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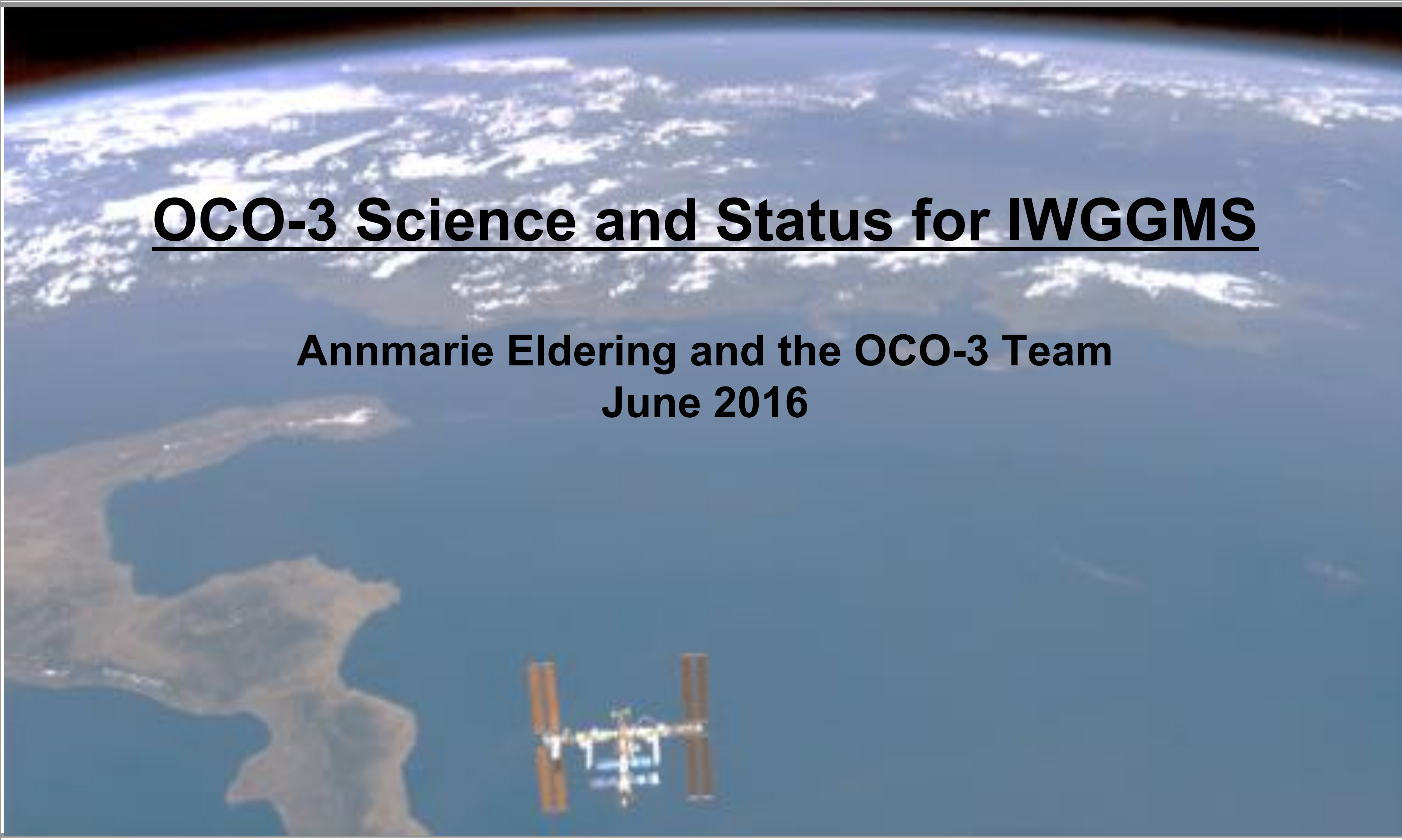

OCO-3 Science and Status for IWGGMS

Annmarie Eldering and the OCO-3 Team
June 2016

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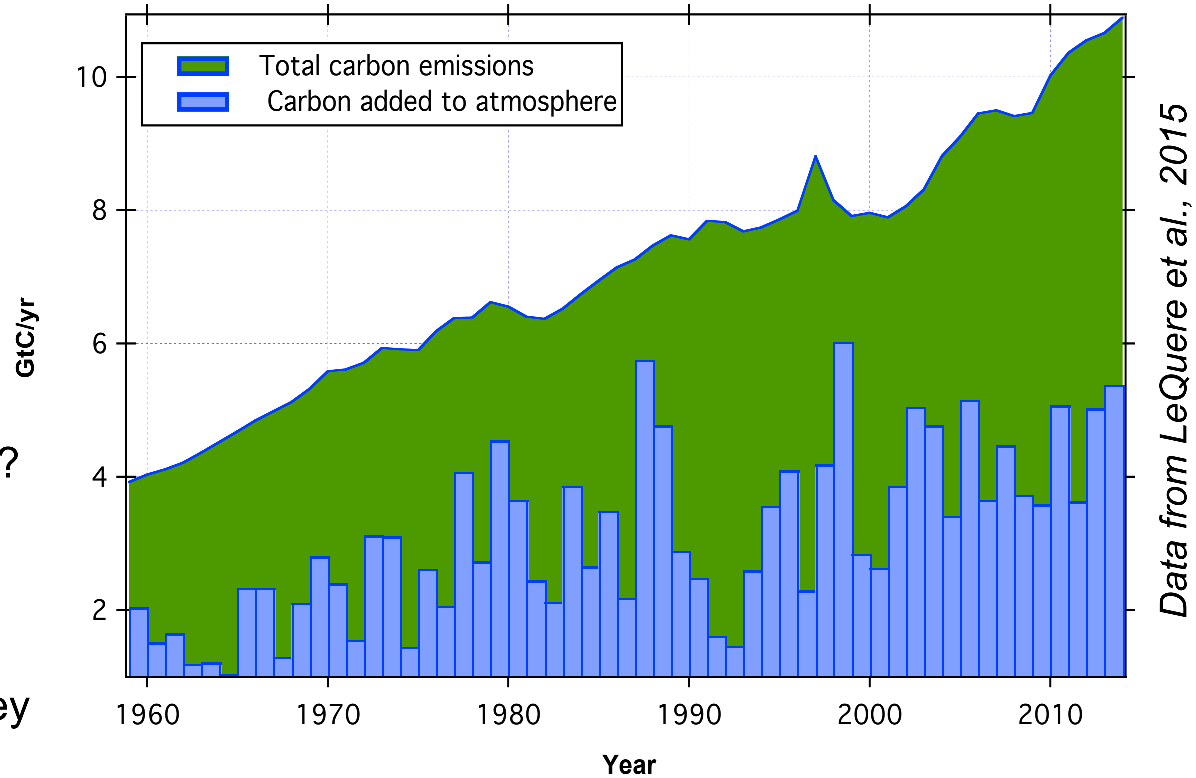
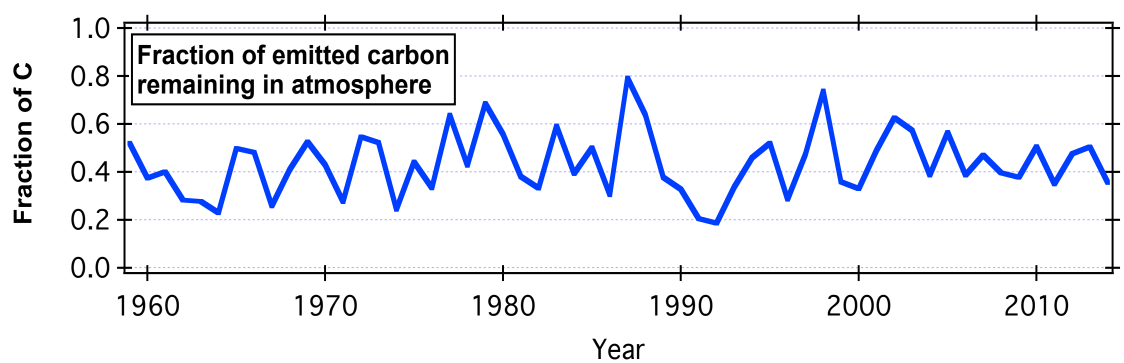
Motivation: How will the atmospheric CO_2 growth rate evolve?

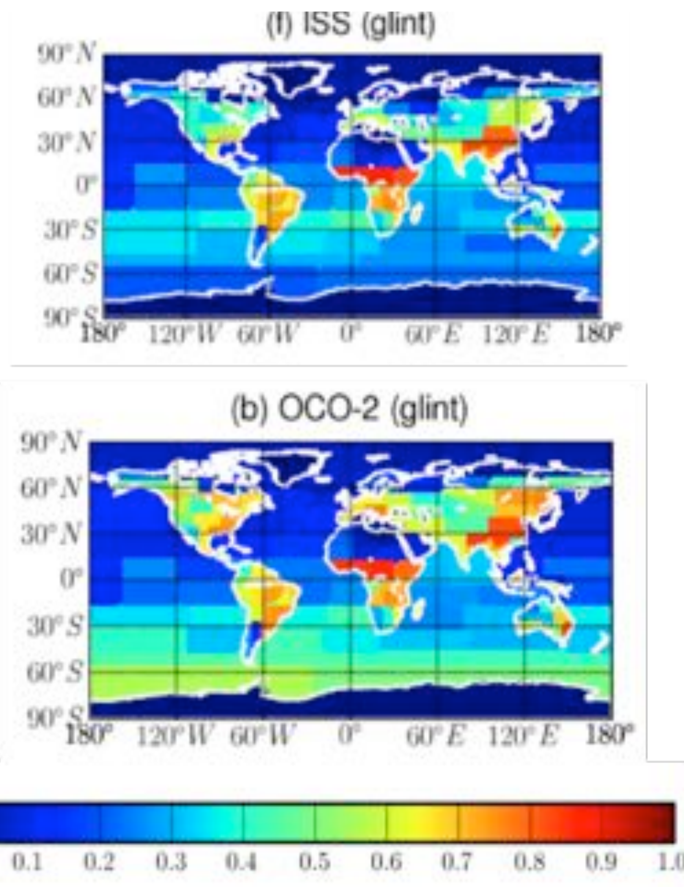
- Humans have added >300 Gt C to the atmosphere since 1958
- Less than half of this CO_2 is staying in the atmosphere
- Where are the *sinks* that are absorbing over half of the CO_2?
  - Land or ocean?
  - Eurasia/North America?
- Why does the CO_2 buildup vary from year to year with nearly uniform emission rates?
- How are variations driven by large scale drivers of atmospheric variability (e. g., ENSO)?
- Can we reduce the uncertainty on each key system within the carbon cycle?
- How will these CO_2 sinks respond to climate change?





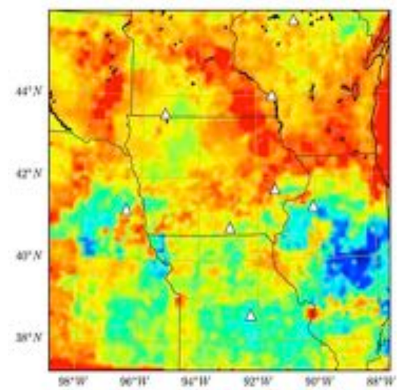
OCO-3 Science Overview

Global Flux Estimates: OCO-2 and OCO-3 impacts (simulated)



Flux error improvement for January
Palmer et al., 2011

Unique Science Opportunities with OCO-3



Midwest Carbon Flux
From Schuh et al., 2013

Terrestrial Carbon Cycle

Process studies enabled by measurements at all sunlit hours, including SIF. ISS will contain complementary instrumentation.

Anthropogenic Emissions

Enabled by enhanced target mode using pointing mirror assembly

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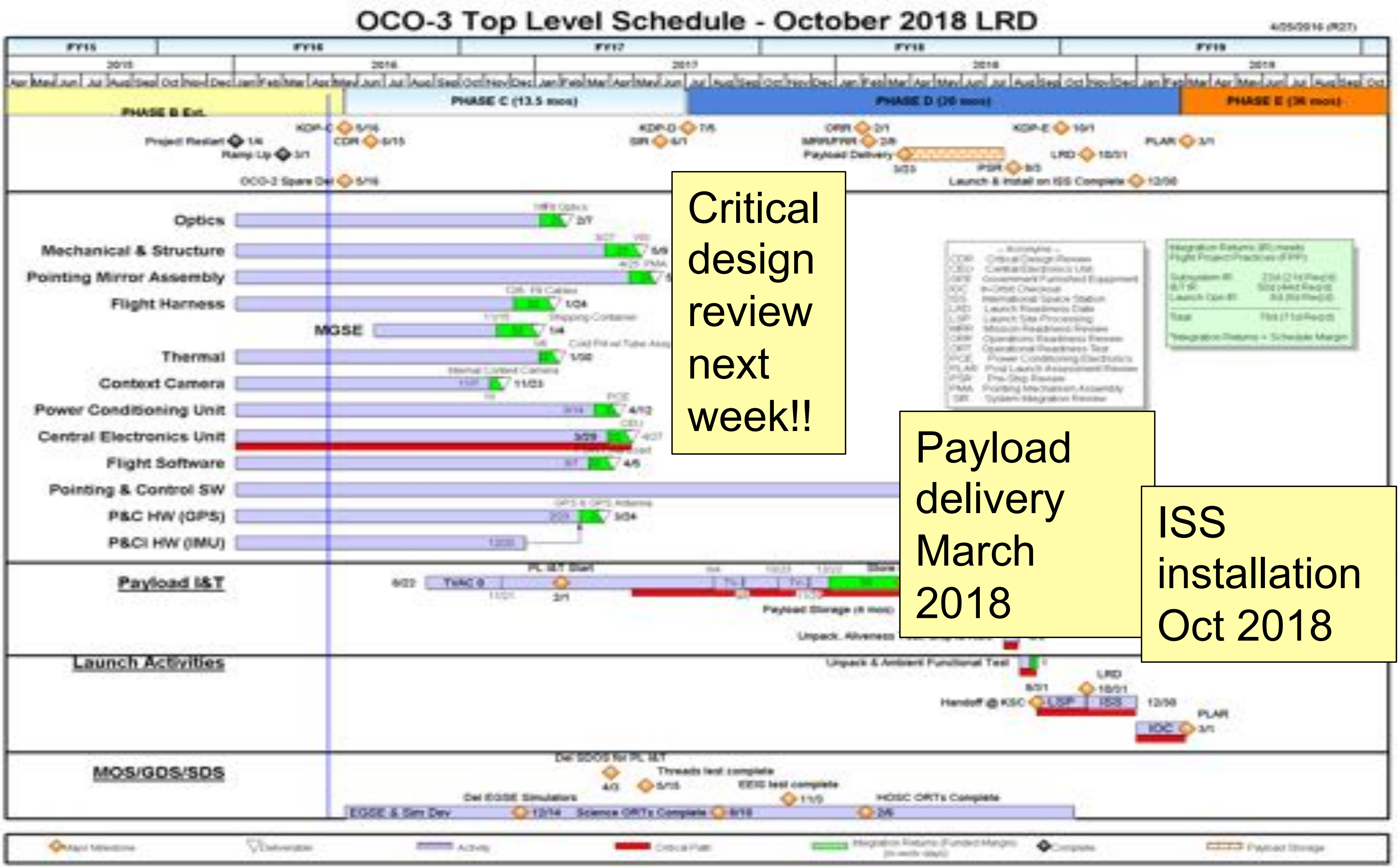
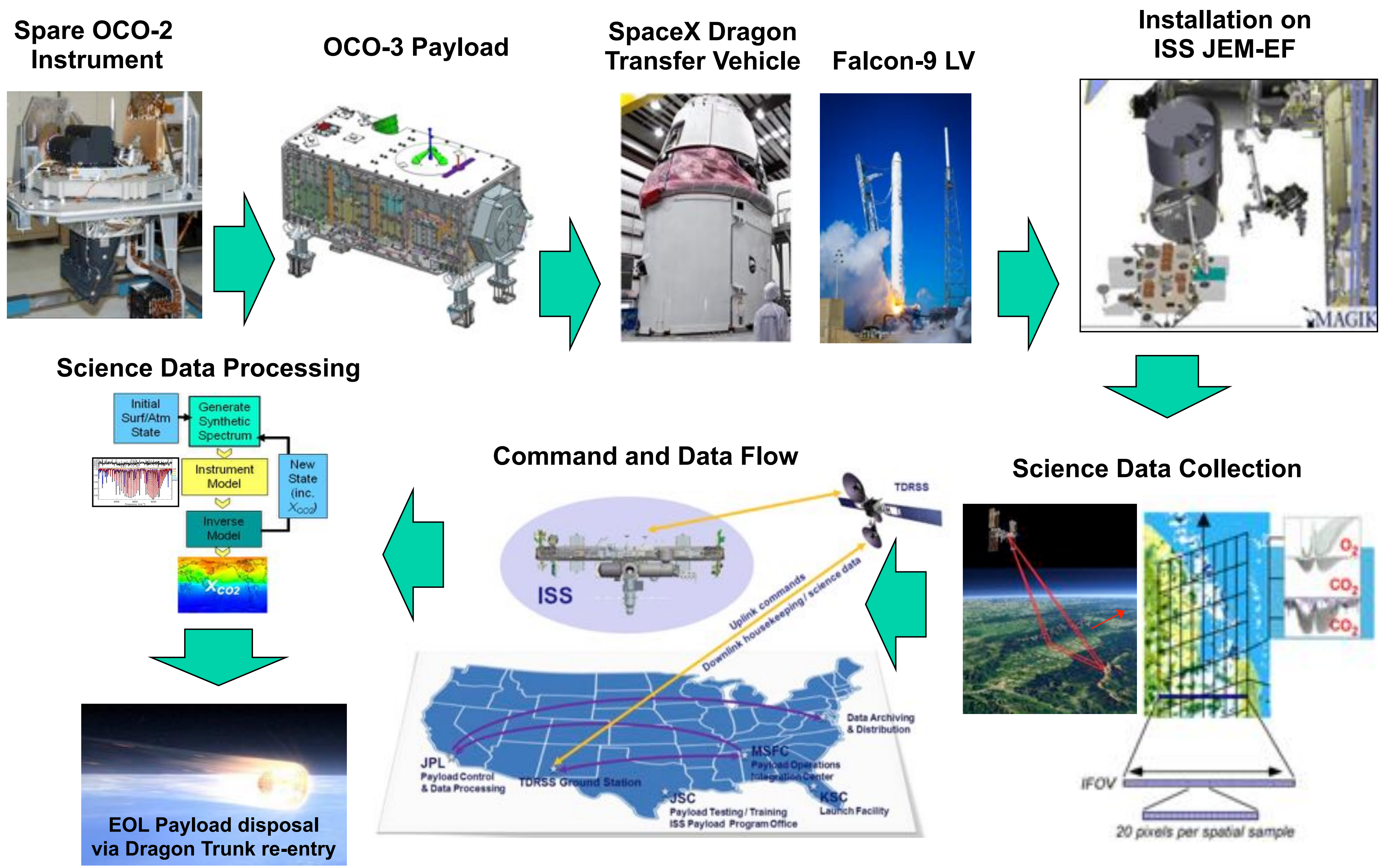
OCO-3 to be installed in ISS in late 2018

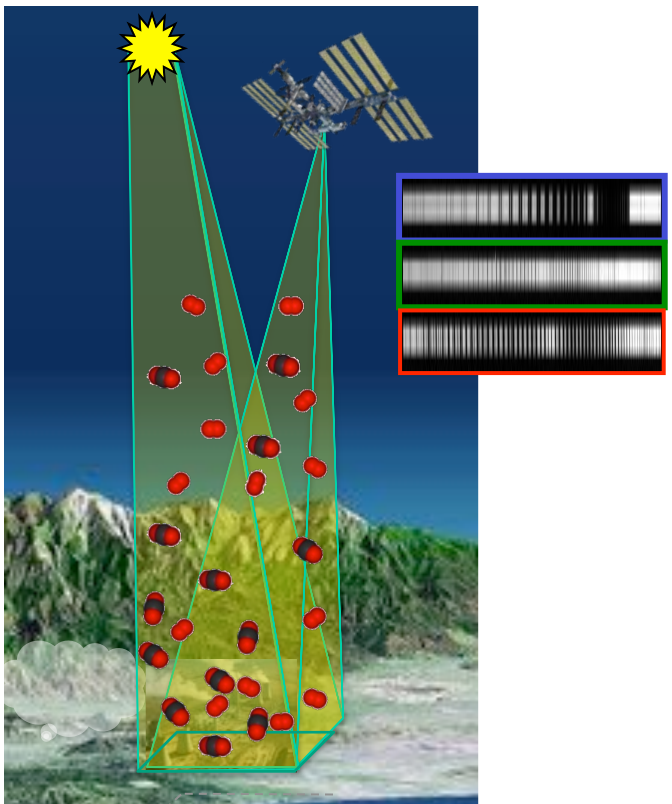


Mission Architecture Remains Unchanged

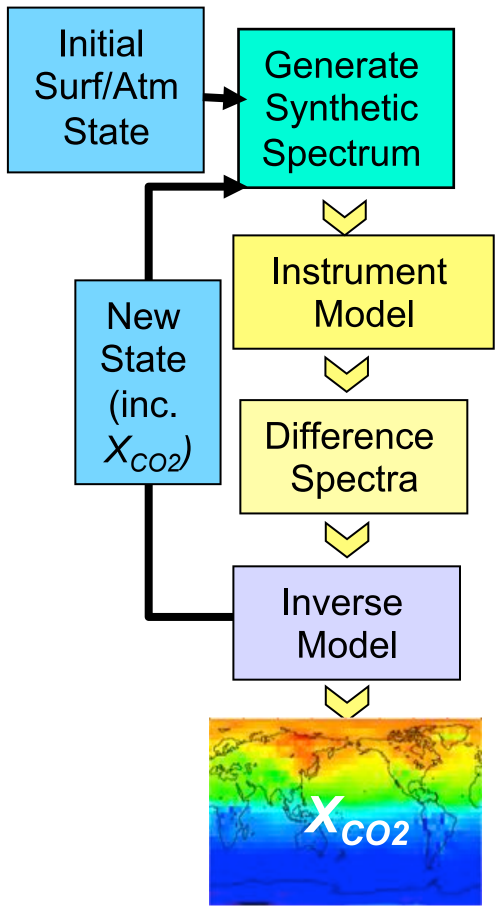


Measurement Approach – Same as OCO-2

Collect spectra of CO_2 & O_2 absorption in reflected sunlight over the globe



Retrieve variations in the *column averaged CO_2 dry air mole fraction, X_{CO2}* over sunlit hemisphere



Validate measurements to ensure X_{CO2} precision of 1 - 2 ppm (0.3 - 0.5%)

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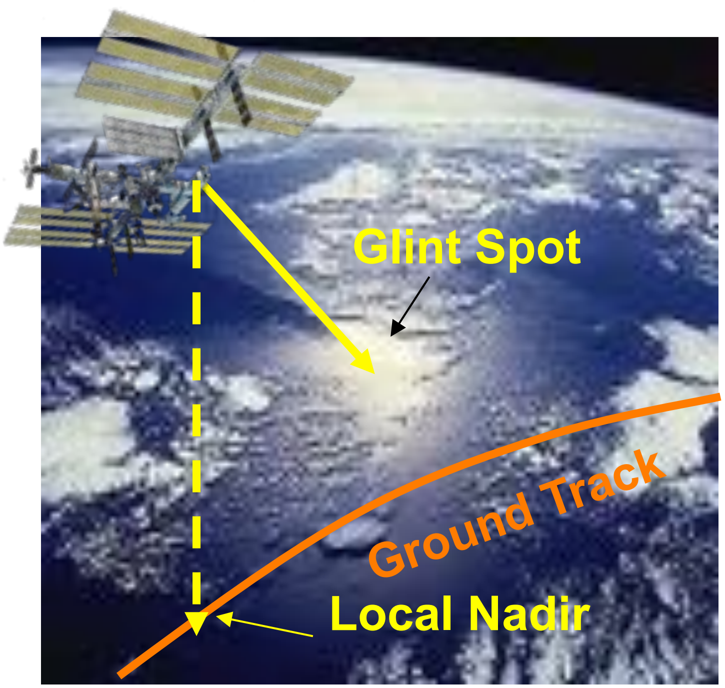
OCO-3 Observation and Science Modes

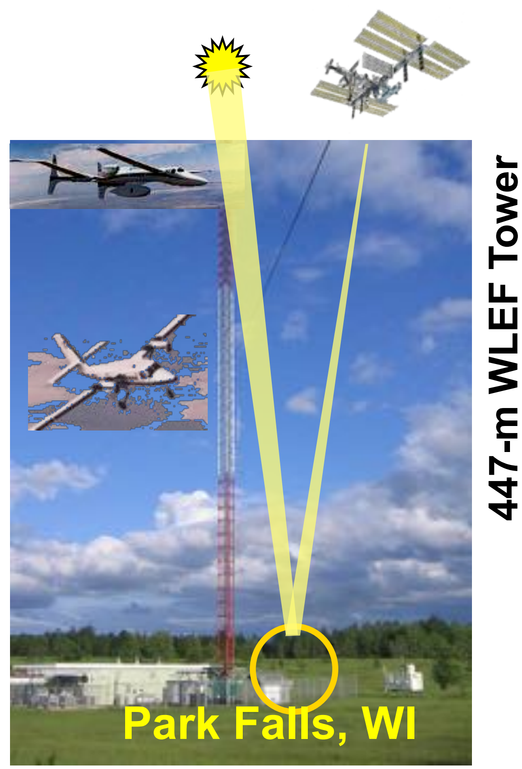
Nadir/Glint Observations:

- Nominal science measurements
- Nadir over land, glint over ocean during daylight → more data collected than OCO-2



Target/ Area map Observations:

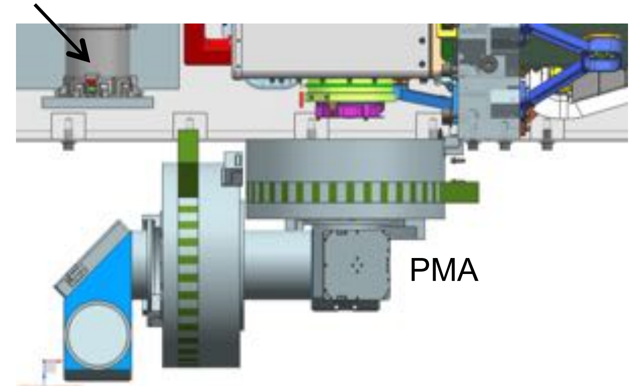
- Validation over ground based FTS sites, field campaigns, other targets
- Snapshot map variant for area mapping



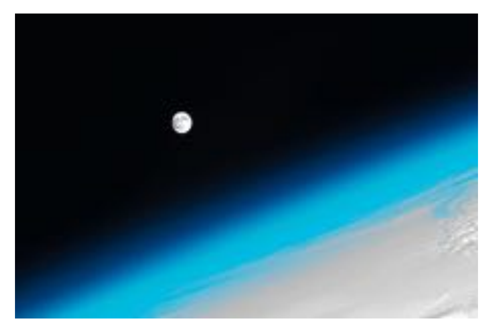
Calibration Measurements:

- Dark and calibrator measurements for radiometric calibration
- Lunar calibration goal for geometric calibration

Calibration System



Lunar view from ISS



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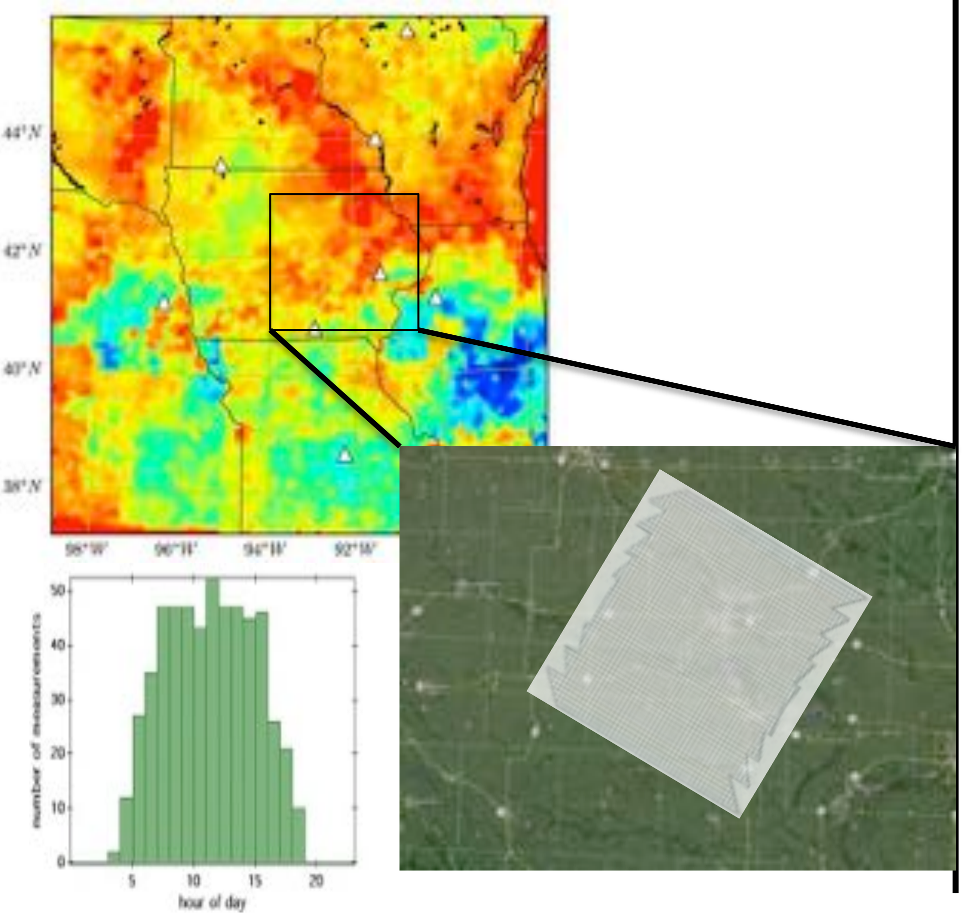
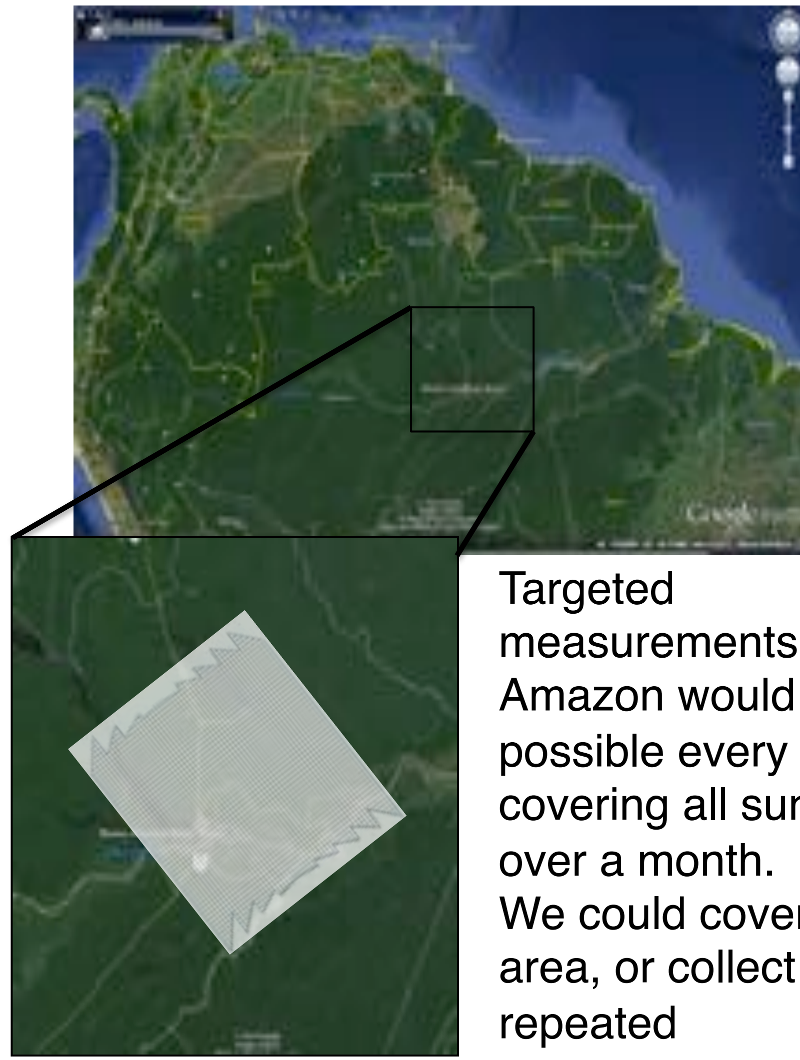
Terrestrial Carbon Cycle Processes can be Studied with Mapping Mode

The Mid-Continent Intensive was a field campaign to study the uptake of CO_2 by crops. OCO-3 measurements would add a dense dataset at varying times of day to such process studies.

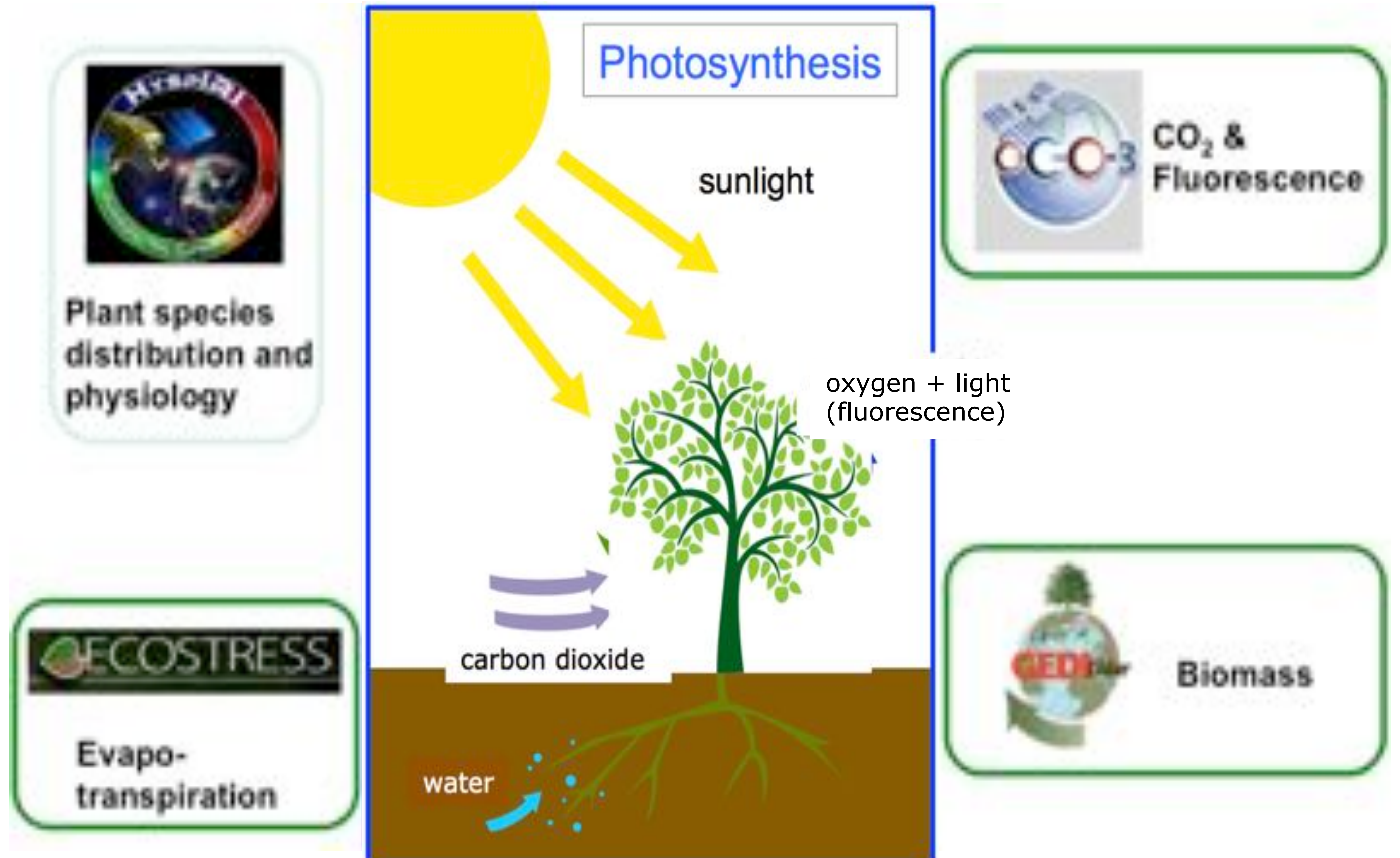


OCO-2 fluxes estimates are the size of states. Process studies are on scale of 1km. OCO-3 can aid in bridging between the process scale and the global scale



Targeted measurements of the Amazon would be possible every day, covering all sunlit hours over a month.
We could cover a wide area, or collect repeated measurements over a smaller region.

OCO-3, ECOSTRESS and GEDI: the ISS Carbon Cycle Opportunity



Unlocking the Fundamental Equation of the Carbon Cycle

Carbon storage = [WUE (ET) + LUE (LIGHT)] x τ

WUE = carbon uptake per unit water use
LUE = carbon uptake per unit light
τ = how long carbon remains in the biosphere

OCO-3 / ECOSTRESS = WUE

OCO-3 / HyspIRI = LUE

OCO-3 / GEDI Lidar = τ

The three key terms can be derived from these instruments

Courtesy of D. Schimel

Uncertainties in CO_2 budget

- Two threats to the carbon cycle budget
  - OCO-2 measurements will reduce uncertainty in global terrestrial carbon fluxes, and the magnitude of the land use change flux.
  - Fossil fuel emissions are increasing, as are the relative uncertainties on these emissions.
  - The fossil fuel uncertainty is beginning to compromise our ability to retrieve natural fluxes, especially in some critical regions.
- By 2020 the absolute uncertainty in global total FFCO2 will likely exceed the absolute uncertainty in the terrestrial land sink (i.e., > 1 GtC/year), with particularly high uncertainty in rapidly increasing source regions
- Flexible measurements from OCO-3 and snapshot mapping allow frequent revisit over strong source regions. Many targets could be visited 10 times per year, resulting in significant decreases in fossil fuel uncertainty.

- OCO-3 measurements are needed before this crossover happens, to maintain the overall $FFCO_2$ uncertainty at an acceptable level.

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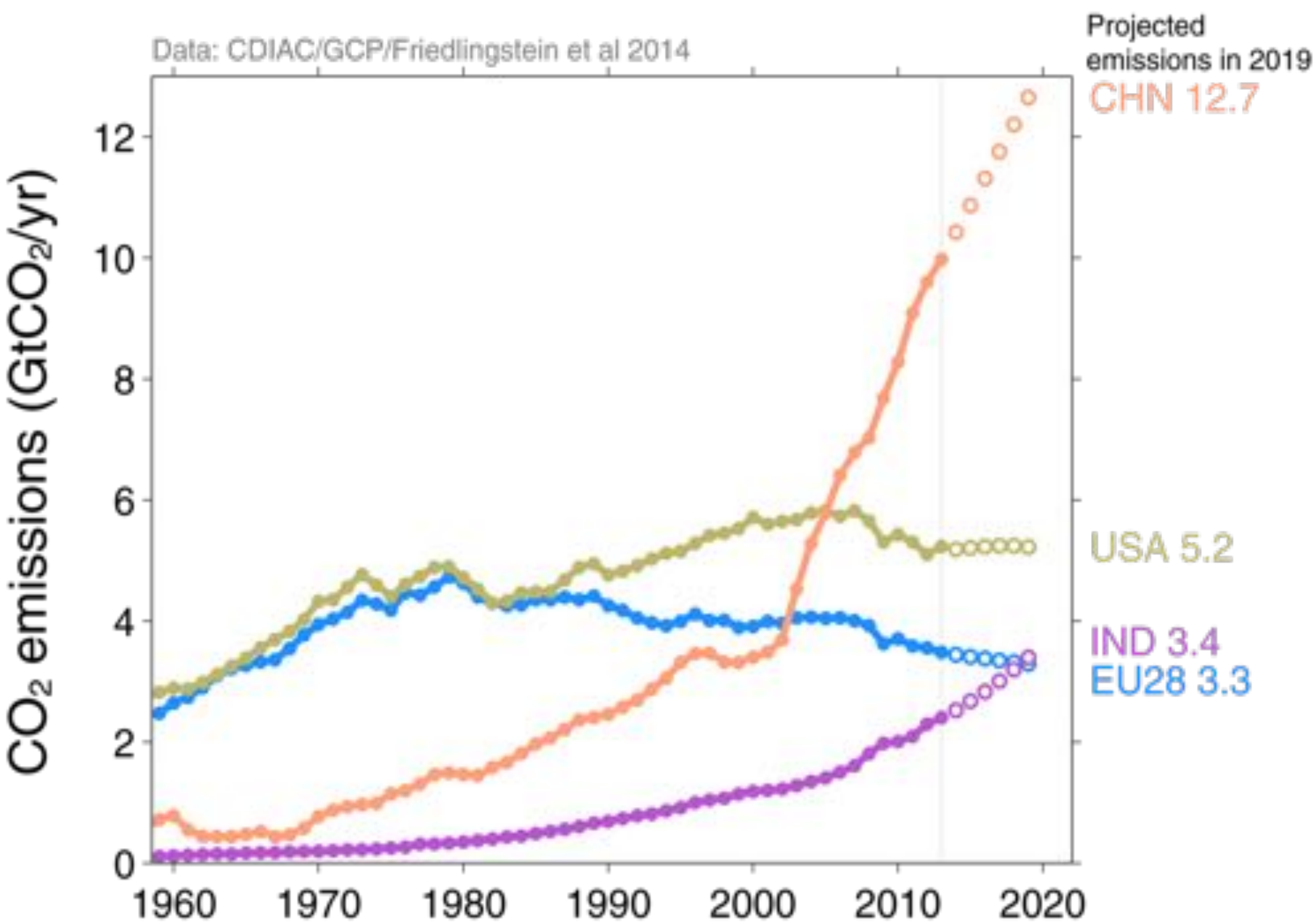
Anthropogenic Emissions: Growth is Large and Uncertain

Rapid emissions growth with large uncertainty at regional and local scales



- 3%/year average global growth rate
- Locally much larger growth rates (50-100% for developing cities, power plants etc)
- Uncertainty at continental scale ranges from 5 to 20%/year
- Uncertainty at process-relevant scales (individual cities and power plants) can be as large as 50-100%

Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend
Source: CDIAC; Friedlingstein et al 2014

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OCO-3 Snapshot Maps

Courtesy of Lars Chapsky

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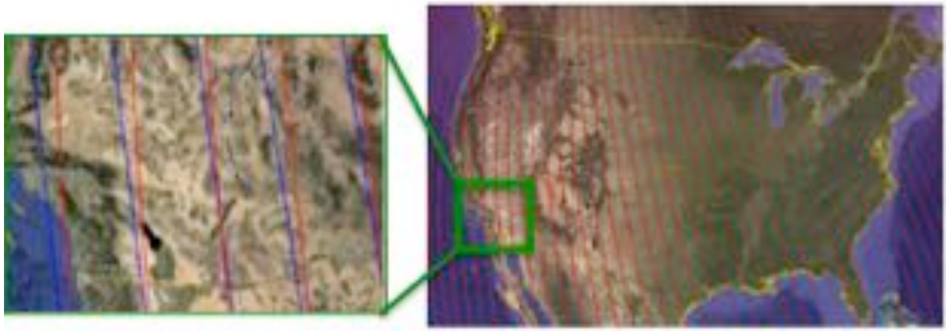
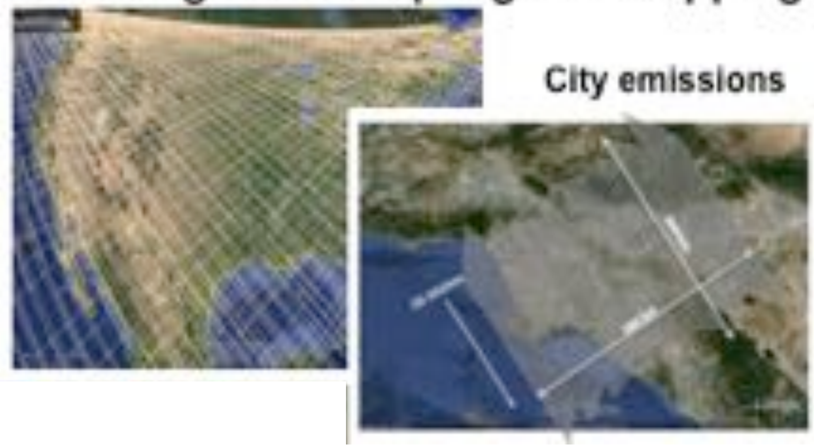
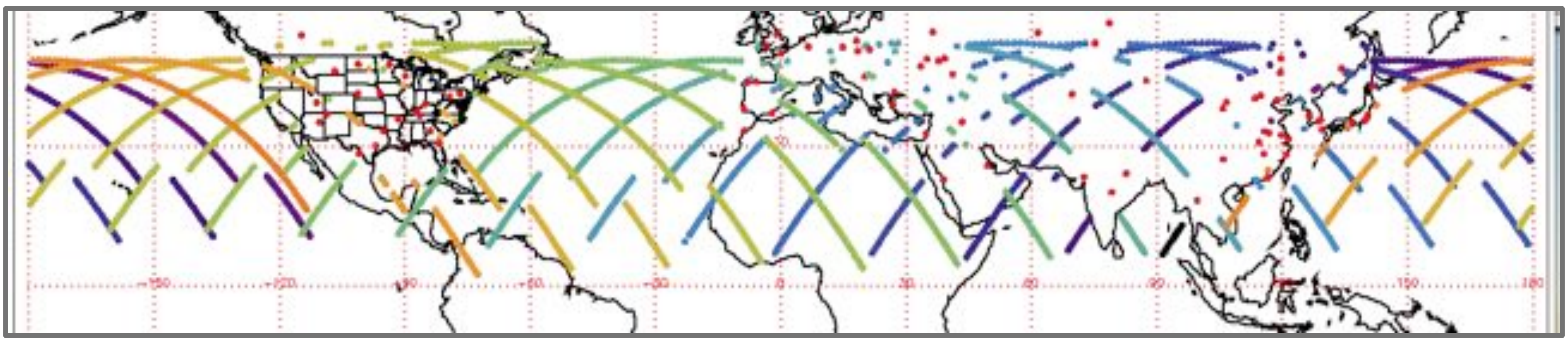
Snapshot Maps Integrate Easily into Global Sampling on OCO-3

OCO-2: global sampling



OCO-3: global sampling and mapping

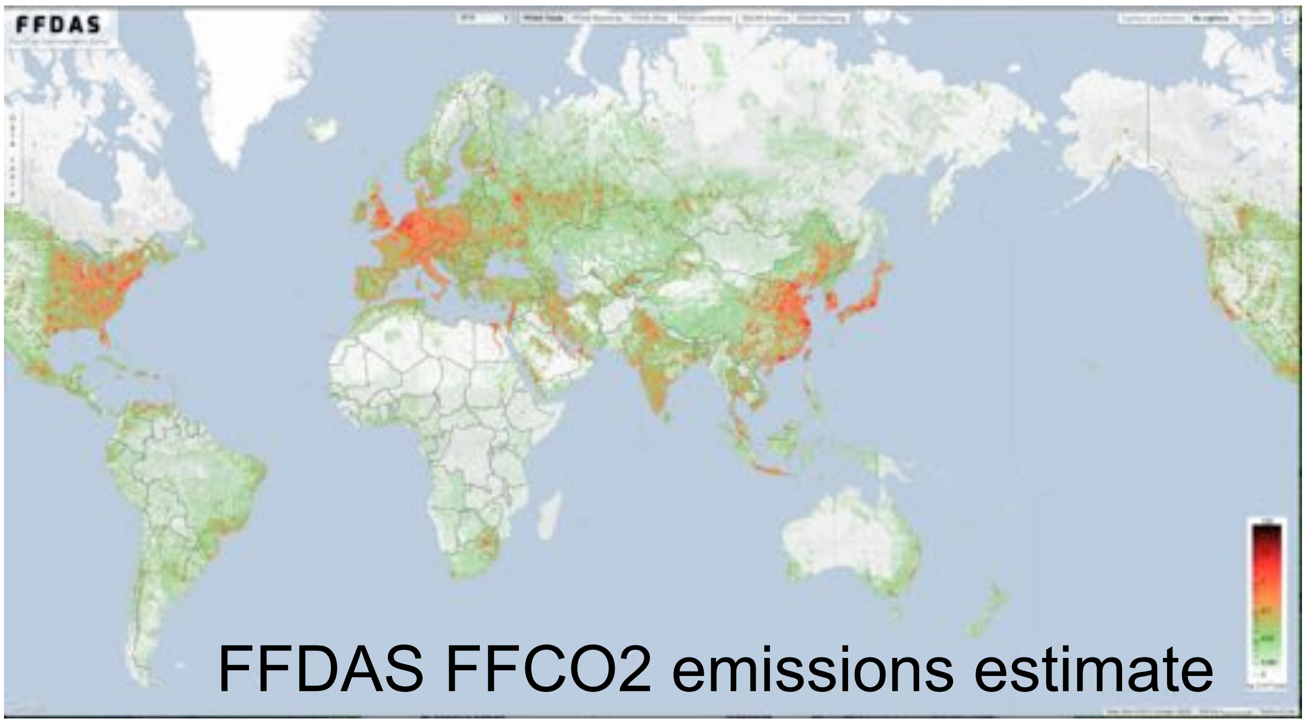


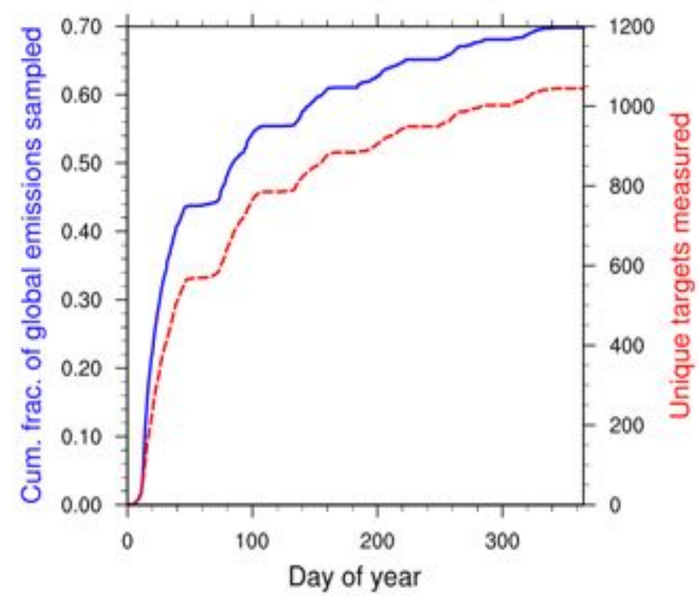


- OCO-3's snapshot mapping mode can be used to focus on localized source emissions
- These maps show maximum usage of snapshot maps (red points) interwoven with standard glint and nadir sampling (other colors)

Designing FFCO2 Sampling for OCO-3

- OCO-3 flexibility allows for a highly customized sampling design
- Aspects to consider in the design include emissions magnitude, emissions uncertainty, desired number of revisits, opportunity cost with respect to other sources
- We defined 1308 sample regions that represent 77% of global emissions (~6 PgC/year) and 55% of FFDAS uncertainty





Courtesy of Ryan Pavlick

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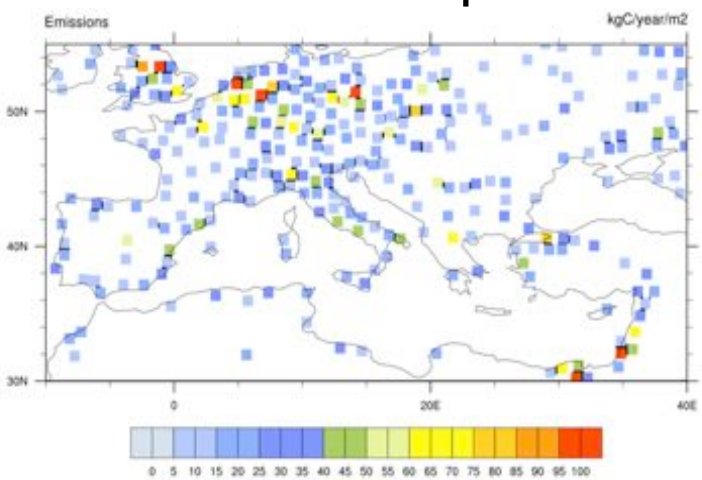
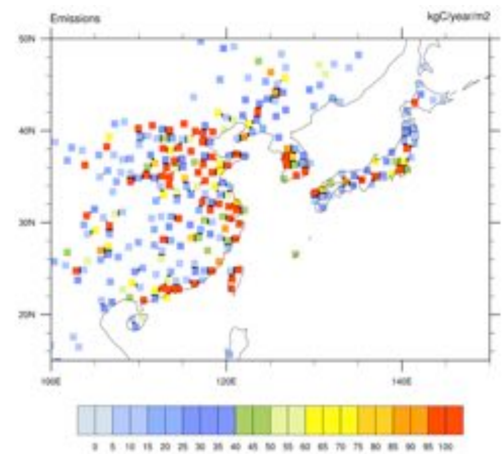
Where to Focus Area Mapping Mode

- OCO-3 Mission Operations team designed a flexible system that can accommodate up to 100 special observations in a day. A prioritization system was developed to optimize selection. We are developing an automated system to update selected targets based on weather data.

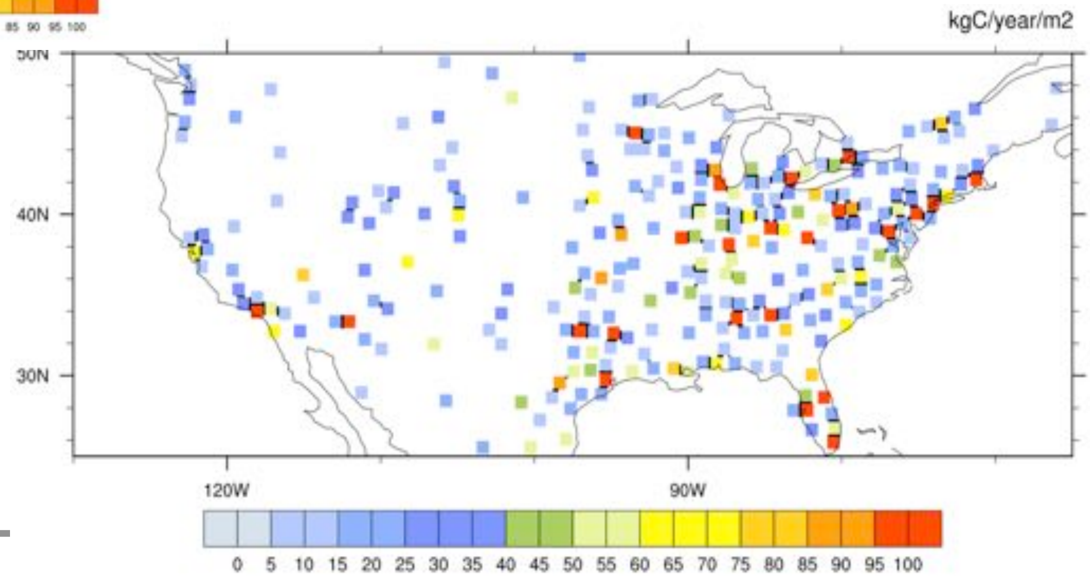
Emissions - Europe



Emissions -Asia

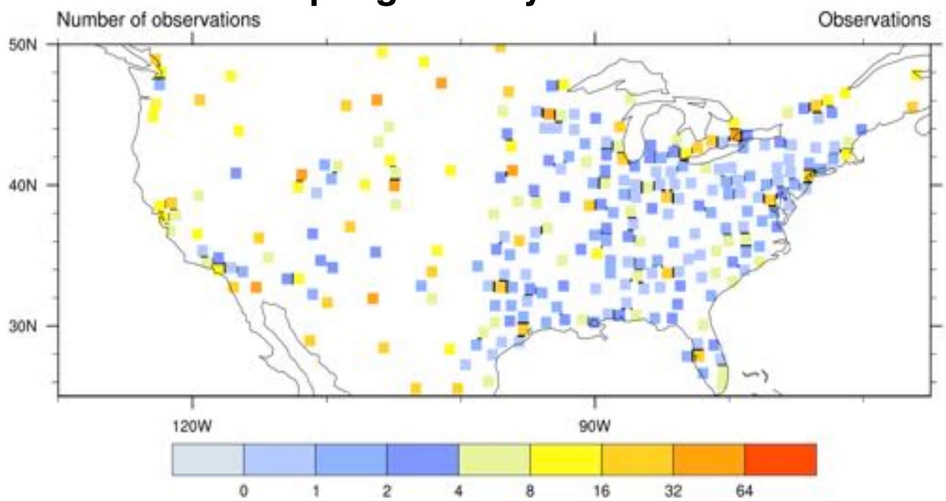


Emissions – North America

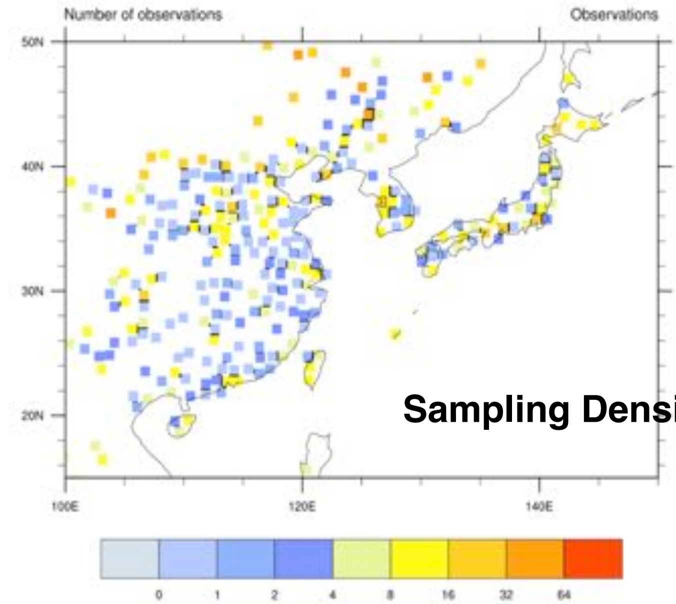


Simulated OCO-3 Snapshot Mapping

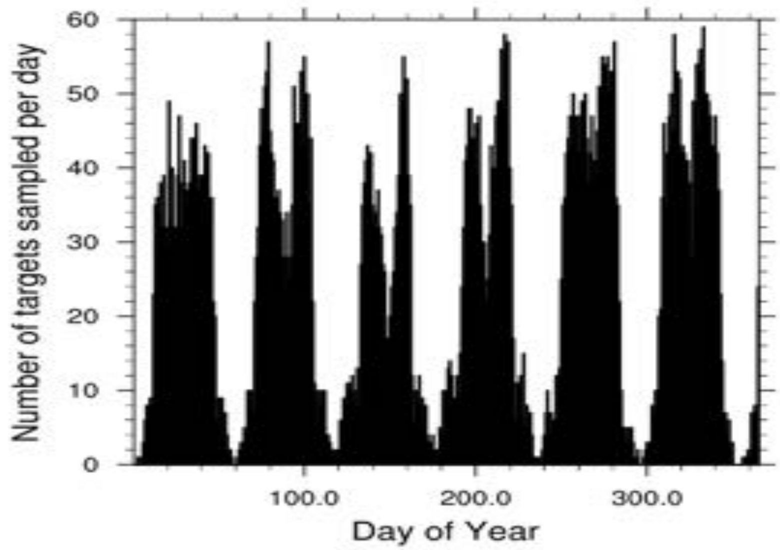
Sampling Density – North America



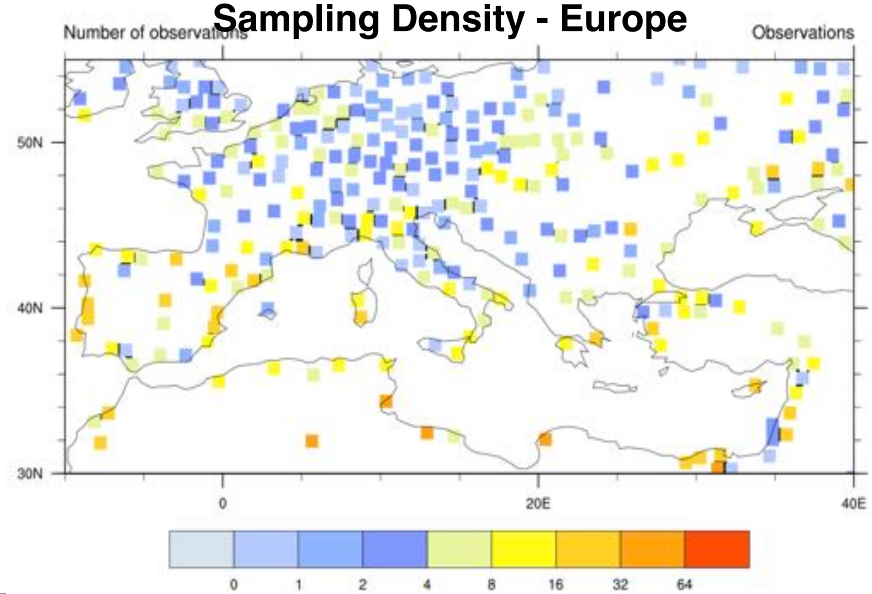
Sampling Density - Asia



Sampling Density over the year

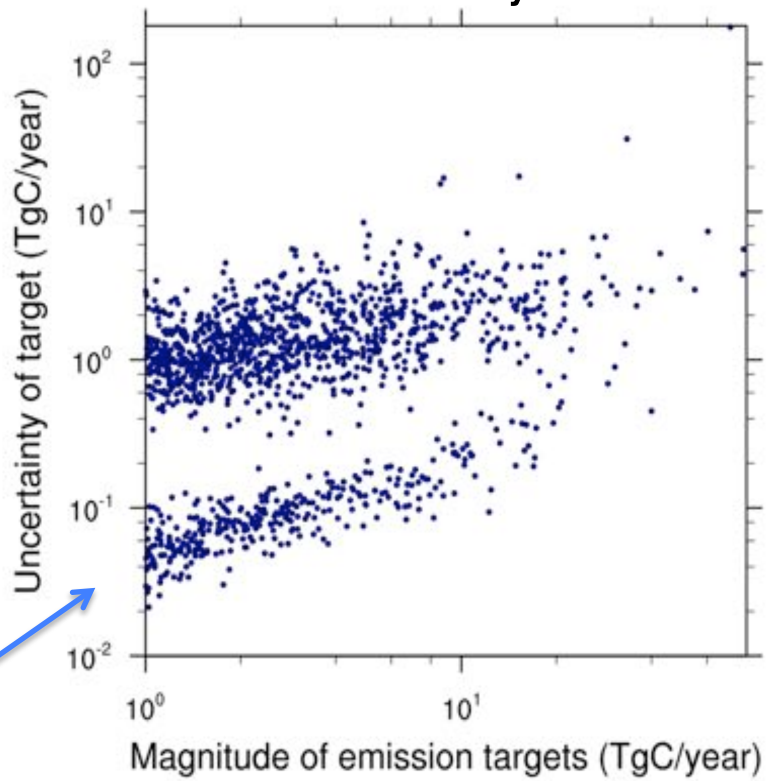


Sampling Density - Europe

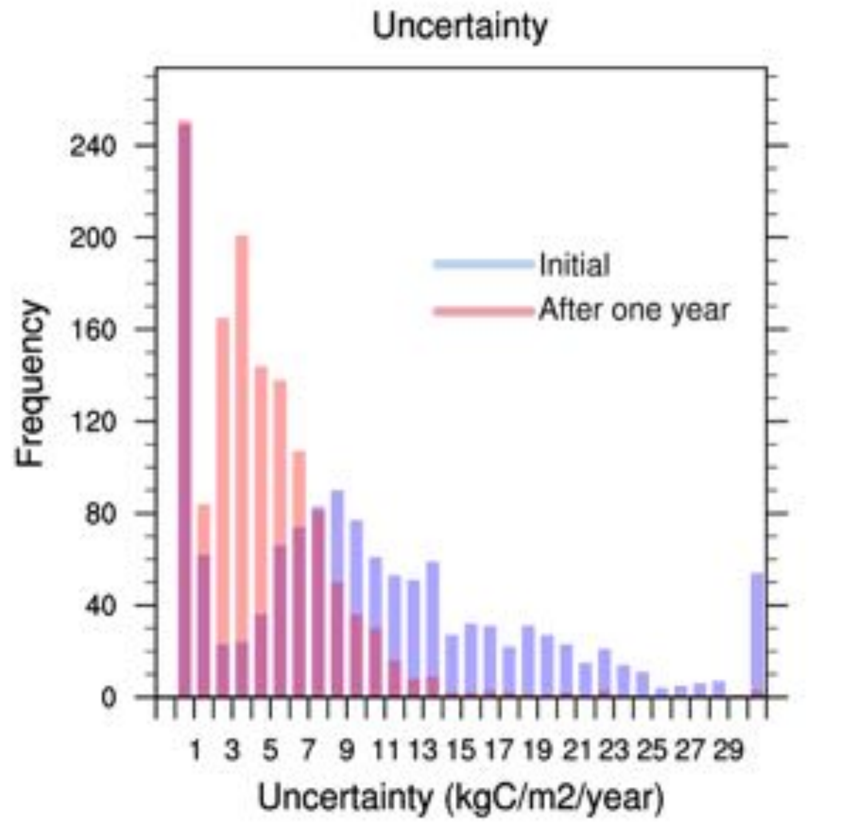


Estimated Uncertainty Reduction

Overall Emissions and Uncertainty



FFDAS predicts low uncertainties in US



The FFCO2 uncertainty reduction is estimated to be 40%. The optimization was successful - after a year of sampling only a few sources had predicted uncertainty larger than 15 $kgC/m^2/year$.

Conclusions

- OCO-3 is a critical element in the continuation of global CO2 measurements focused on understanding the regional sources and sinks of CO2.
- OCO-3 can also contribute to focused study of how space based measurements can constrain rapidly changing anthropogenic emissions. Anthropogenic emissions could be the largest source of uncertainty in the global carbon budget as OCO-2 measurements reduce uncertainty of natural fluxes.
- OCO-3 measurements can be combined with evapotranspiration and biomass measurements to study process details of the terrestrial ecosystem.
- OCO-2 has demonstrated the atmospheric XCO2 can be measured from space with precision of better than 1 ppm.
- OCO-3 has differences including measuring at all polarizations. Much of the data should be of similar quality as OCO-2.