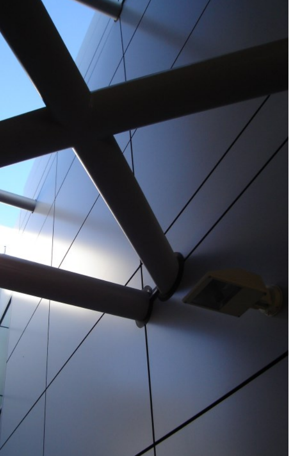

MECHANICAL ENGINEERING

The Department of Mechanical Engineering presents:

The Ph.D. Dissertation Defense of

Christian Bartolome

Thursday, September 18, 2014, 10AM
in Bourns Hall A265

Laboratory and Numerical Modeling of the Formation of Superfog from Wildland Fires

Doctor of Philosophy, Graduate Program in Mechanical Engineering
University of California, Riverside, September 2014
Dr. Marko Princevac, Chairperson

Prescribed burns are a common tool used by wildland managers to reduce hazardous fuel accumulations, enhance wildlife habitat, and stimulate plant regeneration. In 2011, an estimated 8.18×10^6 ha were treated with prescribed fire in the United States, 2.62×10^6 ha were burned for forestry purposes in the southern U.S. Smoke management for prescribed burning has long been a concern because of the potential impacts on air quality and visibility. In rare cases a combination of smoke and fog has crossed over major roadways leading to visibility less than 3 meters, a condition known as superfog resulting in traffic accidents. On the morning January 9, 2008, on the I-4 in Polk County Florida, a superfog event resulting from a nearby prescribed fire caused a 70 car pileup which resulted in 5 fatalities and 38 injuries. In 2011 wildfires caused low visibility events resulting in numerous highway closures over a 3 month period at the Great Dismal Swamp National Wildlife Refuge. There were isolated vehicular accidents caused by low visibility despite the best efforts of highway management. In December 2011 marsh wildfire smoke caused superfog conditions leading to a major car pileup on the I-10 in New Orleans, LA. The accident caused 2 deaths and 61 injuries. In January 2012 a superfog event formed from a nearby wildfire on the I-75 near Gainesville, FL. The pileup included 7 semi-trucks and 12 cars. This tragic incident claimed 10 lives and left 21 injured. Research on the physics and conditions for superfog formation were investigated to assist land managers in the planning of safe prescribed burns in the future.

Superfog is currently hypothesized to form during the smoldering phase of a wildland fire in the night hours. The smoldering phase releases primarily water vapor and particles that can act as cloud condensation nuclei (CCN). Mixing between the cool ambient air, hot water vapor, and CCN will lead to condensation into droplets. The presence of numerous droplets in air causes extreme light scattering, thereby reducing visibility. Physical modeling of droplet formation and measurements of droplet size distributions has been investigated. A combination of 2-dimensional advection diffusion modeling with heat and vapor flux from soils have been applied for stable boundary layer conditions. This model has been developed into an executable program for land managers known as the Superfog Assessment Model (SAM).

Laboratory experiments in a wind tunnel using pine needle fuels beds investigated the impacts of ambient temperature, humidity, fuel moisture content, and fuel bed configuration. Heat and vapor fluxes from smoldering fuel beds were measured to be approximately $1.6\times10^{-3}\ g\ m^{-2}\ s^{-1}$ and $1\ W\ m^{-2}$. Boundary layer experiments in the wind tunnel were used to validate the SAM model.
Through physical modeling and laboratory experiments parameters likely to form superfog have been found. Superfog is likely to form when the wind speeds is less than $1.0\ m\ s^{-1}$, temperature is less than 5^oC, relative humidity is greater than 80%, fuel moisture content is greater than 40%, particles with size 1 mm or smaller, and concentration of particles $10^5\ cm^{-3}$ or greater.