# Using Multi-scale Fire Predictive Indices For The Yarnell Hill Fire

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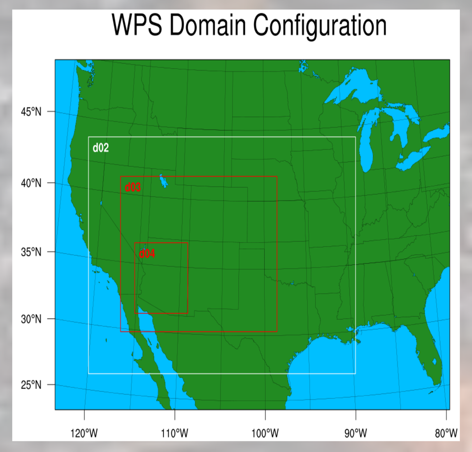
## Introduction

- Major wildfire events induced by high winds in SW U.S.
  - loss of life and property
- Wind surges remain challenging
  - Fundamental dynamical processes and numerical prediction
- Fires share similar roots in complex terrain
  - Wind intensification from complicated, nonlinear interactions among the terrain-induced waves

**Research Objectives:**
Improve understanding of multi-scale atmospheric processes that control the motion and longevity of extreme fire events in complex terrain

- Determine an index that best represents probability of fire initialization
- Determine if any index "propagates" with the fireline

## Data




**Model:** ARW-WRF
- Version 3.9

**Initialization:** NCEP GDAS/FNL 0.25 Degree Global Tropospheric Analyses and Forecast Grids Data

**Grid Dimensions:** 0.777km, top: 100 hPa, levels: 50

**Data**: 1. 21km (not shown) for CONUS June 30th 12Z to July 1st 00Z by 6 hr. increments
2. 0.777km (Above) for AZ June 30th 03Z to July 1st 00Z by 3 hr. increments

**Plotting:** MATLAB and GrADS

## Haines Index (HI)

- Old Fire Index (1980s)
  - Primary purpose is to use the HI as a starting point
- Used to Investigate relevance of the HI with probability of fire initialization
- High HI for 0.777km file best represents the area from trial and error plots
  - Because of the elevation
- HI for Yarnell between 4 and 5 (unitless) for the time depicted in figure 2
- 21km data had similar results but more coarse
- **Conclusion:** Need more detailed time series for better picture, HI should be higher, model just depicts a period of low activity and is limited in available data

| Elevation | Stability (A) Component | | Moisture (B) Component | |
|---|---|---|---|---|
| | *Calculation* | *Categories* | *Calculation* | *Categories* |
| **Low** | 950hPa temperature – 850-hPa temperature | A = 1 if <4°C<br>A = 2 if 4-7°C<br>A = 3 if ≥8°C | 850-hPa temperature – 850-hPa dewpoint temperature | B = 1 if <6°C<br>B = 2 if 6-9°C<br>B = 3 if ≥ 10°C |
| **Mid** | 850-hPa temperature – 700-hPa temperature | A = 1 if <6°C<br>A = 2 if 6-10°C<br>A = 3 if ≥11°C | 850-hPa temperature – 850-hPa dewpoint temperature | B = 1 if <6°C<br>B = 2 if 6-12°C<br>B = 3 if ≥13°C |
| **High** | 700-hPa temperature – 500-hPa temperature | A = 1 if <18°C<br>A = 2 if 18-21°C<br>A = 3 if ≥22°C | 700-hPa temperature – 700-hPa dewpoint temperature | B = 1 if <15°C<br>B = 2 if 15-20°C<br>B = 3 if ≥21°C |

* *Modified from Haines, 1988.*

Figure 1 (top): Haines Index Calculation based on Winkler et. al., 2005.

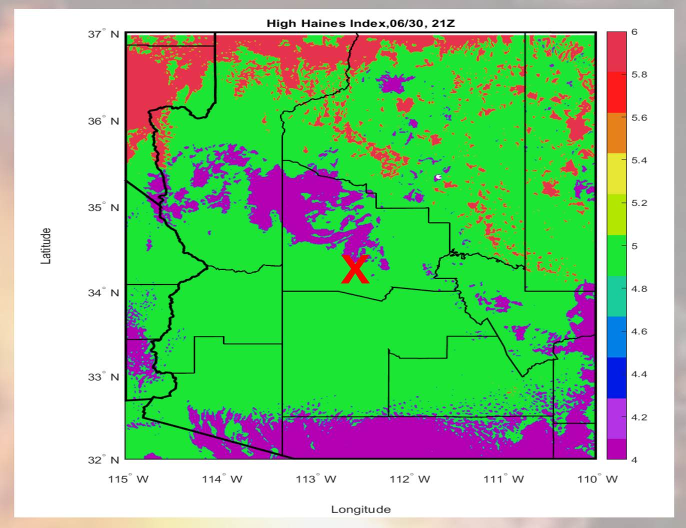



Figure 2 (Right): High Haines Index for Arizona on 6/30 at 21Z, red "x" is location for Yarnell.

## Hot Dry Windy Index (HDW)

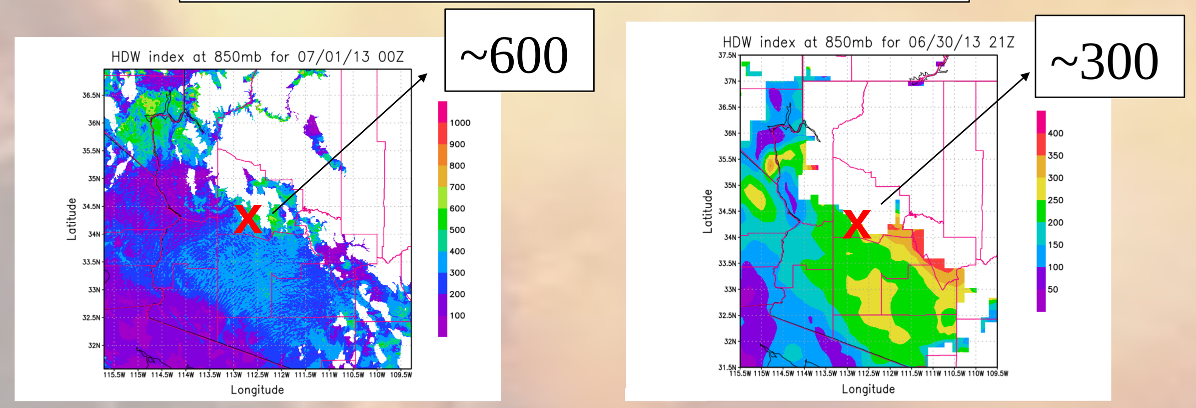



Figure 3 (top): HDW for 0.777km data (left) at 07/01/13 00Z and 21km data (right) for 06/30 21Z, red "x" is approximate location of Yarnell.

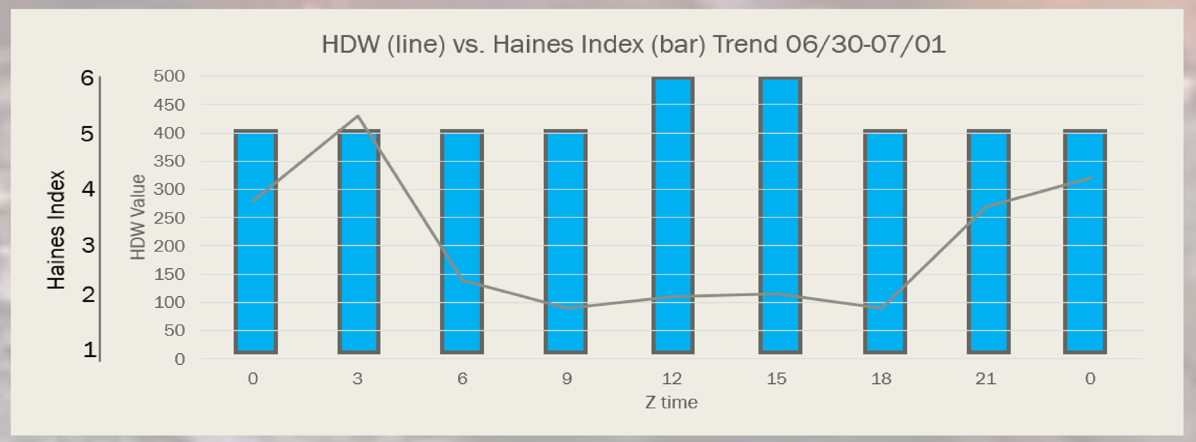



Figure 4 (top): HDW vs Haines. HDW for 21km data performs betters at fire probability since it is more accurate for the environment.

HDW Calculation (within lowest 500m AGL)

$$RH(T,q) = [e(q)/es(T)] \times 100\%$$

$$VPD(T,q) = es(T) - e(q)$$

$$HDW = U \times VPD(T,q)$$

*Based off of Alan Srock et. al., 2018

- HDW more recent
  - Includes moisture and advection terms
- High values occur in the hundreds (unitless for display purposes)
- **Conclusion:** Preliminary result indicate the HDW Index more accurate than the HI to represent fire likelihood

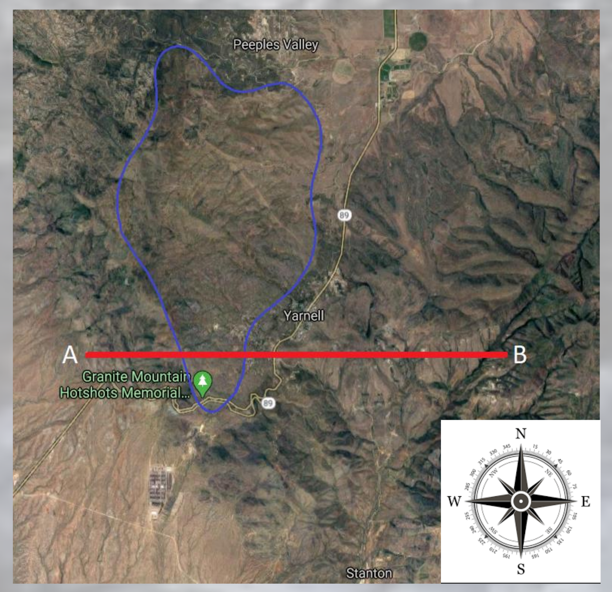
## HDW Cross Section

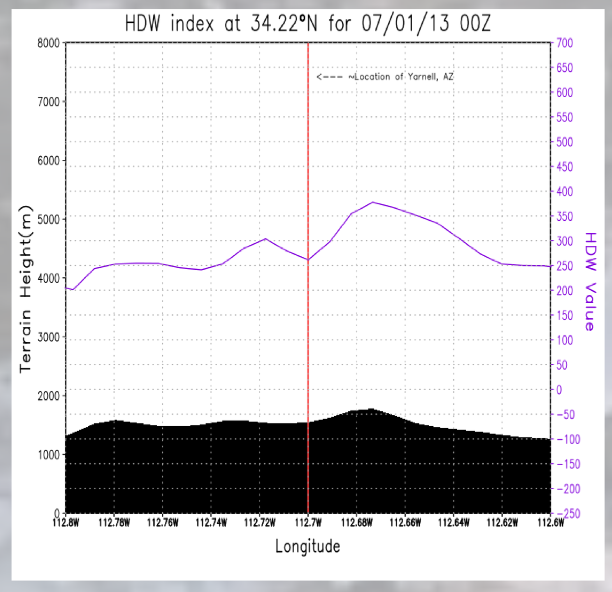
- HDW for 0.777km data appears to adjust with the terrain
- HDW for 21km data not very significant
- Maximum (for Yarnell)
  - 0.777km: ~260 at 00Z
  - 21km: ~350 at 03Z
- Minimum (for Yarnell)
  - 0.777km: ~50 at 18Z
  - 21km: ~50 at 09Z
  - **Conclusion:** Cross section needs to be adjusted to more accurately represent the fire. Higher resolution and different levels also needed

*Note data is taken at 800mb hence different than the top down view

Figure 5 (bottom left): Test cross section taken to see if the HDW Index propagates.

Figure 6 (bottom right): HDW at 07/01 00Z for 0.777km file (finer resolution), blue is approximate maximum fire outline, red is cross section at ~34° N.




## Future Work

- Comparisons to observations and other fires (Figure 8)
- Better representative cross section
- Calculate instability parameters
  - Brunt-Väisälä Frequency
  - Shear Instability
  - Kelvin-Helmholtz Instability
- WRF Simulation(s)

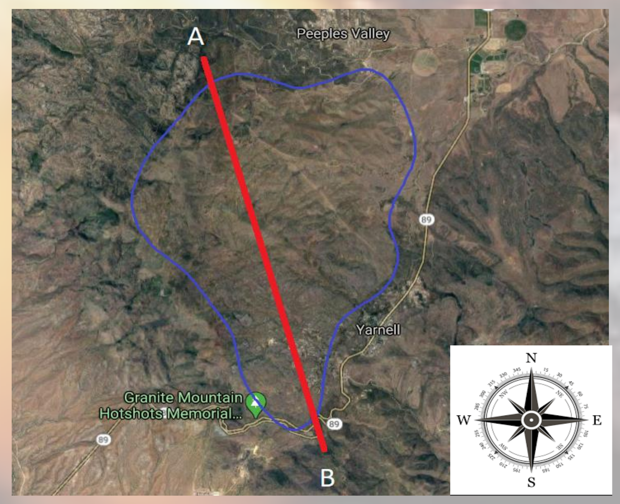



Figure 7 (left): Cross section planned to do for future work, blue is approximate maximum fire outline, red is cross section at ~34° N.

Figure 8 (right): Other Historic Fires in the project.


## References

1. Srock, A. F., Charney, J. J., Potter, B. E., & Goodrick, S. L. (2018). The Hot-Dry-Windy Index: A new fireweather index. *Atmosphere, 9*(7). doi:10.3390/atmos9070279
2. Winkler, J., Potter, B., Wilhelm, D., Shadbolt, R., Bian, X., & Piromsopa, K. (2005). *A climatology of the Haines Index for North America derived from NCEP/NCAR reanalysis fields*

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