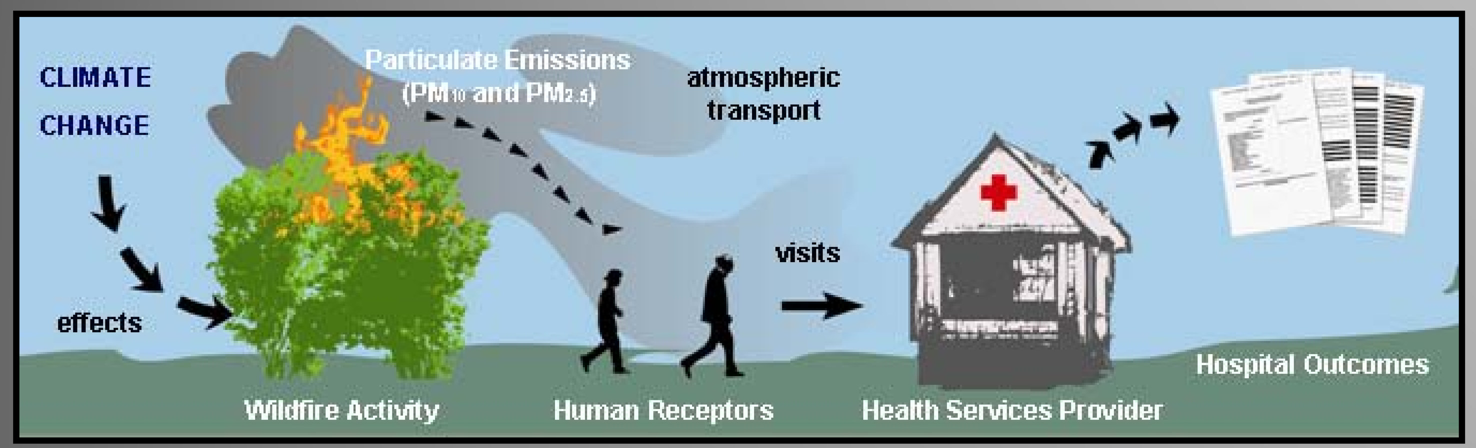
Respiratory Health Impacts of Wildfire Particulate Emissions under Climate Change Scenarios

Presented by N.H.F French & B.W. Koziol

Project Motivation & Research Objectives



The goal of this research is to better understand how to approach forecasting and preparedness for fire-driven air pollution events.
The project objectives are to develop methods to connect wildfire occurrence to health outcomes and to better understand how climate change will affect the frequency and intensity of wildland fire events that produce air quality conditions detrimental to respiratory health.

Syndromic Surveillance Health Data

San Diego County utilizes a locally developed SAS/Minitab/HTML-based syndromic surveillance system called San Diego Aberration Detection and Incident Characterization (SDADIC).

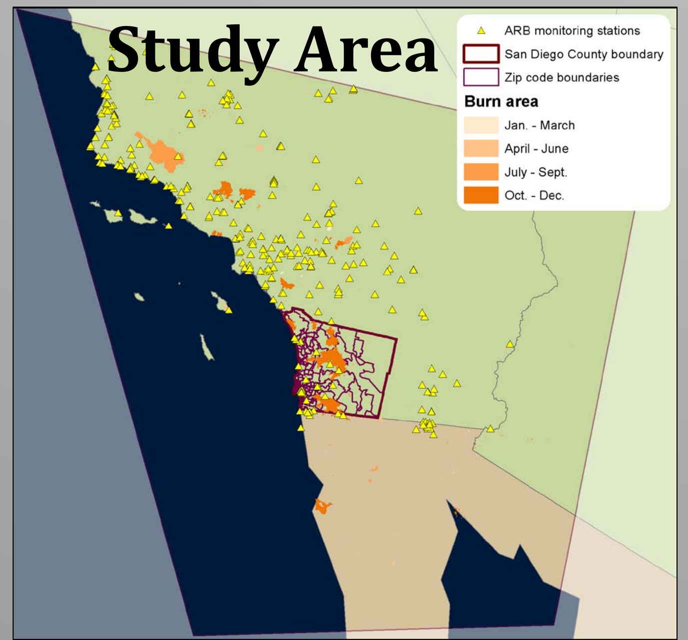
- The SDADIC surveillance system has been used for special events, the 2003 and 2007 wildfires, monitoring ILI trends, detecting reportable disease, chemical events and a case of radiation exposure.
- Ten hospitals participate representing about 50% of the county-wide encounters in a population of 3.2 million with enhancements in progress to include four more hospitals and real-time ADT HL7 data transfer.
- The County monitors 24 distinct syndromes daily that enable an all-hazards detection capability.
- Automated alerts are generated with statistical findings.

	2008	2007	2006
Time Period	Aug - Dec	Aug - Dec	Aug - Dec
Hospitals reporting	13	16	13
Emergency Patient Encounters	193,458	232,626	198,494
Percent of Total Encounters represented in data set	64.2%	86.6%	77.4%

Sample summary of health data for three of the six years used in this study. 2007 was a high wildfire year.

- For this project, data on 8 wildfire respiratory syndromes are included (respiratory, hazardous/toxic, respiratory/chest pain, eye irritation, COPD, burns, difficulty breathing, cardiac problems).
- Patients may be diagnosed with multiple symptoms characteristic of wildfire smoke exposure but SDADIC flags unique patient records to prevent double-counting.
- Data cover 2003 to 2008 inclusive from up to 16 hospitals.

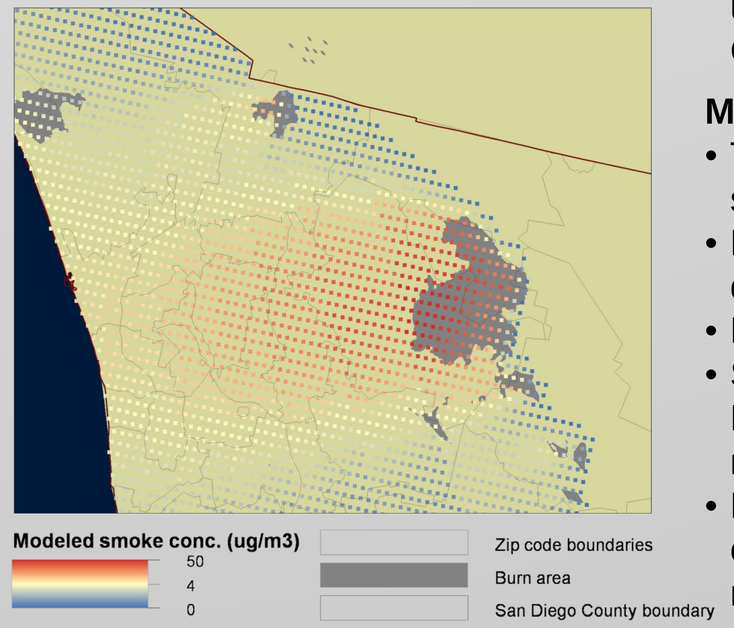
Study Area



The study area shown above is used to model the smoke impacting San Diego County. The comparison of the smoke concentration maps to health data is for zip codes within San Diego County, shown in purple.

Smoke Concentration Mapping

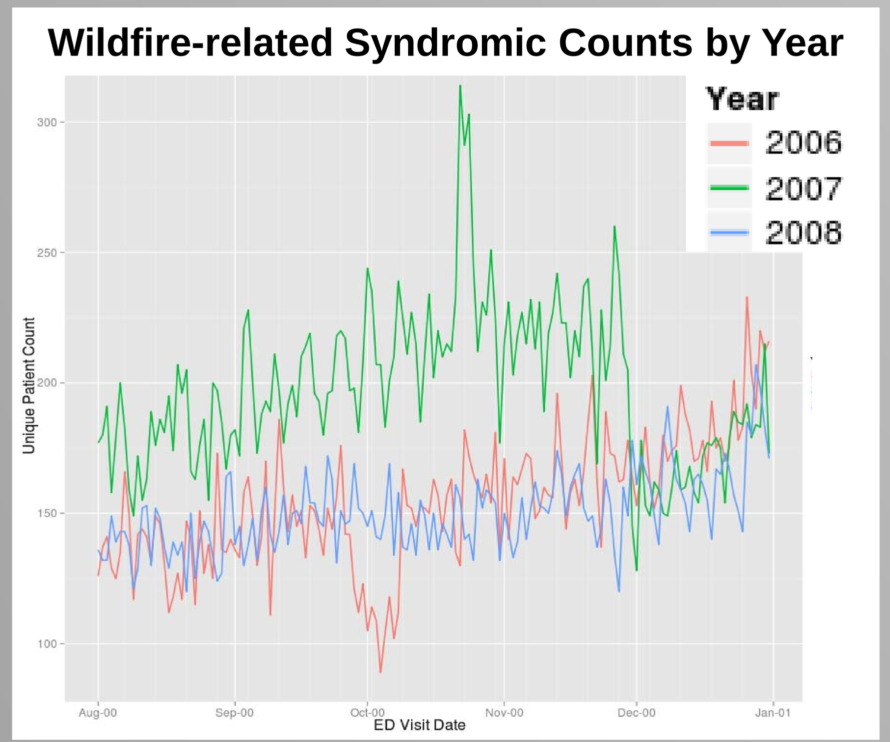
Transport of particulate matter (PM) emissions from 2007 wildland fires in San Diego County were modeled using the HYbrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model. Fire PM sources (2.5 and 10) were estimated using a statistical, empirically-based fuel consumption and emission model (CONSUME) parameterized using weather data and fuel loadings from the Fuel Characteristics Classification System (FCCS).



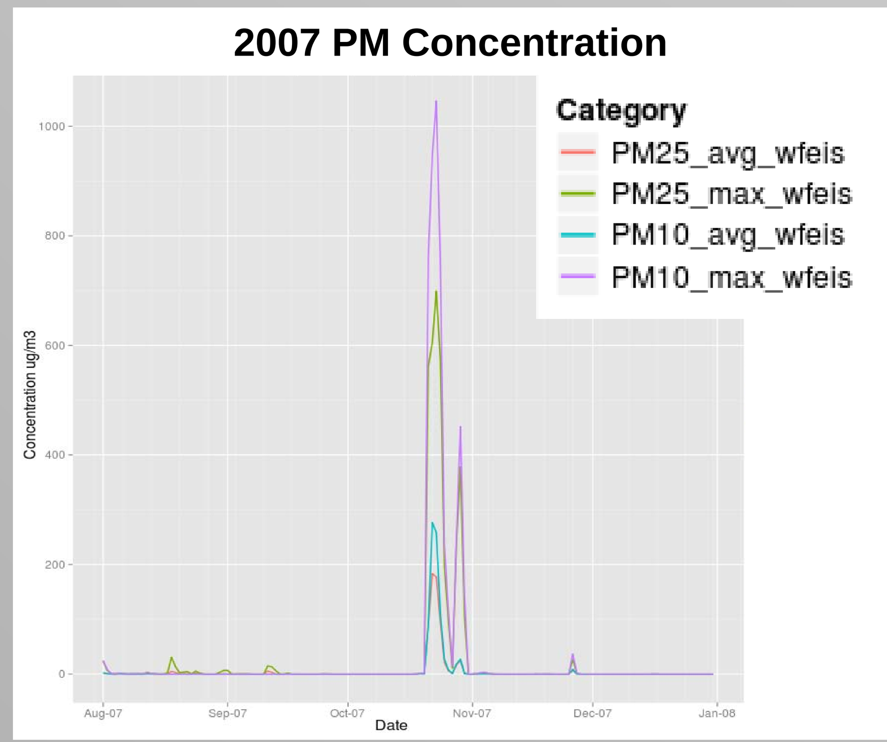
Model Parameters and Assumptions

- The model was run in the dispersion mode, which most accurately simulates the deformation of pollution plumes
- PM assumed to be a purely passive tracer, without reaction or deposition applied
- PM modeled for 3 days after emission
- Simulations driven with meteorological data from the NAM (Eta) Data Assimilation System (EDAS) with a 40 km horizontal resolution, 26 vertical levels, and output every 3 hrs
- Particle-only and hybrid puff-particle simulations were tested to optimize model performance (based off comparisons with surface measurements) and computational resources

Data Assessment & Model Development



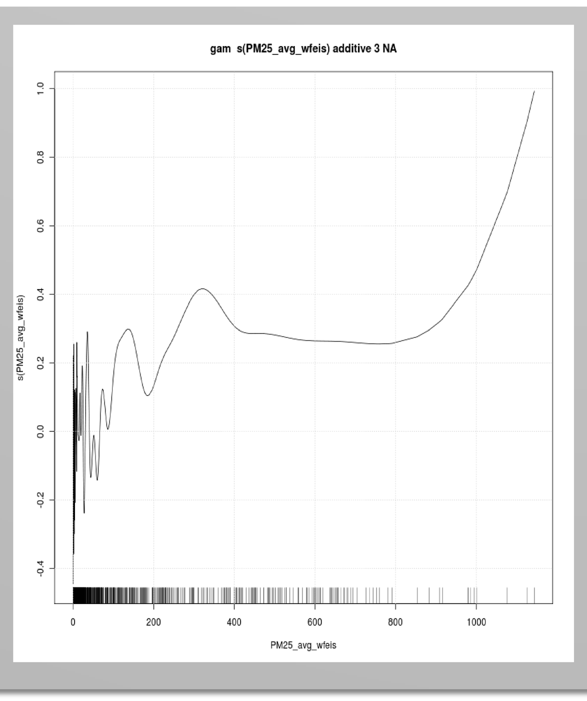
Above shows three years of patient counts for wildfire-related syndromes aggregated by date and zipcode. In 2007, the late October spike in patient ED visits is most likely associated with wildfire smoke. The 2006 and 2007 troughs are a result of non-reporting for some hospitals. Note larger counts overall for 2007 related to increased hospital response and environmental conditions specific to that year
(e.g. low humidity, high temperatures).

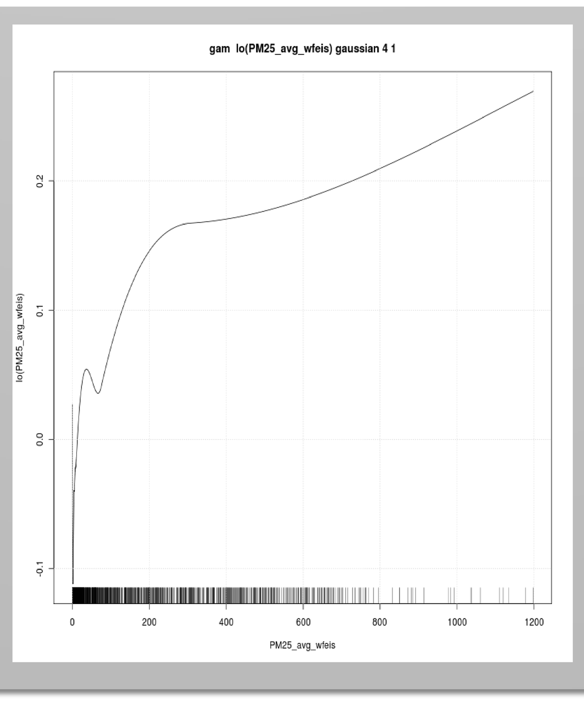


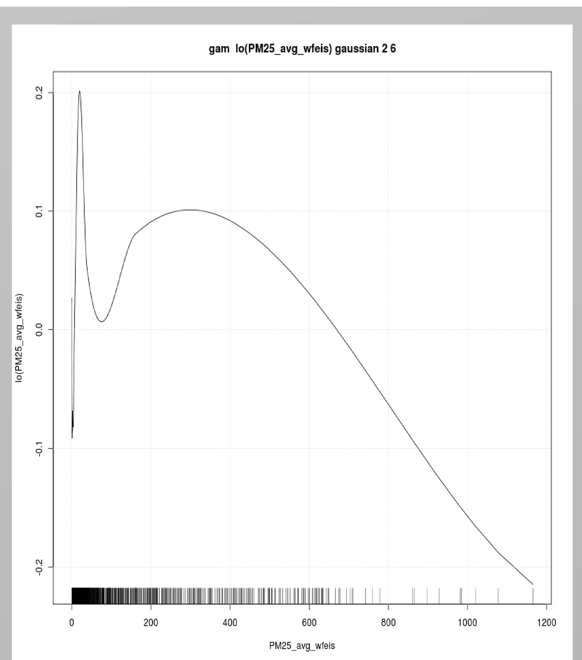
Zipcode-level PM metrics for wildfire are plotted in the above time series for dates in 2007. Notice the time-correlated spikes in PM and wildfire-related syndromes (plot to left) occurring from mid-October to early November. Identifying, and in some cases modeling, confounding variables is necessary to properly characterize the temporal trend evident in patient counts for the time preceding the fire-released PM. Potential confounding variables include weather-related measures (e.g. heat) and anthropogenic $PM_{2.5}$.

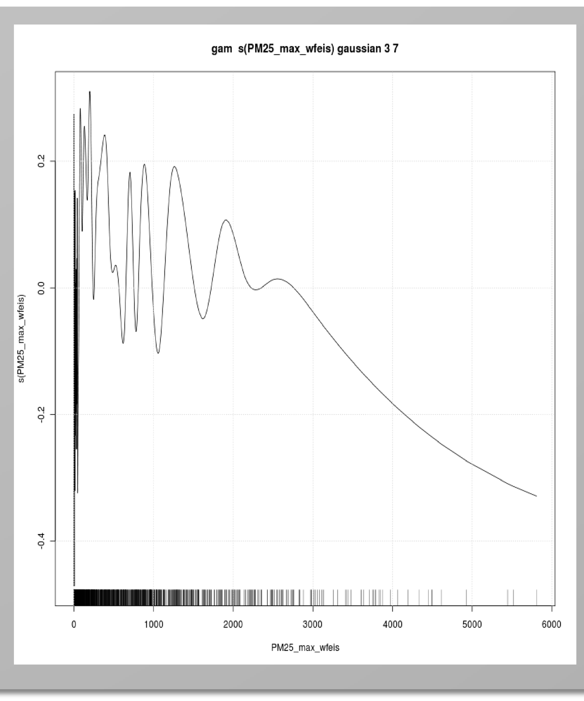
Analysis uses R (v2.13) with a PostgresSQL (v8.4)/PostGIS (v1.5) spatial database backend managed using Python (v2.6) & SQLAlchemy (v0.6).

- Wildfire PM effects are modeled using a syndromic binomial response (zipcode population used for normalization) variable fit using generalized linear and additive modeling with a logit link function.
- Univariate and multivariate formulations are currently under active investigation with deviance criteria used to asses goodness of fit for model selection purposes.
- In addition, lag effects (tdk) resulting from cumulative exposure to elevated PM levels are modeled via additive, Gaussian, and linear weighting functions.
- Scientific and professional judgment in addition to diagnostic plotting and fit metrics will be used to calibrate the shape parameters for the cumulative weighting functions.









Plots above are example "rugplots" for the fitted terms in a generalized additive model for the univariate case of wildfire $PM_{2.5}$ exposure. Hash marks along the bottom edge of the plots represent the density of values occurring in the observational data. Different weighting schemes, smoothing functions, and shape parameters are displayed demonstrating the sensitivity of the fitted terms to model form. The two plots to the left show an intuitive trend of increased ED patients with elevated PM levels while the right two show weighting schemes with over-attenuated lags parameters.

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Next Steps

Model development using historic data

- Continuation of statistical model development will include inclusion of additional variables including anthropogenic $PM_{2.5}$, wildfire PM_{10}, weather.
- Investigations to date indicate a relationship between wildfire activity (PM concentration) and health outcomes can be established.
- Models will be developed with the full six years of data, with accommodations made for data quality issues before 2006.

Development of future fire scenarios and potential respiratory health effects

- Future fire occurrence for 2015 to 2030 will be modeled based on climate change scenarios.
- Wildfire emission and smoke transport models will produce smoke predictions for climate scenarios.
- The health effects model developed with historic data will be applied to future PM conditions to predict possible health outcomes under future conditions..