A prototype for monitoring carbon flux anomalies in near real time using NASA's GEOS system: progress and challenges

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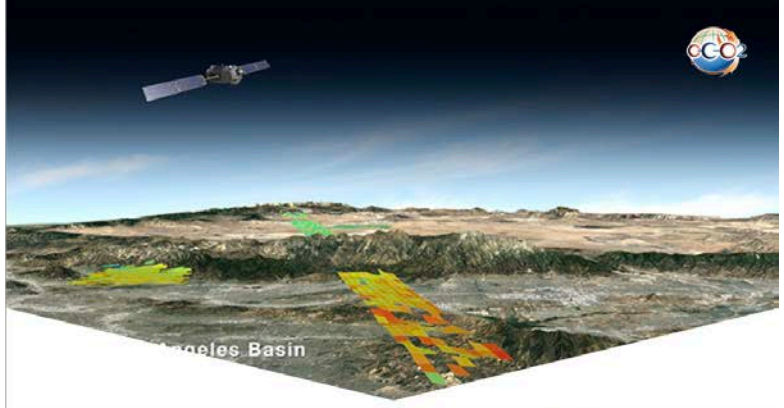
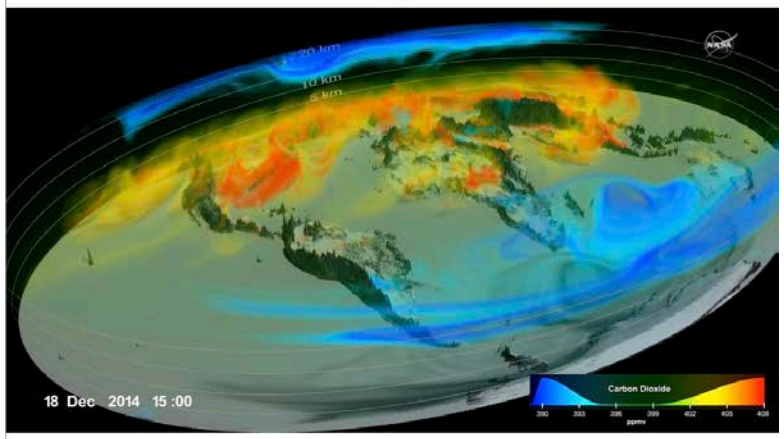
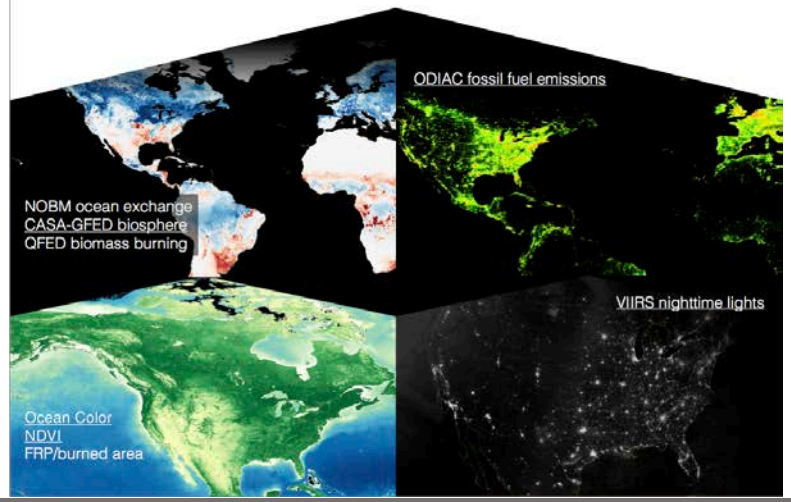






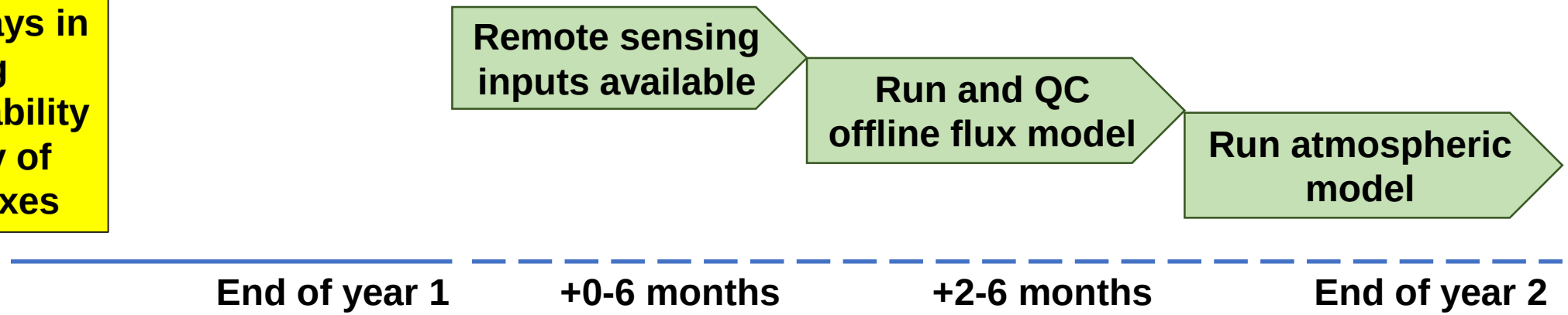
GEOS CMS System Overview

- Satellite observations provide important constraints on carbon flux estimates
- Ocean color and NDVI information inform model-based estimates of ocean (NOBM) and land productivity (CASA-GFED) while observations of fire radiative power, burned area, and nighttime lights support high-resolution fire (GFED, QFED) and fossil fuel (VIIRS) emission inventories
- Flux estimates also incorporate weather information from MERRA-2 to provide a physically consistent flux dataset
- Bottom-up fluxes are transported using NASA's GEOS AGCM, providing high quality, high-resolution simulations of CO_2 and CO
- By assimilating atmospheric CO_2 from OCO-2 and GOSAT, the GEOS-based system also provides atmospheric carbon reanalyses and insights needed to refine flux estimates

Limitations for near-real-time atmospheric monitoring

1. Availability of observationally constrained flux data

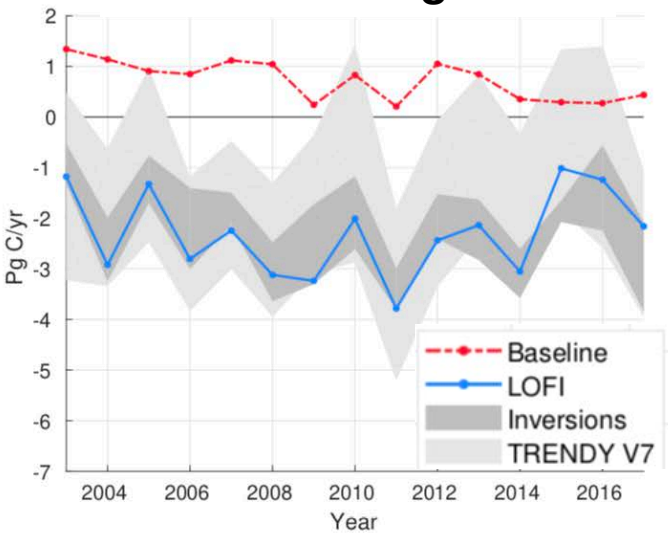
Significant delays in processing decrease availability and reliability of bottom-up fluxes



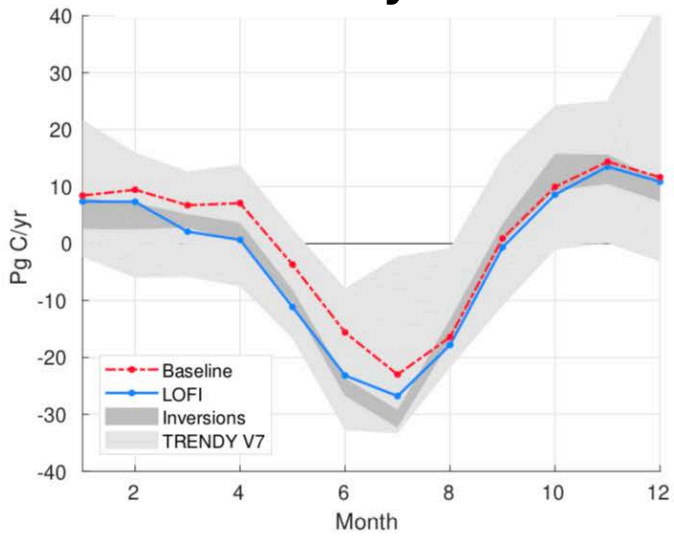
2. Availability of CO_2 observations

1) Improving near-real-time flux estimates

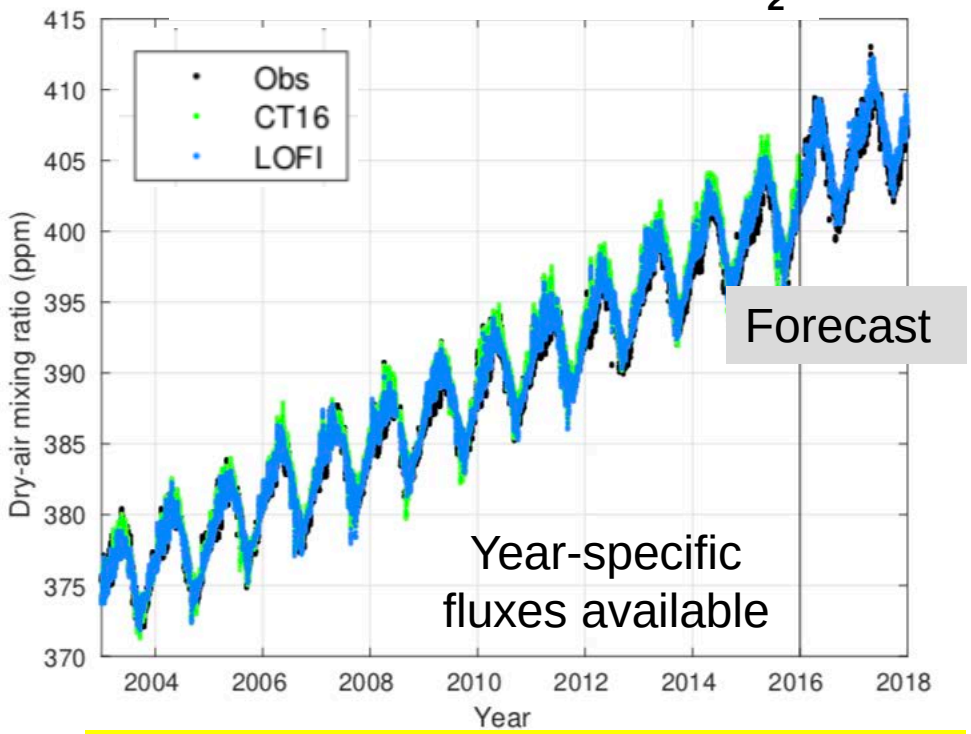
Annual average NBE



Seasonal cycle NBE



Mauna Loa Simulated CO_2

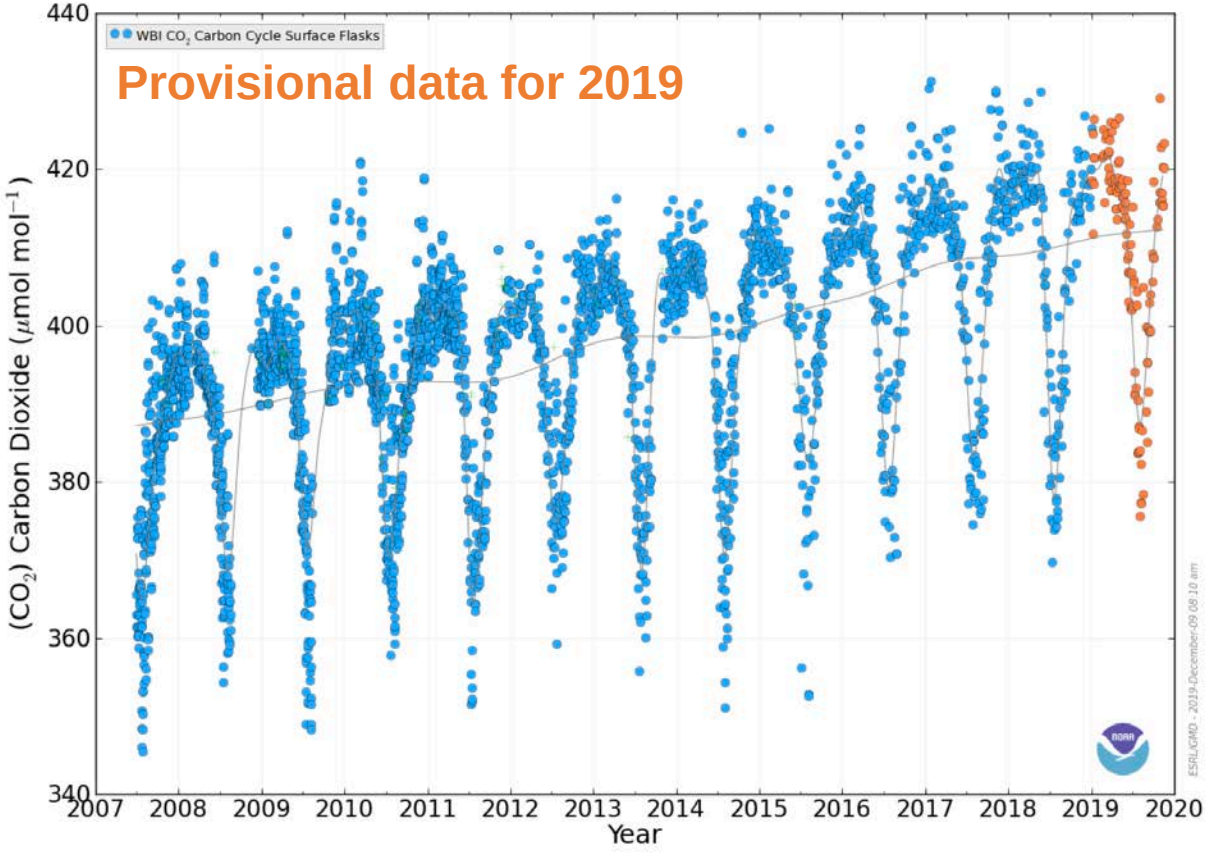


- LoFi flux package uses GEOS CMS bottom up fluxes and adds a land sink constrained by atmospheric growth rate (above)
- When year-specific flux and atmospheric data are not yet available:
  - Climatological spatial distribution is used
  - Flux trends extrapolated
  - Sink magnitude incorporates seasonal forecast of growth rate

Forecast fluxes succeed in reproducing background atmospheric mixing ratios providing support for assimilation of atmospheric obs.

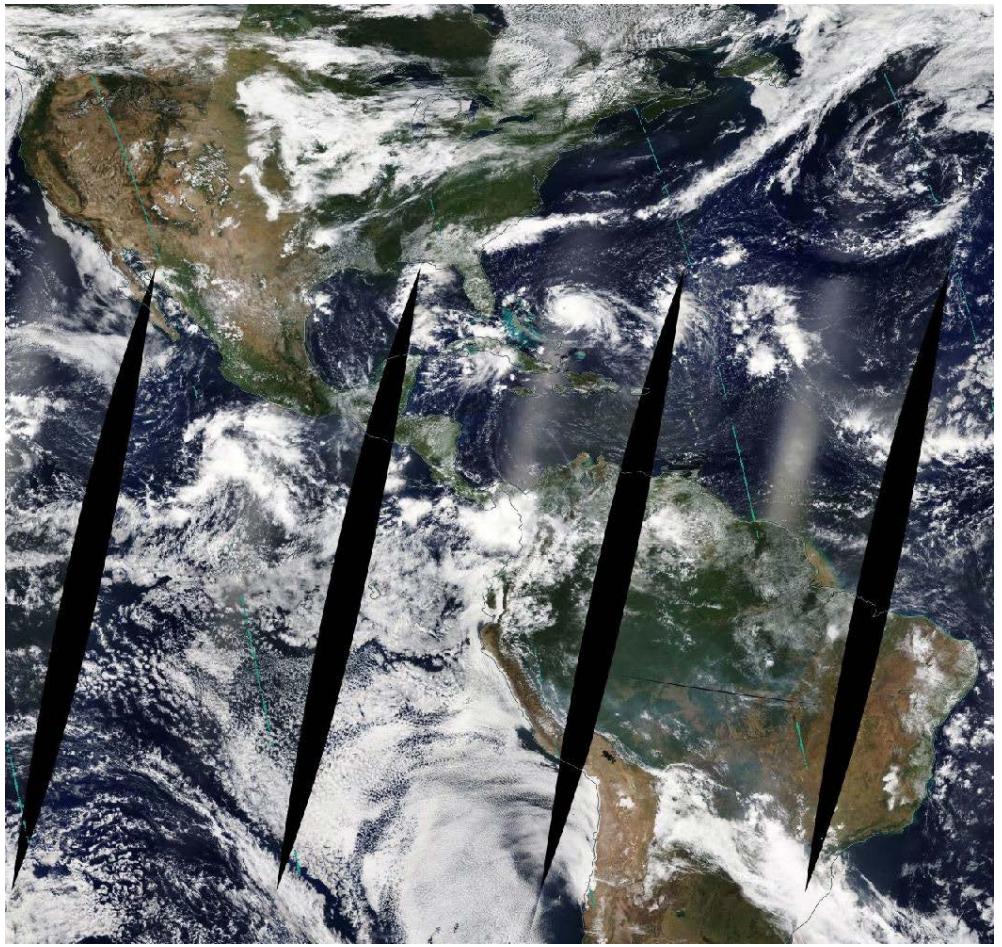
2) Availability of CO_2 data improving, but latency of 1-3 months remains

NOAA NRT Obspack – West Branch Iowa



https://www.esrl.noaa.gov/gmd/dv/iadv/

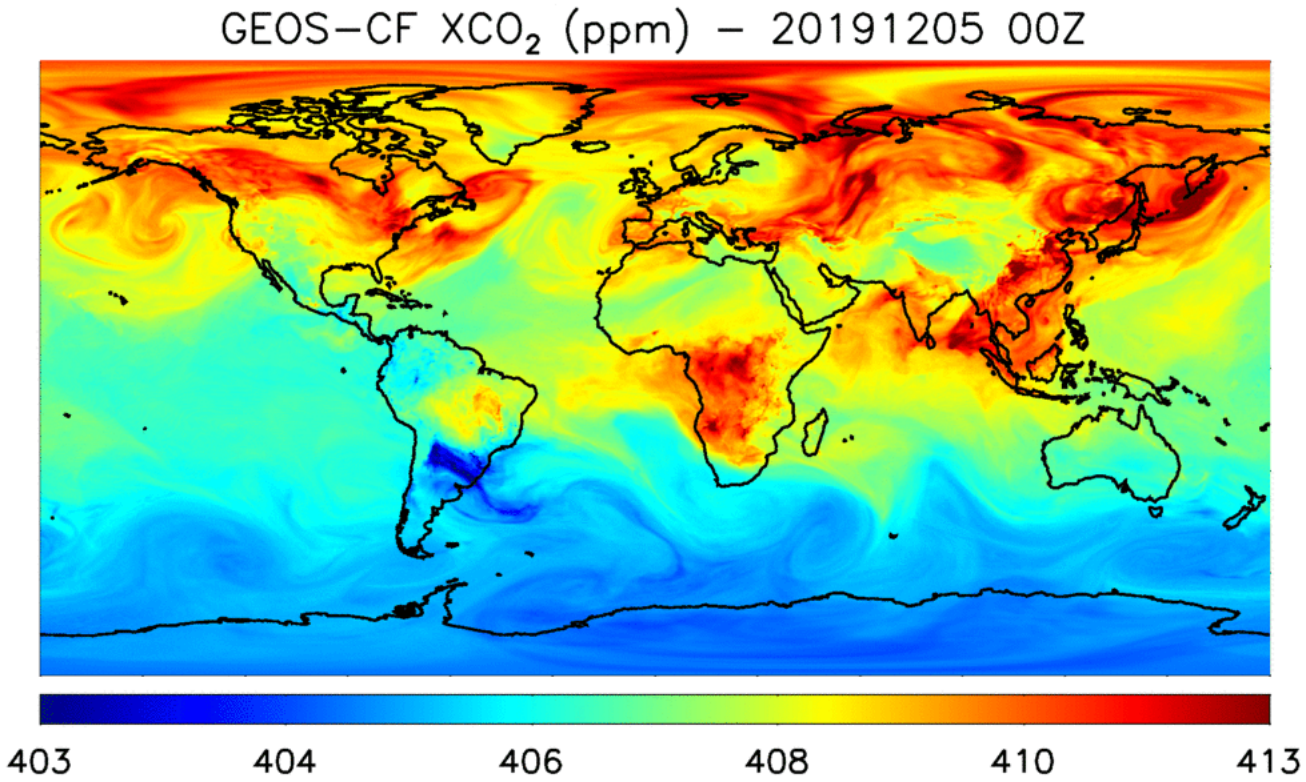
NASA OCO-2 Data – 20190831



https://worldview.earthdata.nasa.gov/

Ability to simulate and forecast carbon weather in NRT

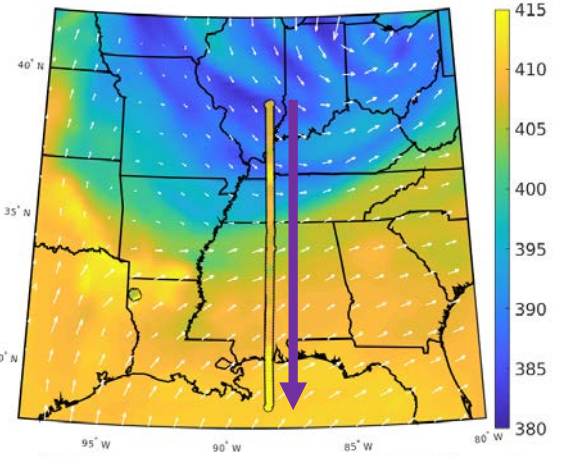
- GEOS Composition Forecast (GEOS-CF) system produces global, 3D distributions of atmospheric composition and 5-day forecasts
- CO_2 fluxes incorporate NRT biomass burning using MODIS fire radiative power + LoFi ocean, land, and fossil fuel
- GEOS-CF also provides estimates of species like CO and NO_2 that provide additional information that may be used for source attribution



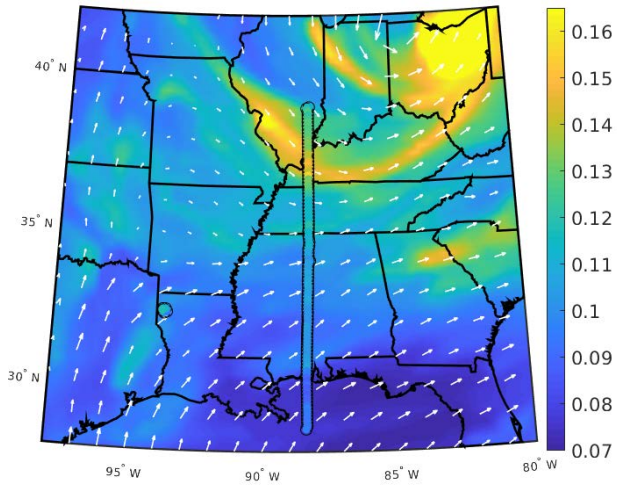
Case study: GEOS-CF forecasts in support of ACT-America

6/20/19
GEOS-CF Replay at 500 m vs. Boundary Layer Aircraft Data

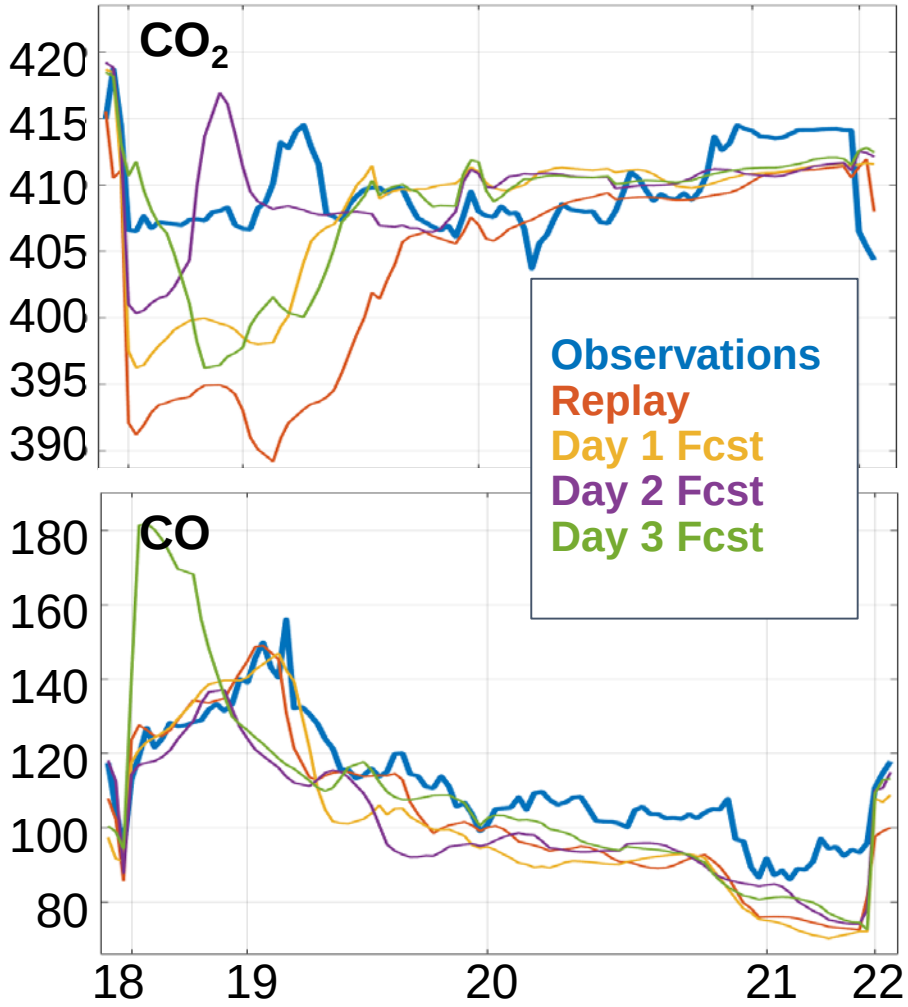
CO_2



CO



GEOS-CF Replay and Forecasts vs. Obs.



- Two day forecasts tend to predict frontal structures and gradients well (see CO)
- Lack of dynamic emissions can hurt skill for CO_2 but mismatch provides valuable information into flux processes

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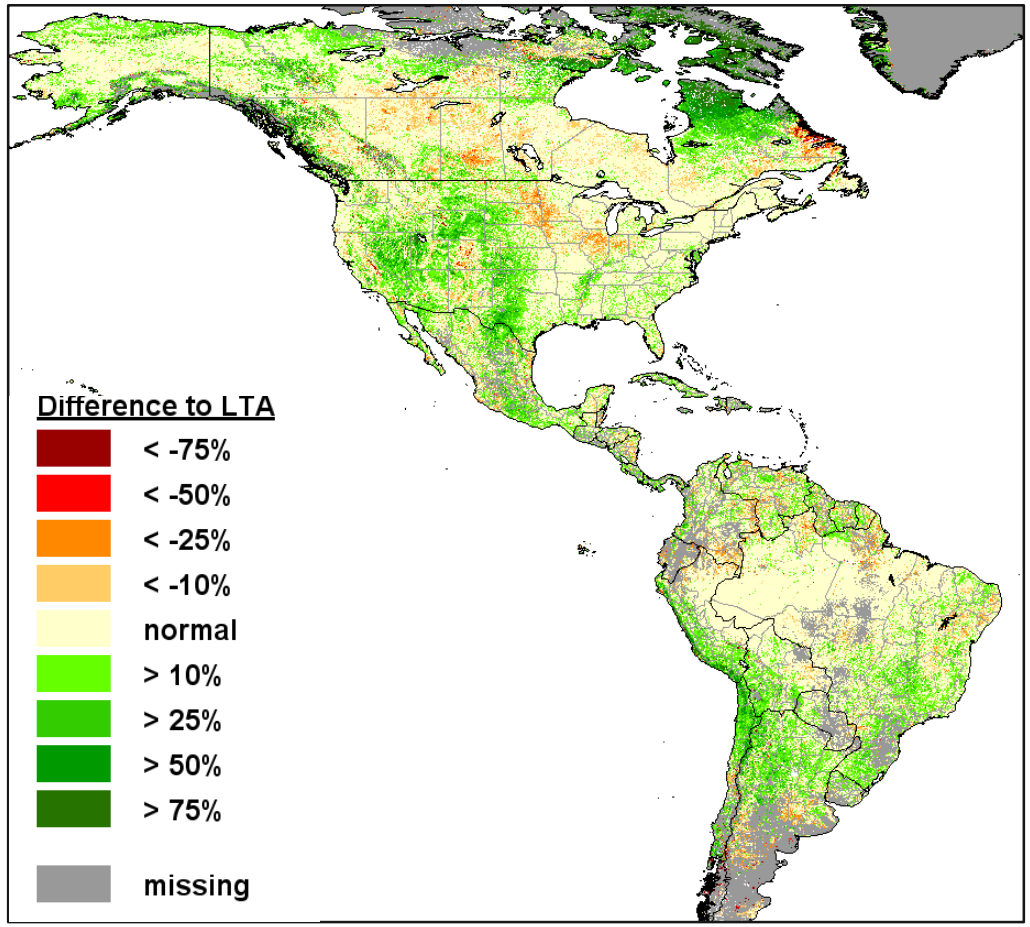
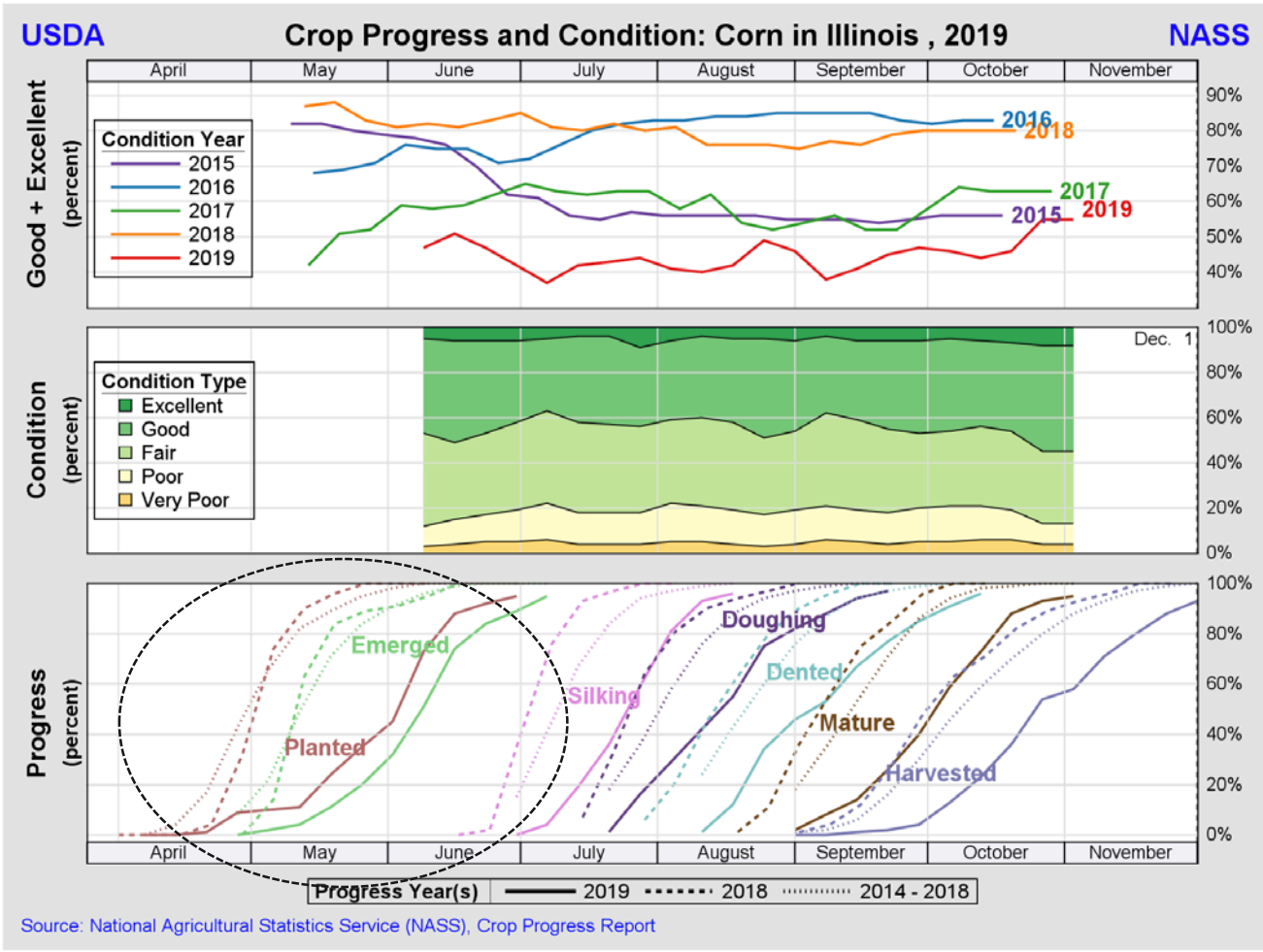
2019 Agricultural anomalies after record floods

201906 NDVI Anomaly



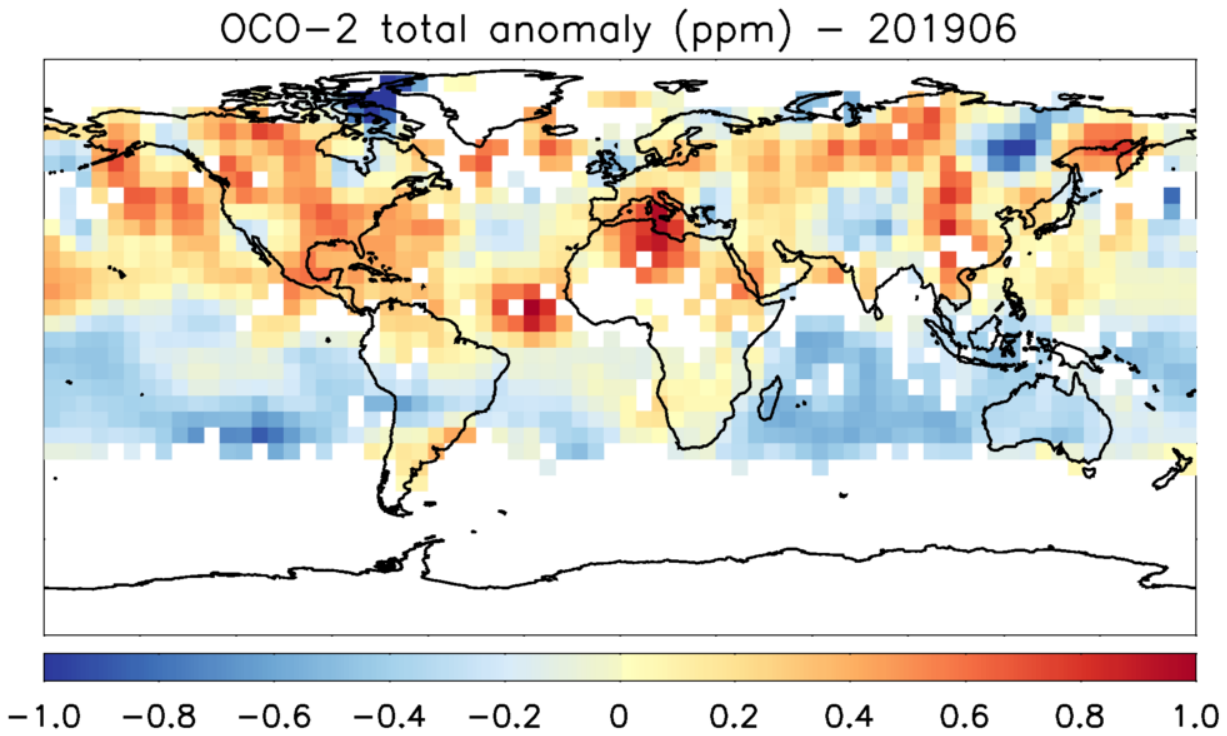
USDA Illinois Corn Progress

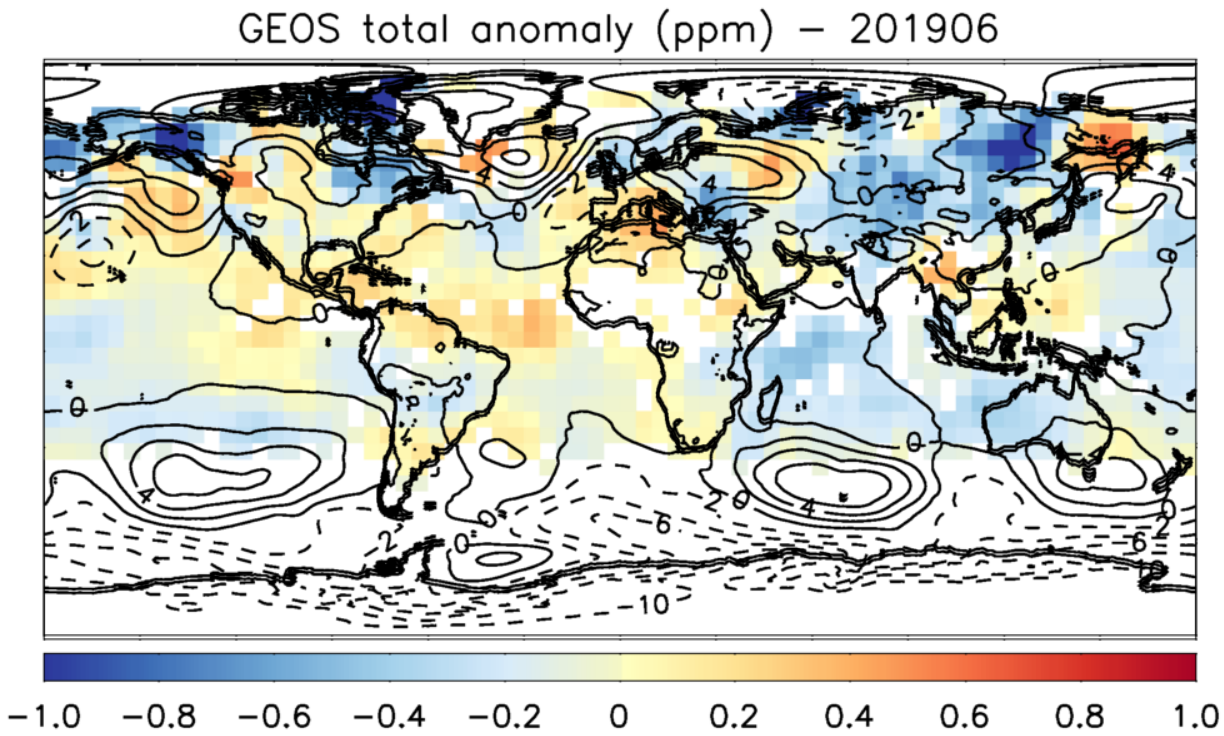


http://www.fao.org/

https://www.nass.usda.gov/

Disentangling flux and weather influences

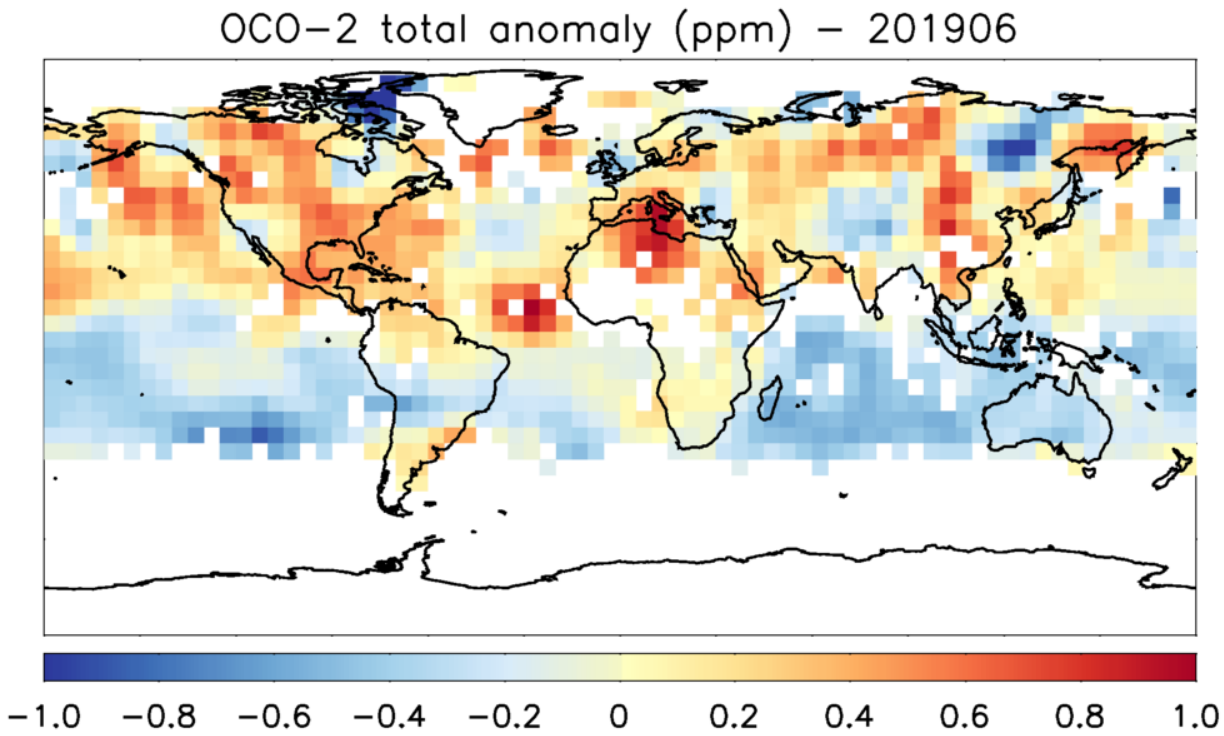


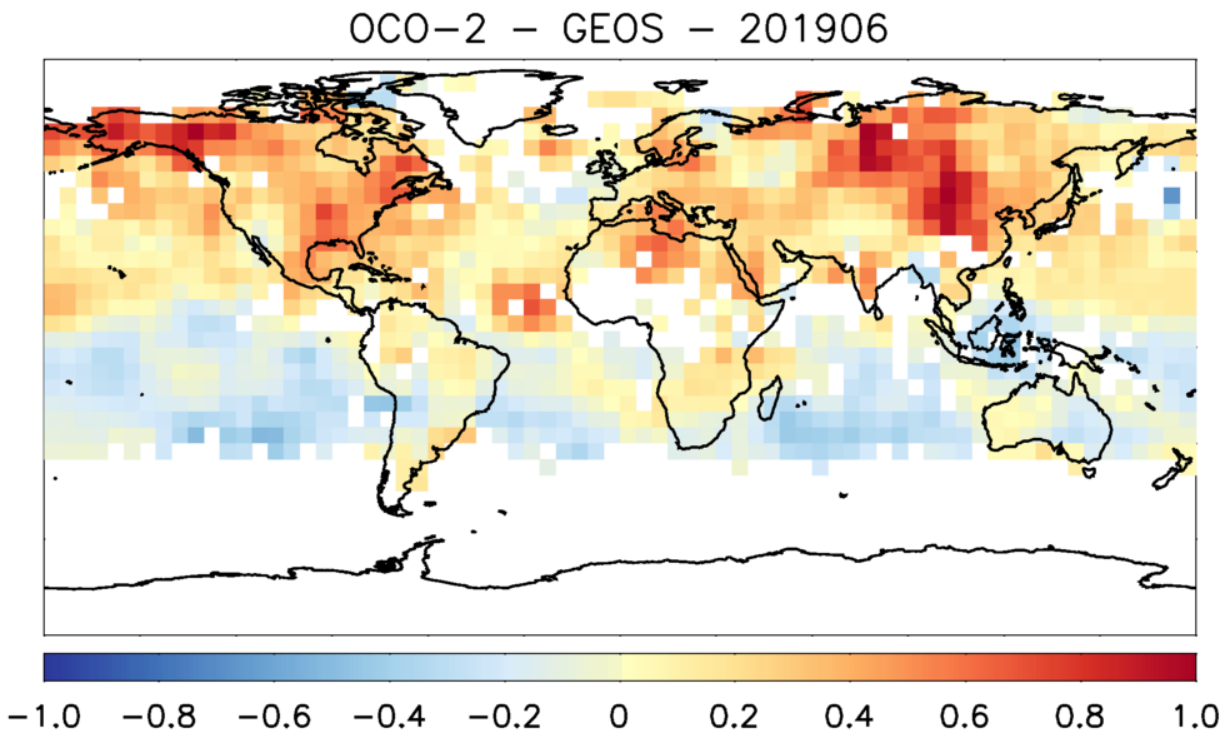


OCO-2 XCO_2 anomaly from 201906 shows the collective influence of weather and flux changes

Anomaly from GEOS run with LoFi fluxes represents weather changes + a small contribution from fires

Disentangling flux and weather influences





Difference in anomalies highlights the role of flux anomalies over US., Europe

Summary and future directions

- Data-driven modeling tools supported by CMS provide the capability to improve understanding of carbon flux changes as they happen
  - Response to 2019 midwestern floods provides an example where an agricultural anomaly can be rapidly identified and analyzed
- Remaining challenges:
  - Availability of CO_2 data limits ability to estimate concentrations, fluxes with less than 2-3 month latency
  - Progress in bottom-up modeling tools can help bridge the gap, but work needs to be done to incorporate NRT information
- CMS has a valuable role to play in understanding user needs - who needs low latency concentration and flux data and what are their requirements?