Spatial-temporal trends in four decades of United States on-road air pollution

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The Team

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Motivation: exposure to Traffic Related Air Pollution (TRAP)

$\boxed{NO_2}$ NO_x $\boxed{CO}$ EC

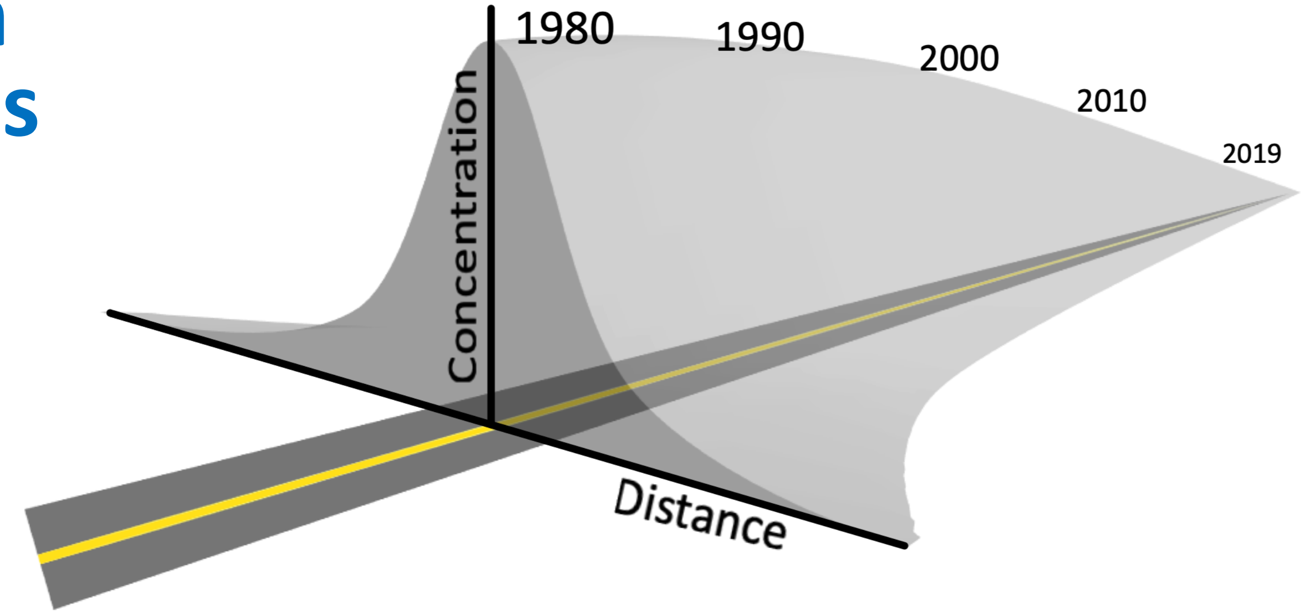
Epidemiology and env. justice researchers approximate exposure using:

- Road proximity
- Chemical Transport Models (e.g., CMAQ)
- Satellite measures

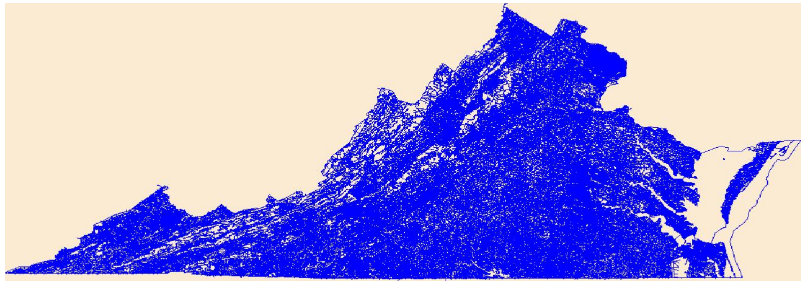
TRAP concentrations have changed in time and space over recent decades

How much information about these gradients is contained in road locations?

How well do CTMs and satellites capture the changes over time and space?



ROADINESS: a road proximity metric



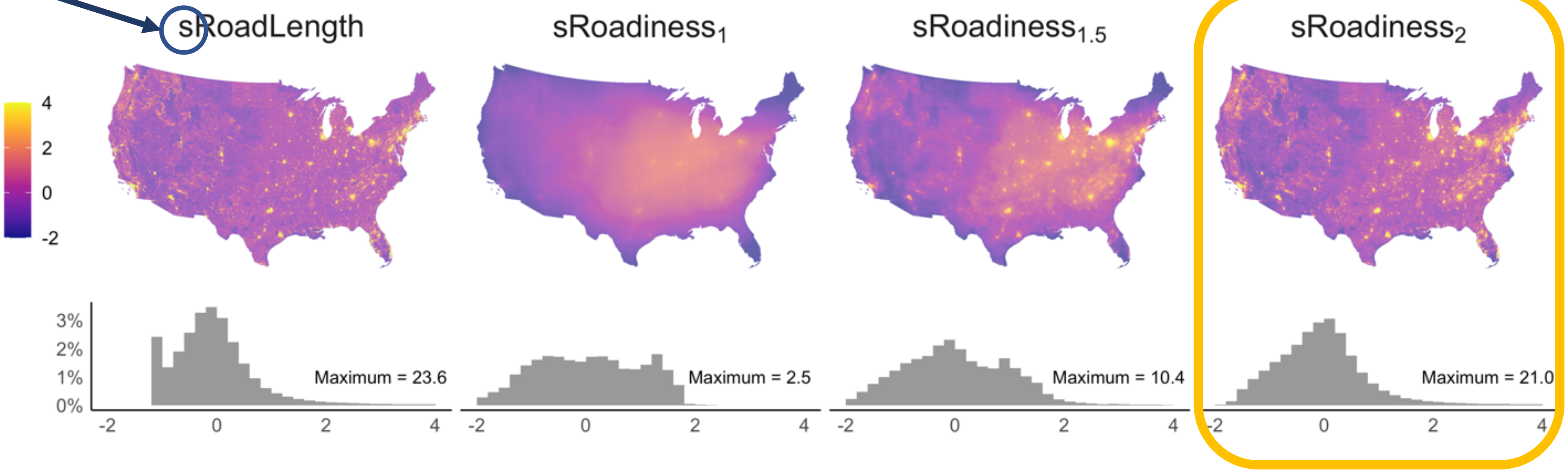
Step 1: Download USGS's road link network

Step 2: Overlay grid and sum road lengths in each cell

Step 3: Roadiness based on inverse distance weighting

$$Roadiness_{D,i} = \sum_{j=1}^{J} \frac{RoadLength_j}{d_{i,j}^{D}}$$

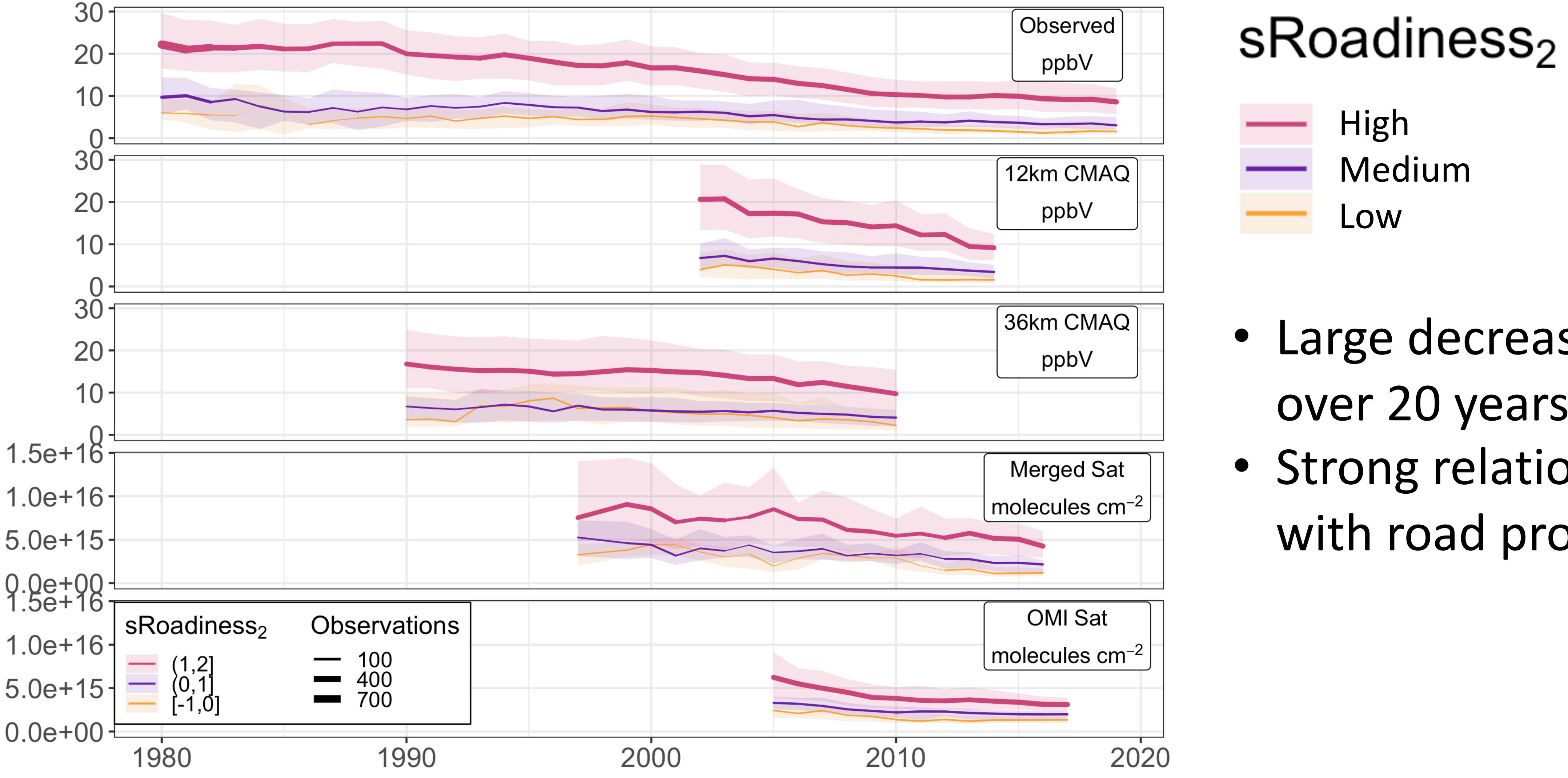
Scaled to Z score



Observation, CMAQ and satellite datasets

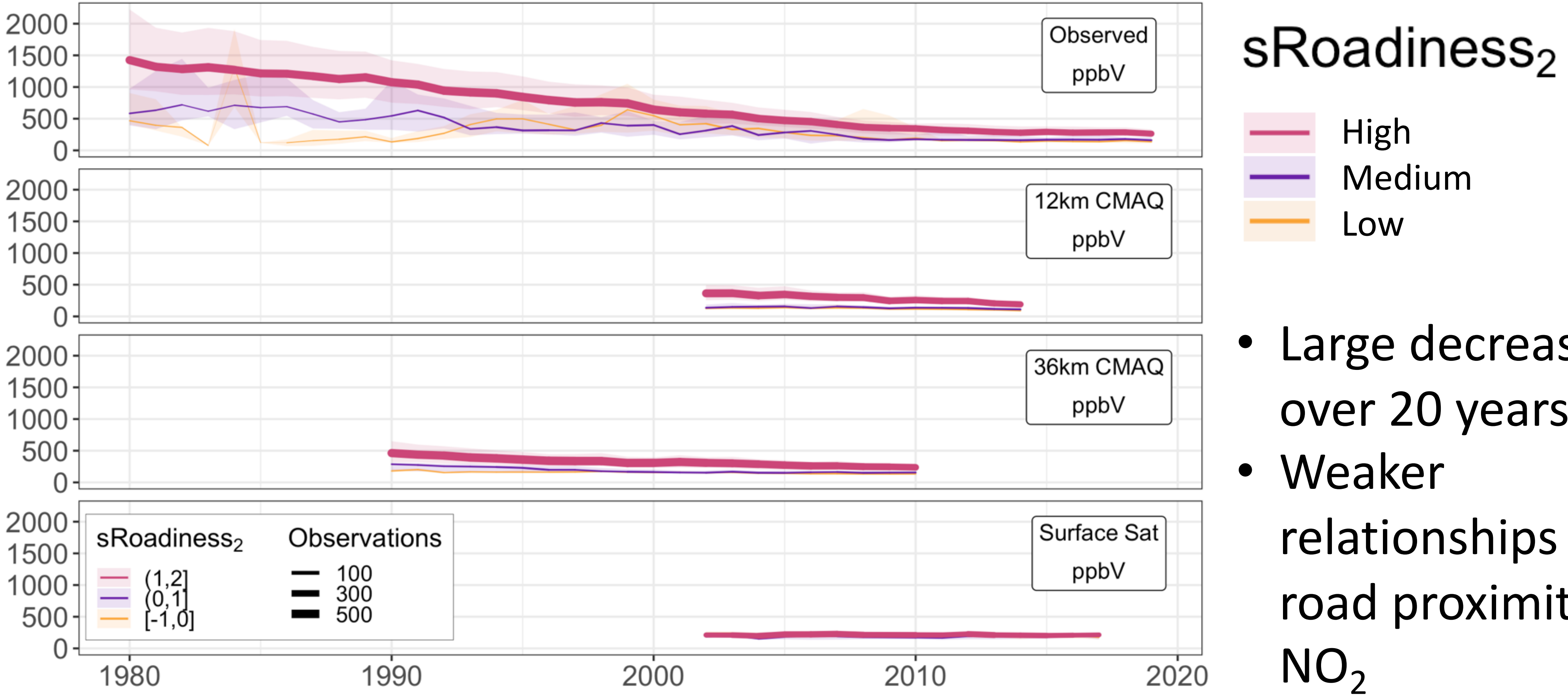
Source	Description	Pollutants	Years	Citation
Observations	Monitors	**NO_2** **NO_x** **CO** **EC**	1980-2019	EPA Air Quality System
CMAQ	36 km	**NO_2** **NO_x**	1990-2010	Astitha et al. 2017
	12 km	**CO** **EC**	2002-2014	CMAS Center 2020
Satellite	OMI	**NO_2**	2005-2019	Boersma, 2018
	Merged	**NO_2**	1997-2016	Georgoulias et al. 2019
	MOPITT	**CO**	2001-2018	Deeter et al. 2003

NO_2 concentrations with road proximity



- Large decreases over 20 years
- Strong relationships with road proximity

CO concentrations with Roadiness



- Large decreases over 20 years
- Weaker relationships with road proximity than NO_2

Hierarchical model: trends in time and space

Meteorology

$$C_{kt}^{G} = \beta_0^G G_g + \beta_R^G R_k G_g + (\beta_1^G + \beta_2^G R_k) t^G G_g + \beta_M^G M_{kt}^G G_g + U_k + S_{kt}$$

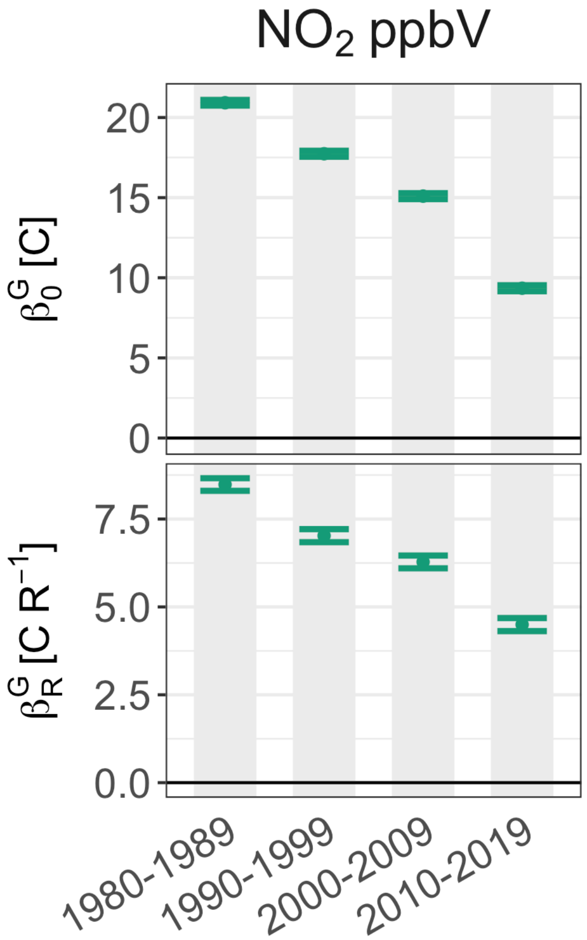
k: monitors
t : time

$U_k \sim N(0, \tau_0^2)$ Monitor-specific random intercept

$S_{kt} \sim N(0, \sigma^2)$ Random (measurement) error

- β_0^G: Average concentration at time $t = 0$
- β_R^G: Concentration-$sRoadiness_2$ relationship at $t = 0$
- β_1^G: Concentration-time relationship
- β_2^G: Concentration-time interaction with $sRoadiness_2$
- G_g: decade or state group

Observed NO_2 decreased over time and flattened over space

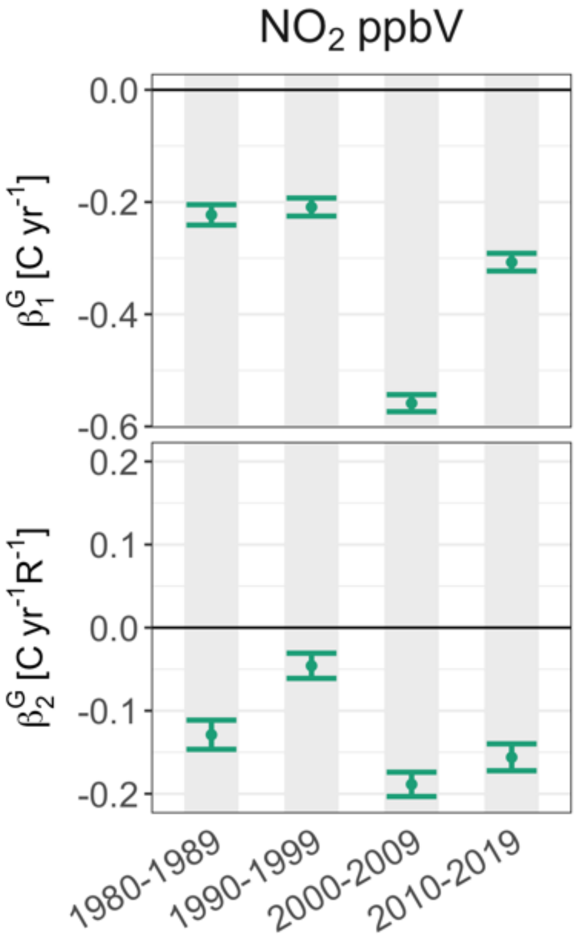


NO_2 decreased on average, 1980-2019

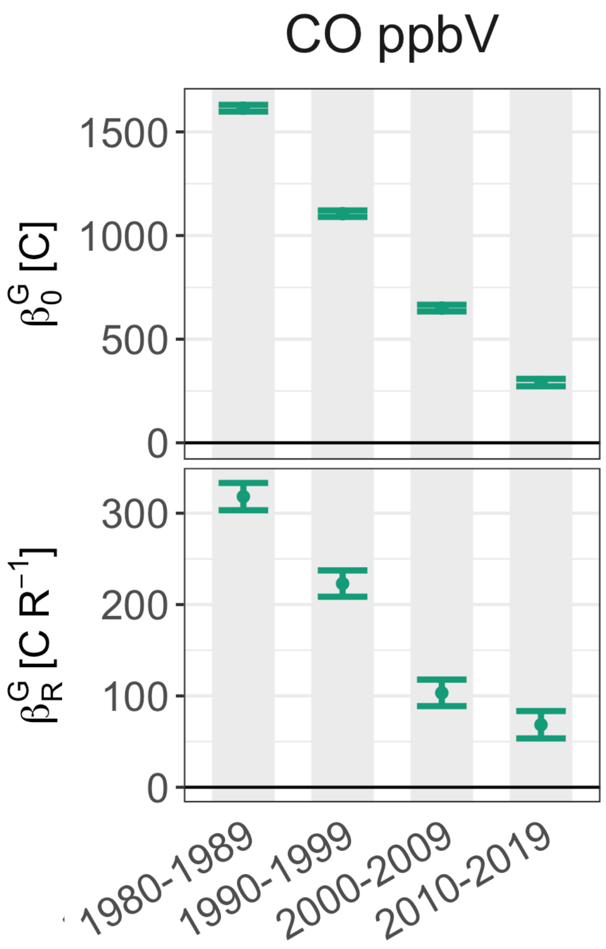
Relationship between conc. and $sRoadiness_2$ weakened

Average decrease per year constant besides 2000-2009

Temporal trend-$sRoadiness_2$ interaction stays negative



Observed CO decreased over time and flattened over space (1980-2019)

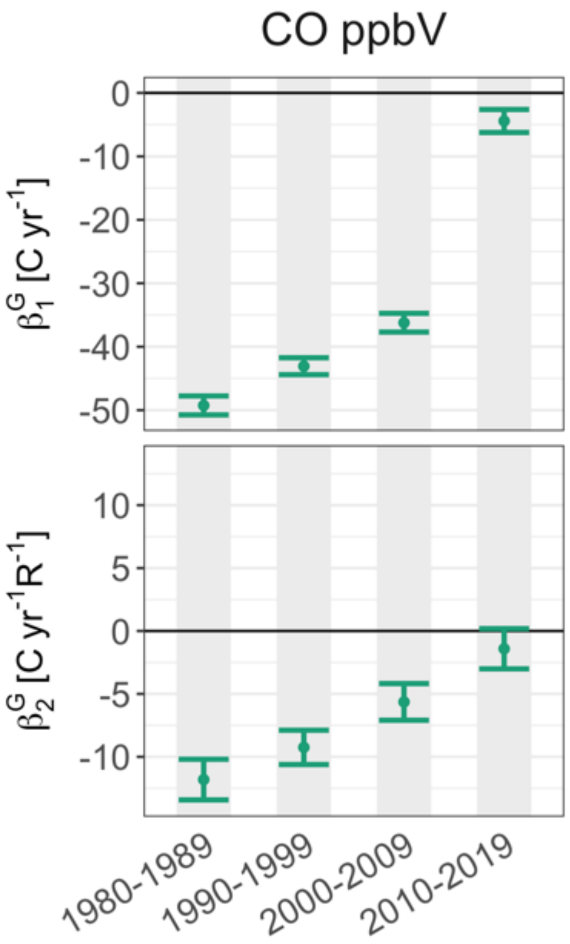


Average CO decreased

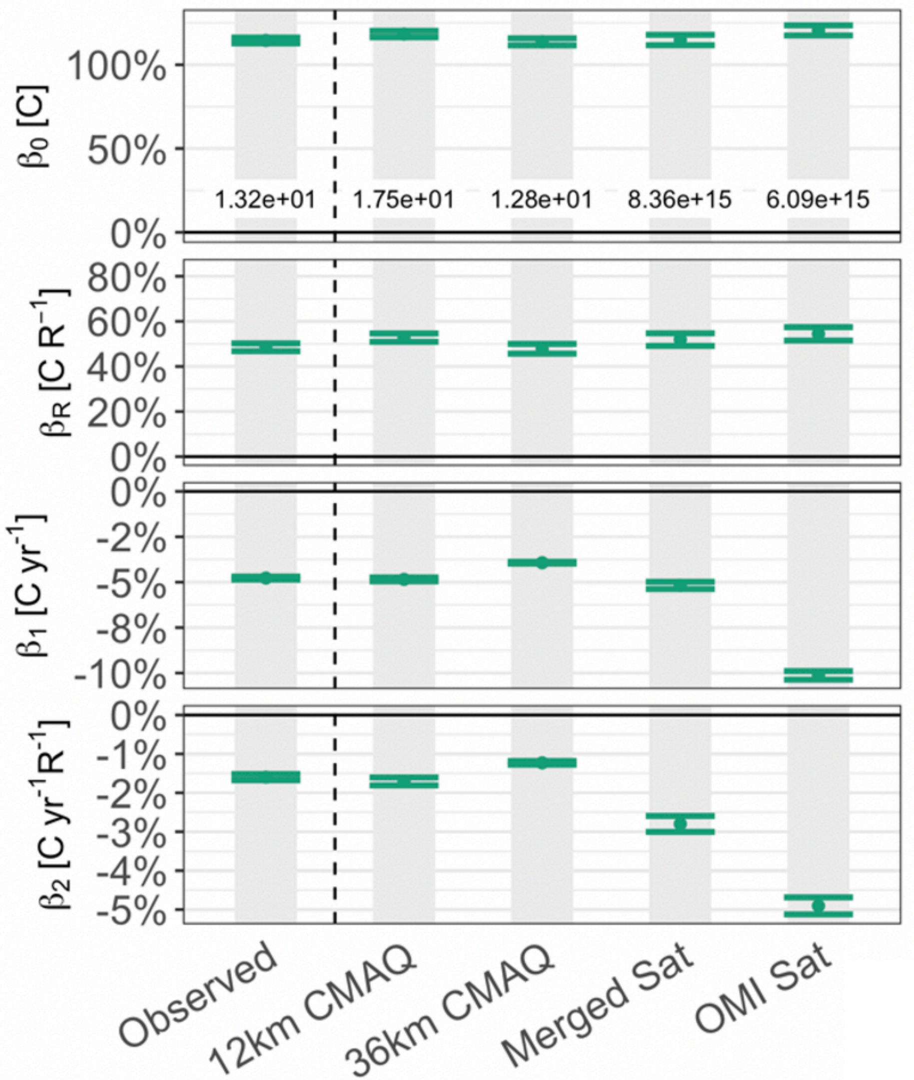
Relationships between conc. and $sRoadiness_2$ weakened

Average decrease per year has become less negative

Temporal trend and $sRoadiness_2$ interaction near zero after 2010



CMAQ products estimate NO_x trends well



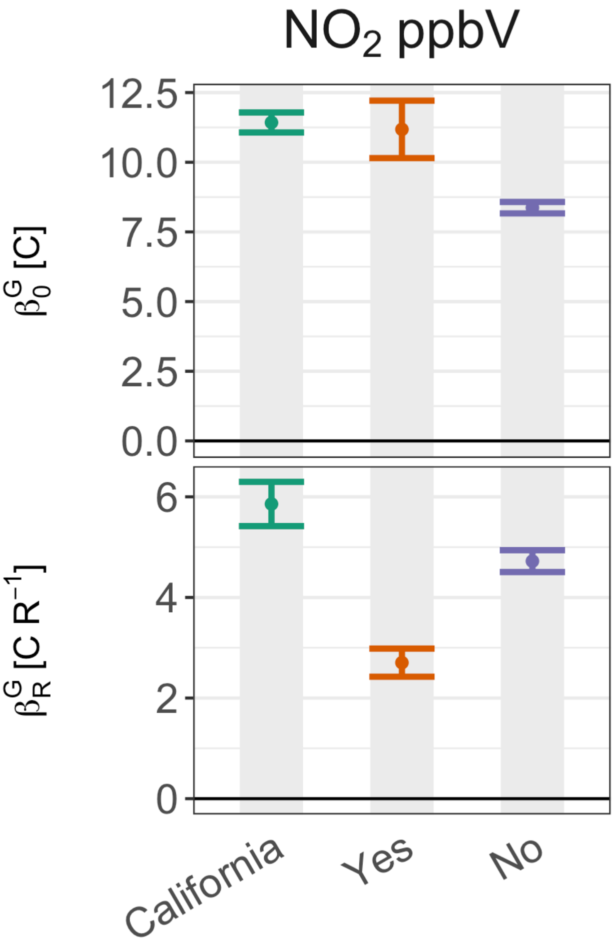
- Coefficients as percent of 2002-2010 mean (dynamic evaluation)
- All models adequately capture relationship with $sRoadiness_2$
- Both 12km and 36km CMAQ estimate trends well
- OMI overly sensitive to temporal trend
- Satellites overly sensitive to $sRoadiness_2$-time interaction

How have trends varied in states that did(n‘t) adopt California’s automobile rules?

- EPA allows states to opt into California’s automobile emissions rules
- Three rules considered:
  - Light-duty criteria pollutant
  - Light-duty greenhouse gas
  - Zero emissions vehicle rules
- Three state groups; 2010-2019
  - California
  - “Yes” states adopted California standards
  - “No” states followed national standards

State	Model year
New York	1993
Massachusetts	1995
Vermont	2000
Maine	2001
Pennsylvania	2001
Connecticut	2008
Rhode Island	2008
New Jersey	2009
Oregon	2009
Washington	2009
Maryland	2011

Observed NO_2 trends in California, Yes, and No states (2010-2019)

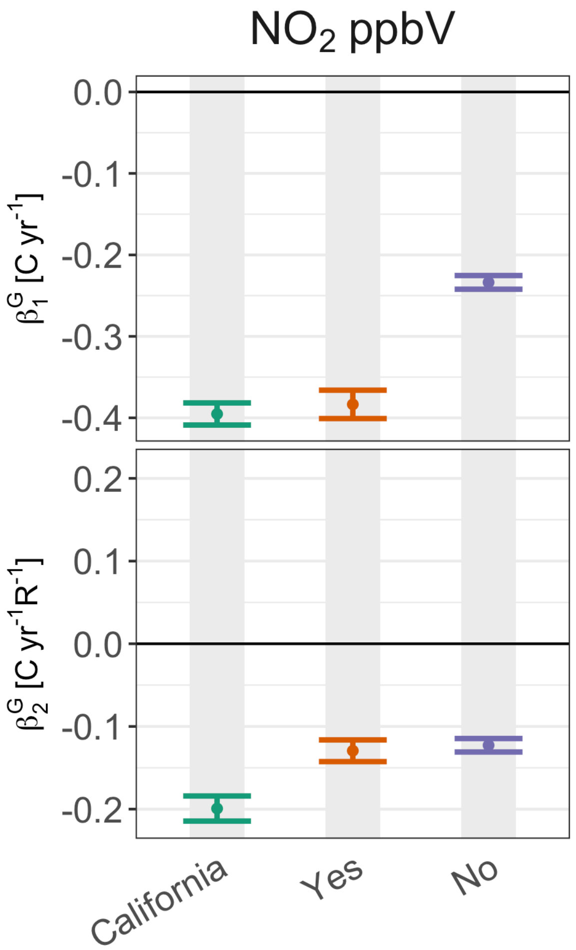


2010 average NO_2 highest in California and Yes states

Relationship between conc. and $sRoadiness_2$ lowest in Yes states

Average change per year most negative in California and Yes states

Temporal trend and $sRoadiness_2$ interaction similar in Yes and No states



Conclusions

- Distance^{-2} maintains strongest relationship with observed concentrations through study period
- TRAP concentrations have flattened in time and space since 1980
  - Declines fastest in areas near roads
  - Continued flattening in recent years
- CMAQ (12km and 36km) captures NO_2 trends across 2002-2010
- Satellite products overly sensitive to NO_2 decreases near roads
- All states saw NO_2 improvements from 2010-2019
  - California had the strongest relationships between road proximity and improvements
  - "Yes" states saw improvements, but no faster near roads than "No" states

Thank you

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