The case for a coordinated Global Greenhouse Gas (GHG) Monitoring Infrastructure

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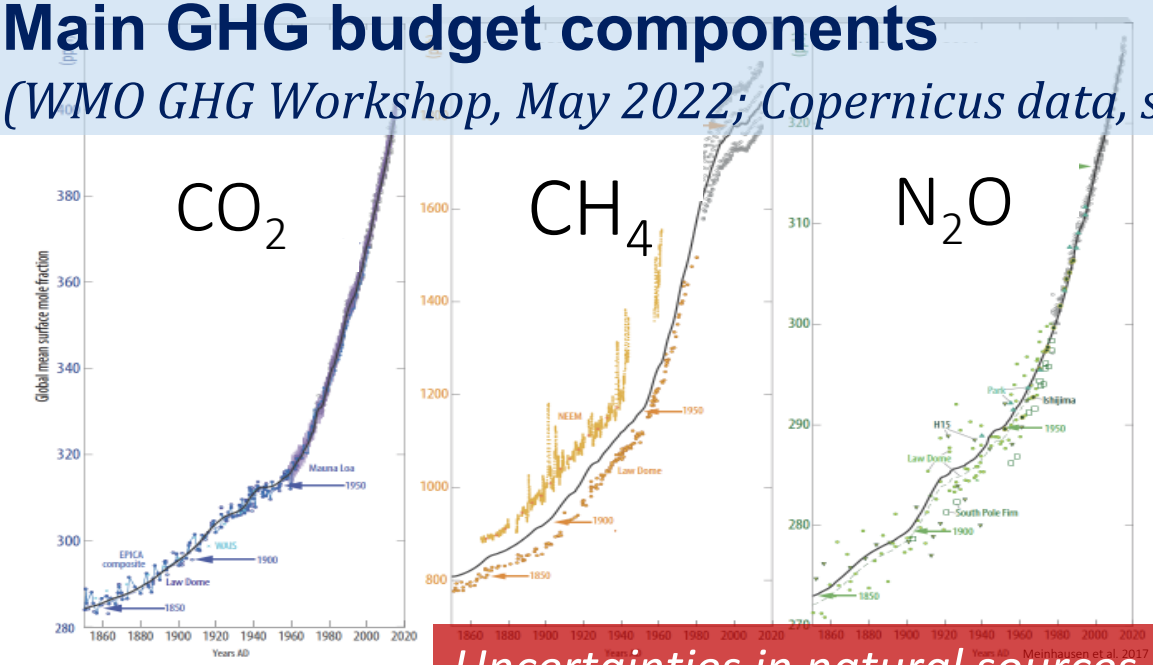
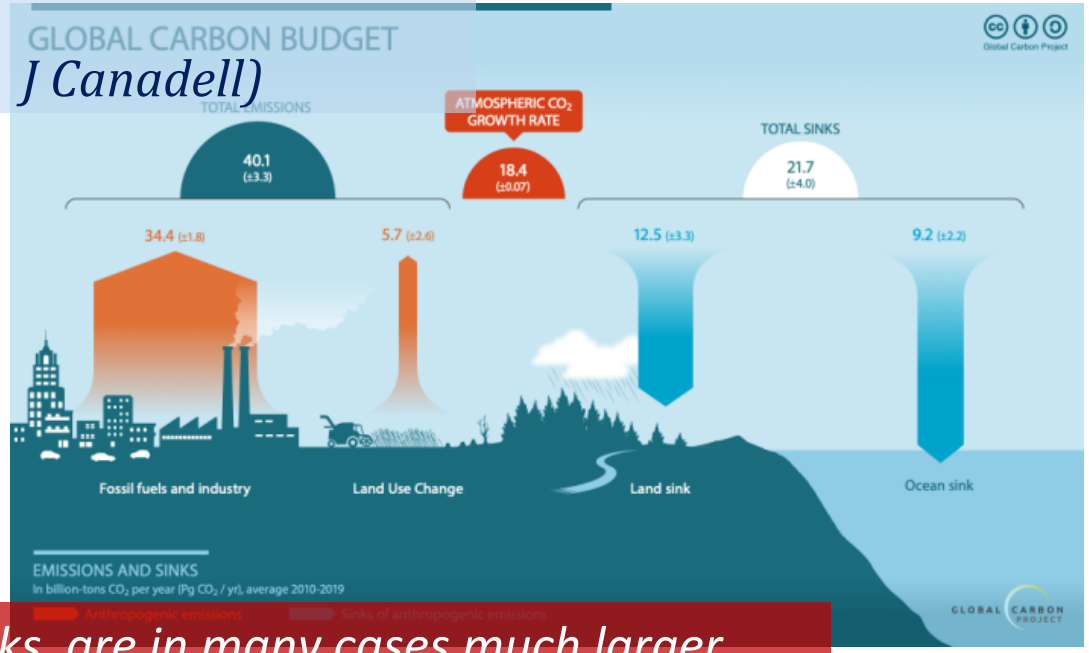
Climate change and mitigation under the Paris Agreement

- After water vapor, carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are the most important greenhouse gases (GHGs), increases in GHG concentrations main drivers of climate change;
- The Paris Agreement (2015) sets clear goals for maximum mean global warming; mitigation approach is developed around limiting net carbon emissions;
- **Not enough is known about the natural elements of the carbon cycle, and how these might change in a changing climate**, and even very accurate estimation of anthropogenic sources and sinks will not be sufficient to plan effective mitigation. *(Crisp et al. 2022);*
- **C. Fuller, WMO Climate Policy Advisors Meeting, March 2022:** *The atmosphere does not care how much carbon we pump into it; what matters for climate is how much carbon is in the atmosphere, not how it got there!*

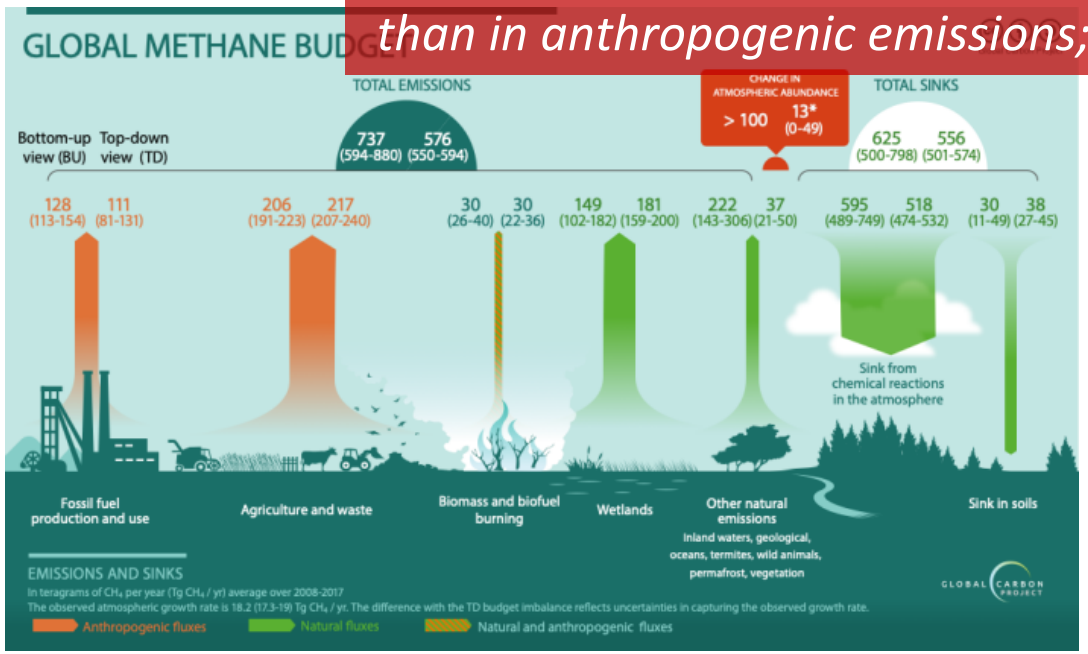
Main GHG budget components

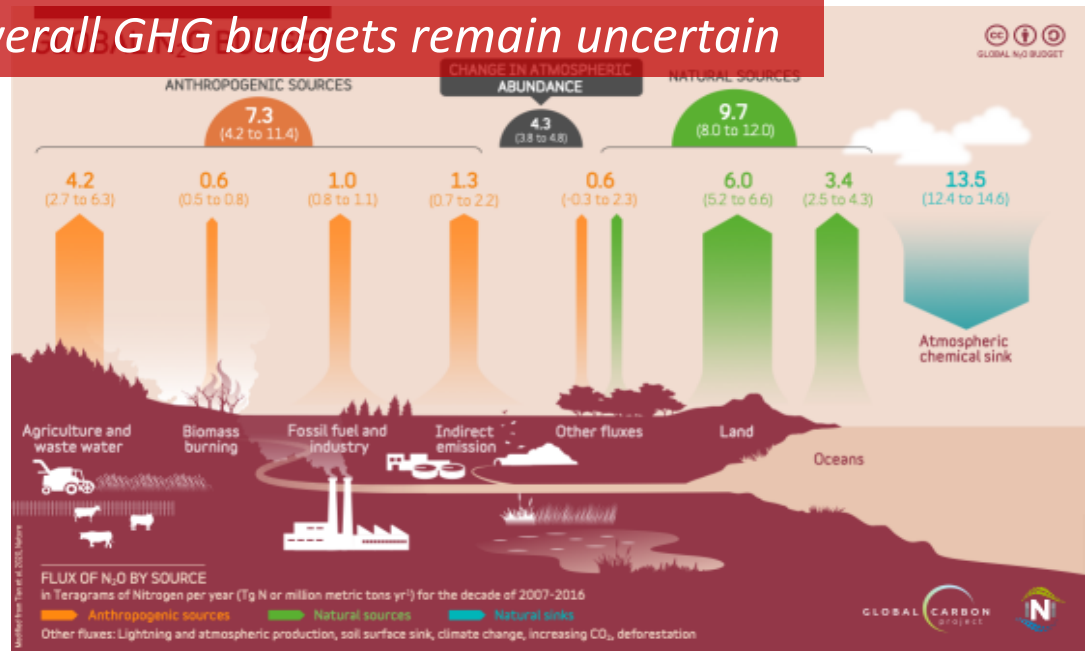
(WMO GHG Workshop, May 2022; Copernicus data, slide by J Canadell)





Uncertainties in natural sources and sinks are in many cases much larger than in anthropogenic emissions; i.e. overall GHG budgets remain uncertain





Greenhouse Gas monitoring, two approaches

Bottom up:

Based on local estimation, modeling of individual sources and sinks of carbon; applicable primarily to anthropogenic emissions;

Advantages

- Detailed, localized information;
- Can provide very accurate estimation of anthropogenic emissions;
- Sector resolving
- Relatively low cost; relying on existing economic data and process modeling

Disadvantages

- Time lag
- Can be biased
- Not applicable in all countries (adequate data may not exist):

Top down:

Based on systematic observations of (primarily) atmospheric carbon over extended periods of time. Combined with modeling/data assimilation;

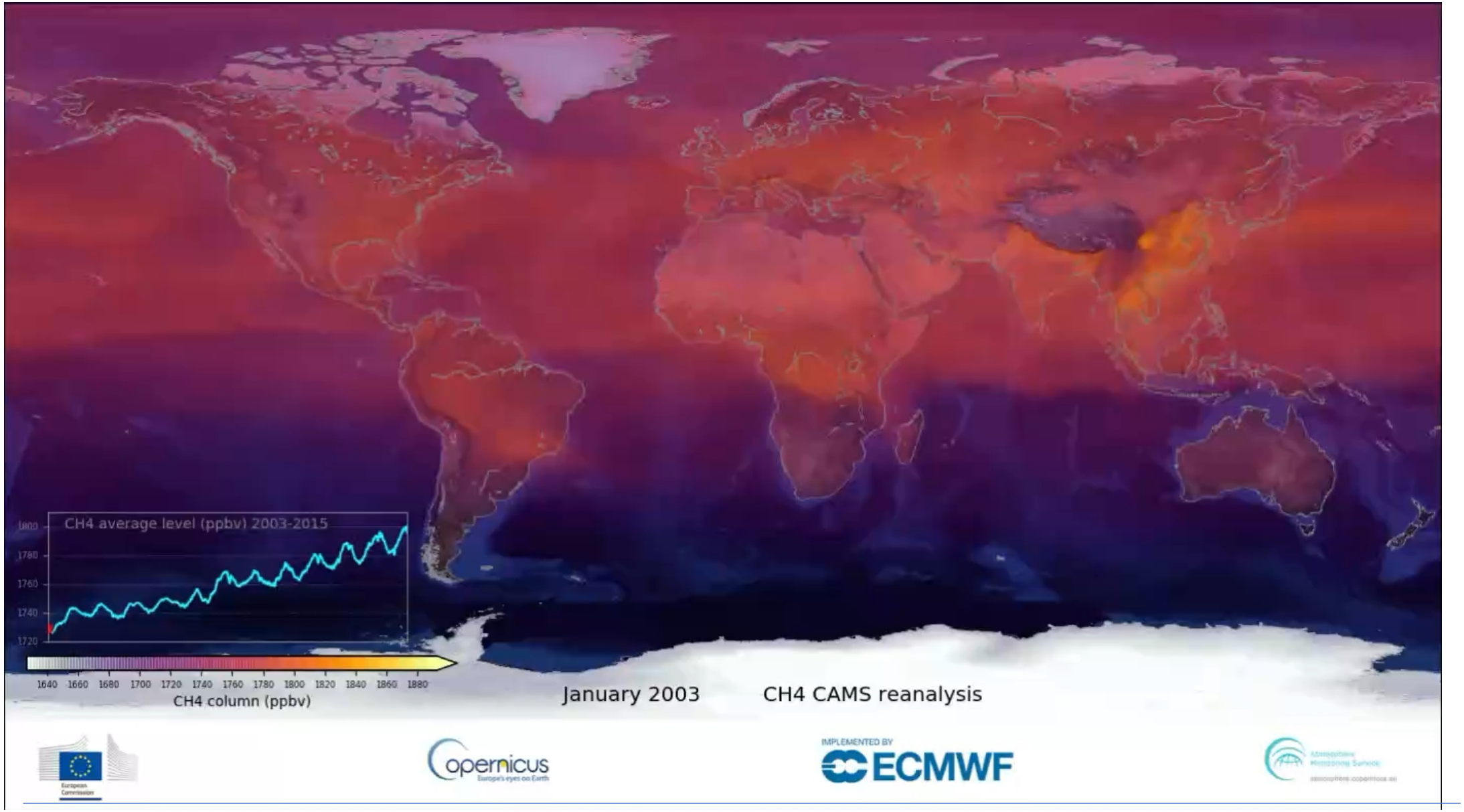
Advantages

- Broad (global) coverage;
- Applies to all carbon sources and sinks;
- Applies also to non-localized sources and sinks (e.g. Southern ocean, boreal forests);
- Quick reporting (can in be done in real time);
- Mass conservation provides powerful constraints on carbon budget;

- Disadvantages
  - Relatively high cost (requires global coverage of observations);
  - Not suitable for detailed emissions estimations on broad, global scale

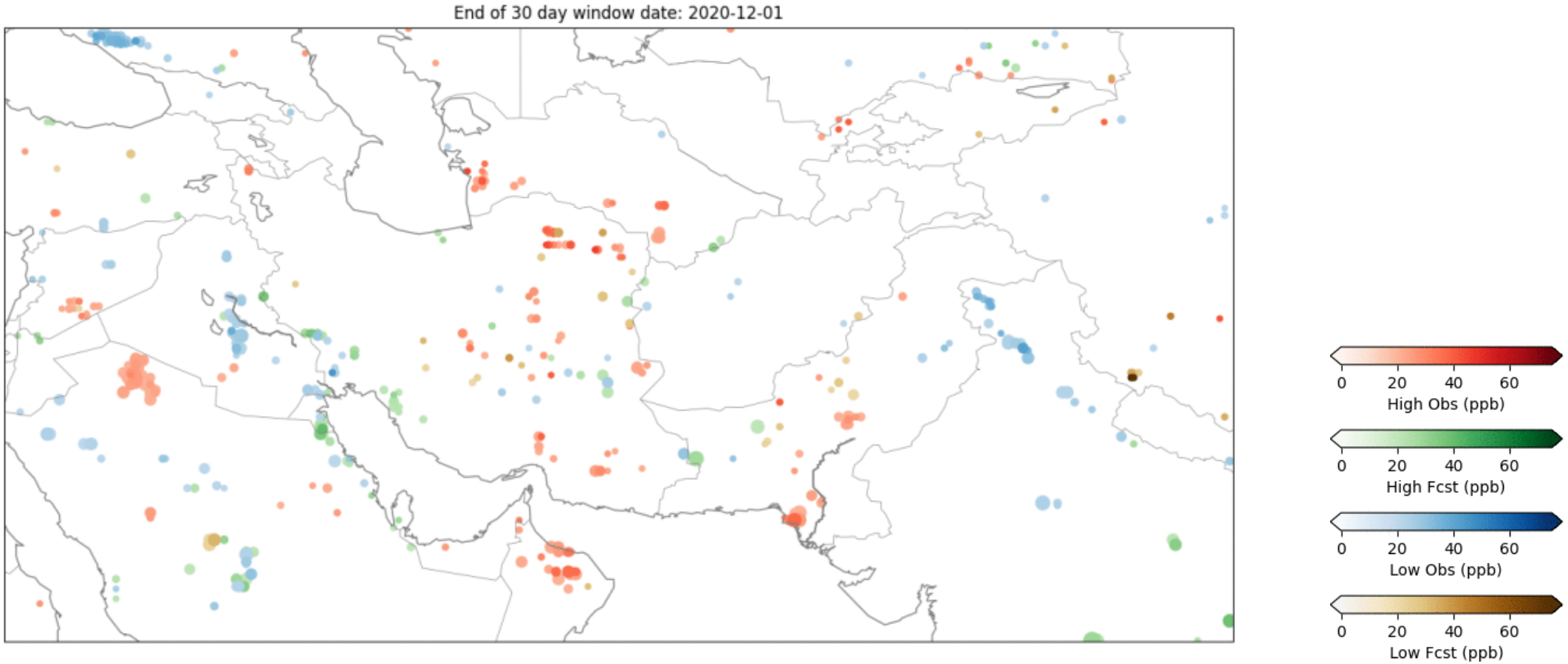
Protoype “top down” data product (concentrations)

(WMO GHG Workshop, May 2022; Copernicus data, slide by V-H Peuch)



Prototype “top down” data product (anomalies)

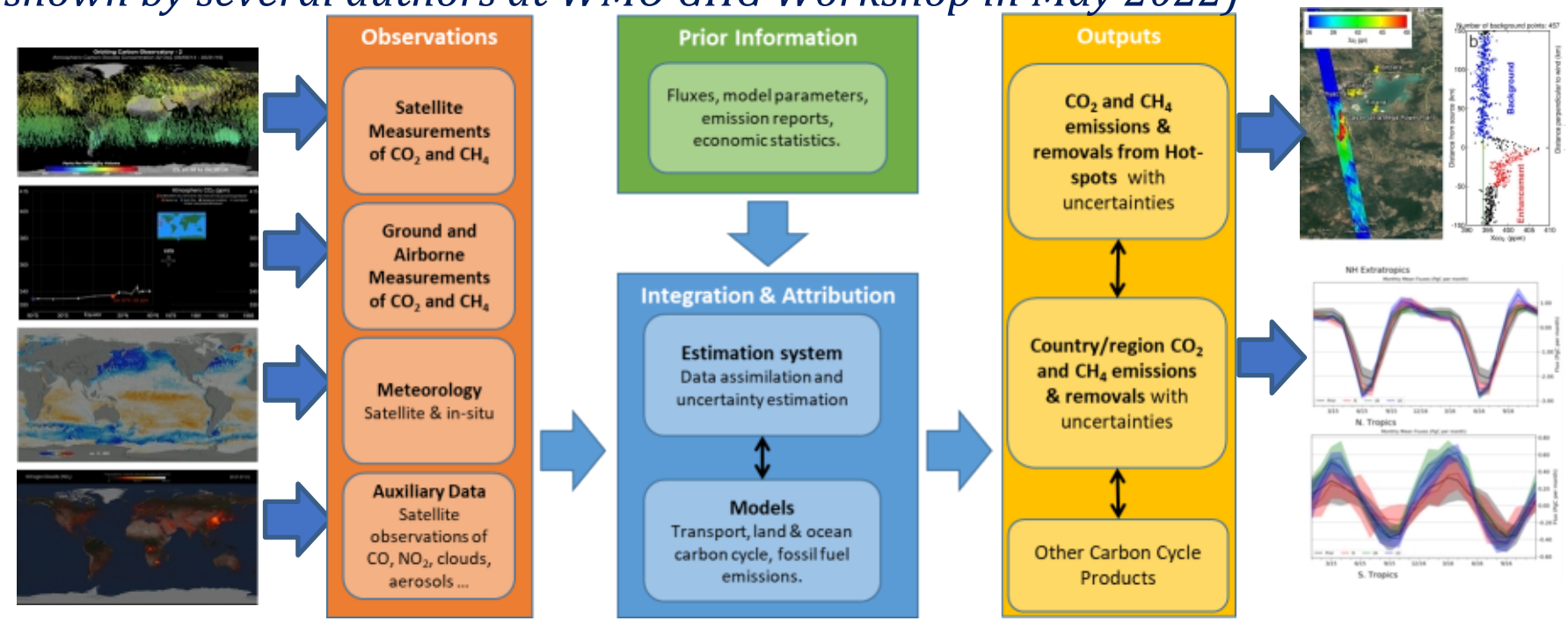
(WMO GHG Workshop, May 2022; Copernicus data, slide by V-H Peuch)



Automated detection of methane anomalies against Sentinel-5P CH_4 observations. Credit: ECMWF. See: Barré et al., ACP, 2021.

Unification of bottom up and top down estimation, adopted as conceptual model for the First Global Stocktake under the Paris agreement

(Graphic shown by several authors at WMO GHG Workshop in May 2022)



Today, a system as depicted in this graphic does not exist; there is no comprehensive and timely international exchange of surface- and space-based GHG observations, no operational assimilation of such data and no international coordinated systematic Intercomparison of near-real time data products;

This means that investments in GHG monitorin are not optimally used, and it entails a risk of fragmentation in the information basis underpinning mitigation action under the Paris Agreement

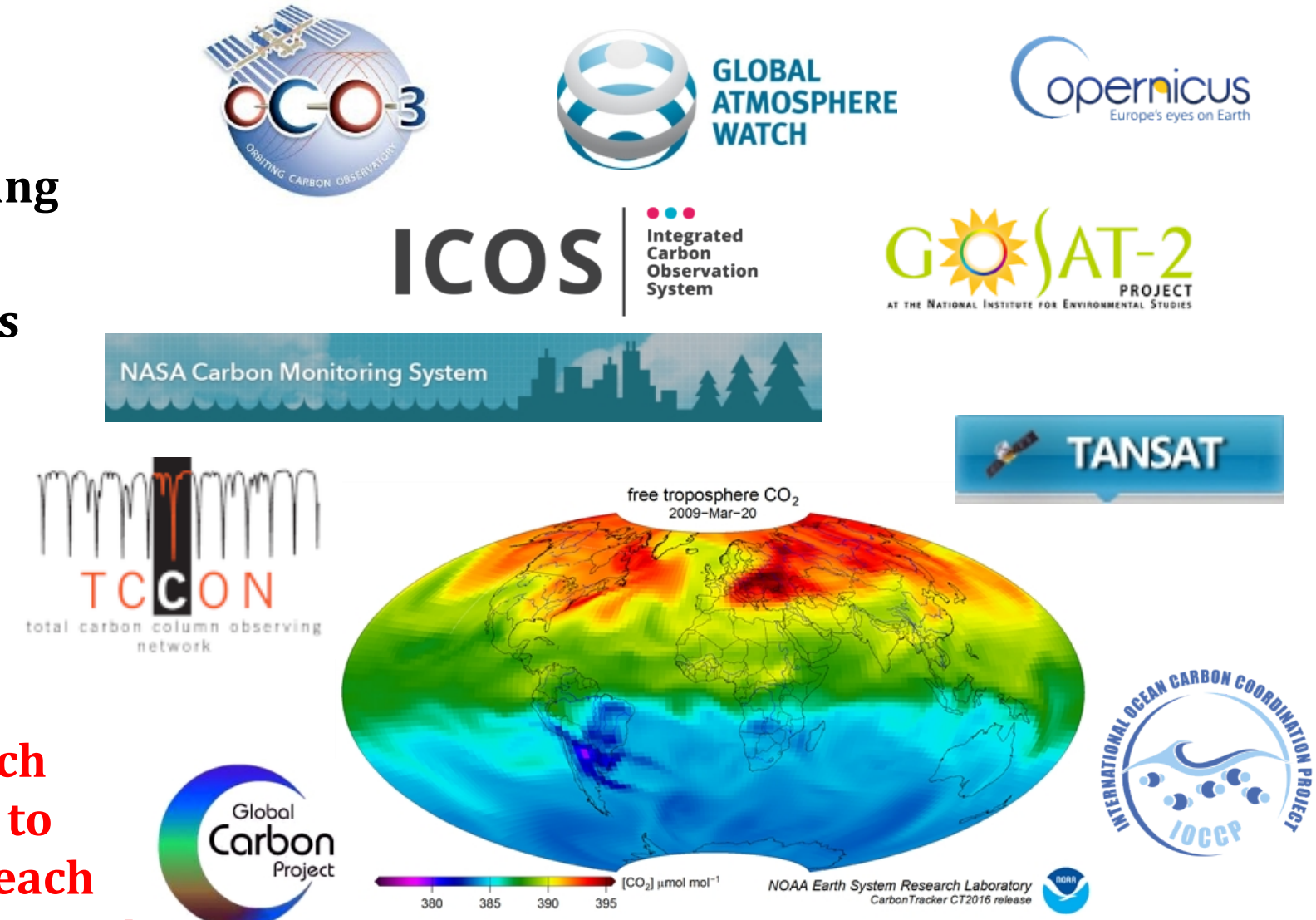
However, many of the required elements do exist or are being developed

Several countries and international organizations investing in carbon monitoring capabilities:

- **Surface-based observations**
- **Space-based observations**
- **Modeling**
- **Data assimilation**

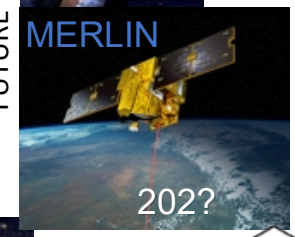
Missing element:

- **Integrated, internationally coordinated global approach allowing these capabilities to complement and leverage each other for optimal overall impact!**



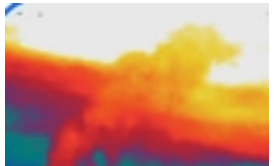
GHG Monitoring is a very complicated landscape with multiple observing assets, programs, campaigns, etc. *(Slide by Sweeney; WMO GHG Workshop, May 2022)*

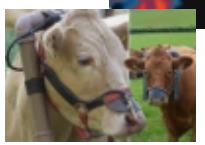
FUTURE

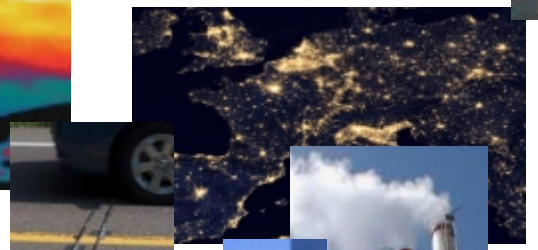


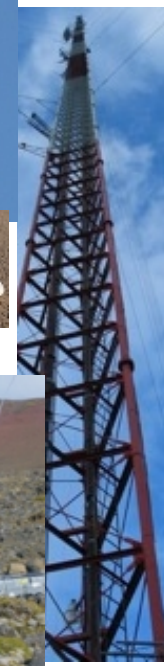
NOAA-20
CrIS

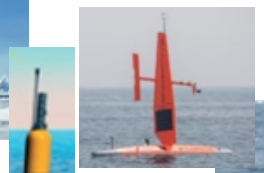
Boeing/Alaska ecoDemonstrator

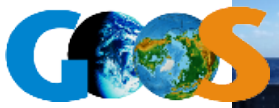


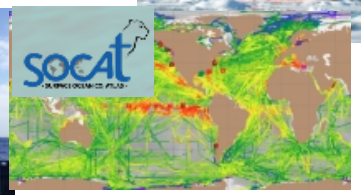












Note: Not a comprehensive depiction of all relevant measurement programs.

… and with multiple stakeholders and coordination mechanisms

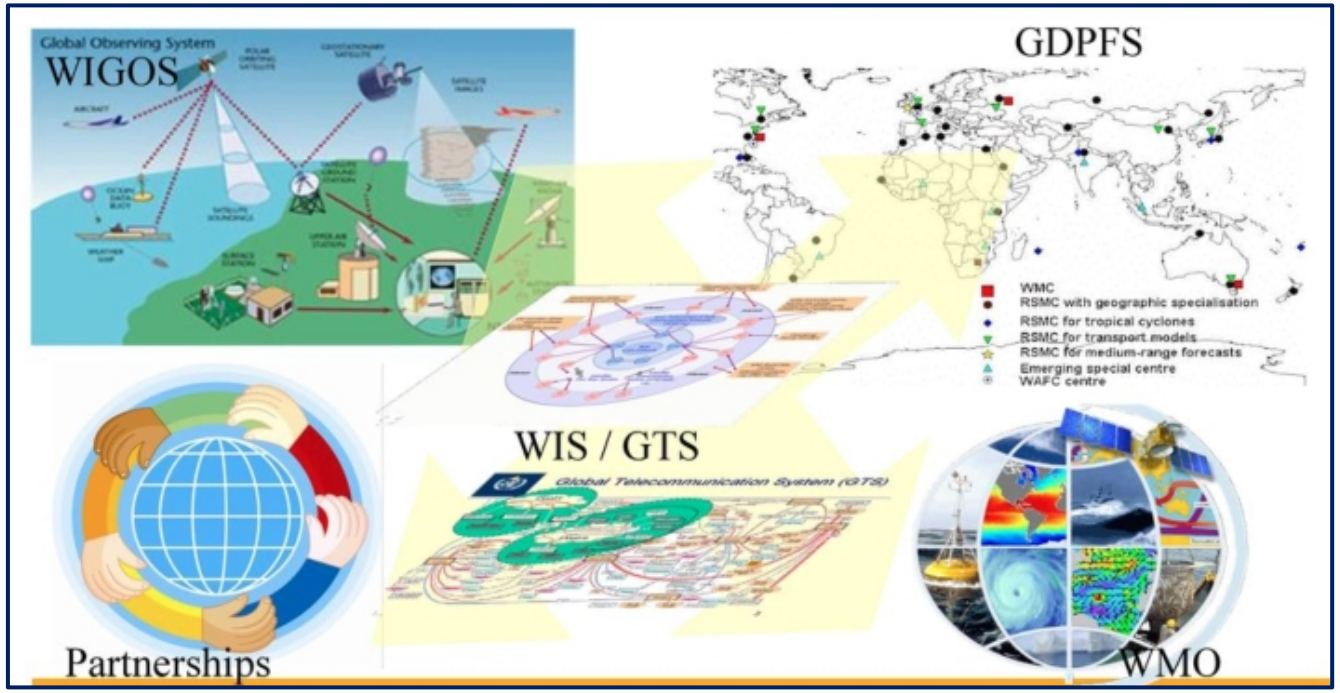
(slide by Dowell; WMO GHG Workshop, May 2022)

Greenhouse gas monitoring would benefit from an integrated, internationally coordinated approach to network design, operation and use of observations to support top-down budget estimation

Required infrastructure:

- **Integrated carbon observing system (surface- and space-based);**
- **NWP-driven modeling with data assimilation tracking CO2, CH4 and N2O;**
- **Timely international exchange of all observations and relevant model data;**
- **Framework for intercomparison of output, possibly also for collaboration on algorithms, model components;**
- **Coupling with ocean and/or land biosphere models;**
- *Potentially tracing of isotopes for source discrimination;*

The WMO World Weather Watch as a paradigm



Main output of GHG monitoring infrastructure

- **Time-continuous, global model estimates of GHG concentrations (mixing ratios) *based on all available monitoring information and capabilities;***
- **Systematic records of discrepancies between all observations and respective model prior ("observation minus background" residuals, or OmB);**
    - *Needed to support direct sources and sinks estimation and for development and improvement of modeling of sources and sinks;*

Coordinated approach will allow various system components to optimally complement each other within a common framework and can help guide balanced investment in the overall system

Potential contributions of WMO

International coordination of the effort; analogous to WMO's role in WIGOS, WIS, GDPFS - and to WCRP's role in AMIP, CMIP

- Consolidated requirements for an integrated satellite- and surface-based observing system;
- *Potentially agreed design for a surface-based observing component, modeled on Global Basic Observing Network (GBON);*
- *Potentially identifying funding sources for the observing network in the least-resourced Members, modeled on Systematic Observations Financing Facility (SOFF);*
- Timely exchange of all satellite- and surface-based GHG observations;
- Collaboration on methodologies and practices for GHG modeling and data assimilation;
- Common file formats and practice for exchange of model fields; common verification and validation methods;
- Comparison of quantitative output data;

Workshop at WMO, May 10-12; “The case for a coordinated Global Greenhouse Gas (GHG) Monitoring Infrastructure”

- Very good engagement;
  - More than 20 external invited experts participated in person; 80 additional participants registered online;
- Surface- and space based observing systems;
- Ocean carbon;
- Land surface observation and modeling;
- Cryosphere;
- Modeling, data assimilation;
- Program and project managers and coordinators;
- WMO Permanent Reprentatives and staff;

Workshop at WMO, May 10-12; A few key recommendations:

(full set of recommendations agreed on during the Workshop are available here)

- **Consensus on the need for a fully integrated, globally coordinated Greenhouse Gas Watch that encompasses**
  - **Integrated observing system, ground-based and space-based assets**
  - **Multi-center modeling and data assimilation systems (transport driven by NWP, including geospatially disaggregated sources and sinks terms);**

- **Consensus that the World Weather Watch would be a useful paradigm for large parts of such a framework; however**
  - **Important elements of it are outside WMO's core mandate and expertise, e.g land surface and ocean observations and modelling**

- **Immediate actions:**
  - **WMO to call for round table discussion with relevant parties**
  - **Seek to expand observing networks in priority regions including the tropics, the Southern Ocean and the Arctic;**
  - **Establish collaboration between existing GHG modeling centers to provide access to common observational datasets and opportunities for intercomparison (lessons learned from NWP, Air Quality forecasts, …);**
  - **Initiate activities to support the current UNFCCC assessment cycle**

EC-75, Agenda Item 4: Strategic And Operational Planning

Doc. 4.(3): Global Greenhouse Gas / Carbon Budget Monitoring System

Draft Resolution 4(3)/1:

{the Council}

{…}

- **Decides** to proceed with the further development of the concept for a WMO-coordinated Greenhouse Gas Monitoring Infrastructure
- **Requests** the Commission for Observation, Infrastructure and Information Systems, in coordination with the Commission for Weather, Climate, Water and Related Environmental Services and Applications and the Research Board, to further develop and refine the concept, with the aim to submit a proposal for its architecture to the 19th World Meteorological Congress in 2023;

{…}

Initial road map

	Event title	Participants	Deliverable/outcome
May 10-12, 2022	Exploratory Workshop: Toward coordinated Global Greenhouse Gas Monitoring Infrastructure	Representatives from INFCOM, WCRP, WWRP, IPCC, GAW, IG3IS, GCOS, CEOS, CGMS, Copernicus, …	Workshop Statement on international coordination of greenhouse gas monitoring, potentially with guidance on WMO's role (if any) in this
June 6-16, 2022	SBSTA-56	Parties to the Paris Agreement	Draft text for RSO conclusion recognizing the need for globally coordinated greenhouse gas monitoring infrastructure
June 20-24, 2022	EC-75	EC Members	Endorsement of concept paper; tasking INFCOM and RB to develop this for Cg-19
Oct 17-19, 2022	Second Climate Observation Conference	GCOS, WMO, EUMETSAT	Scope and program still evolving - tentatively recommendations to COP27
Oct 24-28, 2022	INFCOM-2 (possibly also INFCOM TECO)	Experts from INFCOM, WWRP, GAW, GCOS, …	Refined concept paper, responding to request from EC-75 and input from Symposium; tasking of relevant SCs
Nov 2022	COP-27 Earth Information Day	COP-27 attendees	Presentation of concept for Greenhouse Gas Monitoring infrastructure
Jan 2023	International Greenhouse Gas Monitoring Symposium (TBC)	Open; ideally broader participation than May Workshop,	Broader scoping; initial inventory of scientific and operational issues to be explored.
June 2023	19th World Metorological Congress	WMO Member representatives	Potentially formal decision on WMO role in Greenhouse Gas Monitoring