Are Opportunities to Apply Airborne Dust Research Being Missed?

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\textbf{Southern New Mexico/Western U.S. Dust Symposium} \\
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\textbf{What}: Over 3-days, 4-hours each day, 187 international registrants and 50 speakers representing research, science policy, and public services for health, safety and the environment considered the question, “Are opportunities to apply airborne dust research being missed?” \\
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\textbf{When}: 25-27 October 2021 \\
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\textbf{Where}: A virtual global Zoom room from George Mason University \\
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\textbf{Prologue}: In 2016, the US Environmental Protection Agency (EPA) set requirements for state mitigation plans in areas with “recurring, similar, and exceptional” air pollution events that exceed health-based air quality standards, e.g., three similar windblown dust events in a three-year period. New Mexico’s Luna and Dona Ana counties fall into that category due to high levels of airborne particulate matter (PM\textsubscript{10}). These two counties in EPA Region 6 (EPA 2022) are subject to the EPA mitigation plan requirement (NMED 2017).

As part of New Mexico’s dust mitigation plan, the New Mexico Environment Department (NMED) has convened a semiannual Symposium since 2017 to assemble local and regional stakeholders to discuss air quality conditions and effectiveness of dust mitigation policies.

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Regions well beyond Dona Ana and Luna Counties are affected during these recurring, exceptional events, including much of Arizona, New Mexico, southwest Texas, and northern Mexico (Kelley and Ardon-Dryer 2021; Yin and Sprigg 2010) and throughout the western U.S.A. While outdoor particle pollution appears on the decline, areas of the American west (EPA Regions 6, 7, 8 and 9) remain higher than the National average (EPA 2022).

Daniel Tong, Principal Investigator for NASA-sponsored research on satellite-aided regional dust forecasting, reached out to Armando Paz, convener of the NMED symposia, to suggest an expanded symposium agenda in 2021 to accommodate the growing body of international, dust-relevant research—research of potential lifesaving, life-enhancing implications for the U.S. Southwest. The global research community has, is, and will continue to uncover knowledge needed by NMED and other regulatory agencies in collaboration with stakeholders to mitigate the very risks faced in New Mexico’s southern counties. Adapting that knowledge from research into public benefit—translated for public use and followed by public actions preconditioned in public trust for science and the authority that delivers it—is another matter.

The joint Southern New Mexico/Western U.S. Dust Symposium was announced with calls for summary presentations of ongoing work through a flyer that asked, “Are opportunities to apply dust research being missed?” Federal, state, and local agencies create policies for clean and healthy air that benefit from national and international research. However, the results of research are not easily translated into policy or action.

The October 25-27, 2021 workshop, with 187 registrants and 50 speakers, brought a sample of contemporary research, science policy, and public health, environment, and transportation services in the context of windblown dust into the same “virtual” room. Principal topics included the state-of-science and status of agency missions in research and dust risk forecasting and mitigation. The focus was Southern New Mexico, the U.S. southwest and North America in global context. Discussion groups were drawn from agenda sessions.
The workshop revealed potentially important elements of research, unrecognized and missing from public service and public eye. The following summarizes the research, points of public service, and take-away lessons.

Regional concerns anchoring the workshop include windblown dust across heavily traveled Interstate 10 between Phoenix, Arizona and El Paso, Texas, a focus for study and accident risk mitigation. Tallies of dust related crash victims are incomplete across the Nation, yet substantial (Tong, et al. 2021), e.g., 17 dead, 151 injured, on California’s Interstate Highway, I-5, on 29 November 1991 (Pauley et al. 1996); 8 dead on Utah’s I-15, on 25 July 2021 (Dougherty 2021); Arizona’s 150 dead and 1300 injured over a 50-year period (Lader et al. 2016); and, where I-10 runs through New Mexico’s Lordsburg Playa, more than 21 fatalities between 2012 and 2020 (Botkin and Hutchison 2020).

But repercussions are national: Blincoe et al. (2010) estimate economic costs of one U.S highway crash fatality is $1.4 million and $1 million for a critically injured survivor, whereas EPA puts $10 million for one life lost (Fann et al. 2018). Over 75 percent of costs are borne by society, e.g., through higher insurance premiums, taxes, and transport delays—not necessarily by the people directly involved in the accidents.

Major investments have been made to detect and then warn drivers of visibility hazards. In particular, highway modifications and signage at the high risk, accident hotspots between Phoenix and Tucson, Arizona, and immediately east of the Arizona-New Mexico border through the Lordsburg Playa. But blinding soil dust emissions across the nation’s roadways may come from small (Figure 1) and large arid lands. Causal factors of drought and ecology and land use changes stretch across broad regions, including the Chihuahuan Desert, shared by the U.S. and Mexico or of the American Dust Bowl of the 1930s, a reminder of the consequences of insufficient research and imperfect environmental policy (Figure 2).
FIGURE 1: Local sources of windblown soil dust are a challenge for roadway accident risk reduction. Photo courtesy J. Li (Li et al. 2018)
Figure 2: A December 15, 2021 dust storm over the birthplace of the 1930s Dust Bowl observed by the VIIRS sensor aboard the JPSS1 satellite (Source: NOAA AerosolWatch).

Studies of western arid land aeolian dusts apply also to small-area consequential emissions from sources such as cattle feedlots, agriculture, and off-road recreation sites. Emerging technology to detect, monitor, and control sources, including deep learning remote sensing applications and soil stabilization methods, offer opportunity to predict and prevent many high-risk situations. The overall research agenda is broad.

Ongoing projects track dust emissions from source to sink. The satellite-aided dust forecasting project, for example, uses satellite observations of black-sky albedo to identify dust sources. Land-atmosphere dust model developments allow past and future particulate air quality to be
explored, whether to warn, in 1-km detail of approaching risks a day in advance, or regional estimation of land use and climate change that alter pervasive dust emission conditions. “DustSquared” represents five different institutions in study of mineral dust emission, transport, and deposition in snow, lakes, and streams of the Intermountain West, that affect timing and magnitude of snowmelt and consequences on water supply (https://criticalzone.org/dust2/).

Seminar presentations show: windblown soil and smoke from wildfires, perhaps linked to climate variability, affect ozone and other air pollution; mineral dusts that melt in, and corrupt, new, high-efficiency, high-temperature aircraft jet engines; and mineral dust deposits and abrasions that damage and reduce efficiency of high-tech solar energy development.

Public health implications of windblown soil-and-smoke are a concern across the American West, where arid land wind erosion, mining and wildfires are well known and expected. With water and land use inextricably linked, recent and apparently continuing drought drive away agriculture and return land to its unirrigated, barren aridity; forests become fuel, burn, and release smoke and ash particulates borne by wind from coast to coast. Valley fever (coccidioidomycosis), endemic in the arid and semi-arid west, is a debilitating and sometimes fatal disease caused if its airborne soil-dwelling fungus, *Coccidioides*, is inhaled: 200 deaths/year across the United States (CDC 2021) between 1998–2019 with an underestimated 18,407 cases in 2019 (Figure 3).

**Number of reported coccidioidomycosis cases, 1998 - 2019**

- Arizona
- California
- All other states where coccidioidomycosis is reportable
Independent dust sampling networks trap airborne soil particles for laboratory analysis of *Coccidioides* DNA and other problematic soil content—e.g., microplastics, cyanobacteria, bacteria, mycotoxins, heavy metals, and various radioisotopes. These networks, established for particular and often temporary needs, are at risk from changes in sponsor budgets and mission priorities (Ren et al., 2020).

**What lies ahead?**
Research shows a backlog of promising assets in queue, ready for application, yet missing in public service. Potential users of such latent assets—state government departments responsible for public health, safety, and environmental information—are seldom staffed to monitor research beyond their mainline mission responsibility, much less to adapt, operate, troubleshoot, or monitor performance of products derived, say, from atmospheric science. The sample of research discussed during the three days raised several key points:

**Detected, monitored, and mapped active, dormant, and otherwise potential sources of windblown dust:** As land-atmosphere models have improved, demands for details of dust sources have grown, e.g., recurring source area boundaries and the factors (moisture, vegetation) that trigger or control emissions. Satellite-based remote sensing has filled much of the need. Today it is routine, most often automated, to map active sources into forecast and simulation dust models. Principal sources are now known over much of the Earth (Nickovic et al. 2012; Vukovic 2019; de Souza Oliveira Filho and Pereira 2021). One direction of current research aims to discriminate mineral composition within these mapped sources. Another direction is to control emissions, a contradiction in general belief that arid land dust emissions are a given, to be tolerated and impossible to mitigate.

**1-3-day forecasts of synoptic scale weather-driven airborne particulate matter plume trajectory, downwind concentration, and deposition:** Several dust prediction methodologies, expressed in different model constructions, some combined, have shown promise over the
Western U.S. for more than a decade (e.g., Morain et al. 2010; Vukovic et al. 2014; Sprigg et al. 2014; Sprigg 2016; Tong et al. 2017). Arizona’s Pima County Department of Environmental Quality posts PM$_{2.5}$ daily model forecasts for public education and outreach (https://webcms.pima.gov/cms/One.aspx?portalId=169&pageId=689815 accessed 01/03/2022), provided by Tong’s George Mason University research group. The World Meteorological Organization’s (WMO) North Africa-Middle East-Europe Center for the Sand & Dust Storm Warning Advisory & Assessment System (SDS-WAS) applies several such models (Huneeus et al. 2015) in operational dust forecasts over their region. The WMO SDS-WAS Pan-America Center monitors dust emissions over the Sahara Desert and forecasts the dust plumes that at times cross the Atlantic Ocean, pass through Florida, penetrate the Caribbean region, enter the Gulf of Mexico and circle back eastward over Texas, scattering particles from the Sahara along the way.

However, before public applications are approved, forecast models must pass measures of credibility. To speed transfer of dust forecast models into service, high priority is prescribed for model runs over sufficient time to assess accuracy, precision, false positives/negatives, and other performance measures.

Small scale, very local events (Figure 1) appear beyond forecast capability in the foreseeable future. Sources of the blinding dust, however, can be identified and monitored. Local dust control may be possible. Potential risks may be posted. But operation of a tractor or off-road recreational vehicle in risk-prone areas that could trigger clouds of blinding dust are better addressed today through public education.

**Air quality monitoring networks:** Land/Atmosphere models express current understanding of nature and the processes of windblown particles. Measurement and monitoring of windblown particles offer reality checks of models, truth against theory—how much is known and understood, or not. Since networks are established for many different reasons, and the original reasons for each may grow or diminish over time, priority for a network is in frequent peril. This is an endemic problem for both basic research and for public services: whether to continue a line of research or to make a life-changing public action depends on expected forecast, hindcast, or
outlook credulity. Two prominent examples of at-risk dust monitoring activities were raised: the unique 50+ years of monitoring Saharan dust at Ragged Point on the Caribbean Island of Barbados, a long-term record essential to understand climate and health implications of mineral dusts in general and African dust transport to the Western Hemisphere in particular (Prospero et al. 2021), and the IMPROVE (Interagency Monitoring of Protected Visual Environments) network (Hand et al. 2019). IMPROVE data have become widely applied to understand health implications of outdoor dust-laden air, well beyond its original intended use: to understand degradation of America’s national park vistas. A coordinated outdoor particulate monitoring strategy should preserve essential observations while lowering costs and increasing benefits.

Outlooks of regional particulate air quality in the months and decades ahead:
Commissioned environmental outlooks that apply land/atmosphere weather models with land/climate scenarios can inform lawmakers and public services of air quality consequences—should new rules for land use or projected climate and environmental changes take effect. The same models used to forecast dust (and what’s in it) may yield future scenarios in which to assess new risks and consequences, such as expansion of the endemic range of Valley fever due to climate change (Gorris et al. 2021)

A Principal Takeaway: Efficient and timely transfer of technology is more likely when experts in one mission understand the aims, resources, and exigencies of others’ mission or purpose. An alliance of research, public service and public policy can assemble expertise required to identify priority needs and remove obstacles to progress. Done well, an alliance serves as consensus builder and advocate.

The points above outline an early agenda for a dust-focused alliance: mapping and monitoring of dust sources; skill scoring for research-operational, synoptic dust forecast models; strategic collation of dust monitoring; priority concerns in climate and land use change; and delivery of advanced understanding for public policy and action.

Policy makers, service providers and researchers agree on the goal: lower public risk associated with windblown dust. But too often, service providers are trying to pound a square peg into a
round hole when handed the next research breakthrough. It just doesn’t fit the constraints of service operations. An alliance of services, research, and enabling policies can identify promising technology early and begin its likely many little compromises—on economy, on ease of operation and on information most needed—prior to the anticipated in-situ beta tests of a singular service. The round hole will get a round peg.

Familiarity with research in progress allows smart advanced strategic planning. Service providers will note the research product queue, advocate priority needs, and anticipate new assets for risk reduction. Such will afford time to assess each new asset for its potential operational value and best practices for delivering public information, and, accordingly, time to adjust ongoing operations.

A new acronym was bound to emerge from a gathering such as the one assembled over 25-27 October 2021. Enthusiasm to institutionalize the Symposium/workshop likely gave rise to the proposed Dust Alliance for North America (DANA). This non-profit organization (http://dustalliance.org) is expected to share progress, plans, and data, to overcome technology transfer stumbling blocks, to form consensus, and to advocate the sciences and services for airborne dust risk reduction.

**Conclusions:** Organizers believe the interest of over 180 registrants in the three-day symposium/workshop was due to the agenda of research updates, identification of gaps and bridges between service and science—and anchored by the real-world trials of New Mexico to meet air quality health and safety standards. New Mexico’s air quality issues are similar to those extant, where, as in New Mexico and the American West, the tools to mitigate them may sometimes be available, but invisible, to public services. While institutional mechanisms may differ, how U.S. federal, state and county governments bring research into public service is of great interest, possibly applicable around the world.

The substantial meeting attendance and diversity of stakeholders (Figure 4) is a guide when calling researchers, policy makers, and public services together to focus on common goals and to
build strategic consensus as to how advances in research may transfer more efficiently into public service.

![Stakeholders represented by Workshop registrants](image)

**FIGURE 4: Stakeholders represented by Workshop registrants**

**Epilogue:** The dust alliance urged by Symposium participants is underway. DANA (http://dustalliance.org) held its first seminar in a series on February 11, 2022 with over 100 registrants.

**Data Availability Statement:**

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