Dust Storms, Valley Fever, and Public Awareness

Daniel Tong[1], Morgan Elizabeth Gorris[2], Thomas E. Gill[3], Karin Ardon-Dryer[4], Julian X.L. Wang[1], and Ling Ren[1]

[1]George Mason University
[2]Los Alamos National Laboratory
[3]University of Texas at El Paso
[4]Texas Tech University

November 21, 2022

Abstract

Inspired by Comrie (2021), we discuss a few issues related to dust storms and Coccidioidomycosis (Valley fever). There is inconsistency in the term "dust storm" as used by science communities, and the dust data from NOAA 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, duration, and spatial coverage of dust events. Given abundant evidence that dust storms are a viable driver to transport *Coccidioides*, it is in best public interest to advocate that dust storms may put people at risk for contracting Valley fever.

Hosted file

essoar.10511217.1.docx available at https://authorea.com/users/527222/articles/596581-dust-storms-valley-fever-and-public-awareness

Dust Storms, Valley Fever, and Public Awareness

Daniel Tong[1], Morgan Gorris[2], Thomas E. Gill[3], Karin Ardon-Dryer[4], Julian Wang[1], Ling Ren[1]

1. Department of Atmospheric, Oceanic and Earth Sciences / Center for Spatial Information Science and Systems, George Mason University, Fairfax, VA 22030 USA
2. Information Systems and Modeling & Center for Nonlinear Studies, Los Alamos National Laboratory, Los Alamos, NM 87545 USA
3. Department of Earth, Environmental and Resource Sciences, The University of Texas at El Paso, El Paso, TX 79968 USA
4. Department of Geosciences, Texas Tech University, Lubbock TX, 79409 USA

Correspondence Autor: qtong@gmu.edu (D. Tong)

For Submission to GeoHealth

Abstract:

Inspired by Comrie (2021), we discuss a few issues related to dust storms and Coccidioidomycosis (Valley fever). There is inconsistency in the term "dust storm" as used by science communities, and the dust data from NOAA 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, duration, and spatial coverage of dust events. Given abundant evidence that dust storms are a viable driver to transport *Coccidioides*, it is in best public interest to advocate that dust storms may put people at risk for contracting Valley fever.

Plain Language Abstract:

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 discussed here a few issues on the relationship between dust storms and Valley fever raised by a new study (Comrie, 2021): 1) what is a dust storm? 2) Is it proper to use the Storm Events Database for long-term dust trend analysis? 3) how to represent population exposure to dust and fungi and 4) how to communicate the risk associated with dust storms to the public?

Main text

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, 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 United States (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 coccidioidomycosis, 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.

What is a dust storm?

We note there is inconsistency in the definition and use of the term "dust storm" within different scientific communities (e.g., Lei et al., 2016; Comrie, 2021) 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 *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 (NOAA) 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 each of the 70 dust events used in Comrie (2021) (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, in preparation) 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 hence more appropriate to call these dust records "dust events", instead of "dust storms".

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 and Black, 2008; Ashley and Gilson, 2009; Black and Ashley, 2010; Black and 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 and Black, 2008; Black and 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 and Gilson, 2009; Black and 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, particulate matter 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 2006-2018, 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 (e.g., 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 (Rublee 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.

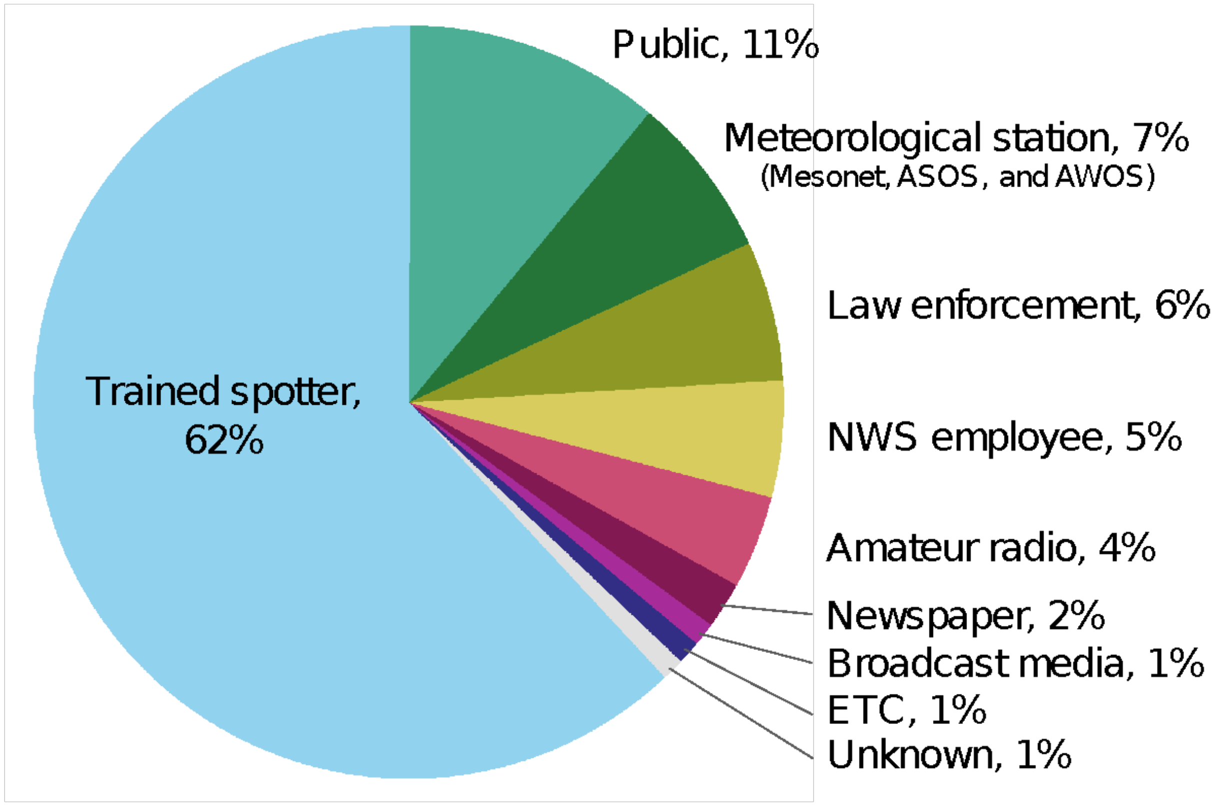

Figure 1. Data sources of reported dust events in the Storm Events Database (NCEI, 2022) from 2006-2018 that were used in Comrie (2021) work. ASOS is Automated Surface Observing Systems, AWOS is Automated Weather Observing System, and ETC and Unknown are unidentified reporting sources.

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 (NRC, 1994):

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

Where N is the number of persons, M is the number of microenvironments (indoor, outdoor, etc.), C_{ij} is the concentration of dust particles, and t_{ij} 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 correlation between dust events and Valley fever cases depends on the presence of infectious *Coccidioides* spores in the ambient air. The geospatial distributions, transport, viability, and pathogenic potential of the causative airborne *Coccidioides* spores remain largely unknown (Behzad et al. 2018), and, like other airborne particles, often complicated by wind patterns and precipitation (e.g., Zhang et al., 2018). Gade and co-workers (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”.

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 2009-2011 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. 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 week 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 et al., 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 dataset.

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 coccidioidomycosis. There is clearly a complicated relationship among soil, airborne dust, and Valley fever since not all dust plumes are created equal. Some may carry more contaminated soil and expose larger populations than others, depending on the original location from which soil particles are emitted. Airborne dust not only has some direct effect on *Coccidioides* transport, but also plays an indirect role in that transported dust can be resuspended by turbulent winds, vehicle tires and tailwinds, human/animal activity, 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; Williams et al., 1979; Pappagianis, 1980), 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.

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 on 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, for example). 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 dataset 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.

Acknowledgment

This work is partially supported by NASA Health and Air Quality Program. M. E. Gorris gratefully acknowledges support from the Los Alamos National Laboratory Laboratory Directed Research and Development program. The authors thank Alan Black for insightful discussion.

References:

ADHS–Arizona Department of Health Services. (2018). Valley Fever 2017 annual report. Retrieved from https://www.azdhs.gov/preparedness/epidemiology-disease-control/valley-fever/in

Ashley, W. S., & Black, A. W. (2008). Fatalities associated with nonconvective high-wind events in the United States. *Journal of Applied Meteorology and Climatology*, 47(2), 717-725.

Ashley, W. S., & Gilson, C. W. (2009). A reassessment of US lightning mortality. *Bulletin of the American Meteorological Society*, 90(10), 1501-1518.

Benedict, K., McCotter, O. Z., Brady, S., Komatsu, K., Cooksey, G. L. S., Nguyen, A., ... & Jackson, B. R. (2019). Surveillance for Coccidioidomycosis—United States, 2011–2017. MMWR Surveillance Summaries, 68(7), 1.

Black, A.W., & Ashley, W.S. (2010). Nontornadic convective wind fatalities in the United States. *Natural Hazards*, 54(2), 355-366.

Black, A. W., & Mote, T. L. (2015). Characteristics of winter-precipitation-related transportation fatalities in the United States. *Weather, Climate, and Society*, 7(2), 133-145.

Behzad, H., K. Mineta, and T. Gojobori. 2018. Global Ramifications of Dust and Sandstorm Microbiota B. Martin [ed.]. *Genome Biology and Evolution,* 10, 1970–1987. doi:10.1093/gbe/evy134.

California Department of Public Health (CDPH) (2022). Valley Fever - Prevention Tips. Available online: https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/ValleyFeverPrevention.as (accessed on April 9, 2022)

Comrie, A.C. (2005). Climate factors influencing coccidioidomycosis seasonality and outbreaks. *Environmental Health Perspectives*, 113(6), 688–692. https://doi.org/10.1289/ehp.7786

Comrie, A.C. (2021). No consistent link between dust storms and Valley fever (coccidioidomycosis). *GeoHealth*, 5(12), e2021GH000504. https://doi.org/10.1029/2021GH000504.

Crum, N. F. (2022). Coccidioidomycosis: A contemporary review. *Infectious Diseases and Therapy,* 11, 713-742. https://doi.org/10.1007/s40121-022-00606-y

Cummings, K. C., McDowell, A., Wheeler, C., McNary, J., Das, R., Vugia, D. J., & Mohle-Boetani, J. C. (2010). Point-source outbreak of coccidioidomycosis in construction workers. *Epidemiology & Infection*, 138(4), 507-511.

Flynn, N. M., Hoeprich, P. D., Kawachi, M. M., Lee, K. K., Lawrence, R. M., Goldstein, E., ... & Wong, G. A. (1979). An unusual outbreak of windborne coccidioidomycosis. *New England Journal of Medicine*, 301(7), 358-361.

Gade, L., O. Z. McCotter, J. R. Bowers, and others. 2020. The detection of Coccidioides from ambient air in Phoenix, Arizona: Evidence of uneven distribution and seasonality. *Medical Mycology,* 58, 552–559. doi:10.1093/mmy/myz093.

Jibson, R. W. (2002). A public health issue related to collateral seismic hazards: the valley fever outbreak triggered by the 1994 Northridge, California earthquake. *Surveys in Geophysics*, 23(6), 511-528.

Lauer, A., Lopez, J., Abarca, S., & Bains, J. (2020). Earthquake-ridden area in USA contains Coccidioides, the Valley Fever Pathogen. *Ecohealth*, 17(2), 248-254.

Lei, H., Wang, J.X., Tong, D.Q., & Lee, P. (2016). Merged dust climatology in Phoenix, Arizona based on satellite and station data. *Climate Dynamics*, 47(9), 2785-2799.

Miller, P.W., Black, A.W., Williams, C.A., & Knox, J.A. (2016). Quantitative assessment of human wind speed overestimation. *Journal of Applied Meteorology and Climatology*, 55(4), 1009-1020.

National Research Council (NRC), (1994). Science and judgment in risk assessment. Appendix C: Calculation and Modeling of Exposure. Washington (DC): National Academies Press (US); 1994. ISBN-10: 0-309-04894-X.

National Weather Service, (2022). Watch/Warning/Advisory definitions. https://www.weather.gov/otx/Watch_Warning_Advisory_Definitions#Blowing%20Dust%20Advisory

National Weather Service, (2021). National Weather Service Instruction 10-1605, Performance and Evaluation, NWSPD 10-16, Storm Data Preparation. https://www.nws.noaa.gov/directives/sym/pd01016005curr.pdf

NCEI, (2022). Storm Events Database, available online: https://www.ncdc.noaa.gov/stormevents/ (accessed on February 23, 2022).

Pappagianis, D. (1980). Epidemiology of coccidioidomycosis. In: Stevens, D.A. (Ed.) Coccidioidomycosis. Current Topics in Infectious Disease. Springer, Boston, MA , 63-85.

Rublee, C. S., Sorensen, C. J., Lemery, J., Wade, T. J., Sams, E. A., Hilborn, E. D., & Crooks, J. L. (2020). Associations between dust storms and intensive care unit admissions in the United States, 2000–2015. *GeoHealth*, *4*(8), e2020GH000260.

Shao, Y., Klose, M., & Wyrwoll, K.H. (2013). Recent global dust trend and connections to climate forcing. *Journal of Geophysical Research: Atmospheres*, 118(19), 11107 - 11118.

Tong, D.Q., Wang, J.X., Gill, T.E., Lei, H., & Wang, B. (2017). Intensified dust storm activity and Valley fever infection in the southwestern United States. *Geophysical Research Letters*, 44(9), 4304-4312.

Trapp, R.J., Wheatley, D.M., Atkins, N.T., Przybylinski, R.W. & Wolf, R. (2006). Buyer beware: Some words of caution on the use of severe wind reports in postevent assessment and research. *Weather and Forecasting*, 21(3), 408-415.

Tsang, C.A., Anderson, S.M., Imholte, S.B., Erhart, L.M., Chen, S., Park, B.J, ... & Sunenshine, R.H. (2010). Enhanced surveillance of coccidioidomycosis, Arizona, USA, 2007–2008. *Emerging Infectious Diseases*, 16(11), 1738–1744. https://doi.org/10.3201/eid1611.100475 \

Weather Underground (2022). Phoenix, AZ Weather History. Available online at: https://www.wunderground.com/history/daily/us/az/phoenix/KPHX/date/2015-8-25 (accessed on April 10, 2022).

Werner, S. B., Pappagianis, D., Heindl, I., & Mickel, A. (1972). An epidemic of coccidioidomycosis among archeology students in northern California. *New England Journal of Medicine,* 286(10), 507-512.

Williams, P. L., Sable, D. L., Mendez, P., & Smyth, L. T. (1979). Symptomatic Coccidioidomycosis following a Severe Natural Dust Storm: An Outbreak at the Naval Air Station, Lemoore, Calif. *Chest,* 76(5), 566-570.

WMO (World Meteorological Organization), 2019. WMO Technical Regulations Annex II Manual on Codes International Codes. I.1.

Zhang, B., Jiao, L., Xu, G., Zhao, S., Tang, X., Zhou, Y., & Gong, C. (2018). Influences of wind and precipitation on different-sized particulate matter concentrations ($PM_{2.5}$, PM_{10}, $PM_{2.5-10}$). *Meteorology and Atmospheric Physics*, 130(3), 383-392.