NASA's Carbon Cycle OSSE Initiative - Informing future space-based observing strategies through advanced modeling and data assimilation

Lesley Ott[1], Piers J. Sellers[1], David Schimel[2], Christopher O'Dell[3], Berrien Moore[4], David F. Baker[3], Abhishek Chatterjee[1,5], Sean Crowell[4], Stephan R. Kawa[1], Steven Pawson[1], Andrew E. Schuh[3]
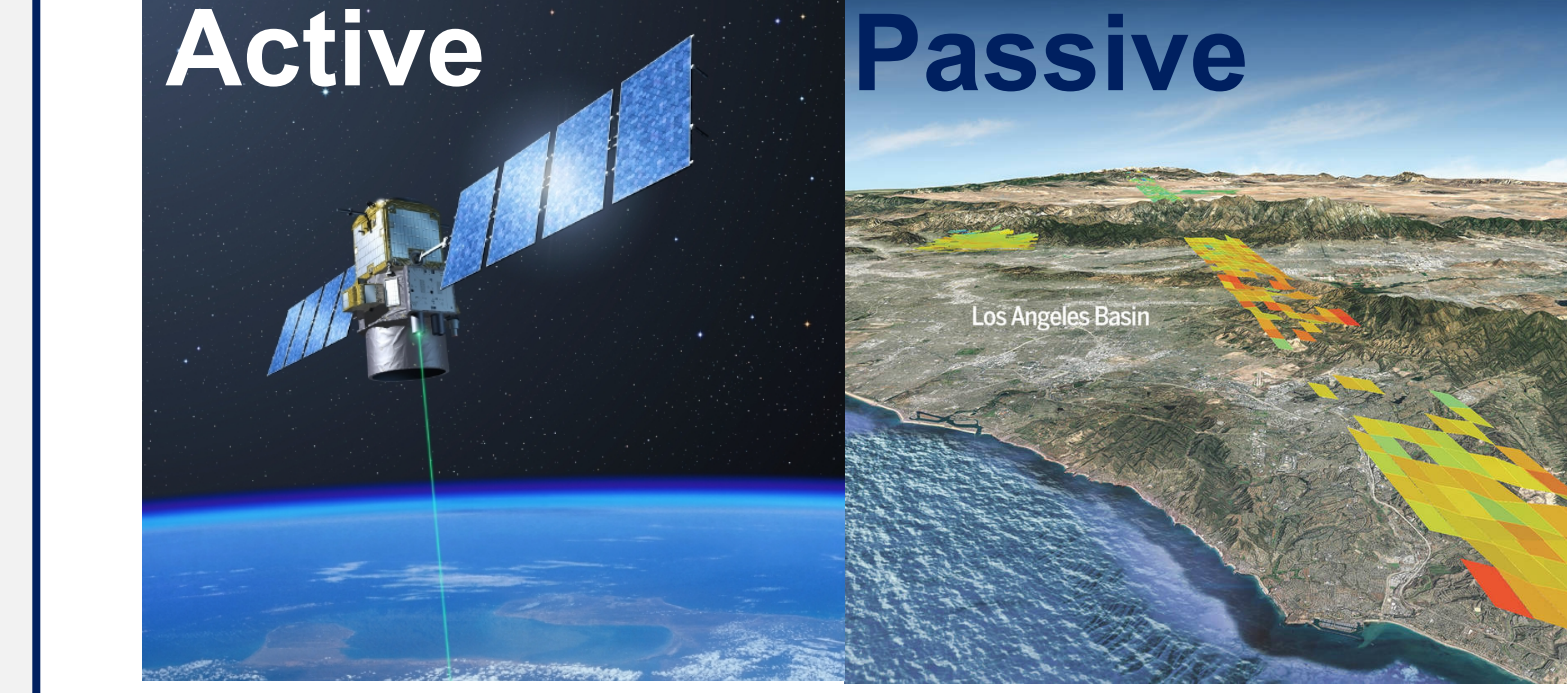
[1]Goddard Space Flight Center, [2]Jet Propulsion Laboratory, [3]Colorado State University, [4]University of Oklahoma, [5]Universities Space Research Association

GMAO — Global Modeling & Assimilation Office

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Motivation

Land and ocean carbon sinks absorb half of human CO_2 emissions. The fate of these sinks in a changing world is unknown, introducing large uncertainties in climate projections. Satellite measurements of atmospheric CO_2 are required to better understand the processes governing carbon uptake. Careful planning of future missions using Observing System Simulation Experiments (OSSEs) can help ensure that they meet the needs of the scientific and policy communities. NASA's Carbon Cycle OSSE Initiative brings together researchers from multiple universities and NASA centers to create model-derived data products in support of informed mission planning.
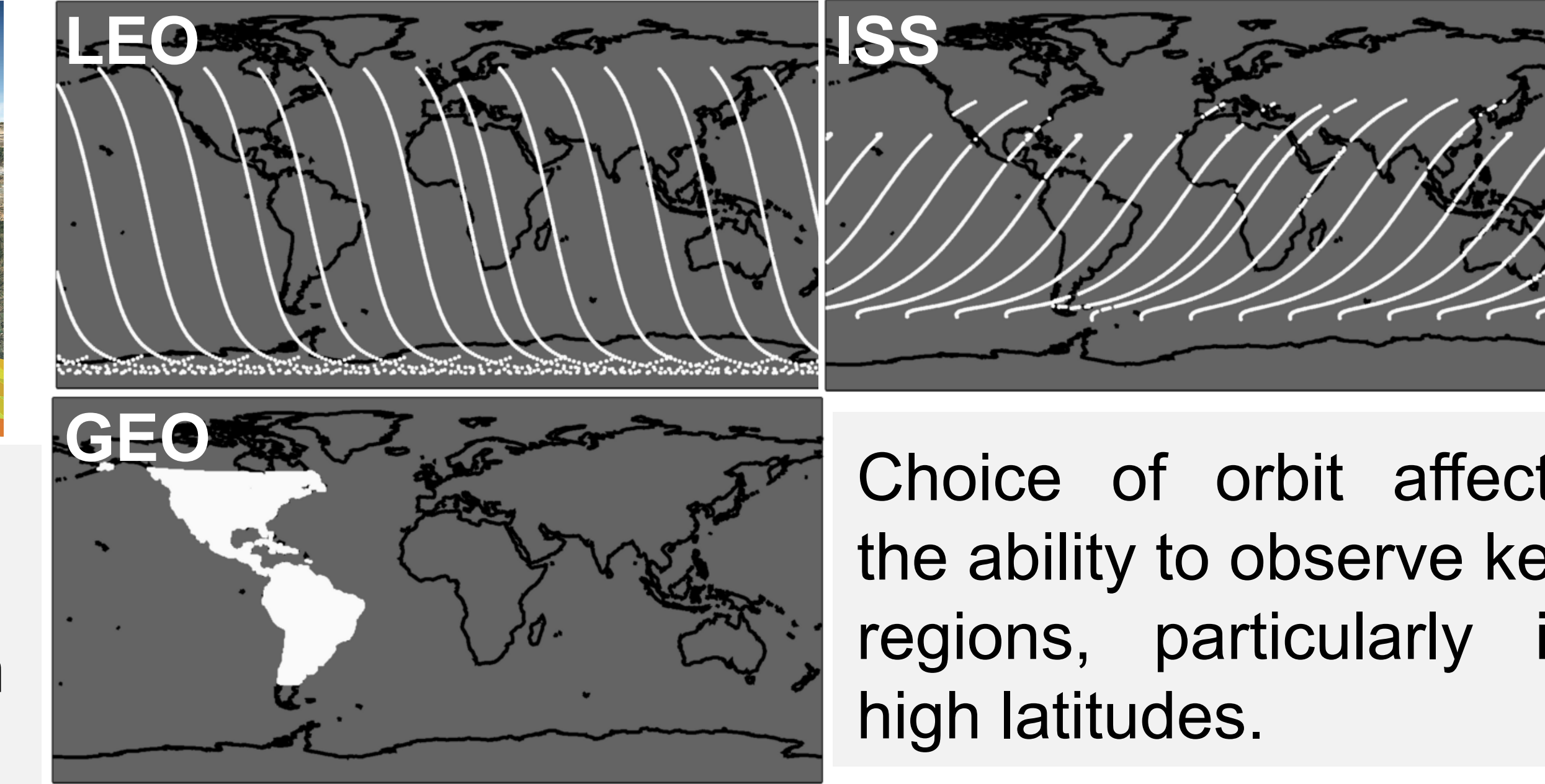
Carbon Cycle OSSE Process

Community assessment of carbon cycle science priorities → Flux change scenarios → GEOS Nature Run; Observationally-derived clear sky probability → Carbon instrument simulators → Synthetic datasets → Inverse model flux estimates; Statistical evaluation of signal detection → Assess ability to infer "true" flux estimate → Science informed mission design

Community Assessment of Priorities

Key Flux Process	Primary Region	Passive LEO	Active LEO	Passive GEO
Human Emissions	Megacities	???	???	●
Arctic-Boreal warming	NH high latitudes	✖	●	✖
Mid-latitude carbon uptake	NH Mid-latitudes	●	●	●
Tropical forests, LUC	Tropical land	●	●	●
Southern Ocean circulation	Southern Ocean	✖	???	✖
Unexplained methane emissions	NH mid- and high latitudes, tropical land	???	●	???

1-mo Clear-sky Samples

0 300 600 900 1200 1500 1800 2100 2400 2700 3000

Clouds Matter

Many of the key regions associated with uncertainty in the carbon cycle are cloudy, obstructing the ability of satellites to observe flux changes. A diurnally-varying, observationally-derived cloud product provides insight into the relative advantages of active and geostationary approaches

Mission Design Affects Science Yield
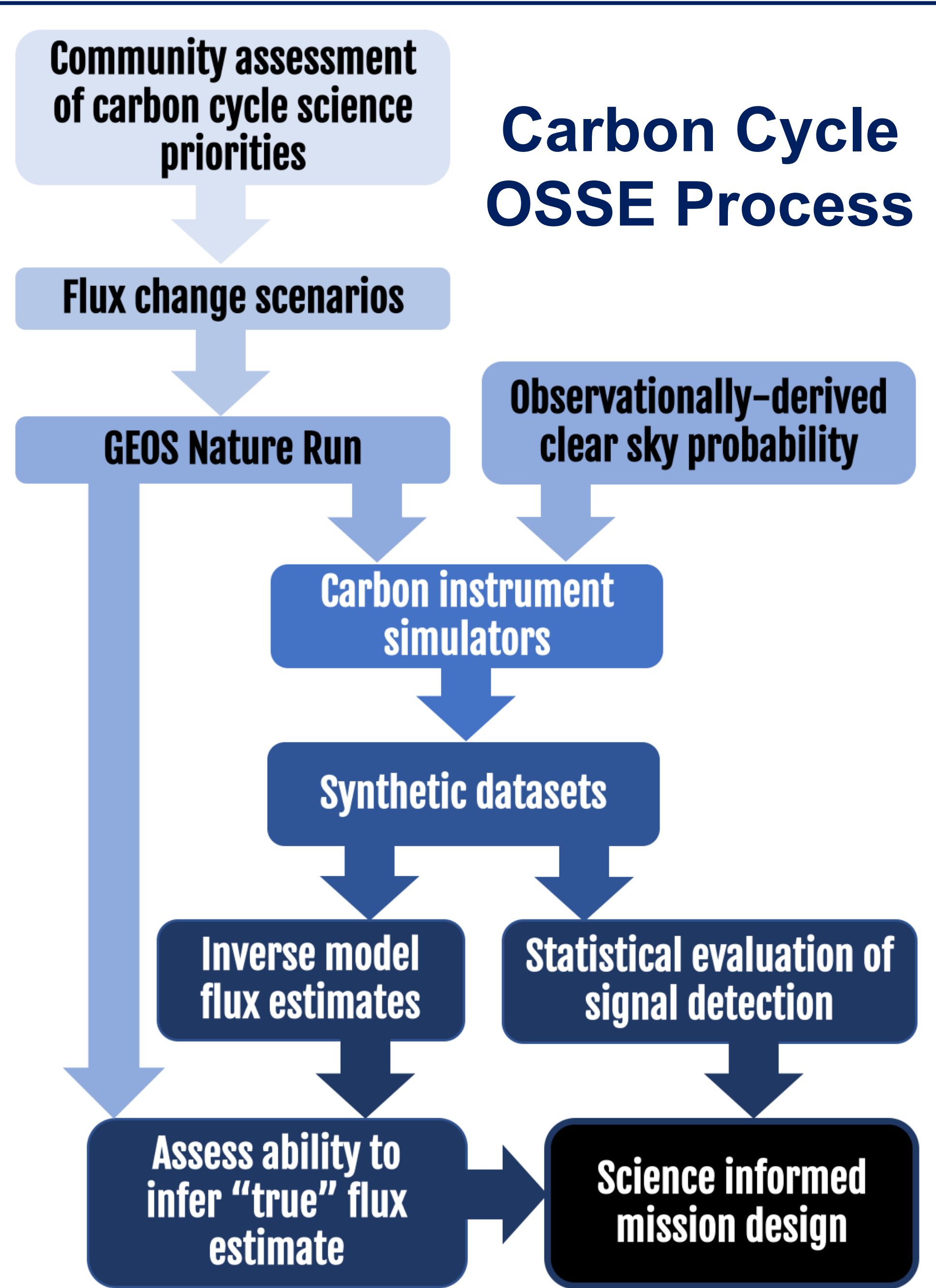
Remote Sensing Technique

Active   Passive

Current satellites measure CO_2 using reflected sunlight while active sensors provide their own illumination.
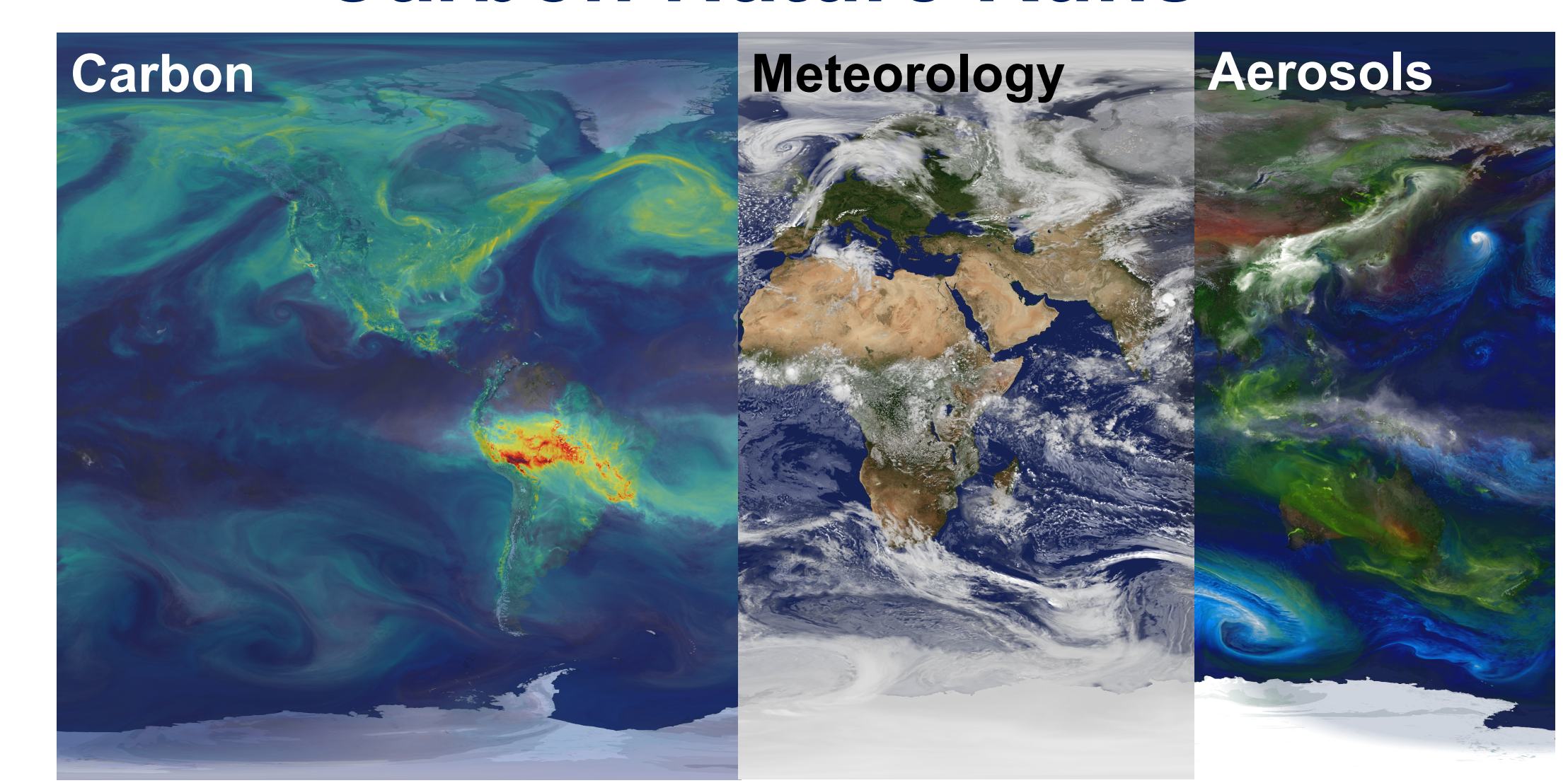
Choice of Orbit

LEO   ISS   GEO

Choice of orbit affects the ability to observe key regions, particularly in high latitudes.

Carbon Nature Runs

Carbon   Meteorology   Aerosols

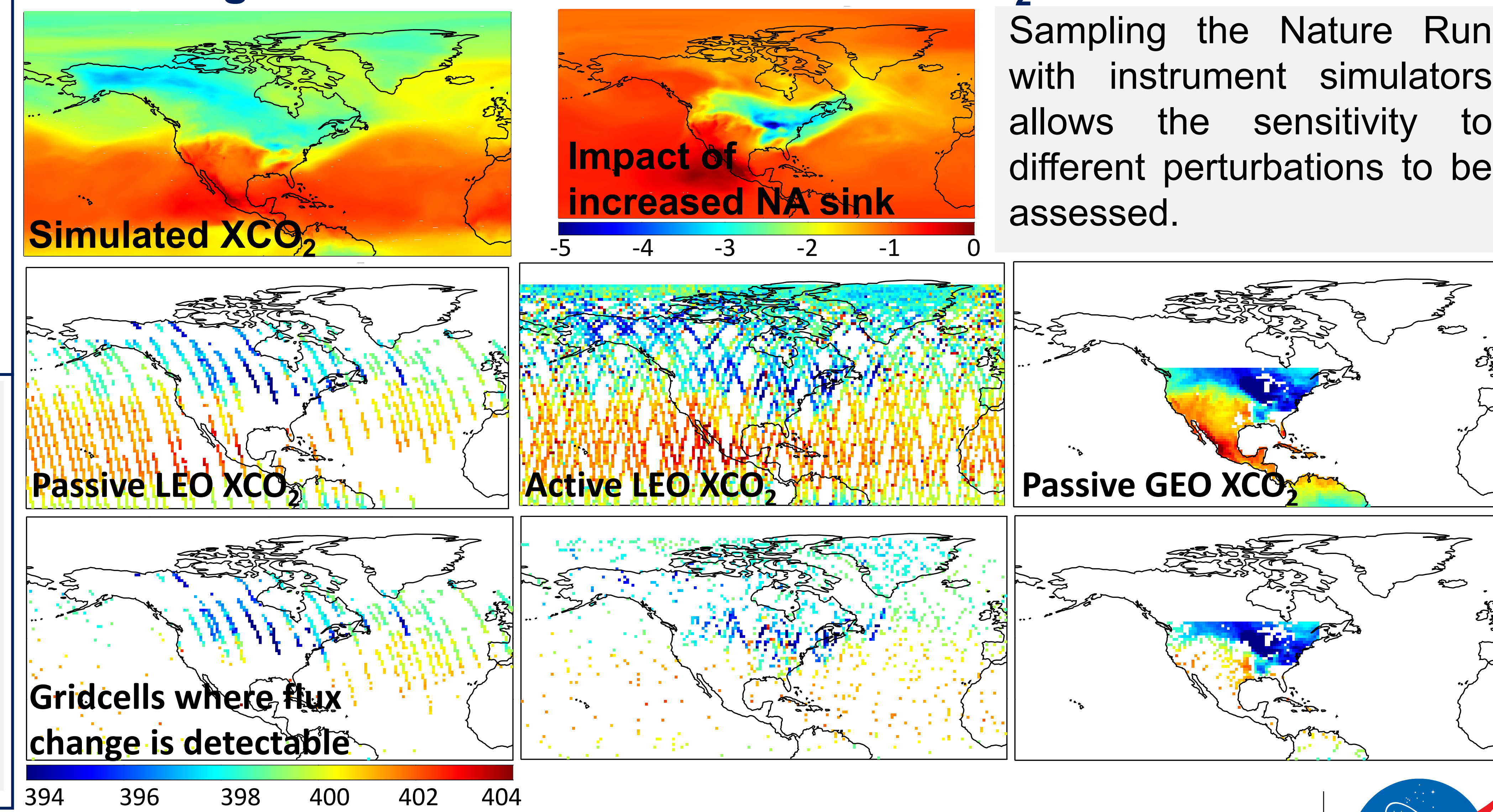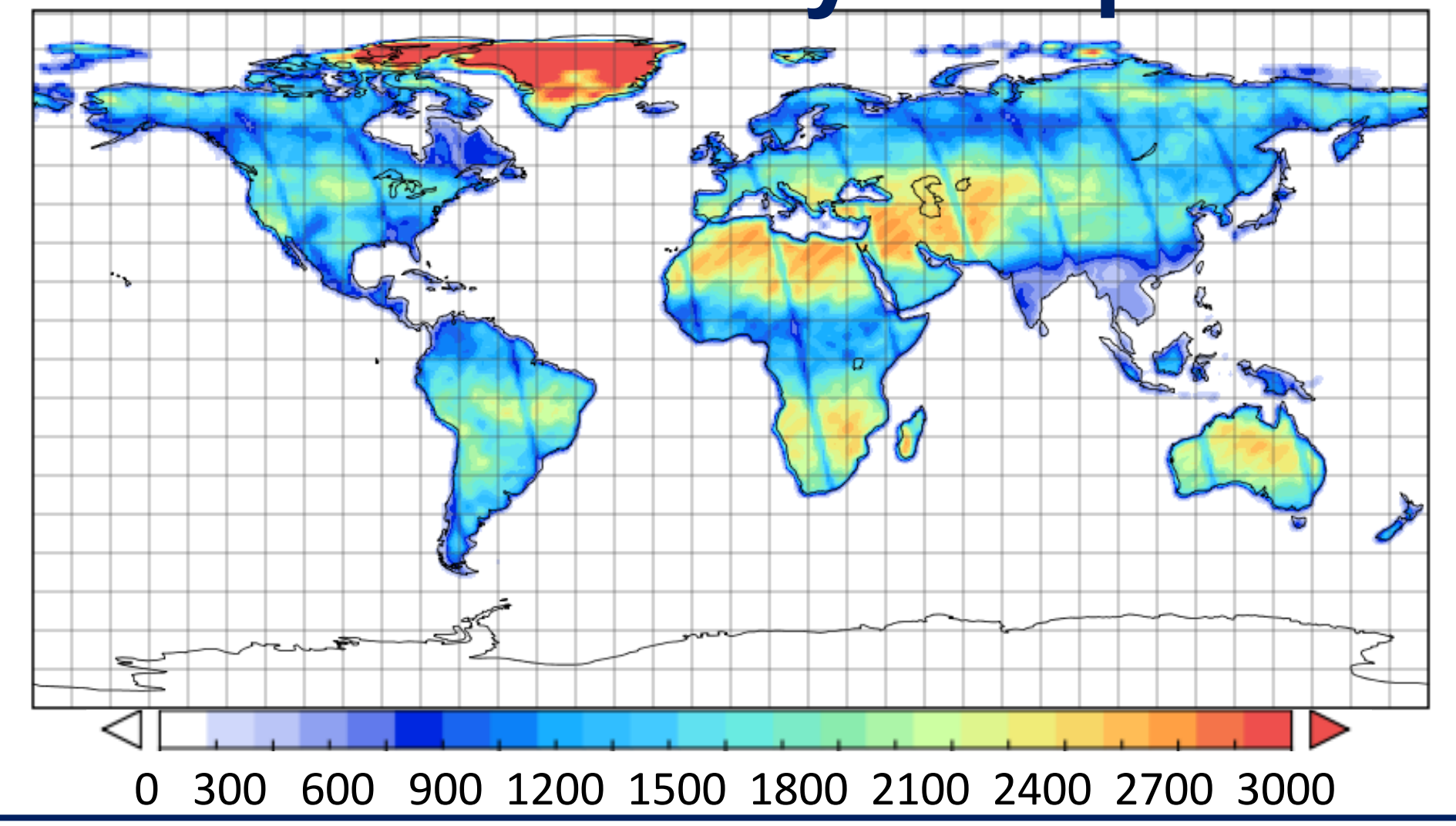### NASA's GEOS Model

The Goddard Earth Observing System (GEOS) supports NASA's Carbon Cycle OSSEs by providing both high-resolution (14-km) carbon and aerosol simulations and a large library of 50-km simulations with perturbed fluxes.

Assessing how different instruments view CO_2

Simulated XCO₂ — Simulated XCO_2

Impact of increased NA sink
-5 -4 -3 -2 -1 0

Sampling the Nature Run with instrument simulators allows the sensitivity to different perturbations to be assessed.

Passive LEO XCO_2 Active LEO XCO_2 Passive GEO XCO_2

Gridcells where flux change is detectable

394 396 398 400 402 404

E-mail: lesley.ott@nasa.gov | Web: gmao.gsfc.nasa.gov

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