THIRTEENTH SYMPOSIUM ON GLOBAL CHANGE AND CLIMATE VARIATIONS

3.9 109-YEAR RECORD OF SURFACE TEMPERATURES IN N. ALABAMA

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1. INTRODUCTION

Every State Climatologist receives numerous and diverse requests for climate information. We often work closely with local and state Development Offices to provide data for potential businesses which must factor in the costs and benefits of climate impacts on their operations. Most requests however come from the media who ask for the most accurate and up-to-date perspective on some type of recent or developing climate anomaly, i.e. has it been this hot before? Is this the hottest summer?

Hampering our ability to answer these requests is the lack of consistently-observed weather variables over the time-scale of a century so that probabilities of events which occur on the order of a few per century may be estimated with some confidence. Customers expect that since Alabama's Office of the State Climatologist is located in Huntsville their requests which deal with temperature in the local area of N. Alabama should be easily accommodated. Unfortunately, this is not the case.

2. DATA AND METHOD

We calculated for every station near Huntsville the summer monthly average (June, July, August or JJA) of the daily maximum temperatures. Then, a deliberately simple technique was applied to produce a complete, homogenized time series to attempt in answering the question, "When was the hottest summer?"

To construct the time series, 13 stations within a 45 km radius of the current NWS site were initially used. These are referred to as the "Near" stations. We also selected 5 stations outside this radius (50 to 85 km or "Far" stations) and again applied the merging technique, creating an independent set of data (Fig. 1).

Observations and metadata were obtained for these 18 stations from (a) National Climatic Data Center's (NCDC's) Climatological Data publications on paper and microfiche, (b) Southeastern Regional Climate Center website, (c) original handwritten paper forms in Alabama's Office of the State Climatologist and (d) U.S. Army data from Redstone Arsenal.

The idea behind the homogenization technique is to identify points in time for each station at which a change of some sort occurred, called a segment break-point. A single station may have a number of segment break-points so that its entire record becomes a set of segments each of which requires some adjustment to make a homogeneous time series. Initially, segment breakpoints were identified in every case when one of the following situations occurred, (a) station move, (b) change in time of observation and (c) clear indication of instrument change.

Much of this break-point information was gathered through reading the original handwritten forms, page by page, on which observers or government validators made notes in the margins. This significant human intervention was required since much of the metadata information (i.e. handwritten notes) on each form is nowhere digitized for easy access. This procedure converted the time series of the 13 *Near* stations into a total of 46 individual segments (Table 1.) However, 2 other break-points of unknown origin were evident after the first reconstruction, so these were included.

Other methods to account for inhomogeneities have been devised and applied to surface data such as these. Perhaps the standard for homogenizing U.S. temperature data has been developed by scientists at National Climatic Data Center (Peterson et al. 1998.) More recently, Hansen et al. (2001) have combined some of Peterson et al.'s adjustments with their own assessments which account for missing data and urbanization. Because these other methods are intended to produce homogeneous time series for large geographic averages, the adjustments are generally systematized for the entire domain. Our study focuses on a very small subset of stations and thus we elected to determine individual, station-specific segment adjustments.

To enhance confidence in the pre-1940 data, which has only 2 stations in the *Near* network, we selected the "best" station from the *Far* network – Florence (FLOR) - which provides data from 1893 to 1979 in 11 segments. So, for the *Near* network average JJA maximum

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temperature we utilize 59 segments determined from the 14 stations. The assumptions are as follows in applying the merging technique for the 59 segments:

- Each segment is a homogeneous time series and differs from other segments by a simple bias.
- Spurious trends over a segment are small and random.
- The calculated segment bias is the same for each of the months June, July and August.
- Remaining time-varying differences between stations are due to random fluctuations in the natural variability of temperatures over the region and to random errors in the measurement systems (including the effect of missing observations).

To merge the individual segments we calculated and removed biases determined during overlapping periods-of-observation with other segments. The individual segment biases were determined by a cumulative/iterative technique in which a bias vector was constructed which related the bias of every segment to a single, reference segment (and thus to every other segment.) This is similar to a ranking system in sporting events which must accommodate the fact many teams have not played in head-to-head competition. We arbitrarily chose the latest segment of HSV1, the NWS Office, as the reference.

In Fig. 2 we show the comparison between the adjusted time series for the 13 *Near* stations and that of the *Near* stations plus FLOR (i.e. 14 stations) containing 48 and 59 segments respectively (both noted as “multiple” segments.) A third time series is included which assumes no discontinuities in each station record, or equivalently, that each station’s complete record is a single homogeneous segment (noted as “single” segments). The difference between this unadjusted time series and the 13 and 14-station networks is shown beneath. With the addition of FLOR, the adjustments are a bit smoother in the early part of the record for the multi-segment method. Also, the addition of FLOR has virtually no impact on the overall 108-year trend. Indeed in one additional computation, the values of ONEO were included so that four stations operating prior to 1940 were available, giving a total of 15 stations in the network. The 108-year trend differences between the 13, 14 and 15 station networks were less than 0.005 °C decade^{-1}, perhaps signifying some level of robustness in the technique.

The general result suggests that between 1893 and the 1920’s stations experienced spurious cooling (Fig. 2, lower). From the 1920’s to about 1970, spurious warming apparently occurred. Since 1970, temperatures have required little adjustment as determined by this method. It is important to note that virtually all of these stations would be considered rural in any reconstruction.

There are few avenues available to assess the confidence of the trend estimate. We are encouraged however that the differences in 109-yr trends of the 13, 14 and 15 station *Near* networks, having 2, 3 and 4 stations respectively in the 1893-1940 period, varied by less than 0.005°C decade^{-1}.

3. DISCUSSION

The completed time series of the JJA mean of the reconstructed local area-average of daily maximum temperatures is displayed in Fig. 3 with the individually-adjusted station values. With this result, I would respond to the “warmest year” question by saying that the year was probably 1925 (34.91 °C) though 1952 (34.75 °C), 1930 (34.74 °C), 1954 (34.72 °C) and 1936 and 1943 (both at 34.59 °C) are within the ±0.4 °C margin of error. The trend since 1893 is –0.13 °C decade^{-1}.

I would point out that none of the nearby stations operating in 1925 are in operation today and even if they were, many discontinuities have crept into the record as to raise suspicion. So, determining the year of the hottest summer is not a trivial matter and this is my best estimate. By the time this analysis method is described to answer the question posed, the inquisitor is generally confused and interest is lost.

Climate data records require estimated levels of uncertainty (NRC 1999, 2000). This single idea is manifestly difficult to transfer to the public and the media who believe “uncertain” often means “erroneous” or “useless.” The implication of this study is that we often cannot provide an absolute answer to the media and the public with the confidence they typically expect from scientists who deal with observations from scientific instruments. Finally, the reader is advised to be wary of pronouncements about extreme events, especially in localized areas (Pielke Sr. et al. 2000.) In perhaps more cases than we would admit, our ability to report an unambiguous extreme value is rather limited as shown by this simple example.

4. REFERENCES

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Table 1 List of homogeneous segments from 14 stations contained within the *Near* network. The full COOP number should include the state prefix 01 (e.g. 01-0390 for Athens). The reasons for designating each segment break-point relative to the previous segment (immediately above) are, “I” instrument change, “L” location change, “T” time of observation change, and “U” unknown. The bias vector **b** indicates the value to be subtracted from the raw temperatures of the segment so as to be consistent with segment #32 which is the current NWS Office in Huntsville.

Segment (**s**)	Station	COOP ID	First entry YYYYMM	Last entry YYYYMM	Reason	No. JJA Months Observed	No. Months Comparison	Bias relative to HSV1 (**b**)
1	**ATHE**	**0390**	**199106**	**199408**		**10**	**31**	**-1.78**
2	ATHE	0390	199506	199708	U	9	27	-0.28
3	ATHE	0390	199806	200008	T	9	27	-0.40
4	**ATN2**	**0395**	**195606**	**195608**		**3**	**14**	**0.29**
5	ATN2	0395	195706	196208	T	18	126	0.09
6	ATN2	0395	196306	198608	L	67	371	0.53
7	ATN2	0395	198706	198808	I,T	5	20	0.47
8	ATN2	0395	198906	199008	L	6	23	0.37
9	**BE2N**	**0655**	**195006**	**196208**		**39**	**200**	**0.74**
10	BE2N	0655	196306	197408	L,T	36	259	0.49
11	BE2N	0655	197506	199406	T	57	203	0.34
12	BE2N	0655	199407	200008	L	20	59	0.66
13	**DECA**	**2207**	**189306**	**190308**		**33**	**64**	**0.99**
14	DECA	2207	190406	191908	T	48	89	0.31
15	DECA	2207	192006	192708	T	24	44	-1.06
16	DECA	2207	192806	193308	T	18	34	-0.47
17	DECA	2207	193406	195408	T	63	145	-0.21
18	DECA	2207	195506	195608	L,T	6	26	0.02
19	DECA	2207	195706	195708	L	3	18	0.07
20	DECA	2207	195806	195908	L	6	41	0.22
21	DECA	2207	196006	196808	L	27	210	0.59
22	**D5SE**	**2209**	**199906**	**199908**		**3**	**12**	**-0.97**
23	FALK	2840	195608	196307		21	146	0.42
24	FALK	2840	196406	197008	L	21	157	0.32
25	FALK	2840	197106	197108	L	3	20	0.88
26	FALK	2840	197206	199206	L	60	245	0.44
27	**HSV0**	**4064**	**194006**	**194008**		**3**	**9**	**0.39**
28	HSV0	4064	194106	194508	L	15	30	0.02
29	HSV0	4064	194606	195406	L	25	63	-0.21
30	**HSV1**	**4068**	**195906**	**196708**		**27**	**209**	**0.66**
31	HSV1	4068	196806	199407	L	80	349	0.30
32	HSV1	4068	199408	200008	L,I	19	56	0.00
33	**MADI**	**4976**	**189406**	**190608**		**39**	**76**	**0.45**
34	MADI	4976	190706	191108	L	15	30	-0.08
35	MADI	4976	191306	191308	L	3	5	1.34
36	MADI	4976	191406	191508	T	6	12	0.73
37	MADI	4976	191706	194808	L	92	185	0.09
38	MADI	4976	194906	194908	T	3	6	0.44
39	MADI	4976	195006	195008	L,T	3	9	0.11
40	MADI	4976	195106	196206	L,T	34	175	0.33
41	MADI	4976	196306	197408	L,T	32	236	0.61
42	**MAYS**	**-**	**189306**	**189308**		**6**	**9**	**-0.49**
43	**NEW2**	**5867**	**195906**	**196108**		**8**	**61**	**0.05**
44	NEW2	5867	196206	196708	L	18	140	-0.41
45	NEW2	5867	196806	197506	L	19	127	0.34

46	**RED0**	**6833**	**195408**	**196908**		**45**	**314**	**-0.15**
47	RED0	6833	197006	197408	U	15	96	1.05
48	**RED1**	**-**	**198106**	**199908**		**54**	**190**	**0.83**
49	**FLOR**	**2971**	**189306**	**191208**		**64**	**116**	**0.03**
50	FLOR	2971	191306	191407	L	4	8	0.52
51	FLOR	2971	191408	192106	L,T	20	34	0.38
52	FLOR	2971	192107	193408	L,T	39	77	-0.47
53	FLOR	2971	193506	193508	T	3	6	-0.71
54	FLOR	2971	193606	194108	L	16	34	0.03
55	FLOR	2971	195407	195607	L	7	29	1.23
56	FLOR	2971	195608	196008	L	13	87	0.43
57	FLOR	2971	196206	196308	L	6	44	1.67
58	FLOR	2971	196406	196508	T	6	48	1.87
59	FLOR	2971	196606	197906	T	36	225	1.36

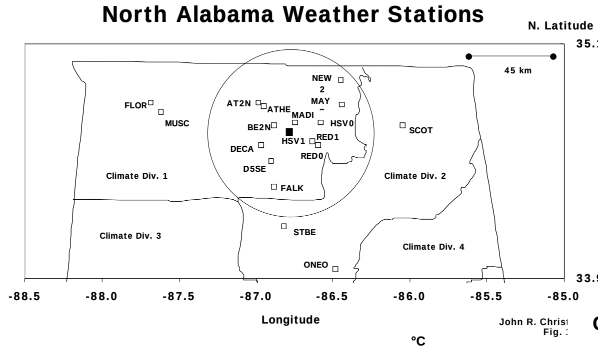

Fig. 1

Fig. 2

Comparison of Time Series of
Single vs. Multiple Segments

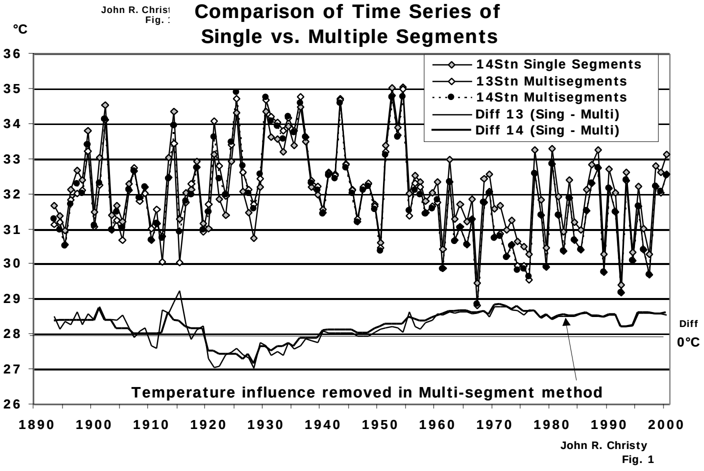

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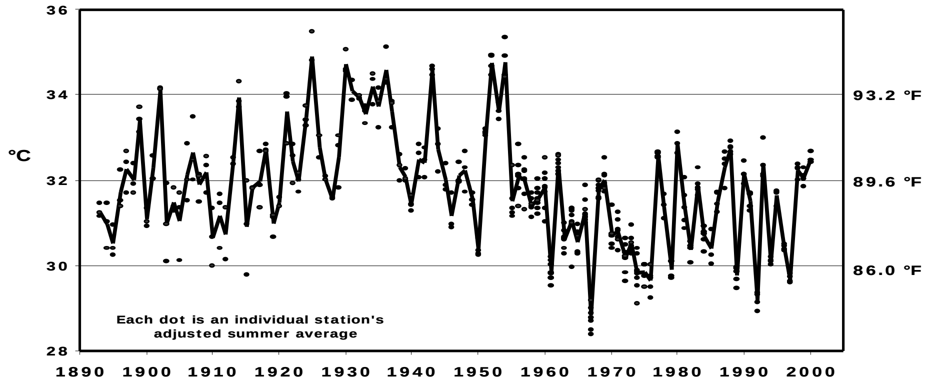
Fig. 1

Summer Daily Average Max. Temperatures
north-central Alabama, 1893-2000

Fig. 3



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