Observed Fire-Atmosphere Interactions During a Low-Intensity Prescribed Fire in a Forested Environment

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Joint Fire Science Program
Research Supporting Sound Decisions
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FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

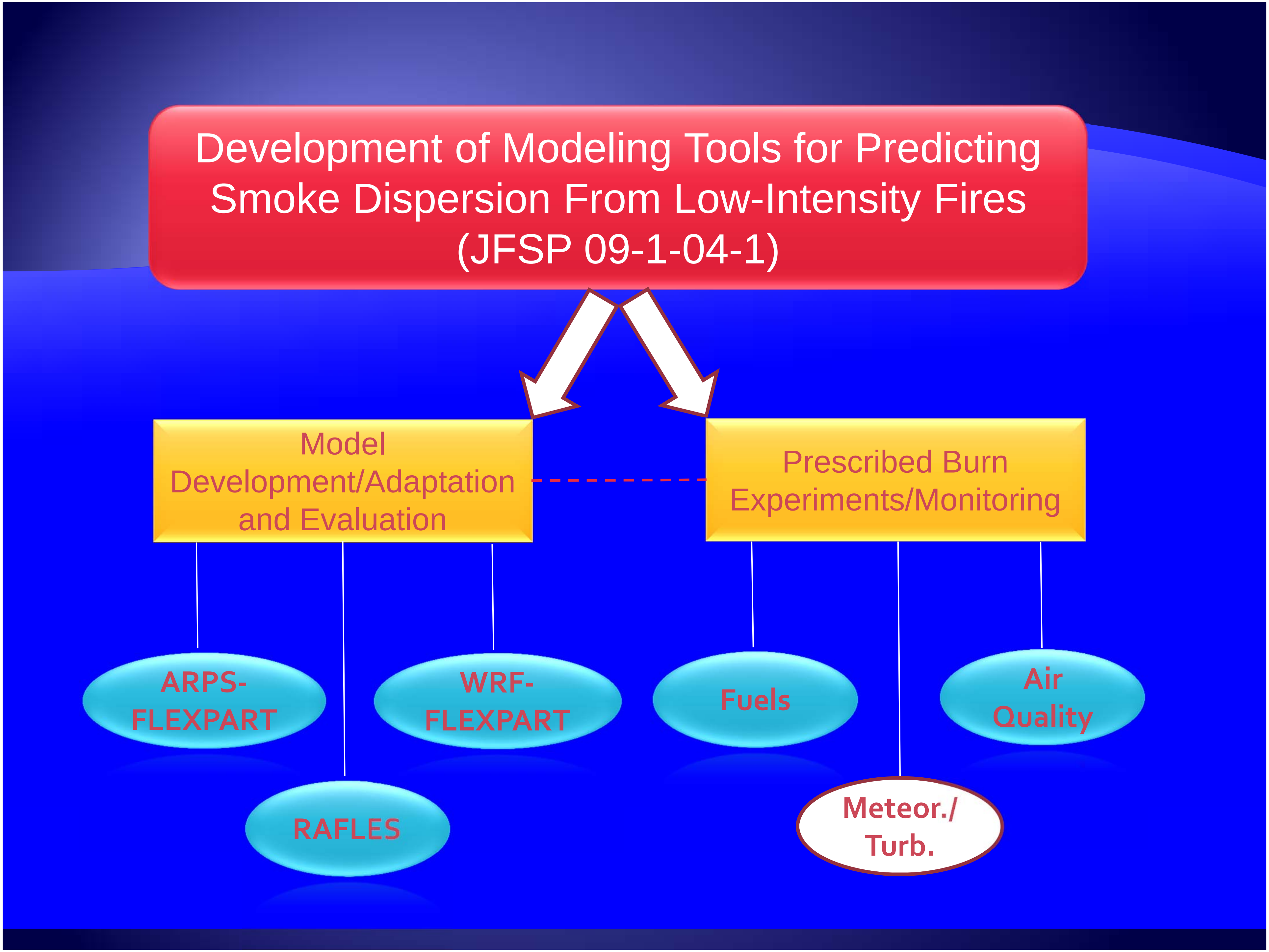
MICHIGAN STATE UNIVERSITY

Northern RESEARCH STATION USDA Forest Service

Development of Modeling Tools for Predicting Smoke Dispersion From Low-Intensity Fires (JFSP 09-1-04-1)

- Adapt one or more fine-scale atmospheric dispersion modeling systems to predict local smoke dispersion within and above forest vegetation layers due to low-intensity fires.

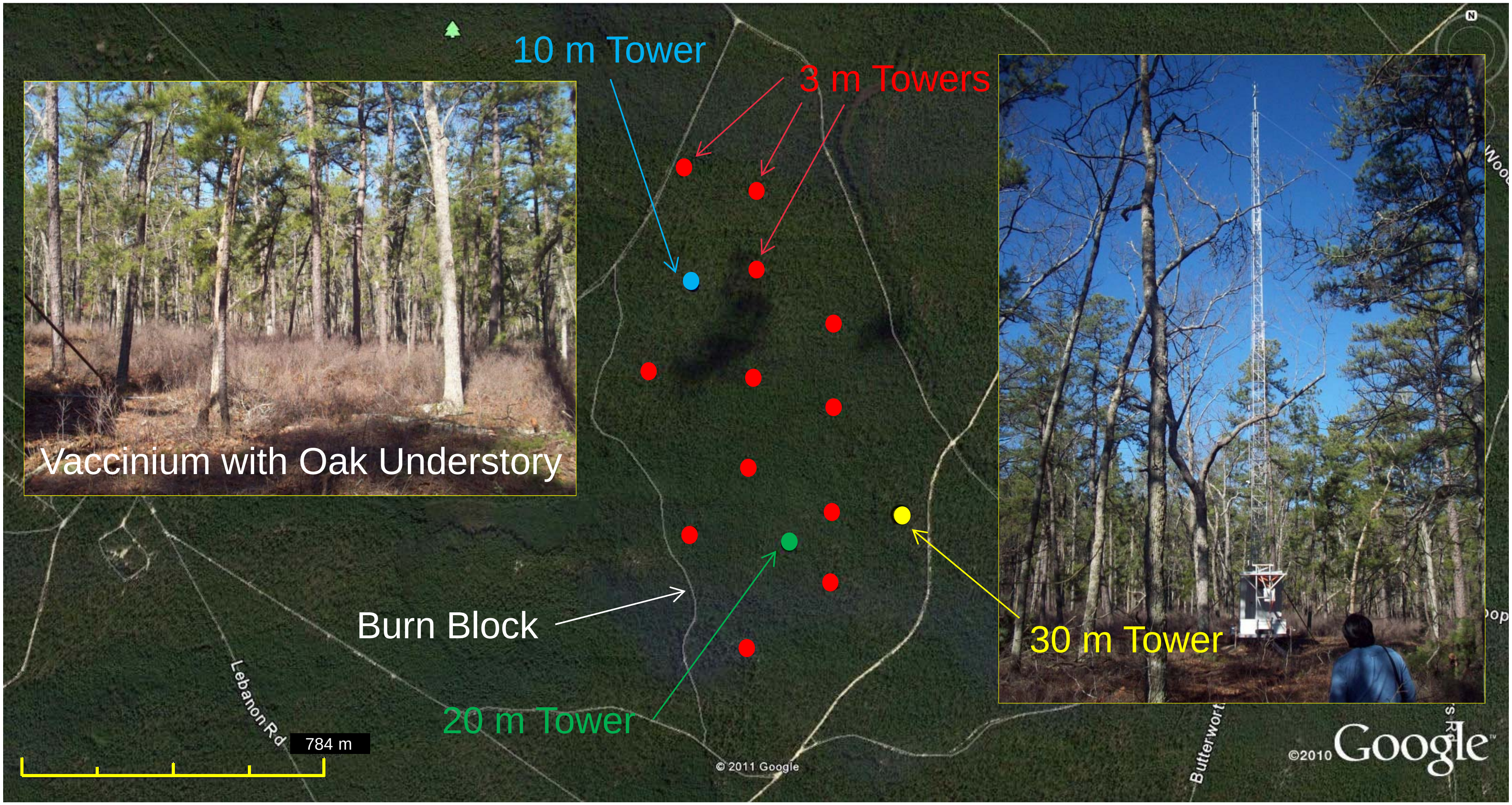
- Compare simulation results from the modeling systems using field observations to understand the performance of the models for different fire types, environmental settings, and atmospheric conditions.


Development of Modeling Tools for Predicting Smoke Dispersion From Low-Intensity Fires (JFSP 09-1-04-1)
Model Development/Adaptation and Evaluation
Prescribed Burn Experiments/Monitoring
ARPS-FLEXPART
WRF-FLEXPART
RAFLES
Fuels
Air Quality
Meteor./Turb.

Prescribed Burn Experiment: Location

- Pine Barrens contain some of the most volatile fire cycle vegetation in the East
- Surrounded by wildland-urban-interface areas
- Parts of the region have been designated as non-attainment areas for $PM_{2.5}$ and ozone
- Smoke emissions and air quality are of major concern to the NJ Forest Fire Service

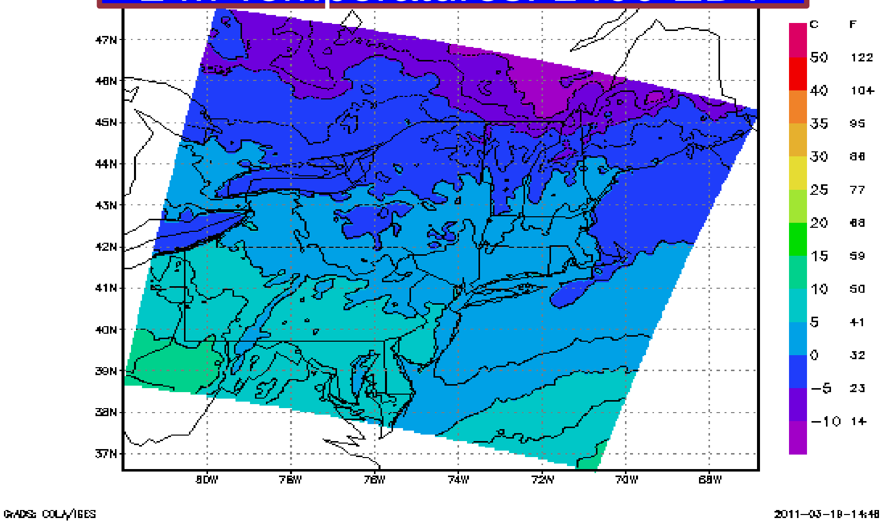
Prescribed Burn Experiment: Meteorological Monitoring Network



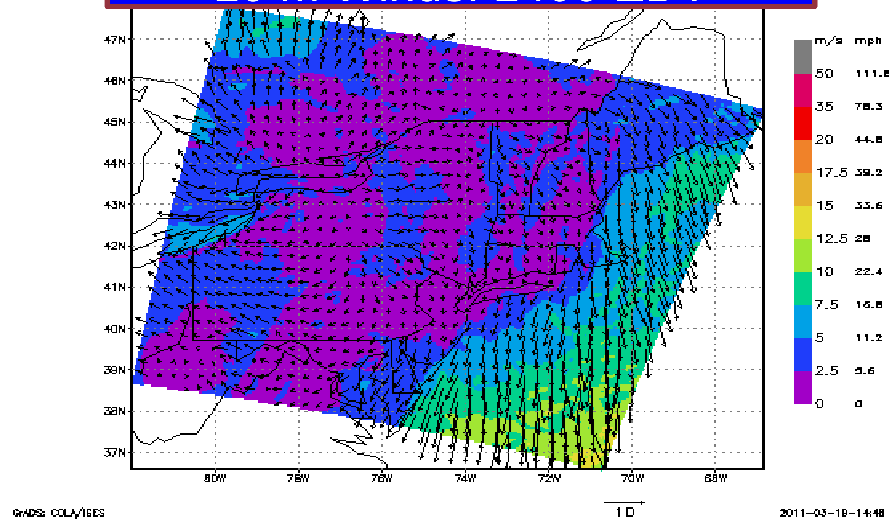
107 hectares (265 Acres); Pitch Pine Overstory (~15 m)

Prescribed Burn Experiment:
Ambient Meteorological Conditions – 20 March 2011

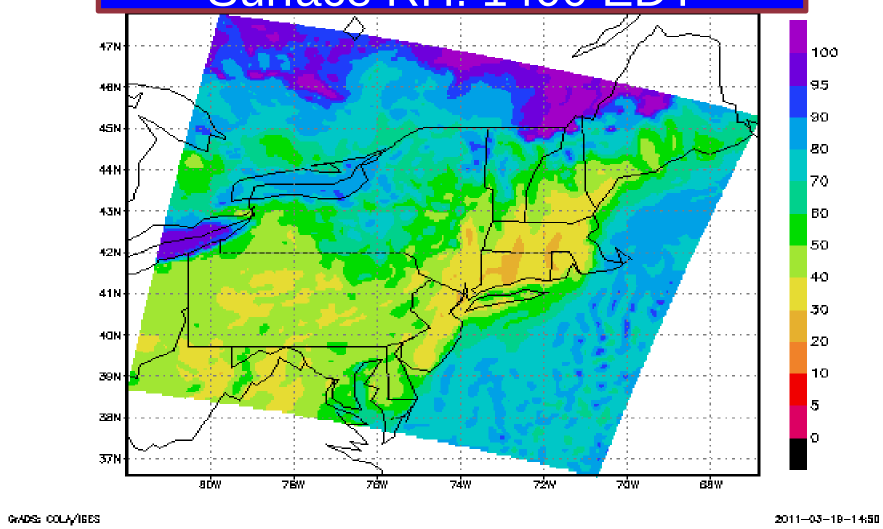
2 m Temperatures: 1400 EDT



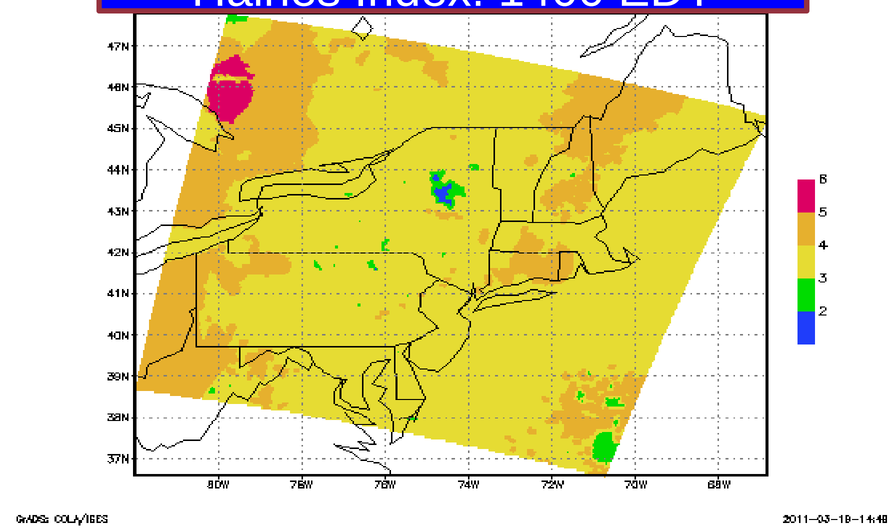
10 m Winds: 1400 EDT



Surface RH: 1400 EDT

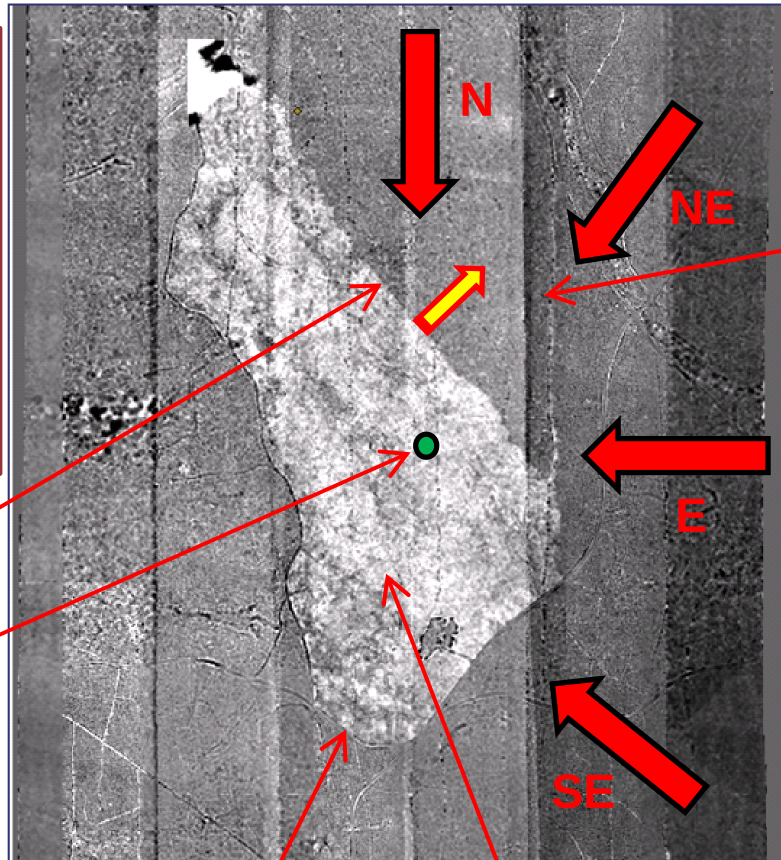


Haines Index: 1400 EDT



Prescribed Burn Experiment: Fire Line Progression

Date: 20-21 March 2011
Ignition: ~1000 EDT
Duration: ~16 hrs
Wind Speed: < 5 ms^{-1}
Wind Dir.: N-NE-E-SE
Fuel Load: 1.48 kg m^{-2}
1 hr FF Moist.: 26.18%
Spread Rate: ~1.5 m min^{-1}



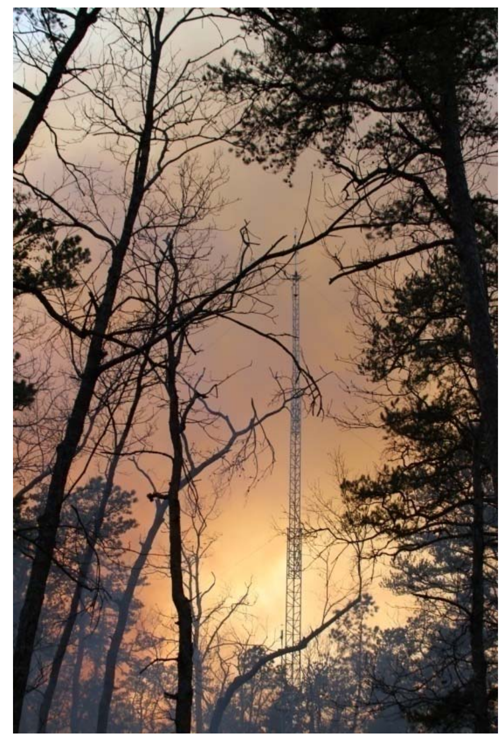
Unburned Area

Fire Line Position: ~1715 EDT

20 m Tower

Initial Ignition: ~1000 EDT

Burned Area



Temperatures

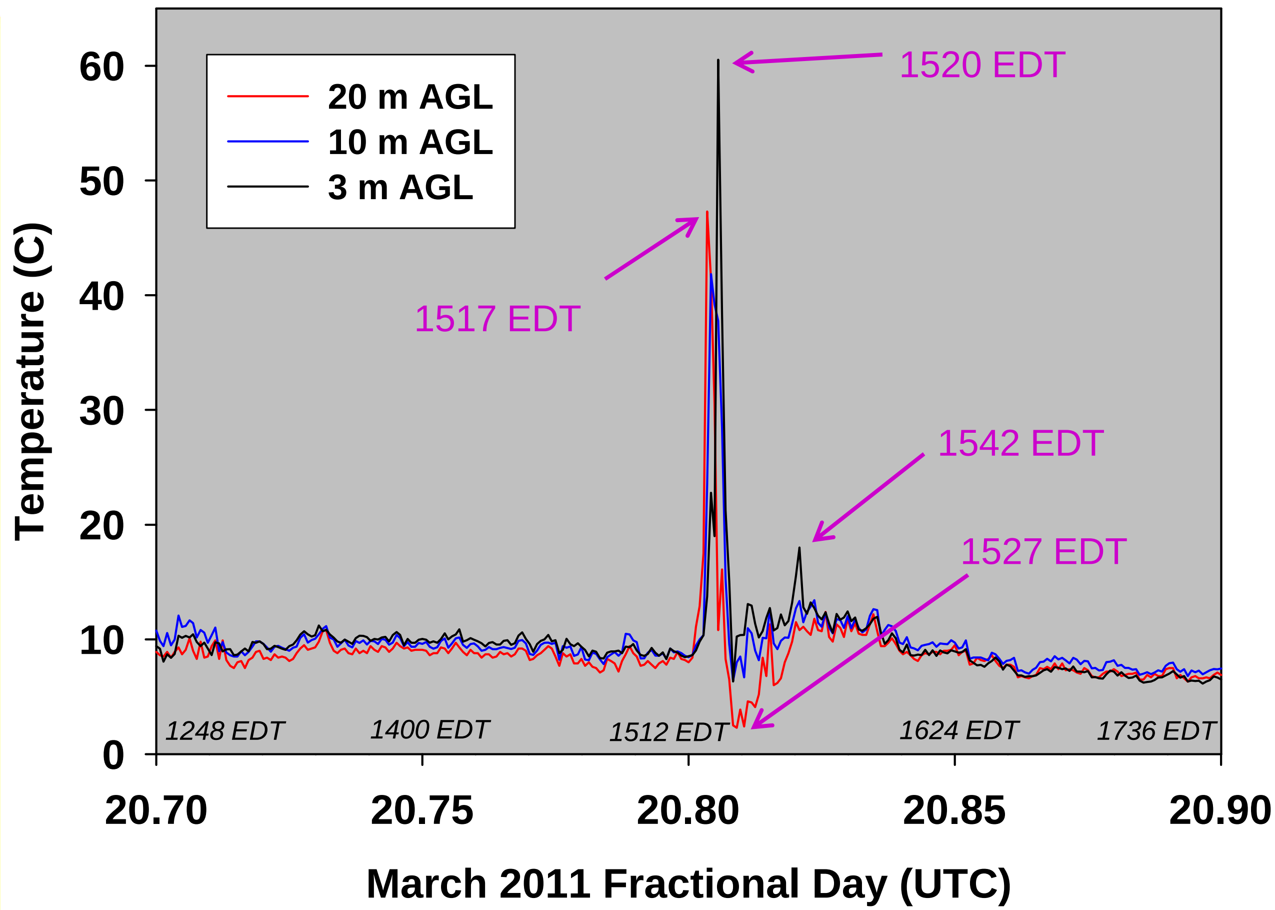
- Convective plume reached the tower top ~3 minutes before fire line passage (enhanced stability 3<z<20m).

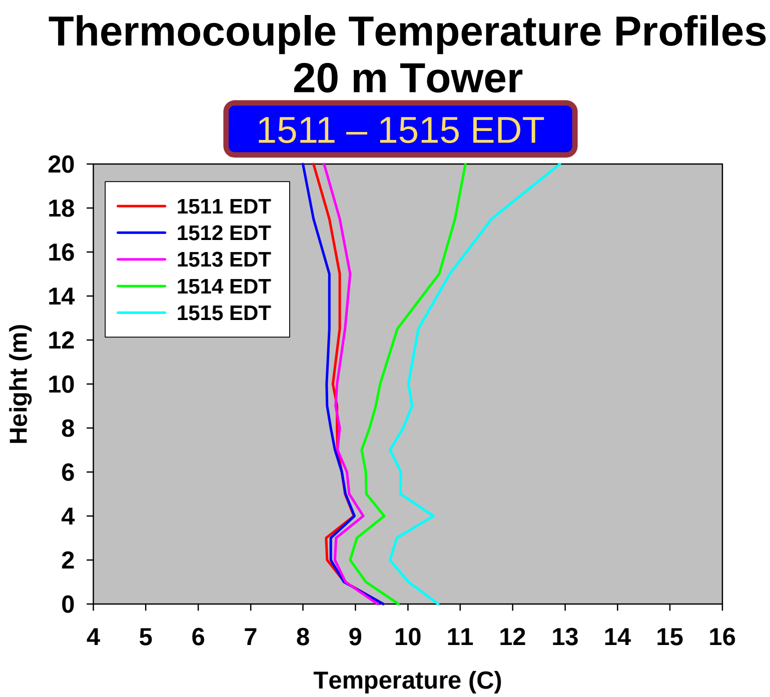
•Fire line passage at 1520 EDT (strongly unstable 3<z<20m).

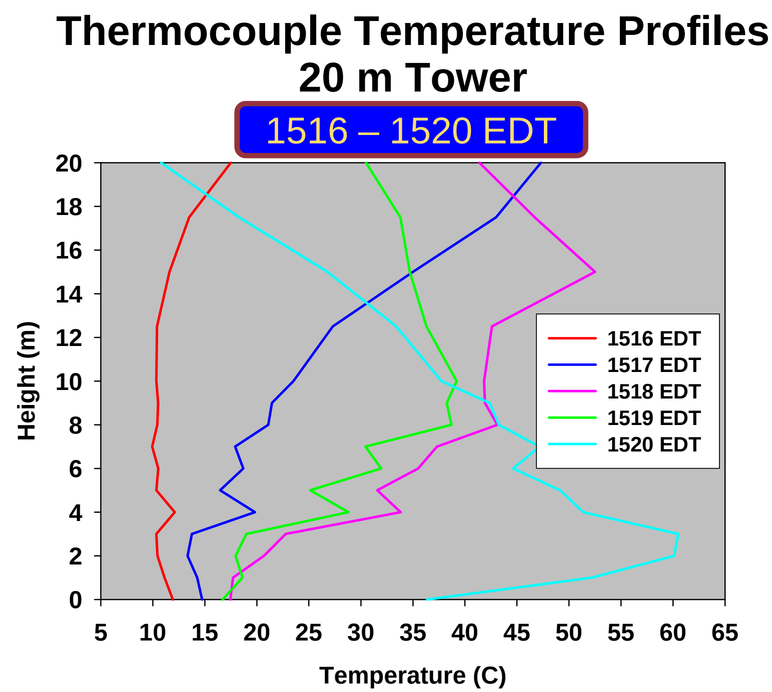
•Temperature dropped ~6 C below ambient temperature at 20 m ~7 minutes after fire line passage (same time as maximum downdrafts).

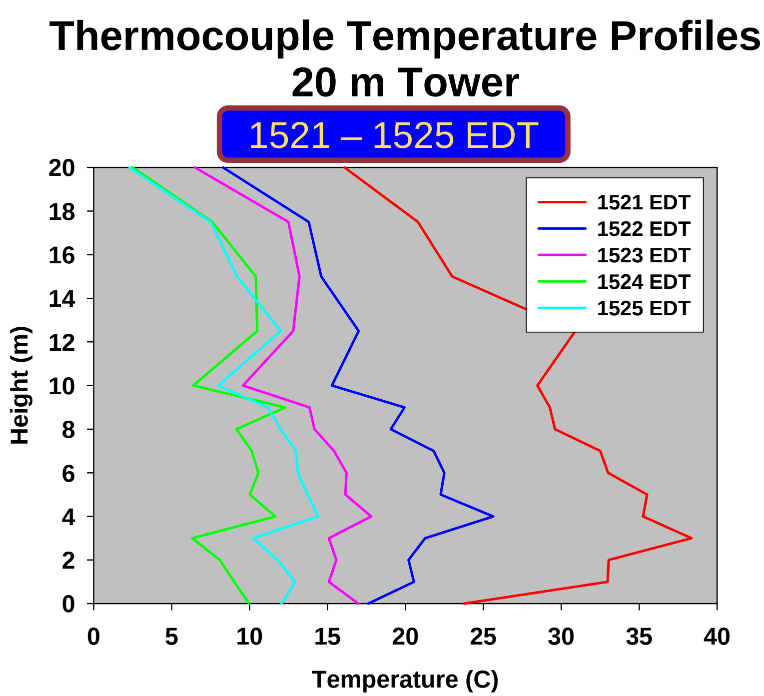
•Temperatures rebounded to ~2-3 C above ambient temperature ~25 minutes after fire line passage and then gradually decreased.

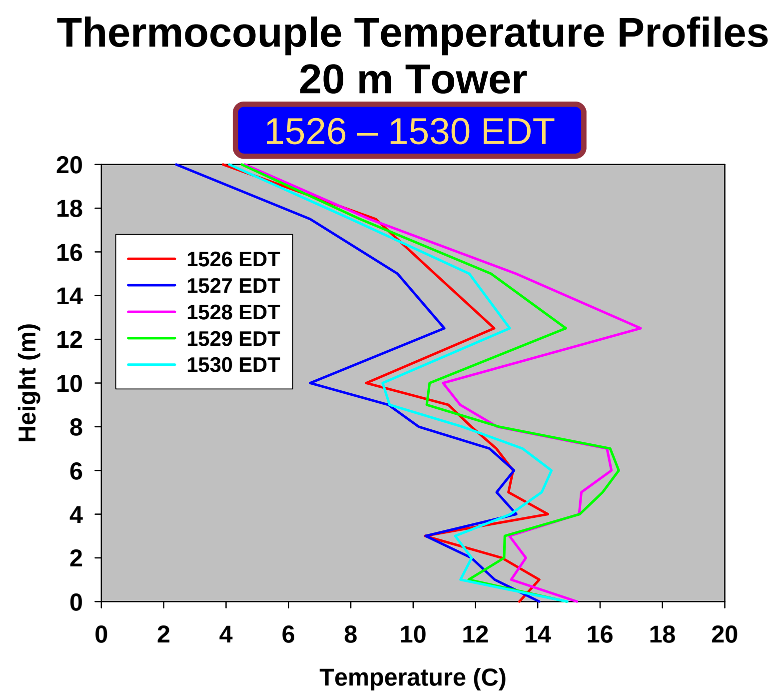
Temperatures at 20 m Tower




Thermocouple Temperature Profiles
20 m Tower
1511 – 1515 EDT
Height (m)
Temperature (C)
1511 EDT
1512 EDT
1513 EDT
1514 EDT
1515 EDT

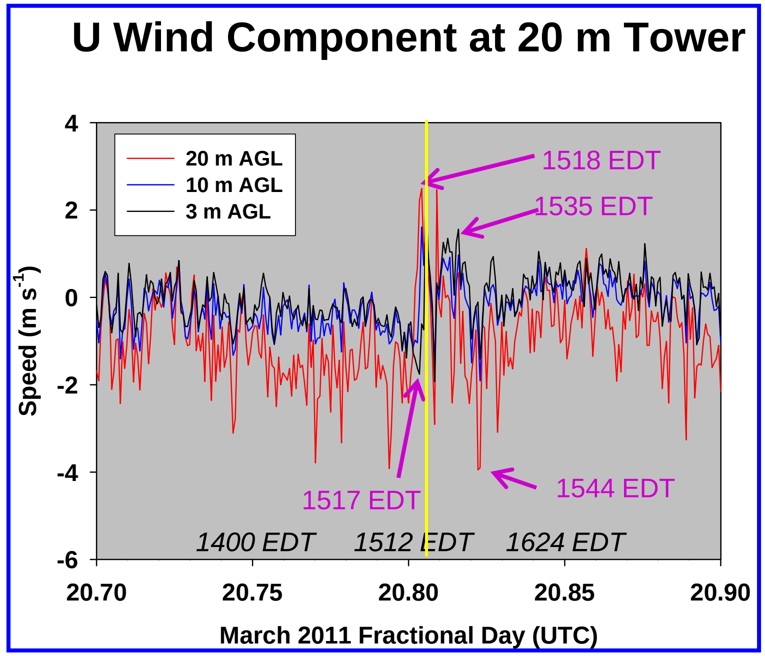

Thermocouple Temperature Profiles
20 m Tower
1516 – 1520 EDT
Height (m)
Temperature (C)
1516 EDT
1517 EDT
1518 EDT
1519 EDT
1520 EDT

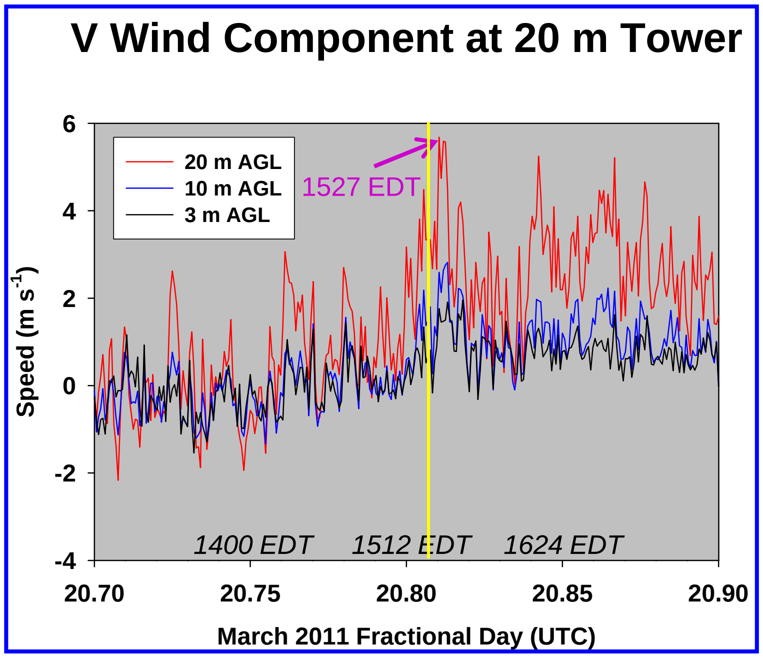

Thermocouple Temperature Profiles
20 m Tower
1521 – 1525 EDT
Height (m)
Temperature (C)
1521 EDT
1522 EDT
1523 EDT
1524 EDT
1525 EDT

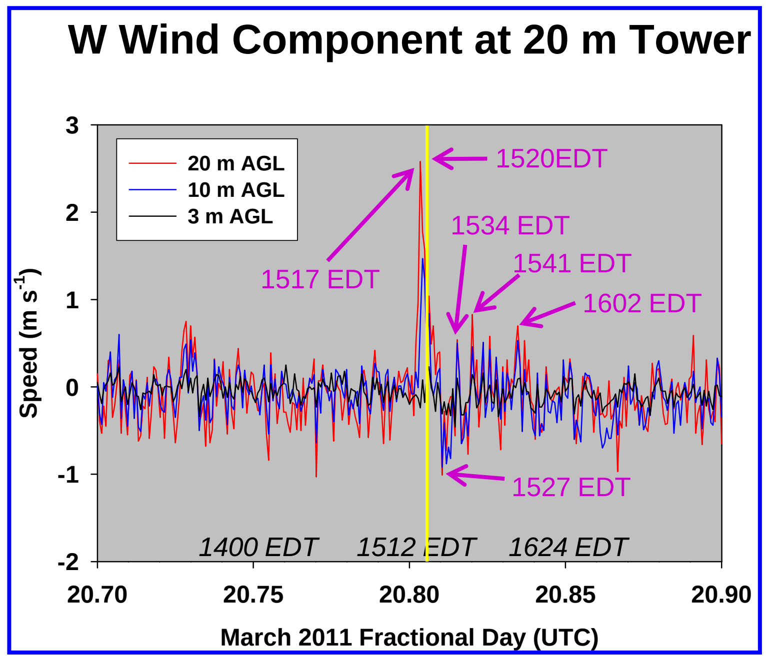

Thermocouple Temperature Profiles
20 m Tower
1526 – 1530 EDT
Height (m)
Temperature (C)
1526 EDT
1527 EDT
1528 EDT
1529 EDT
1530 EDT

Wind Speed

- Light SE winds (U<0, V>0) before fire line passage.
- Stronger sfc. inflow in front of fire line developed ~10 min. before fire line passage (U most negative at 1517 EDT)
- Stronger SW winds after fire line passage (~20 min.) followed by mostly S to SE winds from the surface upward.
- Maximum updrafts above the canopy ~3 min. before fire line passage; maximum downdrafts ~7 min. after fire line passage.







Turbulent Kinetic Energy

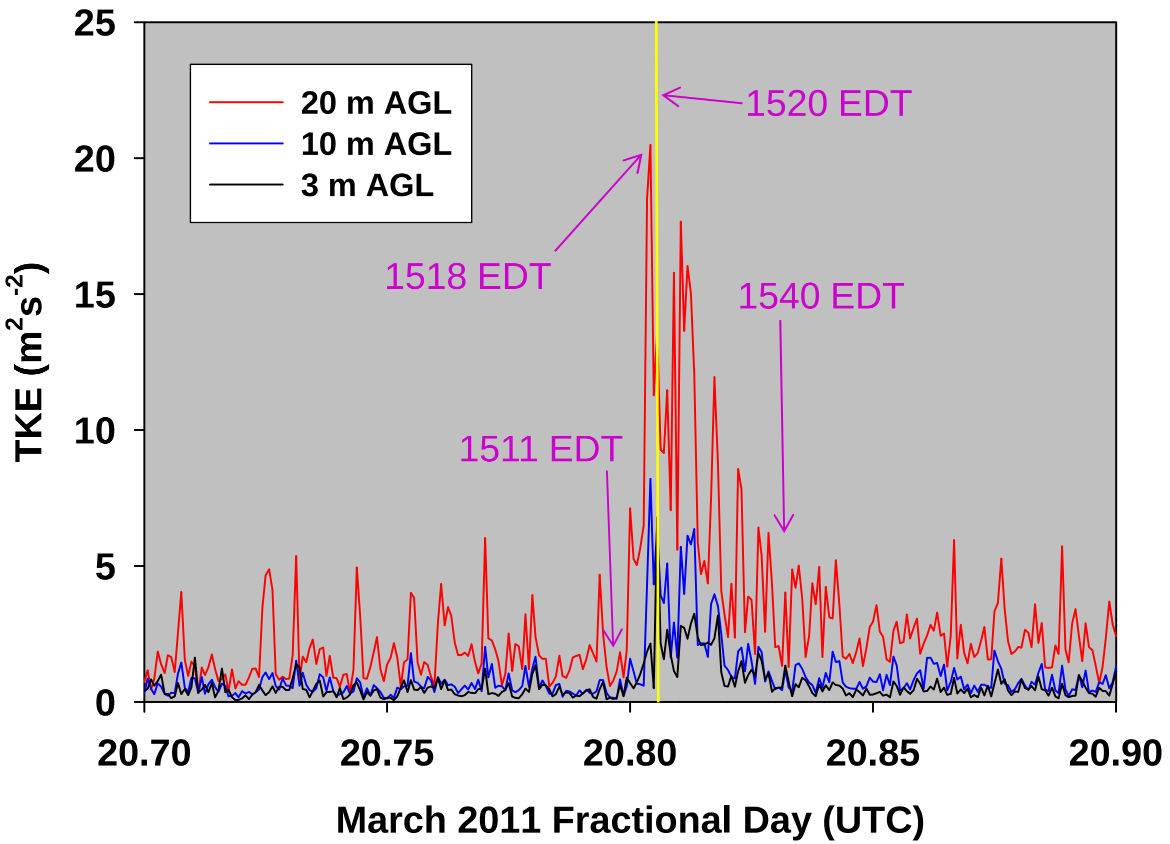
• TKE is consistently higher above the canopy than inside the vegetation layer, even during and after fire line passage.

•TKE begins to increase at all levels ~9 minutes before fire line passage.

•Very turbulent during and after fire line passage.

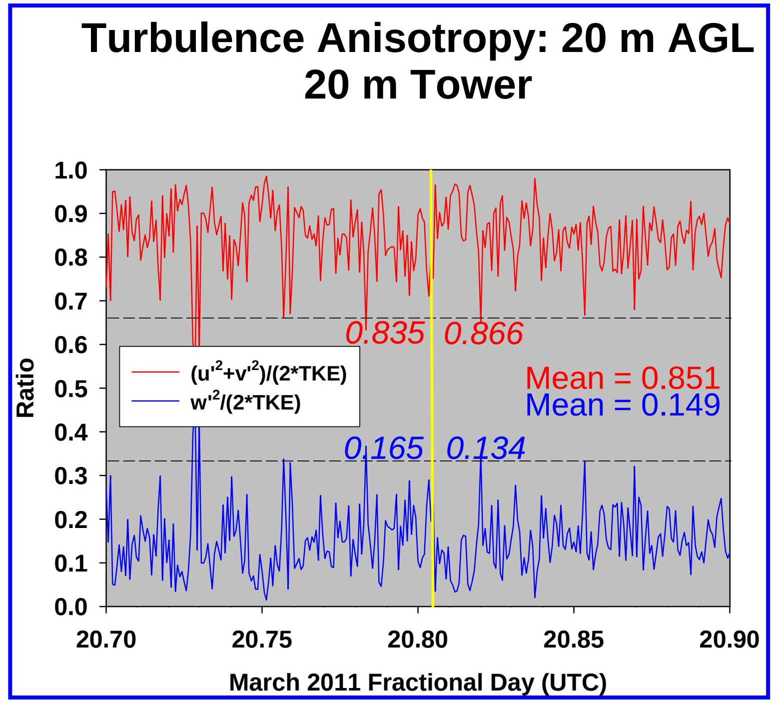
•TKE values near the surface drop to pre-fire line passage values ~20 minutes after fire line passage.

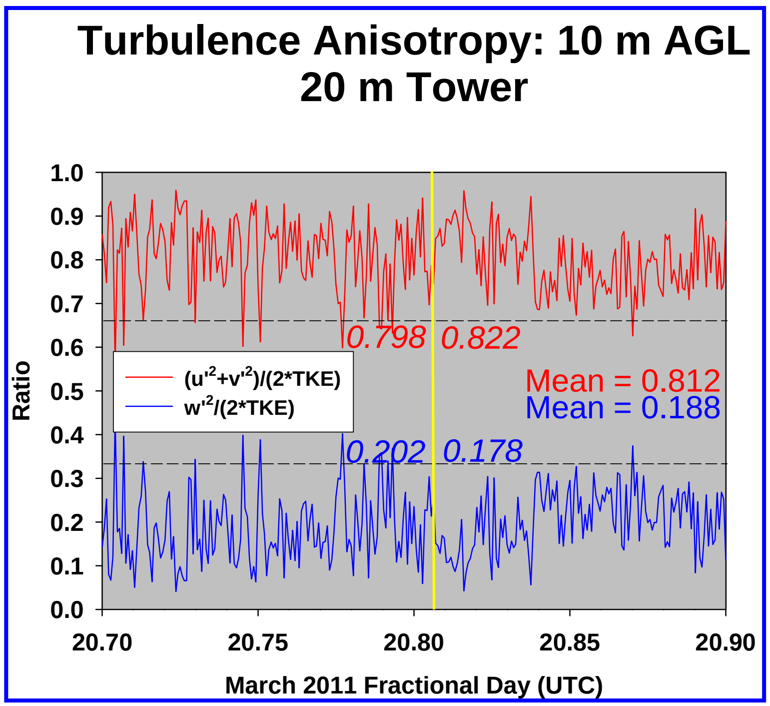
TKE at 20 m Tower

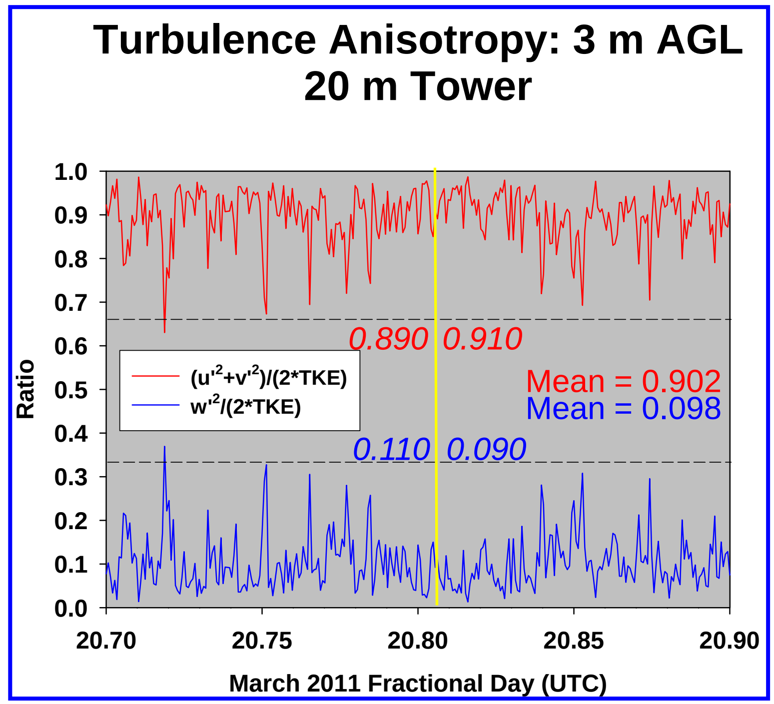


Turbulence Anisotropy

- Turbulence anisotropy is prevalent within and above the forest canopy.
- Most anisotropic near the surface and above the canopy; most of the TKE contained in the horizontal components.
- Turbulence more anisotropic immediately following fire line passage than before.





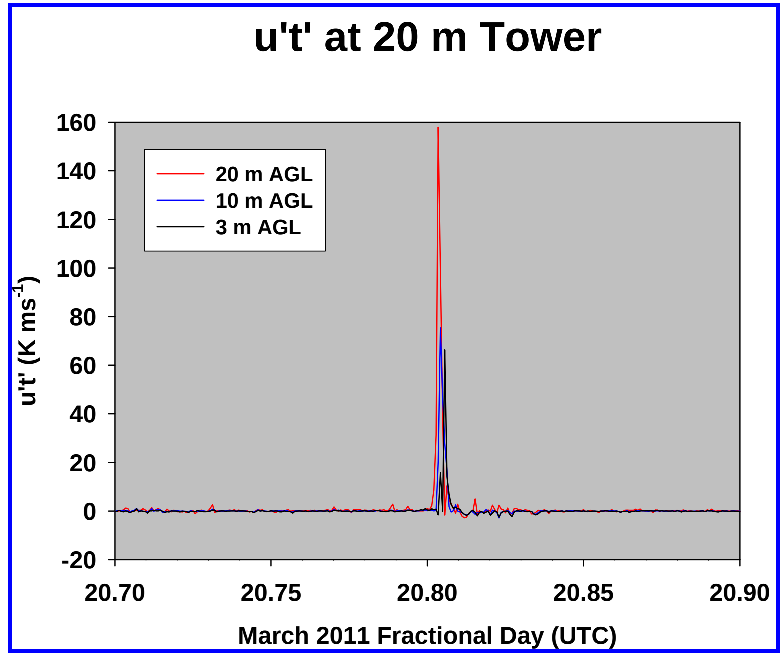


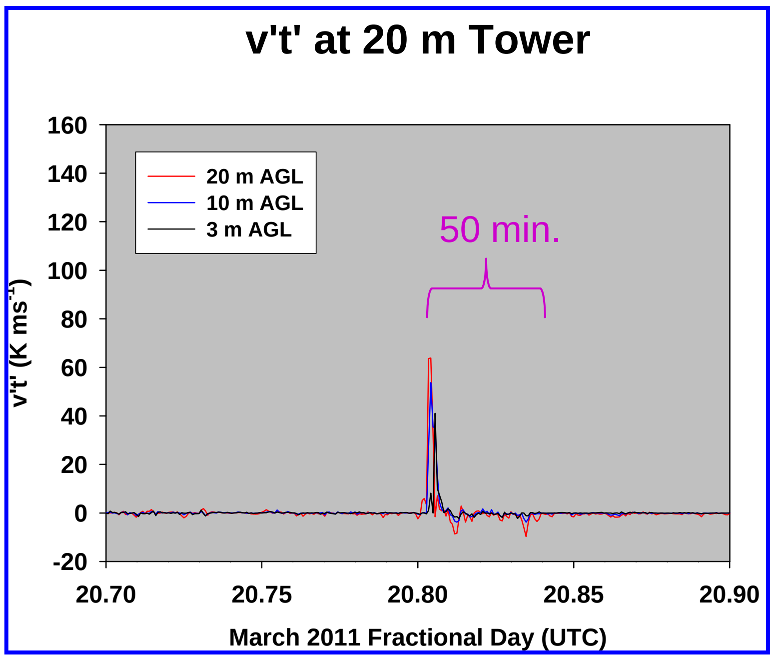
Turbulent Heat Fluxes

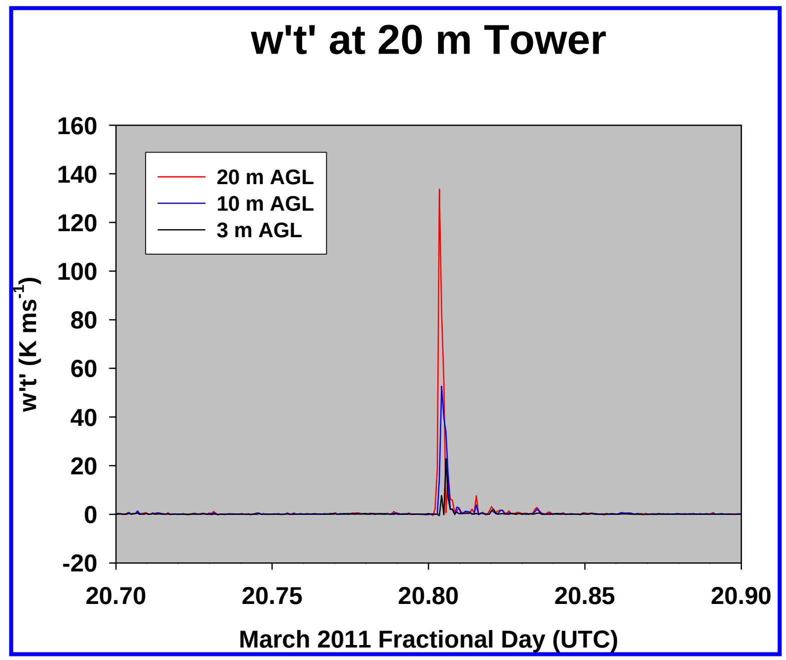
- -1.1 < u’t’ < 2.8; -2.4 < v’t’ < 1.8; -0.2 < w’t’ < 1.2 (K ms^{-1}) at all levels before fire line passage.

- Flux magnitudes were highest above the canopy before, during, and after fire line passage.

- Fire-induced heat-flux oscillations up to ~50 minutes after fire line passage.





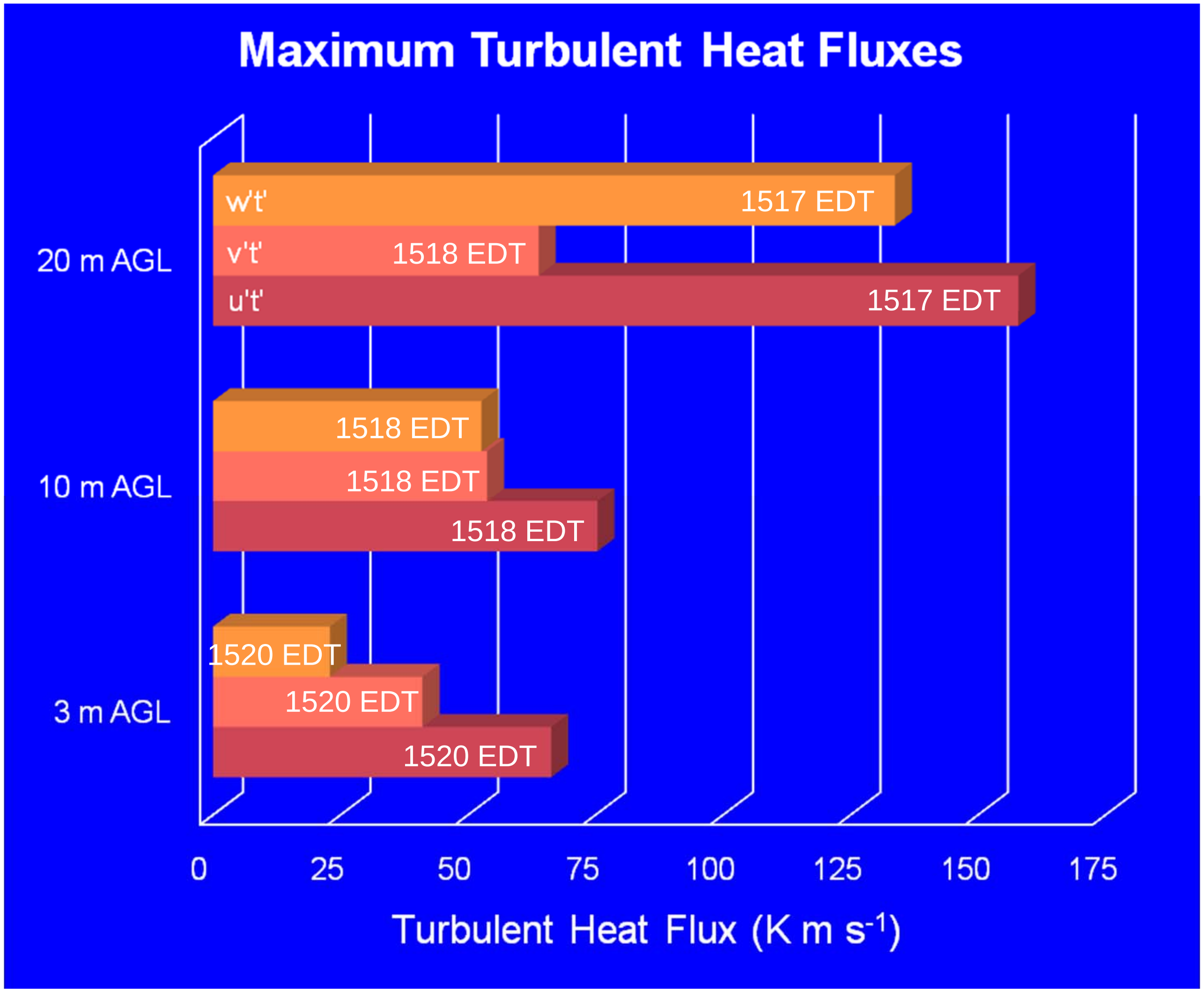


Turbulent Heat Fluxes

- Maximum turbulent heat fluxes in all directions were highest above the canopy.

- $u't'_{max} > v't'_{max}$ and $w't'_{max}$ at all levels.

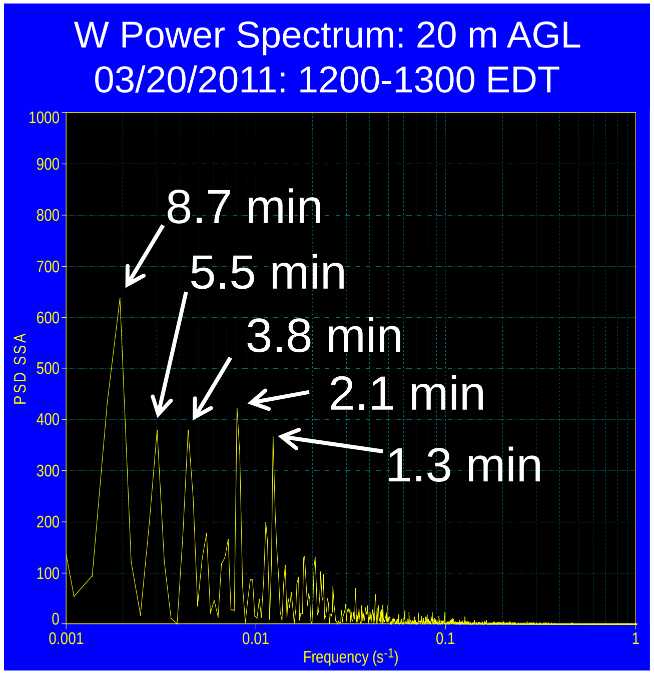
- Turbulent fluxes reached their maximum at the canopy top before they reached their maximum at lower levels in the vegetation layer.

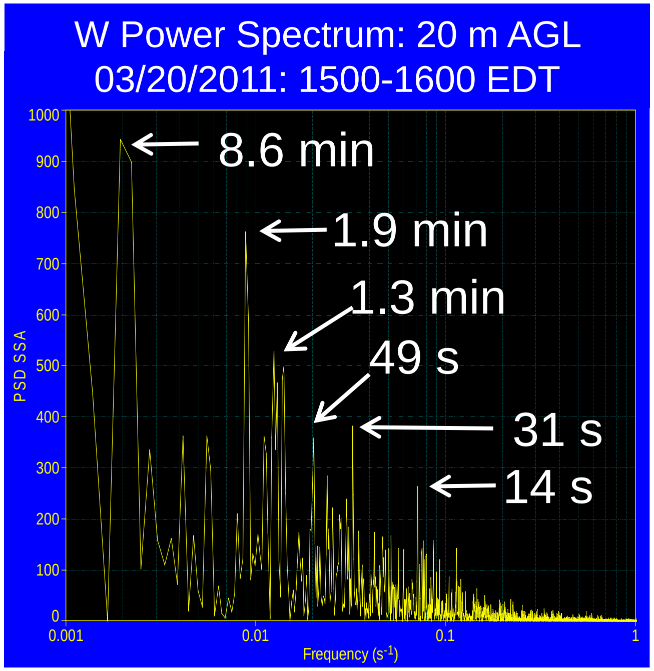


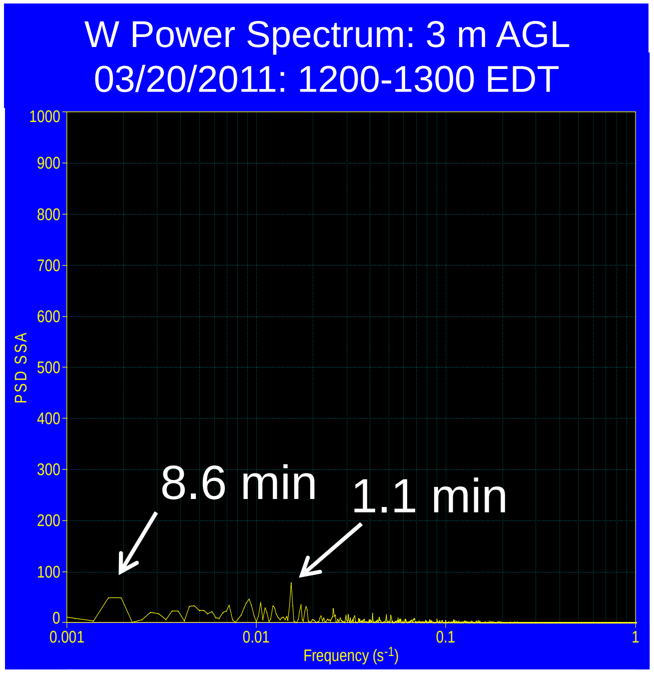
Vertical Velocity Variability

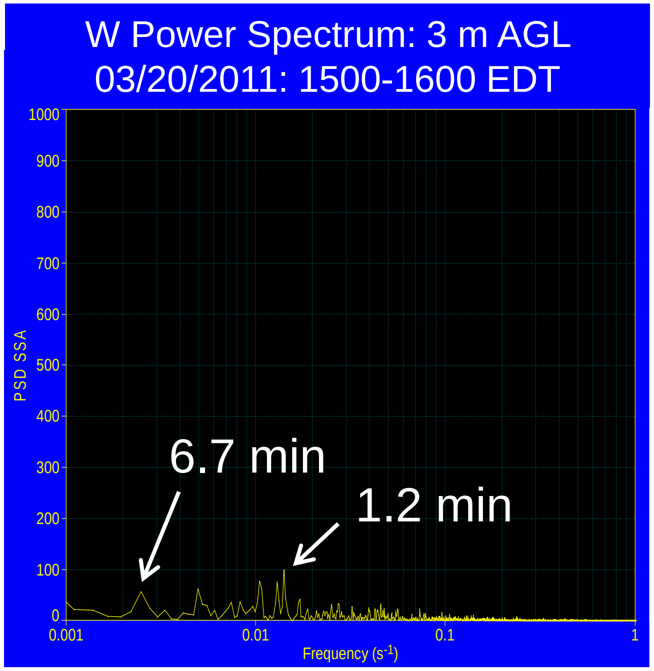
- Higher frequency variability in vertical velocity during fire line passage.

- Relative increase in high frequency vertical velocity variability is most significant above the canopy top.







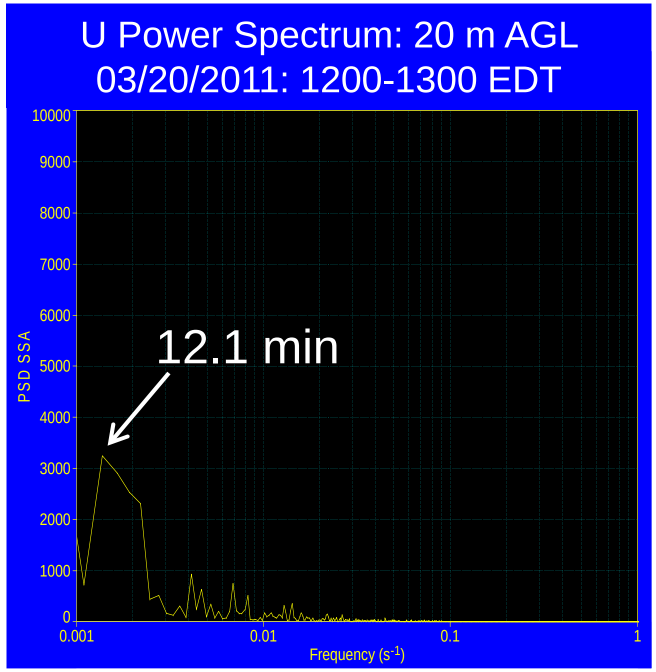


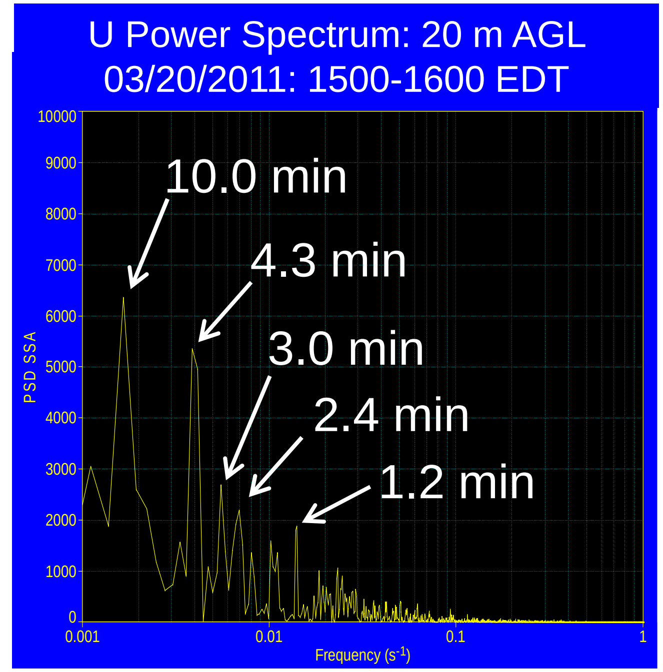
Horizontal Velocity Variability

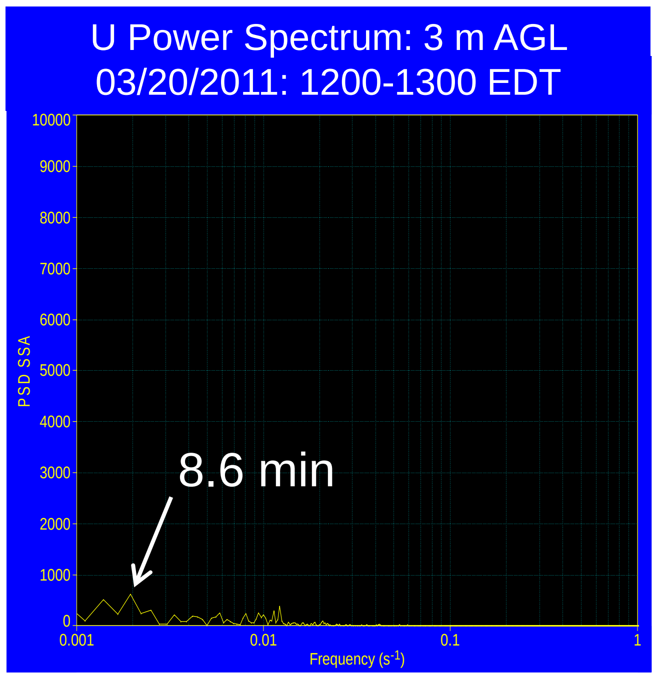
- Higher frequency variability in horizontal velocity during fire line passage.

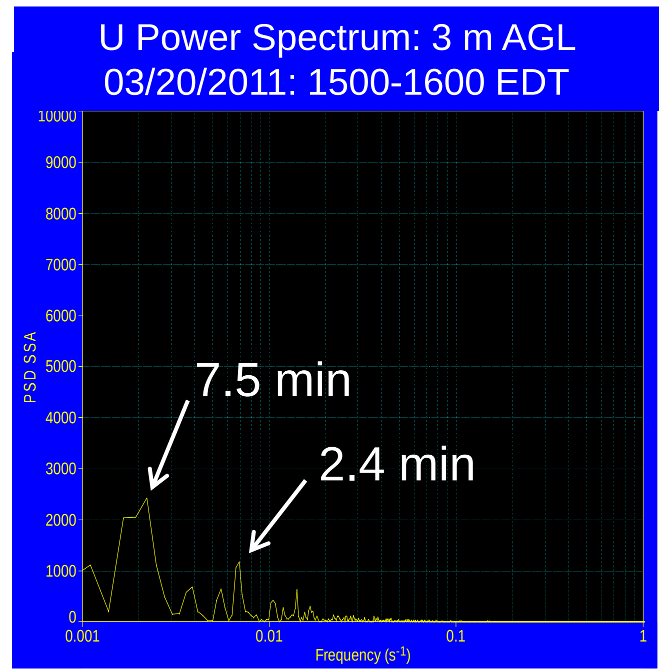
- Relative increase in high frequency horizontal velocity variability is most significant above the canopy top.

- Relatively large increase in PSD for U at 3 m AGL at a period of 7-8 minutes during fire line passage.









Next Steps

- Continue data analyses for all towers.
- Compare observations with data collected from project JFSP-09-1-04-2 (Tara Strand – PI)
- Comparisons of observations with ARPS-FLEXPART and RAFLES simulations.
- Package observational data and upload to the online SEMIP data warehouse.
- Conduct second prescribed burn experiment in NJ Pine Barrens in February-March 2012.
- Incorporate modeling tools into BlueSky framework.