Intermountain West Climate Summary

by The Western Water Assessment

Issued April 23, 2008
Vol. 4, Issue 3

April 2008 Climate Summary

Hydrological Conditions — Drought intensity decreased in areas of western Wyoming and northern Utah in March. However, severe drought persists in southwestern Wyoming. Robust snowpack in the IMW region should bring improvement to drought intensity in southeastern Colorado and across central Wyoming.

Temperature— Temperatures across most of the region were 4 ºF below average in March, except areas of eastern Colorado and southern Utah, which were above average.

Precipitation— Precipitation across most of the region was near or below average in March, especially in areas of Colorado and Utah.

ENSO — La Niña conditions continue, but most models project that SST anomalies will decrease to neutral conditions starting in the summer.

Climate forecasts —There is an increased chance of above average temperatures and below average precipitation across much of the Intermountain West through September.

Opportunity For Decision Makers To Host a Post-doc

The Western Water Assessment is seeking water resources management agencies to be partners in a new postdoctoral program designed to encourage and build the pool of scientists qualified to transfer advances in climate science and climate prediction into climate-related decision frameworks and decision tools. This is the second year of the CLIVAR Climate Prediction Applications program (CPPAP), an activity of the U.S. Climate Variability and Predictability Programme (CLIVAR), and is managed by the University Corporation for Atmospheric Research. CPPAP is an excellent opportunity for water resource decision-makers to partner with a climate-science institution and have a recent PhD graduate work with them on climate service applications. The post-doc will work at the partner agency for two years and help transfer advances in climate science and prediction into decision-making frameworks and operations., The host agency must cover half the postdoctoral salary and provide benefits. Western Water Assessment is interested in partnering with water resource managers, and a joint statement of intent must be submitted by July 1, 2008. Please see http://www.vsp.ucar.edu/ and email jessica.lowrey@noaa.gov if you are interested.

In This Issue

On the Web: http://wwa.colorado.edu

Contact Us - To receive an email when a new Summary is available, please email us at: **wwasummary@wwa.colorado.edu.**

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 This publication was prepared by CIRES/WWA with support in part from the U.S. Department of Commerce/NOAA, under cooperative agreement NA17RJ1229 and other grants.

The Intermountain West Climate Summary is published monthly by Western Water Assessment (WWA), a joint project of the University of Colorado Cooperative Institute for Research in Environmental Sciences (CIRES) and the National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory, researching water, climate and societal interactions.

Global Climate Patterns and Their Impacts on North American Weather

By Julie Malmberg and Jessica Lowrey, Western Water Assessment

Introduction

This article provides a broad overview of various climate patterns and their impacts on weather in North America. The most well-known and widely studied climate pattern is the El Niño – Southern Oscillation (ENSO). Climate patterns are characterized by irregular cyclical variations in oceanic or atmospheric circulations. Oscillations in sea-level pressure and SSTs influence atmospheric circulation patterns. As these patterns shift and change, they affect weather around the world. Rigorous statistical analyses identify teleconnections (or relationships) that cover large geographical regions, over both the oceans and land.

Hemispheric and global-scale climate patterns have been studied for over a century[1]. Climate patterns emerge from naturally reoccurring variations in either the atmospheric circulation or SSTs, or reflect the interplay between the atmosphere and SSTs. Large differences in pressure create strong pressure gradients, which cause the winds to blow quickly and steer the direction of weather systems. Cloudiness, rain, snow, and/or thunderstorms are associated with low-pressure systems due to rising air motions and atmospheric instability. Clear skies are associated with high-pressure systems due to sinking air and less instability. Sea surface temperatures (SSTs) interact with the air above the sea surface, and in turn, influence and are influenced by sea level pressure. In the tropics, warm SSTs are associated with low-pressure because the warm, moist air above the surface of the ocean rises, eventually cools and condenses into clouds, which then can cause precipitation. Conversely, cool SSTs are associated with high-pressure because cooler air is denser and sinks, which inhibits the rising motion needed for cloud formation and weather.

The five climate patterns discussed in this article are either well known or they influence the weather of North America. The climate patterns are presented in order of decreasing influence on the western U.S.: El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), Madden-Julian Oscillation (MJO), Pacific-North American Pattern (PNA), and North Atlantic Oscillation (NAO)/Arctic Oscillation (AO) (Figure 1a).

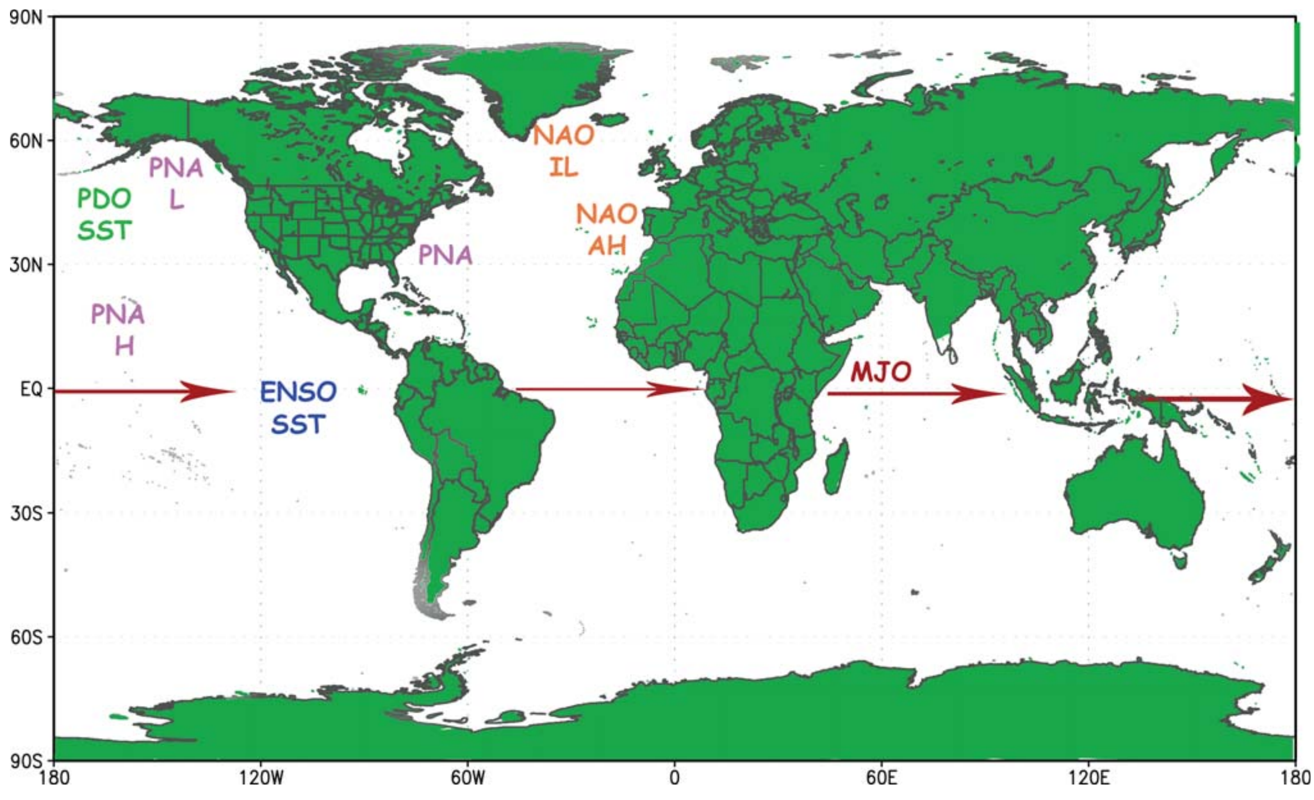

Figure 1a. Locations of the five climate patterns: the El Niño Southern Oscillation (ENSO) reflects SST along the equatorial Pacific Ocean. The Pacific Decadal Oscillation (PDO) reflects SST in the northern Pacific Ocean. The Madden-Julian Oscillation (MJO) reflects a repeating pattern of high and low-pressure systems that moves eastward along the equator. The Pacific-North American Pattern (PNA) reflects pressure differences between a high-pressure system near the Hawaiian Islands and a low-pressure system near Alaska's Aleutian Islands. The North Atlantic Oscillation (NAO)/Arctic Oscillation (AO) reflects pressure differences between the Icelandic Low (IL) and the Azores High (AH).

[1] For a definitive book chapter on climate patterns, see Barry and Carleton (2001).

El Niño Southern Oscillation

The most studied and well-known climate pattern is the El Niño Southern Oscillation (ENSO), which reflects the combined variations of SSTs and the atmospheric circulation in the eastern equatorial Pacific Ocean (Figure 1a). During ENSO-neutral conditions, trade winds over the central and western Pacific blow warm surface water towards the west, causing the sea surface to be warmer in the western Pacific than in the east. During the ENSO-positive or El Niño phase, the trade winds weaken or even reverse, causing warmer than average SSTs in the central and/or eastern Pacific. During the ENSO-negative or La Niña phase, the trade winds strengthen beyond the neutral phase, and the sea surface is cooler than average in the equatorial Pacific (Figure 1b). El Niño and La Niña usually occur every 3-7 years and persist 6-18 months.

ENSO is the most important source of year-to-year climate variability over the tropical Pacific Ocean, and it affects weather conditions around the globe. These impacts are fairly reliable, so scientists have been monitoring and predicting ENSO over the past two decades thanks to technological advances in oceanic and atmospheric monitoring. During El Niño events, winters in North America tend to be warmer than average in the north and wetter than average in the south. The IMW region is in an area that does not show a distinct anomaly due toduring El Niño (CPC, 2005a). During La Niña events, winters in the northwestern U.S. tend to be colder and wetter than average, and winters in the southwestern U.S. tend to be dryer and warmer than average (Goodrich, 2007). The changes in storm tracks and weather events associated with ENSO can also influence other climate patterns. However, the teleconnections between ENSO and the other patterns are not as well understood as ENSO itself.

Pacific Decadal Oscillation

The Pacific Decadal Oscillation (PDO) reflects decadal changes in SSTs in the northern or “extra-tropical” Pacific Ocean (Mantua, 2001; Goodrich, 2007; Figure 1a). When the PDO is positive, the SSTs in the northern Pacific Ocean are colder than average, and when the PDO is negative, the SSTs in the northern Pacific Ocean are warmer than average[2] (Figure 1c). PDO events generally persist for 30 – 50 years.

Whether or not the PDO is independent of ENSO is a controversial topic. However, it is known that the relationship between ENSO and PDO can act to cancel out or reinforce the teleconnections of each other. For example, when El Niño and the negative PDO are in phase, meaning there are warmer than average SSTs in both the equatorial and northern Pacific Ocean, winter

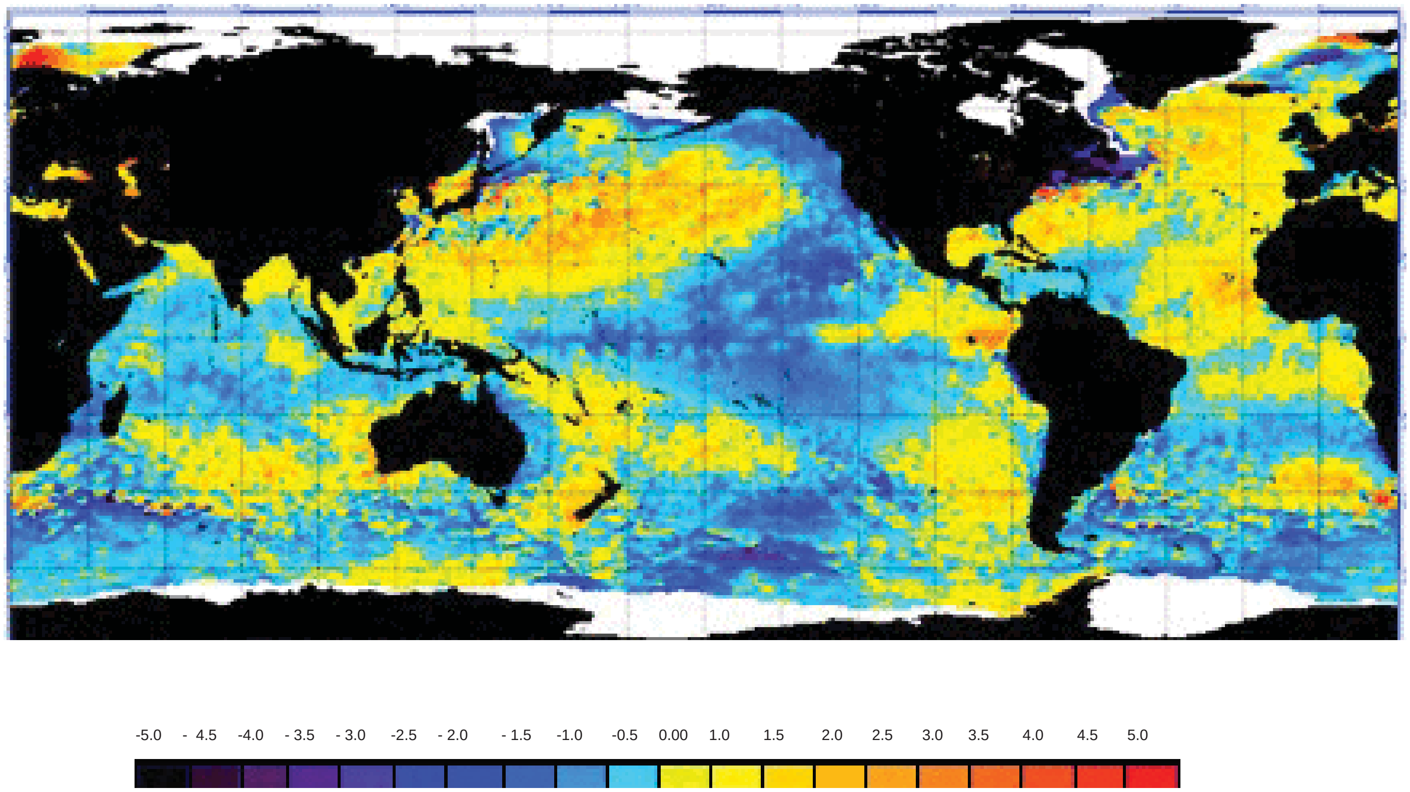

Figure 1b. NOAA/NESDIS 50 KM Global Analysis: SST Anomaly (Degrees C) as of April 3, 2008. Cooler than average SST in the equatorial Pacific indicate a La Niña event. Source: National Climatic Data Center (http://www.ncdc.noaa.gov/oa/climate/elnino/elnino.html)

[2] Note that this is opposite of ENSO, where the positive reflects warm SST, and vice versa.

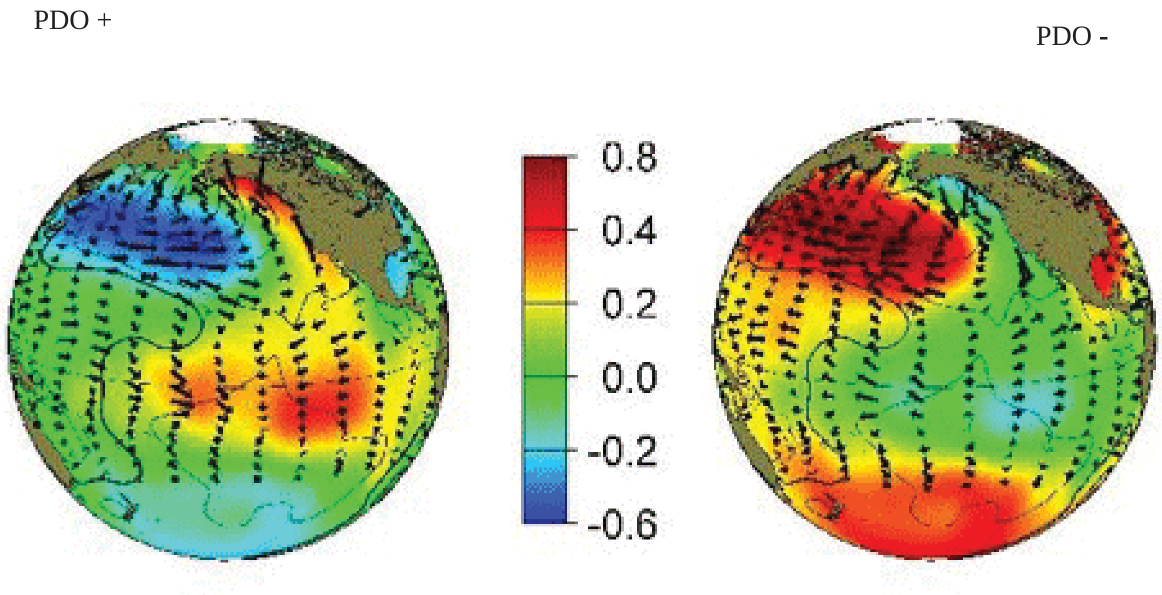

Figure 1c. Differences in SST during positive and negative phases of PDO. The positive phase of the PDO (colder than average SST in the northern Pacific) is on the left, the negative phase (warmer than average temperatures in the northern Pacific) on the right (Mantua, 2001). The scale shows the temperature above or below average in ºC.

precipitation tends to be above average in the southwestern United States and portions of the IMW region. When La Niña and the positive PDO are in phase, and SSTs in the Pacific are below average, winter precipitation tends to be below average in the southwestern United States, including parts of Utah. Finally, during a negative PDO event and a neutral ENSO, winter precipitation is above average for most of the west (Goodrich, 2007).

Madden-Julian Oscillation

The Madden-Julian Oscillation (MJO) is a pattern of suppressed and enhanced rainfall that shifts eastward in the tropics. Anomalous rainfall becomes evident initially over the western Indian Ocean, moves eastward into the equatorial Pacific Ocean, and then into the western hemisphere where the anomalous rainfall pattern becomes less apparent (Figure 1a). A complete revolution around the equator takes about 30 to 60 days (Barry and Carleton, 2001; Figure 1d).

The MJO can "cross paths" with ENSO in the equatorial Pacific Ocean, where regions of enhanced or suppressed precipitation can be amplified or reduced depending on the location of the MJO. The strength of the MJO varies year-to-year and some of this variability is linked to ENSO. The MJO is often strong during weak La Niña years or during ENSO-neutral years. The MJO is often weak or absent during strong El Niño years (CPC, 2002).

The MJO is not as well understood as other climate patterns, so its impacts on the United States are not well defined. Under special circumstances, in the winter, enhanced equatorial precipitation associated with the MJO can be correlated to enhanced precipitation along the west coast of the United States. As areas of enhanced equatorial precipitation move east, areas of enhanced precipitation in the United States move south (CPC, 2002). For example, if the maximum equatorial precipitation is at 120°E, MJO-related rainfall could occur in western Washington. When the maximum equatorial precipitation is at 140°E, MJO-related rainfall could occur in northwestern California. A future focus page in the IMW Climate Summary will discuss the MJO in further detail.

Pacific-North American Pattern

The Pacific-North American Pattern (PNA) is defined by a teleconnection of large-scale pressure anomalies that arc from the Hawaiian Islands, through the North Pacific Ocean and Canada, and then to the Southeastern United States (Figure 1a). The PNA is positive when the Pacific and Southeastern U.S. pressure anomalies are negative and when the Hawaiian and Canadian pressure anomalies are positive. The opposite is true during the negative phase of the PNA. The PNA is highly variable and can change phase within a week, but can also persist for longer periods (up to months).

The PNA can be influenced by ENSO, even though they are distinct climate patterns (Straus and Shukla, 2002). During El Niño, the PNA tends to be in the positive phase, and during La Niña, the PNA tends to be in the negative phase (CPC, 2005). In the western U.S., a positive PNA circulation is generally associated with warm, dry conditions, and a negative PNA circulation is generally associated with cold, wet conditions. (Woodhouse, 2002).

North Atlantic Oscillation/Arctic Oscillation

The North Atlantic Oscillation (NAO) reflects the difference in sea-level pressure between the Icelandic Low (IL), a permanent polar low-pressure system over Iceland, and the he Azores High (AH), a permanent subtropical high-pressure system over the Azores (Figure 1d). When the pressure difference is large, this is considered a high index year, or NAO+. When the pressure difference is small, it is considered a low index year, or NAO-. Like the PNA, the NAO can change phases frequently, but there are persistent periods where it can stay in the same phase. While the NAO is a regional pattern of climate variability over the Atlantic Ocean, many scientists see it as part of the larger, hemispheric pattern called the Arctic Oscillation (AO; Thompson and Wallace, 2000). The NAO/AO has a strong influence on the weather in Western Europe and a weaker influence on the weather in eastern North America. Like several other climate oscillations mentioned above, the NOA/AO impacts can overlap with ENSO. When NAO+ occurs at the same time as a strong El Niño, winters are warmer than average over much of the United States, including over the IMW region (Hurrell et al., 2003).

Conclusion

Climate variations in the oceanic and atmospheric circulation can impact the weather in distant locations. Climate scientists study the teleconnections between climate and regional weather patterns in order to better understand the global climate system and improve short and long-term forecasts. For example, NOAA Climate Prediction Center has improved the skill of seasonal temperature and precipitation forecasts by incorporating ENSO information. Scientists hope that these forecasts will continue to improve for the IMW region as they gain a better understanding of other oscillations like MJO. For more information about the current conditions of climate oscillations and links to new research, see On the Web box.

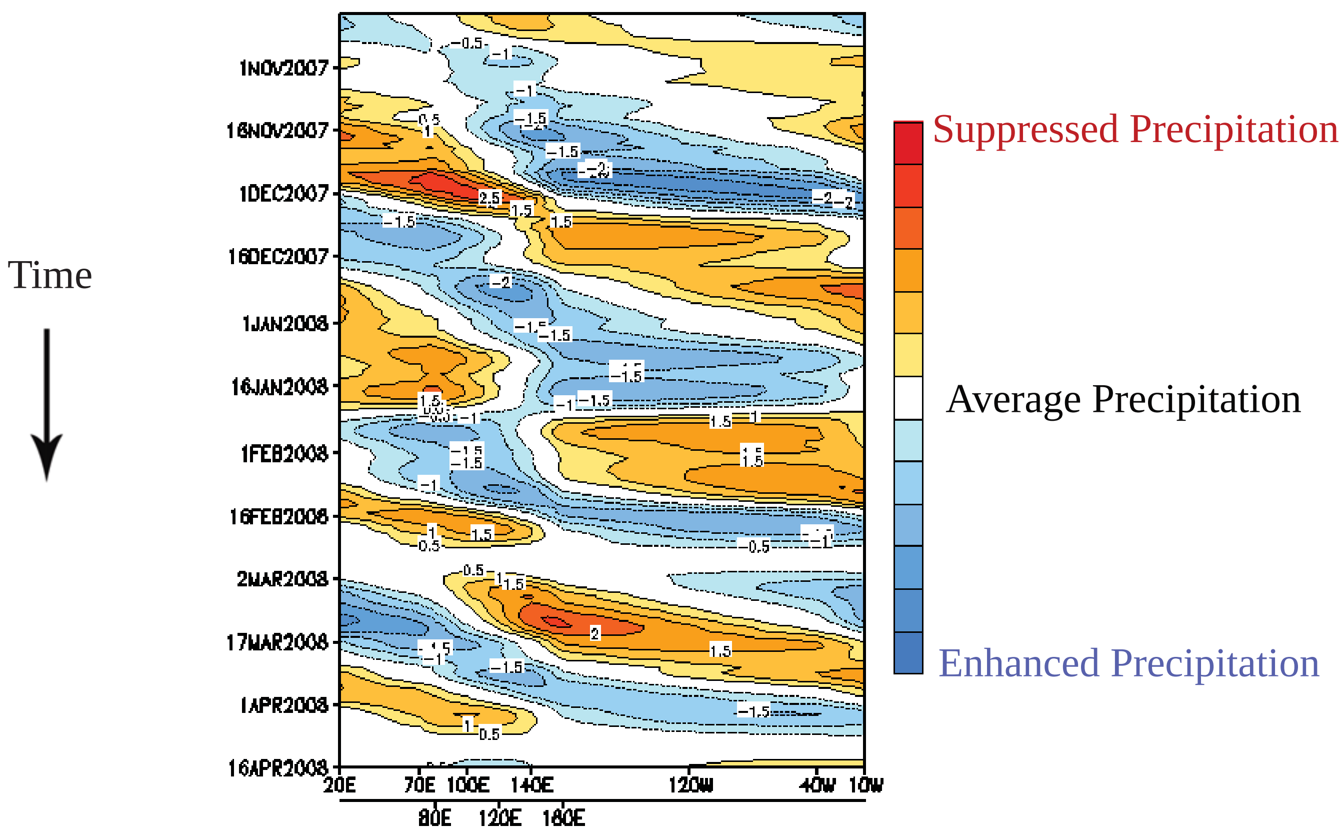

Figure 1d. The MJO Index is computed daily and identifies areas of enhanced or suppressed equatorial precipitation. The MJO Indices – blueish colors represent enhanced precipitation, reddish colors represent suppressed precipitation. The horizontal axis is longitude, and the vertical axis is time. For any given location, precipitation anomalies switch from being suppressed to being enhanced about every 10-30 days, and they move eastward through time. Source: NOAA Climate Prediction Center (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_mjo_index/mjo_index.html

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On the Web

For a general discussion about climate oscillations and teleconnections, see:
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/teleconnections.shtml

For more information about the climate oscillations in this article, use the following links:

- ENSO: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml
- PDO: http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/ca-pdo.cfm
- MJO: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml
- PNA: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/pna.shtml
- NAO: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml

Temperature 03/01/08 – 03/31/08

Monthly average temperature for March 2008 in the Intermountain West region ranged from 15-50 °F (Figure 2a). The warmest areas (above 35 °F) were across most of **Utah** and eastern and southwestern **Colorado**. Temperatures were below average for most of the region (Figure 2b). Northeast **Utah**, southern **Wyoming**, and northwest **Colorado** all reported areas at least 4 °F below average, with some areas reporting 8-10 °F below average. Areas in eastern **Colorado** and southern **Utah** were 0-4 °F above average. A record low minimum temperature of -7 °F on March 6 in Randolph, Utah, broke the previous record low of -6 °F from 1997.

Even though the month of March 2008 was cooler than average for most of the region, March 1 was a day of record high temperatures. A few places that set records on March 1 include Denver, Colorado Springs, and Pueblo, **Colorado**, and Cheyenne, **Wyoming**. The high in Denver was 74 °F, which broke the previous record of 73 °F set in 1974. Colorado Springs recorded a high of 73 °F, which broke the previous high of 69 °F set in 1986, 1974, and 1967. The high temperatures in Pueblo reached 79 °F, breaking the previous high of 76 °F set in 1999 and 1986. Cheyenne's high temperature on March 1 was 67 °F, breaking the old record of 66 °F set in 1941.

Temperatures in March 2007 were higher than temperatures in March 2008 throughout most of the IMW region (Figure 2c). Most of **Wyoming** and eastern **Colorado** were 4-8 °F above average in March 2007. **Utah** was mostly 0-4 °F above average in March 2007, with the northeastern part of the state reporting 4-6 °F above average.

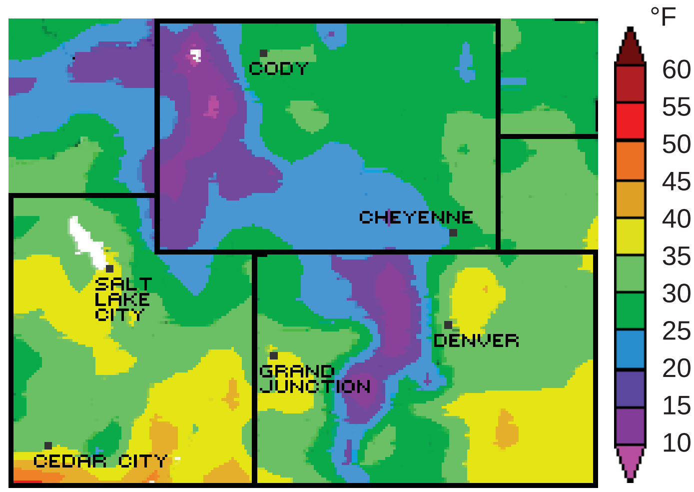


Figure 2a. Average temperature for the month of March 2008 in °F.

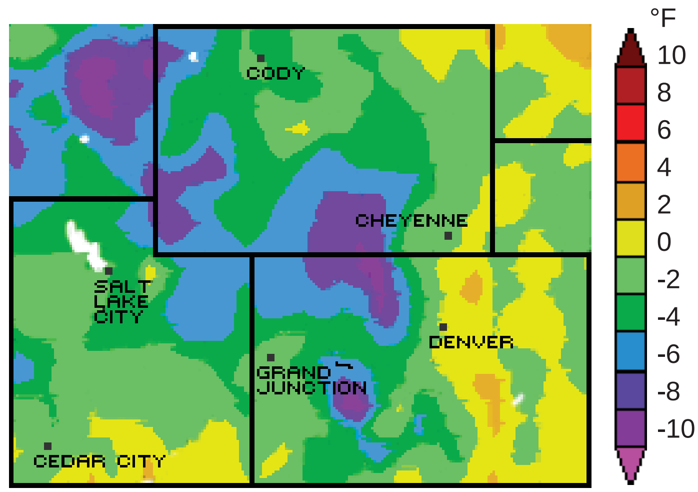


Figure 2b. Departure from average temperature for the month of March 2008 in °F.

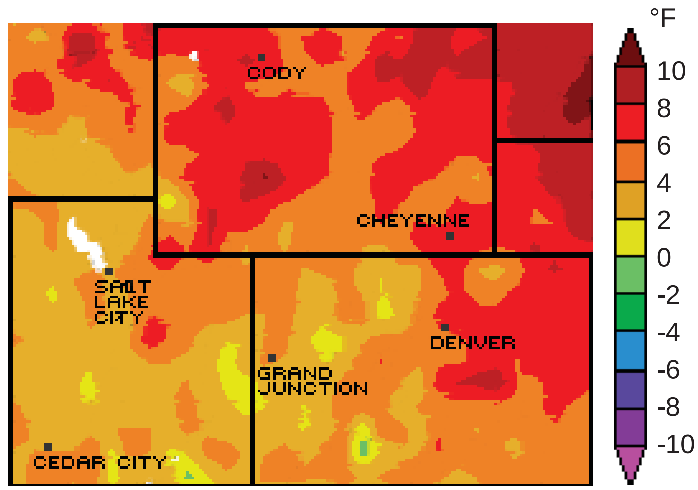


Figure 2c. Departure from average temperature in °F for last year, March 2007.

Notes

Figures 2a-c are experimental products from the High Plains Regional Climate Center. These data are considered experimental because they utilize the most recent data available, which have been subject to minimal quality control. These maps are derived by taking measurements at individual meteorological stations and interpolating (estimating) values between known points to produce continuous categories. Interpolation procedures can cause incorrect values in data-sparse regions. For maps with individual station data, please see web sites listed below. *Average* refers to the arithmetic mean of annual data from 1971- 2000. Departure from average temperature is calculated by subtracting current data from the average. The result can be positive or negative.

On the Web

- For the most recent versions of these and maps of other climate variables including individual station data, visit: http://www.hprcc.unl.edu/products/current.html.
- For information on temperature and precipitation trends, visit: http://www.cpc.ncep.noaa.gov/trndtext.htm.
- For a list of weather stations in Colorado, Utah, and Wyoming, visit: http://www.wrcc.dri.edu/summary.

Precipitation 03/01/08 – 03/31/08

Total precipitation for March 2008 in the Intermountain West region ranged from 0 - 3+ inches (Figure 3a). Northwest and south-central **Wyoming** and north-central **Colorado** received the highest totals (2+ inches). Eastern and southwest **Colorado** and southern **Utah** received the least amount of precipitation (0-0.50 inch). The NWS Boulder-Denver reported that March 2008 was the third driest March since record keeping began in 1872. The NWS Salt Lake City reported that Castle Dale, in central **Utah**, received 0 inches of precipitation for the month of March, which is 0.68 inches below average.

Most of the region had near or below average precipitation for March (Figure 3b). Small areas of western and central **Wyoming** and central **Colorado** reported above average precipitation (120-200%). Most of **Utah** and southern and eastern **Colorado** reported the lowest percent of average (below 80%). Cedar City, located in southwest **Utah**, reported 0.27 inch of precipitation for March, which is 20% of normal.

However, in spite of a dry March, precipitation since the start of the water year was near or above average for a majority of the region (Figure 3c). Areas that are below average include northeast **Wyoming** and eastern **Colorado** (<50% - 70%). Areas with the highest percent of average are in western Colorado, eastern Utah, and southeast Wyoming (110 – 150%+).

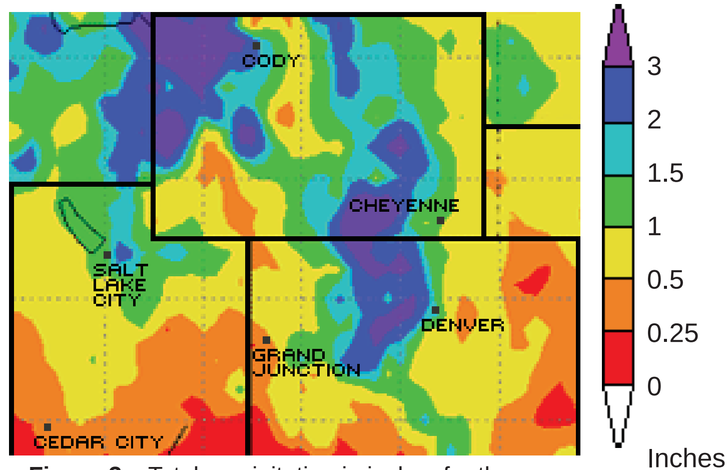


Figure 3a. Total precipitation in inches for the month of March 2008.

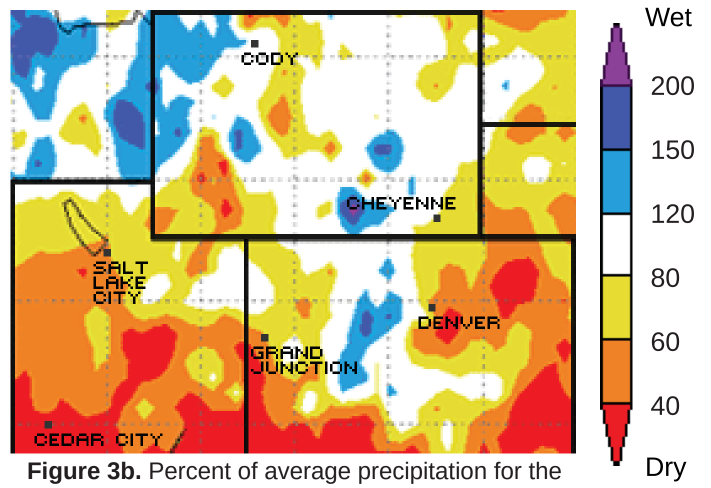


Figure 3b. Percent of average precipitation for the month of March 2008.

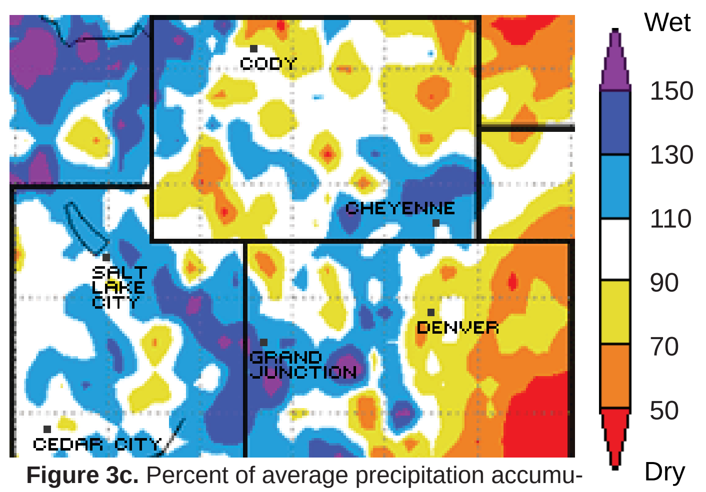


Figure 3c. Percent of average precipitation accumulation since the start of the water year 2008 (Oct. 1, 2007 – March 31, 2008).

Notes

The data in Figs. 3 a-c come from the High Plains Regional Climate Center. These data are considered experimental because they utilize the most recent data available, which have been subject to minimal quality control. These maps are derived by taking measurements at individual meteorological stations and interpolating (estimating) values between known points to produce continuous categories. Interpolation procedures can cause incorrect values in data- sparse regions. For maps with individual station data, please see web sites listed below. The water year runs from October 1 to September 30 of the following year. The 2008 water year began October 1, 2007 (Figure 3c). The water year better reflects the natural cycle of accumulation of snow in the winter and run-off and use of water in the spring and summer. It is a better period of analysis for presenting climate and hydrologic conditions. Average refers to the arithmetic mean of annual data from 1971- 2000. Percent of average precipitation is calculated by taking the ratio of current to average precipitation and multiplying by 100.

On the Web

- For the most recent versions of these and maps of other climate variables including individual station data, visit: http://www.hprcc.unl.edu/products/current.html.
- For precipitation maps like these and those in the previous summaries, which are updated daily visit: http://www.cdc.noaa.gov/Drought/.
- For National Climatic Data Center monthly and weekly precipitation and drought reports for Colorado, Utah, Wyoming, and the whole U. S., visit: http://lwf.ncdc.noaa.gov/oa/climate/research/monitoring.html.
- For a list of weather stations in Colorado, Utah, and Wyoming, visit: http://www.wrcc.dri.edu/index.html.

Regional Standardized Precipitation Index data through 03/31/08

The Standardized Precipitation Index is used to monitor moisture supply conditions. The distinguishing traits of this index are that it identifies emerging droughts months sooner than the Palmer Index and that it is computed on various time scales. 3- and 6-month SPIs are useful in short-term agricultural applications. Longer-term SPIs (12 months and longer) are useful in hydrological applications. This month, we describe the 3-month and the 12-month SPI maps.

Due to near average and below average precipitation across the IMW region in March 2008, 13 of the 14 climate divisions that changed categories in the 3-month SPI between the end of February 2008 and the end of March 2008 changed to dryer categories (Figure 4a). The only climate division to change to a wetter category was the Big Horn division in northern **Wyoming**. In **Utah**, all climate divisions changed from wet categories to the near normal category except the Dixie division in the southwest corner, which remained in the near normal category. All climate divisions in **Colorado** that were in wet categories also changed to the near normal category and the Kansas Drainage division changed from near normal to the moderately dry category.

The 12 month SPI is less sensitive to monthly precipitation anomalies than the 3 month SPI, so the only climate division to change categories in the 12-month SPI was the Powder/Little Missouri/Tongue Drainages division in northern **Wyoming** (Figure 4b). It changed from the very wet category to the moderately wet category. Most of the IMW region is in the near normal category.

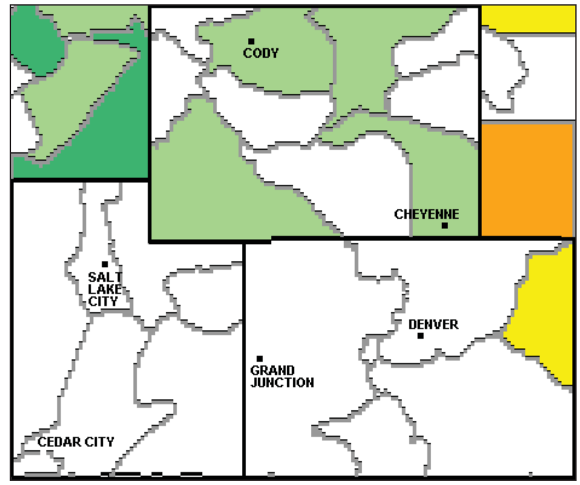


Figure 4a. 3-month Intermountain West regional Standardized Precipitation Index (data from 01/1/08 - 03/31/08).

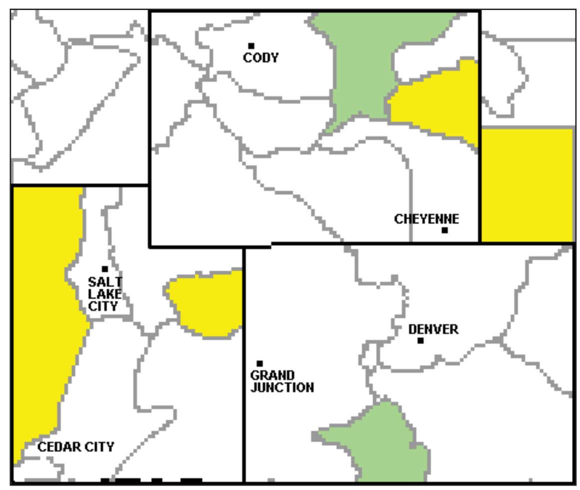


Figure 4b. 12-month Intermountain West regional Standardized Precipitation Index (data from 04/1/07 - 03/31/08).

+3.00 and above	Exceptionally Wet
+2.00 to +2.99	Extremely Wet
+1.25 to +1.99	Very Wet
+0.75 to +1.24	Moderately Wet
-0.74 to +0.74	Near Normal
-1.24 to -0.75	Moderately Dry
-1.99 to -1.25	Very Dry
-2.99 to -2.00	Extremely Dry
-3.00 and below	Exceptionally Dry

Notes

The SPI is an index based on the probability of recording a given amount of precipitation, and the probabilities are standardized so that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median, and half are above the median). The index is negative for drought, and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive. The SPI is computed by the NOAA National Climatic Data Center (NCDC) for several time scales, ranging from one month to 24 months, to capture the various scales of both short-term and long-term drought. The Colorado Climate Center describes the SPI as valuable in monitoring both wet and dry periods, and it can be applied to other types of data (e.g. streamflow, reservoir levels, etc.). Near normal SPI means that the total precipitation for the past 12 months is near the long-term average for one year. An index value of -1 indicates moderate drought severity and means that only 15% would be expected to be drier. An index value of -2 means severe drought with only 2.5% of years expected to be drier.

The 3-month SPI uses data for the last three months and represents short-term precipitation patterns (Figure 4a). The 12-month SPI (Figure 4b) compares precipitation patterns for 12 consecutive months with the same 12 consecutive months during all the previous years of available data. The SPI at these time scales reflect long-term precipitation patterns. Figures 4a and b come from the Western Regional Climate Center, which uses data from the NCDC and the NOAA Climate Prediction Center.

On the Web

- For information on the SPI, how it is calculated, and other similar products for the entire country, visit: http://www.wrcc.dri.edu/spi/spi.html.
- For information on past precipitation trends, visit: http://www.hprcc.unl.edu/products/current.html.
- For SPI products directly form the NCDC, visit: http://lwf.ncdc.noaa.gov/oa/climate/research/prelim/drought/spi.html. These maps use the same data as Figures 4a and b, but the categories are defined slightly differently.

U.S. Drought Monitor conditions as of 3/18/08

The U.S. Drought Monitor (Figure 5) shows the highest drought intensity in the IMW region is in western **Wyoming** (severe drought – D2), however this area is smaller than last month. Above average precipitation in northwest **Utah** and western **Wyoming** in March helped decrease the drought status in those areas (see inset). Lower drought intensity extends through central and eastern Wyoming, and eastern **Colorado**. Drought intensity in southeastern **Colorado** was elevated from abnormally dry (D0) to moderate (D1) since last month, due to below average precipitation.

Notes

The U. S. Drought Monitor (Figure 5) is released weekly (every Thursday) and represents data collected through the previous Tuesday. The inset (lower left) shows the western United States from the previous summary's map.

The U. S. Drought Monitor maps are based on expert assessment of variables including (but not limited to) the Palmer Drought Severity Index, soil moisture, streamflow, precipitation, and measures of vegetation stress, as well as reports of drought impacts. It is a joint effort of several agencies.

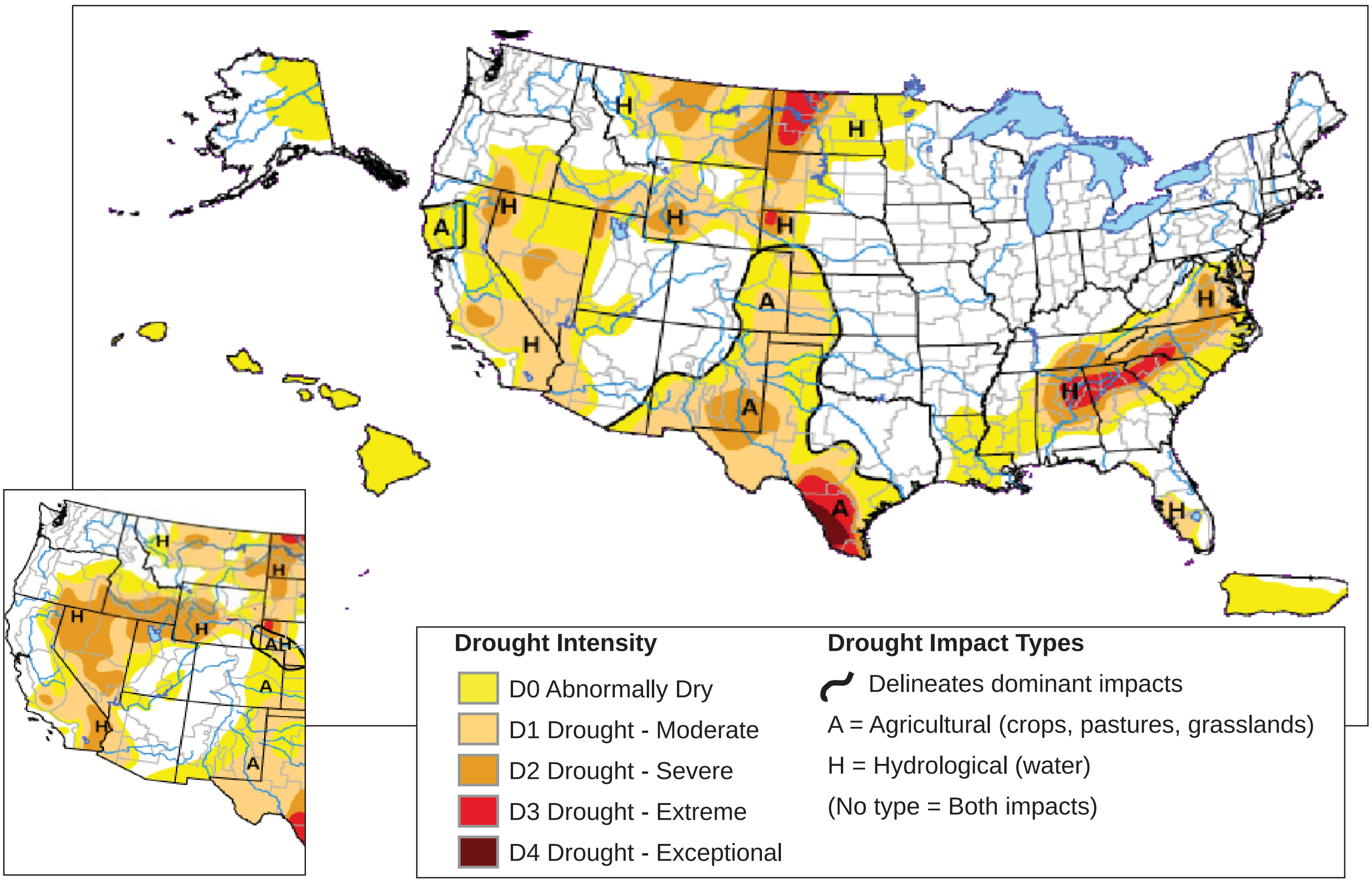


Figure 5. Drought Monitor from April 17, 2008 (full size) and the last summary, March 24, 2008 (inset, lower left) for comparison.

On the Web

- For the most recent Drought Monitor, visit: http://www.drought.unl.edu/dm/monitor/html. This site also includes archives of past drought monitors.
- Drought Impact Reporter (National Drought Mitigation Center): http://droughtreporter.unl.edu/.
- NIDIS Drought Portal: http://www.drought.gov.

Intermountain West Snowpack data through 04/01/08

April 1 snowpack conditions are near or above average for most of the Intermountain West Region, with the exception of several basins in central **Wyoming** (Figure 6). Below average snowfall in March in **Utah** and **Colorado** lead to decreases in snowpack as a percent of average across these states (NRCS). However, almost all basins in both states are still above average. Southern **Colorado** still has the highest SWE as a percent of average in the region with 141% of average in the southeast and 126% of average in the southwest. The rest of the state is near 100% of average. In **Utah**, the lowest SWE is 94% of average in the southwest, and the highest is 112% in the Uintah basin in the northeast. Unlike Colorado and Utah**, Wyoming** received above average precipitation in April. Most of the state has near or above average SWE, with the highest percent of average in the Belle Fouche basin in the northeast (above 130%). The SWE in Wyoming is between 140-160% of the value on April 1, 2007.

Notes

Snow water equivalent (SWE) or snow water content (SWC) refers to the depth of water that would result by melting the snowpack at the measurement site. Snowpack telemetry (SNOTEL) sites are automated stations operated by NRCS that measure snowpack. In addition, SWE is measured manually at other locations called snow courses. SWE is determined by measuring the weight of snow on a "pillow" (like a very large bathroom scale) at the SNOTEL site. Knowing the size of the pillow and the density of water, SWE is then calculated from the weight measurement. Given two snow samples of the same depth, heavy, wet snow will yield a greater SWE than light, powdery snow. SWE is important in predicting runoff and streamflow.

Figure 6 shows the SWE based on SNOTEL and snow course sites in the Intermountain West states, compared to the 1971-2000 average values. The number of SNOTEL or snow course sites varies by basin. Basins with no SNOTEL sites or incomplete data are designated in white on the map. To see the locations of individual SNOTEL sites, see each state's water availability page.

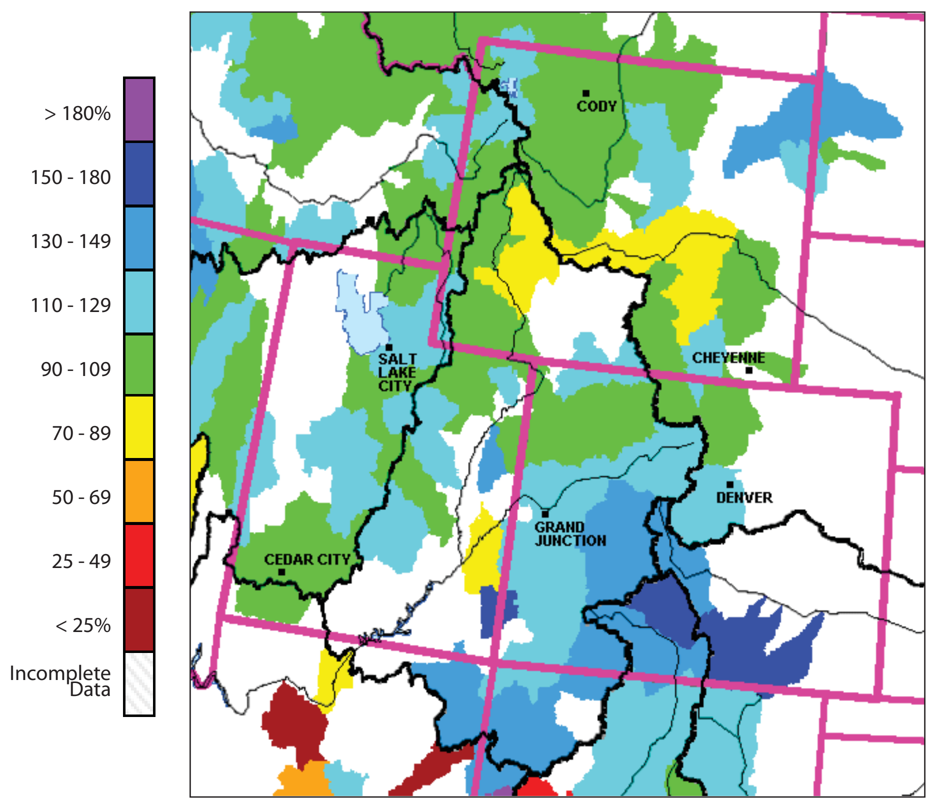


Figure 6. Snow water equivalent (SWE) as a percent of average for available monitoring sites in the Intermountain West as of April1, 2008 (NRCS).

On the Web

- For graphs like this and snowpack graphs of other parts of the western U.S., visit: http://www.wcc.nrcs.usda.gov/snowcourse/snow_map.html.
- For snow course and SNOTEL data updated daily, please visit one of the following sites: River basin data of SWE and precipitation: http://www.wrcc.dri.edu/snotelanom/snotelbasin.
- Individual station data of SWE and precipitation for SNOTEL and snow course sites: http://www.wcc.nrcs.usda.gov/snowcourse/snow_rpt.html or http://www.wcc.nrcs.usda.gov/snotel/.
- Graphic representations of SWE and precipitation at individual SNOTEL sites: http://www.wcc.nrcs.usda.gov/snow/snotel-data.html.

Reservoir Supply Conditions

Starting in January, the Natural Resources Conservation Service (NRCS) and the NOAA/NWS River Forecast Centers project seasonal streamflow volumes in the western U.S. (usually April – July). They update these forecasts at the beginning of each month January through June. Inputs to these forecasts are snowpack conditions and precipitation amounts. Seasonal runoff volume forecasts are made for naturalized flows at specific forecast points along major rivers and upstream of reservoirs. These forecasts are also called reservoir inflow forecasts when the forecast point is located just upstream from a reservoir. Inflow projections are commonly expressed as a range of exceedence probabilities (90-10%) in kaf for a given runoff period. The 50% exceedence probability inflow projection is the most probable projection. Reservoir managers, including the Bureau of Reclamation, use these naturalized streamflow projections when making decisions about actual water use through out the year. However, water management and prior appropriation water rights determine the actual volume of inflow to each reservoir.

Site-specific seasonal runoff volume forecast information from NWS is available at: http://www.cbrfc.noaa.gov/westernwater/. These graphs feature the runoff volume forecasts were issued each month, the observed and average streamflow volumes for each month of the water year, and the historic mean maximum and minimum flow period for the forecast. These graphs allow users to see the evolution of streamflow forecasts by issuance date. For example, projections of inflow into Lake Powell issued April 1 decreased slightly from forecasts issued March 1 (Figure 7).

Intermountain West Reservoir Inflow Projections

Seasonal streamflow volume projections and corresponding reservoir inflow forecasts are near or above average for most basins, with the exception of Southeast Wyoming and along the Utah-Wyoming border (Table 7).

Most probable (50% exceedence) inflow forecasts for **Colorado** reservoirs are near or above average, ranging from a low of 102% of average into Lake Granby to a high of 147% of average into Blue Mesa. Due to current near average reservoir storage and near or above average streamflow projections, USBR anticipates statewide reservoir levels at the end of the snowmelt season will be higher than last year.

In **Utah**, most probable inflow forecasts are above average for Lake Powell and near average everywhere else. Inflow forecast for reservoirs listed range from a low of 105% of average inflow into Utah Lake to a high of 122% of average inflow into Lake Powell. Current statewide reservoir storage is 14% less than last year due to below average streamflows during WY2007. Near average streamflow this year will help increase reservoir storage compared to last year.

In **Wyoming**, most probable seasonal inflow projections are near or below average for southwest basins and are near or above average for remaining southern and northwest basins. These forecasts range from a low of 82% of average into Fontenelle to a high of 120% of average into Seminoe. Despite the below average reservoir inflow projection, the USBR anticipates that Fontenelle will fill by the end of July.

For additional information on regional water supply information, visit the state water availability pages 14-16 and streamflow forecast page 21.

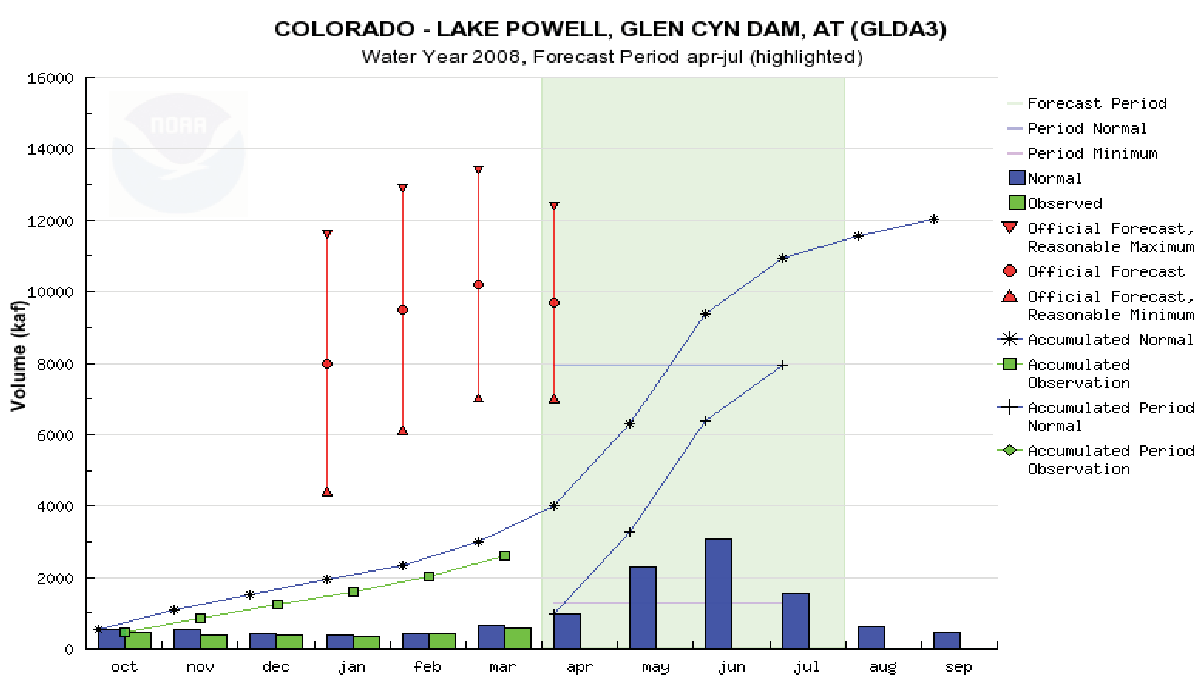


Figure 7: Streamflow volume (kaf) forecast graph for inflow into Lake Powel, generated by the NOAA/NWS. (Data through April 1, 2008.) The evolution of seasonal volume forecasts issued is shown in red vertical lines on the graphs. For inflow into Lake Powell, above average snowpack has resulted in an increase in April-July streamflow volume forecasts since the first forecast was issued in January.

Notes

Site-specific forecast graphs (Figure 7), feature observed and forecasted streamflow information from the NWS Westernwater website (see On the Web box). Users click on a region of the map and then on specific forecast points to load forecast information displayed as a graph. The most probable forecasts (50% exceedence probability) for the current water year are displayed as red circles. Streamflow forecasts are based on NRCS monthly forecasts and other NOAA/NWS RFC forecast points. See May 2007 Intermountain West Climate Summary focus page for detailed description of the graph.

April-July seasonal streamflow volume projections in Table 7 are listed in total volume (kaf) and as a percentage of average. The average is computed for the 1971-2000 base period. April-July inflow projections are natural volume projections, and actual volume will be affected by hydrologic conditions as well as upstream water management. Reservoir inflow projections, streamflow forecasts, and current surface streamflows are based on data collected from April 1-9, 2008 (NRCS, NOAA/NWS).

Seasonal Runoff Volume Forecast (April - July)

State	Reservoir	Minimum: 90% exceedance (KAF)	Most Probable: 50% exceedance (KAF)	Most Probable: 50% exceedance (percent of average)	Maximum: 90% exceedance (KAF)
Colorado	Dillon Reservoir	161	200	120%	245
	Lake Granby	183	230	102%	285
	Blue Mesa	860	1060	147%	1370
	Pueblo Reservoir	360	555	144%	755
Utah	Strawberry (at Solider Springs)	410	68	115%	101
	Utah Lake	210	340	105%	470
	Bear Lake (near Woodruff)	97	120	106%	143
	Lake Powell	7010	9700	122%	12400
Wyoming	Fontonelle	475	705	82%	980
	Flamingo Gorge	430	890	75%	1350

April - September Forecast Period

	Seminole	660	960	120%	1310
	Boysen	360	685	96%	1010
	Buffalo Bill	665	790	110%	915

Table 7: Seasonal runoff (April-July) volume forecast in total volume (kaf) and as a percent of average data as of April 1, 2008. These inflow projections are based on 10, 50, and 90 percent exceedence projections, which means there is a 10, 50, or 90 percent chance that the actual streamflow volume will exceed the amount in the table.

On the Web

- The NOAA/NWS Seasonal Runoff Volume Forecast website is: http://www.cbrfc.noaa.gov/westernwater.
  -For individual site-specific streamflow forecasting information, click on desired region and drag mouse over square box.
  -For individual forecast point plot graphs click on the desired square box.
- Monthly reports from NRCS on water supply conditions & forecasts for major CO river basins, visit: http://www.wcc.nrcs.usda.gov/cgibin/bor.pl.
- Water Supply Outlook for the Upper Colorado River Basin, produced by the CBRFC at: http://www.cbrfc.noaa.gov/wsup/wsup.cgi.

Colorado Water Availability

On April 1, the snowpack has reached its seasonal peak, and spring temperature will determine the speed and timing of melting and the amounts of additional snowfall. On April 2, the majority of SNOTEL stations in Colorado reported near or above average SWE with most stations in the northern mountains at 100-149% of average and most stations in the southern mountains at 125%-200% of average (NRCS; Figure 8a). Snowpack as a percent of average decreased in March due to below average precipitation across most of the state. The Rio Grande, San Juan, Animas, Dolores, and San Miguel basins had the greatest decrease in percent of average snowpack (29 percentage points).

April 1 SWSI values are above or much above average, ranging from a low of 0.2 in the Yampa, White and North Platte basins to a high of 3.6 in the Gunnison basin (NRCS; Figure 8b)). SWSI values decreased in all basins except the South Platte in comparison to last month's values.

Current near average reservoir storage coupled with near or above average projected streamflows will likely result in significant increases in reservoir storage by the end of the runoff period (NRCS). On April 1, statewide reservoir storage ranged from a low of 92% of average in the South Platte basin to a high of 107% of average in the Gunnison basin (not shown). Reservoir inflow projections are near or above average statewide, and water managers in southern basins have been releasing water to prepare for above average spring and summer streamflows (USBR). See page 12 for reservoir inflow forecast information.

Initial spring 2008 runoff forecasts released by the NWS River Forecast Centers project near or above average runoff forecast for most basins, with the highest streamflow forecasts in the San Juan, Animas, Dolores, Rio Grande, Gunnison, and Arkansas basins (130-150% of average). The likelihood of flooding from snowmelt increases if spring temperatures are below average, because summer temperatures would then melt snowpack in a short period, according to State Climatologist Nolan Doesken. For more information on spring and summer streamflow forecasts, see page 21.

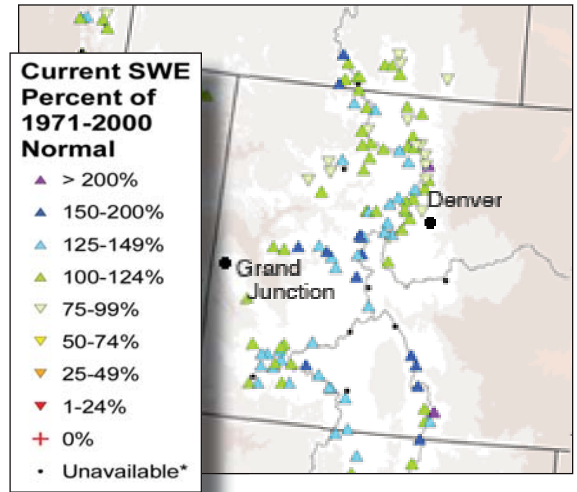


Figure 8a. Current snow water equivalent (SWE) as a percent of normal for SNOTEL sites in Colorado as of April 17, 2008, (NRCS).

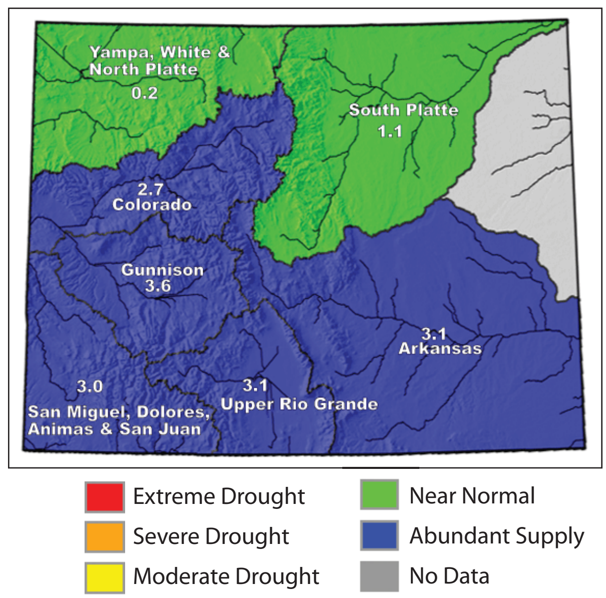


Figure 8b. Accumulated SWE for WY2008 (black line) increased over four inches during February in the Arkansas River Basin, bringing snowpack to 155% of average (NRCS).

Notes

Figure 8a, (NRCS), shows the SWE as a percent of average for each of the major river basins in Colorado. The Surface Water Supply Index (SWSI), Figure 8b developed by the Colorado Office of the State Engineer and the NRCS is used as an indicator of mountain-based water supply conditions in the major river basins of the state. The Colorado SWSI is based on snowpack, reservoir stor¬age, and precipitation for the winter period (November-April). This differs from summer calculations that use streamflows as well. SWSI values in were computed for each of the seven major basins in Colorado on the first of each month, and reflect conditions through the end of the previous month.

On the Web

- For current maps of SWE as a percent of normal (Figure 8a), visit: http://www.wcc.nrcs.usda.gov/gis/snow.html.
- For monthly reports on water supply conditions & forecasts for major CO river basins, visit: http://www.co.nrcs.usda.gov/snow/snow/snow_all.html and click on "Basin Outlook Reports."
- Information on regional weather forecasts and information, visit NWS Denver/Boulder Weather Forecast Office at http://www.crh.noaa.gov/bou/.
- The Colorado Water Availability Task Force information, including agenda & minutes of upcoming & previous meetings is available at: http://www.cwcb.state.co.us/Conservation/Drought/taskForceAgendaMinPres.htm.
- NRCS SWE line graphs by basin like in Figure 8b available at: http://www.co.nrcs.usda.gov/snow/snow/watershed/current/daily/maps_graphs/swe_time.html.
- The Colorado SWSI along with more data about current water supply conditions for the state can be found at: http://www.co.nrcs.usda.gov/snow/fcst/watershed/current/monthly/maps_graphs/index.html.

Wyoming Water Availability

On April 1, the snowpack has reached its seasonal peak, and spring temperature will determine the speed and timing of melting and the amounts of additional snowfall. On April 2, percent of average snowpack in Wyoming is near average in most basins (100-124% of average), highest in Yellowstone and North Platte basins (125-149% of average), and lowest in central basins (75-99% of average) (Figure 9a). SWE has remained the same or increased slightly in most basins since March 1, except for the Belle Fourche and Cheyenne drainages that increased 29 percentage points (NRCS).

Statewide reservoir storage varies across the state (not shown), ranging from a low of 50% of average in the North Platte basin to a high of 102% of average in the Green River basin (NRCS). Reservoir storage in Boysen, Flaming Gorge, Buffalo Bill, Seminoe, and Fontenelle reservoirs are 62%, 104%, 96%, 39%, and 69% of average, respectively. See page 12 for reservoir inflow forecasts.

According to April 1 streamflow projections released by the CBRFC, statewide spring and summer streamflows are expected to range from a low of 75% of average in the Green River basin, to a high of 130% of average in the Little Snake River basin. Streamflow projections have increased in all basins since March 1, except the Upper and Lower North Platte, due to above average precipitation last month.

April 1 SWSI values indicate below average water supply conditions in central basins, while conditions in the Laramie, Upper North Platte, Powder, and Shoshone basins are above average (Figure 9b). SWSI values range from a low of -2.87 in the Big Sandy basin to a high of 3.22 in the Shoshone basin. SWSI values increased in all northern basins, the Lower North Platte River basin, and the Lower Green River basin, and SWSI values decreased in the remaining Southern basins. Wyoming drought intensity decreased statewide in comparison to this time last year, according to the U.S. Drought Monitor.

Notes

Figure 9a, (NRCS), shows the SWE as a percent of average for each of the major river basins in Wyoming. According to the WY NRCS, "The Surface Water Supply Index" (SWSI, Figure 9b) is computed using only surface water supplies for each drainage basin. The computation includes reservoir storage, if applicable, plus the runoff forecast. The index is purposely created to resemble the Palmer Drought Index, with normal conditions centered near zero. Adequate and excessive supply has a positive number and deficit water supply has a negative value. The SWSI does not use soil moisture and precipitation forecast, but the runoff forecast may include these values."

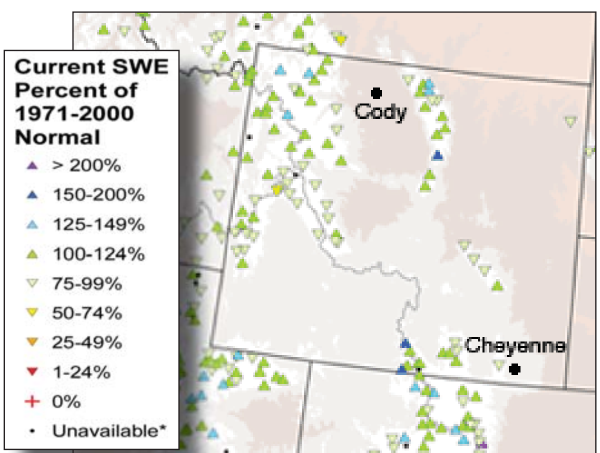


Figure 9a. Current snow water equivalent (SWE) as a percent of normal for SNOTEL sites in Wyoming as of April 17, 2008 (NRCS).

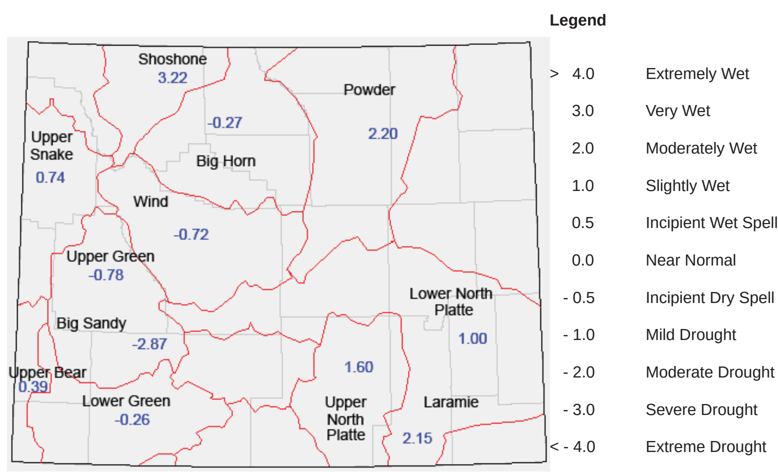


Figure 9b. Wyoming Surface Water Supply Index as of April 17, 2008 (Wyoming NRCS).

On the Web

- For current maps of SWE as a percent of normal (Figure 9a), visit: http://www.wcc.nrcs.usda.gov/gis/snow.html.
- For current SNOTEL data and plots of specific sites, visit: http://www.wcc.nrcs.usda.gov/snotel/.
- The Wyoming SWSI (Figure 9b), along with more data about current water supply conditions for the state can be found at: http://www.wrds.uwyo.edu/wrds/nrcs/nrcs.html.
- For monthly State Basin Outlook Reports on water supply conditions and forecasts for WY river basins, visit: http://www.wcc.nrcs.usda.gov/cgibin/bor.pl.
- Wyoming Water Resource Data system's drought page is located at: http://www.wrds.uwyo.edu/wrds/wsc/dtf/drought.html.

Utah Water Availability

On April 1, the snowpack has reached its seasonal peak, and spring temperature will determine the speed and timing of melting and the amounts of additional snowfall. On April 2, Utah percent of average snowpack was lowest in the Ogden and Bear River basins (75-99% of average; Figure 10a) and highest in the Uintah River basin (125-149% of average). Snowpack as a percent of average decreased in most basins (except the Bear River), and SNOTEL sites in southwest Utah decreased up to 48 percentage points, due to below average precipitation during March. However, snowpack in most basins is still near or above average because of above average snowfall earlier in the season.

SWSI values are near or above average statewide, ranging from a low of -3.15 in the Bear River basin to a high of 2.17 in the Virgin basin (Figure 10b). SWSI values decreased or remained the same in all basins since March.

Although current snowpack is near average in most basins, reservoir storage statewide has declined 14 percentage points since this time last year due to below average streamflows in WY2007. Reservoir levels are near or below average, ranging from a low of 24% of average in the Bear River basin to a high of 80 and 82% of average in the Duchesne and Provo basins, respectively (NRCS). On March 4, the USBR conducted a high flow test on the Colorado River, and released maximum flows of 41,500 cfs for 60 hours to rebuild sandbar deposits and backwaters in Marble and Grand Canyons. Grand Canyon National Park Superintendent Steve Martin said that new sandbars have provided new habitat for local wildlife.

April-July inflow projections into Lake Powell are 122% of average, and the USBR anticipates reservoir pool elevation will increase approximately 30 feet. For reference, in 2005 Lake Powell reservoir pool elevation increased by 31 feet and equaled 2.77 million acre-feet. See page 12 for additional reservoir inflow forecast information. Statewide streamflow projections range from a low of 58% of average on the Bear River to 167% of average on South Creek near Monticello (NRCS). The majority of streamflow projections across the state are near or above average, ranging from 90-120% of average, slightly lower than projections released last month. For additional information on spring and summer streamflow forecasts, see page 21.

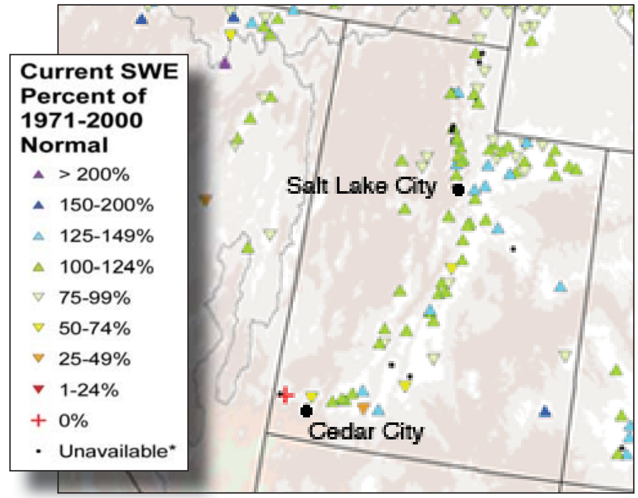


Figure 10a. Current snow water equivalent (SWE) as a percent of normal for SNOTEL sites in Utah as of April 3, 2008 (NRCS).

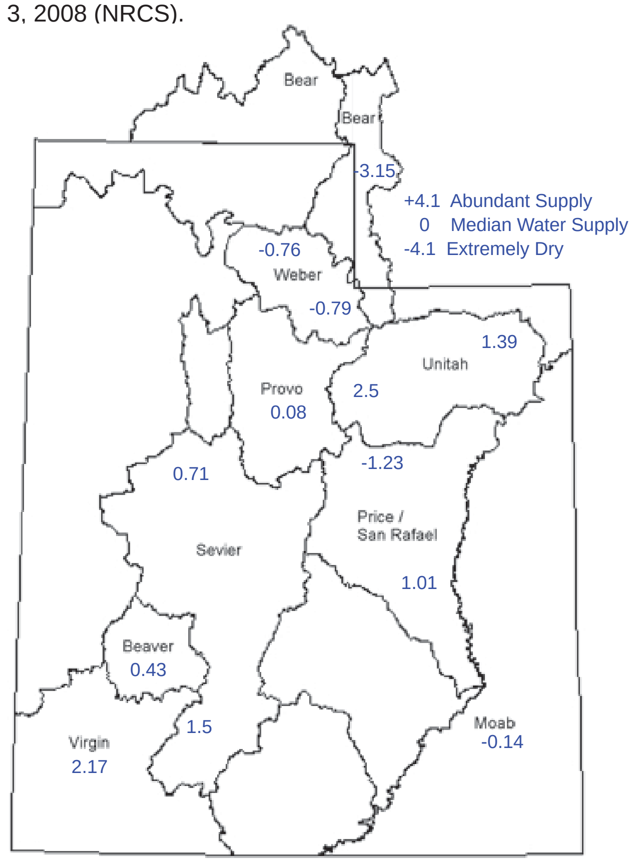


Figure 10b. Utah Surface Water Supply Index as of April 1, 2008 (Utah NRCS).

Notes

Figure 10a shows the SWE as a percent of normal (average) for SNOTEL sites in Utah, courtesy NRCS. According to the UT NRCS, "The Surface Water Supply Index (SWSI, Figure 10b) is a predictive indicator of total surface water availability within a watershed for the spring and summer water use seasons. The index is calculated by combining pre-runoff reservoir storage (carryover) with forecasts of spring and summer streamflow, which are based on current Snowpack and other hydrologic variables. SWSI values are scaled from +4.1 (abundant supply) to -4.1 (extremely dry) with a value of zero (0) indicating median water supply as compared to historical analysis. SWSI's are calculated in this fashion to be consistent with other hydroclimatic indicators such as the Palmer Drought Index and the [Standardized] Precipitation Index." See page 9 for the SPI.

On the Web

- For current maps of SWE as a percent of normal as shown in Figure 10a, go to http://wcc.nrcs.usda.gov/gis/.
- The Utah SWSI, Figure 10b, along with more data about current water supply status for the state, can be found at:
- http://www.ut.nrcs.usda.gov/snow/watersupply/.
- The Palmer Drought Index is found on NOAA's drought page: www.drought.noaa.gov.
- The Utah January Water Supply Outlook is available by state and basin at: http://www.ut.nrcs.usda.gov/snow/watersupply/wsor.html.
- The Lake Powell Status Summary is updated at the first of each month and is available at http://www.usbr.gov/uc/.
- Utah Water Supply Outlook Report provided by the NRCS is available at: http://www.ut.nrcs.usda.gov/snow/watersupply/wsor/2008/wsor_0308.pdf
- "Grand Canyon Flood Created New Sandbars," Associated Press, March 14, 2008. URL:
- http://wwa.colorado.edu/admin/announcement_files/2194-uploaded/announcement-2194-6627.pdf

Temperature Outlook May – August 2008

The temperature outlook for May indicates equal chances (EC) of above-, near, and below average temperature for most of the Intermountain West, with an enhanced probability of above average temperatures in southern **Utah** and the southwest (Figure 11a). This forecast is based on models, long-term trends and composites of observations from previous La Nina episodes. The temperature outlook for the May-July forecast period depicts an increased probability of above average temperatures for most of the western continental U.S. including western **Colorado** and **Wyoming** and all of **Utah** (Figure 11b). The probability of above average temperatures is 50% or more for **Utah** and the western part of the Intermountain region for June - September (Figure 11c-d).

The May 2008 temperature forecast will be updated on April 30st. on the CPC web page. Because of the shorter lead-time, the "zero-lead" forecast (i.e. on the last day of the previous month) often has increased skill over the half-month lead forecasts shown here. The next issue date for the seasonal Outlooks is May 15th.

Notes

The seasonal temperature outlooks predict the likelihood (chance) of temperatures occurring in the *above-average*, *near-average*, and *below-average* categories. The numbers on the maps do not refer to actual temperature values, but to the probability in percent that temperatures will be in one of these three categories.

The CPC outlooks are 3-category forecasts based on climate models in which the skill largely comes from the status of ENSO and recent trends. The categories are defined based on the 1971-2000 climate record; each 1- or 3-month period is divided into 3 categories (terciles), indicating the probabilities that the temperature in the period will fall into the upper third of the years (upper tercile, the middle third of the years (middle tercile, or around average), or the lowest third of the years (lower tercile). The forecast indicates the likelihood of the temperature beinge in the *above-average* (A, orange shading) or *below-average* (B) tercile--with a corresponding decrease in the opposite category. The near-average category is preserved at 33.3% likelihood, unless the anomaly forecast probability is very high. Equal Chances (EC) indicates areas for which the models do not have sufficient skill to predict the temperature with any confidence, representing equal chances or a 33.3% probability for each tercile. For a detailed description, see notes on the precipitation outlook page.

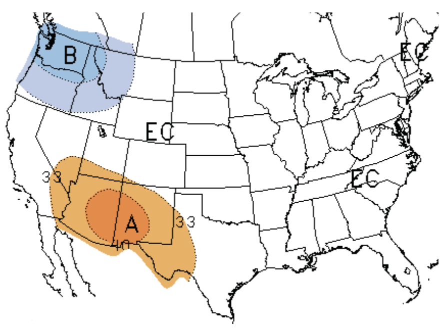


Figure 11a. Long-lead national temperature forecast for May 2008 (released April 17, 2008).

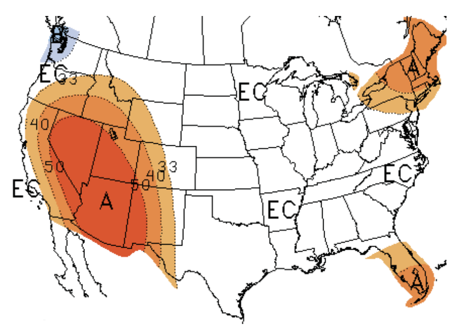
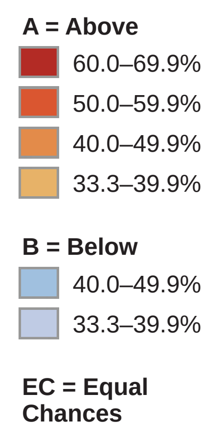


Figure 11b. Long-lead national temperature forecast for May – July 2008 (released April 17, 2008).



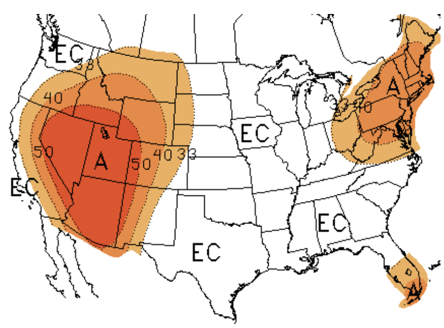


Figure 11c. Long-lead national temperature forecast for June – August 2008 (released April 17, 2008).

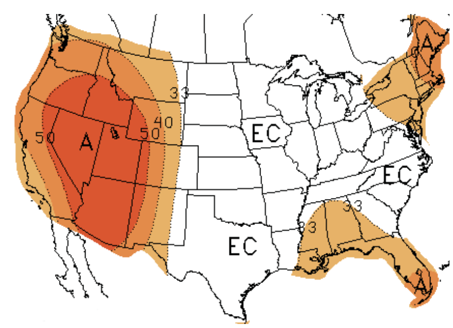


Figure 11d. Long-lead national temperature forecast for July – September 2008 (released April 17, 2008).

On the Web

- For more information and the most recent forecast images, visit: http://www.cpc.ncep.noaa.gov/products/predictions/90day/. Please note that this website has many graphics and may load slowly on your computer.
- The CPC "discussion for non-technical users" is at: http://www.cpc.noaa.gov/products/predictions/90day/fxus05.html.
- For IRI forecasts, visit: http://iri.columbia.edu/climate/forecast/net_asmt/.
- More information about temperature distributions at specific stations in Colorado, Utah, Wyoming, and across the West can be found at the Western Regional Climate Center, http://www.wrcc.dri.edu/CLIMATEDATA.html.

Precipitation Outlook May – August 2008

The CPC outlook for May 2008 calls for equal chances (EC) of above, near, and below average precipitation for most of the Intermountain West (IMW; Figure 12a). However, for the May-July and subsequent forecast periods (12b-d), there is an increased probability of below-average precipitation across much of the IMW and northwestern U.S., including most or all of **Utah, Colorado** and **Wyoming** These forecasts are based to a large degree on the NOAA multi-model consolidation and long-term trends, with consideration given to La Nina composites for the April-July forecast. For August-October and beyond (not shown), there is no information in the forecast for the IMW region, i.e., only equal chances (EC) of above, near, and below average precipitation are depicted on the maps.

The May 2008 precipitation forecast will be updated on April 30st. on the CPC web page. Because of the shorter lead-time, the "zero-lead" forecast (i.e. on the last day of the previous month) often has increased skill over the half-month lead forecasts shown here. The next issue date for the seasonal Outlooks is May 15th.

Notes

The seasonal precipitation outlooks predict the likelihood (chance) of precipitation occurring in the above-average, near-average, and below-average categories. The numbers on the maps do not refer to actual precipitation values, but to the probability in percent that precipitation will be in one of these three categories.

The CPC outlooks are 3-category forecasts based on climate models in which the skill largely comes from the status of ENSO and recent trends. The categories are defined based on the 1971-2000 climate record; each 1- or 3-month period is divided into 3 categories (terciles), indicating the probabilities that the precipitation in the period will fall into the upper third of the years (upper tercile, the middle third of the years (middle tercile, or around average), or the lowest third of the years (lower tercile). each with a 33.3% chance of occurring. The middle tercile is considered the near-average (or normal) precipitation range. The forecast indicates the likelihood of the precipitation occurring in the below-average (B, brown shading) or above-average (A, green shading) --with a corresponding decrease in the opposite category, The near-average category is preserved at 33.3% likelihood, unless the anomaly forecast probability is very high.

Thus, areas with dark brown shading indicate a 40.0-50.0% chance of below-average, a 33.3% chance of near-average, and a 16.7-26.6% chance of above-average precipitation. Light brown shading displays a 33.3-39.9% chance of below-average, a 33.3% chance of near-average, and a 26.7-33.3% chance of above-average precipitation and so on. Green shading indicate areas with a greater chance of above average precipitation. Equal Chances (EC) indicates areas for which the models cannot predict the precipitation with any confidence, representing equal chances or a 33.3% probability for each tercile, indicating areas where the reliability (i.e., 'skill') of the forecast is poor. "N" indicates an increased chance of near-average conditions, but is not forecasted very often.

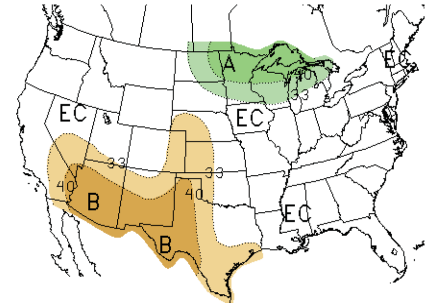


Figure 12a. Long-lead national precipitation forecast for May 2008 (released April 17, 2008).

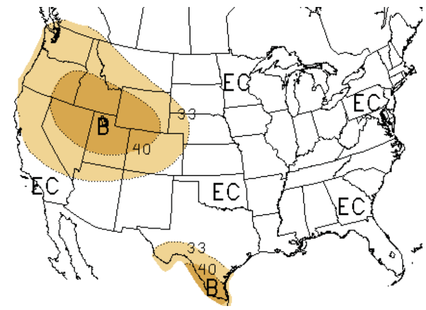


Figure 12b. Long-lead national precipitation forecast for Apr. – July. 2008 (released April 17, 2008).

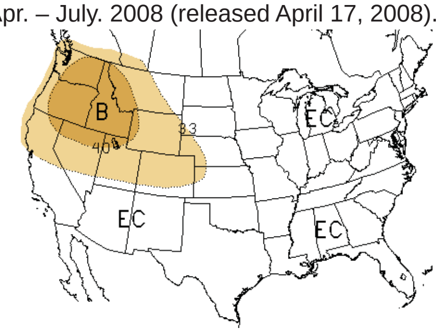
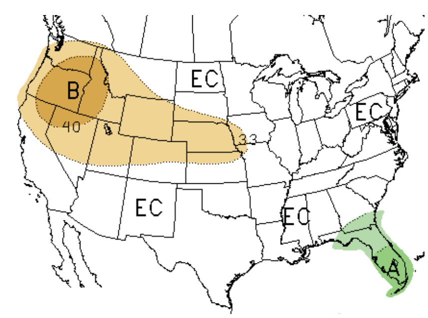


Figure 12c. Long-lead national precipitation forecast for Jun – August 2008 (April 17, 2008).



EC = Equal Chances

A = Above

40.0–49.9%

33.3–39.9%

B = Below

50.0–59.9%

40.0–49.9%

33.3–39.9%

Figure 12d. Long-lead national precipitation forecast for July – September 2008 (released April 17, 2008).

On the Web

- For more information and the most recent CPC forecast images, visit: http://www.cpc.ncep.noaa.gov/products/predictions/90day/. Please note that this website has many graphics and may load slowly on your computer.
- The CPC "discussion for non-technical users" is at: http://www.cpc.noaa.gov/products/predictions/90day/fxus05.html.
- For IRI forecasts, visit: http://iri.columbia.edu/climate/forecast/net_asmt/.
- More information about precipitation distributions at specific stations in Colorado, Utah, Wyoming, and across the West can be found at the Western Regional Climate Center, http://www.wrcc.dri.edu/CLIMATEDATA.html.The NOAA/ESRL experimental guidance product, including a discussion and executive summary, is available on the web at: http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/index.html.

Seasonal Drought Outlook through July 2008

The US Drought Monitor (page 10) has recently shown improvements across much of the Intermountain West based on a robust snowpack, and the anticipation that streamflow, reservoir storage, and soil moisture should all improve. However, because the Seasonal Drought Outlook has already made adjustments for these conditions, changes in drought conditions over the next few months should be relatively small across the region as the snowfall season comes to an end (Figure 13).

Across much of **Wyoming** and the west-central Plains, some improvement is expected, primarily early in the April-June season, based on the climatological increase in precipitation during late spring and forecasts for near- to above-normal precipitation through the last half of April 2008. However, the odds slightly favor below normal precipitation for May 2008 across the west-central Plains, and for the May - July 2008 period farther west, making substantial and widespread improvement that continues through the end of the forecast period unlikely (see page 18 for precipitation outlooks).

This Seasonal Drought Outlook relies less on La Niña composites because of weakening SST anomalies and the fact that La Niña has a less consistent impact on conditions across the country during this forecast period than during the colder times of the year. Tools used in the current Seasonal Drought Outlook include the following CPC products: the official CPC long-lead precipitation outlook for May 2008 and May - July 2008, the 4-month drought termination and amelioration probabilities, various medium- and short-range forecasts and models such as the 6-10 day and 8-14 day forecasts, the soil moisture tools based on the GFS model and the Constructed Analogue on Soil moisture, the CFS seasonal precipitation forecasts and climatology. The next Seasonal Drought Outlook will be issued in two weeks, on May 2nd.

Notes

The Seasonal Drought Outlook (DO) depicts general, large-scale trends from that date through the end of the forecast period (3 to 3.5 months, depending on the date of issue). The delineated areas in the (Figure 13) are defined subjectively based on expert assessment of numerous indicators, including outputs of short- and long-term forecasting models. Areas of continuing drought are schematically approximated from the Drought Monitor (D1 to D4). For weekly drought updates, see the latest Drought Monitor text on the website: http://www.drought.unl.edu/dm/monitor.html. NOTE: The green improvement areas imply at least a 1-category improvement in the Drought Monitor intensity levels, but do not necessarily imply drought elimination.

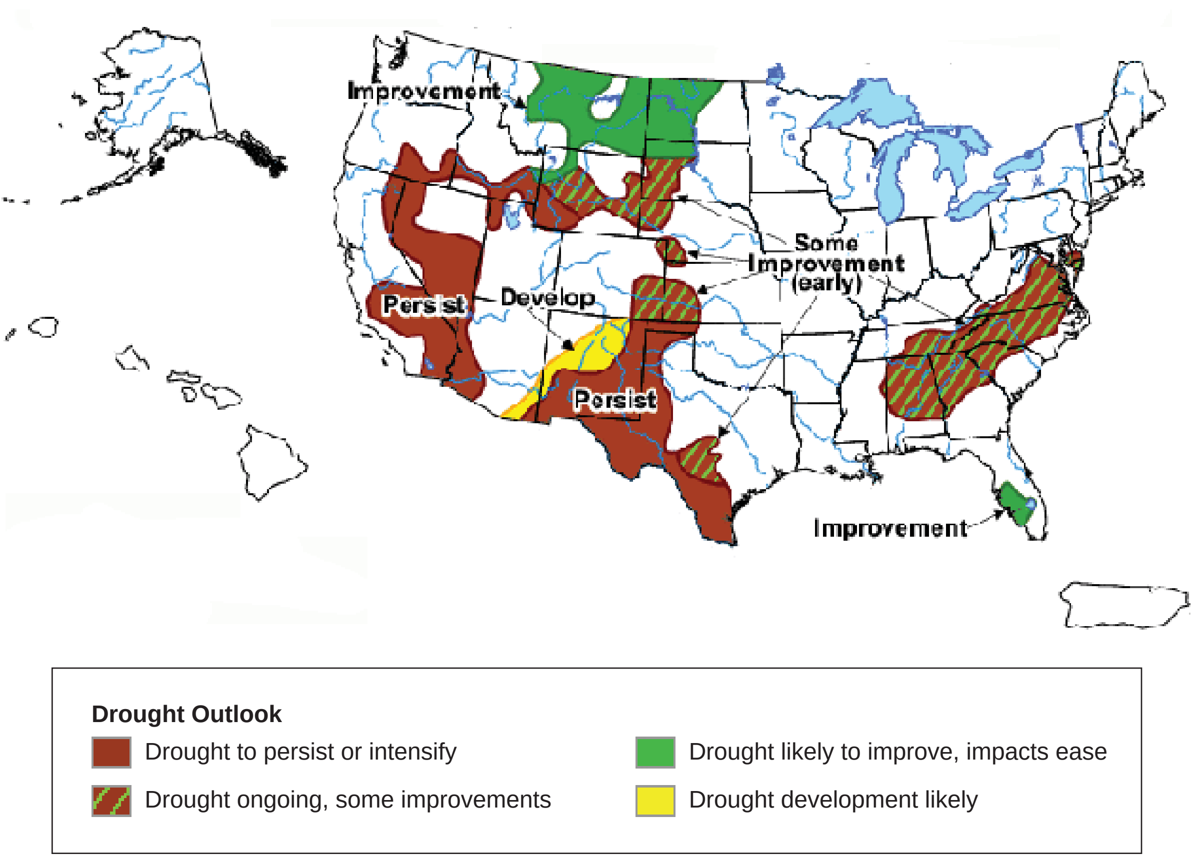


Figure 13. Long-lead national precipitation forecast for April 17 – July 2008

On the Web

- For more information, visit: http://www.drought.noaa.gov/.
- Forecasts of drought termination probabilities can be found at: http://www.ncdc.noaa.gov/oa/climate/research/drought/current.html.

El Niño Status and Forecast

La Niña conditions, or colder than normal SSTs, currently exist in the eastern tropical Pacific and are expected to continue for the next 3 months, according to the NOAA Climate Prediction Center's monthly "ENSO Diagnostic Discussion," issued April 10th. However, this La Niña event has declined to moderate-strength during March 2008 as negative SST anomalies have weakened, and conditions are trending towards neutral conditions (Figure 14a). Weakening La Niña conditions were also observed at this time of year during the last strong La Niña episode in 1999 and 2000.

The spring is a particularly difficult time for forecasting the evolution of ENSO. The International Research Institute for Climate and Society (IRI), a NOAA partner, describes this period as the "Spring Barrier" to ENSO prediction. The models diverge in their ENSO forecasts through the 10-month forecast period, however the majority of the models forecast weak-to-moderate La Niña conditions to continue over the next few months, with SST anomalies decreasing to neutral conditions starting in mid-2008, and a few maintain La Niña conditions throughout the remainder of 2008 (Figure 14b). However, there is considerable spread in the forecasts, with nearly one-half indicating La Niña could continue well into the second half of the year while a couple models develop El Niño conditions. The IRI provides probabilities for these conditions: there is a 60% probability of maintaining La Niña conditions thru the April-June 2008 season, but by mid-2008 the probability of returning to ENSO-neutral conditions increases to the climatological value of 50%.

La Niña impacts are typically less pronounced over the United States in spring than winter. The main April-June impacts for the contiguous U.S. are an increased probability of below-average precipitation over parts of the Southwest extending from Texas to Nevada; these typical impacts are reflected in the monthly and seasonal forecasts (see page 18 for precipitation outlooks).

The ENSO Diagnostic Discussion is a collaborative effort of the several parts of NOAA, including the research labs, the IRI, and other institutions funded by NOAA. The CPC ENSO Diagnostic Discussion will be updated next on May 8th, and the IRI ENSO "Quick Look" on May 15th.

Model Forecasts of ENSO from March 2008

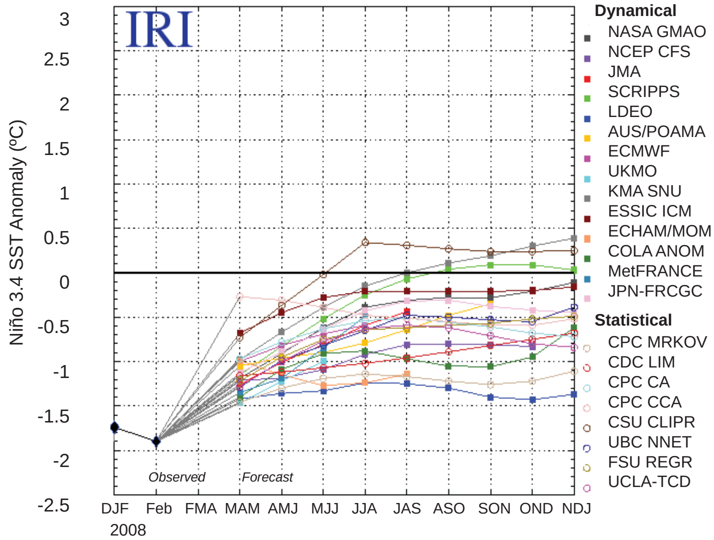


Figure 14b. Forecasts made by dynamical and statistical models for sea surface temperatures (SST) in the Niño 3.4 region for nine overlapping 3-month periods from April 2008 through February 2009 (released April 17, 2008). Forecast graphic is from the International Research Institute (IRI) for Climate and Society.

Observed Sea Surface Temperature Anomalies (C°)

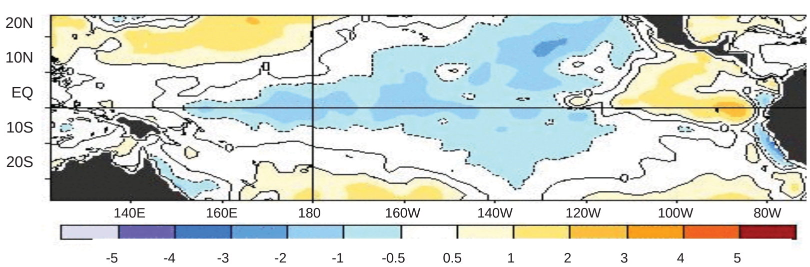
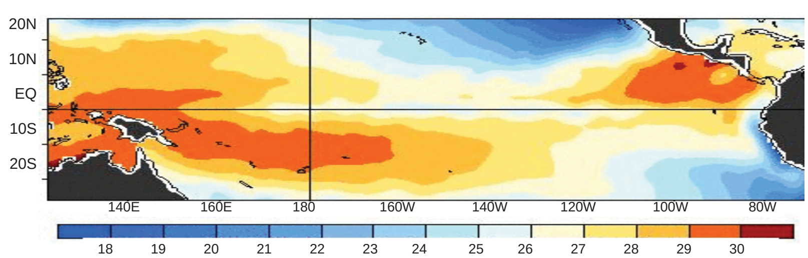


Figure 14a. Observed SST (upper) and the observed SST anomalies (lower) in the Pacific Ocean. The Niño 3.4 region encompasses the area between 120°W-170°W and 5°N-5°S. The graphics represent the 7-day average centered on April 9, 2008.



Notes

Two NOAA graphics in Figure 13a show observed SST (upper) and SST anomalies (lower) in the Pacific Ocean, averaged over a recent 5-day period. Data are from satellite observations and the NOAA TAO array of 70 moored buoys spread out over the Pacific Ocean, centered on the equator. The buoys measure temperature, currents, and winds and transmit data in real-time. NOAA uses these observations to predict short-term (a few months to one year) climate variations.

Figure 13b shows forecasts for SST in the Niño 3.4 region for nine overlapping 3-month periods. "Niño 3.4" refers to the region of the equatorial Pacific from 120°W to 170°W and 5°N to 5°S, which is used as an SST-based index for defining ENSO. Abbreviations represent groups of three months (e.g. SON = Sept-Nov). The expected skills of the models, based on historical performance, vary among the models, and skill generally decreases with lead-time. Forecast skill also varies over the year because of seasonal differences in predictability of the system, e.g., forecasts made between June and December are generally better than those made between February and May. Differences among forecasts reflect both differences in model design and actual uncertainty in the forecast of the possible future SST scenario.

On the Web

- For a technical discussion of current El Niño conditions, visit: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/.
- For updated graphics of SST and SST anomalies, visit this site and click on "Weekly SST Anomalies": http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml#current.
- For more information about El Niño, including the most recent forecasts, visit: http://portal.iri.columbia.edu/climate/ENSO/.

Spring and Summer Streamflow Forecasts for the 2008 Runoff Season

Streamflow projections decreased in parts of **Colorado** and **Utah** since last month due to below average precipitation, however, most basins in these states are projected to have near or above average streamflow this year (NRCS; Figure 15). In **Wyoming**, on the other hand, above average precipitation in March increased streamflow projections there.

In **Colorado**, runoff is expected to be the highest in several decades in the southern basins. Specifically, several forecast points there are for 150% of average. In the north, runoff is also expected to be higher than average (110-130%). A continued dry spring would only affect the runoff in the northern Front Range, which is an area that relies on wet spring storms for a large portion of annual water supplies (NRCS).

In **Utah**, streamflow forecasts range from a low of 58% of average in the Bear River basin in the north, to 167% of average in the southeast near Monticello. Most of the state is near average. Snowmelt has begun in low elevations in northern Utah (6000-7500 ft), and the NRCS cautions water managers to be ready for early runoff. A warm and dry spring could cause early runoff, but a cold and wet spring would slow the runoff.

In **Wyoming**, below average streamflows are projected in most major river basins, but streamflow projections are higher than they were on March 1 due to above average precipitation in March. The highest streamflows as a percent of average are projected for the North Platte in the south and the Powder/Tongue Rivers in the north, both in the 110-129% category.

See reservoir inflow (page 12) for more details about seasonal streamflow forecasts.

Notes

Forecasts of natural runoff are based principally on measurements of precipitation, snow water equivalent, and antecedent runoff, influenced by precipitation in the fall before winter snowfall (Figure 15). Forecasts become more accurate as more of the data affecting runoff are measured (i.e. accuracy increases from January to May). In addition, these forecasts assume that climatic factors during the remainder of the snow accumulation and melt season will have an average affect on runoff. Early season forecasts are, therefore, subject to a greater change than those made on later dates.

The graphic shown here is from the NRCS, but the forecast is a collaborative effort between the NRCS and the NOAA River Basin Forecast Centers. You can see the official NOAA streamflow forecasts on the individual river basin forecast centers' websites. (See On the Web box below for links to the official NOAA forecasts.)

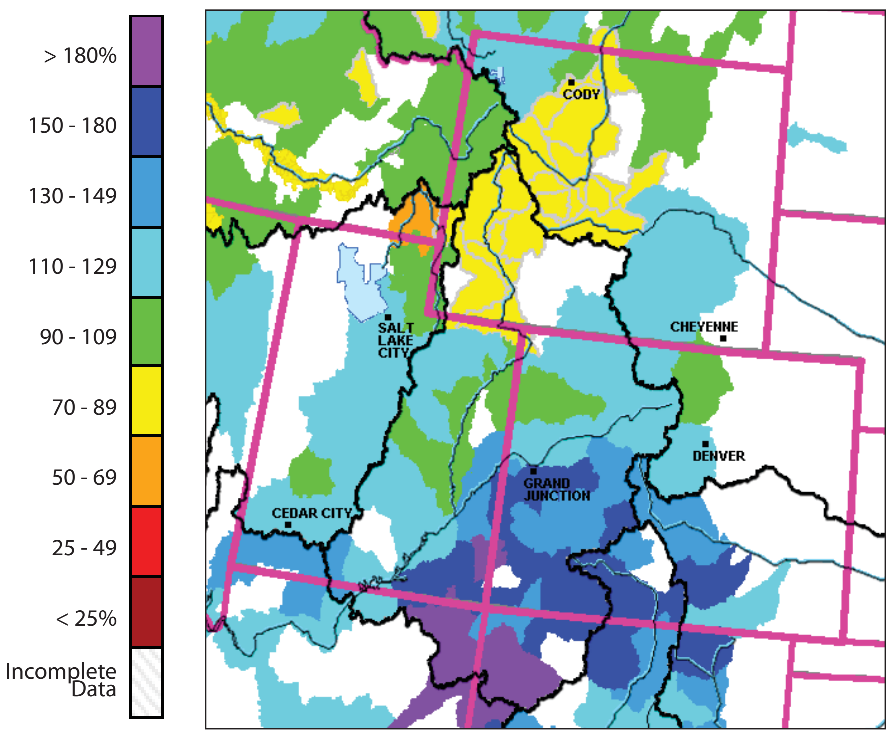


Figure 15. NRCS outlook for natural streamflows for spring and summer in the Intermountain West region as a percent of average streamflows (data through March 1, 2008).

On the Web

For more information about NRCS water supply forecasts based on snow accumulation and access to the graph on this page, visit: http://www.wcc.nrcs.usda.gov/wsf/.

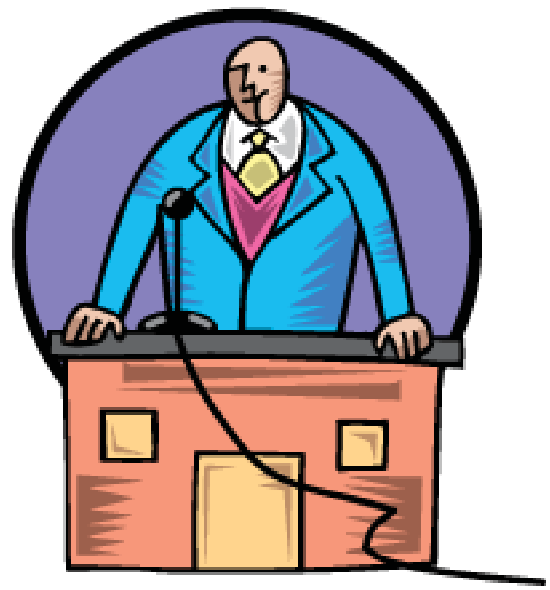
The official NOAA streamflow forecasts are available through the following websites of individual River Forecast Centers:

- Colorado Basin (includes Great Basin): http://www.cbrfc.noaa.gov/.
- Missouri Basin (includes South Platte and North Plate: http://www.crh.noaa.gov/mbrfc/.
- West Gulf (includes Rio Grande): http://www.srh.noaa.gov/wgrfc/.
- Arkansas Basin: http://www.srh.noaa.gov/abrfc/.
- The NOAA CBRFC has a new interactive website that shows streamflow forecasts as inputs to reservoirs: http://www.cbrfc.noaa.gov/westernwater/.

Workshop Summary:
Climate Change Modeling Workshop for Front Range Water Providers February 1, 2008 Denver, Colorado

Climate change has the potential to affect water supplies and water management in the Intermountain West. Water managers are beginning to explore ways to quantify and adapt to potential changes. Several Front Range water providers are working together to fund a study of the potential impacts of climate change on water resources in Colorado. The water providers will use a variety of downscaled GCM projections in two different hydrology models to identify streamflow changes through out the 21st century. WWA is serving on an advisory committee to help the group select GCMs, emissions scenarios, climate variables, and data sets. WWA will also provide guidance on adaptation strategies and communicating the results to governing bodies and the public.

In February, WWA organized an education workshop for the water providers were four presenters explained the fundamentals and differences of GCMs, emissions scenarios, downscaling techniques, and hydrologic modeling. See http://wwa.colorado.edu/resources/climate_change_modeling.html for presentations and other background information. The following are short summaries of each presentation from the workshop.



Climate Models and Emissions Scenarios

Joe Barsugli, CIRES/University of Colorado, affiliated with NOAA Earth system Research Lab, Physical Sciences Division

Dr. Barsugli provided background on three topics: climate sci ence, emissions scenarios, and climate models.

1)The *science of climate change* can be simplified by stating that as humans increase carbon dioxide emissions, we affect the carbon cycle, which changes the energy balance of the earth. The earth heats up, which causes increased evaporation, which also affects the energy balance. Because the energy balance and the water cycle involve the winds and ocean currents, they are changed as well, potentially changing all aspects of climate.

2) *Emissions scenarios* refer to the projected amount of change or increase in carbon dioxide emissions and other drivers of climate change during the 21st century. The scenarios differ mainly in the rate of carbon dioxide increase and in whether or not they lead to a stabilization of greenhouse gas concentrations during the 21st century. The rate of carbon dioxide increase depends on assumptions regarding demographic development, socio-economic development, and technological change. These scenarios are used as inputs to the climate models, and typically, each climate model is run with several emissions scenarios. Three emissions scenarios (B1, A1B, A2) were chosen for intensive climate modeling studies used in the IPCC Fourth Assessment Report, though other scenarios were also considered. It is important to note that emissions scenarios are useful tools, but they are not forecasts.

3) *General Circulation Models (GCMs*), or climate models, simulate all the processes that affect the climate on a global scale, including atmospheric chemistry, ocean circulations, clouds, terrestrial ecology, and large river systems. These models use mathematical equations to represent physical processes to varying degrees of approximation. Different modeling centers make different choices in how to represent these processes. There are 22 GCMs in the IPCC Fourth Assessment Report, and each has its own biases and uncertainties. Often the same model will be run with different initial conditions (the starting state of the physical processes that affect climate), and so there are multiple runs from the same models. Climate models produce output for many parameters and at various time scales. Typically, temperature and precipitation changes for the mid and late 21st century are referenced in articles.

An Overview of Downscaling Techniques Used in Climate Change Science

Christopher J. Anderson, NOAA Earth System Research Lab, Global Services Division

Climate models have a large resolution (limited by computing power), and this resolution is most often larger than both the physical processes that affect climate and the spatial scale of river basins. Therefore, in order to get temperature and precipitation projections that are relevant to river basin scales for water management, one must downscale the results and attempt to remove some of the model biases. Dr. Anderson explained two types of downscaling: dynamical and statistical.

1) *Dynamical downscaling* uses a regional climate model to provide climate change projections based on smaller scale physical processes. These models incorporate GCM output and provide an extra modeling step. Regional climate models require very large amounts of data and computing power, so only a small number of regional climate simulations are generated when downscaling. The results of regional climate models provide additional details but may also contain biases that need correction by statistical techniques. Regional climate models are well suited for understanding processes.

2) *Statistical downscaling* identifies statistical relationships between observations and model simulations of past climate. This method then uses these relationships to remove the bias from GCM output and to provide climate projections on a smaller scale that better reflect the regional differences in climate. The advantage of statistical downscaling is that a large data set can be generated. However, it is impossible to account for changes in statistical parameters in the climate projections since the observations needed to make such corrections do not yet exist.

K-Nearest Neighbor Resampling Technique

Balaji Rajagopalan, University of Colorado, Department of Civil, Environmental and Architectural Engineering

Many water managers make long-range water supply projections based on observed streamflow or weather conditions. The K-NN approach resamples past weather or streamflows to create scenarios for the future. The resampling is based on 'K' historical years that are 'analogs' to the 'current condition'. Thus simulated scenarios have the same statistical properties as the historical data, but they also provide a rich variety of sequences and variability. This framework can be easily modified to generate scenarios based on any user-defined condition. For example, seasonal climate forecast can be used as a condition to generate flow or weather scenarios thus, providing a seasonal ensemble forecast. Or the method can preferentially choose streamflow from years that were below average to simulate a long-term drought. This approach has been applied to a variety of water resources problems especially in Western US.

Dr. Rajagopalan presented two examples of using the Knn method: (1) stochastic weather generation that can be used in hydrologic or agriculture or other process models to provide long term simulation or seasonal forecast and (2) quantifying influent water quality variability to understand regulatory compliance risk in drinking water utilities.

Hydrology Modeling for Climate Change Impacts Studies

Levi Brekke, USBR Water Resources Planning and Operations, Technical Service Center

Hydrologic models can be used to "convert" downscaled temperature and precipitation data from climate models into streamflows. These models simulate the hydrologic system, including rivers, soil moisture, and ground water storage, and the effect of snow, rain and temperature on the resulting runoff. Dr. Brekke described the similarities and differences between three hydrology models: WEAP21, SAC-SMA/Snow17, and VIC. The models tend to produce different runoff responses for a given climate change assumption. One reason is that each model "structure" features a slightly different approach for representing soil moisture storage and distribution, groundwater interaction with surface water, watershed elevation influences, and other water cycle processes (e.g., evapotranspiration). Beyond model "structure" differences, the differences in runoff results can also be caused when the models are not calibrated in a consistent fashion, built to consistent spatial scales, or simulated on consistent time steps.

Dr. Brekke advised the group to consider using multiple hydrologic models in their impacts investigations. If the goal is to determine model preference, he suggested that it may be useful to re-calibrate and validate the models on pairs of historical periods featuring contrasting climates (e.g., earlier wet/cool period for calibration followed by recent warmer/drier period for validation). This would hopefully indicate whether some model(s) may be more confidently applied to a future climate that differs from the "calibration" climate.

On the Web

The workshop agenda, presentations, references, and key terms are available at:

- http://wwa.colorado.edu/resources/climate_change_modeling.html.