Evaluating NEI Trends from 2005 to 2011 by Satellite and Ground NO2 Observations: Implications for the Mobile Source Inventory

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Background

- National Emission Inventory (NEI)
  - Compiled by EPA every three years
  - 2011 most recent, 2014 in development
  - Criteria and hazardous air pollutants
  - Emissions sectors: mobile, non-road, EGUs, point, area, natural sources, etc.
- Used in NAAQS attainment, SIP planning, transport analyses, or other regional air quality planning and modeling
- Are NEI numbers reasonable? How accurate do they capture trends and reflect temporal changes?

Presentation Outline

- Challenges and Approach
- Data Sources
  - AQS
  - OMI
  - NEI
- Comparisons: observation versus NEI
- Emission Sectors
- Mobile Source Inventory
  - Examples
  - Current Status
- Conclusions

Challenges

- Data Coverage and Resolutions
  - Temporal
  - Spatial
- Where and when to focus comparison on?
  - Episodic focus
  - Geographical focus
- Direct Comparison?
  - Does NEI NOx mean the same as observed NOx?

Approach

- Macro-scale comparison
  - Annual trend on CONUS scale
- 2005 data used as a basis for comparison
- Focus on NOx
- Percent differences:

$$\% = \frac{\text{data of target year} - \text{2005 data}}{\text{2005 data}} * 100$$

- Data are plotted by monitoring station or county (on x axis) and grouped by state
- Two adjacent vertical lines demarcate data boundary for the state labeled on the right

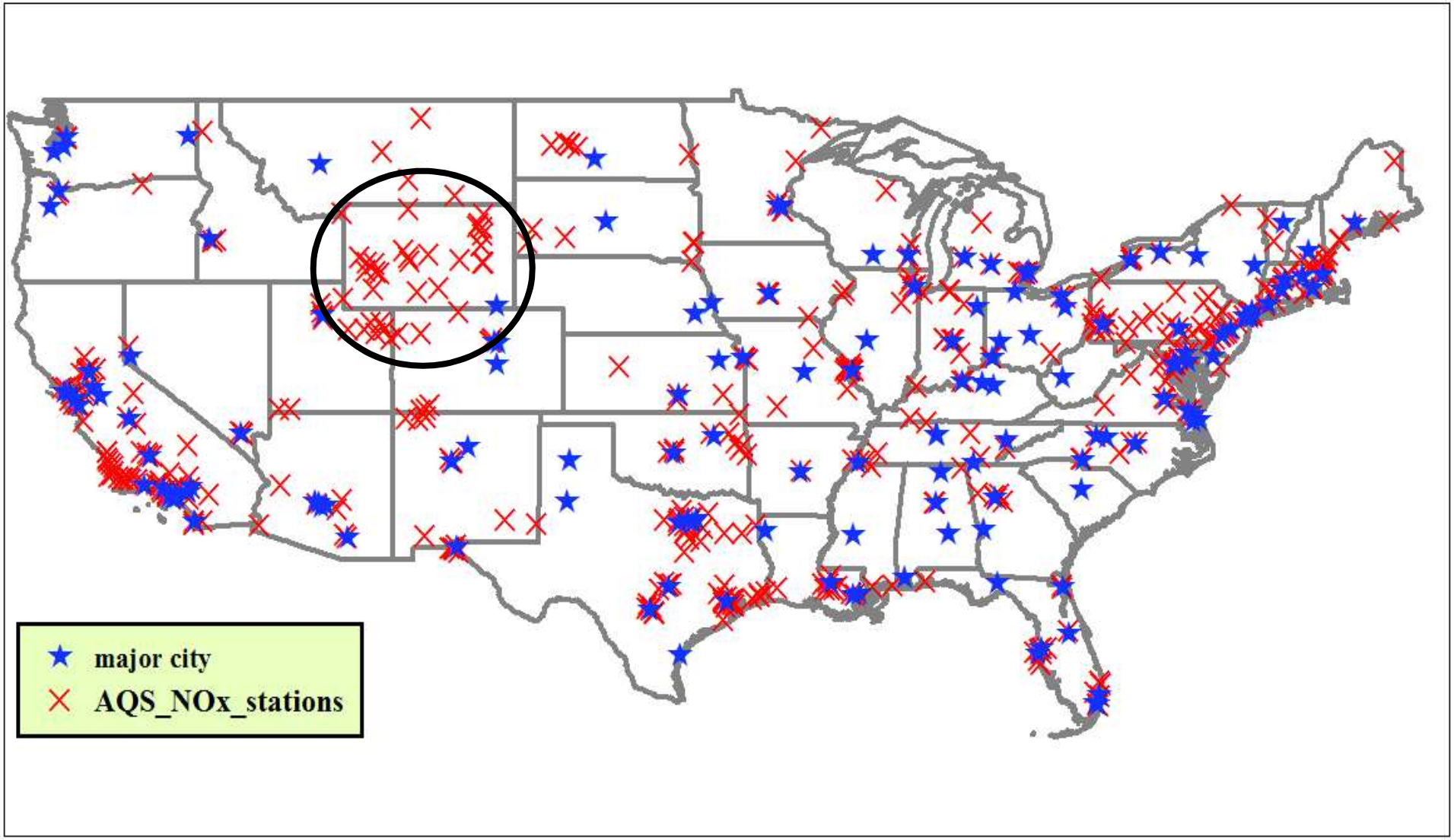
Big picture or trend comparison

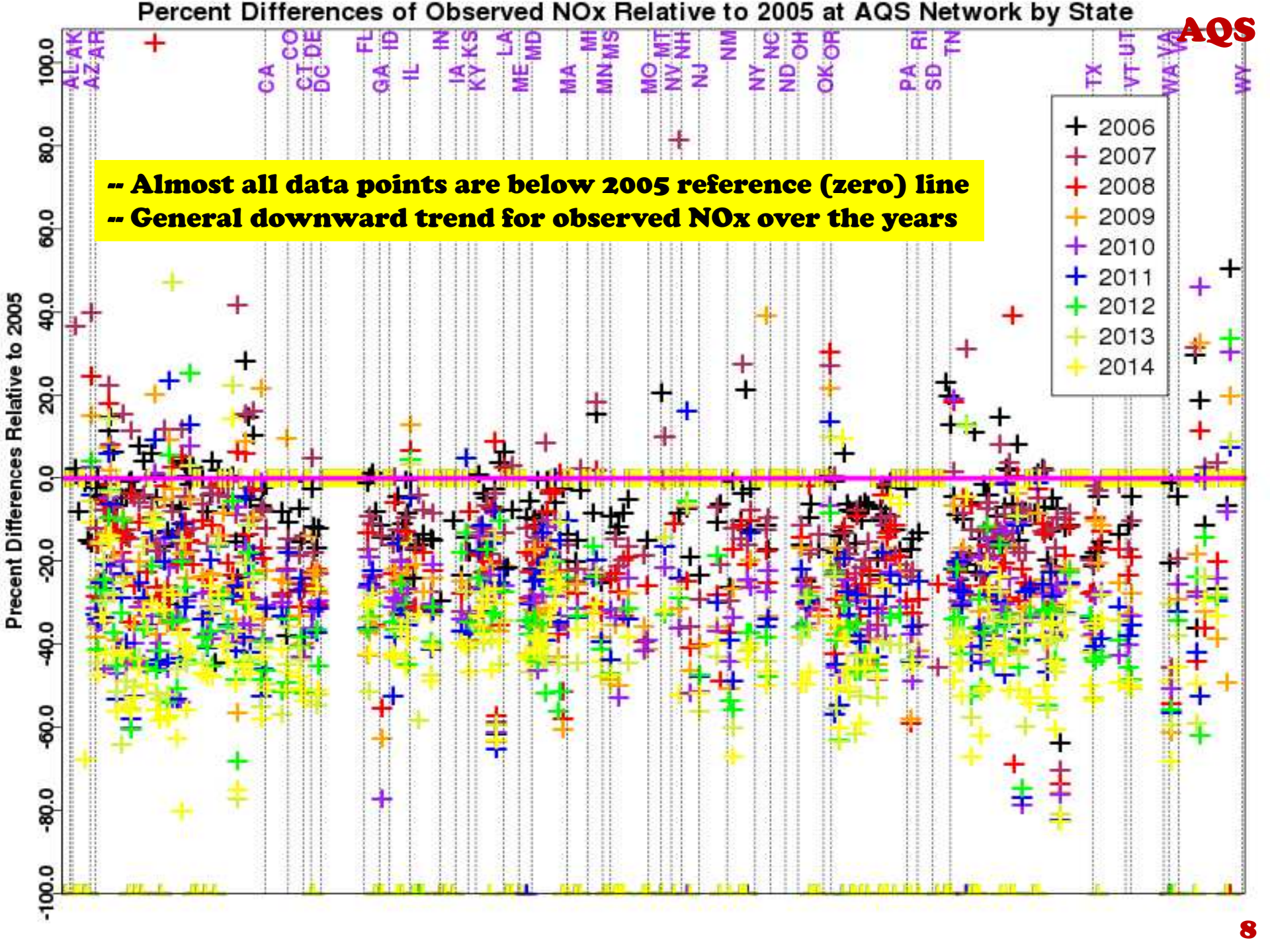
Data Sources

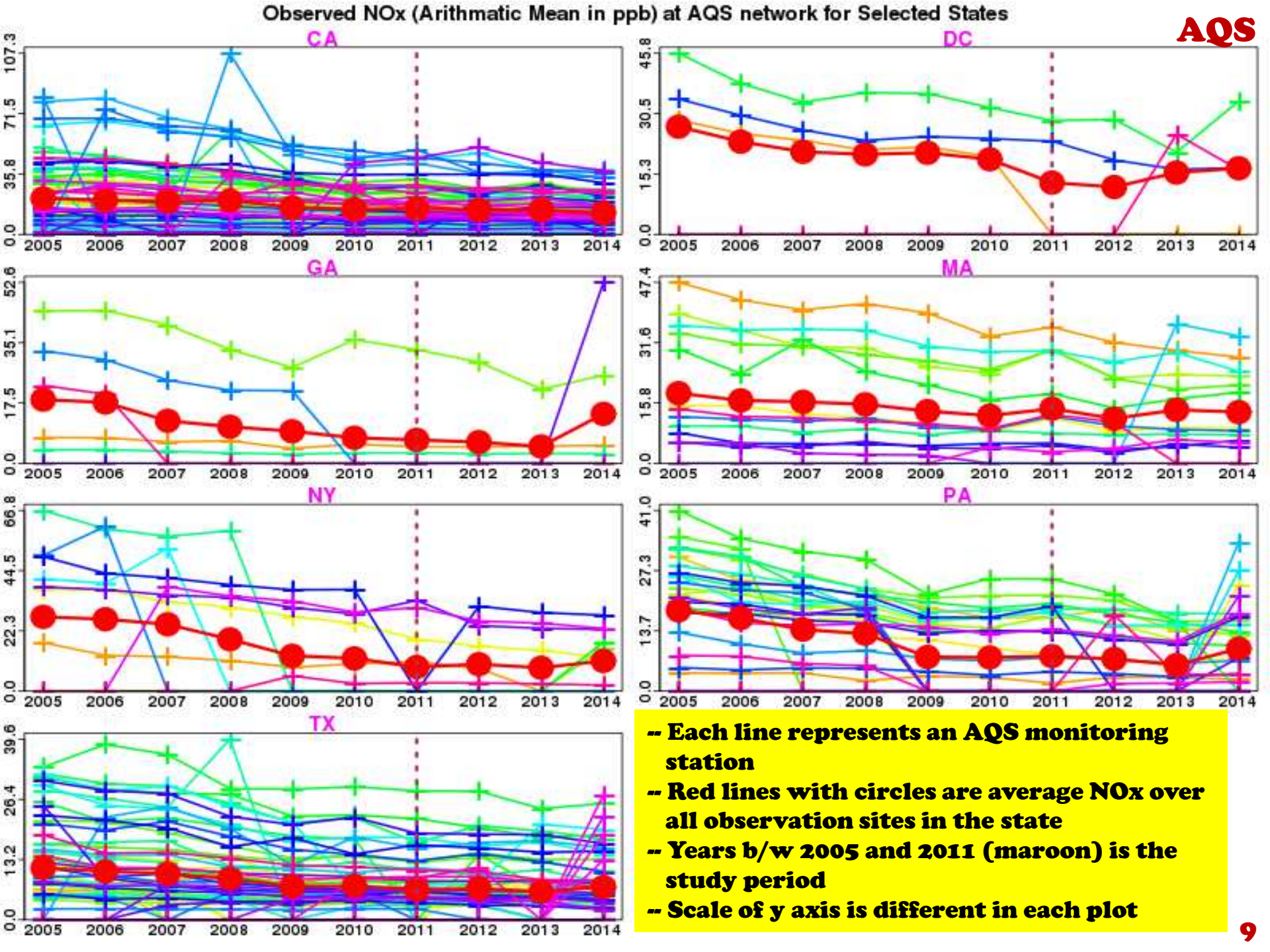
- **Air Quality System (AQS) NOx**
  - 1 hour observed values, arithmetic means in ppb
  - 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 (up to 06/20/2015)
- **Ozone Monitoring Instrument (OMI) NO2**
  - Standard product (version 2.1, collection 3)
  - Average tropospheric vertical column observations by month for 2005 and 2011
- **National Emission Inventory (NEI) NOx**
  - Total NOx in tons/year by county from all emission sectors
  - 2005, 2008, 2011

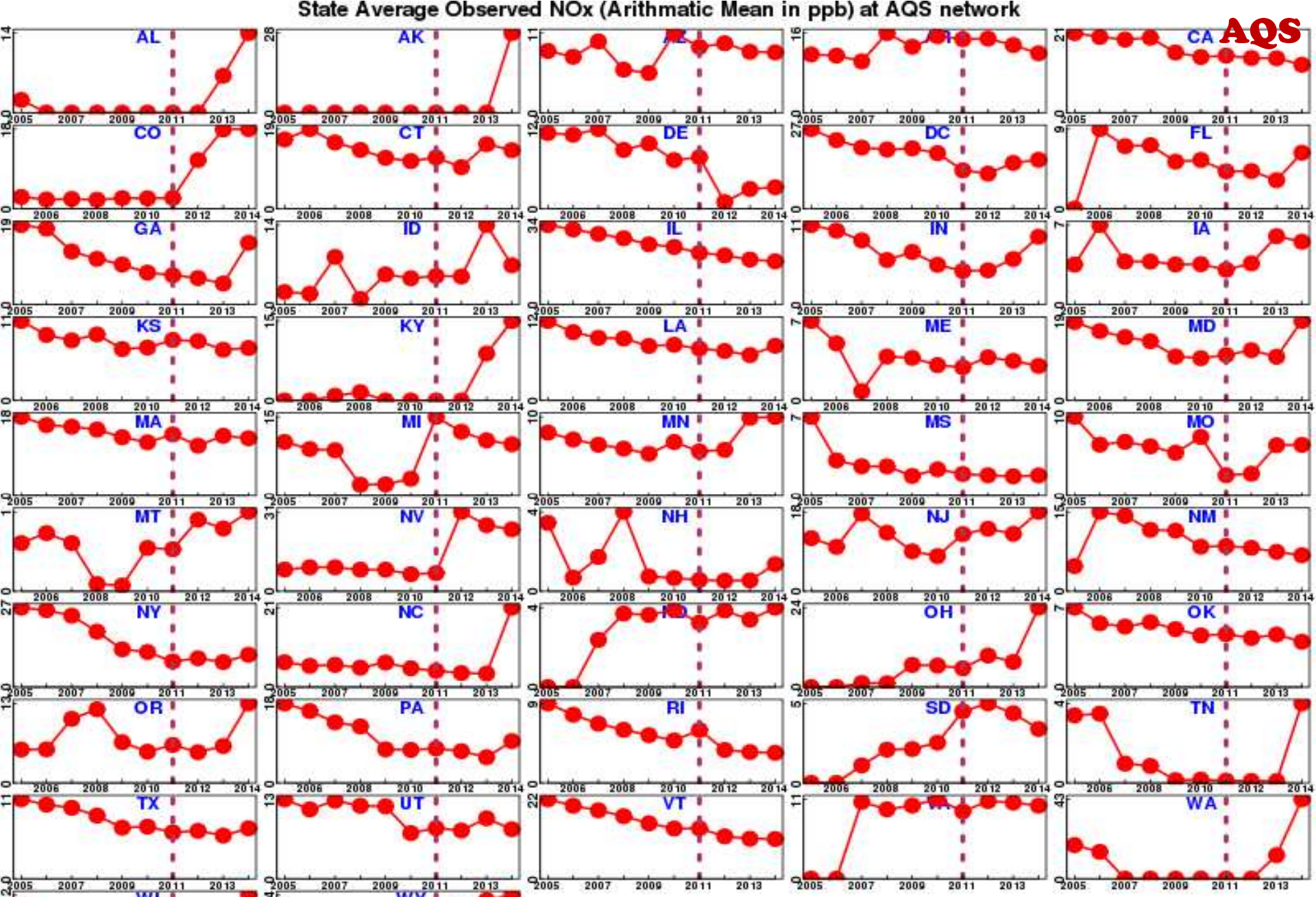
Air Quality System (AQS) Network

NOx Stations

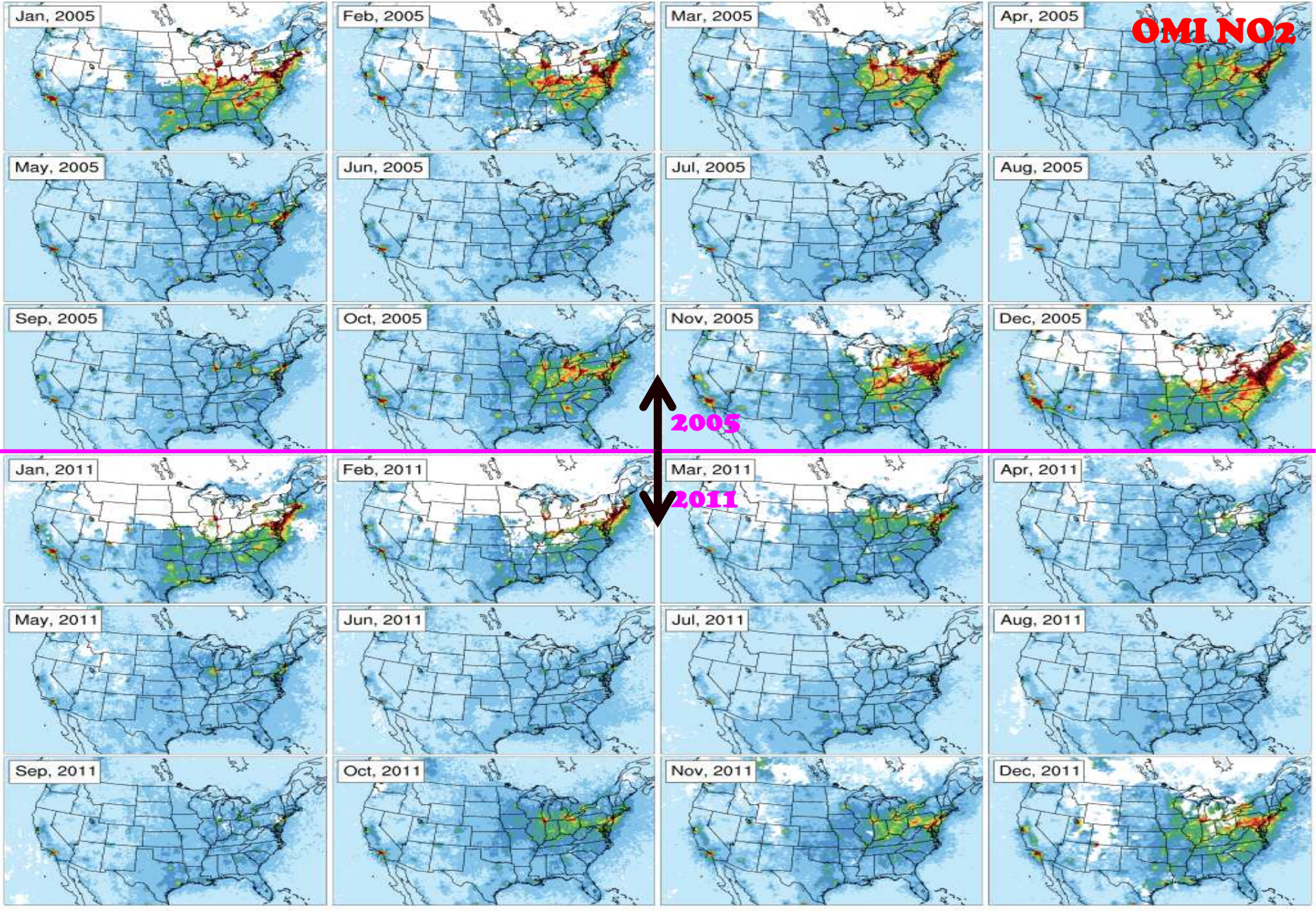



Percent Differences of Observed NOx Relative to 2005 at AQS Network by State
AQS
Precent Differences Relative to 2005
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
AL AK AZ AR CA CO CT DE DC FL GA ID IL IN IA KS KY LA ME MD MA MI MN MS MO MT NV NH NJ NM NY NC ND OH OK OR PA RI SD TN TX VT UT WA VA WV
2006
2007
2008
2009
2010
2011
2012
2013
2014
-- Almost all data points are below 2005 reference (zero) line
-- General downward trend for observed NOx over the years


Observed NOx (Arithmatic Mean in ppb) at AQS network for Selected States
AQS
CA
DC
GA
MA
NY
PA
TX
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
-- Each line represents an AQS monitoring station
-- Red lines with circles are average NOx over all observation sites in the state
-- Years b/w 2005 and 2011 (maroon) is the study period
-- Scale of y axis is different in each plot

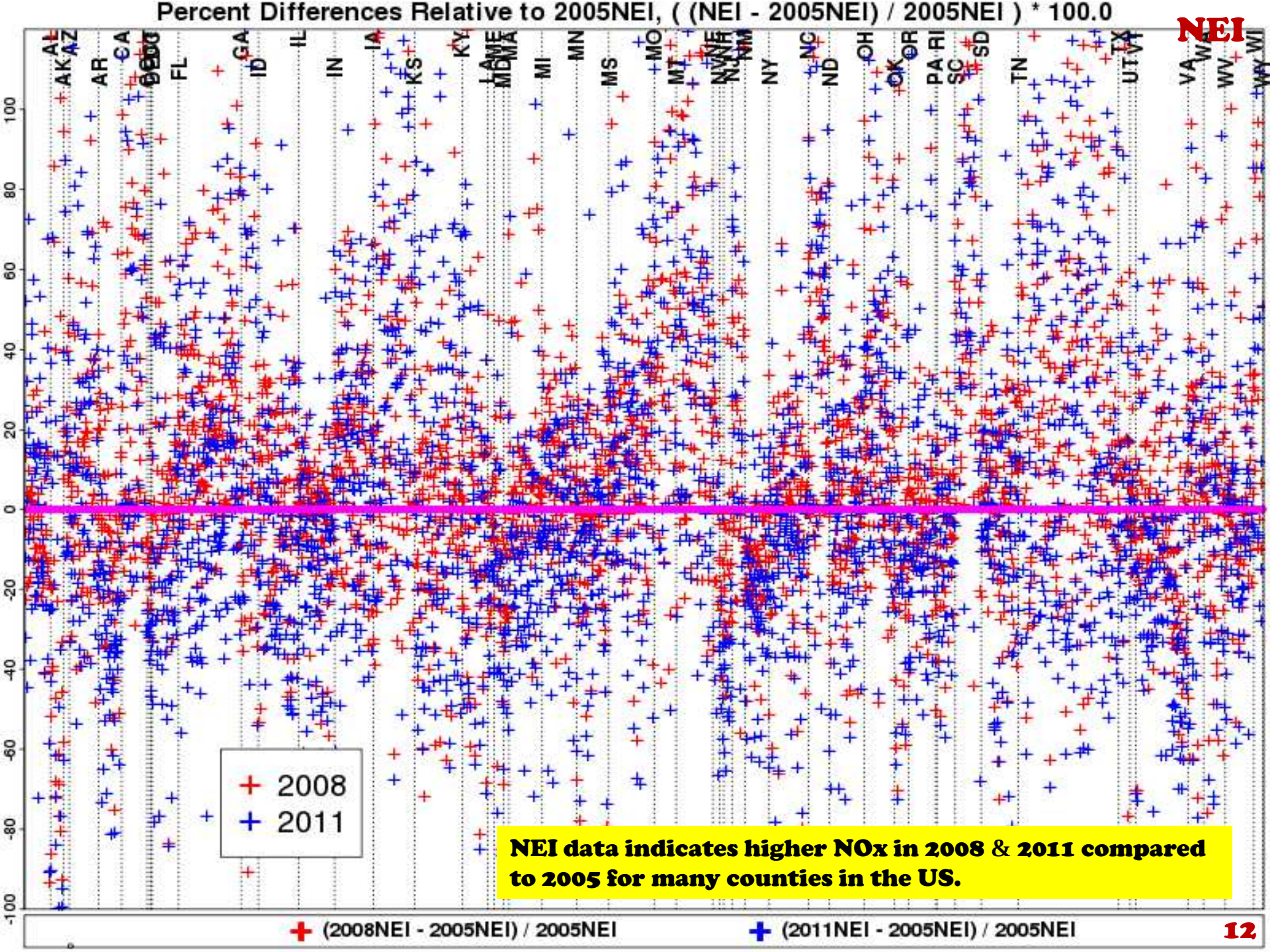


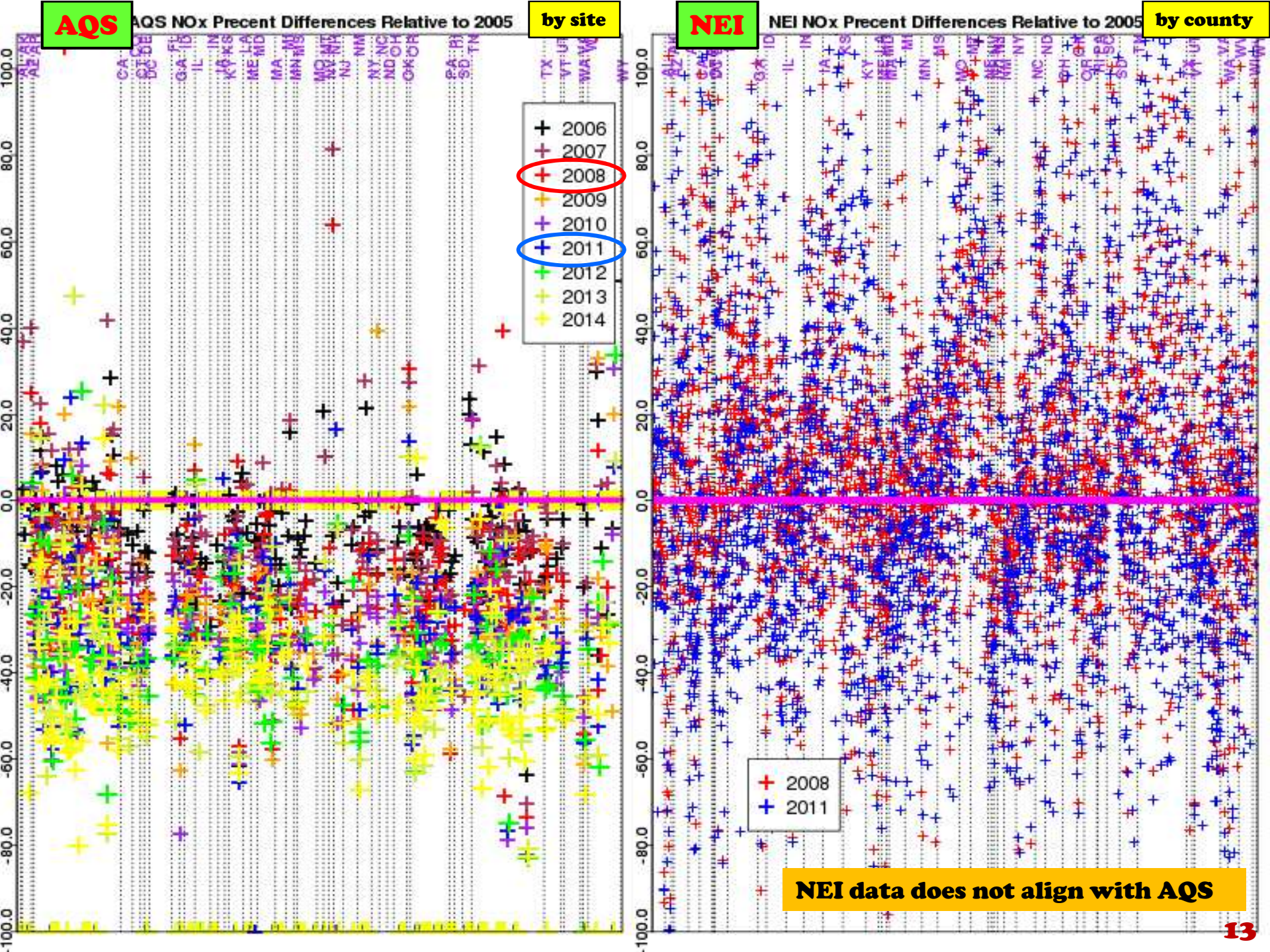
With exception of a few, state average observed NOx exhibits a downward trend from 2005 to 2011



OMI NO2

Satellite data show a downward trend

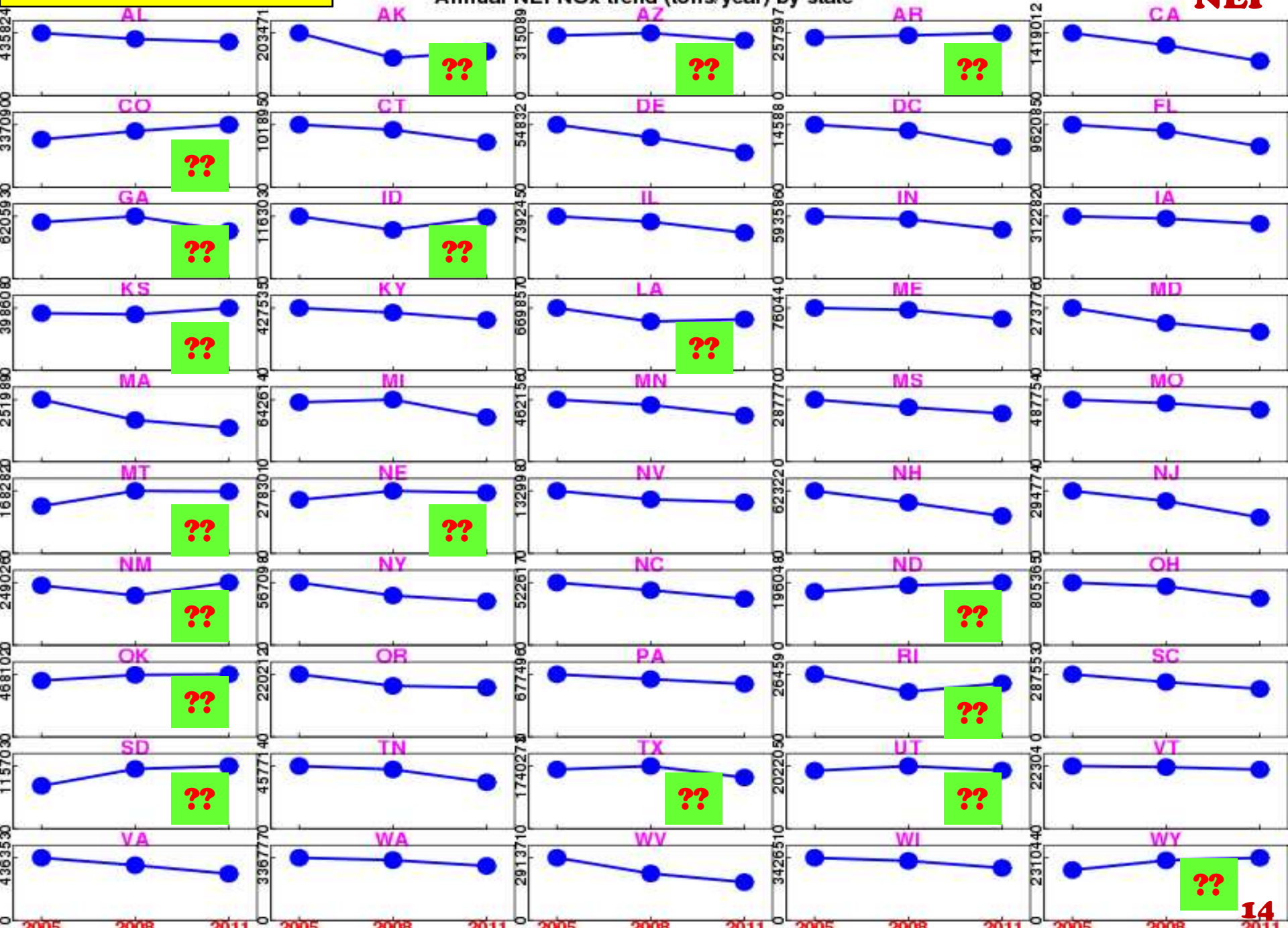

Percent Differences Relative to 2005NEI, ((NEI - 2005NEI) / 2005NEI) * 100.0
NEI
AL AK AZ AR CA CO CT DE FL GA ID IL IN IA KS KY LA ME MD MA MI MN MS MO MT NE NV NH NJ NM NY NC ND OH OK OR PA RI SC SD TN TX UT VT VA WA WV WI WY
100
80
60
40
20
0
-20
-40
-60
-80
-100
2008
2011
NEI data indicates higher NOx in 2008 & 2011 compared to 2005 for many counties in the US.
(2008NEI - 2005NEI) / 2005NEI
(2011NEI - 2005NEI) / 2005NEI
12


AQS
AQS NOx Precent Differences Relative to 2005
by site
2006
2007
2008
2009
2010
2011
2012
2013
2014
NEI
NEI NOx Precent Differences Relative to 2005
by county
2008
2011
NEI data does not align with AQS

2008 was a recession year

Annual NEI NOx trend (tons/year) by state

NEI



NEI Emission Sectors

Which sectors dominate the NEI and may possibly cause the inconsistency with observations?

- **Percent makeup:**

  % = (NOx from individual sector / total NOx) * 100

NEI Emission Sectors

14: Miscellaneous: Livestock and crops, fires (structural, agricultural, wildfires), fugitive dust, etc

13: Natural Resources: Vegetation

12: Off-Highway: Non-road vehicles (recreational, construction, lawn/garden, farm), aircraft, marine, railroad, etc

11: Highway: On-road vehicles (gas and diesel cars, trucks, and buses), refueling

10: Waste Disposal & Recycling: Landfills, waste water treatment, incineration, open burning

09: Storage & Transport: Different storage tanks for oil/gas (e.g. underground tanks, service stations)

08: Solvent Utilization: Degreasing, dry cleaning, wood finishing, plastic coatings, traffic markings, etc

07: Other Industrial Processes: Mills, bakeries, tires, cement, quarries, glass mfg, surface mining, etc

06: Petroleum & Related Industries: Petroleum refineries, oil/gas production, asphalt mfg

05: Metals Processing: Copper, lead, zinc, aluminum

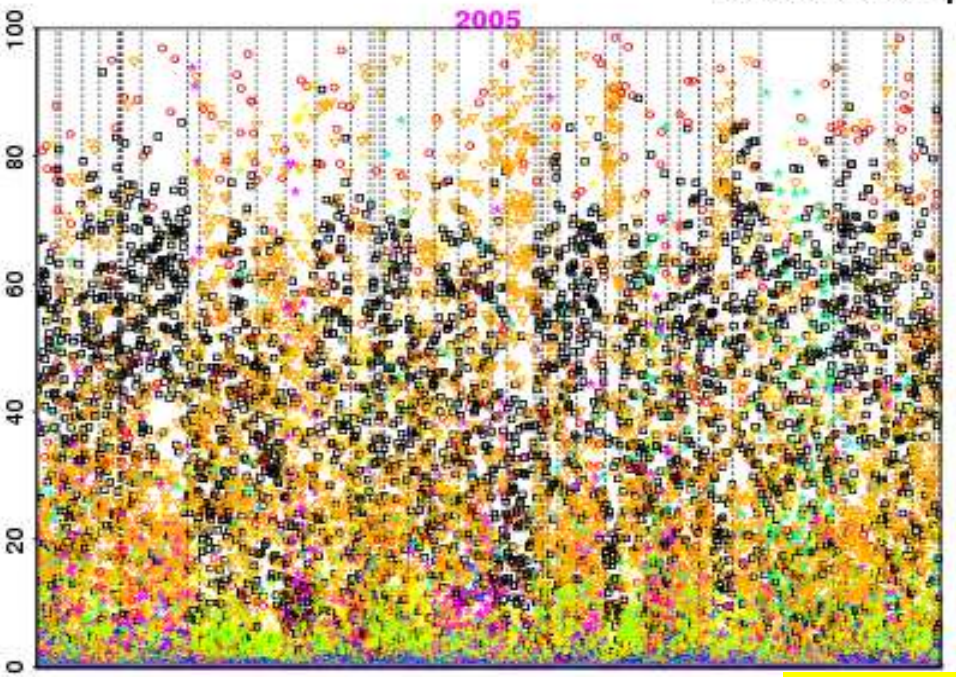
04: Chemical & Allied Product Mfg: Charcoal, plastics, synthetic fibers, paint, printing ink, etc

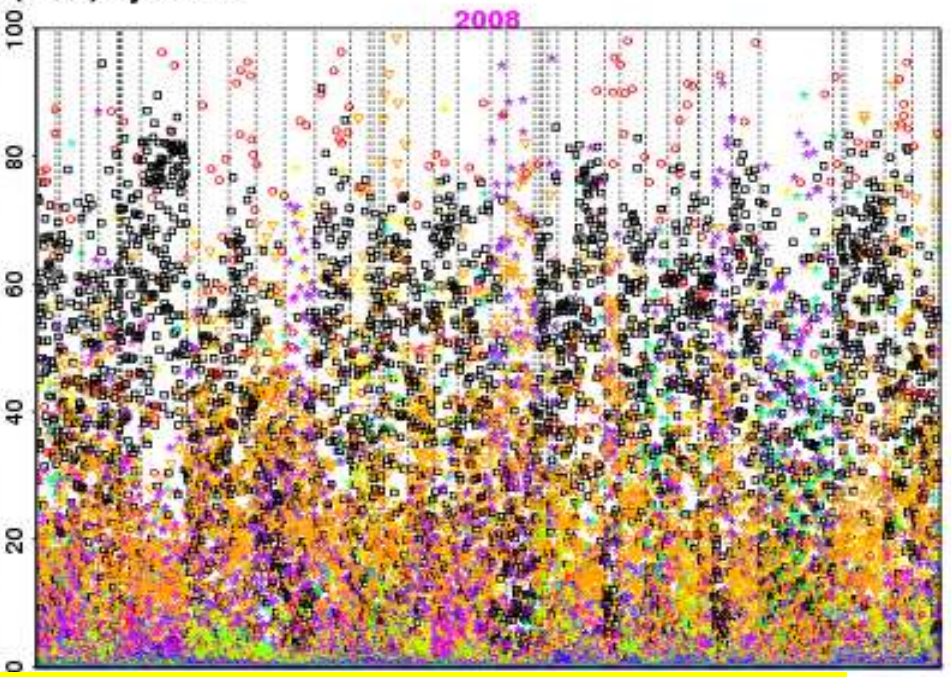
03: Fuel Comb. Other: Residential fuel (fireplaces, wood stoves, oil, gas)

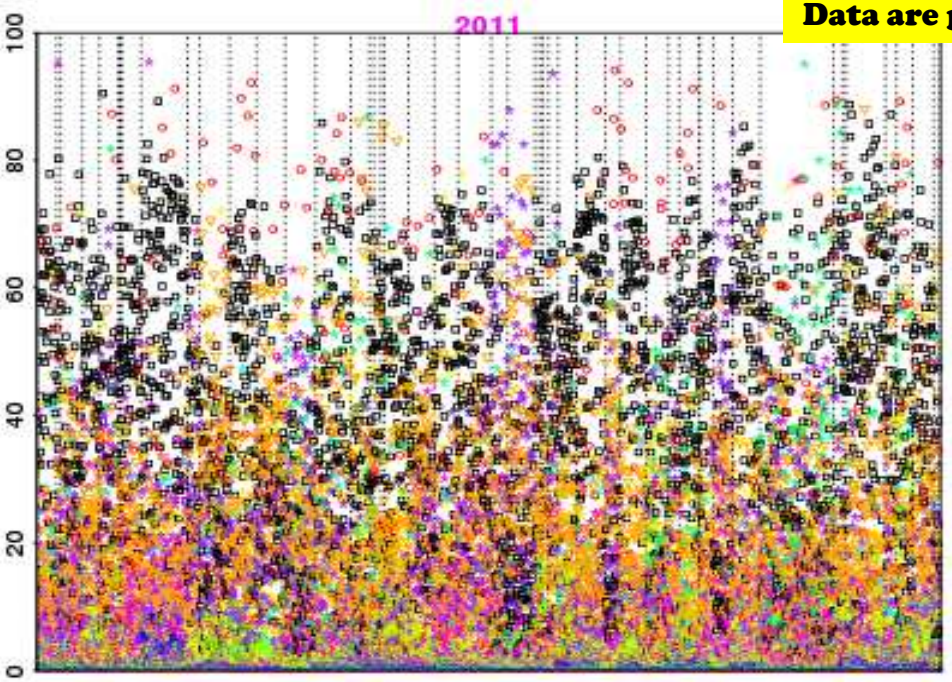
02: Fuel Comb. Industrial: Other industrial fuel uses – coal, oil, gas

01: Fuel Comb. Elec. Util.: Electric Generating Units (EGU) – coal, oil, gas

NEI NOx Makeup (in %) by Sector







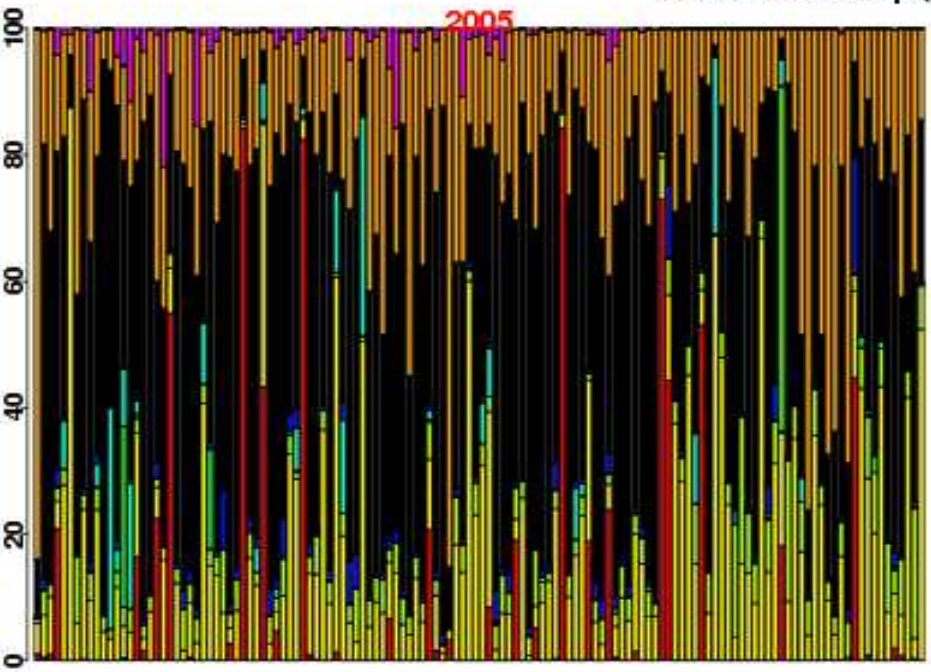
Data are plotted by county (on x axis) and grouped by state

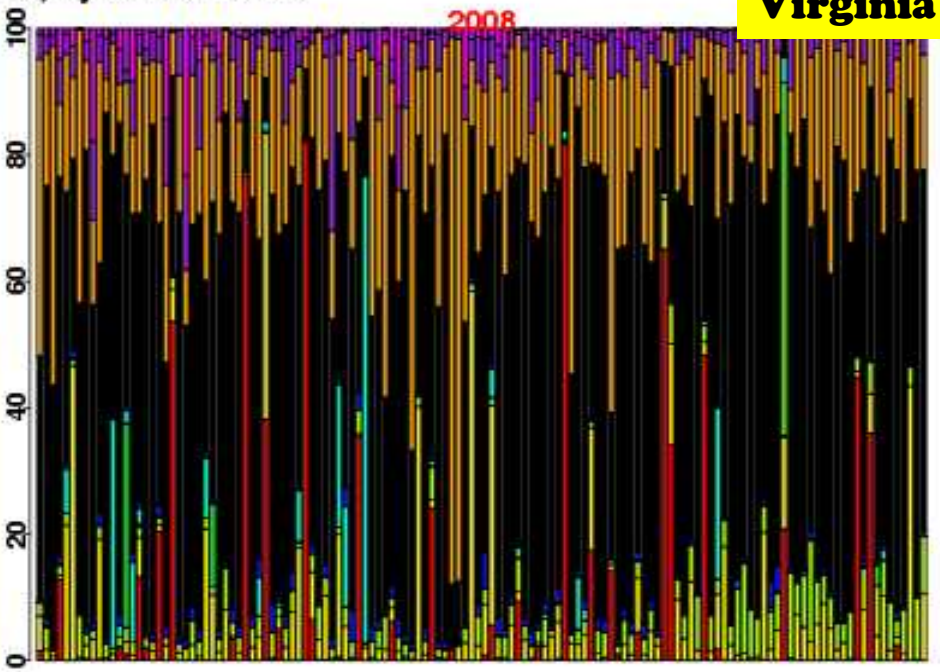
- 14: MISCELLANEOUS
- 13: NATURAL RESOURCES
- 12: OFF-HIGHWAY
- 11: HIGHWAY VEHICLES
- 10: WASTE DISPOSAL & RECYCLING
- 09: STORAGE & TRANSPORT
- 08: SOLVENT UTILIZATION
- 07: OTHER INDUSTRIAL PROCESSES
- 06: PETROLEUM & RELATED INDUSTRIES
- 05: METALS PROCESSING
- 04: CHEMICAL & ALLIED PRODUCT MFG
- 03: FUEL COMB. OTHER
- 02: FUEL COMB. INDUSTRIAL
- 01: FUEL COMB. ELEC. UTIL.

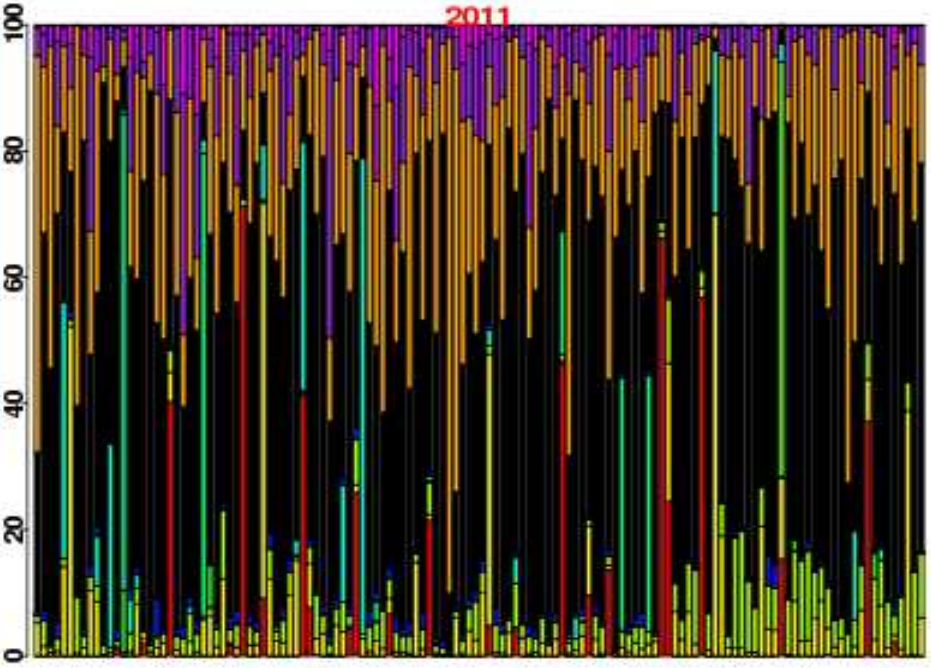
Total data points > 3200 counties * 14 sectors

NEI NOx Makeup (in %) by Sector for VA

Virginia







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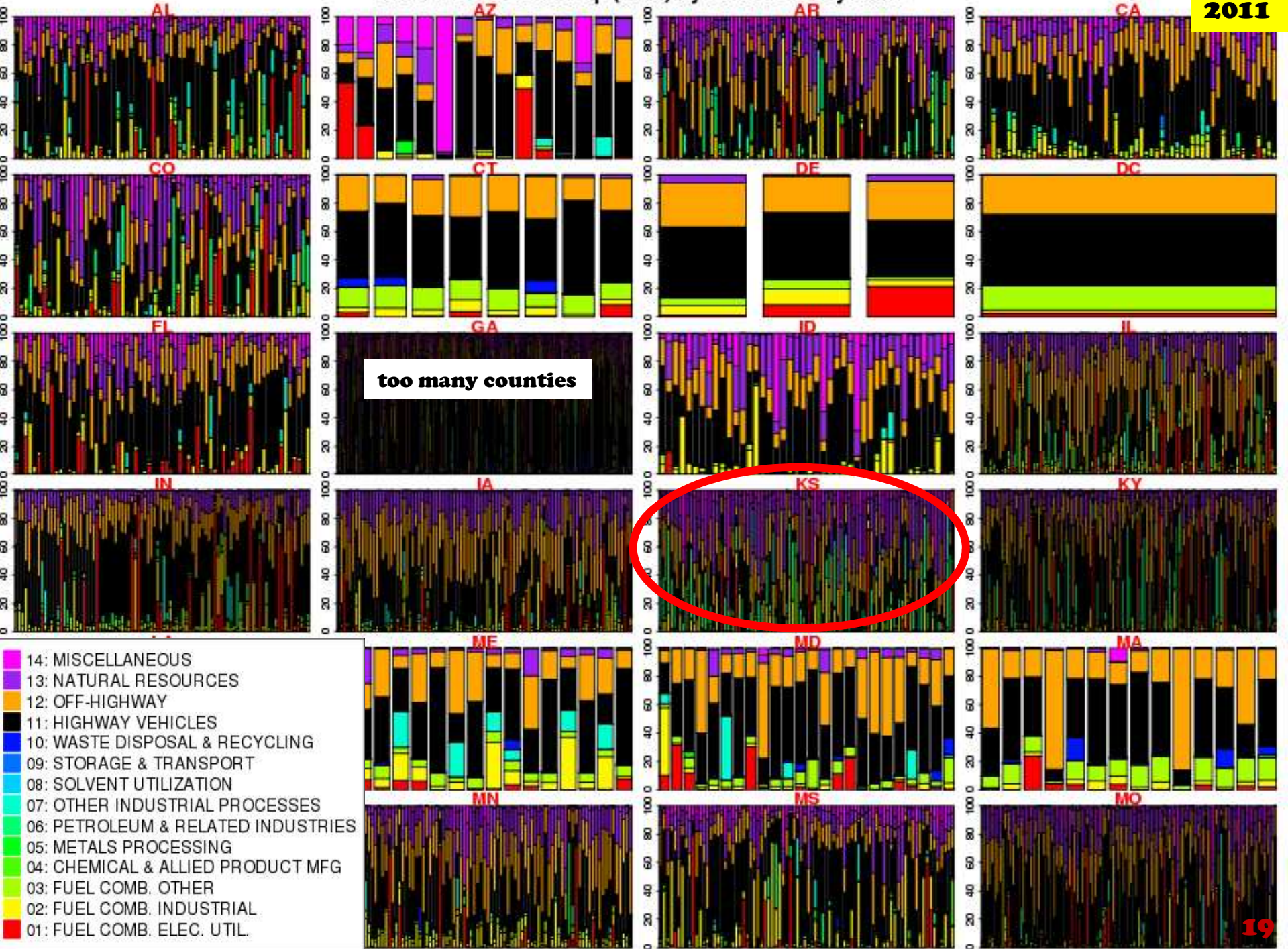
2011 NEI NOx Makeup (in %) by Sector and by State

2011



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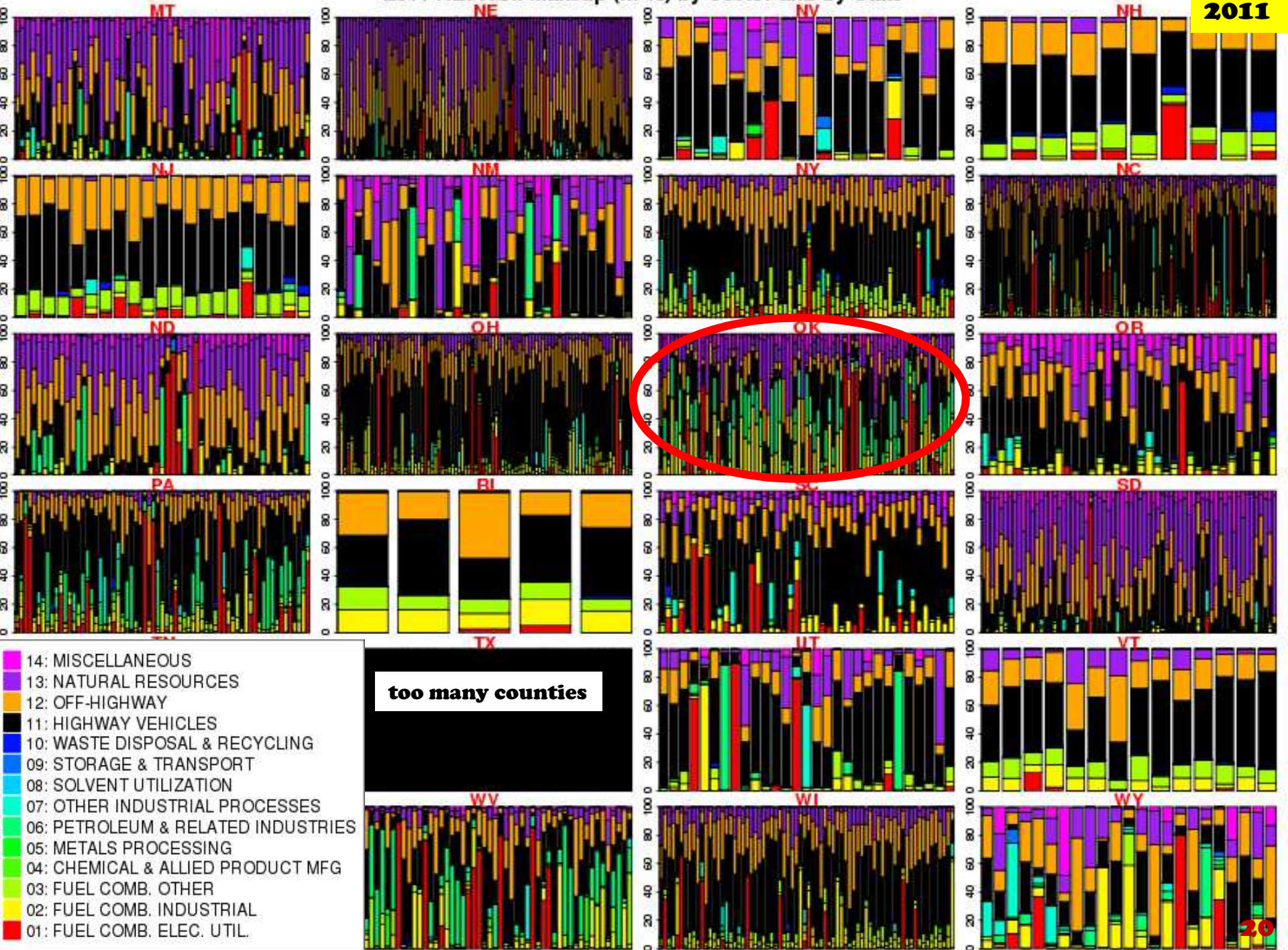
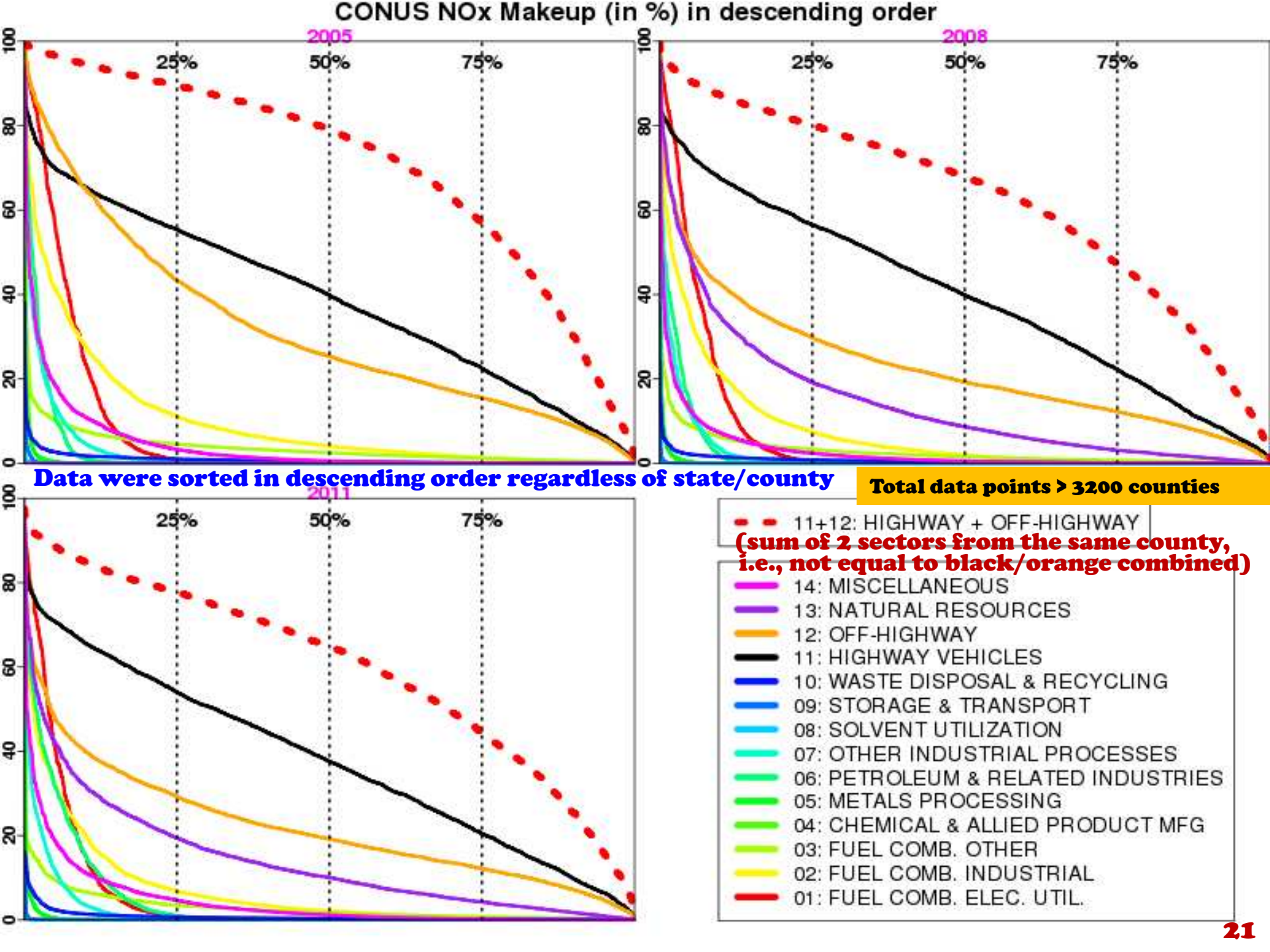
2011




CONUS NOx Makeup (in %) in descending order
2005
2008
2011
25%
50%
75%
0
20
40
60
80
100
Data were sorted in descending order regardless of state/county
Total data points > 3200 counties
11+12: HIGHWAY + OFF-HIGHWAY
(sum of 2 sectors from the same county, i.e., not equal to black/orange combined)
14: MISCELLANEOUS
13: NATURAL RESOURCES
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01: FUEL COMB. ELEC. UTIL.

Summary on Emission Sectors

- The mobile and non-road sectors produce 40% and 25% of NOx emissions, respectively, in half of the counties in the continental US
- The two mobile sectors combined produce 50% of NOx emissions in 75% of the counties in continental US
- Other sectors (such as EGUs) dominate NOx for fewer than 10% of the counties, indicating the more localized or concentrated nature of these sectors
- Unlike Continuous Emission Monitoring System (CEMS) in EGU sector, the mobile sector has no direct measurement from spatially diverse network to ground truth its emission estimates. (Near road monitors may be of some help in future.)

Mobile estimates are highly questionable

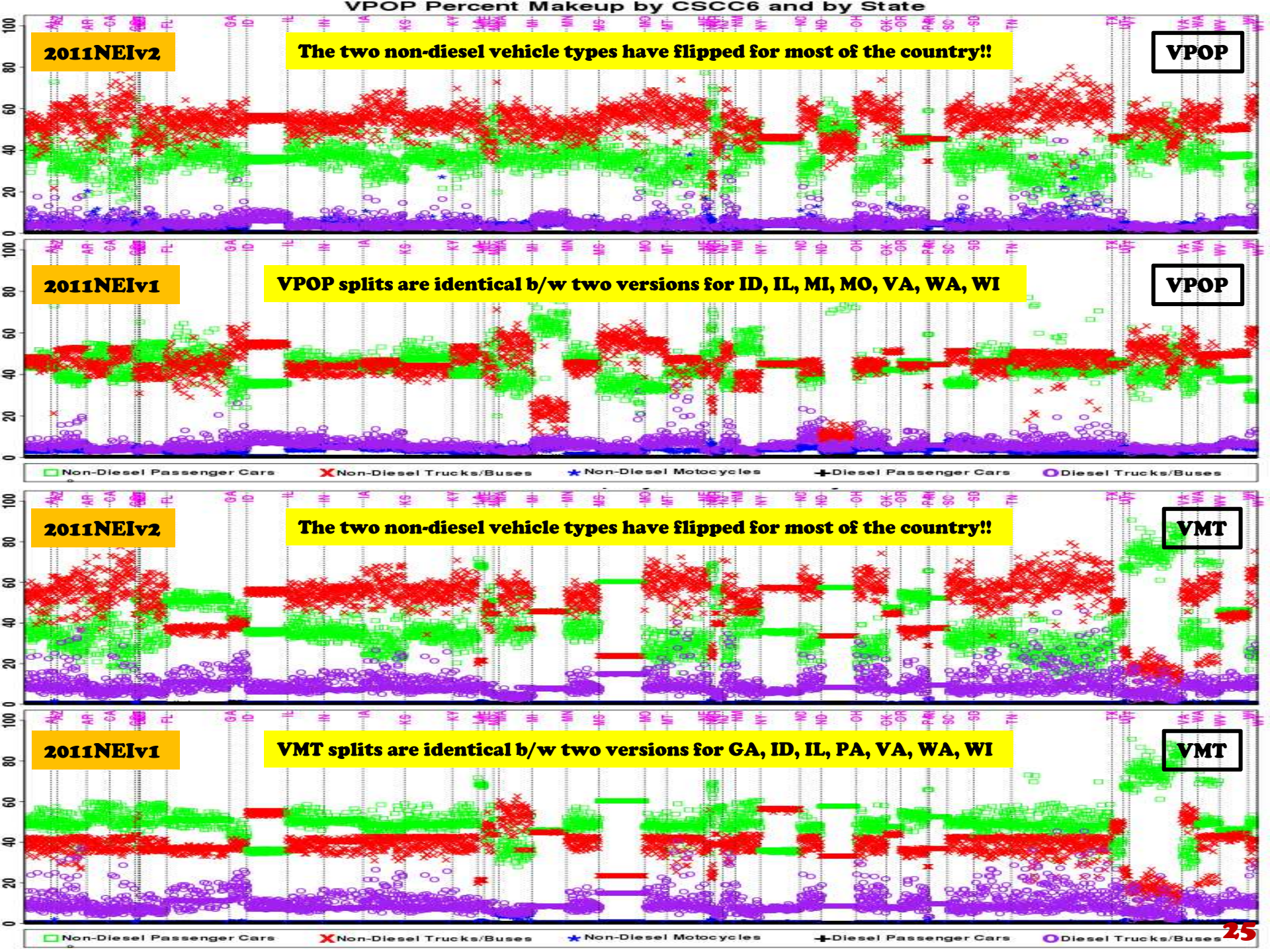
Mobile Source Inventory

- Examples
- Current Status

Example of Inconsistent Mobile Estimates: "Flip" of Passenger Vehicles

- Non-Diesel passenger car and Non-Diesel truck/bus activity have flipped from 2011NEIv1/MOVES2010b to 2011NEIv2/MOVES2014
  - HIGHER VPOP and VMT for trucks/buses
  - LOWER VPOP and VMT for passenger cars
- Systematic and region-wide
- Emission factors for trucks/buses > passenger cars, so the difference matters

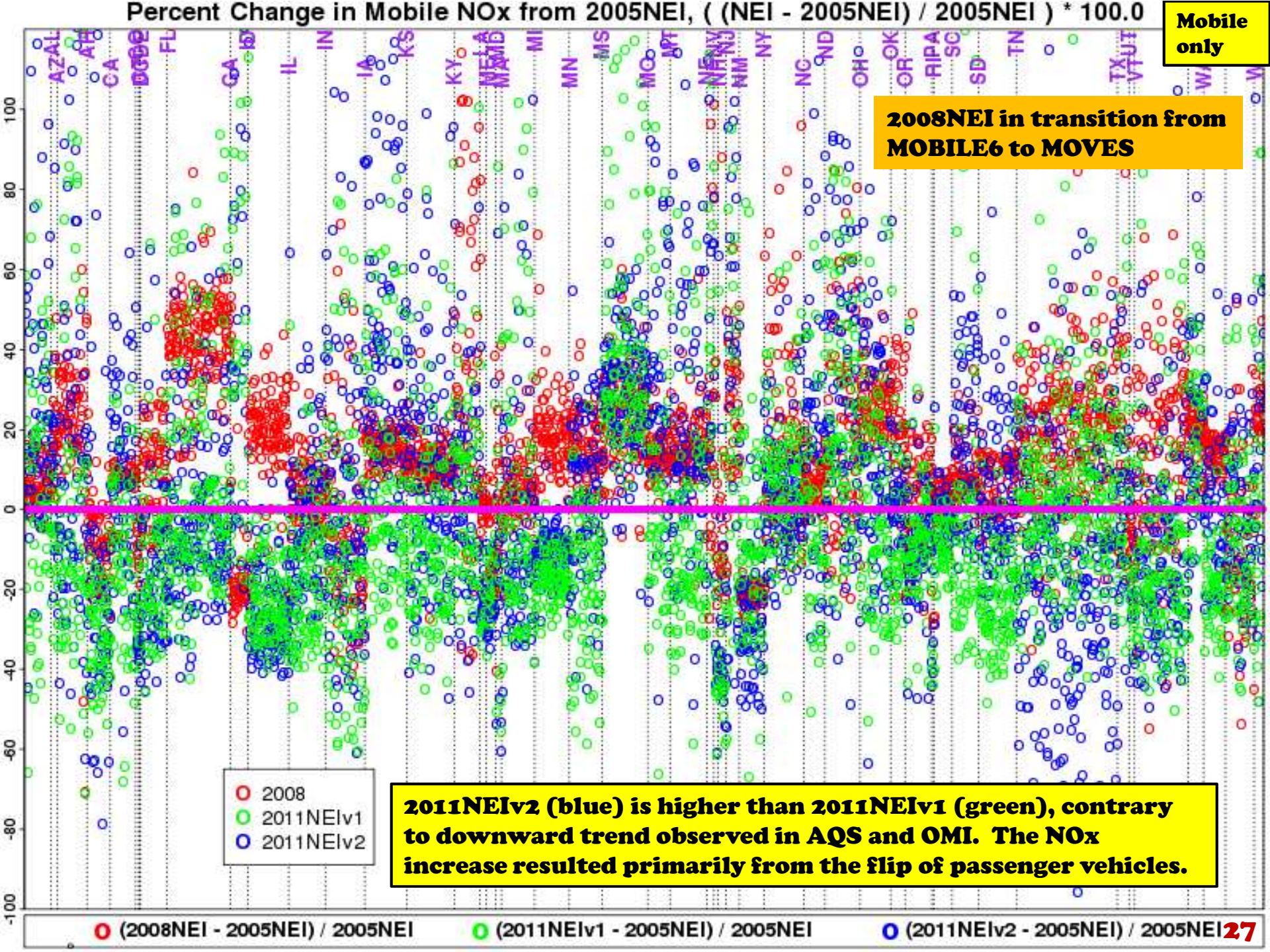
Green: non-diesel passenger cars
Red: non-diesel passenger trucks/buses


VPOP Percent Makeup by CSCC6 and by State
2011NEIv2
The two non-diesel vehicle types have flipped for most of the country!!
VPOP
2011NEIv1
VPOP splits are identical b/w two versions for ID, IL, MI, MO, VA, WA, WI
VPOP
Non-Diesel Passenger Cars
Non-Diesel Trucks/Buses
Non-Diesel Motocycles
Diesel Passenger Cars
Diesel Trucks/Buses
2011NEIv2
The two non-diesel vehicle types have flipped for most of the country!!
VMT
2011NEIv1
VMT splits are identical b/w two versions for GA, ID, IL, PA, VA, WA, WI
VMT
Non-Diesel Passenger Cars
Non-Diesel Trucks/Buses
Non-Diesel Motocycles
Diesel Passenger Cars
Diesel Trucks/Buses

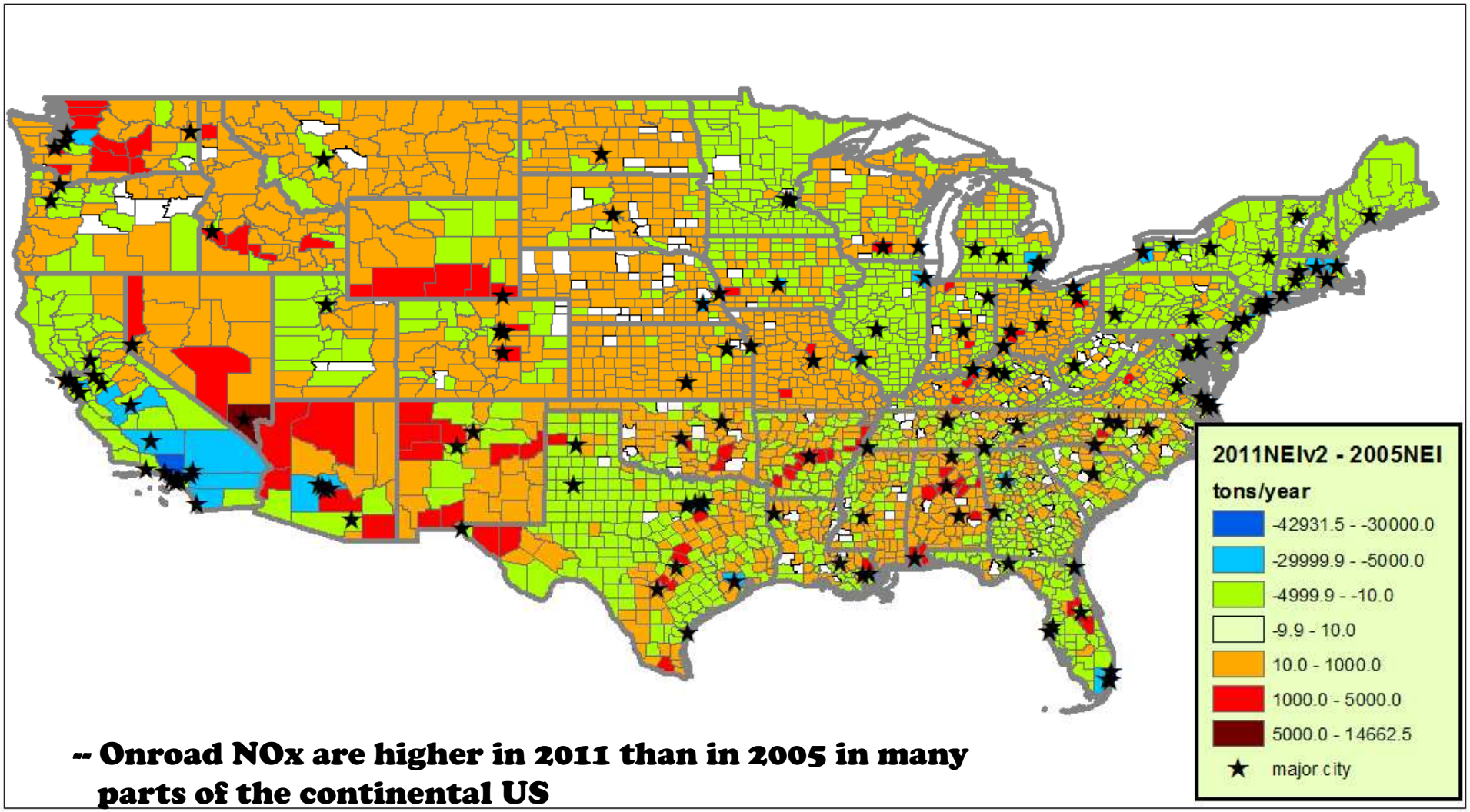
Flip of Passenger Vehicles

- The flip was not due to an improvement in theory or methodology, but rather a result of inconsistent treatment in splitting VPOP for passenger vehicles
- Passenger trucks have weighted more in VPOP than passenger cars in 2011NEIv2
- VPOP splits were used in a VMT calculation scheme to allocate VMT by MOVES vehicle type
- 2011NEIv2 NOx > 2011NEIv1 NOx (as a result of both higher VPOP and higher VMT for trucks)
- This calculation scheme was not used for all counties. States which submitted detailed local data (ex, VA) were omitted from the scheme (another inconsistency)
- Thus far no clear guidance has been provided to help states split aggregated vehicle types into MOVES vehicle types (ex, light-duty passenger truck vs light-duty commercial truck)

The problem is convoluted and related to model fundamental design and input data preparation


Percent Change in Mobile NOx from 2005NEI, ((NEI - 2005NEI) / 2005NEI) * 100.0
Mobile only
2008NEI in transition from MOBILE6 to MOVES
2008
2011NEIv1
2011NEIv2
2011NEIv2 (blue) is higher than 2011NEIv1 (green), contrary to downward trend observed in AQS and OMI. The NOx increase resulted primarily from the flip of passenger vehicles.
(2008NEI - 2005NEI) / 2005NEI
(2011NEIv1 - 2005NEI) / 2005NEI
(2011NEIv2 - 2005NEI) / 2005NEI
27

Onroad NOx from 2005 to 2011



-- Onroad NOx are higher in 2011 than in 2005 in many parts of the continental US

-- Increase in emissions from 2011 to 2005 may not be considered consistent with observations

Status of MOVES and SMOKE-MOVES

- SMOKE-MOVES is complicated, cumbersome, inconsistent, and confusing (few except OAQPS/EPA have used it)
- Several data issues were found in mobile source inventory (including 2011NEI). Improvement has been a slow process.
- Methods adopted by states and EPA are inconsistent
- Nearly two thirds (2/3) of US did not supply county-specific data and relied on model defaults
- Effects of model defaults have not been examined
- Little to no QA is performed for inventory input data
- Issues are magnified by the representative county scheme used in SMOKE-MOVES
- Due to the representative county scheme and widespread use of defaults, the mobile source inventory in 2011NEI has very coarse (low) resolution
- 2011NEI is ill-suited for a contribution-to-monitor type of analysis or assessment
- Development of a quality mobile source inventory is a critical component in air quality modeling

Conclusions

- Satellite and ground NO2 observations show downward trend from 2005 to 2011 and beyond in the continental US
- NOx are higher in 2011NEI and 2008NEI compared to 2005NEI for many counties in the US, inconsistent with trend observed by satellite and AQS network
- Onroad and non-road combined produce 50% of total NOx in 3/4 of the counties in continental US
- Thorough review of NEI and methodologies used for inventory development are urgently needed

Acknowledgements

- **Virginia DEQ:**
  Sonya Lewis-Cheatham, Kristen Stumpf
- **NASA Goddard Space Flight Center:**
  Lok Lamsal

Repository for VADEQ presentations on MOVES and SMOKE-MOVES:

http://www.deq.virginia.gov/Programs/Air/AirQualityAssessments/PhotochemicalModeling/DEQPresentationsonMOVES.aspx

More than five years of effort and 30 plus presentations