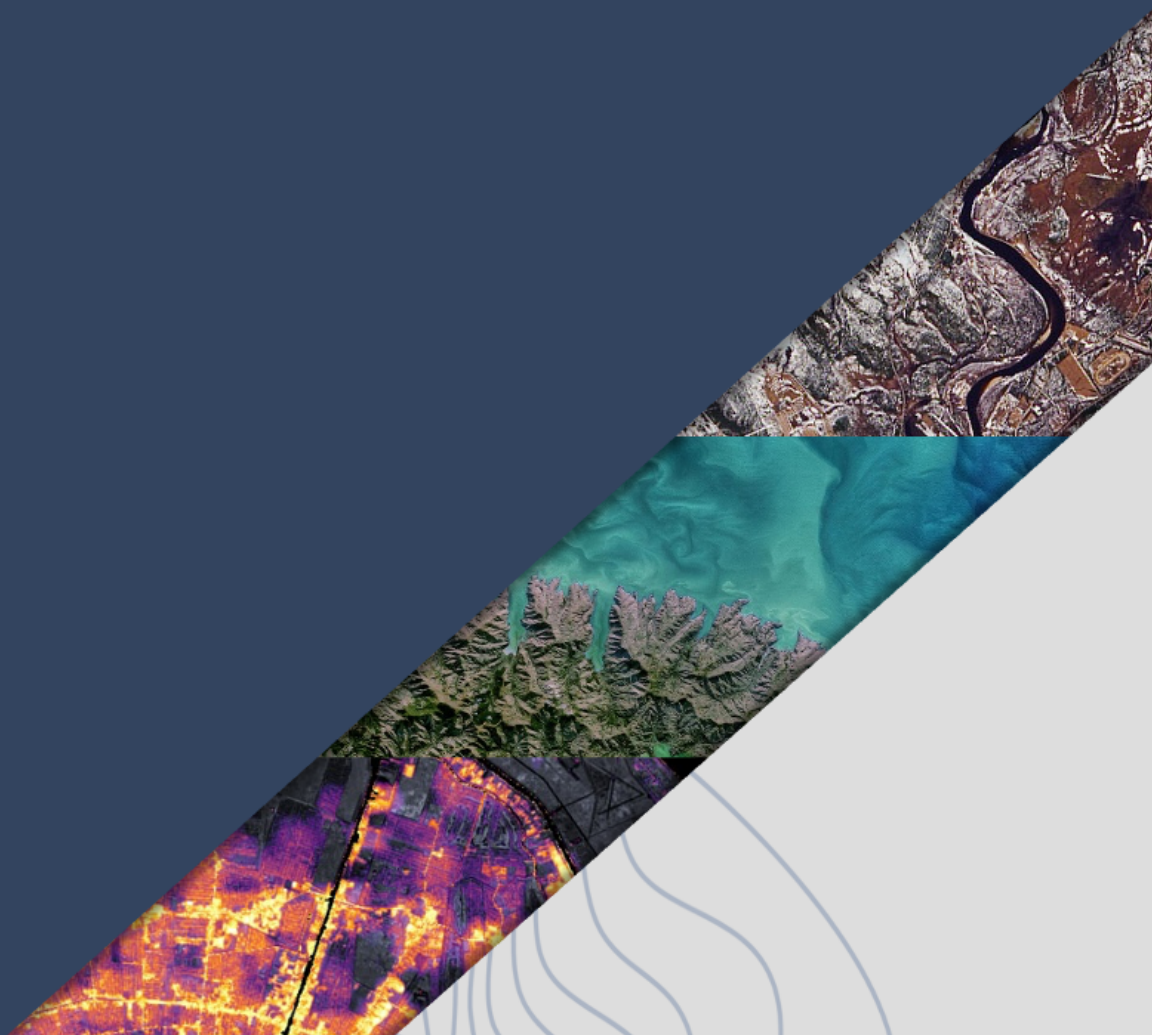
Lessons Learned and Recommendations from Space Agencies' Support for the First Global Stocktake



The Joint CEOS-CGMS Working Group on Climate (WGClimate)

Background

National Greenhouse Gas Inventories (NGHGIs) serve as the official basis for tracking progress under the Paris Agreement, providing critical data for assessing emissions and mitigation efforts. To enhance transparency, the IPCC encourages Parties to verify reported emissions through independent measurement approaches. Satellite observations provide valuable top-down constraints, enhancing the assessment of collective progress and supporting the objectives of the Enhanced Transparency Framework.

With the encouragement of the UNFCCC Secretariat and the Subsidiary Body for Scientific and Technological Advice (SBSTA), the Committee on Earth Observation Satellites (CEOS) provided pilot top-down CO_2 and CH_4 budgets to support GST1 in 2023. Two types of CO_2 and CH_4 flux products were developed:

1) Monthly CO_2 and CH_4 flux maps with uncertainties at 4° latitude by 5° longitude resolution. These regional to global scale products can be used to assess collective progress toward how well the combined efforts by all nations are meeting the overall greenhouse gas emission reduction goals.
2) Monthly CO_2 and CH_4 flux maps at 1° latitude by 1° longitude resolution (by subsampling the 4° latitude by 5° longitude products). These pilot nation-scale products should provide insight into the emissions from medium to large countries (countries larger than France or Turkey). They were intended for use by inventory compilers to assess the completeness of their bottom-up inventories and by policymakers to assess progress toward their Nationally Determined Contributions (NDCs).

These contributions received positive recognition at international settings such as United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) events. However, few national inventory compilers have adopted these satellite-based products to support inventory development or for quality assurance or quality control (QA/QC). This limited acceptance has been attributed primarily to three factors. First, while the guidelines for compiling national inventories from the IPCC Taskforce on Inventories (IPCC-TFI) encourage the use of top-down GHG budgets for inventory QA/QC, Parties to the Paris Agreement have not agreed to mandate their use. Second, most national inventory compilers and policymakers do not understand top-down atmospheric GHG budgets, how to reconcile these products with their bottom-up inventories or how to use them to assess progress toward their NDCs. Finally, the COVID-19 pandemic limited opportunities for capacity building and hindered efforts to enlist "champions" for space-based GHG products among the national inventory and other stakeholders. Recognizing these limitations, CEOS and CGMS are refining their approach to meet the needs of the national inventory community and other stakeholders more directly.

Following the CEOS 39th Strategic Implementation Team meeting in April 2024, the joint CEOS and CGMS (Coordination Group for Meteorological Satellites) Working Group on Climate (WGClimate) was tasked with leading a review to identify lessons from the first Global Stocktake (GST1) to inform future efforts in supporting GST and enhancing the utility of space-based Earth observations. This report summarizes insights and lessons learned from space agencies' support, coordinated through CEOS and CGMS, for GST1 under the Paris Agreement. Below, lessons learned and accompanying recommendations are organized into three key categories (i) GHG flux datasets, (ii) stakeholder engagement and (iii) communication.

1. Lessons and Recommendations on GHG Flux Datasets

Lesson 1.1: The Need for Reconciling GHG Estimates and Quantifying Uncertainties

One of the key challenges faced during GST1 was the apparent discrepancies between satellite-based (top-down) GHG estimates and inventory-based (bottom-up) estimates. These differences stemmed from variations in motivation, methodologies, assumptions, and the geographic, temporal and sectoral scales of measurement. Additionally, there was a lack of standardized approaches to quantify and communicate uncertainties in these estimates. As a result, national inventory compilers expressed hesitancy in incorporating satellite data into their processes, citing concerns over its reliability and compatibility with existing systems.

Recommendation 1.1: Reconciling the Top-Down and Bottom-Up GHG Emission Estimates and Improve Uncertainty Evaluation

Space agencies are encouraged to advance research aimed at reconciling GHG emission estimates derived from the top-down and bottom-up approaches. A key priority is the development of standardized methodologies for quantifying uncertainties in both estimation methods. These methodologies must be transparent and scientifically rigorous to build trust among users. Enhanced communication of uncertainties will empower national inventory compilers to make informed decisions when integrating satellite-derived data. Ultimately, this will facilitate alignment between satellite and inventory-based systems, resulting in more accurate and reliable GHG budgets that can inform climate policy.

Lesson 1.2: Limited Utility for Smaller and Mid-Sized Countries

The spatial resolution of current atmospheric inverse models was insufficient to meet the needs of over 120 smaller and mid-sized countries. Many of these nations require data at finer scales to effectively monitor emissions and inform localized mitigation strategies. Without such granularity, the applicability of satellite data remains limited, potentially excluding these countries from leveraging this valuable resource.

Recommendation 1.2: Develop Higher Spatial Resolution Atmospheric Inverse Models

To address this gap, CEOS and CGMS are encouraged to invest in the development of higher-resolution atmospheric inverse models with a spatial resolution of 1 degree or less that take full advantage of the spatial resolution offered by modern satellite observations. These models should be designed to detect GHG fluxes at scales relevant to regional and national inventories. By providing actionable data to countries with diverse geographic and emissions profiles, these efforts will expand the applicability of space-based observations, enabling a broader range of stakeholders to integrate them into their climate strategies.

Lesson 1.3: Sustainability of GHG Monitoring Systems and Data Provision

A recurring concern among national inventory teams was the long-term availability and consistency of satellite-derived GHG flux data. The transient nature of many research-focused missions that typically have short and uncertain funding profiles, raised questions about the reliability of these datasets for ongoing climate reporting and assessment needs, such as annual inventory validation and global stocktake assessments.

Recommendation 1.3: Operationalize the GHG Monitoring System for Long-Term Data Provision

To ensure a steady and reliable supply of high-quality data, CEOS and CGMS are encouraged to focus on the transition of research to operationalizing GHG monitoring systems. This involves transitioning from research-oriented missions to sustained operational capabilities that prioritize data continuity and reliability. CEOS and CGMS agencies are recommended to improve data consistency and interoperability, and leveraging on public and private missions across all programs to produce multi-sensor products to meet the user needs. By providing consistent products, space agencies can enhance transparency and accountability in national reporting, and bolster the trust of national inventory compilers and other stakeholders.

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2. Lessons and Recommendations on Stakeholder Engagement

Lesson 2.1: Limited Advocacy and Fragmented Representation at UNFCCC Events

Throughout GST1, CEOS and CGMS successfully maintained strong technical relationships with UNFCCC liaisons, underscoring the reliability and value of space-based Earth observations. However, despite this technical strength, their efforts to advocate for the inclusion of these observations in high-level COP negotiations were less robust. A lack of consistent and strategic engagement with key decision-makers based in international bodies, coupled with fragmented representation across UNFCCC events such as COP, SBSTA, and Earth Information Day (EID), constrained the visibility and perceived utility of satellite-derived data. As a result, these critical resources were underrepresented in GST1 outputs and associated policy frameworks.

This fragmented approach diminished the ability of CEOS and CGMS to articulate the indispensable role of satellite-derived data in supporting the goals of the Paris Agreement. Without cohesive advocacy and representation, opportunities to position these observations as fundamental tools for monitoring emissions, informing adaptation strategies, and supporting climate transparency were not fully realized.

Recommendation 2.1.1: Build Stronger Relationships with COP Delegates and Leverage CEOS and CGMS Member Countries at Key UNFCCC Events

To address these gaps and enhance the role of satellite-derived Earth observations in supporting global climate negotiations, CEOS and CGMS are encouraged to implement a more cohesive and proactive strategy that strengthens relationships with national COP delegates and ensures unified representation across UNFCCC events.

Building Strategic Relationships with Key Stakeholders

A central pillar of this approach involves fostering stronger connections with high-level COP delegates. CEOS and CGMS are encouraged to prioritize tailored communication that aligns with the specific priorities of these delegates. By creating targeted briefings, compelling case studies, and engaging demonstrations of satellite data applications, CEOS and CGMS can illustrate the relevance of space-based observations to achieving critical objectives such as emissions monitoring, climate resilience, and transparency under the Enhanced Transparency Framework (ETF).

Recommendation 2.1.2: Identify Champions for spaced-based data among COP Delegates

CEOS and CGMS are encouraged to identify and nurture “COP champions” among key delegates. These champions would serve as influential advocates for integrating space-based data into global climate frameworks. By equipping these individuals with clear, evidence-based messaging and providing ongoing support, CEOS and CGMS can ensure space-based data are effectively represented in international discussions.

Unified and Strategic Representation at UNFCCC Events

To maximize the visibility and impact of satellite-derived data, CEOS and CGMS are encouraged to coordinate a unified presence at critical UNFCCC events. This can be achieved through a dual-track strategy:

Recommendation 2.1.3: Leverage WMO as a Credible Central Channel for Communication at the COPs

CEOS and CGMS are encouraged to collaborate closely with WMO, aligning their initiatives with its globally recognized authority. This partnership will amplify the credibility of CEOS and CGMS contributions, enabling the Earth observation community to present a cohesive and authoritative voice. By participating in WMO-led activities, CEOS and CGMS can ensure that their priorities are seamlessly integrated into broader discussions about the role of Earth observations in supporting and informing climate policy.

Recommendation 2.1.4: Empower National Delegations to Champion Space-based Earth Observations at Earth Information Day (EID) and throughout the COPs

CEOS and CGMS member countries play a vital role in shaping the narrative around Earth observations at events like EID. By proactively engaging with these country delegations and preparing cohesive, impactful submissions, CEOS and CGMS can ensure their priorities are prominently represented. This preparation should include identifying themes well in advance of the August EID submission deadline, crafting clear and actionable messaging, and developing proposals that emphasize the relevance of satellite-derived data in supporting national and global climate related decision making and goals.

Recommendation 2.1.5 Establish a Dedicated "Tiger Team" for Coordination

To ensure these efforts are effectively organized and executed, CEOS and CGMS are encouraged to establish a dedicated "Tiger Team." This team, led by WGClimate leadership and supported by members of the CEOS Chair and CEOS SIT Chair teams, would focus on aligning objectives across space agencies, national delegations, and other relevant stakeholders. Its mandate would include ensuring consistent preparation for EID, enhancing coordination at key events, and transforming EID into a compelling platform for showcasing the transformative potential of space-based data.

This team should develop a comprehensive multi-year engagement strategy aligned with the phases of the GST process. This strategy would serve as a roadmap for consistent, proactive engagement and ensure meaningful contributions to international climate discussions.

The multi-year plan should clearly define key objectives for each COP and EID, ensuring that CEOS and CGMS efforts are strategic and aligned with broader climate goals. A central component of this strategy is the proactive preparation for party submissions. By identifying and finalizing key proposals by June/July each year, CEOS and CGMS can ensure that these submissions meet the August deadlines, maximizing their presence on the COP official agenda.

With this multi-year strategy in place, CEOS and CGMS can ensure sustained, impactful engagement at COPs and EIDs, contributing to the global effort to address climate change.

Through these actions, CEOS and CGMS can build stronger relationships with key stakeholders, enhance the visibility of space-based data, and secure its integration into global climate processes. This coordinated approach will amplify the contributions of satellite-derived Earth observations, establishing them as indispensable tools for supporting Paris Agreement objectives.

Lesson 2.2: Lack of Collaboration with National Inventory Agencies

National inventory compilers were not deeply involved in the design and development of satellite-derived GHG flux products, resulting in a misalignment between the capabilities of these datasets and the specific needs of inventory users. This disconnect hindered the integration of satellite

data into bottom-up inventories. National inventory compilers prefer to use national data over global datasets.

Recommendation 2.2: Enhance Country Engagement Through Targeted Support, Capacity Building, Strategic Partnerships, and Co-Development of GHG Flux Products

Space agencies are encouraged to prioritize collaboration with national inventory agencies from the earliest stages of product development. Hosting workshops, consultations, and co-design sessions will ensure that satellite-derived products align with user needs and adhere to IPCC guidelines. This collaborative approach will increase user trust and confidence in the utility of space-based data, fostering its integration into bottom-up reporting frameworks.

To enhance global collaboration in leveraging space-based Earth observation data for climate action, a **two-pronged engagement approach is proposed**, tailored to the specific needs of developed and developing countries.

1. For **developed countries**, the focus should be on fostering strong partnerships through "twinning" exercises. In this model, representatives from space agencies are paired with counterparts from national inventory agencies to create a robust community of practice. This approach would begin by engaging the champions identified by WGClimate to initiate dialogue, exchange knowledge, and collaboratively co-develop best practices and innovative solutions for integrating Earth observation data into national inventory development and validation processes. By fostering early adopters among these champions, CEOS can support pilot projects that integrate satellite-derived data into national inventories. These collaborative projects can serve as case studies to showcase best practices and highlight the value of space-based data in enhancing inventory accuracy and transparency.
2. For **developing countries**, the emphasis should be on building capacity and providing technical support through a dedicated initiative leveraging the successful SilvaCarbon program to identify champions. This effort would aim to address the unique challenges faced by less-developed regions by offering tailored guidance, tools, and resources to enhance their ability to utilize Earth observation data. Collaboration with WMO's G3W, which prioritizes capacity building in underserved areas through early adopters, would be essential to ensuring the initiative's success and sustainability.

By adopting this dual strategy, the global Earth observation community can foster equitable progress in utilizing space-based capabilities for climate monitoring and mitigation.

Lesson 2.3: Limited Engagement with IPCC Contributions to the Global Stocktakes

Products developed by the Intergovernmental Panel on Climate Change (IPCC) play two critical roles in the global stocktakes. The IPCC Assessment Reports constitute an open, transparent scientific consensus for tracking climate change and projecting future climate impacts. The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC-2006) compiled by the Taskforce on Inventories (IPCC-TFI) establish the good practice methodologies that have been adopted as the basis for compiling national inventory reports by governments reporting under the Paris Agreement.

Assessment Reports: Global, satellite-based remote sensing observations provide the basis for characterizing the contemporary climate, carbon cycle, water cycle, and cryosphere, as well as

greenhouse gas sources and sinks on regional to global scales in the assessment reports. They are also used to formulate and validate the models used for diagnostic and prognostic studies of the Earth system. The latest report (AR6) also highlights recent advances in space-based measurements and inverse modelling studies of greenhouse gas sources and sinks (Chapter 5). In spite of this, there has never been an organized effort within CEOS and CGMS to identify, nominate, and support principal authors or reviewers of these reports or to highlight key contributions of space-based remote sensing products presented there.

Inventories: The IPCC-TFI Co-chairs invited members of the CEOS community to work with the IPCC-TFI on elements of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC-2019). This document augmented the 2006 IPCC-TFI guidelines with specific recommendations for using atmospheric GHG measurements for inventory QA/QC. It also reiterated the value of space-based AFOLU products for characterizing activity over land, as direct inputs to the inventory estimation process. Subsequently, members of the CEOS Atmospheric Composition Virtual Constellation (AC-VC) and Greenhouse Gas Task Team (GHG TT) produced global, national-scale CO_2 and CH_4 budgets. As noted above, these space-based GHG products were delivered to the UNFCCC for use in the first GST, but have not yet been widely used by national governments or their inventory compilers.

Recommendation 2.3.1: Enhanced CEOS-CGMS Support for IPCC Assessment Reports:

Members of CEOS and CGMS Working Groups (WGs) and Virtual Constellations (VCs) should identify candidate authors and expert reviewers for future assessment reports. The CEOS and CGMS Principals should then work with their national governments to nominate these members for those roles. Once an assessment report is published, WGs and VCs should identify key contributions of space-based observations to the primary conclusions of the Summary for Policy Makers and each chapter of the report. These contributions should be highlighted at the COPs and other international climate meetings.

Recommendation 2.3.2: Foster Continuing Dialogue with IPCC-TFI to Enhance the Utility and Encourage the Use of Space-based Observations for Inventory Development and QA/QC.

Members of CEOS and CGMS WGs and VCs should engage in dialogues with the IPCC-TFI and support IPCC Workshops to:

1. Create efficient protocols and tools for comparing and reconciling bottom-up national inventories with bottom-up scientific inventories and top-down atmospheric GHG budgets.
2. Assess methods for combining space-based observations of land use activity and GHG fluxes to produce complementary, regional-scale emission factors that can be used by the IPCC-TFI to populate the Emission Factor Databases that are used by national inventory compilers to develop their bottom-up inventories.
3. Support IPCC initiatives to update the IPCC-TFI Guidance for the use of Earth observation data in national inventories.
4. Develop capacity building materials to train national inventory developers and policy-makers to use space-based GHG and AFOLU products for inventory development and QA/QC.

Lesson 2.4: Limited Engagement with the Global Carbon Project

During GST1, attempts to integrate space-based GHG and AFOLU products into key international scientific inventory efforts, such as the Global Carbon Project (GCP) and its yearly published Global Carbon Budget, relied on individual contributions with little coordination by CEOS and CGMS agencies. This lack of proactive and coordinated engagement limited the visibility and impact of satellite-derived data for shaping critical outputs and informing global climate strategies.

Recommendation 2.4: Strengthen Relationships with International Scientific Inventory Developers

To address these gaps, CEOS and CGMS agencies are encouraged to establish more formal and strategic relationships with the Global Carbon Project. CEOS and CGMS are encouraged to strengthen partnerships with the inverse modelling community supporting the Global Carbon Project by promoting joint initiatives that integrate satellite-derived GHG and AFOLU data into their analyses of carbon budgets and fluxes. By fostering this collaboration, CEOS and CGMS can contribute to the development of comprehensive national and global carbon flux products that better represent the scientific consensus. These products can serve as authoritative benchmarks, bridging gaps between top-down and bottom-up methodologies while addressing the needs of diverse stakeholders. This collaboration will enhance the credibility and utility of satellite-derived data, ensuring their integration into key scientific assessments and climate action frameworks.

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3. Lessons and Recommendations on Communication

Lesson 3.1: Bridging Knowledge Gaps Among Inventory Compilers

A key challenge identified was the lack of familiarity among national inventory compilers with the methodologies, applications, and potential of satellite-derived data. This knowledge gap hindered their ability to integrate these datasets into national inventory systems effectively, limiting both their utility and broader advocacy within inventory frameworks.

Recommendation 3.1: Equip Inventory Compilers with Targeted Training and Resources

To address this challenge, CEOS and CGMS are encouraged to prioritize the development of a robust training framework tailored to inventory compilers. This includes creating detailed step-by-step guides, interactive workshops, and user-friendly documentation that demystify the use of satellite-derived data. These resources should provide practical insights into integrating space-based datasets with existing inventory systems, adhering to IPCC guidelines.

By empowering inventory compilers with the knowledge and confidence to utilize these tools, CEOS and CGMS can foster a skilled and informed network of advocates. This approach will drive greater adoption of satellite-derived data and enhance its integration into national inventory systems, ultimately supporting more accurate and transparent climate reporting.

Lesson 3.2: Addressing Limited Awareness of Space-Based Data Among COP Delegates

Another challenge encountered was the limited understanding among COP delegations of the capabilities and potential of space-based Earth observations in supporting climate goals. This lack of awareness often resulted in missed opportunities to leverage these datasets in climate negotiations, policymaking, and national strategy development.

Recommendation 3.2: Raise Awareness of Space-Based Data Through Targeted Communication

To bridge this awareness gap, space agencies are encouraged to implement tailored communication strategies designed specifically for policymakers and COP delegates. These strategies should include concise and impactful presentations, visually engaging materials, and executive summaries that articulate the relevance of satellite-derived data to national mitigation and adaptation strategies.

Furthermore, case studies showcasing the successful integration of space-based data into national inventories and climate policy should be highlighted. By effectively communicating the value of these datasets, space agencies can build broader support among policymakers and position satellite-derived data as a critical tool in achieving national and global climate goals.

Conclusion

The first Global Stocktake (GST1) in 2023 underscored the transformative potential of space-based Earth observations in advancing global climate action while revealing critical challenges in their integration into policy frameworks, with implications for future global stocktakes every five years. It highlighted the need for targeted strategies to bridge knowledge gaps, enhance communication, and build stronger collaborations with key stakeholders, including national inventory compilers, COP delegations, and international organizations.

By addressing these lessons and executing the recommendations outlined in this report, CEOS and CGMS can ensure that its contributions remain central to international climate action. Initiatives such as providing tailored training for inventory compilers, raising awareness among policymakers, and fostering stronger alignment with UNFCCC and IPCC priorities will position satellite-derived observations as indispensable tools for accurate climate monitoring, reporting, and action.

These collective efforts will not only strengthen the credibility and relevance of satellite-derived Earth observation data but also ensure that they are fully integrated into the Paris Agreement's Enhanced Transparency Framework. Through collaboration, innovation, and strategic engagement, CEOS and CGMS can drive meaningful progress, supporting global efforts to inform, meet and exceed climate goals in the years to come.