Uncertainties in the Surface Temperature Record

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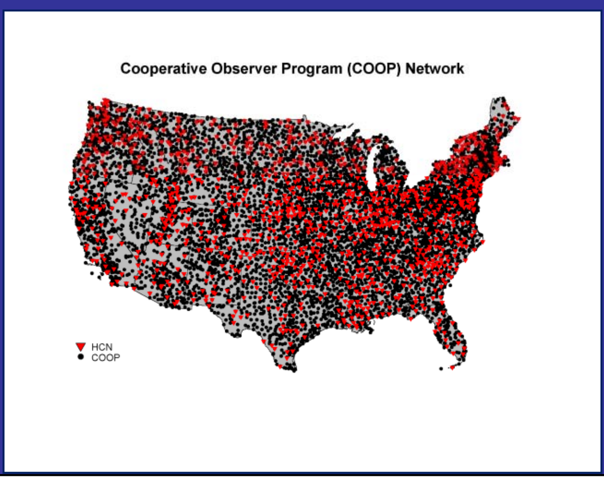
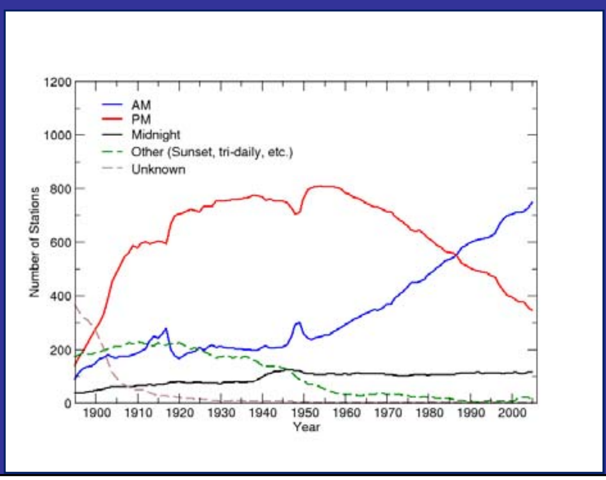
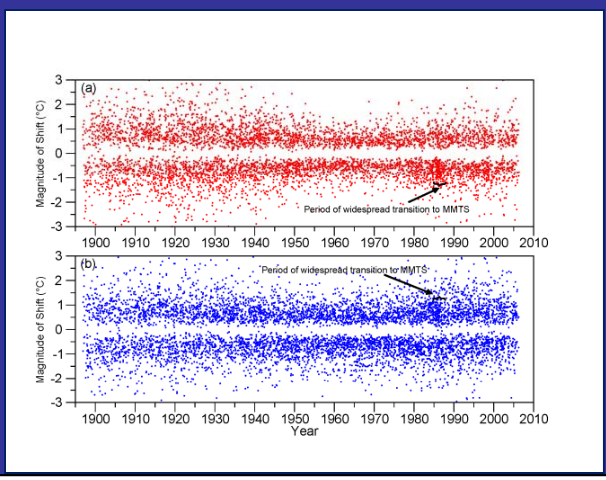




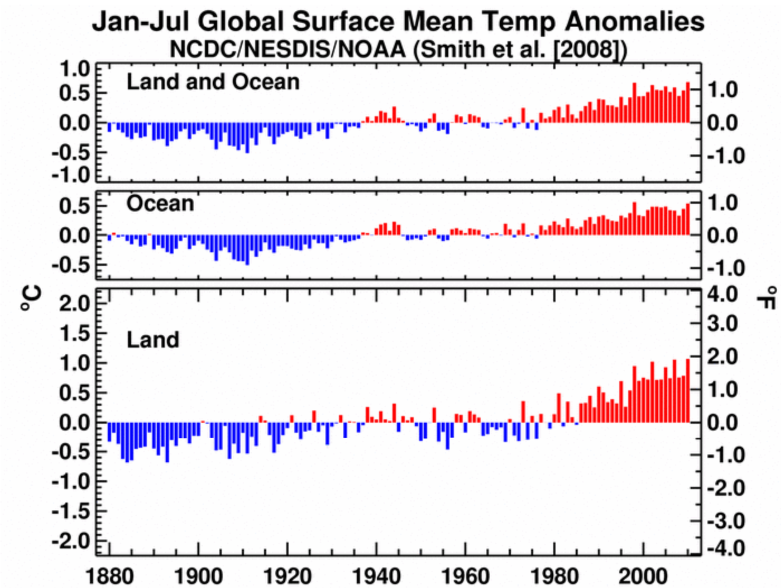


- The datasets
- Sources of uncertainty
- Approaches to address and quantify uncertainty

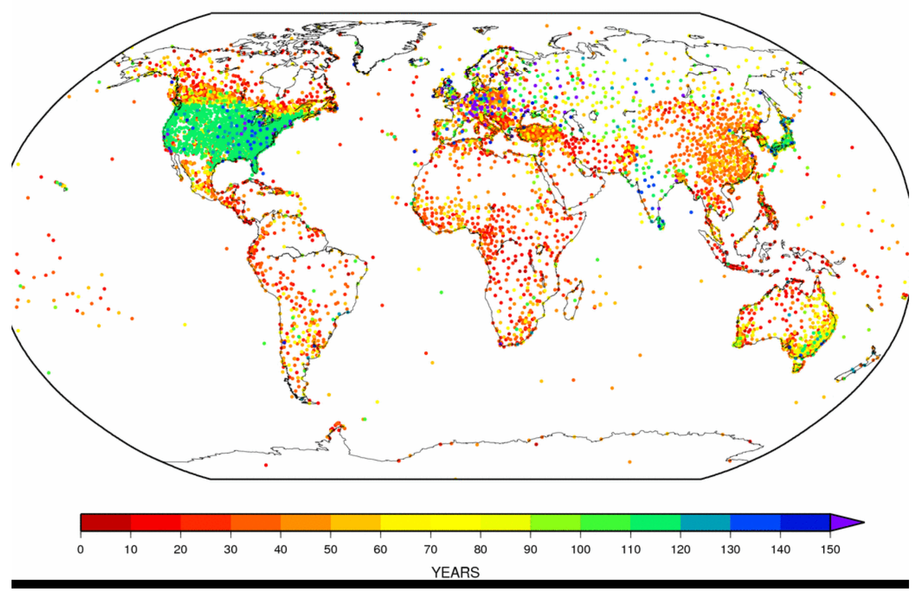
The U.S. Historical and Global Historical Climatology Networks (USHCN and GHCN)

GHCN Monthly

- Version 1 released in 1992
- Version 2 released in 1997
  (Peterson and Vose, 1997)
- Version 3 "Beta" released Sept. 2010 (operational as of Spring 2011)
  - 7000+ stations with mean monthly temperature records (Lawrimore et al. 2011)



Number of years of data for each station in GHCN Monthly mean temperature dataset

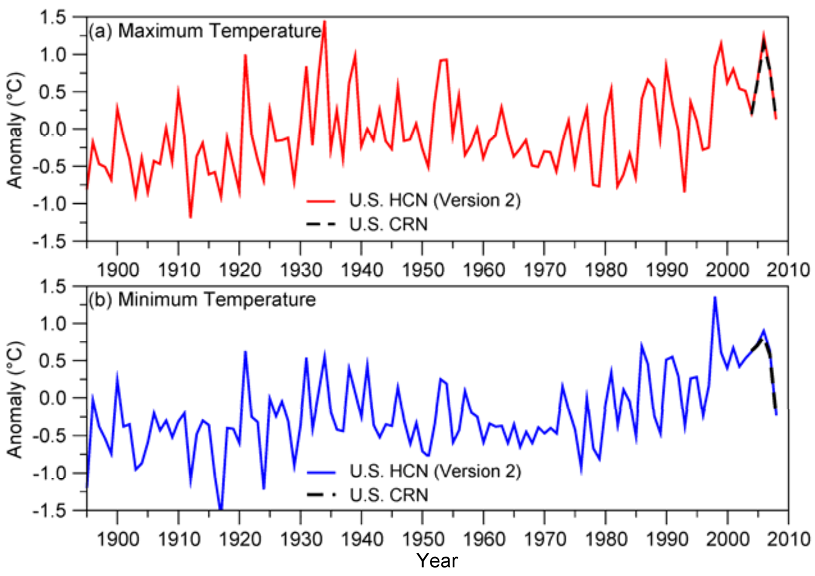


- Version 3 is based on the quality control and homogenization approach used to produce the USHCN Version 2 (but without station histories for stations outside the USA)

USHCN V1	USHCN V2

Released in 1987, with subsequent revisions

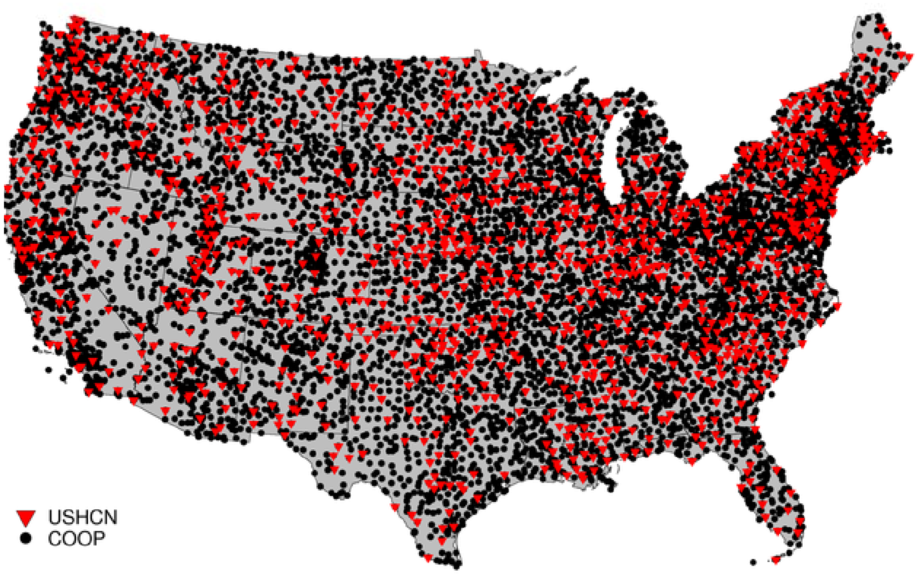
- Time of observation bias (Karl et al. 1986)
- Changes documented in the station history archives (Karl and Williams 1987)
- Urbanization (Karl et al. 1988)
- LiG to MMTS instrument change (Quayle et al. 1991)



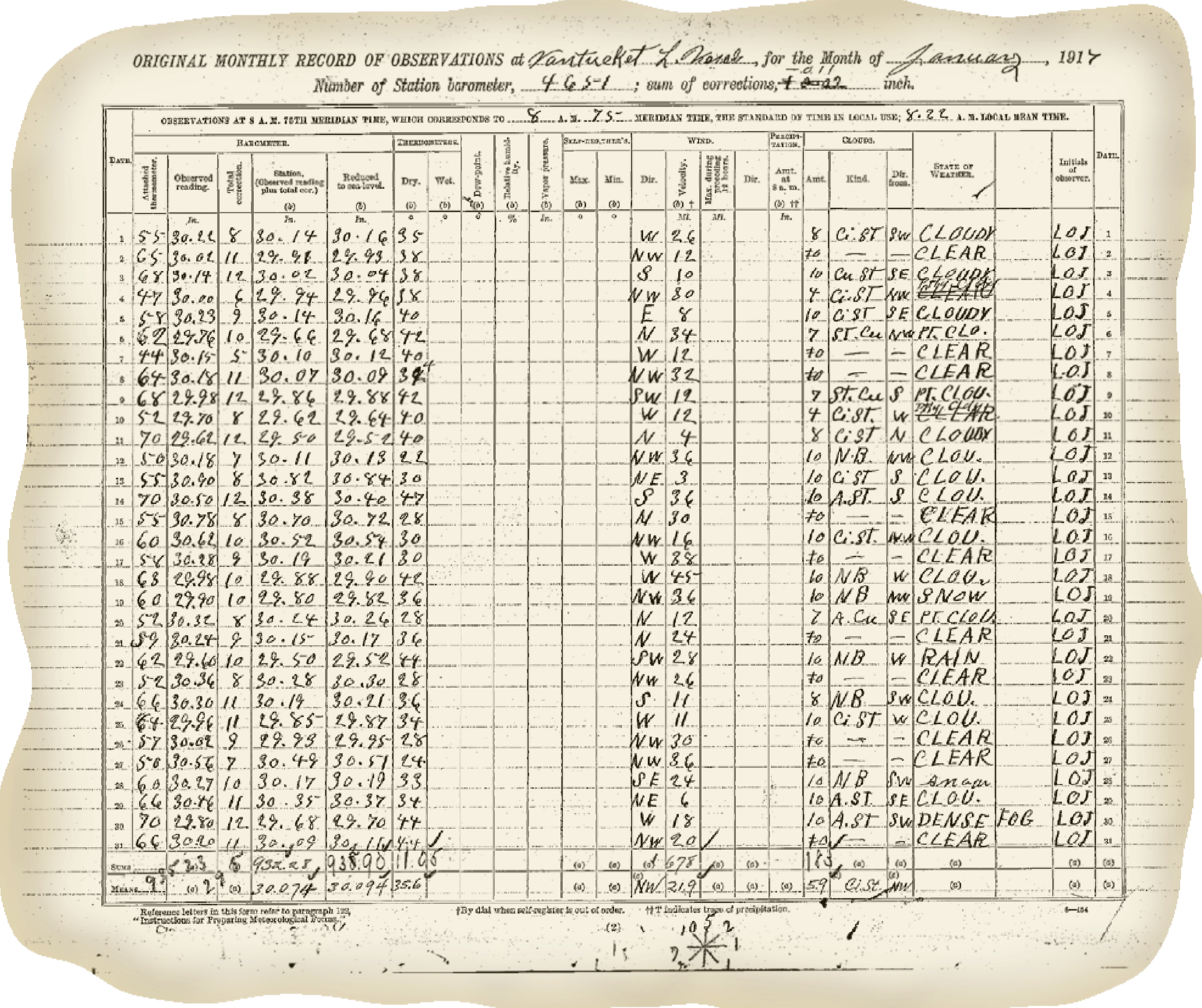
Released in 2009

- Time of observation bias (Karl et al. 1986)
- Documented and undocumented station changes (Menne and Williams 2009)

U.S. Cooperative Observer Program (COOP) Network



Data Received From Many Sources



ORIGINAL MONTHLY RECORD OF OBSERVATIONS at Nantucket L. Island, for the Month of January, 1917

Number of Station barometer, 4651; sum of corrections, -.011 inch.

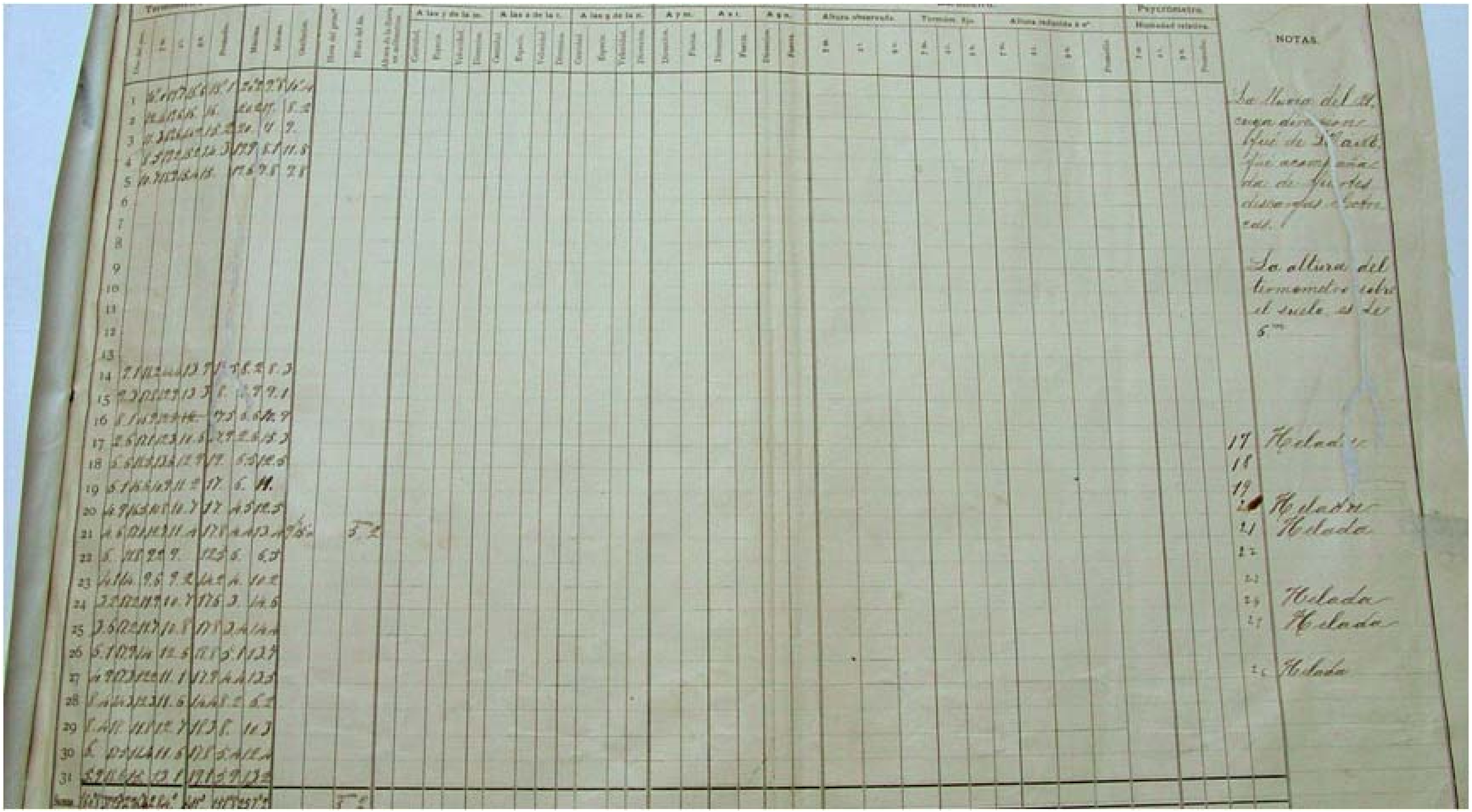
OBSERVATIONS AT 8 A. M. 75TH MERIDIAN TIME, WHICH CORRESPONDS TO 8 A. M. 75 MERIDIAN TIME, THE STANDARD OF TIME IN LOCAL USE; 8.22 A. M. LOCAL MEAN TIME.

Date	Barometer: Attached thermometer	Observed reading (In.)	Total correction	Station (Observed reading plus total cor.) (b) (In.)	Reduced to sea-level (b) (In.)	Thermometers: Dry (b) (°)	Wet (b) (°)	Dew-point (b) (°)	Relative humidity (b) (%)	Vapor pressure (b) (In.)	Self-registers: Max. (b) (°)	Min. (b) (°)	Wind: Dir.	Velocity (b) † (Mi.)	Max. during preceding 12 hours (Mi.)	Dir.	Precipitation: Amt. at 8 a. m. (b) †† (In.)	Clouds: Amt.	Kind	Dir. from	State of Weather		Initials of observer	Date
1	55	30.22	8	30.14	30.16	35							W	26				8	Ci.St	SW	CLOUDY		LOJ	1
2	65	30.02	11	29.91	29.93	38							NW	12				10	—	—	CLEAR		LOJ	2
3	68	30.14	12	30.02	30.04	38							S	10				10	Cu St	SE	CLOUDY		LOJ	3
4	47	30.00	6	29.94	29.96	38							NW	30				4	Ci.ST	NW	~~CLEAR~~		LOJ	4
5	58	30.23	9	30.14	30.16	40							E	8				10	Ci.ST	SE	CLOUDY		LOJ	5
6	62	29.76	10	29.66	29.68	42							N	34				7	ST. Cu	NW	PT. CLO.		LOJ	6
7	44	30.15	5	30.10	30.12	40							W	12				10	—	—	CLEAR		LOJ	7
8	64	30.18	11	30.07	30.09	34							NW	32				10	—	—	CLEAR		LOJ	8
9	68	29.98	12	29.86	29.88	42							SW	12				7	St. Cu	S	PT. CLOU.		LOJ	9
10	52	29.70	8	29.62	29.64	40							W	12				4	Ci.ST.	W	PTLY CLOUDY ~~CLEAR~~		LOJ	10
11	70	29.62	12	29.50	29.52	40							N	4				8	Ci.ST	N	CLOUDY		LOJ	11
12	50	30.18	7	30.11	30.13	22							NW	36				10	N.B.	NW	CLOU.		LOJ	12
13	55	30.90	8	30.82	30.84	30							NE	3				10	Ci.ST	S	CLOU.		LOJ	13
14	70	30.50	12	30.38	30.40	47							S	36				10	A.ST.	S	CLOU.		LOJ	14
15	55	30.78	8	30.70	30.72	28							N	30				10	—	—	CLEAR		LOJ	15
16	60	30.62	10	30.52	30.54	30							NW	16				10	Ci.ST.	NW	CLOU.		LOJ	16
17	56	30.28	9	30.19	30.21	30							W	38				10	—	—	CLEAR		LOJ	17
18	68	29.98	10	29.88	29.90	42							W	45				10	NB	W	CLOU.		LOJ	18
19	60	29.90	10	29.80	29.82	36							NW	36				10	NB	NW	SNOW		LOJ	19
20	52	30.32	8	30.24	30.26	28							N	12				7	A.Cu	SE	PT. CLOU.		LOJ	20
21	59	30.24	9	30.15	30.17	36							N	24				10	—	—	CLEAR		LOJ	21
22	62	29.60	10	29.50	29.52	44							SW	28				10	NB	W	RAIN		LOJ	22
23	52	30.36	8	30.28	30.30	28							NW	26				10	—	—	CLEAR		LOJ	23
24	66	30.30	11	30.19	30.21	36							S	11				8	NB	SW	CLOU.		LOJ	24
25	64	29.96	11	29.85	29.87	34							W	11				10	Ci.ST	W	CLOU.		LOJ	25
26	57	30.02	9	29.93	29.95	28							NW	30				10	—	—	CLEAR		LOJ	26
27	50	30.56	7	30.49	30.51	24							NW	36				10	—	—	CLEAR		LOJ	27
28	60	30.27	10	30.17	30.19	33							SE	24				10	NB	SW	Snow		LOJ	28
29	66	30.46	11	30.35	30.37	34							NE	6				10	A.ST.	SE	CLOU.		LOJ	29
30	70	29.80	12	29.68	29.70	44							W	18				10	A.ST	SW	DENSE	FOG	LOJ	30
31	66	30.20	11	30.09	30.11	44							NW	20				10	—	—	CLEAR		LOJ	31
Sums	1823			932.28	938.90	1106								678				183						
Means	59			30.074	30.094	35.6							NW	21.9				5.9	Ci.St.	NW				

Reference letters in this form refer to paragraph 122, "Instructions for Preparing Meteorological Forms."

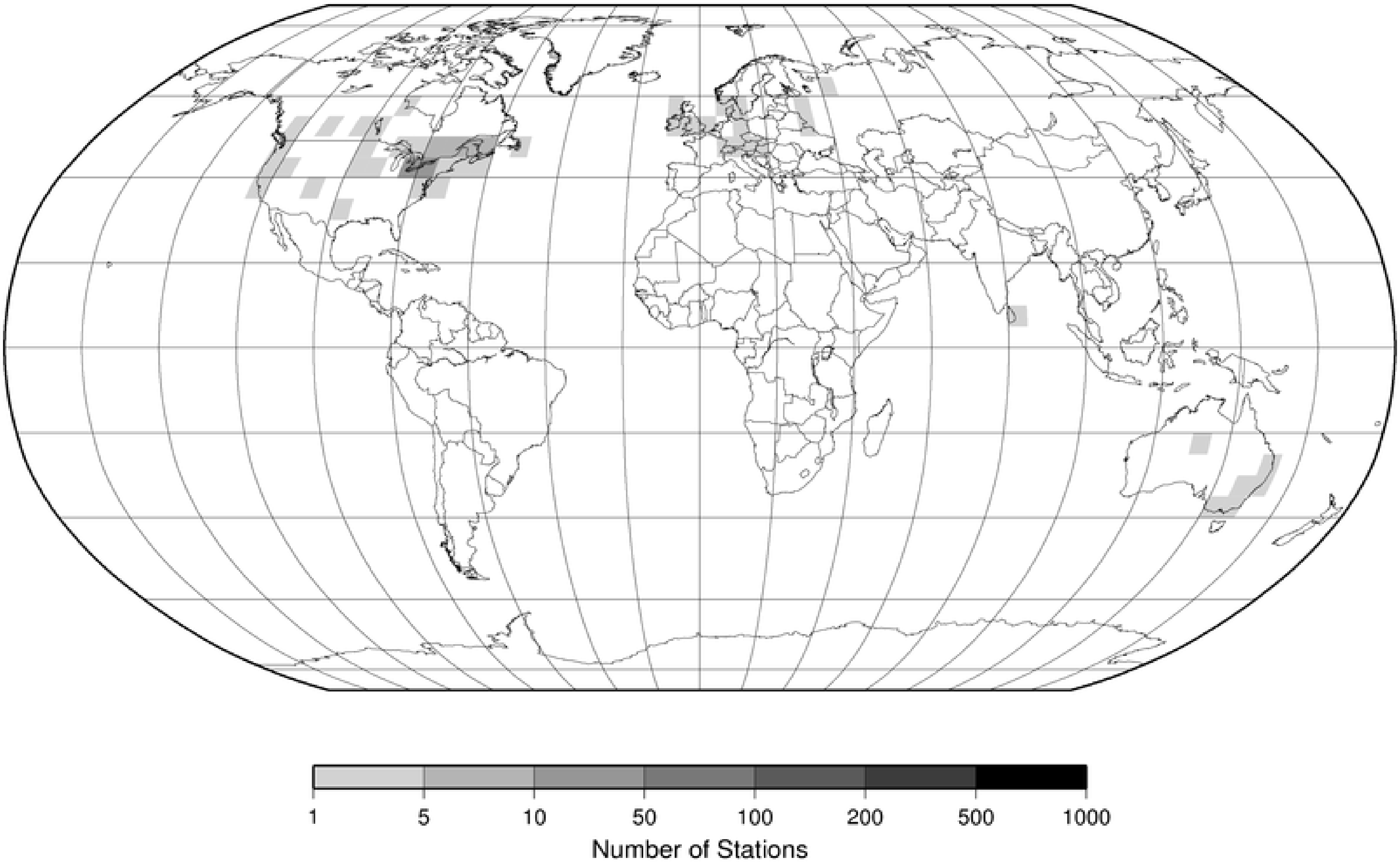
†By dial when self-register is out of order. ††T indicates trace of precipitation.

Imaged data

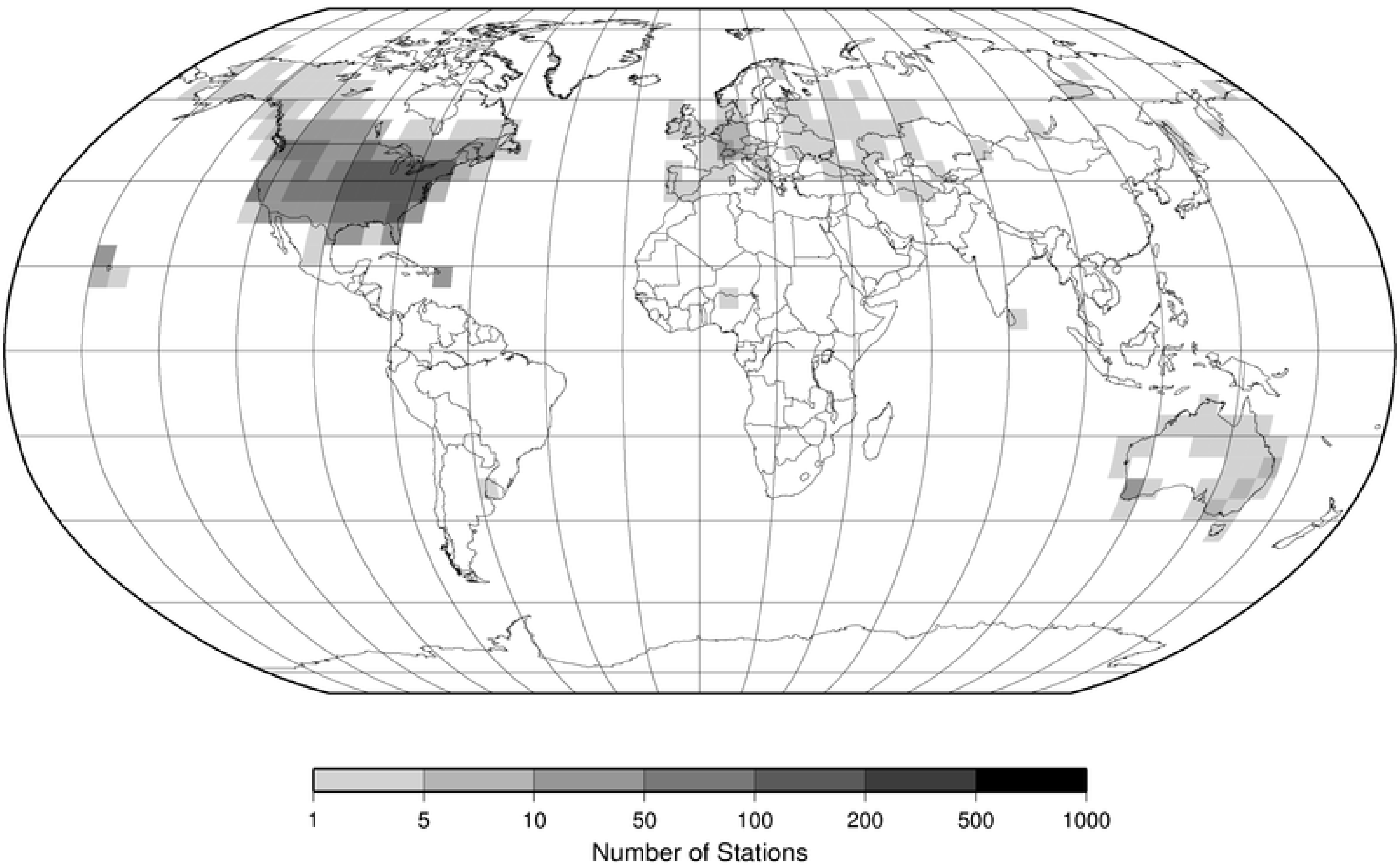


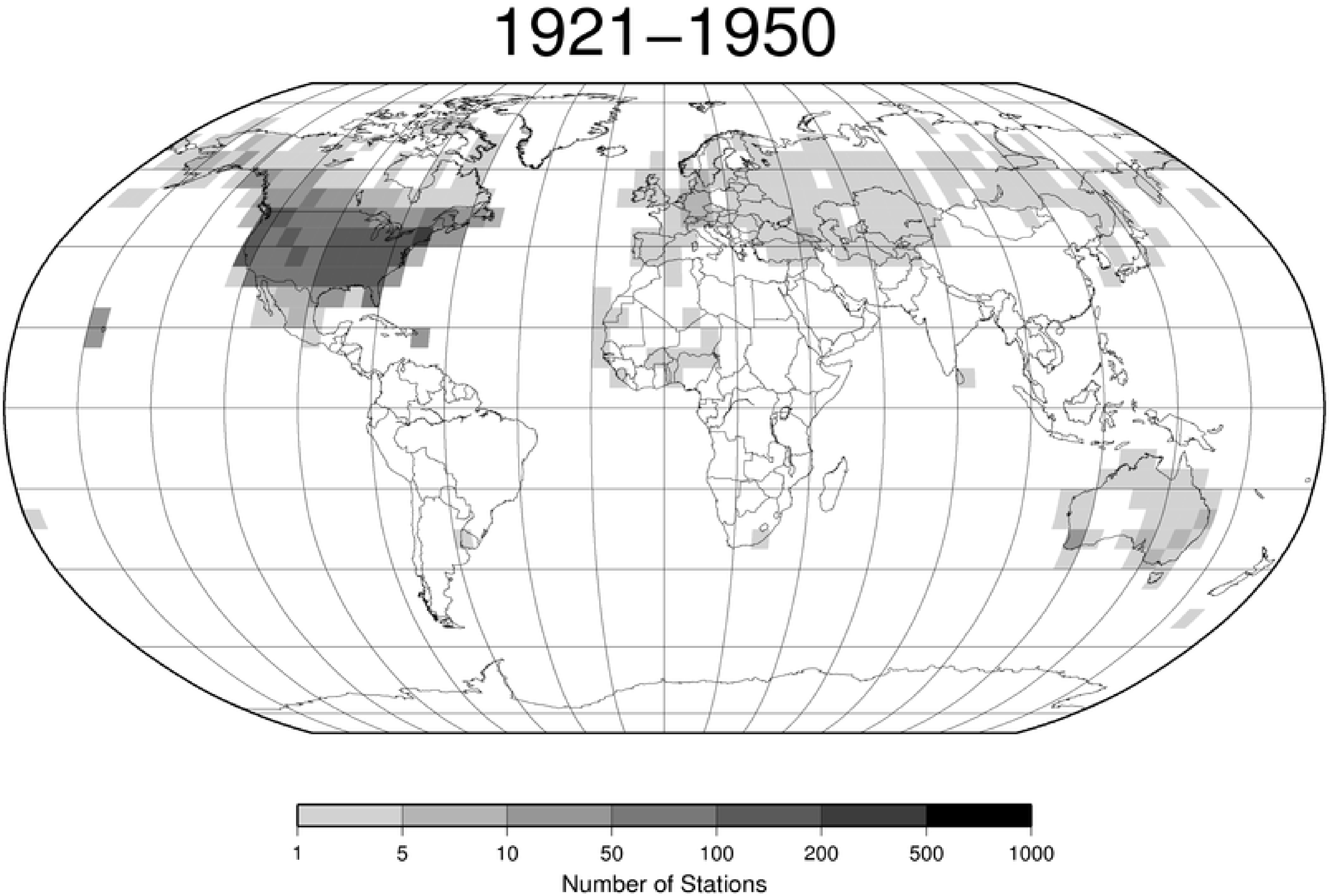
GHCN-Daily

1861–1890

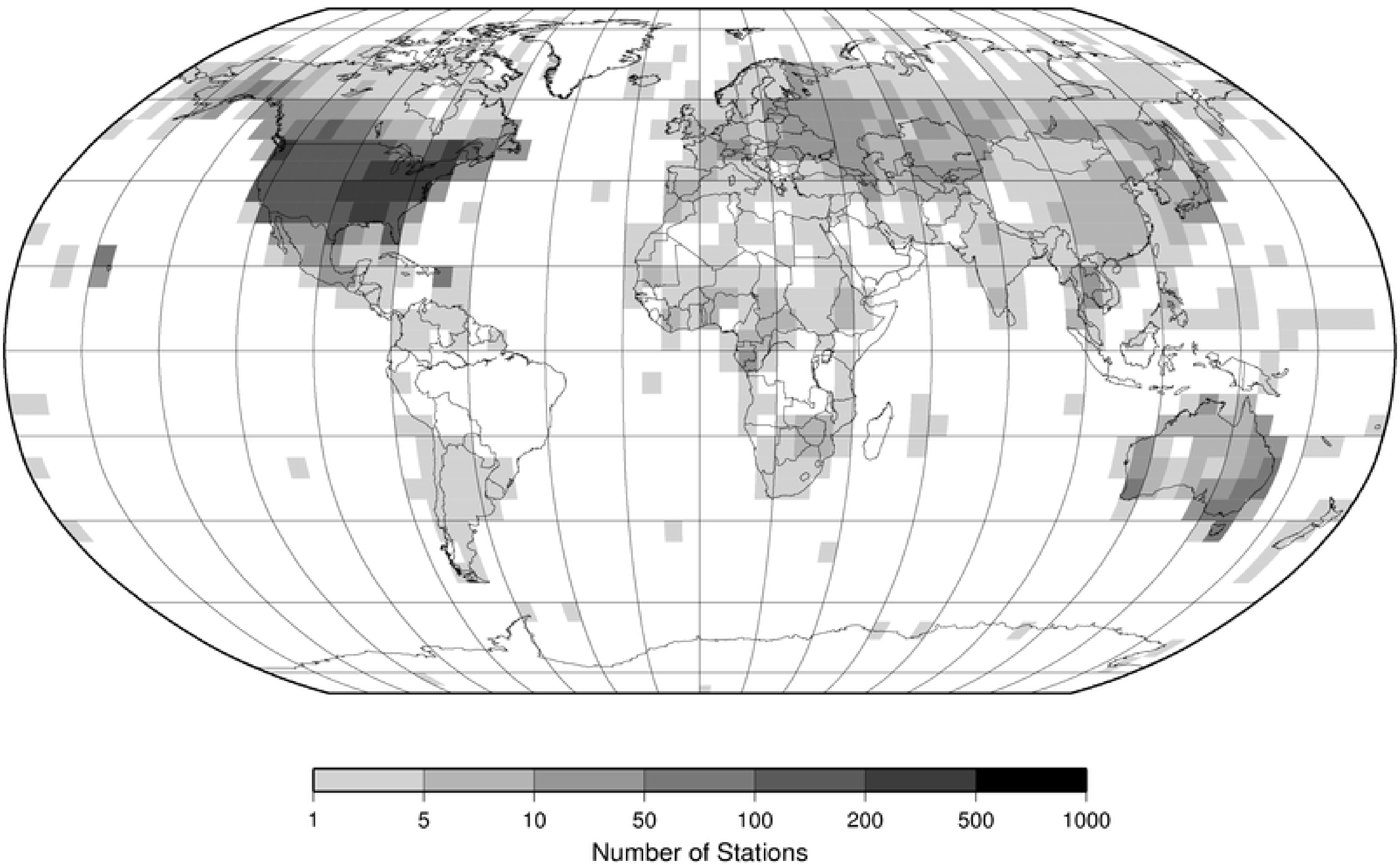


1891–1920

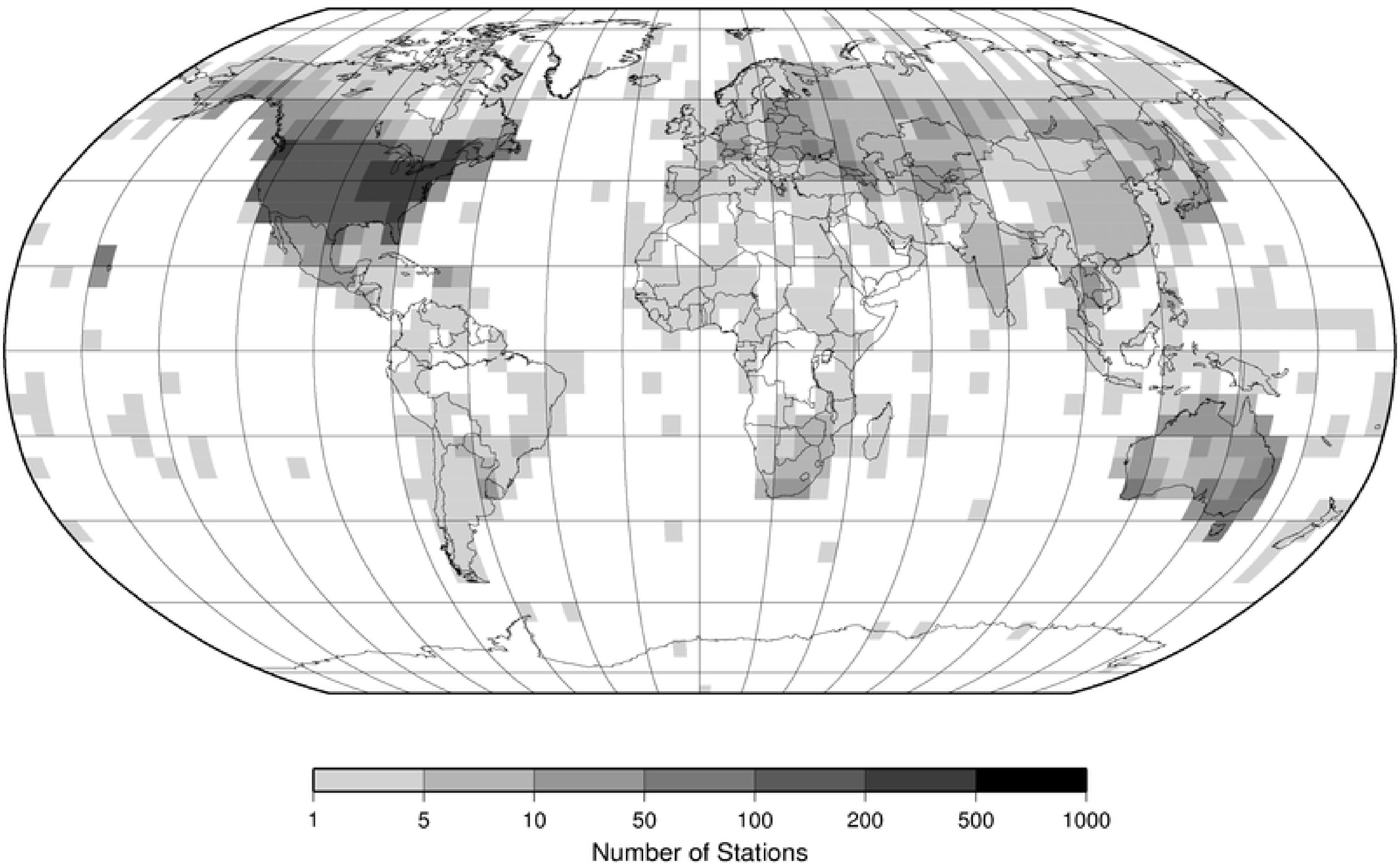



1921–1950
1
5
10
50
100
200
500
1000
Number of Stations

1951–1980

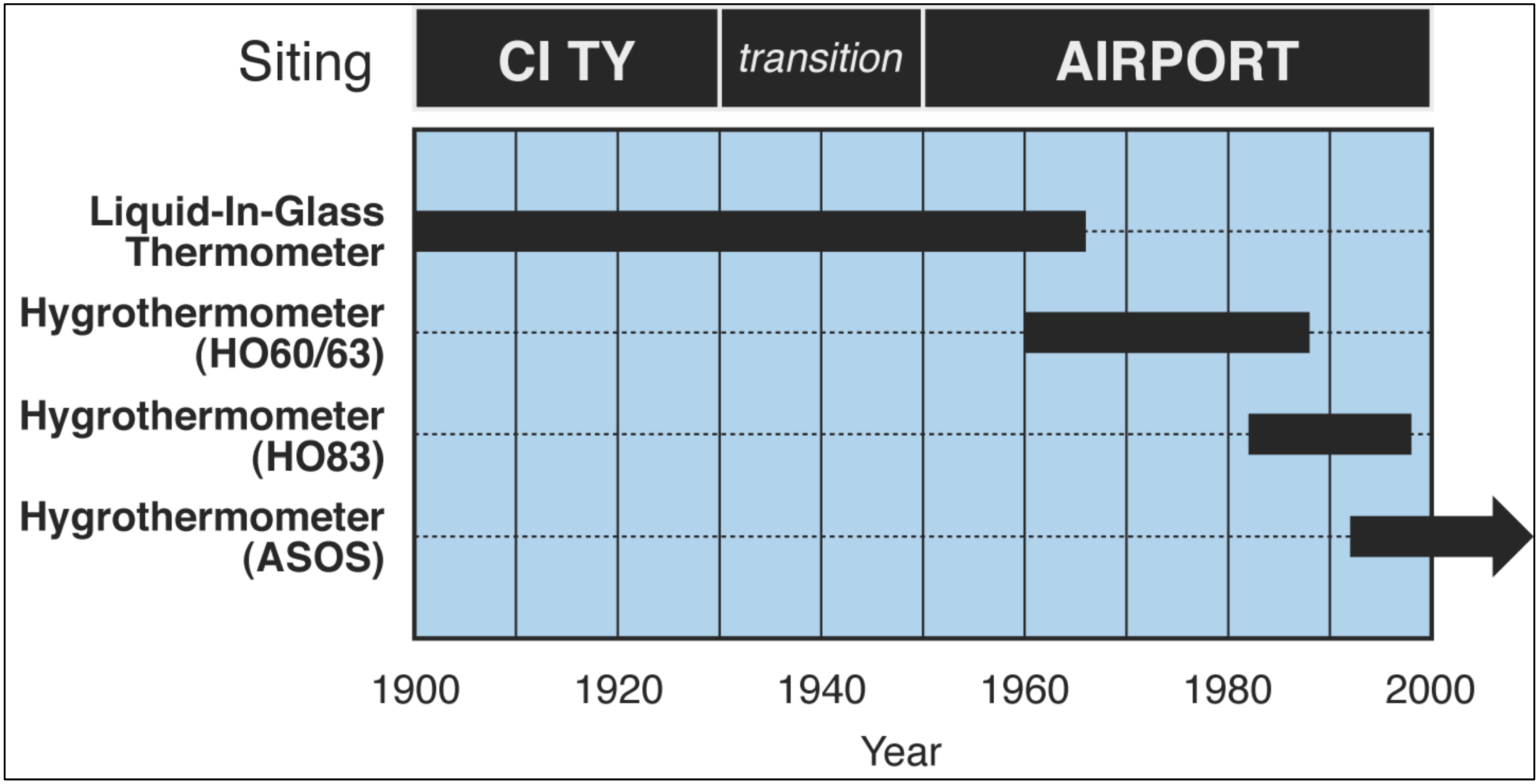


1981–2010

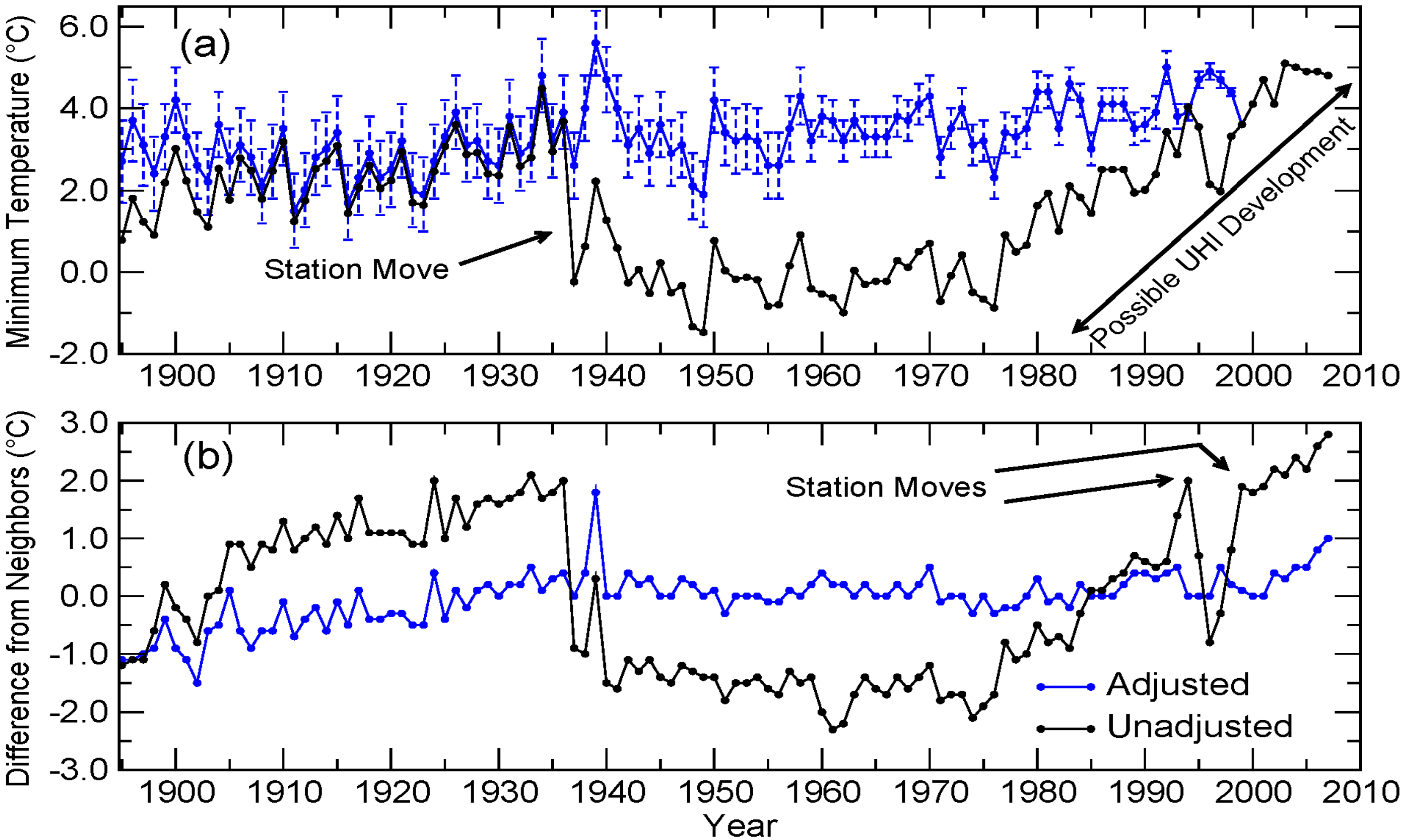


Changes in bias

Station Moves & Instrument Changes



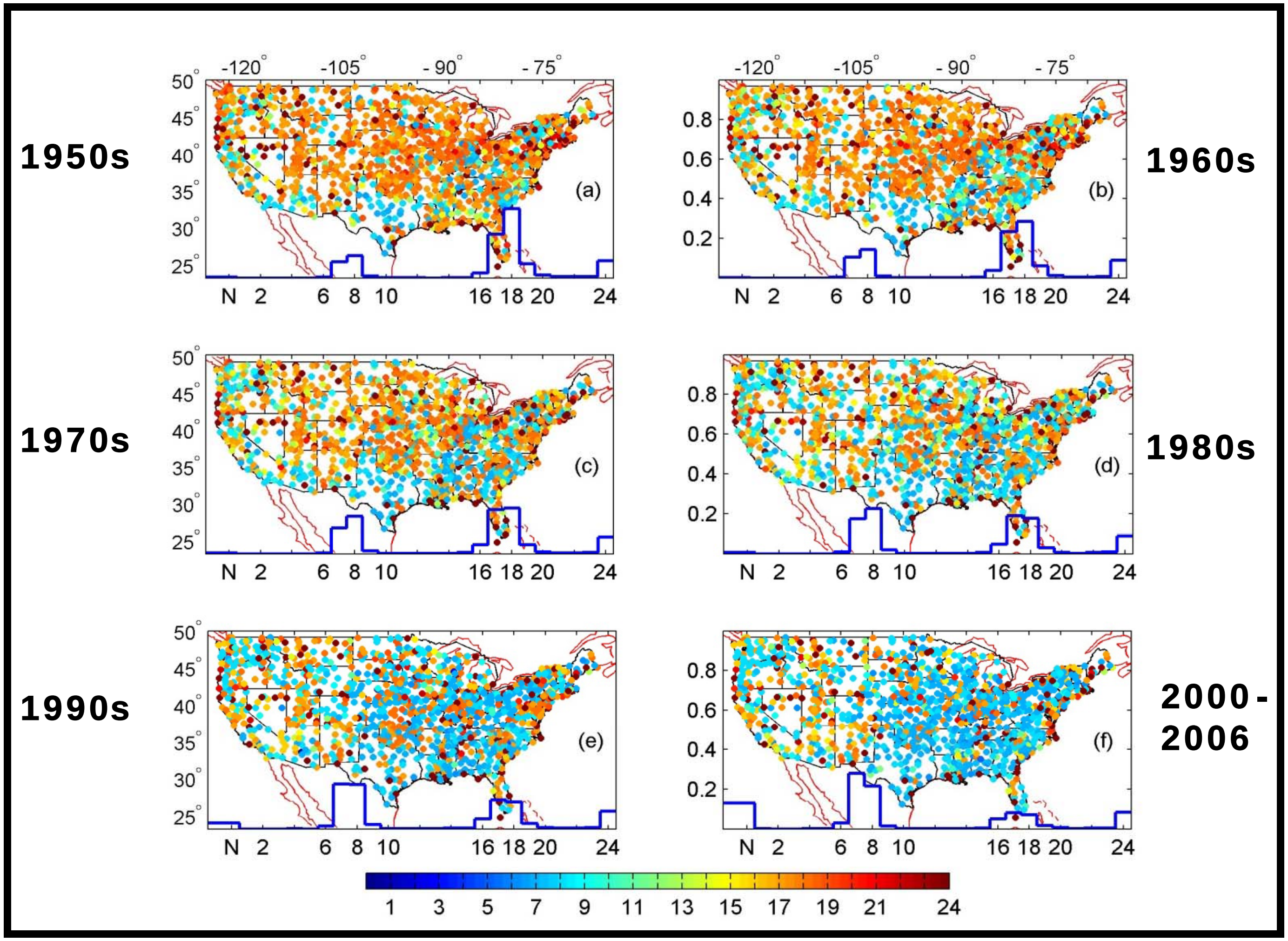
Annual Average Minimum Temperature at Reno, Nevada



(a) Mean annual unadjusted and fully adjusted minimum temperatures at Reno, Nevada. Error bars indicate the magnitude of uncertainty in the adjustments (±1 standard error);

(b) Difference between minimum temperatures at Reno and the mean from its 10 nearest neighbors.

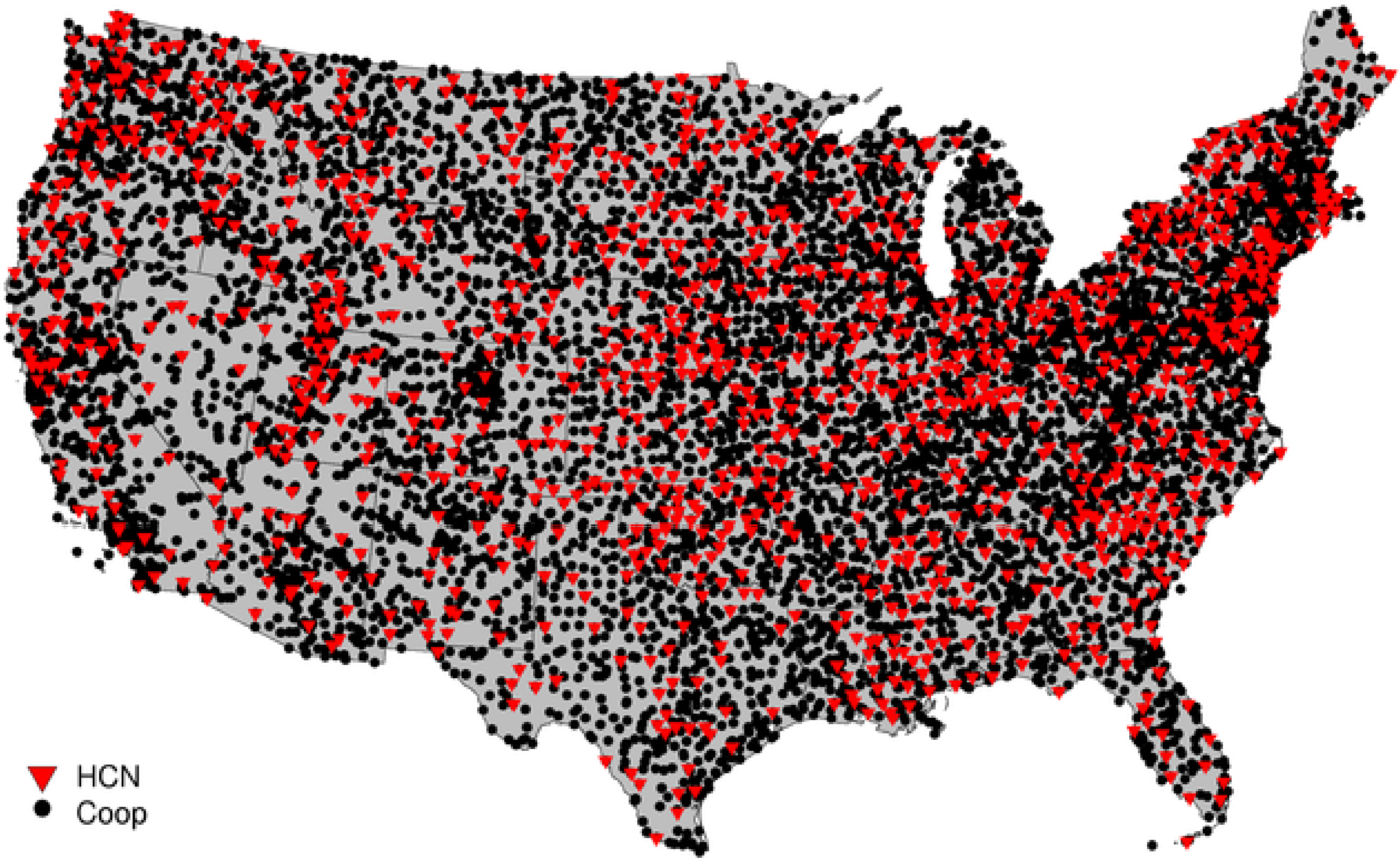
Changes in the Time of Observation



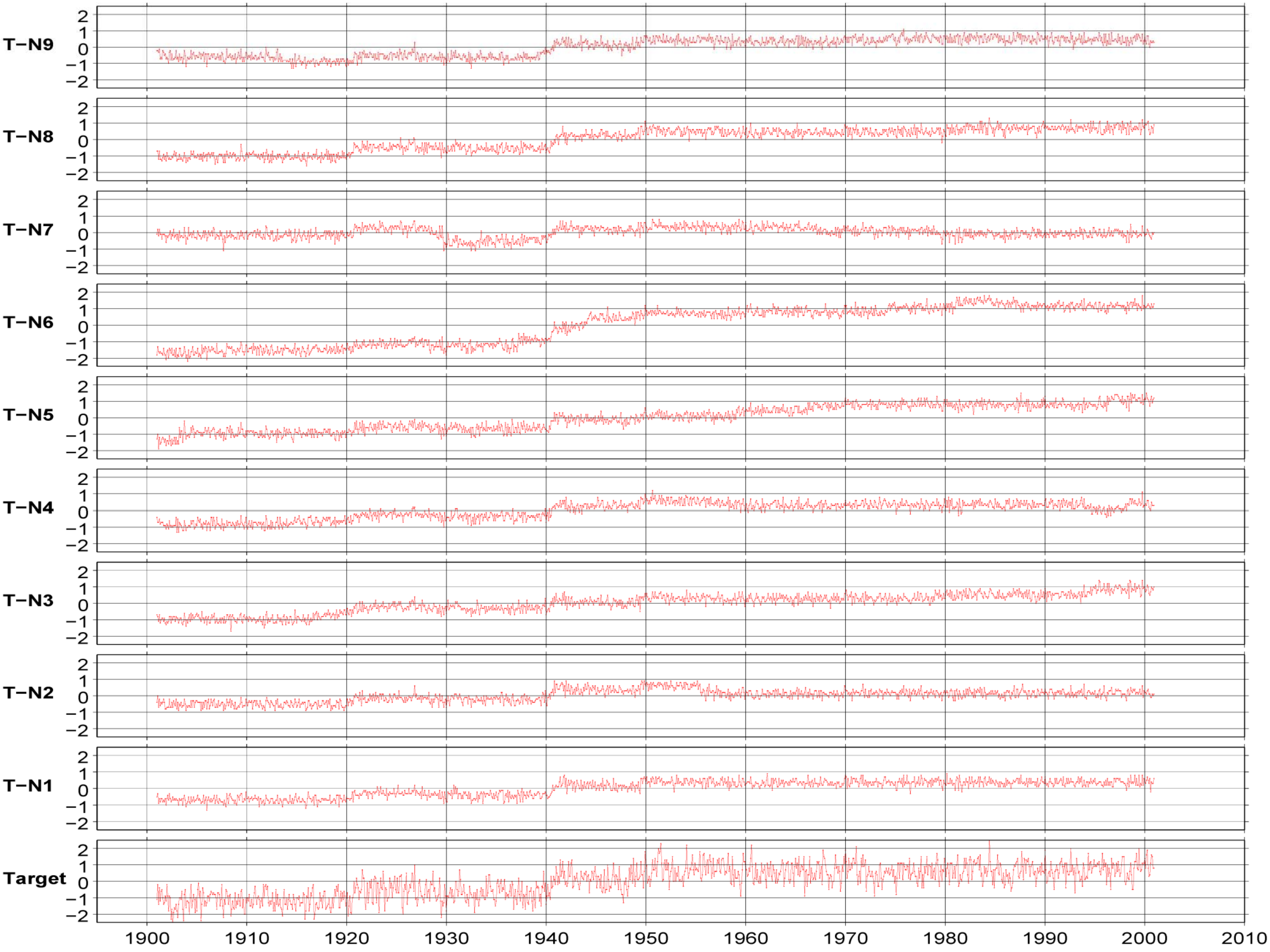
Hour of observation histograms for U.S. HCN stations at bottom of each U.S. decadal map (Figure courtesy of Xioamoa Lin, University of Nebraska-Lincoln)

U.S. Cooperative Observer Network Stations

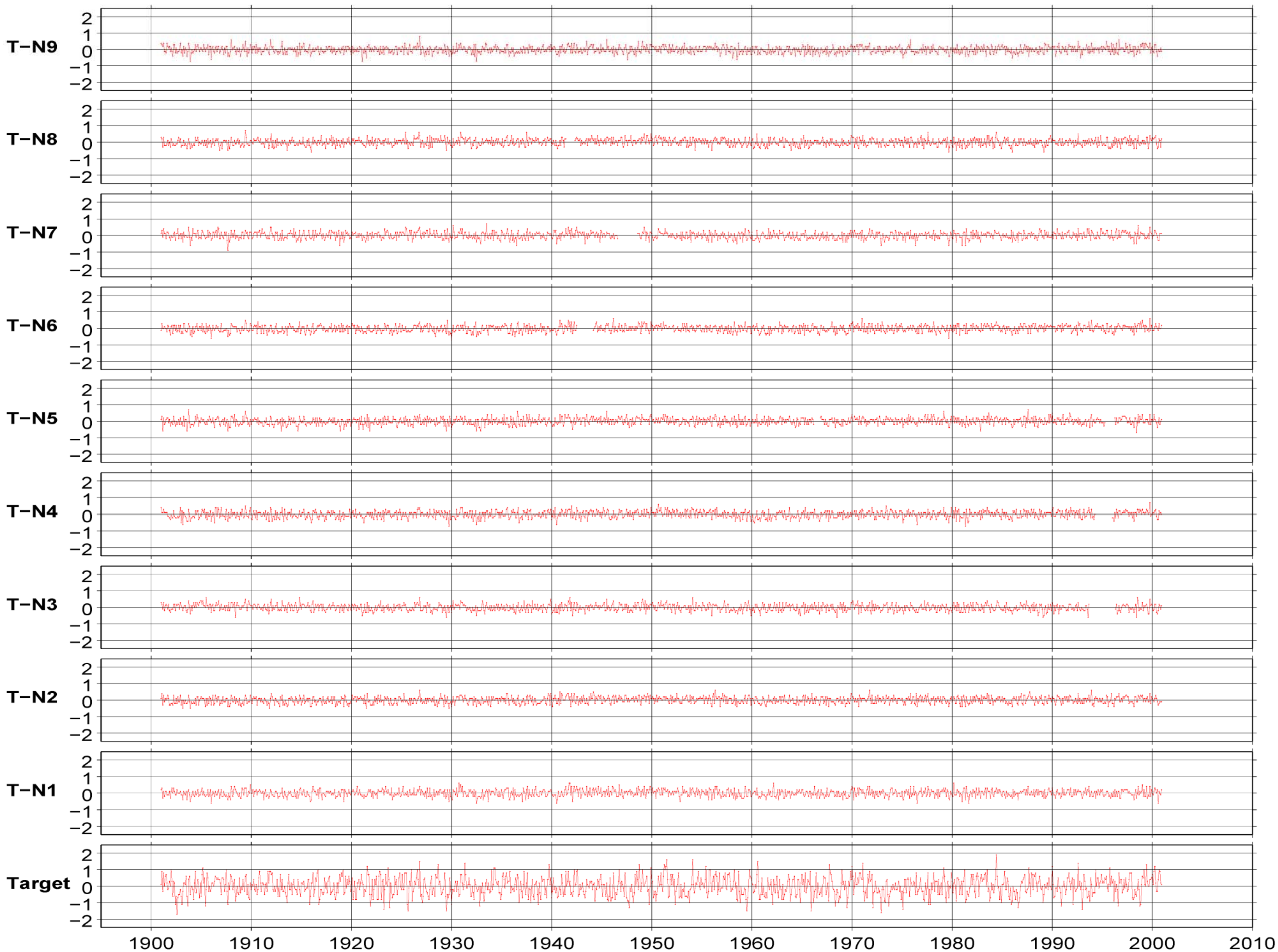
U.S. Cooperative Observer Network



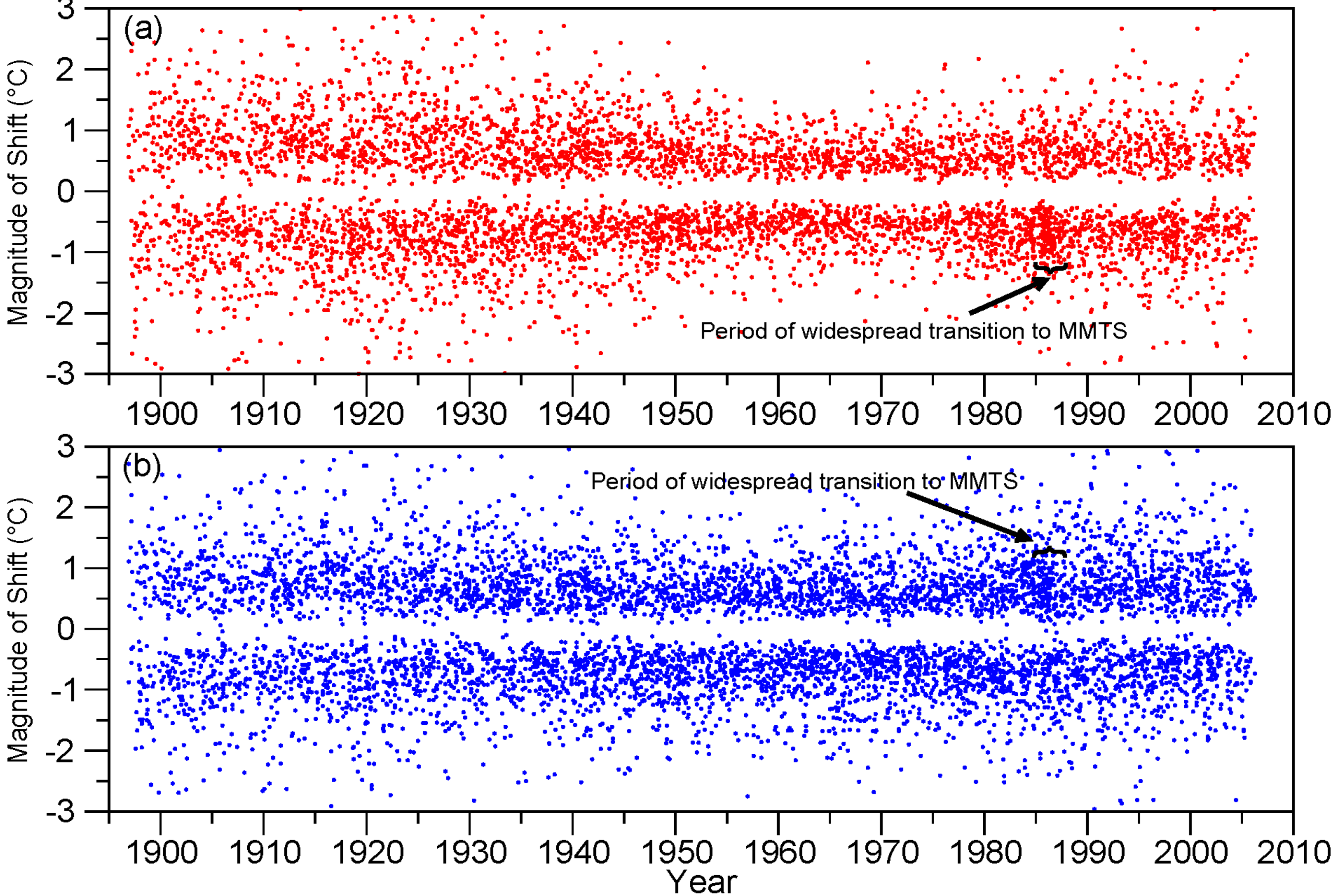
Target series and differences with neighbors before adjustment for undocumented shifts

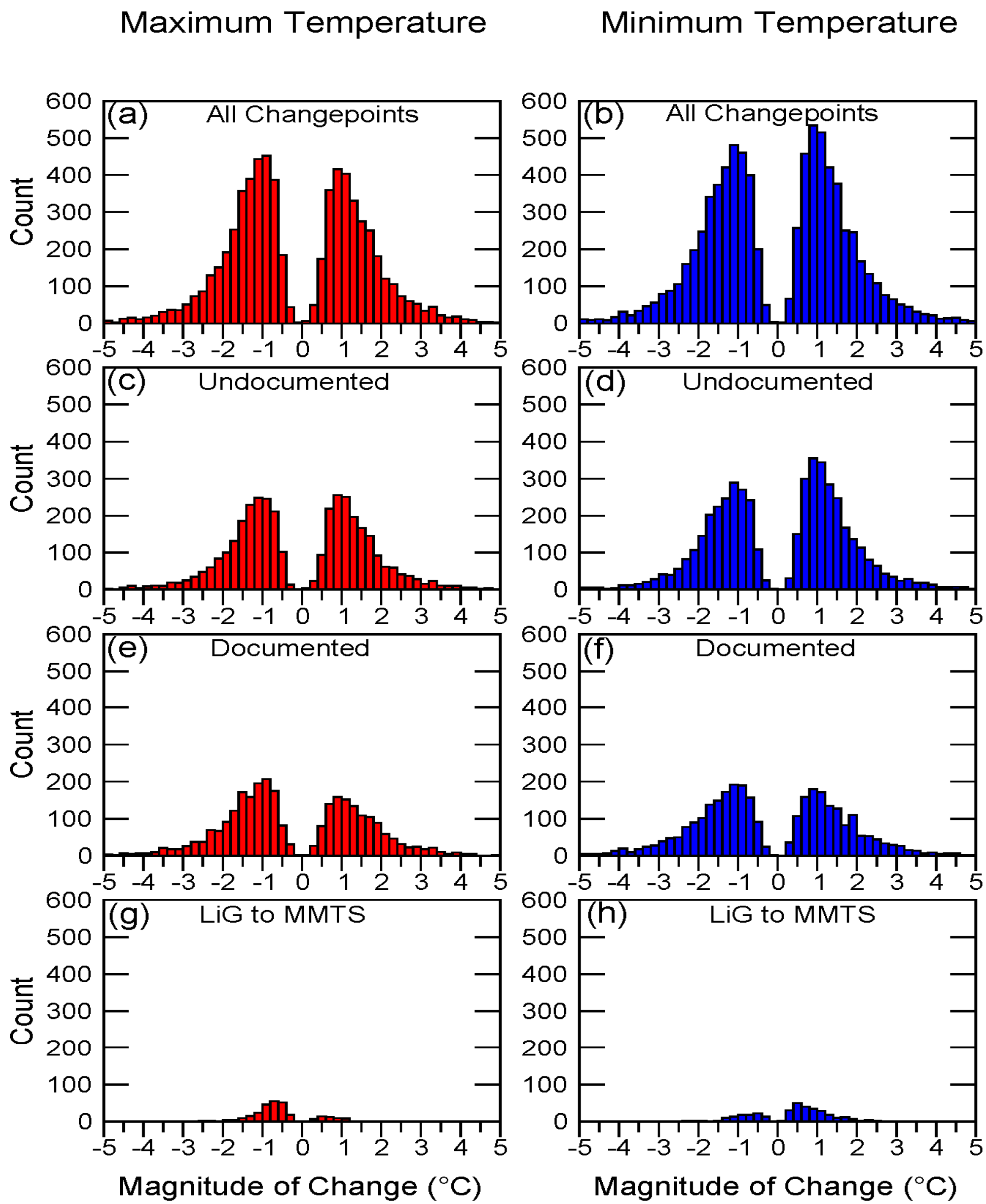


Target series and differences with neighbors after adjustment for undocumented shifts

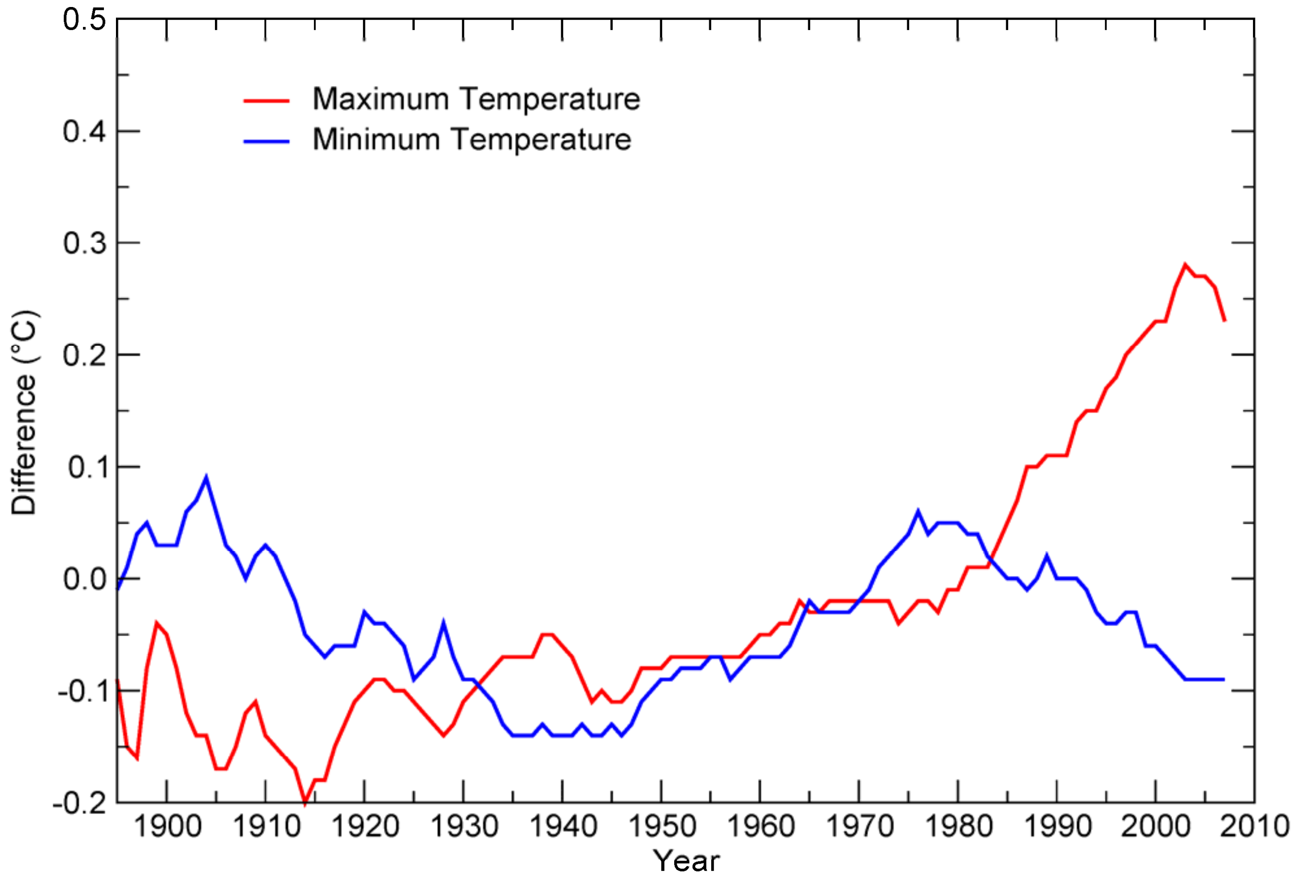


Detected shifts in U.S. HCN mean monthly (a) maximum and (b) minimum temperature series. A negative value indicates that the inhomogeneity led to a decrease in the mean level of the series relative to preceding values.

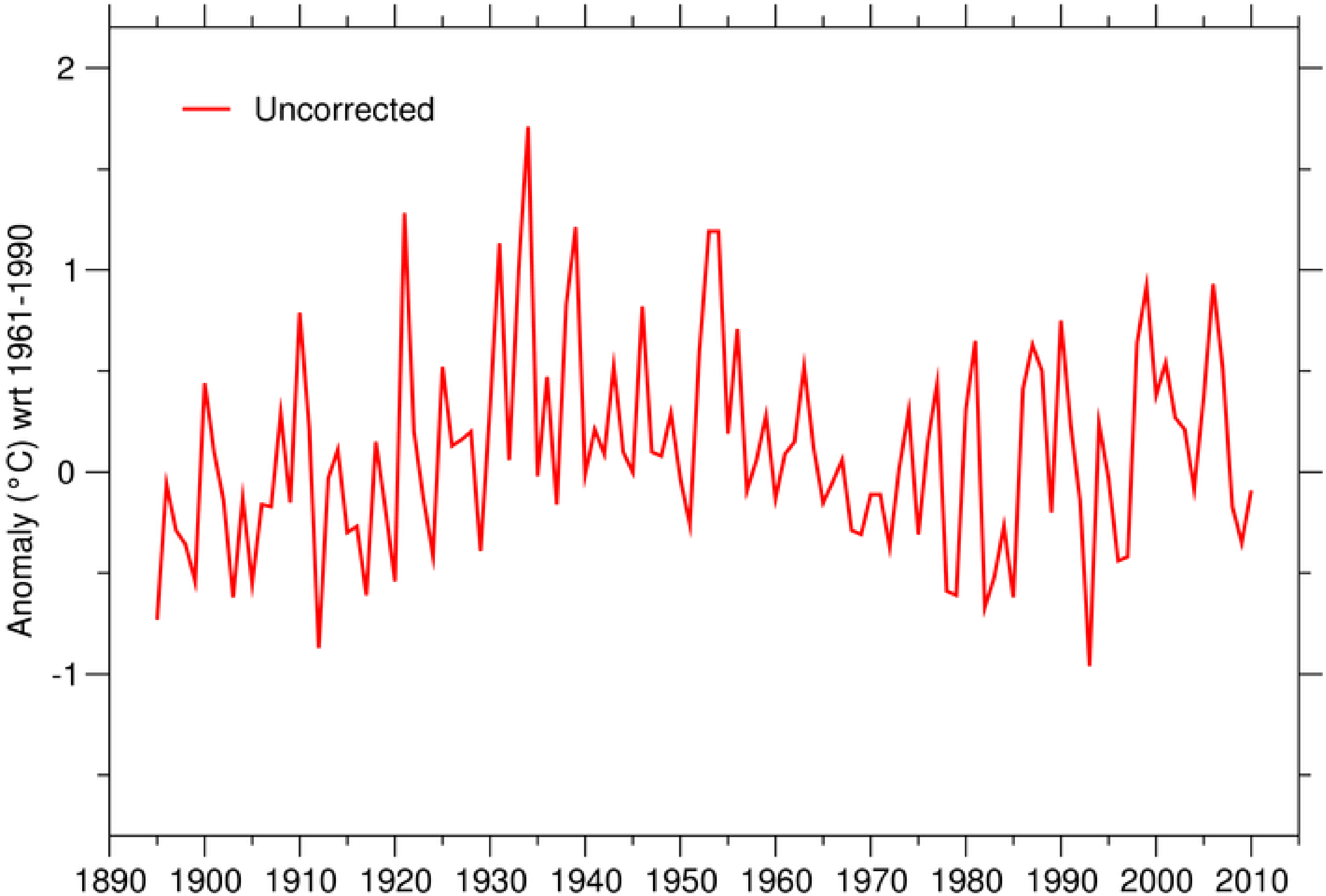



Maximum Temperature
Minimum Temperature
(a) All Changepoints
(b) All Changepoints
(c) Undocumented
(d) Undocumented
(e) Documented
(f) Documented
(g) LiG to MMTS
(h) LiG to MMTS
Count
600
500
400
300
200
100
0
-5 -4 -3 -2 -1 0 1 2 3 4 5
Magnitude of Change (°C)
Magnitude of Change (°C)

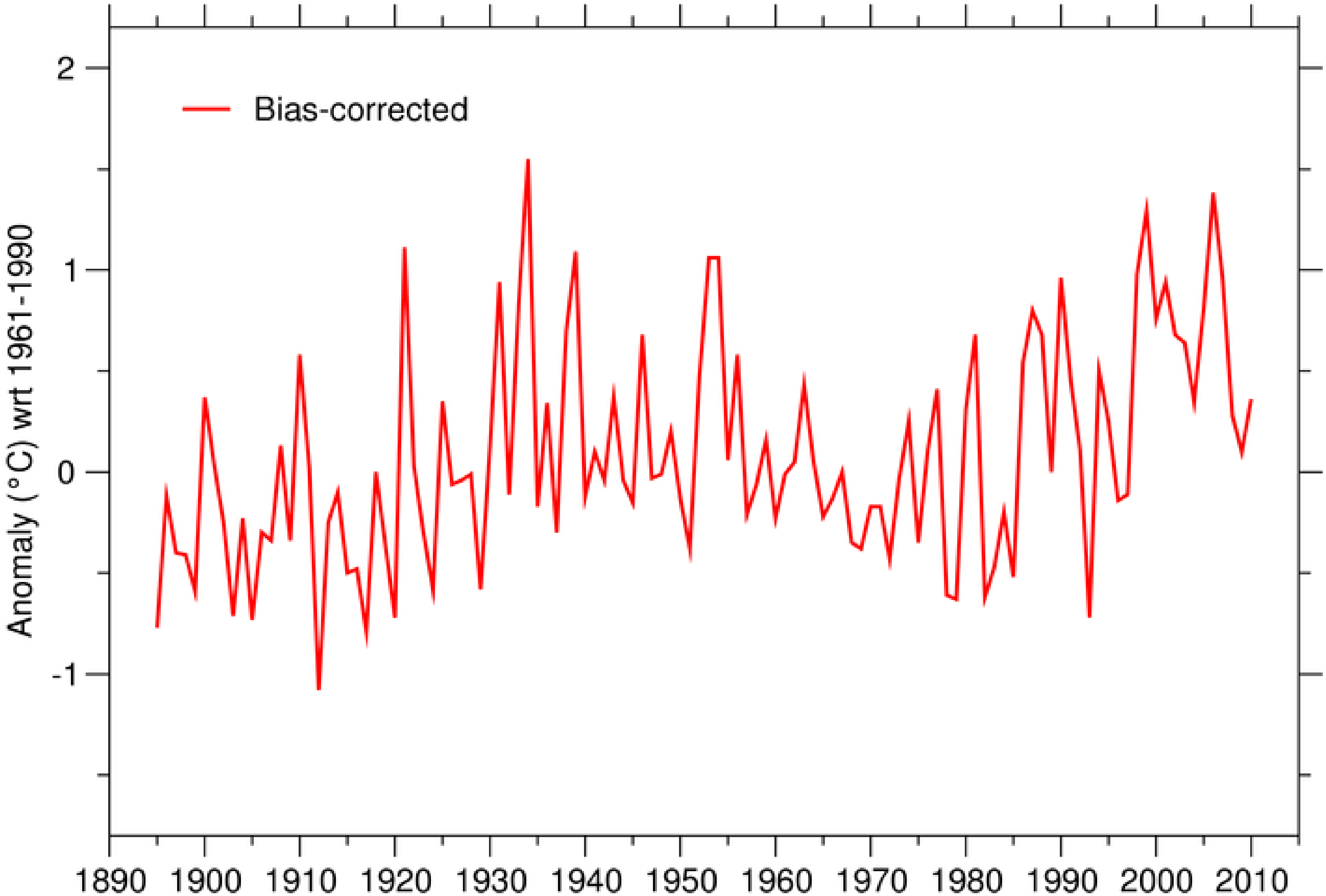
Average annual difference over the United States between the fully adjusted (homogenized) USHCN temperature data and the data adjusted only for the time of observation bias



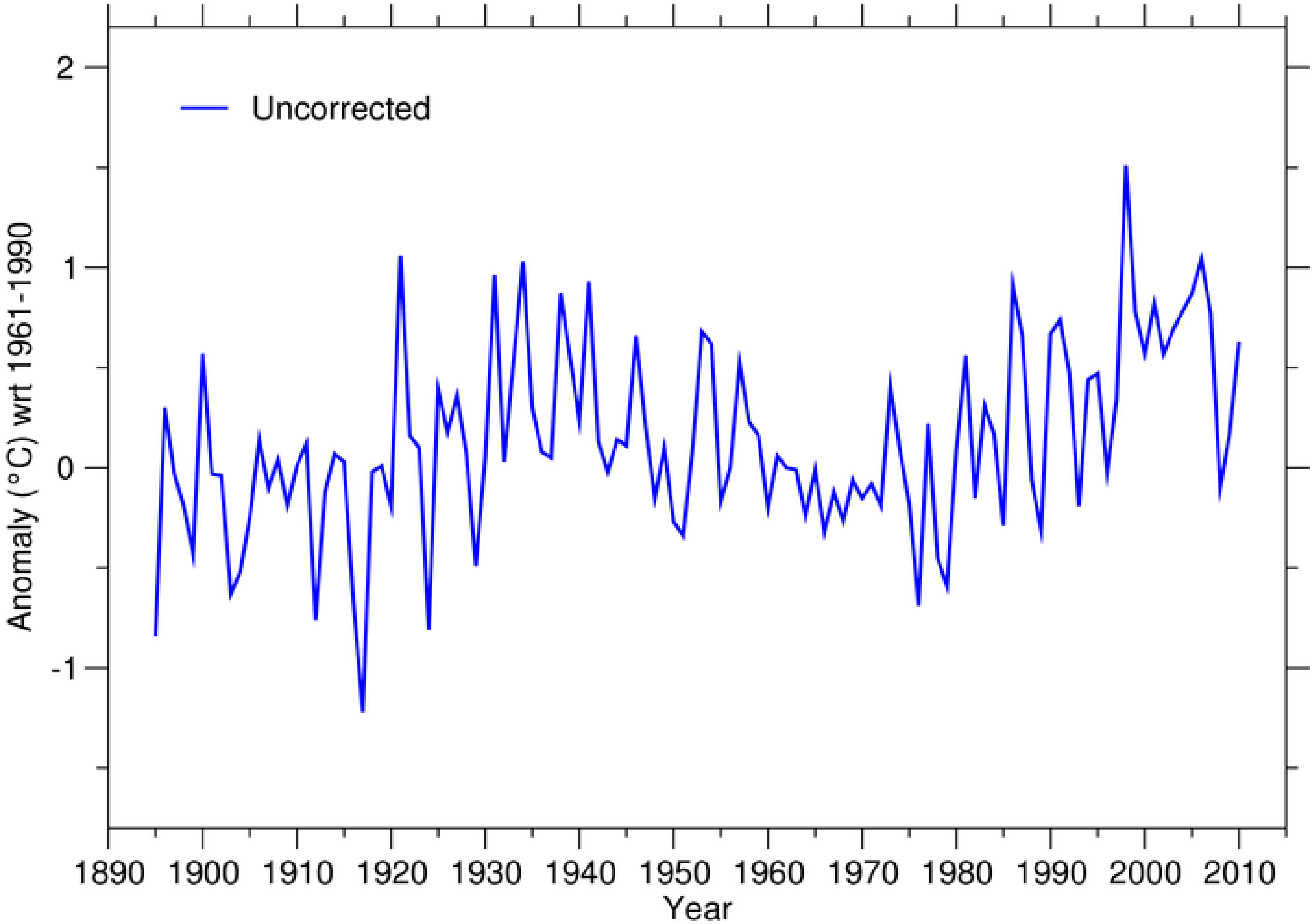
Average across CONUS - Tmax



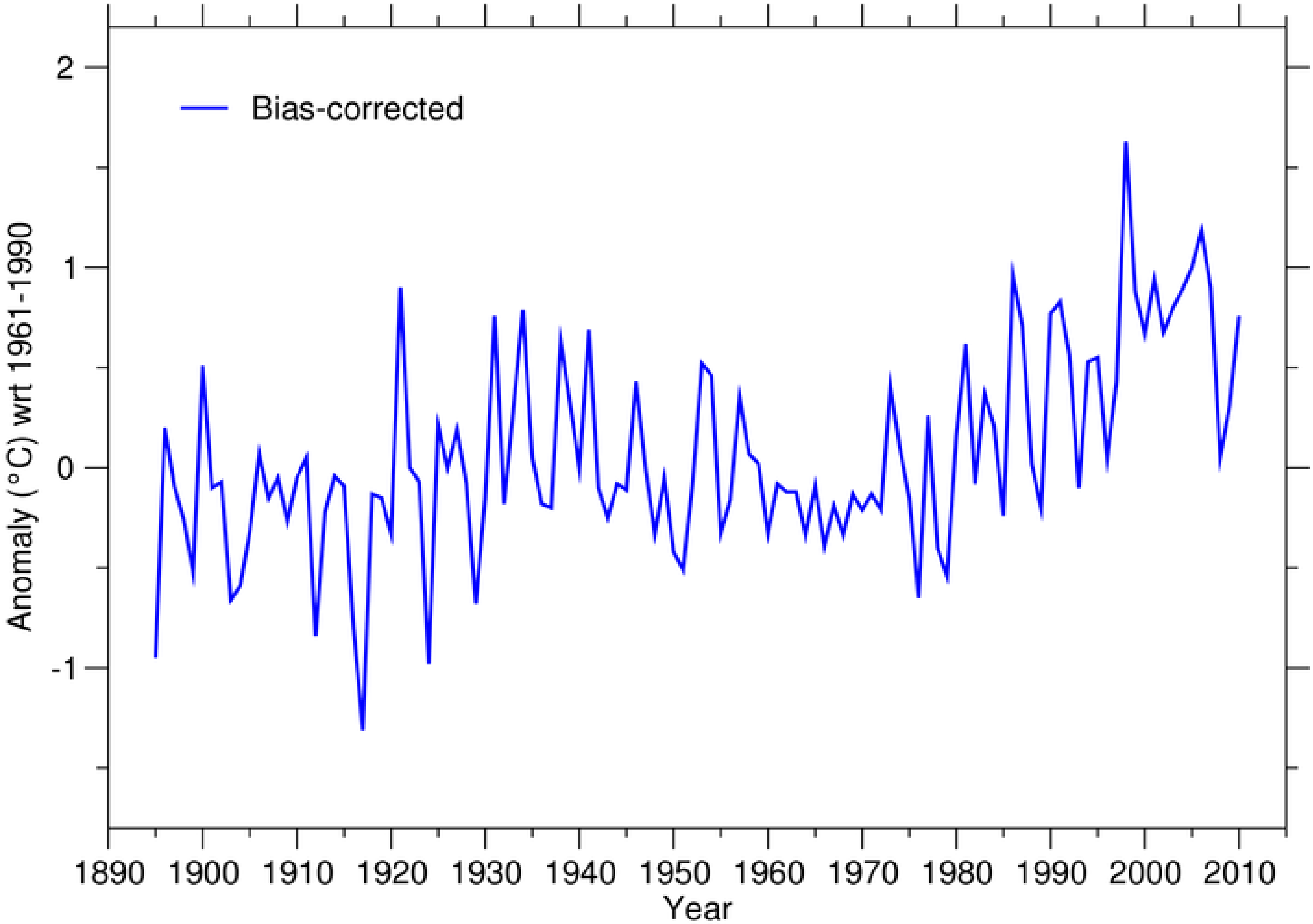
Average across CONUS - Tmax

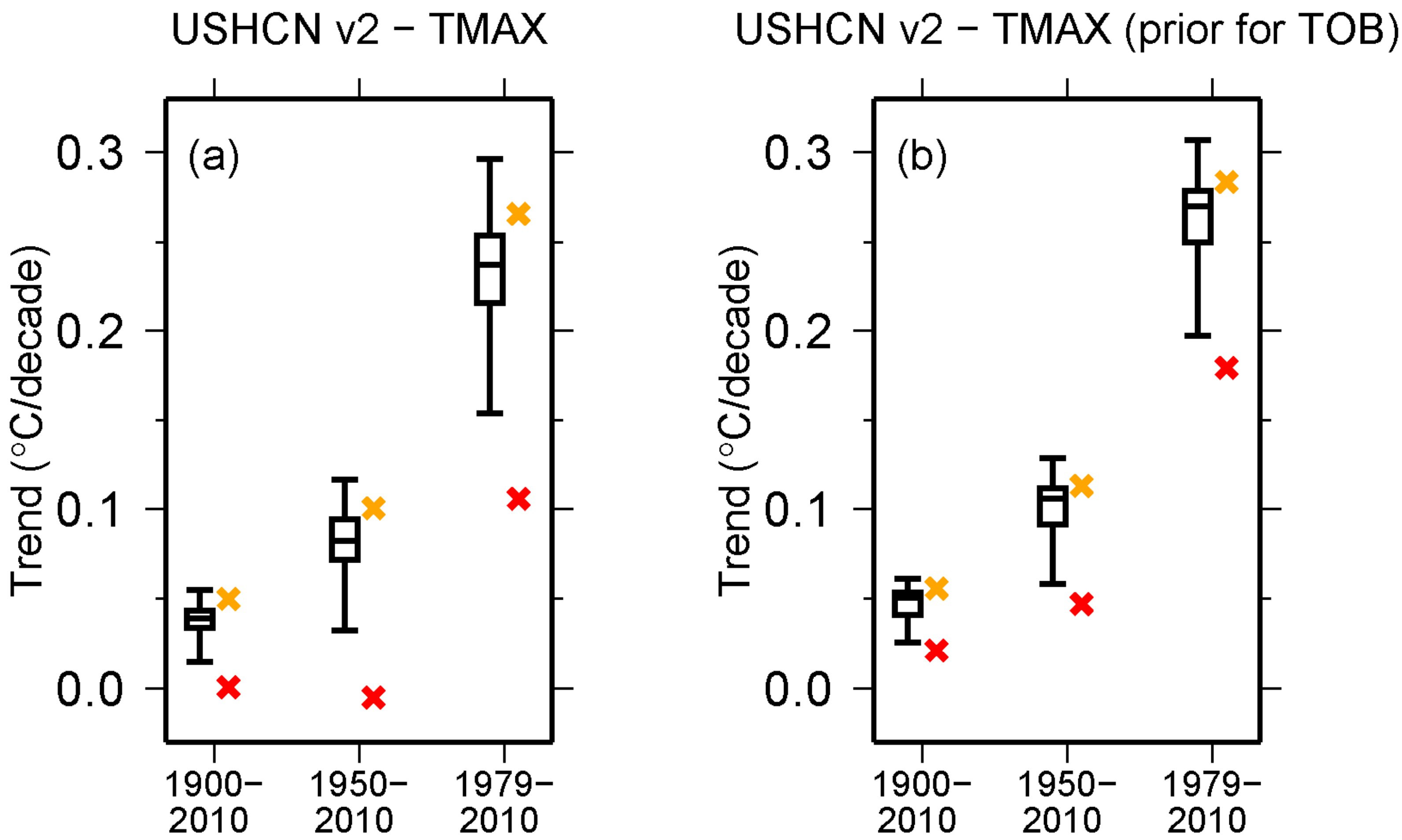


Average across CONUS - Tmin

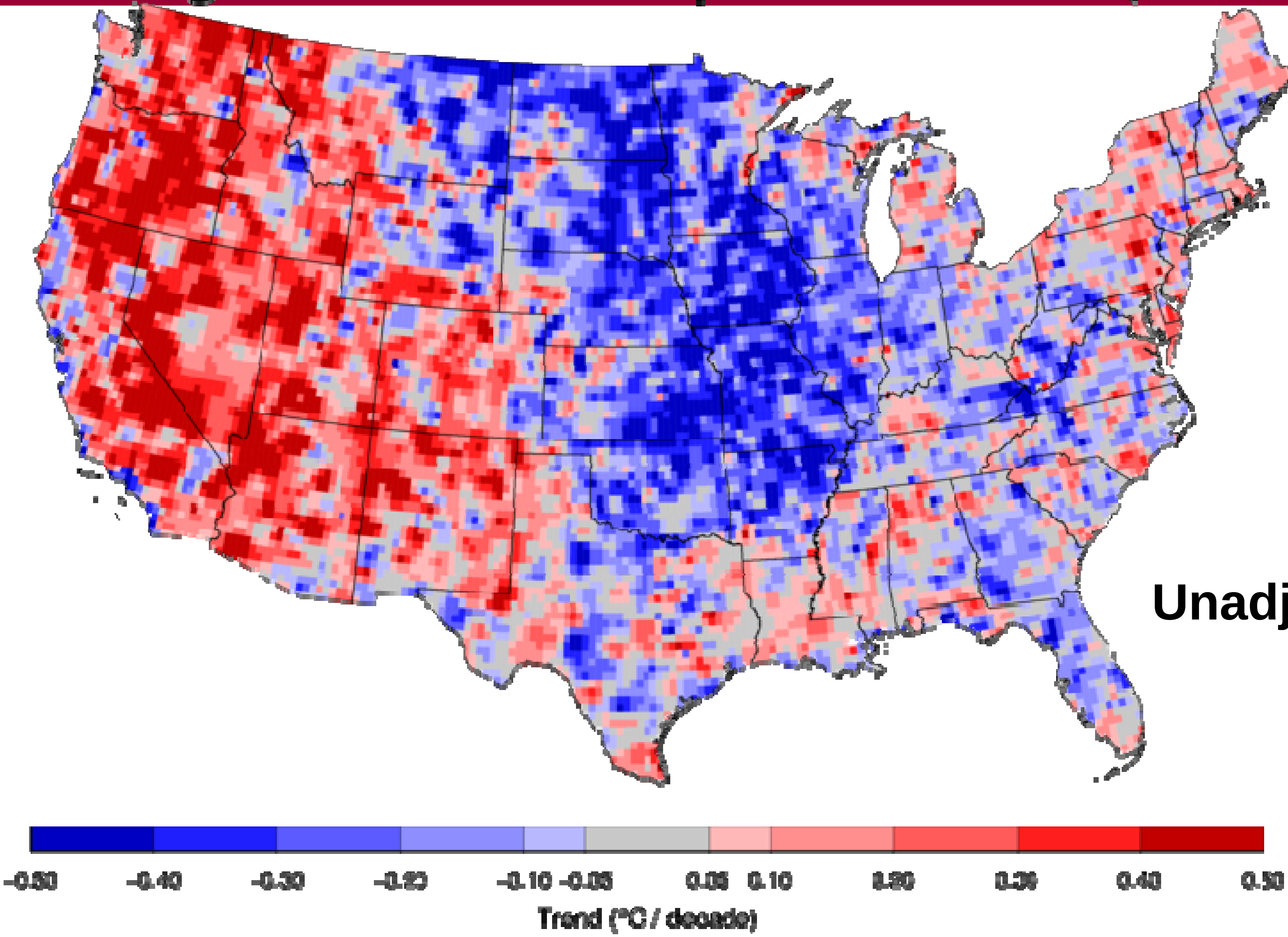


Average across CONUS - Tmin



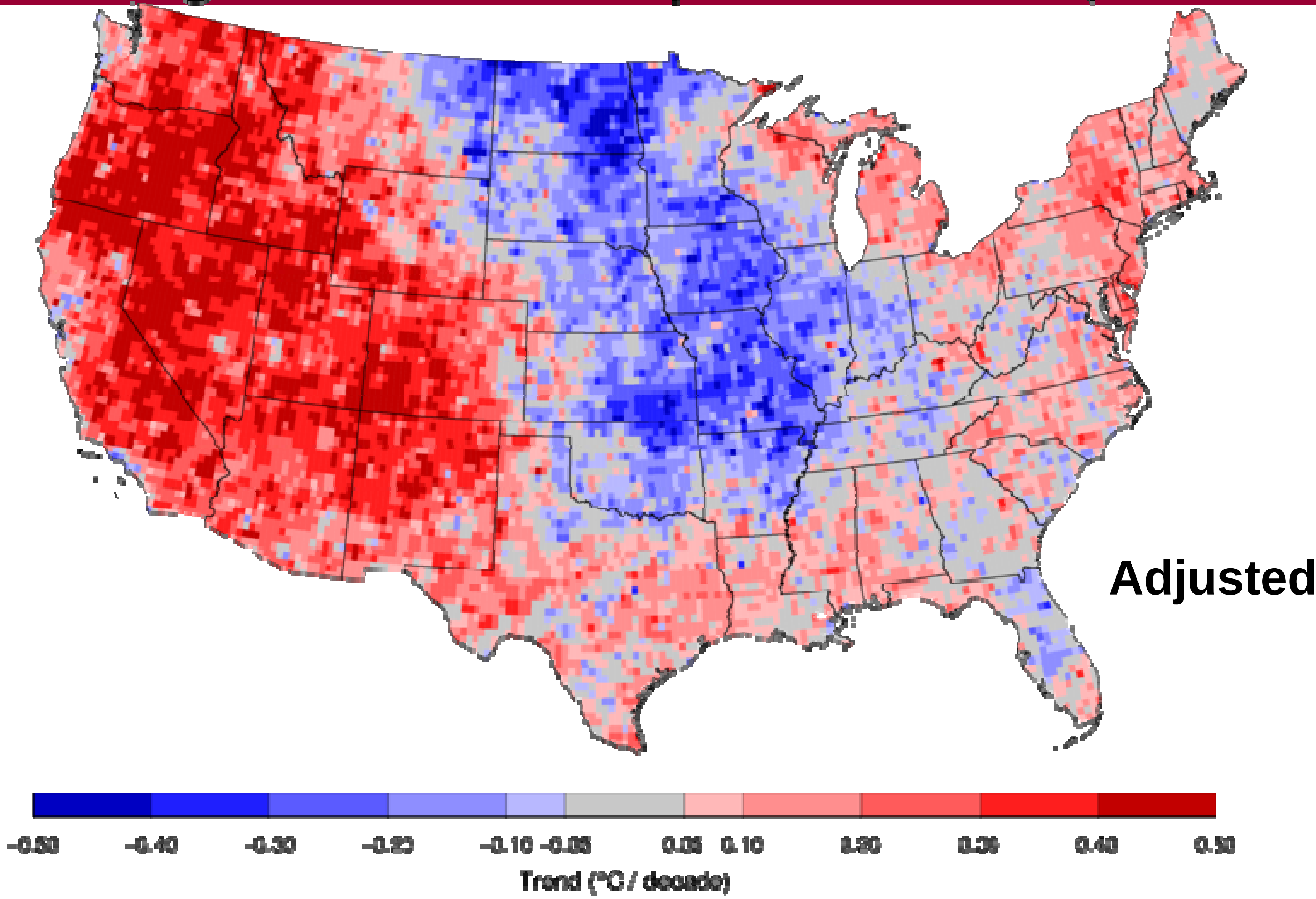

USHCN v2 − TMAX
(a)
0.3
0.2
0.1
0.0
Trend (°C/decade)
1900−
2010
1950−
2010
1979−
2010
USHCN v2 − TMAX (prior for TOB)
(b)
0.3
0.2
0.1
0.0
Trend (°C/decade)
1900−
2010
1950−
2010
1979−
2010

June–August Maximum Temperature Trends (1979–2011)



Unadjusted

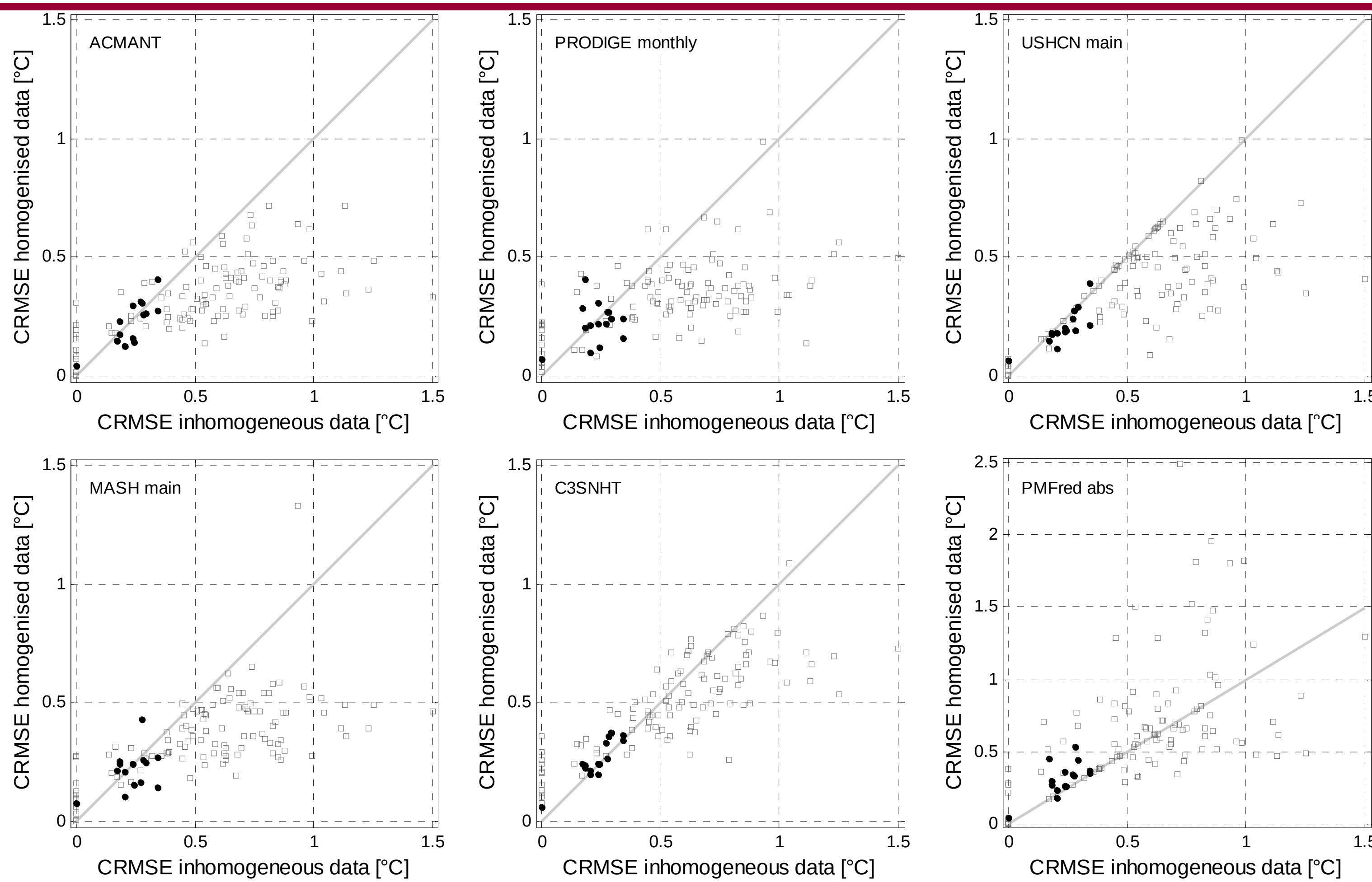
June–August Maximum Temperature Trends (1979–2011)



Ways to Address and Quantify Uncertainty

Benchmarking

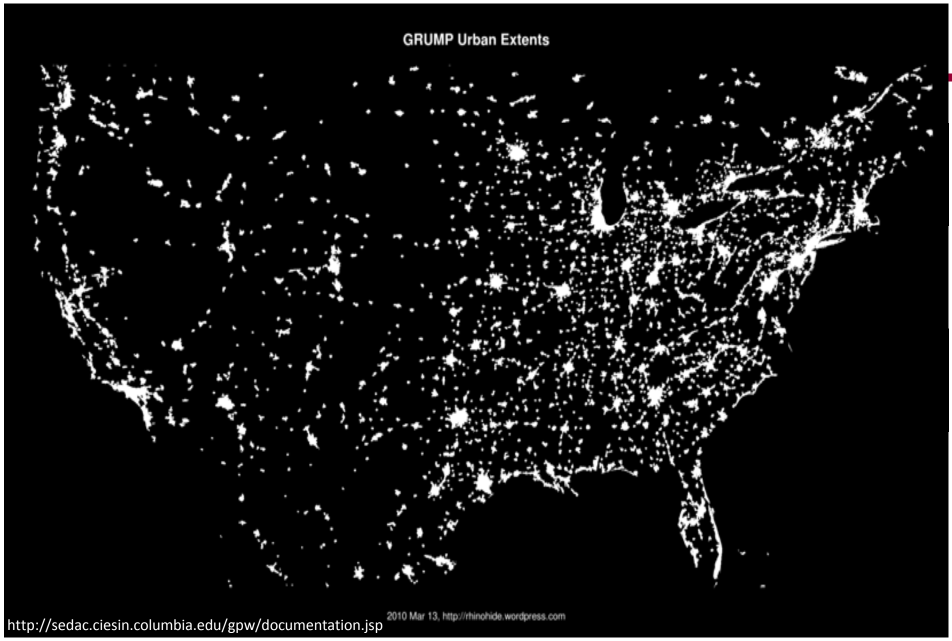
Benchmarking (“COST HOME”)



Scatter plot of the centered RMSE before and after homogenization for selected contributions to the COST HOME Monthly Benchmarking study. The squares display the errors of the stations; the dots show the errors of the network mean (regional climate) time series. Points on the bisect indicate no change, above the bisect the data is made more inhomogeneous, while below the bisect homogenization improved the homogeneity of the data (from Venema et al. 2011).

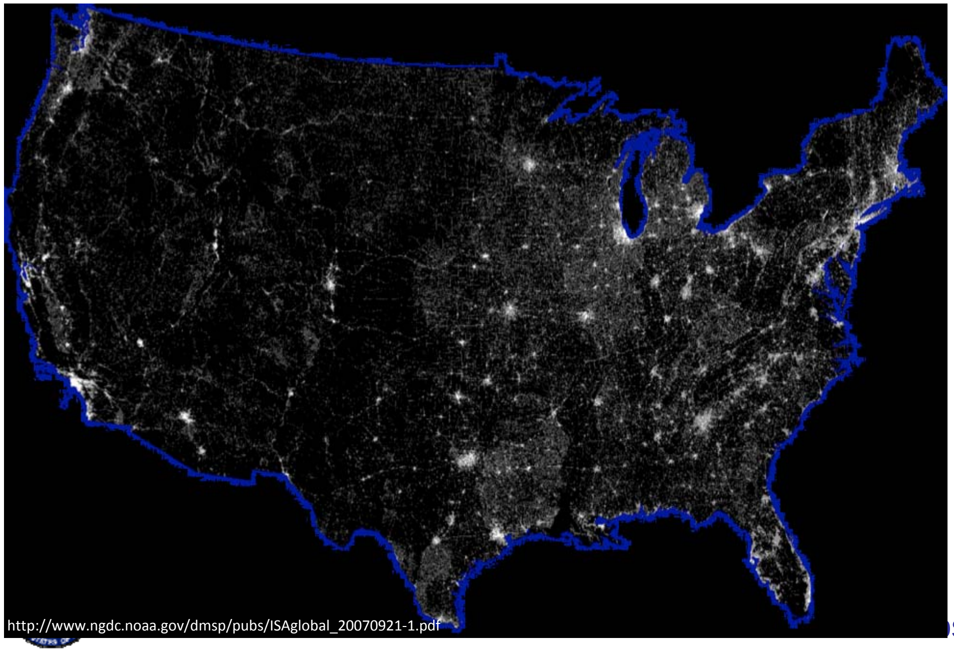
Multiplicity of Approaches

Urban Boundaries (GRUMP)

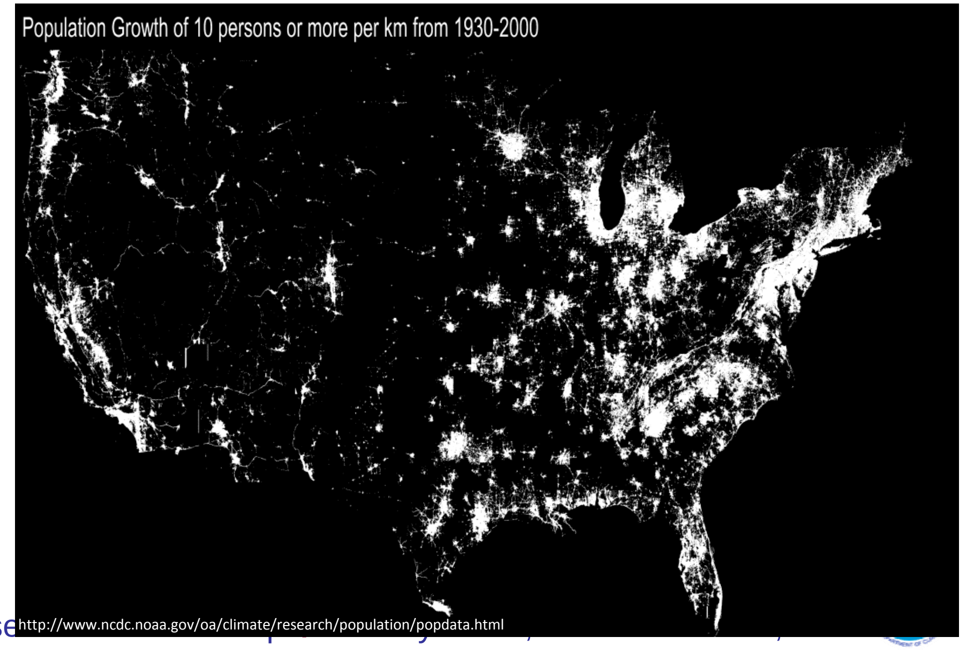


Satellite Nightlights (DMSP)

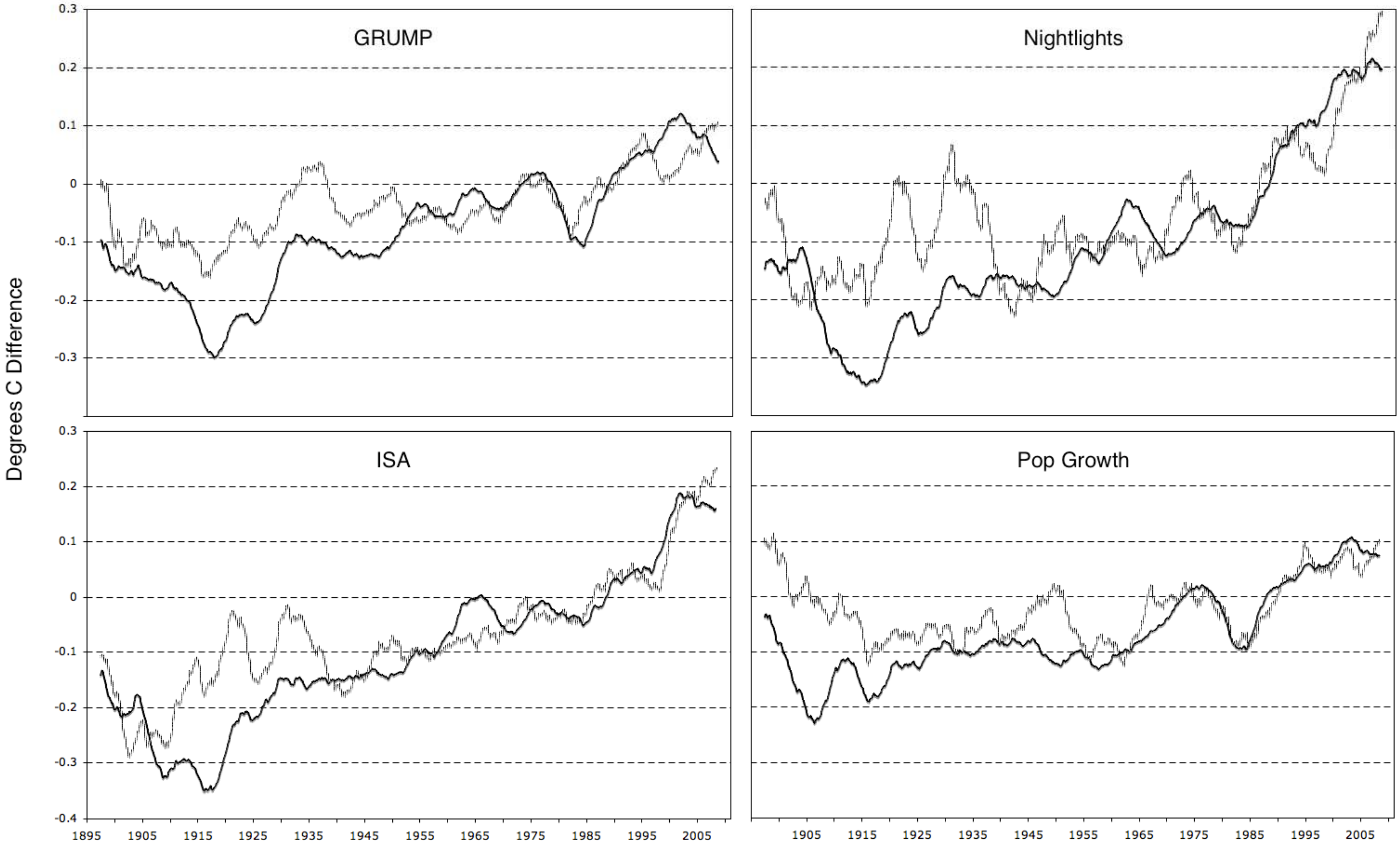
Impermeable Surfaces (ISA)



Population Growth (1930-2000)

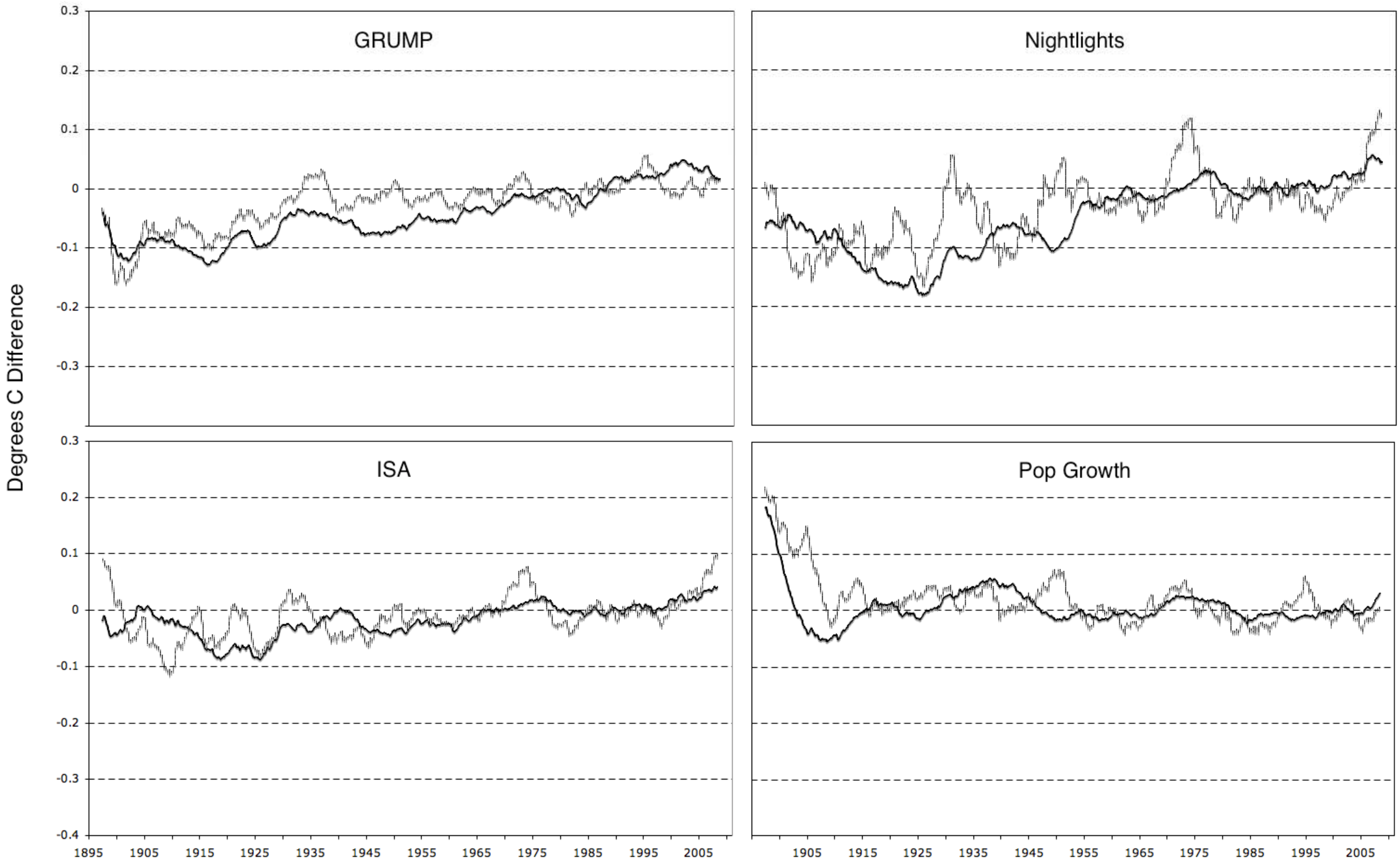


TOB-Adjusted Min Urban-Rural Differences



Running 5-year mean of urban and rural differences for time of observation-adjusted min USHCN station data from 1895 to 2010, using both station-pair (solid line) and spatial gridding (dashed line) methods for GRUMP, Nightlight, ISA (10%), and Population Growth urbanity proxies.

Homogenized Minimum Temperature Urban-Rural Differences



Running 5-year mean of urban and rural differences for all-coop homogenized min USHCN station data from 1895 to 2010, using both station-pair (solid line) and spatial gridding (dashed line) methods for GRUMP, Nightlight, ISA (10%), and Population Growth urbanity proxies.

Bayes Factor Approach to Break Detection

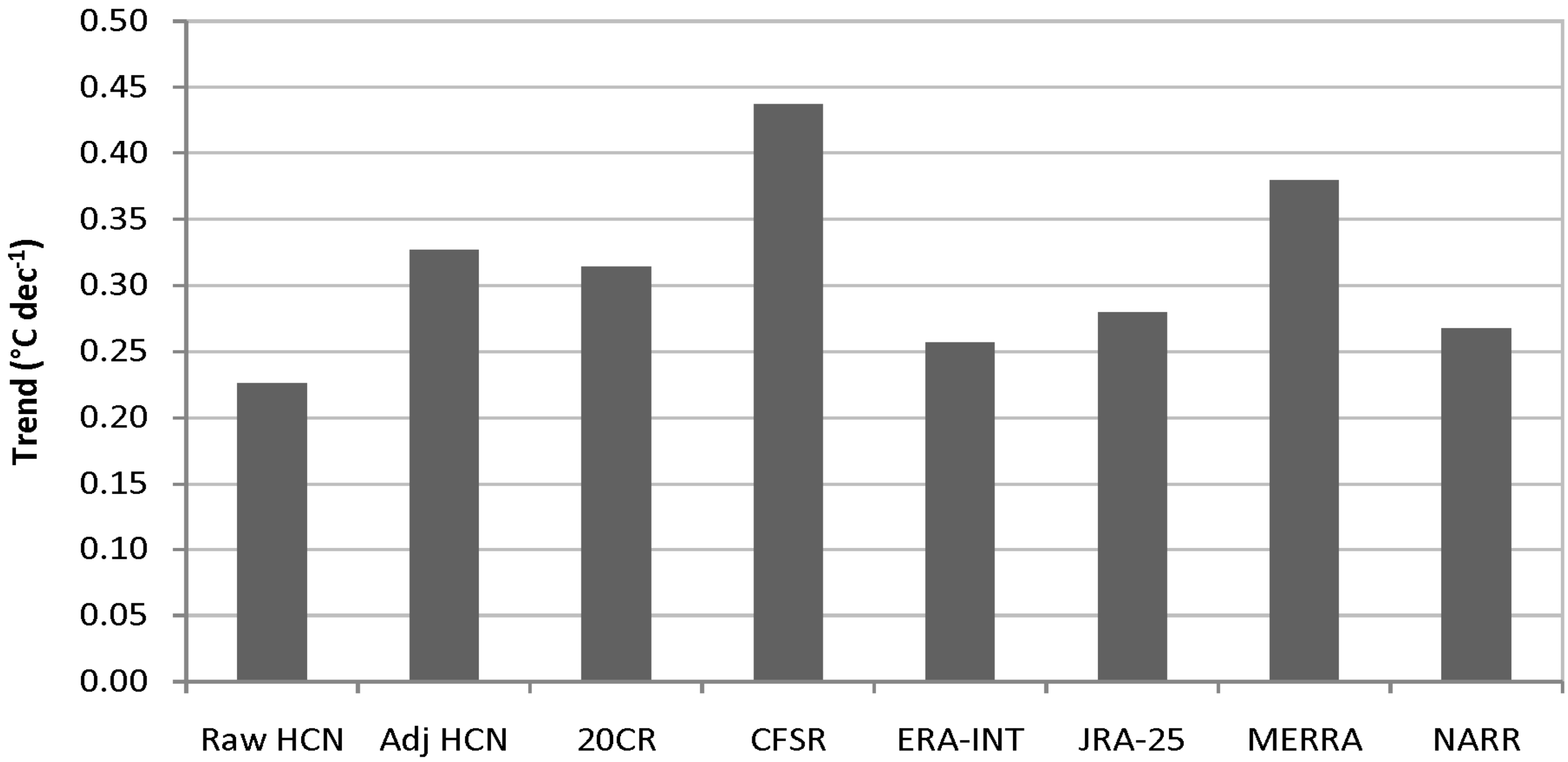
TABLE 2. Simulation 1: δ is the true size of a discontinuity, and $\hat{\delta}$ is the estimated size of a detected discontinuity. The detection rate is equal to the number of detected breaks divided by the number of total breaks and the false discovery rate is equal to the number of false detections divided by the number of the total detections. For detection rates, detected breaks and total breaks, the numbers in the first column are from the algorithm in this paper without the use of metadata and the numbers in the second column are from the current operational algorithm using metadata. The metadata describing the change dates are incomplete and not always accurate. See Table 1.

category	detection rates		detected breaks		total breaks	
$\delta \geq 1.0$	84.51%	73.11%	7150	6190	8461	8467
$1.0 > \delta \geq 0.5$	65.17%	57.71%	8188	7259	12565	12578
$\delta < 0.5$	17.29%	19.38%	3151	3535	18222	18240
all	47.11%	43.23%	18489	16984	39248	39285
category	false discovery rates		false detection		total detection	
$\hat{\delta} \geq 1.0$	1.11%	4.39%	85	318	7630	7251
$1.0 > \hat{\delta} \geq 0.5$	10.12%	6.45%	971	494	9597	7653
$\hat{\delta} < 0.5$	38.02%	20.40%	1422	741	3740	3633
all	11.82%	8.38%	2478	1553	20967	18537

From Zhang et al. submitted

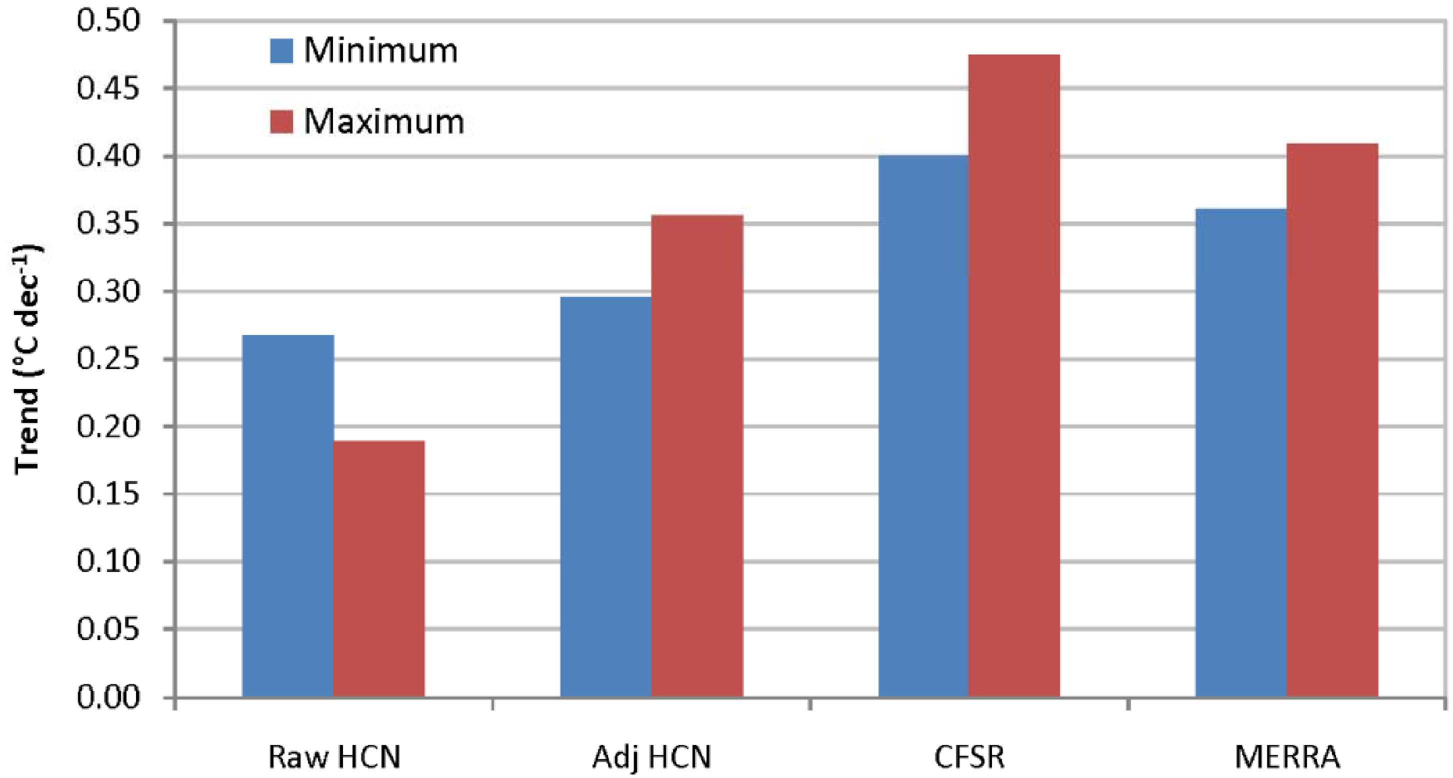
Comparisons with Independent Datasets

Reanalysis



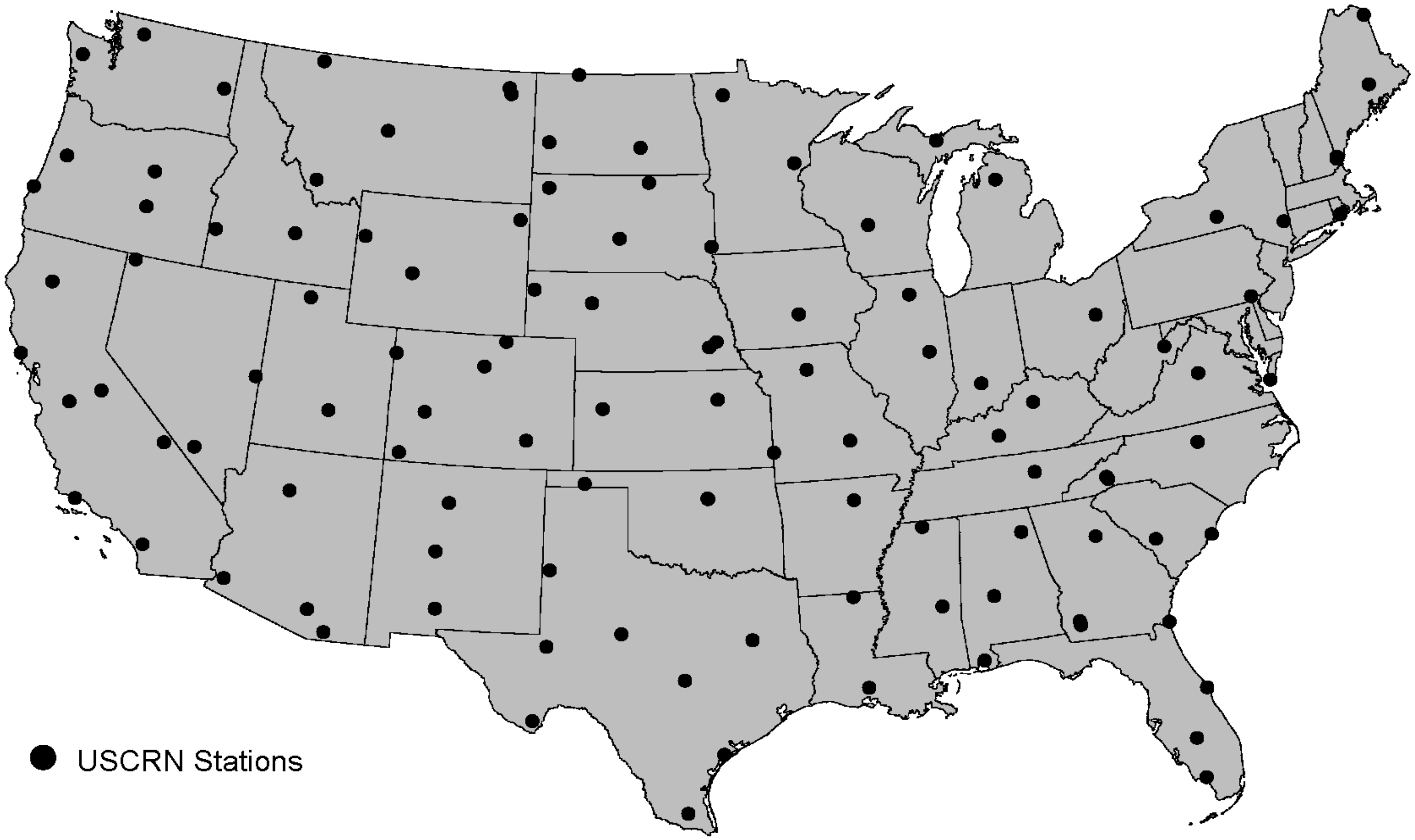
Least-squares trends (°C dec^{-1}) in mean annual maximum and minimum temperature over the conterminous United States during the period 1979-2008. All trends are significant at the 0.05 level. From Vose et al. (in review)

Reanalysis

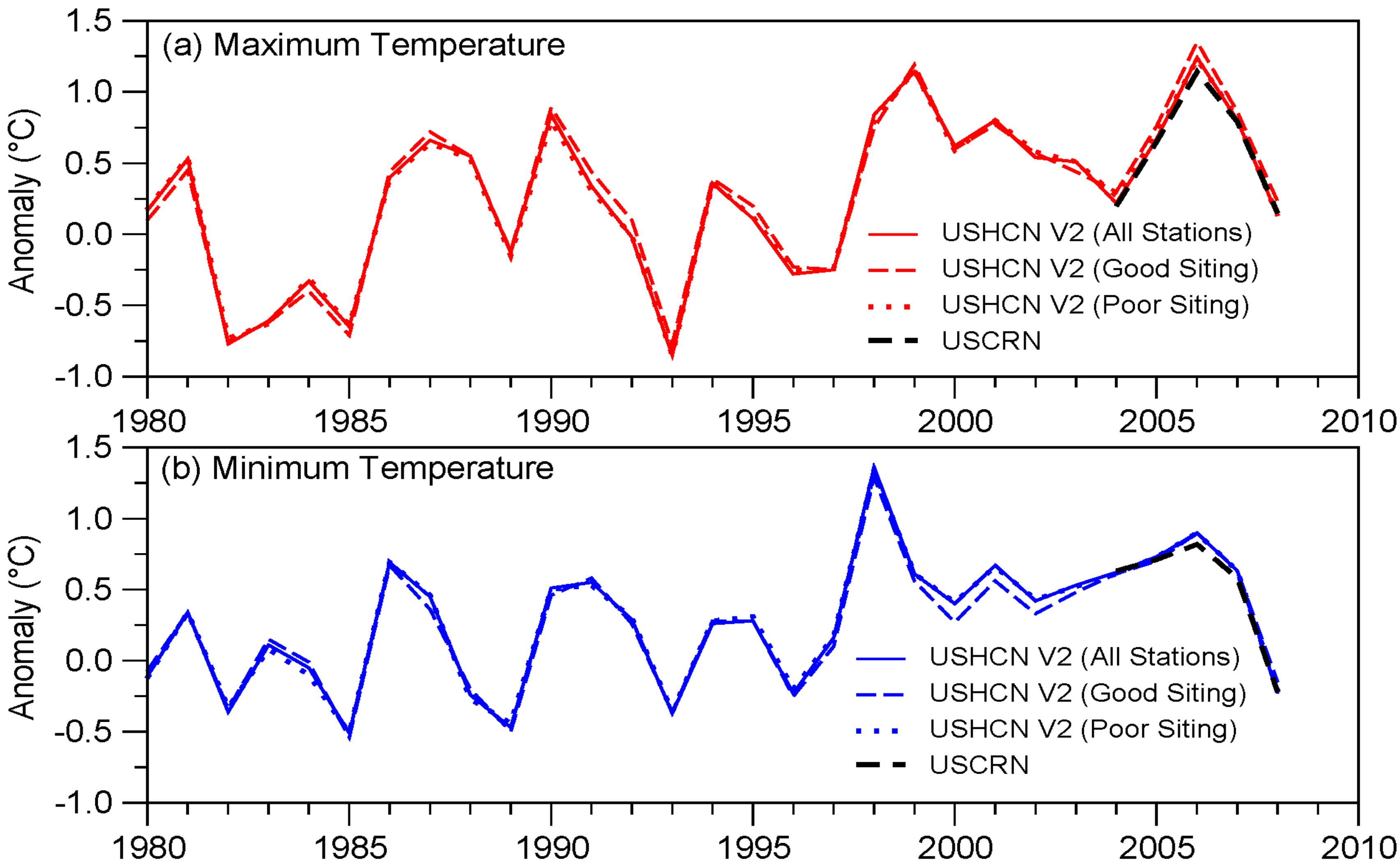


Least-squares trends (°C dec^{-1}) in mean annual maximum and minimum temperature over the conterminous United States during the period 1979-2008. All trends are significant at the 0.05 level. From Vose et al. (in review)

The Climate Reference Network



Annual Average Maximum and Minimum Temperature Anomalies (Conterminous USA)



This is just the beginning…

How you can help

- Come up with novel ways of analyzing the data
- Partake in the benchmarking exercise
- Help construct a more comprehensive uncertainty model
- Provide constructive feedback
- (Even help to find raw data sources)