Issued: March 26, 2008

Southwest Climate Outlook

The University of Arizona.

Source: Dan Ferguson, CLIMAS

Photo Description: Poppies were early indicators of a good wildflower season around Tucson, Arizona earlier this month. Updates of the wildflower season are posted online by the Arizona Sonora Desert Museum and can be found at http://www.desertmuseum.org/programs/flw_blooming.html.

Would you like to have your favorite photograph featured on the cover of the *Southwest Climate Outlook*? For consideration send a photo representing Southwest climate and a detailed caption to: knelson7@email.arizona.edu

In this issue...

CLIMAS

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March Climate Summary

Drought – Continued wet conditions have helped improve short-term drought conditions across much of Arizona this month. Drought conditions expanded across southern and eastern New Mexico due to below-average precipitation in February.

Temperature – Temperatures were close to average across much of Arizona and New Mexico over the past thirty days.

Precipitation – Much of Arizona and northern New Mexico observed below-average precipitation over the past thirty days. Spotty precipitation fell across the northern portions of both states during the period.

ENSO – Strong La Niña conditions persisted again this month across the Pacific Ocean. Sea surface temperatures fell to 3 degrees C in parts of the western Pacific while the Southern Oscillation Index rose to 2.7, both indicative of a strong and mature La Niña.

Climate Forecasts – Seasonal climate forecasts project above-average temperatures and equal-chances for below-average, average, or above-average precipitation. While strong trends in increasing temperatures continue to support an above-average temperature forecast for the Southwest.

The Bottom Line – Arizona and New Mexico appear to be making the transition from an unusually wet and cool winter into a warm and dry spring. Drought conditions have improved across much of Arizona and northern New Mexico, but have deteriorated across southern New Mexico due to persistent below-average precipitation. La Niña is expected to continue through the spring, but typically has diminished impacts on the Southwest during this dry season. Seasonal climate outlooks reflect this diminished impact

Web-based climate resources

Interested in learning more about climate? Online climate learning modules through The University of Arizona Cooperative Extension take you through everything from the difference between weather and climate to explanations of how the El Niño-Southern Oscillation works. The monthly state temperature and precipitation update presents maps and analyses of the progression of Arizona temperature and precipitation during the last four years. The New Mexico Community Collaborative Rain Hail & Snow Network website shows data and maps of precipitation measured by volunteer weather observers in New Mexico.

Arizona Cooperative Extension Climate Learning
http://cals.arizona.edu/watershedsteward/resources/module/Climate/

Arizona State Climate Office Temperature and Precipitation Update
http://www.public.asu.edu/~aunjs/Update.html

New Mexico CoCoRaHS
http://nmcc.nmsu.edu/web/cocorahs/

Table of Contents:

SWCO Staff:

Joe Abraham, *CLIMAS Assistant Staff Scientist*
Deborah Bathke, *New Mexico State Climatologist*
Ashley Coles, *CLIMAS Graduate Research Associate*
Mike Crimmins, *UA Extension Specialist*
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A shift toward aridity

Westerly winds and other forces could make drought-prone regions even drier

By Stephanie Doster and Dan Ferguson

On February 28, 2008, the Climate Assessment for the Southwest (CLIMAS) program hosted a small, informal roundtable with several climate scientists from The University of Arizona. The discussion focused on how a poleward shift in the westerly winds over the northern hemisphere may influence the climate of the Southwest. The following article is based on the roundtable discussion.

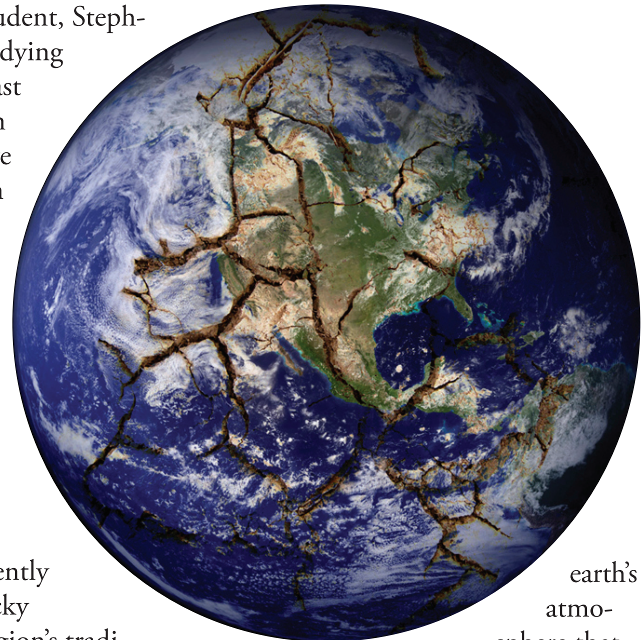
It's been in newspapers, on television, and in radio reports: greenhouse gas emissions from tailpipes and factories are very likely the culprits in global warming, and that in this era of accelerated climate change, the Southwest should brace for drier conditions in the coming decades. But beyond global warming, what are the forces that would drive this shift toward less precipitation?

The answer likely lies in the westerly winds, said Joellen Russell, a climate modeler and assistant professor of geosciences at The University of Arizona (UA).

Recent studies suggest that the westerly winds that blow over the mid latitudes in both the northern and southern hemispheres are shifting toward the poles. The poleward migration of the westerly winds, often referred to as the jet stream, will potentially alter, and perhaps already is changing, winter precipitation patterns in the southwestern United States.

"In the southern hemisphere, there's a very clear signal that over the last thirty to forty years we've seen about a four to six degree shift poleward of the westerly winds in the winter," Russell said. "In the northern hemisphere the shift has not been quite as distinct, in the sense that we've had a slightly weaker shift."

Russell and her graduate student, Stephanie McAfee, have been studying the climate records of the last thirty years in the American West. They believe they have spotted a significant shift in the winter-time location of the jet stream that's influenced the amount of precipitation in the Southwest.



The shift is important to the Southwest, Russell said, because it could change the winter storm track so that the jet stream more consistently flows north around the Rocky Mountains, bringing the region's traditional share of precipitation instead to northern areas of the country. Winter rain and snow make up most of the total precipitation received in Arizona and New Mexico annually, so any large scale change in the winter storm track has the potential to directly affect precipitation totals in the region. It remains unclear how these trends in large-scale atmospheric circulation patterns may influence the summer monsoon season in the Southwest because different forces cause the heavy summer rains.

"When the jet comes in towards the Rockies [during the winter], it has to make a decision whether the storms will break north around the northern edge or break south around the southern edge. We [in the Southwest] like it when they break south, because that means we get rain," Russell said.

The mechanisms for this jet stream shift are not fully understood, but two potential drivers are tied to manmade impacts on the global climate system. A strong body of scientific literature suggests that the depletion of ozone in the stratosphere is causing stratospheric cooling. The stratosphere is a thin layer of the earth's atmosphere that sits above the troposphere, the lowest layer of the earth's atmosphere. Stratospheric cooling is driven by anthropogenic depletion of ozone in the stratosphere.

"That ozone is a gas in the stratosphere that absorbs incoming shortwave radiation from the sun. …Because it's absorbing that radiation, there's heating. So if we reduce the amount of ozone [in the stratosphere], you get less heating," said Jonathan Overpeck, a UA geosciences professor and director of UA Institute for the Study of Planet Earth.

At the same time the stratosphere is cooling from ozone depletion, tropospheric ozone, a greenhouse gas, is building up, trapping more heat and keeping it from escaping to the upper atmosphere, Overpeck said.

Scientists have seen a 0.6 to 0.8 degree Celsius change in the troposphere, where it's warming; the polar stratosphere has cooled almost seven degrees in the Antarctic, Russell said.

continued on page 4

Aridity, continued

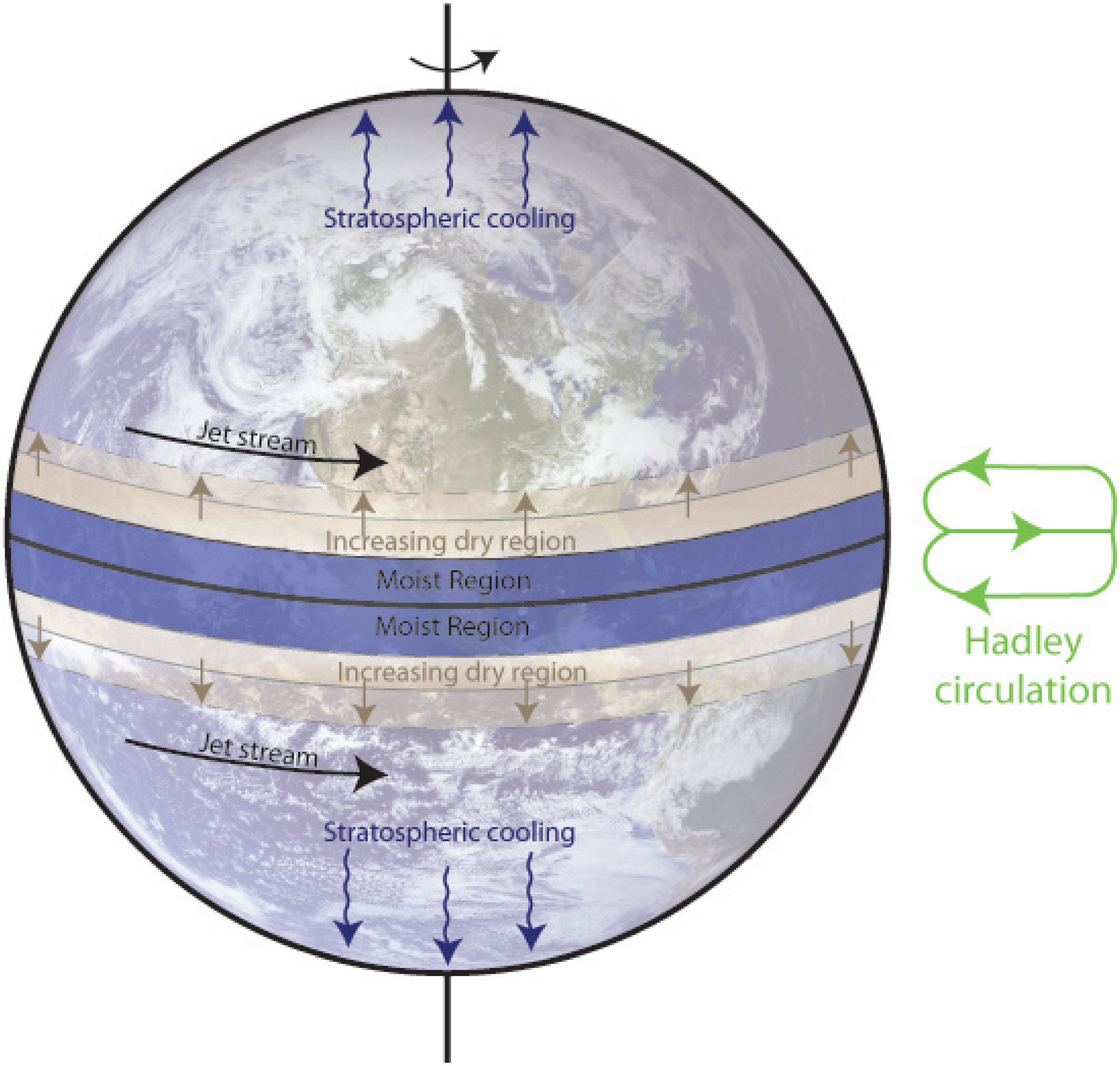


Figure 1. Cooling of the stratosphere from ozone depletion high in the atmosphere and expansion of the Hadley cell from warming oceans are impacting the winter time tracks of the westerly winds over both hemispheres. This change could expand the world's deserts, meaning a potentially drier southwestern United States.

A cooler stratosphere and a warmer troposphere could shift the westerly winds over both the northern and southern hemispheres, in part, because of the polar vortex, that very fast wind that spins around each pole during winter, when the equator-to-pole thermal gradient is steepest.

An increase in the thermal gradient, or change in temperature across a distance, has a direct effect on atmospheric winds. In this case, the increased thermal gradient that results from a cooler stratosphere and a warmer troposphere leads to a poleward pull of the jet streams.

The other mechanism that may be linked to a poleward shift of the jet streams over both hemispheres is the expansion of the Hadley cell, an atmospheric circulation pattern that exerts a strong influence over the climate of the tropics and subtropics.

"The Hadley cell is that convective cell on the equator, where you have warm water creating convection, which then

continued on page 5

Aridity, continued

rains out and creates our lovely rain forests in the tropics," Russell said. Most of the world's deserts, including the Sonoran Desert, exist just beyond that point, at around 30 degrees north and south latitude.

"Because we're trapping more radiation with carbon dioxide, we're warming the tropical oceans, which are then [generating] more convection," Russell said.

Models indicate that increased convection appears to be expanding the Hadley cell, which could mean an expansion of the world's deserts (Figure 1).

"We don't quite know yet whether it's because those dry areas are expanding, or because of something different in the hydrologic cycle associated with the tropical shift," Russell said.

While still an area of active research, it appears that the expansion of the tropics may push the jet stream, and the cooling of the stratosphere due to the ozone holes may pull it, Russell said.

"They're both happening. We can't attribute one way or the other, because we can't distinguish between the impacts," Russell said. "All [the global climate] models agree on very little, but they all agree that the winds are moving poleward in both hemispheres. If you've got a small shift because of the warming in the troposphere, but you've got a big shift because of the ozone loss in the stratosphere, it kind of doesn't matter [which mechanism is dominant], because they both work together."

One uncertainty is how the shifts in the jet stream interact with existing natural variability in the climate system, like El Niño Southern Oscillation and the Pacific Decadal Oscillation, said Chris Castro, UA assistant professor of atmospheric sciences. He added that temperature also will play a role in a more arid southwestern United States.

"There has been a trend toward an increase in snow melt happening earlier. If you look, for example, at Climate Prediction Center forecasts, you can consistently see this bull's eye of above-average temperature anomalies in the Southwest—and this is accounted for nearly entirely by long term temperature trends," Castro said. "Water managers in the western U.S. make most of their planning decisions based on spring snowpack, and this has been decreasing, on average, over the last twenty years or so."

From a water management perspective, warming temperatures—and increased evaporation rates—also create more demand for water, noted Julia Cole, geosciences professor.

Castro agreed, adding that the caveat to water demand in Arizona, at least from an urban water usage perspective, is the onset date of the monsoon. A very recent study by Jeremy Weiss, a UA geosciences researcher, has shown that during recent years, temperatures are higher in the weeks just before the onset of the monsoon, specifically the early to late June period, Castro said.

"That's the trend, but then what controls exactly when the transition period occurs and whether the monsoon is early or late? That's modulated by the natural variability in the climate system. How does that change with global warming? We don't know. What happens during these very climatologically different periods? The pre-monsoon period, and during the monsoon itself?" Castro said. "We really need to adopt the perspective of how climate change is affecting these very climatologically different periods and interacting with natural climate variability. That kind of information will be of much greater relevance to local stakeholders, rather than just describing the mean change for the entire summer."

One trend southwesterners are likely to see, Castro said, is more intense precipitation events, which can lead to flooding and runoff. This has already been occurring over the U.S. during the warm season and during the monsoon in Arizona, according to Castro.

"This means that, in a warming world, Arizona's seasons are becoming even more extreme. The period before the monsoon is getting hotter and drier, but once the monsoon rains come they are more intense. The summer of 2006, the sixth wettest in Tucson, is a very good example," Castro said.

Although not discussed in the roundtable, another player in aridity could be dust, Overpeck said. If increased amounts of the tiny heat-absorbing particles, kicked up by the activities of a growing population and drier conditions, settle on mountain snowpack, the snow would melt earlier in the spring. That would spiral into a positive feedback loop of yet more dust and aridity, Overpeck said.

But regardless of what the models reveal about future climate conditions, Overpeck said, there is one wild card that can throw off even the best climate projections: natural variability. It is unknown how natural variability is interacting with global warming.

"There's a lot of variation in the climate system," Overpeck said. "We could have winters like this winter, which have more than average precipitation."

Stephanie Doster is the Information Specialist for the UA Institute for the Study of Planet Earth.

Dan Ferguson is the Program Manager for the UA Climate Assessment for the Southwest project.

Temperature (through 3/19/08)

Source: High Plains Regional Climate Center

Temperatures generally have averaged between 30 and 40 degrees Fahrenheit in northern Arizona and New Mexico and 20 to 30 degrees F in the highest elevations of north central New Mexico since the start of the water year on October 1 (Figures 1a–b). The lower elevations of southern New Mexico have been between 45 and 55 degrees F, while the warmest areas have been between 55 and 65 degrees F in the southwestern deserts of Arizona. These temperatures have generally been within 2 degrees F of average across both states. Most areas in both states have been about 2 degrees above average. West-central Arizona has averaged 2–4 degrees below average for the water year, while the high elevations in northern New Mexico and north central Arizona have been 0–2 degrees below average. Southwestern and southeastern New Mexico and the White Mountains of eastern Arizona have seen temperatures ranging from 2 to 4 degrees above average. In the past thirty days, the mid-sections of both states have seen colder conditions as the storm track in mid-February moved from southwest Arizona through northeast New Mexico (Figures 1c–d). Temperatures were 0–2 degrees below average across eastern Arizona and northwestern New Mexico. Most of western Arizona and southeastern New Mexico have been 0–2 degrees warmer than average in the past month, as the La Niña finally brought the warmer, drier weather that had been predicted.

Notes:

The water year begins on October 1 and ends on September 30 of the following year. Water year is more commonly used in association with precipitation; water year temperature can be used to measure the temperatures associated with the hydrological activity during the water year.

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.

The continuous color maps (Figures 1a, 1b, 1c) are derived by taking measurements at individual meteorological stations and mathematically interpolating (estimating) values between known data points. The dots in Figure 1d show data values for individual stations. Interpolation procedures can cause aberrant values in data-sparse regions.

These are experimental products from the High Plains Regional Climate Center.

On the Web:

For these and other temperature maps, visit:
http://www.hprcc.unl.edu/maps/current/

For information on temperature and precipitation trends, visit:
http://www.cpc.ncep.noaa.gov/trndtext.shtml

Figure 1a. Water year '07–'08 (through March 19, 2008) average temperature.

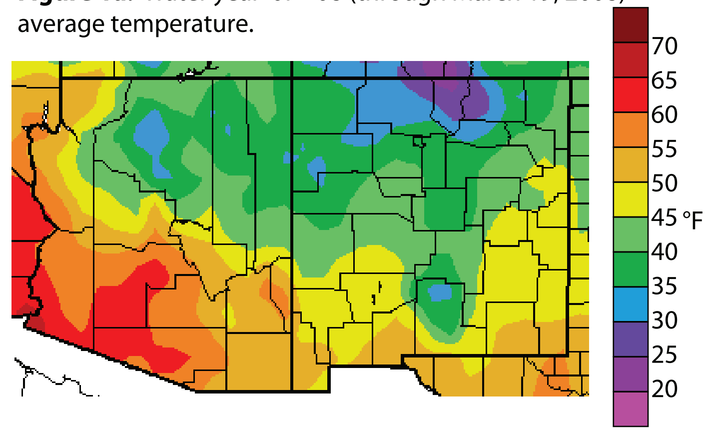


Figure 1b. Water year '07–'08 (through March 19, 2008) departure from average temperature.

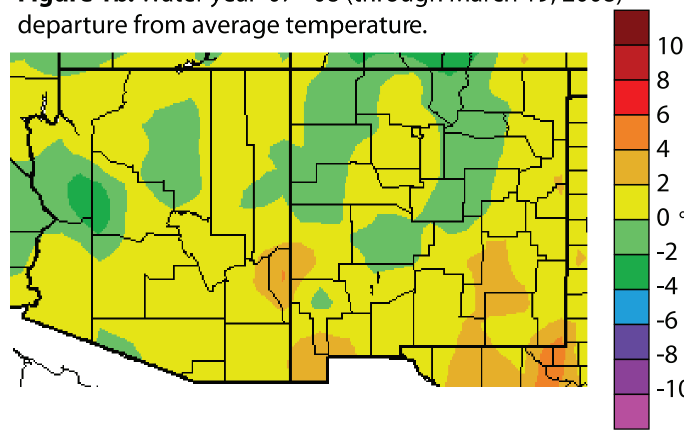


Figure 1c. Previous 30 days (February 19–March 19, 2008) departure from average temperature (interpolated).

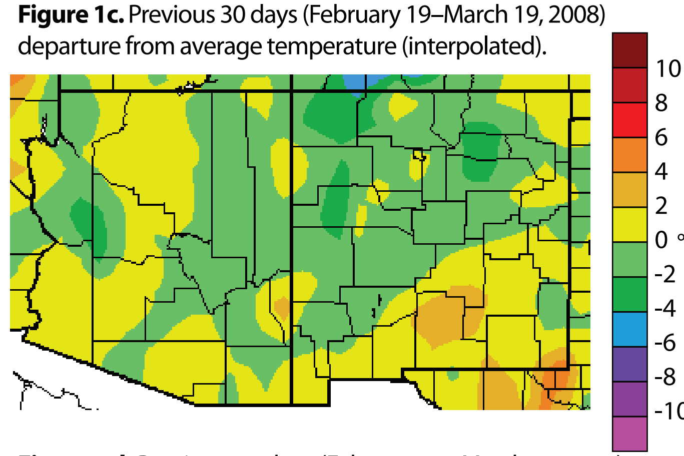
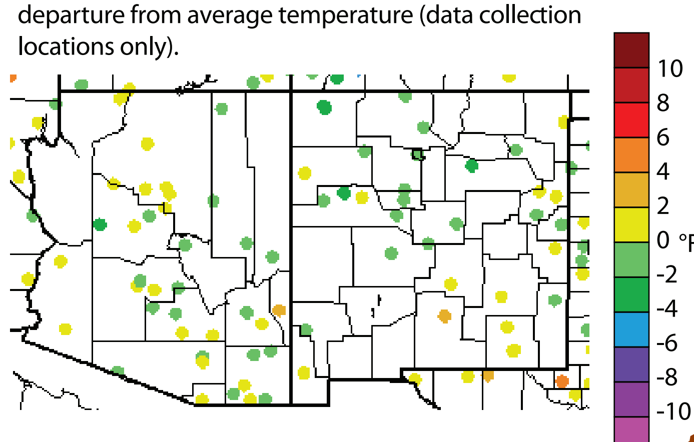


Figure 1d. Previous 30 days (February 19–March 19, 2008) departure from average temperature (data collection locations only).



Precipitation (through 3/19/08)

Source: High Plains Regional Climate Center

Precipitation for the water year has dropped to 90 percent or less of average across the southeastern two-thirds of New Mexico and the southeastern third of Arizona (Figures 2a–b). This is due to the path of the winter storms, which have crossed the two states from southwest to northeast, coming into Arizona just north of Yuma. Few storms have penetrated into southern New Mexico or southeastern Arizona. The northwestern mountains of New Mexico have received 100–150 percent of average winter precipitation, as has west central Arizona and the Colorado Plateau in northern Arizona. Most of the precipitation fell in the earlier part of winter, as the precipitation in the past thirty days has been well below average across most of both states, measuring less than 25 percent of average in the southern half of each state (Figures 2c–d). Notable exceptions during the past thirty days include the northeast plateau of Arizona, the Navajo Nation, some high elevation areas in north central New Mexico, and the northeast corner of New Mexico, which received more than 300 percent of average precipitation. The dry conditions of the past month represent the more typical La Niña pattern; however, the continued cold conditions in the northern half of both states is helping to sustain snow pack and prevent an early snowmelt.

Notes:

The water year begins on October 1 and ends on September 30 of the following year. As of October 1, 2007, we are in the 2008 water year. The water year is a more hydrologically sound measure of climate and hydrological activity than is the standard calendar year.

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.

The continuous color maps (Figures 2a, 2c) are derived by taking measurements at individual meteorological stations and mathematically interpolating (estimating) values between known data points. Interpolation procedures can cause aberrant values in data-sparse regions.

The dots in Figures 2b and 2d show data values for individual meteorological stations.

On the Web:

For these and other precipitation maps, visit:
http://www.hprcc.unl.edu/maps/current/

For National Climatic Data Center monthly precipitation and drought reports for Arizona, New Mexico, and the Southwest region, visit: http://lwf.ncdc.noaa.gov/oa/climate/research/2003/perspectives.html#monthly

Figure 2a. Water year '07–'08 (through March 19, 2008) percent of average precipitation (interpolated).

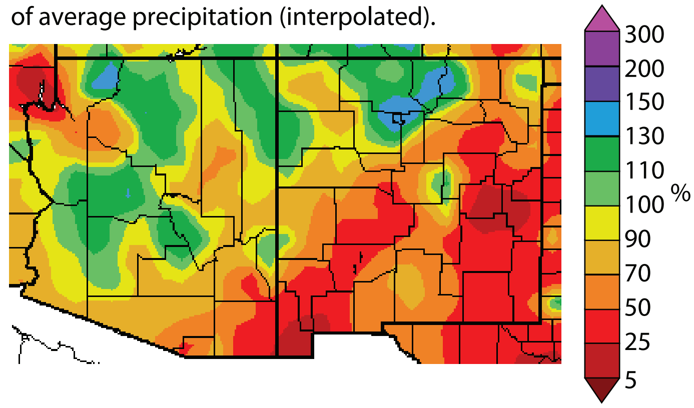


Figure 2b. Water year '07–'08 (through March 19, 2008) percent of average precipitation (data collection locations only).

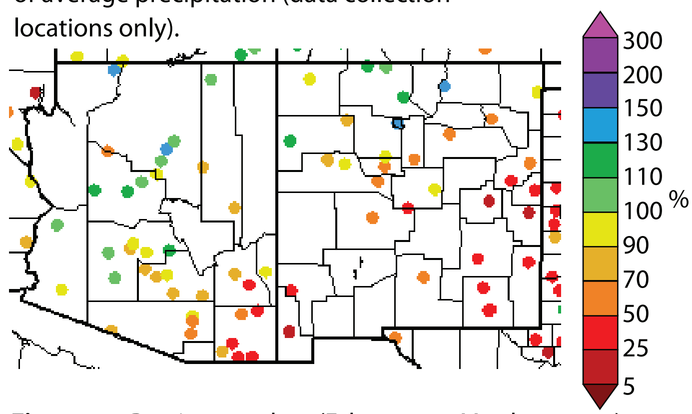


Figure 2c. Previous 30 days (February 19–March 19, 2008) percent of average precipitation (interpolated).

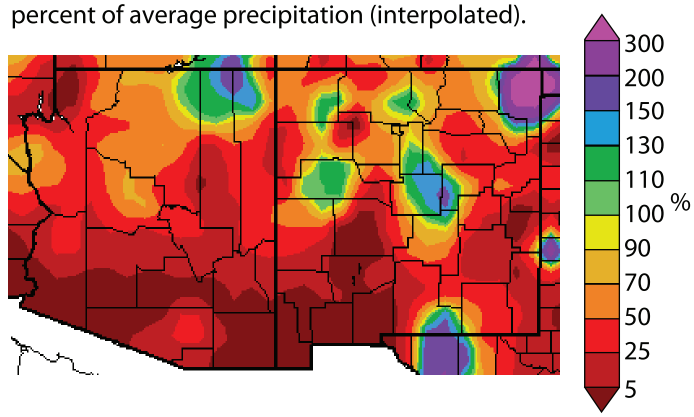
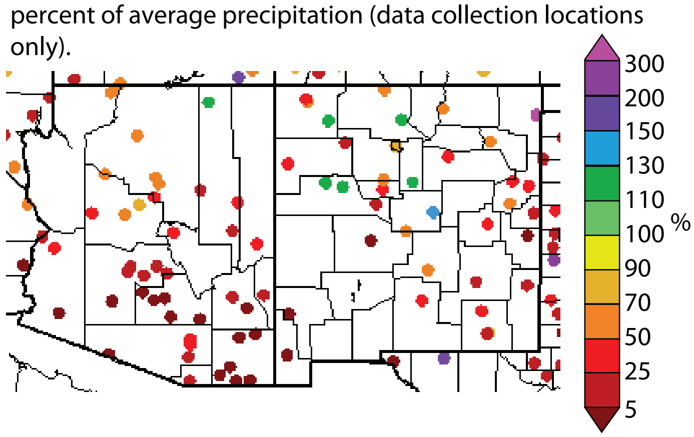


Figure 2d. Previous 30 days (February 19–March 19, 2008) percent of average precipitation (data collection locations only).



U.S. Drought Monitor

(released 3/20/08)

Sources: U.S. Department of Agriculture, National Drought Mitigation Center, National Oceanic and Atmospheric Administration

The weekly U.S. Drought Monitor map depicts increasing drought intensity across eastern New Mexico, where typical dry La Niña conditions have occurred this winter (Figure 3). In New Mexico, the area in moderate drought status increased 20 percent in the last month; Arizona drought status was largely unchanged, with small decreases in the extent of drought along the Arizona-Utah border.

Looking toward the typically dry part of the seasonal cycle, the Southwest Coordination Center predicts above-normal fire potential across most of eastern and southern New Mexico. As abundant grasses are subjected to seasonally dry windy days, the eastern and southern portions of Arizona and New Mexico are likely to see increased potential for significant human-caused fire activity.

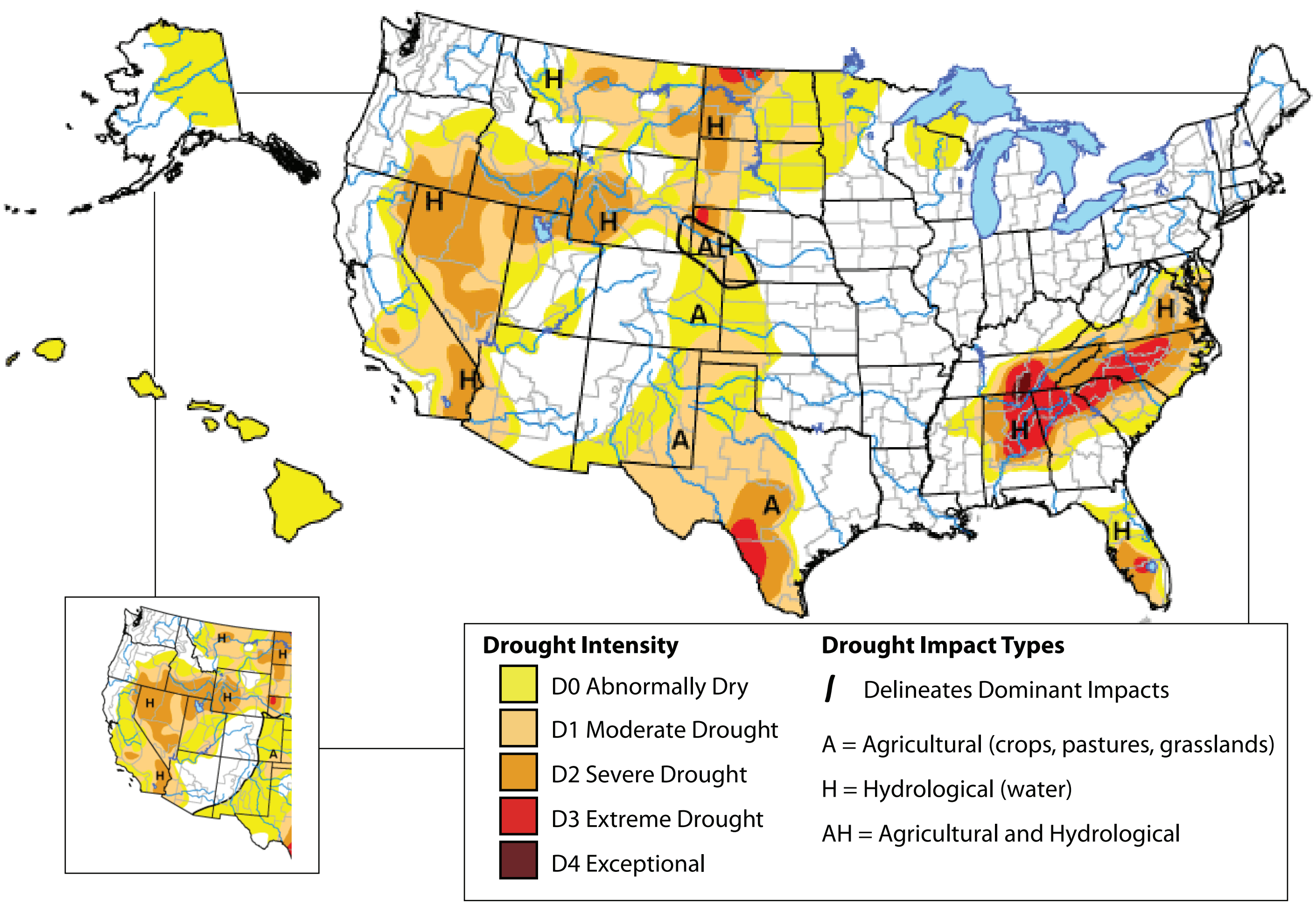
In drought-related news, the Arizona Geological Survey is about to publish the first detailed maps of cracks in the Earth caused by groundwater pumping (*Tucson Citizen*, March 20). The cracks, which can damage buried pipes and homes, do not occur naturally but in dry basins where the groundwater table has dropped hundreds of feet in just tens of years. The cracks have only been found in the desert Southwest.

Notes:

The U.S. Drought Monitor 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 month'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 the several agencies; the author of this monitor is Mark Svoboda, NDMC.

Figure 3. Drought Monitor released March 20, 2008 (full size) and February 21, 2008 (inset, lower left).



On the Web:

The best way to monitor drought trends is to pay a weekly visit to the U.S. Drought Monitor website: http://www.drought.unl.edu/dm/monitor.html

Arizona Drought Status

(through 1/31/08)

Source: Arizona Department of Water Resources

Arizona drought status maps in the February 2008 *Southwest Climate Outlook* were drafts and not the final maps released by the Arizona Department of Water Resources. This month's description of drought status reflects changes made in drought status over the past month that may not be consistent with last months maps.

Above-average precipitation in Arizona over the past thirty days has resulted in the further diminishing of short-term drought conditions across much of the state (Figure 4a). Overall, the short-term drought status in eleven of fourteen watersheds improved one drought-status category compared to last month. Short-term drought status was left unchanged in only the upper and lower Colorado River and lower Gila River watersheds. Currently, short-term designations for all watersheds in the state are abnormally dry or normal.

Long-term drought status is assessed quarterly, and was last updated in January (Figure 4b). Thus, current long-term drought status remains unchanged from last month, and will be updated in the April edition of the Southwest Climate Outlook. Given the favorable conditions this winter, long-term drought condition status is likely to improve.

Figure 4a. Arizona short-term drought status for February 2008.

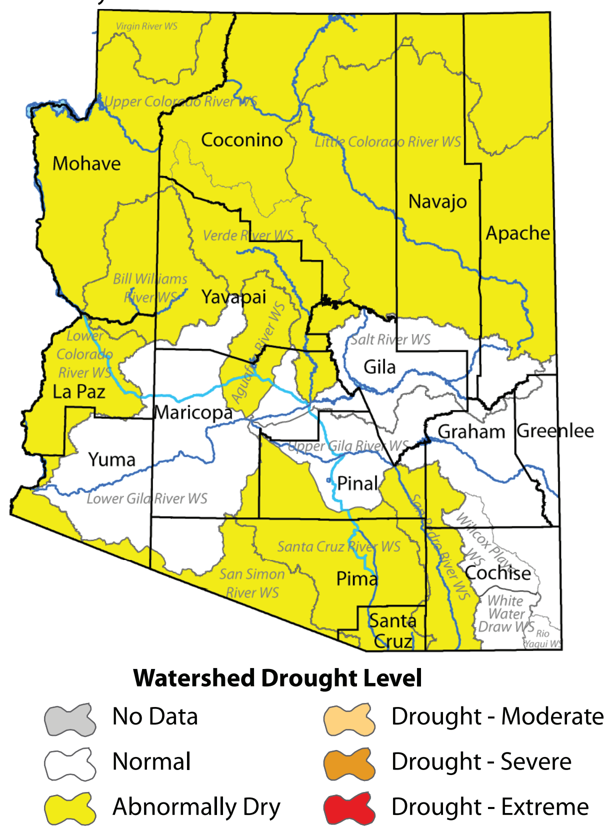
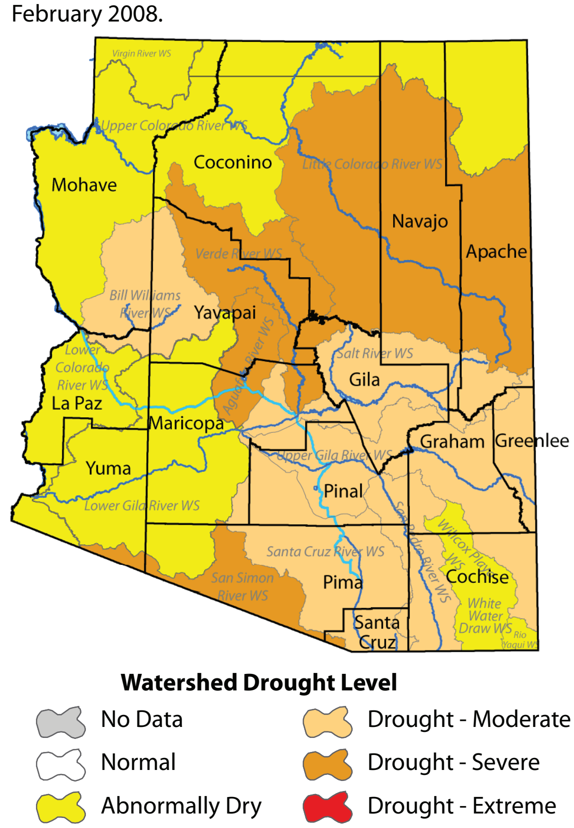


Figure 4b. Arizona long-term drought status for February 2008.



Notes:

The Arizona drought status maps are produced monthly by the Arizona Drought Preparedness Plan Monitoring Technical Committee. The maps are based on expert assessment of variables including, but not limited to, precipitation, drought indices, reservoir levels, and streamflow.

Figure 4a shows short-term or meteorological drought conditions. Meteorological drought is defined usually on the basis of the degree of dryness (in comparison to some "normal" or average amount) over a relatively short duration (e.g., months). Figure 4b refers to long-term drought, sometimes known as hydrological drought. Hydrological drought is associated with the effects of relatively long periods of precipitation shortfall (e.g., many months to years) on water supplies (i.e., streamflow, reservoir and lake levels, and groundwater). These maps are delineated by river basins (wavy gray lines) and counties (straight black lines).

On the Web:

For the most current Arizona drought status maps, visit:
http://www.azwater.gov/dwr/drought/DroughtStatus.html

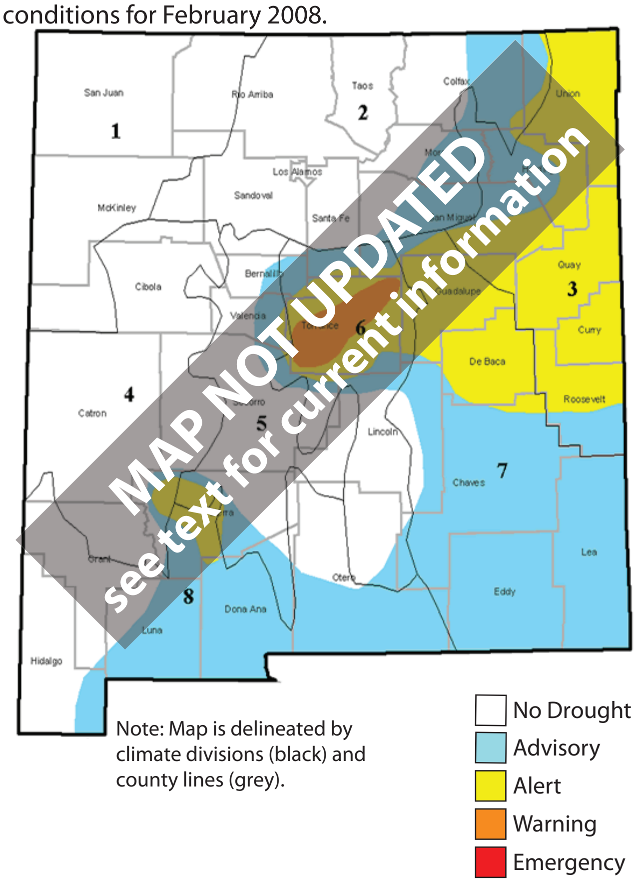
New Mexico Drought Status

(through 1/31/08)

Source: New Mexico State Drought Monitoring Committee

For the most recent report and analysis from the New Mexico Drought Monitoring Work Group, visit http://www.nmdrought.state.nm.us/MonitoringWorkGroup/2008-02-15-dmwg-rpt.pdf. The next New Mexico drought report will appear in the April issue of the Southwest Climate Outlook, after the work group's next meeting.

Figure 5. Short-term drought map based on meteorological conditions for February 2008.



Notes:

The New Mexico drought status map is produced monthly by the New Mexico State Drought Monitoring Committee. When near-normal conditions exist, they are updated quarterly. The map is based on expert assessment of variables including, but not limited to, precipitation, drought indices, reservoir levels, and streamflow.

Figure 5 shows short-term or *meteorological* drought conditions. Meteorological drought is defined usually on the basis of the degree of dryness (in comparison to some "normal" or average amount) over a relatively short duration (e.g., months).

On the Web:

For the most current meteorological drought status map, visit: http://www.srh.noaa.gov/abq/feature/droughtinfo.htm

For the most current hydrological drought status map, visit: http://www.nm.nrcs.usda.gov/snow/drought/drought.html

Arizona Reservoir Levels

(through 2/29/08)

Source: National Water and Climate Center

For the second straight month, storage increased substantially in reservoirs within Arizona's borders (Figure 6). Storage in the Salt River reservoirs increased by more than 200,000 acre-feet during the last month; current levels in these reservoirs are well above last year's levels. Storage in San Carlos Reservoir increased substantially; this reservoir is now at a level higher than any time since 1996. The storage in Lake Mead increased since last month. Lake Powell storage is expected to increase substantially during the spring snowmelt runoff season, which will probably begin in mid-April.

In reservoir and water news, an artificial flood coursed through the Colorado River for sixty hours earlier this month to bolster sandbars that shelter endangered fish (*Salt Lake Tribune*, March 17). The experimental flood, which mimicked pre-Glen Canyon Dam spring floods that redistributed sediment from tributaries, came at the expense of cheap hydropower produced by the dam's turbines.

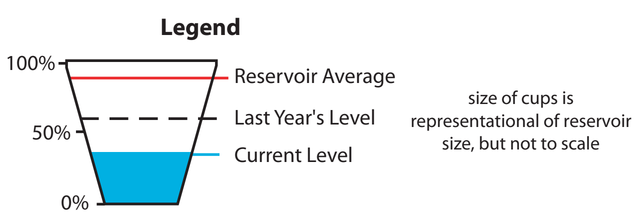
Notes:

The map gives a representation of current storage levels for reservoirs in Arizona. Reservoir locations are numbered within the blue circles on the map, corresponding to the reservoirs listed in the table. The cup next to each reservoir shows the current storage level (blue fill) as a percent of total capacity. Note that while the size of each cup varies with the size of the reservoir, these are representational and not to scale. Each cup also represents last year's storage level (dotted line) and the 1971–2000 reservoir average (red line).

The table details more exactly the current capacity level (listed as a percent of maximum storage). Current and maximum storage levels are given in thousands of acre-feet for each reservoir. One acre-foot is the volume of water sufficient to cover an acre of land to a depth of 1 foot (approximately 325,851 gallons). On average, 1 acre-foot of water is enough to meet the demands of 4 people for a year. The last column of the table list an increase or decrease in storage since last month. A line indicates no change.

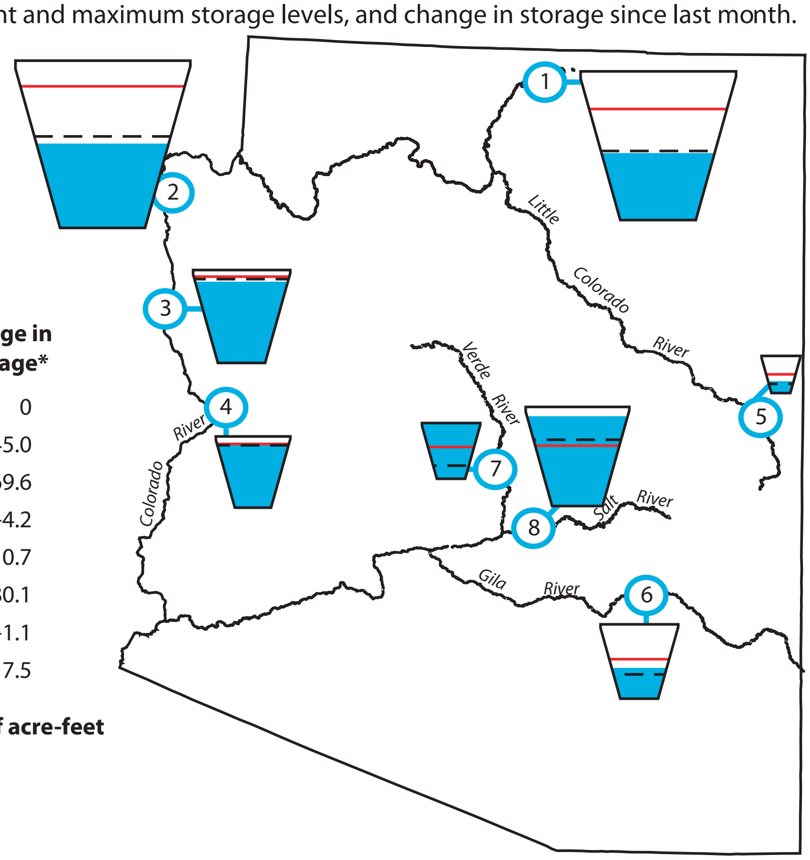
These data are based on reservoir reports updated monthly by the National Water and Climate Center of the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS). For additional information, contact Larry Martinez, NRCS, Larry.Martinez@az.usda.gov.

Figure 6. Arizona reservoir levels for February 2008 as a percent of capacity. The map also depicts the average level and last year's storage for each reservoir. The table also lists current and maximum storage levels, and change in storage since last month.



Reservoir Name	Capacity Level	Current Storage*	Max Storage*	Change in Storage*
1. Lake Powell	45%	10,880.0	24,322.0	0
2. Lake Mead	50%	13,062.0	26,159.0	45.0
3. Lake Mohave	88%	1,593.2	1,810.0	-69.6
4. Lake Havasu	89%	550.8	619.0	-4.2
5. Lyman Reservoir	32%	9.7	30.0	0.7
6. San Carlos	41%	362.2	875.0	80.1
7. Verde River System	98%	281.4	287.4	-1.1
8. Salt River System	90%	1,832.8	2,025.8	217.5

*** thousands of acre-feet**



On the Web:

Portions of the information provided in this figure can be accessed at the NRCS website:
http://www.wcc.nrcs.usda.gov/wsf/reservoir/resv_rpt.html

New Mexico Reservoir Levels

(through 2/29/08)

Source: National Water and Climate Center

New Mexico statewide reservoir storage increased slightly since last month, with the greatest increase at Navajo Reservoir (Figure 7). Since last year, storage has decreased in most of the state's reservoirs; declines centered chiefly in the southern part of the state, which has experienced typical La Niña dryness. There have been notable storage increases since last year at El Vado, Heron, Lake Avalon, and Costilla reservoirs.

In water-related news, New Mexico Governor Bill Richardson signed a bill which allows the state to purchase water rights in the Pecos Valley without buying the underlying land (*New Mexico Business Weekly*, February 27). The new law enables farmers in the Pecos Valley to sell part of their water while keeping their land. The bill improves the ability of New Mexico to meet its Pecos River Compact obligations to provide for the equitable use of the river with Texas.

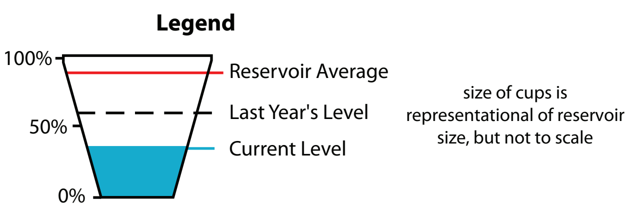
Notes:

The map gives a representation of current storage levels for reservoirs in New Mexico. Reservoir locations are numbered within the blue circles on the map, corresponding to the reservoirs listed in the table. The cup next to each reservoir shows the current storage level (blue fill) as a percent of total capacity. Note that while the size of each cup varies with the size of the reservoir, these are representational and not to scale. Each cup also represents last year's storage level (dotted line) and the 1971–2000 reservoir average (red line).

The table details more exactly the current capacity level (listed as a percent of maximum storage). Current and maximum storage levels are given in thousands of acre-feet for each reservoir. One acre-foot is the volume of water sufficient to cover an acre of land to a depth of 1 foot (approximately 325,851 gallons). On average, 1 acre-foot of water is enough to meet the demands of 4 people for a year. The last column of the table list an increase or decrease in storage since last month. A line indicates no change.

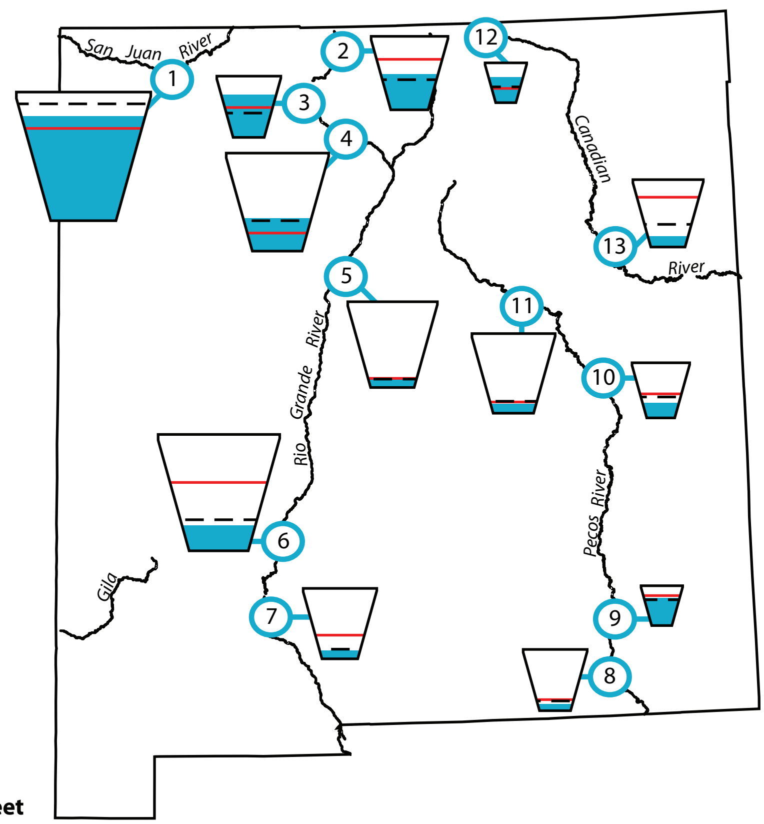
These data are based on reservoir reports updated monthly by the National Water and Climate Center of the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS). For additional information, contact Larry Martinez, NRCS, Larry.Martinez@az.usda.gov.

Figure 7. New Mexico reservoir levels for February 2008 as a percent of capacity. The map also depicts the average level and last year's storage for each reservoir. The table also lists current and maximum storage levels, and change in storage since last month.



Reservoir Name	Capacity Level	Current Storage*	Max Storage*	Change in Storage*
1. Navajo	81%	1,381.1	1,696.0	-75.3
2. Heron	49%	196.1	400.0	0.8
3. El Vado	70%	136.9	195.0	-5.3
4. Abiquiu	33%	183.8	554.5	1.0
5. Cochiti	10%	50.6	491.0	0.4
6. Elephant Butte	22%	482.2	2,195.0	28.5
7. Caballo	12%	39.4	332.0	13.6
8. Brantley	11%	16.5	147.5	2.1
9. Lake Avalon	70%	2.8	4.0	0.4
10. Sumner	27%	28.0	102.0	1.2
11. Santa Rosa	12%	50.8	438.3	0.2
12. Costilla	64%	10.3	16.0	0.5
13. Conchas	16%	41.3	254.2	1.1

*** thousands of acre-feet**



On the Web:

Portions of the information provided in this figure can be accessed at the NRCS website:
http://www.wcc.nrcs.usda.gov/wsf/reservoir/resv_rpt.html

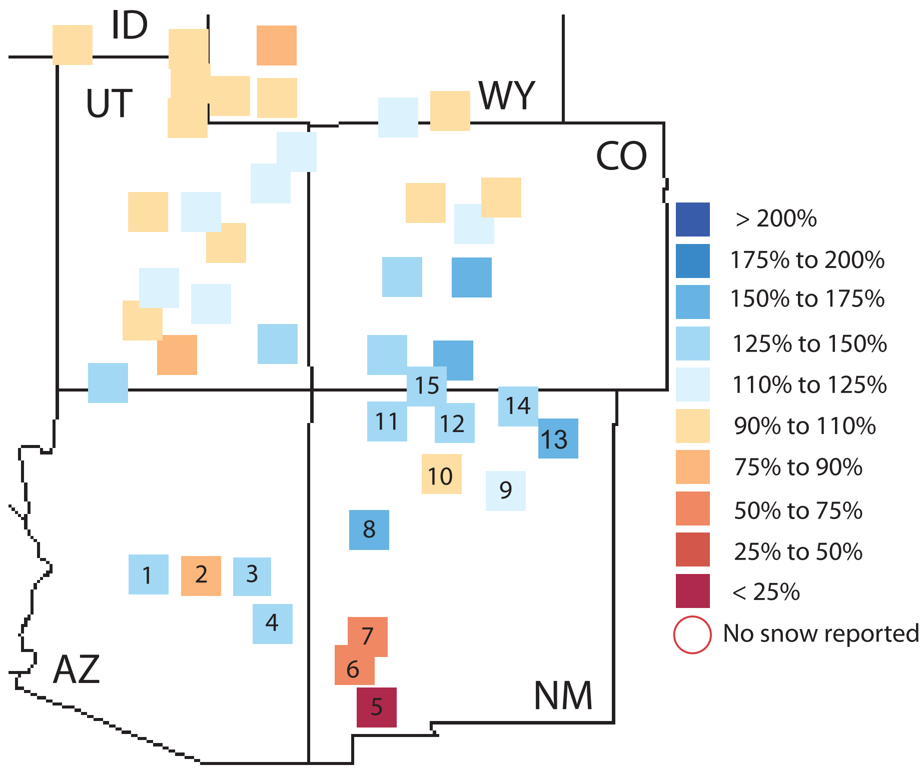
Southwest Snowpack

(updated 3/20/08)

Sources: National Water and Climate Center, Western Regional Climate Center

Snowpack observations at the majority of reporting snow telemetry (SNOTEL) sites in Arizona and New Mexico continue to report above-average Snow Water Content (SWC) (Figure 8). In Arizona, SWC in the Verde and Little Colorado river basins were more than 140 percent of normal, a slight decrease from last month. Along the Mogollon Rim, SWC decreased more than 50 percent from last month to 82 perccent of normal. A strong winter storm with snow and below-average temperatures moved through the region the weekend of March 16 and helped improve SWC values. In New Mexico, SWC continues to be below average—less than 60 percent of normal—in the Mimbres, Gila, and San Francisco basins. In northern New Mexico, SWC is at or well above average for this time of year for all reporting stations, with more than 150 percent of normal SWC in the Cimarron River Basin. John D'Antonio, New Mexico's state engineer, indicated he expected water levels in the upper and middle Rio Grande this spring and summer to be the highest they have been in three decades due to snowmelt (Associated Press, March 21).

Figure 8. Average snow water content (SWC) in percent of average for available monitoring sites as of March 20, 2008.



Arizona Basins
1 Verde River Basin
2 Central Mogollon Rim
3 Little Colorado - Southern Headwaters
4 Salt River Basin

New Mexico Basins
5 Mimbres River Basin
6 San Francisco River Basin
7 Gila River Basin
8 Zuni/Bluewater River Basin
9 Pecos River
10 Jemez River Basin
11 San Miguel, Dolores, Animas, and San Juan River Basins
12 Rio Chama River Basin
13 Cimarron River Basin
14 Sangre de Cristo Mountain Range Basin
15 San Juan River Headwaters

On the Web:

For color maps of SNOTEL basin snow water content, visit: http://www.wrcc.dri.edu/snotelanom/basinswe.html

For a numeric version of the map, visit: http://www.wrcc.dri.edu/snotelanom/basinswen.html

For a list of river basin snow water content and precipitation, visit: http://www.wrcc.dri.edu/snotelanom/snotelbasin

Notes:

Snowpack telemetry (SNOTEL) sites are automated stations that measure snowpack depth, temperature, precipitation, soil moisture content, and soil saturation. A parameter called snow water content (SWC) or snow water equivalent (SWE) is calculated from this information. SWC refers to the depth of water that would result by melting the snowpack at the SNOTEL site and is important in estimating runoff and streamflow. It depends mainly on the density of the snow. Given two snow samples of the same depth, heavy, wet snow will yield a greater SWC than light, powdery snow.

Figure 8 shows the SWC for selected river basins, based on SNOTEL sites in or near the basins, compared to the 1971–2000 average values. The number of SNOTEL sites varies by basin. Basins with more than one site are represented as an average of the sites. Individual sites do not always report data due to lack of snow or instrument error.

Temperature Outlook
(April–September 2008)
Source: NOAA Climate Prediction Center (CPC)

Forecasts for the Southwest are predicting increased chances of above-average temperatures for most of the region through September 2008 (Figures 9a–d). The chance of above-average temperatures through most of Arizona and New Mexico exceeds 50 percent relative to average or below-average temperatures through June. These chances remain above 50 percent for all of Arizona through September; for much of New Mexico, the chance for above-normal temperatures drops to above 40 percent. These forecasts are based primarily on the expectation that long-term trends in above-average temperatures will persist through the spring and into summer.

Notes:

These outlooks predict the likelihood (chance) of above-average, average, and below-average temperature, but not the magnitude of such variation. The numbers on the maps do not refer to degrees of temperature.

The NOAA-CPC outlooks are a 3-category forecast. As a starting point, the 1971–2000 climate record is divided into 3 categories, each with a 33.3 percent chance of occurring (i.e., equal chances, EC). The forecast indicates the likelihood of one of the extremes—above-average (A) or below-average (B)—with a corresponding adjustment to the other extreme category; the "average" category is preserved at 33.3 likelihood, unless the forecast is very strong.

Thus, using the NOAA-CPC temperature outlook, areas with light brown shading display a 33.3–39.9 percent chance of above-average, a 33.3 percent chance of average, and a 26.7–33.3 percent chance of below-average temperature. A shade darker brown indicates a 40.0–50.0 percent chance of above-average, a 33.3 percent chance of average, and a 16.7–26.6 percent chance of below-average temperature, and so on.

Equal Chances (EC) indicates areas where the reliability (i.e., 'skill') of the forecast is poor; areas labeled EC suggest an equal likelihood of above-average, average, and below-average conditions, as a "default option" when forecast skill is poor.

Figure 9a. Long-lead national temperature forecast for April–June 2008.

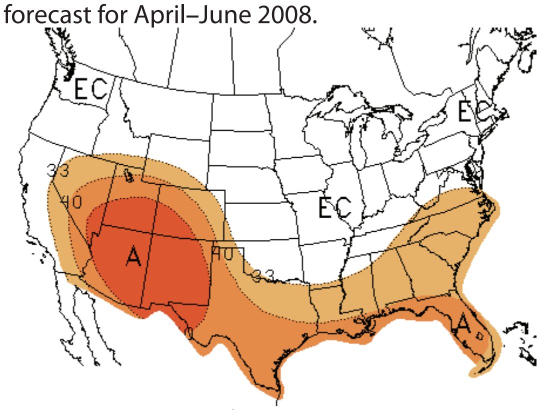


Figure 9b. Long-lead national temperature forecast for May–July 2008.

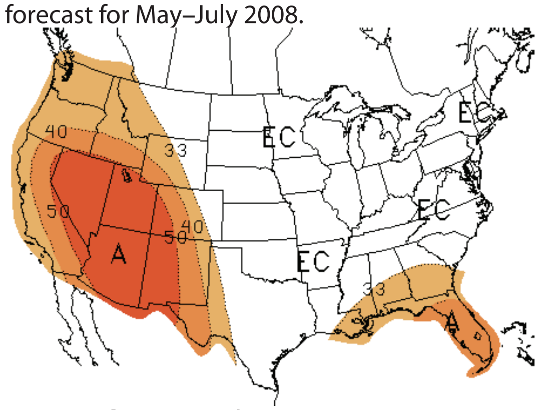


Figure 9c. Long-lead national temperature forecast for June–August 2008.

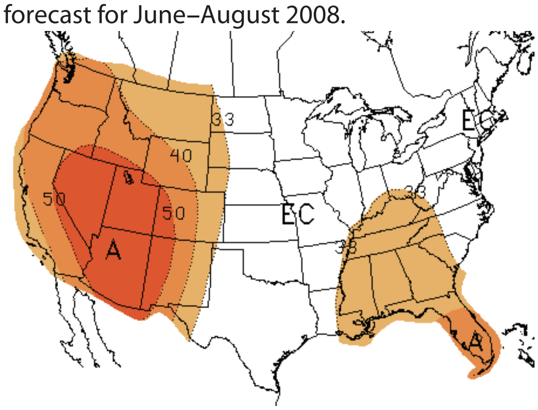
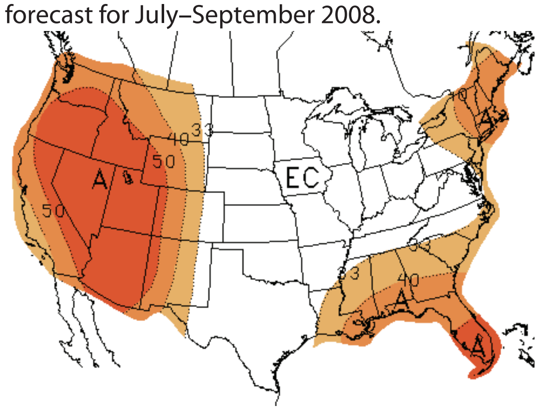


Figure 9d. Long-lead national temperature forecast for July–September 2008.



A= Above

- 50.0–59.9%
- 40.0–49.9%
- 33.3–39.9%

EC= Equal chances. No forecasted anomalies.

On the Web:

For more information on CPC forecasts, visit:
http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/churchill.html
(note that this website has many graphics and may load slowly on your computer)

For IRI forecasts, visit:
http://iri.columbia.edu/climate/forecast/net_asmt/

Precipitation Outlook
(April–September 2008)
Source: NOAA Climate Prediction Center (CPC)

Seasonal forecasts call for increased chances of below-average precipitation through the spring for all of Arizona and New Mexico (Figure 10a). A greater than 33 percent chance of below-average precipitation is forecasted across the Southwest for the April–June period, with chances for below-average precipitation higher (greater than 40 percent) across much of New Mexico for this period. These forecasts are based on the expectation that the current La Niña event will persist through the spring and bring typical La Niña impacts, including below-average precipitation, to the southwestern United States. The forecast for below-average precipitation shifts northward by the May–July period due to diminishing La Niña impacts and increased forecast uncertainty (Figure 10b–d).

Notes:
These outlooks predict the likelihood (chance) of above-average, average, and below-average precipitation, but not the magnitude of such variation. The numbers on the maps do not refer to inches of precipitation.

The NOAA-CPC outlooks are a 3-category forecast. As a starting point, the 1971–2000 climate record is divided into 3 categories, each with a 33.3 percent chance of occurring (i.e., equal chances, EC). The forecast indicates the likelihood of one of the extremes—above-average (A) or below-average (B)—with a corresponding adjustment to the other extreme category; the "average" category is preserved at 33.3 likelihood, unless the forecast is very strong.

Thus, using the NOAA-CPC precipitation outlook, areas with light green shading display a 33.3–39.9 percent chance of above-average, a 33.3 percent chance of average, and a 26.7–33.3 percent chance of below-average precipitation. A shade darker green indicates a 40.0–50.0 percent chance of above-average, a 33.3 percent chance of average, and a 16.7–26.6 percent chance of below-average precipitation, and so on.

Equal Chances (EC) indicates areas where the reliability (i.e., 'skill') of the forecast is poor; areas labeled EC suggest an equal likelihood of above-average, average, and below-average conditions, as a "default option" when forecast skill is poor.

Figure 10a. Long-lead national precipitation forecast for April–June 2008.

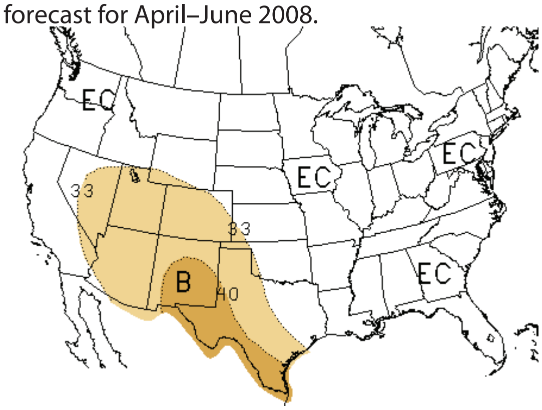


Figure 10b. Long-lead national precipitation forecast for May–July 2008.

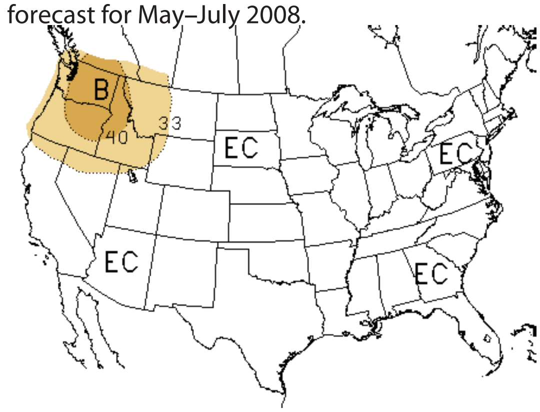


Figure 10c. Long-lead national precipitation forecast for June–August 2008.

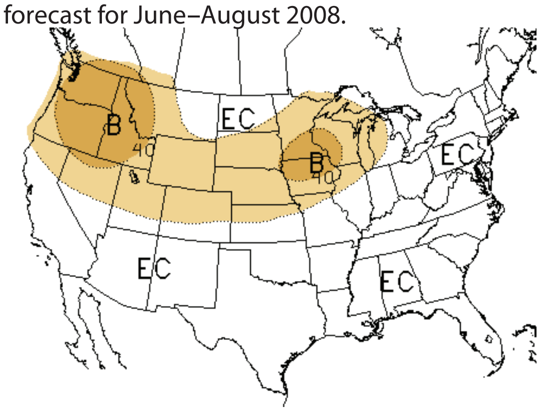
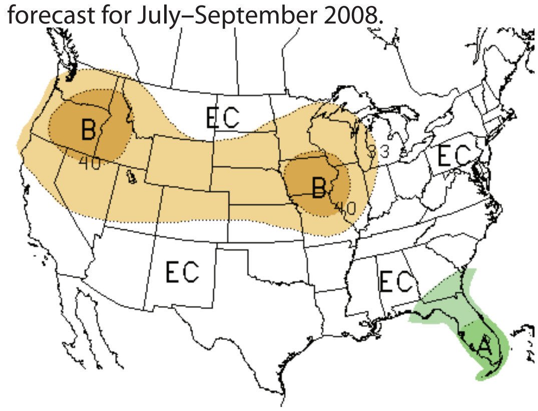


Figure 10d. Long-lead national precipitation forecast for July–September 2008.



B= Below: 33.3–39.9%, 40.0–49.9%, 50.0–59.9%

A=Above: 40.0–49.9%, 33.3–39.9%

EC= Equal chances. No forecasted anomalies.

On the Web:
For more information on CPC forecasts, visit:
http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/churchill.html
(note that this website has many graphics and may load slowly on your computer)

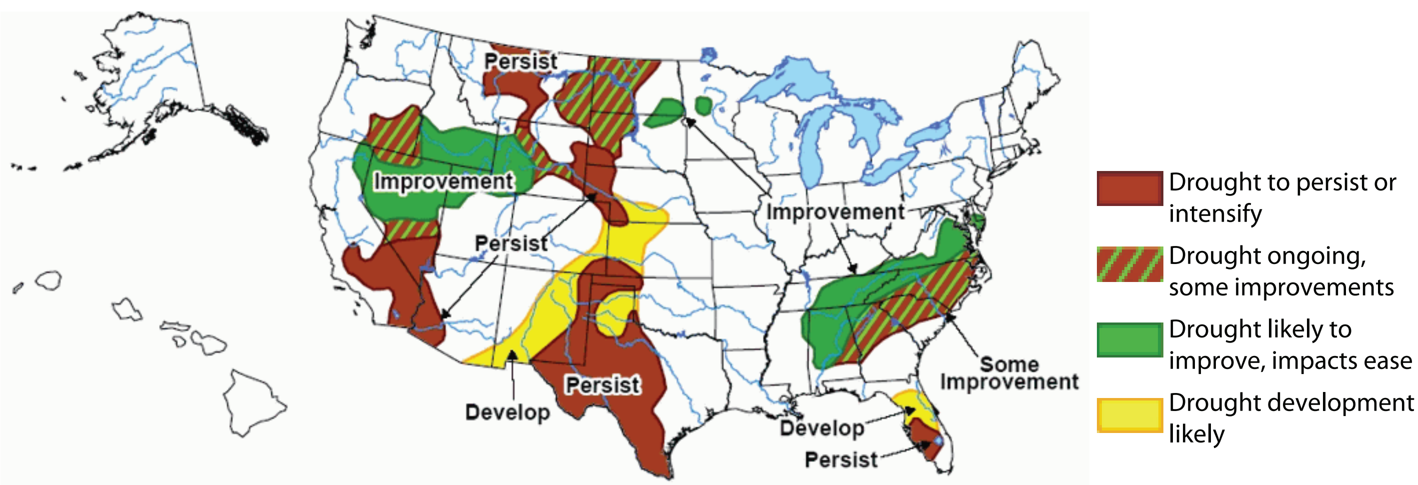
For IRI forecasts, visit:
http://iri.columbia.edu/climate/forecast/net_asmt/

Seasonal Drought Outlook
(through June 2008)
Source: NOAA Climate Prediction Center (CPC)

The latest NOAA Seasonal Drought Outlook predicts that drought will continue to improve across portions of the northern Great Basin and northern Rockies while much of New Mexico and western Kansas will see drought conditions develop (Figure 11). Florida is also expected to see drought conditions expand across middle portions of the state while other southeastern states experience improving conditions due to above-average precipitation. The current outlook is based on precipitation and temperature patterns typical during moderate to strong La Niña events like the strong event currently underway. La Niña events typically bring below-average precipitation to the southern tier states from Arizona to Florida. This is reflected in the seasonal drought outlook where drought conditions are expected to persist in western Arizona, Texas, and Florida and develop across much of New Mexico. Seasonal precipitation forecasts continue to depict an increased chance of below-average precipitation across this region into the early spring (see Figure 10a).

Notes:
The delineated areas in the Seasonal Drought Outlook (Figure 11) are defined subjectively and are based on expert assessment of numerous indicators, including outputs of short- and long-term forecasting models.

Figure 11. Seasonal drought outlook through June 2008 (released March 20, 2008).

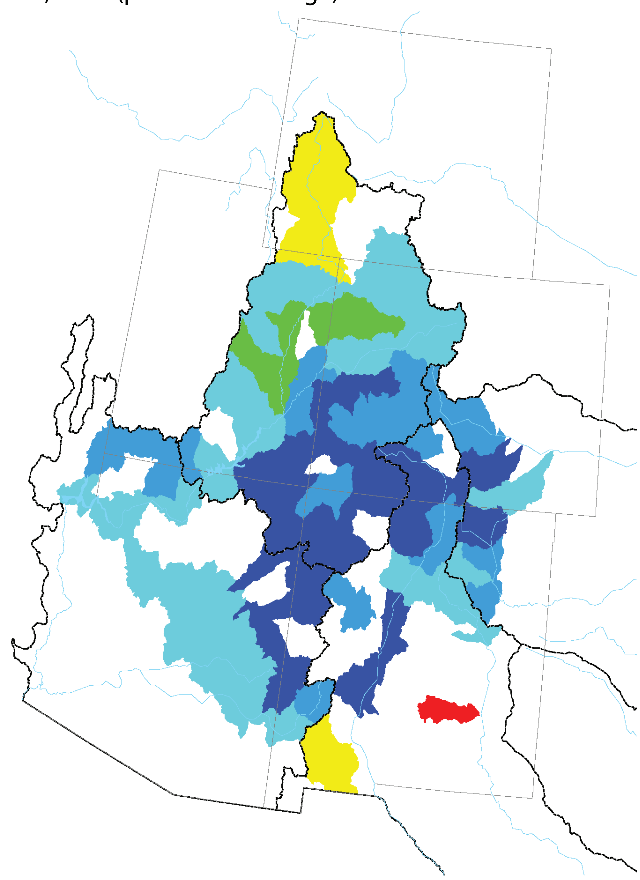


On the Web:
For more information, visit:
http://www.drought.noaa.gov/

Streamflow Forecast
(for spring and summer)
Source: National Water and Climate Center

Changes from last month in forecasted percent-of-average spring and summer streamflow vary across the region, but forecasts remain overwhelmingly positive (Figure 12). With the exception of southwestern New Mexico, snowpack remains near or above normal at all reporting snow telemetry (SNOTEL) locations in the region. Forecasted streamflow in the Verde and Salt River basins in Arizona remains above 100 percent of normal, but has decreased between 20 and 50 percent from last month. Forecasted streamflow in upper Colorado River basins has remained the same or improved slightly over the last month. Forecasts for streamflow in the Four Corners area and along the Rio Grande in New Mexico continue to be near or above 150 percent of normal. The only forecast of below-average streamflow in the region is in southwestern New Mexico.

Figure 12. Spring and summer streamflow forecast as of March 1, 2008 (percent of average).



- much above average (151–180)
- above average (130-150)
- slightly above average (110-129)
- near average (90-109)
- slightly below average (70-89)
- below average (50-69)
- much below average (<50)
- no forecast

Notes:
The forecast information provided in Figure 12 is updated monthly by the National Water and Climate Center, part of the U.S. Department of Agriculture's Natural Resources Conservation Service. Unless otherwise specified, all streamflow forecasts are for streamflow volumes that would occur naturally without any upstream influences, such as reservoirs and diversions. The USDA-NRCS only produces streamflow forecasts for Arizona between January and April, and for New Mexico between January and May.

The NWCC provides a range of forecasts expressed in terms of percent of average streamflow for various statistical exceedance levels. The streamflow forecast presented here is for the 50 percent exceedance level, and is referred to as the most probable streamflow. This means there is at least a 50 percent chance that streamflow will occur at the percent of average shown in Figure 12.

On the Web:
For state river basin streamflow probability charts, visit:
http://www.wcc.nrcs.usda.gov/cgibin/strm_cht.pl

For information on interpreting streamflow forecasts, visit:
http://www.wcc.nrcs.usda.gov/factpub/intrpret.html

For western U.S. water supply outlooks, visit:
http://www.wcc.nrcs.usda.gov/water/quantity/westwide.html

El Niño Status and Forecast

Sources: NOAA Climate Prediction Center (CPC), International Research Institute for Climate and Society (IRI)

The La Niña event of 2007–08 has been running strong across the equatorial Pacific Ocean this past month. The Southern Oscillation Index (SOI) jumped from 1.9 in January to 2.7 in February, indicating a strong atmospheric response to below-average sea surface temperatures (SSTs) across the Pacific Ocean (Figure 13a). The IRI reports that many other oceanic and atmospheric metrics are reinforcing that the current conditions reflect a strong La Niña event. SSTs are up to 3 degrees Celsius below average near the International Date Line, and strong easterly wind anomalies persisted along the equator again this month, helping to reinforce the cold SST pattern. Some warming in SSTs has occurred again this month in the far eastern Pacific Ocean along the coast of South America. This appears to be related to some weak westerly wind anomalies originating from the coldest SSTs in the central Pacific near the International Date Line. It is not clear whether this warming in the eastern Pacific Ocean suggests that the current event is weakening. IRI notes that all other metrics indicate that La Niña conditions are strong and persistent across the rest of the Pacific basin.

El Niño Southern Oscillation (ENSO) forecasts produced by the NOAA-CPC and IRI both project that there is a high likelihood that La Niña conditions will continue to persist through the remainder of the spring into early summer (Figure 13b). The strength of the current event suggests a slow return to neutral conditions by mid-summer. Forecasts by IRI indicate an 85 percent chance of La Niña conditions persisting through March–May. This chance falls to 40 percent by the July–September season, when it is even with a 40 percent chance of neutral conditions returning. Seasonal precipitation forecasts for the Southwest continue to project increased chances of below-average precipitation through the spring.

Notes:

Figure 13a shows the standardized three month running average values of the Southern Oscillation Index (SOI) from January 1980 through February 2008. The SOI measures the atmospheric response to SST changes across the Pacific Ocean Basin. The SOI is strongly associated with climate effects in the Southwest. Values greater than 0.5 represent La Niña conditions, which are frequently associated with dry winters and sometimes with wet summers. Values less than -0.5 represent El Niño conditions, which are often associated with wet winters.

Figure 13b shows the International Research Institute for Climate and Society (IRI) probabilistic El Niño-Southern Oscillation (ENSO) forecast for overlapping three month seasons. The forecast expresses the probabilities (chances) of the occurrence of three ocean conditions in the ENSO-sensitive Niño 3.4 region, as follows: El Niño, defined as the warmest 25 percent of Niño 3.4 sea-surface temperatures (SSTs) during the three month period in question; La Niña conditions, the coolest 25 percent of Niño 3.4 SSTs; and neutral conditions where SSTs fall within the remaining 50 percent of observations. The IRI probabilistic ENSO forecast is a subjective assessment of current model forecasts of Niño 3.4 SSTs that are made monthly. The forecast takes into account the indications of the individual forecast models (including expert knowledge of model skill), an average of the models, and other factors.

Figure 13a. The standardized values of the Southern Oscillation Index from January 1980–February 2008. La Niña/El Niño occurs when values are greater than 0.5 (blue) or less than -0.5 (red) respectively. Values between these thresholds are relatively neutral (green).

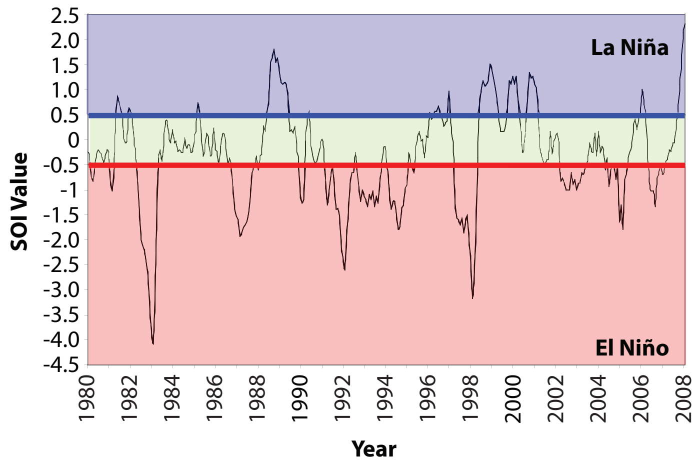
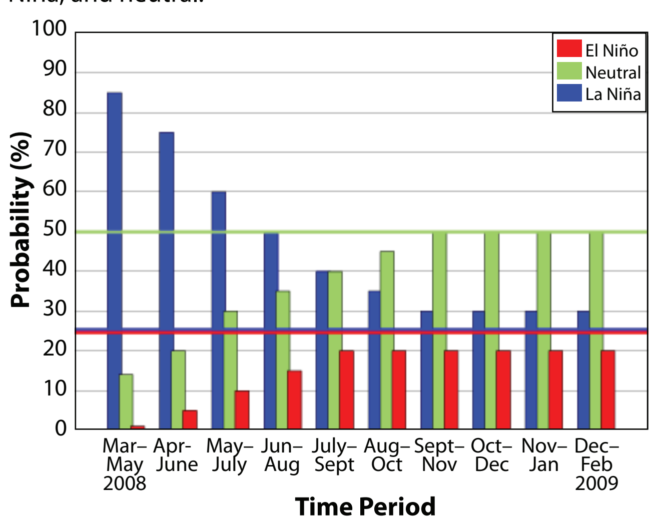


Figure 13b. IRI probabilistic ENSO forecast for El Niño 3.4 monitoring region (released March 20, 2008). Colored lines represent average historical probability of El Niño, La Niña, and neutral.



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 more information about El Niño and to access graphics similar to the figures on this page, visit:
http://iri.columbia.edu/climate/ENSO/

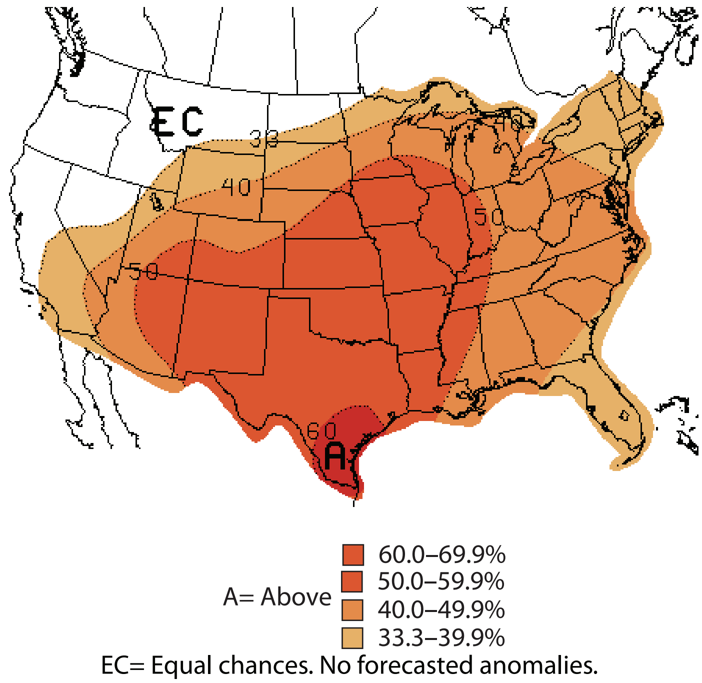
Temperature Verification

(December 2007–February 2008)

Source: NOAA Climate Prediction Center (CPC)

The NOAA-CPC seasonal temperature outlook for December 2007–February 2008 predicted increased chances of above-average temperatures for most of the United States, including probabilities of above-average temperature (greater than 50 percent) throughout the Southwest (Figure 14a). These predictions were based on a combination of long-term trends and expected effects associated with a moderate to strong La Niña episode in the Pacific Ocean. Temperatures generally did not follow this pattern in Arizona and New Mexico, with slightly below-average observations across much of the region. An unusually persistent trough in the mid-latitude jet stream brought unsettled and cool weather to the Southwest through the winter season. Seasonal forecasts expected conditions more typical of La Nina events, such as a dominant ridge of high pressure across the Southwest and accompanying warm and dry conditions. These typical La Nina conditions were present across other regions, including Texas and Florida where precipitation has been below-average throughout the winter (Figure 14b).

Figure 14a. Long-lead U.S. temperature forecast for December 2007–February 2008 (issued November 2007).



Notes:

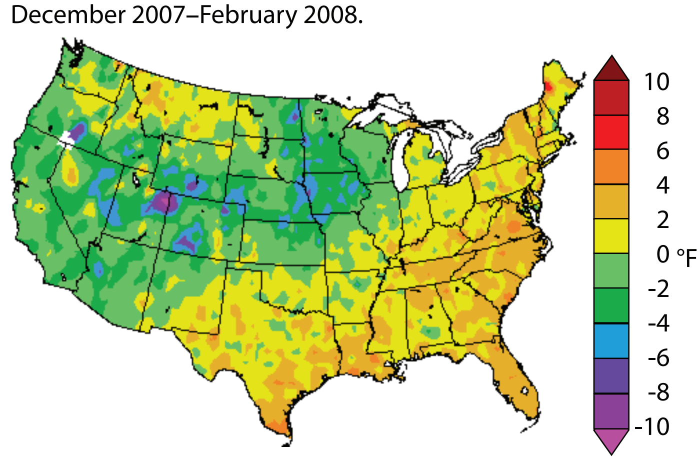
Figure 14a shows the NOAA Climate Prediction Center (CPC) temperature outlook for the months December 2007–February 2008. This forecast was made in November 2007.

The outlook predicts the likelihood (chance) of above-average, average, and below-average temperature, but not the magnitude of such variation. The numbers on the maps do not refer to degrees of temperature.

Using past climate as a guide to average conditions and dividing the past record into 3 categories, there is a 33.3 percent chance of above-average, a 33.3 percent chance of average, and a 33.3 percent chance of below-average temperature. Thus, using the NOAA CPC likelihood forecast, in areas with light brown shading there is a 33.3–39.9 percent chance of above-average, a 33.3 percent chance of average, and a 26.7–33.3 percent chance of below-average precipitation. Equal Chances (EC) indicates areas where reliability (i.e., the skill) of the forecast is poor and no prediction is offered.

Figure 14b shows the observed departure of temperature (degrees F) from the average for the December 2007–February 2008 period. Care should be exercised when comparing the forecast (probability) map with the observed temperature maps. The temperature departures do not represent probability classes as in the forecast maps, so they are not strictly comparable. They do provide us with some idea of how well the forecast performed. In all of the figures on this page, the term average refers to the 1971–2000 average. This practice is standard in the field of climatology.

Figure 14b. Average temperature departure (in degrees F) for December 2007–February 2008.



On the Web:

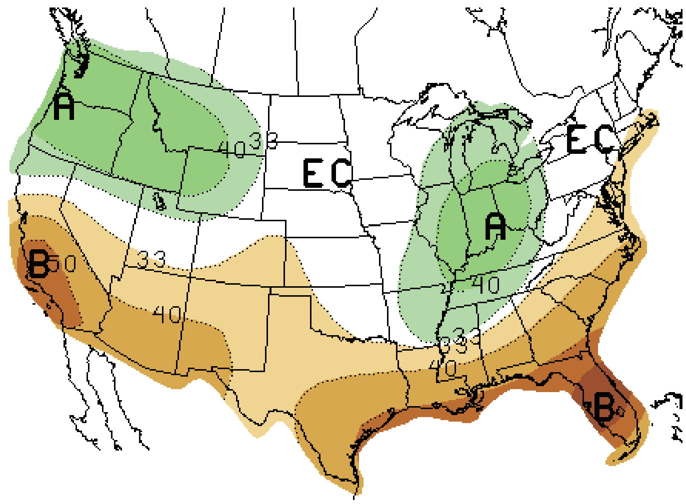
For more information on CPC forecasts, visit:
http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/churchill.html

Precipitation Verification
(December 2007–February 2008)

Source: NOAA Climate Prediction Center (CPC)

The NOAA-CPC seasonal precipitation outlook for December 2007–February 2008 predicted increased probabilities of below-average precipitation in the Southwest, central and southern California, and the central and southern Great Plains (Figure 15a). The outlook also predicted increased probabilities of above-average precipitation for the Pacific Northwest and Northern Rockies. The overall spatial pattern of observed precipitation was largely incorrect with respect to the outlook for the Southwest (Figure 15b). Much of Arizona received precipitation that was between 110 and 200 percent of normal. However, a large part of New Mexico, with the exception of the northwest corner of the state, received precipitation that was average to slightly below-average. Although unusual for moderate La Niña events, a storm track has persisted through this winter, bringing multiple wet and cold storms through Arizona. In contrast with the seasonal precipitation forecasts, this persistent jet stream pattern also has left parts of the Northwest and northern Great Plains with below-average precipitation. Dry conditions expected with La Niña events have developed across southern states from New Mexico to Florida, as projected in the December–February forecast.

Figure 15a. Long-lead U.S. precipitation forecast for December 2007–February 2008 (issued November 2007).



A= Above
- 40.0–49.9%
- 33.3–39.9%

B= Below
- 60.0–69.9%
- 50.0–59.9%
- 40.0–49.9%
- 33.3–39.9%

EC= Equal chances. No forecasted anomalies.

Notes:

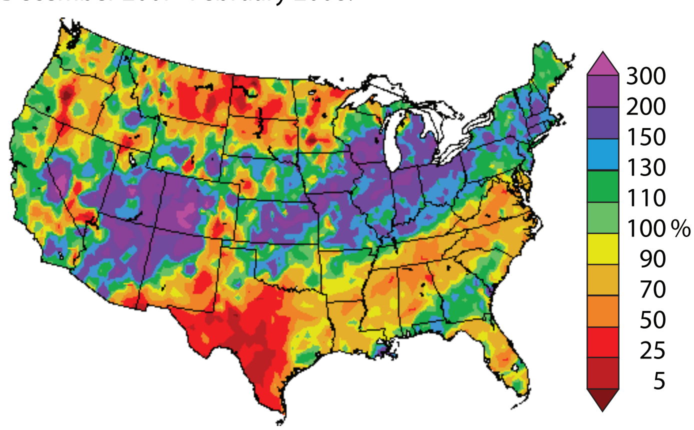
Figure 15a shows the NOAA Climate Prediction Center (CPC) precipitation outlook for the months December 2007–February 2008. This forecast was made in November 2007.

The outlook predicts the likelihood (chance) of above-average, average, and below-average precipitation, but not the magnitude of such variation. The numbers on the maps do not refer to inches of precipitation. Using past climate as a guide to average conditions and dividing the past record into 3 categories, there is a 33.3 percent chance of above-average, a 33.3 percent chance of average, and a 33.3 percent chance of below-average precipitation. Thus, using the NOAA CPC likelihood forecast, in areas with light brown shading there is a 33.3–39.9 percent chance of above-average, a 33.3 percent chance of average, and a 26.7–33.3 percent chance of below-average precipitation. Equal Chances (EC) indicates areas where reliability (i.e., the skill) of the forecast is poor and no prediction is offered.

Figure 15b shows the observed percent of average precipitation for December 2007–February 2008. Care should be exercised when comparing the forecast (probability) map with the observed precipitation maps. The observed precipitation amounts do not represent probability classes as in the forecast maps, so they are not strictly comparable, but they do provide us with some idea of how well the forecast performed.

In all of the figures on this page, the term average refers to the 1971–2000 average. This practice is standard in the field of climatology.

Figure 15b. Percent of average precipitation observed from December 2007–February 2008.



On the Web:

For more information on CPC forecasts, visit:
http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/churchill.html