

Toward a reliable, space-based CO₂ data assimilation framework: Current status and future directions

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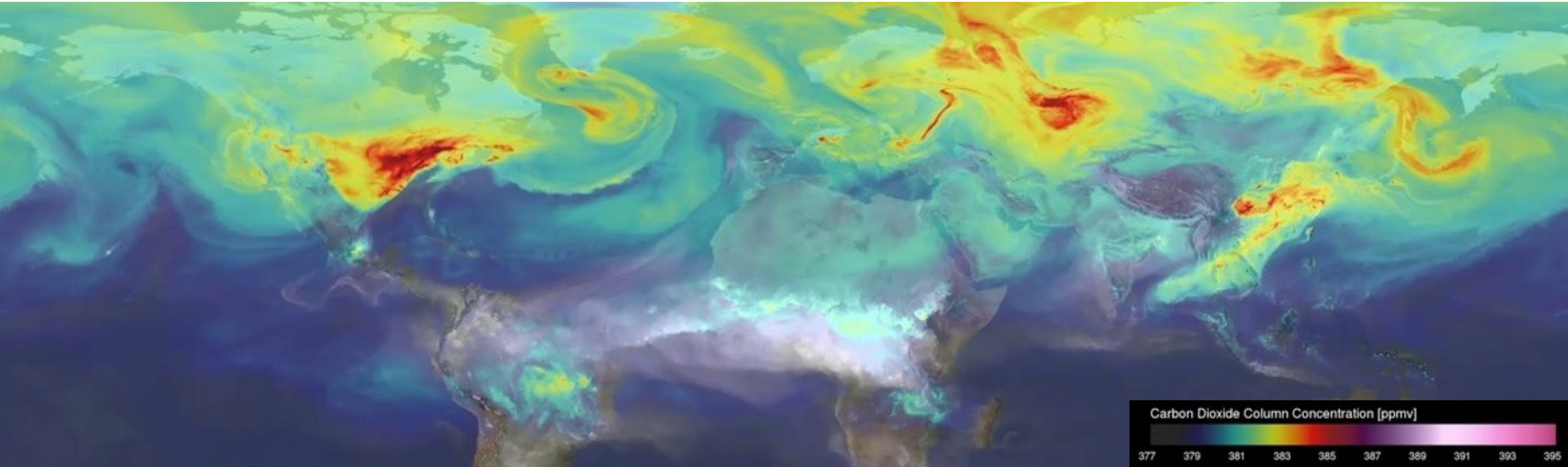
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Presented at NOAA's UV-Vis-NIR Workshop

Why we assimilate carbon dioxide observations



- Ability to merge data from multiple satellites, leverage information on surface processes
- Facilitates evaluation against non-coincident observations
- Can provide easier to use L3 and L4 datasets in support of satellite data users
- Better understanding of human emissions and natural flux processes
- Ability to track global changes in concentration, quantify radiative forcing and temperature impacts

Overview of state estimation approach

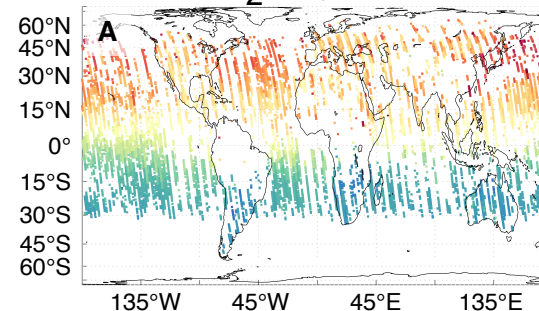
Produced by assimilating bias-corrected OCO-2 retrievals into the GEOS Constituent Data Assimilation System (CoDAS)

Data product: 3D CO₂ concentration fields at 10-50km, 3-6 hr frequency

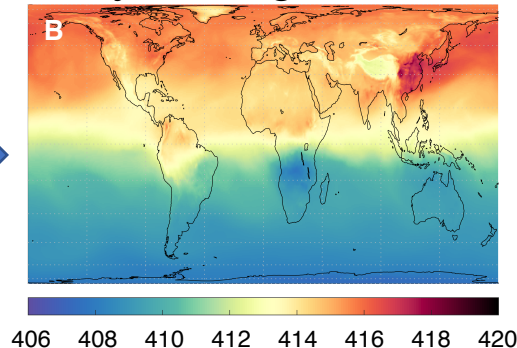
When OCO-2 data are unavailable, gaps are filled using:

- All previous good quality OCO-2 retrievals
- MERRA-2 wind and atmospheric transport fields
- Observationally-informed, low latency flux package that includes information from:
 - ODIAC (previous years)
 - CASA-GFED NEE (previous years)
 - NOAA *in situ* growth rate (previous years + forecast using SST information)
 - QFED fires (NRT)

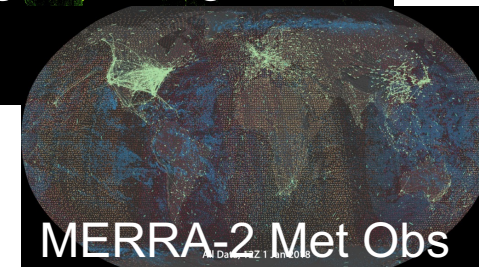
16 days of cloud-screened OCO-2 XCO₂ – 4/1-16/2020



16-day average L3 XCO₂



Complementary observations



Example application: Tracking recent changes in CO₂ concentrations

GEOS assimilates OCO-2 retrievals to produce gap-filled concentration products and anomalies, typically 2-3 months behind real time

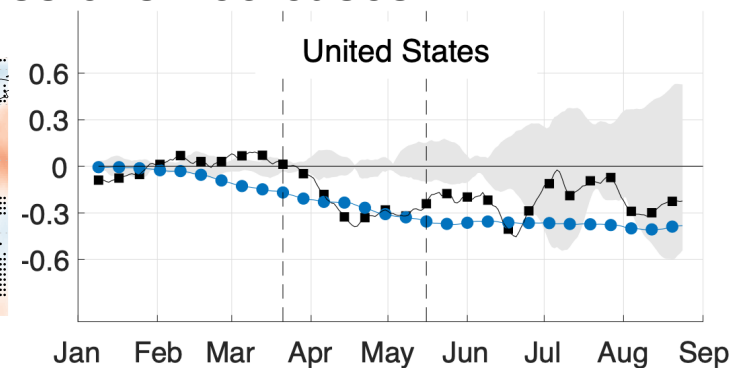
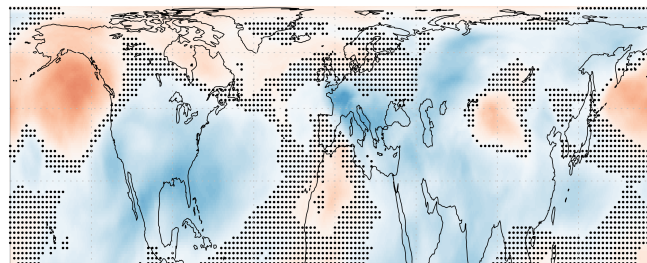
Data can be compared to reference simulations without assimilation that are used to quantify and remove the circulation-driven anomaly

This method has been used to track emissions during COVID and can also reveal the impact of land, ocean and fire anomalies including the 2020 Australian wildfires

Concentration fields support NASA and international dashboards aiming to provide information on recent environmental change

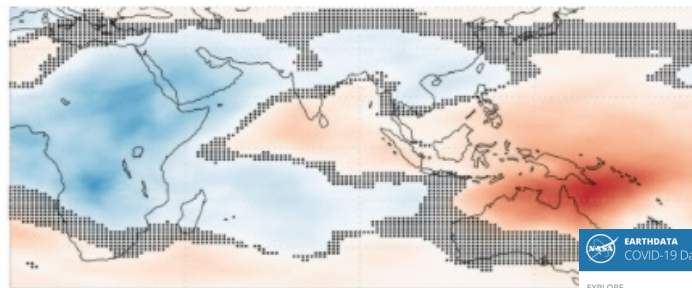
COVID-19: Emissions Decreases

April 1–16

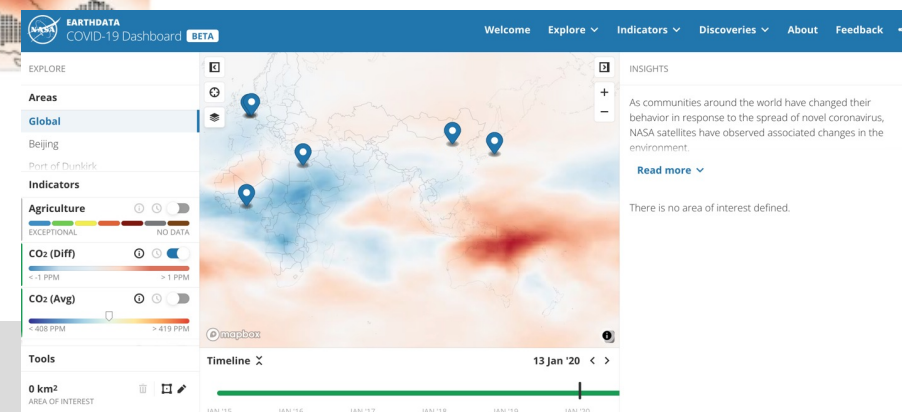


2020 Australian Wildfires

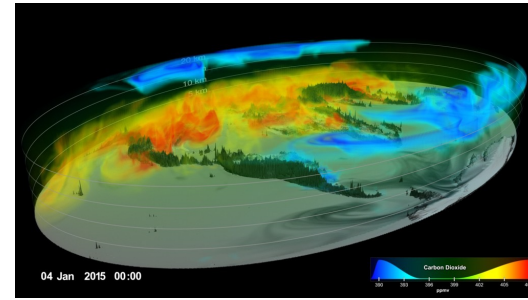
January 11-26



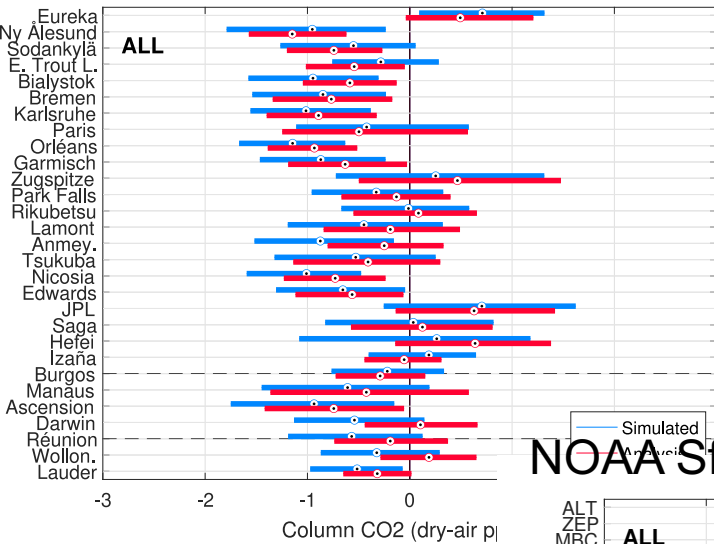
Anomaly and concentration maps available on NASA's Earth Data Dashboard



State estimation approach facilitates rigorous benchmarking against independent data



TCCON **Obs – Ana**, **Obs – Sim**

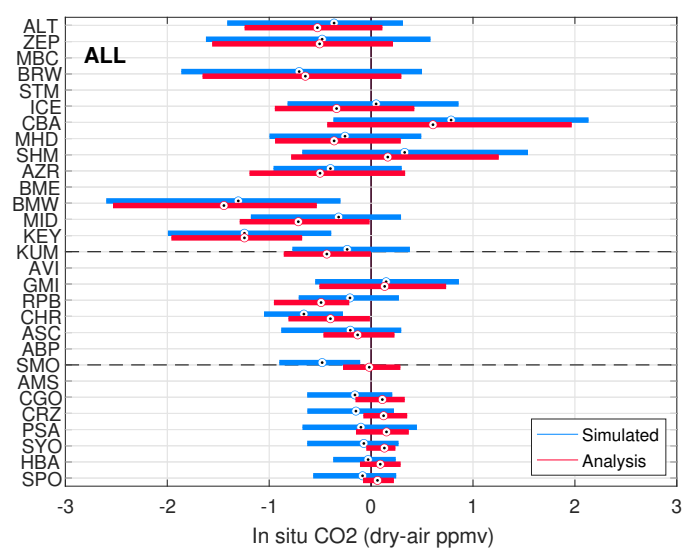


Extensive evaluation against:

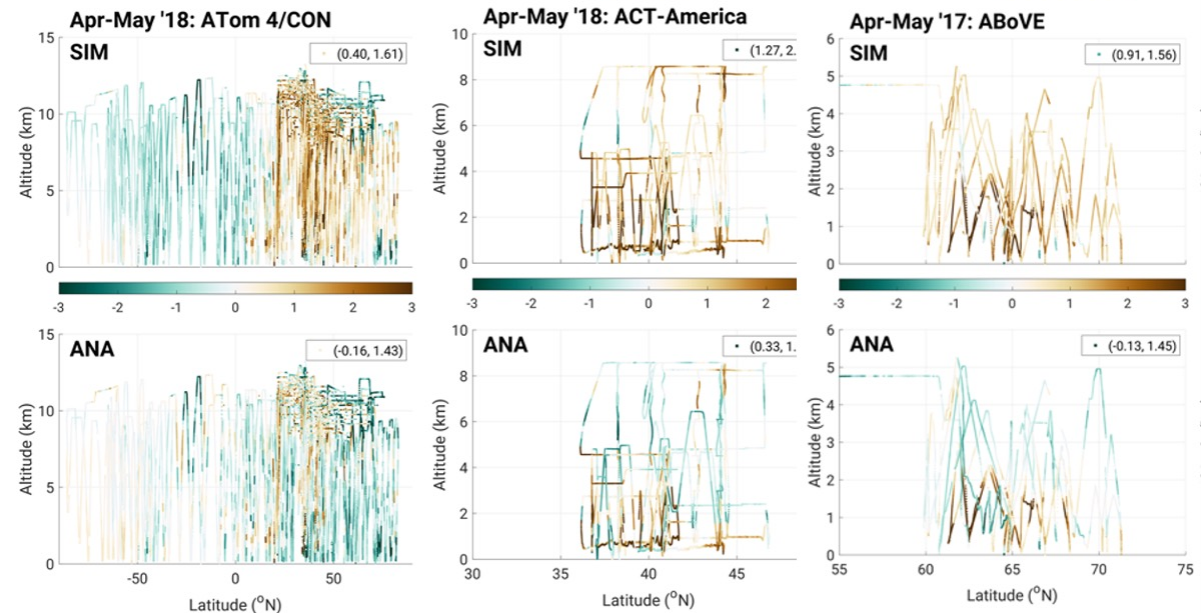
- TCCON network
- NOAA surface stations
- NOAA and NASA aircraft campaign data

Comparisons through 2020 included in GEOS OCO L3 User's Guide with updates provided via GMAO's page

NOAA Sfc. **Obs – Ana**, **Obs – Sim**



Example comparisons against AToM, ACT-America, and ABoVE



Overview of flux inversion products

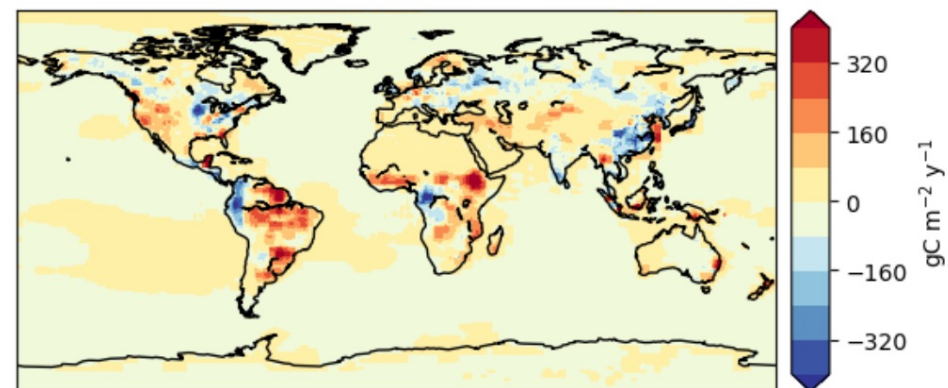
Produced by community of researchers using offline chemical transport models capable of assimilating satellite retrievals and *in situ* data

OCO-2 inversions have been coordinated through the OCO-2 MIP - includes NOAA contributed model and leadership in analysis, benchmarking tools
(<https://gml.noaa.gov/ccgg/OCO2/>)

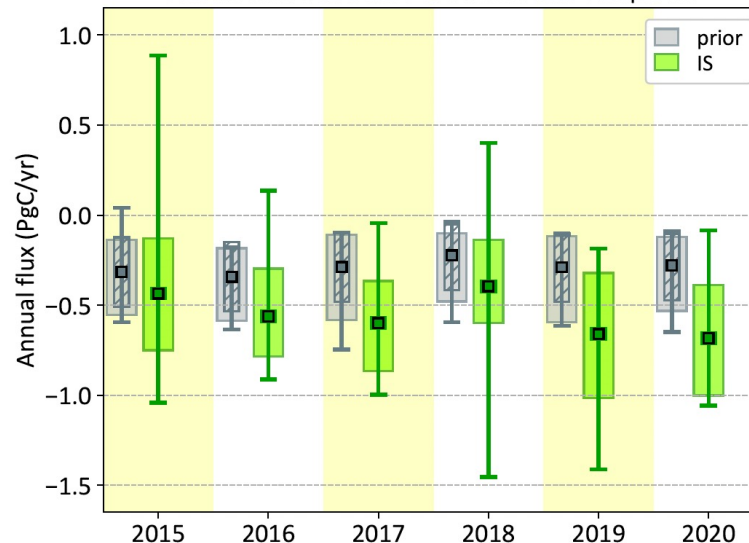
Data product: 2D surface fluxes at 100s of km resolution, weekly-monthly frequency

Example application: Quantifying regional CO₂ fluxes

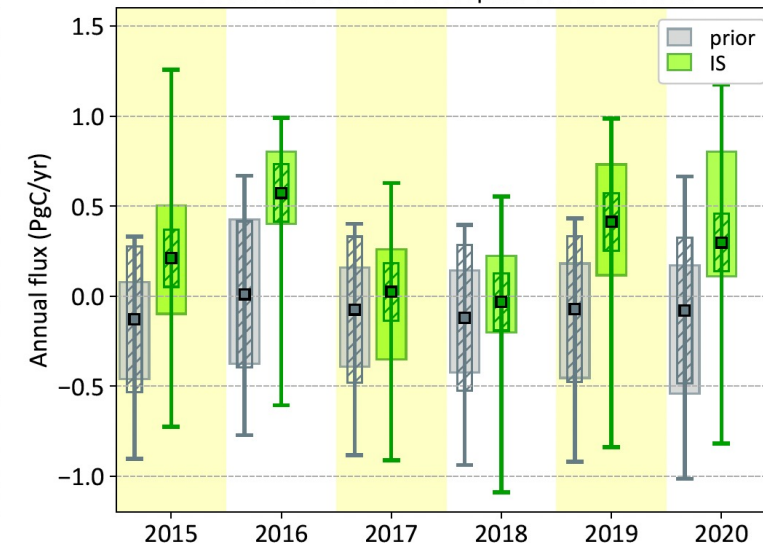
EnsMean: LNLGOGIS Net 2015 Annual Flux



Annual land flux from North American Temperate



Annual land flux from Tropical South America



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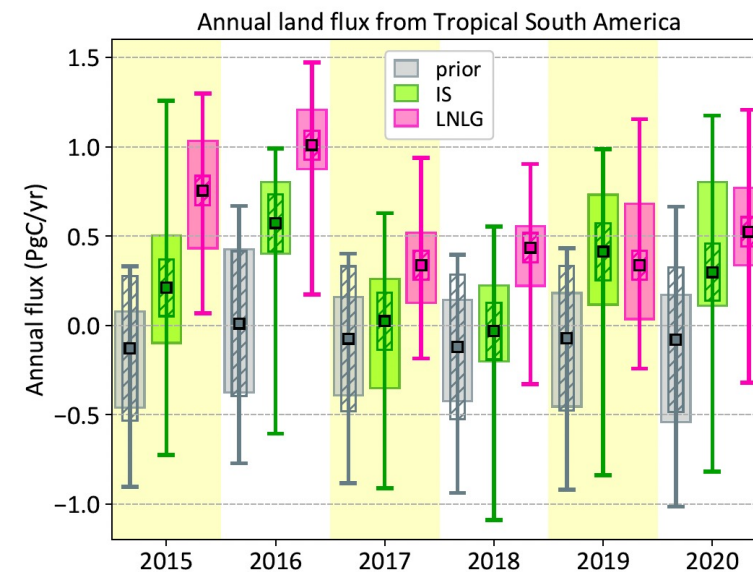
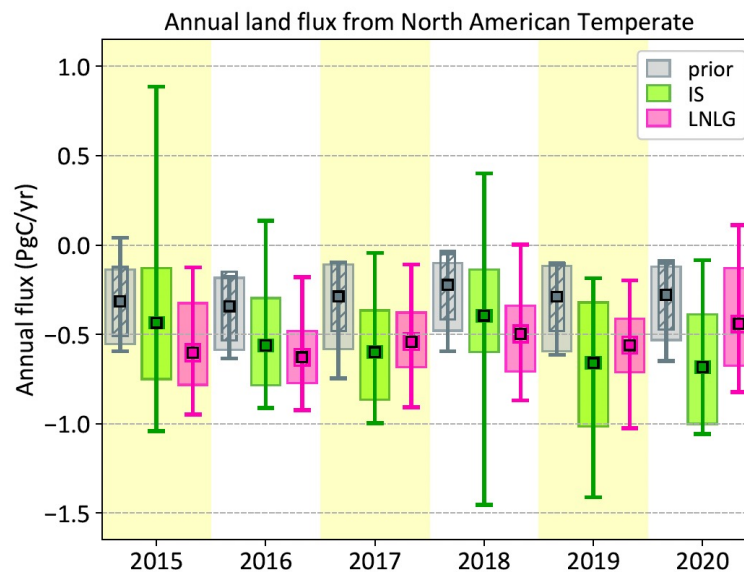
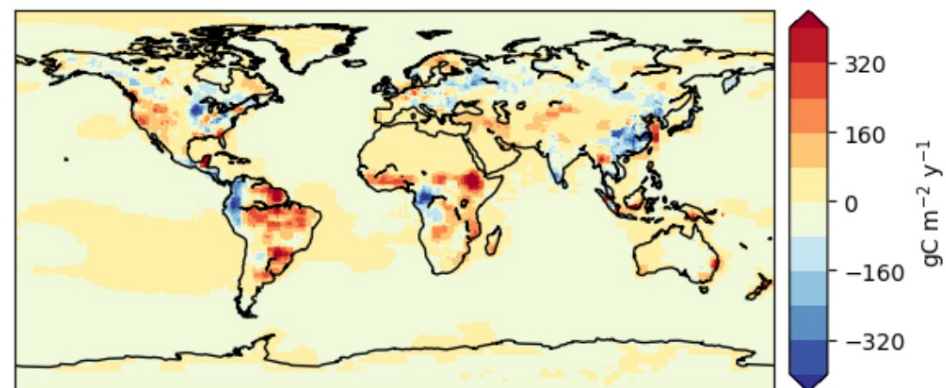
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Example application: Quantifying regional CO₂ fluxes

- In well-observed areas (left), satellite data inversions are generally consistent with *in situ* inversions
- In the tropics right), satellite data can add information and reduce uncertainty

EnsMean: LNLGOGIS Net 2015 Annual Flux



Future directions in CO₂ assimilation

- Defining GeoCarb observing strategy and L3 and L4 products for GeoCarb (~2024-25 launch) – will be the world's first geostationary GHG mission
- Including CO₂ and CH₄ state estimation in NASA's upcoming Reanalysis of the 21st Century (R21C). Currently evaluating assimilation of TROPOMI and CrIS retrievals for CH₄.
- Exploring ways to reduce latency of CO₂ analysis (currently limited by availability to retrievals)
- Expanding cyberinfrastructure, data services to support easier access, greater interoperability of CO₂ flux and concentration products

<https://svs.gsfc.nasa.gov/4890>

