Numerical Simulations of the Meteorological Conditions Above a Grassfire on a Slope

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Introduction

• In this study we utilize the Advanced Regional Prediction System (ARPS) model to examine the meteorological conditions above a grassfire on a steep (~30%) slope.
• This work is one part of a two-part modeling effort to simulate smoke behavior associated with a prescribed grassfire at a U.S. Environmental Protection Agency (EPA) Superfund site near Palmerton, PA.
• In this presentation we describe a multi-scale atmospheric modeling approach and examine
  o simulated meteorological conditions likely to influence smoke behavior predictions, including mean and turbulent flow in the vicinity of the fire
  o parcel trajectories to help visualize transport of air parcels released from the burn site at different stages during the fire

Field Experiment

• Prescribed fire was conducted on 14 April 2013 at Lehigh Gap EPA Superfund Site near Palmerton, PA.
• The topography in the vicinity of the burn site consisted of a west-southwest – east-northeast oriented ridgeline, with the burn site located on the north-facing slope (left image).
• Vegetation consisted primarily of dried grasses with scattered defoliated trees; areas of exposed shale rock were also present.
• Three instrumented flux towers (control, crank-up, pole; center and right images) collected data prior to, during, and following the burn.
• Test image: Test burn began in northeast corner at 1212 EST (#1); ignition continued along southeast perimeter 1212-1325 EST (#1-2); fire spread downslope along western perimeter 1325-1346 EST (#4); ignition along northwest flank about 1356 EST (#7). Apuole headline followed; burn completed by 1400 EST.

ARPS Model Overview

• ARPS Version 5.12
  o Developed at the University of Oklahoma (Xue et al. 2000, 2001, 2003)
  o Three-dimensional atmospheric modeling system
  o Designed to simulate macroscale [O(10 m)] – mesoscale [O(100 m)] flows and utilizes a terrain-following coordinate system
  o May be initialized with a 3D external dataset (e.g., reanalysis data) or with a single sounding (homogeneous initialization)
  o Numerous options for configuring physical parameterizations (e.g., sub-grid scale turbulence)
  o Extensive suite of post-processing software (e.g., 2D and 3D plotting, soundex extraction, parcel trajectory code, data conversion, model verification)
  o Clean well-documented code well-suited to user modification (e.g., ARPS-CANOPY (Kiefer et al. 2013))
• ARPS is run in one-way nested mode with five domains (see table)
  o Initial and boundary conditions for D1 provided by 12-km North American Mesoscale (NAM) model
  o D1-D4: U.S. Geophysical Survey (USGS) terrain and land-cover data (30-arc sec) interpolated to model grid
  o D5: Shuttle Radar Topography Mission (SRTM) terrain data (1-arc sec) interpolated to model grid; USGS roughness length manually adjusted
• D5: Fire parameterized as surface heat flux. Steady heat flux value (5 kW m$^{-2}$) derived from flux tower data. Timing based on tower data, photographs, and video.

Model Configuration

• Test burn
  o 1212 EST release time
  o Western perimeter: 1346 EST release time
  o Test burn
  • ARPS simulations of wind speed and direction, temperature, and turbulent kinetic energy (TKE) (Fig. 1)
  • Parcel trajectory analysis
  • Boundary flux towers are labeled.

Summary and Conclusions

• ARPS model has been applied to a prescribed fire event at an EPA Superfund Site in complex terrain near Palmerton, PA.
• Model produces too little TKE and somewhat underestimates wind speeds at the flux tower locations; temperature is underestimated, although temperature trends are captured by the model.
• Parcel trajectory analysis suggests that transport of air parcels through gap is sensitive to where in burn unit parcels are released and whether parcels are released during early or later stages of the burn event.
• Ongoing efforts include (1) investigation into TKE underestimation by the model and (2) simulation of smoke transport/diffusion and validation against particulate matter (PM2.5) and carbon monoxide (CO) measurements.

Acknowledgements

Support for this research was provided by Environmental Protection Agency (Emergency Action No. 114A-1124230-03). Special thanks go to the Lehigh Gap Nature Center, Silvex, LLC, the PA Department of Natural Resources, and the fire departments of East Penn Township, Bowmanstown and Palmerton, PA.