Appendix C: Section IV. Water Resources in the Yellowstone River Basin: Climate and Historical Drought

Climate

Historical climate (temperature and precipitation) data for 10 stations in the Yellowstone River Basin was downloaded from the NOAA, National Climate Data Center's, U.S. Historical Climate Network (USHCN):

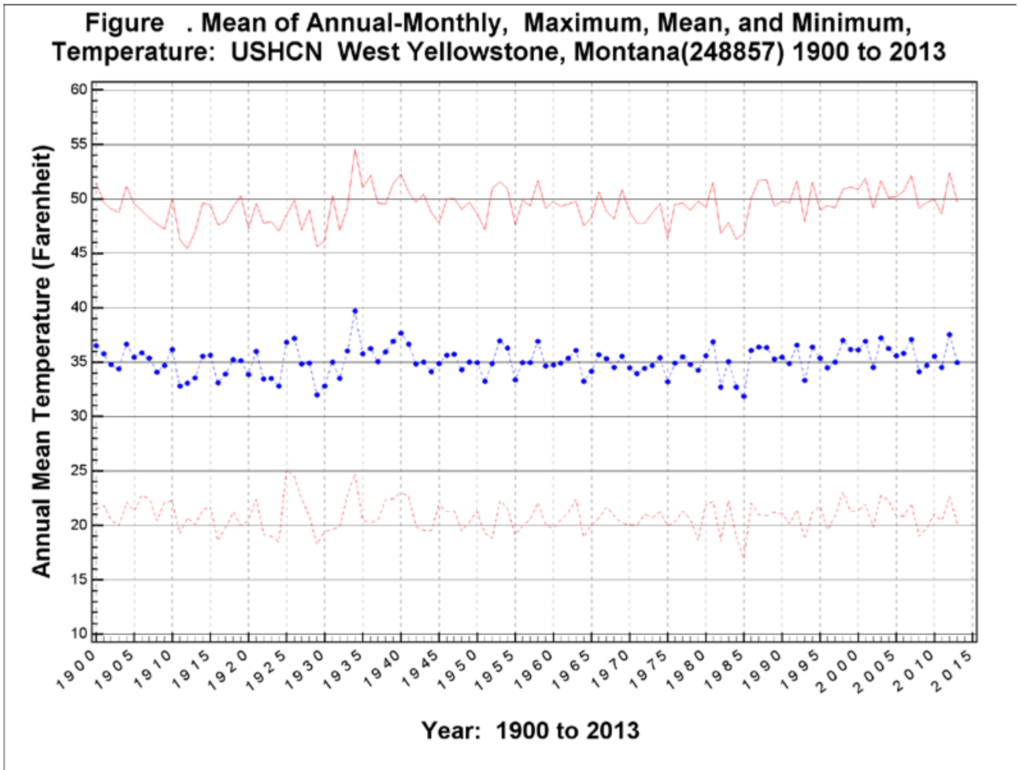
USHCN Historical Temperature and Precipitation Data and Graphs

A. West Yellowstone, Montana
B. Redlodge, Montana
C. Dubois, Wyoming
D. Worland, Wyoming
E. Huntley, Montana
F. Hysham, Montana
G. Miles City, Montana
H. Sheridan, Wyoming
I. Glendive, Montana
J. Midwest, Wyoming

The USHCN datasets provide summaries of monthly temperature and precipitation observations for 1,218 stations across the contiguous United States. The USHCN is a high-quality network of COOP stations with maximum, minimum, and mean temperature and precipitation, specially selected for analyzing long-term variability and change in the 48 contiguous United States. The stations in the network were chosen based on length of record, spatial distribution, and to minimize the number of station changes that can affect the homogeneity of the record. A methodology has been developed and is applied to test known station changes for their impact on the homogeneity, and data are adjusted if the change causes a statistically significant change in the time series. An urban warming correction based on population is also applied. The data set is a consistent network through time, which minimizes any biasing due to network changes through time (see links below for a more complete description of the data.

http://www.ncdc.noaa.gov/oa/climate/research/ushcn/
ftp://ftp.ncdc.noaa.gov/pub/data/ushcn/v2.5/readme.txt

Monthly USHCN data for the period 1900 (or in some cases the late 1890's) to 2013 were imported into SAS (Statistical Analysis System v. 9.1.3) software for analysis and plotting. The monthly values of maximum, mean (average) and minimum temperature were summed and averaged over the calendar year to provide annual-mean values of maximum, mean and minimum temperature; monthly values of total precipitation were summed to annual precipitation and plotted by calendar year—in the precipitation graphs, horizontal dashed lines are the period averages (Figures 1.A. to 1.J.).



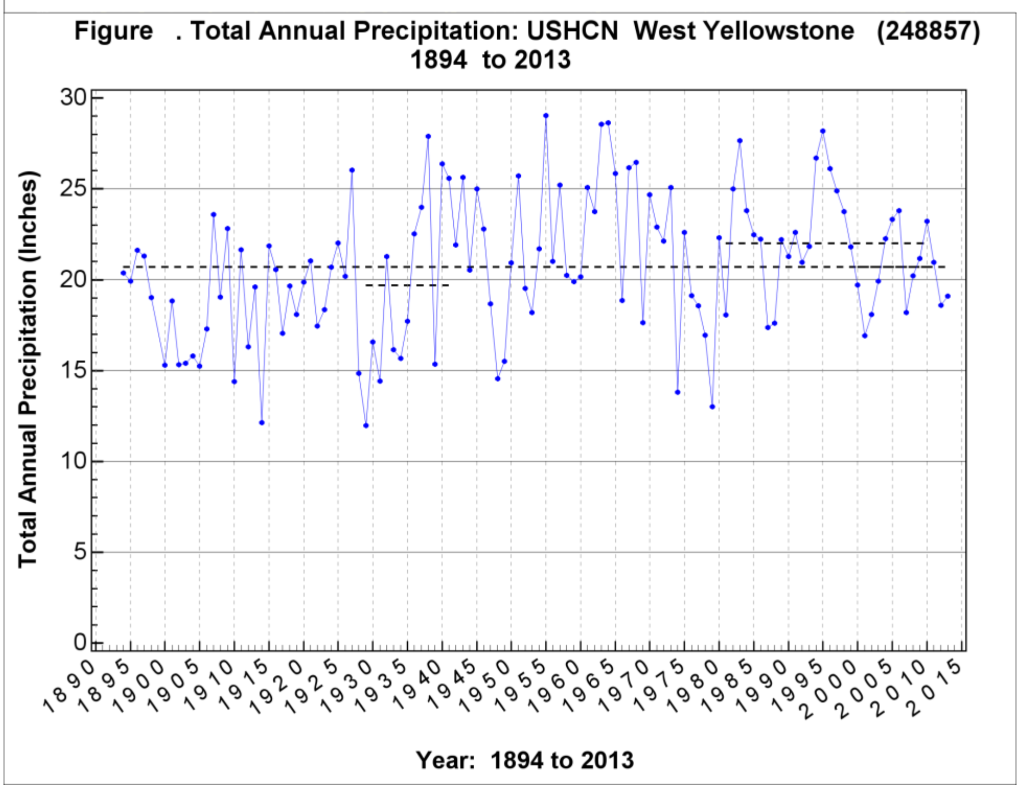


Figure 1.A. West Yellowstone, Montana: Annual Temperature (1900-2013) and Annual Precipitation (1894-2013; dashed lines represent averages for different periods).

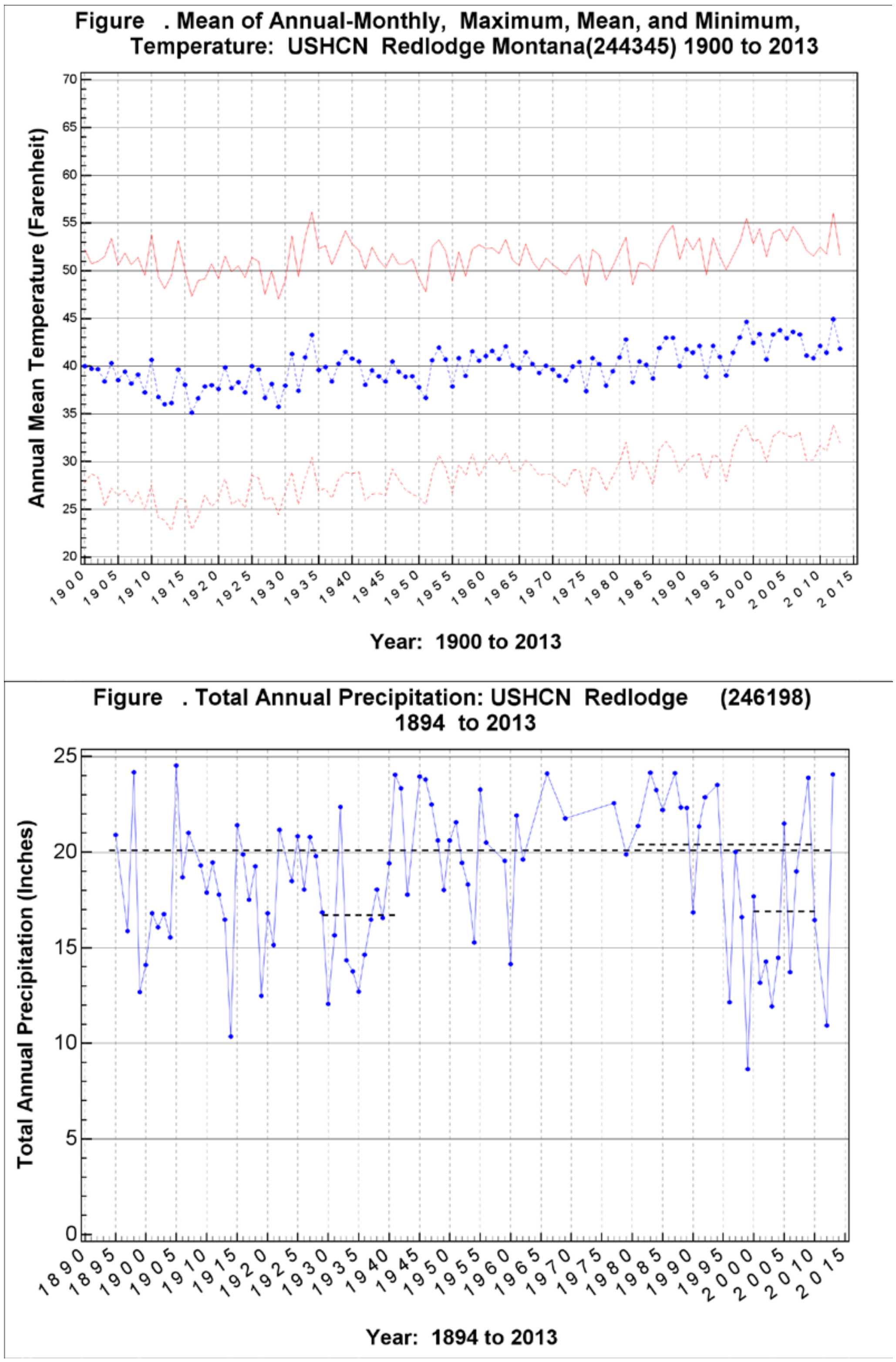
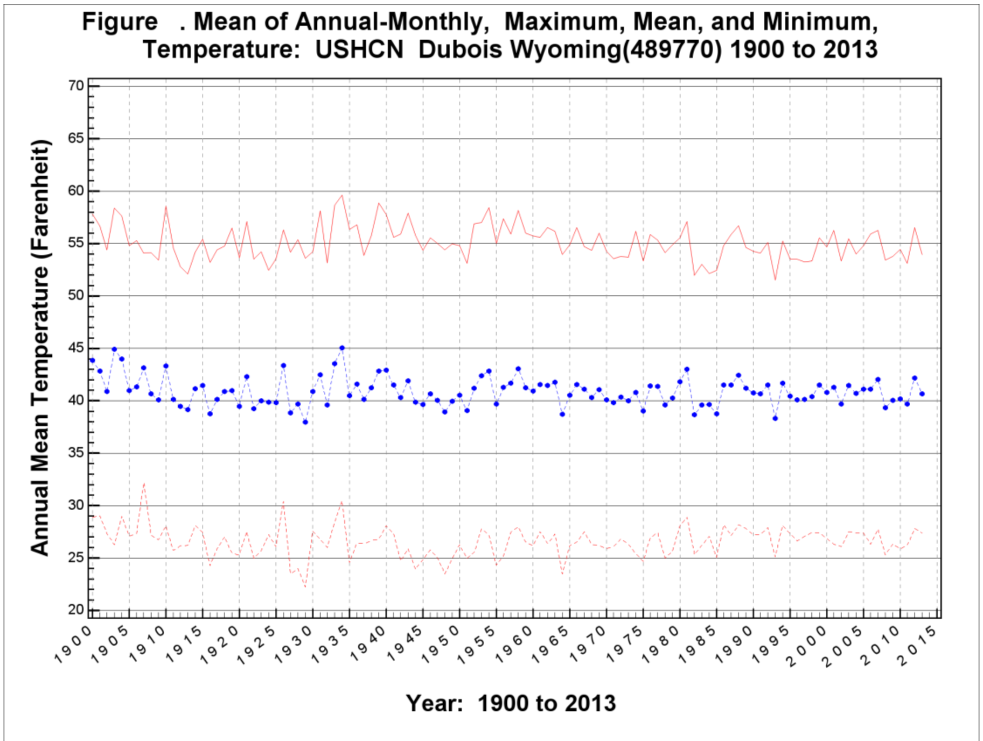


Figure 1.B. Redlodge, Montana: Annual Temperature (1900-2013) and Annual Precipitation (1894-2013; dashed lines represent averages for different periods)



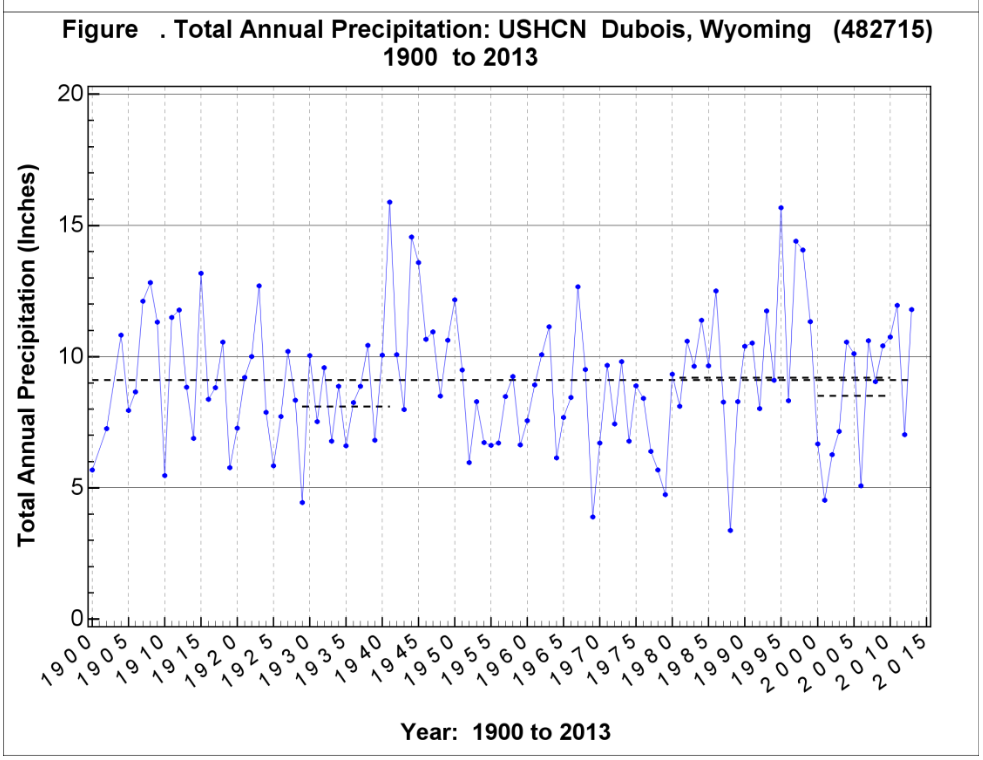
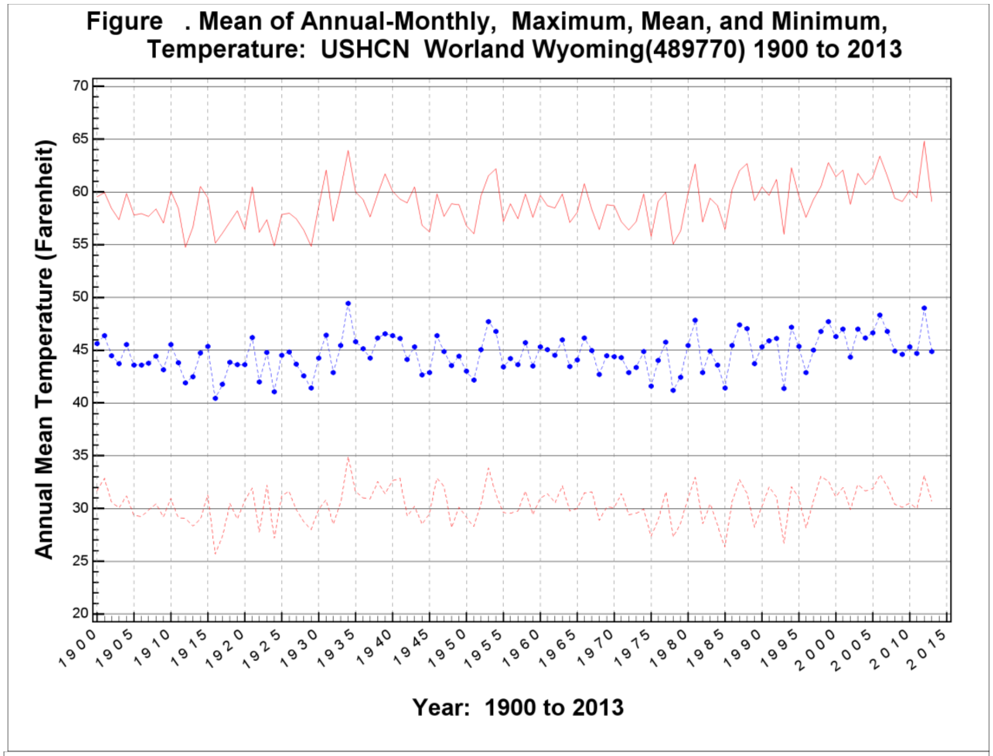


Figure 1.C. Dubois, Wyoming: Annual Temperature (1900-2013) and Annual Precipitation (1900-2013; dashed lines represent averages for different periods.)



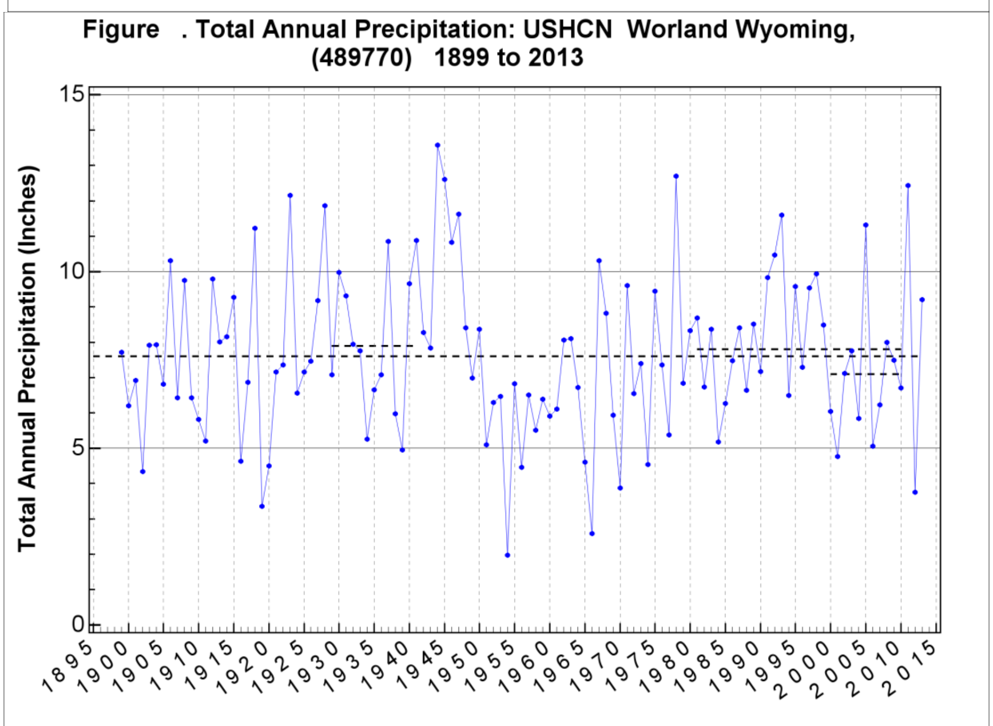
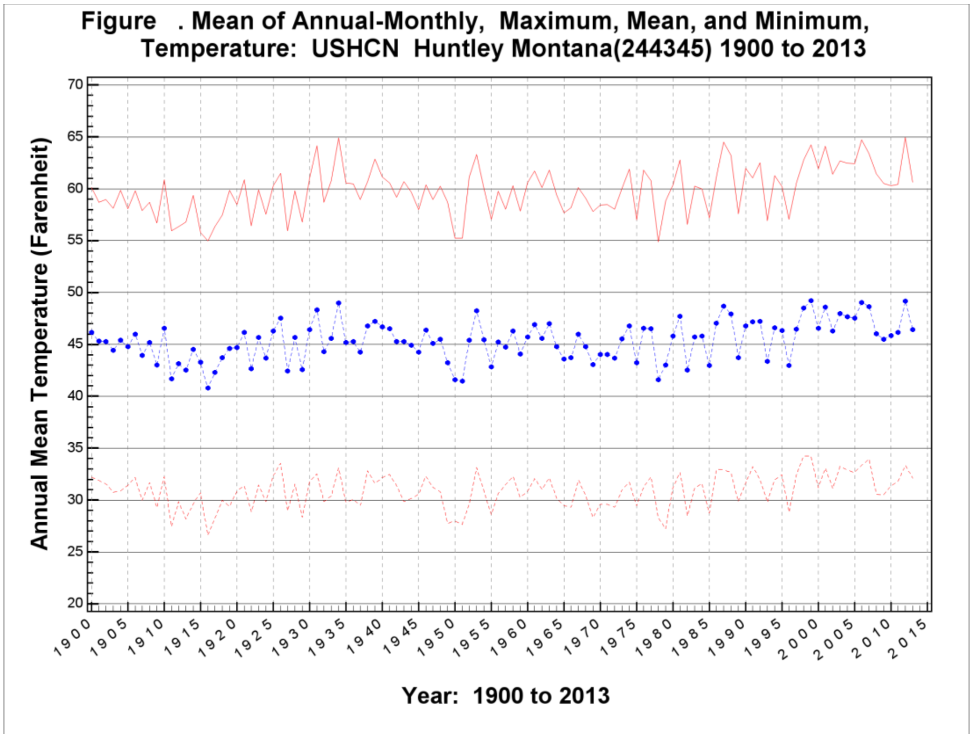


Figure 1.D. Worland Wyoming: Annual Temperature (1900-2013) and Annual Precipitation (1899-2012; dashed lines represent averages for different periods)



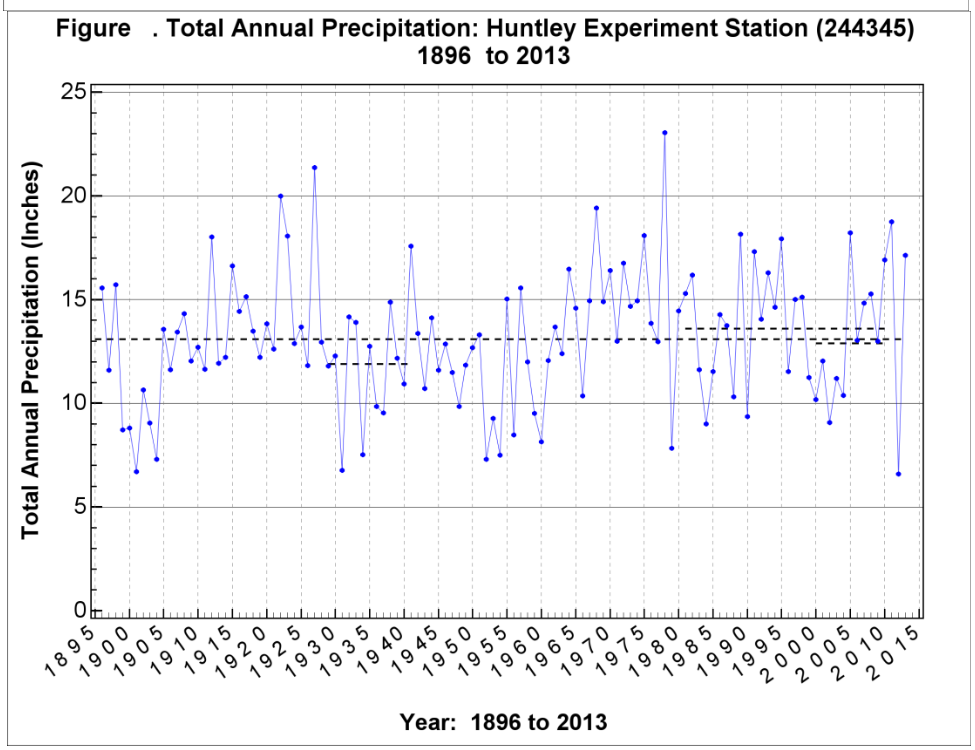
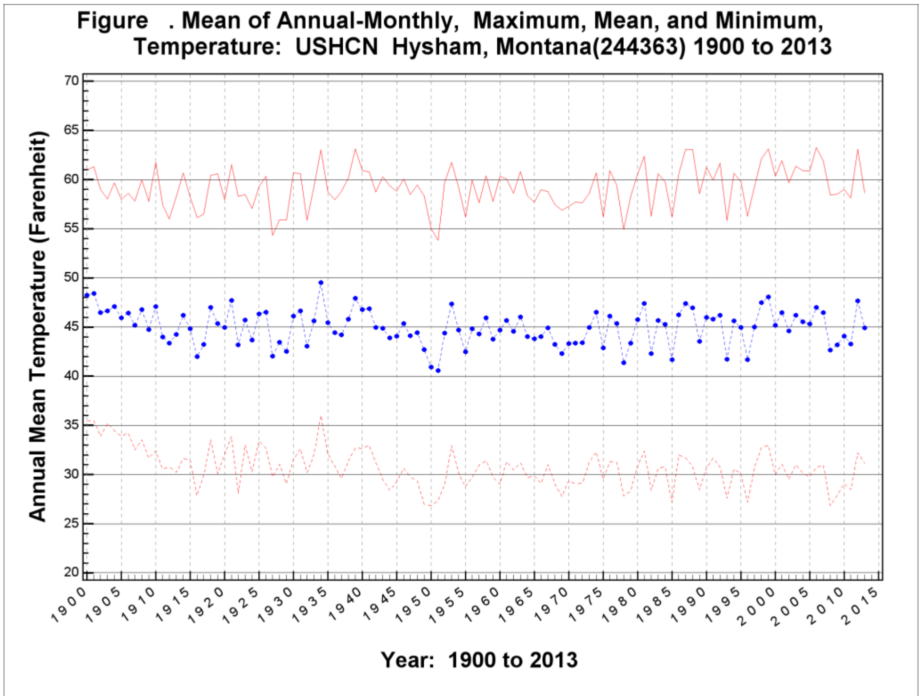


Figure 1.E. Huntley, Montana: Annual Temperature (1900-2013) and Annual Precipitation (1986-2013; dashed lines represent averages for different periods)



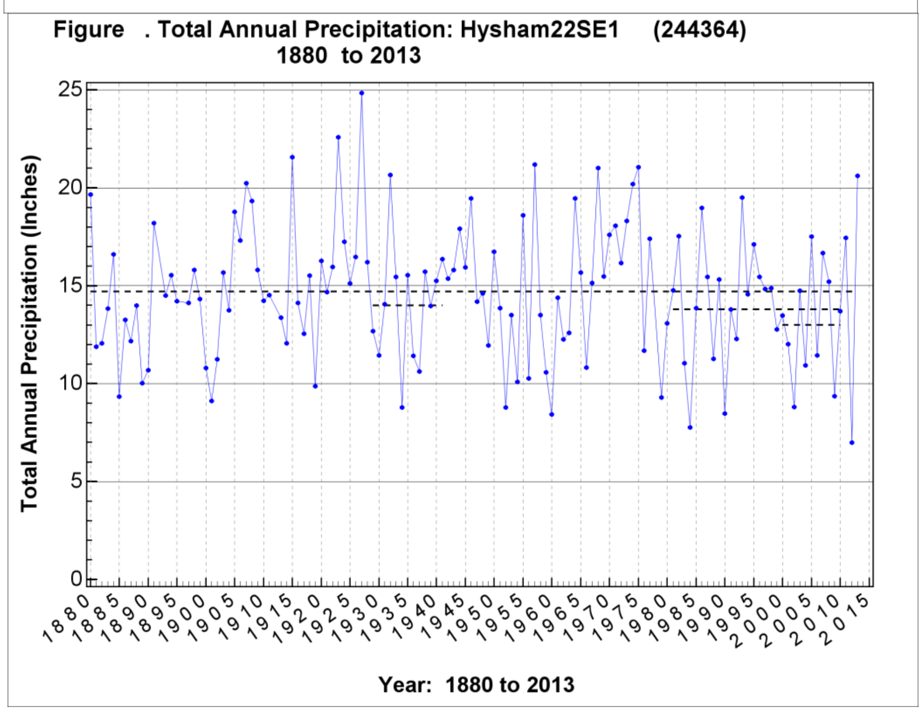


Figure 1.F. Hysham, Montana: Annual Temperature (1900-2013) and Annual Precipitation (1880-2013; dashed lines represent averages for different periods)

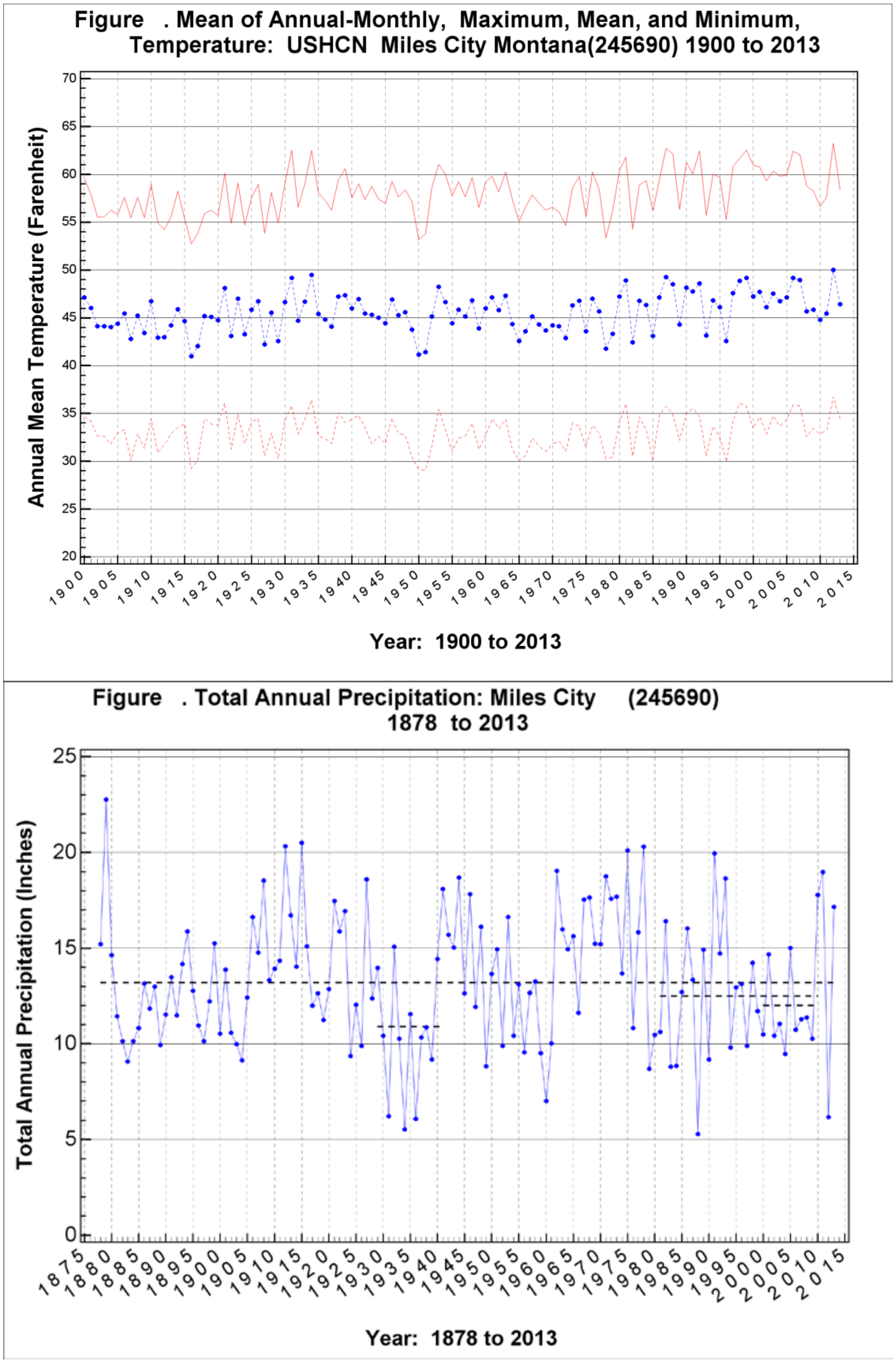
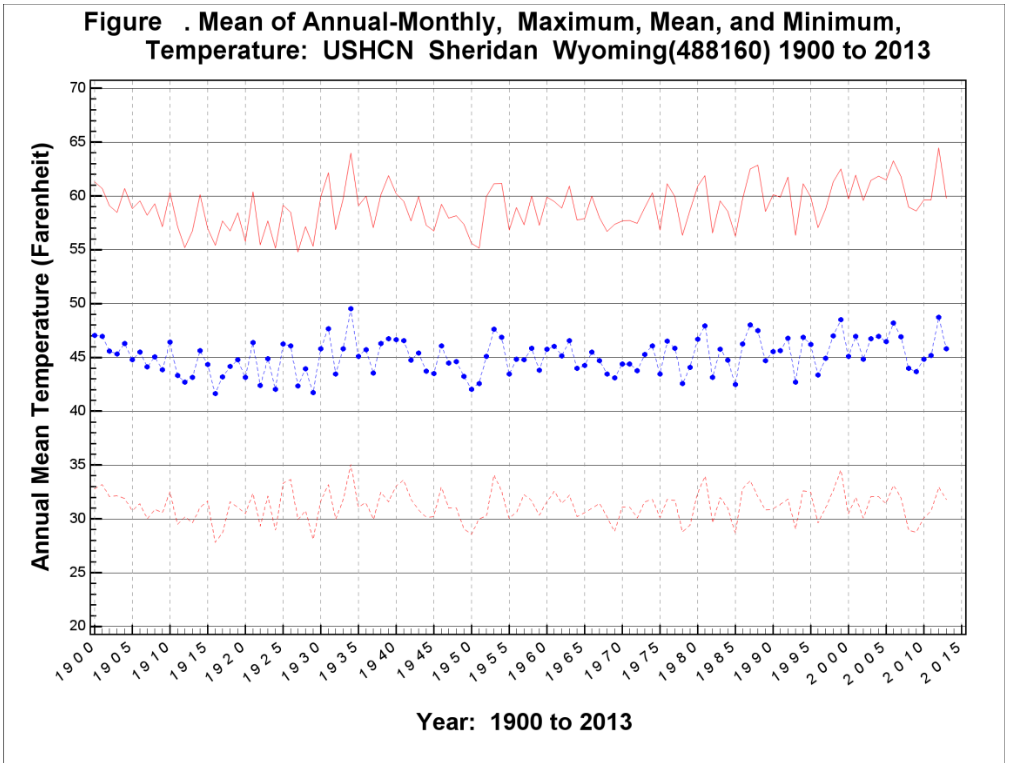


Figure 1.G. Miles City, Montana: Annual Temperature (1900 to 2013) and Annual Precipitation (1878-2013; dashed lines represent averages for different periods)



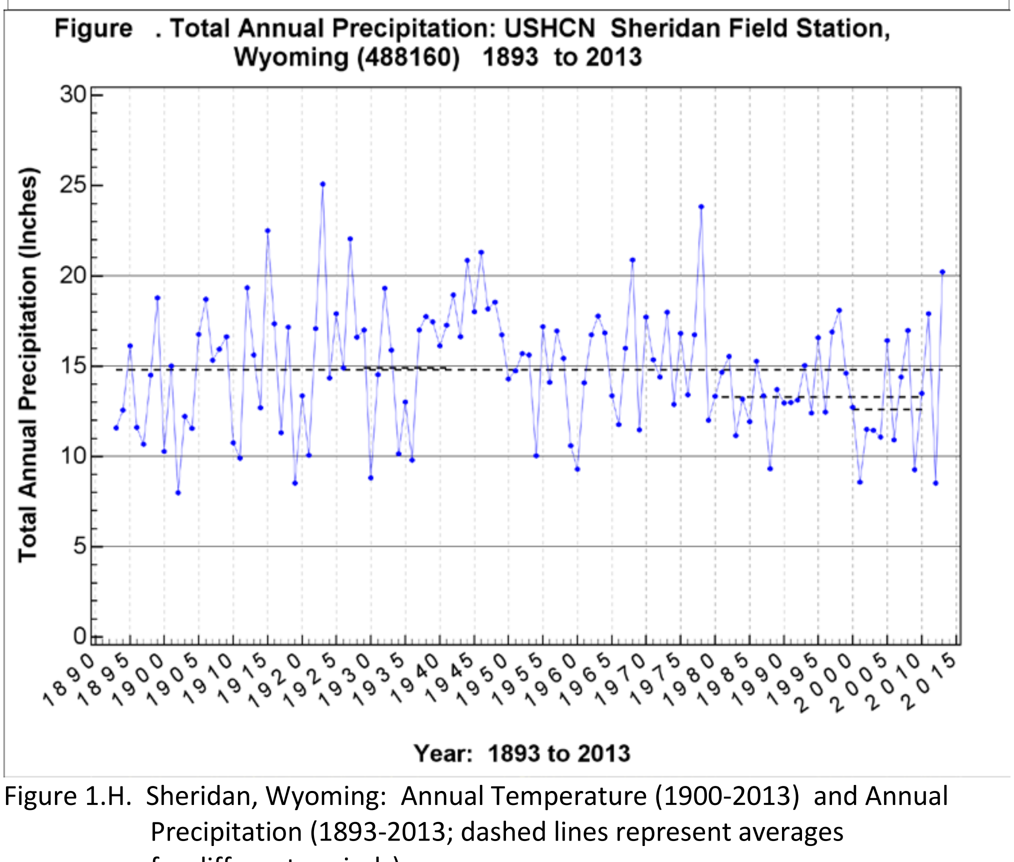
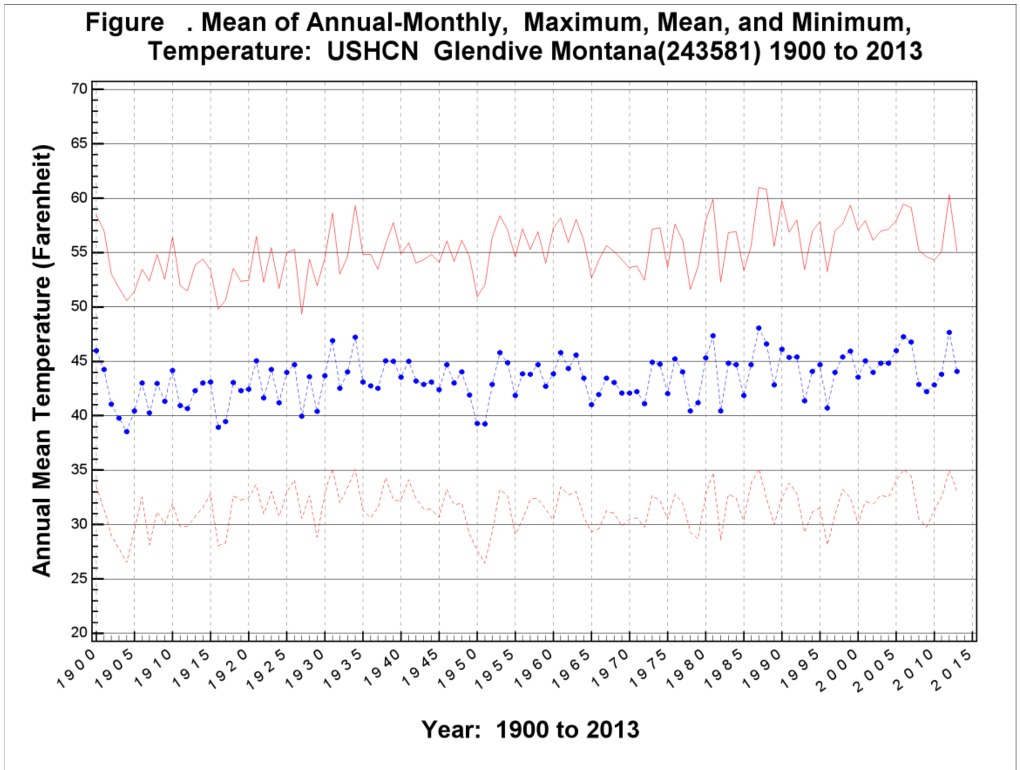


Figure 1.H. Sheridan, Wyoming: Annual Temperature (1900-2013) and Annual Precipitation (1893-2013; dashed lines represent averages for different periods)



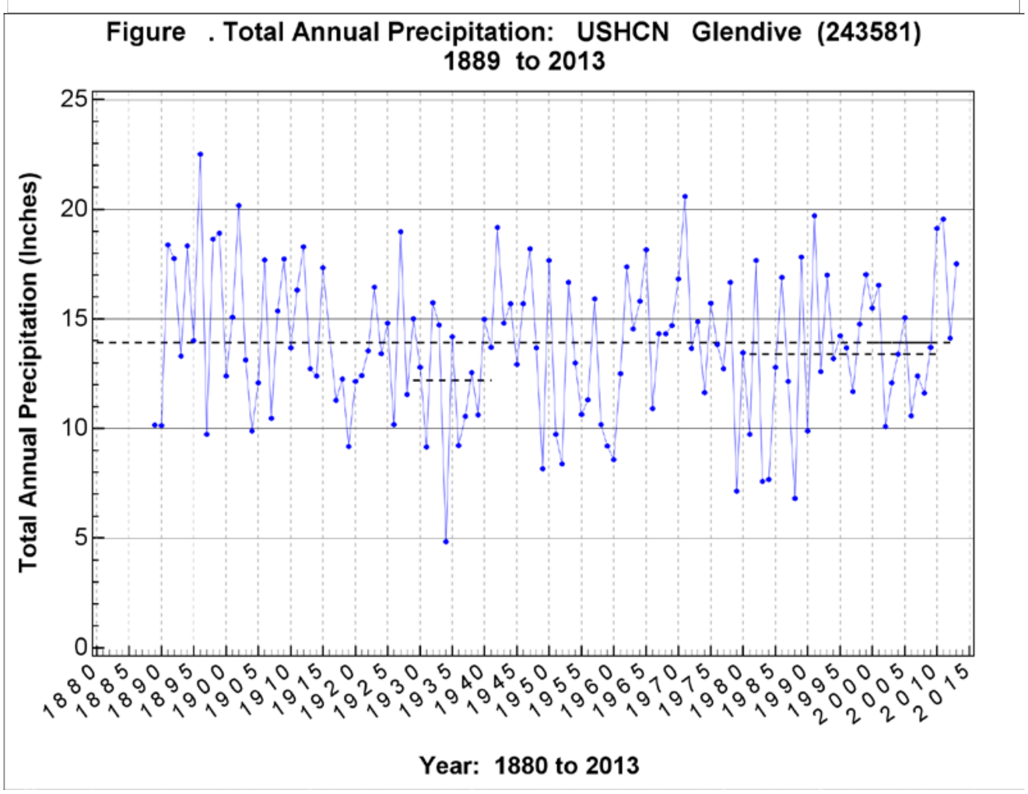


Figure1.I. Glendive, Montana: Annual Temperature (1900-2013) and Annual Precipitation (1889-2013; dashed lines represent averages for different periods)

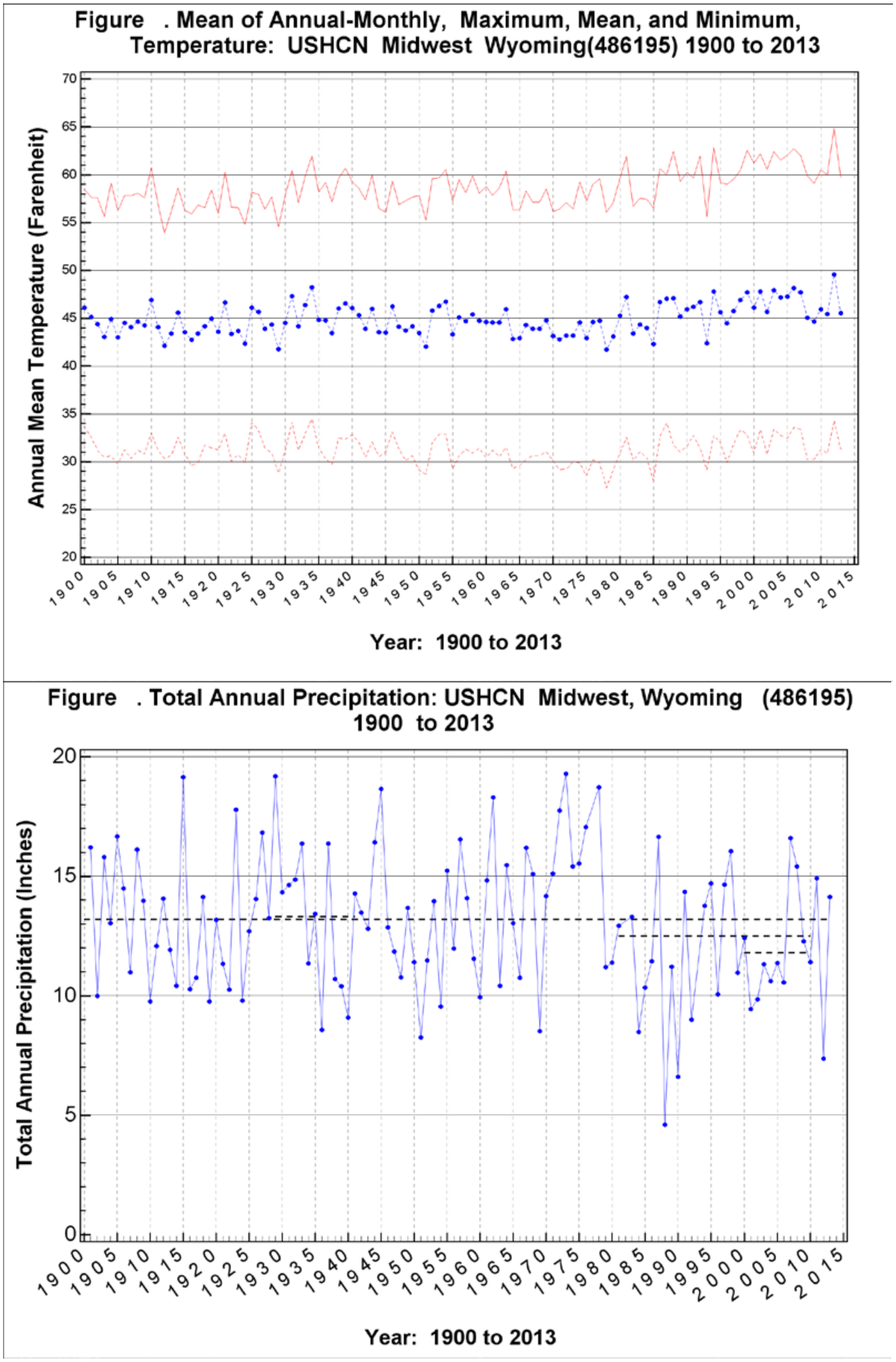


Figure 1.J. Midwest, Wyoming: Annual Temperature (1900-2013) and Annual Precipitation (1900-2013 ; dashed lines represent averages for different periods)

Historical Droughts in Montana

In the Upper Yellowstone and Bighorn River Basins (Figure IV. 2), the April 1 Snow Water Equivalent (SWE) during the 1929-1941 drought was about 30 percent less than the average value over the period from 1400 to 1950 A.D. April 1 SWE during the drought of the early to mid- 2000's was also about 30 percent less than the long-term mean, however the 1929-1941 drought was more persistent and extended several years longer in duration. A period of extended high snowpack occurred from about 1650 to 1890 that matches a period of cool wet conditions (Little Ice Age) during which local glaciers in the Beartooths, Bighorns and Wind River Mountains advanced and occurrence of fires was low.. While snowpack accumulation is an important variable influencing runoff and water supply, some years with average to slightly below average snowpack have produced extreme low-flow periods in the historical record. These low-flow periods occur in response to elevated summer temperatures that increase demand for and use of water.

Pederson and others (2011) conclude that "The increasing role of warming on large-scale snowpack variability and trends foreshadows fundamental impacts on streamflow and water supplies across the western United States. In much of this region, snow- pack declined since the 1950s, and continued reductions are expected throughout the 21st century and beyond. When coupled with increasing demand, additional warming- induced snowpack declines would threaten many current water storage and allocation strategies and lead to substantial strain on related infrastructure and overall supplies.
Changes in the amount of snowpack accumulation and timing of snowmelt have affected the hydrographs of streams by reducing the overall volume of runoff, and creating earlier spring runoff

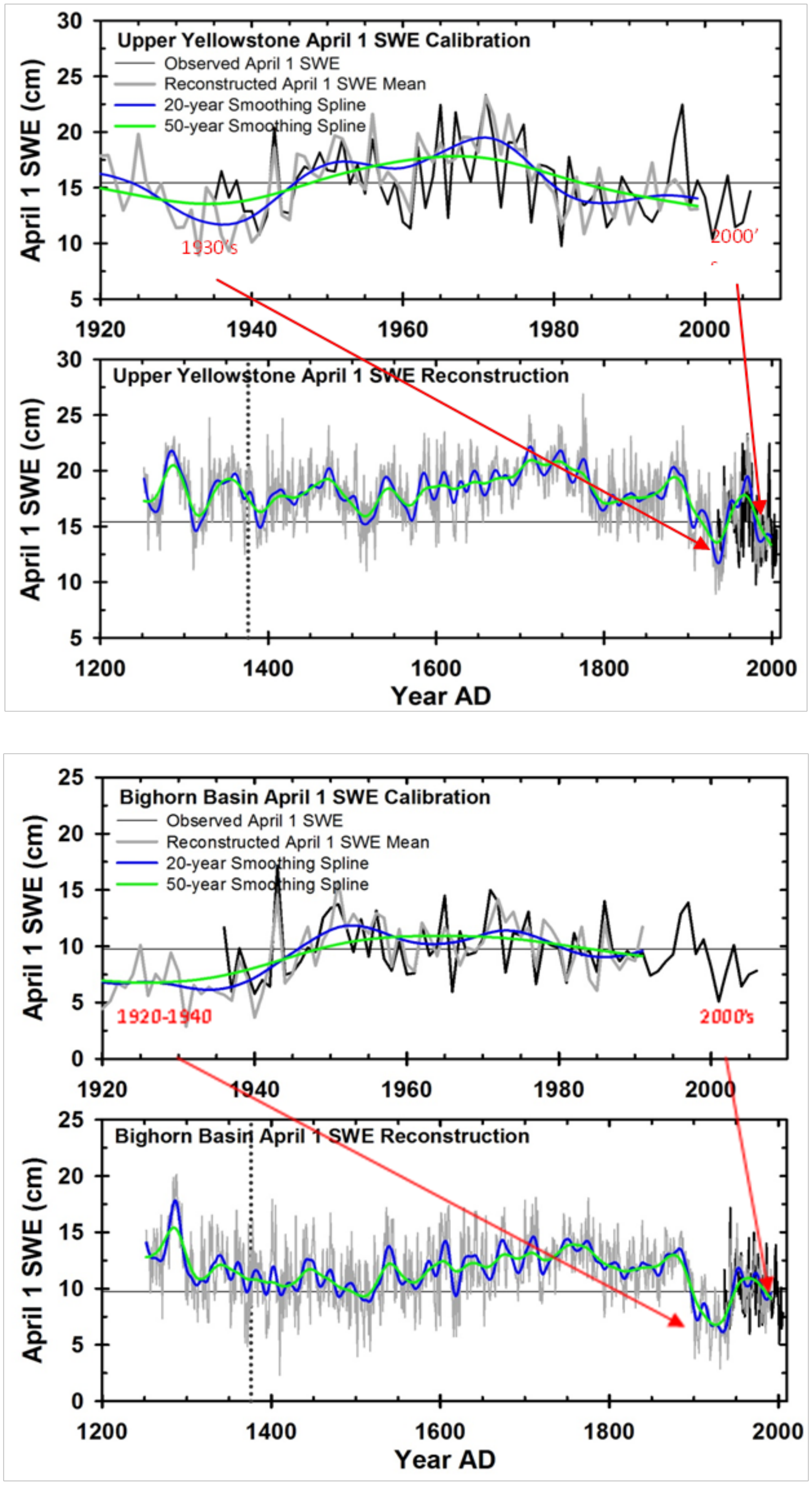


Figure IV.2. Observed and Estimated April 1 Snow Water Equivalent: Period 1200 to 2010. Upper Yellowstone and Bighorn River Basins.
(Pederson et.al., 2011).