Children's Health Project: Linking PM10 to Asthma in central Phoenix

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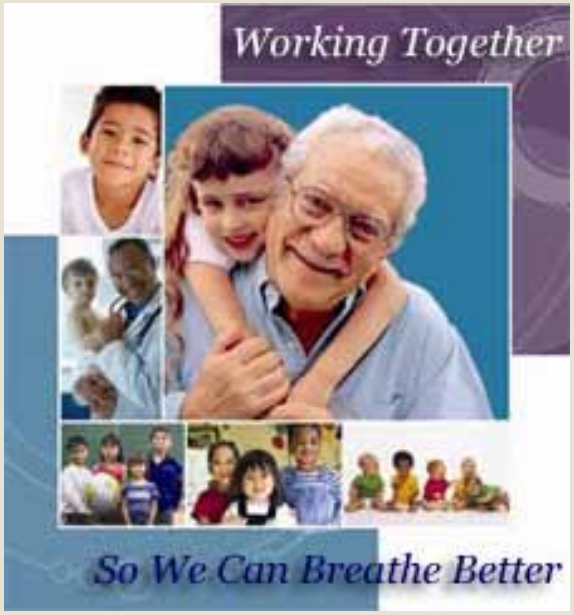


Grant: USEPA
Partnership:
✓Arizona Department of Environmental Quality (ADEQ)
✓Arizona Department of Health Services (ADHS)
✓Environmental Fluid Dynamics Program – Arizona State University (EFD-ASU)
✓Center for Health Information and Research - Arizona State University (CHIR-ASU)

Project goals:

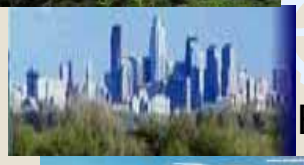
- Share and exchange health and air quality data
- Develop data analysis tools (detection of PM10 - asthma correlations)
- Propose a system to forecast PM10 concentrations (central Phoenix)
- Propose an effective system to warn the public (especially asthmatics)

Integrated Air Quality – Health Warning System

PM10 continuous data:
MC - Maricopa County Air Quality Department; ADEQ

Health data:
ADHS;
CHIR-ASU

Monitoring



Emission data collection

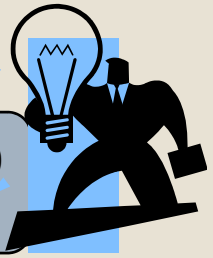
Western Regional Air Partnership Inventory (WRAP)

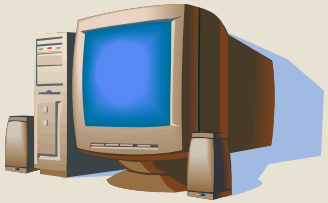
High resolution interpolation:
- Inverse Distance Weighting (IDW)
- Ordinary Kriging

Data

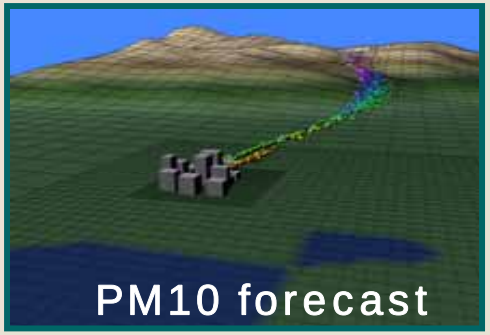
Better spatial estimation

Asthma/PM10 correlation





User interface
Graphics; GIS



Modeling:
- Deterministic – MM5/SMOKE/CMAQ
- Statistical – EnviNNet neural network

Warning system

Available PM10 concentration data

- Observations (hourly data 2004 - 2007)
- Numerical modeling (hourly data): November 2005, March 11 - April 9, 2006
- Interpolation (daily PM10 concentrations)
  (IDW: 2005, 2006; Ordinary Kriging: December 2007 - February 2008)

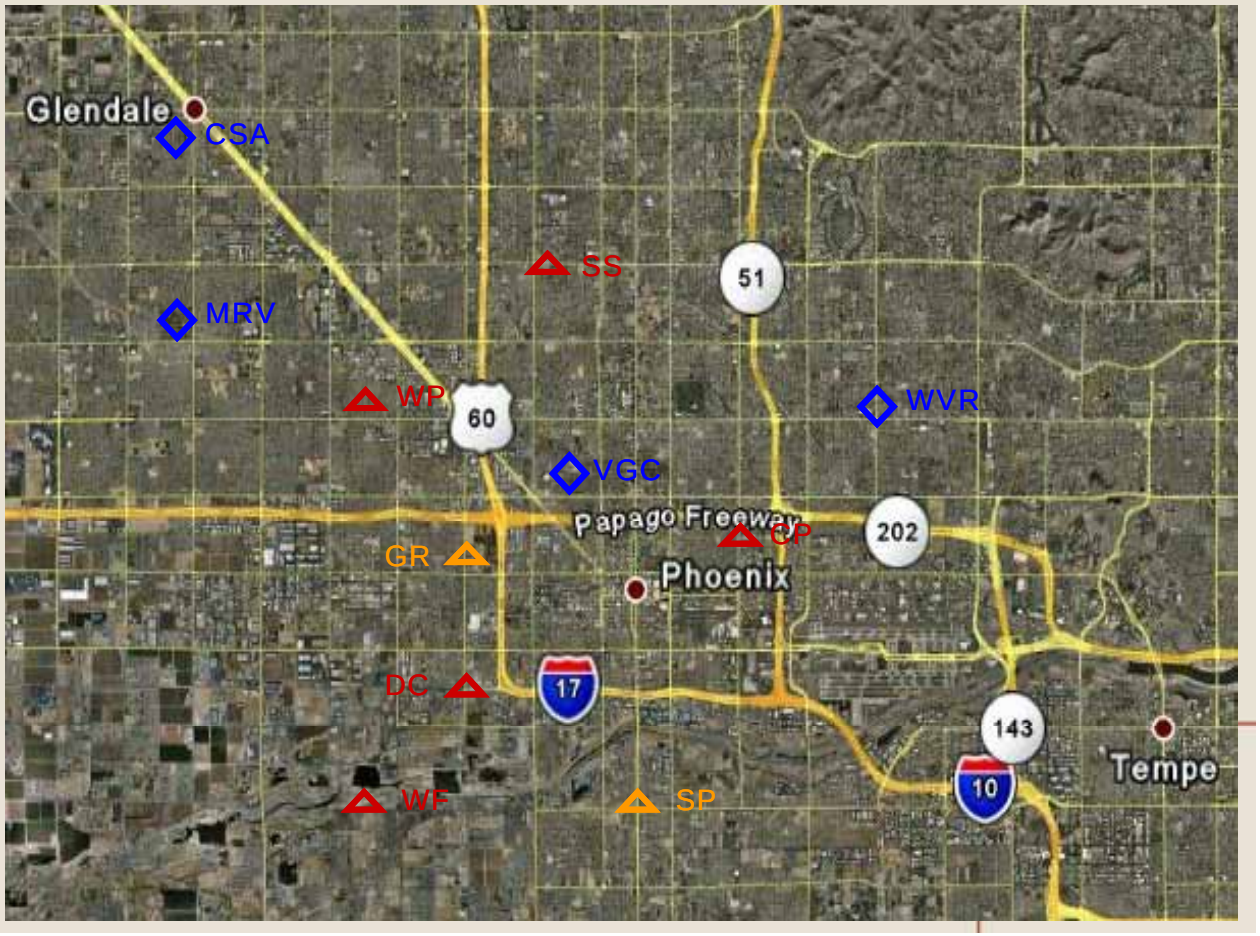
Monitors:

Permanent:

CP - Central Phoenix (MC)
DC - Durango Complex (MC)
WF - West 43rd Avenue (MC)
WP - West Phoenix (MC)
SS – Supersite (ADEQ)
GR – Greenwood (MC)
SP – South Phoenix (MC)

Temporary (ASU):

MRV - Maryvale
VGC - Valley Garden Center
WVR - Weaver's Auto Service
CSA - Community Service



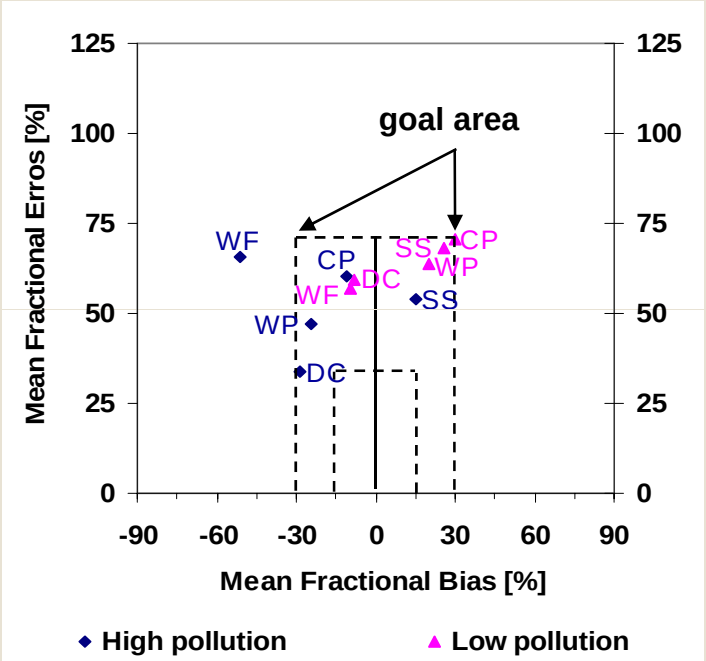
Numerical simulations – MM5/SMOKE/CMAQ

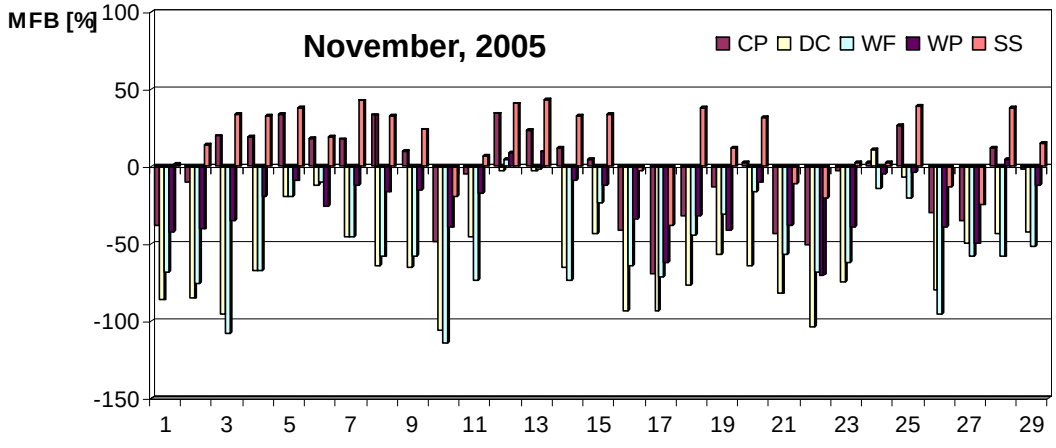
Mean Fractional Error (MFE)

$$MFE = \frac{2}{N}\sum_{i=1}^{N}\left|\frac{P_i - O_i}{P_i + O_i}\right|$$

Mean Fractional Bias (MFB)

$$MFB = \frac{2}{N}\sum_{i=1}^{N}\left(\frac{P_i - O_i}{P_i + O_i}\right)$$





- Good model performance
- Worst prediction – WF, DC
- Overpredicted the lower and underprediced the higher
- Better IA - elevated PM10

Site	MAE	RMSE	IA
	November, 2005		
CP	26.1	34.4	0.68
WP	27.8	42.0	0.72
SS	62.2	1.4	0.86
DC	52.5	85.8	0.55
WF	62.2	90.0	0.51
	March 11 - April 9, 2006		
CP	25.0	33.1	0.44
WP	22.8	30.3	0.59
SS	22.2	29.5	0.47
DC	23.9	35.9	0.68
WF	25.3	42.1	0.60

MAE – Mean Absolute Error
RMSE – Root Mean Square Error

$$IA = 1 - \frac{\sum_{i=1}^{N}(P_i - O_i)^2}{\sum_{i-1}^{N}\left(\left|P_i - \overline{O}\right| + \left|O_i - \overline{O}\right|\right)}$$

IA - Index of Agreement

CMAQ: not the only way to predict air quality
EnviNNet: one alternative

CMAQ - numerical model with many advantages, but difficult to employ

EnviNNet - a neural network predictive system

✓ *Input*: air pollutant and meteorological observations

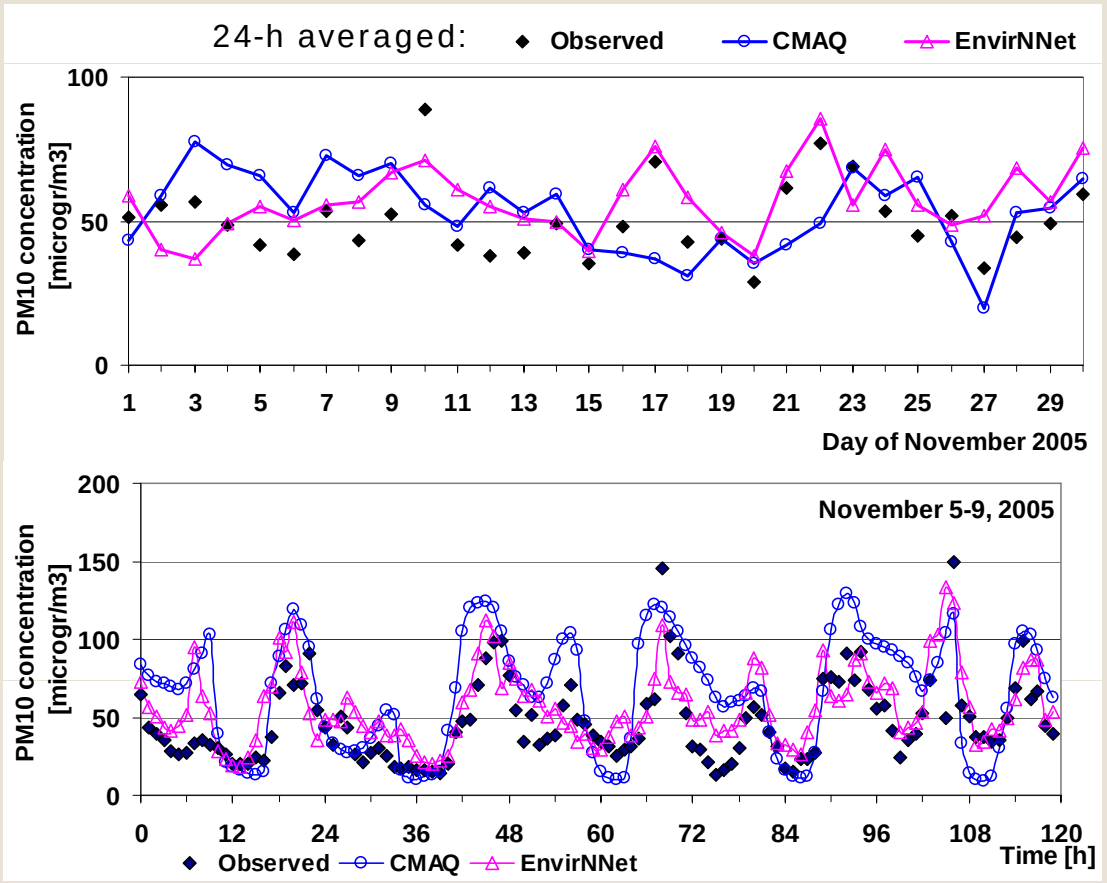
✓ Followed by statistical analyses - PM10 trends and peaks

✓ Augmented with modeling - forecast meteorological conditions based on different scenarios

✓ *Output*: produces reliable estimates of air pollutant concentrations one or more days in advance near a specific monitoring site

CMAQ / EnviNNet - comparison

- ✓ EnviNNet: better correlation and lower calculated errors
- ✓ EnviNNet: better performance for daily averaged PM10 concentrations; satisfactory prediction of peaks



Model	MAE	RMSE	IA
	November, 2005		
CMAQ	26.1	34.4	0.68
EnviNNet	19.0	25.0	0.77
	5-9 November, 2005		
CMAQ	18.9	31.9	0.75
EnviNNet	16.5	20.1	0.82

MAE – Mean Absolute Error
RMSE – Root Mean Square Error

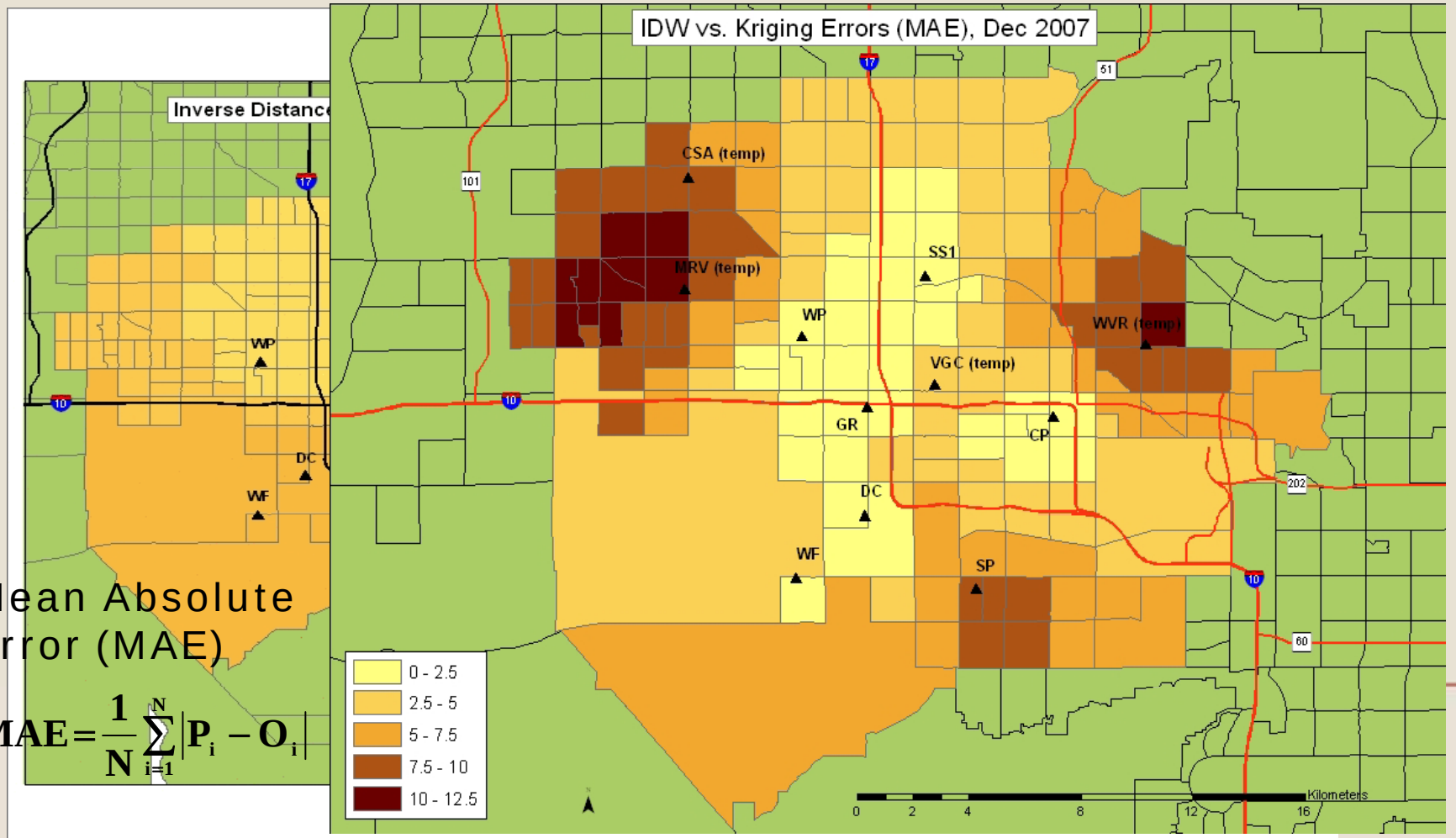
IA – Index of Agreement

$$IA = 1 - \frac{\sum_{i=1}^{N}(P_i - O_i)^2}{\sum_{i-1}^{N}\left(|P_i - \overline{O}| + |O_i - \overline{O}|\right)}$$

IDW and Kriging Interpolations – comparison

IDW - a weighted average is taken; simple and quick

Ordinary Kriging – estimates spatial variation; minimizes the error



Mean Absolute Error (MAE)

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|P_i - O_i|$$

Summary – Air Quality

✓ Elevated PM10 in southwest Phoenix along the Salt River; emission inventory update is necessary

✓ MM5 - overestimated the low wind speeds during stable conditions; could not capture the rapid changes of wind direction; needs improvement

✓ CMAQ - underestimated the higher and overestimated the lower PM10 with better correlations for the higher values

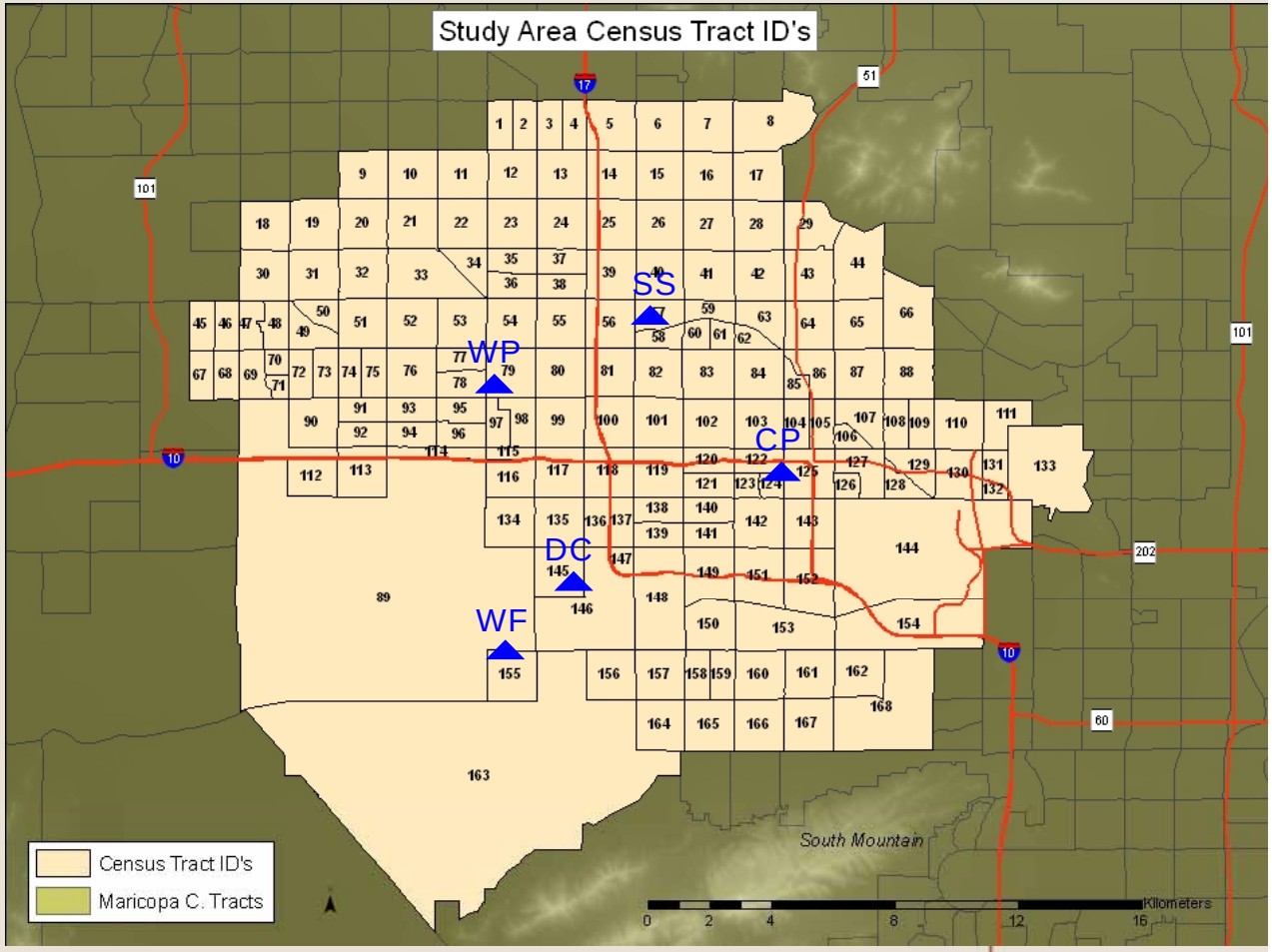
✓ EnviNNet - much easier and quicker to use than CMAQ; better in predicting PM10 concentrations

✓ Inverse Distance Weighting and Ordinary Kriging methods – not large differences between spatial PM10 fields for central Phoenix

Asthma cases and census tracts

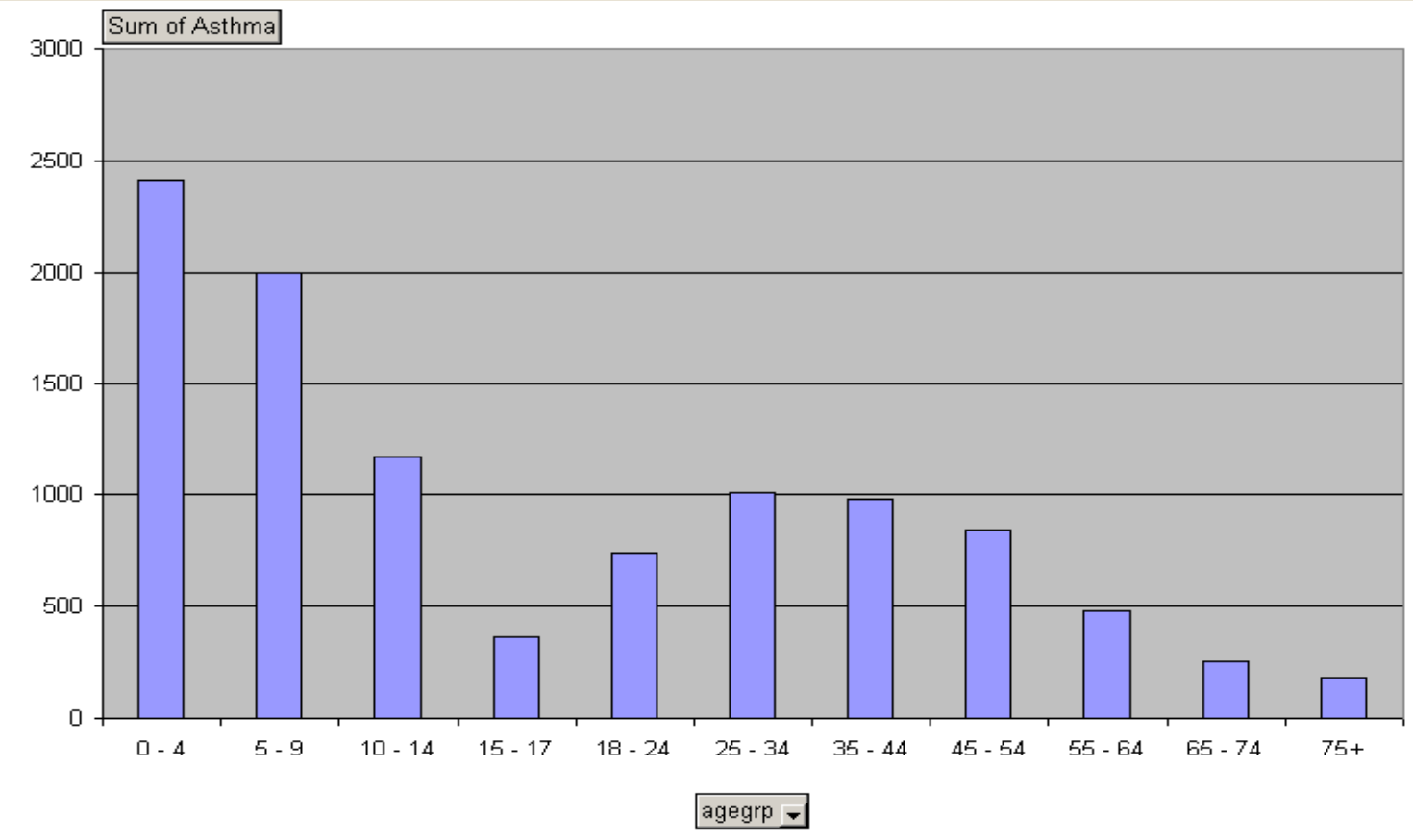
- PM10 is provided by MC, ADEQ and EFD-ASU
- Asthma data from ADHS and CHIR-ASU
- One-day gap: (2005 -2006)

#Cases	Distance from sensor (miles)	
Age	2	5
All	3,400	10,433
< 18	2,065	5,948



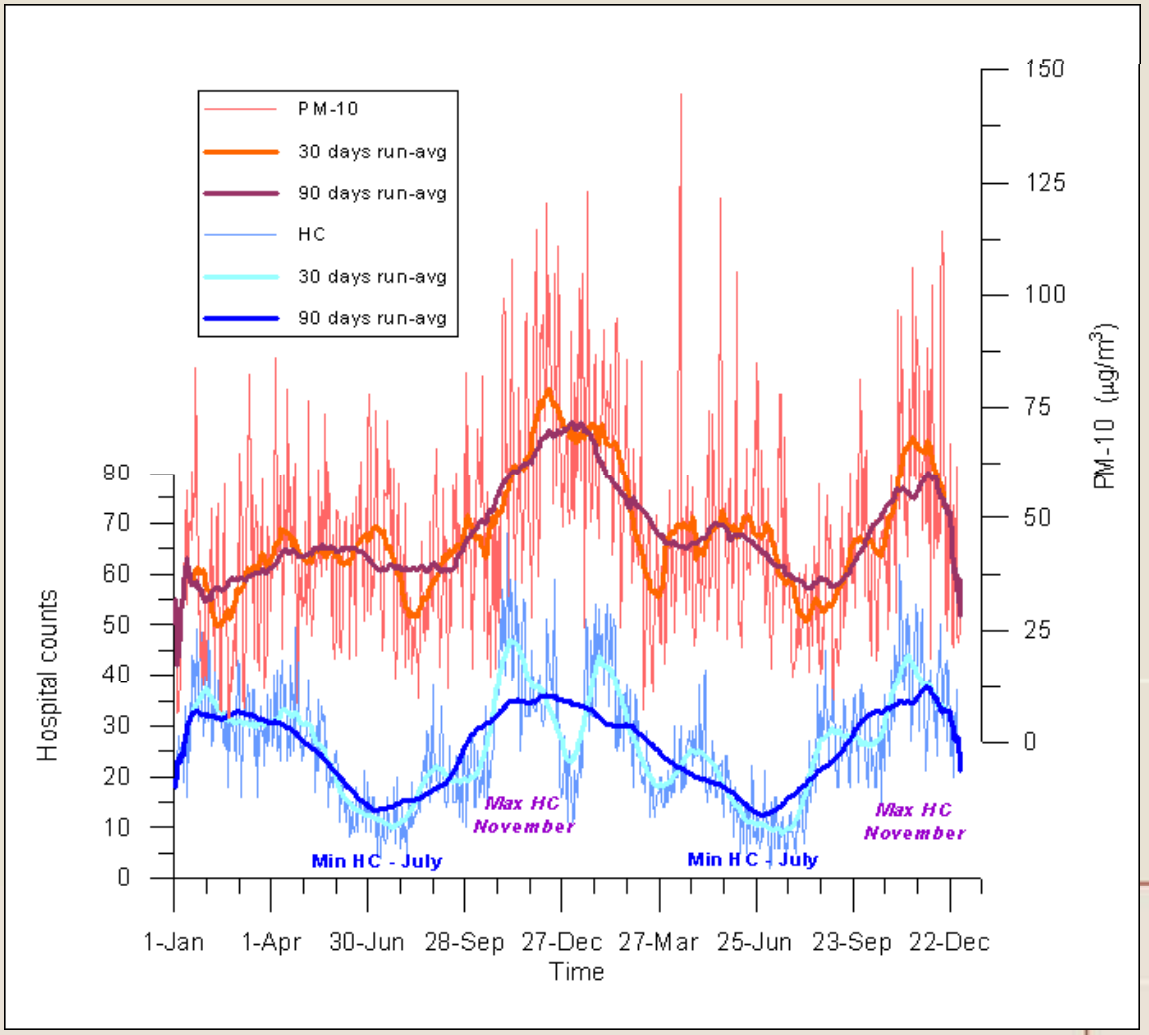
ADHS Asthma Data Summary (5 miles)

Asthma Events by Age Group



Air Quality and Asthma Events

- Seasonality present
- But relationship?



Case-Crossover Analysis

- Suited to a transient effect (with a short delay) of an intermittent exposure on an acute disease that occurs infrequently
  - Other analyses have been done previously, such as time series, Poisson regression, GLMM
- Case is paired with itself at a different, random time to make a control (referent) and reduce confounding effects
  - Control period 28 days, 3 controls per each case

Same patient at different times

	Day						
Week	1	2	3	4	5	6	7
1		Case					
2		Control					
3		Control					
4		Control					

Case-Crossover Analysis

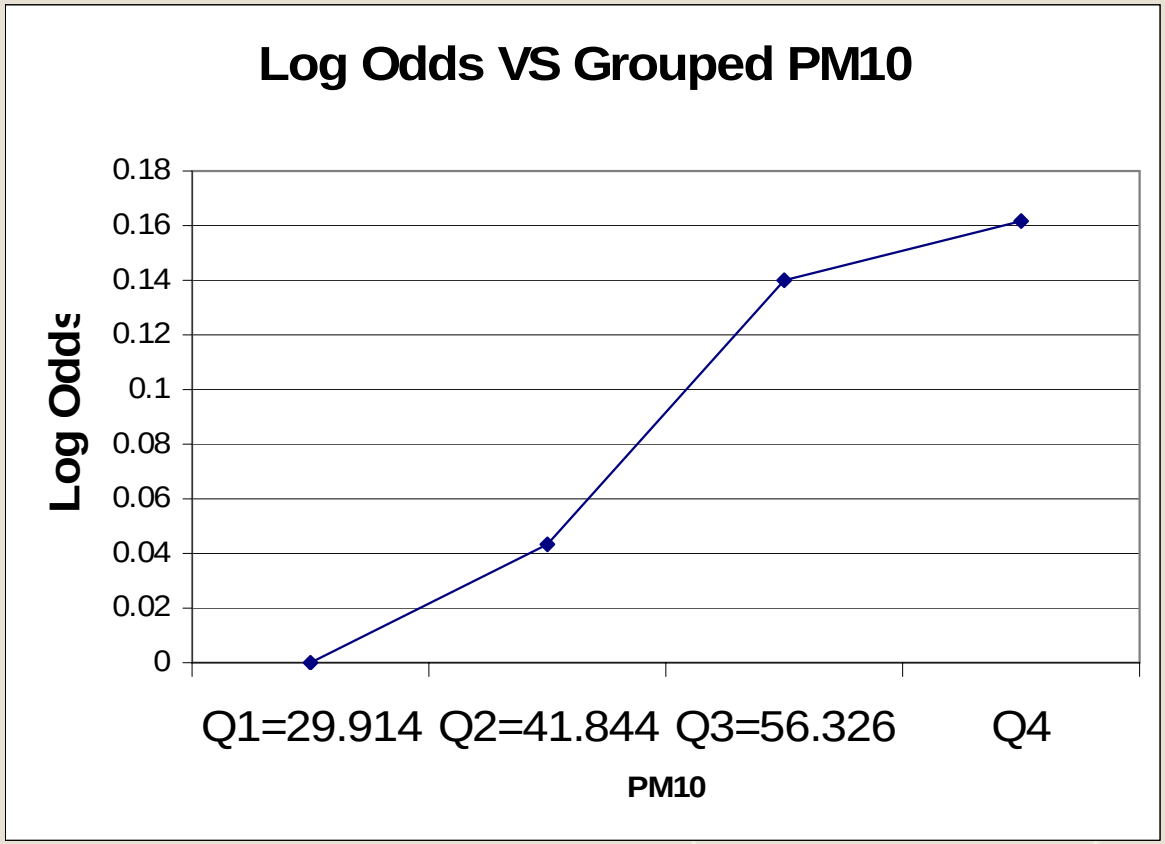
- Effects of interest
  - PM10 from **census tract (IDW)**
    - Dailymean PM10
    - Meanlag PM10 for 2, 3, 4, 5, 6 days were considered
- Interactions
  - Age x Dailymean
  - Age x Meanlag 2, 3, 4, 5, 6
  - Gender x Dailymean,
  - etc.
- Age divided in 4 groups: 0-4, 5-9, 10-14, and 15-17
- Other pollutants such as ozone, etc. not in this study

Health Effects with PM10

- ✓ Statistically significant relationship detected
- ✓ For all ages the adjusted odds ratio shows
- ✓ Approximately a 6.6% increase in asthma risk for a PM10 increase from 30 to 55 $\mu g/m^3$
- ✓ Risk increase could be from 1% to 12%, with high confidence
- ✓ Excluding preschoolers (age 0-4) the adjusted odds ratio shows
- ✓ 14% increase in asthma risk for a PM10 increase from 30 to 55 $\mu g/m^3$
- ✓ Risk increase could be from 7% to 20%, with high confidence

Health Effects versus PM10 Quartiles Excluding Preschoolers

- ✓ Approximate linearity over range of PM10
- ✓ Odds compared to baseline PM10 at level Q1 = 29.9 mg/m^3
- ✓ ADHS 5-mile radius, 7-day gap, 28-day stratum, census tract IDW



Excluding Preschoolers Analysis

- Statistical details
- Excluding preschoolers age 0-4

ADHS 5-mile radius, 7-day gap, 28-day stratum, with preschoolers excluded, census tract IDW

Variable	Coefficient	Chi Square	P-Value
Dailymean	0.00356	13.2741	0.0003

Covariate	Odds Ratio	95% CI
Dailymean		
Crude OR	1.004	(1.002, 1.005)
Adjusted OR*	1.138	(1.069, 1.208)

*IQR for dailymean = 36.42
Q1 = 29.91, Q3 = 56.33

Children's Health Assessment Study

- Demonstrated capability for various organizations to collaborate
  - Link data, but also
  - Plan studies, cooperate for analysis, communicate finding, summarize results
  - Disseminate to other stakeholders (asthma coalition, AZHQ data partners, UofA)
- Data preprocessing and database comparisons
  - Cleaning, sample sizes, confounding factors, controls (referents) design, links to air quality
- Environmental/air quality models
- Demonstrated ability to link health effects to environmental data with scientific credibility
- Disseminated capability for relatively complex analysis to relate health effects with environmental factors


Thank you!