EPA
United States
Environmental Protection
Agency

Examining Projected Changes in Weather and Air Quality Extremes Between 2000 and 2030 using Dynamical Downscaling

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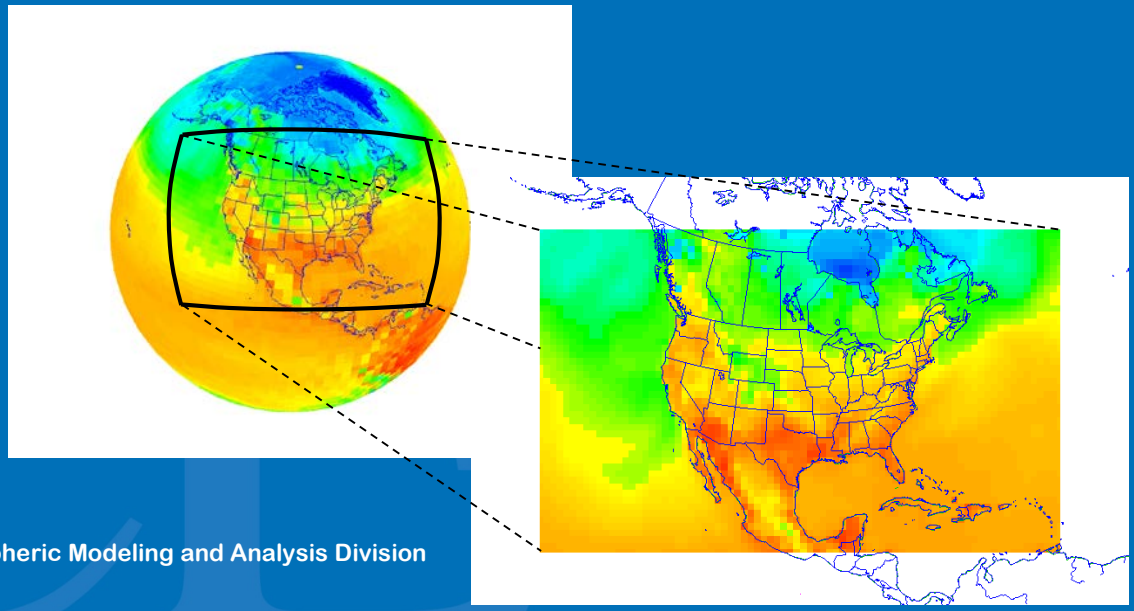


Office of Research and Development
National Exposure Research Laboratory, Atmospheric Modeling and Analysis Division

Developing Downscaling Methodology for Air Quality-Climate Change Simulations

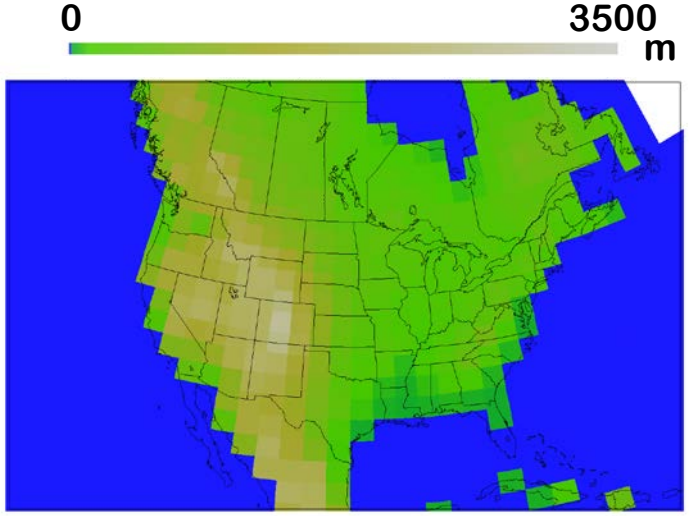
- Reanalysis-driven runs to develop downscaling methodology
  - 20-year runs with historical data at 1.875° grid size (comparable to GCM)
  - Evaluate 36-km RCM results against higher-resolution reanalyses
  - Nudging: consistency with driving fields (at both 36-km and 12-km grid spacing) and realistic extremes

    See Bowden et al. (*J. Climate*, 2012), Otte et al. (*J. Climate*, 2012), Bowden et al. (*Clim. Dyn.*, 2013), Bullock et al. (*JAMC*, 2014).

- Develop downscaled fields using GCM simulations
  - AR5 Ensemble: time slices, RCPs, GCMs
    - NASA GISS ModelE2, NCAR CESM, NOAA GFDL CM3, …
- Examine air quality-climate change interactions

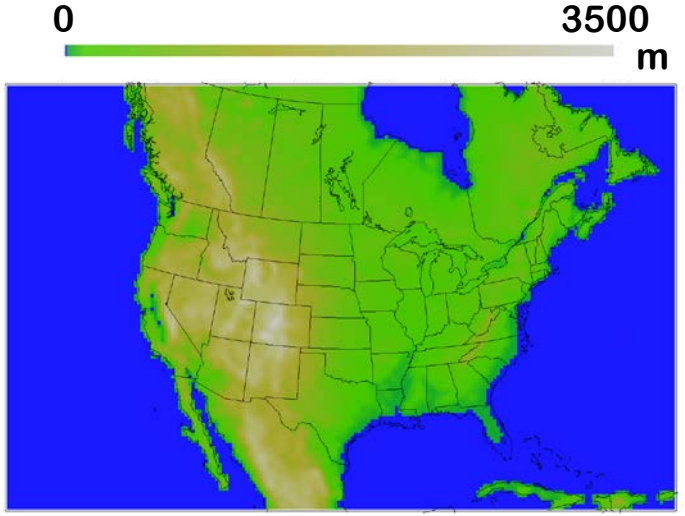
Downscaling NASA/GISS ModelE2 using WRF

- **ModelE2**: AR5 runs at 2° x 2.5°
  - 40 hybrid layers up to 0.1 hPa
  - ca. 2000 (“1995–2005”) and RCP 6.0 ca. 2030 (“2025–2035”)
  - Used at 6-h intervals



Elevation (ModelE2)

- **WRFv3.2.1**
  - Ingest ModelE2 on native vertical structure
  - 108-36-km, two-way-nested domains
  - 34 layers up to 50 hPa
  - Continuous 11-year runs (no reinitialization)
  - Spectral nudging of wavelengths >1500 km only above PBL

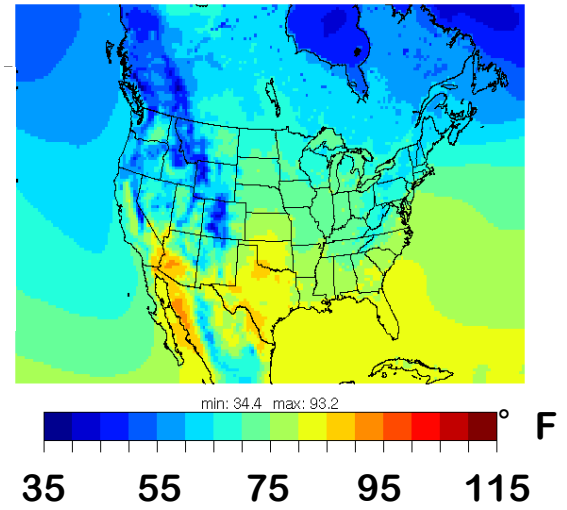


Elevation (WRF 36-km)

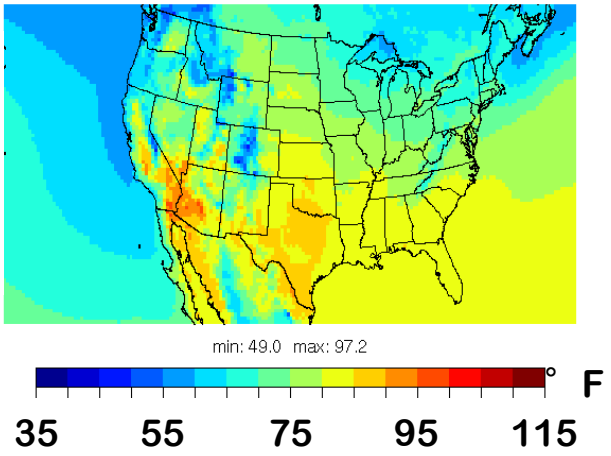
Contemporary Climate vs. Reanalysis

July
11-Year Mean
2-m Temp

ModelE2-WRF (ca. 2000)

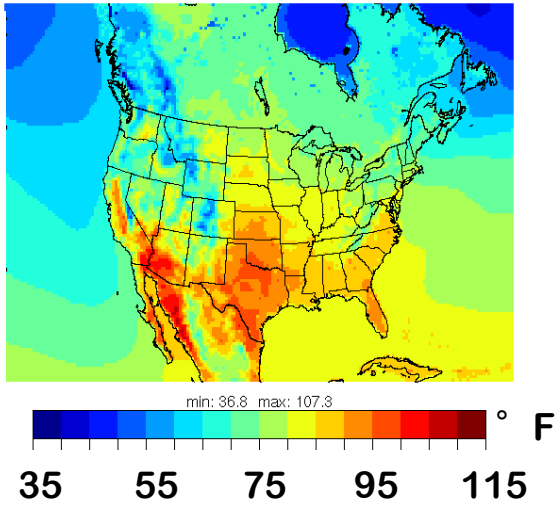


NARR (1995-2005)

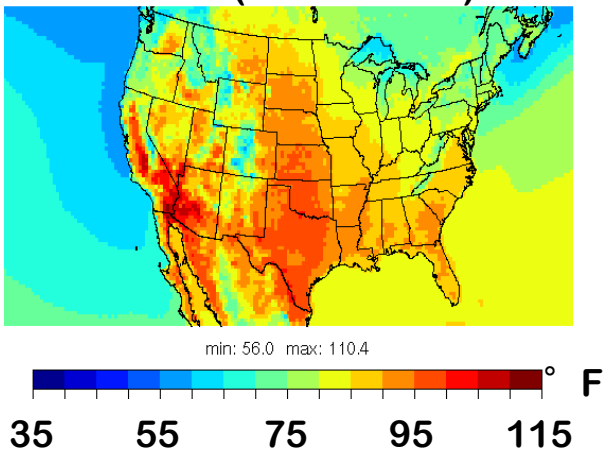


July
11-Year Mean
Daily Max
2-m Temp

ModelE2-WRF (ca. 2000)



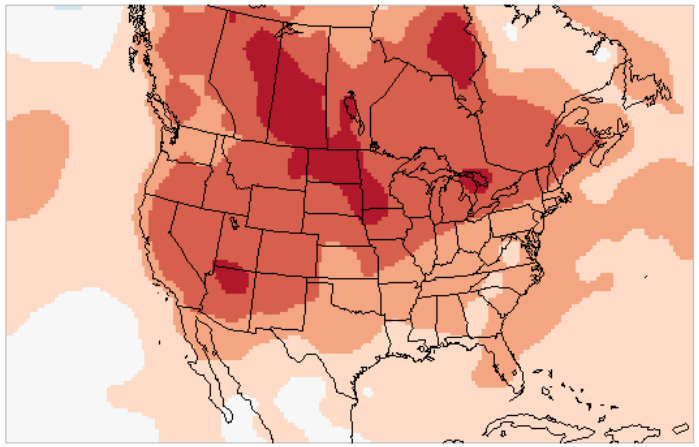
NARR (1995-2005)



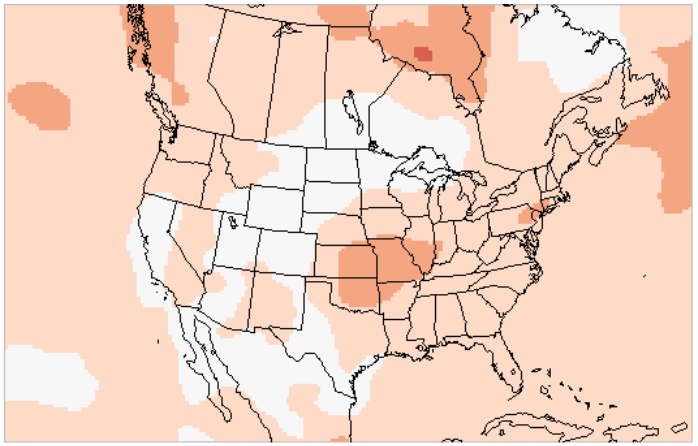
ModelE2-WRF has a slight cool bias compared to reanalysis.

Changes (2030–2000) in Mean 2-m Temperature: ModelE2 vs. WRF

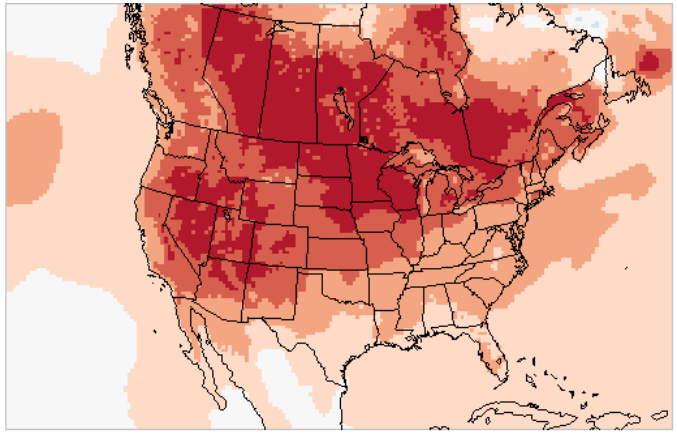
January: ModelE2



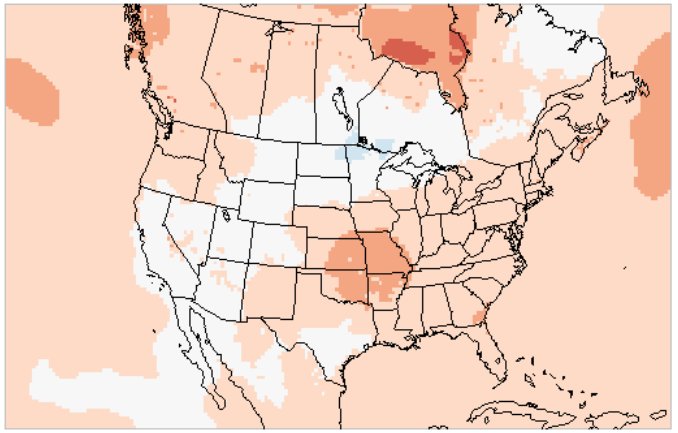
July: ModelE2

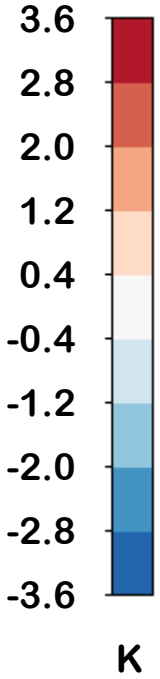


January: WRF



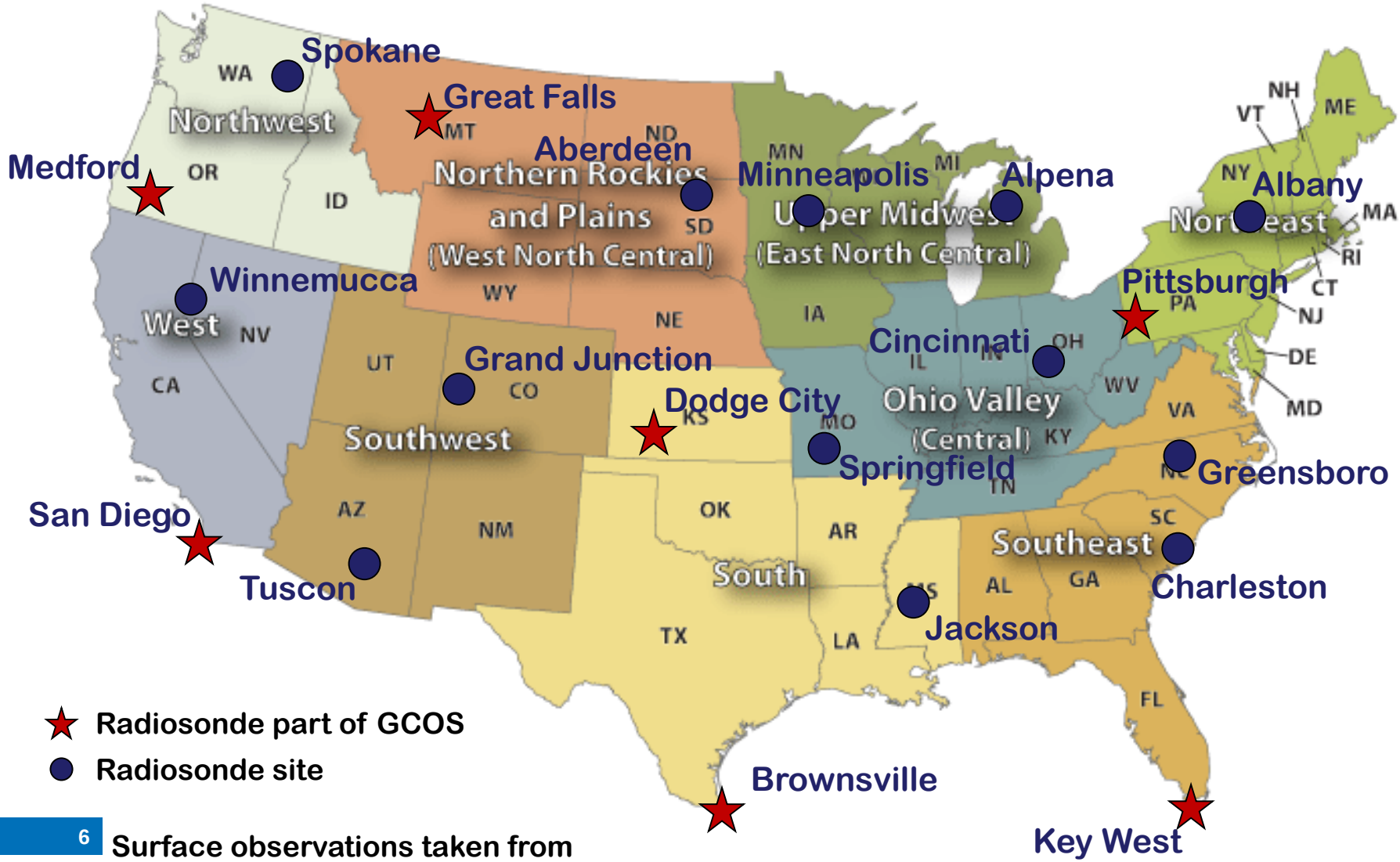
July: WRF





More pronounced warming in winter than summer. WRF generally more intense than ModelE2 with local differences.

U.S. Climate Regions with selected observation sites superimposed

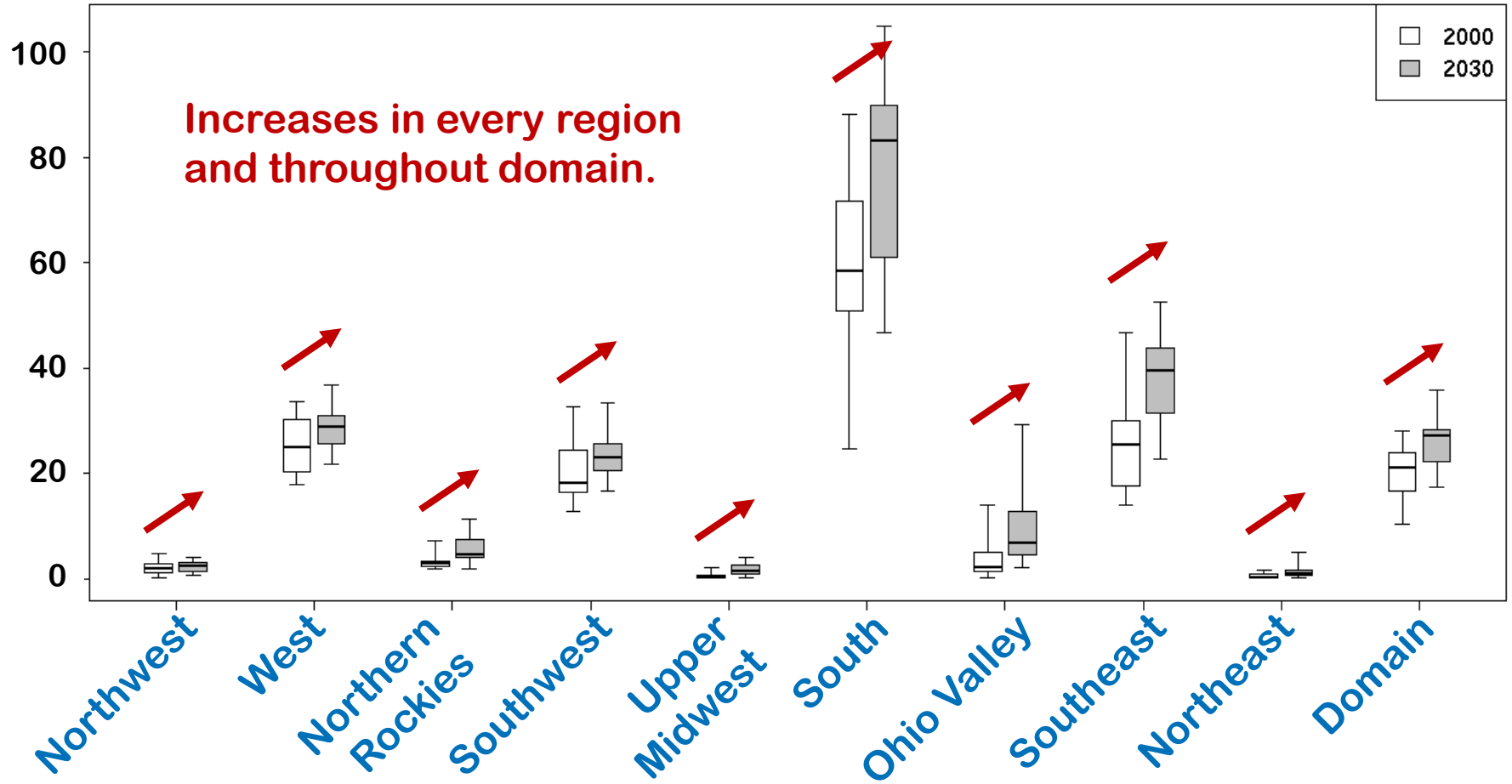


Surface observations taken from Global Historical Climatology Network

Map courtesy www.ncdc.noaa.gov

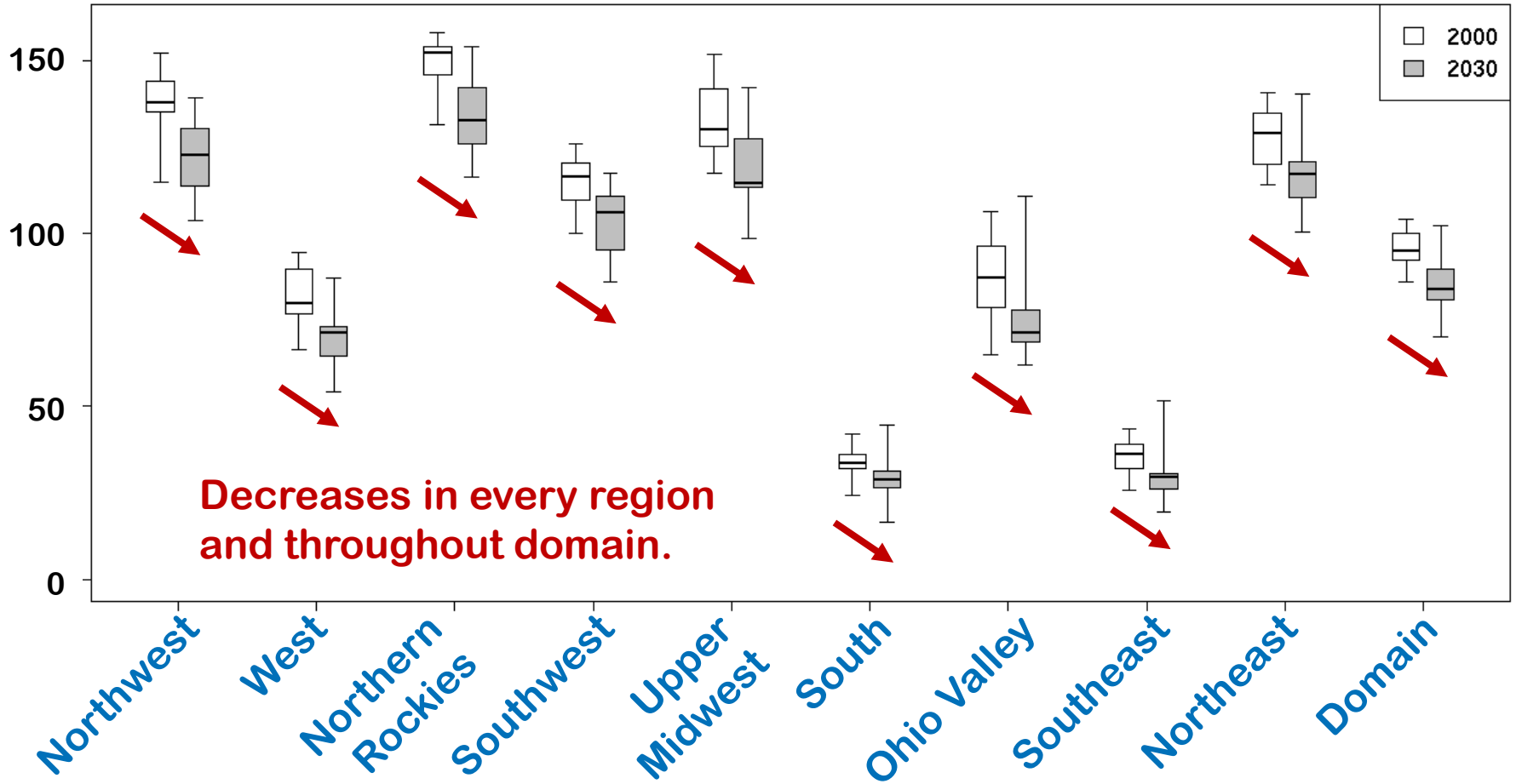
Change in Annual Number of "Hot Days" (>90° F)

→ *Comparison by NCDC Climate Region*

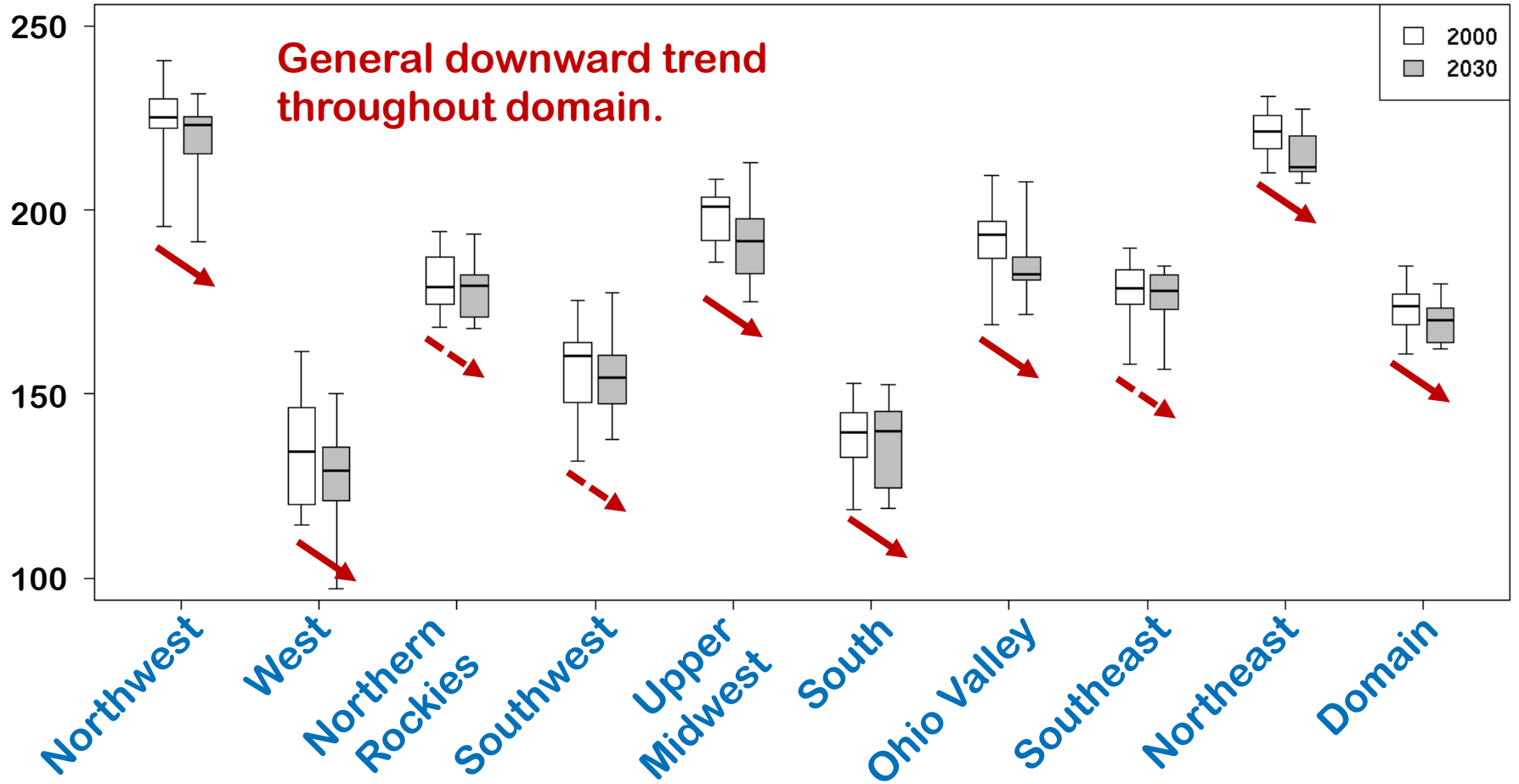


Change in Annual Number of "Freeze Days"

→ *Comparison by NCDC Climate Region*

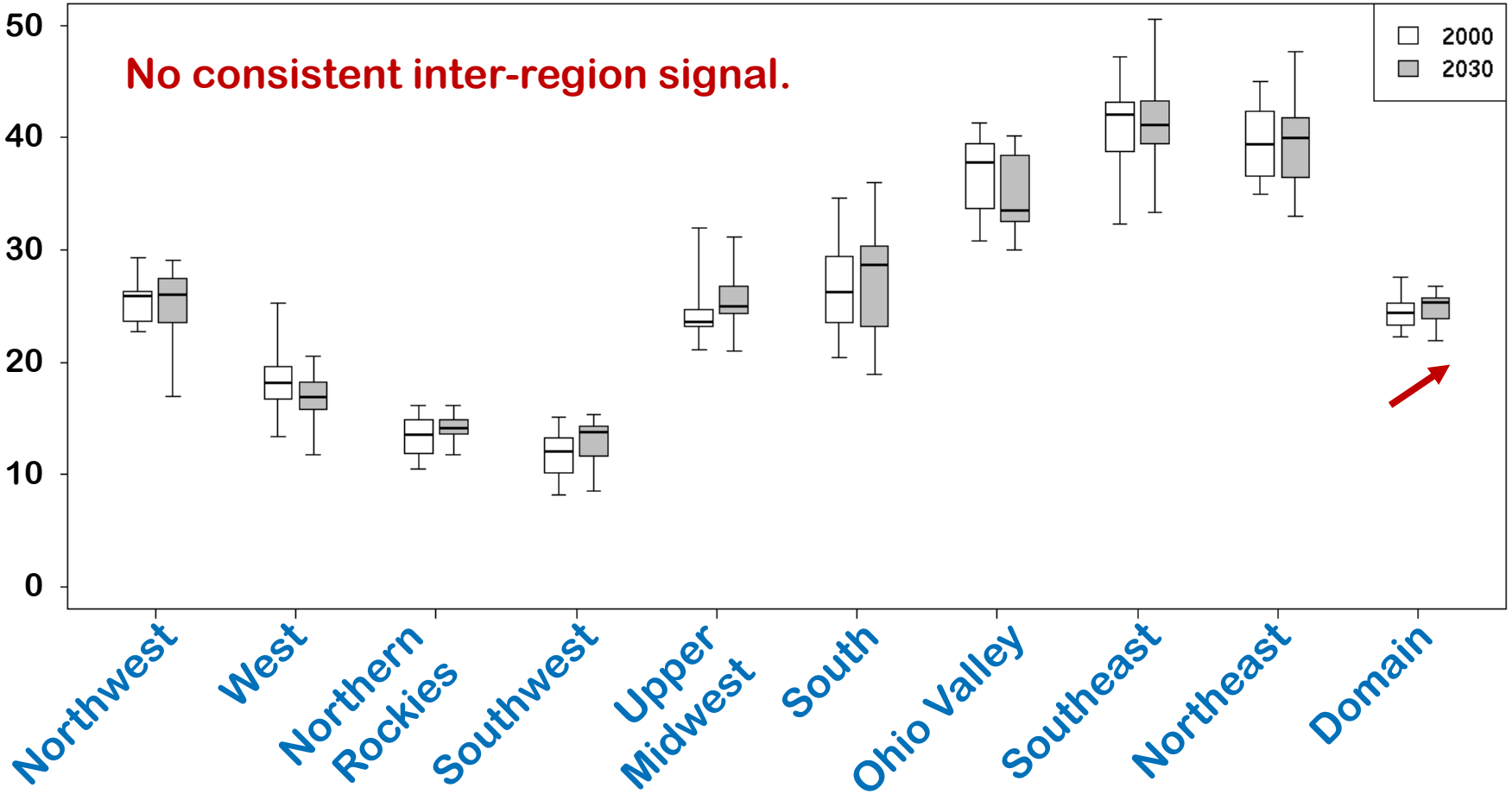


Change in Number of Days with Precipitation
→ *Comparison by NCDC Climate Region*



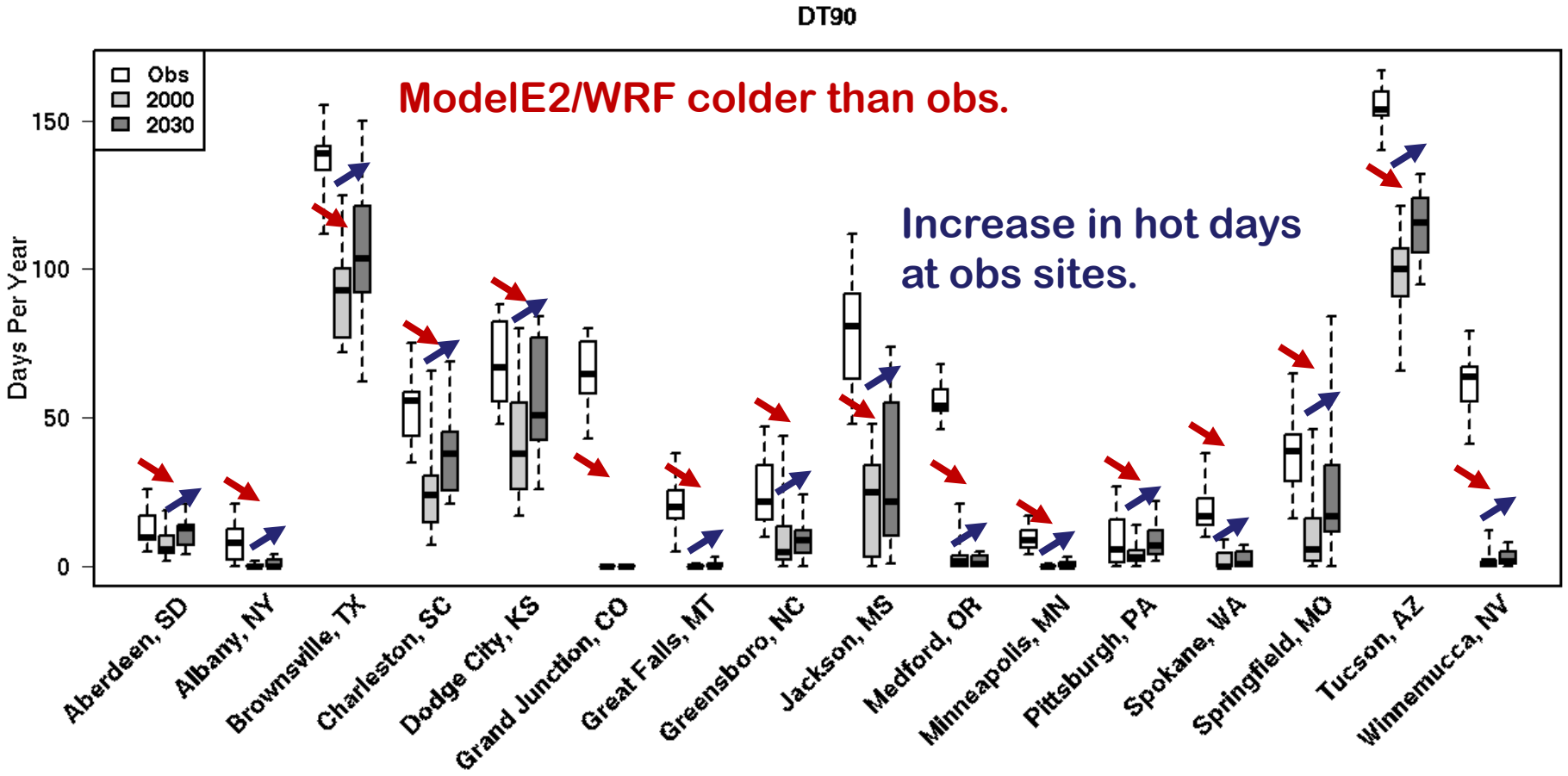
Change in Annual Number of Days with >0.5" Precipitation

→ *Comparison by NCDC Climate Region*



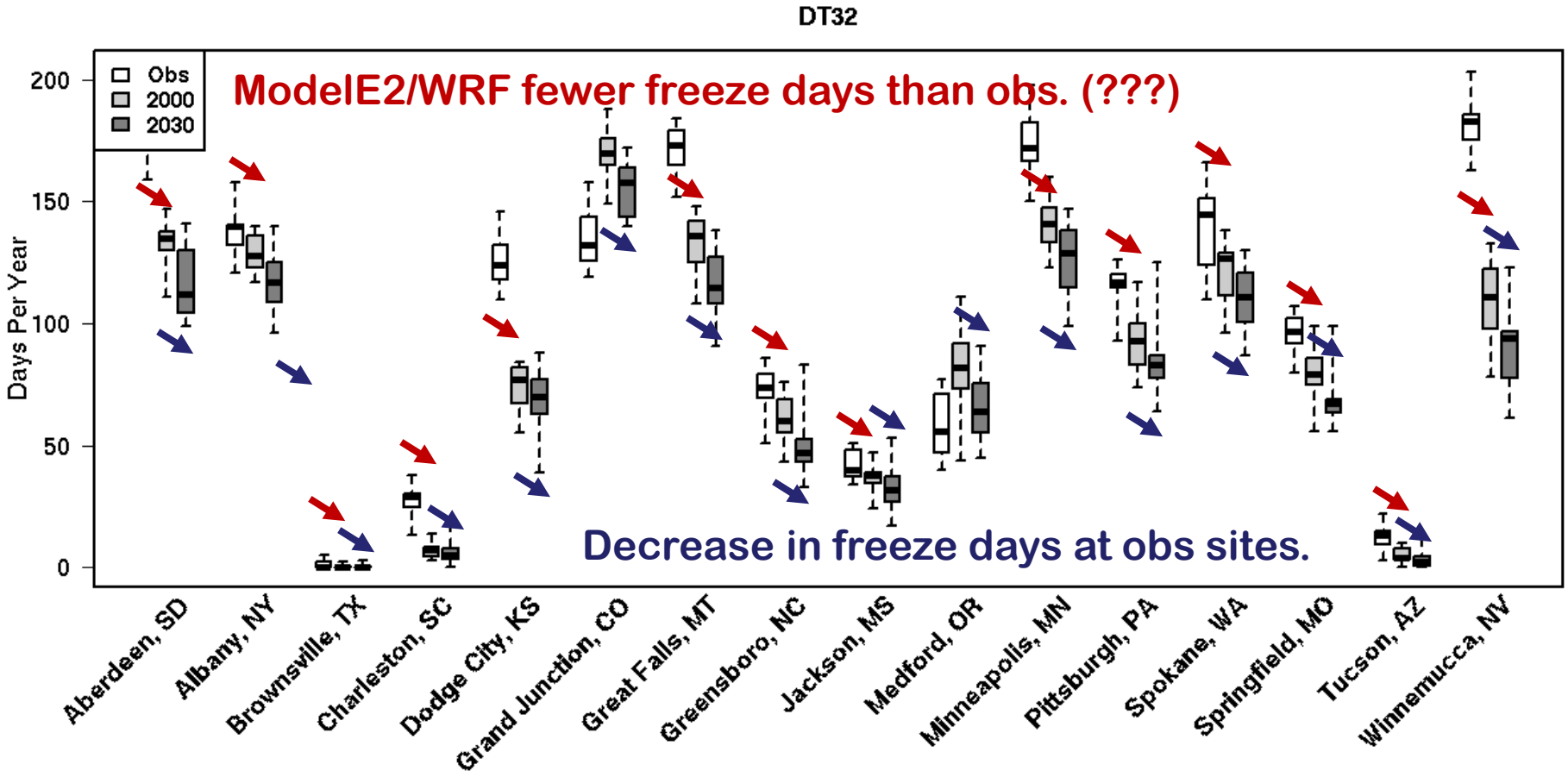
Change in Annual Number of "Hot Days" (>90° F)

→ *Comparison at Observation Sites*

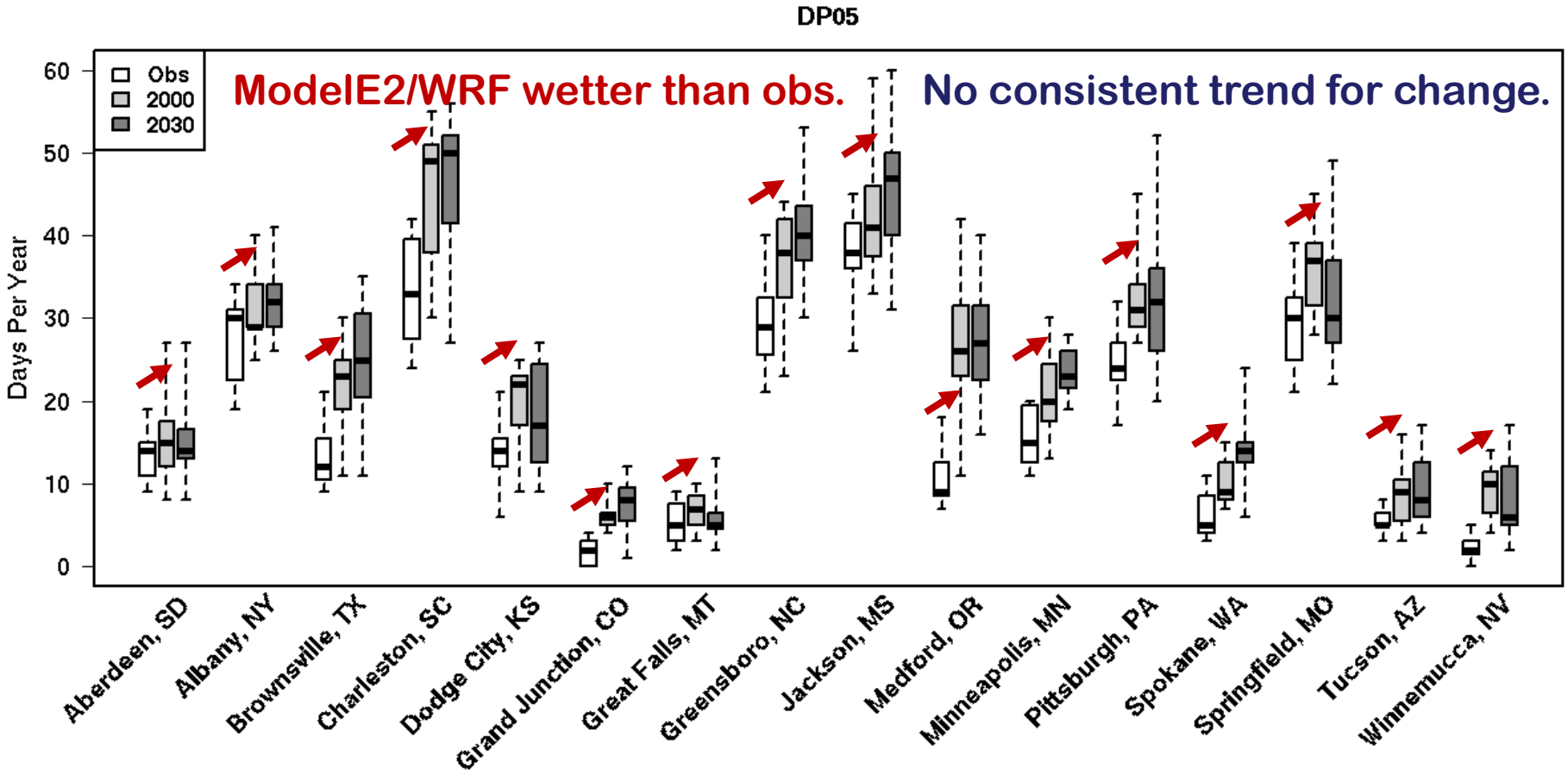


Change in Annual Number of "Freeze Days"

→ *Comparison at Observation Sites*



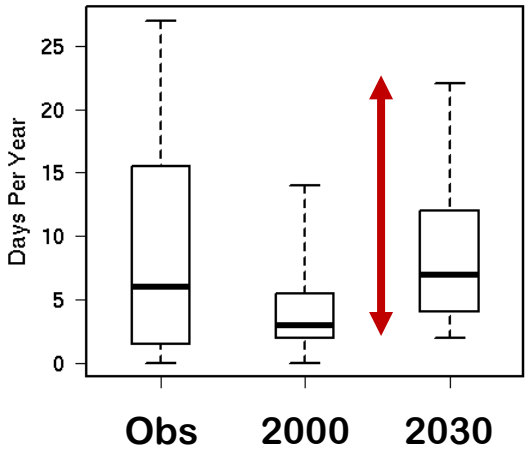
Change in Annual Number of Days with >0.5" Precipitation
→ *Comparison at Observation Sites*



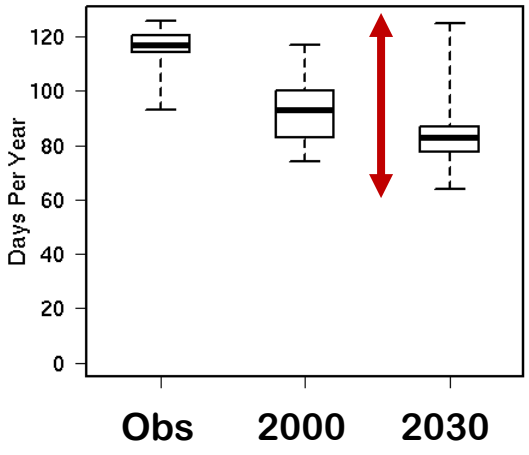
Comparison at GCOS Site: Pittsburgh, PA

More inter-annual variability in hot, cold, and wet days.

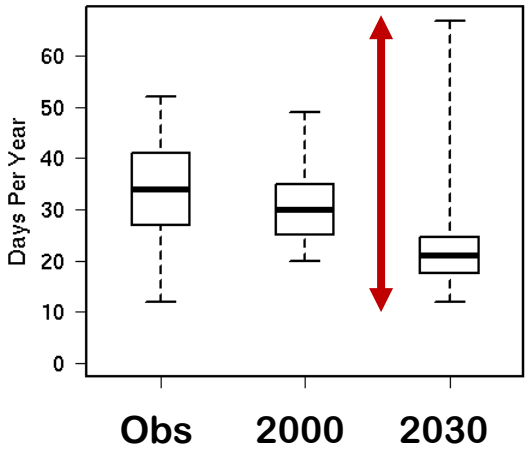
Temp > 90° F



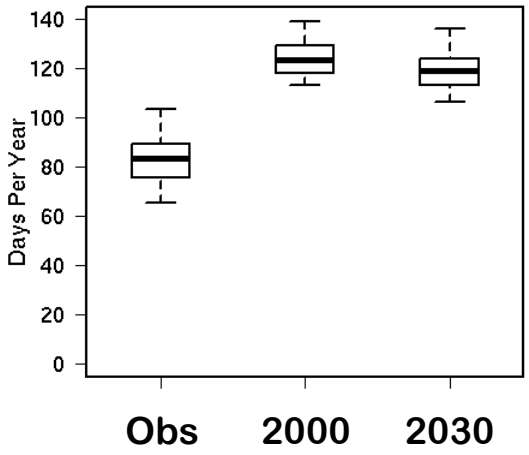
Temp < 32° F



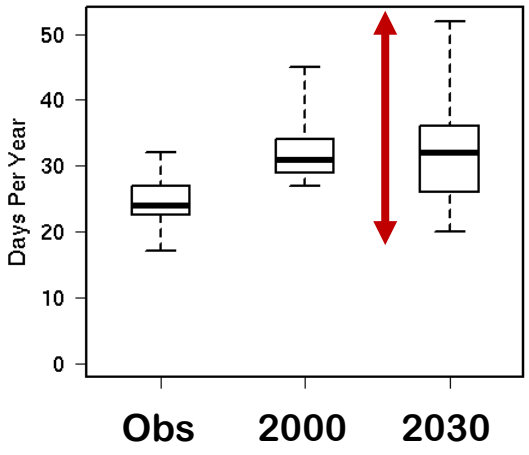
Max Temp < 32° F



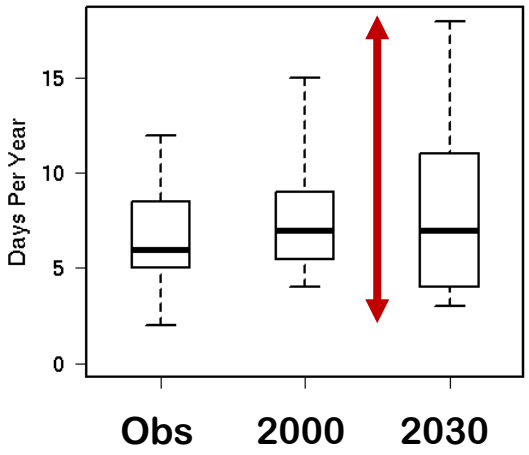
Precip > 0.1”



Precip > 0.5”



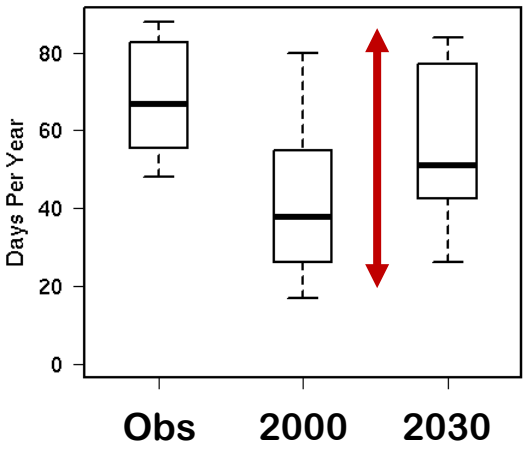
Precip > 1.0”



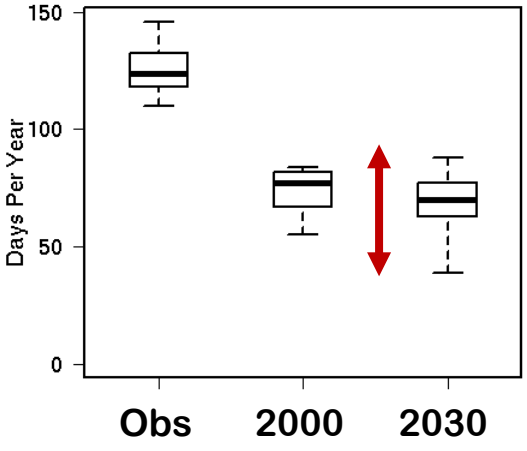
Comparison at GCOS Site: Dodge City, KS

More inter-annual variability in hot, cold, and wet days.

Temp > 90° F



Temp < 32° F



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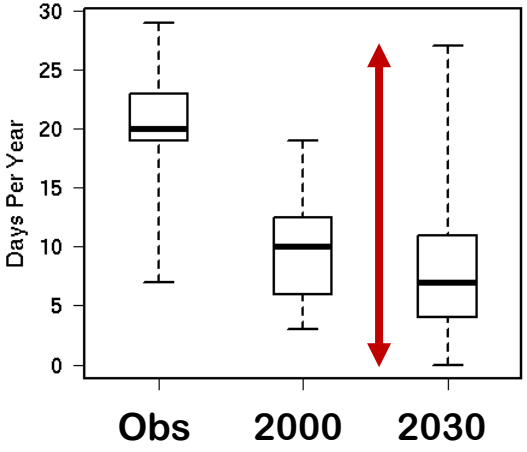
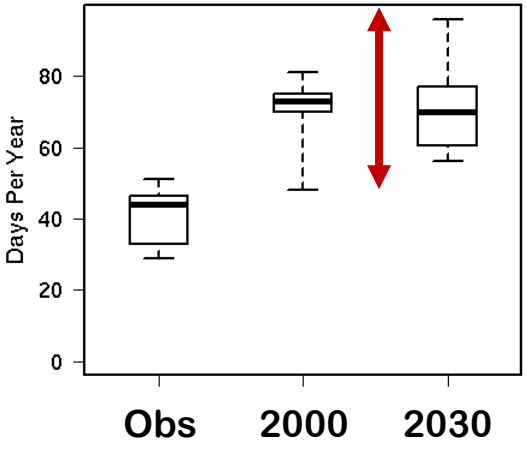
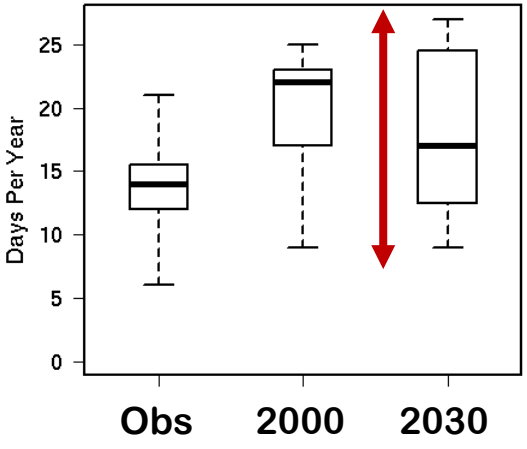


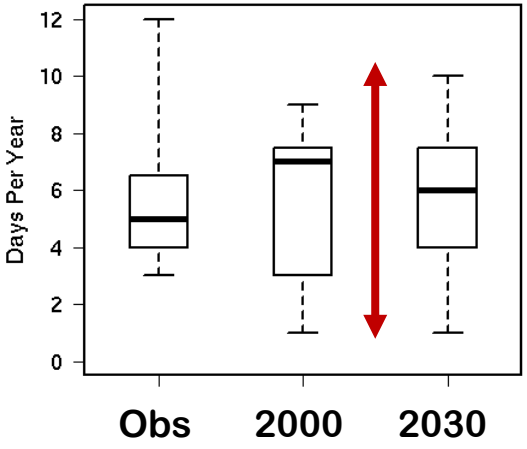
Precip > 0.1”



Precip > 0.5”

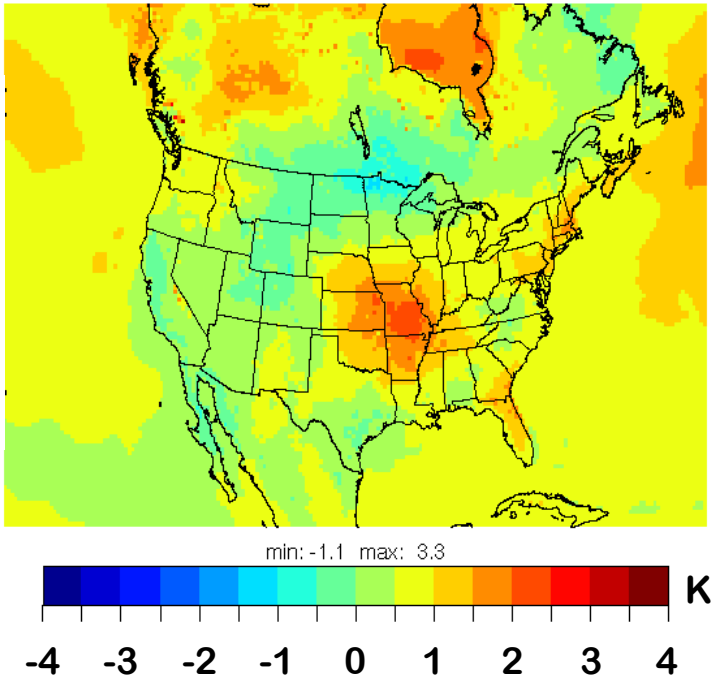


Precip > 1.0”

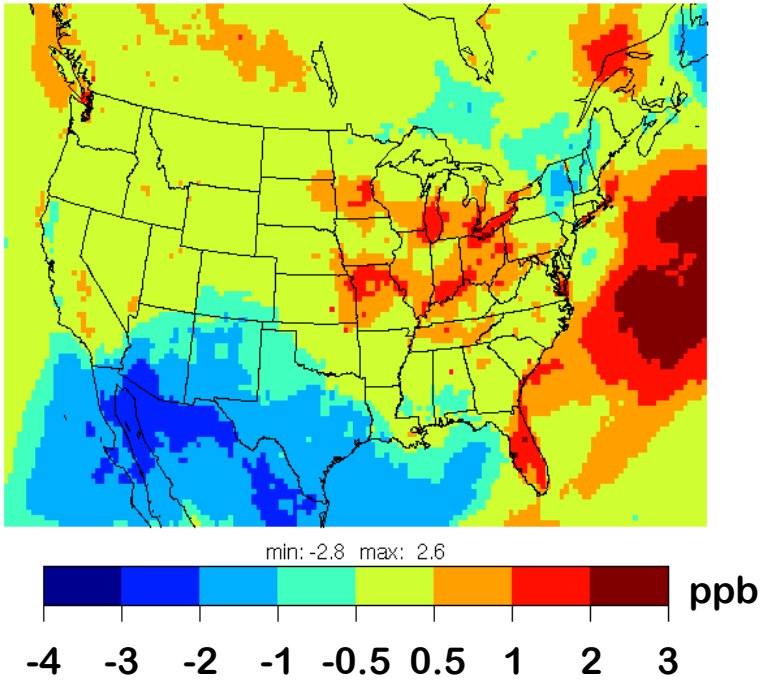


Changes in Air Quality under Future Climate with Constant Anthropogenic Emissions

July: Change in Daily Max 2-m Temperature

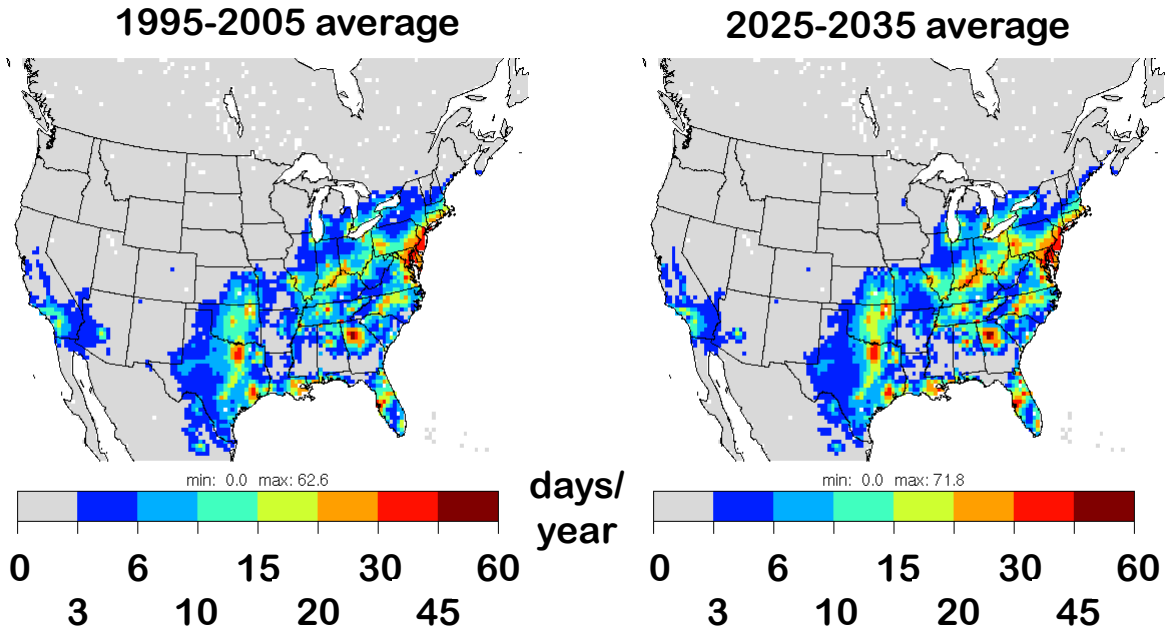


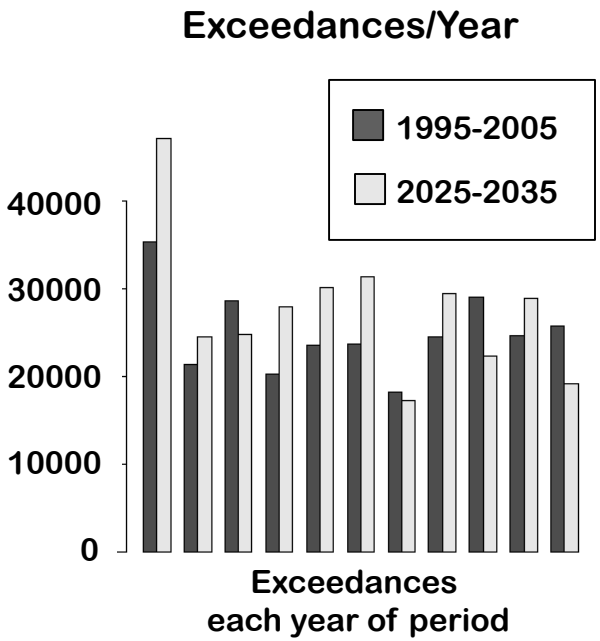
JJA: Change in Max Daily 8-h O_3



Increases of 0.5–2 ppb daily 8-hourly maximum O_3, largely consistent with area of warming of 0.5–2 K in central/eastern U.S.

AQ–CC: Annual Frequency of Exceeding 75 ppb MDA8





Small (statistically insignificant, p=0.4) increase in frequency of exceeding 75 ppb threshold

Preliminary Conclusions for Downscaled Climate Change Using ModelE2 (RCP 6.0) and WRF for 2000 to 2030

- Downscaled ModelE2-WRF has cool bias for "2000" compared to reanalysis and observations over comparable 11-year period.
- RCP6.0: Warming projected for most of U.S. for 2000–2030.
  - Fewer freeze days, more "hot days"
- Fewer days of precipitation throughout U.S.
- Inconsistent change nationwide in extreme precipitation events.
- Some sites suggest more inter-annual variability in extreme events.
- Small increase in days >75 ppb O_3 NAAQS due to climate change
- *This is only one instantiation of projected regional climate change.*