Climate Science

Visualizing Climate / Climate Variability and Short-Term Forecasting

VISUALIZING CLIMATE

Driving Question: *How are the unique climate characteristics of different locations on Earth routinely displayed so their climates can be systematically compared?*

Educational Outcomes: To describe how climate has traditionally been held to be the synthesis of weather conditions, both the average of parameters, generally temperature and precipitation, over a period of time and the extremes in weather over the period of record. To portray the statistical descriptive information of climate in graphs, typically as the magnitude of the average value (or extremes) versus the months of the year. To examine climographs of various locations which show relationships between temperature and precipitation during the yearly cycle.

Objectives: After completing this investigation, you should be able to:

• Portray the statistical climate values of mean monthly temperature and average total monthly precipitation in the graphical form called the climograph.
• Compare and contrast temperature and precipitation distributions on climographs from different locations.
• Explain how climograph patterns can be related to climate forcings.
• Relate certain patterns of temperature and precipitation to particular climate classification types.

Portraying Climates of Various Locations With Climographs

Every location on Earth has climate characteristics that distinguish it from other locations. It is desirable to systematically describe these characteristics so that the climates of various locations can be compared. This investigation focuses on climate as described by average values alone. It is important to remember that by relying on average values, only a generalized and incomplete picture of the climate is provided. A *climograph* is a commonly used tool to portray the climate of a given locale and compare climates from various places. A climograph can be drawn to show monthly mean temperatures and average precipitation totals (rain plus melted snow and ice) for a single station through the year on the same graph. **Figures 2 - 7** are climographs for six locations in the United States which give examples of major climate types discussed in the Climate Classifications of Chapter 13 in the textbook.

A climograph can provide at a glance the magnitudes and ranges of monthly mean temperatures and average monthly precipitation totals throughout the year. These statistics are genetically tied to various climate-determining factors which vary systematically from place to place. It is possible to relate distributions of temperature and precipitation to specific climatic forcings to gain a more comprehensive understanding of the controls of the climate in a specific area. Because these

controls and the climates which result have significant impact on other aspects of the Earth system (human housing, fresh water supply, agriculture, health, etc.), such an understanding has widespread applications. It is also desirable to have a shorthand classification for the major types of recurrent temperature and precipitation patterns so one may be able to generalize about climates up to the global scale.

By convention, as shown in **Figures 2 - 7**, climographs are usually constructed with time of year displayed horizontally across the base of the graph. The initial letter of the month is listed at mid-month along the bottom, with the precipitation scale along the left vertical axis and mean temperature scale on the right axis. Mean monthly precipitation totals (rain plus melted snow and ice) are presented as a bar graph. The mean temperature values are plotted as points and connected by a curve. In the U.S., climate data are prepared with precipitation in inches and temperatures in degrees Fahrenheit. **Use the data and grid in Figure 1 below to make a climograph for Boston, MA. Mark a short horizontal line at mid-month to note the position of the mean total precipitation value of that month and fill in the space below to create a bar. (Use Figures 2 - 7 as a guide.) Place a dot at mid-month at the level denoting the mean monthly temperature value. When all the months are plotted, connect the temperature dots with curved line segments to represent the march of average monthly temperature.**

1. Your completed climograph for Boston, MA (Figure 1) shows that the mean monthly temperature rises from near freezing during the winter months (Dec, Jan, and Feb) to means around 70 °F during the summer months (June, Jul, and Aug) and then falls as winter approaches. The observed temperatures from which the means are computed result mainly from the seasonal swing of solar heating, which in turn is largely determined by latitude. As a general rule, the higher the latitude the lower the winter season temperatures. The lowest mean monthly temperature in Boston occurs in **[(*January*) (*December*)].**

2. This minimum monthly temperature **[(*is*)(*is not*)]** within a month or so of the time of minimum receipt of solar radiation in a mid latitude, Northern Hemisphere location.

3. Where solar heating varies significantly between the winter and summer solstices, the range of temperature, indicated by the amplitude of the temperature curve on a climograph, is relatively large. Where the amplitude is relatively small, the seasonal temperature contrast is also small. Examine the temperature curve on the climograph for Hilo, HI (**Figure 2**). The range of mean monthly temperatures for Hilo is about **[(*5*)(*20*)(*30*)]** Fahrenheit degrees.

4. From the shape of the curve and range of temperature, it is evident that Hilo experiences relatively **[(*little*)(*significant*)]** variation in solar heating through the course of a year.

5. The highest mean monthly temperature in Hilo occurs in August. This temperature is about **[(*76*) (*86*)]** °F.

6. The lowest mean monthly temperature is about **[(*71*)(*81*)]** °F in both Jan. and Feb.

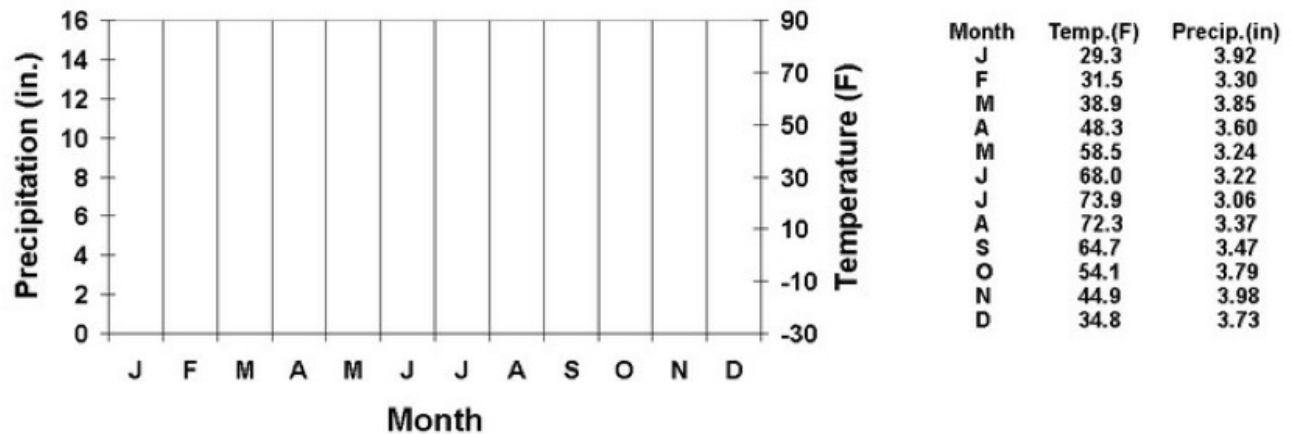7. These temperatures suggest that Hilo is a **[(*high*)(*low*)]** latitude location.

Boston (42 N, 71 W)

Month	Temp.(F)	Precip.(in)
J	29.3	3.92
F	31.5	3.30
M	38.9	3.85
A	48.3	3.60
M	58.5	3.24
J	68.0	3.22
J	73.9	3.06
A	72.3	3.37
S	64.7	3.47
O	54.1	3.79
N	44.9	3.98
D	34.8	3.73

Figure 1.
Humid Continental Climate (Dfa) - Boston

8. The month of occurrence of the highest mean temperature suggests that Hilo is located in the **[(*Northern*)(*Southern*)]** Hemisphere.

9. Temperature and temperature range can also be influenced by large bodies of water (ocean or large lake). Generally speaking, a maritime influence will moderate temperatures in places that would normally be colder in winter and warmer in summer based on latitude alone. The seasonal range in temperatures is likely to be less due to a maritime influence; that is, the temperature curve on the climograph will exhibit less amplitude. In continental locations or locations downwind of large land masses, temperatures tend to be higher in summer and lower in winter. As a result, the seasonal temperature range will be far greater than for places surrounded by or downwind of a large water body. It is likely that Hilo's relatively low annual temperature range **[(*is*)(*is not*)]** moderated by the surrounding Pacific Ocean.

10. Examine the climograph for Fairbanks, AK (**Figure 6**). The highest mean monthly temperature is **[(*62*)(*82*)]** °F.

11. The lowest mean monthly temperature for Fairbanks is **[(*–10*)(*10*)]** °F.

12. These temperatures suggest that Fairbanks is a **[(*high*)(*low*)]** latitude location.

13. The average monthly temperatures in Fairbanks cover a range of about **[(*70*)(*50*)(*30*)]** Fahrenheit degrees.

14. This range of temperatures suggests that Fairbanks has a **[(*continental*) (*maritime*)]** climate.

15. Compare the annual temperature range for Boston, on the Atlantic coast, (**Figure 1**) and Seattle, WA, near the Pacific coast, (**Figure 5**). Seattle's annual temperature range is **[(*greater than*) (*less than*)]** that of Boston.

16. These cities are at approximately the same latitude and both are located near the coast. The climate control causing the difference in annual temperature range is the influence of the prevailing westerly wind at both locations. For Seattle, the temperature range is influenced mainly by the **[(ocean)(continent)]** which is upwind and in Boston by prevailing winds blowing from the continent.

17. Climate classification systems allow climate differences and similarities to be expressed in a "shorthand" form. The broad-scale climate boundaries in the *Köppen* climate classification system (see Chapter 13 of the text) are based on patterns in annual and monthly mean temperature and precipitation, which closely correspond to the limits of vegetative communities. The major classifications of *Tropical Humid* (A), *Subtropical* (C), *Snow Forest* (D), and *Polar* (E) are based on temperature; the group *Dry* (B) is based on precipitation; and the group *Highland* (H) applies to mountainous regions. Temperatures for both Fairbanks and Boston place them both in the **[(Tropical Humid (A)) (Subtropical (C))(Snow Forest (D))(Polar (E))]** climate classification.
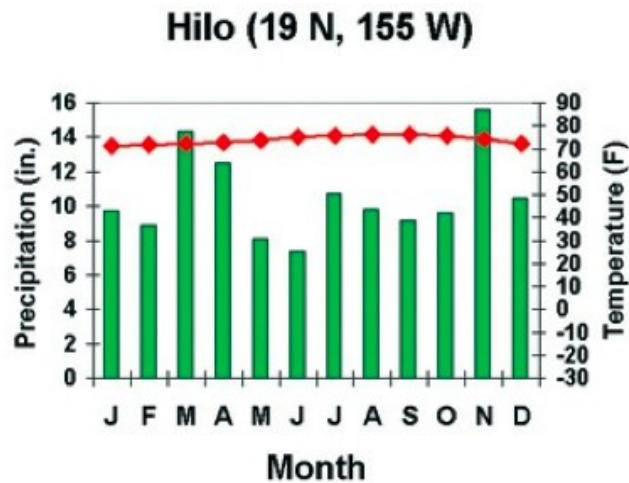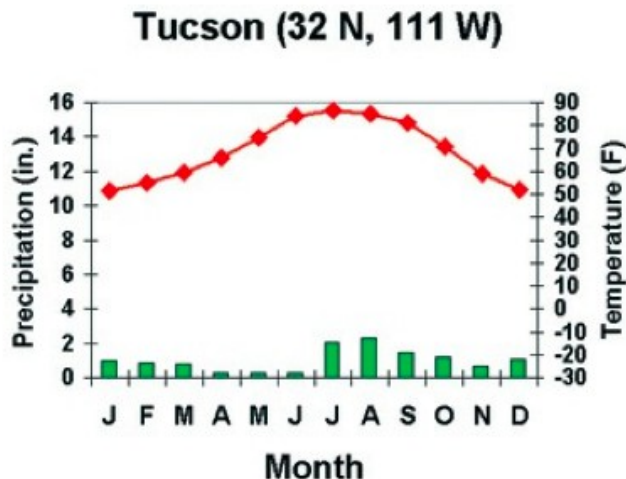

Figure 2.
Tropical Wet Climate (Af) - Hilo.

Figure 3
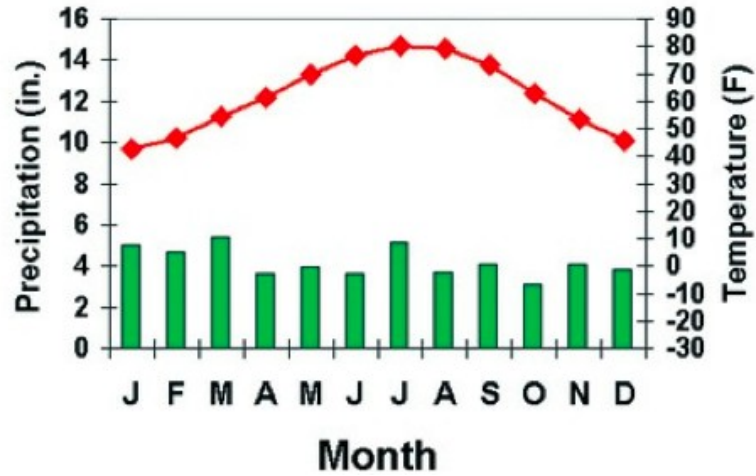Subtropical Desert Climate (BWh) - Tucson.

Atlanta (33 N, 84 W)

Figure 4.
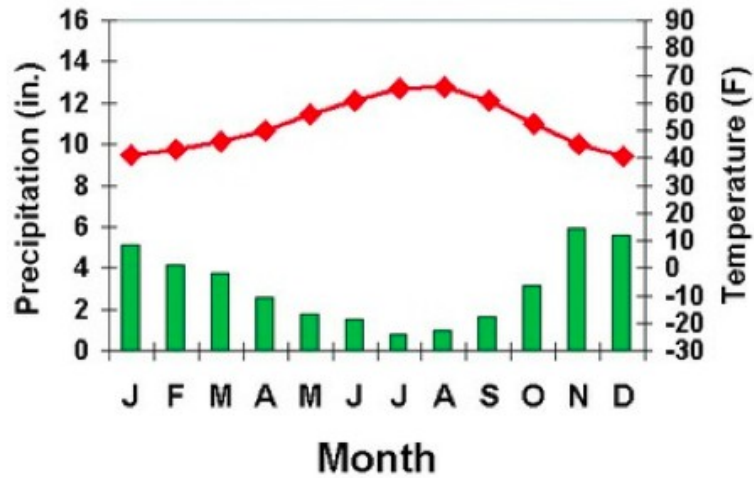Subtropical Humid Climate (Cfa) - Atlanta.

Seattle (47 N, 122 W)

Figure 5.
Marine West Coast Climate (Cfb) - Seattle.
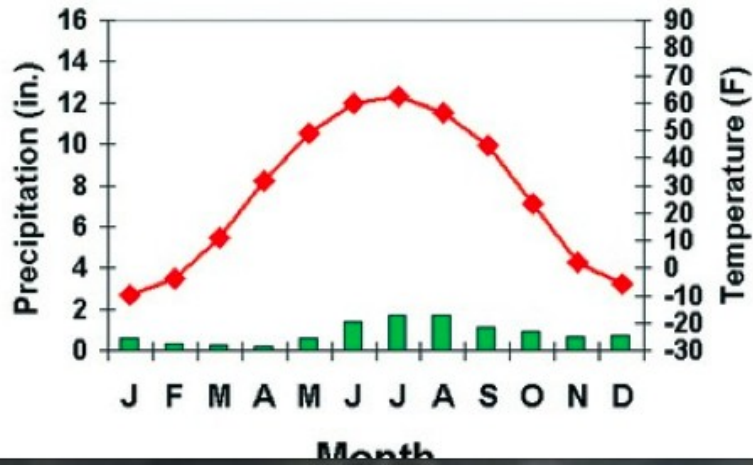
Fairbanks (64 N, 147 W)

Figure 6.
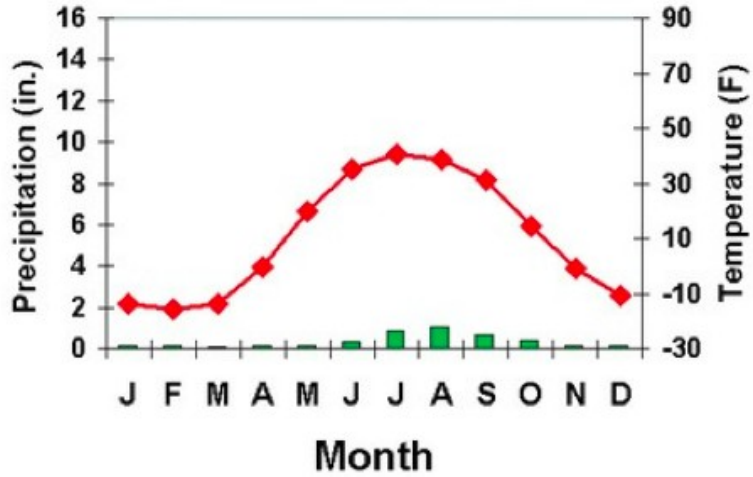Subarctic Climate (Dfc) - Fairbanks.

Barrow (71 N, 156 W)

Figure 7.
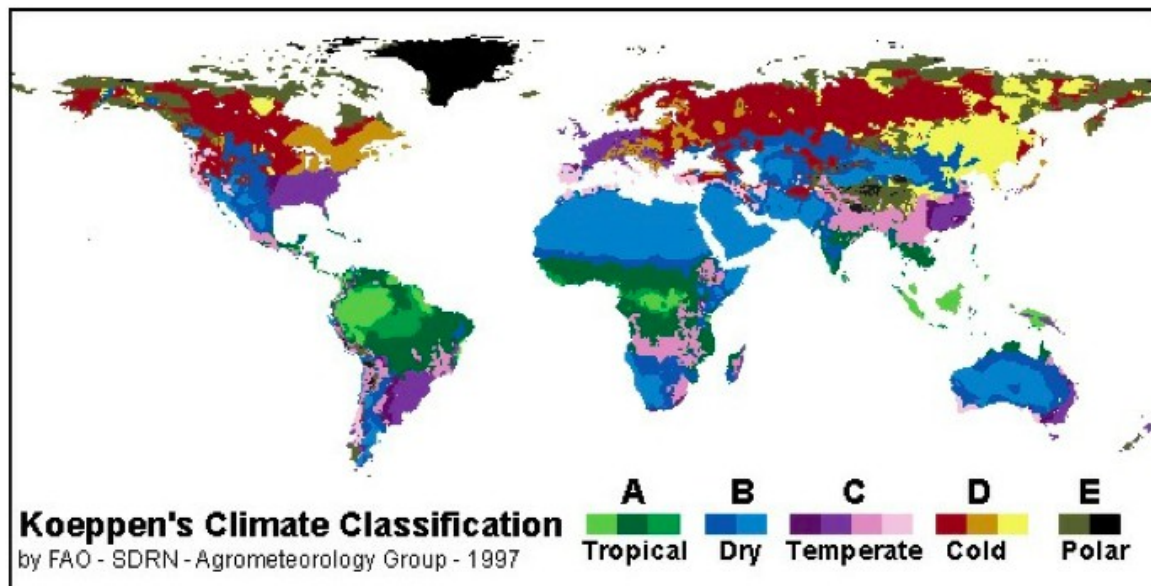Polar Tundra Climate (Et) - Barrow.

Figure 8. Koeppen's Climate classification. (*Adapted from UN Food and Agriculture Organization, Sustainable Development website*.)

18. The second letter of the Boston (Figure 1) and Fairbanks (Figure 6) classifications corresponds to seasonal precipitation regimes with an "f" signifying year-round precipitation. According to their climographs and climate classifications, Boston and Fairbanks have **[(*similar*)(*very different*)]** month-to-month uniformity in their precipitation regimes.

19. Arid and Semiarid climates can be caused by several climate controls. Locations on the eastern side of planetary-scale, semi-permanent subtropical high pressure systems, such as those occurring around 30 degrees N in the Atlantic and Pacific Ocean basins, are characterized by subsiding air, which inhibits cloud formation and precipitation. The western side of such systems, by contrast, tends to be humid. The cause of dryness in Tucson, AZ, for example, is due mainly to its position
[(*east*)(*west*)] of a subtropical high pressure system which persists off the southwest U.S. coast in the Pacific.

20. Atlanta, GA, at about the same latitude as Tucson, but in the southeastern United States, is humid because it is located **[(*east*)(*west*)]** of the Bermuda-Azores subtropical high over the Atlantic Ocean basin.

21. Dry or wet conditions can also be caused by location upwind or downwind of a mountain range. Areas to the lee of high mountains tend to be dry because of the "wringing out" of moisture on the wet, windward slopes (due to orographic lifting, cooling and condensation) and the compressional warming of air which occurs as the air descends on the leeward slopes. The

atmospheric stability caused by cold ocean currents offshore can also prevent precipitation by stabilizing the overlying air and inhibiting convection. On the other hand, instability cloudiness and precipitation can occur if ocean currents are relatively warm. Tucson, located downwind of the Coastal Ranges and the cold California Current, is **[(*probably*)(*not likely*)]** drier because of the influence of mountains and ocean currents.

22. The **Figure 8** world map showing the Koeppen (or Köppen) climate classification system demonstrates the actual application of climatic controls. For example, on this Mercator projection map, horizontal lines (if they were drawn) would represent constant latitudes. Therefore, at similar latitudes across the Eurasian land mass, Europe to the west is shown in purple, indicating a temperate climate while eastern Asia is in yellow indicating a cold type climate. The climate control primarily at work in these climate types is the prevailing wind circulation in relation to **[(*elevation*)(*proximity to large bodies of water*) (*Earth's surface characteristics*)].**

23. The region of Tibet in south central Asia is shown in the greenish-brown of a polar type climate although it is surrounded by dry or temperate climates. This classification is most likely the result of Tibet's **[(*elevation*)(*proximity to large bodies of water*)(*Earth's surface characteristics*)].**

Summary: Climate classification systems have been devised to simplify and organize climate types by grouping together climates having common characteristics. Such systems allow climate differences and similarities to be expressed. The climograph is a commonly used tool that shows the relationships between temperature and precipitation during the yearly cycle.

Suggestions for further investigations: For interactive maps where cities in the United States may be selected to display their climographs, go to: *http://www.drought.unl.edu/DroughtBasics/WhatisClimatology/ClimographsforSelectedUSCities.aspx*. For interactive maps where climographs for international cities can be selected, go to: *http://www.drought.unl.edu/DroughtBasics/WhatisClimatology/ClimographsforSelectedInternationalC*

You can make your own climographs with monthly average temperatures and precipitation totals from *http://www.worldclimate.com*. Monthly and annual values are provided in both English and metric units. By inputting data to spreadsheet software, graphing can be easily accomplished allowing comparisons among stations.

CLIMATE VARIABILITY AND SHORT-TERM FORECASTING

Driving Questions: *How are NOAA's Climate Prediction Center's temperature and precipitation outlooks interpreted? Can these outlooks show evidence of forcings of weather systems by recognized patterns of variability in Earth's climate such as El Niño/La Niña?*

Educational Outcomes: To describe how descriptive climate data can provide past and present perspectives for planning purposes. To identify sources of climatic outlooks for periods of months to

a year or more. To explain how to interpret climatic outlook products.

Objectives: After completing this investigation, you should be able to:

• Identify where to find climatic outlooks for periods of months to a year or more.
• Explain how to interpret climatic outlook products.

Descriptive Climate Data, Its Uses, and Sources

Descriptive climate data provide valuable past and present perspectives for planning purposes. Farmers use their knowledge of climate to determine what crops to plant and when to plant and harvest. Utilities use climate data for planning production and distribution of energy supplies and the reallocation among types of such supplies. The building industry is interested in the design of structures, including their necessary strength, heating and cooling energy requirements, and the associated building codes that regulate them. People look to climate data as they plan future activities (e.g., outdoor weddings, vacations, and sporting events). Even more valuable would be a reliable expectation of what future climatic conditions would be.

In the U.S., NOAA's National Climatic Data Center in Asheville, NC, compiles U.S. data as well as being a depository for much worldwide data on weather and the environment. NOAA's Climate Prediction Center (CPC) and other organizations apply these data to numerical models and objective analyses in the production of near-future outlooks for climatic conditions. The term *outlook* is preferred to *forecast* because the future values are typically given in broad categories (i.e. above, below or normal) with probabilistic likelihoods of occurrence.

The CPC, one of the National Centers for Environmental Prediction of the National Weather Service, issues outlooks for temperature and precipitation for periods of six to ten days out to the year ahead. The CPC's website *(http://www.cpc.noaa.gov/)* also monitors several recognized patterns of variability in Earth's climate system such as persistent drought patterns, El Niño/La Niña phases, and climatic oscillations (North Atlantic, Arctic, Antarctic, Pacific-North American).

Figure 1 is composed of samples of the three-month outlooks for temperature (left) and precipitation (right) for the United States. [The latest three-month outlook can be seen at: *http://www.cpc.ncep.noaa.gov/products/predictions/90day*.] The sample outlooks in Figure 1 were issued on 21 April 2011 for the May/June/July 2011 time period. In the left temperature map, shades of brown/red depict regions that were expected to be above normal (A) while shades of blue depict regions expected to be below normal (B). White areas (EC) in the U.S., including Alaska, represent locations where there was no clear climatic signal and there were therefore equal chances of the seasonal averages being either above or below normal. Within each shaded area, the increasing confidence of that outcome is shown by the hue and dashed boundary lines. For example, the temperatures for the three months across much of the Southwest including Arizona, New Mexico and southwestern Texas were expected to be above normal with 50% or more likelihood. The precipitation outlook in the map to the right depicted expected precipitation totals to be equally likely as above or below normal in white while those below were in brown and above in green.

1. For the left temperature map, it was expected that the average May/June/July 2011

temperatures would be above the climatological norm in the Southwest and Gulf Coast states. With the exception of temperatures in the Northeast expected to be normal, below normal temperatures were expected generally in the **[(*eastern*)(*northern*)(*southwestern*)(*southern*)]** tier of states into the Mid-Atlantic region.

2. As shown in the precipitation outlook map on the right in Figure 1, above normal precipitation totals were anticipated to occur from New England to the Mid-Atlantic, in the central Midwest and along the northern Plains at the Canadian border. Generally below normal precipitation totals were expected in which area?
[(*along the western Gulf Coast*)(*Florida*)(*Northwest states*)(*Alaska*)].

3. Consider the combination of temperature and precipitation anomalies (*departures from normal*) anticipated for the state of Texas for the three-month period. One can characterize southeastern Texas as being expected to be relatively **[(*warmer and drier*) (*warmer and wetter*)(*cooler and drier*)(*cooler and wetter*)]** than normal.

4. Consider the combination of temperature and precipitation anomalies anticipated for eastern Montana and North Dakota during the same time period. One can characterize eastern Montana and North Dakota as likely to be relatively **[(*warmer and drier*) (*warmer and wetter*)(*cooler and drier*)(*cooler and wetter*)]** than normal.

5. Based on the temperature and precipitation anomalies anticipated for Alaska, one could expect May/June/July 2011 to be
[(*warmer and drier than normal*)(*warmer and wetter than normal*) (*cooler and drier than normal*)(*cooler and wetter than normal*)
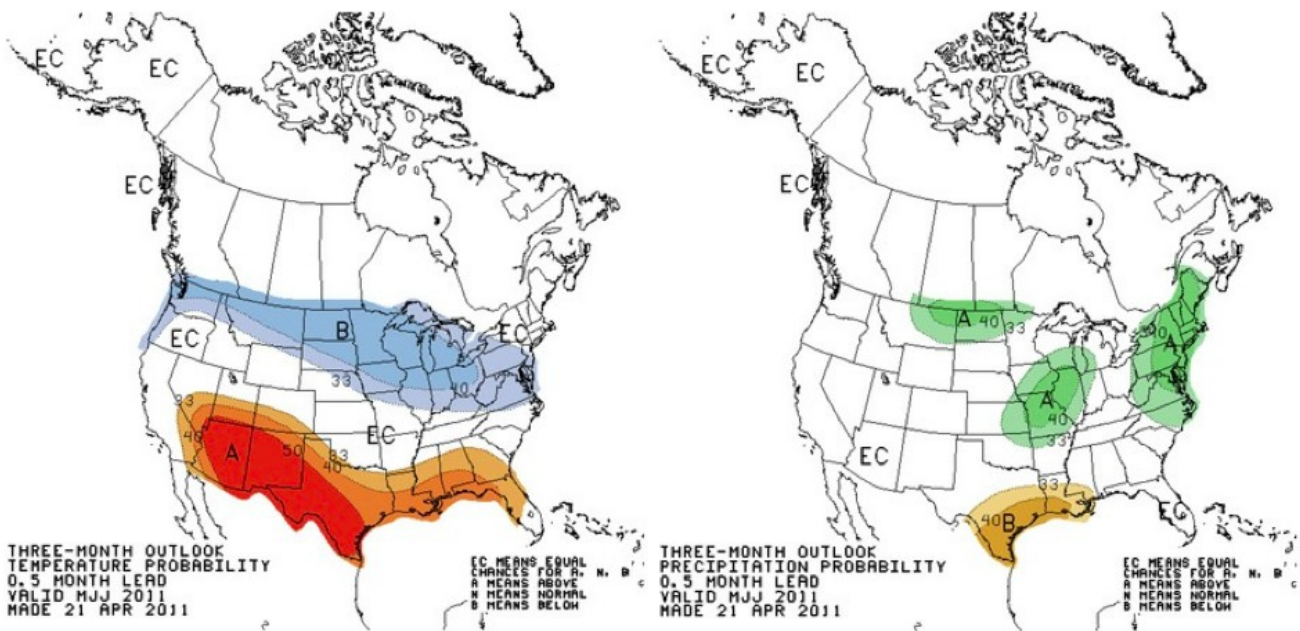**(*equally likely above or below normal in temperature and/or precipitation*)]**.

THREE-MONTH OUTLOOK TEMPERATURE PROBABILITY 0.5 MONTH LEAD VALID MJJ 2011 MADE 21 APR 2011

THREE-MONTH OUTLOOK PRECIPITATION PROBABILITY 0.5 MONTH LEAD VALID MJJ 2011 MADE 21 APR 2011

6. Finally, consider the same time period for New England (*Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut*). It was expected to be **[(*warmer than normal but equally likely for above or below normal in precipitation*) (*cooler than normal but equally likely for above or below normal in precipitation*) (*equally likely above or below normal in temperature but wetter than normal*) (*equally likely above or below normal in temperature but drier than normal*) (*equally likely above or below normal in temperature and/or precipitation*)].**

La Niña Impacts on U.S. Weather: The climate outlooks of NOAA's CPC are based on a number of factors including ENSO, regional climatic trend continuance, 30-60 day tropical oscillation (Madden-Julian oscillation), North Atlantic Oscillation, Pacific Decadal Oscillation, persistently wet/dry soil moisture conditions, statistical forecast tools, and dynamical forecast models. The tropical Pacific statement from the CPC issued on 7 April 2011 stated, "La Niña weakened for the third consecutive month ... La Niña will continue to have global impacts even as the episode weakens through the Northern Hemisphere spring".

The CPC reported on 9 June 2011 that a transition in the tropical Pacific Ocean from La Niña conditions to ENSO-neutral conditions occurred during May 2011. However, the CPC expected lingering La Niña-like atmospheric impacts into the 2011 summer. Therefore, it is likely that the May/June/July 2011 outlook was based largely on the climatic variability signal of La Niña. Precipitation expectations also involved some soil moisture conditions.

Figure 2 from the CPC shows a composite of thirteen years of temperature anomalies and their frequency (top) and precipitation anomalies and frequency (bottom) for the years when La Niña conditions prevailed during May/June/July (MJJ).
The anomalies map to the left on each level shows the average amount of the anomaly while the frequency map to the right displays the percentage of the years when those anomalous conditions existed. In the left temperature anomalies map, yellow and brown shadings indicate positive anomalies (i.e. average temperatures above normal) while blues show negative anomalies. The frequency shadings on the right indicate in yellows and browns occurrences in greater than half of the years while blues show less than half occurrences of that anomaly sign. The precipitation maps are in blue for positive anomalies (*wetter than normal*) while yellows and browns are negative (*drier*). The frequency shadings are the same as for the temperatures.

7. As a general pattern characteristic of La Niña during MJJ, the central portion of the U.S. could be described as relatively **[(*warm and dry*)(*warm and wet*)(*cool and dry*)(*cool and wet*)].**

8. This La Niña MJJ pattern, particularly for western Nebraska and western Kansas, has been noted in **[(*less than*)(*more than*)]** half of the La Niña years.

MJJ LA NINA TEMPERATURE ANOMALIES (C)
AND FREQUENCY OF OCCURRENCE (%)

MJJ LA NINA PRECIPITATION ANOMALIES (MM)
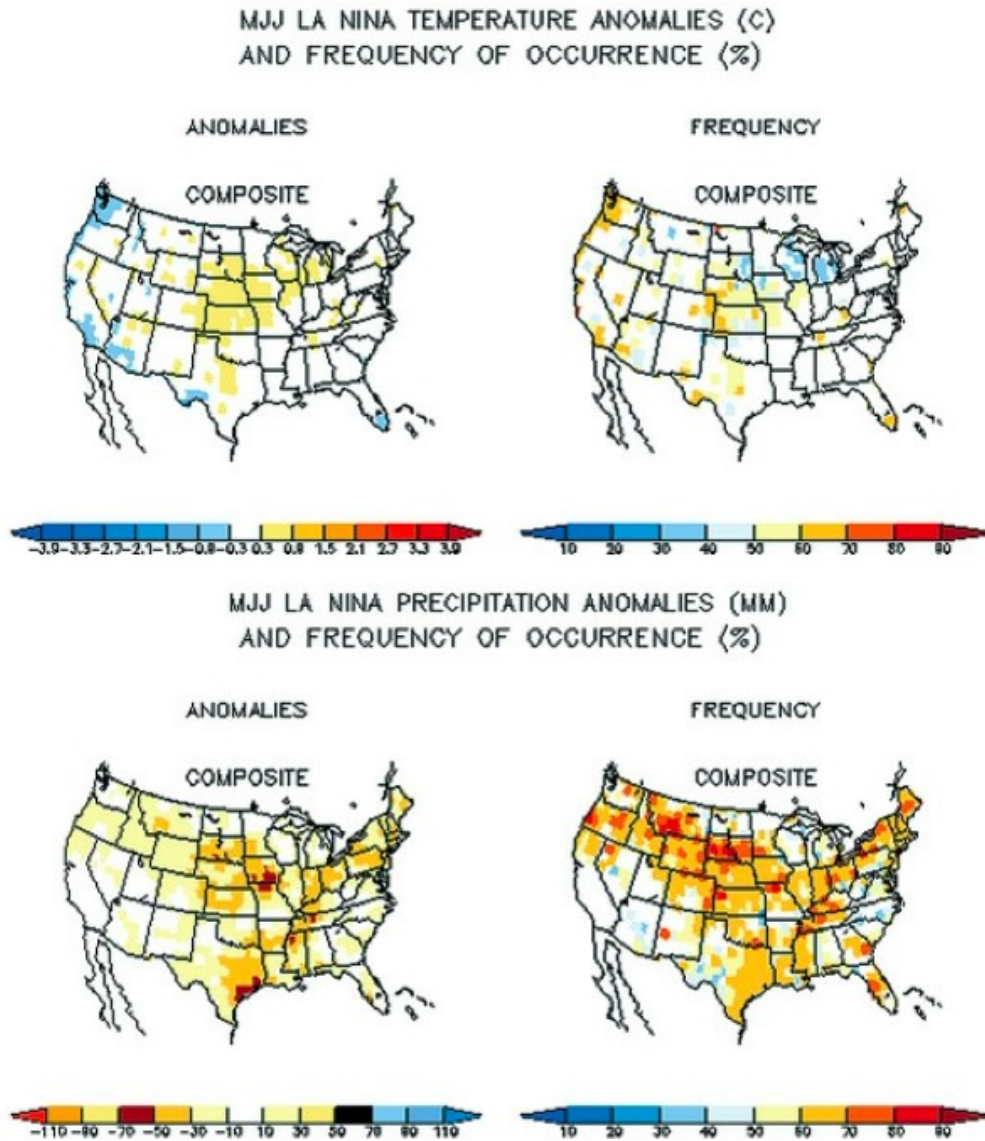AND FREQUENCY OF OCCURRENCE (%)

Figure 2.
Early summer season temperature (in degrees Celsius) and precipitation (in millimeters)
anomalies and frequencies from thirteen La Niña years.

9. In Figure 2, areas of relatively strong precipitation deficits were indicated to occur during La Niña years in southern Iowa - northern Missouri and along the Gulf Coast in Texas. The precipitation outlook of Figure 1 suggested that this below normal precipitation during May to July 2011 was more likely to occur in those portions of **[(*Iowa*)(*Texas*]**.

The latest ENSO statements from CPC can be found at
http://www.cpc.ncep.noaa.gov/
products/analysis_monitoring/enso_advisory/index.shtml.

As knowledge of other climatic variations inherent in Earth's climate system become better understood, short to medium range climate forecasting ("Outlooks") will rely on their signals for

information of use to agriculture, energy, and transportation sectors of the economy to minimize impacts and save money. Information regarding these various internal fluctuations: North Atlantic Oscillation, Pacific Decadal Oscillation, Arctic and Antarctic Oscillations, can be accessed from the RealTime Climate Portal, under **Climate Variability** links.

Summary: Climatic data provide valuable information for planning purposes. These outlooks result in numerous benefits by enabling many sectors (e.g., agriculture, building industry) to plan ahead for efficient use of resources and taking actions to reduce possible losses.