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AC-VC GHG White Paper

Atmospheric Composition Virtual Constellation

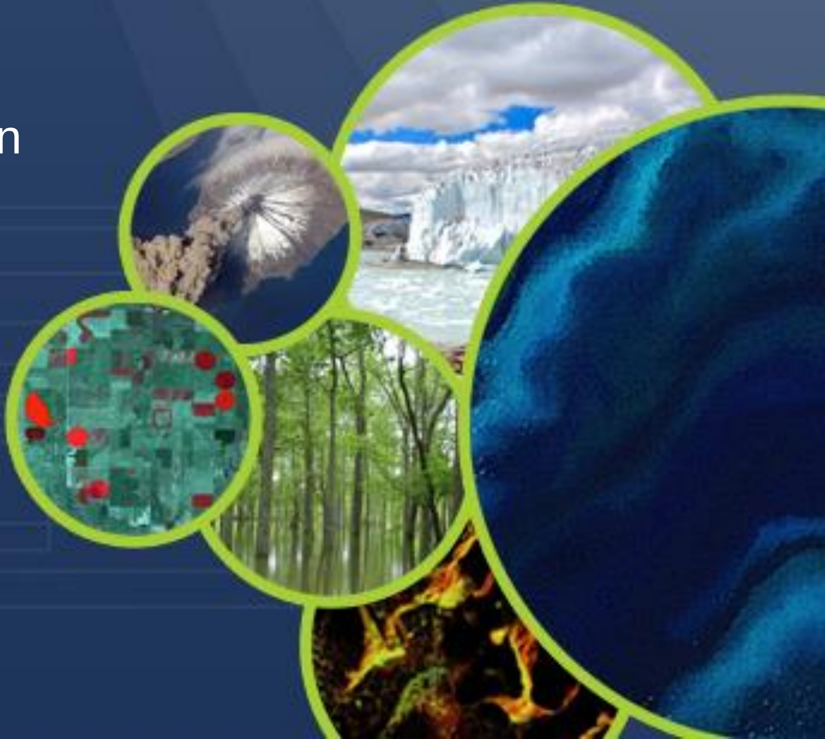
SIT Tech Workshop 2017 Agenda Item #

Side Meeting "UNFCCC/IPCC Engagement"

CEOS Strategic Implementation Team Tech Workshop

ESA/ESRIN, Frascati, Italy

13th-14th September 2017



Progress since the CEOS SIT-32

The primary focus of the AC-VC Greenhouse Gas (GHG) effort since the CEOS SIT-32 meeting has been the development of the GHG White Paper.

Community contributions to the White Paper were solicited at the following meetings:

- 6-8 June: IWGGMS-13, Helsinki, Finland
  - Discussion of Requirements of Future GHG missions
- 11-16 June: CGMS Jeju Korea
  - WG-II/WG-III GHG joint session on carbon observations
  - CGMS Plenary Session G: Carbon Observations
- 28-30 June: CEOS he AC-VC-13 in Paris, France
  - Devoted the afternoon session to a discussion of the AC-VC GHG White Paper

White Paper Chapters

Contributions from participants at the CGMS and CEOS AC-VC meeting were incorporated into the White Paper structure:

- Chapter 1: Need for space-based measurements of CO_2 and CH_4
- Chapter 2: Existing space-based GHG Satellites and near term plans
- Chapter 3: Lessons Learned from GOSAT and OCO-2
- Chapter 4: Integrating Near-term Missions into a Virtual Constellation
- Chapter 5: Defining GHG Constellation Requirements
- Chapter 6: Candidate Constellation Architectures
- Chapter 7: Ongoing studies of operational GHG constellations: the Copernicus CO2 Sentinels
- Chapter 8: The Transition from Science to Operations
- Chapter 9: Conclusions

Need for space-based measurements of CO_2 and CH_4

- Reduce uncertainty in fossil fuel emission inventories and their time evolution
  - Review origin, content, and limitations of present GHG inventories
  - New requirements from UNFCCC Paris agreement (e.g. “global stocktaking”)
  - Summarize challenges of discriminating and quantifying anthropogenic emissions in context of natural carbon cycle
- Monitoring and predicting changes in the natural carbon cycle associated with climate change and human activities
  - Deforestation, degradation, fire
  - Changes in CO_2 and CH_4 associated with drought, temperature stress, melting permafrost
  - Ocean thermal structure and dynamics

Existing space-based GHG Satellites and near term plans

Most existing and planned GHG missions are "science" missions, designed to identify optimal methods for measuring CO_2 and CH_4, not "operational" missions designed to deliver policy relevant GHG products focused on anthropogenic emissions

PAST

PRESENT

CO_2 Only
CH_4 Only
CO_2 + CH_4
CO_2 + CH_4 + CO

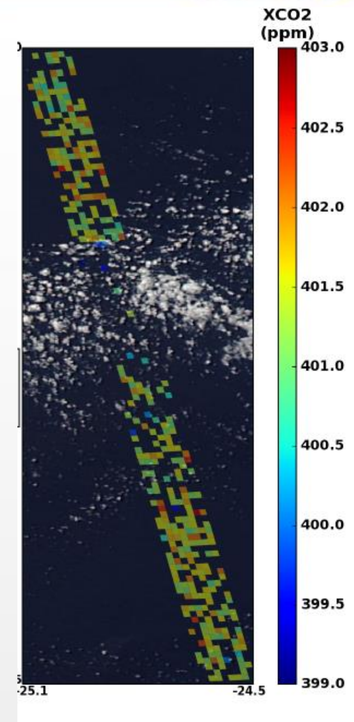
NEAR FUTURE

2020's*

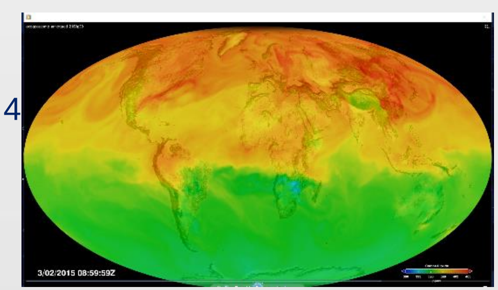
* Pre-decisional, for planning and discussion purposes only.

Lessons learned from GOSAT and OCO-2

- High accuracy and low bias are both essential
- High spatial resolution (footprint area < 4 km^2)
  - Critical for quantifying emissions from compact sources
    - X_{CO2} anomaly associated with a given CO_2 injection is inversely proportional to the area of the footprint
  - Critical for gathering data in presence of patchy clouds
- Imaging rather than sampling the CO_2 and CH_4 field
  - Critical for tracking emission plumes and resolving anthropogenic emission sources from the natural background
- High resolution transport models for flux inversion
  - Critical for quantifying at the scale of cities
  - Needed for resolving anomalies associated with CO_2/CH_4 "weather" from local sources and sinks
- Proxies (SIF, CO, and NO_2) may be needed for attribution



OCO-2 track through patchy clouds



GEOS-5 XCO2 Weather

Integrating Near-term Missions into a Virtual Constellation

A multi-satellite GHG constellation could

- Exploit the benefits of observations from low Earth orbit (LEO), geostationary orbits (GEO), and Highly Elliptical Orbits (HEO)
- Reduce revisit times in the presence of optically-thick clouds
- Improve spatial coverage without requiring very broad swaths that
    - Are technically difficult and expensive to implement
    - Large atmospheric path lengths at the swath edges are more likely to be contaminated by clouds
- Collect coincident observations of proxies (CO, NO_2, SIF) to facilitate the interpretation of the measurements
- Provide resiliency to the loss/degradation of individual satellites
- Facilitate data quality improvements through cross calibration and cross validation

Partnerships will help realize these objectives

Defining Constellation Requirements

- Existing studies indicate that different approaches can be combined to define the measurement requirements needed to meet the demanding GHG flux requirements
  - Point source mass balance methods show the sensitivity needed to quantify localized sources (cities, individual power plants)
  - Signal detection experiments provide insight into the amplitude of X_{CO2} and X_{CH4} anomalies associated with persistent flux changes and their dependence on wind speed at local to global scales
  - Realistic, end-to-end OSSEs are adequate for assessing flux uncertainties associated with sensor precision, resolution, and coverage in the presence of realistic transport and clouds
  - Flux inversion experiments combining data from in situ, TCCON, GOSAT and OCO-2 are being validated against “withheld data” (from aircraft or surface stations) to provide insight into the impact of biases in concentration measurements and transport

A Candidate GHG Constellation Architectures

The coverage, resolution, and precision requirements could be achieved with a constellation that incorporates

- A constellation of (3 or more) satellites in LEO with
  - A broad (~200) km swath with a mean footprint size < 4 km^2
  - A single sounding random error near 0.5 ppm, and vanishing small regional scale bias (< 0.1 ppm) over > 80% of the sunlit hemisphere
  - One (or more) satellites carrying ancillary sensors (CO, NO_2, CO_2 and/or CH_4 Lidar)
- A constellation with 3 (or more) GEO satellites
  - Monitor diurnally varying processes (e.g. rush hours, diurnal variations in the biosphere)
  - Stationed over Europe/Africa, North/South America, and East Asia
- One or more and one or more HEO satellites to monitor carbon cycle changes in the high arctic

Ongoing studies of operational GHG constellations: the Copernicus CO_2 Sentinels

The high-level **monitoring system** objectives are to

1. provide policy-relevant information (trends, impacts of measures),
2. support national emission inventories,
3. observe strong point & area sources (e.g., power plants and cities)
   - *As part of an integrated system comprising: satellite - in-situ – modelling - emission inventory components, for provision of timely input to policymakers*

In view of the above system objectives, the following mission objective of the space component has been tentatively formulated:

The CO_2 mission shall monitor anthropogenic CO_2 emissions using high spatial resolution imaging of total column CO_2

Moving Forward from “Science” to “Operational” GHG Missions

- With the exception of the Sentinels, all of the existing and planned GHG missions are “science” missions, designed to identify optimal methods for measuring CO_2 and CH_4, not “operational” missions designed to deliver policy relevant GHG products focused on anthropogenic emissions
- Following the model developed by the operational meteorological satellite constellation, future GHG constellation will also need to focus on orbit and mission coordination, data distribution, data exchange, and data format requirements
- To fully exploit the information collected by future GHG constellations, the missions will also have to invest in training and capacity building as well as public outreach
- CEOS should exploit the experience of CGMS and other organizations to foster the development of these capabilities

Conclusions

- Data from a future, coordinated GHG constellation that combines LEO, GEO, and HEO vantage points could meet the measurement accuracy, precision, resolution, and coverage requirements
- To provide reliable, verifiable constraints on GHG inventories as well as the response of the natural carbon cycle to climate change, advances are needed in:
  - Laboratory measurements of gas absorption cross sections
  - pre-launch and on-orbit calibration capabilities,
  - GHG retrieval algorithms
  - flux inversion algorithms
  - GHG concentration and flux validation techniques
- Open data policies that encourage the cross-calibration of sensors, the cross validation and free exchange of space based data products will accelerate the development of these capabilities and the acceptance of their results by scientists and policy makers

White Paper Status and Schedule

- Rapid progress was made in May and June, but summer vacations and other commitments slowed progress during July and August.
- We are still targeting an end-to-end draft of the white paper by the end of calendar year 2017
- The target due date for publication is the 2018 CEOS SIT plenary