Committee on Earth Observation Satellites

# AC-VC Comments on the Greenhouse Gas Guidebook

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# Supporting success of post-COP21 actions to reduce climate-disrupting GHG emissions

The overall goal is to develop a sound, scientific, measurement-based approach that that exploits the space-based perspective:

- reduces uncertainty of national emission inventory reporting,
- identifies large and additional emission reduction opportunities, and
- provides nations with timely and quantified guidance on progress towards their emission reduction strategies and pledges (Nationally Determined Contributions, NDCs)

In support of these efforts, atmospheric measurements of greenhouse gases from satellites will

- Improve the frequency and accuracy of inventory updates for nations not well equipped for producing reliable inventories, and
- help to “close the budget” by measurement over ocean and over areas with poor data coverage

These objectives require spaceborne measurements with reduced uncertainty

# Objectives of 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
- Monitor and predict 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

# Overview of CEOS AC-VC Review of GHG Guidebook

- Members of the CEOS AC-VC provided inputs to the GHG Guidebook as individuals and as a team
- Most of the comments on early drafts of the Guidebook focused on factual information about past, current and future mission capabilities and products or proposed editorial changes to clarify the text of Chapters 1 and 2
- Reviews returned more recently included similar suggestions, but also included many more comments and suggestions for the general scope and organization of Chapter 3, including:
  - A more complete description of the impact of spatially- and temporally coherent biases on mass balance and flux inversion methods, and a discussion of uncertainty quantification
  - The need to include a roadmap for future developments and goals of mass balance and flux inversion efforts

# Updates to Chapter 2

- Several comments about the objectives, design, and products of SCIAMACHY are incorrect
- Several small corrections are needed in description of the OCO-2 spectrometers and measurement approach.
- The Chinese satellites Feng Yun-3D (2017), 3G (2020), and Gaofen-5 (2018) need to bee added to the “third generation of greenhouse gases remote sensing missions” pg 2-4.
- The Copernicus Sentinel 5 mission (2020) and the Sentinel 7 constellation (2025-26) should be described because they bring new capabilities (high resolution 2-d imaging of CO2, CH4, CO).
- The discussion of the satellite instruments should include a description of the calibration steps and methods.
- The GHG product descriptions could be clarified.
- The description of the retrieval algorithms is confusing.
- A description of bias detection and correction methods is needed.

# Updates to Chapter 3

- The discussion of the flux inversion methods presented here is unnecessarily confusing and much of it is more relevant to methods that use accurate, but sparse surface data than those that use spatially-dense, but less accurate satellite data.
  - Simple block diagrams illustrating the relationship between concentration anomalies, winds, and fluxes would be helpful
- There is surprisingly little discussion of HOW the atmospheric measurements from space and ground-based systems can be used to inform the inventory process, or how atmospheric measurements are complementary to inventory methods
  - Inventories are source specific, but some sources are missed (especially for $CH_4$, but also $CO_2$), and sinks are missed
  - Atmosphere concentrations integrate all sources & sinks, but are more difficult to attribute, include different sources of error, and have to contend with “noise” from the natural carbon cycle

# Updates to Chapter 3 – A discussion of Bias

- There is no discussion of the impacts of spatially- and temporally-coherent biases in the concentration measurements or how these issues can be addressed
  - There little discussion of the actual benefits of high spatial resolution and coverage of space based measurements relative to the more accurate but sparse ground-based measurements – flux inversion models hide errors in places with no constraint.
  - There is a discussion of transport biases, but the specific relationship between transport errors, concentration errors, and flux uncertainties is very ambiguous to most readers.
- There is no discussion of how CO2 or CH4 fluxes will be validated or how biases in fluxes can be identified and corrected
  - Validation against aircraft a postiori concentration profiles
  - Validation against flux tower networks

# Updates to Chapter 3 – A Flux Inversion Roadmap

- This chapter is unnecessarily negative because it focuses on current or past limitations of flux inversion models rather than on recent progress from ongoing developments using combinations of space based and ground-based observations.
- The guidebook would benefit from a Roadmap that identifies the improvements needed in concentration observations, transport, and inversion methods over the next decade
  - Concentrations – recent progress on bias detection/correction, recent improvements in precision (0.5 ppm) and coverage, and expected dramatic improvements in spatial resolution and repeat frequency (2 km x 2 km on daily to weekly timescales)
  - An ongoing revolution in transport modeling as we transition from low resolution models to global mesoscale models, etc.
  - New insights into inversion approaches (KF, LETKF, 4-d Var)

# Updates to Chapter 3 - Synergies in Measurements and Models

- From the measurement standpoint, there has always been a realization that we will have to combine space based measurements with ground and aircraft based measurements to meet the demanding accuracy, resolution and coverage requirements
- There is currently no discussion of how space-based, ground-based and aircraft based observations should be combined in flux inversion and mass balance models.
- There is also no discussion of how results from mass balance models, characterizing the largest emission sources, can/should be combined with flux inversion models to refine national inventories.
- Mass balance models are better for point sources. If this approach is taken, the flux inversion models can focus on the natural background and small scale sources missed by the mass balance approaches.

# A note on Terminology

- The terminology "inverse models" is ambiguous in this context, because inverse models are used both the retrieval and flux inversion process.  The specific models referenced here should be classified as "global- to regional-scale carbon flux inversion models." This can subsequently be shortened to "flux inverse models"

# The promise and challenge for space-based GHG measurements

The primary assets of space based GHG measurements include

- Spatial coverage
  - Observations over both land and ocean
- Temporal resolution and sampling
  - Hourly sampling needed to resolve diurnal cycle and plumes
  - Daily to weekly sampling needed to resolve $CO_2$ weather
  - Monthly measurements required over multiple years to resolve seasonal and inter-annual variability in $CO_2$
- Spatial resolution and sampling
  - Sensitivity to point sources scales with area of footprint
  - Small measurement footprints enhance sensitivity to point sources and reduce data losses due to clouds

The primary challenge is precision and accuracy

- High precision required to resolve the small (< 1%) variations in $CO_2$ and $CH_4$ associated with sources and sinks
- High accuracy essential to avoid regional-scale biases