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Assessment of HRRR Historical Hot Dry Windy Index and Related Fields for the Western US

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Introduction and Background

WIRED GLOBAL CENTER
U.S.-Canada Center on Climate-Resilient Western Interconnected Grid

https://resilience.utah.edu/

- Our role is to contribute to the needs for accessible datasets, tools, and management of both gridded and observational data and metadata
- Meteorological focus on extreme heat, wind, and fire concerns for assessment of power grid performance, risk, and resilience

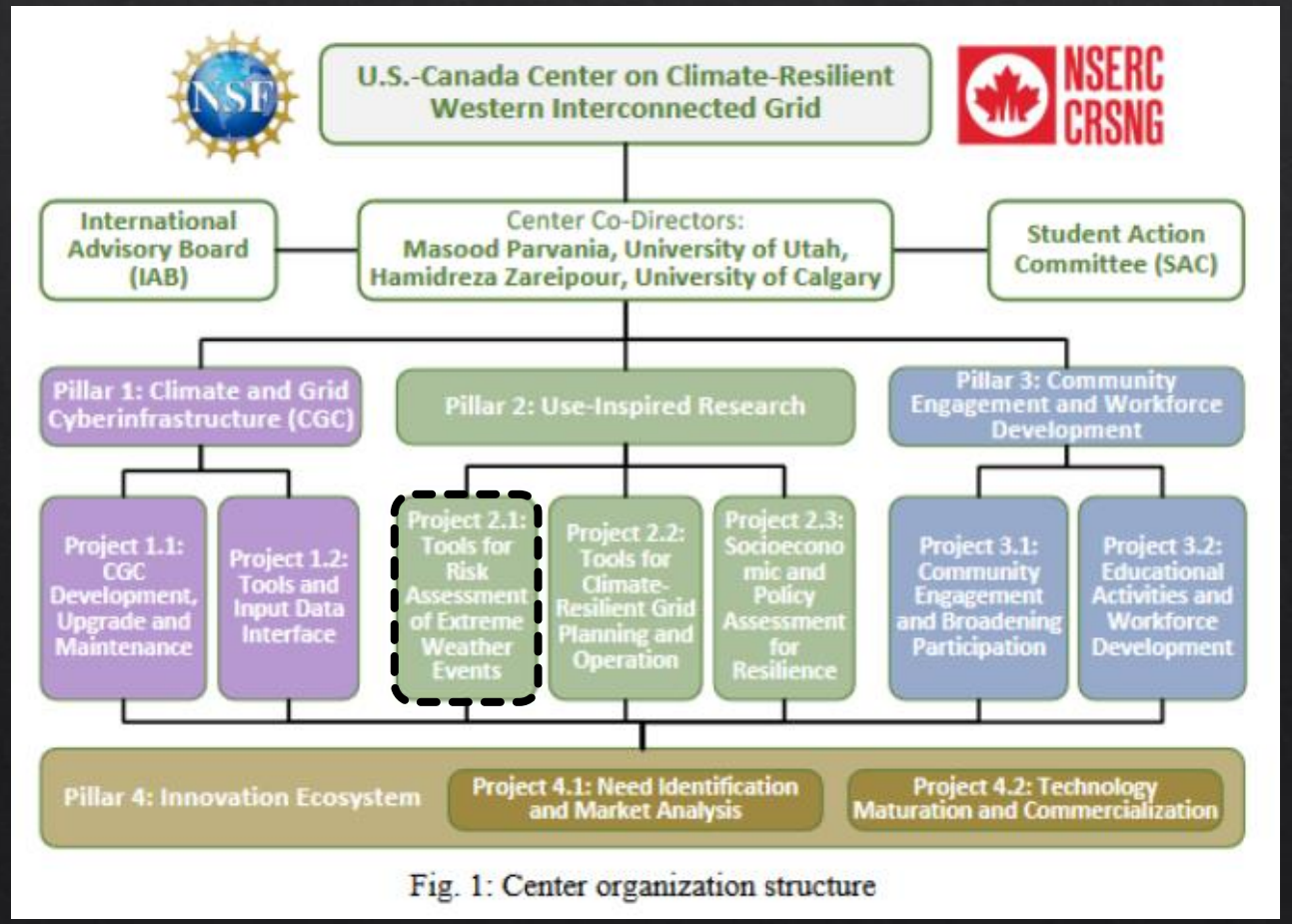
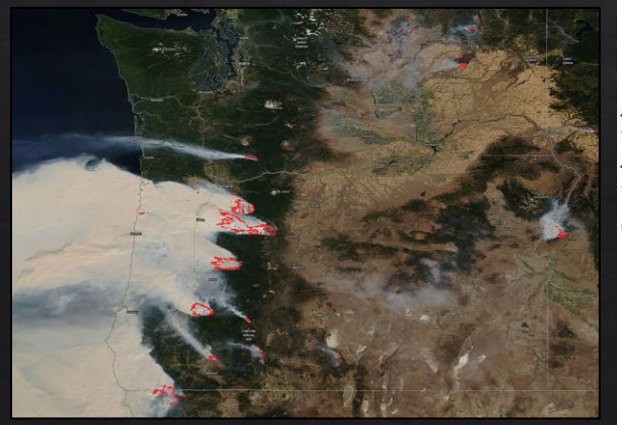


Fig. 1: Center organization structure

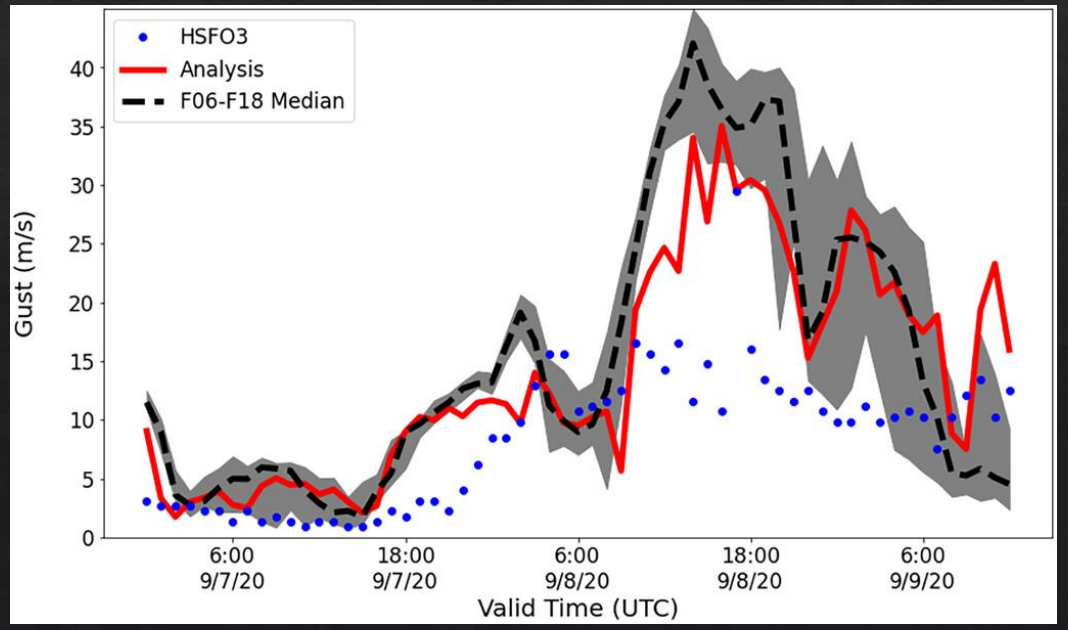
Introduction and Background

- Blaylock et al. (2018): Evaluated 3-yr NOAA High Resolution Rapid Refresh (HRRR) grib2-formatted percentiles through the Open Science Grid (OGS)

- Gowan et al. (2022): Development of the use of Zarr format for improved temporal access to HRRR data for wildfire-related initiatives



Gowan et al. (2022)



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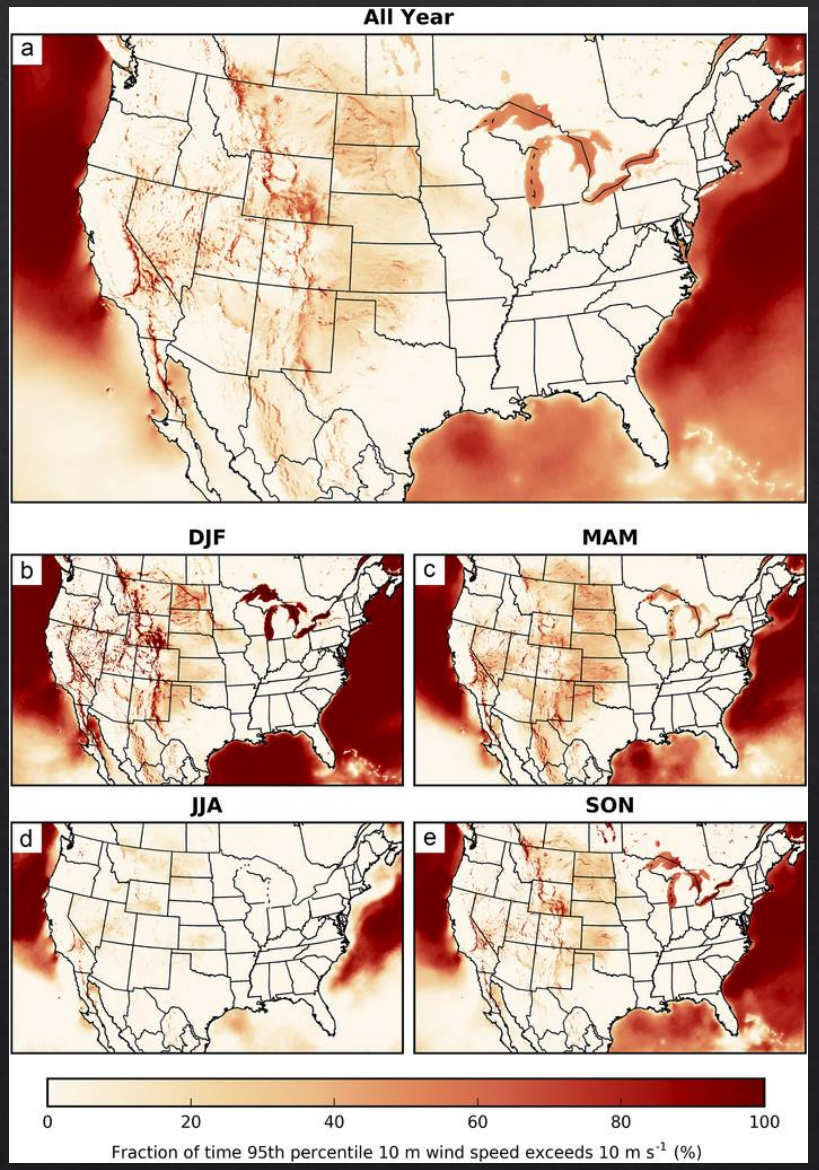
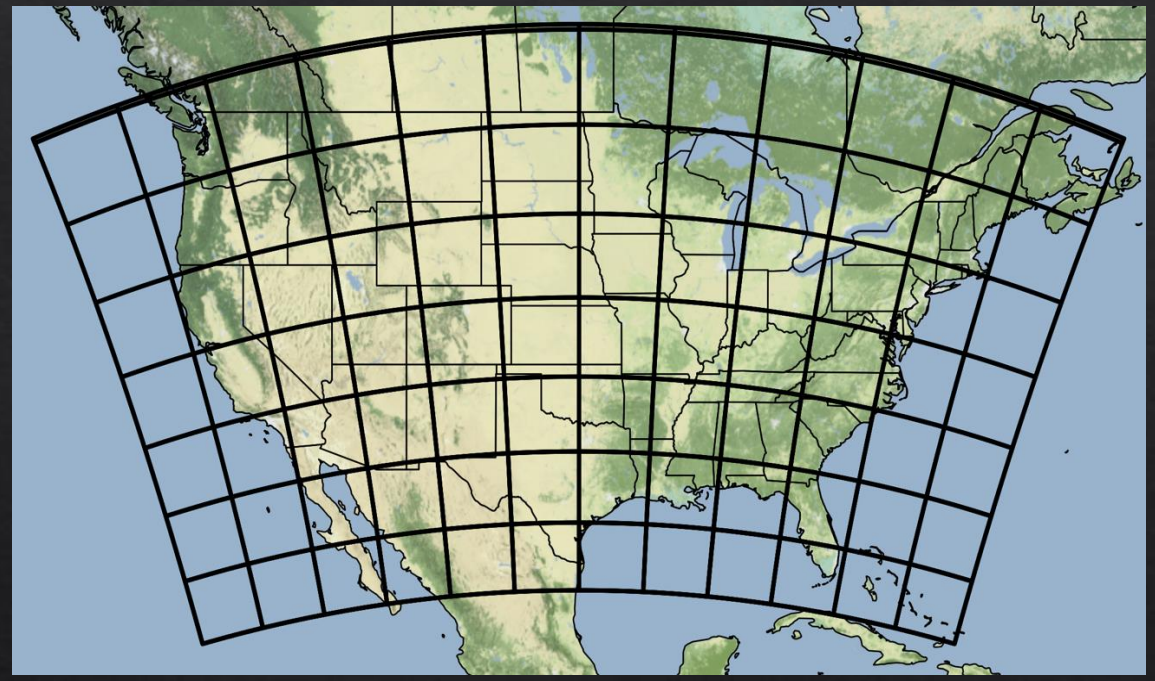


Blaylock et al. (2018)

Cloud-Based HRRR Zarr Format Repository

- Jacques et al. (2023) AMS Annual Meeting: R2O deployment of routinely-updating Zarr-formatted archive of HRRR surface and pressure-coordinate data objects as part of Amazon Web Services (AWS) Sustainability Data Initiative (ASDI) Program



Operational HRRR CONUS grid per variable (1799 x 1059) broken up into 96 spatial "chunks" of size 150 x 150

HRRR Zarr Store Name	Forecast Hours Included	Final Array Dimensions
Analysis (**hh**z_anl.zarr)	F00	1 x 150 x 150
Forecast (**hh**z_fcst.zarr)	F01-F18 hourly F01-F48 every 6 h	18 or 48 x 150 x 150

Zarr Dataset Resources:
https://mesowest.utah.edu/html/hrrr/
https://hrrrzarr.s3.amazonaws.com/index.html

HRRR Archive Percentile Dataset - Methodology

- WIRED Need: Historical probabilistic datasets at spatial resolutions better representing complex terrain where critical utility infrastructure are located

- Building upon previous work, 8 years of the HRRR Zarr-formatted archive (2016-2023) used to develop a percentile-focused dataset over the WIRED domain for 5 variables:

    - 2m Temperature
    - 2m Relative Humidity
    - 10m Wind Speed
    - Vapor Pressure Deficit (VPD): Calculated via 2m Temp and RH
    - Hot Dry Windy Index (HDW): Product of VPD and 10m Wind Speed

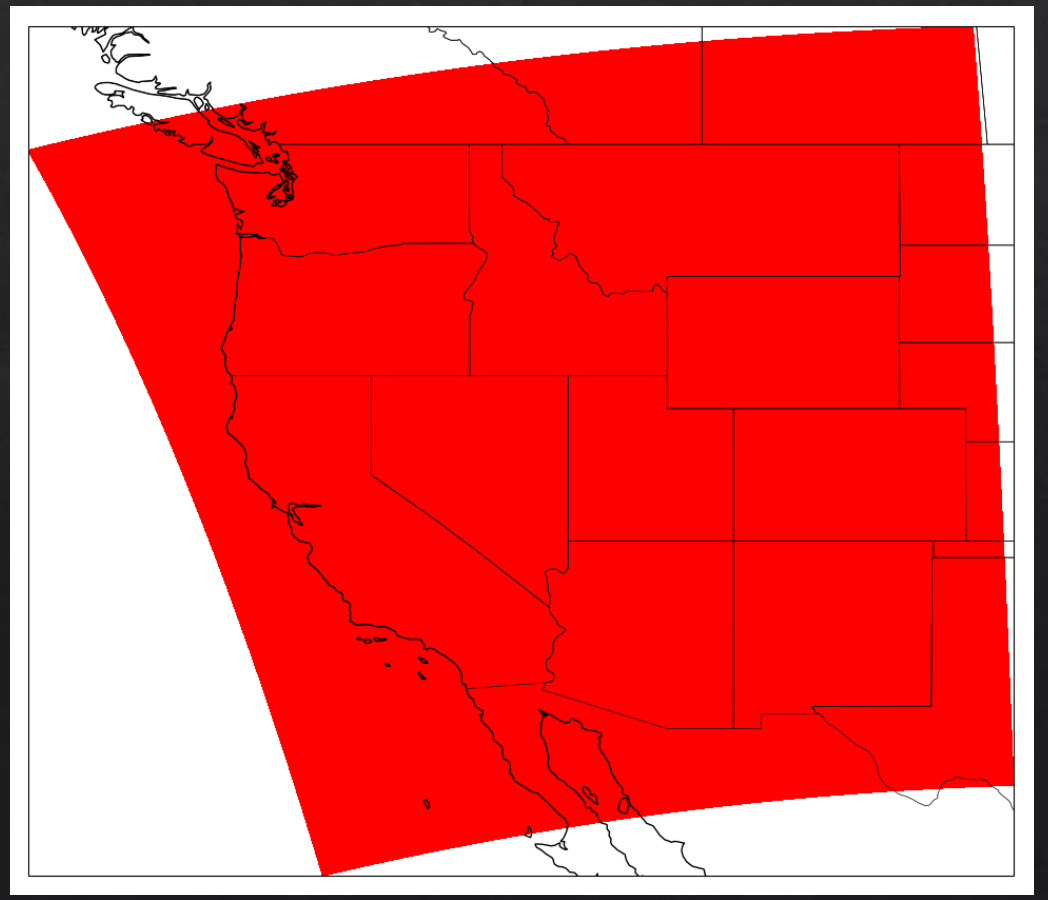
HRRR Archive Percentile Dataset - Methodology

- Percentiles at each HRRR grid point (figure below) were computed for each calendar hour of the year (e.g., percentiles calculated for 19 UTC on July 25)

- Sampling Strategy: Percentiles each hour computed from historical HRRR analysis (F00) within ±3 days and ±1 hr of desired time

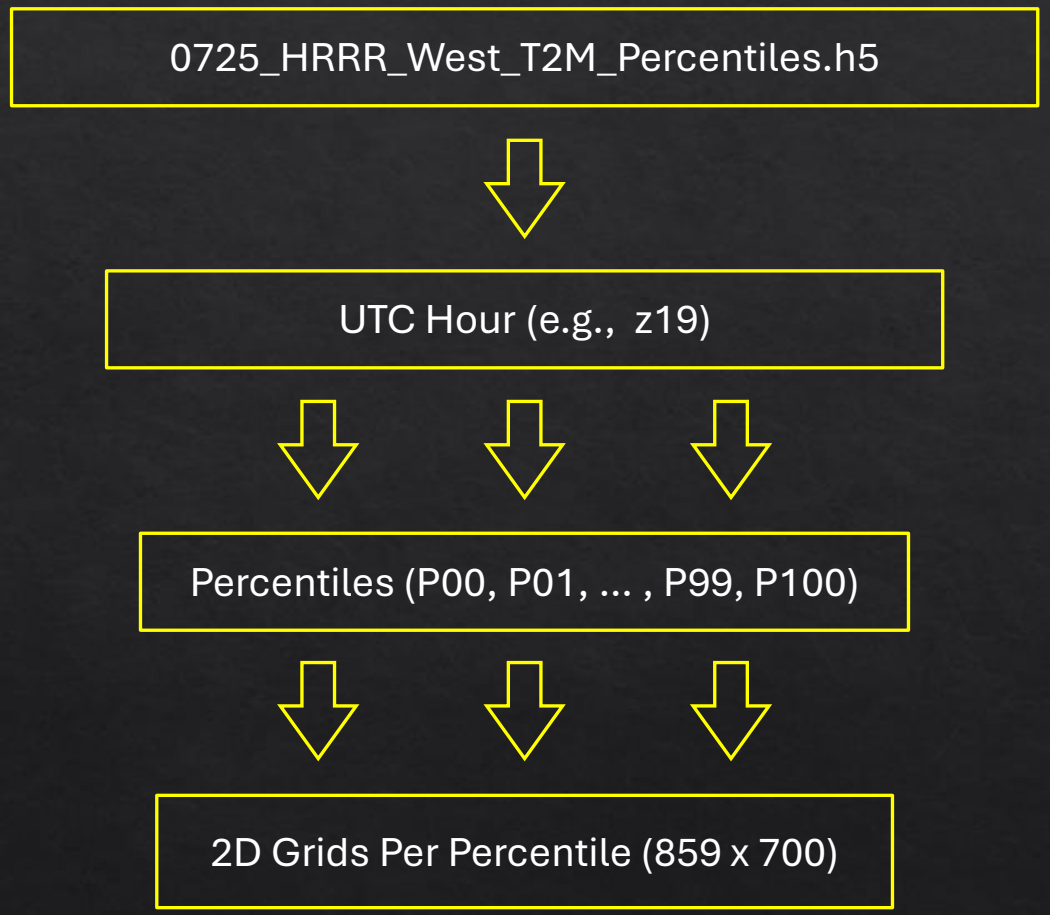
- E.g., 19 UTC on July 25 computed from:
  - 18-20 UTC from 22-28 July each year
  - 8 years of archive (2016-2023)
  - 8 * 7 * 3 = max 168 historical values for each HRRR grid point shown in figure

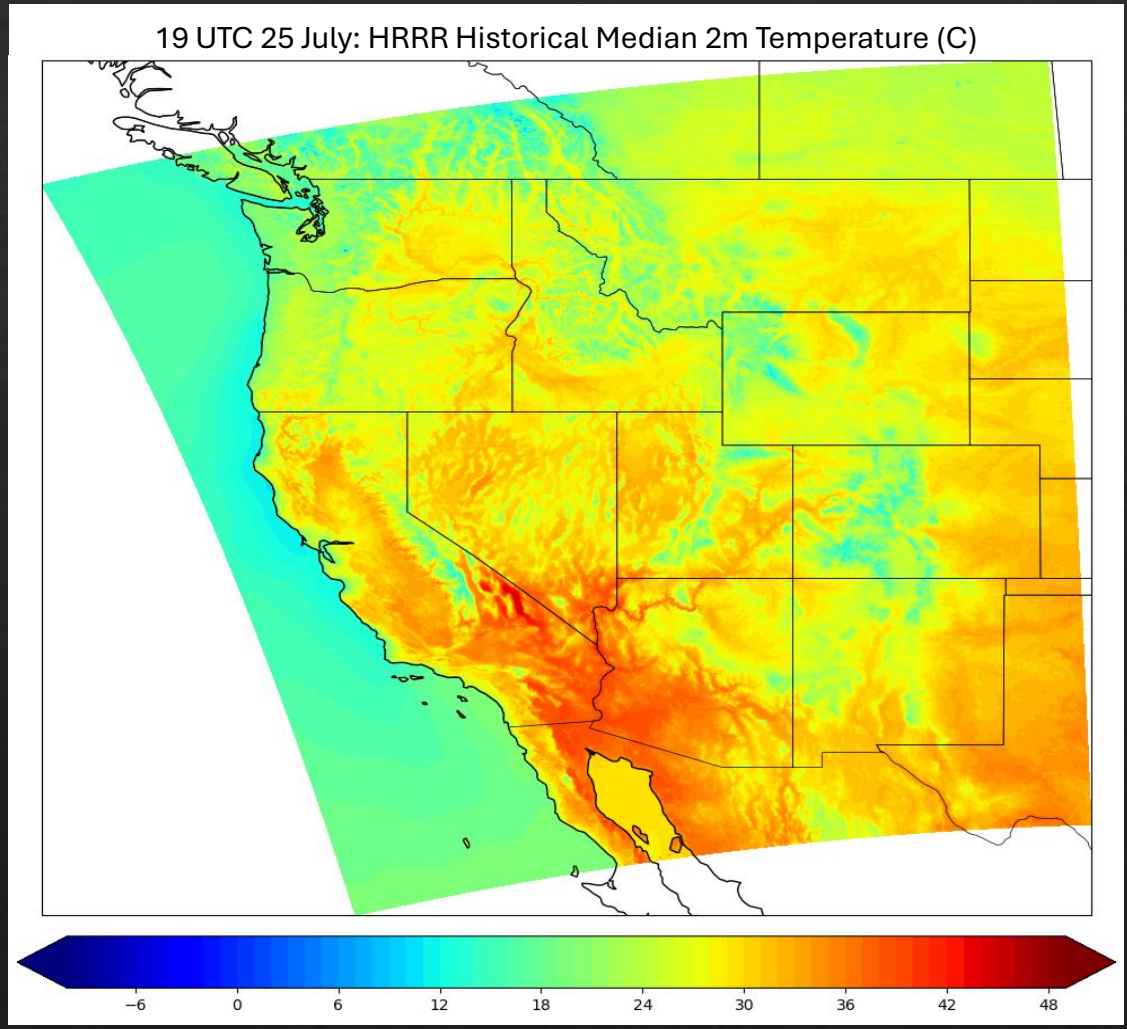
- Current year (2024) intentionally left out of the initial percentiles archive



HRRR Archive Percentile Dataset - File Structure

- Percentiles stored in Hierarchical Data Format version 5 (HDF5) by time and variable



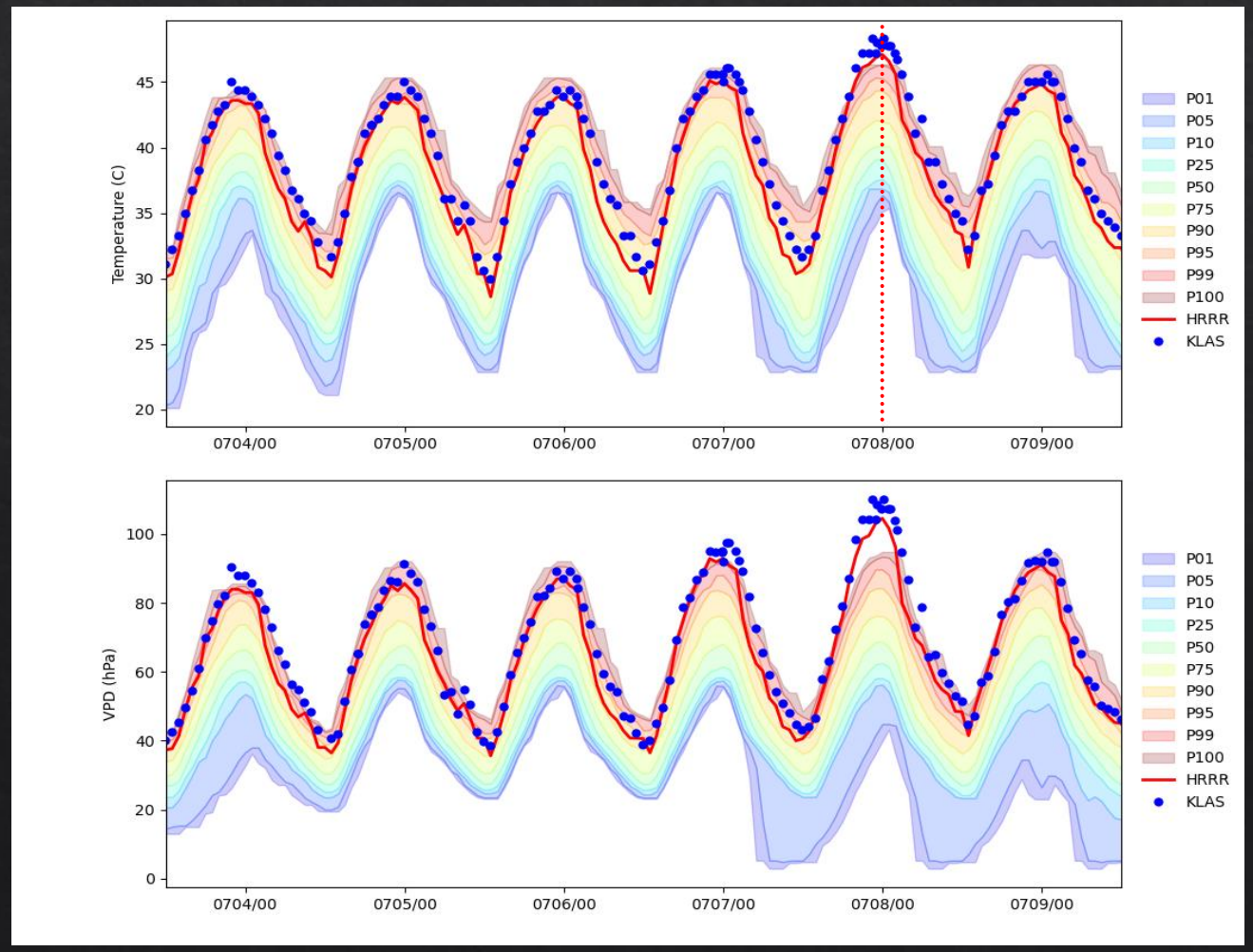


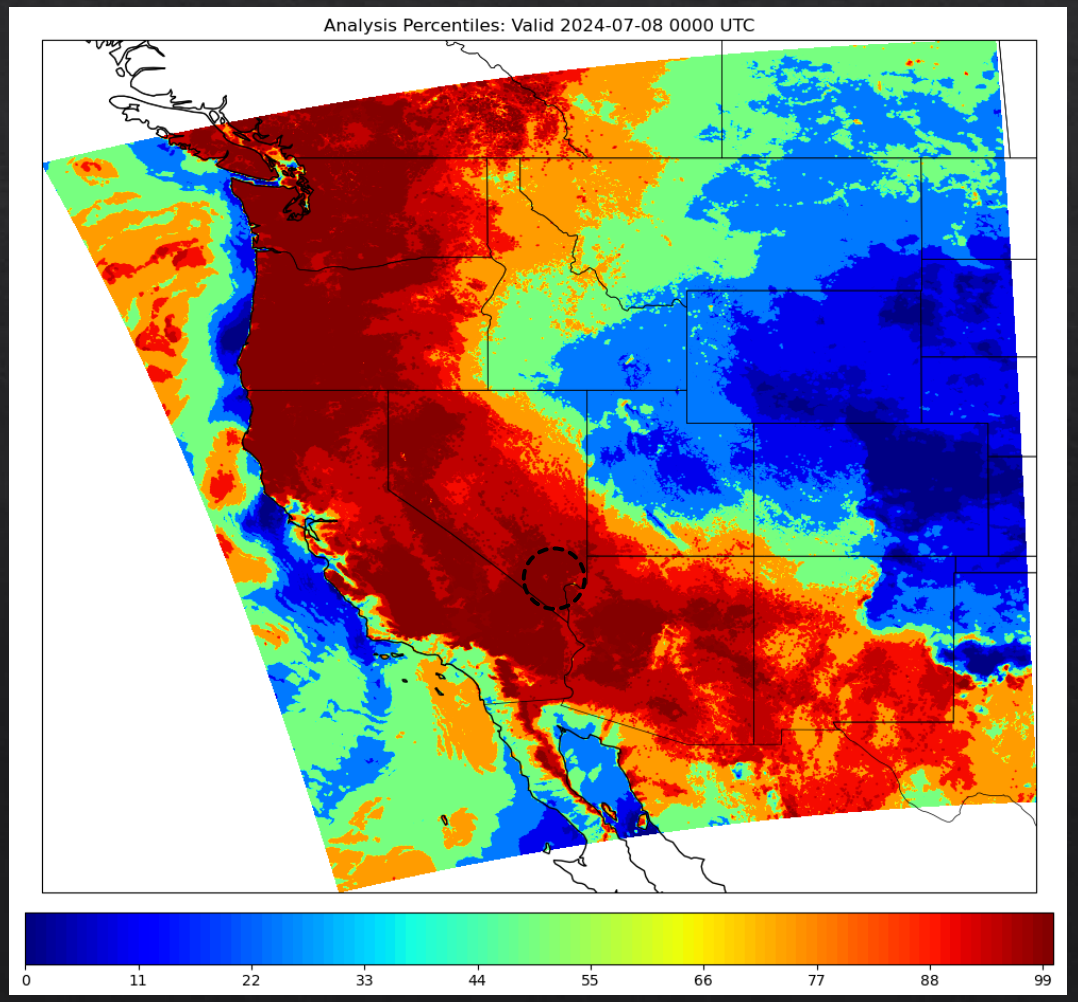
Example: Median (50th Percentile) 2m Temperature for 19 UTC 25 July:

0725_HRRR_West_T2M_Percentiles.h5:/z19/P50

Current Year Events: July 2024 Western US Heat Wave

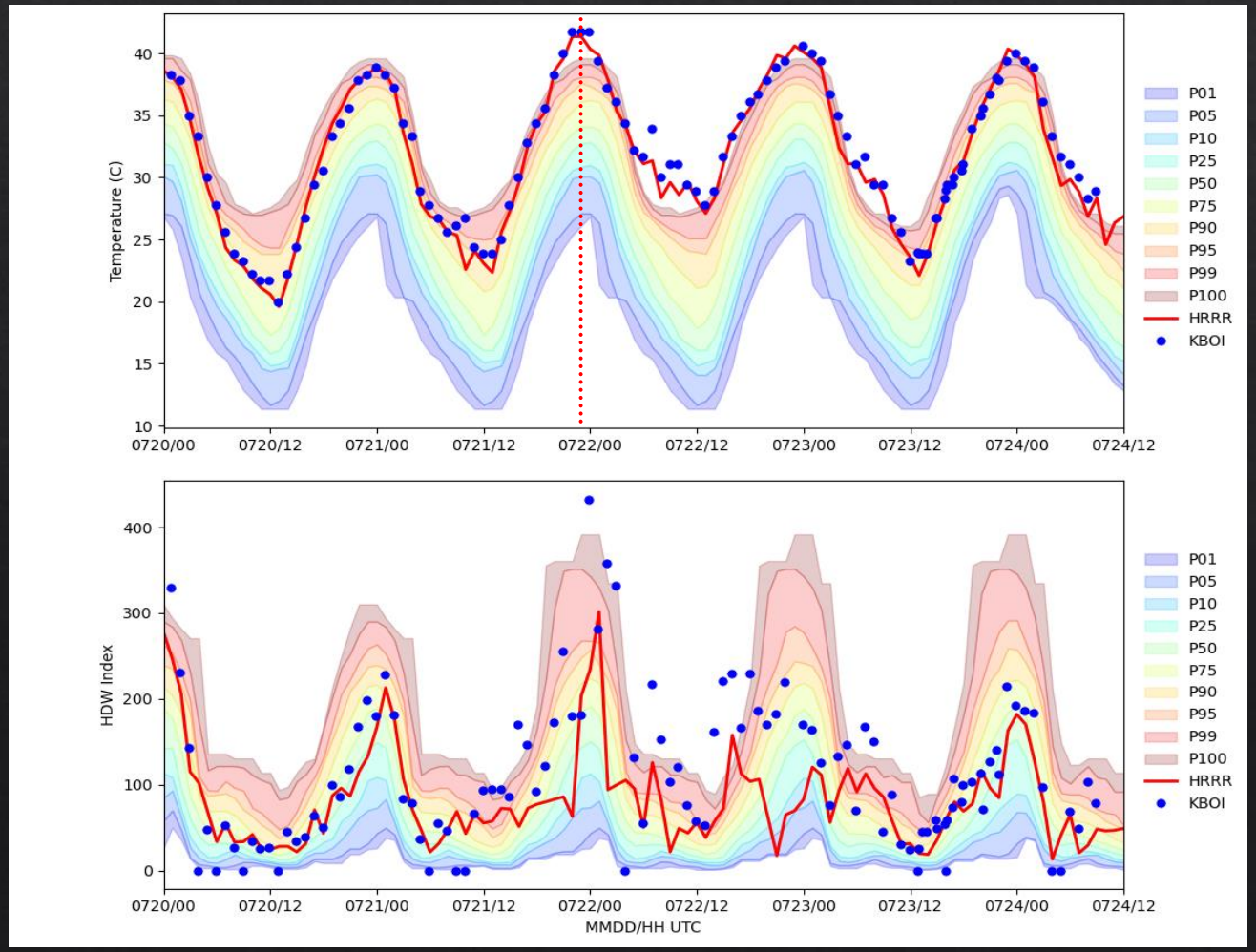
- Prolonged heat wave across western US during July 2024
  - KLAS: Maximum Temperature 48.9 C (120 F) on 7 July 2024
  - Observations and HRRR analysis eclipse 8-year historical record

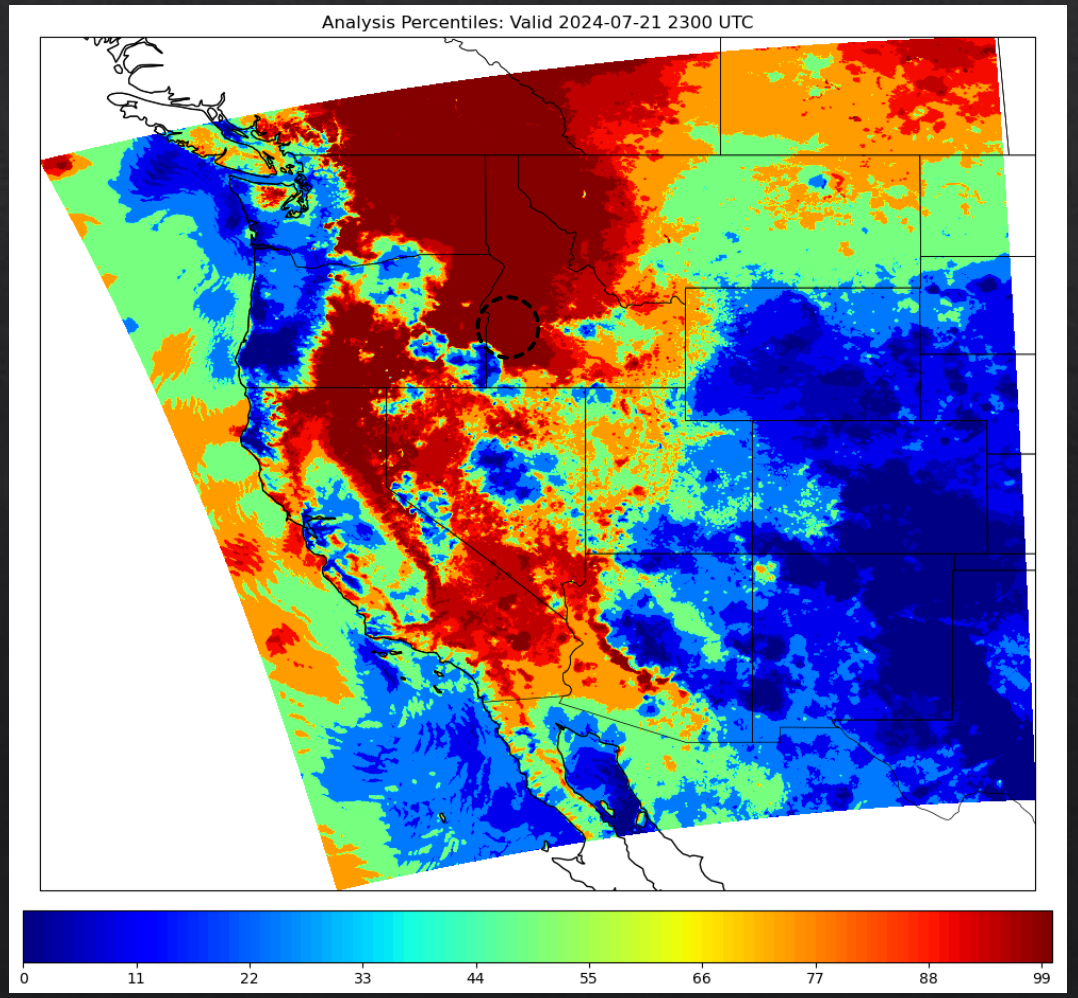




Current Year Events: July 2024 Western US Heat Wave Part II

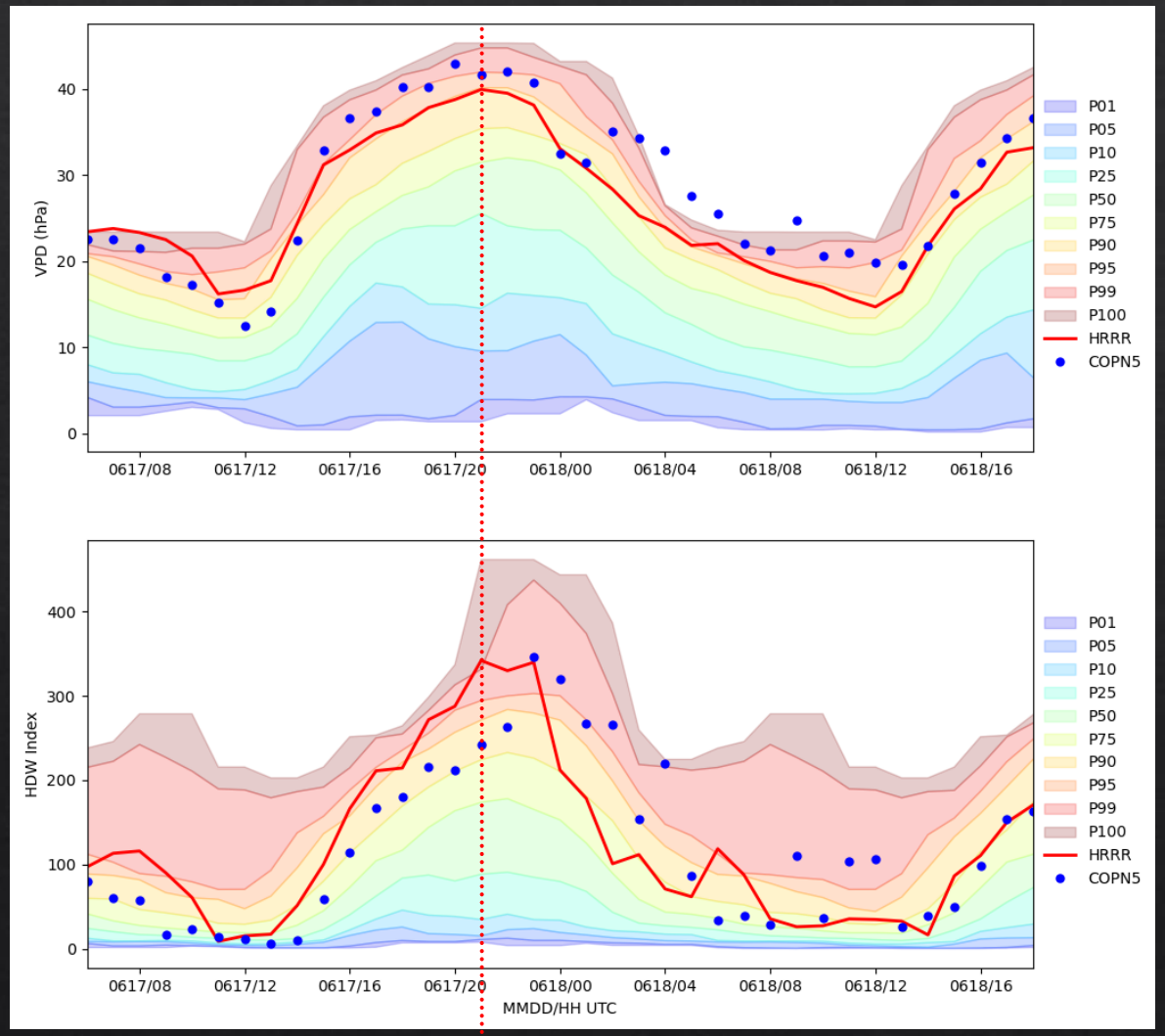
- 2024 AMS Mountain Meteorology Conference: Boise, ID
  - KBOI: Maximum Temperature 42.2 C (108 F) on 21 July 2024
  - Max VPDs 55-70 hPa, KBOI 10m wind speeds 3-7 m s^{-1}



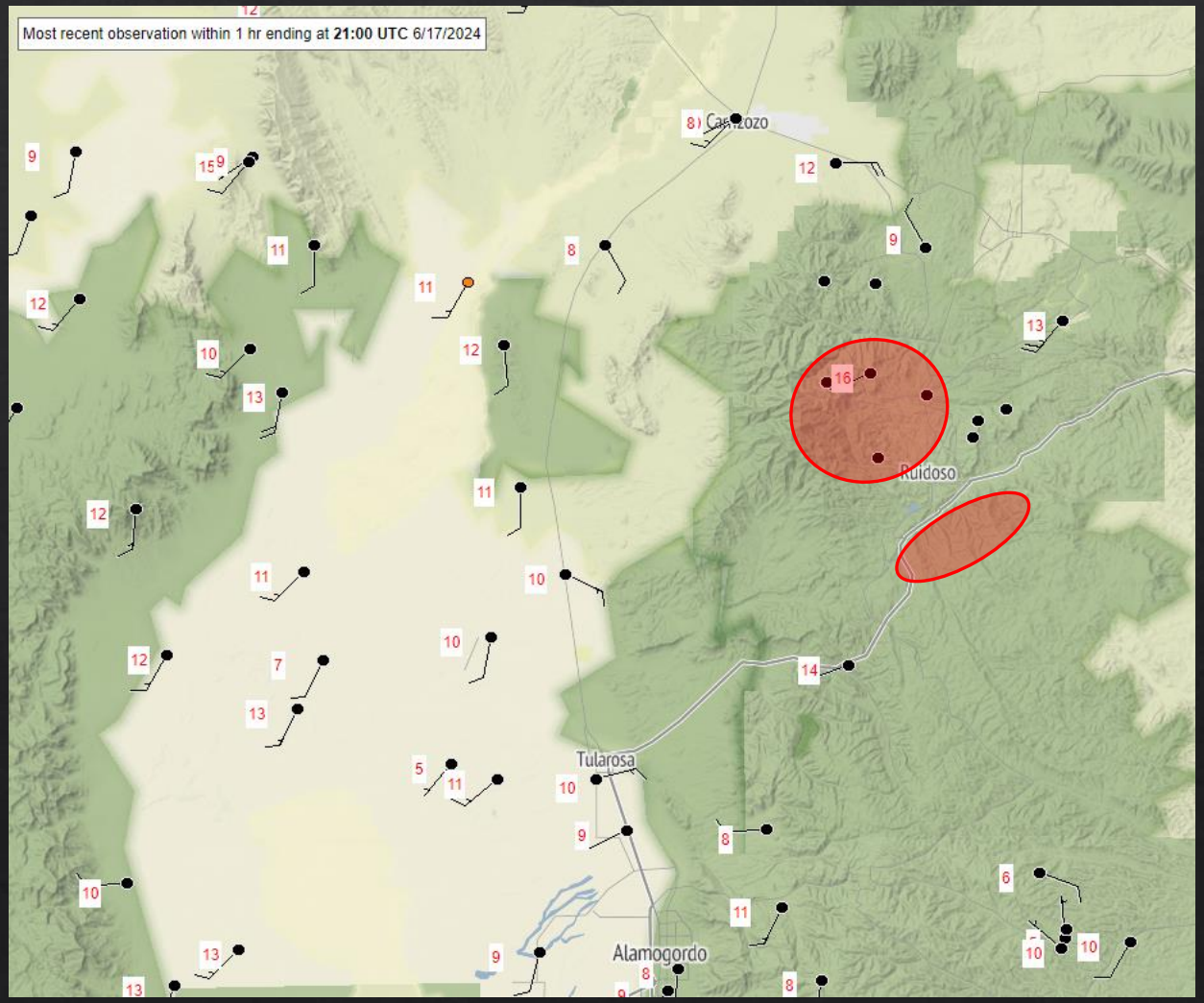


Current Year Events: June 2024 New Mexico Wildfires

- South Fork and Salt Fires: Ignited on 17 June 2024 in south-central New Mexico



2100 UTC 17 June 2024



Historical Percentile Access - Prototype Web Tools

- Some initial web-based tools are being developed to access the percentile datasets

- Point Time Series: leverage HRRR percentiles w.r.t. real-time HRRR forecast, analysis, and surface observational data:

HRRR HDW Time Series Interface

This interface provides real-time and historical time series access to NOAA High Resolution Rapid Refresh (HRRR) forecast data for the location selected. Variables available include 2m air temperature, 2m relative humidity, 10m wind speed, derived Vapor Pressure Deficit (VPD), and derived Hot Dry Windy Index (HDW).

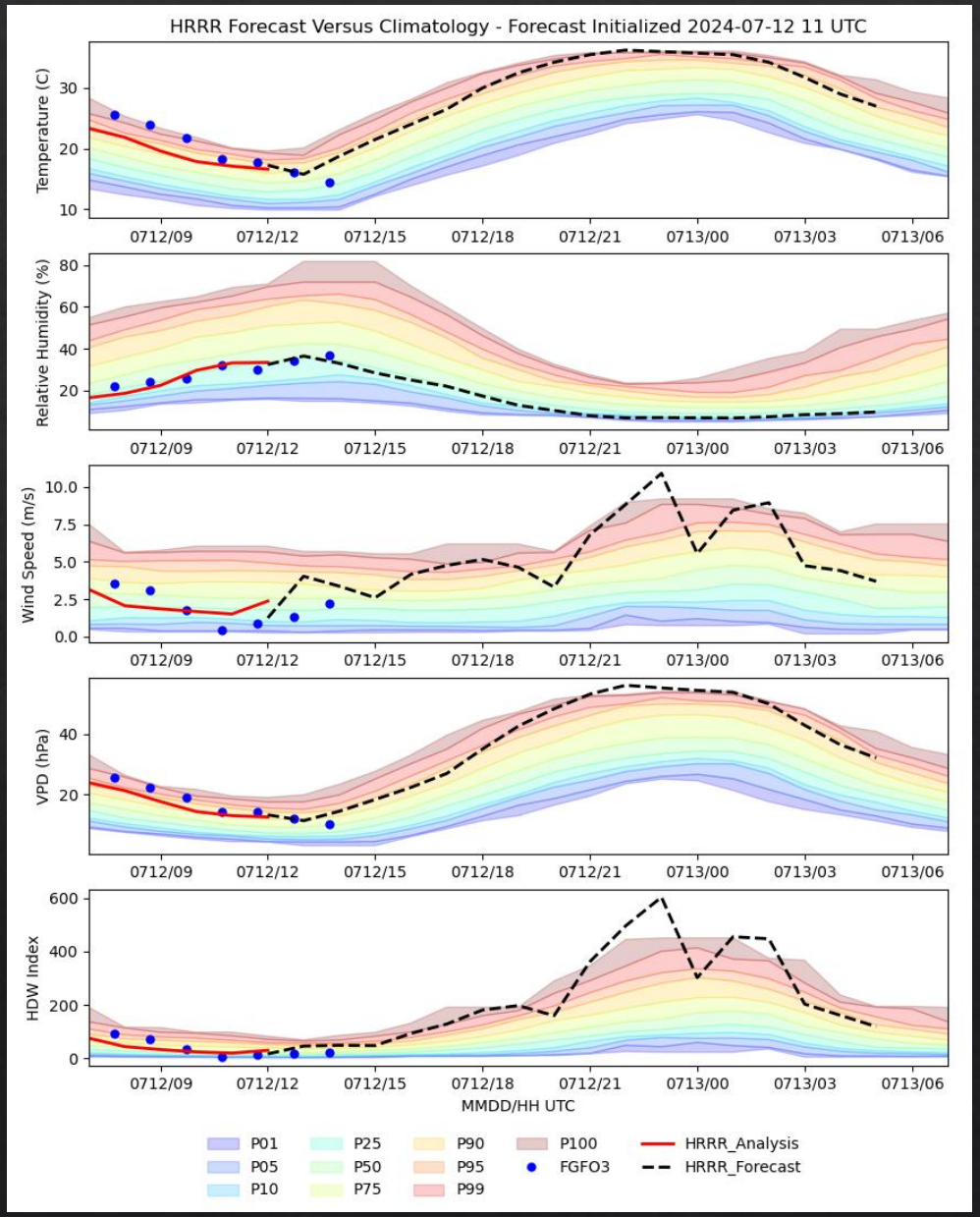
The generated plot provides HRRR analysis (forecast hour 0) time series for available model runs (solid red line), the HRRR forecast time series for the model run selected (black dashed line), and percentile thresholds generated from an 8-year (2016-2023) HRRR climatology dataset. If a station identifier is selected, available time series observations are also plotted (blue dots).

Change Location

Clicking "Get Current Location" will find the closet HRRR gridpoint to your location if within the climatology dataset domain. Otherwise, you can either enter latitude and longitude coordinates (decimal degrees), or enter a MesoWest Station ID, then click "Change Location"

Get Current Location OR **Latitude:** **Longitude:** OR **Station ID:** FGFO3 Change Location

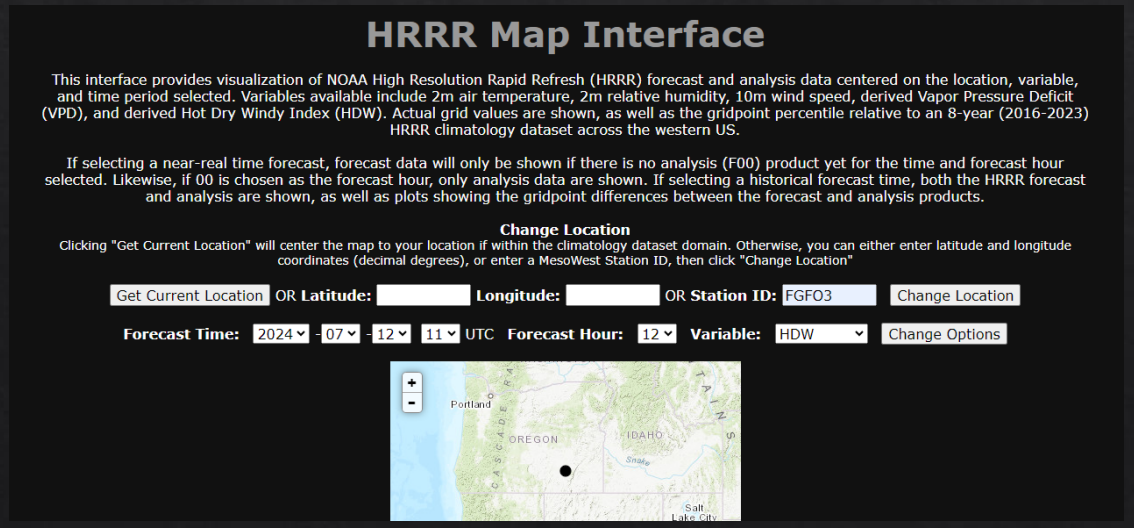
Change Forecast Time: 2024 - 07 - 12 11 UTC Change Time

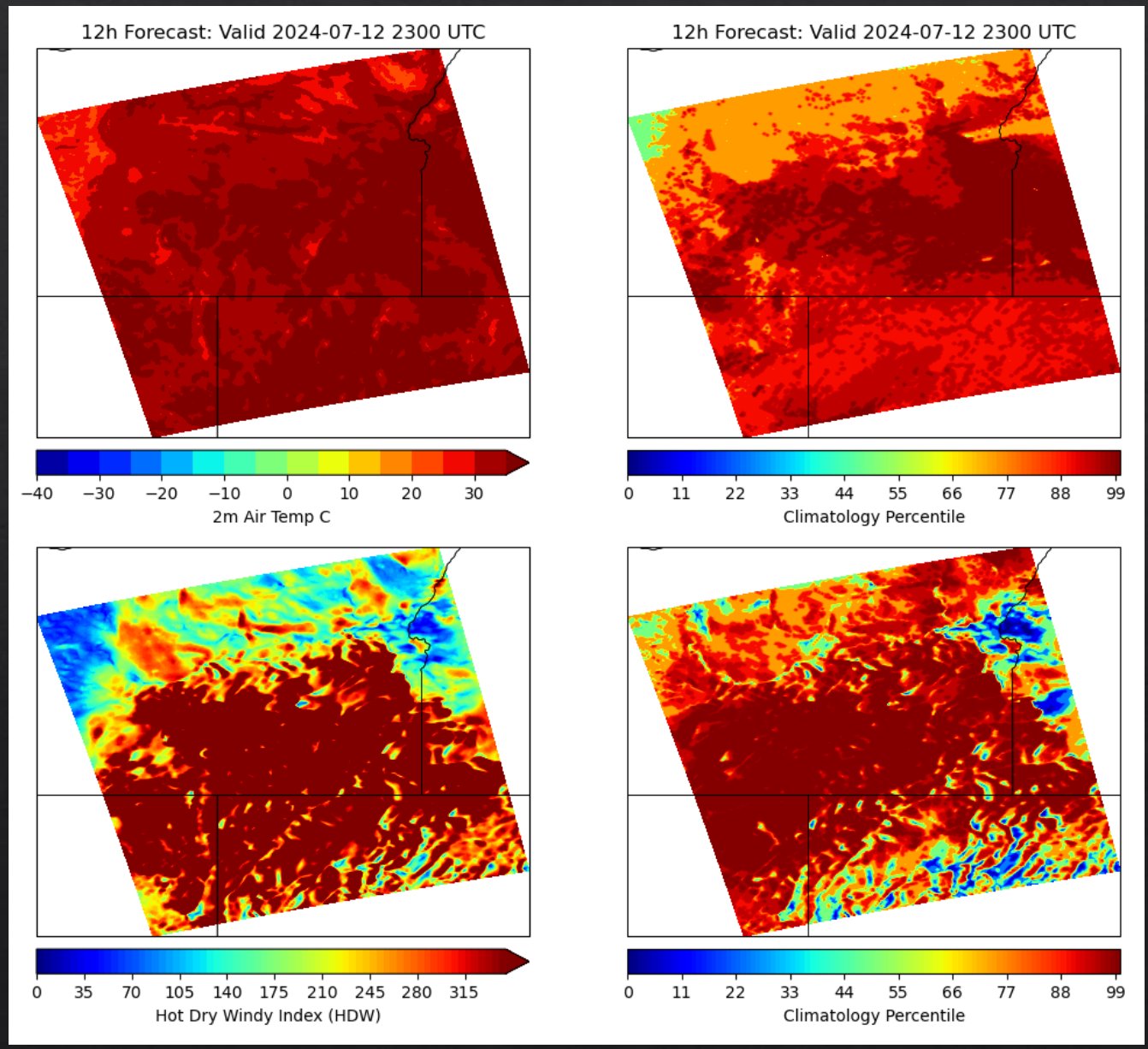


Historical Percentile Access - Prototype Web Tools

- Map tool being developed as well

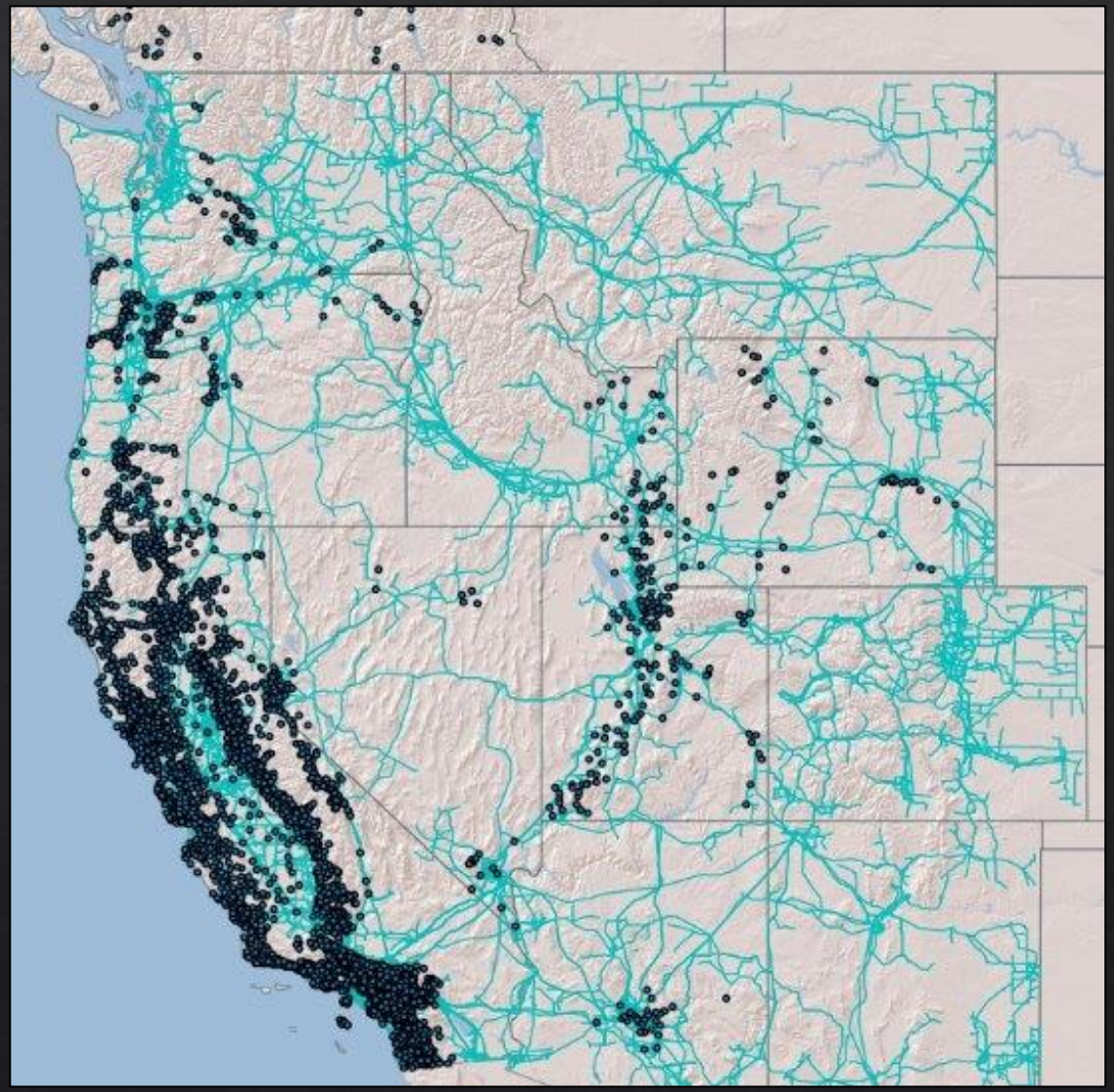
- HRRR forecast and analysis products visualized as:
  - Measurement quantity
  - Historical percentile
  - Forecast vs. Analysis comparison





Historical and Percentile Datasets - WIRED Applications

- WIRED Research: tools and assessment along critical utility infrastructure
- Plentiful observational data along critical stretches of western US utilities courtesy of commercially-supported initiatives
- Many utilities partner with Western Weather Group (WWG) for install and transmission of weather station data
- Utilities and WWG work with Synoptic Data PBC for data access, display, and dissemination to entities like MesoWest (https://mesowest.utah.edu) and NOAA



Major utility lines (cyan) and 2024 utility-operated surface weather station installations (markers)

Historical and Percentile Datasets - WIRED Applications

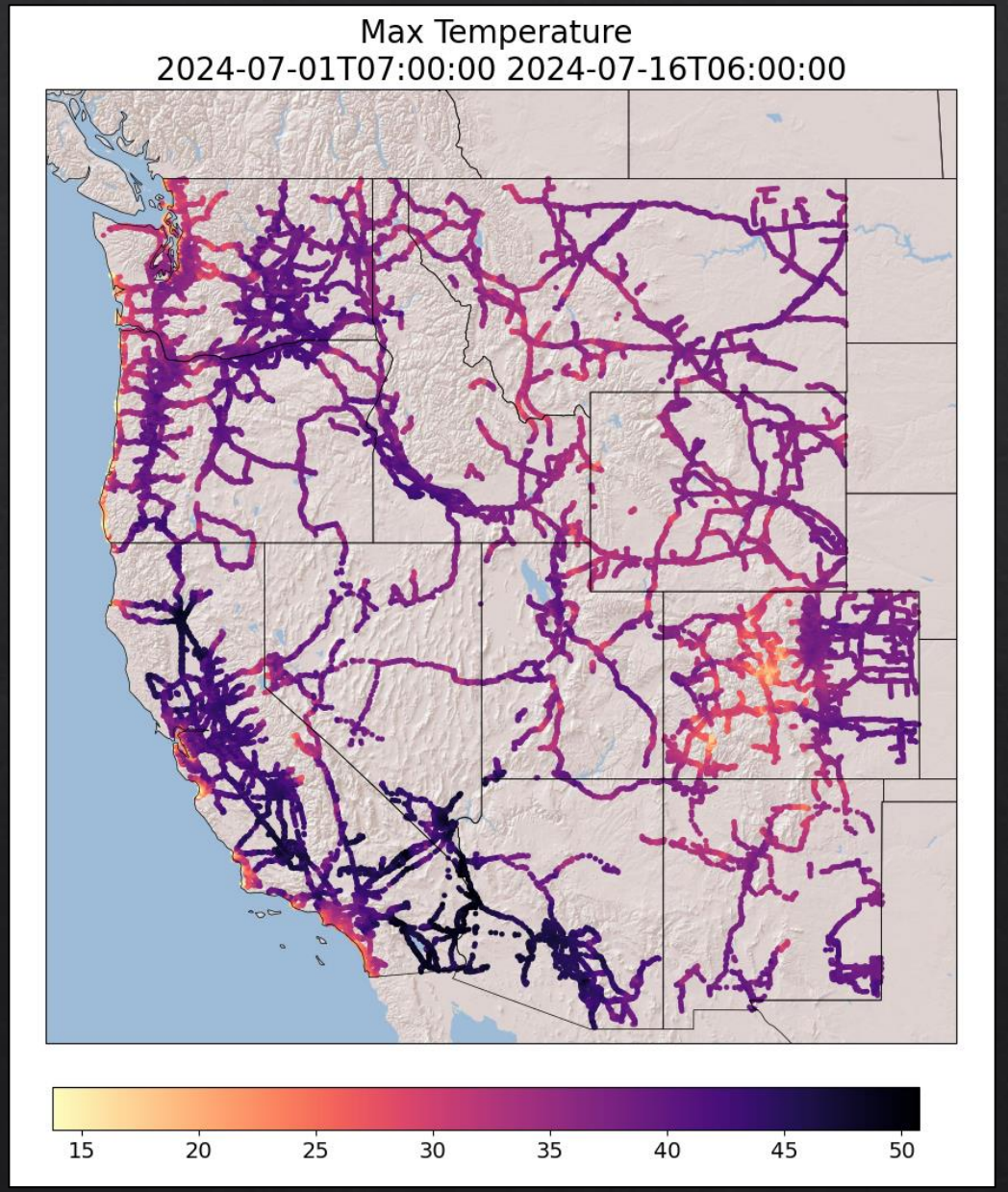
- Work underway to merge historical Zarr-formatted HRRR archive, historical percentile datasets, and available utility information into products focused on WIRED needs

- Infrastructure Extreme Heat Example:

  - Maximum HRRR Analysis (F00) 2m Temperature over 15 days of the July heat wave across the Western US

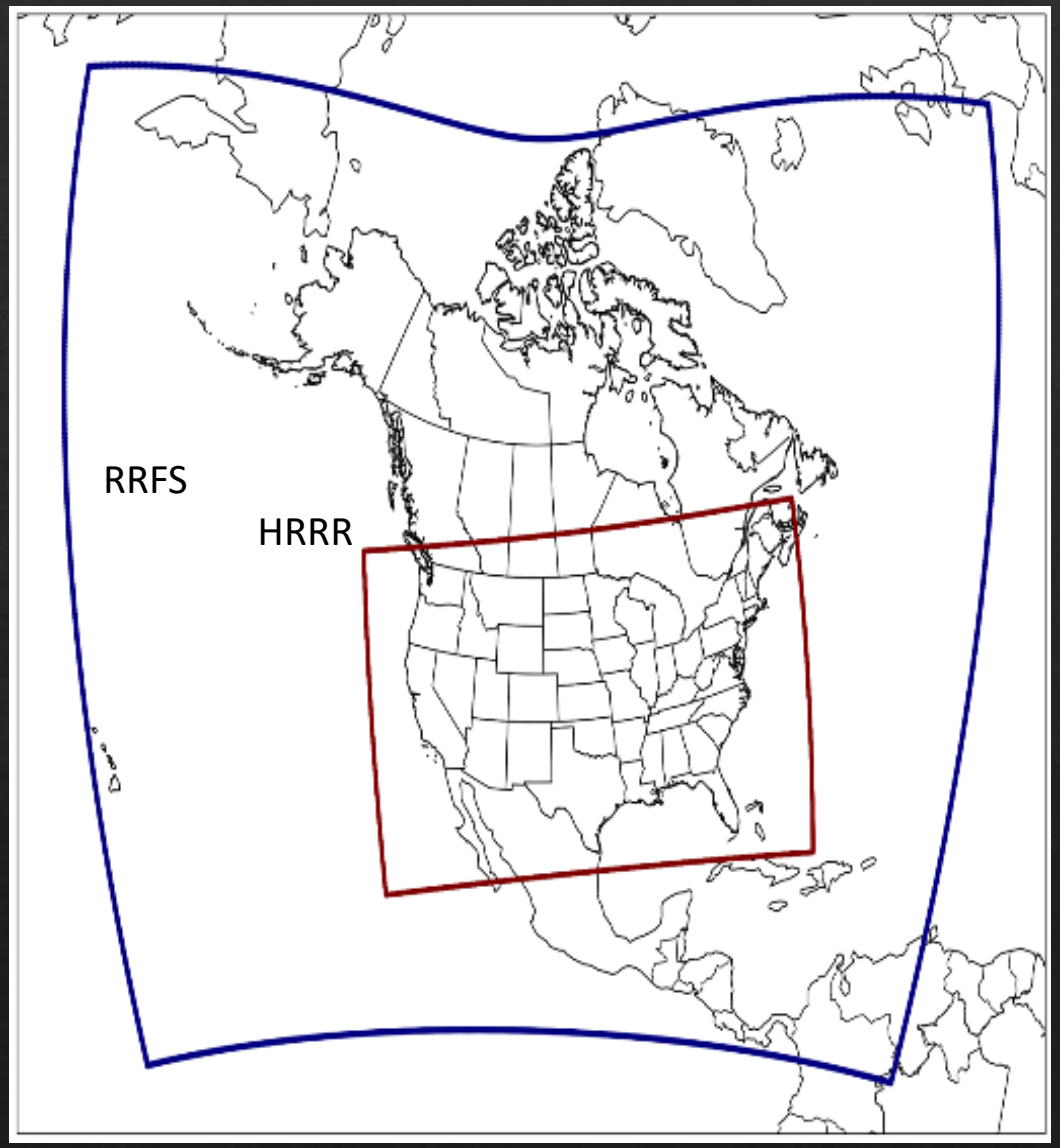
  - Data displayed along large utility lines

  - Zarr Advantage: Processed 24*15 = 360 HRRR analysis times in a few seconds



Future Work

- Continue to support ASDI operations that are routinely adding to the HRRR Zarr AWS archive
- Potential expansion of the percentile dataset beyond the initial 5 heat and fire-focused variables currently produced
- Updating the existing percentile dataset beyond the end of 2023 as HRRR continues to run operationally
- Rapid Refresh Forecast System (RRFS)?
  - RRFS can cover additional WIRED spatial domain into Western Canada
  - Ensembles add another dimension of data



Summary

- To support the needs of the WIRED Global Center, we are developing tools and methods to efficiently access and analyze historical gridded meteorological data with a focus on electrical grid resilience for extreme heat and wildfire

- Through prior funded initiatives involving collection and archive of HRRR model data:

  - Development of 8-year historical percentile dataset for 5 heat and fire-related quantities for analysis along critical stretches of utility infrastructure pertinent to WIRED needs

  - Organization of hourly surface analysis (F00) data in Zarr-formatted files for faster access to historical data at spatial and temporal scales of interest

- Work expected to continue and expand as WIRED dataset creation, storage, and access needs evolve, and as the HRRR continues to run operationally

Acknowledgements and References

- We thank the Amazon Sustainability Data Initiative for continuing support of the storage and access to the HRRR Zarr-formatted repository effort.

- We thank the University of Utah Center for Higher Performance Computing (CHPC) for providing ongoing IT resources for the computation of the HRRR percentiles dataset and web tools development.

References

Blaylock, B. K., J. D. Horel, and C. Galli, 2018: High-Resolution Rapid Refresh Model Data Analytics Derived on the Open Science Grid to Assist Wildland Fire Weather Assessment. *J. Atmos. Oceanic Tech.*, **35**, 2213–2227, doi:10.1175/JTECH-D-18-0073.1

Gowan, T. A., J. D. Horel, A. A. Jacques, and A. Kovac, 2022: Using Cloud Computing to Analyze Model Output Archived in Zarr Format. *J. Atmos. Oceanic Tech.*, **39**, 449-462, doi:10.1175/JTECH-D-21-0106.1