The Development of a System to Analyze and Compare Colonial Era Weather Data to more Modern Data to Investigate Climate Change

By Marni Wasserman

Motivation

- High School Research Program
- Statistics/Actuarial Science
- Looked on Society of Actuaries website to see research being done
- Contacted Mr. John Buchanan, Climate Change Student Outreach Chairperson
- Formulated Project

Purpose

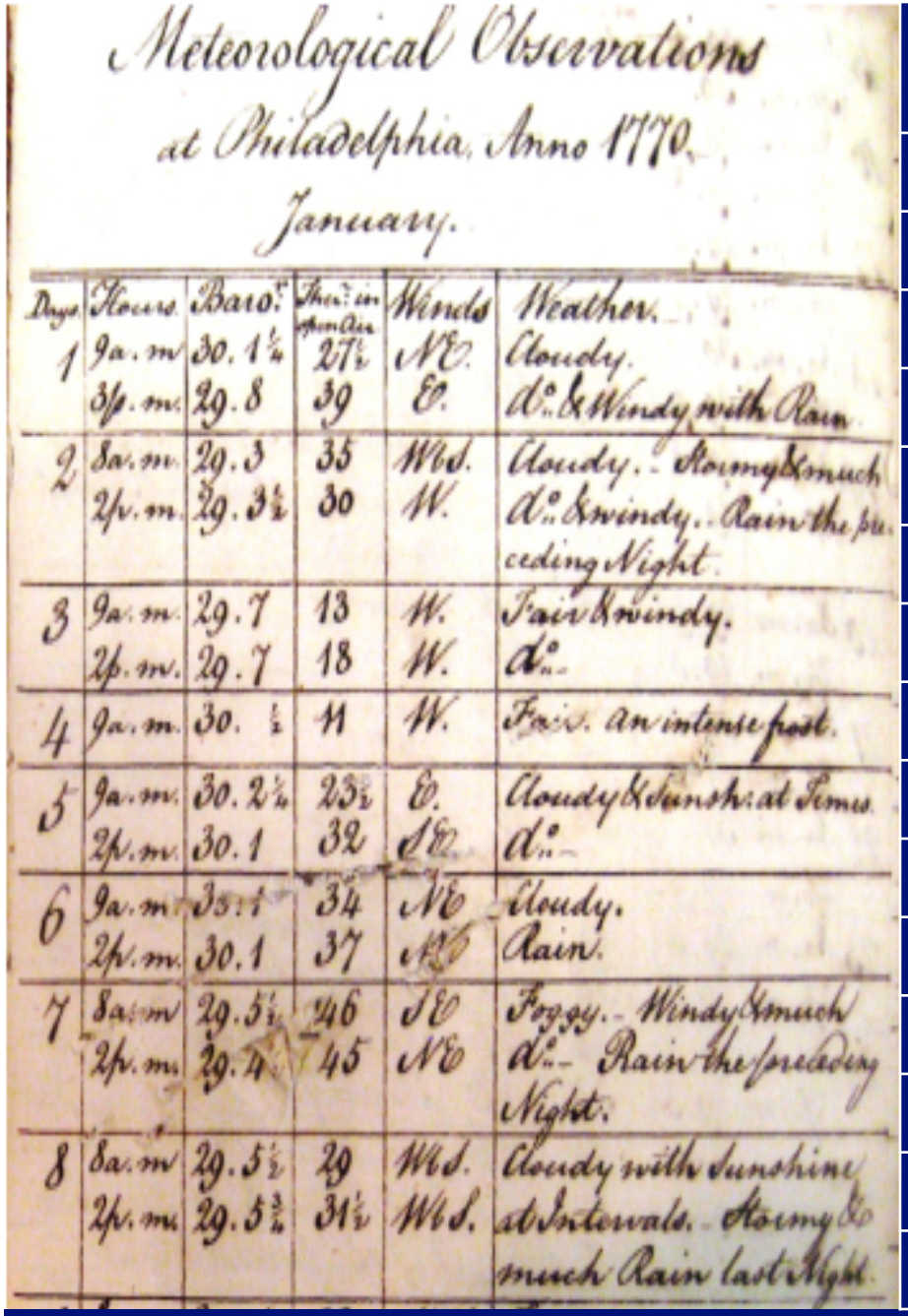
- Determine effectiveness of using colonial era weather data
- Create easily adaptable model for comparing data
- Produce data that can be used in the public domain for future studies

Ways of Collecting Past Temperature

- Temperature proxies: tree rings, ice core isotopes, coral reefs, bore holes, lake/ ocean sediment
  - relative temperatures
  - verify colonial temperature readings

Phineas Pemberton

- Member of American Philosophical Society; “citizen scientist”
- Kept continuous record of temperature and weather conditions from 1746-1776
- Readings taken 2 miles west of Philadelphia
- Latitude: 39º57’ Longitude: 75º10’



Meteorological Observations
at Philadelphia, Anno 1770.
January.

Days	Hours	Baro.r	Ther.r in open Air	Winds	Weather.
1	9a.m.	30. 1¼	27½	NE.	Cloudy.
	3p.m.	29. 8	39	E.	do. & Windy with Rain.
2	8a.m.	29. 3	35	Wbs.	Cloudy. - Stormy & much
	2p.m.	29. 3½	30	W.	do. & windy. - Rain the pre-
					ceding Night.
3	9a.m.	29. 7	13	W.	Fair & windy.
	2p.m.	29. 7	18	W.	do.
4	9a.m.	30. ½	11	W.	Fair. an intense frost.
5	9a.m.	30. 2¼	23½	E.	Cloudy & Sunshine at Times
	2p.m.	30. 1	32	SE.	do.
6	9a.m.	30. 1	34	NE	Cloudy.
	2p.m.	30. 1	37	NE	Rain.
7	8a.m.	29. 5½	46	SE	Foggy. - Windy & much
	2p.m.	29. 4	45	NE	do. - Rain the preading
					Night.
8	8a.m.	29. 5½	29	Wbs.	Cloudy with Sunshine
	2p.m.	29. 5¾	31½	Wbs.	at Intervals. - Stormy &
					much Rain last Night.

Day	Time	Barometric Pressure	Temperature	Wind	Conditions
1-Jan	9:00 AM	30.1 1/4	27.5	NE	A
	3:00 PM	29.8	39	E	ABC
2-Jan	8:00 AM	29.3	35	WS	AC
	2:00 PM	29.3 1/2	30	W	ACB
3-Jan	9:00 AM	29.7	13	W	DB
	2:00 PM	29.7	18	W	DB
4-Jan	9:00 AM	30 1/2	11	W	DG
5-Jan	9:00 AM	30.2 1/4	23.5	E	AF
	2:00 PM	30.1	32	SE	AF
6-Jan	9:00 AM	30.1	34	NE	A
	2:00 PM	30.1	37	NE	C
7-Jan	8:00 AM	29.5 1/2	46	SE	EB
	2:00 PM	29.4	45	NE	EBC
8-Jan	8:00 AM	29.5 1/2	29	WS	AF
	2:00 PM	29.5 3/4	31.5	WS	AFC

Courtesy of APS Library

Climate Change Debate

- Human activity versus Natural
- Human Activity Causes – increase in greenhouse gases
- “Most of the observed increase…very likely due to anthropogenic greenhouse gas concentrations” (IPCC AR4, 2007)
- Natural – interglacial period, increase in solar activity (Tanneeru, 2008)
- Only 5% of increase in temperature is due to human activities (Pinto, 2007)

Possible Effects of Increase in Temperature

- Rising sea levels
- Glacier and polar ice melting
- Change in weather patterns
- More intense precipitation events
- Decrease in agricultural stability
- Extinction, endangerment and changing ranges of species
- Increase of disease vectors

Data Analyzed

- All from Philadelphia, PA
  - (39º57’ latitude and 75º00’20’’ longitude)
- 1759 (digitized Pemberton data)
- 1767-1770 (digitized Pemberton data)
- 1878-1882 (NOAA)
- 2005-2009 (NOAA)

Analysis

- Temperature mean over 5 year periods in each century
- Temperature mean for January, February, July and August, over the 5 year periods in each century
- Analyzed relationship between carbon dioxide levels and temperature change

Summary of Years

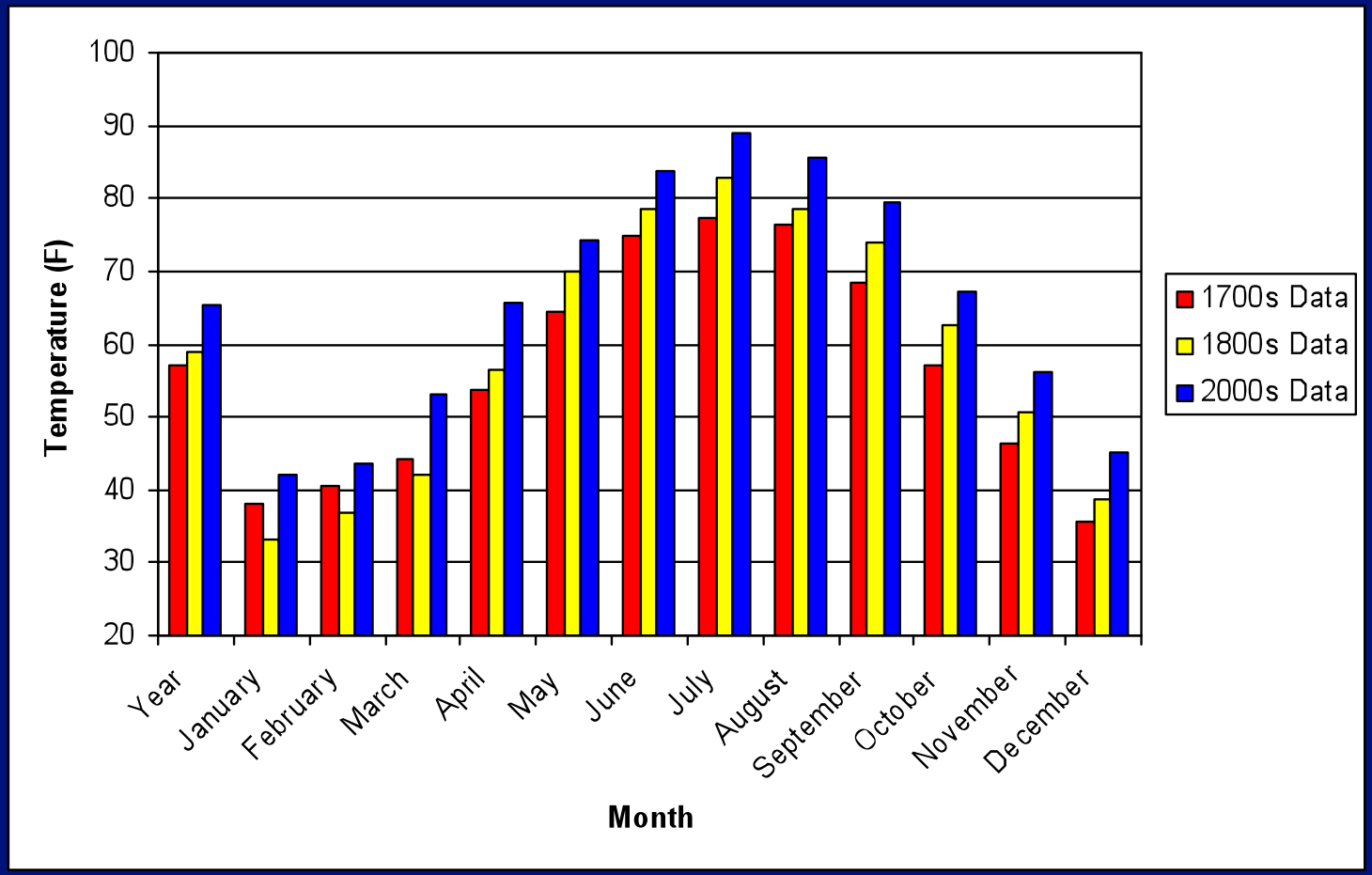


Figure 1 – Monthly Mean Temperature in Philadelphia, PA

Temperature Differences

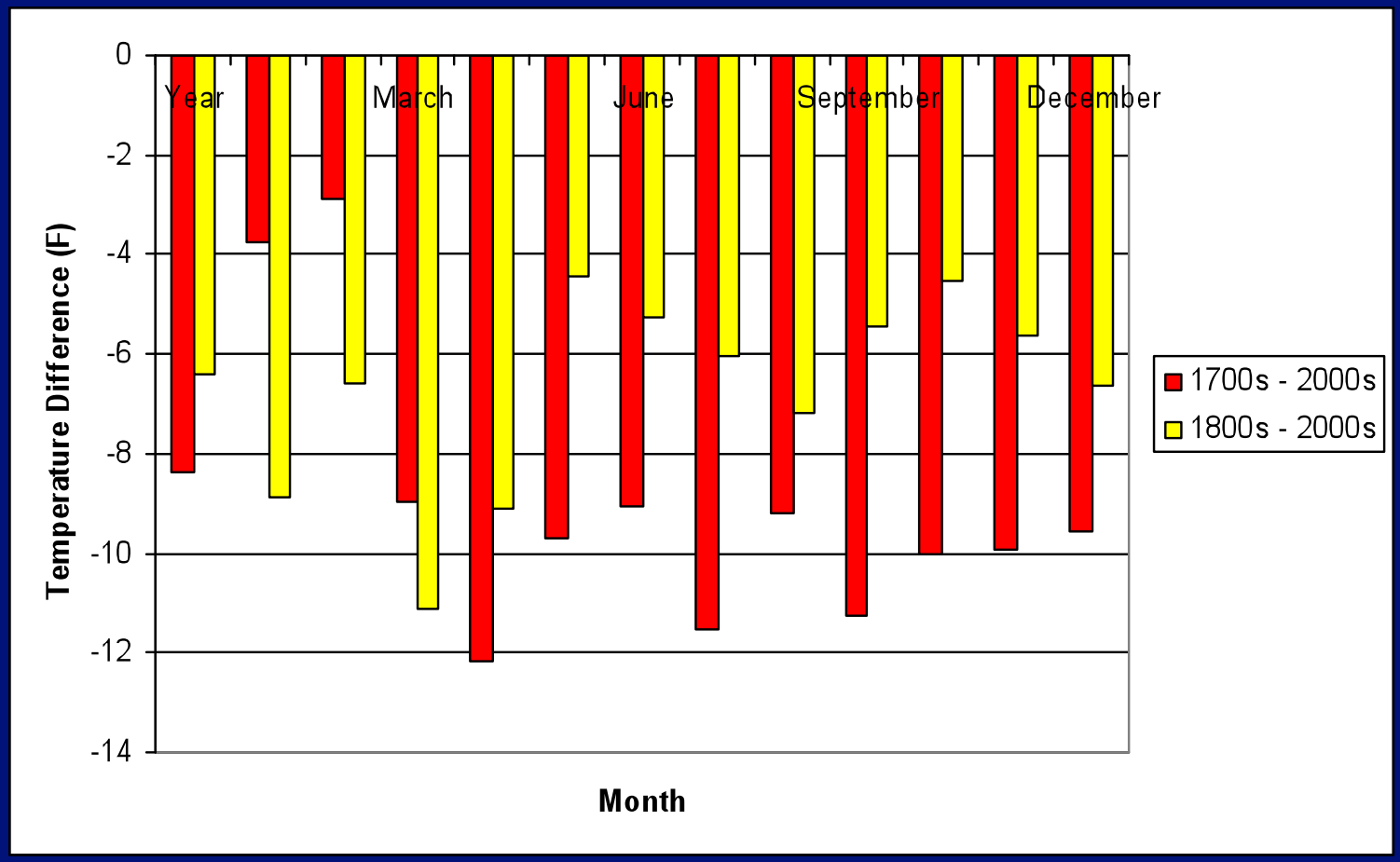
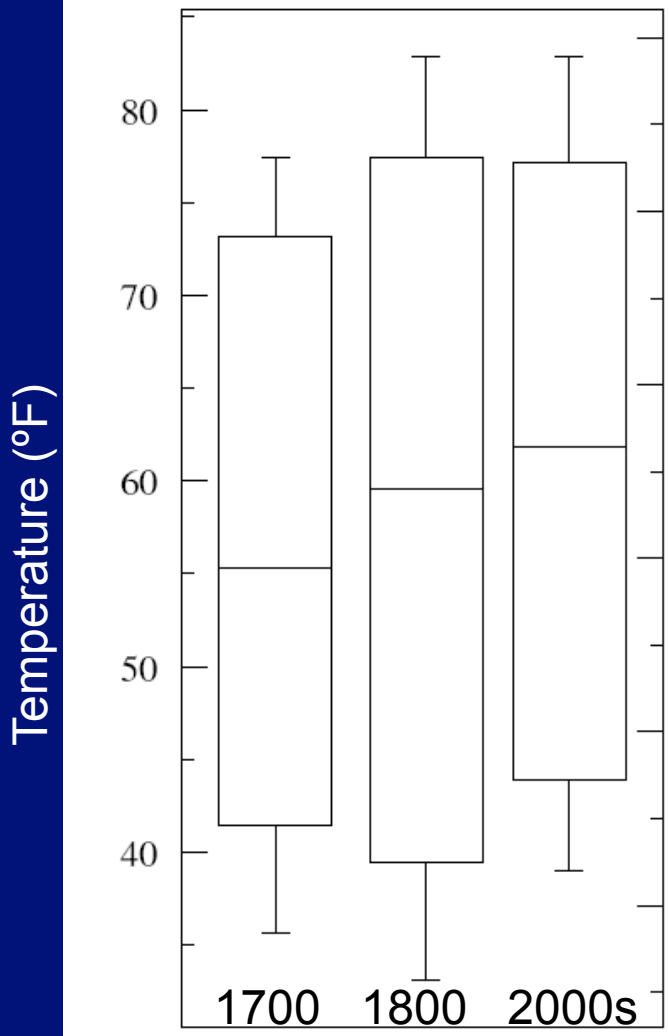


Figure 2 - Temperature Difference Between Centuries in Philadelphia, PA

Yearly Stats

Table 1 – Mean Temperature for 5 Year Averages	
Yearly Philadelphia	Mean
1700	56.1
1800	59
2000	65.4

Table 2 – T-test Values		
Yearly Philadelphia	p-value	Significant
1700s vs. 1800	0.6105	no
1700s vs. 2000	0.1647	no
2000s vs. 1800	0.2313	no



Temperature by Month

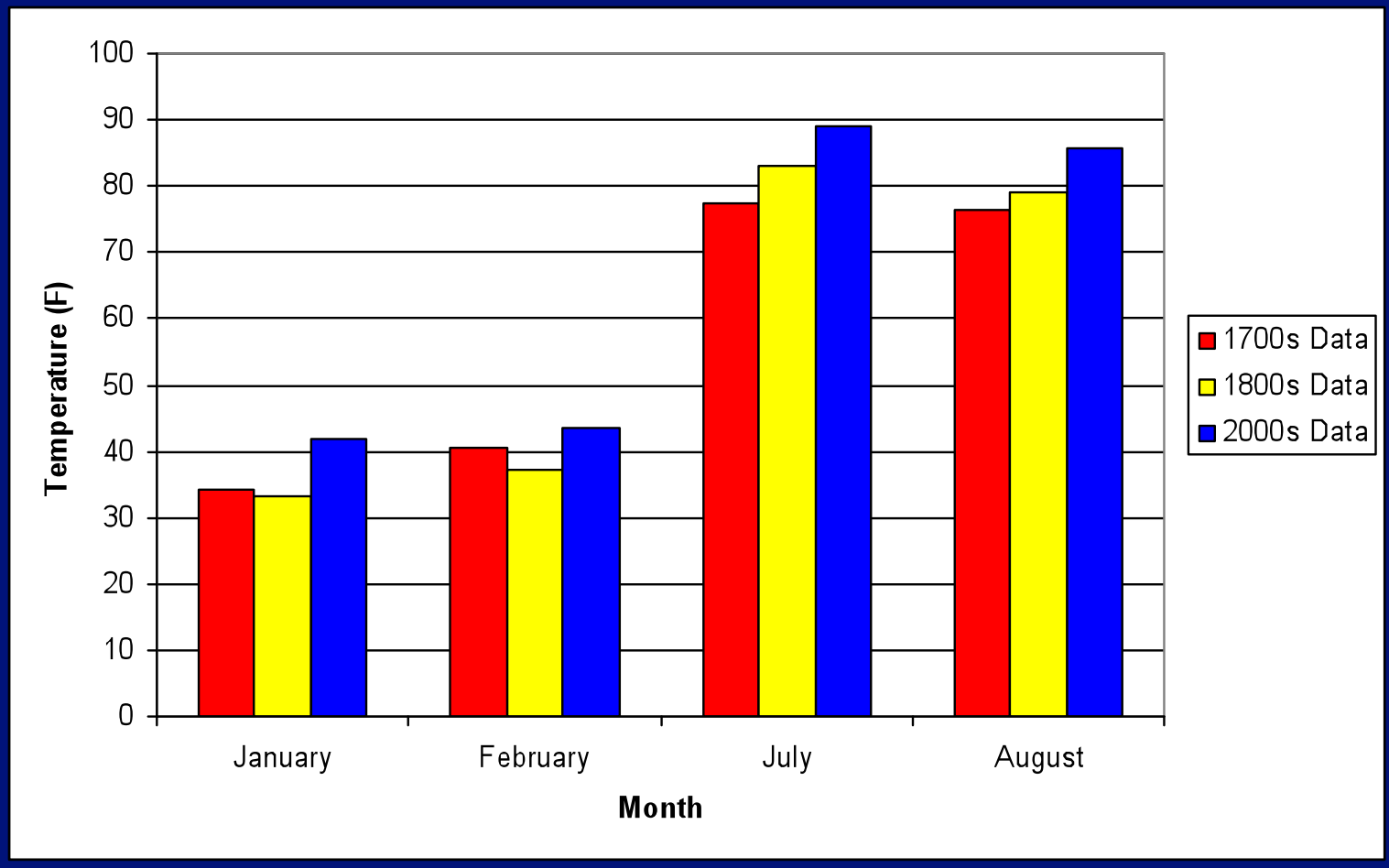


Figure 4 – Mean Temperature For Certain Months in Philadelphia, PA

Monthly Stats

Table 3 – Monthly Means for 5 Year Averages								
Monthly Philadelphia	January		February		July		August	
	Mean	95%	Mean	95%	Mean	95%	Mean	95%
1700	38.2	38.2±1.72	40.5	40.5±1.83	77.4	77.4±0.91	76.5	76.5±0.92
1800	33.1	33.1±1.47	36.8	36.8±1.69	82.9	82.9±0.93	78.6	78.6±0.92
2000	42	42±1.74	43.5	43.5±1.87	89	89±1.06	85.7	85.7±0.95

Table 4 – Monthly T-test Values								
Monthly Philadelphia	January		February		July		August	
	p-value	significant	p-value	significant	p-value	significant	p-value	significant
1700s v 1800	0.1362	no	0.0109	yes	<0.0001	yes	0.0003	yes
1700s v 2000	<0.0001	yes	0.014	yes	<0.0001	yes	<0.0001	yes
2000s v 1800	<0.0001	yes	0.0001	yes	<0.0001	yes	<0.0001	yes

Days above 80, 85, 90 ºF

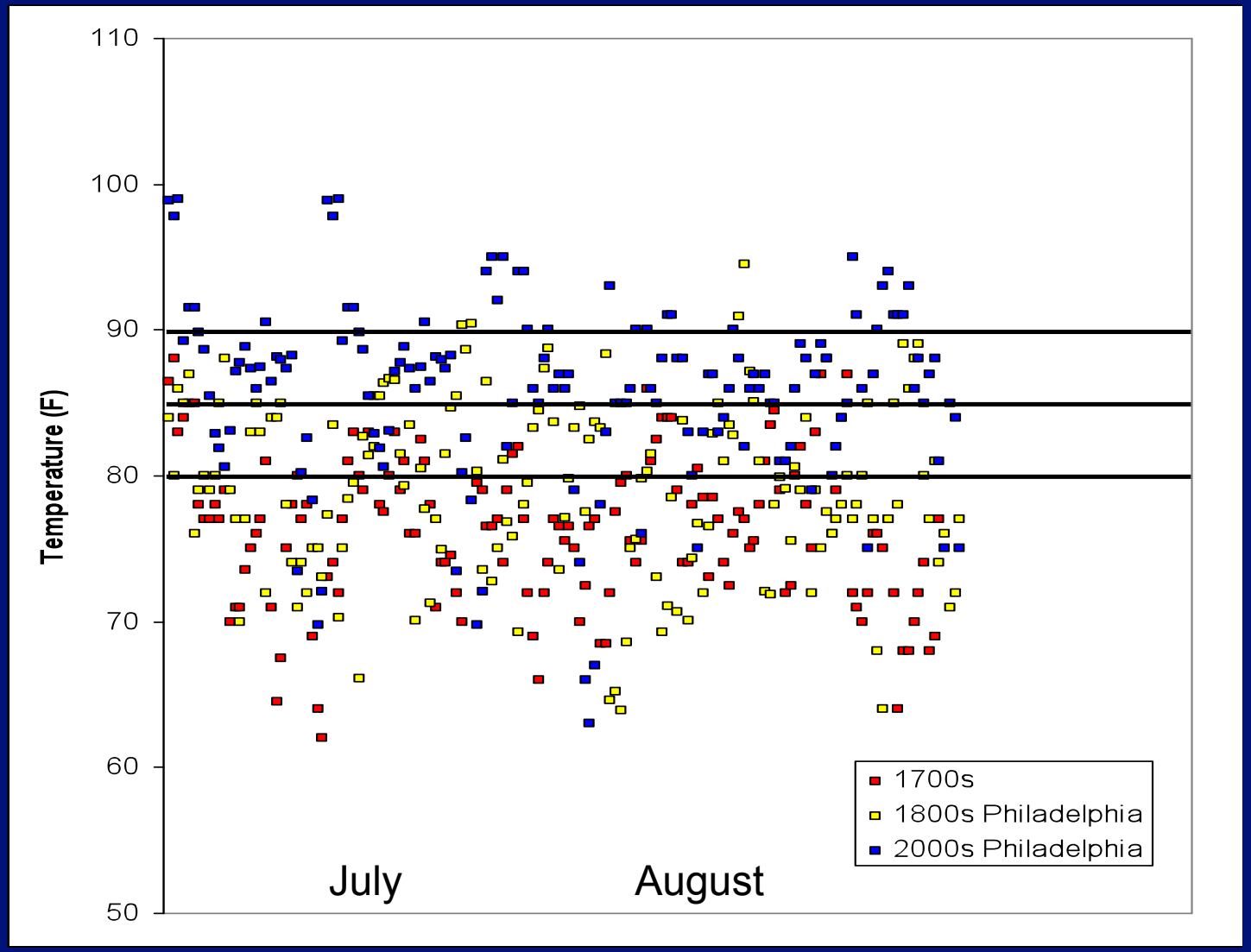


Figure 5 – Comparison of Number of Days in the 1700s, 1800s and 2000s Over 80, 85 and 90ºF

Daily Comparisons

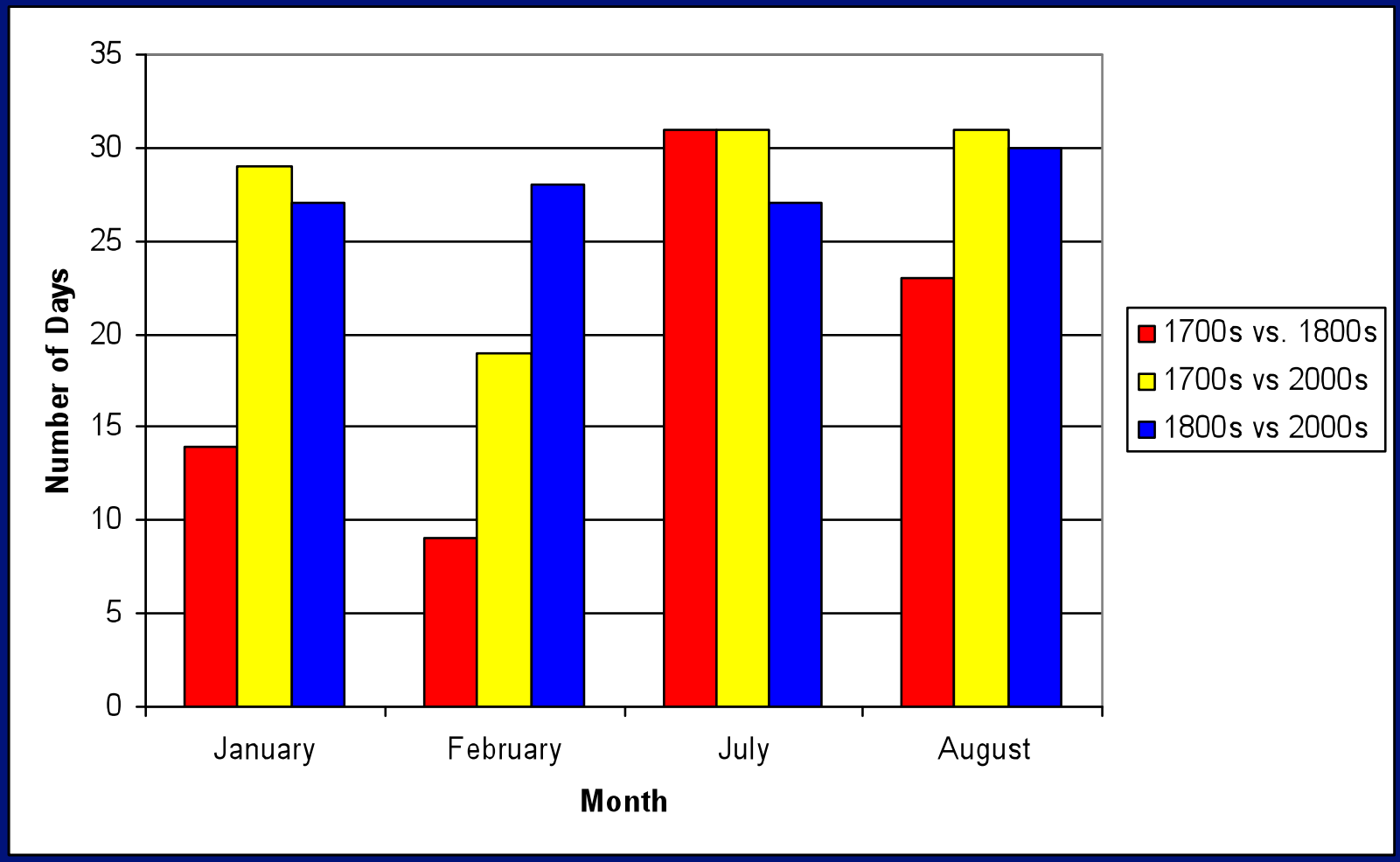


Figure 6 – Number of days per month in which the later time period was warmer than the earlier time period

Homogenization

- Most raw data is un-homogenized
  - different equipment
  - different locations,
  - different times
    - Accounted for by looking at 10 neighboring weather stations

Homogenization Graph

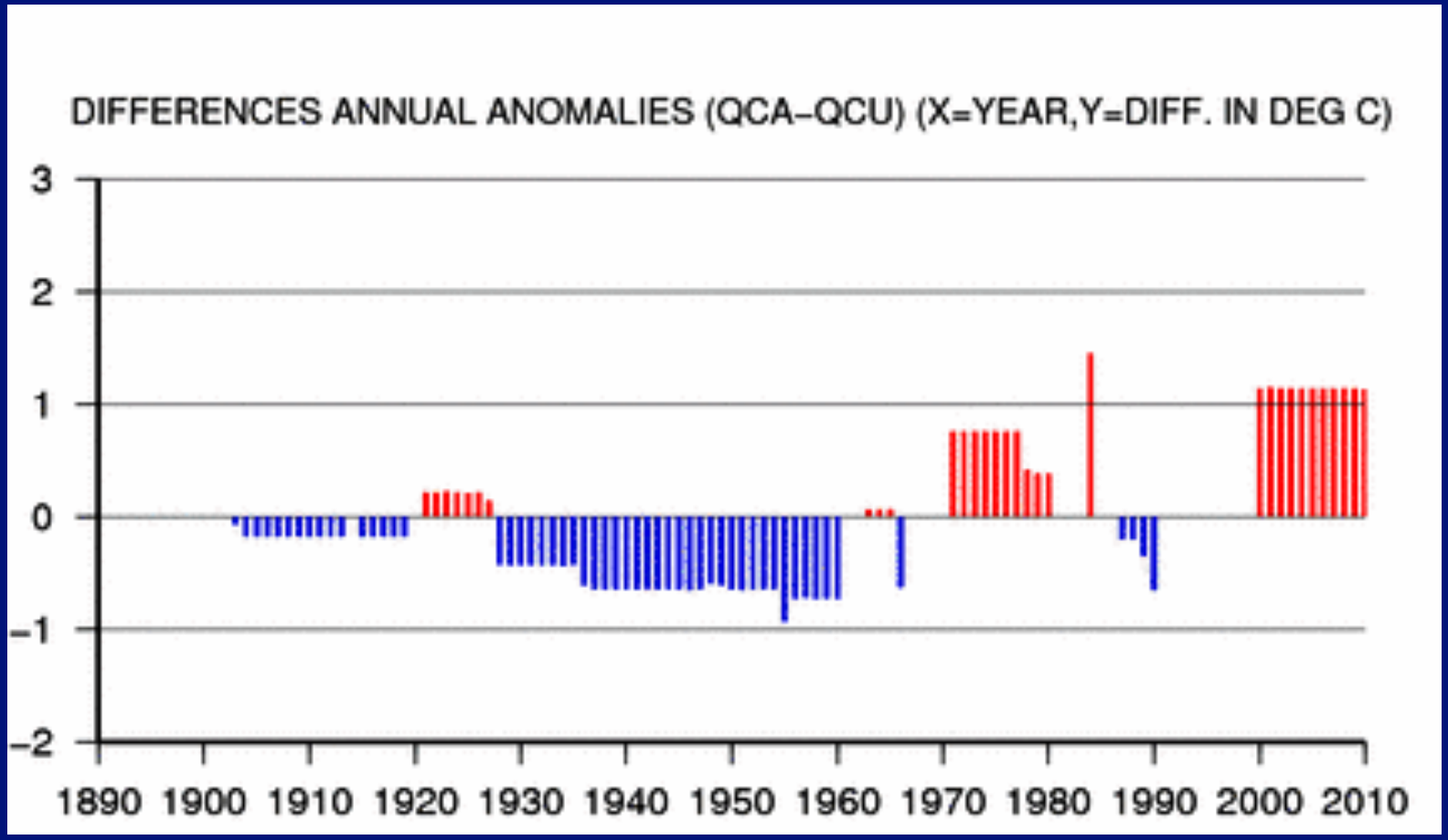


Figure 8 - Raw vs. Adjusted - West Chester PA Anomalies
Source: NOAA – Russell Vose email 10/27/2010

Carbon Data

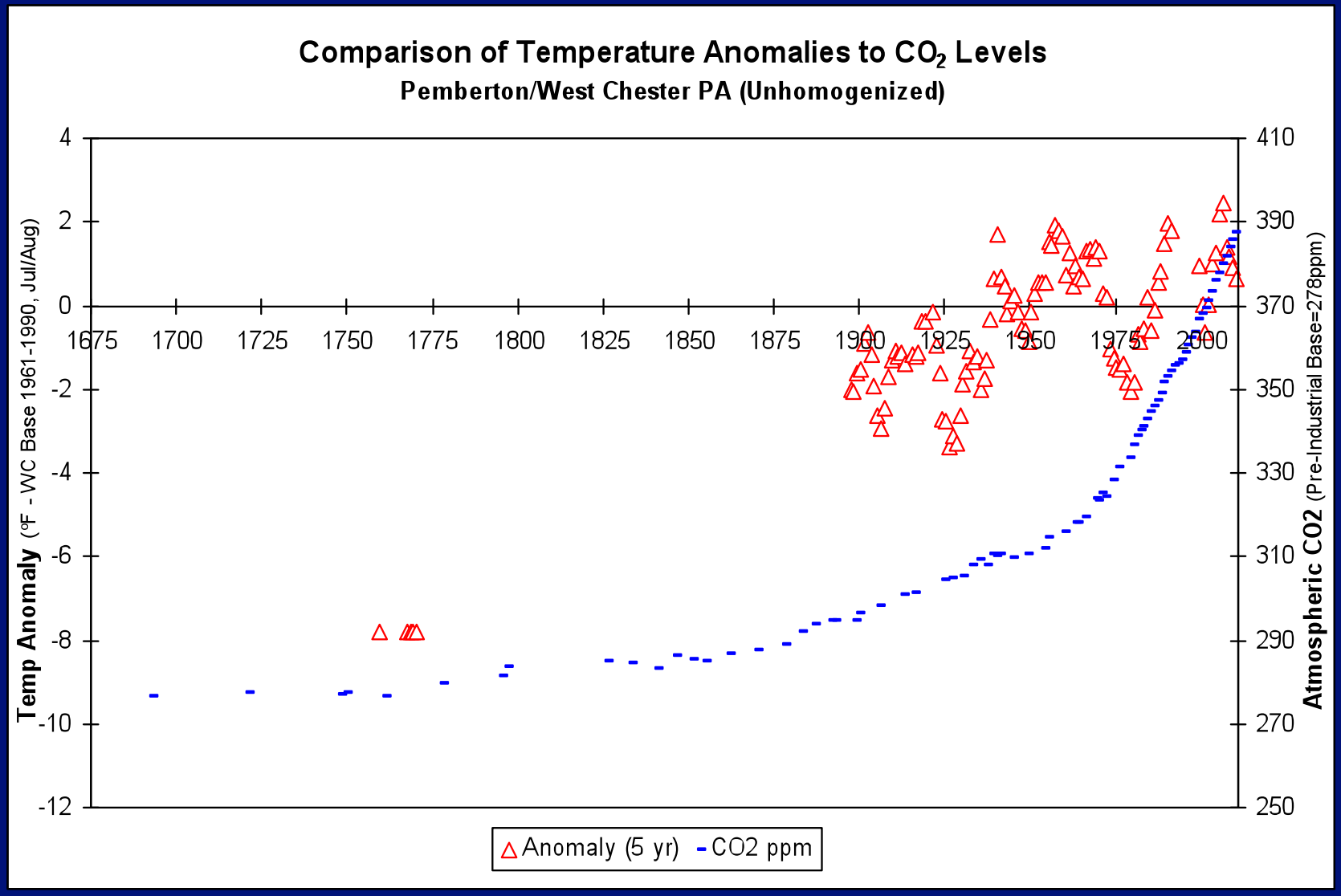


Figure 7 - CO_2 Source: NOAA – James Butler email 9/27/2010

Conclusion

- Overall temperature has increased since 1759
  - In this sample (unadjusted), between 30-40% of the raw increase occurred in the 1800s vs. the 2000s
- Temperature in each month did not increase steadily from 1759 to 2009
  - Winter months increased less than summer
- Variations from average now more extreme
  - Currently many more days over 80, 85 and 90ºF

Improvements

- Use 20-30 year baseline averages for recent climate indications
- Adopt standard climatological statistical methods
- Use Aggregated Greenhouse Gas Index rather than CO_2 component only

Future Research

- Analysis of pressures and conditions
- Compare results to other well established studies
- Look in other historical societies to see where this data is located
- Join scientists and students to expand database of usable data

Acknowledgements

- Third Atmospheric Circulation Reconstructions over the Earth Workshop (NOAA, NASA, NSF and U.S. CLIVAR)
- Mr. John Buchanan, Climate Change Student Outreach Chairperson for the Casualty Actuarial Society
- Mr. Gilbert Compo, Climate Diagnostics Center NOAA
- Eric Freeman, National Climactic Data Center
- Mr. Richard Kurtz – Teacher
- Administration and Faculty, Commack Union Free School District

Appendix

West Chester – Summary of Years

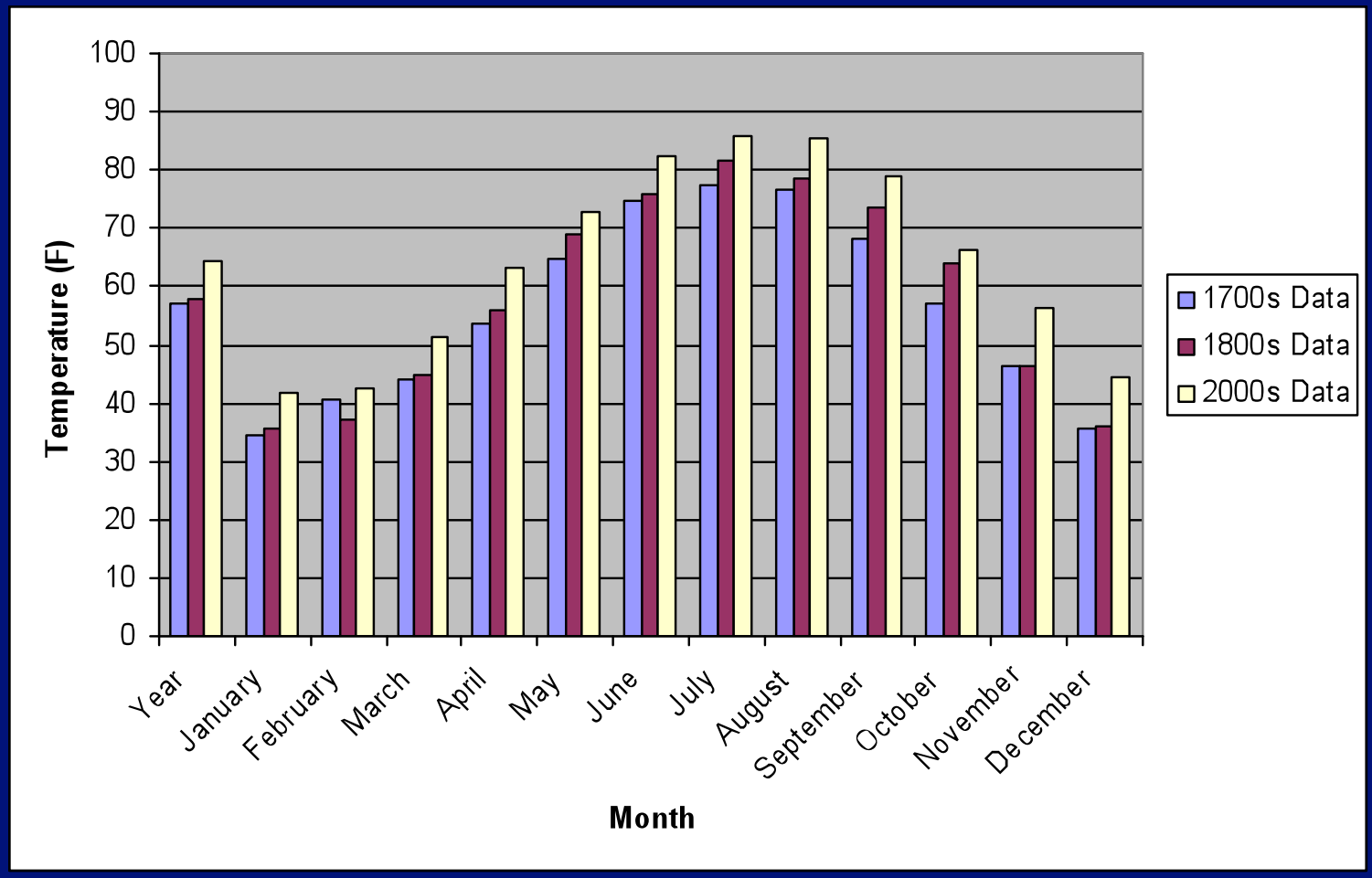


Figure 4 – Monthly mean temperature in West Chester, PA

West Chester - Temperature Difference

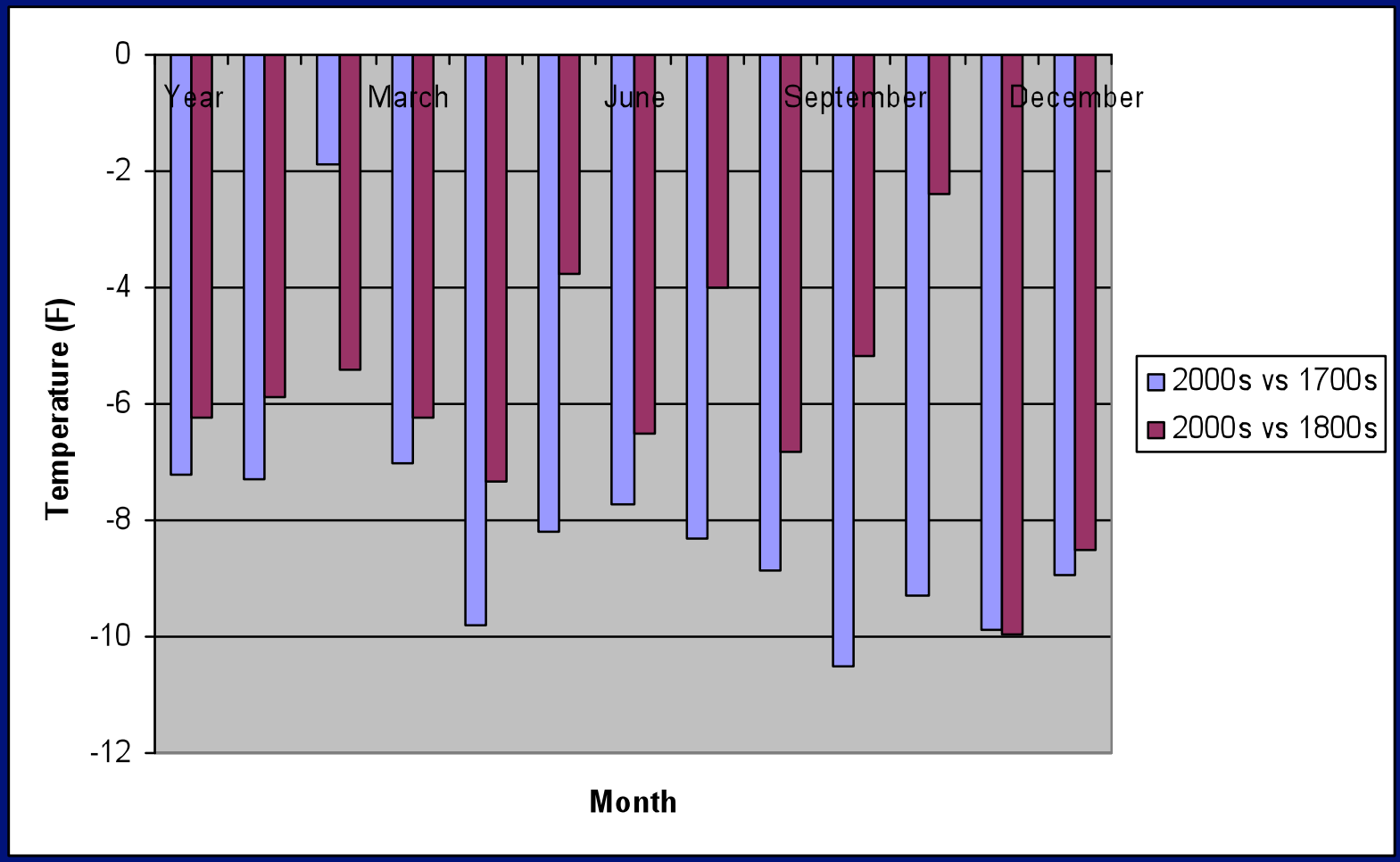


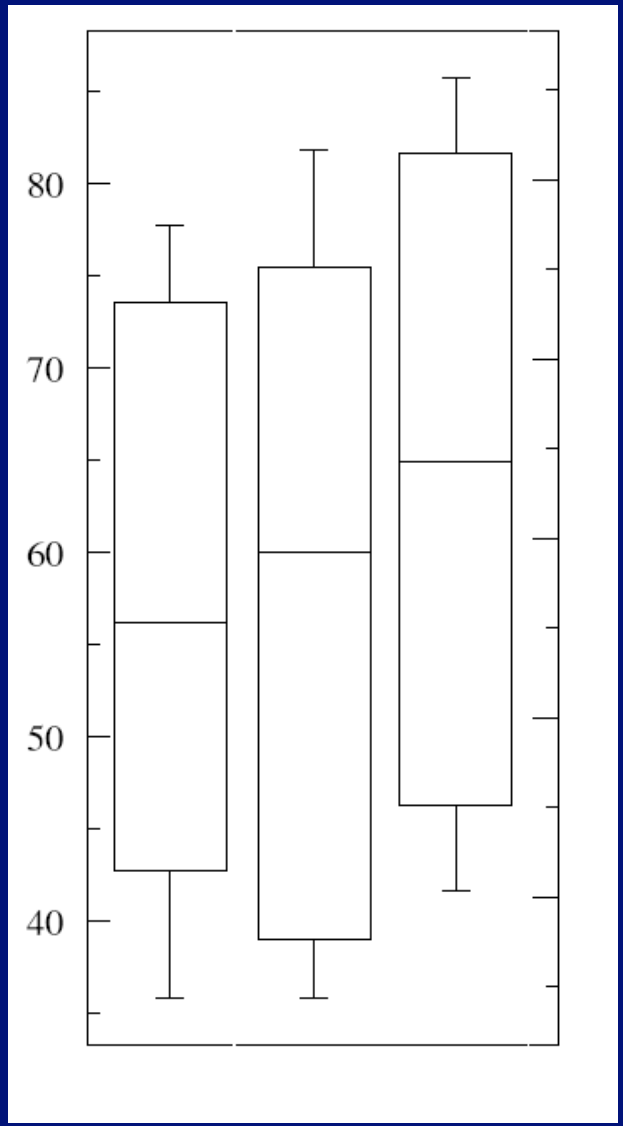
Figure 5 - Temperature difference between centuries in West Chester, PA

West Chester Yearly Stats

Yearly West Chester	Mean	95% Confidence Intervals
1700	56.1	56.1±10.08
1800	58.3	58.3±10.13
2000	64.3	64.3±9.89

Yearly West Chester	p-value	hypothesis	significant
1700s v 1800	0.6058	null	no
1700s v 2000	0.183	null	no
2000s v 1800	0.7517	null	no

West Chester – Yearly Box Plot



West Chester – Temperature by Month

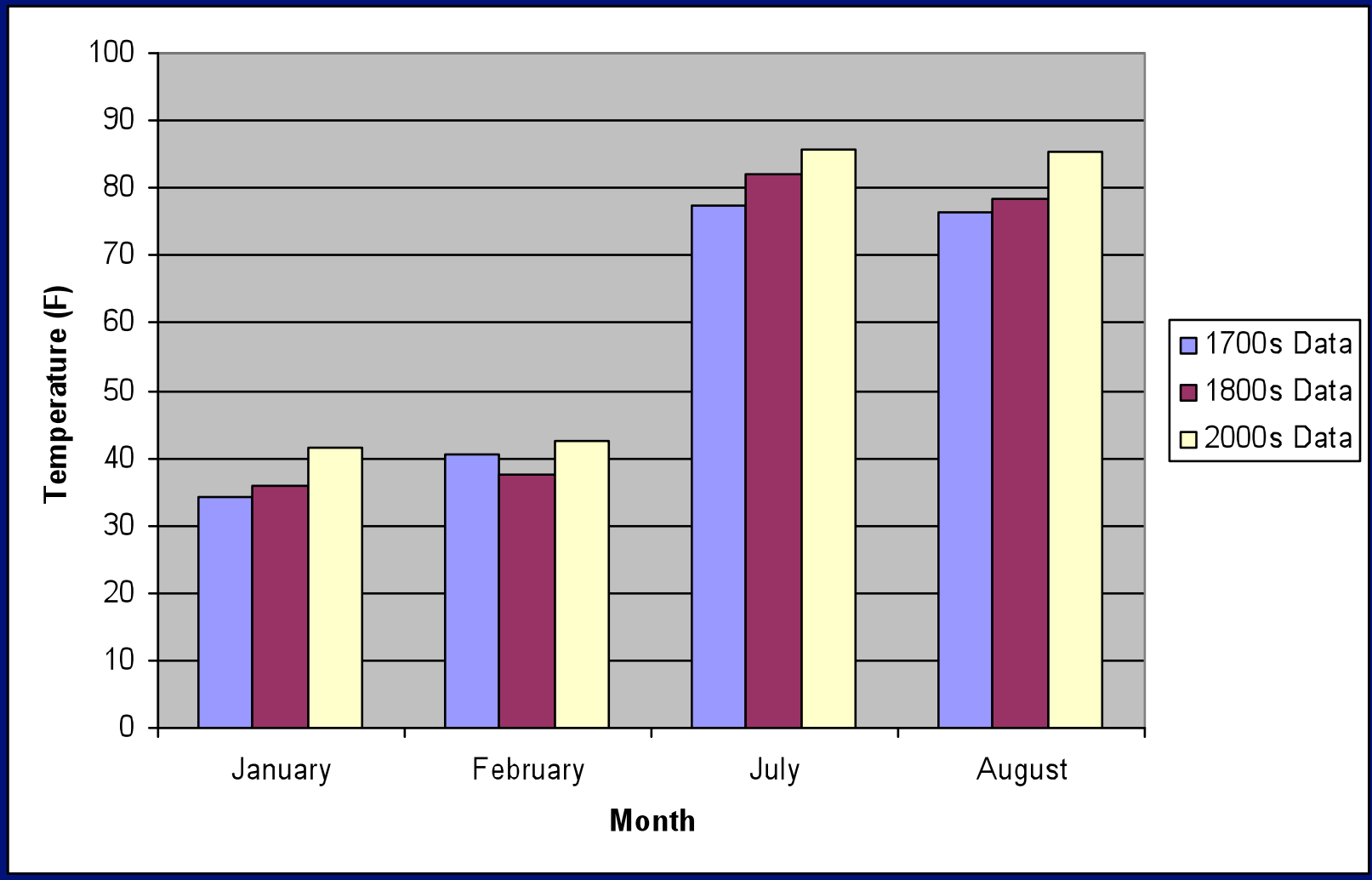


Figure 6 – Mean temperature for certain months in West Chester, PA

West Chester Monthly Stats

Monthly West Chester	January		February		July		August	
	Mean	95%	Mean	95%	Mean	95%	Mean	95%
1700	34.4	34.4±1.74	40.4	40.4±1.77	77.4	77.4±0.88	76.5	76.5±0.97
1800	33.4	33.4±1.5	37.1	37.1±1.64	81.8	81.8±0.95	79.2	79.2±0.92
2000	41.7	41.7±1.77	42.5	42.5±1.78	85.7	85.7±0.87	85.4	85.4±1.04

	January			February			July			August		
Monthly West Chester	p-value	hypothesis	significant	p-value	hypothesis	significant	p-value	hypothesis	significant	p-value	hypothesis	significant
1700s v 1800	0.1936	null	no	0.0071	null	no	<0.0001	alternative	yes	0.0003	alternative	yes
1700s v 2000	<0.0001	alternative	yes	0.0591	null	no	<0.0001	alternative	yes	<0.0001	alternative	yes
2000s v 1800	<0.0001	alternative	yes	0.0002	alternative	yes	<0.0001	alternative	yes	<0.0001	alternative	yes