

CRITICAL FINDINGS

From Fire to Plume: The Role of Vorticity and Fuel Moisture on the Near-Field Plume Structure and Ember Dynamics

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TECHNOLOGY OVERVIEW

- Physics-based models using computational fluid dynamics and energy budget analyses describe the structure and dynamics of heat, moisture, and embers.
- New models consider the effects of fuel moisture, canopies, fire intensity, and atmospheric stratification on the near-field plume.
- High-resolution measurements near the flame sheet characterize vorticity and entrainment.
- Wind fields are statistically characterized as wind libraries using the offset elliptical normal (OEN) model.
- Fire Dynamic Vision (FDV) provides statistical characterizations of the near-field plume and fire spread.
- Data-driven models and simplified models provide statistical characterizations of simulations of the near-field plume.
- Simulated data, FDV, and OEN, including a desktop application, are distributed through the SERDP Wildland Fire Science Initiative (WFSI) data portal.

- Simulated and measured data were statistically analyzed and validated with results from the literature.
- Analyzed datasets, software, and wind libraries were disseminated through the WFSI data portal.

CRITICAL FINDINGS

- A vorticity budget equation revealed how forest canopies and burn unit edges influenced vorticity and fire behavior.
- Fuel moisture content (FMC) affected the turbulence structure within the plume: low FMC enhanced the decay of vortical energy, while high FMC maintained more coherent vortical structures.
- Thermal conditions of embers affected their lift and drag coefficients, thereby affecting their transport properties.
- Plume height could be parameterized in terms of the Byram's convective number, buoyancy flux, and Brunt-Väisälä frequency.
- The OEN model provided a richer characterization than traditional wind roses, including detailed information about wind-generating mechanisms (see Figure).
- Parameterizing plume behavior using data-driven neural networks required prohibitively large amounts of clean data.
- FDV effectively captured statistical descriptions of fire and plume dynamics.
- Physics-based models could be trained with substantially less data than required for data-driven networks.

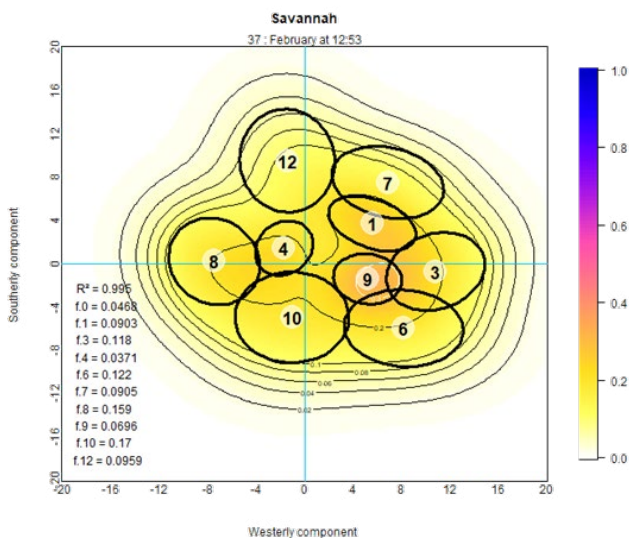
About SERDP

The Strategic Environmental Research and Development Program (SERDP) develops and demonstrates innovative, scalable technologies that enhance military readiness, improve warfighter capabilities, and strengthen defense infrastructure. The programs prioritize common sense, cost-effective solutions that support operational effectiveness and reduce regulatory burdens at military installations.

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The Offset Elliptical Normal model applied to data collected in February at the Savannah airport. The colors represent probabilities of observing a particular wind, and each ellipse corresponds to a particular wind mechanism. The legend shows the frequency of each of the ellipses.

RESEARCH APPROACH

- Five technical objectives focused on physics-based modeling, high-resolution measurements, and data-driven models.