Using Remote Sensing to Assess Uranium Dust Exposure From Abandoned Uranium Mines on the Navajo Nation

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INTRODUCTION

Background:
- Native American and Alaskan Native lands contain the majority (96%) of all uranium deposits in the United States (U.S. DOE, 2021).
- The Navajo Nation contains 523 documented abandoned uranium mines (AUMs) within the reservation (U.S. EPA, 2023)
- 21 AUMs reside in the central region including Chinle, Black Mesa, Chilchinbito, Rough Rock, Rough Roint, Blue Gap, & Cottonwood (U.S. EPA, 2023).

Problem/Concern:
- Since 1980s the mines were abandoned and toxic metals left exposed (Brugge, D. & Goble, R., 2002).
- Semi-arid conditions((Tome, M. & Möller, G. 2025) and winds could potentially lead to higher threats of uranium-contaminated dust becoming airborne.
- Inhalation of PM10(inhalable dust) showed substantial signs of elevated risk for heart and lung damage.(Katherine E Zychowski. *et al* 2018)

Research Question:
Does wind direction and speed influence aerosol optical depth (AOD) in communities near abandoned uranium mines in the central region of the Navajo Nation?

Hypothesis:
Northeast winds will show the highest AOD, and wind speed will show a positive correlation with AOD. This could indicate a potential wind-driven transport of contaminated dust.

METHODS

Study Area:
Central Region Navajo Nation, Arizona
Monitored stations:
- Chinle, Black Mesa, Chilchinbito, Rough Rock, Rough Point, Blue Gap, & Cottonwood
- Collection Years: 2019-2023

Data Sources:
- MODIS MCD19A2 (470nm) = AOD collection
- ERA5-Land (10m) = Wind speed & direction

Analysis:
- Monthly averages calculated per station
- Wind directions (N, NE, E, SE, S, SW, W, NW)
- Polar Plot : Mean AOD by wind direction per each station.
- Scatter Plot: AOD vs wind speed per each wind station.

Statistical Method:
- Linear regression model:
  - $AOD = \beta_0 + \beta_1 \times (\text{wind speed}) + \varepsilon$
    - β_0 = no change
    - β_1 = slope change of 1 meter per second
    - ε = margin of error

RESULTS

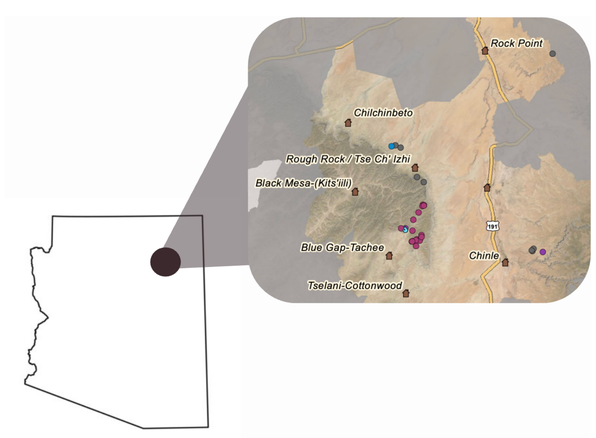

Figure 1: Map of Arizona with an expansion of the area of study with the seven communities (monitored stations), and the pink dots representing the abandoned uranium mines (AUMs).

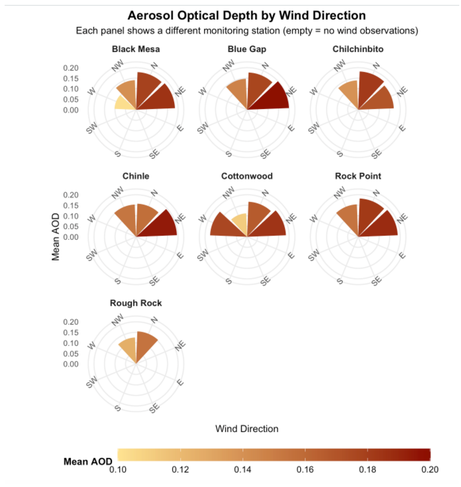

Figure 2: Mean AOD by wind directions for each monitoring station (2019-2023). Yellow-orange-red gradient shows increasing AOD (0.10->0.20). NE winds show highest AOD at all stations.

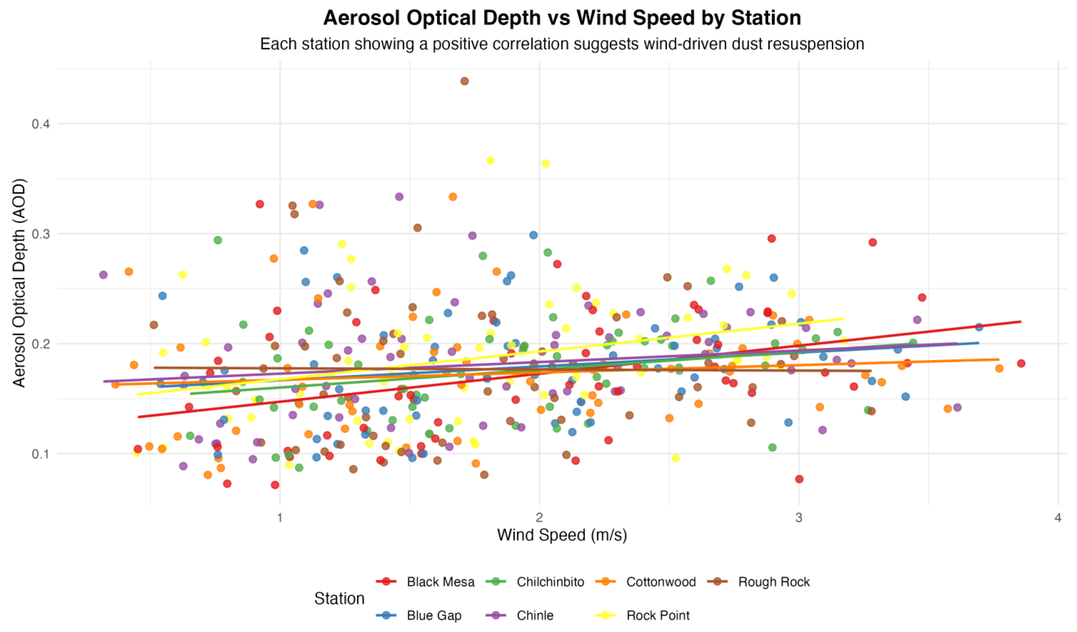

Figure 3: Mean AOD vs wind speed for each monitoring station(2019-2023), colored by each station. The positive slope of the regression line at each monitoring site confirms wind-driven dust resuspension.

DISCUSSION

Hypothesis Partially Supported:
The hypothesis that northeast winds show the highest AOD and wind speed correlates positively with AOD was supported. However, we cannot confirm the aerosols originated from the AUMs.

Key Findings:
- NE winds trajectory showed the highest mean AOD (0.189) at all seven monitoring stations, compared to W winds which showed the lowest mean AOD (0.125).
- Linear regression confirmed a positive correlation between wind speed and AOD, but the this relationship was statistically significant ($p < 0.05$) at only two stations: Black Mesa and Rock Point.

FUTURE RESEARCH

Limitations:
- AOD measures total column aerosols and cannot distinguish between dust sources or specific metals.

Next steps:
Future work includes:
- Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) modeling
  - Integrate forward and backward trajectories to confirm AUM source contributions to the communities.
  - Identify specific pathways and settling zones.
- Risk Indexing for monitoring stations
  - Index stations from high to low based on:
    - Proximity to AUMs
    - Wind pathways

CITATIONS

Brugge, D., & Goble, R. (2002). The history of uranium mining and the Navajo people. *American journal of public health, 92*(9), 1410-1419. https://ajph.aphapublications.org/doi/full/10.2105/AJPH.92.9.1410

Zychowski, K. E., Kodali, V., Harmon, M., Tyler, C. R., Sanchez, B., Ordonez Suarez, Y., ... & Campen, M. J. (2018). Respirable uranyl-vanadate-containing particulate matter derived from a legacy uranium mine site exhibits potentiated cardiopulmonary toxicity. *Toxicological Sciences, 164*(1), 101-114. https://doi.org/10.1093/toxsci/kfy064

U.S. Environmental Protection Agency. (2020, December 17). *Central AUM regional factsheet.* Retrieved from https://www.epa.gov/sites/default/files/2021-01/documents/central_aum_regional_factsheet-2020-12-17.pdf

U.S. Department of Energy, Office of Legacy Management. (2021, December 15). *DOE Office of Legacy Management launches campaign to address abandoned uranium mines on tribal lands.* Retrieved from https://www.energy.gov/lm/articles/doe-office-legacy-management-launches-campaign-address-abandoned-uranium-mines-tribal

Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS). https://cds.climate.copernicus.eu/datasets/reanalysis-era5-single-levels?tab=overview. Date Accessed: 2026-04-15

Lyapustin, A., & Wang, Y. (2022). *MODIS/Terra+Aqua Land Aerosol Optical Depth Daily L2G Global 1km SIN Grid V061* [Data set]. NASA Land Processes Distributed Active Archive Center. https://doi.org/10.5067/MODIS/MCD19A2.06. Date Accessed: 2026-04-15