Intermountain West Climate Summary

by The Western Water Assessment

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November 2007 Climate Summary

Hydrological Conditions – Drought persists in Utah and western Wyoming, but if wet conditions typical of La Nina occur, drought conditions may improve in Wyoming and northern Utah. However, dry conditions associated with La Nina may exacerbate drought in southern Utah and southern Colorado.

Temperature – Temperatures across most of the region ranged from 2°F below average to 4°F above average. Some areas in central Colorado and parts of Wyoming were 4-6°F above average.

Precipitation – Precipitation patterns across the region were consistent with a moderate La Nina: southern Utah and southern Colorado had below 50% of average precipitation, while areas in northwest Wyoming had over 120% of average.

ENSO – A moderate La Niña event is underway in the Pacific Ocean, and is likely to persist through March 2008 and may gradually diminish in Spring 2008.

Climate Forecasts – Expected La Niña impacts during December 2007 – April 2008 are above average precipitation in the Pacific Northwest (including western Wyoming) and below average precipitation in the Southwest, including southern Colorado and southern Utah. There is an increased chance of above average temperatures across the Intermountain West.

New NIDIS Drought Portal

A new resource is available to access comprehensive information on emerging and ongoing droughts, and to enhance the nation's drought preparedness. The NIDIS Drought Portal (http://www.drought.gov) features information, products, and resources useful in drought monitoring, planning, forecasting, and prevention at a regional and continental scale. Visit the U.S. Drought Monitor, page 10 for additional information.

Colorado River Shortage Sharing EIS

The USBR has issued the final *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead*, particularly under low reservoir conditions. This Environmental Impact Statement (EIS) highlights six alternative coordinated operation strategies for Lakes Powell and Mead that minimize Lower Basin shortages and maintain Upper Basin delivery requirements. The WWA participated in providing guidance to USBR on climate variability and change for this effort, which is a Technical Report as Appendix U. The EIS and related documents are available at: http://www.usbr.gov/lc/region/programs/strategies.html.

In This Issue

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

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Brad Udall – WWA Director
Andrea Ray, Jessica Lowrey – Editors/Writers
Christina Alvord, Julie Malmberg – Writers
Barb DeLuisi - Graphic Designer
Klaus Wolter, Gary Bates – Asst. Editors

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Impacts, Adaptation, and Vulnerability: A Summary of the Report from IPCC Working Group 2 and Implications for the Western U.S.

By Andrea Ray, NOAA Earth Systems Research Laboratory and the Western Water Assessment

This summer the Intergovernmental Panel on Climate Change (IPCC) released its report on "Impacts, Adaptation and Vulnerability," a contribution to the IPCC Fourth Assessment Report. This report is based on the IPCC assessment of the physical basis for climate change, and assesses how climate interacts with human and ecological systems in terms of potential negative and positive consequences and the potential to respond or adapt.

Introduction

The Intergovernmental Panel on Climate Change (IPCC) is an international panel of experts organized under the United Nations and the World Meteorological Organization. The role of the IPCC is to "assess on a comprehensive, objective, open and transparent basis" the scientific, technical, and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts, and options for adaptation and mitigation. The goal of the IPCC is to articulate a scientific consensus on climate change based on peer-reviewed and published data and findings accepted by at least 90% of the research community. The IPCC conducts its work primarily through three Working Groups (WG), which include hundreds of scientists from over 100 countries. For example, the Working Group 1 (WG1) report, *Climate Change 2007: The Physical Science Basis*, included over 600 authors from 40 countries, and was reviewed by over 620 scientific experts. The shorter "Summary for Policymakers" of that report was ultimately adopted and accepted by 113 governments at a meeting in Geneva, Switzerland in February 2007. The other two working groups – WG2 on Impacts, Adaptation, and Vulnerability, and WG3 on Mitigation – had similar participation by a large number of scientists from around the world, including a number of Boulder scientists. Roger Pulwarty, a scientist at the NOAA Earth System Research Laboratory who has participated in the Western Water Assessment, is an author of the IPCC WG2 Technical Report on Climate Change and Water.

> ***"A global assessment of data since 1970 has shown it is likely that anthropogenic warming has had a discernible influence on many physical and biological systems,"*** **Working Group 2 Summary for Policymakers.**

The IPCC has issued three previous assessment reports, in 1990, 1995, and 2001. Each report has found the state of the science is consistently moving forward, with increasingly firm conclusions that human activity is enhancing global climate change. The significance of the IPCC's work is underscored by the announcement this fall that the IPCC and former Vice President Al Gore will share the 2007 Nobel Peace prize for their efforts to disseminate knowledge about climate change, and to lay the foundations for the measures to counteract such change.

This article describes the findings of the WG2 on "Impacts, Adaptation and Vulnerability." This group assessed the scientific, technical, environmental, economic and social aspects of the vulnerability to climate change of, and the negative and positive consequences for, ecological systems, socio-economic sectors and human health. Building on the WG1 report, which focused on the physical basis for climate change, the WG2 report moves into the human and ecological realms, and a set of concepts that embody how society interacts with climate. WG2 concluded, *"A global assessment of data since 1970 has shown it is likely that anthropogenic warming has had a discernible influence on many physical and biological systems"* (IPCC, 2007a). WG2 issued a Summary for Policymakers, a Technical Summary and separate technical report chapters assessing the impacts of climate change on key sectors including water, ecosystems, food, coasts, and health, and on various regions such as North America and Latin America.

Observed Impacts of Climate Change on the Natural and Human Environment

The WG1 report established that changes in many physical and biological systems are linked to anthropogenic (human-induced) warming (IPCC, 2007b). WG2 reviewed additional evi-

Key Definitions

Impacts: the actual consequences (losses or gains) resulting from climate change, including climate variability and extremes.

Adaptation: a process by which individuals, communities and countries seek to cope with the consequences of climate change.

Vulnerability: the potential for negative outcomes or consequences, incorporating a human judgment of value. It is the extent to which climate change will damage or harm a system. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the system's sensitivity and adaptive capacity.

Adaptive Capacity: the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Sensitivity: the degree to which a system will respond to a change in climatic conditions.

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems	Water resources	Human health	Industry, settlements and society
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	Virtually certain[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks [5.8.1, 4.4.5]	Effects on water resources relying on snow melt; effects on some water supply [3.4.1, 3.5.1]	Reduced human mortality from decreased cold exposure [8.4.1, T8.3]	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism [7.4.2, 14.4.8, 15.7.1]
Warm spells/ heatwaves. Frequency increases over most land areas	Very likely	Reduced yields in warmer regions due to heat stress; wildfire danger increase [5.8.1, 5.4.5, 4.4.3, 4.4.4]	Increased water demand; water quality problems, e.g., algal blooms [3.4.2, 3.5.1, 3.4.4]	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated [8.4.2, T8.3, 8.4.1]	Reduction in quality of life for people in warm areas without appropriate housing; impacts on elderly, very young and poor [7.4.2, 8.2.1]
Heavy precipitation events. Frequency increases over most areas	Very likely	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils [5.4.2]	Adverse effects on quality of surface and groundwater; contamination of water supply; water stress may be relieved [3.4.4]	Increased risk of deaths, injuries, infectious, respiratory and skin diseases [8.2.2, 11.4.11]	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property [T7.4, 7.4.2]
Area affected by drought increases	Likely	Land degradation, lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire [5.8.1, 5.4, 4.4.4]	More widespread water stress [3.5.1]	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases [5.4.7, 8.2.3, 8.2.5]	Water shortages for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration [T7.4, 7.4, 7.1.3]
Intense tropical cyclone activity increases	Likely	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs [5.4.5, 16.4.3]	Power outages cause disruption of public water supply [7.4.2]	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders [8.2.2, 8.4.2, 16.4.5]	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, potential for population migrations, loss of property [7.4.1, 7.4.2, 7.1.3]
Increased incidence of extreme high sea level (excludes tsunamis)[c]	Likely[d]	Salinisation of irrigation water, estuaries and freshwater systems [3.4.2, 3.4.4, 10.4.2]	Decreased freshwater availability due to salt-water intrusion [3.4.2, 3.4.4]	Increased risk of deaths and injuries by drowning in floods; migration-related health effects [6.4.2, 8.2.2, 8.4.2]	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above [7.4.2]

Table 1a.
[a] See WGI AR4 Table 3.7 for further details regarding definitions.
[b] Warming of the most extreme days and nights each year.
[c] Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
[d] In all scenarios, the projected global average sea level at 2100 is higher than in the reference period [WGI AR4 10.6]. The effect of changes in regional weather systems on sea-level extremes has not been assessed.

Examples of possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid- to late 21st century. These do not take into account any changes or developments in adaptive capacity. Examples of all entries are to be found in chapters in the full WG2 Assessment (see sources in brackets). The first two columns of this table (shaded yellow) are taken directly from the WG I Fourth Assessment (AR4 Table SPM.2). The likelihood estimates in column 2 relate to the phenomena listed in column 1. The direction of trend and likelihood of phenomena are for SRES projections of climate change [IPCC, 2007b, Table TS.5 and abbreviated caption].

dence including ecological data sets and global synthesis of data, and they concluded that *observational evidence from all continents and most oceans indicates that natural systems are being affected by regional climate changes, particularly temperature increases* (IPCC, 2007a). Findings of WG2 include high confidence[1] that hydrologic systems around the world are being affected: they find increased runoff and earlier spring peak discharge in many glacier-and snow-fed rivers [14.21[2]] including a shift in the magnitude and timing of hydrologic events. For example, April 1 snow water equivalent (SWE) has declined 15-30% in the western mountains of North America, particularly at lower elevations and primarily due to warming, not changes in precipitation. They express very high confidence that recent warming is strongly affecting terrestrial biological systems, including "earlier timing of spring events, such as leaf-unfolding, bird migration, and egg-laying" [1.3] and "poleward shifts in ranges in plant and animal species" [1.3, 8.2, 14.2]. These impacts are summarized in Table 1a.

The WG2 concludes with high confidence that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems [1.4]. This conclusion is based on two lines of evidence: 1) consistence between observed and modeled changes and 2) the spatial agreement between significant global warming and consistent impacts at the global scale. This global synthesis is illustrated in Figure 1a. From 80,000 data series in 577 studies, WG2 selected 29,000 data series in 75 studies that (i) ended in 1990 or later; (ii) spanned a period of at least 20 years; (iii) showed a significant change in either direction, as assessed in the individual studies. They found that more than 89% of the changes to physical systems (snow, ice, and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine, and freshwater) are significant with the direction of change expected as a response to observed warming from 1970-2004. Most of these data series (over 28,000) were from studies of terrestrial biological systems in Europe where temperatures have increased 0.2 – 2.0 °C during that time. In North America, many studies are in the Western U.S.

Impacts in the Intermountain West

Although the WG2 report did not focus specifically on regions at the scale of the interior Western U.S., this region has charac-

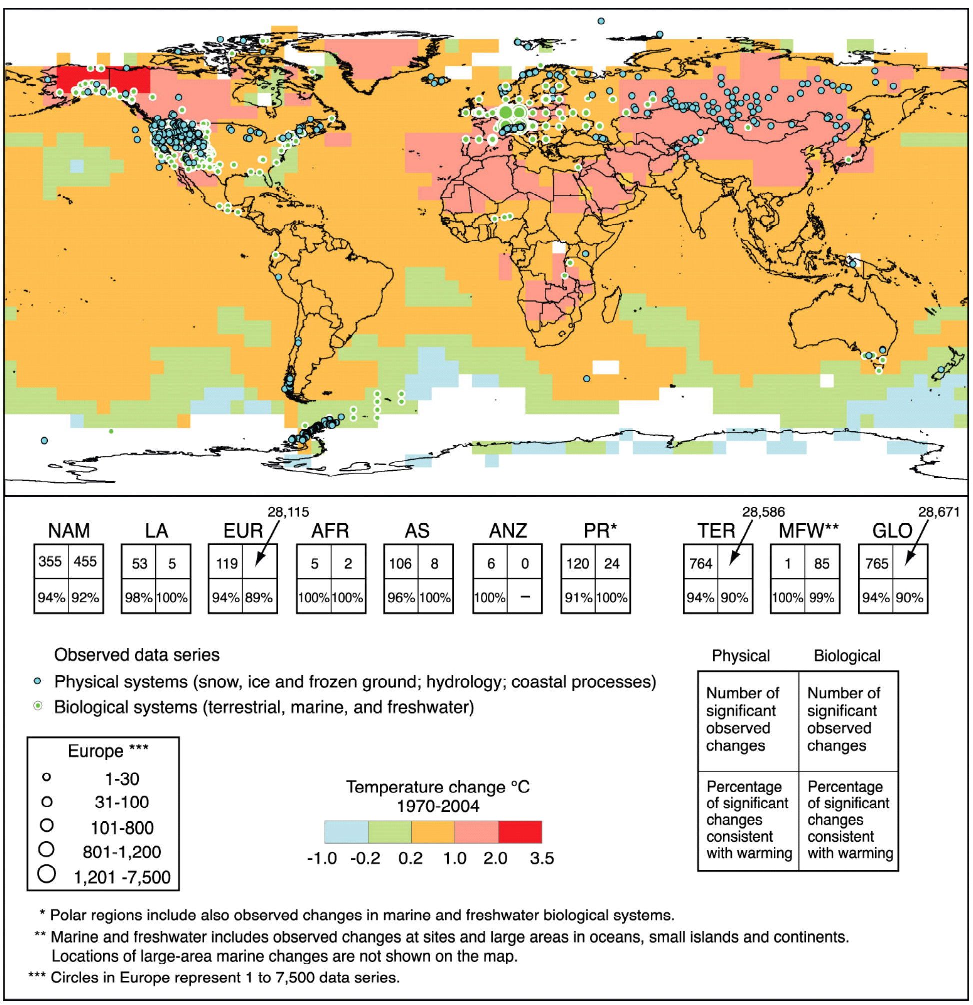
[1] The IPCC uses the following levels of confidence to express expert judgments on the correctness of the underlying science: *very high confidence* represents at least a 9 out of 10 chance of being correct; *high confidence* represents about an 8 out of 10 chance; *medium confidence* represents about a 5 out of 10 chance; *low confidence* represents about a 2 out of 10 chance; *very low confidence* represents less than a 1 out of 10 chance.
[2] These numbers refer to sections in the technical report chapters, for example chapter 14, section 2. http://www.ipcc-wg2.org/

teristics identified by the WG2 as the most vulnerable to climate change. In particular, its economies are closely linked with climate-sensitive resources, including water and ecosystems, which are already sensitive to weather events (e.g., drought, floods, and storms). In addition, rapid urbanization and population growth are occurring, and there is an ongoing shift from agricultural to urban water use. The affects of climate change will vary widely by location and scale (as with global impacts). There are several potential direct impacts and concerns resulting from increased temperatures (considered very likely)[3] and decreased precipitation (considered likely). In the Interior West these include:

- Decreased water supply reliability, in particular, supplies relying on snow melt
- Increased surface water evaporation and evapotranspiration rates
- Decreased hydropower production
- Reduced minimum flows for fish and estuaries
- Earlier peak flow timing
- Greater likelihood of extreme events: drought, flood

Direct impacts may cascade in a chain of impacts to create indirect, or second order and higher order effects. For example, increased wildfire may result in more areas at risk for post-fire erosion, then decreased water quality and enhanced flooding. Wildfire or increased temperatures may also create more opportunity for invasive and pest species, which in turn have higher order effects on plant and animal migration and landscape transformation. Other examples of potential indirect impacts and concerns include:

- Increased water and energy demands for warm season cooling
- Amplified urban heat islands
- Stress on ecosystems
- Enhanced insect-related disturbances



Symbol	Name
Continental Regions	
NAM	North America
LA	Latin America
ER	Europe
AFR	Africa
ANZ	Asia
PR	Australia and New Zealand
Global Scale	
TER	Terrestrial
MFW	Marine and Freshwater
GLO	Global

Figure 1a. Locations of significant changes in data series of physical systems (snow, ice and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine and freshwater biological systems), are shown together with surface air temperature changes over the period 1970-2004. White areas do not contain sufficient observational climate data to estimate a temperature trend. The 2x2 boxes show the total number of data series with significant changes (top row) and the percentage of those consistent with warming (bottom row). The numbers of studies from the seven regional boxes (NAM, …, PR) do not add up to the global (GLO) totals because numbers from regions except Polar do not include the numbers related to Marine and Freshwater (MFW) systems. Locations of large-area marine changes are not shown on the map [IPCC, 2007a, Figure TS.1 and abbreviated caption].

[3] The IPCC uses the following terms to indicate the assessed likelihood, using expert judgment, of an outcome or a result: *Virtually certain* > 99% probability of occurrence, *Extremely likely >95%, Very likely > 90%, Likely > 66%, More likely than not > 50%, Unlikely< 33%, Very unlikely < 10%, Extremely unlikely < 5%.*

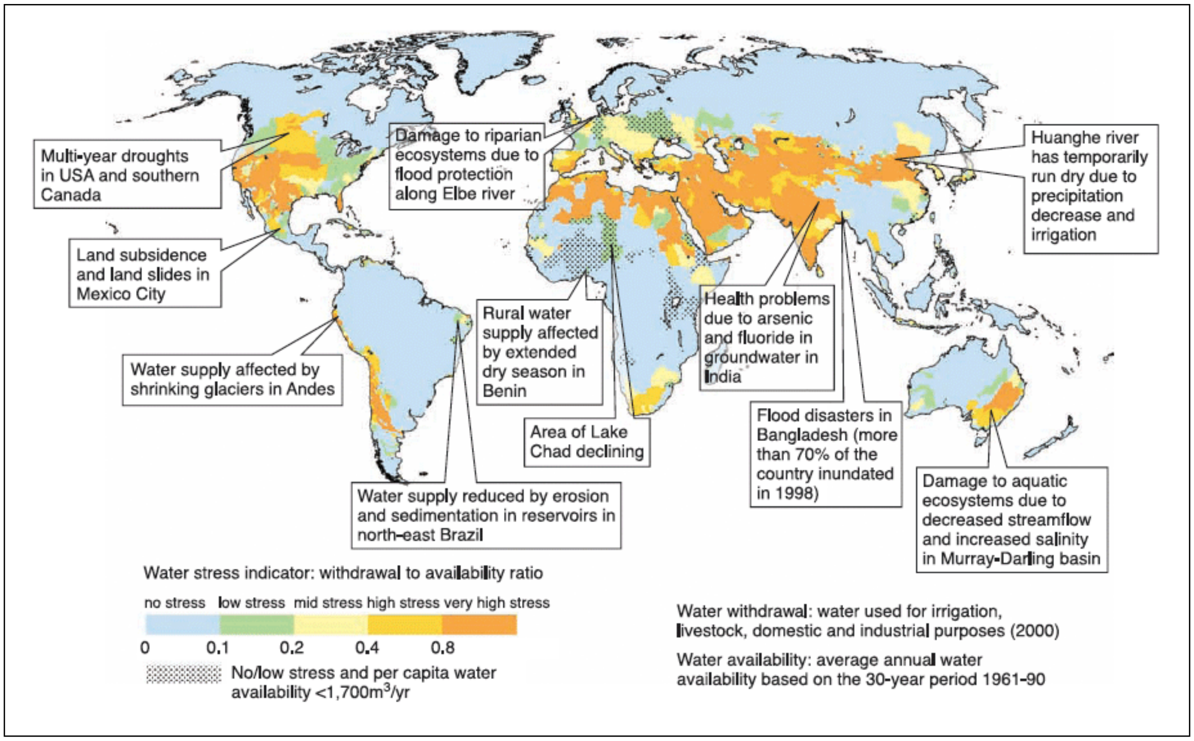


Figure 1b. Examples of current vulnerabilities of freshwater resources and their management that are likely to be exacerbated by climate change. In the background, a water stress map [IPCC, 2007a, Figure 3.2 and abbreviated caption].

Vulnerability

Vulnerability is the extent to which climate change will damage or harm a system, and the potential for negative outcomes or consequences. Vulnerability is a function of the physical climate impacts to which a system is exposed, and the system's sensitivity and adaptive capacity; it can be exacerbated by the presence of other stresses. Vulnerabilities exist inherently in the institutions and cultures of a system, and are exposed when events occur such as drought. WG2 has identified vulnerable areas worldwide with respect to water resources (Figure 1b).

The Western U.S. is vulnerable to climate change because its economies are closely linked with climate-sensitive resources, including water and ecosystems. Even without climate change, the region's water supply is undergoing stresses from population growth, urbanization, the shift in water use and ownership from agricultural to urban, and shifts in the economy among agricultural, mining and resource extraction, recreation, industries and services. Each of these factors is resulting in over-allocation of water resources, which will be more stressed with future changes in the hydrologic system related to climate. Other factors that affect how various sectors and subpopulations in the region are vulnerable to climate include poverty and inequal access to resources, affects of economic globalization and other economic trends influencing the region. Actual vulnerability to climate change in North America depends on the effectiveness and timing of adaptation and the distribution of coping capacity [14.2].

Adaptation

Adaptation is a process by which individuals, communities and countries seek to cope with the consequences of climate change. Societies adapt to climate as part of their culture, including laws, policies and practices, and even architecture. Differences in climate partly explain the differences in water law between the arid areas of southern Europe and the Western U.S. and wetter/less arid areas in northern Europe and the eastern U.S. Adaptation to climate change, however, has been an idea that many have been reluctant to discuss (Pielke et al., 2007). For some, it represents an admission that climate change is occurring. For others, including some advocates of greenhouse gas emissions reductions, it represented the idea that we could not react in time to minimize damages and we have given up trying. However, as Pielke and his co-authors describe, perspectives have changed. A common view now is that adaptation is needed because climate change is underway and the system is already committed to a certain level of warming based on past greenhouse gas emissions, even if mitigation actions drastically reduce future emissions.

The WG2 asserts that a portfolio of adaptation and mitigation measures can diminish the risks associated with climate change. Potential responses include: purely technical (e.g. infrastructure defenses against sea level rise) to behavioral (e.g. altered food and recreational choices) to managerial (e.g. altered farm practices) to policy (e.g. planning regulations). The WG2 technical summary also describes adaptation measures that are in place or

	Food, fibre and forestry	Water resources	Human health	Industry, settlement and society
Drying/ Drought	*Crops*: development of new drought-resistant varieties; intercropping; crop residue retention; weed management; irrigation and hydroponic farming; water harvesting *Livestock*: supplementary feeding; change in stocking rate; altered grazing and rotation of pasture *Social*: Improved extension services; debt relief; diversification of income	Leak reduction Water demand management through metering and pricing Soil moisture conservation e.g., through mulching Desalination of sea water Conservation of groundwater through artificial recharge Education for sustainable water use	Grain storage and provision of emergency feeding stations Provision of safe drinking water and sanitation Strengthening of public institutions and health systems Access to international food markets	Improve adaptation capacities, especially for livelihoods Incorporate climate change in development programmes Improved water supply systems and co-ordination between jurisdictions
Increased rainfall/ Flooding	*Crops*: Polders and improved drainage; development and promotion of alternative crops; adjustment of plantation and harvesting schedule; floating agricultural systems *Social*: Improved extension services	Enhanced implementation of protection measures including flood forecasting and warning, regulation through planning legislation and zoning; promotion of insurance; and relocation of vulnerable assets	Structural and non-structural measures. Early-warning systems; disaster preparedness planning; effective post-event emergency relief	Improved flood protection infrastructure "Flood-proof" buildings Change land use in high-risk areas Managed realignment and "Making Space for Water" Flood hazard mapping; flood warnings Empower community institutions
Warming/ Heatwaves	*Crops*: Development of new heat-resistant varieties; altered timing of cropping activities; pest control and surveillance of crops *Livestock*: Housing and shade provision; change to heat-tolerant breeds *Forestry*: Fire management through altered stand layout, landscape planning, dead timber salvaging, clearing undergrowth. Insect control through prescribed burning, non-chemical pest control *Social*: Diversification of income	Water demand management through metering and pricing Education for sustainable water use	International surveillance systems for disease emergence Strengthening of public institutions and health systems National and regional heat warning systems Measures to reduce urban heat island effects through creating green spaces Adjusting clothing and activity levels; increasing fluid intake	Assistance programmes for especially vulnerable groups Improve adaptive capacities Technological change
Wind speed/ Storminess	*Crops*: Development of wind-resistant crops (e.g., vanilla)	Coastal defence design and implementation to protect water supply against contamination	Early-warning systems; disaster preparedness planning; effective post-event emergency relief	Emergency preparedness, including early-warning systems More resilient infrastructure Financial risk management options for both developed and developing regions

Table 1b. Examples of current and potential options for adapting to climate change for vulnerable sectors. All entries have been referred to in chapters in the WG2 Fourth Assessment (AR4). Note that, with respect to ecosystems, generic rather than specific adaptation responses are required. Generic planning strategies would enhance the capacity to adapt naturally. Examples of such strategies are: enhanced wildlife corridors, including wide altitudinal gradients in protected areas [IPCC, 2007a, Table TS.6 and abbreviated caption].

being developed to cope with these changes.

Some adaptive responses are occurring, but more extensive adaptation is needed. The WG2 has identified a number of adaptive responses (Table 1b). In the Intermountain West these might include incorportion of the potential for climate change into policies. For example:

- Water management practices at multiple spatial and organizational scales
- Infrastructure planning, forest and water management plans, energy planning

Pathways for Adaptation and Response to Climate Change

A number of efforts are underway to elevate the adaptive capacity in the region. The National Integrated Drought Information System (NIDIS) seeks to enhance the nation's drought preparedness and provide comprehensive information on emerging and ongoing events resulting from chronic hydrologic shortages that are expected to increase in the west under climate change (NIDIS, 2007). Agencies are taking steps to build resilience to climate variations into their long-term planning. For example, the U.S. Bureau of Reclamation studied methods to incorporate climate change information into its Colorado River Basin planning studies (Brekke et al., 2007). The U.S. Forest Service has also recognized significant vulnerabilities to the forest and grassland resources it manages, and is seeking to develop and demonstrate adaptation strategies, including new natural resource management and use strategies and options to help reduce the negative effects of climate variability and change. Next year they will issue their Global Change Research Strategy for 2009-2019, which will reflect these adaptation goals. In Colorado, the state Climate Action Plan was recently unveiled by Governor Bill Ritter, that will assess the climate-induced changes in streamflows and the effects on the yield of individual water rights and the pattern of calls on Colorado's rivers, and assist water users to prepare for and adapt to large-scale droughts that are a likely effect of increased temperatures (Ritter, 2007).These efforts and others underway have the potential to assist policymakers, planners, managers and individuals in the Intermountain West to anticipate changes and prepare for them.

References

Brekke, L. et al., 2007. *Climate technical work group report: review of science and methods for incorporating climate change information into Reclamation's Colorado River Basin planning studies.* Appendix U in: Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead. Posted 2 Nov 2007 at http://www.usbr.gov/lc.

Field, C.B., et al., 2007: *North America. Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Work ing Group 2 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 617-652.

IPCC, 2007a: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp. http://www.ipcc.ch/ipccre ports/ar4-wg2.htm.

IPCC, 2007b: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. http://www.ipcc.ch/ipccreports/.ar4-wg1.htm.

Kundzewicz, Z.W., et al., 2007: *Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden -and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 173-210.

NIDIS, 2007. *National Drought Information System Implementation Plan: A pathway for national resilience.* http://www.drought.gov/.

Pielke, R.J., G. Prins, S. Rayner, and D. Sarewitz, 2007: *Climate Change 2007: Lifting the taboo on adaptation*. Nature, 445, 597-598.

Ritter, B., 2007. *Colorado Climate Action Plan: A strategy to address global warming*. Posted 5 Nov 2007 at http://wwa.colorado.edu/resources/water_and_climate/impacts_adaptation_and_vulnerability.html.

On the Web

- WWA has created a new webpages designed to provide background, context, and links associated with the IPCC process: http://wwa.colorado.edu/resources/water_and_climate.
- IPCC Working Group 1 Fourth Assessment Report: http://www.ipcc.ch/ipccreports/.ar4-wg1.htm.
- IPCC Working Group 2 Fourth Assessment Report: http://www.ipcc.ch/ipccreports/ar4-wg2.htm.
- NIDIS: http://www.drought.gov

Temperature 10/1/07 - 10/31/07

Monthly average temperature for October 2007 in the Intermountain West region ranged from 35-60°F (Figure 2a). The coldest areas (below 45°F) were in western and south central **Wyoming** and the north central **Colorado** mountains. Temperatures across most of the region ranged from 2°F below average to 4°F above average. However, some areas in central **Colorado** and parts of **Wyoming** were 4-6°F above average (Figure 2b).

Both record high and record low temperatures were set across the Intermountain West region in October. A record maximum temperature of 91°F was set in Pueblo, **Colorado**, on October 6th, breaking the previous record of 89°F set in 1993. A high temperature of 72°F in Casper, **Wyoming**, on October 25th tied the previous record set in 1990. Several low temperature records were set on October 6th in **Utah**, including a low of 45°F in Salt Lake City, breaking the previous record of 53°F in 1970. Grand Junction, **Colorado**, broke a 52-year low temperature record on October 7th with a temperature of 31°F. The previous record was 32°F.

In comparison, average temperatures in October 2006 were lower than temperatures in October 2007 throughout most of the IMW region (Figure 2c). South central **Wyoming**, areas in south central **Colorado**, and locations across **Utah** were 3-6°F cooler on average in October 2006 than in October 2007.

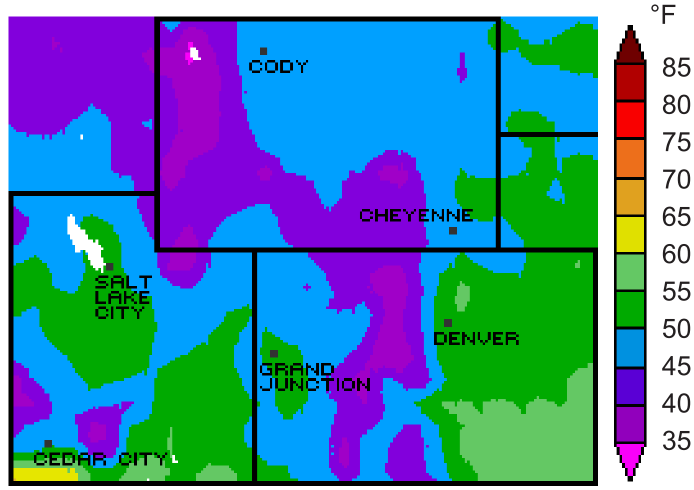


Figure 2a. Average temperature for the month of October 2007 in °F.

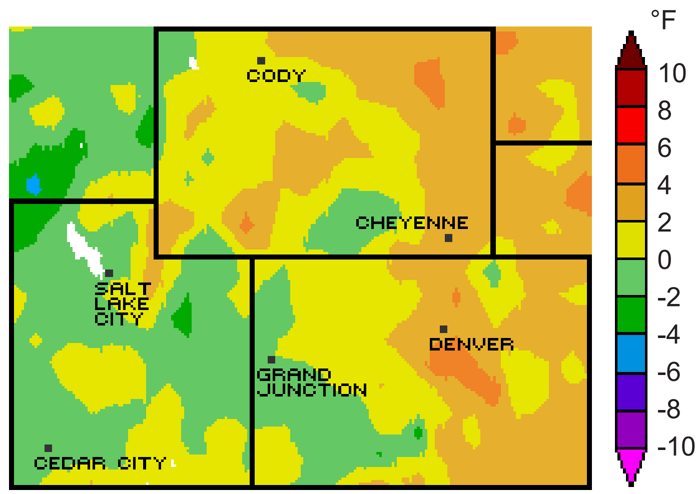


Figure 2b. Departure from average temperature for the month of October 2007 in °F.

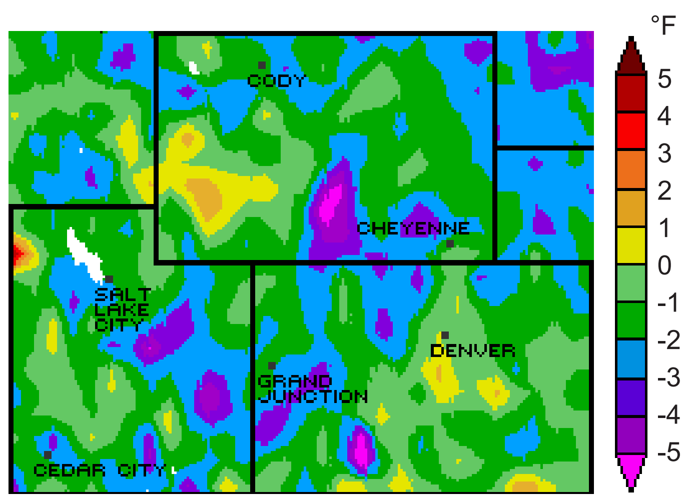


Figure 2c. Departure from average temperature in °F for last year, October 2006.

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 10/1/07 - 10/31/07

The 2008 water year began on the first of October, so only two precipitation maps are shown this month. The percent average precipitation for the month of October also represents the percent average for the first month of Water Year 2008. Total precipitation in the IMW region for October 2007 ranged from 0-3+ inches (Figure 3a). Northwest and south-central **Wyoming**, the area around Salt Lake City, **Utah**, and north-central **Colorado** received the highest totals (2+ inches). Southwest **Utah** and southeast **Colorado** received the least amount of precipitation (>0 – 0.25 inch).

Precipitation as a percent of average varied widely for the month of October (Figure 3b). Locations in southern **Utah** and southern **Colorado** were below average with some areas reporting values less than 40% of average. The NWS reported that several locations in southeast **Utah** received 0% of normal, including the Cedar City Airport. Northwest and southeast of **Wyoming** and north-central **Colorado** reported the highest percent of average (150-200+%). A new 24-hour record precipitation amount was set at Denver International Airport on October 13th and 14th. A total of 2.65 inches of precipitation fell in 24-hours and broke the previous 24-hour record of 2.58 inches set in 1892.

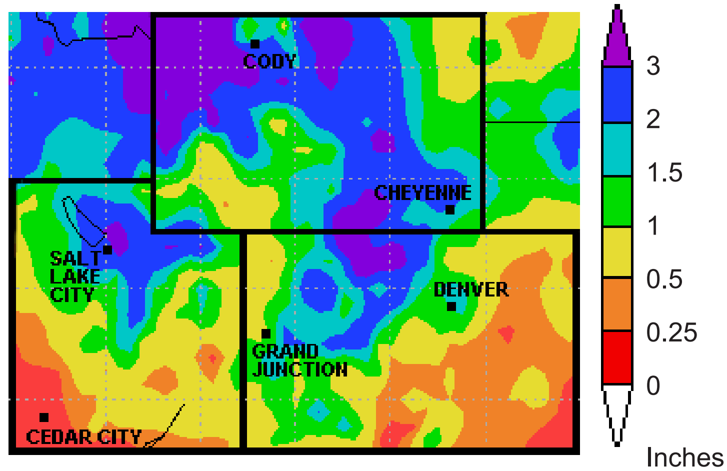


Figure 3a. Total precipitation in inches for the month of October 2007.

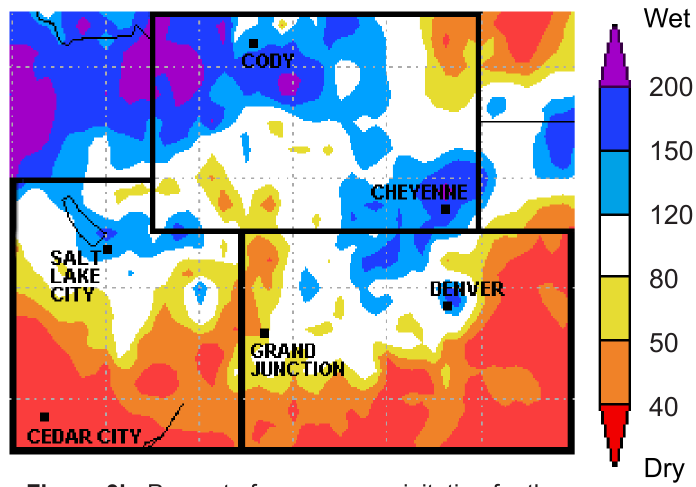


Figure 3b. Percent of average precipitation for the month of October 2007. Note that this is also the percent average precipitation to date for the 2008 water year.

Notes

The data in Figs. 3 a-b come from NOAA's Climate Prediction Center. The maps are created and updated daily by NOAA's Earth System Research Laboratory (see website below). These maps are derived by taking measurements at individual meteorological stations and interpolating (estimating) values between known data points to produce continuous categories. The water year runs from October 1 to September 30 of the following year. The 2008 water year began October 1, 2007. 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 1996-2006. This period of record is only eleven years long because it includes SNOTEL data, which was included in this dataset beginning in 1996. 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.

U.S. Drought Monitor conditions as of 11/13/07

The U.S. Drought Monitor (Figure 4) shows a decrease in drought severity in parts of each state in the Intermountain West region, and some increase in parts of **Colorado** since the mid-September Drought Monitor (see inset). However, most of these changes occurred between mid-September and mid-October, so the October 16 Drought Monitor (not shown) looks essentially the same as November 13 (Figure 4).

Above average precipitation in September and early October helped decrease drought status in the region. Rain in mid-September in northeast **Utah** increased reservoir storage there and brought drought status down from severe (D2) to moderate (D1), but the rest of the state is still in the severe category. Rain in early October in western **Wyoming** brought drought status in some areas down from extreme (D3) to severe (D2), which is the status for all of western **Wyoming** now. Finally, in late September and early October, rains in western and northern **Colorado** brought those areas out of drought (down from moderate-D1 and abnormally dry-D0), but continued dryness in eastern **Colorado** has moved that area from no drought into abnormally dry conditions (D0).

The NIDIS Drought Portal was released on November 1, 2007: http://www.drought.gov. The Drought Portal is a clearinghouse for drought information for the U.S., featuring climate and hydrological data and forecasts, drought impacts, planning resources, and educational tools. The goal of the Drought Portal is to help local, state, and federal decision makers monitor, prepare for, respond to, and mitigate drought conditions.

The Drought Portal is a collaborative effort, involving input from multiple agencies including NOAA/NWS, U.S. Department of Agriculture, and the National Drought Mitigation Center. The Drought Portal will be updated and improved continually, and NIDIS welcomes feedback from users. You can submit feedback by clicking on "Contact Us" link located at the top right corner of the homepage.

Notes

The U. S. Drought Monitor (Figure 4) 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.

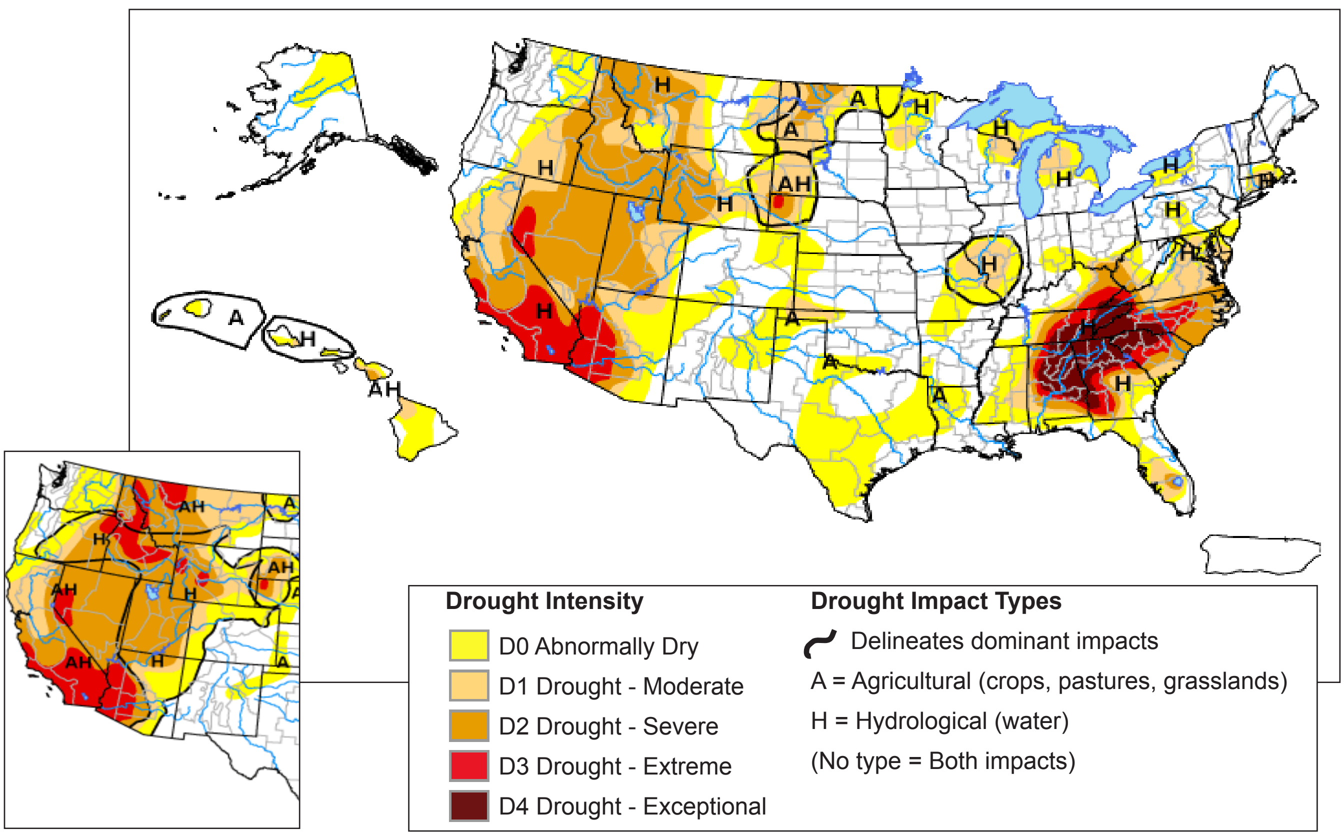


Figure 4. Drought Monitor from November 13, 2007 (full size) and the last summary, September 18, 2007 (inset, lower left) for comparison.

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.

Regional Standardized Precipitation Index data through 10/31/07

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. This month we feature Regional SPI maps at two time scales: 3-months and the 12-month map. 3- and 6-month SPIs are useful in short-term agricultural applications, while longer-term SPIs (12 months and longer) are useful in hydrological applications. By comparing the two SPI maps one can see how the precipitation over the last 3-months compares to the precipitation over the previous year. For example, the 3-month SPI shows that in the past three months, conditions have been average or wetter-than-average in most of the IMW region (Figure 5a). There are no climate divisions drier than near normal. However, dry conditions between 3 and 12 months ago account for dry climate divisions on the 12-month SPI (Figure 5b).

Since the 12-month SPI in the September IMW Climate Summary, all climate divisions in eastern **Colorado** moved from wet to the near normal category due to below average precipitation in the eastern and southern divisions in October. The 3-month SPI shows that western Colorado had above average precipitation during the last three months, however this was not enough to bring western Colorado to a wetter category in the 12-month SPI.

In **Wyoming**, seven climate divisions changed on the 12-month SPI since September. Five moved to drier categories, two moved to wetter categories. In general, the western part of the state is drier than the east. The 3-month SPI shows that extremely wet conditions in the Lower Platte division during the last 3-months allowed the region to change from near normal conditions to moderately wet conditions on the 12-month SPI.

All the climate divisions in **Utah** moved to drier categories on the 12-month SPI, except around Salt Lake City where it stayed the same. The whole state is now in moderately dry or very dry categories, with the exception of the Southeast division, which is near normal. All of Utah had near normal precipitation according to the 3-month SPI, but the dry conditions 3 to 12 months ago still keep Utah in the dry categories on the 12-month SPI.

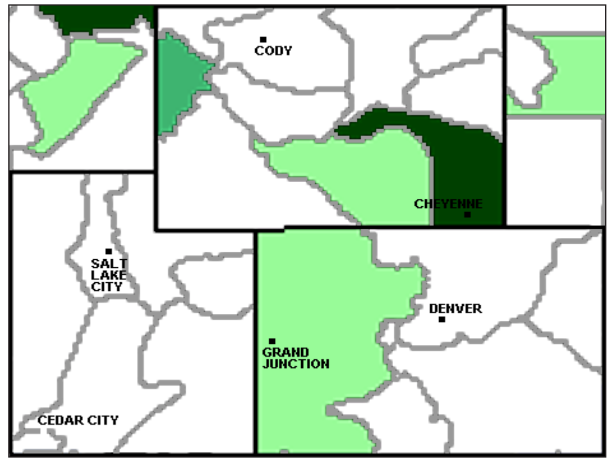


Figure 5a. 3-month Intermountain West regional Standardized Precipitation Index (data from 08/01/07 - 10/31/07).

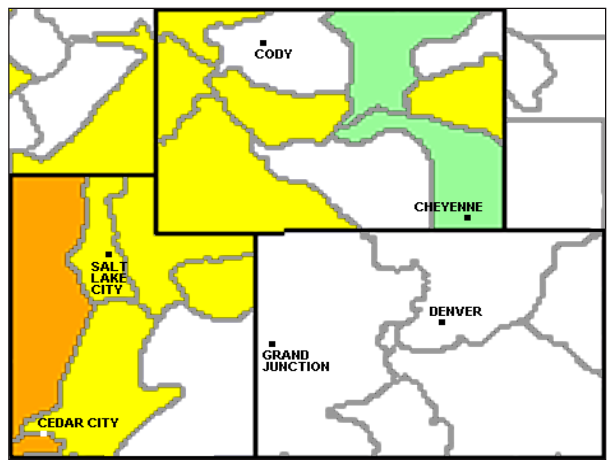


Figure 5b. 12-month Intermountain West regional Standardized Precipitation Index (data from 11/1/06 - 10/31/07).

+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.

A 12-month SPI is used for the Intermountain West region (Figure 5b) and 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. The 3-month SPI uses data for the last three months and represents short-term precipitation patterns (Figure 5a). The graphics in Figures 5a and b comes from the Western Regional Climate Center, which uses data from the NCDC and the NOAA Climate Prediction Center.

On the Web

- 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 Figure 5, but the categories are defined slightly differently.

The 2007 Water Year in Review

The water year reflects the natural cycle of snow accumulation in the winter, run-off in the spring, and reservoir storage in the summer. The 2007 water year (WY2007), from October 1, 2006-September 30, 2007, was characterized by near and above average snowpack and streamflow conditions along the northern Continental Divide in **Colorado**, and near to below average snowpack and streamflow conditions across western **Colorado** and the Green River basin in **Utah**. In **Wyoming**, drought status was downgraded by the U.S. Drought Monitor (USDM), despite continued near to below average precipitation statewide. In **Utah**, drought conditions developed due to below average snowpack and streamflows. For current USDM status and Seasonal Drought Outlook visit pages 10 and 19. This page reviews the 2007 water year by evaluating fall precipitation, winter snowpack, spring snowmelt, summer streamflows, reservoir storage, and change in drought status (as defined by the USDM) over the last year for the Intermountain West states of **Colorado**, **Wyoming**, and **Utah**.

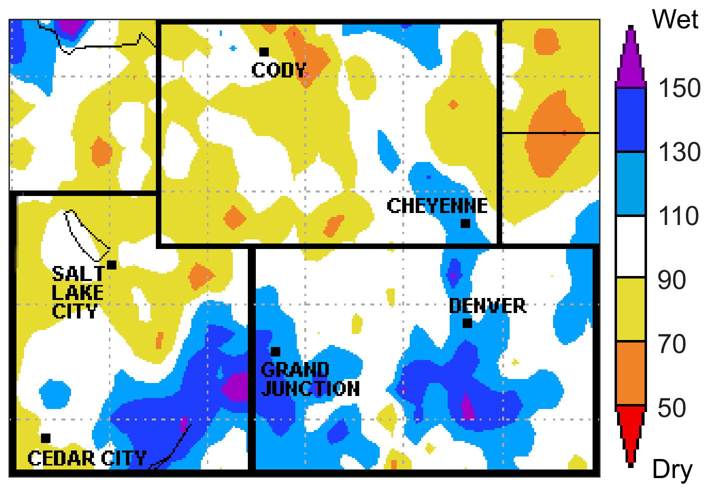


Figure 6a. Cumulative percent of normal precipitation for WY2007.

Colorado

Colorado moved out of drought status in WY2007, which was attributed to near average snowpack and streamflows along the northern Continental Divide, and above average reservoir storage statewide. Cumulative percent of normal precipitation for WY2007 was near or above average statewide (90-150%) (Figure 6a). In October-December 2006, SWE values varied across the state, but were consistently above average along the northern Continental Divide, ranging from 100-160% of average. According to the NWS, two significant winter storms in December produced 27.7 inches of snowfall in the Denver Metro area, contributing to above average snowpack in the South Platte basin. By January 1, state-wide snowpack was 96% of average, ranging from a low of 85% in the Gunnison basin to a high of 111% average for the South Platte basin. By April 1, however, above average temperatures in February and March contributed to premature snowmelt, and snowpacks fell below average, ranging from a low of 58% of average in the San Juan, Animas, Dolores, and San Miguel basins to a high of 94% of average in the South Platte basin (Figure 6b). Following the spatial pattern of winter snowpack, the 2007 reservoir inflow season (April-July) was characterized by streamflows in the near normal category in the east (25th-75th percentile in the South Platte and Arkansas basins) and streamflows in the below average category in the west (>10th-24th percentiles across the Yampa, Colorado, Gunnison, San Juan, Animas, Dolores, and San Miguel basins), according to the USGS. By the end of July, reservoirs were near seasonal peak storage levels and Blue Mesa, Lake Dillon, Granby, Pueblo, and Turquoise storage were all above average (Table 6). According to the USBR 2008 Draft Annual Operating Plan (AOP) for Colorado River Reservoirs, storage in Blue Mesa increased by 15,000 af during WY2007, only 1.8% of capacity.

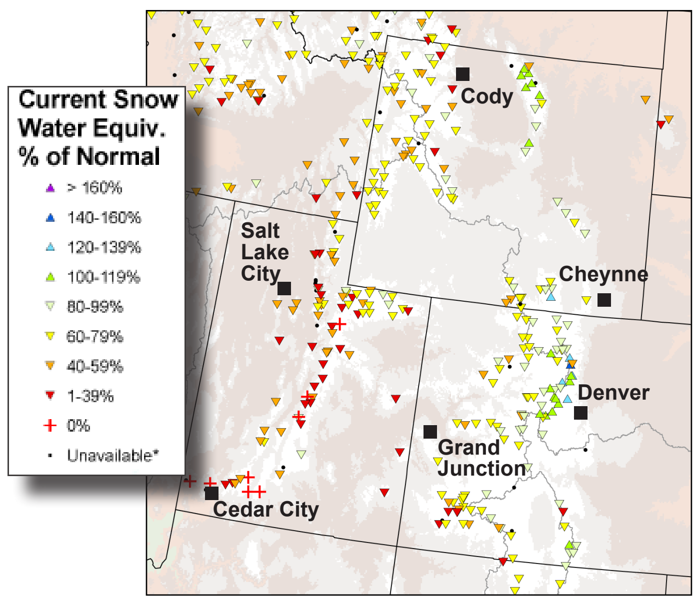


Figure 6b. April 1, 2007 snow water equivalent (SWE) as a percent of normal for SNOTEL sites in Colorado, Wyoming, and Utah, from NRCS. Peak SWE values typically occur during April. Note: this is provisional data.

Wyoming

The drought status decreased across Wyoming during WY2007, notably in eastern basins. Drought classification statewide in October 2006 was extreme (USDM - D3) but by October 2007 it was downgraded to severe (USDM - D2) in western basins and moderate (USDM - D1) in eastern basins. Cumulative percent of normal precipitation for WY2007 ranged from near average (90-130%) in north central basins to below average (50-90%) across western, eastern, and southern basins (Figure 6a). Below average snowfall in October-December 2006 resulted in below average January 1 SWE values (40-99%) across the state with a few stations reporting above average conditions (100-139%) in the Laramie and North Platte basins. Above average March snowfall in eastern Wyoming brought enough additional precipitation to downgrade drought status (USDM – D2 to D1) in that region by April 1. By June 1, streamflows were near average

The 2007 Water Year in Review cont.

Reservoir	Current Water (KAF)	Total Capacity (KAF)	% Full	% of Average
Colorado				
Blue Mesa Res.	783.2	829.5	94%	113%
Lake Dillon	258.7	254.0	102%	104%
Lake Granby	434.4	539.7	80%	104%
Pueblo	196.6	354.0	56%	110%
Turquiose Lake	122.6	129.4	95%	107%
Utah				
Bear Lake	539.5	1,302.0	41%	49%
Lake Powell	12,894.1	24,322.0	53%	61%
Strawberry Res.	952.1	1,106.5	86%	134%
Utah Lake	819.0	870.9	94%	94%
Wyoming				
Boysen Res.	476.9	741.6	64%	67%
Buffalo Bill Res.	621.1	644.1	96%	113%
Flaming Gorge Res.	3,123.1	3,749.0	83%	97%
Fontenelle Res.	226.7	344.8	66%	84%
Seminoe Res.	458.2	1,017.3	45%	64%

KAF = Thousands of Acre Feet

Table 6. July 1-3, 2007 reservoir data, when reservoirs are near their seasonal peak.

(25th-75th percentile) for northeast Wyoming and below average (>10th-24th percentile) for the western and southern basins according to the USGS. Reservoir peak seasonal storage occurred by July 1 and was below average for most reservoirs (Table 6). The USBR reported April-July unregulated inflow into Green River basin reservoirs Flaming Gorge and Fontenelle was 31% and 34% of average, respectively, and storage in Flaming Gorge and Fontenelle storage decreased 60,000 (1.6% of capacity) and 49,000 af (14% of capacity), respectively during WY2007.

Utah

Drought conditions developed across Utah during WY2007 due to below average snowpack and streamflows. Cumulative percent of normal precipitation for WY2007 was below average (90-50%) in the western and northern basins, and near or above average (90-150%) in eastern and southern basins (Figure 6a). The NWS reported that a large storm brought subtropical moisture on October 6-8, 2006, producing 3.00+ inches of precipitation in a 24-hour period near the CO-UT border. Runoff in the San Juan, Dirty Devil, and San Rafael rivers responded to the storm event, contributing to a 6.2 feet elevation gain in Lake Powell storage, a very unusual increase for this time of year, according to the USBR. Despite above average conditions in October 2006, water supplies began to decrease due to below average SWE across the state (39-99%) in October-December, with the southeast and southwest basins reporting the lowest averages. By April 1, most of the SNOTEL stations were reporting less than 80% of average SWE (Figure 6b), and Utah was classified in the moderate (USDM - D1) drought category. By June 1, the majority of SNOTEL sites were melted out. Statewide streamflows were in the below average category (<10th-24th percentile) with the exception of a few streams in north-central Utah, where streamflows were in the near average category (25th-75th percentile), according to the USGS. By the end of July, statewide drought status increased to severe (USDM - D2). Reservoir storage in July ranged from a low of 49% of average for Bear Lake to a high of 134% of average for Strawberry (Table 6). The USBR reported that peak seasonal storage for Lake Powell was 53% of average and of capacity and April-July unregulated inflow was 51% of average. During WY2007, storage in Lake Powell increased 41,000 af (0.17% of capacity) according to the USBR 2008 Draft AOP for Colorado River System Reservoirs. Current Utah drought status is severe (USDM - D2) in western basins and moderate (USDM - D1) in eastern basins.

Notes

Figure 6a shows cumulative percent of normal precipitation for WY2007 (October 1, 2006-September 30, 2007) produced using data from The NOAA's Climate Predic¬tion Center. This map is derived by taking measurements at individual meteorological stations and interpolating (estimat¬ing) values between known data points to produce continuous categories. Average refers to the arithmetic mean of annual data from 1996-2006. This period of record is only eleven years long because it includes SNOTEL data, which was included in this dataset beginning in 1996. Percent of average precipitation is calculated by taking the ratio of current to average precipitation and multiplying by 100.

Figure 6b shows the SWE as a percent of normal (average) for SNOTEL sites in Colorado, Wyoming and Utah, from the Natural Resources Conservation Service (NRCS).

Table 6 shows reservoir capacity and percent of average as of July 1-3, 2007. The first percentage shown in the table is the current contents divided by the total capacity. The second percentage shown is the percent of average water in the reservoir for this time of year. Reservoir status is updated at different times for individual reservoirs.

On the Web

- For current streamflow information from USGS, visit: http://water.usgs.gov/waterwatch/.
- Water Supply Outlook information for the Upper Colorado River Basin, produced by the
- For current SNOTEL data and plots of specific sites, visit: http://www.wcc.nrcs.usda.gov/snotel/.
- For monthly State Basin Outlook Reports on water supply conditions and forecasts for CO river basins, visit: http://www.wcc.nrcs.usda.gov/cgibin/bor.pl.
- Individual reservoir information including management agency, operations, and storage content, visit the WWA website at: http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/links.html, and click on individual links.
- The Bureau of Reclamation 2008 Draft Annual Operating Plan for Colorado River Reservoirs is available at: http://www.usbr.gov/lc/region/g4000/AOP2008/AOP08_draft.pdf.

Colorado Water Availability

The current water supply status is shaped by winter snowpack, reservoir storage, temperature, and precipitation as we move into the main snow accumulation season. Transition to mid winter weather patterns, characterized by frequent storm systems from the Pacific and downsloping conditions along the Front Range, is expected by the end of November, according to Colorado State Climatologist, Nolan Doesken. Currently, a moderate La Niña is well developed in the Pacific, however impacts of La Niña on winter precipitation in Colorado are inconsistent.

The north-central mountains along the Continental Divide have some SNOTEL stations reporting near to above average snowpack (100-160% of average), but the rest of the state is below average (>79% of average) (Figure 7). It is very early in the water year and average snowpack depth is low, so a few inches of additional snow can make a big difference in the percent of average. Due to above average snowfall and sophisticated snowmaking operations, A-Basin ski resort located in Summit County near Loveland Pass, was the first to open in the nation on October 17.

Reservoir storage across the state is near or above average due to conservative releases last winter and near average spring and summer streamflows. According to Denver Water, system reservoir storage is currently 93% of capacity. Under the most probable inflow scenarios (50 % exceedence), Blue Mesa is expected to fill in 2008, according to the USBR Draft Annual Operating Plan for the Colorado River Reservoirs. These inflow scenarios were developed by the NWS Colorado River Basin Forecast Center, using the Ensemble Streamflow Prediction (ESP) Model. At this time of year, ESP accounts for antecedent streamflows and current soil moisture levels with the Sacramento Soil Moisture Accounting Model, which uses continuous soil moisture accounting.

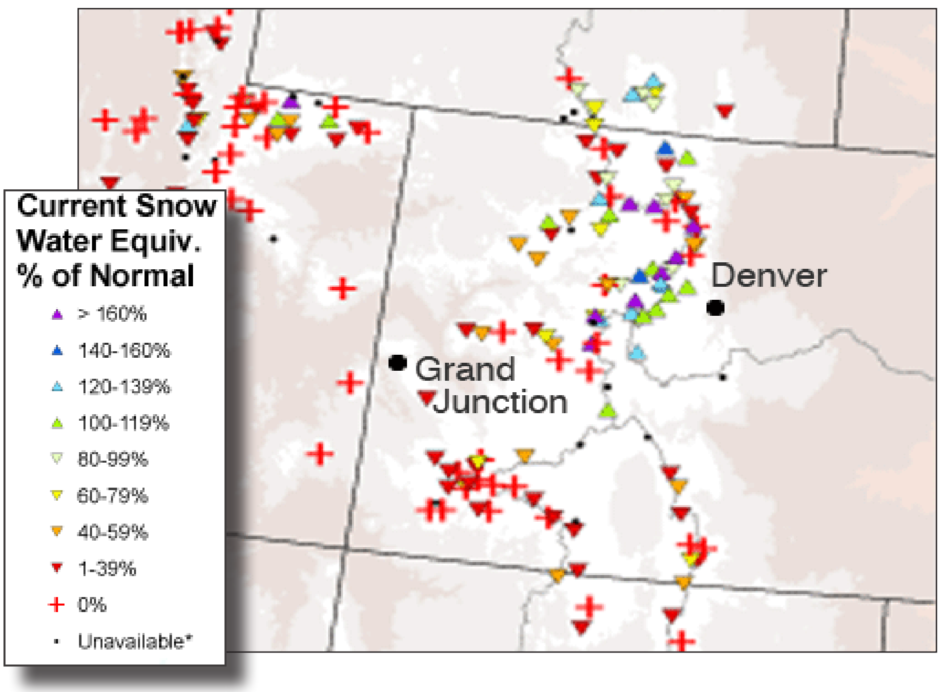


Figure 7. Current snow water equivalent (SWE) as a percent of normal for SNOTEL sites in Colorado as of November 1, 2007, courtesy NRCS. Note: this is provisional information.

On the Web

- For current maps of SWE as a percent of normal as shown in Figure 7, 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/.
- Individual reservoir information including management agency, operations, and storage content, visit the WWA website at: http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/links.html, and click on individual links.
- The Bureau of Reclamation 2008 Draft Annual Operating Plan for Colorado River Reservoirs is available at: http://www.usbr.gov/lc/region/g4000/AOP2008/AOP08_draft.pdf.
- 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/index.html.
- The Colorado Water Availability Task Force information, including agenda & minutes of upcoming & previous meetings are available at: http://www.cwcb.state.co.us/Conservation/Drought/taskForceAgendaMinPres.htm.

Wyoming Water Availability

The current water supply status is shaped by winter snowpack, reservoir storage, temperature, and precipitation as we move into the main snow accumulation season. Impacts from the moderate La Niña on Wyoming precipitation are inconsistent, with the exception of the northwest corner of the state where above average precipitation events have been linked La Niña conditions.

On November 1, SWE values were mostly above average (up to 160%) across the northern half of Wyoming, and near or below average for most SNOTEL stations in the south (some as low as 0% of average) (Figure 8). It is very early in the water year and average snowpack depth is low, so a few inches of additional snow can make a big difference in the percent of average. Wyoming needs above average winter snowpack and spring/summer streamflows to replenish reservoir storage and water supplies across the state, especially in the North Platte basin, according to WY State Climatologist, Steve Gray. Without this, water shortages in the North Platte basin could reach critical levels next spring, according to John Lawson, area manager of the Bureau of Reclamation Wyoming Office.

Most probable 2008 April-July inflow projection (50% exceedence) for Fontenelle is 590,000 af or 54% of average, according to the USBR Draft Annual Operating Plan for the Colorado River Reservoirs. This inflow projection exceeds storage capacity, therefore the USBR expects that Fontenelle will spill in 2008 and plans to lower storage to 111,000 af by April 1 to anticipate spring inflows. These inflow scenarios were developed by the NWS Colorado River Basin Forecast Center, using the Ensemble Streamflow Prediction (ESP) Model. At this time of year, ESP accounts for antecedent streamflows and current soil moisture levels with the Sacramento Soil Moisture Accounting Model, which uses continuous soil moisture accounting.

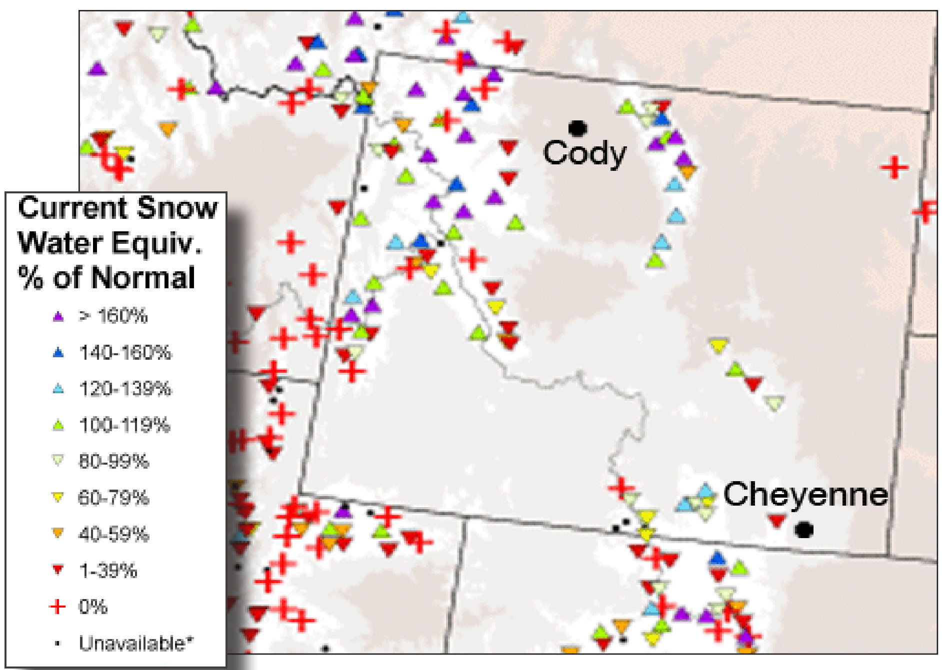


Figure 8. Current snow water equivalent (SWE) as a percent of normal for SNOTEL sites in Wyoming as of November 1, 2007, courtesy NRCS. Note: this is provisional information.

On the Web

- For current maps of SWE as a percent of normal as shown in Figure 8, 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/.
- Individual reservoir information including management agency, operations, and storage content, visit the WWA website at: http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/links.html, and click on individual links.
- The Bureau of Reclamation 2008 Draft Annual Operating Plan for Colorado River Reservoirs is available at: http://www.usbr.gov/lc/region/g4000/AOP2008/AOP08_draft.pdf.

Utah Water Availability

The current water supply status is shaped by winter snowpack, reservoir storage, temperature, and precipitation as we move into the main snow accumulation season. Impacts from the moderate La Niña on Utah winter precipitation are largely inconsistent, but La Niña tends to bring drier conditions to southern Utah.

As of November 1, SWE is below average across Utah with the exception of a few SNOTEL stations in the northeast (Figure 9a). Most stations are reporting 0-39% of average. It is very early in the water year and average snowpack depth is low, so a few inches of additional snow can make a big difference in the percent of average. Reservoir storage across the state is below average and also lower than reservoir levels at this time last year (Figure 9b). According to the USBR Draft Annual Operating Plan for Colorado River Reservoirs, Flaming Gorge storage was 679,000 acre-feet on September 30, 2007, which is 94% of average and 81% full.

The Utah Water Users Association Annual Water Summit Conference will be held on December 4, 2007 at the Davis Convention Center in Layton, Utah. For more information, email Carly Burton at utahwatersuers@aol.com, or visit: http://www.utahwaterusers.com

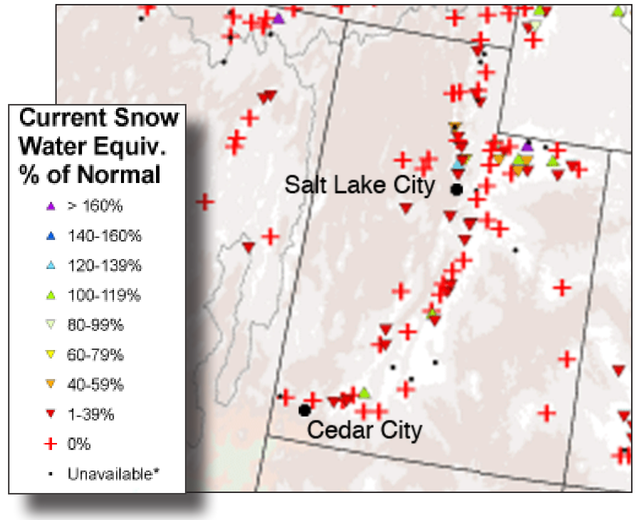


Figure 9a. Current snow water equivalent (SWE) as a percent of normal for SNOTEL sites in Colorado as of November 1, 2007, courtesy NRCS. Note: this is provisional information.

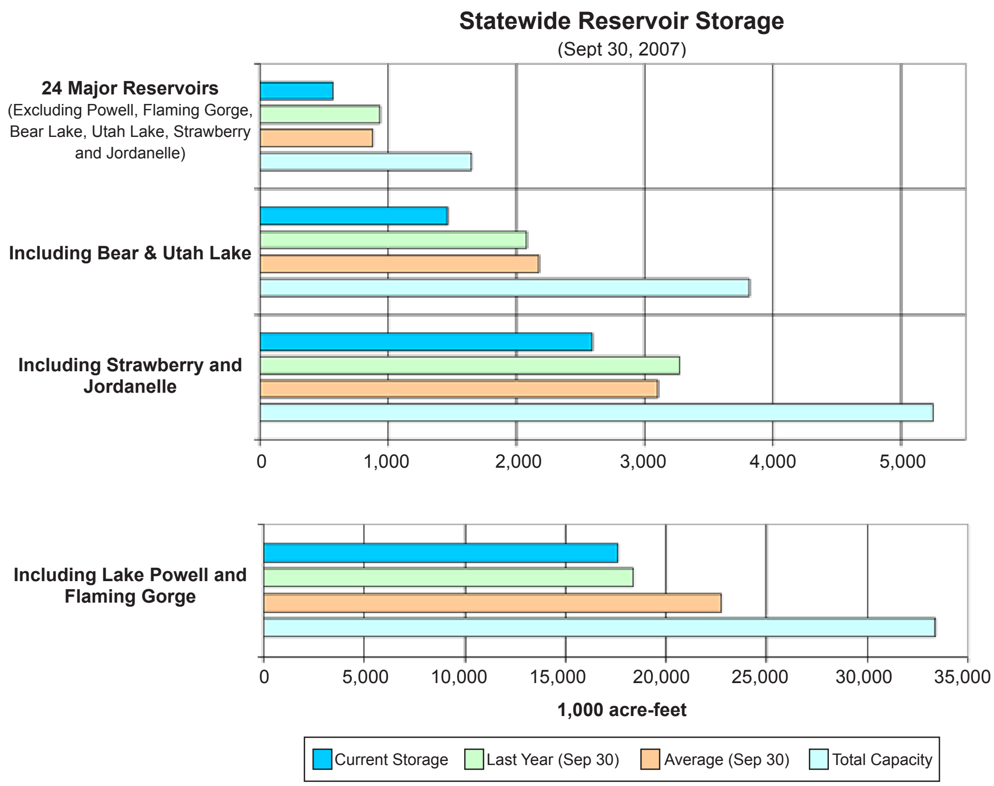


Figure 9b. Current storage conditions for major Utah reservoirs as of September 30, 2007, compared to average, last year at the same time and total capacity, courtesy of the Utah Department of Water Resources.

On the Web

- For current maps of SWE as a percent of normal as shown in 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/.
- Utah Division of Water Resources statewide reservoir storage graphs like Figure 9b available at: http://www.water.utah.gov/WaterConditions/ReservoirStorage/default.asp.
- Individual reservoir information including management agency, operations, and storage content, visit the WWA website at: http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/links.html, and click on individual links.
- The Bureau of Reclamation 2008 Draft Annual Operating Plan for Colorado River Reservoirs is available at: http://www.usbr.gov/lc/region/g4000/AOP2008/AOP08_draft.pdf.

Temperature Outlook December 2007 – April 2008

La Niña conditions are expected to have considerable impact on U.S. temperatures in December, in combination with recent trends. La Niña is typically associated with above average temperatures in the southeastern half of the U.S., roughly east of the Continental Divide and south of **Wyoming**. Long-term warming trends over the western U.S. augment the influence of La Niña on Arizona and **Utah**. In other areas, La Niña is associated with below average temperatures: these include the northern Rockies, Pacific Northwest and much of Alaska. However, the recent trend of above average temperatures would tend to cancel this out, and the result is that actual temperatures are expected to be closer to climatological averages from the 1971-2000 period.

In the outlooks released November 15th by the NOAA Climate Prediction Center, most of **Colorado** and southeastern **Utah** have increased chances of above average temperatures in December (Figure 10a). For the forecast periods from December 2007 through April 2008 (Figures 10b-d), the Intermountain West and much of the continental U.S. have increased odds of being warmer than average. For large areas, the probability of warmer than average temperatures rises above 50%, which indicates a greatly reduced chance of cooler than average temperatures on a seasonal time scale.

The December temperature forecast will be updated on November 30th 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. The Seasonal Outlooks will be updated next on December 21st.

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 being 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.

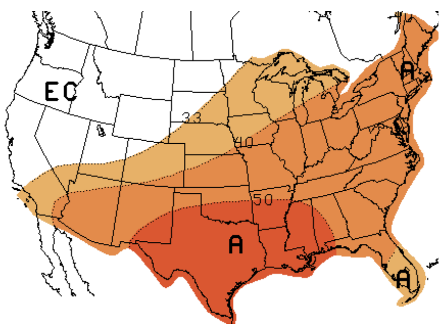


Figure 10a. Long-lead national temperature forecast for Dec. 2007 (released Nov. 15, 2007).

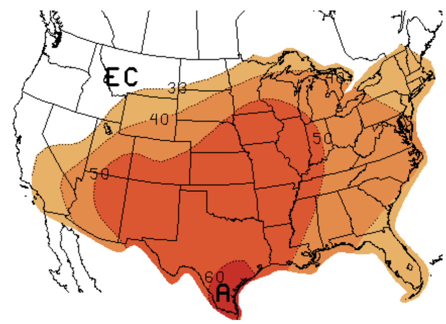
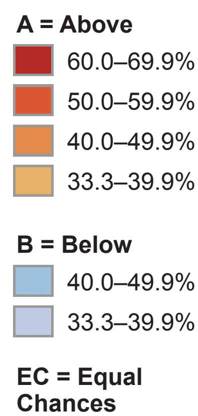


Figure 10b. Long-lead national temperature forecast for Dec. 2007 – Feb. 2008 (released Nov. 15, 2007).



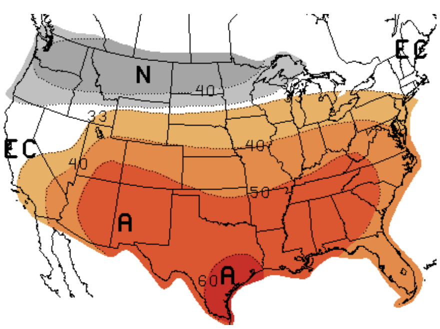


Figure 10c. Long-lead national temperature forecast for Jan. – Mar. 2008 (released Nov. 15, 2007).

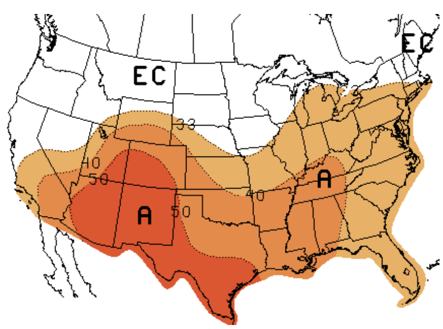


Figure 10d. Long-lead national temperature forecast for Feb. – Apr. 2008 (released Nov. 15, 2007).

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 December 2007 – April 2008

La Niña conditions are expected to have considerable impact on U.S. precipitation in December. According to NOAA/CPC, La Niña winters are associated with above average precipitation in the Pacific Northwest and below average precipitation over much of the southern part of the country. A broad range of forecast tools used by NOAA and the International Research Institute for Climate and Society (IRI) supports this typical climate anomaly. The precipitation outlooks for December 2007 through April 2008 are derived almost entirely from composites of moderate La Niñas, i.e., the observed records of past events, with probabilities adjusted to reflect the expected moderate La Niña conditions. While there are significant temperature trends in the region, precipitation trends are not significant.

The Intermountain West includes areas that tend to have a similar signal as the Pacific Northwest, and areas that tend to have a signal similar to the southwestern U.S. In the outlook for December 2007, southeastern **Colorado** is in the region with a slightly increased chance of below aveage precipitation (Figure 11a), and in the December 2007-February 2008 period through the February-April 2008 forecast periods, southern parts of **Colorado** and **Utah** are included in the regions with a slightly increased chance of below average precipitation (Figures 11b-d). In the northern parts of the Intermountain West (northern **Utah** and western **Wyoming**), there is a slightly increased chance of above average precipitation. Between these areas of opposite signals, for other areas of the intermountain West, the outlooks indicate "EC" or "equal chances" of above-average, near-normal or below-average precipitation.

The December precipitation forecast will be updated on November 30th 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. The Seasonal Outlooks will be updated next on December 21st.

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.

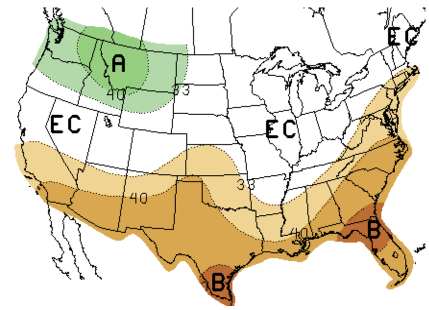


Figure 11a. Long-lead national precipitation forecast for Dec. 2007 (released Nov. 15, 2007).

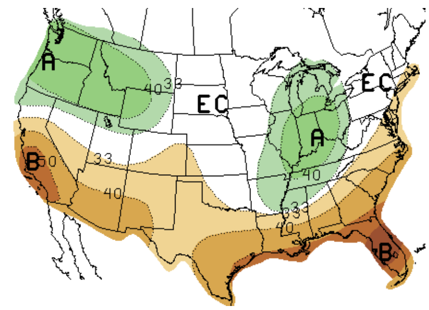


Figure 11b. Long-lead national precipitation forecast for Dec. 2007 – Feb. 2008 (released Nov. 15, 2007).

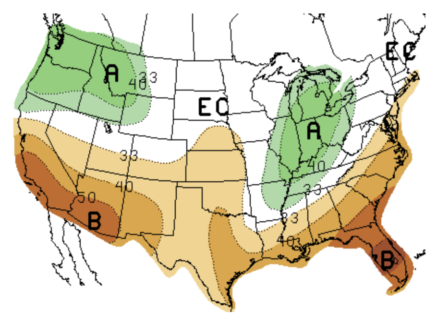


Figure 11c. Long-lead national precipitation forecast for Jan. – Mar. 2008 (released Nov. 15, 2007).

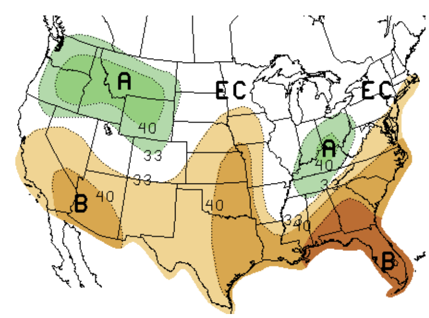


Figure 11d. Long-lead national precipitation forecast for Feb. – Apr. 2008 (released Nov. 15, 2007).

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%

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 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.

Seasonal Drought Outlook through February 2008

With the strengthening and expected persistence of La Niña conditions through early 2008, the current Drought Outlook (DO) is based precipitation anomalies that typically occur during La Niña episodes. In addition, the current DO was based on the latest short and medium range forecasts, official December 2007 -February 2008 Seasonal Climate Outlooks from the Climate Prediction Center, climatological averages, and initial drought conditions. The DO depicts general, large-scale trends through the end of February 2008 (3.5 months, Figure 12). This product projects changes in status of the U.S. Drought Monitor (USDM, see page 10), which currently designates most of the western U.S. as in drought.

Consistent with La Niña signal of above average precipitation in the Pacific Northwest, the DO projects improvement across the northern Great Basin, northern Rockies, and northern High Plains, including parts of **Utah** and **Wyoming**. An unusually widespread area of drought development is expected from the southern Rockies, including southern **Colorado** into the southern High Plains. Drought conditions are expected to persist in much of the Southwest, including southern **Utah**, because of the below average precipitation forecasts for the winter in the Southwest.

The next DO will be issued in two weeks, on December 6th.

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 11) 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.

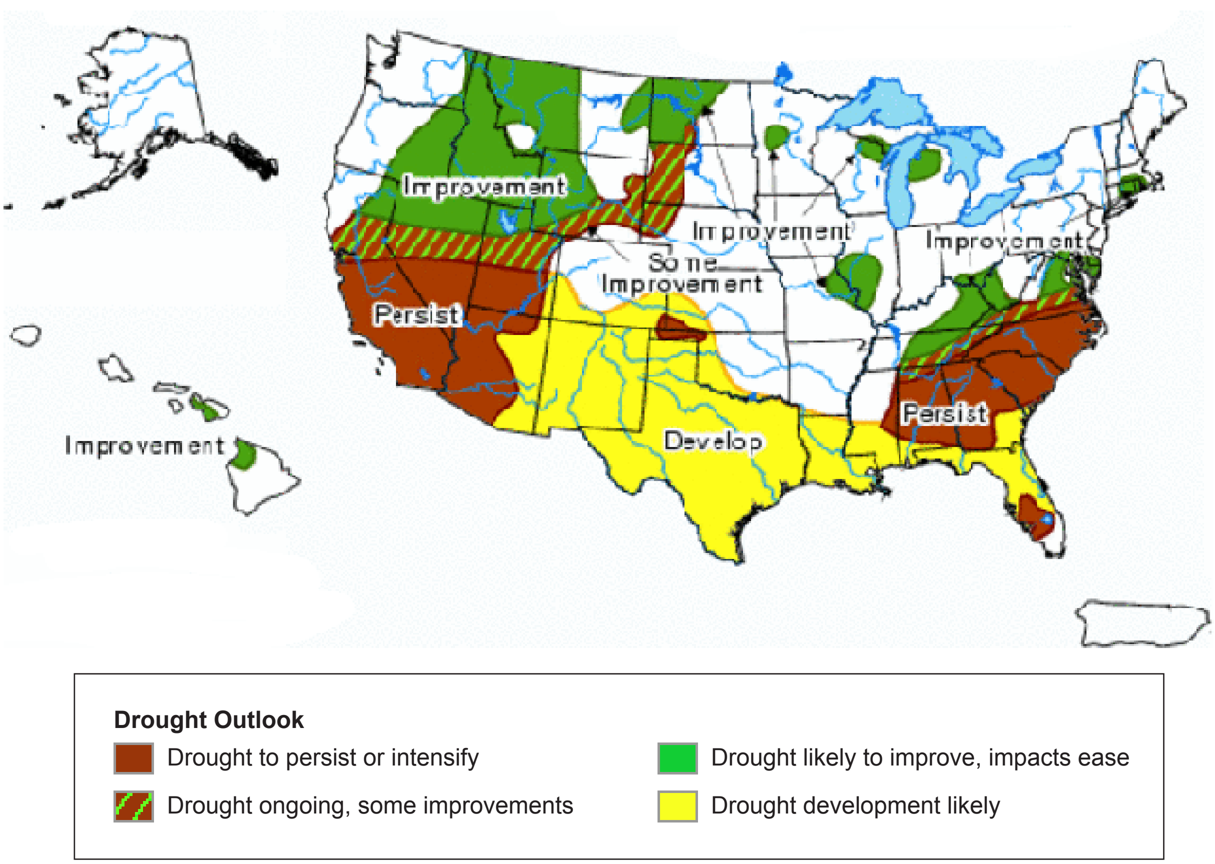


Figure 12. Seasonal Drought Outlook for November 15, 2007 through February 2008 (release date November 15, 2007).

On the Web

- For more information, visit: http://www.drought.noaa.gov/.
- Drought termination probabilities: http://www.ncdc.noaa.gov/oa/climate/research/drought/current.html

El Niño Status and Forecast

La Niña conditions continue to strengthen (La Niña refers to the periodic cooling of sea surface temperatures (SSTs) in the central and east-central equatorial Pacific that typically occur every three to five years). SSTs are below average throughout the central and eastern equatorial Pacific Ocean, and averaged 1.5º C below normal in early November, where a value of 1-1.5º C below average indicates moderate La Niña conditions (Figure 13a). The heat content in the upper 300 meters of the ocean is currently about -1.2° C (2.2° F) below average, indicating a substantial volume of cold water reinforcing the conclusion that the SSTs will remain below normal through the end of the year. Convection (i.e., clouds producing rain and transferring heat between the ocean and the atmosphere) is suppressed over much of the equatorial pacific. Low-level easterly winds are stronger than normal over the central tropical pacific. Collectively, these oceanic and atmospheric conditions reflect moderate La Niña conditions.

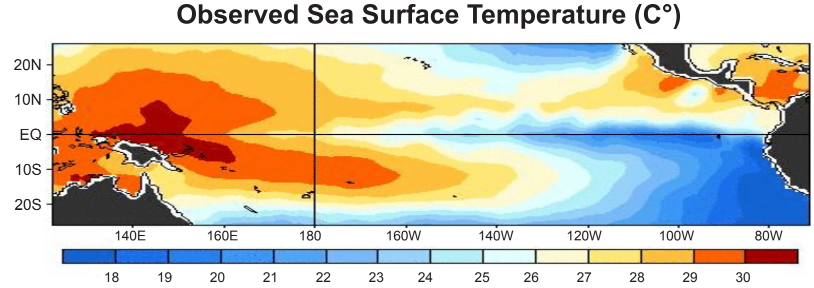
These observations agree with recent predictions from most dynamical and statistical models for this fall and winter, and support a prediction of moderate La Niña conditions over the next few months (Figure 13b). The consensus of model forecasts for Nino 3.4 SSTs indicate that the current cold SST anomalies are likely to persist through the remainder of the year and then gradually diminish in spring 2008. Specifically, NOAA reports a 98% confidence that the Nino 3.4 SSTs will remain below the -0.5° C threshold associated with La Nina conditions through the January-March 2008 forecast period, 80% through February-April 2008 and about a 50% in March-May 2008.

The CPC ENSO Diagnostic Discussion and the IRI ENSO “Quick Look” will be updated next on December 21st.

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.



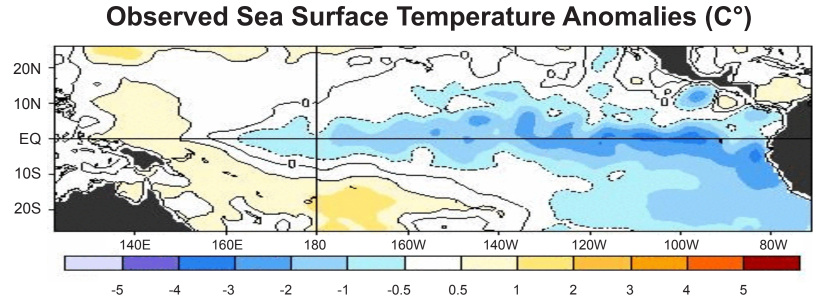


Figure 13a. Observed SST (upper) and the observed SST anomalies (lower) in the Pacific Ocean. The Niño 3.4 region encompasses the area between 120°W-170°W and 5°N-5°S. The graphics represent the 7-day average centered on November 7, 2007.

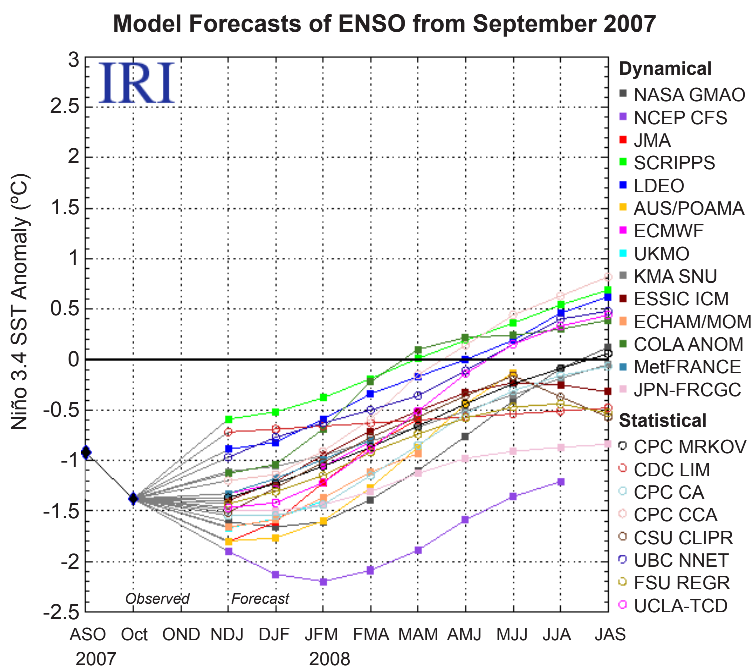


Figure 13b. Forecasts made by dynamical and statistical models for sea surface temperatures (SST) in the Niño 3.4 region for nine overlapping 3-month periods from November 2007 through September 2008 (released November 14, 2007). Forecast graphic is from the International Research Institute (IRI) for Climate and Society.

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/.

Overview of Western Water Assessment's "Water Rights and Climate Change Project"

Researchers: Doug Kenney (CU Natural Resources Law Center), Bobbie Klein (CU Center for Science and Technology Policy Research), Chris Goemans (Department of Agricultural and Resource Economics, CSU), and Christina Alvord (WWA)

Introduction

In recent years, the hydrograph of most Western rivers has shifted toward an early onset of spring snowmelt runoff tied to increasing temperatures (Stewart, et. al 2005, Regonda, et. al 2005). Under the prior appropriation system, surface water rights in the western U.S. may be limited to time of use components such as specific annual starting and ending dates or by broad terms such as "irrigation season." Changes in streamflow timing have the potential to impact western water rights in at least two ways: 1) the timing of diversions and 2) the length of the growing season. First, if spring runoff comes earlier, water rights holders may wish to divert, store and use water starting at an earlier date. Second, earlier runoff is correlated with warmer spring temperatures, which could potentially lengthen the growing season, resulting in increased demands. The relationship between earlier snowmelt and the timing of water rights has not been studied, so the WWA launched the "Water Rights and Climate Change Project," in summer 2007. It will identify how changes in the timing of spring snowmelt may impact the administration of prior appropriation surface water rights in the western U.S.; assess how a mismatch between hydrographs and temporal elements of surface water rights could cause administrative and legal complications; and identify the mechanisms available to remedy these complications. This article provides an overview of project goals, methods, and preliminary findings.

Project Steps and Completed Tasks

Over a 12-month period, Kenney, Klein, Goemans, and Alvord will conduct literature reviews, interviews with key water administrators, and in-depth analysis of state water laws. A literature review, an overview of Colorado water law regarding timing issues, and a review of timing language found in western interstate compacts are complete. They can be found on the Project's website (see On the Web box). Researchers assessed evidence of a change in snowmelt timing and reviewed statutes and administrative processes for water rights for all 11 western states. They developed a typology categorizing states based on snowmelt signal and time of use legal regimes (Table 1). The project will then select 4-6 case study states to analyze water rights decrees to better understand how temporal limitations will affect future appropriations if spring snowmelt continues to run-off earlier. Interviews with water administrators in these states will further help identify potential solutions to this problem.

Table 13. Hydrologic and Legal Trends in Streamflow Timing in the 11 Western States (Preliminary Assessment)

Timing Elements in Water Rights	Trend Toward Significantly Earlier Spring Snowmelt	
	Strong	Weak / Inconclusive
(A) **Explicit Timing Requirement.** Statutes, rules and/or case law explicitly require fixed time of year limitations in documents establishing water rights.	• Washington (stream adjudications and possibly permits) • California • Idaho • Northern Utah • Northwestern Montana (stream adjudications)	• Northern New Mexico • Utah (except northern)
(B) **Some Attention to Timing.** Statutes, rules and/or state-prescribed application forms require that fixed time of year be stated in the application for a right, but are silent as to whether time of year must be included in documents establishing water rights.	• Eastern Oregon • Eastern Arizona • Northwestern Montana (permits) • Nevada (permits) • Western Wyoming (transfers)	• Arizona (except eastern)
(C) **Silent on Timing Issues.** Statutes, application forms, water decrees, or case law may include fixed time of year limitations as an element of water rights, but it is not required.	• Western Wyoming (except transfers) • Nevada (stream adjudications)	• Colorado

Table 13: Preliminary results from an assessment of hydrologic changes and legal regimes. Certain states have varying strengths (strong or weak/inconclusive) of early snowmelt signal and are placed in multiple categories, however note that legal regimes are uniform in each state. This typology is currently under review, and comments, revisions, and other relevant observations are strongly encouraged (see On the Web box for contact information).

Preliminary Findings

An assessment of snowmelt trends and legal and administrative documents shows that earlier snowmelt in western states could potentially create problems for water rights that are limited by specific calendar dates or a season. The trend in

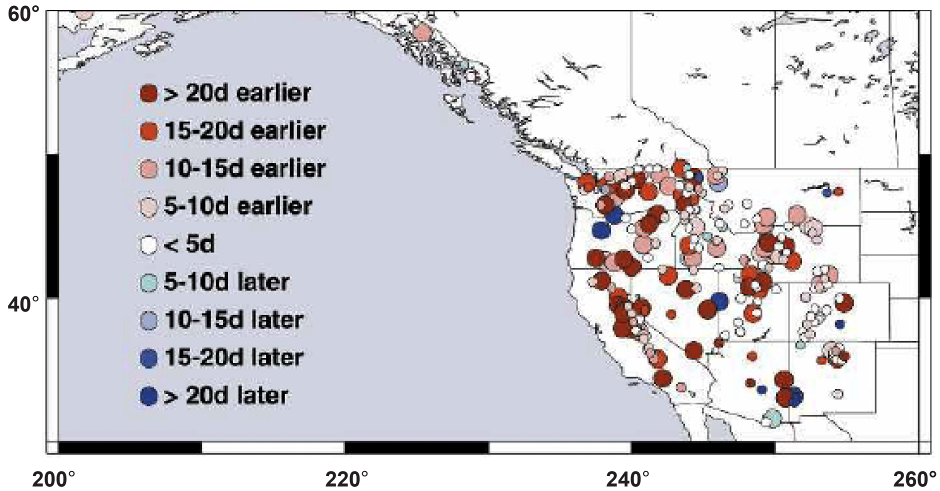


Figure 13: Stewart et., al 2005 finds that spring pulse onset of snowmelt based on gauge station data from 1948-2000 is most prominent in the Sierras and Cascades in the Pacific Northwest. However, some stations are reporting later onset of snowmelt, making it difficult to characterize strength of early snowmelt by state [Stewart, et al., 2005, Figure 2a].

earlier snowmelt and runoff is most pronounced in the Pacific Northwest, occurring as much as four weeks earlier compared to gauge records from the second half of the twentieth century (Stewart et al., 2005, Regonda et al., 2005) (Figure 13). The trend toward earlier runoff is much less pronounced (and more difficult to statistically document) in most other regions of the West. In most mountains below 8200 feet, there is a negative correlation between earlier runoff and elevation; earlier runoff has been more prominent at lower elevations.

Research of western interstate compact apportionments showed great diversity in how the timing of diversions is specified. Of particular interest is that six out of the sixteen compacts surveyed include specific spring dates (and thus are presumably sensitive to a change in snowmelt timing); eight states are signatories to these six compacts, with Colorado a signatory to four.

A wide range of water rights across the West are potentially threatened directly or inadvertently by earlier timing of spring snowmelt. A review of state statutes, administrative rules, online application forms, and case law also revealed varying degrees of time of use components ranging from states that require specific calendar dates for all water rights (e.g., CA, WA, ID, UT) to those that do not (e.g., NW, WY). In at least one state (CO), temporal components vary from specific calendar dates, to unspecified "season" of use, to no mention of time of use limitations depending on the water right and type of use. Thus, there are at least three types of water rights that can potentially be problematic with earlier snowmelt and streamflows: rights defined by explicit dates can be threatened by changing supply and demand patterns; and rights defined as "seasonal" can expand along with the demand season, likely detrimental to more junior rightsholders. Finally, rights with no time of use limitations potentially put all junior rights at risk because senior rights-holders can divert when water is available, resulting in potential injury to junior water right holders who are restrained by junior standing and/or time of use limitations. Research in coming months will identify additional vulnerabilities associated with at-risk rights and potential administrative and management solutions. Visit the project web site for project materials, updates, and contact information (see On the Web box).

References

Regonda, S.K., B. Rajagopalan, M. Clark and J. Pitlick, 2005: Seasonal cycle shifts in hydroclimatology over the western United States, *J. Clim.*, 372-384. http://civil.colorado.edu/~balajir/my-papers/regonda-etal-jclim.pdf

Stewart, I.T., D.R. Cayan and M.D. Dettinger, 2005: Changes toward earlier streamflow timing across western North America, *J. Clim.*, 1136-1155. http://earth.boisestate.edu/home/jmcnamar/seltopics/2006/stewart_timing.pdf

On the Web

The majority of materials and initial project papers (drafts) are available on the "Water Rights and Climate" website: http://wwa.colorado.edu/current_projects/water_rights__climate_change.html. These materials are being made available in draft form in an effort to generate attention, feedback, and insights from the water resources community.

- Please direct corrections, comments and questions to project leader Doug Kenney at Douglas.kenney@colorado.edu.
- For a review of early snowmelt studies, see the article by Udall and Bates, "Climatic and Hydrologic Trends in the Western U.S.: A Review of Recent Peer-Reviewed Research" in the January 2007 issue of the Intermountain West Climate Summary available at: http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/January_2007.pdf