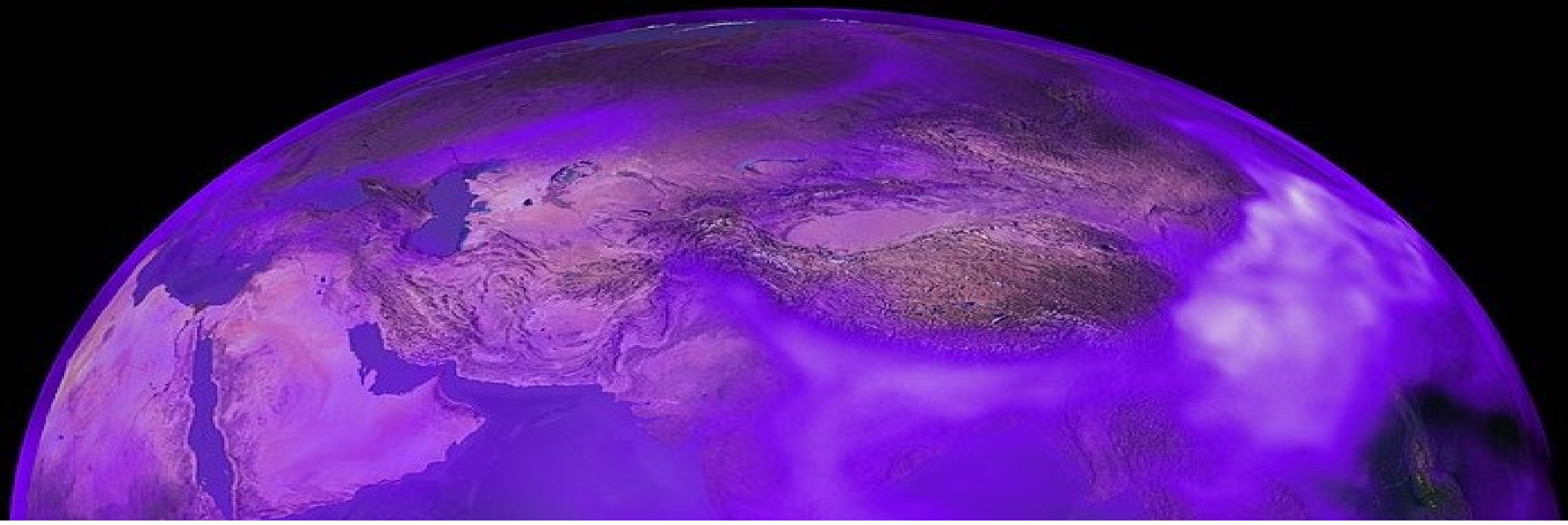

IPCC Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories

Report of IPCC Expert Meeting

5-7 September 2022, Geneva, Switzerland

Task Force on National Greenhouse Gas Inventories

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INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

Supporting material prepared for consideration by the Intergovernmental Panel on Climate Change (IPCC). This supporting material has not been subject to formal IPCC review processes.

IPCC Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories was organised by the IPCC Task Force on National Greenhouse Gas Inventories (TFI). It was held in a hybrid format at the World Meteorological Organization (WMO) Headquarters in Geneva, Switzerland, from 5 to 7 September 2022.

This meeting report was prepared jointly by the Co-Chairs of the IPCC TFI (Eduardo Calvo Buendia and Kiyoto Tanabe) as well as the Technical Support Unit (TSU) of the TFI (Sandro Federici, Baasansuren Jamsranjav, Pavel Shermanau) and the IGES Fellow/TSU scientific advisor of the Institute for Global Environmental Strategies (IGES) (Takeshi Enoki), and subjected to review by the meeting participants.

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Preface

We are pleased to present this report of the IPCC Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories held in a hybrid format at the World Meteorological Organization (WMO) Headquarters in Geneva, Switzerland, from 5 to 7 September 2022.

There is significant interest in exploring how atmospheric measurements can be used as a tool to assess and guide improvements to national greenhouse gas inventories (NGHGI), including through inverse modelling. In the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 IPCC Guidelines*), the benefit of use of atmospheric measurement data was referred to, but practical guidance on how to use could not be provided. After the *2006 IPCC Guidelines* were produced, there has been a move towards establishing dedicated national greenhouse gas monitoring networks for this purpose in some countries, and also there has been advancement in science and technologies relating to atmospheric measurements. Taking that into account, guidance on the use of atmospheric measurements for verification of national GHG inventories was updated and elaborated in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2019 Refinement*), Volume 1, Chapter 6.

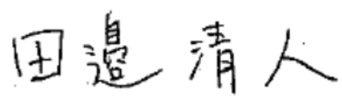
Research and monitoring activities involving the collection, archiving and distribution of data on atmospheric concentration of GHGs, as well as of other Short-lived Climate Forces (SLCF), could in some cases provide information of benefit to the improvement of national inventories.

This expert meeting aimed to discuss issues relating to the use of atmospheric observation data and models in verification of national GHG inventories building on guidance provided in the *2019 Refinement*. The meeting brought different communities together – experts on atmospheric observation of GHGs and inverse modelling and experts on national emission inventories. The invitees were identified and selected by the Bureau of TFI (TFB) in accordance with the Appendix A to the Principles Governing IPCC Work. Discussion and conclusions of this expert meeting are described in this report.

This expert meeting report is not to pre-empt future IPCC work, but to support the development of IPCC materials that will assist countries to make better estimates of emissions, for example the Methodology Report on SLCFs to be produced during the IPCC 7th assessment cycle (AR7 cycle).

We would like to thank all those involved in this meeting, namely, the scientists and experts who participated, the members of TFB and the TFI Technical Support Unit, for their contribution, that enabled to make this meeting a success. We also extend our appreciation to the WMO for hosting this expert meeting.

Eduardo Calvo Buendia
Co-Chair
Task Force on National Greenhouse Gas Inventories
Intergovernmental Panel on Climate Change



Kiyoto Tanabe
Co-Chair
Task Force on National Greenhouse Gas Inventories
Intergovernmental Panel on Climate Change

List of Acronyms and Abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
AR6	Sixth Assessment Report
AR7	Seventh Assessment Report
BOG	Break-Out Group
CH_4	Methane
CO_2	Carbon Dioxide
EF	Emission Factor
EFDB	Emission Factor Database
F-gases	Fluorinated greenhouse gases, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6), Nitrogen trifluoride (NF_3), etc.
GHG	Greenhouse Gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
N_2O	Nitrous Oxide
NGHGI	National Greenhouse Gas Inventory
SLCF	Short-Lived Climate Forces
TFB	Task Force Bureau
TFI	Task Force on National Greenhouse Gas Inventories
TSU	Technical Support Unit
UNFCCC	United Nations Framework Convention on Climate Change
WG	Working Group
WMO	World Meteorological Organization

Executive Summary

The IPCC, at its 54th (bis) Session (December 2021), decided that the TFI hold an Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories (Decision IPCC-LIV(bis)-2, according to the document IPCC-LIV(bis)/Doc.2, Add. 1). The IPCC Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories was held in a hybrid format at the World Meteorological Organization (WMO) Headquarters in Geneva, Switzerland, from 5 to 7 September 2022.

At the opening plenary, informative presentations were made to provide participants with background information on atmospheric observation, covering topics such as comparison of greenhouse gas (GHG) inventories and inversions, space-based measurements, carbon balance, uncertainties, discriminating anthropogenic and natural fluxes, case studies, remote observations, etc. After the plenary session, experts split up into four break out groups (BOGs) to discuss the following:

- Potential of using atmospheric observations to verify GHG inventories.
- Examples of comparisons between atmospheric observations and national inventories that have led to implemented or planned improvements in inventories or where emission estimates derived from atmospheric observations have been incorporated into a bottom-up inventory.
- Emerging datasets from atmospheric observations could be used to test and verify particular IPCC default values and associated uncertainties.
- Spatial and temporal gridding of NGHGIs to allow comparison with atmospheric observation data.
- Terminology and classifications of sources/sinks and associated natural and anthropogenic GHG fluxes.

The BOG discussions and conclusions were presented and discussed at the closing plenary. Some of the key findings of the BOG discussions were as follows:

- There is potential for atmospheric observations to be used for verification of national GHG inventories, depending on sector/category. Verification of inventories using data derived from atmospheric observation and inverse models is not necessarily leading to direct changes in the emission estimates, but rather as a starting point for further improvement of the inventory.
- Inverse analysis systems are not yet standardized; therefore, there is room for additional progress and refinement of emission estimates and uncertainties derived from atmospheric observation and inverse models. Identifying robust signals and robust differences between an inverse analysis and inventory data requires judicious expert review of sources/sinks to assure that comparisons are based on valid comparisons of the elements that are actually included in the estimates and assessment of results.
- In addition to inverse models, direct measurement of the flux from a GHG sources, forward models, process models, and others could contribute to the verification of national GHG inventories.
- Atmospheric observation is a rapidly maturing science and future work is planned and underway that will advance further the capabilities for atmospheric observations to help verification of national GHG inventories. Ongoing dialogue and development of capacity between GHG inventory compilers and atmospheric observation researchers is critical to advance the understanding of the contents of the products of the two communities and enhancing their consistency in verification exercises.
- There are some examples of where the comparison between atmospheric observations and national inventories have been carried out effectively.

The Co-Chairs concluded that a forum for exchange of information among inventory compilers and atmospheric observation researchers is useful, and a long-term interaction may be beneficial. Atmospheric measurements have proved useful in verifying national GHG inventory data in specific cases, and examples were presented at the meeting. These case studies and the lessons learned should be shared with other countries to further promote the interaction between atmospheric observation and national GHG inventories. This expert meeting was not intended to produce specific methodological guidance, but the discussion and conclusions documented in this report are expected to inform future work of TFI.

1. Introduction

- **Background and relevant IPCC decision for the Expert Meeting**

There is significant interest in exploring how Atmospheric measurements can be used as a tool to assess and guide improvements to national greenhouse gas inventories (NGHGI), including through inverse modelling. In the *2006 IPCC Guidelines*, the benefit of use of atmospheric measurement data was referred to, but practical guidance on how to use could not be provided. After the *2006 IPCC Guidelines* were produced, there has been a move towards establishing dedicated national GHG monitoring networks for this purpose in some countries, and there has been advancement in science and technologies relating to atmospheric measurements. Taking that into account, guidance on the use of atmospheric measurements for verification of NGHGI was updated and elaborated in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2019 Refinement*), Volume 1, Chapter 6.

Research and monitoring activities involving the collection, archiving and distribution of data on atmospheric concentration of GHGs, as well as of other Short-lived Climate Forces (SLCF), could in some cases provide information of benefit to the improvement of national inventories. Development and improvement of source-specific emission factors are becoming increasingly important to keep enhancing the quality of GHG estimates, especially for those sectors and categories where development and application of new technologies impact the associated rate of emissions.

With this background and context, and considering rapid advancement in science and technologies relating to atmospheric measurements, the IPCC, at its 54th (bis) Session (December 21), decided that the TFI hold an Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories (Decision IPCC-LIV(bis)-2, according to the document IPCC-LIV(bis)/Doc.2, Add. 1).

The objectives of the expert meeting were of the following:

I. *Assess and critique recent datasets as well as new and operational systems, platforms, instruments/sensors and methods/models to derive, from atmospheric observations, representative emission rates from source categories over time periods of interest.*
II. *Assess and evaluate the usability of these recently available datasets as well as new operational systems, platforms, instruments/sensors and methods/models to derive, from atmospheric observations, comparative data to verify IPCC default factors and uncertainties as well as to allow inventory-compilers to verify their emission estimates through application of IPCC good practice methods and approaches.*
III. *Assess and evaluate useful examples of comparisons between atmospheric observations and national inventories that are consistent with good practice provided in the 2019 Refinement to the 2006 IPCC Guidelines on National Greenhouse Gas Inventories (e.g., following the steps provided in tables 6.3 and box 6.5 of Volume 1) that have led to implemented or planned improvements in national inventories.*
IV. *Assess and evaluate available examples where emission estimates derived from atmospheric observations have been incorporated into a bottom-up inventory framework, including the associated resources (technical, human, funds) needed in their implementation.*
V. *Assess and evaluate the usefulness of efforts (including resource implications) to grid (spatially and temporally) national emissions inventory and the use of these gridded products in comparisons with atmospheric observations.*

By achieving these objectives, this expert meeting is expected to support the development of IPCC materials that will assist countries to make better estimates of emissions, for example the Methodology Report on SLCFs to be produced during the IPCC 7th assessment cycle (AR7 cycle).

- **Organization of the IPCC Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories**

The IPCC Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories was held in a hybrid format on 5-7 September 2022 at the World Meteorological Organization (WMO) Headquarters in Geneva, Switzerland, and virtually via ZOOM and MS Teams platforms. Prior to the meeting, TSU together with TFB elaborated the guiding note (see Annex 1) to the meeting participants and the agenda for the meeting (see Annex 2).

At the opening plenary (5 September), following the welcome address and explanation of background of the expert meeting by TFI Co-Chairs, presentations were delivered to inform the discussion at this meeting. After the opening plenary session, the meeting split into break out groups (BOGs) and held in parallel in the second day (6 September) and in the morning of the third day (7 September).

Four BOGs were formed on the following topics:

- BOG 1: CO_2 emissions from fuel combustion
- BOG 2: Fugitive CH_4 emissions
- BOG 3: AFOLU GHG emissions
- BOG 4: F-gases

At the closing plenary, each of four BOGs reported on its discussion, which was followed by a brief plenary discussion on the BOG topics. The expert meeting was closed by expression of appreciation by TFI Co-Chairs to all the participants and TSU. (See List of Participants in Annex 3).

- **Outcome of the IPCC Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories**

Discussion and conclusions of the expert meeting are summarized in Chapter 2 of this meeting report. In addition, the outcomes of BOGs work are published on the IPCC TFI website at this same page.

2. Meeting discussion and conclusions

2.1 Plenary discussions

In the opening plenary, the TFI Co-Chairs explained that the expert meeting aimed to discuss issues relating to the use of atmospheric observation data and models in verification of national GHG inventories building on guidance provided in the *2019 Refinement*. The meeting is not aiming to revise existing guidance or to add additional guidance, but to provide opportunities for experts in the GHG inventory and atmospheric measurement communities to share an understanding of the activities in the communities.

The participants took stock of the *2019 Refinement* which states that, "comparisons with atmospheric measurements are not established as a standard tool for verification to be applied by an inventory compiler. Still, considerable scientific progress in this area needs to be noted and inventory compilers may wish to take advantage of the potential of this approach, as it gives independent data for verification." It also outlines five steps to allow comparison of atmospheric measurements with NGHGI's sources/sinks: Confirm that observation-based and inventory estimates represent the same time period and sources/areas (temporal and spatial gridding of the inventory and observation-based estimates); determine what data were used and how this data can be compared to the emission inventory (categories' definitions); Assess how the estimation procedure treats anthropogenic and natural emissions, to confirm that the estimates compare with emissions included in the inventory; confirm that seasonal variability of the emissions and other effects have been considered in the comparison; and assess the uncertainties of the estimated emissions, and note whether the discrepancy is statistically significant.

During the opening plenary session, ten presentations were made to provide participants with background information on atmospheric observation, covering topics such as comparison of GHG inventories and inversions, space-based measurements, carbon balance, uncertainties, discriminating anthropogenic and natural fluxes, case studies in New Zealand and Mongolia, remote observations, etc.

At BOGs, meeting participants were asked to discuss the following five issues:

- Assess and critique recent estimation techniques that utilise atmospheric observations as well as operational systems, platforms, instruments/sensors and methods/models for their potential use for verification of national inventory sectoral emission estimates, consistent with the guidance provided in the *2019 Refinement*.
- Assess and evaluate successful examples of: (i) comparisons between atmospheric observations and national inventories that are consistent with good practice provided in the *2019 Refinement* that have led to implemented or planned improvements in national inventories; and (ii) available examples where emission factors derived from atmospheric observations have been incorporated into a bottom-up inventory framework.
- Assess the possibility that emerging datasets from atmospheric observations could be used to test and verify particular IPCC default values (emission factors) and associated uncertainties;
- Discuss the use of gridding (spatial and temporal) of NGHGIs to allow comparison with atmospheric observation data.
- Discuss terminology and classifications of sources/sinks and associated natural and anthropogenic GHG fluxes to find a common understanding of consistency and differences in atmospheric observation data and GHG inventory estimates.

At the closing plenary, BOG representatives presented their response to the five issues. A summary of findings of the BOGs were of the following:

- There is potential for atmospheric observations to be used for verification of GHG inventories, depending on sector/category. Verification of inventory emissions using inversion data is not necessarily leading to direct changes in the inventory-based emissions, but rather as a starting point for further improvement of the inventory.
- Inverse analysis systems are not yet standardized; therefore, there is room for additional progress and refinement of emission estimates and uncertainties. As a result, identifying robust signals and robust differences between an inverse and inventory estimates require expert judicious review of sources/sinks actually included in the estimates and assessment of results.

- Use of atmospheric observations for assessing emission inventories is a rapidly maturing science and future work is planned and underway that will advance further the capabilities for atmospheric observations to provide more accurate verification of regional- and national-scale emission magnitudes. Ongoing dialogue and development of capacity between GHG inventory compilers and researchers is critical for continued progress.
- There are some examples of where the comparison between atmospheric observations and national inventories have been carried out. In some countries, atmosphere-derived emission estimates for F-gases are included in their NGHGIs.
- There is a need to gain more experience using atmospheric observations and inversions to evaluate AFOLU sectoral GHG inventories.
- Successful examples of comparisons occur when there is respectful communication between both atmospheric and inventory-focused communities to better understand emission estimates, trends, and their uncertainties. Also, a dedication to continuous and long-term engagement in this collaborative process is critical for success.
- It may be difficult to use atmosphere-based estimates to gain insights into specific default emission factors because current inverse systems provide total emissions from the sum of all emissive processes -including natural sources- while the default EF may be based on carbon content of specific fuels or be for a specific process among many.
- Geographically or temporally gridded NGHGI information can facilitate more accurate comparisons with atmosphere-based emission estimates to identify areas of improvement. There is a need to determine the appropriate spatial and temporal scales for comparing inversion and inventory-derived emissions.
- Very useful to have interactions between inventory compilers and atmospheric observation researchers to enhance the common understanding of issues and also to develop a glossary of terms, as some terms may have different meanings in the two communities.

The Co-Chairs concluded that a forum for exchange of information among inventory compilers and atmospheric observation researchers is useful, and a long-term interaction may be beneficial. Atmospheric measurements are useful to verify GHG inventories, and examples were presented at the expert meeting. By sharing these case studies and the lessons learned with other countries it is hoped that the interaction between atmospheric observation researchers and the GHG inventory community will be advanced so that ultimately our understanding of GHG emissions magnitudes and source contributions will be improved. There is no methodological guidance newly developed as a result of the expert meeting, but the findings will be documented for future TFI to benefit from the rich discussions held between all experts.

2.2 CO_2 emissions from fuel combustion

The following experts participated in the Combustion CO_2 BOG: Philippe Ciais, Richard Engelen, Rebecca Garland, Veronika Ginzburg, Michel Alexandre Grutter de la Mora, Chia Ha, Miao Lang, Bundit Limmeechokchai, Zhu Liu, Greg Marland, Batouli Said Abdallah, Marko Scholze, Steven J. Smith, Hiroshi Suto, Jocelyn Turnbull, Yogesh K. Tiwari, Masataka Watanabe, Jung-Hun Woo, Yousuke Yamashita

Facilitator:	Dario Gómez
Rapporteur:	Ole-Kenneth Nielsen
TSU:	Takeshi Enoki

1. **Assess and critique recent estimation techniques that utilise atmospheric observations as well as operational systems, platforms, instruments/sensors and methods/models for their potential to be used for the verification of national inventory sectoral emission estimates, consistent with the guidance provided in the 2019 Refinement.**
   - ✓ Examples of utilising land-based, airborne and satellite data to estimate CO_2 emissions all yielding useful results in terms of verification
   - ✓ Examples of both national and subnational applications
   - ✓ No examples of estimates based on atmospheric observations that has the level of sectoral detail that is required in national emission inventories
   - ✓ More potential for verification in countries with less developed statistical systems
   - ✓ Can be used to identify gaps or areas for future improvements in the inventories
   - ✓ While it may not be possible to significantly improve fossil CO_2 emission estimates for all countries, estimates derived using atmospheric observations can be used to build trust
   - ✓ Challenge to distinguish between fossil and biogenic CO_2 – need to measure additional chemical or isotopic markers
   - ✓ Probably a need to combine satellite data with land-based measurements
   - ✓ Verifying emission trends might be easier than the emission level depending on the national circumstances
   - ✓ Not clear what the uncertainties are of the estimates based on atmospheric observations – uncertainties need to be smaller or comparable to the inventory estimate for it to make sense for verification
   - ✓ A lot of future work is planned and underway that will advance further the capabilities for atmospheric observations to provide more accurate verification

2. **Assess and evaluate successful examples of: *comparisons between atmospheric observations and national inventories that are consistent with good practice provided in the 2019 Refinement that have led to implemented or planned improvements in national inventories; available examples where emission factors derived from atmospheric observations have been incorporated into a bottom-up inventory framework***
   - ✓ Some examples of good consistency between national inventories and estimates based on atmospheric observations – no known examples of where national inventories have been improved based on atmospheric measurements
   - ✓ No known examples of atmospheric observations having been used to derive CO_2 emission factors for fuel combustion and applied in a national inventory
   - ✓ Difficult for atmospheric observations to be used to derive emission factors for fuel combustion – could be different for other CO_2 emission sources, e.g. in connection with fugitive emissions from fuels
   - ✓ Atmospheric observations could be used to identify incorrect fuel information, e.g. the share of biofuels in road fuels
   - ✓ Atmospheric observations could be used to verify emissions from large point sources

3. **Assess the possibility that emerging datasets from atmospheric observations could be used to test and verify particular IPCC default values (emission factors) and associated uncertainties**
   - ✓ In terms of fuel combustion, it is unlikely that atmospheric observations could be used to verify IPCC default emission factors as the emission factors are based on carbon content in specific fuels

4. **Discuss the use of gridding (spatial and temporal) of NGHGIs to allow comparison with atmospheric observation data**
   - ✓ Very useful – not necessarily just for atmospheric observation researchers(e.g. local authorities and feedback to inventory compilers of gaps in knowledge)
   - ✓ Lots of ongoing activities – important to share knowledge and data
   - ✓ Requires a lot of data handling
   - ✓ Balance between cost and benefit
   - ✓ Important with close collaboration between inventory compilers and modellers

5. **Discuss terminology and classifications of sources/sinks and associated natural and anthropogenic GHG fluxes to find a common understanding of consistency and differences in atmospheric observation data and GHG inventory estimates**
   - ✓ Has not observed major issues at this meeting for CO_2 from fuel combustion
   - ✓ International transport is only included as a memo item in the national emission inventories
   - ✓ Different methodological tiers – relevant for atmospheric observation researchers to know, e.g. if using Tier 1 default EFs where full oxidation is assumed, If national or plant-specific EFs are used (Tier 2 or Tier 3), full oxidation may or may not be assumed
   - ✓ Useful with a glossary
   - ✓ Important to be clear on the difference between concentrations and emissions
   - ✓ Very useful to have interactions between inventory compilers and modellers to enhance the common understanding of the issues

6. **Additional relevant publications**
   - ✓ On uncertainties related to latitude longitude coordinates of emissions from point sources: A spatial uncertainty metric for anthropogenic CO_2 emissions (Woodard et al. 2014), Uncertainty in gridded CO_2 emissions estimates (Hogue et al. 2016), Large Uncertainties in Urban-Scale Carbon Emissions (Gately & Hutyra 2017)
   - ✓ For energy data changes: Hoesly R.M. and S.J. Smith. 2018. "Informing energy consumption uncertainty: an analysis of energy data revisions." Environ. Res. Lett. 13 124023. https://doi.org/10.1088/1748-9326/aaebc3

2.3 Fugitive CH_4 emissions

The following experts participated in the Fugitive CH_4 BOG: Dominique Blain, Steven Hamburg, Matthew Johnson, Bryce Kelly, Zhou Lingxi, Bram Maasakkers, Prabir Kumar Patra, Cynthia A. Randles, Steve Smyth, Rob Sturgiss, Oksana Tarasova, Irina Yesserkepova, Daniel Varon, Felix Vogel.

Facilitator:	Melissa Weitz
Rapporteur:	Anna Romanovskaya
TSU:	Baasansuren Jamsranjav

1. **Assess and critique recent estimation techniques that utilise atmospheric observations as well as operational systems, platforms, instruments/sensors and methods/models for their potential to be used for the verification of national inventory sectoral emission estimates, consistent with the guidance provided in the 2019 Refinement**
   - ✓ A lot of potential for use of these techniques for assessment of GHG inventories for CH_4 fugitive emissions
   - ✓ Rapidly maturing science
   - ✓ Ongoing dialogue and development of capacity between GHG inventory compilers and researchers is critical (design of studies and appropriate interpretation of results)
   - ✓ Appropriate technique depends on question being asked:
     - particular target: verification of the national inventory for fugitive CH_4 or development of Tier 3 EFs or conduction of Tier 3 measurement for inventory reporting
     - specific source in question: level of detail required
     - scale: time and space (source level, facility level, basin level, national), (e.g., snap shot through long-term measurements) versus annual inventories and time series considerations
     - approach to upscaling/downscaling of measurements (representativeness)
     - relevance of single technique or to use the combination of techniques
     - trace gases (isotopes, stoichiometry, etc.) for precise interpretation
   - ✓ Idea from the group: to develop a matrix (set of matrixes) for use in collaboration between inventory compilers and atm. researchers to assess available different techniques for different scales and different purposes (e.g., level versus trend) (Table 6.2, Volume 1)

     QUESTION (inventory-relevant)⇔TECHNIQUES (atmospheric-based)⇔IMPLEMENTATION
     - could include mass balance, spectroscopy, long-term observation, simple inversion, modelling, etc. and different vehicles: cars, towers, aircrafts, satellites
     - "living" list of techniques – to be updated periodically taking into account rapid developments in that science, including information on uncertainty
   - ✓ The matrix (set of matrixes) referred to in the previous bullet can be developed, but time is needed
     - Recommendation for future work of TFI

2. **Assess and evaluate successful examples of: *comparisons between atmospheric observations and national inventories that are consistent with good practice provided in the 2019 Refinement that have led to implemented or planned improvements in national inventories;***
   - ✓ Examples discussed from Annex I (lack for non-Annex I):
     - Canada:
       - aircraft used to compare emissions totals and source-level breakdown for the area
       - *planned to measure EFs for specific provinces*
     - Australia: aircraft QA process for CH_4 inventory in total and for coal seam gas particularly
     - US: satellite (e.g., TROPOMI datasets) and aircraft used for comparison for production and distribution (oil/gas)
     - China: in situ comparison for coal CH_4 emissions

- Poland and Romania: aircraft spectrotechnics, large subnational scale – fugitive emissions for coal mines (Poland) oil and gas (Romania)
- ✓ A lot of examples of EFs however subnational scale: California, Canada
- ✓ Improvements in the industrial reporting
- ✓ Idea from the group: encourage submission of new developed EFs in the IPCC EFDB

3. Assess the possibility that emerging datasets from atmospheric observations could be used to test and verify particular IPCC default values (emission factors) and associated uncertainties

- ✓ Opinion of the group: testing and verification of Tier 1 default EFs may not be worth the effort due to variability (geographically, practices, etc), complexity of measurements, costs, level of disaggregation of data obtained
  - Other potential uses include informing decision by country to use or not use Tier 1 EF, development of Tier 2 EF
- ✓ New default EFs from atmospheric observation would not necessarily lower the associated uncertainties compared to 2019 Refinement: different features\specific of different individual sources
- ✓ Uncertainties of measurements and inventory estimates are different (sampling size, equipment, modelling versus IPCC uncertainties of estimates)

4. Discuss the use of gridding (spatial and temporal) of NGHGIs to allow comparison with atmospheric observation data

- ✓ Gridding is critically important step for inverse modelers
  - Gridded versions of national GHG inventories (consistent with sectors, sources in GHG inventories) improve our ability to compare GHG inventory results with atmospheric observations
  - Note that uncertainty is impacted with spatial, temporal, allocations etc.
- ✓ Spatial resolution needed:
  - depends on the individual sources and could be different, depends on types of observation
- ✓ Temporal gridding:
  - for fugitive emissions is difficult to obtain
  - fugitive emissions can vary greatly over time
  - limited data to grid temporal variability for fugitives
- ✓ Additional value of gridding:
  - Information to local communities (including environmental justice information, mitigation)
  - Improved priors for atmospheric studies
- ✓ Connected to the question of capacity of inventory teams in different countries
  - is a barrier to wide use atmospheric observation across reporting countries under the Paris Agreement (only few countries have a such experience)
- ✓ Some countries could resist of doing gridding
  - e.g. confidential (or lack of) information
- ✓ Idea of the group: to develop recommendations on the gridding of the national GHG inventory data
  - further work for TFI

5. Discuss terminology and classifications of sources/sinks and associated natural and anthropogenic GHG fluxes to find a common understanding of consistency and differences in atmospheric observation data and GHG inventory estimates

- ✓ constrain[1] – Atmospheric observation: "what we have information on." Inventory: "not be able"
- ✓ scale[2] - how different scales are matching inventory

[1] Atmospheric observation community uses this term to mean: "what we have information on." Inventory often interprets the term to mean: "not be able"

[2] The temporal and spatial scales may differ between atmospheric observations and inventories and this should be taken into consideration for comparisons

- ✓ fugitive - Atmospheric observation: general understanding. Inventory: according to IPCC definition
- ✓ validation/verification - Atmospheric observation: validation of models. Inventory: defined verification in IPCC Guidelines
- ✓ natural versus anthropogenic - provide list of sources from IPCC Guidelines to atmospheric observation community
- ✓ biogenic and thermogenic and pyrogenic - and how it does and does not relate to natural versus anthropogenic
- ✓ uncertainty [3] - Atmospheric observation: scientific interpretation of measurements conducted. Inventory: IPCC methodology related to the total calculated emission
- ✓ concentrations versus emissions (fluxes) - measured atmospheric concentrations versus emissions in inventories
- ✓ upscaling/downscaling - how national totals are obtained from measurements
- ✓ time frames – how annual data are obtained for the inventory
- ✓ completeness - Atmospheric observation: all sources covered in measurements. Inventory: IPCC definitions
- ✓ individual source versus source category - measured individual source versus defined source categories in inventories
- ✓ time series consistency - how possible to ensure using atmospheric observation in line with IPCC Guidelines
- ✓ Inventory development requirements versus research needs to get a result[4]

[3] Uncertainty information provided in inventories and in atmospheric observation research may have different meanings. Uncertainty in the inventories should be estimated in accordance with the agreed IPCC methodology and based on the uncertainty of activity data and emission factors. Uncertainty for research could include uncertainty in the modelization, uncertainties in the sources/sinks contributing to the measured flux and trend as well as uncertainty in the actual boundaries of the territory to which measured fluxes and trends pertain etc."

[4] Inventory and atmospheric observation community may use the term "requirement" different--Inventory considers requirements of IPCC/UNFCCC and research considers it to mean what is needed to get a result (the specifics of which may not be a requirement for inventories)

2.4 AFOLU GHG emissions

The following experts participated in the AFOLU GHG BOG: Antonio Bombelli, Pep Canadell, Frank J. Denten, Savitri Garivait, Giacomo Grassi, Werner Leo Kutsch, Toshihiro Kuwayama, Douglas MacDonald, Sara Mikaloff-Fletcher, Sini Niinistö, Wolfgang Alexander Obermeier, Riitta Kristiina Pipatti, Lucia Perugini, Ana, Maria Roxana Petrescu, Lars Peter Riishojgaard, Yasna Rojas, Wanqi Sun, Rona Louise Thompson, Luciana Vanni Gatti, Sara Venturini, Yohanna Villalobos Cortes, Thomas Charles Wirth.

Facilitator:	Maria Jose Sanz Sanchez
Rapporteurs:	Stephen Ogle
TSU:	Sandro Federici

1. **General Comments**
   - ✓ Focused on atmospheric observations that are used in inversion frameworks to estimate fluxes
   - ✓ Verification of inventory using inversion data is not necessarily leading to direct changes in the emissions reporting (i.e., directly using the inversion results for reporting), but rather as a starting point for further investigation of the inventory methods as well as the inversion framework
   - ✓ Goal is to reduce uncertainty by identifying issues with underlying data
   - ✓ Inventories may also be useful for improving atmospheric inversions
   - ✓ In general, developing country parties to the UNFCCC face more challenges to use atmospheric observations for evaluating inventories
     - Global inversions may provide some insights into key categories
     - Not clear that inversions can be used directly in evaluating inventories in developing countries, particularly smaller countries
   - ✓ Questions that can be asked in these comparisons:
     - Is the inventory accurate?
     - Is the inversion accurate?
     - What are the drivers of the stock changes or GHG fluxes?
     - Are trends and spatial patterns consistent between the inventory and inversion?

2. **Assess and critique recent estimation techniques that utilise atmospheric observations as well as operational systems, platforms, instruments/sensors and methods/models for their potential to be used for the verification of national inventory sectoral emission estimates, consistent with the guidance provided in the 2019 Refinement**
   - ✓ Overarching conclusion: Need to gain more experience using atmospheric observations and inversions to evaluate AFOLU sectoral GHG inventories.
     - Best examples from evaluation of CH_4 and N_2O emissions in AFOLU sector
   - ✓ Considerations for conducting an informative analysis based on recent inversion and inventory comparisons
   - ✓ Scale of inversion is important
     - Regional inversions critical for small countries, and to evaluate subnational fluxes in larger countries
     - Global inversions may be useful for large countries
     - Estimates of fluxes should be consistent across scales, as such regional inversions need to be consistent with the global inversions and with rates of emissions measured at the local scale
   - ✓ Prior fluxes for inversions is a large source of uncertainty
     - Could use the inventory as a prior if adequate for purposes but will likely need data beyond the inventory to estimate the full flux, particularly for CO_2
     - In AFOLU, lateral fluxes associated with harvested woody products, crop harvest and transport, indirect N_2O emissions, and hydrological flows contribute to the uncertainty in the estimates
   - ✓ Transport is another large source of uncertainty in inversion frameworks
     - May contribute to mismatch in inversion fluxes compared to inventory

- Depends on topography and complexity of atmospheric structure

✓ Atmospheric observations of concentrations have considerably less uncertainty, but quality and quantity of atmospheric observations are another consideration
  - Interpretation of tall tower and aircraft observations are a more direct inference on the concentrations, and need to be expanded in some regions (initiative led by WMO)
  - Satellite data provide additional information on atmospheric concentrations to support the inversions
  - In turn, satellite data are providing opportunities for inversion analysis in regions where this was not possible in the past

✓ Inventory compilers need to be actively involved in these comparisons
  - Providing context about the inventory analysis
  - Expressing needs for improving the inventory
  - Evaluating differences and unexplained inconsistencies from the comparison

3. **Assess and evaluate successful examples of: *comparisons between atmospheric observations and national inventories that are consistent with good practice provided in the 2019 Refinement that have led to implemented or planned improvements in national inventories;***

✓ Comparison 1: New Zealand Example
  - Inversion system applied to evaluate CO_2
  - Inversion System: Surface measurements and Langragian Bayesian inversion system
  - Finding C sink in the inversion analysis that has not been identified in the inventory along coastal areas
    - ▪ May be associated with lateral flows of sediment and/or water
    - ▪ New studies initiated to investigate these possibilities
  - Publications: Steinkamp et al. 2017, ACP; Geddes et al. 2020, Report to Ministry of Primary Industries

✓ Comparison 2: Australia Example
  - Inversion system applied to evaluate CO_2
  - Inversion System: OCO-2 Satellite data with Data Assimilation
  - Finding a sink in rangelands that has not been identified in the inventory
    - ▪ Maybe associated with precipitation patterns, woody encroachment, and/or management
    - ▪ Planning to further investigate these differences with inventory team
  - Publications: Villalobos et al. 2020, ACP; Villalobos et al. 2021, ACP; Villalobos et al. 2022, ACP

✓ Comparison 3: United States Example
  - Inversion system applied to investigate impact of freeze-thaw process on soil N_2O emissions
  - System: Tower observations and observations made from aircraft were interpreted with Carbontracker Lagrangian Bayesian Inversion system
  - Findings showed that freeze-thaw periods coinciding with large emission pulses consistent with the small set of experimental data.
  - Inversion informed model development leading to an improvement in the inventory that has been incorporated into UNFCCC reporting
  - Publication: Nevison et al. 2018, GBC; Del Grosso et al. 2022, PNAS

✓ Comparison 3: Subnational Example from US State of California
  - Inversion system applied to emissions from dairy operations
  - Inversion System: Lagrangian Bayesian Inversion System
  - Inversion suggested that they were under-estimated
  - Mobile and airborne measurements confirmed that the inventory emission factors were accurate and the inversion was not accurate in this case.
  - Publication: Amini et al. 2022, ES&T

4. **Assess the possibility that emerging datasets from atmospheric observations could be used to test and verify particular IPCC default values (emission factors) and associated uncertainties**
   - ✓ Tier 1 Emission Factor Evaluation: Soil N_2O emissions
     - Inversion system applied to estimate N_2O fluxes in Brazil, United States, China, South Asia, and Europe
     - Estimated implied emission factors based on N inputs (i.e., dividing the emissions by the inputs) combining direct and indirect emissions
     - Found that Tier 1 factors from the 2006 GL were lower than implied emission factors from the inversion analysis and that implied emission factors increased over time, or with higher applications rates. The study did not consider the differentiation between direct and indirect emissions or natural emissions
     - Note: *2019 Refinement* has updated these factors so could be further investigation
     - Regardless, example of how atmospheric data could be used to evaluate default factors
     - Publication: Thompson et al. 2019, NCC

5. **Discuss the use of gridding (spatial and temporal) of NGHGIs to allow comparison with atmospheric observation data**
   - ✓ Inventory compiler needs sufficient resources and time to participate in the gridding of inventory data
     - Compiler has the detailed understanding of these data and should be involved in this process even if the compiler is not gridding the data
   - ✓ Need to determine the appropriate spatial and temporal scales for comparing the inversion and inventory before gridding the inventory data
     - e.g., comparisons at finer scales may not be informative if uncertainties are large
   - ✓ Need to determine where uptake and release are occurring, particularly the lateral flows of materials that may lead to processes that drive uptake and release of the GHGs occurring in different locations that are not easily identified.

6. **Discuss terminology and classifications of sources/sinks and associated natural and anthropogenic GHG fluxes to find a common understanding of consistency and differences in atmospheric observation data and GHG inventory estimates**
   - ✓ Anthropogenic GHG Emissions
     - Managed land proxy leads to inconsistency between inversion and inventory estimates
   - ✓ Differences in application of inventory methods
     - Particularly differences among inventory Tier methods
     - Tier 1 v. Tier 3 for soil N_2O has a different level of estimation and can lead to inconsistencies
   - ✓ Missing sources in the inventory
     - Some sources may not be estimated depending on policy relevance but leads to inconsistencies in comparisons with the inversion
     - e.g., Herbaceous biomass and dead organic matter
   - ✓ Attribution of inversion flux to individual source categories
     - Fluxes are based on gases but source categories are often further subdivision of gases into categories such as direct and indirect soil N_2O emissions
     - Inversions may provide some information on emissions if separation of activities across the country (e.g., pixels dominated by forest, cropland etc., rice fields, may provide some insight on sources categories)
     - However, more heterogeneous land use patterns and mobile sources on the landscape such as livestock systems in this sector will be difficult to disaggregate and also evaluating livestock systems in this sector which are more mobile across the landscape
   - ✓ Interannual variability

  - Not always addressed in the inventory whereas this is part of the inversion, leading to inconsistencies
  - Longer term climate change is imposed on these patterns, but may not be addressed in the inventory
  - May be able to extract interannual variability out of the atmospheric data as the time series increase in length
- ✓ Inversions may only capture short term trends that may not result in longer-term changes in stocks consistent with fluxes observed in inversions

2.5 F-gases

The following experts participated in the Fgas BOG: Peter Brown, Philip L. DeCola, Fatma Betül Demirok, Mark Hunstone, Alistair James Manning, Stephen Montzka, Anita Ganesan, Kokou Sabi, Bo Yao

Facilitator:	Jongikhaya Witi
Rapporteur:	Deborah Ottinger
TSU:	Pavel Shermanau

1. **Assess and critique recent estimation techniques that utilise atmospheric observations as well as operational systems, platforms, instruments/sensors and methods/models for their potential to be used for the verification of national inventory sectoral emission estimates, consistent with the guidance provided in the 2019 Refinement**
   - ✓ Both atmospheric scientists and inventory compilers should be aware of the uncertainties in the emissions derived from atmospheric observations.
   - ✓ For the most commonly used inverse modelling approach, these uncertainties may result from any of the components of the modelling system, including gas abundance measurements, priors, weather prediction models, transport models, inverse systems, and concentrations upwind of the region of interest.
   - ✓ One way to better understand these uncertainties is to calculate results based on multiple versions of these components.
   - ✓ Priors are supplied as inputs to inversions, and priors with a range of detail (from uninformed to extensively informed) supply different but useful emissions estimates (an entirely independent estimate vs. a refinement of the inventory estimate) to the inventory community for the purpose of verification (as defined in the *2019 Refinement*) of national emission estimates.
   - ✓ Recognize that inverse analysis systems are not yet standardized; therefore, there is room for additional progress and refinement of emission estimates and uncertainties derived using these systems. As a result, identifying robust signals and robust differences between an inverse and inventory result requires expert judicious review and assessment of results. Robust signals are best identified or confirmed through consideration of multiple configurations of inversion models and observations.

2. **Assess and evaluate successful examples of: *comparisons between atmospheric observations and national inventories that are consistent with good practice provided in the 2019 Refinement that have led to implemented or planned improvements in national inventories; available examples where emission factors derived from atmospheric observations have been incorporated into a bottom-up inventory framework***
   - ✓ Atmosphere-derived emission estimates for F-gases are included in NIRs to the UNFCCC for four different countries.
   - ✓ These successful examples all include ongoing respectful communication between both atmospheric and inventory-focused communities to better understand emission estimates, trends, and their uncertainties. The best examples include those where there was a dedication to continuous and long-term engagement in this collaborative process.
   - ✓ Useful outcomes have resulted from:
     - A sustained and consistent back-and-forth process.
     - Establishing a regular, predictable schedule for updated comparisons (e.g., annually). This builds long-term relationships and avoids having to reassemble the relevant expertise and data on an ad-hoc basis.
     - Bringing in additional expertise, e.g., from emitting industry.
   - ✓ Insight into what is driving emissions has been gained by combining on-the-ground knowledge of sources (from the inventory agency) with analysis of
     - temporal and spatial patterns in emissions (e.g., seasonality in emissions) and

- emissions of different trace gases (including F-GHGs) that may be emitted separately or together in characteristic ratios with the F-GHGs.
- ✓ Given that useful comparisons take time, successful programs have prioritized certain gases/sources over others.

3. Assess the possibility that emerging datasets from atmospheric observations could be used to test and verify particular IPCC default values (emission factors) and associated uncertainties

- ✓ It is difficult to use atmosphere-based estimates to gain insights into specific default factors because current inverse systems generally provide total emissions from the sum of all emissive processes.
- ✓ In addition, emissions for many F-gas source categories depend on multiple parameters (in addition to activity data), making it challenging to determine which of these parameters should be adjusted.
  - Nevertheless, in some cases, country-specific parameters have been informed by atmosphere-derived emissions among other datasets. In the long term, these country-specific factors could inform IPCC default values.
- ✓ Targeted pilot atmospheric measurement projects can provide insights into specific processes (e.g., associated with fluorochemical production).

4. Discuss the use of gridding (spatial and temporal) of NGHGIs to allow comparison with atmospheric observation data

- ✓ Geographically or temporally disaggregating National GHGI information can facilitate more accurate comparisons with atmosphere-based emission estimates when the latter aren't representative of an entire country or year.
- ✓ Furthermore, the disaggregated inventory can be used to extrapolate atmosphere-based results representative of a limited portion of a country or time period to the entire country or year.
- ✓ Finally, disaggregated National GHGI information can help identify regions of a country where atmospheric observations should be best situated in order to capture emissions from the most emissive regions.

5. Discuss terminology and classifications of sources/sinks and associated natural and anthropogenic GHG fluxes to find a common understanding of consistency and differences in atmospheric observation data and GHG inventory estimates

- ✓ Important for both inventory compilers and atmospheric science community to use consistent GWPs in aggregations across GHGs when comparisons are made. (Inventory compilers are likely to prefer the current UNFCCC-adopted GWP values.)
- ✓ We propose including a glossary for the following terms:
  - Gas abundance measurements,
  - priors
  - uninformed (flat) vs. informed
  - weather prediction models,
  - transport models,
  - inverse systems,
  - “background concentrations” or concentrations upwind of the region of interest

6. Additional Observations

- ✓ Atmospheric measurements are currently informing refinements to existing industrial GHG reporting programs (e.g., updated emission factors used by facilities for reporting).
- ✓ May be useful to establish a forum for the regular exchange of ideas among inventory compilers regarding verification using atmosphere-based estimates.

Annex 1: Materials for the Meeting

Guiding Note

(Prepared by Task Force Bureau to help participants have focused discussion consistently with the decision by the IPCC at its 54th(bis) Session)

Focus

the use of atmospheric observation data and models in verification of national greenhouse gas (GHG) inventories

National GHG Inventories scope and associated requirements

National GHG inventories provide information on the level and trend of GHG emissions and removals associated with human activities which is essential to the assessment of human impacts on the climate system. National GHG inventories are important for policy makers to plan actions to curb those emissions as well as to quantify the results of implemented actions to reduce the atmospheric concentration of GHGs, so tracking progress by countries in achieving the goal of United Framework Convention on Climate Change (UNFCCC).

Under the UNFCCC, countries are required to develop and report national GHG inventories consistent with the IPCC Guidelines, to ensure transparency, accuracy, completeness, consistency and comparability of their national GHG inventories. For example, under the Paris Agreement, all Parties shall use the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 IPCC Guidelines*) in accordance with Decision 18/CMA.1 "Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement".

IPCC methods are generally based on bottom-up calculation of estimates through the quantification of processes and activities that cause GHG emissions and removals (i.e., activity data) at the level of source category and the application of associated emission/removal factors. At higher tiers, for certain source categories, IPCC methods may make use of country-specific and facility-specific data based on in-situ measurements and other information. Use of remote (i.e., top-down) estimation methods using atmospheric concentration is in its early stages.

In the *2006 IPCC Guidelines*, the benefit of use of atmospheric measurement data was referred to, but practical guidance on how to use these data was not provided. Taking into account developments in GHG monitoring networks and advances in technologies since 2006, guidance on the use of atmospheric measurements for assessment and improvement of national GHG inventories was updated and elaborated in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2019 Refinement*), Volume 1, Chapter 6.

Further, the development and improvement of source-specific emission factors are becoming increasingly important to keep enhancing the quality of GHG estimates, especially for those sectors and categories where development and application of new technologies impact the associated rate of emissions, and the use of atmospheric observation data and models may support verification of EFs.

Nowadays, atmospheric observations are based on a large variety of platforms (e.g., ground-based (including vehicle-based mobile laboratories), ship-borne, aircraft-borne, satellite-borne), sensors/instruments (e.g., infrared absorption spectroscopy, UV-visible differential optical absorption spectroscopy, solid-state and electrochemical sensors), and models applied to derive activity-dependant fluxes and/or time-dependant rates of change in atmospheric concentrations. Such large variability provides for an improved capacity to monitor emissions under a variety of circumstances.

Discussion at the expert meeting can be articulated in the following items:

I. Take stock of efforts by inventory compilers to implement the *2019 Refinement* guidance on use of atmospheric measurements to improve national GHG inventories, through examples that are consistent with good practice provided in the *2019 Refinement* (e.g., following the steps provided in Tables 6.3 and Box 6.5 of Volume 1). Examples and case studies should include both efforts to incorporate observations data directly into GHG inventories, and efforts to use observations to provide independent assessments of GHG inventory results that have led to identification of areas for improvement for GHG Inventories.

II. Assess and critique advances in datasets as well as new and operational systems, platforms, instruments/sensors and methods/models since 2019, and their relevance to improving national GHG inventories consistent with the IPCC Guidelines.

III. Assess the strengths and limitations of this experience with the *2019 Refinement* and develop recommendations for how implementation can be improved in the future, including through improved technical, human and financial resources.

Potential BOGs

A.

- ✓ Assess and critique recent estimation techniques that utilise atmospheric observations as well as other new and operational systems, platforms, instruments/sensors and methods/models for their potential to be used for the verification of national inventory sectoral emission estimates, consistent with the guidance provided in the *2019 Refinement*;
- ✓ Assess the possibility that emerging datasets from atmospheric observations could be used to test and verify particular IPCC default values and associated uncertainties.
- ✓ The assessment should consider the use of gridding of NGHGIs to allow comparison with atmospheric observation data.

Focus on combustion CO_2
Discuss items for both approaches: 1. satellite-based measurements; 2. - close-range atmospheric measurements

B.

- ✓ Assess and critique recent estimation techniques that utilise atmospheric observations as well as other new and operational systems, platforms, instruments/sensors and methods/models for their potential to be used for the verification of national inventory sectoral emission estimates, consistent with the guidance provided in the *2019 Refinement*;
- ✓ Assess the possibility that emerging datasets from atmospheric observations could be used to test and verify particular IPCC default values and associated uncertainties.
- ✓ The assessment should consider the use of gridding of NGHGIs to allow comparison with atmospheric observation data.

Focus on fugitive CH_4
Discuss items for both approaches: 1. satellite-based measurements; 2. close-range atmospheric measurements

C.

- ✓ Assess and critique recent estimation techniques that utilise atmospheric observations as well as other new and operational systems, platforms, instruments/sensors and methods/models for their potential to be used for the verification of national inventory sectoral emission estimates, consistent with the guidance provided in the *2019 Refinement*;
- ✓ Assess the possibility that emerging datasets from atmospheric observations could be used to test and verify particular IPCC default values and associated uncertainties.

- ✓ The assessment should consider the use of gridding of NGHGIs to allow comparison with atmospheric observation data.

Focus on AFOLU N_2O, CH_4, CO_2
Discuss items for both approaches: 1. satellite-based measurements; 2. close-range atmospheric measurements

D.

- ✓ Assess and critique recent estimation techniques that utilise atmospheric observations as well as other new and operational systems, platforms, instruments/sensors and methods/models for their potential to be used for the verification of national inventory sectoral emission estimates, consistent with the guidance provided in the *2019 Refinement*;
- ✓ Assess the possibility that emerging datasets from atmospheric observations could be used to test and verify particular IPCC default values and associated uncertainties.
- ✓ The assessment should consider the use of gridding of NGHGIs to allow comparison with atmospheric observation data.

Focus on F-gases
Discuss items for both approaches: 1. satellite-based measurements; 2. close-range atmospheric measurements

Discussion points

a. Consider covering all/most significant sources of emissions of the relevant GHG(s)

b. GHG Inventory compiler data/QAQC needs relevant to observations

c. Discussion how to clarify terminology and classifications to find a common understanding of consistency and differences in atmospheric observation data and GHG inventory estimates

Annex 2: Agenda

IPCC Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories

5 – 7 September 2022

WMO HQ, Geneva - Switzerland

Agenda

Day 1 – Monday, 5 September 2022

<table>
<tr><td rowspan="7">Day 1

8:30-17.00
(CEST)
Geneva Time
(UTC+2)</td><td colspan="2">**Part I – Opening Plenary**</td></tr>
<tr><td>8:30 – 9:00</td><td>➢ Registration of participants</td></tr>
<tr><td rowspan="2">9.00 - 10.00</td><td>➢ Welcome
• IPCC Secretary (Abdalah Mokssit) – *5 min*
• IPCC TFI Co-Chairs Eduardo Calvo Buendia and Kiyoto Tanabe – *5 min*
➢ Adoption of Agenda
• IPCC TFI Co-Chairs Eduardo Calvo Buendia and Kiyoto Tanabe – *5 min*</td></tr>
<tr><td>➢ Introductory presentation on Scope, Context, BOGs (+Q&A)
• IPCC TFI TSU – *45 min*</td></tr>
<tr><td>10.00 - 12.25</td><td>➢ Presentations & Q&A *(30 min each)*
• Comparing national greenhouse gas budgets reported in UNFCCC inventories against atmospheric inversions - *Philippe Ciais*
• Pilot national-scale estimates of CO_2 and CH_4 emissions and removals from space-based measurements - *Masataka Watanabe*
• CarbonWatch NZ: combining measurements of GHGs in the air above New Zealand in a bird's eye view of New Zealand's carbon balance – *Sara Mikaloff-Fletcher*
• Emissions, Methods, Uncertainty, and Evaluation - *Steven J. Smith*
+ coffee break *(25 minutes)* [at 10:30]</td></tr>
<tr><td>12.25 - 13.55</td><td>*Lunch*</td></tr>
<tr><td>13.55 - 17.20</td><td>➢ Presentations & Q&A *(30 min each)*
• Gridding CH_4 estimates from national GHG inventories for comparison with atmospheric observation data and discriminating among anthropogenic and natural fluxes – *Bram Maasakkers*
• Monitoring and validating CH_4 point sources with remote observations – *Matthew Johnson*
• The role of the International Methane Emissions Observatory in Strengthening National Greenhouse Gas Inventories – *Steven Hamburg*
• Airborne Amazon Carbon budget and CH_4 emissions – *Luciana Vanni Gatti*
• Use of remote observation to verify N_2O emissions from Land – *Stephen Ogle*
• F-gas inventories and comparisons with atmospheric observations – *Deborah Ottinger*
+ coffee break (25 minutes) [at 15:30]</td></tr>
</table>

Day 2 – Tuesday, 6 September 2022

Day 2 **9:00-17.00 (CEST)** *Geneva Time (UTC+2)*

Part II – Break-out groups (BOG) presentations and discussion

BOG	Item	Facilitator	Rapporteur	TSU staff
1	**CO_2 emissions from fuel combustion**	Dario Gomez	Ole-Kenneth Nielsen	Takeshi Enoki
2	**Fugitive CH_4 emissions**	Melissa Weitz	Anna Romanovskaya	Baasansuren Jamsranjav
3	**AFOLU GHG emissions**	Maria Jose' Sanz Sanchez	Stephen Ogle	Sandro Federici
4	**F-gases**	Jongikhaya Witi	Deborah Ottinger	Pavel Shermanau

Time	BOG	Programme
9.00 - 12.30	**BOG 1**	➢ Presentations & Q&A *(30 min each)* • Estimates of CO_2 emissions from airborne sensors - *Hiroshi Suto* ➢ Discussion *(all day)*
	BOG 2	➢ Presentations & Q&A *(30 min each)* • Estimating fugitive CH_4 emissions from the detection of CH_4 plumes using aeroplane flyovers - *Bryce Kelly* ➢ Discussion *(all day)*
	BOG 3	➢ Presentations & Q&A *(30 min each)* • Using satellite observations to model net carbon dioxide emissions from AFOLU (REgional Carbon Cycle Assessment and Processes (RECCAP) under the Global Carbon Project - *Yohanna Villalobos Cortes* ➢ Discussion *(all day)*
	BOG 4	➢ Presentations & Q&A *(30 min each)* • High precision F-gas measurement instruments and application in estimate Chinese F-gas emission - *Bo Yao* • F-gas emissions monitoring through atmospheric observation - *Alistair James Manning* ➢ Discussion *(all day)*
12.30 - 14.00	*Lunch*	
14.00 – 17.20	**BOG 1**	➢ Discussion *(all day)*
	BOG 2	➢ Discussion *(all day)*
	BOG 3	➢ Discussion *(all day)*
	BOG 4	➢ Discussion *(all day)*

Coffee Breaks: 20 minutes each at 10:30 and 15:30

Day 3 – Wednesday, 7 September 2022

<table>
<tr><td rowspan="10">Day 3

9:00-17.00
(CEST)
Geneva Time (UTC+2)</td><td colspan="3">**Part II – Break-out groups (BOG) presentations and discussion**</td></tr>
<tr><td rowspan="4">9.00 - 12.30</td><td>**BOG 1**</td><td>➢ Discussion *(all morning)*</td></tr>
<tr><td>**BOG 2**</td><td>➢ Discussion *(all morning)*</td></tr>
<tr><td>**BOG 3**</td><td>➢ Discussion *(all morning)*</td></tr>
<tr><td>**BOG 4**</td><td>➢ Discussion *(all morning)*</td></tr>
<tr><td>12.30 - 14.00</td><td colspan="2">*Lunch*</td></tr>
<tr><td colspan="3">**Part III – Closing Plenary**</td></tr>
<tr><td>14.00 – 16:35</td><td colspan="2">➢ BOGs’ Presentations + QA *(35 min each)*
• BOG 1 – *Ole-Kenneth Nielsen*
• BOG 2 – *Anna Romanovskaya*
• BOG 3 – *Stephen Ogle*
• BOG 4 – *Deborah Ottinger*
+ coffee break (15 minutes)</td></tr>
<tr><td>16:35-17:20</td><td colspan="2">➢ Discussion and conclusions *(45 min)*</td></tr>
<tr><td>17:20-17:30</td><td colspan="2">➢ Closing remarks
IPCC TFI Co-Chairs Eduardo Calvo Buendia and Kiyoto Tanabe – *10 min*</td></tr>
</table>

Coffee Breaks: 20 minutes at 10:30 and 15 minutes at 16:20

Annex 3: List of Participants

Dominique Blain
Environment and Climate Change Canada
Canada

Antonio Bombelli
GCOS Global Climate Observing System, WMO
Switzerland

Peter Brown
Ricardo Energy & Environment
United Kingdom

Eduardo Calvo Buendia (TFI Co-Chair)
Universidad Nacional Mayor de San Marcos (UNMSM)
Peru

Pep Canadell
CSIRO Climate Science Centre
Australia

Philippe Ciais
Laboratoire des Sciences du Climat et de l'Environnement / IPSL, CEA-CNRS-UVSQ, Université Paris-Saclay
France

Philip L. DeCola
University of Maryland, Department of Atmospheric and Oceanic Sciences
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Fatma Betül Demirok
Turkish Statistical Institute (TurkStat)
Turkiye

Frank J. Dentener
Institute for Environment and Sustainability - Joint Research Centre of the European Commissions
The Netherlands

Richard Engelen
Copernicus Atmosphere Monitoring Service
Project Coordinator of CoCO2
Copernicus Department
European Centre for Medium-Range Weather Forecasts
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Anita Ganesan
University of Bristol - School of Geographical Sciences - Atmospheric Chemistry
Cabot Institute for the Environment
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Savitri Garivait
The Joint Graduate School of Energy and Environment (JGSEE), King Mongkut's University of Technology Thonburi (KMUTT)
Thailand

Rebecca Garland
University of Pretoria
South Africa

Veronika Ginzburg
Yu.A. Izrael Institute of Global Climate and Ecology
Russian Federation

Dario Gómez
Comisión Nacional de Energía Atómica
(Atomic Energy Commission of Argentina)
Argentina

Giacomo Grassi
Directorate Sustainable Resources
Institute for Environment and Sustainability - Joint Research Centre of the European Commissions
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Michel Alexandre Grutter de la Mora
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Universidad Nacional Autonoma de Mexico – UNAM
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Chia Ha
Environment and Climate Change Canada
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Steven Hamburg
Environmental Defense Fund/ International Methane Emissions Observatory- UNEP
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Carleton University
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Bryce Kelly
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Australia

Miao Lang
Meteorological Observation Center of China Meteorological Administration (MOC/CMA)
China

Bundit Limmeechokchai
Sirindhorn International Insitute of Technology, Thammasat University
Thailand

Werner Leo Kutsch
director general of ICOS ERIC
Germany

Toshihiro Kuwayama
California Air Resources Board
United States

Zhu Liu
Associate Professor at Tsinghua University
Department of Earth System Science
China

Bram Maasakkers
SRON Netherlands Institute for Space Research
The Netherlands

Douglas MacDonald
Environment and Climate Change Canada
Canada

Alistair James Manning
UK Met Office
United Kingdom

Greg Marland
Appalachian State University
United States

Sara Mikaloff-Fletcher
National Institute for Atmospheric and Oceanic Research (NIWA)
New Zealand

Stephen Montzka
NOAA Global Monitoring Laboratory
United States

Ole-Kenneth Nielsen
Aarhus University
Denmark

Sini Niinistö
Statistics Finland, FI GHG inventory team
Finland

Wolfgang Alexander Obermeier
Ludwig Maximilian University of Munich
Germany

Steven Ogle
Colorado State University, Natural Resource Ecology Laboratory and Department of Ecosystem Science and Sustainability
United States

Deborah Ottinger
U.S. Environmental Protection Agency
United States

Prabir Kumar Patra
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
India/Japan

Lucia Perugini
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