Committee on Earth Observation Satellites

The Role of GOSAT-3 in Atmospheric Inventories

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Objectives

- Introductions to atmospheric CO_2 and CH_4 inventories
- Operating and planned space-based sensors
- A prototype atmospheric CO_2 and CH_4 inventory to support the 2023 Stocktake
- GOSAT-3 support for the second Stocktake (2023-2028)
  - This period is not adequately covered by other planned space based GHG platforms
  - New technologies that could improve the spatial resolution, coverage and repeat frequency
- GOSAT-3 could serve as a critical pathfinder for the operational GHG constellations scheduled for deployment later in the 2020s

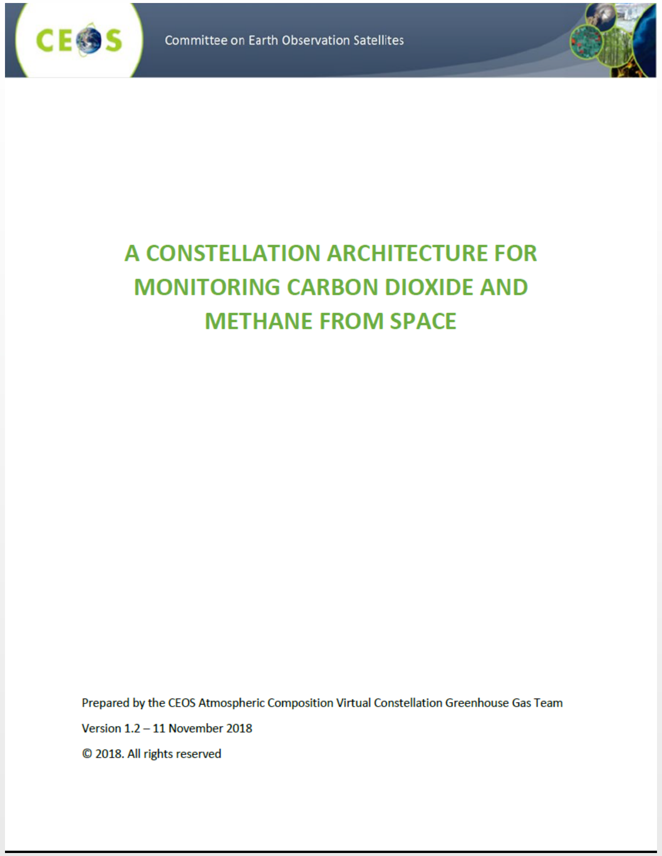
Atmospheric Inventories in the Context of the Paris Agreement

- Atmospheric measurements of CO_2 and CH_4 from ground-, airborne- and space-based sensors could reduce uncertainty in national emission inventory reports by:
  - providing nations with timely, quantified guidance on progress towards their emission reduction strategies and pledges (NDCs)
  - identifying additional emission reduction opportunities;
  - tracking changes in the natural carbon cycle caused by human activities (deforestation, degradation of ecosystems, fire) and climate change
  - Helping to close the carbon budget by providing measurements over ocean and over land areas with poor data coverage (tropical forests, polar regions)

The CEOS Architecture for Monitoring Atmospheric CO_2 and CH_4 Concentrations

The Committee on Earth Observations Satellites (CEOS) commissioned the Atmospheric Composition Virtual Constellation (AC-VC) team to write a white paper defining a global architecture for monitoring atmospheric CO_2 and CH_4 concentrations from instruments on space-based platforms

- 166-page document, 88 authors from 47 organizations
- Executive Summary (2 pages)
- Body of report (75 pages)
- Technical Appendices (42 pages)


Committee on Earth Observation Satellites

A CONSTELLATION ARCHITECTURE FOR MONITORING CARBON DIOXIDE AND METHANE FROM SPACE

Prepared by the CEOS Atmospheric Composition Virtual Constellation Greenhouse Gas Team

Version 1.2 – 11 November 2018

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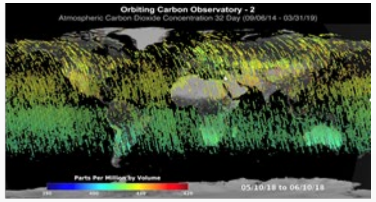
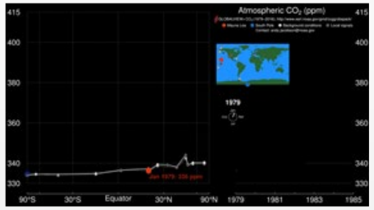
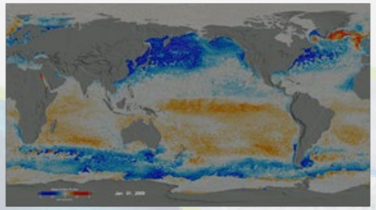
http://ceos.org/document_management/Virtual_Constellations/ACC/Documents/CEOS_AC-VC_GHG_White_Paper_Publication_Draft2_20181111.pdf

Space-based Measurements: Only One Component of an Atmospheric GHG Inventory System







Observations

Satellite Measurements of CO_2 and CH_4

Ground and Airborne Measurements of CO_2 and CH_4

Meteorology
Satellite & in-situ

Auxiliary Data
Satellite observations of CO, NO_2, clouds, aerosols …

Prior Information

Fluxes, model parameters, emission reports, economic statistics.

Integration & Attribution

Estimation system
Data assimilation and uncertainty estimation

↕

Models
Transport, land & ocean carbon cycle, fossil fuel emissions.

Outputs

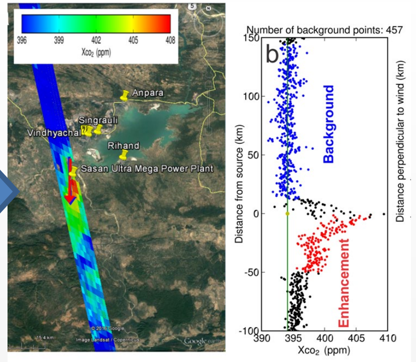
CO_2 and CH_4 emissions & removals from Hot-spots with uncertainties

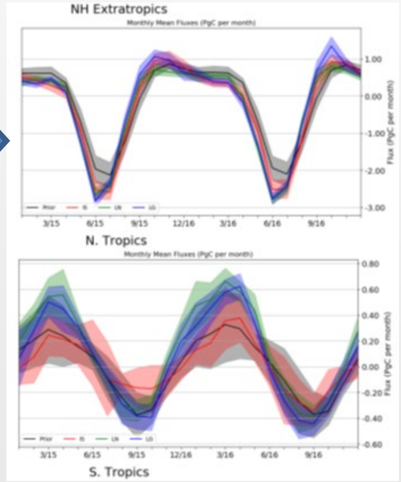
↕

Country/region CO_2 and CH_4 emissions & removals with uncertainties

↕

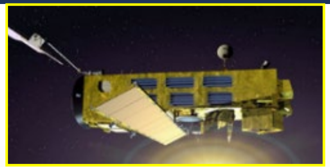
Other Carbon Cycle Products



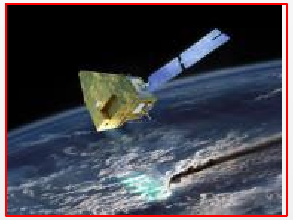


Collecting GHG Observations from Space: The Evolving Fleet

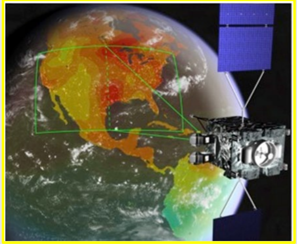
- **Space agencies have supported several pioneering space-based GHG sensors :**
  - **ESA's ENVISAT SCIAMACHY,**
  - **Japan's GOSAT TANSO-FTS, NASA's OCO-2, China's TanSat AGCS, Feng Yun-3D GAS and Gaofen-5 GMI, Copernicus Sentinel 5 Precursor TROPOMI.**
- **Other sensors just added to the fleet:**
  - **Japan's GOSAT-2 TANSO-FTS-2 and NASA's ISS OCO-3**
- **Others are under development:**
  - **CNES MicroCarb, CNES/DLR MERLIN, NASA's GeoCarb**









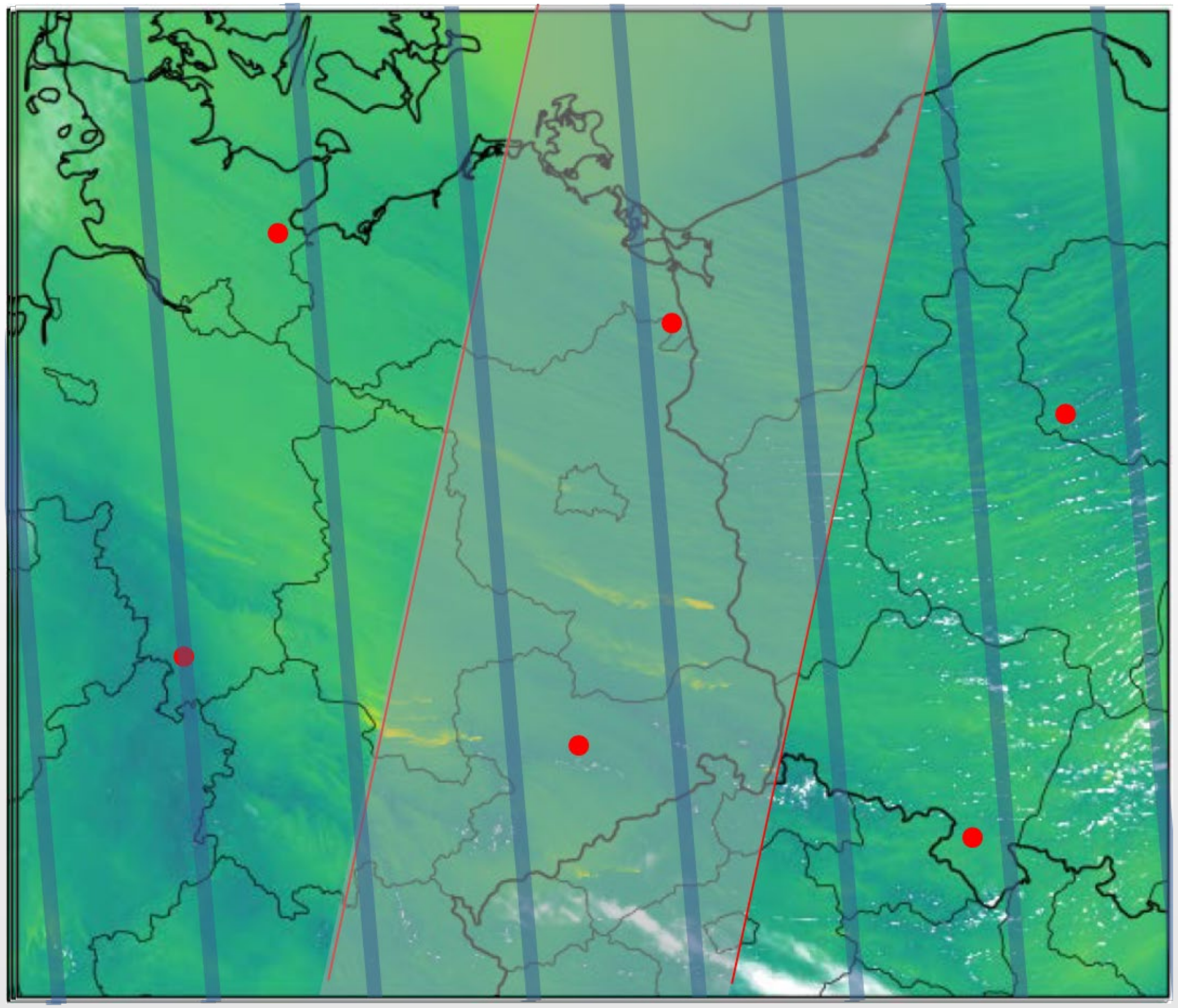
A Candidate Operational CO_2/CH_4 Constellation Architecture

The coverage, resolution, and repeat frequency requirements could be achieved with a constellation that incorporates:

- **A constellation of 3 (or more) satellites in LEO with**
  - **A broad (> 250 km) swath with a footprint size < 4 km^2**
  - **A single sounding random error near 0.5 ppm, and vanishing small regional scale bias (< 0.1 ppm)**
  - **Ancillary sensors to identify plumes (CO, satellites NO_2)**
- **A constellation with 3 (or more) GEO satellites**
  - **Stationed over Europe/Africa, Americas, and East Asia**
  - **Monitor diurnally varying processes (e.g. rush hours, diurnal variations in the biosphere)**

Next Steps: Operational LEO GHG Constellations

- **Copernicus CO_2 Sentinel (2025+)**
  - **3 or 4 LEO satellites in an operational GHG constellation**
  - **Primary spectrometer measures O_2 (0.76 μm A-band), CO_2 (1.61 and 2.06 μm), CH4 (1.67 μm)**
  - **Ancillary instrument include**
    - o **NO_2 (0.450 μm) at a spatial resolution of 2 km x 2 km along a 200-300 km swath for plumes**
    - o **A cloud/aerosol multi-angle polarimeter**



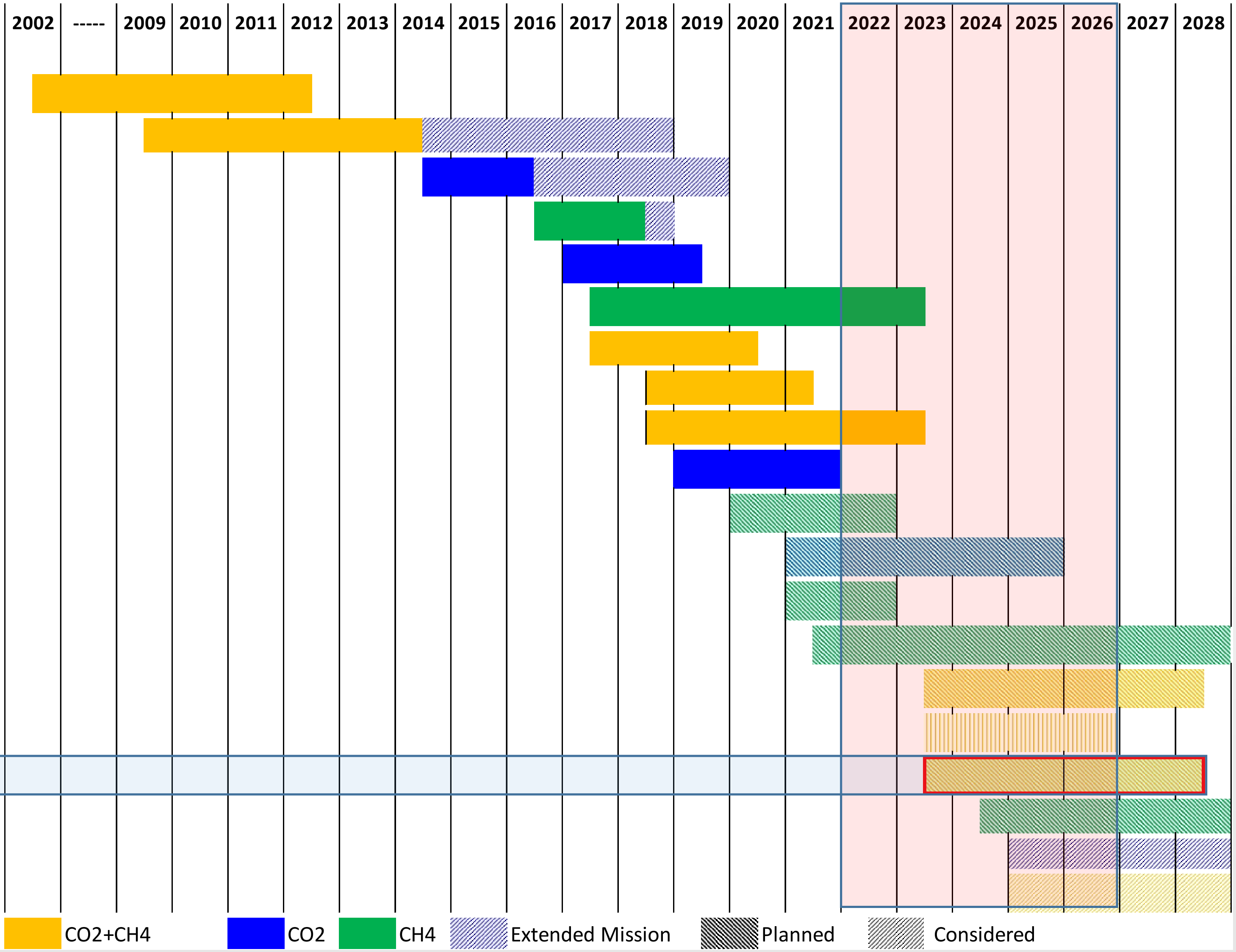
Developing Atmospheric GHG Inventories

The CEOS AC-VC GHG White Paper recommends the following approach:

1. Refine requirements and implementation plans for atmospheric flux inventories
    - Foster collaboration between the space-based and ground-based GHG measurement and modeling communities and the bottom-up inventory and policy communities
2. Produce a prototype atmospheric CO_2 and CH_4 flux inventory that is available in time to inform the bottom-up inventories for the 2023 global Stocktake
    - Exploit capabilities of CEOS), Coordination Group on Meteorological Satellites (CGMS) and the WMO Integrated Global Greenhouse Gas Information System (IG3IS)
3. Use the lessons learned from this prototype flux product to refine the requirements for a future, purpose-built, operational, atmospheric inventory system
    - more completely addresses the inventory process in time to support the 2028 global Stocktake.

The GHG Constellation Time Line

Satellite, Instrument (Agencies)	CO_2	CH_4	Swath	Sample
ENVISAT SCIAMACHY (ESA)	●	●	960 km	30x60 km^2
GOSAT TANSO-FTS (JAXA-NIES-MOE)	●	●	3 pts	10.5 km (d)
OCO-2 (NASA)	●		10.6 km	1.3x2.3 km^2
GHGSat (Claire)		●	12 km	0.0004 km^2
TanSAT (CAS-MOST-CMA)	●		20 km	1x2 km^2
Sentinel 5P TROPOMI (ESA)		●	2600 km	7x7 km^2
Feng Yun 3D GAS (CMA)	●	●	7 pts	10 km (d)
GaoFen-5 GMI	●	●	5-9 pts	10 km (d)
GOSAT-2 TANSO-FTS (JAXA-MOE-NIES)	●	●	5 pts	10.5 km (d)
OCO-3 (NASA)	●		11 km	4 km^2
Bluefield Technologies		●	25x20 km	0.0004 km^2
MicroCarb (CNES)	●		13.5 km	40 km^2
MethaneSAT (EDF)		●	200 km	1 km^2
MetOp Sentinel-5 series (Copernicus)		●	2670 km	7x7 km^2
Feng Yun 3G (CMA)	●	●	100 km	< 3 km^2
GEOCARB (NASA)	●	●	2800 km	3x6 km^2
GOSAT-3 (JAXA-MOE-NIES)	●	●	TBD	TBD
MERLIN (DLR-CNES)		●	100 m	0.14 km (w)
TanSat-2 Constellation	●	●	3x100 km	2x2 km^2
CO2 Sentinel (Copernicus)	●	●	3x250 km	2x2 km^2



The Critical Need for GOSAT-3 Data to Support the 2028 Stocktake

- Several satellites (GOSAT, GOSAT-2, OCO-2, OCO-3, TanSat) are providing atmospheric CO_2 data during the 2016-2021 period covered by the 2023 Stocktake
  - The Prototype Atmospheric Inventory will primarily use OCO-2 and GOSAT data
- Most of these satellites will no longer be operating during the period between the first and second Stocktakes (2023-2028)
  - MicroCarb should still be in service, but is expected to provide less coverage than OCO-2
  - GeoCarb should be operating by 2024, but only views North and South America land areas
  - The Copernicus constellation will be deployed in late 2025 trough 2026, but will have less than one year of data before the 2026 cutoff for the 2028 Stocktake
- A wide-swath GOSAT-3 CO_2 mission launched in the 2023-2024 timeframe would provide a critical bridge between the 2023 and 2028 Stocktakes
- Experience with wide-swath CO_2 data from GOSAT-3 could also accelerate the utilization of data from the Copernicus CO_2 Sentinels

GOSAT-3 as a Flagship for Japanese Technology

- As currently conceived, GOSAT-3 will carry broad swath (~400 km), high spatial resolution (2 km x 2 km) greenhouse gas sensor that will
  - Gather 25 times as many soundings as OCO-2
  - Provide global coverage of Earth's surface area in less than one week
  - Be deployed 2-3 years earlier than other broad-swath greenhouse gas sensors, like those included in by the Copernicus constellation
- With these capabilities, GOSAT-3 will clearly demonstrate Japanese technology leadership in space-based greenhouse gas measurements
  - Providing timely insight to policy makers on
    - Status of emission reduction strategies
    - Opportunities for additional emission reductions
    - Changes in the natural carbon cycle associated with human activities and climate change