Climate impact on airborne particulate matter concentrations in California using seven year analysis periods

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The effect of global climate change on the annual average concentration of fine particulate matter (PM2.5) in California was studied using a climate-air quality modeling system composed of global through regional models. Output from the NCAR/DOE Parallel Climate Model (PCM) generated under the "business as usual" global emissions scenario was downscaled using the Weather Research and Forecasting (WRF) model followed by air quality simulations using the UCD/CIT airshed model. The system represents major atmospheric processes acting on gas and particle phase species including meteorological effects on emissions, advection, dispersion, chemical reaction rates, gas-particle conversion, and dry/wet deposition. The air quality simulations were carried out for the entire state of California with a resolution of 8-km for the years 2000–2006 (present climate with present emissions) and 2047–2053 (future climate with present emissions). Each of these 7-year analysis periods was analyzed using a total of 1008 simulated days to span a climatologically relevant time period with a practical computational burden. The 7-year windows were chosen to properly account for annual variability with the added benefit that the air quality predictions under the present climate could be compared to actual measurements. The climate-air quality modeling system successfully predicted the spatial pattern of present climate PM2.5 concentrations in California but the absolute magnitude of the annual average PM2.5 concentrations were under-predicted by ~4–39% in the major air basins. The majority of this under-prediction was caused by excess ventilation predicted by PCM-WRF that should be present to the same degree in the current and future time periods so that the net bias introduced into the comparison is minimized.

Surface temperature, relative humidity (RH), rain rate, and wind speed were predicted to increase in the future climate while the ultra violet (UV) radiation was predicted to decrease in major urban areas in the San Joaquin Valley (SJV) and South Coast Air Basin (SoCAB). These changes lead to a predicted decrease in PM2.5 mass concentrations of ~0.3–0.7 $\mu g\ m^{-3}$ in the southern portion of the SJV and ~0.3–1.1 $\mu g\ m^{-3}$ along coastal regions of California including the heavily populated San Francisco Bay Area and the SoCAB surrounding Los Angeles. Annual average PM2.5 concentrations were predicted to increase at certain locations within the SJV and the Sacramento Valley (SV) due to the effects of climate change, but a corresponding analysis of the annual variability showed that these predictions are not statistically significant (i.e. the choice of a different 7-year period could produce a different outcome for these regions). Overall, virtually no region in California outside of coastal + central Los Angeles, and a small region around the port of Oakland in the San Francisco Bay Area experienced a statistically significant change in annual average PM2.5 concentrations due to the effects of climate change in the present~study.

The present study employs the highest spatial resolution (8 km) and the longest analysis windows (7 years) of any climate-air quality analysis conducted for California to date, but the results still have some degree of uncertainty. Most significantly, GCM calculations have inherent uncertainty that is not fully represented in the current study since a single GCM was used as the starting point for all calculations. The PCM results used in the current study predicted greater wintertime increases in air temperature over the Pacific Ocean than over land, further motivating comparison to other GCM results. Ensembles of GCM results are usually employed to build confidence in climate calculations. The current results provide a first data-point for the climate-air quality analysis that simultaneously employ the fine spatial resolution and long time scales needed to capture the behavior of climate-PM2.5 interactions in California. Future downscaling studies should follow up with a full ensemble of GCMs as their starting point, and include aerosol feedback effects on local meteorology.

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