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

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Previous GHG OSSE efforts

- 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 are subject to significant methodological weaknesses:

  - 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
  - Lack of maturity of inverse models makes it tough to separate weaknesses in satellite from weaknesses in model

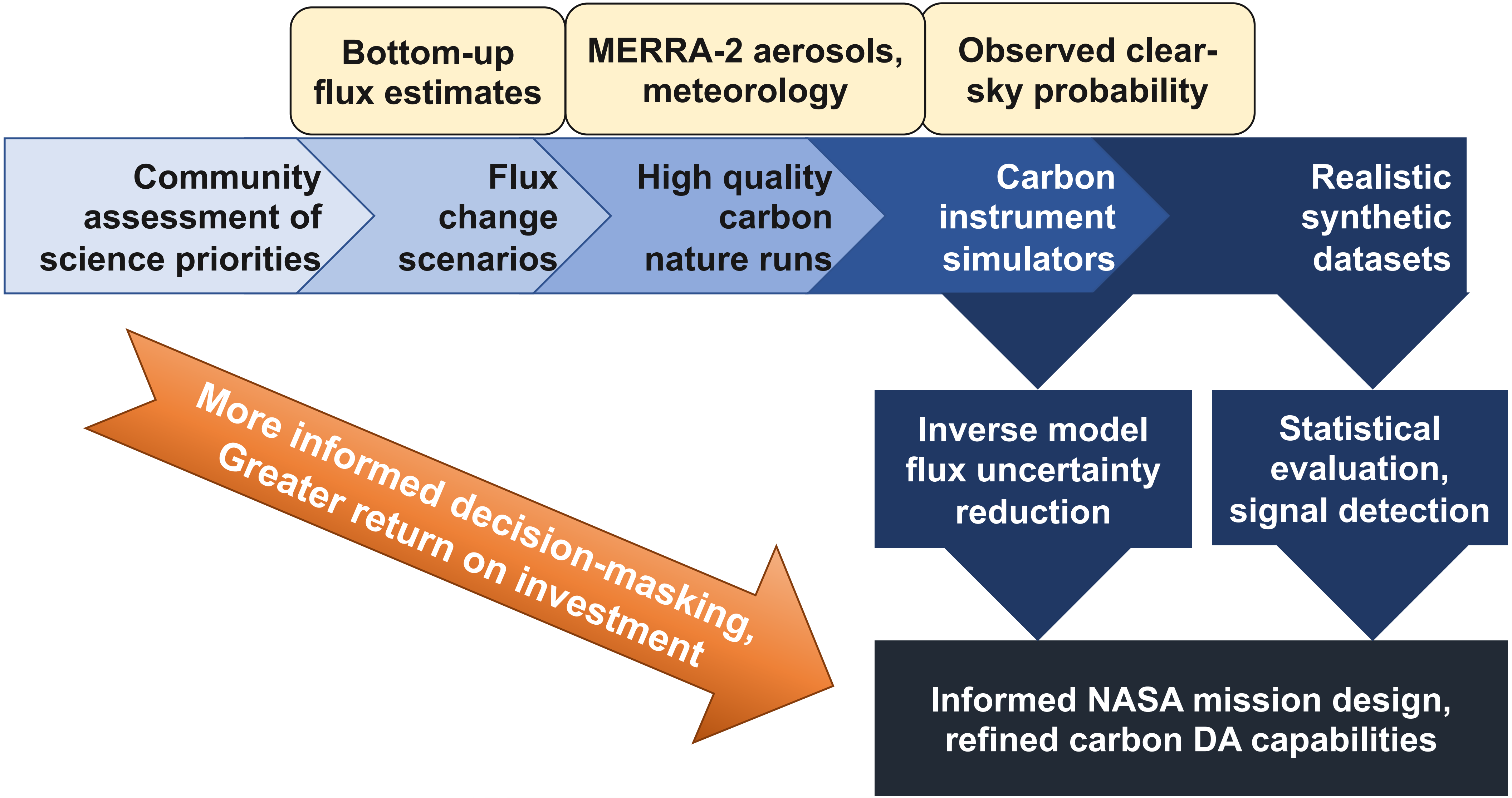
Need for integrated OSSE system design to support future missions, advanced capabilities

Leverage existing observationally-derived products

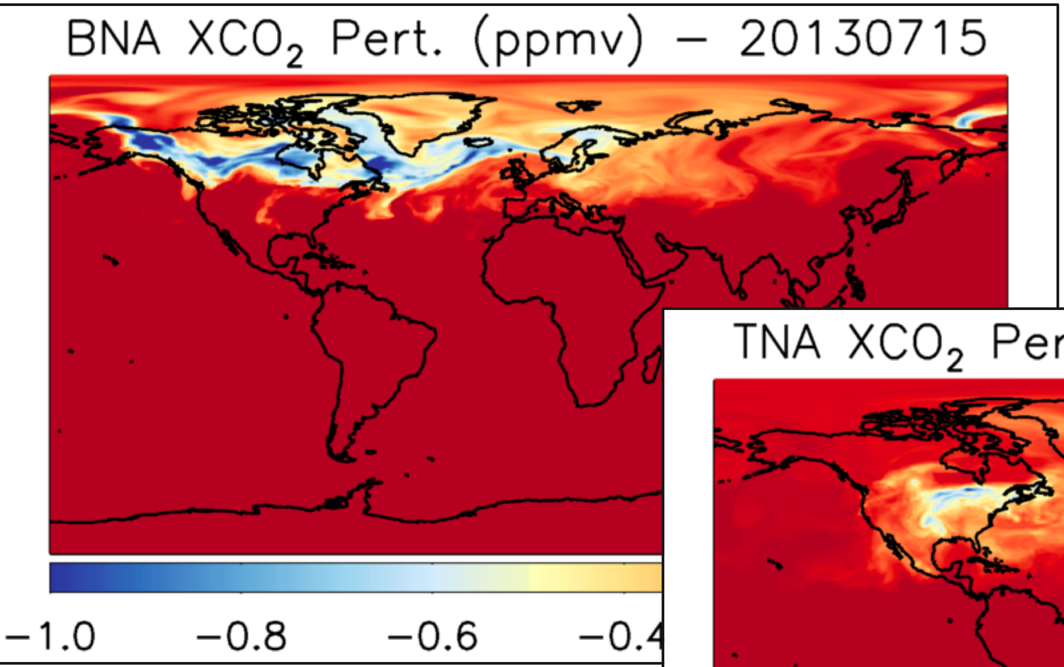
Produce new datasets in support of US, international OSSE efforts

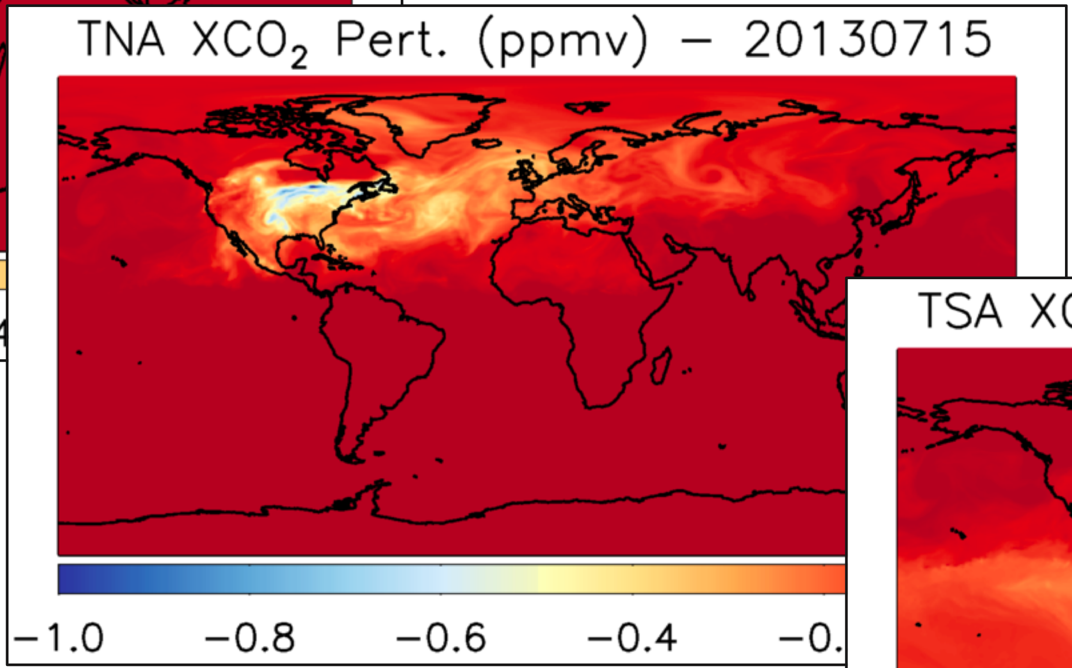
Implement new metrics for assessing missions

Improve ability to deliver missions that fill key data, knowledge gaps

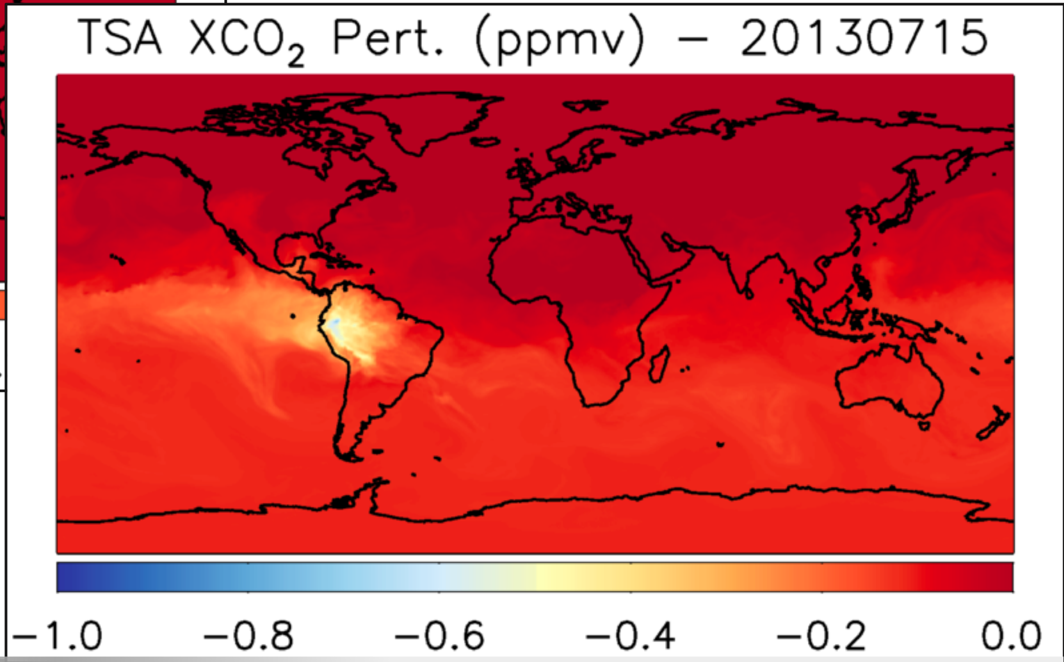


GEOS tagged tracer approach supports simultaneous analysis of multiple emission scenarios





Example of a 0.5 Pg C sink applied to American regions



Current library of simulations includes dozens of regional biosphere and fossil fuel tracers

Building up instrument simulator infrastructure

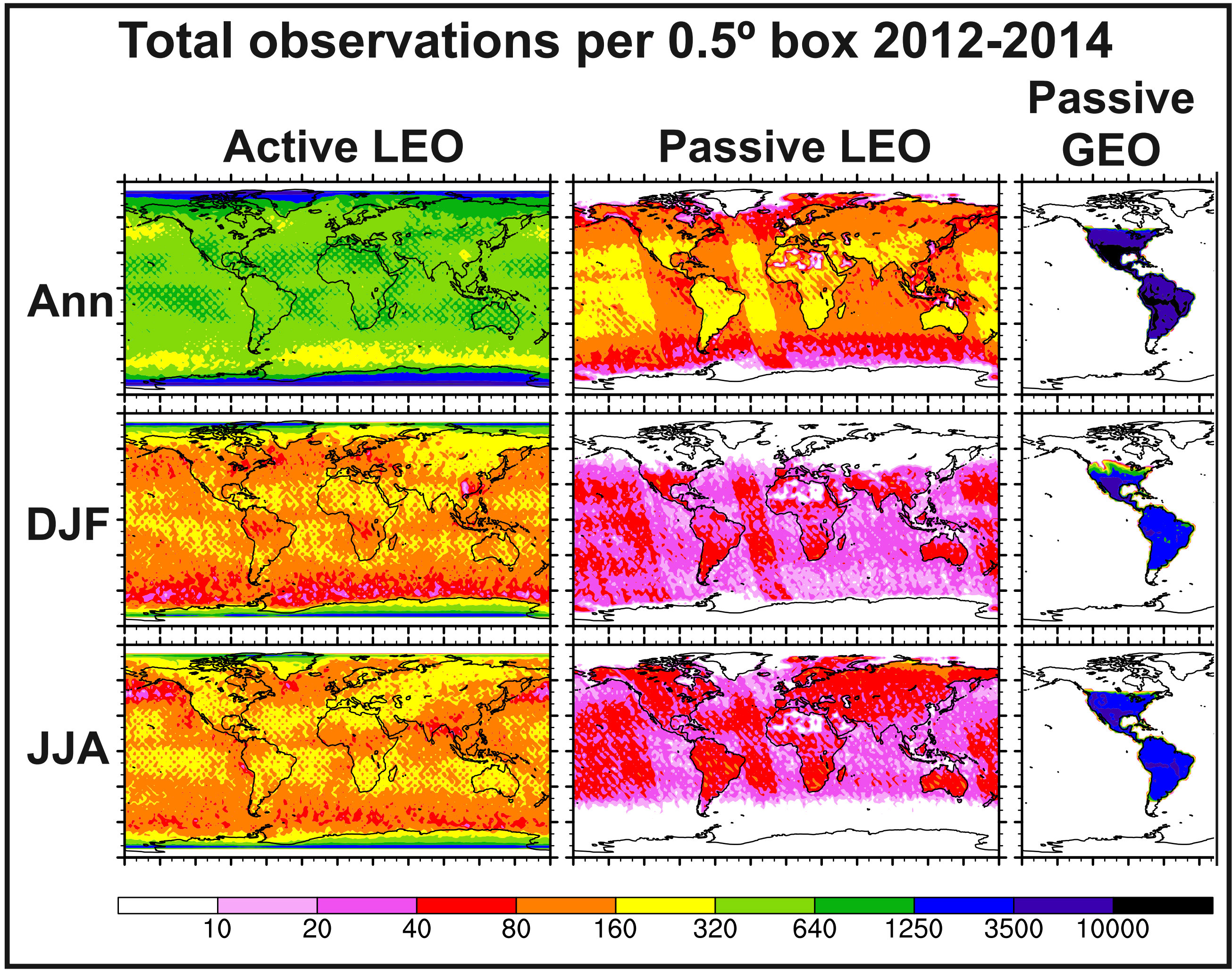
Two classes of instrument simulators

Economy class:

- Model sampled at measurement locations to produce XCO_2
- Simple screening based on clouds, aerosols, albedo, solar zenith angle
- Random and systematic errors based on current missions, aircraft observations

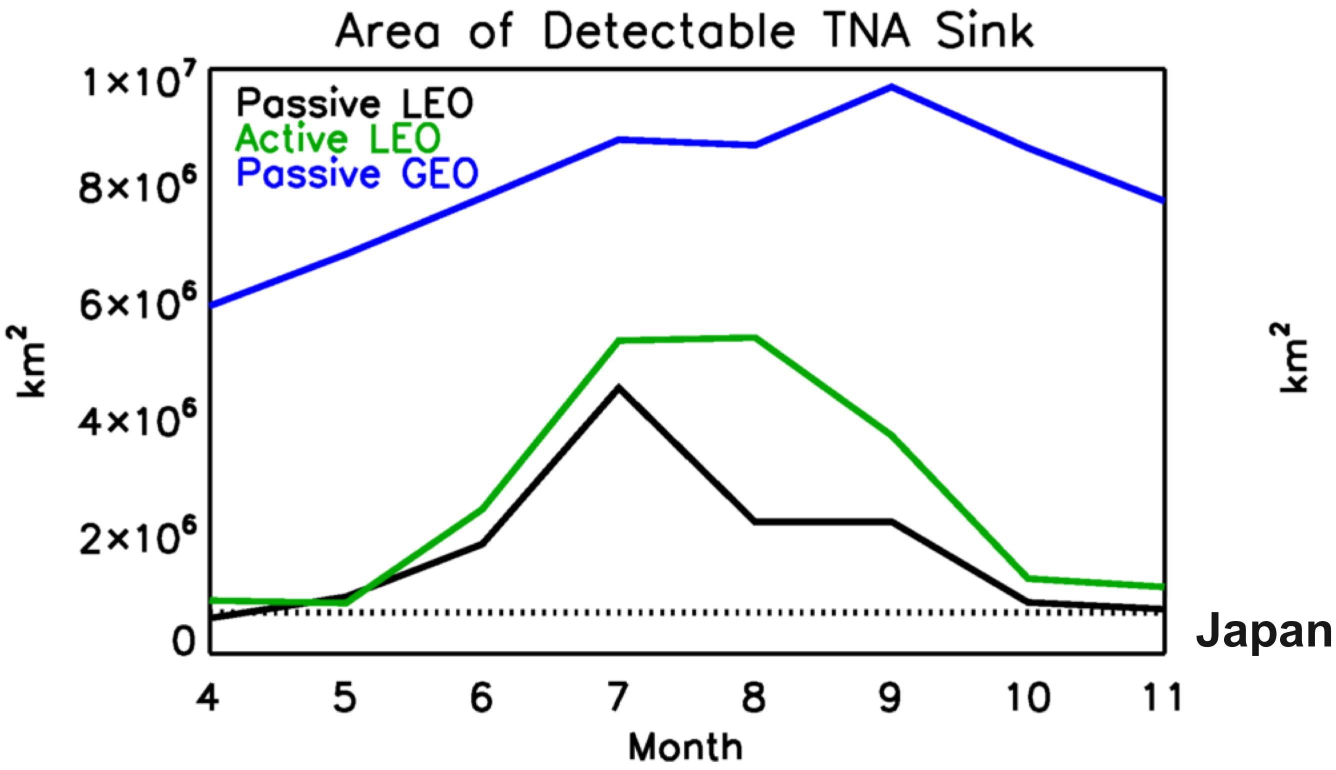
Business class:

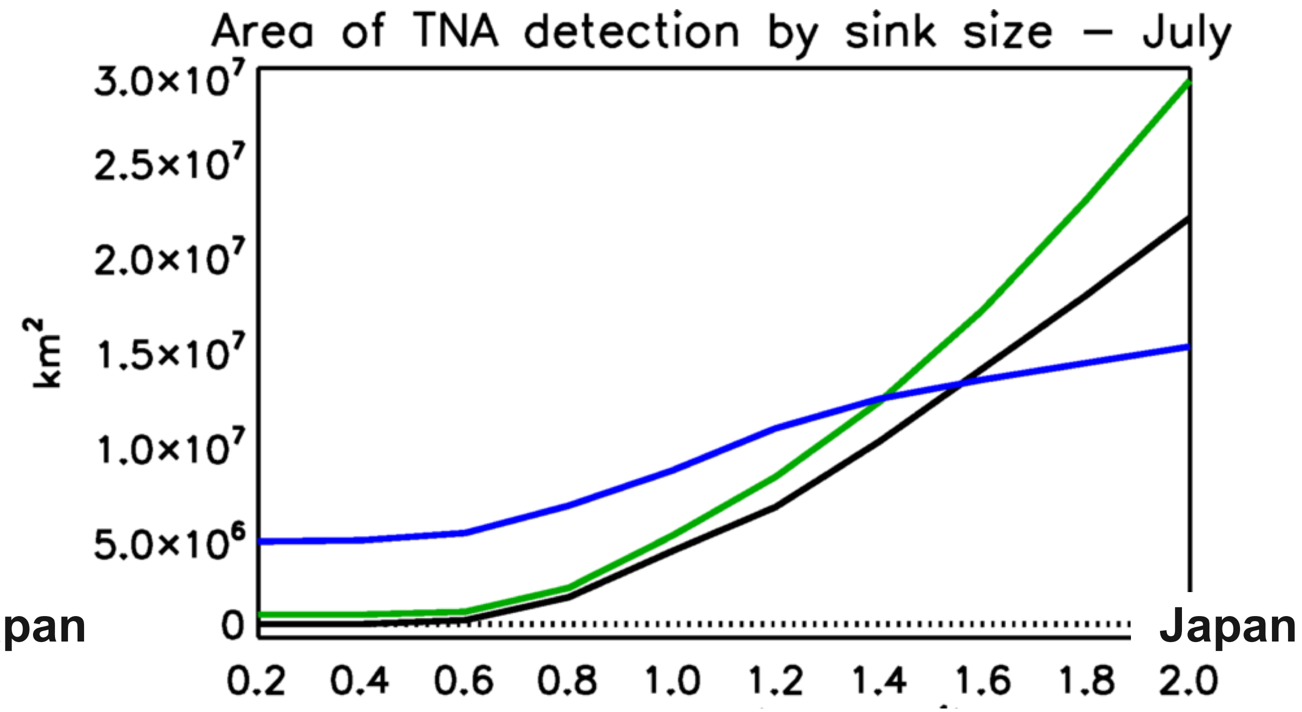
- Simulate L1 radiances from model data
- Use actual retrieval algorithm to estimate XCO_2



Most of the time we're in economy, but we're really trying to get closer to business

Examples of signal detection: how the picture of a detectable sink changes by season and size



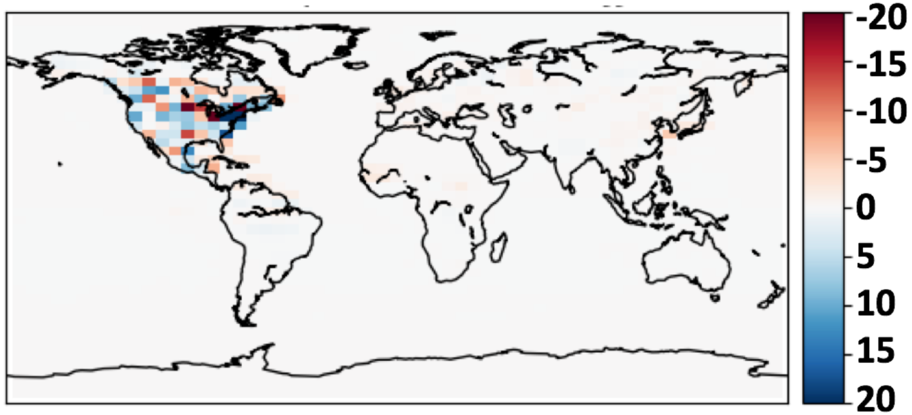


- **‘Detectable area’ – area over which the difference between the baseline and perturbation would be larger than the variance of simulated measurements**
- **This example shows how the area over which a flux perturbation is detected varies by season (for a 1 PgC sink) and sink size for each observing system**

Examples of inverse model evaluation: need for constellation observing

True TNA flux perturbation – JJA ($gC\ m^{-2}\ yr^{-1}$)

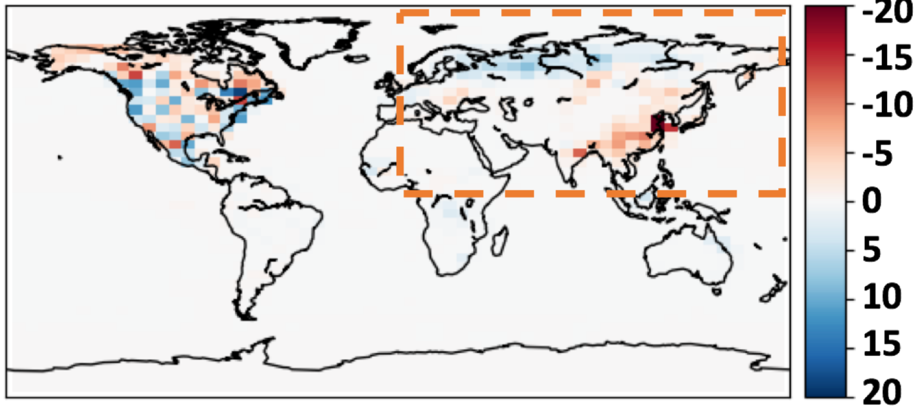
Passive LEO – Truth-Posterior Flux



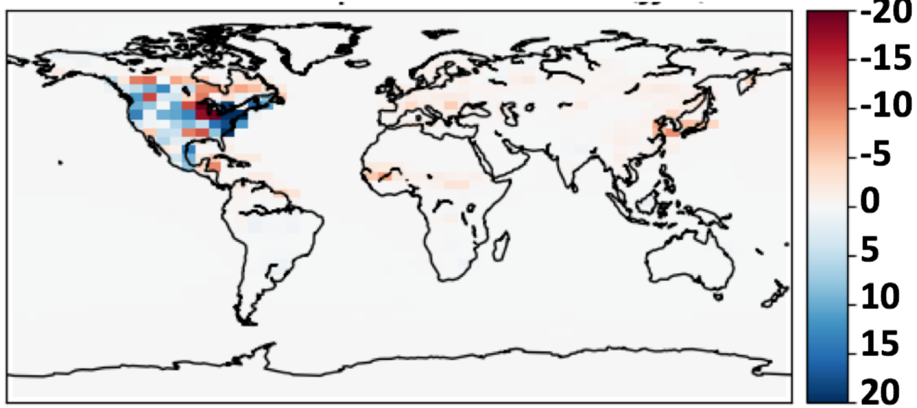
Parallel inverse experiments attempting to retrieve 0.2 PgC sink over NA:

- Random error only
- Perfect transport
- 50% prior uncertainty globally

Passive GEO – Truth-Posterior Flux



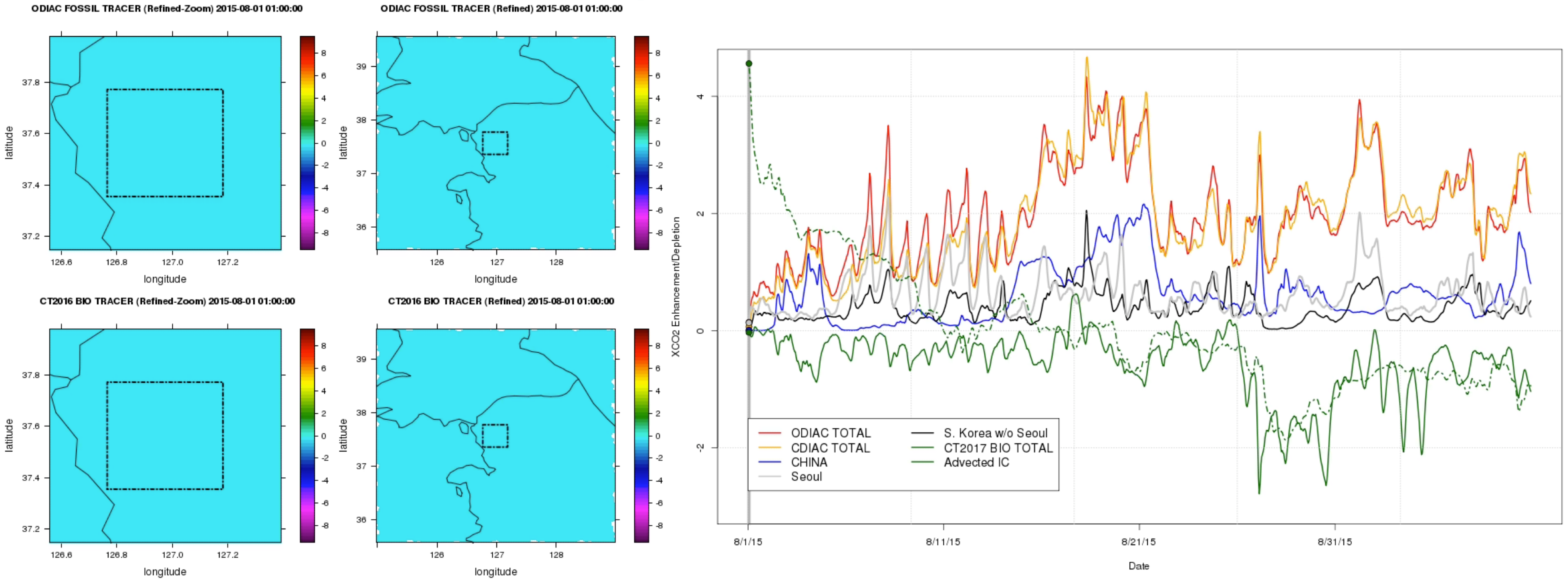
Active LEO – Truth-Posterior Flux



All missions succeed in identifying sink region, but GEO inversion creates spurious sources, sinks

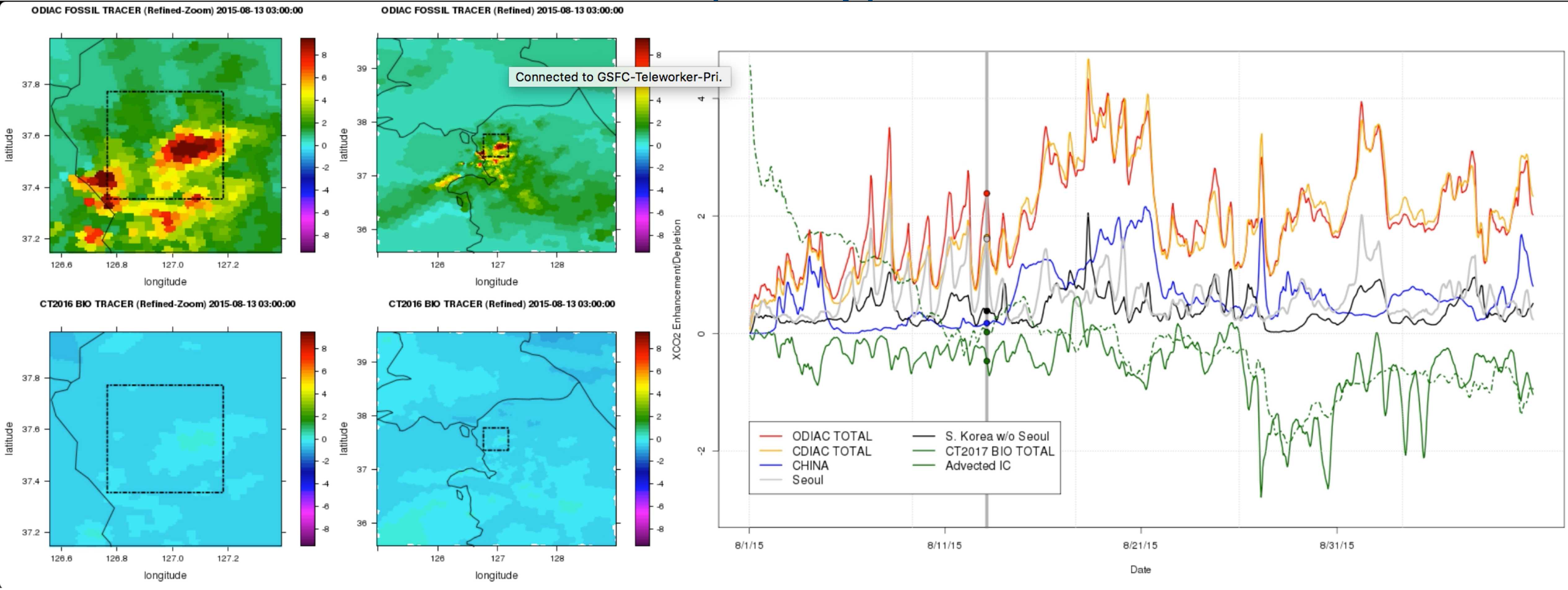
Credit: S. Crowell, OU

Examining global cities using a global, variable resolution model: Example from Seoul, Korea



Tagged tracers + variable resolution supports evaluation of dozens of cities simultaneously

Examining global cities using a global, variable resolution model (backup)



Tagged tracers + variable resolution supports evaluation of dozens of cities simultaneously

Moving toward a more complete evaluation of observing approaches

Observing realistic time and space gradients	A	B	C
Latitudinal gradients	--	--	√
Longitudinal gradients	√	--	√
Seasonal cycle (phase and amplitude)	√	√	√
Vertical information	--	--	--
Information content	--	√	√

Ability to address science requirements	A	B	C
Ability to detect small bio perturbation	X	√	X
Ability to detect large bio perturbation	√	√	√
Ability to differentiate nearby bio perturbations	--	√	--
Ability to observe urban emissions (small-medium)	X	√	X
Ability to observe urban emissions (large)	--	√	--
Sensitivity in key regions - Arctic	X	X	√
Sensitivity in key regions - Amazon	X	√	--
Sensitivity in key regions – Southern Ocean	X	X	--
Ability to improve inverse estimate in perturbed area	√	√	√
Ability to improve inverse est. in unperturbed area	√	--	√
Ability to improve inverse estimate globally (land)	√	--	√
Ability to improve inverse estimate globally (ocean)	--	X	√

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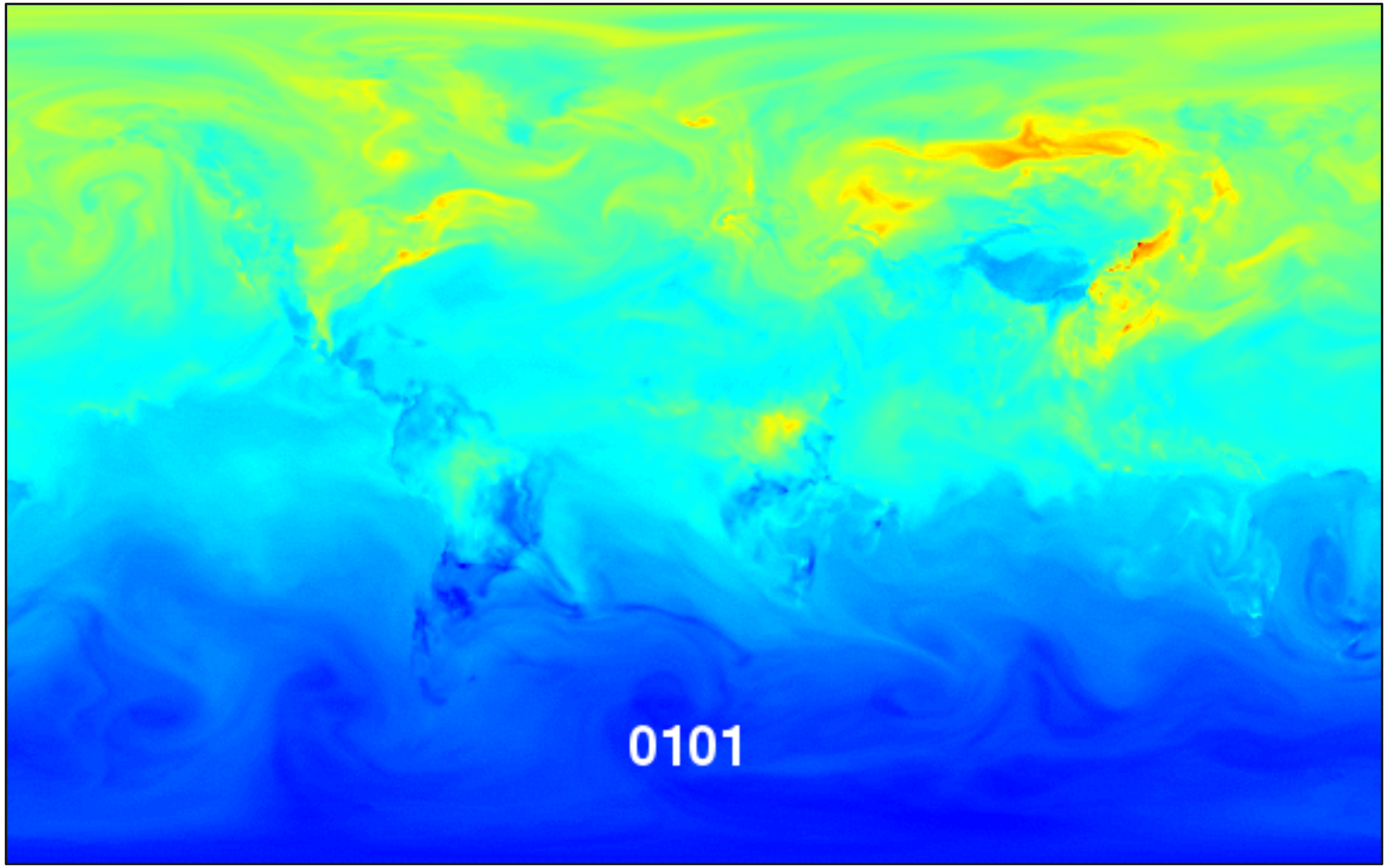
Summary and conclusions

- Collaboration between universities, NASA centers has helped to standardize datasets, expand metrics used to evaluate new satellite missions
- Much progress on building infrastructure that we need to ‘harden’ inversion systems, but lots more left to do
- Urgent need to develop techniques that combine multiple satellite datasets



Opportunities for collaboration:

- **Realistic prior flux errors**
- **Better information on systematic errors**
- **Better assessment of transport model errors**

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