P2

Evaluation of the WRF-Fire model with observational data from a prescribed fire experiment

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1. Introduction

Low-intensity prescribed fires (LIPF) can be a viable tool for managing forest ecosystems. However, LIPF may modify the atmospheric environment by inducing fire-atmosphere interactions that can lead to turbulence production in and around the fire front. As part of a Joint Fire Science Program project to develop modeling tools for predicting smoke dispersion from LIPF, the USDA Forest Service - Northern Research Station conducted LIPF experiments on March 20, 2011and again on March 6, 2012 on 2 different forested plots in the New Jersey Pine Barrens. These experiments collected various meteorological and air-quality data using several meteorological towers and surface stations within and around the burn plots, and the data have been used for model evaluation. In this poster, we report the work on using the meteorological data from the March 6, 2012 LIPF experiment to evaluate the coupled atmosphere and fire modeling system called WRF-FIRE that is based on the Weather Research and Forecasting (WRF) numerical weather prediction (NWP) model and the SFIRE surface wildland fire behavior module. Unlike some other fire behavior models where the coupling is one-way, i.e., atmospheric data are used to drive the fire behavior model and no feedback from the fire to the atmospheric environment is allowed, the in-core or two-way coupling of the WRF NWP model with a wildland fire physics module allows explicit treatment of the effects of a wildfire on the atmospheric environment and the feedback to fire behavior. Although recent studies have used WRF-FIRE to examine the sensitivity of simulated fire characteristics to external factors known to affect fire behavior, the WRF-FIRE model has not been validated extensively by real-world observations. This is because the coupled model has been made available to the user community only recently and because validation of such a system requires detailed measurements of both fire behavior and conditions of the atmosphere surrounding the fire. The LIPF experiment provides a unique opportunity to evaluate WRF-Fire using real-world data. The evaluation focuses on how qualitatively well WRF-FIRE is able to reproduce the observed meteorological fields in the burn plot.

2. Model configuration and observational data

In WRF-FIRE, the coupling between fire and the atmospheric environment is two-way: wind velocity from WRF is used in calculating the rate of spread of fires while the heat released from the fire feeds back into WRF dynamics affecting the atmosphere in the vicinity of the fire. For this study, the WRF NWP model is configured with 4 two-way nested grids with a grid resolution ranging from 6250 m in the outermost grid to 50 m in the innermost grid (Table 1). The outermost domain is 500 km x 500 km in size that encompasses the Northeast US and a portion of northwestern Atlantic Ocean while the innermost domain is 4 km x 4 km in size that is centered over the burn plot in the New Jersey Pine Barrens (Fig. 1). All four domains use the same vertical grid configuration with 43 vertically stretched levels with the lowest level at about 7 m above ground level (AGL). At the surface of the innermost grid, 10x10 fire cells occur within each atmospheric cell. The time-step for WRF is 15 s for the outermost grid and 0.56 s for the innermost domain. The static surface data needed by the WRF-Fire model are downloaded from the Landfire website (http://landfire.cr.usgs.gov/viewer/), which includes the U.S. 13 Anderson fire behavior fuel model data and topographic elevation data, all at 30 m resolution. The surface fuel at each point is specified categorically using 13 standard fire behavior fuel models.

Four simulations were performed (Table 2). Two of the simulations are designed to examine the influence of fire on the atmospheric environment by turning the fire on or off. Another two simulations compare the RANS (Reynolds-average Navier-Stokes) approach with the LES (Large-eddy simulation) approach in WRF. The RANS approach integrates the whole turbulence spectrum so that turbulence modeling assumptions are required for the statistical closures. The LES approach applies a filtering operation to the Navier-Stokes equations and resolves explicitly the dynamics of the unsteady large scales of turbulence while modeling the small scale turbulence motions. All four simulations were run for 36 hours starting at 00:00 UTC, Mar. 6, 2012 and continuing until 12:00 UTC, Mar. 7, 2012, with 6 hours of spin-up time. The model was initialized with data from the North American Regional Reanalysis (NARR). For the two simulations with fire, the fire was ignited near the southern boundary of the plot at 1500 UTC (1000 EST) Mar. 6 and continued for 14 hours to end at 0500 UTC (0000 EST) Mar. 7 near the northwest corner of the plot (Fig. 2). Note that this was not how the actual managed backing fire on Mar. 6 spread across the plot. Because of the differences between the actual fire and the way the fire was set up in the model, it is impractical to compare the model results with actual observational data quantitatively. However, qualitative comparisons are still useful and help us understand the sensitivity of the WRF-FIRE-simulated atmospheric environment to the inclusion of fire.

The simulated results are qualitatively compared to data collected on 3 meteorological towers (Fig. 2, right panel) in the burn plot during the LIPF experiment on March 6 and 7, 2012. Three-dimensional sonic anemometers (10-Hz: U, V, W, T) were mounted at 3, 10, and 30 m AGL on a 30-m tower; at 3, 10, and 20 m AGL on a 20-m tower; and at 3 and 10 m AGL on a10-m tower. For detailed tower locations and other information, please refer to Poster P9 by Heilman et al.

Table 1. WRF-Fire model domain configuration

Domains	D1	D2	D3	D4
Resolution (m)	6250	1250	250	50
Grid Points (EW)	81	101	71	81
Grid Points (NS)	81	101	71	81
Vertical Layers	43	43	43	43

Table 2. List of numerical simulations

Simulation cases	Fire	LES
No Fire No LES	No	No
No Fire With LES	No	Yes
With Fire No LES	Yes	No
With Fire With LES	Yes	Yes

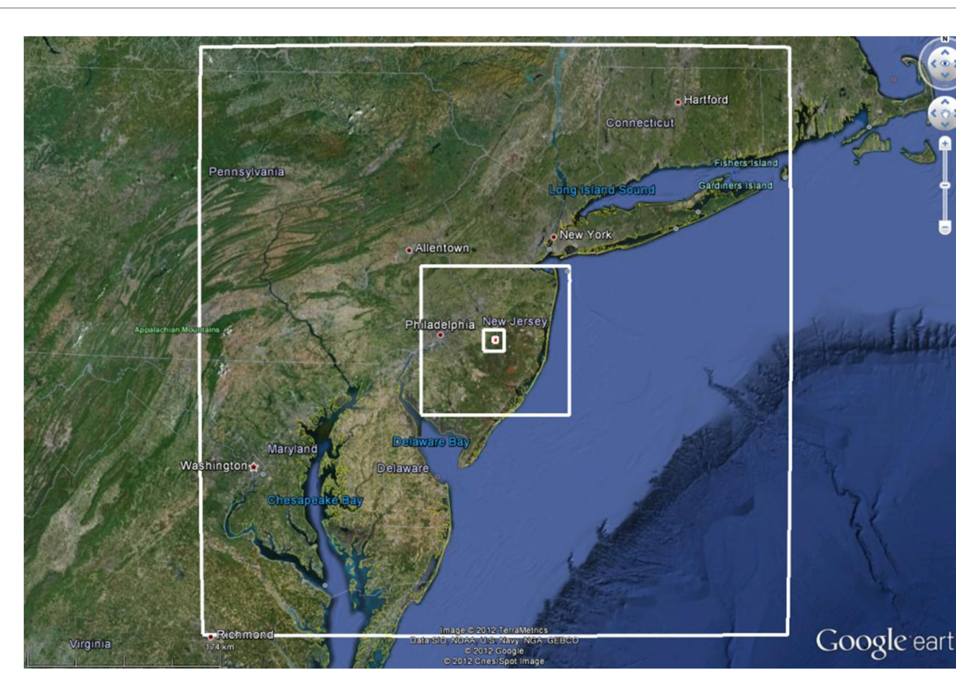

Figure 1. The four 2-way nested WRF-FIRE model domains centered over the forested burn plot on March 6, 2012 in the New Jersey Pine Barrens.

3. Results

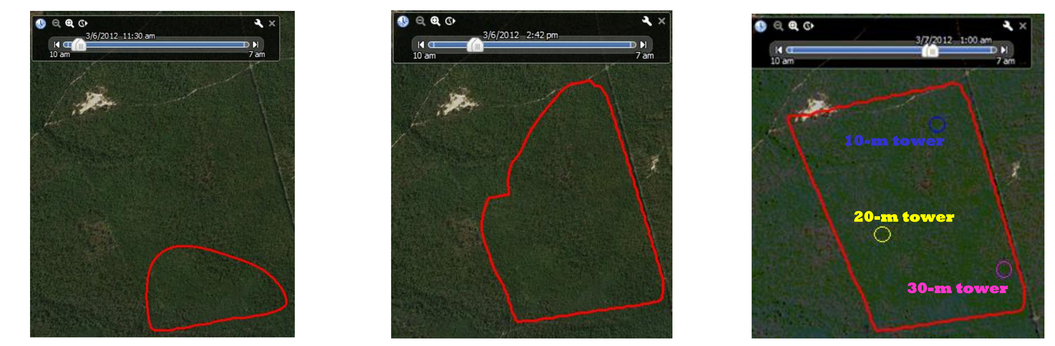

Figure 2. Three sample stages (from left to right) of fire progression in the model. The red line indicates the area of fire. The fire was ignited at 1000 EST Mar. 6 near the southern boundary of the burn plot and continued for 14 hours to end at 0000 EST Mar. 7 near the northwest corner of the plot. The experimental burn plot is bounded by roads, and 3 meteorological towers are also marked as open-circles in different colors (right panel). In order to confine the model fire within the plot, fuels outside the plot were artificially removed. See Poster P9 for a description of the actual fire spread on the day of the burn.

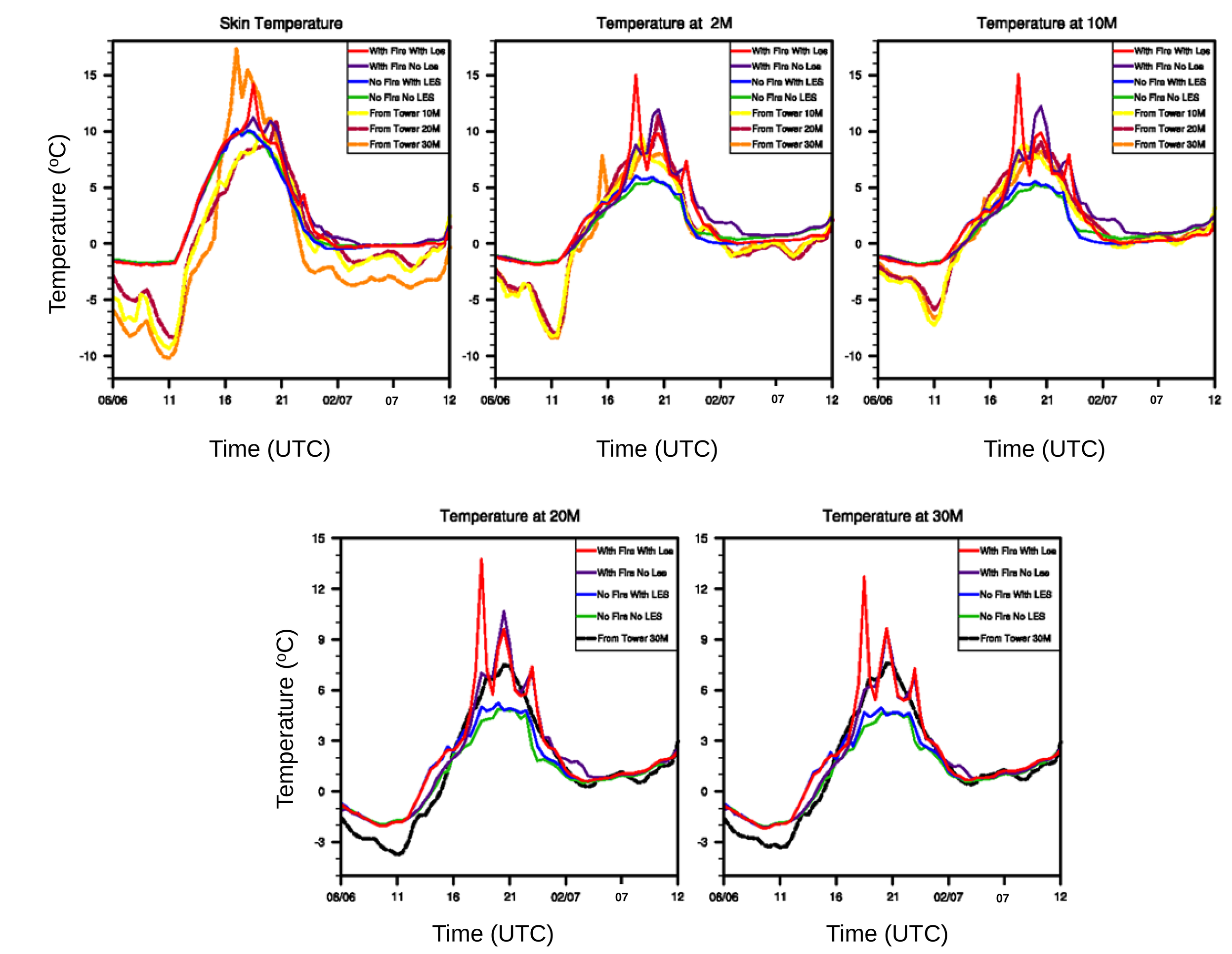

Figure 3. WRF-FIRE simulated temperatures at surface, 2 m, and 10 m AGL compared to the data at the same levels from the 10-, 20-, and 30-m towers (upper panels); simulated temperatures at 20 m and 30 m AGL compared to the observed data at 20 m AGL from the 20-m tower, and to the observed data at 30 m AGL from the 30 m tower (lower panels).

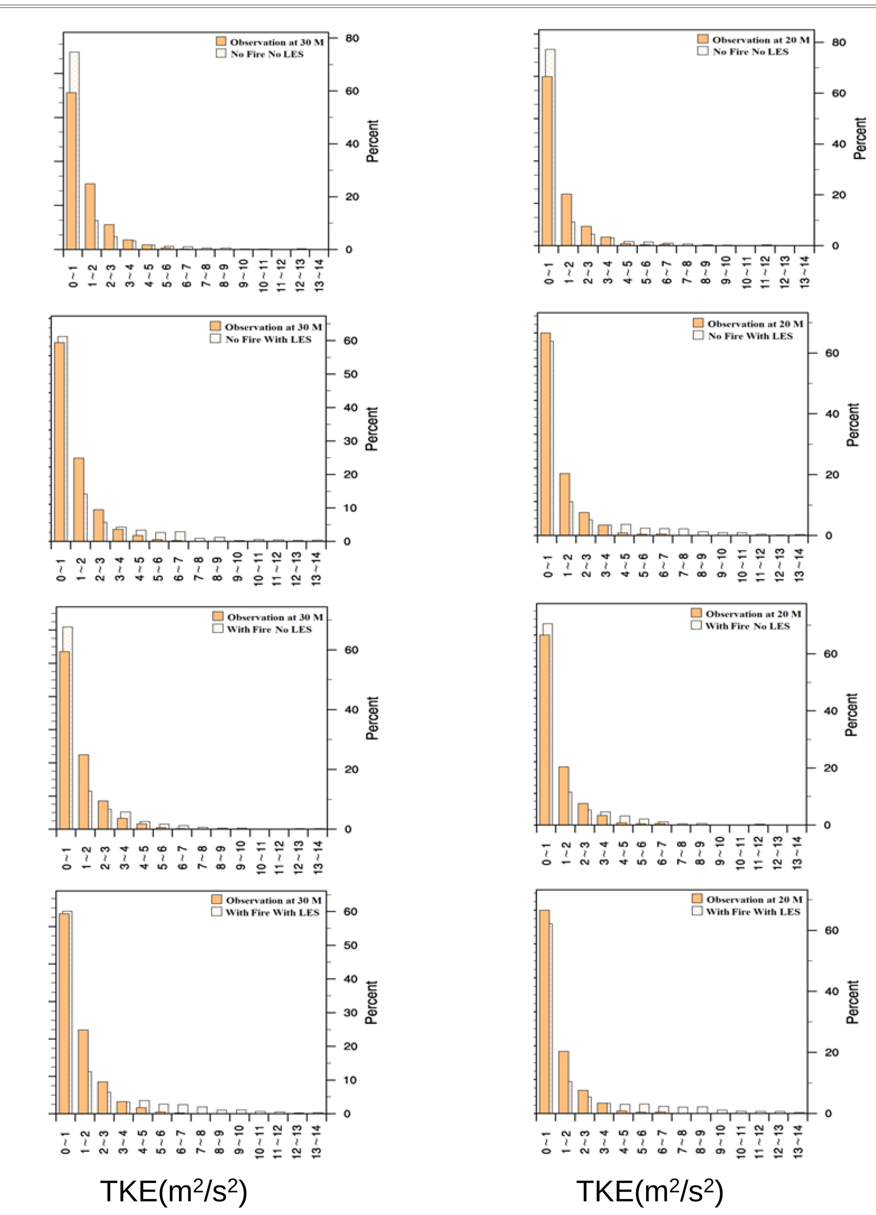

Figure 4. Comparisons of WRF-FIRE simulated distribution histograms of turbulent kinetic energy (TKE) at 20 m and 30 m AGL to the observed data at 20 m AGL from the 20-m tower, and to the observed data at 30 m AGL from the 30 m tower. The frequency is calculated based on 1-min mean TKE for the entire fire period from 1500 UTC, Mar 6 to 0500 UTC, Mar 7, 2012.

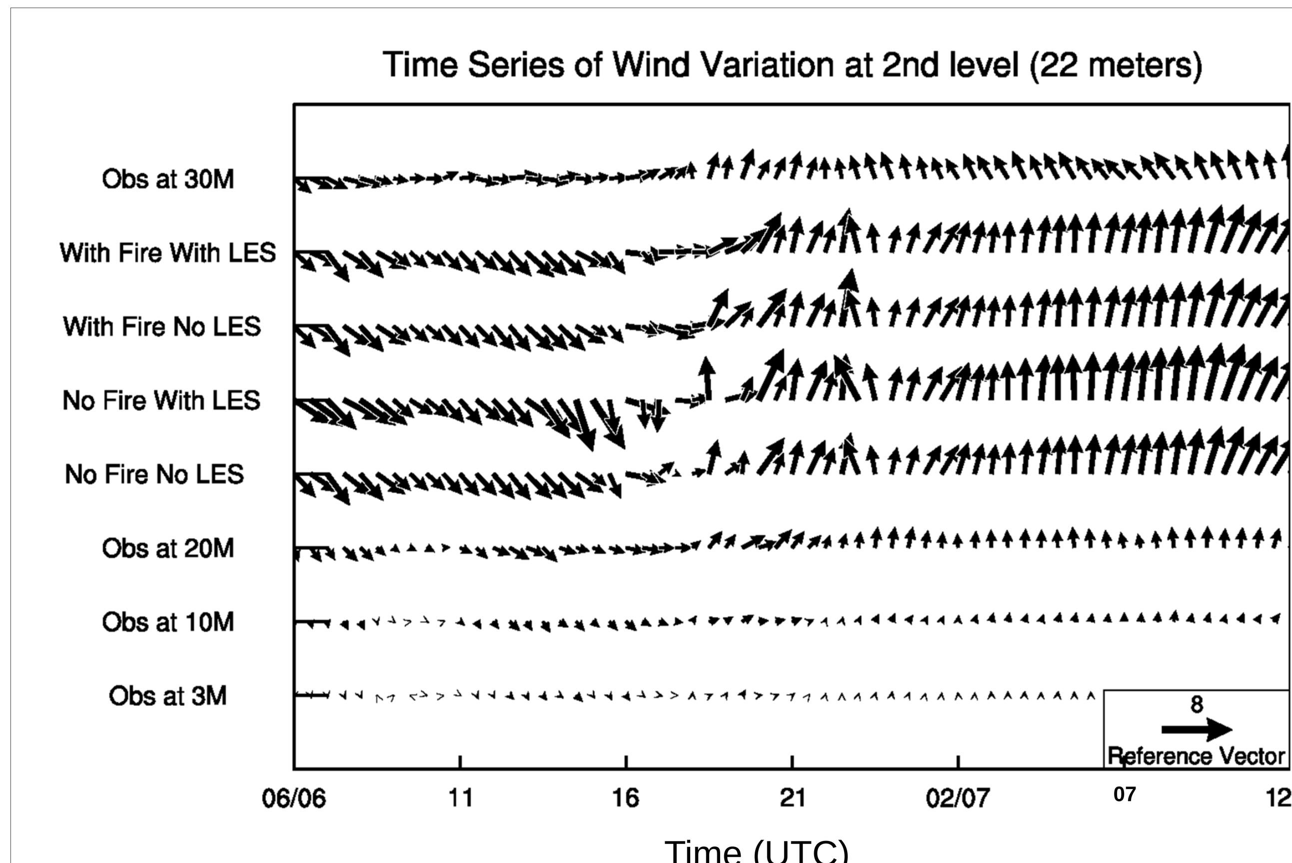

Figure 5. Comparison of WRF-FIRE simulated and observed wind speeds (m/s) and directions at the 30-m tower location. The WRF-FIRE output data are at 22 m AGL and the observations are at 4 different levels (3, 10, 20, and 30 m AGL).

4. Conclusion

Based upon 4 sensitivity tests of simulated WRF-FIRE meteorological and turbulent fields, our preliminary results suggest the following:

•WRF-FIRE simulated temperatures and wind directions in the burn plot are, qualitatively, in agreement with the observations. The wind speeds in all simulations are somewhat stronger compared to the observed wind speeds; in other words, the bias in simulated wind speed is not a result of the feedback from the fire module.

• WRF-FIRE simulated temperature fields are sensitive to the fire; simulations without the feedback from the fire produced lower temperature and weaker turbulence as well.

•Running WRF-FIRE in RANS or LES modes has a large impact on the simulated turbulence characteristics, with the LES mode generating higher TKE.

• More work is necessary in validating WRF-FIRE quantitatively using meteorological data collected from *in situ* instrumentation during wildland fire events.

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