Use of a High-Resolution Atmospheric Model for Pre-Burn Instrumentation Deployment Guidance

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Background

Strategic Environmental Research and Development Program (SERDP)

Project Context

SERDP
DOD ▪ EPA ▪ DOE

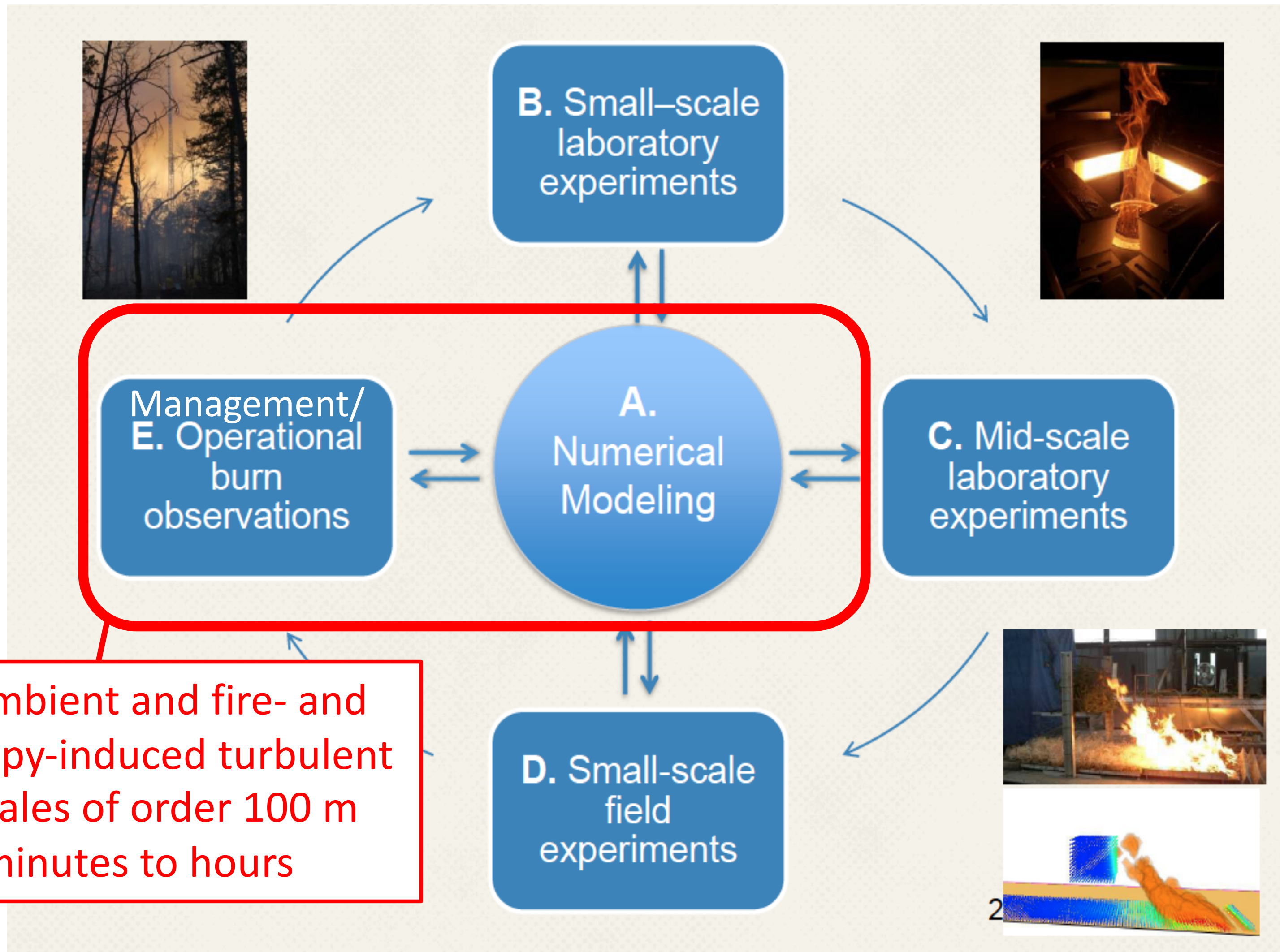
IMPROVED UNDERSTANDING OF **WILDLAND FIRE COMBUSTION PROCESSES** FOR DEPARTMENT OF DEFENSE MANAGED ECOSYSTEMS

- Given the prevalence of the use of prescribed fire by Department of Defense (DoD) managers to mimic historical, low-intensity surface fires, a primary focus is improved understanding of the processes involved in **fine-fuel heat exchange**, **ignition**, and **fire spread** and how they may be affected by **fuel condition**.
- Outcomes of proposed research should be developed in a manner that enables them to be incorporated into fire behavior models useful for predicting ecological effects and emissions responses.

Low-intensity, backing fires: Broad range of relevant scales (order of sub-millimeter to 10 km)

Adapted from Nick Skowronski's North Atlantic Fire Science Exchange webinar [2 May 2018]

Background



Studying ambient and fire- and forest canopy-induced turbulent flows on scales of order 100 m to 10 km, minutes to hours

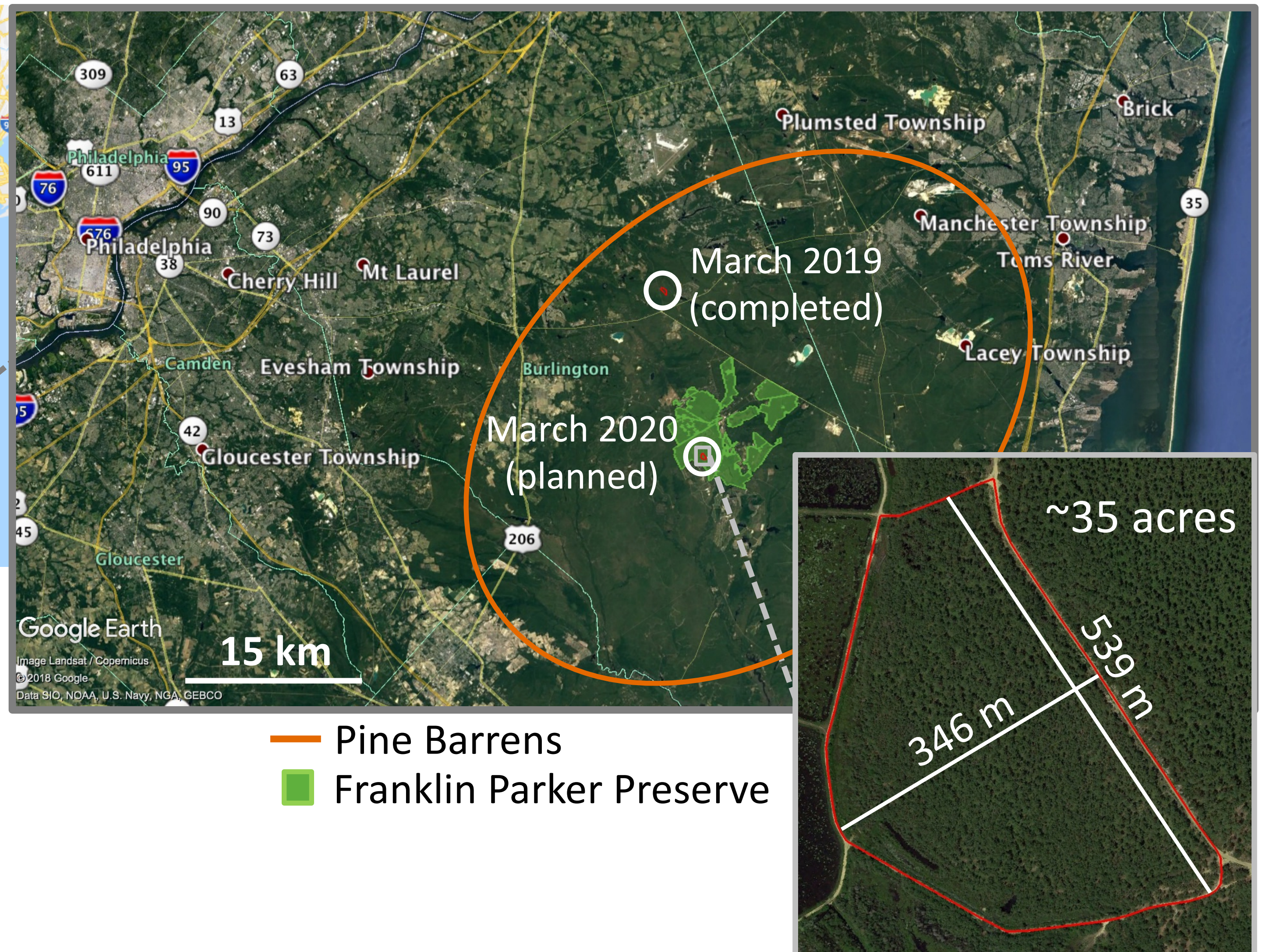
Adapted from Nick Skowronski's North Atlantic Fire Science Exchange webinar [2 May 2018]

Background

Model studies of ambient and fire- and forest canopy-induced turbulence can

- Lead to improvements in prediction of smoke dispersion, tree mortality, fire behavior, etc.
- Help answer questions that field campaigns alone are unable to address (more degrees of freedom)
- Provide guidance for instrument placement prior to field campaigns

2020 SERDP management-scale burn site: Franklin Parker Preserve, NJ



Pine Barrens

Franklin Parker Preserve

http://gonehikin.blogspot.com/2012/01/franklin-parker-preserve-nj.html

Objective

Use high-resolution atmospheric simulations to help guide the deployment of a monitoring network for a management-scale prescribed fire experiment. Identify areas of burn block with:

- Stronger gradients in simulated variables
- Less sensitivity of simulated variables to changes in fire and background conditions
- Simulated phenomena of interest (e.g., vortices)

****The preliminary results shown here are intended as a proof-of-concept ****

ARPS-CANOPY overview

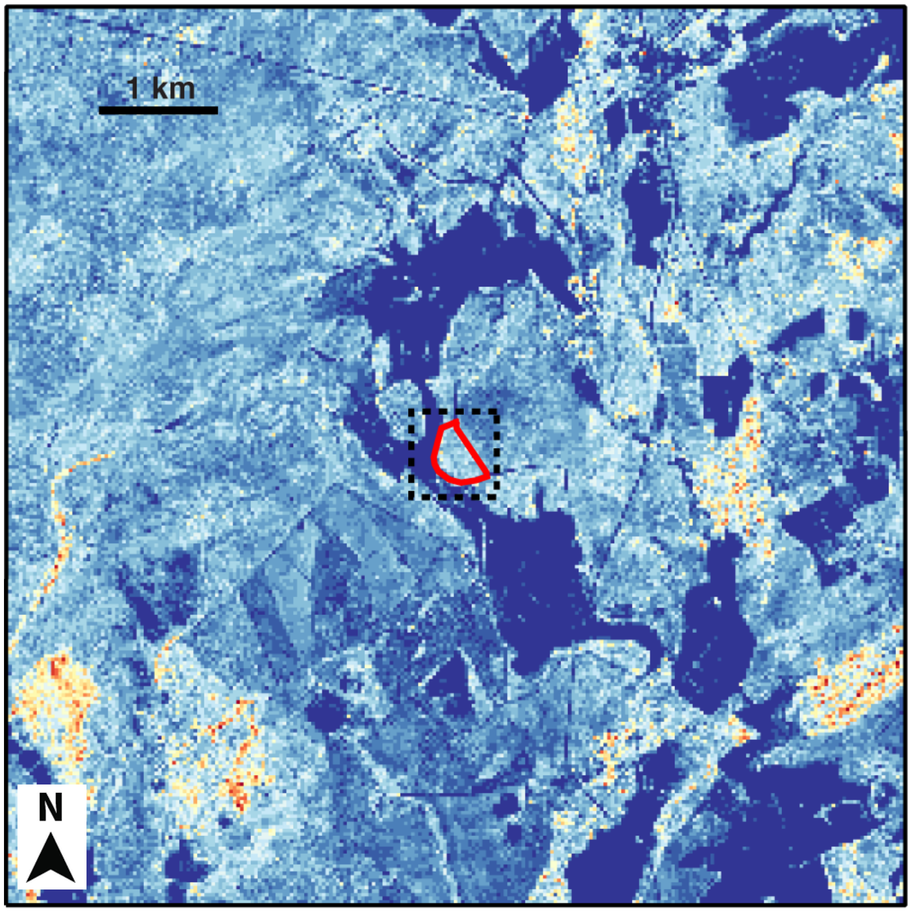
- Core: Advanced Regional Prediction System (ARPS) (Xue et al. 2000,2001)
  - Atmospheric model developed for weather prediction at multiple scales
- Canopy sub-model (Kiefer et al. 2013):
  - Explicitly accounts for canopy drag, enhancement of turbulence dissipation, and wake turbulence production
  - Parameterizes heating/cooling of vegetation elements, shading of ground surface, and canopy-atmosphere moisture exchange
  - Canopy is represented by a plant area density profile
- Fire is parameterized as an area of enhanced surface vertical heat flux (one-way coupled to atmosphere)

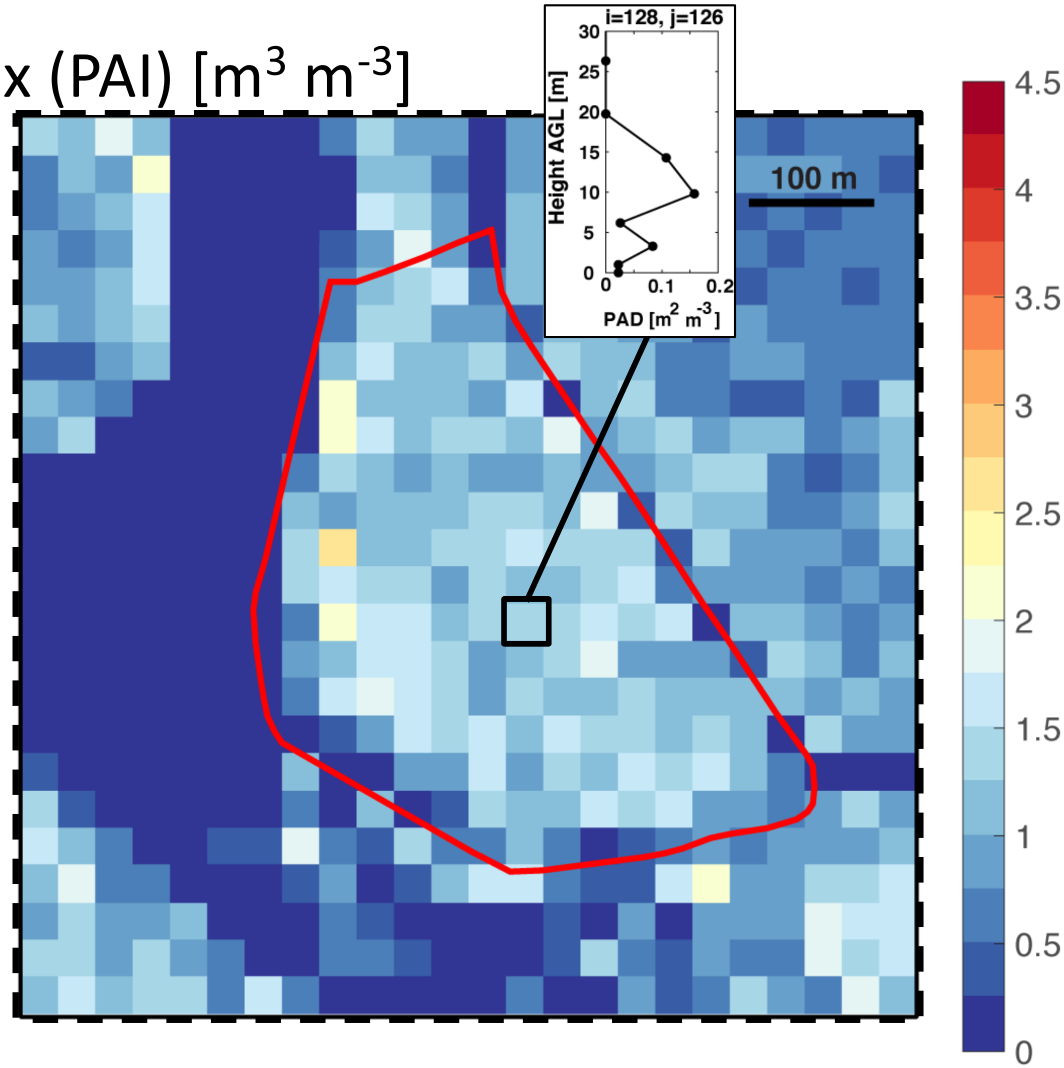
Model setup and experiment design

LiDAR-derived plant area density dataset

Δx = 30 m
Δz_{min} = 2 m

Plant area index (PAI) [m^3 m^{-3}]





Model setup and experiment design

1 m min^{-1}
spread rate
(steady-state)

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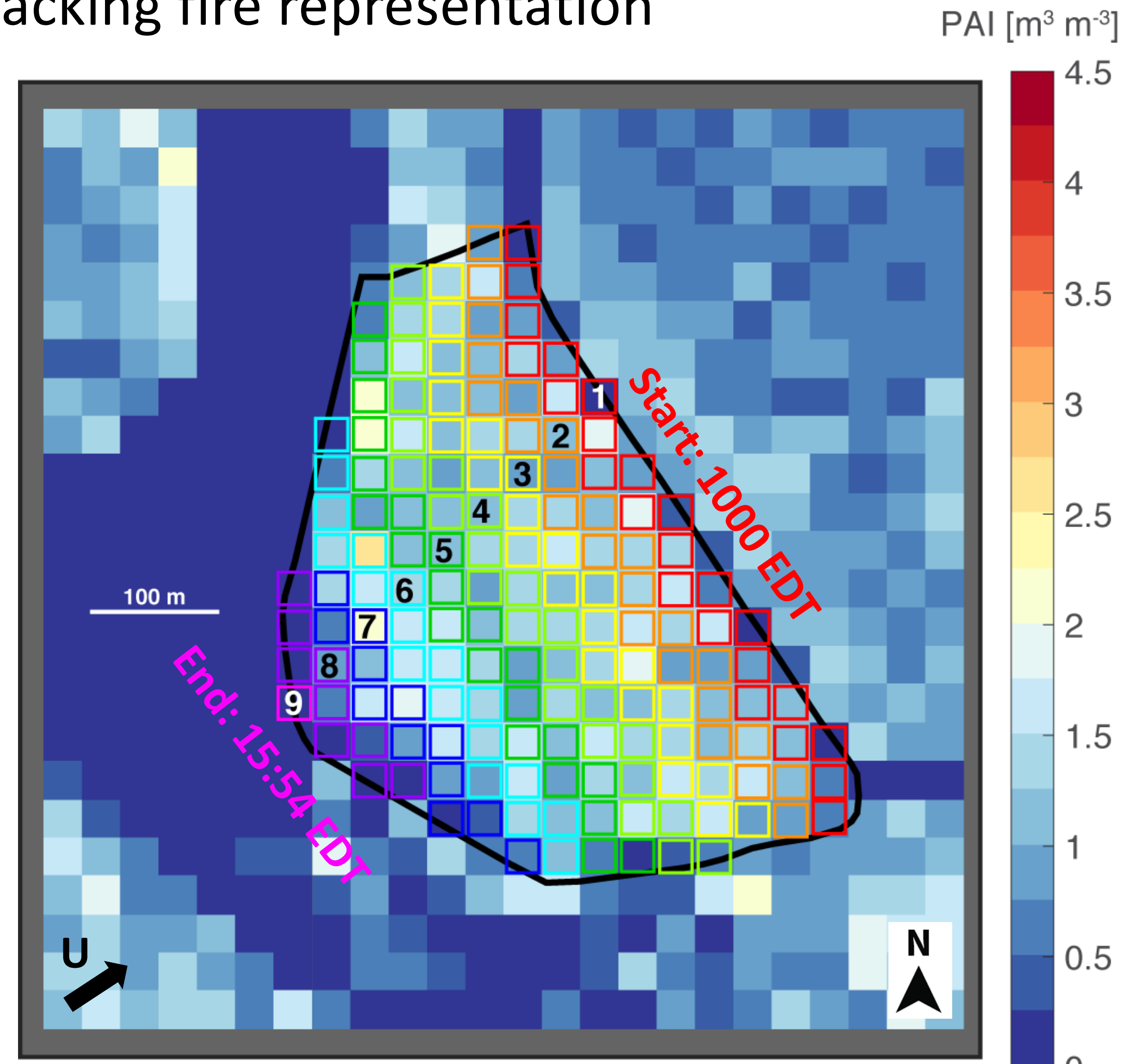
5 hr 54 min burn period

Surface heat flux varied four ways:
0, 5, 10, 25 kW m^{-2}

Backing fire representation



Model setup and experiment design

Model initialization

- Model initialized with idealized wind and temperature profiles
- Constrained by location (central NJ), time of year (March), time of day (0800 EDT), and burn block details (shape, backing fire mode)

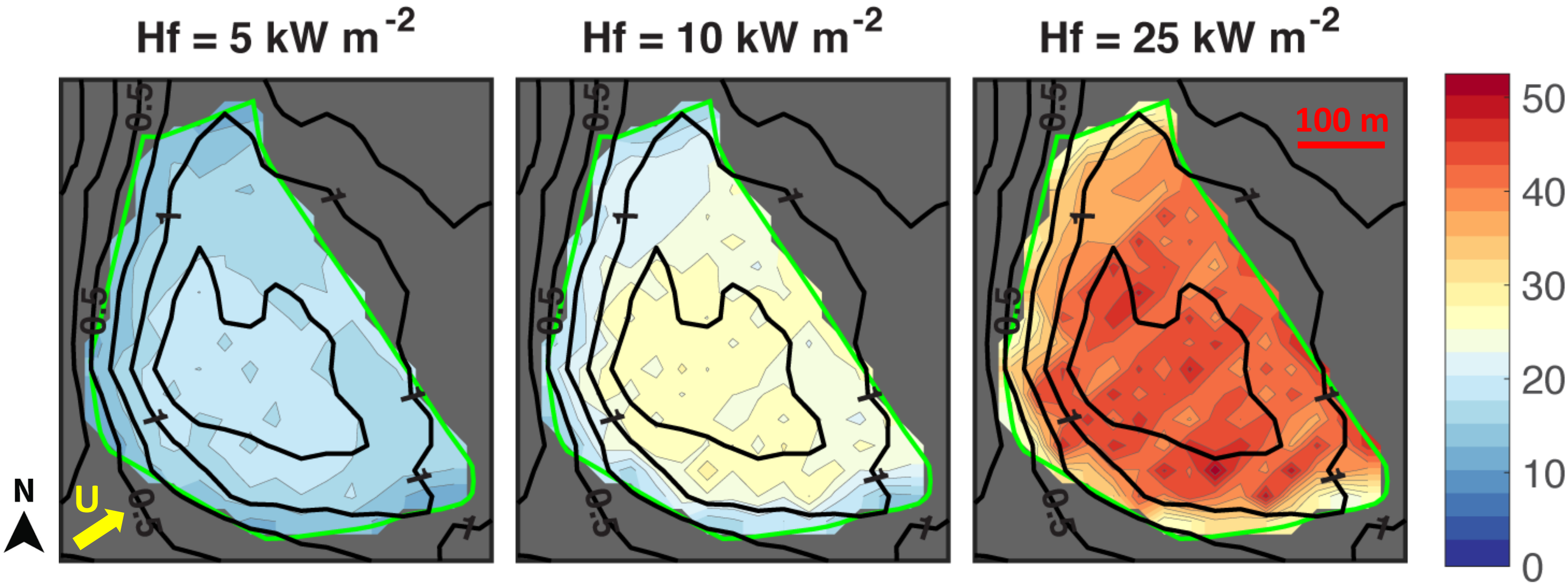
$WS_{1\text{-m}}$	$WS_{500\text{-m}}$	WD_{ALL}	$T_{1\text{-m}}$	$RH_{1\text{-m}}$
1.4 ms^{-1} (3.1 mph)	2.5 ms^{-1} (5.6 mph)	236.5^o (WSW)	1.3 ^oC (34.3^oF)	62.2 %

- Surface energy budget appropriate for mid-March
- Flat terrain

Results

1 m AGL Temperature [^{o}C]

1-min mean
Burn period 90th percentile

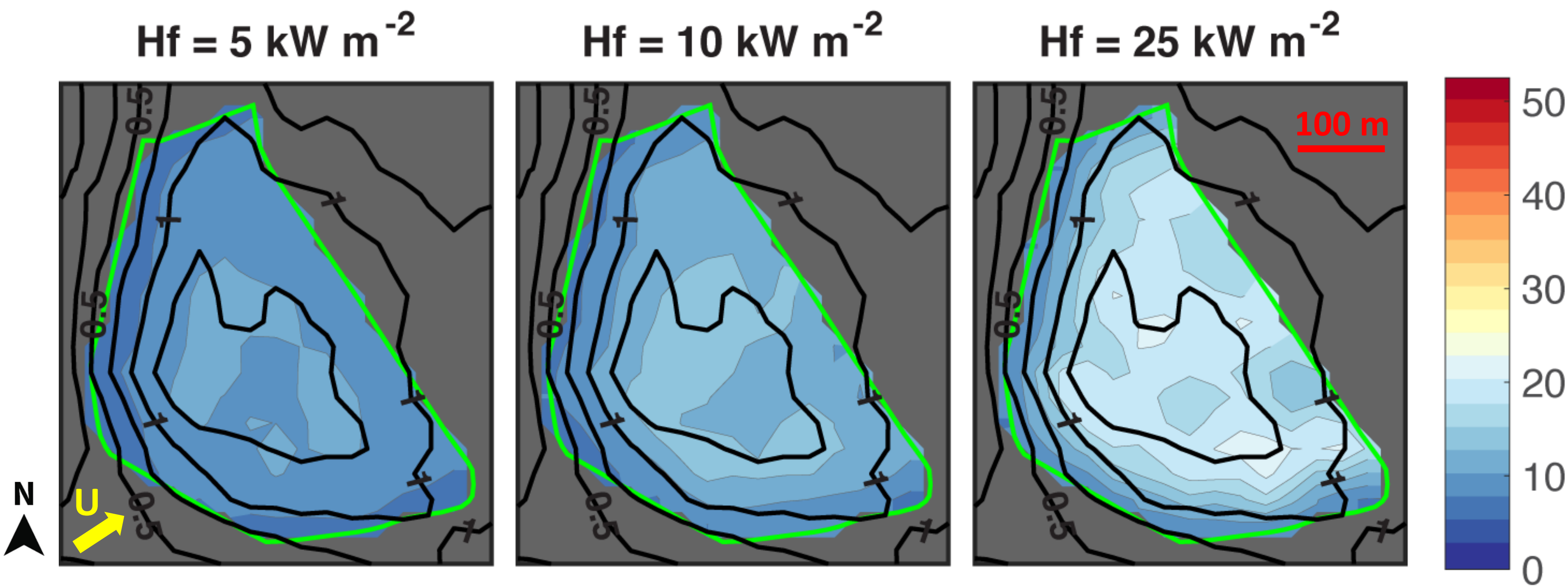


- Temperature gradient strongest near southern and western perimeter
  – Consistent across cases
- Interior heterogeneity increases with increasing heat flux

Results

9.8 m AGL Temperature [°C]

1-min mean
Burn period 90th percentile



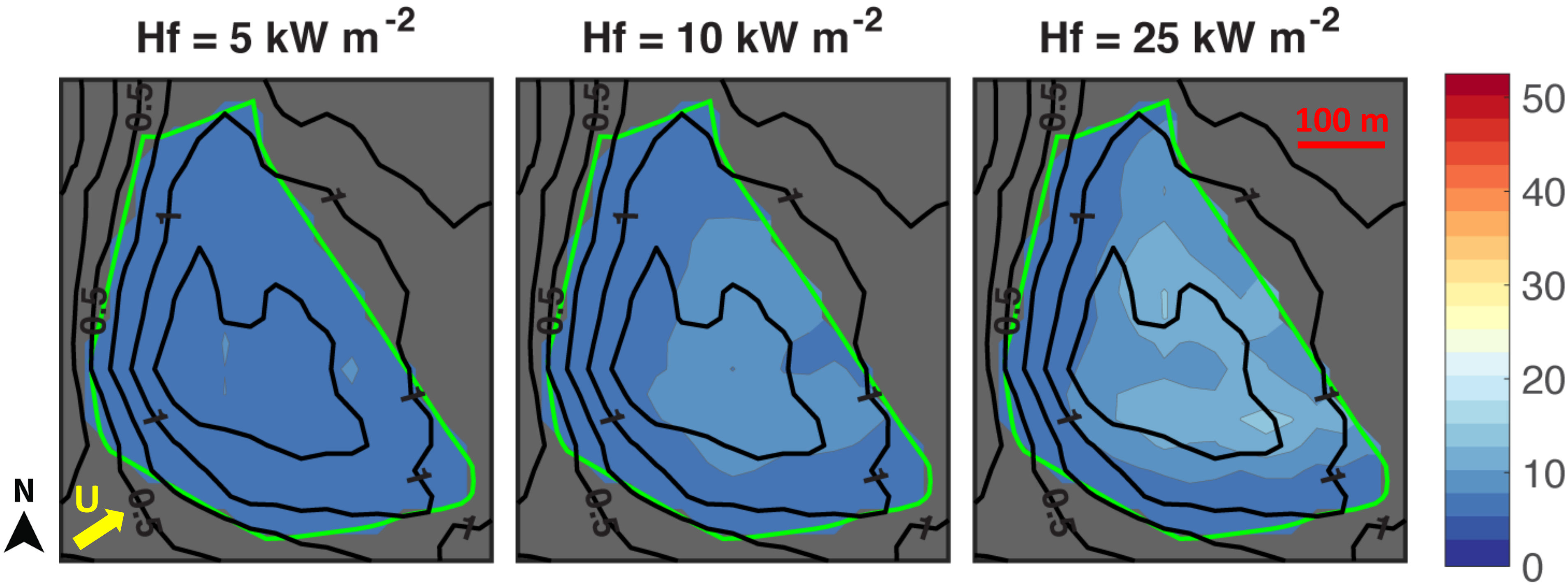
- **Denser vegetation → higher temperatures**
  - **Consistent across cases**

Results

26.3 m AGL Temperature [^oC]

1-min mean

Burn period 90th percentile



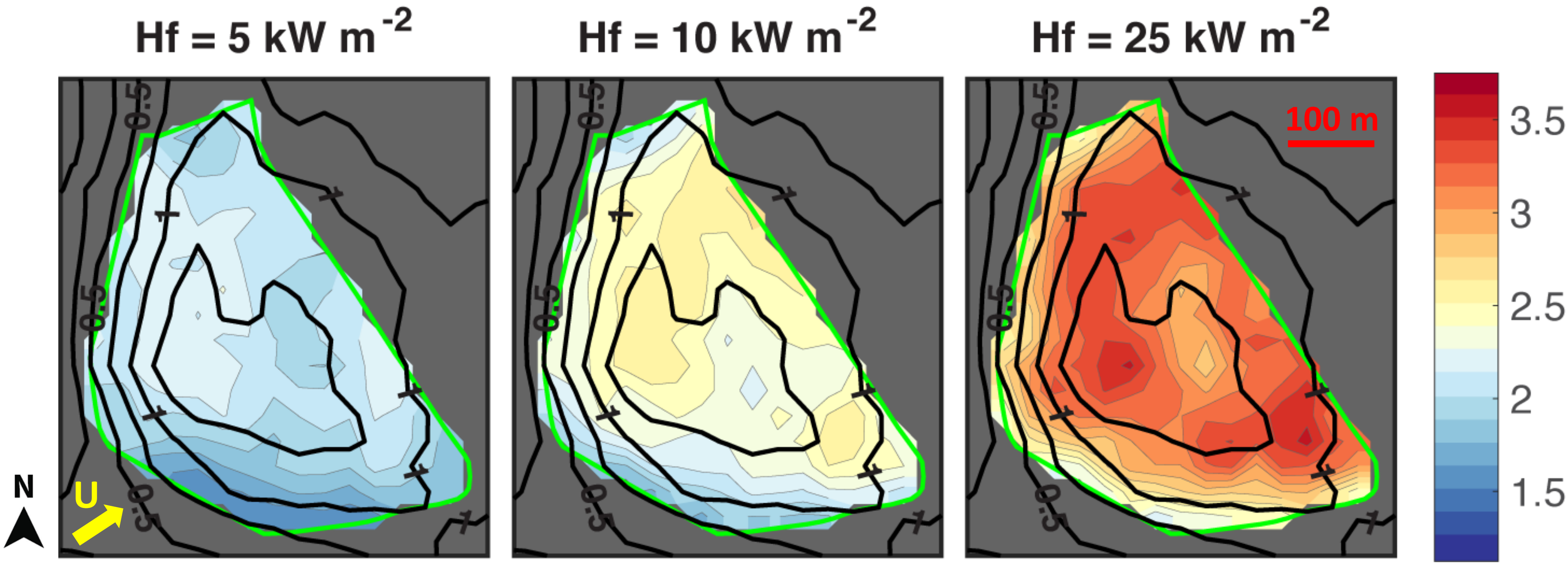
- **Denser vegetation → higher temperatures**
  - **Consistent across cases**
- **Pattern more homogeneous than at other levels**

Results

1 m AGL Wind speed [m s^{-1}]

1-min mean

Burn period 90th percentile



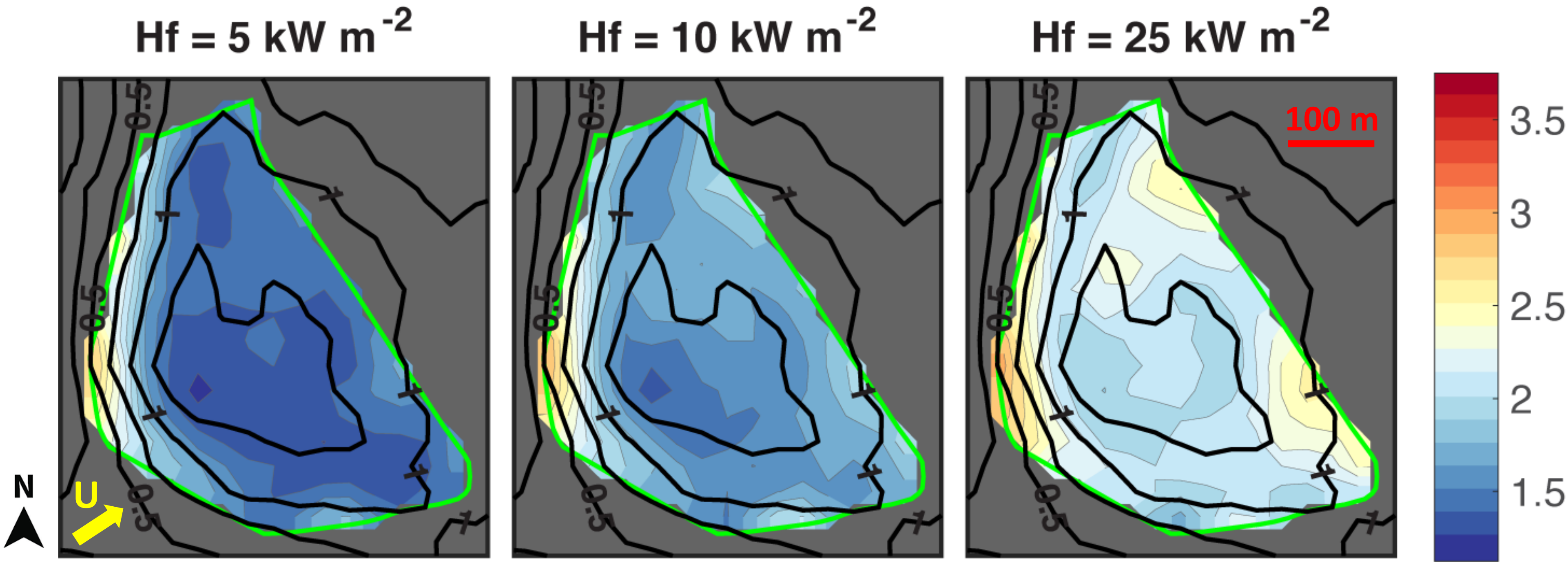
- **Wind speed gradient strongest near southern perimeter**
  - **Consistent across cases**
- **Spatial pattern of wind speed consistent across cases**

Results

9.8 m AGL Wind speed [m s^{-1}]

1-min mean

Burn period 90th percentile



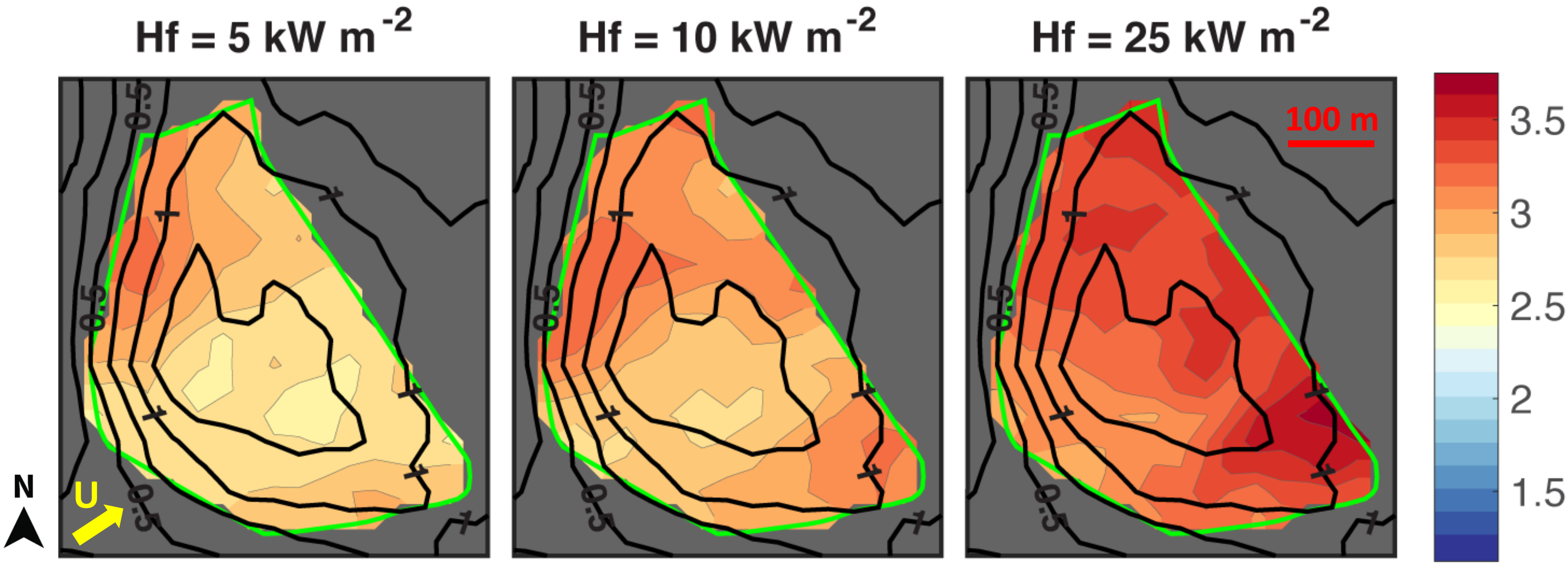
- **Wind speed gradient strongest near western perimeter**
  - **Consistent across cases**
- **Magnitude of upwind gradient weakens with increasing heat flux**

Results

26.3 m AGL Wind speed [m s^{-1}]

1-min mean

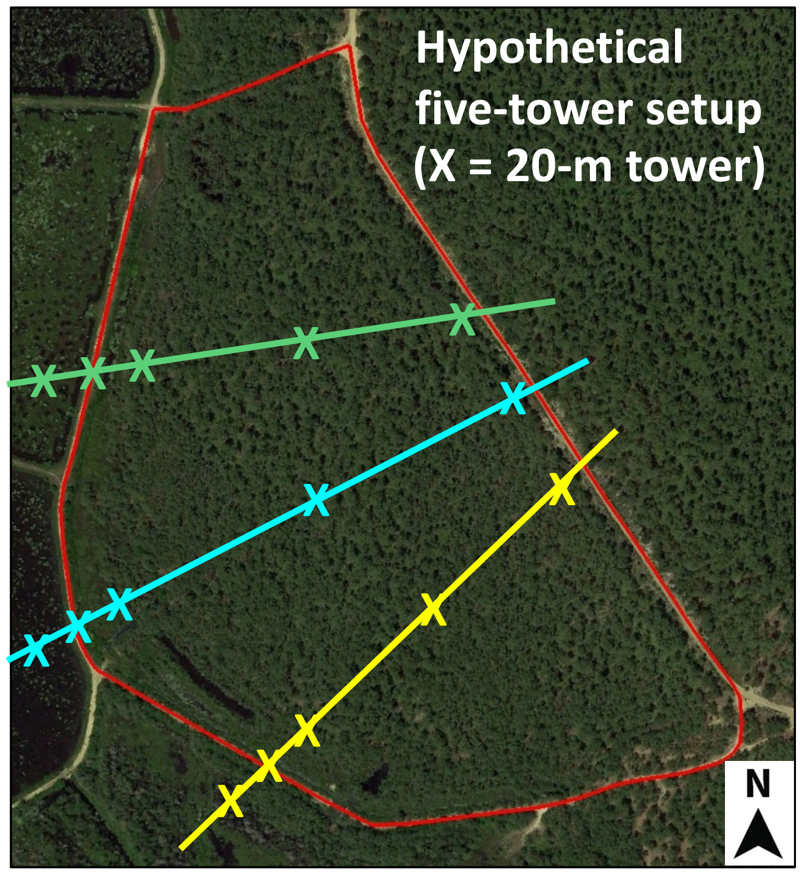
Burn period 90th percentile



- Spatial pattern inconsistent across cases
- Pattern noticeably different at all three levels

Summary & Conclusions

- Modeling framework developed here shows promise for informing instrumentation deployment strategy
  - Preliminary results shown here suggest one or more linear arrangements, with clustering where simulated gradients were overall strongest



Summary & Conclusions

- Modeling framework developed here shows promise for informing instrumentation deployment strategy
- Deployment recommendations may depend on variables of greatest interest: e.g., **temperature, wind speed**, turbulent quantities (turbulent kinetic energy, sweeps/ejections), radiation
- Actual deployment strategy subject to late adjustments based on weather forecasts, and above all, on-the-ground expertise

Next Steps

- Perform ARPS-CANOPY simulations of 13 March 2019 prescribed fire in Silas Little Exp. Forest, NJ
- Perform additional sensitivity simulations of Franklin Parker Preserve fire (planned: 2020):
  - Vary background weather conditions (wind, stability)
- Synthesize findings of pre-burn simulations to provide guidance for 2020 field deployment

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