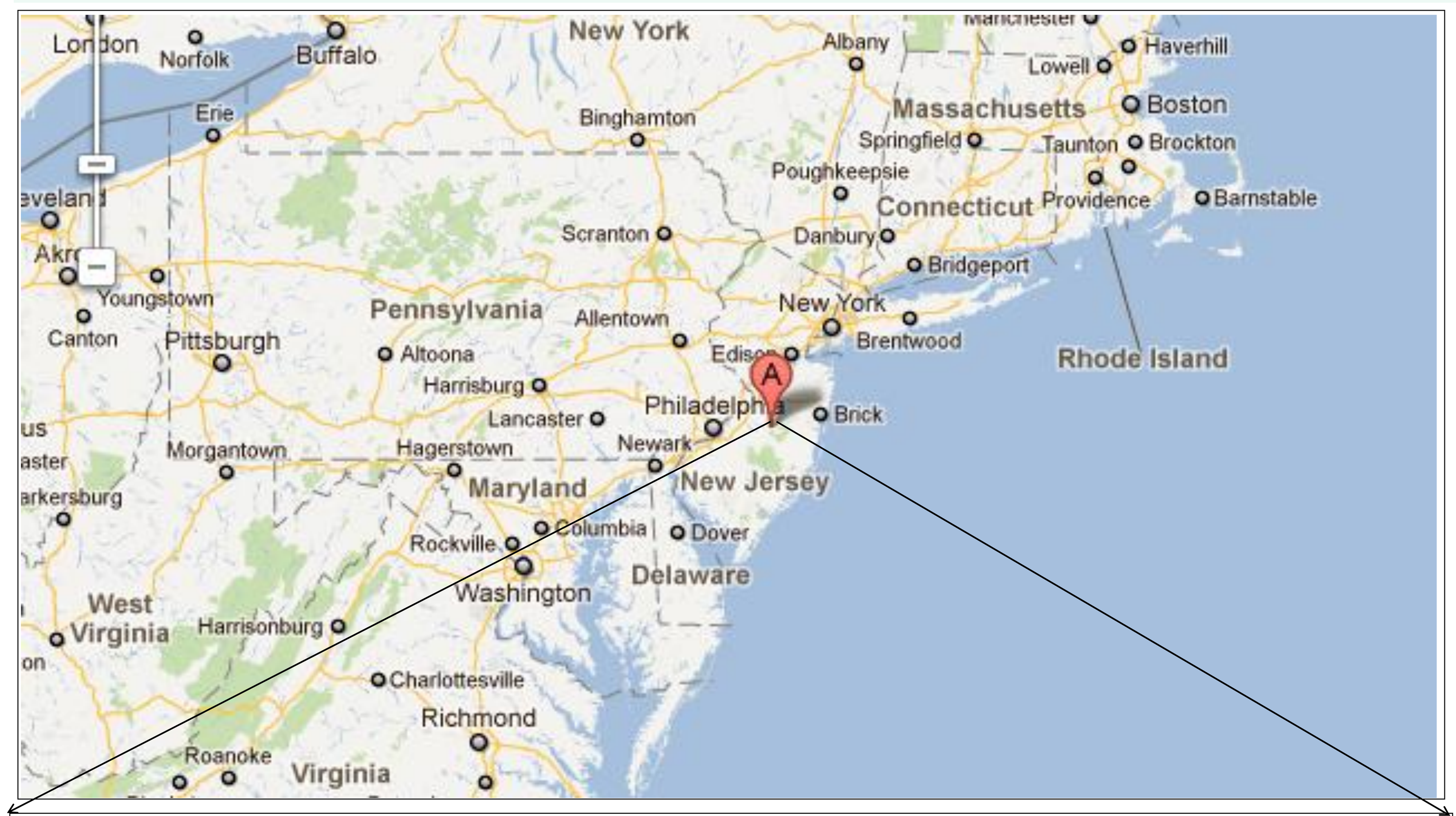
Observations of atmospheric canopy layer turbulence generated by a low-Intensity prescribed fire

X. Bian, W. Heilman, J. Charney, J. Hom, K. Clark, N. Skowronski, M. Gallagher, and M. Patterson
USDA Forest Service, East Lansing, MI

S. Zhong, M. Kiefer, and R. Shadbolt
Michigan State University, East Lansing, MI

Introduction

Low-intensity prescribed fires (LIPF) can be a viable tool for managing forest ecosystems. However, LIPF may radically modify the atmospheric environment within canopy layers by inducing strong fire-atmosphere interactions. These interactions can lead to intense turbulence production in and around the fire front, and this turbulence effects the dispersion of smoke. As part of a broad Joint Fire Science Program (JFSP) project to develop modeling tools for predicting smoke dispersion from low-intensity fires, the USDA Forest Service - Northern Research Station conducted a LIPF on a forested plot in the New Jersey Pine Barrens (Figure 1) to collect meteorological and air-quality data that can be used for model validation. In this study, we analyze turbulence data to understand atmospheric turbulence production associated with LIPF.



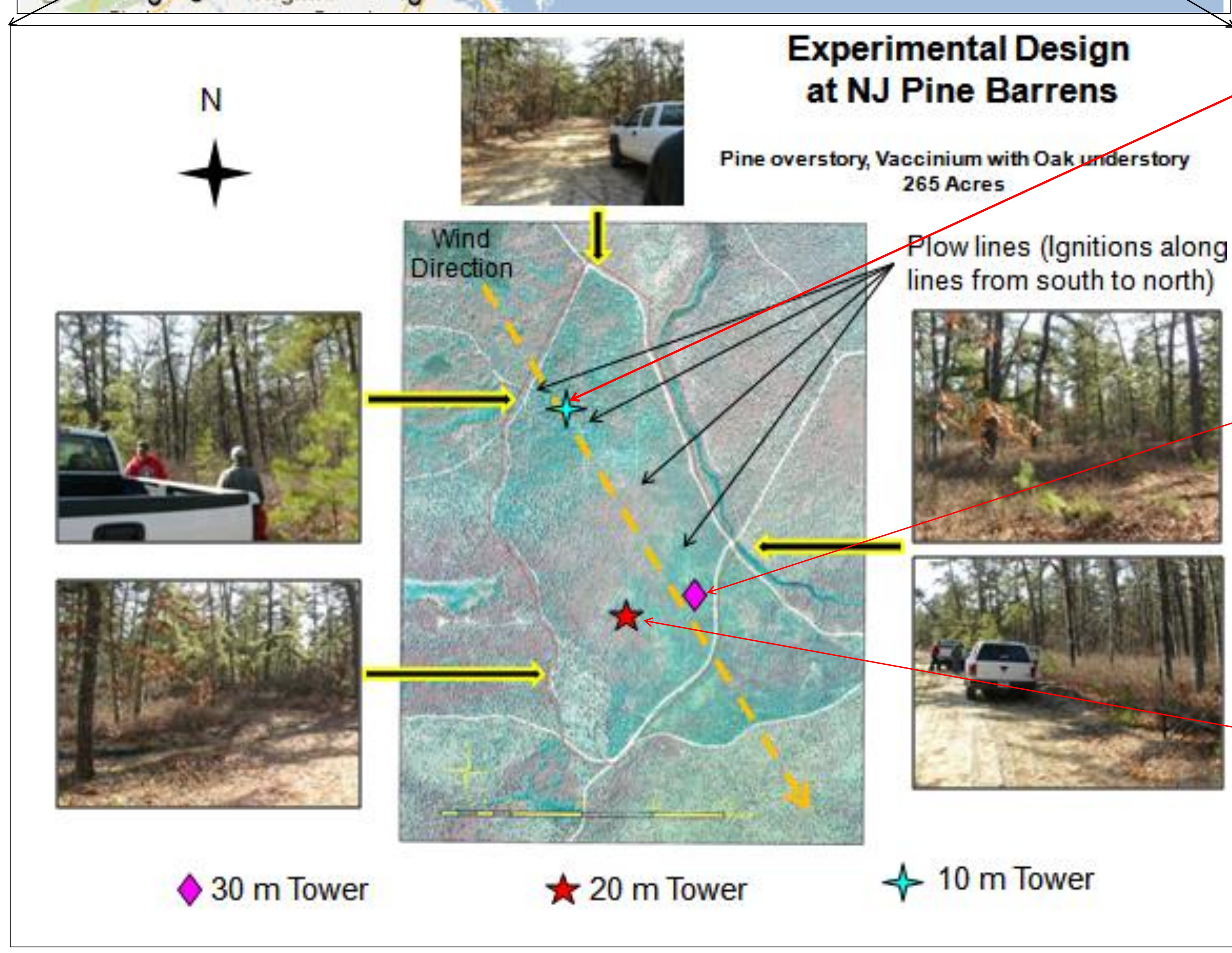


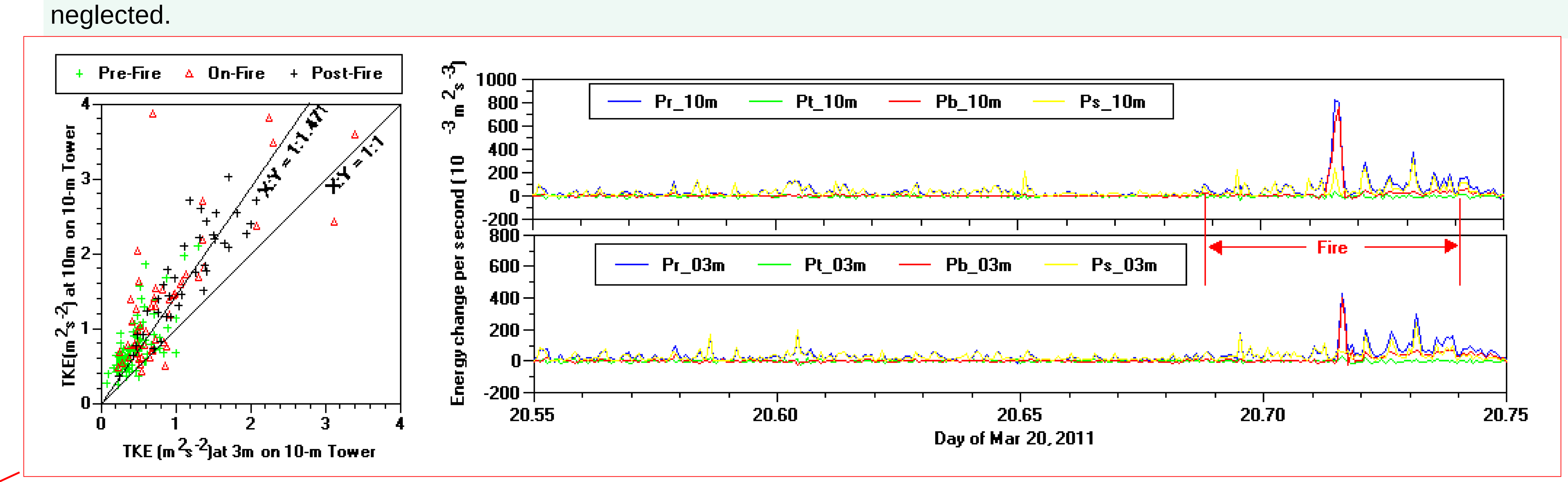
Figure 1. High frequency sonic anemometer data collected on March 20, 2011 from the LIPF experiment conducted in the New Jersey Pine Barrens. There are 3-level sonic anemometers (10-Hz U,V,W,T) on a 30-m-tower at heights of 3, 10, and 30 m AGL; 3-level sonic anemometers (10-Hz U,V,W,T) on a 20-m-tower at heights of 3, 10, and 20 m AGL; and 2-level sonic anemometers (10-Hz U,V,W,T) on a 10-m-tower at heights of 3 and 10 m AGL.

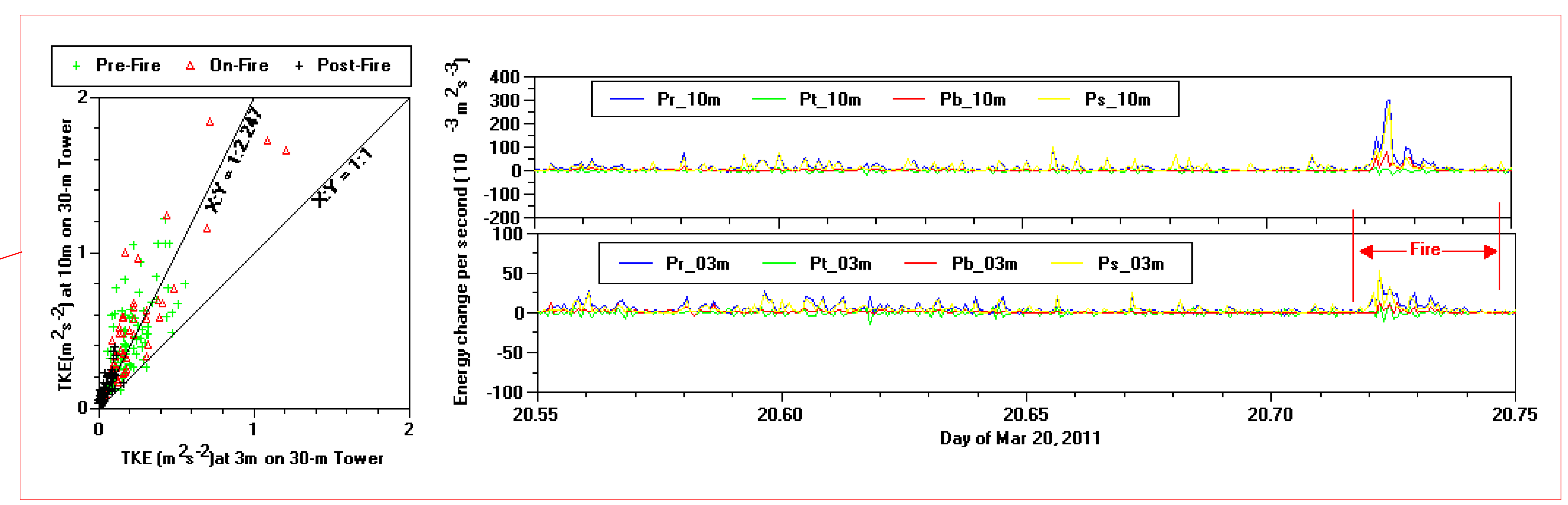
Data

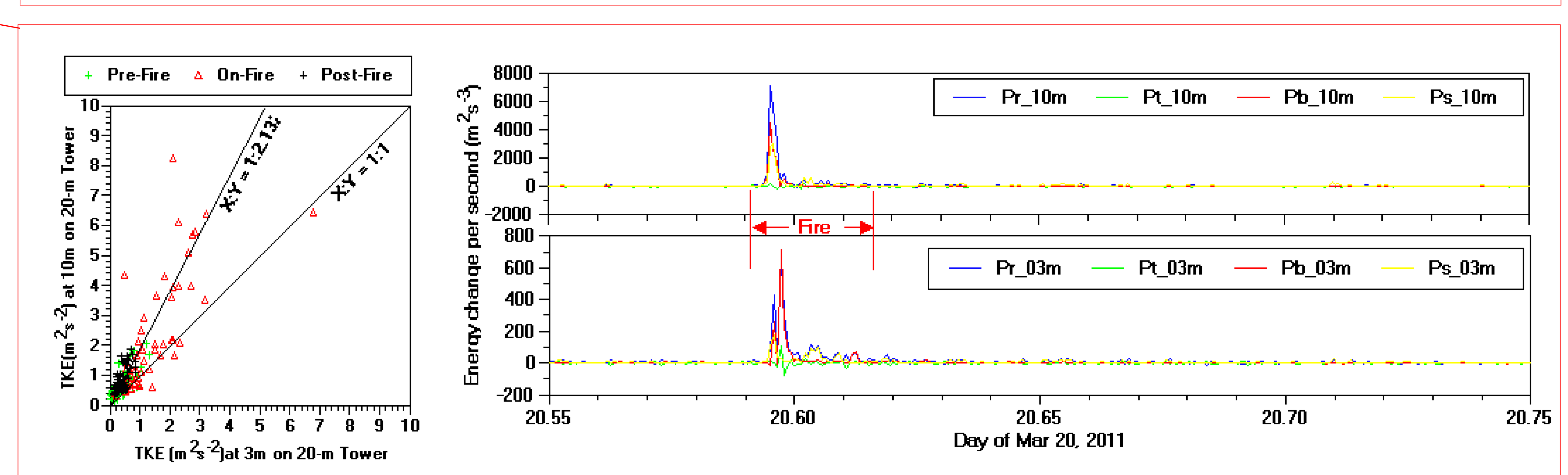
The data used in the analyses were measurements of the three-dimensional wind components (U, V, and W) and temperature (T) from sonic anemometers on the three flux towers within the plot during the LIPF on March 20, 2011. The sampling rate was10 Hz and data in this study from two levels (3 and 10 m AGL) among 3 towers (Figure 1) were used to assess the ambient and fire-induced atmospheric turbulence regimes.

Analysis Method

LIPF may induce or change the behavior of turbulent eddies in the lower atmosphere. The amount of energy in these turbulent eddies is defined as turbulent kinetic energy or TKE. TKE can be produced mechanically by wind shear and/or thermally by buoyancy effects, both of which can be calculated from the data. The TKE budget equation can be written as $Pr = Pb + Ps - Pt$, where Ps is wind shear production, Pb represents buoyancy production or dissipation, and Pt is the local time rate of change of TKE or TKE storage that can also be estimated using the data. Pr represents the residual of the TKE budget equation, which includes TKE diffusion, advection, dissipation, and other higher-order terms. Using the data, we estimated the four terms in the vicinity of the fire front during the LIPF experiment. A small Pr indicates that local change of TKE is mainly a balance between the two production terms (Ps and Pb) and a large residual would suggest the importance of other factors that should not be neglected.







Results and Conclusion

The analyses of turbulence data collected before, at, and post fire front indicate that

- The LIPF can generate turbulence that is much greater than turbulence in the ambient atmosphere.
- The production of turbulence at the surface near the fire front was associated with increased variance in the 3D winds, specially in vertical direction, while buoyancy was strongest at higher levels within the fire plume.
- Turbulence at 10-m level nearly doubled that at 3-m level, indicating that the assumption of 'constant flux layer' near the surface is no longer valid in the LIPF environment.
- The residual term is generally small in the ambient environment, but quite large at the fire front and somewhat large immediate before and after the fire front, indicating that other factors in addition to shear and buoyancy are important to local turbulence behavior. Further analyses are needed to identify these specific factors.

Acknowledgments.

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Joint Fire Science Program

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