Monitoring the Planet's Climate

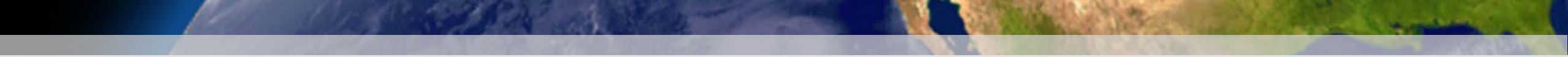
Deke Arndt

Chief, Climate Monitoring Branch,
NOAA's National Centers for Environmental Information

12 October 2016

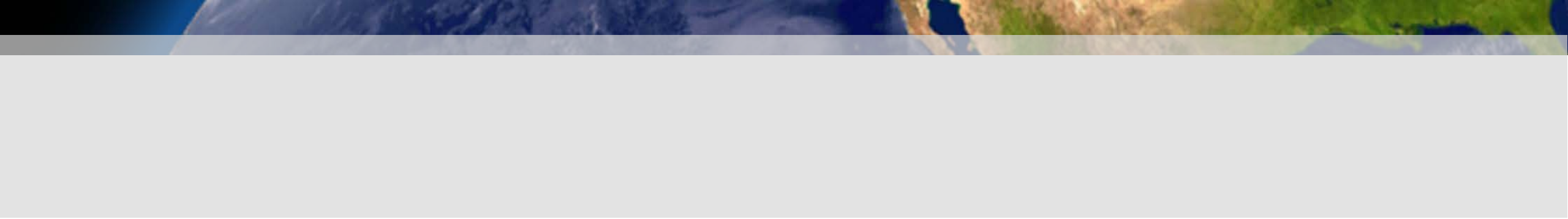
Nat'l Centers for Environmental Information (NCEI) - Asheville

- Asheville, NC (and points beyond!) since early 1950s
- Climate Monitoring Branch established 1998
  - Mission: "monitor and assess the state of the climate"
  - We deal in data – the *observed* climate.
  - This complements, informs and draws from larger climate science (the *understood* climate)



Briefly …

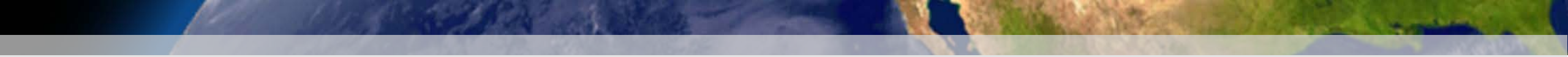
- Hello from the Climate Monitoring Branch
- Some Climate Monitoring and Prediction Tools
- Where does that stuff come from?



Hello from the Climate Monitoring Branch

NCEI Monitoring Branch & US Drought Portal

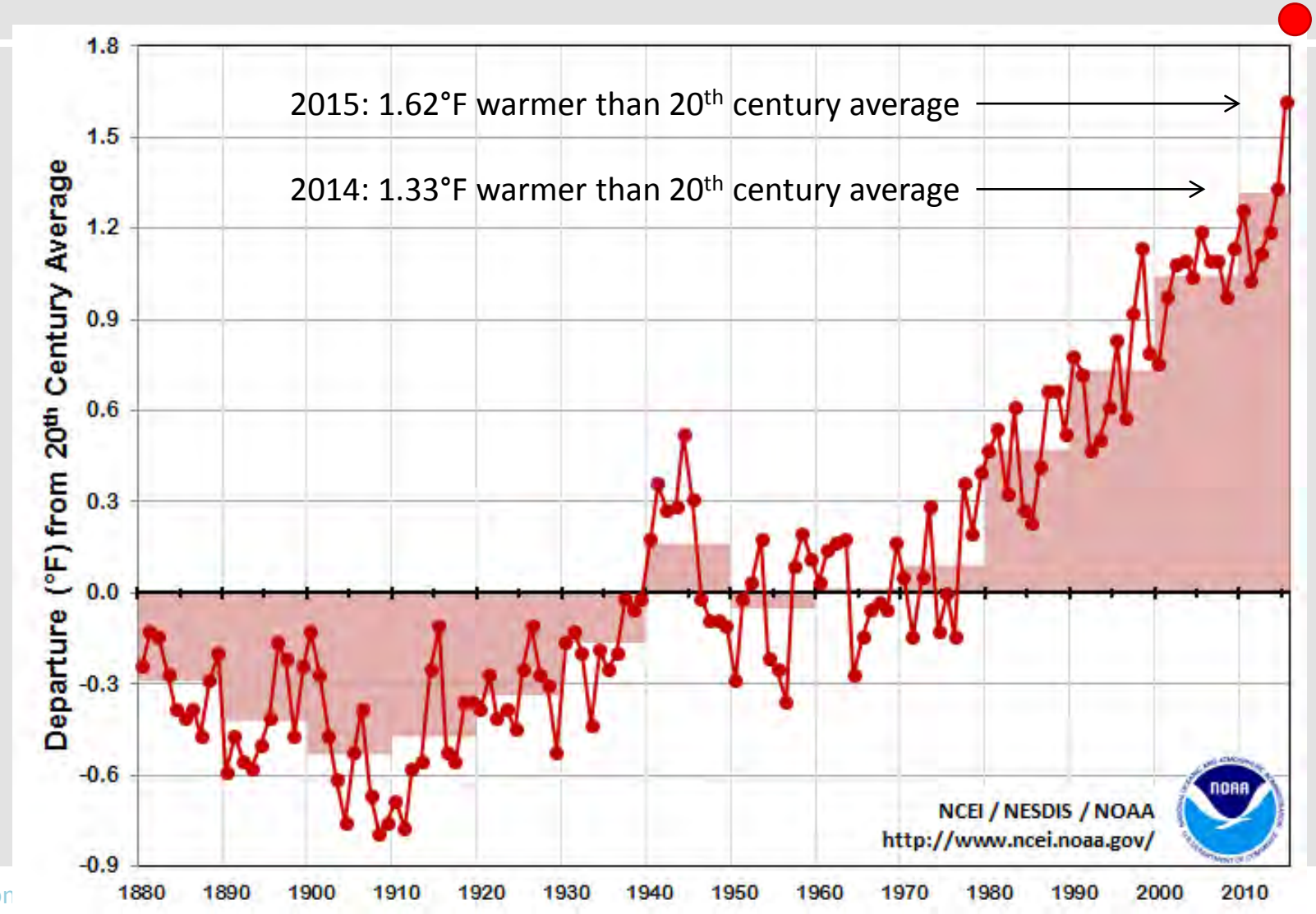
http://www.ncdc.noaa.gov/climate-monitoring and http://www.drought.gov



Around the world, in ~~80 days~~ eight slides

Globally: Surface Temperature

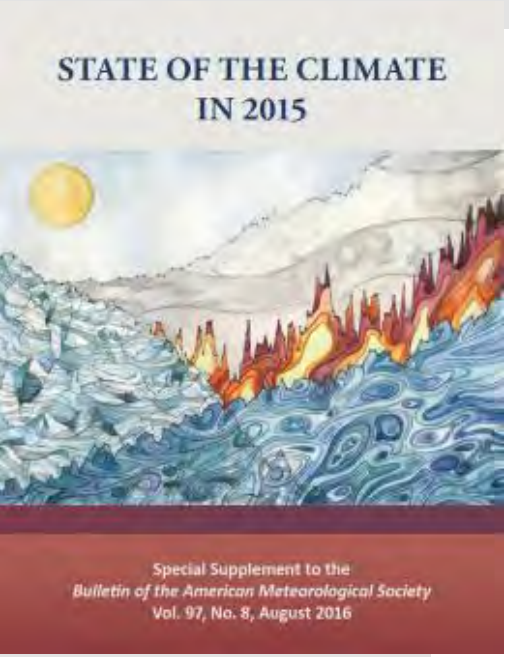
http://www.ncdc.noaa.gov/sotc/global & https://www.ncdc.noaa.gov/cag/time-series/global

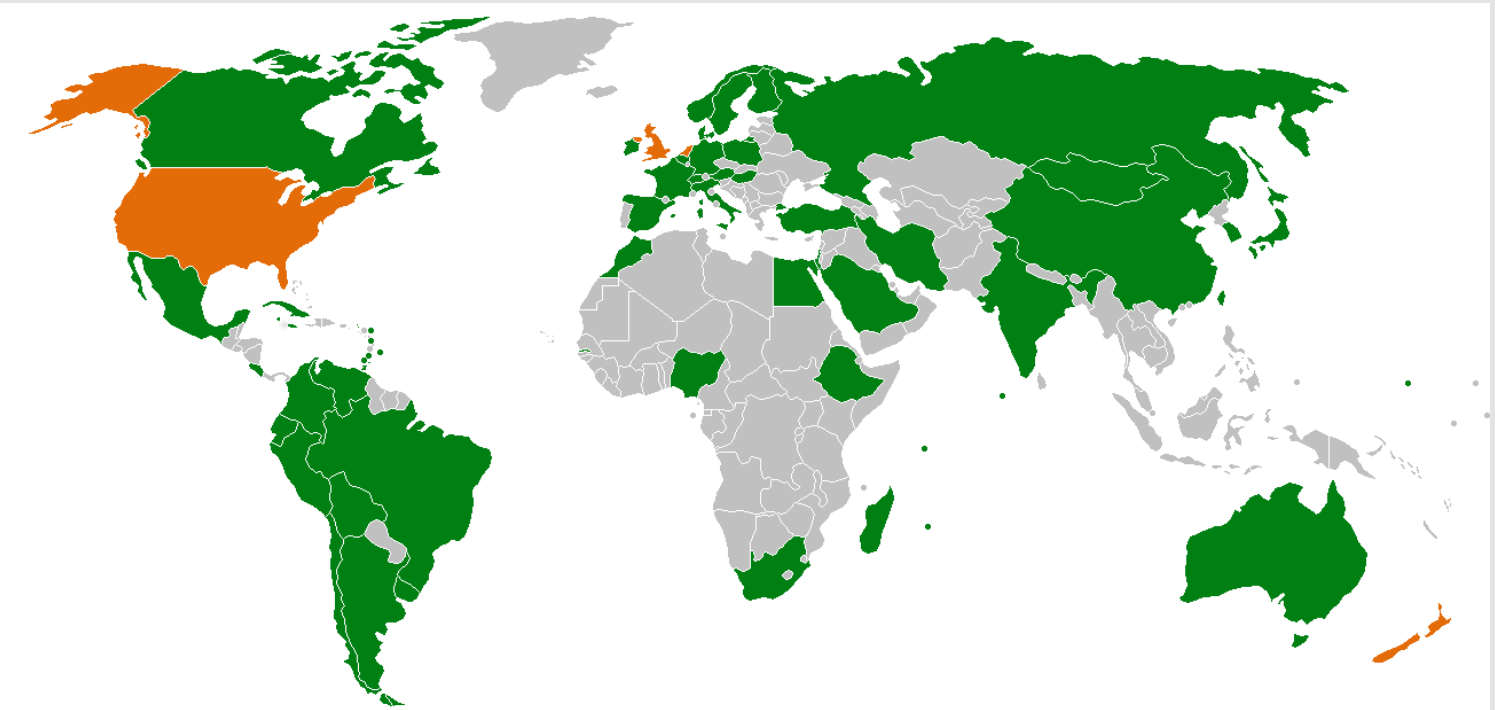


2016 so far
+1.85°F

State of the Climate in 2015

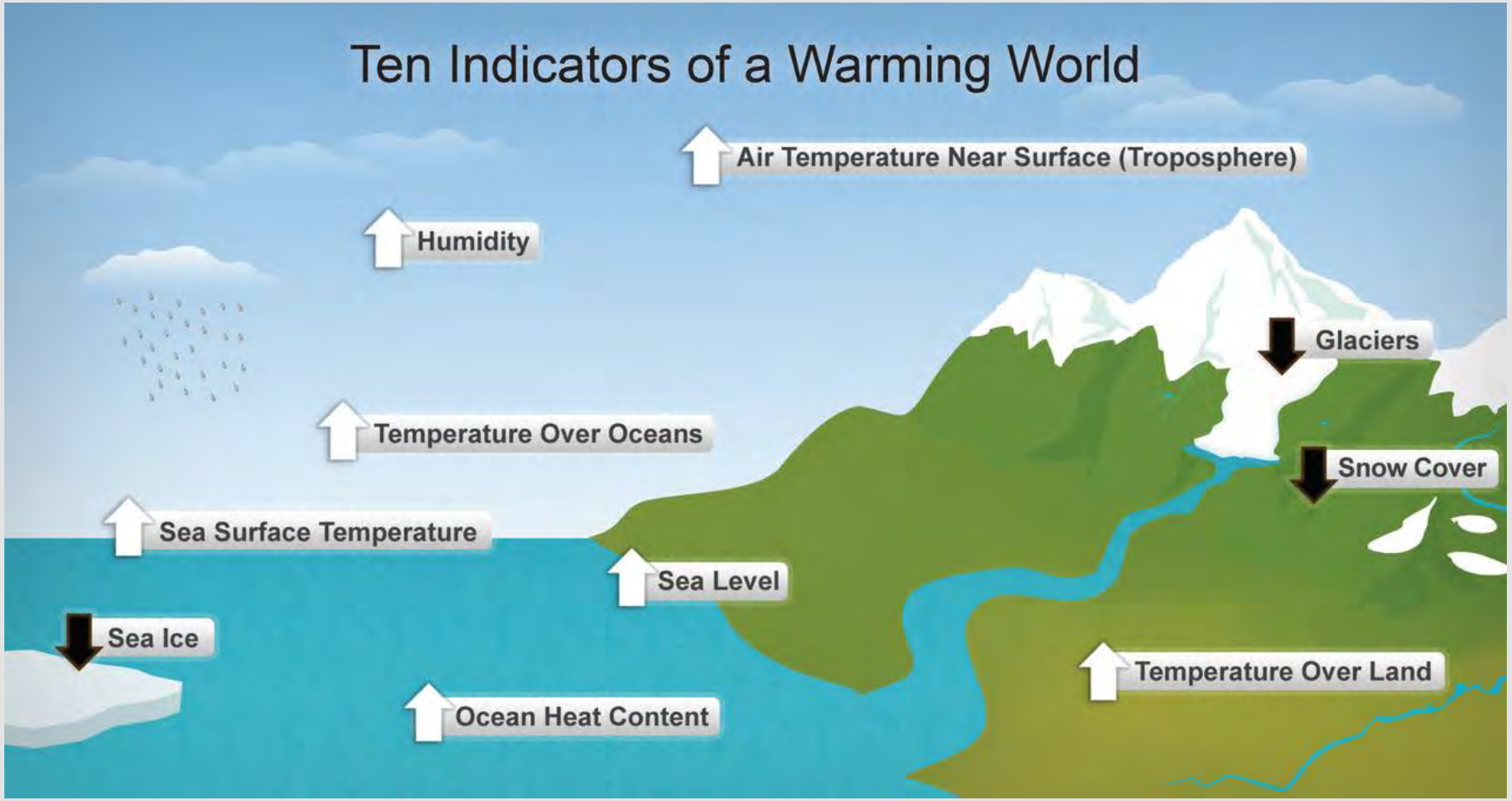
http://www.ncdc.noaa.gov/bams

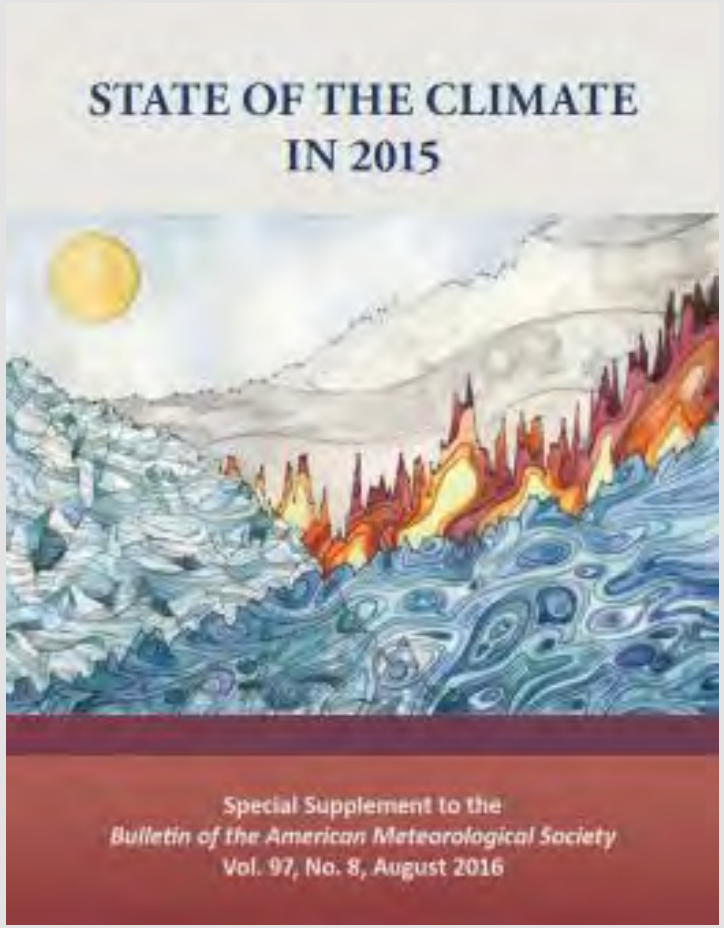




456 authors from 62 countries; 17 editors on 3 continents

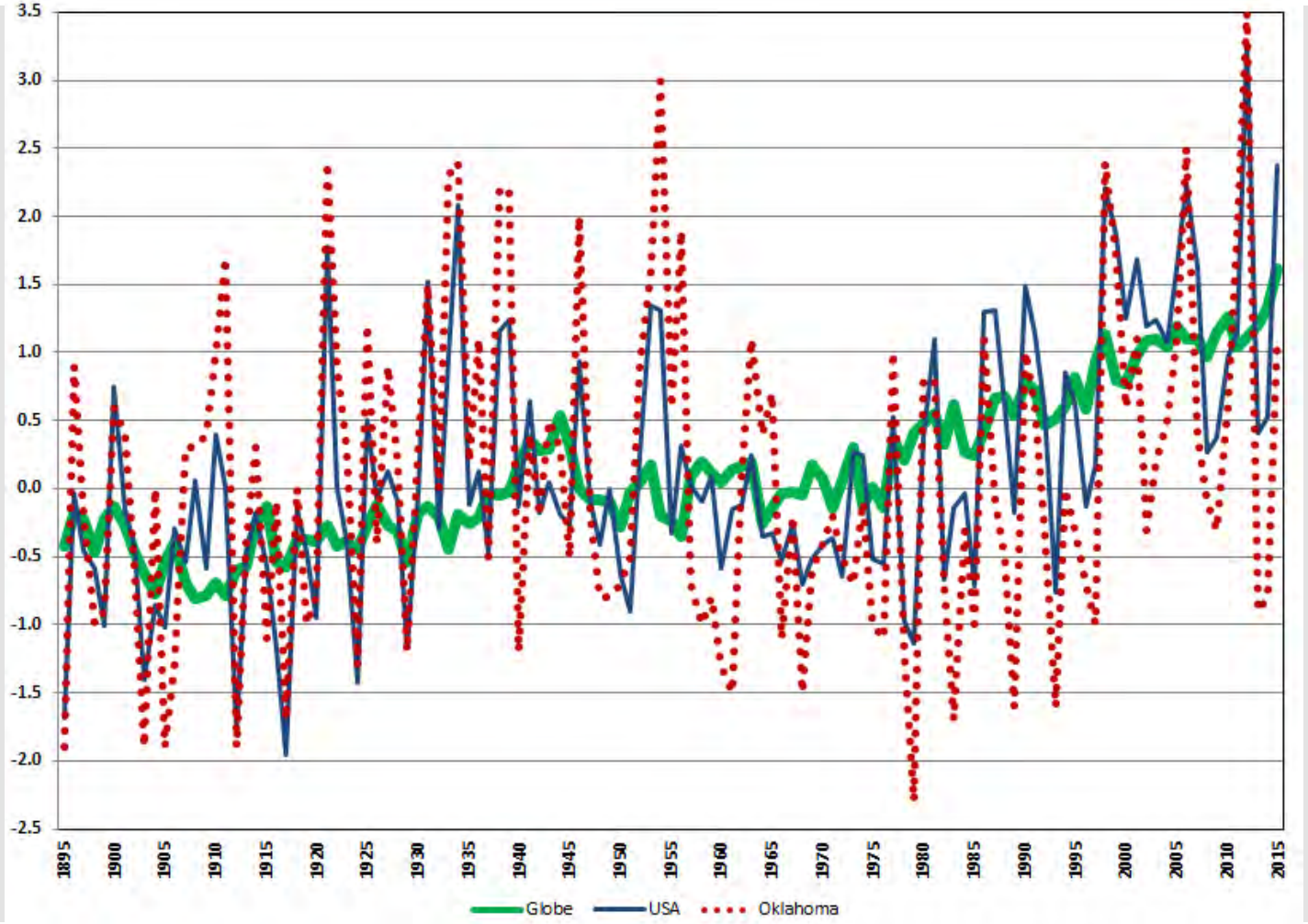
State of the Climate in 2015





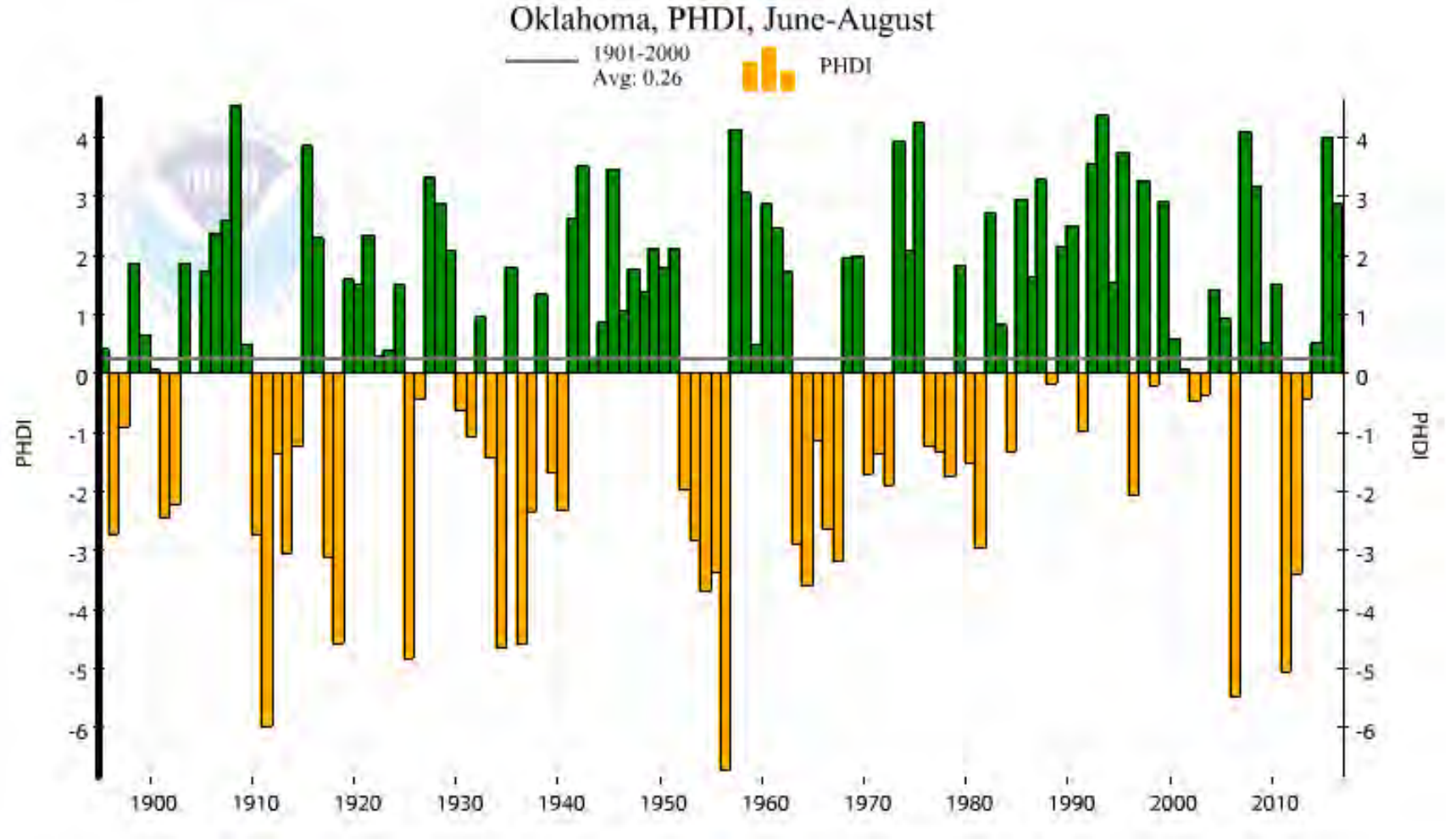
Variability Increases with Local Focus

Temperatures since 1895: Globe, USA, Oklahoma



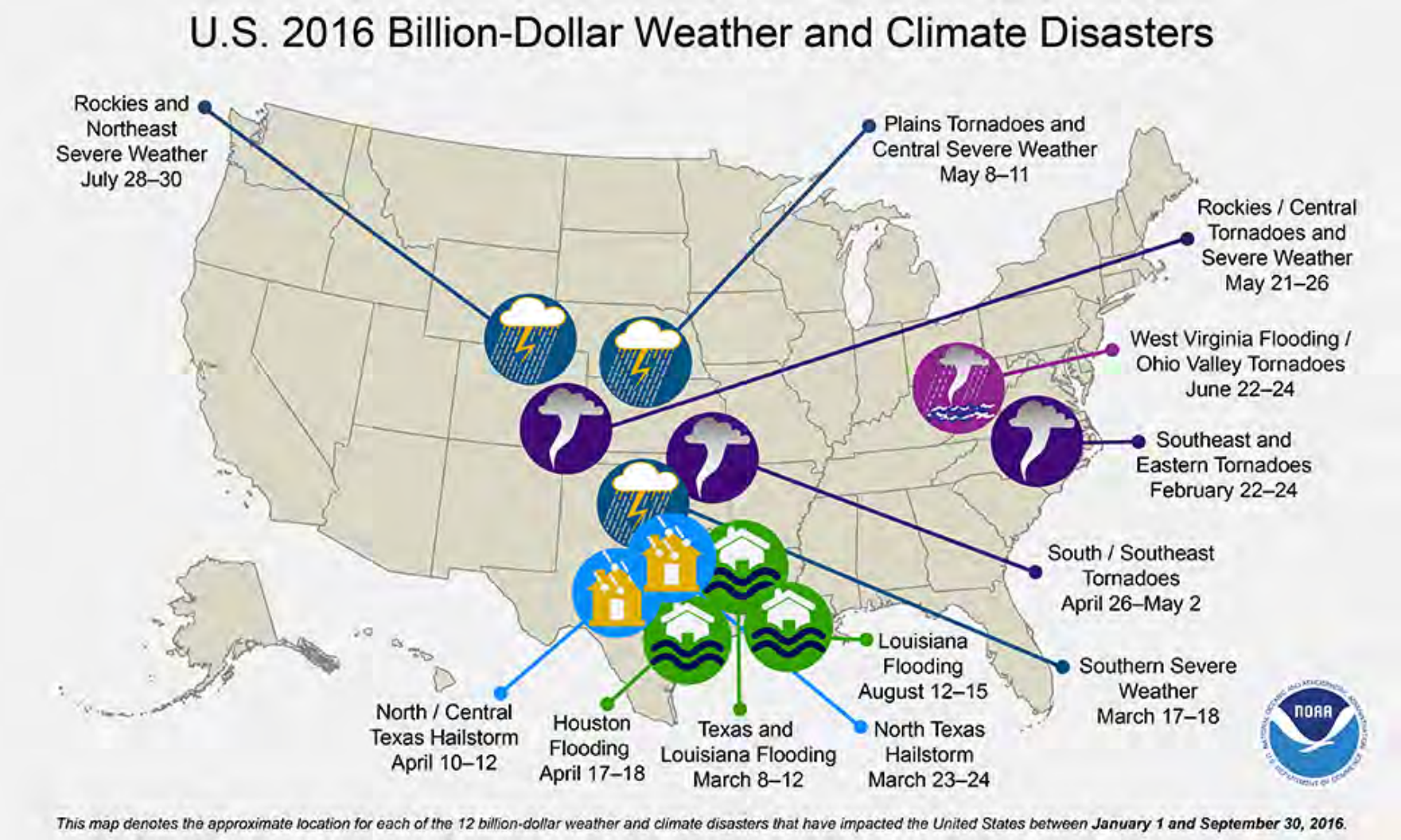
Climate at a Glance: https://www.ncdc.noaa.gov/cag

Summer Drought



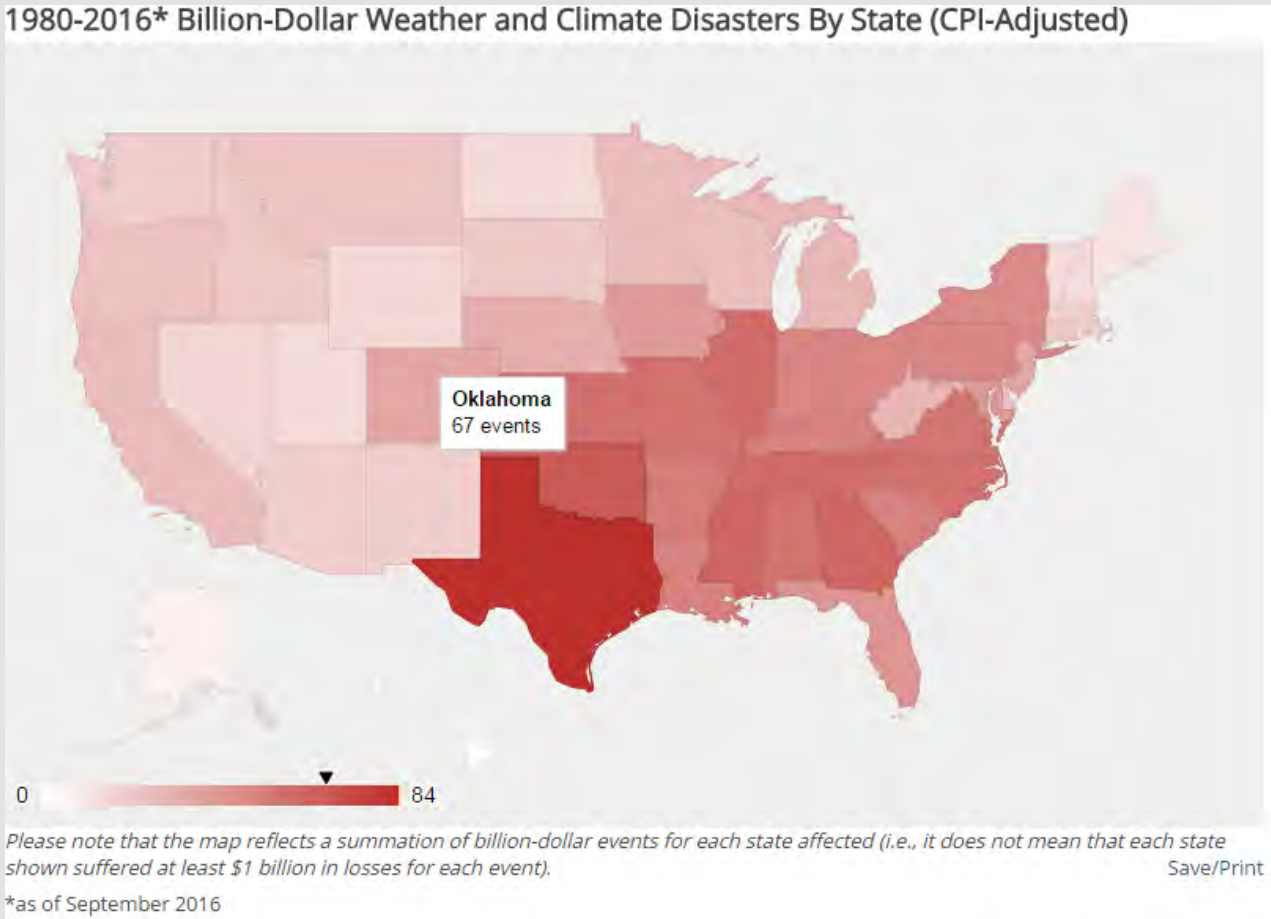
Climate at a Glance: https://www.ncdc.noaa.gov/cag

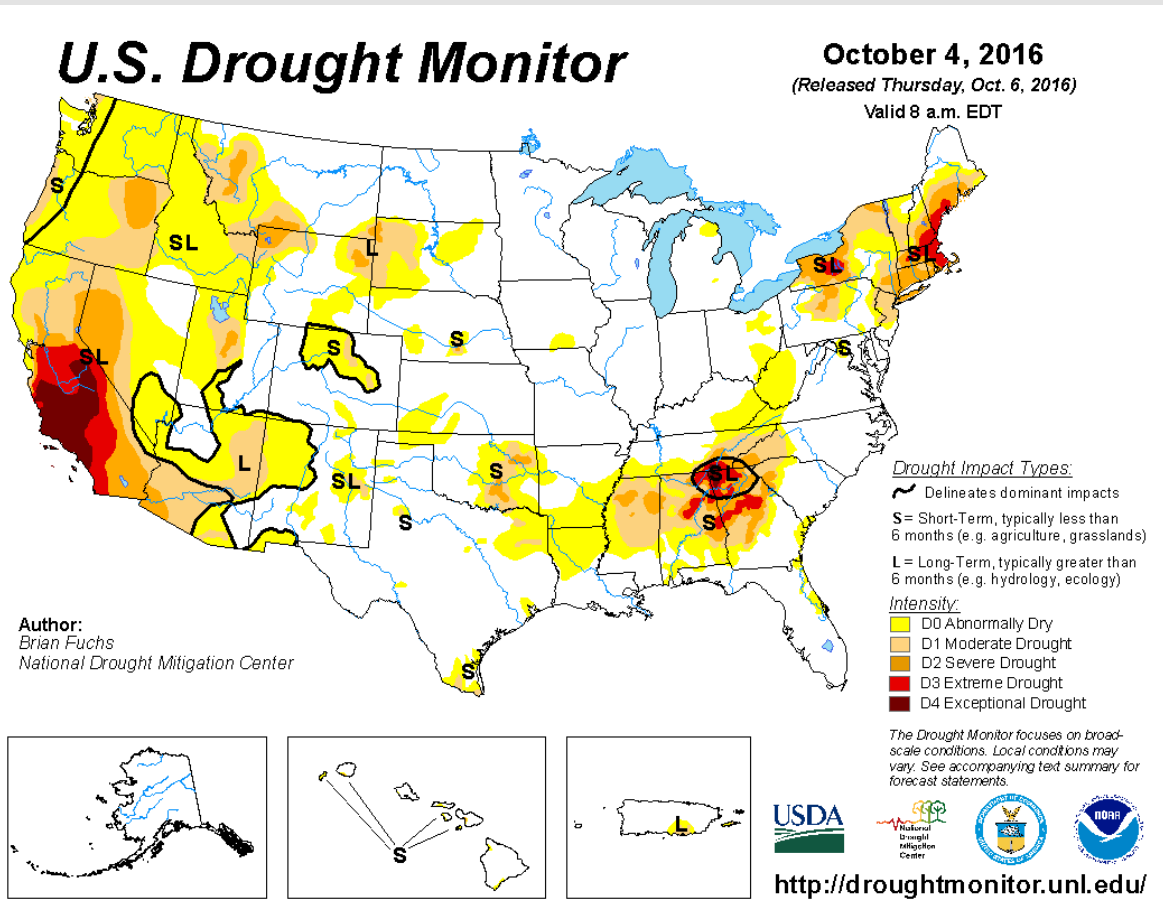
Billion Dollar Disasters



Billion Dollar Disasters: https://www.ncdc.noaa.gov/billions

Big Events Matter

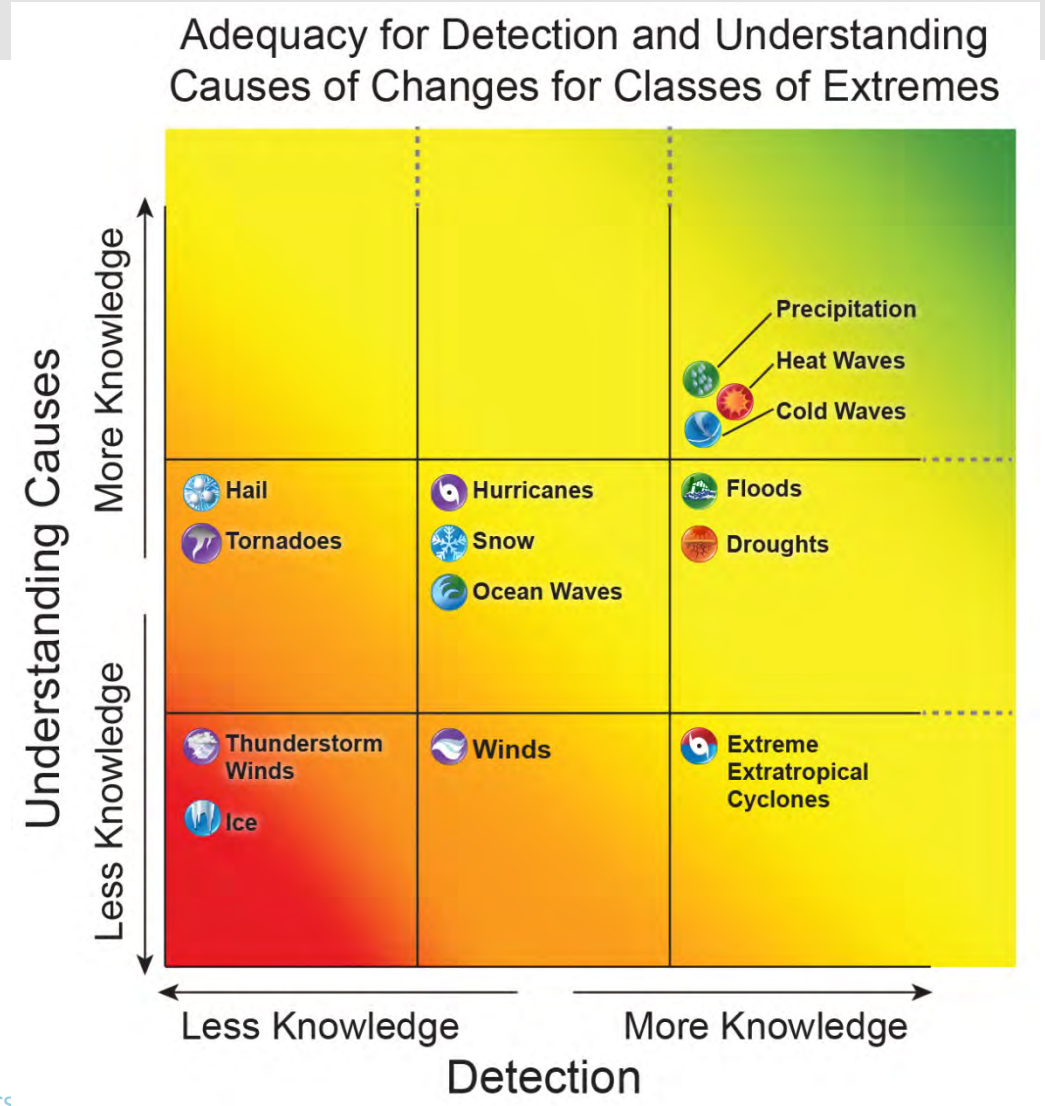




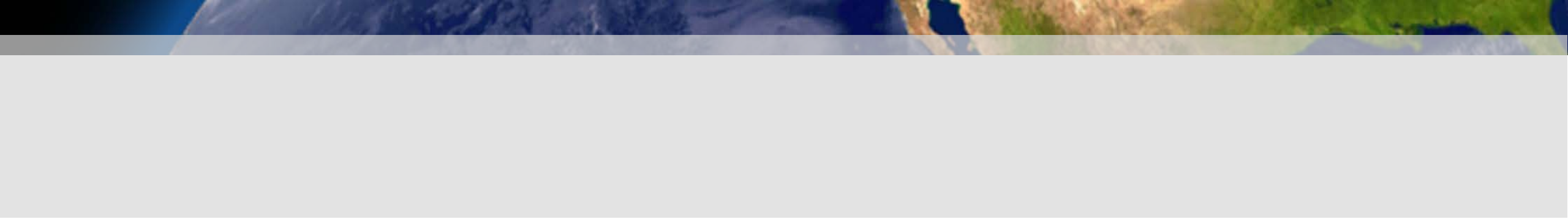
Relationship between weather & climate

Literature Review: Stallone et al. (1976)

Extreme Weather & Climate series: *BAMS*



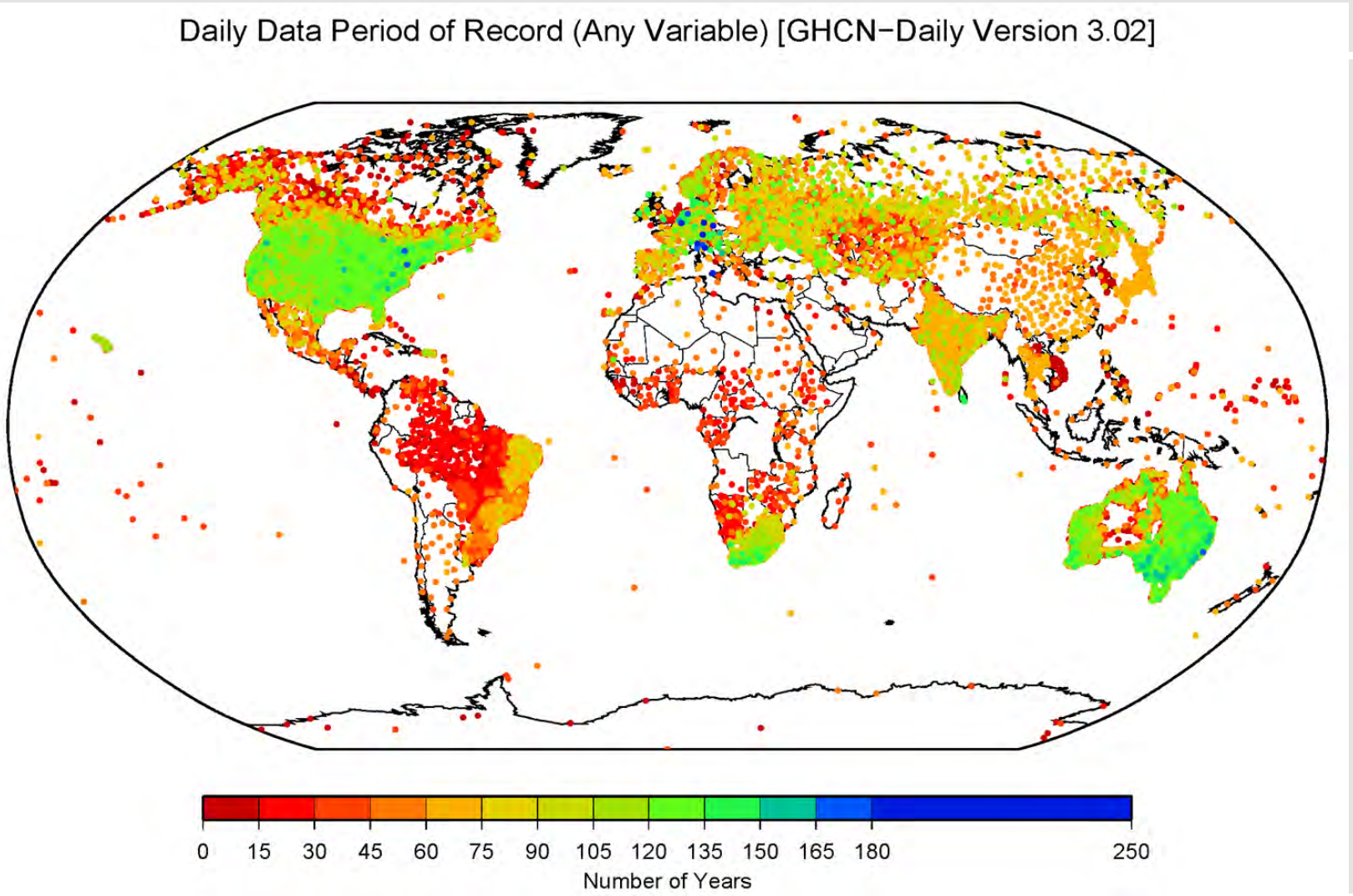
- "Monitoring & Understanding Change …" State of knowledge series (*BAMS,* 2013 & 14)
  - … in extreme storm statistics. Kunkel, et al. **94**(4), 499-514.
    - http://journals.ametsoc.org/doi/full/10.1175/BAMS-D-11-00262.1
  - … in heat waves, cold waves, floods and droughts in the US. Peterson, et al. **94**(6), 821-834.
    - http://journals.ametsoc.org/doi/full/10.1175/BAMS-D-12-00066.1
  - … in extreme winds, waves, and extratropical storms. Vose, et al. **95**(3), 377-386.
    - http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-12-00162.1
  - … in CMIP5 Climate Model Analyses. Wuebbles, et. al., **95**(4), 571-583.
    - http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-12-00172.1



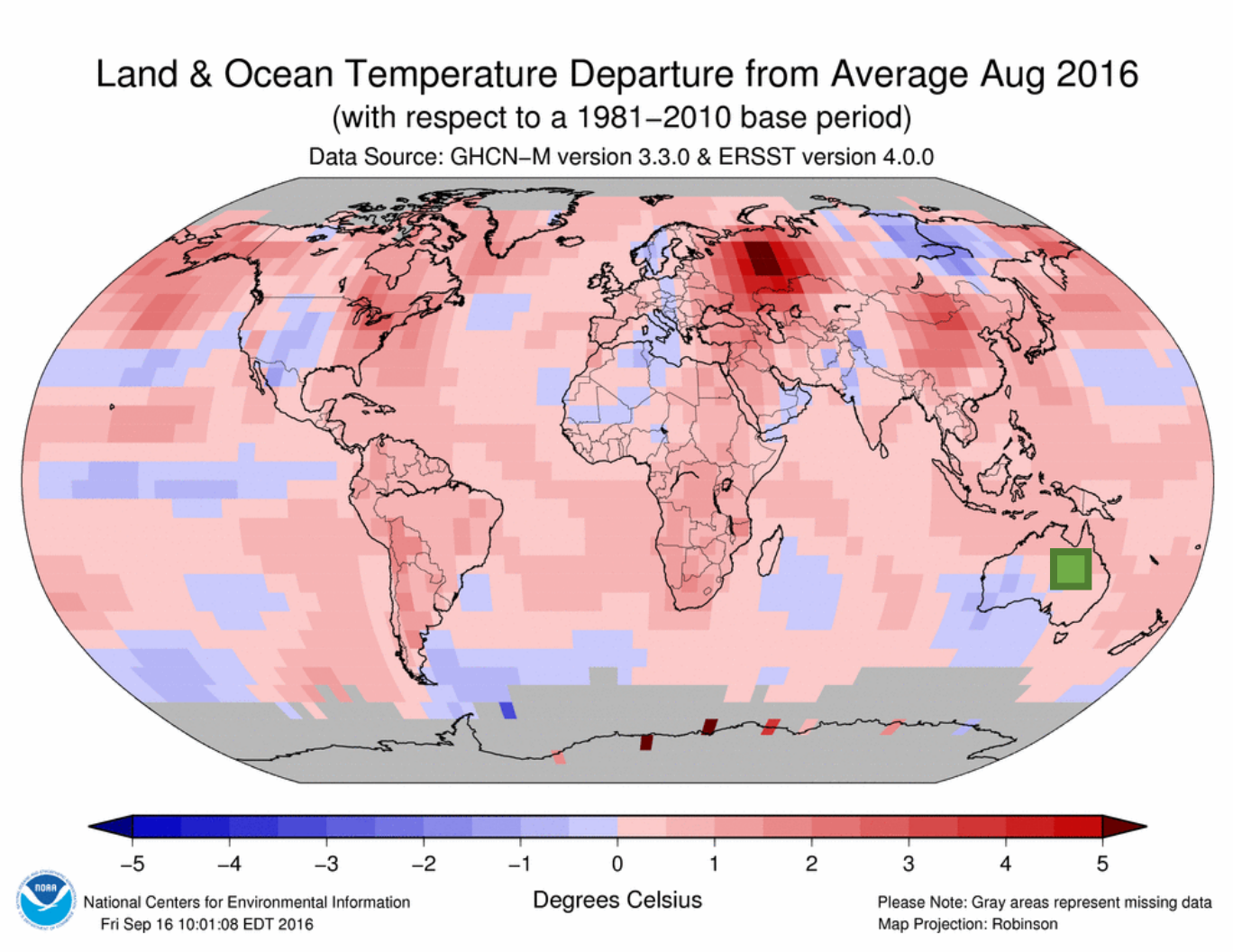
Where does that stuff come from?

Where does that come from?

Where do the observations come from?



Globe derived from Grid boxes



Grid box derived from stations, buoys, ships

X Normal monthly average temperature at station "X"

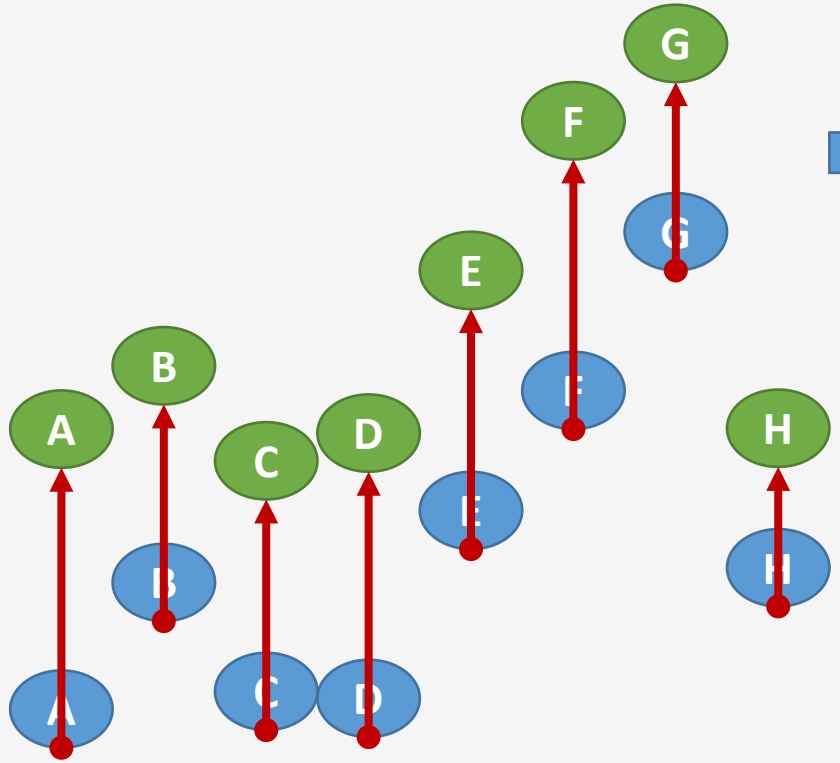
X Observed monthly average temperature at station "X"

"Anomaly"
(departure from normal)

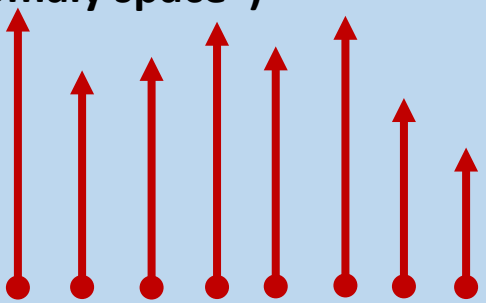
Step 1: Compute Station anomalies

Warmer →

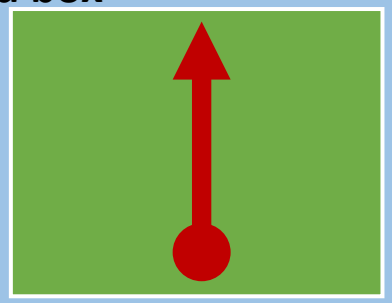
← Cooler

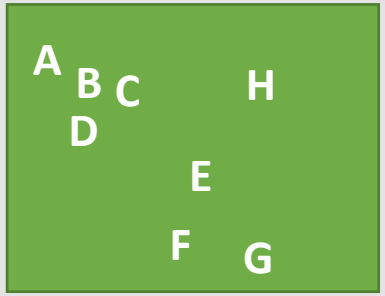


Step 2: Keep anomalies; scrap obs (work in "anomaly space")

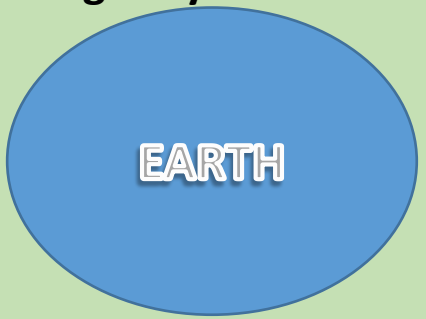


Step 3: Compute avg anomaly for grid box





Step 4: Average grid boxes. Weight by latitude

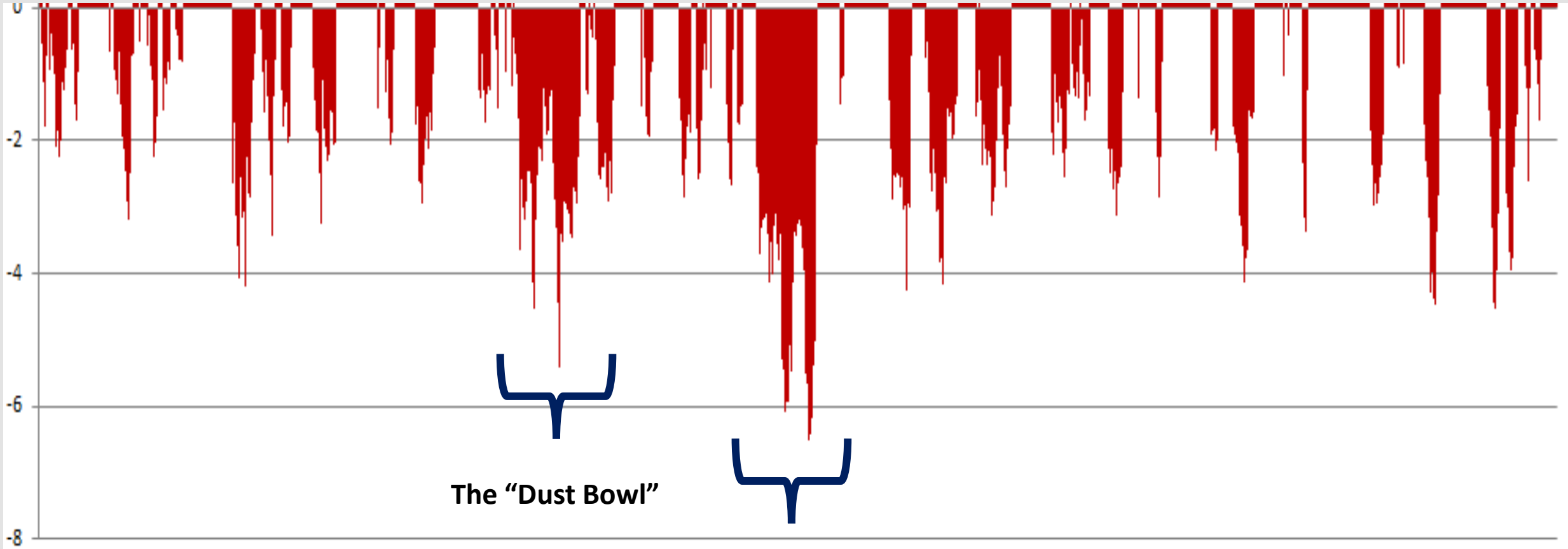


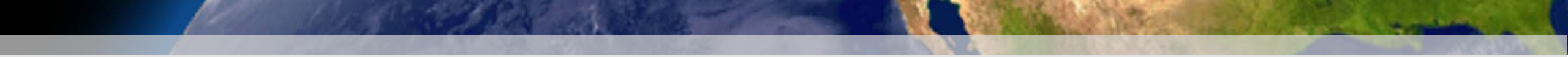
It's more complicated than that …

- Ships and (most) buoys move; weather stations and (some) buoys don't
- Account for changes in station distribution/location and station environment by quantifying changes in relationship with neighbors
- Some grid cells drop off of maps upon switching from 1961-90 "normals" to 1981-2010 base period for mapping
- They aren't lost to the global calc, but show up as "missing"

The Drought Decade

Palmer Hydrologic Drought Index: OKCD2



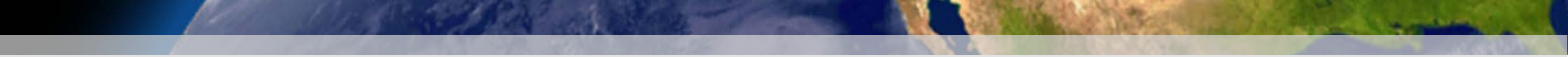


Thank you for your time.

Deke Arndt
Derek.Arndt@noaa.gov
https://www.ncdc.noaa.gov/climate-monitoring

Technical Slides

- Station Siting
- Corrections
- In situ vs. Satellite-derived temperatures
- Precision
- Dealing with dropouts
- Where do I find this stuff?



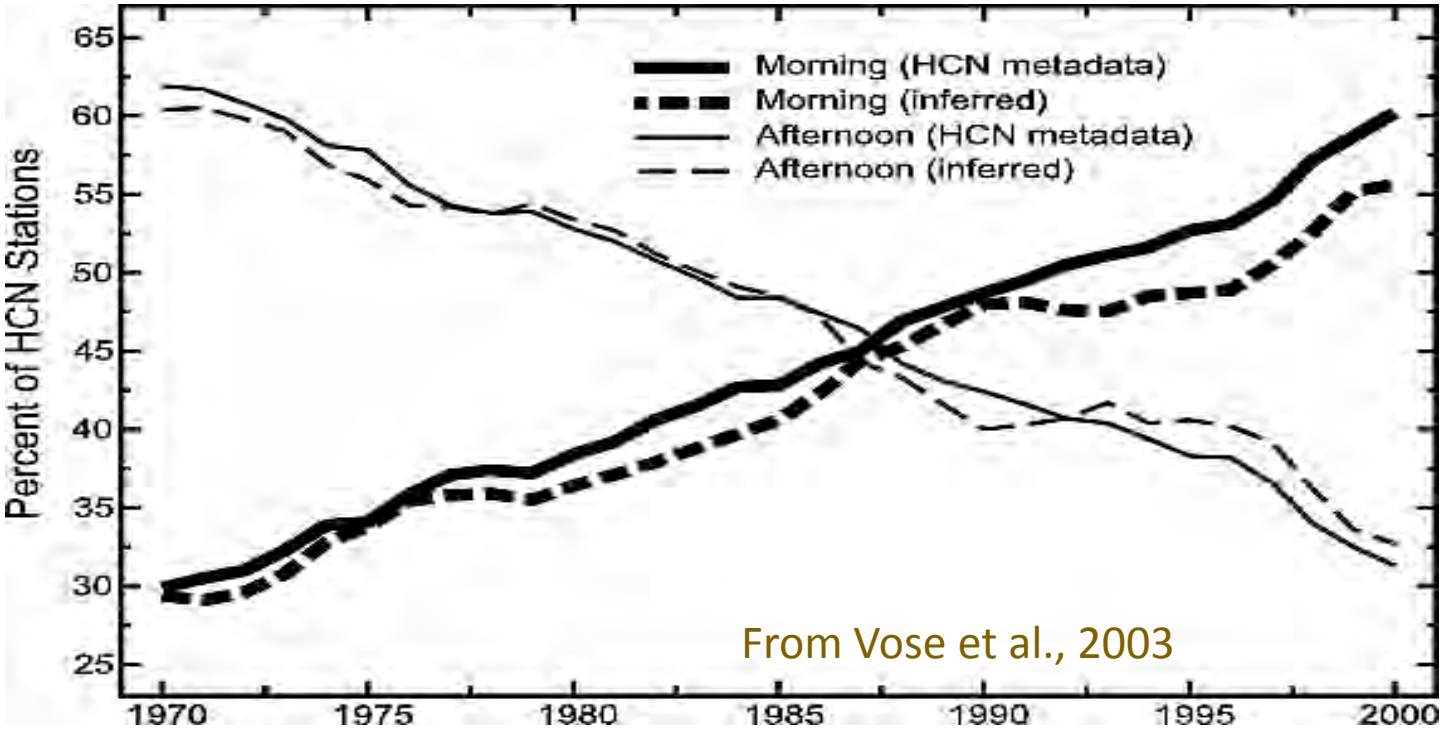
First, good news

- The surface temperature record has been extensively scrutinized this past decade
- This led to improvements in network and station metadata, algorithms which detect and correct disruptions in time-series, and ultimately, a more robust and understood US and Global temperature time series.

Major Known Causes of Station Shifts

- Time of observation changes
- Changes in instrumentation
- Changes in station environment
- All of these can be documented or undocumented

Observation of Time of Observation over Time



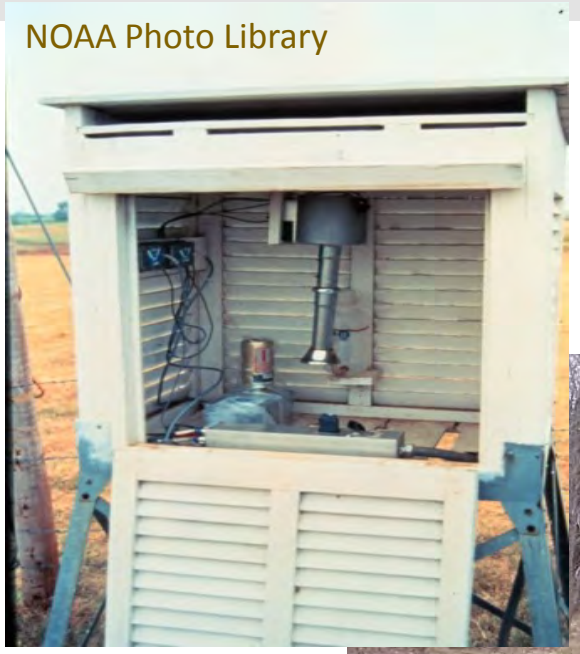
From Vose et al., 2003

- We have become a nation of morning observers.
- This introduced a cool bias over time.
- TOB is a statistical correction for this effect.

Literature: Vose, R. S., C. N. Williams Jr., T. C. Peterson, T. R. Karl, and D. R. Easterling (2003), An evaluation of the time of observation bias adjustment in the U.S. Historical Climatology Network, *Geophys. Res. Lett.*, **30**, 2046, doi:10.1029/2003GL018111, 20.

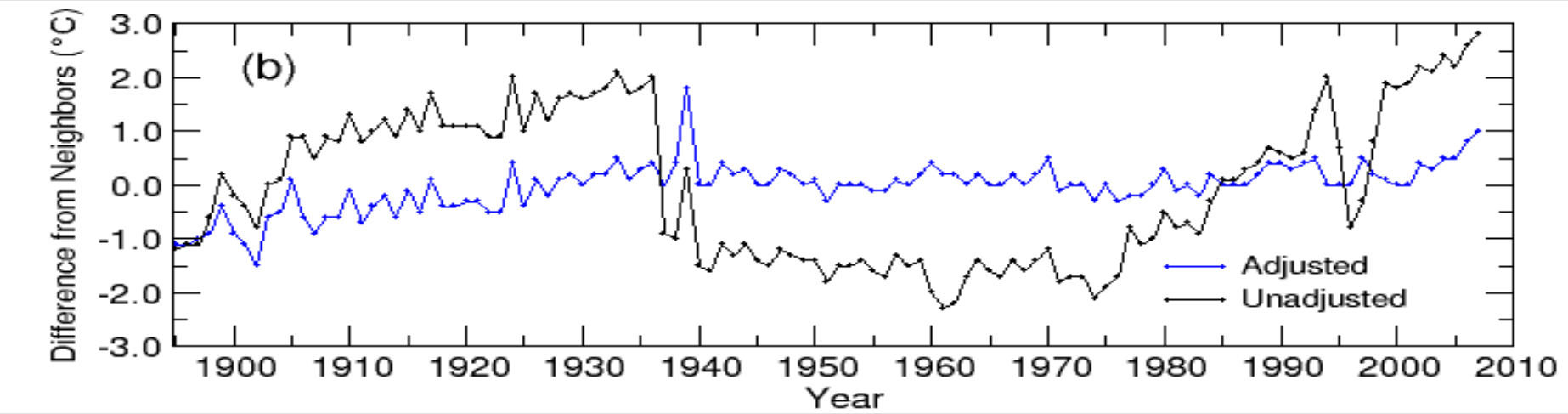
Changes in instrumentation and siting

- 1980s: Much of the network shifted from traditional shelters and liquid in glass to MMTS package
- Closer to structures, but much cooler instrument package



Literature: Menne, M.J., C.N. Williams Jr., and R.S. Vose, 2009: The United States Historical Climatology Network monthly temperature data–Version 2. *Bulletin of the American Meteorological Society*, 90, 993-1007.

Urbanization and Ruralization



Reno, Nevada T_{min}: comparison with neighbors

Urban signal associated with 14%-21% of the rise in *unadjusted* T_{min} since 1895 and 6%-9% since 1960. Homogenization ***effectively removes this urban signal from individual and aggregate station records such that it becomes insignificant*** during the last 50–80 years.

Z. Hausfather, M.J. Menne, C.N. Williams, T. Masters, R. Broberg, and D. Jones, "Quantifying the effect of urbanization on U.S. Historical Climatology Network temperature records", *J. Geophys. Res. Atmos.*, vol. 118, pp. 481-494, 2013. http://dx.doi.org/10.1029/2012JD018509

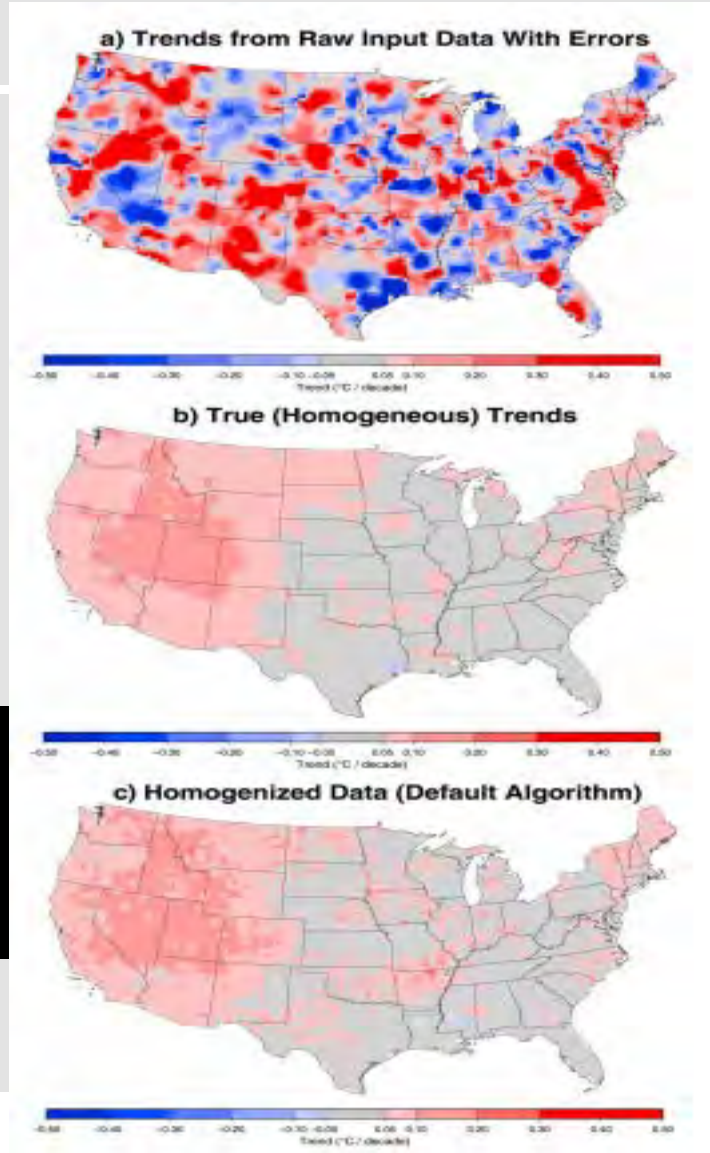
Effects of these issues on CONUS

- Changes in observation practice had different effect on T_{max} vs T_{min} trends
- Before any sort of homogenizaton:
- T_{max} … widespread shifts artificially cooled the true rate of change
  - Artificial cooling since 1950: changing time of observation
  - Artificial cooling (primarily mid-1980s): liquid-in-glass thermometers → MMTS electronic resistance thermistors
- T_{min} … these shifts work in opposition to each other.
  - Artificial cooling since 1950: changing time of observation
  - Some artificial cooling from 1930-50: station moves to somewhat cooler micro-climates (ruralization)
  - Artificial warming since the mid-1980s: associated with installation of MMTS.
  - Conclusion: raw T_{min} data likely underestimate overall trend since 1950 (when time of obs shifts dominate) and overestimate overall trend since 1979 (when shifts associated with MMTS installation dominate).

Literature: Menne, M. J., C. N. Williams, Jr., and M. A. Palecki, 2010: On the reliability of the U.S. surface temperature record. *Journal of Geophysical Research*, 115, D11108, doi:10.1029/2009JD013094.

How do we know corrections work?

- NCDC uses homogenization algorithm designed to account for shifts and reduce the error in trend calculations
- Benchmarking experiments broadly affirmed the approach
- Comparison with hourly reanalyses also indicate corrections are in correct direction



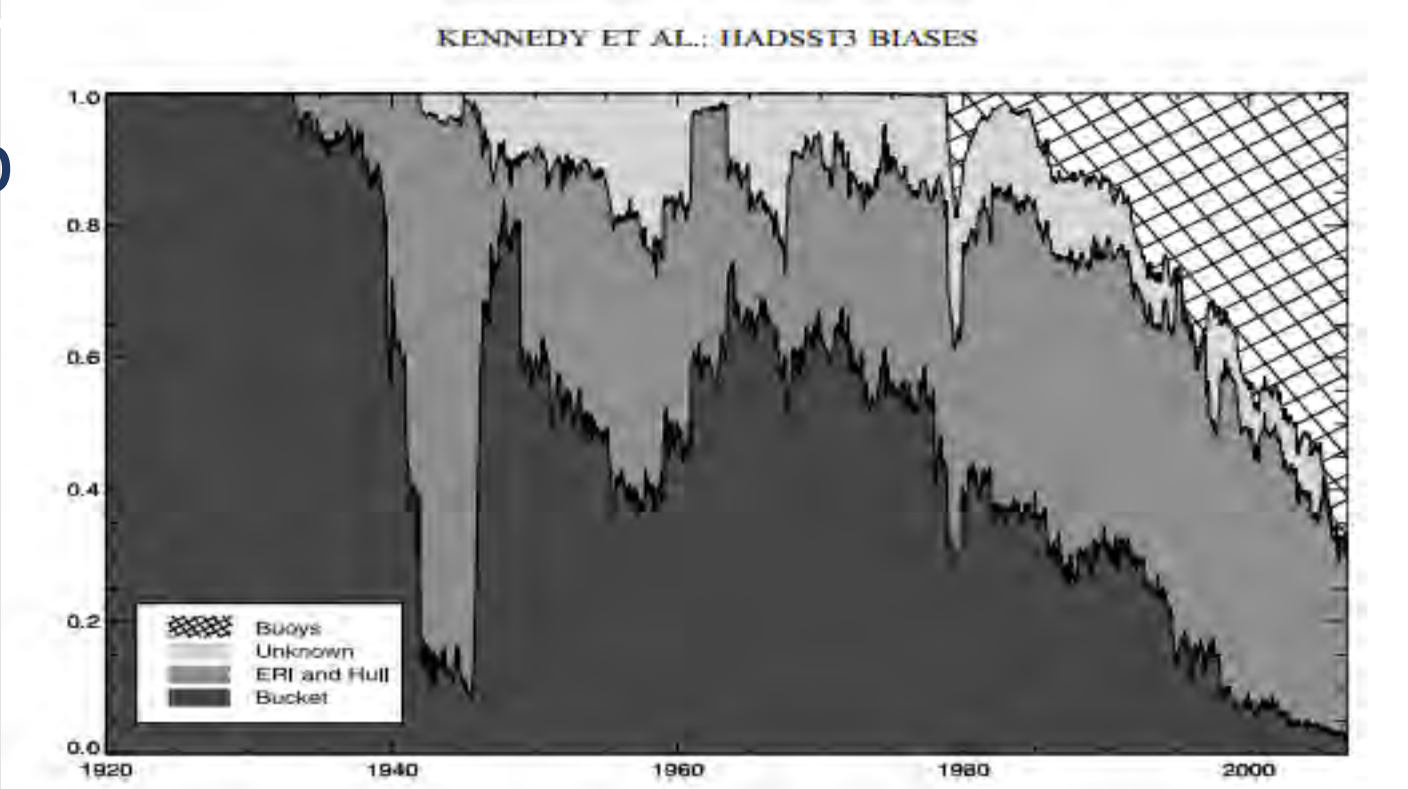
- Vose, R.S., S. Applequist, M.J. Menne, C.N. Williams Jr., and P. Thorne (2012), An intercomparison of temperature trends in the U.S. Historical Climatology Network and recent atmospheric reanalyses, *Geophys. Res. Lett.*, **39**, L10703, doi:10.1029/2012GL051387
- Williams, C.N., M.J. Menne, and P.W. Thorne, 2012: Benchmarking the performance of pairwise homogenization of surface temperatures in the United States. *Journal of Geophysical Research- Atmospheres*, **117**, D5, doi:10.1029/2011JD016761.
- Zhang, J., W. Zheng, and M.J. Menne, 2012: A Bayes factor model for detecting artificial discontinuities via pairwise comparisons. *Journal of Climate*, 25, 8462-8474, doi: 10.1175/JCLI-D-12-00052.1.

Why adjust the past?

- Rationale: adjusted datasets should reflect what the data would show with today's instrumentation and practices.
- Keep unadjusted data available for people who wish to use unadjusted data or develop their own routines.

Data drives the direction of corrections

- Ex.: Sea surface temperatures make up 2/3 of the global temperature average
  - Mid-century: bucket to engine
  - Resulting adjustment reduces 20th century warming trend



Kennedy, J.J., N.A. Rayner, R.O. Smith, D.E. Parker, and M. Saunby (2011), Reassessing biases and other uncertainties in sea surface temperature observations measured in situ since 1850: 2. Biases and homogenization, *J. Geophys. Res.*, **116**, D14104, doi:10.1029/2010JD015220.

T_{sfc} vs. TLT: Related but not Equated

Surface Temperature

- Represents: meteorological surface temperature (approx. 1.5m AGL)
- Measured by thousands of in-situ stations
- Common datasets: GHCN, nClimDiv, CRUTemp
- Challenges: environment drift, changing instruments

Temp of Lower Trop

- Represents: bulk temperature from sfc to about 8,000m (26,000 ft)
- Measured by: indirect; derived from radiances in microwave frequencies
- Common datasets: RSS, UAH
- Challenges: orbital drift, changing instruments,

Precision

- How do we come up with 0.1 or 0.01 values when individual stations measure in whole degrees?

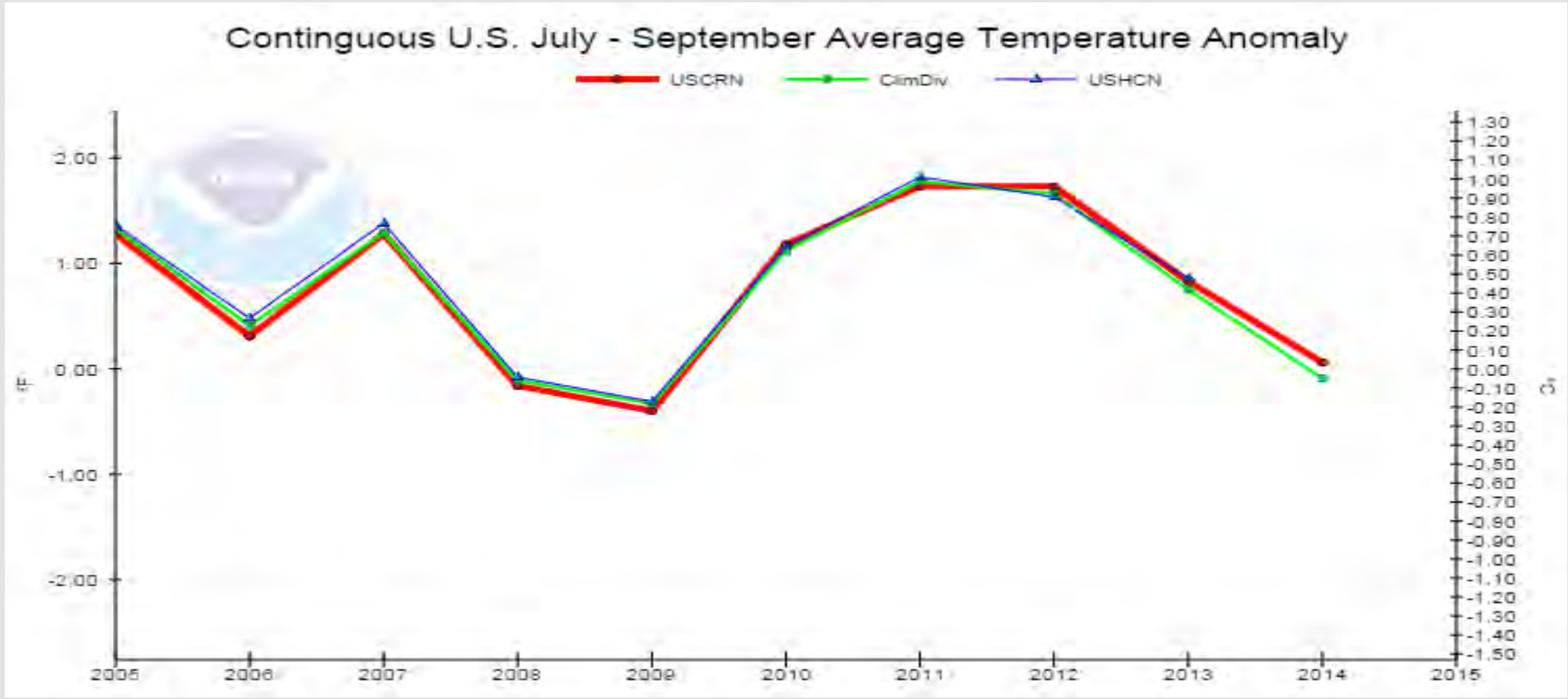
Team	GP	MIN	FGM	FGA	FG%	3FGM	3FGA	3FG%	FTM	FTA	FT%	OREB	DREB
Atlanta Hawks	82	48.4	37.3	81.6	45.8%	9.4	25.8	36.3%	17.0	21.7	78.1%	8.7	31.3
Boston Celtics	82	48.1	36.5	83.9	43.5%	7.0	21.1	33.3%	16.2	20.8	77.7%	12.0	30.5
Brooklyn Nets	82	48.5	35.7	77.9	45.9%	8.6	23.4	36.9%	18.4	24.4	75.3%	8.8	29.4
Charlotte Bobcats	82	48.5	36.3	82.1	44.2%	6.3	17.9	35.1%	18.0	24.4	73.7%	9.5	33.2
Chicago Bulls	82	48.6	34.7	80.2	43.2%	6.2	17.8	34.8%	18.1	23.3	77.9%	11.4	32.7
Cleveland Cavaliers	82	48.6	37.0	84.8	43.7%	7.1	20.0	35.6%	17.0	22.7	75.1%	12.1	32.1
Dallas Mavericks	82	48.4	39.6	83.6	47.4%	8.8	22.9	38.4%	16.8	21.1	79.5%	10.2	30.7
Denver Nuggets	82	48.2	38.4	85.9	44.7%	8.6	23.9	35.8%	19.1	26.3	72.6%	12.3	33.1
Detroit Pistons	82	48.2	38.8	86.9	44.7%	6.2	19.3	32.1%	17.3	25.7	67.0%	14.6	30.8
Golden State Warriors	82	48.4	39.5	85.4	46.2%	9.4	24.8	38.0%	15.9	21.1	75.3%	10.9	34.4
Houston Rockets	82	48.4	38.0	80.5	47.2%	9.5	26.6	35.8%	22.1	31.1	71.2%	11.2	34.1
Indiana Pacers	82	48.2	36.0	80.2	44.9%	6.7	18.8	35.7%	18.1	23.3	77.9%	10.2	34.5

NBA.com

Dealing with Dropouts

- Claim: The loss of stations in colder climates creates artificial warming
- Truth: Absolute temperatures are not used to calculate the global temperature
  - Global temperature calculations are made using local departures from climatological average
  - Anomalies in colder climates are often warmer (larger positive) than in warmer climates; i.e., poleward stations actually show more warming.

Compared to Climate Reference Network



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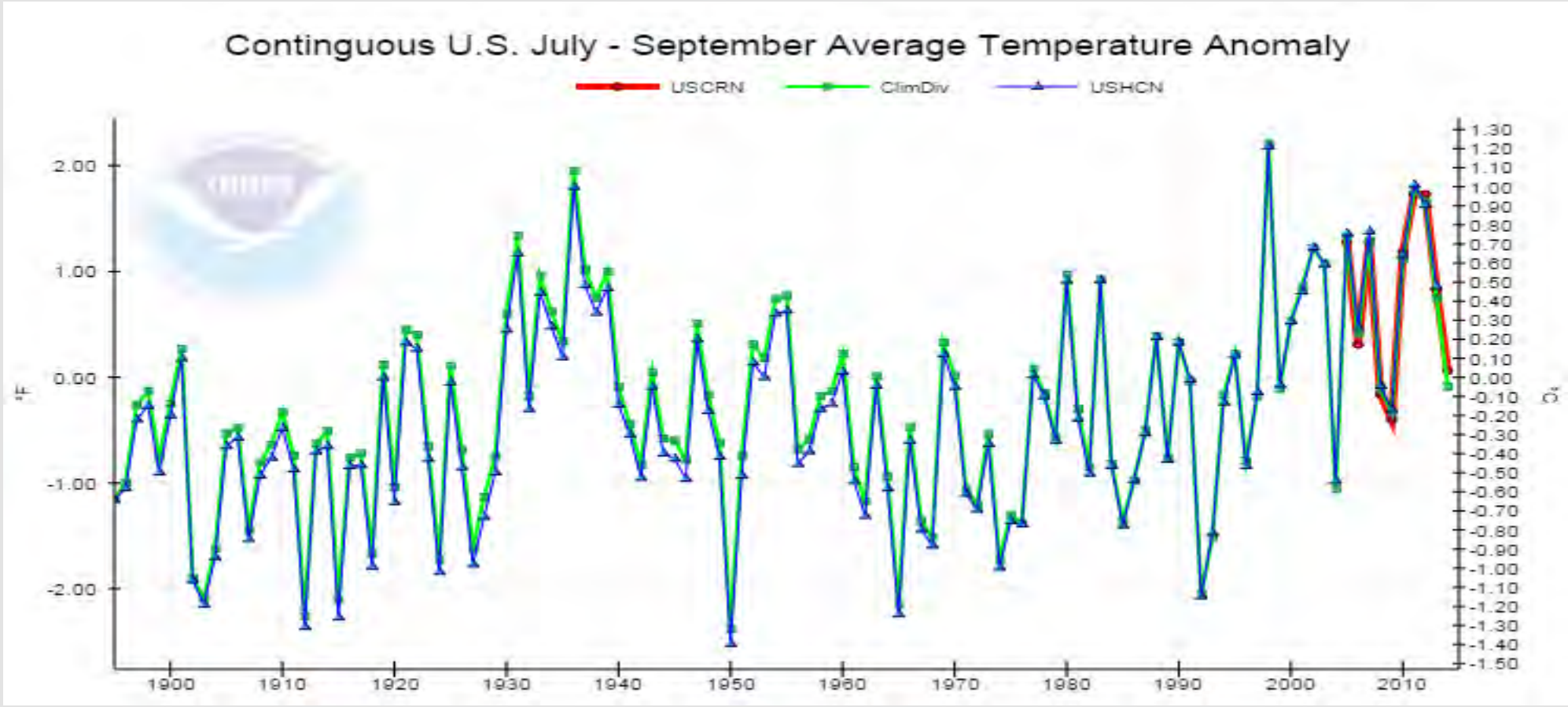

Data Specific to this Presentation

- Global, US temperature time series:
  - Climate at a Glance: http://www.ncdc.noaa.gov/cag
  - Also for states, climate divisions within states
- Raw and Adjusted HCN data:
  - http://www1.ncdc.noaa.gov/pub/data/ghcn/v3/
  - “qcu” files: unadjusted (raw)
  - “qca” files: adjusted
- Comparison CONUS temperature methods to CRN:
  - http://www.ncdc.noaa.gov/temp-and-precip/national-temperature-index/

Thank you for your time.
Good luck this week.
Do your best.

Deke Arndt
Derek.Arndt@noaa.gov
https://www.ncdc.noaa.gov/climate-monitoring