World Meteorological Organization submission

to SBSTA 56 on matters relating to Article 6 of the Paris Agreement – 6.2 (Reporting, recording and tracking)

I. Mitigation reporting requirements

In 2015, 196 Parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached the landmark Paris Agreement to strengthen the global response to climate change. Article 6 of the Agreement stresses the need to deliver an overall mitigation of global emissions and proposes market-based mechanisms to assist in the process. The CMA.3 decision, "Guidance on cooperative approaches referred to in Article 6, paragraph 2, of the Paris Agreement", calls on Parties to "Quantify the Party's mitigation information in its Nationally Determined Contribution (NDC) in tons of CO_2 equivalent, including the sectors, sources, GHGs and time periods covered by the NDC, the reference level of emissions and removals for the relevant year or period, and the target level for its NDC; or where this is not possible, provide the methodology for the quantification of the NDC in tons of CO_2 equivalent".

According to Article 13, which calls for the enhanced transparency of mitigation and adaptation actions, Parties are requested to report their national anthropogenic emissions by sources and removals by sinks of greenhouse gases, "using good practice methodologies accepted by the Intergovernmental Panel on Climate Change and agreed upon by the Conference of the Parties serving as the meeting of the Parties to the Agreement"and provide information necessary to track progress made in implementing and achieving their NDCs.

II – Emission estimates

National emissions are estimated using good practice methodologies approved by the Intergovernmental Panel on Climate Change (IPCC) and developed by the Task Force on National Greenhouse Gas Inventories (TFI). In 2019 the IPCC plenary approved the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories that includes best available practices to estimate National Greenhouse Gas (GHG) emissions.

An emission inventory is an accounting of the amount of GHGs emitted into the atmosphere. It usually involves combining source-specific emission factors with activity data, a process often called "bottom-up". The quality of the reports is assured through reviews by third parties; these reviews only check for consistency of the applied procedures with the guidelines but do not provide an evaluation against independent information. Many national inventory reports have a latency of about two years (emission estimates for year Y become available in year Y+2), which limits the ability of the Parties to monitor progress towards their NDCs targets in a timely manner. Annual emissions inventories prepared as part of national reporting do not allow the tracking of the variable seasonal-dependent emissions of many economic sectors (e.g. agriculture). Aggregation to national totals limits the understanding of the geographical distribution of emission.

In 2010 the atmospheric, carbon cycle, and climate change science communities produced a number of studies on the potential for atmospheric GHG concentration measurements and model analyses to independently asses and help to inform improved estimates of GHG emission inventories. These studies concluded that a realization of this approach would require additional investment in research, increasing the density of well-calibrated atmospheric GHG measurements and improving atmospheric transport modelling and data assimilation capabilities. Improvement in observational and modelling capabilities since 2010 has resulted in an increased accuracy and utility of atmospheric GHG observations for emission estimates.

Peer reviewed publications on observation-based GHG quantification demonstrated that there is a substantial difference between reported emission and what is seen in the real world. For example, a 2021 WMO report on unexpected emissions of CFC-11 demonstrated how observations of CFC-11 helped to identify the unexpected increase in emissions in 2013 and its sources (global CFC-11 emissions were expected to decrease steadily after 2010 as a result of its full phaseout). After publication of evidence on this emission increase in a peer reviewed paper [1]in 2018, emissions were substantially lower in 2019.

III. Observation-based emission estimates as support for identification of efficient mitigation opportunities

In contrast to emissions inventories, observation-based approaches to tracking emissions and removal of CO_2, CH_4 and other GHGs directly build on the measurements of their concentrations in the atmosphere at high spatial and temporal resolution using ground-based, airborne and space-based sensors. These measurements are processed using inverse atmospheric modelling systems (on global, regional and even facility scales) to generate top-down estimates of GHG fluxes between the surface and the atmosphere ("top-down" quantification of emissions). The inverse modelling system (essentially a weather forecast model run in reverse) simulates atmospheric transport and optimizes the GHG fluxes so as to reproduce the observed distribution of each GHG in the context of the modelled wind field. Inverse models can integrate both global concentration fields and observations from individual sites. Due to the integrating nature of the atmosphere, the observation-based, "top-down" approach has the advantage of accounting for the net real-world emissions and cannot miss or double count sources.

Contributions from individual sources to the overall estimated GHG fluxes can only partiallybe distinguished using observation-based approaches (e.g. through co-emitted gases, isotopic composition or overlaying the flux filed with activity data) and represents an area of on-going research. Although these "top-down" atmospheric GHG tracking methods cannot always distinguish emissions by sector and category as can be done through bottom-up GHG inventories, observation-based methods complement inventory-based methods by providing an integral constraint on net emissions and removals by all sources and sinks on spatial scales ranging from individual large power plants or urban areas to nations or the entire globe. Similarly, they can provide the information needed to track changes in the strength of ocean and land sinks as they respond to human activities and climate change. They therefore provide an independent way of assessing the collective progress toward the overall objectives of the Paris Agreement.

Due to the limited capabilties of developing countries to collect the statistical data necessary to develop accurate emission inventories, these countries could greatly benefit from independent "top-down" estimates. In most countries, but especially in developing ones, this will require setting up additional measurement and modelling infrastructure. Given the widely varying existing infrastructure and needs of different countries, a tiered approach to observations will be helpful in addressing those needs, ranging from basic to very detailed emission information.

[1] Montzka, S. A., Dutton, G. S., Yu, P., Ray, E., Portmann, R. W., Daniel, J. S., ... & Elkins, J. W. (2018). An unexpected and persistent increase in global emissions of ozone-depleting CFC-11. Nature, 557(7705), 413-417

Observation-based emissions estimates are scalable and can be consistently implemented from facility to national scale. The information products can be tailored to the needs of users and stakeholders to guide/target emission reduction actions and quantify their impact.

IV. International standards and good practices for observation-based emission estimates

As implied in Article 13, consistency between emission estimates through international standards and collaboration frameworks are needed which at the same time respond to the different needs and capabilities of Parties. Such framework is provided by the Integrated Global Greenhouse Gas Information System (IG^3IS) spearheaded by WMO. IG^3IS (https://ig3is.wmo.int) combines accurate atmospheric measurements with enhanced socioeconomic activity data and model analyses to better quantify greenhouse gas emissions. The approach and the set of the good practices are outlined in the IG^3IS Implementation plan [2]. The solutions that are recommended depend on the user and stakeholder communities' requirements and may range from simple direct observation-based assessments such as mass balance approach, to complex modelling systems. Benchmarking and comparison exercises are established in IG^3IS to ensure comparability of modelling systems, while it is recommended that observations be traceable to WMO established standards and scales.

IG^3IS is a UNFCCC-recognized framework. In June 2019 the 50th session of SBSTA welcomed the adoption by the WMO of the IG^3IS Science Implementation plan and recognized IG^3IS as an innovative science-based framework that supports the needs of a broad range of users and encouraged the use of the framework by Parties.

The IPCC TFI has included the use of IG^3IS methods in their recently published "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories". Substantial updates were included in Volume 1 Chapter 6 concerning Quality Assurance / Quality Control and Verification as part of compiling and reporting national emission inventories. The document recognizes that utilization of atmospheric measurements combined with inverse modelling and analysis represents a demonstrated and high-value approach for emissions verification. The guidebook recognizes the diversity of the approaches and refers to the IG^3IS Science Implementation Plan as the reference document for good practice methodological guidelines for "how atmospheric measurements and analysis methods can deliver valuable information for inventory verification".

V. Current state of observation-based emission estimates

Currently, observation-based emission estimates are produced and reported in partnership with their national inventory-compiling agencies by the United Kingdom, Switzerland, Australia (for halogenated industrial gases only), and New Zealand for carbon dioxide. In 2021 the Republic of Korea initiated a national multiscale project to establish observation-based emission estimates capabilities. A growing number of other countries, including Germany, Japan, France and the United States are initiating programs to merge observation-based emission information with IPCC TFI activity and emission-factor based estimates.

Some of the cities already implementing observation-based emission estimates are Paris, Los Angeles, Tokyo, Beijing, Zhengzhou, Indianapolis, Toronto, Montreal, San Francisco, Baltimore, Washington DC, Seoul, Mexico City, London, Munich, Vienna, Salt Lake City, Boston, and many other cities have programs under development. There is great interest in addressing emissions from industrial sectors with a large uncertainty and with large contribution to GHG forcing such as emissions from short-lived climate pollutants (SLCPs) such as methane and HFCs. Efforts are being

[2] https://library.wmo.int/doc_num.php?explnum_id=10034

made by a number of organizations to implement observation-based methods to locate and quantify intermittent super-emissions of methane such as those from the global oil & gas supply chain[3][4][5], from solid waste and waste-water facilities as well as from agricultural activities like large dairy farm digestors. A number of successful actions are being implemented around the world such as in North American oil and gas-producing regions, and the state of California has used such methods to locate and quantify its state-wide emissions of methane from all industrial sources.

VI. Recommendations

The initial successful implementation in a number of countries and cities has demonstrated the substantial value of observation-based emission estimates. Value-added identified based on lessons learned through implementation of such methods to date includes:

1) The provision of additional information to inventory builders and national governments in support of their efforts to reduce uncertainty of national emission inventory reporting to UNFCCC and/or assistance in guiding national GHG policy and regulations;

2) Support to non-state actors, such as cities and states, that represent large GHG source regions (e.g., megacities) in the form of actionable information on their GHG emissions at relevant spatial, temporal and sectoral resolutions needed to evaluate and guide progress towards emission reduction goals;

3) The provision of information to governments and private industry that will help locate and quantify previously unknown emissions-reduction opportunities, such as fugitive methane emissions from industrial sources.

Collectively, on a global scale, such efforts can be valuable in supporting the Paris Agreement global stocktake.

Observation-based estimates of GHG emissions and removals provide a critical new source of data for tracking GHG emissions, removals and trends, complementing bottom-up GHG inventories. Observation-based methods provide estimates of net emissions and removals at national to facility scales. It would be beneficial for the Parties to the Convention to utilize observation-based emission estimates to improve the reliability of emission reporting in support of their mitigation actions and in the context of tracking emission reductions under NDCs. WMO/IG^{3}IS offers a common framework for observation-based estimates as stated in the SBSTA-50 conclusions, and can become an important contributor to the transparency mechanism.

In the race for net zero emissions, many policies rely on nature-based solutions. At the same time, the state of ecosystem services and the potential for nature-based solutions is poorly quantified. The Parties would benefit from observation-based evidence of the state and performance of such systems, which can be critical to the success of nature-based climate policies.

Requirements for observation-based GHG mitigation decision-support systems addressing mitigation action on multiple scales – from national, to landscape, urban and facilities scales – can be established through a dialogue with stakeholders through expert engagement. WMO can provide

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[3] Lauvaux, T. et al., 2022: Global assessment of oil and gas methane ultra-emitters. Science 375, 557ff

[4] Vogel, F, 2022: chasing after methane's ultra-emitters, Science, 375, 6580, 490-491)./doi/10.1126/science.abm1676

[5] Lin, J.C., Bares, R., Fasoli, B. et al. Declining methane emissions and steady, high leakage rates observed over multiple years in a western US oil/gas production basin. Sci Rep 11, 22291 (2021). https://doi.org/10.1038/s41598-021-01721-5

the necessary expertise to inform the process of formulating such requirements and designing, building and operating such systems.

There is a recognition that support for observation-based methods supposes substantial developments of the observational and analysis infrastructure. WMO is currently exploring the possibility to foster the development of an internationally coordinated, operational Global Greenhouse Monitoring Infrastructure, modelled on its World Weather Watch, to directly observe and model greenhouse gas concentrations in the atmosphere and the relevant fluxes between atmosphere, land and oceans. The development of this initiative is being undertaken in consultation with representatives of existing observing activities, both in situ and space-based, with relevant modeling and data assimilation activities and with the potential user community. The WMO Executive Council in June 2022 will make an initial decision on whether and how to move forward with this initiative.