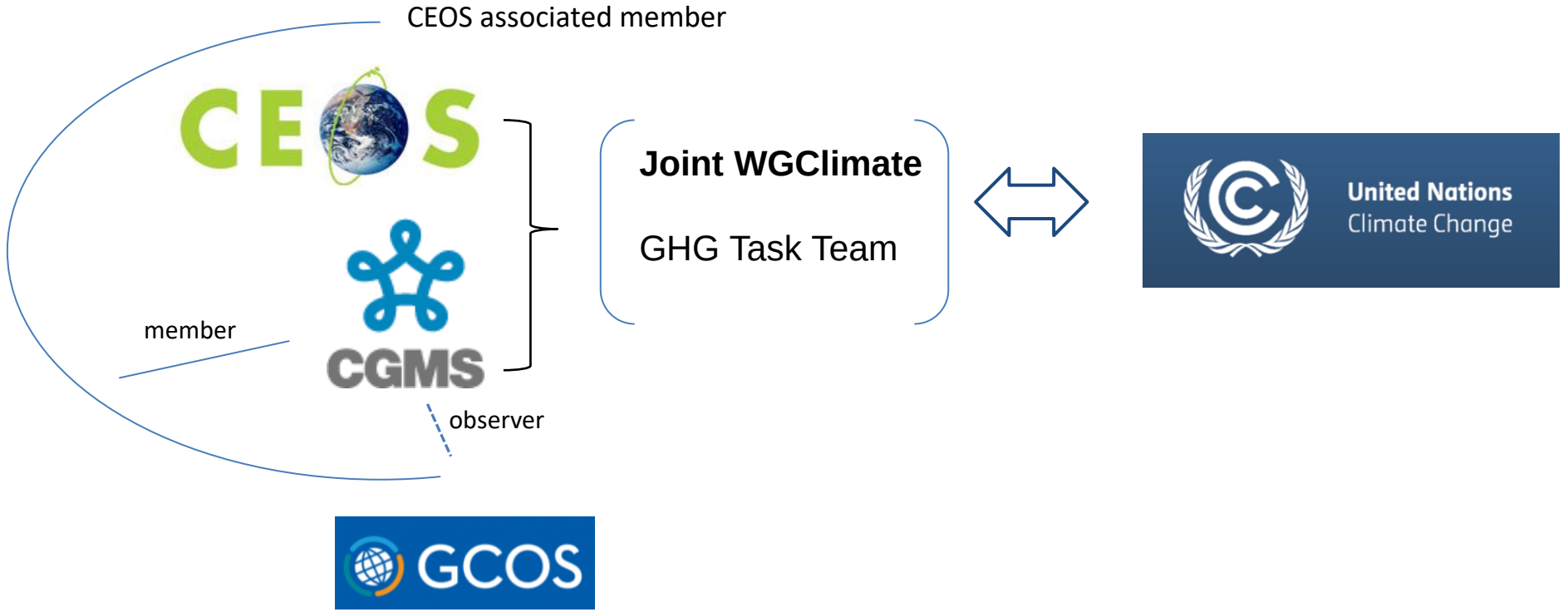
Space-based observation supporting the systematic observation of the climate system

Albrecht von Bargen (DLR), Chair Joint CEOS / CGMS Working Group on Climate

albrecht.von-bargen@dlr.de

Session 1, World Space Forum 2021, December 7th, 2021

Who we are



WGClimate
The Joint CEOS/CGMS Working Group on Climate

WGClimate core elements

- ***ECV Inventory*** permanently populated and verified. Version 4.0 (06/07 2021) will have ~1,600 climate data record entries
- ***Gap analysis*** on satellite CDR

- ***Use Cases for CDRs*** based on ECV inventory
- Demonstrates their value in climate applications and services
- Benefit: Web appearance and WMO-sponsored publication

See also under http://climatemonitoring.info

- Unambiguous ***entry point*** to UNFCCC
- Coordinating CEOS / CGMS SBSTA statements during COP and contributions to SBSTA/RSO Earth Information Day a.o.
- Representing CEOS (& CGMS) in the writing team for the synthesis paper on the coordinated contribution of the systematic observation community to the first Global Stocktake

GHG Task Team

- Guided by CEOS AC/VC white paper & *CEOS/CGMS GHG roadmap*
- Members from CEOS and CGMS major WGs
- In-situ community represented
- Corresponding activity: CEOS AFOLU roadmap

- "Space element" in ***GCOS:*** contribute to status report, support implementation plan
- ***GCOS requirements***:
  Regular dialogue with and support to GCOS on application oriented requirements
- Advocating space observations in ***GEO Climate Change Working Group***

Addressing Observational Needs of UNFCCC

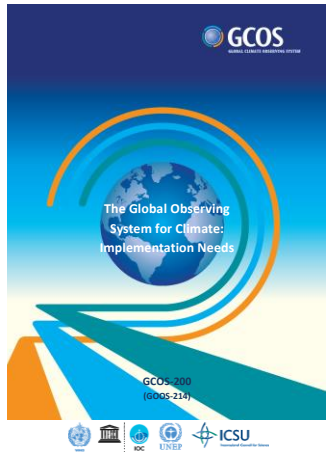
United Nations Climate Change

COP-21 Paris Agreement: Adaptation (Article 7(c)):
Strengthening scientific knowledge on climate, including research, **systematic observation of the climate system** and early warning systems, in a manner that informs climate services and supports decision-making.

Reports on Progress @ SBSTA/COP

Needs and Requirements

Coordinated Response

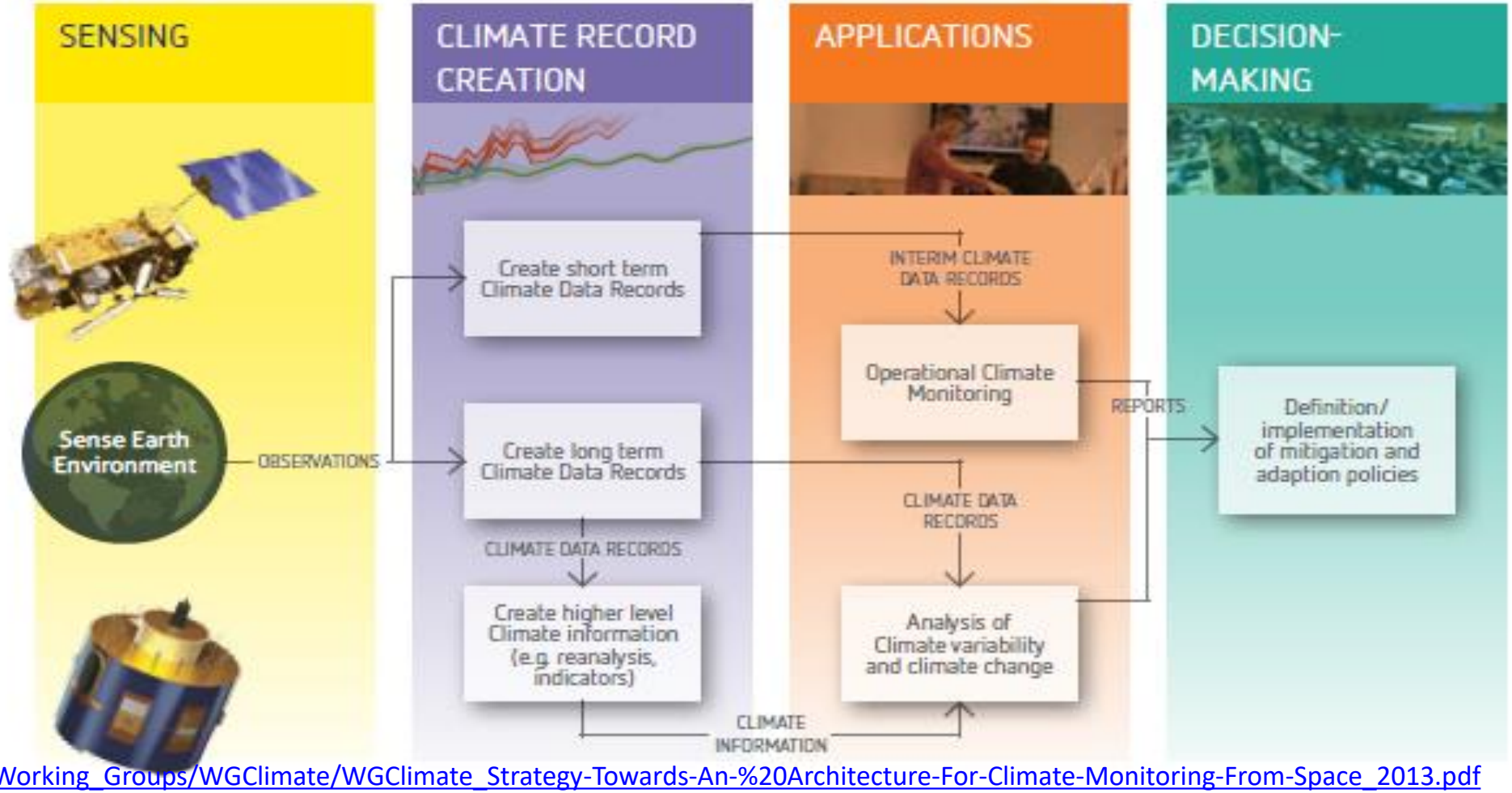


GLOBAL CLIMATE OBSERVING SYSTEM
KEEPING WATCH OVER OUR CLIMATE

WGClimate
The Joint CEOS/CGMS Working Group on Climate

WGClimate
The Joint CEOS/CGMS Working Group on Climate

The Architecture for Climate Monitoring from Space



http://ceos.org/document_management/Working_Groups/WGClimate/WGClimate_Strategy-Towards-An-%20Architecture-For-Climate-Monitoring-From-Space_2013.pdf

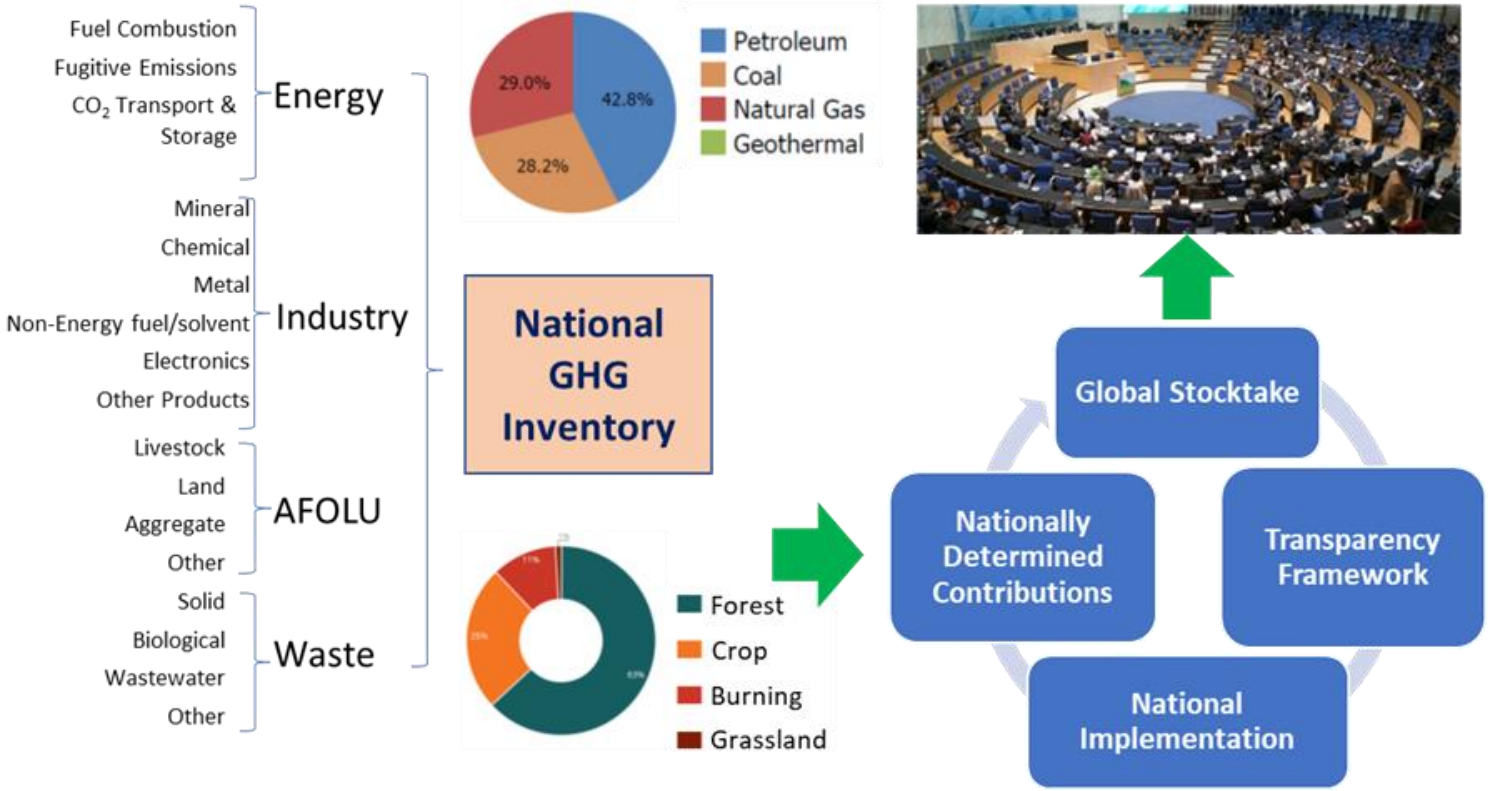
Specific Tailored Information

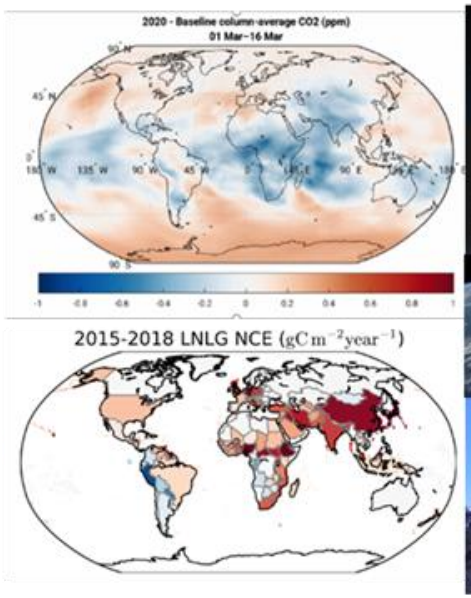
- ***Global Stocktake***
  - Mitigation: Creating Top-Down GHG Budgets / A Systems Approach
  - Mitigation: Agriculture, Forest and Other Landuse (AFOLU)

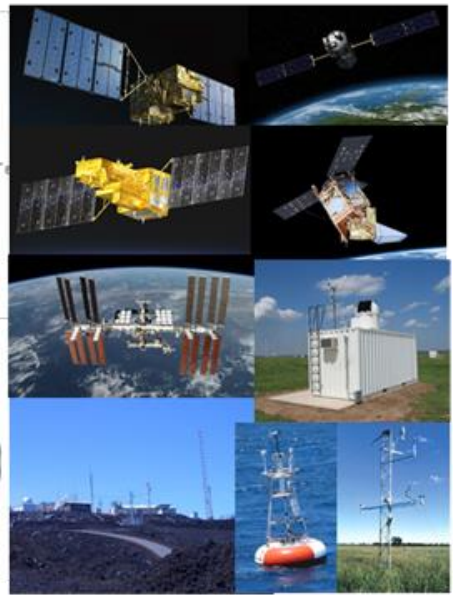
- ***Space capabilities for climate***
  - Sustained ECV Inventory approach for Climate Data Records
  - Use cases for application of Climate Data Records

Mitigation – Greenhouse Gases

Bottom-up national GHG inventories can be combined with top-down atmospheric GHG budgets to produce a more complete and transparent input to Global Stocktake







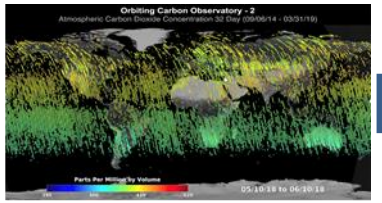
Bottom-up GHG Inventories

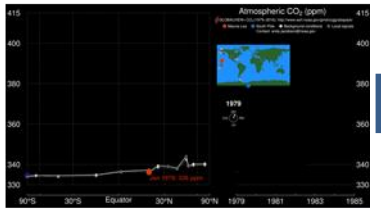
Top-down GHG Budgets

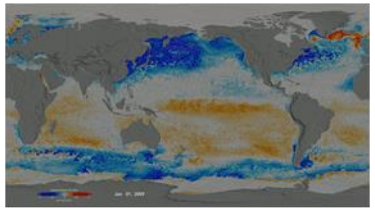
A Systems Approach to Deliver Atmospheric CO_2 and CH_4 Inventories

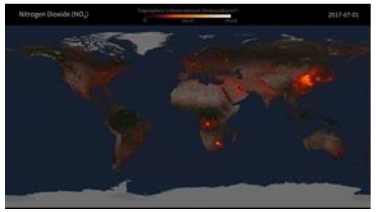
The Committee on Earth Observation Satellites

CGMS









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

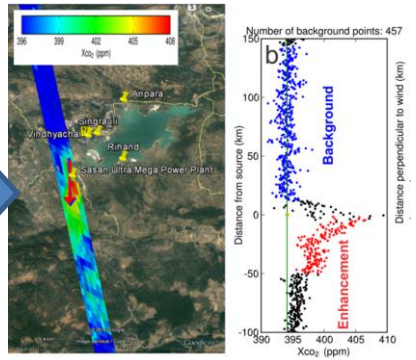
Fluxes, model parameters, emission reports, economic statistics.

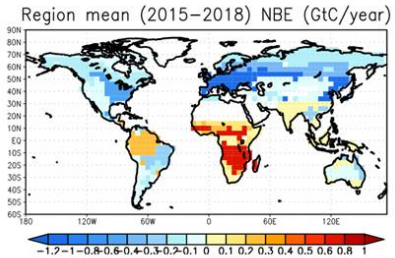
Integration & Attribution

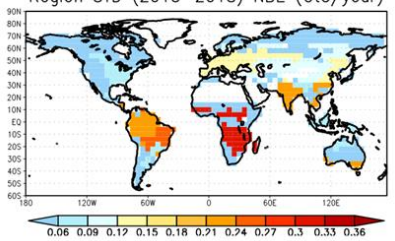
- **Estimation system** Data assimilation and uncertainty estimation
- **Models** Transport, land & ocean carbon cycle, fossil fuel emissions.

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







WGClimate

The Joint CEOS/CGMS Working Group on Climate

Supporting the Global Stocktakes

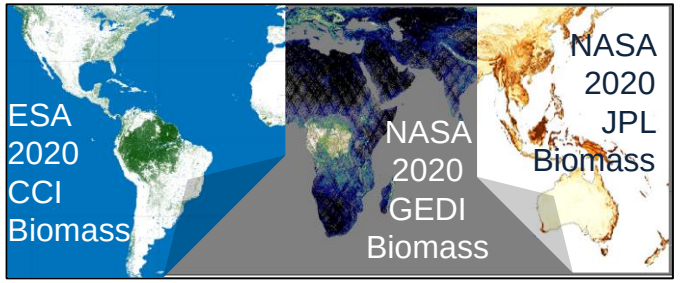
PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

2015 2017 2019 2021 **Global Stock Take 1** using inventories through 2021 **2023** 2026 **Global Stock Take 2** using inventories through 2026 **2028**

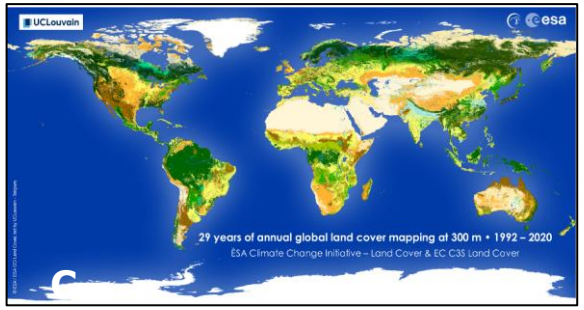
- **CEOS-CGMS GHG Whitepaper** (2017)
- **Pilot Inventory requirements** (2019)
- **Pilot atmospheric CO_2/CH_4 inventory** (2021)
- **Refined atmospheric GHG requirements** (2023)
- **Initial Operational GHG Constellation Deployment** (2026)
- **Refined atmospheric GHG inventory** (2026)

Mitigation - AFOLU

Agriculture, Forestry and Other Land Use (AFOLU) contributes the second largest source of emissions (after fossil fuel use) globally, and is the primary source of emissions in many developing nations

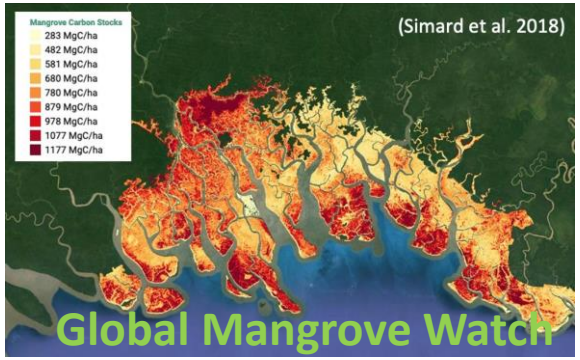


Aboveground Biomass Density (Mg/ha)

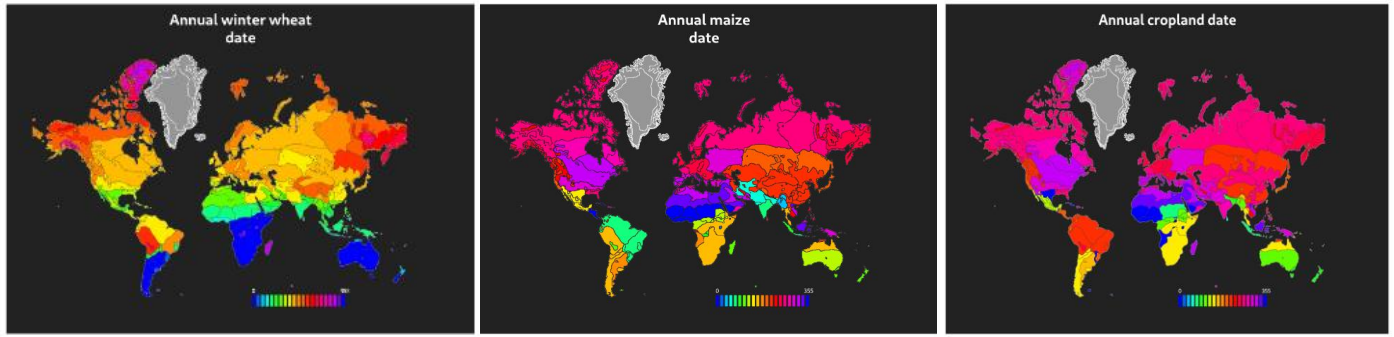


Land Cover

Forests



Mangroves



Agriculture

40+ Years Global Land Monitoring Datasets available

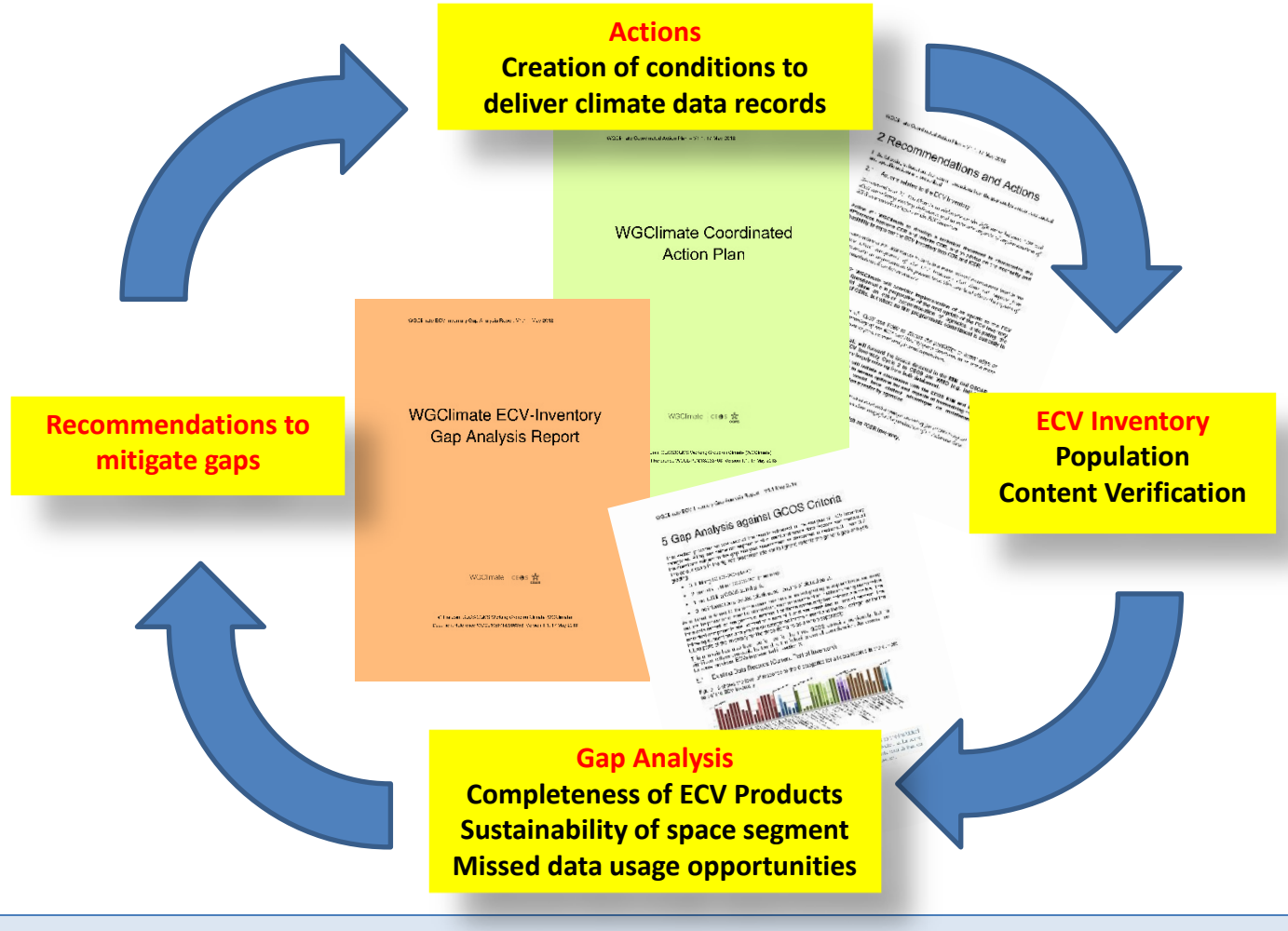
Interface to and Feedback from External Communities

Engagement with external stakeholders and end users is fundamental to the success of the systems approach:

- Engagement with the emission inventory community is critical to the iterative feedback approach
  - Through existing international coordination mechanisms (e.g. Global Emissions InitiAtive - https://www.geiacenter.org)
  - Through working with champion users – «beta testers»
- Continued engagement with international policy frameworks, i.e. UNFCCC/SBSTA, IPCC TF I: Partner in the Synthesis Report of the Observation Community for the GST
- Engagement with technical entities at international level, i.e. WMO IG^{3}IS and Joint Programmes supporting the Convention, i.e., GCOS, as well as the broader modelling community
- Continuous presence at COP and SBSTA
  - CEOS / CGMS statement at SBSTA opening session during COP
  - Earth Information Day and other side events

Sustaining Space Capabilities for Climate

ECV Inventory & Gap Analysis



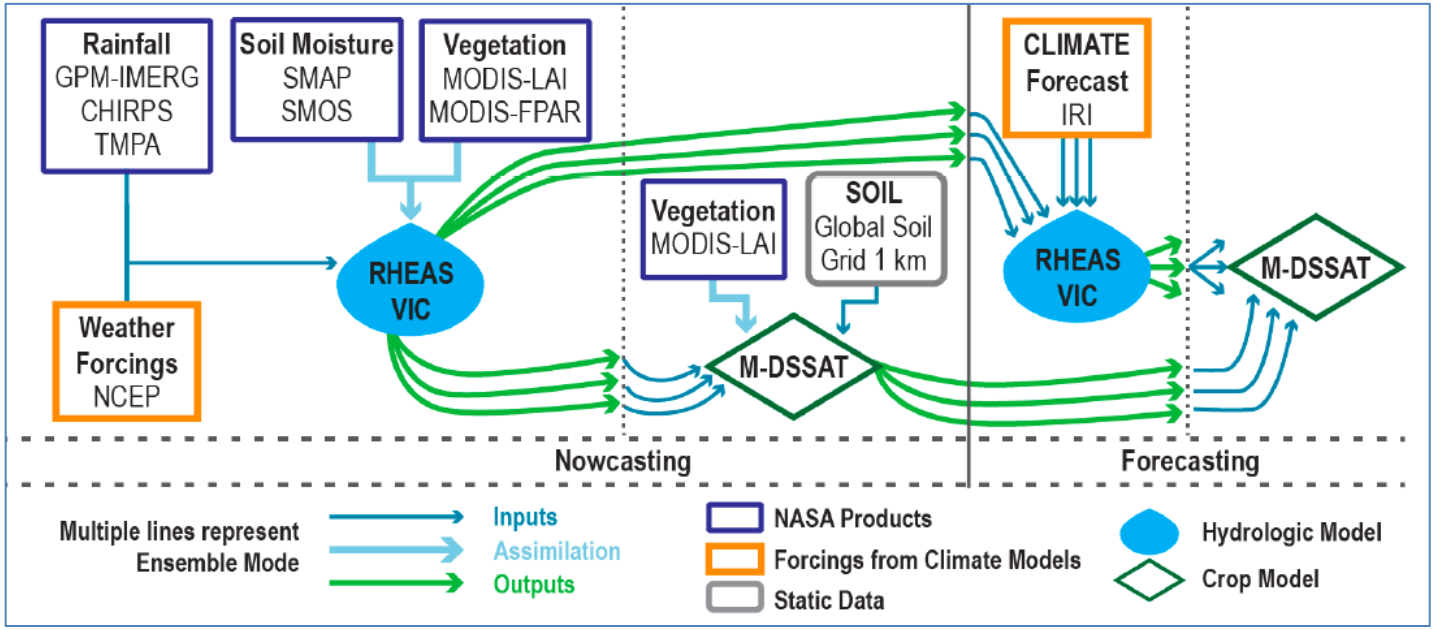
- The ECV Inventory fully describes *current* and *planned* provision of space-based ECV data sets
- WG Climate gap analysis used to address actions
- Data access is free and open for more than 98% of the data records
- Basis for GCOS Status Report contribution
- The 2021 Inventory fills previously identified gaps (supporting also the Global Stocktake)
- Feedback to GCOS, hence to UNFCCC
- ***Analysis of Global Stocktake CDR-related needs may extend the variable set beyond current GCOS-listed ECVs***
  (examples: mangroves, agriculture, a.o.)
- Special needs on
  Re-processing, calibration, and validation

Sustaining Space Capabilities for Climate
Use Cases of CDRs Aiding Decision-Making

Use case objectives

- Demonstrate the value of Climate Data Records (CDRs) for decision making, including agriculture, coastal/flood management, food security, mitigation/adaptation, disaster risk reduction, and protocol monitoring, etc.
- Support capacity building by providing use cases for training activities and receiving use cases from them.
- Achieve a better understanding of the application needs.

Climate data records from satellite observations are used as input to hydrologic model (VIC) and crop model (DSSAT) to provide food security analysis for advance planning.



Take Away Messages

- Use of space-based observations of documented quality can support Global Stocktakes by providing evidence for the success of the implementation of the Paris Agreement
- The GHG constellation architecture follows a systems approach, bringing together top-down and bottom-up emission estimates for carbon dioxide and methane. Space agencies and service providers will grant free and open web-based access to the top-down data and derived information for use by Parties in support of the development of their national inventories
- Space agencies provide long-term observations for 35 of the 37 GCOS ECVs accessible by satellite, including Carbon Cycle ECVs such as GHGs, aboveground biomass, and permafrost. Data access is globally free and open for more than 98% of the data records. Finally: such CDRs provide detailed insight in climate observations
- Analysis-related Global Stocktake will lead to an extension of the ECV inventory portfolio beyond the current GCOS ECV list as supportable by available space-borne observation capabilities
- Use cases from satellite observation climate data records aids decision-making in various application areas

Back-up slides

The Space Architecture Exploits the Evolving Fleet of CO_2 and CH_4 Satellites

- **Space agencies have supported several pioneering space-based GHG sensors**
  - SCIAMACHY on ESA's ENVISAT
  - 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, Japan's GOSAT-2 TANSO-FTS-2 and NASA's ISS OCO-3
- **Under development**
  - CNES MicroCarb, CNES/DLR MERLIN, Copernicus CO2M Constellation, Japan's GOSAT Folow-on, NASA's GeoCarb, CarbonMapper, DLR CO2Image, …..

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 to 10 satellites in LEO with
  - Broad (> 250 km) swaths with a footprint size < 4 km^2
  - Single sounding random error < 0.5 ppm
  - 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
  - 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