Association of Changes in Air Quality With Incident Asthma in Children in California, 1993-2014

COLLABORATIVE ON HEALTH AND THE ENVIRONMENT

JULY 23, 2019 WEBINAR

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RATIONALE

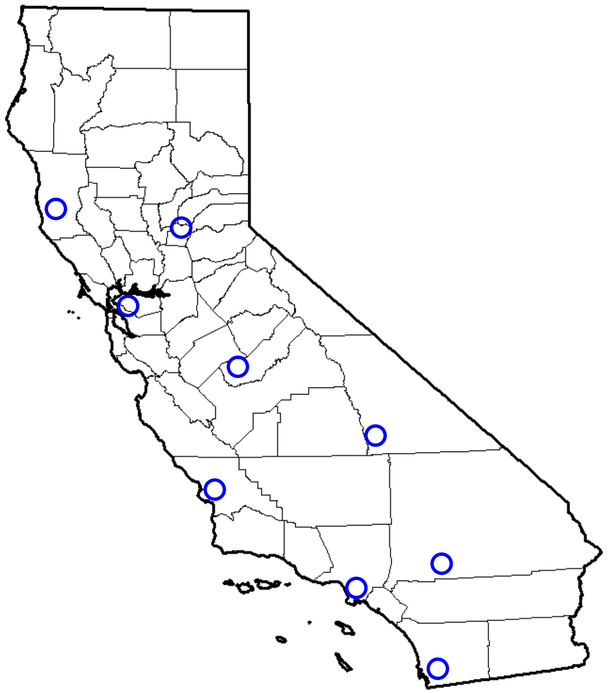
Air pollution exposure is a well-established cause of asthma exacerbation in children

Whether air pollutants play a role in the development of childhood asthma, however, remained uncertain

Objective: *To examine whether decreasing regional air pollutants were associated with reduced incidence of childhood asthma*

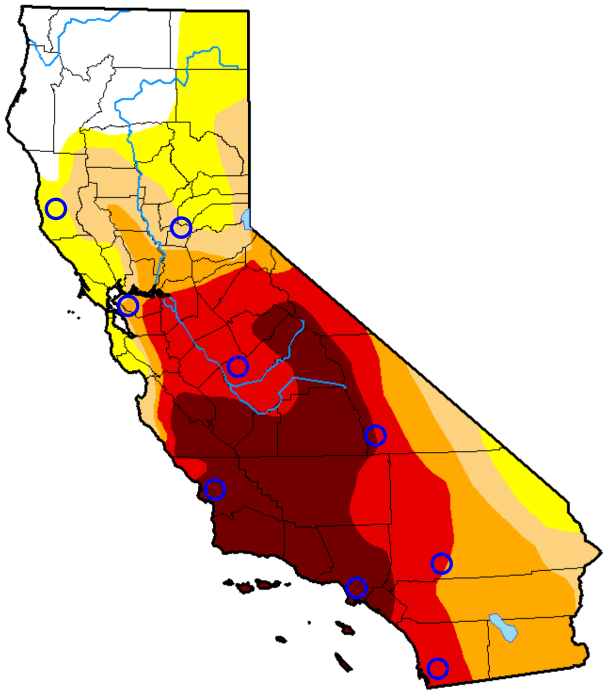
Garcia, E., Berhane, K. T., Islam, T., McConnell, R., Urman, R., Chen, Z., & Gilliland, F. D. (2019). Association of Changes in Air Quality With Incident Asthma in Children in California, 1993-2014. *JAMA, 321*(19), 1906-1915. doi:10.1001/jama.2019.5357

THE USUAL ANALYSIS



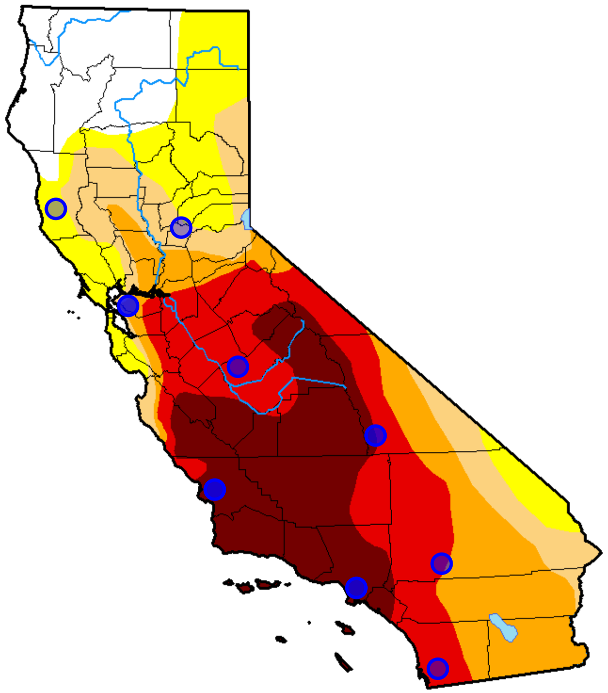
- Recruit over some geographic space

THE USUAL ANALYSIS



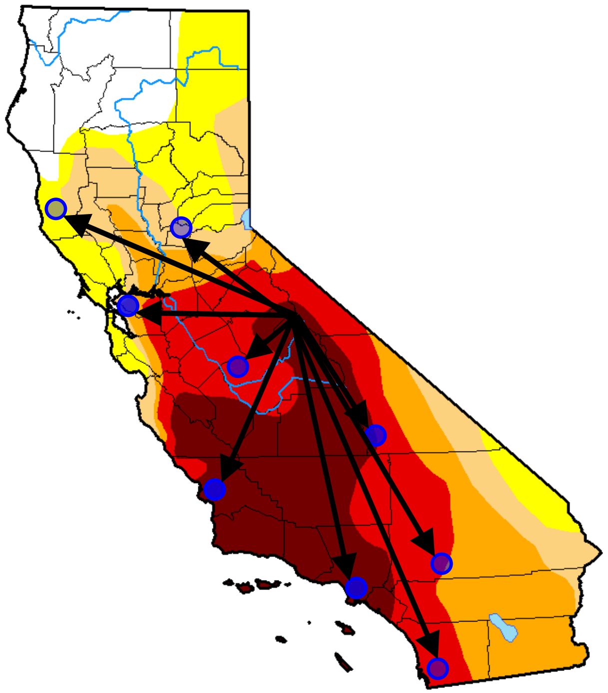
- Recruit over some geographic space
- Assess exposure

THE USUAL ANALYSIS



- Recruit over some geographic space
- Assess exposure
- Follow for outcome

THE USUAL ANALYSIS



- Recruit over some geographic space
- Assess exposure
- Follow for outcome
- Compare outcome by exposure level, which is tied to geographic space

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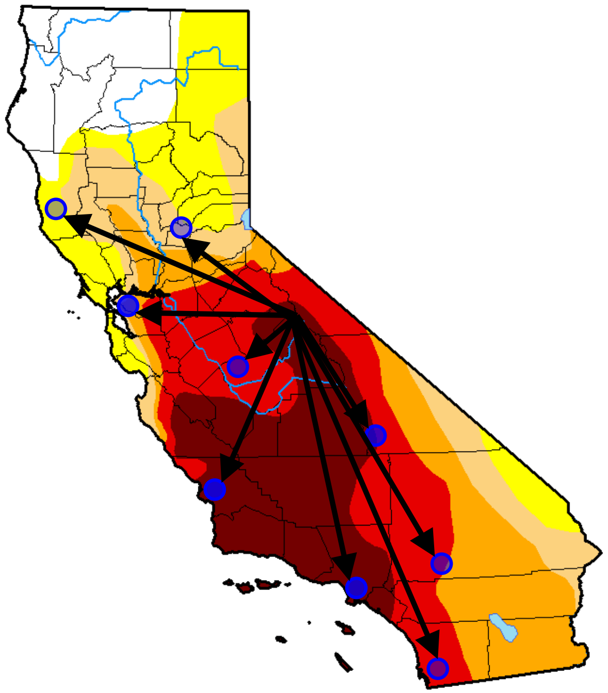

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- Assess exposure
- Follow for outcome
- Compare outcome by exposure level, which is tied to geographic space
  - Concerned about unmeasured spatial confounding

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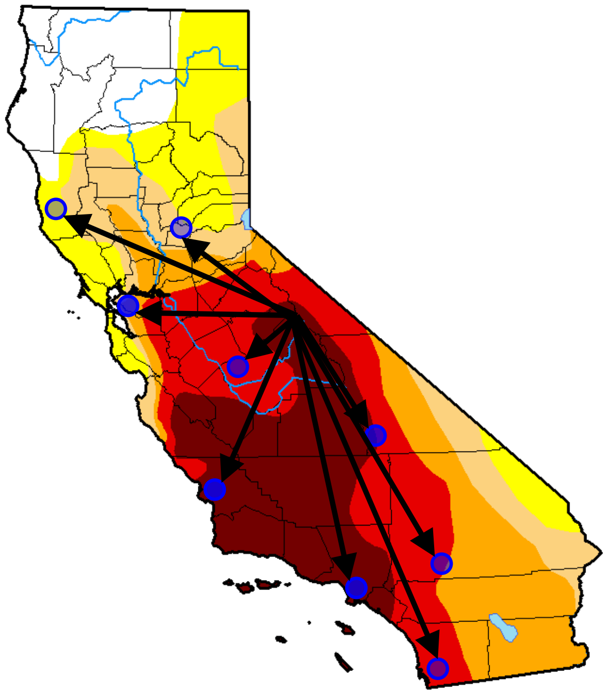


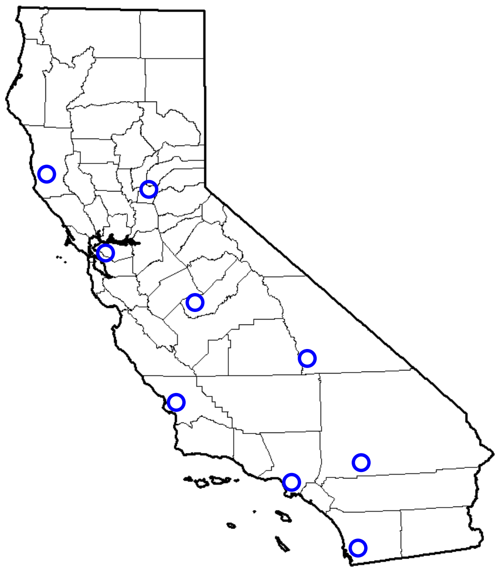
- Recruit over some geographic space
- Assess exposure
- Follow for outcome
- Compare outcome by exposure level, which is tied to geographic space
  - Concerned about unmeasured spatial confounding

Confounding variable: A variable (factor) that is associated with the exposure (e.g., air pollution) and is causally related to the outcome (e.g. asthma incidence), causing a spurious (artificial) association

Example: Access to green space

WHAT IF INSTEAD…

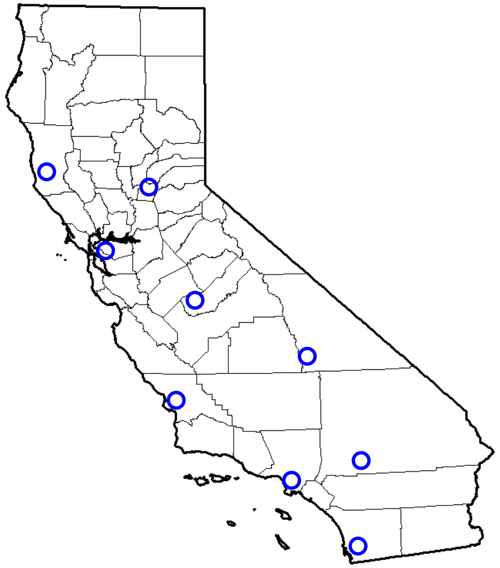
- Recruit in same geographic space, at different times



2000

WHAT IF INSTEAD…

- Recruit in same geographic space, at different times



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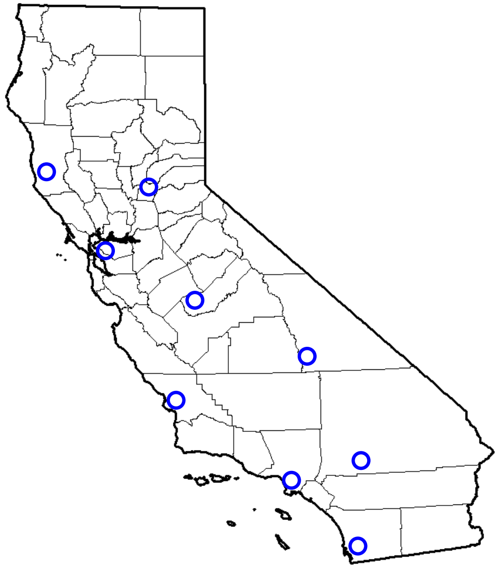
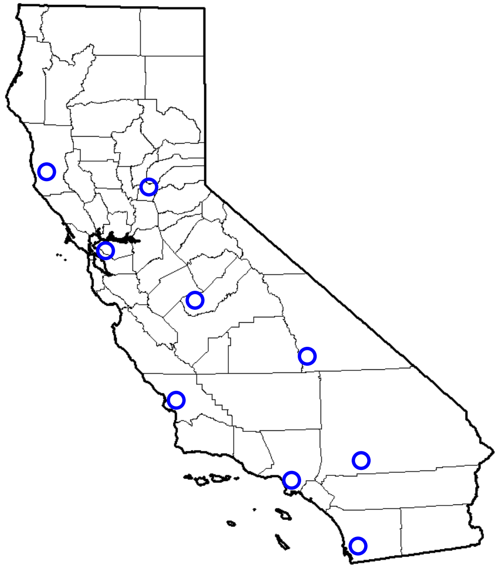


2005

WHAT IF INSTEAD…

- Recruit in same geographic space, at different times



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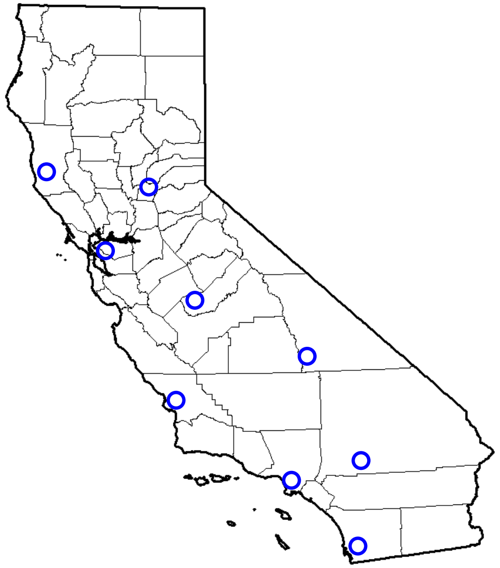
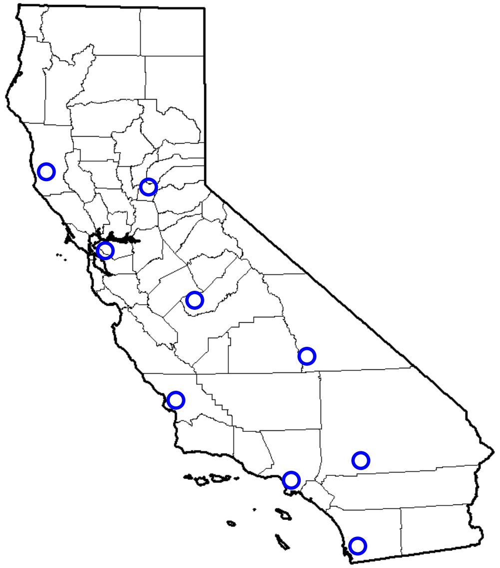


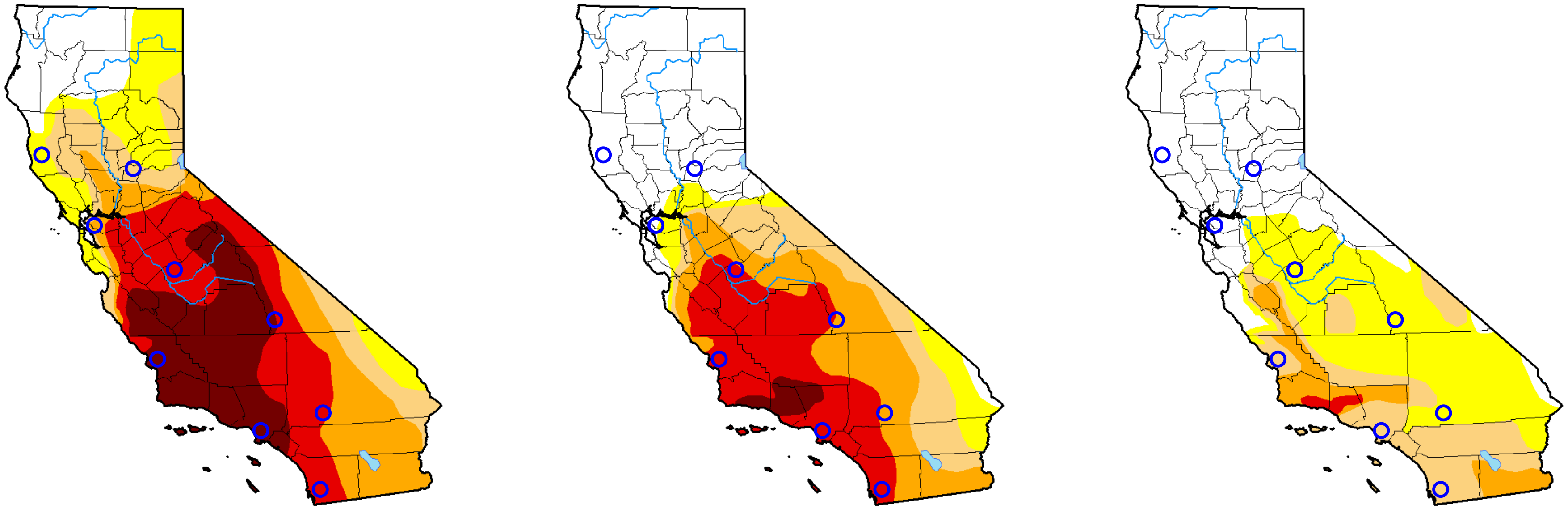
2005



2010

WHAT IF INSTEAD…

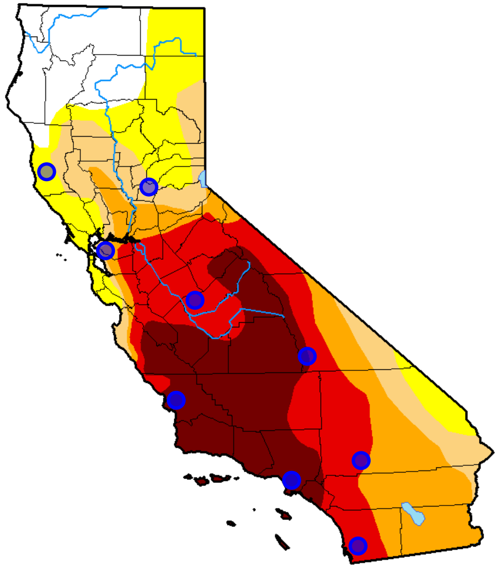
- Air pollution changed over time



2000 2005 2010

WHAT IF INSTEAD…

- Follow for outcome



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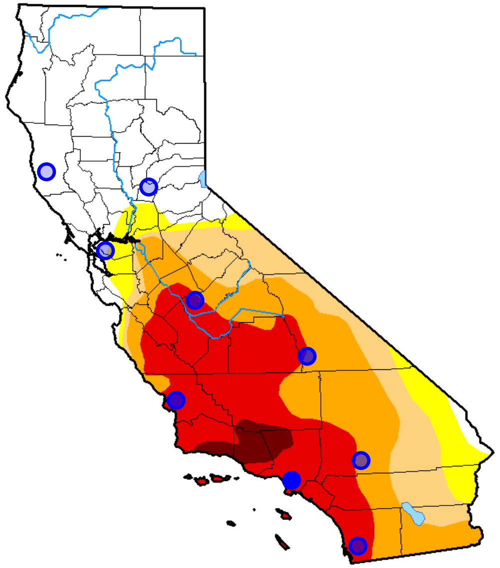

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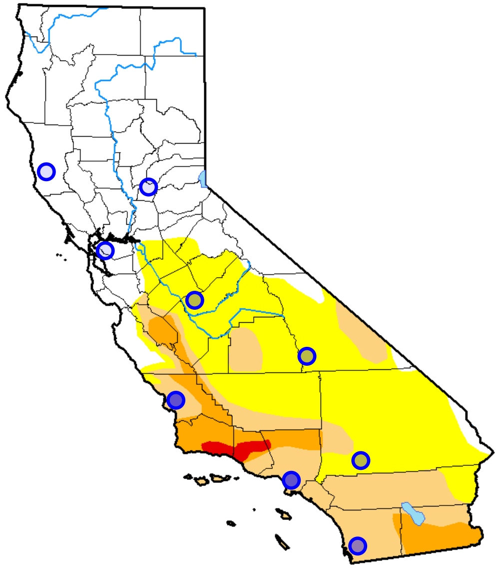
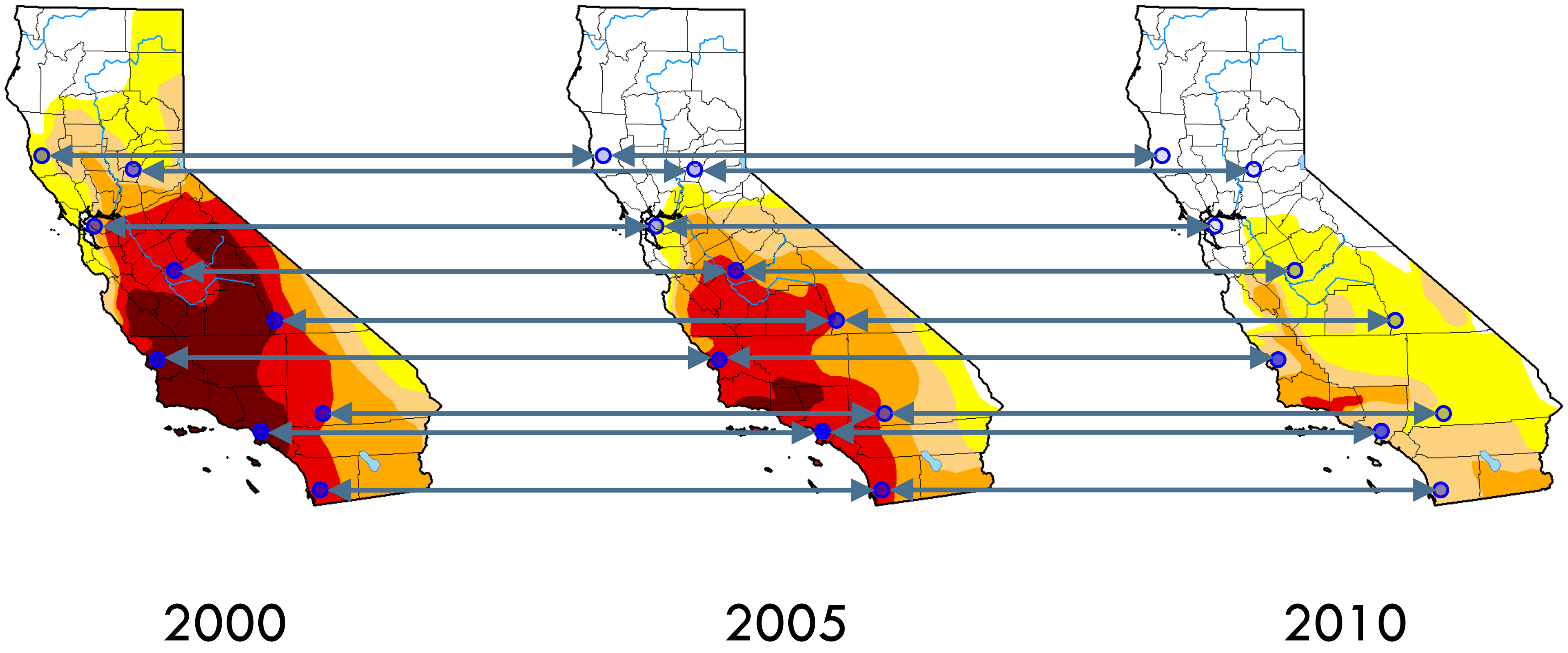


2010

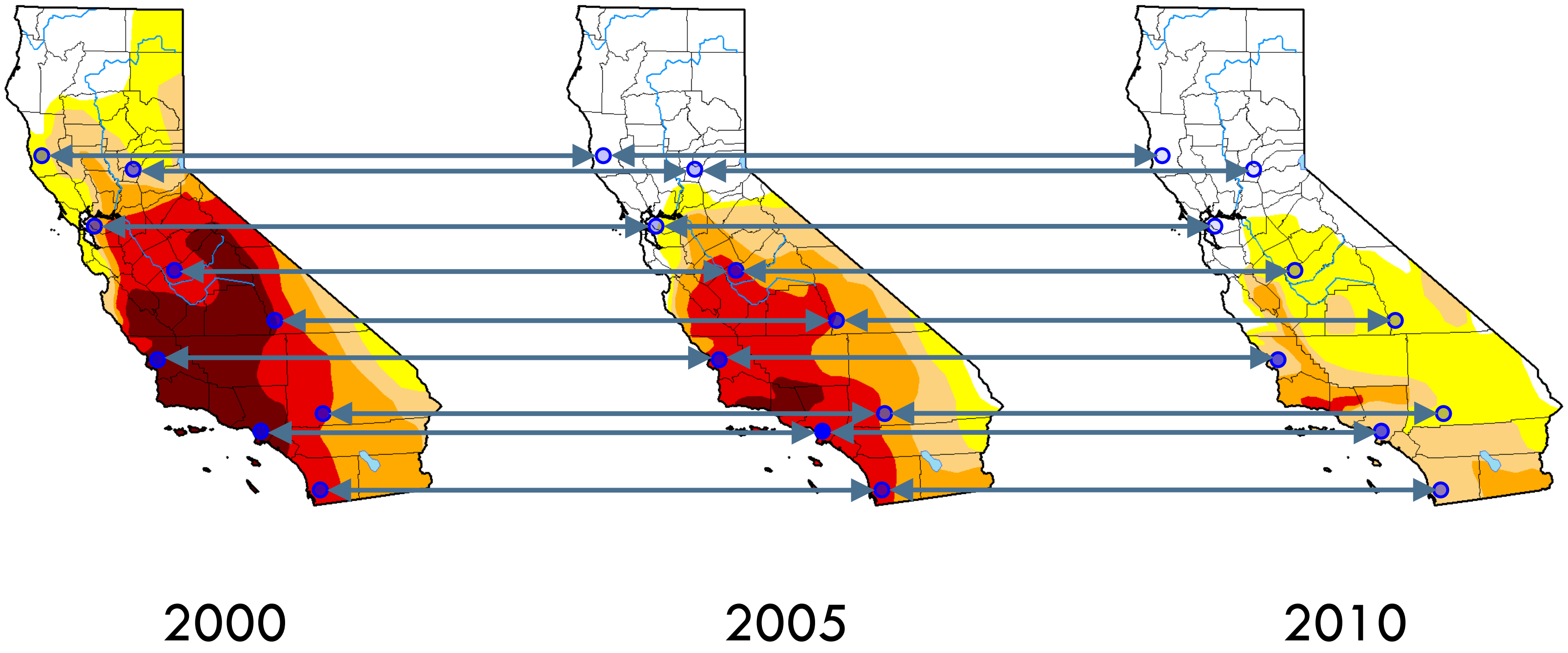
WHAT IF INSTEAD…

- Compare within the same geographic space



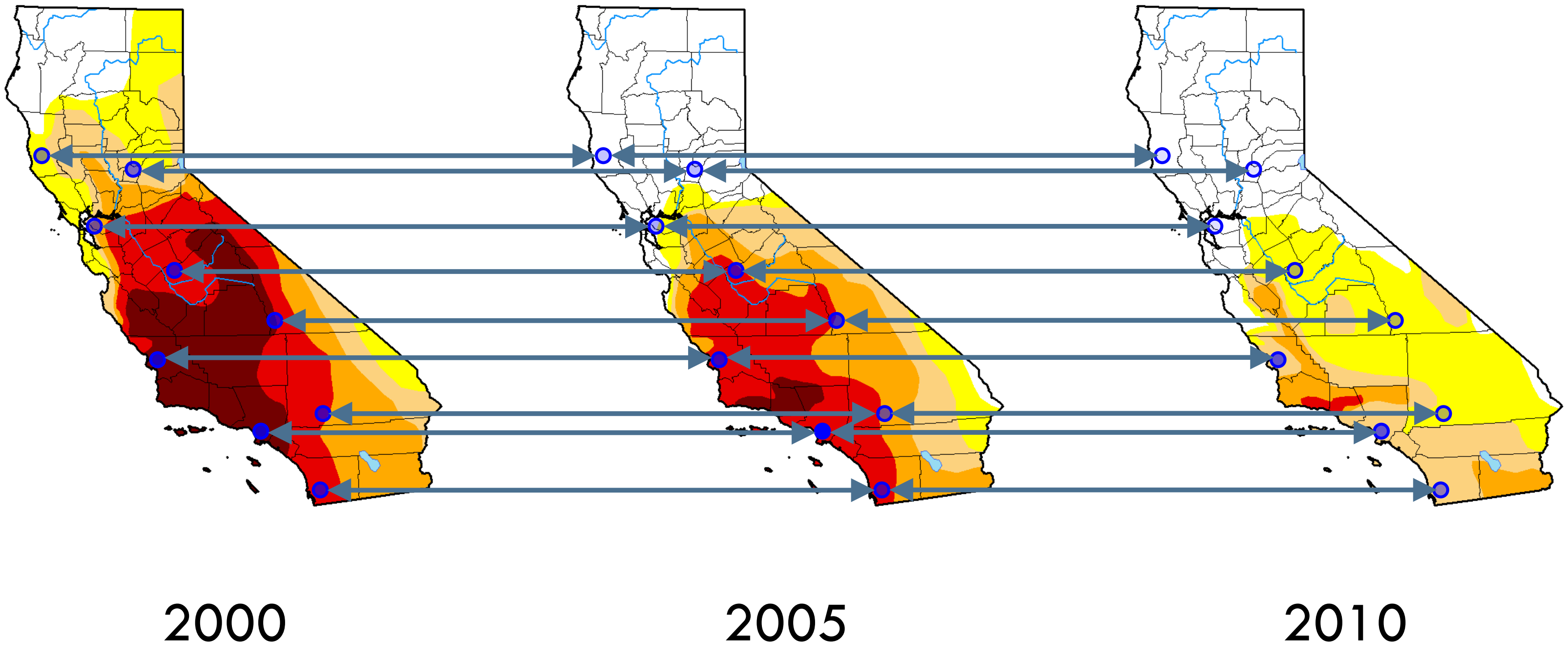
WHAT IF INSTEAD…

- Compare within the same geographic space
  - Control unmeasured spatial confounders



WHAT IF INSTEAD…

- Compare within the same geographic space
  - Control unmeasured spatial confounders
    - ➢ People living in the same communities will be similar to each other



BENEFIT OF THIS DESIGN

Control for unmeasured community-level [spatial] confounders

Take advantage of a natural experiment

Quantify the health benefits associated with reducing air pollution

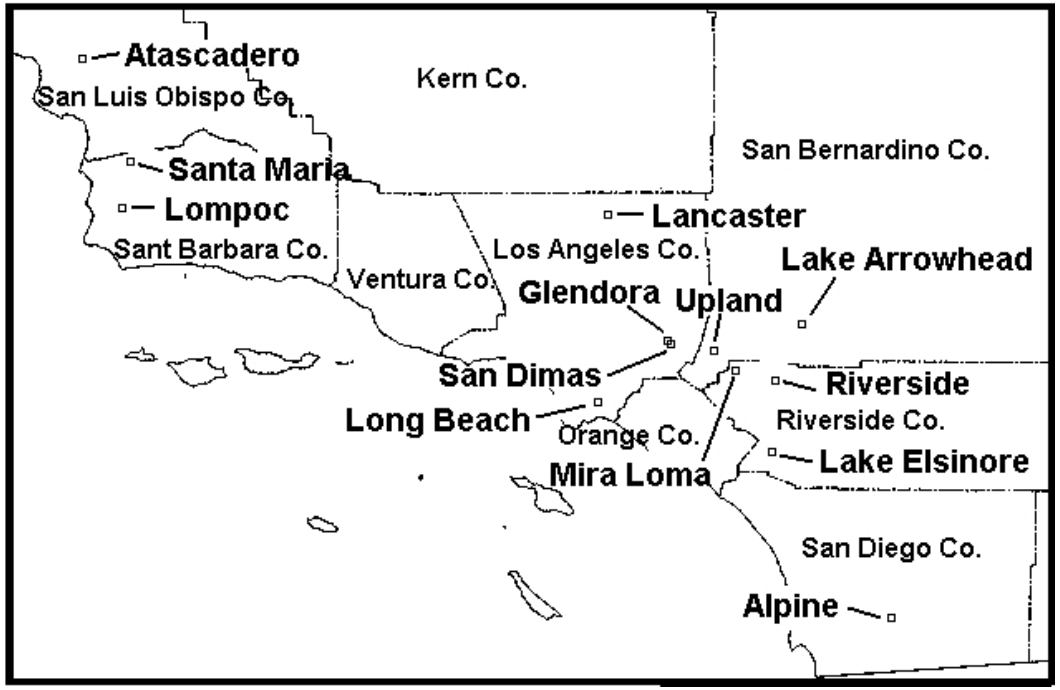
Previously used this study design for lung function growth and bronchitis symptoms in children (Gauderman 2015; Berhane 2016)

WHAT WE DID-DETAILS

Data from the Southern California Children's Health Study (CHS)

Long-term study of cardiopulmonary health outcomes in children

Began in 1993 when 12 communities were selected representing air pollution levels and mixtures in Southern California



AIR POLLUTANTS EXAMINED

Focused on 4 key air pollutants

Have legal regulatory standards

Known to have health effects

1. Nitrogen Dioxide (NO_2)
2. Ozone (O_3)
3. Particulate Matter <2.5 µm ($PM_{2.5}$)
4. Particulate Matter <10 µm (PM_{10})

Photo credit: Praytino via Flickr

WHAT WE DID-DETAILS

3 cohorts from the CHS (N=4,140)

Restricted to participants from the same 9 communities

Followed for 8 years (~4^{th} grade to high school graduation)

- 1993-2001 (N=1,093)
- 1996-2004 (N=1,170)
- 2006-2014 (N=1,877)

Prospectively assessed for MD-diagnosed asthma via questionnaire (N cases=525)

WHAT WE DID-DETAILS

Multilevel Poisson model

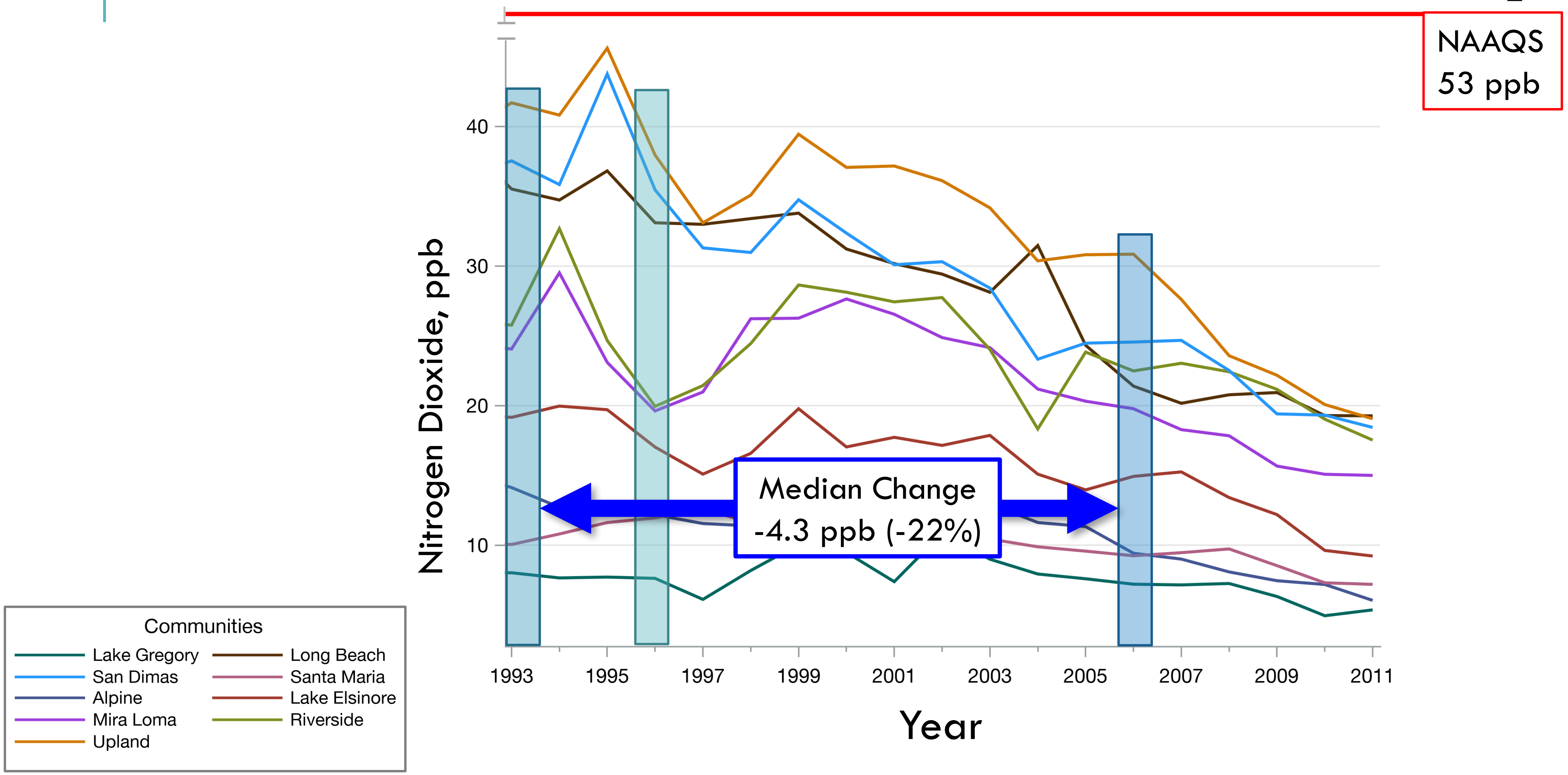
- Random effect for cohort nested within town and fixed effect for town
- Adjusted for potential confounders identified *a priori*: age, sex, race, ethnicity, gas stove in home, sports participation, ambient temperature, and residential traffic

Exposure: Community-level annual average pollutant concentration in baseline year for each cohort

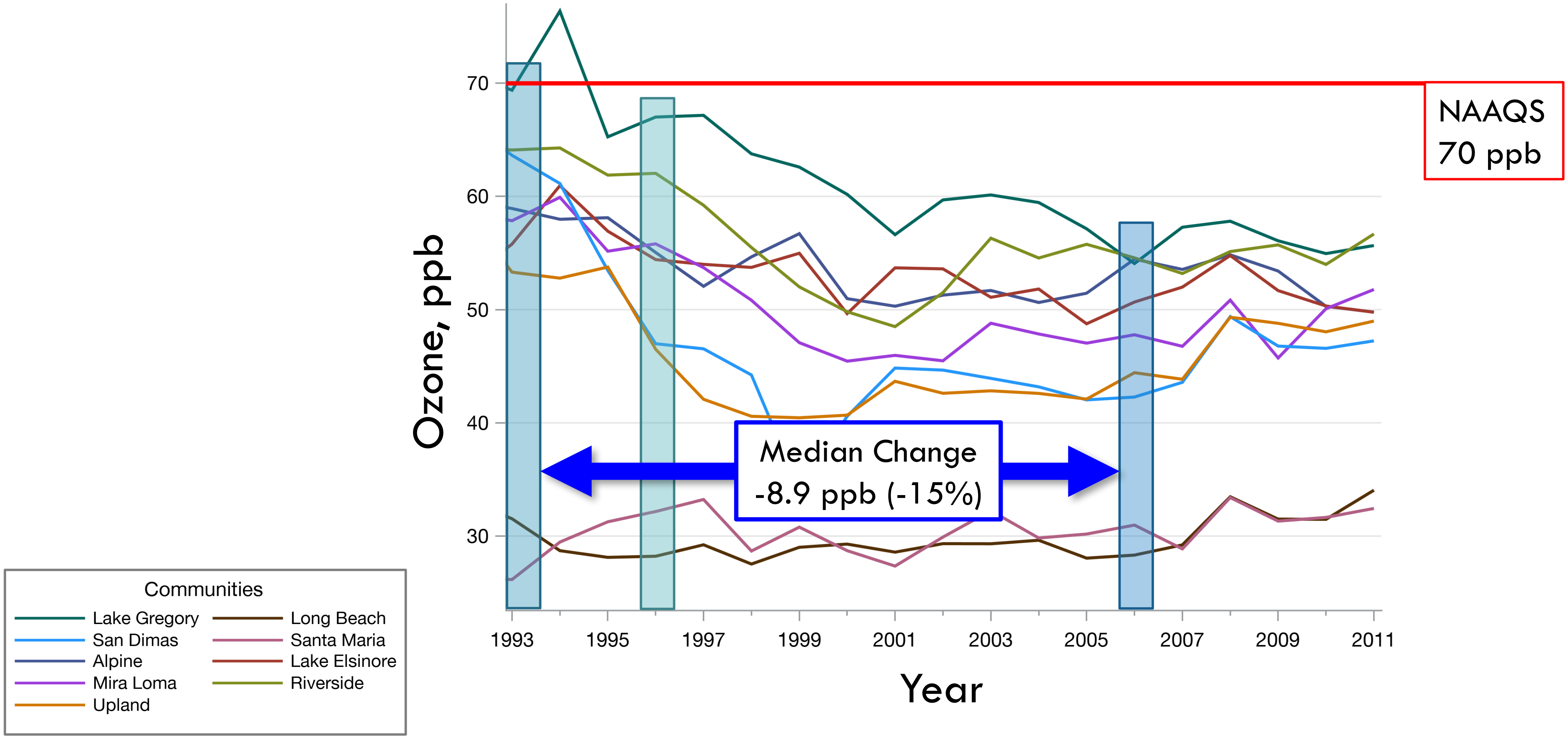
- 1993, 1996, 2006

Outcome: Asthma incidence during follow up

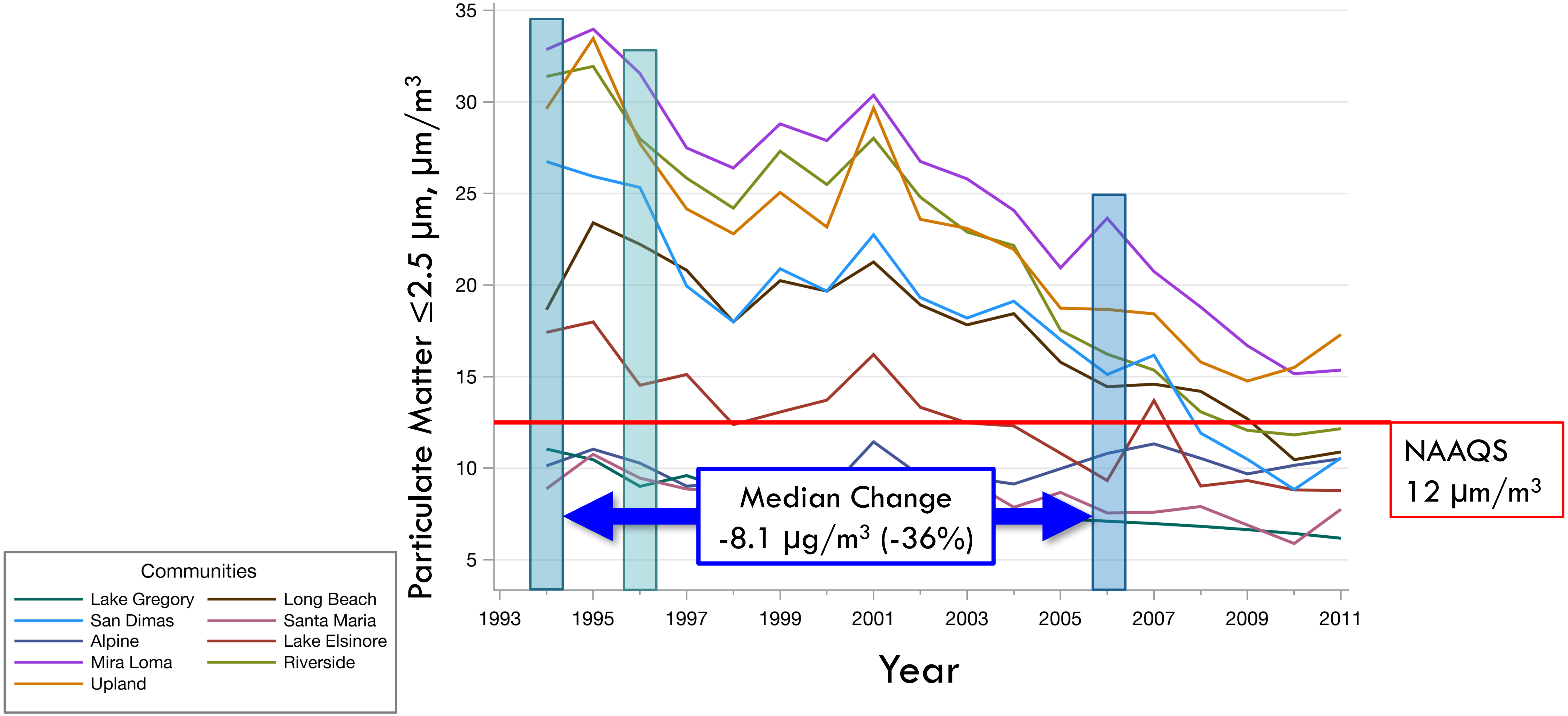
TAKING ADVANTAGE OF A NATURAL EXPERIMENT: NO_2



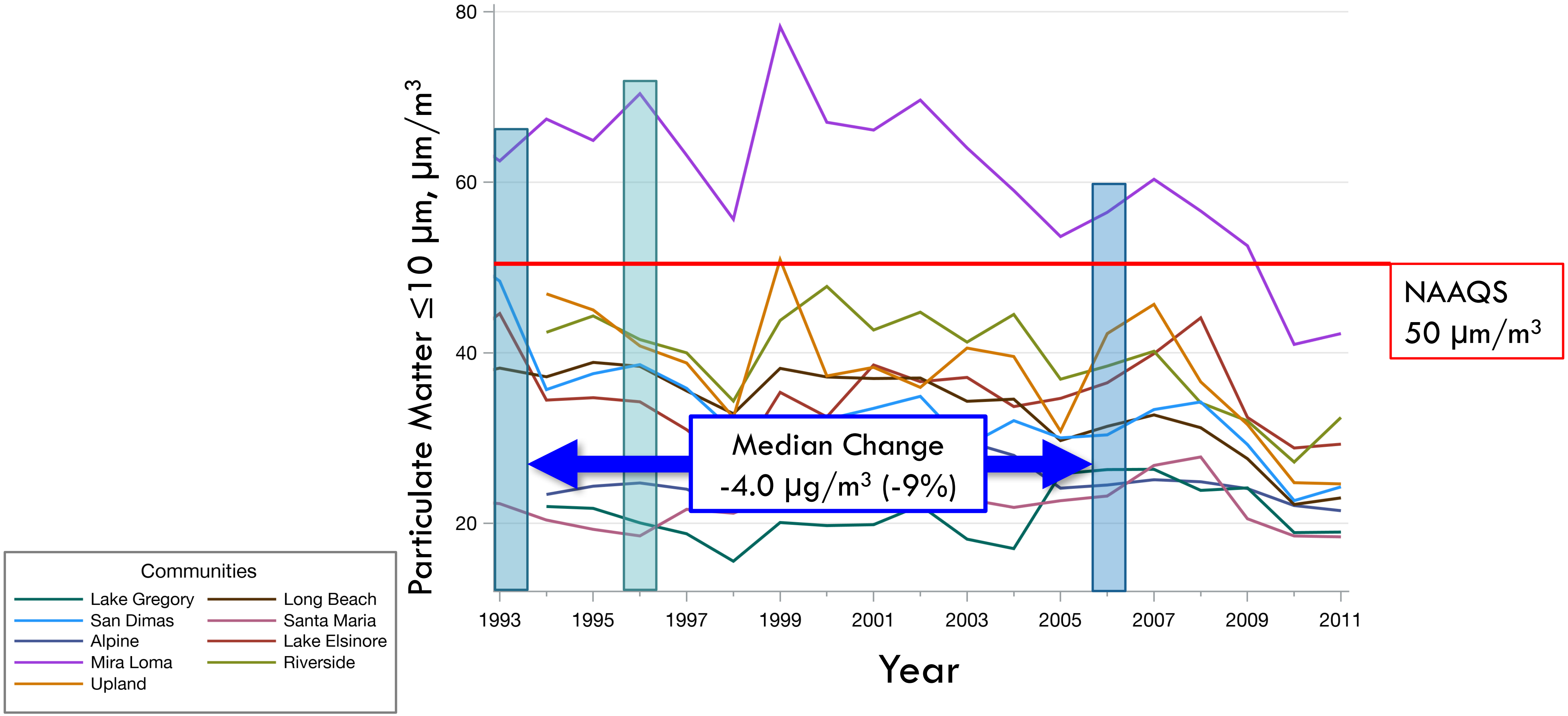
TAKING ADVANTAGE OF A NATURAL EXPERIMENT: O_3



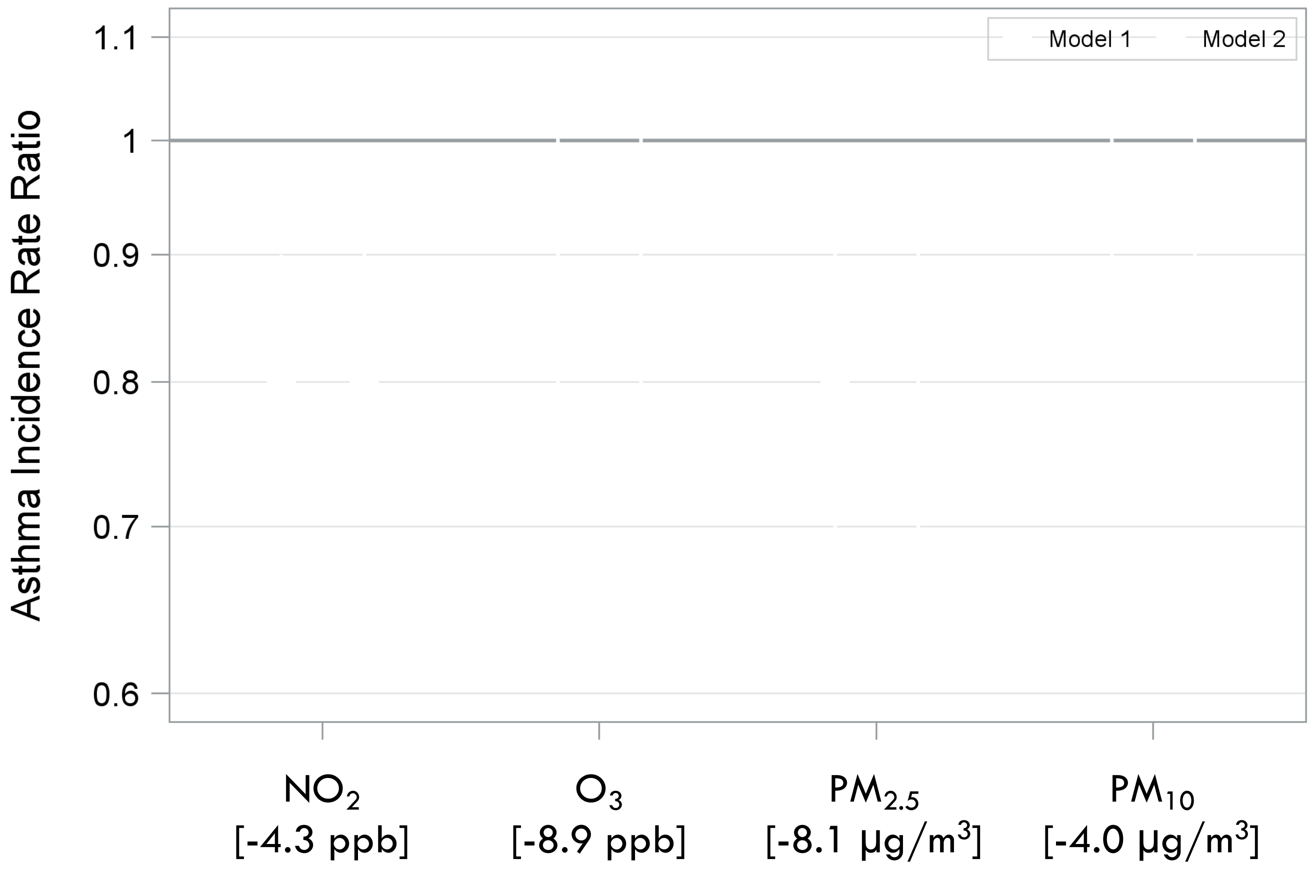
TAKING ADVANTAGE OF A NATURAL EXPERIMENT: $PM_{2.5}$



TAKING ADVANTAGE OF A NATURAL EXPERIMENT: PM_{10}



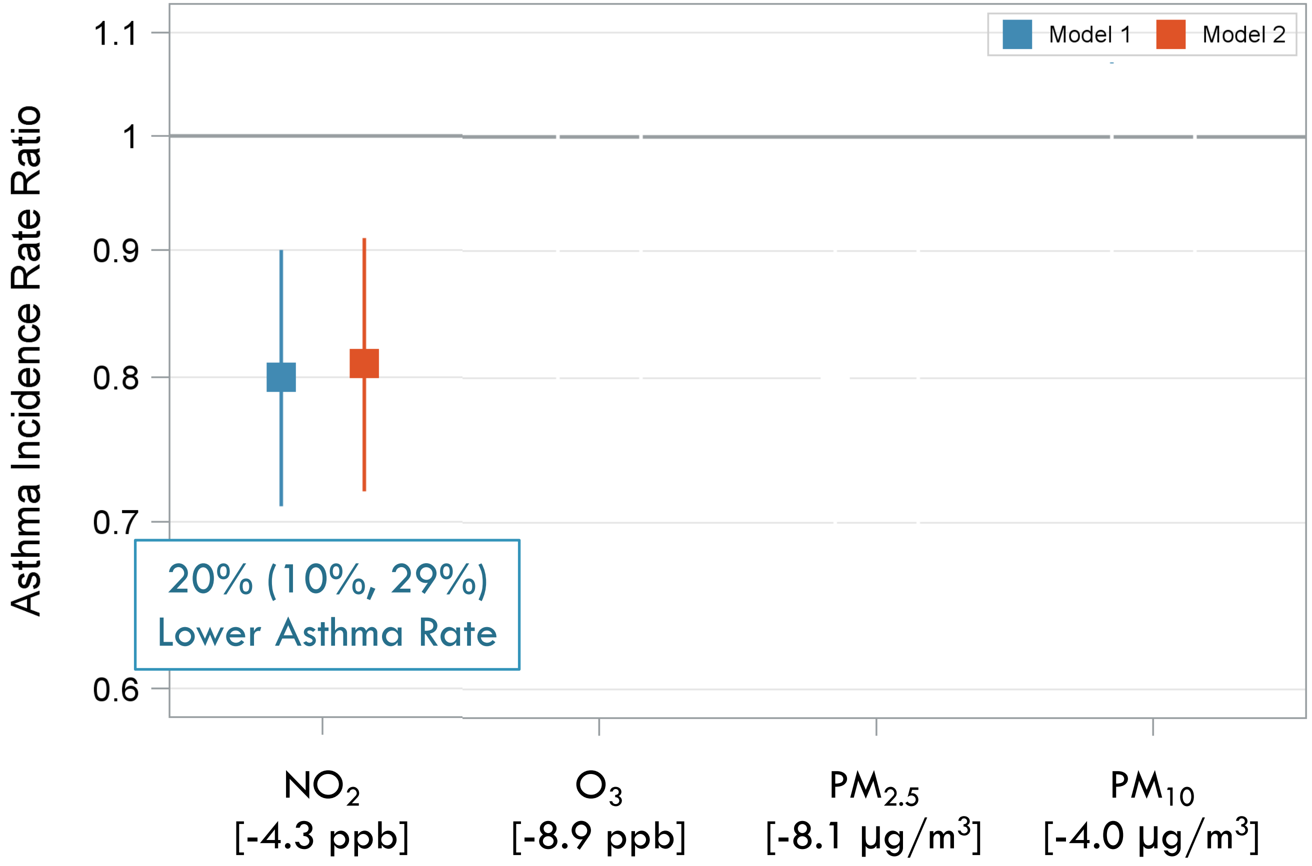
OUR FINDINGS



Model details

- 1: Adjusted for age at baseline, sex, ethnicity, race, gas stove in home, sports participation, and community-level average temperature for baseline year (N=4,140)
- 2: Additionally adjusted for residential traffic (N=3,942)

REDUCTION IN NO_2 ASSOCIATED WITH LOWER ASTHMA INCIDENCE RATE



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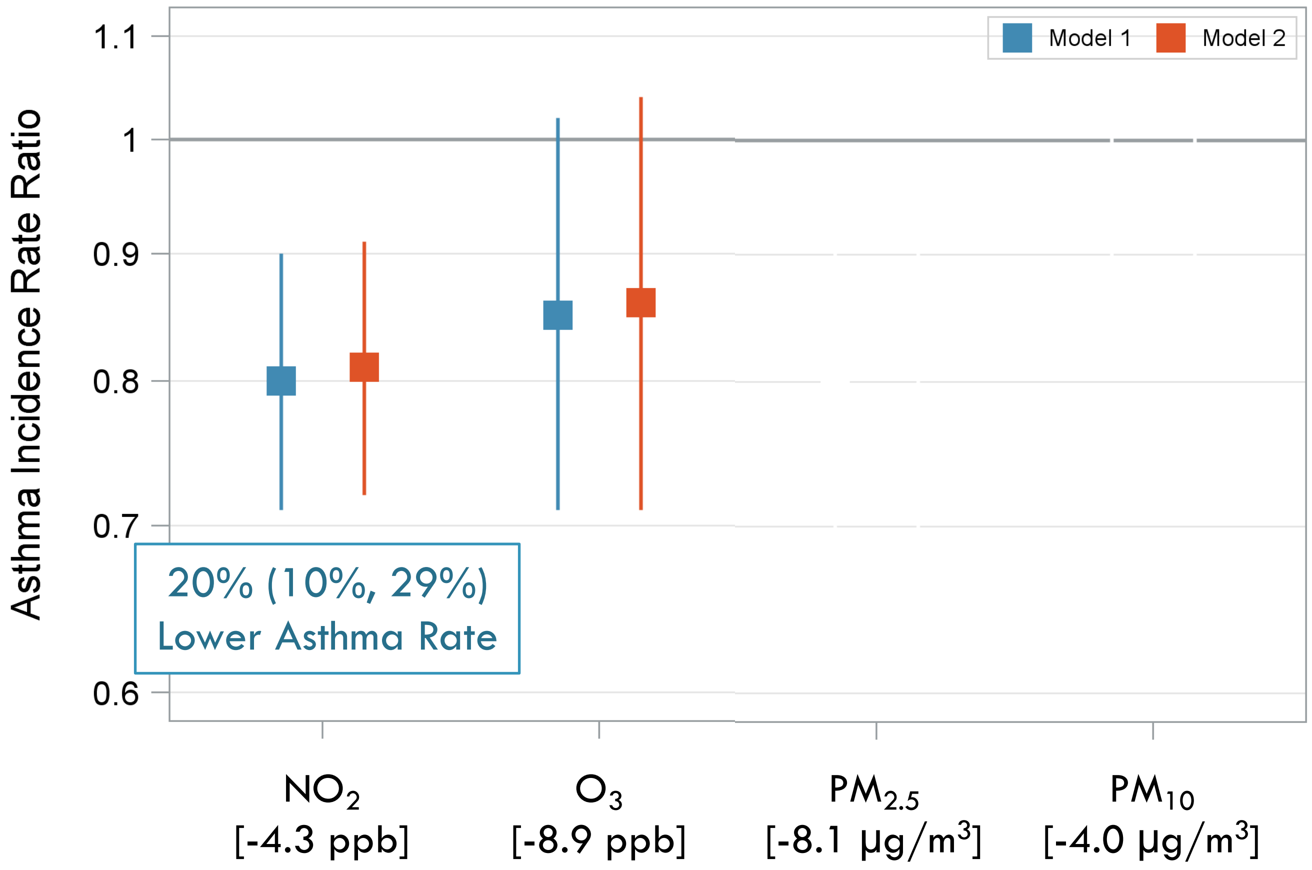

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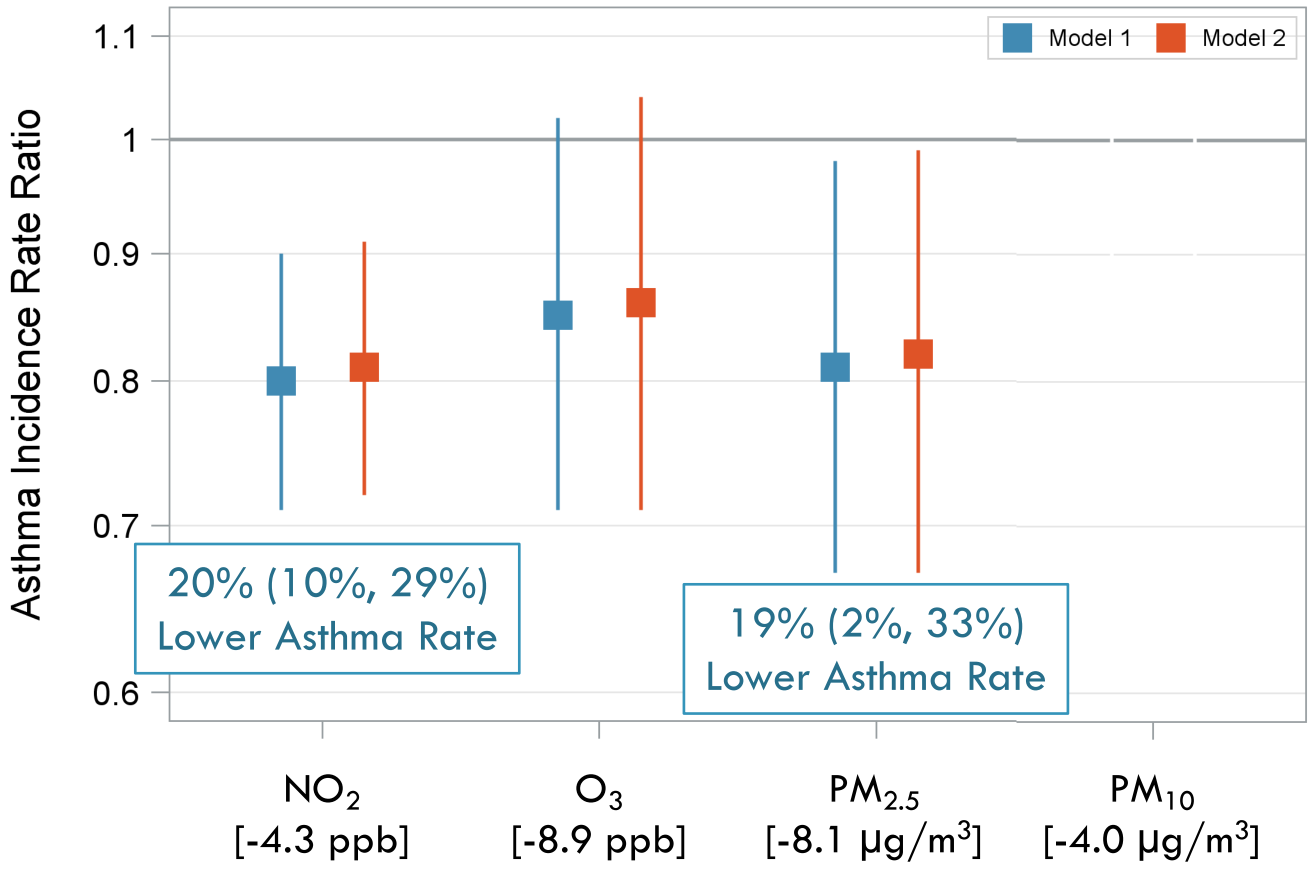
REDUCTION IN NO_2 AND $PM_{2.5}$ ASSOCIATED WITH LOWER ASTHMA INCIDENCE RATE



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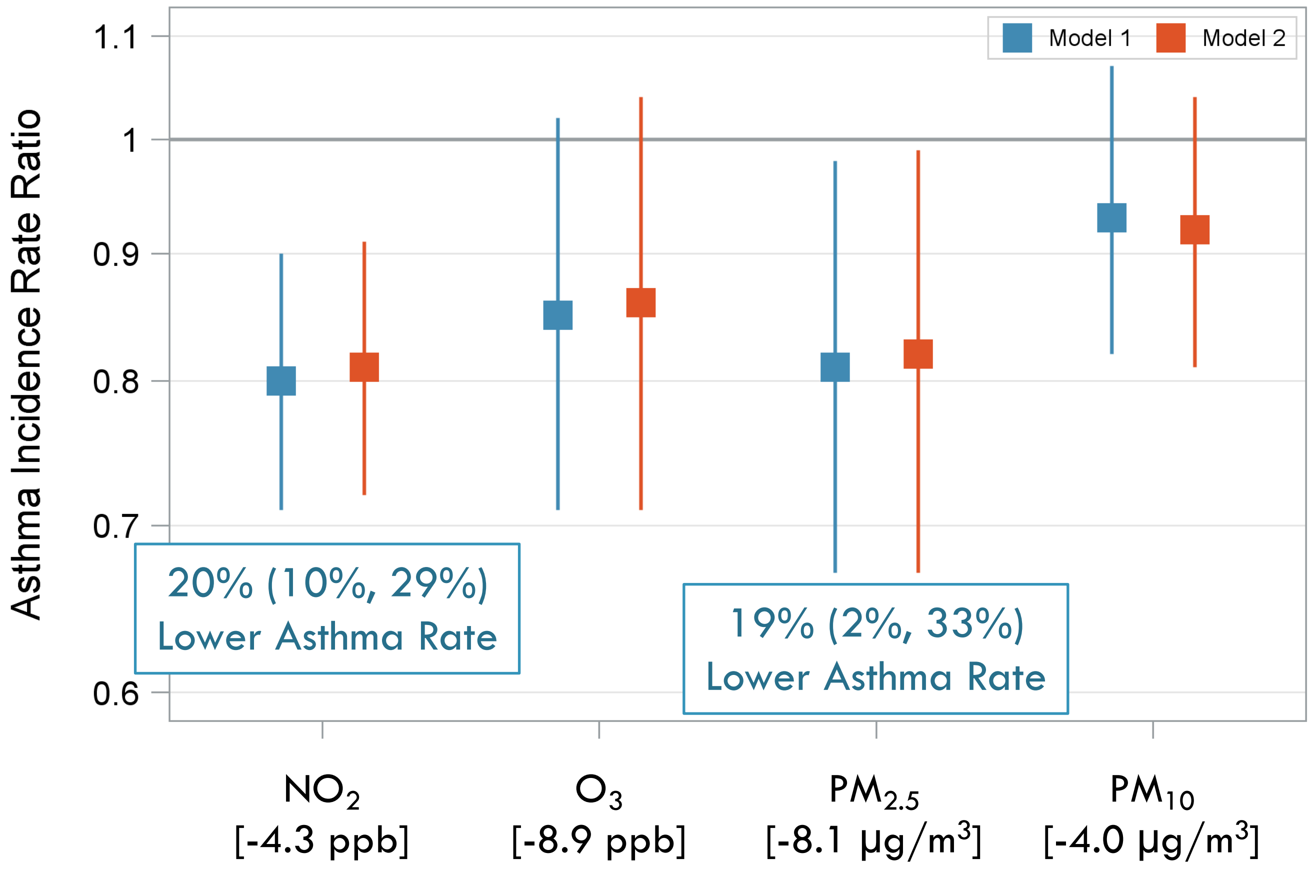

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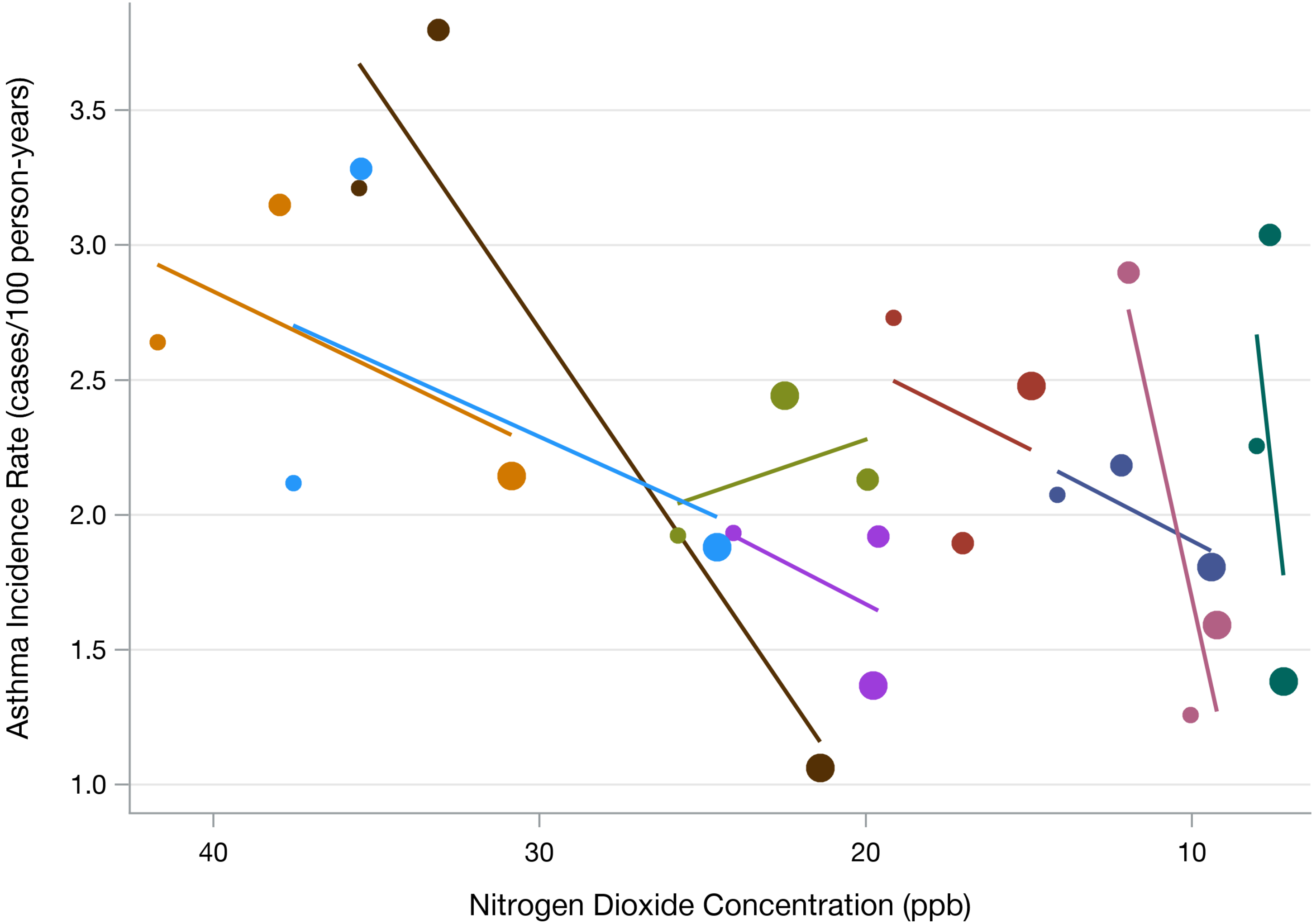
CHANGE IN NO_2 AND ASTHMA INCIDENCE

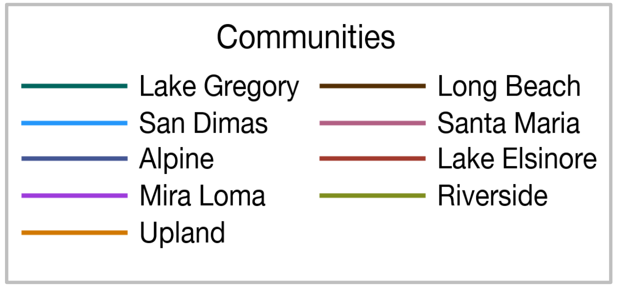


Dot size indicates cohort

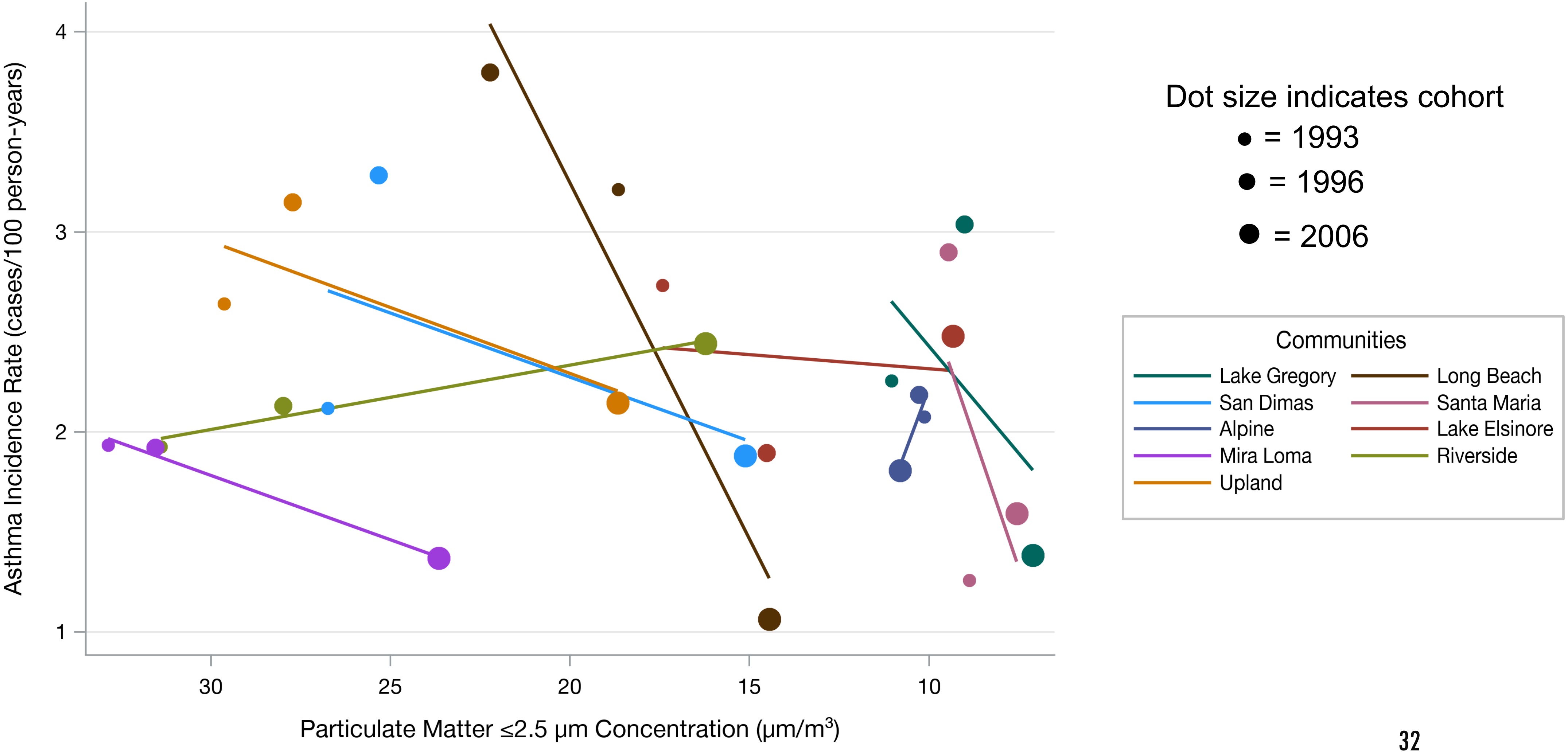
= 1993

= 1996

= 2006



CHANGE IN $PM_{2.5}$ AND ASTHMA INCIDENCE



FINDINGS FROM ADDITIONAL ANALYSES

No evidence of effects estimates differing by air pollution level (high v. low), sex, race, ethnicity, parental educational attainment, or use of Spanish (versus English) language baseline questionnaire

NO_2 findings held up in a variety of sensitivity analyses

SUMMARY OF RESULTS

There have been great reductions in air pollutant concentrations between 1993 and 2006 in this region, including 22% for NO_2 and 36% for $PM_{2.5}$

Cleaner air was related with lower rates of new-onset asthma in children

- A reduction of 4.3 ppb NO_2 was associated with 20% (10%, 29%) lower rate of asthma
- A reduction of 8.1 µg/m^3 $PM_{2.5}$ was associated with 19% (2%, 33%) lower rate of asthma

Findings for NO_2 were robust to a variety of sensitivities analyses

There was no evidence that the findings were driven by a subgroup of children

CONCLUDING REMARKS

Provides further evidence for the causal link between ambient NO_2 exposure and incident childhood asthma

Effects observed in communities with a mean baseline NO_2 concentration of 24 ppb—well below the current US EPA annual standard of 53 ppb

Policy implications for NO_2 air quality regulations

ACKNOWLEDGEMENTS

Co-authors

- Kiros T. Berhane
- Talat Islam
- Rob McConnell
- Robert Urman
- Zhanghua Chen
- Frank D. Gilliland

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We thank the participating students and their families, the school staff and administrators, the regional and state air monitoring agencies, and the members of the study field team

THANK YOU

Questions?

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DISTRIBUTION OF SELECTED PARTICIPANT CHARACTERISTICS FROM THE CHILDREN'S HEALTH STUDY, 1993-2014

		Cohort Follow-up Period, N (%)		
Characteristic	**All Participants, N (%)**	**1993-2001**	**1996-2004**	**2006-2014**
Subjects	4140	1093	1170	1877
Person-years of follow-up	24254	6201	6842	11211
Incident asthma cases	525	139	184	202
Age at baseline	9.5 (0.6)	9.9 (0.5)	9.5 (0.4)	9.3 (0.7)
Sex				
Female	2179 (52.6)	569 (52.1)	606 (51.8)	1004 (53.5)
Male	1961 (47.4)	524 (47.9)	564 (48.2)	873 (46.5)
Ethnicity				
Hispanic	1686 (42.2)	307 (28.4)	413 (35.5)	966 (55.2)
Non-Hispanic	2310 (57.8)	776 (71.7)	750 (64.5)	784 (44.8)
Race				
Asian/Pacific Islander	178 (4.6)	60 (5.6)	56 (4.8)	62 (3.8)
Black	145 (3.7)	50 (4.7)	54 (4.7)	41 (2.5)
Native American Indian/Other	890 (23)	182 (17)	249 (21.5)	459 (27.8)
White	2273 (58.6)	704 (65.7)	692 (59.8)	877 (53.2)
Mixed	392 (10.1)	76 (7.1)	106 (9.2)	210 (12.7)
Residential traffic-related pollution, mean (SD), ppb	19.6 (22.1)	27.5 (27.8)	20.5 (23.3)	14.9 (15.8)

RESULTS TABLE

	Model 1	Model 2
NO_2 [-4.3 ppb]	0.80 (0.71, 0.90)	0.81 (0.72, 0.91)
O_3 [-8.9 ppb]	0.85 (0.71, 1.02)	0.86 (0.71, 1.04)
$PM_{2.5}$ [-8.1 µg/m^3]	0.81 (0.67, 0.98)	0.82 (0.67, 0.99)
PM_{10} [-4.0 µg/m^3]	0.93 (0.82, 1.07)	0.92 (0.81, 1.04)

Rate Ratio (RR) per median change in air pollutant concentration from 1993 to 2006

Model details

- 1: Adjusted for age at baseline, sex, ethnicity, race, gas stove in home, sports participation, and community-level average temperature for baseline year
- 2: Additionally adjusted for residential traffic (N=3,942)

SENSITIVITY ANALYSES RESULTS

Sensitivity Analysis	N	N cases	NO_2 RR (95% CI)	$PM_{2.5}$ RR (95% CI)
Excluded one town				
Alpine	3665	471	0.80 (0.71, 0.90)	0.80 (0.65, 0.99)
Lake Elsinore	3724	468	0.77 (0.68, 0.87)	0.73 (0.59, 0.90)
Lake Gregory	3651	466	0.80 (0.71, 0.91)	0.84 (0.69, 1.02)
Long Beach	3731	466	0.86 (0.75, 0.98)	0.87 (0.71, 1.06)
Mira Loma	3645	477	0.80 (0.71, 0.90)	0.80 (0.65, 1.00)
Riverside	3679	464	0.80 (0.70, 0.90)	0.71 (0.56, 0.89)
San Dimas	3715	467	0.77 (0.67, 0.89)	0.84 (0.67, 1.04)
Santa Maria	3650	471	0.81 (0.72, 0.91)	0.82 (0.67, 0.99)
Upland	3660	450	0.80 (0.70, 0.91)	0.84 (0.67, 1.05)
Excluded subjects reporting wheeze or 3+ months of cough in prior 12 months at baseline	3723	411	0.81 (0.71, 0.92)	0.79 (0.62, 0.99)
Adjusted for:				
Income, education, and insurance	4140	525	0.79 (0.70, 0.89)	0.80 (0.65, 0.98)
In utero smoking exposure	4140	525	0.80 (0.71, 0.90)	0.81 (0.66, 0.98)
Pests, pets, and carpet	4140	525	0.81 (0.71, 0.91)	0.82 (0.68, 1.00)

Rate ratios scaled to -4.3 ppb for NO_2 and -8.1 μg/m³ for $PM_{2.5}$.

Models adjusted for community as a fixed effect, age at baseline, sex, ethnicity, race, gas stove in home, participation in sports, and community-level average temperature for baseline year.

RECENT META-ANALYSIS ON AIR POLLUTION & INCIDENT CHILDHOOD ASTHMA

Meta-analysis of 21 papers published before Sept 2016 (Khreis 2017)

Pollutant	Random-effect risk estimate
NO_2	1.05 (1.02, 1.07) per 4 µg/m^3
$PM_{2.5}$	1.03 (1.01, 1.05) per 1 µg/m^3
PM_{10}	1.05 (1.02, 1.08) per 2 µg/m^3