

Data Products Test Procedures

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Introduction

A series of testing procedures were performed on the results generated for the Columbia River Basin Climate Change Scenarios Project (CBCCSP) to ensure complete and robust products. The following products were included in the tests:

- raw output from the Variable Infiltration Capacity (VIC) hydrologic model for a suite of climate change scenarios;
- streamflow timeseries derived from the hydrologic model output;
- extreme streamflow statistics and monthly summaries for 16 focus sites; and,
- derived watershed summary products and GIS layers.

The purpose of this document is to describe the test procedures performed on the remaining data products. Our objective is to provide a transparent review of the data products and to describe the quality assurance and control procedures.

1. Test Procedures

A set of testing procedures was established to identify potential errors in the CBCCSP data products. Unique tests were developed to identify errors occurring at various points along the sequence of modeling and post processing steps, from the preliminary raw hydrologic output to the post-processing products of routed flows and monthly summaries. This section describes the tests performed on each type of product.

1.1 Raw hydrologic model (VIC) output and routed flows

Hydrologic simulations were performed for 77 climate change scenarios, including traditional composite delta method scenarios, transient bias-corrected and statistically downscaled scenarios, and hybrid delta method scenarios. The VIC model was applied over the Pacific Northwest (defined as the Columbia River basin and coastal drainages of Washington and Oregon) on a grid-scale of 1/16th degree latitude and longitude. There are 24,108 model grid cells in this domain. Raw CBCCSP data products, stored in “flux files” for each model grid cell, include meteorological data, baseflow, runoff and other hydrologic data on a daily time step. For 297 sites within the domain, the daily and monthly routed streamflows were estimated separately for each

scenario. The routed streamflows were computed by the convolution of runoff and baseflow according to a predefined stream network.

Testing was performed on each of the 24,108 grid cell output files from each VIC simulation as well as routed streamflow files for each of the 297 sites to ensure that the files were complete and contained reasonable data. Four tests were applied to each scenario:

1. Check for the correct number of output files to ensure simulation was complete
2. Check the number of rows in each output file to ensure complete files
3. Check the sum of the dates in each file to ensure complete files
4. Check the file size of each output file to ensure complete files

Following is a more detailed description of each test:

1. For each scenario, we checked whether there are 24,108 output files from the VIC model simulation. Similarly, for each scenario, we verified that there are 297 routed streamflow files corresponding to the number of modeled streamflow locations. For each streamflow location, both daily and monthly time series files are provided. We checked to verify that all daily time step files exist for each site.
2. For each scenario, we checked whether each of the 24,108 VIC output files contains the correct number of rows, dependent on whether it is a traditional delta method, hybrid delta method, or transient run. Similarly, we verified that for each of the 297 streamflow sites, the daily time step files contain the correct number of rows. For the transient scenarios, climate modeling centers terminated their future simulations in different years, ranging from 2098 to 2100. Row checks account for these variations.

3. For each scenario, we verified the sums of the date columns (year, month, and day) for each of the 24,108 VIC output files, and for each of the daily streamflow files at each site. The sums of dates in each file vary depending on the type of scenario and time period; however, for a single scenario, each type of output file should have identical date sums. This consistency allows for a simple check to help identify files with basic write errors. Table 3 summarizes the criteria used to check sums of year, month, and day columns in each file. As with the file size checks in step 3, the discrepancies in the numbers of years simulated in the transient runs were taken into account.

4. Lastly, for each scenario, we also checked whether the file size for each of the 24,108 VIC output files and for each of the 297 daily streamflow time step files fall within the typical range. File sizes vary depending on the type of scenario and time period. Table 1 summarizes the criteria used to check file size. File size checks account for the variation in years simulated by the transient scenarios.

Table 1. Summary of complete output file size per scenario

Scenario Type	VIC Output File Size	Daily Streamflow File Size
Historical	6.27 MB	760 KB
Composite Delta	6.27 MB	760 KB
Hybrid Delta	6.27 MB	760 KB
Transient		
1950-2100	10.4 MB	1.258 MB
1950-2099	10.3 MB	1.250 MB
1950-2098	10.2 MB	1.243 MB

Table 2. Summary of complete date sums per scenario

Scenario Type	VIC Output Date Sum	Daily Streamflow Date Sum
Historical	65,878,670 (year)	65,878,670 (year)
	219,190 (month)	219,190 (month)
	528,563 (day)	528,563 (day)
Composite Delta	65,878,670 (year)	65,878,670 (year)
	219,190 (month)	219,190 (month)
	528,563 (day)	528,563 (day)
Hybrid Delta	65,878,670 (year)	65,878,670 (year)
	219,190 (month)	219,190 (month)
	528,563 (day)	528,563 (day)
Transient		
1950-2100	111,682,763 (year)	111,682,763 (year)
	359,756 (month)	359,756 (month)
	867,511 (day)	867,511 (day)
1950-2099	110,916,263 (year)	110,916,263 (year)
	357,374 (month)	357,374 (month)
	861,773 (day)	861,773 (day)
1950-2098	110,150,128 (year)	110,150,128 (year)
	354,992 (month)	354,992 (month)
	856,035 (day)	856,035 (day)

1.2 Focus sites

The site-specific products generated as part of the CBCCSP project amount to approximately 3,300 plots, plus six times as many summary tables. In order to design testing procedures that are manageable in scope yet thorough in coverage, 16 streamflow sites were selected that are impacted by a dominant portion of the domain. Sites were selected based on two criteria:

1. Downstream of major tributaries of the Columbia River Basin or downstream of major coastal drainages
2. Contributing upstream basin area larger than about 5,500 sq mi for major tributaries of the Columbia River Basin and 1,200 sq. mi. for coastal drainages

The Columbia River at The Dalles, which is a location that integrates the effects of much of the model domain, is one of the included sites. Table 4 shows a brief summary of each site. These 16 “anchor” sites are the focus of the error tests described below.

Table 3. Focus sites for error testing

	VIC ID #	VIC Name	River Name	Basin Area (mi ²)
Main Columbia River Basin	1021	WANET	Pend Oreille	25,800
	1022	BRILL	Kootenay	19,300
	2009	SPALD	Clearwater	9,570
	2034	SALMO	Salmon	13,550
	4001	OWYHE	Owyhee	11,160
	4020	JOHND	John Day	7,580
	4029	REREG	Deschutes	10,500
	4063	WILPO	Willamette	11,200
	6031	LLAKE	Spokane	6,020
	6039	OKANA	Okanagan	8,080
	6069	YAKKI	Yakima	5,615
	6078	ICEHA	Snake	108,500
	4030	DALLE	Columbia	237,000
Coastal Drainages	6005	CHEPO	Chehalis	1,294
	6016	SNOMO	Snohomish	1,537
	6021	SKAMO	Skagit	3,093

1.3 Summary Plots and Streamflow Statistics

Error checks were performed by reviewing the summary hydrologic products for the 16 "anchor" sites listed in Table 4. Following is a more detailed description of each check:

1. Mean annual streamflow was inspected for each scenario to check whether it corresponds well with the climate change signal in precipitation. For example,

Figure 1 (below) shows changes in streamflow and precipitation for each climate change scenario relative to the historical simulation for the Columbia River at The Dalles. Changes in streamflow correspond well with changes in precipitation in both magnitude and direction.

2. Changes in peak snow water equivalent (SWE) were inspected for “anchor” sites and compared to corresponding changes in precipitation and temperature. As shown in Figure 2, percentage changes in peak SWE and precipitation were plotted with degree changes in mean temperature from October to March relative to the historical simulation. For the 2020s and 2040s, changes in peak SWE correspond more closely with changes in precipitation than with changes in temperature. In other words, for most of the scenarios, larger increases in precipitation correspond with smaller decreases in peak SWE. Toward the end of 21st century, temperature has the greatest influence on changes in peak SWE. There are more scenarios whose peak SWE responds primarily to temperature increases when comparing scenarios for the 2020s and 2040s (see red circles in Figure 2). Finally, for the 2080s, changes in temperature are the major determinant of changing peak SWE.
3. The 6-panelled plots of the mean seasonal cycle projected for VIC monthly summary products were also inspected for anomalies, excessive departures from the historical pattern or from the ensemble model mean, or for other potentially unrealistic values. The 9 VIC monthly summary products include combined flow (runoff plus baseflow), evapotranspiration (ET), tall crop potential evapotranspiration (PET4), short crop potential evapotranspiration (PET5), precipitation, soil moisture, streamflow, snow water equivalent (SWE), and average temperature.
4. Scenarios were flagged if flood statistics were either 50% above or below the mean over all hybrid delta runs. For example, the 50% test on the flood statistics for “anchor” site 1021 (Waneta Dam on the Pend Oreille River)

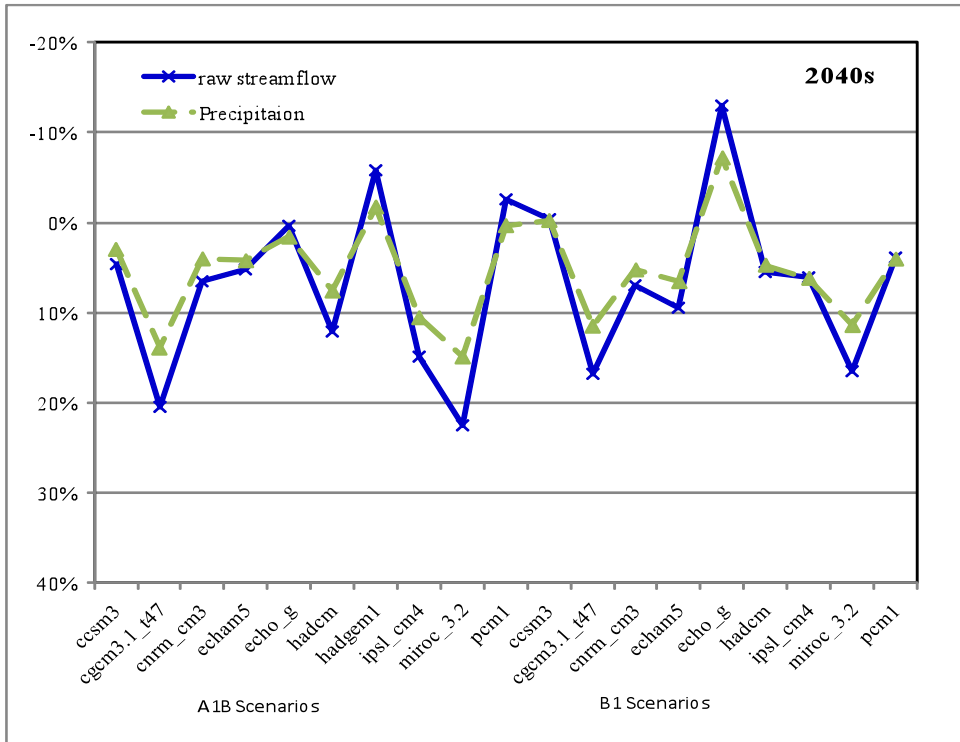
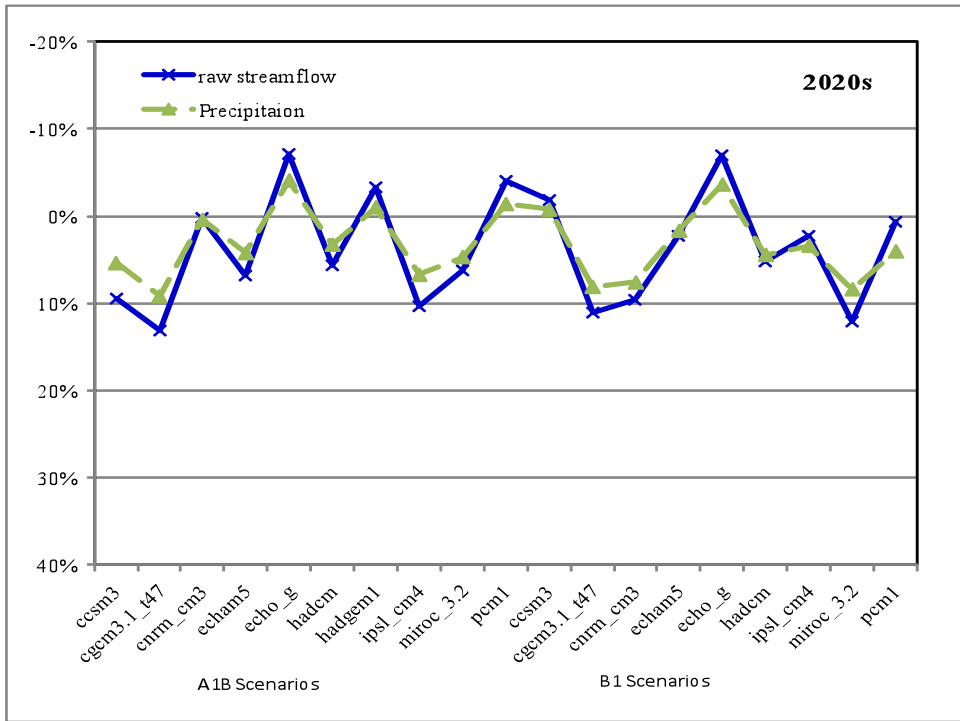
indicated anomalously high values generated by the miroc_3.2 model in the 2080s under both the A1B and B1 scenarios, as depicted in Figure 3. When anomalous values were found using these tests, extreme streamflow values were checked for consistency with monthly averaged precipitation and temperature. In the example presented in Figure 3, the monthly precipitation nearly doubles in December and temperatures rise above freezing earlier in the spring for the miroc_3.2 model, indicating that the extremely high flood statistics are a realistic consequence of a shift in streamflow timing. Using these metrics, the extreme streamflow output resulted in anomalously high values for 5 sites under three model scenarios. However, in each case, the particular model generating the suspiciously high values can be justified by the higher precipitation and/or temperature monthly mean values for the identified model.

Together, these four tests were intended to reveal suspect anomalies emerging from both the seasonal timing and magnitude of water balance variables and flood statistics, with a primary emphasis on the effects of changes in temperature and precipitation on streamflow and snowpack. These checks are essentially independent of checks on file statistics described above, and are intended to confirm that the changes in hydrological variables are related well to the seasonal changes in temperature and precipitation in the climate change scenarios.

The organization of the CBCCSP data facilitates the effort of tracing anomalies back to their source. When an anomaly was found at a particular streamflow site, other upstream and downstream sites were inspected to assess the geographic extent of the error. Inspection of the summary tables allowed for quick identification of the anomalous model and scenario. Data in the summary tables were then compared with values in the monthly summary files and, ultimately, the raw output files to help identify the origin of potential errors.

2. Conclusions

The quality assurance and control procedures ensure a high level of quality and reliability in the CBCCSP data products. Redundant tests verify both the statistics of the raw output files and validate a number of key simulation products to confirm that the signals in the simulations are both reasonable in magnitude and seasonal timing and are consistent with the changes in temperature and precipitation changes for each scenario. The “anchor” sites selected for post-processing checks are strategically located downstream of major tributaries, thus maximizing the number of contributing grid cells for each check. Comparison of streamflow statistics with changes in temperature and precipitation permits an assessment of internal consistency among summary products, important for distinguishing between changes in streamflow timing and anomalous streamflow projections. Anomalies, when identified, can be rapidly traced back to their origin and corrected.



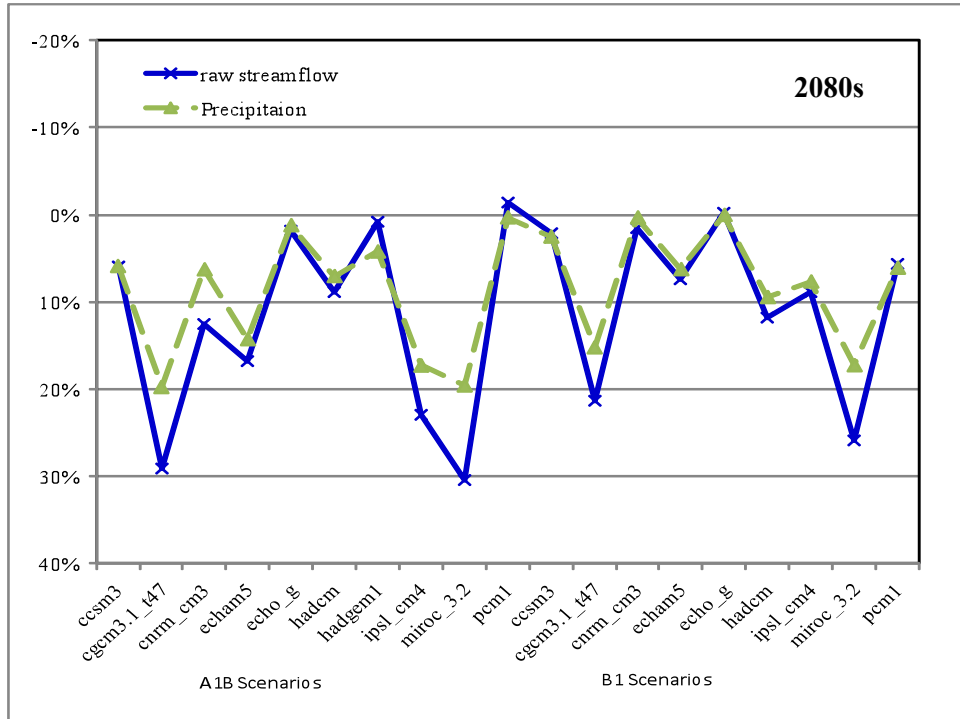
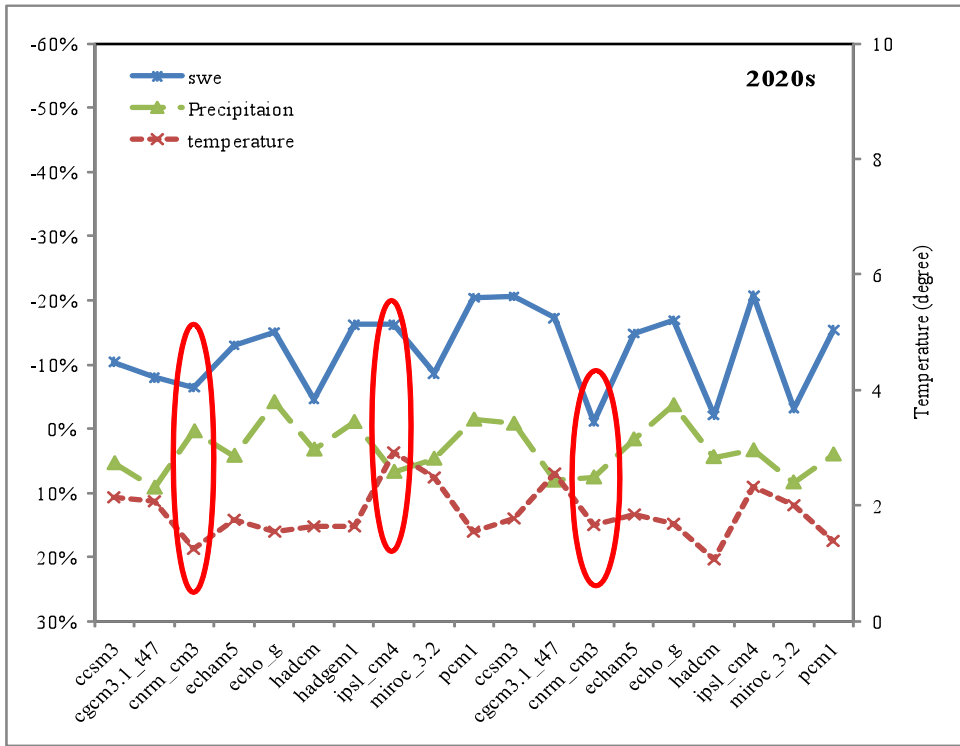


Figure 1. Changes in streamflow and precipitation for each climate change scenario relative to historical run for the Columbia River at The Dalles for three time periods



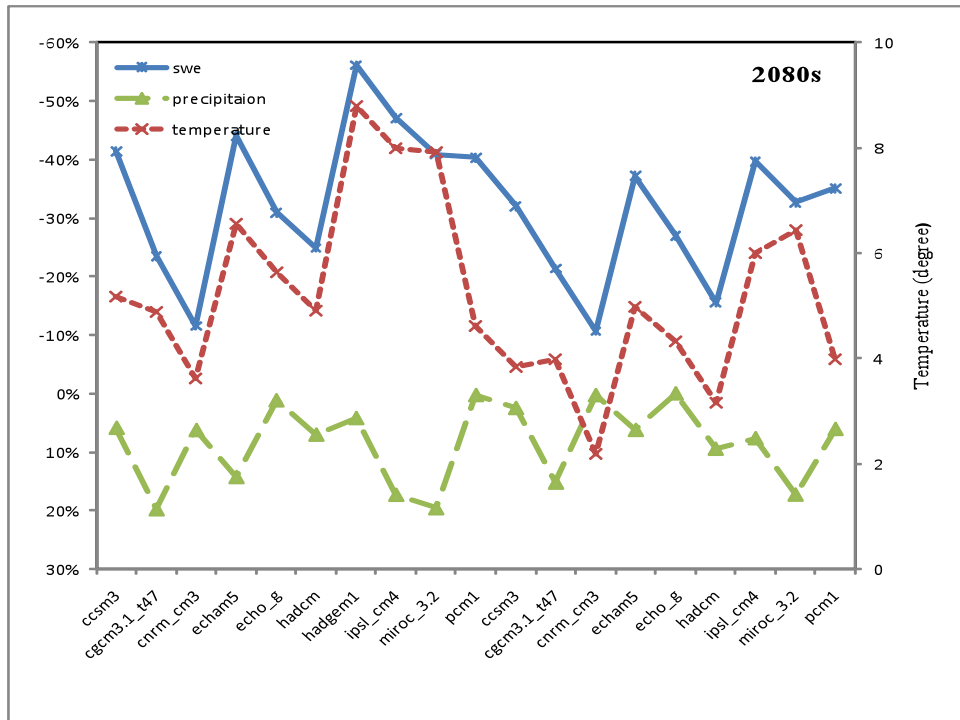


Figure 2. Changes in snow water equivalent (SWE), precipitation and temperature (°C) for each climate change scenario relative to historical run for The Dalles for three time periods

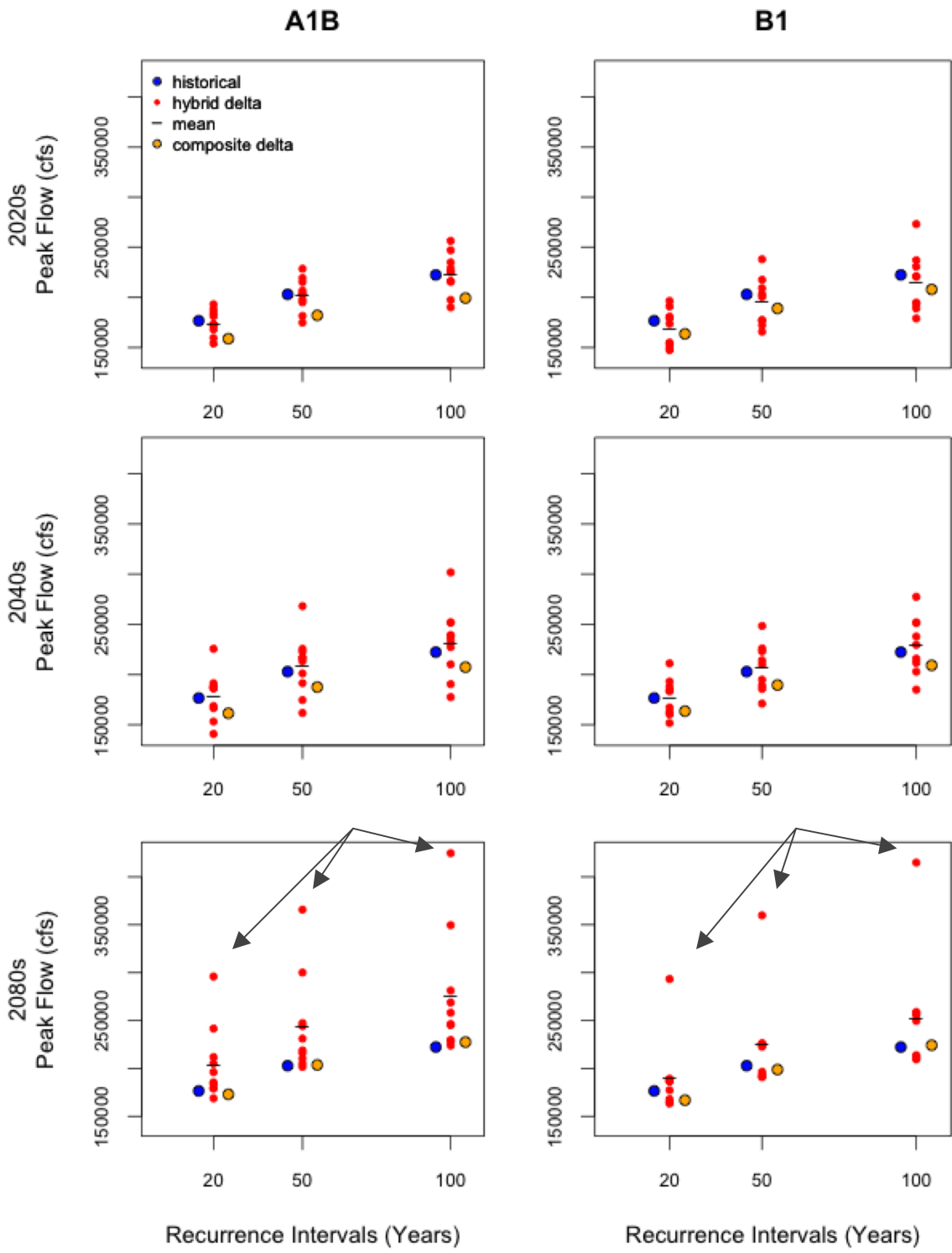


Figure 3. Flood statistics for site 1021 (Pend Oreille River at Waneta Dam). The miroc_3.2 model (as indicated by the arrows) generated the anomalously high results in the 2080s for both scenarios