Potential Local to Regional Scale Impacts from Wildfire Re-emission of Hypothetical Radiological Contamination Incidents

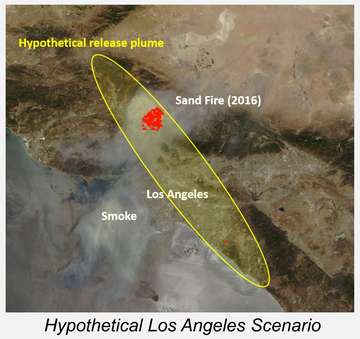
Kirk Baker[a], Sang Don Lee[a], Paul Lemieux[a], Scott Hudson[a], Wei Min Hao[b], Stephen Baker[b], Emily Lincoln[b] [a] U.S. Environmental Protection Agency, [b] U.S. Forest Service

Kirk Baker | baker.kirk@epa.gov

Background

Radiological release incidents can potentially contaminate wide areas with radiological materials. Decontamination efforts are typically focused on populated areas which means radionuclides may be left in forested areas for long periods of time. Large wildfires in contaminated forested areas have the potential to reintroduce these radionuclides into the atmosphere and cause exposure risks to first responders and downwind communities. The most notable radionuclide contaminant released from radiological incidents is radiocesium (137Cs) due to high yields and long half-life of 30.2 years. An Eulerian 3D photochemical transport model was used to estimate potential ambient impacts of 137Cs re-emission due to wildfire following hypothetical radiological release scenarios.

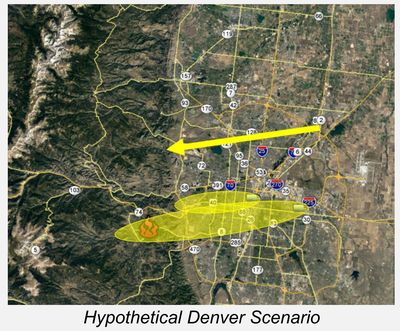
Photograph of a wildfire in a forested region of Japan contaminated by radioactive material. Source: http://wildfiretoday.com/2017/05/06/firefighters-faced-with-wildfire-in-radioactive-area-near-fukushima-nuclear-power-plant/



Hypothetical Los Angeles Scenario

The Community Multiscale Air Quality (CMAQ) model was applied to estimate local to regional scale 137Cs impacts for an area covering northern Colorado and southern California using 4 km sized grid cells. Emissions from a large hypothetical wildfire were introduced into the wildland-urban interface (WUI) impacted by a previous hypothetical radiological release event. Episodes were selected to capture typical fire seasons in these areas.

For modeling purposes, laboratory based particulate matter (PM) 133Cs emission factors were adjusted downward based on a comparison of the laboratory measurements of 133Cs in the initial fuel with multiple sources of post-incident 137Cs litter fuel contamination levels measured near Fukushima and Chernobyl.



Hypothetical Denver Scenario

PM Cs emissions were based on a laboratory study that examined the partitioning of 133Cs (a stable, non-radioactive isotope of Cs) between airborne particulate matter and residual non-entrained ash when pine needles and peat were doped with Cs. Table 1 provides information used to generate PM 133Cs emissions, which include laboratory experiments measuring fuel, 133Cs content of the fuel, and 133Cs measured in the air as a rate of mass per fuel burned (g133Cs/kg litter burned). Table 1 includes measurements reported in Hao et al., (2018) and additional measurements performed in 2018 at the same facility following methods described in Hao et al., (2018).

Left: Picture of fire emissions testing at Missoula Fire Sciences laboratory burn chamber (schematic at right)

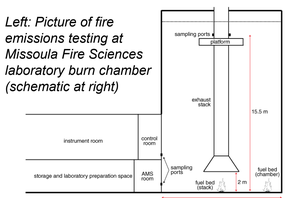
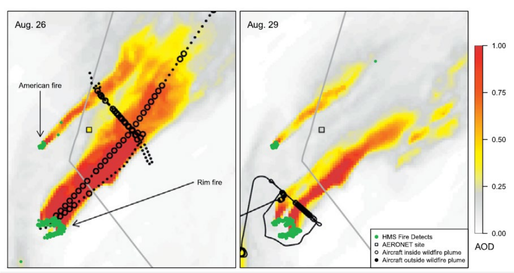


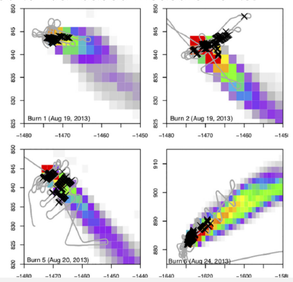
Table 1. Laboratory measurement data.

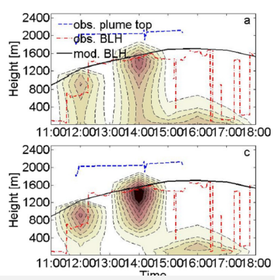
		Fuel Measurements				Ambient PM2.5			Ambient Coarse PM			Ambient PM > 10 microns		
Run	Fuel type	Fuel Weight (kg)	Fuel Burned (kg)	Cs Fuel Weight (g)	Cs per Fuel Weight (g/kg)	Total Cs in PM25 (g)	Cs emitted of total fuel burned (g/kg)	% Cs emitted of Cs fuel	Total Cs in coarse PM (g)	Cs emitted of total fuel burned (g/kg)	% Cs emitted of Cs fuel	Total Cs in PM > 10 micron (g)	Cs emitted of total fuel burned (g/kg)	% Cs emitted of Cs fuel
March 2016 run 6	Pine needle	5.55	5.2	9.6	1.7	0.03	0.006	0.004	0.00	0.000	0.00	0.11	0.021	1.15
March 2016 run 7	Pine needle	5.24	4.9	13.3	2.5	0.000	0.000	0.000	0.00	0.000	0.00	0.31	0.063	2.33
March 2016 run 8	Pine needle	5.16	4.8	10.8	2.1	0.000	0.000	0.000	0.00	0.000	0.00	0.12	0.025	1.11
Feb 2018 run 1 (blank)	Pine needle	6.65	6.35	0.04	0.0066	0.000	0.000	0.000	0.00	0.000	0.00	0.00	0.000	0.00
Feb 2018 run 2 (blank)	Sage	5.82	5.60	0.05	0.0085	0.000	0.000	0.000	0.00	0.000	0.00	0.00	0.000	0.00
Feb 2018 run 3	Pine needle	6.29	5.84	8.81	1.4	0.000	0.000	0.000	0.00	0.000	0.00	0.43	0.074	4.93
Feb 2018 run 4	Pine needle	6.29	5.79	8.81	1.4	0.000	0.000	0.000	0.00	0.000	0.00	0.26	0.044	2.91
Feb 2018 run 5	Pine needle	6.32	5.85	8.84	1.4	0.000	0.000	0.000	0.05	0.008	0.52	0.59	0.100	6.63
Feb 2018 run 6	Sage	6.15	5.91	9.84	1.6	0.000	0.000	0.000	0.00	0.000	0.00	0.05	0.009	0.52
Feb 2018 run 7	Sage	6.20	5.94	14.26	2.3	0.000	0.000	0.000	0.00	0.000	0.00	0.55	0.092	3.85
Feb 2018 run 8	Sage	5.80	5.51	9.87	1.7	0.000	0.000	0.000	0.04	0.008	0.46	0.13	0.024	1.33

Wildfire Plume Transport Evaluations for the CMAQ model

Separate evaluation has been done comparing CMAQ-predicted wildfire smoke plumes against satellite products (left), aircraft chemical measurements (center), and lidar plume top measurements (right). These studies suggest the modeling system does well at representing local to regional scale smoke transport and vertical placement of smoke plumes (Baker et al, 2018; Zhou et al, 2018). Not shown, but the modeling system also does well representing the surface mixing layer height in southern California and Denver compared to lidar based measurements.







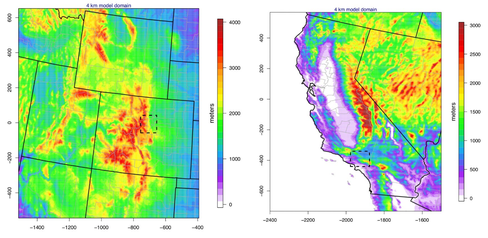
Acknowledgements: The authors would like to recognize the contributions of James Beidler, Chris Allen, Lara Reynolds, Kathy Brehme, Luke Valin, Jim Szykeman

U.S. Environmental Protection Agency
Office of Air Quality Planning & Standards

Modeled Impacts

Figure at Right. Episode maximum modeled ambient concentration for 137Cs in for the hypothetical Denver scenario and both Los Angeles hypothetical scenarios. Maximum exposure for each episode at 4 km (left column) and 1 km (right column).

Figure below. Model domains for Denver (left) and California (right). The extent shown for each region represents the entirety of the 4 km square sized grid cell domain. The 1 km domains are shown as dashed black lines. Color contours show terrain height.



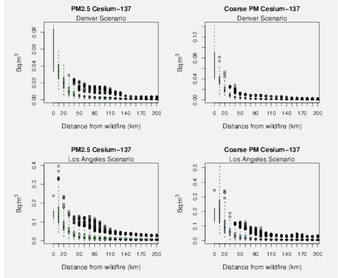
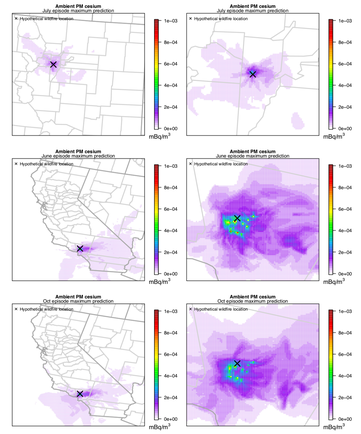


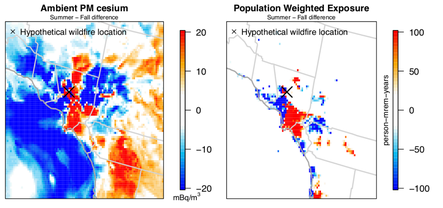
Figure above. Distribution of hourly maximum modeled ambient PM2.5 and coarse PM 137Cs by distance from the wildfire.

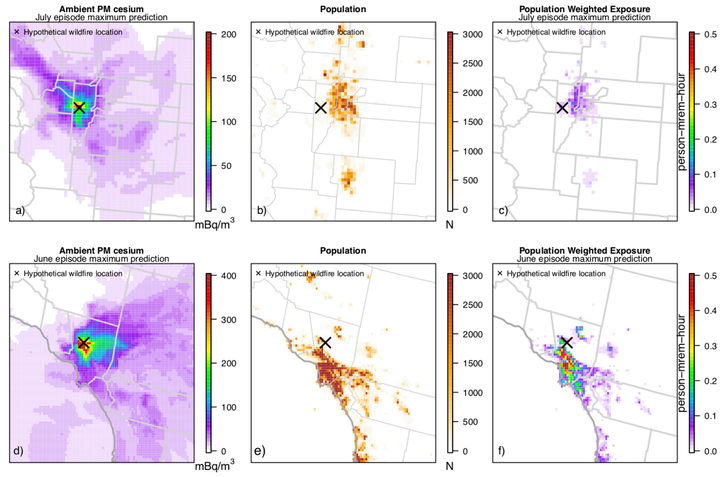


Modeled Exposure

Figure at right. Episode maximum values of PM2.5 cesium dosage, population, and population exposure shown for the Denver (top row) and June Los Angeles (bottom row) hypothetical scenarios.

Figure below. The difference in episode maximum values of PM2.5 cesium dosage (left) and population exposure (right) are shown between the June and Fall Los Angeles hypothetical scenarios. Warm colors indicate higher levels in the summer scenario and cool colors show higher levels in the fall scenario.





Conclusions & Implications

- While ambient concentrations tended to be highest near the fire, highest exposure (person-rems) was downwind where wind flows moved smoke to high population areas.
- Seasonal variations in meteorology (wind flows) can result in differential population impacts even in the same metropolitan area.
- Modeled hypothetical incident ambient levels 137Cs both near these wild fires and further downwind in nearby urban areas were well below levels that would necessitate population evacuation or warrant other protective action recommendations such as shelter-in-place.
- These results suggest that 1) decontamination efforts focused on forests should not be elevated in priority solely based on potential downwind exposures due to future wildfires in the contaminated area and 2) firefighters would not be expected to be at elevated risk from 137Cs re-emission.

- Baker, K., Woody, M., Valin, L., Szykman, J., Yates, E., Iraci, L., Choi, H., Soja, A., Koplitz, S., Zhou, L., 2018. Photochemical model evaluation of 2013 California wild fire air quality impacts using surface, aircraft, and satellite data. Science of The Total Environment 637, 1137-1149.
- Hao, W.M., Baker, S., Lincoln, E., Hudson, S., Lee, S.D., Lemieux, P., 2018. Cesium emissions from laboratory fires. Journal of the Air & Waste Management Association 68, 1211-1223.
- Zhou, L., Baker, K.R., Napelenok, S.L., Pouliot, G., Elleman, R., O'Neill, S.M., Urbanski, S.P., Wong, D.C., 2018. Modeling crop residue burning experiments to evaluate smoke emissions and plume transport. Science of The Total Environment 627, 523-533.