Spatiotemporal Patterns and Synoptics of Extreme Wet-Bulb Temperature in the Contiguous United States

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- WBT extremes matter for **impacts on human health and the economy** (Davis et al. 2016; Willett & Sherwood 2012; Sherwood & Huber 2010), and are **projected to strongly increase** in the future (Pal & Eltahir 2016; Schär 2016)

- However, the meteorology of WBT extremes remains little-studied in comparison to that of T extremes, particularly with **regards to regional differences**
  - like T, WBT extremes are typically on the order of a few hours (Schär 2016)
  - unlike T, they are functions of both T and q, making for **an additional source of variability**

- In this work:
  - We produce the **first characterization of hourly WBT extremes across the US**
  - We do some **synoptic analysis of the meteorology** of these extremes, though much work remains to paint a more-complete picture

Two primary data sources:

Observations

Hourly temperature, moisture, and surface wind from 175 stations in the Integrated Surface Database, strictly quality-controlled

Dataset available on Github at http://github.com/cr2630/finalhourlystationdataset

Reanalysis

3-hourly, 32-km temperature, moisture, and winds from the North American Regional Reanalysis (Mesinger et al. 2006)

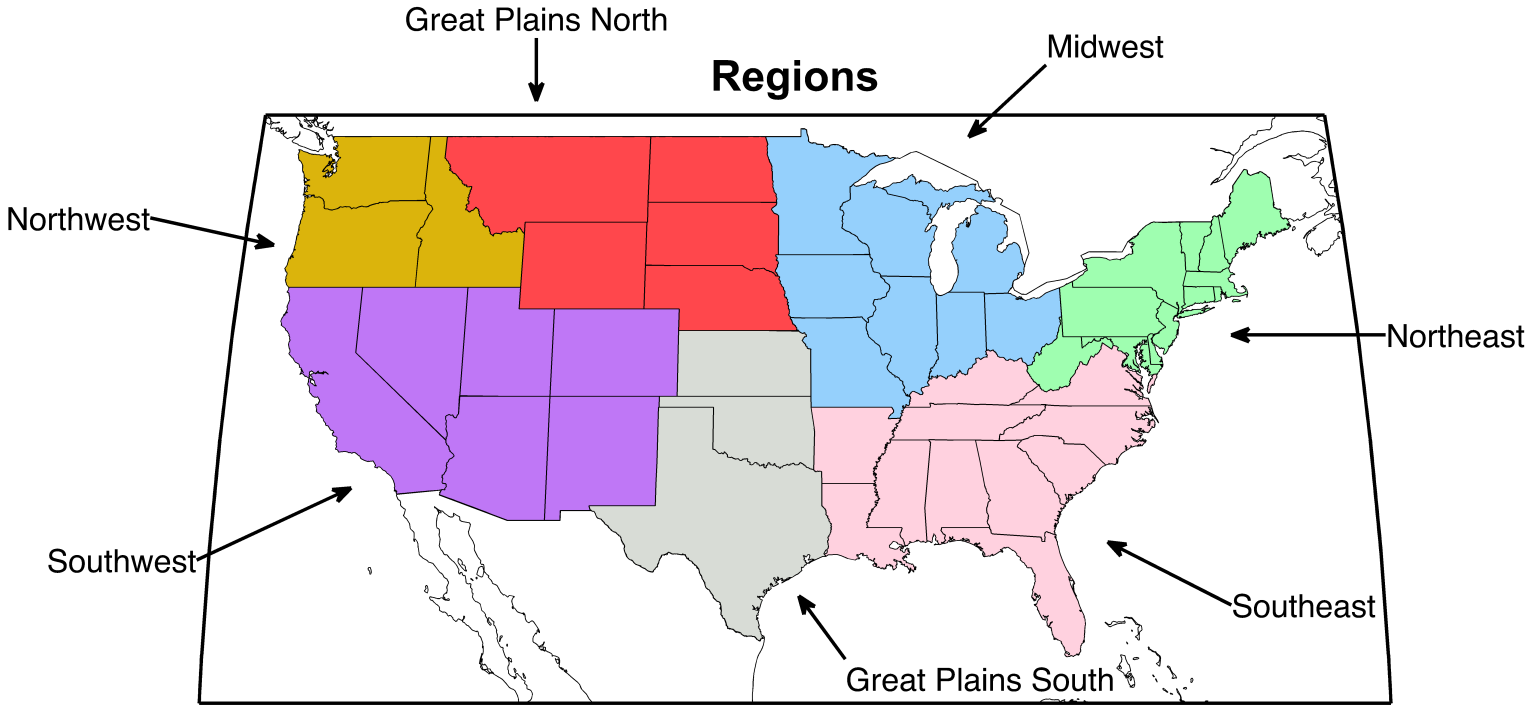
Daily, 2.5° geopotential height from NCEP Reanalysis II (Kanamitsu et al. 2002)

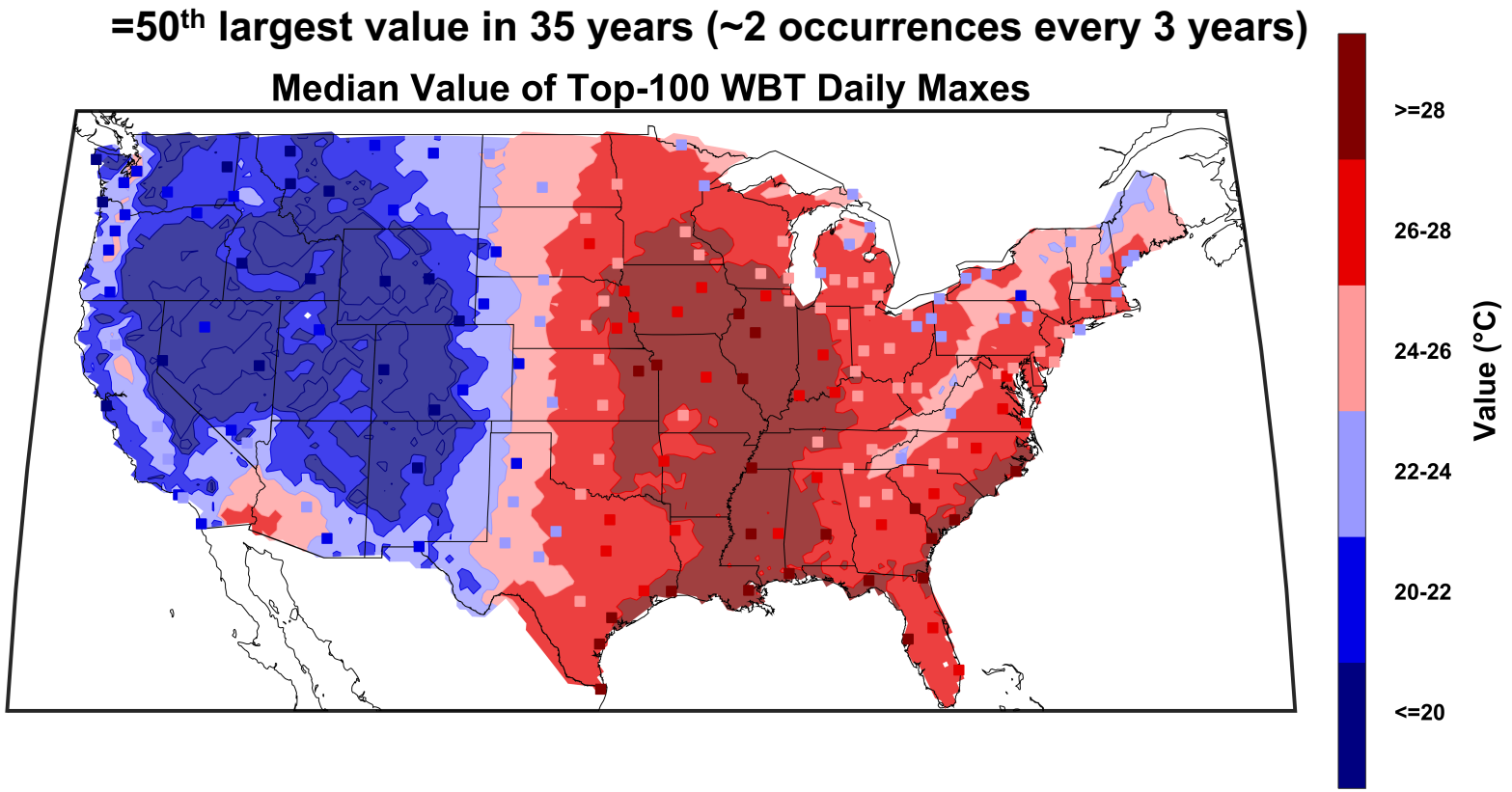
Daily, 0.25° SST from NOAA Optimum Interpolated SST (Reynolds et al. 2002)

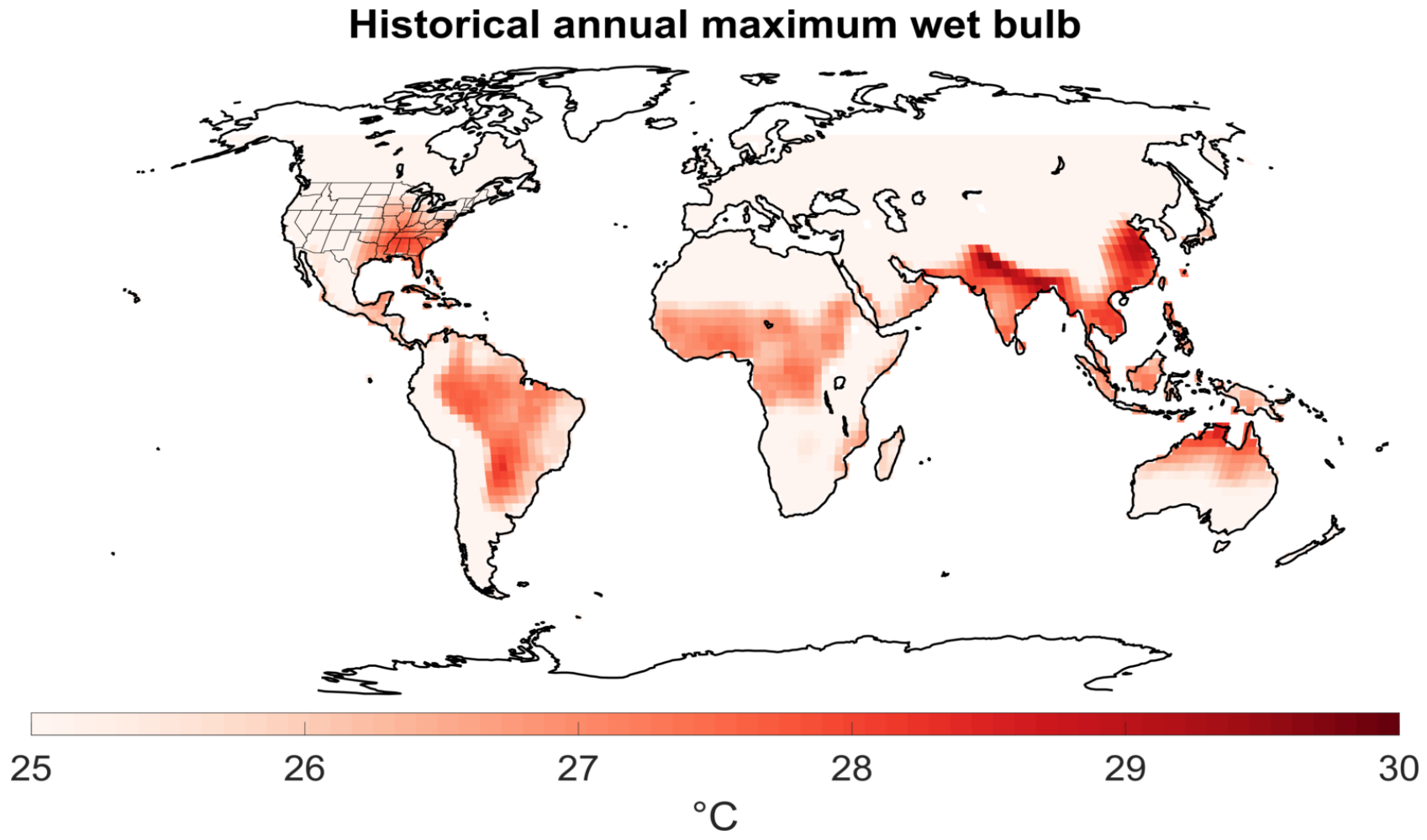
Extremes are the 100 highest daily maxima of WBT for each station over 1981-2015

days are treated separately following the methodology of McKinnon et al. 2016

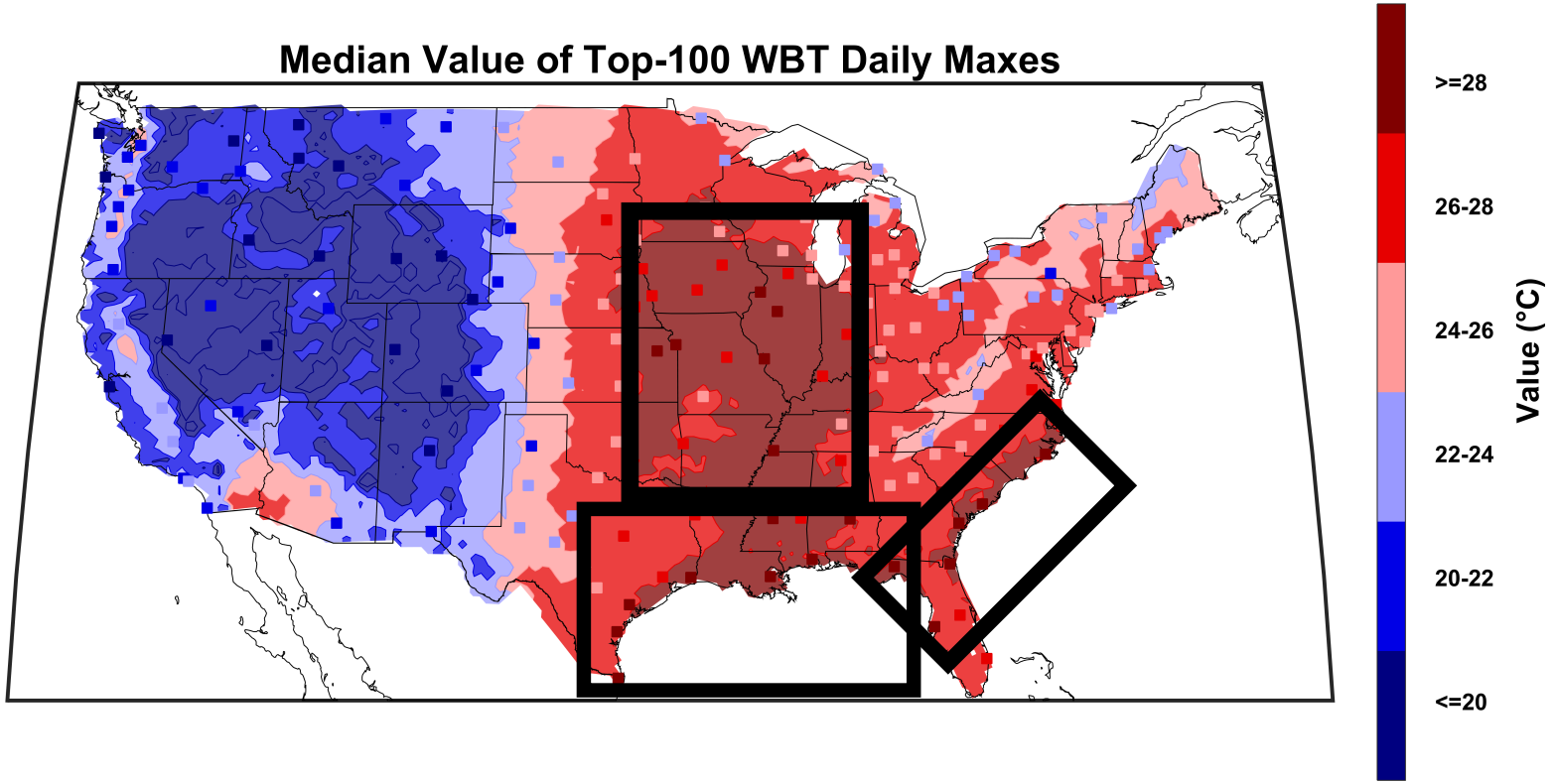
Stations ($14 <= n <= 39$) are averaged over each National Climate Assessment region




=50th largest value in 35 years (~2 occurrences every 3 years)
Median Value of Top-100 WBT Daily Maxes
>=28
26-28
24-26
22-24
20-22
<=20
Value (°C)

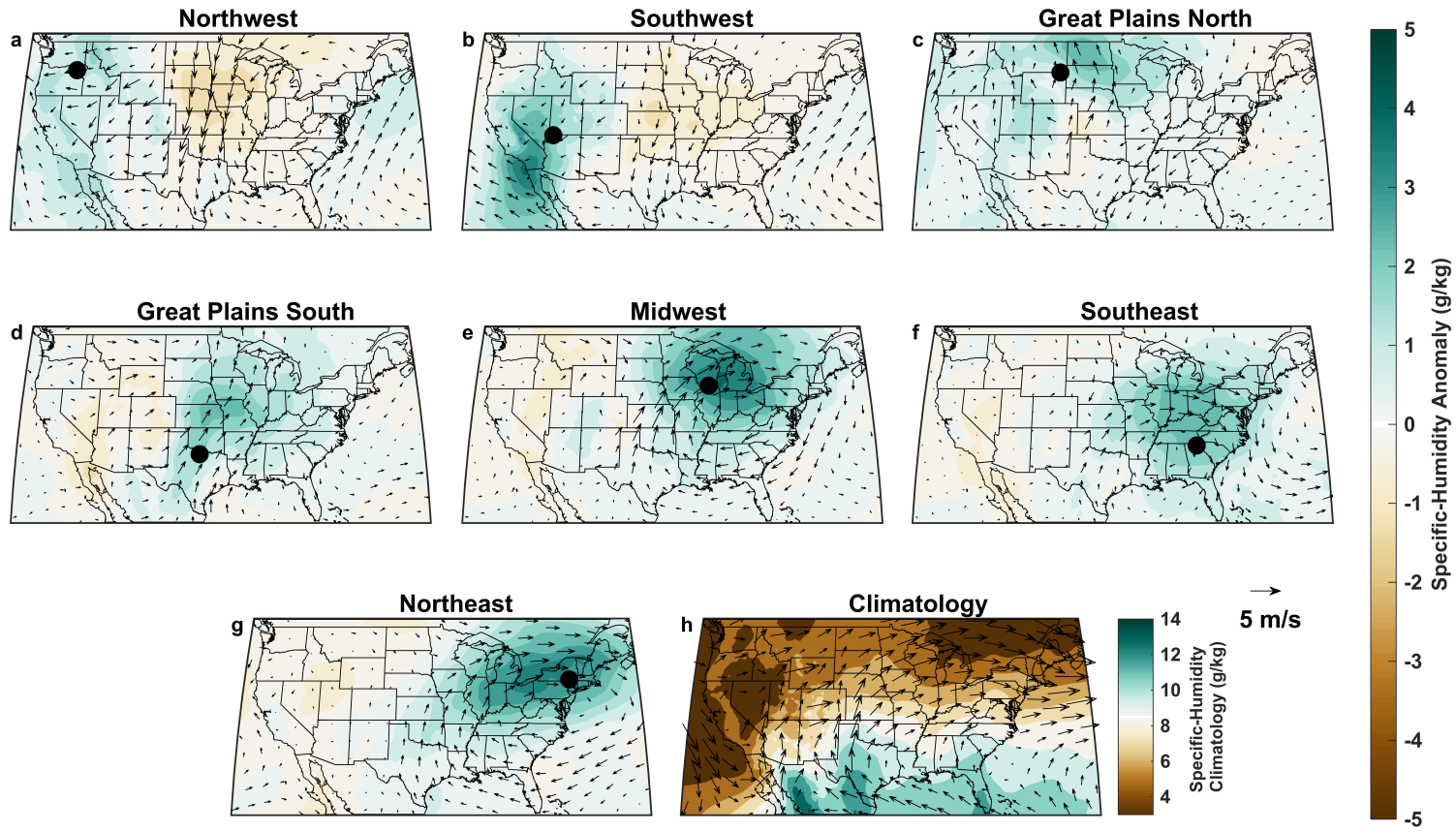


Coffel et al., in prep.



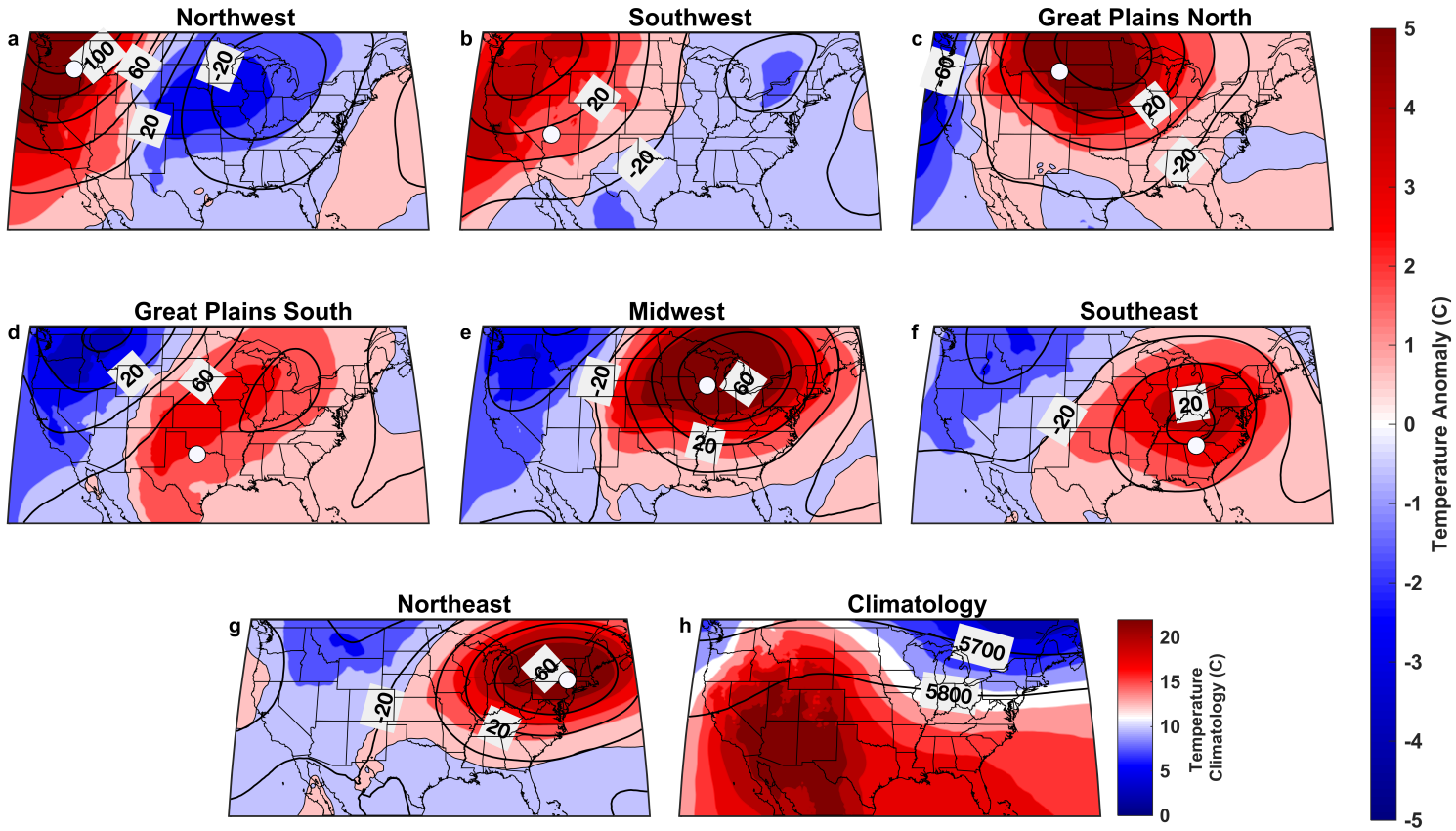
→ Extreme WBT relevant for impacts across the eastern U.S., particularly in the outlined regions

Composite anomalies of 850-mb wind and specific humidity



→ Extreme WBT closely associated with anticyclonic flow, typically from the continental interior

Composite anomalies of 850-mb temperature and 500-mb geopotential height [z500]
(white dot = region center)

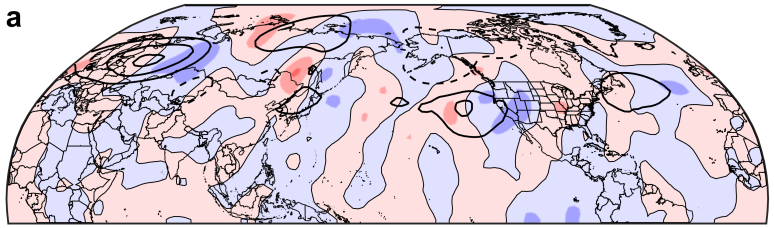


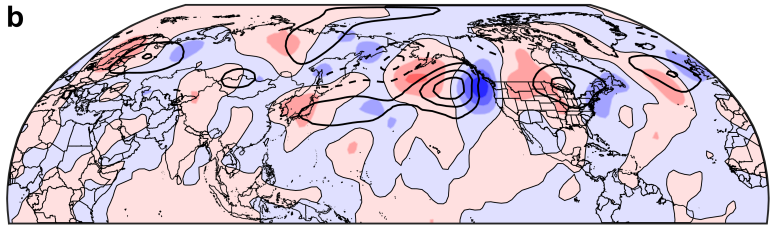
→ Generative mechanisms of extreme WBT vary by region

Wave-activity analysis (method following Teng & Branstator 2017)

Anomalies of z200 (contours, negative dashed) and v200 (shading) for the Midwest

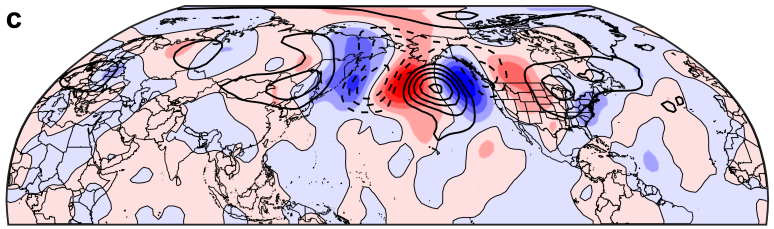
-20 days

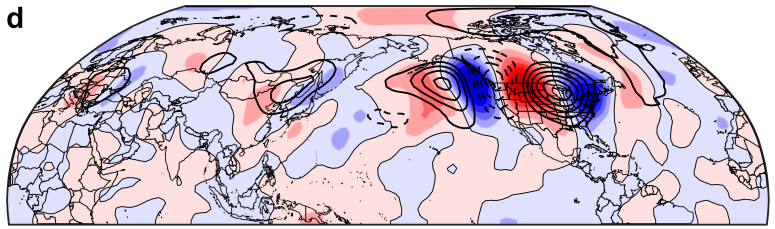




-10 days

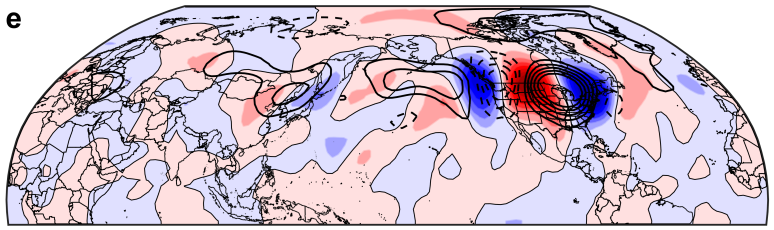
-5 days

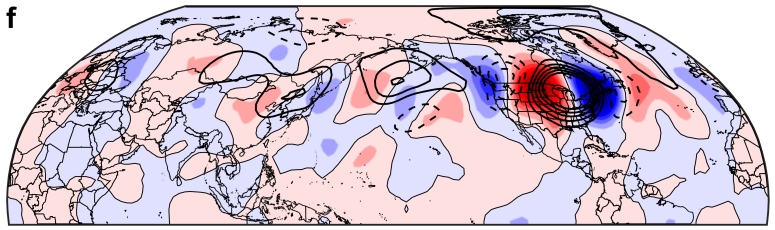




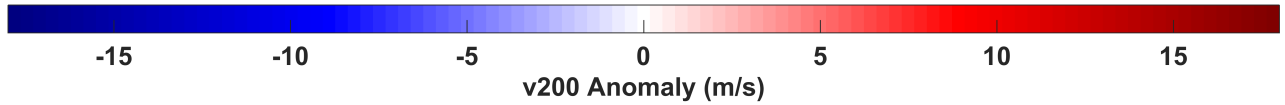
-2 days

-1 day



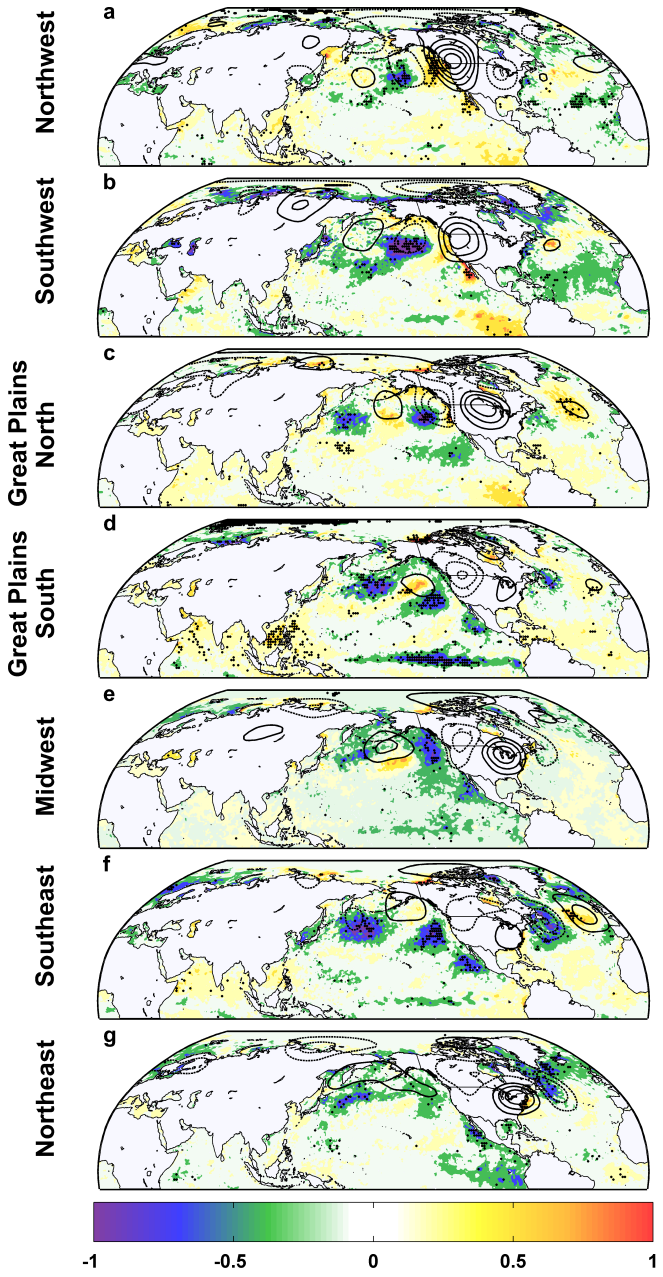


Event

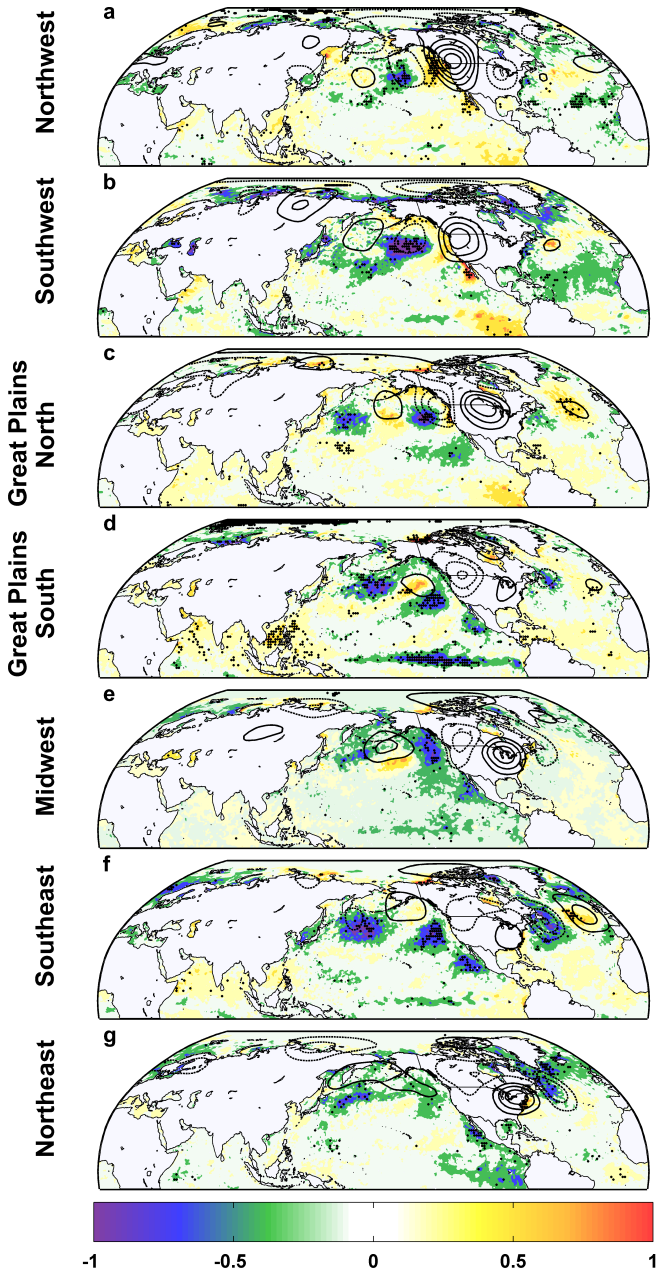


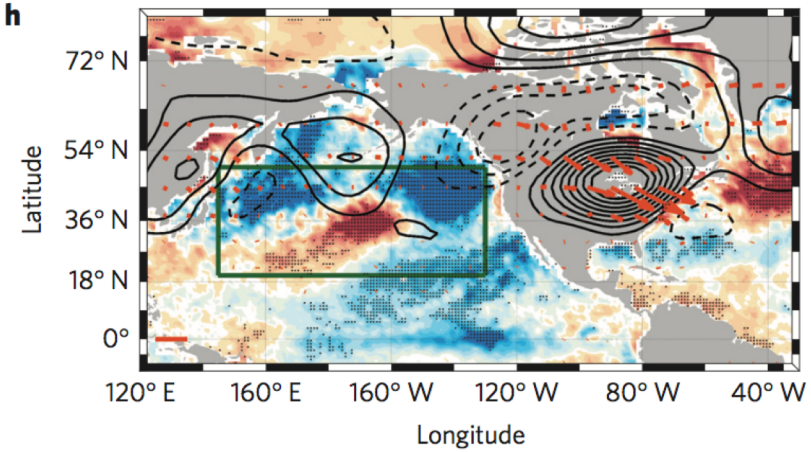
→ WBT extremes are preceded by a coherent mid-latitude wavetrain

Composite anomalies of z500(20-m intervals, negative dashed) and SST (shading, stippling at 95% significance)



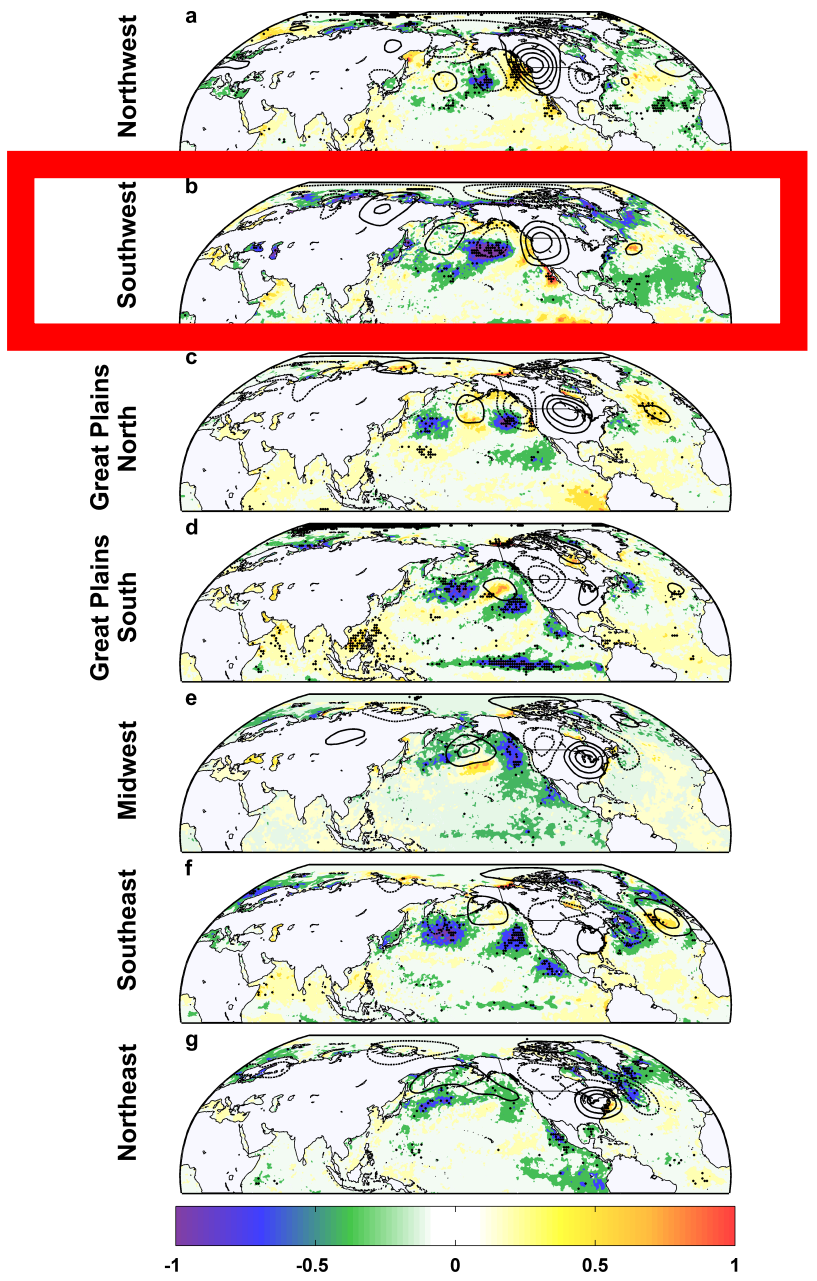
Composite anomalies of z500(20-m intervals, negative dashed) and SST (shading, stippling at 95% significance)





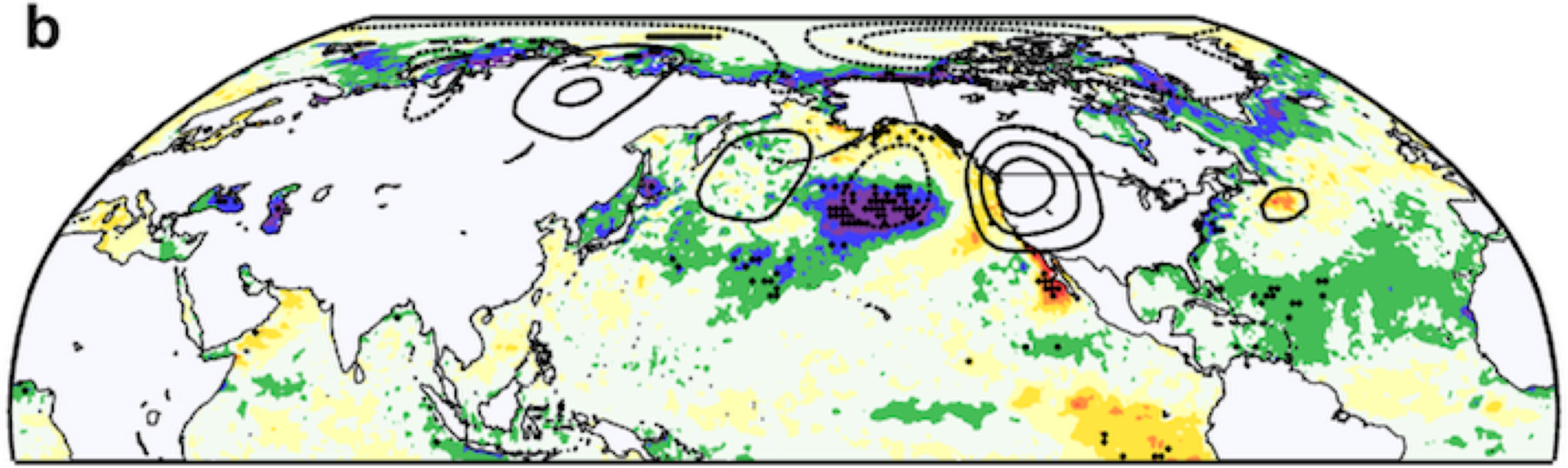
McKinnon et al. 2016, Figure 3

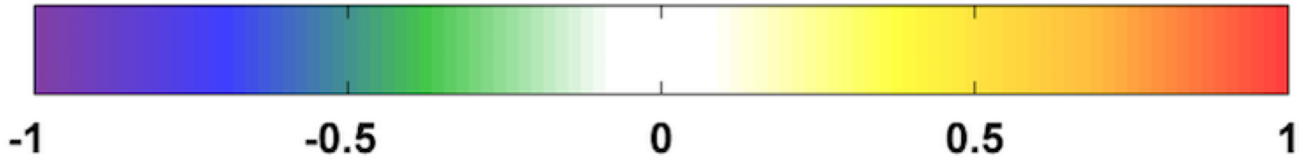
Composite anomalies of z500(20-m intervals, negative dashed) and SST (shading, stippling at 95% significance)



Southwest

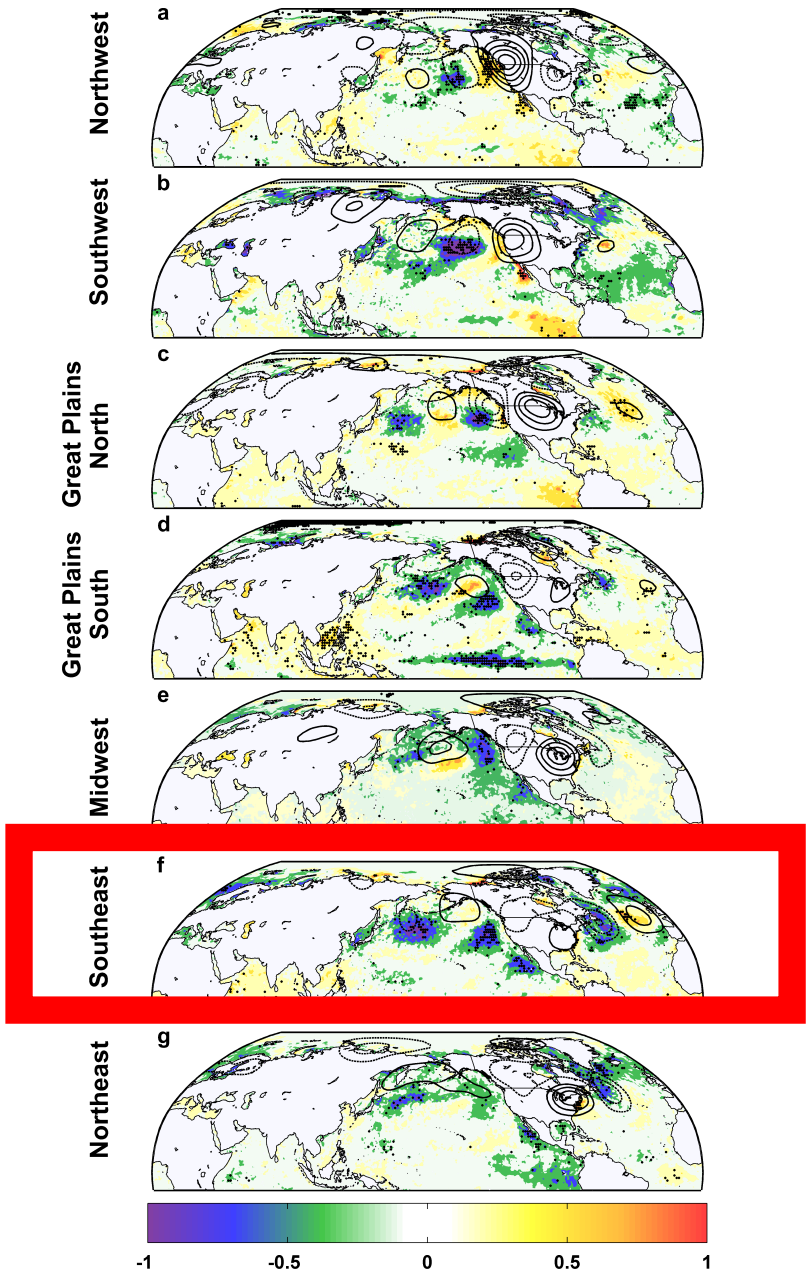
b





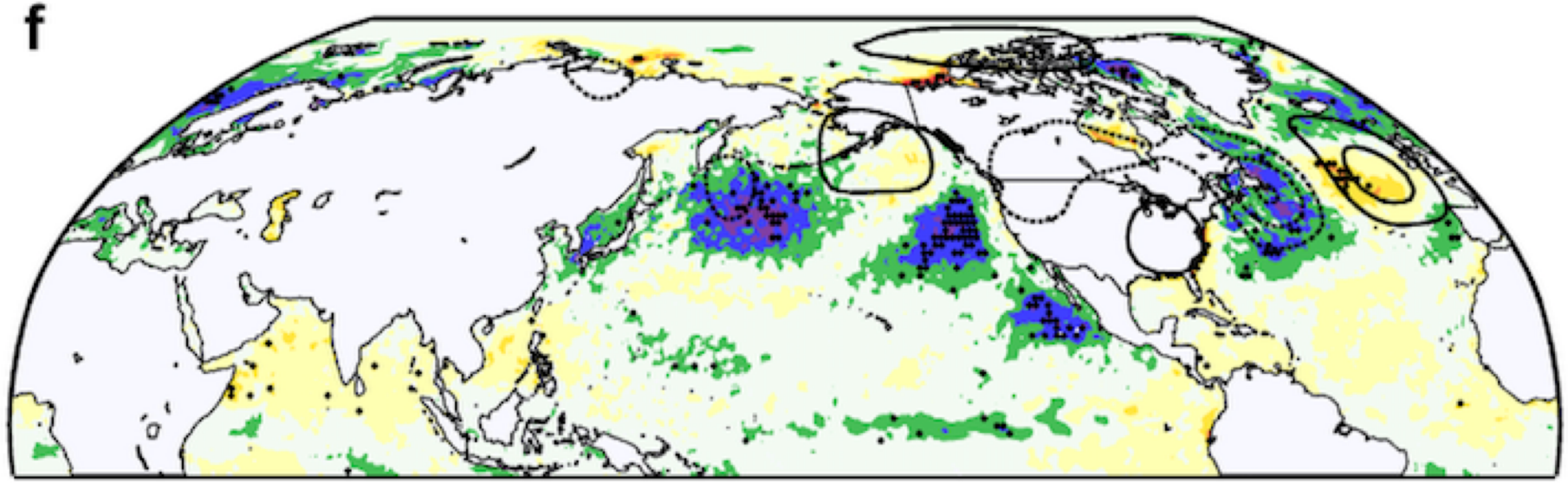
SST Anomaly (K)

Composite anomalies of z500(20-m intervals, negative dashed) and SST (shading, stippling at 95% significance)



Southeast

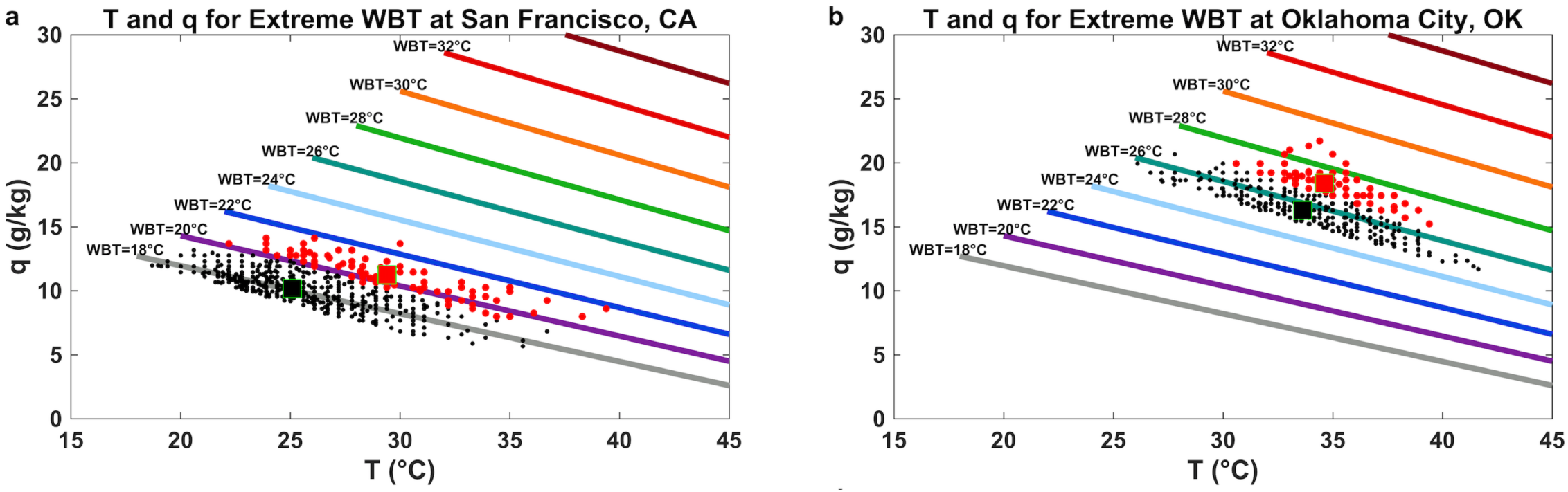
f



SST Anomaly (K)

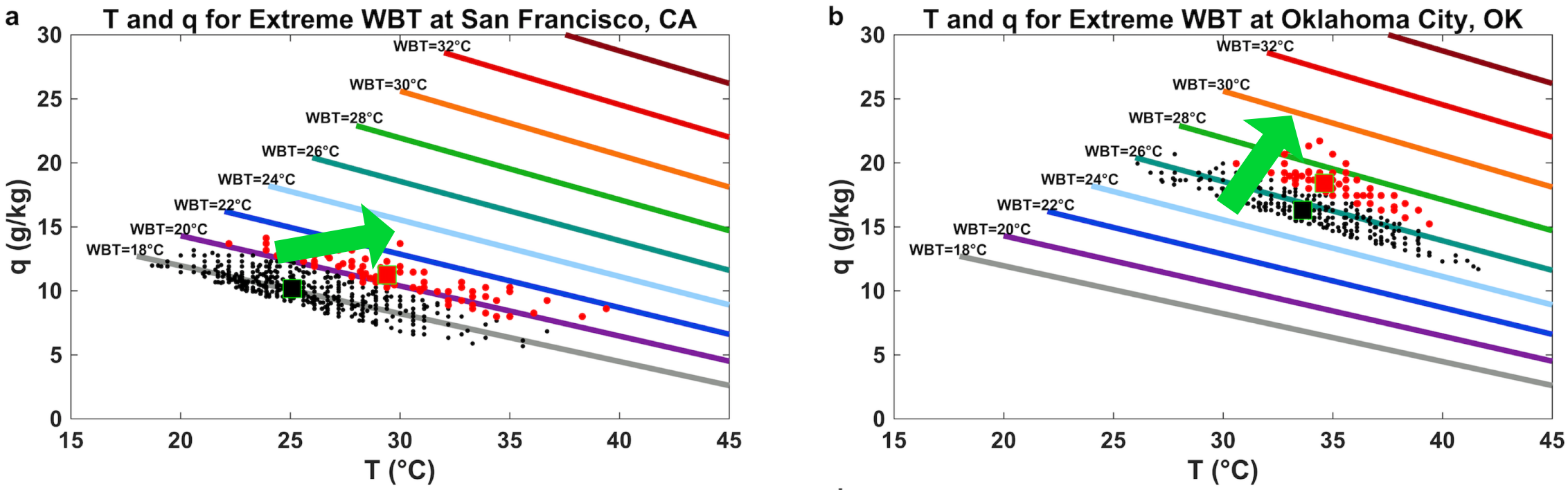
→ Remote, mid-latitude SSTs are often the strongest anomaly signature

What separates the most-extreme WBTs from the merely elevated?



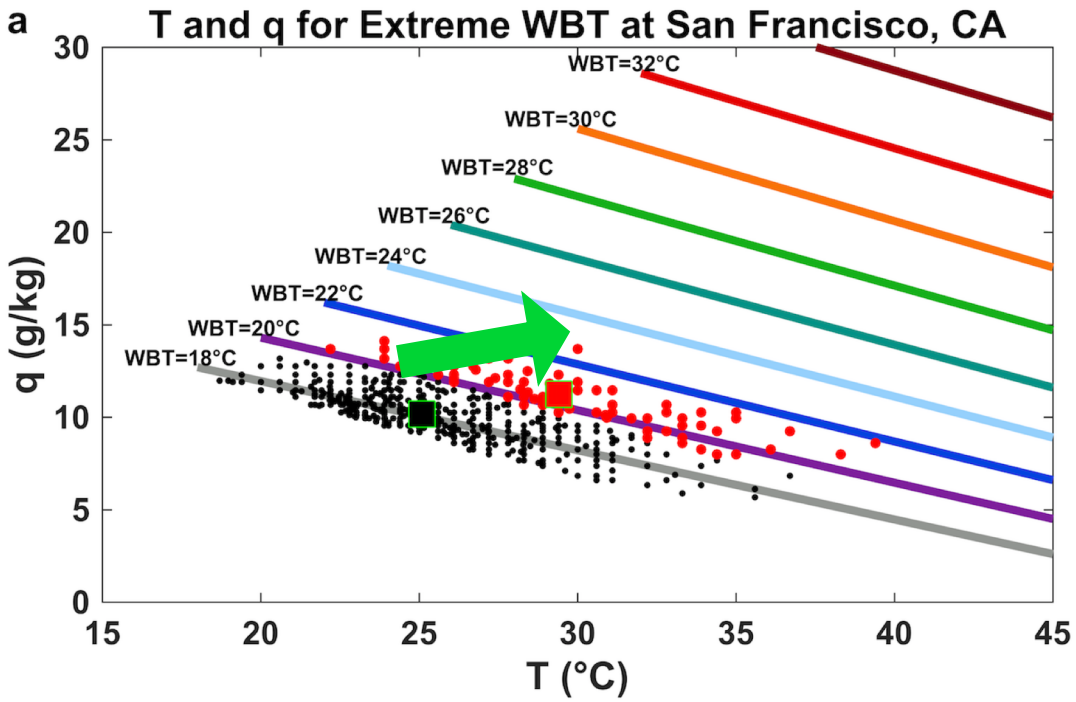
WBT days #1-100

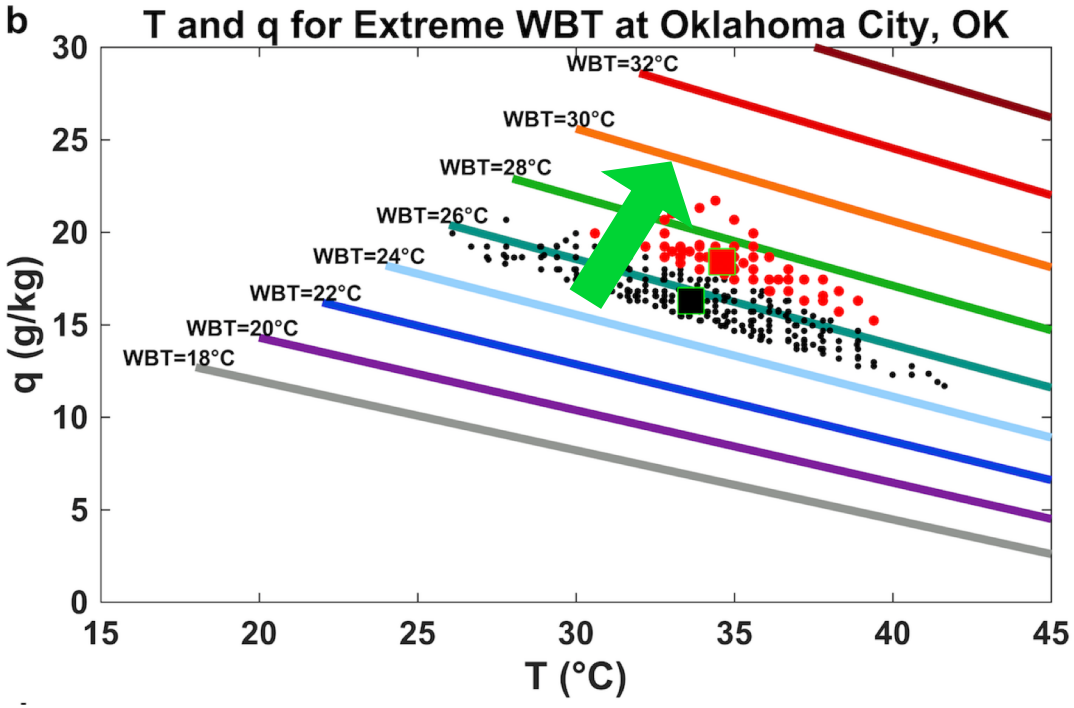
WBT days #101-1000

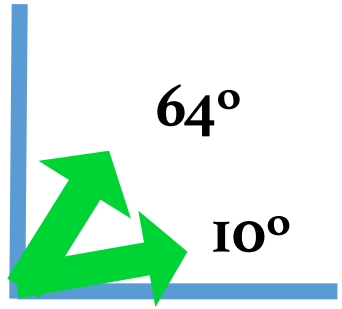


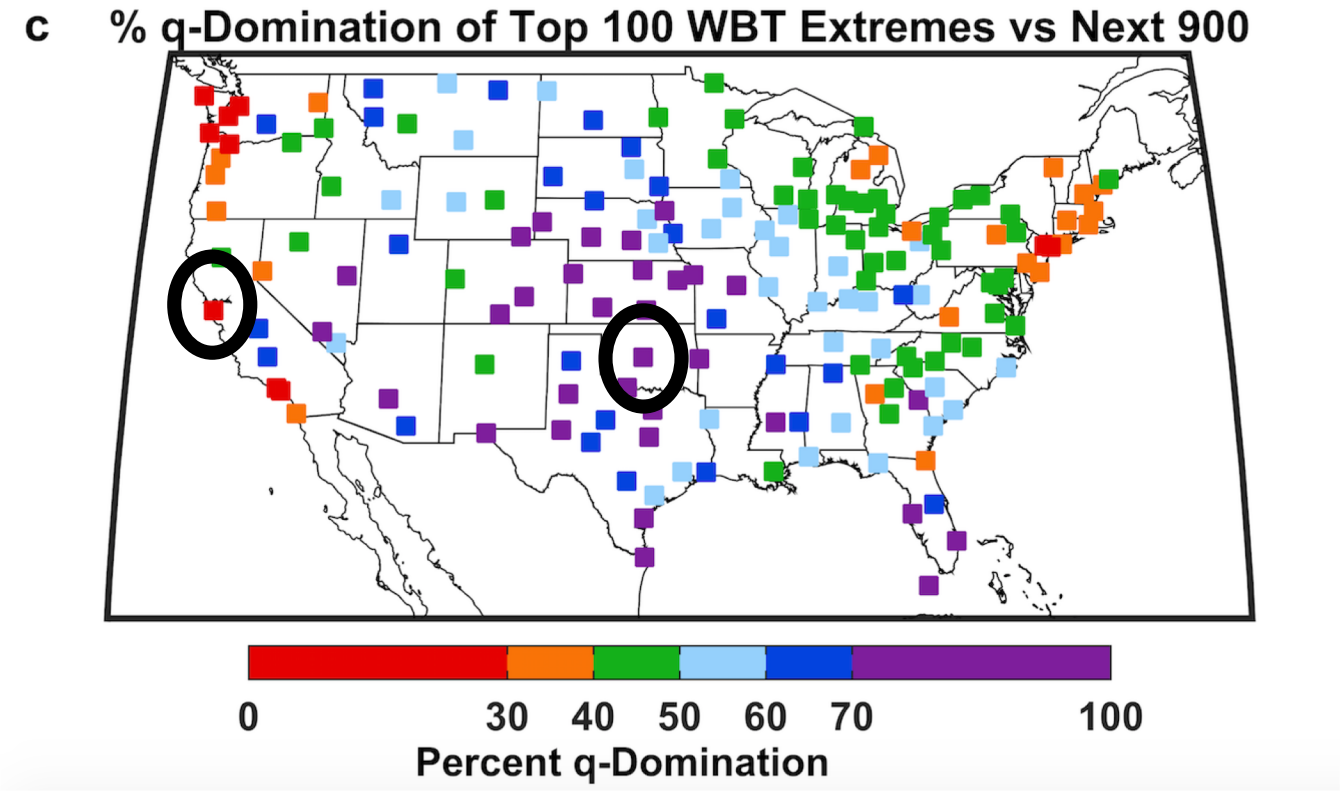
WBT days #1-100

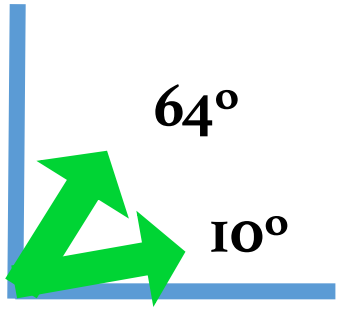
WBT days #101-1000


a
T and q for Extreme WBT at San Francisco, CA
WBT=32°C
WBT=30°C
WBT=28°C
WBT=26°C
WBT=24°C
WBT=22°C
WBT=20°C
WBT=18°C
q (g/kg)
T (°C)

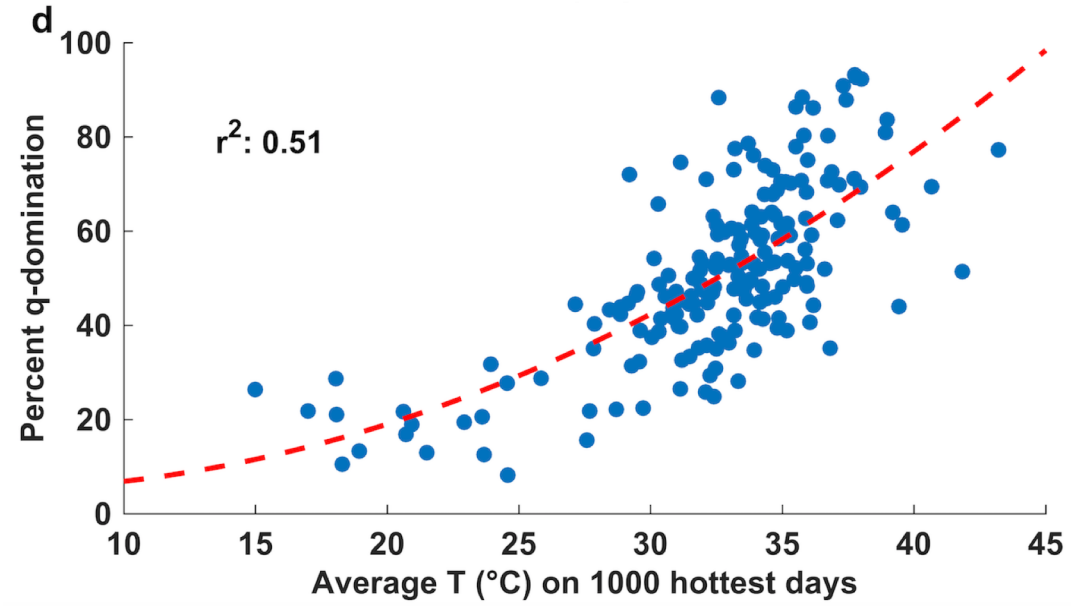

b
T and q for Extreme WBT at Oklahoma City, OK
WBT=32°C
WBT=30°C
WBT=28°C
WBT=26°C
WBT=24°C
WBT=22°C
WBT=20°C
WBT=18°C
q (g/kg)
T (°C)

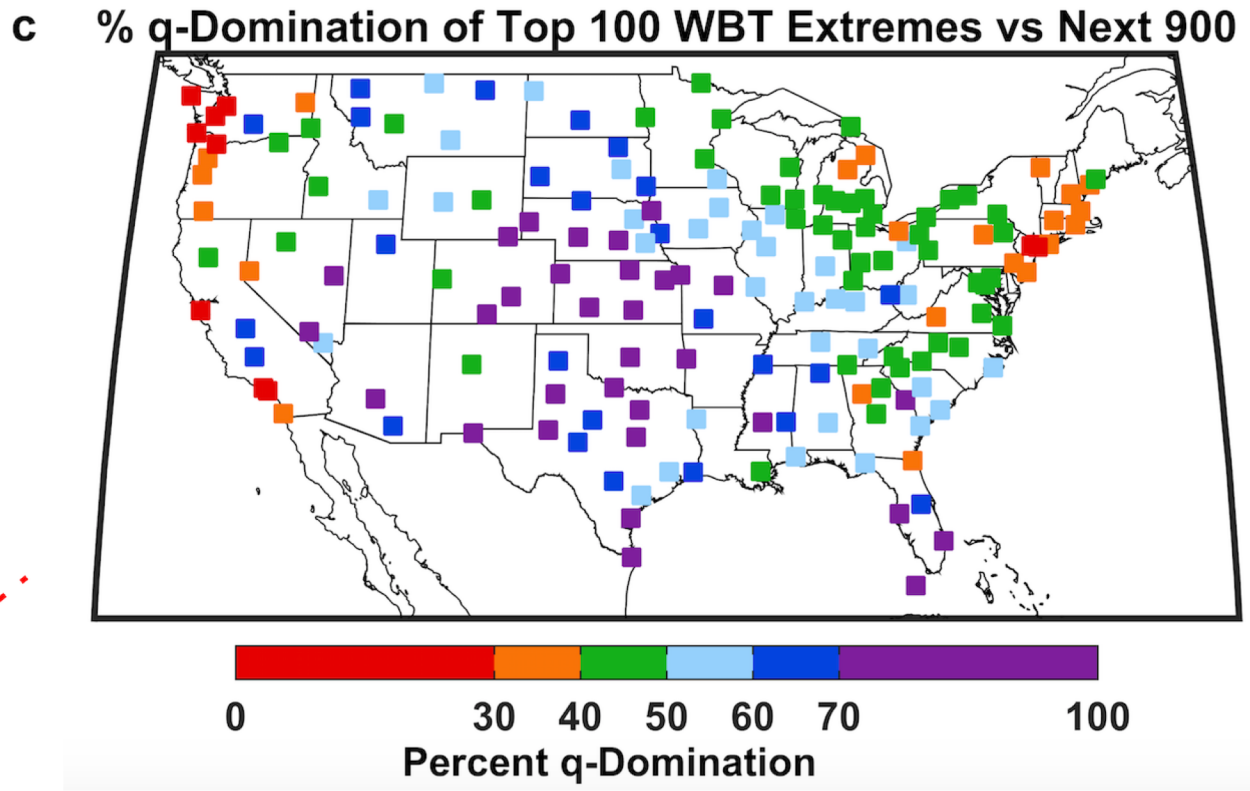

64°
10°





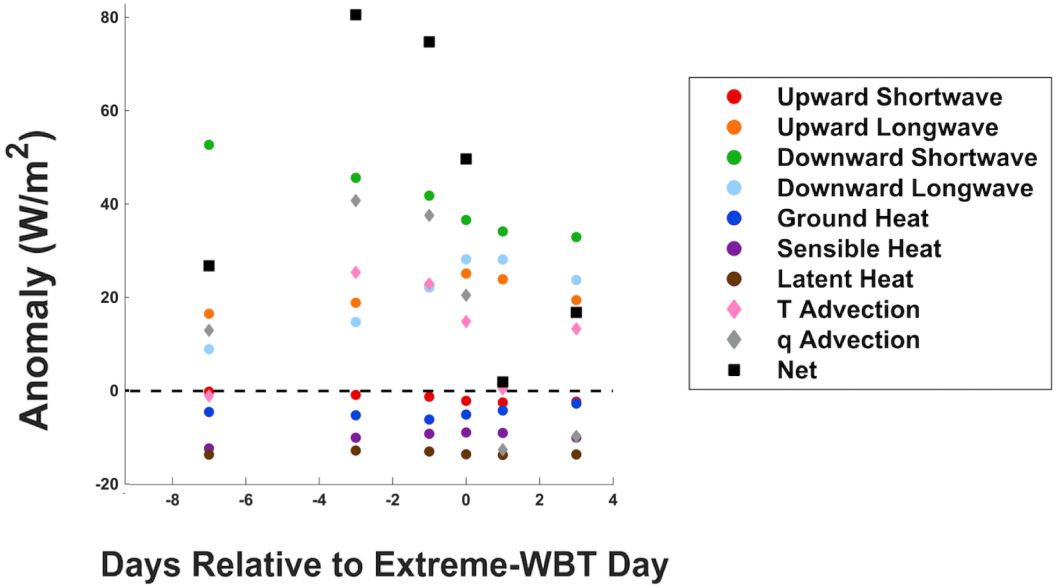
→ Larger role of anomalous q in regions with hot, dry summers





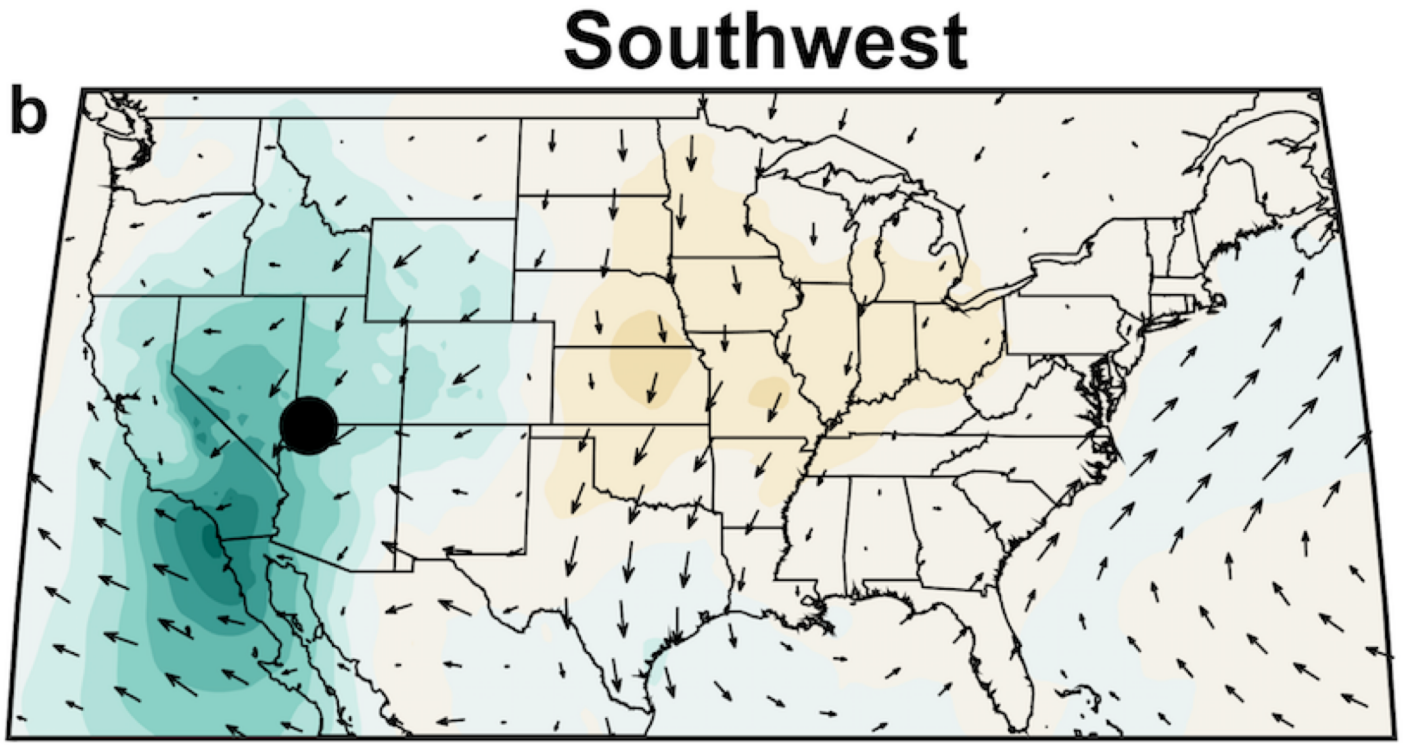
→ Hotter and drier summers projected for much of the land area in the subtropics and mid-latitudes (Cook et al. 2014), and also greater non-linearity of WBT with respect to q than T (Stull 2011), suggesting a possible general increase in this metric

Energy-Flux Anomalies for Extreme-WBT Days in the Southwest



→ Primary contributors to WBT extremes in the arid Southwest:

- increased shortwave radiative flux (on ~7-day timescale)
- increased moist low-level advection (on ~3-day timescale)


Southwest
b

Conclusions

- The timing and magnitude of WBT extremes vary considerably from region to region, and the generative mechanisms differ as well
- Remote, not local, SSTs are more strongly correlated with extreme-WBT occurrence in most regions
- Importance of anomalous q is greater in hotter and drier climates, with possible implications for the future