Hourly, daily, and seasonal patterns of atmospheric CO_2 along an urbanization gradient

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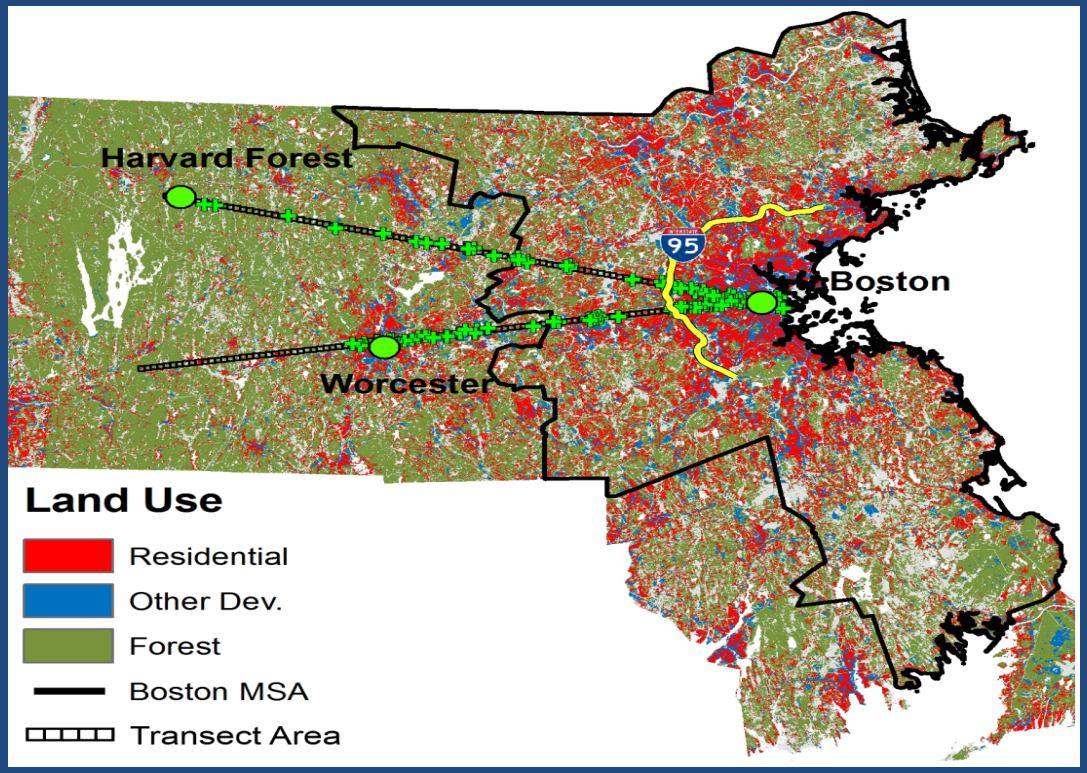
- Cities comprise ~3% of global land cover (UNFPA, 2007)
- Urban areas consume 67% of global energy and emit 71% of the CO_2 worldwide (IEA 2008).
- By 2050 up to 70% of the population will live in cities; urban land cover will expand up to 2.5 times its current extent (UNFPA 2007).

Boston Ultra-EX (Hutyra and Philips, BU):

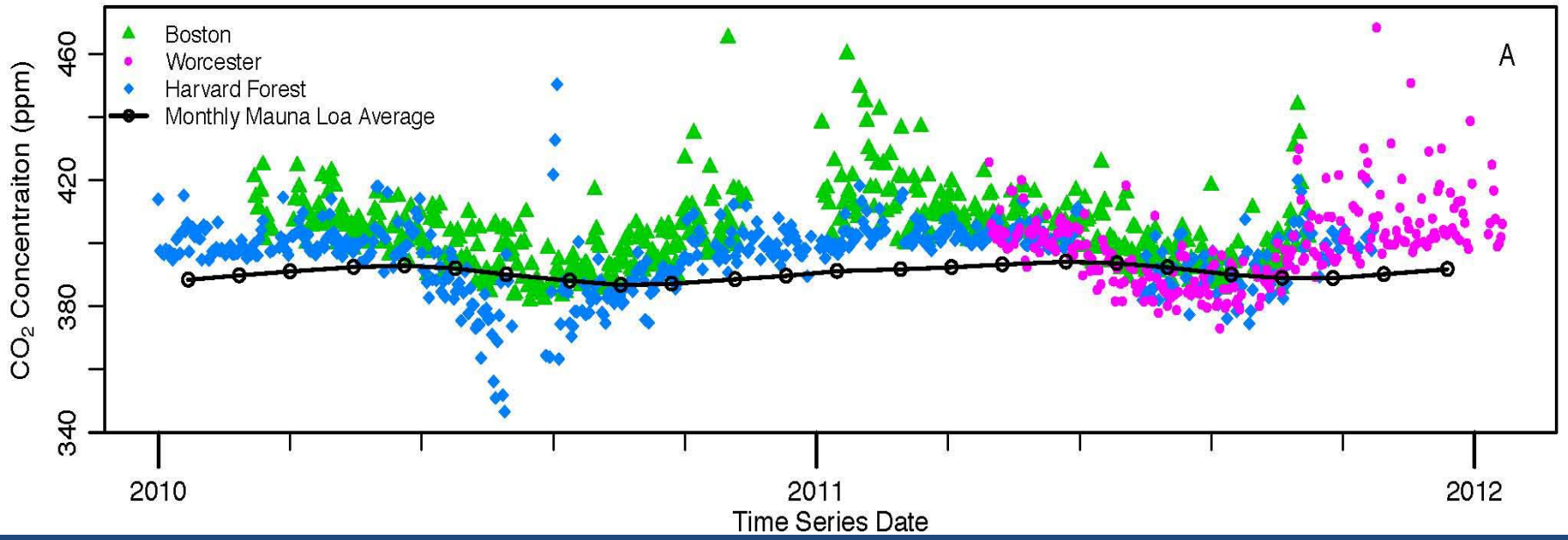
"How do humans and their built and natural environments interact to produce geospatially and temporally varied CO_2 exchange in a region?"



- Study the urban-rural gradient from Boston to central MA
- Use CO_2 to trace natural and anthropogenic processes

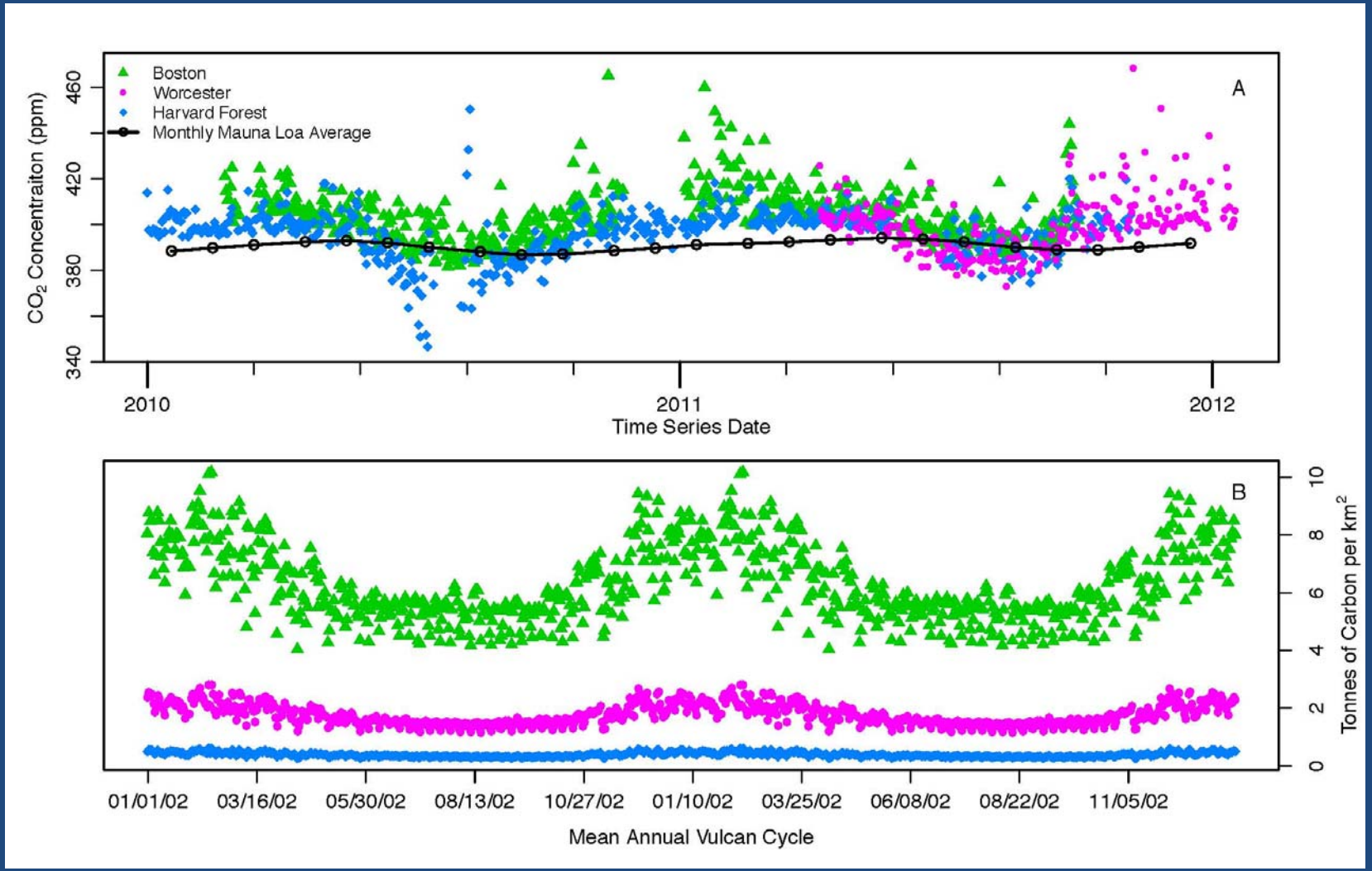
CO_2 and meteorological measurements being made at:

- Boston (high-density, large urban center) – since 2/2010
- Worcester (secondary urban center, close to undisturbed forest) – since 4/2011
- Harvard Forest (forest-dominated) – since 1989



Observations

- Average difference between Boston and Harvard Forest largest in summer (16 ppm), smallest in winter (11 ppm)
- Weekday CO_2 enhancement largest at Boston (3.3 ppm), smallest at Harvard Forest (0.9 ppm)
- Mean CO_2 mixing ratios were 408.2 ± 0.2, 401.5 ± 0.4, and 393.0 ± 0.3ppm at Boston, Worcester, and Harvard Forest, respectively



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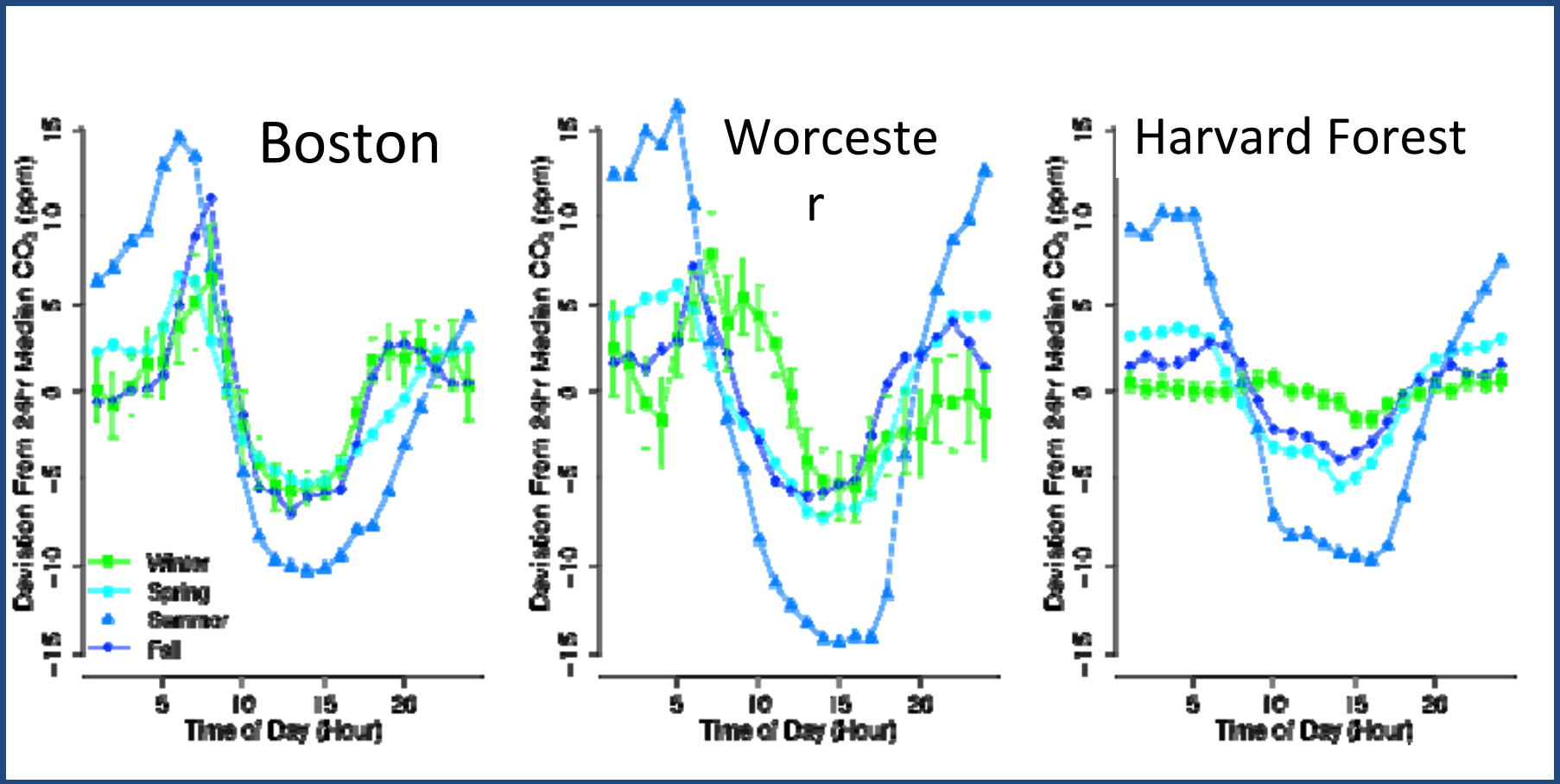
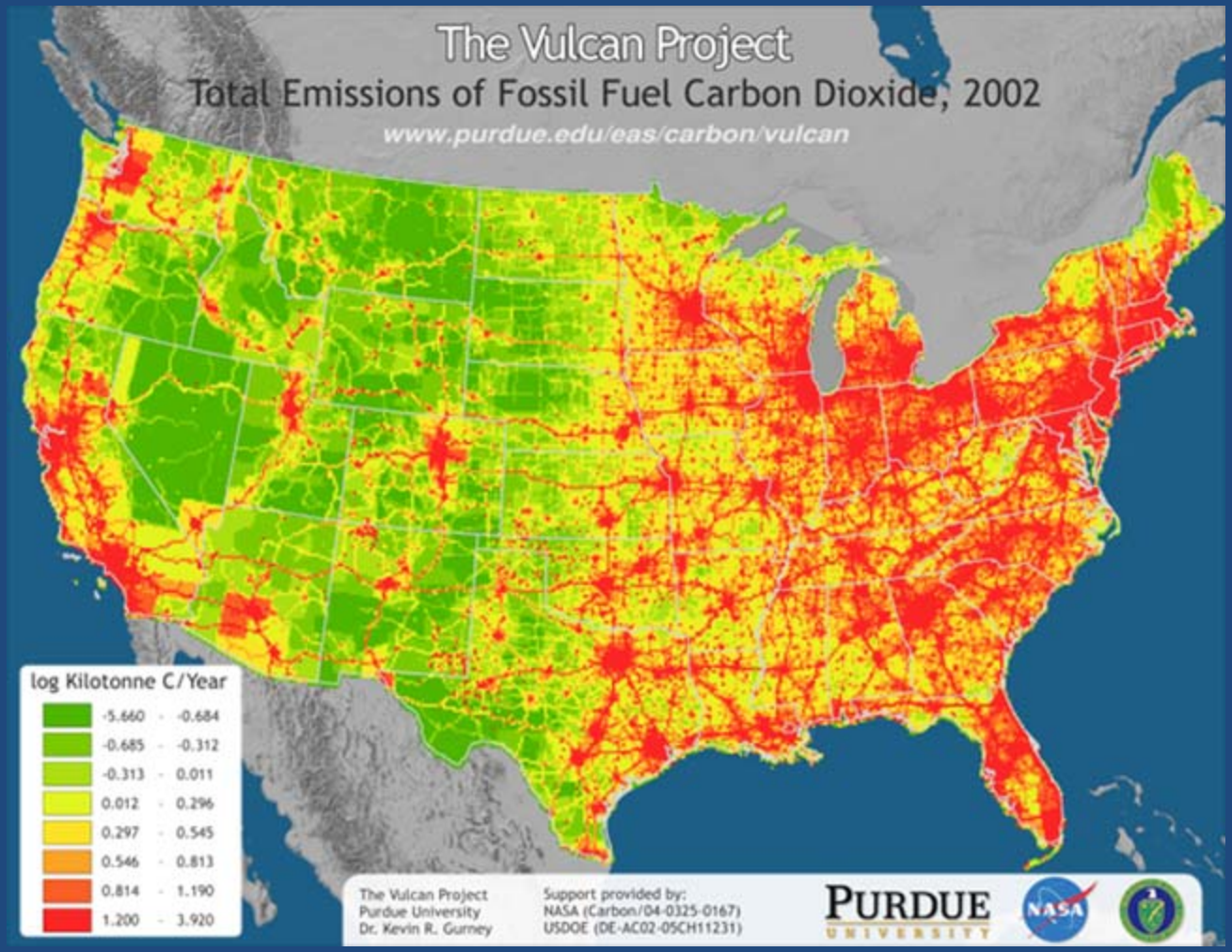


- CO_2 uptake signal seen at all three locations
- Early afternoon minima as biospheric uptake and atmospheric mixing are maximized
- Early morning CO_2 maxima reflect buildup of biogenic and anthropogenic emissions under a stable atmosphere

Where next?

- Expanding observational network to incorporate new sampling locations: Prudential Building (Boston), Nahant (coastal north of Boston), UMASS-Boston (on Boston Harbor)

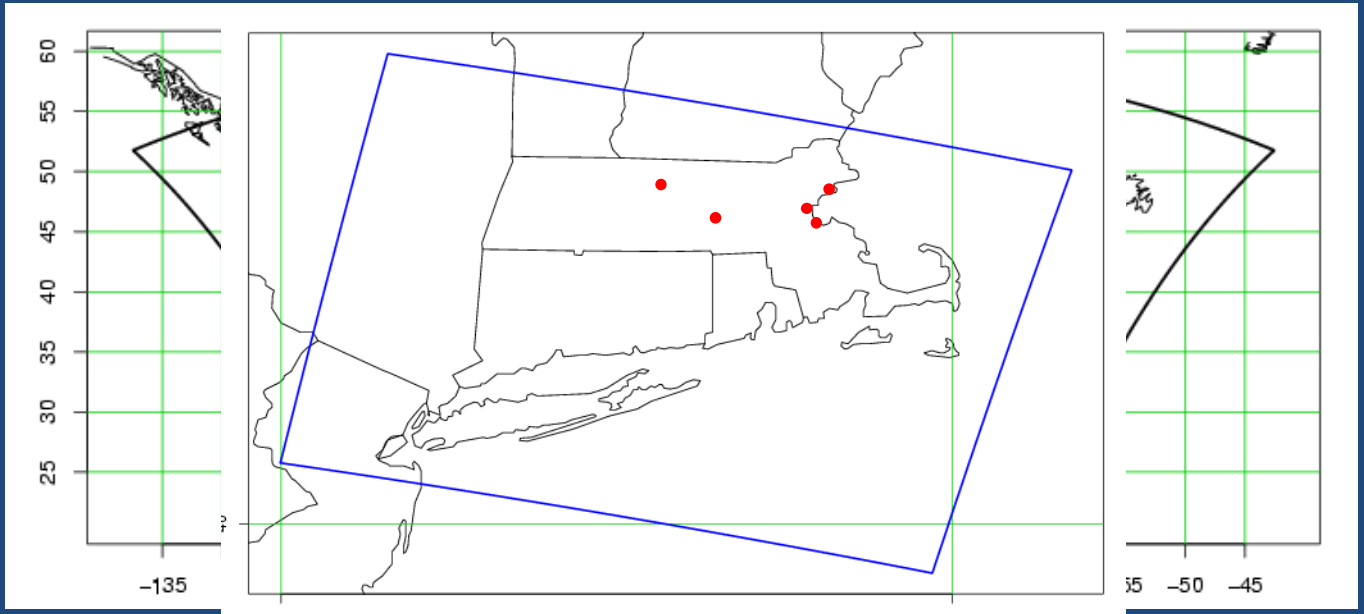
- This CO_2 data is being assimilated into a model-data fusion framework to independently infer high-resolution sources and sinks of CO_2 from the spatially dispersed concentration time series



- Mean fossil fuel CO_2 emissions for MA: ~ 12.3 MgC ha^{-1} yr^{-1} (half from the Boston MSA)
- Mean CO_2 sink at Harvard Forest: ~2.5 MgC ha^{-1} yr^{-1}
- Atmospheric CO_2 signal integrates biogenic and anthropogenic processes

Where next?

- The Stochastic Time-Inverted Lagrangian Transport (STILT) model is being run on nested domains of 36, 12, 4, and 1.3 km
- Combined with a meteorological model (WRF), estimates of urban sources from this project, modeled vegetation sources and sinks
- Because STILT is time-inverted, it will directly **estimate surface fluxes on the basis of observed concentrations** and a priori boundary conditions



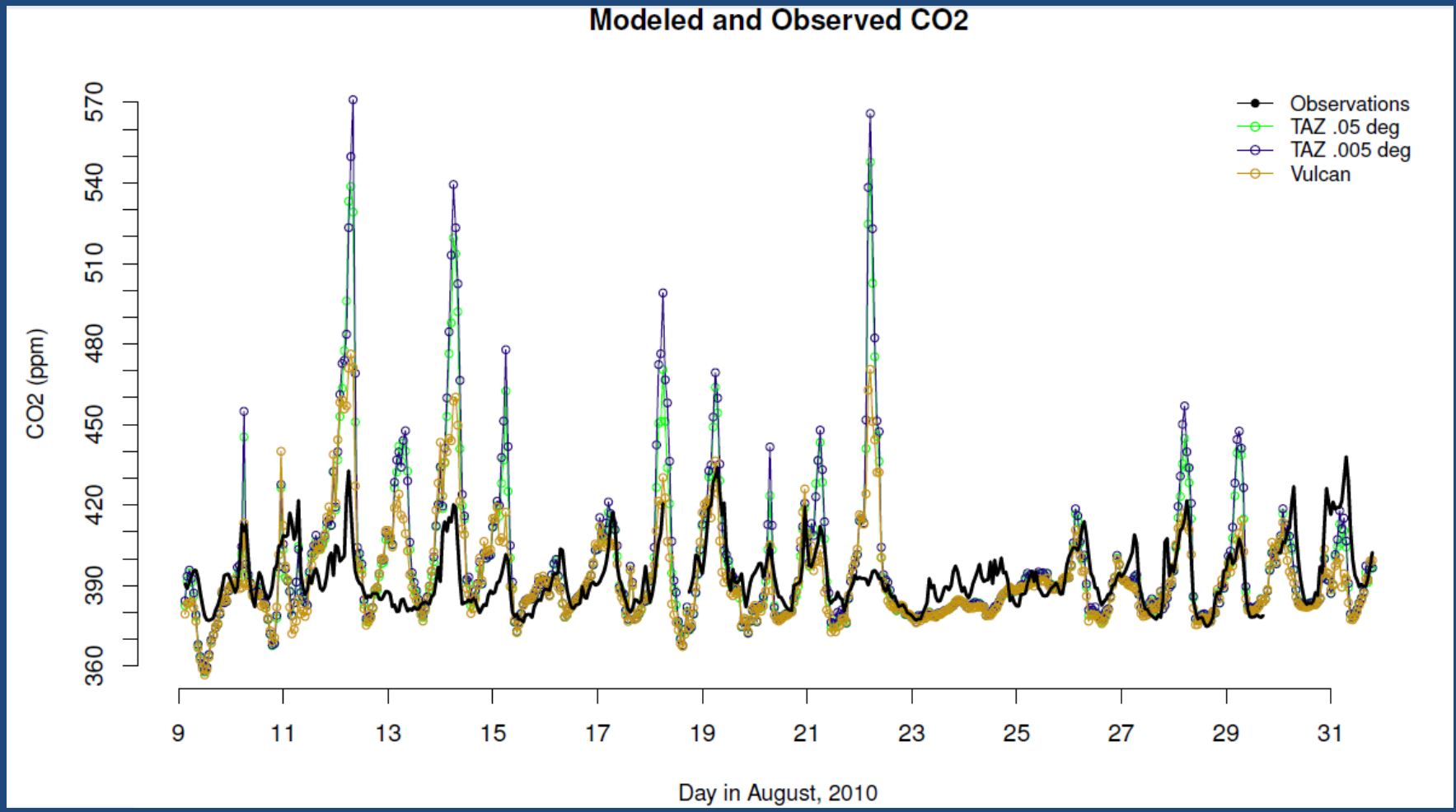


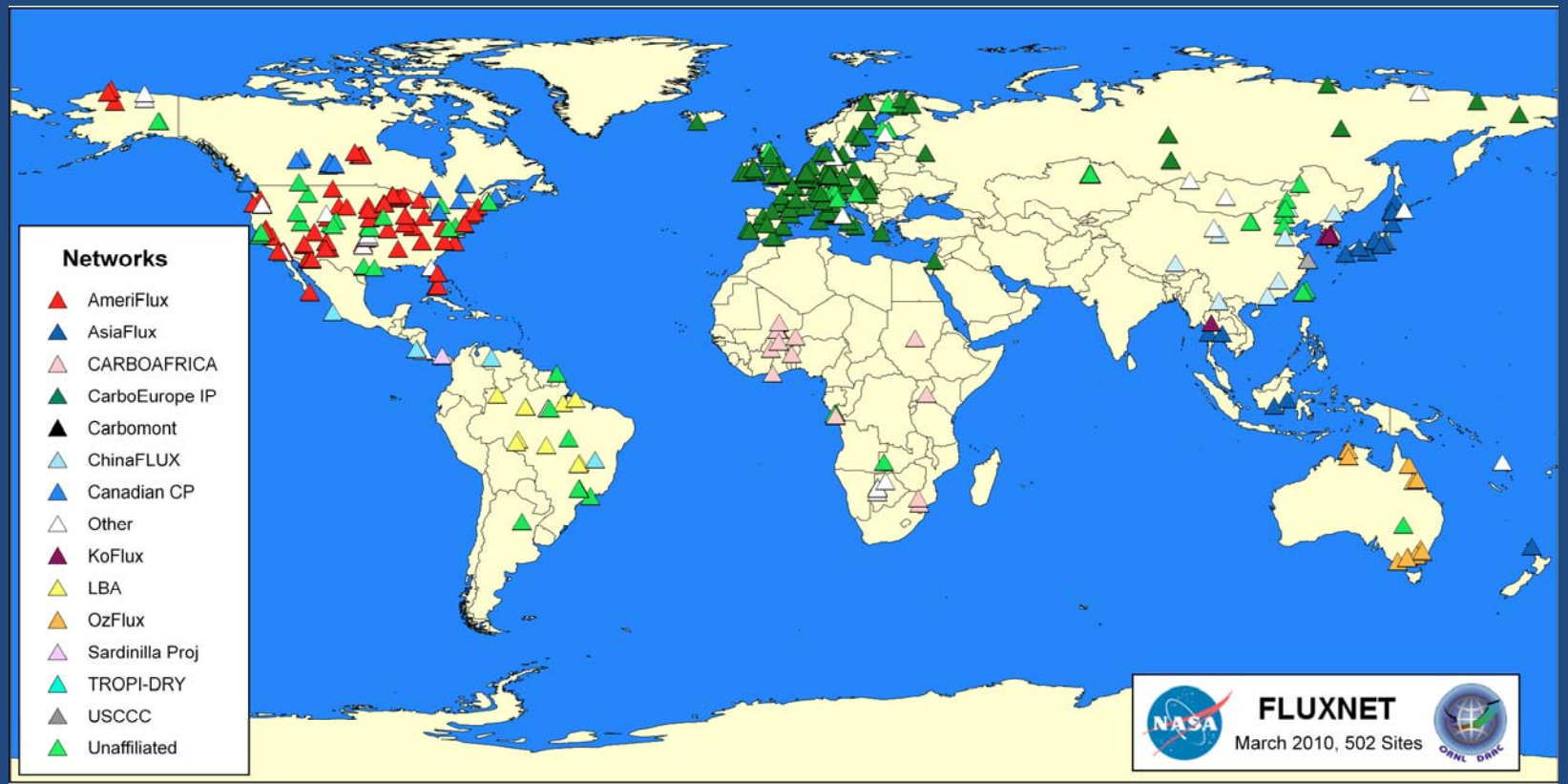
Figure courtesy Levi, McKain, and Wofsy

- STILT captures the basic timing, shape of CO_2 observations
- Model overestimates CO_2 during mid-morning; combination of vehicular emissions, difficulties modeling destratification of PBL, and biospheric transition

Our current observational network is focused on ‘natural’ and managed ecosystems, not on urban regions where emissions dominate.

Any future international treaty to reduce emissions of GHGs will require monitoring, reporting, and verification

Coupling observations with models is critical to distinguishing natural and anthropogenic sources and sinks of carbon dioxide



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