High winds and high [PM_{10}]

Pima Association of Governments

10 June 2010

By Peter Hyde, Arizona State University

Peter.hyde@asu.edu; 602 451 3487

American Association of Aerosol Research specialty conference on Air Pollution and Health: bridging the gaps from sources to health outcomes

22-26 March 2010, San Diego, California

- Purpose: to better understand the linkages between air pollution and health outcomes across the source to health effects paradigm

- Disciplines: sources, atmospheric sciences, exposure, dose, and health effects

Scientific themes

1. Pollutants and Sources Associated With Health Effects
2. Reliability of Methods, Models, and Approaches
3. Pollutant Characterization and Population Exposure
4. Relation between Exposure and Dose
5. Mechanisms of Action and Biomarkers of Exposure and Effects
6. Susceptible Populations
7. Confounding and Other Factors
8. Accountability
9. Regulatory and Policy Implications

- American Association of Aerosol Research: specialty conference http://aaar.2010specialty.org/

- Now, concerning high winds and elevated [PM_{10}] in south-central AZ

Symbols and abbreviations

- [brackets] concentration in ambient air
- PM particulate matter
- PM_{10} PM ≤ 10 microns
- $PM_{2.5}$ PM ≤ 2.5 microns, or “fine PM”
- $PM_{10-2.5}$ PM 2.5 to 10 microns, or “coarse PM”
- Note: $[PM_{10}] = [PM_{2.5}] + [PM_{10-2.5}]$
- Note: diameter of human hair ≈ 40 – 120 microns

High winds and elevated [PM_{10}] in south-central AZ

- Emissions of windblown dust
- [PM_{10}] exceedances in Pinal County in 2009
- Three (unsuccessful) attempts to understand this phenomenon
- Prospects for PM_{10} attainment

Windblown dust emissions – 1

- Should be simple, but it's not: why?
- Depends on
  - surface roughness,
  - surface moisture,
  - degree of the disturbance of the soil,
  - how much up-wind "fetch" there is, and
  - the physical composition of the soil
    - Particle size distribution of the surface layer
    - Soil type: clay, silt, sand, etc.

Windblown dust emissions – 2

1. Comparison of Dust Production Model computations with measurements performed on a loamy soil in Spain, and on a sandy soil in Niger, shows:

   (a) that coalescing crusts on soils with a high content in fine particles can efficiently limit saltation, and

   (b) that binding energies of PM20 particles within soil aggregates are larger in fine-textured soils than in sandy soils.

2. The potential of a soil for fine-dust production does not increase with its clay content.

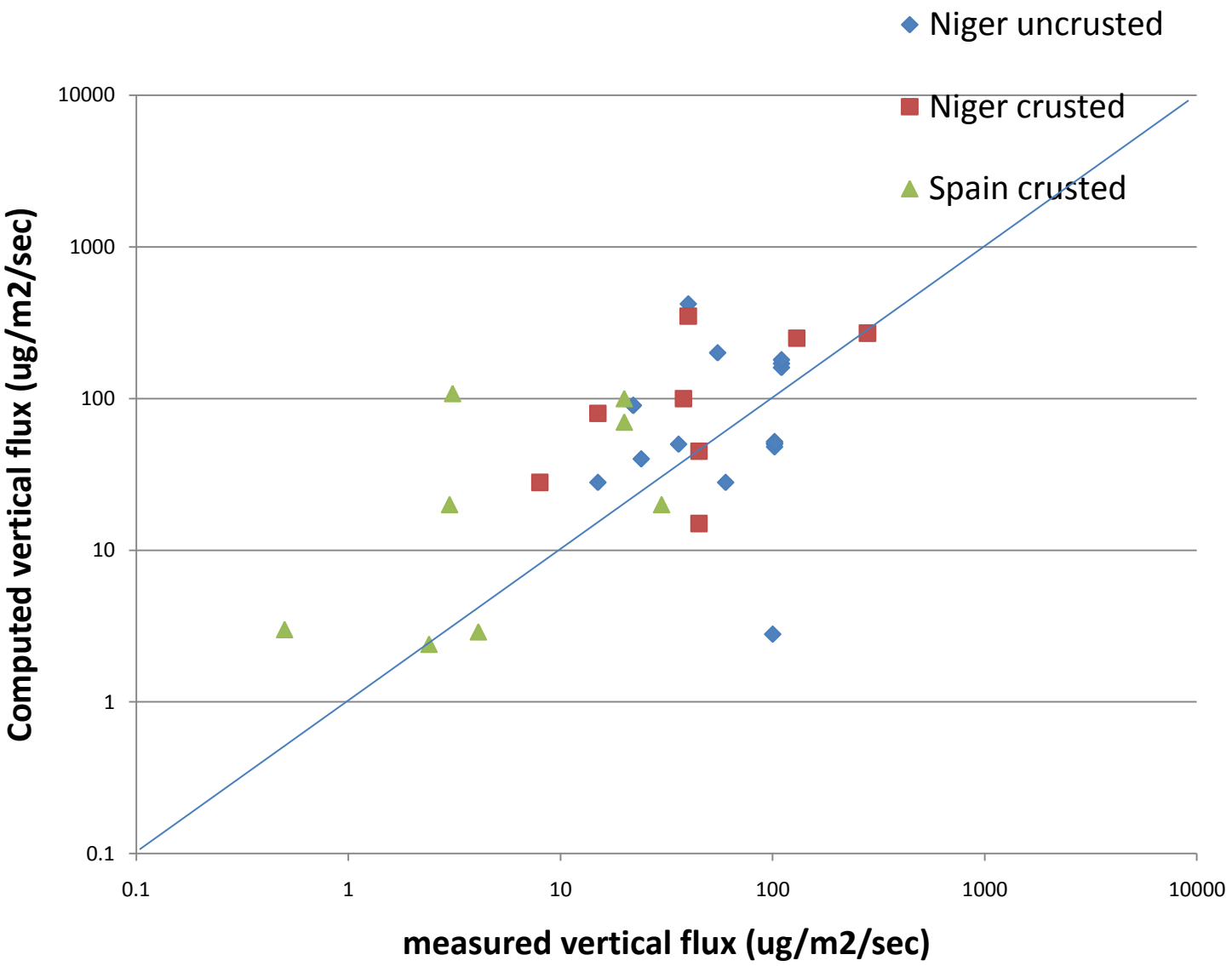
Windblown dust emissions – 3

3. In summary, soils that are most prone to nutrient-rich particle losses are those that are most prone to saltation, that is to say sandy ones. Unfortunately, these soils are generally those that are already poor in fine particles from the start.

L. Gomes et al (2003), Validation of a dust production model from measurements performed in semi-arid agricultural areas of Spain and Niger, *Catena* **52**, 257-271

Windblown dust emissions – 4: equation for vertical dust flux, F_v

- $Fv = k\, u^*[C(z_{1)} - C(z_2)]/[\ln(z_2-z_1) - \Psi(z_2/L) + \Psi(z_1/L)]$
- where k is Von Karman's constant,
- u^* is wind friction velocity,
- C is dust concentration at heights z_1 and z_2, and
- Ψ is a corrective function for non-neutral (diabatic) conditions of the atmospheric vertical structure indicated by the Monin–Obukhov stability index, z/L.
- (Note: the corrections introduced by the corrective functions Ψ were between 2.5% and 15%.)


Niger uncrusted
Niger crusted
Spain crusted
Computed vertical flux (ug/m2/sec)
10000
1000
100
10
1
0.1
0.1
1
10
100
1000
10000
measured vertical flux (ug/m2/sec)

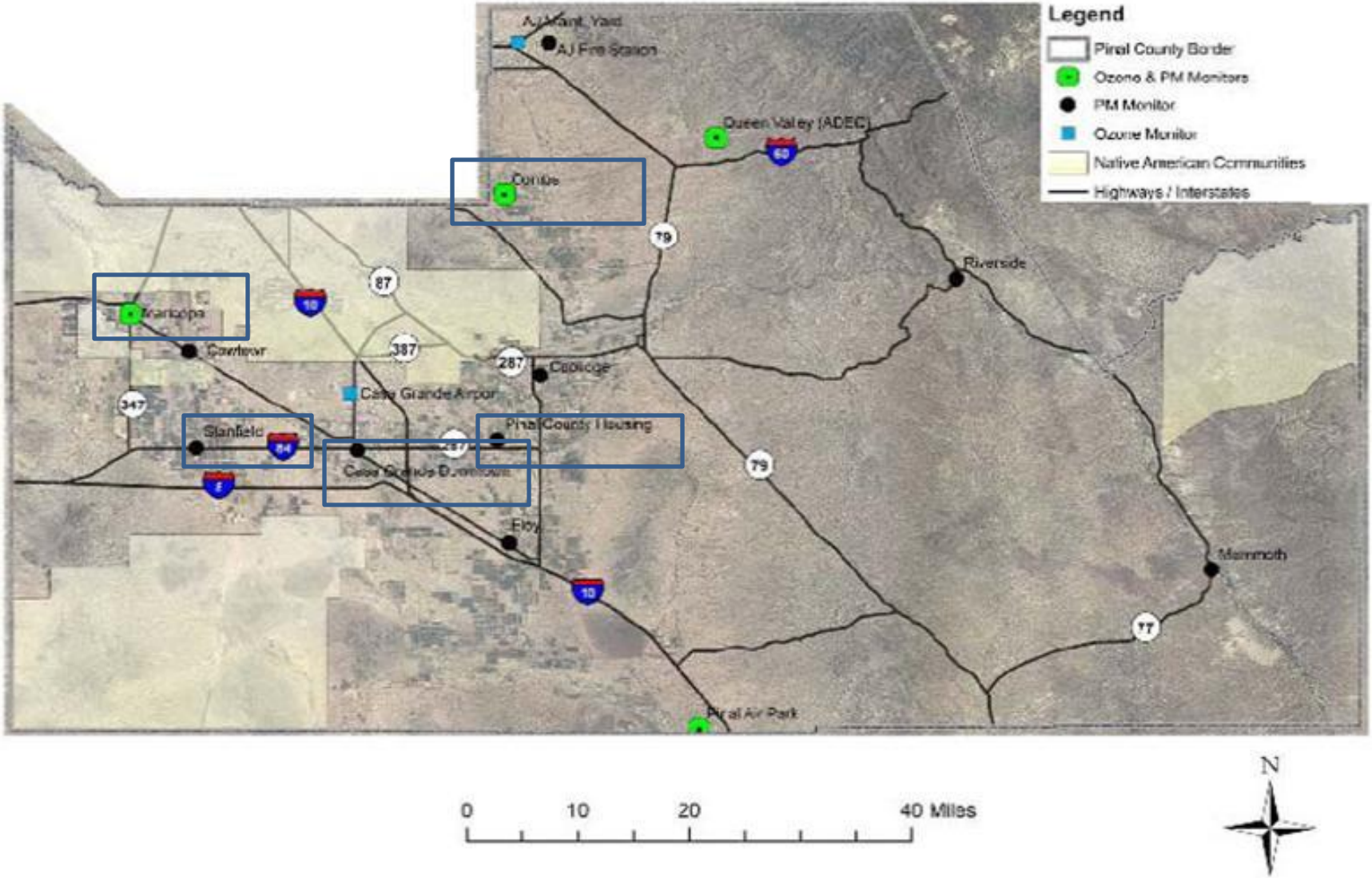
Ambient [PM_{10}] Pinal County 2009

- 50 exceedances of the 24-hr standard at 5 sites (excluding “Cowtown”)
- 6 exceedances occur under stagnant or light-wind conditions
- 44 occur during high winds
- Let’s examine two days, one with low winds and the other with high winds.

Five PM_{10} monitoring sites

- Combs School CS
- Maricopa MA
- Pinal County Housing PH
- Stanfield SF
- Casa Grande CG

Pinal County Air Quality Control District
Ambient Air Quality Monitoring Network



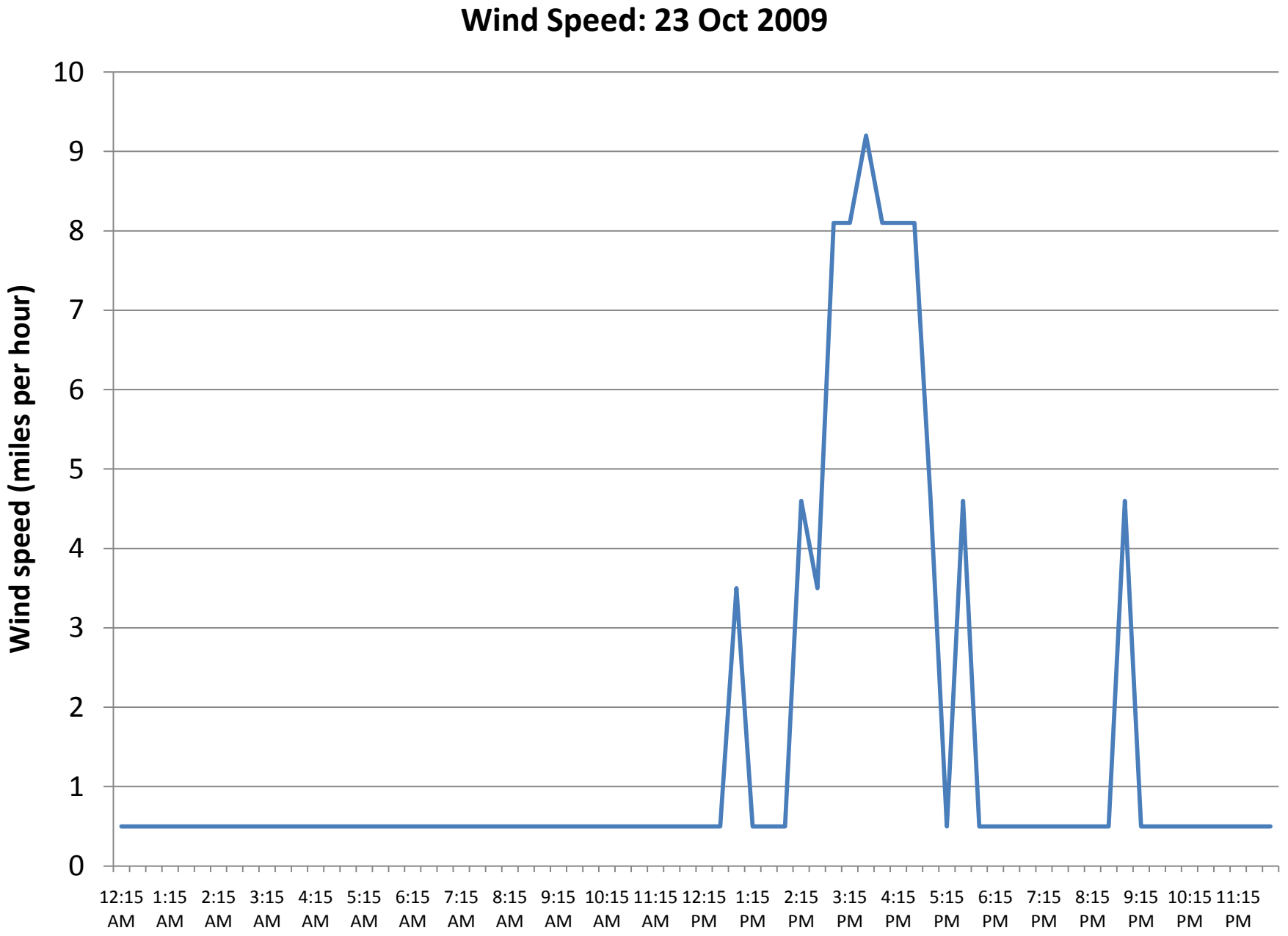
Distances between monitors

Monitor to monitor	miles
Combs School (CS) to Pinal County Housing (PH)	21.6
Pinal County Housing (PH)* to Casa Grande (CG)*	14.6
Casa Grande (CG) to Stanfield (SF)*	13.5
Stanfield (SF) to Maricopa (MA)	13.5
Maricopa (MA) to Combs School (CS)	35.1
Area in square miles	520.7

* Note: Pinal County Housing, Casa Grande, and Stanfield are on the same east-west axis

Elevated PM_{10} under light winds

- 23 October 2009: a single exceedance of 166 ug/m3 at Stanfield
- Max wind speed at Casa Grande airport was 9 miles/hour
- Other 4 sites: from 71 to 102 ug/m3
- $[PM_{10}]_{concentration} = [PM_{10}]_{localized} + [PM_{10}]_{regional} + [PM_{10}]_{background}$

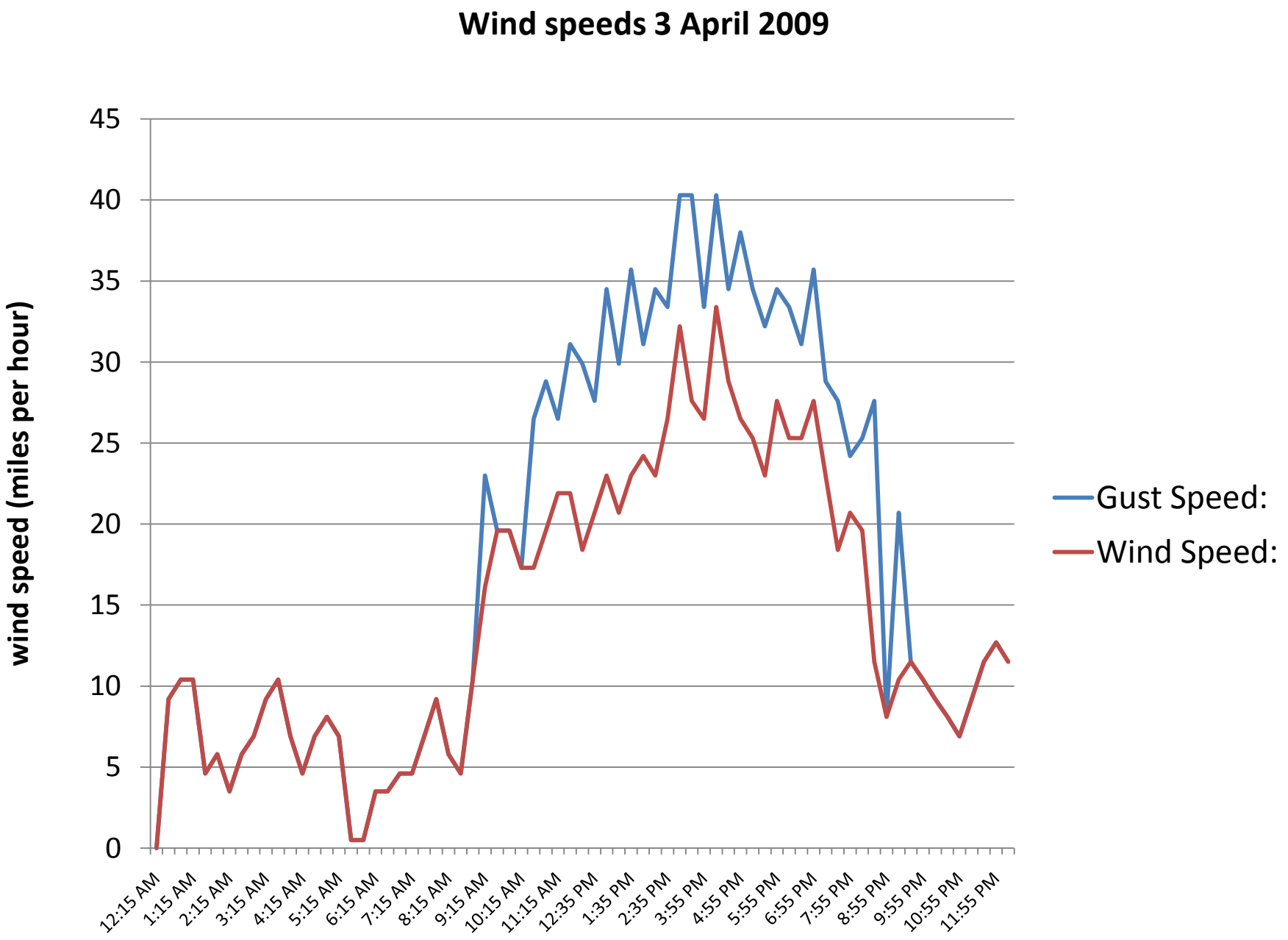

Wind Speed: 23 Oct 2009
Wind speed (miles per hour)
0
1
2
3
4
5
6
7
8
9
10
12:15 AM
1:15 AM
2:15 AM
3:15 AM
4:15 AM
5:15 AM
6:15 AM
7:15 AM
8:15 AM
9:15 AM
10:15 AM
11:15 AM
12:15 PM
1:15 PM
2:15 PM
3:15 PM
4:15 PM
5:15 PM
6:15 PM
7:15 PM
8:15 PM
9:15 PM
10:15 PM
11:15 PM

Why Stanfield but not the others?

- Because this monitoring site was affected by higher localized PM_{10} emissions than were the other four
- Regional and background contributions to PM_{10} concentration by definition do not vary among closely spaced monitoring sites
- Dispersive capacity of the boundary layer varies little in an area of this size

Elevated PM_{10} under high winds

- In 2009 in Pinal County, [PM_{10}] exceedances in high winds are 8 times as frequent as [PM_{10}] in low winds
- [PM_{10}] in high winds, average = 329 ug/m3, n = 44
- [PM_{10}] in low winds, average = 174 ug/m3, n = 6
- High winds come two ways:
  - Monsoon: July – September
  - Dry cold fronts: spring and (to a lesser extent) fall and winter


Wind speeds 3 April 2009
wind speed (miles per hour)
45
40
35
30
25
20
15
10
5
0
12:15 AM
1:15 AM
2:15 AM
3:15 AM
4:15 AM
5:15 AM
6:15 AM
7:15 AM
8:15 AM
9:15 AM
10:15 AM
11:15 AM
12:35 PM
1:35 PM
2:35 PM
3:55 PM
4:55 PM
5:55 PM
6:55 PM
7:55 PM
8:55 PM
9:55 PM
10:55 PM
11:55 PM
Gust Speed:
Wind Speed:

Elevated [PM_{10}] in high winds on 3 April 2009

- Two of five sites exceeded the 24-hour standard of 150 ug/m3
- Pinal County Housing 381 ug/m3
- Stanfield 210
- Casa Grande 93
- Combs School 131
- Maricopa 116

Three attempts to understand the phenomenon of elevated [PM10] under high and low winds in south-central Phoenix

- 1996-97: State Implementation Plan (SIP) Technical Analysis for high PM_{10}
- 2002-05: SIP Technical analysis for high PM_{10}
- 2006 Maricopa Association of Governments source-attribution study of high PM_{10}

Prospects for PM_{10} attainment in Pinal County (and in the Gila River Indian Community)

- Difficult because of agricultural, feed lot, and dirt road sources of emissions

- Difficult because desert background of [PM_{10}] tends to be 20% of the measured concentrations at any monitor (based on Organ Pipe National Monument and other background sites)

Thanks for your attention

- Questions?