High resolution fossil fuel carbon inventories: progress, status and application to NACP research

or,

How are we doing, understanding and quantifying the 800 lb gorilla?

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Scope

Initial *operational* goals:

- Achieve fossil fuel C emissions (CO_2, CH_4, CO) for North America at scales that are <50 km, and sub-diurnal
- Multiple years
- As close to real-time as possible
- Data driven, include isotopes

Boundary condition for DA or budget studies

Added value results:

- FF-specific diagnosis, attribution, prediction, decision support
- Powerful linkage to human dimensions
- Powerful outreach tool with multiple meanings and value

To do this:

- Process-based model/data product (analogue to TBM development)….. Energy, economics, demography, sociology move beyond “inventory”

History

First data products were tables and accompanying graphs …

Keeling, 1978

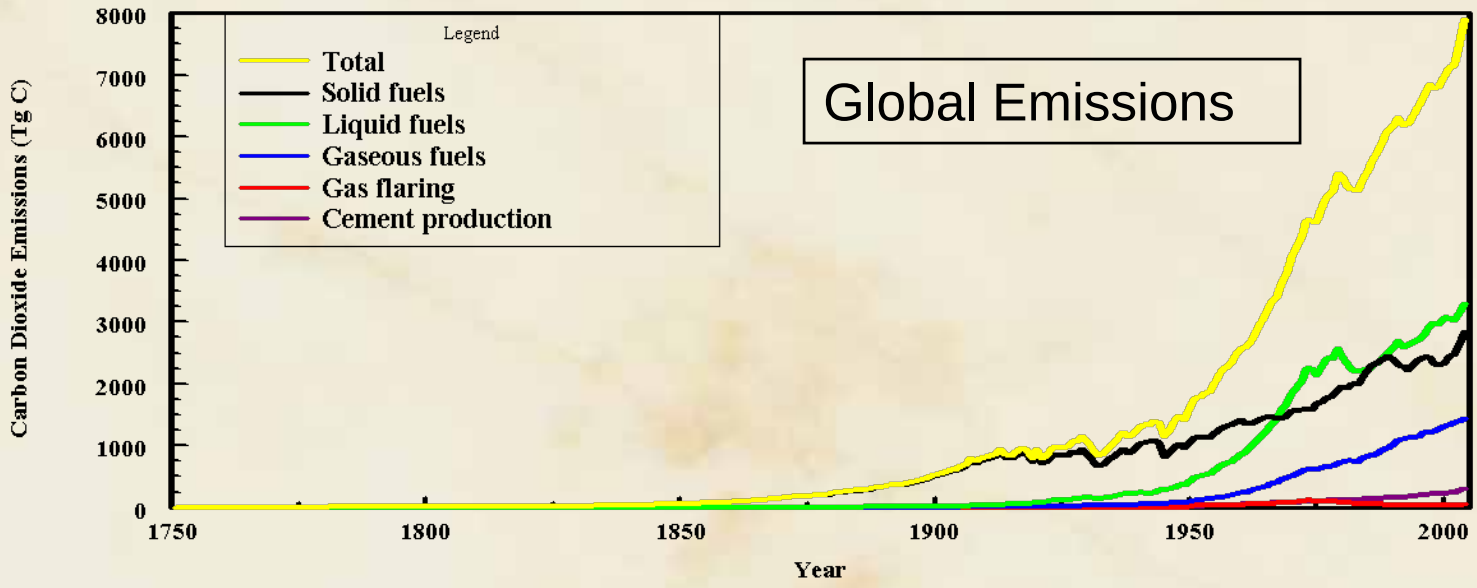
Rotty, 1983

Marland et al., 1985

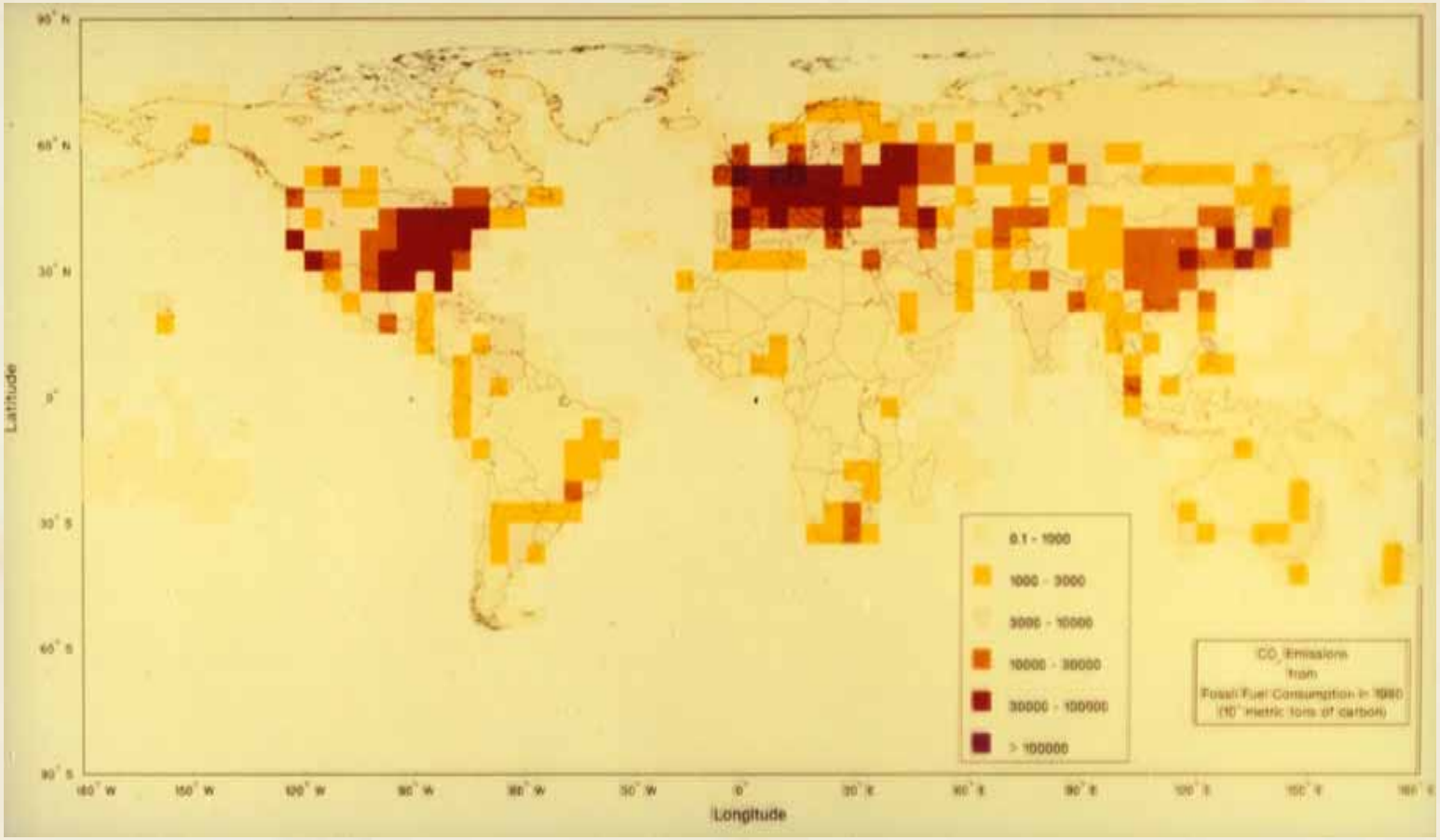
Carbon Dioxide Emissions
from Fossil Fuel Consumption and Cement Production
in Million Metric Tons of Carbon
(Per Capita in Metric Tons)

---------- COUNTRY : HUNGARY ----------

Year	Gases	Liquids	Solids	Cement	Total	Per Capita
50	0.192	0.334	4.205	0.109	4.839	0.518
51	0.204	0.481	5.030	0.129	5.843	0.616
52	0.252	0.579	6.210	0.144	7.185	0.749



Gridded emissions

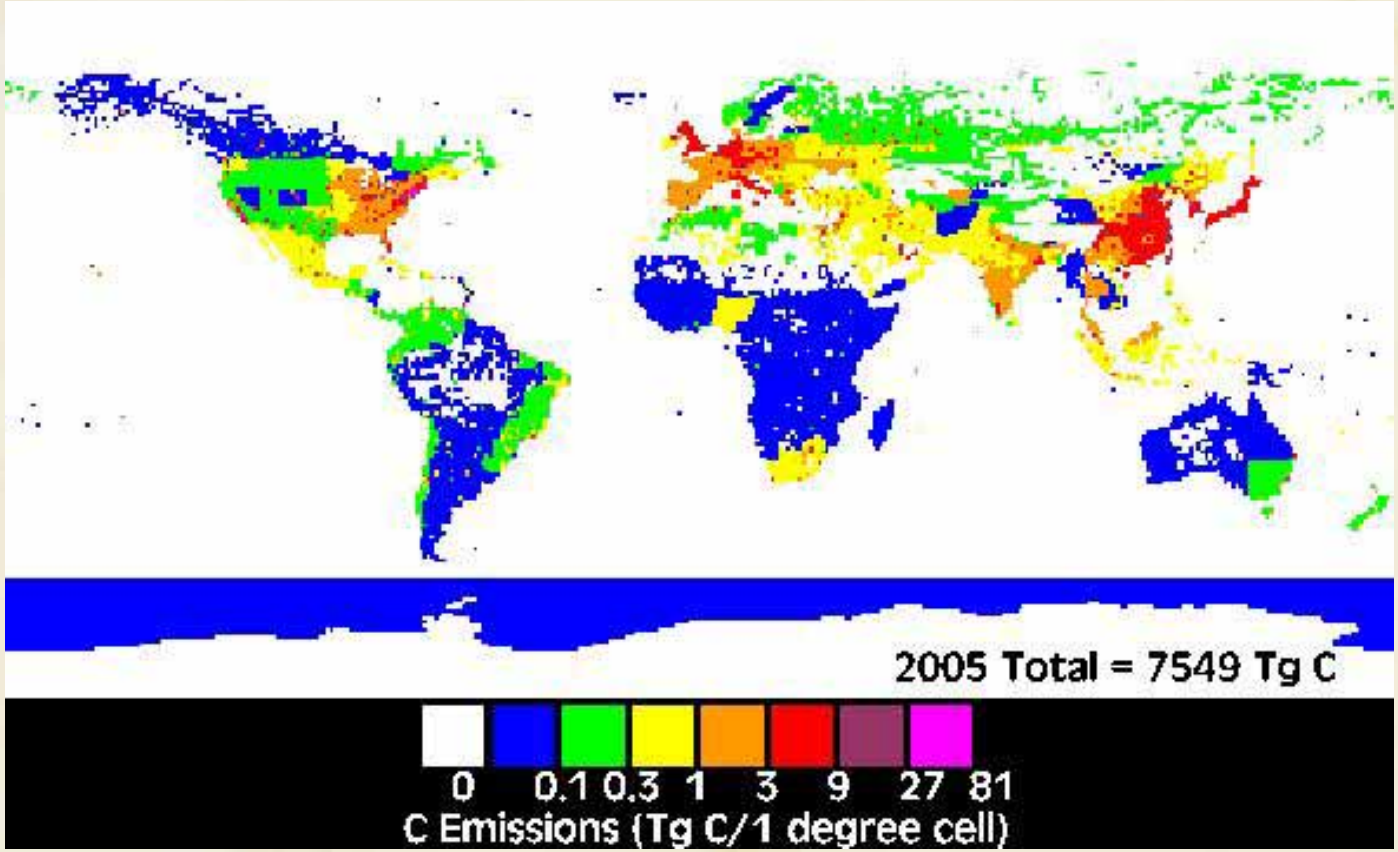


Marland et al., 1985

Marland et al., 1985 using consumption

5º x 5º with population ρ and industrial concentration

Adding more space & time



Andres et al., 1996: moved to 1° x 1° with decadal res time series (now to annual). *Brenkert et al.*, database.

EDGAR in the late 1990s - more sectoral/fuel detail

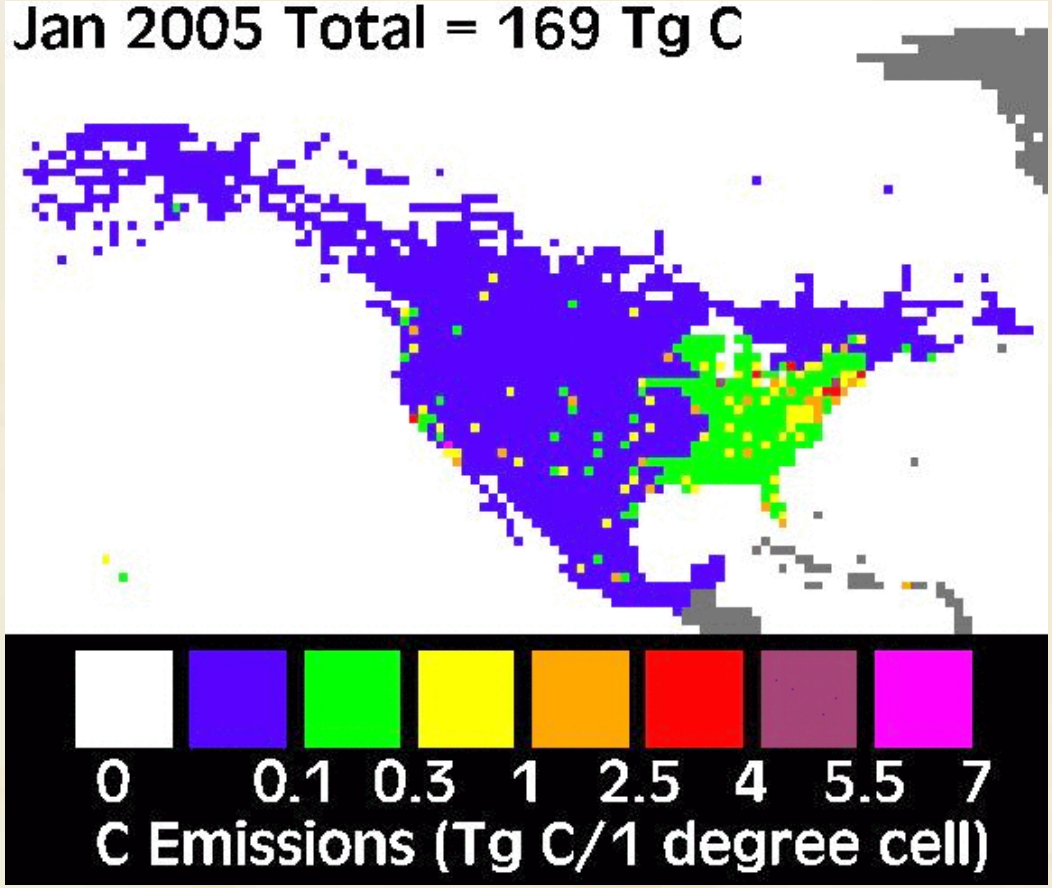
DOE et al. United States estimates

EIA State Energy Data System: ~supply-based. Annual state/fuel/sector CO2 emissions

Gregg & Andres, 2008

Blasing, Gregg, Andres: monthly/state/fuel (based on DOE/EIA data

Andres NA monthly 1x1 (pop density-based)



- Monthly, 1950 – 2005
- 21 countries explicit
- grid cell estimated error: 10 – 100%
- Mass and $\delta^{13}C$

***Andres* in prep, 2009**

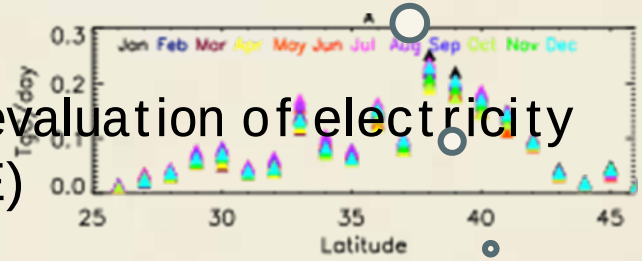
Recent focused studies

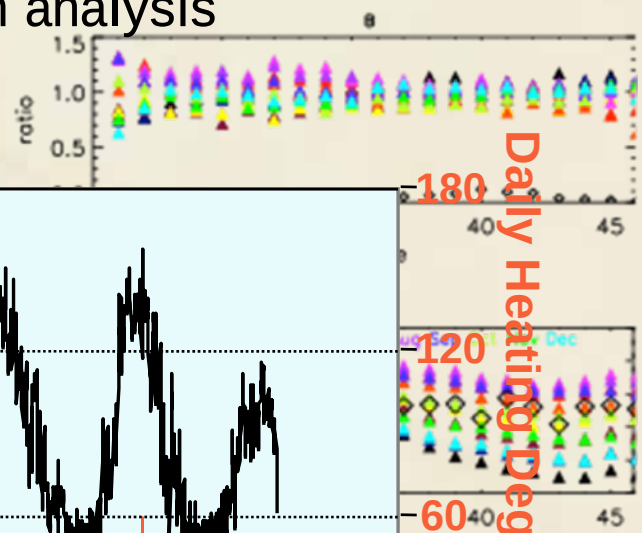
Miller et al. Radiocarbon evaluation: poster today

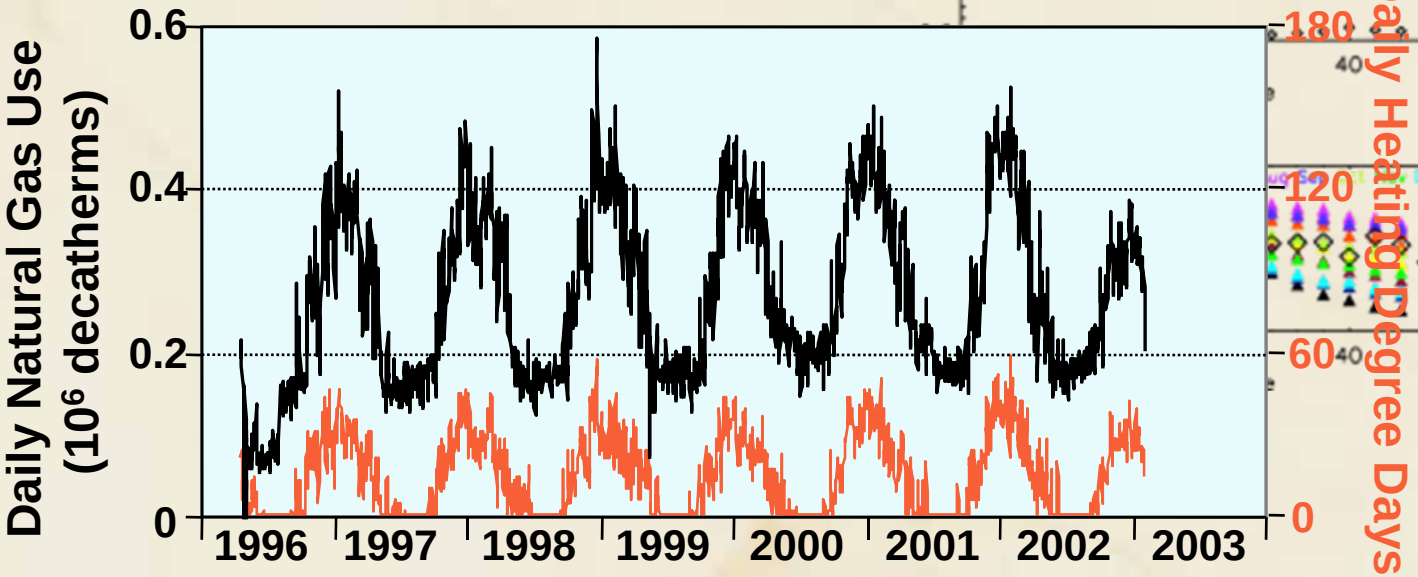
Petron et al., 2008: detailed examination of electricity production (CEMs) dataset.

Ackerman & Sundquist, 2008: evaluation of electricity production dataset (EPA v DOE)

Pataki et al., 2009: single urban analysis







"Vulcan": high-resolution process-based fossil fuel CO_2 inventory project

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- Knauf Insulation, Showalter Trust

CO_2FFEE

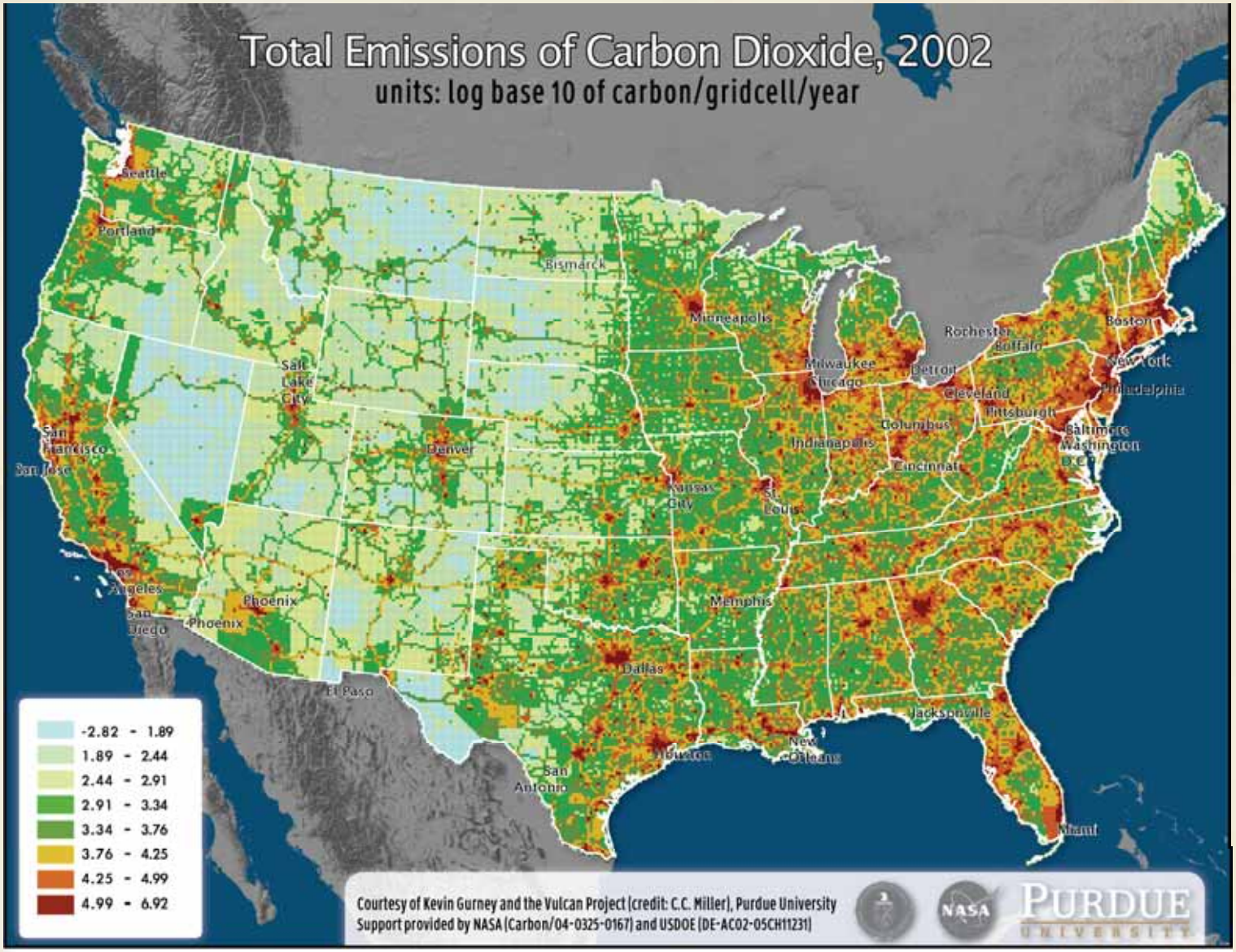
Manipulate existing AQ to generate CO_2

Data Source	National Emissions Inventory				ETS/CEM	NMIM NCD	Aero 2k
Data Type	**Non-road**	**Non-point**	**Point**	**Airport**	**Power Production**	**On road**	**Aircraft**
Pollutant Utilized	Activity/ population	NO_x	CO	CO	CO_2	VMT/ population	CO_2
Incoming Resolution: Space/Time	County; Monthly	County; Annual	Lat/Lon; Annual	Lat/Lon; Annual	Lat/Lon; Hourly	County; Monthly	1^oX 1°; Monthly
Conditioning Data		Census; EIA sector/state/ fuel/month sales	EIA sector/ state/fuel/ month sales			GIS Road Atlas; Mobile 6.2	
Final Resolution: Space/Time	County; Monthly	Census tract; Month	Lat/Lon; Month	Lat/Lon; Annual	Lat/Lon; Hourly	Road segment; Hourly	1^oX 1°; Monthly
Sector	Mobile	Comm. Res. Ind. Electric	Comm. Res. Ind. Electric	Mobile	Electric	Mobile	Mobile

CO_2 Emissions

Results

Version 1.1 now available



www.purdue.edu/eas/carbon/vulcan

Gurney et al., PNAS submitted, 2009

Transport

Over 200,000
YouTube views

Andrysco Gurney, Benes & Corbin, *Comp Graph & App*, 2008 (sim from RAMS)

Evaluation

2002 Vulcan fossil CO_2 (GtC/year) evaluation

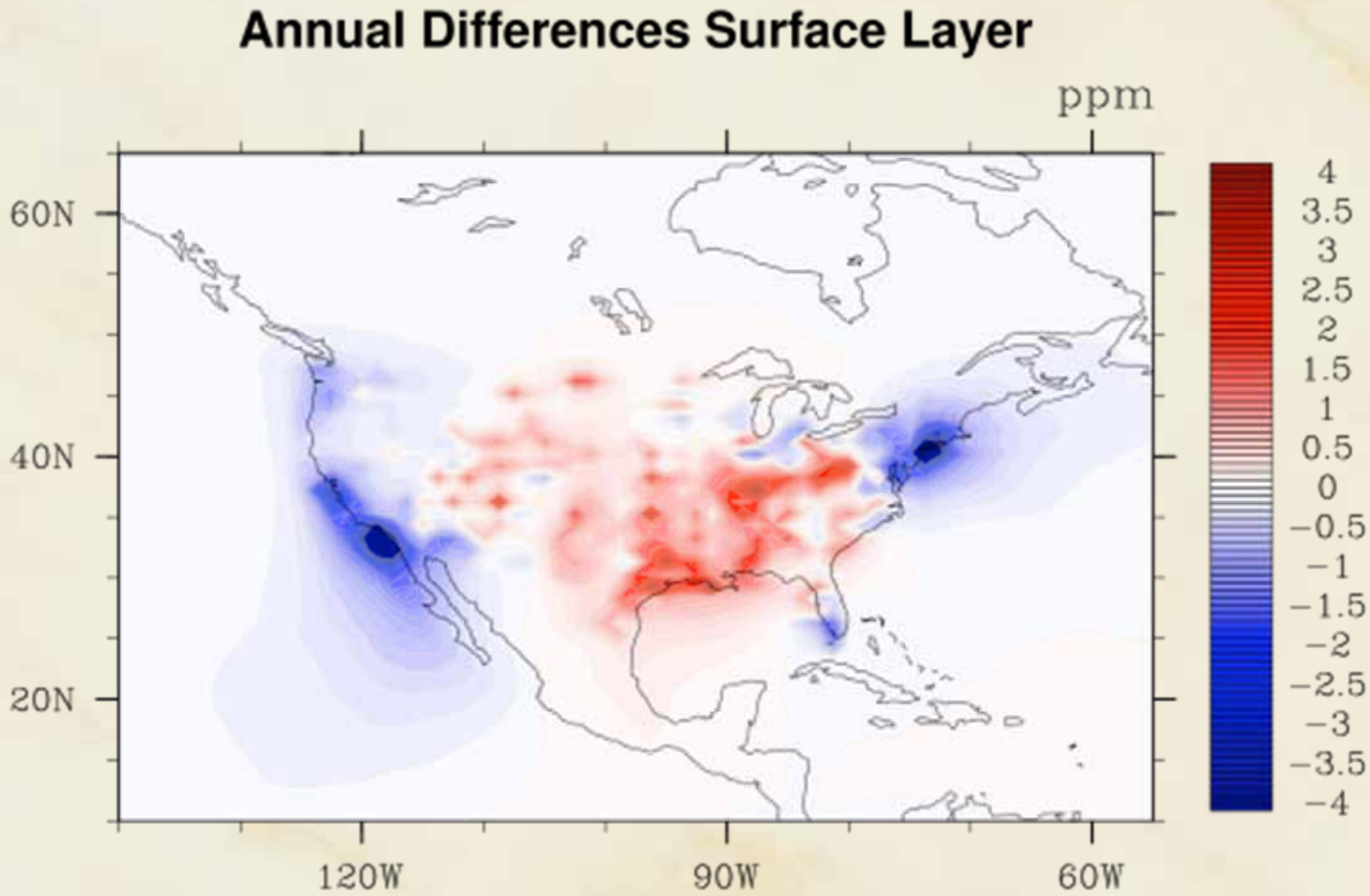
Sector	*DOE/EIA (MtC/year)*	*Vulcan (MtC/year)*	*% diff (Vulcan – EIA)*	*EPA (MtC/yr)*
Commercial	62.4	65.4	4.8%	
Industrial	289.1	282.7	-2.2%	
Residential	100.2	100.5	0.3%	
Mobile	515.1	553.8	7.5%	516.3
onroad		440.2		379.1
nonroad		49.8		72.6
aircraft		64.8		64.6
Electric	616.3	615.9	-0.1%	
Total	1583.1	1618.3 (-2.7% / +11.1%)	2.2%	

[1] DOE/EIA [2007].
[2] This represents the % difference between the DOE/EIA and the Vulcan estimate.

Vulcan uncertainty – *range* of CO EF variation

Gurney et al., PNAS submitted, 2009

Implications

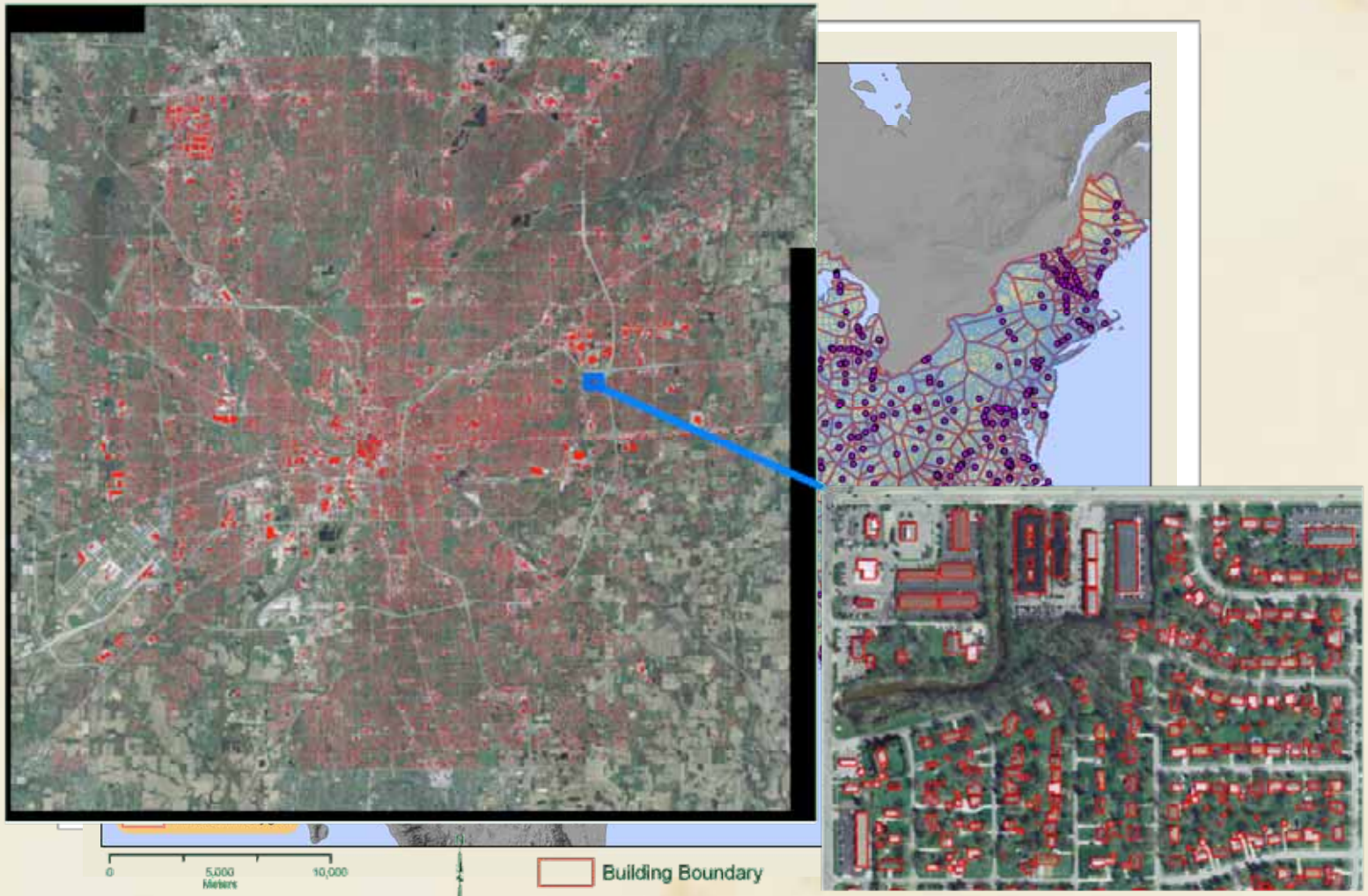


Vulcan – Brenkert 1x1, PCTM sim

Vulcan larger over industry and electric power, lower over coastal population centers

Improving space and time

Improving mobile temporal structure: FOIA request turned up >6000 traffic monitoring stations



Improving res/comm space/time - urban building “skin” model

Conclusions

- DOE/EIA/UN-based estimation at 1 degree (state)/monthly for all NA, multiple years.
- Combustion based estimate (Vulcan) available for U.S. at 10 km/hourly (fuel/comb. tech./sector). Or, at "native" resolution (points, lines, census tract).
  - Canada/Mexico, complete traffic flow (Spring/Summer '09)
  - 1980 to 2008 (6 months behind real)
  - Hestia – urban scale data product with bldg footprints
  - Socio-economic analysis
- Research moving towards urban-scale process models (fossil fuel "weather" instead of climate!)
- "Dual" decision support opportunity!! We are DOING both
- Strong human dimensions linkage (energy, economics, sociology, etc)

What do we need to do?

- Connect supply (production) with demand (combustion) in explicit, process-driven manner.
  - Electricity grid, pipeline system, geosequestration
- Move to as close to real-time as possible (months)
- Isotopic fingerprint associated with fuel and its physical source
- Better uncertainty estimation
- Web 2.0 concept: interactive platform
  - Public, local managers/knowledge feeds directly into “system”
  - Powerful engagement!
  - Trading system? Assessment tool?
- Strategize stable funding avenues

Please see these posters for more fossil fuel data set details and discussion

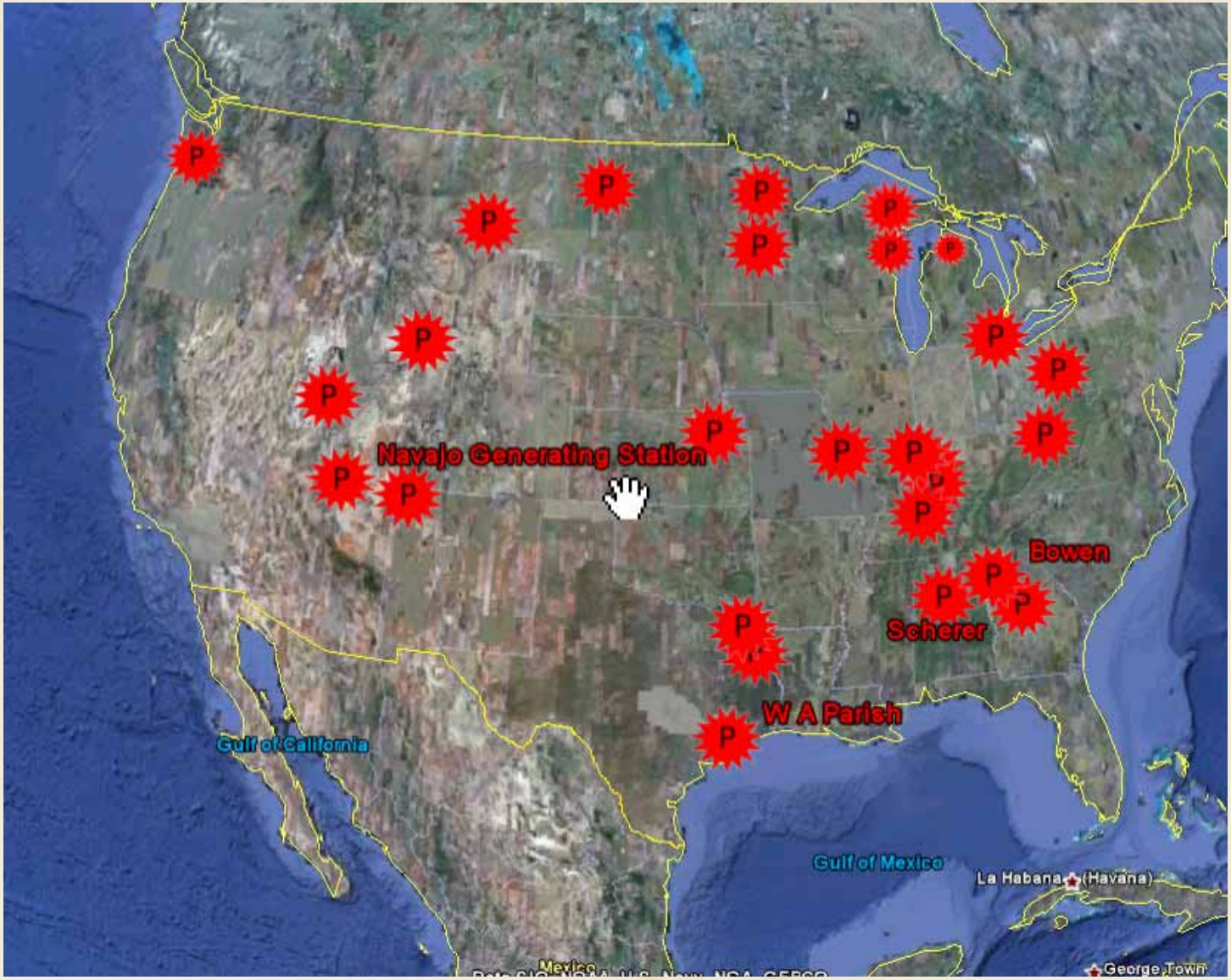
Andres et al., poster #1, A Latitudinal, Longitudinal, and Monthly Description of the Fossil-Fuel-Carbon-Dioxide Emissions for the Countries of the North American Carbon Program

Gurney et al., poster #11, The Vulcan Project: Methods, Results, and Evaluation

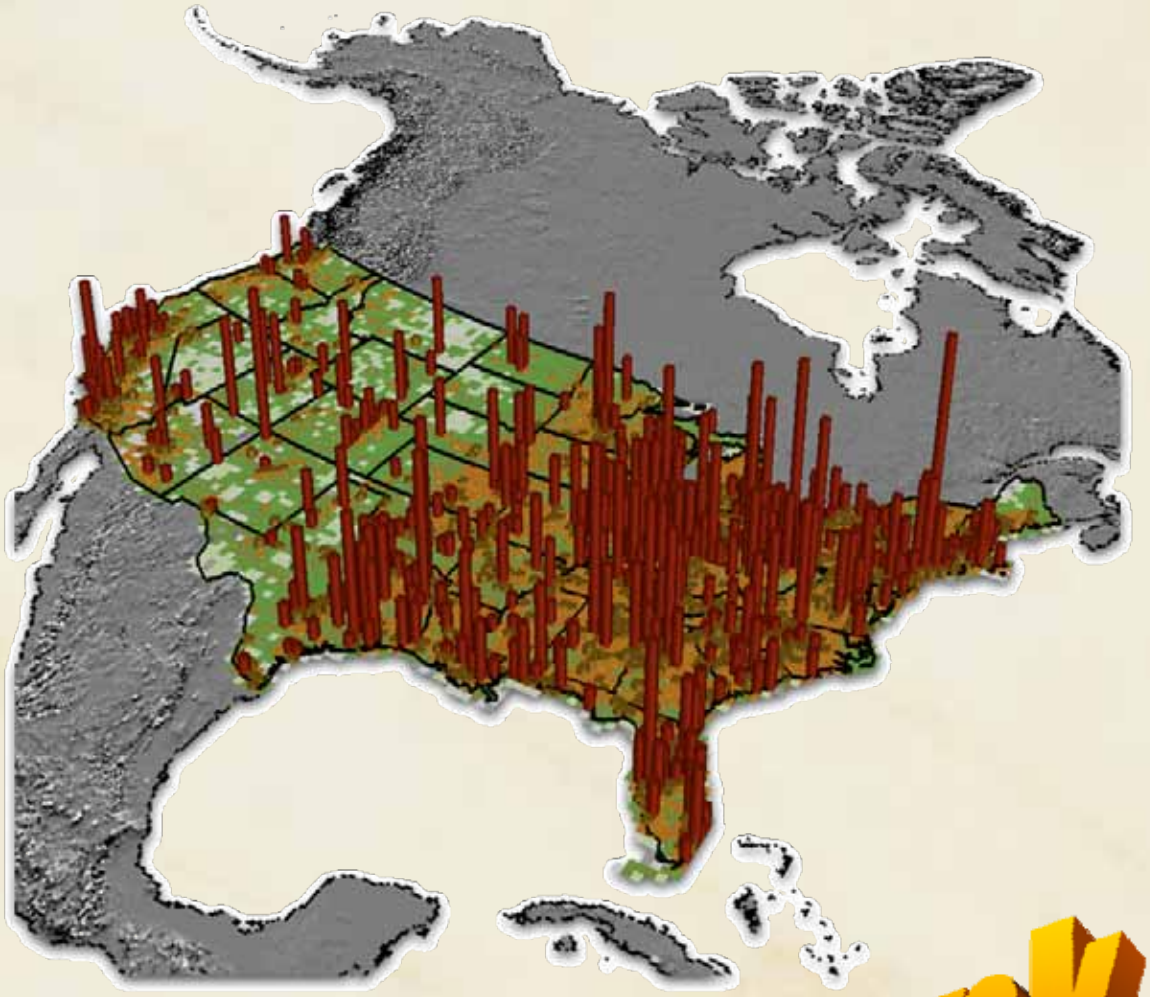
Miller et al., poster #58, Using radiocarbon measurements to evaluate fossil fuel emission inventories

All of these posters will be available on Tuesday @ 4 PM

Google Earth



Release: Thursday February 19, 2009
www.purdue.edu/eas/carbon/vulcan/GEarth/



Thank You!

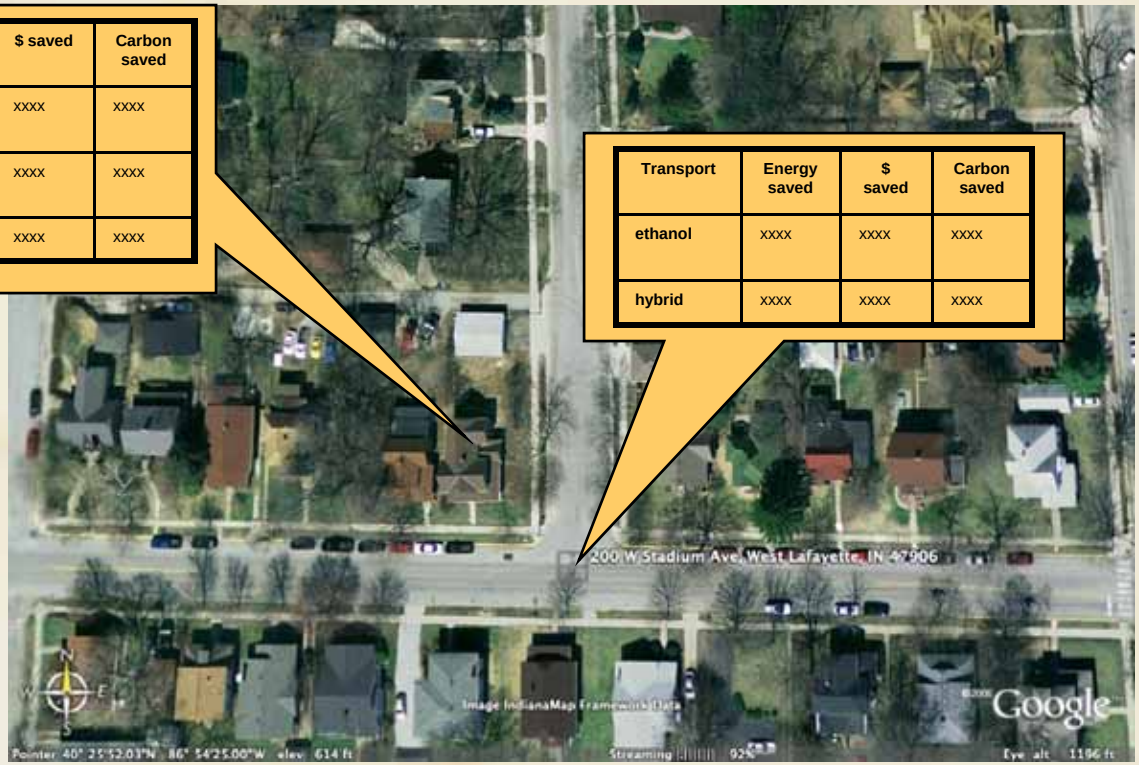
Public empowerment

Offers an *unprecented, visceral* connection to "solution technology"

Links consumers and producers within a digital world where a consumer has control over options

Insulation	Energy saved	$ saved	Carbon saved
R13 to R15	xxxx	xxxx	xxxx
R15 to R18	xxxx	xxxx	xxxx
windows	xxxx	xxxx	xxxx

Transport	Energy saved	$ saved	Carbon saved
ethanol	xxxx	xxxx	xxxx
hybrid	xxxx	xxxx	xxxx



Climate change in
The living room
Leveraged off of
now-familiar platform

Some attributes

- Methodological consistency
- 2-way data structure
- Grassroots == world
- National goals to local action
- Efficiency
- Urban comparison
- Everybody trades
- Assessment, verification
- Visualize solutions/connections

Scientific credibility, ensure value

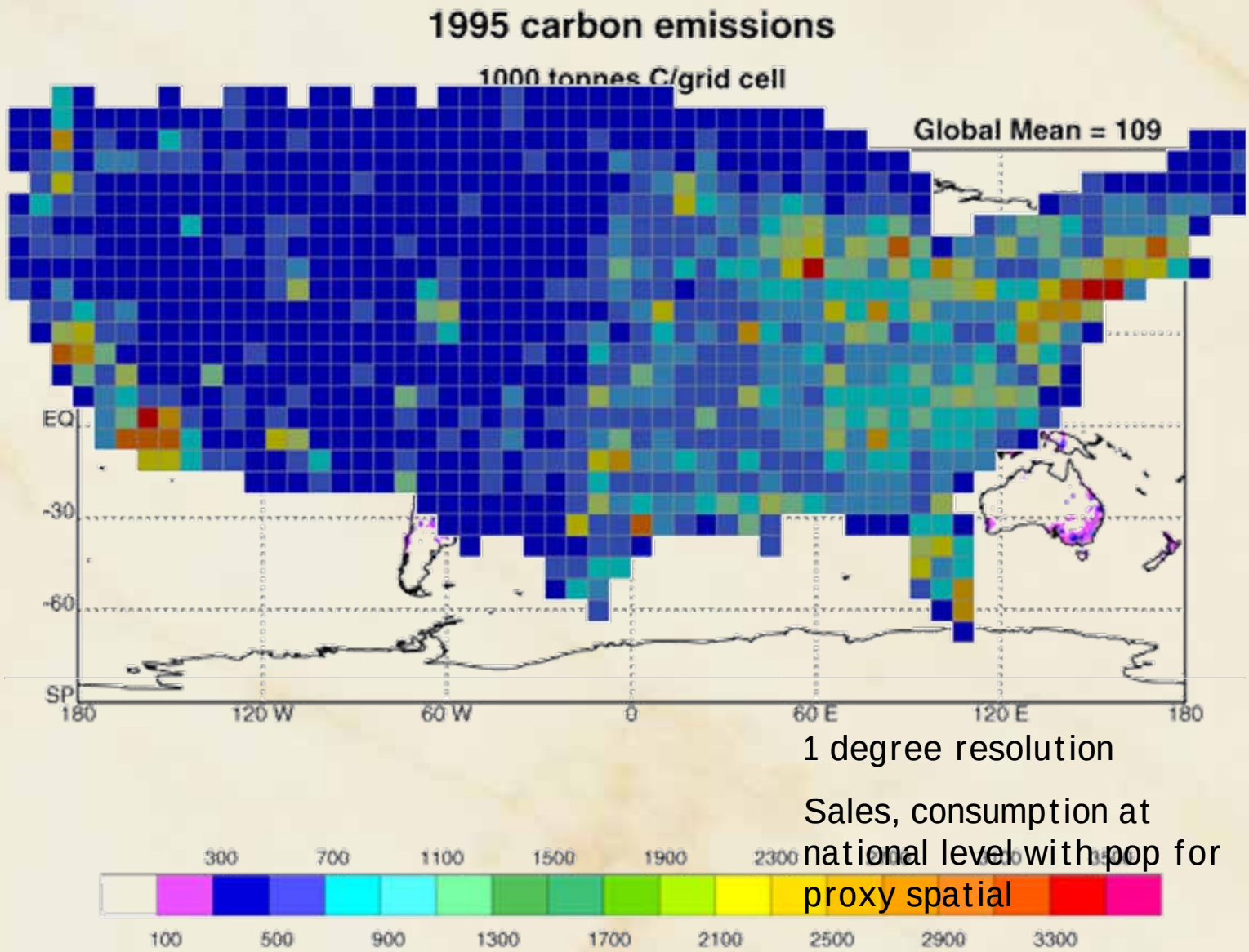
Downscale?.....TRANSCEND SCALE

Data implications

Higher resolution (temporal/spatial/mass and del 13 C) will allow better elucidation of important mechanisms in the global/regional carbon cycle

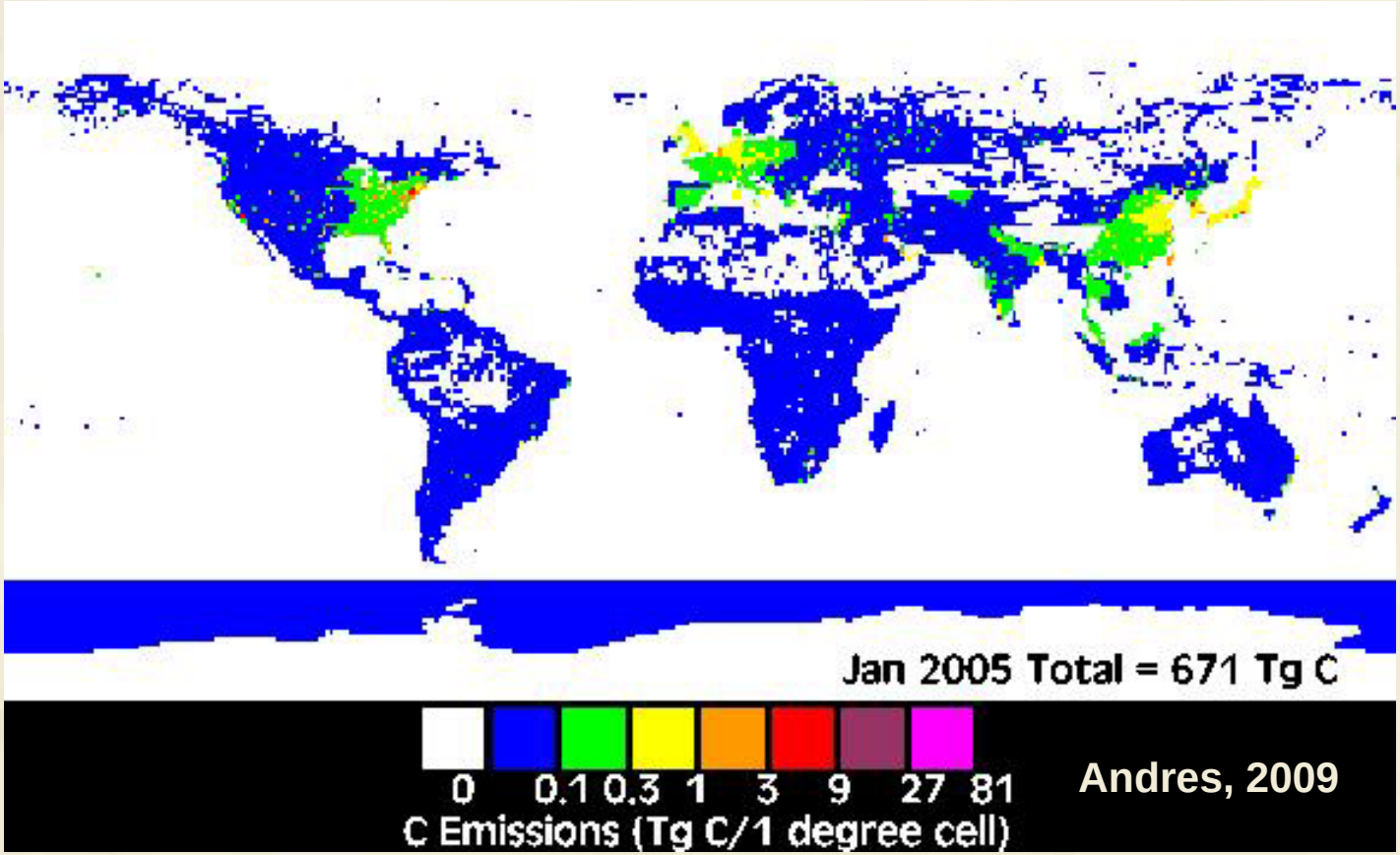
Reduction of errors in fossil fuel CO_2 allow better estimation of other C cycle fluxes

What have we been using?



1 degree resolution

Sales, consumption at national level with pop for proxy spatial



As spatial resolution can be increased, so can temporal resolution. This rendition is shown in the same format as the last slide, but now in a monthly time slice instead of an annual time slice. We do not see as much detail in this rendition because the values portrayed are approximately 1/12 of the last slide and the scale has remained unchanged.

Methods: key details

Emissions data sources:

- National emissions inventory (**NEI**) for CO/NOx
  - Strengths (process, points, fuel)
  - weaknesses (area estimated, limited QA/QC)
- **CEMS** for power production: CO_2 direct, hourly

Spatial:

- Area (resid/comm) at county/annual/fuel/process, downscale w/ US census
- Mobile is month/county/road/vehicle/fuel, downscale w/ GIS road atlas

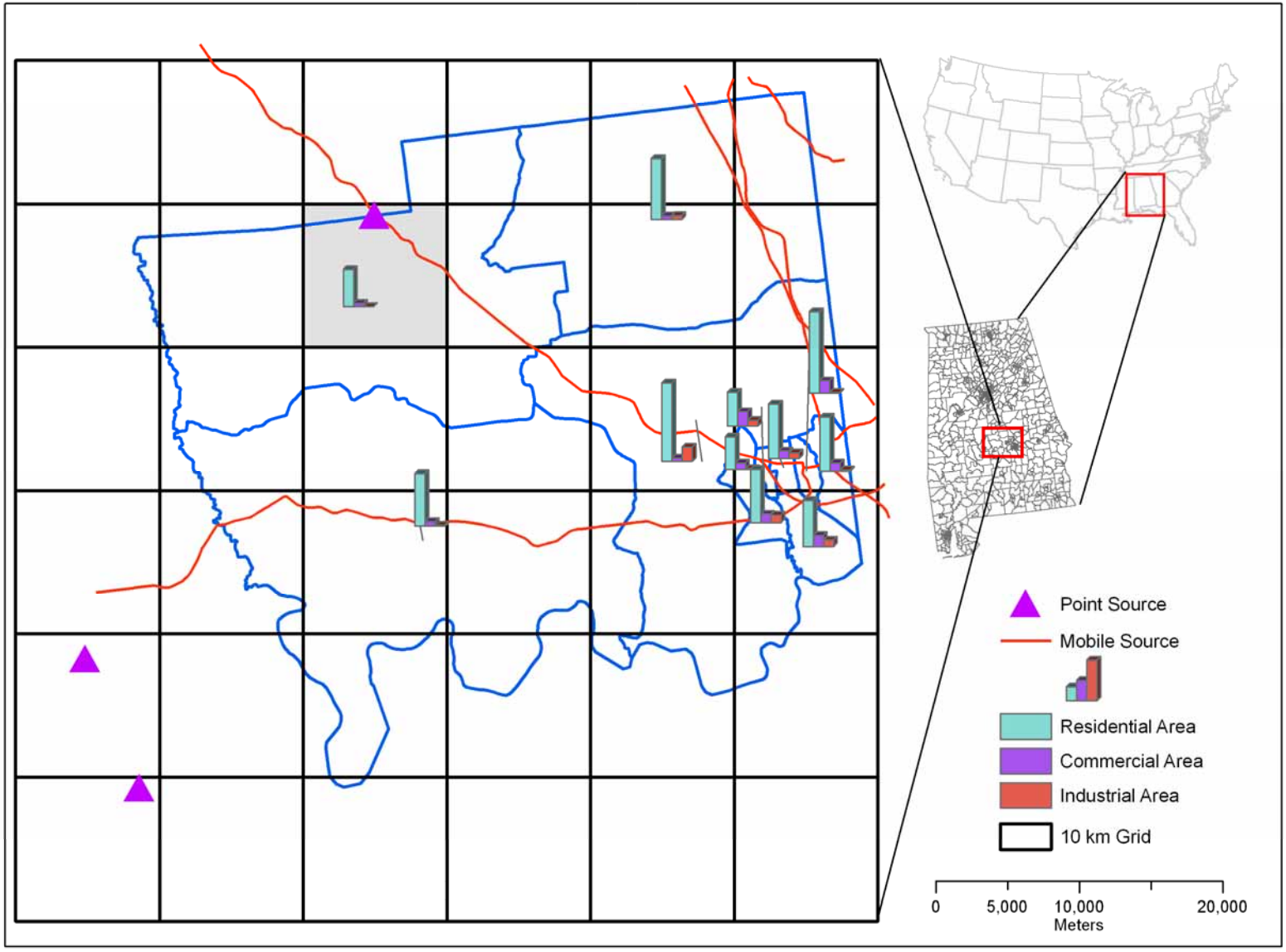
Temporal:

- CEMS - provided
- mobile downscale by WIM studies

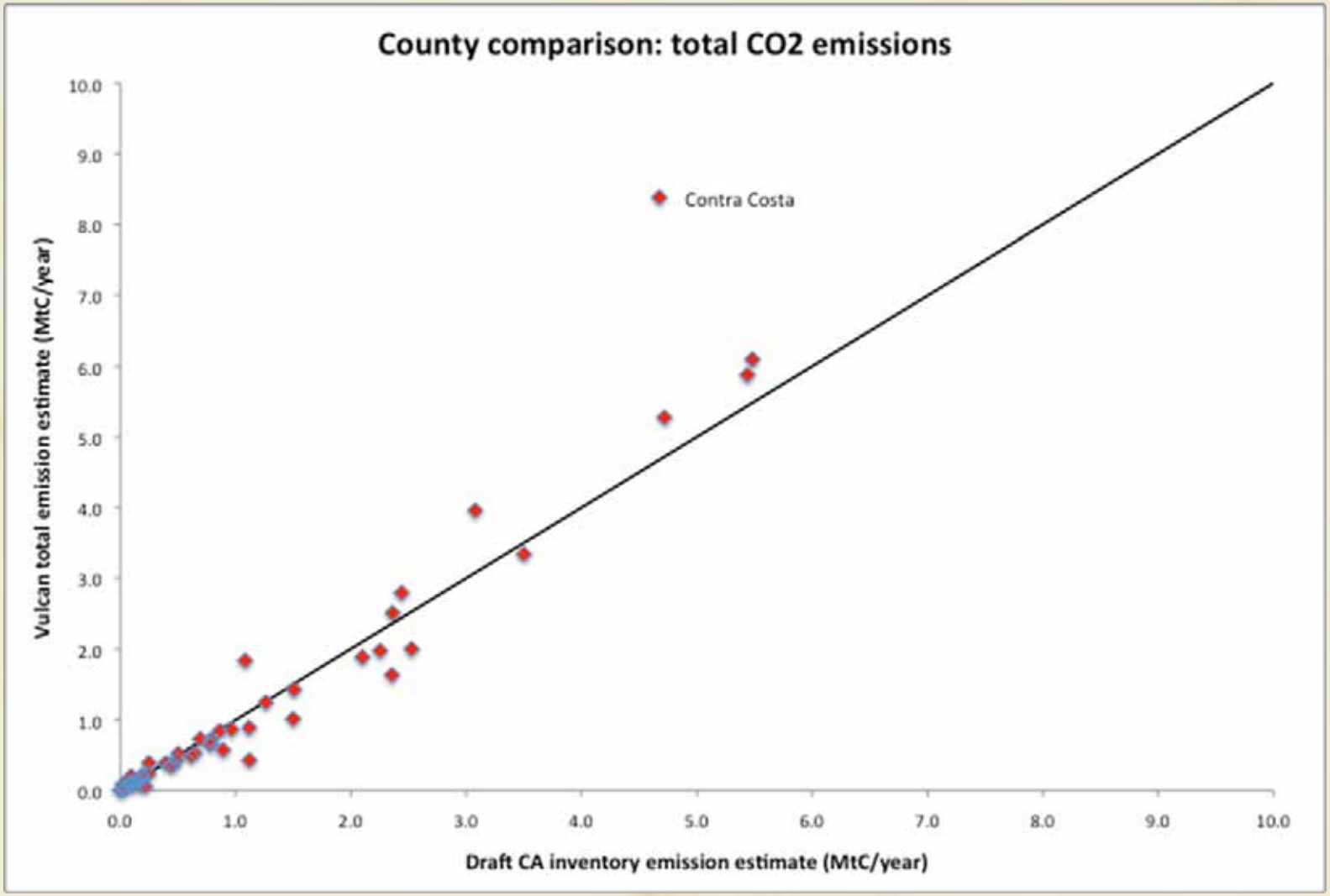
QA/QC:

- big offenders corrected, but more to do.

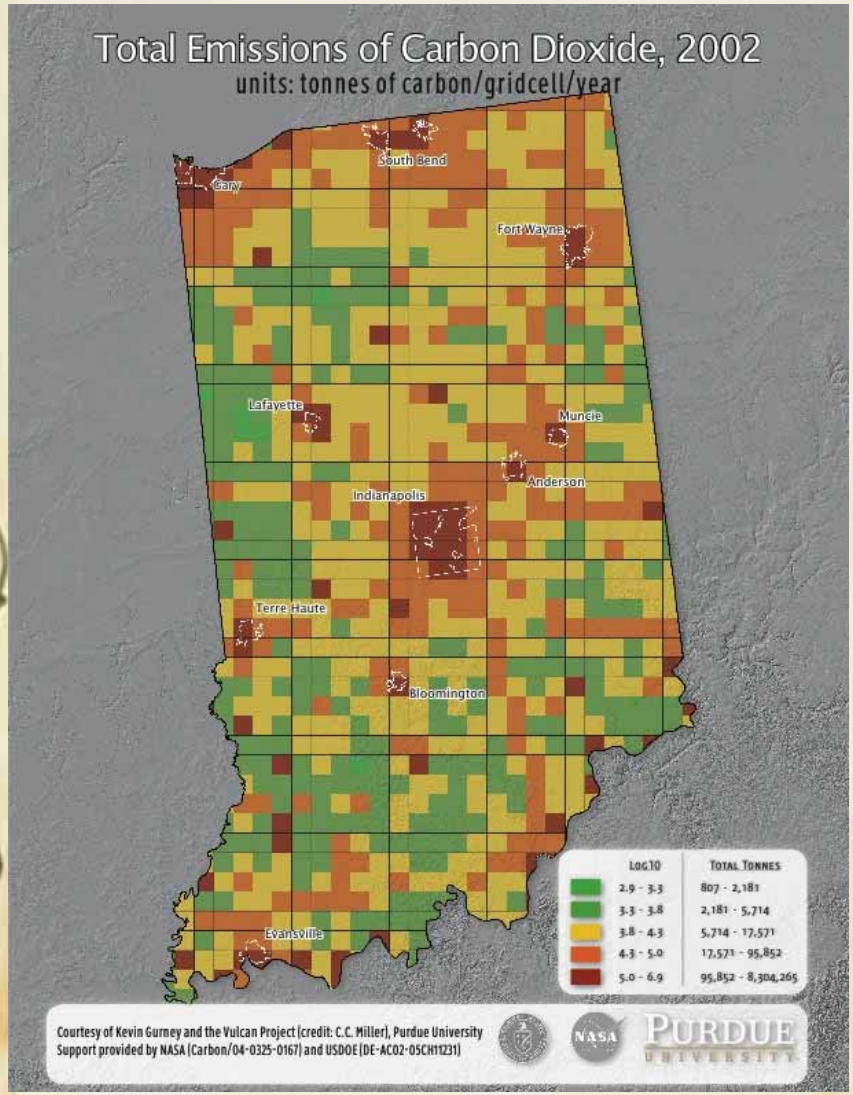
Vulcan Methods

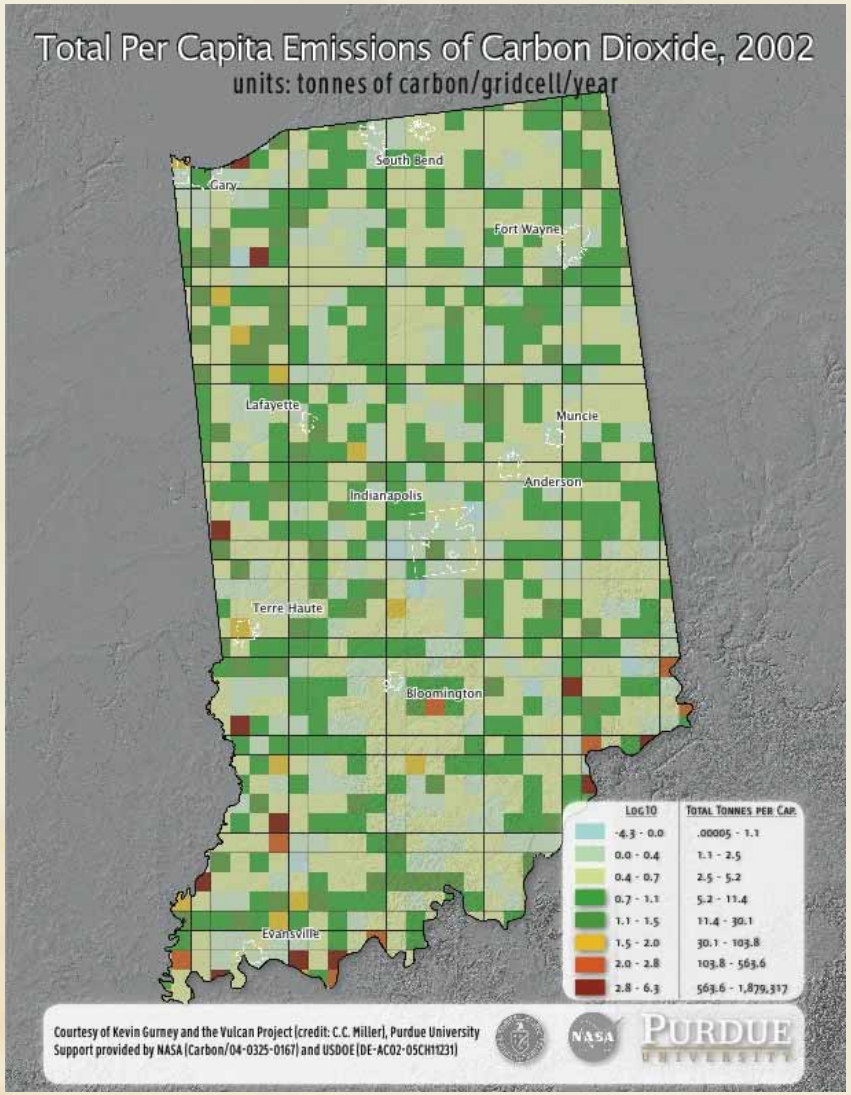


Evaluation: CA data (preliminary)



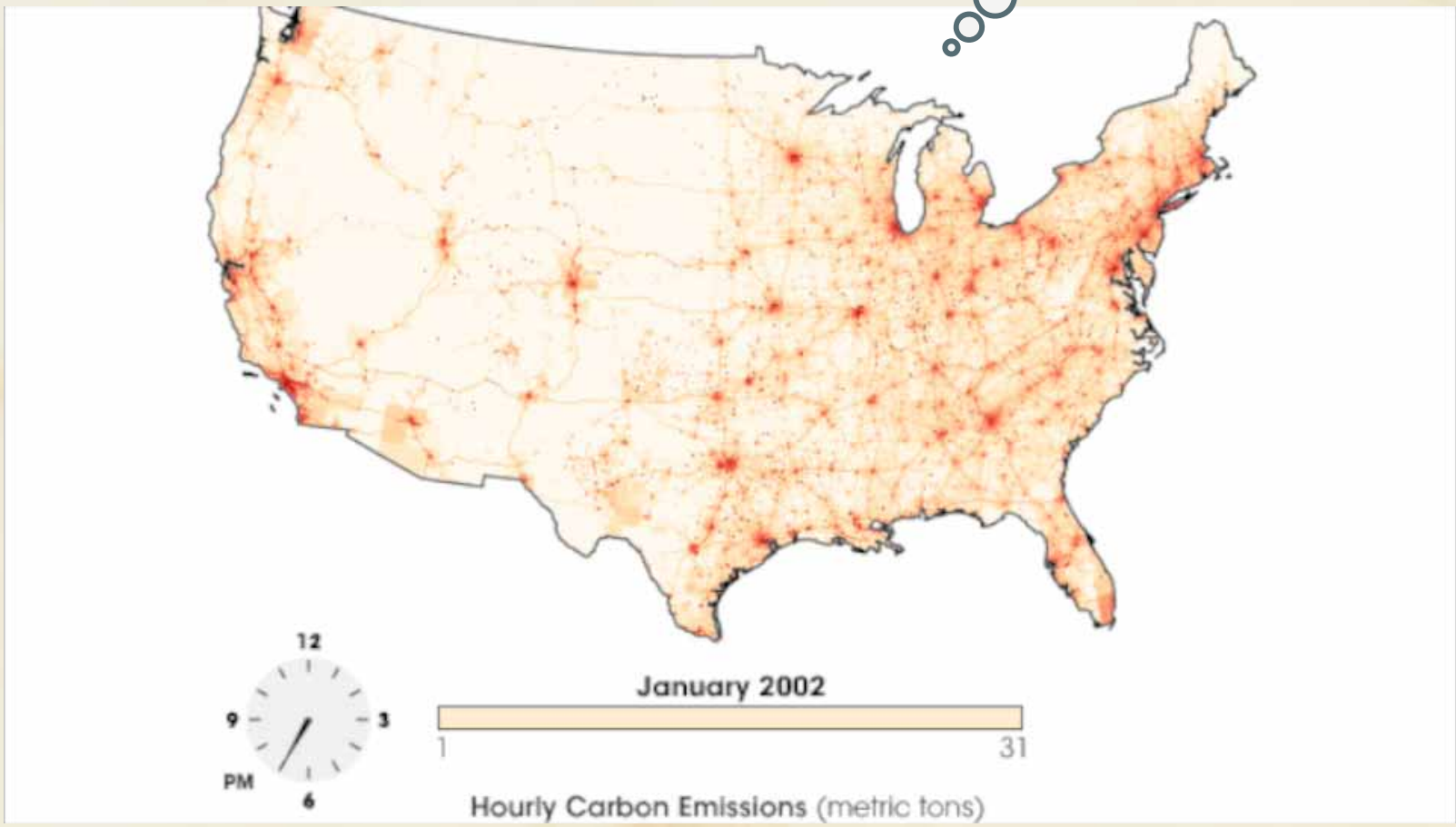
Extension/Application





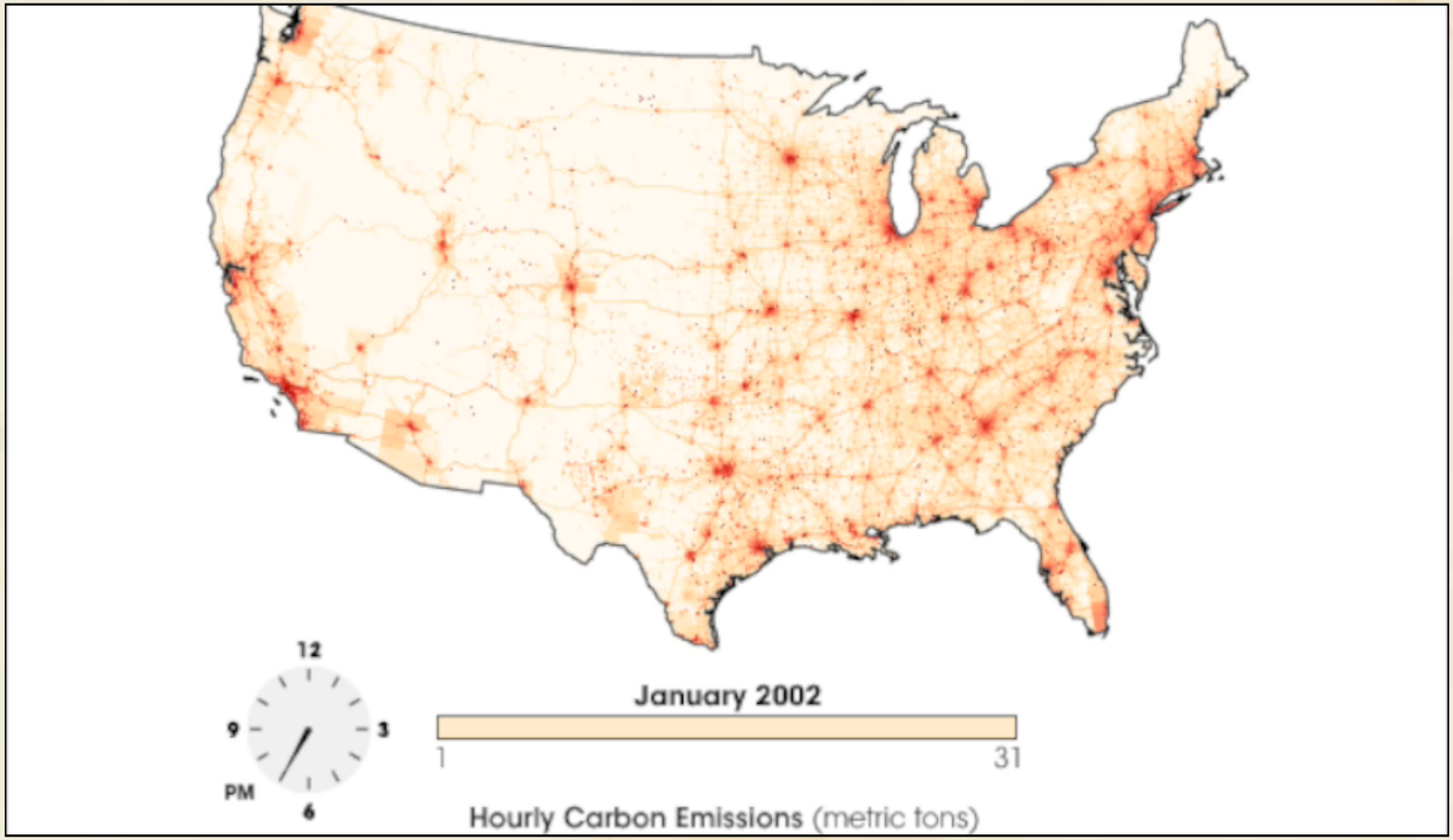
Dynamic Emissions

Power production and transport are only time dependent sources



Courtesy of NASA

Concentration Comparison

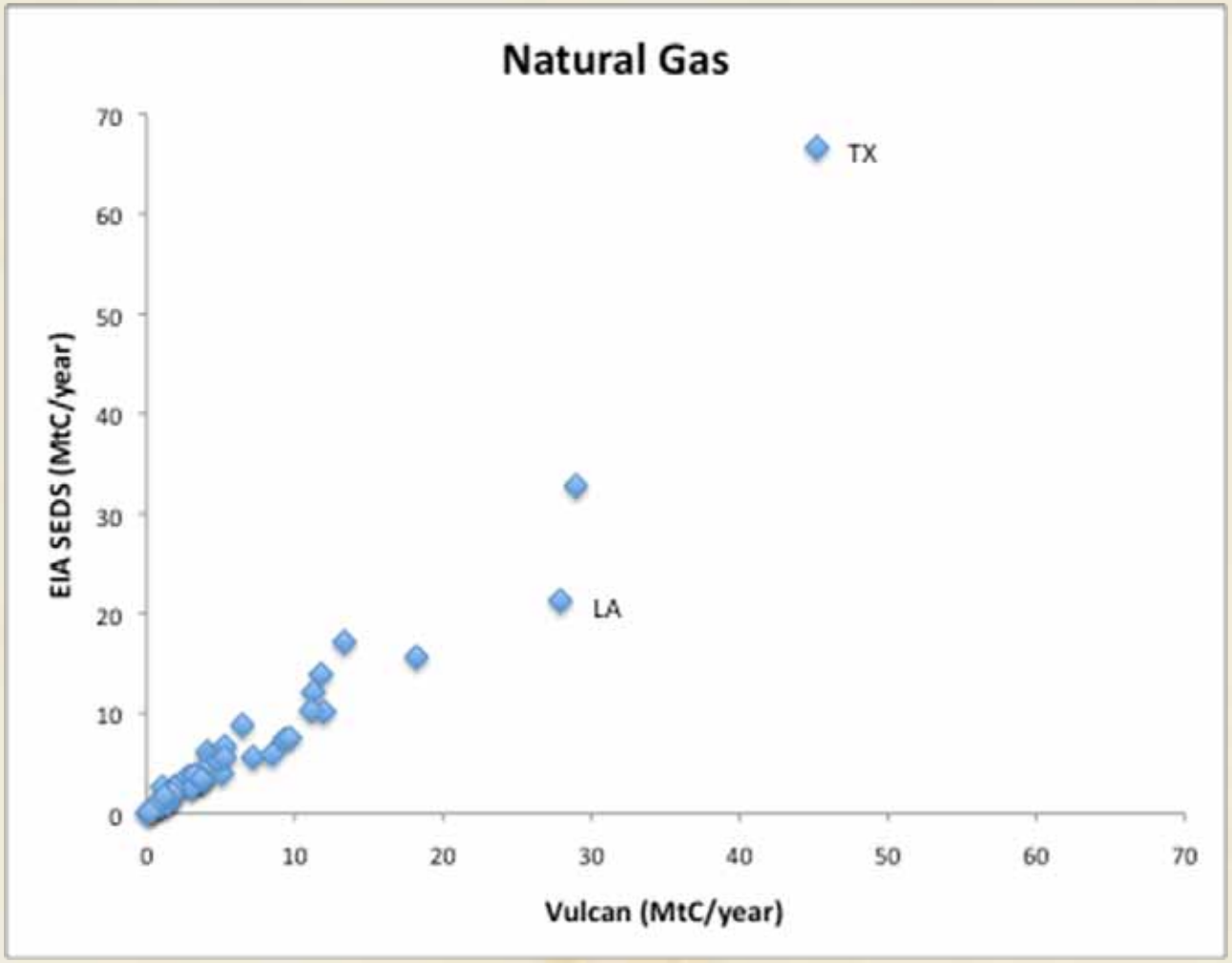


Courtesy Kathy Corbin, CSU

Hestia

www.purdue.edu/climate/hestia

Evaluation: EIA SEDS



VULCAN LINKS

- VULCAN Google Earth Application: http://www.purdue.edu/eas/carbon/vulcan/GEarth/index.html
- YouTube Video (4/2008): http://www.youtube.com/watch?v=eJpj8UUMTaI&feature=email