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The joint CEOS/CGMS Working Group on Climate

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Pilot, Country-scale Top-down Budgets of CO_2 Emissions and Removals Associated with Terrestrial Carbon Stock Changes

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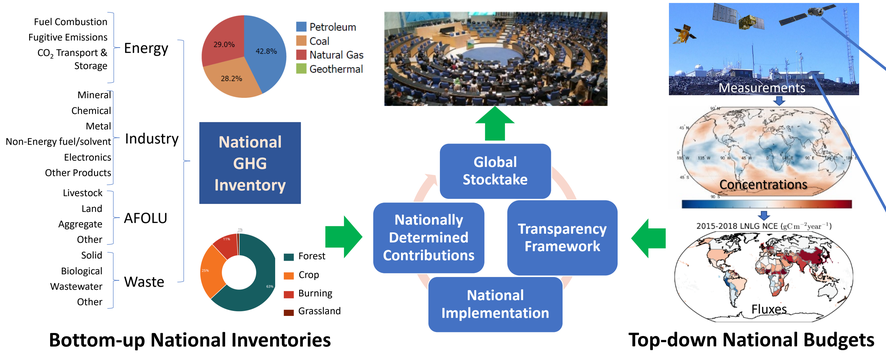
To support the 2023 Global Stocktake (GST), Parties to the Paris Agreement are compiling inventories carbon dioxide (CO_2) emissions and removals to assess progress toward their Nationally Determined Contributions (NDCs) to emission reductions.

These inventories are based on bottom-up methods that estimate annual emissions and removals of CO_2 from sectors specified in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

CO_2 emissions and removals can also be estimated from spatially- and temporally-resolved measurements of their concentrations using atmospheric inverse methods.

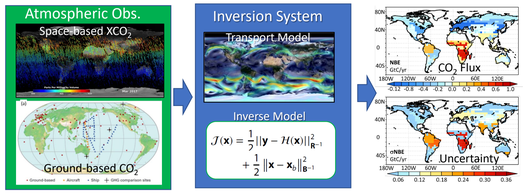
Top-down atmospheric CO_2 emission budgets derived from these fluxes are not as process-specific as bottom-up inventories, but complement those methods by providing a transparent, integrated constraint on fluxes from all processes on spatial scales spanning large power plants or urban areas to nations or the entire globe. Here, we focus on emissions and removals by the biosphere.

The primary objective of these pilot top-down CO_2 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 transparent Global Stocktake



Bottom-up National Inventories

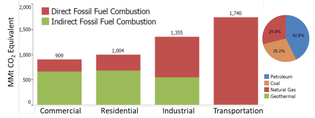
Top-down National Budgets



Top-Down Budgets

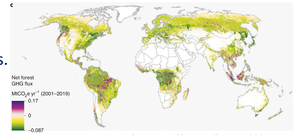
Observations of atmospheric CO_2 provide an integral constraint on emissions and removals to

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



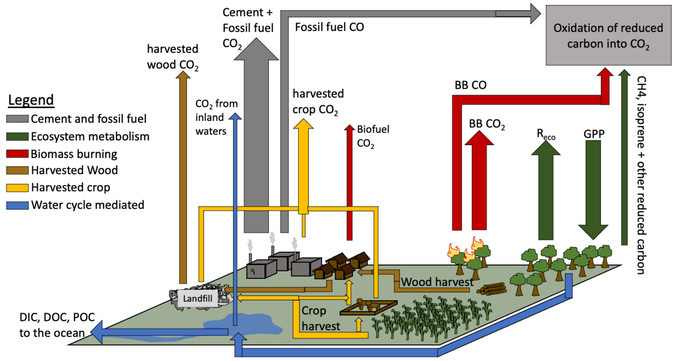
Bottom-Up Inventories

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

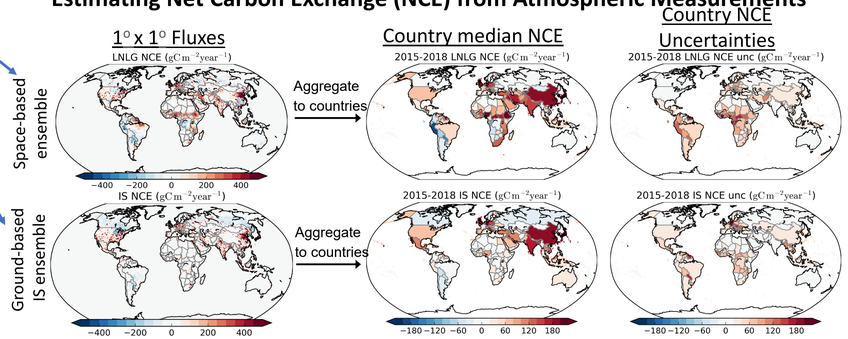


Harris et al. Nature Climate Change, 2021

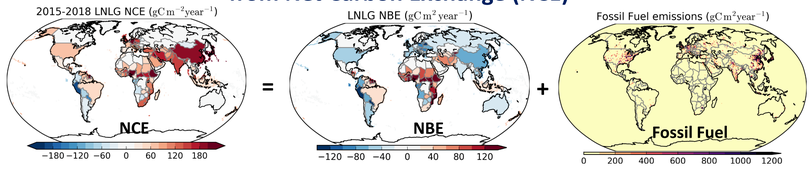
Processes Contributing to Carbon Dioxide (CO_2) Emissions and Removals



Estimating Net Carbon Exchange (NCE) from Atmospheric Measurements

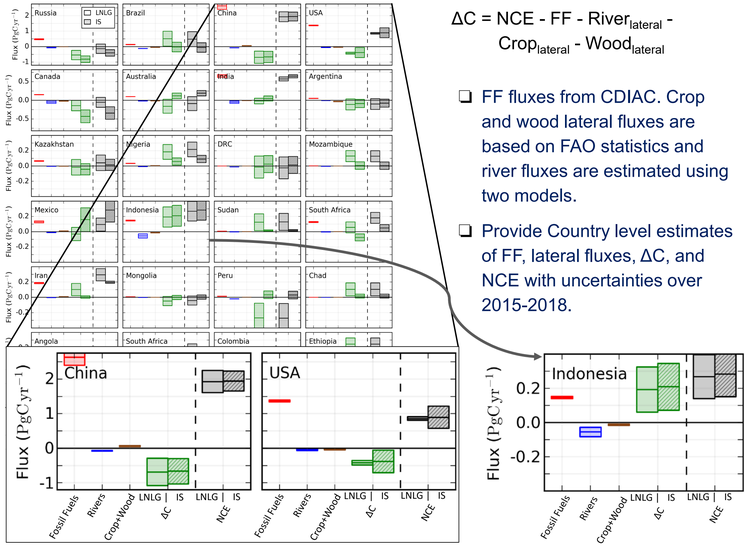


Estimating Net biospheric Exchange (NBE) and Carbon Stock Changes (ΔC) from Net Carbon Exchange (NCE)



The Net carbon exchange (NCE) includes contributions from **Net Biospheric Exchange** (NBE) and **Fossil Fuels**. Inverse models derive estimates of NCE. Spatially-resolved estimates of NBE (middle) can be derived by subtracting the fossil fuel contributions (right) from NCE. Here, fossil fuel emissions are prescribed to derive national-scale estimates of NCE and NBE. Carbon emissions to the atmosphere (ΔC) are then computed as $\Delta C = NBE - River_{lateral} - Crop_{lateral} - Wood_{lateral}$

Country-level Carbon Stock Change, ΔC



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

- FF fluxes from CDIAC. Crop and wood lateral fluxes are based on FAO statistics and river fluxes are estimated using two models.
- Provide Country level estimates of FF, lateral fluxes, ΔC, and NCE with uncertainties over 2015-2018.

2015-2018 mean and standard deviation of NCE and its fossil fuel, biospheric (ΔC), and lateral contributions for a selection of countries. Note that different rows have different y-axis limits. For many countries, the biosphere is a net sink of CO_2. For some tropical countries (Indonesia, Nigeria, Chad, and Brazil), the biosphere has become a source.

Preliminary Conclusions

The derived country-level CO_2 budgets:

- generally show robust signals for large countries (e.g., USA, Russia, China).
- have larger uncertainties for much smaller countries due to limitations in the resolution and coverage of the existing observing system.
- also show anomalously large CO_2 emissions over tropical land, but these result are difficult verify due to the limited availability of independent ground-based and airborne *in situ* CO_2 measurements.

Next Steps

For future stocktakes, these limitations will be addressed with:

- expanded ground, airborne and space-based atmospheric CO_2 observing systems
- improved inverse modeling systems.

These systems are expected to provide a more complete and accurate description of CO_2 emissions and removals for future Global Stocktakes.

For more information, see http://ceos.org/gst