

Summary of Breakout 3a:

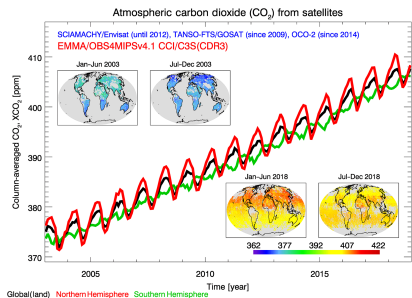
Atmospheric monitoring for quantifying GHG emissions

e.g. atmospheric retrievals of CO₂, CH₄, halocarbon, NO₂, CO, etc, and inverse modelling to derive sources and sinks (i.e. top-down)

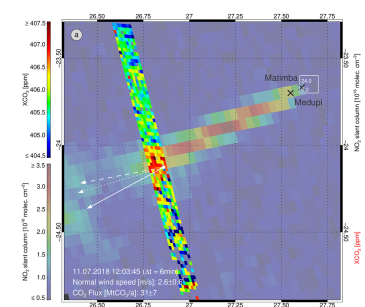
Facilitators:

- **Michael Buchwitz, University of Bremen, e-mail: buchwitz@uni-bremen.de**
- **Rob Parker, University of Leicester, e-mail: rjp23@leicester.ac.uk**

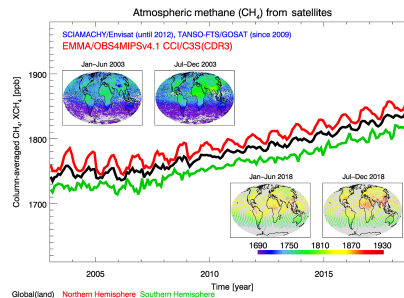
XCO₂: Multi-sensor merged



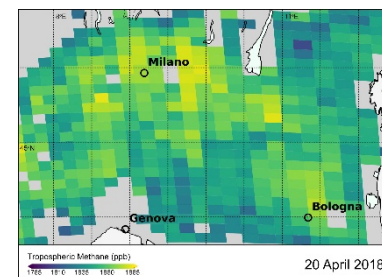
XCO₂/OCO-2 & NO₂/S5P



XCH₄: Multi-sensor merged



XCH₄/S5P



Breakout 3a: Atmospheric monitoring for quantifying GHG emissions

Seed questions:

Q1: Identify case studies based on existing work that illustrate how EO can already support the Paris agreement.

- What has been done already and what can we do already now ?

Q2: Are there R&D case studies that may in the next 5-10 years lead to new types of actionable information supporting Paris Agreement goals?

- What should we do in a follow-on programme ?

Q3: How can the CCI community contribute to the first Global Stocktake in 2023? (i.e., ideas for projects in CCI+ Phase 2)

- What should we do in Phase 2 ?

EO for UNFCCC Paris



General recommendations for CCI+ Phase 2 and follow-on programmes:

Priority 1: *Fundament of CCI is R&D to develop and/or further improve satellite retrieval algorithms and to use them to generate highest-quality ECV data products as needed for the challenging climate applications. This is the basis for all higher level products / assessments and needs to be the focus of CCI+ Phase 2 and follow-on programmes. **User feedback: Make it better, reduce biases, increase the yield, ... !***

Priority 2: *Use of the ECV data products (and other information + modelling etc.) for important climate-relevant applications (including Paris, ...)*

Priority 3+: *Other*



EO for UNFCCC Paris

How to contribute via atmospheric GHG observations?:



EU, ESA, EUMETSAT, ECMWF, ...

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RESEARCH ARTICLE | 10 FEBRUARY 2020

Janssens-Maenhout et al., 2020

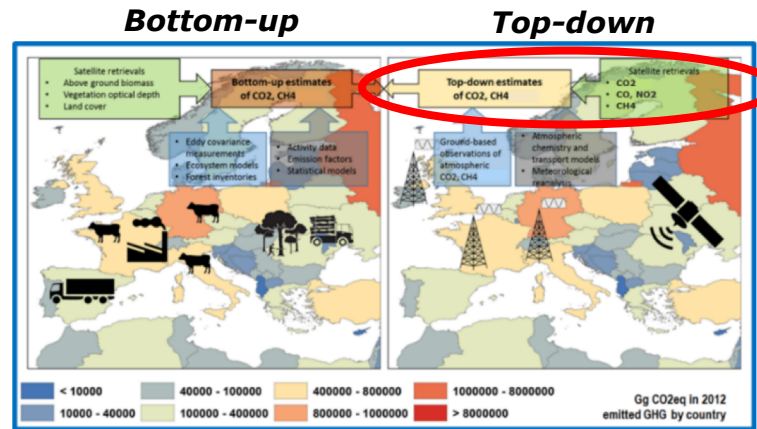
Towards an operational anthropogenic CO₂ emissions monitoring and verification support capacity

G. Janssens-Maenhout, B. Pinty, M. Dowell, H. Zunker, E. Andersson, G. Balsamo, J.-L. Béty, T. Brunhes, H. Bösch, B. Bojlov, D. Brunner, M. Buchwitz, D. Crisp, P. Gais, P. Cournet, D. Dee, H. Denier van der Gon, H. Dolman, M. Drinkwater, O. Dubovik, R. Engelen, T. Fehr, V. Fernandez, M. Heimann, K. Holmlund, S. Houweling, R. Husband, O. Juvvins, A. Kentarchos, J. Landgraf, R. Lang, A. Löscher, J. Marshall, Y. Meijer, M. Nakajima, P. Palmer, P. Peylin, P. Rayner, M. Scholze, B. Sierk, J. Tamminen, P. Verdonck

Abstract

Under the Paris Agreement progress of emission reduction efforts is tracked on the basis of regular updates to national Greenhouse Gas (GHG) inventories, referred to as **bottom-up** estimates.

However, only **top-down** atmospheric measurements can provide observation based evidence of emission trends. ...



How to „Support Paris“ via atmospheric observations?

- **Atmospheric observations** (satellites & other; CO₂ & non-CO₂ GHGs)
- **Meteorological information**
- **Inversion methods** (e.g., forward/inverse models)
- **A priori information**
- **GHG emissions and sinks, incl. trends etc.**
- **Comparisons with (national) inventories**
- **Providing complementary information (Mechanism?: Via Copernicus? Other?)**

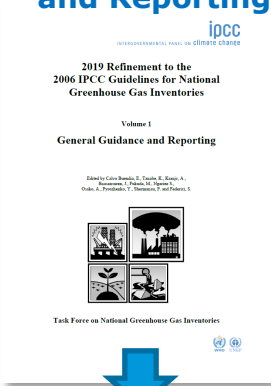
EO for UNFCCC Paris

How to contribute via atmospheric GHG observations?:

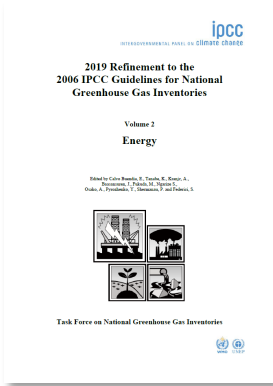
IPCC Guidelines:

<https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/>

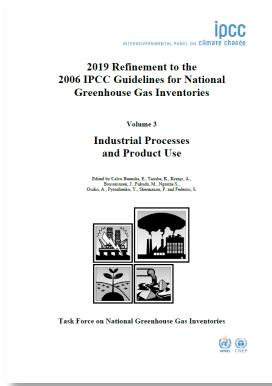
General Guidance and Reporting



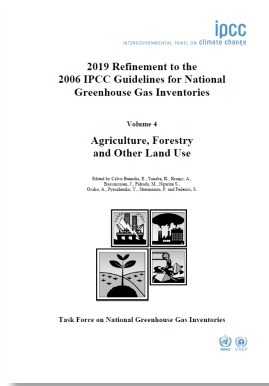
Energy



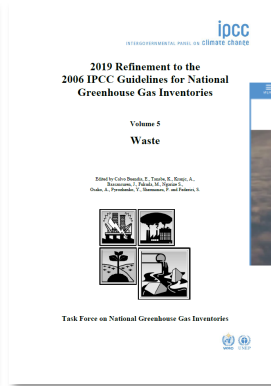
IPPU



AFOLU



Waste



6.10.2.2 SUMMARY OF COMPONENTS NEEDED FOR GHG EMISSION INVENTORY VERIFICATION USING ATMOSPHERIC MEASUREMENTS

- Via inventory verification
- Via providing complementary information

Jansens-Maenhout et al., 2020:

"... The UNFCCC's Subsidiary Body for Scientific and Technological Advice (UNFCCC-SBSTA, 2017, 2019) as well as the IPCC Task Force on the 2019 Refinement to the 2006 Guidelines (IPCC-TFI, 2019) acknowledged the complementary capability offered by GHGs monitoring through in-situ as well as satellite observations. ..."

<https://journals.ametsoc.org/bams/article/doi/10.1175/BAMS-D-19-0017.1/345576/Towards-an-operational-anthropogenic-CO2-emissions>

Breakout 3a: Seed question 1:

Identify case studies based on existing work that illustrate how EO can already support the Paris agreement.

- So far, for CO₂, most satellite top-down inversion studies focused on terrestrial carbon fluxes assuming that anthropogenic emissions are well known (eg., Basu et al., 2013; Miller and Michalak, 2020)
- Although existing satellites have not been optimized to obtain information on anthropogenic CO₂ emissions there are first peer-reviewed publications addressing this important aspect. Examples:
 - **CO₂ emissions / emission trends for large areas (e.g. Europe, East Asia, ...):**
 - Schneising et al., ACP, 2013, using SCIAMACHY XCO₂
 - Reuter et al., Nature Geoscience, 2014, using SCIAMACHY XCO₂ and NO₂
 - **CO₂ localized emission sources (power plants, cities, ...):**
 - Nassar et al., GRL, 2017; Zheng et al., ACPD, 2020; Wu et al., Environ. Res. Lett., 2020 using OCO-2/XCO₂
 - Reuter et al., ACP, 2019, using OCO-2/XCO₂ & S5P/NO₂
 - **CO₂ emissions of China during COVID-19 pandemic** via S5P/NO₂: Zheng et al., in review, 2020
- **Methane:** Several studies have been conducted using SCIAMACHY and GOSAT (see, for example, publication list on <https://climate.esa.int/en/projects/ghgs/publications/>)
 - Especially S5P (but also GHGSat) permits to obtain detailed information on localized CH₄ emission sources (e.g., oil and gas fields). Some initial publications (e.g., Zhang et al., 2020; Schneising et al., 2020) but far from fully exploited.

Breakout 3a: Seed question 1:

Identify case studies based on existing work that illustrate how EO can already support the Paris agreement.

- The CCI community has facilitated the use of CCI data via the climate and inverse modelling communities (and subsequently impact upon the Paris Agreement) through a variety of mechanisms:
 - **Making CCI data available in standard formats**, e.g. OBS4MIP: Reuter et al., 2020 – “Ensemble-based satellite-derived carbon dioxide and methane column-averaged dry-air mole fraction data sets (2003–2018) for carbon and climate applications”
 - **Building the data into widely used tools**, e.g. ESMValTool: Lauer et al., 2017 – “Benchmarking CMIP5 models with a subset of ESA CCI Phase 2 data using the ESMValTool”
 - **Contributing to influential and highly-cited studies**, e.g. Saunio et al, 2020 – “The Global Methane Budget 2000–2017”
 - **Using the CCI data to perform our own carbon and climate-relevant research:**
 - Reuter et al., 2019 - Towards monitoring localized CO₂ emissions from space: co-located regional CO₂ and NO₂ enhancements observed by the OCO-2 and S5P satellites
 - Reuter et al., 2017 - How much CO₂ is taken up by the European terrestrial biosphere?
 - Gier et al., 2020 - Spatially resolved evaluation of Earth system models with satellite column averaged CO₂
 - Schneising et al., 2020 - Remote sensing of methane leakage from natural gas and petroleum systems revisited
 - Parker et al., 2018 - Evaluating year-to-year anomalies in tropical wetland methane emissions using satellite CH₄ observations
 - Ganesan et al., 2017 - Atmospheric observations show accurate reporting and little growth in India’s methane emissions
 - Gloor et al, 2018 - Tropical land carbon cycle responses to 2015/16 El Niño as recorded by atmospheric greenhouse gas data
 - etc. (see, e.g., <https://climate.esa.int/en/projects/ghgs/publications/>)

Breakout 3a: Seed question 1:

Identify case studies based on existing work that illustrate how EO can already support the Paris agreement.

- (Also) Important:
 - Developing countries
 - Covid-19 related assessments
 - Networks (such as TCCON etc.):
 - Sufficient funding needed
- Is there a place where info is collected?
 - Publications list on GHG-CCI website: <https://climate.esa.int/en/projects/ghgs/publications/>
 - Crisp et al. CEOS White Paper: http://ceos.org/document_management/Meetings/Plenary/32/documents/CEOS_AC-VC_White_Paper_Version_1_20181009.pdf

Breakout 3a: Seed question 2:

Are there R&D case studies that may in the next 5-10 years lead to new types of actionable information supporting Paris Agreement goals?

- Derive CO₂ and CH₄ emission information & compare with inventories:
 - Exploitation of existing satellite missions (OCO-2/3, GOSAT-1/2, TanSat, S5P, GHGSat, ...)
 - To obtain Paris relevant emission information
 - To prepare for upcoming passive imaging NIR/SWIR missions (S5, CO2M, ...)
 - Exploitation of upcoming passive (MicroCarb, S5, CO2M, ...) and active (MERLIN) missions stand alone and in combination; possibly also in combination with TIR (IASI, ...)
- MircoCarb will be launched 2021 (TBC)
- S5-A will be launched 2021 (TBC)
 - CH₄ similar as S5P (likely even more data due to „Proxy XCH₄“); CO similar as S5P; covers also CO₂ absorption lines (but currently no XCO₂ product foreseen)
- MERLIN will be launched 2024/25 (TBC):
 - Dusk/dawn orbit; stand alone and active/passive combination (e.g., MERLIN+IASI), ...; for bias correction of passive XCH₄, ...
- Proposed TANGO mission (2024, TBC)
- CO2M satellites will be launched in 2026 (TBC):
 - The challenging applications requires R&D on all aspects (not only for CO₂ but also for CH₄, for NO₂ to get info on CO₂, ...)

Breakout 3a: Seed question 2:

Are there R&D case studies that may in the next 5-10 years lead to new types of actionable information supporting Paris Agreement goals?

- Merging different sensors to get consistent CDR:
 - How to do this optimally esp. in the future new high-res satellites (e.g., CO2M)?
 - Existing: GHG-CCI/C3S Level 2 EMMA and Level 3 Obs4MIPS products
 - Aerosol-CCI has developed an approach
 - Several other ongoing activities (eg in Italy)
- Timeliness of data / inventories for GST ?
 - Data needed well before GST date(s)
- Observing systems for cities etc.:
 - Satellites + other obs, esp. ground based column networks
 - Needed for stand alone assessments (emissions), cal/val, comparisons concentrations and emissions, ...

Breakout 3a: Seed question 3:

How can the CCI community contribute to the first Global Stocktake in 2023? (i.e., ideas for projects in CCI+ Phase 2)

- Ongoing CCI+ Phase 1 ends in 2022; Phase 2: 2021/22 – 2024/5 (3 years) ?
- First GST in 2023 will be based on year 2021 inventories
- Contributions via atmospheric observations:
 - Derive CO₂ and CH₄ emission information & compare with inventories
 - Exploitation of existing satellite missions (OCO-2/3, GOSAT-1/2, TanSat, S5P, GHGSat, MicroCarb, S5, ...) to obtain Paris relevant emission information:
 - On CO₂ sources (and sinks) via XCO₂ (possibly also via NO₂, CO)
 - On CH₄ sources via XCH₄
- Mechanism?: How to get EO data into GST ?