Observing The Global Carbon Cycle from Space

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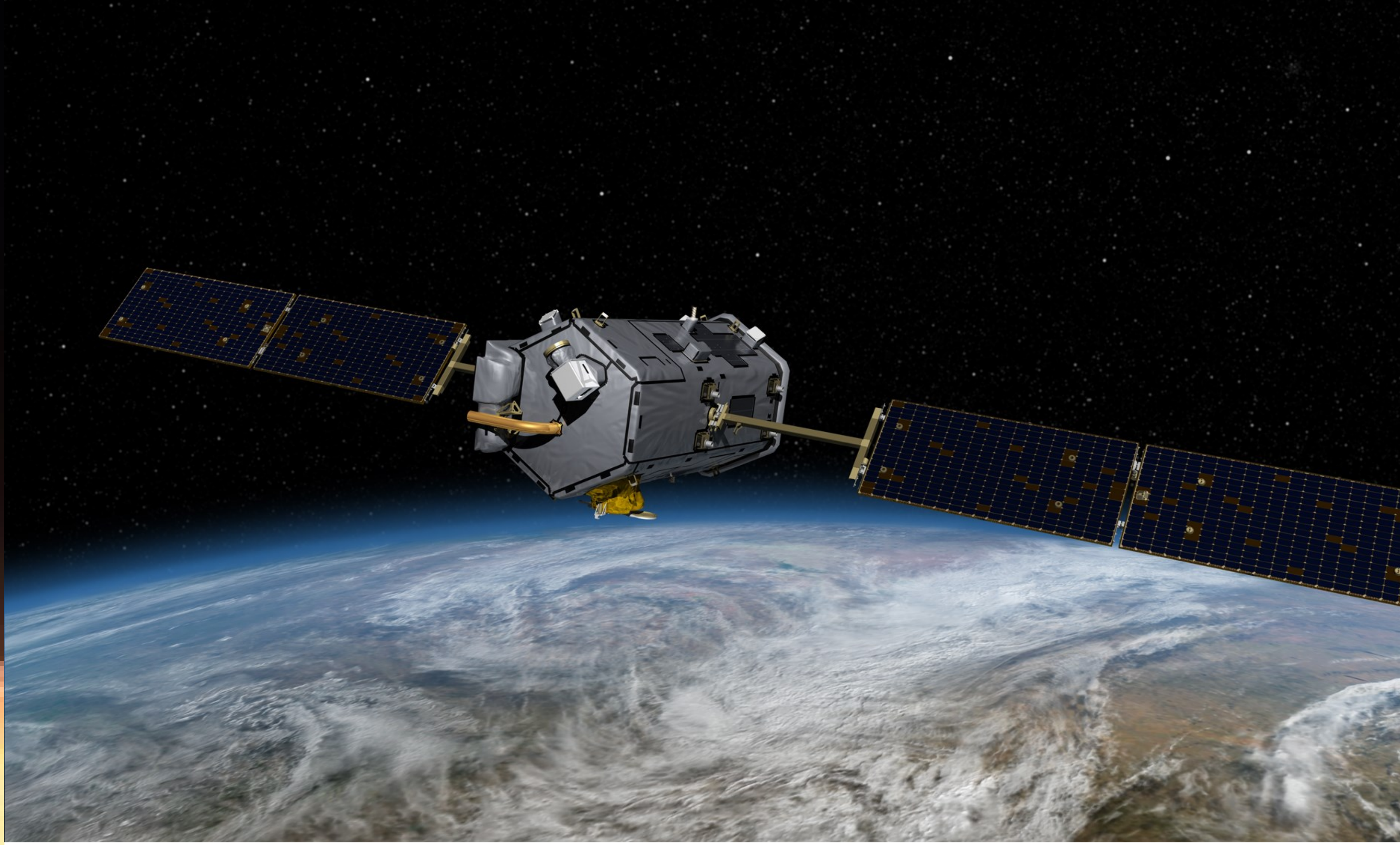
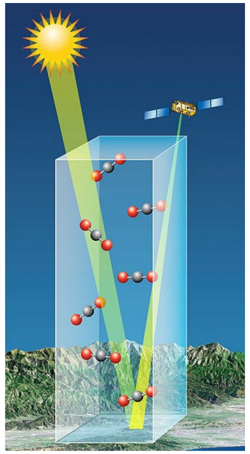


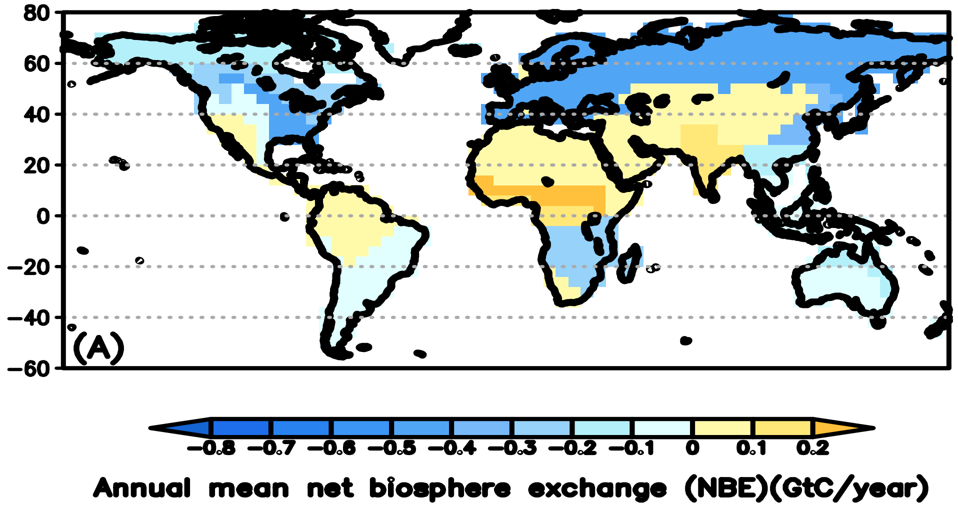
OCO-2 and the Era of CO_2 from Space

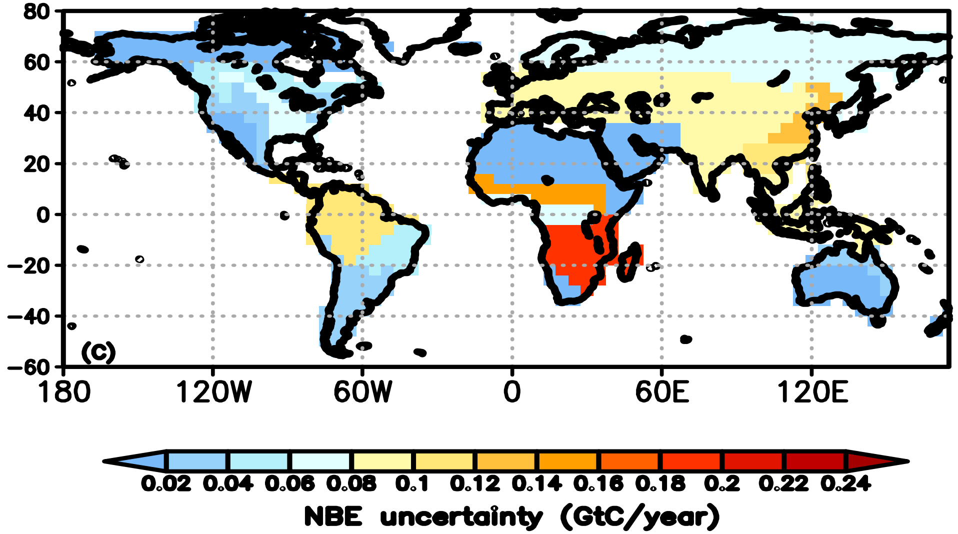
Fluxes to concentrations to fluxes…



Real fluxes in the real world → Atmospheric Transport → Concentrations in the atmosphere | Observed from Space → Modeled Atmospheric Transport → Estimated Fluxes

Top-Down Flux Estimates and Uncertainties





Carbon-Climate Feedbacks are Strong, Producing Significant Interannual Variability

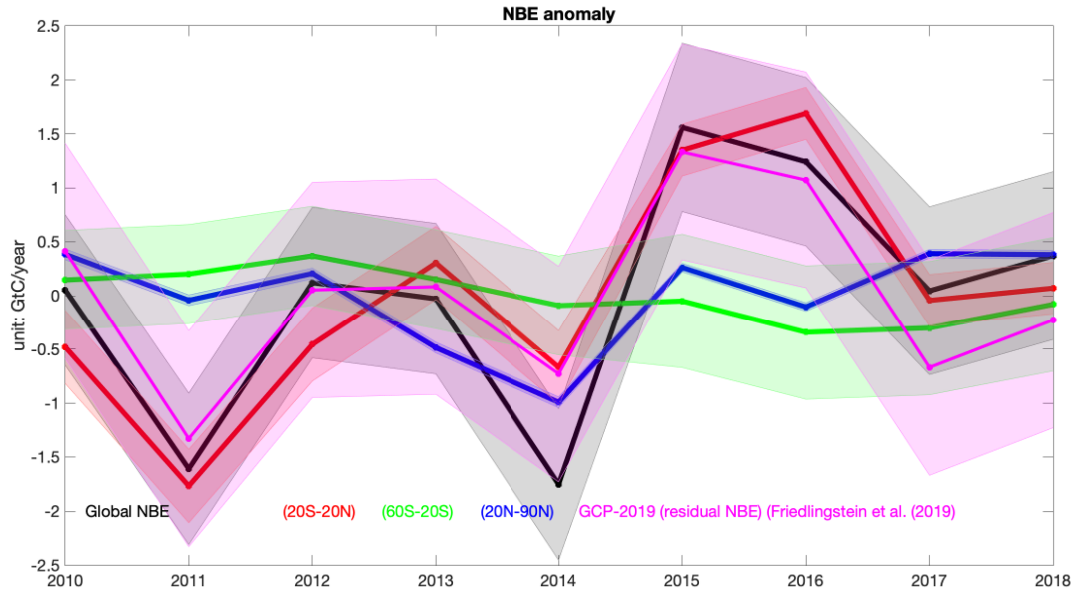
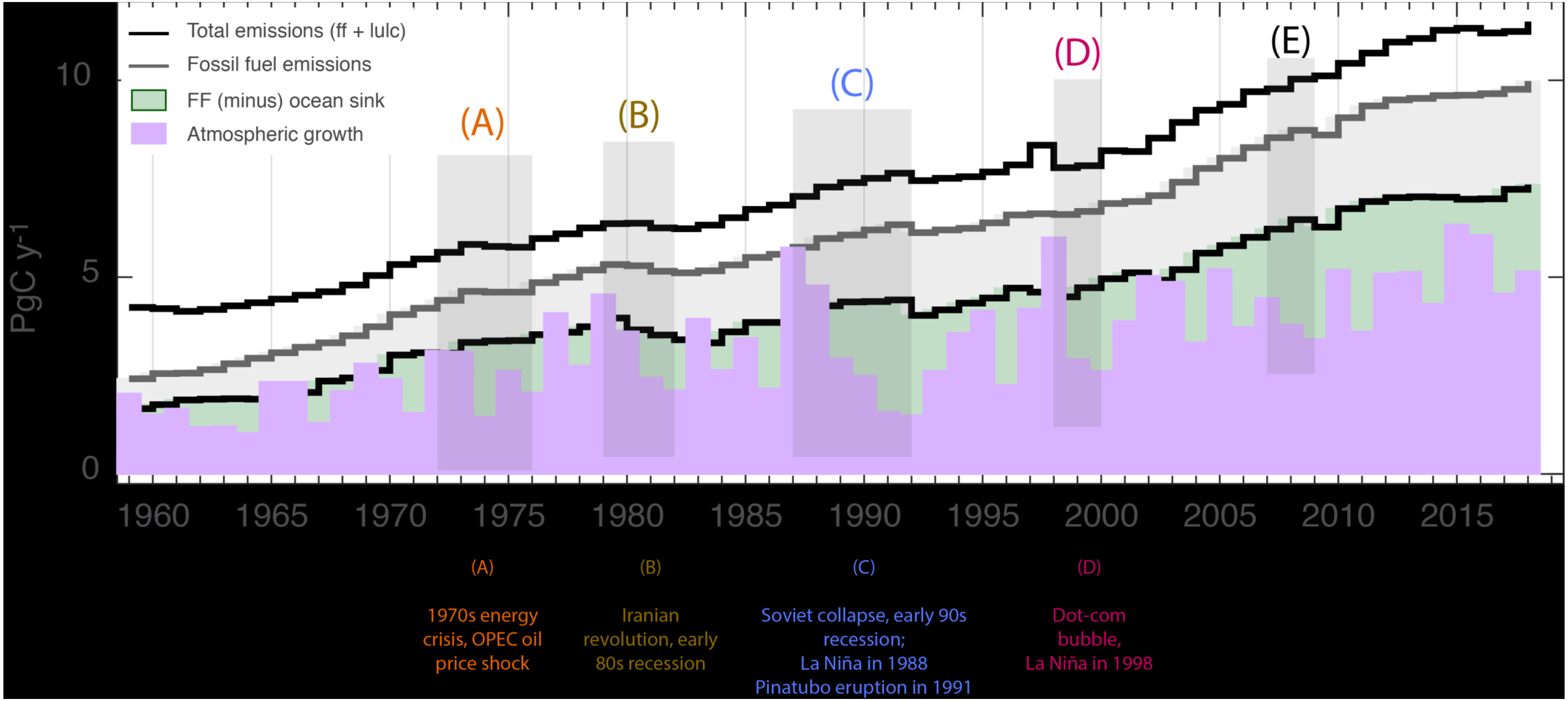
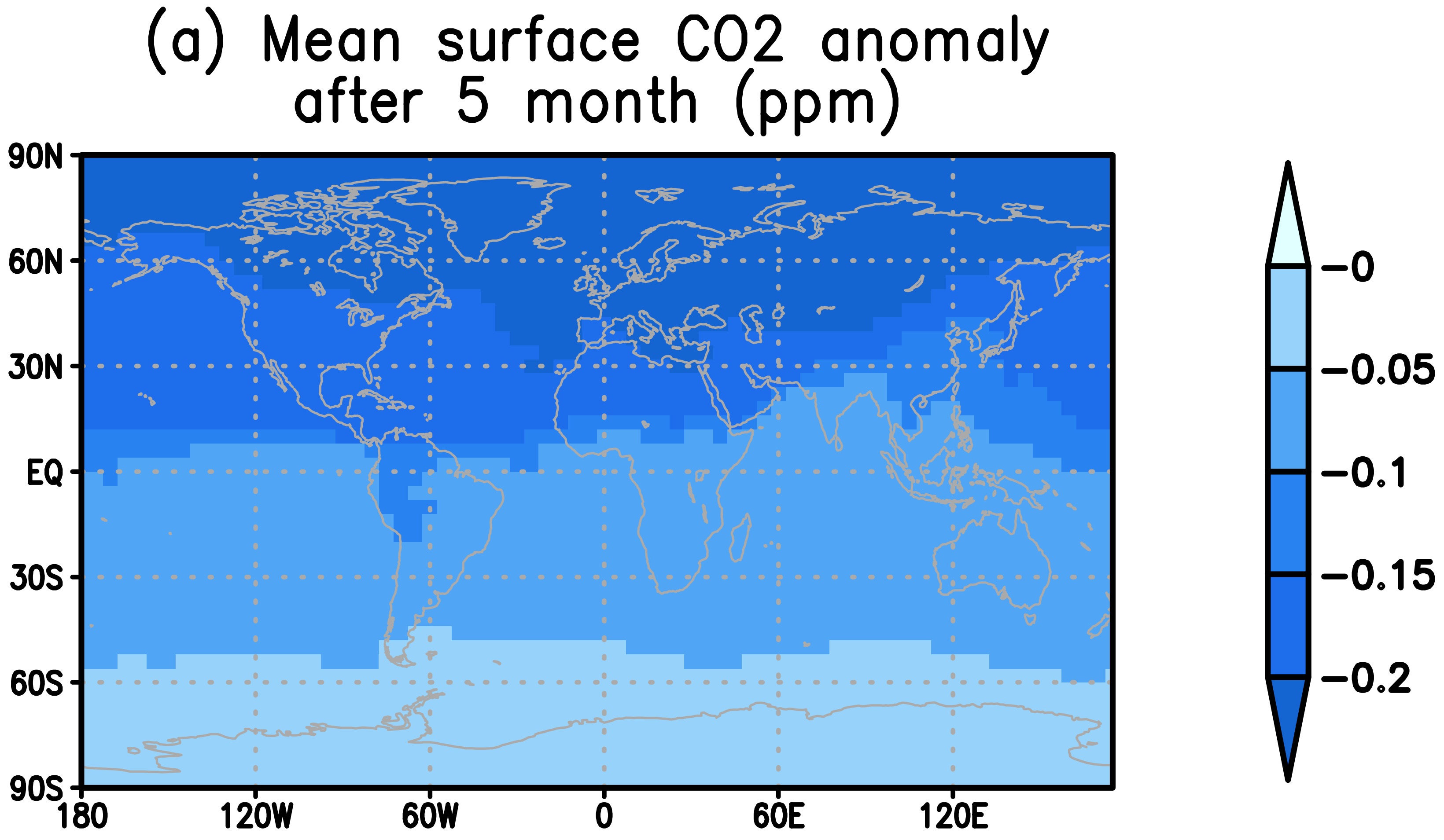


Figure: 6 The NBE interannual variability over the globe (black), the tropics (20°S–20°N), SH mid-latitudes (60°S–20°S), and NH mid-latitudes (20°N–9°0N). For reference, the residual net land carbon sink from GCP (Friedlingstein et al., 2019) and its uncertainty is also shown (magenta).

Societal Changes Affect the Growth Rate of CO_2



But, not very much:
Global surface CO_2 anomaly after 5 months



Carbon Capture and Storage: is it Observable?

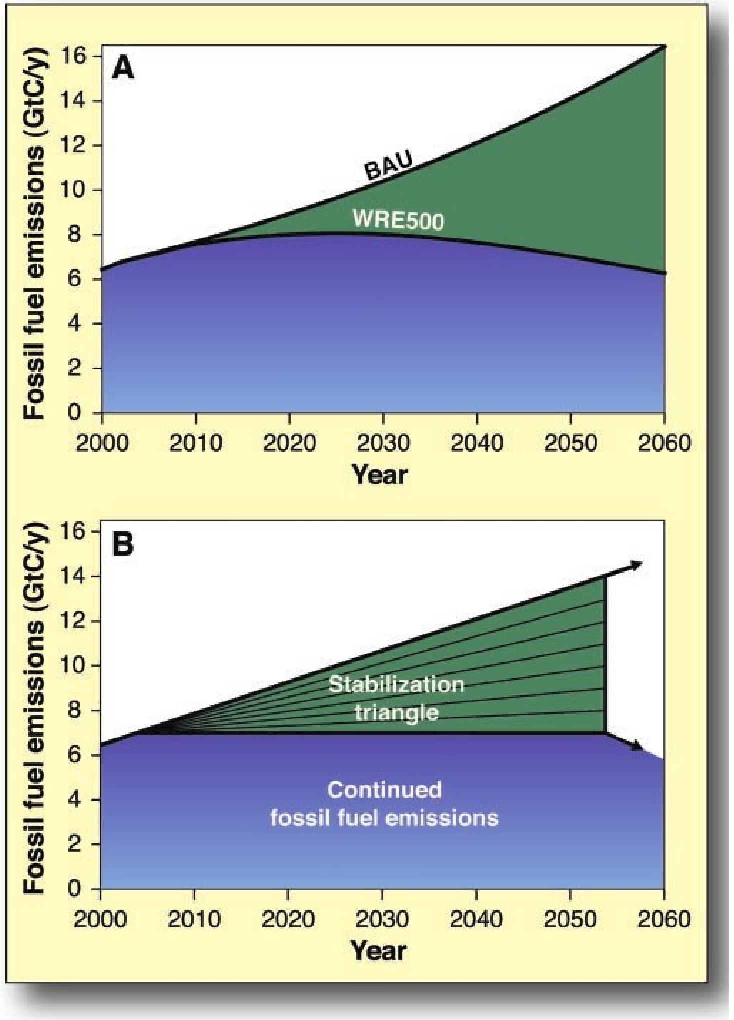
Table 1. The global carbon budget for 1990 2007, updated and inclusive with all terrestrial fluxes attributed to processes or regions

	Flux 1990 2007)		
Carbon budget component	Average annual flux, Pg C·y 1	Uncertainty, Pg C·y 1	Source
Atmospheric increase AI)	3.6	0.4	GCP
Fossil plus cement FpC)	6.9	0.1	GCP
Tropical gross deforestation TGD)	2.9	0.5	35)
Ocean uptake OU)	2.3	0.5	GCP
Tropical regrowth after deforestation TRD)	1.6	0.5	35)
Northern extratropical uptake all processes) NEU)	1.2	0.1	combined
Tropical plus southern CO_2 effect uptake TpS)	1.4	0.4	combined

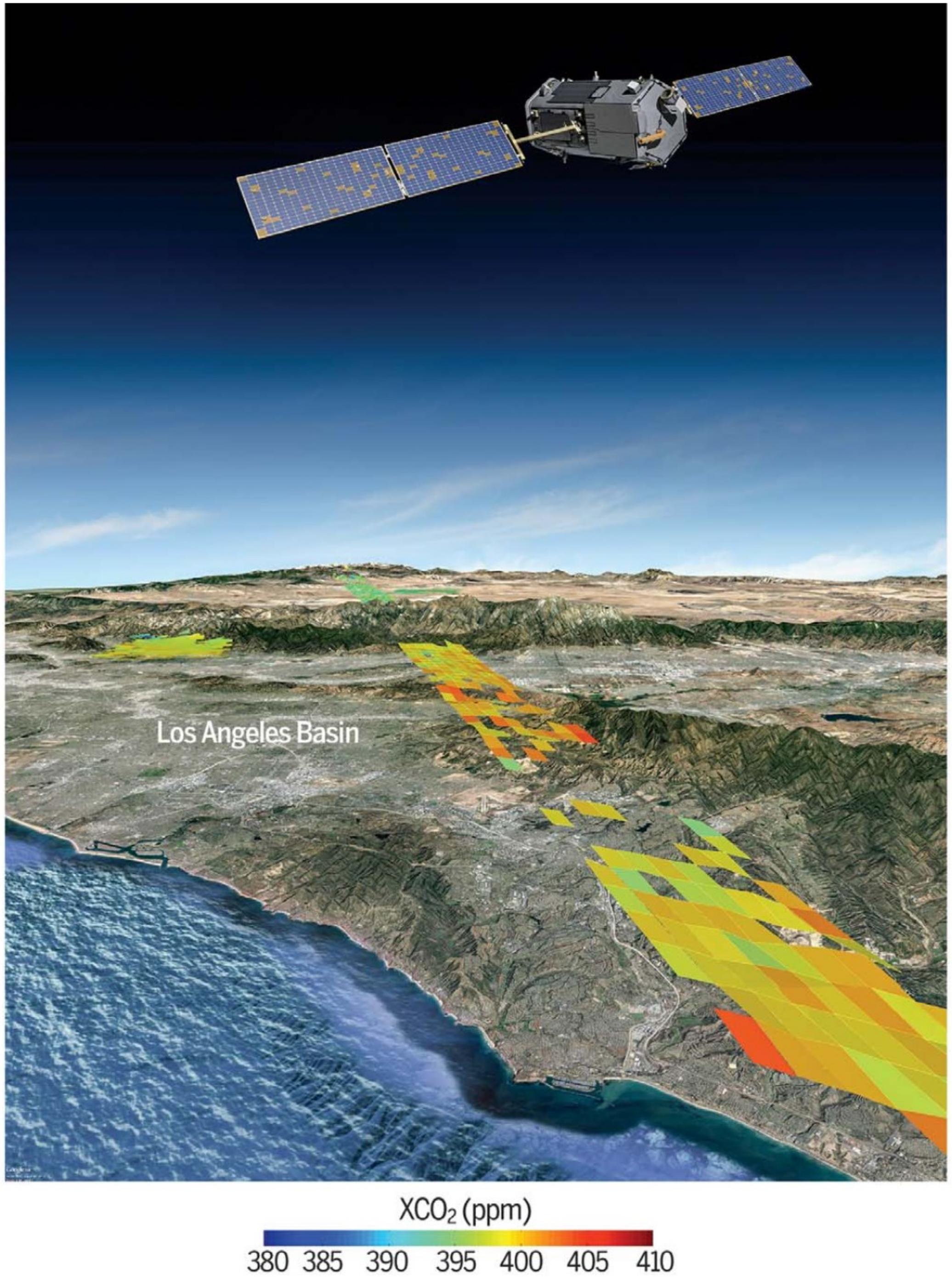
This table combines the GCP 2013 carbon budget with the additional flux estimates derived in this paper. This budget has a residual error of 0.3 Pg C·y 1, within the uncertainty of the total budget 1 Pg C·y 1). The values in the NEU and TpS rows are weighted means of Pan et al. 35) and TRENDY estimates see *SI Text*). Note that most carbon budgets e.g., GCP) include a terrestrial term estimated by difference and so sum to zero. Budget summary: AI = FpC TGF OU TRD NEU TpS *residual uncertainty)*; 3.6 = 6.9 2.9–2.3–1.6–1.2–1.4 *0.3 1.0).*

"Wedges"—Are they observable?

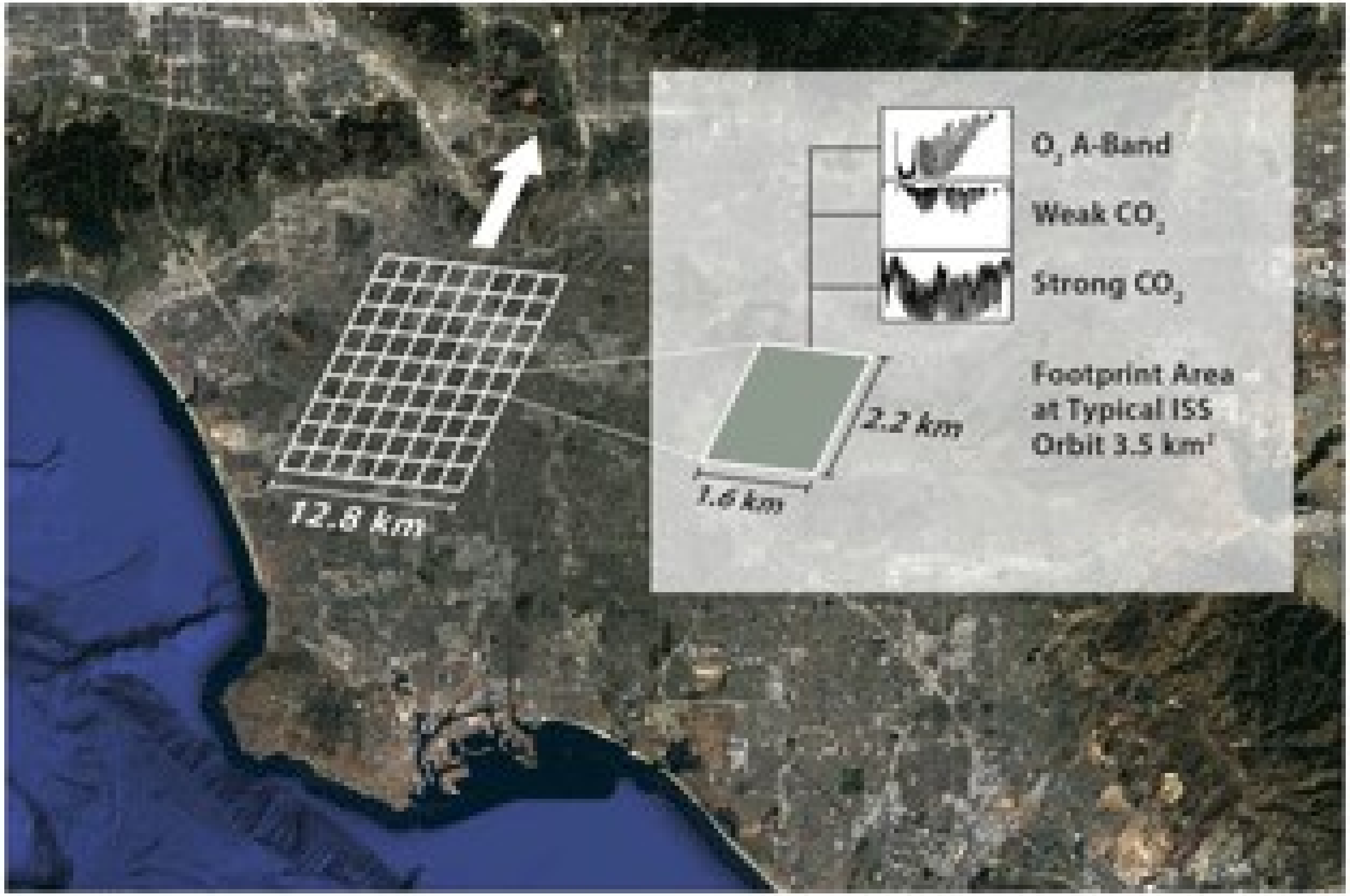
- Pacala and Socolow proposed the useful wedge model, with ~10-12 technologies each reducing emissions or capturing CO_2.
- A key observing challenge is detecting change due to wedges early, when they are small.
- And, that's just what we can't do with global inverse schemes.



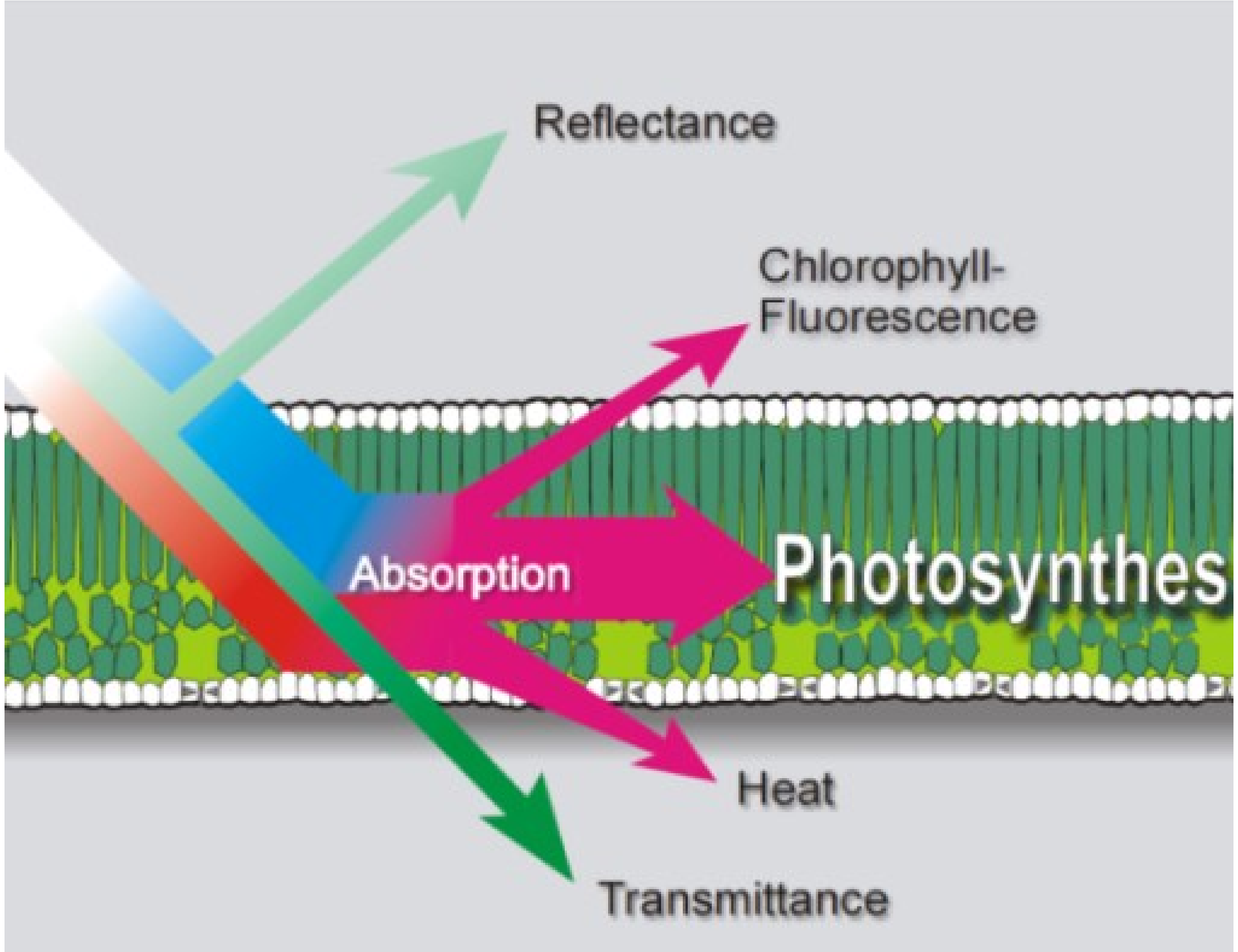
Megacity Approach



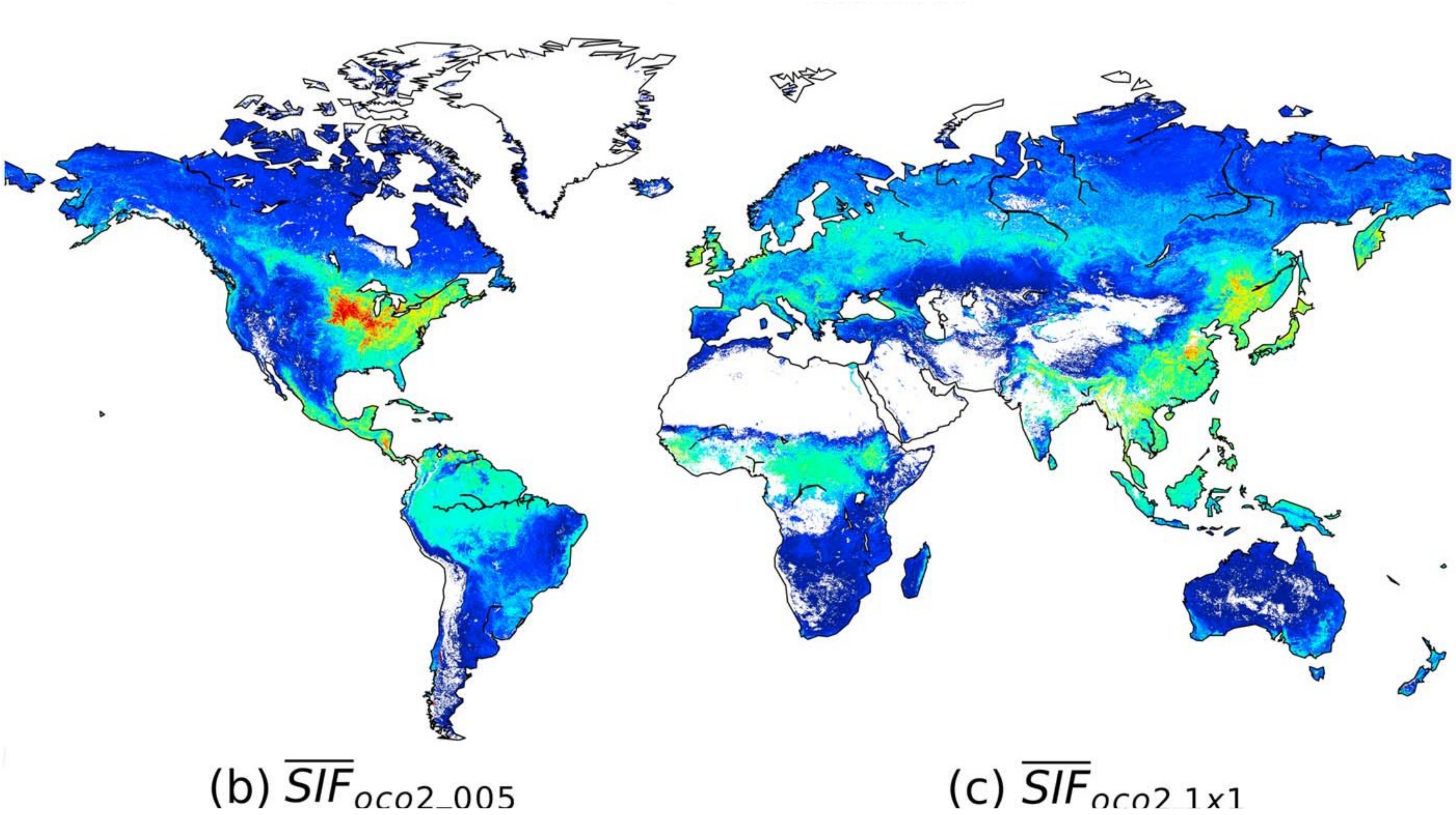
OCO-3 Snapshot Area Mapping Mode Samples ~100 urban areas worldwide (~85% of global emissions)



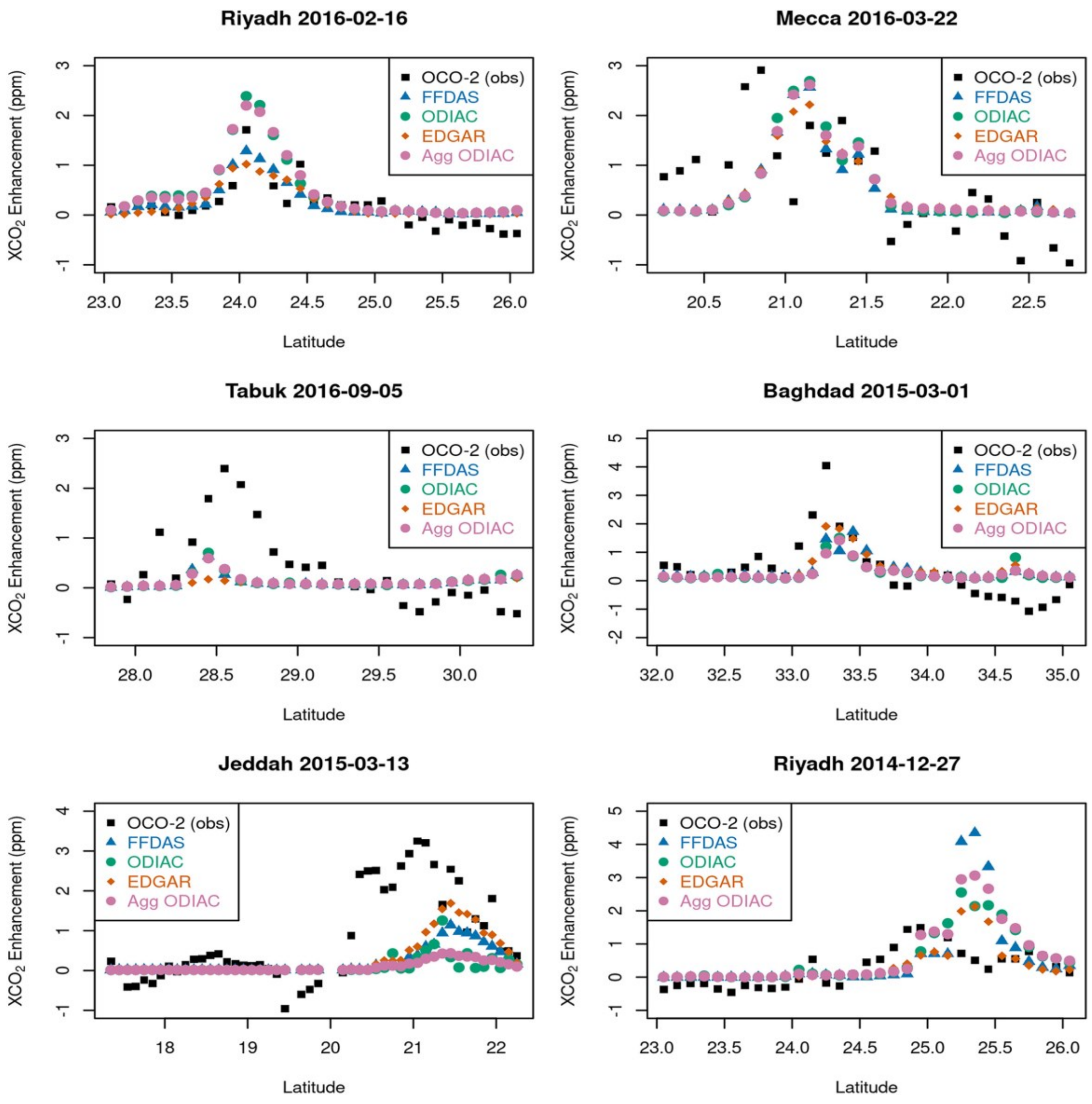
Solar-induced fluorescence: a new tool



SIF: a global measure of carbon uptake by photosynthesis

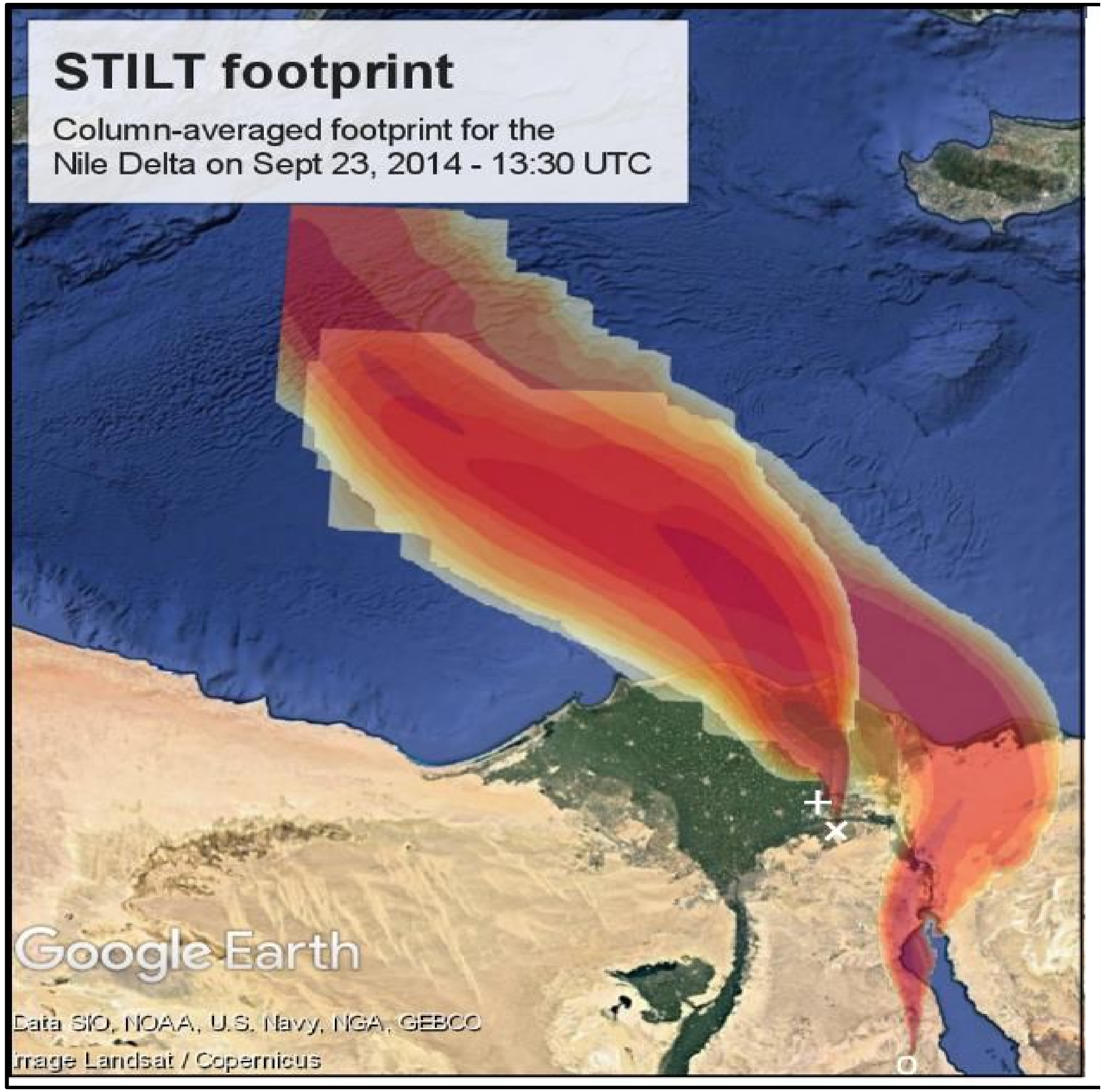


Urban estimates in the Middle East suggest larger emissions than inventories



Yang EG, et al. Using Space-Based Observations and Lagrangian Modeling to Evaluate Urban Carbon Dioxide Emissions in the Middle East. Journal of Geophysical Research: Atmospheres. 2020 Apr 16;125(7)

Source and Sink Modeling at Finer and Finer Scales



Shekhar A, Chen J, Paetzold JC, Dietrich F, Zhao X, Bhattacharjee S, Ruisinger V, Wofsy SC. Anthropogenic CO 2 emissions assessment of Nile Delta using XCO 2 and SIF data from OCO-2 satellite. Environmental Research Letters. 2020 Jun 15.

Even in areas with strong sources, photosynthesis can take up significant amounts of the emitted CO_2

Mitigation required eventual MAJOR reductions in net emissions*

- Global-top down analyses can confirm budgets over relatively long time periods—1-5 years—given interannual variability but cannot verify specific actions.
- Point-source analyses aided from space can confirm or reject both net emissions (emissions – removal) and photosynthesis (SIF) at city-region scales.
- Ongoing space assets (OCO-2/3, GeoCarb, Sentinel, Tansat) provide ongoing space-based observations into the future.
- Space-based methods provide an independant reference context within which reported CSC, uptake and mitigation may be assessed at megacity-regional scale.