

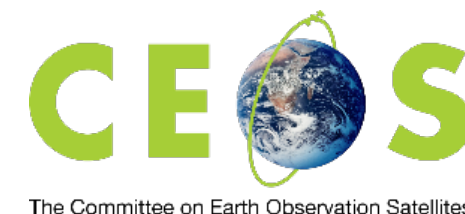
Status of Joint CEOS/CGMS WGClimate

Jörg Schulz, EUMETSAT

Chair Joint CEOS/CGMS Working Group on Climate

Albrecht von Bargaen, DLR

Vice Chair Joint CEOS/CGMS Working Group on Climate



Achievements since last meeting

- Delivered the space agency statement to SBSTA-51 on 2nd December 2019 in Madrid, Spain and successfully participated in the Earth Info Day. Comprehensive report from SBSTA Chair featuring architecture for space-based climate monitoring and constellation architecture for GHG was published 30 April 2020;
- Finished population and verification (almost) of ECV Inventory #3.0;
- Worked hard on gap analysis but are behind schedule and further hampered by COVID-19
- Presented first version of GHG Roadmap document to CEOS SIT-35
- Updated CEOS work plan
- Planned CGMS-48

- (<https://unfccc.int/sites/default/files/resource/EarthInformationDay2019.SummaryReport.pdf>);

Research and Systematic Observation
EarthInformationDay.2019.1.SummaryReport

Page 21 onwards has coverage of WGClimate featuring GHG constellation.

Earth Information Day 2019

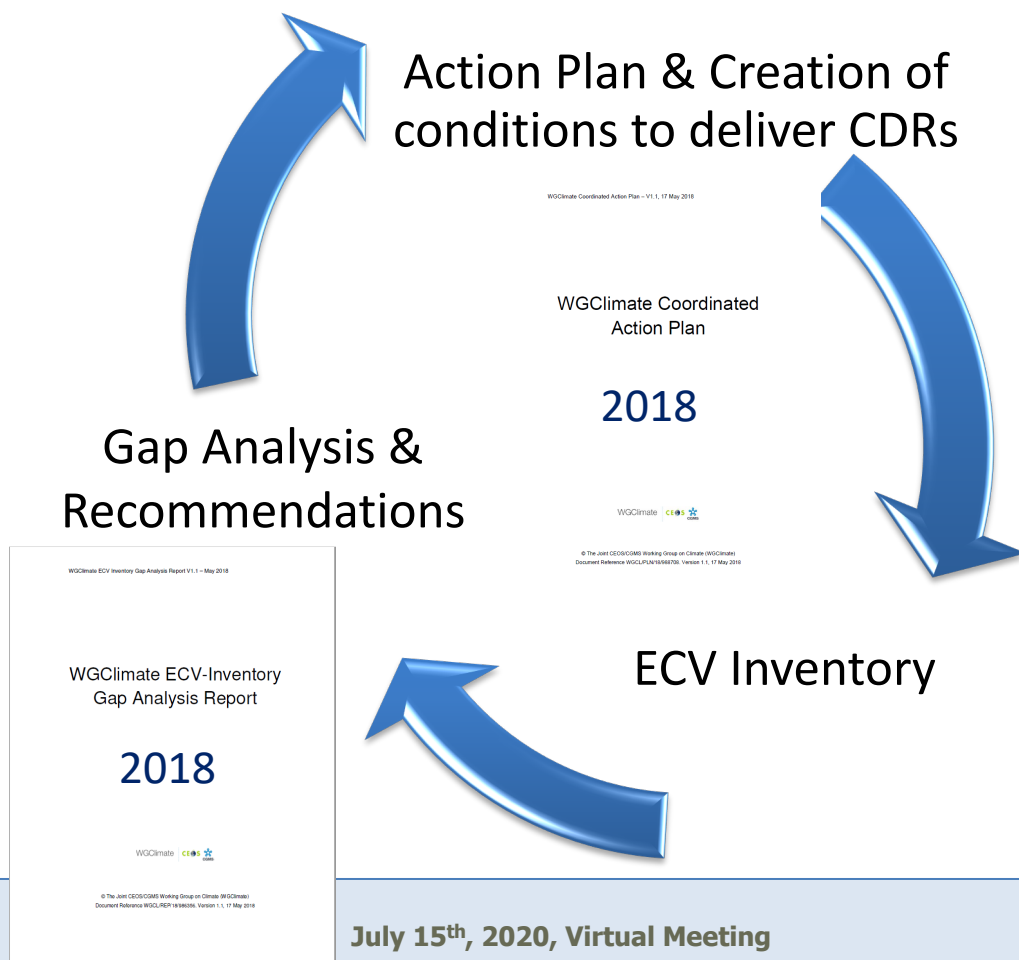
3 December 2019, Madrid, Spain

Implementing observation

- Systematic observation, in-situ and space-based, is the foundation for knowledge of the Earth – climate monitoring, information for GCOS essential climate variables (land, atmosphere and ocean) and climate indicators. It feeds into such products as the WMO statement on the state of the global climate and all climate services.
- Space agencies have developed the Constellation Architecture for Monitoring Carbon Dioxide and Methane from Space providing a system approach for emission estimates for carbon dioxide and methane.

- WGClimate core:
 - ECV inventory
 - ECV gap analysis
 - Definitions / Terms wrt climate records
 - Climate application studies
- GHG task team

Recurrent actions CMRS-17, 20, and 21



- ECV Inventory fully describes current and planned implementation arrangements (ECV-by-ECV) within the Architecture
- Content fully verified and updated annually with approval from CEOS and CGMS
- Informs space agency planning, improves availability and interoperability of climate data records
- Feeds material for all future responses of the space agencies to the GCOS status report and IP
- Is used by Climate Services to chose CDRs, e.g. Copernicus Climate Change Service
- Users can download the ECV Inventory content for own analysis, find direct access points to CDRs in the Inventory, get access to WGClimate gap analysis results and planned actions.

July 15th, 2020, Virtual Meeting

Gap Analysis Topics

Related to the objectives of the WG Climate the gap analysis addresses three topics:

1. Existence of Climate Data Records
2. Analysis of Inventory Entries against GCOS Criteria
3. Analysis for specific ECVs
 - An analysis as to whether the ECV inventory misses a known existing or planned climate data record;
 - An analysis of missing measurements in the future that would be required to continue existing and planned data records or to establish new ones with enhanced quality;
 - An analysis of the missed opportunities for creating a climate data record from existing past and planned future measurements from space.

ECV CDR Inventory and Gap Analysis

WGClimate ECV Inventory Gap Analysis Report V1.1 – May 2018

WGClimate ECV-Inventory
Gap Analysis Report

4	Inventory Content (Covered ECVs).....
4.1	Relative portions of ECVs per GCOS Domain
4.2	Detailed View on Temporal Coverage per ECV Product.....
5	Gap Analysis against GCOS Criteria
5.1	Existing Data Records (Current Part of Inventory)
5.2	Planned Data Records (Future Part of the Inventory).....
6	Gap Analysis for Selected ECV Products
6.1	CO ₂
6.2	CH ₄
6.3	Precipitation.....
6.4	Sea Surface Temperature.....
6.5	Sea Surface Salinity
6.6	Land Surface Temperature
6.7	Leaf Area Index
6.8	Above-ground Biomass.....

- Automatic assessment
- Statistical analysis tools and graphical display
 - Statistical analysis tools and graphical display on the web interface
 - Analysis of delta to version #2

Detailed analysis per ECV / ECV Product:

- Assesses progress for 8 ECVs addressed last year
- Selected 13 additional ECVs (5 atmosphere, 5 land, 3 ocean) not addressed before that are specifically part of 2016 GCOS-IP actions
- Postponed 2 land (FAPAR, Glaciers) and 1 atmosphere (lightning) due to missing support

WGClimate CDR Definitions

- WGClimate pays attention for clear definitions regarding climate data records and its different “flavors” (FCDR, ICDR, TCDR, CDR, etc.)
(original lead with Christopher Merchant, now with Jeff Privette)
- To close out that activity WGClimate decided (a) the formation of a small-scale group (4 egg-heads max.) and (b) the inclusion of WGCV expertise
- In communication with the WGCV chair Kurt Thome (NASA) had been nominated to support Jeff Privette (NOAA), Jörg Schulz (EUMETSAT), and Christopher Merchant (U. of Reading)
- WGClimate highly appreciates your support!

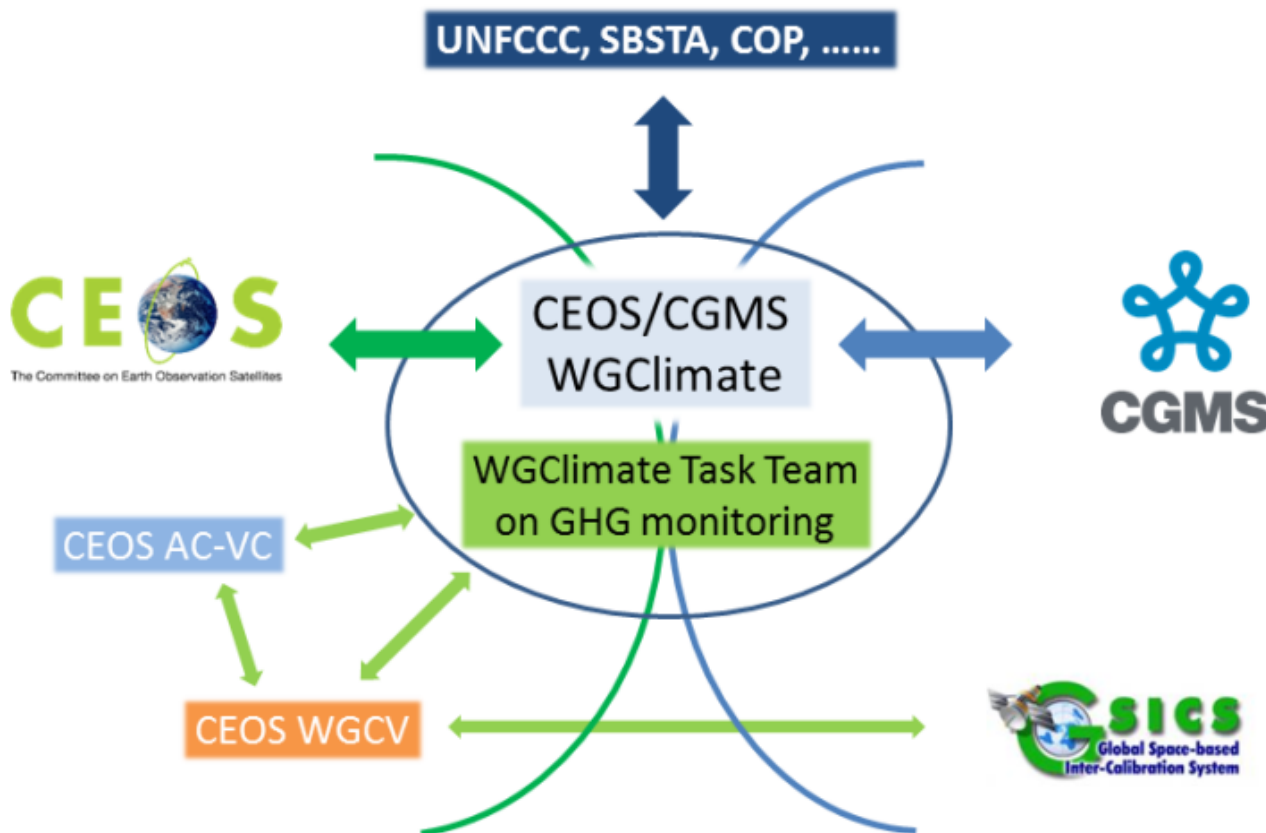
Status on GHG Task Team

Mark Dowell & Albrecht von Bargaen

EC & DLR

Joint CEOS/CGMS WGClimate GHG Task Team Leads

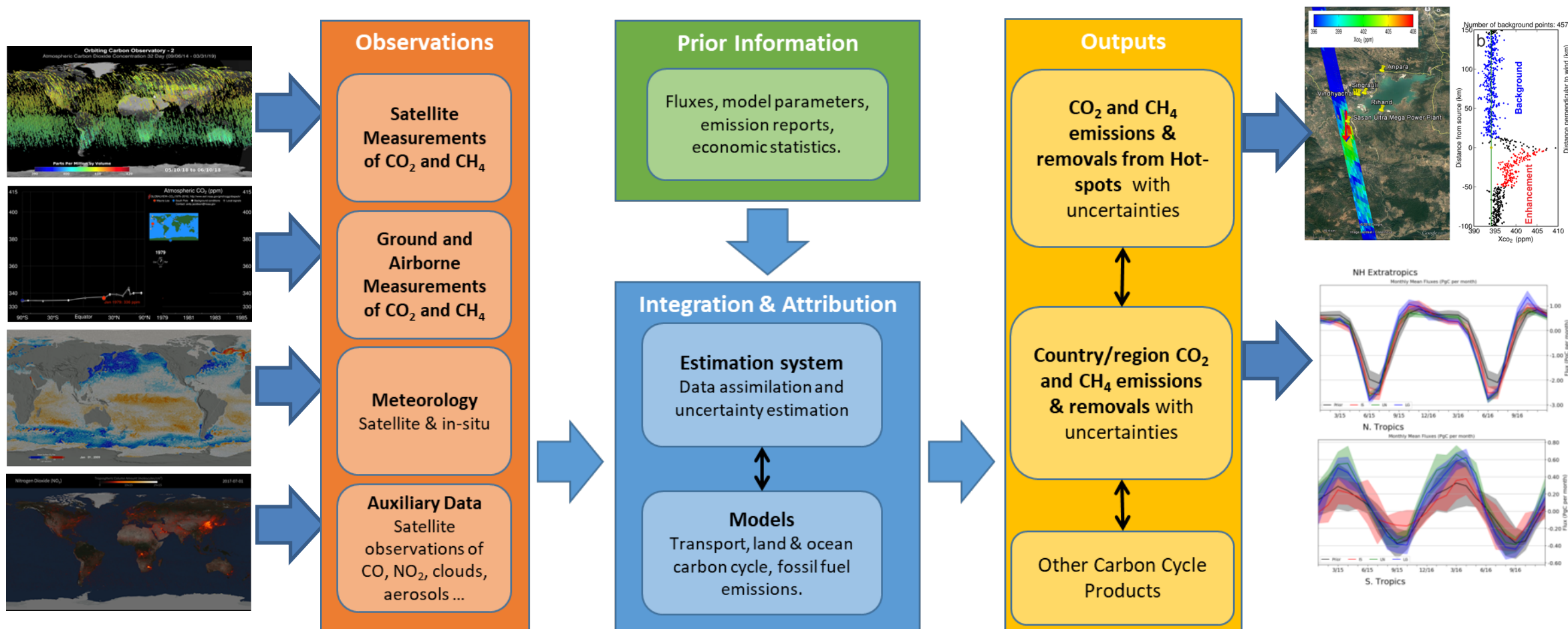
Key Players in the GHG Roadmap/Project Plan



Roles of GHG TT

- Create and maintain roadmap to implement actions proposed in the AC-VC white paper
- Establish primary user interface to Users (Inventory and Policy) and ensure feedback on prototype products
- Provide a whole system overview and track requirements, capabilities, and deliverables
- Identify additional resource needs and relevant CEOS/CGMS Agencies to dedicate appropriate resources

A System Approach is Adopted to Deliver Atmospheric CO₂ and CH₄ Inventories



Staff Resource Request

1. Agencies are asked to continue/increase support to the GHG relevant staff (time & travel) contributing to the technical implementation tasks in AC-VC and WGCV
2. For WGClimat GHG Task Team, the following “profiles” are requested:
 - Core team ensuring linkages to internal CEOS/CGMS entities (i.e. WGClimat – Dowell/von Barga, AC-VC – Crisp, WGCV – Kuze)
 - CEOS and CGMS Agency staff representing GHG missions/programmes
 - Agency staff from “operational” agencies to ensure operational transition
 - Agency Staff/Experts with links to Inventory Community
 - Agency Staff/Experts involved in modelling aspects
3. The GHG Task Team would include ~12 members, typically dedicating 1 PM/yr of effort each with those leading specific activities dedicating closer to 2 PM/yr. Support should include necessary travel budgets for attending meetings/workshops.

Agencies who have already offered resources

- CNES: C. Deniel & F. Chevelier for GHG Task Team
- DLR: Albrecht von Bargaen
- ESA: Y. Meijer for GHG Task Team
- EUMETSAT: R. Lang for GHG Task Team, R. Husband supporting on Sys. Eng. Aspects
- UKSA: P. Palmer for GHG Task Team & offer to host/support workshops
- JAXA/NIES H. Tanimoto
- EC: support workshop GHG/AFOLU workshop + modelling competence for Task Team (TBC. R. Engelen)
- CGMS WG representative will be added end of August 2020

Proposed working practices

- GHG Task Team to address a number of parallel activities/“tasks” with assigned members – see discussion
- Bi-Monthly telecons of all members - more frequent at activity level, as necessary
- Dedicated annual meeting (of “opportunity”?)
- Dave and Akihiko provide links to AC-VC and WGCV we will try to identify equivalents for GSICS and CGMS WGs
- CEOS Associates (e.g. GCOS, WCRP, WMO), and others GEO, UNFCCC Sec also welcome to provide active involvement
- Milestones and Event reporting (CEOS Plenary, SIT, CGMS Plenary, SBSTA, COP, other)
- Lead/Co-lead rotation: co-lead ex-officio Climate vice-chair, lead: Mark will rotate off CEOS Plenary 2021

GHG Roadmap Status Update

Mark Dowell & Albrecht von Bargaen

Joint CEOS/CGMS WGClimate GHG Task Team Lead

The CEOS Architecture for Monitoring Atmospheric CO₂ and CH₄ Concentrations

The CEOS Atmospheric Composition Virtual Constellation (AC-VC) white paper defines a global architecture for monitoring atmospheric CO₂ and CH₄ 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)

A CONSTELLATION ARCHITECTURE FOR
MONITORING CARBON DIOXIDE AND
METHANE FROM SPACE

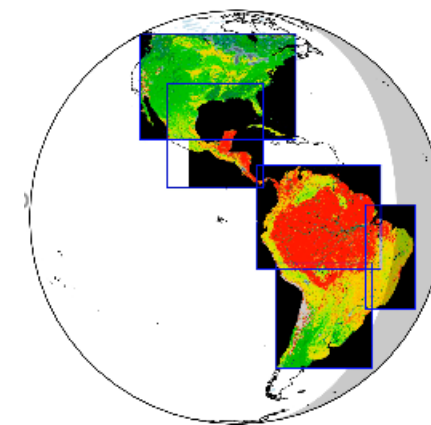
Prepared by the CEOS Atmospheric Composition Virtual Constellation Greenhouse Gas Team
Version 1.2 – 11 November 2018
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[http://ceos.org/document_management/Virtual_Constellations/ACC/Documents/CEOS
AC-VC GHG White Paper Publication Draft2 20181111.pdf](http://ceos.org/document_management/Virtual_Constellations/ACC/Documents/CEOS_AC-VC_GHG_White_Paper_Publication_Draft2_20181111.pdf)

A Candidate Operational CO₂/CH₄ Constellation Architecture

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

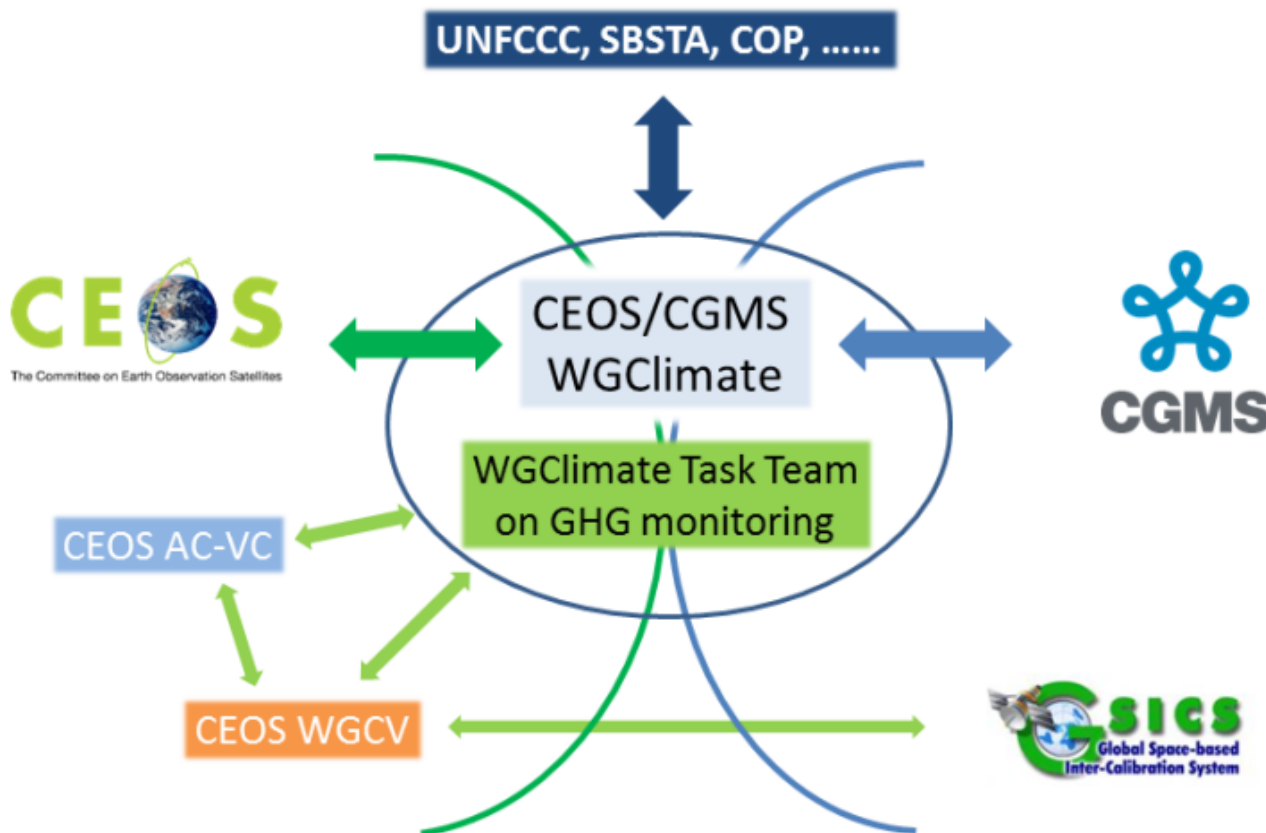
- A constellation of 3 (or more) satellites in LEO with
 - Broad (> 250 km) swaths with a footprint size < 4 km²
 - Single sounding random error < 0.5 ppm
 - Vanishing small regional scale bias (< 0.1 ppm)
 - Ancillary sensors to identify plumes (CO, satellites NO₂)
- A constellation with 3 (or more) GEO satellites
 - Stationed over Europe/Africa, Americas, and East Asia
 - Diurnally varying processes (e.g. rush hours, photosynthetic uptake)
- Possible augmentations include:
 - Active (lidar) satellites in LEO for night-time/polar night coverage
 - Satellites in HEO for improved high latitude coverage and repeat frequency



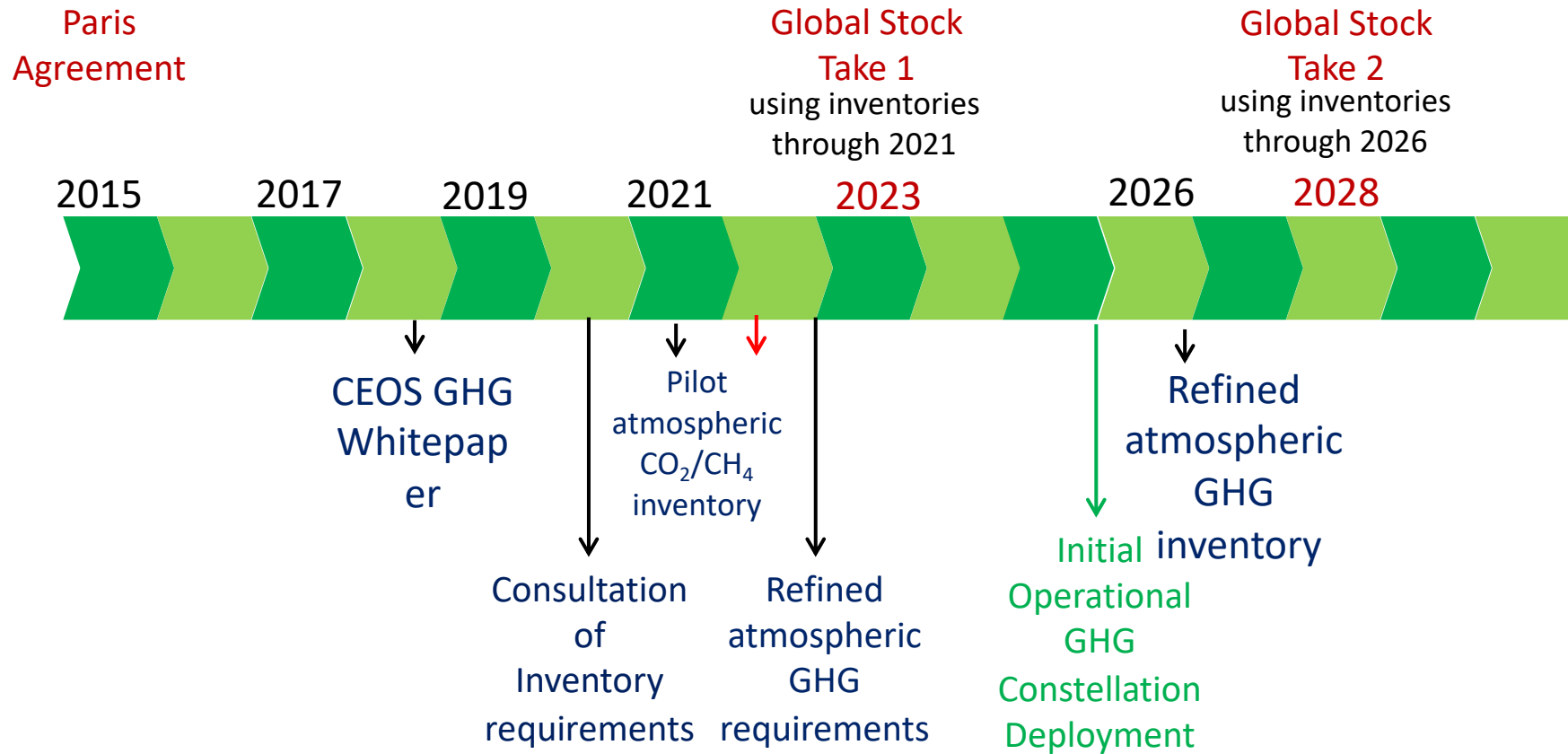
The Greenhouse Gas Roadmap Objectives

- GHG Roadmap Objectives:
 - A prototype end-to-end system that yields estimates of CO₂ and CH₄ fluxes supporting the first global stocktake; and
 - An Initial Operational System for producing future atmospheric CO₂ and CH₄ flux products for use in future Global Stocktakes.
- The roadmap document has established a more rigorous approach to the terminology:
 - *“Pilot phase providing access to targeted products from individual CEOS and CGMS Agency programs to establish appropriate relationships with stakeholders and users (e.g. National Inventory Agencies) to enhance to uptake of Earth Observation based datasets informing the national reporting needs”.*
- The delivery of each system version is accompanied by a requirements refinement process leading to the additional objective:
 - Establishing the end-to-end requirements for a system that delivers atmospheric CO₂ and CH₄ flux products for use in stocktakes (with requirements apportioned to each system version).

Key Players in the GHG Roadmap/Project Plan



GHG Roadmap Timeline



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- **WGClimate GHG Task Team**

- Create and maintain a roadmap to implement actions proposed in the AC-VC white paper
- Establish primary user interface to Users (Inventory and Policy) and ensure feedback on prototype products
- Provide a system engineering overview and track requirements, capabilities, and deliverables
- Identify additional resource needs and relevant CEOS Agencies to dedicate appropriate resources

- **WGCV ACSG**

- Identify best practices for prelaunch calibration of CO₂ and CH₄ concentration sensors and facilitate the exchange and harmonization of approaches and reference standards
- Identify best practices for on-orbit calibration of GHG sensors and disseminate standards including solar, lunar, and surface vicarious validation sites

- **AC-VC GHG Team**

- Coordinate ongoing agency activities to implement a prototype atmospheric GHG inventory system that incorporates products from a virtual constellation of sensors by 2021
- Coordinate efforts to trade studies on constellation architecture
- Coordinate development of a more complete atmospheric GHG inventory for the 2028 Stocktake

Status GHG Task Team Activities

- Mature GHG Roadmap and Project Plan developed specifying deliverables, responsible organizations, schedules and resources
- Establishing interfaces with National Inventory community
 - Worked with the Copernicus H2020 VERIFY Project to organize an atmospheric inventory workshop @ Global Emissions IniActive (GEIA)
- Establishing interfaces with stakeholders (UNFCCC/SBSTA & GCOS)
 - Support UNFCCC/SBSTA & GCOS at COP-25 & Earth Information Day
- Workshop on synergies and opportunities between GHG and AFOLU Earth Observation communities working in support of UNFCCC
- Engaged Atmospheric GHG Community
 - Presented Roadmap to AC-VC, Jun 2019; workshop @ AGU Dec. 2019
- Progress in Atmospheric Inventory Development
 - ESA/CCI, Copernicus CAMS, OCO-2, NASA CMS and others
- Progress in identification of GHG validation capabilities

GHG Roadmap Status and Next Steps

- The Roadmap is a living document, we have a version available for consultation, and will continue to revise/refine it as we start to address the work required (see Annex C)
- We will continue efforts to:
 - establish links to national inventory community to refine needs for atmospheric inventories
 - Enhance links with critical interfaces at GCOS, IPCC and IG3IS following WMO reorganization
 - Foster integration of CGMS Working Groups
 - Prepare for endorsement of the GHG Roadmap/Project Plan at 2020 Plenary

GHG Cal/Val roadmap and Case study toward Global Stocktake 2023 and 2028

Akihiko KUZE

(Earth Observation Research Center, Japan Aerospace Exploration
Agency)

CEOS WGCV

May 7, 2020

Define best practices and facilitate exchange and harmonization of approaches for instrument cross-calibration in coordination with CEOS WGCV and GSICS - text from Rec#10: The strategy for cross-calibrating the GOSAT and OCO-2 instruments has employed common standards, including observations of the sun, Moon, and surface vicarious calibration sites, such as Railroad Valley, Nevada, U.S.A. Additional effort by WGCV and GSICS is needed to maintain and improve the quality of these standards to better address the calibration needs of space-based CO₂ and CH₄ sensors

(1) GOSAT, OCO-2 calibrations are documented and published

Cross-Calibration

Solar reflected light sensors, radiance spectra and column density intercomparison: F. Kataoka, et al., "The Cross-Calibration of Spectral Radiances and Cross-Validation of CO₂ Estimates from GOSAT and OCO-2", MDPI Remote Sens., 9, 1158-1179 (2017).

Thermal infrared sensors: F. Kataoka, et al., "Calibration, Level 1 Processing, and Radiometric Validation for TANSO-FTS TIR on GOSAT," IEEE Trans. Geosci. Remote Sensing, 57., 3490-3500 (2019).

Vicarious Calibration

Method, Uncertainty level: A. Kuze et al., "Long term vicarious calibration of GOSAT sensors; techniques for error reduction and new estimates of degradation factors", Trans. Geosci. Remote Sensing, 52, 3991-4004 (2014).

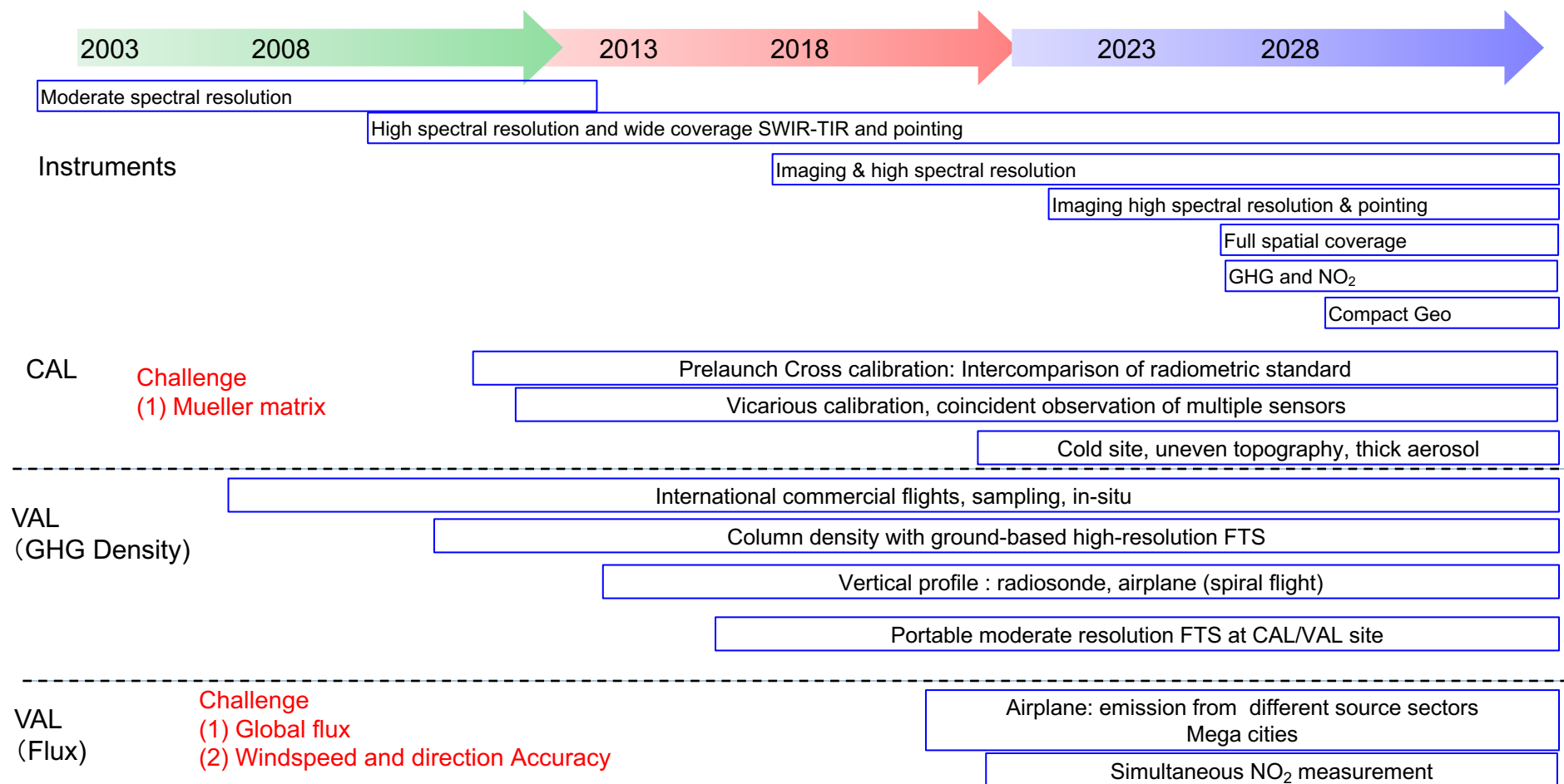
Uncertainty: Bruegge, et al., "Bi-Directional Reflectance Factor Determination of the Railroad Valley Playa". Remote Sens. 11, 2601, (2019)

(2) Intercomparison identified error sources caused by individual instrument and common database. (FTS, grating specific bias, Solar data)

(3) Consistent radiance spectra and retrieved density have demonstrated the effectiveness of GHG observation from space.

(4) Long term cross calibration can correct step change of bias caused by instrument anomaly in orbit.

GHG Cal/Val Roadmap (draft) toward global stocktake 2023 and 2028



Next step

What WGCV can do

- All the satellite data level 1 and Level 2 are free and open.
- However, calibration and validation dataset are not easy to access yet.
- <Already available>
 - Total Carbon Column Observing Network (TCCON)
 - Comprehensive Observation Network for Trace gases by AirLiner (CONTRAIL)
- <Best practice from OCO-GOSAT collaboration>
 - Cross calibration: from prelaunch to 10-year on orbit
 - Vicarious calibration and validation at CEOS Railroad Valley and other sites
- <Dataset to be prepared by WGCV>
 - GHG vertical profile (Radiosonde, Airplane,) (partial column density improve global flux estimation)
 - Campaign dataset funded by space agencies (intense measurement, forward model validation)

Case study toward Global Stocktake 2023 and 2028 by GOSAT

1. GST 2023: global flux estimation using existing GHG satellites
2. GST 2028 goal: both global and local flux estimations using next generation satellites
3. Case study toward GST2023: local flux index from selected mega cities (5-6) of different region using existing GOSAT data

<Done> Sensitivity study

NIES NICAM XCO₂ simulation

The model can distinguish Emission (ODIAC)

(1) Vegetation (NIES VISIT)

<almost Done> Monthly average for GOSAT and GOSA-2 for selected target cities.

<To do> Information contents from GOSAT data

2 (center, upwind), 3 by 3 or 4 by 4 points are enough?

<To do> Megacity Flux Index

Simply Calculate

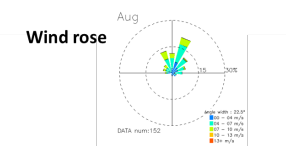
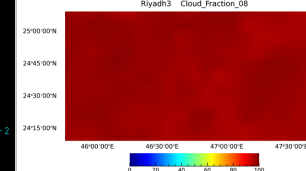
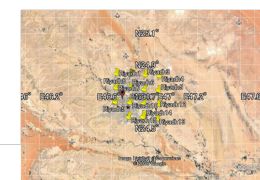
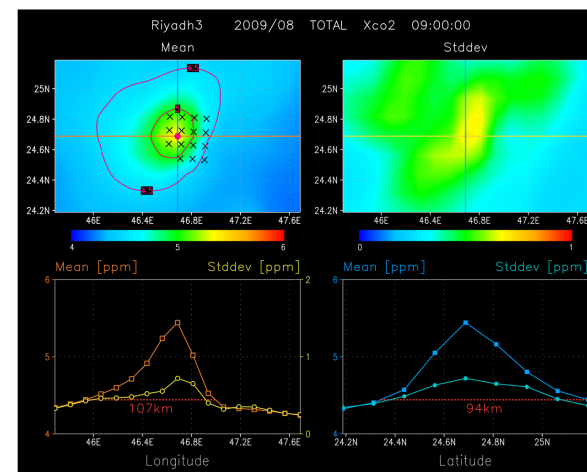
$\Delta\text{XCO}_2 \times \text{Wind speed at airports such as Riyadh Airport}$

Select reference and enhanced from GOSAT target points within the local area

<To do > Modify sampling pattern

City-level flux index of Riyadh, New York or LA, Beijing, Tokyo, New Delhi, (Tentative),

Riyadh (Aug)



Emission from Cities using 2016-2020 GOSAT data NICAM CO₂ model, GOSAT sampling pattern (4 by 4 points per orbit path) wind, clear sky ratio (Riyadh)

Activities status update of CEOS WGCV Atmospheric Composition Subgroup and the CGMS GSICS

and Towards an operational GHG monitoring system

B. Bojkov (WGCV/ACSG), R. Munro (CGMS/GSICS),

R. Lang (WGClimate GHG TT)

WGClimate 12

Status at WGClimate 10 Marrakech, Short-term:

1. Address the WP action CV-18 with respect to CO₂, CH₄ (and CO, N₂O) Level-2 products
2. Identify the current shortcomings/gaps/sustainability in GHG Cal/Val, and formulate recommendations on the medium- to long-term way forward ² i.e. specific focus on GHG Fiducial Reference Measurement (FRM)
3. Prepare a position/way forward paper to close the action CV-18 by mid-2020

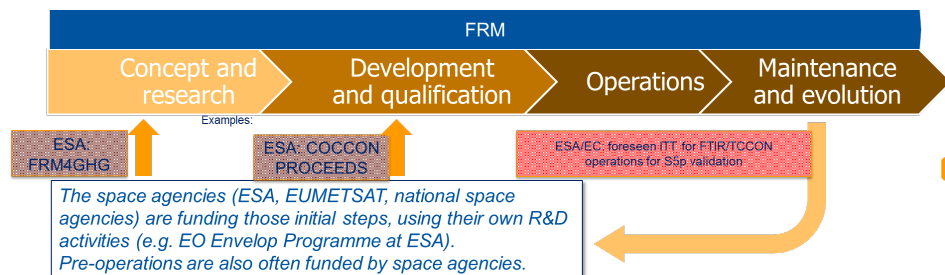
- Status at WGClimat 10 Marrakech, Medium to long term:
 4. Based on the expected outcome of the short-term, address a) improvements/gaps in the (inter-) calibration of sensors (in cooperation with GSICS), b) the level-2 validation infrastructures (GB algorithm inter-comparisons, and geographical/geophysical gaps for FRMs)
 5. Identify long-term validation needs (2025-on) and potential process study needs (e.g. aircraft campaigns to characterise sources, challenging geophysical conditions)
 6. Work towards an operational reporting on the quality of space-borne GHG measurements and the underlying Cal/Val infrastructure

Ground-based network / FRM capacity analysis for GHG Cal/Val

On Activity 2, 4b and 5:

European coordination meeting on GHG FRMs took place in April 2019 at EUMETSAT, focussing on the current status and long-term sustainability of the European Monitoring and Verification Support (MVS) capacity, for identifying the current shortcomings/gaps/sustainability in GHG Cal/Val.

E.g. through a report on European greenhouse gas column Cal/Val network sustainability by EEA, and we are currently putting together a position paper, which is planned for summer (short term objective).



European coordination meeting on GHG FRMs at EUMETSAT April 2019

Report on European greenhouse gas column cal/val network sustainability

Framework Service Contract EEA/IDM/15/026/LOT 1 for Services supporting the European Environment Agency's (EEA) implementation of cross-cutting activities for coordination of the in-situ component of the Copernicus Programme Services

Report on European greenhouse gas column cal/val network sustainability

DRAFT VERSION

Dietrich G. Feist,
Mahesh Kumar Sha,
and Thorsten Warneke

Issue: 0.9
Date: 20/11/2019



EUMETSAT

Ground-based network capacity analysis for CO2M Cal/Val

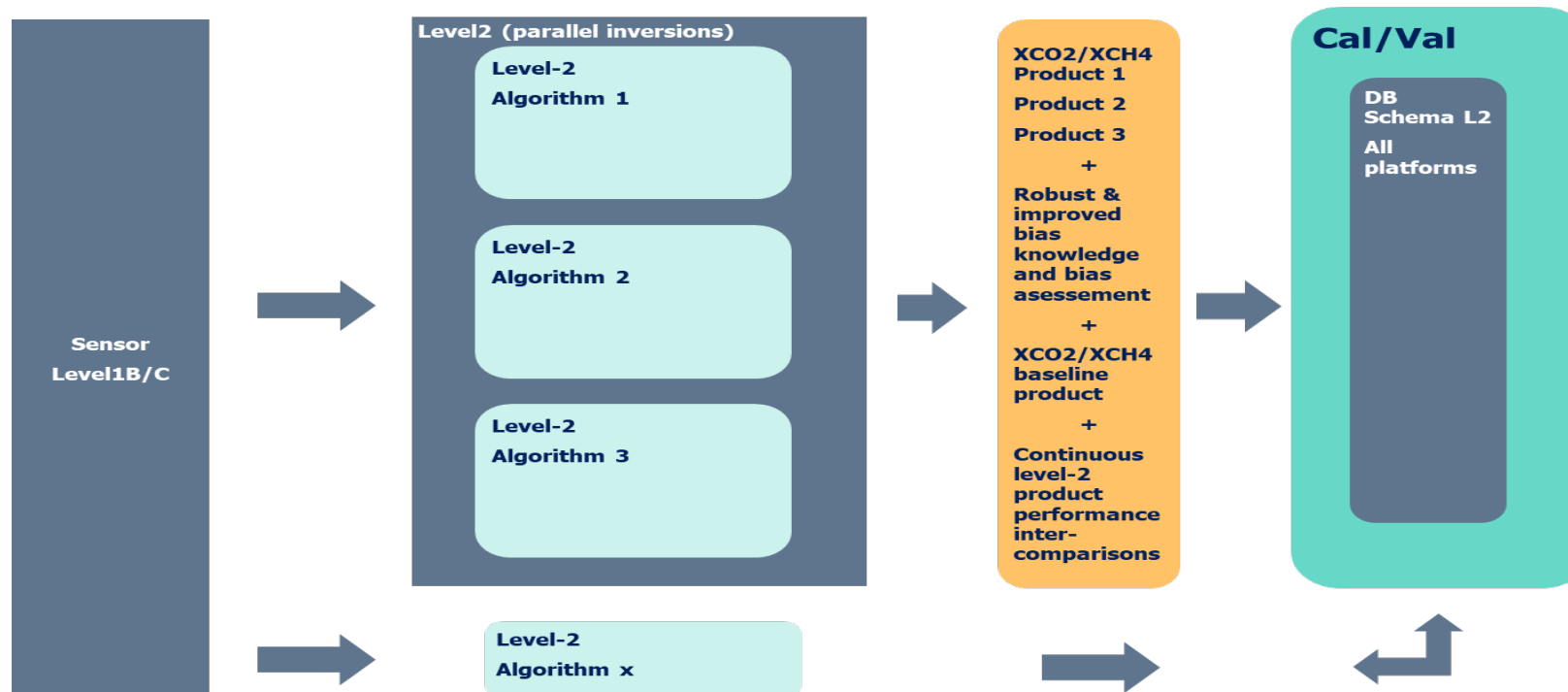
Doc.No.: EUMTSS/DOC/201116755
Issue: 1.0
Date: 20 April 2020
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GHG level-2 validation infrastructures and inter-comparisons

On Activity 1, 3 and 6:

Progressing in proposing integrated operational systems and infra-structures for continuous and robust level-2 algorithm inter-comparisons and Cal/Val, in an operational context (and in the context of CO2M – the space component of the European MVS). Short-term objective is to report on initial system engineering results 2020/21 TBC).



On Activity 4a:

GSICS - UVNS spectrometer sub-group inter-calibration related activities, with an activity in the sub-group on S5p / GOSAT inter-calibration currently delayed (as the GSICS meeting was also impacted by Covid-19) and to be restarted again soon (medium term objective).

Outlook for UVNS Spectrometer Sub-Group

Addressing the following aspects for UV – SWIR spectrometers

- On-ground characterization (workshop planned for October 2020)
- Solar calibration
- Lunar calibration
- Inter-calibration
- Polarization
- Development of common methods for use of invariant targets & vicarious calibration sites with homogeneous surface over sufficiently large area.

Way forward (general)

- The general text of the roadmap will be updated regarding the CGMS contribution / responsibility
- Some minor finishing at the objectives
- Update provided to CGMS plenary end of August 2020
- Consolidation of Annex C (work plan / activities)
 - Proposal for changes by VCs, WGs, and individual agencies (August 8, 2020)
 - Consolidation in one draft (August 15, 2020)
 - Close-out discussion end of August / beginning of September 2020
 - Approval CEOS plenary
- Roadmap is a living document: Annex B and C updated periodically
Annex B: GHG task team members; Annex C: work plan / activities

Way forward (recommendation)

- WGClimate observed in May an alteration of input
- First agreed input from WCGV during WGCV 10 (2019) (Objectives 1-6) which had been reflected in the roadmap
- Additional input during recent WGClimate meeting (highly appreciated and welcomed)
- WGCV shall align all its input for the work plan consolidation in 2020 to support a consolidated roadmap approved during CEOS plenary
- PoC of work plan: R. Husband (EUMETSAT), A. von Bargaen (DLR)