Exploring the value of future geostationary satellite-based atmospheric composition data for improving health and air pollution injustice in the US

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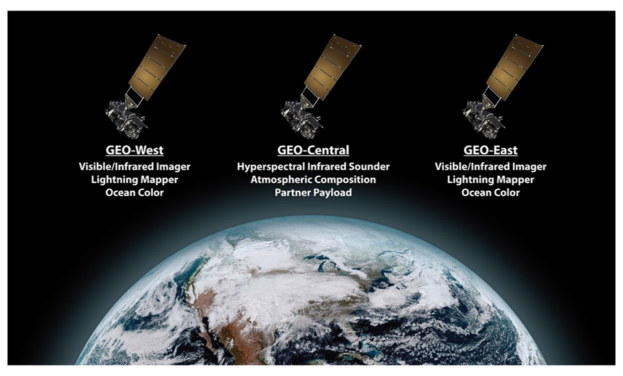
1. Motivation and Background

NOAA is currently planning its next generation of geostationary satellites, GeoXO.

- The geostationary extended observations (GeoXO) is intended to be a continuation and expansion of the GOES-R series.
- The mission is currently in the planning phase and is expected to become operational in the 2030s.
- GeoXO will have hourly atmospheric composition measurements of trace gases and particles.



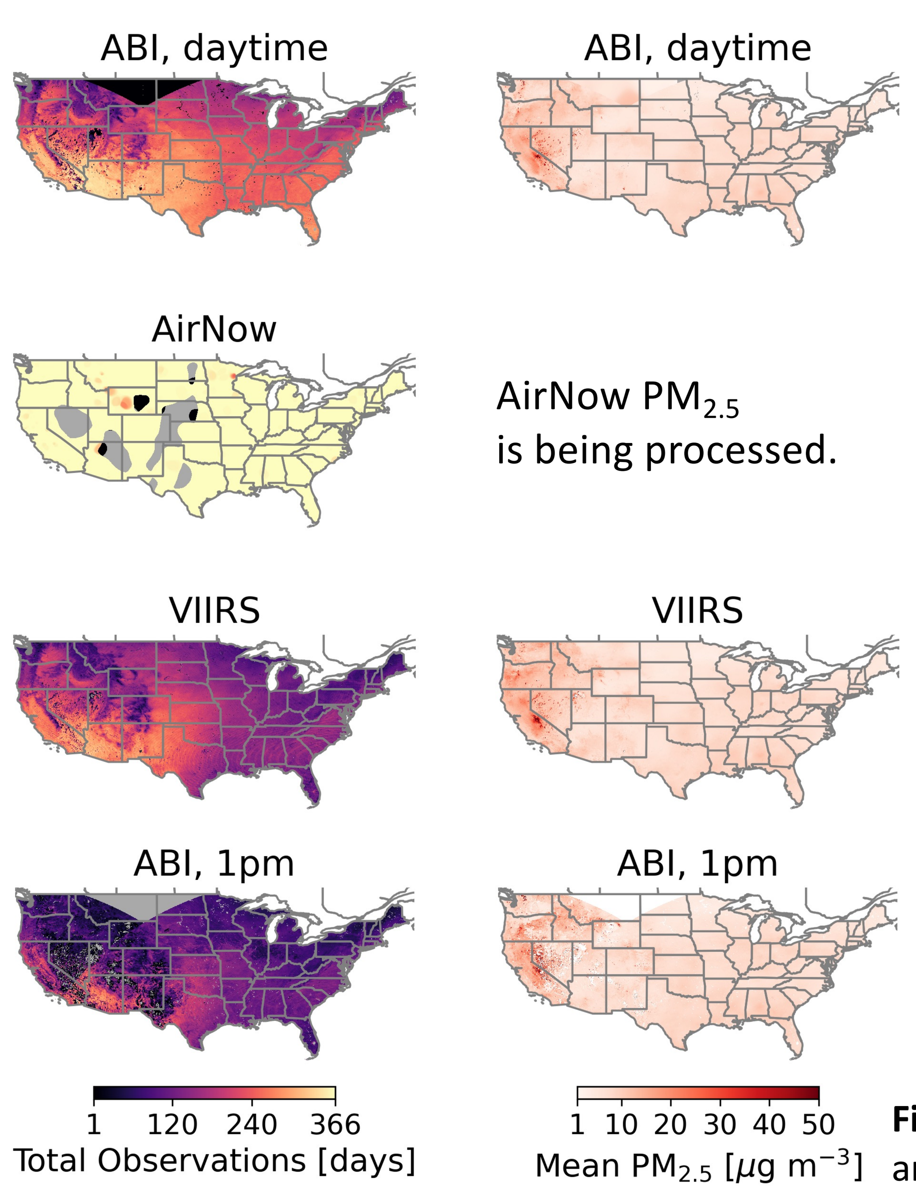
Geostationary observations of atmospheric composition could lead to many environmental health and justice benefits.

- Short-term pollution events, which are increasing in frequency and intensity in parts of the US due to western wildfires, can easily be missed by sparse monitoring networks and even polar-orbiting satellites.
- Accurate assessments of exposure disparities to air pollutants require high spatial resolution observations unavailable from the EPA AQS monitoring network.
- Improved observations of these modern air quality challenges, which could be obtained via geostationary satellites, are critical.

We quantify the health and economic benefits of applying geostationary satellite observations for identifying air quality alert days in the US.

- Currently, air quality alerting is predominately monitor-based, although this can vary across local air monitoring agencies.
- While informing the public of poor air quality days is important, air quality alerts are one of many possible GeoXO benefits and should be combined with additional, system-based strategies to protect health from poor air quality. We plan to explore these in future works.

2. We assess the temporal & spatial completeness of four near-real time $PM_{2.5}$ datasets.



Geo Case (represents GeoXO)
Hourly surface $PM_{2.5}$ concentrations derived from ABI Aerosol Optical Depth (AOD) during daylight hours on GEOS-16 and GOES-17.

Monitor Case (represents status quo)
Daily surface $PM_{2.5}$ concentrations based on AirNow monitors and associated reporting areas used for AQI reporting to inform air quality alerts.

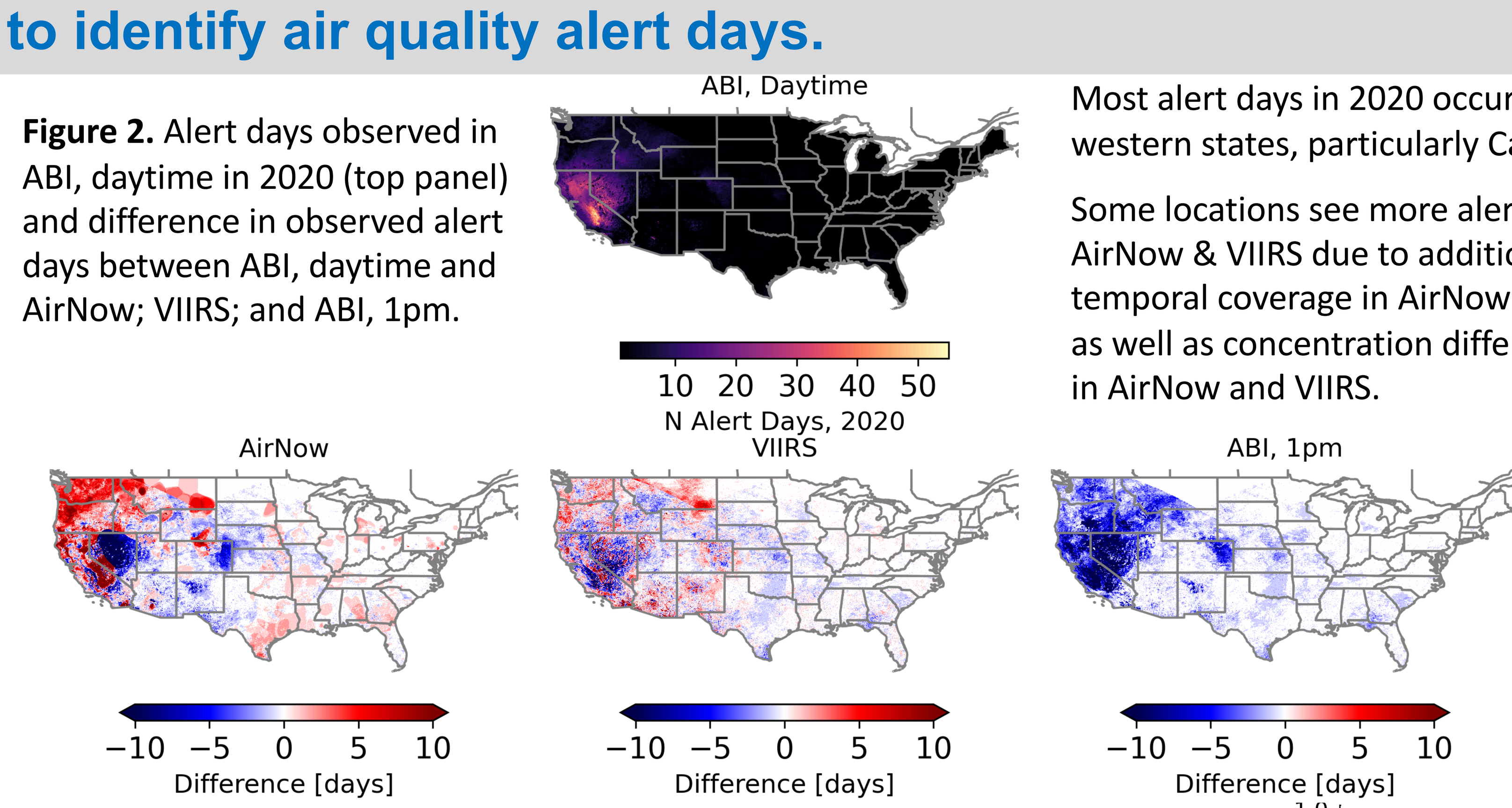
Leo Case (apples-to-oranges)
Daily surface $PM_{2.5}$ concentrations derived from AOD from the VIIRS instrument on the Aqua satellite, overpass ~1:30 pm local time.

Leo-proxy Case (oranges-to-oranges)
Daily surface $PM_{2.5}$ values derived from daytime AOD from ABI (geo case) but masking values where 1pm ABI retrieval is missing/invalid.

Figure 1. Total observation count (left column) and 2020 annual mean $PM_{2.5}$ (right column) for each dataset.

3. Missing observations impact the ability of these datasets to identify air quality alert days.

Figure 2. Alert days observed in ABI, daytime in 2020 (top panel) and difference in observed alert days between ABI, daytime and AirNow; VIIRS; and ABI, 1pm.

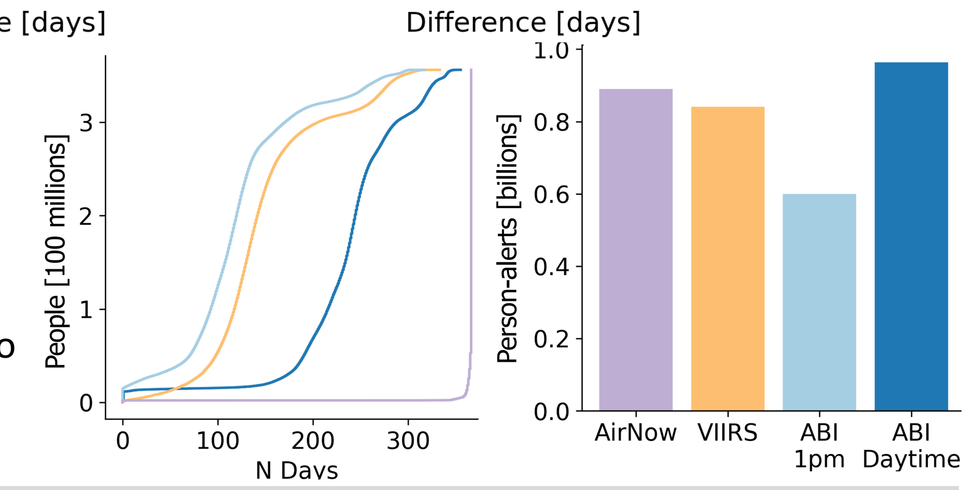


Most alert days in 2020 occurred in western states, particularly California.

Some locations see more alert days in AirNow & VIIRS due to additional temporal coverage in AirNow as well as concentration differences in AirNow and VIIRS.

Figure 3. Cumulative population by number of days with observations in each dataset (left) and total number of person-alerts observed (right).

For reference, 1 billion person-alerts is equivalent to everyone in the US experiencing 3 alerts per year.



4. We use a health impact assessment to quantify health & economic implications of missed alert days.

We assume alerted populations take action to reduce exposure based on previous works.

Exposure Reduction Action	Likelihood of Taking Action in Response to Wildfire[a] Mean ± SD	Effectiveness of Action[b] Mean ± SD	Average Overall Exposure Reduction[c]
Reduced activity	64.4% ± 18.5	No data	--
Stayed inside	63.0% ± 12.8	49.8% ± 22.8	31.4%
Ran home HVAC system	38.0% ± 31.1[d]	64.0% ± 32.8	24%
Evacuated	20.5% ± 18.4	100%	24%

Abbreviated table 6.1 from EPA's 2021 CAIF report[1]

On average across multiple studies, remaining indoors is estimated to lead to population exposure reduction of ~30%.

$PM_{2.5}$ exposure adjusted by:

$$PM_{2.5}\ \text{exposure} = (1 - 0.3 \times S) \times \text{ambient } PM_{2.5}$$

S = 0 on non alert days
S = 1 on alert days

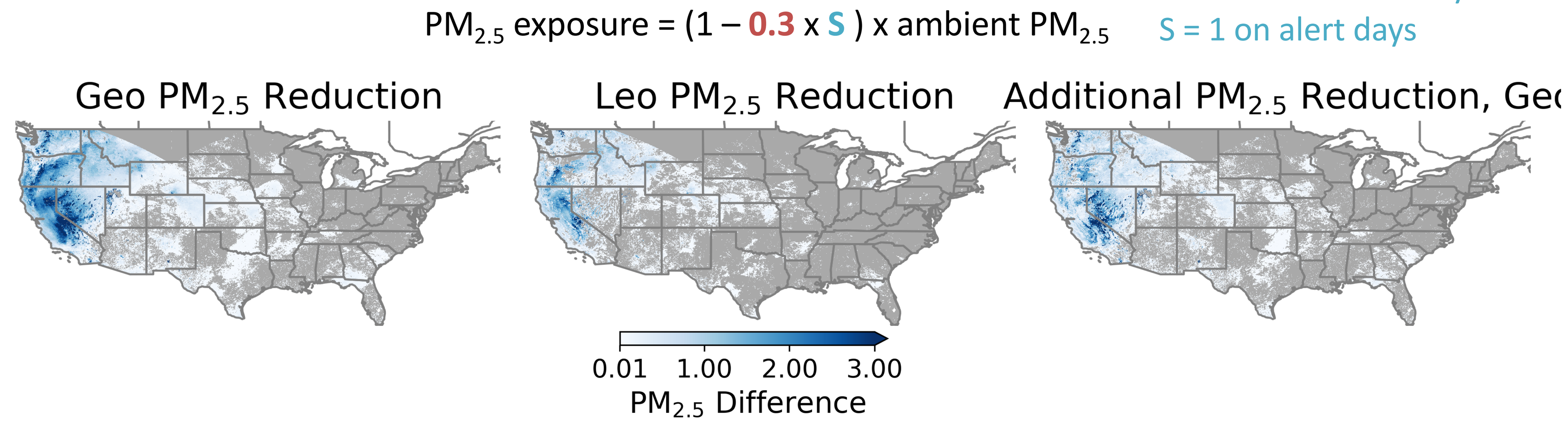
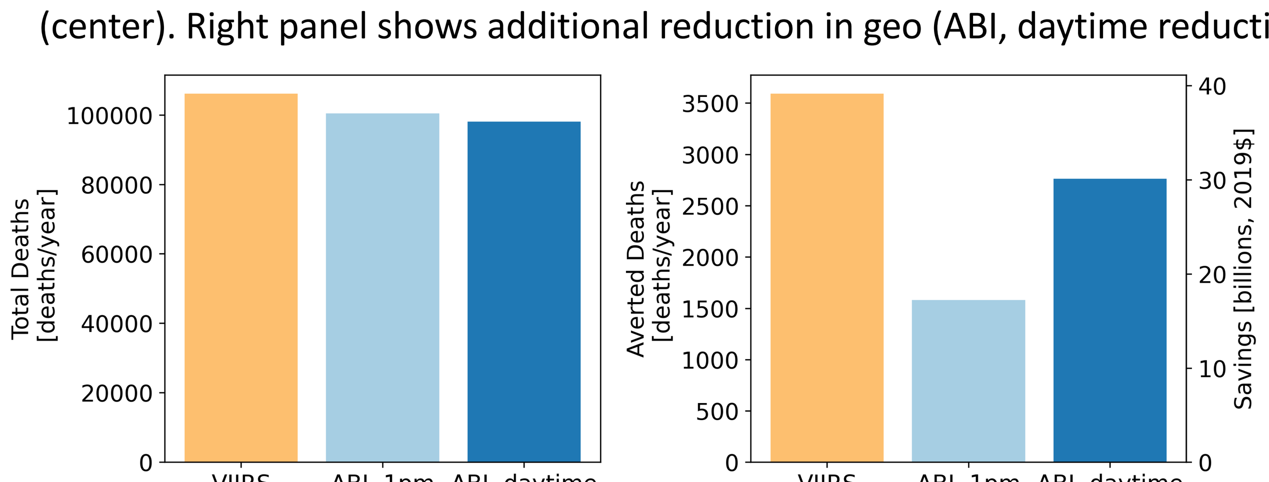


Figure 4. Reduction in 2020 annual-mean $PM_{2.5}$ using ABI, daytime based alerts (left) and ABI, 1pm alerts (center). Right panel shows additional reduction in geo (ABI, daytime reduction – ABI, 1pm reduction).



HIA function:

$$Deaths = Pop \times B \times (1 - e^{-\beta \Delta PM2.5})$$

Pop = population
B = county-level baseline mortality rate
β from Turner et al., 2016[2]

Associated cost estimated using value of statistical life of $10.9 million [2019$, US DOT[3]].

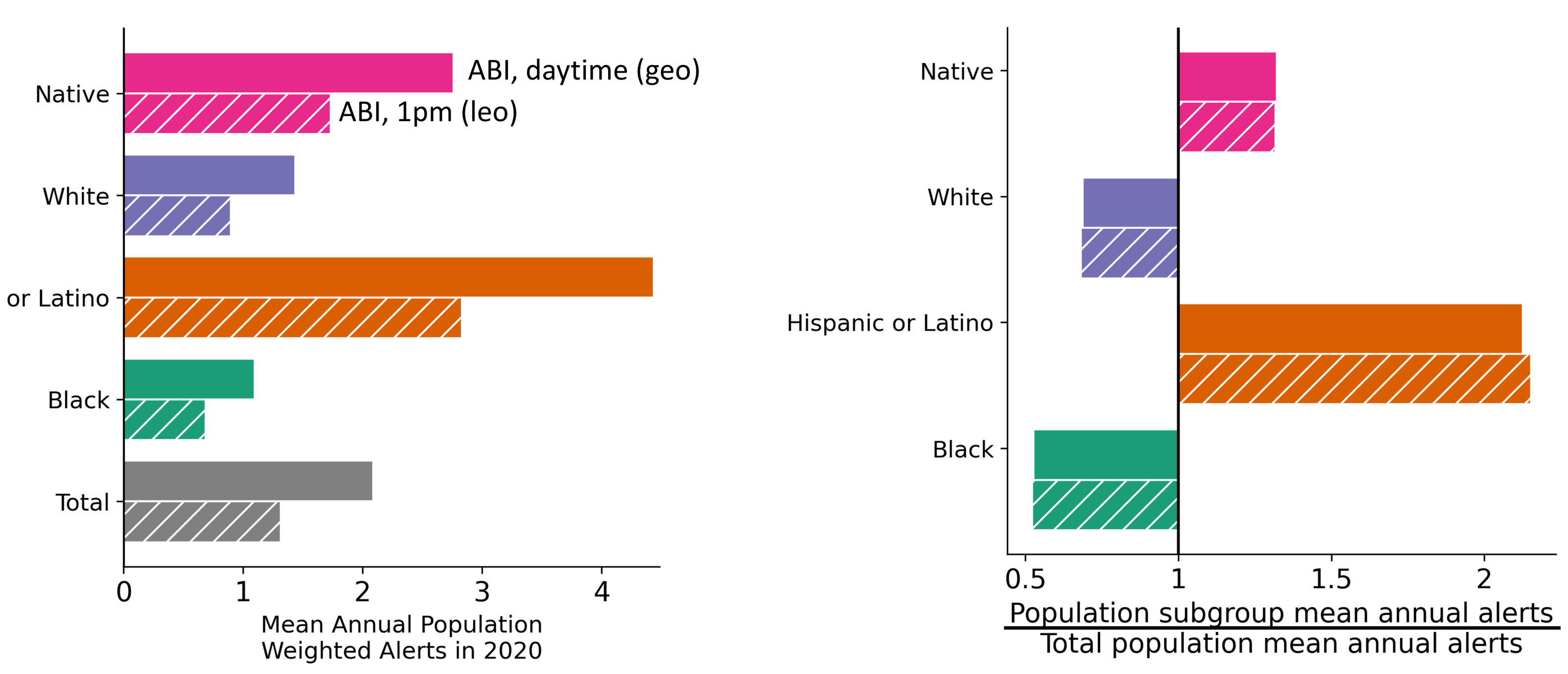
Figure 5. Total $PM_{2.5}$-attributable mortality using $PM_{2.5}$ from each dataset (left) and averted mortality and associated economic savings with air quality alerts and subsequent behavior modification (right).

5. The satellite-based datasets observe similar disparities in exposure to short-term pollution events.

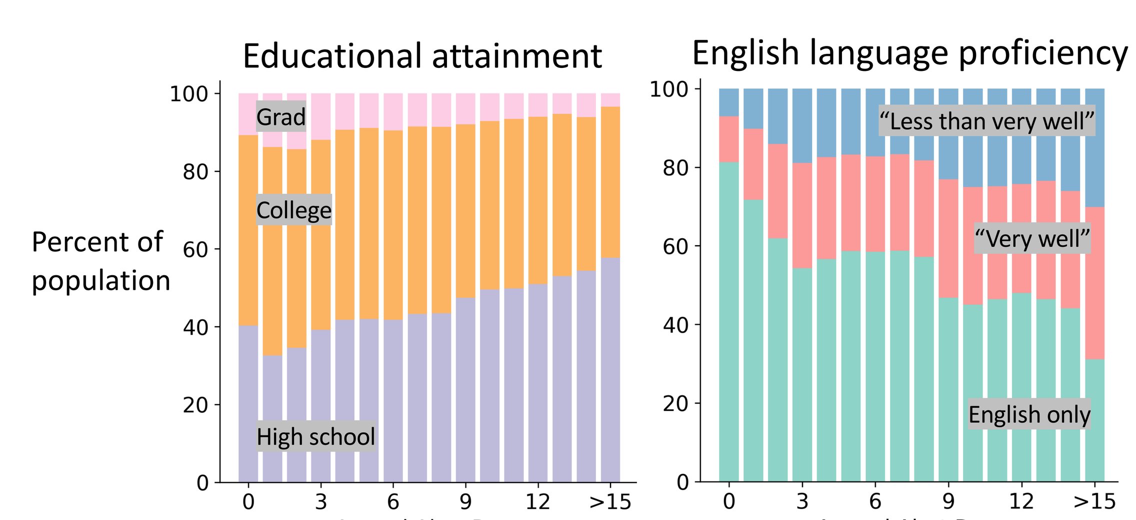
We use demographic data from the 2015-2019 5-year American Community Survey (ACS) to investigate how alert day observations vary by demographic groups.

Geo observes more alert days across each racial/ethnic group compared to leo.

Both geo and leo based alerts find Native and Hispanic/Latino populations were exposed to disproportionately more alert days in 2020.



We also use the ACS data to assess additional characteristics of the populations exposed to a high number of alert days in 2020. Figure uses ABI, daytime based alerts.



Populations exposed to more frequent $PM_{2.5}$ alert days in 2020 were more likely to:

- Have lower educational attainment
- Speak English "less than very well"

6. Implications and References

Implications

- The methodology presented here allows us to incorporate health benefits of atmospheric composition observations from geostationary satellites into economic analysis to support future satellite missions.
- Geostationary satellites can observe more short-term pollution events than comparative polar-orbiting based data. This leads to the identification of more air quality alert days, and assuming behaviour modification in alerted populations, a health benefit of 1.4k fewer $PM_{2.5}$ attributable mortality and associated economic savings of over 10 billion (2019$).
- We find geostationary and polar-orbiting satellite based datasets observe similar disparities in exposure to air quality alert days. Native and Hispanic/Latino populations experience more alert days than other racial and ethnic groups.
- This work is ongoing. We are actively working to incorporate monitor-based alerts, which is currently the predominate data source used for issuing air quality alerts to our knowledge.

Acknowledgements

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References

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