Extreme heat and the NWS/CPC: forecasting and sensitivity to definition

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ERT
Exceed Expectations

Incredible proliferation of Extreme Heat

Analysis: Half the global population saw all-time record temperatures over past decade

By Dr Zeke Hausfather
Design by Tom Prater
23 April 2023
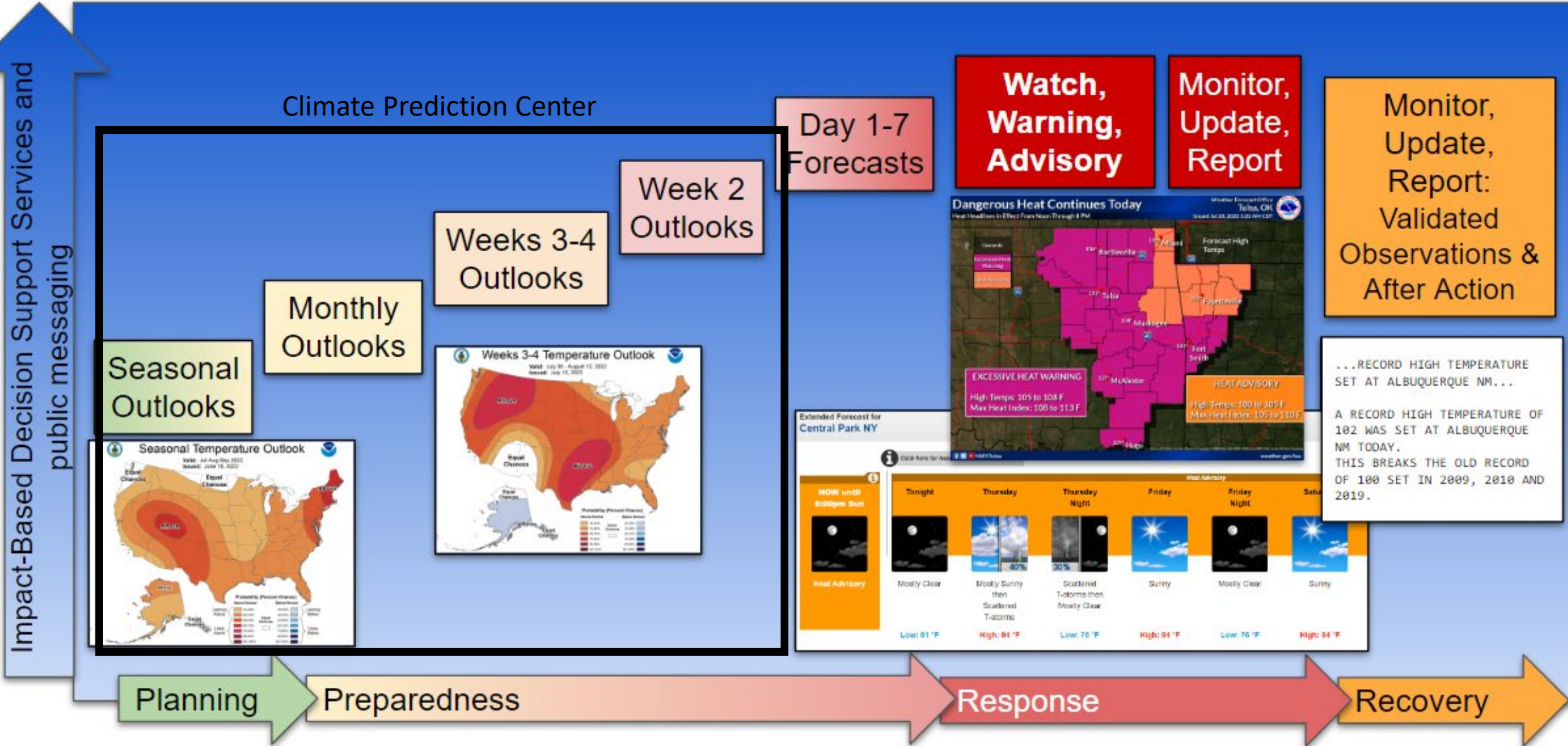
Areas experiencing record heat over the past 6 years
2017
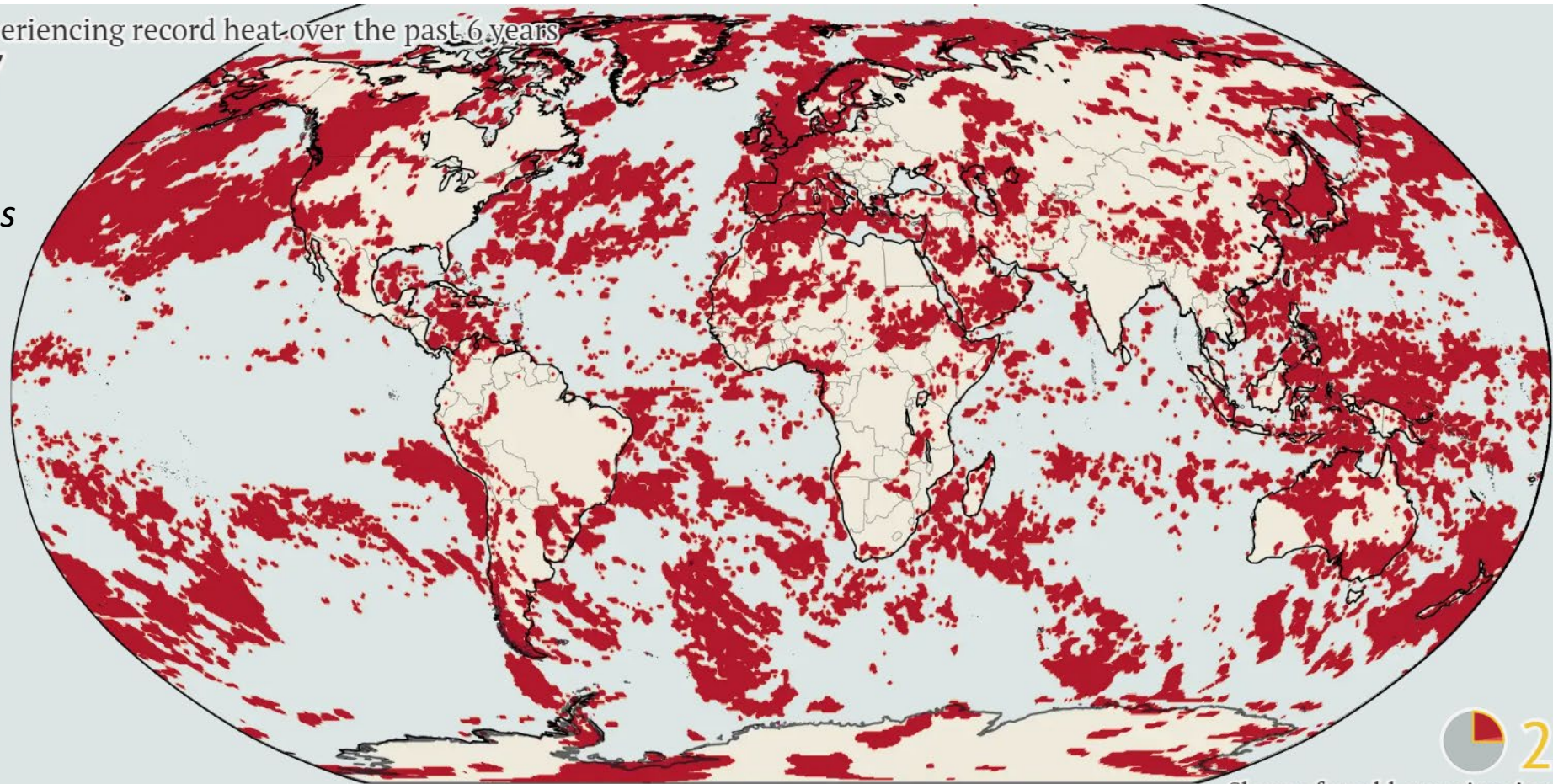
"red shading indicates areas that saw their warmest daily temperatures since 1950"
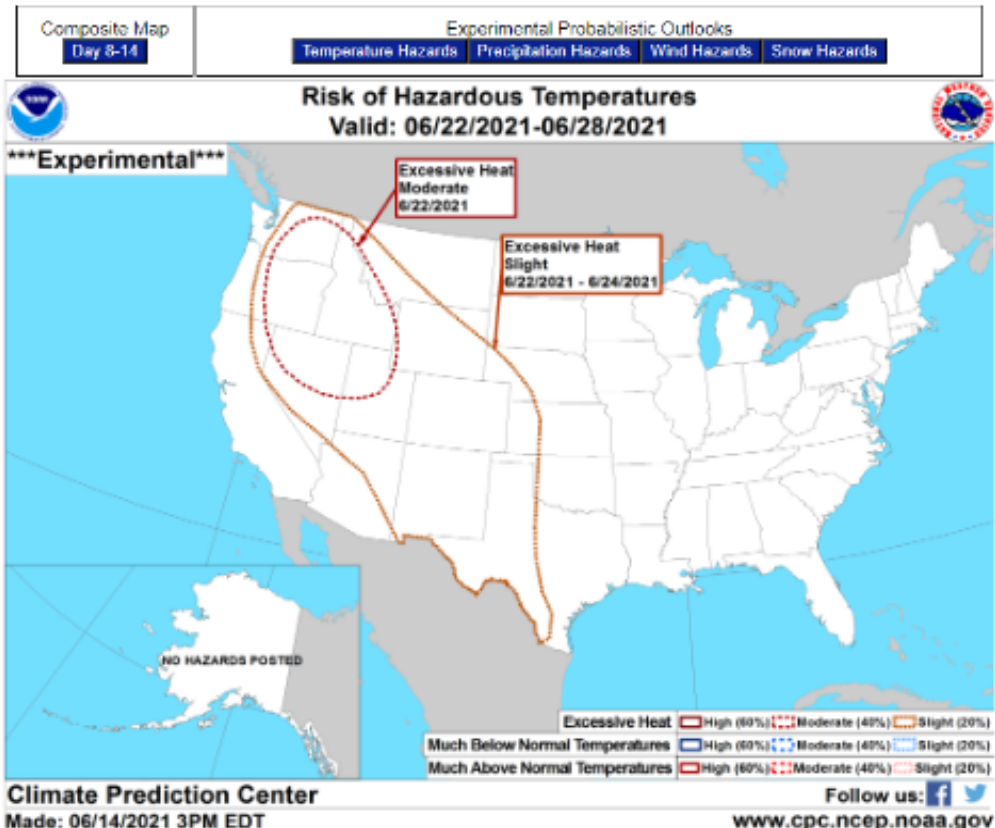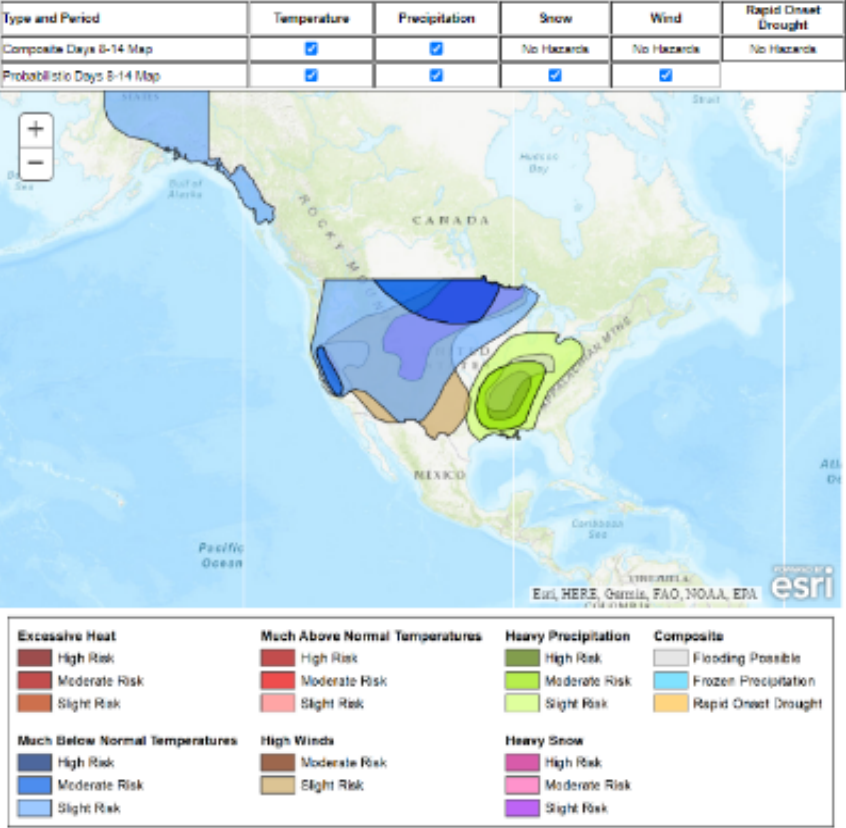
25.1%

Share of world experiencing record heat

National Weather Service and Extreme Heat/Heat Waves

Week 2 Extreme Heat forecasts at the CPC

Front page: "8-14 Day U.S. Hazards Outlook"; https://www.cpc.ncep.noaa.gov/products/predictions/threats/threats.php


- Issued weekdays (M-F) at 3 PM in both interactive GIS interface (left) and as static graphics (middle)
- The temperature related hazards are 'Excessive Heat' and 'Much Above Normal Temperatures'
- Probabilities in three levels: high, moderate, slight
- The associated forecast discussion provides additional information on context and impacts

These forecasts show the probability of extreme temperatures in Week 2!

Week 2 Extreme Heat forecasts at the CPC
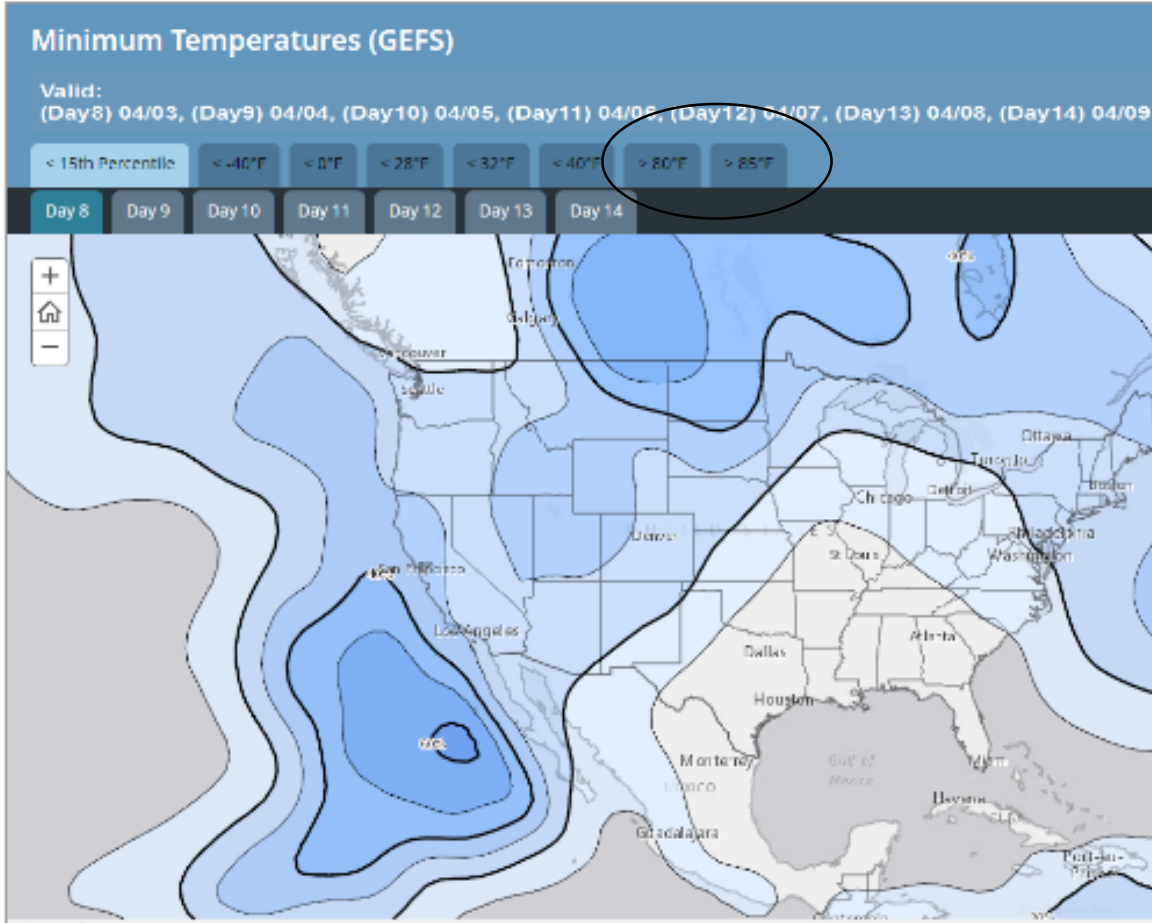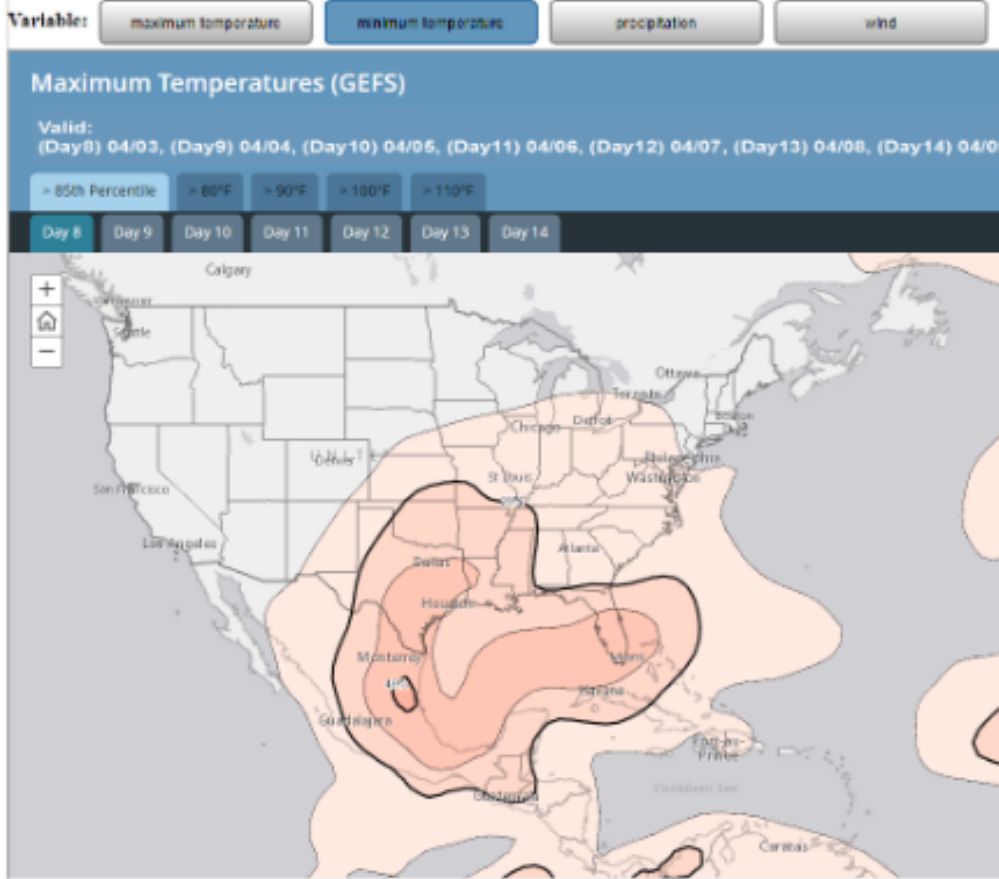
This is an interactive tool based on post-processed ensemble model output (GEFS). Probabilities are available by target date, maximum vs minimum temperatures and various thresholds. Thresholds both relative and absolute in nature.

These forecasts show the probability of individual days with extreme temperatures in Week-2!

Week 2 Extreme Heat forecasts at the CPC

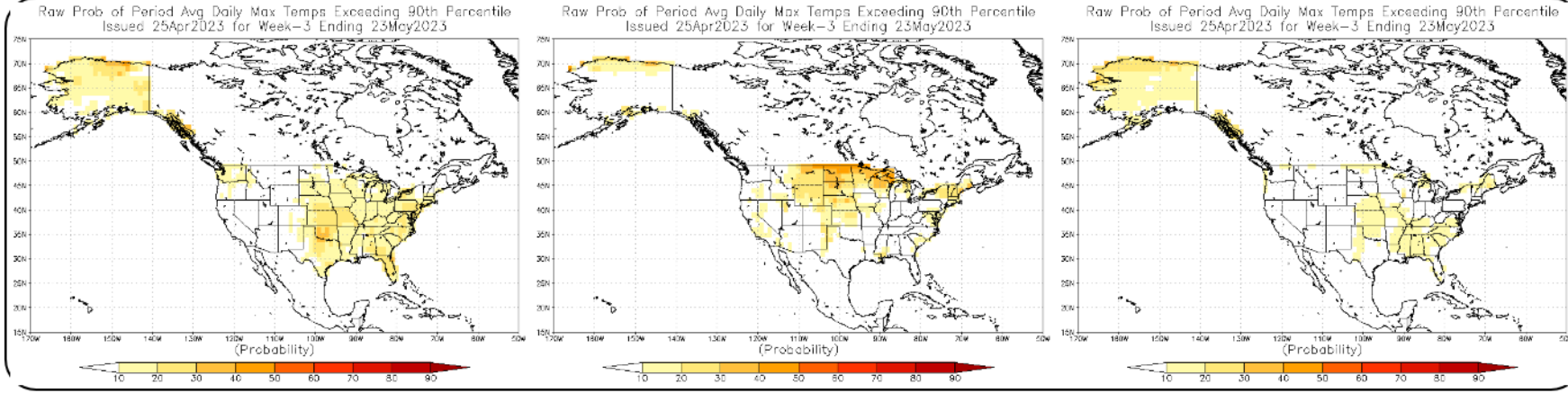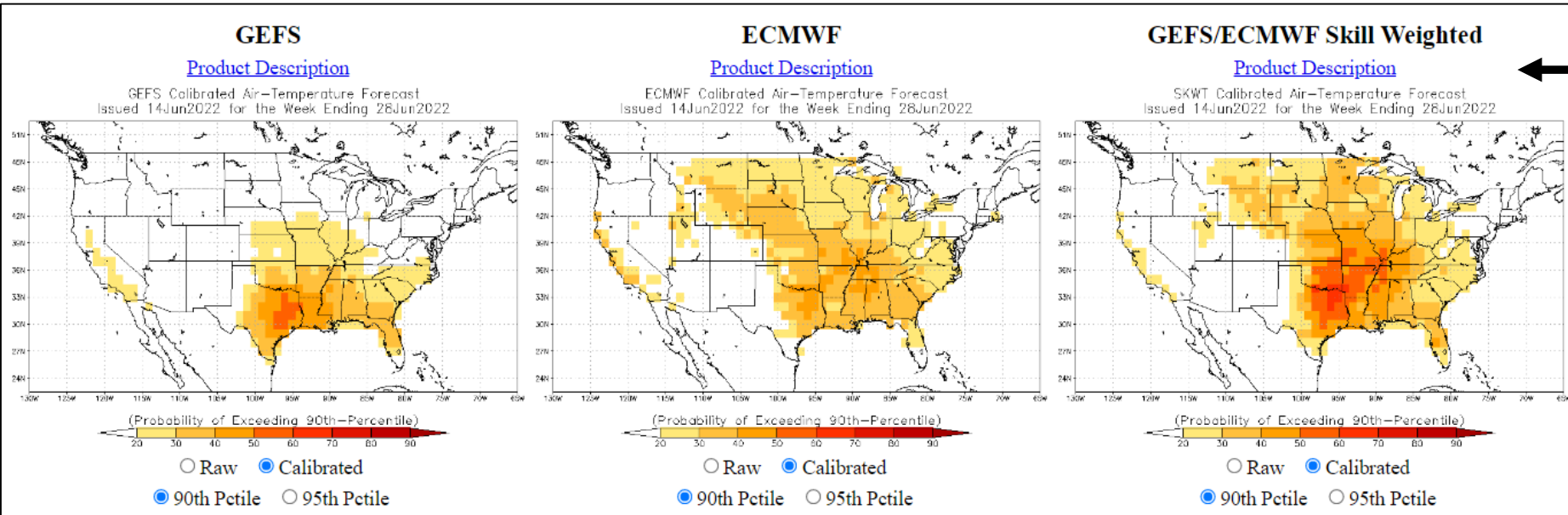
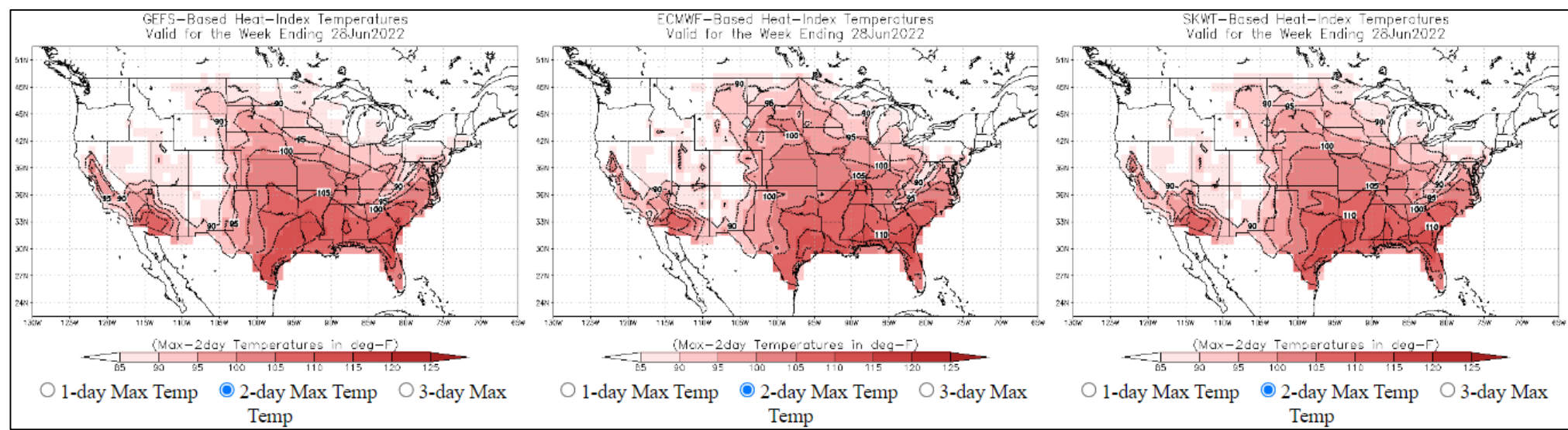Week 3 average
90th percentile chances
Daily max air T
Vs
Daily mean air T
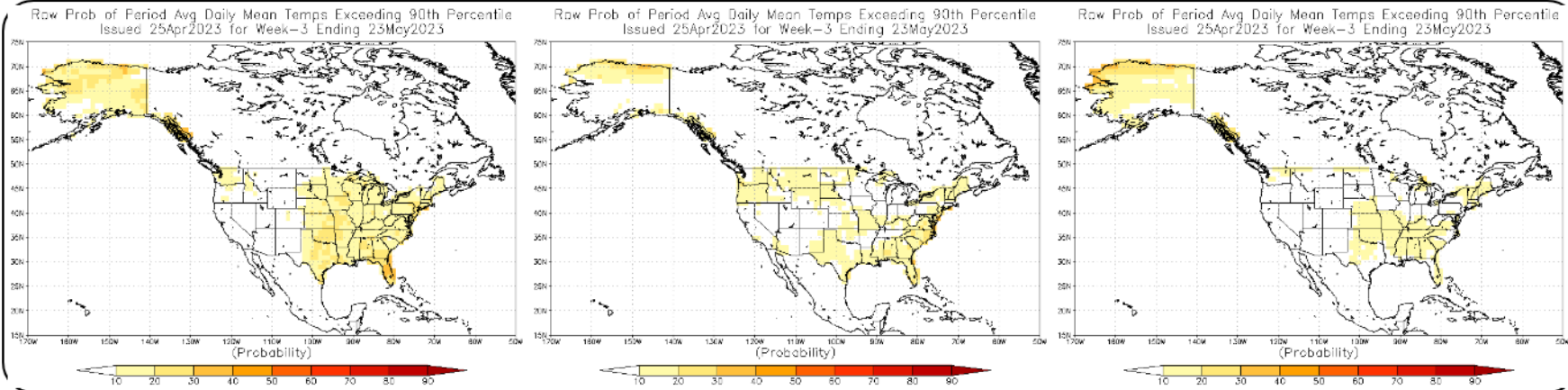
Week 2 Extreme Heat forecasts at the CPC

Week 2 Probs of consecutive 90th percentile daily max air T

Week 2 Estimated maximum 2-day mean daily max heat index

Extreme Heat considerations/variability across sectors

What the NWS focuses on currently

Public health
1. Exposure variable (air T, HI, WBGT, HeatRisk)
2. Regional variability (threshold, variable)
3. Seasonal variability (threshold)
4. UHI interactions (threshold implications)
5. Vulnerability variability (spatial, temporal)
6. Activity (youth, sports, labor)

Labor
1. Sectors
   1. Agriculture
   2. Construction
2. Impact:
   1. occupational injuries
   2. fatalities
   3. low productivity
3. Biometric variable (air T, WBGT, HI, etc.)
4. Equipment impacts

Wildfire and Drought
1. Enhanced risk (flash drought, litter moisture, dry heat/humid)
2. Enhanced chance of occurance
3. Pollution (wildfires)
4. Spread (wildfires)
5. Regional variability (threshold, variable)
6. Seasonal variability (threshold)

Agriculture
1. Ranching
   1. Cattle
2. Crops
   1. maize
   2. soybean
   3. wheat yields
   4. Irrigation methods
3. Water stress vulnerability
4. Timing of heat

Infrastructure
1. Airports (Density altitude: T, humidity, atmospheric pressure)
2. Roads (prolonged daily mean T, upper soil level moisture content)
3. Rails/trains (daily maximum T, daytime cloud cover)
4. Energy distribution (daily minimum temperature, atmospheric moisture, wind speed, drought, spatial size of event)

Questions about sensitivity to extreme heat definition

- Do increased *thresholds* simply decrease frequency? Does event *duration* do the same?

- What percent of extreme hot periods qualify as extremely hot *regardless* of the meteorological variable?

- Do extremely warm *weeks* equate to extremely hot *events*?

A simple data exploration of extreme heat definition

- Dataset: NCEP-NCAR's R1 reanalysis; 1989-2022; May 15-Sep 15; CONUS; 2x2 degree res.
- Extract meteorological variables
  - 6-hourly 2m atmospheric temperature
  - 6-hourly 2m maximum atmospheric temperature
  - 2m dewpoint temperature
- Calculated daily summary variables
  - Daily maximum air temperature
  - Daily mean air temperature
  - Daily maximum sWBGT
  - Daily maximum Heat Index

No NWS Heatrisk

- sWBGT = "simplified WBGT"
  - "approximate form requiring only temperature and humidity and explicitly assuming fixed moderately high solar radiation and low wind speeds" (Bureau of Meteorology)
- Week average vs Events
  - 7-day mean
  - Event: 2, 3, or 4 consecutive dates within the week
- Percentiles:
 - Calculated relative to similar calendar dates in the 1991-2020 period

How does event frequency change with increased duration or threshold?

| National average	Daily summery	
Event duration	max air T	max heat index
2 days (90th pctl)	16%	15%
3 days (90th pctl)	6%	6%
4 days (90th pctl)	3%	2%

National average	Rate of the occurance		
Daily summary	90 pctl	95 pctl	98.5 pctl
Daily maximum air temperature	16%	7%	3%
Daily maximum heat index	15%	9%	3%
Daily mean air temperature	17%	9%	4%
Daily maximum sWBGT	16%	8%	3%

portion of weeks with 2-day events that also had 3 day events
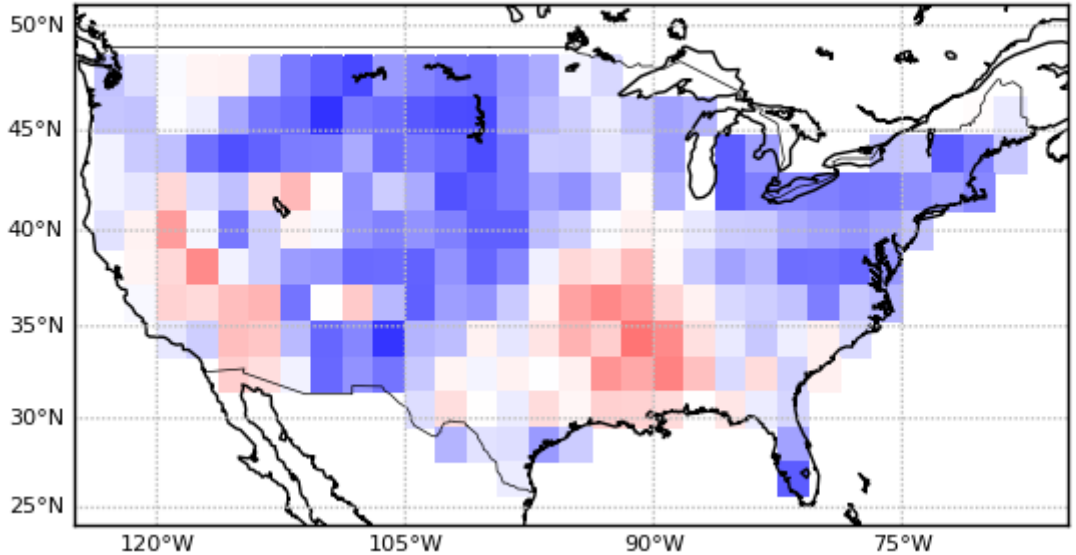
portion of weeks with 90th pctl events that also had 95th pctl events
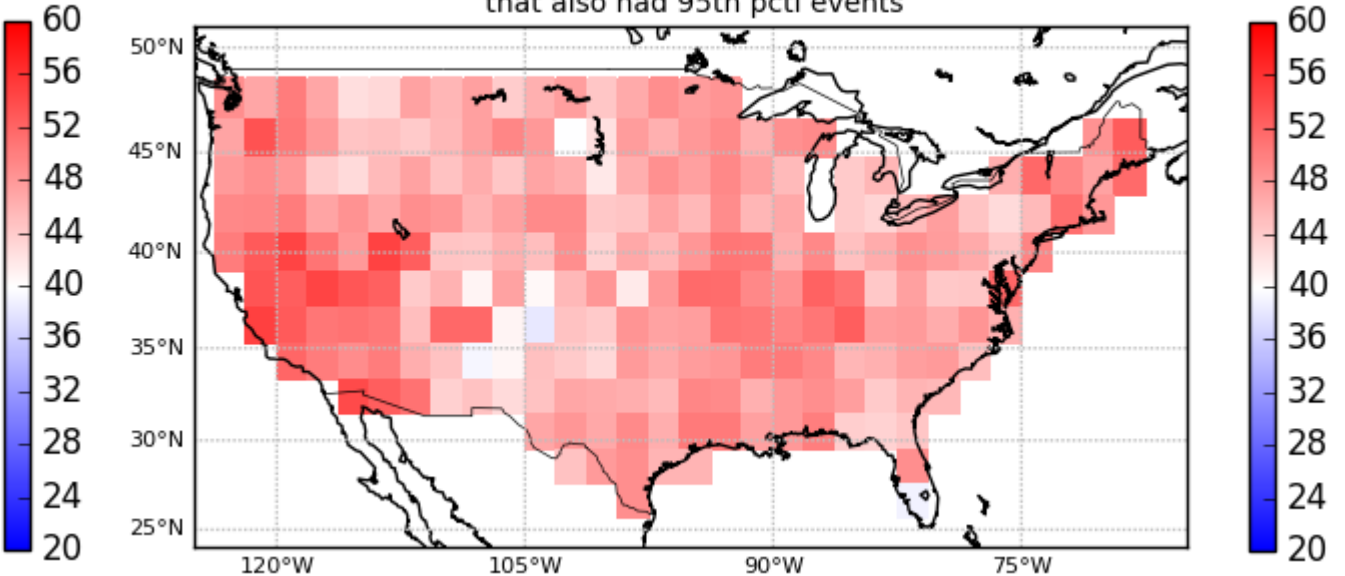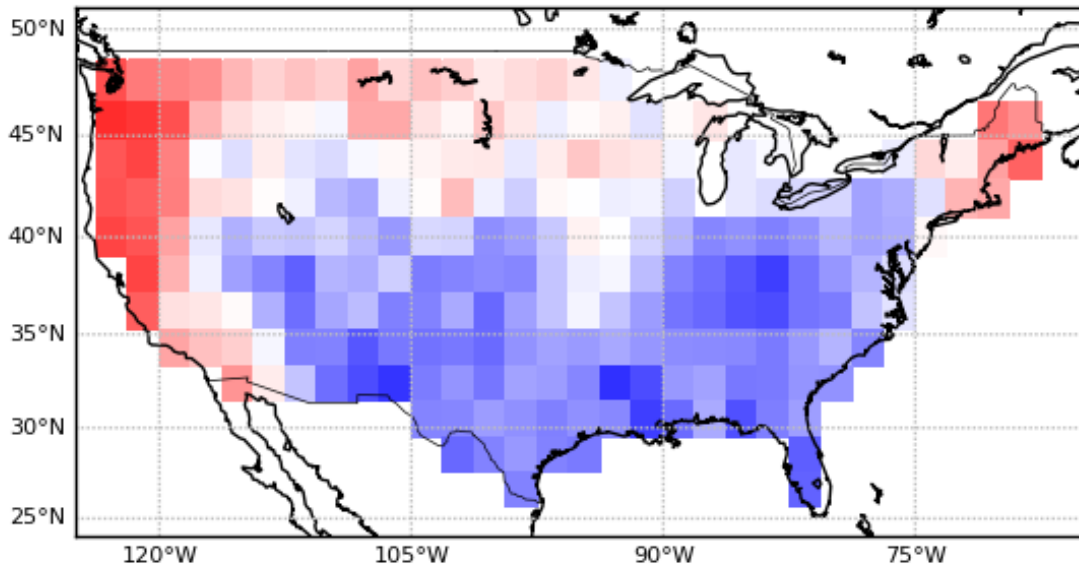
figures display the percent of weeks / events that span all 4 daily summary variables out of those that qualify in any individual variable; at the 90th percentile threshold

# Percent extreme heat that span daily met summaries?

"What percent of weeks qualifying as extremely hot via **any single** daily summary, also qualify as extremely hot in **all** daily summaries (considered)"

Time scale	National average rate
Weekly averages >= 90th pctl	34%
Events within week (2 day of 90th pctl)	37%

portion of heat events that span all 4 metrics

portion of hot weeks that span all 4 metrics
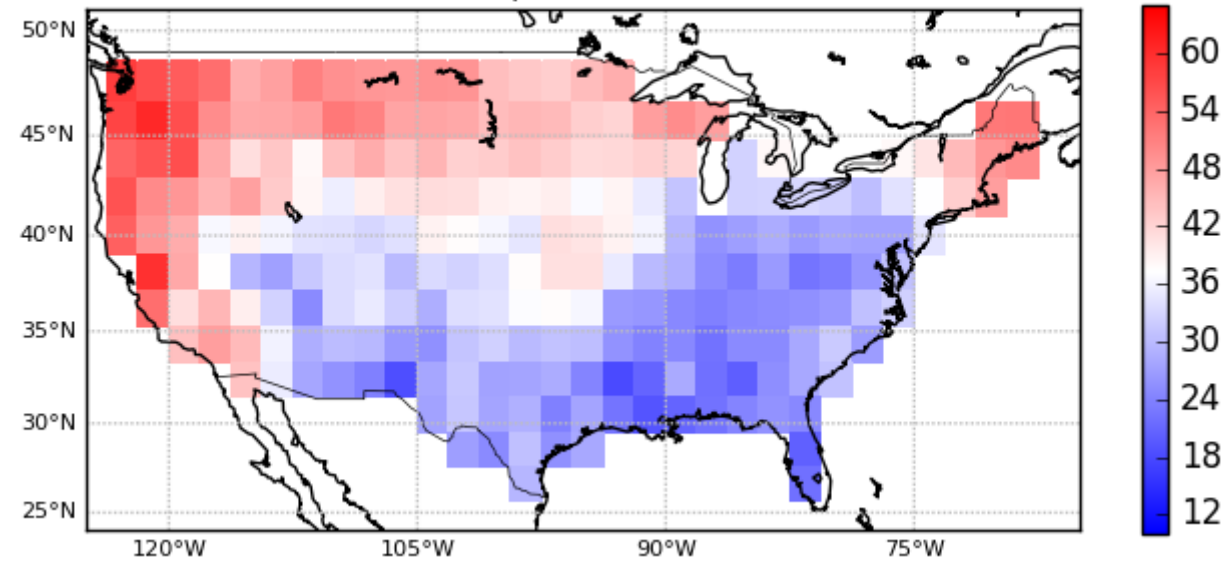
figures display the percent of weeks / events that span all 4 daily summary variables out of those that qualify in any individual variable; at the 90th percentile threshold

Extremely hot weeks and weeks with extremely hot dates: Interchangeable?

daily summary	Weekly avg extreme given a 2-day event takes place	2-day event given extreme weekly avg
Daily maximum air temperature	21%	33%
Daily maximum heat index	20%	31%
Daily mean air temperature	21%	37%
Daily maximum sWBGT	19%	31%

portion of weeks containing 2-day heat events that were also extremely hot weeks
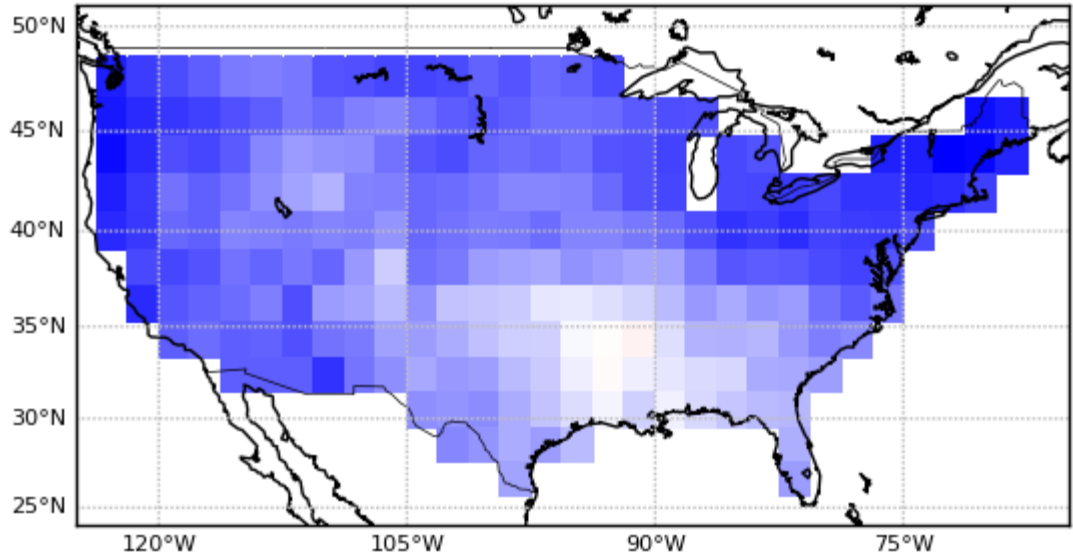
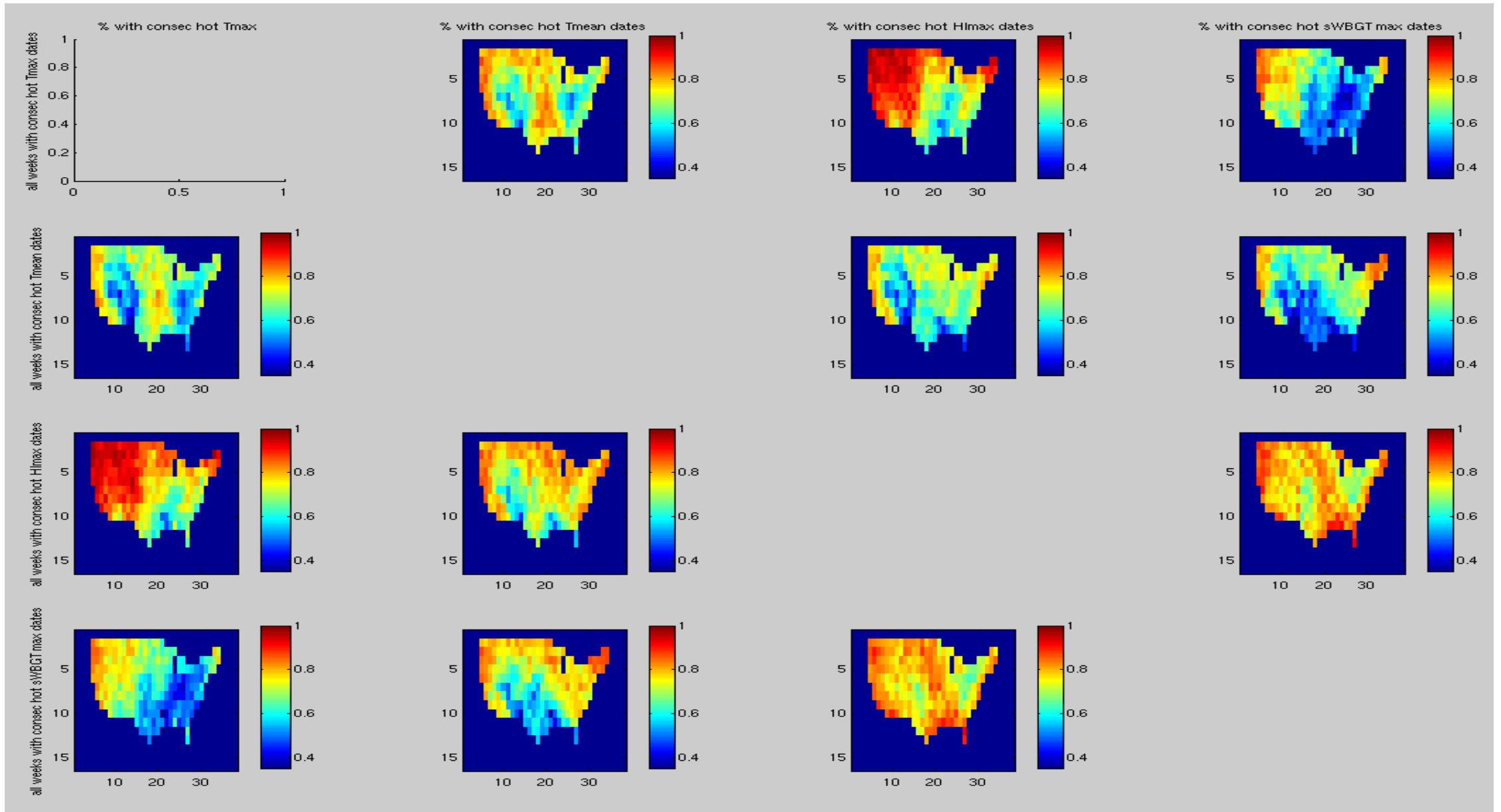portion of extremely hot weeks that also contained 2-day heat events
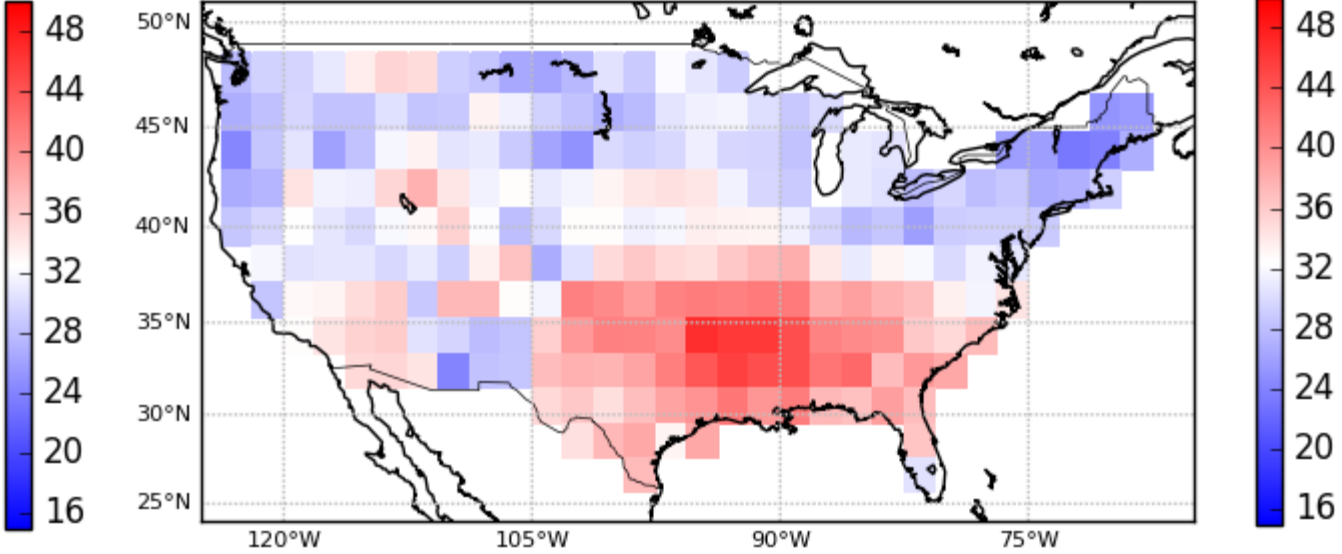
figures display the mean of all (4) daily summary variables at the 90th percentile

Take-aways and analysis conclusions

- Overview of CPC-NWS heat related
  - ✓ Product for subseasonal: Days 8-14 US Hazards report
  - ✓ Tool for public decision support: Probabilistic extremes tool

- Analysis findings
  - ✓ Increased thresholds and event duration -> frequency decrease
    - Uniform decrease with threshold, regional variability in duration-related decrease
  - ✓ Only about a 3rd of the time does a heat event span the various ways to describe a day's heat stress exposure levels
    - Upper bound
    - Closer to a half time frequency: Northwest, Northern Plains and Northeast regions
  - ✓ Only a 4th of the time extreme weeks and sub-weekly heat 'events' interchangeable
    - Forecasts of extreme weeks more likely to have 'events', than vice-versa
    - Interchangeability highest in Lower Mississippi Valley / Southeast

Extras

Extras