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Satellite Measurement of GHG Emissions: Prospects for Enhancing Transparency and Answerability under International Law

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Abstract:
Recent technological advancements are facilitating the use of satellite remote-sensing techniques for the measurement of atmospheric concentrations of greenhouse gas (GHG) emissions. This article evaluates the potential for these satellite-enabled measurements to contribute to transparency and answerability for state emissions, with a focus on international space law and policy and the Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC). We show that in the context of the international space governance framework, the dissemination of integrated emissions data sets has the potential to enhance public answerability for states' mitigation performance. Under the Paris Agreement, there is scope for space-based measurement techniques to provide an independent data source to support verification activities for national emission inventories, and for aggregated data to be utilized as part of the global stocktake under Article 14. There are, however, a number of impediments to translating these transparency gains into enhanced answerability for states' emissions-reduction pledges.

Keywords: International space law, Paris Agreement, Satellites, Greenhouse gas emissions, Transparency, Accountability

1. INTRODUCTION

Satellite observation is a powerful tool for monitoring the earth remotely, without needing permission from the sensed territory. In addition to this traditional monitoring role, there is an emerging capability for using satellite remote sensing to *measure* atmospheric concentrations of greenhouse gas (GHG) emissions.[1] With the development of new commercial satellite systems that can measure GHG emissions from sources on the scale of industrial facilities,[2] and NASA's Geostationary Carbon

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[1] As Hardwick and Graven explain, '[s]atellite measurements derive atmospheric concentrations of gases using the properties of gases to absorb electromagnetic radiation at specific wavelengths': S. Hardwick & H. Graven, 'Satellite Observations to Support Monitoring of Greenhouse Gas Emissions' (2016) Grantham Institute Briefing Paper (No. 16), p. 4, available at: https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/Satellite-observations-to-support-monitoring-of-greenhouse-gas-emissions-Grantham-BP-16.pdf.
[2] See GHGSat, 'GHGSat Global Emissions Monitoring' (2018), available at: www.ghgsat.com; on the recent partnership between California and Planet Labs, see J. Rainey, 'California Gov. Jerry Brown to Launch Satellite to Track Greenhouse Gas Emissions', *NBC News* online, 15 Sept. 2018, available at: https://www.nbcnews.com/news/us-news/california-gov-jerry-brown-launch-satellite-track-greenhouse-gas-emissions-n909811.

Cycle Observatory (GeoCARB) mission which will measure daily the total concentration of carbon dioxide (CO_2), carbon monoxide (CO) and methane (CH_4) in the atmosphere with a horizontal ground resolution of 3–6 miles (5–10 kilometres),[3] more accurate remote attribution data are becoming available.[4] Such measurements made from space-borne platforms can augment the bottom-up calculation-based approaches typically used in state GHG inventories, and would allow improved integrated estimates of emissions utilizing top-down quantification data. The World Meteorological Organization (WMO) is developing a framework to harness these new developments in atmospheric concentration measurement capabilities and provide a fully integrated emissions information system,[5] and a group of 60 space agencies have signed the New Delhi Declaration which aims to develop an 'international, independent system for estimating and curbing anthropogenic GHG emissions based on accepted data'.[6] Such developments hold significant promise for facilitating the creation of independent data sets to enhance the comparability, replicability, and verifiability of state GHG emissions information.[7]

Against this backdrop, this article evaluates the potential for satellite-enabled measurements of atmospheric GHG concentrations to contribute to transparency and answerability for state emissions, with a focus on international space law and policy[8] and the Paris Agreement[9] to the United Nations Framework Convention on Climate Change (UNFCCC).[10] This is an exploratory analysis as these satellite technologies and techniques, as well as the relevant regulatory frameworks under the United Nations (UN) climate regime, are still evolving. Recognizing that greater transparency should not be

[3] The GeoCARB mission is planned to launch around 2022: NASA, 'NASA Announces First Geostationary Vegetation, Atmospheric Carbon Mission', Press Release, 6 Dec. 2016, available at: https://www.nasa.gov/press-release/nasa-announces-first-geostationary-vegetation-atmospheric-carbon-mission.
[4] R. Nasser, 'Space-based Measurements to Quantify Anthropogenic CO_2 and CH_4 Emissions' (2016), available at: http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/15647/2604456/191-bd0a81fe7f3b09692172638a5915c012_NassarRay.pdf; T. Aganaba-Jeanty, 'Satellites, Remote Sensing and Big Data: Legal Implications for Measuring Emissions', Centre for International Governance Innovation, CIGI paper No. 15, Nov. 2017, p. 7, available at: https://www.cigionline.org/publications/satellites-remote-sensing-and-big-data-legal-implications-measuring-emissions.
[5] WMO & United Nations Environment Programme (UNEP), *Concept Paper and Annotated Outline, EC-68/Doc 4.5(1)* (2016), available at: www.wmo.int/pages/prog/arep/gaw/ghg/documents/EC_68_ConceptPaper_IG3IS_DRAFT_V14.pdf.
[6] CNES, 'New Delhi Declaration Comes into Effect: Worlds Space Agencies Working to Tackle Climate Change', Press Release, 18 May 2016, available at: https://presse.cnes.fr/en/new-delhi-declaration-comes-effect-worlds-space-agencies-working-tackle-climate-change.
[7] See Aganaba-Jeanty, n. 4 above.
[8] See, e.g., 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), London (United Kingdom), Moscow (Russia), Washington, DC (US), 27 Jan. 1967, in force 10 Oct. 1967, Art. 1, available at: https://treaties.un.org/doc/Publication/UNTS/Volume%20610/volume-610-I-8843-English.pdf .
[9] Paris (France), 12 Dec. 2015, in force 4 Nov. 2016, available at: http://unfccc.int/paris_agreement/items/9485.php.
[10] New York, NY (US), 9 May 1992, in force 21 Mar. 1994, available at: https://unfccc.int/resource/docs/convkp/conveng.pdf.

seen as an end in itself,[11] we apply elements of Gupta and van Asselt's analytical framework for evaluating the relationship between transparency and accountability.[12] As these authors note, in the context of the Paris Agreement, which has eschewed a sanctions-based enforcement model, the answerability elements of accountability, pertaining to relations, standards and judgments, are more pertinent than the enforceability dimensions, relating to sanctions and redress.[13] Similarly, as there are no binding emissions-reduction commitments for states under international space law, enforceability considerations do not apply. Accordingly, we focus on the relationship between the aspects of transparency that relate to the answerability elements of accountability. We build upon Gupta and van Asselt's framework by emphasizing the technical dimensions of transparency in this context, which highlights the importance of data that is independent, replicable, accessible, and comparable. This focus on the technical and normative dimensions of transparency, and the relationship with answerability, yields new insights into the opportunities and challenges for utilizing emissions data facilitated by remote-sensing measurement capabilities under existing international legal frameworks.

Our analysis shows that there will be transparency gains arising from advancements in satellite-enabled measurement techniques and the public dissemination of the resulting integrated data sets. These gains are possible as the principles of international space law permit remote sensing of territories and sharing of data in some circumstances, without the permission of the state being observed.[14] Non-state actors can play an important role in naming and shaming states for failing to meet their international mitigation pledges, contributing to public answerability.[15] The standards against which transparent emissions data are assessed will likely be derived from the UN climate regime due to the lack of emission-mitigation targets under international space law.

There is also potential for improvements in the transparency of emissions data to translate into enhanced answerability for states under the Paris Agreement. Satellite-enabled measurement data could be used by states to verify their own emissions inventory reports, or as a reference point in the internationally coordinated expert review process under Article 13(11) of the Paris Agreement. However, it is unclear whether the latter option will be acceptable to states as remote-sensing

[11] S. Marks, 'Naming Global Administrative Law' (2005) 37 *New York University Journal of International Law and Politics*, pp. 995-1001, at 998.
[12] A. Gupta & H. van Asselt, 'Transparency in Multilateral Climate Politics: Furthering (or Distracting From) Accountability?' (2017) 11(2) *Regulation &* Governance, pp. 1-17.
[13] Ibid., p. 5.
[14] Outer Space Treaty, n. 8 above, Art. 1.
[15] R. Leal-Arcas & A. Morelli, 'The Resilience of the Paris Climate Agreement: Negotiation and Implementing the Climate Regime' (2019) 31(1) *Georgetown Environmental Law Review* (forthcoming).

measurements and sharing of data without the permission of the sensed state conflicts with the emphasis on non-intrusive transparency measures that are respectful of national sovereignty under the Agreement's enhanced transparency framework.[16] Furthermore, aggregated atmospheric measurement data could be used as an input into the global stocktake under Article 14. However, the absence of political judgments in this facilitative process limits the prospects for answerability arising from the global stocktake. Thus, there are a number of impediments to achieving greater answerability through the enhanced transparency afforded by satellite-enabled measurement techniques.

This article proceeds in four parts. Section 2 outlines the framework for evaluating the transparency-answerability relationship that will be applied in Section 4. Section 3 provides an overview of the issues with data quality and transparency in the current GHG inventory practices under the UN climate regime, and the potential for emerging atmospheric measurement techniques to address these concerns. A number of international initiatives seeking to harness space-based GHG measurement capabilities, both within and beyond the UN climate regime, are also canvassed. In Section 4, the analytical framework from Section 2 is applied to evaluate the prospects of increased transparency facilitated by advances in satellite technology and big data leading to enhanced answerability for states' GHG mitigation commitments. The options under both international space law and policy and the Paris Agreement are explored. Section 5 concludes and suggests that increased international cooperation is required to address concerns about new atmospheric measurement techniques, while encouraging access to the data collected.

2. THE RELATIONSHIP BETWEEN TRANSPARENCY AND ACCOUNTABILITY

Transparency is an emerging norm in global environmental governance,[17] but should not be pursued for its own sake.[18] The definition of transparency is contested.[19] For present purposes, we adopt a broad conceptualization of transparency as 'a governance of *information*, including demands for active transparency and access to information, but also demands for confidentiality and privacy, and for legal or political controls on the gathering and use of policy-shaping information'.[20] This

[16] See Paris Agreement, n. 9 above, Art. 13(3); Aganaba-Jeanty, n. 4 above, p. 9.
[17] See, e.g., A. Gupta & M. Mason (eds), *Transparency in Global Environmental Governance: Critical Perspectives* (The MIT Press, 2014); D.B. Hunter, 'The Emerging Norm of Transparency in International Environmental Governance', in: P. Ala'i & R.G. Vaughn (eds), *Research Handbook on Transparency* (Edward Elgar, 2014), pp. 343-67, at 343.
[18] Marks, n. 11 above, p. 998.
[19] See generally M. Lodge, 'Accountability and Transparency in Regulation: Critiques, Doctrines and Instruments', in J. Jordana & D. Levi-Faur (eds), *The Politics of Regulation: Institutions and Regulatory Reforms for the Age of Governance* (Edward Elgar, 2004), pp. 124-44.
[20] B. Kingsbury & L. Casini, 'Global Administrative Law Dimensions of International Organizations Law' (2009) 6 *International Organizations Law Review*, pp. 319-58, at 325.

definition acknowledges the tension between secrecy and disclosure, as well as the substantive choice associated with providing access to the information that underpins the exercise of power.[21]

From a normative perspective, there is frequent contestation over 'what transparency is good for' in a particular context.[22] Potential rationales associated with the pursuit of transparency include enhancing accountability,[23] good governance,[24] and democratization by promoting the informed participation of states or citizens.[25] However, in the process of implementing global regulation, alternative rationales for disclosure, such as rationalizing expert decision making, facilitating markets for environmental goods, or augmenting private authority and gain, tend to come to the fore.[26] In this article, we focus on evaluating if and how the increase in transparent information on GHG emissions generated by emerging satellite capabilities can contribute to states' answerability for their mitigation commitments, adding to the literature on the transparency-accountability nexus.[27]

Accountability is a salient concern of global environmental governance and related fields, the prominence of which has been enhanced by the growing body of work on global administrative law.[28] Like definitions of transparency, there are diverse understandings of accountability in the literature. These include broad[29] and narrow[30] definitions, and can feature both mechanistic and normative

[21] E. Fisher, 'Transparency and Administrative Law: A Critical Evaluation' (2010) 63 *Current Legal Problems*, pp. 272-314, at 275-6; see also M. Donaldson & B. Kingsbury, 'The Adoption of Transparency Policies in Global Governance Institutions: Justifications, Effects, and Implications' (2013) 9 *Annual Review of Law and Social Science*, pp. 119-47, at 122-4.
[22] A. Florini, 'Introduction: The Battle Over Transparency', in: A. Florini (ed.), *The Right to Know: Transparency for an Open World* (Columbia University Press, 2007), pp. 1-16, at 1.
[23] M. Bovens, 'Analysing and Assessing Accountability: A Conceptual Framework' (2007) 13(4) *European Law Journal*, pp. 447-68, at 450.
[24] D. Esty, 'Good Governance at the Supranational Level: Globalizing Administrative Law' (2005-6) 115 *Yale Law Journal*, pp. 1490-562, at 1530-1.
[25] A. Gupta & M. Mason, 'Disclosing or Obscuring? The Politics of Transparency in Global Climate Governance' (2016) 18 *Current Opinion in Environmental Sustainability*, pp. 82-90, at 83.
[26] Ibid.
[27] See, e.g., Gupta & van Asselt, n. 12 above; D. Ciplet et al, 'The Transformative Capability of Transparency in Global Environmental Governance' (2018) 18(3) *Global Environmental Politics*, pp. 130-50, at 136-7; J. Fox, 'The Uncertain Relationship between Transparency and Accountability' (2007) 17(4) *Development in Practice*, pp. 663-71, at 664.
[28] See, e.g., B. Kingsbury, N. Krisch & R.B. Stewart, 'The Emergence of Global Administrative Law' (2005) 68 *Law and Contemporary Problems*, pp. 15-61, at 17; N. Krisch & B. Kingsbury, 'Introduction: Global Governance and Global Administrative Law in the International Legal Order' (2006) 17(1) *The European Journal of International Law*, pp. 1-13, and the other articles in the Symposium issue of the *European Journal of International Law*, pp. 1-278; S. Cassese (ed.), *Research Handbook on Global Administrative Law* (Edward Elgar, 2016).
[29] See, e.g., R.W. Grant & R. O. Keohane, 'Accountability and Abuses of Power in World Politics' (2005) 99(1) *American Political Science Review*, pp. 29-43, at 36; J. L. Mashaw, 'Structuring a "Dense Complexity": Accountability and the Project of Administrative Law' (2005) 5(1) *Issues in Legal Scholarship*, pp. 1-38, 27.
[30] See, e.g., R.B. Stewart, 'Remedying Disregard in Global Regulatory Governance: Accountability, Participation, and Responsiveness' (2014) 108(2) *American Journal of International Law*, pp. 211-70, at 244-55; J. Black, 'Constructing and Contesting Legitimacy and Accountability in Polycentric Regulatory Regimes' (2008) 2(2) *Regulation and Governance*, pp. 137-64, at 150.

dimensions.[31] For the purpose of evaluating the desirability and utility of satellite-enabled emissions measurement capabilities, a functional approach to accountability is preferable. From this perspective, accountability can be analyzed in terms of its components: 'accountability of whom; to whom; for what; and by what means'.[32]

It is also helpful to differentiate between two dimensions of accountability relations: *answerability* and *enforceability*.[33] Gupta and van Asselt disaggregate answerability and enforceability into five elements:

- *Relations:* agreeing on **who** is to be held account (and **to whom**);
- *Standards:* agreeing on standards of performance against which to be held to account (i.e. agreeing on accountability **for what**);
- *Judgments:* agreeing on a process by which to assess if standards are being met (i.e. the **how** of accountability);
- *Sanctions:* agreeing on (legal, reputational, financial) **penalties** if standards are not met; and
- *Redress:* agreeing on the scope and modalities of **liability and compensation** for harm inflicted as a result of standards not being met.[34]

Relations, standards and judgments relate to answerability, whereas sanctions and redress constitute the enforceability component of accountability.[35] In the context of the Paris Agreement, the answerability dimensions are most pertinent as states have explicitly eschewed an enforcement-oriented approach to compliance focused on sanctions and legal redress.[36] That is, unlike the Kyoto Protocol's Enforcement Branch, which provides for the use of economic sanctions in the event of industrialized states' non-compliance,[37] the parties to the Paris Agreement have not agreed to sanctions or other enforceability measures for deficient performance.[38] Moreover, there are no binding emissions-reduction commitments for states under international space law, and thus no formal consequences for failing to meet the requisite standards. Accordingly, the primary focus of this analysis will be on the answerability components of accountability.

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[31] C. Harlow, 'Accountability as a Value for Global Governance and Global Administrative Law', in: G. Anthony, J-B. Auby, J. Morison & T. Zwart (eds), *Values in Global Administrative Law* (Hart Publishing, 2011), pp. 174-82.
[32] B. Kingsbury, 'Global Environmental Governance as Administration: Implications for International Law', in D. Bodansky, J. Brunnée & E. Hey (eds), *The Oxford Handbook of International Environmental Law* (Oxford University Press, 2007), pp. 63-84, at 66. See also C. Scott, 'Accountability in the Regulatory State' (2000) 27(1) *Journal of Law and Society*, pp. 38-60, at 41-2.
[33] Gupta & van Asselt, n. 12 above, p. 3.
[34] Ibid.
[35] Ibid.
[36] Ibid., p. 5.
[37] A. Zahar, 'A Bottom-Up Compliance Mechanism for the Paris Agreement' (2017) 1(1) *Chinese Journal of Environmental Law*, pp. 69-98, at 80.
[38] That is, a 'soft' facilitative version of compliance is preferred over 'hard' accountability: H. Winkler, B. Mantlana & T. Letete, 'Transparency of Action and Support in the Paris Agreement' (2017) 17(7) *Climate Policy*, pp. 853-872, at 862.

Corresponding transparency arrangements can be linked to the disaggregated elements of answerability, providing benchmarks for evaluating the transparency-answerability relationship. Specifically, Gupta and van Asselt propose that the following transparency elements are relevant to the relations, standards and judgments aspects of answerability outlined above:

- *Transparency from **whom**:* who has to be transparent (and **to whom**)?
- *Transparency about **what**:* what **aspects of performance** are to be made transparent?
- *Transparency **how**:* **reporting and review** processes to make visible if standards are being met.[39]

These three elements are required for transparency to promote answerability, and provide valuable criteria for evaluating the potential benefits of transparent emissions data generated by satellite measurement techniques. The focus on transparency of whom, to whom, for what, and by what means, and on the nexus with relations, standards and judgments, facilitates evaluation of the extent to which transparency arrangements promote or hinder answerability – in this instance, states' answerability for their emissions-reduction pledges under the Paris Agreement.

We build upon Gupta and van Asselt's framework by expanding on the technical dimensions of transparency in the context of GHG emissions inventories. 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 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, there is an expectation 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'.[40] From this standpoint, transparency requires the provision of methodologies, data and data sources, assumptions, and quantifiable information, which should be clearly explained to facilitate replication, comparability and assessment of reported information by diverse stakeholders.[41] This dimension of transparency in emissions inventories is critical because, as the experience in the context of other multilateral environmental agreements (MEAs) has shown, poor data quality stemming from inaccurate and incomplete data can undermine both the transparency and accountability of compliance decisions predicated on this information.[42] These technical insights into the importance of independent, comparable, replicable

[39] Gupta & van Asselt, n. 12 above, p. 4 (Figure 1).
[40] IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl.
[41] Aganaba-Jeanty, n. 4 above, p. 2. See also UNFCCC, *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), p. 4.
[42] See, e.g., D.G. Victor, *Global Warming Gridlock: Creating More Effective Strategies for Protecting the Planet* (Cambridge University Press, 2011), p. 230; S. Oberthür, *Production and Consumption of Ozone-Depleting Substances*

and verifiable emissions data complement Gupta and van Asselt's framework for analyzing the relationship between transparency and answerability.

3. THE TRANSPARENCY POTENTIAL OF ATMOSPHERIC EMISSIONS MEASUREMENT TECHNIQUES

Before proceeding to apply the analytical framework articulated in Section 2 to atmospheric measurement of GHG emissions under international space and climate governance frameworks, this section first outlines the ways in which such measurements have the potential to improve the technical transparency of GHG emissions reporting. We start by providing a brief overview of the current processes for preparing state emissions inventories under the UNFCCC, and the data quality issues that have arisen in this context. We then explore the potential advantages of satellite-enabled measurement techniques to redress these data quality concerns, and enhance the transparency of national emissions data.

3.1 Limitations of Current Emissions Data under the UNFCCC

The current practice under the UNFCCC is for states to report their GHG emissions data, compiled in accordance with IPCC Guidelines,[43] in national inventory reports that are submitted to the UNFCCC Secretariat. These guidelines allow for three categories of approaches to determine emissions, which are increasingly demanding in terms of complexity and data requirements:

- calculations using statistical information, especially for fossil fuel use;
- satellite measurements of land use using imagery;[44] and
- tracer-transport inversion, a technique based on atmospheric and/or oceanic measurements of the gases and mathematical models of air and water flow. [45]

The first listed statistical method for calculating emissions is the most widely adopted as fossil fuel use is the dominant source of CO_2 emissions in most countries.[46] Emissions data are derived from figures calculated using activity data and emission factors for each GHG. These calculation-based

1986-1999: The Data Reporting System under the Montreal Protocol (Deutsche Gesellschaft fur Technische Zusammenarbeit, 2001), pp. 11-32.

[43] See, e.g., Kyoto Protocol to the United Nations Framework Convention on Climate Change, Kyoto (Japan), 11 Dec. 1997, in force 16 Feb. 2005, available at: http://unfccc.int/resource/docs/convkp/kpeng.pdf, Art. 5(2).

[44] The focus of this article is on satellite measurements of atmospheric concentrations and estimating fossil fuel CO_2 emissions as an emerging capability, rather than the existing use of satellite imagery for land-use monitoring referred to in the IPCC Guidelines.

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

[46] Ibid.

methodologies have significant scope for error due to the inherent uncertainty in quantifying emission factors, coupled with the uncertainty in the activity data to which they are applied.[47]

While the accuracy of the underlying data and emission factors has generally been improving over time,[48] concerns about data quality persist. As calculation-based approaches depend on the availability of activity data and the accuracy of emission factors, the quality of inventories varies significantly between countries and contributes to uncertainty in global estimates.[49] Using atmospheric measurements, Levin et al show that some emissions reported to the UNFCCC have been underestimated by 70–80%, reinforcing the need for an additional layer of top-down review of emission estimates to verify bottom-up calculations.[50] Inventories also frequently require revision, especially for more heterogeneous and dispersed sources such as methane from waste management and pipeline transmission, which are difficult to estimate.[51] For example, the German methane (CH_4) emissions for 2001 reported to the UNFCCC were revised upward in 2004, resulting in an increase of reported CH_4 emissions of approximately 70% for the whole-time series 1990–2001.[52] As Weiss and Prinn observe, 'the discrepancies are large enough to call into serious question the reliability of the emission factors that are used in bottom-up emissions accounting'.[53] Such discrepancies raise significant concerns about the accuracy and completeness of national inventory reports primarily based on calculation-based methodologies, and draw into question governance decisions predicated on this information.

A related issue is poor quality baseline data, which is subsequently revised. Based on 2010 data, Zahar analyzed how states respond to expert review teams' (ERT) scrutiny of emissions inventories under the Kyoto Protocol.[54] He found that dialogue between states and the ERT during the review frequently led to voluntary revision of initial estimates. Specifically, 34 out of 37 Annex B parties'

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[47] R. Simnett, M. Nugent & A. L. Huggins, 'Developing an International Assurance Standard on Greenhouse Gas Statements' (2009) 23(4) *Accounting Horizons*, pp. 347-63, at 353-4.
[48] OECD Environment Directorate, *Identifying and Addressing Gaps in the UNFCCC Reporting Framework*, prepared by J. Ellis & S. Moarif, OECD/IEA Climate Change Expert Group Paper No. 2015(7) (2015), available at: http://www.oecd.org/environment/cc/Identifying-and-addressing-gaps.pdf.
[49] Aganaba-Jeanty, n. 4 above, p. 4.
[50] 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*, pp. 2655-62.
[51] Aganaba-Jeanty, n. 4 above, p. 4.
[52] P. Bergamaschi et al., 'Inverse Modelling of National and European CH_4 Emissions Using the Atmospheric Zoom Model TM5' (2005) 5 *Atmospheric Chemistry & Physics*, pp. 2431-60.
[53] R.F. Weiss & R.G. Prinn, 'Quantifying Greenhouse-Gas Emissions from Atmospheric Measurements: A Critical Reality Check for Climate Legislation' (2011) 369(1943) *Philosophical Transactions: Mathematical, Physical & Engineering Sciences*, pp. 1925-42, at 1935.
[54] A. 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 Law*, pp. 313-24; UNFCCC, *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), p. 7.

base-year estimates reviewed were voluntarily revised, or 'adjusted' by the ERT in rare instances.[55] Twenty-three of these parties (i.e. 62% of the total of 37 reviewed parties) had initially advantageously over-reported their emissions in the base year, with 11 parties under-reporting their base-year emissions estimates to their own disadvantage.[56] The expectation that baseline data are revisable and 'negotiable', which has also been evident in the compliance systems of other MEAs,[57] underscores the need for independent and reliable data on GHG emissions.

Recent developments in satellite-enabled measurement techniques have the potential to address some of the deficiencies in bottom-up emissions data, with concomitant transparency benefits. Satellite technologies can be used to isolate the anthropogenic component from highly accurate atmospheric GHG concentration measurements, which facilitates verification of bottom-up estimates of emissions.[58] Moreover, as foreshadowed above, there is an emerging capability for satellite remote sensing to quantify CO_2 emissions and other GHG concentrations from large-scale point sources, such as industries, power plants and megacities.[59] Gurney recommends a hybrid approach that takes advantage of the 'best' estimate of a flux, irrespective of the method used, taking into account considerations of 'accuracy, cost, availability and political viability, in addition to the usual scientific metrics'.[60] These existing and emerging satellite measurement techniques can contribute to technical transparency by quantifying GHG emissions in a way that is accurate, independent, and replicable. As is shown below, such techniques can enhance the flexibility of the transparency options available, and broaden the range of actors to whom states are potentially answerable for their emissions progress.

3.2 International Initiatives to Improve Access to Transparent Emissions Data

A number of international initiatives, both within and beyond the UNFCCC, seek to harness the potential of satellite-enabled capabilities to improve the monitoring, measurement, and verification practices for GHG emissions. Under the UN climate regime, atmospheric monitoring and measurement techniques are currently addressed under provisions for research and systematic observation. Article 4(1)(g) of the UNFCCC requires states to, inter alia, promote and cooperate on

[55] Annex B parties are those included in Annex B of the Kyoto Protocol that agreed to a target for their GHG emissions in the first commitment period.
[56] Zahar, n. 54 above, p. 319.
[57] See, e.g., the Montreal compliance system discussed in J. Klabbers, 'Compliance Procedures', in: D. Bodansky, J. Brunnée & E. Hey (eds), *The Oxford Handbook of International Environmental Law* (Oxford University Press, 2007), pp. 995-1009, at 996.
[58] Weiss & Prinn, n. 53 above, p. 1931.
[59] Hardwick & Graven, n. 1 above, p. 7.
[60] K. Gurney, 'Beyond Hammers and Nail: Mitigating and Verifying Greenhouse Gas Emissions' (2013) 94(2) *Eos, Transactions, American Geophysical Union*, pp. 199-200.

'systematic observation and development of data archives related to the climate system'. In 2004, the first implementation plan for global climate observations to be coordinated by the Global Climate Observing System[61] was finalized, and later extensively updated at the tenth conference of the Parties to the UNFCCC (COP 10) in 2010.[62] However, as discussed in the following section, the potential uses of atmospheric emission measurements under the UN climate regime are far broader than the focus on research and systematic observation of the climate system as a whole in Article 4(1)(g) suggests.

Beyond the UN climate regime, the WMO, a UN specialized agency, is seeking to develop enhanced technical capabilities for a fully integrated emissions information system. In June 2015, the 17th 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 … with temporally explicit socioeconomic emission inventory data'.[63] The objectives of the IG3IS project are:

- to reduce uncertainty of national emissions inventory reporting to the UNFCCC;
- to locate and quantify previously unknown emissions reduction opportunities such as fugitive methane emissions from industrial sources;
- 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 provide support for the Paris Agreement's global stocktake.[64]

The long-term WMO vision 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.[65] There is thus growing international interest in combining satellite-enabled measurement techniques and big data to provide access to transparent emissions data to inform monitoring, reporting, and verification activities.

National space agencies have also underlined their commitment to using space-based emissions data to develop an inclusive global data set, with a view to 'establishing an international approach to

[61] The GCOS is sponsored by the WMO, Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO), UNEP, and the International Council for Science.
[62] UNFCCC, 'Update on the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC', UN Doc FCCC/SBSTA/2010/MISC.9, 17 Sept. 2010, available at: https://unfccc.int/resource/docs/2010/sbsta/eng/misc09.pdf.
[63] WMO & UNEP, n. 5 above.
[64] P. DeCola & WMO Secretariat, 'An Integrated Global Greenhouse Gas Information System (IG3IS)' (2017) 66(1) *WMO Bulletin*, available at: https://public.wmo.int/en/resources/bulletin/integrated-global-greenhouse-gas-information-system-ig3is.
[65] WMO & UNEP, n. 5 above.

estimating greenhouse gas emission changes for global use based on internationally accepted data'.[66] Recognizing the significant contribution of satellite data to climate change studies and disaster management support, the heads of space agencies from around the world expressed their determination to strengthen their role in informing decisions under the UN climate regime as part of the Mexico Declaration in September 2015.[67] Thereafter, following the signing of the Paris Agreement on 12 December 2015, more than 60 space agencies endorsed the New Delhi Declaration in April 2016 and committed to the development of an international, independent system for measuring GHG emissions to support the objectives of the Paris Agreement.[68] While the Declaration does not create legally binding obligations under international law, it does represent the consensus of two multilateral institutions and 58 states, including the world's leading space powers. One practical step towards implementation was agreed during the Paris Climate 'One Planet' Summit in December 2017, leading to the establishment of a Climate Space Observatory under the Paris Declaration.[69] Details of this Declaration, which according to media reports was adopted by Austria, China, Germany, the EU, India, Israel, Italy, Japan, Norway, Romania, Sweden, Switzerland, Ukraine, the United Arab Emirates and the United Kingdom,[70] are yet to be finalized. The initiators are seeking to coordinate this observatory under the framework of the Outer Space Regime.[71] This means that the proposed space climate observatory is likely to be coordinated under an international space governance framework rather than under international climate law.

4. SATELLITE-ENABLED EMISSIONS MEASUREMENT: PROSPECTS FOR ENHANCING TRANSPARENCY AND ANSWERABILITY

Concerns about data quality and transparency in national emissions inventories under the UN climate regime, combined with recent advances in satellite-enabled emissions measurement capabilities, raise the question: in what ways, if any, can an increase in transparent data facilitated by satellites and big data contribute to states' answerability for their emissions-reduction pledges? As explained in Section

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[66] One Planet Summit, 'Paris Declaration: "Towards a Space Climate Observatory"', 11 Dec. 2017, available at: https://www.oneplanetsummit.fr/IMG/pdf/paris_declaration_towards_a_space_climate_observatory.pdf, p. 1

[67] International Academy of Astronautics, 'Summit Declaration', 18 Sept. 2015, available at: iaaweb.org/iaa/Scientific%20Activity/declarationmexico.pdf.

[68] Declaration of New Delhi, 'Heads of Space Agencies Decide to Join Efforts in Support of COP 21 Decisions', May 2016, on file with first author; CNES, n. 6 above. The participating countries are Algeria, Saudi Arabia, Argentina, Austria, Australia, Azerbaijan, Belgium, Belorussia, Bolivia, Brazil, Canada, Chile, China, Columbia, 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, Singapore, South Africa, Spain, South Korea, Sweden, Switzerland, Turkey, United Arab Emirates, UK, US (NASA-NOAA-CEOS), Ukraine, Vietnam, France, Thailand and two institutions, the International Academy of Astronautics and the European Space Agency.

[69] One Planet Summit, n. 66 above.

[70] 'World's Space Agencies Propose Setting up Climate Observatory', 11 Dec. 2017, available at: https://phys.org/news/2017-12-world-space-agencies-climate-observatory.html.

[71] One Planet Summit, n. 66 above, p. 2.

2, focusing on transparency of actions, actors and process, and the relationship with relations, standards and judgments, facilitates evaluation of the extent to which transparency arrangements promote answerability. This section applies the analytical frame to the international space governance framework and the UN climate regime, with a focus on the Paris Agreement. In the former context, it shows that the public dissemination of integrated emissions data sets in accessible formats has the potential to enhance answerability for states' mitigation performance through non-state actor scrutiny and review. Under the Paris Agreement, there is scope for space-based measurement data to contribute to verification activities for national emissions inventories. However, the emphasis on non-intrusive transparency measures that are respectful of national sovereignty under the enhanced transparency framework is likely to present a barrier to technical expert review teams referring to such data in verification processes under Article 13(11) of the Paris Agreement. Aggregated measurements could also provide a reference point for the global stocktake under Article 14, yet the absence of political judgments in the stocktake process detracts from the prospects of increasing answerability through improvements in transparency in this context.

4.1 International Space Law and Policy

A number of key principles of international space law pertain to both earth observations and satellite-enabled atmospheric measurement techniques. The Outer Space Treaty states that the exploration and use of outer space are to be carried out for the benefit and interests of all countries, and shall be 'the province of all mankind'.[72] The principles of sovereignty which extend to airspace do not extend to outer space.[73] Space is subject to the principles of free exploration and use of outer space, which have enabled states to perform earth observations without the permission of the state being observed.[74] Whilst this creates contention in some areas, it is tempered by the Outer Space Treaty's calls for international cooperation and for due regard to the interests of all other states in carrying out state activities in space.[75]

In terms of whose information is transparent to whom, the data policy regulations that apply to space-based data allow data about a state to be transparent to the observing state, to a monitored or 'sensed' state, and to other states on a non-discriminatory basis. The global standard for satellite earth observation data policy regulation is articulated in the UN General Assembly's 1986 Remote Sensing Principles.[76] As the principles themselves are articulated in a General Assembly resolution, they are

[72] Outer Space Treaty, n. 8 above, Art. 1.
[73] Ibid., Art. 2.
[74] Ibid., Art. 1.
[75] Ibid., Art. 9; Aganaba-Jeanty, n. 4 above, p. 10.
[76] Principles Relating to Remote Sensing of the Earth from Outer Space, GA Res 41/65, UNGAOR, 1986, UN Doc A/RES/41/65 (Remote Sensing Principles), available at: http://www.un.org/documents/ga/res/41/a41r065.htm.

not legally binding, but to the extent that they represent state practice,[77] they have considerable weight. The 'sensed' state —that is, the territory that is being monitored—has no veto to prevent the remote sensing activity. Moreover, the sensed state does not have 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 vantage point of space. However, by virtue of principle XII of the Remote Sensing Principles, once the primary data and the processed data concerning its territory are produced, the sensed state shall have access to them on a non-discriminatory basis and on reasonable cost terms. This means that, for a particular set of remote-sensing data concerning its territory, the sensed state does not differ from any other state with regard to the terms under which it can access the data.[78] In practice, access to earth observation data can be hampered by restrictive access and pricing policies, and is ultimately subject to the political, strategic, and military considerations of the most powerful states.[79]

The extent to which space data are shared impacts on which state activities are transparent to whom. While some nations make data from their unclassified, government-owned earth observation satellites publicly available without charge, facilitating open access to important climate data, such practices are by no means universal.[80] A number of international initiatives seek to promote unrestricted international exchange of free environmental data. For example, the Global Earth Observation System of Systems (GEOSS)[81] has developed open data-sharing principles which accord with transparency aims. These data-sharing principles stipulate that:

- there will be full and open exchange of data, metadata and products shared within GEOSS, recognizing relevant international instruments and national policies and legislation;

[77] Implementation of these principles at the domestic level takes different forms, ranging from a focus on the satellite system, the data, the transaction or a combination of these: J.I. Gabrynowicz, *The Land Remote Sensing Laws and Policies of National Governments: A Global Survey* (National Center for Remote Sensing, Air, and Space Law at the University of Mississippi School of Law, 2007).

[78] Aganaba-Jeanty, n. 4 above, pp. 10-1. To prevent sharing of sensitive information, individual agreements can be entered into between the satellite asset owner and the sensed state. An example of this is the Kyl-Binganam Amendment to the 1997 US National Defense Authorization Act: see National Defense Authorization Act for Fiscal Year 1997, § 1064, 110 Stat. 2422 (1996) (enacted) and A. Zerbini & M. Fradley, 'Higher Resolution Satellite Imagery of Israel and Palestine: Re-assessing the Kyl-Binganam Amendment' (2018) March *Space Policy*, pp. 1-15. However, such agreements are rare as they run counter to the trend of open data policies, and would only occur in strategic circumstances.

[79] M. Onoda, 'Satellite Earth Observation as "Systematic Observation" in Multilateral Environmental Treaties' (2005) 31(2) *Journal of Space Law*, pp. 339-412; A. 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(1) *Journal of Space* Law, pp. 45-65, at 46.

[80] M. Borowitz, *Open Space: The Global Effort for Open Access to Environmental Satellite Data* (The MIT Press, 2017), p. 2.

[81] GEOSS was established by the Group on Earth Observations (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 and independent earth observation, information, and processing systems that interact and provide access to diverse information for a broad range of users: GEO, 'About GEOSS' (2018), available at: https://www.earthobservations.org/geoss.php.

- 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.[82]

In a similar vein, the purpose of the WMO World Data Centres is to collect data from contributors[83] of the Global Atmosphere Watch programme, to archive the processed data, make the data publicly available, and provide support in the 'quality assurance, analysis and interpretation' of these data.[84] Despite these initiatives, a number of impediments to the sharing of space data remain, including the culture that data sharing is not part of the producers' mission, the cost implications, restrictions to promote commercial sales, and national security concerns.[85] Each of these factors contributes to gaps in the availability of environmental data from satellites, undermining the potential for answerability through transparency.

The range of stakeholders who have access to states' environmental data is expanding as private actors increasingly collect, use, store, and disseminate space data. Alongside national space agencies, private sector actors and non-governmental organizations (NGOs), such as GHGSat Inc. and the Environmental Defense Fund, are developing capabilities to measure GHG emissions from industrial sources using remote-sensing microsatellites.[86] California has recently announced a partnership with earth observation satellite operators Planet Labs to launch a satellite to track GHG emissions by 2021.[87] Some of these operators are storing large satellite datasets on the cloud. For example, Planet Labs has announced that they are using the Google cloud and DigitalGlobe through Amazon's cloud services.[88] Thus, state data are potentially transparent to state and non-state actors, and the broader public via the cloud.

States are likely to have significant concerns about sensitive integrated emissions data being available on the cloud, especially as national governments are unable to track or restrict the individuals who

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[82] GEO, 'GEO Data Sharing Principles Implementation' (2018), available at: https://www.earthobservations.org/geoss_dsp.shtml.
[83] World Data Centre for Greenhouse Gases, 'List of Contributors', available at: https://gaw.kishou.go.jp/documents/db_list/organization
[84] World Data Centre for Greenhouse Gases, 'About WDCGG', available at: https://gaw.kishou.go.jp/about_wdcgg/wdcgg
[85] Borowitz, n. 80 above, p. 267.
[86] Networks of Centres of Excellence in Canada, 'Monitoring Greenhouse Gases from Space' (2016), available at: http://www.nce-rce.gc.ca/Research-Recherche/Stories-Articles/2017/MonitoringGreenhouse-SurveillerEmissions_eng.asp.
[87] Rainey, n. 2 above.
[88] M. Dhane, 'Planet Labs Satellite Data is now on Google Cloud', *Geospatial World* (2017), available at: https://www.geospatialworld.net/planet-labs-satellite-data-google-cloud; S. Scoles, 'The Best Way to Transmit Satellite Data? In Trucks. Really?', *Wired*, 17 May 2017, available at: https://www.wired.com/2017/05/best-way-transmit-satellite-data-trucks-really.

access the cloud.[89] In an integrated data environment, even if information has been voluntarily provided by users, aggregated data from both government and non-government sources might provide additional information about users that they did not necessarily wish to disclose.[90] Recognizing these transparency opportunities and challenges, new technologies are needed that can receive, archive, process, analyze, and distribute the actionable information, and develop the security protocols necessary for the level of information sharing required for sensitive state data.[91] Such systems should seek to strike a balance between the transparency benefits of publicly available environmental data, including emissions information, and the need for privacy, confidentiality, and data sovereignty.

If integrated emissions data sets are made publicly available, answerability may be promoted through a greater role for non-state actors in reviewing the accuracy, completeness, and comparability of states' reported emissions. According to Guzman, reputational impact and sanctions are two key factors contributing to state compliance with international law.[92] With regard to the former factor, public 'naming and shaming' is an indirect enforcement strategy used by international organizations, NGOs, and the media to promote public accountability for international law violations.[93] This relates to Brown Weiss and Jacobson's argument that transparency can promote compliance with MEAs by bringing the behaviour of states and targeted actors 'into the open for appropriate scrutiny'.[94] Research and civil society organizations have already played a role in scrutinizing the underlying assumptions and data in states' individual nationally-determined contributions (NDC)[95] under the Paris Agreement.[96] In a similar vein, non-state actors can monitor transparent information on state

[89] Aganaba-Jeanty, n. 4 above, p. 12.
[90] P. De Filippi & S. McCarthy, 'Cloud Computing: Centralization and Data Sovereignty' (2012) 3(2) *European Journal for Law and Technology*, available at: http://ejlt.org/article/view/101/234.
[91] W. Croi, F. M. 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* (Martinus Nijhoff Publishers, 2013), pp. 379-98, at 379; Aganaba-Jeanty, n. 4 above, p. 13.
[92] A.T. Guzman, 'A Compliance-Based Theory of International Law' (2002) 90(6) *California Law Review*, pp. 1823-87, at 1846, 1861.
[93] Leal-Arcas & Morelli, n. 15 above. This approach has been widely used by NGOs in the field of international human rights law since 1975: see, e.g., E.M. Hafner-Burton, 'Sticks and Stones: Naming and Shaming the Human Rights Enforcement Problem' (2008) 62(4) *International Organization*, pp. 689-716.
[94] E. Brown Weiss & H.K. Jacobson, 'Assessing the Record and Designing Strategies to Engage Countries', in: E. Brown Weiss & H.K. Jacobson (eds), *Engaging Countries: Strengthening Compliance with International Environmental Accords* (The MIT Press, 1998), pp. 511-54, at 543. In a related vein, Kline and Raustiala note that remotely-sensed satellite data can have a deterrent effect on states by making non-compliance observable and costly: K. Kline & K. Raustiala, 'International Environmental Agreements and Remote Sensing Technologies', Background paper prepared for the Workshop on Remote Sensing and Environmental Treaties, Building More Effective Linkages, 4-5 Dec. 2000, Columbia University, New York, U.S., available at: http://sedac.ciesin.columbia.edu/rs-treaties/rs-treaties_bckgnd.pdf, pp. 15-6, 30.
[95] Paris Agreement, n. 9 above, Art. 4(2).
[96] H. van Asselt, 'The Role of Non-State Actors in Reviewing Ambition, Implementation, and Compliance under the Paris Agreement' (2016) 6(1-2) *Climate Law*, pp. 91-108, at 104-5.

emissions enabled by satellite and big data technologies,[97] and exert public pressure on states to be answerable to the international community for their mitigation progress.

Questions remain, however, as to against what standards the transparent information is to be measured, and what is the process for reaching judgments about this information. The standards of performance for GHG emissions against which states are held to account in international law are found in the Kyoto Protocol and the Paris Agreement. Under the Kyoto Protocol, each Annex I Party committed to achieve differentiated, legally-binding emissions targets of at least 5% below 1990 levels in the first commitment period (2008-2012).[98] The Paris Agreement, in contrast, imposes a collective obligation on all parties to hold 'the increase in the global average temperature to well below 2°C [degrees Celcius] above pre-industrial levels', and each state is required to specify its own NDC to the global climate change response, which will be progressively strengthened.[99] These emissions-mitigation commitments under the UN climate regime can provide standards against which publicly available space-based emissions data can be assessed, contributing to enhanced answerability through public scrutiny and review. However, how judgments about the achievement of these standards will be reached is unclear as there is no formal mechanism for review by non-state actors, and due process guarantees do not apply.

4.2 The Paris Agreement

The Paris Agreement provides a suite of processes for promoting accountability for state emissions-reduction pledges, and there is scope for satellite-enabled measurements to provide a data source to inform a number of these processes. The Paris Agreement allows states to set their own mitigation targets in their NDCs and provides for four key oversight arrangements for state reports submitted through the formal reporting system – the transparency framework for action and support,[100] multilateral consideration of progress,[101] global stocktakes,[102] and the formal non-compliance process.[103] In this sub-section, we examine the prospects for satellite-enabled emissions measurement data to be used as a reference point in national inventory reports, technical expert review, and the global stocktake.

[97] However, there remains a risk that if large volumes of technical information on states' progress towards their international environmental commitments are made available, yet require sophisticated expert knowledge and English language skills to interpret, the ability of some state and non-state actors to utilize this information for accountability purposes will be undermined.
[98] Kyoto Protocol, n. 43 above, Art. 3(1).
[99] Paris Agreement, n. 9 above, Arts 2 and 4(3).
[100] Ibid., Art. 13.
[101] Ibid., Art. 13(11).
[102] Ibid., Art. 14.
[103] Ibid., Art. 15.

Improving state emissions inventories

As satellite technology continues to develop, there is an opportunity for states to use remote-sensing measurement techniques to verify the emissions levels and trends reported in their national inventory reports. Under Article 4(13) of the Paris Agreement, parties are required to 'account for' their NDCs in a way that promotes 'environmental integrity, transparency, accuracy, completeness, comparability and consistency'. Each Party is required to, inter alia, submit to the UNFCCC Secretariat a national emissions inventory report, and information 'necessary to track progress' toward implementing and achieving its NDC,[104] which will be subject to technical expert review and multilateral consideration of process.[105] The national inventory report of 'anthropogenic emissions by sources and removals by sinks of greenhouse gases' is to be prepared 'using good practice methodologies accepted by the Intergovernmental Panel on Climate Change (IPCC)'.[106] The current IPCC Guidelines were published in 2006,[107] and the 2019 Refinements to the 2006 Guidelines are due to be published in May.[108] As part of these revisions, the IPCC is updating and elaborating upon the guidance on quality assurance and verification as it acknowledges that the existing guidance is outdated, 'especially the guidance on comparisons with atmospheric measurements and new datasets' given recent developments in, among other things, atmospheric concentration data and independent monitoring of carbon stocks and fluxes.[109] Thus, there is increasing recognition that atmospheric measurement data can be used to check and corroborate data in emissions inventories, thereby enhancing technical transparency, but this guidance is likely to be advisory rather than mandatory in recognition of some states' capacity constraints.

A number of initiatives are already being undertaken to improve the verification of national inventory reports using satellite-enabled measurement techniques. For example, the United Kingdom's second biennial report highlights the use of an inversion modelling technique, informed by high-frequency, high-precision measurements of atmospheric trace gases, to verify the emissions levels and trends reported in its GHG inventory.[110] Switzerland, and to a lesser extent Australia, also utilize top-down

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[104] Ibid., Art. 13(7).
[105] Ibid., Art. 13(11).
[106] Ibid., Art. 13(7)(a).
[107] IPCC, n. 40 above.
[108] IPCC, '2019 Refinements to the 2006 IPCC Guidelines for National GHG Inventories' (2018), available at: https://www.ipcc-nggip.iges.or.jp/home/2019refinement.html.
[109] IPCC, '44th Session of the IPCC: Decisions adopted by the Panel', 17-20 Oct. 2016, Bangkok (Thailand), p. 40, available at: http://www.ipcc.ch/meetings/session44/p44_decisions.pdf.
[110] UK Department of Energy and Climate Change, *The UK's Second Biennial Report under the United Nations Framework Convention on Climate Change* (Department of Energy and Climate Change, 2015), p. 25, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/491405/UK_Second_Biennial_Report_Web_Accessible.pdf.

quantification and analysis to inform improvements to their bottom-up emissions inventory reporting.[111] In the European Union, a European integrated observation system[112] is proposed to monitor fossil CO_2 emissions using independent atmospheric observations, which will, in time, provide an 'operational independent verification system'.[113] By the mid-2030s, this system aims to 'enable the accurate, transparent and consistent quantification of fossil CO_2 emissions and their trends at the scale of megacities, important industrial sites, small regions, countries, and the Earth as a whole'.[114] Provided that there is clarity around the methodologies, data and data sources, and assumptions underpinning these data, satellite-enabled techniques hold considerable promise for enhancing the technical transparency of states' national inventories. These transparency gains can, in turn, contribute to greater answerability for states' progress toward achieving their NDCs by reducing uncertainty in reported information.

Such initiatives are being led by industrialized states at this stage due to the resource-intensive nature of these sophisticated data infrastructures. Capacity-building support may be required for other states—particularly developing states—to develop similar initiatives.[115] In this regard, it is notable that Article 13(14) and (15) of the Paris Agreement mandates that support shall be provided to developing countries for implementing the transparency requirements and for building transparency-related capacity. Paragraph 85 of the decision accompanying the Agreement establishes a Capacity-Building Initiative for Transparency to build institutional and technical capacity and support developing country parties, upon request, in meeting the enhanced transparency requirements under Article 13.[116] In the absence of support to develop and maintain the satellites and other infrastructure required to utilize atmospheric measurement techniques, the potential transparency benefits of these techniques to verify states' emissions inventories will remain patchy and largely untapped.

The enhanced transparency framework

Accurate information about state GHG emissions reveals trends and sets the baseline against which mitigation action can be measured. It is thus pivotal to the success of the Paris Agreement. Conversely, failure to correctly measure and report emissions might not only erode trust between

[111] DeCola & WMO Secretariat, n. 64 above.
[112] The system will consist of a suite of coordinated multi-scale, multi-type carbon observations, including aircraft, satellite, and *in situ* data, and a data assimilation system and distribution system: European Commission, *Towards a European Operational Observing System to Monitor Fossil CO_2 Emissions: Final Report from the Expert Group* (European Commission, 2015), p. 46, available at: edgar.jrc.ec.europa.eu/news_docs/CO2_report_22-10-2015.pdf.
[113] Ibid., pp. 9, 46.
[114] Ibid., p. 9.
[115] Under Art. 13(9) Paris Agreement, n. 9 above, developed states are required to report on the financial, technology transfer, and capacity-building support they provide to developing countries. Developing countries should also report on the financial, technology transfer, and capacity-building support needed and received: ibid., Art. 13(10).
[116] Ibid., p. 12.

parties, but also could lead to a misreading of the progress made in achieving targets. Therefore, the process of quantifying emissions, as well as information on the implementation and achievement of NDCs, must be transparent. To this end, an enhanced transparency framework for action and support is established under Article 13(1) in order to build 'mutual trust and confidence' and promote 'effective implementation'. As articulated in Article 13(5), the purpose of this framework is to provide a clear understanding of climate change action, including clarity and tracking of progress toward achieving parties' individual NDCs, and informing the global stocktake. The modalities, procedures, and guidelines (MPGs) for the enhanced transparency framework were agreed as part of the Katowice Climate Package in December 2018.[117] This transparency framework will play a critical role in promoting states' answerability for the realization of their NDCs and ultimate achievement of the Paris Agreement's overall objective.[118]

Prima facie, satellite-enabled emissions measurement data could serve as a valuable independent reference point for internationally-coordinated review processes under Article 13(11), enhancing states' answerability to the technical expert review (TER) teams. One shortcoming of the current expert review team (ERT) process under the UNFCCC and Kyoto Protocol is that while the ERT may use relevant technical information in the review process, ERTs are unable to refer to data from independent, non-state sources to verify reports, unless the data was formally supplied to that source by the authorities of the state under review.[119] The main checks ERTs have been able to make are: (1) comparisons with a state's historically reported data, (2) conformity with standard IPCC methodologies, (3) country-level statistics on the production, import, and export of fuel from the International Energy Agency, and (4) comparisons with the types of issues reported in other states' reports.[120] The review powers granted to ERTs prioritize deference to state sovereignty,[121] and the limitations on ERTs' ability to independently verify emissions data means that while reviewed emissions inventories are deemed to be legally compliant, they may not be in scientific compliance.[122]

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[117] UNFCCC, draft decision -/CMA.1, 'Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement', FCCC/CP/2018/L.23, 15 Dec. 2018, available at: https://unfccc.int/sites/default/files/resource/Informal%20Compilation_proposal%20by%20the%20President_rev.pdf.
[118] D. Bodansky, 'The Paris Climate Change Agreement: A New Hope?' (2016) 110(2) *American Journal of International Law*, pp. 288-319, at 311; A. Huggins, *Multilateral Environmental Agreements and Compliance: The Benefits of Administrative Procedures* (Routledge, 2018), pp. 151-7.
[119] A. Zahar, 'Verifying Greenhouse Gas Emissions of Annex 1 Countries: Methods We Have and Methods We Want' (2010) 1(3) *Climate Law*, pp. 409-27, at 413, citing UNFCCC Secretariat, *Handbook for Review of National GHG Inventories* [nd], ch 2, pp. 11–12.
[120] Decision 22/CMP.1, Guidelines for Review under Article 8 of the Kyoto Protocol, FCCC/KP/CMP/2005/8/Add.3, 30 Mar. 2006, at para. 65.
[121] A. Huggins, 'The Desirability of Depoliticization' (2015) 4(1) *Transnational Environmental Law*, pp. 101-24, at 109-10.
[122] T. Berntsen, J. Fuglestvedt & F. Stordal, 'Reporting and Verification of Emissions and Removals of Greenhouse Gases', in: O.S. Stokke, J. Hovi & G. Ulfstein (eds), *Implementing the Climate Regime: International Compliance* (Earthscan, 2005), pp. 85-105, at 86.

Measurement of emissions using satellite remote-sensing techniques would provide an independent counterpoint to state-provided information, and has the potential to considerably enhance the robustness of the TER processes under the Paris Agreement. This is significant as the TER processes will inform the multilateral consideration of progress and the non-compliance mechanism under the Paris Agreement,[123] both of which play a role in holding states to account for their emissions-reduction pledges.

Although satellite-enabled approaches to measuring GHG emissions may be consistent with the expected revisions to the IPCC guidelines, a broader question remains as to whether such approaches are congruent with Article 13(3) of the Paris Agreement. This provision emphasizes that the enhanced transparency framework should be implemented in a 'facilitative, non-intrusive, non-punitive manner, respectful of national sovereignty'. Ellis and others highlight measures that can ensure a non-intrusive process that 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.[124]

In the light of these elements of a non-intrusive process under the UN climate regime, it is likely that remote sensing of territories and possible sharing and use of these data as an independent source without the permission of the state being observed, could be seen as intrusive and lacking the requisite deference to national sovereignty.[125] Thus, the use of atmospheric measurement data without state consent is likely to be in tension with the requirements of Article 13(3).

A related issue is that if only a small number of states or actors have the capacity to produce satellite measurement data, and one state or actor's data are chosen as an authoritative source for emissions measurements, other states may be concerned about the independence of these data. Moreover, in the

[123] Paris Agreement, n. 9 above, Art. 13(5)-(6); UNFCCC, draft decision -/CMA.1, 'Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement', FCCC/CP/2018/L.23, 15 Dec. 2018, available at: https://unfccc.int/sites/default/files/resource/Informal%20Compilation_proposal%20by%20the%20President_rev.pdf, para. 190(b); UNFCCC, draft decision –CMA.1, 'Modalities and Procedures for the Effective Operation of the Committee to Facilitate Implementation and Promote Compliance Referred to in Article 15, Paragraph 2, of the Paris Agreement', FCCC/CP/2018/L.5, 14 Dec. 2018, available at: https://unfccc.int/sites/default/files/resource/l05_2.pdf, para. 22(b).

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

[125] Aganaba-Jeanty, n. 4 above, p. 9.

absence of systematic and universal monitoring, decisions need to be made about where satellite gaze is directed. For example, new satellite operators such as Planet Labs, who have the largest constellation of earth observation satellites, have the capacity to monitor the entire planet on a daily basis, and use machine learning to detect trends and priority areas of focus.[126] The previously mentioned European integrated observation system will have a data assimilation and forecasting system and aims to quantify fossil CO_2 emissions and their trends at the scale of megacities, important industrial sites, small regions, and countries,[127] again raising questions about how observational focal points will be identified. Decisions about where to direct satellite gaze may raise potential equity concerns, and are likely to be politically contested.[128] Therefore, the requirements of Article 13(3) and these relational concerns will likely pose an obstacle to remotely-sensed emissions data contributing to enhanced answerability in the technical expert review process.

The global stocktake

Given its emphasis on collective progress rather than individual state accountability, there may be greater scope for referring to aggregated atmospheric measurement data as part of the global stocktake, and providing information on emissions mitigation as envisaged by the WMO IG3IS project.[129] The stocktake will be held every five years, beginning in 2023, and its aim is to assess 'collective progress towards achieving the purpose of this Agreement and its long term goals'.[130] Aggregated emissions measurement data could contribute to assessing collective mitigation progress, and thus states' mutual answerability for their shared goal of limiting increases in the global average temperature to well below 2°C above pre-industrial levels.[131] The MPGs include an option for input from non-party stakeholders in the global stocktake process,[132] potentially providing an opportunity for consideration and discussion of independent data and measurements. Article 14(1) of the Paris Agreement specifies that the stocktake will be conducted in a facilitative manner 'in the light of equity and the best available science', and its focus will be on mitigation, adaptation, and the means of

[126] Planet Labs, 'Planet Imagery and Archive' (2018), available at: https://www.planet.com/products/planet-imagery/
[127] European Commission, n. 112 above, p. 8.
[128] For an analysis of these issues in the context of the use of satellite imagery for monitoring compliance with domestic land-clearing laws, see R.L. Bartel, 'When the Heavenly Gaze Criminalises: Satellite Surveillance, Land Clearance Regulation and the Human-Nature Relationship (2005) 16(3) *Current Issues in Criminological Justice*, pp. 322-39.
[129] DeCola & WMO Secretariat, n. 64 above.
[130] Paris Agreement, n. 9 above, Art. 14(1) and 14(3).
[131] Paris Agreement, n. 9 above, Art. 2. On mutual answerability or accountability, see Winkler, Mantlana & Letete, n. 38 above, p. 862.
[132] UNFCCC, Draft decisions 1/CP.23 and 3/CMA.1, Proposal by the President, 15 Dec. 2018, available at: https://unfccc.int/sites/default/files/resource/Informal%20Compilation_proposal%20by%20the%20President_rev.pdf, Annex IX, para. 38(i).

implementation and support.[133] Given this emphasis on a facilitative process, political judgments are likely to be avoided,[134] detracting from answerability through transparency in this context.

5. CONCLUSION

Atmospheric measurement technology is improving rapidly, and holds significant promise for increasing the accessibility and assessability of state GHG emissions data. Applying and expanding upon elements of Gupta and van Asselt's framework for analyzing the transparency-accountability relationship, this article has shown that there are a number of impediments to translating these transparency gains into enhanced answerability for states' emissions-reduction pledges. In the context of international space law and policy, there have been rapid advancements in satellite remote-sensing measurement techniques and public access to the resultant data, with concomitant benefits for transparency and, to a lesser extent, answerability. In terms of *relations*, non-state actors such as research and civil society organizations may scrutinize integrated emissions data sets, as has already occurred for the assumptions and data in states' NDCs. In the absence of mitigation commitments under international space law, the *standards* for any such scrutiny will likely be sourced from international climate law. As public 'naming and shaming' by non-state actors is an indirect and unofficial enforcement strategy, the processes for reaching *judgments* about the achievement of these standards are opaque and unclear.

Satellite-enabled emissions data also has the potential to enhance transparency under the Paris Agreement, although the flow-on benefits for answerability are again less clear. As is already occurring in some instances, states can use satellite remote-sensing measurement techniques to verify their own emissions inventory reports, which contributes to technical transparency by providing quantified, accurate and replicable GHG emissions data. The capacity constraints of some states is likely to limit the widespread uptake of such techniques unless capacity-building support is provided. In addition, atmospheric measurement approaches could be used as an independent data source as part of the internationally-coordinated technical expert review process under the Paris Agreement, using the *standards* in the enhanced transparency framework, the accompanying MPGs finalized in late 2018, and the revised IPCC Guidelines anticipated to be published in May 2019. In terms of *relations*, information sourced through remote sensing of territories and data sharing, without the permission of the observed state, is likely to be resisted by some states given the emphasis on non-intrusive measures that are respectful of national sovereignty under the enhanced transparency framework. Despite this, there may be scope for aggregated atmospheric measurement data to feed

[133] Paris Agreement, n. 9 above, Art. 14(1); ibid paras. 9, 30.
[134] Gupta & van Asselt, n. 12 above, p. 13.

into the global stocktake under Article 14, thus contributing to states' mutual answerability for their collective mitigation goals. However, given the emphasis on a facilitative process, the absence of political *judgments* will mean that the global stocktake falls short of achieving answerability.

We suggest that increased international cooperation is required to address concerns about satellite-enabled measurement techniques, while encouraging access to the information collected. Because the New Delhi Declaration signals the intent of a group of 60 space agencies to develop an international system for estimating and reducing anthropogenic GHG emissions, initiators of the Declaration should consider establishing an open forum where a wide variety of stakeholders can discuss issues around measuring emissions and the linkages with other climate initiatives, supporting capacity building and addressing data policy issues.[135] This work, in combination with other similar initiatives under the WMO and EU, could feed into the UNFCCC process and support the transparency goals of the Paris Agreement.[136] There is also an important role to be played by international environmental lawyers in contributing to technical and policy discussions to promote the integration of existing legal frameworks and satellite measurement techniques as the scientific integrity of the latter increases.[137] Through such cooperation and dialogue, the potential transparency and answerability benefits afforded by emerging satellite-enabled measurement capabilities can be harnessed and shared across multiple climate governance forums.

[135] Such stakeholders may include space agencies, governmental bodies, international organizations, private companies, universities, and research institutes.
[136] 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. The Global Precipitation Measurement (GPM) mission governance structure provides an interesting example of such an arrangement: see further Aganaba-Jeanty, n. 4 above, at pp. 14, 16.
[137] R. Purdy, 'Using Earth Observation Technologies for Better Regulatory Compliance and Enforcement of Environmental Laws' (2009) 22(1) *Journal of Environmental Law*, pp. 59-87, at 86.