



## Dust Storms, Valley Fever, and Public Awareness

Daniel Q. Tong<sup>1</sup> , Morgan E. Gorris<sup>2</sup> , Thomas E. Gill<sup>3</sup> , Karin Ardon-Dryer<sup>4</sup> , Julian Wang<sup>1</sup>, and Ling Ren<sup>1</sup>

### Key Points:

- Contradicting common perception, the Storm Events Data are from diverse sources and unsuitable for assessing dust-Valley fever relationships
- There is inconsistency in the term “dust storm” used by science communities, and frequency, magnitude, and duration of dust storms matter
- It is in best public interest to advocate the public message that dust storms may put people at risk for contracting Valley fever

### Correspondence to:

D. Q. Tong,  
[qtong@gmu.edu](mailto:qtong@gmu.edu)

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### Author Contributions:

**Conceptualization:** Daniel Q. Tong, Thomas E. Gill  
**Data curation:** Karin Ardon-Dryer  
**Formal analysis:** Daniel Q. Tong, Karin Ardon-Dryer  
**Funding acquisition:** Daniel Q. Tong  
**Visualization:** Morgan E. Gorris  
**Writing – original draft:** Daniel Q. Tong, Morgan E. Gorris  
**Writing – review & editing:** Morgan E. Gorris, Thomas E. Gill, Karin Ardon-Dryer, Julian Wang, Ling Ren

<sup>1</sup>Department of Atmospheric, Oceanic and Earth Sciences, Center for Spatial Information Science and Systems, George Mason University, Fairfax, VA, USA, <sup>2</sup>Information Systems and Modeling & Center for Nonlinear Studies, Los Alamos National Laboratory, Los Alamos, NM, USA, <sup>3</sup>Department of Earth, Environmental and Resource Sciences, The University of Texas at El Paso, El Paso, TX, USA, <sup>4</sup>Department of Geosciences, Texas Tech University, Lubbock, TX, USA

**Abstract** We discuss several issues raised by Comrie (2021, <https://doi.org/10.1029/2021GH000504>), which uses a crowdsourced data set to study dust storms and coccidioidomycosis (Valley fever). There is inconsistency in the term “dust storm” used by science communities. The dust data from National Oceanic and Atmospheric Administration Storm Events Database are from diverse sources, unsuitable for assessing dust-coccidioidomycosis relationships. Population exposure to dust or *Coccidioides* needs to consider the frequency, magnitude, and duration of dust events. Given abundant evidence that dust storms are a viable driver to transport pathogens, it is in best public interest to advocate dust storms may put people at risk for contracting Valley fever.

**Plain Language Summary** Valley fever is an infectious disease caused by inhaling soil-dwelling fungi living in the Americas, with the highest infection rate in the same regions frequented by dust storms. We discuss a few issues on the relationship between dust storms and Valley fever raised by a new study Comrie (2021, <https://doi.org/10.1029/2021GH000504>): (a) What is a dust storm? (b) Is it proper to use the Storm Events Database for long-term dust trend analysis? (c) How to represent population exposure to dust and fungi, and (d) How to communicate the risk associated with dust storms to the public.

## 1. Introduction

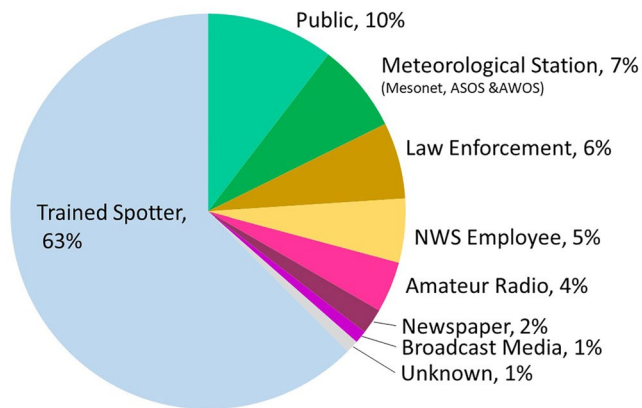
Coccidioidomycosis, commonly known as Valley fever, is an infectious disease caused by inhaling soil-dwelling fungi *Coccidioides* living in the Pan-American region, including the western United States (US), Mexico, and Central and South America (Barker et al., 2019). The Centers for Disease Control and Prevention (CDC) reported 218,392 cases between 1998 and 2019 in the US (CDC, 2022). Despite recent progress, many fundamental questions remain unanswered regarding this widespread disease, such as where these fungi live in the soil and how they become airborne and inhaled by humans and animals.

The recent study by Comrie (2021) presented a review of past studies and an analysis of the correlation between dust storms and Valley fever. The author concluded that “there is no reliable evidence that all or most dust storms consistently lead to subsequent increases in coccidioidomycosis cases” and proposed that “we should stop saying or implying things like ‘haboobs cause more Valley fever.’” While we applaud the effort by Comrie (2021) to investigate linkages between dust storms and Valley fever, we argue this messaging inappropriately dismisses the risk of contracting Valley fever from dust storms. Our perspective demonstrates why dust storms should still be considered a risk for Valley fever and proposes several important questions in Valley fever and dust research that warrant further discussion by the community.

## 2. What Is a Dust Storm?

We note there is inconsistency in the definition and use of the term “dust storm” within different scientific communities (Comrie, 2021; Lei et al., 2016) and in the public vernacular. The World Meteorological Organization (WMO) defines a dust storm as a blowing dust event that reduces visibility to 1 km or less (WMO, 2019). Operational weather warning in the USA National Weather Service (NWS) adopts more stringent criteria for defining a dust storm, including visibility of ¼ mile or less (NWS, 2022). The dust events in which the visibility is not so significantly reduced and/or wind is not so strong are classified and listed in weather observations as

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**Figure 1.** Data sources of reported dust events in the Storm Events Database (NCEI, 2022) from 2006 to 2018 that were used in Comrie (2021) work. ASOS is Automated Surface Observing Systems, AWOS is Automated Weather Observing System, and unknown are unidentified reporting sources.

*blowing dust, haze, or just dust* (while they may still be referred to as “dust storms” by the public and in news and social media).

Comrie (2021) used the “dust storm” data from the USA National Oceanic and Atmospheric Administration Storm Events Database of the National Centers for Environmental Information (NCEI, 2022), and considered all dust events from this database as “dust storms.” However, following the definition of the WMO (2019) or National Weather Service (2022), not all dust events in the Storm Events Database are *dust storms*. As an example, we examined visibility values in 70 of the 76 dust events (for 2006–2018 only, excluding six events in 2019–2020) used in Comrie (2021), of which only 68 had visibility data, and found 32 events (47%) reported as dust storms in the database did not meet the WMO “dust storm” definition, having visibility >1 km (0.6 mi). An additional ~30 qualifying dust storms in the Phoenix area during 2006–2017 (Ardon-Dryer et al., 2021) were missing in the Storm Events Database and not included by Comrie (2021) and may have also affected the interpretation of dust impacts. Since Comrie (2021) did not employ any criteria to separate dust storms from less extreme dust weather, it is more appropriate to call these records “dust events,” instead of “dust storms”.

There has been no consistent practice of defining “dust event” or “dust storm,” or method of identification of dust exposure used in epidemiological studies in the US. Comrie (2021) and Rublee et al. (2020) used the Storm Events Database, Herrera-Molina et al. (2021) and Schwartz et al. (1999) used a combination of particulate matter (PM) concentrations and wind speed, Tong et al. (2017) used a combination of PM concentrations and PM chemistry from air quality monitoring networks, Grineski et al. (2011) used daily NWS weather records of any dust-related phenomenon (“blowing dust,” “widespread dust,” “drifting dust,” “blowing sand,” “drifting sand,” “sand storm,” “widespread sand,” “dust storm,” or “dust haze”), Norton and Gunter (1999) used a combination of PM concentrations and weather records, and Hefflin et al. (1994) used a combination of visibility and wind speed from a weather station. None of these studies adopted the WHO or NWS definitions of a “dust storm,” even in part. Clearly, a more consistent standard for a windblown dust exposure for epidemiological studies is called for to standardize and compare results.

### 3. Is the Storm Events Database Appropriate for Quantitative Trend Analysis?

The Storm Events Database is known to be an inconsistent and inaccurate record of severe weather (Ashley & Black, 2008; Ashley & Gilson, 2009; Black & Ashley, 2010; Black & Mote, 2015; Miller et al., 2016), and inaccurate in comparison to meteorological definitions of dust weather events—thus precluding its use for an accurate assessment of dust-Valley fever relationships. As written in the Storm Events Database guidelines, events recorded therein can be gathered from sources outside of the NWS (Figure 1) and that information may be unverified by the NWS (NWS, 2021). The NWS does not assess the accuracy or validity of the information, and human observations of wind phenomena in the Storm Events Database (Ashley & Black, 2008; Black & Ashley, 2010; Miller et al., 2016; Trapp et al., 2006), even by NWS-trained spotters (Miller et al., 2016), and of other severe weather (Ashley & Gilson, 2009; Black & Mote, 2015) in the Storm Events Database are documented to suffer frequent inaccuracies and missing events. Therefore, it is likely that dust events may be incorrectly defined, incorrectly reported, and/or unreported in this database. Appropriately assessing dust exposures requires understanding meteorological observations, PM, and/or visibility data (Lei et al., 2016).

To illustrate the potential shortcomings with the Storm Events Database, we explored the sources of dust event reports in the Storm Events Database from 2006 to 2018, a large portion of the dates (2006–2020) in Comrie (2021). This included 70 of the 76 dust reports in Comrie (2021) (Figure 1). Contradicting the perception that these data “are based primarily on information from trained spotters and law enforcement officers” (Comrie, 2021), the Storm Events Database included very diverse sources, with a large portion from untrained public, automatic weather stations, amateur radio, and other media. The automatic weather observations of dust events themselves are known to cause inconsistency in reports and have been previously excluded from global dust trend analyses (Shao et al., 2013).

In summary, although the Storm Events Database contains useful information collected from many sources, for the same reason it cannot be considered a rigorous source for long-term trend analysis, nor for examining relationship between dust events and coccidioidomycosis. Note that the Storm Events Database has been increasingly applied to study the effects of dust weather on societal issues, such as violent crimes (Jones, 2022) and human health (Ruble et al., 2020), thus this issue of whether the Storm Events Data is appropriate for quantitative trend analysis needs to be critically discussed and understood more broadly.

#### 4. How Can We Quantify Population Exposure to Dust and/or *Coccidioides*?

Comrie (2021)'s binary measure of dustiness may not reliably represent population exposure to dust or *Coccidioides*. Comrie (2021) used “dust storms” in the Storm Events Database to mark each month as either dusty or non-dusty. Dust events, whether they rise to the level of a dust storm or not, vary vastly in size and duration. A dust event can be short-lived and highly localized, only affecting a small population. It can also be long-lasting and widespread, affecting millions of people. Furthermore, some dust storms are missing from the Storm Events Database. The total exposure of a population to dust particles is the sum of the individual exposures  $E_i$  of all persons in the population (revised from NRC, 1994):

$$E_{\text{Pop}} = \sum_{i=1}^M \sum_{j=1}^N C_{i,j} \Delta t_{i,j} \quad (1)$$

where  $M$  is the number of persons,  $N$  is the number of microenvironments (indoor, outdoor, etc.),  $C_{i,j}$  is the concentration of airborne dust, and  $\Delta t_{i,j}$  is the exposure time for a person in the microenvironment  $j$ . The binary indicator for dustiness used by Comrie (2021) implies that the magnitude of the population exposure is independent of the frequency, magnitude, duration, and spatial coverage of each dust event.

The linkage between dust and Valley fever infection depends not only on the ambient concentration of dust particles, but also the presence of *Coccidioides* spores in the dust, the viability of the spores, and the susceptibility of the exposed host. Therefore, the host exposure to viable fungi can be further expressed as:

$$E_{\text{Pop}} = \sum_{i=1}^M \sum_{j=1}^N C_{i,j} f_{i,j} V_{i,j} S_j \Delta t_{i,j} \quad (2)$$

where  $f_i$  is the fraction of *Coccidioides* in the dust,  $V_{i,j}$  is the viability of transported spores,  $S_j$  is the susceptibility to *Coccidioides* infection of person  $j$ . The geospatial distribution, transport, viability, and pathogenicity of *Coccidioides* spores remain largely unknown (Behzad et al., 2018), and, like other airborne particles, often complicated by wind patterns and precipitation (Zhang et al., 2018). Gade et al. (2020) proved high heterogeneity of the spatial and temporal distribution of the airborne *Coccidioides* arthroconidia during a dust storm in the metropolitan area of Phoenix, Arizona. It is, however, premature to claim that this study “found no consistent links connecting wind and dust conditions to increases in coccidioidomycosis” (Comrie, 2021). Gade et al. (2020) cautioned that their study was based on “a single time point,” did not examine “daily wind patterns as well as soil disturbing activities,” and “broader sampling over larger geographic areas and longer periods” is needed to “correlate human diseases with the presence in the environment.” Future work needs to address the uncertainties in these key factors, such as listed in Equation 2, so that process-level understanding of the mechanisms causing Valley fever infection can be achieved to inform risk analysis and policy making.

#### 5. How Can We Most Accurately Measure the Number of Valley Fever Cases?

Another important issue raised by Comrie (2021) is the artifacts in disease case reporting, which can affect the interpretation of the correlation between dust and coccidioidomycosis. Valley fever cases are misdiagnosed, underreported, and undergo changes in reporting practices (Benedict et al., 2019). For instance, Comrie (2021) cautioned that the finding of Tong et al. (2017), which reported a positive correlation between dust storm frequency and Valley fever incidence, may have been influenced by a major artifact in disease case reporting due to a 2009 change in laboratory case definition (ADHS, 2018). We appreciate this potential data report issue, which was not recorded or brought to our attention until after Tong et al. (2017) was published. We removed coccidioidomycosis case data from 2009 to 2011 and reexamined the correlation between dust frequency (number of dust records to that of total data records) and coccidioidomycosis case counts in Maricopa and Pima Counties,

AZ. The correlation ( $r$ ) became stronger after excluding the 2009–2011 data, with  $r$  increasing from 0.51 to 0.69 in Maricopa County and from 0.36 to 0.52 in Pima County. In both cases, the  $p$ -value remains smaller than 0.001. This suggests that while the data issue will affect the results to some extent, it does not change the major conclusion from the Tong et al. (2017) study. Comrie (2021) also cautioned that a time lag between dust storms and coccidioidomycosis cases was not considered in Tong et al. (2017), which examined yearly, not monthly, correlations. Due to the 1–3 weeks incubation period of coccidioidomycosis (Crum, 2022) and further lag between symptom onset and submission of a case report, the time lag between exposure and case reporting is estimated to be 1–1.5 months (Comrie, 2005; Tsang et al., 2010), which should not significantly affect variations on an annual scale. Nevertheless, the data reporting issue, considering its potential effect on interpreting scientific findings, needs to be explicitly included in the coccidioidomycosis case data set.

## 6. How Should We Communicate Haboob-Associated Valley Fever Risk?

Ultimately, we are concerned with the statement that “we should stop saying or implying things like ‘haboobs cause more Valley fever’” (Comrie, 2021). Currently, public health agencies advise residents to “Stay inside and keep windows and doors closed when it’s windy outside and the air is dusty, especially during dust storms” (California Department of Public Health or CDPH, 2022). It has been recognized that there are other sources of Valley fever-causing dust and soil exposures beyond dust weather, such as earthquakes (Jibson, 2002; Lauer et al., 2020), construction (Cummings et al., 2010), excavation (Werner et al., 1972) and even yard work (CDPH, 2022). To our knowledge, no prior studies claim that *all*, *most*, or *only* dust events result in increases in Valley fever. There is clearly a complicated relationship among soil, airborne dust, and Valley fever since not all dust events are created equal. Some may carry more contaminated soil and expose a larger population than others, depending on the weather conditions and the original location from which soil particles are emitted. The emitted dust, once transported to downwind areas, can be resuspended by turbulent winds, vehicle tires and tailwinds, human/animal activities, or other forces. There is abundant evidence, however, that dust is a viable driver to transport *Coccidioides*, and hence poses risk for coccidioidomycosis infection (Flynn et al., 1979; Pappagianis, 1980; Williams et al., 1979), as acknowledged by Comrie (2021). Therefore, to stop saying “haboobs cause more Valley fever” could imply to the public that there is *no link*, rather than *no consistent link* between dust storms and coccidioidomycosis. Such a statement is not only misleading, but also may result in potentially substantial harm to society by suggesting the false pretense that dust storms are not a cause for *Coccidioides* exposure.

## 7. Moving Forward

From our perspective and reflecting on the aforementioned issues raised by Comrie (2021), we have five suggestions for improving research between dust events and Valley fever. First, the weather and climate communities should agree upon consistent terms to define dust events and dust storms, and these terms need to be clearly communicated to the public and other research communities that might use such data (public health and economics, etc.). This will create a consistent metric to evaluate studies between dust and societal impacts. Second, the weather and climate community should create a quality-controlled and assured data set of dust events and storms. The strengths and limitations of different datasets need to be explicitly communicated across different disciplines and communities, so that the uncertainties of the data sources can be accounted for in future studies. Third, future research should focus on the mechanisms of airborne transport of *Coccidioides* and creating mechanistic models to evaluate the risk of contracting Valley fever during wind or dust events. There is also a need to acquire new datasets over a long time and large geographical range to dive into the physical processes of the emission, dispersion, and population exposure of airborne *Coccidioides* spores as well as their viability and infectivity at receptor locations. Fourth, future research should account for changes in reporting practices in Valley fever cases and incorporate potential lagged relationships between environmental drivers and changes in case counts. Lastly, we should be careful to not dismiss windblown dust as a potential risk for Valley fever. Reliable environmental and health datasets will help us to better understand the mechanisms of population exposure to airborne dust and *Coccidioides* spores and to communicate the risk associated with dust exposure such as from wind storms and from occupational/recreational activities.

## Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

## Data Availability Statement

The Storm Events Database is accessible from National Oceanic and Atmospheric Administration National Center of Environmental Information: <https://www.ncei.noaa.gov/pub/data/swdi/stormevents/csvfiles/>. The Coccidioidomycosis infection rate data are provided from: <https://www.maricopa.gov/5813/Valley-Fever>. The dust data used in this study are available [http://air.csiss.gmu.edu/aq/papers/GH\\_ValleyFever2022/](http://air.csiss.gmu.edu/aq/papers/GH_ValleyFever2022/).

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