Pilot National-scale Estimates of Carbon Dioxide and Methane Emissions and Removals from Space-based Measurements

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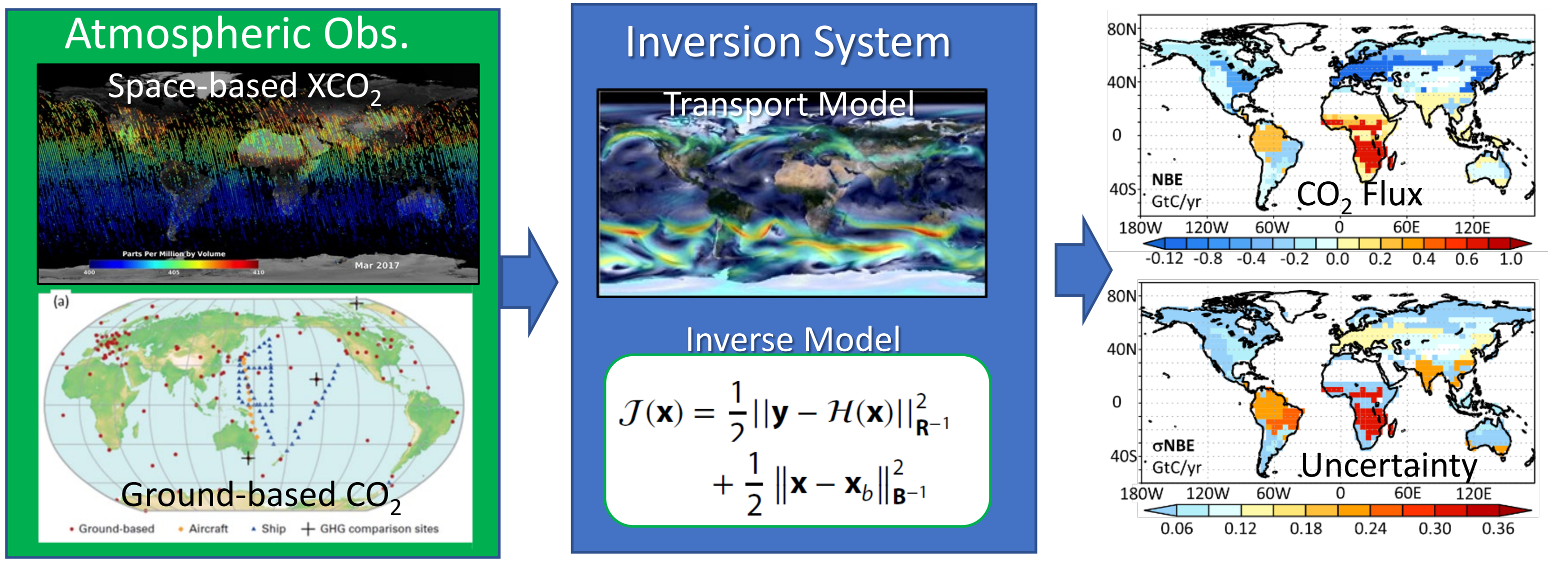
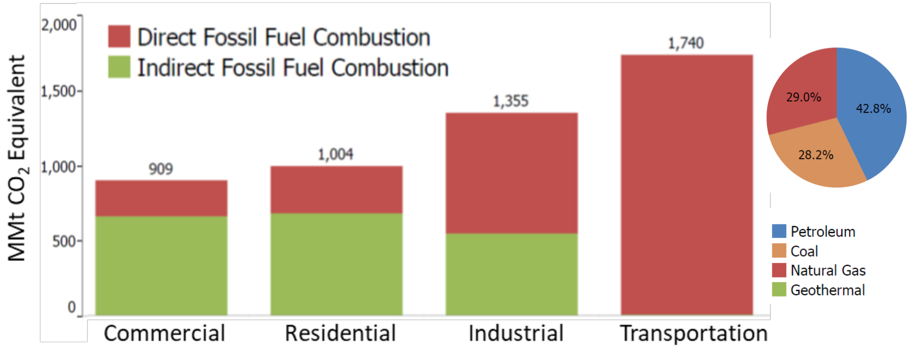
Combining Bottom-up and Top-down Inventories to Support the Global Stocktake



Top-Down Budgets

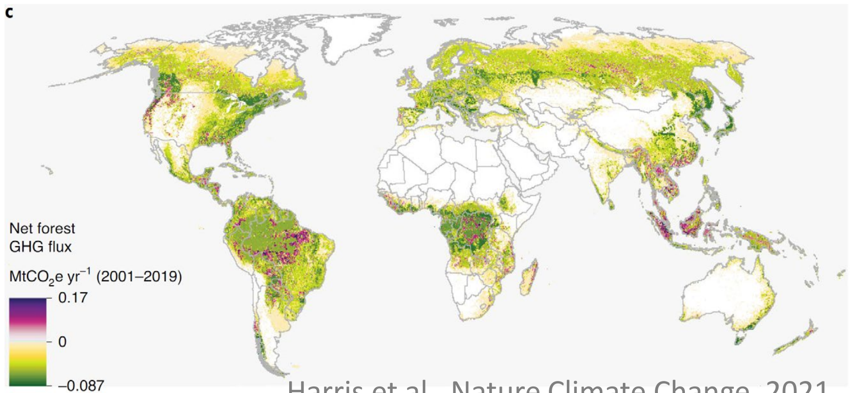
Observations of atmospheric CO_2 and CH_4 provide an integral constraint on emissions and removals to

- Track emission hot spots and rapid changes
- Detect emission changes from the natural carbon cycle caused by human activities and climate change



Bottom-Up Inventories

- Sector-specific estimates of emissions from known sources.
- Earth Observations play a critical role for tracking land use change.



Harris et al. Nature Climate Change, 2021

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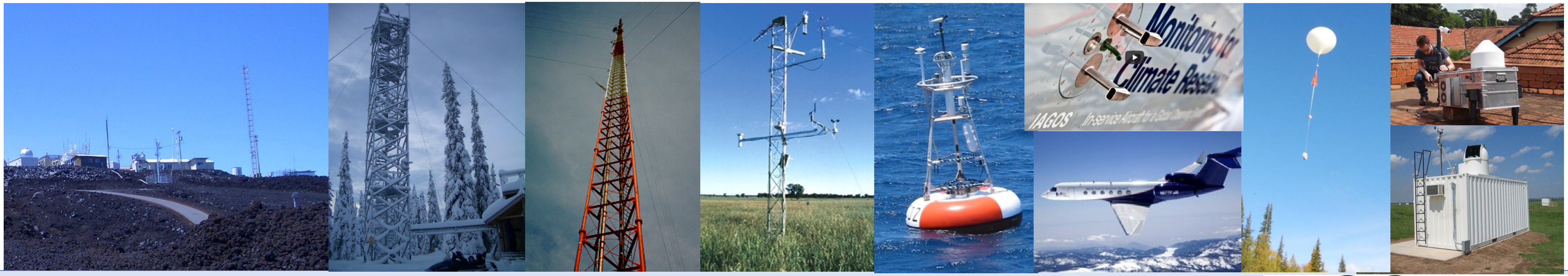
Growing Capabilities in Ground-based and Space-based Atmospheric GHG Measurements

CGMS

Space-based measurements of CO_2 and CH_4 from a growing fleet of satellites are less precise and accurate but provide high spatial and temporal resolution and greater coverage of the globe.

Ground-based measurements from the WMO Global Atmospheric Watch (GAW) Network and its partners provide accurate estimates of atmospheric GHG concentrations and their trends on local and global scales.



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Several GHG Satellites are Coming on Line

Satellite, Instrument	Agency/Origin	CO_2	CH_4	Public	Private	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GOSAT TANSO-FTS	JAXA-NIES-MOE/Japan	●	●	●											
OCO-2	NASA/USA	●		●											
GHGSat-D - Claire	GHGSat/Canada		●		●										
Sentinel 5P TROPOMI	ESA/Europe		●	●											
GaoFen-5 GMI	CHEOS/China	●	●	●											
GOSAT-2 TANSO-FTS-2	JAXA-NIES-MOE/Japan	●	●	●											
OCO-3	NASA/USA	●													
GHGSat C1/C2 - Iris, Hugo	GHGSat/Canada		●		●										
MethaneSAT	EDF/USA		●		●										
MicroCarb	CNES/France	●		●											
Carbon Mapper[1]	Carbon Mapper LLC/USA	●	●	●	●										
GeoCarb	NASA/USA	●	●	●											
MetOp Sentinel-5 series	EC Copernicus/Europe		●	●											
GOSAT-GW	JAXA-NIES-MOE/Japan	●	●	●											
MERLIN	DLR/Germany-CNES/France		●	●											
CO2M	EC Copernicus/Europe	●	●	●											

CO_2+CH_4 | CO_2 Only | CH_4 Only

Extended Mission | Planned | Phased Deployment

[1]Carbon Mapper is a public/private partnership between California and Carbon Mapper LLC.

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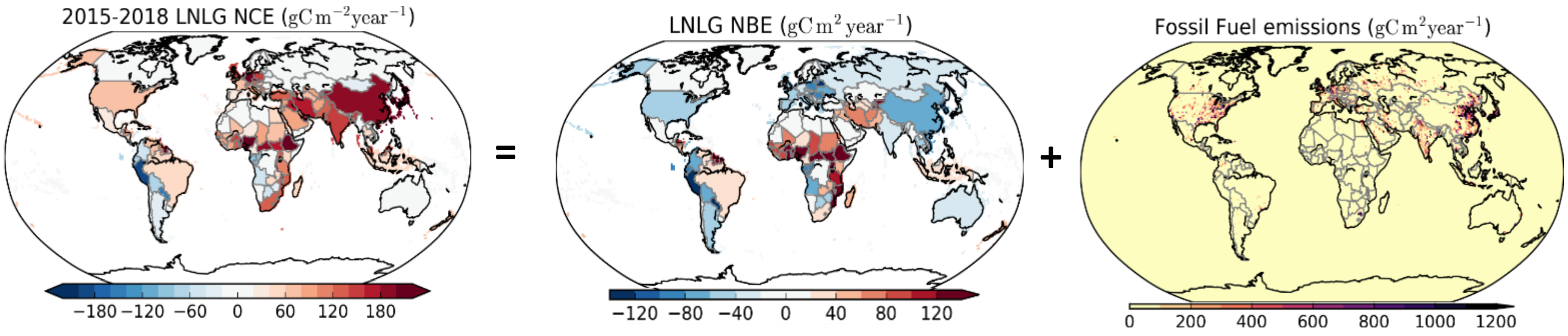
Creating Top-down CO_2 Budgets

Measurements of atmospheric CO_2 from Ground-based networks and Spacecraft are being analyzed with atmospheric inverse methods to estimate their net emissions and removals from human activities and the natural biosphere and ocean.



Net Carbon Exchange (NCE) = **Net Biospheric Exchange (NBE)** + **Fossil Fuel**

CO_2 Emissions/Removals are Derived from Carbon Stock changes by Sector and Country

Committee on Earth Observation Satellites

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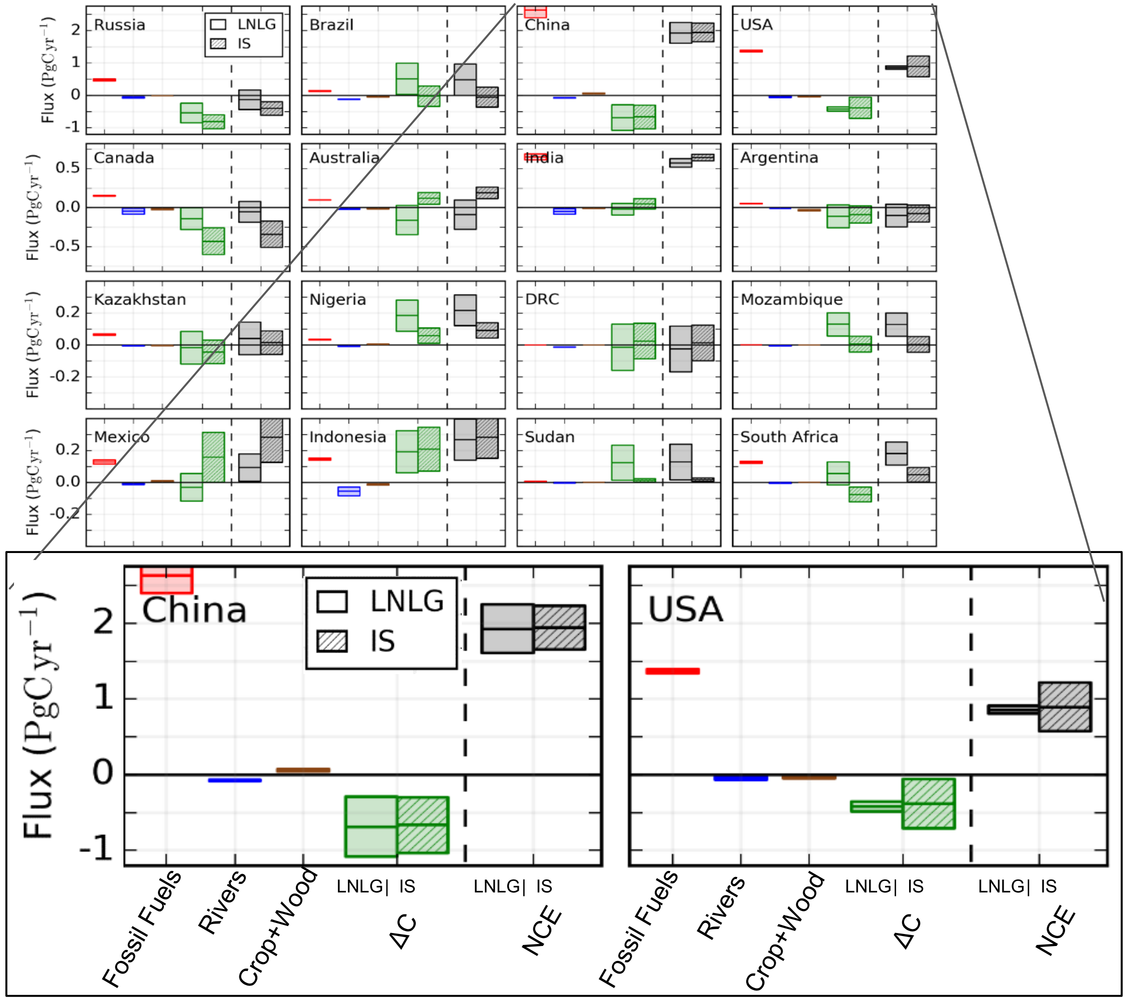
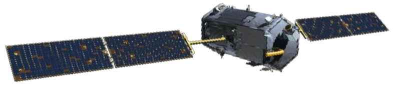


Plots by Brendan Byrne (NASA/JPL) and the OCO-2 Flux MIP

CO_2 emissions, expressed as **Net Carbon Exchange (NCE)** between surface and atmosphere derived from *in situ* (IS) and OCO-2 (LNLG) CO_2 data



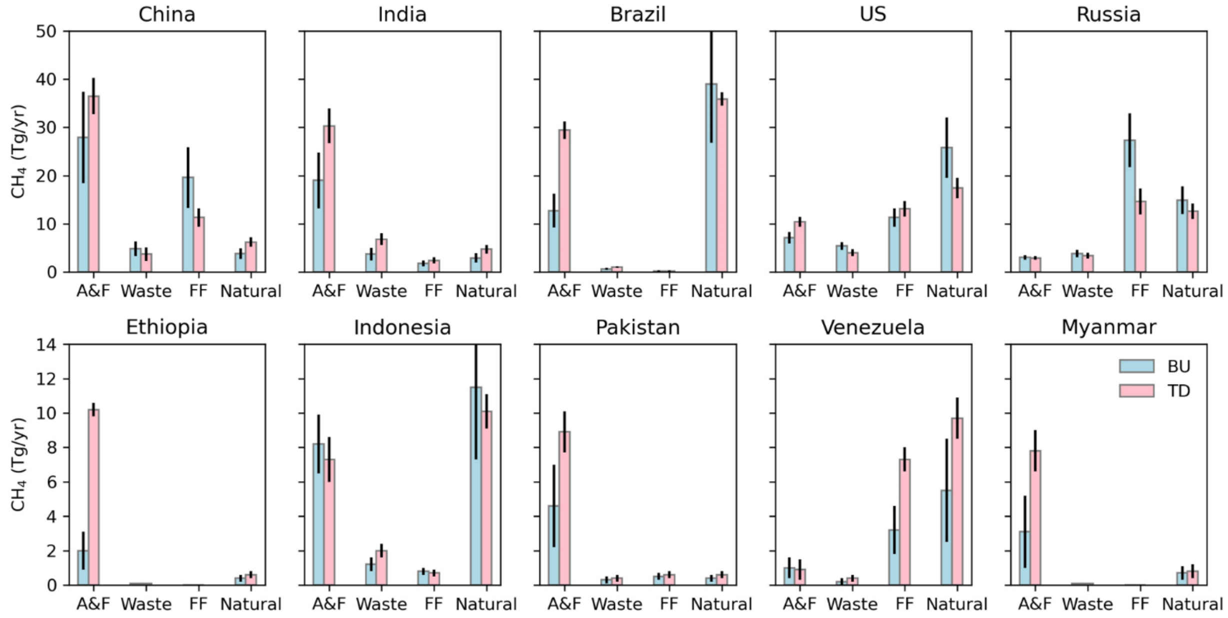
- NCE can be further subdivided into **fossil fuel** emissions (FF), **lateral carbon fluxes** due to rivers, crop, and wood, and **changes in land carbon (ΔC):**

$$\Delta C = NCE - FF - River_{lateral} - Crop{+}Wood_{lateral}$$

- **ΔC can be compared with bottom-up estimates of carbon stock changes by Agriculture, Forestry and Other Land Use (AFOLU)**

CH_4 Emissions by Sector and Country

- Top-down estimates of CH_4 emissions derived from GOSAT measurements:
  - Can resolve total emissions for about 58 countries
- Top 5 emitting countries emit about half of all anthropogenic CH_4 emissions
  - Consistent with bottom-up inventory data
- Most emissions are from the agricultural sector, primarily livestock



A&F = Agriculture and Fires

Waste

FF = Fossil fuels (coal, oil, gas)

N = Natural (Wetlands and seeps)

Plots by John Worden and the CMS-Flux Team (NASA/JPL)

Tracking Emissions from Localized Hot Spots

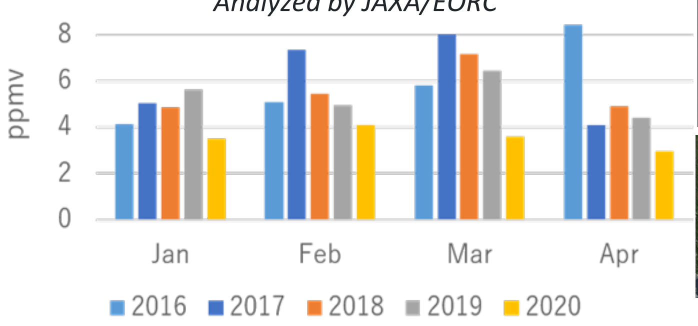
Pilot products are also being developed to track emissions from localized sources including large urban areas, power plants and oil fields

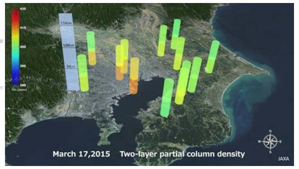
- The GOSAT team accelerated the development of an upper/lower tropospheric product to track effects of COVID-19 lockdowns on emissions from large urban areas
- The OCO-2 and TROPOMI teams are combining CO_2 and NO_2 to quantify emissions from powerplants and large urban areas
- The TROPOMI team is tracking methane emissions from fossil fuel extraction, and collaborating with the GHGSat team to track intense plumes

Existing capabilities do not yet have the resolution or coverage needed to track all local sources, but can illustrate methods for tracking emissions from hot spots for future GST's

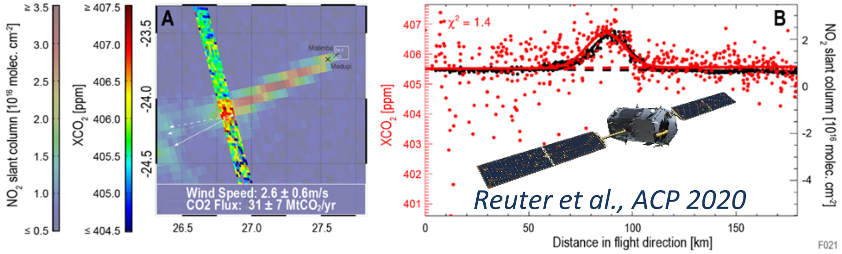
GOSAT observes CO_2 over Tokyo

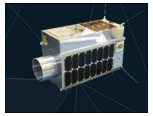
Analyzed by JAXA/EORC

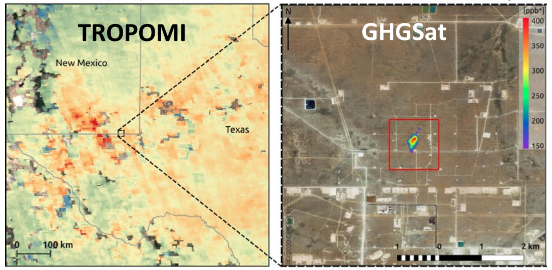




OCO-2 XCO_2 and TROPOMI NO_2 combined to quantify CO_2 emission by large South African power Plants







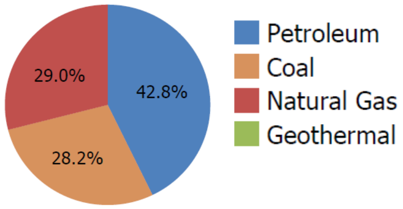
TROPOMI and GHGSat observe CH_4 emissions over Texas oil fields

Zehner et al. (IWGGMS-16, 2020)

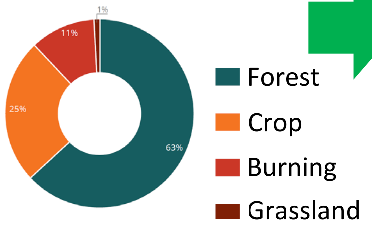
Pilot CEOS GHG Products for the GST #1

The primary objective of these pilot top-down GHG products is to start a conversation with stakeholders and users to establish the utility and best practices for combining bottom-up and top-down methods to enable a more complete and accurate Global Stocktake

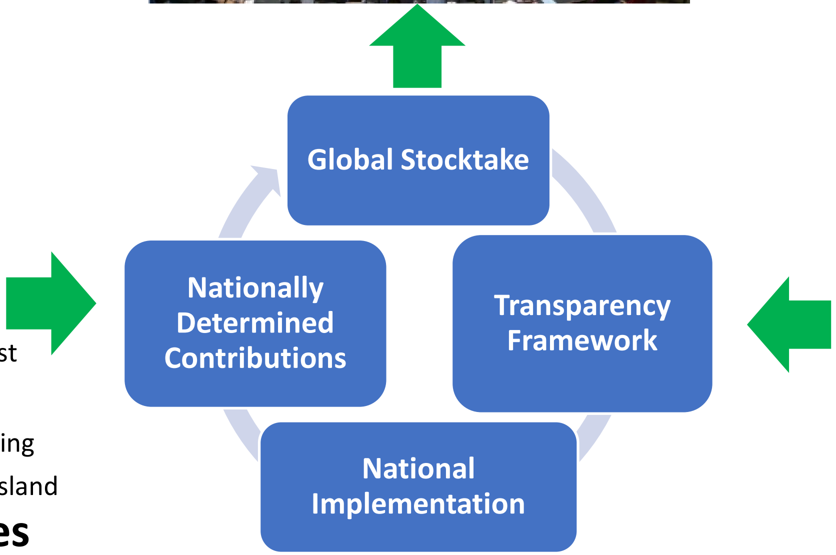
- Energy
  - Fuel Combustion
  - Fugitive Emissions
  - CO_2 Transport & Storage
- Industry
  - Mineral
  - Chemical
  - Metal
  - Non-Energy fuel/solvent
  - Electronics
  - Other Products
- AFOLU
  - Livestock
  - Land
  - Aggregate
  - Other
- Waste
  - Solid
  - Biological
  - Wastewater
  - Other

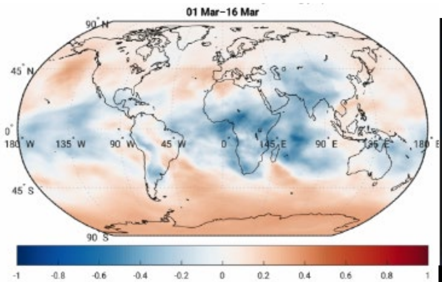


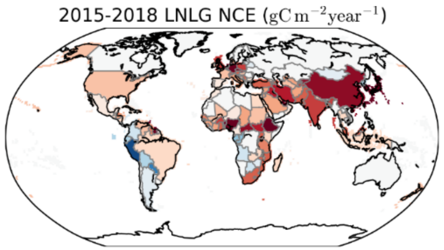
National GHG Inventory



Bottom-up GHG Inventories







Top-down GHG Budgets

For More Information, See:
https://ceos.org/gst/ghg.html

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