Climate and Health: Basic Science and Decision Support for Valley Fever

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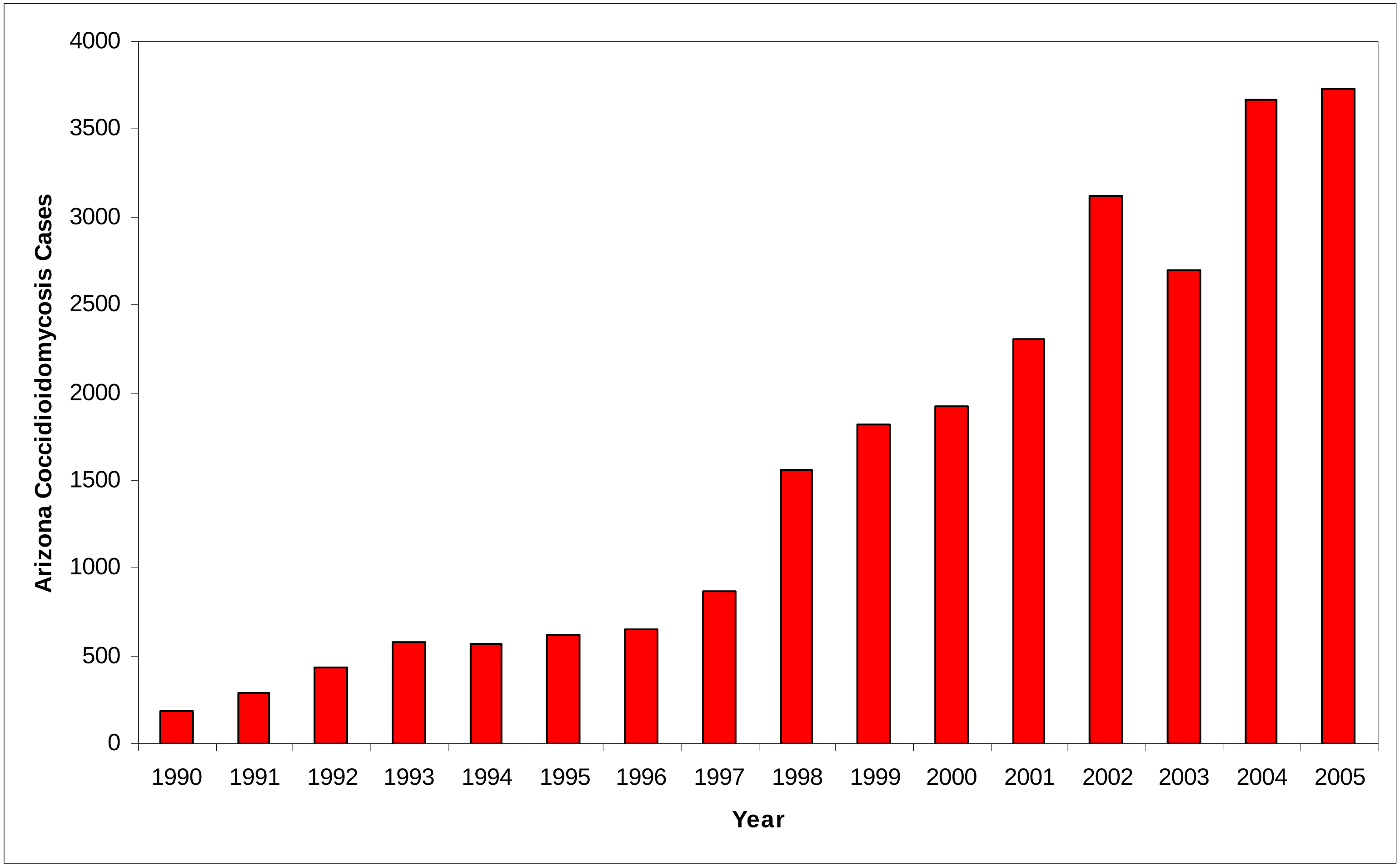
CLIMAS
Arizona Disease Control Research Commission
This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R8327540

An Emerging Valley Fever Epidemic in Arizona



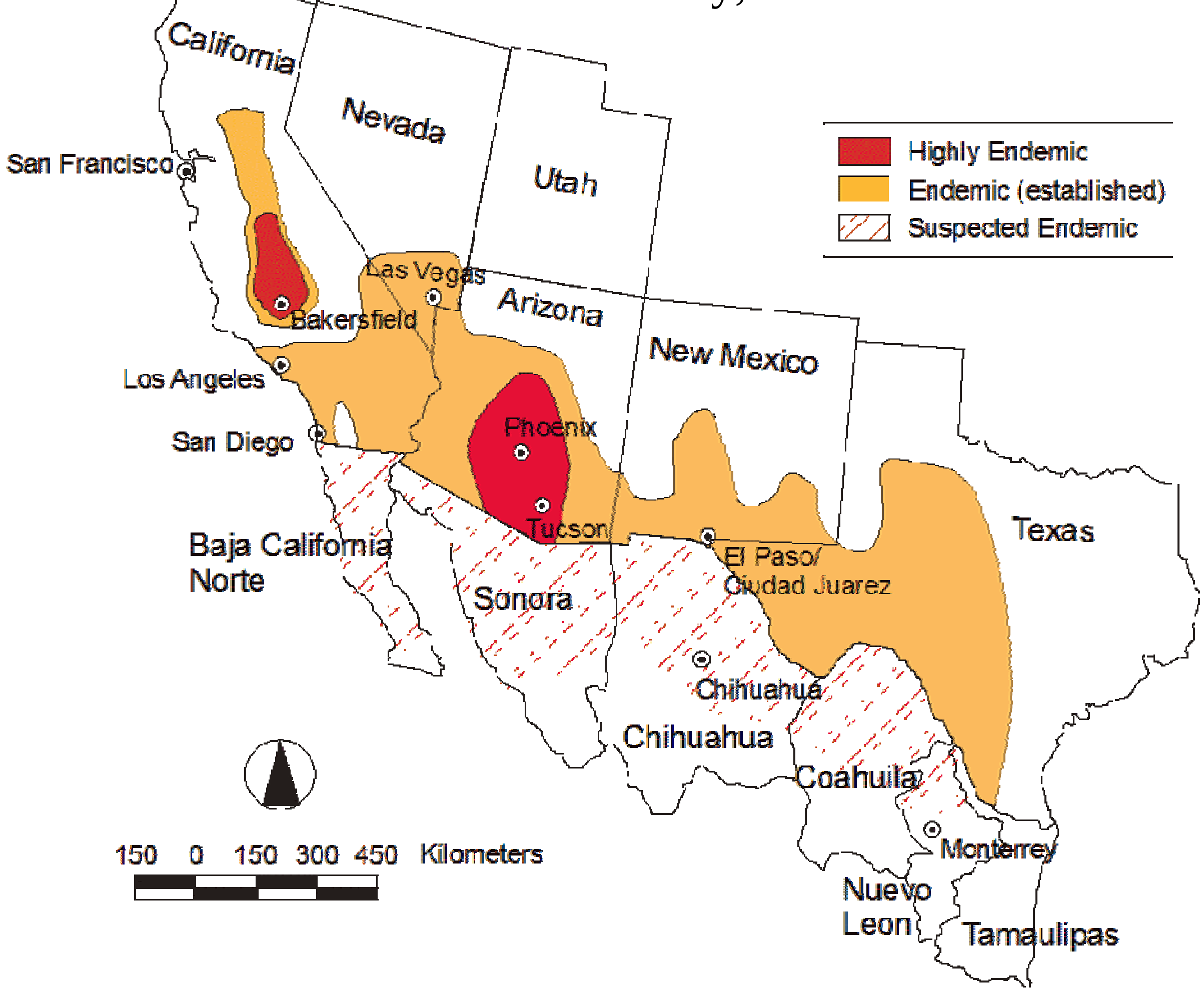
Source: AZ Dept of Health Services

Cocci Background

- Valley fever (coccidioidomycosis) caused by soil-dwelling fungi, *Coccidioides immitis & Coccidioides posadasii*
  - Fungus responds to changes in climate conditions
- When fungal spores become airborne and are inhaled, infection may occur
  - Flu-like symptoms (fever, cough, etc.) in early stages
  - May disseminate from lungs to other parts of body
- Range of cases
  - Asymptomatic/Inapparent - 60%
  - Mild to Moderate - 30%
  - Complications - 5% to 10%
  - Fatal - less than 1%
- Greater regional mortality/morbidity than Hanta or West Nile viruses
  - 2004 severe cases: AZ = 3665, USA = 6056
  - Deaths: 6-10% of reported cases (estimated in AZ)

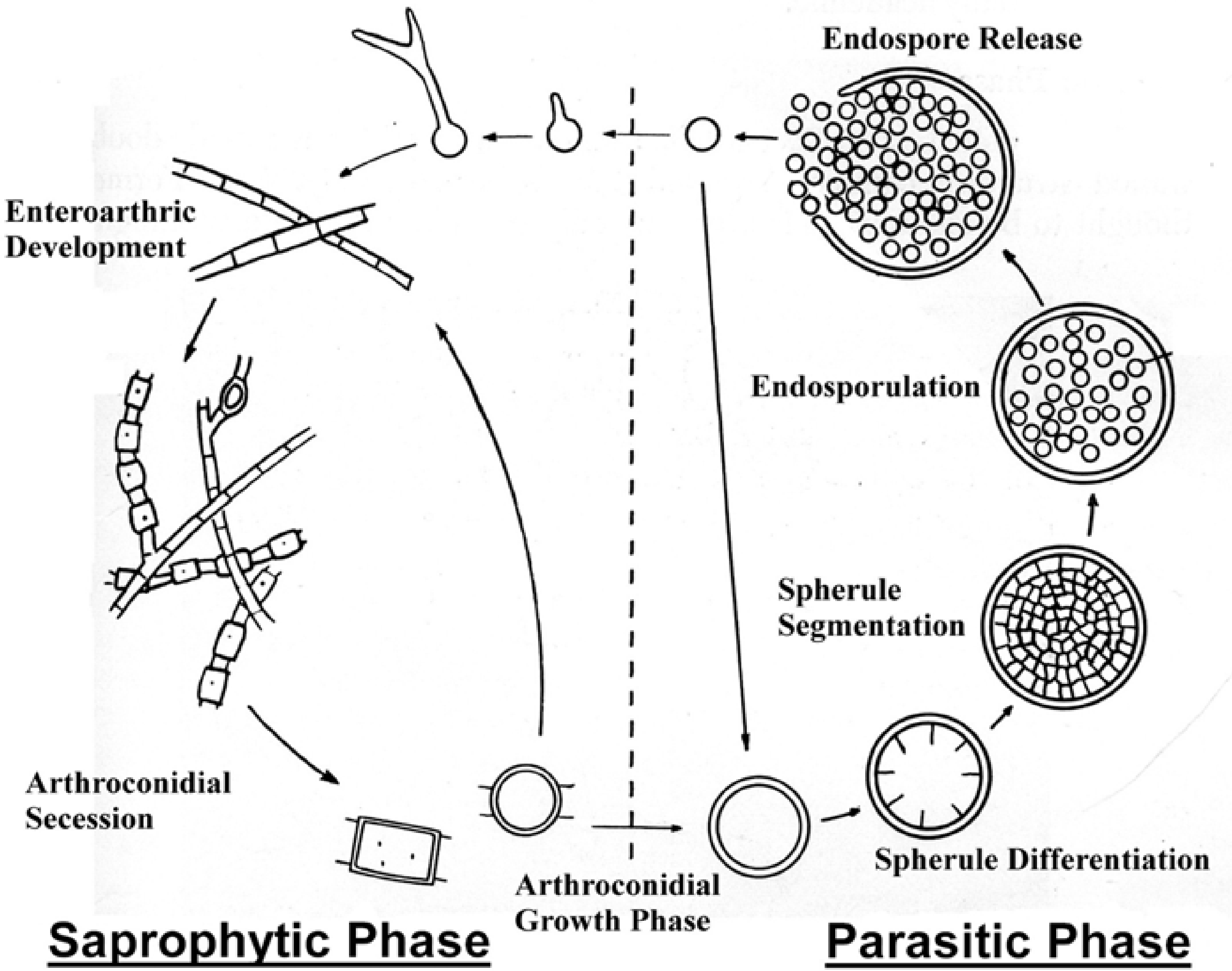
Valley Fever Endemic Zone

- Named originally for the San Joaquin Valley, CA
- Highly endemic in Pima and Maricopa Counties, AZ and Kern County, CA

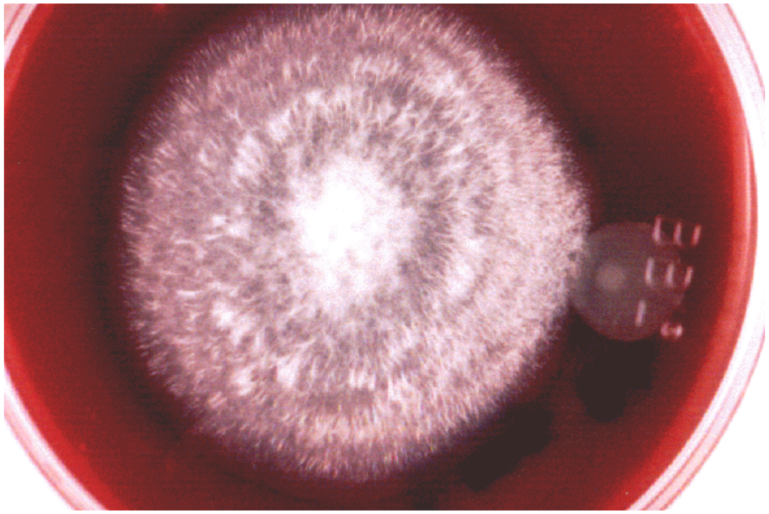


- Also endemic to parts of Central and South America (only found in dry climates of the Western Hemisphere, not in other deserts)

Lifecycle of *Coccidioides spp.*



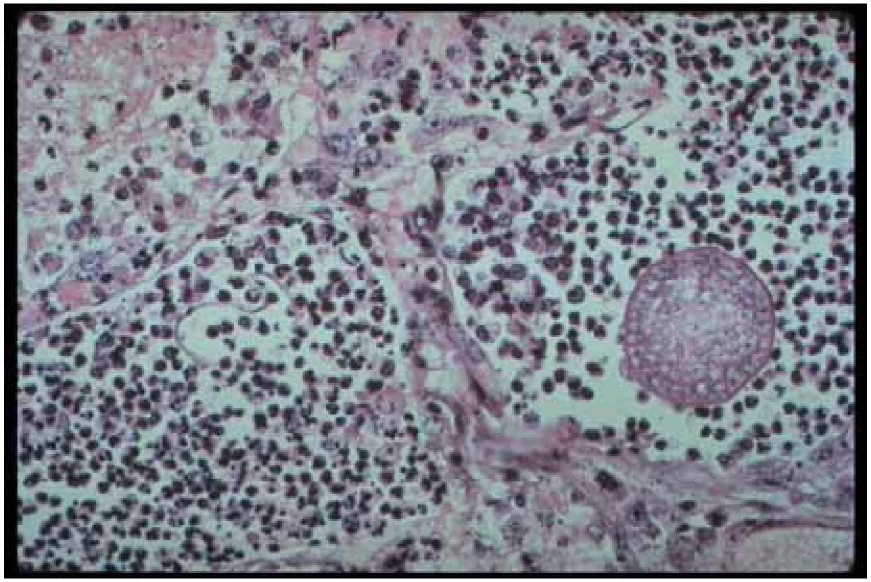
Coccidioides



Mycelial form of mature Coccidioides colony growing on blood agar culture medium

Photos: VFCE

Arthroconidia (spores)



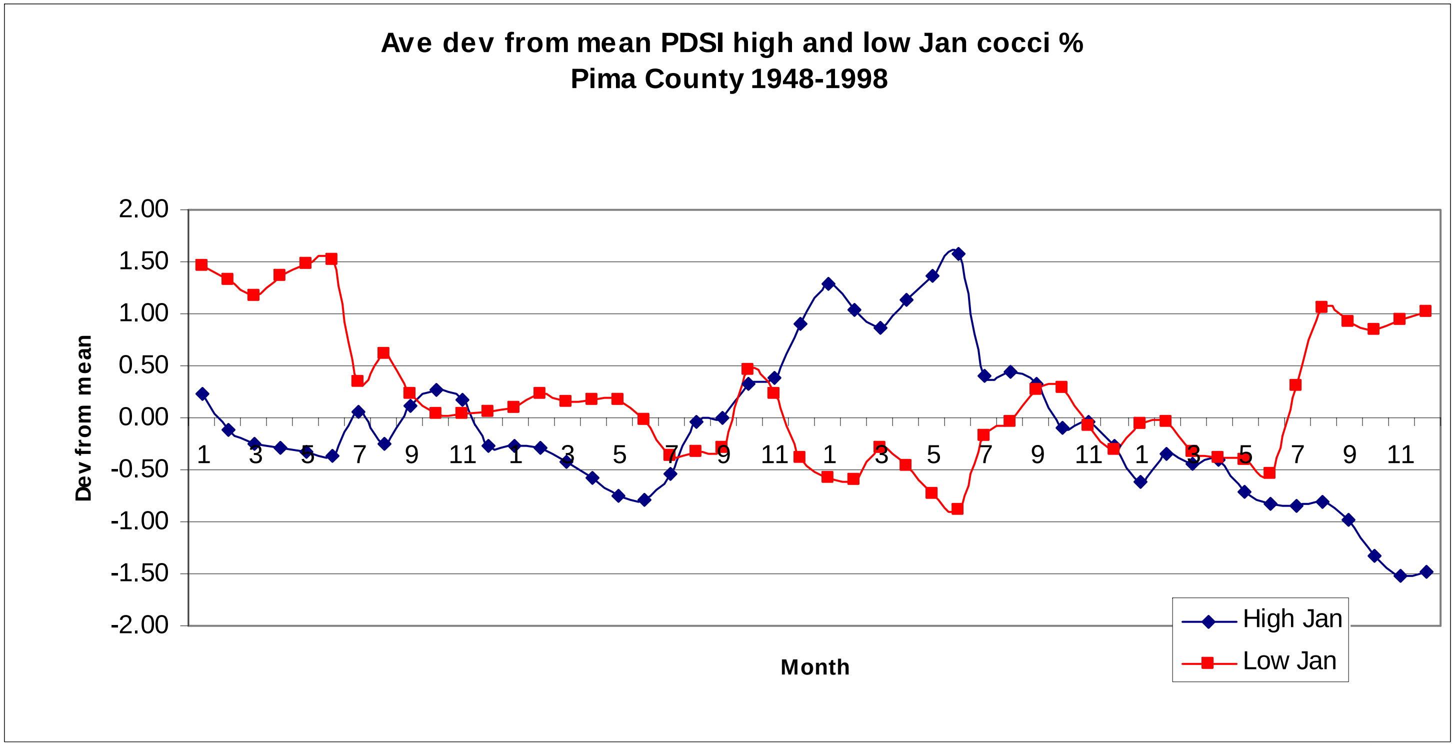
Spherule and endospores in lung tissue

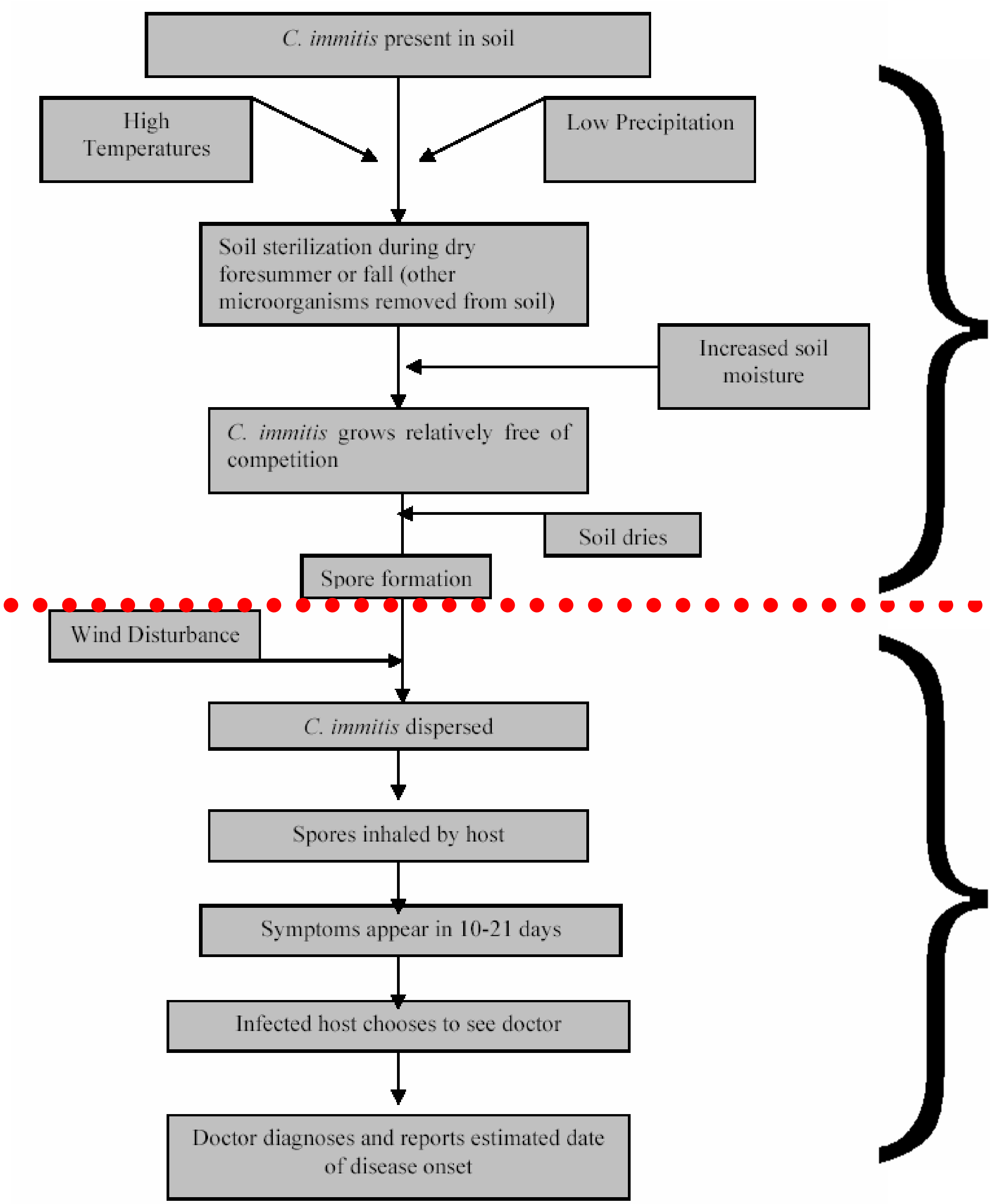
Previous Cocci-Climate Research

- Initial cocci-climate links established in 1950s and 1960s
  - Many anecdotal relationships between climate and incidence identified, but few quantitative studies
    - e.g., Hugenholtz 1957, bivariate correlation of incidence to climate in Maricopa County; Maddy 1965
- Early 1990s outbreak in California
  - Possible link to drought (Jinadu 1995)
- Most recently, work by my group and by CDC/ADHS
  - Kolivras et al. 2001, *Aerobiologia*, lit. review
  - Kolivras & Comrie 2003, *Int. J. Biometeorol.*, multivariate models
  - Comrie 2005, *Env. Health Persp.*, seasonal precip/dust models
  - Park et al. 2005, *J. Infect. Dis.*, multivariate model (a.k.a. Komatsu et al. 2003, *MMWR)*
  - UA work in progress/gray lit: Tabor, O'Rourke, Fisher/Bultman et al.

Findings From Our Previous Work

- Kolivras & Comrie 2003
- Superposed Epoch Analysis
  - Multi-year composites of antecedent monthly temp, precip, PDSI
- Palmer Drought Severity Index (PDSI) = clearest signal
  - Alternating pattern of moist and dry conditions leading up to low and high incidence in January, but not specific enough for accurate forecasting in all months





Climate

Focus modeling on two main hypotheses: “Grow” & “Blow”

- Soil: grow the fungus and form spores

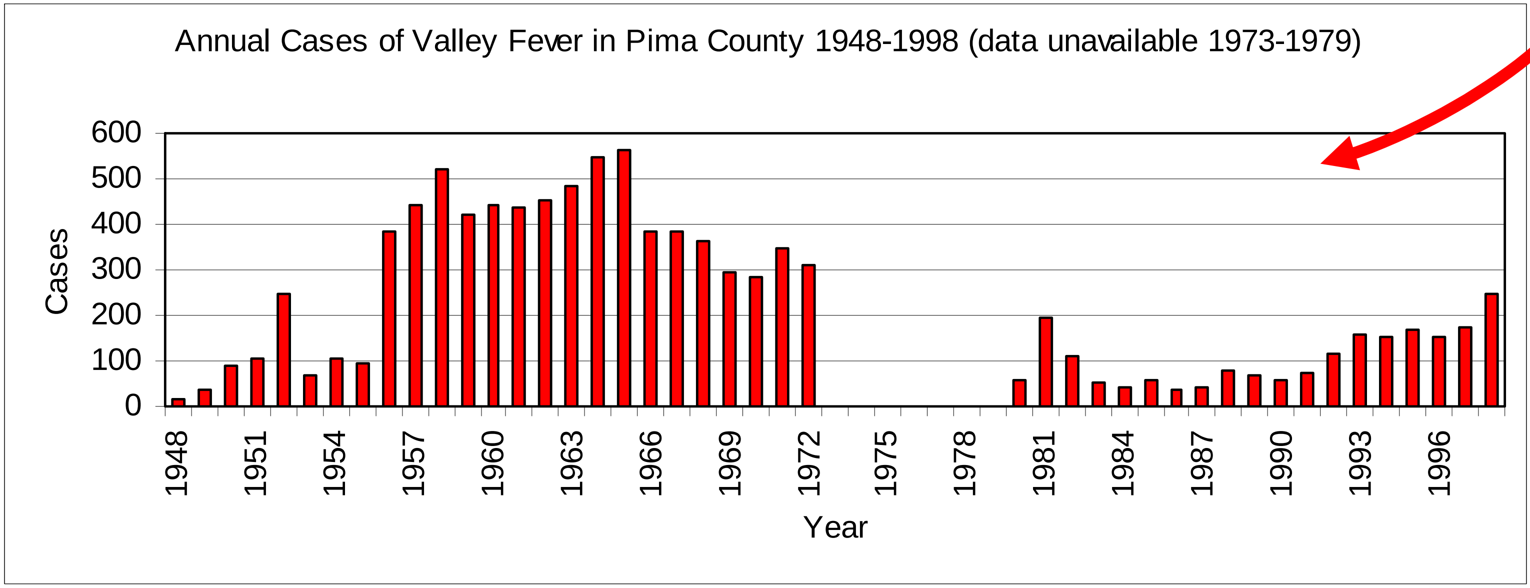
- Air: disperse spores by disturbance and/or wind

Research Approach

- Improve understanding of relationships between climate variability and valley fever *incidence* in humans
  - No useful data on actual spores in soil or air
- Develop multivariate predictive models
  - Could ultimately use climate forecasts too
- Interdisciplinary research and stakeholder group
  - Climatologists, geographers, MDs, epidemiologists, mycologists, microbial geneticists, soil scientists
  - Collaboration on research & outreach with UA Valley Fever Center for Excellence, and Arizona Department of Health Services
- Develop a decision-support system with public health stakeholders
  - Enables preparedness, sensitive-group warnings, enhanced surveillance and targeted intervention

Data

- Monthly climate data from NCDC/WRCC
  - Precipitation
    - In previous studies also tried temp (min, max, mean, dewpoint), PDSI, wind speed
- Monthly dust data (PM10) from Pima DEQ
- Cocci incidence from ADHS for Pima County
  - Initially 1948-present, but large inhomogeneity issues
  - More recently, 1990s onward (nationally notifiable since mid-1990s)

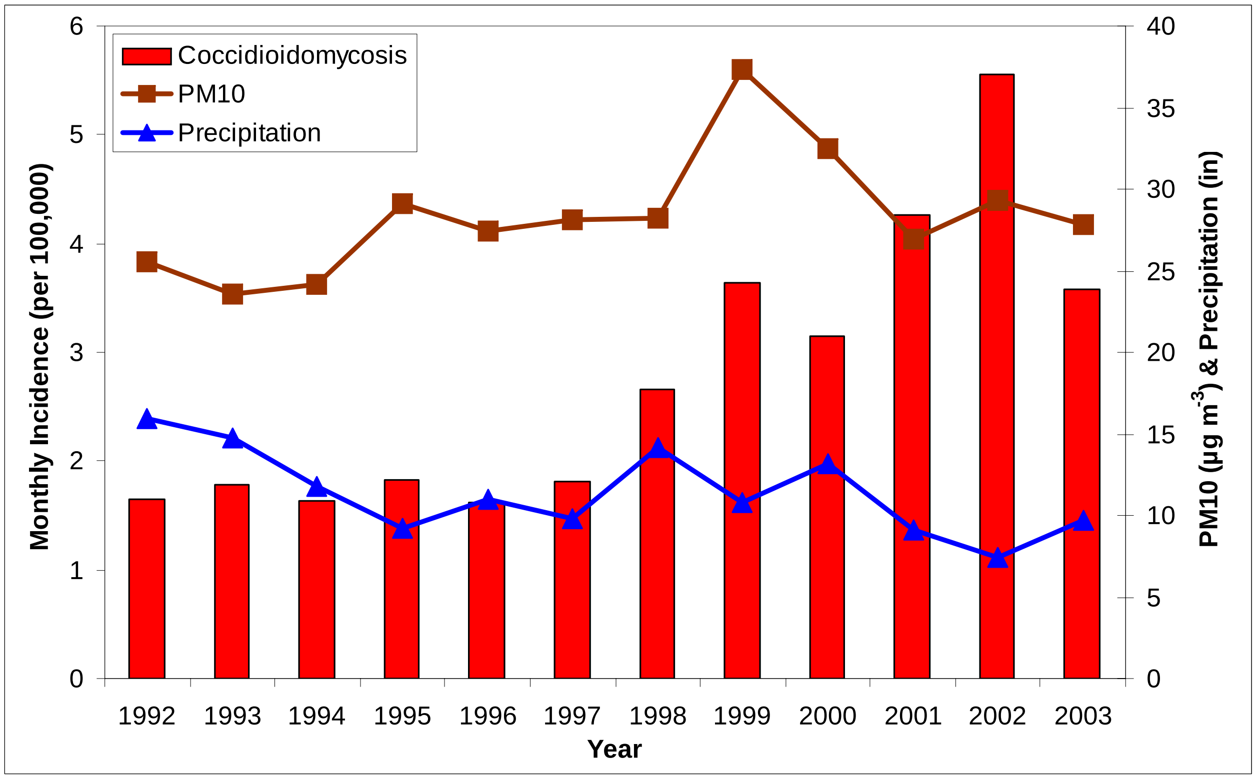


Refined Methods

- Address homogeneity – use most recent and reliable records only
  - 1992-2003 (both ‘good’ + ‘reportable’ periods)
  - 1997-2003 (‘reportable’ period alone)
- Health data pre-processing
  - Estimate exposure dates (for keying to climate)
  - Adjust for several kinds of delay: incubation delay after exposure, estimated date of symptom onset, diagnosis date and reporting date
  - Data contained some onset dates, typically only diagnosis & report date
  - Most effective was case-by-case monthly moving-window adjustment
  - 14-day incubation plus current-month mean onset-diagnosis/-report lag
- Aggregate data to the seasonal level
  - Diminish noise in cocci and precip data
  - Highlight the alternating wet and dry seasons – conceptually simpler
    - Was successful with fire-climate analyses (similar ecological lag issues)
- Parsimonious variable choice for regressions
  - Only antecedent precip, concurrent dust, and cocci (all seasonal)

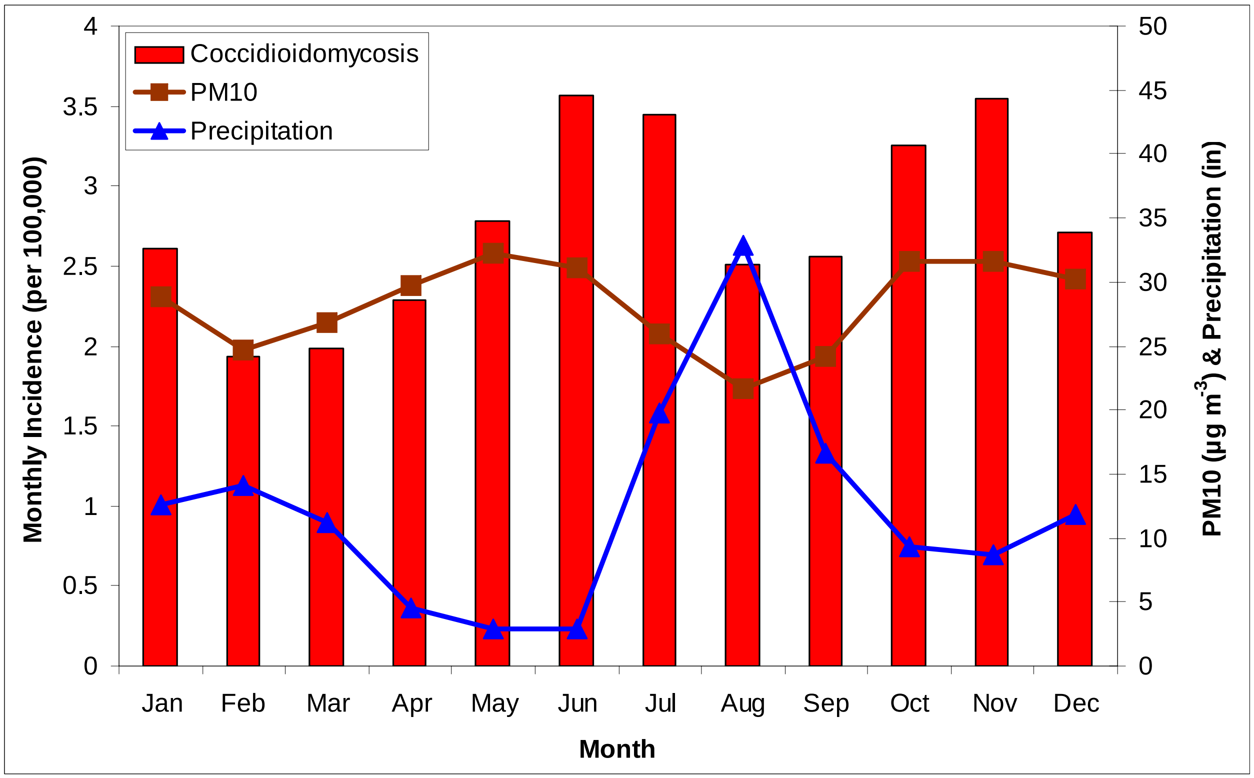
Valley Fever Epidemic

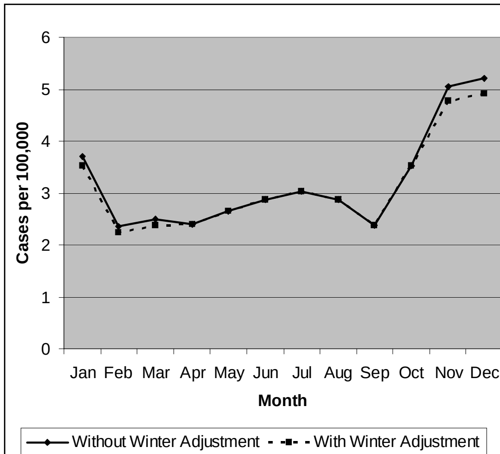
- Based on estimated exposure dates; Pima County, AZ
- Variable dust (PM10) pattern
- Precip shows drought trend from 1999-2003, but cocci incidence was rising before that



Seasonality of Estimated Exposure Date

- Confirmed bi-modal peaks in public health records, not previously identified (but long suspected)
- PM10 is inverse of precip, and roughly matches cocci
  - But, looking closely, wet/dry seasonal amounts and cocci lags are inconsistent (perhaps because precip inhibits dust too: need multivariate analysis)





AZ reported "raw" incidence 1998-2001, incl. effect of winter visitors (Park et al. 2005)

Table 1. Model performance and standardized (beta) coefficients for the four seasonal regression models predicting coccidioidomycosis rates from concurrent PM_{10} and concurrent and antecedent precipitation, 1992-2003. Seasons falling before or after the period including the concurrent season through four years earlier are marked as not applicable (N/A). For precipitation variables, Fall-0 denotes the concurrent fall, Winter-4 denotes the winter occurring four years earlier, etc. with the seasons furthest back in time at the bottom of the table. Entries in bold indicate model variables that were also present in a 1997-2003 subset analysis.

	Foresummer	Monsoon	Fall	Winter
Performance				
Adjusted R^2	***0.98	**0.60	**0.61	***0.95
Dust				
PM_{10}	***0.75			***0.44
Precipitation				
Winter-0	N/A	N/A	N/A	
Fall-0	N/A	N/A	***-0.49**	**-0.35
Monsoon-0	N/A			
Foresummer-0	***0.47			***0.49
Winter-1	*0.20			**-0.32
Fall-1	*-0.25			
Monsoon-1				
Foresummer-1		*0.45	****0.73**	*****0.56**
Winter-2				
Fall-2				
Monsoon-2				
Foresummer-2	*****1.36**	****0.64**		
Winter-3				
Fall-3				
Monsoon-3				
Foresummer-3				
Winter-4				
Fall-4				N/A
Monsoon-4	***-0.93		N/A	N/A
Foresummer-4		N/A	N/A	N/A

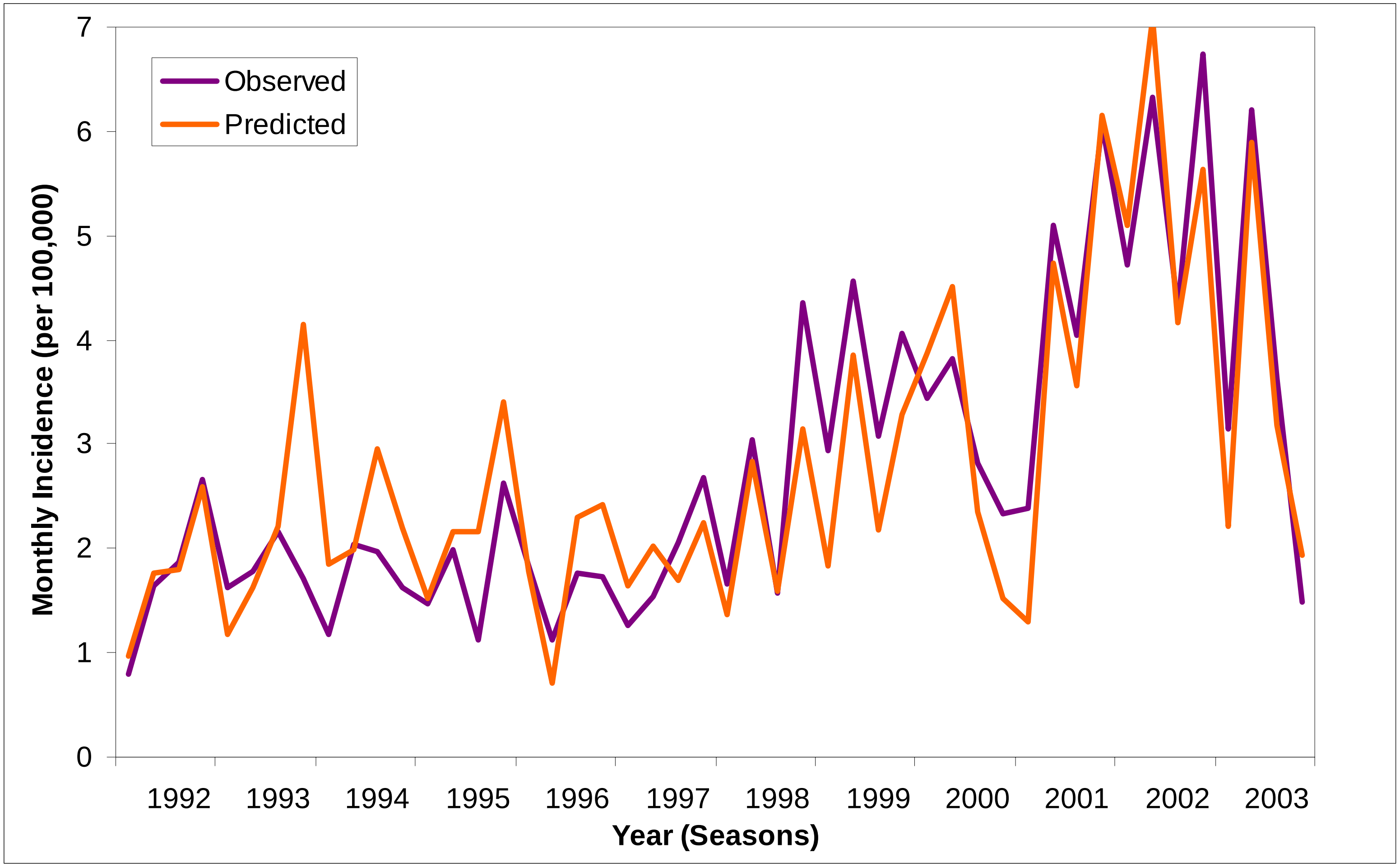
*** ≤ 0.001 significance; ** ≤ 0.01 significance; * ≤ 0.05 significance

Identify antecedent moisture and dispersion relationships via regression

Four seasons:
- AMJ, JAS, ON, DJFM
- lags up to four years

Two major findings:
- Concurrent Dispersion
- Foresummer Precip
  - 18-24 months ahead

Pima County Valley Fever
Observed & Modeled Seasonal Incidence



Cross-Validated $R^2 = 0.8$

Conclusions & Implications

- Striking role of arid foresummer in both data periods
  - Precipitation during this hottest and driest part of the year (AMJ), as opposed to other wetter seasons, is most favorable for *Coccidioides* growth in the environment
    - Antecedent foresummer precip alone has cross-val. R^2 of 0.27 with cocci
  - Typically a time of soil desiccation and vegetation dormancy, so the ability to grow opportunistically in the foresummer may be a competitive advantage of *Coccidioides* over other soil biota
- Spores can accumulate and remain viable for years after a wetter foresummer
- Dust (PM10) is a good proxy for dispersion in winter & foresummer
  - Negative precip dispersion role in fall (rather than dust)
- Although initially elusive, careful data processing led to dramatic improvements in explained variance using a simple and robust model
  - Can be implemented for use by public health decision-makers
  - Need to validate model elsewhere (e.g., Maricopa county)
- Overall: strong support for climate-cocci hypotheses ("Grow *and* Blow"):
  - Fungal growth in the longer term
  - Spore dispersion and exposure in the short term
- New work (EPA-funded): develop and test expanded model in rest of Arizona
  - Add spatial information using satellite soil moisture

Thank you!

- Published Paper
  - Comrie (2005) in *Environmental Health Perspectives*

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