

# Air Pollution and Health in Children

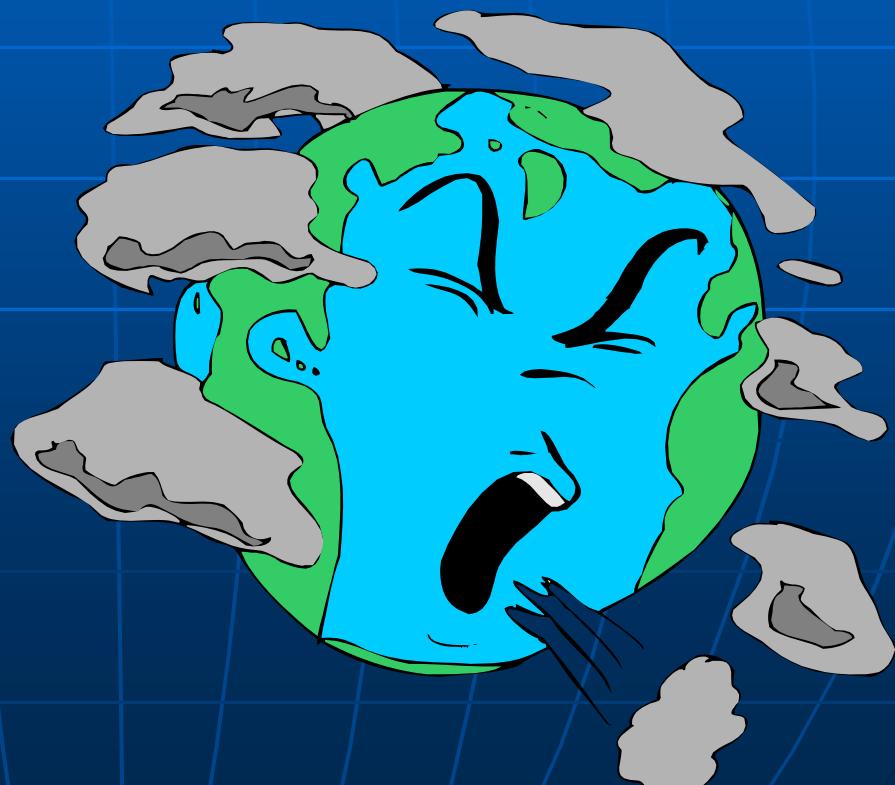


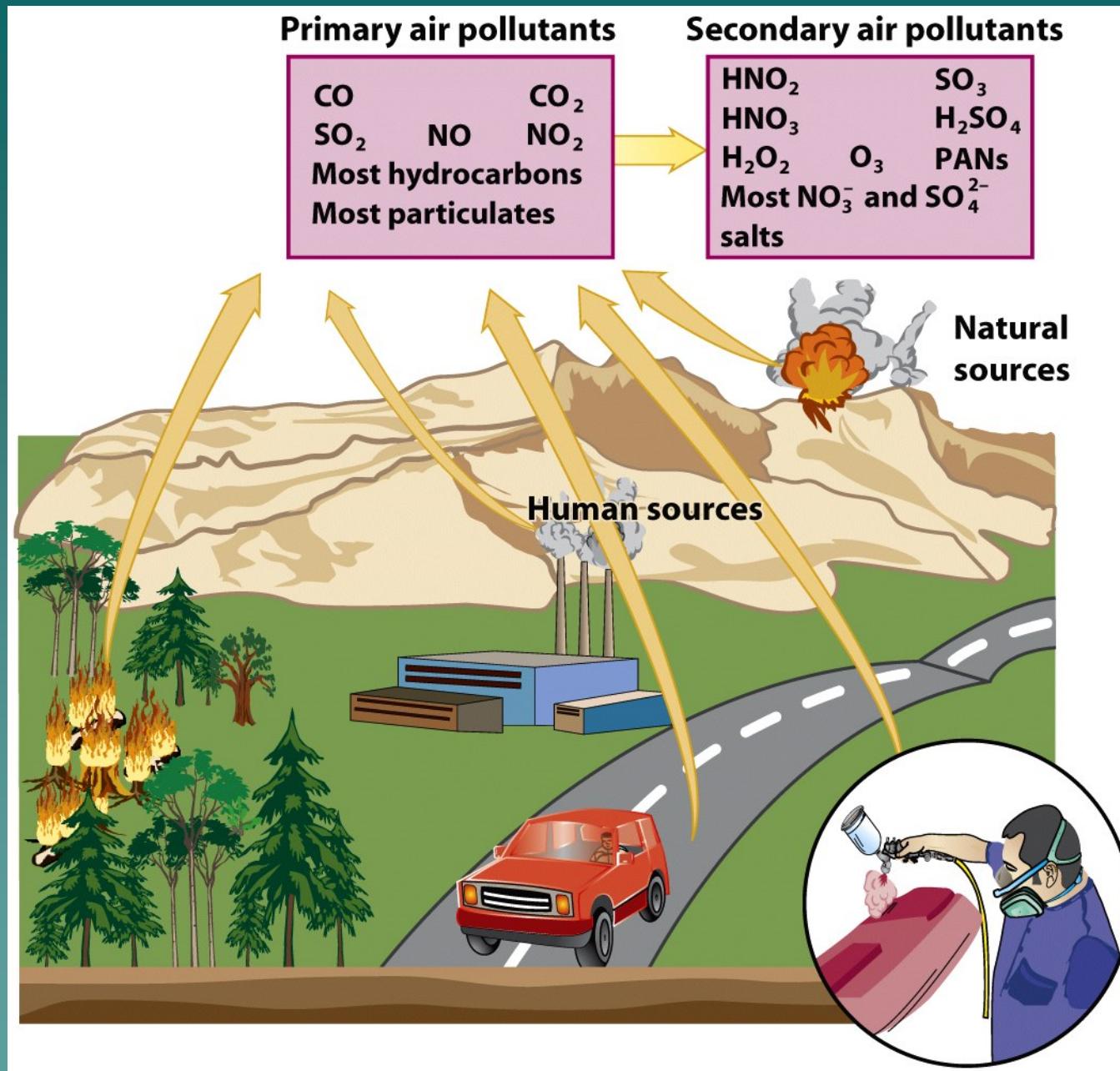
**Jim Gauderman, Ph.D.  
The 'Children's Health Study'  
Department of Preventive Medicine  
Keck School of Medicine of USC**



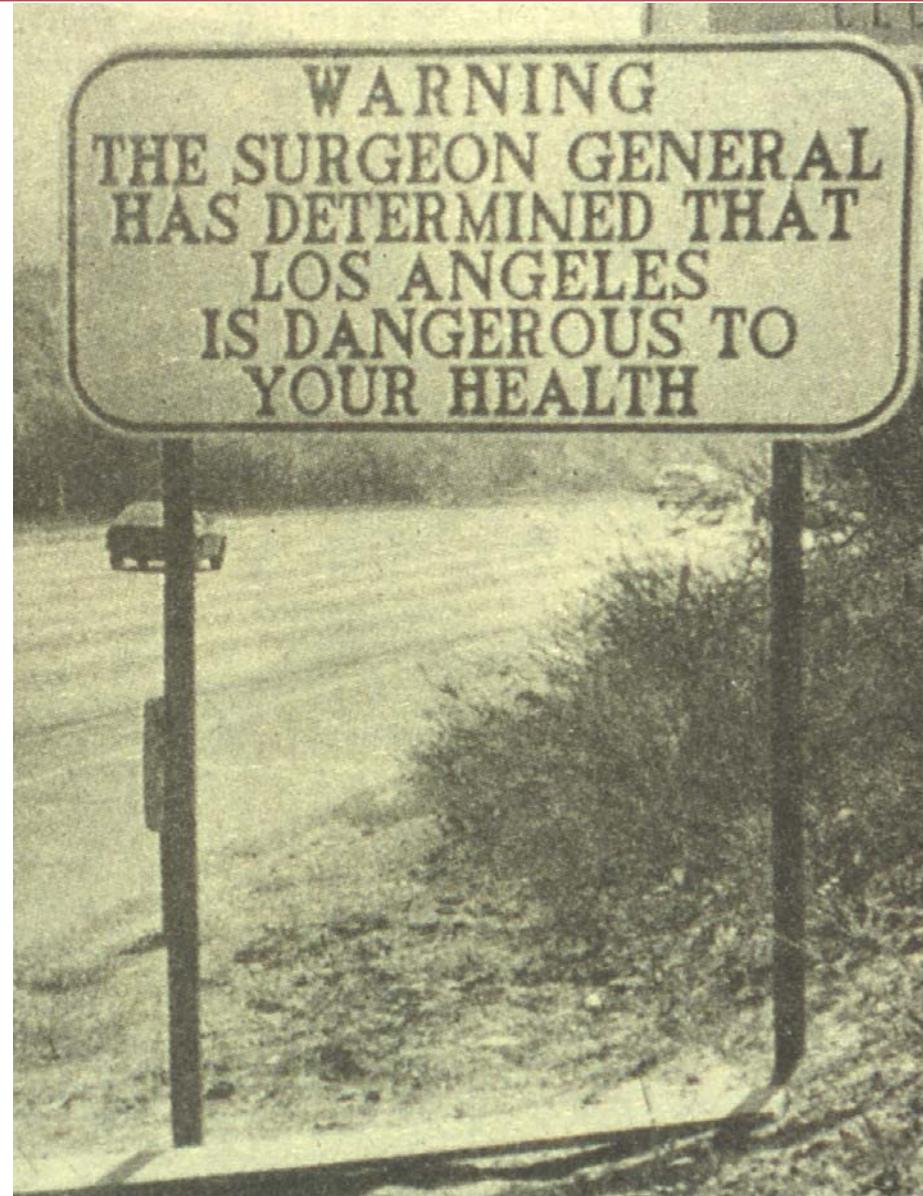
# Air Pollution: What is it?

Any visible or invisible particle or gas found in the air that is not part of the original, normal composition.



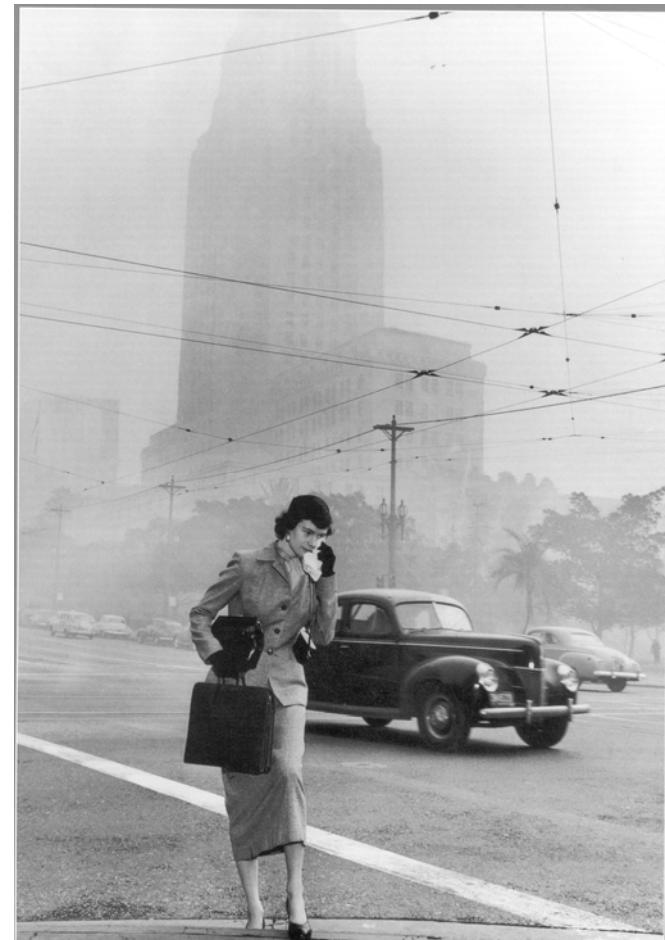


**Don't we  
already know  
air pollution  
is bad for us?**



# Well Established

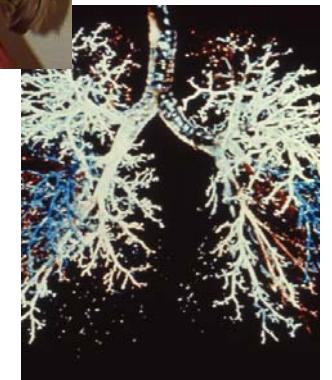
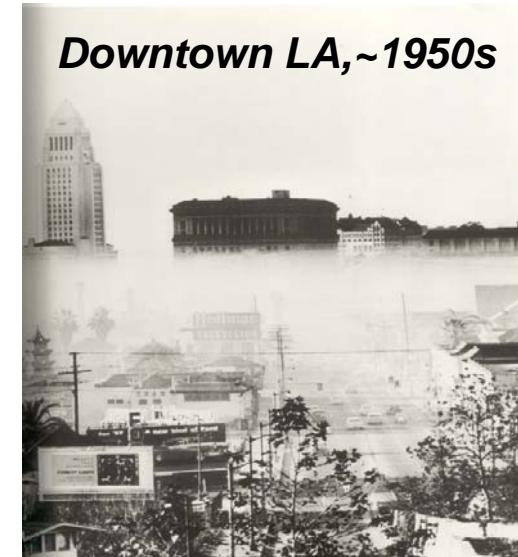
- Air pollution causes acute (short-term) effects, e.g.
  - Physician visits
  - Lung function changes
  - Acute symptoms in asthmatics and other susceptible subgroups



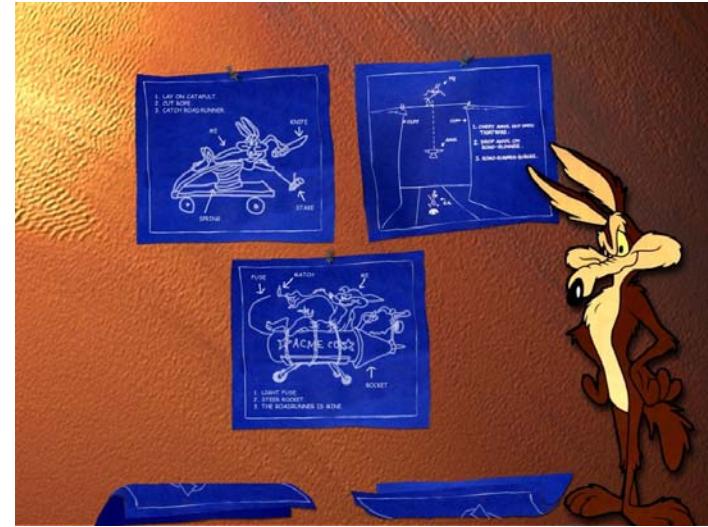
## Less-well Understood...

Does outdoor air pollution cause chronic health effects?

- ↑ Asthma risk?
- ↓ Lung function growth?

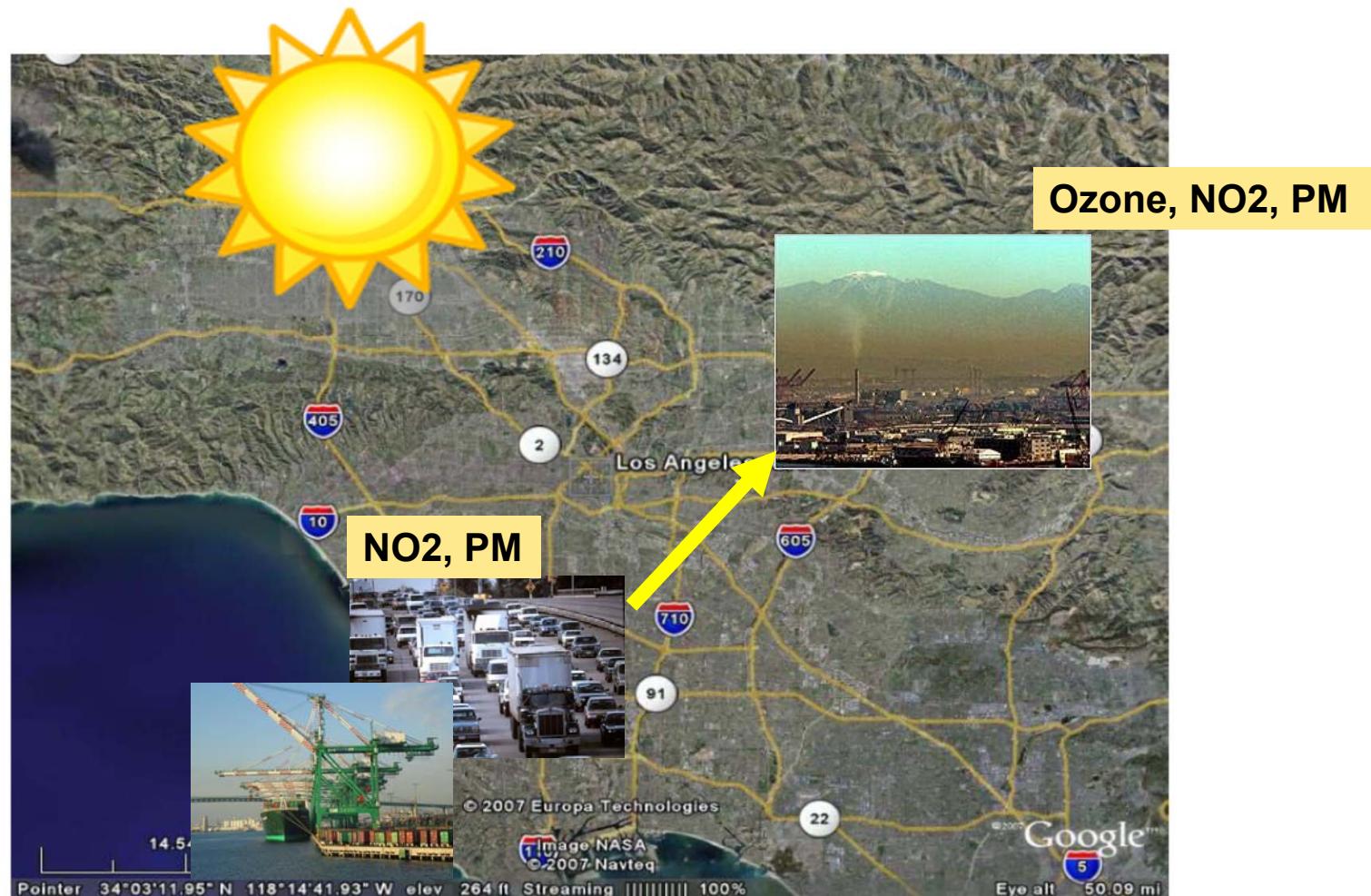


# The CHS Plan...

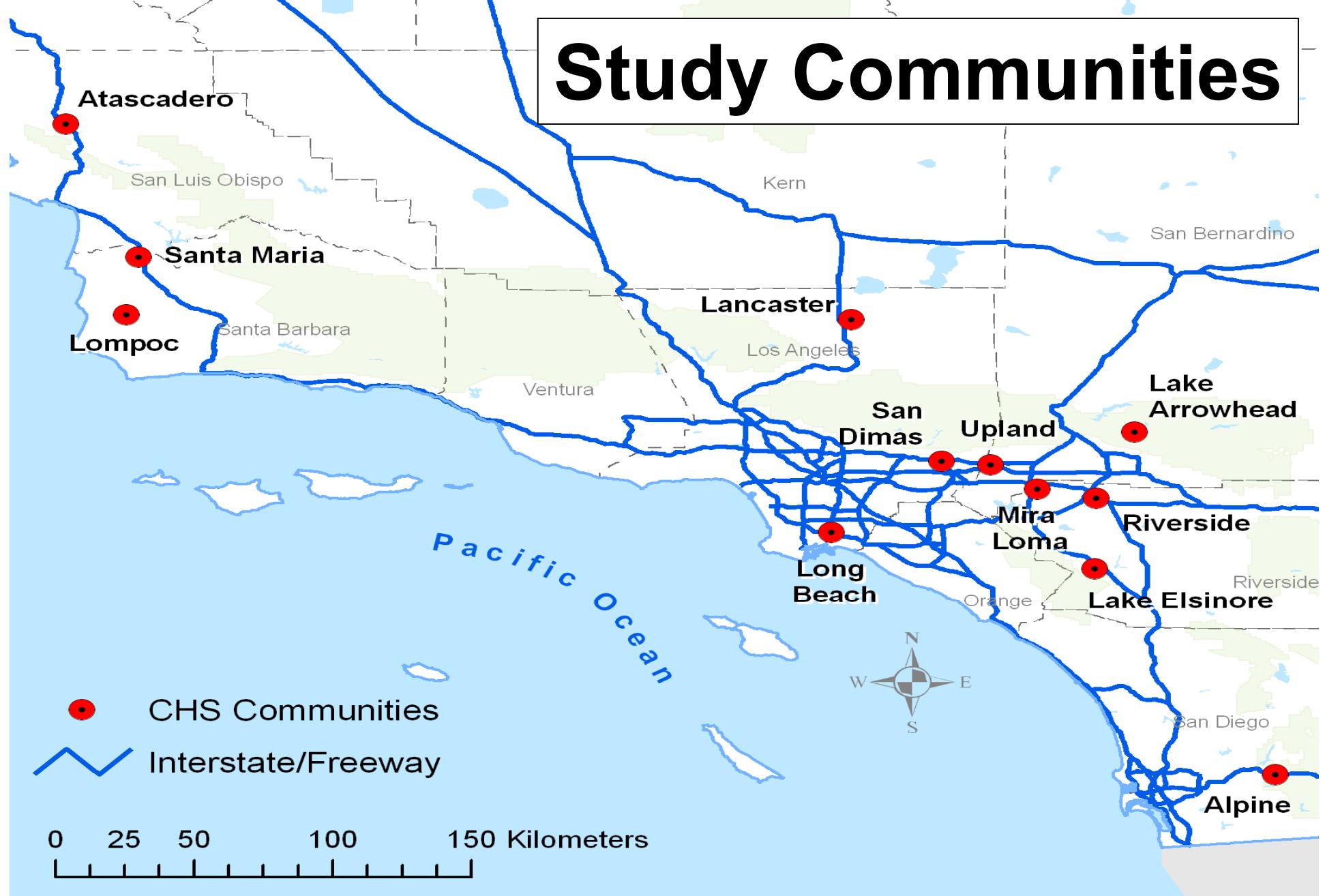


- 1) Find CA communities with a range of pollution profiles
- 2) Recruit volunteers & “measure” their health
- 3) “Follow” their health over several years
- 4) Concurrently measure air pollution exposure
- 5) See if changes in health are related to exposure

# Pollution in the L.A. Basin



# Study Communities

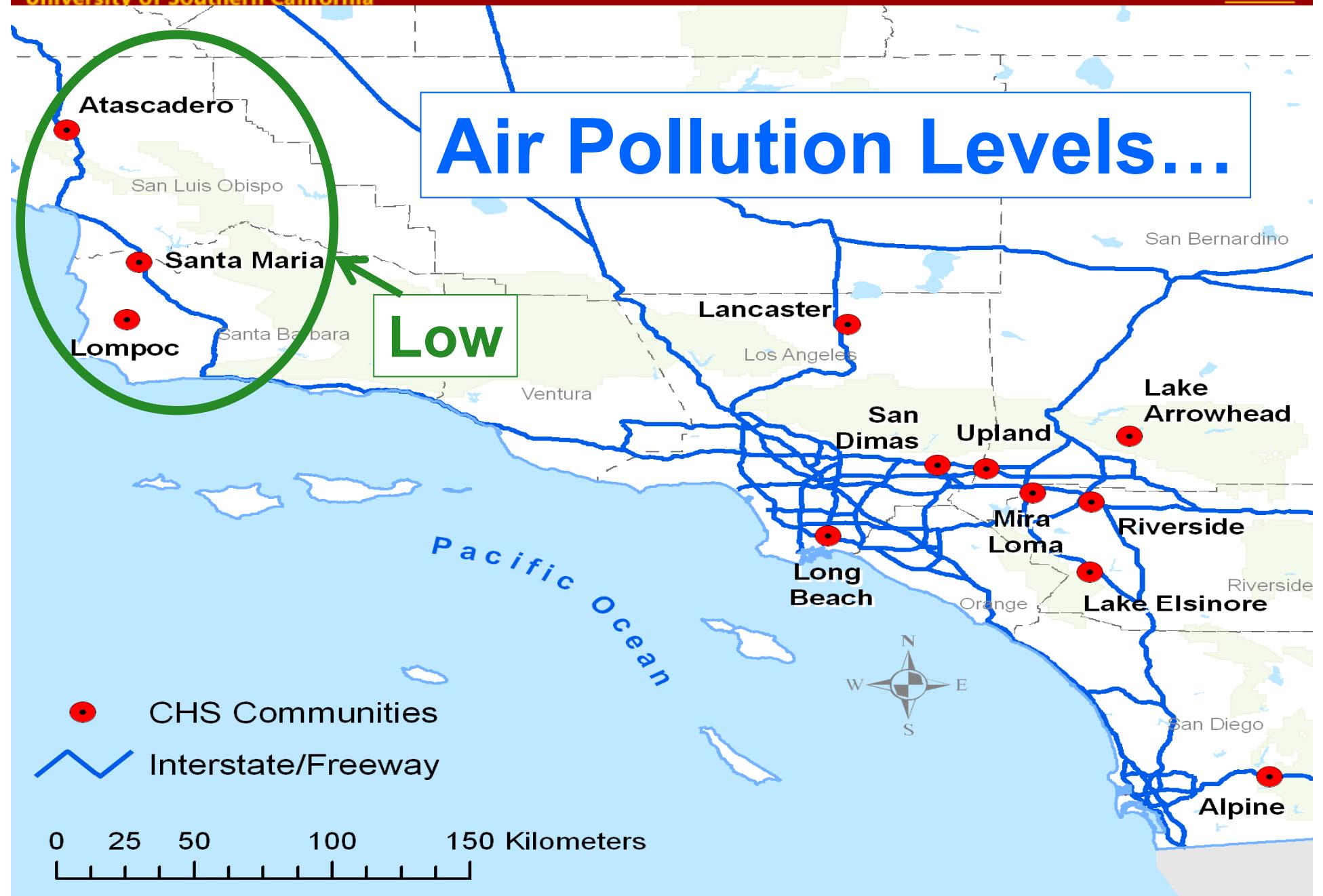


# Community Air Monitoring

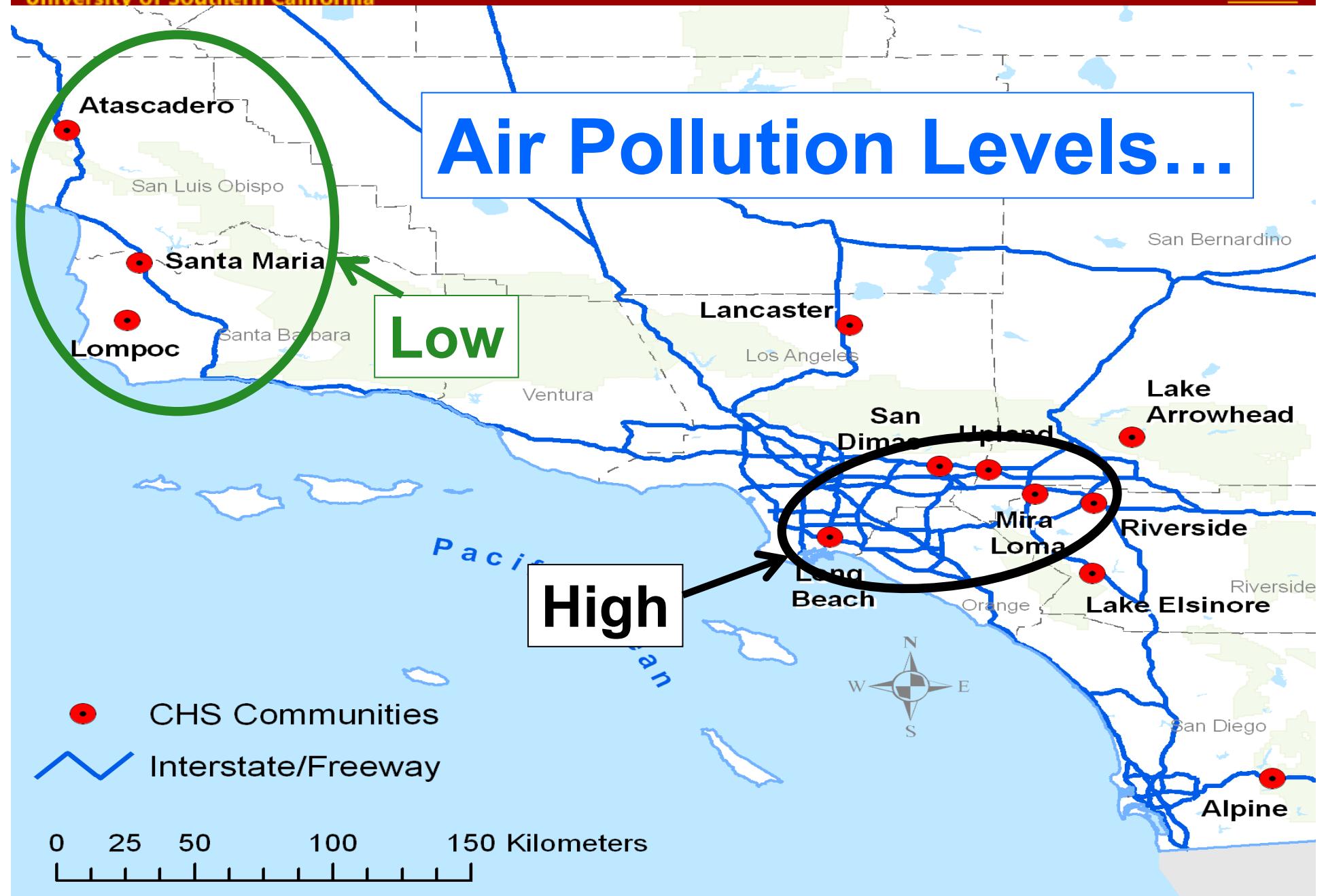
## Since 1994



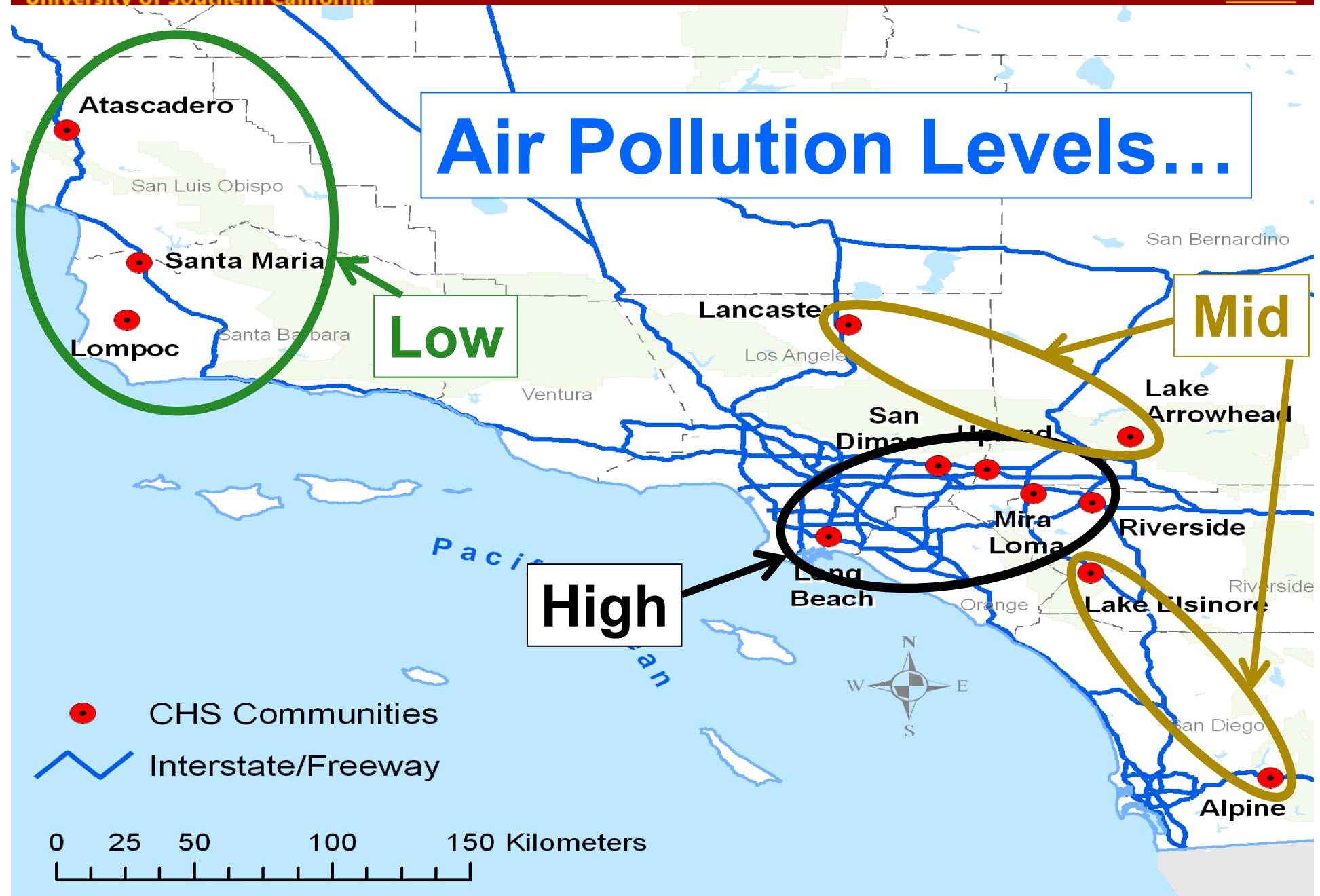
# Air Pollution Levels...



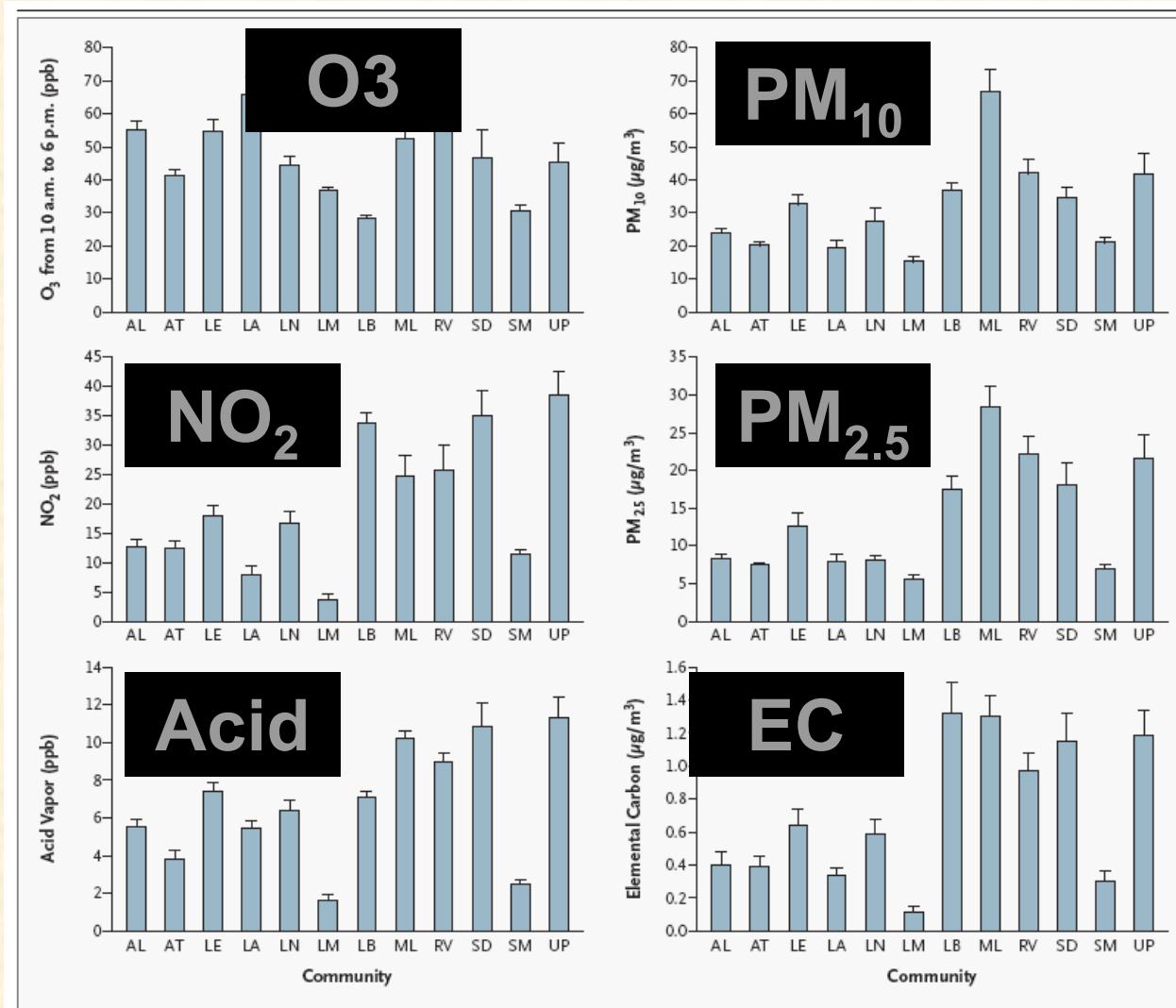
# Air Pollution Levels...



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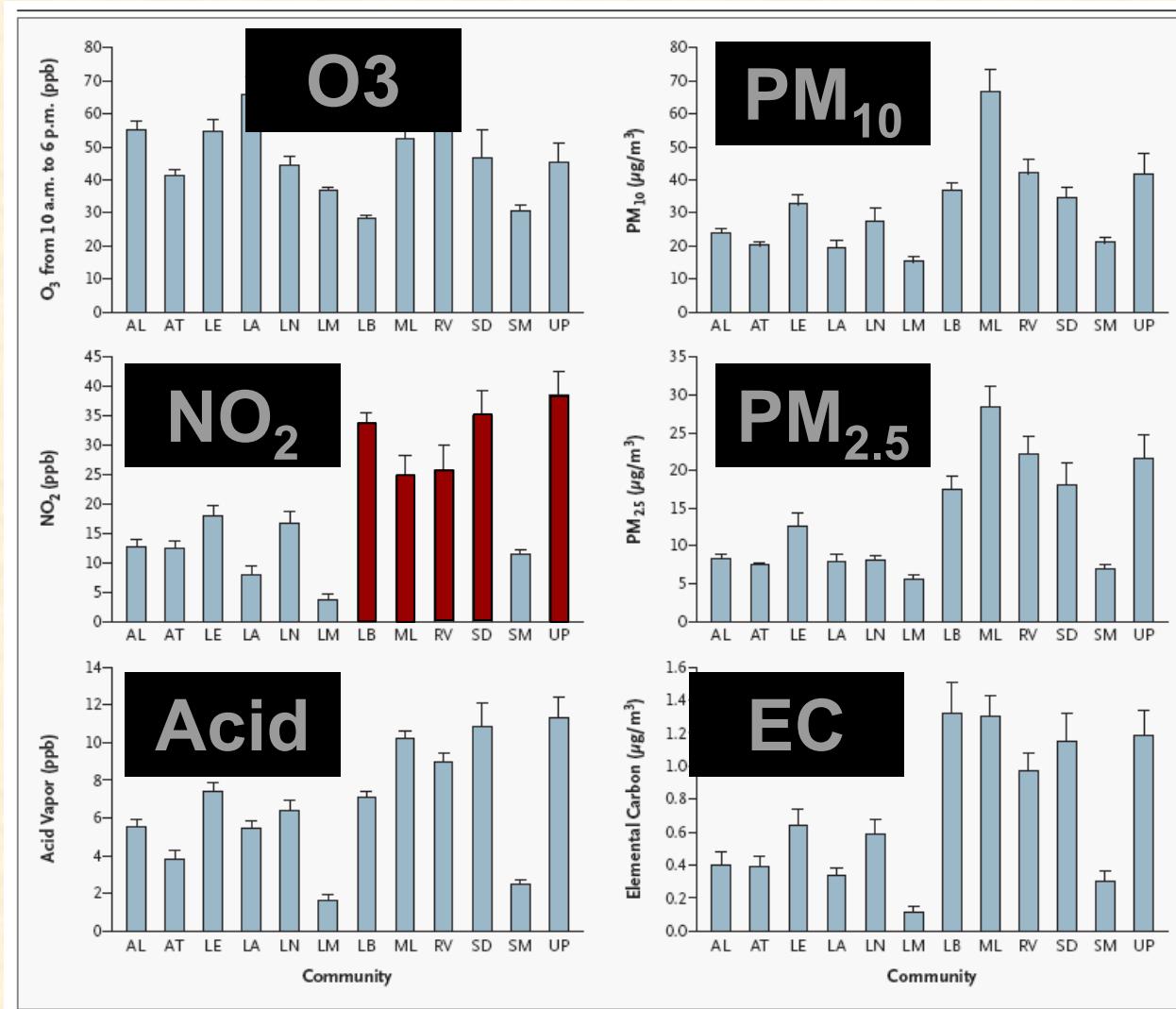


# Mean pollutant levels, 1994-2000



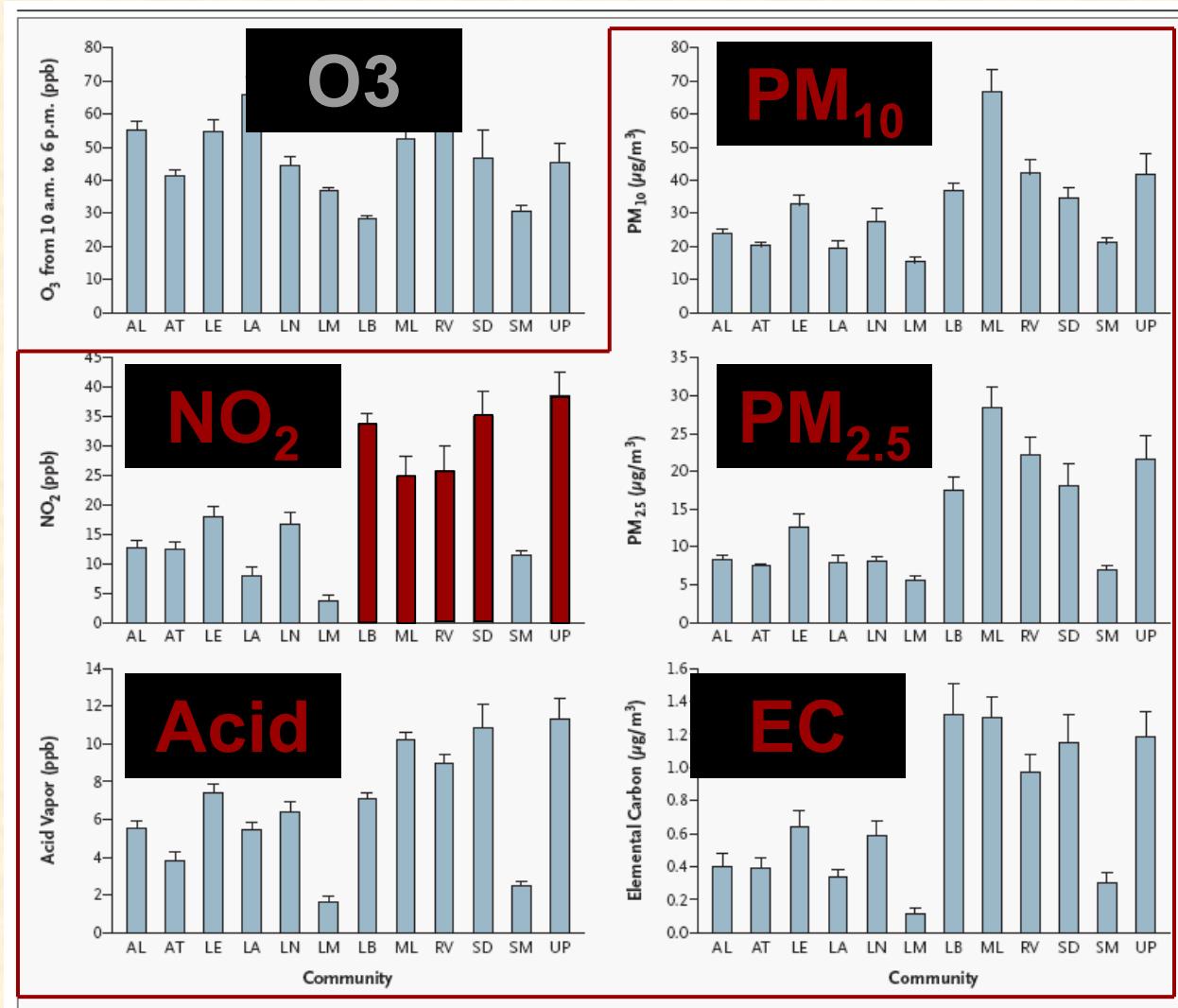
Southern California has a wide range of many pollutants found in the U.S.

# Mean pollutant levels, 1994-2000



The L.A.  
Basin ...

# Mean pollutant levels, 1994-2000



The L.A.  
Basin ...  
has  
elevated  
levels of  
all of  
these  
pollutants

# Demographic Characteristics

**TABLE 3**  
**NUMBER OF SUBJECTS AND DEMOGRAPHIC CHARACTERISTICS BY COMMUNITY**

Community	Eligible Subjects	Subjects with Baseline Questionnaire Information		White	Black	Asian	Other	Hispanic	Male	Income > \$50,000
		(%)								
Alpine	396	298 (75)		84.0	0.4	0.8	14.8	12.8	49.8	37.5
Atascadero	371	260 (70)		84.1	0.4	0.4	15.1	11.4	40.5	36.3
Lake Elsinore	397	316 (80)		76.9	2.3	1.7	19.1	23.8	53.1	25.6
Lake Gregory	402	347 (86)		83.8	0.6	1.5	14.1	16.2	48.5	36.3
Lancaster	350	266 (76)		70.4	5.8	2.5	21.3	26.8	45.7	29.4
Lompoc	410	305 (74)		72.5	8.7	0.8	18.0	19.3	50.0	32.6
Long Beach	414	325 (79)		37.9	16.1	21.8	24.2	22.3	47.9	31.1
Mira Loma	438	308 (70)		66.8	1.1	1.4	30.7	34.0	46.3	29.4
Riverside	469	369 (79)		43.9	14.0	6.4	35.7	38.4	47.1	21.4
San Dimas	397	303 (76)		61.6	5.8	8.8	23.8	29.7	47.8	34.3
Santa Maria	371	300 (81)		46.3	1.6	2.8	49.3	60.1	48.1	12.9
Upland	428	279 (65)		69.4	2.6	8.7	19.3	16.7	49.6	65.6
Total	4,843	3,676 (76)		66.1%	5.1%	4.9%	23.9%	26.0%	47.9%	32.2%

# Annual Questionnaires about health & home operating characteristics

Active smoking?

Height?

Weight?

Pets?

Asthma?

Gas stove?

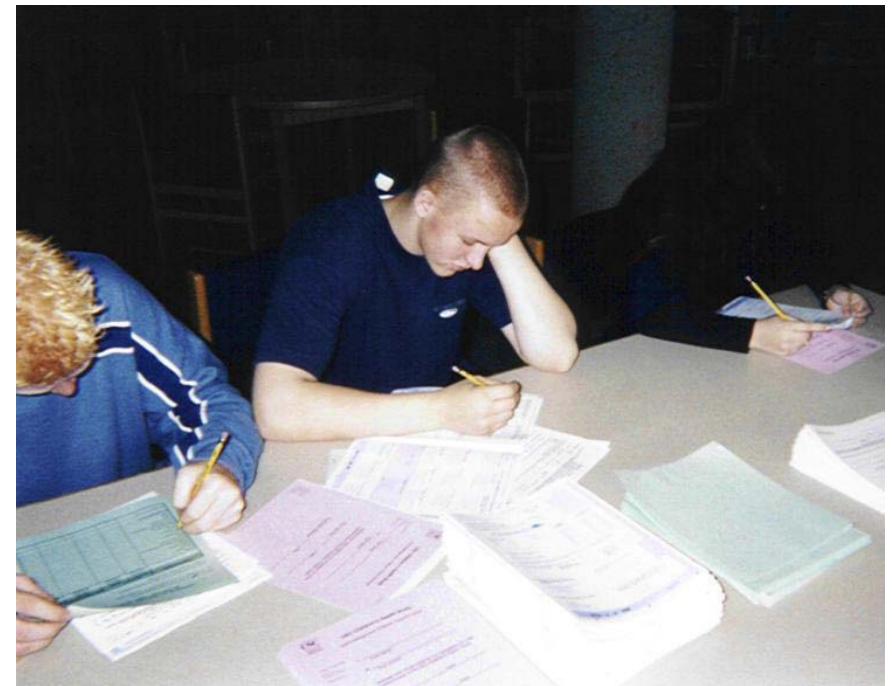
Passive Smoking?

Diet

Exercise?

mold?

Medication?



# Annual Lung Function Tests



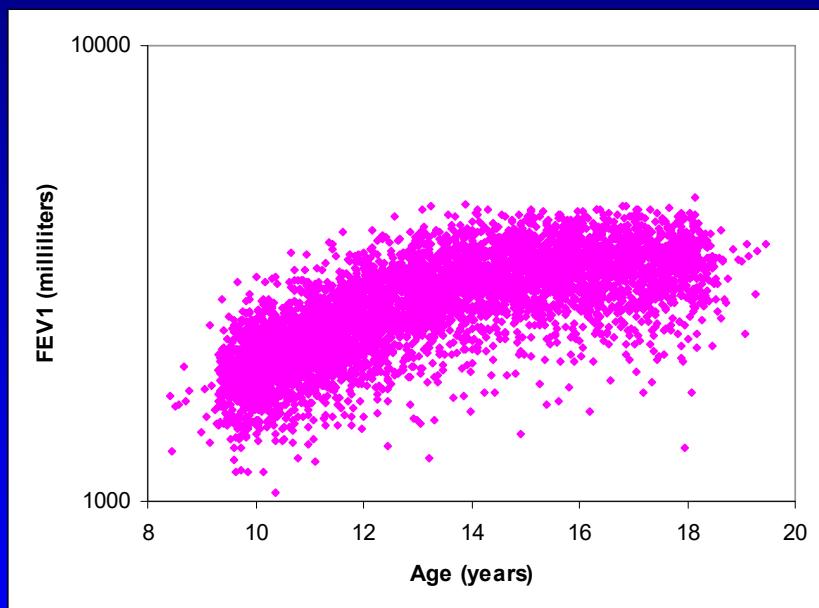
## What do we collect?

- FEV<sub>1</sub> : How much air expired in 1 second
- FVC: Total amount of air expired

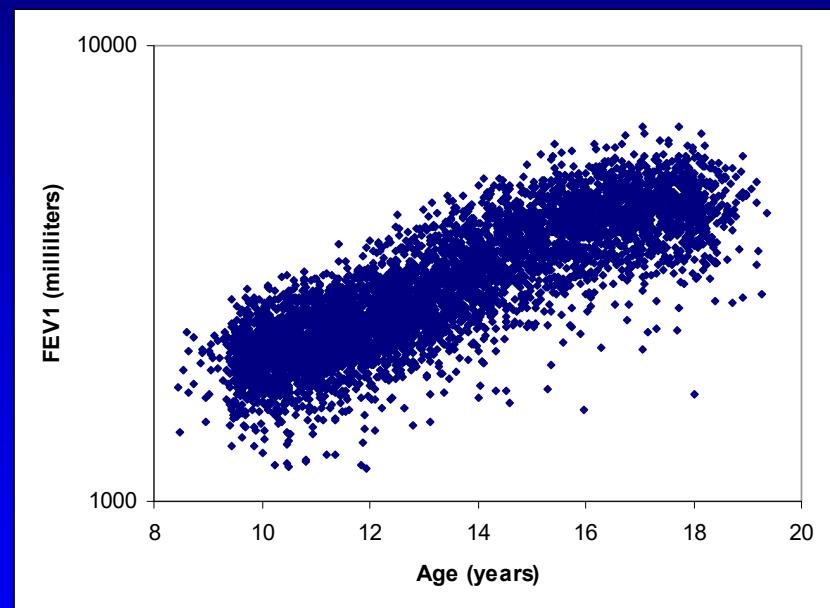
These allow us to track lung growth over time

# $\text{FEV}_1$ Growth Over 8 Years

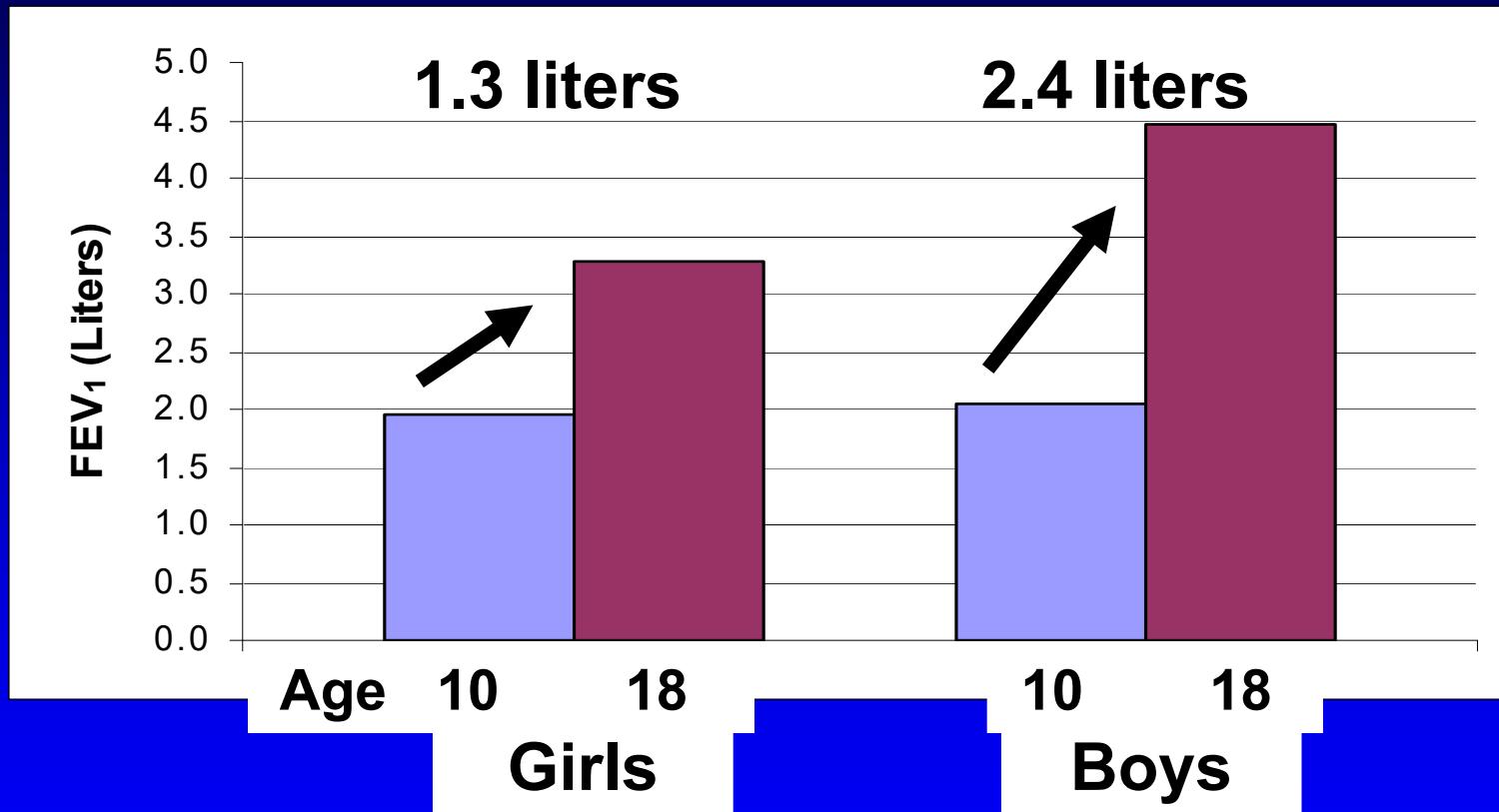
Girls



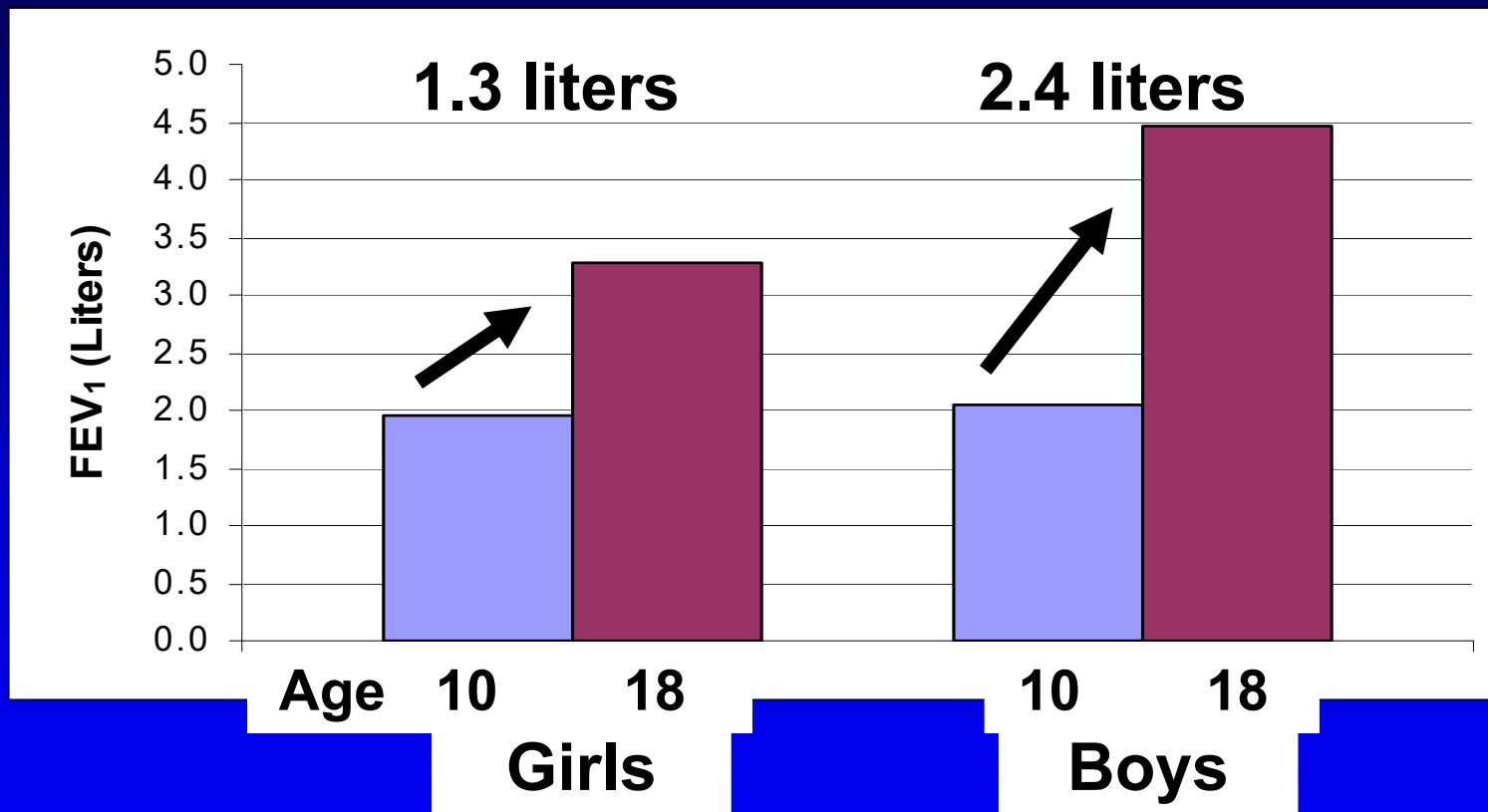
Boys



# Average FEV<sub>1</sub> in Girls and Boys



# Average FEV<sub>1</sub> in Girls and Boys



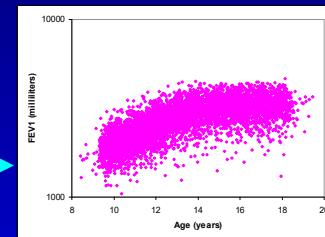
**Key Question:** Does 8-year growth vary across communities with respect to pollution?

# 3-Stage Model

(Berhane et al., 2004, Gauderman et al, 2007)

- $Y = LF$ ,  $t = \text{age}$

1:  $Y_{cij} = a_{ci} + b_{ci} t_{cij}/8 + \delta f(t_{cij}) + e_{cij}$   
–  $b_{ci}$  = 8-yr LF growth

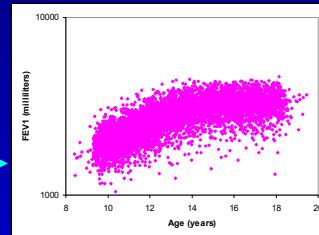


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–  $b_{ci}$  = 8-yr LF growth



2:  $b_{ci} = b_c + \beta_1(Z_{ci} - Z_c) + e_{ci}$   
–  $\beta_1$ : within-community traffic effect

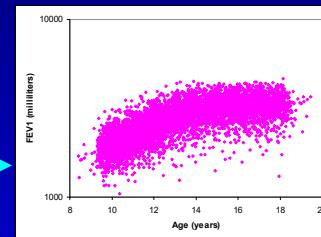


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3:  $b_c = \lambda + \beta_2 X_c + e_c$   
–  $\beta_2$  : between-community pollution effect

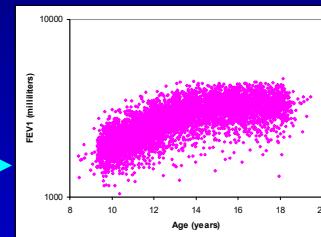


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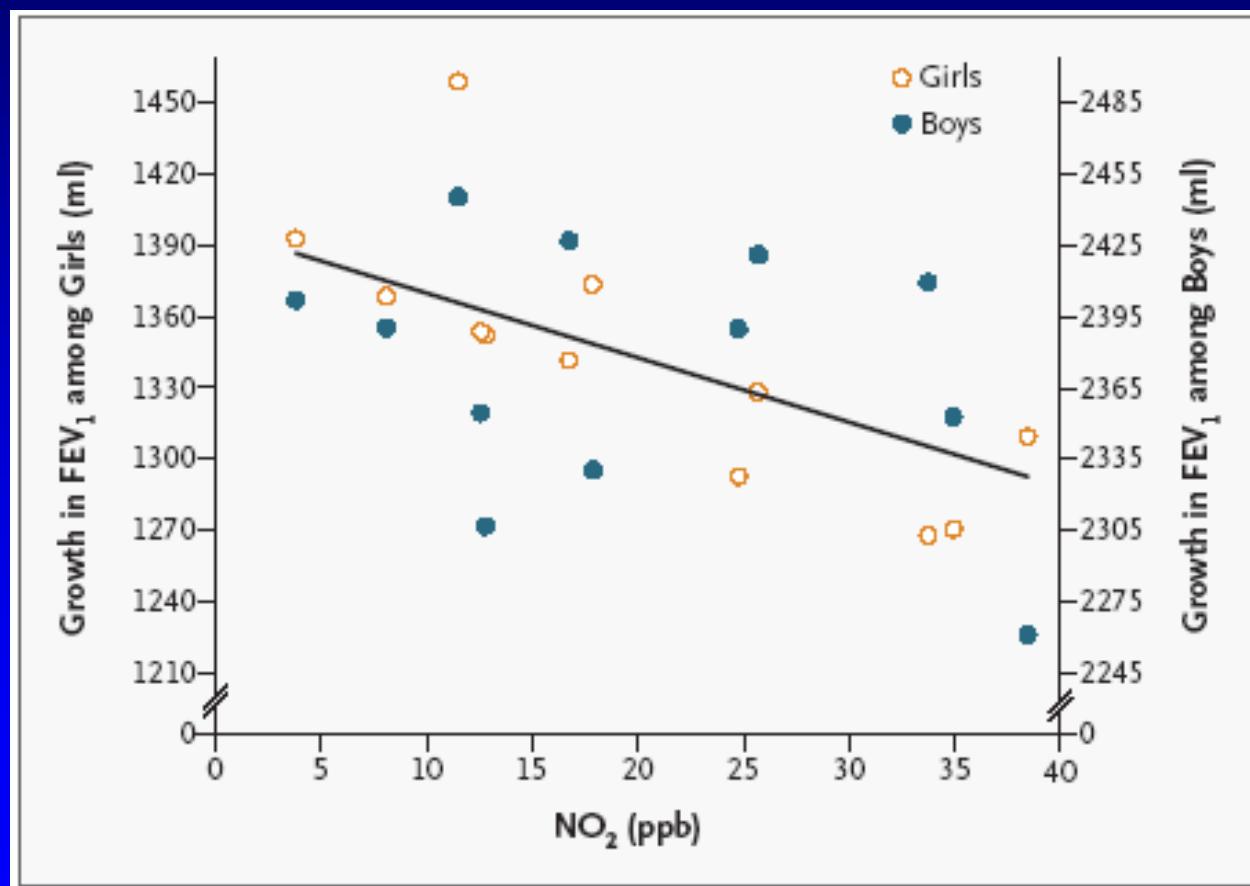


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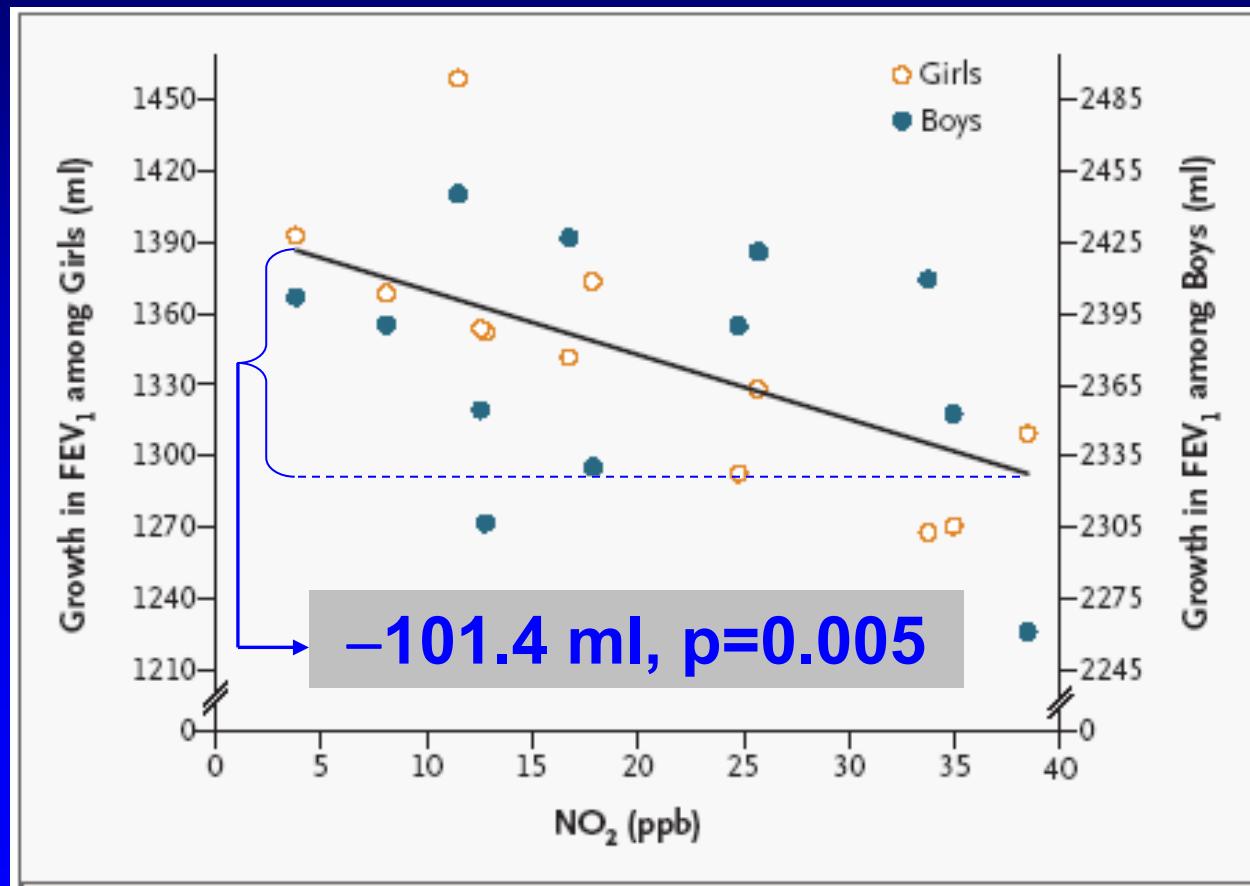


- Fit as single mixed model

# 8-yr FEV<sub>1</sub> Growth in Girls and Boys vs. 7-year average NO<sub>2</sub> levels



# 8-yr FEV<sub>1</sub> Growth in Girls and Boys vs. 7-year average NO<sub>2</sub> levels



# 8-yr Growth vs. Air Pollution

**Table 3.** Difference in Average Growth in Lung Function over the Eight-Year Study Period from the Least to the Most Polluted Community.\*

Pollutant	FVC		FEV <sub>1</sub>		MMEF	
	Difference (95% CI) <i>ml</i>	P Value	Difference (95% CI) <i>ml</i>	P Value	Difference (95% CI) <i>ml/sec</i>	P Value
O <sub>3</sub>						
10 a.m.–6 p.m.	-50.6 (-171.0 to 69.7)	0.37	-22.8 (-122.3 to 76.6)	0.62	85.6 (-130.0 to 301.1)	0.40
1-Hour maximal level	-70.3 (-183.3 to 42.6)	0.20	-44.5 (-138.9 to 50.0)	0.32	45.7 (-172.3 to 263.6)	0.65
NO <sub>2</sub>	-95.0 (-189.4 to -0.6)	0.05	-101.4 (-164.5 to -38.4)	0.005	-211.0 (-377.6 to -44.4)	0.02
Acid vapor	-105.2 (-194.5 to -15.9)	0.03	-105.8 (-168.8 to -42.7)	0.004	-165.0 (-344.8 to 14.7)	0.07
PM <sub>10</sub>	-60.2 (-190.6 to 70.3)	0.33	-82.1 (-176.9 to 12.8)	0.08	-154.2 (-378.3 to 69.8)	0.16
PM <sub>2.5</sub>	-60.1 (-166.1 to 45.9)	0.24	-79.7 (-153.0 to -6.4)	0.04	-168.9 (-345.5 to 7.8)	0.06
Elemental carbon	-77.7 (-166.7 to 11.3)	0.08	-87.9 (-146.4 to -29.4)	0.007	-165.5 (-323.4 to -7.6)	0.04
Organic carbon	-58.6 (-196.1 to 78.8)	0.37	-86.2 (-185.6 to 13.3)	0.08	-151.2 (-389.4 to 87.1)	0.19

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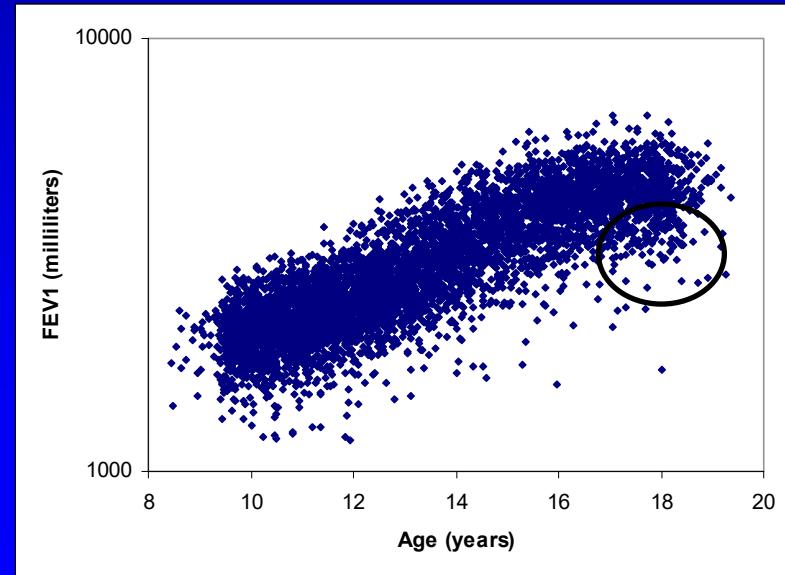
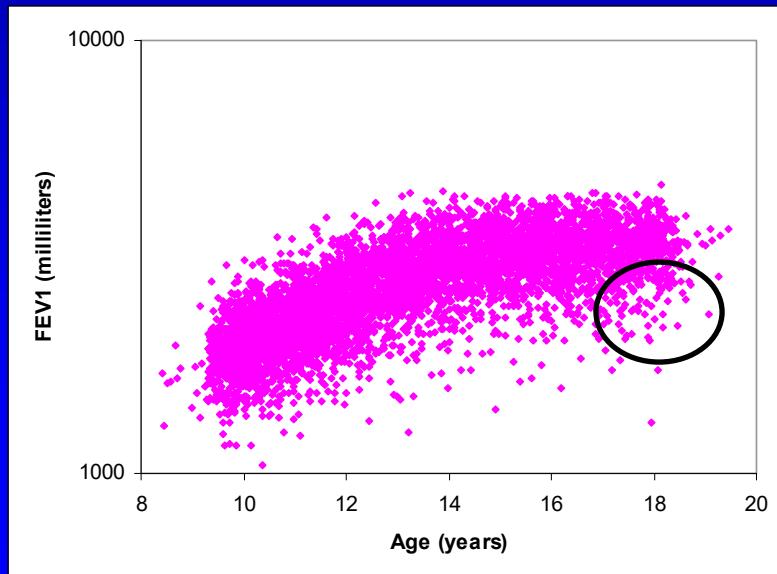
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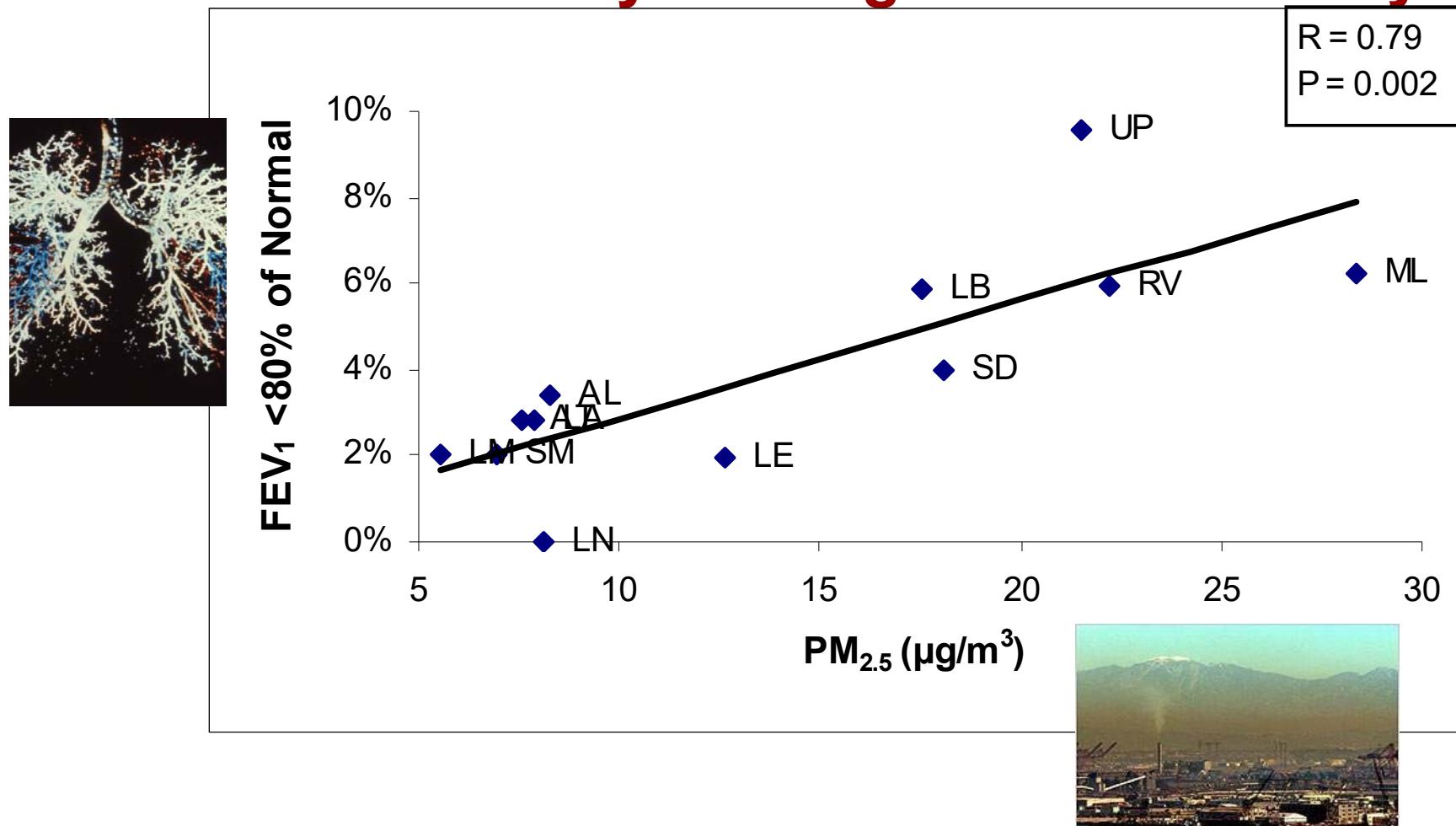
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# 8-year Growth Deficits

- What is the net effect?
- Are the results clinically meaningful?
  - How many kids have FEV  $< 80\%$  of normal at age 18?



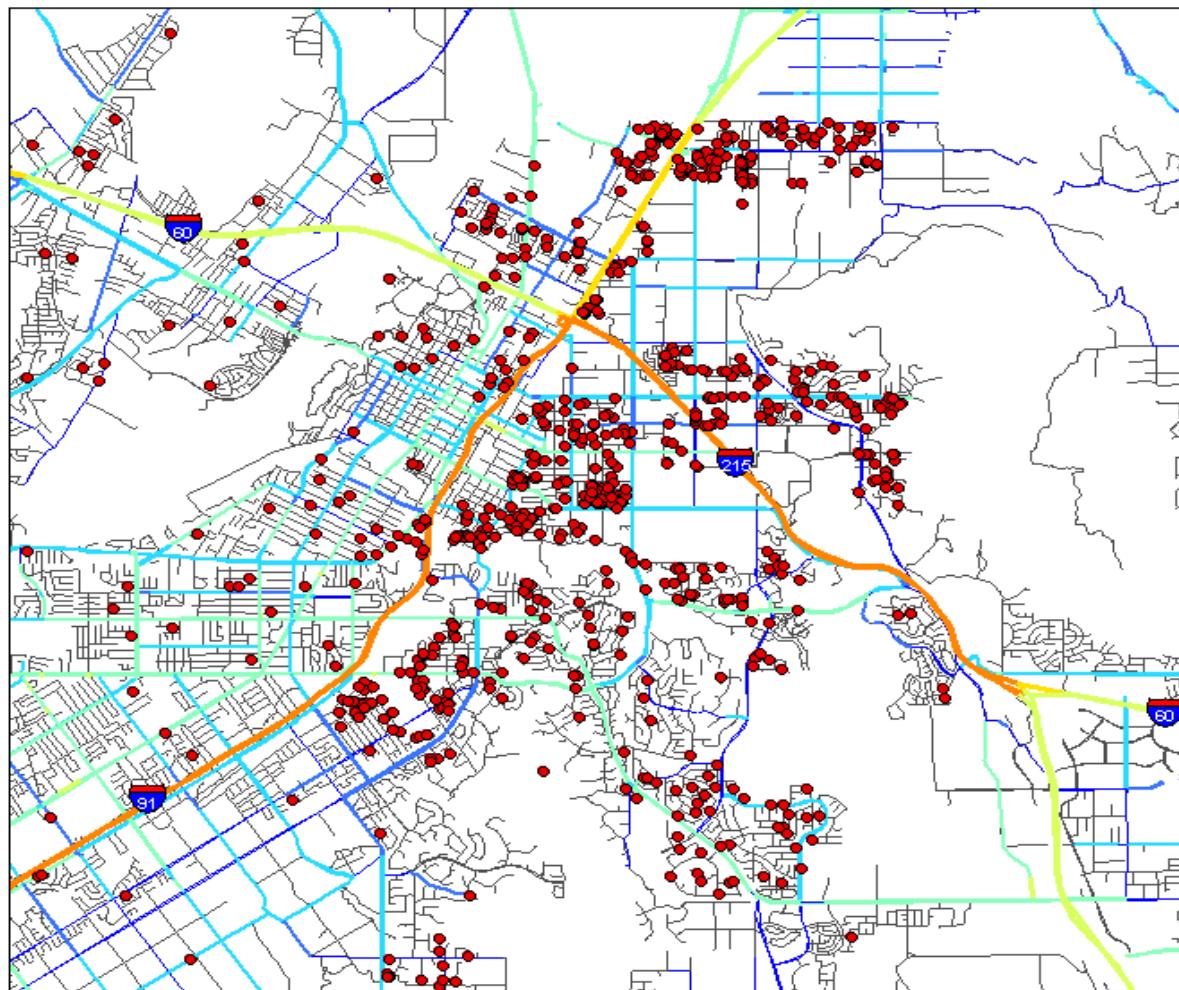
# Abnormally Low Lung Function is More Likely in a High PM Community



# What About Local Exposures?



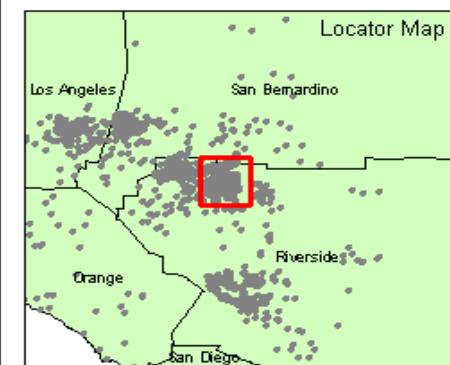
## Riverside



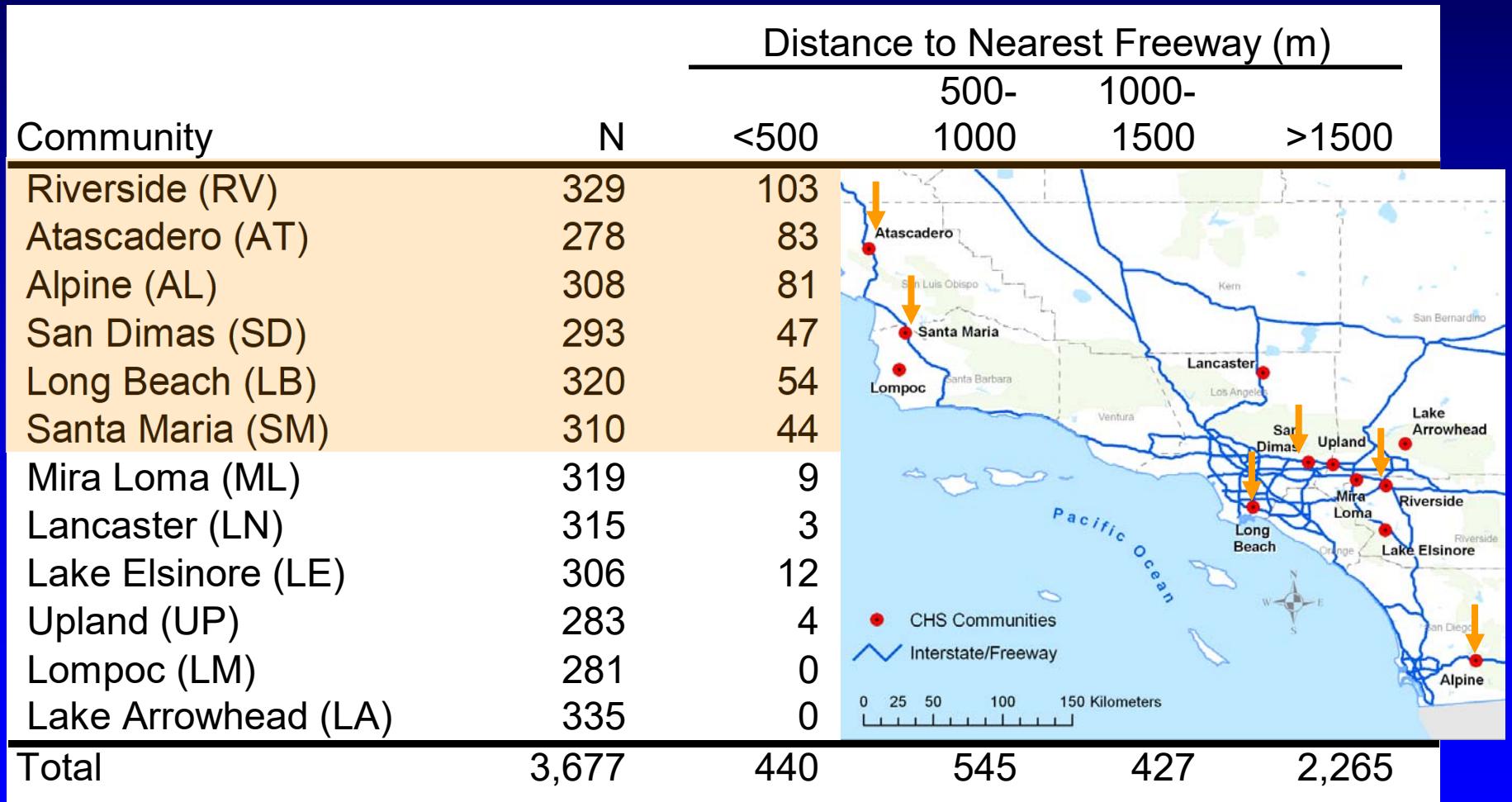
### Legend

- Residence Locations
- TeleAtlas Road Links
- Annual Average Daily Traffic
  - 10 - 3,000
  - 3,001 - 5,000
  - 5,001 - 10,000
  - 10,001 - 25,000
  - 25,001 - 50,000
  - 50,001 - 75,000
  - 75,001 - 150,000
  - 150,001 - 231,000
- Local Road

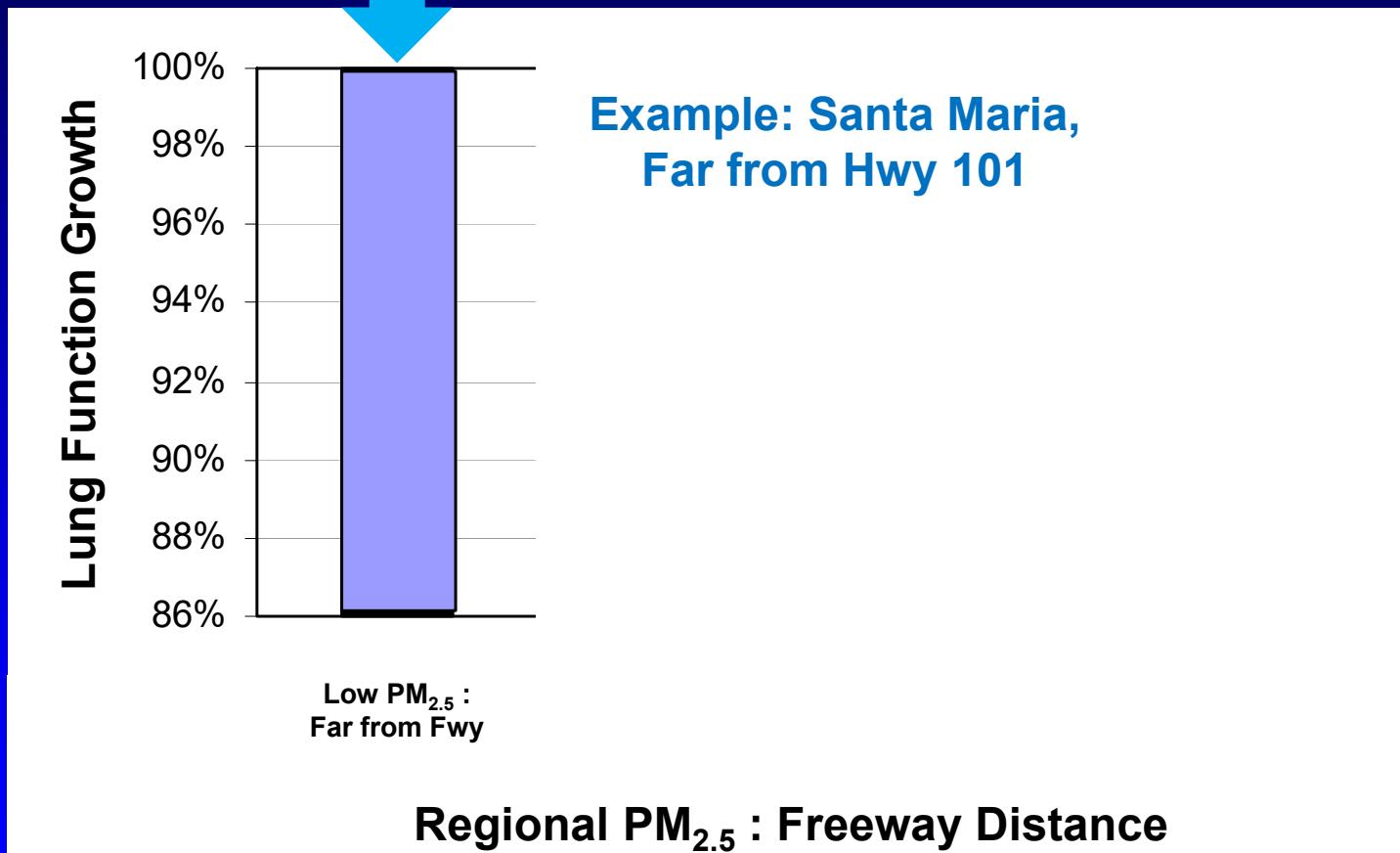
0 1 2 Kilometers



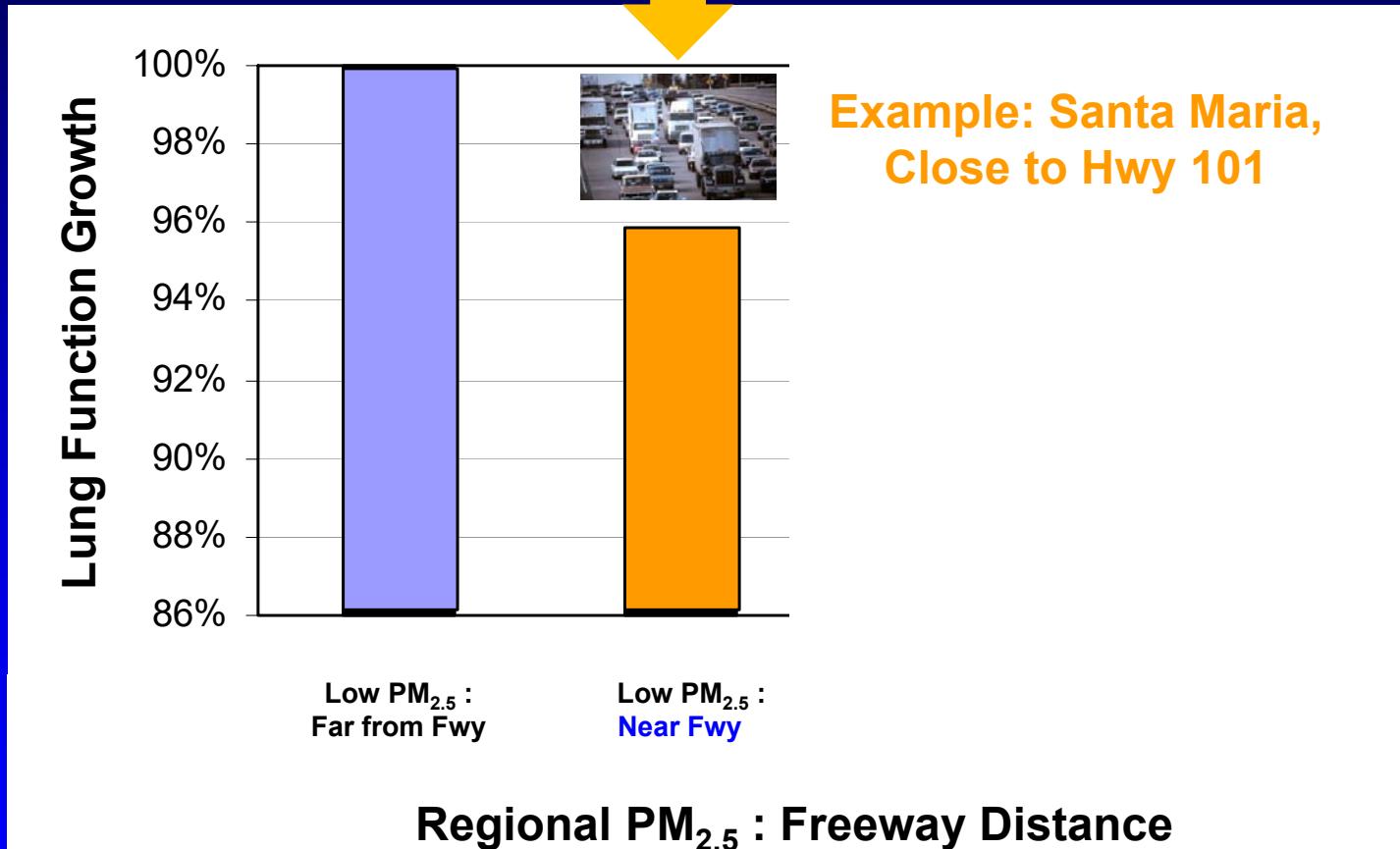
# Children Living Near Freeways



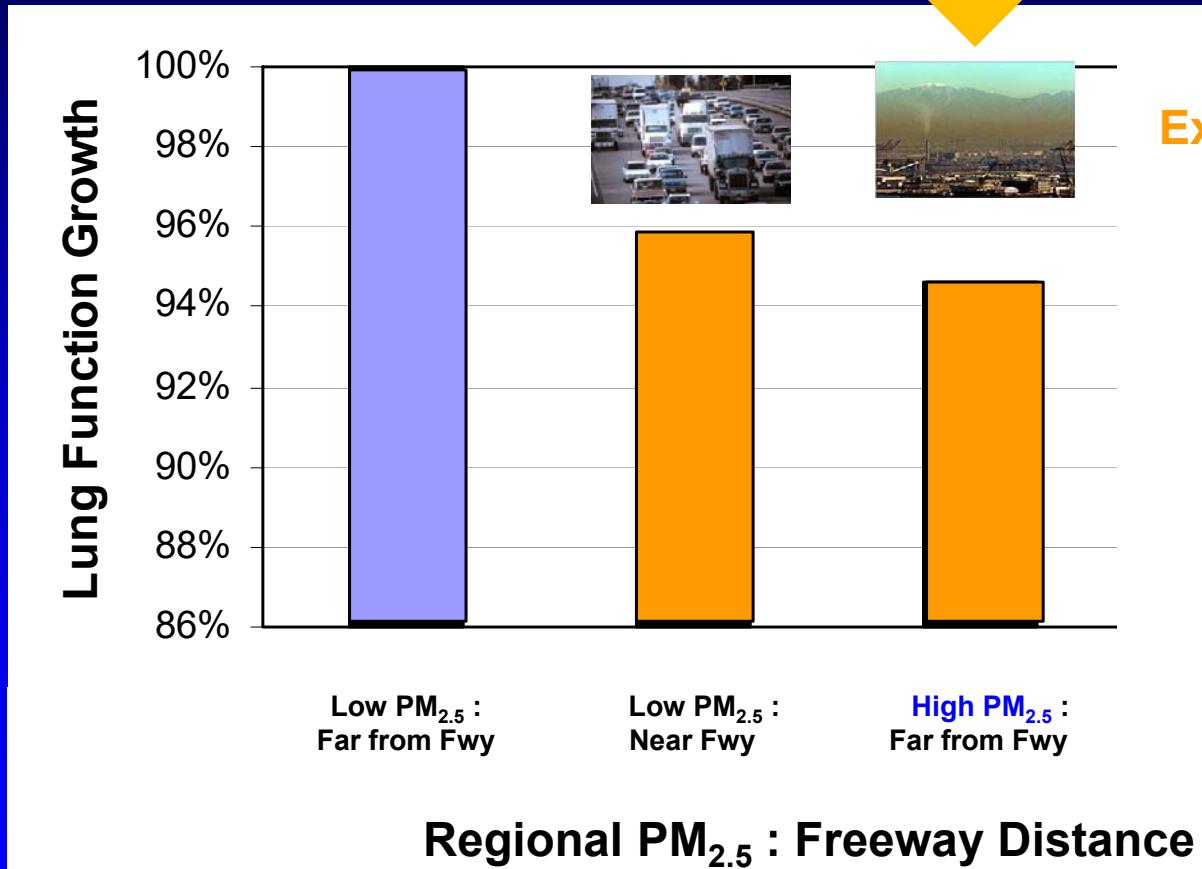
# Children living FAR FROM A FREEWAY in a LOW POLLUTION area have the best lung function



# Living NEAR A FREEWAY reduces lung function

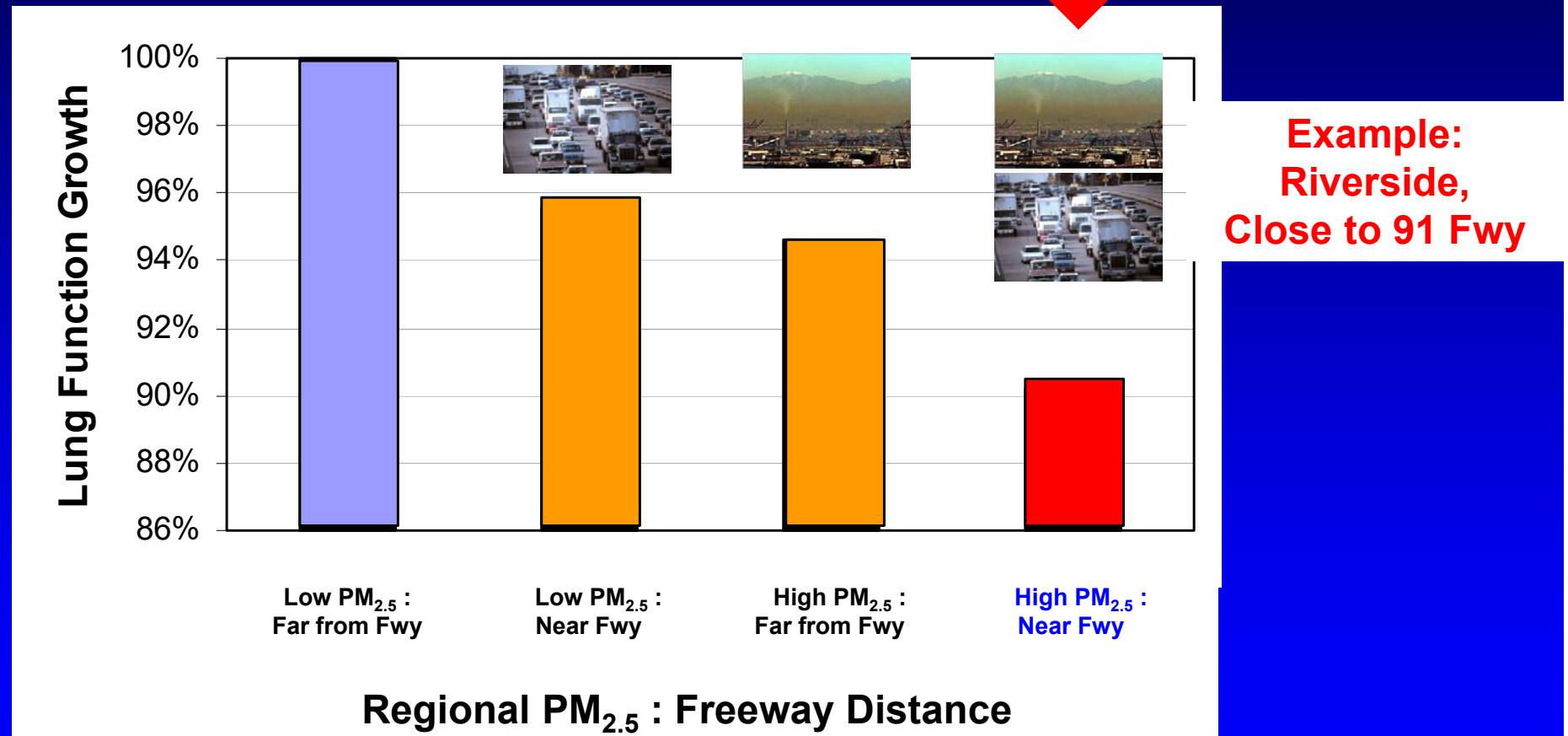


# Living in a SMOGGY AREA reduces lung function

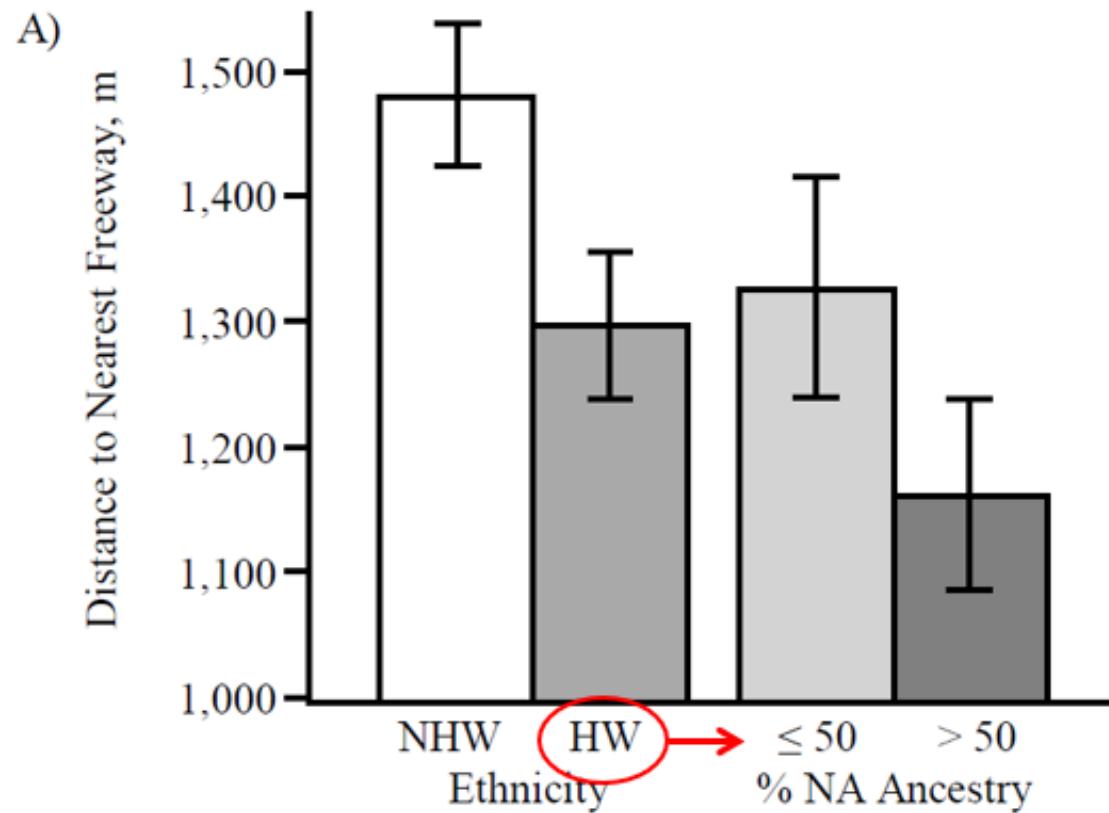


Example: Riverside,  
Far from 91 Fwy

# Living NEAR A FREEWAY in a SMOGGY AREA leads to the greatest reductions in lung function



# Non-Hispanic White (NHW) vs. Hispanic White (HW) Residential distance to freeways



Weaver & Gauderman, 2017

# Association of Living <75m from a Busy Road with Asthma

*NHW and HW Children*

If OR=1.0 → No difference in asthma for <75m vs. >75m from a busy road

Variable	No. of Participants <sup>a</sup>	Ever Asthma		Prevalent Asthma		Incident Asthma	
		OR <sup>b</sup>	95% CI	OR <sup>b</sup>	95% CI	OR <sup>b</sup>	95% CI
Ethnicity							
NHW	741	0.91	0.51, 1.65	0.96	0.48, 1.90	0.81	0.33, 1.99
HW	790	2.10 <sup>c</sup>	1.30, 3.39	1.77	1.00, 3.15	2.20 <sup>c</sup>	1.14, 4.25
<i>P</i> value <sup>d</sup>		0.03 <sup>e</sup>		0.18		0.077	

Abbreviations: CI, confidence interval; HW, Hispanic white; NA, Native American; NHW, non-Hispanic white; OR, odds ratio.

<sup>a</sup> Total number of participants in subgroup with asthma data available.

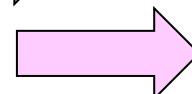
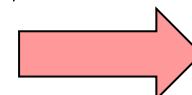
<sup>b</sup> Odds ratios for the corresponding asthma outcome versus living within 75 m of a major road, adjusted for age at baseline, study community, and sex.

<sup>c</sup>  $P \leq 0.01$ .

<sup>d</sup> Test for multiplicative interaction between living within 75 m of a major roadway and ethnicity.

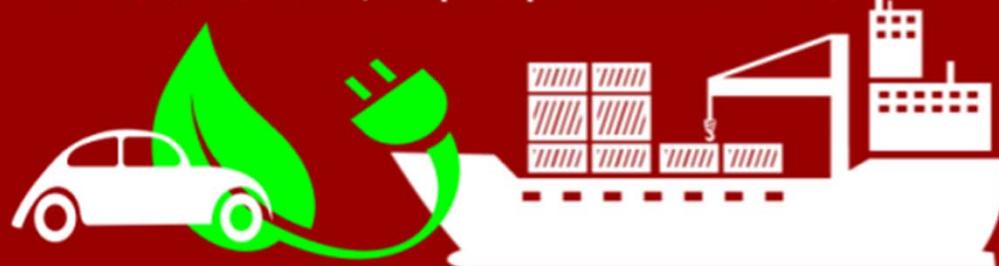
<sup>e</sup>  $P \leq 0.05$ .

But what if, over time,  
the air got *cleaner*  
where they lived & grew up?



# What kinds of policies?

Electric vehicles, ship at-port electrification



Cleaner fuel for trucks, ships & trains



Newer & cleaner engines

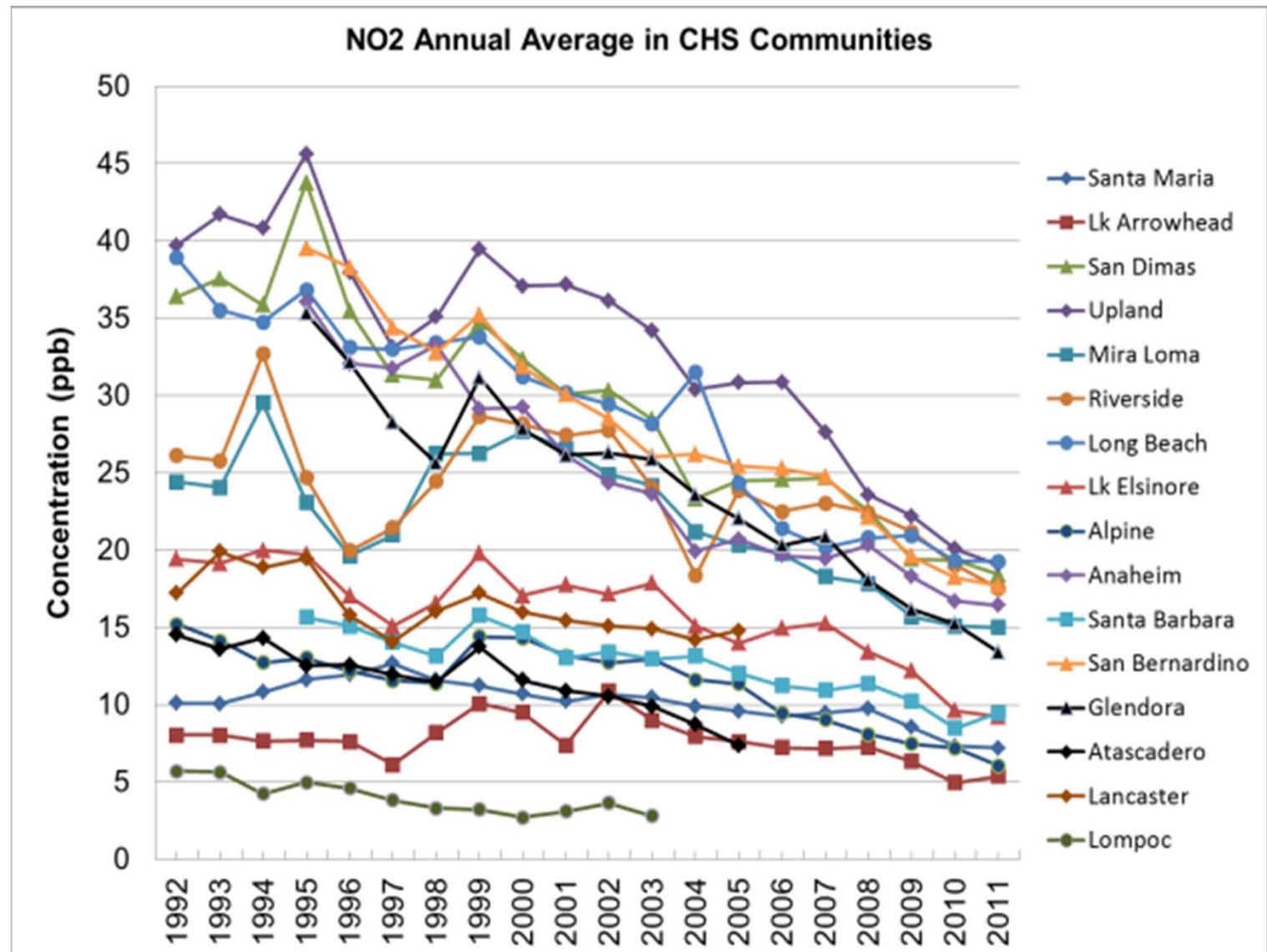


... plus many other policies affecting on-road, off-road, and stationary sources

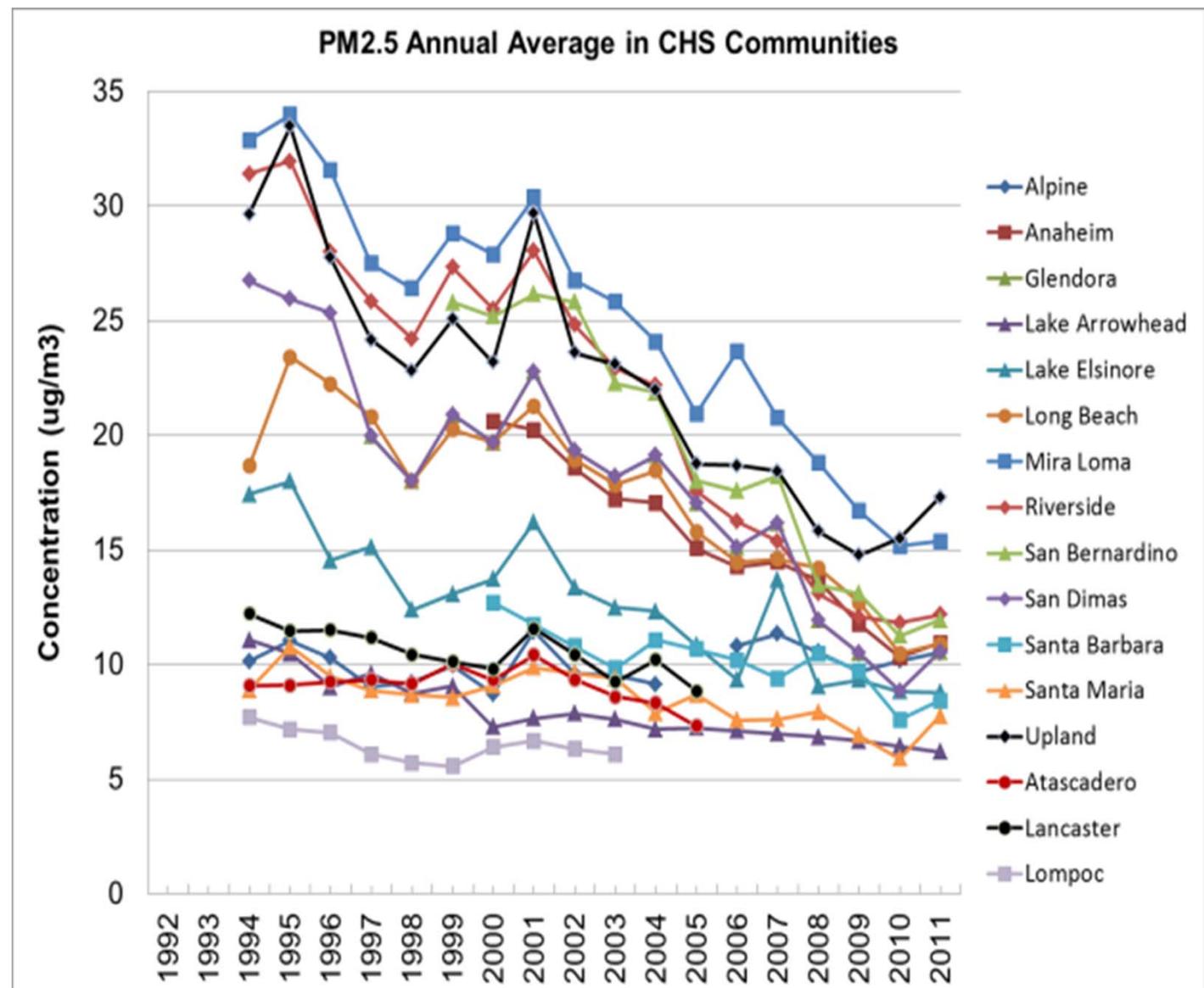
## Despite growth across the region...



Average NO<sub>2</sub>  
declined  
28% to 53%



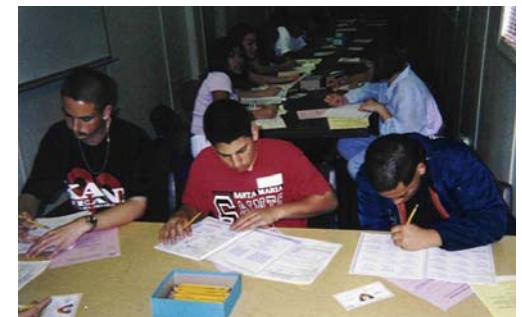
Average PM<sub>2.5</sub>  
declined  
13% to 54%



# CHS Cohorts

Cohort	N	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14
A	938	10	11	12																			
B	937	7	8	9	10	11	12																
C	1806	4	5	6	7	8	9	10	11	12													
D	2081				4	5	6	7	8	9	10	11	12										
E	5927										K	1	2	3	4	5	6	7	8	9	10	11	12
(ALL)	11689																						

**Overlap across cohorts: 11 – 15 years of age on average**



# *The NEW ENGLAND JOURNAL of MEDICINE*

ESTABLISHED IN 1812

MARCH 5, 2015

VOL. 372 NO. 10

## Association of Improved Air Quality with Lung Development in Children

W. James Gauderman, Ph.D., Robert Urman, M.S., Edward Avol, M.S., Kiros Berhane, Ph.D., Rob McConnell, M.D., Edward Rappaport, M.S., Roger Chang, Ph.D., Fred Lurmann, M.S., and Frank Gilliland, M.D., Ph.D.

### EDITORIAL



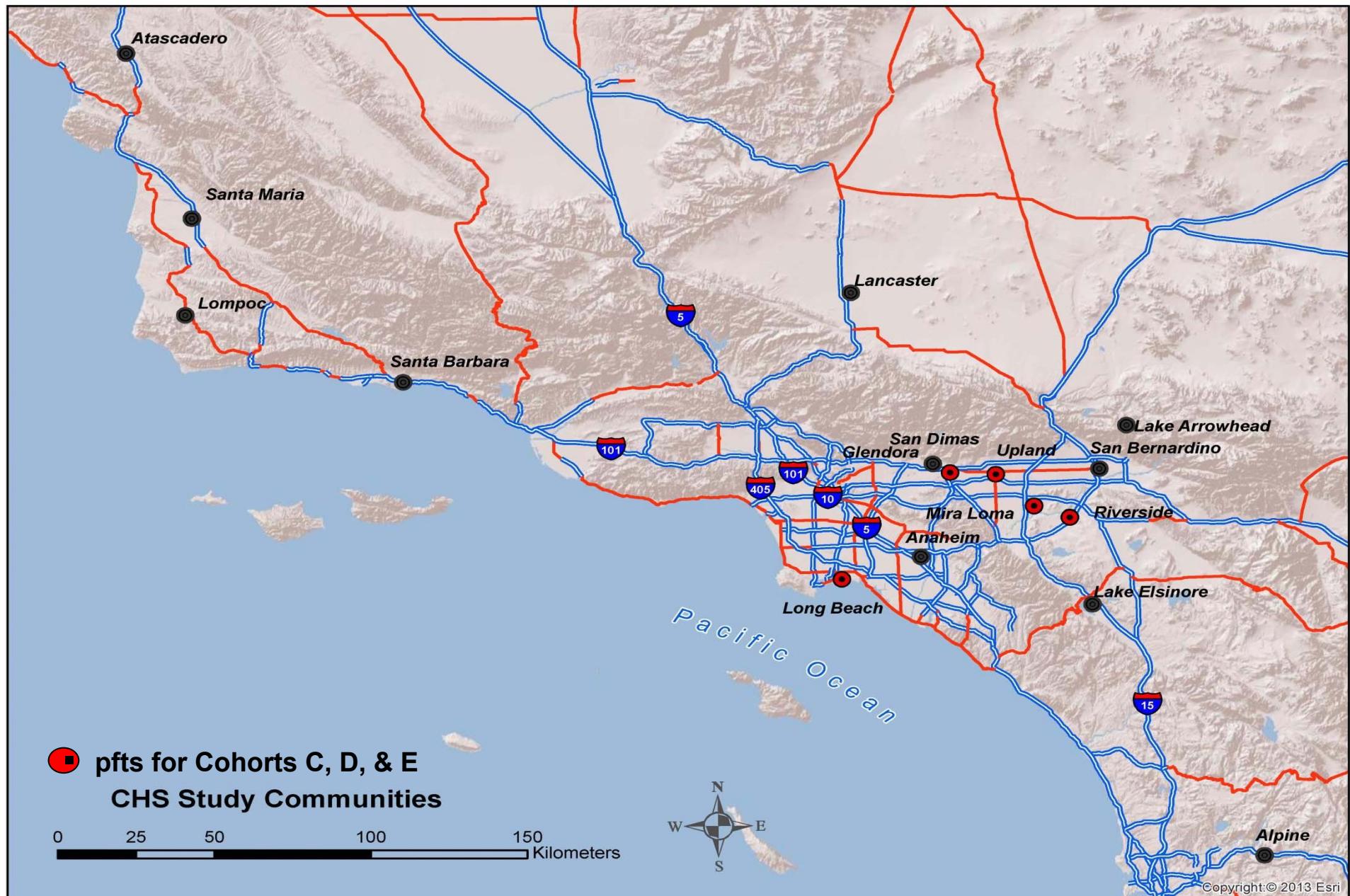
#### Cleaner Air, Bigger Lungs

Douglas W. Dockery, Sc.D., and James H. Ware, Ph.D.

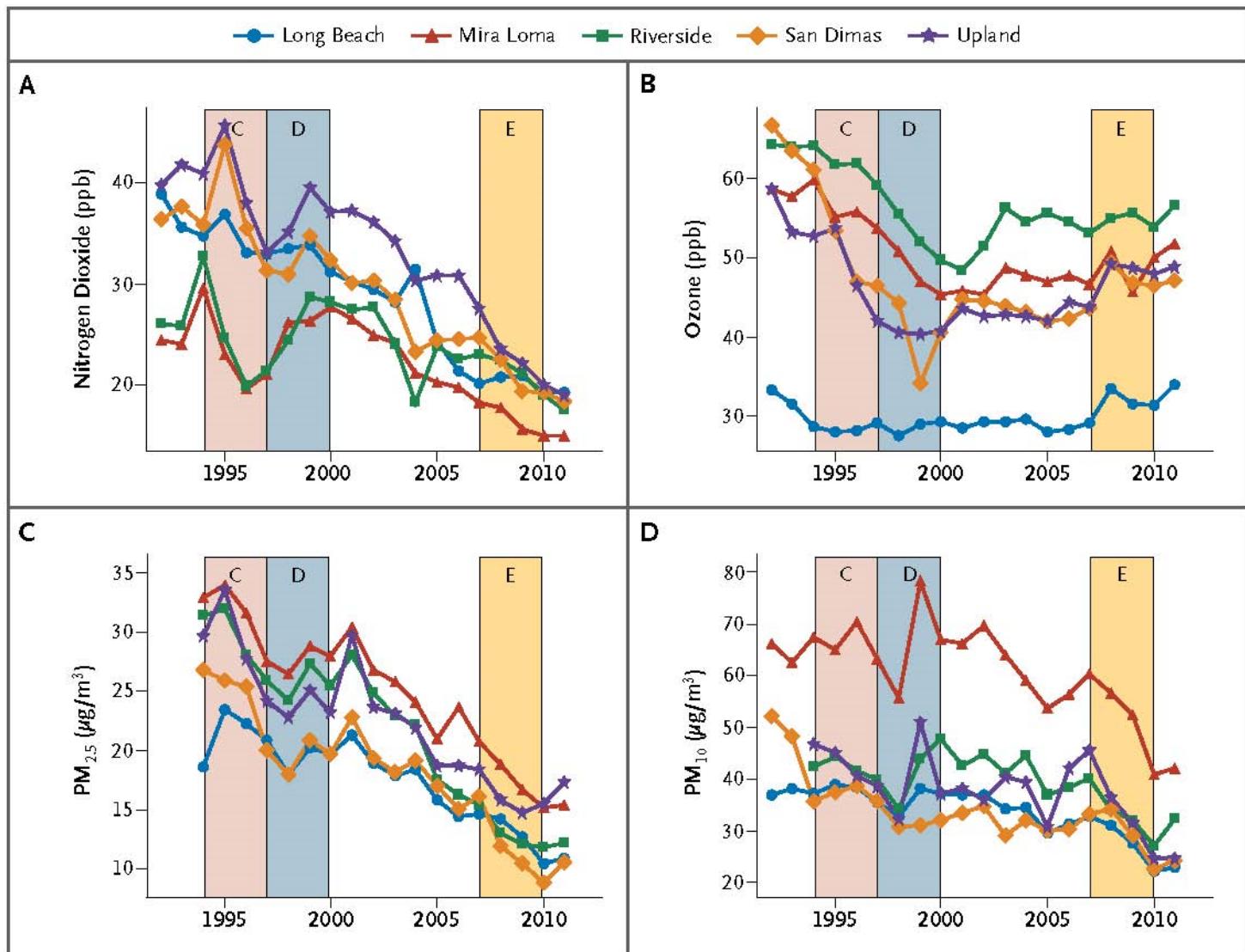
In the latter half of the 20th century, Los Angeles had, by many measures, higher levels of photochemical air pollutants than any other major city in the United States (Fig. 1). To address this problem, the California Air Resources Board and its partners became leaders in quantifying the

growth in the children recruited in 1993,<sup>2</sup> 1997,<sup>4</sup> and 2003.<sup>5</sup>

The consistency of findings in the three separate cohorts is compelling. Moreover, the investigators sought to minimize the potential for confounding by controlling for known individual

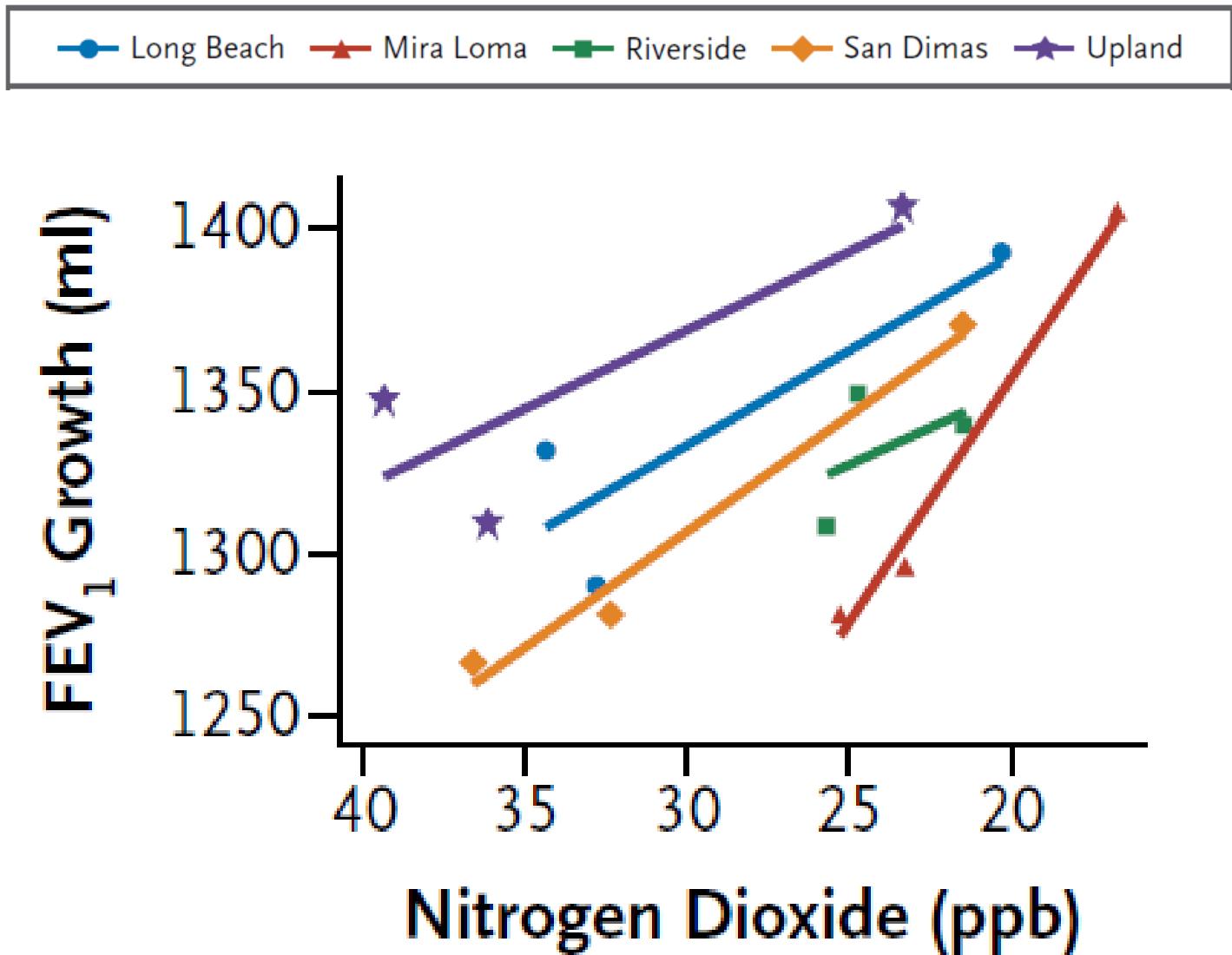


**Exposure  
periods  
(age 11-15)  
for  
CHS Cohorts  
C,D,E**



Improved  
air quality,  
better lung  
function  
growth...

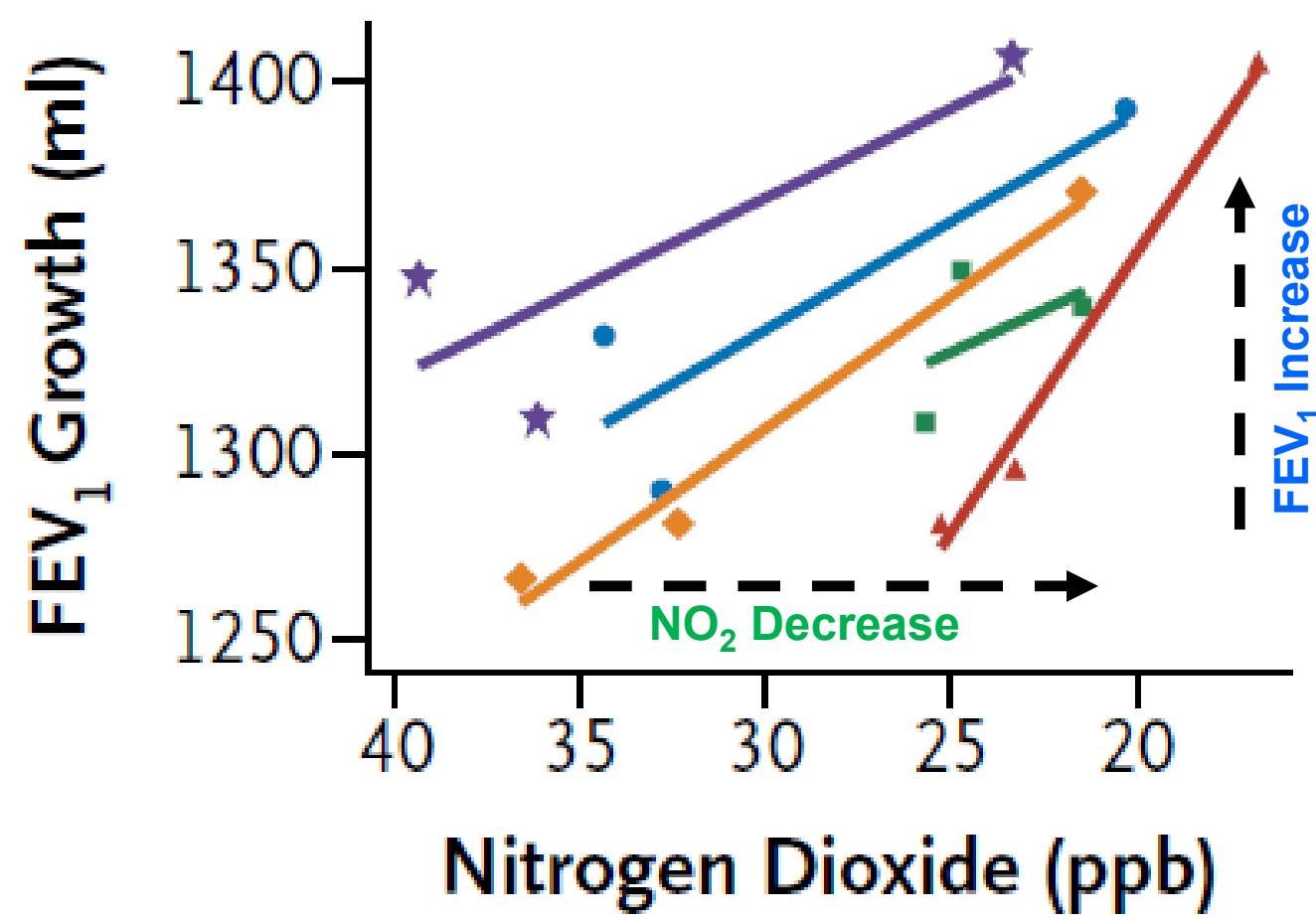
in all 5  
towns

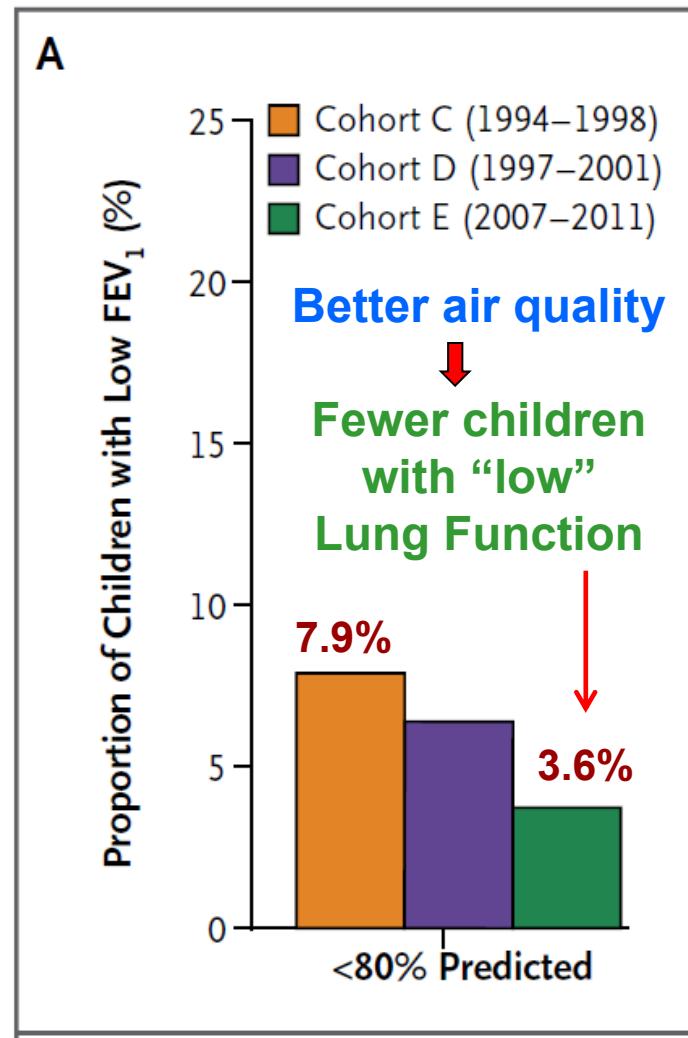


Improved air quality, better 4-yr lung function growth...  
in all 5 towns

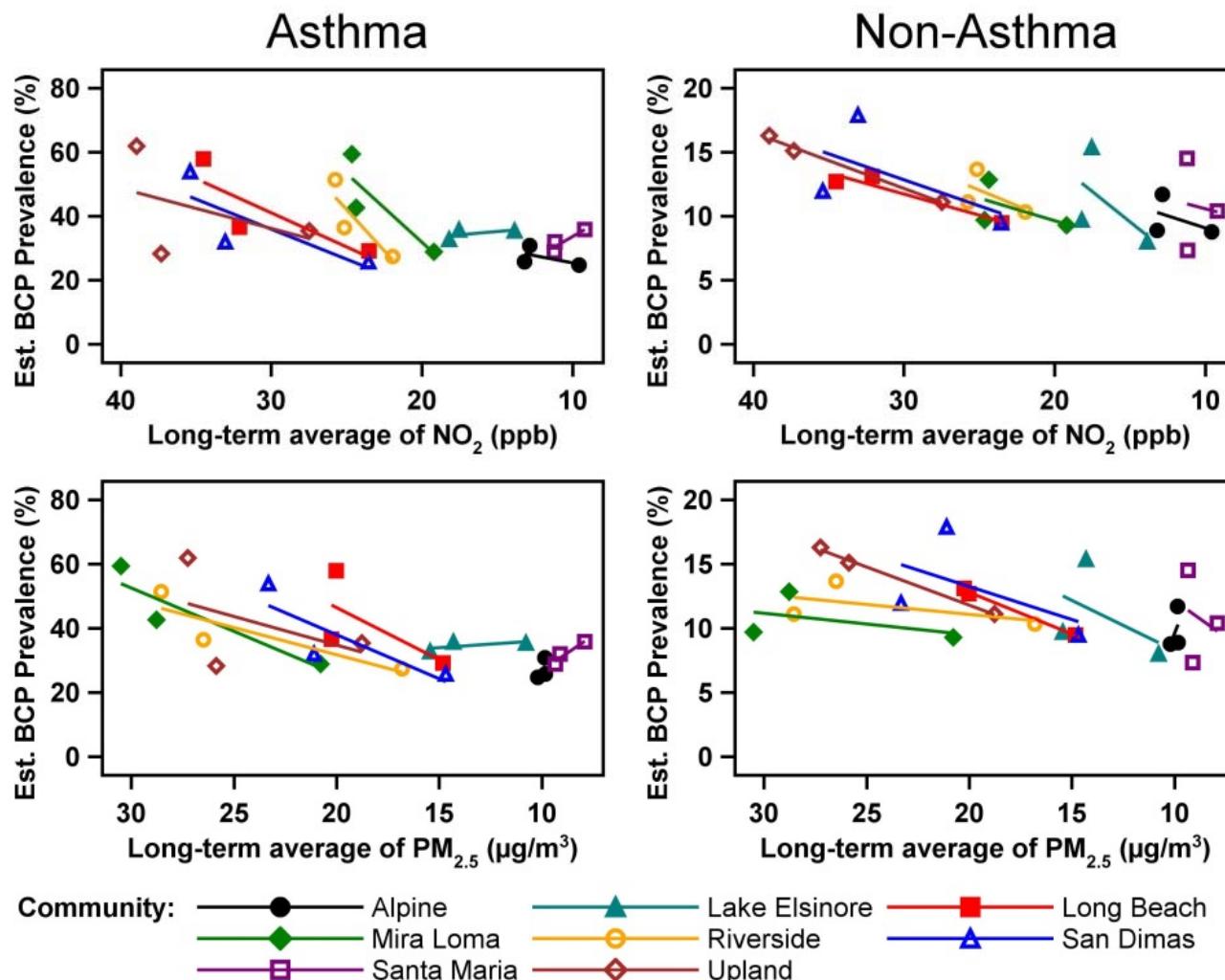
On average:

- ❖ 14.1 ppb Decrease in  $\text{NO}_2$
- ❖ 91.4 ml Increase in  $\text{FEV}_1$  growth





# Bronchitis prevalence vs. long-term pollution



Berhane et al.,  
JAMA, 2016

# **How This Information Gets Used**

**Cynics might say...**

**we've spent lots of \$\$ to show:**

**(1) air pollution is bad for you;**

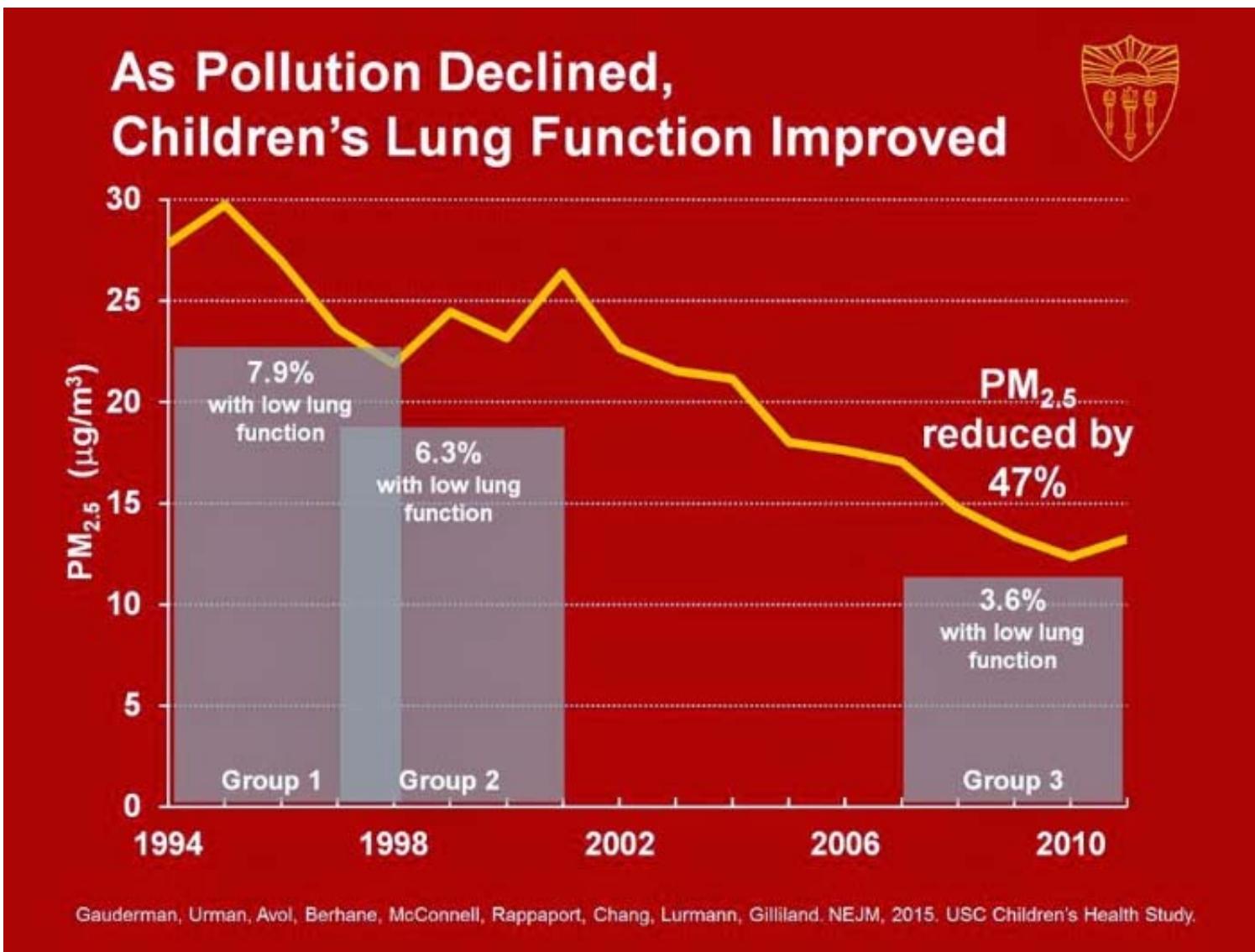
**(2) you shouldn't play in/near the street!**

**... But how do we use this information?**

# Science and Policy

- It starts with good science
- Aim for top journals
- Get to know the ‘players’
  - Other scientists
  - Government staff
  - Media outlets
- Get help developing materials

# “Info-Graphics”



# Newspaper Interviews



# Federal Testimony

## Gauderman Testifies on Air Quality, Health

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OCTOBER 25, 2007

**W.** James Gauderman, professor of preventive medicine at the Keck School of Medicine of USC, did not have to travel all the way to Washington, D.C. to have his voice heard by U.S. lawmakers. In fact, he only had to go as far as San Bernardino, where he testified Oct. 10 at the U.S. Senate Committee on Environment and Public Works field hearing on “Air Pollution Challenges for California’s Inland Empire,” organized by committee chair Sen. Barbara Boxer (D-Calif.).

Gauderman discussed results of the USC Children’s Health Study, which includes the smog-plagued cities of Riverside, Mira Loma, Upland and San Dimas. The USC research shows that children who breathe polluted air face an increased risk of asthma and stunted lung development, effects that adversely impact health well into adulthood. “Reducing levels of air pollution in Southern California is essential,” Gauderman told the committee. “Our health and our children’s health depend on it.”

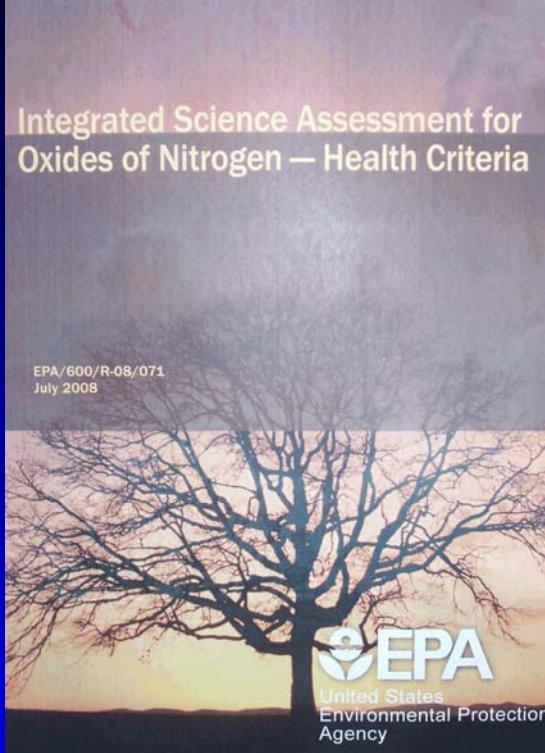
## Local Testimony



L.A. City Council Hearing

# Radio/YouTube

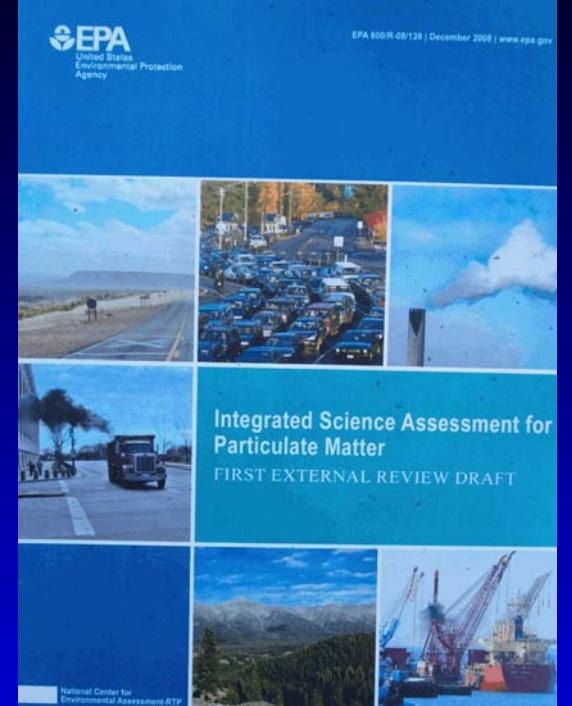




# CHS & Policy

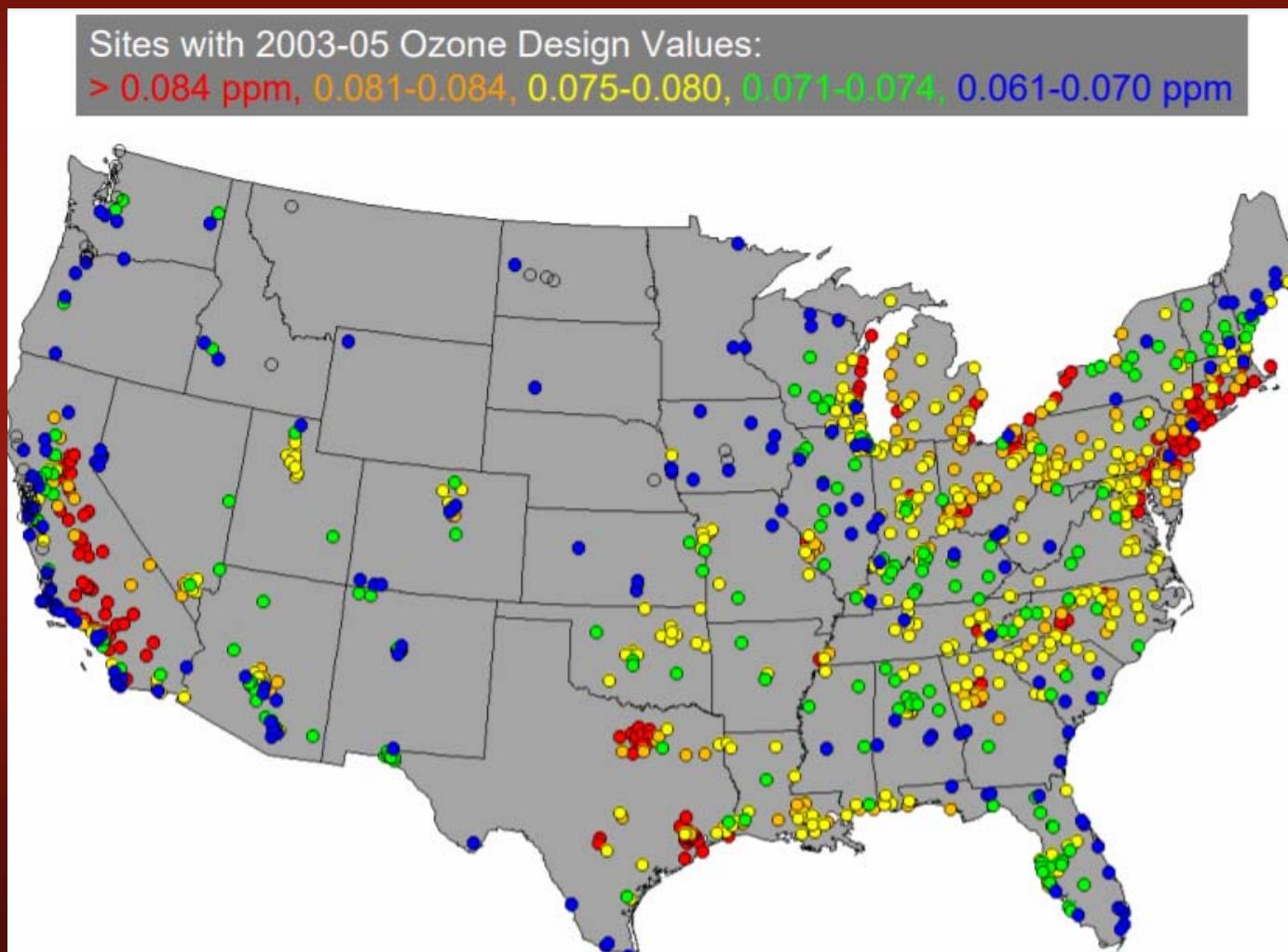
An aerial photograph of a city skyline, likely Los Angeles, showing a dense cluster of buildings under a hazy, blue-tinted sky, illustrating air pollution.

**NEW SMOG STANDARDS**  
EPA PROPOSES STRONGER SMOG REGULATIONS BUT  
HEALTH EXPERTS WARN IT MAY NOT BE ENOUGH

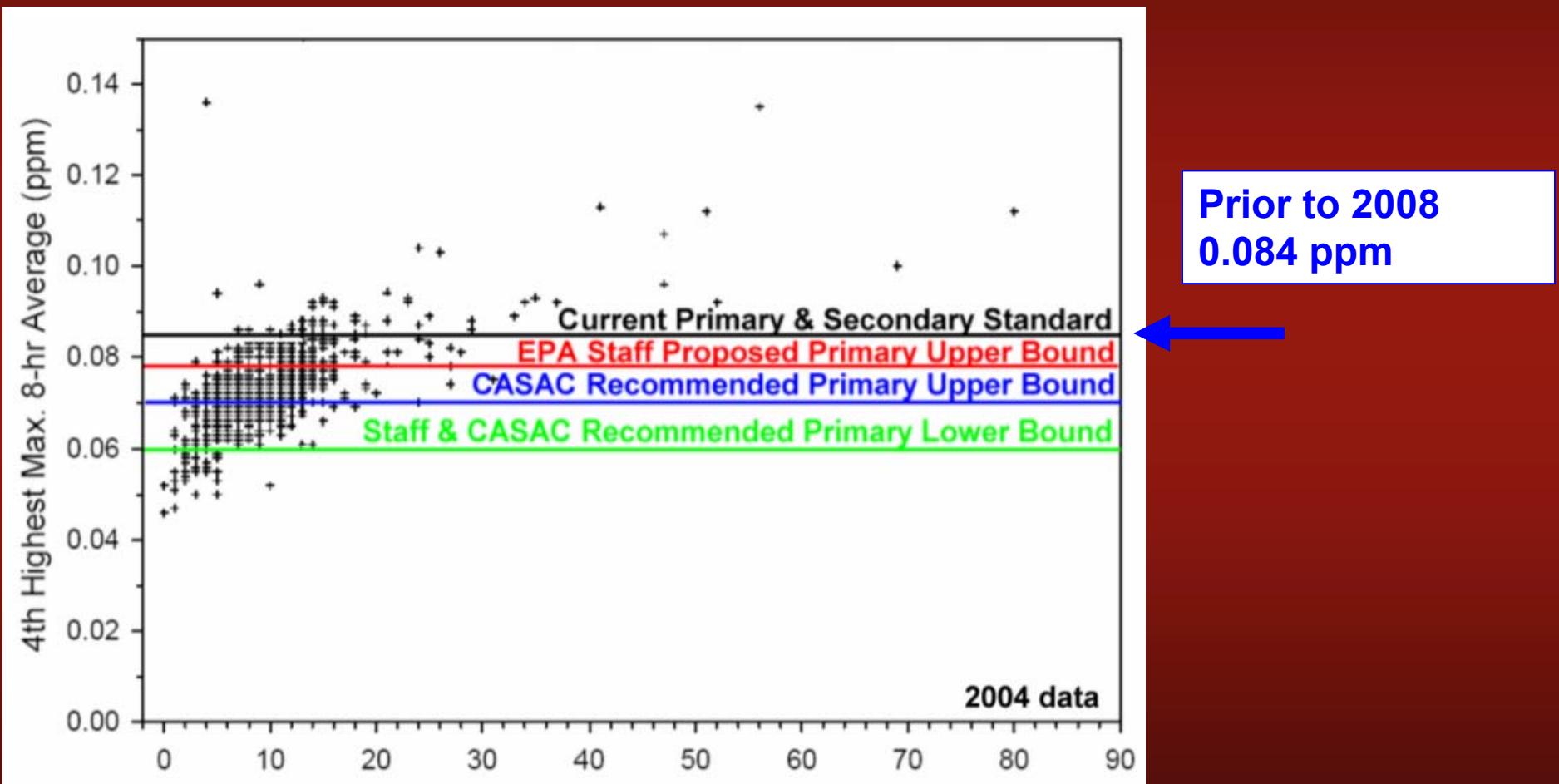


**Ozone:** Gauderman (2007); Avol (2104)  
**NOx/SOx:** Avol (2009)  
**PM2.5:** Avol (2011); McConnell (2018)

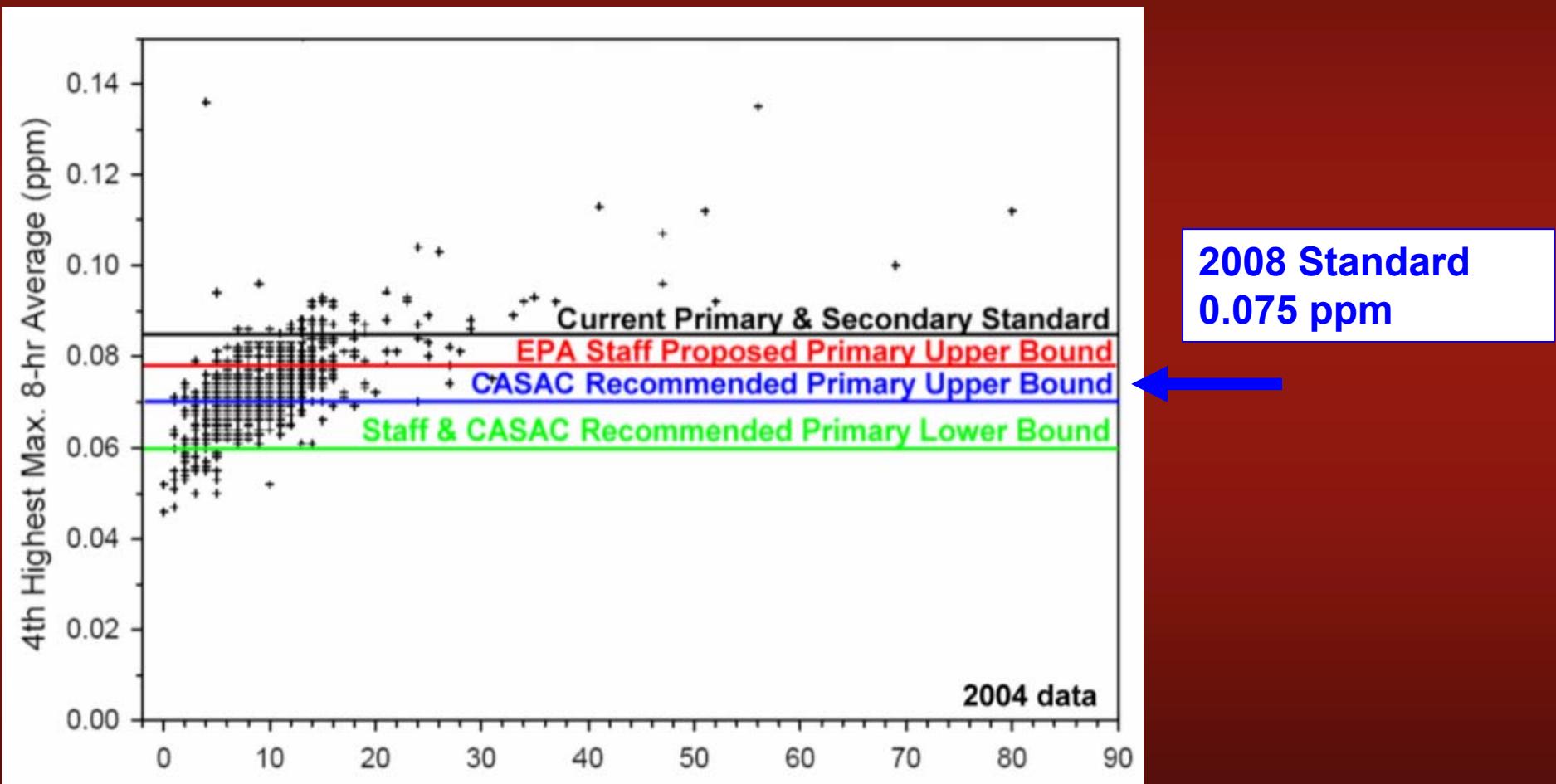
# EPA Clean Air Scientific Advisory Committee: O3 Panel



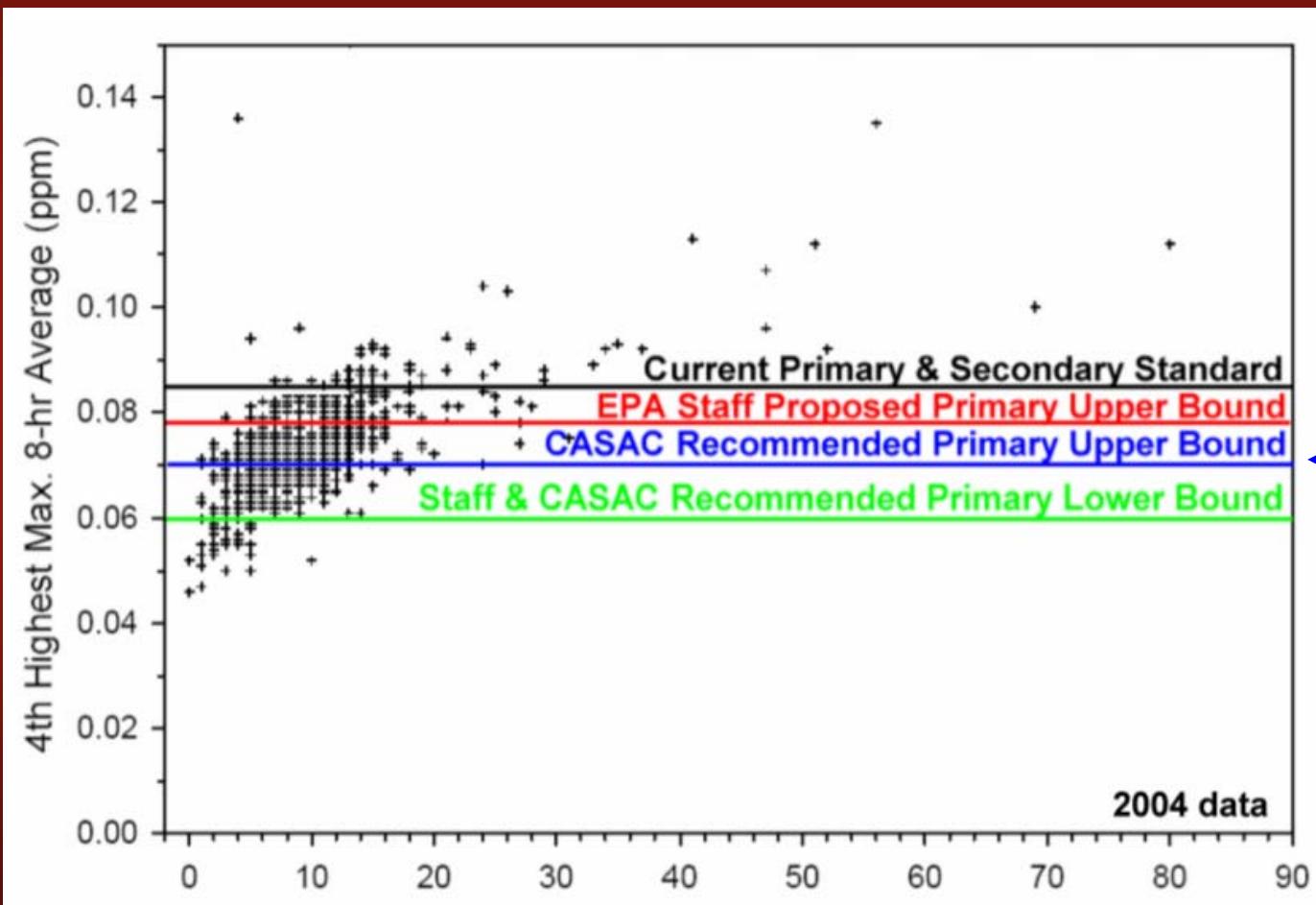
# EPA Clean Air Scientific Advisory Committee: O3 Panel



# EPA Clean Air Scientific Advisory Committee: O3 Panel

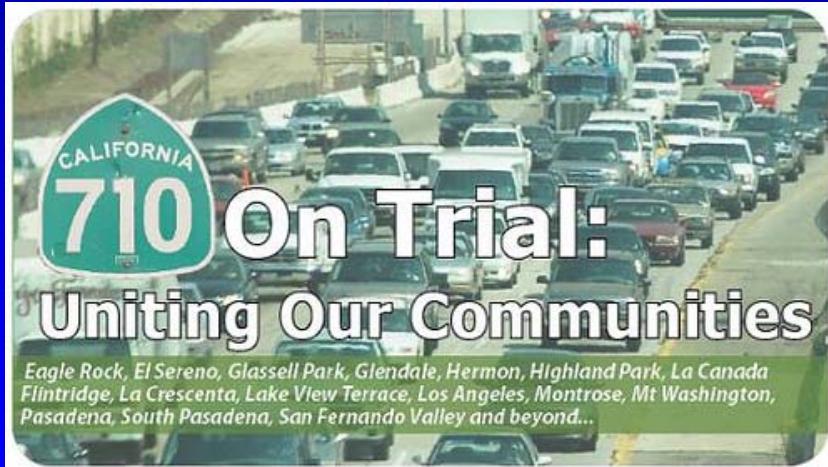


# EPA Clean Air Scientific Advisory Committee: O3 Panel





# Regional Transportation Decisions



## I-710 Freeway Construction Alternatives

### ALTERNATIVE 5A



Widen I-710 from 8 to 10 lanes

### ALTERNATIVE 6A/6B\*



Widen I-710 from 8 to 10 lanes  
Build adjacent 4 lane elevated freight corridor  
\* Include zero emissions requirements, automated guidance

### ALTERNATIVE 6C



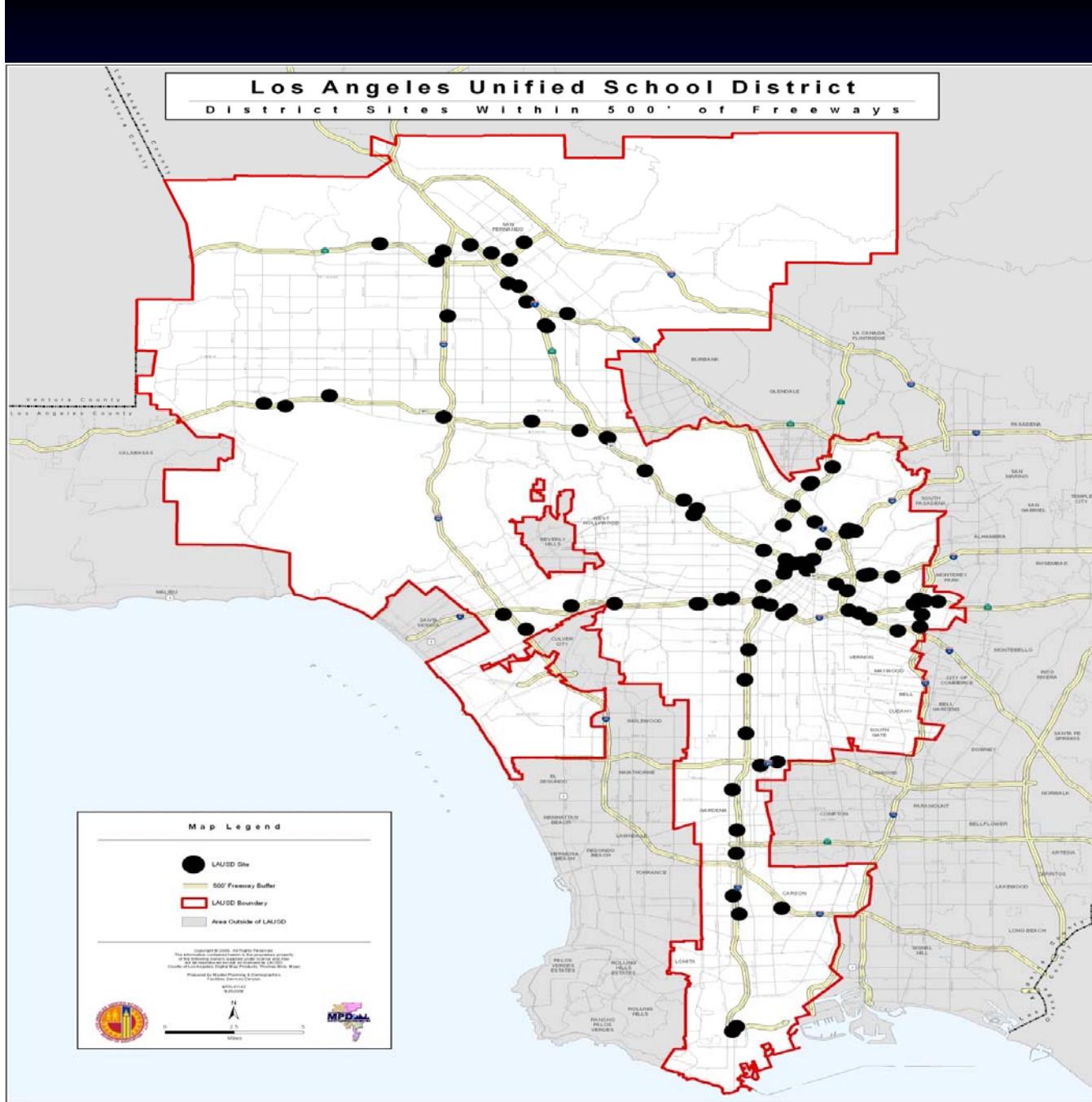
Widen I-710 from 8 to 10 lanes  
Build adjacent 4 lane elevated freight corridor,  
include zero emissions requirements with automated  
guidance and add tolling feature to freight corridor

Note: Alternative 1 is to have no expansion

Paul Penzella Staff Artist

# School Siting





## Schools within 500' of Freeways

Distance	Number of Schools
500 ft	90
200 ft	57
100 ft	37

# Translating Science to Policy

Los Angeles Times  
**latimes.com.**

<http://www.latimes.com/news/local/la-me-freeways24sep24,1,4824480.story>  
*From the Los Angeles Times*

## Schools still rise close to freeways

L.A. Unified continues to build near roads that spew pollution despite a state law and evidence of health hazards.  
By Evelyn Larrubia  
Los Angeles Times Staff Writer

September 24, 2007

Despite a state law that seeks to prevent schools from being built near freeways and mounting evidence that road pollutants harm children's lungs, the Los Angeles Unified School District is in the process of adding seven new schools to the more than 70 already located close to highways.

Los Angeles Times

<http://www.latimes.com/news/local/la-me-freeways23jan23,1,7974792.story>  
*From the Los Angeles Times*

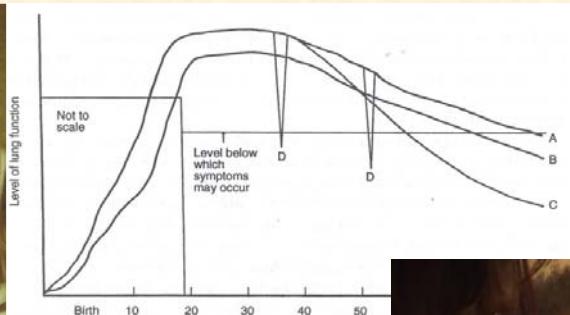
## Board acts to limit new schools near freeways

L.A. Unified officials will have to do more to reduce students' exposure to airborne pollution.  
By Evelyn Larrubia  
Los Angeles Times Staff Writer

January 23, 2008

# Summary

- Based on 20+ years of the CHS...  
Air pollution is associated with chronic health effects



# Summary

- Regional and local exposures are important



# Summary

- **Reductions in air pollution are associated with measurable improvements in children's health**



# Summary

- We cannot get complacent!
  - More cars, trucks, industry, population, etc. are projected

# Summary

- We cannot get complacent:
  - More cars, trucks, industry, population, etc. are projected

**...but hard work to improve air quality pays off!**

