Researchers, decision makers, and managers involved with water resources have grappled for years with how to better represent land surface hydrological conditions, such as runoff and soil moisture, over large areas. The University of Washington and Princeton University have addressed their needs with the development of surface hydrological monitoring and forecasting tools (for technical details, see Wood and Lettenmaier 2006). These tools provide information that contributes to the prediction of surface hydrology conditions and ultimately streamflow and drought over areas from tens of miles (or kilometers) up to the global scale. Such predictions are valuable to water providers, reservoir operators, ecosystem managers and others as they plan for key decisions, like irrigation supply allocations or emergency management preparations, for upcoming seasons. The basis of these tools is the use of hydrological modeling and ensemble forecast techniques, which are described below, to produce daily simulations of current land surface hydrology and monthly hydrological forecasts, with lead times of up to one year.

Depending on the spatial and temporal resolution of the input data, the tools can be used for monitoring or forecasting hydrologic state (the geographic distribution of physical conditions related to water supply), streamflow, and drought. For example, the combination of geographic data about soil moisture, temperature, evapotranspiration, and runoff could be used to describe the hydrologic state, which varies by season, year, and topography within a watershed. Researchers involved in developing the tools have assembled a continuous record of daily meteorological station input data, including precipitation, minimum and maximum air temperature, and wind speed. These variables are known as forcings, and they provide hydrology models with the input information needed to simulate the surface hydrological conditions; in this sense, the inputs to the model force the response of the model. The data begin in 1915 (U.S.) and 1925 and are available on the web.
Executive Summary

In General – Pacific Ocean conditions appear favorable for a transition to an El Niño episode, beginning during the summer months. El Niño favors tropical storm activity in the East Pacific but inhibits tropical storm activity aimed at the U.S. from the Atlantic Ocean. Spring precipitation was below average to average across the region. The most recent SMN forecasts predict average to above average precipitation for the border region for August and below average precipitation for Baja California.

Temperature – March-May seasonal temperatures were near average for the western part of the border region and above-average in more interior locations.

Precipitation – Spring precipitation was mostly below average across the border region with an influx of precipitation in some areas during May.

Precipitation Forecast – SMN forecasts predict above-average July precipitation for northern Chihuahua, Coahuila; and coastal Sonora. For August, SMN predicts near-average precipitation for most of the country. The most recently released SMN forecast (not shown in this summary) predicts above-average August precipitation in northern Sonora and Chihuahua. The forecast changes to above-average precipitation for Baja California and average to below-average precipitation in Chihuahua in September.

ENSO – Ocean temperatures are warming in the eastern tropical Pacific Ocean, heralding an El Niño episode. The El Niño will probably get into full gear during the winter. El Niño usually brings above-average winter precipitation to the border region.

Disclaimer – This packet contains official and non-official forecasts, as well as other information. While we make every effort to verify this information, please understand that we do not warrant the accuracy of any of these materials. The user assumes the entire risk related to the use of this data. CLIMAS disclaims any and all warranties, whether expressed or implied, including (without limitation) any implied warranties of merchantability or fitness for a particular purpose. In no event will CLIMAS or The University of Arizona be liable to you or to any third party for any direct, indirect, incidental, consequential, special or exemplary damages or lost profit resulting from any use or misuse of this data.

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surface hydrology, continued

(Mexico), and go through the present. Every day, the research team updates the data and interpolates them to a regular latitude-longitude grid, with grid spacings of either one-half or one-eighth degrees, depending on the application.

Using these gridded data sets, the scientists run hydrologic models to produce simulations of streamflow, soil moisture, and snow water equivalent (the amount of water in a given volume of snow; this quantity will vary, depending on the density of the snow) for the historical period up to the present day. The simulated hydrological data can be used to generate snapshots of the surface hydrological conditions, including soil moisture, runoff, evapotranspiration, and other variables. These predictions are affected by a number of surface atmospheric factors, such as solar and longwave radiation, relative humidity, and surface air temperature. As a practical matter however, the predictions are mainly influenced by precipitation and are modulated by local geology and land use. Figure 1 shows a recent estimation of soil moisture conditions relative to past conditions (i.e., as percentiles of the historical record; reds are below median conditions, greens are above, and whites are the 50th percentile—the median or mid-point of past conditions). The research team has two tools that use these procedures at two resolutions: a High-Resolution “Nowcast” (HRN; one-eighth degree, or approximately 12 x 12 km [7.5 mi.]) and the Surface Water Monitor (SWM; one-half degree, approximately 48 x 48 km [30 mi.]). The HRN (Figure 1a) produces a daily estimation of surface hydrological conditions. The SWM estimates surface hydrology using four land surface hydrology models to reduce the uncertainty in the estimates of the hydrological state produced by one single model. The outputs of one of these models (Variable Infiltration Capacity model, or VIC) become the initial conditions that are used to predict drought three months in advance.

Streamflow Prediction

On the first and fifteenth day of each month, the West-wide Seasonal Hydrological Forecast System (WSHFS) uses the HRN’s daily estimation to produce one-month time scale forecasts of land surface hydrological variables and streamflow for up to one year in advance. The WSHFS uses the initial conditions generated for the first and fifteenth of each month and produces soil moisture, runoff, snow water equivalent, and streamflow forecasts through an ensemble technique. The ensemble technique consists of running the land surface model 40 times, each time starting the model with current initial conditions but forcing the model with historical meteorological data from a different year from the period 1960 to 1999. This produces 40 different simulations of streamflow that are used to calculate probabilities of above- or below-average streamflow, which represent the future streamflow for the forecast period. This can also be used in a selective mode to simulate only those years with similar El Niño–Southern Oscillation (ENSO) conditions as at present; taking advantage of the strong climate patterns generated by the El Niño and La Niña phases of ENSO increases the forecast skill.

Figure 1b shows the current streamflow status with respect to the historical simulated streamflow for more than 250 streamflow stations throughout the U.S. and more than 20 in México (Munoz-Arriola et al. 2008). The southwestern U.S. and northwestern México in particular show conditions that range from below average to average. Figure 1c shows the naturalized values for stations in the San Juan River Basin (a tributary of the Colorado River Basin in the

Figure 2. Low resolution (spatial resolution: one-half degree [48 x 48 km] grid size) multi-model Surface Water Monitor drought forecasts. Figure 2a shows “Nowcasts” of soil moisture percentiles (as of June 3) using the following multiple land surface hydrology models: Variable Infiltration Capacity model (VIC); NOAH model (NOAH); Sacramento Soil Moisture Accounting Model (SAC); and Community Land Model (CLM) (http://www.hydro.washington.edu/forecast/monitor/curr/conus.mexico/main_sm.multimodel.shtml). Figure 2b shows the one-month lead drought forecast (made on May 27) using soil moisture percentiles as a drought index (http://www.hydro.washington.edu/forecast/monitor/outlook/index.shtml).
Tree ring studies for the border region

By Kelli Hoover, University of Colorado, and Gregg Garfin, University of Arizona

As reservoir levels declined, forest fires raged, and rangelands were devastated during the last decade in semi-arid North America, severe drought commanded the attention of resource managers, farmers, ranchers, and others. They asked how long the drought will last, how severe this drought is compared to those in the past, and how frequently do droughts like this occur.

To help answer these questions, researchers have an invaluable tool: they use annual growth rings of many trees in the region to extend, or reconstruct, gaged-based measurements of climate and streamflow. Because gaged records usually extend only 50 to 100 years, these reconstructions can provide resource managers and others with a much longer perspective—sometimes more than 1,000 years—on droughts, streamflow, climate of the past, and societal implications of climate change. At the same time, the reconstructions provide a baseline from which to measure future climate changes.

Dendrochronology: Tree-ring science

Dendrochronology, the systematic application of tree rings to reconstruct past variations in climate, began in the southwestern United States in the 1920s. Since then, scientists have refined techniques to precisely date and measure the physical and chemical characteristics of tree rings to extract information about climate, streamflow, fire ecology, and many other environmental phenomena.

In the border region, tree growth is closely associated with moisture variability. Trees, growing on dry rocky sites, are especially sensitive to variations in precipitation and evapotranspiration, and their ring records show annual variations that are closely linked to regional climate.

To analyze tree rings, small cores—the width of a pencil (4 mm)—are taken from living trees. Sometimes sections are cut from well-preserved dead trees. These cores and samples are taken back to the laboratory where they are examined under a microscope, dated, and measured. Combining core samples from many trees at a site and many sites in a region is useful to scientists in several ways: it allows them to compare the distinctive sequential patterns of large and small rings in each sample and assign precise calendar dates to each ring; use mathematical methods to remove non-climatic factors from the tree-ring measurements and develop robust chronologies to use in reconstructing past environmental variations; and account for locally absent and false rings. These types of tree rings occur when tree growth temporarily shuts down—during an intense dry spell, for example—and one annual growth ring appears very similar to two rings. Locally-absent rings occur as a result of severe drought or temperatures that are too low or too high to allow growth throughout the entire circumference of the tree for that particular year.

Scientists use statistical methods (often linear regression equations) to relate the chronologies of tree growth to gage records of precipitation, streamflow, or other variables for the period during which historical and tree-ring records overlap. The accuracy of the statistical relationships is tested on independent data, or data that have intentionally been left out of the initial statistical analysis.

Tree-ring variations usually account for 50 to 80 percent of the variation in annual or cool season precipitation or streamflow in western North America. However, reconstructing summer variations is trickier and requires scientists to analyze only part of the annual growth ring. One annual ring consists of earlywood, which grows at a rapid rate in the early part of the growth season, and latewood, which grows more slowly at the end of the season. In the border region, growth begins to slow during the hottest, driest time of year—before the summer monsoon—so scientists analyze the latewood to reconstruct summer precipitation.

By assuming that the documented relationships between tree growth and environmental factors extend back in time, scientists can apply the statistical relationship to the full tree-ring record, revealing estimates of annual climatic factors for the length of the chronology—often for more than 500 years in western North America.

Tree rings and the monsoon

The North American Monsoon (henceforth, monsoon) produces the majority of annual precipitation in the border region. Summer monsoon precipitation is highly variable and brief, but intense rains can cause substantial flooding. However, few reconstructions of summer precipitation exist. In part, this is because the majority of annual ring growth occurs early in the growing season, before the monsoon arrives, and in part because even latewood growth can be limited by factors other than precipitation during the summer season. A study by The University of Arizona’s Dave Meko and Chris Baisan showed that tree-ring chronologies developed solely from the latewood portion of the annual ring correlate well with monsoon precipitation. For the time period 1868–1992, Meko and Baisan hindcasted (made a prediction of the past) 14 dry summers, 13 of which were confirmed as dry by weather station records. The results of their study show a

continued on page 6
southwestern U.S.) and Oviachic in the Yaqui River Basin. (Naturalized values are historical, gaged streamflow data values that have been adjusted to remove the effects of human water management and use.) At the river basin sites, the forecasted streamflow is either below average or near average. This is mainly due to factors such as the pre-monsoon drought period, which reduces moisture in the watershed, and neutral ENSO conditions, which reduce the predictive skill of the technique.

Hydrological and Drought Monitoring and Prediction
The SWM is a low-resolution version of the HRN that includes a range of tools to monitor surface hydrological conditions and drought forecasts. In the HRN, the monitoring and forecasting tools are based on the simulations made only by the VIC model alone. In contrast, in the SWM, daily hydrological conditions are obtained from VIC and three other land surface hydrological models, as well as the average of all of these models (Table 1; Wang et al. 2009). The SWM forecasts use similar procedures to the WHSFS, but SWM forecasts are applied over the entire U.S. and will be expanded to include Mexico in the near future (see Figure 2a). Different methods of soil moisture and runoff calculations, which are used as indices of drought, account for some of the differences between the estimates from the SWM and the WHSFS. Figure 2b shows the one-month lead times for the forecast initialized May 27 showing drought conditions over Southern California but a reduction in drought area over Arizona and New Mexico.

The systems described above monitor and predict hydrologic conditions, and also function as research tools. Some of the systems presented above are used to evaluate techniques developed by different water-related agencies (such as NOAA and the USDA-NRCS National Water and Climate Center), and advanced forecasting methods. To compare and improve its products, the research team currently collaborates with several government agencies in the U.S. that produce their own forecasts. The team is in the process of transferring some of its systems to Mexican agencies such as Instituto Mexicano de Tecnología del Agua (IMTA) and regional offices of the Comisión Nacional del Agua. In fact, the researchers are currently developing a virtual hydrological modeling and forecast center, located at IMTA, which has started to provide training and open access to different agencies and academic centers.

<table>
<thead>
<tr>
<th>Model</th>
<th>Version</th>
<th>Soil</th>
<th>Veg</th>
<th>Snow</th>
<th>Time Step</th>
<th>Input Met Data</th>
<th>Outputs</th>
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<td>4.0.6</td>
<td>3 physically-based layers; Sub-grid variation in infiltration</td>
<td>Multiple tiles per cell</td>
<td>2-layer energy balance</td>
<td>24 h (no snow) 1 h (snow)</td>
<td>Ascii; Daily P, T min/max, Wind</td>
<td>Ascii; Daily; Cumulative moisture fluxes</td>
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<tr>
<td>CLM</td>
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<td>10 physically-based layers</td>
<td>Multiple tiles per cell</td>
<td>5-layer; Energy balance</td>
<td>1 h</td>
<td>NetCDF; Sub-daily P, T, wind, Pressure, Q, Rad</td>
<td>NetCDF; Daily; Average moisture flux rates</td>
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<td>Single veg type per cell</td>
<td>1-layer; Energy balance</td>
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<td>NetCDF; Daily; Average moisture flux rates</td>
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<td>1 h</td>
<td>NetCDF; Sub-daily P, T, wind, Pot. Evap.</td>
<td>NetCDF; Daily; Average moisture flux rates</td>
</tr>
</tbody>
</table>


Table 1. Physics formulations and input/output features of the models in the University of Washington Surface Water Monitor (Note: this table is oriented toward interested scientists and expert users of hydrologic models).
strong potential to reconstruct regional monsoon precipitation.

**Border region studies**

Dendrochronology has taken off rapidly in Mexico, and a number of multi-century reconstructions of streamflow and precipitation have been developed for the northwestern part of the country. These studies give insight into how past climatic events may have shaped the history of the region, through depletion of food and water resources, rapid spread of epidemic diseases, and increased strain on tensions between natives and colonists.

In 2003, Malcolm Cleaveland and his colleagues at the University of Arkansas reconstructed winter precipitation for the state of Durango, Mexico, for the years 1386 to 1993. The most severe drought in the Durango reconstruction occurred during 1540–1579. It correlates chronologically with tensions between native people in the region and Spanish settlers that led to the Chicameca War.

Scientific evidence shows that this drought period may have resulted in two extensive outbreaks of disease in Mexico (Acuna-Soto et al. 2002). It is estimated that nearly 80 percent of the native Mexican population died between 1545 and 1548 as a result of “coliztli” (“pest” in Nahuatl)—probably hemorrhagic fever, according to recent epidemiological evidence. A second outbreak from 1576 to 1578 is estimated to have killed nearly 50 percent of the remaining population. According to tree-ring reconstructions, the harsh climate was synchronous with the outbreak, suggesting drought could have exacerbated the spread of disease.

In Chihuahua, Mexico, the 1950s drought rates as the most severe in a 345-year record (1647–1992) of winter and spring precipitation reconstructed by Sara Díaz-Castro of Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) and her colleagues. A second severe drought period, 1798–1810, corresponds with the timing of Mexico’s War of Independence. Another study by Díaz-Castro and her colleagues reconstructs 134 years (1862–1992) of cool season (fall, winter, and spring) precipitation for Baja California Sur. This record, too, shows exceptionally severe drought during the 1940s–1950s, which closely corresponds to variations in the El Niño-Southern Oscillation.

In 2005, Jose Villanueva-Díaz of Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) and his colleagues reconstructed 228 years (1765–1993) of cool season streamflow from the Nazas River Basin in Durango, Mexico. Droughts in his record are closely associated with cultural events, such as increased migration of people into more urban areas during the severe drought of the 1990s, the Mexican War of Independence during the drought of 1797–1811, and severe droughts of 1880–1896 and 1907–1910, which may have exacerbated social tensions leading up to the 1910 Mexican Revolution (Villanueva-Díaz et al. 2005).

A related study by Matt Therrell of the University of Arkansas and others, including Villanueva-Díaz, determined that a brief but severe drought from 1785 to 1787 encompassed the infamous “El Año del Hambre” (The Year of Hunger) in colonial Mexico.

**Future work**

Tree-ring records show that some past droughts exceed 20th century droughts in both duration and severity. As regional populations and temperatures rapidly increase, the American Southwest and northwestern Mexico may be at increased risk of famine, disease, and other hardships that have been linked to drought in the past few centuries. Additional tree-ring reconstructions of flows in key streams, and of summer precipitation, are needed to provide a baseline of climate variability so that resource managers can better prepare for regional drought.

Dendrochronological reconstructions of past climate changes provide information that can be used by water managers, especially north of the border, where reservoir storage depends greatly on winter precipitation to which conifer trees are sensitive. Streamflow reconstructions by Meko and The University of Arizona’s Connie Woodhouse are used by the U.S. Bureau of Reclamation and other water management agencies concerned with variations in Colorado River flows (see *Southwest Climate Outlook*, May 2007). The reconstructions give managers more information on the range of streamflow variation (such as drought), as well as records of year-to-year sequences of flows, which are critical to understanding reservoir performance during drought. These scientists are now developing experimental reconstructions of Rio Grande flows, which will be featured in future issues of the *Border Climate Summary*.

**Selected References**


May temperatures were 1–4 degrees Celsius (around 2–8 degrees Fahrenheit) warmer than average for much of the region (Figures 1a-b). The most anomalous temperatures were in Southern California and Arizona, where May temperatures ranged from 3 to 4 degrees C above average. Tucson, Phoenix, and Flagstaff, Ariz., recorded record maximum temperatures in mid-May. The month was the warmest on record for Las Vegas, Nev., and second warmest on record for Tucson and Flagstaff. Particularly notable was a record-breaking stretch of 14 consecutive days in which May maximum temperatures exceeded 38 degrees C (100 degrees F) in Phoenix; the previous record, 13 consecutive days, was set in 1984. Spring season temperatures were average for Southern California, western Arizona, the Baja California peninsula, and coastal Sonora and Sinaloa (Figures 1c-d). Seasonal temperatures were 1–2 degrees C above average in Chihuahua, Durango, eastern Arizona, and New Mexico.

**Notes:**
Maps of recent temperature conditions were produced by the National Oceanic and Atmospheric Administration’s Climate Prediction Center (NOAA-CPC). Temperature anomalies refer to departures from the 1971–2000 arithmetic average of data for that period.

**On the Web:**
For more information:
http://www.cpc.ncep.noaa.gov/products/Drought/Atm_Circ/2m_Temp.shtml
May provided a small amount of rainfall to an otherwise dry spring season (Figures 2a-b). Most of this rainfall came in the third week of May. This was more than the average for the month throughout much of the west of mainland Mexico, Arizona, and western New Mexico. Seasonally, however, precipitation in these areas ranged from below average to average (Figures 2c-d). Southern California and all of Baja California received only traces of precipitation during March-May. Precipitation there has been far below average this spring; however, the late spring is usually dry in the coastal states.

Notes:
Maps of recent precipitation conditions were produced using data from the National Oceanic and Atmospheric Administration’s Climate Prediction Center (CPC). Precipitation anomalies refer to departures from the 1971–2000 arithmetic average of data for that period. Percentage of normal is masked out where normal precipitation is less than 0.1 mm per day.

On the Web:
For more information:
http://www.cpc.ncep.noaa.gov/products/Drought/Atm_Circ/2m_Temp.shtml
The December 2008–May 2009 Standard Precipitation Index (SPI) shows that most areas have received average precipitation over this six-month period (Figure 3). No part of the border region has received above-average precipitation during this time. Some areas showed below-median SPI values, which indicates reduced precipitation compared to the historical record; these areas included southern Baja California Sur, coastal Sonora and Sinaloa, western Chihuahua, and eastern New Mexico. This lack of precipitation is reflected in the North American Drought Monitor map (Figure 4).

**Notes:**
Source: NOAA National Climatic Data Center and Servicio Meteorológico Nacional.

The Standardized Precipitation Index (SPI) expresses precipitation in units that correspond to a normal or “bell-curve” statistical distribution. The values are standardized so that an index of zero indicates the average precipitation. The index values correspond to standard deviation units. This gives the user an immediate sense of how recent precipitation compares with the historical record. 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 use of a common statistical distribution allows users of the SPI to compare drought severity across regions with markedly different climates.

The National Oceanic and Atmospheric Administration (NOAA) and Servicio Meteorológico Nacional (SMN) have provided the individual station data that are used to calculate SPI on this map. The continuous color map is derived by taking measurements at individual meteorological stations and mathematically interpolating (estimating) values between known data points. Interpolation procedures can cause peculiar values in data-sparse regions.

**On the Web:**
For more information:

For a primer on SPI, visit http://www.climas.arizona.edu/forecasts/archive/oct2002/oct2002figs/16_The_SPI.html.
The May North American Drought Monitor (NADM) map (Figure 4) indicates little change in drought status since the February map appeared in the April Border Climate Summary. A few areas have seen changes, however. Abnormally dry conditions have expanded into central Arizona and farther south in Sinaloa. Abnormally dry conditions in Southern California and southeastern New Mexico have intensified to severe drought. The small spring season precipitation totals were not enough to relieve the majority of the region from these abnormally dry conditions. The extreme and exceptional drought status in south-central Texas has been persistent. San Antonio, Tex., implemented Stage I water restrictions in April due to the low levels of the Edwards Aquifer (http://droughtreporter.unl.edu/map.jsp).

Notes:
The North American Drought Monitor maps are based on expert assessment of variables including (but not limited to) the Standardized Precipitation 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, including NOAA’s National Climatic Data Center, NOAA’s Climate Prediction Center, the U.S. Department of Agriculture, the U.S. National Drought Mitigation Center, Agriculture and Agrifood Canada, the Meteorological Service of Canada, and the National Meteorological Service of México (SMN - Servicio Meteorológico Nacional).

On the Web:
For more information: http://www.ncdc.noaa.gov/oa/climate/monitoring/drought/nadm/
**Streamflow Forecast**

The six-month Ensemble Streamflow Prediction (ESP) forecast, released June 15 by the University of Washington and Princeton University, predicts mostly average or below-average streamflow (ranging from 30 percent below average to 10 percent above average) for gages on both sides of the Mexico-U.S. border region. The average flow is based on the period from 1960 through 1999. Forecasts for stations in Baja California, Sonora, Sinaloa, Chihuahua, and Durango predict six-month streamflow volumes of 90–110 percent of average. This includes gages on rivers such as the Rio Yaqui (Sonora and Chihuahua, 97–98 percent of average), Río Conchos (Chihuahua, 97 percent of average), and Río Piaxtla (Sinaloa, 94 percent of average). The forecast predicts 70–90 percent of average streamflow volume for the next six months for the Colorado and Little Colorado rivers at several gages in Arizona. Forecasts for Colorado River tributaries, such as the Gunnison (Colorado), Dolores (Colorado), San Juan (Utah), and Virgin rivers (Utah) all predict well below-average flows (42–85 percent of average) for the latter half of 2009. In California, The forecast for the San Joaquin River predicts 41 percent of average flows for the latter half of 2009. The forecast for the Rio Grande, near Albuquerque, New Mexico, predicts 113 percent of average flow.

The seasonal predictions for the summer months, from the International Research Institute for Climate and Society (IRI; not shown), show slightly increased chances of above-average precipitation for the New Mexico-Chihuahua border region. IRI October–December seasonal forecasts show slightly increased chances of above-average precipitation for most of northern Mexico and Texas. The IRI and Servicio Meteorológico Nacional (SMN) (Figure 5) forecasts are consistent with the ESP streamflow forecasts.

**Notes:**
The forecast information provided in Figure 5 is updated monthly by the University of Washington and Princeton University using ensemble streamflow prediction (ESP) techniques. The average of a group (ensemble) of forecasts is generated by using recent meteorology to initialize the Variable Infiltration Capacity (VIC) hydrologic model. Streamflow volume estimates are based on 40 VIC model runs, using meteorological data from the period 1960–1999. These estimates, shown in Figure 5, are expressed in terms of the percent of the 1960–1999 average streamflow at each gage.

**Figure 6.** United States and Mexico streamflow forecast through December 15.

1. San Joaquin
2. Boquilla
3. Hoover Dam
4. Davis Dam
5. Parker Dam
6. Alamo Dam
7. Imperial Dam
8. Virgin, UT
9. Near Hurricane, UT
10. Littlefield, AZ
11. Lee’s Ferry
12. Desert View, AZ
13. Near Cameron, AZ
14. Near Grand Canyon
15. Imuris
16. Near Bluff, UT
17. Oviachic
18. La Junta
19. Novillo
20. Cubil
21. Paso Nacori
22. Angostura
23. Guadalupe
24. Huapaca
25. Casas Grandes
26. Near Mcphee, CO
27. Near Bayfield, CO
28. Navajo Reservoir
29. Abraham Gonzalez
30. Albuquerque
31. Ixpalino
32. Near Del Norte, CO
33. Near Lobatos, CO
34. Near Chamita
35. Villalba
36. Las Sardinas
37. Zacatecas

**On the Web:**
For more information:
http://www.hydro.washington.edu/forecast/westwide/sflow/index.6mons.shtml#seas_vol
Precipitation Forecast

The Servicio Meteorológico Nacional (SMN) predicts total precipitation for Mexico in July will be 3 percent below average (Figure 6a). The prediction is based on years with similar patterns of precipitation, atmospheric circulation, and ocean temperatures, which affect the climate of the region; for this forecast, the years are 1956, 1967, 1977, 1992, and 2002. SMN predicts well below-average precipitation for the Baja California peninsula, but 50–100 percent above-average July precipitation for northern Chihuahua and Coahuila and coastal Sonora. For August (Figure 6b), SMN predicts near-average precipitation for most of the country. August forecasts for Baja California Norte and Coahuila show precipitation totals that are more than 20 percent below-average. For September (Figure 6c), SMN forecasts 50 percent greater-than-average rainfall for Nuevo León, whereas the agency forecasts more than 20 percent drier-than-average conditions for Chihuahua, eastern Sonora, northern Durango, and most of Baja California. These forecasts agree well with forecasts from the NOAA Climate Prediction Center (not shown). Forecasters agree the summer rains are likely to produce greater-than-average precipitation during the first half of the monsoon season along much of the border. The development of El Niño conditions in the Pacific Ocean could change the forecasts for the second half.

Notes:
This forecast was prepared by the Servicio Meteorológico Nacional (SMN). The forecast methodology was developed by Dr. Arthur Douglas (Creighton University, retired) in collaboration with SMN scientists.

The forecasts are based on the average of precipitation values from analogous years in the historical record. Selection of analogous years is based on statistical analysis of factors in oceanic and atmospheric circulation known to influence precipitation in Mexico. Unique combinations of climate indices are used in the forecasts each month. A statistical method known as cluster analysis is used to identify evolving climate patterns observed in the historic record and place each year in historical context; the years with the evolving climate patterns most similar to the current year are selected. Average atmospheric flow patterns and surface precipitation anomalies are constructed with the historic data and compared with the climatological average.

Examples of atmospheric and oceanic factors used in identifying analogue years, include: Pacific and Atlantic Ocean temperatures, tropical upper atmosphere oscillations, the position and strength of persistent high and low atmospheric pressure centers, and other factors.

The maps show predicted percent of monthly average precipitation. The legend shows the ranges of predicted percent of average precipitation associated with each color. Blues and greens indicate above-average precipitation; yellows and reds indicate below-average precipitation. White indicates precipitation within 20% of the climatological average (based on data from 1941-2002).
ENSO
(El Niño – Southern Oscillation)

The NOAA Climate Prediction Center (CPC) states that conditions favor a transition into an El Niño episode between June and August. CPC notes that although ENSO-neutral conditions persisted across the equatorial Pacific Ocean during May, sea surface temperature (SST) anomalies increased for the fifth consecutive month. The Southern Oscillation Index (SOI), a measure of the air pressure fluctuations in the equatorial Pacific Ocean, decreased slightly from 0.7 to -0.4 (Figure 7a). In general, prolonged periods of negative SOI values coincide with abnormally warm ocean waters across the eastern tropical Pacific typical of El Niño episodes.

The International Research Institute for Climate and Society (IRI) states that there is less than a 5 percent chance that conditions will evolve into another La Niña during the remainder of 2009 (Figure 7b). Whether El Niño develops or ENSO-neutral conditions continue to persist is less certain. According to CPC, considerable spread in the model forecasts continues. However, current observations, recent trends, and the dynamical model forecasts indicate that conditions are favorable for a transition from ENSO-neutral to El Niño conditions during June through August. The IRI states that the probability of such a transition is about 55 percent.

As a result, the CPC has issued an El Niño Watch as part of its new ENSO Alert System. The new system was devised to provide a succinct and standardized way of communicating ENSO conditions to the general public. An El Niño Watch is issued when an El Niño event may develop during the next three months based on current observations and forecasts. An El Niño event could bring an increased chance of precipitation to the Southwest later this fall and through the upcoming winter.

Figure 7a. The standardized values of the Southern Oscillation Index from January 1980–May 2009. La Niña/El Niño occurs when values are greater than 0.5 (blue) or less than -0.5 (red) respectively. Values between these thresholds are relatively neutral (green).

Figure 7b. IRI probabilistic ENSO forecast for El Niño 3.4 monitoring region (released June 18, 2009). Colored lines represent average historical probability of El Niño, La Niña, and neutral.

Notes:
Figure 7a shows the standardized three-month running average values of the Southern Oscillation Index (SOI) from January 1980 through May 2009. The SOI measures the atmospheric response to sea surface temperature (SST) changes across the tropical Pacific Ocean. The SOI is strongly associated with climate effects in parts of Mexico and the United States. Values greater than 0.5 represent La Niña conditions, which are frequently associated with dry winters and sometimes with wet summers in the southwestern U.S. and northwestern Mexico. Values less than -0.5 represent El Niño conditions, which are often associated with wet winters in those regions.

Figure 7b shows the IRI probabilistic El Niño-Southern Oscillation (ENSO) forecast for overlapping three month seasons. The forecast expresses the probabilities (chances) of the occurrence of three ocean conditions in the ENSO-sensitive Niño 3.4 region, as follows: El Niño is defined as the warmest 25 percent of Niño 3.4 SSTs during the three month period in question, La Niña is defined as the coolest 25 percent of Niño 3.4 SSTs, and neutral conditions are defined as SSTs falling within the remaining 50 percent of observations. The IRI probabilistic ENSO forecast is a subjective assessment of monthly model forecasts of Niño 3.4 SSTs. The forecast takes into account the indications of the individual forecast models (including expert knowledge of model skill), an average of the models, and other factors.

On the Web:
For more information: http://iri.columbia.edu/climate/ENSO/currentinfo/update.html