THE WATER RESOURCES AND CLIMATE ASSESSMENT TOOL (WARCAT) DEVELOPED FOR THE SANTA CRUZ ACTIVE MANAGEMENT AREA (SCAMA)

By

Eylon Shamir, Jason A. Sperfslage, Randall J. Banks and Cristopher R. Spencer

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Hydrologic Research Center

11440 West Bernardo Court, Suite 375

San Diego, CA 92127 USA

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ABSTRACT

This Technical Note describes the Water Resources and Climate Assessment Tool (WARCAT) website that was developed for the Santa Cruz Active Management Area (SCAMA) (url: https://warcat.hrcwater.org/SCAMA). This web site is designed as a one-stop portal that serves pertinent and timely information with respect to decision making for optimal water resources management and planning at the Santa Cruz Active Management Area (SCAMA). The portal provides an intuitive presentation of current relevant hydrological and meteorological datasets. The portal harmonizes regional database and provides a seasonal hydrologic and climate first order forecasts. The datasets are assembled in real-time from the Arizona Department of Water Resources, US Geological Survey, US National Weather Service, National Centers for Environmental Prediction (NCEP), and the Santa Cruz County ALERT system.

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The WARCAT-SCAMA website url: https://warcat.hrcwater.org/SCAMA

Users are cautioned in their use of information from the WARCAT portal. The real-time datasets presented are freely available from their respective agencies with various levels of quality control procedures. Please refer to the Disclaimers and Use page for additional information in this regard. Links to the data agencies can be found on the Links page.

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1. INTRODUCTION

This report summarizes the ideas and features of the Water Resources and Climate Assessment Tool (WARCAT) website that was developed for the Santa Cruz Active Management Area (SCAMA) (url: https://warcat.hrcwater.org/SCAMA). This web site is designed to provide water managers, stakeholders and other interested individuals with information that facilitates assessment of the current hydrologic conditions in the SCAMA. The SCAMA, located in the Sonora desert in Southern Arizona, relies on local groundwater reservoirs to meet the water demand of its residents. In this arid region, the availability of the local water resources is tightly connected to the region's variable climate. Thus, these resources must be carefully managed in order to reliably provide water for the residents and to sustain the health of the vibrant vegetation corridor along the Santa Cruz River. The WARCAT provides an information portal that assimilates real-time hydrological and meteorological data from different sources to present pertinent information in an intuitive manner in order to enrich understanding of the current hydrologic conditions.

The datasets analyzed by WARCAT are from various observations and forecasts sources. The observed datasets which are being retrieved and updated in real time, include streamflow discharge from the U.S Geological Survey, daily precipitation from National Oceanic and Atmospheric Administration (NOAA) and the SCAMA ALERT System, groundwater levels from Arizona Department of Water Resources (ADWR) and inflow-outflow of the Nogales International Wastewater Treatment Plant (NIWTP) from AZ Department of Environmental Quality. The observations of the current condition are presented in comparison to various historical references such as recent years, El Nino and La Nina years, as well as historical quantiles.

The forecast data in WARCAT are based on the Climate Forecast System (CFS) from the National Centers of Environmental Prediction (NCEP-NOAA) for precipitation and the Colorado Basin River Forecast Center (CBRFC) of the National Weather Service (NWS) for short-term streamflow forecasts. The information from these two sources is analyzed and presented in the form of monthly precipitation forecasts (up to 3 months) and short-term streamflow forecasts

(out to 5 days). The monthly precipitation forecasts in conjunction with the historical record of streamflow are used to produce an ensemble of streamflow projections for the upcoming month, for the Santa Cruz River near Nogales. The appropriate tercile of the projected ensemble is marked based on the categorical analysis of the monthly precipitation forecast.

2. Real time Observations

2.1 Streamflow

Daily streamflow data are routinely downloaded from the U.S. Geological Survey. Real-time data, quality controlled data, statistical indices and gauge information are available from: http://waterdata.usgs.gov/az/nwis/nwis. The streamflow discharge for a given location can be plotted for three selected durations: Water Year [1 October - 30 September], Winter [1 October - 30 April] and Summer [1 May - 30 September]. The streamflow discharge units can be displayed in Cubic Feet per Second (CFS), Cubic Meter per Second (CMS), Kiloliter per Second (KLPS), Acre Feet per Day (ACFTD), or Mega Gallon per Day MGD. All units can be displayed as daily intervals. The ACFTD and MGD units can also be displayed as cumulative values from the beginning of the selected duration. (i.e. water year, winter or summer). The daily streamflow is defined as the average flow rate during 24 hours, ending at midnight Mountain Standard Time [MST].

Figure 2.1 is a screenshot example of a streamflow plot for the Santa Cruz River station near Nogales, Arizona. The metadata of the station and a location map is shown in the right panel. In the time series panel (left) several indices are available for activation by selecting check boxes that include the streamflow condition for the selected duration (i.e. water year, summer or winter), the current selected duration (red), the four previous years, (blue), and all the available historical years (gray).

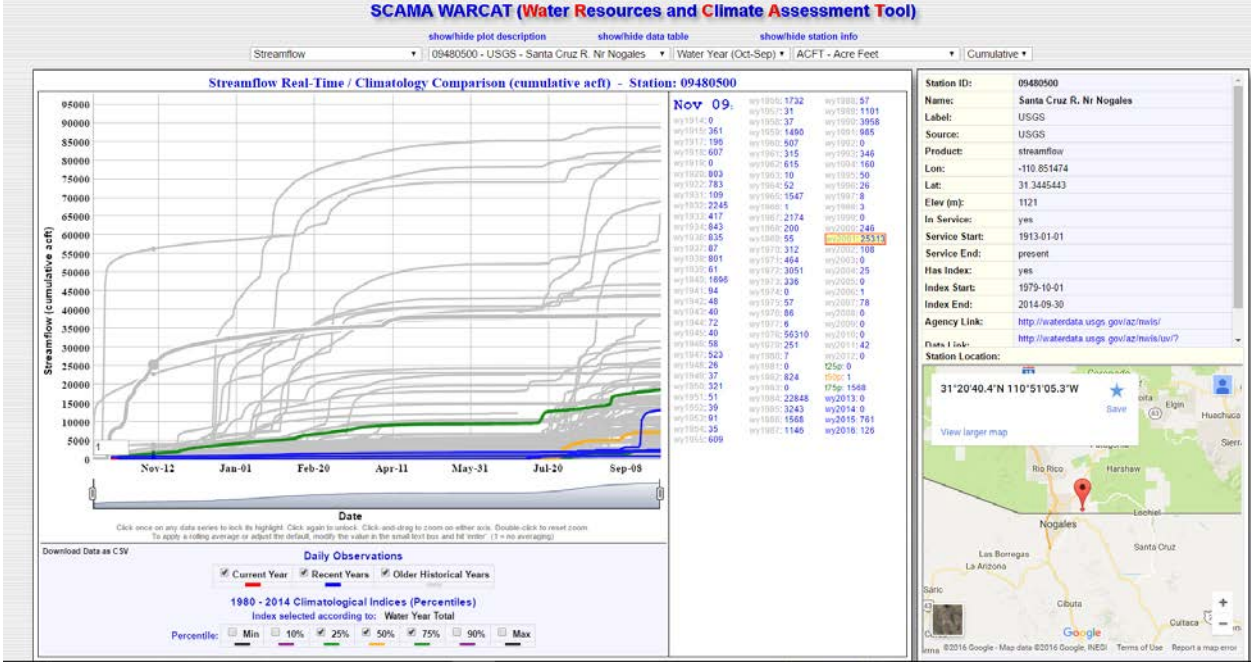

Figure 2.1: An example of a streamflow plot.

In addition, these time series are compared to climatological indices that were calculated for the selected duration (water years, winter or summer) for gauges that have data available for 1980-2014. The climatological percentiles (minimum, 10%, 25%, 50%, 75%, 90%, and maximum) are assigned based on the selected duration total. In other words, the percentiles were calculated based on the value at the end of the duration. For example, when water year is selected as the duration of interest, the total cumulative flow at the end of the water years (September 30) during 1980-2014 were used as the distribution sample for the calculation of percentiles.

Six USGS streamflow gauges are currently included in the WARCAT (Figure 2.2). Five of the gauges are located on the main stem of the Santa Cruz River and one is located in Nogales Wash, a tributary to the Santa Cruz River. Two of the USGS gauges are, as of October 2016, inactive. These are the Lochiel gauge at the border crossing from U.S. to Mexico and the Amado gauge, which measures the flow at the boundary between the Santa Cruz and Tucson AMAs.

Figure 2.2: The USGS streamflow gauges indicated as red dots that are included in WARCAT-SCAMA

2.2. PRECIPITATION

Daily precipitation data are reported as the cumulative precipitation during 24 hours ending at midnight Mountain Standard Time [MST]. The precipitation data are routinely downloaded from two sources:

1) National Centers for Environmental Information [NCEI], NOAA

NCEI real-time data, quality controlled data, statistical indices and gauge information are available from: https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/global-historical-climatology-network-ghcn

Note that this dataset is not updated in real time and therefore may not be adequate for evaluation of the hydrologic conditions during events. There are 26 gauges available for the region in which 14 gauges are active, as of October 2016. The available NCEI active gauges are shown in Figure 2.3

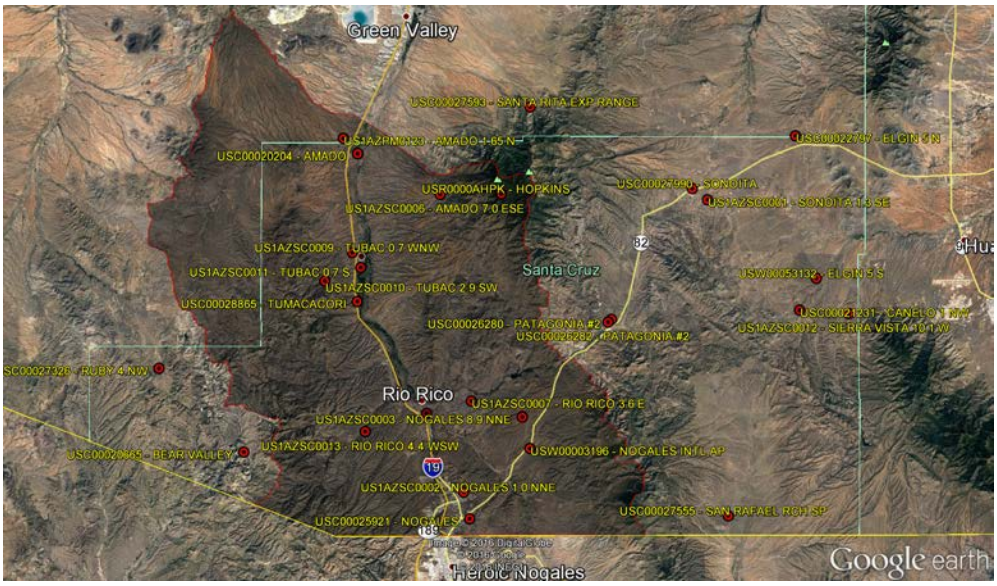

Figure 2.3: The NCEI-NOAA precipitation gauges (indicated as red dots) included in WARCAT-SCAMA

2) <u>The Santa Cruz County ALERT System</u>

The data from the ALERT system provided by Mr. Brian Iserman from JE Fuller Hydrology and Geomorphology, Inc. The dataset can be directly accessed from:

http://jefullerdata.com/ADWR/SantaCruz/index60m.html

The ALERT dataset consists of instantaneous rainfall records that are being reported in real time. However, in the WARCAT the reports from the gauges are aggregated to their daily accumulation values. Therefore, as the case for the NCEI dataset, the WARCAT site should not be used to evaluate the precipitation distribution during the unfolding of a precipitation event. Eighteen active precipitation gauges are included in the WARCAT-SCAMA (Figure 2.4). Five of these gauges are located in Mexico.

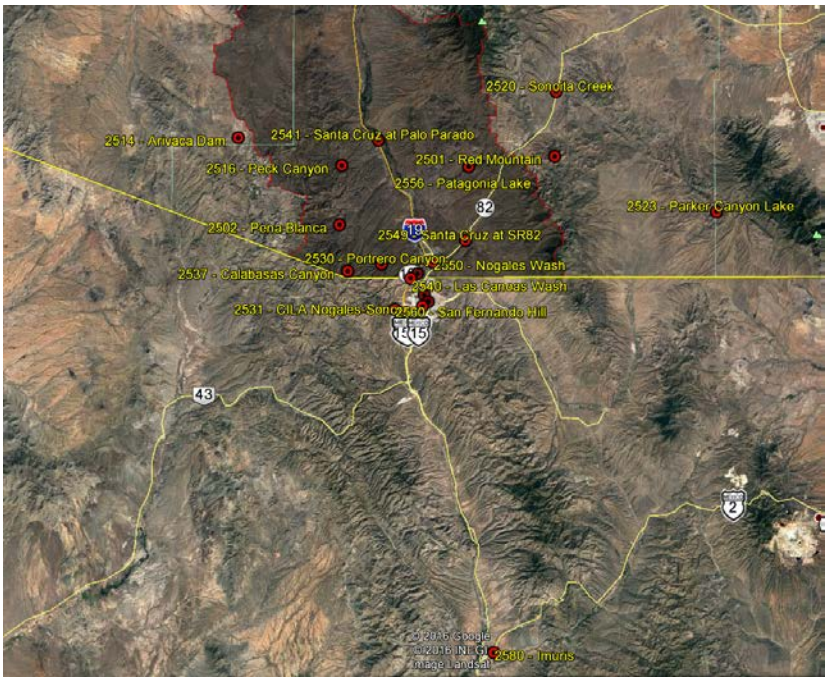

Figure 2.4: The Santa Cruz County ALERT precipitation gauges (indicated as red dots) included in WARCAT-SCAMA

2.3 GROUNDWATER

Well data are routinely downloaded from the Groundwater Site Inventory [GWSI], Arizona Department of Water Resources [ADWR]. Real-time data, quality controlled data, statistical indices and detailed wells information are available from ADWR: https://gisweb.azwater.gov/waterresourcedata/GWSI.aspx

The groundwater data for selected Index Wells can be presented in WARCAT as either Depth to Water (i.e. a time series of measured well's depth to water (feet) from the land surface above it), or as Water Level (i.e. a time series of measured well's water level above sea level (feet)). The climatological indices presented in the plots are the percentiles of the entire available historical record of the pertinent well, as calculated in October 2015 (Figure 2.5). The blue dots indicate manual measurements and the red dots indicate reports from real time automatic sensors, which are available only for seven wells. The values in the WARCAT display of the automatic gauges are the daily averages as reported by ADWR. Following a consultation with Keith Nelson from ADWR, twenty-two index wells were selected as being informative wells that represent the

ground water conditions in the SC-AMA. An example plot of from the Elephant Head well which has both manual and automatic records is shown in Figure 2.5.

Figure 2.5: An example of groundwater level plot

All the historic data available for the well are presented in the plot and were used for the calculation of the Climatological Indices. It is possible that some of the data samples were reported by different sources and were collected using different measurement methods. Some of the samples may also be flagged and include remarks about their conditions during the measurement. This information and flags can be accessed via the link provided in the GWSI station information tab. The locations of the index wells that are presented in WARCAT are shown in Figure 2.6.

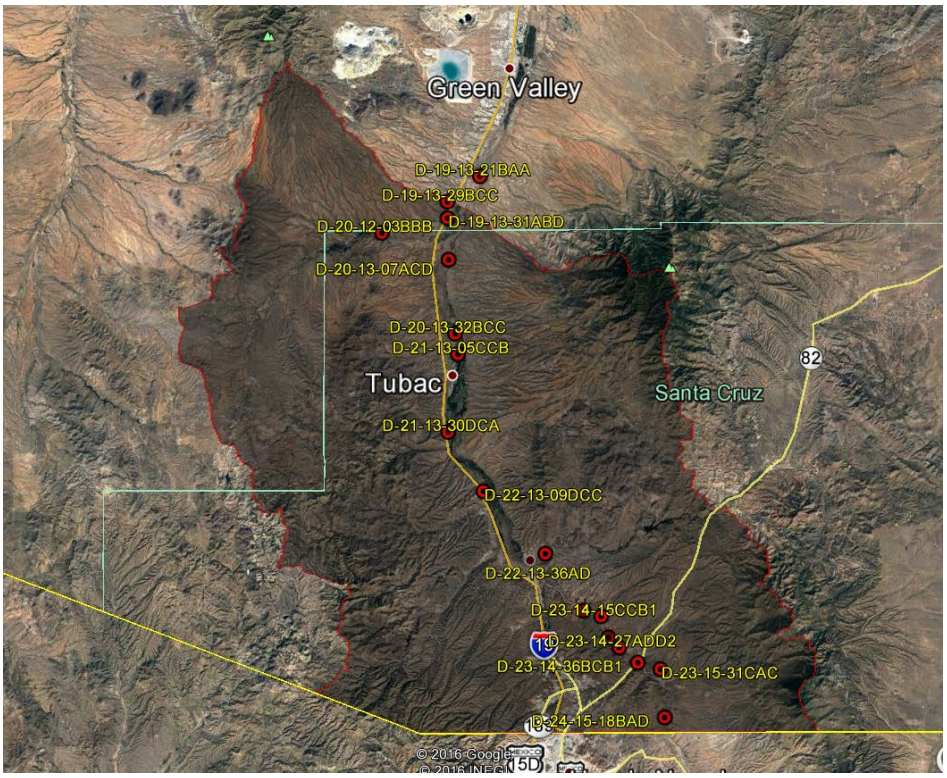

Figure 2.6: The GWSI-ADWR selected index wells (red dots) that are included in WARCAT-SCAMA

2.4 Nogales International Wastewater Plant

Inflow, outflow and Manhole One flow data are available for the Nogales International Wastewater Treatment Plant [NIWPT], which is operated by the International Boundary and Water Commission (IBWC) (Figure 2.7). In support of this project, the flow data have been prepared by the Arizona Department of Environmental Quality (ADEQ). Information about the treatment plant is in:
http://www.ibwc.state.gov/Organization/Operations/Field_Offices/Nogales.html

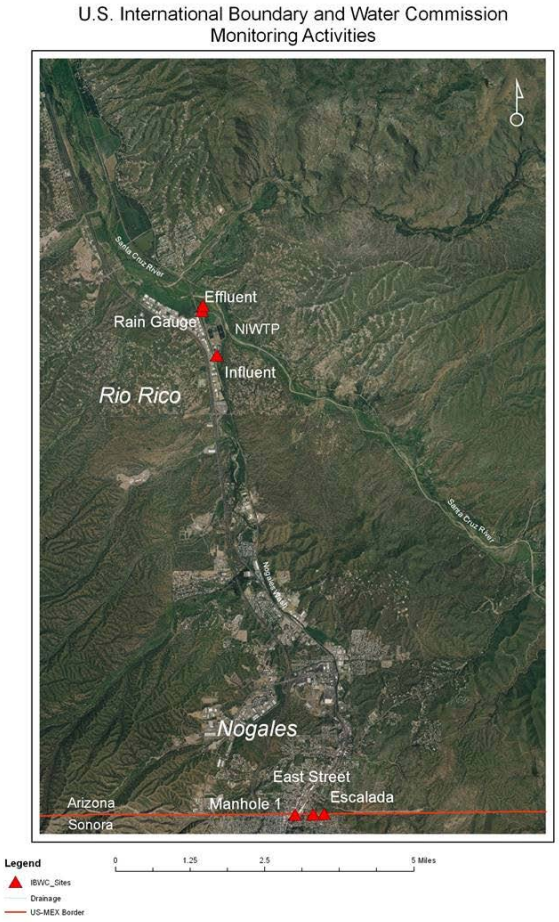

Figure 2.7: Sampling locations for the NIWTP

3. FORECAST PRODUCTS

The forecast data in WARCAT relies on the Climate Forecast System (CFS) from the National Centers of Environmental Prediction (NCEP-NOAA) for precipitation and on the Colorado Basin River Forecast Center (CBRFC) of the National Weather Service (NWS) for short-term streamflow forecasts.

NCEP-NOAA has been routinely producing seasonal outlooks using the coupled forecast system model (CFSv2) (Saha et al. 2014). The operational seasonal forecasts are produced four times daily at 00, 06, 12, and 18 UTC and at each time four ensemble-members that are varied by their initial conditions are produced. The forecasts' numerical output (1^{o}x1^{o}; 6-hourly intervals) of

one of the ensemble members extends up to 9-month and includes an array of variables at various levels throughout the atmosphere, radiative and energy fluxes at the surface, and surface variables. NCEP also produced a dataset of retrospective forecasts from the CFSv2, often termed reforecast. The reforecast dataset consists of seasonal (9-month) forecasts every 5 days during 1982-2010 with 4 forecasts per day (00, 06, 12, and 18 UTC).
WARCAT uses the precipitation average of the four CFSv2 grid-cells that cover the SCAMA domain [31-31.5o North latitude;-111.0-111.5o East Longitude] (Figure 3.1).

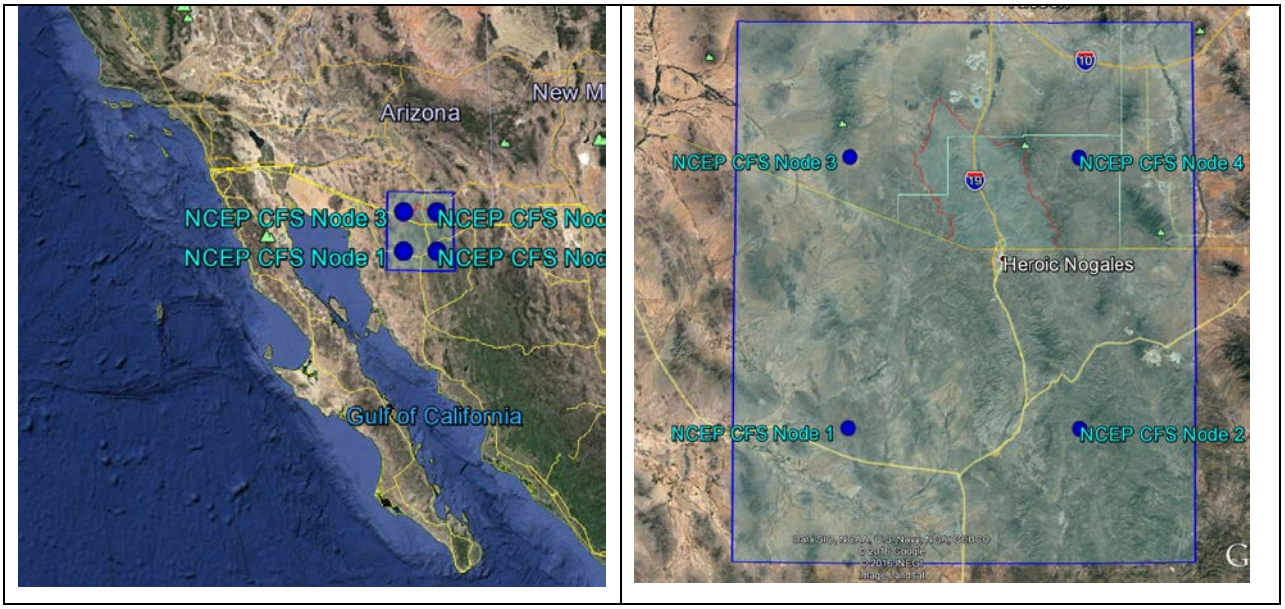

Figure 3.1: NCEP CFS domain that is used in WARCAT based on four $1^{o}x1^{o}$ CFS grid cells, shown as nodes for their centroids.

The skill of the seasonal CFS precipitation forecast for the WARCAT domain was evaluated in Shamir (2017). The CFS showed a fairly good skill for the winter months (mainly January-February) with skill extending up to 4-month lead-time. On the other hand, the only substantial skill that was discerned for the summer was the one-month lead-time for predicting above normal conditions in July.

3.1 Precipitation Forecast

The WARCAT CFS precipitation forecasts are shown in three type of plots: 1) 20-day forecast, 2) 3-month forecast and 3) 3-month wetness categories

1. CFS Time Series 20-day forecast

In this plot (Figure 3.2), the 20-day rainfall forecasts in millimeter per 6-hour estimated for the Santa Cruz AMA domain (Figure 3.1) from the thirty-two most recently available CFS forecasts are shown. The 32 forecasts consist of the latest 8 (~2-day) initialization times, each of which includes four ensemble members (4x8=32). The forecasts become available about 10 hours following their initializations. The forecasts for each of the ensemble members are presented in different colors, shaded from lighter to darker tones to indicate older to newer forecasts, respectively. The Average (blue) and the Median (red) lines are shown as the summary of the 32 recent forecast realizations.

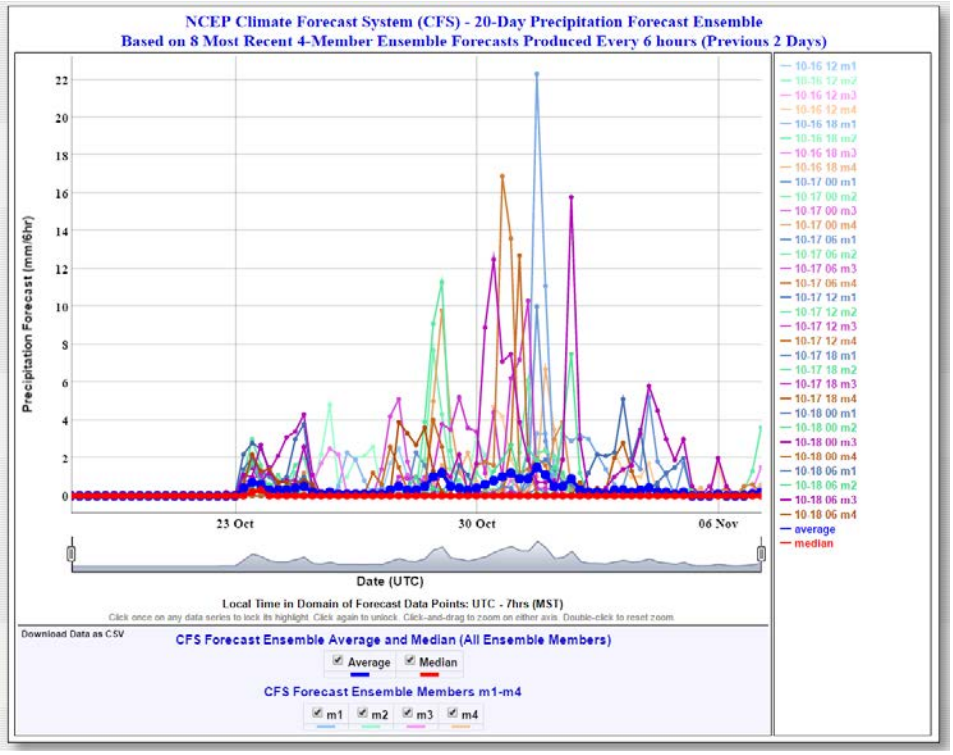

Figure 3.2: 20-day CFS precipitation forecasts.

2. 3-month precipitation forecast

Although NCEP runs four ensemble members in each initialization time, only the first ensemble member has a forecast lead-time that is sufficient for the 3-month forecast analysis presented in Figure 3.3. The plot in this Figure includes the 40 most recent forecasts for each month (10 days, 4 time a day). The newer 20 forecasts are indicated as red dots and the older 20 forecasts are indicated as blue dots. The large dots are the median values of the newer (red), older (blue) and all the 40 forecasts (gray). The forecast is *only* valid for the indicated month. For example, during any day in January the presented forecast will be for the total precipitation in February, March and April.

These monthly forecasts are displayed with respect to climatological percentiles indices [check boxes] that were calculated from the CFS reforecast dataset (1980-2010). This dataset was used to derive the distribution sample of the precipitation forecasts from a given month to each of the following three months.

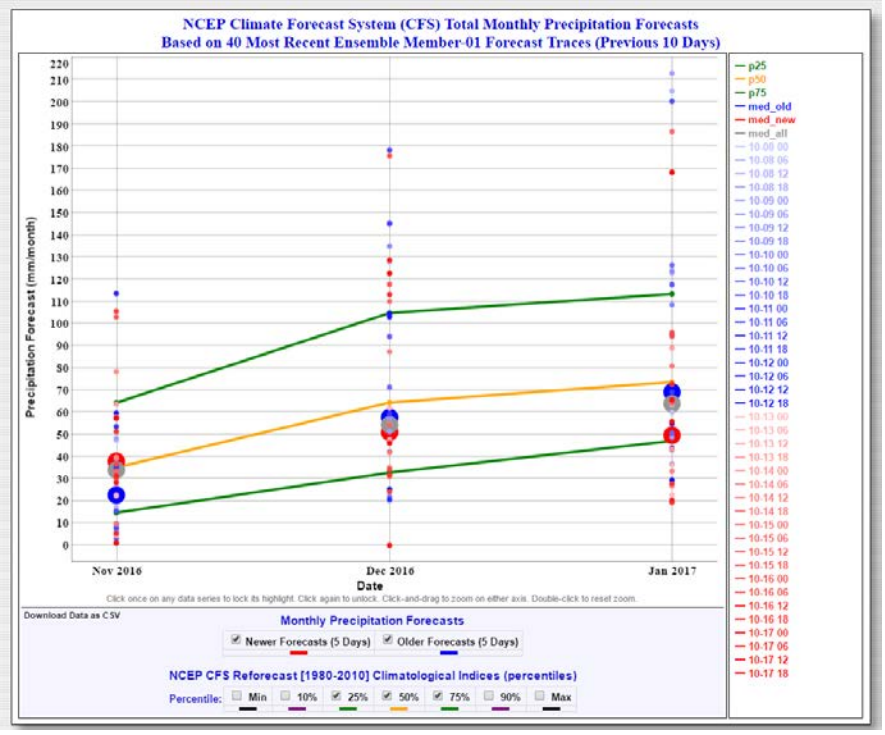

Figure 3.3: Three-month CFS precipitation forecasts.

3. 3-month wetness category forecast

In this bar graph (Figure 3.4), WARCAT presents an analysis of the 20 most recent forecasts (5 days, 4 times per day) for each month. Again, only the first ensemble member (out of 4) is included in this analysis. Each monthly precipitation forecast is assessed whether it falls in the lower, middle or higher tercile, which are referred to as dry, normal and wet, respectively. The tercile values were calculated from the reforecast dataset (1980-2010). The dry, normal and wet colored bars present the number of forecasts in percent in each category. A dominant forecast is selected in case that one category exceeds the other two categories by at least 20%. It is possible, and often the case, that this analysis does not yield a decision for a dominant monthly forecast category of wetness. The presented forecast is only valid for the indicated month. For example, during any day in January, the presented forecast will be for the total precipitation in February, March and April.

The lower three panels in Figure 3.4 are time series of all the categorical forecasts [i.e. dry, normal and wet] that were issued for the three target forecast months. This time series is a continuous presentation of the analysis presented in the above Bar Graph that analyzes the CFS NCEP first ensemble member. These plots aim to examine the forecast persistence for a given target month.

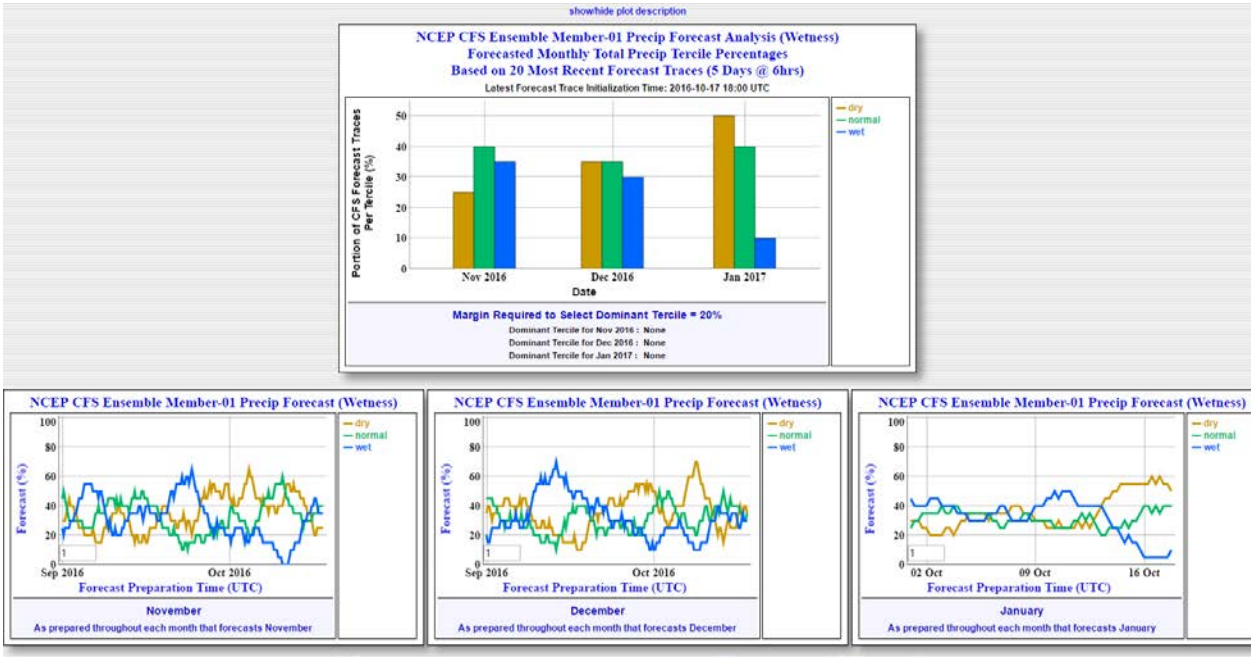

Figure 3.4: 3-month CFS wetness category forecasts.

3.2 Streamflow Forecast

The streamflow forecasts are provided for the Santa Cruz River near Nogales (USGS 09480500) at the border crossing from Mexico to Arizona. The forecasts is provided as monthly projections and 5-day forecasts

1. Streamflow monthly projections

The streamflow projections are shown in Figure 3.5 for the USGS gauge on the Santa Cruz River near Nogales, at the border crossing from Mexico. The projections are provided as the next month cumulative flows [Acre-Feet] that were observed in each of the previous 36 years (Figure 3.5). These projections are colored and divided into lower, middle and higher terciles and indicated in the plot as dry, normal, and wet categories, respectively. The tercile assignment of the historical streamflow record is based on the total monthly flow of the following month. The dominant tercile (colored in purple), is based on the analysis of the CFS forecast of wetness category for the next month (Figure 3.4). The duration of the projection shown in Figure 3.5 spans from current time until the end of the following month.

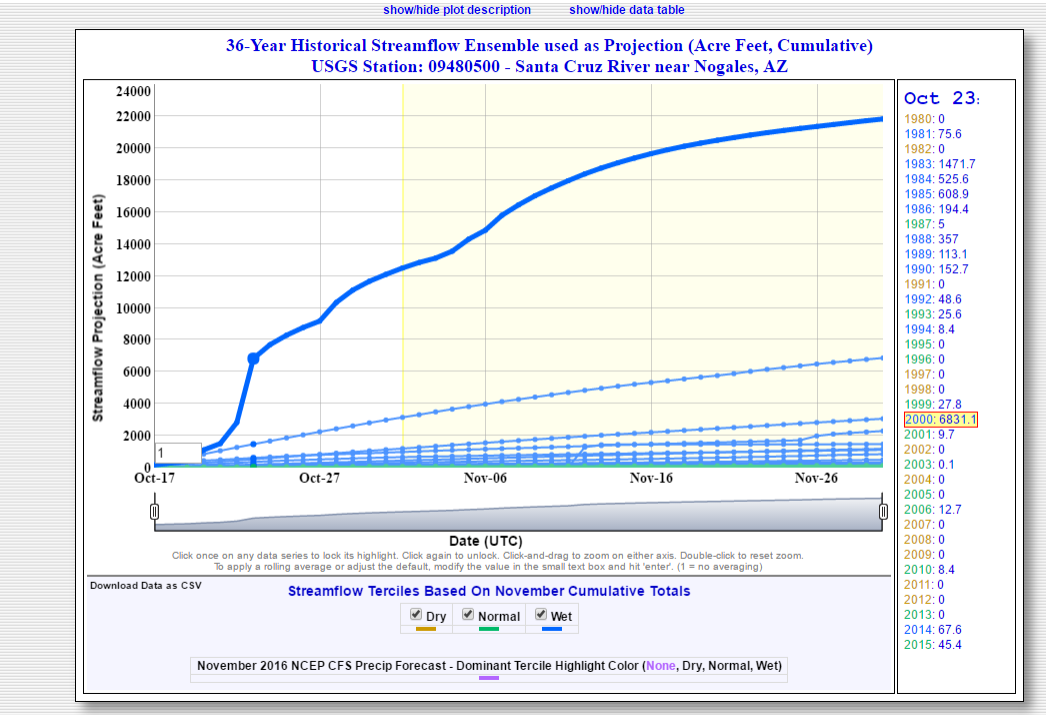

Figure 3.5: One-month streamflow projections

2. Streamflow 5-day forecast

Streamflow 5-day forecasts are available from the Colorado Basin River Forecast Center (CBRFC), NOAA. More information about the streamflow forecast is available from the CBRFC website: http://cbrfc.noaa.gov/.

The streamflow forecasts for this site are routinely acquired by WARCAT from CBRFC every six hours. The plot in Figure 3.6 presents 5-day flow forecast (cubic feet per second (cfs)) since current time in hourly intervals from the most recently available 12 acquired forecasts. The forecasts are presented from lighter to darker shades of green to indicate older to newer forecasts, respectively. The Average (blue) and the Median (red) lines are shown as the summary of these 12 recent forecasts.

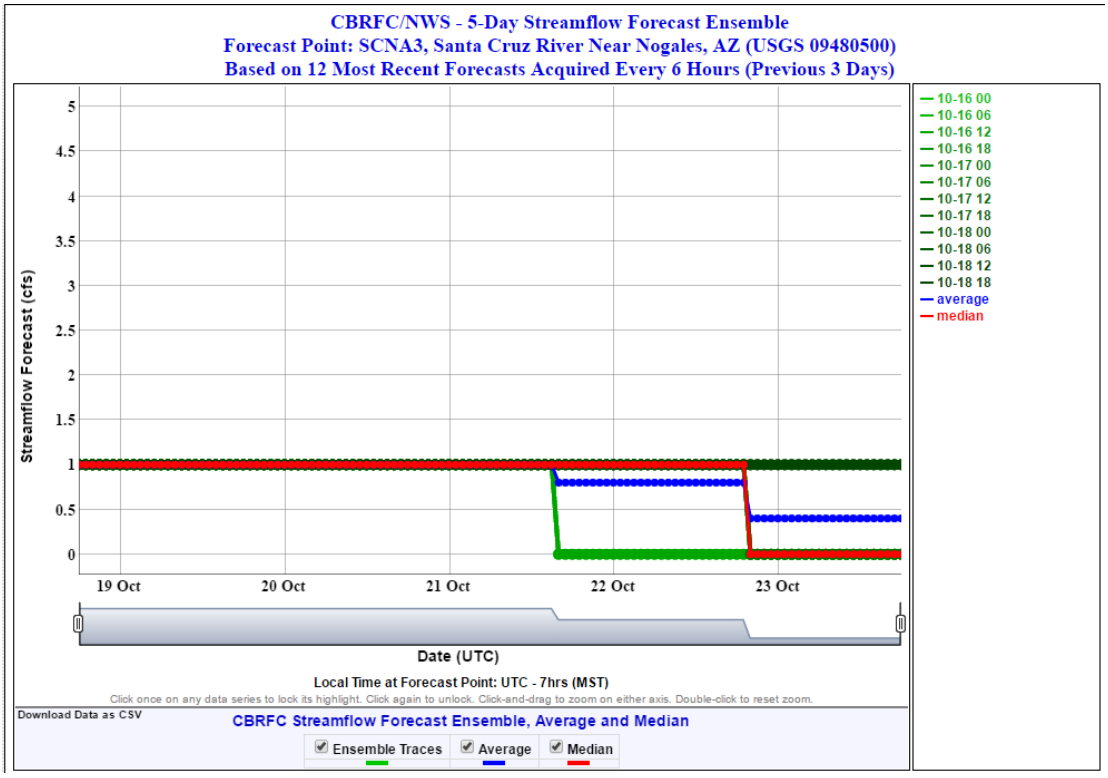

Figure 3.6: Five-day streamflow forecasts

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