NASA's Carbon Cycle OSSE Initiative - Informing future space-based observing strategies

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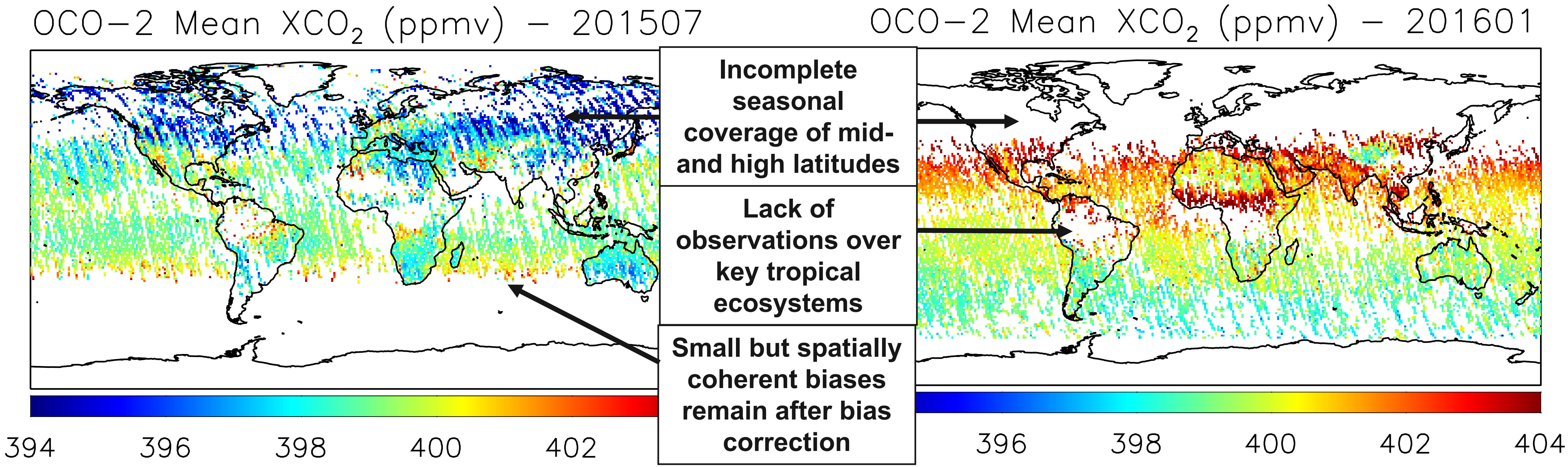
Motivation

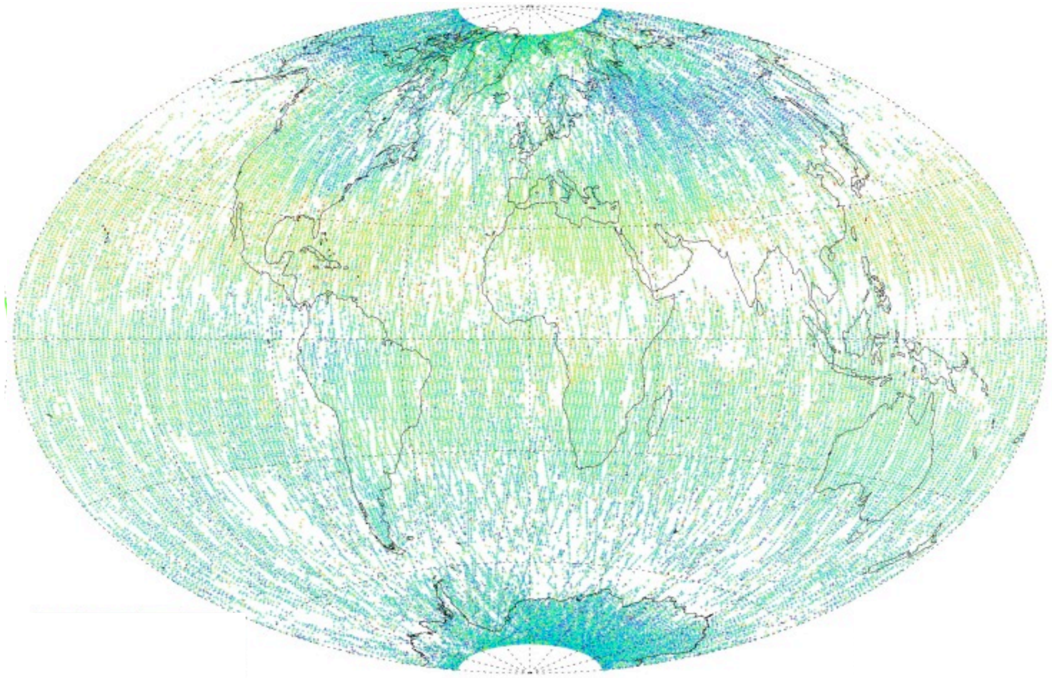
Despite significant technological advances, limitations in current GHG observing satellites have prevented accurate estimation of regional scale fluxes



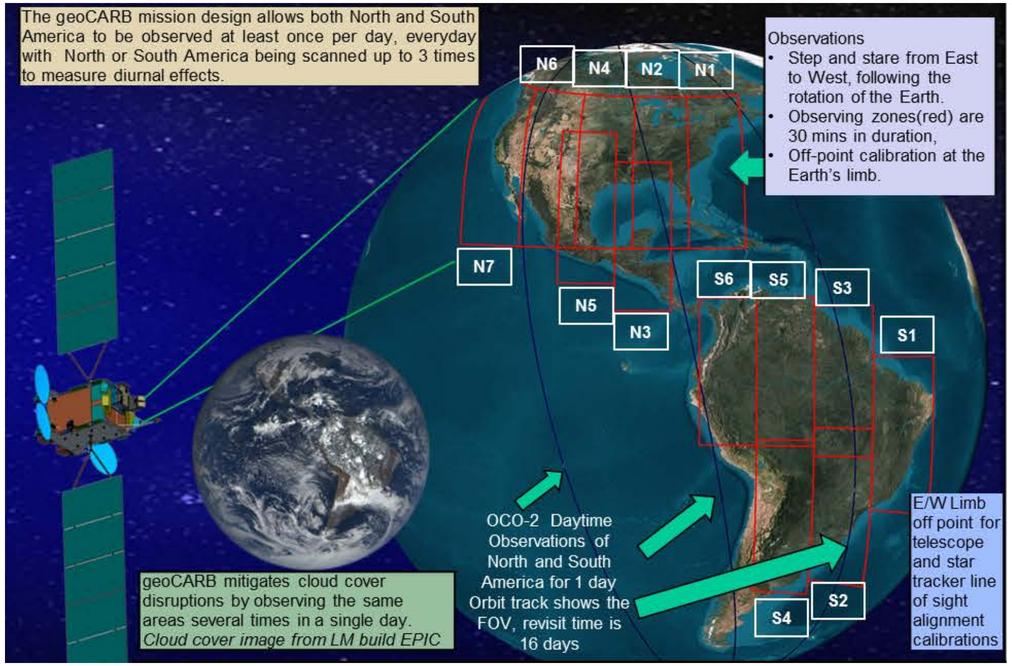
Alternate Mission Concepts

Finding new ways to observe data sparse regions and to reduce the impact of systematic errors is a key part of building a more robust carbon observing constellation

Simulated Coverage for Active Mission in July



GeoCarb – Daily observations over the Americas



Limitations of previous OSSE efforts

- Observing System Simulation Experiments (OSSEs) play an important role in assessing the value of new candidate observing systems

- Also needed to test and improve inverse modeling systems

- However, most OSSE efforts are focused on justifying a single mission and contain significant weakness

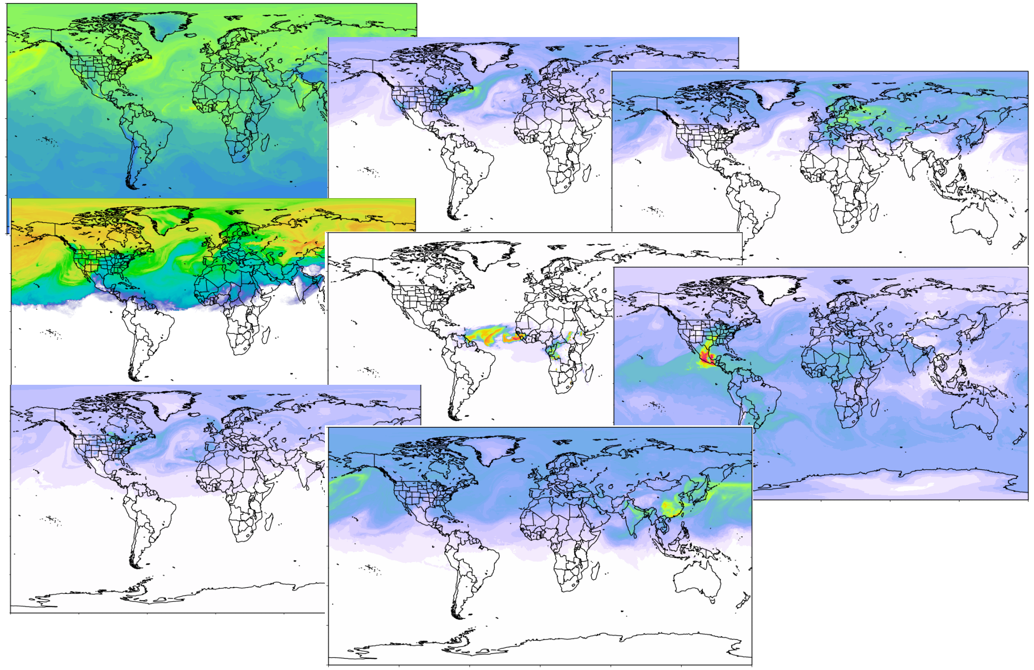
    - Inconsistent assumptions about the role of random, systematic errors
    - Lack of information about diurnal cloud variability
    - Lack of context about value added in context of existing, planned missions

NASA's Carbon Cycle OSSE Initiative

- Collaborative effort between (NASA GSFC, JPL, University of Oklahoma, Colorado State University
- Funding for 2 years of preliminary activities focused on generating data products to support consistency of Carbon Cycle OSSE efforts:
  - GEOS Carbon Nature Runs
    - 50-km, 7-year GEOS-5 Carbon Nature Run (including CO, CO_2, and CH_4) simulating ~50 tracers that represent realistic carbon cycle perturbations
    - 14-km 2-year simulation representing limited number of tracers (ongoing)
  - Multi-sensor cloud probability dataset
  - Pseudo-datasets for generic passive and active LEO and passive GEO missions created by sampling the Nature Run using instrument simulator models
  - Baseline single instrument inversions (ongoing)
  - All data free and publicly available

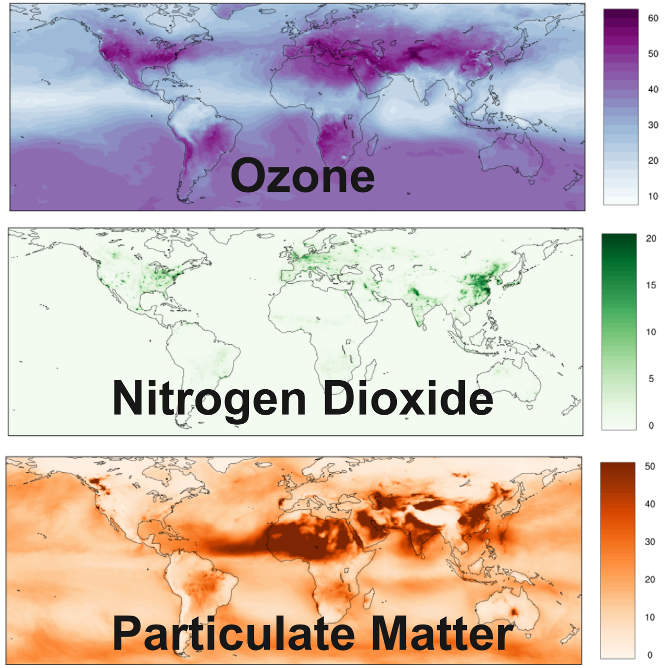
GMAO Capabilities in Support of AC, GHG Nature Runs

Supports large number of tagged tracers

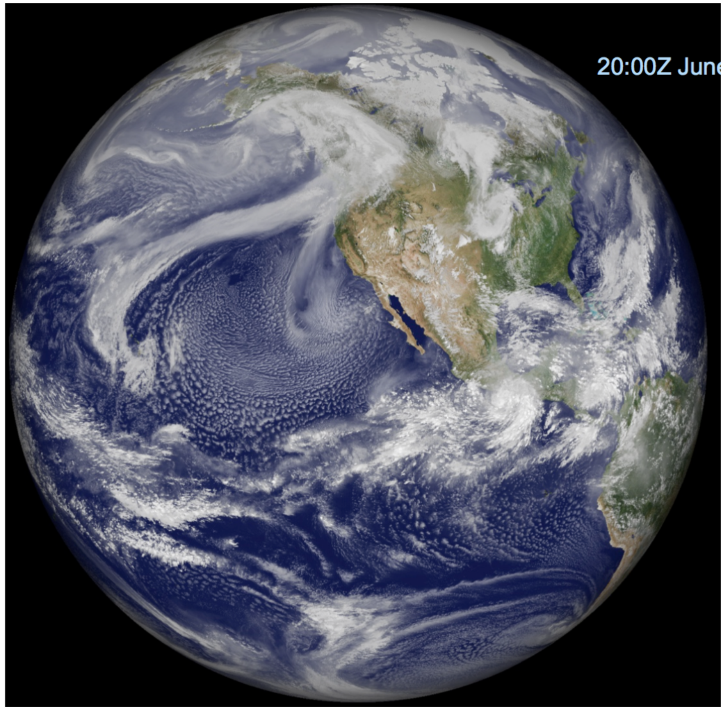


Supports carbon OSSE effort

Ability to run chemistry of varying complexity



Capable of running globally at resolutions from 3 - 200 km

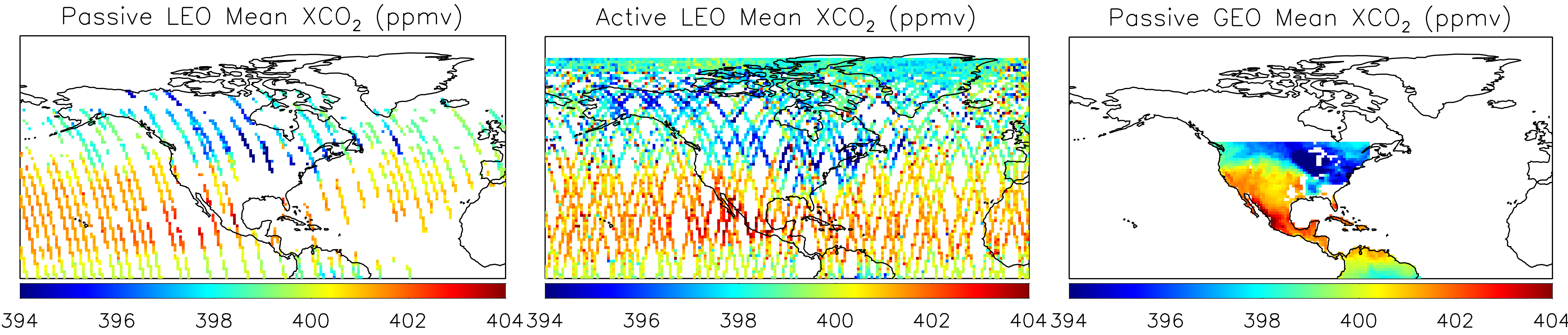


Carbon OSSE Flux Change Scenarios

- Growing uncertainty in fossil fuel emissions, megacities
  - 25 tracers designed to cover a range of latitudes, cities with both growing and static emissions, city pairs in close proximity, and cities in challenging observing environments (e.g. coastal, near agricultural region)
- Response of Arctic/Boreal Zone to warming
  - Moderate and high emission scenarios based on CLM simulations of CO_2, CH_4 (Koven et al., 2015)
- Mid-latitude carbon uptake / Tropical carbon uptake changes
  - Includes separate GPP and respiration tracers for 7 continental scale regions based on TRANSCOM region definitions (Gurney et al., 2003)
- Southern Ocean flux change
  - Uses two time-varying ocean flux estimates to assess ability to observe interannual sink variations
- Methane emission changes (anthropogenic and natural)
  - Tagged emissions from 7 wetland regions (Bloom et al., 2017), US fracking emissions (Maasakkers et al., 2016), and biomass burning

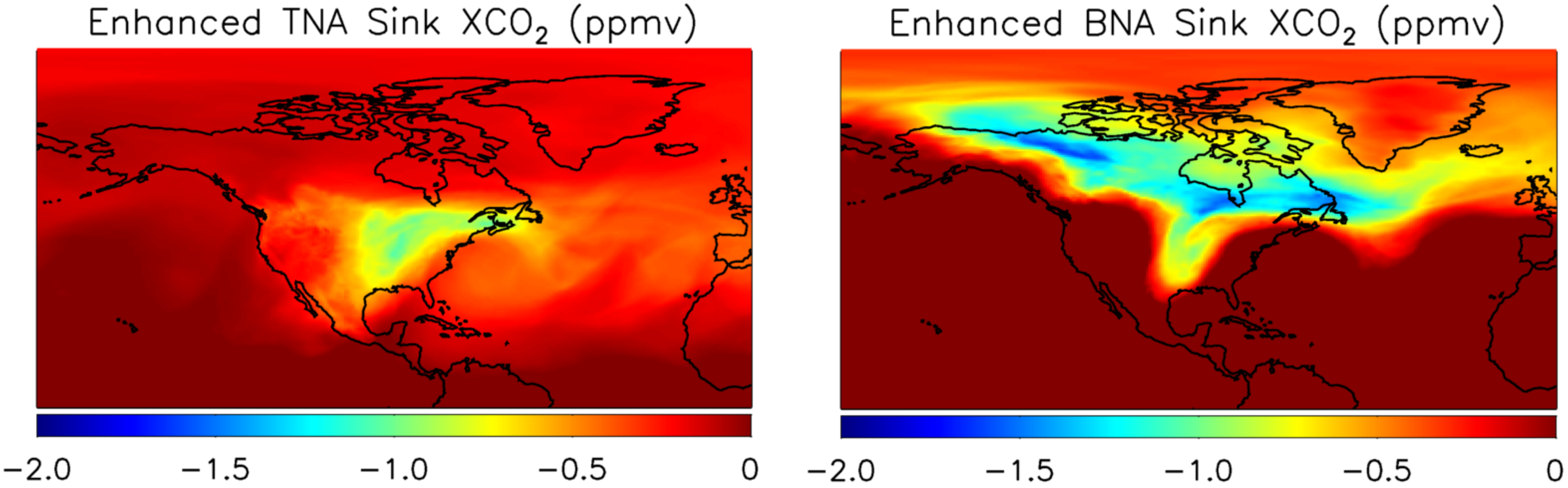
Nature Run Sampling

- Pseudo-datasets created by sampling Carbon Nature Run fields at measurement locations, applying estimated averaging kernel
- Assumes only random errors, work on implementing biases due to aerosols, airmass, and surface reflectance
- Uses MERRA-2 cloud and aerosol statistics



Average of 7 days of simulated psuedo-data

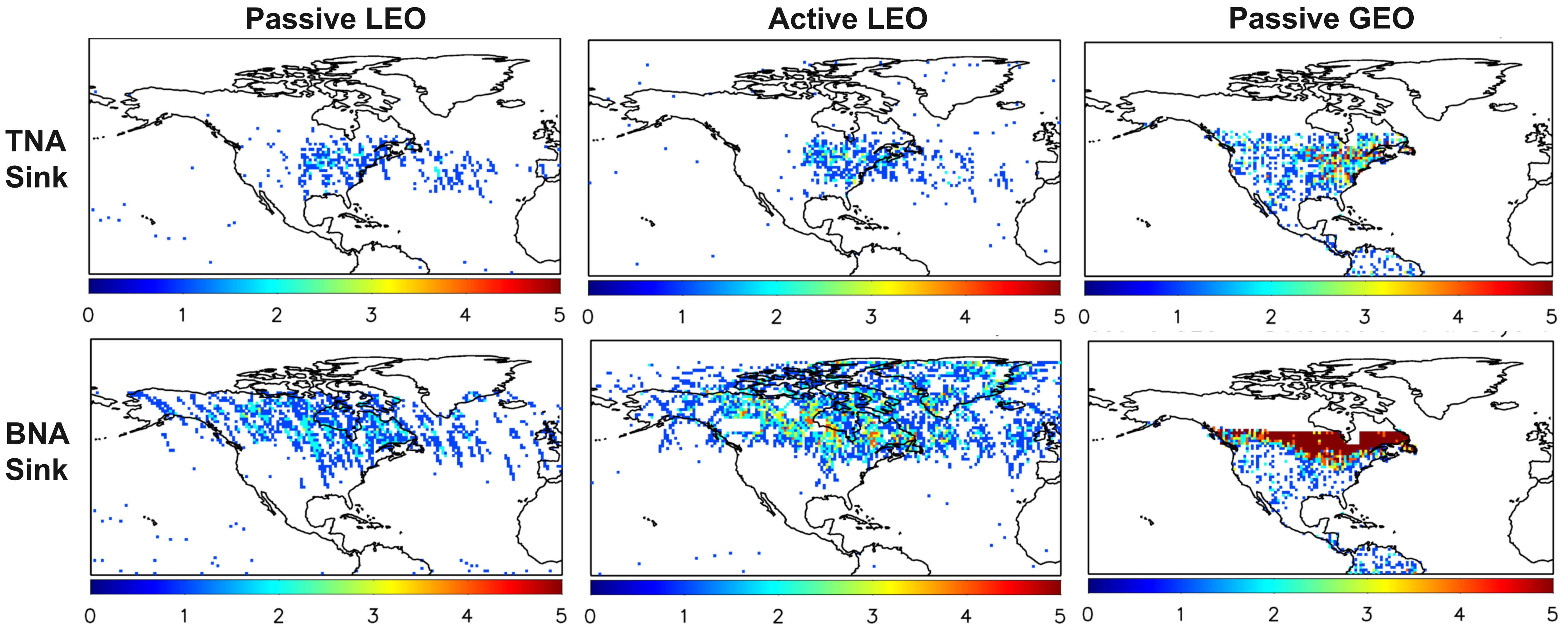
Comparison of 1 Pg C Sink for Temperate, Boreal North America



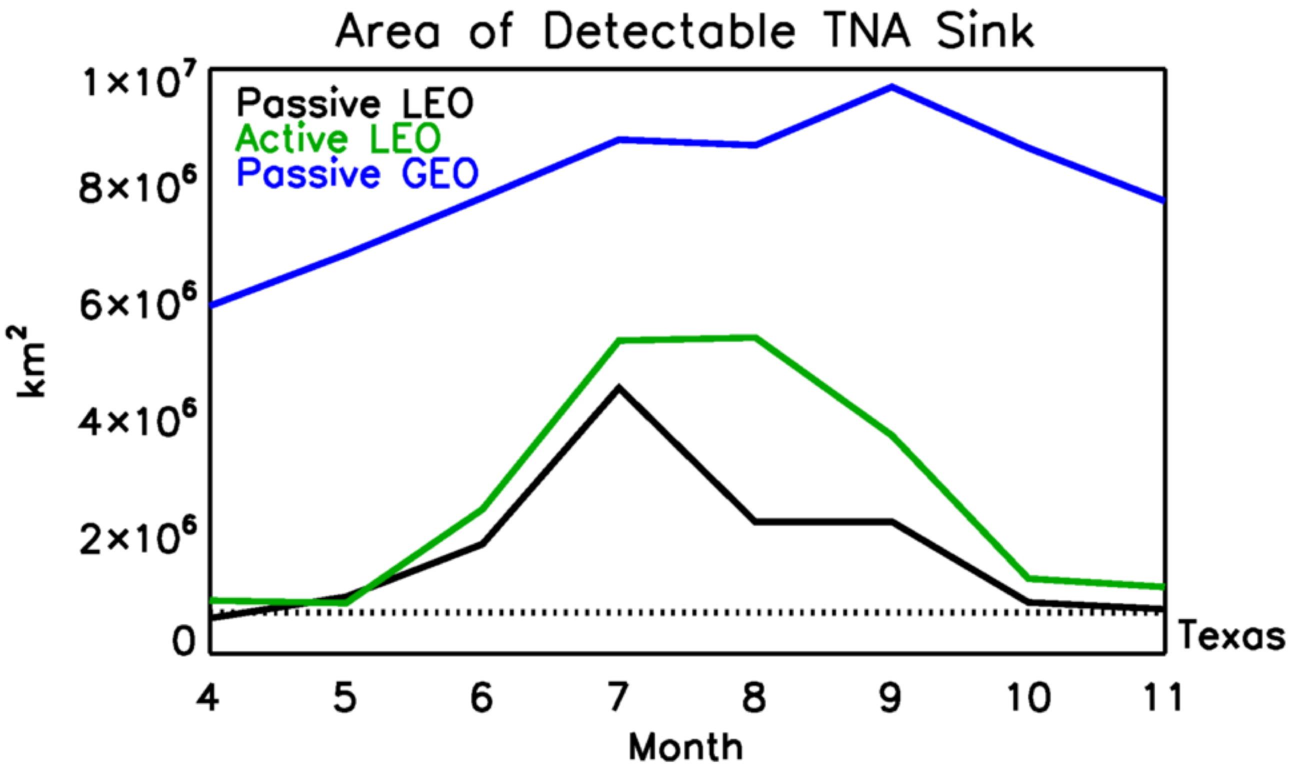
- Imposing a smaller, more realistic 1 Pg C sink results in a smaller concentration signature ranging form 1-2 ppm
- The BNA perturbation has a larger impact on concentrations because it is applied over a smaller spatial area than TNA
- One week averages show the that large flux differences can maintain coherence outside of the perturbation region

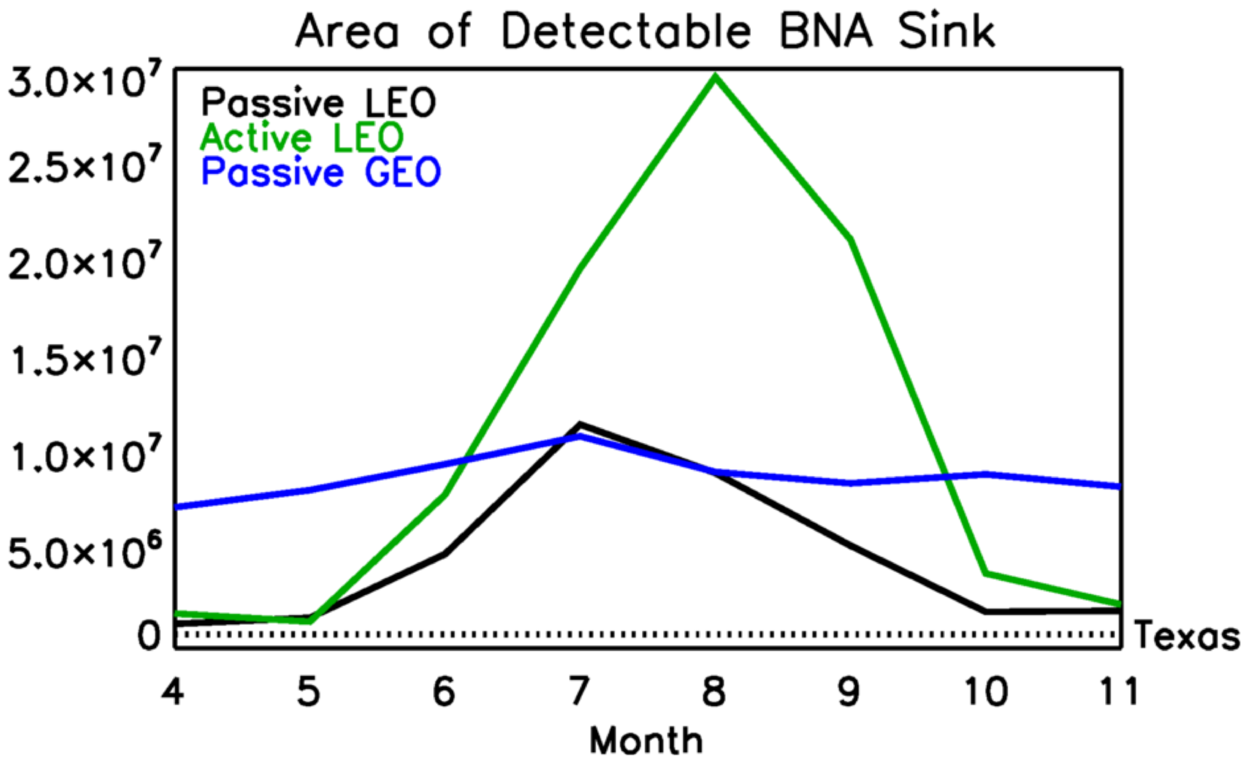
Comparison of 1 Pg C Sink for Temperate, Boreal North America

days during 201307 where flux perturbation is detectable



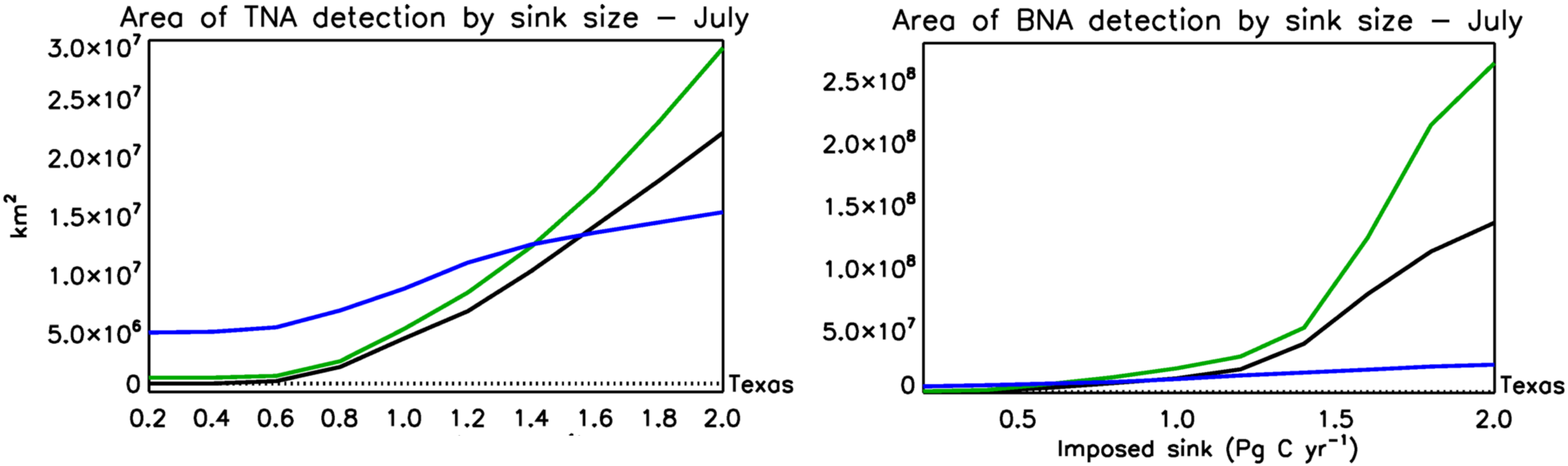
Seasonal variations in detectable area





- **Detectable area provides a simple metric for assessing the ability of different systems to observe flux changes**
- **This example shows how the area over which a flux perturbation is detected varies by season and observing system**

Variations in detectable area due to sink strength in July



Detectable area can also be used to examine how well different systems observe flux perturbations of different magnitudes

Ongoing Work

- Working on documenting these datasets and releasing publicly
- Producing ensemble of single instrument inverse flux estimates for biosphere flux scenarios
- Moving from 50 to 14-km nature run to explore urban cases, aerosol influence

Future OSSE Needs

- Develop ability to assess how new satellites fit into the GHG constellation
- Need framework for assessing the benefit of other trace gas measurements (CO, NO_2)
- Move toward retrieval OSSEs for GHGs to more realistically represent measurement errors
- Need a better way for representing transport error influence – could be addressed through coordinated nature run efforts