Climate controls on Valley Fever incidence in Kern County, California, USA

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Definition:

Coccidioidomycosis (Valley Fever) is a systemic infection caused by inhalation of airborne spores from *Coccidioides immitis*, a soil-dwelling fungus found in the southwestern United States, parts of Mexico, and Central and South America.

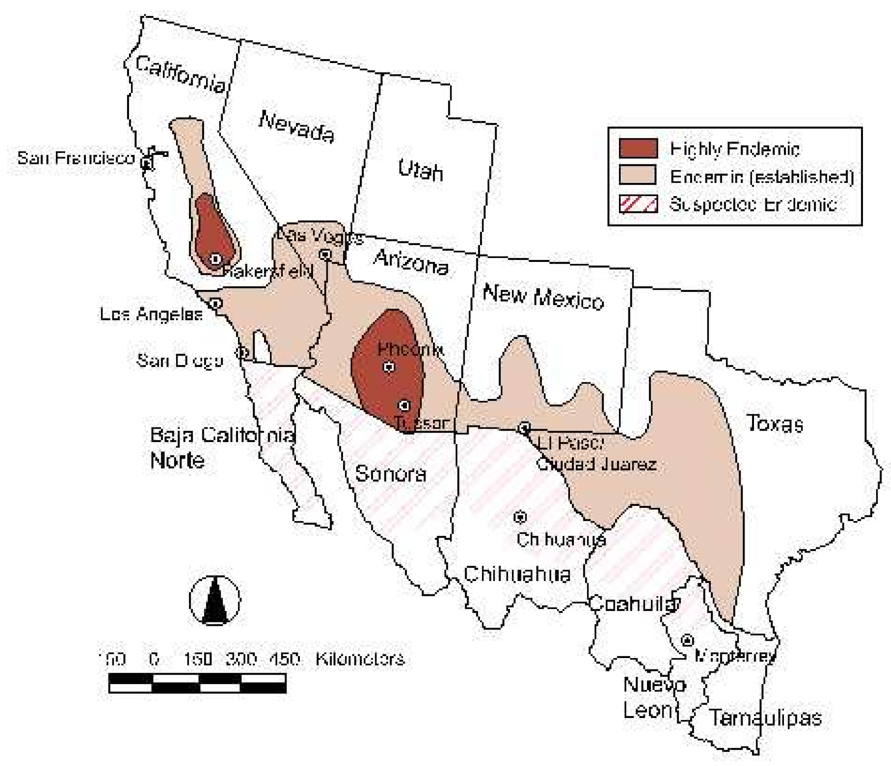

Figure 1: Areas endemic to Valley fever, after *Kirkland and Fierer* [1996]:

Objectives:

- Identify climate predictors of Valley Fever in KC endemic region
- Compare to epidemiology to Tucson AZ, an endemic region with different climate
- Assess potential of climate and aerosol modeling to predict and prepare for outbreaks

Motivation:

In 1991–1995 a valley fever epidemic increased incidence N 10-fold to about 3,000 cases per year. The recent trend in N is, well, not reassuring!

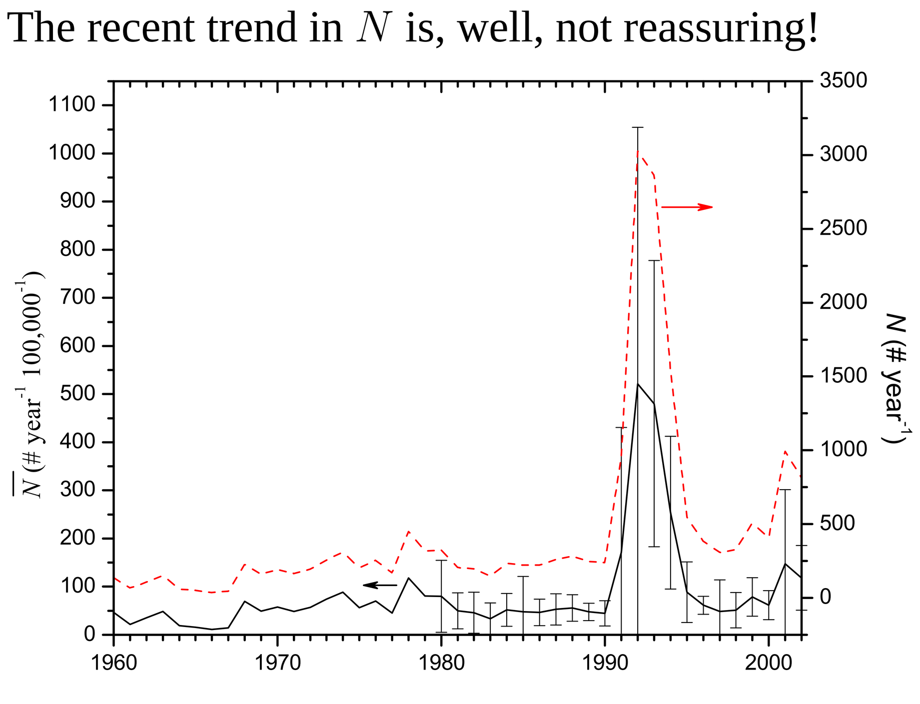

Figure 2: Annual incidence $\bar{N}$ [# yr^{-1} (100,000)$^{-1}$] (solid line) and total number of reported cases N [# yr^{-1}] (dashed line) of Valley Fever in Kern County from 1960–2002. Bars show two standard deviations of monthly incidence statistics (projected to annual rates) beginning in 1980.

Strategy:

Analyze links between climate and *C. immitis* epidemiology and climate statistics from Kern County, California. Focus on monthly anomalies.

Methods:

Monthly incidence data available from California Department of Health Services (CDHS), 1980–2002. Compare to monthly Kern Co. climatology constructed from NOAA SAMSON (1961–1990), ISHO (1995–2000), HUSWO (1990–1995), Hanford Forecast data (2001–2002). We analyze climatological means $\bar{x}$, anomalies x'_n, of monthly time-series x_n:

$$\bar{x} = \frac{1}{N}\sum_{n=1}^{n=N} x_n \quad (1)$$

$$x'_n = x_n - \bar{x} \quad (2)$$

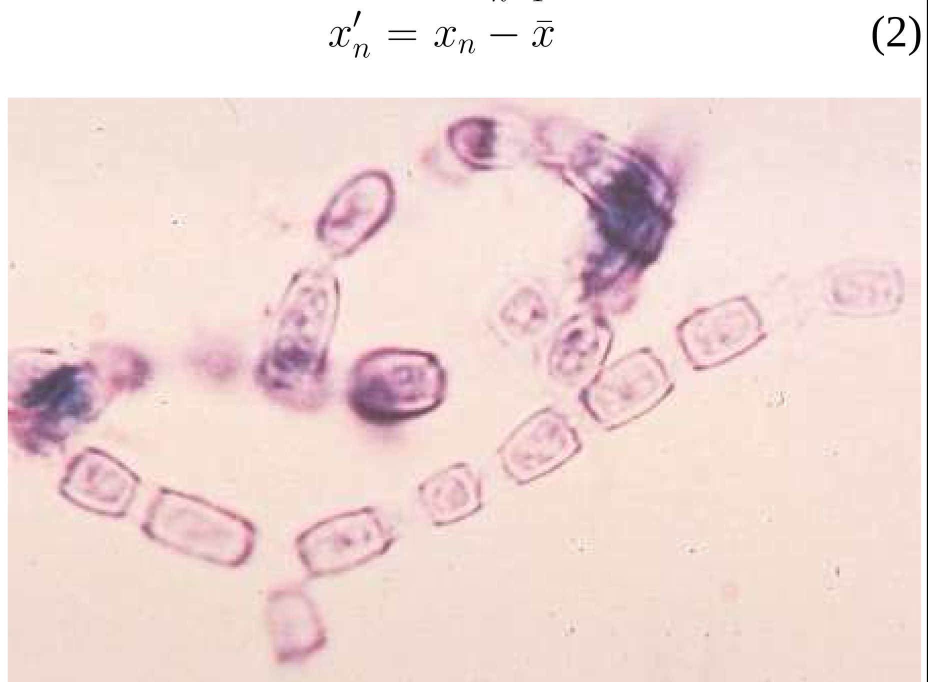

Figure 3: *C. immitis* arthroconidia colony prior to secession and sporulation [*Valley Fever Center for Excellence*, 2003].

Results:

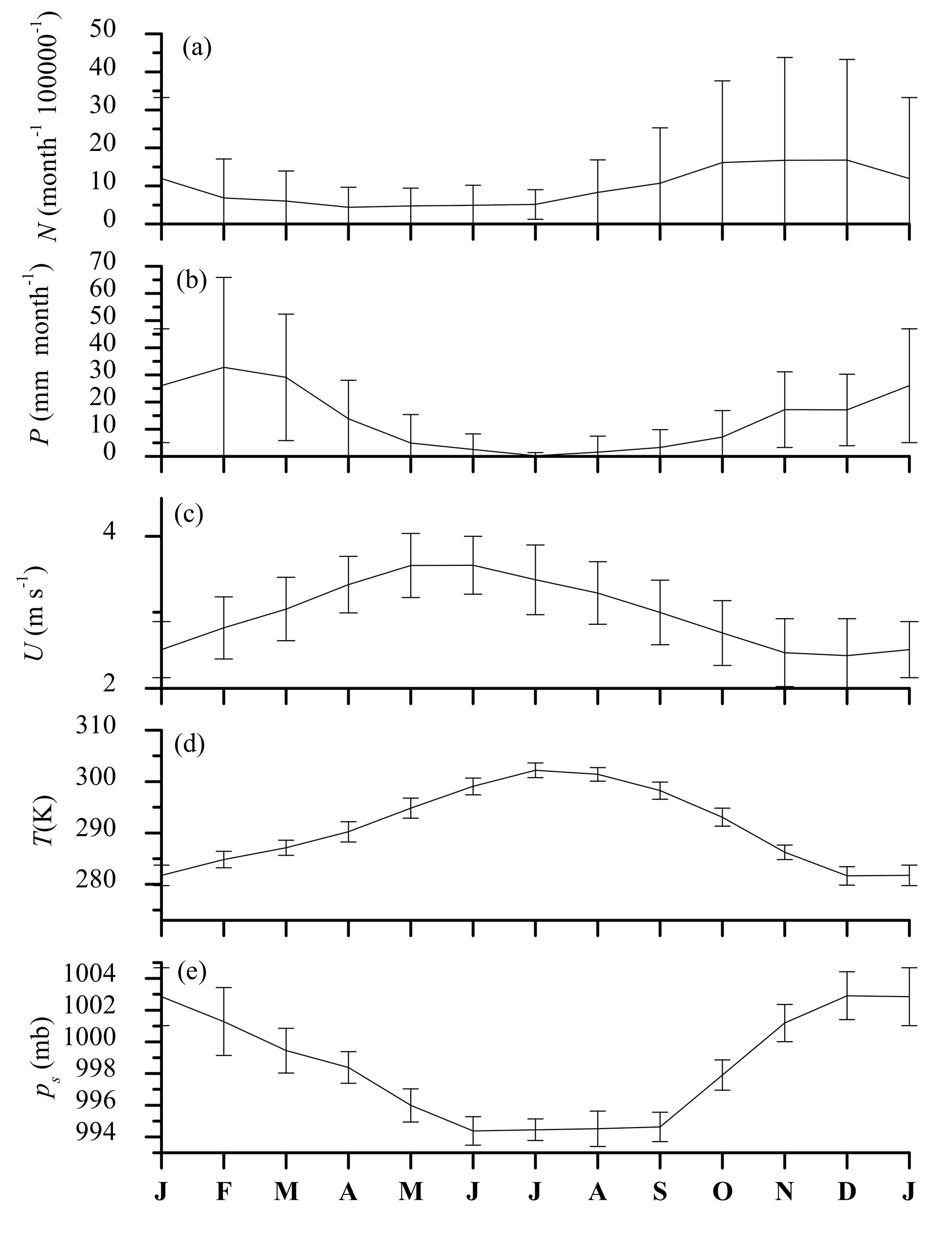

Figure 4: Climatology of coccidioidomycosis incidence and potential climate risk factors in Kern County from 1980–2002. Shown are monthly mean (a) incidence N [# month^{-1}] (b) precipitation P [mm month^{-1}], (c) wind speed U [m s^{-1}], (d) surface temperature T [K], (e) surface pressure p_s [mb]. Bars span two standard deviations of the inter-annual variability computed separately for each month. Standard deviations computed using 1980–present data for incidence, 1961–present for climate.

- N variability strongly linked to wintertime P

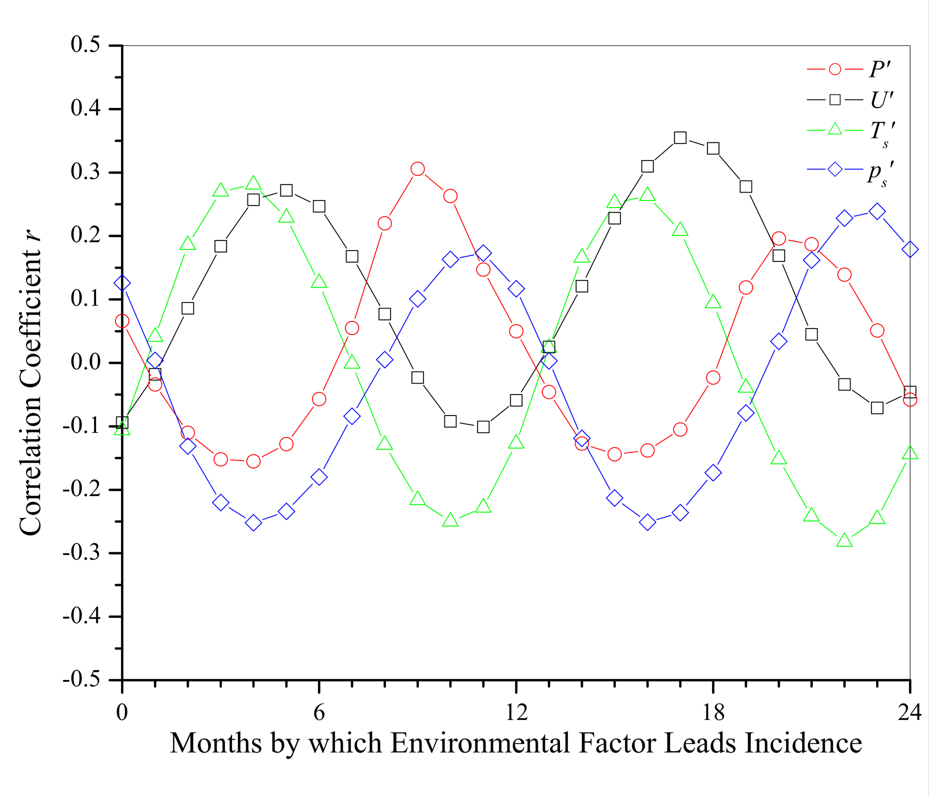

Figure 5: Lag correlation coefficient r between climatological valley fever anomaly N' in Kern County and climatological anomalies of four potential climate risk factors: wind speed U' (squares), precipitation P' (circles), surface temperature T'_S (triangles), and surface pressure p'_s.

- Incidence anomalies are most strongly linked to P' nine months prior, U' five months prior, T'_S four months prior. Climate anomalies up to three years antecedent affect incidence. Lags are due to soil moisture memory, soil sterilization by drought, dust storm seasonality, and disease incubation and reporting time.

Significance:

Table 1 summarizes the peak correlation coefficients r and r_s, and the associated confidence statistic p, between valley fever anomalies and climate anomalies in Figure 5.

Table 1: **Peak Correlations with Climate Anomalies**

Anomaly	# mo.[a]	r[b]	r_s[c]	p[d](%)
Precipitation	4	−0.16	−0.25	0.77
Precipitation	9	0.31	0.24	1.5×10^{-5}
Precipitation	15	−0.14	−0.26	2.0
Wind Speed	5	0.27	0.30	5.4×10^{-4}
Wind Speed	11	−0.10	−0.19	9.7
Wind Speed	17	0.36	0.39	7.2×10^{-8}
Temperature	4	0.28	0.35	2.3×10^{-4}
Temperature	10	−0.25	−0.32	0.0027
Temperature	16	0.26	0.31	0.0012
Sfc. Pressure	4	−0.25	−0.35	0.0027
Sfc. Pressure	11	0.17	0.22	0.46
Sfc. Pressure	16	−0.25	−0.37	0.0027

[a]Number of months by which climate anomaly leads valley fever anomaly for this correlation
[b]Pearson correlation coefficient
[c]Ranked (Spearman) correlation coefficient
[d]Confidence statistic (probability in percent that incidence and climate factor are uncorrelated)

Incidence and Co-variation of Climate:

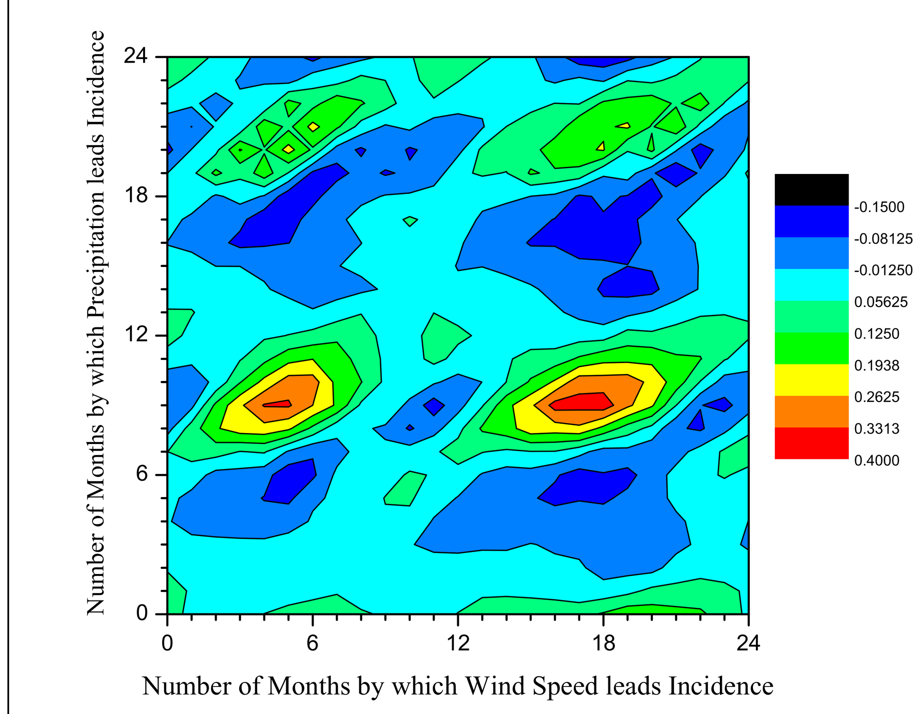

Figure 6: Lag correlation coefficient r between N' and $P'U'$ from 1980–2002.

- A windy month immediately following a wetter than normal season is more likely to result in increased incidence. An enhanced dispersal mechanism (wind) acting on soils which have dried for four months since a wet month favors coccidioidomycosis.

Epidemic Years:

As shown in Figure 2, Kern County experienced a valley fever epidemic from 1991–1995. During this period, annual incidence increased five-to-tenfold, from 50 to 500 yr^{-1} (100,000)$^{-1}$. The most recent incidence reports, for 2001–2002, also show a significant increase above the long term background level. Thus understanding factors contributing to epidemic outbreaks is of current concern in California.

To help distinguish environmental from demographic causes of the 1991–1995 epidemic, we separately analyze seven time periods.

Table 2: **Time Series Analyzed Separately**

	Description	Start	End	# mo.[a]
A	Entire 23 year record	1980	2002	276
B	Until epidemic start	1980	1990	132
C	Until epidemic end	1980	1995	192
D	Epidemic omitted	1980	2002	216
E	Epidemic end to 2002	1996	2002	84
F	Epidemic only	1991	1995	60
G	Epidemic start to 2002	1991	2002	144

[a]Number of months in period

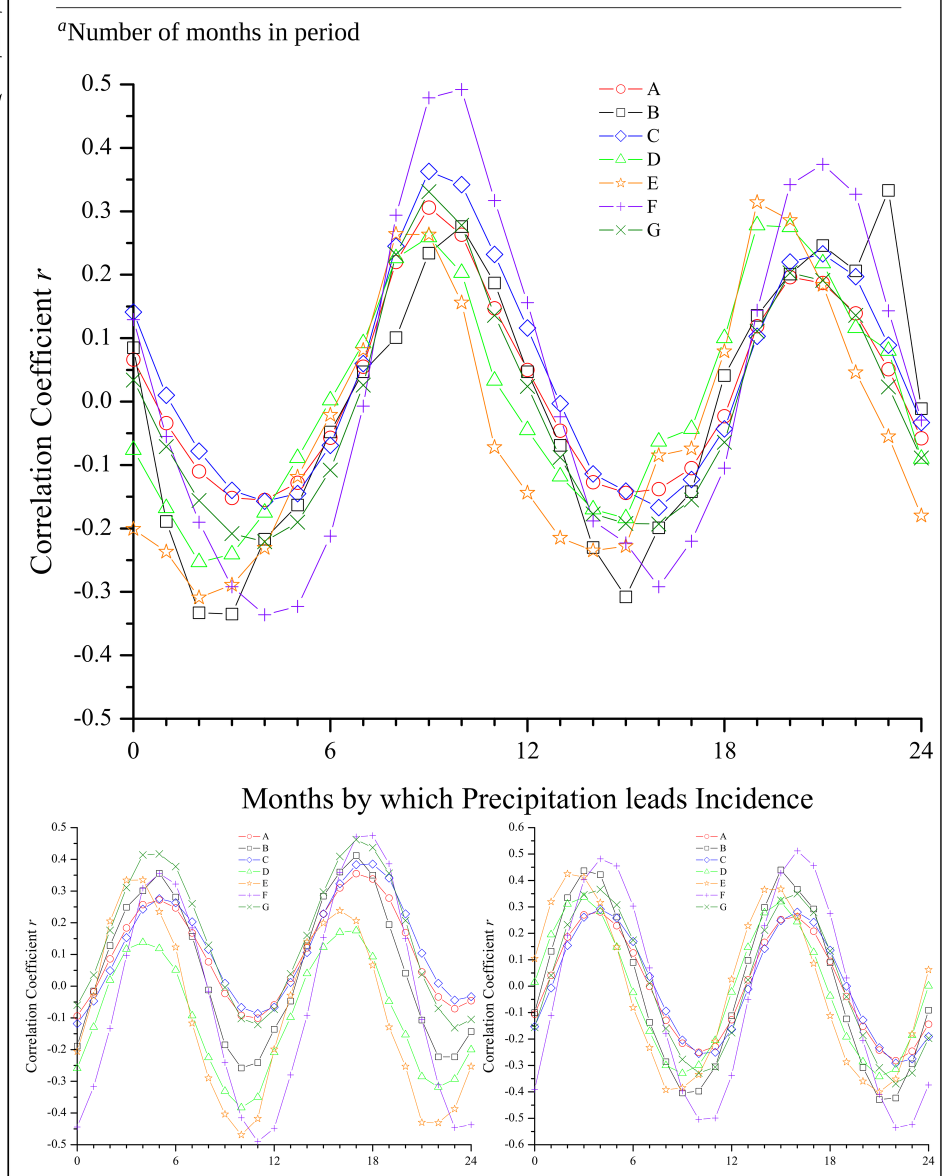

Figure 7: Lag correlation coefficient r between Valley Fever anomaly N' and (a) precipitation anomaly P', (b) wind speed anomaly U', and (c) surface temperature anomaly T'_S for periods in Table 2.

- Correlation magnitudes change significantly among periods
- Rainfall anomalies play a stronger role in promoting valley fever in epidemic years than in non-epidemic years
- The 1991–1995 epidemic began a decadal shift toward stronger links between N' and U'

Understanding C. immitis Lifecycle:

- Kern County data are consistent with conceptual model of *Pappagianis* [1988]: *C. immitis* thrives during wet periods following droughts because it tolerates hot, dry periods better than competing soil organisms. As moisture-induced blooms achieve maturity and soils dry, *C. immitis* colonies become susceptible to dispersal and human infection during wind events.

Conclusions:

- Monthly precipitation, wind speed, and temperature anomalies are the strongest predictive variables explaining up to 20% of incidence anomalies. This is similar to findings in Pima County, AZ [*Kolivras and Comrie*, 2003], except wind anomalies are much more important in Kern County.
- Rainfall anomalies have a stronger influence on valley fever in epidemic years than in non-epidemic years, whereas wind speed anomalies show little change.
- The epidemic is significantly associated with anomalously wet periods 9–10 months antecedent, and with anomalously dry, warm, and windy periods 4–6 months antecedent.
- Given the small size of arthroconidia (2–20 μm), we speculate that saltation-sandblasting, not direct wind entrainment, is the likeliest mechanism for arthroconidial rupture and dispersal.

Potential Future Directions:

- Apply to regional forecasts of SW US Dust
- Will expected changes in LSLZ climate zone change habitat?
- Will DEAD with soil fungus model simulate spatial patterns of incidence?

Figure 8: Santa Ana winds bring desert dust to Los Angeles, February 9, 2002 (NASA).

- If increased precipitation expands its endemic habitat into the Mojave, *C. immitis* may "hitchhike" rides into town on similar dust storms.

References

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