Air Toxics, Environmental Justice and COVID-19:

Geospatial Analyses across New Jersey and the US

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New Jersey Clean Air Council Public Hearing

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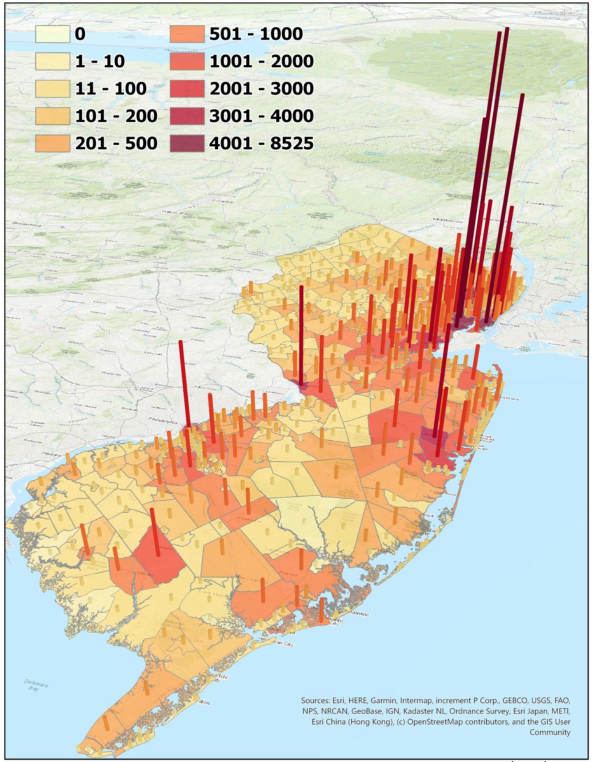

COVID-19 cases reported by NJ municipalities as of 9/24/2020 (i.e., by the end of the "first wave" of the pandemic)

The Rationale for Studying Air Toxics in Relation to Environmental Justice and COVID-19

- Why is it important to understand the relationship between disparities in chronic low-level exposures to Air Toxics and disparities in COVID-19 mortality?
  - *Why is it important to understand this relationship in a sociodemographic and environmental justice context?*
- Because regulatory decision making for Air Toxics relies on assessments of their potential human health effects
  - *Because exposures to individual or co-occurring Air Toxics may contribute to increased vulnerability to respiratory infection (and in particular COVID-19) in a cumulative manner*
  - *Because cumulative exposures are especially relevant for overburdened (e.g., minority) communities and among sensitive populations (e.g., very young children)*
- Geospatial Analytics (including Geostatistical and Machine Learning methods) allow quantification of the associations between COVID-19 mortality and chronic exposures to Air Toxics while controlling for other risk factors (environmental, behavioral, sociodemographic)

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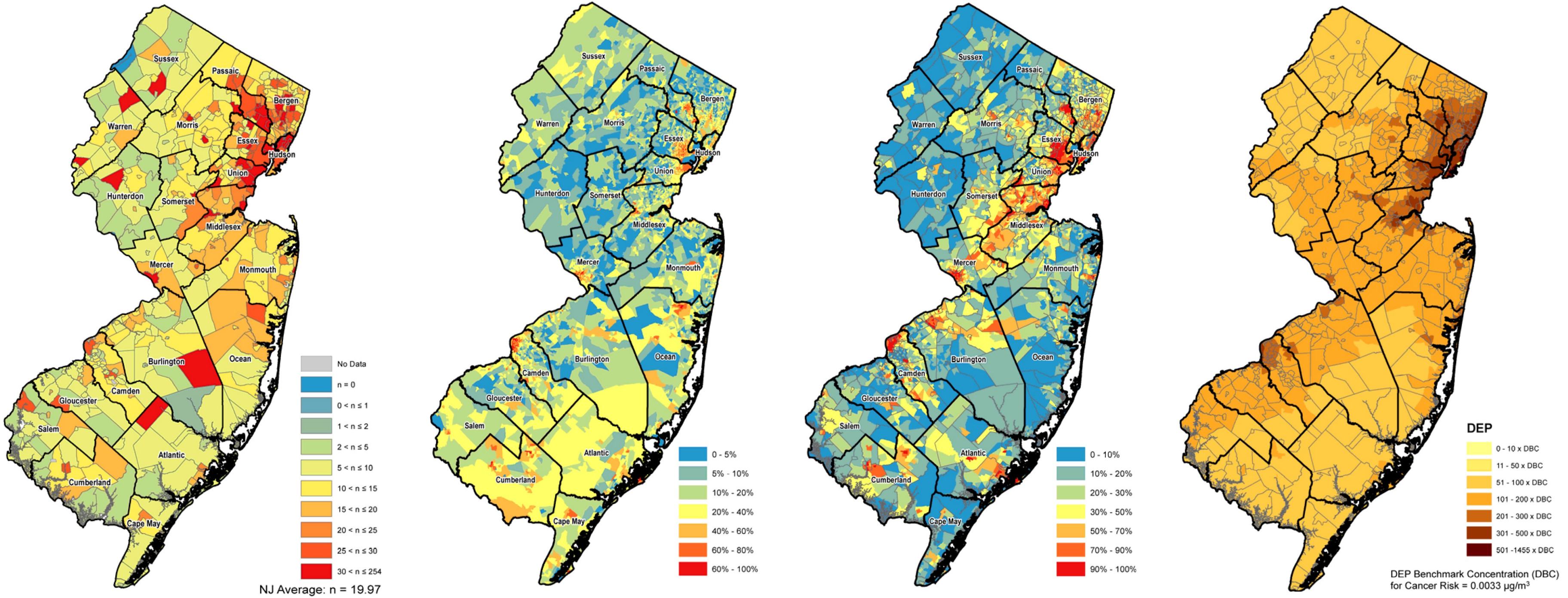
SPATIAL PATTERNS OF COVID-19 SPREAD AND OF SELECTED SOCIAL AND ENVIRONMENTAL DETERMINANTS OF HEALTH ACROSS NJ



[a] COVID-19 **[b] low income** **[c] minorities** **[d] diesel particles**

Spatial heterogeneity and overlap of COVID-19 and of demographic, environmental and socioeconomic factors across New Jersey. [a] Confirmed cases of COVID-19 per 1,000 population at municipality level (7/23/2020). [b] Percentage of low-income population (<2-times poverty level) at census tract level (2017).[c] Percentage of minority populations at census tract level (2017). [d] Airborne diesel emission particle levels (from the 2014 USEPA National Air Toxics Assessment).

NUMEROUS STUDIES ASSESSED ENVIRONMENTAL FACTORS INFLUENCING COVID-19 INCIDENCE AND SEVERITY

BUT AIR POLLUTION CONSIDERATIONS FOCUSED ALMOST EXCLUSIVELY ON CRITERIA POLLUTANTS

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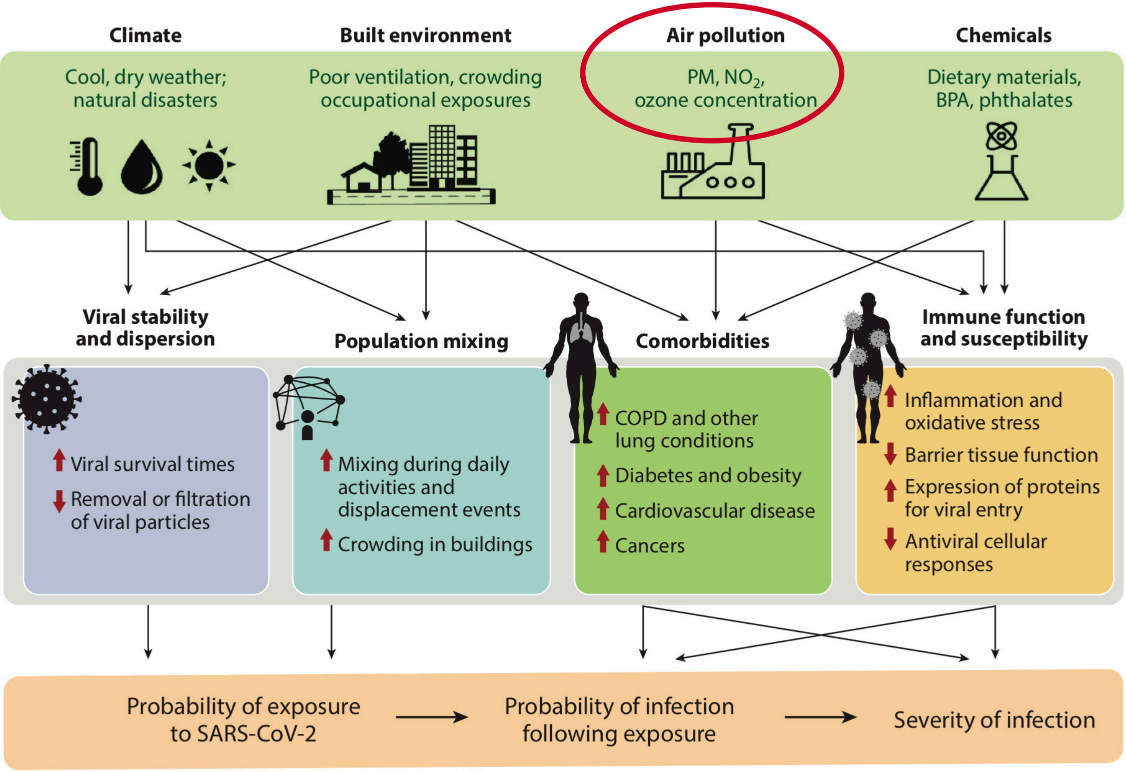
ANNUAL REVIEWS

Annual Review of Public Health

Environmental Factors Influencing COVID-19 Incidence and Severity

Amanda K. Weaver,[1] Jennifer R. Head,[2] Carlos F. Gould,[3,4] Elizabeth J. Carlton,[5,*] and Justin V. Remais[1,*]



SCIENCE ADVANCES | RESEARCH ARTICLE

CORONAVIRUS

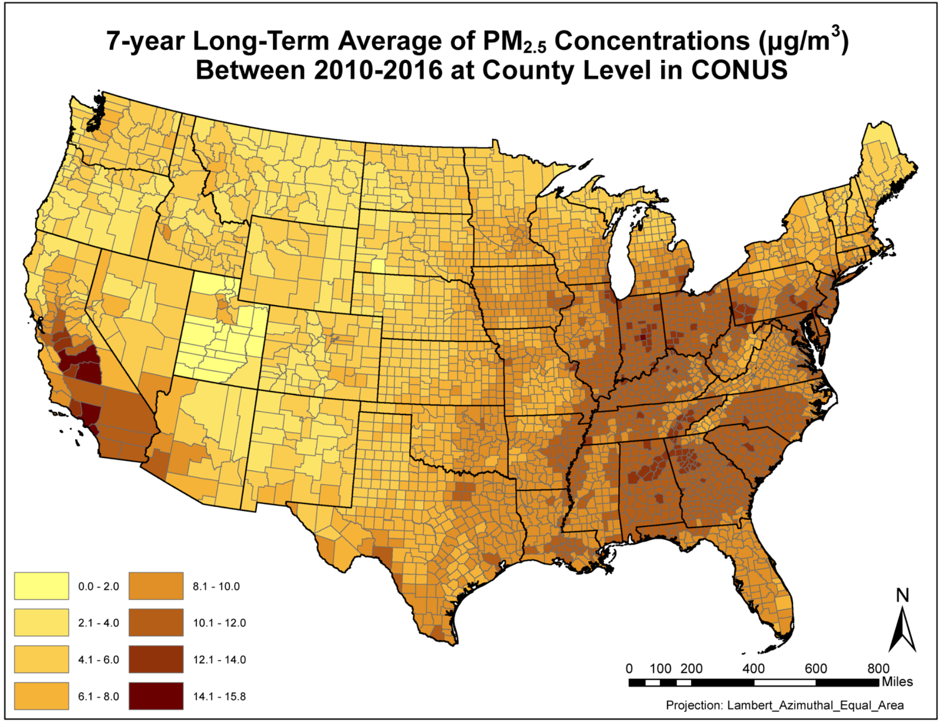
Air pollution and COVID-19 mortality in the United States: Strengths and limitations of an ecological regression analysis

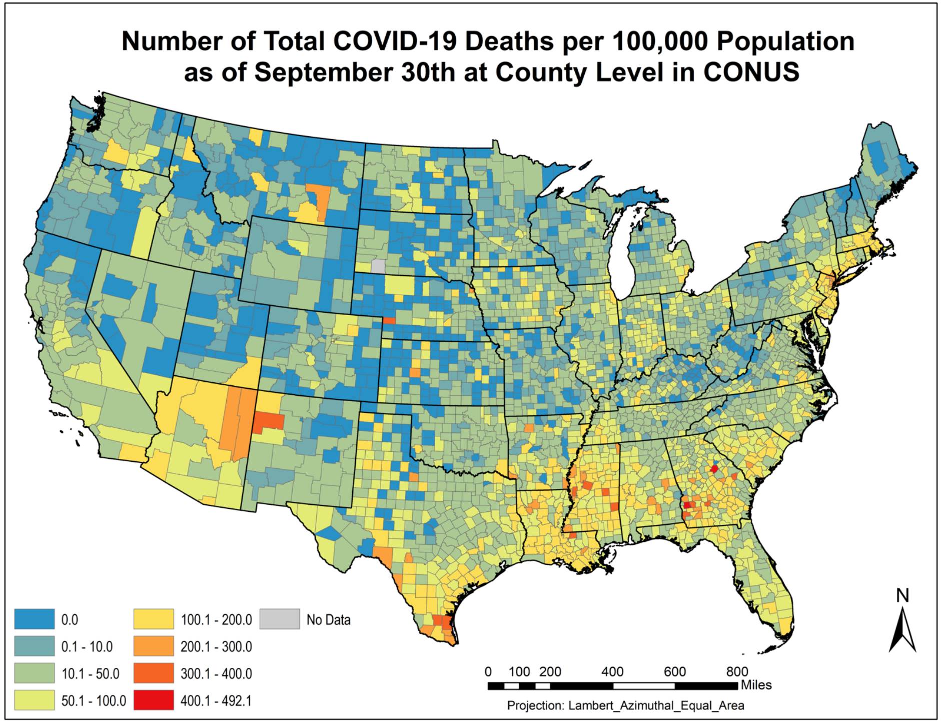
X. Wu[1]*, R. C. Nethery[1]*, M. B. Sabath[1], D. Braun[1,2], F. Dominici[1†]

"…increase of 1 µg/m³ in the long-term average PM2.5 is associated with a statistically significant 11% (95% CI, 6 to 17%) increase in the county's COVID-19 mortality rate…"

Several ecological studies (and one cohort study) found consistent positive associations of elevated COVID-19 incidence and mortality with past PM2.5 levels; similar associations have been established for NO_2 - but not for O_3

County-Level CONUS Exposure-Wide Association Analysis of COVID-19 for the First Wave of the Pandemic (March to September 2020)





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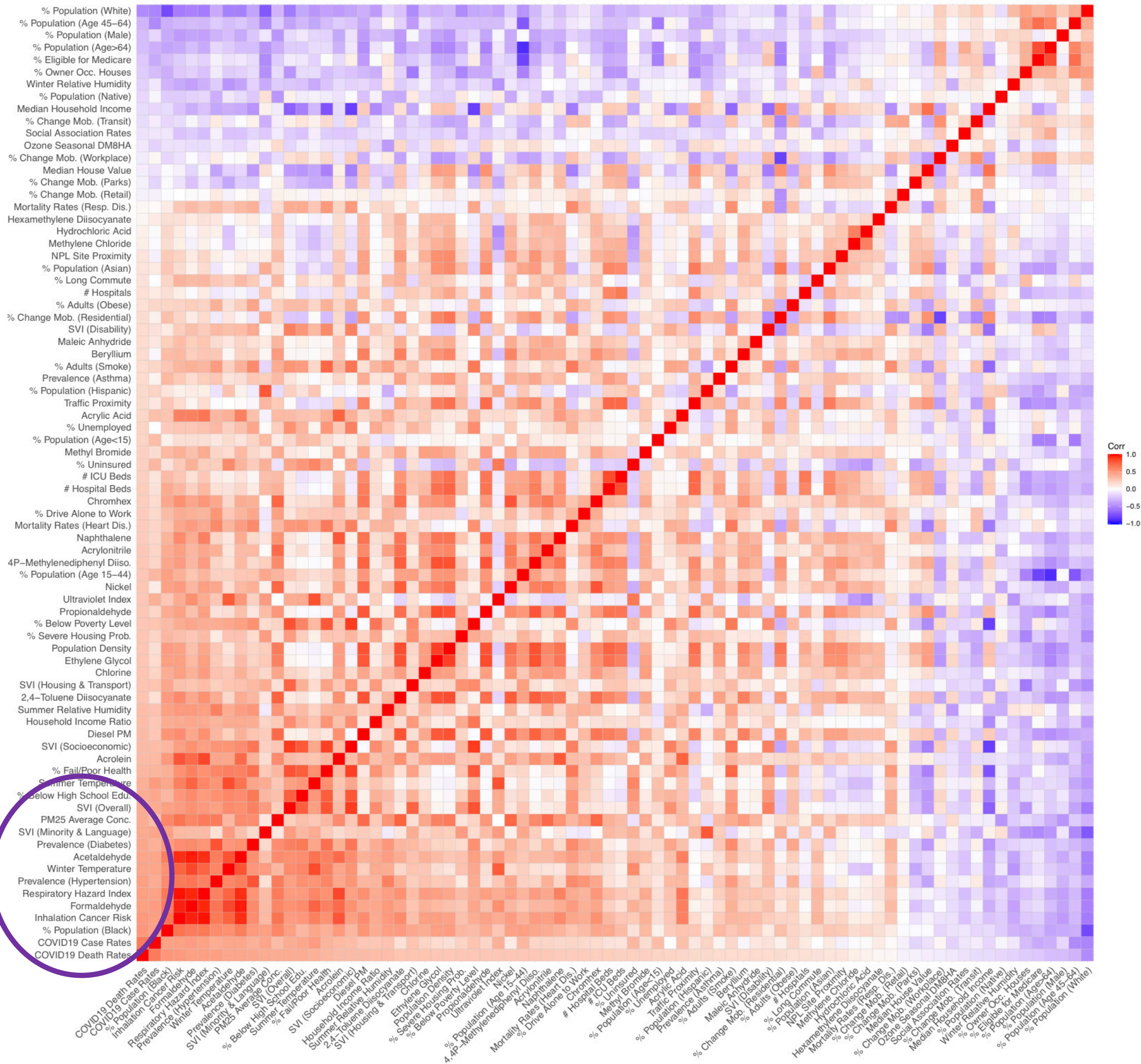
COVID-19
Exposure-Wide Association Study–CONUS

Correlations of the numbers of confirmed COVID-19 case and death rates with a range of Demographic, Environmental and Socioeconomic (DES), behavioral and health factors for the 3,092 CONUS counties (as of September 30, 2020)

- *The Spearman Correlation Matrix* summarizes our results from an Exposure-Wide Analysis that considered a range of DES/H factors (76 shown):
  - *the matrix has been ordered, so COVID-19 cases are presented in the first (bottom) row; the closer the rows of the other variables are to the bottom row, the higher is their correlation with the number of confirmed COVID-19 cases*



Two Studies Assessed in A Systematic Manner the Impact of Air Toxics on COVID-19 Outcomes

- Nationwide (CONUS) County-Level Study by SUNY (Petroni *et al.*, 2020)
- New Jersey Statewide Municipality-Level Study by Rutgers (Ren *et al.*, 2023)

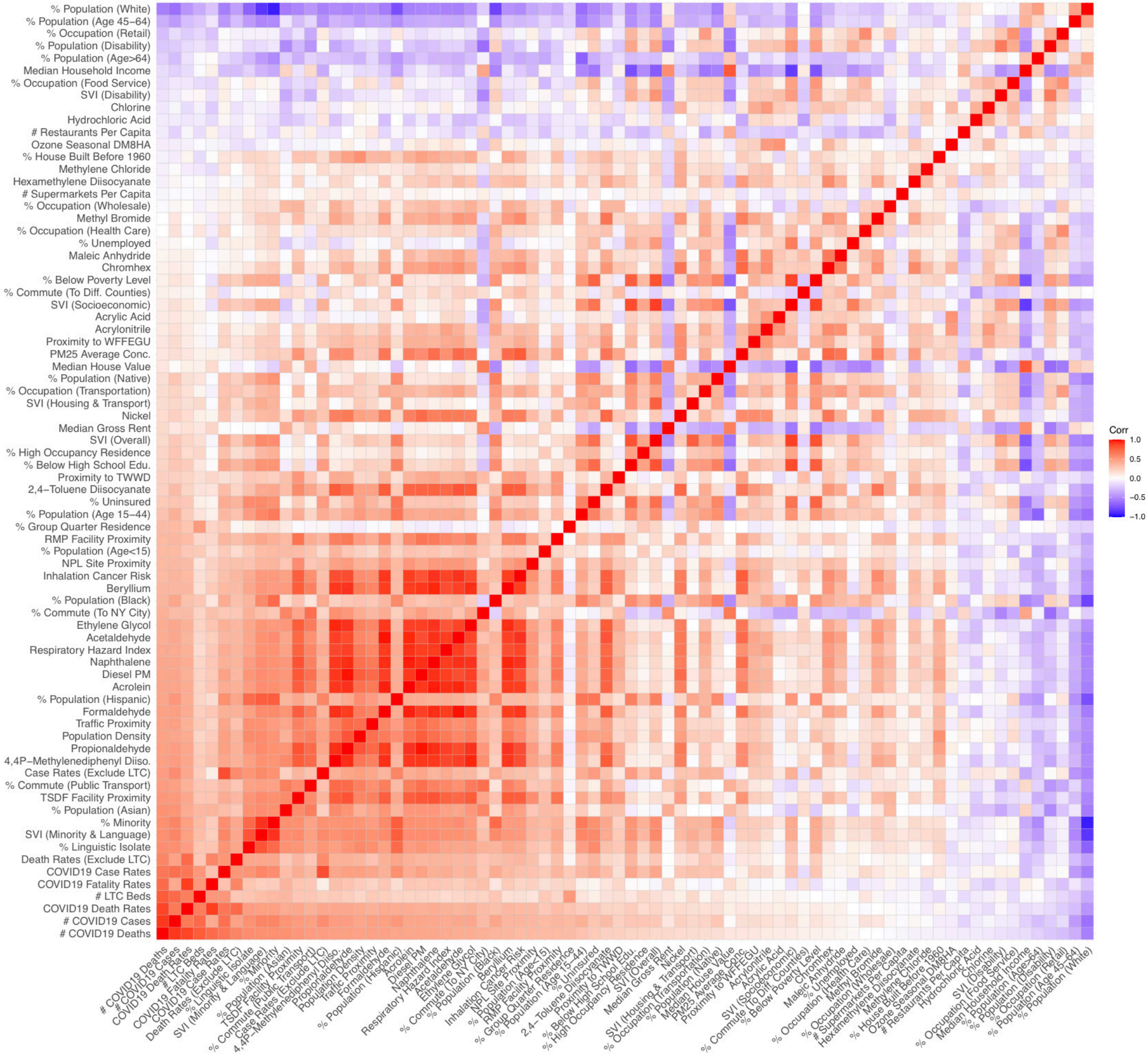
- Both studies implemented hierarchical statistical models, relating COVID-19 mortality to chronic individual and cumulative exposures to Air Toxics, while controlling for individual pollutants and multiple known environmental, demographic, and socioeconomic risk factors
  - *Considered both the combined respiratory Hazard Index (HI) and individual respiratory Hazard Quotients (HQ) for specific Air Toxics*
    - *Formaldehyde, acetaldehyde, acrolein, naphthalene, and diesel PM were selected because they are, on average across the US, the top contributors to respiratory HQs (collectively they account for over 50% of the total US respiratory HI in 2014)*
    - *Since most Air Toxics levels have been decreasing over time, the NATA modeled estimates of concentrations and respiratory HQs for 2014 were used to approximate the average levels between the years 2010 and 2019*
  - *Our (Rutgers) study systematically evaluated consistency and robustness of findings using six alternative Geostatistical models and two Machine Learning models*

COVID-19

EXPOSURE-WIDE ASSOCIATION STUDY – NJ

Correlations of the numbers of confirmed COVID-19 cases and deaths with a range of Demographic, Environmental and Socioeconomic (DES) factors for the 565 municipalities of New Jersey

- *The Spearman Correlation Matrix* summarizes results from our Exposure-Wide Analysis that considered a range of DES factors:
  - *the matrix has been ordered, so COVID-19 cases are presented in the first (bottom) row; the closer the rows of the other variables are to the bottom row, the higher is their correlation with the number of confirmed COVID-19 cases*



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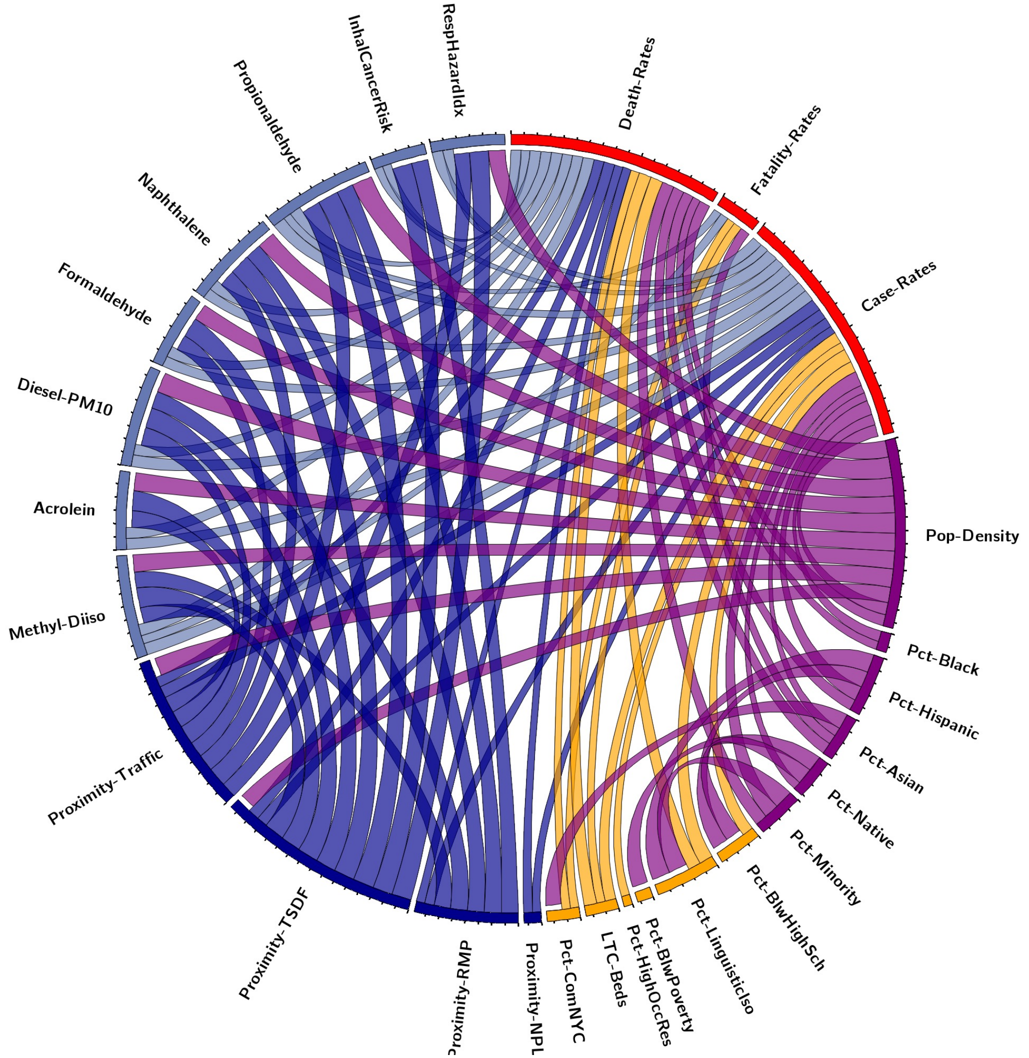
COVID-19
Exposure-Wide Association Study – NJ

Correlations of the numbers of confirmed COVID-19 cases and deaths with a range of Demographic, Environmental and Socioeconomic (DES) factors for the 565 municipalities of New Jersey

- *The Spearman Correlation Chord Plot provides an alternative visual representation of our Exposure-Wide Analysis: only factors with Spearman correlation values > 0.3 are included in this plot*



Levels of Air Toxics Across the 565 NJ Municipalities (mid-2010s)

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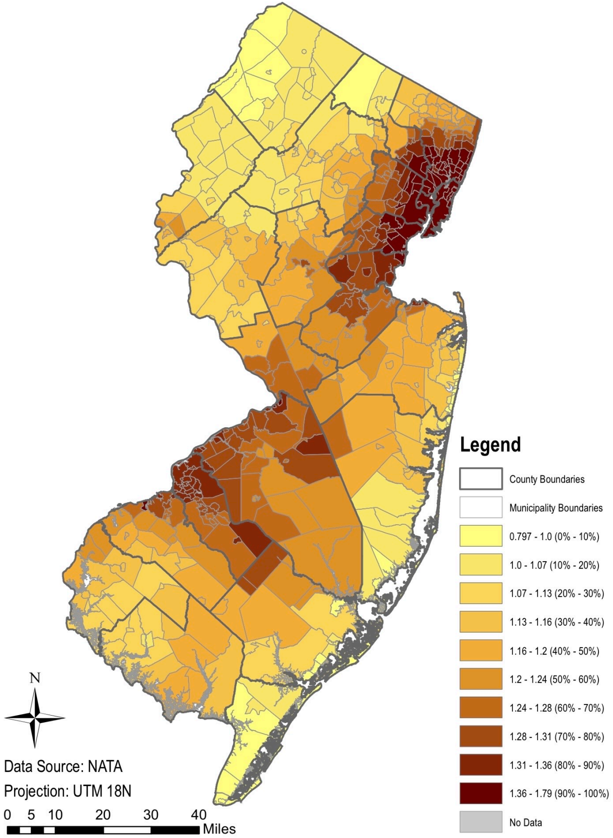
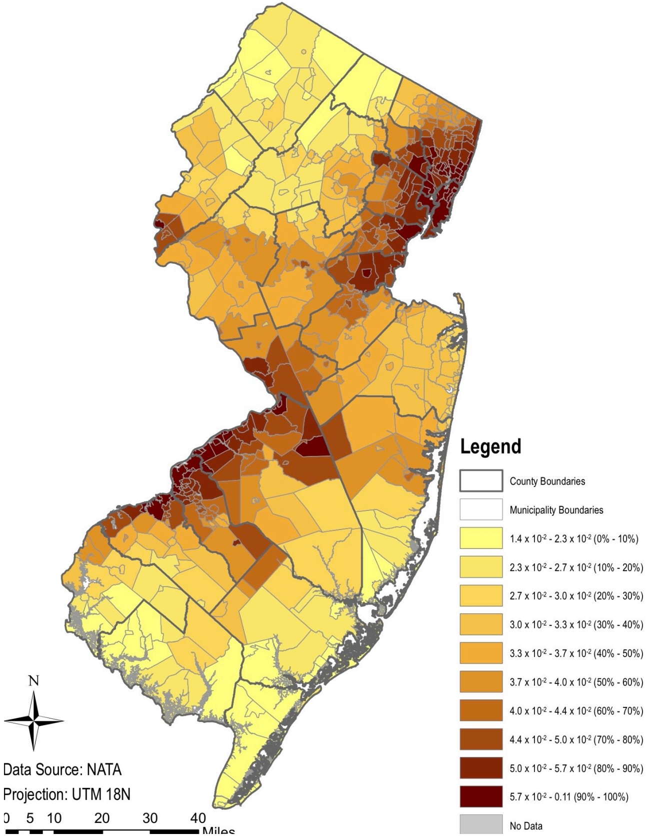
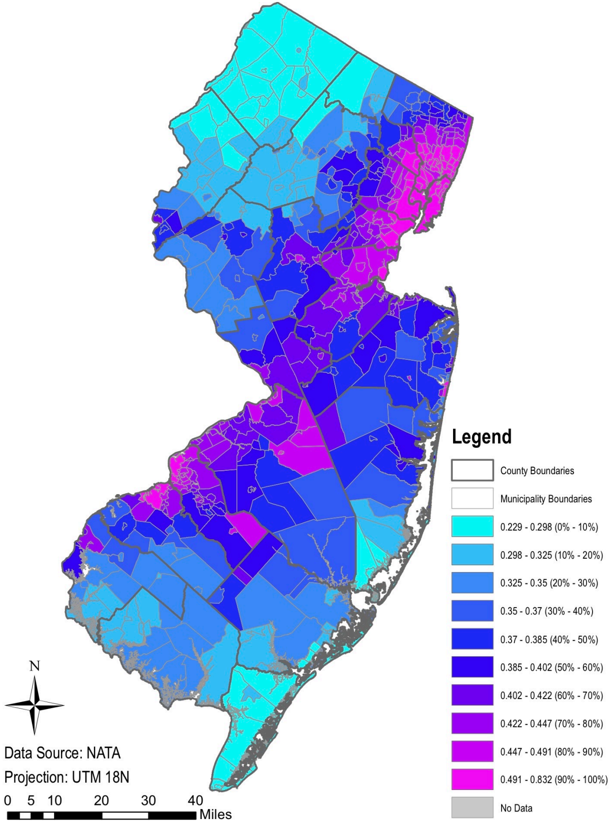


Formaldehyde (RfC = 9.8 µg/m^3)



Naphthalene (RfC = 3 µg/m3)



Respiratory Hazard Index (HI)

COVID-19 Mortality Rate Ratio Change by Air Pollutant for NJ and the US

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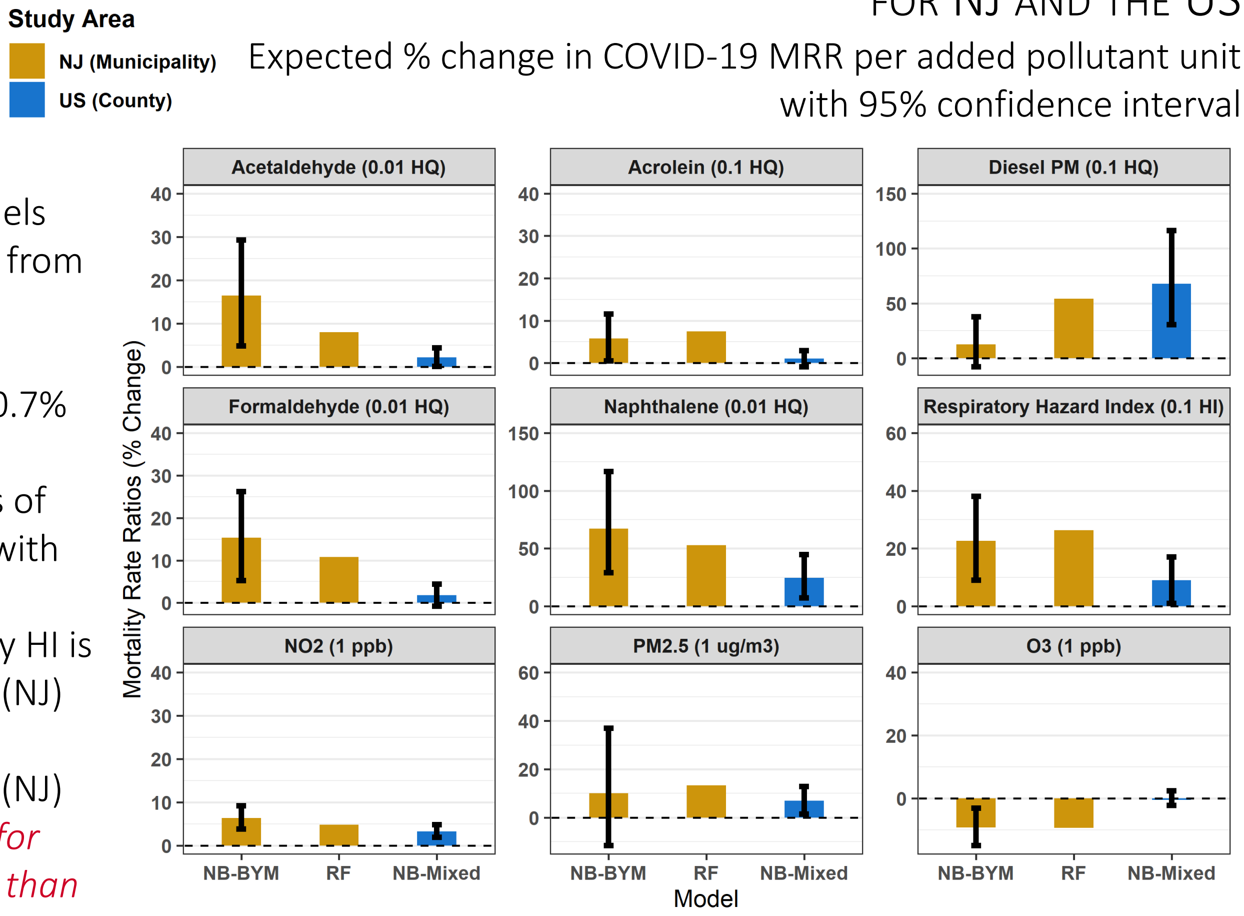
Expected % change in COVID-19 MRR per added pollutant unit with 95% confidence interval

NJ results from the best performing geostatistical and machine learning models are compared here with national results from other studies for their consistency

- Increase of 1 μg/m³ in PM2.5 concentration is associated with a 10.7% (-16.6%, 47.0%) MRR increase in NJ
- Very small increases in chronic levels of respiratory air toxics are associated with significant increases in MRR
- 10% increase in Air Toxics Respiratory HI is associated with >20% MRR increase (NJ)
- 1% increase in Formaldehyde HQ is associated with >10% MRR increase (NJ)
    - *These increases in MRR occur for levels of Air Toxics much lower than their chronic respiratory hazard RfCs*



RF: Random Forest Machine Learning model; NB-Mixed: Negative Binomial Mixed Effects Model
NB-BYM: Negative Binomial Besag-York-Mollie Model; HI: Hazard Index; HQ: Hazard Quotient

CONCLUSIONS

- Chronic exposures to Air Toxics at low levels below their chronic non-cancer reference concentrations (RfC) may heighten population vulnerability to COVID-19
  - *Statistically significant associations of both individual and cumulative chronic Air Toxics exposures with county-level COVID-19 mortality have been found for CONUS*
  - *Statistically significant associations of both individual and cumulative chronic Air Toxics exposures with municipality-level COVID-19 mortality have been found for New Jersey*
  - *Though the studies assessing associations of Air Toxics exposures with COVID-19 have limitations, as they primarily rely on modeled estimates and aggregated data, they demonstrate robust consistency in findings both nationwide and for New Jersey*
- Exposures to Air Toxics are higher in overburdened communities, where many other environmental, demographic and socioeconomic factors represent additional risks leading to adverse COVID-19 outcomes

RECOMMENDATIONS

- The potential links between chronic exposures to Air Toxics and COVID-19 mortality should be considered when evaluating the efficacy of pollution prevention strategies
  - *The plausible biological mechanisms (Adverse Outcome Pathways) that may increase vulnerability to COVID-19 due to chronic Air Toxics exposures are also potentially relevant to other infections and respiratory diseases*
  - *The fact that statistically significant associations of disparities in COVID-19 mortality with disparities in individual and cumulative chronic exposures to Air Toxics are found for low levels and small increases of their concentrations, should inform policy making*
- Expanded monitoring of Air Toxics, including focused studies involving local and personal monitoring in overburdened communities, should be considered in order to reduce uncertainties in the assessment of health risks and improve chemical risk management and public health policy

Referencess

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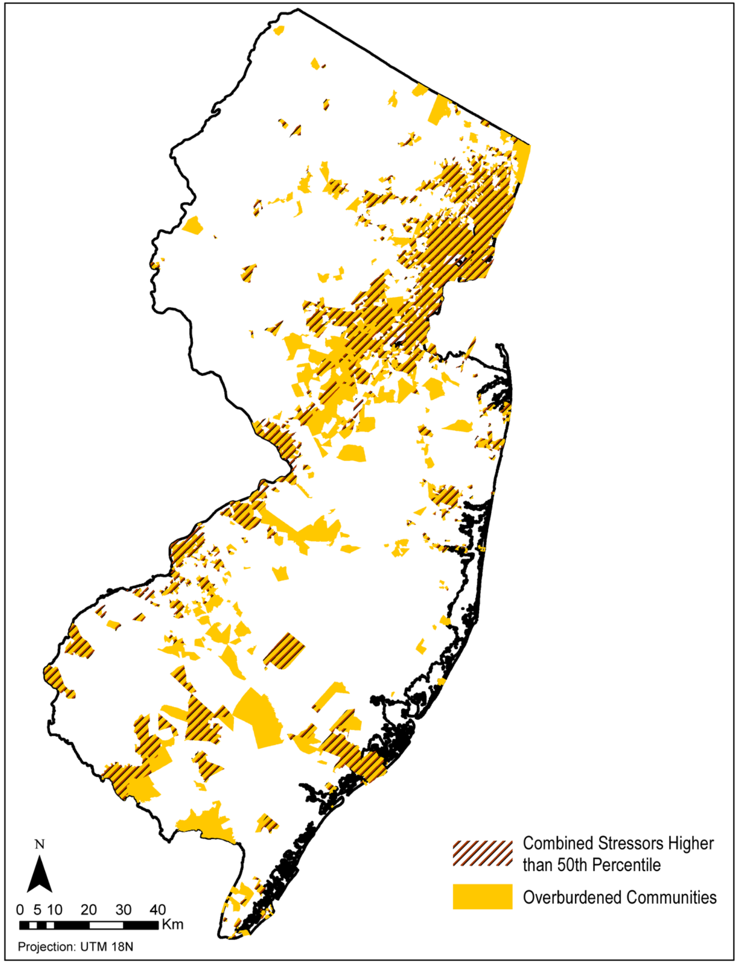
Data

- Multiple Organizations sharing/exchanging information on COVID-19; a (very) partial list includes: *CDC (COVID-19,WONDER, SVI); USEPA (NATA, NEI, TRI, EJScreen); USCB (COVID-19, ACS); USBL; AHRQ; NJDOH; NJDEP; the Models of Infectious Disease Agent Study (MIDAS); the JHU CSSE dashboard; the COVID Tracking Project (The Atlantic); the NY Times GitHub repository; Christoph Schoenenberger; the Yu group (Berkeley); the Mordecai group (Stanford); Google mobility data; the Unacast SD scoreboard; NJ local health departments and NJ media*

Supplementary Slides

From NJDEP EJMAP

Overlap of overburdened communities with areas where combined stressors are above the 50th percentile statewide



LEVELS OF CRITERIA POLLUTANTS ACROSS THE 565 NJ MUNICIPALITIES (2016)

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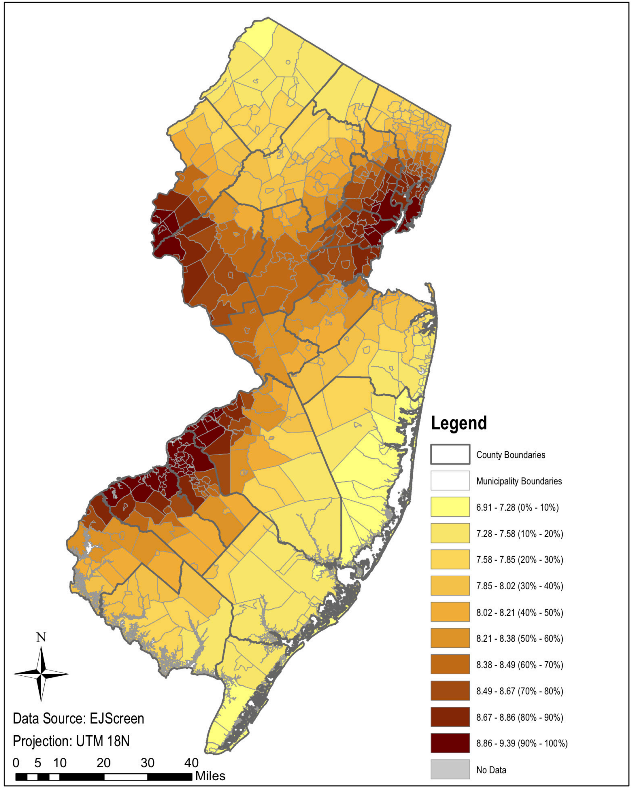
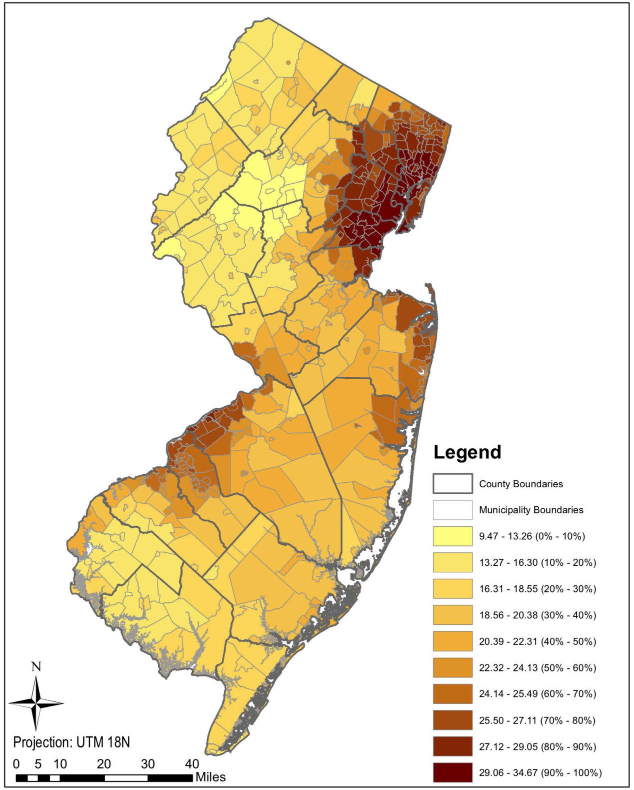
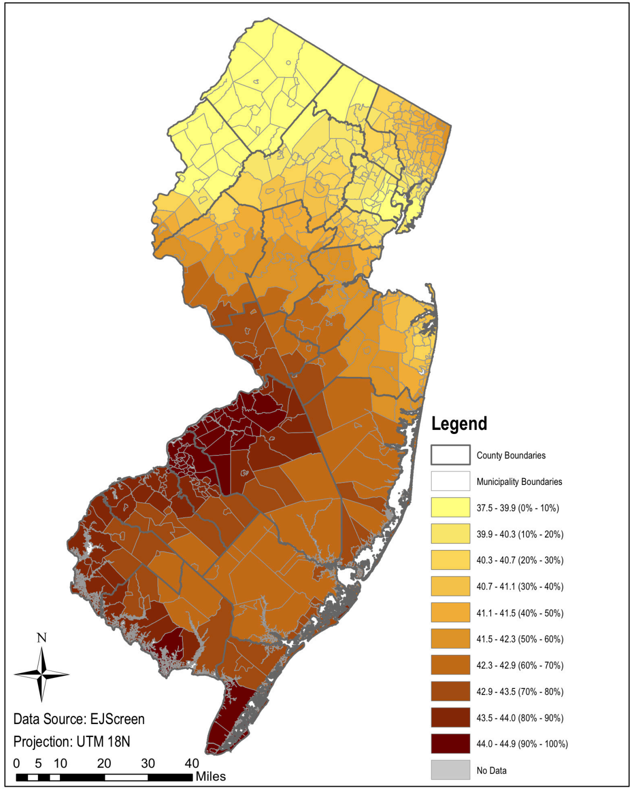
Decile Ranking of New Jersey Municipalities by Annual Average Ambient $PM_{2.5}$ Concentrations (µg/m³) for Year 2016



Decile Ranking of New Jersey Municipalities by Annual Average Daily max 1 hour Average Ambient NO_2 Concentrations (ppb) for Year 2016



Decile Ranking of New Jersey Municipalities by Annual Average Daily max 8 hour Average Ambient Ozone Concentrations (ppb) for Year 2016



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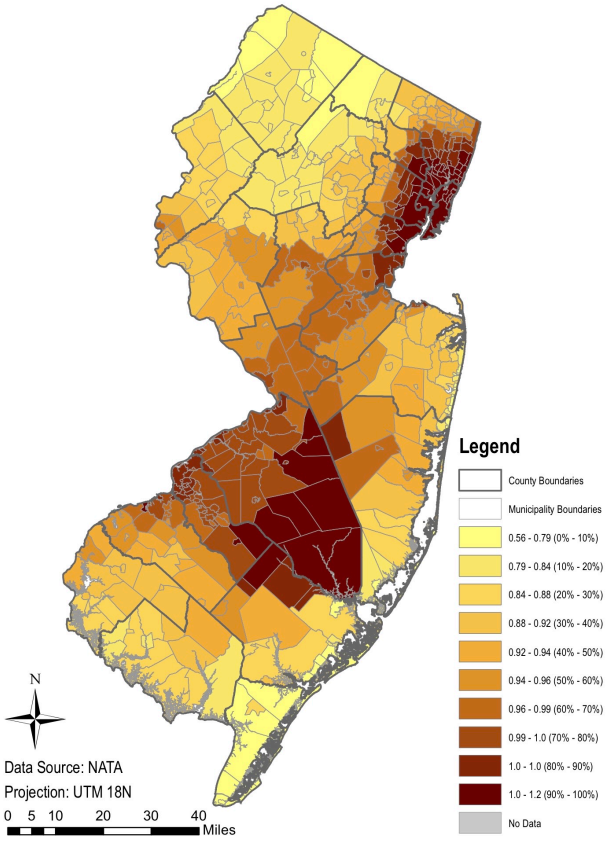
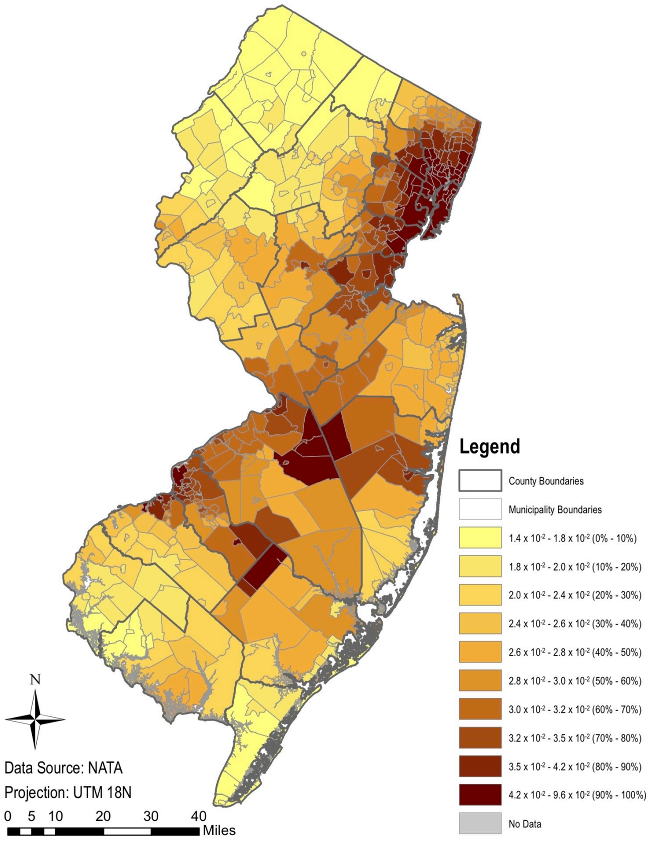
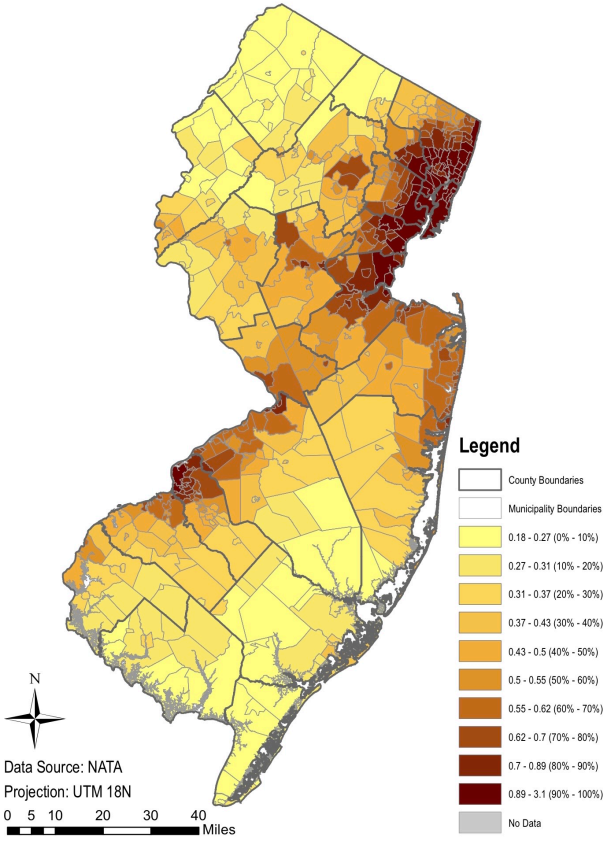
LEVELS OF AIR TOXICS ACROSS THE 565 NJ MUNICIPALITIES (MID-2010S)



Acetaldehyde (RfC 9 μg/m^3)



Acrolein (RfC 0.035 μg/m^3)



Diesel PM (RfC 5 μg/m^3)

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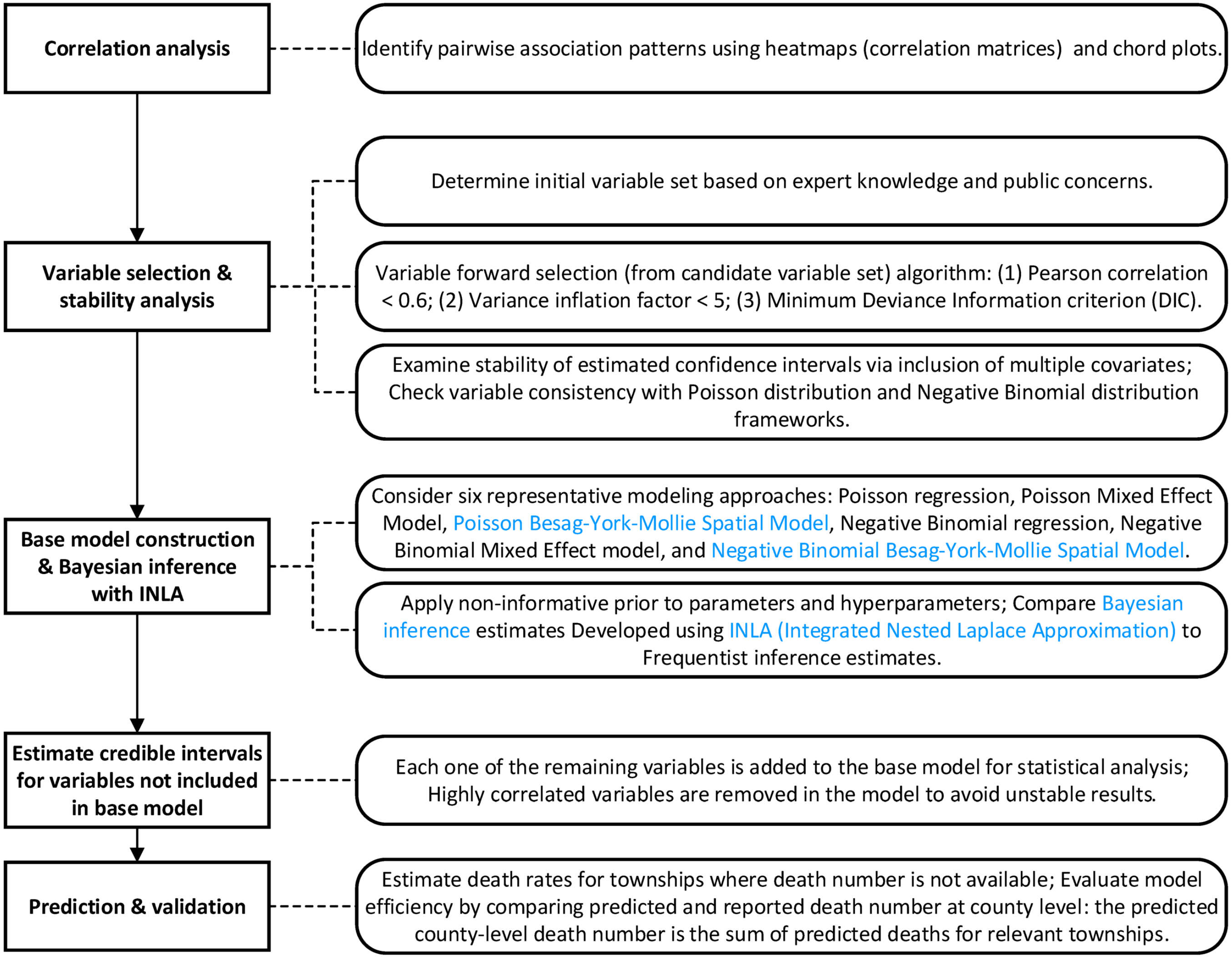
COVID-19 Exposure-Wide Association Study - NJ

A multivariate Bayesian spatial statistical modeling framework for quantifying local effects of environmental and socioeconomic and factors on COVID-19 outcomes



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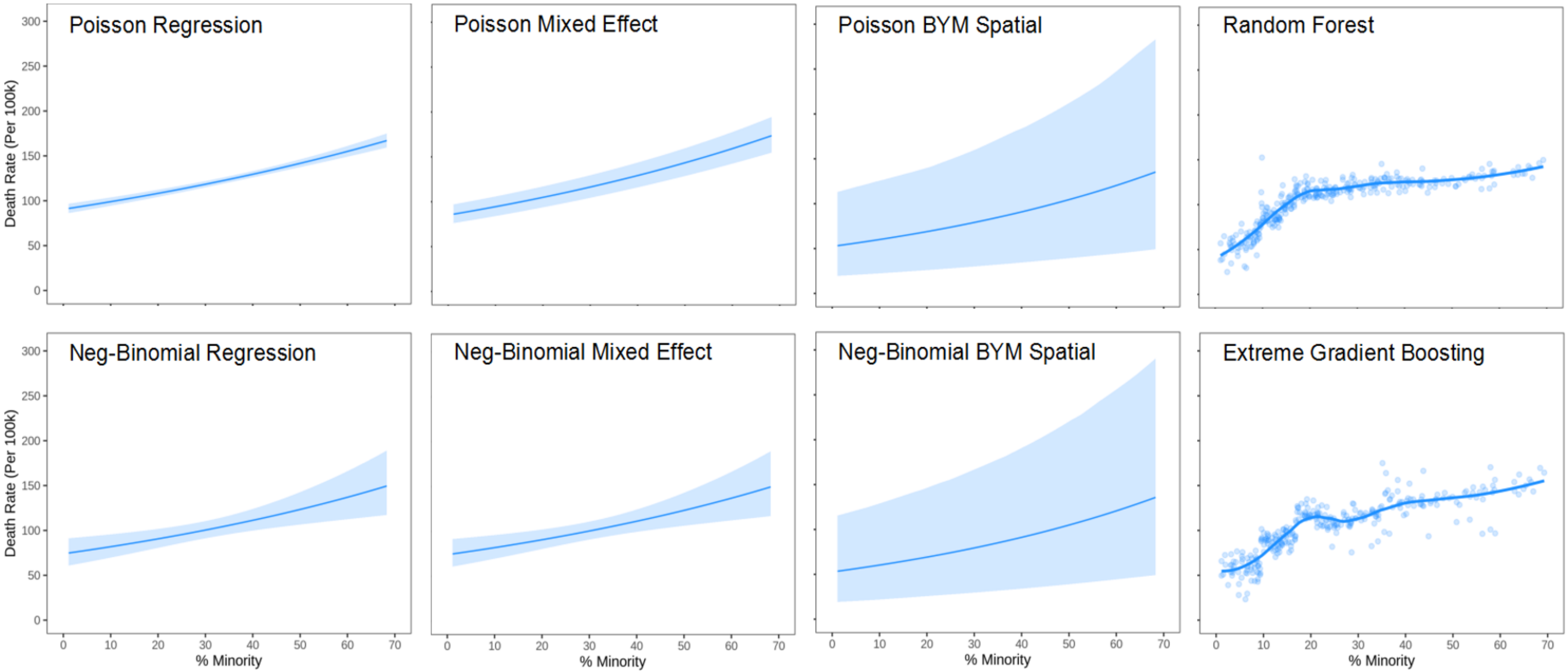
EXAMPLE RESULTS (% MINORITY VS COVID-19 DEATH RATE) ACROSS ALL NJ MUNICIPALITIES FROM SIX GEOSTATISTICAL AND TWO MACHINE LEARNING MODELS



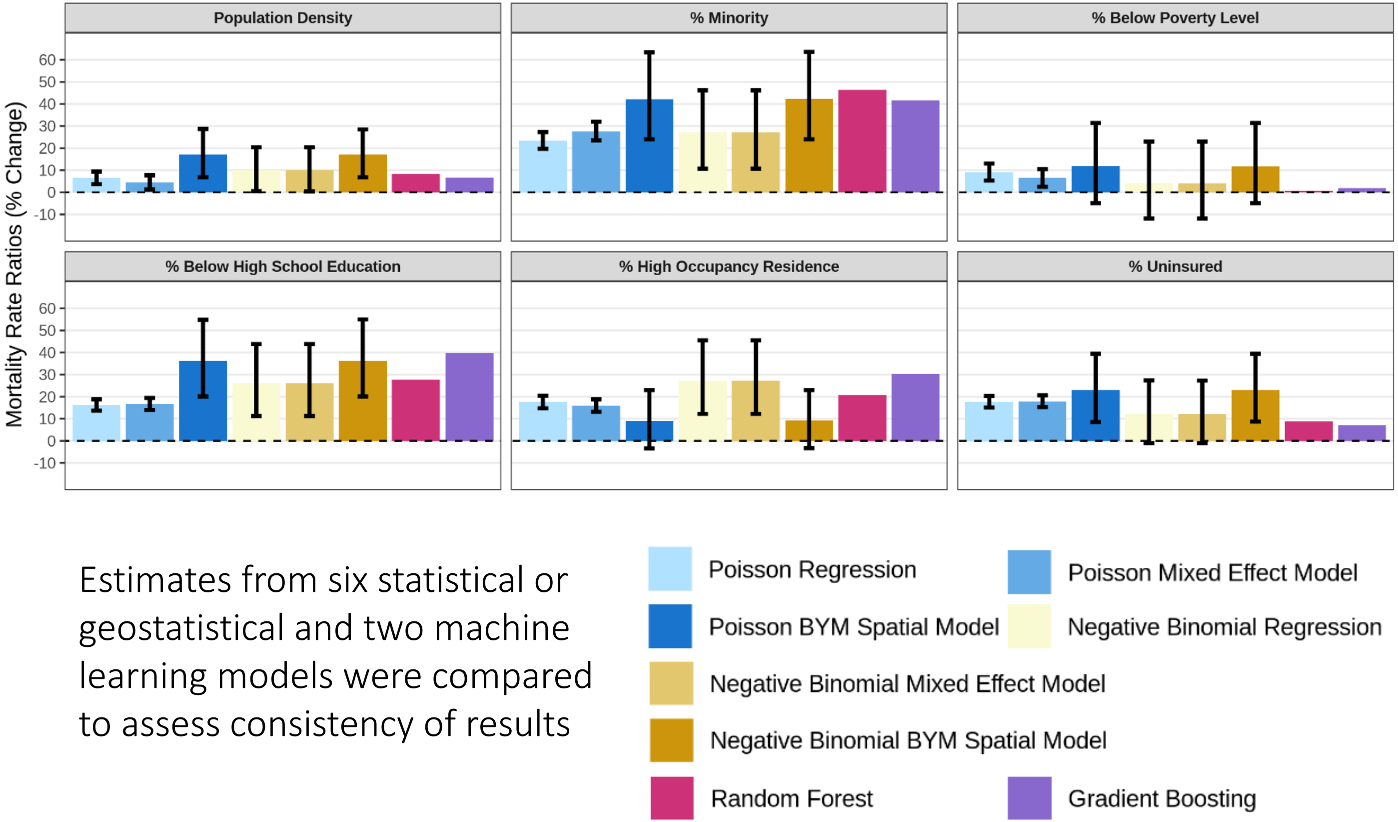
COVID-19 Mortality Rate Ratio Change for Selected Social Factors at Municipality Level across NJ

Expected % change in COVID-19 MRR per standard deviation of the factor with 95% confidence interval

Interpretation:

- A standard deviation increase (23.4%) in % minority is associated with 42.3% (24%, 63.6%) increase in mortality rate;
- a standard deviation increase (6.3%) in % below high school education is associated with 36.3% (20.1%, 55%) increase in mortality rate

(Ren *et al.,* 2023)



Estimates from six statistical or geostatistical and two machine learning models were compared to assess consistency of results