Appendix B. Climate and Hydrology Projection Graphs

The graphs presented here were downloaded from the Climate Impacts Group at the University of Washington (http://www.hydro.washington.edu/2860/) . Each graph shows a spread of future projections (light red shading) that represent the range of outputs from 10 separate *general circulation models* (GCMs). Those models have been downscaled to particular regions and watersheds and then coupled to the *Variable Infiltration Capacity* (VIC) hydrologic model (Liang et al. 1994). These projections are based on the A1B greenhouse-gas emissions scenario that assumes some future actions are taken to reduce the emission of carbon dioxide and other greenhouse gases relative to historic and recent trends. The graphs show projected hydrology and climate change effects for three time periods: the 2020's, the 2040's, and the 2080's. Qualitative assessments of climate change vulnerabilities of U.S. Fish and Wildlife Service Pacific Region National Fish Hatcheries were based primarily on the 2040's projections.

Graphs are presented here for two locations in the Methow River (Winthrop, Pateros) and eight locations in the Columbia River from Bonneville Dam to Wells Dam. Graphs for the Methow River at Winthrop represent climate change effects at Winthrop NFH and the Methow River watershed. Graphs for the Columbia River represent climate change effects in the "migration corridor" for salmon and steelhead originating at Winthrop NFH.

Each graph is labeled (a), (b), (c), (d), (e) or (f). Brief descriptions of those graphs follow.

Graph (a): Raw streamflow. Long term average, monthly streamflow (October through September) at the point of measurement, measured as cubic feet per second (cfs). The blue line shows the simulated historical value, the red line shows the ensemble average of the outputs for 10 downscaled GCMs, and the red shaded area shows the range of outputs for the 10 GCMs for each of three future time periods.

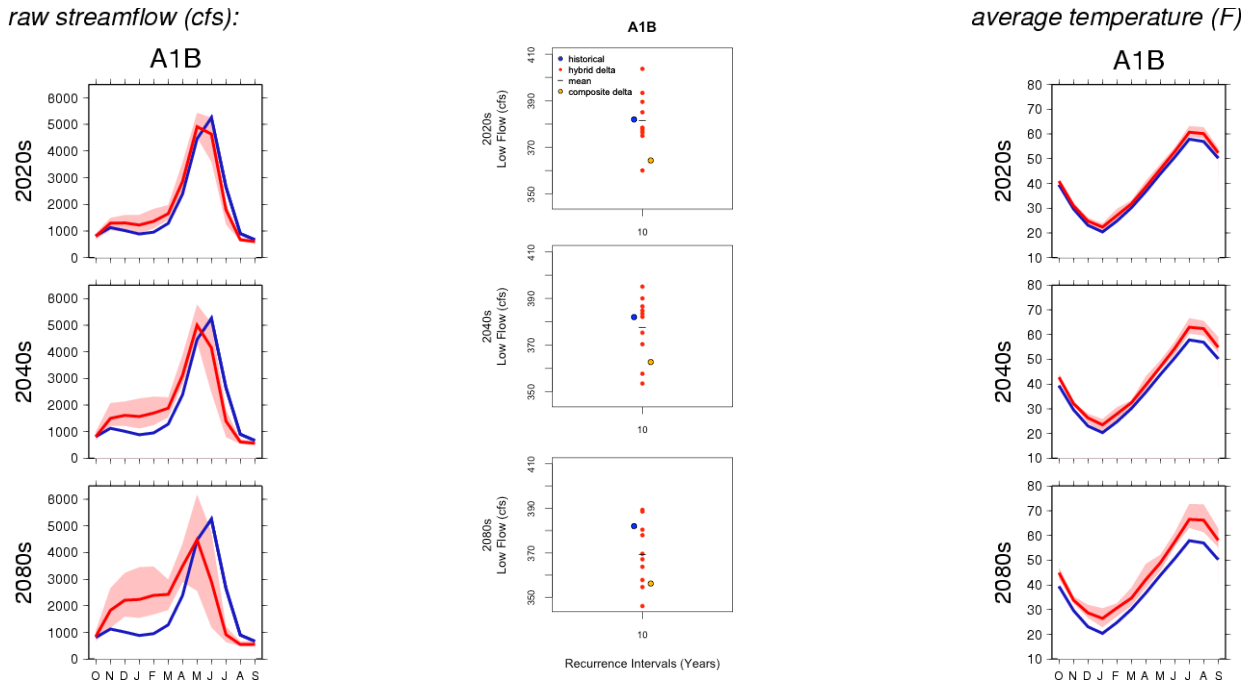
Graph (b): Simulated low streamflow at the measurement point in the watershed, measured in cubic feet per second (cfs), quantified by 7Q10 statistics. "7Q10" is the estimated minimum flow that occurs over 7 consecutive days in 10% of the years (estimated 7-day low flow that occurs, on average, once every10 years). Blue circles show the simulated historical values; red circles show the values for 10 downscaled GCMs; the horizontal black line shows the ensemble average of the 10 downscaled models, and the orange circles show the values for the composite delta downscale method. (Units: cfs)

Graph (c): Monthly average air temperature over the entire watershed upstream from the point of measurement (Units: degrees F). The blue line shows the simulated historical value, the red line shows the ensemble average of the outputs for 10 downscaled GCMs, and the red shaded area shows the range of outputs for the 10 GCMs for each of three future time periods.

Graph (d): Monthly average total precipitation (October through September) over the entire watershed upstream of the measurement point expressed as an average water depth (Units: inches). This variable is a primary component of the simulated water balance and quantifies total precipitation of rain and snow upstream of the point of measurement. The blue line shows the simulated historical value, the red line shows the ensemble average of the outputs for 10 downscaled GCMs, and the red shaded area shows the range of outputs for the 10 GCMs for each of three future time periods.

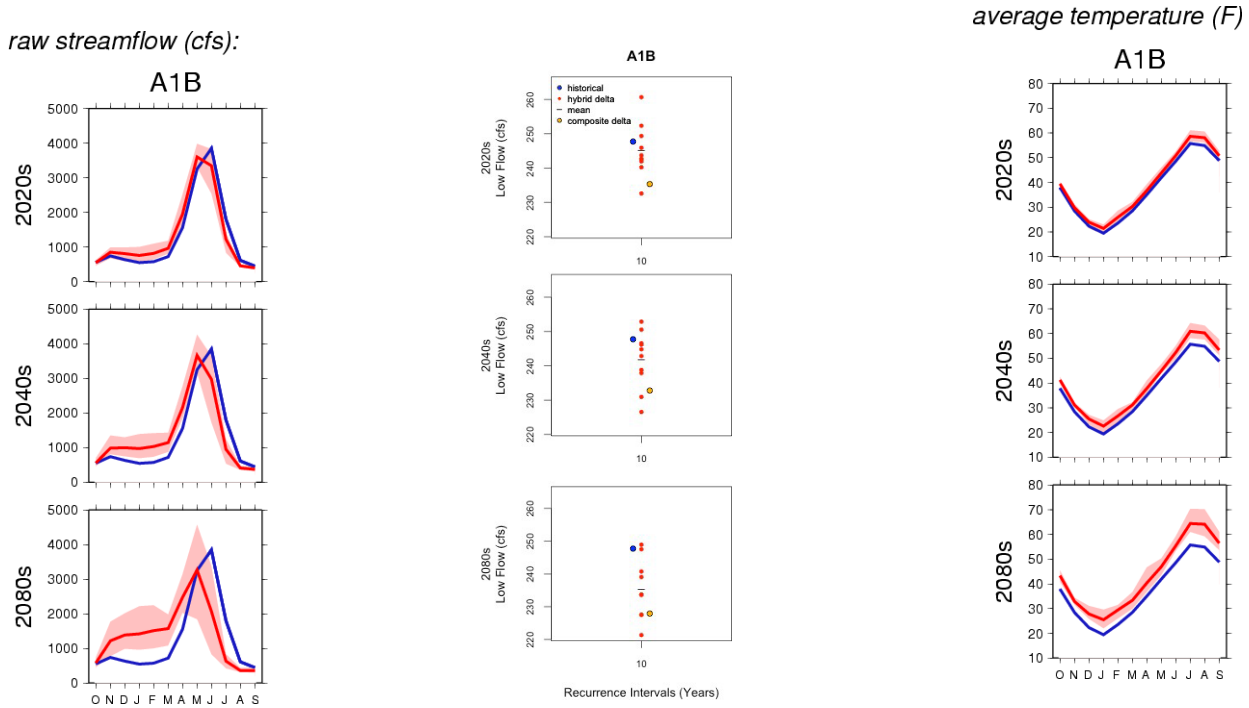
Graph (e): Simulated peak streamflow at the measurement point in the watershed for 20, 50 and 100-year peak flows (Units: cfs). These graphs show simulated projected peak flows expected in 5%, 2% and 1% of the years, respectively over a 100-year period for each of three time periods. Blue circles show the simulated historical values; red circles show the values for 10 downscaled GCMs; the horizontal black line shows the ensemble average of the 10 downscaled models, and the orange circles show the values for the composite delta downscale method (Units: cfs).

Graph (f): Water volume equivalent of projected snow pack on first day of month averaged over the entire watershed upstream of the point of measurement, expressed as an average water depth (Units: inches). This variable is a primary component of the simulated water balance, and quantifies natural storage as snowpack. The blue line shows the simulated historical value, the red line shows the ensemble average of the outputs for 10 downscaled GCMs, and the red shaded area shows the range of outputs for the 10 GCMs for each of three future time periods.



(a) (b) (c)

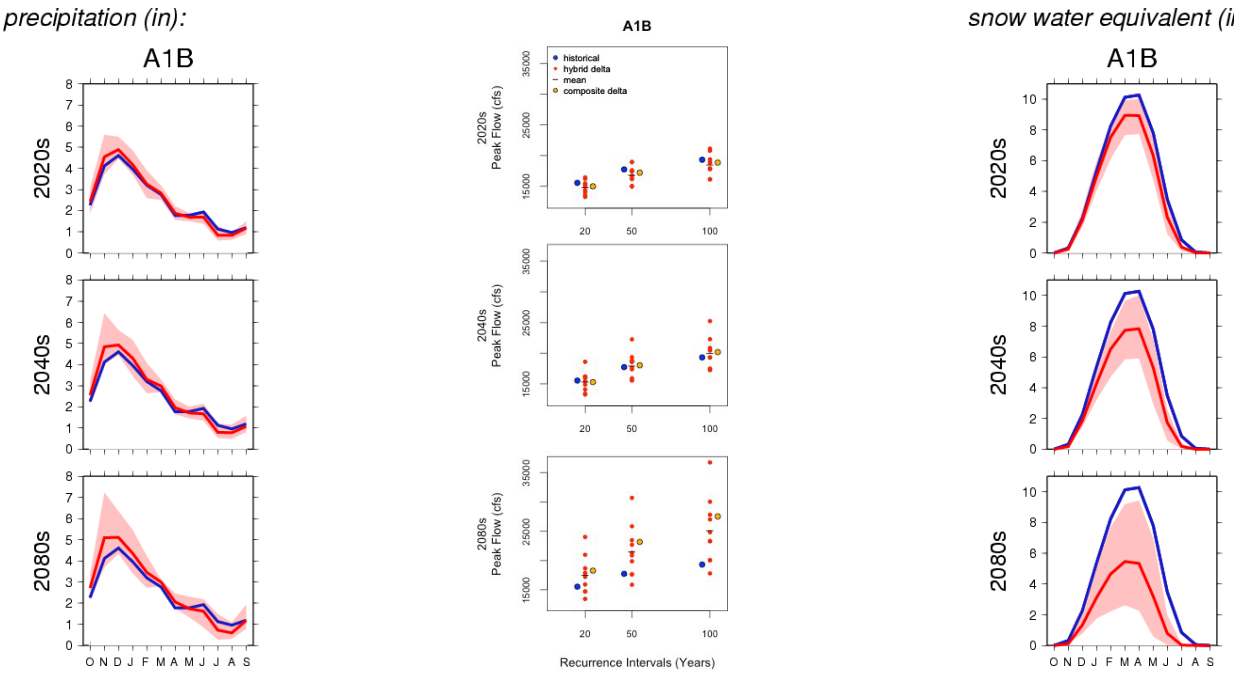
Methow River at Pateros



(a) (b) (c)

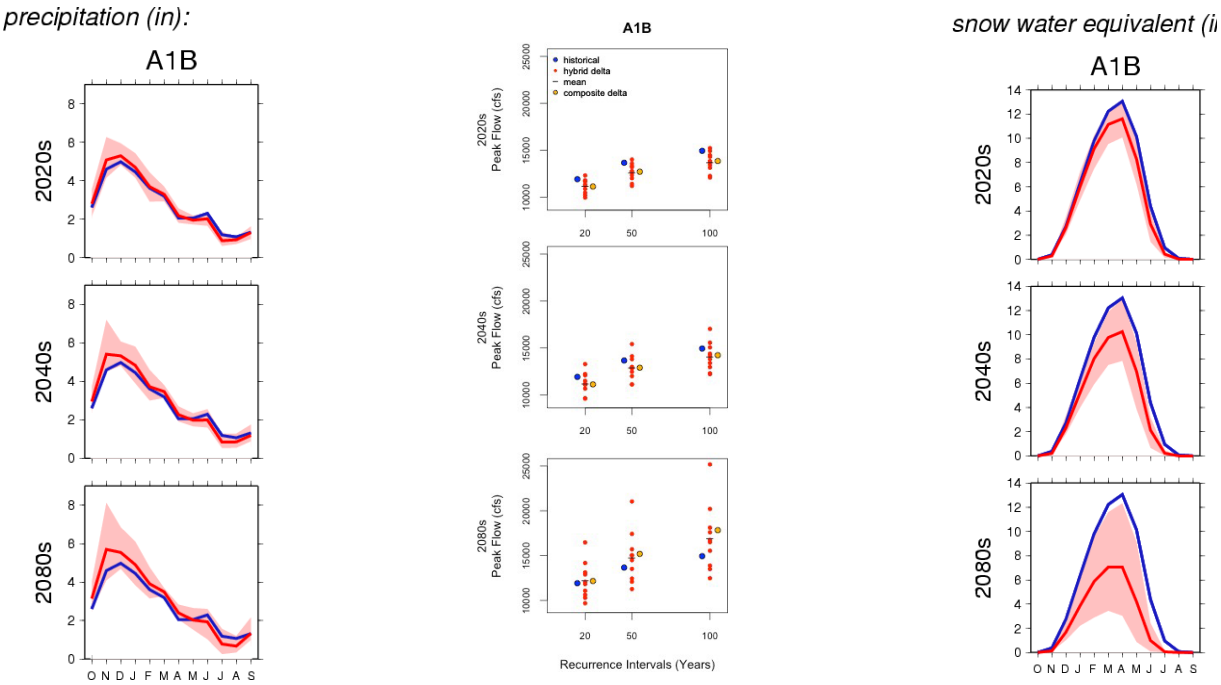
Methow River at Winthrop

Fig. B1. Climate and hydrology projections (mean streamflow, low flow, and air temperature) for the Methow River at Pateros and Winthrop (CIG 2011). Blue: 1971-1999 historic mean. Red: Mean and range of outputs from 10 models. For low flow (middle graphs), horizontal line = average of the 10 projections, and orange dot = composite model output.



(d) (e) (f)

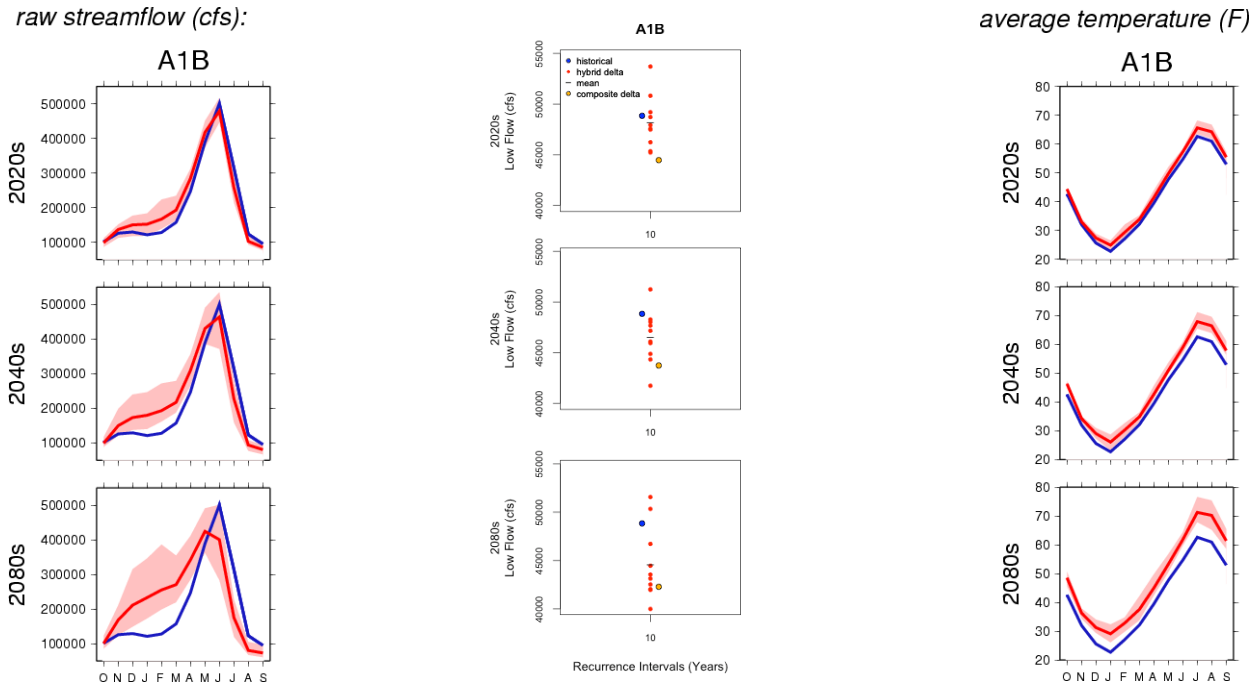
Methow River at Pateros



(d) (e) (f)

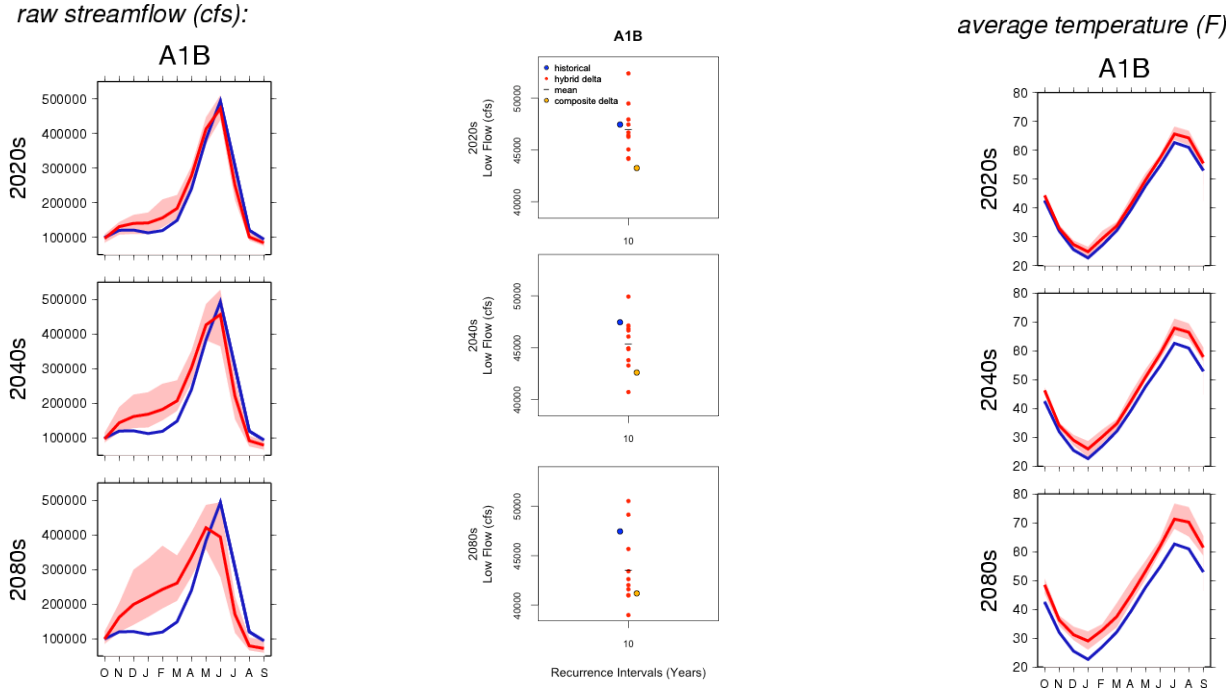
Methow River at Winthrop

Fig. B1. Continued: Climate and hydrology projections (mean precipitation, peak flow, and equivalent water volume of snow pack in inches) for the Methow River at Pateros and Winthrop (CIG 2011).



(a) (b) (c)

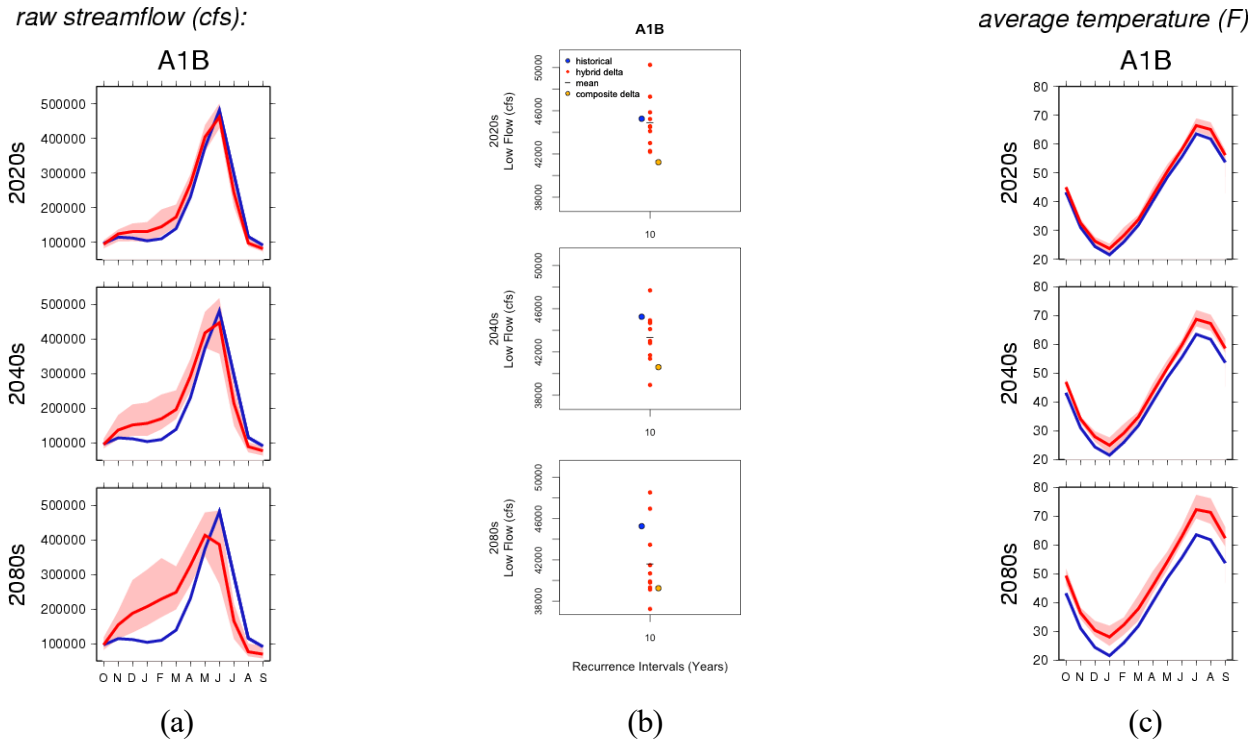
Columbia River at Bonneville Dam



(a) (b) (c)

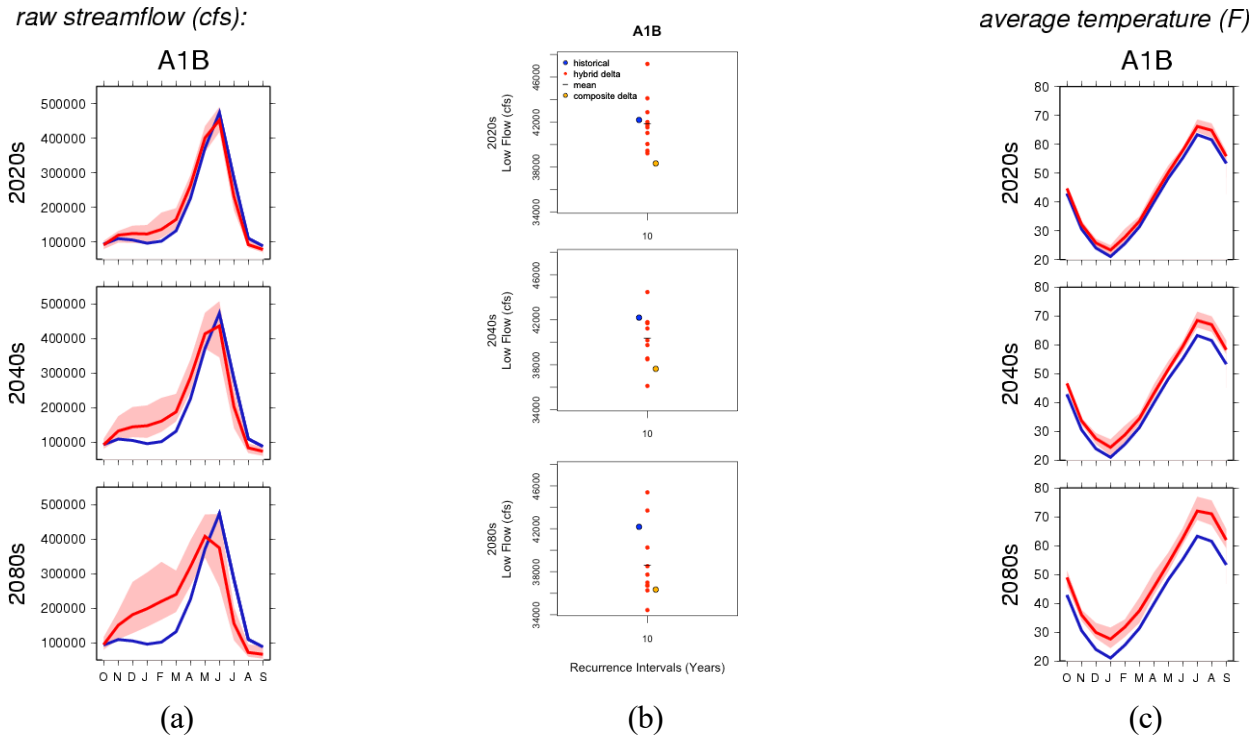
Columbia River at The Dalles Dam

Fig. B2. Climate and hydrology projections (mean streamflow, low flow, and air temperature) for the Columbia River at Bonneville Dam and The Dalles Dam (CIG 2011). Blue: 1971-1999 historic mean. Red: Mean and range of outputs from 10 models. For low flow (middle graphs), horizontal line = average of the 10 projections, and orange dot = composite model output.



(a) (b) (c)

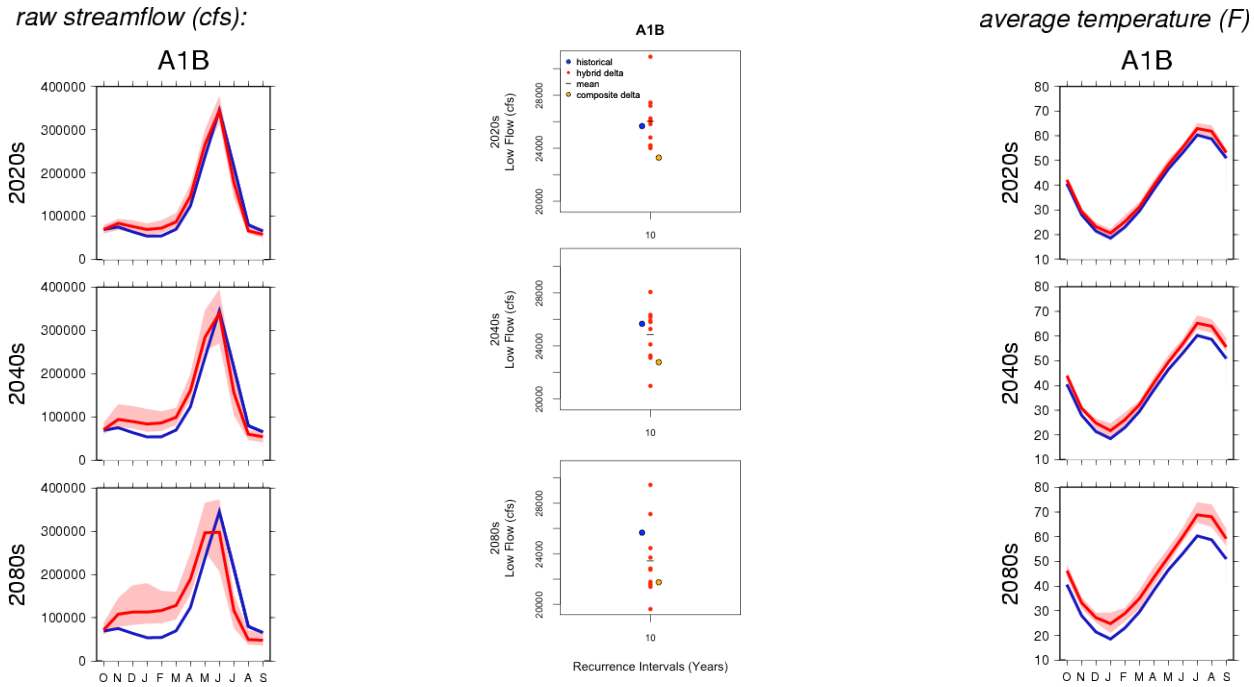
Columbia River at John Day Dam



(a) (b) (c)

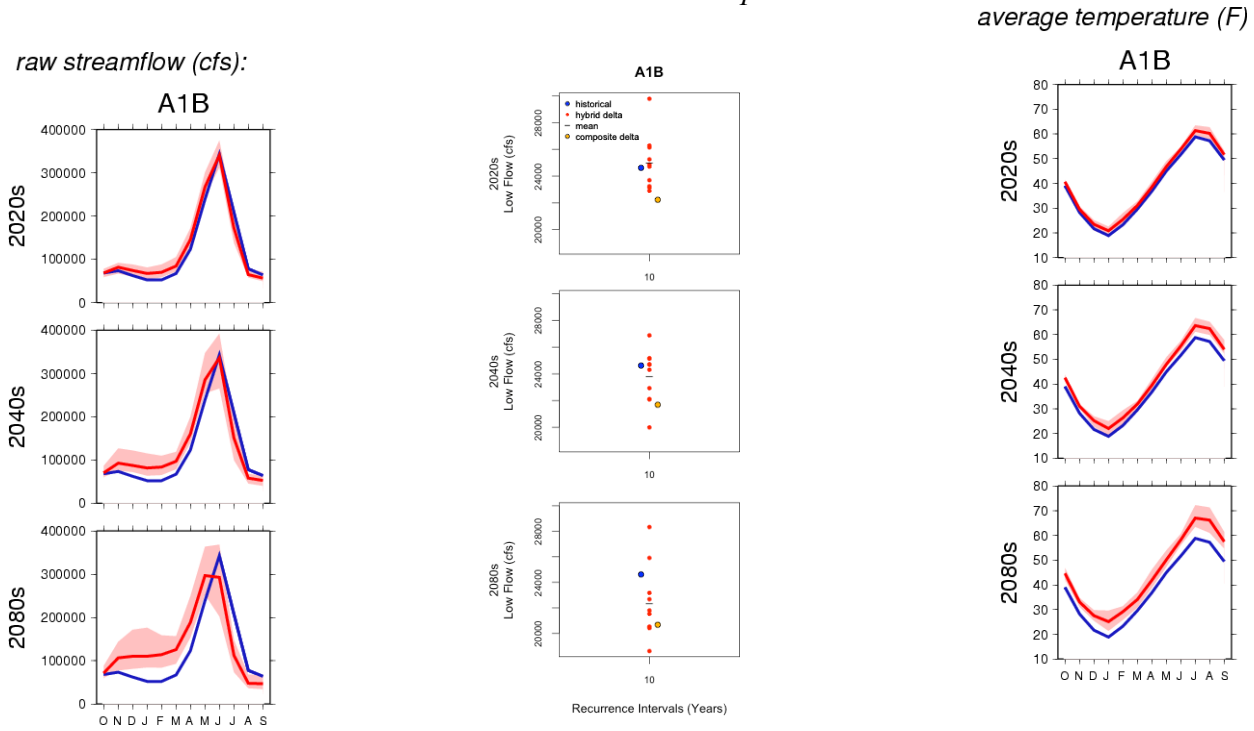
Columbia River at McNary Dam

Fig. B3. Climate and hydrology projections (mean streamflow, low flow, and air temperature) for the Columbia River at John Day Dam and McNary Dam (CIG 2011). Blue: 1971-1999 historic mean. Red: Mean and range of outputs from 10 models. For low flow (middle graphs), horizontal line = average of the 10 projections, and orange dot = composite model output.



(a) (b) (c)

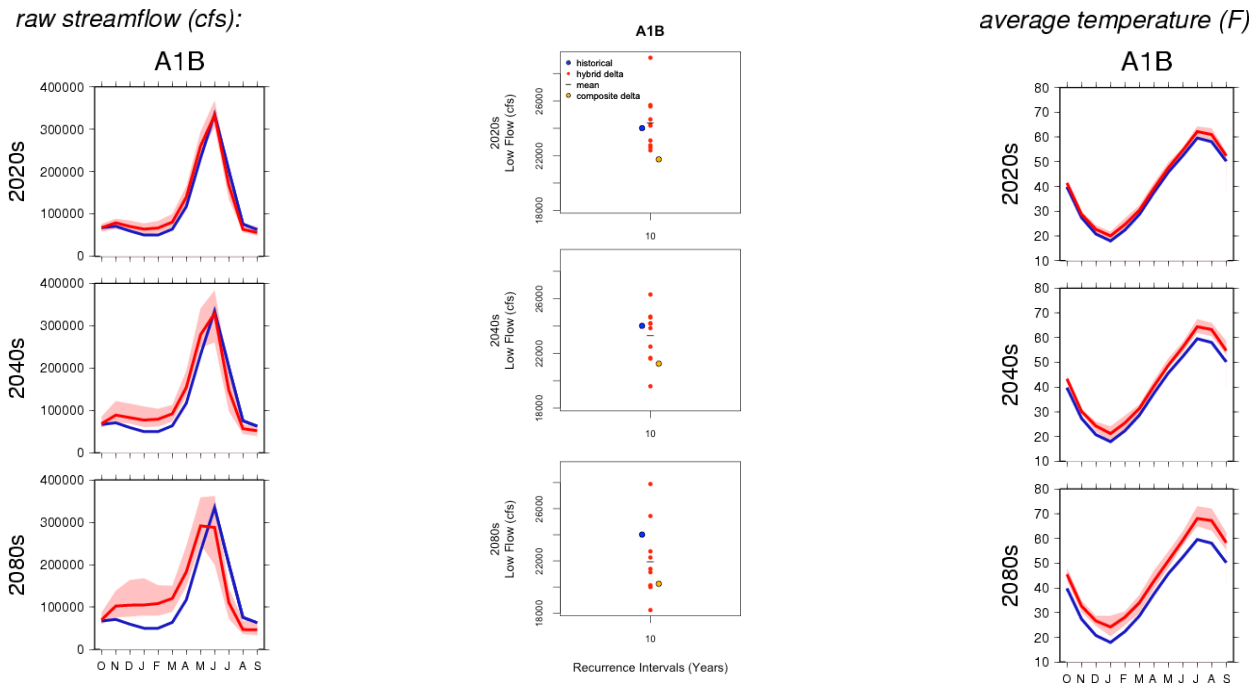
Columbia River at Priest Rapids Dam



(a) (b) (c)

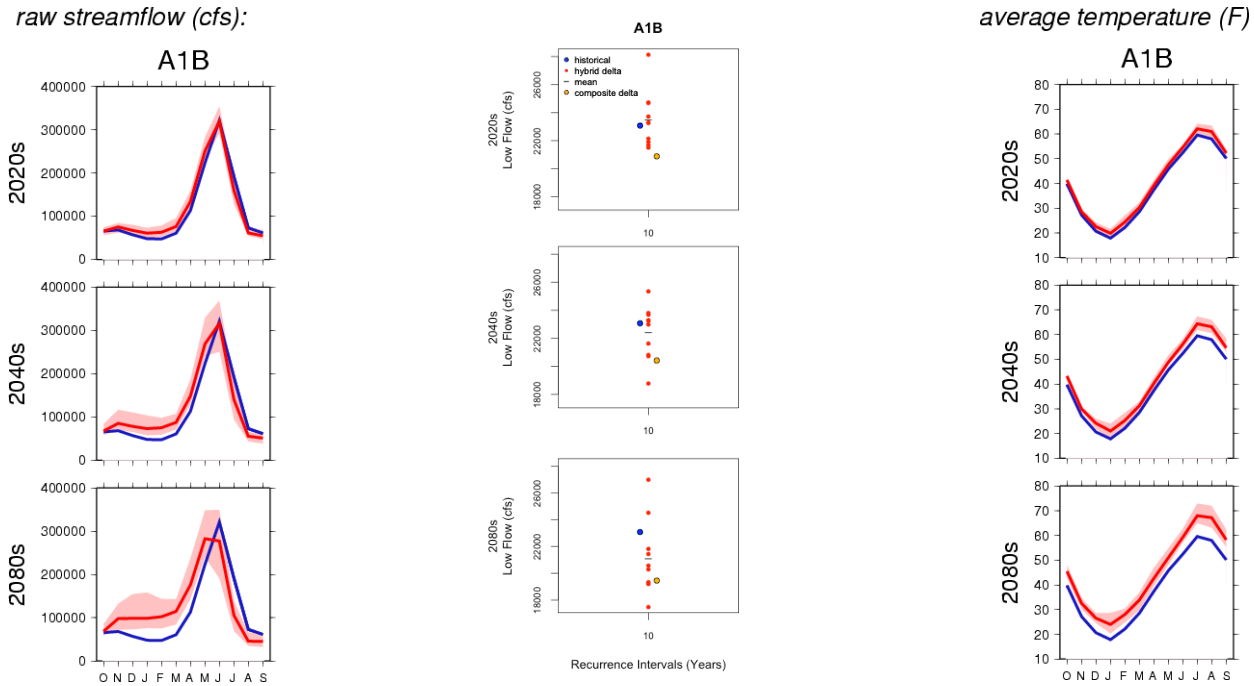
Columbia River at Rock Island Dam

Fig. B4. Climate and hydrology projections (mean streamflow, low flow, and air temperature) for the Columbia River at Priest Rapids Dam and Rock Island Dam (CIG 2011). Blue: 1971-1999 historic mean. Red: Mean and range of outputs from 10 models. For low flow (middle graphs), horizontal line = average of the 10 projections, and orange dot = composite model output.



(a) (b) (c)

Columbia River at Rocky Reach Dam



(d) (e) (f)

Columbia River at Wells Dam

Fig. B5. Climate and hydrology projections (mean streamflow, low flow, and air temperature) for the Columbia River at Rocky Reach Dam and Wells Dam (CIG 2011). Blue: 1971-1999 historic mean. Red: Mean and range of outputs from 10 models. For low flow (middle graphs), horizontal line = average of the 10 projections, and orange dot = composite model output.