Leveraging satellite-derived air quality datasets for environmental health applications

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• Why is satellite remote sensing so useful for understanding health impacts of air pollution?
• Tracking global air quality and climate change indicators
  • Urban air quality and health
  • “Natural” sources of PM$_{2.5}$
• Environmental justice: exposure between the monitors
• Epidemiology: understanding concentration-response relationships
• Limitations and future directions
Air pollution continues to be a leading health risk factor in nearly all countries

>90% of people worldwide live with PM$_{2.5}$ concentrations above the World Health Organization guideline


GBD 2019 Study
https://vizhub.healthdata.org/gbd-compare/
Satellite remote sensing has transformed our ability to understand air pollution disease burdens globally.

2004: **Surface air quality monitors**, 800,000 premature deaths associated with urban \( \text{PM}_{2.5} \) (Cohen et al. 2004)

2010: **Global chemical transport model**, 3.7 million \( \text{PM}_{2.5} \) and 700,000 ozone deaths globally (Anenberg et al. 2010)

2012: **Satellite observations, global chemical transport model, and ground observations combined**, 3.2 million \( \text{PM}_{2.5} \) and 152,000 ozone deaths (Lim et al. 2012)

2016-2020: **methods refined**, ~4 million \( \text{PM}_{2.5} \) and 200,000 ozone deaths (Forouzanfar et al. 2016, etc.)

**Future**: geostationary satellites, low-cost sensors, mobile monitoring, ???

2010: **Global \( \text{PM}_{2.5} \) concentrations from satellite AOD** (van Donkelaar et al. 2010)
PM$_{2.5}$ mortality in 250 cities worldwide

Shaddick et al. 2018
New decision-support tool: Pathways-AQ
Heterogeneity in PM$_{2.5}$-attributable cases per 100,000 people at census tract level

PM$_{2.5}$ at 0.01° x 0.01°
(van Donkelaar et al. 2016)

Census tract disease rates from CDC 500 Cities
(https://www.cdc.gov/500cities/)

Preliminary results. 
Do not cite or quote.
Tracking indicators of air quality and climate change

GeoHealth

RESEARCH ARTICLE
10.1021/acsgeohealth.0c00014

Future Fire Impacts on Smoke Concentrations, Visibility, and Health in the Contiguous United States

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Key Points:
- We provide the first estimates of future smoke health and visibility impacts.
- Future fire impacts on smoke concentrations and visibility can lead to serious health issues.
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Citations:

Using Satellites to Track Indicators of Global Air Pollution and Climate Change Impact: Lessons Learned From a NASA-Supported Stakeholder Collaborative

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Abstract:
The 2013 NASA Health and Air Quality Applied Science Team (HASTAG) “Indicators” Tiger Team collaborated between NASA-supported scientists and civil society stakeholders aimed at developing satellite-derived global pollution and climate indicators. This paper summarizes our experiences and lessons learned. Together, the teams developed methods to track wildfires, dust storms, sulfur oxides, urban green spaces, nitrogen dioxide concentrations and air quality, tropospheric ozone concentrations, and urban particulate matter. Participatory knowledge production can lead to more actionable information but requires time, flexibility, and continuous engagement. Ground measurements are still needed for ground truthing, and sustained collaboration over time remains a challenge.

Plain Language Summary:效果在土壤卫星遥感对地面观测的辅助。

Tracking indicators of air quality and climate change: Impacts of lessons learned from a NASA-supported stakeholder collaborative. GEO Health 1(1), 27-48. doi:10.1021/acsgeohealth.0c00014

Using Satellites to Track Indicators of Global Air Pollution and Climate Change Impact: Lessons Learned From a NASA-Supported Stakeholder Collaborative. GEO Health 1(1), 27-48. doi:10.1021/acsgeohealth.0c00014

The authors develop the tools needed to answer the questions of the project participants. Attribution Notice: This project was supported by the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Energy (DOE).

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Satellite-based population direct exposure to wildfire

Slide courtesy Yang Liu (speaking on Thursday!)

Watts et al. Lancet. 2020
Dust Storm and Valley fever Spikes

Slide courtesy Daniel Tong

(Source: Tong et al., GRL, 2017)
Health effects of air pollution: the knowns

PM$_{2.5}$ causal and likely causal effects (U.S. EPA ISA 2020)
- Mortality
- Cardiovascular disease
- Cancer
- Respiratory disease
- Nervous system

The unknowns... Concentration-response relationships at HIGH and LOW concentrations

Integrated exposure response curves
3-4 million PM$_{2.5}$ deaths

Curves using ambient air pollution studies only
8.9 million PM$_{2.5}$ deaths (more linear at high end)

Considering concentrations < GBD counterfactual (2.4-5.9 µg/m$^3$)
10.2 million PM$_{2.5}$ deaths (steep curve at low end)

Cohen et al. 2017
Burnett et al. 2018
Vohra et al. 2021
The unknowns... health effects of air pollution mixtures, interactive effects with other environmental risk factors
Concluding thoughts

• Satellite remote sensing has transformed environmental health surveillance capabilities

• Limitations of satellite data for health applications
  • Temporal coverage/flyover time
  • Spatial resolution
  • Ability to discern components/mixtures
  • There is still disagreement between surface concentration estimates from different methods

• Some thoughts for future directions
  • Important to have continuous record of remote sensing datasets
  • Use remote sensing to screen areas for locating ground monitors, integrating multiple datasets

Diao et al. 2019
Jin et al. 2019
extra
Identifying air pollution exposure inequities (NO$_2$)

In many cities, the post-lockdown NO$_2$ amounts in the least white communities are still ~50% larger than the pre-lockdown NO$_2$ amounts in the most white communities.
Progression of satellite capabilities over time

TEMPO NO₂

? 

Goldberg et al. 2021