United States Streamflow Probabilities based on Forecasted La Niña, Winter-Spring 2000

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Although for the last 5 months the Tahiti-Darwin Southern Oscillation Index (SOI) has hovered close to normal, the “equatorial” SOI has remained in the La Niña category and predictions are calling for La Niña conditions this winter. In view of these predictions of continuing La Niña and as a direct extension of previous studies of the relations between El Niño-Southern Oscil-lation (ENSO) conditions and streamflow in the United States (e.g., Redmond and Koch, 1991; Cayan and Webb, 1992; Redmond and Cayan, 1994; Dettinger et al., 1998; Garen, 1998; Cayan et al., 1999; Dettinger et al., in press), the probabilities that United States streamflows from December 1999 through July 2000 will be in upper and lower thirds (terciles) of the historical records are estimated here. The processes that link ENSO to North American streamflow are discussed in detail in these diagnostics studies. Our justification for generating this forecast is threefold: (1) Cayan et al. (1999) recently have shown that ENSO influences on streamflow variations and extremes are proportionately larger than the corresponding precipitation teleconnections. (2) Redmond and Cayan (1994) and Dettinger et al. (in press) also have shown that the low-frequency evolution of ENSO conditions support long-lead correlations between ENSO and streamflow in many rivers of the conterminous United States. (3) In many rivers, significant (weeks-to-months) delays between precipitation and the release to streams of snowmelt or ground-water discharge can support even longer term forecasts of streamflow than is possible for precipitation. The relatively slow, orderly evolution of El Niño-Southern Oscillation episodes, the accentuated dependence of streamflow upon ENSO, and the long lags between precipitation and flow encourage us to provide the following analysis as a simple prediction of this year’s river flows.

Historical daily flow records from 1253 streamflow gages across the US were used to compute daily statistics and winter (December-March) and spring (April-July) seasonal averages for each gage’s period of record. Seasons were defined in these terms for this analysis in order to differentiate between winter-season rainfall/early-snowmelt runoff and the delayed springtime snowmelt runoff. The streamflow records analyzed all are from gages in the US Geological Survey’s Hydroclimatic Data Network (Slack and Landwehr, 1992), a network of gages determined to be largely free from human influences or station changes. Observations between 1948 and (as recently as) 1995 have been compiled and included for the streams analyzed here. The gages analyzed here provide streamflow series that begin no later than 1948 and end no earlier than 1991.

Probabilities that seasonal flows will be in the upper or lower tercile of their historical distributions during a La Niña were determined as follows: At 774 sites with records that spanned 10 or more La Niñas, the historical La Niña flows were compared to the terciles of flow from the entire period of record (La Niñas and El Niños included). Stations in which La Niña flows historically have occurred in upper and lower terciles more than +/-10% beyond the 33% of occurrences that would be expected of a random distribution of flows are plotted in the two panels of Fig. 1 as a circle with a radius proportional to the deviation of the La Niña probability from 33% (its anomalous probability of occurrence) is plotted at each station. Black dots correspond to anomalously frequent occurrences (more than 43% chance of being in the tercile) and white dots correspond to anomalously rare occurrences (less than 23% chance of being in the tercile).

During winter, probabilities of upper-tercile mean-daily flows (Fig. 1a) are enhanced in the Northwest, along parts of the Gulf Coast, and along the Atlantic Coastal Plain. Probabilities of upper-tercile flows are diminished in southern California, in the southern Great Basin, in New England, and especially in the upper Mississippi and Ohio River basins. Many rivers have increased or decreased probabilities that exceed 20% of their climatological means. Probabilities of near-normal flows (not shown) are diminished moderately in rivers scattered across the nation. However, most of the change in probabilities shown in Fig. 1a is accommodated by probabilities of lower-tercile flows in Fig. 1b that are broadly the negative of the upper-tercile probabilities.

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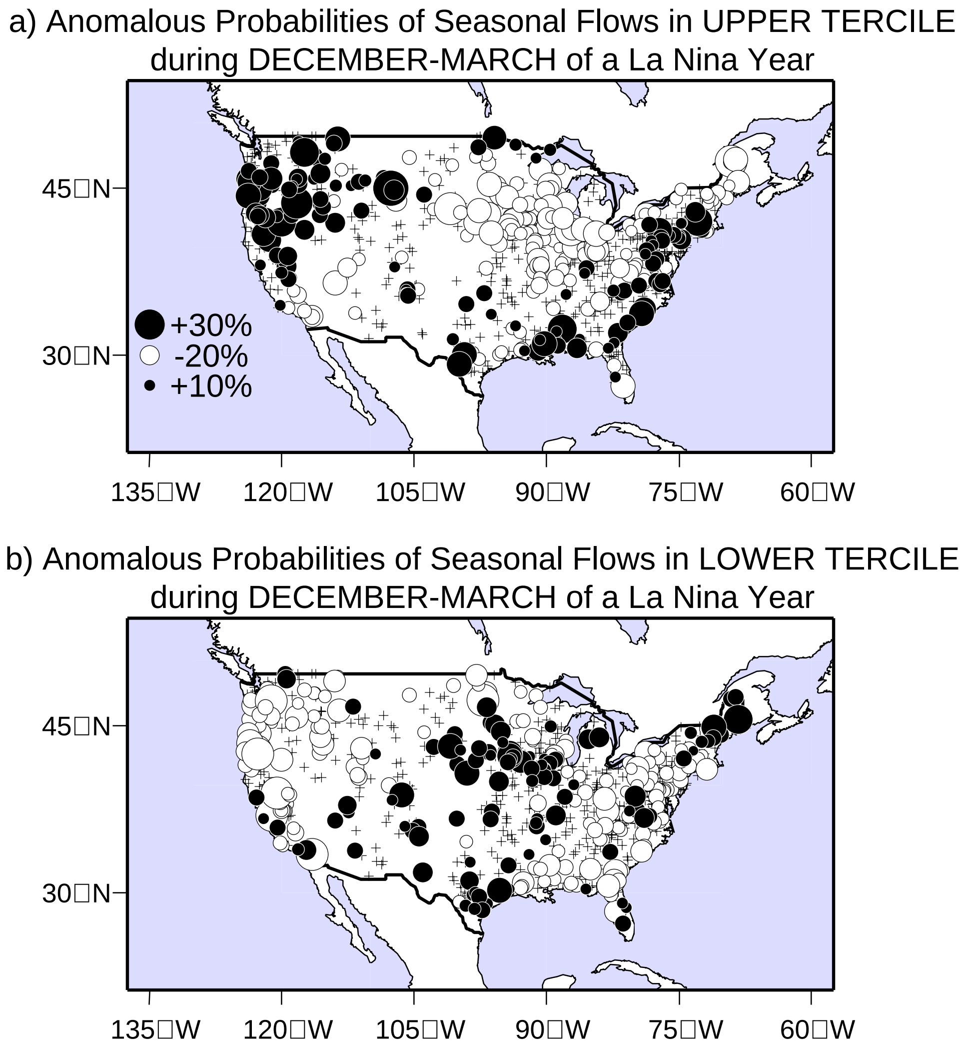

Figure 1. -- Anomalous probabilities of occurrence of seasonal-mean December-March flows in the (a) upper tercile and (b) lower tercile of historical flows at selected rivers in the conterminous United States, based on historical flows during tropical La Niña episodes. Black dots indicate rivers with probabilities at least 10% greater than the 33% probabilities expected of a random sampling (that is, greater than 43%); white dots indicate rivers with probabilities at least 10% less than the expected 33% (that is, less than 23%); dots are scaled so that the radii are proportional to the probability in excess of 33% and small crosses indicate rivers that do not reach probability thresholds for the dots.

Anomalous winter climate influences often do not register in streamflow records until the springtime thaw several months later. During spring, probabilities of upper-tercile mean-daily flows are generally accentuated relative to the winter probabilities and more spatially coherent. In other words, historically the strongest La Niña influences on streamflow volume in the United States have occurred in the spring and early summer, which usually is the period during which seasonal flows are highest. Probabilities of upper-tercile flows (Fig. 2a) are enhanced in the Northwest, in North Dakota and Minnesota, and along the Appalachians. Probabilities of upper-tercile flows are diminished from the southwestern states to Iowa, along the western Gulf Coast, in peninsular Florida, and in New England. Probabilities of middle-tercile flows (not shown) are diminished in many rivers, and no rivers have responded to La Niñas with more nearly normal flows. Instead, the anomalous likelihoods of upper-tercile flows are almost universally negatives of the probabilities of lower-tercile flows (Fig. 2b).

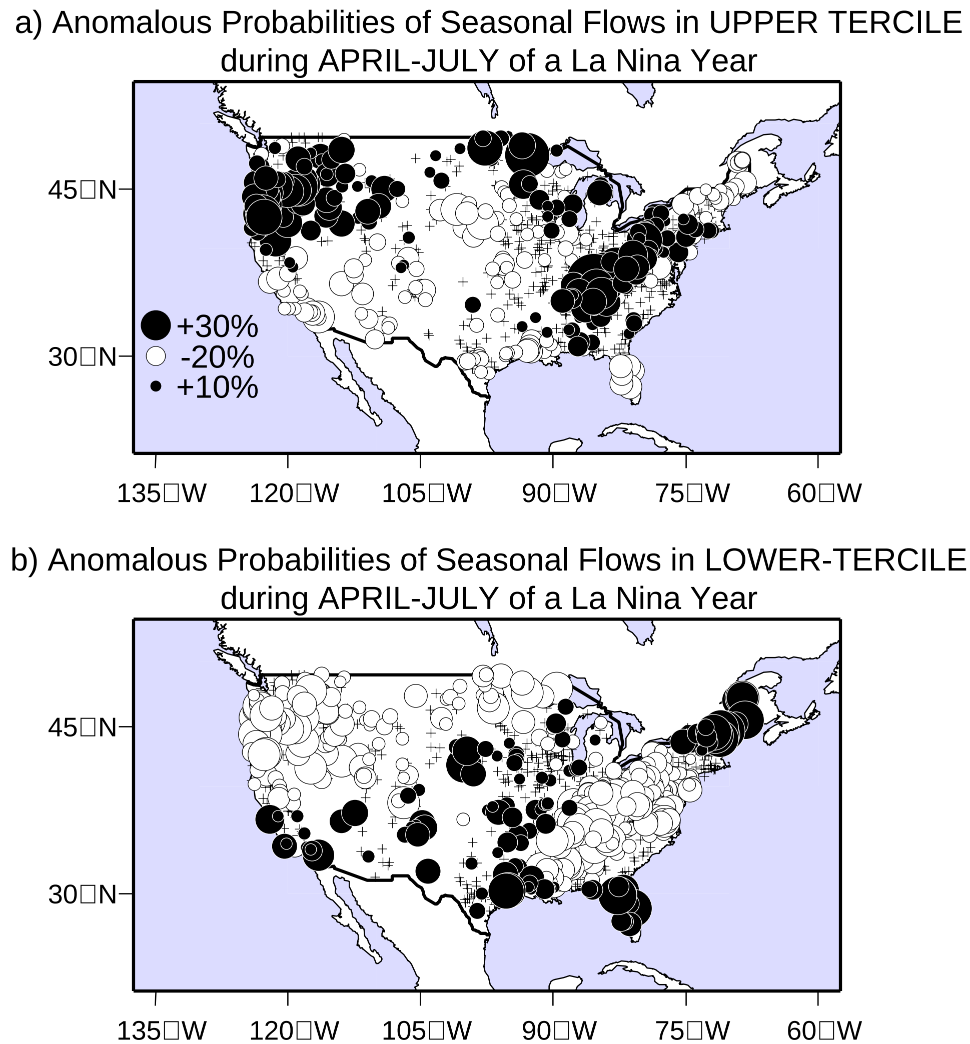

Figure 2. -- Same as Figure 1, except for seasonal-mean flows during April-July.

Probabilities of extreme daily streamflow events were analyzed according to the methods developed by Cayan et al. (1999), as follows: For each day of the calendar year, historical daily flow records at each stream were ranked, and 90th-percentile (P90) flow thresholds were determined for each Julian date of the year. The daily flow records from non-ENSO years then were compared to these P90 thresholds to develop counts of how often the thresholds have been exceeded each year. The counts represent the amount of time each year that flows in a given river were in the highest 10 percent of their historical distribution for that time of year. The non-ENSO year counts were ranked and threshold numbers of counts were divided into terciles to delineate years with anomalously frequent and anomalously rare P90 occurrences. Finally January-July daily flows during historical La Niña years were compared to these tercile thresholds to determine how much more or less likely P90 events are during La Niñas like this year's.

The probabilities of more than normal numbers of high flows that exceed seasonally varying 90th-percentile ranges during January through July are enhanced in the northwestern states and along the Eastern seaboard (Fig. 3a), Probabilities of more-than-normal numbers of P90 flows are diminished this year in the southwestern states and upper Mississippi basin. Probabilities of fewer than normal numbers of high flows (Fig. 3b) are roughly opposite the probabilities of more P90 flows than normal.

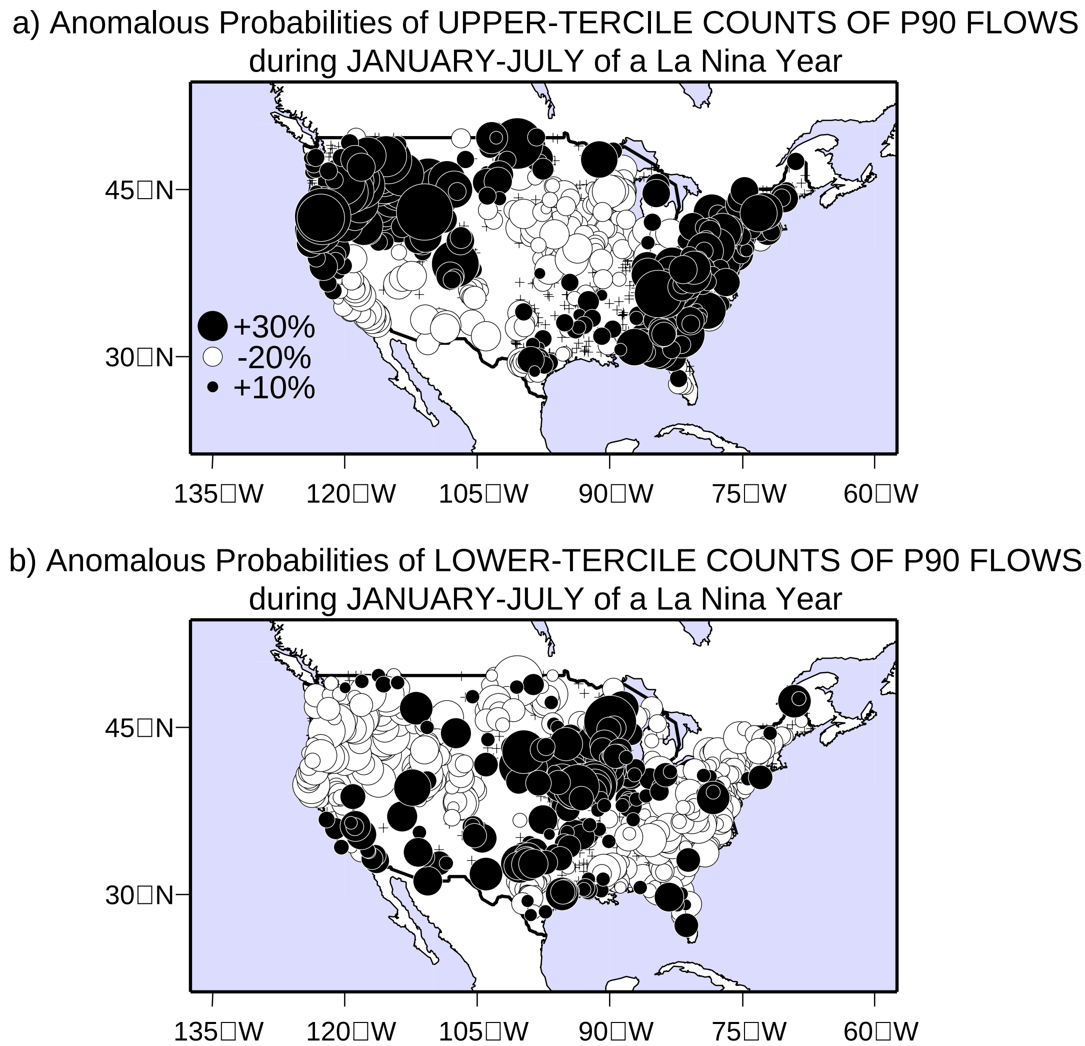

Figure 3. -- Anomalous probabilities of occurrence of anomalously (a) high and (b) low numbers of days with streamflows exceeding seasonally adjusted daily 90-th percentile levels in selected rivers in the conterminous United States; same coloring and scalings as in Figure 1.

Finally, a common depiction of flood frequencies is the annual-flood series, which consists of the single highest daily flow from each year of record at a given stream. Webb and Betancourt (1990) and Cayan and Webb (1992) have diagnosed long-term variations of the annual-flood series of the Santa Cruz River in Tucson, Arizona, to find that ENSO status modulates the return intervals of floods of all sizes. Our task here is to predict the likelihood that this year's maximum flood will be among the largest in the historical record; we do not attempt to forecast the flood magnitudes more closely than by tercile. Using the same methods and format as in the preceding paragraphs, Fig. 4 shows the anomalous probabilities that this year's maximum daily flow rate will be in the upper-tercile of the historical annual-flood series. As with the P90 statistics, the probability that this year's annual flood will rank in the upper-tercile of the historical annual-flood series is enhanced in the Northwest (in many cases, amounting to twice the normal probabilities) and diminished in the Southwest. In the eastern states, probabilities of large annual floods are more scattered than were the P90 statistics, but consistently reflect higher probabilities of upper-tercile annual floods in the rivers along the Appalachians, Great Lakes, and north central states, and lower probabilities in many rivers of the northern Mississippi basin.

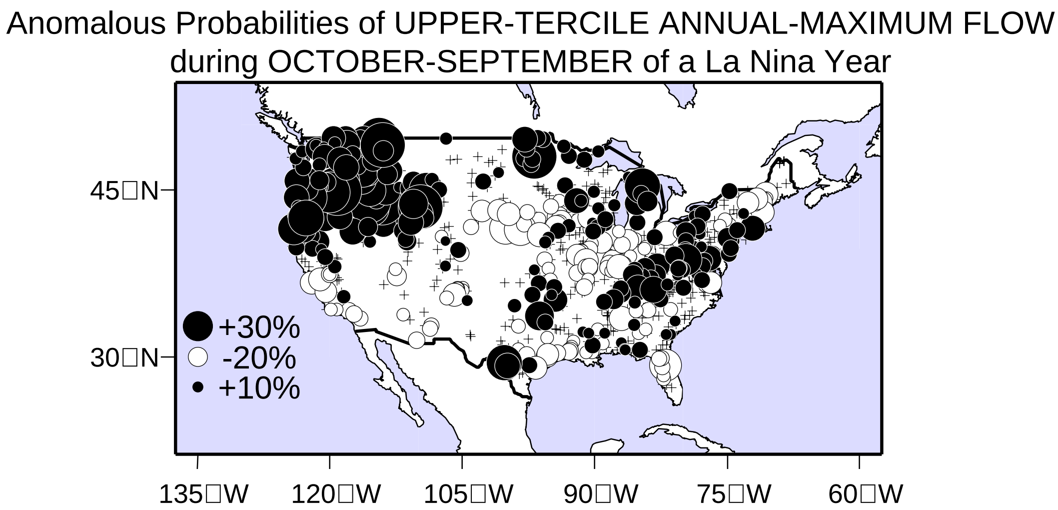

Figure 4. -- Anomalous probabilities of occurrence of a maximum-daily flow during October 1999 to September 2000 that is among the upper tercile of historical annual maximum-daily flows; same coloring and scalings as in Figure 1.

Historically, the anomalous probabilities shown here may be modulated by the status of the North Pacific Oscillation (NPO: e.g., Gershunov et al., 1998), but, this year, the NPO is hovering near neutral. Thus, the state of the NPO this year provides no sound basis for further modifying the La Niña-based streamflow probabilities presented here.

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