

Megacities Carbon Project & other carbon monitoring projects

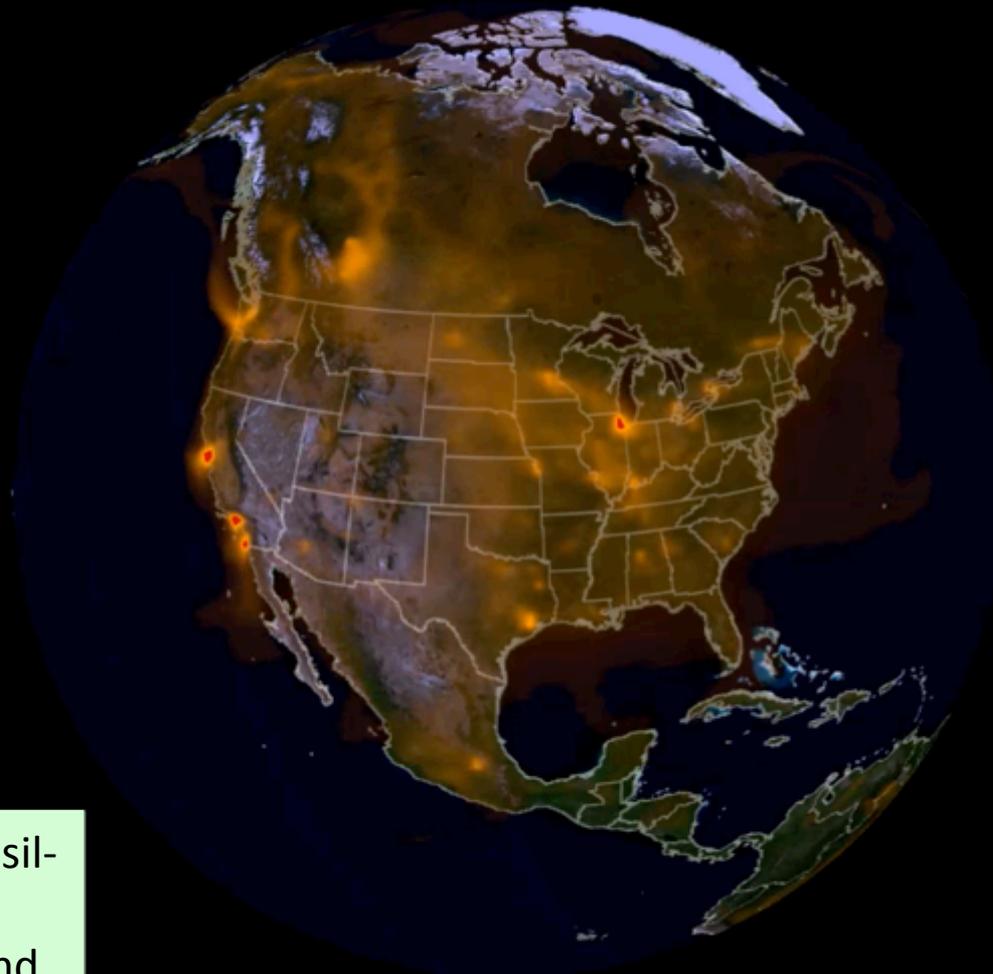
Riley Duren
NASA Jet Propulsion Laboratory
California Institute of Technology
megacities.jpl.nasa.gov

courtesy NASA/JPL-Caltech
megacities.jpl.nasa.gov

Megacities project is supported by NIST, NASA, NOAA, CARB, KISS
Co-PI's: Riley Duren (JPL), Chip Miller (JPL), Kevin Gurney (ASU), Ralph Keeling (Scripps), Ray Weiss (Scripps), Marc Fischer (LBNL)



Why focus on cities?



80% of the world's fossil-fuel CO₂ emissions come from <5% of land

Cities (and their power plants) are the largest emitters₃

Cities and states: climate first-responders



<http://www.c40cities.org>

Linking sub-national carbon markets

GLOBAL CARBON MARKETS

Carbon trading is seen by many as the most effective market-based system to encourage greenhouse gas emission reductions. The World Bank estimated that carbon trading worth a total of \$176bn took place during 2011.

Despite struggling carbon prices, a host of new trading schemes have been announced as countries, regions and even big business identify the positive impact that carbon trading can have not just on the environment, but economically too.

There are a number of different trading mechanisms in operation but most either auction or assign allowances to emit a quota of CO₂. This creates an incentive to reduce emissions so that excess carbon credits can be sold to those who exceed their allocation of emissions.

Microsoft: The company became the first major corporation to introduce a "track and tax" system. Departments across 100 countries will be allocated an emissions budget for energy use and air travel. Overuse will require offsets to be purchased out of the offending department's own budget.

UN/Kyoto Protocol: Countries with emissions reduction targets as part of the Kyoto Protocol trade emissions allowances with each other or can purchase offsets through the Clean Development Mechanism, which in turn funds low-carbon projects in the developing world.

Western Climate Initiative (WCI): The tie-up between California and several Canadian provinces is still under development but will eventually represent a significant chunk of global emissions. Initially CO₂ from power stations will be traded but transport emissions could be included in 2015, which would increase the scope of the scheme drastically.

Regional Greenhouse Gas Initiative (RGGI): Covers electricity producers in nine US states in the north east of the country including New York and Massachusetts. It has a goal to reduce emissions by 10% before 2018.

Mexico: The previous government established strong climate change legislation including a 30% reduction in emissions by 2020. A voluntary cap and trade mechanism has been proposed however there are few details available on its design and a change in government as of December 1, 2012 could affect the plans.

EU Emissions Trading Scheme (ETS): The trading scheme covers around half of the group's emissions and unlike many systems, it includes some emissions from the transport sector, specifically aviation. Charges on aviation apply to any flight using EU airports regardless of whether the airline is based, creating tension with other countries. The EU is targeting an emissions reduction of 20% by 2020.

China: The world's largest emitter will begin regional pilot schemes in seven cities from 2013 onwards with a view to establishing a national market in the future. Heavy emitting industries and electricity producers will be included at first. An agreement with the EU will see some cooperation with the design of China's trading platforms.

Tokyo: The city-wide scheme applies to large office buildings and industrial infrastructure, which are required to use a combination of renewable energy and efficiency measures to stay within a prescribed emissions cap.

South Korea: An increasingly active country in climate change diplomacy, as host of the Green Climate Fund and the Global Green Growth Institute, South Korea will also begin carbon trading in 2015. More than half the country's emissions will be covered by the scheme, which includes 500 of its heaviest emitters.

Taiwan: The island hopes to reduce emissions back to 2005 levels by 2020 and has requested that 270 of its largest emitters begin reporting their emissions ahead of the launch of a cap and trade system.

Vietnam: The country announced plans to reduce its emissions from forestry and agriculture by 20% in May 2012. A carbon trading scheme will be established to meet the goal. No further details are available.

India: The country's mandatory Perform, Achieve and Trade (PAT) scheme differs slightly from the other platforms given binding energy efficiency targets rather than emission allowances. Over achievers can trade the fruits of their labour with other companies.

Australia: The country launched a carbon price of A\$23 per tonne of CO₂ emitted with 300 of the country's largest emitters included. A link-up with the EU market is scheduled for 2018.

New Zealand: Although the system includes only every second tonne of carbon emitted, the New Zealand trading scheme does cover a wide range of sectors including agriculture, energy, liquid transport fuels and waste. It also rewards sectors such as forestry with credits for absorbing CO₂ from the atmosphere.

Emerging sub-national carbon markets value ~\$500B/year (2011) *if there's sufficient trust to link & trade*

Vision: Global carbon monitoring system

Duren, R.M and C.E.Miller (2012), Measuring the Carbon Emissions of Megacities, *Nature Climate Change* 2, 560–562 (2012) doi:10.1038/nclimate1629.

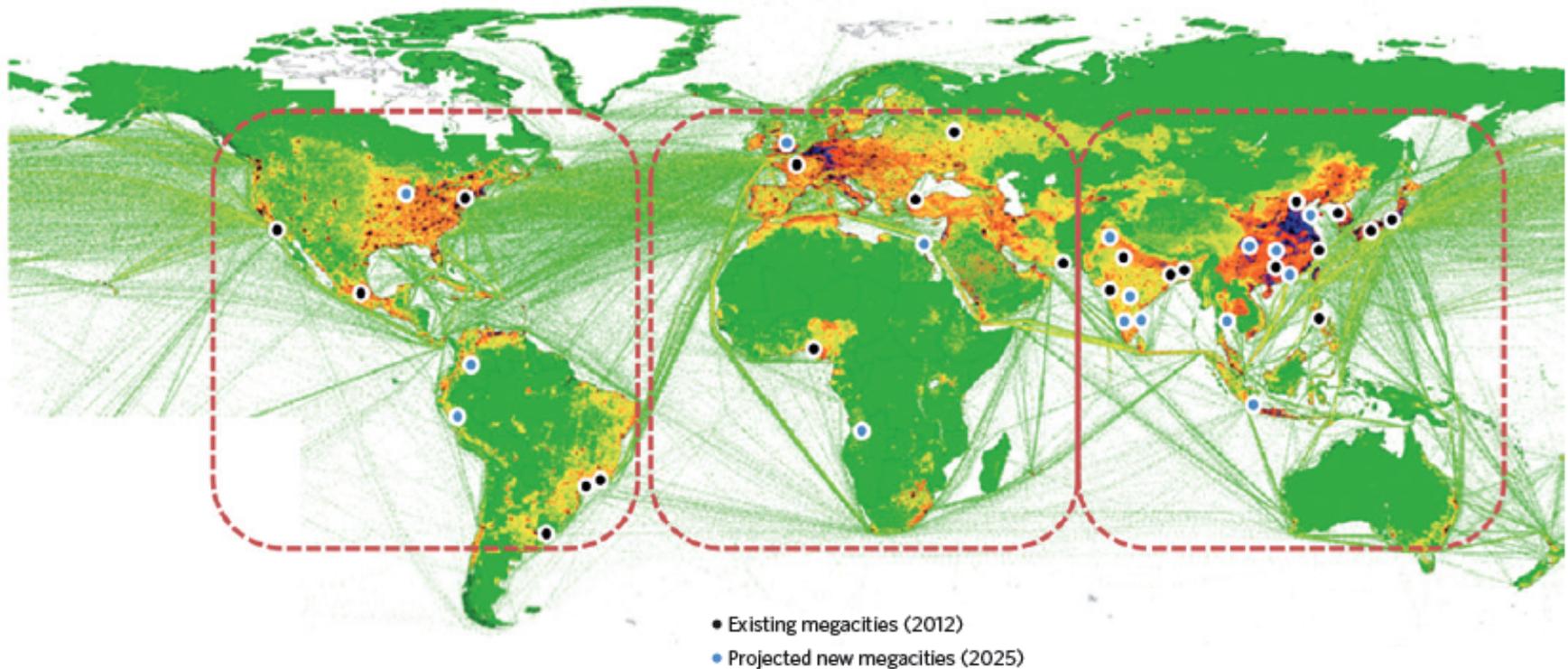


Figure 1 | A strategy for monitoring megacity carbon emissions. A 10-km-resolution gridded inventory of anthropogenic greenhouse-gas emissions in carbon dioxide equivalents indicates the distribution and intensity of emission sources, ranging from 0–55 Mg C per cell per year. Urban areas are indicated in orange, red and black. The darkest areas correspond to the emissions of urban and heavily industrialized areas. The black circles indicate proposed surface measurement networks concentrated within and around the 23 existing megacities. Blue circles indicate the 14 additional megacities projected to exist by 2025 (ref. 17). The dashed rectangles indicate the fields of regard of three remote-sensing instruments that if hosted on commercial communication satellites in geostationary orbit would offer sustained, wall-to-wall measurements of column-averaged carbon dioxide, methane and carbon monoxide mixing ratios several times per day for the vast majority of the Earth's populated areas. With such a system, a typical megacity would be sampled by over 2,500 measurements per day on average. An existing network of surface remote-sensing stations enables calibration of satellite data. Emission map taken from European Commission-Joint Research Council/Netherlands Environmental Assessment Agency (PBL). Emission Database for Global Atmospheric Research (EDGAR) version 4.0 (<http://edgar.jrc.ec.europa.eu>) 2009.

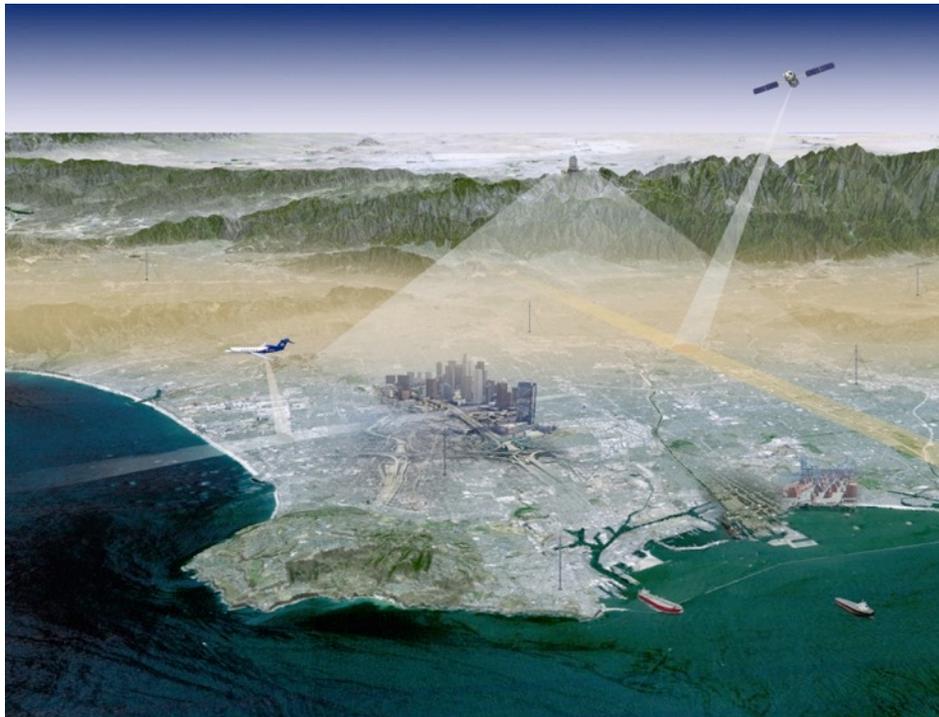
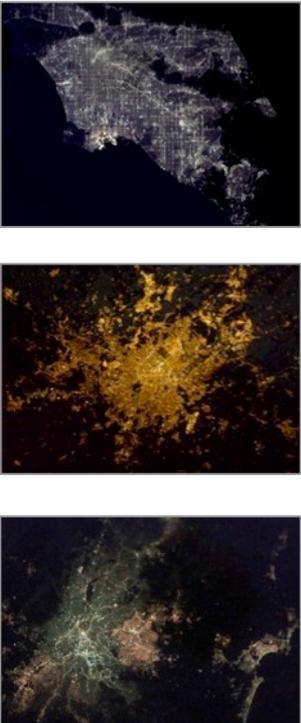
Pilot: Megacities Carbon Project

NATURE CLIMATE CHANGE | VOL 2 | AUGUST 2012 | www.nature.com/natureclimatechange

Measuring the carbon emissions of megacities

Riley M. Duren and Charles E. Miller

Carbon emissions from cities represent the single largest human contribution to climate change. Here we present a vision, strategy and roadmap for an international framework to assess directly the carbon emission trends of the world's megacities.



What are the carbon emissions of cities and how are they changing?

Why are emissions changing (which sectors, policies, and behaviors are responsible)?

Are mitigation efforts having the intended effect?

How reliable is carbon market data from other cities?

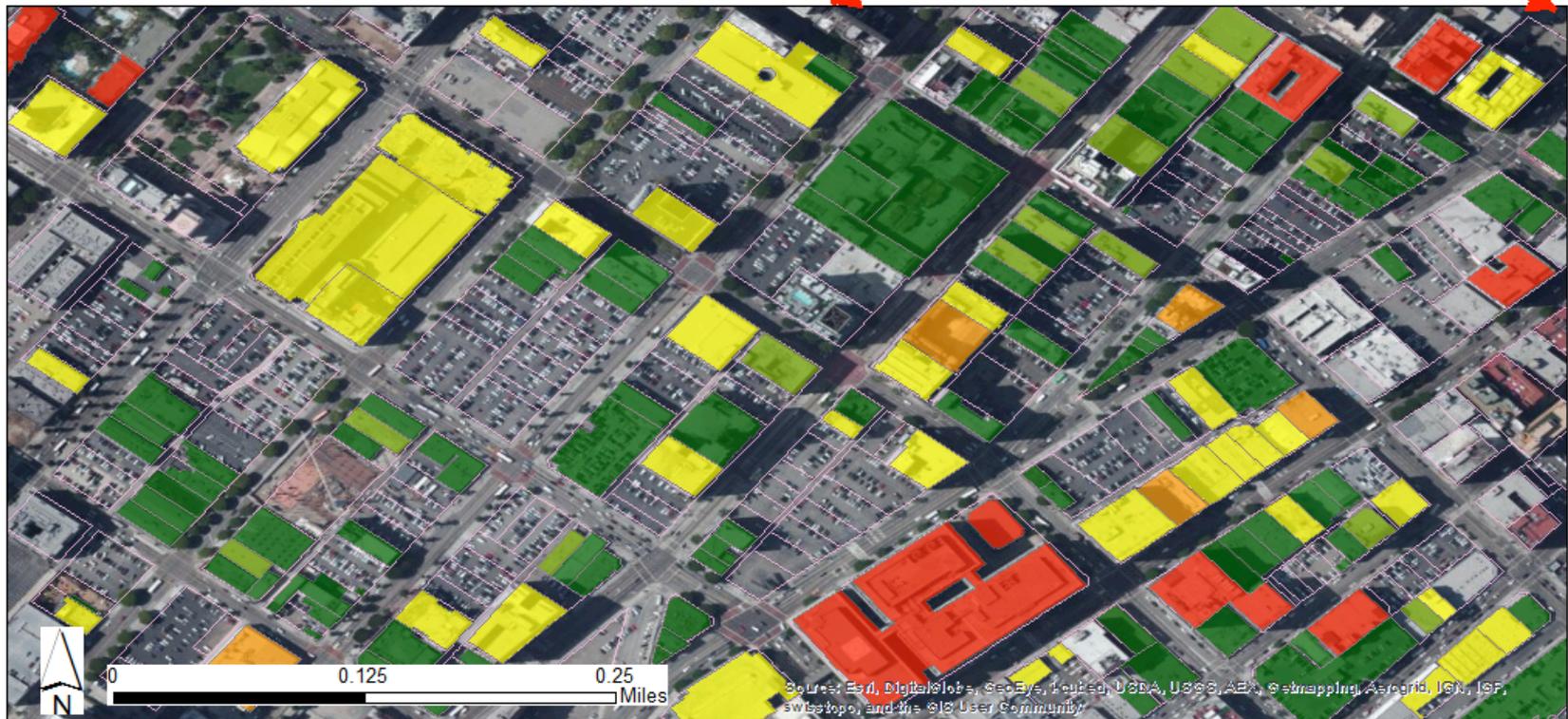
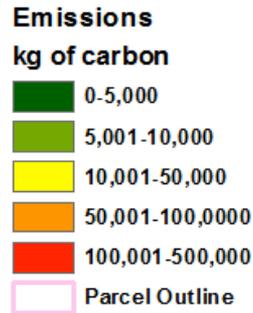
Can we share data transparently between cities?

L.A. County Parcel: Building Classification

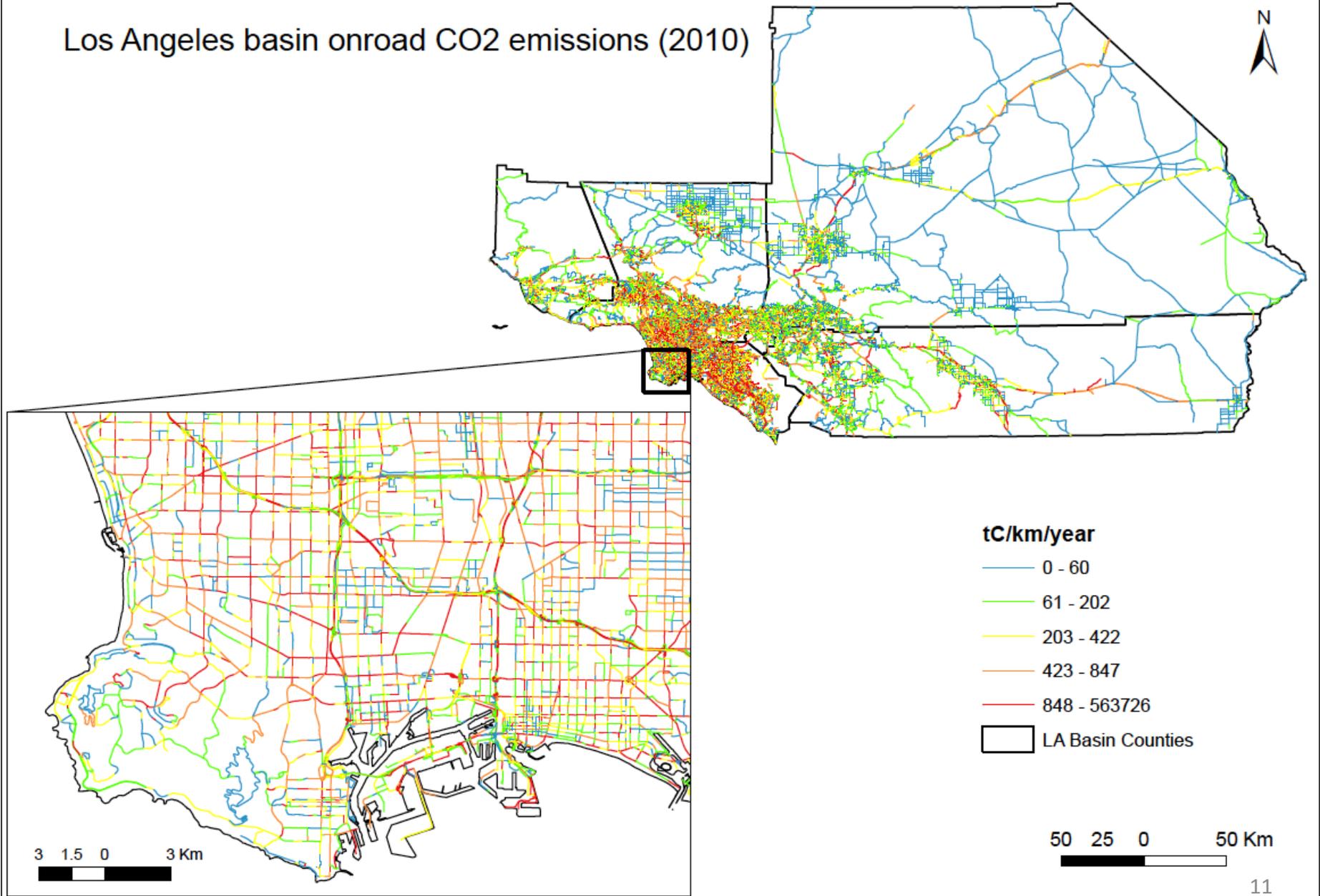
- | | |
|---|---|
|  No Data |  lodging (pre-1980) |
|  IND miscellaneous |  other (post-1979) |
|  apartment 5 or more unit (pre-1980) |  other (pre-1980) |
|  apartment 5 or more units (post-1979) |  restaurant (pre-1980) |
|  education (post-1979) |  single family detached (pre-1980) |
|  large office (post-1979) |  small office (pre-1980) |
|  large office (pre-1980) |  small retail (post-1979) |
|  large retail (post-1979) |  small retail (pre-1980) |
|  large retail (pre-1980) |  warehouse (post-1979) |
|  lodging (post-1979) |  warehouse (pre-1980) |



L.A. County Building Footprint: Building Emissions



Los Angeles basin onroad CO2 emissions (2010)

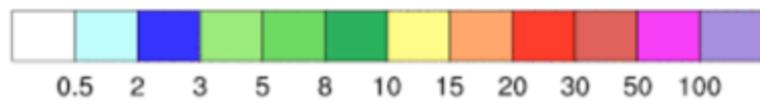
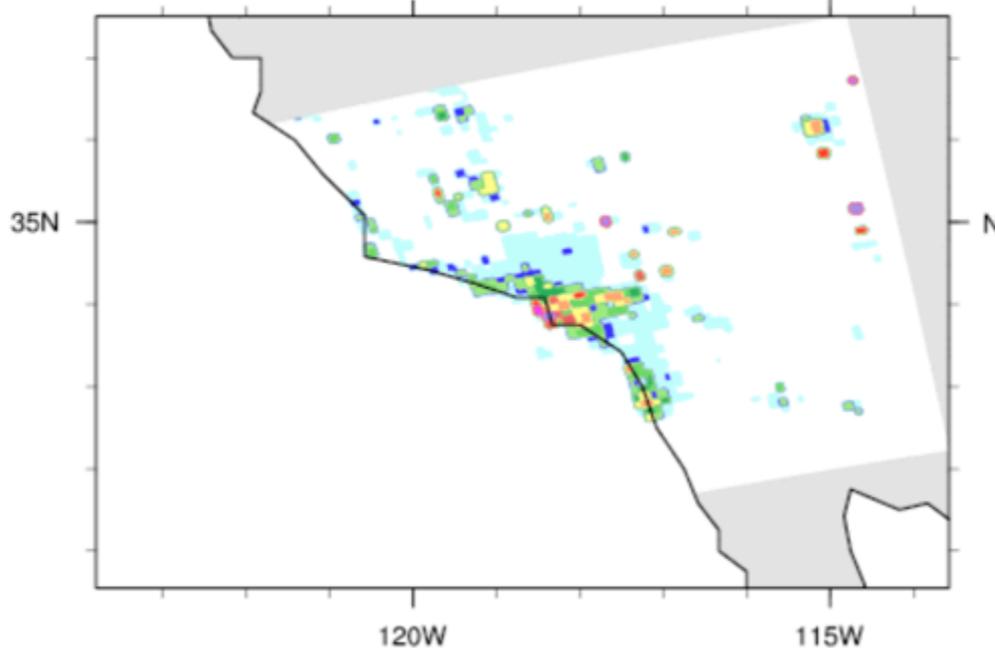


(2) High-resolution atmospheric CO₂ modeling (currently 4km for SoCal – moving to 1km)

2011-10-02_08:00:00

Fossil Fuel CO₂ Emissions

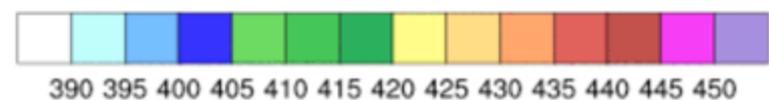
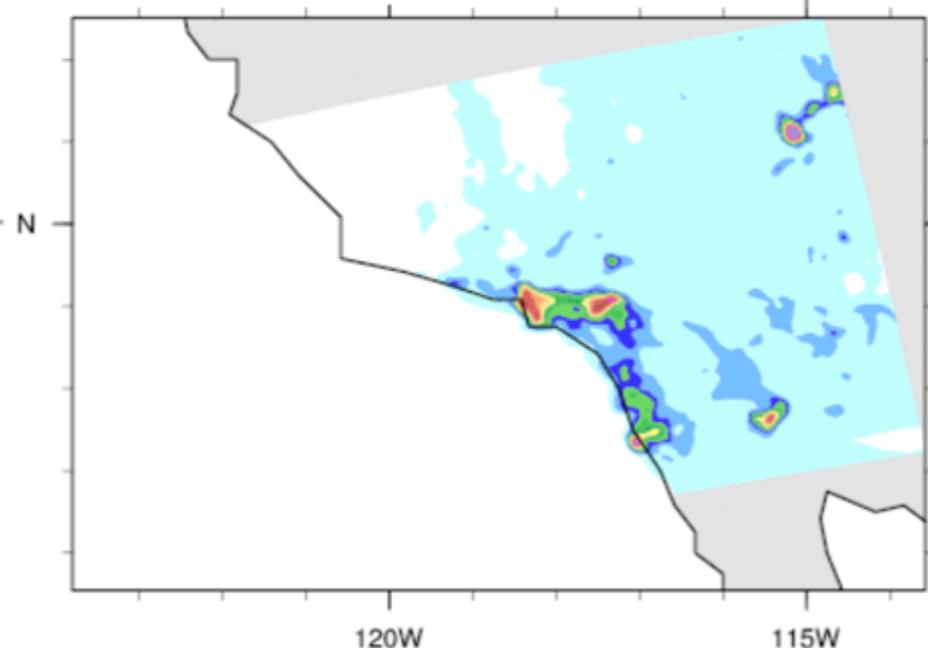
$\times 10^3 \text{ mol/km}^2/\text{hr}$



2011-10-02_08:00:00

Atmospheric CO₂ concentrations

ppmv

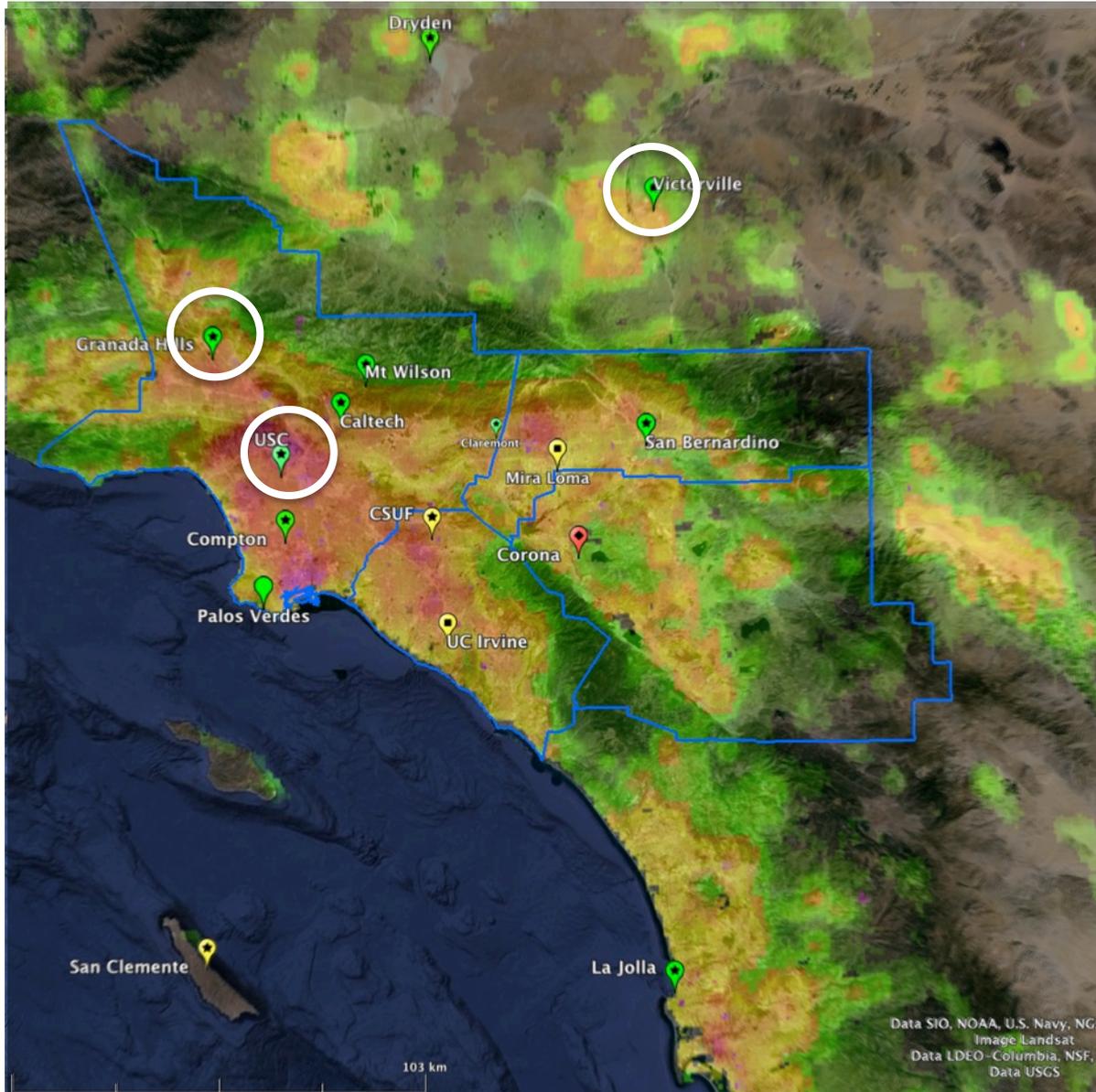


Solve for this

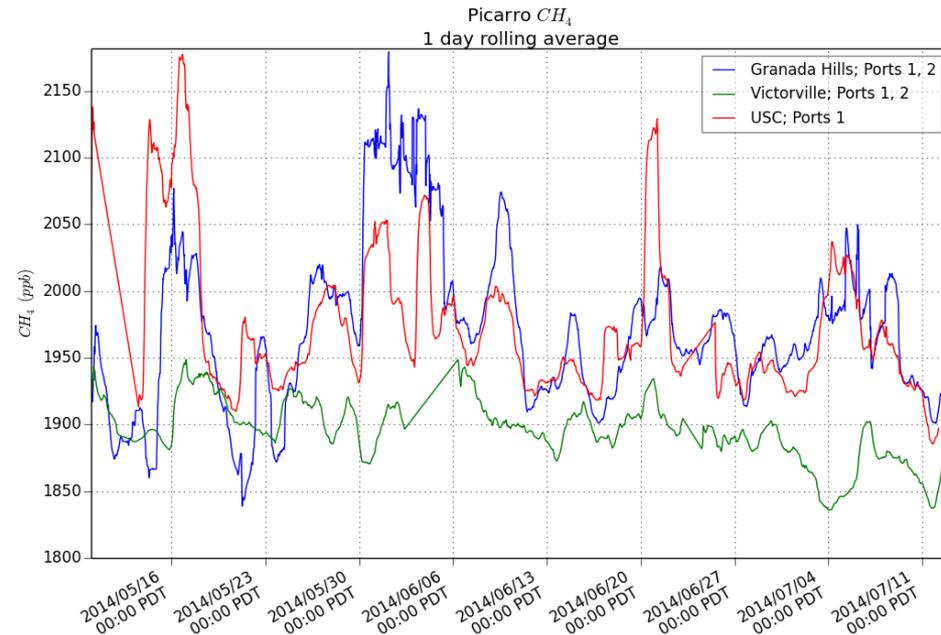
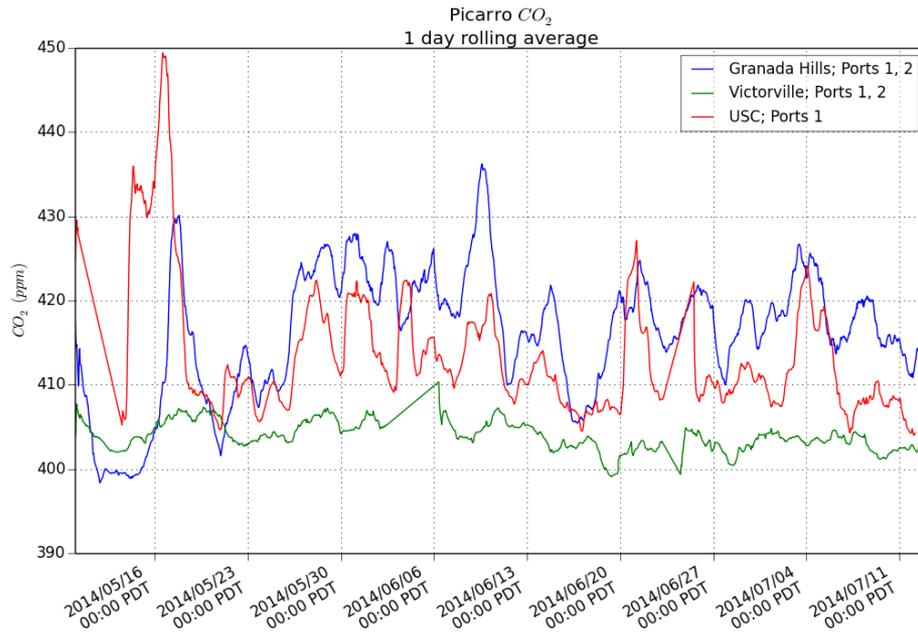
Measure this



(3) Surface measurement network



CO₂ and CH₄ vary significantly across SoCal



Preliminary, uncalibrated data

For illustration only

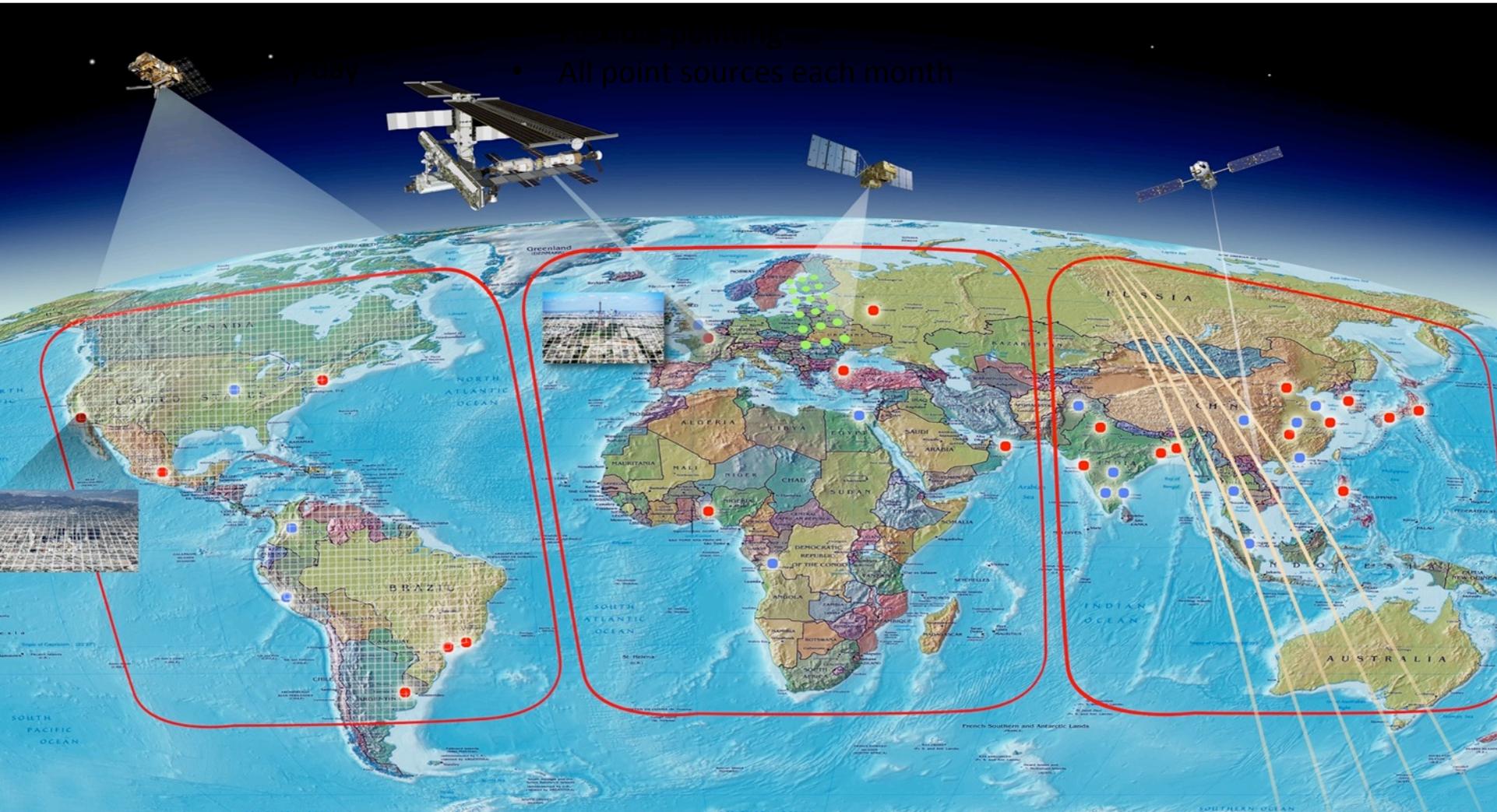
(4) Emerging satellite capabilities

Geostationary (20xx?)

OCO-3 on ISS (2017?)

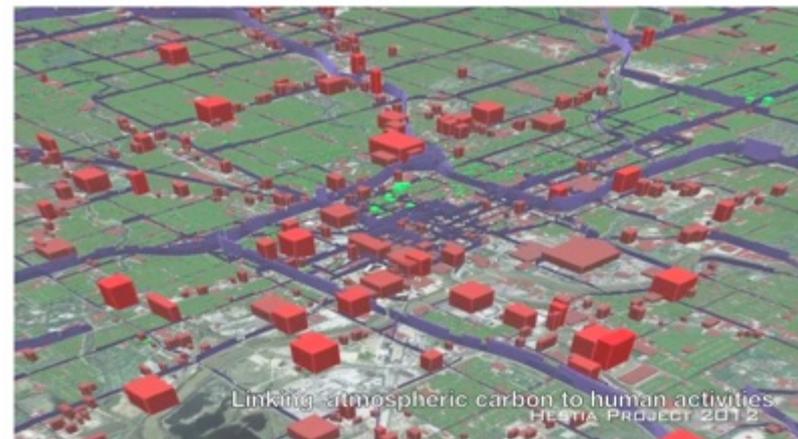
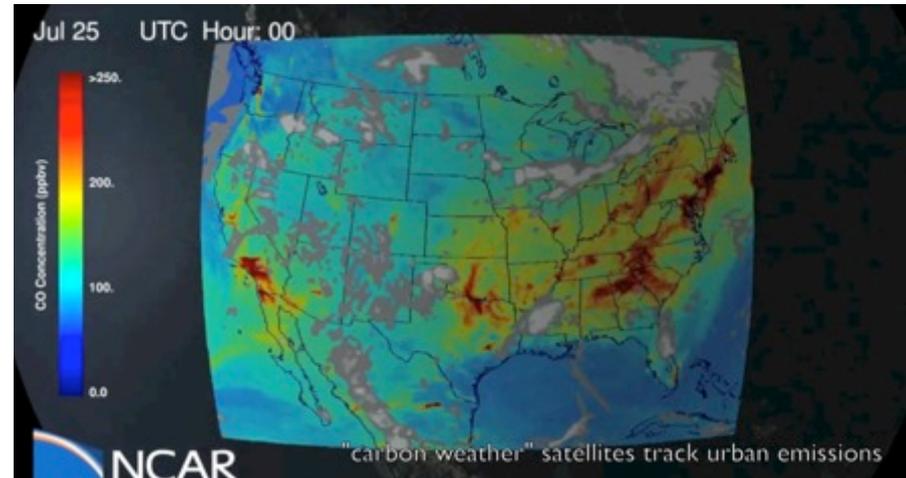
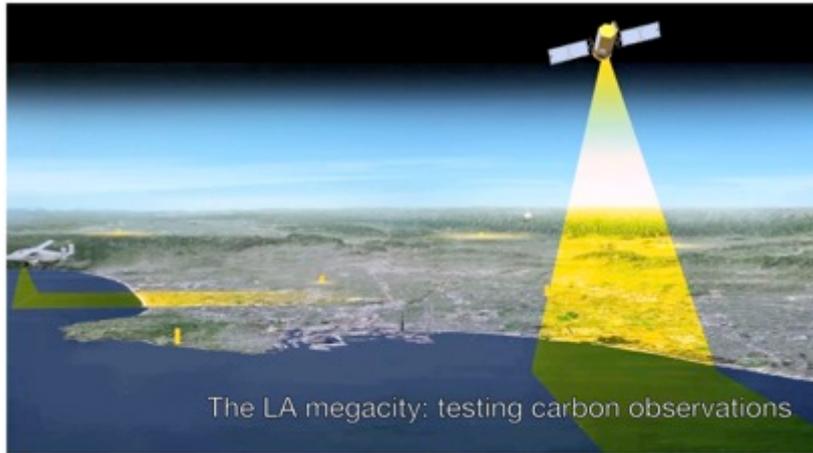
GOSAT (2009-?)

OCO-2 (2014-2016)



(5) Putting it all together

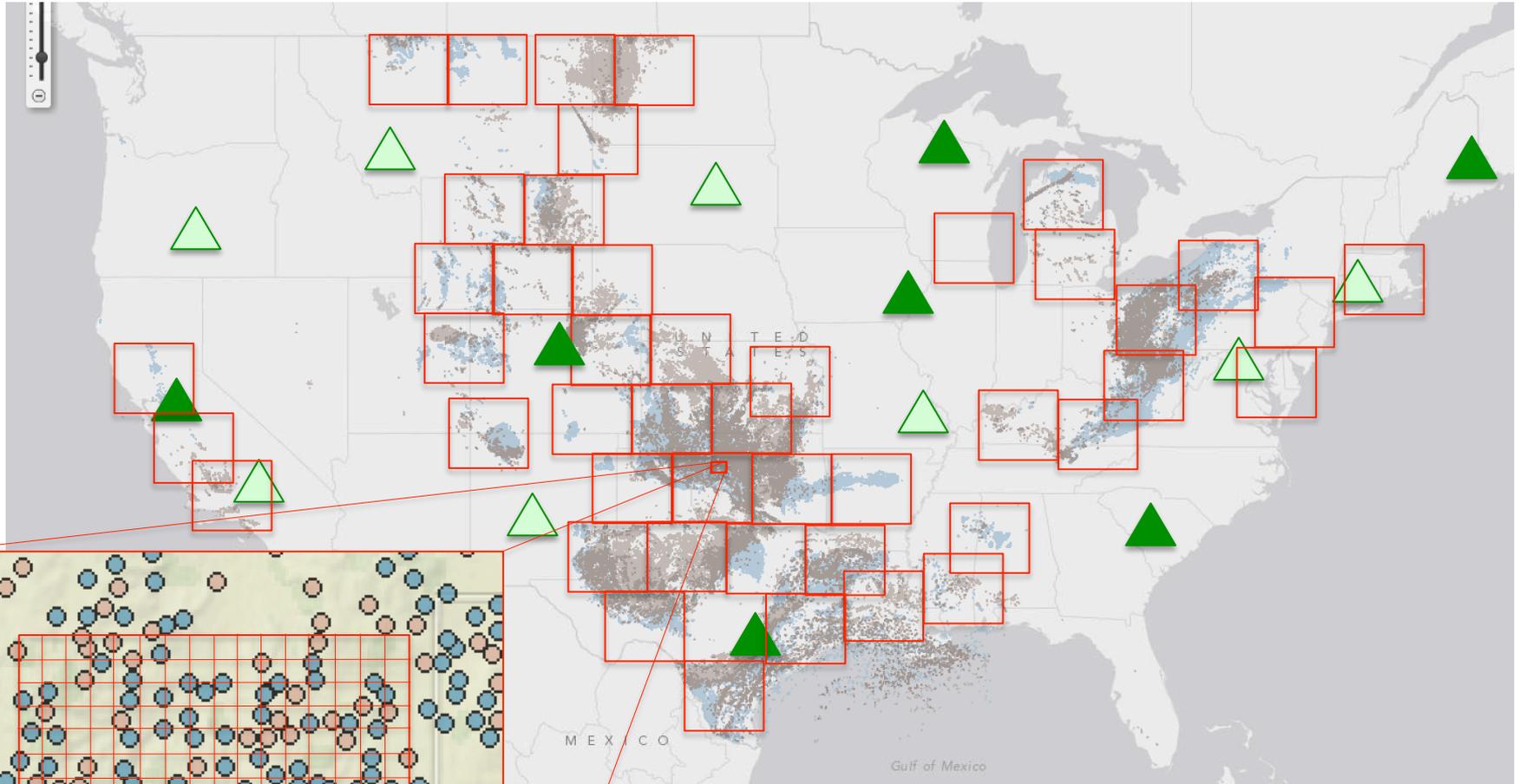
Linking cause & effect for decision making



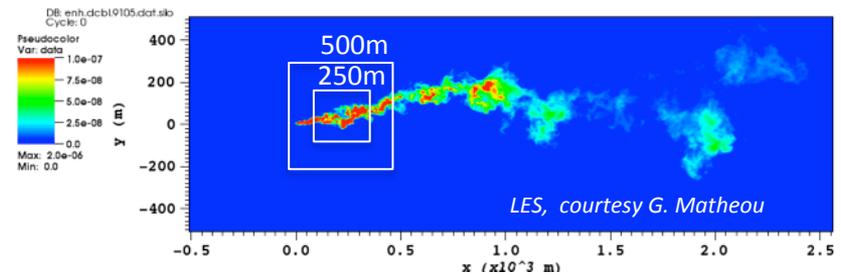
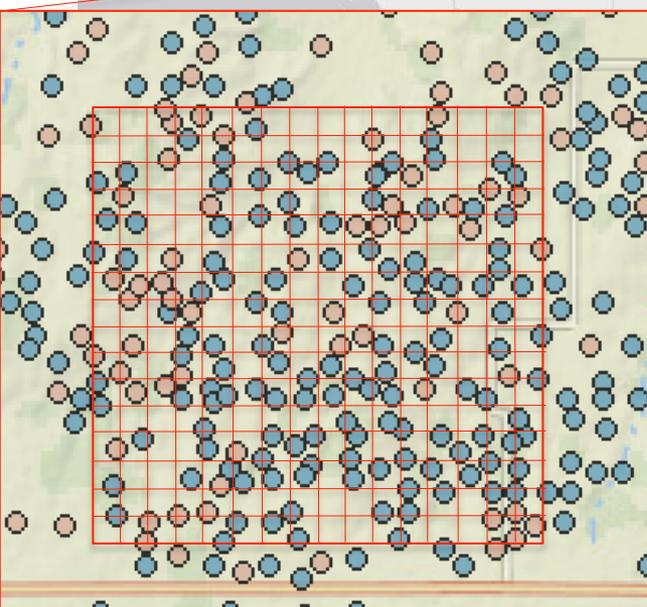
Combining observations from satellites, aircraft, and surface stations
with transparent emission data sets

Other, related carbon projects

Concept for national methane monitoring system



Duren and Miller, Nature Climate Change, 2014, in prep



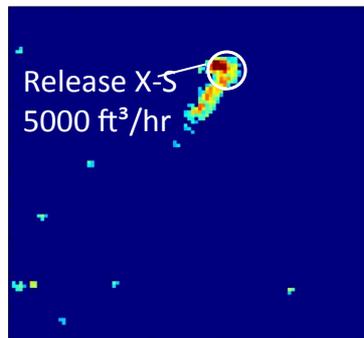
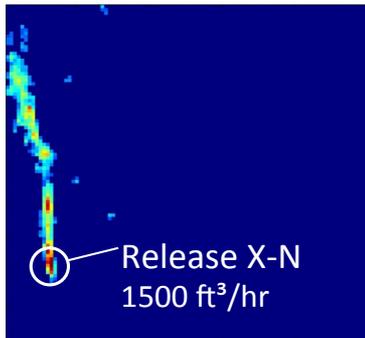
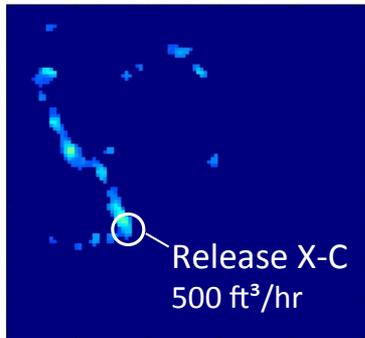
Mapping methane leaks with aircraft

Controlled release experiment (RMOTC, June 2013)

X-C: 43.30°N, 106.22°W: Flux = 500 ft³/hr

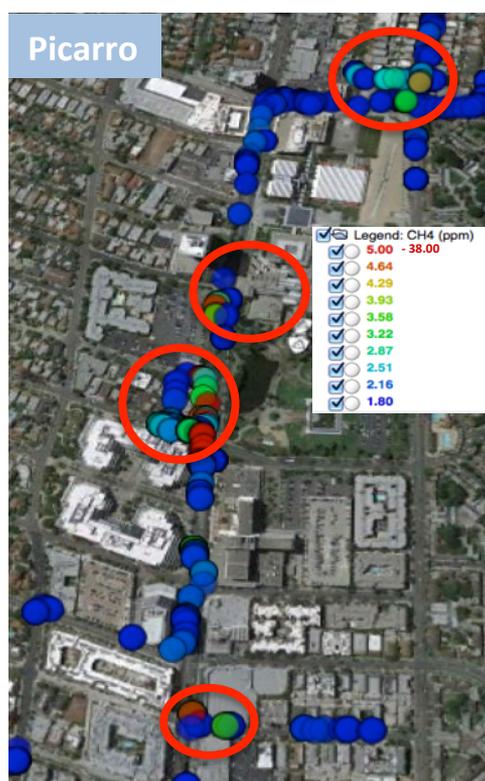
X-N: 43.33°N, 106.23°W: Flux = 1500 ft³/hr

X-S: 43.30°N, 106.22°W: Flux = 5000 ft³/hr



Hyperspectral Thermal Emission Spectrometer (HyTES)

Operational field test (La Brea Tar Pits, July 2014)



*CH₄ from roof-top sewer vents?
(to be confirmed)*



HyTES images
courtesy
Simon Hook,
Glynn Hulley
(JPL)

More broadly: NASA's Carbon Monitoring System

carbon.nasa.gov

Enabling technology development program

NASA Mission & instrument data sets



30+ space & airborne missions & instruments relevant to air, land & oceans

Research & Analysis
(Carbon cycle,
Atmo comp)

Applied Science
(Climate,
Agriculture, Air-
quality)

CMS program

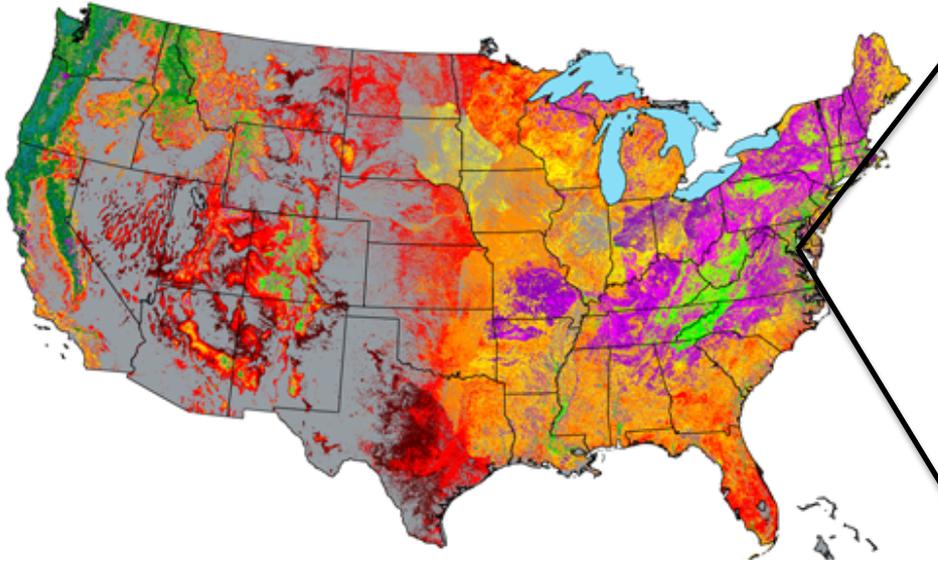
37 pilot projects
(scales: global, national, state/
province, region, urban)

CMS Data Products

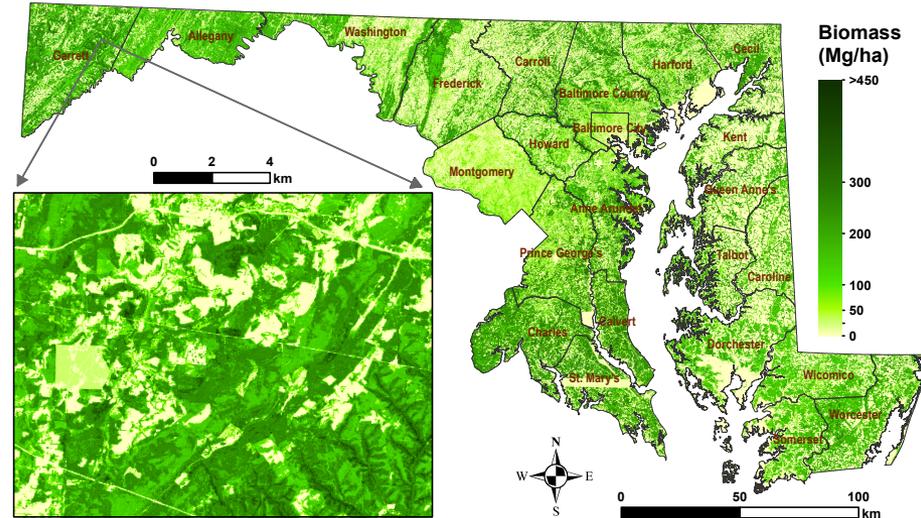
User Community

Data from US & international partner
agencies

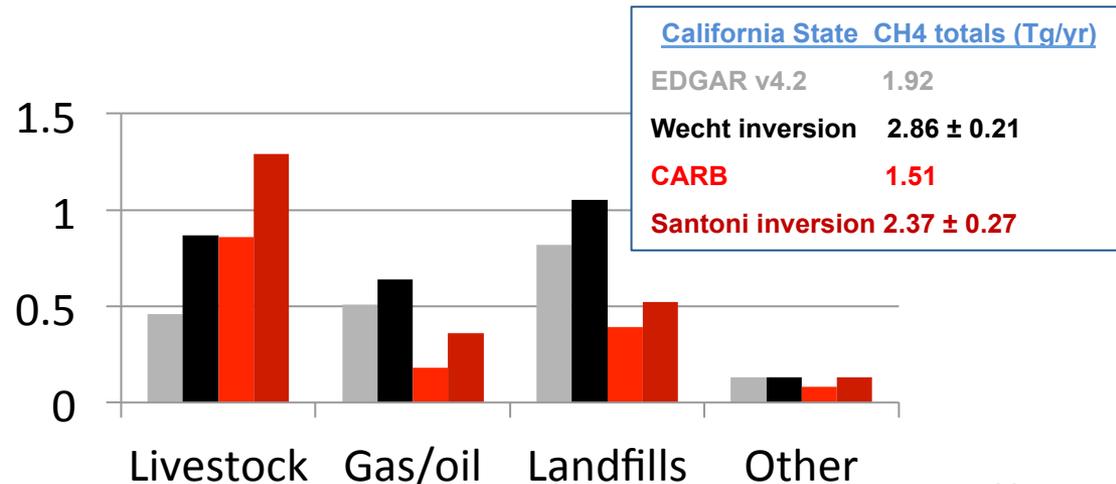
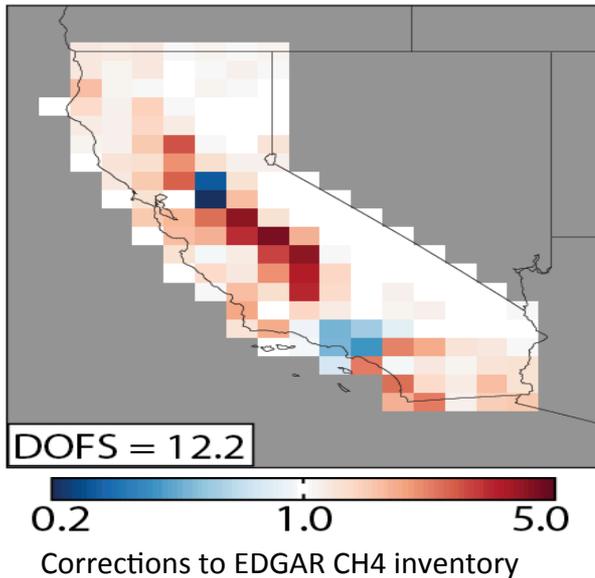
Some examples of CMS products



US forest biomass map- 250m (source: Sassan Saatchi, JPL)



Local scale (30m) biomass map for counties in Maryland (Source: Ralph Dubayah, U. Maryland)



(source: Daniel Jacob, Kevin Wecht, Harvard)



Thank you

Riley.M.Duren@jpl.nasa.gov
megacities.jpl.nasa.gov
carbon.nasa.gov



© Riley Duren