Implications of Hot-Dry-Windy Spatiotemporal Sensitivity

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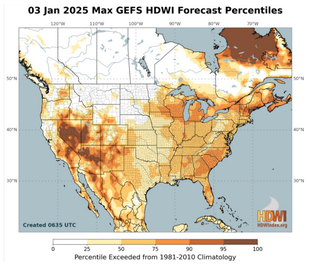
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Background

Fire weather indices, such as the Hot-Dry-Windy Index (HDWI), are regularly used in wildfire operations to guide resource allocation and ensure safe and effective management. It is important to understand how indices computed from different data sources behave statistically. The HDWI is a once-daily maximum value produced operationally by the U.S. Forest Service (USFS) out to seven days on a 0.5° spatial grid. It was designed by Srock et al. (2018) to use predictable, synoptic-scale components of weather forecasts indicative of where atmospheric conditions are likely to promote especially dangerous fire behavior. However, there may be inconsistencies in the HDWI at higher temporal and spatial resolutions; users have furthermore raised questions about how this index is calculated and the possible consequences of using alternative methods.



Approach

The HDWI uses the maximum windspeed (WS) and vapor pressure deficit (VPD) values, relative to local historical percentiles, from any level within the lowest 500 meters of the atmosphere. A potential temperature stability check masks layers that differ from the surface by more than 1.0°C. The highest HDWI value across three daily time steps is adopted (06Z, 12Z, 00Z); this method is implemented operationally with short-term forecasts and hosted by the USFS (https://hdwindex.fs2c.usda.gov/index.html).*

The vertical HDWI methodology identifies the most extreme scenario (i.e., highest value) that could arise from WS and VPD in the lowest 500 mb. Including vertical data in the calculation multiplicatively increases the required data. The time subset (i.e., using 'fire day' forecast hours versus 'full day' forecast hours) highlights peak fire activity over diurnal cycles.

We used four derivation methods to directly compare the operational method with minor modifications to ease processing needs, forecast clarity, and possible overnight impacts that might be missed in the time subset. To simplify the calculation, we derived HDWI using only surface values of WS and VPD and 4x daily (full day) and 3x daily (fire day) data.

Long Name	Abbreviation	Vertical Layers	24 Hours
Surface Full Day Derivation	surface	N	Y
Surface Fire Day Derivation	surface(s)	N	N
Layer Full Day Derivation	layer	Y	Y
Layer Fire Day Derivation*	layer(s)	Y	N

The calculation for each scenario involves three reanalysis data sets of varying spatial resolutions: CONUS404, ERA5, and NCEP v2.

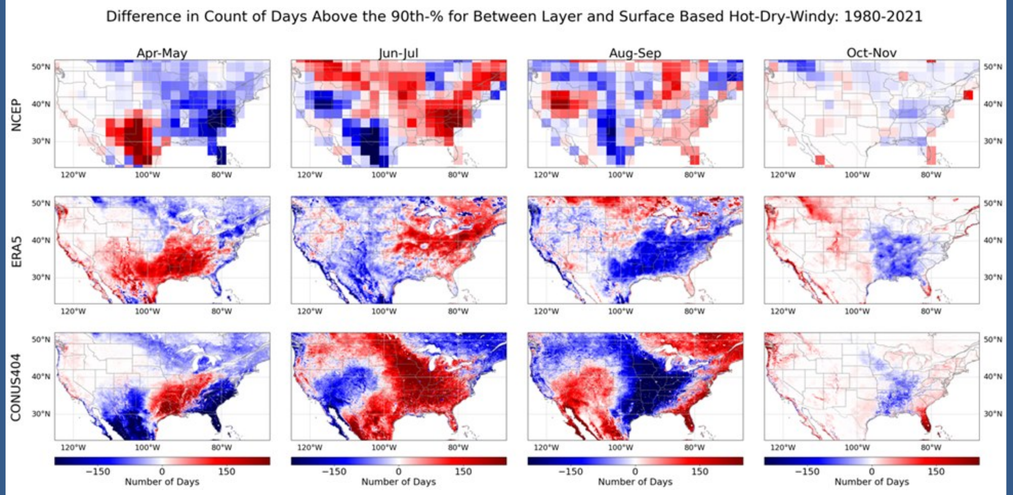
Surface calculations: 10-m wind components, 2-m temperature, and surface pressure were used for all three reanalyses; VPD was derived with specific humidity for NCEP and dew point for ERA5 and CONUS404.

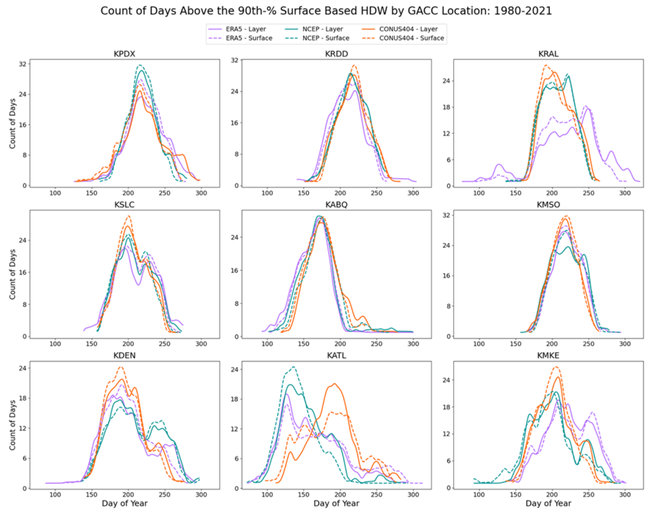
Layer calculations: wind components and temperature were used at standard pressure levels (e.g., 950 mb). VPD at each pressure level was derived from relative humidity for NCEP, dew point for ERA5, and water vapor mixing ratio for CONUS404.

Production Agency	Reanalysis	Resolution
National Oceanic and Atmospheric Administration Physical Sciences Laboratory (NOAA PSL)	NCEP II	2.5° x 2.5°
European Centre for Medium-Range Weather Forecast (ECMWF)	ERA5	0.25° x 0.25°
U.S. Geological Survey (USGS) | National Center for Atmospheric Research (NCAR)	CONUS404	4 km x 4 km

Vertical Derivation & Spatial Sensitivity

HDWI days above the 90th percentile identified by the surface derivation versus layer derivation illustrate a propagation-like pattern throughout wildfire season, with the surface-derived and layer-derived HDWI indicating different seasonality in extreme fire weather days.





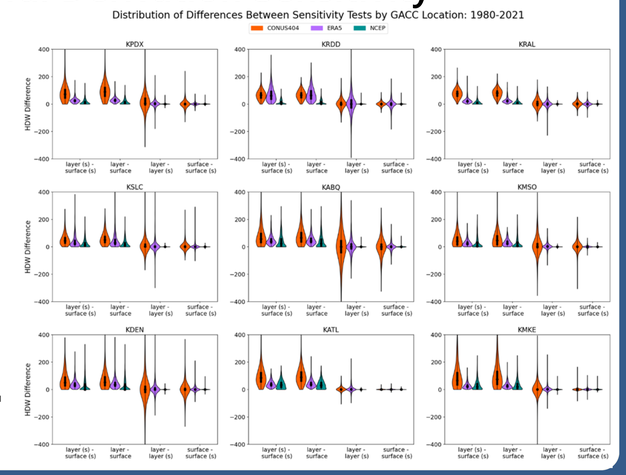
Although surface- and layer-derived values are highly correlated, the absolute values of surface-derived values are less than those of layer-derived values and differ in their distribution. However, surface derivations can still serve to identify extreme conditions at certain locations.

HDWI is sensitive to spatial scales and vertical integration by location, which highlights the need for regionally validated forecasts, irrespective of the model used.

Temporal Derivation Sensitivity

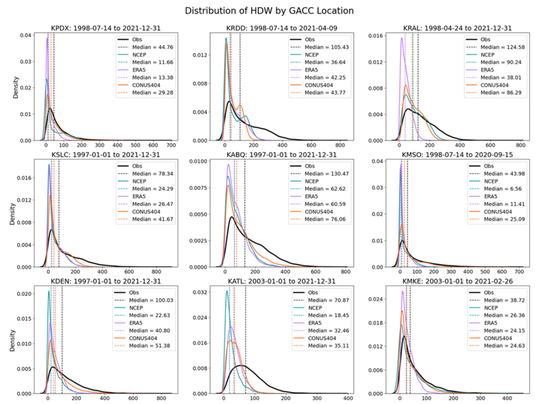
The 24-hr HDWI has a similar overall distribution as the operational 'fire-day' derivation, especially at coarser resolutions.

(Right) Distribution of differences between derived HDWI values at each CONUS GACC location.



Comparison with Observations

Both accuracy and the correlation between reanalysis data and observational data varied as a function of location.



(Above) Distribution of surface-derived HDWI values at each CONUS GACC location.

Future Work

Forecast volatility, accuracy, confidence, and reliability will have a major impact on usability and trust in the field. Depending on the forecast product used, these metrics may still be related to the method of derivation.

- Extend assessment beyond reanalysis and into the forecast space
- Evaluate impact of distribution functions on volatility of percentile-translated values
- Regional assessment of fire occurrence and behavior in the context of surface- and layer-derived HDWI
- Investigate the lag-lead relationship between surface- and layer-derived HDWI and implications for subseasonal prediction

References: Srock, A.F.; Charney, J.J.; Potter, B.E.; Goodrick, S.L. The Hot-Dry-Windy Index: A New Fire Weather Index. Atmosphere 2018, 9, 279. https://doi.org/10.3390/atmos9070279; NCEP-DOE AMIP-II Reanalysis (R-2): M. Kanamitsu, W. Ebisuzaki, J. Woollen, S-K Yang, J.J. Hnilo, M. Fiorino, and G. L. Potter. 1631-1643, Nov. 2002, *Bulletin of the American Meteorological Society*.; Rasmussen, R. M., C. Liu, K. Ikeda, F. Chen, J. Kim, T. Schneider, D. Gochis, A. Dugger, and R. Viger. 2023. Four-kilometer long-term regional hydroclimate reanalysis over the conterminous United States (CONUS), 1979-2020. Research Data Archive at the National Center for Atmospheric Research, Computational and Information Systems Laboratory. https://doi.org/10.5065/ZYY0-Y036. Accessed Dec 1, 2023.; Hersbach, H, Bell, B, Berrisford, P, et al. The ERA5 global reanalysis. *Q J R Meteorol Soc*. 2020; 146: 1999– 2049. https://doi.org/10.1002/qj.3803