with municipalities for urban statistics and uptake of results, and with environmental protection agencies for joint development of a high-density urban network because many surface stations are located too far from intense natural and anthropogenic sources to enable robust determination of global trends and seasonal cycles.[33]

Awareness by policy makers of the discrepancies found between reported bottom-up emissions and emissions determined from atmospheric measurements has, so far, been limited. The WMO highlights certain countries as case studies for the measurement approach, including Australia, New Zealand, Switzerland and the United Kingdom.[34] The United Kingdom's second biennial report, for example, highlights the use of an atmospheric modelling technique to verify the emissions levels and trends reported in the GHG inventory. The UK Department of Energy & Climate Change maintains a research program of high-frequency, high-precision measurements of atmospheric trace gases in one of its research stations. The observations enable estimates of UK emissions to be derived using an inverse modelling technique, which links its national meteorological office's atmospheric

28 *Global observing systems for climate*, Dec 11/CP.9, UNFCCC COPOR, 9th Sess, UN Doc FCCC/CP/2003/6/Add1 (2004) 20; *Buenos Aires Programme of Work on Adaptation and Response Measures*, Dec 1/CP.10, UNFCCC COPOR, 10th Sess, UN Doc FCCC/CP/2004l10lAddl (2005) 2.

29 WMO & United Nations Environment Programme, *Concept paper annotated outline*, EC-68/Doc 4.5(1), online: <www.wmo.int/pages/prog/arep/gaw/ghg/documents/EC_68_ConceptPaper_IG3IS_DRAFT_V14.pdf>.

30 DeCola & WMO Secretariat, *supra* note 26.

31 WMO & United Nations Environment Programme, *supra* note 29.

32 Oksana Tarasova, "Progress with the Implementation of an Integrated Global Greenhouse Information System (IG3IS)", online: WMO <www.wmo.int/pages/prog/sat/meetings/documents/IPET-SUP-3_Doc_08-06_IG3IS-ppt.pdf>.

33 National Research Council of the National Academies, *supra* note 16.

34 Oksana Tarasova & Phil DeCola, "Integrated Global GHG Information System (IG3IS): Evidence Based Policy Support and Evaluation", online: WMO <www.wmo.int/pages/prog/sat/meetings/documents/IPET-SUP-2_Doc_09-05_Oksana-IG3IS-ppt.pdf>.

dispersion model and independently verifies bottom-up (inventory) emissions estimates.[35]

In a similar move toward integrated services, the European Commission has proposed the "European integrated observation system dedicated to the monitoring of fossil CO_2 emissions using independent atmospheric observations."[36] The proposed system consists of a suite of coordinated multi-scale, multi-type carbon observations, a data assimilation system capable of integrating the suite of observations as well as an appropriate data infrastructure and distribution system. The observations would include energy data, emissions factors and an observational infrastructure component including aircraft, satellite and *in situ* data, and a decision support system. The rationale for this project is that "such a capacity would provide the European Union with a unique and independent source of actionable information, which would address multiple stages of the policy cycle. This would include: in the definition phase, an overview of baseline reference conditions and interpretation of the spatial/geographic implications of proposed targets, in the implementation phase, critical independent information relating to monitoring, reporting and verification activities and, finally, in post-evaluation exercises on the impacts of the implemented policies."[37]

The Case for Satellite Sensors

A high level of uncertainty is associated with satellite-based inverse flux estimates, due to the limitations of currently available satellite observations. However, with new commercial satellite systems that potentially can measure GHG emissions from sources on the scale of industrial facilities,[38] and game changers such as NASA's Geostationary Carbon Cycle Observatory (known as GeoCARB) mission, set to launch around 2022 (and which will measure the daily total concentration of CO_2, CO and CH_4 in the atmosphere, with a horizontal ground resolution of 3–6 miles [5–10 kilometres]),[39] it is only a matter of time until more accurate remote attribution data become available.[40] Satellite earth observation is powerful for its ability to monitor the entire earth remotely, without needing permission from the sensed territory, or to have a uniform dataset. The focus of this paper is on satellite measurements of atmospheric concentrations and estimating fossil fuel CO_2 emissions as an emerging capability, as against the existing use of satellite imagery primarily for land-use monitoring. However, as land-use change is the second-largest source of anthropogenic GHG emissions (after fossil fuel combustion), attention to developments in this area is also important.[41]

Situations in which additional sensors from space would be beneficial in GHG emissions monitoring include the following:

→ Large-scale fugitive emissions of CH_4. The findings of a 2017 study by the Alberta Energy Regulator and Green Path Energy found that the oil and gas industry is under-reporting methane emissions in Alberta.[42] In fact, "the actual emissions at oil and gas facilities from pneumatic devices are 60 per cent higher than estimates used to compile Canada's GHG inventory."[43]

35 UK, Department of Energy and Climate Change, *The UK's Second Biennial Report under the United Nations Framework Convention on Climate Change* (London: Department of Energy and Climate Change, 2015) at 26, online: <www.gov.uk/government/uploads/system/uploads/attachment_data/file/491405/UK_Second_Biennial_Report_Web_Accessible.pdf>.

36 EC, *Towards a European Operational Observing System to Monitor Fossil CO_2 Emissions: Final Report from the Expert Group* (Brussels: EC, 2015), online: <edgar.jrc.ec.europa.eu/news_docs/CO_2_report_22-10-2015.pdf>.

37 *Ibid*. In support of access to this information, Europe has a regulatory framework that supports the dissemination of information by fostering "open data" for "environment" purposes. The INSPIRE Directive aims to create an EU spatial data infrastructure for the purposes of EU environmental policies or activities that may have an impact on the environment. Also, the PSI Directive encourages EU member states to make as much public-sector information available for re-use as possible. See EC, *Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)*, [2007] OJ, L 108/1; *Directive 2003/98/EC of the European Parliament and of the Council of 17 November 2003 on the re-use of public sector information*, [2003] OJ, L 345/90.

38 See GHGSat homepage, online: <www.ghgsat.com/>.

39 National Aeronautics and Space Administration (NASA), Press Release, "NASA Announces First Geostationary Vegetation, Atmospheric Carbon Mission" (6 December 2016), online: <www.nasa.gov/press-release/nasa-announces-first-geostationary-vegetation-atmospheric-carbon-mission>.

40 Ray Nasser, "Space-based Measurements to Quantify Anthropogenic CO_2 and CH_4 Emissions", online: <http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/15647/2604456/191-bd0a81fe7f3b09692172638a5915c012_NassarRay.pdf>.

41 Hardwick & Graven, *supra* note 15.

42 GreenPath Energy Ltd, *GreenPath 2016 Alberta Fugitive and Vented Emissions Inventory Study* (commissioned by the Alberta Energy Regulator, 2017), online: <www.greenpathenergy.com/wp-content/ uploads/2017/03/GreenPath-AER-Field-Survey-Results_March8_Final_JG.pdf>.

43 Environmental Defence, *Canada's Methane Gas Problem: Why Strong Regulations Can Reduce Pollution, Protect Health, and Save Money* (Toronto: Environmental Defence, 2017), online: <environmentaldefence.ca/wp-content/uploads/2017/04/17-72_MethaneLeaks_Primer_FINAl.pdf>.

- → Various requirements for the quantification of emissions released during carbon capture and storage (CCS). The requirements include CCS site characterization, emissions modelling, assessment of the risk of emissions leakage and actual emissions monitoring.[44]
- → For estimating fossil fuel CO_2 emissions using satellite CO_2 data, detection of large-scale point sources, such as industries, power plants and megacities.[45]

In both the WMO and European Commission proposals highlighted above, the projects could be augmented through access to an "international, independent system for estimating and curbing anthropogenic GHG emissions."[46] Such a system was proposed as part of the New Delhi Declaration signed by 60 space agencies in April 2016.[47] The declaration calls for "evolving space-based operational tools combining in-situ measurements and increased computing resources" and cooperation to "cross-calibrate instruments and cross-validate measurements." This new initiative follows on from the Mexico Declaration in September 2015 by heads of space agencies, which stated that "satellite observations are the key element of a global measuring system aimed at verifying the reality of commitments taken in line with the United Nations Framework Convention on Climate Change."[48] The claim is that "a comprehensive, coordinated and inclusive global data set would help further global understanding and is a necessary step in establishing an international approach to estimating emission changes for global use based on internationally accepted data."[49] The New Delhi Declaration creates no legally binding obligation under international law, but represents the consensus of 58 states (and two multilateral institutions) and a possible intent to develop space-related projects to support the Paris Agreement objectives. This declaration can shape the practice of states and other actors, as the heads of space agencies from around the world have reaffirmed their commitment to work together within a coordinated international framework with users, service providers and policy makers.

The 2006 IPCC guidelines on national inventories recognize that an ideal condition for verification of inventories is the use of fully independent data as a basis for comparison, but they are conservative about applying atmospheric measurement techniques using satellite and other remotely sensed data sources.[50] However, current efforts for a planned 2019 methodological update to the 2006 IPCC guidelines to improve guidance for countries on verification procedures highlights that the 2006 guidance is outdated, and that there is a need to discuss various ways to verify emissions estimates in the context of the latest science, with case examples of atmospheric concentration data, independent monitoring of carbon stocks and fluxes and other approaches.[51] The European Commission envisions an operational phase of its system with a level of accuracy compliant to policy needs only by the mid 2030s. That time frame reflects the state of technology and international ambition of governemnt actors as it stands today. However, near-term initiatives in the private sector are something to be watched.[52]

44 CO_2 Capture Project, "CCS Browser: A Guide to CO_2 Capture and Storage", online: <www.ccsbrowser.com/#>.

45 Hardwick & Graven, *supra* note 15.

46 Centre National d'Etudes Spatiales (CNES), Press Release, "New Delhi Declaration Comes into Effect – World's Space Agencies Working to Tackle Climate Change" (18 May 2016), online: <https://presse.cnes.fr/en/new-delhi-declaration-comes-effect-worlds-space-agencies-working-tackle-climate-change>.

47 Declaration of New Delhi, May 2016, "Heads of Space Agencies Decide to Join Efforts in Support of COP 21 Decisions" (3 April 2016), on file with author [New Delhi Declaration]; CNES, *supra* note 46. The 58 countries are Algeria, Argentina, Australia, Austria, Azerbaijan, Belgium, Belarus, Bolivia, Brazil, Canada, Chile, China, Colombia, Czech Republic, Denmark, Ecuador, Egypt, Estonia, Finland, France, Gabon, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Kazakhstan, Luxembourg, Malaysia, Mexico, Morocco, Netherlands, Nigeria, Norway, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Turkey, Ukraine, United Arab Emirates, United Kingdom, United States (NASA-NOAA-CEOS), Vietnam, Thailand; and two institutions: the International Academy of Astronautics and the European Space Agency.

48 International Academy of Astronautics, *Summit Declaration* (18 September 2015), online: <iaaweb.org/iaa/Scientific%20Activity/declarationmexico.pdf>.

49 New Delhi Declaration, *supra* note 47.

50 IPCC, *supra* note 5, Chapter 6: Quality Assurance/Quality Control and Verification, online: <www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_6_Ch6_QA_QC.pdf>. It states: "It should be recognized that the complexity as well as the limited application potential of atmospheric models to inventory verification, particularly at a national level, can restrict their utility to many inventory compilers." The guidance continues by cautioning that "the uncertainties associated with the atmospheric models themselves may not be sufficiently quantified or may be too large for the model to be used effectively as a verification tool."

51 Phil DeCola et al, "Integrated Global GHG Information System (IG3IS): Evidence Based Policy Support and Evaluation: Paris Agreement on Climate Change" (2016), online: <www.wmo.int/pages/prog/arep/gaw/ghg/documents/IG3ISOverviewCharts_October2016.pdf>.

52 Networks of Centres of Excellence in Canada, "Monitoring Greenhouse Gases from Space" (2016), online: <www.nce-rce.gc.ca/Research-Recherche/Stories-Articles/2017/MonitoringGreenhouse-SurveillerEmissions_eng.asp>.

Legal Issues

Consistency with the Paris Agreement?

Article 13(3) of the Paris Agreement calls for implementation of the enhanced transparency framework in a "facilitative, non-intrusive, non-punitive manner, respectful of national sovereignty." As noted above, an important question is whether proposed new satellite-enabled approaches to monitoring GHG emissions are consistent with article 13(3), considering that remote sensing of territories and possible sharing of the data, without permission of the state being observed, could be seen as intrusive and contrary to national sovereignty. How does international law permit this activity, and what have been some conditions to support the principle of non-intrusiveness in climate change governance?

"Facilitative, Non-intrusive, Non-punitive Manner, Respectful of National Sovereignty"

Under the existing transparency framework regarding the assessment/consultations, there are separate processes for developed countries — International Assessment and Review (IAR) — and developing countries — International Consultation and Analysis (ICA)/Facilitative Sharing of Views (FSA).[53]

Transparency mechanisms can be contentious for several reasons, based on the concern that information revealed through transparency procedures could be used against parties to challenge their implementation of NDCs. These dynamics have been evident in UNFCCC debates over ICA of voluntary developing country mitigation actions, and monitoring, reporting and verification (MRV) relating to REDD+ (reducing emissions from forest-related activities).[54] Under these mechanisms, similar language to article 13(3) is used. The ICA is to be "non-intrusive, non-punitive and respectful of national sovereignty [of non-Annex 1 parties], and does not include… discussion about the appropriateness of [their] domestic policies and measures."[55] For REDD+, the guidelines and procedures for technical assessment do not go beyond a "facilitative, non-intrusive, technical range of information," as the assessment team "shall refrain from making any judgement on domestic policies taken into account in the construction of forest reference emissions levels."[56] In both of these examples there is an emphasis that domestic policies should not be discussed as part of the review, to meet the non-intrusive requirement. The WMO project discussed above highlights an approach that supports domestic processes, that "the IG3IS effort is aimed at improving the granularity of observations and analyses, *in order to support* the planning and management of Intended Nationally Determined Contribution (INDC) mitigation efforts by nations."[57]

Under the enhanced transparency framework of the Paris Agreement, all parties participate in a common system of review and multilateral consideration of process, but there is flexibility in scope for those developing countries that need it. But, as article 13(11) and (12) of the Paris Agreement emphasizes *achievement* of NDCs, the proposed outcome appears to go beyond simply sharing views, which could support using independent remote-sensed data to supplement existing statistical systems. The experience of the Kyoto Protocol is instructive. One shortcoming of the ERT process under the Kyoto Protocol is that while the ERT may use relevant technical information in

53 *The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention*, Dec 1/CP.16, UNFCCC COPOR, 16th Sess, UN Doc FCCC/CP/2010/7/Add.1 (2011) at 2, online: <unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2>. The IAR process comprises two steps: a technical review of the national reports of each developed country, followed by the multilateral assessment of the progress toward achieving the economy-wide target by developed-country parties, see UNFCCC, "The International Assessment and Review Process", online: <http://unfccc.int/focus/mitigation/the_multilateral_assessment_process_under_the_iar/items/7549.php>. The ICA process comprises two steps: a technical analysis of Biennial Update Report by a team of experts and a facilitative sharing of views in the form of workshop under the Subsidiary Body for Implementation, see UNFCCC, "International Consultation and Analysis for Non-Annex I Parties", online: <unfccc.int/national_reports/non-annex_i_parties/ica/items/8621.php>.

54 Michael Mason & Aarti Gupta, "Transparency" in Karin Bäckstrand & Eva Lövbrand, eds, *Research Handbook on Climate Governance* (Cheltenham: Edward Elgar, 2015) at 446–57.

55 *Composition, modalities and procedures of the team of technical experts for undertaking the technical analysis of biennial update reports from Parties not included in Annex I to the Convention*, UNFCCC COPOR, 19th Sess, Annex, UN Doc FCCC/CP/2013/10/Add.2/Rev.1 (2013) 14 at para 1, online: <www.ciesin.columbia.edu/repository/entri/docs/cop/FCCC_COP19_dec20.pdf>.

56 *Guidelines and procedures for the technical assessment of submissions from Parties on proposed forest reference emission levels and/or forest reference levels*, UNFCCC COPOR, 19th Sess, Annex, UN Doc FCCC/CP/2013/10/Add.1 (2014) 36 at paras 1, 4, online: <unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=34>.

57 WMO, "Integrated Global Greenhouse Gas Information System (IG3IS)" online: <www.wmo.int/pages/prog/arep/gaw/ghg/IG3IS-info.html>.

the review process,[58] not only is the availability of independent data to check self-reported emissions limited, but Zahar stipulates that the ERT are prohibited from using data from a non-state source to verify reports, if that data was not formally supplied to that source by the authorities of the state under review.[59] Essentially, the review is more a review of compliance with IPCC guidelines and consistency within a state rather than a mechanism to test the claims of emissions reductions.

Jane Ellis et al highlight measures to ensure a non-intrusive process and approaches that can help ensure a process is respectful of national sovereignty:

- → formalized procedures for continued communication;
- → providing opportunities for the country concerned to comment on review results;
- → limiting the distribution of results;
- → establishing a clear mandate, and potentially also a mutually agreed set of criteria, upon which to measure progress; and
- → taking account of the implications of each country's legal and political systems and the needs and views of the country concerned.[60]

If such international independent data becomes available, at an accuracy level that is acceptable, states would need to consider how it should be used. Either a process would need to be agreed to feed the data into the review process, or states could use it to support their own submissions. The mandate and governance of the institution with ownership over the data would be a consideration, as well as the international legal framework that governs the activity of the data collection, especially the guarantees it provides regarding data sharing.

International Regulation for Remote Sensing Satellite Technology

The significance of international law in relation to monitoring Earth is found in three major principles of international space law. First, the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty) states that the exploration and use of outer space (including the moon and other celestial bodies) are to be carried out for the benefit and interests of all countries, and shall be "the province of all mankind."[61] Second, the treaty calls for international cooperation and for due regard to interests of all other states in carrying out activities of states.[62] However, space is subject to the principles of free exploration and use of outer space, which is the principle that has enabled states to perform global observations of the earth without permission of the state being observed.[63] The global standard for satellite earth observation *data policy* regulation is laid down in the United Nations General Assembly 1986 Principles Relating to Remote Sensing of the Earth from Space (Remote Sensing Principles).[64] The principles themselves are not legally binding, being a General Assembly resolution, but to the extent that they represent state practice, they have considerable weight. The territory being monitored, referred to as the "sensed state," has no veto to prevent it from being "sensed,"[65] or even an exclusive, free or preferential right of access to the data as a result of article 1 of the Outer Space Treaty, which allows states to observe other states from the non-sovereign

58 *Guidelines for Review under Article 8 of the Kyoto Protocol*, Draft Dec -/CMP.1, UNFCCC COPOR, advance unedited version, at para 66, online: <https://unfccc.int/files/meetings/cop_11/application/pdf/cmp1_08_guidelines_for_review_art8.pdf>.

59 Alexander Zahar, "Verifying Greenhouse Gas Emissions of Annex 1 Countries: Methods We Have and Methods We Want" (2010) 1:3 Climate L 409, citing UNFCCC Secretariat, *Handbook for Review of National GHG Inventories* [nd], ch 2 at 11–12.

60 OECD, Environment Directorate, *Design Options for International Assessment and Review (IAR) and International Consultations and Analysis (ICA)*, prepared by Jane Ellis et al, OECD/IEA Climate Change Expert Group information paper, Doc No COM/ENV/EPOC/IEA/SLT(2011)4 (2011), online: <www.oecd.org/env/cc/49101052.pdf>.

61 *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, 610 UNTS 205, 6 ILM 386 art 1 (entered into force 10 October 1967) [Outer Space Treaty].

62 *Ibid*, art 9.

63 *Ibid*, art 1.

64 *Principles relating to remote sensing of the earth from outer space*, GA Res 41/65, UNGAOR, 1986, UN Doc A/RES/41/65.

65 Note, however, that states can make agreements between themselves. For example Section 1064, Public Law No. 104-201, (the 1997 Defense Authorization Act) referred to as the Kyl-Bingaman Amendment, requires that "a department or agency of the United States may issue a license for the collection or dissemination by a non-Federal entity of satellite imagery with respect to Israel only if such imagery is no more detailed or precise than satellite imagery available from commercial sources." "Commercial sources" here refers to non-US firms.

vantage point of space. However, according to principle XII of the Remote Sensing Principles, as soon as the primary (raw) data and the processed data concerning the territory under its jurisdiction are produced, the sensed state shall have access to them on a non-discriminatory basis and on reasonable cost terms. The sensed state shall also have access to the available analyzed information concerning the territory under its jurisdiction in the possession of any state participating in remote sensing activities on the same basis and terms, particular regard being given to the needs and interests of the developing countries.

In other words, for a particular set of remote sensing data concerning its territory, the "sensed state" does not differ from any other state engaged in remote sensing activities. While Atsuyo Ito argues that the common interpretation of non-discriminatory access is that the sensing states have the obligation to provide the data to the sensed states under the same conditions as other states that wish to access the data,[66] there may be an argument that a third-party state (neither the sensing state nor the sensed state) may be in a different position — that they would have no right (either discriminatorily or not) to the data. So, for example, if Canada is sensing Mongolia, China doesn't have a "right" to that data, whereas Mongolia does, as a denial of such a request could be considered contrary to the Remote Sensing Principles.[67] However, according to another interpretation, some argue that "[a]lthough Principle XII appears to give privilege to sensed States as far as access to data is concerned, on the ground that after all remote sensing does interfere with sovereign rights of the sensed State, on closer examination the privilege does not extend very far, as there is only access 'on a nondiscriminatory basis.' It follows that the observing state may retain data if it does this on equal terms in relation to any other state."[68] Implementation of the Remote Sensing Principles on the national level takes different forms, ranging from a focus on the satellite system, the data, the transaction or a combination of these.[69] Practical experience has shown that access to Earth observation data is ultimately subject to the political, strategic and military considerations of the most powerful states.[70]

Examples of National Regulation

In integrating data sets from a variety of sensors, it must be considered that the collection of certain types of data raises issues under various national laws and regulations. Depending on the data being collected, certain regulations may mandate how it should be protected. Applicable regulations may provide an obligation to use reasonable security measures to protect the information, and those obligations may extend to storage vendors. The licensing authority of the satellite system first regulates collection and distribution of satellite data. The consequence is that integrated data sources that include raw satellite data could raise security concerns depending on how the data is stored and shared, especially if it's on the "cloud."[71] The cases of Canada and Germany are instructive.

→ **Regulating the remote sensing system:** The Canadian Remote Sensing Space Systems Act distinguishes between raw data and remote sensing products.[72] Alhough there are exceptions, the minister of Foreign Affairs must first provide clearance for all customers of raw data. Section 8(6) generally prohibits the communication of raw data to third parties. Prohibition is founded in the fact that raw data "can be manipulated to reveal a great deal about the capabilities of satellites that might permit an adversary to develop methods to counter observation or to deceive observation

66 Atsuyo Ito, "Improvement to the Legal Regime for the Effective Use of Satellite Remote Sensing Data for Disaster Management and Protection of the Environment" (2008) 34 J Space L 45.

67 Ram Jahku, "International Law Governing the Acquisition and Dissemination of Satellite Imagery" (2003) 29 J Space L 65 at 88.

68 Masami Onoda, "Satellite Earth Observation as 'Systematic Observation' in Multilateral Environmental Treaties" (2005) 31:2 J Space L 339. Note also there are other techniques such as the "Buy to Deny" policy. To restrict sale of commercial high-resolution satellite imagery of Afghanistan during the war, the US administration acquired an exclusive right for all data concerning Afghanistan collected by space imaging.

69 JI Gabrynowicz, *The Land Remote Sensing Laws and Policies of National Governments: A Global Survey* (University, MS: National Center for Remote Sensing, Air, and Space Law at the University of Mississippi School of Law, 2007).

70 Onoda, *supra* note 68.

71 Cloud computing is a way of providing IT functions such as information storage, processing power and computer programs as services over the internet, through the use of external (often remote) servers. See Kommerskollegium (National Board of Trade Sweden), *How Borderless is the Cloud? An Introduction to Cloud Computing and International Trade* (Stockholm: National Board of Trade, 2012), online: <www.wto.org/english/tratop_e/serv_e/wkshop_june13_e/how_borderless_cloud_e.pdf>.

72 *Remote Sensing Space Systems Act*, SC 2005, c 45, online: Government of Canada <laws-lois.justice.gc.ca/eng/acts/R-5.4/page-1.html#h-1>.

by such systems."[73] Conversely, section 8(7) generally permits the communication of "remote sensing products" to third parties. The act focuses on raw data and remote sensing products as two distinct products, when they are the poles at either extreme of a fine gradient of possible products that result from different degrees of transformation. There is a divergence among industry about the level of protection that should be accorded to raw data.

→ **Regulating the who and why of data transactions:** The Act for the "Protection of the Security of the Federal Republic of Germany Against Endangerment by the Distribution of Highly Detailed Terrestrial Satellite Data" applies to data with high informational value where it is generated or processed. The main feature of this act is a sensitivity check administered by the distributor. Based on criteria given by the ministries, the distributor must check whether a transaction might endanger national security and foreign policy interests. If the check shows sensitivity, the distributor must either decline the transaction or apply for a licence to the Federal Office of Economics and Export Control who make the determination. Here there is less discussion about raw data, metadata, and so on, and more discussion about who uses the data, why, and the context of the transaction.[74]

Legal Clarity around Cloud Computing

To take advantage of the technology, producers and purchasers of raw data are exploring putting their data on the cloud, making it more accessible to many users.[75] This is evidenced by recent announcements by Earth observation satellite operators Planet Labs that they are using the Google cloud and DigitalGlobe through Amazon's cloud services.[76] The potential benefits of cloud computing are numerous in terms of cost savings, computing power, processing time, accessibility and ease of dissemination, and many seek to take advantage of this. However, there is no way for governments to track or restrict the individuals that access the cloud. The problem of cloud computing therefore is that "it is difficult to determine its precise origin and ownership and even more difficult to contain."[77] These concerns are important in the context of remote sensing satellite information. As highlighted in a review of the Canadian Remote Sensing Space Systems Act, "if a remote sensing system operator transfers their raw data to a cleared client, that client is prohibited from putting the raw data they now possess on the cloud."[78] The review highlights that a "potential issue may appear when a client mixes the raw data they receive from a Canadian operator with the raw data (or other information) received from a non-Canadian provider and put the resulting product in the cloud." The review also poses an unanswered question: "Does Canada have the authority to regulate such material?" Further, there is currently no collective international framework for the management of issues related to cloud computing. To address this, the review recommends harmonized international rules related to the cloud so that anyone operating in the cloud, regardless of their physical location, is subjected to the same regulations. In the EU context, the Cloud Select Industry Group has developed the Cloud Service Level Agreement Standardisation Guidelines and two codes of conduct on data protection, which could serve as interesting case studies.[79]

In recognition that the New Delhi Declaration highlights the importance of increasing computing resources and of the need to encourage research communities, two important technical considerations emerge. First, central to an integrated monitoring solution will be a system to receive, archive, process, analyze and distribute the actionable information.[80] Increasing volumes of data will inevitably create challenges in efforts

73 T Gillon, "Regulating Remote Sensing Space Systems in Canada — New Legislation for a New Era" (2008) 34 J Space L 19 at 27.

74 Gabrynowicz, *supra* note 69 at 14.

75 Emerging Canadian technology such as the EMSAT software is a flexible data aggregation, data management and visualization platform that leverages powerful cloud computing and sensor/satellite communication technologies to deliver accurate real-time environmental monitoring.

76 Meenal Dhane, "Planet Labs Satellite Data is now on Google Cloud", *Geospatial World* (13 March 2017), online: <www.geospatialworld.net/planet-labs-satellite-data-google-cloud/>; Sarah Scoles, "The Best Way to Transmit Satellite Data? In Trucks. Really?", *Wired* (17 May 2017), online: <www.wired.com/2017/05/best-way-transmit-satellite-data-trucks-really/>.

77 Ram Jakhu & Aram Daniel Kerkonian, *Independent Review of the* Remote Sensing Space Systems Act (Montreal: Institute of Air and Space Law at McGill University's Faculty of Law, 2017), online: <www.international.gc.ca/arms-armes/assets/pdfs/2017_review_of_remote_sensing_space_systems_act.pdf>.

78 *Ibid*.

79 Ingo Baumann, "Cloud Computing Policy and Regulations for Space Data: A Legal Assessment", online: <www.espi.or.at/images/documents/space_data/14._Baumann.pdf>.

80 See Maerospace's "Information Factory" model, online:< http://maerospace.com/our-model/>.

to interpret the significance of that data.[81] Machine learning and artificial intelligence, focused on developing algorithms for data analysis, will therefore play a part in advances. This raises several legal questions, including questions about liability for automated decision making and potential for identification of individuals. Second, supporters of the New Delhi Declaration may engage their research community to investigate the potential of new computing technologies to address the security risk of sharing integrated data sets and develop the security protocols necessary for the level of information sharing required to support the Paris Agreement transparency goals.[82] These systems should take into account, among other things, the need for privacy, confidentiality and data sovereignty. In an integrated data environment, as highlighted in research by Primavera De Filippi and McCarthy, even though information was voluntarily provided by users, aggregated data might provide further information about users that they did not necessarily want to disclose.[83]

The Need for Transparency Goals Cooperation: Developing Country Support

Articles 13(14) and 13(15) of the Paris Agreement mandate that support shall be provided to developing countries for implementing the transparency requirements and for the building up of transparency-related capacity. According to Arunabha Ghosh and Sumit Prasad, there are often no institutional mechanisms in place to monitor the associated emissions (and reductions of emissions). Without such procedures, many developing countries fear they would find themselves disadvantaged during multilateral reviews. They would also struggle to request appropriate financial and technological support for their low-carbon transitions. This is one reason, the authors argue, that developing countries seek differentiation within the transparency rules.[84] One way that support can be provided is through increased international cooperation in developing and utilizing the tools required to aid transparency. The decision to adopt the Paris Agreement emphasizes, in its preamble, the need to uphold and promote international cooperation to mobilize stronger and more ambitious climate action by all parties and by non-party stakeholders.[85]

Paragraph 85 of that decision establishes a Capacity-building Initiative for Transparency, to build institutional and technical capacity and support developing country parties, upon request, in "meeting enhanced transparency requirements."[86] It aims, *inter alia*, to provide tools, training and assistance for meeting the provisions stipulated in article 13. To date, the supported projects have been focused on enhancing capacity to develop MRV methodology frameworks, methodological frameworks for estimating land-based emissions, and improving national GHG inventories through learning from regional peer-exchange programs.[87] More support is required, though. Japan has highlighted that developing countries are disproportionately affected by the inability to access the latest information about climate change, due to the lack of essential computing resources.[88] As such, developing and sharing computing technology carries promise in the fight against climate change. The New Delhi Declaration presents an opportunity in this regard, bearing in mind the consensus around developing "computing resources."

Article 7(7)(c) of the Paris Agreement also calls for strengthened cooperation for "systematic observation" of the climate system in the

81 Robert L Glicksman et al, "Technological Innovation, Data Analytics and Environmental Enforcement" (2017) 44:1 Ecology LQ 41 at 88.

82 W Croi, FM Foeteler & H Linke, "Introducing Digital Signatures and Time-Stamps in the EO Data Processing Chain" in R Purdy & D Leung, eds, Evidence from Earth Observation Satellites (Leiden, Netherlands: Martinus Nijhoff Publishers, 2013) at 379.

83 Primavera De Filippi & Smari McCarthy, "Cloud Computing: Centralization and Data Sovereignty" (2012) 3:2 Eur J L & Technology.

84 Arunabha Ghosh & Sumit Prasad, "Shining the Light on Climate Action: The Role of Non-party Institutions" CIGI, Fixing Climate Governance Series Paper No 6, September 2017.

85 United Nations Framework Convention on Climate Change, Conference of the Parties, *Adoption of the Paris Agreement*, Dec CP.21, UNFCCC, 21st Sess, UN Doc FCCC/CP/2015/L.9/Rev.1, at Preamble, online: <https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf>.

86 *Ibid* at para 85.

87 "New Coordination Platform for Transparency Will Help Implement Paris Climate Agreement", *Global Environment Facility* (20 April 2017), online: <www.thegef.org/news/new-coordination-platform-transparency-will-help-implement-paris-climate-agreement>.

88 *Japan's submission regarding its views on possible topics for consideration at the Ninth meeting of the Research Dialogue to be held at SBSTA 46 (May 2017)*, online: <www4.unfccc.int/Submissions/Lists/OSPSubmissionUpload/53_263_131362854751957513-JAPAN_SBSTA46_SUBMISSION_%28RD9%29.pdf>.

context of enhancing action on *adaptation*, so it informs climate services and supports decision making. This is significant because observations for adaptation at the local level include focus on meteorological parameters such as temperature, precipitation, soil moisture and sea level. But, with evolving attribution capabilities of monitoring systems that could support decisions at the local level, cooperation for systematic observations could continue to apply to and encourage *mitigation* goals as well, linking ECV, in particular the newly proposed ECV on anthropogenic GHG fluxes and emissions estimations.[89] Cooperation here may encourage the outcome that states that could benefit from the availability of this data can have access to it.

Governance Models: Data-sharing Approaches

Any cooperation that results from the New Delhi Declaration would likely be implemented by a web of memoranda of understanding (MOUs) and implementing agreements, either between states or agency-to-agency. But, to be relevant to implementing the Paris Agreement, it will be necessary for more stakeholders to benefit from and access the information. The Global Precipitation Measurement (GPM) mission governance structure provides an interesting case. The GPM mission was designed by NASA and the Japanese Space Agency (JAXA) from its inception as an international satellite mission. Its objective is to advance global precipitation measures from space by deploying the space-borne GPM Core Observatory as a reference standard to unify a constellation of microwave sensors of GPM partners participating in the mission, to provide global precipitation measurements for scientific research and societal applications.

NASA has in place agreements on GPM collaboration with JAXA and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). There are also bilateral MOUs in place with the Indian space agency and the French space agency (the Centre National d'Etudes Spatiales [CNES]). NASA also has an inter-agency agreement with the National Oceanic and Atmospheric Administration (NOAA) on GPM cooperation. The agreements and MOUs specify conditions for mission governance.[90] While GPM partners make data available to each other, there is also provision for third parties to access the data as GPM participants. For example, EUMETSAT designates the National Meteorological Services of its member and cooperating states and the European Centre for Medium-Range Weather Forecasts as GPM participants. The approved GPM participants have access to the same data, products and services as the GPM partners.

This governance structure allows participants beyond the immediate space agency partners to benefit from the cooperation, while ensuring clear leadership.

The WMO project is focused on developing the methodological standard for the flux inversion technique, but it has important advantages as a coordinating body for an independent international data source.[91] Careful thought would be required as to the data-sharing policy, however, based on the data dissemination policy of the WMO World Data Centre for Greenhouse Gases.[92] The purpose of the World Data Centres is to collect data from contributors[93] to the Global Atmosphere Watch program, to archive the processed data and to make the data publicly available.[94] The policy requires that "an offer of co-authorship will be made through personal contact with the data providers or owners whenever substantial use is made of their data."

89 GCOS Secretariat and the Land Cover Project Office from GOFC-GOLD, *GCOS Workshop on Observations for Climate Change Mitigation: Geneva, Switzerland, 5–7 May 2014* (Geneva: WMO, 2014), online: <www.wmo.int/pages/prog/gcos/Publications/gcos-185.pdf>.

90 *Agreement for Cooperation on the Development and Operations Activity of the Global Precipitation Measurement Mission between the United States of America and Japan*, 19 December 2008, TI Agree 08-1219A (entered into force 19 December 2008), online: <www.state.gov/documents/organization/195325.pdf>; *Memorandum of Understanding for the Global Precipitation Measurement Mission between the United States and the European Organization for the Exploitation of Meteorological Satellites*, 28 June 2013, TI Agree 13-726 (entered into force 26 July 2013), online: <www.state.gov/documents/organization/219583.pdf>; *Implementing Arrangement between the United States and India for Cooperation on Global Precipitation Measurement and Megha-Tropiques*, 20 March 2012, TI Agree 12-326.1 (entered into force 26 March 2012), online: <www.state.gov/documents/organization/209798.pdf>.

91 Sébastien Philippe, "Bringing Information Credibility Back Into Transparency: The Case for a Global Monitoring System Of Green House Gas Emissions" (Program on Science and Global Security at Princeton University, 2016), online: <https://arxiv.org/abs/1607.02191>.

92 WMO Global Atmosphere Watch, *Revision of the World Data Centre for Greenhouse Gases Data Submission and Dissemination Guide* (Geneva: WMO, 2009), online: <ds.data.jma.go.jp/gmd/wdcgg/pub/products/manual/WDCGG_GUIDEV11.pdf>.

93 "List of Contributors", online: World Data Centre for Greenhouse Gases <ds.data.jma.go.jp/gmd/wdcgg/cgi-bin/wdcgg/contributor.cgi>.

94 "Introduction to the WMO WDCGG", online: World Data Centre for Greenhouse Gases <ds.data.jma.go.jp/gmd/wdcgg/introduction.html>.

This requirement of co-authorship may impede the verification potential of the data set because potential authors would not be independent of the data provider. In a system of integrated data with divergent users and contributors, an attempt to balance the data owner's protection and freedom to use the information will be required. In that case, the Global Earth Observation System of Systems (GEOSS) open data-sharing principles serve as a case study, although GEOSS is not without its challenges.[95] Established by the Group on Earth Observation (GEO), a unique global network connecting 105 member states, government institutions, academic and research institutions, data providers, businesses, engineers, scientists and experts, GEOSS is a set of coordinated, independent Earth observation, information and processing systems that interact and provide access to diverse information for a broad range of users in both public and private sectors.[96] GEOSS links these systems to strengthen the monitoring of the state of the earth. It facilitates the sharing of environmental data and information collected from the large array of observing systems contributed by countries and organizations within GEO. The data-sharing principles stipulate the following:

- → there will be full and open exchange of data, metadata and products shared within GEOSS, recognizing relevant international instruments and national policies and legislation;
- → all shared data, metadata and products will be provided with minimum time delay and at minimum cost; and
- → all shared data, metadata and products being free of charge or no more than cost of reproduction will be encouraged for research and education.[97]

Attention must also be paid to other governance initiaves such as the Strategy Towards an Architecture for Climate Monitoring from Space.[98] The authors, comprised of representatives from the Committee on Earth Observation Satellites, the Coordination Group for Meteorological Satellites and the WMO, highlight that the strategy is intentionally high-level, conceptual and inclusive, so that a broad consensus can be reached, and all relevant entities can identify their potential contributions. It calls for a constellation of research and operational satellites; broad, open datasharing policies; and contingency planning.

Conclusion

Two important questions were posed by this paper: how is transparency enhanced by emerging monitoring technology and measurement techniques; and are proposed new satellite-enabled approaches to monitoring GHG emissions consistent with article 13(3) of the Paris Agreement, considering that remote sensing of territories and possible sharing of the data, without permission of the state being observed, could be seen as intrusive and contrary to national sovereignty?

As a first step to enhancing transparency, it is essential that discrepancies between bottom-up methods of estimating GHG emissions and atmospheric measurements be recognized. Augmented and integrated GHG emission measurement technologies and data sets could bring to light the efficiency challenges of emissions reduction programs. Since emission control legislation is national or regional in scale, not global, top-down emission estimates will likely be determined at these levels, as a basis for national initiatives. However, a global system with the capability to produce internationally accepted independent data could serve the enhanced transparency framework proposed under article 13 of the Paris Agreement.

While emerging satellite-enabled emissions measurement techniques are potentially intrusive, such activity is entirely consistent with international space law. To address concerns, however, it is noteworthy that at a minimum the

95 Catherine Doldirina, "Open Data and Earth Observations: The Case of Opening Up Access to and Use of Earth Observation Data Through the Global Earth Observation System of Systems" (2015) 6 J Intellectual Property, Information Technology & Electronic Commerce L 73.

96 "About GEOSS", online: Group on Earth Observations <www.earthobservations.org/geoss.php>.

97 "GEO Data Sharing Principles Implementation", online: Group on Earth Observations <www.earthobservations.org/geoss_dsp.shtml>.

98 M Dowell et al, "Strategy Towards an Architecture for Climate Monitoring from Space" (2013) at 39, online: <www.ceos.org; www.wmo.int/sat>; <www.cgms-info.org/>.

sensed state is entitled to non-discriminatory access to the data. This capability to remotely determine GHG emissions and its use for climate transparency is projected to be operational by 2035. This is consistent with the Paris Agreement if states either use available remotely sensed data to meet their own transparency requirements, or as part of the modalities, procedures and guidelines, they agree that technical expert review can refer to independent internationally accepted data sources.

The stated objective of the New Delhi Declaration adopted by 60 space agencies is for the agencies to cooperate to cross-calibrate their instruments, cross-validate their measurements and centralize the data from their Earth-observing satellites, ultimately seeking to support the objectives of the Paris Agreement. The short-term significant impact, however, could come from cooperation to strengthen developing states' computing power, determine how to ensure security in satellite data sharing and storage, develop the required analytics system, and increase public awareness about the benefits of the initiative. By creating an open forum for discussion as part of a program of work under the New Delhi Declaration, space agencies, governmental bodies, international organizations, private companies, universities and research institutions can all participate to determine the best tools to enhance transparency and fulfill the declaration's sentiment. This could feed into the UNFCCC process and leverage other similar initiatives under the WMO and the European Commission to support the transparency goals of the Paris Agreement.

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