

Requirements for operational GHG observations from space

AC-VC-22 6.17

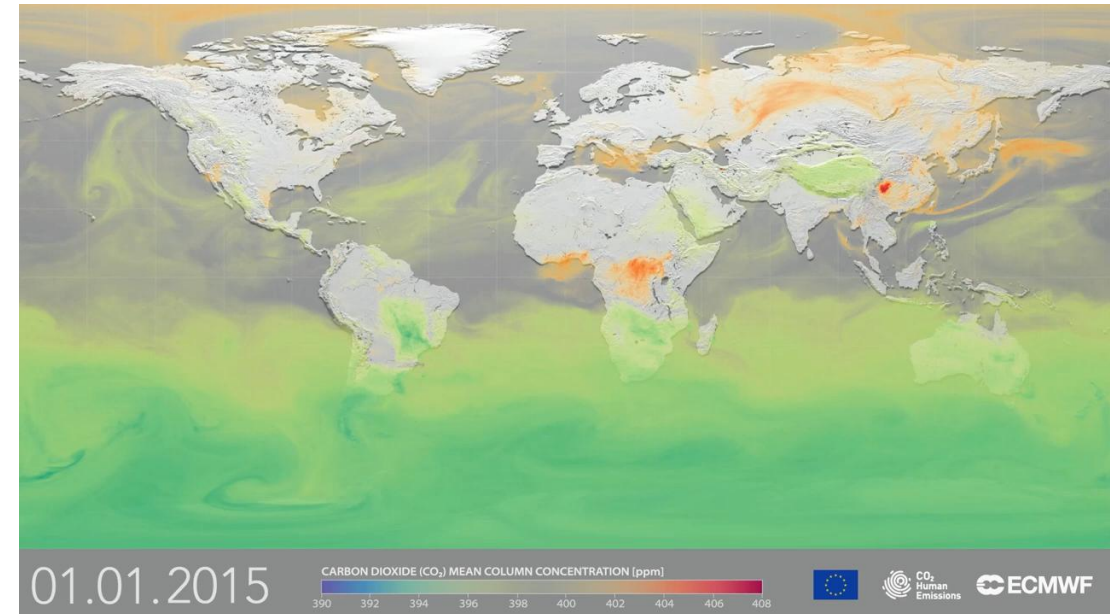
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The G3W Flagship translating research to operations

What: The Global Greenhouse Gas Watch - G3W fills critical information gaps optimally combining **Earth Observations** with **Earth System Models** to **reduce the uncertainty** in assessing the efficacy of Climate Action.

How: Timely Policy-relevant information on GHGs concentrations and fluxes allowing the assessment of both the **Natural & Human** influences on climate change <https://wmo.int/activities/global-greenhouse-gas-watch-g3w>

Why : an **Earth System Approach** is a must-have because **Earth's climate responds to the laws of Climate Physics** and depends upon Atmospheric GHGs, NOT upon Claimed Offset of Carbon emissions or Good-will Pledges.



Animation source: Copernicus Earth Observation Programme / ECMWF CAMS

WMO Global Greenhouse Gas Watch: *an internationally coordinated operational monitoring of greenhouse gas fluxes in support of climate change mitigation action under the Paris Agreement*

Key elements

- Integrated global greenhouse gas observing system (spanning surface to space-based);
- **24/7 operational GHG modeling/assimilation** (multiple systems), providing top-down flux estimates;
- Routine internationally coordinated intercomparison and verification of model output;

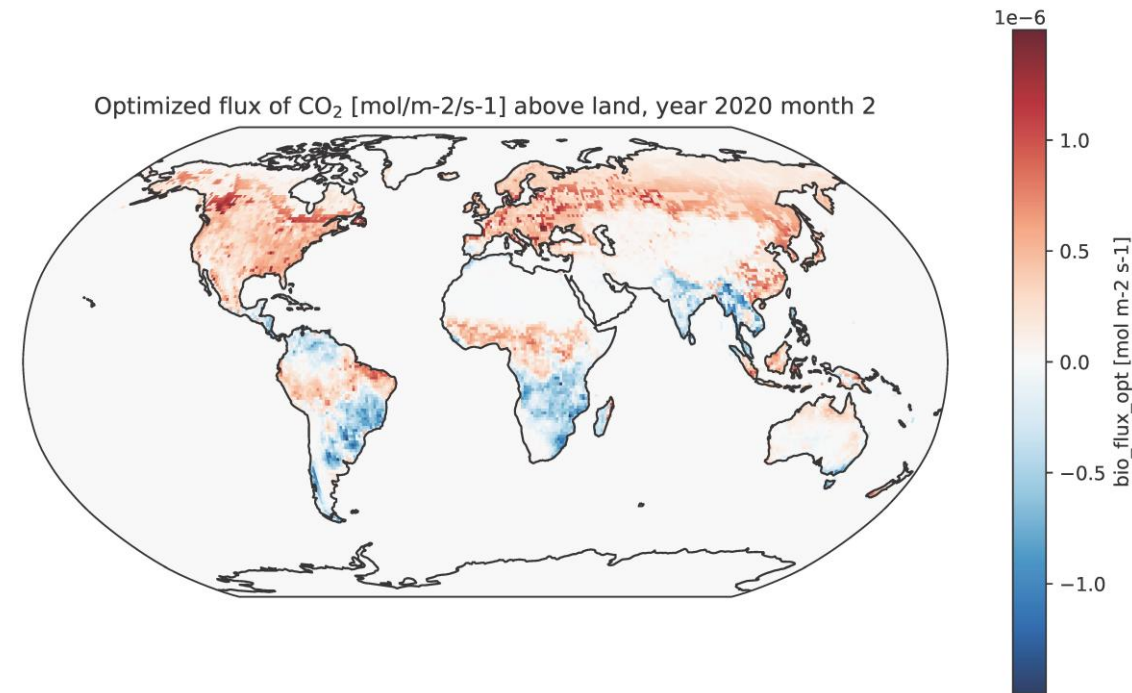
- Governments of 193 countries now committed to developing coordinated top-down GHG flux estimation with open access to input and input data;

Primary output

- Time-continuous global fields of CO₂, CH₄ and N₂O concentrations;
- Consolidated, top-down, monthly estimates of GHG fluxes at **global 100 x100 km resolution (1 x 1 km goal)**;

Users of G3W outputs

- Parties to the Paris Agreement (e.g., as input to GST and support for national reporting);
- Regional and local users, e.g., via IG3IS;
- Carbon markets, e.g., verification of offsetting;
- Science community working on GHG budgets;
- IPCC, for emission pathways, future scenarios;



Key-conclusions from the G3W workshop concerning GHG operational product provision



- The users of level-2 data (operational Monitoring and Verification Support assimilation systems) will need the **timely provision of data (ideally at high availability and low revisiting frequency)**
- For the monthly reporting of top-down, monthly estimates of GHG fluxes at a **global 100 x100 km resolution (1 x 1 km goal) continuous** assimilation is required at a significantly lower frequency (ideally <24h TBC).
- Key-scientific performance product criteria are meanwhile well established through the CEOS/CGMS white paper and implementation plan
- **Instruments with (some) mapping capabilities operated according to these constraints** are key to serving such an operational system
- The main requirements qualifying such products/missions fit for purpose for an operational GHG observing system (complementing scientific product quality performance and assurance) are (TBC):
 - ✓ **Revisiting time (mapping capabilities)**
 - ✓ **Product timeliness**
 - ✓ **Product availability**

Recent WMO RRR

Observational requirements for GHG (GAW vs G3W) – ongoing

Task: Revisiting the requirements for GHG

[WMO OSCAR](#) | [Application Area: 2.6 Atmospheric Composition Forecasting and Monitoring](#)

➔ To be split in “Atmos composition long-term monitoring” and “***Atmospheric composition analysis and forecasting***”

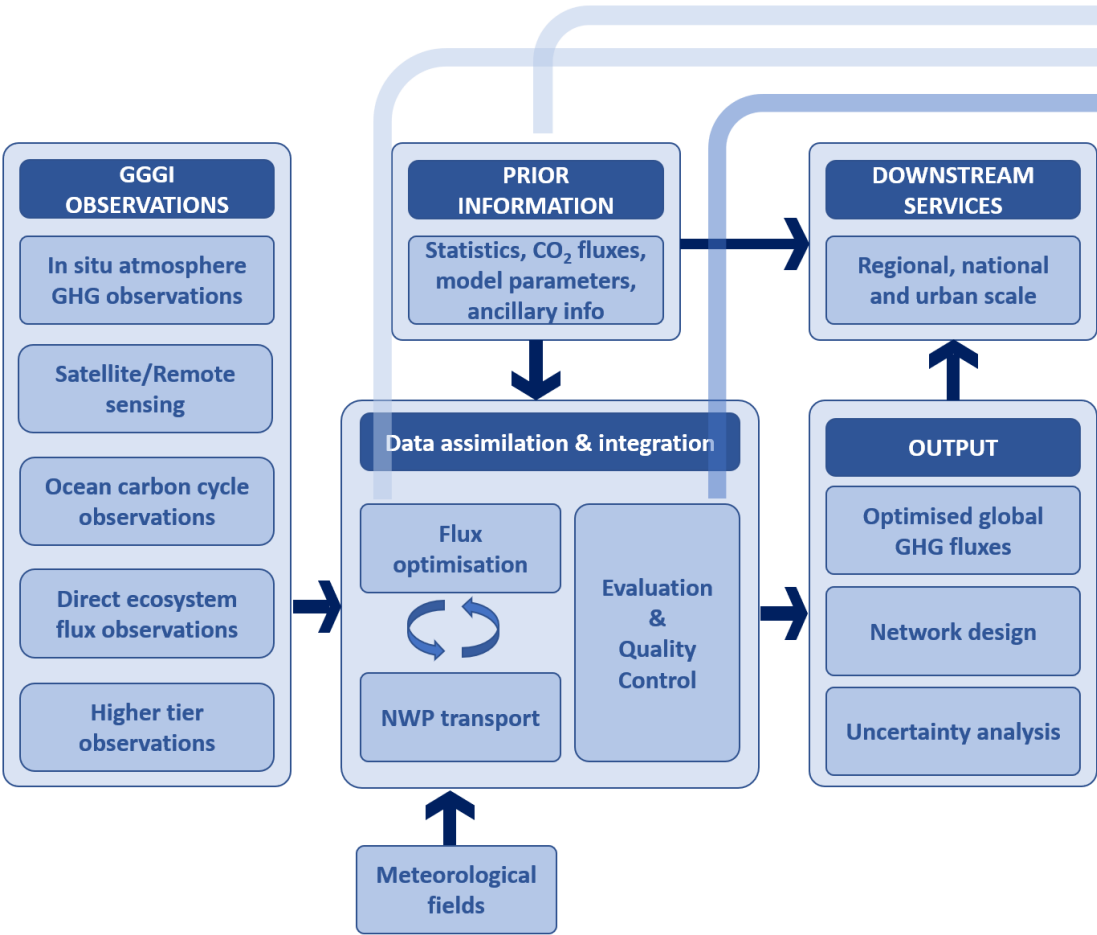
Proposal for update (courtesy Prabir Patra):

Id	Variable	Layer	App Area	ATP	Uncertainty	Layer/s Quality	Coverage Quality	Stability / year	Hor Res	Ver Res	Obs Cyc	Timeliness	Coverage	Conf Level	Val Date	Source	General Comment
CO2 column averaged								Draft!									
	XCO2 mole fraction	total column	G3W analysis and forecasting	0.5	0.5 ppm			0.25 ppm	100 km		60 min	24 h	Global	firm	06/03/2026	Based on Patra et al., (JGR, 2003) and multi-model simulation and GOSAT/OCO data analysis	Requirement for uncertainty is at 2-sigma for single-shot retrievals
					1.0 ppm			0.25 ppm	500 km		24 h	7 d					
					2.0 ppm			0.5 ppm	2000 km		7 d	15 d					

GHG satellite products supporting Monitoring and Verification Support (MVS) Capacities



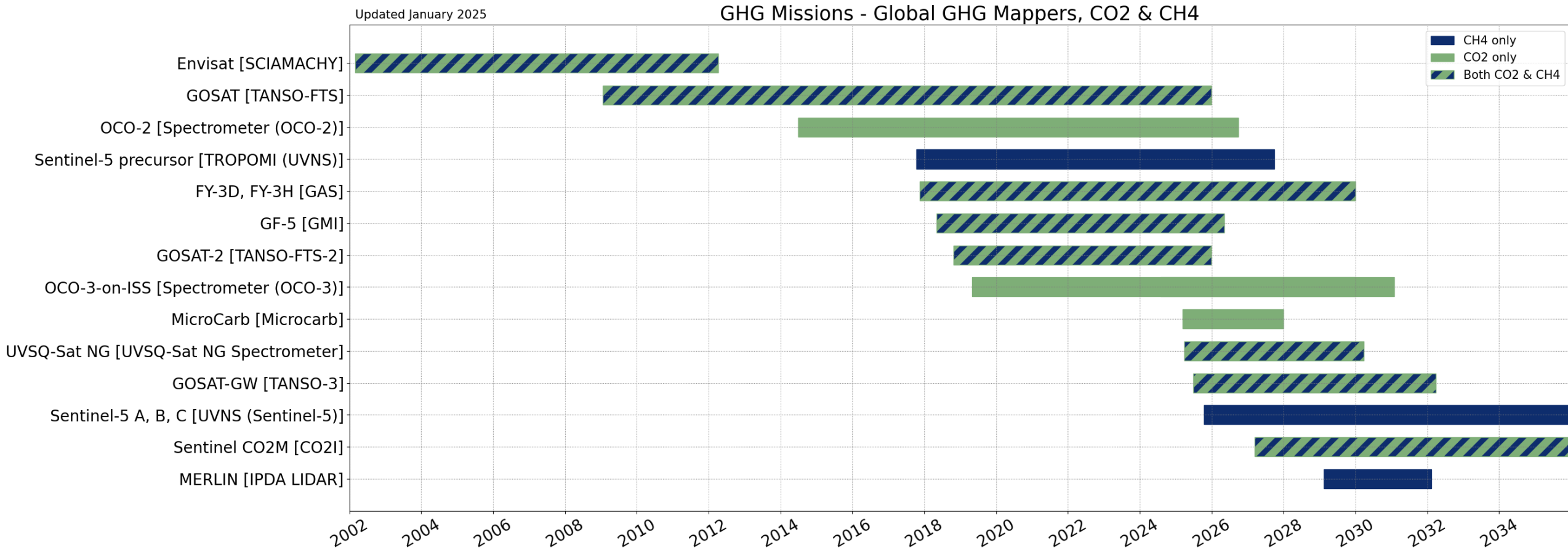
GHG mapper



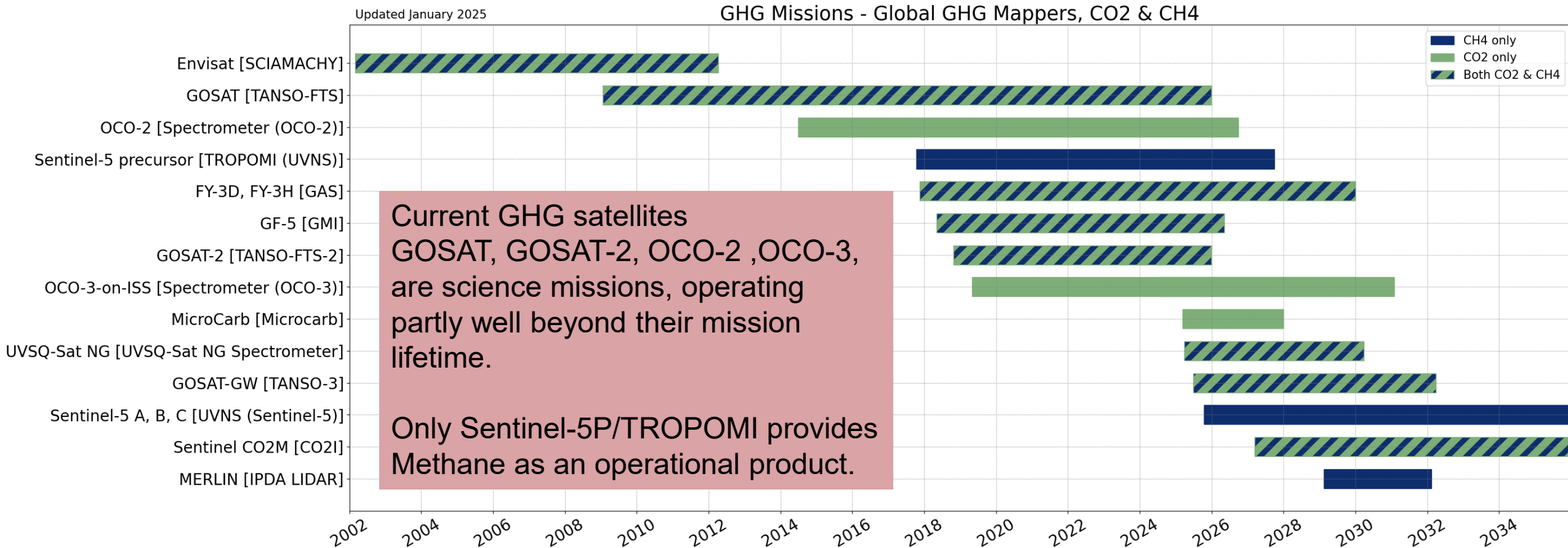
	NRT (<24 hour)	Assimilated (<1 month)	Evaluation (+1 year)	Data from other years	Prior fluxes	Global assimilation & attribution	Evaluation & QC
in- situ CO ₂ , CH ₄							
¹⁴ CO ₂							
Other tracers							
Ground based FTIR							
Satellite remote sensing							
Vertical profiles							
Ocean flux/fCO ₂							
Ecosystem indices (satellite)							
Landcover information							
Economic statistics, activity							
Ecosystem flux data							
Other tracers							
Urban GHG data							
Isotopologues							
SIF							
Ancillary data							
N ₂ O, SF ₆							
In situ synops							

Free after CoCO2 project scheme

GHG missions (mapper) with significant potential for operational product assimilation in GHG Monitoring and Verification Support Capacities



GHG missions (mapper) with significant potential for operational product assimilation in GHG Monitoring and Verification Support Capacities



GHG mapping satellite missions and their performance

Status at CEOS white paper and in WG-climate roadmap

Main GHG products from existing GHG missions

Product	Spatial resolution	Precision	Bias
CO ₂	<8-2 km ²	0.7 ppm	<0.5 ppm
CH ₄	<8-2 km ²	10 ppb	<5 ppb
Solar Induced Fluorescence (SIF)	<8-2 km ²	0.7 mW m ⁻² sr ⁻¹ nm ⁻¹	<0.2 mW m ⁻² sr ⁻¹ nm ⁻¹

- Mapping capabilities
- Spatial resolution sufficient to attribute emissions to large sources, cities, regions to country scale
- Re-visit time 3-14 days

GHG products (precursors) currently not addressed (TIR only)

Product	Spatial resolution	Precision	Bias
N ₂ O	<8-2 km ²	TBD	TBD
NH ₃ (N ₂ O precursor)	<8-2 km ²	TBD	

- Currently only from TIR (e.g. IASI / IASI-NG / IRS)
- Weak/no sensitivity to surface
- MTG/IRS potential for improved temporal observation of free troposphere <1h

Ancillary products supporting GHG products and emission monitoring

Product	Spatial resolution	Precision	Bias
Proxy-CO ₂ Proxy-CH ₄	<8-2 km ²	<0.7 ppm	<1 ppm
NO ₂	<8-2 km ²	1.5x10 ¹⁵ molec/cm ²	<3.5x10 ¹⁵ molec/cm ²
CO	<8-2 km ²	<10%	<15%
Aerosols	<16 km ²	0.05 AOD, 500 m LH	<0.05 AOD, 500 m LH
Clouds	<4-2 km ²	<1% of FOV	

- Ideally to be provided from the same platform
- Alternatively to be provided from tandem / train platform configuration

Towards operational GHG products

Requirements definition



- Revisit-time, timeliness and availability criteria for GHG products are key to make GHG products from any mission with sufficient mapping capabilities operational.

Revisit-time: Time between two observations of any target within a given area (e.g. latitude band, or disk).

Product timeliness/latency: Duration between sensing-time and product availability at operational user reception point.

Availability: Fraction of data available with respect to the amount of data that can theoretically be produced by design.

- Such requirements are, however, often challenging to implement and require significant resources and significant and sustainable funding for operations (and quality control).
- To be more inclusive the use of threshold, breakthrough and goal criteria is proposed for such requirements.

Executive summary of the WP

The **GHG task-team of the WGclimate** is asking the **plenary for CGMS-54 to endorse its proposal for GHG product requirements for future operational MVS systems from global space-based GHG mappers.**

With this proposal, the GHG task-team is implementing its **activity A53.01 under Annex I of the CEOS CGMS WGclimate roadmap to propose a set of requirements for space-based GHG products from operational missions** supporting the efforts by WMO G3W and UNEP IMEP, as well as addressing the needs of future operational GHG MVS systems.

In addition, the GHG task-team is **addressing item 5.4 of the CGMS High Level Priority Plan (HLPP) to “Engage with WMO and other initiatives to create an integrated global operational greenhouse gas observing system** that combines space-based and surface-based assets to deliver fit-for purpose data products. Engage with WMO, CEOS, and other parties to define the requirements for the space-based operational observing system.”

Definition of requirement categories (derived from WMO RRR definitions)

Threshold - limit at which the product is of some use for GHG emission quantification.

Breakthrough - is considered the current engineering target for MVS systems for monitoring sources down to the 0.5 ppm (XCO₂) and 10 ppb (XCH₄) anomaly level and supporting MVS monthly emission budget reporting.

Goal - monitoring sources at or below the 0.5 ppm (XCO₂) and 10 ppb (XCH₄) anomaly level and supporting MVS daily emission budget reporting.

The following product quality performance requirements apply for operational GHG products from global mappers (for definition of terms see the WGclimate GHG roadmap):

Product	Spatial resolution	Precision			Bias		
		threshold	breakthrough ¹	goal	threshold	breakthrough ¹	goal
XCO2	8-2km	1 ppm	0.7 ppm	0.2 ppm	1 ppm	0.5 ppm	0.2 ppm
XCH4	8-2km	20 ppb	10 ppb	5 ppb	15 ppb	5 ppb	2 ppb

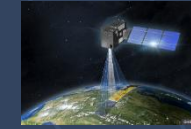
^[1] “breakthrough” is considered the engineering target

The following requirements concern the GHG product provision and are proposed in addition to the product performance requirements. These product provision requirements qualify the products as operational:

Product attribute	threshold	breakthrough ¹	goal
Product revisit time	<14 days	<4 days	<1 days
Product Timeliness / Latency	<1 week	<24h	<5h
Availability	>85%	>95%	>99%
Operator driven anomaly response	<1 week	<24h	<12h

^[1] “breakthrough” is considered the engineering target

GHG operational product provision characteristics (fit for operational purposes) – complete list



Extended GHG monitoring mission operational product characteristics:

Product	Characteristic			Type
Product revisit time	<14 days	<4 days	<1 days	
Product Timeliness / Latency	<1 week	<24h	<5h	
Availability	>85%	>95%	>99%	
Operator driven anomaly response	<1 week	<24h	<12h	
Product format	Human and API readable Annotated using CFI standard			hdf5/netcdf4
Product specifications	Freely available (including level-1)			pdf
Product QA	Continuous product monitoring and verification Regular (repeated) validation cycles			
Typical data provision policy	1) Free, full and open 2) Restricted but community certified and independently monitored			

WGClimate

The Joint CEOS-CGMS
Working Group on Climate

*Solar Induced Fluorescence

Requirements for critical auxiliary information needed by GHG mission products complete list

Auxiliary information required/supporting GHG monitoring mission

Product	Requirement	Type
Digital Surface Model	<30-200 m spatial; <1 m vertical	Top of Canopy
Model atmosphere (Surface pressure, temperature, humidity)	Dry-air profile <0.1%	
Model atmosphere priors	CO ₂ , CH ₄ , CO, N ₂ O, NH ₃	
Land surface Bi-directional Reflectance Distribution Function (BRDF) coefficients	<1000-200 m	
Surface type (IGBP)	<500-200 m	
Snow-ice flag and type	<500-200 m	
Water Leaving Reflectance	<1000-200 m	

Next steps for the WG-climate GHG task-team (product and validation leads):

- Recommend operational requirements for ground-based reference GHG data for use in commissioning and validation of products from operational GHG mapping systems (contributing to the integrated global operational greenhouse gas observing system)