Exposure Estimation for MAPLE: Mortality-Air Pollution associations in Low Exposure environments

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Background

Uncertainty remains in the association between mortality and long-term exposure to ambient fine particulate matter (PM2.5) at low concentrations. A paucity of air quality monitors in regions with low concentrations inhibits exposure assignment from ground-based monitors alone. Reduced ground-based monitoring for historical time periods also poses challenges for exposure assignment in cohort studies.

Objective

To develop PM2.5 concentration estimates across Canada by combining satellite remote sensing, chemical transport modeling, and ground-based monitoring.

Methods

We developed estimates of PM2.5 concentrations at 1km by 1km resolution across North America for each year from 1981 to 2012 (and ongoing out to 2016). The estimates were based on a combination of satellite remote sensing of aerosol optical depth (AOD), relating AOD to PM2.5 using the GEOS-Chem chemical transport model, and integrating these concentrations with ground-based monitoring data through geographically weighted regression. Estimates prior to 1998 included additional PM10 and total suspended particles (TSP) ground-based monitoring information.

We deployed targeted ground-based monitoring of the relationship between AOD and PM2.5. This monitoring is being used to evaluate and improve the GEOS-Chem calculation of the relation between AOD and PM2.5.

Annual concentration estimates are also developed for O3 and NO2 using a combination of ground-based monitoring, chemical transport modeling, and for NO2, land use information and satellite remote sensing.

PM2.5 Surfaces

Satellite-based PM2.5 estimates were consistent with ground-based monitors (R² = 0.82, slope=0.97) across North America even when large fractions were withheld for cross-validation (excluding up to 70% of monitors decreased R² to 0.78).

Root-mean-squared-error decreased slightly with decreasing PM2.5 concentrations from 1.5 µg/m³ for the full dataset to 1.3 µg/m³ for concentrations < 8 µg/m³.

Historical PM2.5 surfaces benefitted from PM10 and TSP data.

Ongoing analysis of ground-based monitoring

Initial targeted ground-based monitoring identified the mass scattering efficiency (the relationship between PM2.5 and scatter) as a key factor affecting the relation between AOD and PM2.5.

Development of the representation of aerosol size and aerosol hygroscopicity in the GEOS-Chem model improved the simulation of mass scattering efficiency.

Conclusion

A combination of satellite remote sensing, chemical transport modeling, and targeted ground-based monitoring offers valuable information about ambient air quality at low concentrations.

Figures:

1. Exposure estimation development process for PM2.5
2. Performance of satellite-derived PM2.5 overall (left) and for low PM2.5 (<10 µg/m³, right).
3. Historical evolution of PM2.5
4. Measured relationships between AOD and PM2.5.
5. Performance of GEOS-Chem simulation of mass scattering efficiency (αPM2.5 / scatter) for default (left) and revised (right) that uses a revised treatment of particle size and hygroscopicity.

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