P5.1 UP-TO-DATE MONTHLY CLIMATE MAPS FOR THE CONTERMINOUS UNITED STATES

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1. INTRODUCTION

A high-quality, topographically-sensitive, 103-year data set of monthly maximum and minimum temperature and precipitation on a 2.5-min (4-km) grid over the conterminous United States became available via the World Wide Web in 2002 (Daly et al. 2000, Gibson et al. 2002). The development of this data set was made possible though a grant from the NOAA Office of Global Programs. The gridded data and documentation can be downloaded from http://ncdc.noaa.gov/pub/data/prism100. These data sets are unprecedented in their combination of high quality, century-long temporal extent, and fine spatial detail. They enable users to perform a wide variety of analyses, including:

- Analysis of frequency, duration, and spatial patterns of extreme climatological events, such as drought and flooding, and extreme heat and cold
- Analysis of local and regional trends of climate variations
- Investigation of relationships between climatological variability and large-scale forcing mechanisms (e.g., ENSO or QBO)
- Transient ecological and natural resource modeling for use in global change assessment

This data set spans the years 1895-1997. Immediately after its release, there were calls for the data set to be updated to a more current year. An opportunity to do so arose with the establishment of the US Forest Service National Fire Risks and Impacts Project. Within this project, a program to produce seasonal predictions of national fire risks and impacts was begun under the leadership of Ron Neilson of the USFS PNW Research Station in Corvallis, Oregon. Predictive capability was needed for estimating fire fighting needs, as well as the risks of prescribed-fire "escapes." A major input to the fire prediction system was a steady, reliable stream of near-real-time monthly spatial climate products that could be easily transferred to a vegetation/fire model. Oregon State University's Spatial Climate Analysis Service (SCAS) was asked to provide the necessary climate data sets.

2. METHODS

Providing such a data stream required that an operational system be developed that could be run on a regular basis. This differed from SCAS' typical work, which consisted of well-defined mapping and research projects. It required creating an infrastructure for assimilating raw observational data from many sources, in many formats, and in many stages of readiness; intelligently assessing the quality and usefulness of these data; creating realistic map products that capture important geophysical effects on climate, such as topography and coastal influences; and delivering them to modelers in a timely and reliable fashion.

The method developed consisted of the following steps: (1) assimilate observational data; (2) perform quality control (QC) on the observations; (3) and produce grids from the point data and deliver the gridded data to the client. These steps are discussed below.

2.1. Assimilating the Observational Data

The first step in the process was the assimilation of station data from as many reliable sources as possible. To avoid developing redundant capability in this area, SCAS turned to the Western Regional Climate Center (WRCC) for its station data needs. WRCC is a major climate data repository for many networks, and specializes in rapid turnaround of observational data in near real-time. Over a several-month period, a data transfer protocol was worked out, whereby on or near the first of each month, WRCC would deliver daily ASOS data for the previous month, and the latest versions of the COOP data for preceding months. For example, on October 2, 2003, WRCC provided the following COOP data for the US and possessions:

Feb 2003: final
Mar 2003: preliminary
Apr 2003: preliminary
May 2003: quick look/provisional*
Jun 2003: quick look/provisional*
Jul 2003: quick look/provisional*
Aug 2003: quick look/provisional*
Sep 2003: provisional for the west only
**No provisional data for AK, HI, PI, PR or VI*

SNOTEL data for the previous month were accessed by SCAS directly from the USDA-NRCS ftp site. In the future, RAWS (Remote Automatic Weather Station) data, available in near real-time, may be added to the data stream by WRCC.

2.2. Quality Control of Station Data

Spatial modeling and mapping of climatic observations place higher demands on data quality than traditional, point-based analyses. Previous experience with spatial modeling projects has demonstrated the problems experienced with insufficiently QC'ed data

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sets. A single outlier has the capability to cause spatial abnormalities, sometimes quite large and obvious. The outlier may not appear unusual in a time series plot for a single station, but spatial analyses can often show the inconsistency of the outlier in relation to values from nearby stations. Quality control of the observational data is an especially critical step in the mapping process where preliminary, largely unchecked, data are being used.

A spatial QC system developed during the construction of the NOAA 103-year gridded data set is used to identify and omit observations that appear to be in error (Gibson et al., 2002). The spatial QC system uses a version of PRISM (Daly et al. 1994, 1997, 2002) that makes predictions for individual points in space, rather than producing gridded output. This point version of PRISM (sometimes referred to as ASSAY_QC) makes a prediction for each station for each month, in the absence of that station's data value. Large differences between the predicted and observed values indicate that there is a discrepancy between the station observation and those from surrounding stations. To determine what constituted a "large" discrepancy on a consistent basis, the QC system was trained with a manual QC method that used human expertise to determine observation validity.

2.3. Gridding and Delivering the Datasets

PRISM (Parameter-elevation Regressions on Independent Slopes Model) was used to create the gridded climate data sets. PRISM is a knowledge-based system that uses point data, a digital elevation model (DEM), and many other geographic data sets to generate gridded estimates of monthly and event-based climatic parameters (Daly et al. 1994, 1997, 2002). PRISM has been used extensively to map precipitation, dew point, and minimum and maximum temperature over the United States, Canada, China, and other countries (USDA-NRCS 1998, Daly and Johnson 1999, Daly et al. 2000, Plantico et al. 2000, Gibson et al. 2002, Daly et al. 2003).

Near real-time PRISM mapping of climate required an approach slightly different than the standard modeling procedure. The amount of station data available for recent months was much less than that available for the high-quality climatological PRISM precipitation and temperature maps, such as the peer-reviewed PRISM 1961-1990 mean precipitation maps (USDA-NRCS 1998). Data sources available for long-term mean maps but not readily available for recent months included most COOP stations, storage gauges, snow courses, and others. This meant that mapping climate in recent months using available data only would sacrifice a significant amount of the spatial detail present in the 1961-1990 mean climate maps.

A pilot study to identify ways of capturing more spatial detail in the recent climate maps was undertaken. Tests showed that the 1961-90 mean monthly climate maps were excellent predictors of a given month's climate, much better than elevation, which is typically used as the underlying, gridded predictor variable in PRISM applications. The relationships between 1961-90 mean monthly and individual monthly climate values were strong because much of the incorporation of the effects of various physiographic features on climate patterns had already been accomplished through the careful creation of the 1961-90 grids with PRISM.

Based on the results of the pilot study, PRISM was parameterized to use existing 1961-90 mean monthly grids of minimum and maximum temperature, precipitation, and dew point as the predictor grids in the interpolation of these climate elements for recent months. The PRISM weighting functions for distance, "elevation" (now the 1961-90 climatology), topographic facet, atmospheric layer, orographic effectiveness, and coastal proximity were all retained. This allowed observed deviations from normal to be interpolated with sensitivity to physiographic factors, such as might occur when a month has below normal temperatures along the coast and above-normal temperatures inland.

PRISM was run in this fashion for the period January 1998 to December 2002 to complete a seamless time series from 1895 to 2002. Starting in 2002, PRISM has been run operationally to produce grids of the most recent month, as well as previous months for which there are new station data available. When a new version of a monthly grid is produced, it replaces the old one. The resulting process is akin to a several-month temporal moving window of modeling and re-modeling of climate elements. Each month typically goes through about 6-9 iterations, depending on the length of time for all of the COOP data to be finalized. Occasionally it is necessary to update a month in the more distant past if new data, or a new version of the present data, become available. For example, the USDA-NRCS occasionally releases corrections to SNOTEL data a year or more after the data are observed.

Grids are delivered to the client via ftp at two resolutions: 0.5 degrees and 2.5 minutes. 2.5 minutes is the native resolution of the grids, and the 0.5-degree resolution is achieved by applying a Gaussian filter to the 2.5-minute grids. The format of the grids is currently ARCInfo ASCII GRID. Deliveries are typically made before the 15th of the month.

3. RESULTS AND DISCUSSION

The station data available for a given month generally decreases as months become more recent. Figure 1a shows the density and distribution of precipitation stations received in the October 2, 2003 data transfer for September, 2003, and Figure 1b shows precipitation stations received for February 2003 from the same data transfer. Precipitation data sources for September were primarily ASOS and SNOTEL, with a few COOP sites in the western US. For February, most of the COOP data were available in final form, adding greatly to the density and coverage of stations. Figure 2 shows the station distributions of dew point for the same months. Dew point is observed at a small number of mainly first-order ASOS stations. Because ASOS data are available in near real-time, there is little change to the overall number of available stations as time goes by.

In Figure 3 are examples of the gridded PRISM output for July 2003 at its native 2.5-minute resolution. These maps were created in August after the data distribution for that month, so the station density available was very similar to that shown in Figure 1a for precipitation and temperature and Figure 2a for dew point. These are primarily ASOS and SNOTEL, except for dew point, which is ASOS only. Using 1961-90 mean climate maps as the predictor grids in PRISM applications makes it possible to retain the level of spatial detail depicted in the 1961-90 maps at a fraction of the station density.

4. CONCLUSIONS AND FURTHER WORK

An operational system has been developed which produces detailed, high-quality, gridded data sets of monthly precipitation, maximum and minimum temperature, and dew point over the conterminous US within two weeks of the end of the month. This system, in combination with historical projects, has allowed the development of a constantly extended monthly climate time series that spans January 1895 to the month just ended. A new parameterization of PRISM allows it to take advantage of the predictive power of the 1961-90 climatological grids by using them as predictor grids, rather than a DEM. This result is more detailed grids that possess much of the expected spatial patterns in climate (e.g., orographic and coastal effects) with minimal station data. Rigorous QC of the station observations is performed, because of the demands placed on station data by the mapping process, and use of preliminary, largely unchecked data.

These spatial data products are freely available to the general public. We anticipate having them available for download from the PRISM web site (http://www.ocs.oregonstate.edu/prism) in winter 2004, but in the meantime can be obtained on a case-by-case basis from the SCAS. As such, they should be valuable sources of information for drought monitoring, water supply forecasting, long-term weather outlooks, and providing contextual information for extreme weather and climate events.

Further work envisaged under sponsorship of the US Forest Service National Fire Risks and Impacts Project includes:

- Update current 1950-1993 Alaska monthly climate time series to the present, and begin operational mapping for Alaska
- Create a long-term monthly solar radiation climatology for the US
- Create a century-long series of 2.5-minute and 0.5-degree daily climate grids for all climate variables for the conterminous US and Alaska

Indefinite continuance of the near real-time monthly mapping project is not guaranteed. Monthly updates of the current data sets will continue for as long as funding is available from the US Forest Service or other agencies. If funding ends, there will be a need to find long-term support for continued operation.

There is great potential for the products described above to continue under a proposed program with similar, but broader, goals, called the Western Climate Mapping Initiative (WestMap). This initiative was put forth by a consortium consisting of University of Arizona, Oregon State University, Desert Research Institute/WRCC, USDA/NRCS, SCRIPPS/CAP, and NOAA/CDC. WestMap consists of three primary interwoven segments:

1) Data development and operations
2) Error assessments, data analyses and diagnostics
3) Data access, visualization and educational resources.

WestMap aims to provide an easily accessible, comprehensive package of 1 km monthly (or better) resolution climate data series, with associated accuracy estimates, online analysis tools, and educational resources to the highly diverse user communities of the United States. Key applications of WestMap products are envisaged in five broad areas:

- Drought mitigation/monitoring
- Climate variability
- Water management
- Global change modeling/assessment
- Forecasts (initial conditions)
- Downscaling of forecasts (limits of predictability, model verification).

The consortium, with extensive climate-related expertise, shares a common need for and interest in fine-scale gridded climate data for a myriad of western U.S. climate-related research and stakeholder driven considerations. The WestMap consortium has since begun pursuing funding partners to fully implement the WestMap initiative.

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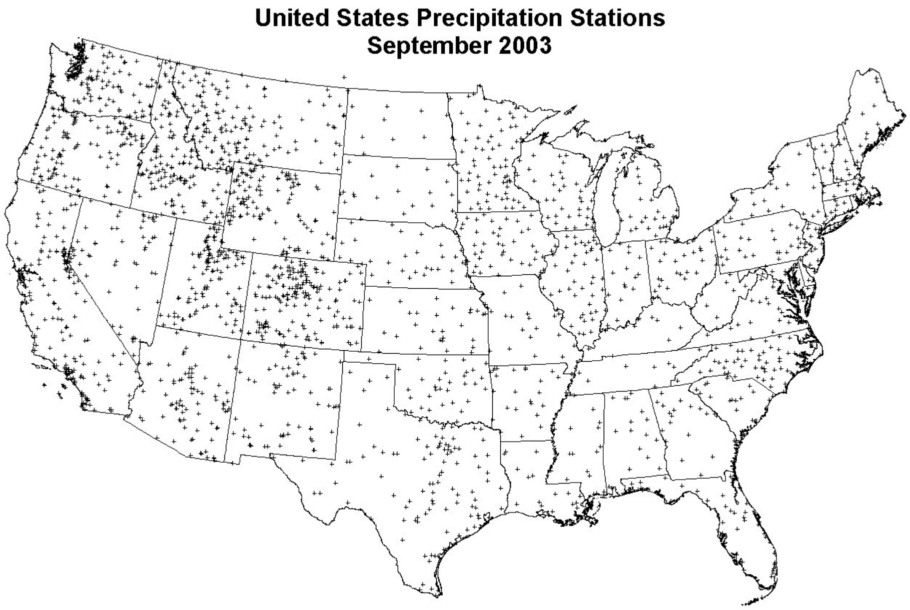
(a)



(b)

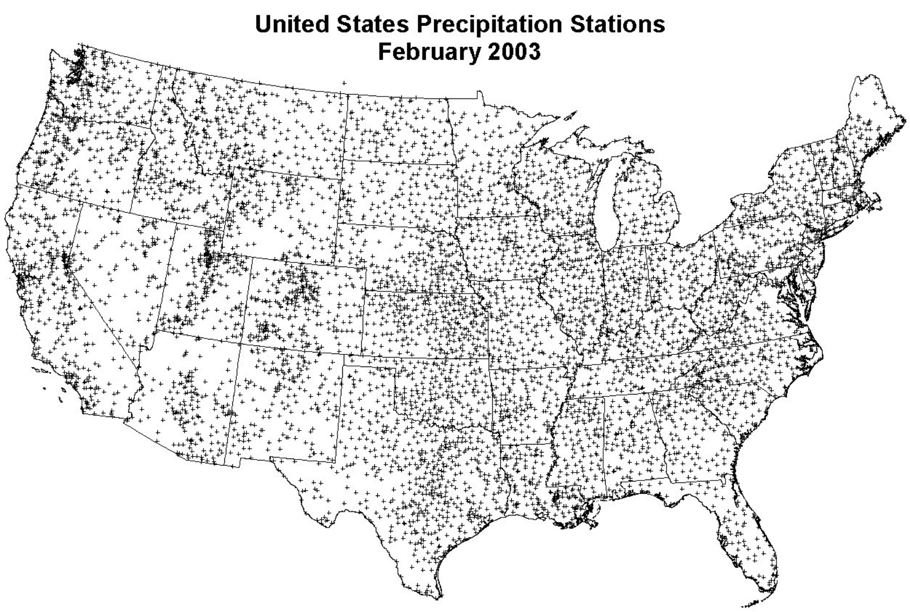
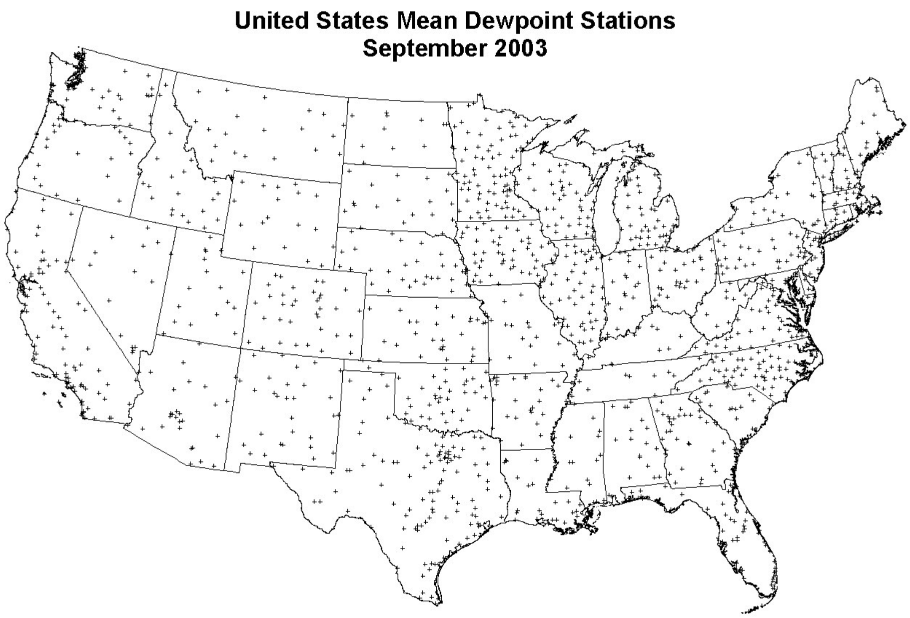


Figure 1. Precipitation stations received on October 2, 2003 for (a) September, 2003; and (b) February 2003.

(a)



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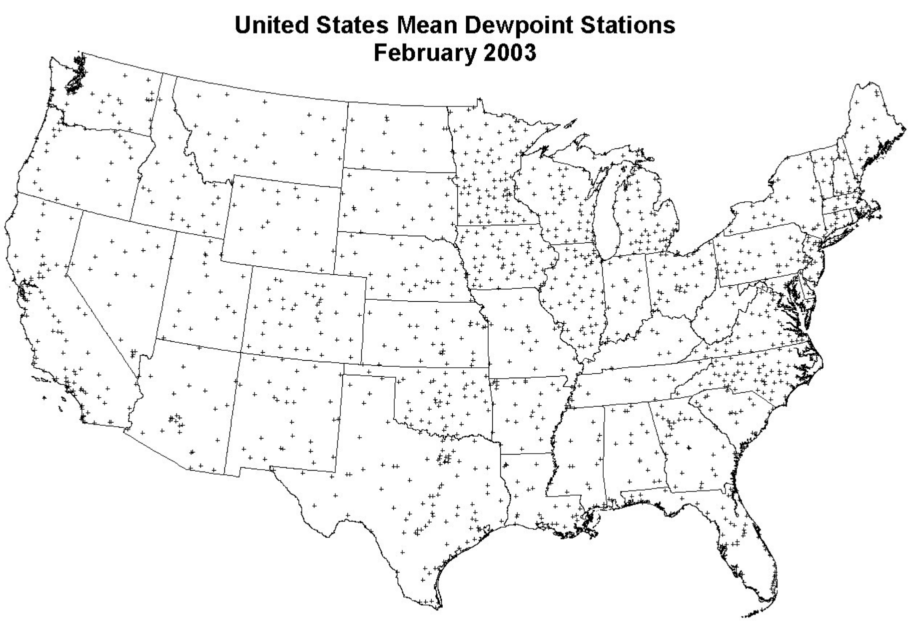
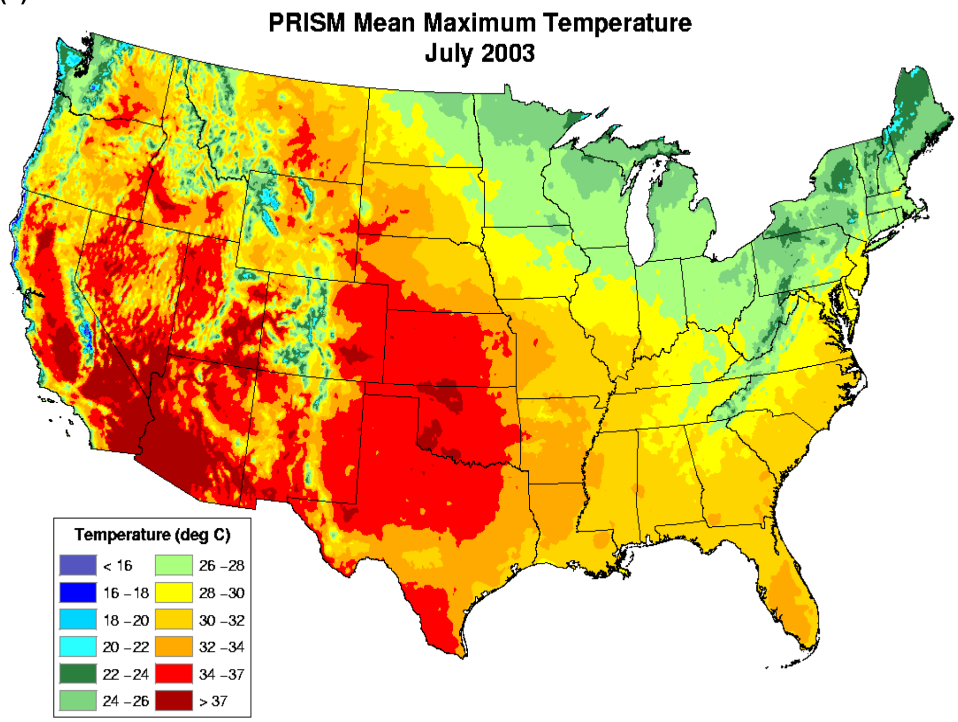
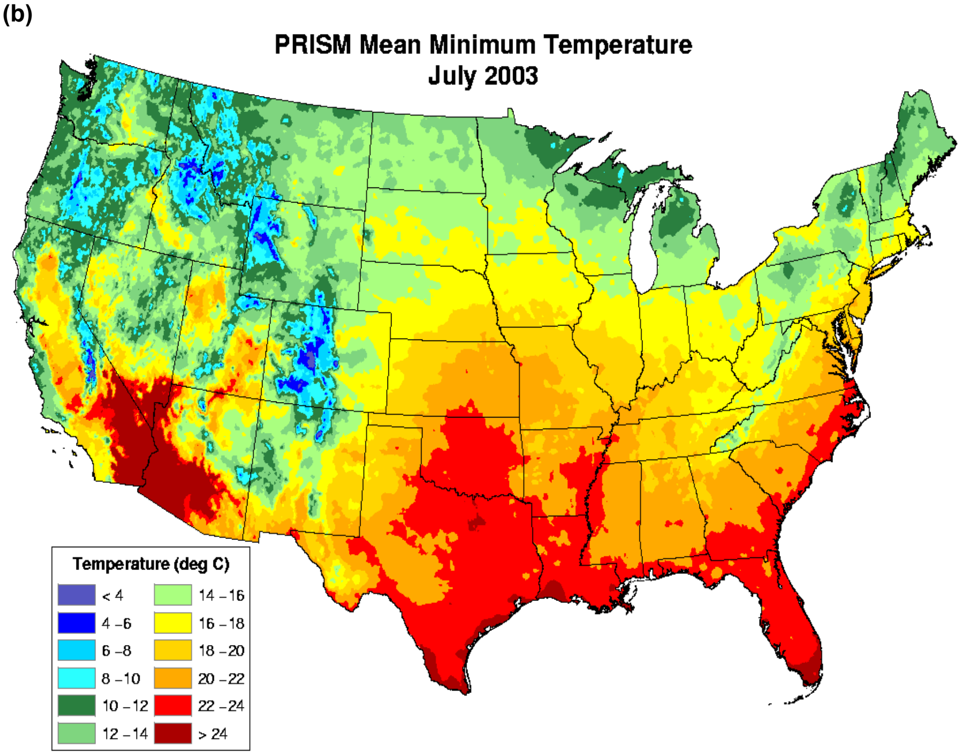


Figure 2. Dew point stations received on October 2, 2003 for (a) September, 2003; and (b) February 2003.

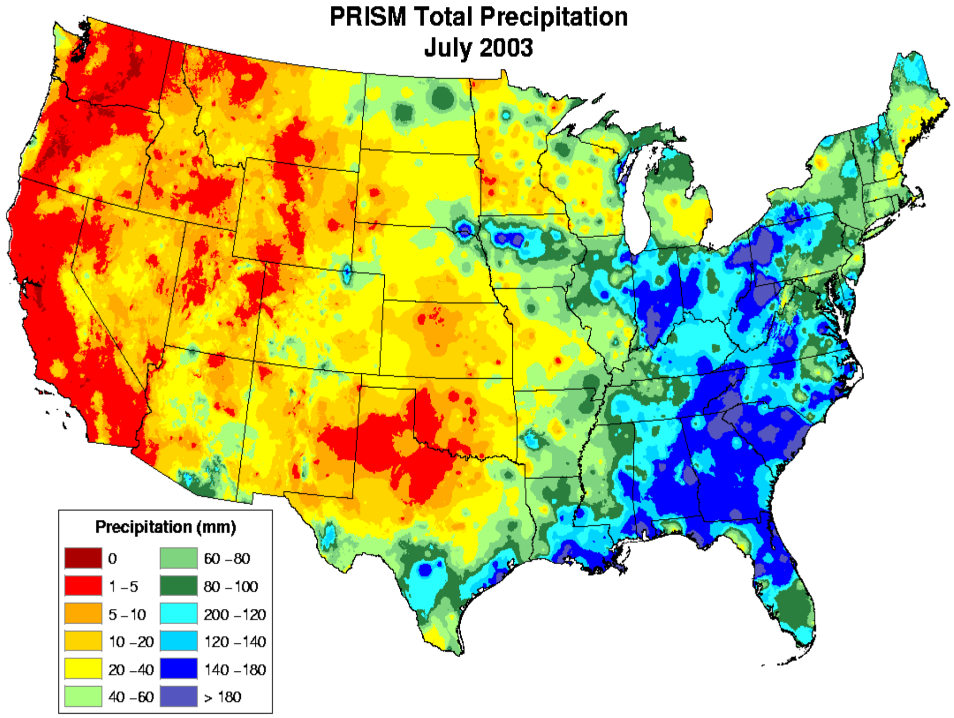
(a)


PRISM Mean Maximum Temperature
July 2003
Temperature (deg C)
< 16
16 – 18
18 – 20
20 – 22
22 – 24
24 – 26
26 – 28
28 – 30
30 – 32
32 – 34
34 – 37
> 37

(b)


PRISM Mean Minimum Temperature
July 2003
Temperature (deg C)
< 4
4 – 6
6 – 8
8 – 10
10 – 12
12 – 14
14 – 16
16 – 18
18 – 20
20 – 22
22 – 24
> 24

(c)



(d)

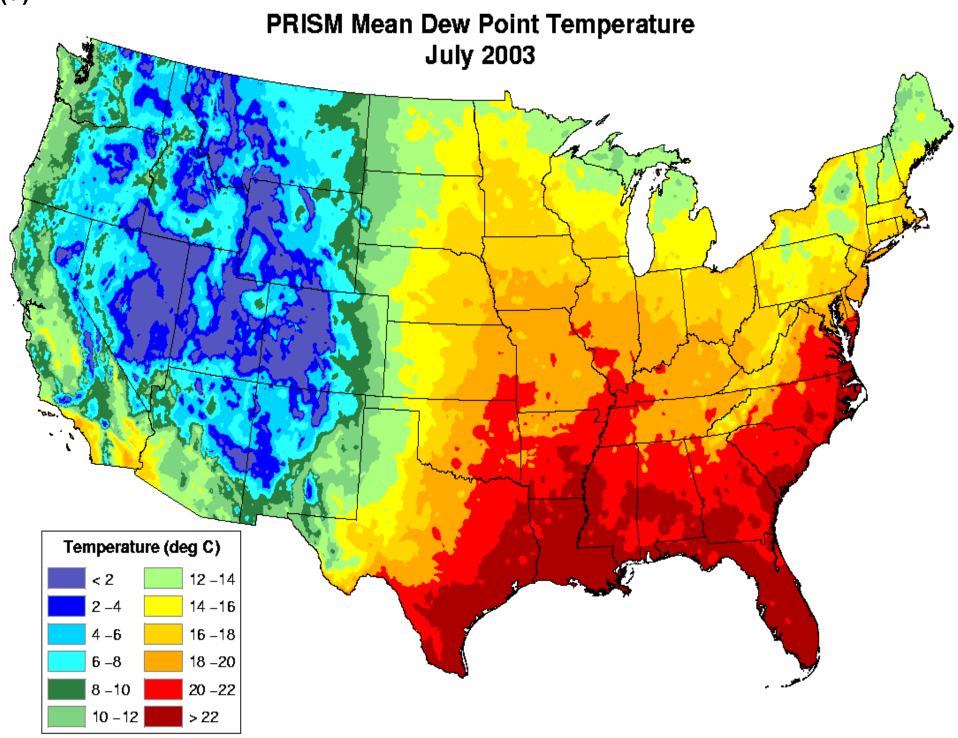


Figure 3. Maps of (a) maximum temperature, (b) minimum temperature, (c) precipitation, and (d) dew point for July 2003, created August 12, 2003. Station data available were very similar to those shown in Figure 1a for precipitation and temperature and Figure 2a for dew point. These are primarily ASOS and SNOTEL, except for dew point, which is ASOS only.