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The impact of abnormal temperatures and precipitation in May 2006 on seasonal runoff forecasts of the Columbia River

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Abstract

Application of the HyMet forecasting model to the Columbia River in the Pacific NW reveals that two abnormal but compensating weather events in May 2006 sharply decreased then increased basin water storage, significantly altering seasonal runoff forecasts. First, a week of hot, dry conditions that covered nearly all of Western North America from May 14-20 caused an unusual increase in evapo-transpiration, sublimation and high rates of snowmelt runoff. Water storage in the basin above Grand Coulee Dam decreased approximately 14 % and the January-July forecast declined from 108% to 102% of average. This event was followed by a week of unprecedented rates of precipitation in Washington and Oregon that recovered most of the lost water storage and caused the January-July forecast to rebound to 111% *. Although a cause and effect mechanism relating the two events has not been demonstrated, it is suggested that the extreme temperatures caused high rates of oceanic evaporation that precipitated as rain and snow in the Columbia basin during the following week. Further research may disclose the influence that global warming may have had in causing these extraordinary weather phenomena.

* Based on the 1969-2005 period.

Introduction

The Columbia River hydroelectric system is one of the leading economic assets of the United States, generating over 600 GWh of energy each year valued at as much as $50 billion. In addition, Columbia River streamflow and groundwater used for irrigation-agriculture produces food crops valued at $3.5 billion annually, and its flows are essential for commercial fisheries. Seasonal forecasts of the volume of water produced from the melting snowpack and groundwater outflow in the Columbia Basin enhance the value of runoff. Information derived from weekly or bi-weekly runoff forecasts are used by public and private utilities, energy traders, farmers, and financial institutions in the Pacific NW for operational planning.

Forecasting Columbia River streamflow

Accurate forecasts of Columbia River seasonal inflows have substantial economic value; consequently the National Weather Service and other federal agencies invest several million dollars each year for instrumentation, hydrologic modeling, labor, helicopter time and other supporting services to forecast runoff in the Columbia basin (Day et al, 1992: Pica, 1997: Laurine, et al, 1996, 2003). Several attempts have been made to incorporate ENSO (El Nino Southern Oscillation) indices into the seasonal forecasts; some have been successful, others have not (Hamlet and Lettenmaier, 1999). The most critical hydrologic factor required to produce forecasts with the highest accuracy is precise knowledge of the amount and altitude distribution of water stored in the basin on the day of the forecast (Tangborn, 1991). Several different approaches have been used to determine the spatial extent and volume of basin water storage, the most prominent is the vast network of SnoTel and Snow Survey sites established and operated by several US Federal and British Columbia agencies.

Alternative forecasting methods are also available, one of which is the HyMet (formerly HM) forecasting model that has been used for the past three decades to forecast streamflow in western United States, including the Columbia River (Tangborn and Rasmussen, 1976 and 1977, Tangborn 1987 and 1991).

One advantageous feature of the HyMet model is that it requires only daily observations of precipitation and temperature collected by the NWS network of cooperative weather stations, consequently the costs of data collection are miniscule. There is an added advantage of greater forecasting versatility because input data are near real-time and in daily time increments. Based on seasonal forecasts for the past six years, accuracy of the HyMet forecasts are slightly greater than those produced by the National Weather Service. Daily observations from fifty-three precipitation and four temperature cooperative weather stations, selected as the most representative of Columbia basin conditions, are used in the HyMet model. Weather station selection, a critical factor in streamflow forecasting models, uses a split- sample procedure and only those stations that demonstrate high forecast accuracy are weighted and retained. These data are applied in the model to calculate precipitation as rain or snowfall, snowmelt, evapo-transpiration, sublimation and other hydrological parameters at each 50 meter (165-foot) altitude interval throughout the basin (Figure 1).

Abnormal meteorological conditions in May 2006

Temperatures throughout the Columbia Basin in May are normally in the 10-13 ° C (50-55° F) range and precipitation over the basin above Grand Coulee Dam averages about 64 mm (2.5 inches) for the month. However, from May 14 to 21, 2006, both the daily maximum and minimum temperatures were from 4-11° C (8-20 ° F) above the historical average (Figure 2). The week following this un-seasonal heat wave was marked by unprecedented precipitation rates in the Columbia basin. The 53-station average used for Grand Coulee Dam was 230 % of normal for the week, with some stations reporting as high as 450 % of normal for the week of May 22-28. The resulting increase in basin water storage, occurring mostly as groundwater storage due to heavy precipitation as rain, caused the HyMet Jan-Jul forecast on May 28 to rebound to a point higher (111 %) than it was before the high temperature event, as shown in Figure 3. (all

The impact of these unprecedented high temperatures on basin water storage was significant. During the week of May 15-21 in the basin above Grand Coulee Dam, water storage averaged over the basin decreased from 420 to 360 mm (16.6 to 14.3 inches or 110.5 to 97.5 % of average). Part of this decline was due to snowmelt that was discharged from the basin as direct runoff (the peak inflow at Grand Coulee Dam was 167% of average on May 21 and flooding occurred in many areas), and in part due to apparent high rates of evapo-transpiration and sublimation (as simulated by the HyMet model). The basin-averaged snowpack water content decreased 51 %, from 290 mm (11.3 inches) on May 15 to 140 mm (5.5 inches) on May 21, and the January-July forecast decreased from 108 to 102%. Cumulative ET plus sublimation from October 1 was 85 mm (3.33 inches) on May 15, increasing to 162 mm (6.36 inches) on May 21. A comparable high rate of evaporative losses from this basin had not previously been observed during the 1969-2005 period.

Impact on hydrology and runoff forecasts

The effect of these basin water losses on the Grand Coulee runoff forecast was unusually severe for this time of the season. The Jan-Jul HyMet forecast was 108 % on May 14 and 102% on May 21, a drop of 6 % during the week (Figure 2). Consequently, the expected inflow at Grand Coulee was reduced from 67.9 MAF (millions of acre-feet*) on May 14 to 64.3 MAF on May 21, a decrease of 3.6 MAF. Each MAF of inflow translates to approximately $25 million in revenue from power generation at Grand Coulee Dam, thus there was a potential loss in energy revenue at this dam valued at approximately $90 million, the result of a week of high temperatures and associated meteorological phenomena (e.g. low humidity, high evapo-transpiration).

* 1 million acre-feet = 1.234 billion cubic meters

It is unusual for Columbia basin water storage, consequently the Jan-Jul runoff forecast, to fluctuate so widely this late in the season because the forecast is defined by the total volume of runoff between January 1 and July 31. More than half of the Jan-Jul total usually has occurred by June 1, and the forecast this year at the end of May is composed of 62% observed and 38% predicted inflow. Also, basin water storage (snowpack water content plus groundwater storage) is firmly established by mid-May and negligible changes are expected afterward.

The high temperatures of May 14-21 observed in the Columbia basin were prevalent in all the western states (Figure 4). However, the high rates of precipitation during the following week were more confined to the Pacific NW (Figure 5). It can be reasoned that widesread high temperatures caused increased evaporation from the Pacific Ocean and charged the atmosphere with excess water vapor, which then occurred as precipitation over the Pacific NW the following week. Both the temperature and the precipitation events were abnormal, and the juxtaposition of a heat wave followed by heavy precipitation is even more unusual. Although a similar situation did not occur during the 2007 season, these extraordinary meteorological events may be a warning of unpredictable and severe weather that lies ahead.

Conclusions

Two extreme and large-scale temperature and precipitation events of May 2006 in western United States produced a rapid decline then a recovery in Columbia River basin water storage, significantly but temporarily altering the seasonal runoff forecasts. Further analysis is needed to determine if these large-scale events, which fortunately were compensating with regard to basin water storage and runoff, are physically and climatologically related, and if they are the first indication the influence global warming will have on future water supplies.

Acknowlegement

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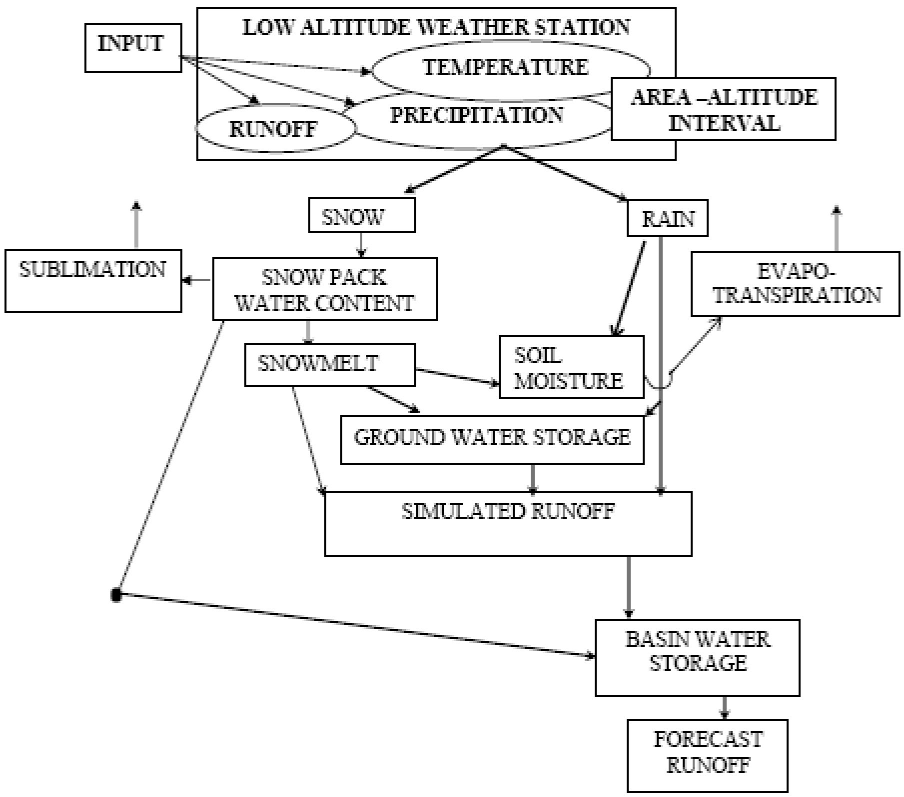

Figure 1. Simplified flow chart for the HyMet model that represents water routing for each day of the 1966-2006 period for each of the 58 area-altitude intervals and for the total basin above Grand Coulee Dam, and used to produce the seasonal forecasts each week based on the calculated basin water storage.

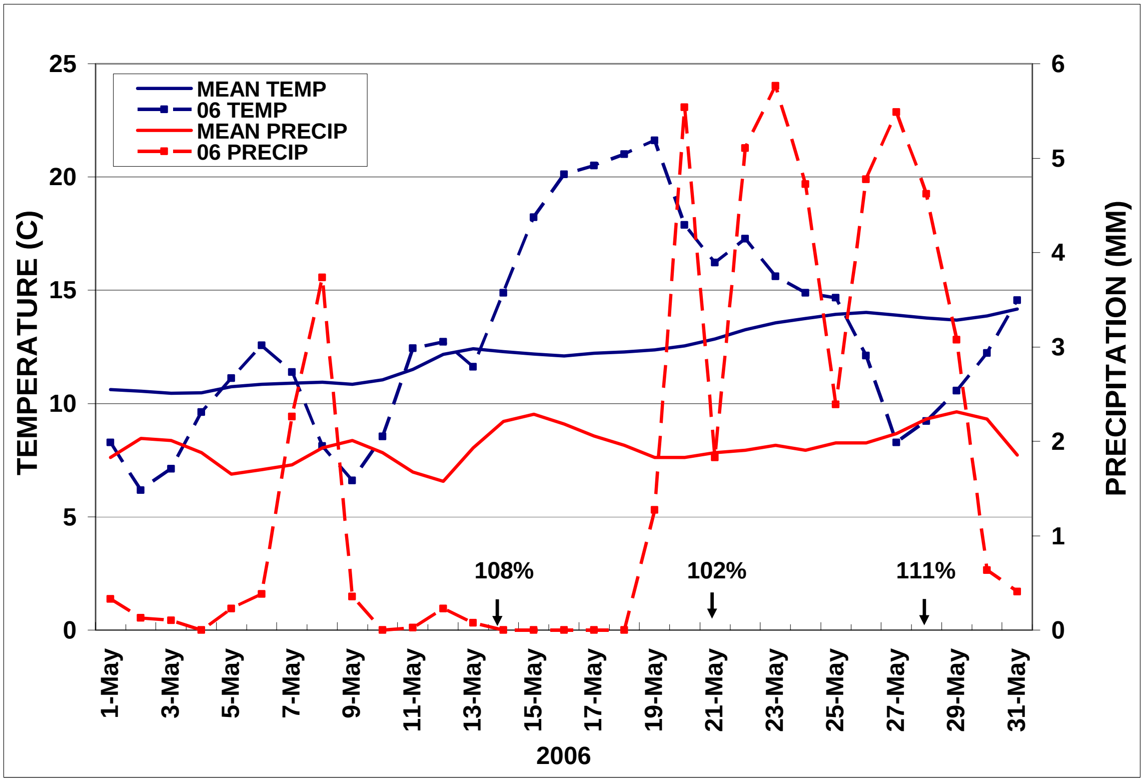

Figure 2. Mean daily temperature (1969-2005 average of the daily maximum and minimum) in the Columbia basin (solid blue line) and during the month of May in 2006 (dashed blue line), and mean daily precipitation (1969-2005 average, solid red line) and in 2006 (dashed red line) into the basin in May. HyMet forecasts on May 14, 21 and 28 (arrows) are shown as percent of normal January-July inflows.

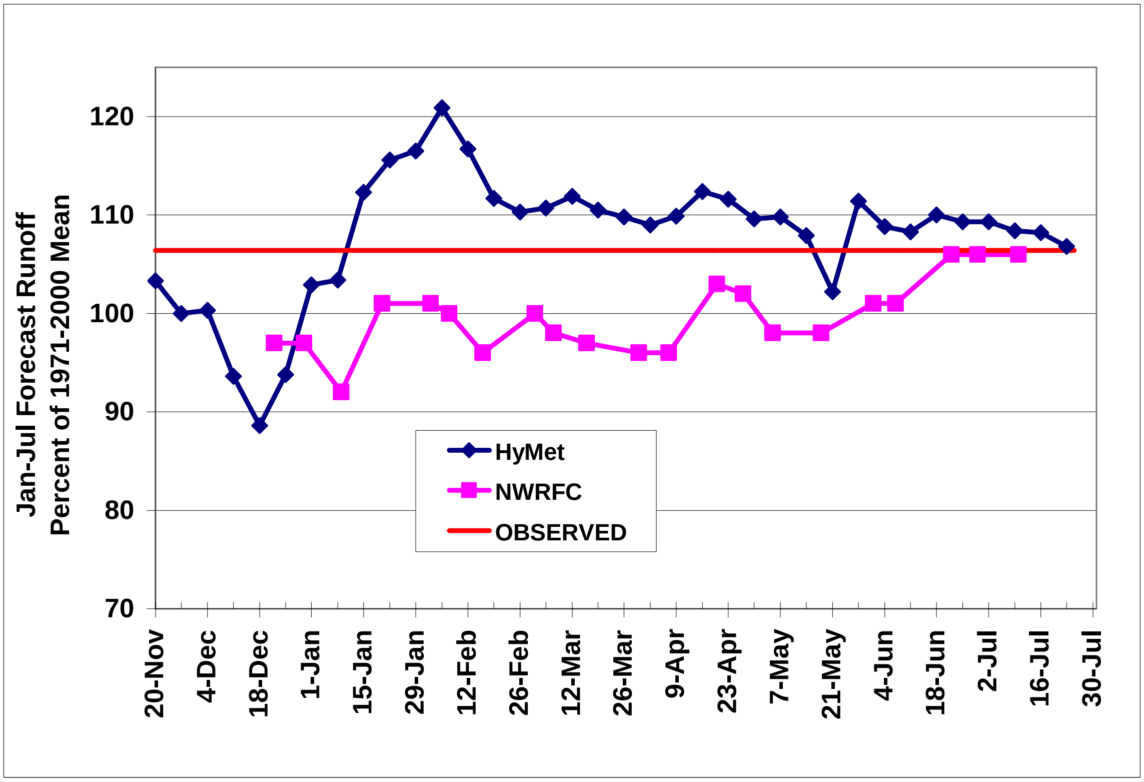

Figure 3. Comparison the HyMet and NWRFC (Northwest River Forecast Center) Jan-Jul forecasts during the 2005-2006 season. Hymet forecasts are run each week starting in mid-November and NWRFC forecasts are usually biweekly, starting in mid- December. The May 21-26 dip and recovery of forecast runoff appears for the weekly HyMet forecasts but not for NWRFC, likely because their forecasts are made at two-week intervals. The mean error of forecasts from December 22 to July 10 are 7.0% for 21 forecasts made by NWRFC and 5.8% for 30 forecasts made by HyMet.

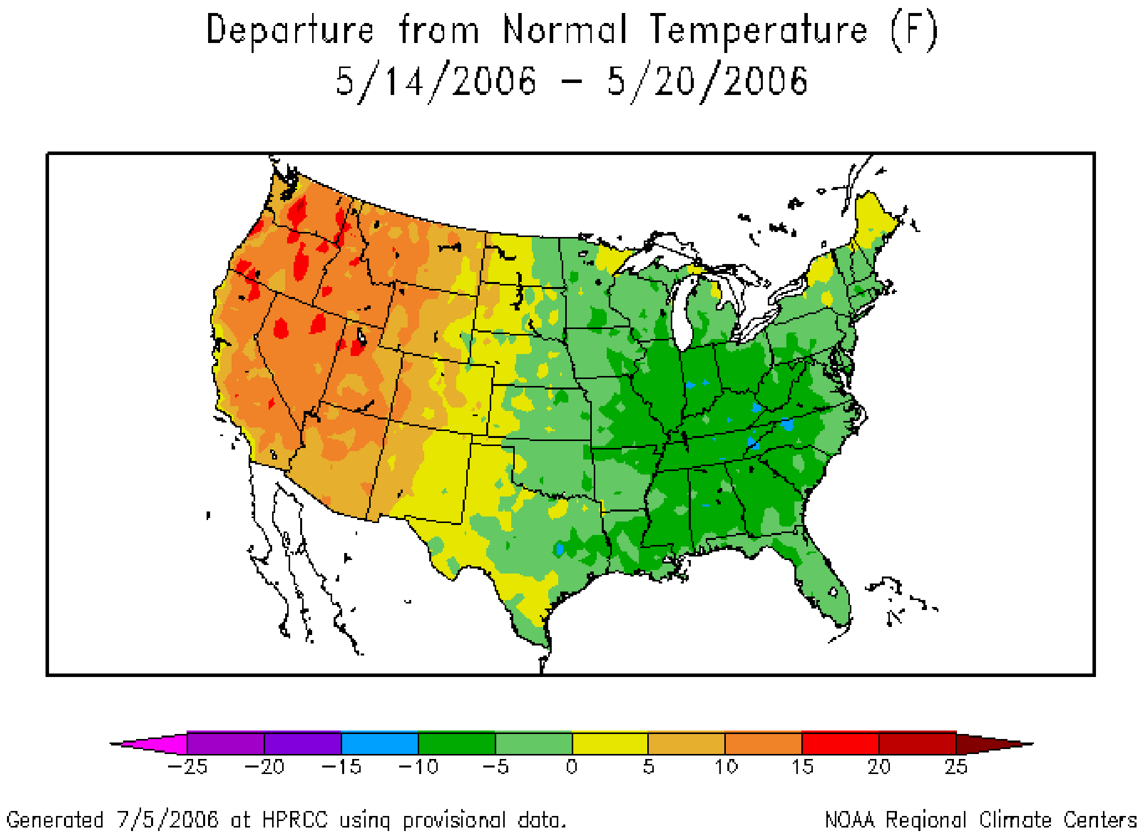

Figure 4. Temperature departures during the week of May 14-20, 2006 indicate that most of the western states, and particularly the Pacific NW, had temperatures that were 15-25 ° F (8-14 ° C) above the historical average (High Plains Regional Climate Center, University of Nebraska).

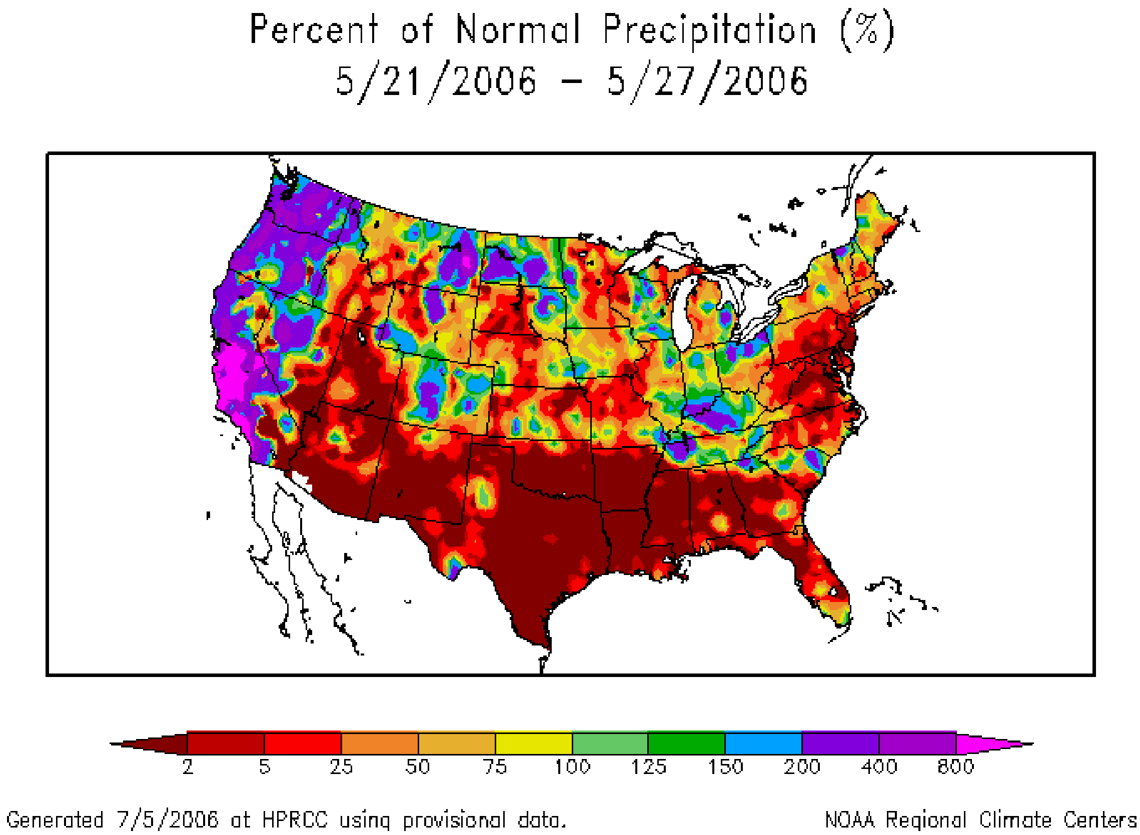

Figure 5. Precipitation (as a percent of normal) during the week of May 21-27 demonstrate that the Pacific NW and California received 2 to 8 times as much as usually occurs during this week (High Plains Regional Climate Center, University of Nebraska)