Improved Air Quality and Children's Respiratory Health

Does Cleaning the Air Lead to Better Health?

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Our Path Today…

- A quick review of the Children's Health Study (CHS)
- Air quality trends in southern California
- How children's health changed as air quality changed

Children's Health Study

- **A "10-year" health study (est. 1992)**
  …going on 23 years now!

- **Funded by:**

NIEHS

California Environmental Protection Agency
Air Resources Board

NATIONAL INSTITUTES OF HEALTH

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

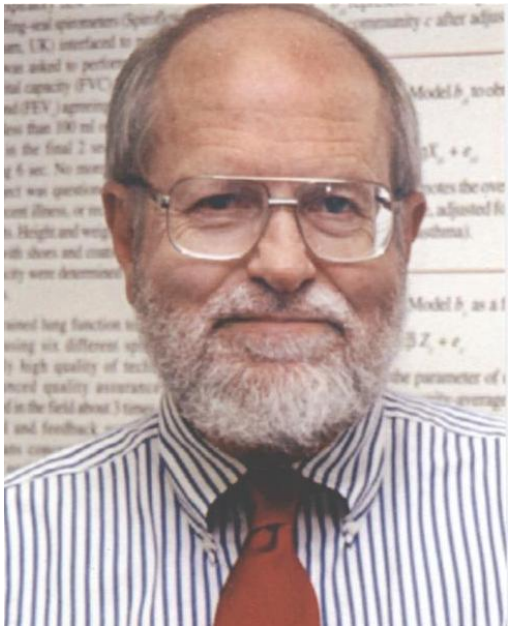
HEI

& the Hastings Foundation

The USC Children's Health Study

Original PI:

John Peters



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Rancho Los Amigos Medical Center / LAREI

Aerosol Dynamics, Inc

South Coast Air Quality Management District

San Diego Air Pollution Control District

San Luis Obispo/Tri-Counties Air Pollution Control District

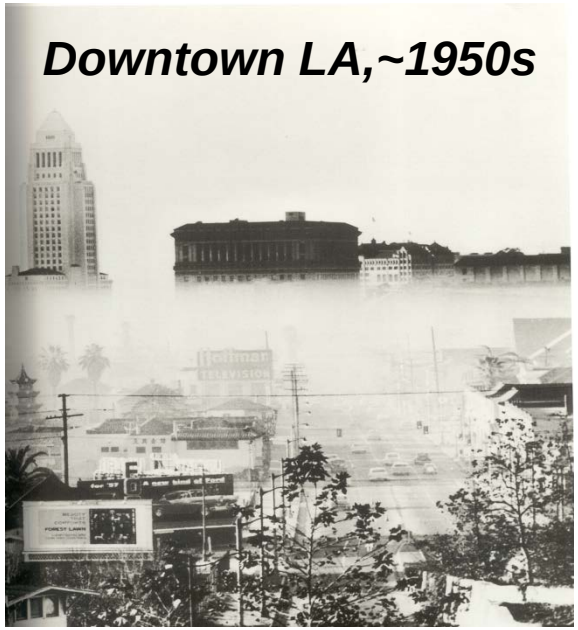
Mojave Air Pollution Control District

Antelope Valley Air Pollution Control District

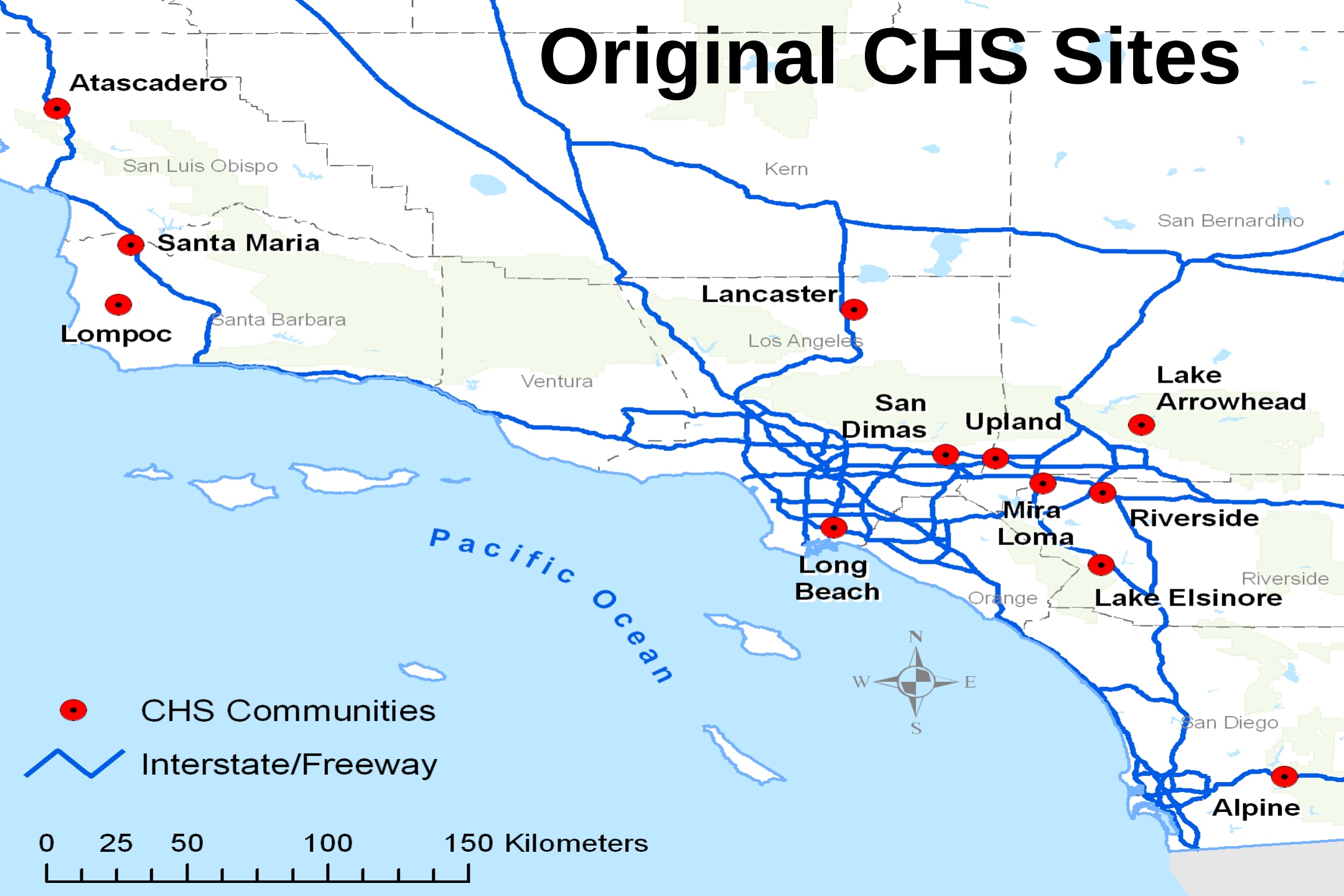
California Air Resources Board

Public Health Question…

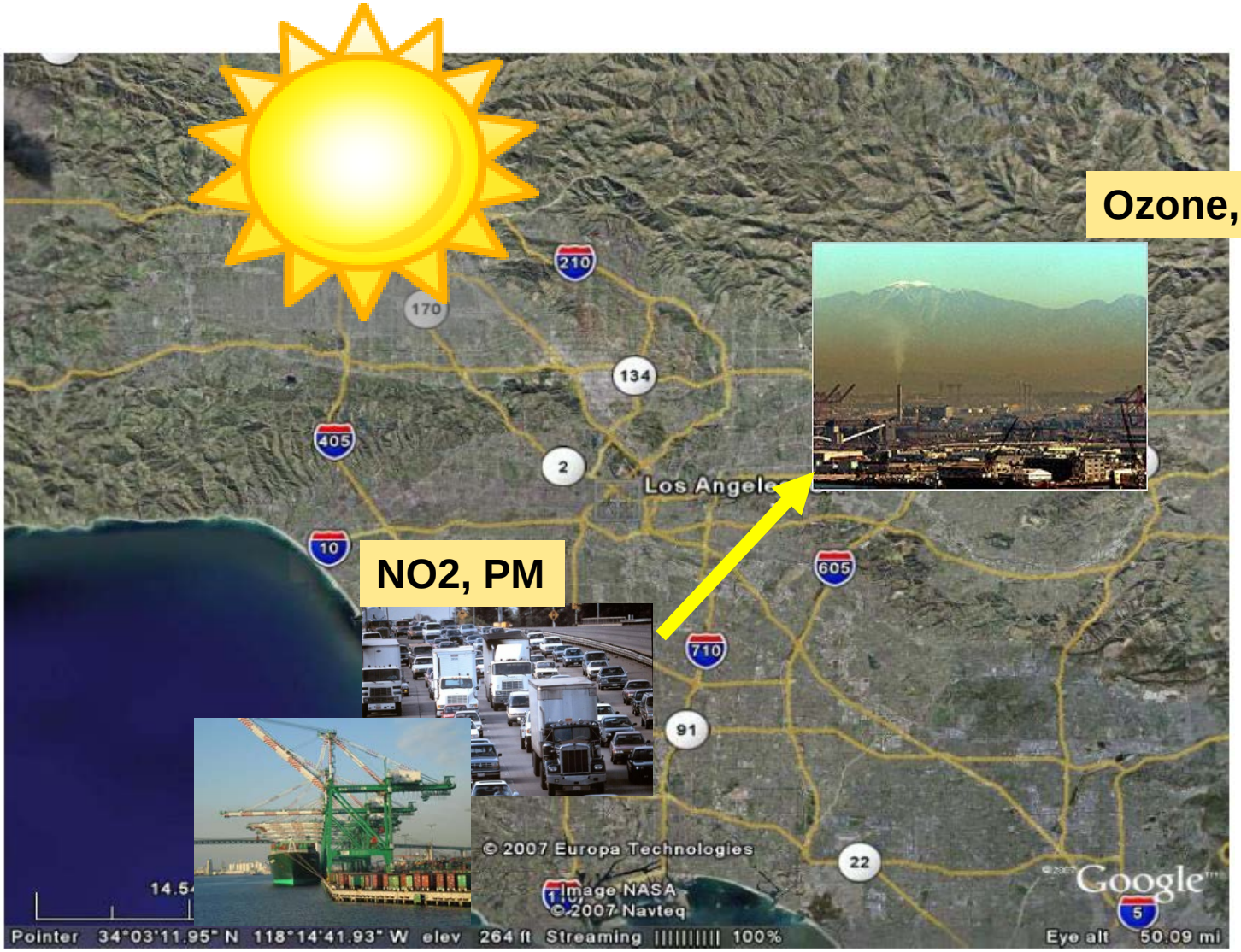
Does outdoor air pollution cause *chronic* health effects?



Original CHS Sites

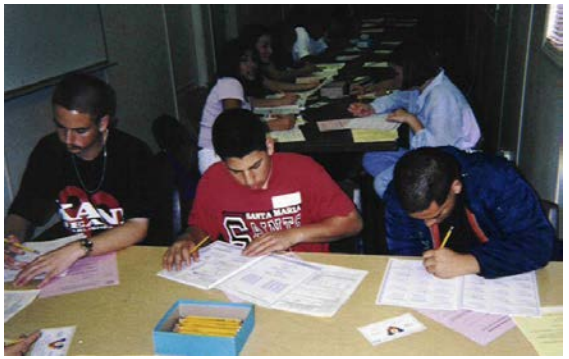


Pollution in the L.A. Basin



CHS Cohorts, By School Year & Class Grade

Co-hort	N	School Year '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																						



Annual Spirometry

Lung function measures:

- Forced expiratory volume in first second of exhalation (FEV_1)
- Forced vital capacity (FVC)
- Maximal mid-expiratory flow (MMEF)
- Peak expiratory flow rate (PEFR)

Annual Questionnaires about health & home operating characteristics

Active smoking?

Height?

Weight?

Pets?

Asthma?

Gas stove?

Respiratory illnesses?

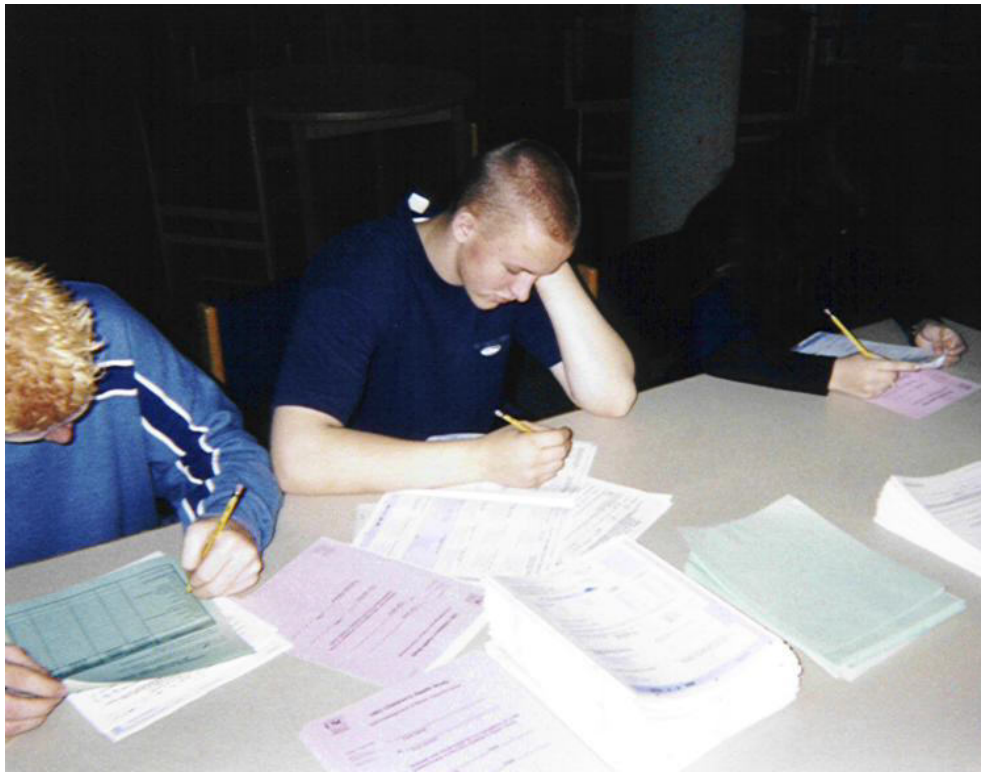
Passive Smoking?

Exercise?

mold?

Diet

Medication?



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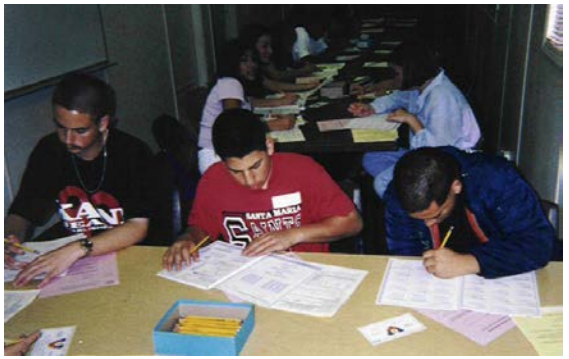
(ALL)	11689																						

Cohort C: Followed from 10 to 18 years of age



The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 SEPTEMBER 9, 2004 VOL. 351 NO. 11

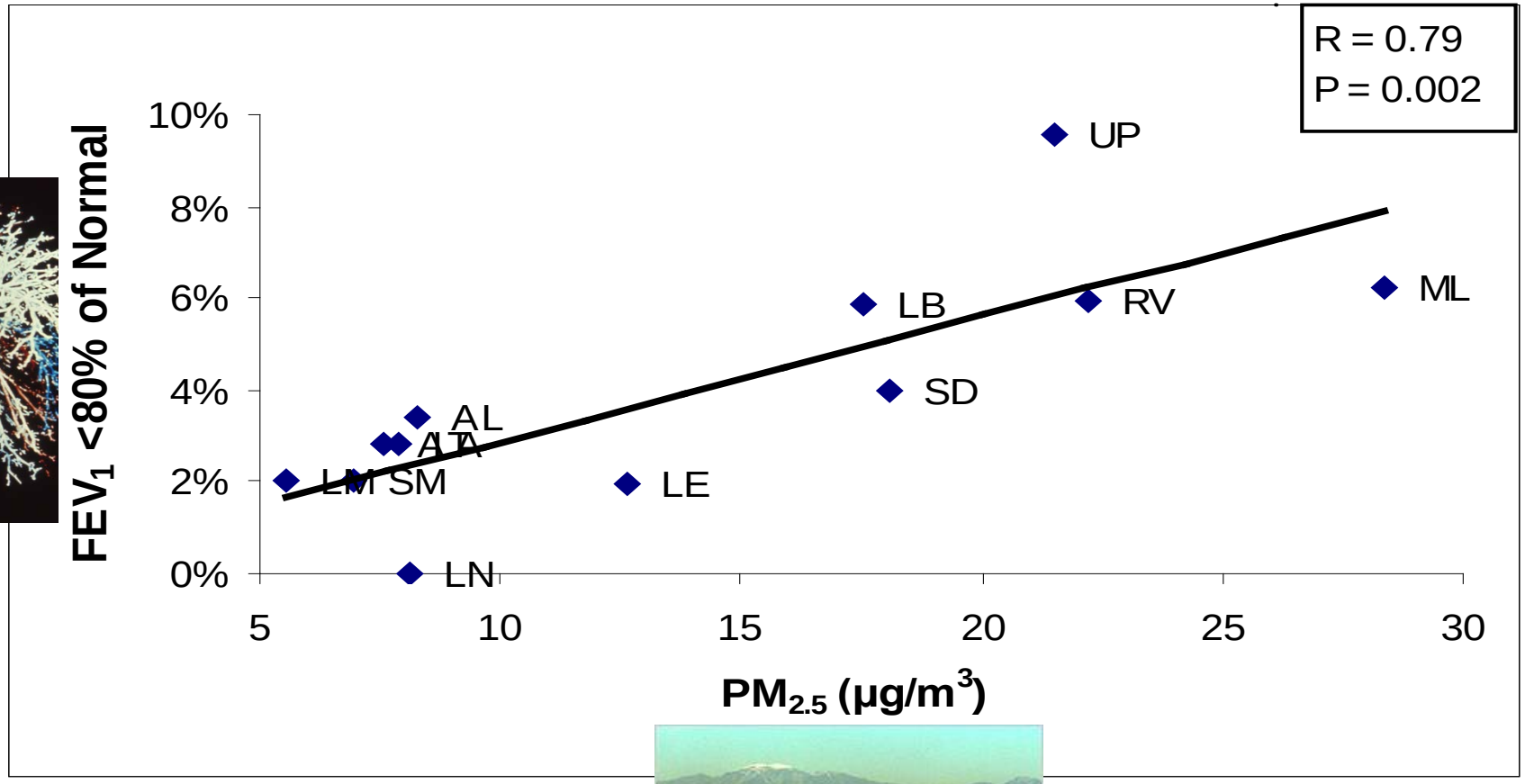
The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age

W. James Gauderman, Ph.D., Edward Avol, M.S., Frank Gilliland, M.D., Ph.D., Hita Vora, M.S., Duncan Thomas, Ph.D., Kiros Berhane, Ph.D., Rob McConnell, M.D., Nino Kuenzli, M.D., Fred Lurmann, M.S., Edward Rappaport, M.S., Helene Margolis, Ph.D., David Bates, M.D., and John Peters, M.D.

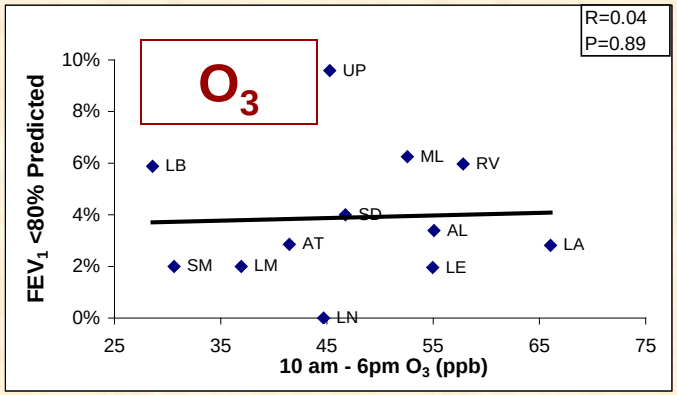
CONCLUSIONS

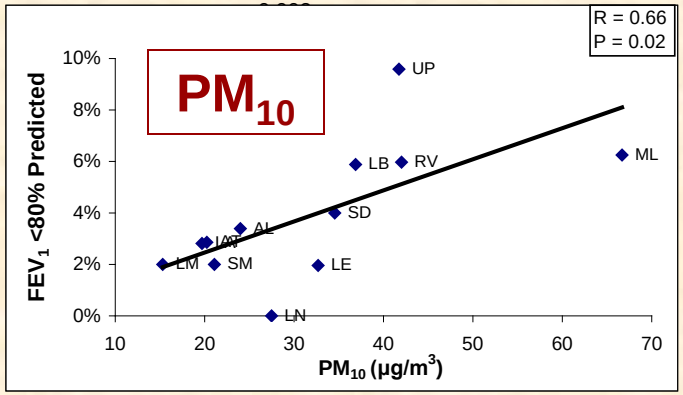
The results of this study indicate that current levels of air pollution have chronic, adverse effects on lung development in children from the age of 10 to 18 years, leading to clinically significant deficits in attained FEV_1 as children reach adulthood.

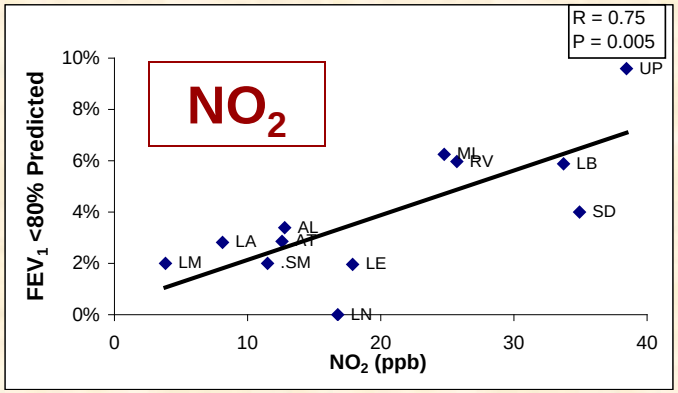
Abnormally Low Lung Function is More Likely in a High PM Community

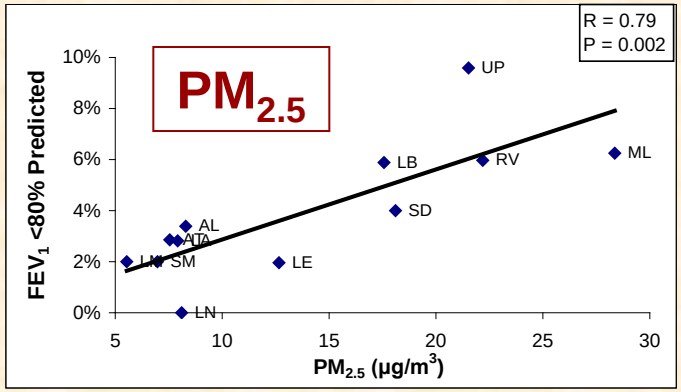


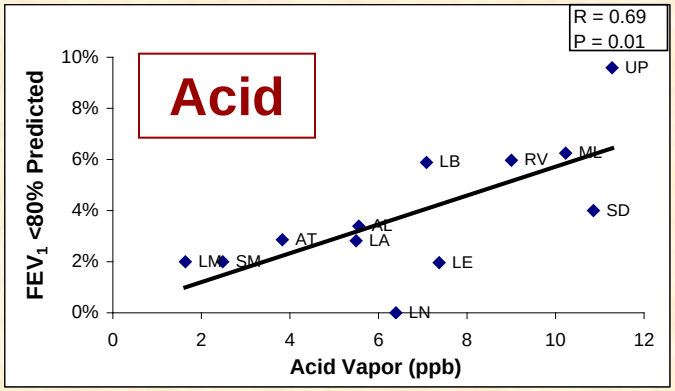
Low FEV_1 at Age 18 vs. Pollution

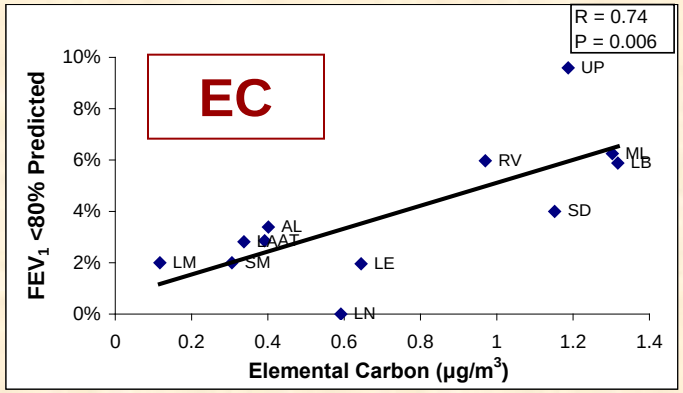




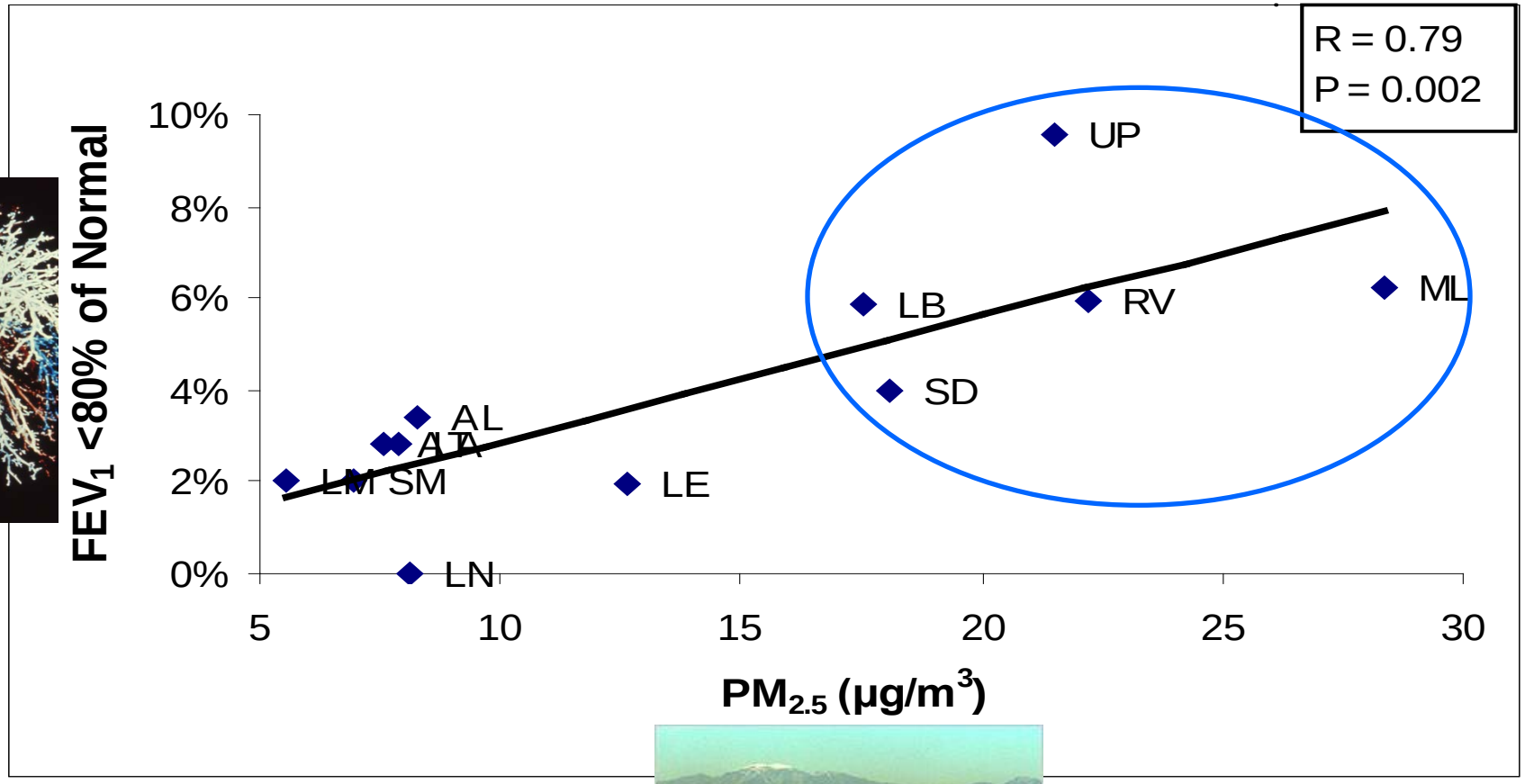






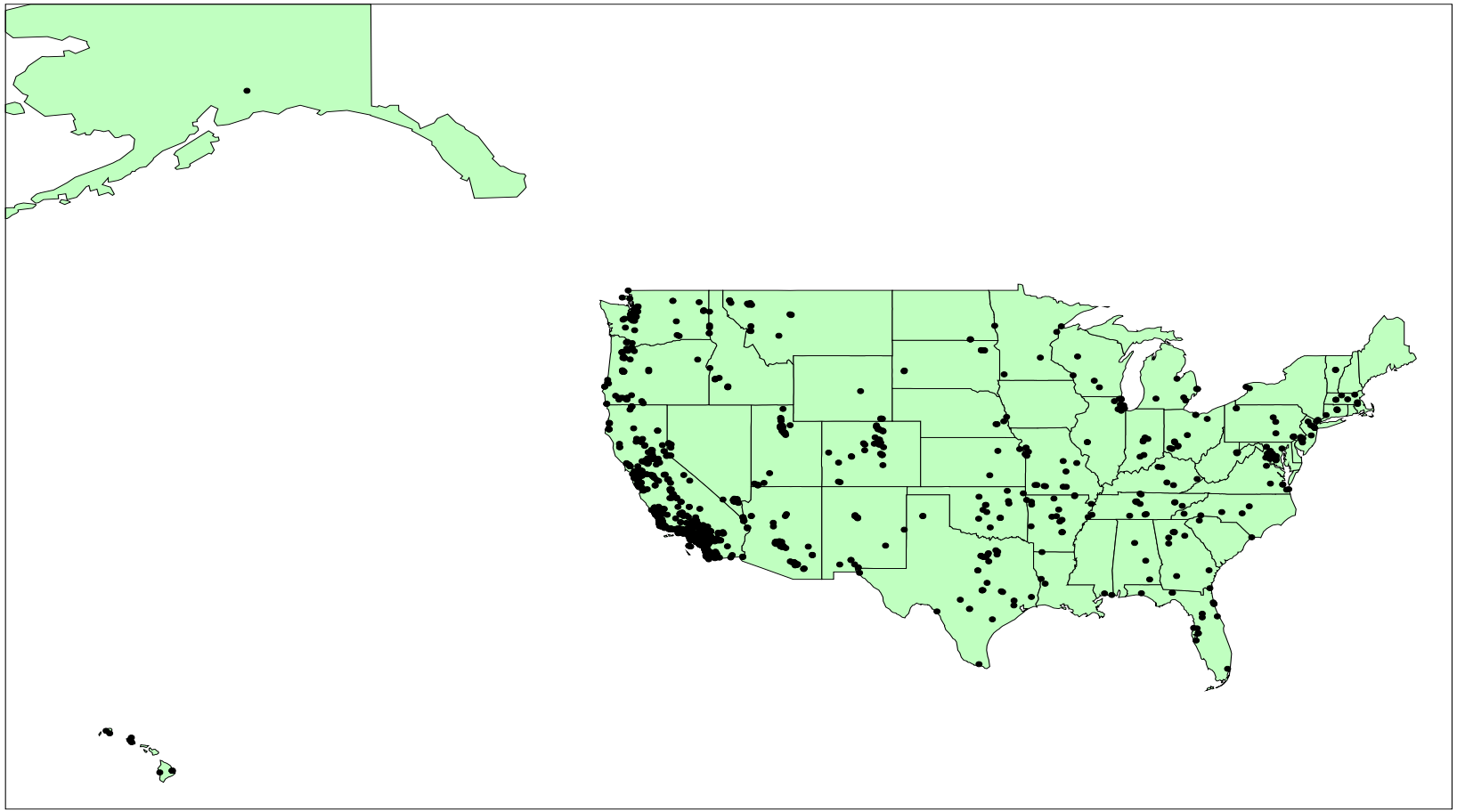


Abnormally Low Lung Function is More Likely in a Polluted Community



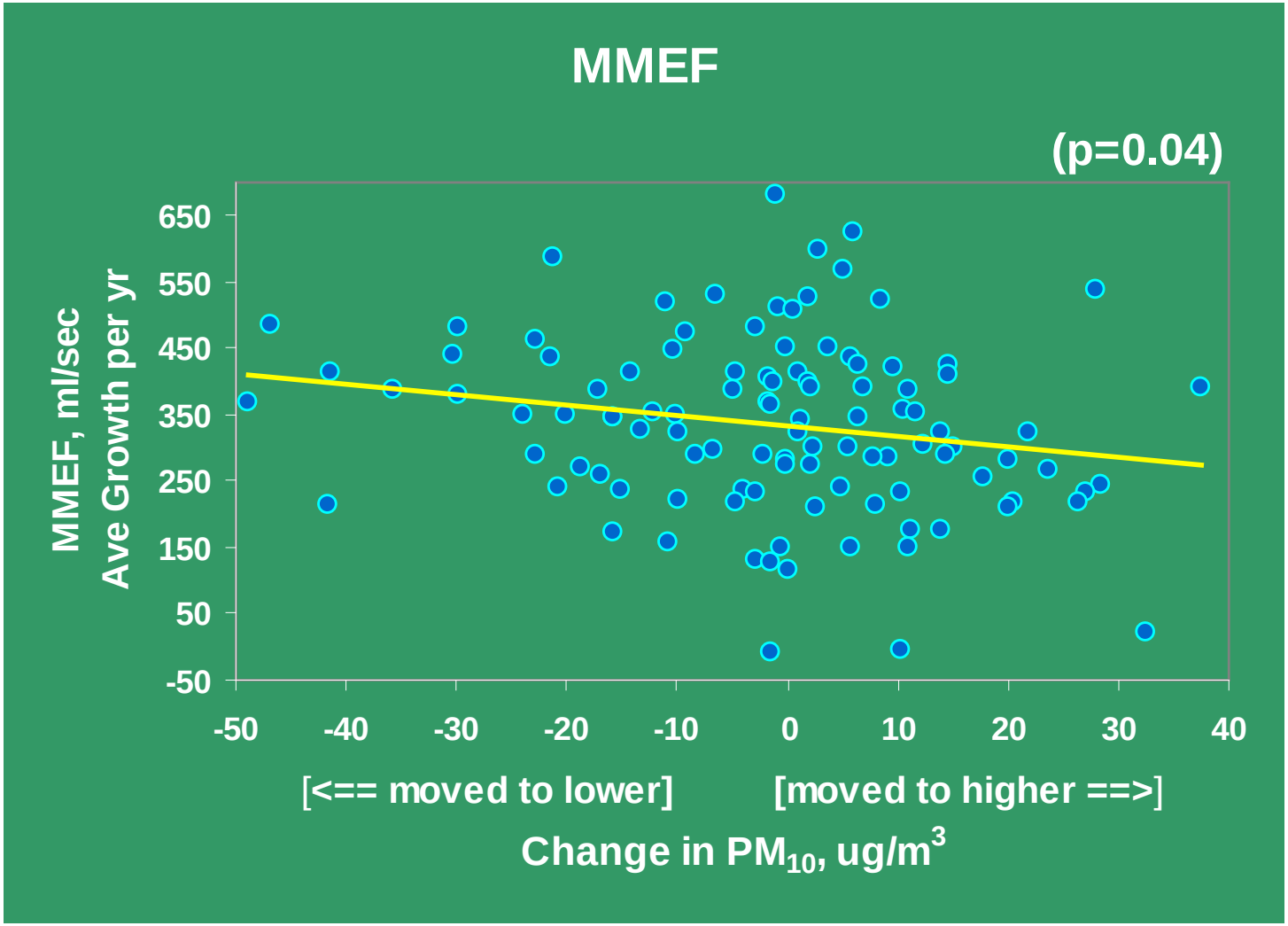
CHS Movers Study

What happens to health when children move?



… Some to higher pollution, some to lower …

Lung Function Growth in Movers



(Avol et al., 2001)

But what if, over time,

the air got *cleaner*

where they stayed & grew up?

HEI contract to answer this question

Emissions reduction policies and recent trends in Southern California's ambient air quality

JAWMA, 65:3, 324-335, (2015)

Fred Lurmann,[1] Ed Avol,[2,*] and Frank Gilliland[2]

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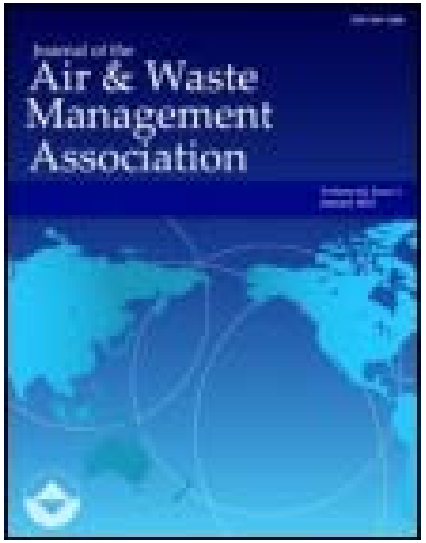
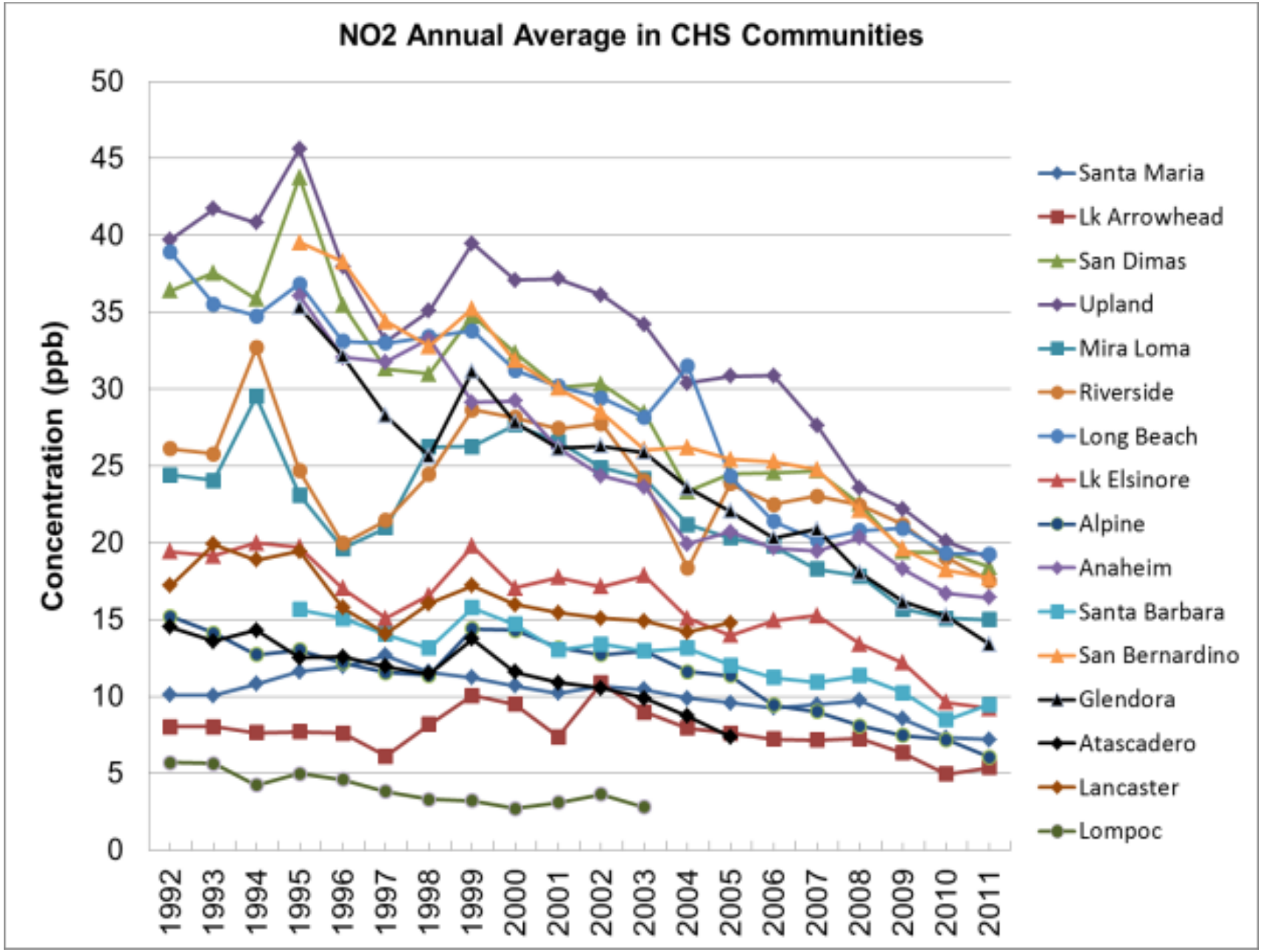
[2] *Department of Preventive Medicine, University of Southern California, Los Angeles, CA, USA*

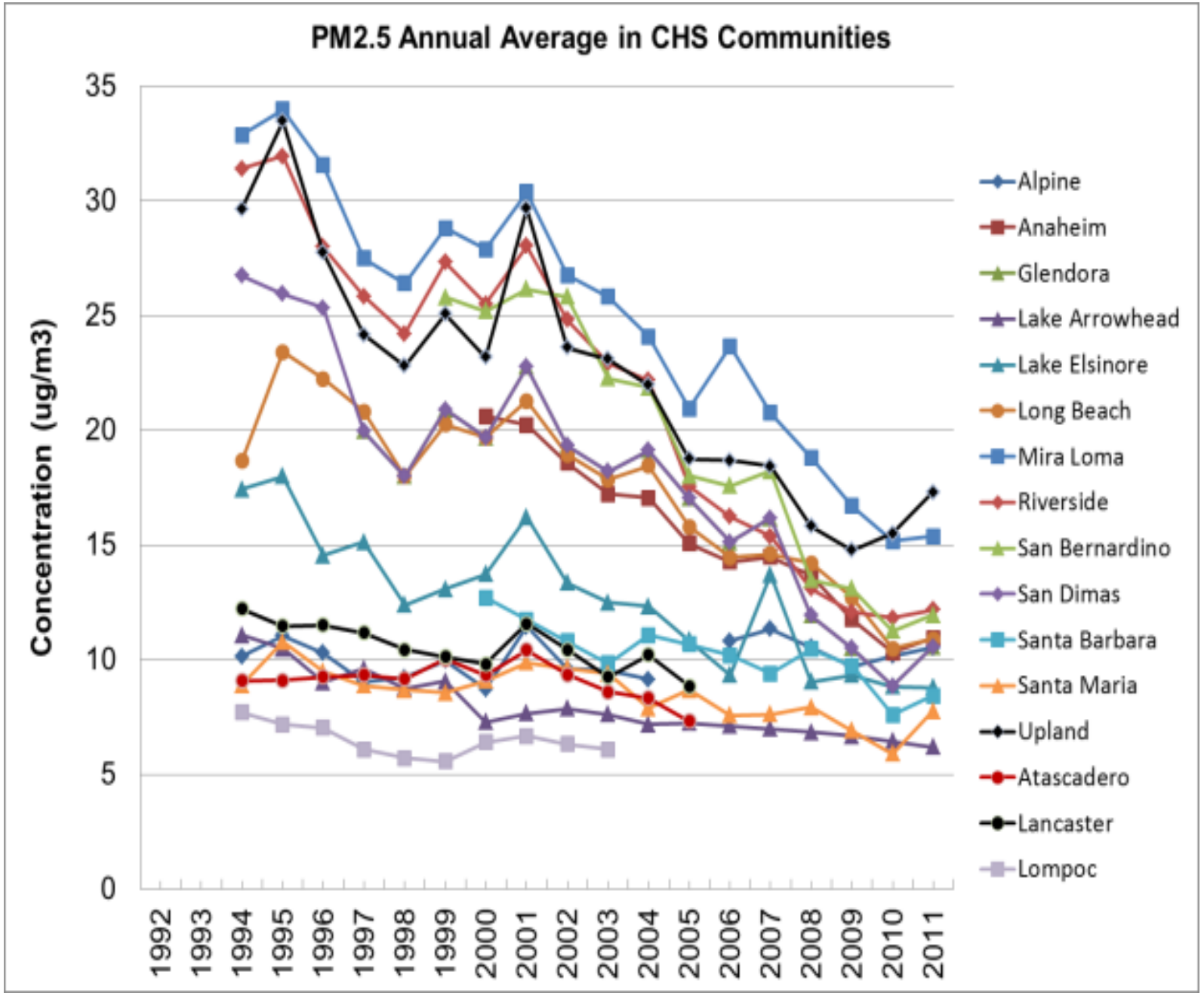
[*] *Please address correspondence to: Ed Avol, Department of Preventive Medicine, University of Southern California, 2001 N. Soto St, Los Angeles, CA 90089, USA; e-mail: avol@usc.edu*



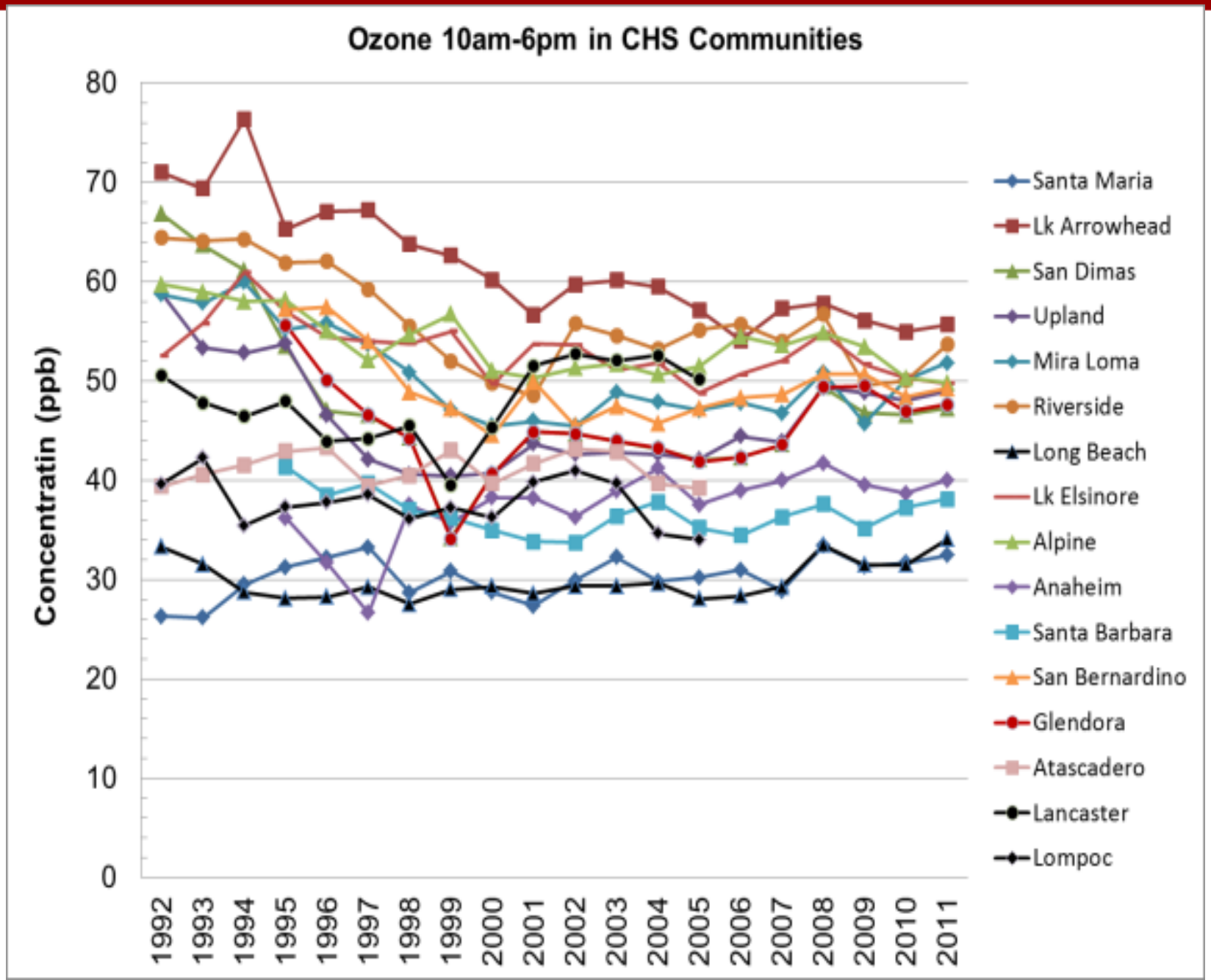
Between 1994 & 2011, average NO_2 *declined* 28% to 53%



Between 1994 & 2011, average $PM_{2.5}$ *declined* 13% to 54%



Average O_3 declines were more moderate (or increased slightly)



Regulatory Policies Affecting Trends in California (1985-2012)

Regulatory Policy	Adoption Date
On-road Emissions:	
Low-emission vehicle standards for light-duty and medium-duty vehicles (LEV, LEV II)	1990, 1998
Reformulated gasoline	1988, 1990, 1991
On-board diagnostics standards for light-duty vehicles	1985, 1989
Medium-duty and heavy-duty truck gasoline emission standards	1995
Heavy-duty diesel truck engine emissions standards	1998, 2001
Clean diesel fuel requirements	2003
Financial incentives for replacement or retrofit high-polluting vehicles, engines & equipment (e.g., the Carl Moyer Program)	1998-2012
Cleaner port (drayage) trucks	2007
Off-Road Emissions:	
Cleaner diesel fuel for ocean-going vessels, harbor craft, and trains	2004, 2008
Reduced port auxiliary engines and incinerator use, hoteling	2007
Cleaner locomotive engines in Southern California	1997, 2010
Stationary diesel engines standards for in-use agricultural engines	2007
Stationary Point Sources:	
NOx and SOx reductions from *RE*gional *CL*ean *A*ir *I*ncentives *M*arket (RECLAIM)	1994
New Source Review (NSR)	1990
Source-specific emissions standards	1988-2002
Area Sources:	
Low-emission certificate programs for products and equipment	1988-2012
Unpaved and paved road dust control measures	2008
Water heater and small boiler emission standards	1999, 2004

CHS Cohorts, By School Year & Class Grade

Co-hort	N	School Year '93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14
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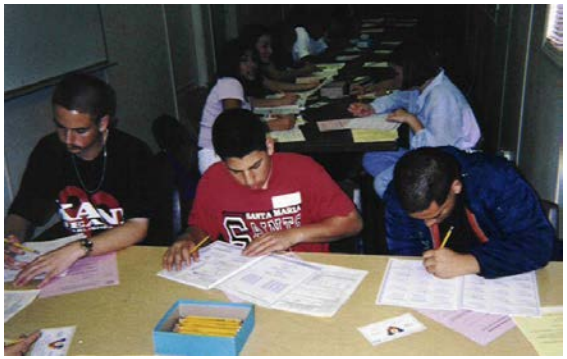
(ALL)	11689																						

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



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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.

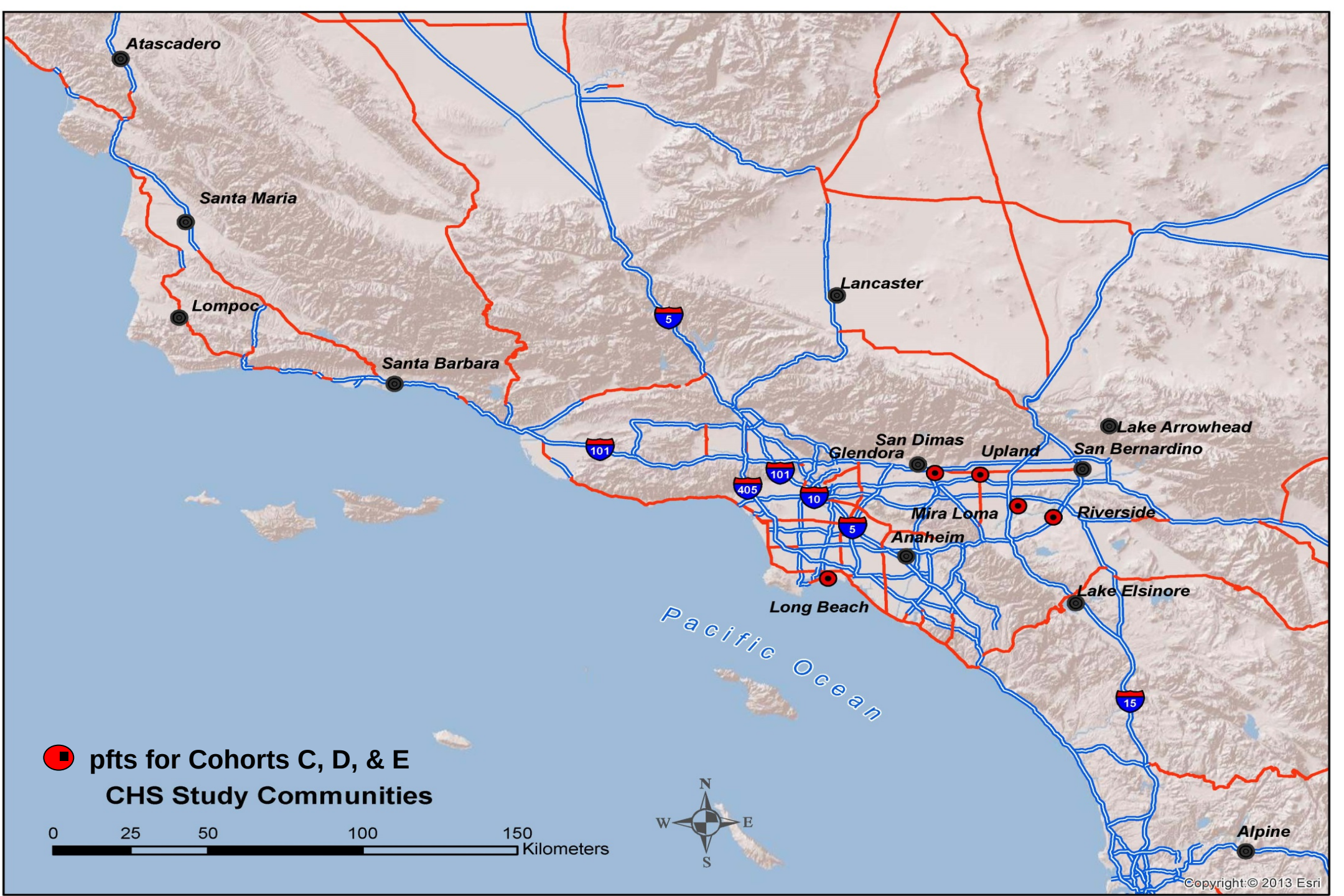
EDITORIAL

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,[2] 1997,[4] and 2003.[5]

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


Atascadero
Santa Maria
Lompoc
Santa Barbara
Lancaster
Lake Arrowhead
San Dimas
Glendora
Upland
San Bernardino
Mira Loma
Riverside
Anaheim
Long Beach
Lake Elsinore
Alpine
Pacific Ocean
5
101
405
10
15
pfts for Cohorts C, D, & E
CHS Study Communities
0 25 50 100 150
Kilometers
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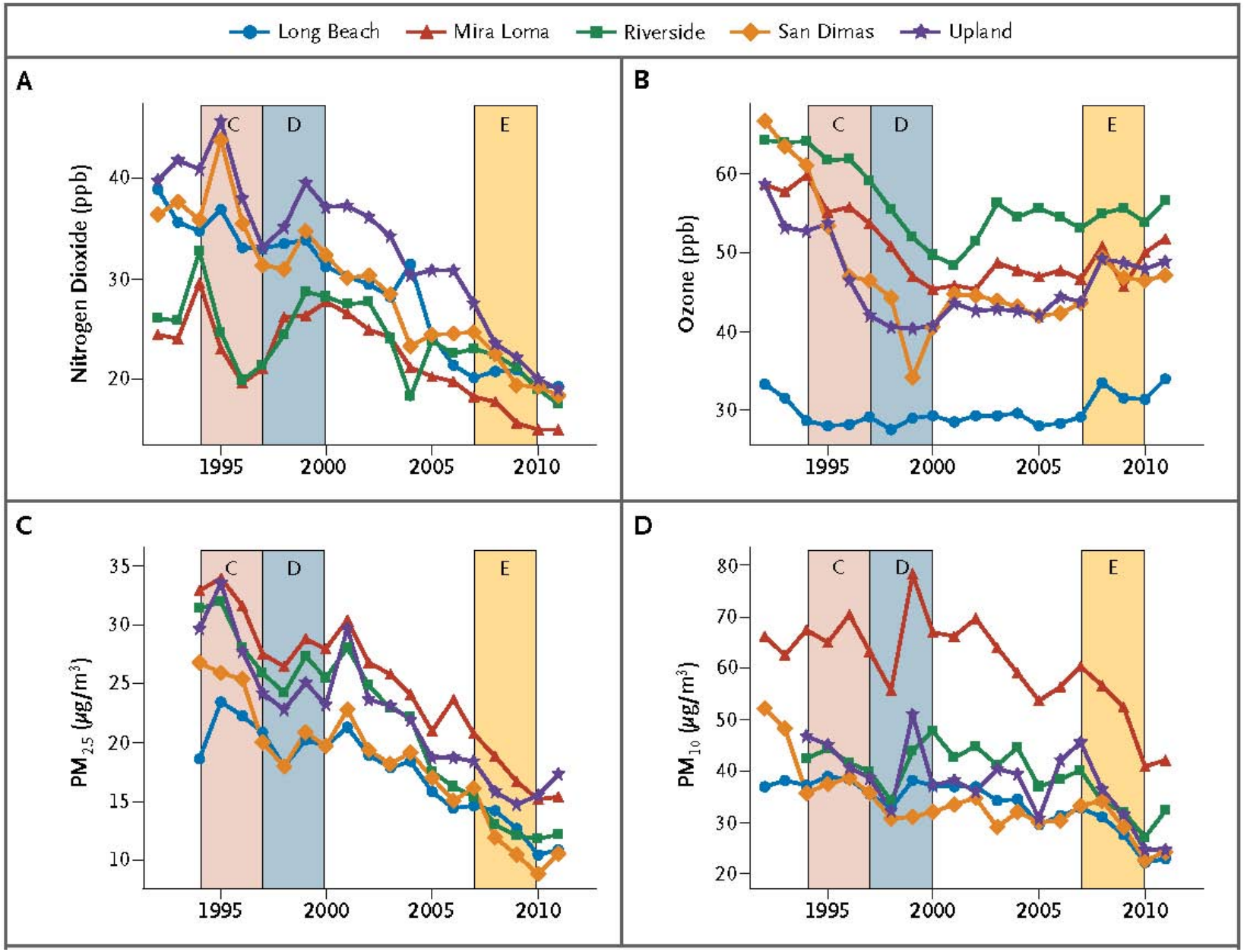
Exposure periods (age 11-15) for CHS Cohorts C,D,E



Change in Exposure: Cohort C to E

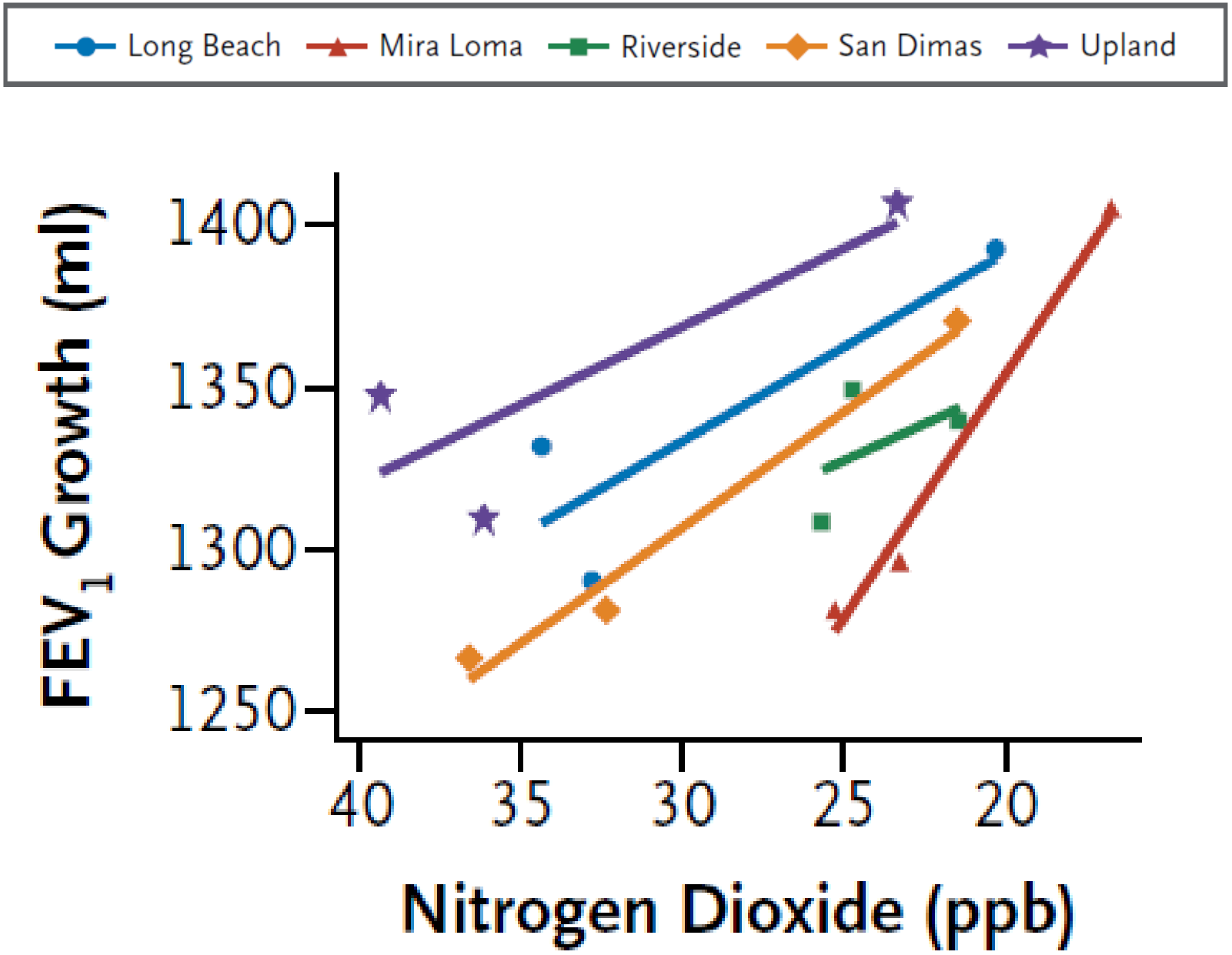
Supplemental Table S2: Mean pollutant levels corresponding to the colored bands in Figure 1

Pollutant	Cohort	Years	Long Beach	Mira Loma	Riverside	San Dimas	Upland
NO_2 (ppb)	C	1994-1997	34.4	23.3	24.7	36.6	39.4
	D	1997-2000	32.9 (-4.5%)	25.3 (8.5%)	25.7 (4.0%)	32.4 (-11.6%)	36.2 (-8.1%)
	E	2007-2010	20.3 (-41.0%)	16.7 (-28.3%)	21.4 (-13.2%)	21.5 (-41.3%)	23.4 (-40.7%)
O_3 (10a-6p, ppb)	C	1994-1997	28.6	56.2	61.9	52	48.8
	D	1997-2000	28.8 (0.7%)	49.3 (-12.3%)	54.1 (-12.5%)	41.4 (-20.5%)	40.9 (-16.1%)
	E	2007-2010	31.4 (10.0%)	48.4 (-13.9%)	54.5 (-11.9%)	46.6 (-10.5%)	47.5 (-2.6%)
PM_{10} ($\mu g/m^3$)	C	1994-1997	37.5	66.5	42.1	36.9	42.9
	D	1997-2000	35.9 (-4.2%)	66.0 (-0.7%)	41.5 (-1.4%)	32.5 (-12.0%)	39.9 (-7.1%)
	E	2007-2010	28.4 (-24.2%)	52.6 (-20.8%)	33.4 (-20.7%)	29.9 (-19.1%)	34.7 (-19.2%)
$PM_{2.5}$ ($\mu g/m^3$)	C	1994-1997	21.3	31.5	29.3	24.5	28.7
	D	1997-2000	19.7 (-7.5%)	27.6 (-12.2%)	25.7 (-12.2%)	19.6 (-19.9%)	23.8 (-17.2%)
	E	2007-2010	13.0 (-38.9%)	17.8 (-43.3%)	13.1 (-55.3%)	11.9 (-51.6%)	16.1 (-43.9%)

Mean pollutant level over the indicated 4-yr period in each community (values in parentheses are the percent change compared to Cohort C)

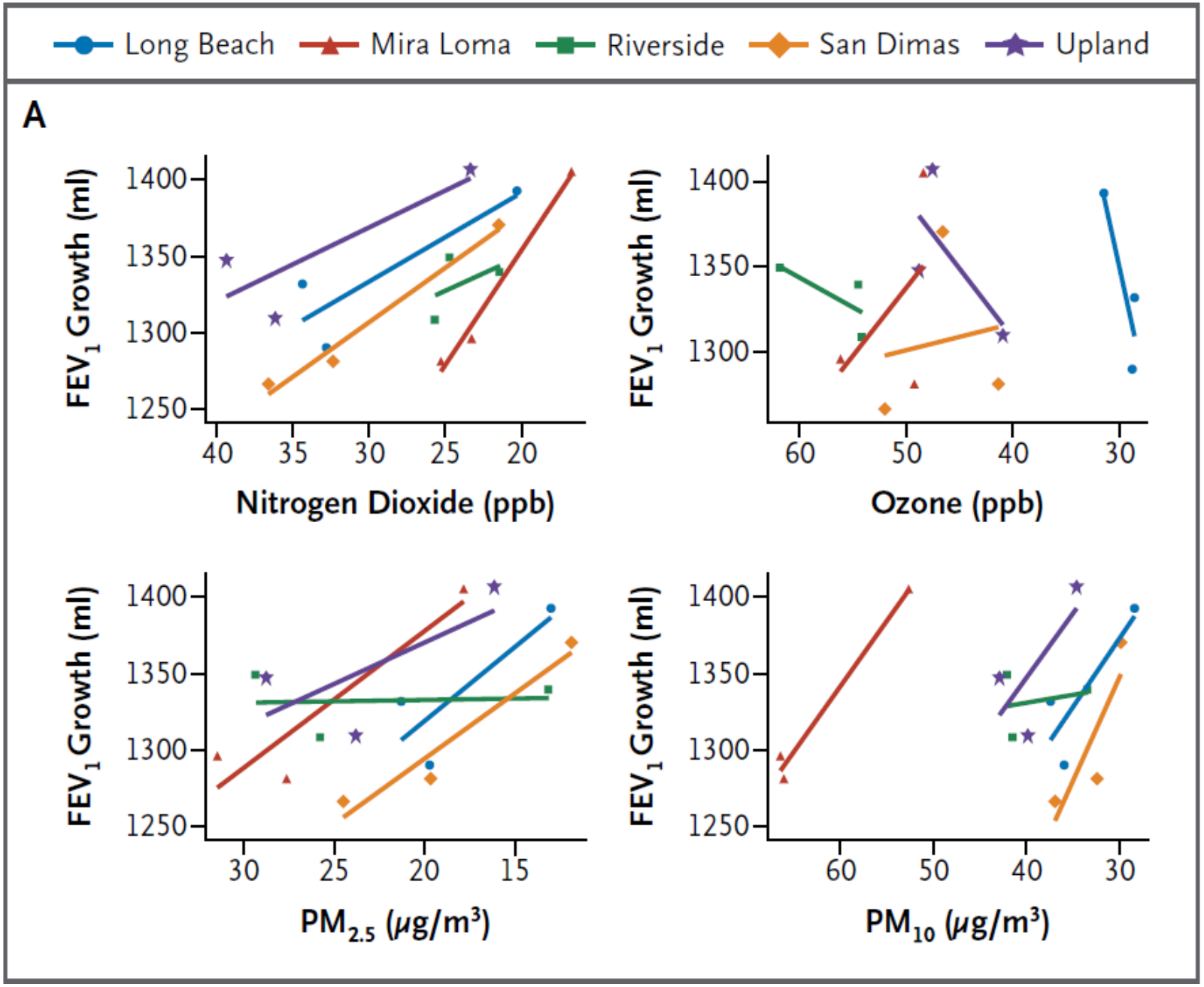
Improved air quality, better lung function growth…

<u>in all 5 towns</u>



Similar patterns:

- NO_2
- $PM_{2.5}$
- PM_{10}



4-Yr Lung Function Growth vs. Pollution Decreases

Lung Function	Pollutant	Growth, age 11 to 15 Difference		P-value
FEV_1	NO_2	91.4	(47.9, 134.9)	<0.001
	O_3 (10-6)	-6.7	(-51.0, 37.5)	0.77
	PM_{10}	65.5	(27.2, 103.7)	<0.001
	$PM_{2.5}$	65.5	(17.1, 113.8)	0.008
FVC	NO_2	168.9	(127.0, 210.7)	<0.001
	O_3 (10-6)	-7.3	(-79.3, 64.6)	0.84
	PM_{10}	113.1	(60.0, 166.1)	<0.001
	$PM_{2.5}$	126.9	(65.7, 188.1)	<0.001

Estimated differences in lung function growth are scaled to decreases of 14.1 ppb in NO_2, 5.5 ppb in O_3 (10 am - 6 pm), 8.7 $\mu g/m^3$ in PM_{10}, and 12.6 $\mu g/m^3$ in $PM_{2.5}$

Compared to Cohorts C and D…

- **Cohort E has more:**
  - Hispanics (58% vs. 32%)
  - Asthma, insurance, A/C, gas stoves
- **Cohort E has less:**
  - Smoking, ETS, in-utero smoke exposure
  - Pests, pets, dogs, cats, carpet
- **All are potential confounders…**

4-Yr Lung Function Growth vs. Pollution Decreases

Lung Function	Pollutant	Growth, age 11 to 15 Difference		P-value
FEV_1	NO_2	91.4	(47.9, 134.9)	<0.001
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Potential Confounders

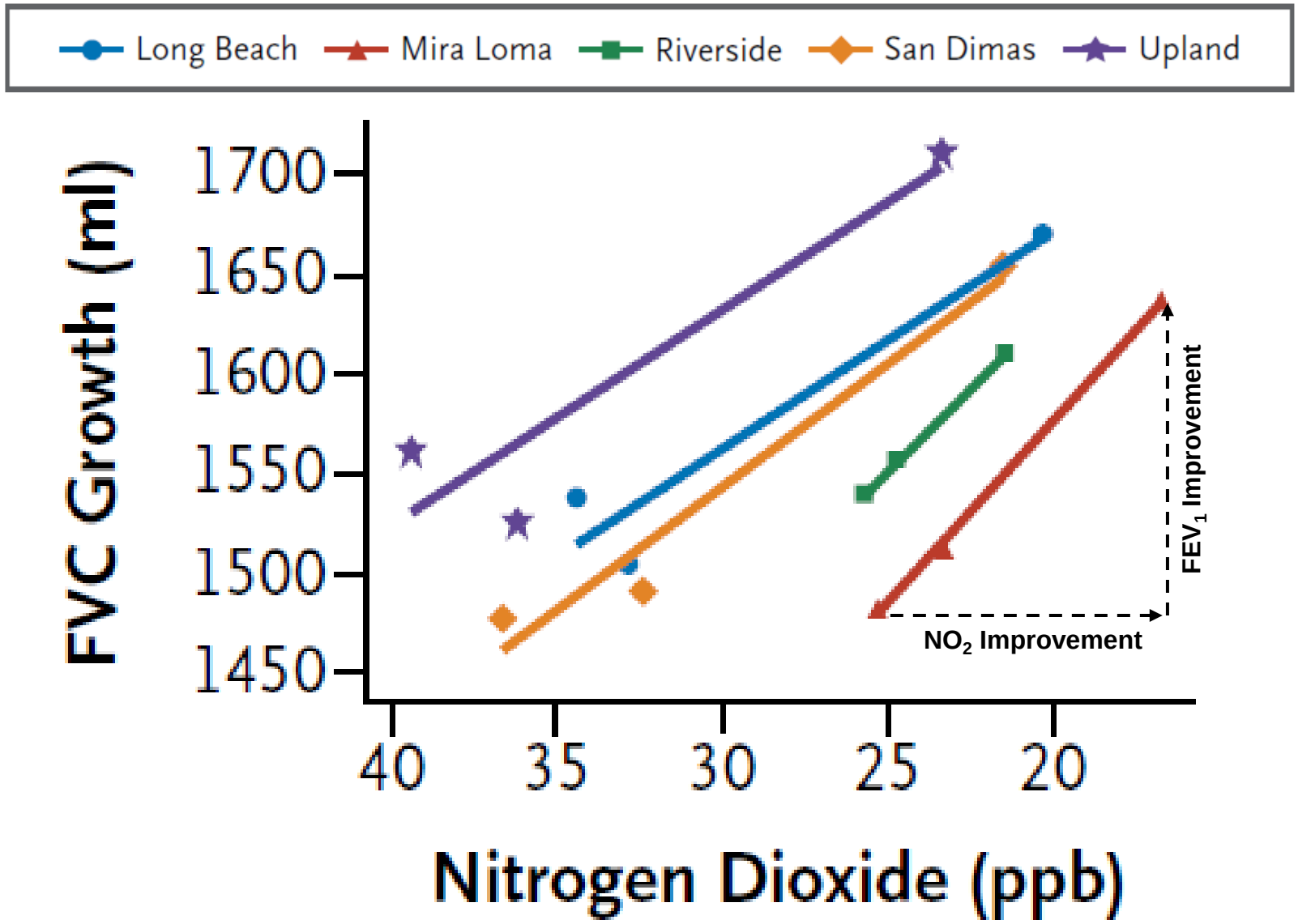
Model	FEV_1 growth, age 11 to 15 Difference	P-value	FVC growth, age 11 to 15 Difference	P-value
Base model (NO_2)*	91.4 (47.9, 134.9)	<0.001	168.9 (127.0, 210.7)	<0.001
Additional Adjustments				
Base + education	90.7 (47.6, 133.9)	<0.001	168.4 (126.8, 210.0)	<0.001
Base + insurance	89.1 (45.6, 132.7)	<0.001	166.5 (127.4, 205.7)	<0.001
Base + in-utero smoke	90.7 (47.3, 134.1)	<0.001	168.6 (126.8, 210.5)	<0.001
Base + passive smoke exposure	90.6 (47.4, 133.7)	<0.001	168.5 (126.8, 210.2)	<0.001
Base + active tobacco smoking	90.9 (47.5, 134.4)	<0.001	167.8 (126.9, 208.7)	<0.001
Base + acute O_3	94.0 (51.9, 136.0)	<0.001	169.7 (128.4, 210.9)	<0.001
Base + asthma	92.6 (49.3, 136.0)	<0.001	168.1 (126.4, 209.9)	<0.001
Base + pests	89.2 (46.4, 131.9)	<0.001	169.2 (127.2, 211.2)	<0.001
Base + pets	87.4 (44.1, 130.7)	<0.001	167.4 (125.1, 209.6)	<0.001
Base + dog	90.7 (46.3, 135.1)	<0.001	169.9 (126.9, 213.0)	<0.001
Base + cat	88.7 (45.2, 132.1)	<0.001	165.8 (124.5, 207.1)	<0.001
Base + carpet	88.6 (45.8, 131.5)	<0.001	167.8 (126.1, 209.5)	<0.001
Base + mildew/mold	91.2 (47.4, 135.0)	<0.001	168.6 (126.7, 210.6)	<0.001
Base + water damage	91.2 (47.8, 134.7)	<0.001	168.7 (127.0, 210.4)	<0.001
Base + gas stove	92.0 (48.4, 135.6)	<0.001	170.0 (128.0, 212.0)	<0.001
Base + air conditioning	90.7 (47.3, 134.2)	<0.001	168.4 (126.9, 209.9)	<0.001
Base + date of home construction	91.8 (48.1, 135.5)	<0.001	168.7 (126.9, 210.4)	<0.001

Subgroup Effects?

Model	FEV_1 growth, age 11 to 15 Difference	P-value	FVC growth, age 11 to 15 Difference	P-value
Base model (NO_2)*	91.4 (47.9, 134.9)	<0.001	168.9 (127.0, 210.7)	<0.001
Subgroups				
Girls only	70.9 (29.3, 112.5)	<0.001	113.0 (71.4, 154.6)	<0.001
Boys only	112.4 (43.1, 181.8)	0.002	236.3 (165.4, 307.2)	<0.001
Non-hispanic white	84.2 (21.3, 147.1)	0.0087	168.8 (109.3, 228.4)	<0.001
Hispanic white	104.4 (42.8, 165.9)	0.0009	179.0 (107.3, 250.7)	<0.001
Non-asthmatics only	82.2 (35.1, 129.4)	<0.001	139.2 (97.0, 181.4)	<0.001
Asthmatics only	150.8 (43.2, 258.5)	0.006	306.9 (195.0, 418.9)	<0.001
Complete data at ages 11 and 15	87.8 (45.3, 130.2)	<0.001	161.7 (122.0, 201.3)	<0.001

No ‘Control’ community

- **But degree of improvement across towns varies**



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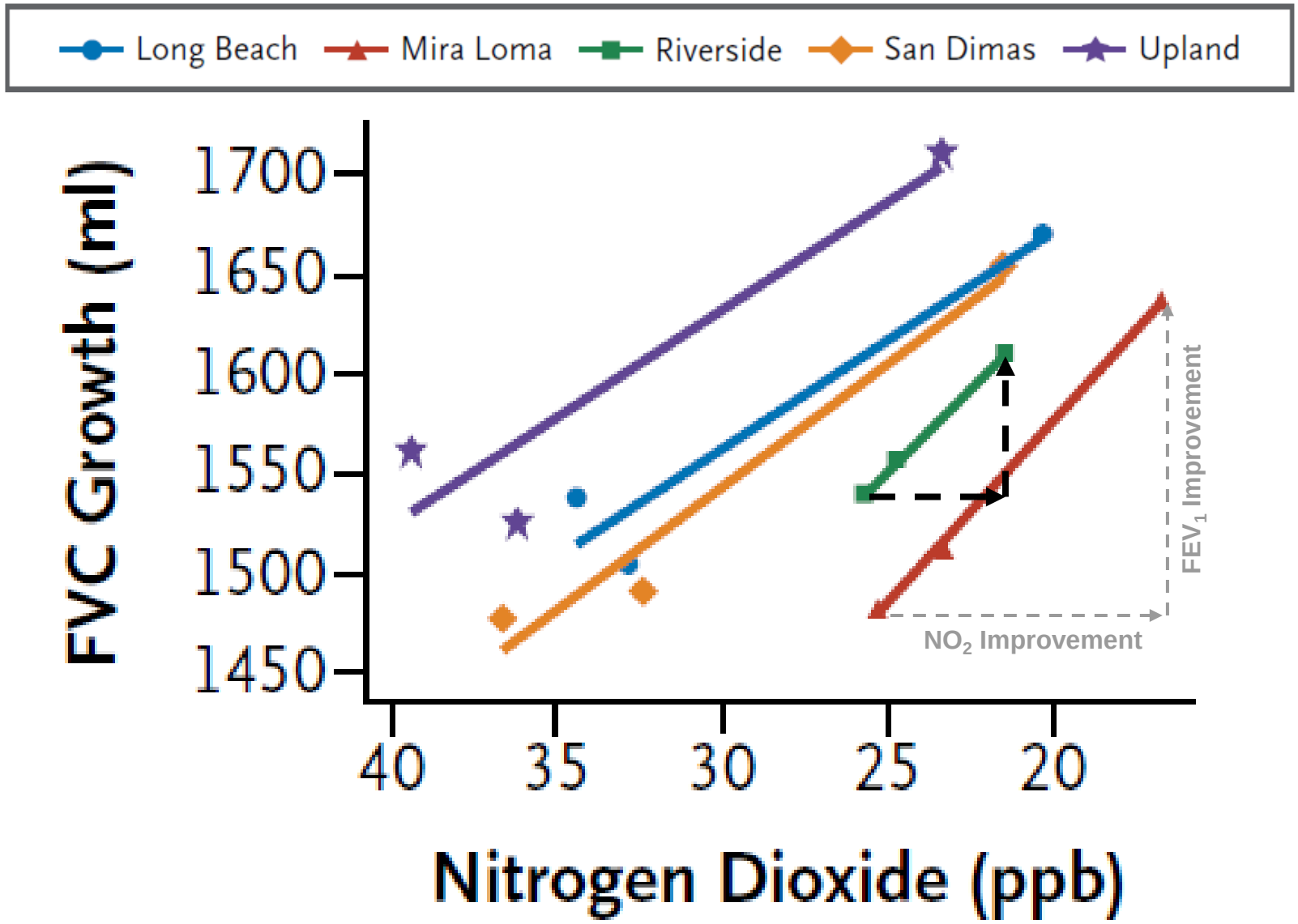
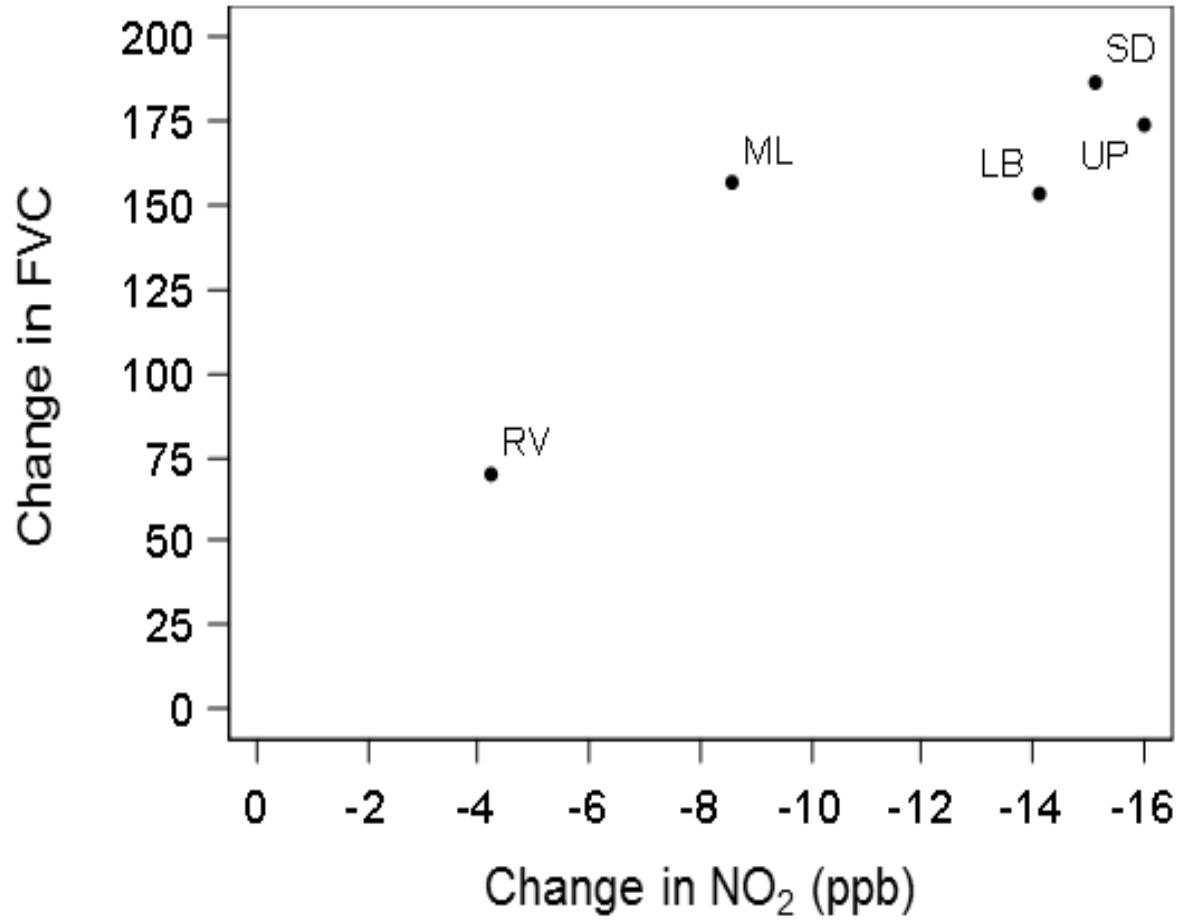
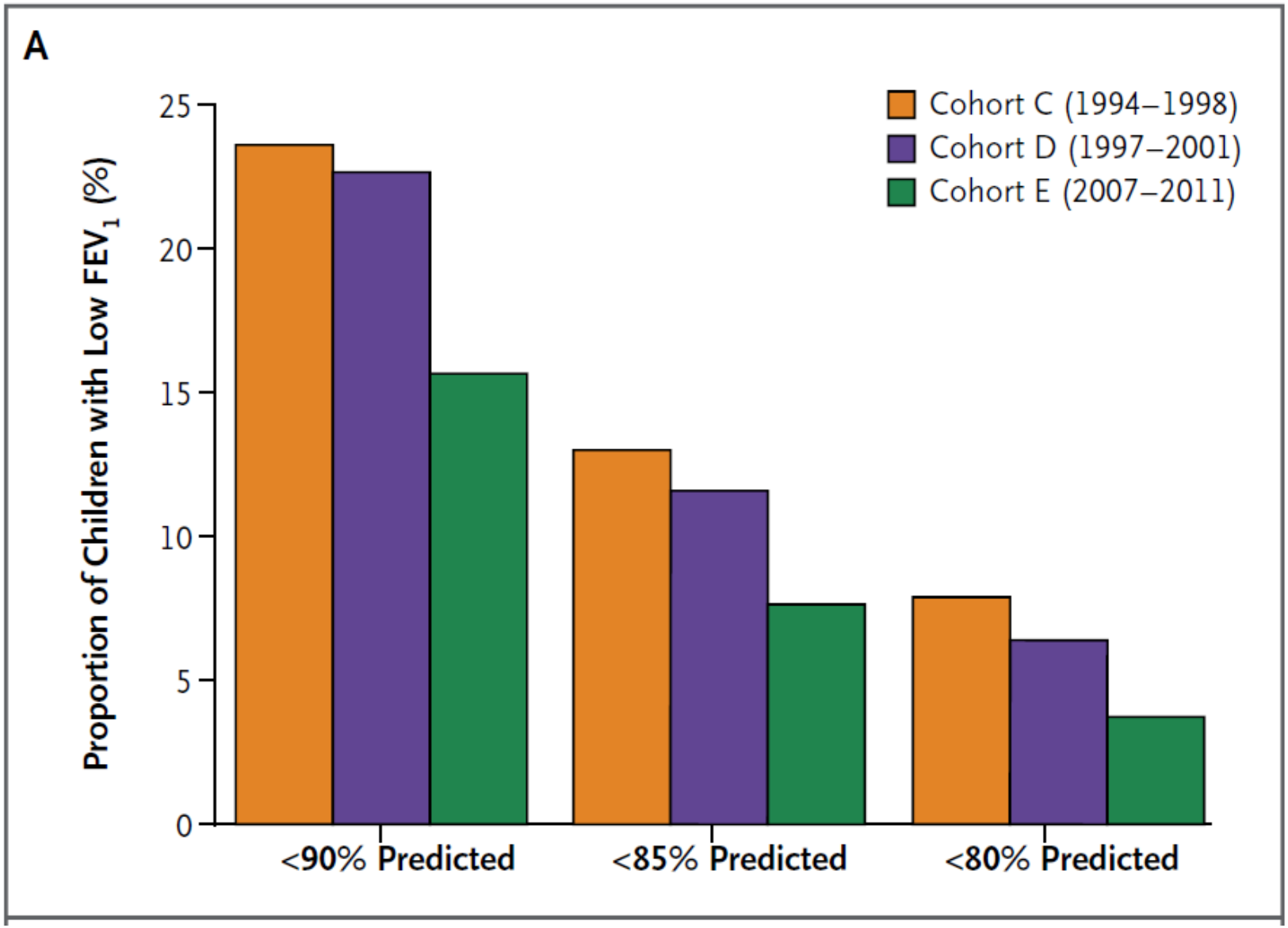


Change in FVC growth vs. Change in NO_2



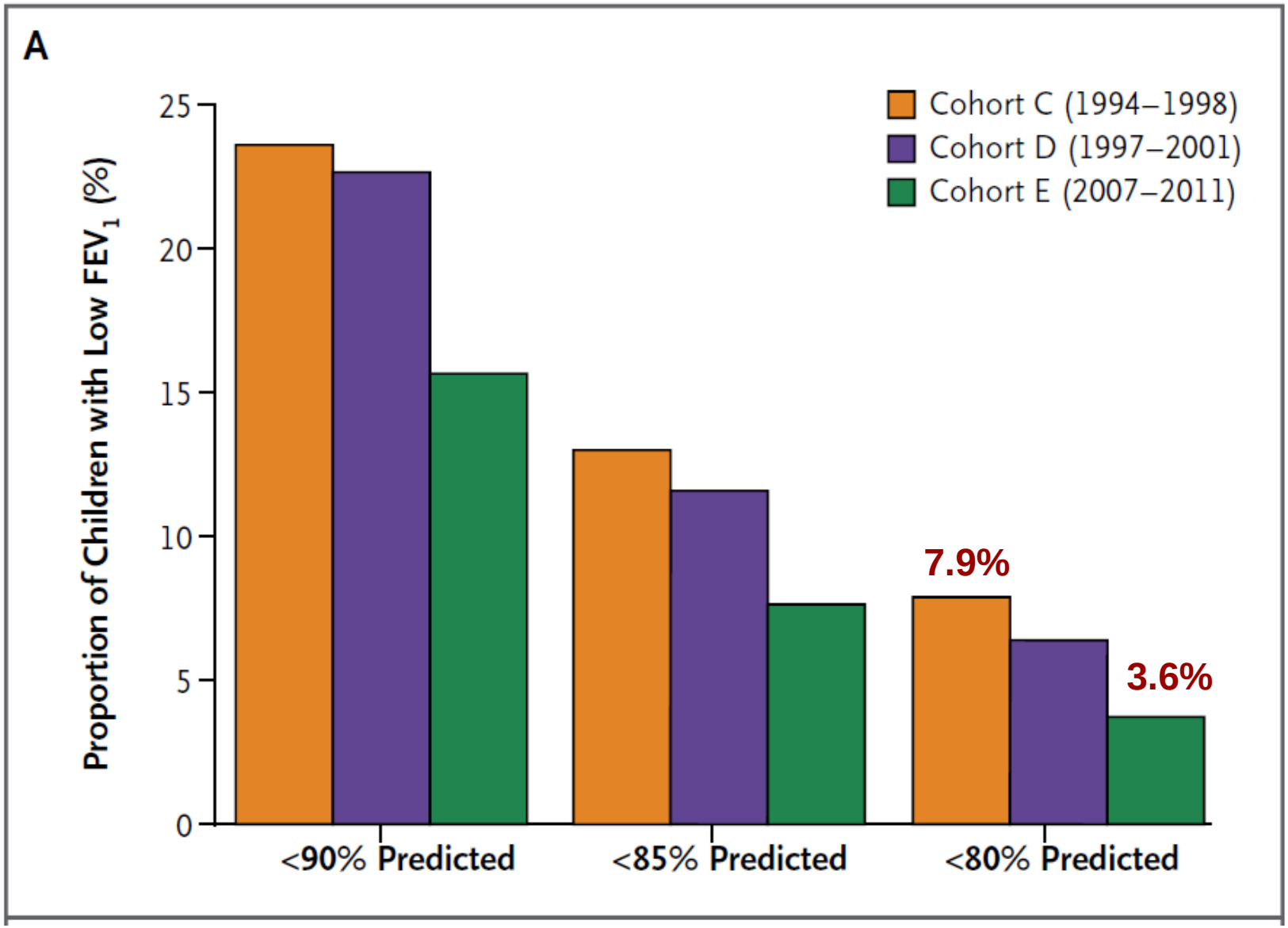
→ **We might expect little change in lung function growth with zero change in NO_2**

Better air quality … fewer children with "low" FEV_1 at age 15



Adjusted for age, sex, race, ethnicity, height, height^2, BMI, BMI^2, respiratory illness

Better air quality … fewer children with "low" FEV_1 at age 15



Adjusted for age, sex, race, ethnicity, height, height^2, BMI, BMI^2, respiratory illness

Summary

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

Summary

- **We can’t get complacent:**
  - **NAAQS not yet achieved for PM, O_3 in so. Cal.**
  - **More cars, trucks, industry, population, etc. are projected**
- **Future reductions in pollution may be difficult…**

Summary

- **We can't get complacent:**
  - **NAAQS not yet achieved for PM, O_3 in so. Cal.**
  - **More cars, trucks, industry, population, etc. are projected**
- **Future reductions in pollution may be difficult…**

…but hard work to improve air quality pays off!



Questions?

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