Committee on Earth Observation Satellites

Space-based Atmospheric CO_2 and CH_4 Inventories to Support the Global Stocktake

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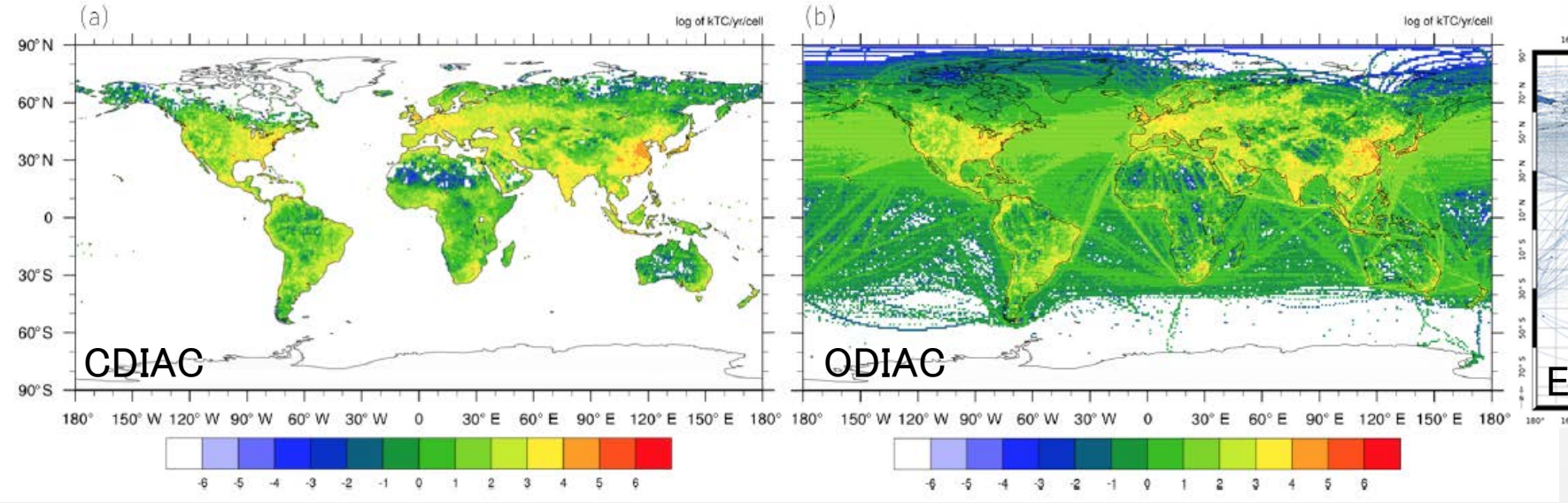
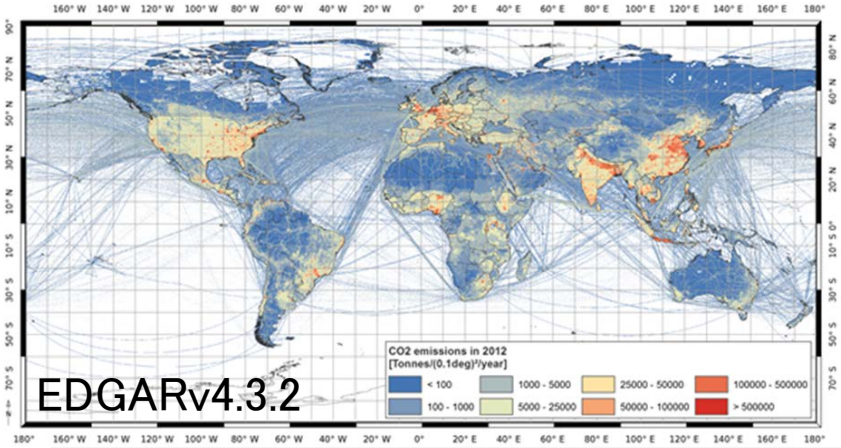
Atmospheric Inventories of CO_2 and CH_4

- Ground-based, airborne, and space-based atmospheric CO_2 and CH_4 measurements are now being assimilated into atmospheric transport models to estimate emissions on scales spanning individual large power plants to nations
- The objective is to develop top-down global inventories for these two gases that:
  - reduce uncertainties in national emission inventory reports
  - identify additional emission reduction opportunities
  - provide nations with timely and quantified guidance on progress towards their emission reduction targets and pledges (Nationally Determined Contributions, NDCs), and
  - track changes in the natural carbon cycle caused by human activities (deforestation, degradation of ecosystems, fire) and climate change.

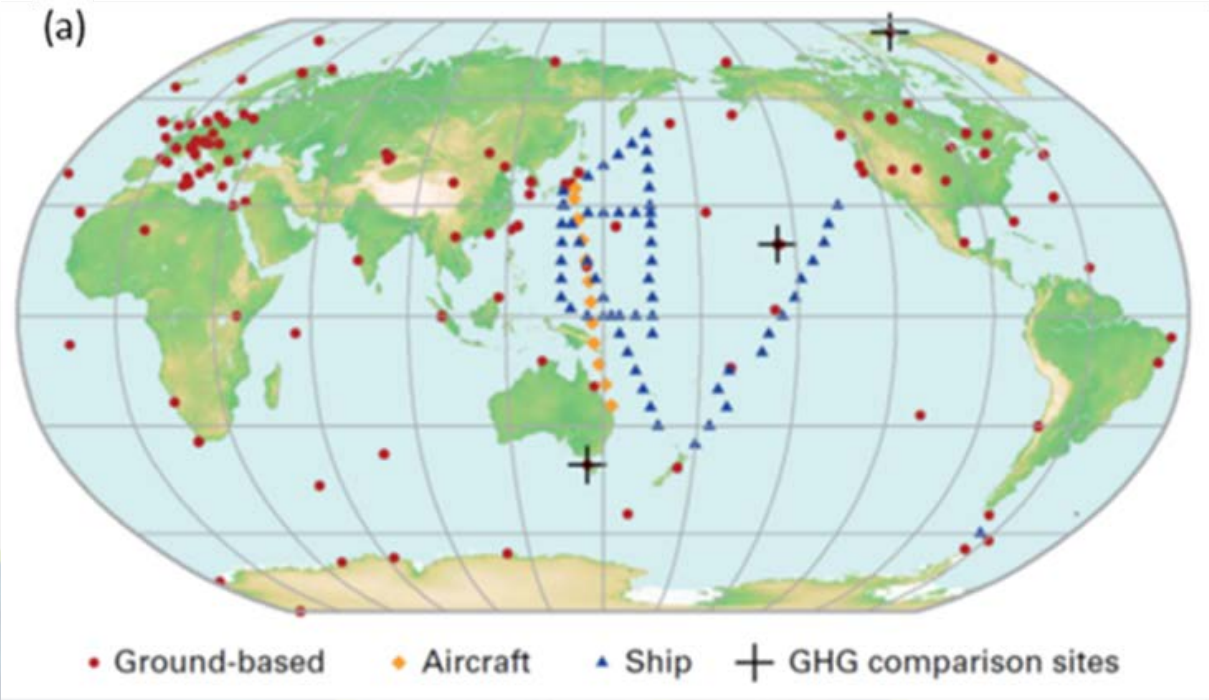
National Statistical Inventories Provide the Basis for the Stocktakes

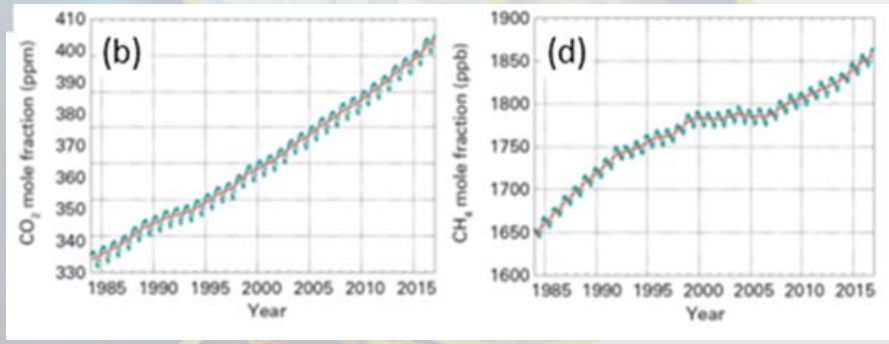




- National statistical and scientific inventories provide source-specific estimates CO_2 and CH_4 emissions into the atmosphere for most, but not all anthropogenic sources.
- They provide less insight into the natural carbon cycle or its changes due to anthropogenic activities and climate change.

A Role for Atmospheric CO_2 and CH_4 Inventories





Ground and space-based atmospheric measurements of CO_2 and CH_4 complement Statistical Inventory methods by providing an integral constraint on the net amount of these gases that are added to or removed from the atmosphere by all processes.

Ground-based measurements from the WMO Global Atmospheric Watch (GAW) Network and its partners provide the most accurate available estimates of atmospheric CO_2 and CH_4 concentrations and their trends on global scales, but their spatial coverage and resolution are limited.

Collecting GHG Measurements from Space: the Evolving Fleet

Space agencies have supported several pioneering space-based GHG sensors:

- German-Dutch-Belgian 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.

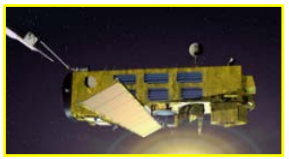
Other sensors just added to the fleet:

- Japan's GOSAT-2 TANSO-FTS-2 and NASA's ISS OCO-3

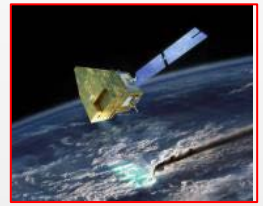
Others are under development:

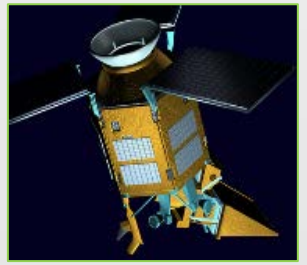
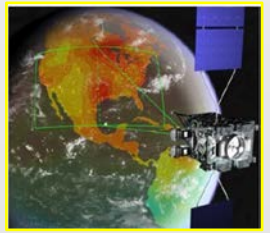
- CNES MicroCarb, CNES/DLR MERLIN, NASA's GeoCarb, Japan's GOSAT Follow-on, and the Copernicus CO2M

These spacecraft demonstrate the measurement approach, but more resolution, coverage, and resiliency are needed for an operational system.

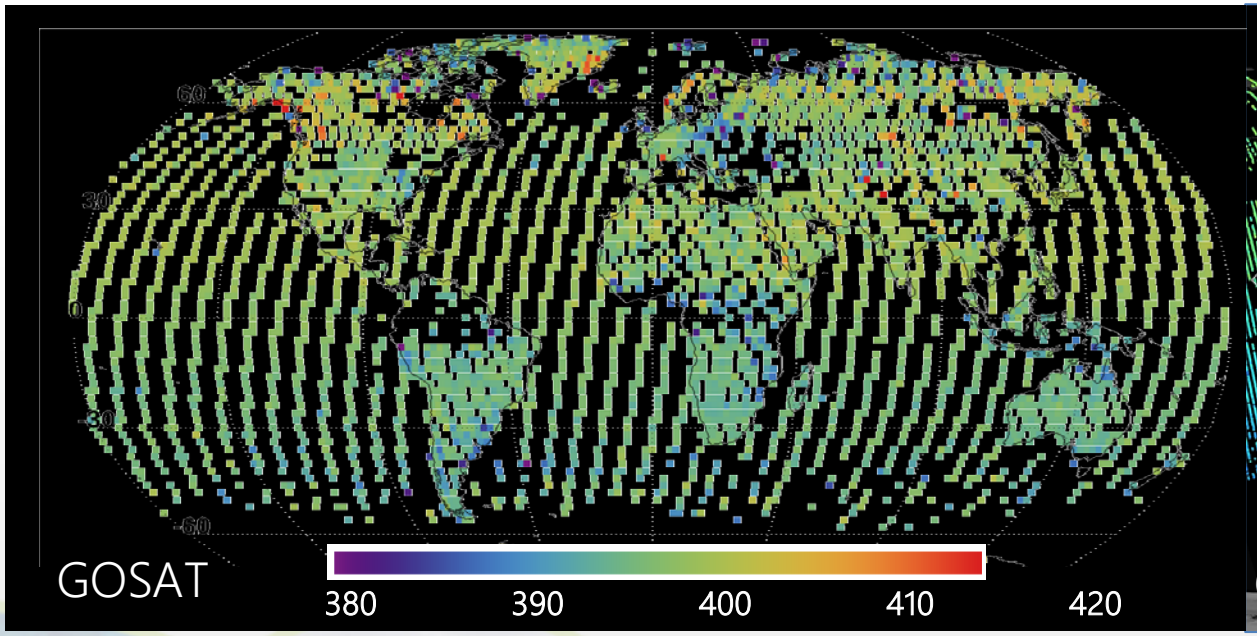


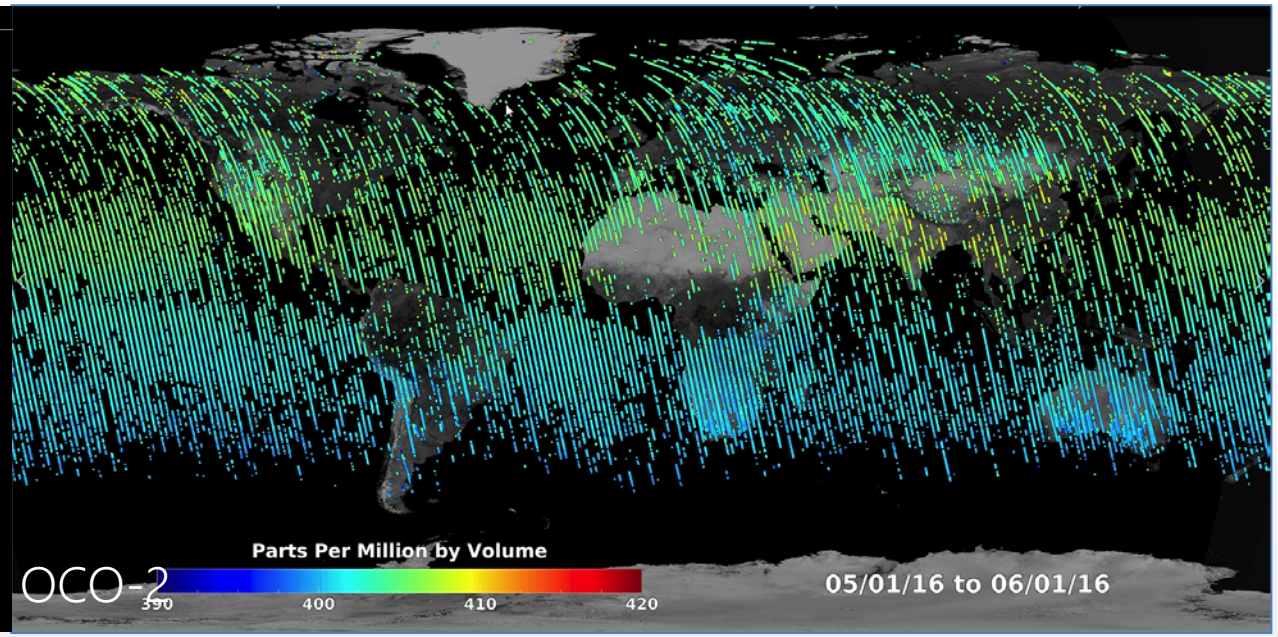


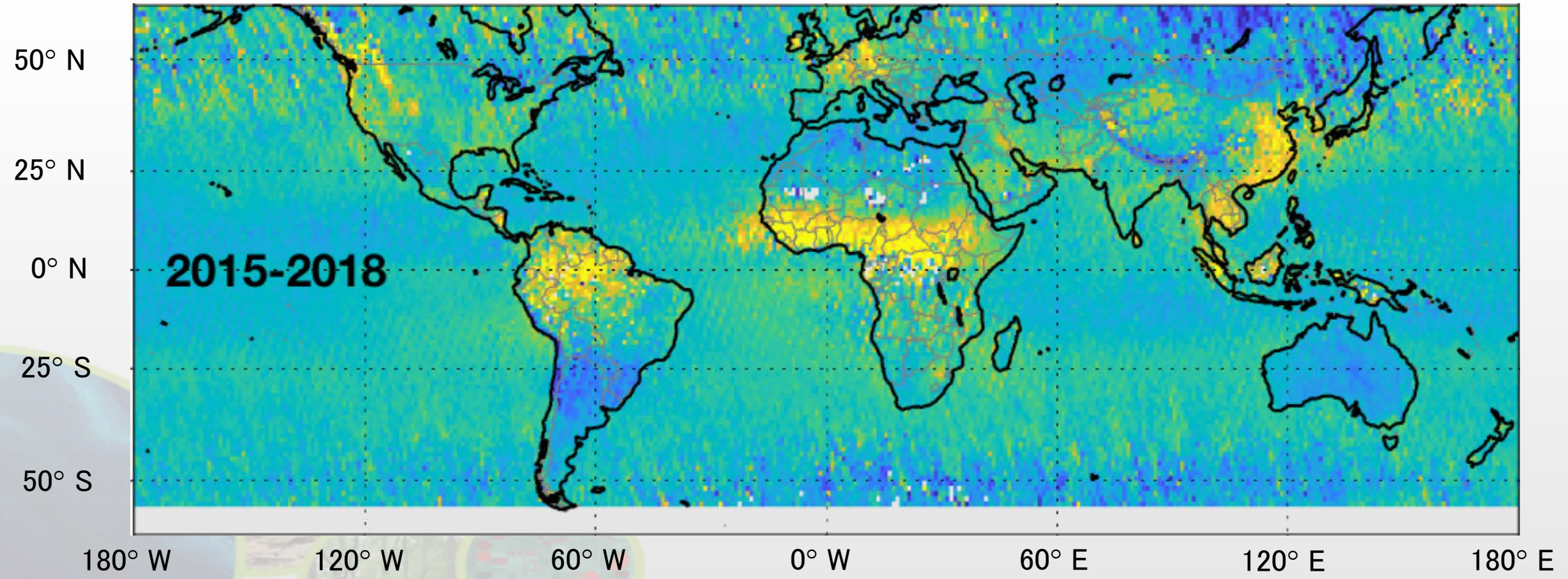
Space-based CO_2 and CH_4 Measurements Provide Increased Coverage and Resolution





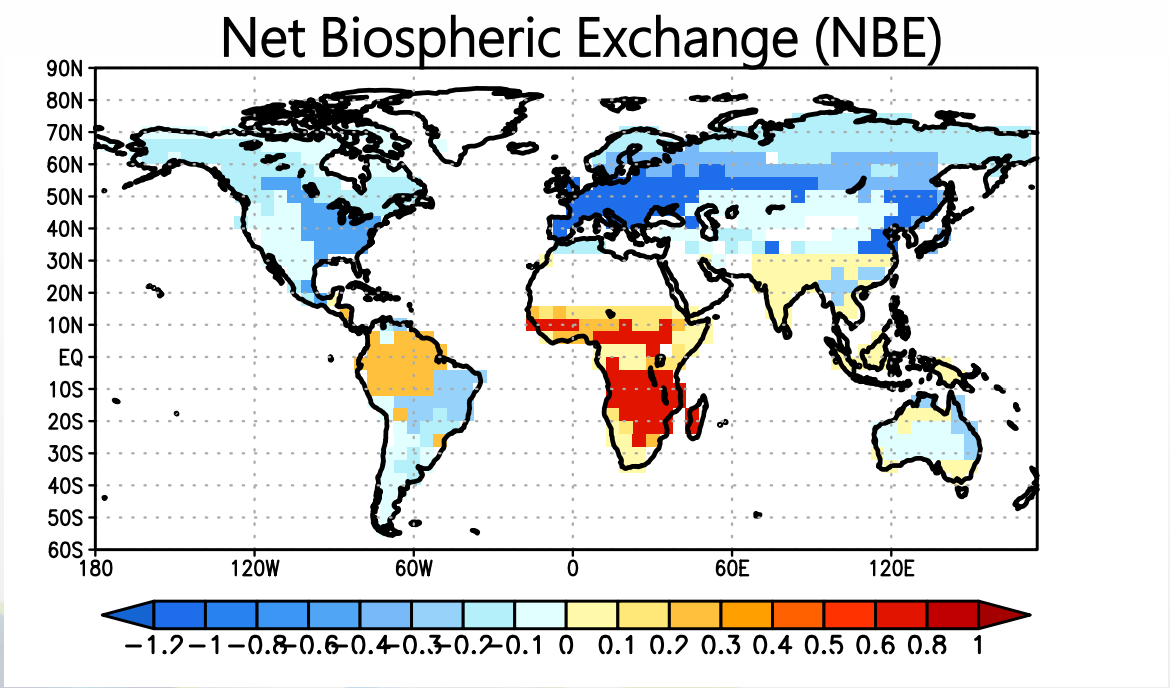
Spatially-resolved estimates of the column-averaged CO_2 and CH_4 dry air mole fractions, XCO_2 and XCH_4, like those from NASA's Orbiting Carbon Observatory-2 (OCO-2) and Japan's Greenhouse gases Observing SATellite (GOSAT) are less precise and accurate than ground-based *in situ* data but provide high spatial and temporal resolution and greater coverage of the globe.

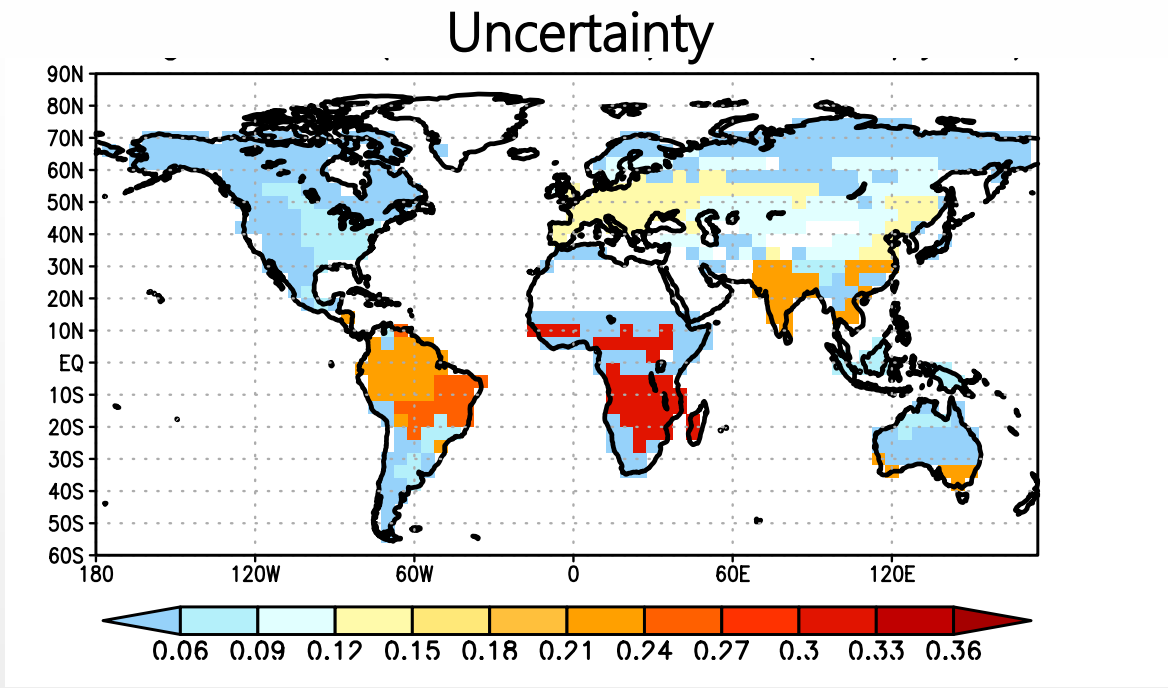
Space-based Measurements provide maps of natural and anthropogenic CO_2 emissions



Hakkarainen et al., 2019

Gridded Atmospheric CO_2 Inventories

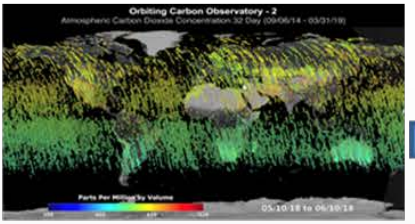


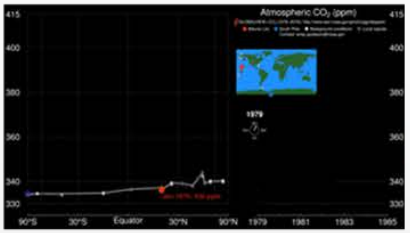


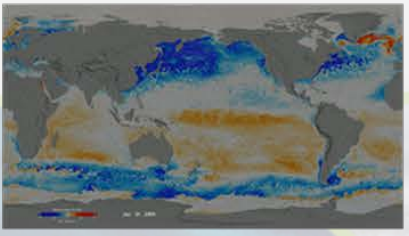
J. Liu et al., CMS Flux Project, 2019

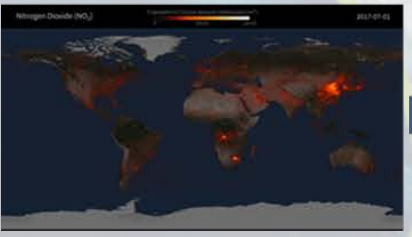
Flux Inversion models that assimilate space-based CO_2 estimates as well as ground based *in situ* measurements describe some aspects of the atmospheric CO_2 emissions and uptake better than conventional, bottom-up statistical inventories – such as the total Net Biospheric Exchange (NBE). They also provide estimates of uncertainty.

A System Approach for Atmospheric Inventories









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

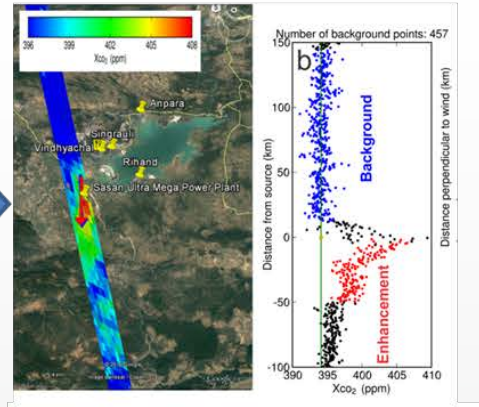
Fluxes, model parameters, emission reports, economic statistics.

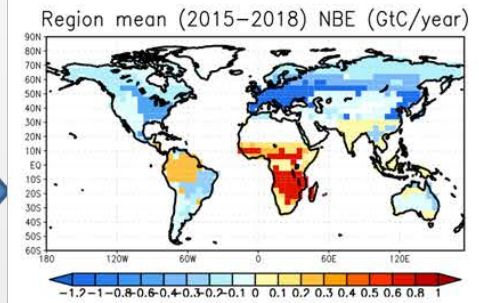
Integration & Attribution

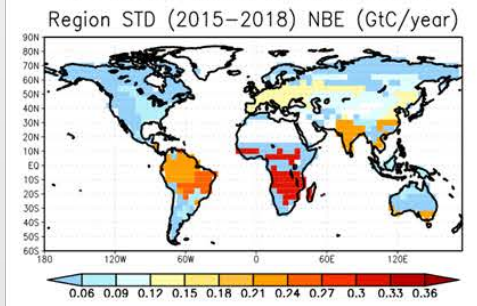
- **Estimation system** Data assimilation and uncertainty estimation
- **Models** Transport, land & ocean carbon cycle, fossil fuel emissions.

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







Measurements | Models | Products

Implementing Space-Based Atmospheric Inventories for Informing Stocktakes

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 lessons learned from the prototype flux product to refine requirements for a future, purpose-built, operational, atmospheric constellation that better addresses the inventory process in time to support the 2028 global Stocktake.