# Development of a Fine Scale Smoke Dispersion Modeling System. Part II – Case Study of a Prescribed Burn in the New Jersey Pine Barrens

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# Motivation

- Prescribe forest ecology a
  - Such fir y and confine
  - Produce rea for extende quality, public h

- Needed: Modeling tools capable of simulating smoke transport and dispersion from low-intensity fires

# Modeling of Smoke Dispersion from Low-Intensity Fires

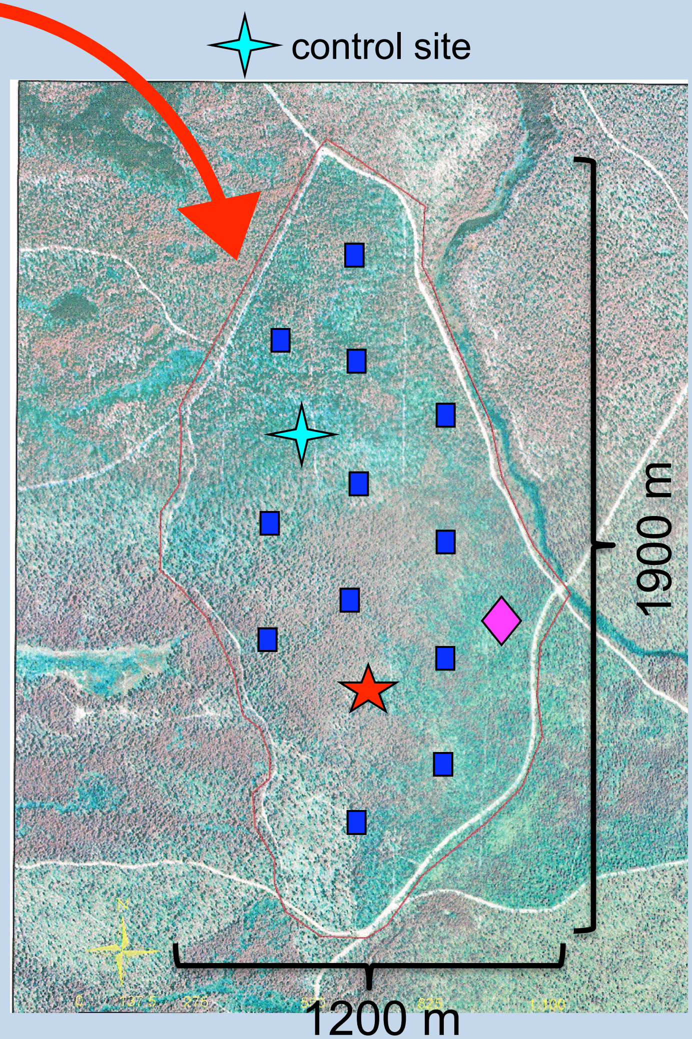
- Particularly challenging due to the effect on dispersion of critical factors such as
  - near-surface meteorological conditions
  - local topography
  - vegetation
  - atmospheric turbulence within and above vegetation layers
- Important: Exchange of particles through vegetation canopy

# Overall Modeling Strategy

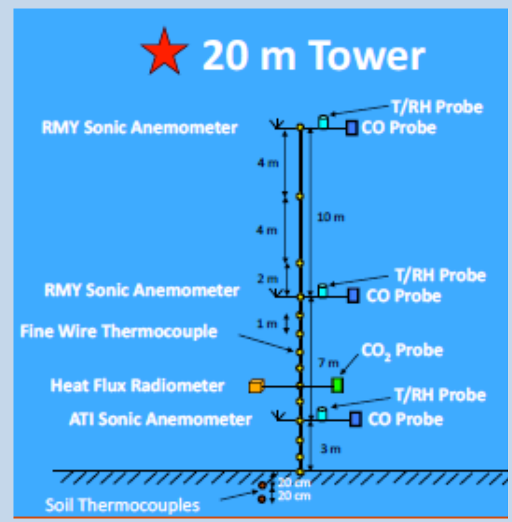
- Run simulations of prescribed fire cases using selected NWP models:
  - Advanced Regional Prediction System (ARPS), WRF, RAFLES
  - Primary validation dataset: 20 March 2011 prescribed burn in the NJ Pine Barrens
- Provide meteorological data to dispersion module: Pacific Northwest National Laboratory (PNNL) Integrated Lagrangian Transport (PILT) Model

# Field Experiment Design

20 March 2011


30 m Tower
10 m Tower
3 m Tower




*Courtesy Warren Heilman, John Hom*

# Model Overview

- Advanced Regional Prediction System (ARPS) Version 5.2.12 (Xue et al. 2003)
  – Three-dimensional atmospheric modeling system
  – Designed to simulate microscale [O(10 m)] through regional scale [O($10^6$ m)] flows
- Standard ARPS lacks the capability to model atmospheric variables (e.g, wind, temperature) within a multi-layer canopy
- Standard ARPS accounts for the bulk effect of a vegetation canopy on the free atmosphere within single layer

# Modifications to ARPS model

(1) Momentum Equation: Pressure and Viscous Drag force term

(2a) SGS TKE Equation: Wake energy sink (eddies larger than canopy elements lose TKE to wake scales and heat)

(2b) SGS TKE Equation: Wake energy production (mean flow and resolved eddies interact with canopy elements)

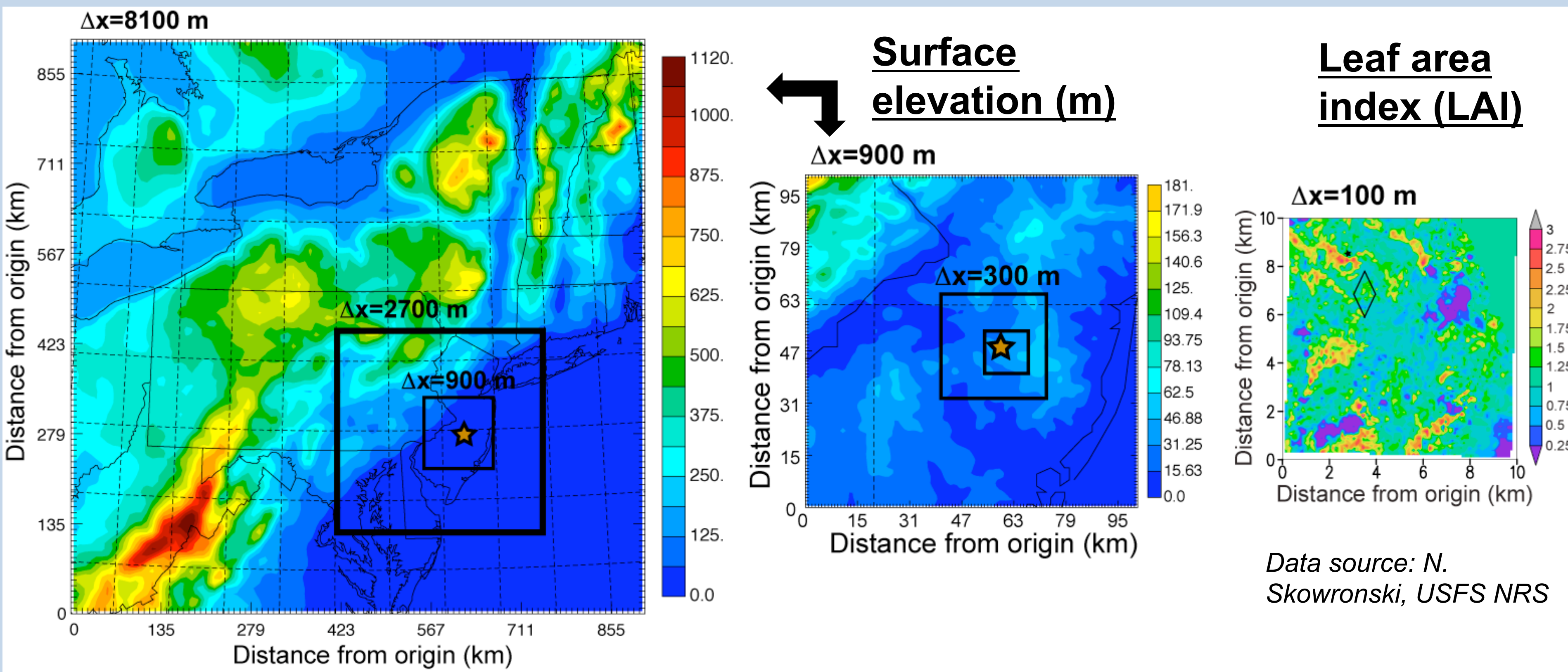
(3a) Radiation Scheme: Net radiation computed at canopy top; downward-decaying profile of net radiation prescribed inside canopy

(3b) Land Surface Model: Ground net radiation flux attenuated

*(1,2a) Dupont and Brunet (2008); (2b) Kanda and Hino (1994); (3a,b) Yamada (1982), Sun et al. (2006)*

# Modeling Experiment Design

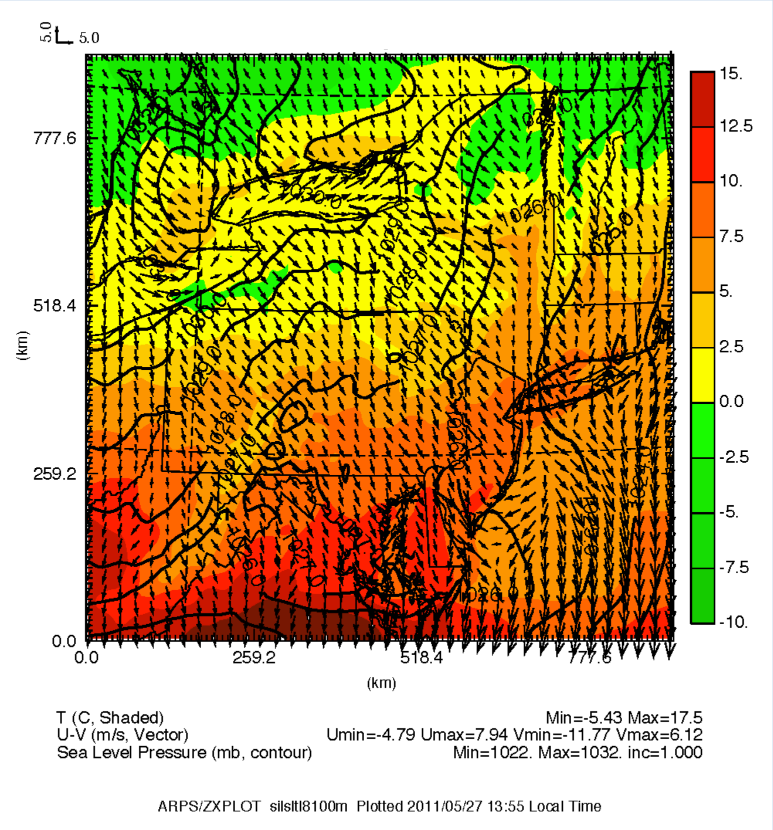
- Model initialized from North American Regional Reanalysis at 00 UTC 19 Mar 2011
- Five 1-way nested domains: $\Delta x = \Delta y$ = 8100m, 2700m, 900m, 300m, 100m
- Innermost nest: Vertical grid spacing is 2 m (9 levels, on average, inside canopy)
- Canopy applied to innermost nest only. Bulk effect of canopy represented by frontal area density, which when vertically integrated yields leaf area index (LAI)



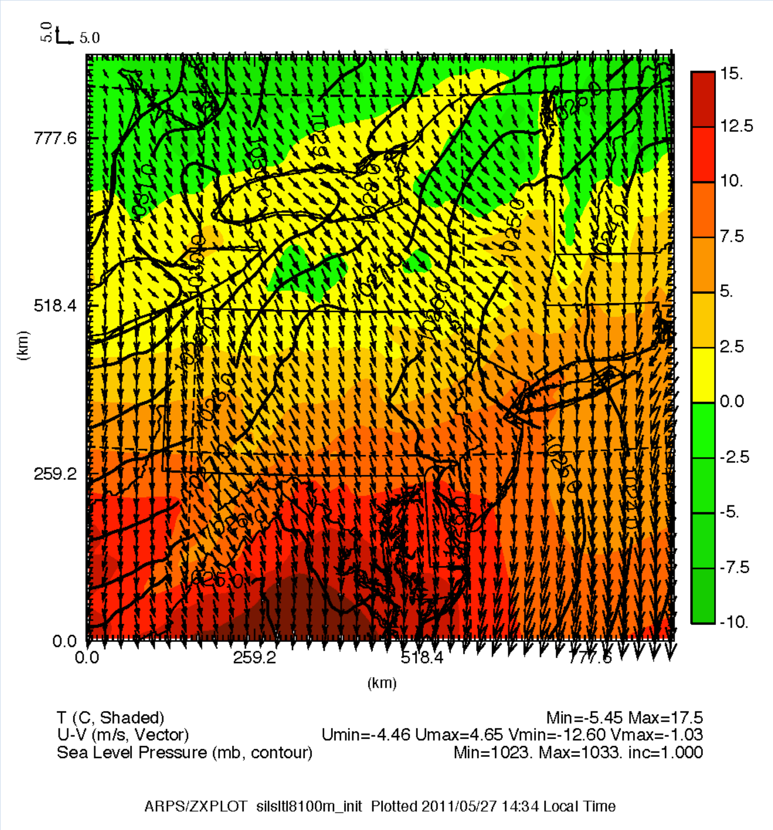
# 19 Mar: Pre-burn day

Outermost grid: Instantaneous surface fields

**ARPS – 1700 EDT 19 Mar**



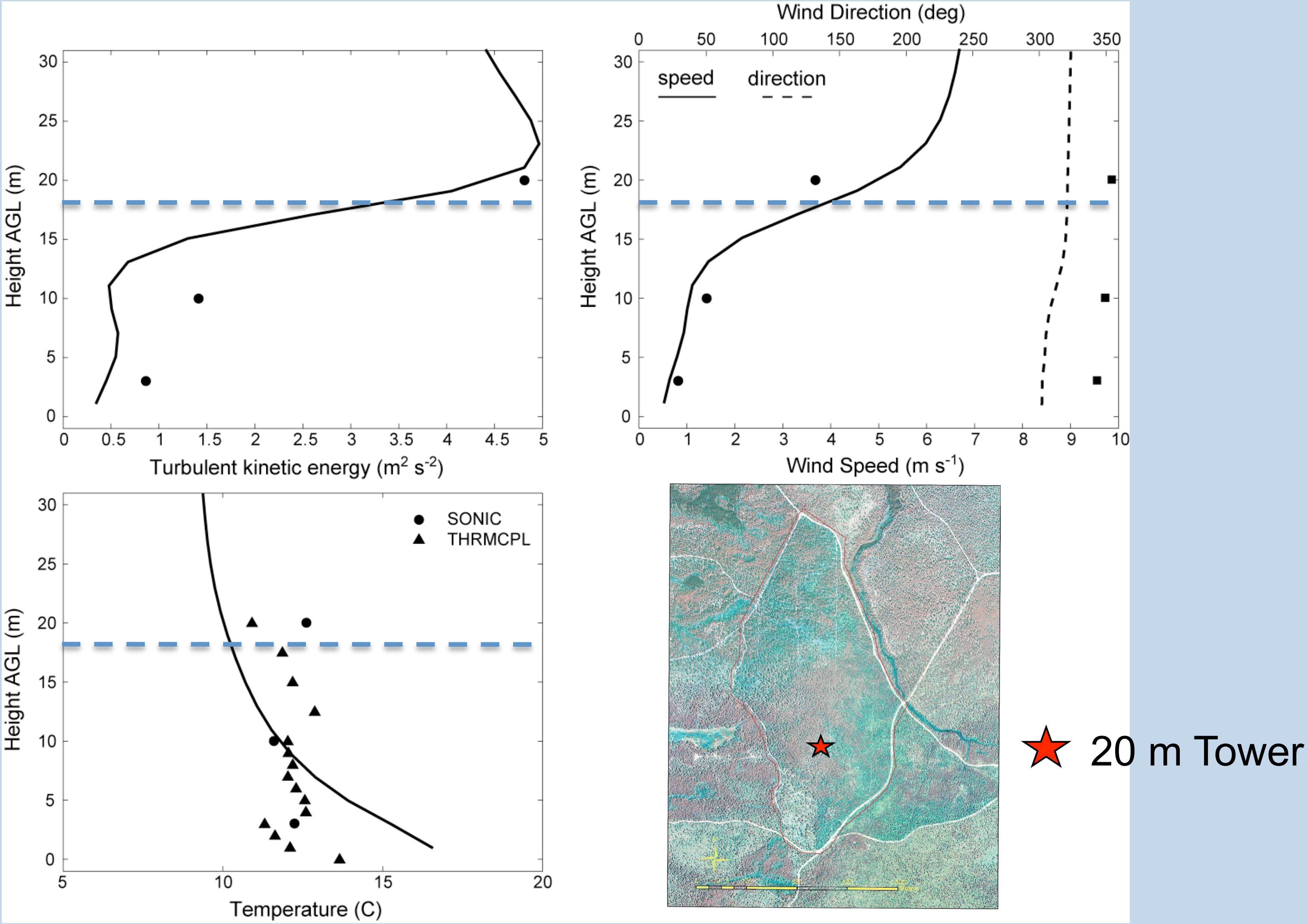

**NARR – 1700 EDT 19 Mar**




** no explicit canopy drag **

# 19 Mar: Pre-burn day

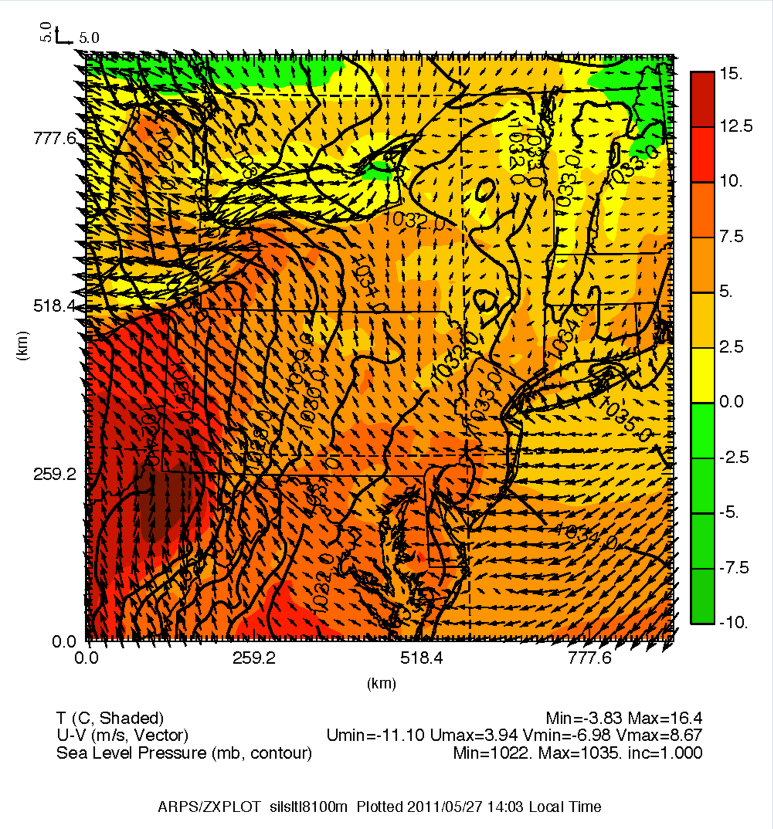
Innermost grid: 3 hour mean profiles (1430-1730 EDT)



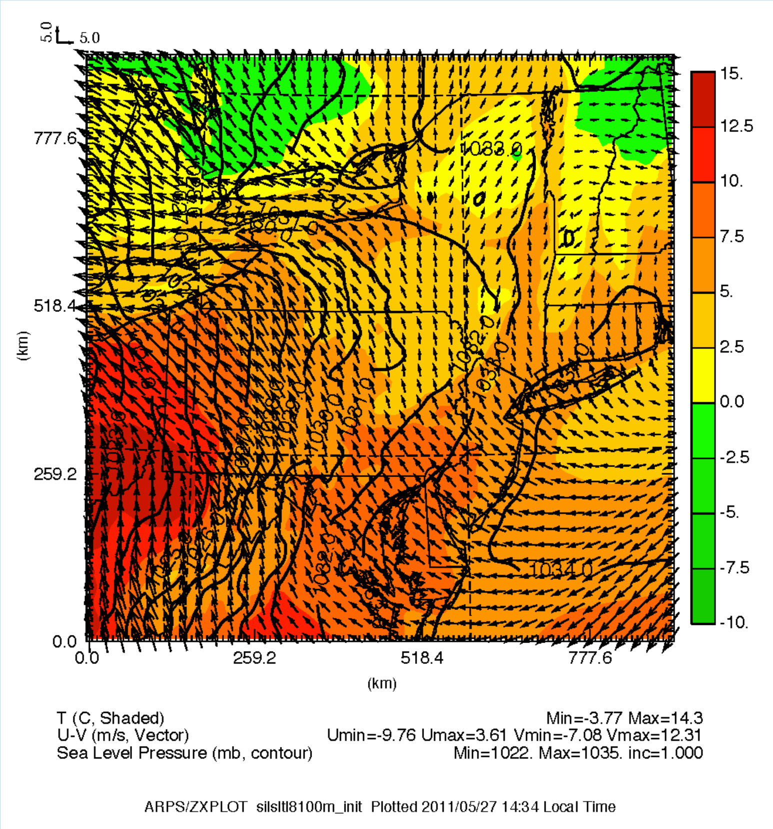
# 20 Mar: Burn day

Outermost grid: Instantaneous surface fields

**ARPS – 1700 EDT 20 Mar**



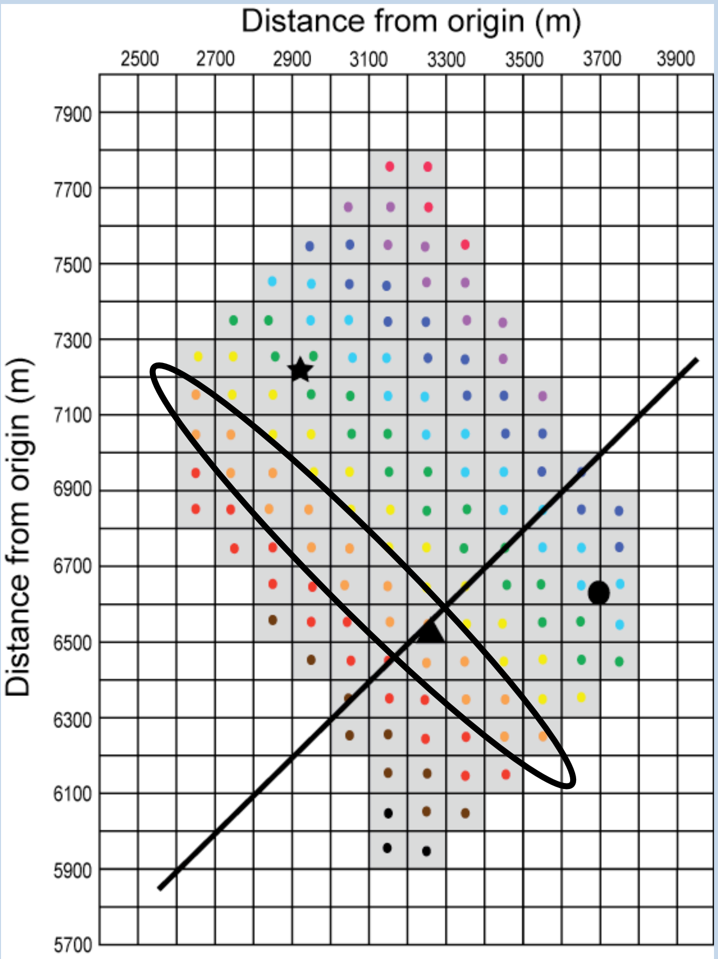

**NARR – 1700 EDT 20 Mar**

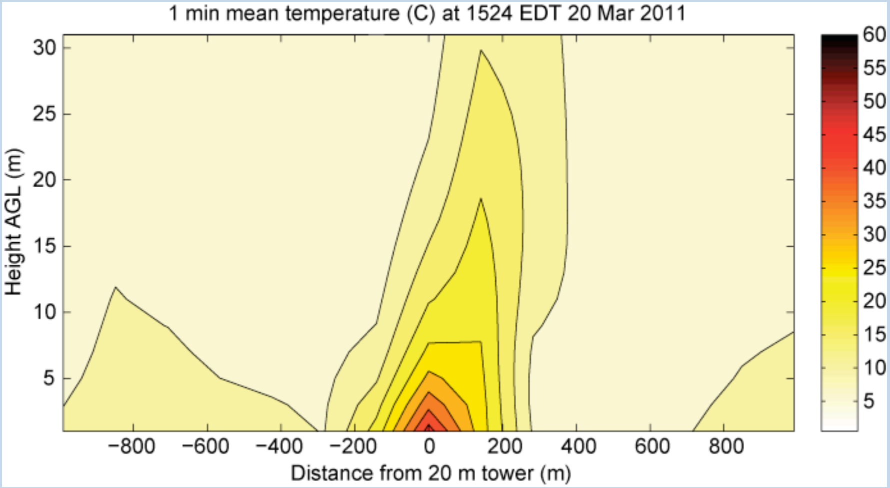


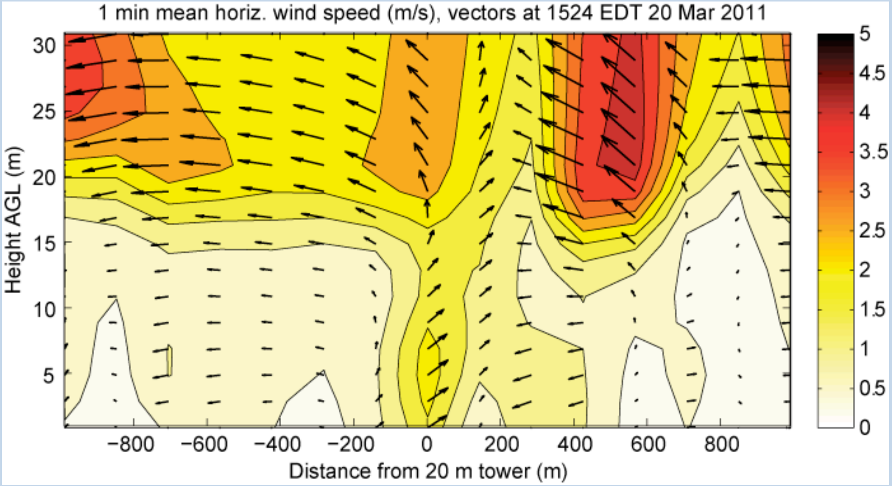

** no explicit canopy drag and no fire **

# 20 Mar: Burn day

Innermost grid: Simulated hot plume at 1524 EDT

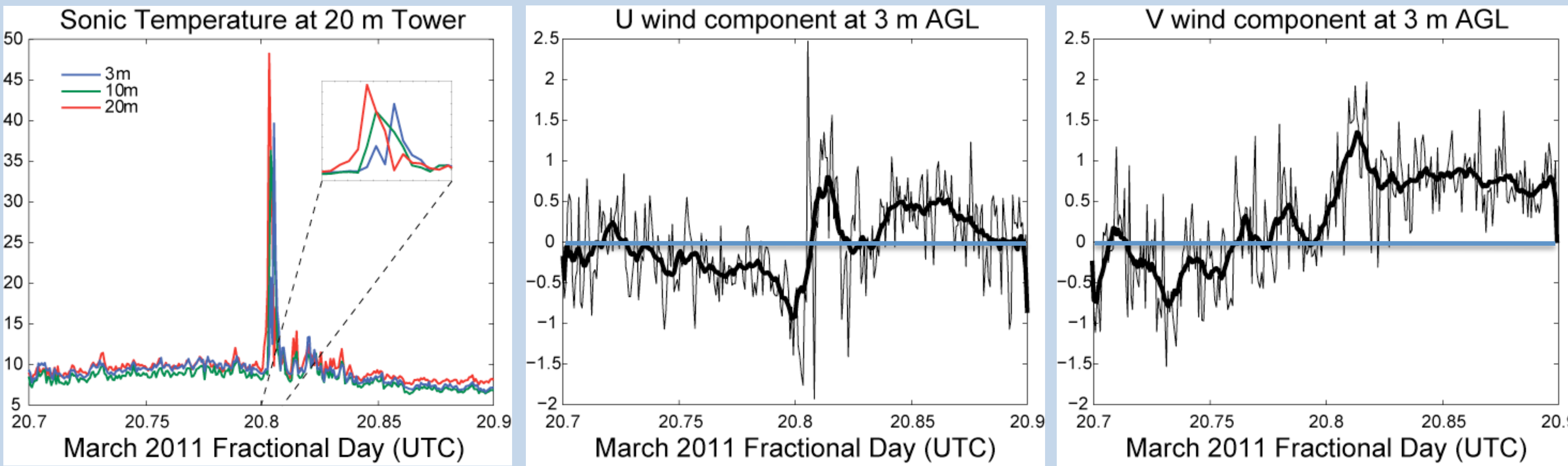


# 20 Mar: Burn day

20 m Tower Observations




- Hot air from fire first observed at 20 m AGL
- Arrival of fire coincides with wind shift at 3 m AGL from very light easterly to 2-3 m $s^{-1}$ southwest winds

# Summary

- ARPS model is able to reproduce large-scale patterns on 19 and 20 March 2011
- Simulated mean flow profiles for 19 March qualitatively agree with tower observations
- Mar 20: Simulated plume cross-sections show:
  - plume tilted into wind
  - Winds either side of fire directed inward, wind field stronger on southwest side of fire

# Ongoing Efforts / Future Work

- Further refine fire parameterization (e.g., surface heat flux, timing)
- Use meteorological data from 20 March simulation as input to smoke dispersion model and validate against PM 2.5 measurements
- Compute budget of resolved TKE
- Revise model code to make fire parameterization more user-flexible

# Acknowledgements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- Sylvain Dupont (INRA – France)



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http://www.geo.msu.edu/firesmoke/