



VIC-GL - DynWat Model Deployment

November 25, 2024

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Citation

Schnorbus, M.A, 2024: *Pacific Region VICGL-DynWat Model Deployment*. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC, 89 pp.

About PCIC

The Pacific Climate Impacts Consortium (PCIC) is a regional climate service centre at the University of Victoria that provides practical information on the physical impacts of climate variability and change in the Pacific and Yukon Region of Canada. We collaborate with climate researchers and regional stakeholders to produce knowledge and tools in support of long-term planning. For more information see <http://www.pacificclimate.org/>.

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Acknowledgement

We gratefully acknowledge the financial support from the British Columbia Salmon Restoration and Innovation Fund (BCSRIF), which is co-funded by the federal Department of Fisheries and Oceans (DFO) and the Province of British Columbia. The work represented in this report also benefitted from the efforts of PCIC employees, both past and present, who contributed technical expertise to the project, including Md. Shahabul Alam, and Ameneh Mollasharifi Targhi.

The model deployment work benefitted from data that was not available from conventional sources, which was prepared and provided by several people, including glacier thinning and area data from Brian Menounos (University of Northern British Columbia), and water temperature data collected and organized by Dave Hutchinson and Daniel Peters (Environment and Climate Change Canada).

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1 Introduction

1.1 Background

Fisheries management must address the effects of climate change across a diversity of species and aquatic environments (Hunter et al., 2015). However, climate risk is a complex process that requires understanding of the variability in climate change vulnerability between species, populations, and habitats. Climate change risk, or vulnerability, assessments are important tools to aid in the adaptation process, raise awareness, and advance scientific understanding (IPCC, 2014). Vulnerability assessments can be used to explore the spatial variability of climate risk and can be used to identify and prioritize at-risk salmon populations (FAO, 2015; Hunter et al., 2015). In this context vulnerability assessment can provide a relative comparison across salmon species and populations to highlight populations that, depending upon management priorities, are high priorities for conservation and/or recovery efforts.

Climate change vulnerability assessments are typically based on scoring systems determined via expert elicitation. Given the importance of this work to DFO management and given DFO's regulatory authority on salmon management as an agency, it is deemed critical that this expert driven process engage a broader group of salmon experts inside the Department of Fisheries and Oceans, among Indigenous communities, academia, etc. In this context it was determined that PCIC's aim should be limited to providing key knowledge and data inputs to facilitate the vulnerability assessment process. Specifically, PCIC's contribution is to solely focus on quantification of historical and future flow and temperature exposure in freshwater life stages, such as adult migration and egg-to-fry incubation (McDaniels et al., 2010; Healey, 2011). Consequently, work has focussed on the exploration and development of suitable flow and thermal exposure indicators derived from hydrologic projections that best capture and quantify hazards in the freshwater environment over a large spatial domain and at multiple temporal scales (daily, weekly, monthly, and seasonally). This data, and associated tool, would then support assessments of ecological vulnerability to climate change across diverse salmon habitats and populations.

It was decided that PCIC, working in collaboration with DFO personnel, would generate exposure data at two 'scales' of assessment: (a) a detailed fine-scale assessment specifically tagged to representative Sockeye and/or Chinook Salmon indicator stocks (Hyatt et al., 2015; Stiff et al., 2018b, 2018a, 2017, 2015a, 2015b, 2013), and (b) a broader-scale regional assessment at coarser resolution along the entire BC Coast. The intent was to use output from the VIC-GL model for the broad-scale regional analysis of climate change impacts.

This report details the deployment of the VIC-GL model chain in support of the broad-scale exposure assessment. Complementary to this approach, the RAVEN model was deployed to conduct more detailed hydrologic modelling of smaller watersheds for the fine-scale risk assessment, and this deployment is covered in Schoeneberg et al. (2024). An overview of the deployment process, including a description of the study area, is given in Section 3 of this report. Deployment of the VIC-GL model is covered in Section 4 and deployment of DynWat is covered Section 5. Section 5 covers verification of the combined VIC-GL – DynWat modelling chain.

2 Overview

2.1 Study Area

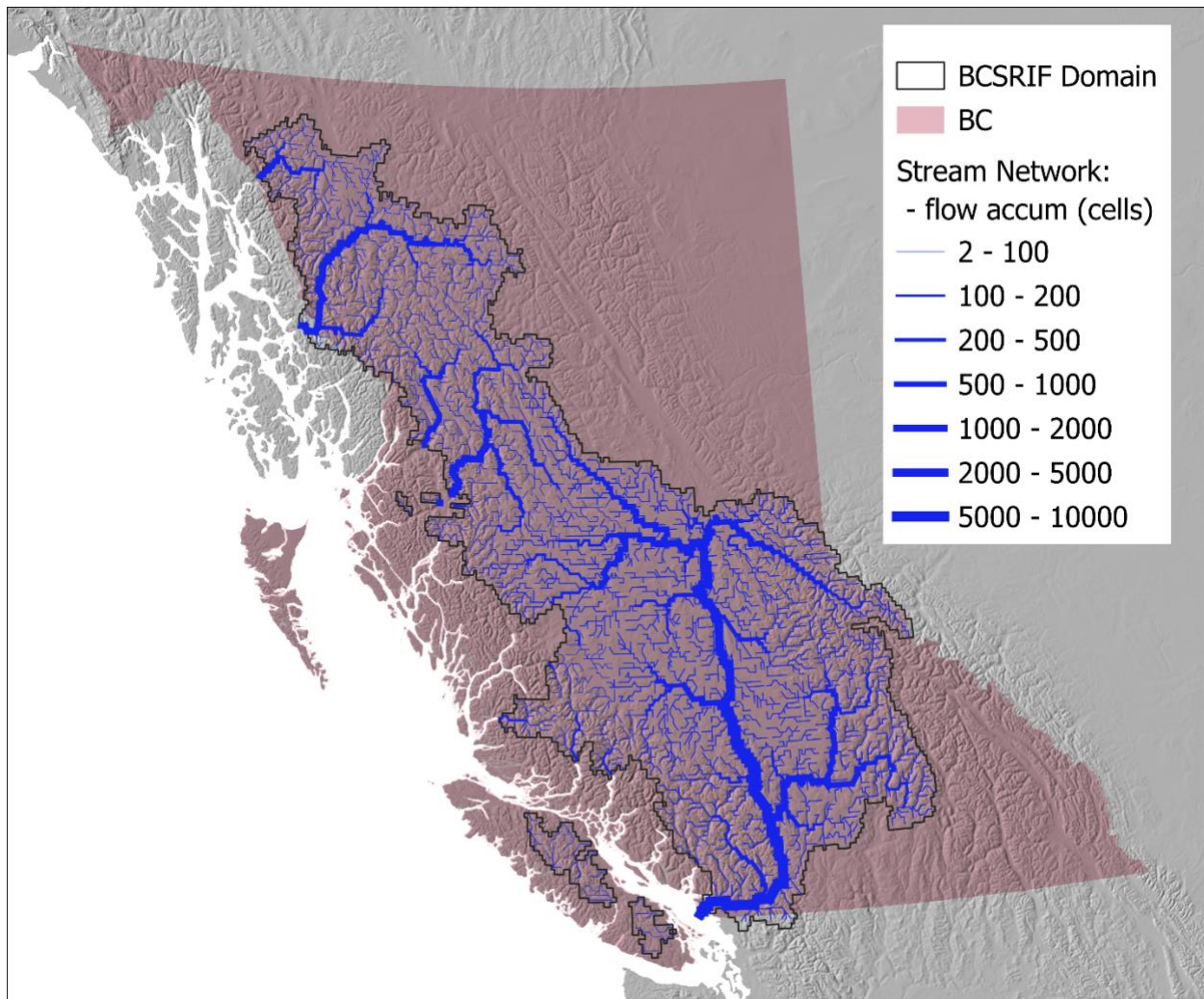


Figure 1. Stream network topology for the study domain (Fraser plus gauged portions of the BC Coast). Stream network lines are sized by flow accumulation (given as number of upstream VICGL cells).

The study domain, which we term the Pacific Region, includes the ‘gauged’ portion of the BC mainland and Vancouver Island areas draining to tidewater along the Pacific Coast (Figure 1). These drainage areas are gauged in that they are upstream of Water Survey of Canada (WSC) hydrometric sites selected for possessing long, reliable data records. This region is home to a wide diversity of salmon species and includes four major basins that drain to sea along the BC coast: Fraser River, Nass River, Skeena River, and Stikine River. Although recent observations have documented potential increases in presence and abundance of Pacific salmon across Canada’s Western Arctic (Babaluk et al., 2000; Carothers et al., 2019; Chila et al., 2021), arctic drainages were excluded from the study domain. The study area spans a large

geographic region and therefore encompasses a number of distinct ecoregions, defined by physical and ecological features including climate, physiography, oceanography, hydrology, vegetation, wildlife, as well as soil type, flora and fauna communities, and aquatic systems (Demarchi, 2011). Most of BC’s major drainages start along the Pacific coast and extend well into the interior of BC.

2.2 Deployment Workflow

The final production of streamflow and water temperature projections utilised the VIC-GL hydrology model coupled to the DynWat streamflow and water temperature routing model (‘Hydrologic Projections’, Figure 2).

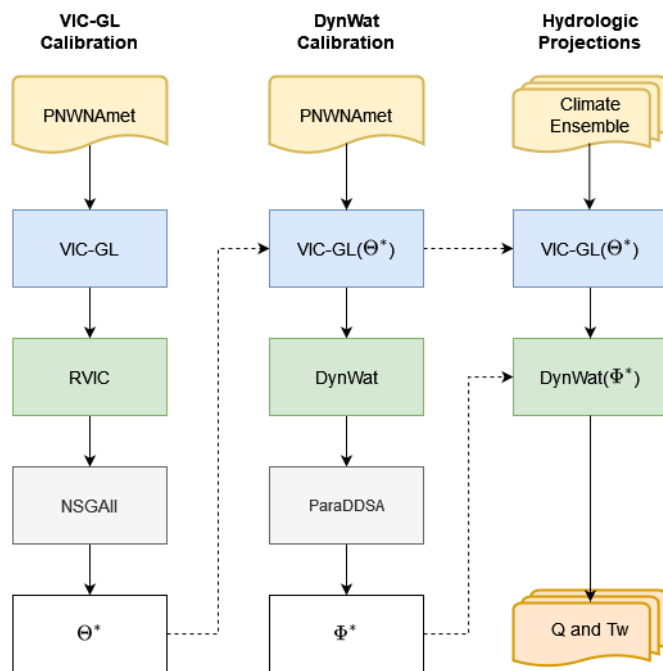


Figure 2. Deployment and calibration process for the combined VIC-GL – DynWat model chain. Major steps include calibration of the VIC-GL model and calibration of the DynWat model.

Each model in the modelling chain requires a unique set of parameters, and several of these parameters are adjusted in a calibration process to optimize model performance with respect to observations. As VIC-GL was calibrated to streamflow (among other variables), the process required a streamflow routing model. Therefore, calibration of VIC-GL requires repeated iteration of both VIC-GL and the routing model. Consequently, step 1 of the calibration process used RVIC as the routing model which, as a source-to-sink model is a much more efficient (i.e. faster) than DynWat (Figure 2). In step 2 the DynWat model was calibrated by using historical output from the calibrated VIC-GL model (Figure 2). In this process the output from VIC-GL is fixed and only the only the DynWat model is subjected to repeated iterations.

3 VICGL Deployment

Most of the pertinent details regarding deployment of the VIC-GL model are covered in the VIC Generation 2 Deployment Report (Volume 6) (Schnorbus, 2020), and only a brief summary is provided herein.

3.1 Model description

Hydrologic projections were produced using an upgraded version of the Variable Infiltration Capacity (VIC) hydrology mode (M.A. Schnorbus, 2018). VIC is a spatially distributed macro-scale hydrologic model that calculates water and energy balances in a grid cell, with sub-grid variability of the soil column, land surface vegetation classes and topography represented statistically. The model computes the water fluxes for a range of hydrologic processes such as evapotranspiration, snow accumulation, snowmelt, infiltration, soil moisture and surface and subsurface runoffs. The present version uses three-soil layers to represent soil moisture processes. The model uses variable infiltration curves to represent the spatial heterogeneity of runoff generation and uses the Arno conceptual model (Todini, 1996) for subsurface flow generation. Surface runoff from the upper two soil layers is generated when the moisture exceeds the storage capacity of the soil. Spatial variability is modelled by sub-dividing the model domain into a computational grid with a spatial resolution of 0.0625°. Sub-grid variability is described using hydrologic response units (HRUs), which are derived using vegetation classes and 200-m elevation bands. The model runs at a 3-hour temporal resolution, but output is aggregated to a daily resolution. Detailed description of the VIC model is available in Liang et al. (1994, 1996) and Cherkauer et al. (2003). The VIC model has seen extensive application in the study of climate change impacts in British Columbia (Curry et al., 2019; Islam et al., 2017; Schnorbus et al., 2014; Shrestha et al., 2016, e.g. 2012; Werner et al., 2013).

For many catchments, glaciers provide water to streams, especially during summer and early autumn when seasonal snowpacks have been depleted. Increased emissions of greenhouse gasses will accelerate warming in the decades ahead leading to strong mass loss and subsequent retreat of alpine glaciers. Therefore, to simulate more accurately the response of the cryospheric components of the basin, we have produced an upgraded version of the VIC model, called VIC-GL, that explicitly models glacier mass balance (accumulation, melt and runoff) and glacier dynamics (change in glacier area).

The VIC-GL model is not designed to allow lateral communication between cells; hence, it can't be used to directly model hydrologic or cryospheric features that occupy more than a single cell (such as large lakes or ice fields), or that flow from one cell into another cell (such as valley glaciers). Consequently, glacier dynamics is simulated by coupling VIC-GL to the UBC Regional Glaciation Model (RGM). The RGM model is described in detail by Jarosch et al. (2013) and Clarke et al. (2015). In the coupled system, glacier surface mass balance estimated with the VIC-GL model is converted to a high-resolution 100-m equal-area grid. This gridded mass balance field is then used to force the RGM model, the output of which is updated surface topography that reflects changes in the spatial distribution of glacier thickness. VIC-GL is subsequently updated with the new glacier areas. Coupling takes place on an annual basis and occurs at the end of the water year (30 September). RGM requires an estimate of the bed (or sub-glacial) topography, and we use the results from Clarke et al. (2013). Glacier thickness at the end of each water year is calculated as the difference between the updated surface topography and static bed topography. The description of the new glacier surface mass and energy balance routines in VIC-GL is described in (M.A. Schnorbus, 2018; M. A. Schnorbus, 2018).

3.2 Hydrologic Response Units

Representation of sub-grid variability in the VIC model uses Hydrologic Response Units (HRUs), which are computational elements that are considered homogeneous from a hydro-climatological perspective. HRUs are created based on land cover classification and elevation; landscape elements are grouped into hydro-climatically homogeneous units if they have the same land cover class and are within the same elevation band. Sub-grid variability is determined by dividing each VIC grid cell into a collection of HRUs, where the HRU acts as the fundamental computational element of the model. The number of HRUs, and hence the effective model resolution, is then governed by the fidelity of the land cover classification (i.e., number of classes) and the vertical resolution employed (i.e. band discretization). In the current application of VIC-GL a band width of 200-m was used. Note that HRUs do not retain any information on the original spatial organization of landscape elements as all areas of the same vegetation class within an elevation range are lumped together into a single HRU. Figure 3 shows the distribution of land cover by elevation band in the study domain. Just under 60% of the total area is forested (classes N-TeSp-1 through MF), 11% is classed as Barren, 10% is Water (although much of this is ocean), and 6% of the area is glacier ice. Just over 50% of the study area is below and elevation of 1000 m; 77% is below and elevation of 1500 m, and 94% is below and elevation of 1800 m (Figure 3).

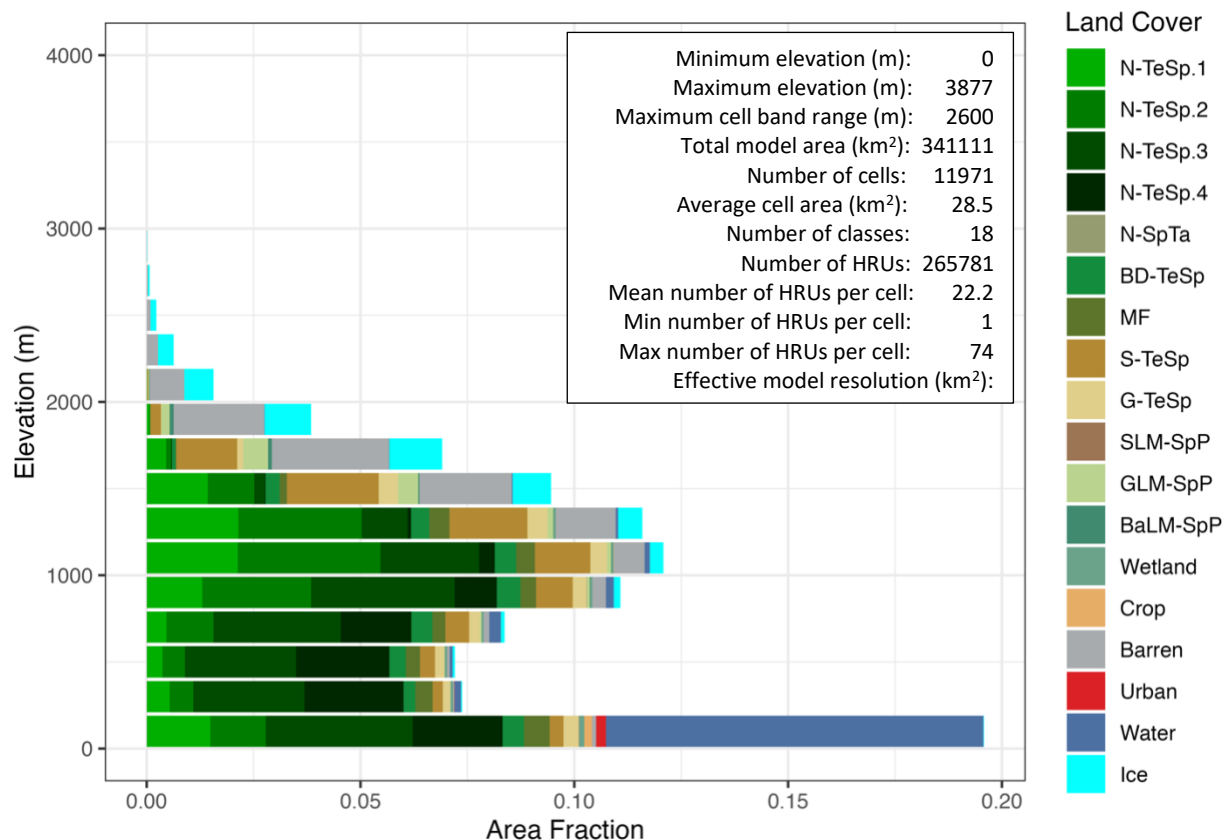


Figure 3. Vegetation class by elevation band for the modelling domain.

3.3 Routing and Topological network

During model calibration surface water routing is applied as a post-processing step in the modelling chain using the RVIC model (<https://rvic.readthedocs.io/en/latest/>), which is based on the numerical schemes described in (Lohmann et al., 1998, 1996). RVIC is a very computationally efficient source-to-sink model which makes it very well suited for calibration, which requires thousands of model iterations. A two-step process is used to rout runoff and baseflow generated in each VIC-GL model cell: in-grid routing and channel routing. In-grid routing conceptually moves surface runoff through the sub-grid drainage network to the main channel using a transfer function that essentially describes the time distribution for runoff reaching the outlet of a grid box. The transport of water within the channel is modelled using a one-dimensional diffusive wave approximation to the full Saint Venant equations.

The channel network is determined by assigning a ‘dominant’ flow direction to each grid cell where runoff from each cell can only flow in one of eight flow directions (N, NE, E, SE, S, SW, W or NW) to a neighbouring cell. The resultant sub-basin and channel topology is shown in Figure 1.

3.4 Forcing Data

During model calibration, VIC-GL was forced using a gridded meteorological data set produced specifically for the 2nd generation modelling. This data set, called PNWNAmet, contains daily observations gridded at 1/16° (same spatial resolution as VIC-GL) with the variables of maximum and minimum temperature, precipitation and average wind speed (Werner et al., 2019). The PNWNAmet dataset was created over a domain covering northwest North America (40°N to 72°N and -169°W to -101°W). PNWNAmet was created using the trivariate thin plate spline interpolation method with the algorithm implemented by Nychka et al. (2017). Minimum temperature, maximum temperature and precipitation were interpolated separately using latitude, longitude and 1971-2000 climatology from ClimateWNA (v5.10) as predictors. Precipitation occurrence and square root transformed precipitation amounts were interpolated separately on each day, combined, and transformed back to original units. After interpolation, the raw daily minimum/maximum temperature and precipitation surfaces were rescaled so that their climatological monthly means matched those of ClimateWNA following Hunter and Meetemeyer (2005). In addition, wind data is included from the 20th Century Reanalysis V2 (20CR2) (Compo et al., 2011). Werner et al. (2019) provide full details. In order to run the model at sub-daily resolution, as well as estimate additional forcings required for energy balance calculations (solar and longwave radiation, vapor pressure, and atmospheric pressure) PNWNAmet was post-processed using the Metsim meteorological simulator (<https://metsim.readthedocs.io/en/develop/index.html>), which is based on MT-CLIM (see <https://www.umt.edu/numerical-terradyamic-simulation-group/project/mt-clim.php> for references).

3.5 Model Calibration

Calibration of the VIC-GL model employs a multi-objective calibration paradigm. This approach exploits several different data sources to produce an optimized model based on explicitly constraining separate hydrologic processes. A multi-objective approach recognizes there are multiple ways in which a model can be best fit to the data. Hence, multi-objective problems tend not to have unique solutions. Using a Pareto-optimized set of parameters accepts that there is no “best” parameter set (model) and reflects uncertainty due to errors in the model structure, boundary conditions (i.e., meteorological data,

hydrometric data, and soil, vegetation, and topography parameters) and observations. The model was calibrated to observations of streamflow, snow cover, and glacier mass balance and to an ensemble of various evapotranspiration products.

Modelled VIC-GL fluxes for all sub-basins were calibrated using the improved version of the non-dominated sorting genetic algorithm (NSGA-II) (Deb et al., 2002), an automatic evolutionary algorithm that solves the multiple objective global optimization problem. NSGA-II converges to and provides a sample of the Pareto frontier, which is a set of all parameter vectors that produce non-dominated values of the objective function vector. Implementation of the NSGA-II algorithm was accomplished using the *mco* R package (Mersmann, 2014).

A thorough description of the VIC-GL calibration process can be found in Schnorbus (2017).

4 DynWat Deployment

4.1 Model Description

In this study we used the dynamical 1-D water energy routing (DynWat), that solves the transport of water and energy in a gridded river network (van Beek et al., 2012; Wanders et al., 2019).

For simulating streamflow it is assumed that each grid cell has a single channel reach and discharge in each reach is calculated by the kinematic wave approximation of the Saint-Venant equation (Fread, 1992). This entails that at the end of each time step, a new stage for the simulated discharge is calculated under an assumption of a rectangular channel and passed on to the next time step to estimate the wetted perimeter of the flow and the corresponding roughness coefficient (Dingman, 2015). Waterbodies are treated as contiguous water surfaces with a variable water height and surface area that changes instantaneously with the net inflow over that area, where net inflow is the balance of inflow and outflow. The inflow includes the incoming river discharge and outflow is calculated in analogy to the weir formula as the discharge over a rectangular cross section (Bos, 1989). The discharge at the outlet of waterbodies is added within the time step as lateral inflow to the kinematic wave approximation of the downstream river reach (Wanders et al., 2019).

For calculating the energy balance DynWat assumes that each channel reach experiences full vertical mixing. Within each fully mixed water volume the energy balance is solved by considering the local energy balance plus energy advected by water flowing in and out of the channel reach. For waterbodies, the assumption of complete vertical mixing is invalid. In this case DynWat assumes a model composed of two well-mixed layers, an upper epilimnion layer and a lower hypolimnion layer. The volume of both layers varies as a function of net inflow. The volume of upper epilimnion layer is set by assuming a constant layer thickness (or thermocline depth), which is determined as a function of waterbody fetch length, and the hypolimnion constitutes the remaining waterbody volume. Surface energy exchange and lateral advection of energy occurs exclusively in the epilimnion layer. Energy is distributed between the two layers by assuming the hypolimnion temperature remains fixed at 4°C, which corresponds to the temperature of maximum water density. The temperature of the epilimnion layer is determined by solving the resultant energy balance. The DynWat model also includes processes for the formation and breakup of ice cover and dynamic coupling of surface water abstraction and reservoirs operations. The model can simulate daily water temperatures with 5 min (or finer) temporal disaggregation to ensure stable model simulations in smaller streams and lakes (Wanders et al., 2019). At PCIC additional modifications have also been made to simulation of the energy balance, river ice, and estimation of waterbody outflow, and these are described in Section 4.2.

In our implementation the DynWat model is used in a stand-alone configuration to allow off-line coupling with the VIC-GL model. In this case DynWat is supplied with the following hydrological inputs:

1. surface runoff from rainfall,
2. surface runoff from snow or glacier melt, and
3. baseflow or groundwater discharge.

The model also needs additional information on the meteorological input, such as temperature, precipitation, and radiation terms. The temperature of surface runoff and baseflow also must be specified. The DynWat model runs on the same computational grid as VIC-GL, with the same resultant

stream topology as used by RVIC (Figure 1). In the current implementation of DynWat all reservoirs treated as natural lakes. Hence, in those stream reaches affected by flow regulation the resultant streamflow and water temperature values reflect hypothetical natural conditions.

A full description of the model is available in Wanders et al. (2019) and recent modifications undertaken at PCIC are described in the following section.

4.2 Upgrades

Main upgrades include:

1. Modifications to simulation of the energy balance,
2. Upgrades in the simulation of river Ice,
3. Adjustments to the way in which waterbody outflow is estimated.

These upgrades are detailed in the following paragraphs. The upgraded version of code can be found at <https://github.com/mschnorb/waterTemperatureModel>.

4.2.1 Energy balance

The following changes have been made in the calculation of surface energy balance for each river reach:

1. Instead of estimating shortwave from annual solar radiation climatology and daily cloud cover, daily shortwave radiation is now provided directly as an input. The original sunshine hours tables and daily cloud cover are no longer required as model inputs.
2. Replaced constant atmospheric emissivity with estimate based on air temperature and vapor pressure as per Idso (1981). Vapor pressure must still be supplied as an input.
3. Split surface runoff to account for separate rain and melt sources, with different source temperatures for each. The land temperature, or temperature of lateral inflow, is now calculated as:

$$T_{land} = \frac{R_{rain}}{R_{tot}} \max(0.1, (T_{air} - \delta_{rain})) + \frac{R_{melt}}{R_{tot}} (T_{th} + \delta_{melt}) + \frac{I}{R_{tot}} \max(0.1, T_{air}) + \frac{B}{R_{tot}} \max(0.1, T_{soil}) \quad (1)$$

where $R_{tot} = R_{rain} + R_{melt} + I + B$, the sum of rainfall-sourced surface runoff, melt-sourced surface runoff, interflow, and baseflow, respectively, T_{air} is the air temperature, T_{soil} is the soil temperature, T_{th} is the ice temperature threshold (0°C), and δ_{rain} and δ_{melt} are, respectively, the reduction in the temperature of falling rain and the increase in the temperature of melting snow and ice.

4. The model now has three methods of estimating soil temperature, which is used as a proxy for the temperature of baseflow (more realistically, this is intended as the temperature of baseflow once it reaches the main channel via the in-grid surface routing network, and should, therefore, also account for local surface heating during this transit period).

5. The original method uses a daily running mean of annual air temperature. The choice of annual air temperature requires a separate forcing file providing the daily running mean of annual air temperature.
6. The second method uses a smoothing function of daily air temperature as a proxy for soil temperature,

$$T_{soil}[t] = (1 - \kappa)T_{soil}[t - 1] + \kappa \cdot T_{air}[t] \quad (2)$$

The choice of ‘smoothing’ requires specification of the smoothing parameter κ and an initial soil temperature map (or a default spatially uniform value, which is hardcoded). If smoothing is chosen the code also dumps soil temperature to state. As $\kappa \rightarrow 0$ the degree of smoothing increases (annual amplitude decreases and seasonal lag with air temperature increases), and when $\kappa=0$, $T_{soil}[t] = T_{soil}[t-1] = T_{soil}[0]$. As κ increase the degree of smoothing decreases (annual amplitude increases and seasonal lag with air temperature decreases), and when $\kappa=1$, $T_{soil}[t] = T_{air}[t]$.

7. The third method uses the Mohseni et al. (1998) 4-parameter non-linear model which was originally designed to predict stream temperature as a function of air temperature. When choosing this method, the soil temperature is calculated as

$$T_{soil}[t] = \frac{\mu + (\alpha - \mu)}{(1 + e^{\gamma(\beta - \bar{T}_a[t])})} \quad (3)$$

where $\bar{T}_a[t]$ is the running mean air temperature over the period $t, t-1, \dots, t-n-1$, and n is the averaging period in days. If this method is selected, δ_{melt} is not treated as a parameter, but is instead specified as a fraction of T_{soil} , where $\delta_{melt}[t] = f \cdot T_{soil}[t]$. The choice of ‘mohseni’ requires specification of the four regression parameters, the averaging period, n , and the fraction, f , an initial average air temperature map (or a default spatially uniform value, which is hardcoded), and an initial number of time steps used for estimating the initial average air temperature (or a default of n is assumed). With this method the code also saves soil temperature to state.

8. The choice of the soil temperature method and required inputs/parameters (e.g. annual air temperature input file, soil temperature initial state and kappa, or average air temperature initial state and time steps to average temperature initial state) are specified in the configuration file. If the soil temperature method is ‘annual’ or ‘smoothing’, then δ_{melt} must be specified in the configuration file. If the soil Temperature method is ‘mohseni’ then δ_{melt} is estimated by the melt fraction, f .
9. Methods ‘annual’ and ‘smoothing’ are approximations of the inter-annual variation of soil temperature and do not really account local heat transfer that may occur during in-grid routing (i.e. they assume that baseflow is the temperature of groundwater, which is equivalent to the depth-averaged soil temperature) when it reaches the main channel. Method ‘mohseni’ attempts to reflect the temperature of baseflow-sourced water more accurately as a function of

both the source groundwater temperature, plus additional energy transfer during in-grid routing by using equation (3), but using a running–average air temperature. The averaging period can be adjusted to either increase/decrease the influence of the source temperature (by increasing/decreasing the averaging period), whereas 4-parameter non-linear regression more accurately reflects the effect of local energy exchange during routing (note that original use of (3) was to estimate weekly average stream temperature as a function of weekly average air temperature).

10. Replaced the simply parameterized empirical heat transfer to water with an explicit representation of turbulent exchange of sensible heat (for both ice and water surfaces), also including a stability correction based on the bulk Richardson approach.

4.2.2 River Ice

River ice simulation has been upgraded by adopting the model of Shen and Chiang (1984) for growth and decay of river ice. Modifications include:

1. The ice surface temperature determined analytically from previous surface energy balance and ice thickness (as opposed to using air temperature)
2. replaced the empirical heat transfer to ice with a semi-empirical approach that accounts for water velocity and depth
3. estimate water velocity from discharge and channel geometry, which is derived from channel storage and water surface area
4. apply separate thickness change calculations for ice surface (melt only) and ice bottom (melt or growth)
5. the fraction of solar radiation assumed to penetrate through the ice is based on a bulk extinction coefficient
6. the thermal conductivity of ice calculated as function of ice temperature

4.2.3 Waterbodies

Some slight adjustments have been made in the way that waterbody outflow is calculated. These include:

1. Ensuring that the fraction of reservoir/lake surface area in each cell is scaled to be consistent with water body surface area provided as separate input.
2. The weir coefficient is now specified as a parameter in the initialization file, either as a PCRaster map file (i.e., spatially variable) or as a constant value (i.e., spatially uniform).
3. Removed all default 'minimum' lake outflow settings. Lake outflow is now strictly a function of live storage (storage above sill elevation), where $0.0 \leq \text{lake outflow} \leq \text{live storage}$ (i.e. lake outflow can be zero and maximum outflow limited to live storage volume).

4.3 Input and Parameters

4.3.1 Static Input

The dynWat model runs on a computational grid with a spatial resolution of $1/16^\circ$. Certain parameter values that define the computational grid, flow topology, etc., are static in time but spatially variable and are supplied as maps. These parameters are described in the following sub-sections.

4.3.1.1 Cell Area

The area of each grid cell, which varies as a function of latitude.

4.3.1.2 Flow Direction

A 'dominant' flow direction is assigned to each grid cell in the exact same manner as that employed for the RVIC model (see Section 3.3). Hence, dynWat runs on the same network topology as that shown in Figure 1.

4.3.1.3 Channel Gradient

This parameter specifies the channel slope in each grid cell. Channel slope is approximated by using a high-resolution digital elevation model and taking the difference in elevation of the minimum and 10th percentile elevation in each $1/16$ -degree computational cell divided by the flow distance. The flow distance is assumed to be the diagonal length of each cell. The 7.5 arc-second mean elevation product of the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) (Danielson and Gesch, 2011) was used as the high-resolution DEM.

4.3.1.4 Waterbodies

The effect of waterbodies (lakes and reservoirs) on discharge and water temperature is modelled explicitly in dynWat. Based on a minimum size threshold of 5 km^2 , a total of 90 waterbodies are included in the model domain, ranging in size from 6.5 to 830 km^2 . The location of the modelled waterbodies is given in Figure 4. Waterbody properties are described below and summarised in Table A1 of Appendix A.

4.3.1.5 Waterbody Parameters

Maximum capacity/storage: The volume of water body at maximum capacity (assumed to be volume below the outflow sill elevation). The value for each cell is the total for each individual waterbody.

Surface area: The surface area of each waterbody, which is assumed to occur when the water body is at maximum capacity. The value for each cell is the total area for each individual waterbody.

Fraction cell area: the surface area of a waterbody in each grid cell as a fraction of grid cell area.

Shape factor: The shape factor, f , is an empirical parameter that governs the dependence of both surface area and volume on depth. The relationship between depth, d , and area and volume is given by, respectively:

$$A = \frac{d^2 f^2}{a} \quad (4)$$

$$V = \frac{d^3 f^2}{b}, \quad (5)$$

where $a = 1$ for lakes and 2 for reservoirs, and $b = 3$ for lakes and 6 for reservoirs. The relationship between volume and area can then be written as

$$V = \frac{cA^{1.5}}{f}, \quad (6)$$

where $c = a^{1.5}/b$.

Waterbody Type: The type of waterbody can be either a natural lake [1] or a reservoir [2]. The relation between area, volume and depth is treated differently between lakes and reservoirs (see Shape Factor). Lakes and reservoirs also differ in the way that outflow is simulated. For the current application all waterbodies are treated as natural lakes.

Waterbody ID: An identification number unique to each water body that currently uses the BC Geographical Names Information System (BCGNIS) ID from the BC Freshwater Atlas.

4.4 Data Collection and processing

Waterbody area was obtained from the BC Freshwater Atlas (FWA; <https://www2.gov.bc.ca/gov/content/data/geographic-data-services/topographic-data/freshwater>). Only waterbodies with a surface area greater than 5 km² are explicitly included in the model. Values of waterbody capacity, and maximum depth were obtained from lake and reservoir bathymetry data collected from various sources, although data for most lakes was obtained from bathymetric maps published by the government of British Columbia (Government of British Columbia, 2024) (Table A1).

For most waterbodies the shape factor was estimated directly from water body area (from the FWA) and maximum depth (from bathymetry) by inverting equation (4). Otherwise, if bathymetry data was unavailable the shape factor was regionalized from surrounding lakes and maximum depth was estimated from surface area, again using equation (4). To maintain a consistent *area – f – volume* relationship, waterbody storage is estimated from equation (6) using observed surface area, A , and observed or estimated values for maximum depth. We note that waterbody volume estimated from (6) and those from the bathymetry maps (where available) are not necessarily consistent (Table A1) and can differ by as much as 50%.

4.5 Input

4.5.1 Meteorology and Hydrology

The dynWat model requires input of mean daily air temperature, total daily precipitation, daily vapor pressure, shortwave radiation, longwave radiation, wind speed, and potential evapotranspiration for water surfaces. All the required meteorological forcings are provided as VIC-GL output. DynWat is also forced with baseflow and surface runoff, which is also supplied from VIC-GL (Table 1). Surface runoff is divided into rainfall-sourced and melt-sourced, which have different temperature boundary conditions.

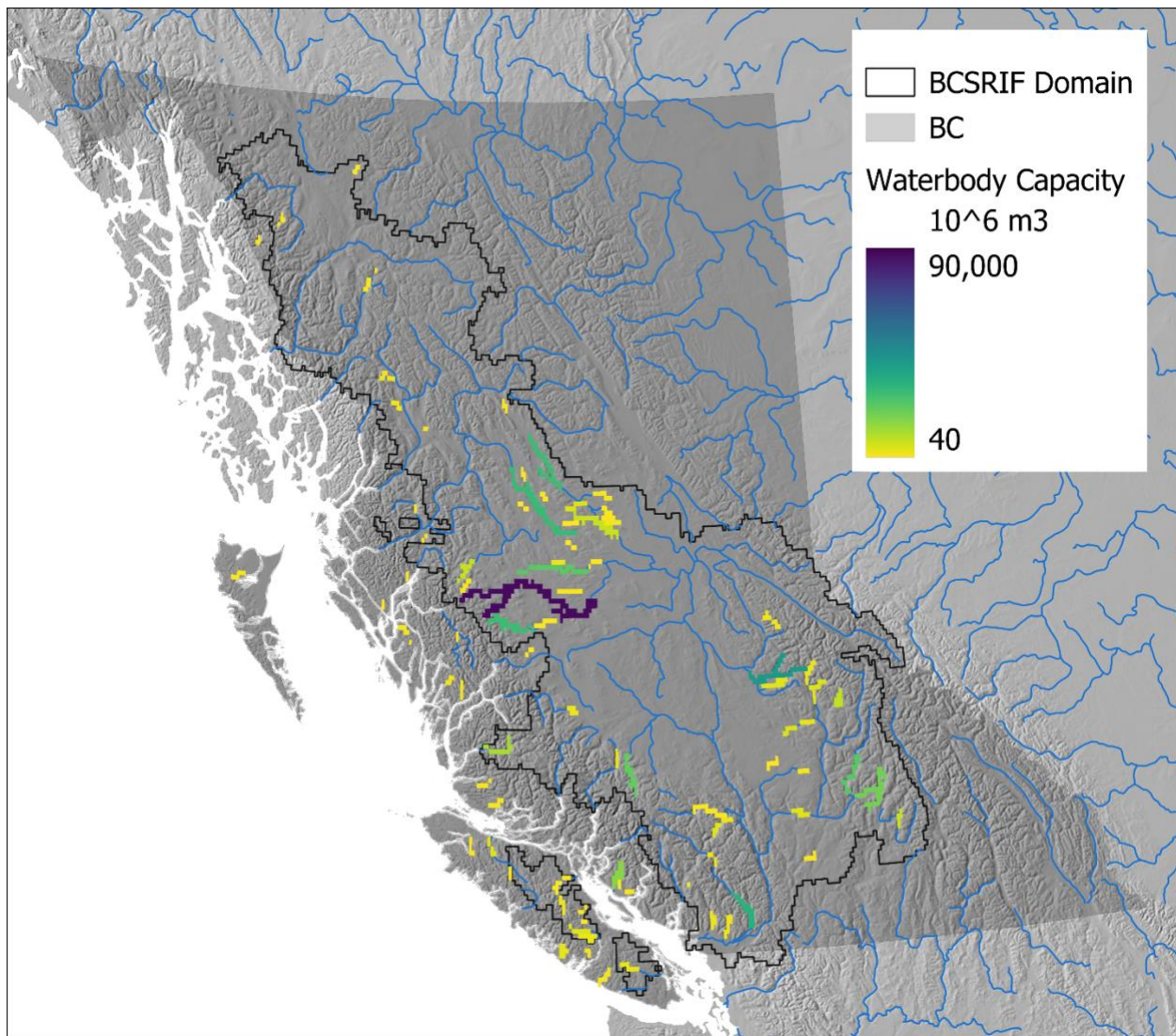


Figure 4. Location of modelled waterbodies in dynWat. Color scale shows maximum capacity of each waterbody.

4.6 Model Calibration

4.6.1 Calibration Procedure

DynWat calibration also employed a multi-objective approach. Calibration was conducted using the PA-DDS multi-objective optimization algorithm, which is an asynchronous parallel implementation of the Dynamically Dimensioned Search (DDS) family of algorithms (Asadzadeh and Tolson, 2012; Tolson and Shoemaker, 2007). We used PA-DDS, as implemented in the OSTRICH calibration toolkit (<https://usbr.github.io/ostrich/>), with four objective functions, three for streamflow and one for temperature. Ten parameters were adjusted as part of the calibration procedure, which are summarised in Table 2.

Table 1. DynWat meteorology and hydrology forcings

Description	VIC-GL Variable	Notes
<i>Meteorology</i>		
Air temperature	AIR_TEMP	
Precipitation	PREC	Converted to m
Wind speed	WIND	
Shortwave radiation	SHORTWAVE	
Longwave radiation	LONGWAVE	
Potential evapotranspiration	PET_H2O	Converted to m
<i>Hydrology</i>		
Baseflow	BASEFLOW	Converted to m
Surface runoff from rainfall	RUNOFF_RAIN	Converted to m
Surface runoff from melt	RUNOFF_SNOW	Converted to m

The objective functions used in the procedure are the squared difference between the actual value and the theoretical perfect score of four metrics, the Kling-Gupta Efficiency (*KGE*) for streamflow, the Nash-Sutcliffe Efficiency for log-transformed streamflow (*LNSE*), the streamflow bias (*BIAS*) and the p-factor (*PFAC*) for water temperature. For each metric, m , an objective function is calculated as

$$F_i(n) = (o_i - m_i(n))^2, \quad (7)$$

where m_i is the value for the modelled data, o_i is the ‘observed’, or target, value, for metric i and calibration iteration n . For a given iteration each metric is the mean over all stations, i.e., $m_i(n) = \frac{1}{K} \sum_{j=1}^K m_{i,j}(n)$, where K is the number of stations. Each objective function is weighted equally.

The Kling-Gupta efficiency (*KGE*) is a goodness-of-fit indicator widely used in the hydrologic sciences for comparing simulations to observations (Gupta et al., 2009). It is calculated as

$$KGE = \sqrt{(r - 1)^2 + (\alpha - 1)^2 + (\beta - 1)^2} \quad (8)$$

where r is the correlation coefficient, $\alpha = \frac{\hat{\sigma}_s}{\hat{\sigma}_o}$, and $\beta = \frac{\bar{s}}{\bar{o}}$, for simulated values s and observations o . For a perfect model the Kling-Gupta efficiency equal one. *KGE* is not a traditional skill score (i.e. a metric that measures improvement over a reference model), but Knoben et al. (2019) have shown that using mean flow as a predictor results in $KGE \approx -0.41$. Hence, a model that has a $KGE > -0.41$ performs better than the mean flow. The target value for the *KGE* in equation (7) is 1.0.

The Nash–Sutcliffe model efficiency coefficient (*NSE*) is used to assess model predictive skill and is defined as one minus the ratio of the error variance of the modeled time-series divided by the variance of the observed time-series (Nash and Sutcliffe, 1970)

$$NSE = 1 - \frac{\sum_{t=1}^T (o_t - s_t)^2}{\sum_{t=1}^T (o_t - \bar{o})^2} \quad (9)$$

In the situation of a perfect model with an estimation error variance equal to zero, the resulting Nash–Sutcliffe Efficiency equals 1 ($NSE = 1$). Conversely, a model that produces an estimation error variance equal to the variance of the observed time series results in a Nash–Sutcliffe Efficiency of 0.0, which indicates that the model has the same predictive skill as the mean of the time-series. In the case of a modeled time series with an estimation error variance that is larger than the variance of the observations, the *NSE* becomes negative, and the observed mean is a better predictor than the model. The *LNSE* is simply the *NSE* applied to log-transformed values. The target value for the *LNSE* in equation (7) is 1.0.

The streamflow bias is simply the absolute value of the mean of the observed time series minus the mean of the simulated time series

$$BIAS = |\bar{o} - \bar{s}|. \quad (10)$$

The target value for *BIAS* is in equation (7) is 0.

The p-factor (*PFactor*) is the percentage of observations that are within a given uncertainty range. For a given location with observed spot measurements x and simulated time series z , *PFactor* is calculated as

$$PFactor = \frac{1}{N} \sum_{y=1}^{365} \sum_{i=0}^{N_y} \mathbf{1}_{A_y}(x) \quad (11)$$

where N is the total number of temperature observations, $y = 1, \dots, 365$ is the day number (leap days are excluded), N_y ($0 \leq N_y \leq N$) is the number of observations on day number y , and $\mathbf{1}_{A_y}$ is the indicator function

$$\mathbf{1}_{A_y}(x) := \begin{cases} 1 & \text{if } x \in A_y \\ 0 & \text{if } x \notin A_y \end{cases} \quad (12)$$

where $A_y = [F_{zy}^{-1}(0.05), F_{zy}^{-1}(0.95)]$ and F_{zy} is the cumulative distribution function of simulated water temperature for day number y . The target value for *PFAC* in equation (7) is 0.9, i.e., if the simulated values, z , perfectly reproduce the observed daily climatology then 90% of the N spot observations should fall within the simulated ranges defined by A_y .

For computational purposes the calibration was broken into two spatial domains, the BC Coast (all watersheds except the Fraser) and the Fraser. The Final calibrated parameters for both domains are shown in Table 2.

4.6.2 Calibration Data

Streamflow time series data were obtained from the Water Survey of Canada (WSC) and the stations used for calibration are summarised in Table A2. Water temperature data derives from several datasets collected by Environment and Climate Change Canada (under several programs) and the Department of Fisheries and Oceans (Table 3). The water temperature data are available as spot temperature measurements, i.e., measurements taken at irregular intervals, usually manually. Although sampled irregularly, many sites have sufficiently large samples (either sampled relatively frequently and/or sampled over a long period) that a reasonably complete water temperature climatology can be constructed. At several sites, the temperature record is merged using data collected from different agencies (and programs). Figure 5 shows an example for the South Thompson River at Chase, BC. Water temperature observation sites are described in Table A3. The location of all streamflow and water temperature sites used for calibration is given in Figure 6. Note that a handful of water temperature sites are hybrid stations where data from two nearby stations (i.e. both located in the same VIC-GL grid) has been merged into a single data set, e.g. Chilcotin River at Alexis Creek (DFO station CR50) and Chilcotin River upstream of Christie Road Bridge (ECCC station BC08MB007).

During dynWat model calibration baseflow, surface runoff from rainfall, and surface runoff from melt were provided from a retrospective VIC-GL simulation driven by PNWNAmet observed meteorological data (Figure 2 and Section 3.4).

Table 2. DynWat calibration parameters

Parameter	Description (with units)	Calibration Range	Calibrated Values	
			BC Coast	Fraser
<i>mohseniMax</i>	Maximum water temperature (°C)	[30, 45]	45	37
<i>mohseniShift</i>	Air temperature at function inflection point (°C)	[1, 15]	13	13
<i>mohseniSlope</i>	Steepest slope of function (-)	[0.10, 0.20]	0.18	0.18
<i>meltTempScale</i>	Scaling factor on <i>soilT</i> to calculate <i>deltaTMelt</i> (-)	[0.10, 0.50]	0.28	0.34
<i>avgPeriodTemp</i>	Air temperature averaging period (day)	[1, 30]	18	7
<i>manningsN</i>	Manning's roughness (-)	[0.02, 0.07]	0.021	0.028
<i>tau</i>	Hydraulic geometry coefficient for channel width (m)	[2.00, 8.00]	5.88	5.30
<i>phi</i>	Hydraulic geometry exponent for channel width (-)	[0.40, 0.55]	0.50	0.52
<i>beta</i>	Kinematic wave parameter (-)	[0.55, 0.70]	0.60	0.66
<i>fetchExp</i>	Fetch coefficient for thermocline depth calculation (-)	[0.40, 0.70]	0.46	0.64

Table 3. Sources of Water Temperature Data

Data ID	Description	Source
DFO	Summer water temperature collected by the Department of Fisheries and Oceans	Patterson et al. (2007); Hague et al.(2008); Thompson et al. (2010)
EC-WQ	Temperature data collected as part of the Canada-B.C. water quality monitoring program	Ministry of Environment and Climate Change Strategy (2020)
EC-WSC	WSC spot temperature measurements taken by technicians during field visits to gauge sites	Hutchinson (personal communication)

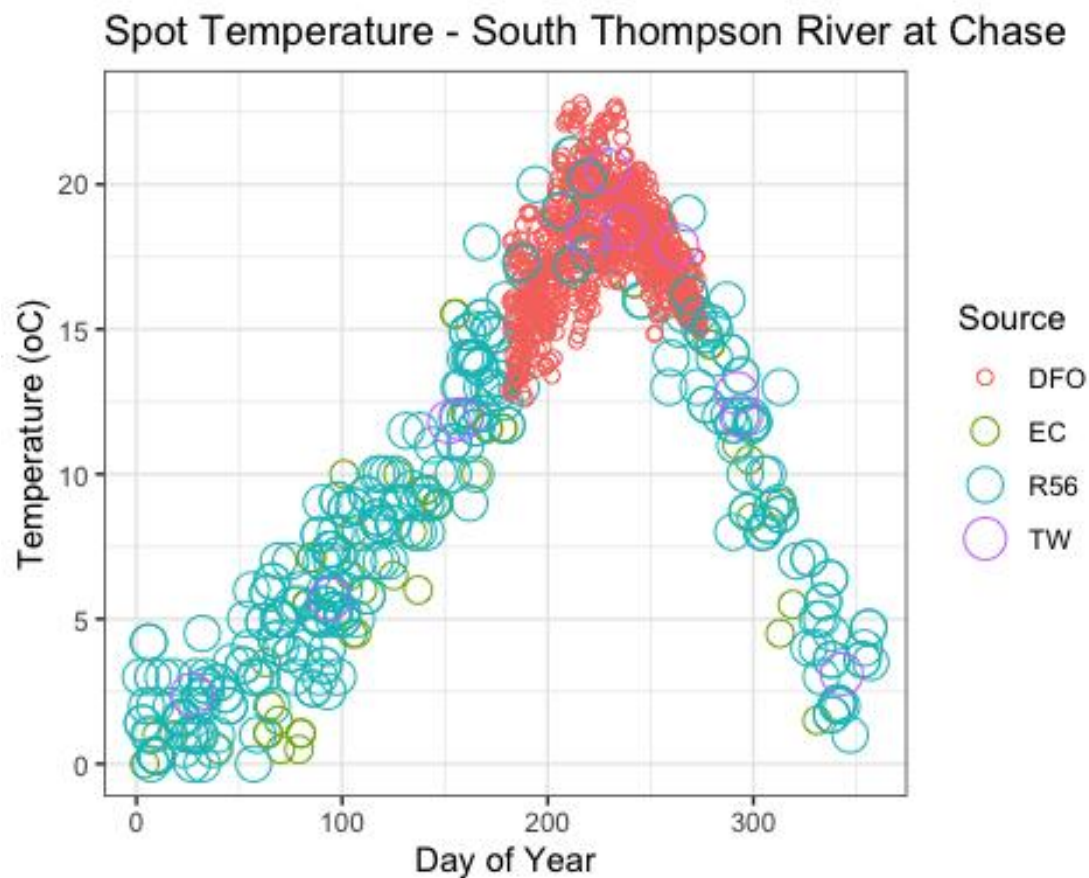


Figure 5. Spot temperature measurements for the South Thompson River at Chase composed of data collected by DFO (station STR60) and Water Survey of Canada (EC/R56/TW; station 08LE031)

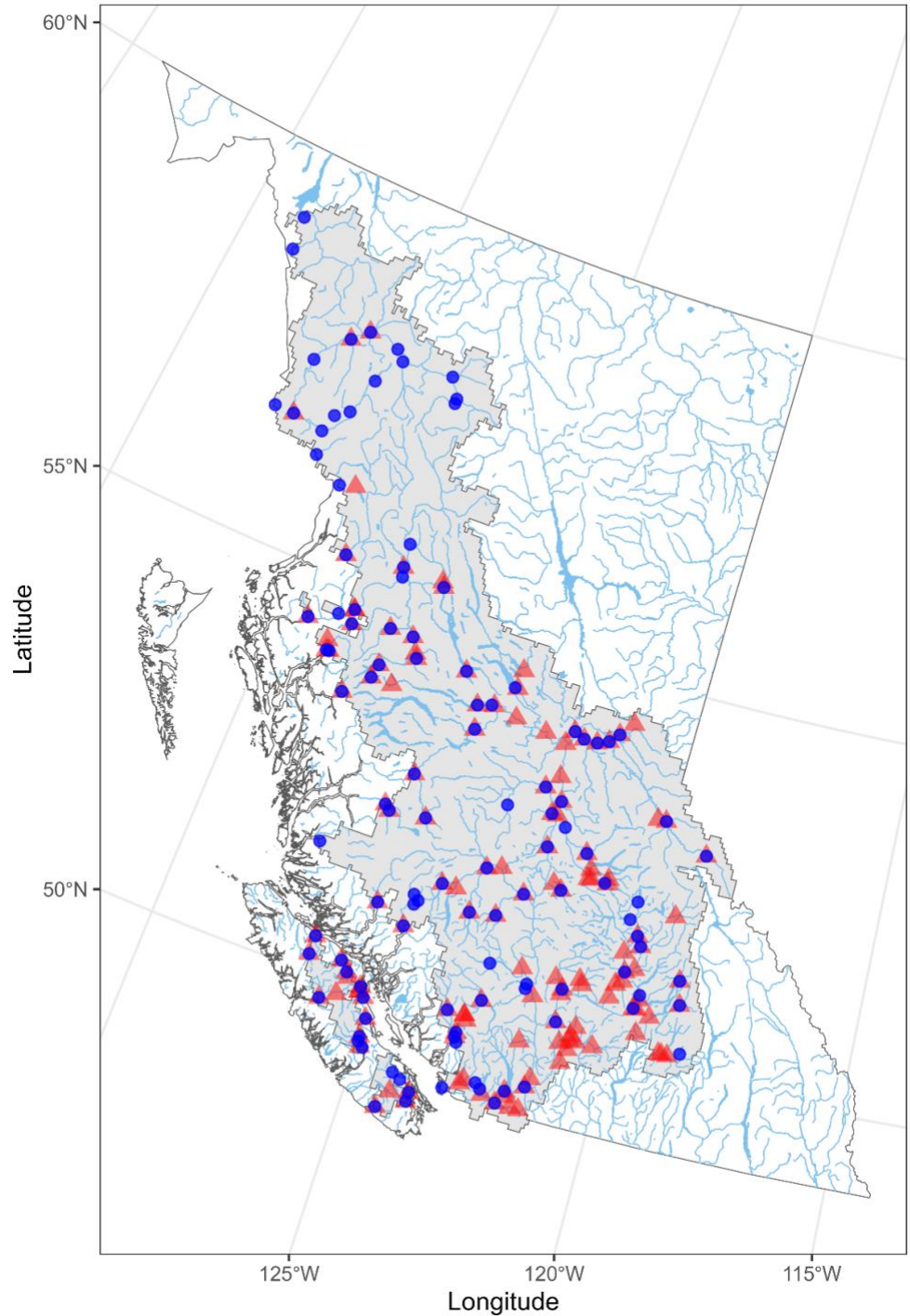


Figure 6. Location of streamflow (blue dots) and temperature (red triangles) calibration stations within the study domain (grey background).

5 Verification

5.1 Streamflow

Streamflow performance metrics are summarised in Figure 7. Across all stations *KGE* has a respectable median value of 0.78, but ranges between -4.2 (HOMAI) and 0.94 (BARRM). For the majority of stations (97%) the value of *KGE* exceeds 0.3, and only one station has value < -0.41 (HOMAI). The median *LNSE* across all stations is 0.73, with a range of -17.3 (SOMAA) to 0.925 (TAKUT). The *LNSE* value exceeds zero for 91% of stations (97 stations) and exceeds 0.75 for 46% of stations (49 stations). The *NSE* metric is also shown for comparison (median of 0.67; range of -30.1 (HOMAA) to 0.91 (BARRM)). Comparing *LNSE* to *NSE* suggests that low flow performance is slightly better than high-flow performance. Relative bias has a median of -0.01, and a range of -0.73 (SOMAA) to 3.72 (HOMAI); however, 67% of stations have *RBIAS* between -10 and 10%, which is the accepted observational error range (86% have *RBIAS* between -20% and 20%). Values of *KGE*, *LNSE* and *RBIAS* for each station are mapped in Figure 8 and listed in Table B1 of Appendix B. The calibrated VIC-GL and DynWat models provide good overall streamflow performance, however, performance can be quite poor at certain locations and may not be fit for certain purposes.

To aid in the interpretation of the streamflow metrics, sample hydrographs for eight stations are provided in Figure 9. Hydrographs for all stations are provided as Figure C1 in Appendix C. The plots compare observed and simulated daily climatological hydrographs and sample stations that range from excellent to poor. The first four plots (A through D) represent good VIC-GL – dynWat performance for different streamflow regimes, ranging from predominantly nival (Skeena), nival-glacial (Bella Coola) to pluvial (Cowichan and Chemainus). The remaining four plots provide examples of poor model behavior and give some clues as to conditions that may result in poor streamflow performance. In many cases, poor performance is simply due to large biases in runoff and baseflow. Although it is difficult to diagnose specific sources of runoff bias, typical reasons include biased precipitation and inaccurate specification of initial glacier conditions (likely the case for Homathko and Dean, respectively) (see also CHEAB and CAYOO in Table B1 and Figure C1). The presence of flow regulation and flow diversion can also affect model performance as only natural flow conditions are simulated. Such would be the case for the Campbell River (CAMPC; Figure 9F) for example (see also SOMAA in Table B1 and Figure C1).

5.2 Water Temperature

The *PFactor* metric for water temperature is summarised over all sites as a box plot in Figure 7C and values for individual sites are mapped in Figure 8. Individual *PFactor* values for all sites are also listed in Table B2 of Appendix B. Over all locations *PFactor* has a median value of 0.62, with an interquartile range of 0.5 to 0.74 and a total range of 0.16 (Sproat River near Port Alberni) to 0.97 (Horsefly River at Horsefly). Recall that the optimum value for *PFactor* is actually 0.90.

To aid in the interpretation of *PFactor* values, observed and simulated daily water temperature is provided in Figure 10 for eight stations. Graphs for all stations are provided as Figure D1 in Appendix D. The plots compare observed and simulated daily climatological water temperature, where observed is plotted as spot measurements and simulated is plotted as a median with the 10th- to 90th-percentile range. The sample stations range from excellent to poor performance. The highest *PFactor* value (0.97) occurs for the Horsefly River at Horsefly (Figure 10A). However, it should be noted that the observed data at this location are seasonal (summer only) when the range in the simulated water temperature is

greatest. Hence, the *PFactor* for this site may be an overconfident assessment of model performance, and is in fact slightly higher than the optimum value of 0.90. Results for the stations San Juan River near Port Renfrew (Figure 10B), Stuart River near Fort St. James (Figure 10C), and Stikine River at Telegraph Creek (Figure 10D) are examples of good model performance, where results demonstrate correct seasonality, low bias, and the range of the simulated captures the spread in the observations reasonably well. However, the fact that observations are weighted to the summer period at Stuart River near Fort St. James likely explains the high *PFactor* value at this location (which also exhibits what appear to be unrealistically narrow temperature ranges in the simulated results). Results for the Nicola River near Spences Bridge (Figure 10E) and the Skeena River at Usk (Figure 10F) are also informative, in that although the simulated water temperature at both sites displays good seasonality, seasonal biases are present which tends to lower the *PFactor* values. Simulated water temperature is overestimated in the Nicola in summer and overestimated in the Stikine during the winter. The Homathko River at inlet to Tatlayoko Lake (Figure 10G) and Homathko River at the Mouth (Figure 10H) are examples of sub-par model performance. For the Homathko at the Inlet, the range of the simulated data is too narrow and summer water temperature is overestimated. Simulated data for Homathko at the outlet shows poor seasonality and bias throughout the year. The reason for the poor performance at the Homathko at the Inlet is due to highly biased precipitation resulting in a gross overestimate of streamflow, mostly in the form of snowmelt runoff (HOMAI in Figure 9). The higher streamflow would tend to increase the influence of advection, which would tend to suppress instream heating and maintain the instream temperature close to the temperature of lateral inflow (in this case, mostly snowmelt), resulting in overly narrow climatological range in the simulated temperature (although this does not quite explain the overestimated summer water temperature). The poor performance at the Homathko at the outlet is, admittedly, more difficult to explain. The hydrograph at this location (HOMAM in Figure C1) show a slight bias in summer, but nothing grossly amiss.

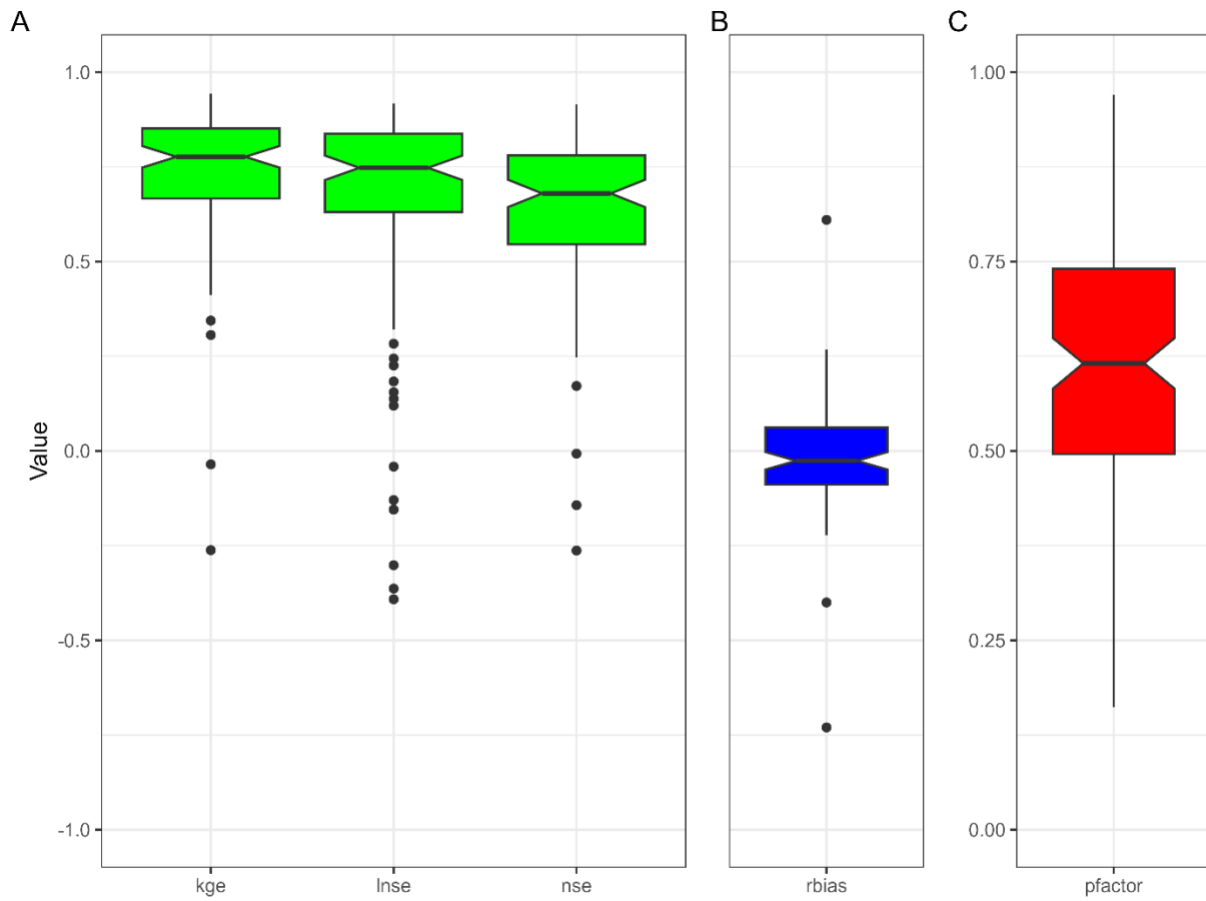


Figure 7. Boxplots of A) flow metrics *KGE*, *LNSE*, and *NSE* with limits $(-\infty, 1]$ and best fit equal 1, B) relative bias with limits $(-\infty, \infty)$ and best fit equal 0, and C) temperature *PFactor* with limits $[0, 1]$ and best fit equal 0.90 for all stations in the study domain.

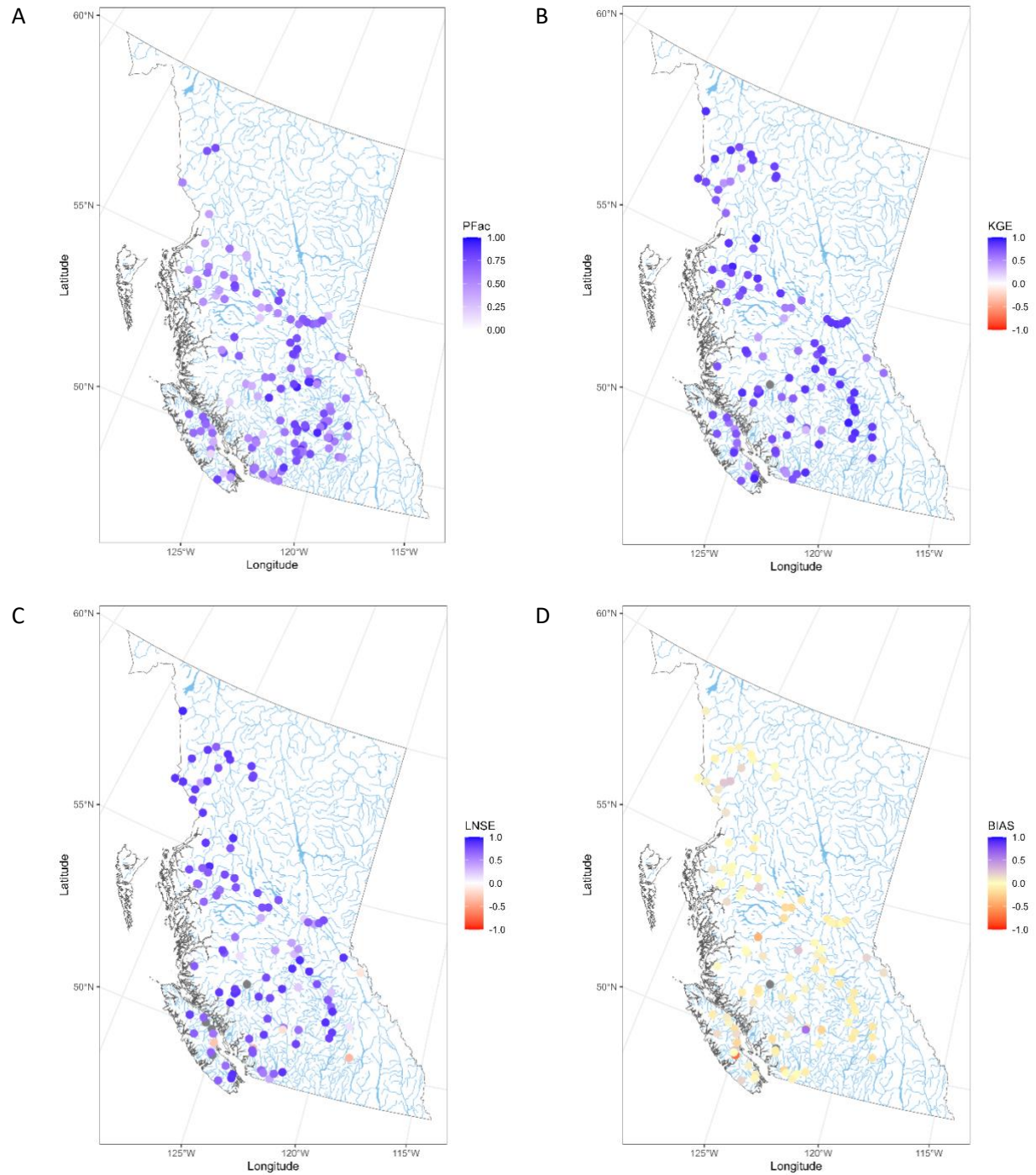


Figure 8. Temperature and flow metrics for the combined VIC-GL – DynWat model for the Fraser and BC Coast domains showing A) Temperature PFactor, B) Streamflow KGE, C) Streamflow LNSE, and D) Streamflow BIAS.

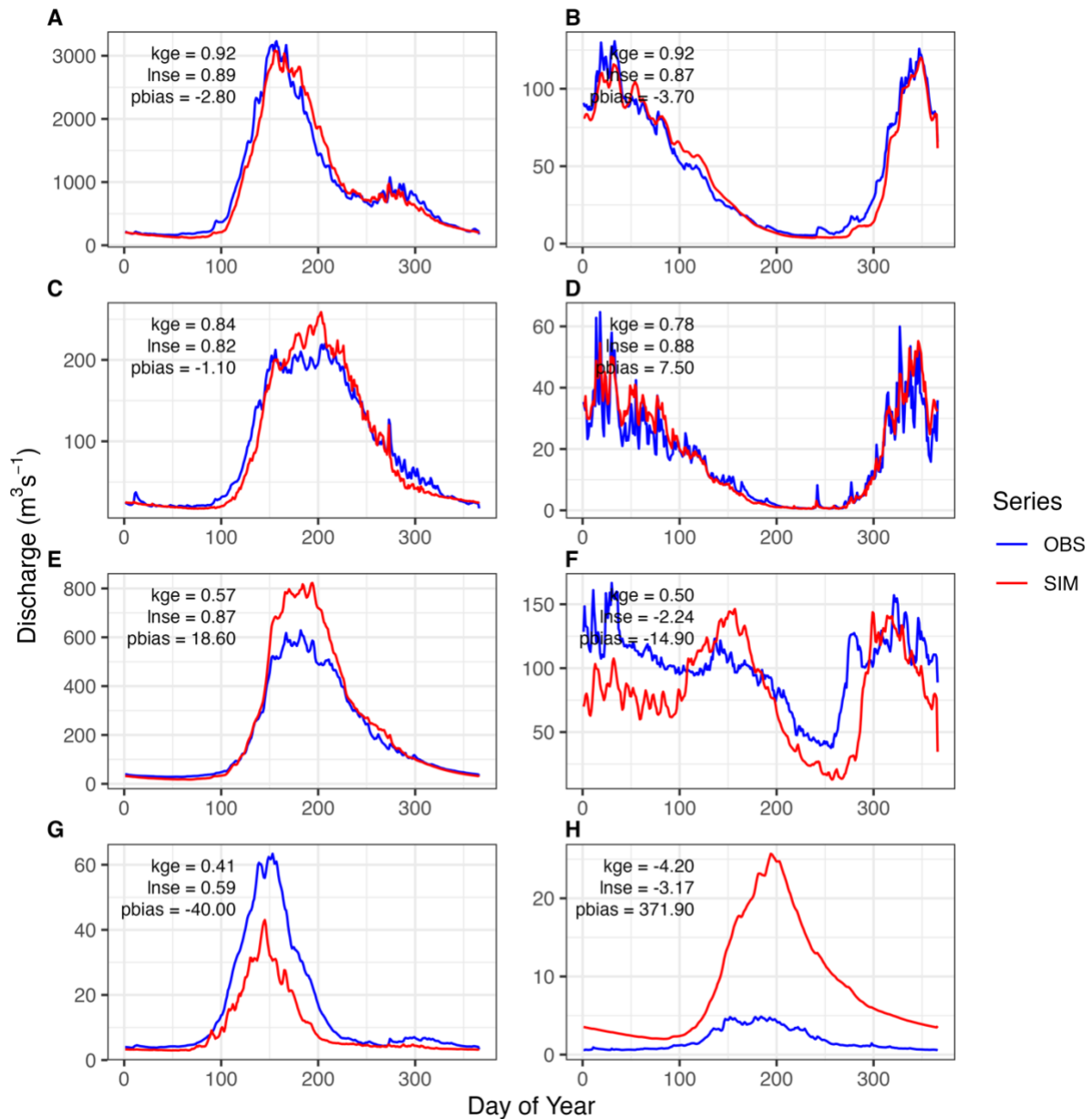


Figure 9. Sample of flow validation plots comparing simulated and observed climatological daily average flow for stations A) Skeena River at Usk (SKEEU), B) Cowichan River near Duncan (COWIC), C) Bella Coola River above Burnt Bridge Creek (BELLB), D) Chemainus River near Westholme (CHEAW), E) Fraser River at McBride (FRSMC), F) Campbell River near Campbell River (CAMPC), G) Dean River Below Tanswanket Creek (DEANT), and H) Homathko River at inlet to Tatlayoko Lake (HOMAI). Locations are ordered by decreasing *KGE*.

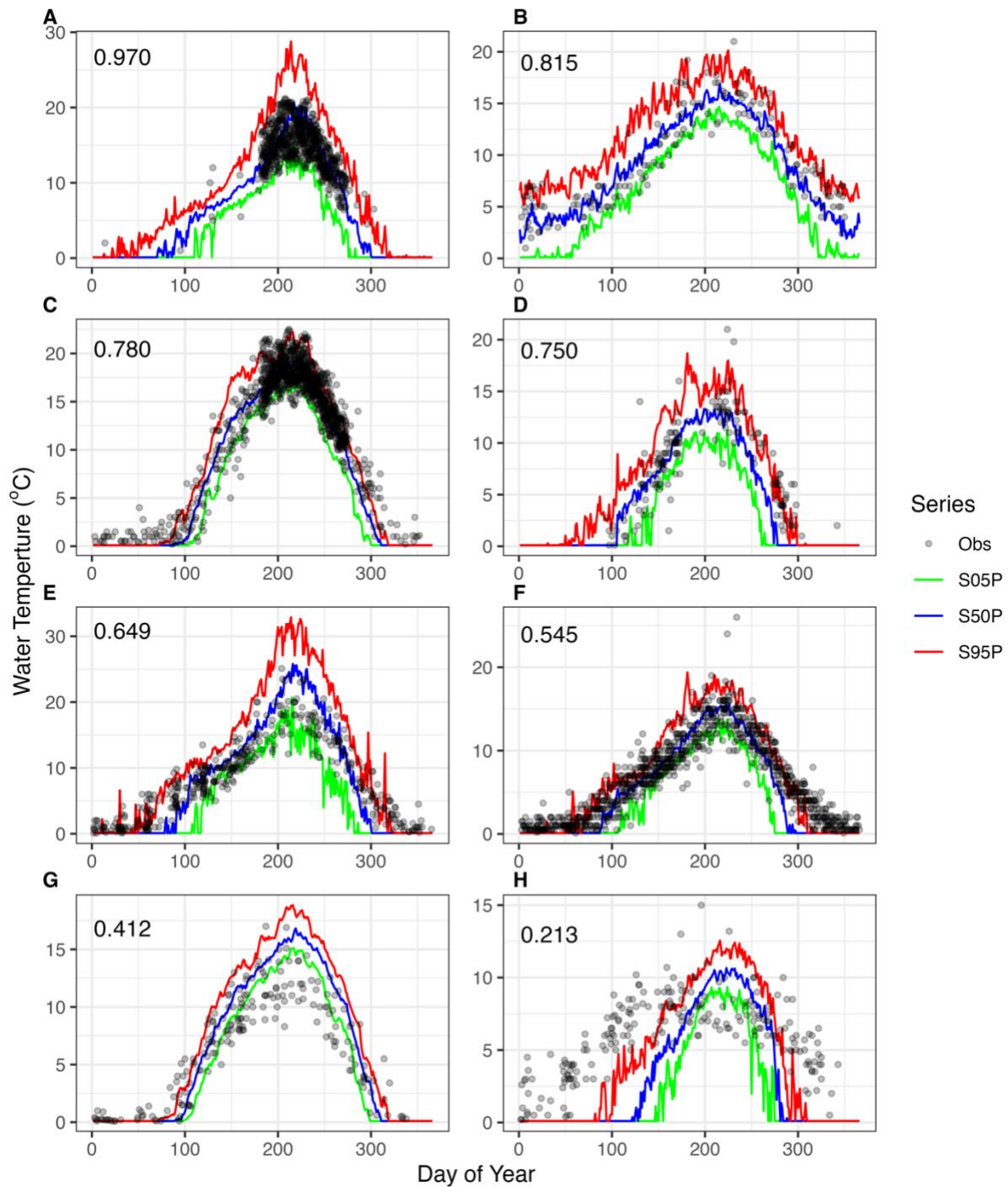


Figure 10. Sample of temperature validation plots comparing range of simulated data to spot observations for stations A) Horsefly River at Horsefly, B) San Juan River near Port Renfrew, C) Stuart River near Fort St. James, D) Stikine River at Telegraph Creek, E) Nicola River near Spences Bridge, F) Skeena River at Usk, G) Homathko River at inlet to Tatlayoko Lake, and H) Homathko River at the Mouth. Each panel shows the *PFactor* for that location, and locations are ordered by decreasing *PFactor*.

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Appendix A: Additional Tables

Table A1. Waterbody Properties

BCGNIS ^a ID	BCGNIS Name	Obs Storage ^b (10 ⁶ x m ³)	max Depth ^b (m)	Area ^c (km ²)	shape factor ^d	Est Storage ^e (10 ⁶ x m ³)	Est/Obs Storage (-)	Source for Depth & Storage or Shape Factor
8823	Adams Lake	23189.4	457	132.3	25.2	20161.4	0.87	Government of British Columbia (2024)
28159	Alice Lake	335	71	10.9	46.4	256.9	0.77	Government of British Columbia (2024)
36500	Anchor Lake ^g		121	10.7	27.0	432.1		Shape factor from average of Ellerslie, Huaskin and Owikeno Lakes
10024	Anderson Lake	3700.4	215	29.4	25.2	2104.8	0.57	Government of British Columbia (2024)
17676	Azure Lake	4792.0	318	31.5	17.6	3337.8	0.70	Government of British Columbia (2024)
18240	Babine Lake	26847.9	186	467	116.2	28962.1	1.08	McDonald and Hume (1984)
15534	Bear Lake	266.8	75	18.8	57.9	471.4	1.77	Government of British Columbia (2024)
32805	Bonaparte Lake	1358.6	98	33.6	59.1	1096.3	0.81	Government of British Columbia (2024)
9161	Bowser Lake		152	35.9	39.3	1808.0		Government of British Columbia (2024)
16747	Buttle Lake ^k	2459	91	67.7	90.0	2034.6	0.83	BC Hydro (2012)
17768	Campbell Lake		76	24.4	65.3	623.9		Michalski and Schlag (2014)
33681	Canim Lake	4718.6	208	56.3	36.0	3915.3	0.83	Government of British Columbia (2024)
38399	Carpenter Lake	911.3	55	46.7	124.3	856.6	0.94	https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/lower-mainland/brgmon-10-yr3-2018-10-31.pdf
38406	Charlotte Lake	2670.2	101	66.2	80.7	2236.6	0.84	Government of British Columbia (2024)
13034	Cheslatta Lake	937.7	73	41.3	88.6	999.2	1.07	Government of British Columbia (2024)
33890	Chilko Lake	21585.9	366	186.6	37.3	22745.9	1.05	Government of British Columbia (2024)
10944	Clearwater Lake	3380.0	197	34.1	29.7	2240.7	0.66	Government of British Columbia (2024)
2552	Comox Lake	1292	170	21.2	27.1	1202.7	0.93	Michalski and Schlag (2014)
12225	Cowichan Lake	3109.1	152	62.3	51.9	3153.1	1.01	Government of British Columbia (2024)
14305	Cunningham Lake	757.1	65	31.8	86.8	688.0	0.91	Government of British Columbia (2024)
10186	Eddontenajon Lake	337.8	72	10.4	45.0	251.9	0.75	Government of British Columbia (2024)
16894	Ellerslie Lake	1900	205	26.5	25.1	1809.2	0.95	Government of British Columbia (2024)
11193	Elsie Lake	86.7	21	6.5	122.5	46.3	0.53	Government of British Columbia (2024)

BCGNIS ^a ID	BCGNIS Name	Obs Storage ^b (10 ⁶ x m ³)	max Depth ^b (m)	Area ^c (km ²)	shape factor ^d	Est Storage ^e (10 ⁶ x m ³)	Est/Obs Storage (-)	Source for Depth & Storage or Shape Factor
18486	Eutsuk Lake	28458.9	305	251.2	52.0	25521.1	0.90	Government of British Columbia (2024)
11924	Francois Lake	23087.9	244	254.2	65.2	20716.3	0.90	Government of British Columbia (2024)
2293	Fraser Lake	725.3	30	54.3	241.9	552.2	0.76	Government of British Columbia (2024)
12584	Fulton Lake ^g		75	14.6	51.0	364.6		Shape factor from Taltapin Lake
4435	Gamble Lake ^g		138	13.9	27.0	639.8		Shape factor from average of Ellerslie, Huaskin and Owikeno Lakes
13292	Garibaldi Lake	1200.1	259	10.1	12.3	876.2	0.73	Government of British Columbia (2024)
11015	Great Central Lake	6573.5	250	53	29.1	4410.5	0.67	Michalski and Schlag (2014)
33504	Green Lake	275.3	36	28.8	149.3	345.5	1.25	Government of British Columbia (2024)
15330	Harrison Lake	32782.2	279	222.6	53.4	20719.6	0.63	Government of British Columbia (2024)
16092	Haslam Lake	654.5	151	11.6	22.6	586.2	0.90	Government of British Columbia (2024)
20706	Henderson Lake	1503	250	15.5	15.7	1283.8	0.85	Michalski and Schlag (2014)
21467	Hobson Lake	2480.0	175	34.0	33.3	1984.8	0.80	Government of British Columbia (2024)
24528	Horsefly Lake	3884.2	191	58.0	40.0	3684.5	0.95	Government of British Columbia (2024)
31988	Huaskin Lake	1377	175	21.5	26.5	1254.5	0.91	Government of British Columbia (2024)
3335	Ian Lake ^g		162	19.2	27.0	1038.6		Shape factor average of Ellerslie, Huaskin and Owikeno Lakes
17267	Inzana Lake	1281.8	95	35.6	62.5	1130.9	0.88	Government of British Columbia (2024)
10747	Isaac Lake	1962.4	174	32.7	32.8	1899.5	0.97	Government of British Columbia (2024)
3643	Jesse Lake ^g		46	11.7	74.2	179.8		Shape factor average of Lakelse and Kitsumkalan Lakes
11312	Kamloops Lake	4140.8	151	49.8	46.7	2502.1	0.60	Government of British Columbia (2024)
11942	Kennedy Lake	2482	145	65.3	55.7	3152.8	1.27	Michalski and Schlag (2014)
12613	Kinaskan Lake ^g		117	27.9	45.0	1091.6		Shape factor from Eddontenajon Lake
2311	Kitlope Lake ^g		137	11.9	25.1	545.2		Shape factor from Ellerslie Lake
4084	Kitsumkalum Lake	1486.1	139	19.1	31.4	882.6	0.59	Government of British Columbia (2024)
4902	Lakelse Lake	124	32	13.7	116.9	149.3	1.20	Government of British Columbia (2024)
9926	Lillooet Lake	2300.0	128	32.2	44.3	1374.7	0.60	Government of British Columbia (2024)
10387	Link Lake ^g		185	25	27.0	1543.2		Shape factor from average of Ellerslie, Huaskin and Owikeno Lakes

BCGNIS ^a ID	BCGNIS Name	Obs Storage ^b (10 ⁶ x m ³)	max Depth ^b (m)	Area ^c (km ²)	shape factor ^d	Est Storage ^e (10 ⁶ x m ³)	Est/Obs Storage (-)	Source for Depth & Storage or Shape Factor
7908	Lois Lake	1016	141	24.1	34.8	1131.6	1.11	Government of British Columbia (2024)
31514	Long Lake ^g		171	21.3	27.0	1213.6		Shape factor from average of Ellerslie, Huaskin and Owikeno Lakes
19250	Mabel Lake	7177.8	201	59.6	38.5	3987.3	0.56	Government of British Columbia (2024)
34238	Mahood Lake	3120.0	208	33.0	27.6	2289.0	0.73	Government of British Columbia (2024)
28109	Meziadin Lake	2188	134	36.6	45.2	1638.6	0.75	Government of British Columbia (2024)
14919	Morice Lake ^g		233	97.5	42.3	7586.6		Shape factor average of Bowser and Meziadin Lakes
14948	Morrison Lake ^g		72	13.3	51.0	317.0		Shape factor from Taltapin Lake
15893	Murtle Lake	8160.0	333	76.6	26.3	8504.6	1.04	Government of British Columbia (2024)
16516	Nanika Lake ^g		129	29.6	42.3	1269.0		Government of British Columbia (2024)
21094	Nicola Lake	586.7	57	25.1	87.9	476.6	0.81	Government of British Columbia (2024)
29465	Nimpkish Lake	4653.4	320	38.1	19.3	4068.6	0.87	Michalski and Schlag (2014)
21185	Nitinat Lake ^g		160	27.1	32.5	1446.9		Shape factor average of Cowichan, Great Central, Henderson and Sproat Lakes
2824	Ootsa Lake	87797.5	305	829.1	94.4	84296.4	0.96	https://en.wikipedia.org/wiki/Nechako_Reservoir
31611	Owikeno Lake		370	93.7	26.2	11590.1		http://skeenafisheries.ca/images/uploads/documents/2016_Owikeno_Lake_hydroacoustic_report_final.pdf and https://publications.gc.ca/collections/collection_2012/mpo-dfo/Fs97-6-2457-eng.pdf
38414	Pinchi Lake	1328.9	68	55.5	110.4	1249.3	0.94	Government of British Columbia (2024)
23263	Pitt Lake	2442.9	143	53.4	51.2	2538.8	1.04	Government of British Columbia (2024)
22752	Powell Lake		350	124.4	31.8	14452.3		Shape factor average of Haslam and Lois Lakes
30796	Quesnel Lake	41800.0	511	271.7	32.3	46281.0	1.11	Petticrew et al. (2015) https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/lower-mainland/brgmon-6-yr1-2015-03-31.pdf
24987	Seton Lake	2100.0	151	25.0	33.1	1260.2	0.60	Government of British Columbia (2024)
25475	Shuswap Lake	19128.8	162	307.4	108.5	16551.2	0.87	Government of British Columbia (2024)
26260	Sigutlat Lake	783.2	98	19	44.5	621.3	0.79	Government of British Columbia (2024)
25636	Sproat Lake	2343.2	195	42.4	33.4	2757.2	1.18	Government of British Columbia (2024)
14587	Stave Lake	2040.1	101	56.4	74.4	1899.1	0.93	Government of British Columbia (2024)

BCGNIS ^a ID	BCGNIS Name	Obs Storage ^b (10 ⁶ x m ³)	max Depth ^b (m)	Area ^c (km ²)	shape factor ^d	Est Storage ^e (10 ⁶ x m ³)	Est/Obs Storage (-)	Source for Depth & Storage or Shape Factor
16235	Stuart Lake	7277.5	97	359.3	196.2	11572.8	1.59	Government of British Columbia (2024)
3567	Swan Lake ^g		134	17.7	31.4	790.5		Shape factor from Kitsumkalum Lake
23860	Takla Lake	28370.0	287	247.1	54.8	23623.9	0.83	Government of British Columbia (2024)
23888	Taltapin Lake	833	96	21.4	48.4	690.8	0.83	Government of British Columbia (2024)
3425	Tatlayoko Lake	4255.6	210	39.3	29.9	2759.8	0.65	Government of British Columbia (2024)
25406	Tatsamenie Lake	1012	142	16.5	28.6	780.7	0.77	Government of British Columbia (2024)
24680	Tchesinkut Lake	2079.3	149	35.8	40.2	1780.3	0.86	Government of British Columbia (2024)
21797	Tetachuck Lake	750.0	61	54.8	120.8	1118.1	1.49	Government of British Columbia (2024)
2671	Tezzeron Lake	876.3	43	80.8	207.7	1165.9	1.33	Government of British Columbia (2024)
25938	Tochcha Lake		71	29.6	77.0	698.4		Mean of similar sized lakes in region (Cunningham, Inzana and Nation)
27643	Trembleur Lake	4810.6	103	116.2	104.9	3977.6	0.83	Government of British Columbia (2024)
32191	Tuya Lake	626	54	31.3	103.7	564.4	0.90	Government of British Columbia (2024)
3091	Upper Campbell Lake	371.7	40	30.5	139.4	414.6	1.12	BC Hydro (2012)
30139	Victoria Lake	683	110	15.9	36.3	584.6	0.86	Government of British Columbia (2024)
3776	Whalen Lake ^g		172	21.6	27.0	1239.4		Shape factor from average of Ellerslie, Huaskin and Owikeno Lakes
31401	Whiting Lake ^g		141	16.3	28.6	767.0		Shape factor from Tatsamenie Lake
30652	Woss Lake	994.6	154	14	24.4	724.8	0.73	Government of British Columbia (2024)

^a B.C. Geographical Names Information System

^b Storage and depth from bathymetry maps, unless otherwise stated

^c Surface area from B.C. Freshwater Atlas

^d Estimated from *Area* and max *Depth*, unless stated otherwise

^e Calculated from Equation (6)

^g Maximum depth estimated from shape factor

^h Includes Upper Campbell Lake

Table A2. Hydrometric Stations Used for dynWat Calibration.

STATION ID	NAME	LONG NAME	VIC-GL LON	VIC-GL LAT	START	END	DOMAIN
08LD001	ADAMS	ADAMS RIVER NEAR SQUILAX	-119.65625	50.96875	1971-01-01	2000-12-31	Fraser
BCHAL	BCHAL	ALOUETTE RIVER AT ALOUETTE DAM	-122.46875	49.28125	1971-01-01	2000-12-31	Fraser
08HB023	ASHMO	ASH RIVER BELOW MORAN CREEK	-125.03125	49.40625	1990-01-01	2010-12-31	BC Coast
08FB006	ATNAM	ATNARKO RIVER NEAR THE MOUTH	-126.03125	52.34375	1990-01-01	2010-12-31	BC Coast
08EC001	BABIB	BABINE RIVER AT BABINE	-126.65625	55.34375	1990-01-01	2010-12-31	BC Coast
08KE016	BAKER	BAKER CREEK AT QUESNEL	-122.59375	52.96875	1971-01-01	2000-12-31	Fraser
08LB020	BARRM	BARRIERE RIVER AT THE MOUTH	-120.09375	51.21875	1971-01-01	2000-12-31	Fraser
08DC006	BEARB	BEAR RIVER ABOVE BITTER CREEK	-129.90625	56.09375	1990-01-01	2010-12-31	BC Coast
08FB007	BELLB	BELLA COOLA RIVER ABOVE BURNT BRIDGE CREEK	-126.15625	52.40625	1990-01-01	2010-12-31	BC Coast
08MB006	BIGCR	BIG CREEK ABOVE GROUNDHOG CREEK	-123.09375	51.46875	1971-01-01	2000-12-31	Fraser
08LF002	BONAP	BONAPARTE RIVER BELOW CACHE CREEK	-121.28125	50.78125	1971-01-01	2000-12-31	Fraser
08KD007	BOWRB	BOWRON RIVER BELOW BOX CANYON	-122.09375	54.03125	1971-01-01	2000-12-31	Fraser
BCHLJ	BCHLJ	BRIDGE RIVER AT LA JOIE DAM	-122.90625	50.84375	1971-01-01	2000-12-31	Fraser
08EE013	BUCKM	BUCK CREEK AT THE MOUTH	-126.65625	54.34375	1990-01-01	2010-12-31	BC Coast
08EE004	BULKQ	BULKLEY RIVER AT QUICK	-126.90625	54.59375	1990-01-01	2010-12-31	BC Coast
08HD003	CAMPC	CAMPBELL RIVER NEAR CAMPBELL RIVER	-125.34375	50.03125	1990-01-01	2010-12-31	BC Coast
08ME002	CAYOO	CAYOOSH CREEK NEAR LILLOOET	-122.03125	50.65625	1971-01-01	2000-12-31	Fraser
08GA043	CHEAB	CHEAKAMUS RIVER NEAR BRACKENDALE	-123.15625	49.84375	1990-01-01	2010-12-31	BC Coast
08HA001	CHEAW	CHEMAINUS RIVER NEAR WESTHOLME	-123.71875	48.90625	1990-01-01	2010-12-31	BC Coast
08MB005	CHILB	CHILCOTIN RIVER BELOW BIG CREEK	-122.65625	51.84375	1971-01-01	2000-12-31	Fraser
08MA001	CHILK	CHILKO RIVER NEAR REDSTONE	-123.59375	52.03125	1971-01-01	2000-12-31	Fraser
08MH001	CHILLI	CHILLIWACK RIVER AT VEDDER CROSSING	-121.96875	49.09375	1971-01-01	2000-12-31	Fraser
08LA007	CLEAO	CLEARWATER RIVER AT OUTLET OF CLEARWATER LAKE	-120.21875	52.15625	1971-01-01	2000-12-31	Fraser
08LA001	CLEAS	CLEARWATER RIVER NEAR CLEARWATER STATION	-120.03125	51.71875	1971-01-01	2000-12-31	Fraser
08KE009	COTTO	COTTONWOOD RIVER NEAR CINEMA	-122.46875	53.15625	1971-01-01	2000-12-31	Fraser
08HA011	COWID	COWICHAN RIVER NEAR DUNCAN	-123.71875	48.78125	1990-01-01	2010-12-31	BC Coast

STATION ID	NAME	LONG NAME	VIC-GL LON	VIC-GL LAT	START	END	DOMAIN
08FC003	DEANA	DEAN RIVER BELOW TANSWANKET CREEK	-125.78125	52.90625	1990-01-01	2010-12-31	BC Coast
08FC005	DEANT	DEAN RIVER NEAR ANAHIM LAKE	-125.21875	52.40625	1990-01-01	2010-12-31	BC Coast
08LE024	EAGLE	EAGLE RIVER NEAR MALAKWA	-118.78125	50.96875	1971-01-01	2000-12-31	Fraser
08GA071	ELAHM	ELAHO RIVER NEAR THE MOUTH	-123.46875	50.09375	1990-01-01	2010-12-31	BC Coast
08HB002	ENGLP	ENGLISHMAN RIVER NEAR PARKSVILLE	-124.15625	49.09375	1990-01-01	2010-12-31	BC Coast
08EG012	EXCHT	EXCHAMSIKS RIVER NEAR TERRACE	-129.34375	54.34375	1990-01-01	2010-12-31	BC Coast
08CG006	FORRC	FORREST KERR CREEK ABOVE 460 M CONTOUR	-130.71875	56.90625	1990-01-01	2010-12-31	BC Coast
08KA004	FRSHA	FRASER RIVER AT HANSARD	-121.84375	54.09375	1971-01-01	2000-12-31	Fraser
08MF005	FRSHP	FRASER RIVER AT HOPE	-121.46875	49.40625	1971-01-01	2000-12-31	Fraser
08KA005	FRSMC	FRASER RIVER AT MCBRIDE	-120.09375	53.28125	1971-01-01	2000-12-31	Fraser
08KA007	FRSMG	FRASER RIVER AT RED PASS	-119.03125	52.96875	1971-01-01	2000-12-31	Fraser
08MH028	FRSMT	FRASER RIVER AT THE MOUTH	-123.09375	49.09375	1971-01-01	2000-12-31	Fraser
08MC018	FRSRP	FRASER RIVER NEAR MARGUERITE	-122.46875	52.53125	1971-01-01	2000-12-31	Fraser
08HC001	GOLDU	GOLD RIVER BELOW UCONA RIVER	-126.09375	49.71875	1990-01-01	2010-12-31	BC Coast
08MG013	HARRI	HARRISON RIVER NEAR HARRISON HOT SPRINGS	-121.84375	49.28125	1971-01-01	2000-12-31	Fraser
08FF002	HIRSM	HIRSCH CREEK NEAR THE MOUTH	-128.59375	54.03125	1990-01-01	2010-12-31	BC Coast
08GD008	HOMAI	HOMATHKO RIVER AT INLET TO TATLAYOKO LAKE	-124.40625	51.65625	1990-01-01	2010-12-31	BC Coast
08GD004	HOMAM	HOMATHKO RIVER AT THE MOUTH	-124.90625	50.96875	1990-01-01	2010-12-31	BC Coast
08GD006	HOMAT	HOMATHKO RIVER AT TRAGEDY CANYON	-124.84375	51.28125	1990-01-01	2010-12-31	BC Coast
08GD005	HOMAN	HOMATHKO RIVER BELOW NUDE CREEK	-124.78125	51.34375	1990-01-01	2010-12-31	BC Coast
08KH010	HORSE	HORSEFLY RIVER ABOVE MCKINLEY CREEK	-121.03125	52.28125	1971-01-01	2000-12-31	Fraser
08CG004	ISKUJ	ISKUT RIVER ABOVE SNIPPAKER CREEK	-130.84375	56.65625	1990-01-01	2010-12-31	BC Coast
08CG003	ISKUK	ISKUT RIVER AT OUTLET OF KINASKAN LAKE	-130.15625	57.53125	1990-01-01	2010-12-31	BC Coast
08CG001	ISKUS	ISKUT RIVER BELOW JOHNSON RIVER	-131.65625	56.71875	1990-01-01	2010-12-31	BC Coast
08FE003	KEMAP	KEMANO RIVER ABOVE POWERHOUSE TAILRACE	-127.96875	53.59375	1990-01-01	2010-12-31	BC Coast
08EB004	KISPH	KISPIOX RIVER NEAR HAZELTON	-127.71875	55.40625	1990-01-01	2010-12-31	BC Coast
08FF001	KITIH	KITIMAT RIVER BELOW HIRSCH CREEK	-128.65625	54.03125	1990-01-01	2010-12-31	BC Coast

STATION ID	NAME	LONG NAME	VIC-GL LON	VIC-GL LAT	START	END	DOMAIN
08CC001	KLAPT	KLAPPAN RIVER NEAR TELEGRAPH CREEK	-129.71875	57.90625	1990-01-01	2010-12-31	BC Coast
08GE002	KLINM	KLINAKLINI RIVER EAST CHANNEL (MAIN) NEAR THE MOUTH	-125.59375	51.15625	1990-01-01	2010-12-31	BC Coast
08MG005	LILLO	LILLOOET RIVER NEAR PEMBERTON	-122.84375	50.34375	1971-01-01	2000-12-31	Fraser
08LA008	MAHOO	MAHOOD RIVER AT OUTLET OF MAHOOD LAKE	-120.28125	51.90625	1971-01-01	2000-12-31	Fraser
08GA054	MAMOM	MAMQUAM RIVER ABOVE MASHITER CREEK	-123.09375	49.71875	1990-01-01	2010-12-31	BC Coast
08KB003	MCGRE	MCGREGOR RIVER AT LOWER CANYON	-121.65625	54.21875	1971-01-01	2000-12-31	Fraser
08CG005	MOREM	MORE CREEK NEAR THE MOUTH	-130.40625	57.03125	1990-01-01	2010-12-31	BC Coast
08ED002	MORIH	MORICE RIVER NEAR HOUSTON	-127.40625	54.09375	1990-01-01	2010-12-31	BC Coast
08GD007	MOSLD	MOSLEY CREEK NEAR DUMBELL LAKE	-124.90625	51.40625	1990-01-01	2010-12-31	BC Coast
08HB034	NANAC	NANAIMO RIVER NEAR CASSIDY	-123.96875	49.03125	1990-01-01	2010-12-31	BC Coast
08ED001	NANIK	NANIKA RIVER AT OUTLET OF KIDPRICE LAKE	-127.46875	53.90625	1990-01-01	2010-12-31	BC Coast
08DB001	NASSS	NASS RIVER ABOVE SHUMAL CREEK	-129.09375	55.28125	1990-01-01	2010-12-31	BC Coast
08JB003	NAUTL	NAUTLEY RIVER NEAR FORT FRASER	-124.65625	54.09375	1971-01-01	2000-12-31	Fraser
08KF001	NAZKO	NAZKO RIVER ABOVE MICHELLE CREEK	-123.59375	52.90625	1971-01-01	2000-12-31	Fraser
08JA017	NECHC	NECHAKO RIVER BELOW CHESLATTA FALLS	-124.84375	53.71875	1971-01-01	2000-12-31	Fraser
08LG006	NICOL	NICOLA RIVER NEAR SPENCES BRIDGE	-121.21875	50.34375	1971-01-01	2000-12-31	Fraser
08HF005	NIMPW	NIMPKISH RIVER ABOVE WOSS RIVER	-126.59375	50.21875	1990-01-01	2010-12-31	BC Coast
08LB047	NTHMB	NORTH THOMPSON RIVER AT BIRCH ISLAND	-119.90625	51.59375	1971-01-01	2000-12-31	Fraser
08HD011	OYSTW	OYSTER RIVER BELOW WOODHUS CREEK	-125.21875	49.90625	1990-01-01	2010-12-31	BC Coast
08EC004	PINKT	PINKUT CREEK NEAR TINTAGEL	-125.46875	54.40625	1990-01-01	2010-12-31	BC Coast
08CA003	PITMM	PITMAN RIVER NEAR THE MOUTH	-128.40625	57.96875	1990-01-01	2010-12-31	BC Coast
08HB006	PUNTO	PUNTLEDGE RIVER AT COURTENAY	-125.03125	49.65625	1990-01-01	2010-12-31	BC Coast
08KH001	QUESL	QUESNEL RIVER AT LIKELY	-121.59375	52.59375	1971-01-01	2000-12-31	Fraser
08KH006	QUESQ	QUESNEL RIVER NEAR QUESNEL	-122.21875	52.84375	1971-01-01	2000-12-31	Fraser
08HD007	SALMM	SALMON RIVER ABOVE MEMEKAY RIVER	-125.71875	50.15625	1990-01-01	2010-12-31	BC Coast
08KC001	SALMO	SALMON RIVER NEAR PRINCE GEORGE	-122.65625	54.09375	1971-01-01	2000-12-31	Fraser
08HD006	SALMS	SALMON RIVER NEAR SAYWARD	-125.90625	50.28125	1990-01-01	2010-12-31	BC Coast

STATION ID	NAME	LONG NAME	VIC-GL LON	VIC-GL LAT	START	END	DOMAIN
08MC005	SANJO	SAN JOSE RIVER ABOVE BORLAND CREEK	-121.90625	52.03125	1971-01-01	2000-12-31	Fraser
08HA010	SANPO	SAN JUAN RIVER NEAR PORT RENFREW	-124.28125	48.59375	1990-01-01	2010-12-31	BC Coast
BCHST	BCHST	SETON RIVER AT SETON DAM	-122.03125	50.71875	1971-01-01	2000-12-31	Fraser
08LE027	SEYMO	SEYMOUR RIVER NEAR SEYMOUR ARM	-118.90625	51.28125	1971-01-01	2000-12-31	Fraser
BCHSG	BCHSG	SHUSWAP RIVER AT SUGAR DAM	-118.53125	50.34375	1971-01-01	2000-12-31	Fraser
08EB005	SKEEB	SKEENA RIVER ABOVE BABINE RIVER	-127.78125	55.71875	1990-01-01	2010-12-31	BC Coast
08EB003	SKEEG	SKEENA RIVER AT GLEN VOWELL	-127.65625	55.28125	1990-01-01	2010-12-31	BC Coast
08EF001	SKEEU	SKEENA RIVER AT USK	-128.40625	54.65625	1990-01-01	2010-12-31	BC Coast
08BB002	SLOKA	SLOKO RIVER NEAR ATLIN	-133.65625	59.09375	1990-01-01	2010-12-31	BC Coast
08HB017	SOMAA	SOMASS RIVER NEAR ALBERNI	-124.90625	49.28125	1990-01-01	2010-12-31	BC Coast
08LE031	STHOM	SOUTH THOMPSON RIVER AT CHASE	-119.71875	50.78125	1971-01-01	2000-12-31	Fraser
08CA001	SPATM	SPATSIZI RIVER NEAR THE MOUTH	-128.09375	57.65625	1990-01-01	2010-12-31	BC Coast
08GA022	SQUAB	SQUAMISH RIVER NEAR BRACKENDALE	-123.15625	49.78125	1990-01-01	2010-12-31	BC Coast
08HB009	STAMG	STAMP RIVER NEAR GREAT CENTRAL	-125.03125	49.34375	1990-01-01	2010-12-31	BC Coast
BCHSF	BCHSF	STAVE RIVER AT STAVE FALLS DAM	-122.34375	49.21875	1971-01-01	2000-12-31	Fraser
08JB002	STELL	STELLAKO RIVER AT GLENANNAN	-124.96875	54.03125	1971-01-01	2000-12-31	Fraser
08FC001	STIKB	STIKINE RIVER ABOVE BUTTERFLY CREEK	-131.78125	57.46875	1990-01-01	2010-12-31	BC Coast
08CB001	STIKG	STIKINE RIVER ABOVE GRAND CANYON	-129.96875	58.03125	1990-01-01	2010-12-31	BC Coast
08CE001	STIKS	STIKINE RIVER AT TELEGRAPH CREEK	-131.15625	57.90625	1990-01-01	2010-12-31	BC Coast
08CA002	STIKT	STIKINE RIVER BELOW SPATSIZI RIVER	-128.09375	57.71875	1990-01-01	2010-12-31	BC Coast
08CF003	STIKW	STIKINE RIVER NEAR WRANGELL	-132.15625	56.71875	1990-01-01	2010-12-31	BC Coast
08JE001	STUAR	STUART RIVER NEAR FORT ST. JAMES	-124.28125	54.40625	1971-01-01	2000-12-31	Fraser
08BB001	TAKUT	TAKU RIVER NEAR TULSEQUAH	-133.53125	58.65625	1990-01-01	2010-12-31	BC Coast
08MA003	TASEK	TASEKO RIVER AT OUTLET OF TASEKO LAKES	-123.65625	51.40625	1971-01-01	2000-12-31	Fraser
08EE020	TELKT	TELKWA RIVER BELOW TSAI CREEK	-127.46875	54.59375	1990-01-01	2010-12-31	BC Coast
08HF004	TSITC	TSITIKA RIVER BELOW CATHERINE CREEK	-126.59375	50.46875	1990-01-01	2010-12-31	BC Coast
08CD001	TUYAT	TUYA RIVER NEAR TELEGRAPH CREEK	-130.78125	58.09375	1990-01-01	2010-12-31	BC Coast

STATION ID	NAME	LONG NAME	VIC-GL LON	VIC-GL LAT	START	END	DOMAIN
08DD001	UNUKS	UNUK RIVER NEAR STEWART	-130.71875	56.34375	1990-01-01	2010-12-31	BC Coast
08FA002	WANNO	WANNOCK RIVER AT OUTLET OF OWIKENO LAKE	-127.21875	51.65625	1990-01-01	2010-12-31	BC Coast
08KG001	WESTR	WEST ROAD RIVER NEAR CINEMA	-122.90625	53.28125	1971-01-01	2000-12-31	Fraser
08KD006	WILLO	WILLOW RIVER ABOVE HAY CREEK	-122.40625	54.03125	1971-01-01	2000-12-31	Fraser
08EG011	ZYMAT	ZYMAGOTITZ RIVER NEAR TERRACE	-128.71875	54.53125	1990-01-01	2010-12-31	BC Coast
08EF005	ZYMOO	ZYMOETZ RIVER ABOVE O.K. CREEK	-128.34375	54.46875	1990-01-01	2010-12-31	BC Coast

Table A3. Water Temperature Stations Used for dynWat Calibration.

STATION ID	LONG NAME	START_DATE	END_DATE	N	VIC_GL LAT	VIC-GL LON	DOMAIN	SOURCE
08LD001	ADAMS RIVER NEAR SQUILAX	1949-03-03	2011-08-02	357	50.90625	-119.65625	Fraser	WSC
08HB023	ASH RIVER BELOW MORAN CREEK	1959-07-15	2011-10-13	384	49.40625	-125.03125	BC Coast	WSC
08FB006	ATNARKO RIVER NEAR THE MOUTH	1965-06-25	2011-09-14	760	52.34375	-126.03125	BC Coast	WSC
08EC001	BABINE RIVER AT BABINE	1949-10-01	2011-08-30	370	55.34375	-126.65625	BC Coast	WSC
08EC013	BABINE RIVER AT OUTLET OF NILIKITWA LAKE	1972-04-28	2011-08-30	382	55.40625	-126.71875	BC Coast	WSC
08KE016	BAKER CREEK AT QUESNEL	1963-07-12	2011-09-14	518	52.96875	-122.59375	Fraser	WSC
08LB020	BARRIERE RIVER AT THE MOUTH	1952-04-30	2011-07-20	649	51.21875	-120.09375	Fraser	WSC
08LB069	BARRIERE RIVER BELOW SPRAGUE CREEK	1915-03-17	2011-07-20	599	51.28125	-119.90625	Fraser	WSC
08FB007	BELLA COOLA RIVER ABOVE BURNT BRIDGE CREEK	1963-12-05	2011-09-15	673	52.40625	-126.15625	BC Coast	WSC
08LC039	BESSETTE CREEK ABOVE BEAVERJACK CREEK	1970-03-25	2011-10-11	462	50.28125	-118.90625	Fraser	WSC
08LC042	BESSETTE CREEK ABOVE LUMBY LAGOON OUTFALL	1970-01-28	2011-10-14	461	50.28125	-118.96875	Fraser	WSC
08MB006	BIG CREEK ABOVE GROUNDHOG CREEK	1974-09-17	2011-09-27	462	51.46875	-123.09375	Fraser	WSC
08LB038	BLUE RIVER NEAR BLUE RIVER	1984-01-10	2011-09-08	341	52.09375	-119.34375	Fraser	WSC
08LF002	BONAPARTE RIVER BELOW CACHE CREEK	1958-08-22	2011-09-26	650	50.78125	-121.28125	Fraser	WSC
08KD007	BOWRON RIVER BELOW BOX CANYON	1977-01-19	2011-10-25	286	54.03125	-122.09375	Fraser	WSC
08EE013	BUCK CREEK AT THE MOUTH	1972-05-17	2011-08-31	408	54.34375	-126.65625	BC Coast	WSC
08EE004	BULKLEY RIVER AT QUICK	1900-06-25	2011-08-30	446	54.59375	-126.90625	BC Coast	WSC
08EE003	BULKLEY RIVER NEAR HOUSTON	1980-04-09	2011-08-31	235	54.40625	-126.71875	BC Coast	WSC
08HD003	CAMPBELL RIVER NEAR CAMPBELL RIVER	1951-01-20	2011-10-03	403	50.03125	-125.34375	BC Coast	WSC
08LE112	CHASE CREEK ABOVE THE MOUTH	1996-08-15	2011-09-23	329	50.78125	-119.65625	Fraser	WSC
08GA072	CHEAKAMUS RIVER ABOVE MILLAR CREEK	1982-03-26	2011-09-22	250	50.03125	-123.03125	BC Coast	WSC
BC08GA0010/ E269864	CHEAKAMUS RIVER BELOW SEWAGE TREATMENT PLANT	2004-03-08	2020-02-25	353	50.09375	-123.09375	BC Coast	ECCC
08GA043	CHEAKAMUS RIVER NEAR BRACKENDALE	1958-03-06	2011-10-12	562	49.84375	-123.15625	BC Coast	WSC
08HA001	CHEMAINUS RIVER NEAR WESTHOLME	1954-08-05	2011-09-13	552	48.90625	-123.71875	BC Coast	WSC
CR50/ BC08MB0007	CHILCOTIN RIVER AT ALEXIS CREEK CHILCOTIN RIVER UPSTREAM OF CHRISTIE ROAD BRIDGE	1996-07-01	2020-01-07	1102	52.09375	-123.28125	Fraser	DFO/ECCC

STATION ID	LONG NAME	START_DATE	END_DATE	N	VIC_GL LAT	VIC-GL LON	DOMAIN	SOURCE
08MA002	CHILKO RIVER AT OUTLET OF CHILKO LAKE	1914-03-18	2011-09-13	770	51.65625	-124.09375	Fraser	WSC
08MA001	CHILKO RIVER NEAR REDSTONE	1949-05-10	2011-09-12	837	52.03125	-123.59375	Fraser	WSC
08MH016	CHILLIWACK RIVER AT OUTLET OF CHILLIWACK LAKE	1949-09-14	2011-08-25	439	49.09375	-121.46875	Fraser	WSC
08MH001	CHILLIWACK RIVER AT VEDDER CROSSING	1951-05-17	2011-09-22	636	49.09375	-121.96875	Fraser	WSC
08MH103	CHILLIWALK RIVER ABOVE SLESSE CREEK	1957-06-19	2011-08-25	350	49.09375	-121.65625	Fraser	WSC
08MB005	CHILLOTIN RIVER BELOW BIG CREEK	1971-05-05	2011-09-27	453	51.84375	-122.65625	Fraser	WSC
08LA001	CLEARWATER RIVER NEAR CLEARWATER STATION	1950-05-22	2011-09-21	515	51.71875	-120.03125	Fraser	WSC
08LG010	COLDWATER RIVER AT MERRITT	1961-01-27	2011-09-08	376	50.03125	-120.84375	Fraser	WSC
08LG048	COLDWATER RIVER NEAR BROOKMERE	1957-03-07	2011-09-23	633	49.84375	-120.90625	Fraser	WSC
08KE009	COTTONWOOD RIVER NEAR CINEMA	1954-04-13	1999-03-17	378	53.15625	-122.46875	Fraser	WSC
08HA002	COWICHAN RIVER AT LAKE COWICHAN	1949-11-16	2011-09-20	398	48.84375	-124.09375	BC Coast	WSC
08HA011	COWICHAN RIVER NEAR DUNCAN	1968-01-20	2011-09-20	325	48.78125	-123.71875	BC Coast	WSC
08LF007	CRISS CREEK NEAR SAVONA	1961-12-14	2011-09-26	585	50.90625	-120.90625	Fraser	WSC
08LF027	DEADMAN RIVER ABOVE CRISS CREEK	1954-08-27	2011-09-30	584	50.96875	-120.96875	Fraser	WSC
08FC003	DEAN RIVER BELOW TANSWANKET CREEK	1971-11-30	2011-08-31	370	52.90625	-125.78125	BC Coast	WSC
08FC005	DEAN RIVER NEAR ANAHIM LAKE	1997-05-14	2007-08-11	202	52.40625	-125.21875	BC Coast	WSC
08KA001	DORE RIVER NEAR MCBRIDE	1913-11-14	2011-09-08	434	53.28125	-120.28125	Fraser	WSC
08LE024	EAGLE RIVER NEAR MALAKWA	1913-08-23	2011-10-05	609	50.96875	-118.78125	Fraser	WSC
08GA071	ELAHO RIVER NEAR THE MOUTH	1981-02-05	2011-09-27	250	50.09375	-123.46875	BC Coast	WSC
08HD018	ELK RIVER ABOVE CAMPBELL LAKE	1991-03-12	2011-08-30	258	49.84375	-125.78125	BC Coast	WSC
08EG012	EXCHAMSIKS RIVER NEAR TERRACE	1962-05-19	2011-08-23	320	54.34375	-129.34375	BC Coast	WSC
08MF040	FRASER RIVER ABOVE TEXAS CREEK	1951-05-16	2011-09-28	545	50.59375	-121.84375	Fraser	WSC
08KA004	FRASER RIVER AT HANSARD	1914-09-11	2011-09-21	1569	54.09375	-121.84375	Fraser	WSC
08MF005	FRASER RIVER AT HOPE	1910-02-14	2020-03-12	3946	49.40625	-121.46875	Fraser	WSC
08KA005	FRASER RIVER AT MCBRIDE	1953-04-29	2011-10-26	510	53.28125	-120.09375	Fraser	WSC
08MH024	FRASER RIVER AT MISSION	1915-01-20	2011-09-12	2056	49.15625	-122.28125	Fraser	WSC
08MH126	FRASER RIVER AT PORT MANN PUMPING STATION	1958-07-19	2011-07-12	992	49.21875	-122.78125	Fraser	WSC

STATION ID	LONG NAME	START_DATE	END_DATE	N	VIC_GL LAT	VIC-GL LON	DOMAIN	SOURCE
FR190	FRASER RIVER AT [QUALARK HELLS GATE]	1995-07-01	2005-09-30	1004	49.53125	-121.40625	Fraser	DFO
08KA007	FRASER RIVER AT RED PASS	1950-08-04	2019-06-24	1906	52.96875	-119.03125	Fraser	WSC
08KB001	FRASER RIVER AT SHELLEY	1951-01-24	2011-09-22	1433	53.46875	-122.65625	Fraser	WSC
BC08MC0001/ 08MC018	FRASER RIVER [AT NEAR] MARGUERITE	1951-01-21	2020-03-17	1316	52.53125	-122.46875	Fraser	ECCC/WSC
08MF035	FRASER RIVER NEAR AGASSIZ	1959-07-19	1976-12-19	1762	49.21875	-121.78125	Fraser	WSC
08HC001	GOLD RIVER BELOW UCONA RIVER	1910-01-06	2011-03-16	298	49.71875	-126.09375	BC Coast	WSC
08LG041	GUICHON CREEK AT OUTLET OF MAMIT LAKE	1981-11-25	2011-09-09	447	50.34375	-120.78125	Fraser	WSC
08LG067	GUICHON CREEK AT THE MOUTH	1984-04-25	2011-09-08	391	50.21875	-120.84375	Fraser	WSC
08MG013	HARRISON RIVER NEAR HARRISON HOT SPRINGS	1951-05-03	2011-09-20	285	49.28125	-121.84375	Fraser	WSC
08LF015	HAT CREEK NEAR CACHE CREEK	1957-04-19	1994-12-07	304	50.90625	-121.46875	Fraser	WSC
08FF002	HIRSCH CREEK NEAR THE MOUTH	1977-01-19	2011-08-11	323	54.03125	-128.59375	BC Coast	WSC
08GD008	HOMATHKO RIVER AT INLET TO TATLAYOKO LAKE	1963-05-30	2011-09-13	402	51.65625	-124.40625	BC Coast	WSC
08GD004	HOMATHKO RIVER AT THE MOUTH	1957-02-27	2011-10-05	330	50.96875	-124.90625	BC Coast	WSC
08KH010	HORSEFLY RIVER ABOVE MCKINLEY CREEK	1955-02-23	2011-09-03	539	52.34375	-120.96875	Fraser	WSC
08KH031	HORSEFLY RIVER ABOVE QUESNEL LAKE	2004-09-08	2020-03-29	375	52.40625	-121.40625	Fraser	WSC
HOR22/08KH007	HORSEFLY RIVER AT HORSEFLY	1949-05-07	2005-09-08	842	52.28125	-121.34375	Fraser	DFO/WSC
08CG001	ISKUT RIVER BELOW JOHNSON RIVER	1959-05-02	2019-10-21	806	56.71875	-131.65625	BC Coast	WSC
08FE003	KEMANO RIVER ABOVE POWERHOUSE TAILRACE	1971-11-29	2011-08-10	283	53.59375	-127.96875	BC Coast	WSC
08EB004	KISPIOX RIVER NEAR HAZELTON	1963-07-04	2011-08-31	423	55.40625	-127.71875	BC Coast	WSC
08FF001	KITIMAT RIVER BELOW HIRSCH CREEK	1963-02-22	2011-09-15	461	54.03125	-128.65625	BC Coast	WSC
08GE002	KLINAKLINI RIVER EAST CHANNEL (MAIN) NEAR THE MOUTH	1977-01-25	2011-09-25	258	51.15625	-125.59375	BC Coast	WSC
08LB078	LEMIEUX CREEK NEAR THE MOUTH	1977-01-11	2011-08-19	501	51.46875	-120.21875	Fraser	WSC
08MG005	LILLOOET RIVER NEAR PEMBERTON	1914-09-09	2011-10-11	449	50.34375	-122.84375	Fraser	WSC
08FF003	LITTLE WEDEENE RIVER BELOW BOWBYES CREEK	1966-08-24	2011-09-15	404	54.15625	-128.71875	BC Coast	WSC
08LB072	LOUIS CREEK AT THE MOUTH	1977-01-06	1996-05-17	251	51.09375	-120.09375	Fraser	WSC
08KB003	MCGREGOR RIVER AT LOWER CANYON	1960-01-15	2011-09-16	455	54.21875	-121.65625	Fraser	WSC
08KH020	MCKINLEY CREEK BELOW OUTLET OF MCKINLEY LAKE	1971-05-17	2011-09-03	426	52.28125	-120.96875	Fraser	WSC

STATION ID	LONG NAME	START_DATE	END_DATE	N	VIC_GL LAT	VIC-GL LON	DOMAIN	SOURCE
08KH019	MOFFAT CREEK NEAR HORSEFLY	1963-06-09	2011-09-04	533	52.28125	-121.40625	Fraser	WSC
08ED002	MORICE RIVER NEAR HOUSTON	1969-06-11	2011-08-09	223	54.09375	-127.40625	BC Coast	WSC
08JB008	NADINA RIVER AT OUTLET OF NADINA LAKE	1964-11-04	2011-08-31	371	53.90625	-126.96875	Fraser	WSC
08MF065	NAHATLATCH RIVER BELOW TACHEWANA CREEK	1973-04-27	2011-10-12	292	49.96875	-121.84375	Fraser	WSC
08ED001	NANIKA RIVER AT OUTLET OF KIDPRICE LAKE	1950-09-11	2011-08-09	281	53.90625	-127.46875	BC Coast	WSC
08DB001	NASS RIVER ABOVE SHUMAL CREEK	1977-01-31	2011-09-10	293	55.28125	-129.09375	BC Coast	WSC
08JB003	NAUTLEY RIVER NEAR FORT FRASER	1951-09-17	2011-09-15	605	54.09375	-124.59375	Fraser	WSC
08JC002	NECHAKO RIVER AT ISLE PIERRE	1950-06-08	2011-07-21	701	53.96875	-123.28125	Fraser	WSC
BC08KE0010	NECHAKO RIVER AT PRINCE GEORGE	1984-07-24	2020-03-11	1547	53.90625	-122.78125	Fraser	ECCC
08JC001	NECHAKO RIVER AT VANDERHOOF	1949-09-24	2011-09-15	887	54.03125	-124.03125	Fraser	WSC
08JA017	NECHAKO RIVER BELOW CHESLATTA FALLS	1980-07-03	2011-09-13	337	53.71875	-124.84375	Fraser	WSC
08LG049	NICOLA RIVER ABOVE NICOLA LAKE	1958-11-18	2011-08-31	683	50.15625	-120.34375	Fraser	WSC
08LG065	NICOLA RIVER AT OUTLET OF NICOLA LAKE	1983-01-04	2011-09-16	582	50.15625	-120.71875	Fraser	WSC
08LG007	NICOLA RIVER NEAR MERRITT	1956-07-24	2009-06-23	577	50.15625	-120.84375	Fraser	WSC
08LG006	NICOLA RIVER NEAR SPENCES BRIDGE	1957-07-23	2011-09-27	772	50.34375	-121.21875	Fraser	WSC
08HF005	NIMPKISH RIVER ABOVE WOSS RIVER	1990-01-23	2011-09-09	232	50.21875	-126.59375	BC Coast	WSC
08LB047	NORTH THOMPSON RIVER AT BIRCH ISLAND	1957-07-13	2011-09-21	439	51.59375	-119.90625	Fraser	WSC
08LB064	NORTH THOMPSON RIVER AT MCLURE	1956-10-25	2011-09-19	691	51.03125	-120.21875	Fraser	WSC
NTR15	NORTH THOMPSON RIVER AT RAYLEIGH	1996-07-01	2005-09-08	777	50.84375	-120.28125	Fraser	DFO
08HD011	OYSTER RIVER BELOW WOODHUS CREEK	1977-04-29	2011-09-19	340	49.90625	-125.21875	BC Coast	WSC
08EC004	PINKUT CREEK NEAR TINTAGEL	1977-01-11	2011-08-24	360	54.40625	-125.46875	BC Coast	WSC
08MH035	PITT RIVER NEAR PORT COQUITLAM	1965-07-02	1989-03-31	641	49.28125	-122.71875	Fraser	WSC
08HB006	PUNTLEDGE RIVER AT COURTENAY	1977-04-26	2011-10-03	230	49.65625	-125.03125	BC Coast	WSC
08KH001	QUESNEL RIVER AT LIKELY	1950-06-15	2011-07-25	266	52.59375	-121.59375	Fraser	WSC
QR1/ 08KH006	QUESNEL RIVER [AT NEAR] QUESNEL	1912-04-12	2011-08-25	1144	52.96875	-122.46875	Fraser	DFO/WSC
126400	QUINSAM RIVER AT HIGHWAY	1971-05-20	2012-09-24	600	49.96875	-125.34375	BC Coast	USGS
08HD005	QUINSAM RIVER NEAR CAMPBELL RIVER	1957-02-26	2011-10-03	400	49.96875	-125.34375	BC Coast	WSC

STATION ID	LONG NAME	START_DATE	END_DATE	N	VIC_GL LAT	VIC-GL LON	DOMAIN	SOURCE
08HD015	SALMON RIVER ABOVE CAMPBELL LAKE DIVERSION	1981-07-29	2011-09-01	321	50.09375	-125.65625	BC Coast	WSC
08HD007	SALMON RIVER ABOVE MEMEKAY RIVER	1960-10-06	2011-10-04	389	50.15625	-125.71875	BC Coast	WSC
08LE020	SALMON RIVER AT FALKLAND	1977-01-10	2011-10-11	541	50.46875	-119.53125	Fraser	WSC
BC08LE0004/ 08LE021	SALMON RIVER AT HWY 1 BRIDGE SALMON RIVER NEAR SALMON ARM	1977-01-28	2020-03-05	1292	50.71875	-119.34375	Fraser	ECCC/WSC
08KC001	SALMON RIVER NEAR PRINCE GEORGE	1958-11-07	2011-09-28	572	54.09375	-122.65625	Fraser	WSC
08HD006	SALMON RIVER NEAR SAYWARD	1957-03-01	2011-09-09	329	50.28125	-125.90625	BC Coast	WSC
08MC040	SAN JOSE RIVER ABOVE BORLAND CREEK	1984-03-29	2011-06-09	367	52.03125	-121.90625	Fraser	WSC
08HA010	SAN JUAN RIVER NEAR PORT RENFREW	1977-01-18	2011-09-15	267	48.59375	-124.28125	BC Coast	WSC
08LE027	SEYMOUR RIVER NEAR SEYMOUR ARM	1955-08-03	2011-09-21	382	51.28125	-118.90625	Fraser	WSC
08LC003	SHUSWAP RIVER NEAR LUMBY	1949-06-08	2011-10-14	362	50.28125	-118.78125	Fraser	WSC
08EF001	SKEENA RIVER AT USK	1951-02-01	2019-03-25	1225	54.65625	-128.40625	BC Coast	WSC
920092	SKEENA RIVER AT USK FERRY	1966-08-22	2002-03-31	638	54.65625	-128.40625	BC Coast	USGS
STR60/08LE031	SOUTH THOMPSON RIVER AT CHASE	1950-10-19	2011-09-20	1295	50.78125	-119.71875	Fraser	DFO/WSC
08LG008	SPIUS CREEK NEAR CANFORD	1970-05-30	2011-09-27	543	50.09375	-121.03125	Fraser	WSC
08HB008	SPROAT RIVER NEAR ALBERNI	1977-02-08	2011-10-13	298	49.28125	-124.96875	BC Coast	WSC
08GA002	SQUAMISH RIVER NEAR BRAKENDALE	1959-01-27	2011-10-13	355	49.78125	-123.15625	BC Coast	WSC
08JB002	STELLAKO RIVER AT GLENANNAN	1952-01-28	2011-09-15	512	54.03125	-124.96875	Fraser	WSC
08CE001	STIKINE RIVER AT TELEGRAPH CREEK	1954-08-31	2011-08-05	329	57.90625	-131.15625	BC Coast	WSC
SR113/ 08JE001	STUART RIVER [AT NEAR] FORT ST. JAMES	1958-10-27	2011-09-14	1352	54.40625	-124.21875	Fraser	DFO/WSC
08DA005	SURPRISE CREEK NEAR THE MOUTH	1967-05-29	2011-09-20	343	56.15625	-129.53125	BC Coast	WSC
08MA003	TASEKO RIVER AT OUTLET OF TASEKO LAKES	1982-06-08	2011-09-27	309	51.40625	-123.65625	Fraser	WSC
08EE020	TELKWA RIVER BELOW TSAI CREEK	1977-01-21	2011-08-29	337	54.59375	-127.46875	BC Coast	WSC
TR80	THOMPSON RIVER AT ASHCROFT	1995-07-06	2005-09-30	951	50.71875	-121.28125	Fraser	DFO
BC08LF0001/ 08LF051	THOMPSON RIVER [AT NEAR] SPENCES BRIDGE	1951-11-23	2014-12-15	2155	54.40625	-121.40625	Fraser	ECCC/WSC
08JE004	TSILCOH RIVER NEAR THE MOUTH	1977-02-01	2011-09-14	387	54.65625	-124.21875	Fraser	WSC
08HF004	TSITIKA RIVER BELOW CATHERINE CREEK	1977-01-25	2011-08-18	233	50.46875	-126.59375	BC Coast	WSC

STATION ID	LONG NAME	START_DATE	END_DATE	N	VIC_GL LAT	VIC-GL LON	DOMAIN	SOURCE
08CD001	TUYA RIVER NEAR TELEGRAPH CREEK	1959-06-09	2011-08-02	309	58.09375	-130.78125	BC Coast	WSC
08KG001	WEST ROAD RIVER NEAR CINEMA	1952-08-22	2011-10-19	327	53.28125	-122.90625	Fraser	WSC
08MC005	WILLIAMS LAKE RIVER AT OUTLET OF WILLIAMS LAKE	1968-06-15	1996-06-12	325	52.09375	-122.09375	Fraser	WSC
08KD006	WILLOW RIVER ABOVE HAY CREEK	1975-08-12	2011-07-28	371	54.03125	-122.40625	Fraser	WSC
08ME025	YALAKOM RIVER ABOVE ORE CREEK	1983-01-06	2011-09-28	360	50.90625	-122.21875	Fraser	WSC
08EF005	ZYMOETZ RIVER ABOVE O.K. CREEK	1961-11-24	2011-09-23	550	54.46875	-128.34375	BC Coast	WSC

Appendix B: Verification Summaries

Table B1. Streamflow verification values for each station. Stations are listed in alphabetical order by name.

STATION NAME	STATION ID	DA (km ²)	N	KGE	LNSE	BIAS (%)
ADAMS RIVER NEAR SQUILAX	08LD001	3210	6795	0.89	0.84	-10
ALOUETTE RIVER AT ALOUETTE DAM	BCHAL	-	7305	0.52	0.66	-22
ASH RIVER BELOW MORAN CREEK	08HB023	387	5844	0.62	0.16	27
ATNARKO RIVER NEAR THE MOUTH	08FB006	2550	5844	0.80	0.72	5
BAKER CREEK AT QUESNEL	08KE016	1550	7305	0.75	0.28	6
BARRIERE RIVER AT THE MOUTH	08LB020	1140	7305	0.94	0.89	-4
BEAR RIVER ABOVE BITTER CREEK	08DC006	350	5203	0.65	0.85	13
BELLA COOLA RIVER ABOVE BURNT BRIDGE CREEK	08FB007	3720	5844	0.84	0.82	-1
BIG CREEK ABOVE GROUNDHOG CREEK	08MB006	1010	7305	0.70	0.78	-5
BONAPARTE RIVER BELOW CACHE CREEK	08LF002	5020	7305	0.50	0.63	-22
BOWRON RIVER BELOW BOX CANYON	08KD007	3330	7015	0.87	0.39	-10
BRIDGE RIVER AT LA JOIE DAM	BCHLJ	988	7305	0.80	0.77	13
BUCK CREEK AT THE MOUTH	08EE013	565	5837	0.67	0.73	21
BULKLEY RIVER AT QUICK	08EE004	7340	5844	0.87	0.77	-6
CAMPBELL RIVER NEAR CAMPBELL RIVER	08HD003	1470	3288	0.50	-2.24	-15
CAYOOSH CREEK NEAR LILLOOET	08ME002	885	7305	0.31	-0.15	61
CHEAKAMUS RIVER NEAR BRACKENDALE	08GA043	965	5647	-0.26	-0.39	104
CHEMAINUS RIVER NEAR WESTHOLME	08HA001	355	5844	0.78	0.88	8
CHILCOTIN RIVER BELOW BIG CREEK	08MB005	19200	7305	0.86	0.86	5
CHILKO RIVER NEAR REDSTONE	08MA001	6880	7305	0.85	0.78	-6
CHILLIWACK RIVER AT VEDDER CROSSING	08MH001	1230	6911	0.75	0.36	-7
CLEARWATER RIVER AT OUTLET OF CLEARWATER LAKE	08LA007	2950	5231	0.88	0.24	-10
CLEARWATER RIVER NEAR CLEARWATER STATION	08LA001	10300	7305	0.91	0.65	-7
COTTONWOOD RIVER NEAR CINEMA	08KE009	1910	6664	0.83	0.45	-1
COWICHAN RIVER NEAR DUNCAN	08HA011	826	5844	0.92	0.87	-4
DEAN RIVER BELOW TANSWANKET CREEK	08FC003	3720	5844	0.41	0.59	-40

STATION NAME	STATION ID	DA (km ²)	N	KGE	LNSE	BIAS (%)
DEAN RIVER NEAR ANAHIM LAKE	08FC005	1060	1328	0.52	0.14	10
EAGLE RIVER NEAR MALAKWA	08LE024	932	7305	0.86	-0.04	-8
ELAHO RIVER NEAR THE MOUTH	08GA071	1200	5844	0.76	0.75	-16
ENGLISHMAN RIVER NEAR PARKSVILLE	08HB002	319	5844	0.47	0.63	6
EXCHAMSIKS RIVER NEAR TERRACE	08EG012	370	5844	0.80	0.78	13
FORREST KERR CREEK ABOVE 460 M CONTOUR	08CG006	311	3509	0.45	0.34	23
FRASER RIVER AT HANSARD	08KA004	18000	7305	0.83	0.71	-1
FRASER RIVER AT HOPE	08MF005	217000	7305	0.89	0.87	-9
FRASER RIVER AT MCBRIDE	08KA005	6890	7305	0.57	0.87	19
FRASER RIVER AT RED PASS	08KA007	1710	7305	0.62	-0.13	14
FRASER RIVER NEAR MARGUERITE	08MC018	114000	7305	0.87	0.88	-9
GOLD RIVER BELOW UCONA RIVER	08HC001	992	5844	0.74	0.69	15
HARRISON RIVER NEAR HARRISON HOT SPRINGS	08MG013	7890	7204	0.75	0.67	-1
HIRSCH CREEK NEAR THE MOUTH	08FF002	353	5844	0.63	0.66	-1
HOMATHKO RIVER AT INLET TO TATLAYOKO LAKE	08GD008	486	5844	-4.20	-3.17	372
HOMATHKO RIVER AT THE MOUTH	08GD004	5680	5844	0.76	0.89	10
HOMATHKO RIVER AT TRAGEDY CANYON	08GD006	4070	2281	0.87	0.87	-9
HOMATHKO RIVER BELOW NUDE CREEK	08GD005	1960	2281	0.88	0.86	-3
HORSEFLY RIVER ABOVE MCKINLEY CREEK	08KH010	790	7305	0.87	0.75	-10
ISKUT RIVER ABOVE SNIPPAKER CREEK	08CG004	7230	3761	0.73	0.84	10
ISKUT RIVER AT OUTLET OF KINASKAN LAKE	08CG003	1250	4126	0.60	0.76	17
ISKUT RIVER BELOW JOHNSON RIVER	08CG001	9500	5844	0.77	0.86	7
KEMANO RIVER ABOVE POWERHOUSE TAILRACE	08FE003	556	5844	0.71	0.65	16
KISPIOX RIVER NEAR HAZELTON	08EB004	1880	5844	0.78	0.73	-9
KITIMAT RIVER BELOW HIRSCH CREEK	08FF001	1990	5844	0.71	0.66	-1
KLAPPAN RIVER NEAR TELEGRAPH CREEK	08CC001	3550	4122	0.85	0.84	-3
KLINAKLINI RIVER EAST CHANNEL (MAIN) NEAR THE MOUTH	08GE002	5780	5844	0.88	0.85	-8

STATION NAME	STATION ID	DA (km ²)	N	KGE	LNSE	BIAS (%)
LILLOOET RIVER NEAR PEMBERTON	08MG005	2100	6939	0.80	0.83	7
MAHOOD RIVER AT OUTLET OF MAHOOD LAKE	08LA008	4710	1461	0.81	0.74	-9
MAMQUAM RIVER ABOVE MASHITER CREEK	08GA054	334	730	0.75	0.72	8
MCGREGOR RIVER AT LOWER CANYON	08KB003	4780	7305	0.83	0.77	-11
MORE CREEK NEAR THE MOUTH	08CG005	844	3743	0.53	0.84	25
MORICE RIVER NEAR HOUSTON	08ED002	1900	5844	0.79	0.62	-5
MOSLEY CREEK NEAR DUMBELL LAKE	08GD007	1550	3742	0.76	0.83	-14
NANIKA RIVER AT OUTLET OF KIDPRICE LAKE	08ED001	732	5760	0.74	0.68	1
NASS RIVER ABOVE SHUMAL CREEK	08DB001	18400	5844	0.86	0.85	-3
NAUTLEY RIVER NEAR FORT FRASER	08JB003	6030	7305	0.58	0.77	-21
NAZKO RIVER ABOVE MICHELLE CREEK	08KF001	3240	4991	0.62	0.42	25
NECHAKO RIVER BELOW CHESLATTA FALLS	08JA017	15500	7305	0.34	0.32	-16
NICOLA RIVER NEAR SPENCES BRIDGE	08LG006	7100	7305	0.88	0.81	-6
NIMPKISH RIVER ABOVE WOSS RIVER	08HF005	783	3986	0.79	0.83	-9
NORTH THOMPSON RIVER AT BIRCH ISLAND	08LB047	4490	7305	0.88	0.87	-6
OYSTER RIVER BELOW WOODHUS CREEK	08HD011	302	5844	0.74	0.60	14
PINKUT CREEK NEAR TINTAGEL	08EC004	808	5398	0.85	0.76	-1
PITMAN RIVER NEAR THE MOUTH	08CA003	2730	3743	0.81	0.82	1
PUNTLEDGE RIVER AT COURTENAY	08HB006	583	5804	0.63	-0.30	-21
QUESNEL RIVER AT LIKELY	08KH001	5970	7305	0.85	0.88	-5
QUESNEL RIVER NEAR QUESNEL	08KH006	12000	7305	0.86	0.90	-9
SALMON RIVER ABOVE MEMEKAY RIVER	08HD007	439	5844	0.61	-7.84	4
SALMON RIVER NEAR PRINCE GEORGE	08KC001	4230	7143	0.83	0.18	-8
SALMON RIVER NEAR SAYWARD	08HD006	1210	5844	0.75	0.68	7
SAN JOSE RIVER ABOVE BORLAND CREEK	08MC005	1990	6122	0.66	0.23	7
SAN JUAN RIVER NEAR PORT RENFREW	08HA010	578	4767	0.74	0.69	18
SETON RIVER AT SETON DAM	BCHST	1017	7305	0.71	0.57	-14

STATION NAME	STATION ID	DA (km ²)	N	KGE	LNSE	BIAS (%)
SEYMOUR RIVER NEAR SEYMOUR ARM	08LE027	805	7305	0.82	0.12	-13
SHUSWAP RIVER AT SUGAR DAM	BCHSG	1113	7305	0.80	-0.36	-13
SKEENA RIVER ABOVE BABINE RIVER	08EB005	12400	4109	0.92	0.88	-3
SKEENA RIVER AT USK	08EF001	42300	5844	0.92	0.89	-3
SOMASS RIVER NEAR ALBERNI	08HB017	1280	5844	-0.04	-17.31	-73
SOUTH THOMPSON RIVER AT CHASE	08LE031	15800	7305	0.85	0.81	-12
SPATSIZI RIVER NEAR THE MOUTH	08CA001	3400	3743	0.79	0.83	5
SQUAMISH RIVER NEAR BRACKENDALE	08GA022	2350	5478	0.80	0.73	-8
STAMP RIVER NEAR GREAT CENTRAL	08HB009	456	5580	0.85	0.68	0
STAVE RIVER AT STAVE FALLS DAM	BCHSF	1170	7305	0.46	0.56	-1
STELLAKO RIVER AT GLENANNAN	08JB002	3600	7175	0.56	0.75	-19
STIKINE RIVER ABOVE BUTTERFLY CREEK	08FC001	36000	3761	0.88	0.83	-6
STIKINE RIVER ABOVE GRAND CANYON	08CB001	18800	3742	0.86	0.87	-4
STIKINE RIVER AT TELEGRAPH CREEK	08CE001	29000	5844	0.88	0.85	-3
STIKINE RIVER BELOW SPATSIZI RIVER	08CA002	7690	3763	0.84	0.79	2
STIKINE RIVER NEAR WRANGELL	08CF003	50900	5844	0.84	0.86	1
STUART RIVER NEAR FORT ST. JAMES	08JE001	14200	7305	0.63	0.73	-12
TAKU RIVER NEAR TULSEQUAH	08BB001	15500	1095	0.89	0.92	6
TASEKO RIVER AT OUTLET OF TASEKO LAKES	08MA003	1520	6618	0.66	0.82	7
TELKWA RIVER BELOW TSAI CREEK	08EE020	367	5844	0.77	0.77	1
TUYA RIVER NEAR TELEGRAPH CREEK	08CD001	3550	5809	0.75	0.69	6
UNUK RIVER NEAR STEWART	08DD001	1480	4108	0.72	0.80	6
WANNOCK RIVER AT OUTLET OF OWIKENO LAKE	08FA002	3900	5844	0.75	0.70	2
WEST ROAD RIVER NEAR CINEMA	08KG001	12400	7305	0.82	0.40	-3
WILLOW RIVER ABOVE HAY CREEK	08KD006	2860	6349	0.86	0.69	-5
ZYMAGOTITZ RIVER NEAR TERRACE	08EG011	376	3795	0.76	0.68	2
ZYMOETZ RIVER ABOVE O.K. CREEK	08EF005	2850	5844	0.77	0.71	2

Table B2. Water temperature verification values for each station. Stations are listed in alphabetical order by name.

STATION NAME	STATION ID	DA (km ²)	N	PFactor
ADAMS RIVER NEAR SQUILAX	08LD001	3210	357	0.31
ASH RIVER BELOW MORAN CREEK	08HB023	387	384	0.59
ATNARKO RIVER NEAR THE MOUTH	08FB006	2550	760	0.75
BABINE RIVER AT BABINE	08EC001	6350	370	0.33
BABINE RIVER AT OUTLET OF NILIKITWA LAKE	08EC013	6760	382	0.37
BAKER CREEK AT QUESNEL	08KE016	1550	518	0.81
BARRIERE RIVER AT THE MOUTH	08LB020	1140	649	0.58
BARRIERE RIVER BELOW SPRAGUE CREEK	08LB069	624	599	0.61
BELLA COOLA RIVER ABOVE BURNT BRIDGE CREEK	08FB007	3720	673	0.47
BESSETTE CREEK ABOVE BEAVERJACK CREEK	08LC039	769	462	0.72
BESSETTE CREEK ABOVE LUMBY LAGOON OUTFALL	08LC042	632	461	0.56
BIG CREEK ABOVE GROUNDHOG CREEK	08MB006	1010	462	0.87
BLUE RIVER NEAR BLUE RIVER	08LB038	272	341	0.60
BONAPARTE RIVER BELOW CACHE CREEK	08LF002	5020	650	0.86
BOWRON RIVER BELOW BOX CANYON	08KD007	3330	286	0.66
BUCK CREEK AT THE MOUTH	08EE013	565	408	0.72
BULKLEY RIVER AT QUICK	08EE004	7340	446	0.47
BULKLEY RIVER NEAR HOUSTON	08EE003	2370	235	0.79
CAMPBELL RIVER NEAR CAMPBELL RIVER	08HD003	1470	403	0.38
CHASE CREEK ABOVE THE MOUTH	08LE112	297	329	0.80
CHEAKAMUS RIVER ABOVE MILLAR CREEK	08GA072	297	250	0.52
CHEAKAMUS RIVER BELOW SEWAGE TREATMENT PLANT	BC08GA0010/E269864	-	353	0.62
CHEAKAMUS RIVER NEAR BRACKENDALE	08GA043	956	562	0.70
CHEMAINUS RIVER NEAR WESTHOLME	08HA001	355	552	0.85
CHILCOTIN RIVER AT ALEXIS CREEK CHILCOTIN RIVER UPSTREAM OF CHRISTIE ROAD BRIDGE	CR50/BC08MB0007	13000	1102	0.64

STATION NAME	STATION ID	DA (km ²)	N	PFactor
CHILKO RIVER AT OUTLET OF CHILKO LAKE	08MA002	2130	770	0.33
CHILKO RIVER NEAR REDSTONE	08MA001	6880	837	0.61
CHILLIWACK RIVER AT OUTLET OF CHILLIWACK LAKE	08MH016	335	439	0.58
CHILLIWACK RIVER AT VEDDER CROSSING	08MH001	1230	636	0.34
CHILLIWALK RIVER ABOVE SLESSE CREEK	08MH103	650	350	0.55
CHILLOTIN RIVER BELOW BIG CREEK	08MB005	19200	453	0.76
CLEARWATER RIVER NEAR CLEARWATER STATION	08LA001	10300	515	0.53
COLDWATER RIVER AT MERRITT	08LG010	917	376	0.74
COLDWATER RIVER NEAR BROOKMERE	08LG048	316	633	0.75
COTTONWOOD RIVER NEAR CINEMA	08KE009	1910	378	0.83
COWICHAN RIVER AT LAKE COWICHAN	08HA002	594	398	0.25
COWICHAN RIVER NEAR DUNCAN	08HA011	826	325	0.44
CRISS CREEK NEAR SAVONA	08LF007	479	585	0.84
DEADMAN RIVER ABOVE CRISS CREEK	08LF027	878	584	0.74
DEAN RIVER BELOW TANSWANKET CREEK	08FC003	3720	370	0.77
DEAN RIVER NEAR ANAHIM LAKE	08FC005	1060	202	0.70
DORE RIVER NEAR MCBRIDE	08KA001	409	434	0.73
EAGLE RIVER NEAR MALAKWA	08LE024	932	609	0.46
ELAHO RIVER NEAR THE MOUTH	08GA071	1200	250	0.50
ELK RIVER ABOVE CAMPBELL LAKE	08HD018	132	258	0.61
EXCHAMSIKS RIVER NEAR TERRACE	08EG012	370	320	0.43
FRASER RIVER ABOVE TEXAS CREEK	08MF040	154000	545	0.59
FRASER RIVER AT HANSARD	08KA004	18000	1569	0.63
FRASER RIVER AT HOPE	08MF005	217000	3946	0.59
FRASER RIVER AT MCBRIDE	08KA005	6890	510	0.57
FRASER RIVER AT MISSION	08MH024	228000	2056	0.67
FRASER RIVER AT PORT MANN PUMPING STATION	08MH126	232000	992	0.65

STATION NAME	STATION ID	DA (km ²)	N	PFactor
FRASER RIVER AT QUALARK/HELLS GATE	FR190	-	1004	0.86
FRASER RIVER AT RED PASS	08KA007	1710	1906	0.48
FRASER RIVER AT SHELLEY	08KB001	32400	1433	0.75
FRASER RIVER AT/NEAR MARGUERITE	BC08MC0001/08MC018	114000	1316	0.67
FRASER RIVER NEAR AGASSIZ	08MF035	218000	1762	0.68
GOLD RIVER BELOW UCONA RIVER	08HC001	992	298	0.64
GUICHON CREEK AT OUTLET OF MAMIT LAKE	08LG041	871	447	0.64
GUICHON CREEK AT THE MOUTH	08LG067	1230	391	0.88
HARRISON RIVER NEAR HARRISON HOT SPRINGS	08MG013	7890	285	0.34
HAT CREEK NEAR CACHE CREEK	08LF015	658	304	0.82
HIRSCH CREEK NEAR THE MOUTH	08FF002	353	323	0.58
HOMATHKO RIVER AT INLET TO TATLAYOKO LAKE	08GD008	486	402	0.41
HOMATHKO RIVER AT THE MOUTH	08GD004	5680	330	0.21
HORSEFLY RIVER ABOVE MCKINLEY CREEK	08KH010	790	539	0.74
HORSEFLY RIVER ABOVE QUESNEL LAKE	08KH031	-	375	0.65
HORSEFLY RIVER AT HORSEFLY	08KH007	2310	842	0.97
ISKUT RIVER BELOW JOHNSON RIVER	08CG001	9500	806	0.54
KEMANO RIVER ABOVE POWERHOUSE TAILRACE	08FE003	556	283	0.48
KISPIOX RIVER NEAR HAZELTON	08EB004	1880	423	0.61
KITIMAT RIVER BELOW HIRSCH CREEK	08FF001	1990	461	0.30
LEMIEUX CREEK NEAR THE MOUTH	08LB078	443	501	0.77
LILLOOET RIVER NEAR PEMBERTON	08MG005	2100	449	0.23
LITTLE WEDEENE RIVER BELOW BOWBYES CREEK	08FF003	180	404	0.51
LOUIS CREEK AT THE MOUTH	08LB072	515	251	0.81
MCGREGOR RIVER AT LOWER CANYON	08KB003	4780	455	0.74
MCKINLEY CREEK BELOW OUTLET OF MCKINLEY LAKE	08KH020	431	426	0.50
MOFFAT CREEK NEAR HORSEFLY	08KH019	548	533	0.90

STATION NAME	STATION ID	DA (km ²)	N	PFactor
MORICE RIVER NEAR HOUSTON	08ED002	1900	223	0.41
NADINA RIVER AT OUTLET OF NADINA LAKE	08JB008	369	371	0.57
NAHATLATCH RIVER BELOW TACHEWANA CREEK	08MF065	712	292	0.49
NANIKA RIVER AT OUTLET OF KIDPRICE LAKE	08ED001	732	281	0.31
NASS RIVER ABOVE SHUMAL CREEK	08DB001	18400	293	0.40
NAUTLEY RIVER NEAR FORT FRASER	08JB003	6030	605	0.49
NECHAKO RIVER AT ISLE PIERRE	08JC002	42700	701	0.65
NECHAKO RIVER AT PRINCE GEORGE	BC08KE0010	50000	1547	0.60
NECHAKO RIVER AT VANDERHOOF	08JC001	25200	887	0.51
NECHAKO RIVER BELOW CHESLATA FALLS	08JA017	15500	337	0.20
NICOLA RIVER ABOVE NICOLA LAKE	08LG049	1500	683	0.78
NICOLA RIVER AT OUTLET OF NICOLA LAKE	08LG065	2960	582	0.57
NICOLA RIVER NEAR MERRITT	08LG007	4300	577	0.61
NICOLA RIVER NEAR SPENCES BRIDGE	08LG006	7100	772	0.65
NIMPKISH RIVER ABOVE WOSS RIVER	08HF005	783	232	0.71
NORTH THOMPSON RIVER AT BIRCH ISLAND	08LB047	4490	439	0.58
NORTH THOMPSON RIVER AT MCLURE	08LB064	19600	691	0.57
NORTH THOMPSON RIVER AT RAYLEIGH	NTR15	-	777	0.92
OYSTER RIVER BELOW WOODHUS CREEK	08HD011	302	340	0.65
PINKUT CREEK NEAR TINTAGEL	08EC004	808	360	0.63
PITT RIVER NEAR PORT COQUITLAM	08MH035	1640	641	0.58
PUNTLEDGE RIVER AT COURTENAY	08HB006	583	230	0.34
QUESNEL RIVER AT LIKELY	08KH001	5970	266	0.39
QUESNEL RIVER AT/NEAR QUESNEL	QR1/08KH006	12000	1144	0.69
SALMON RIVER ABOVE CAMPBELL LAKE DIVERSION	08HD015	268	321	0.65
SALMON RIVER ABOVE MEMEKAY RIVER	08HD007	439	389	0.75
SALMON RIVER AT FALKLAND	08LE020	1030	541	0.54

STATION NAME	STATION ID	DA (km ²)	N	PFactor
SALMON RIVER AT HWY 1 BRIDGE SALMON RIVER NEAR SALMON ARM	BC08LE0004/08LE021	1550	1292	0.57
SALMON RIVER NEAR PRINCE GEORGE	08KC001	4230	572	0.71
SALMON RIVER NEAR SAYWARD	08HD006	1210	329	0.70
SAN JOSE RIVER ABOVE BORLAND CREEK	08MC040	1990	367	0.94
SAN JUAN RIVER NEAR PORT RENFREW	08HA010	578	267	0.82
SEYMOUR RIVER NEAR SEYMOUR ARM	08LE027	805	382	0.83
SHUSWAP RIVER NEAR LUMBY	08LC003	2000	362	0.47
SKEENA RIVER AT USK	08EF001	42300	1225	0.54
SOUTH THOMPSON RIVER AT CHASE	SRT60/08LE031	15800	1295	0.53
SPIUS CREEK NEAR CANFORD	08LG008	775	543	0.76
SPROAT RIVER NEAR ALBERNI	08HB008	351	298	0.16
STELLAKO RIVER AT GLENANNAN	08JB002	3600	512	0.35
STIKINE RIVER AT TELEGRAPH CREEK	08CE001	29000	329	0.75
STUART RIVER AT/NEAR FORT ST. JAMES	SR1130/08JE001	14200	1352	0.78
SURPRISE CREEK NEAR THE MOUTH	08DA005	218	343	0.41
TASEKO RIVER AT OUTLET OF TASEKO LAKES	08MA003	1520	309	0.35
TELKWA RIVER BELOW TSAI CREEK	08EE020	367	337	0.55
THOMPSON AT/NEAR SPENCES BRIDGE	BC08LF0001/08LF051	54600	2155	0.27
THOMPSON RIVER AT ASHCROFT	TR80	-	951	0.78
TSILCOH RIVER NEAR THE MOUTH	08JE004	431	387	0.71
TUYA RIVER NEAR TELEGRAPH CREEK	08CD001	3550	309	0.77
WEST ROAD RIVER NEAR CINEMA	08KG001	12400	327	0.78
WILLIAMS LAKE RIVER AT OUTLET OF WILLIAMS LAKE	08MC005	2240	325	0.81
WILLOW RIVER ABOVE HAY CREEK	08KD006	2860	371	0.74
YALAKOM RIVER ABOVE ORE CREEK	08ME025	581	360	0.64
ZYMOETZ RIVER ABOVE O.K. CREEK	08EF005	2850	550	0.64

Appendix C: Streamflow Hydrographs

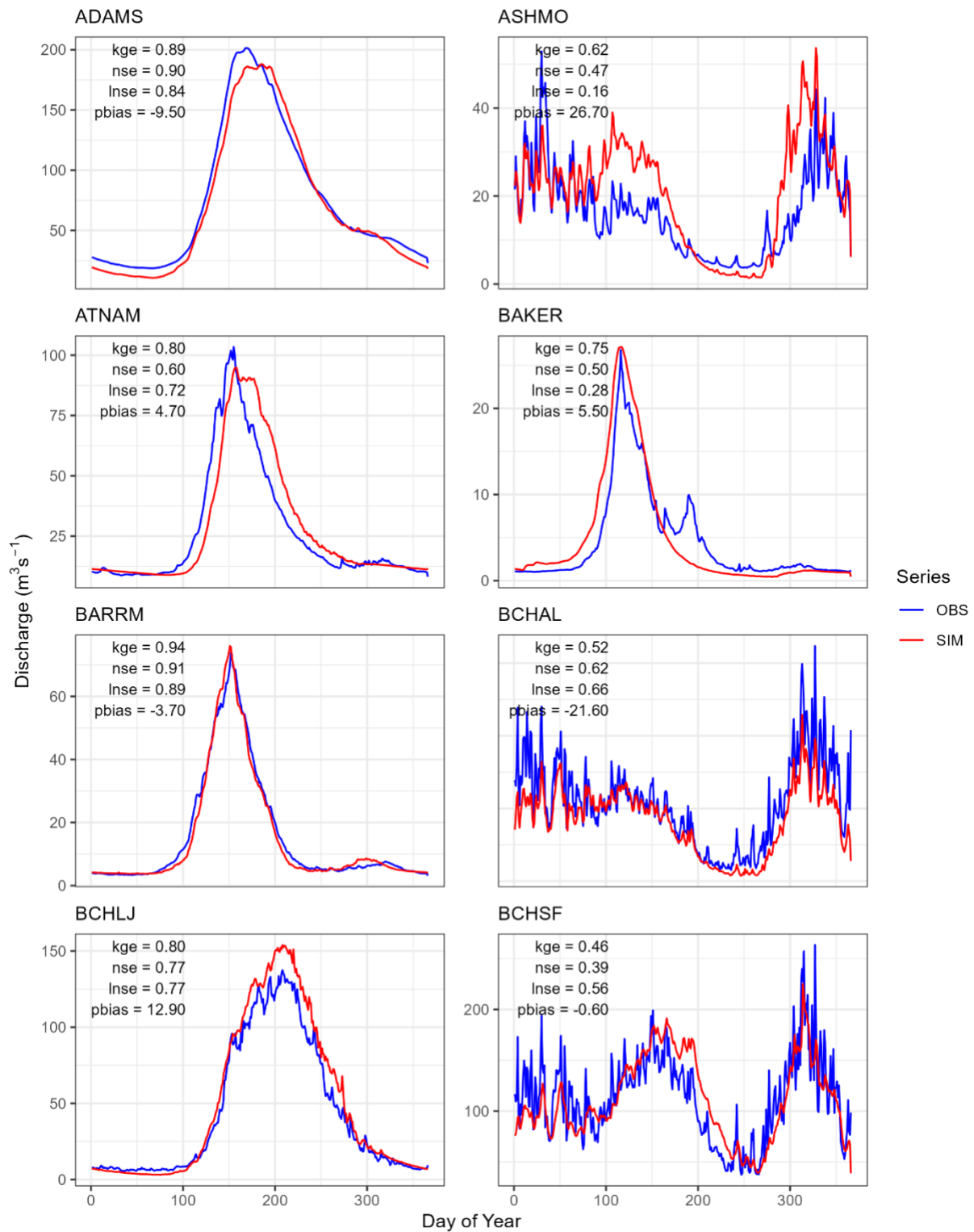


Figure C1. Streamflow validation plots comparing simulated and observed climatological daily average flow for all calibration sites in the BC Coastal domain.

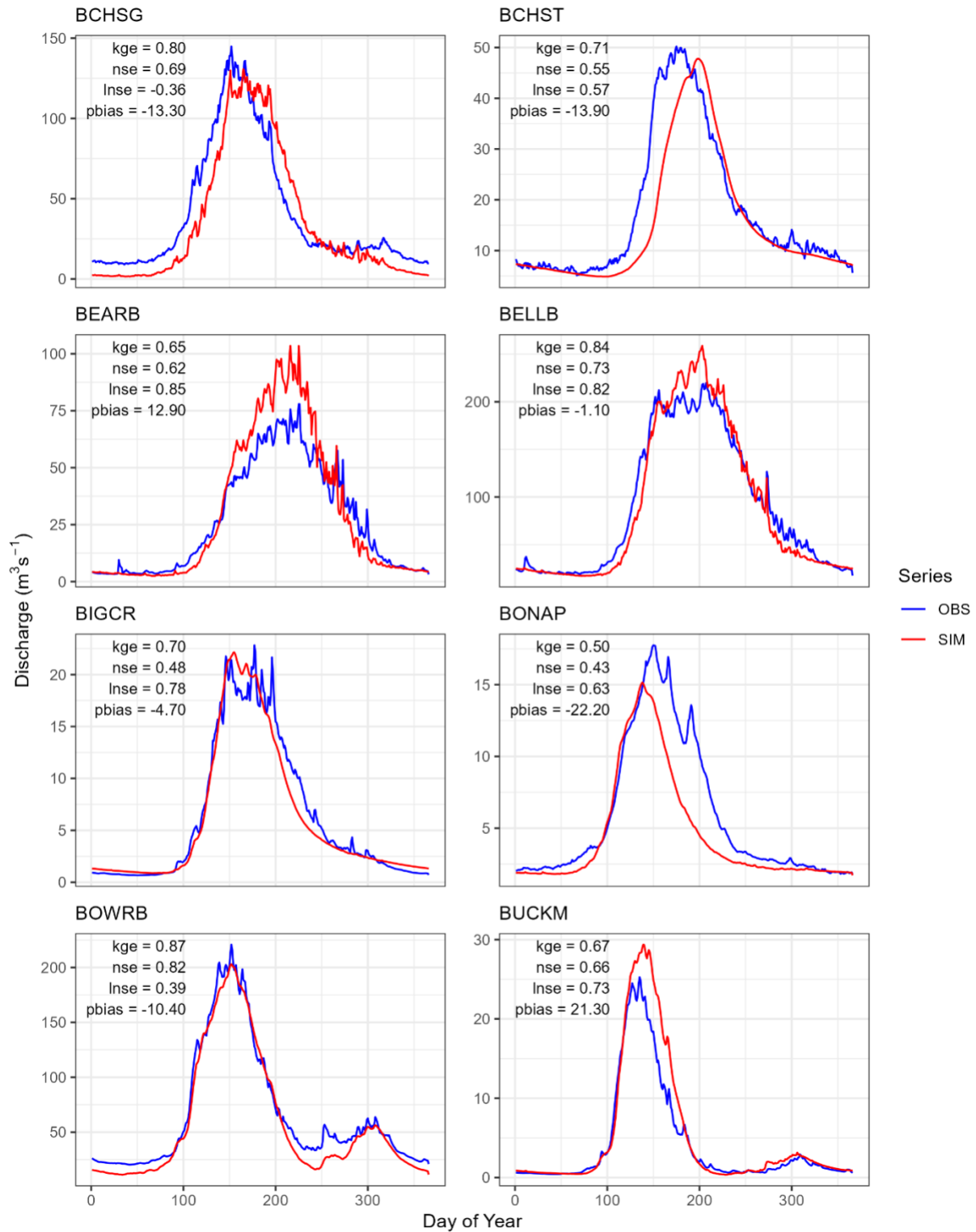


Figure C1 Continued.

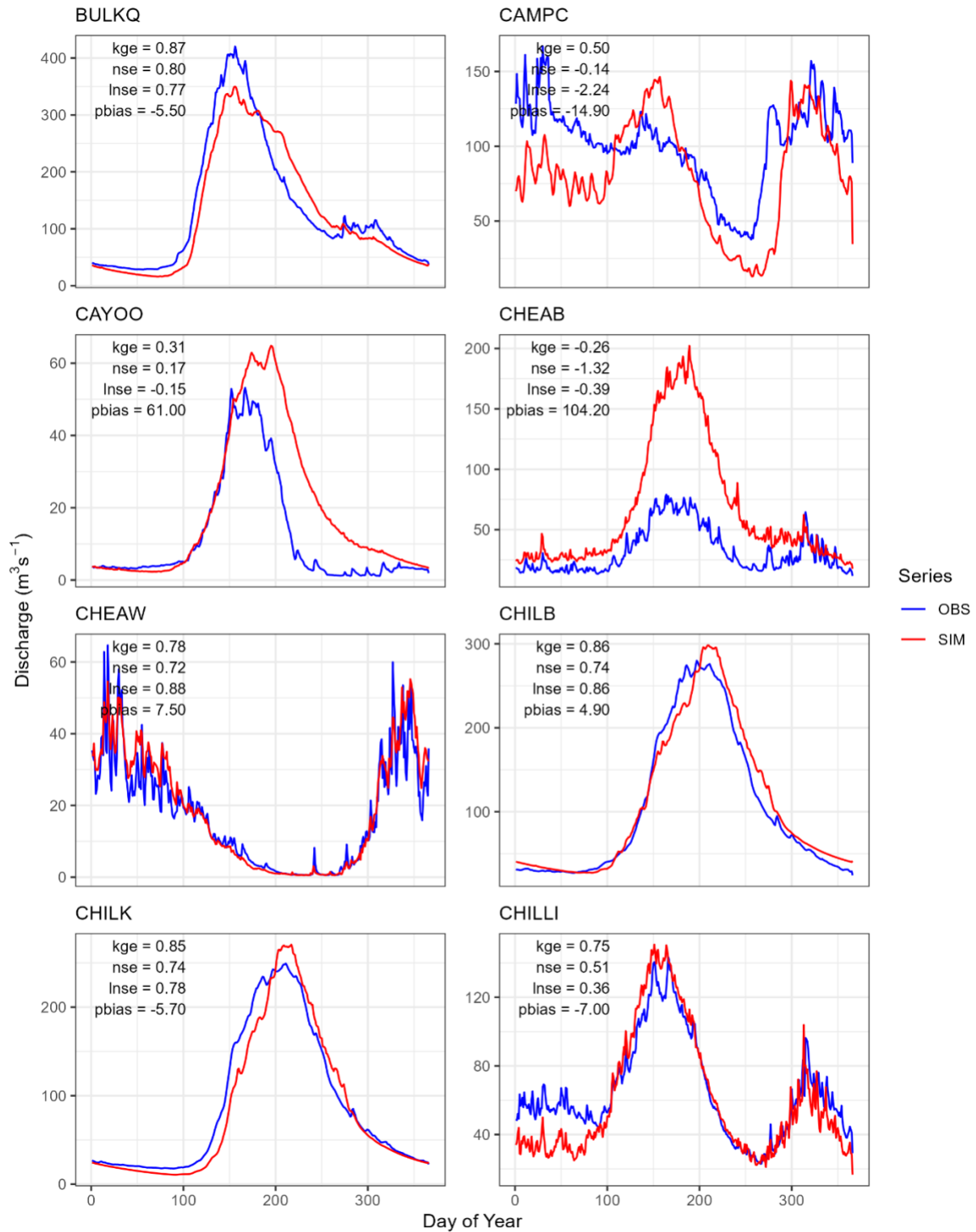


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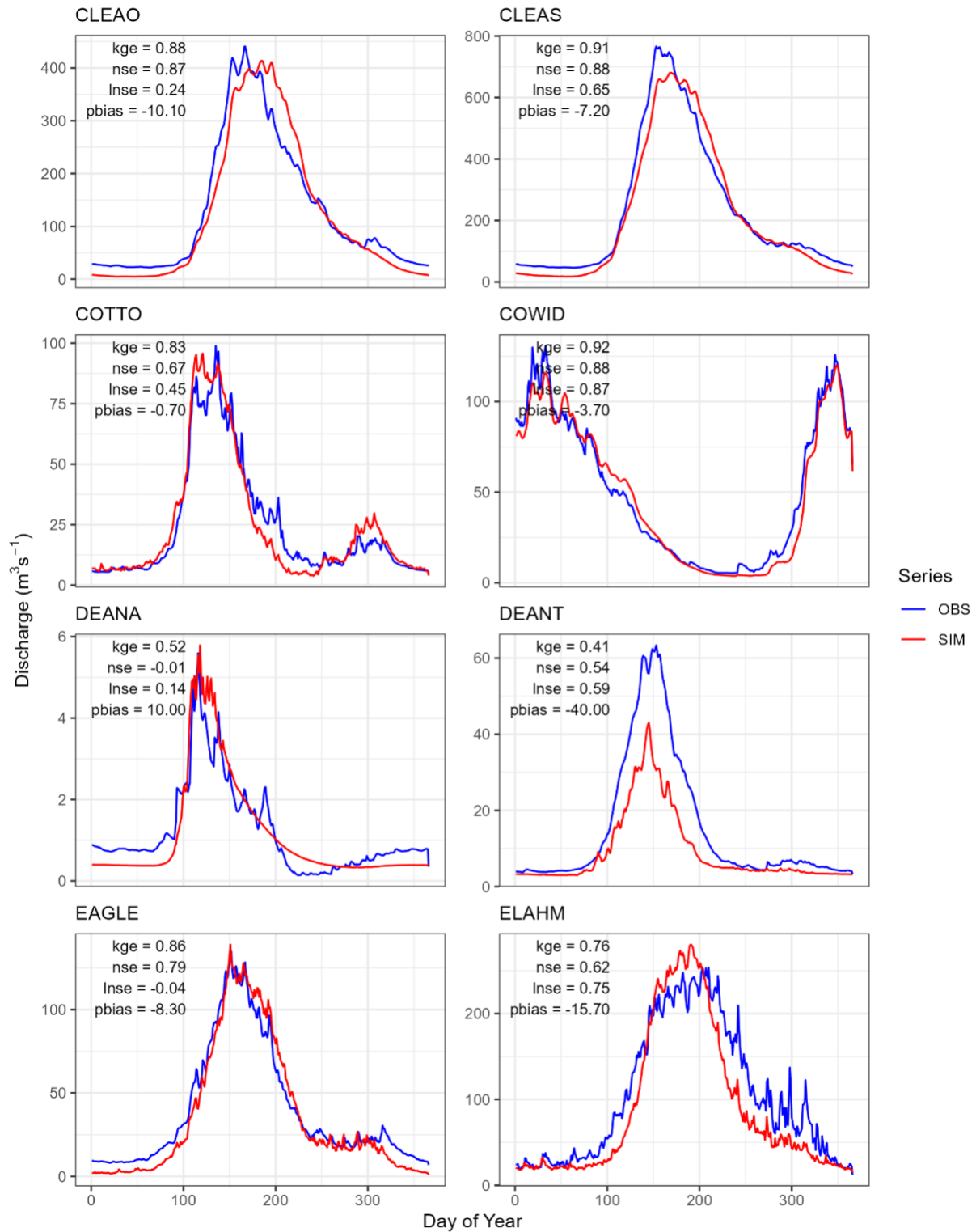


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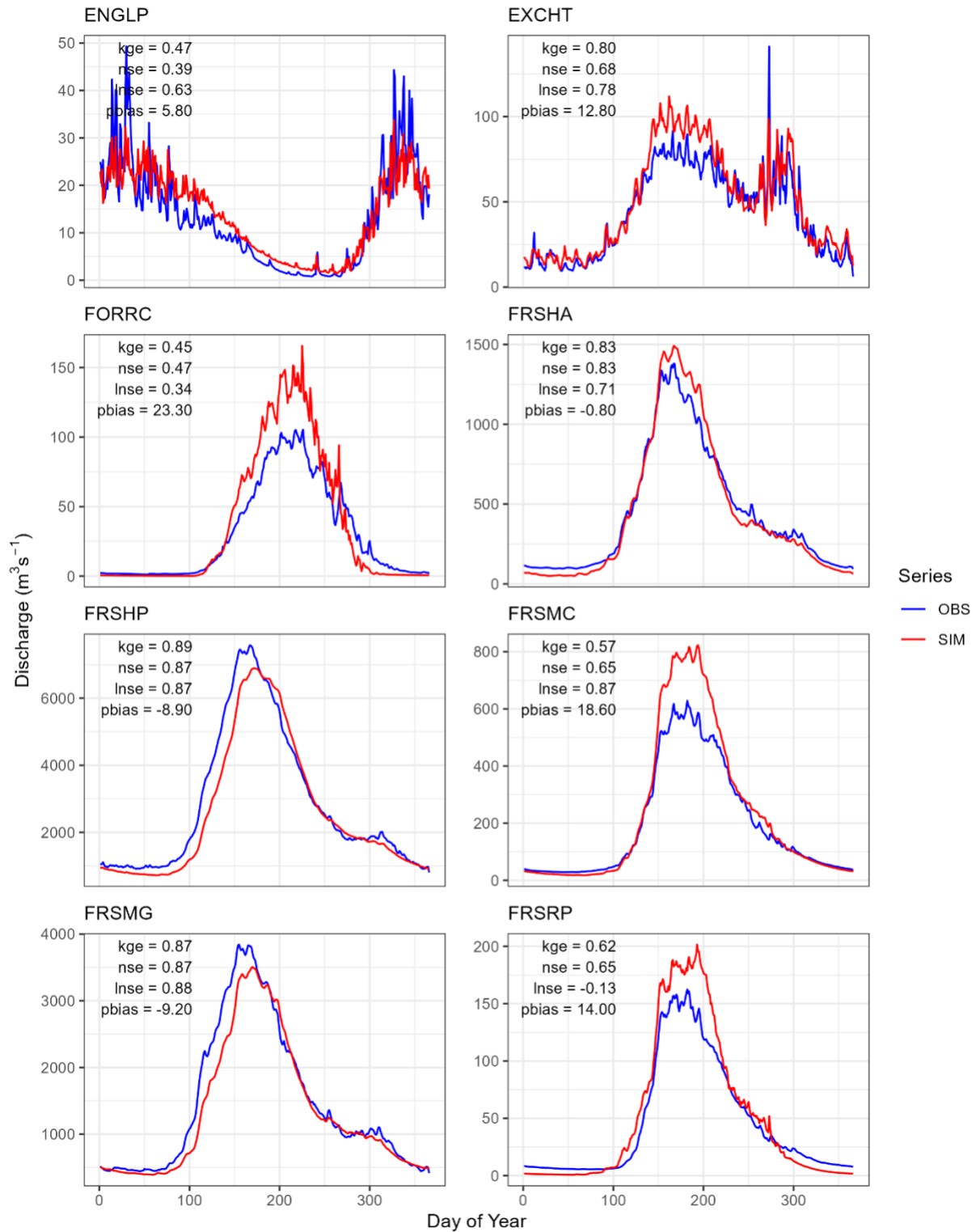


Figure C1 Continued.

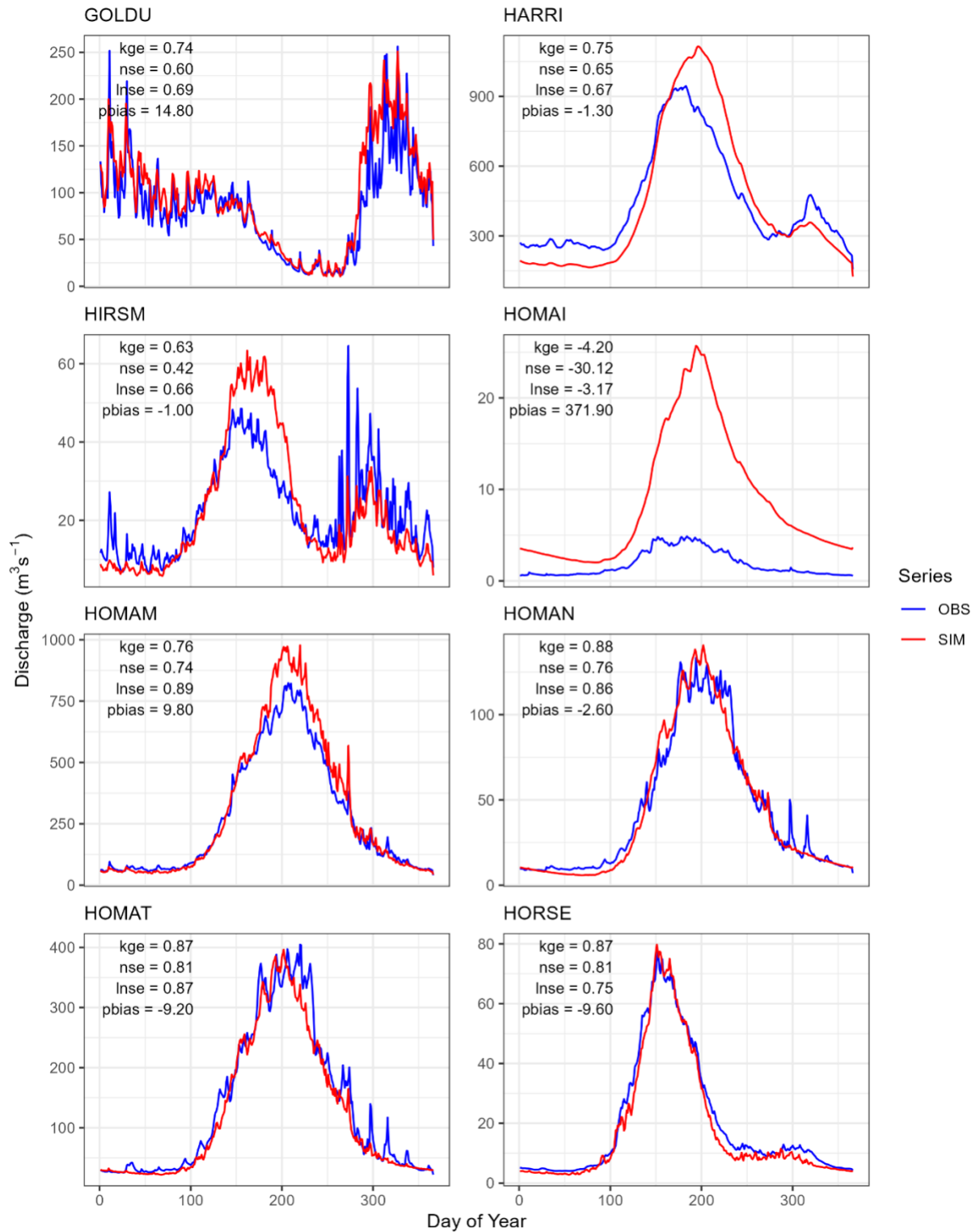


Figure C1 Continued.

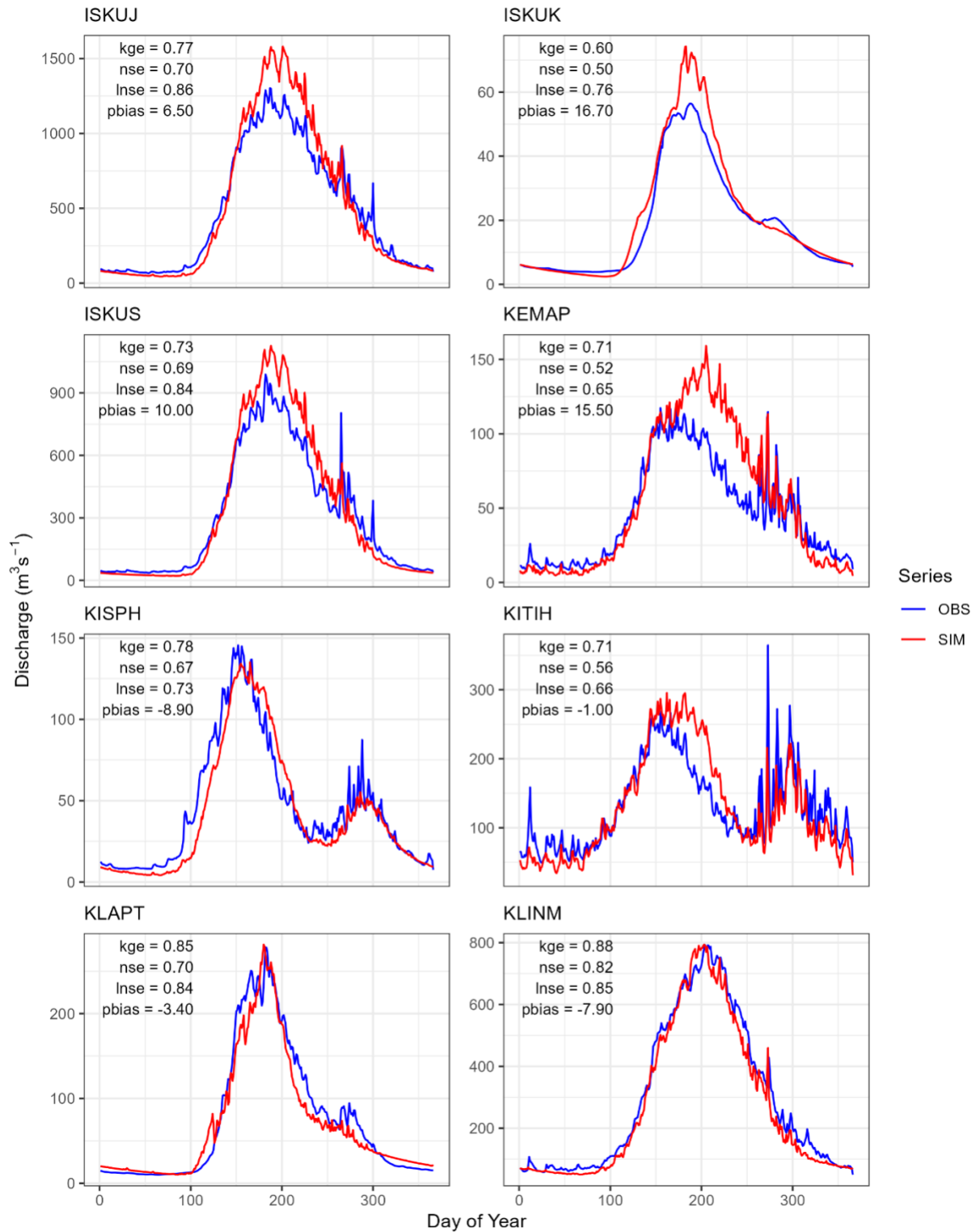


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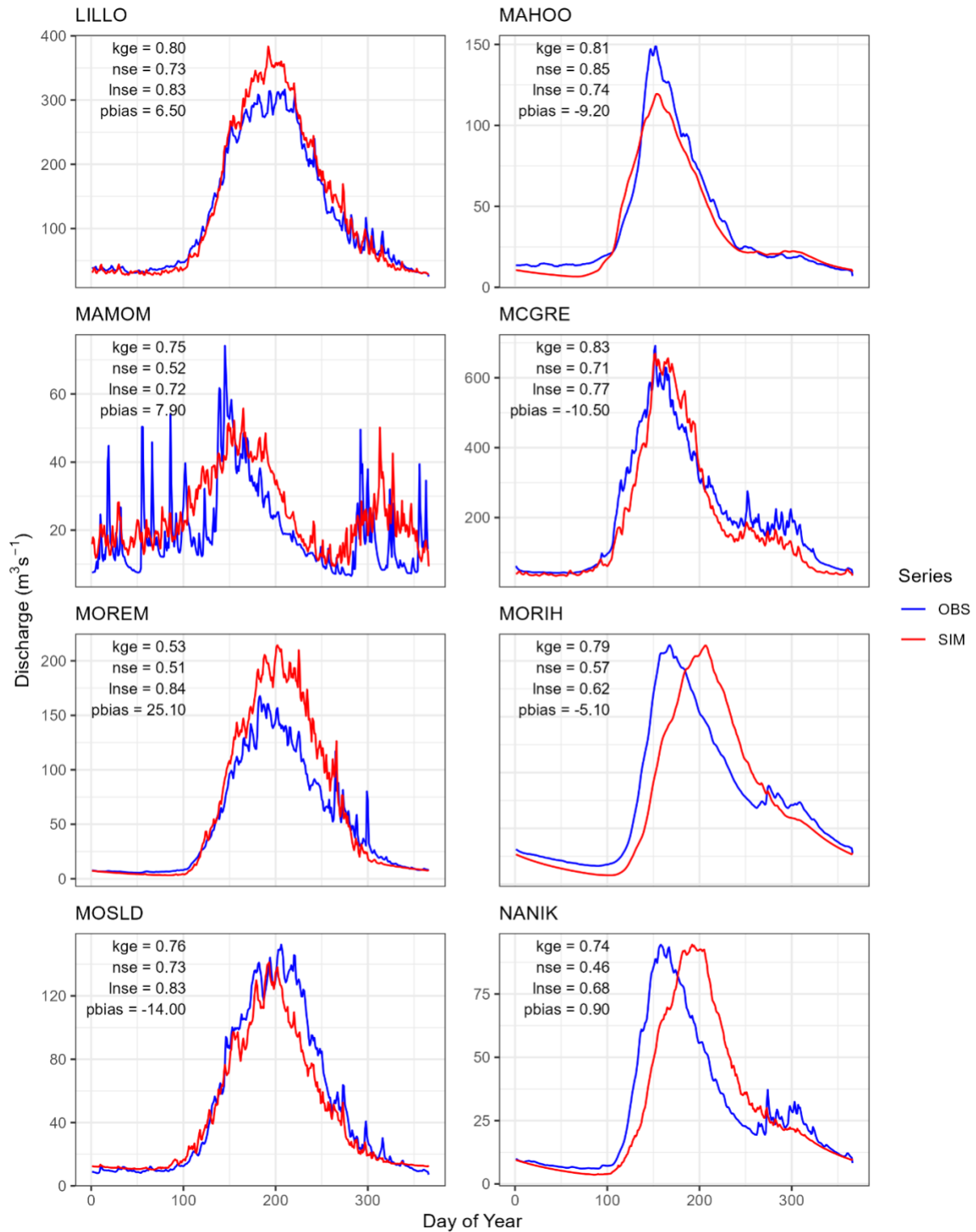


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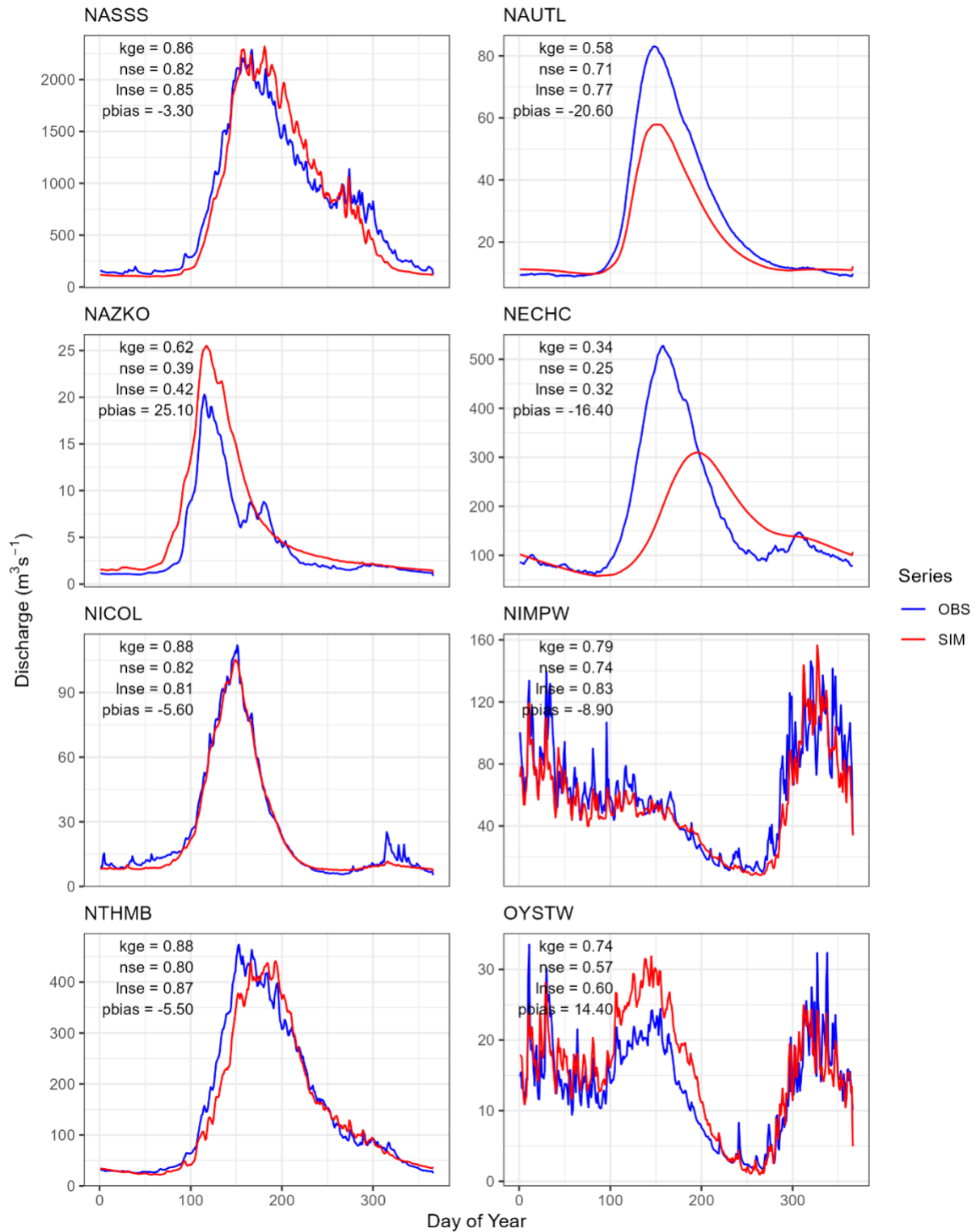


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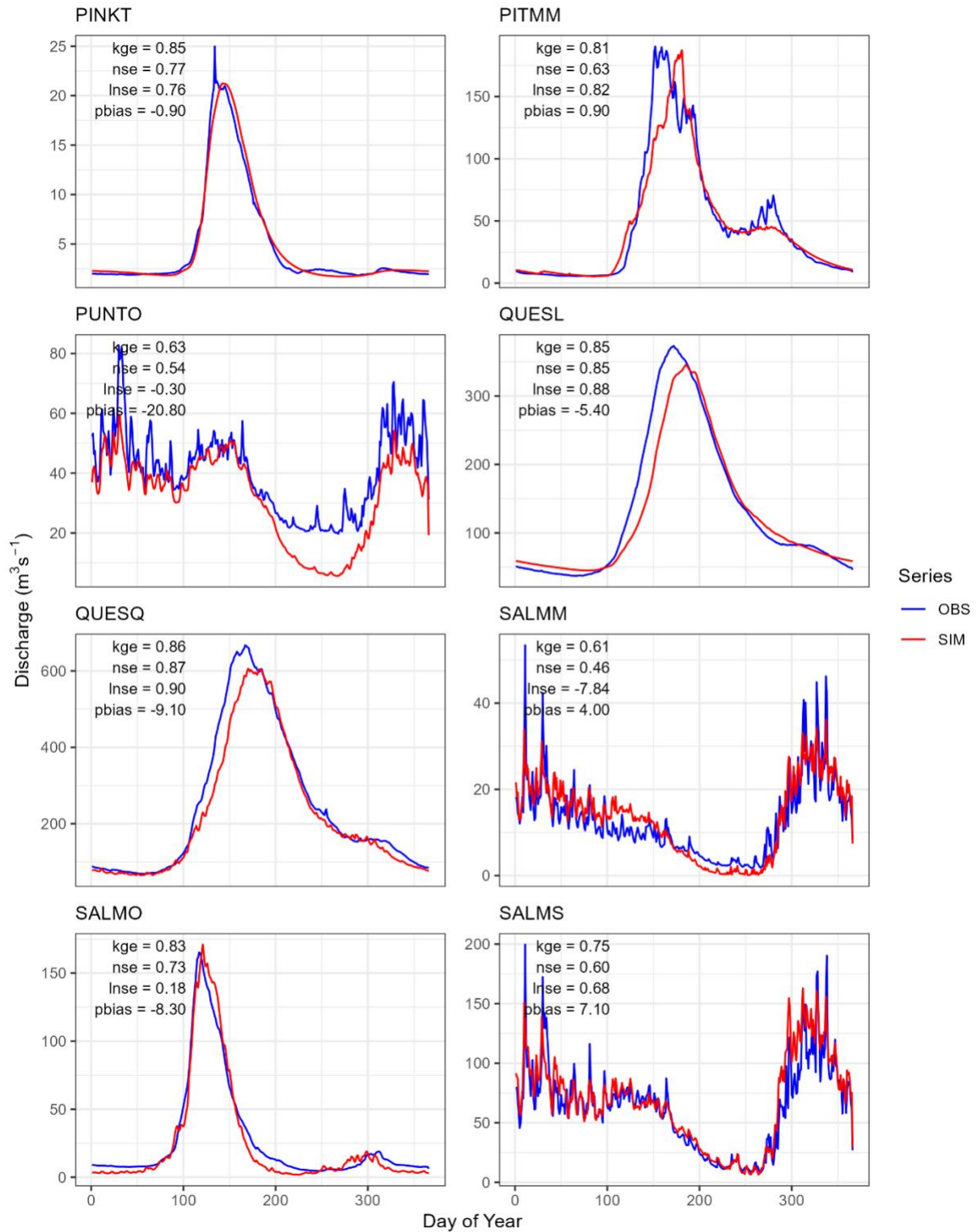


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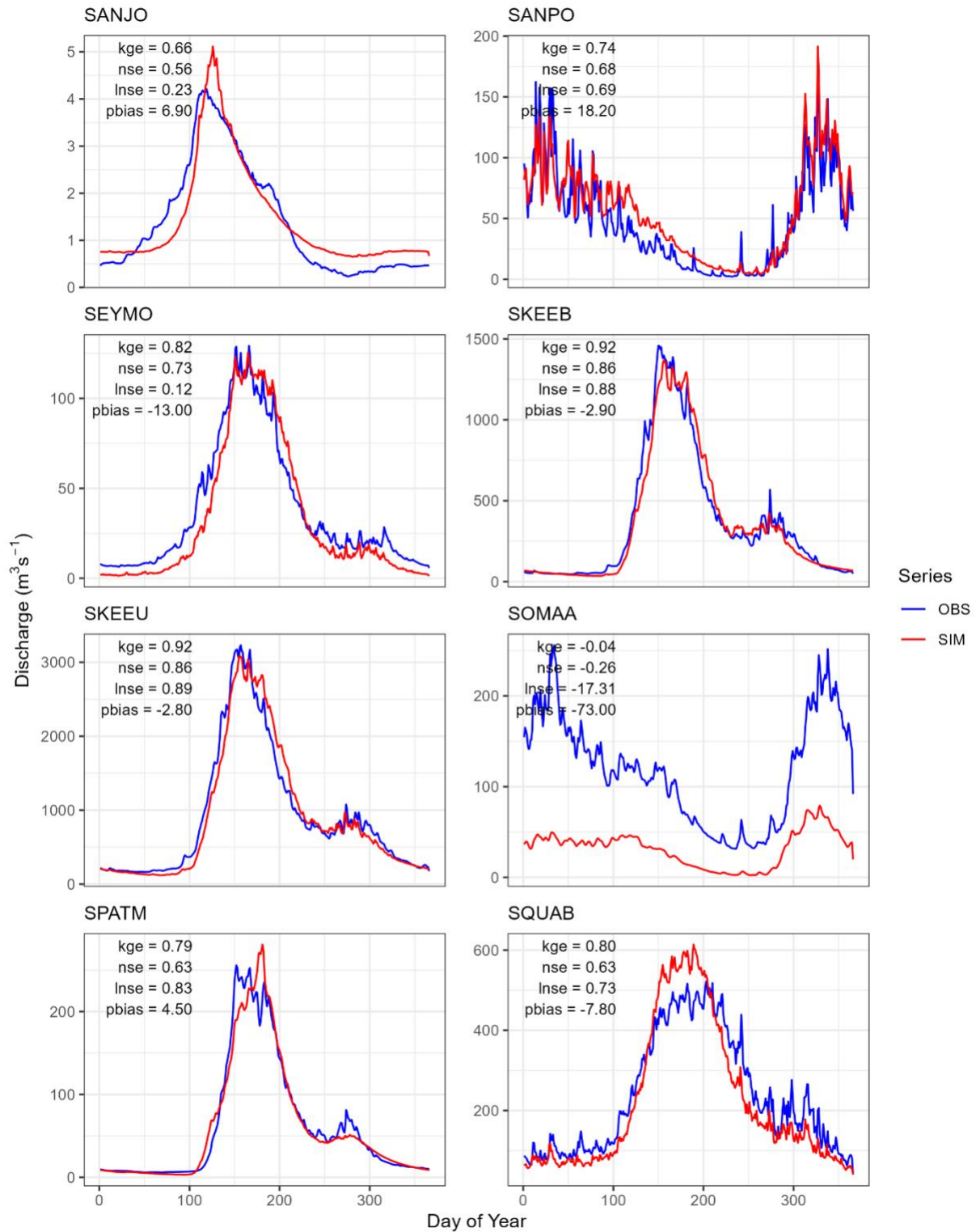


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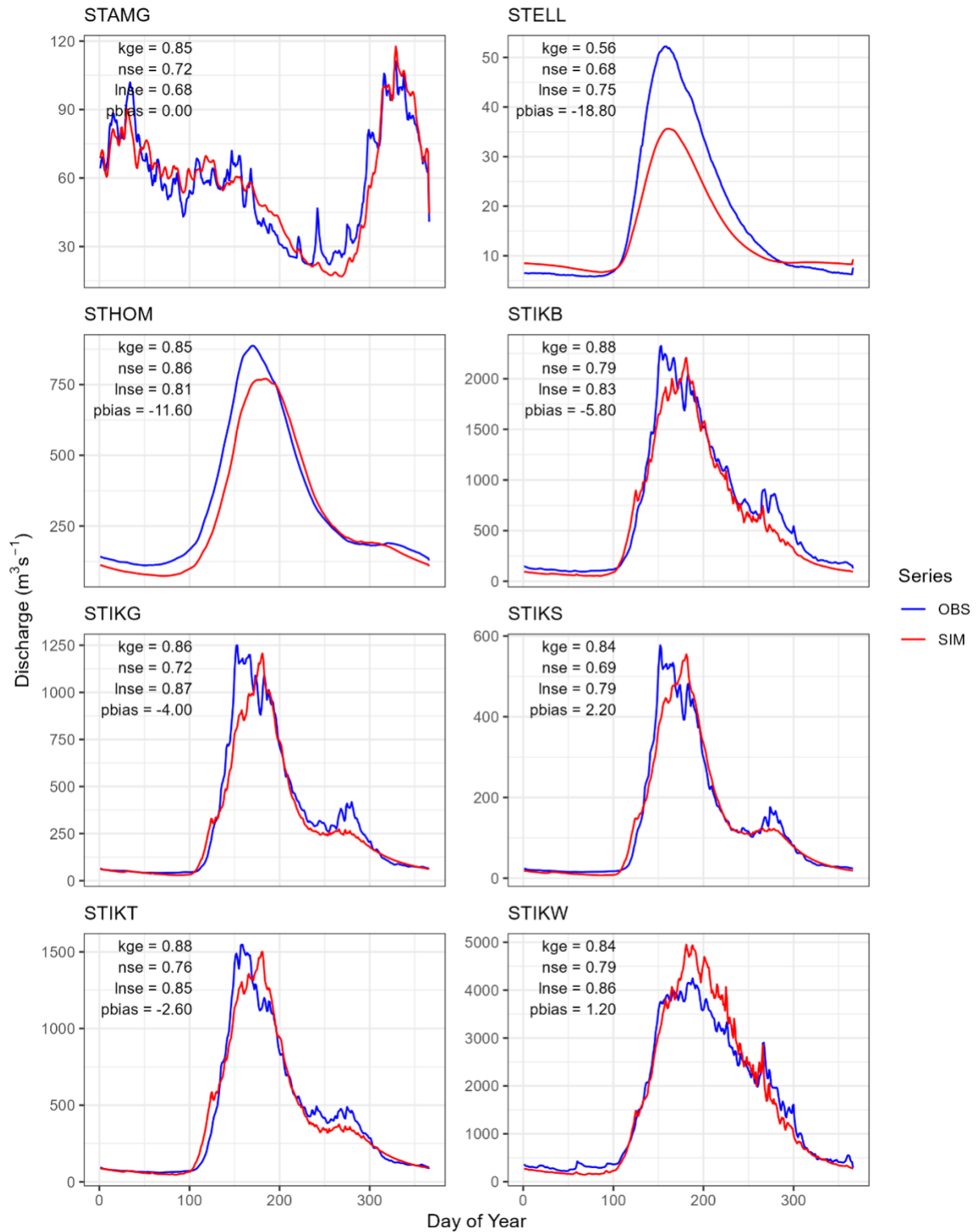


Figure C1 Continued.

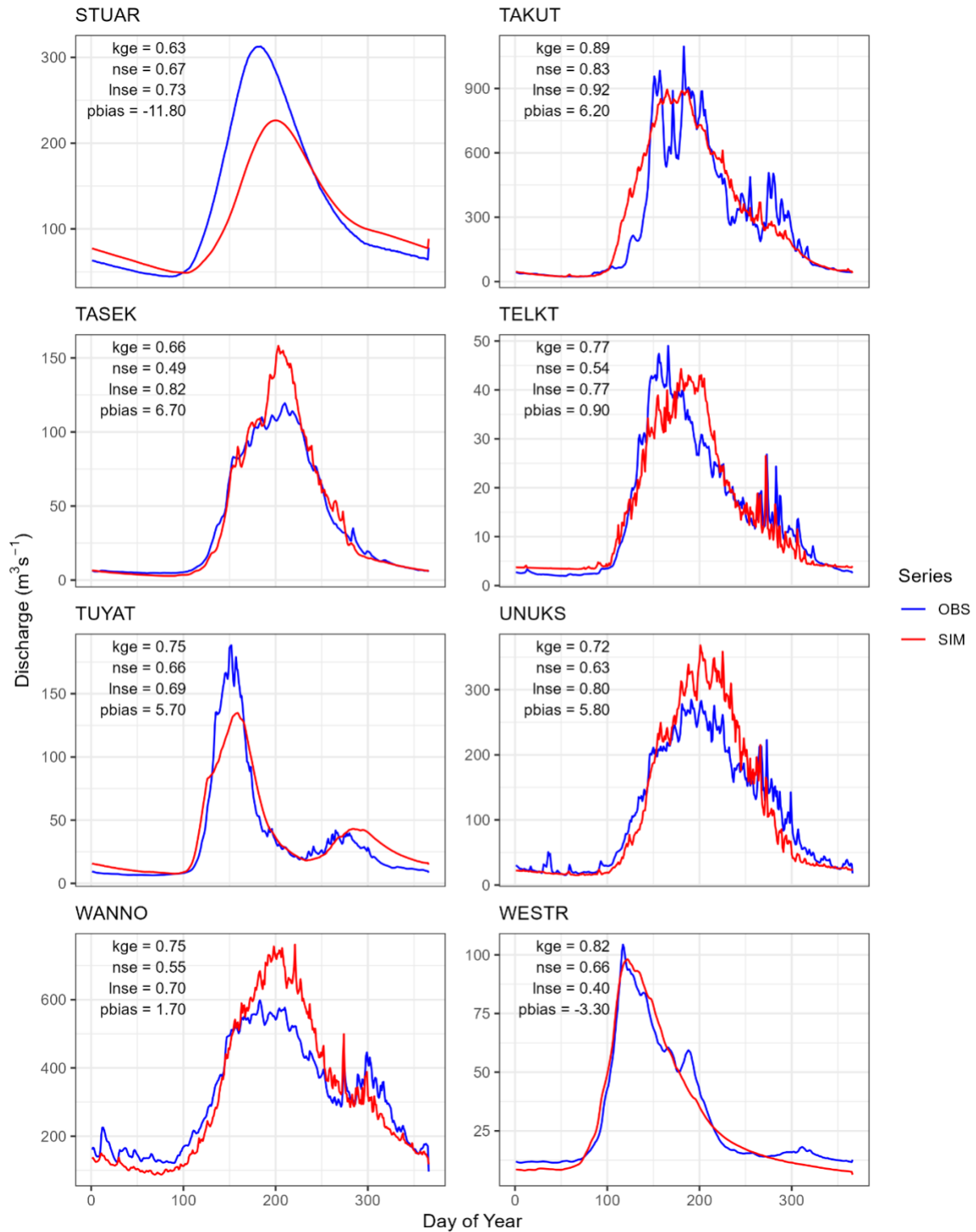


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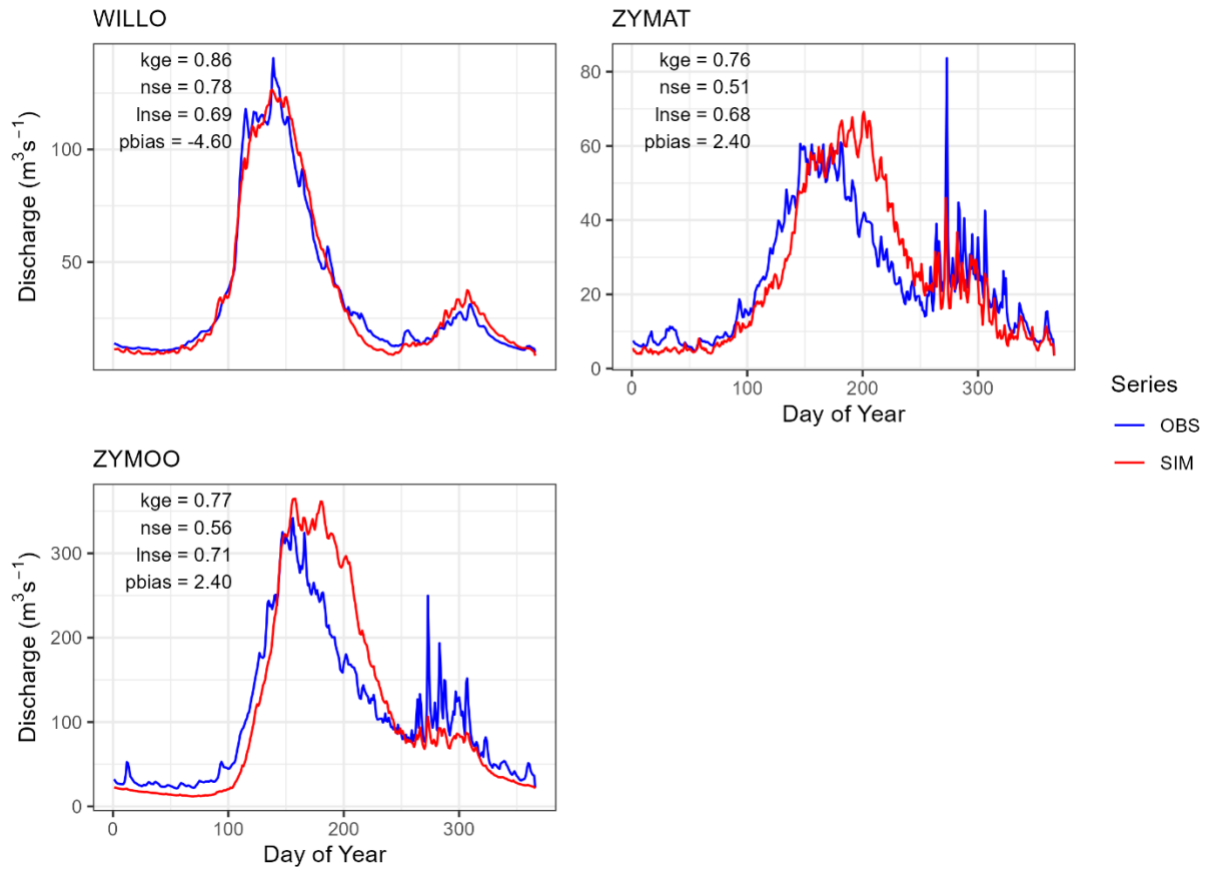


Figure C1 Continued.

Appendix D: Water Temperature Graphs

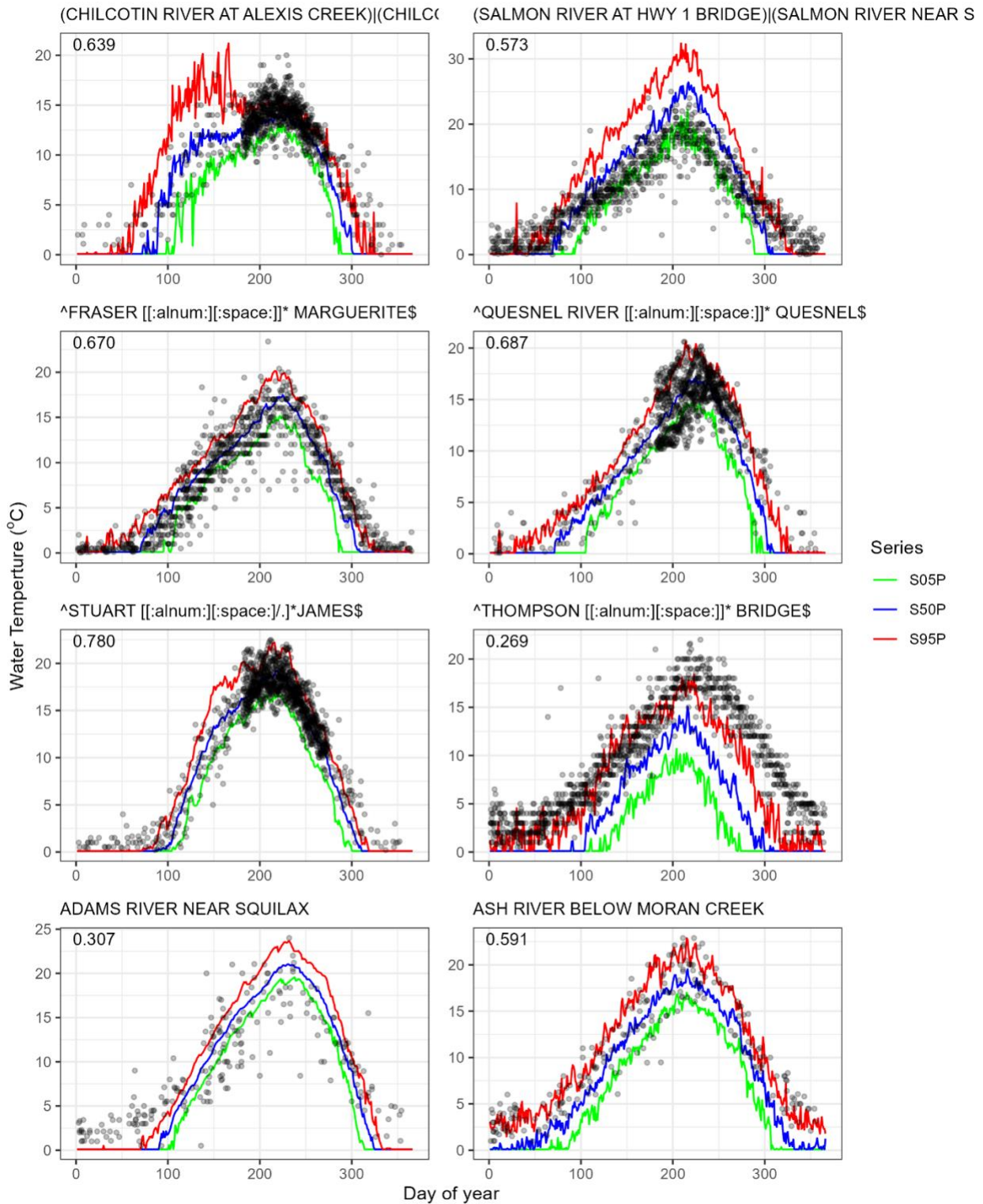


Figure D1. Temperature validation plots comparing range of simulated data to spot observations for stations. Each panel shows the PFactor for that site.

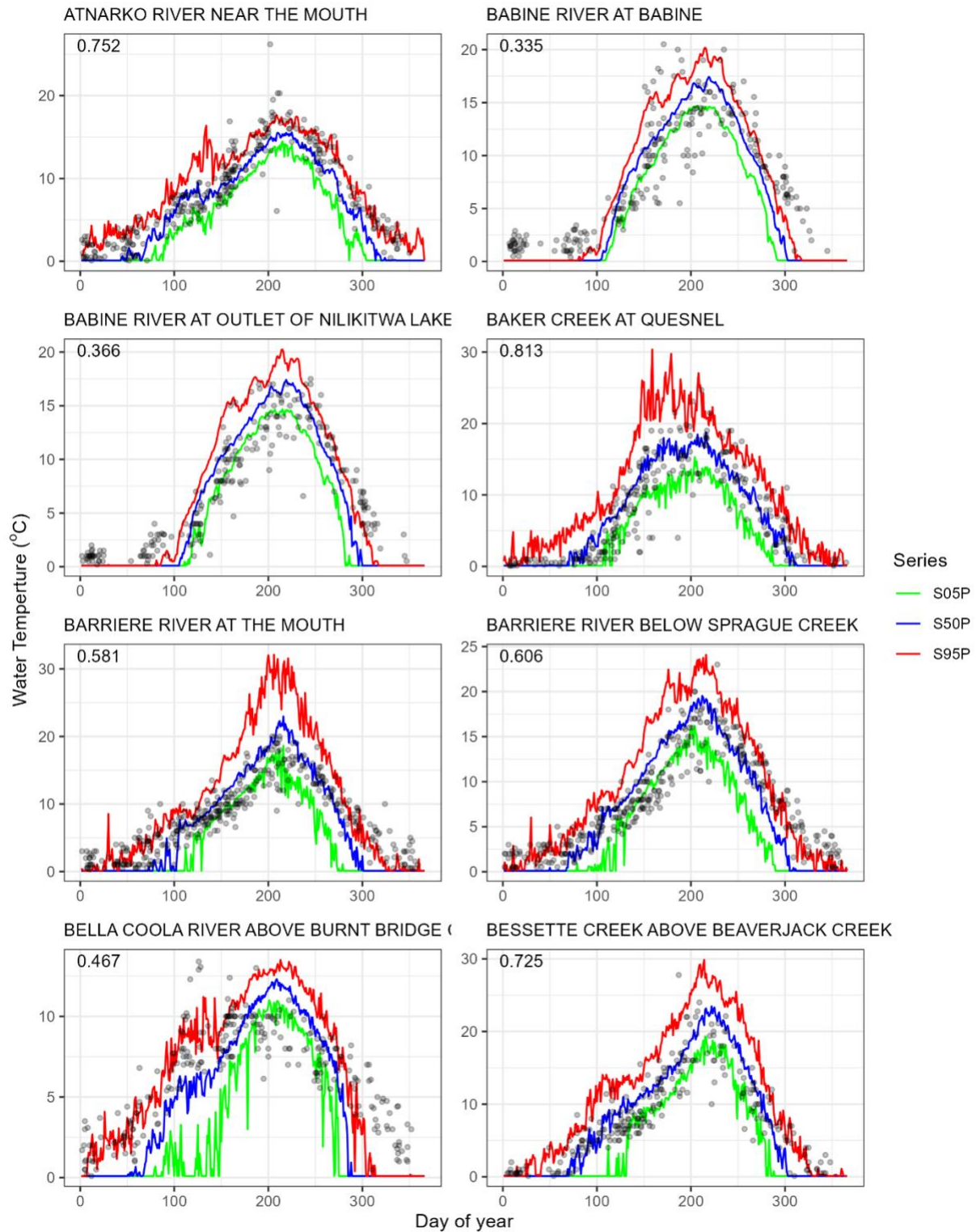


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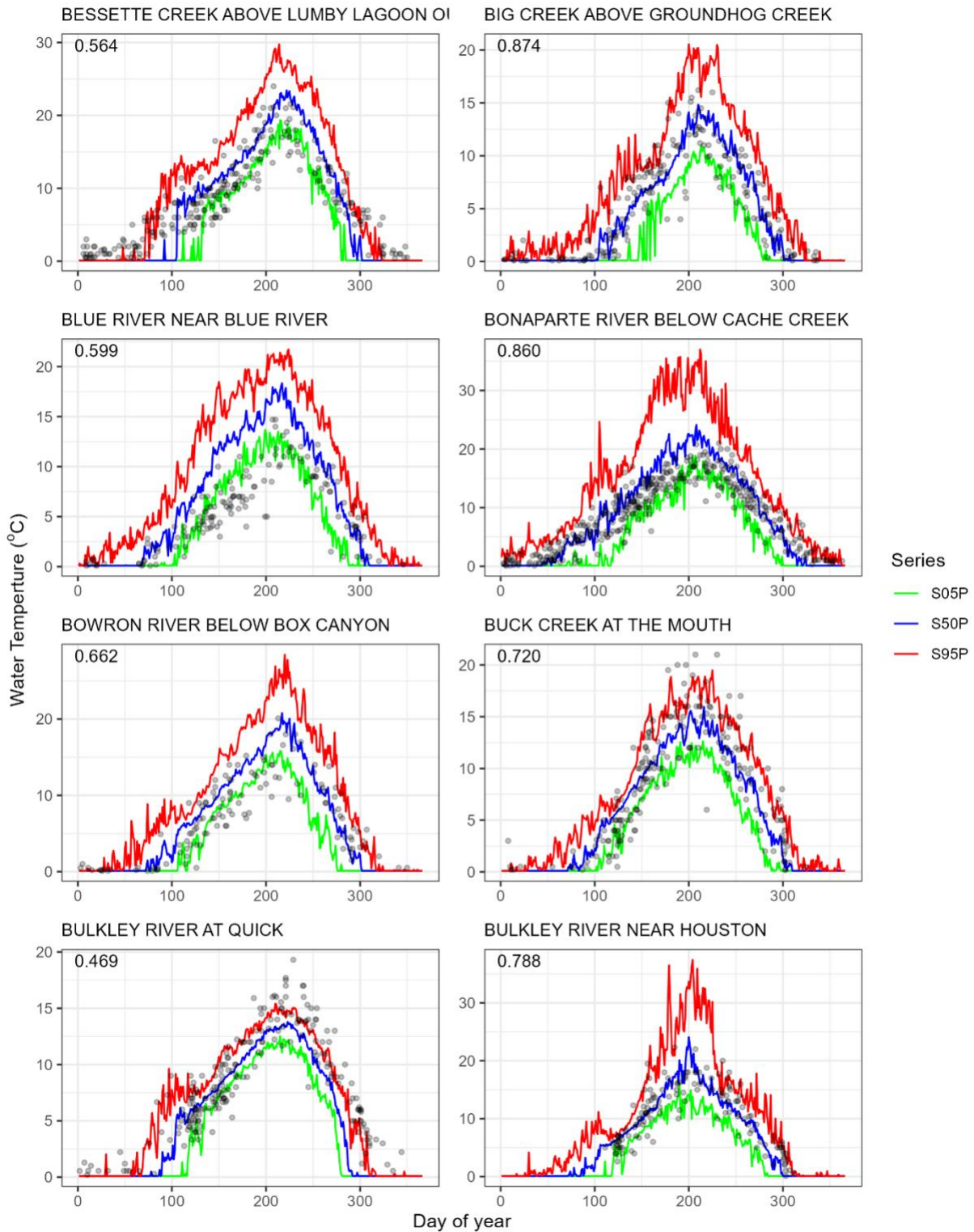


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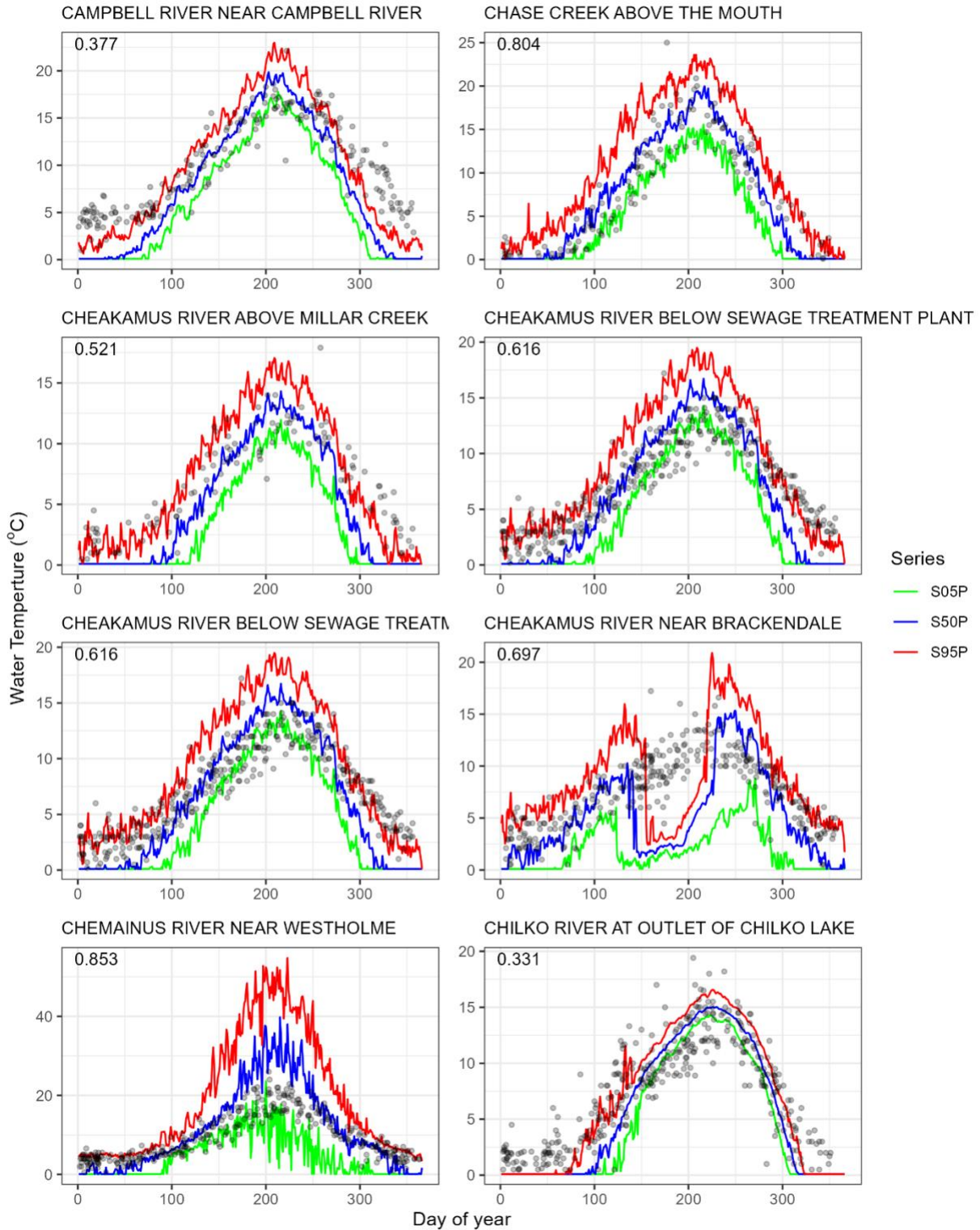


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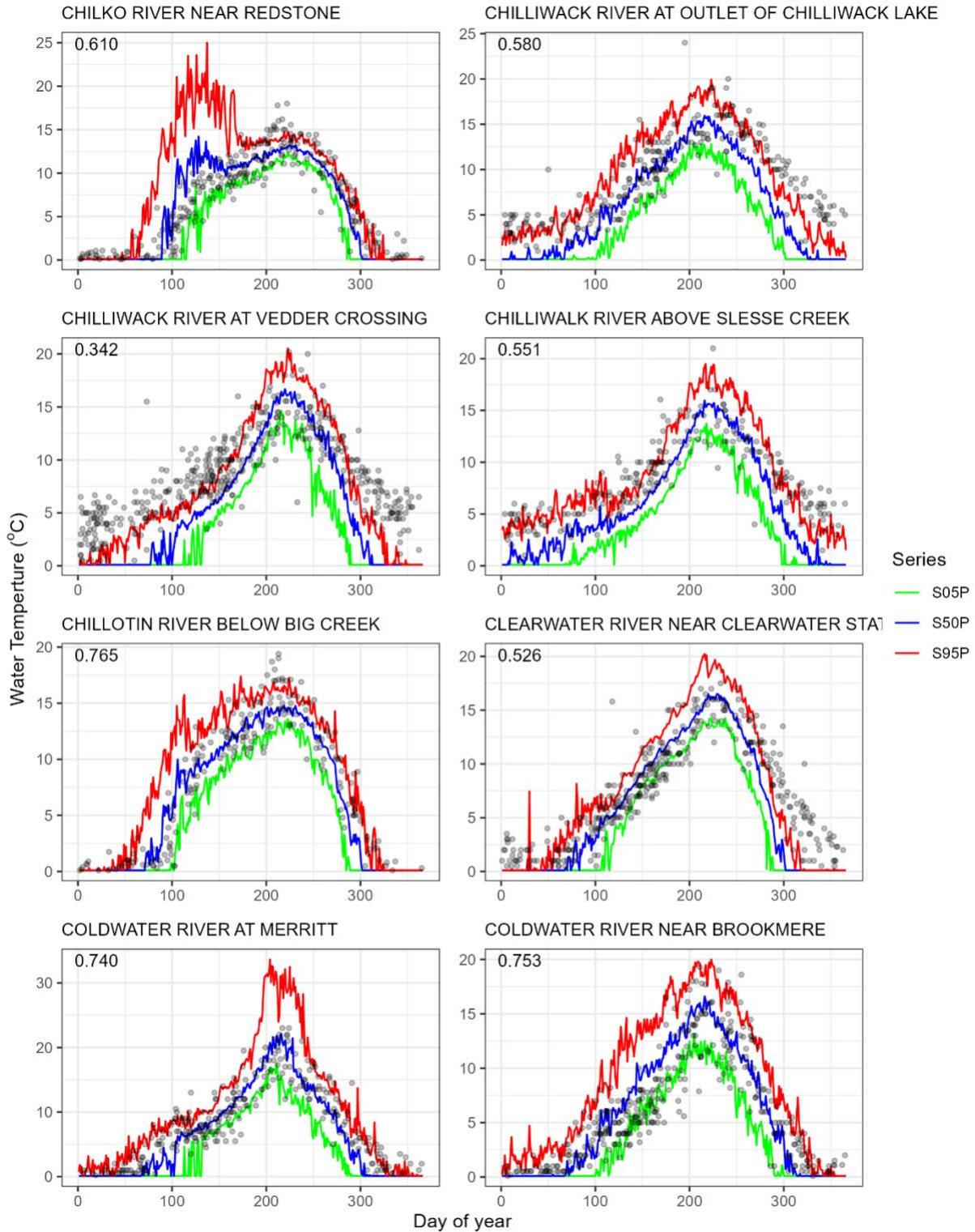


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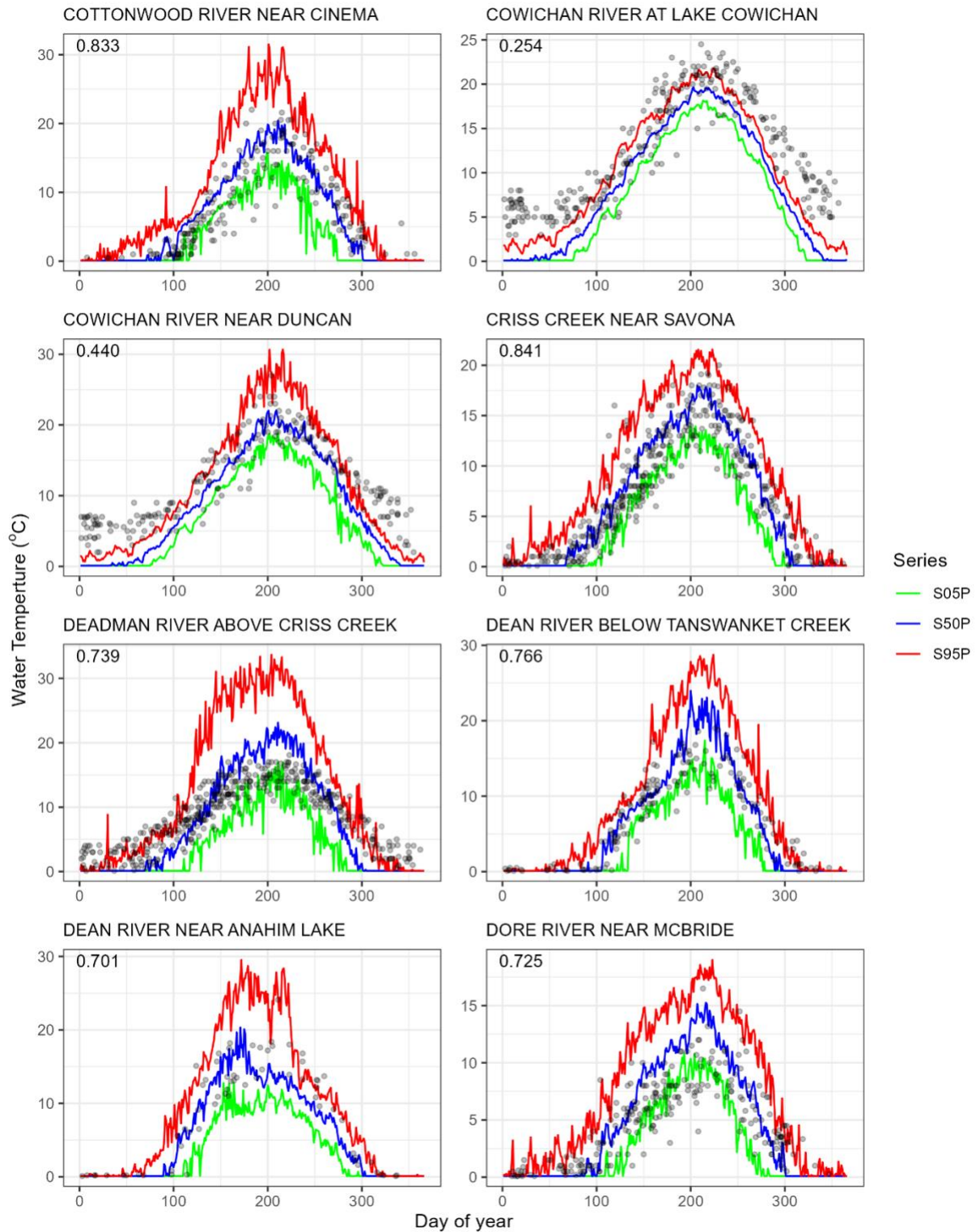


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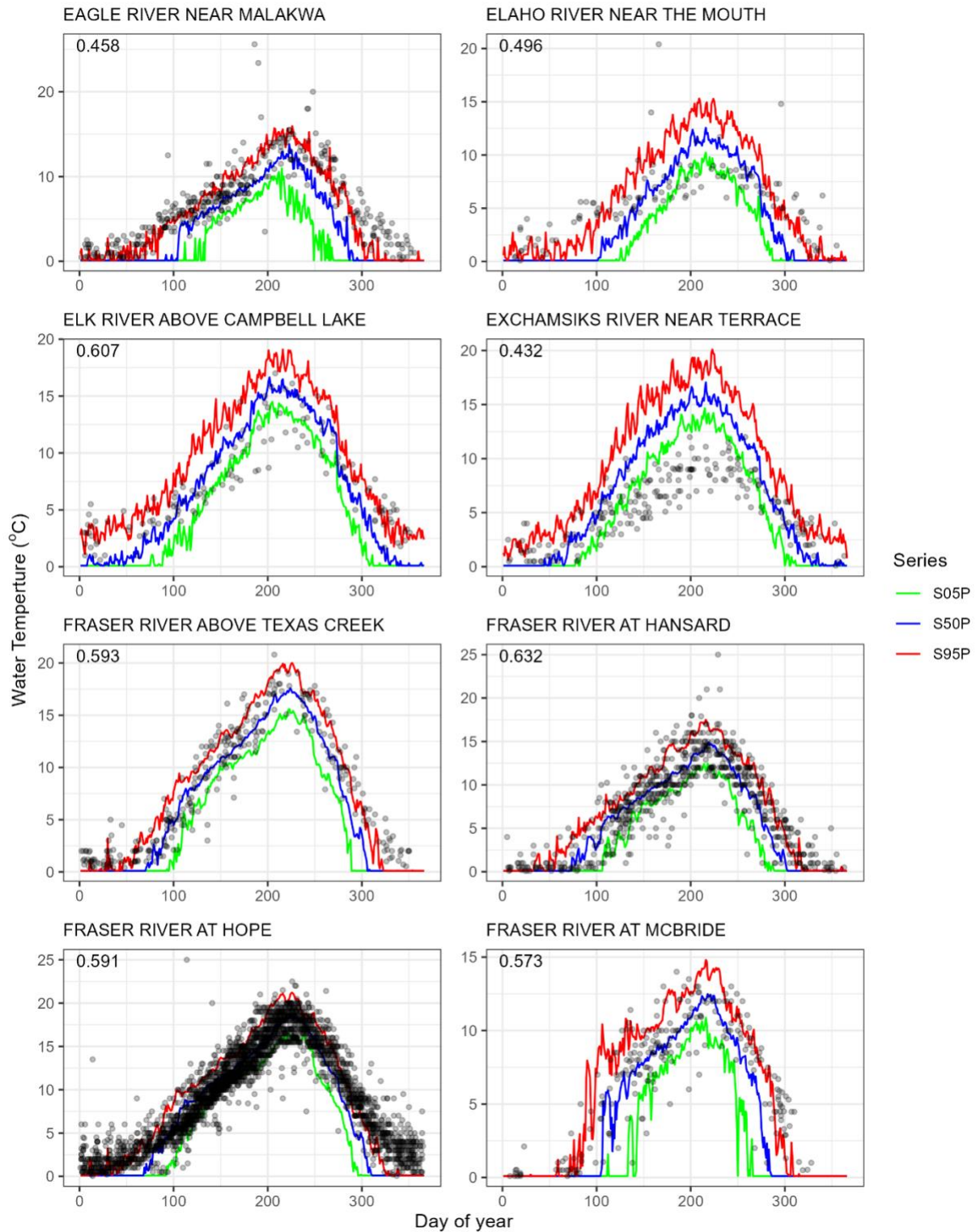


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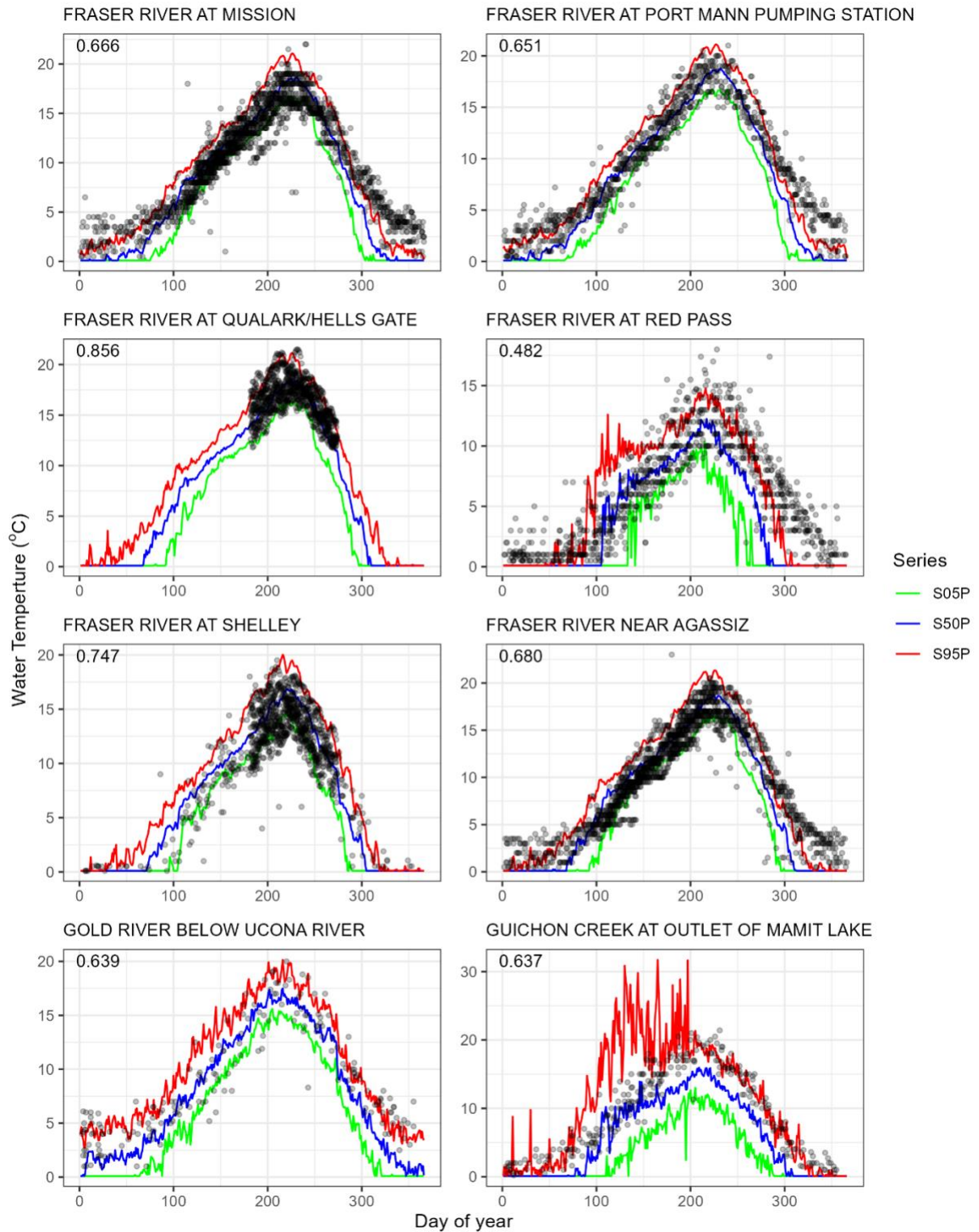


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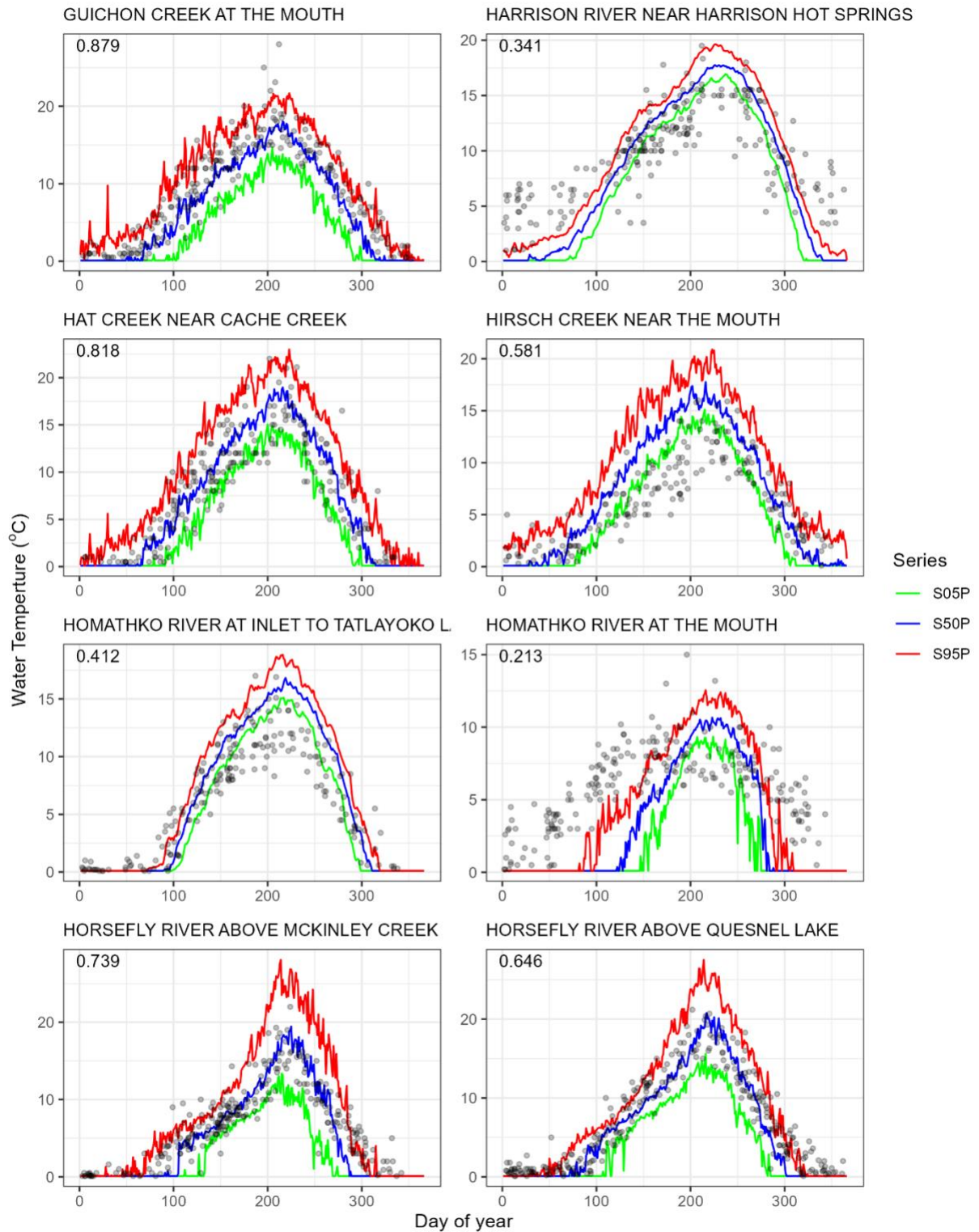


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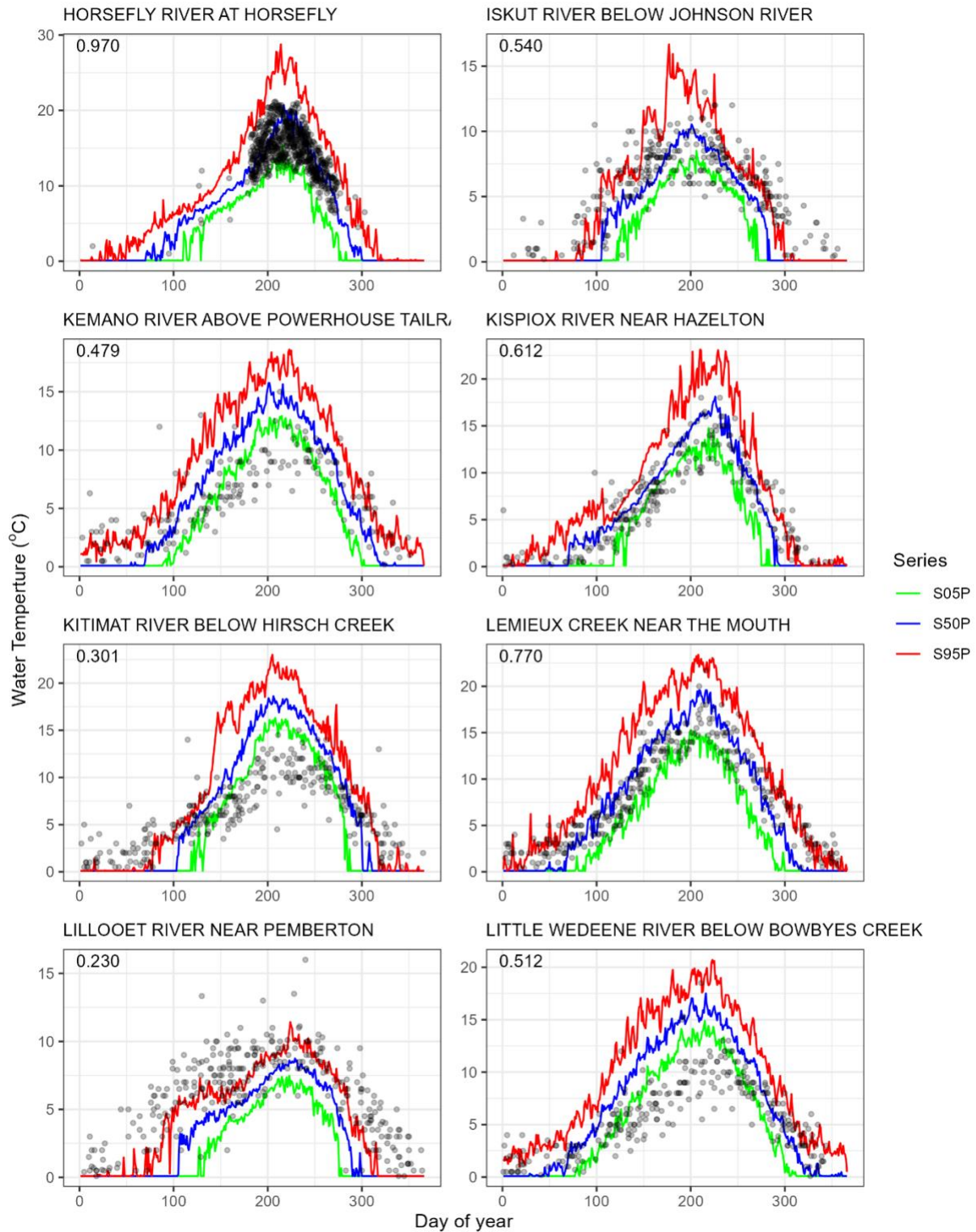


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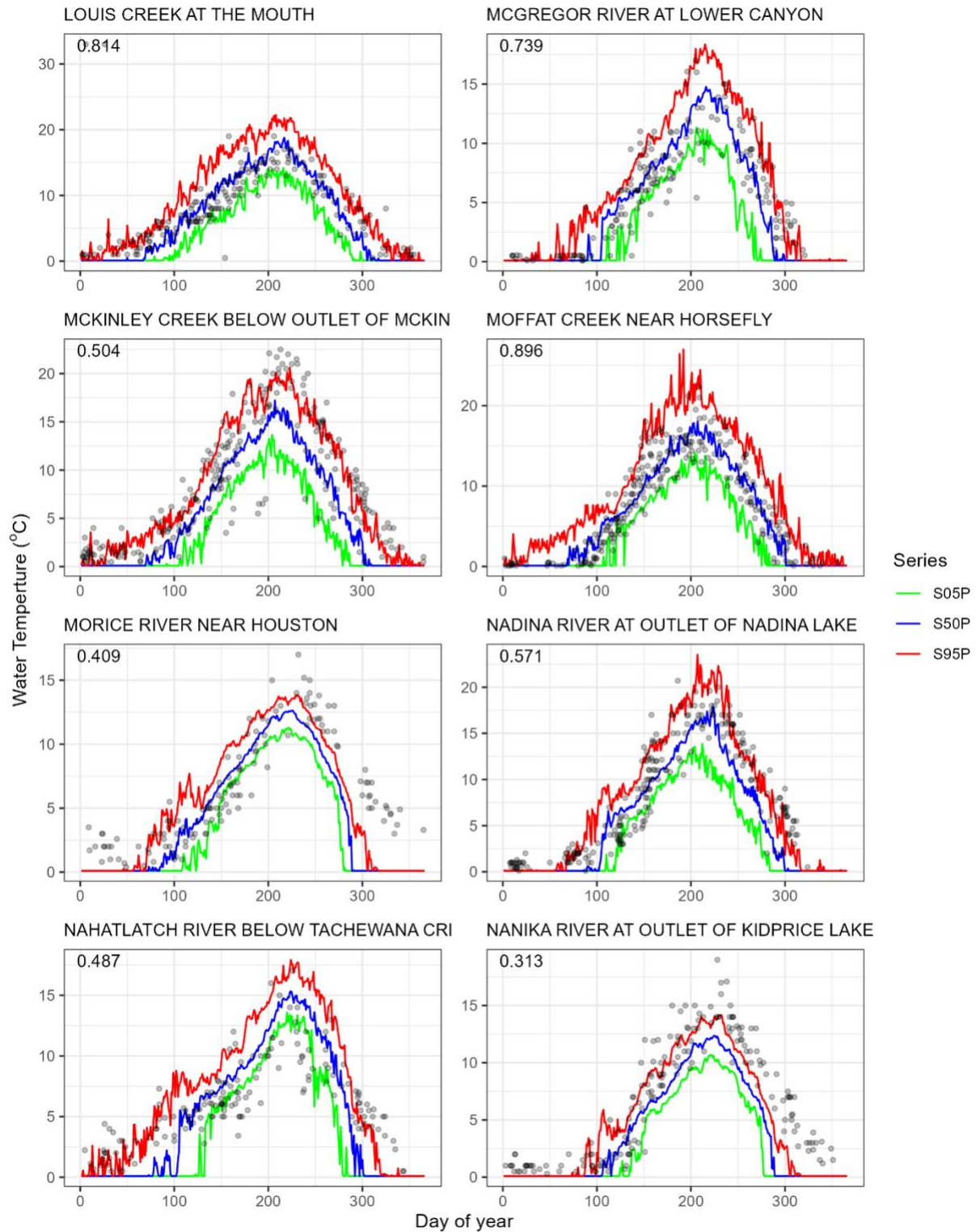


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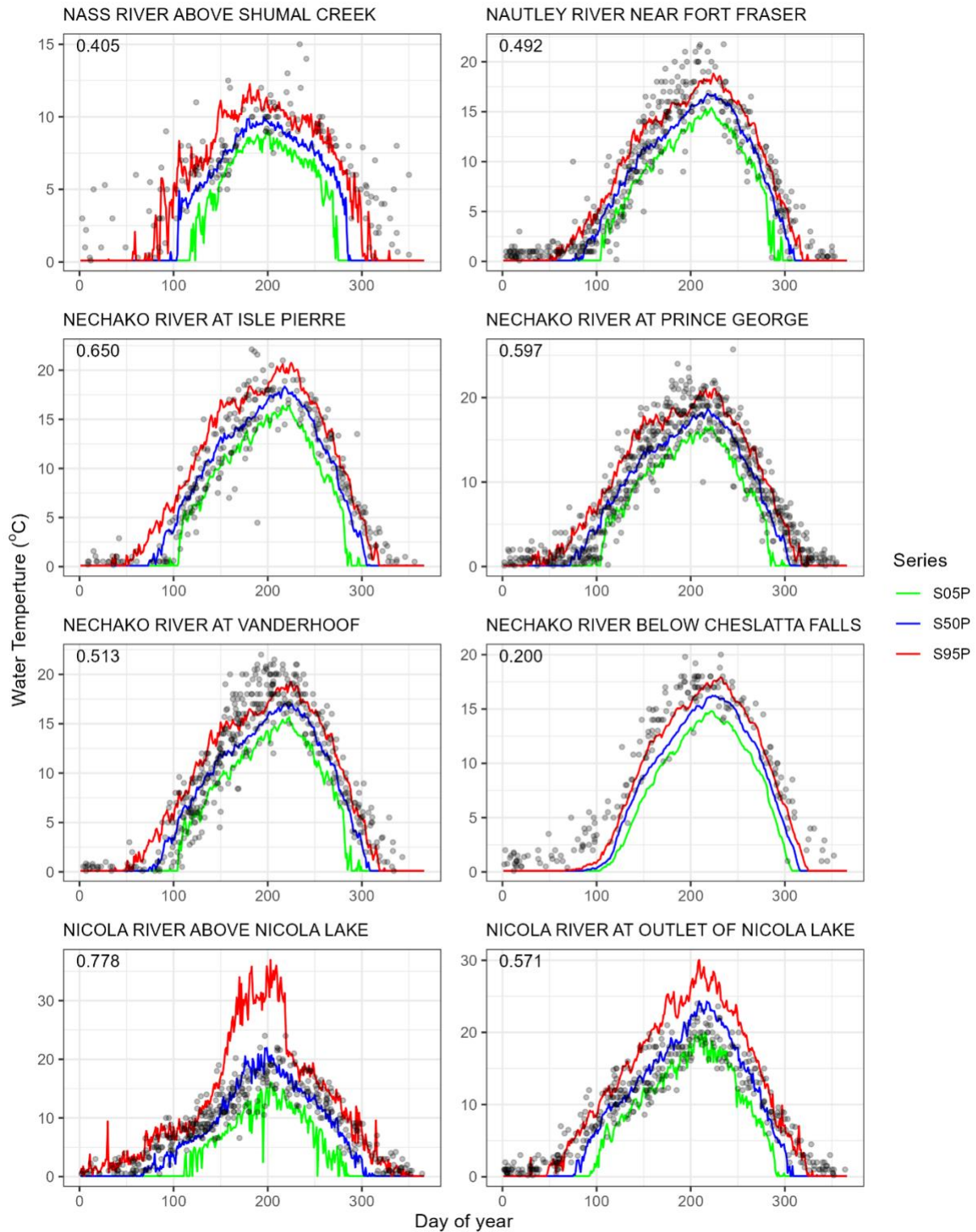


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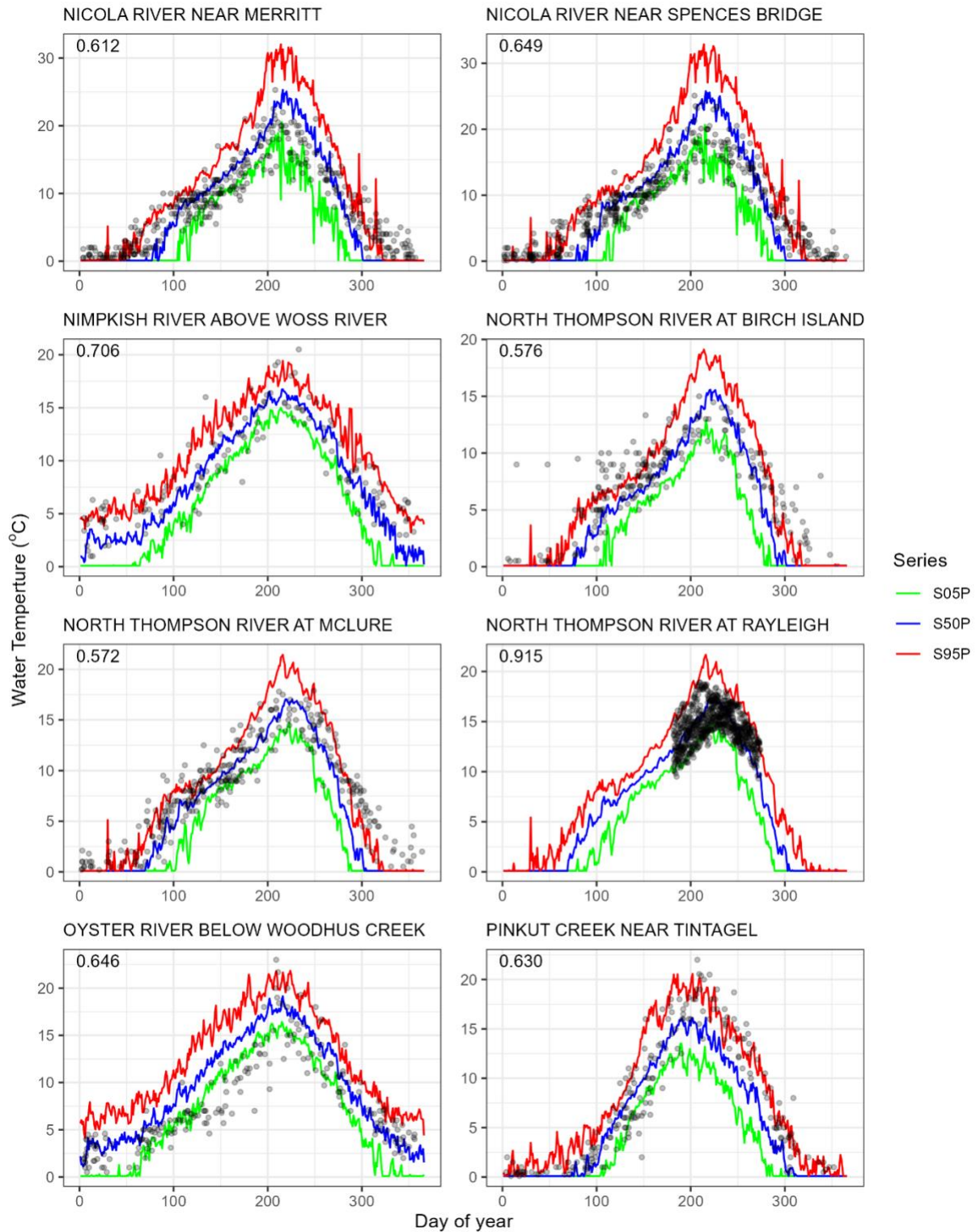


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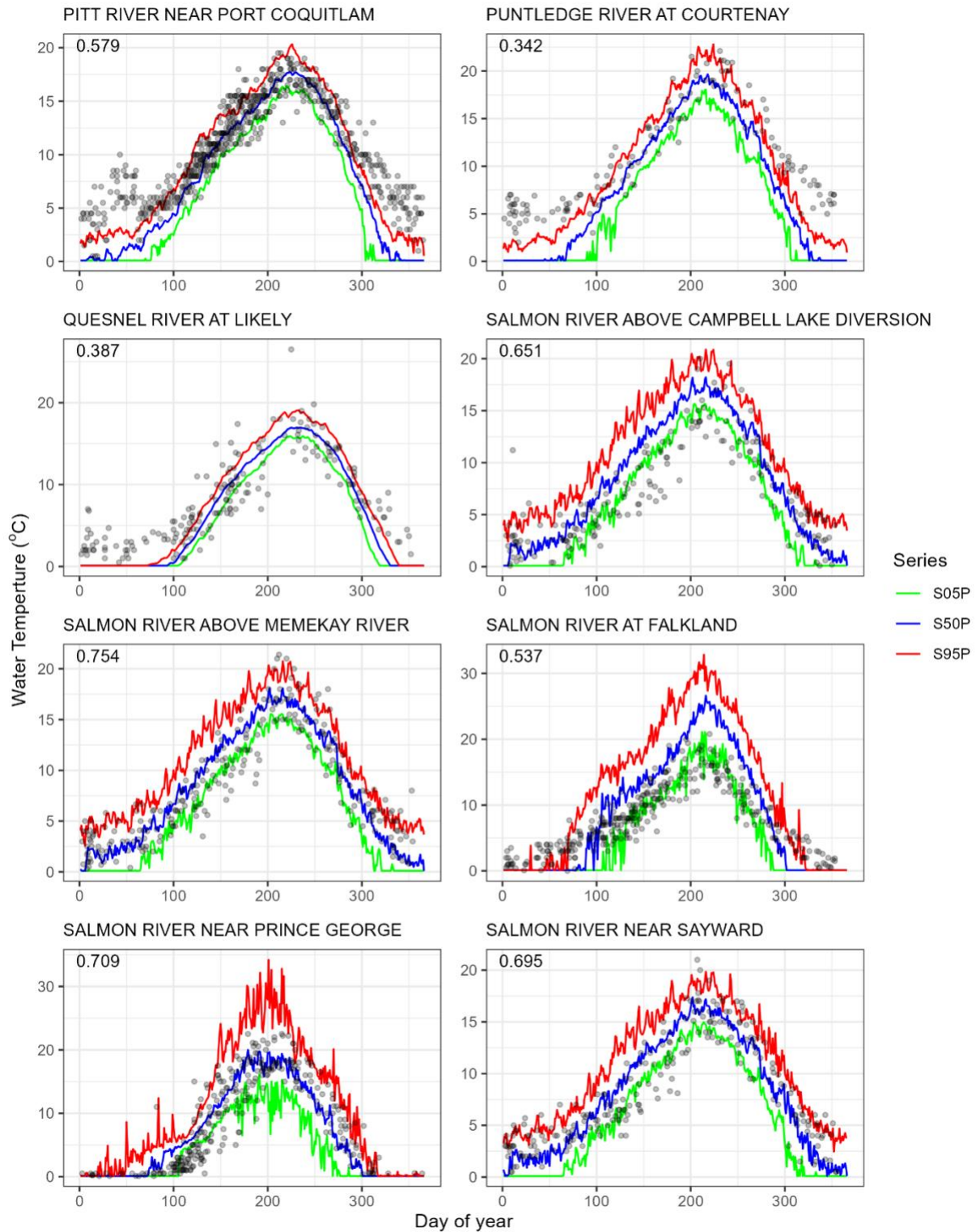


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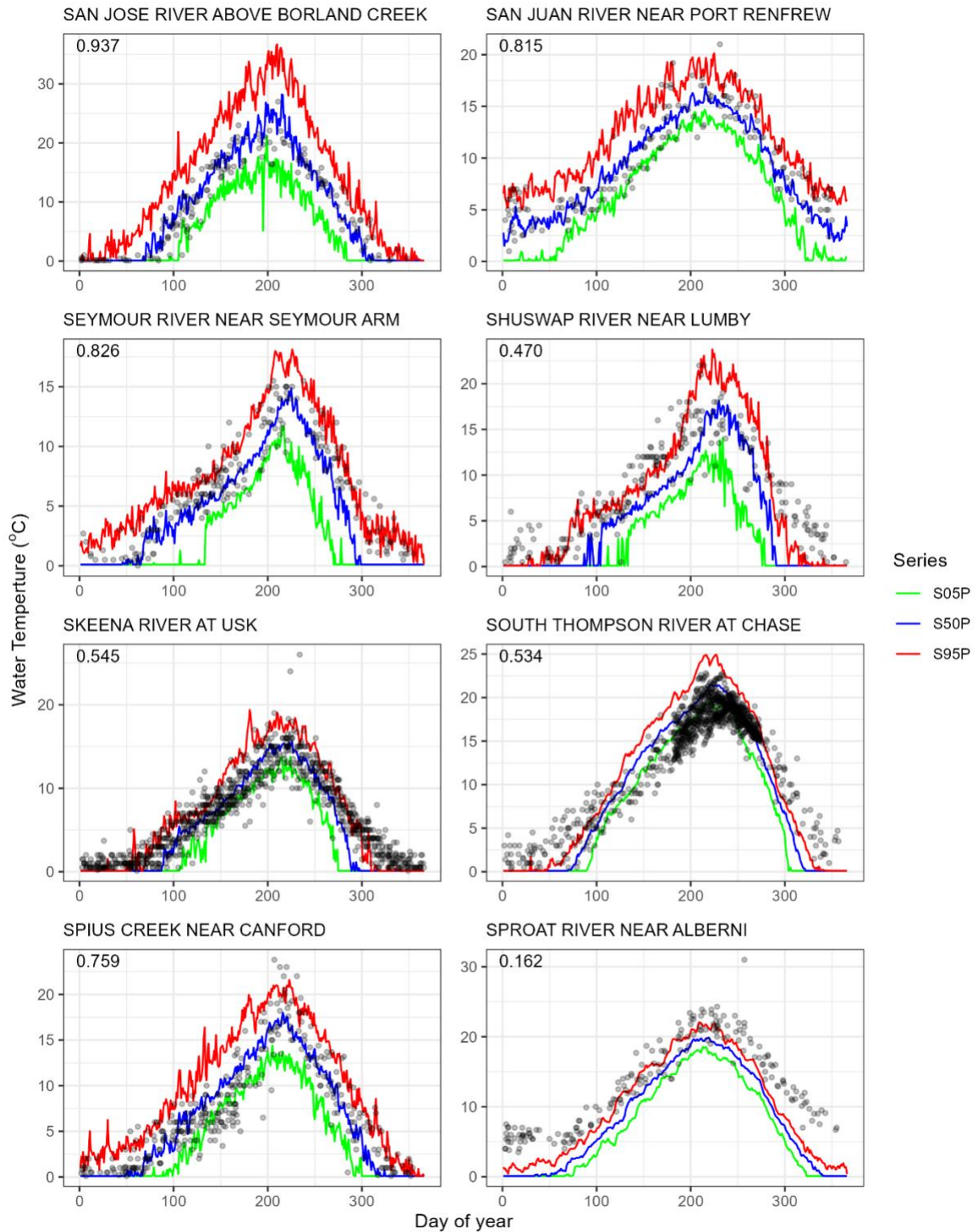


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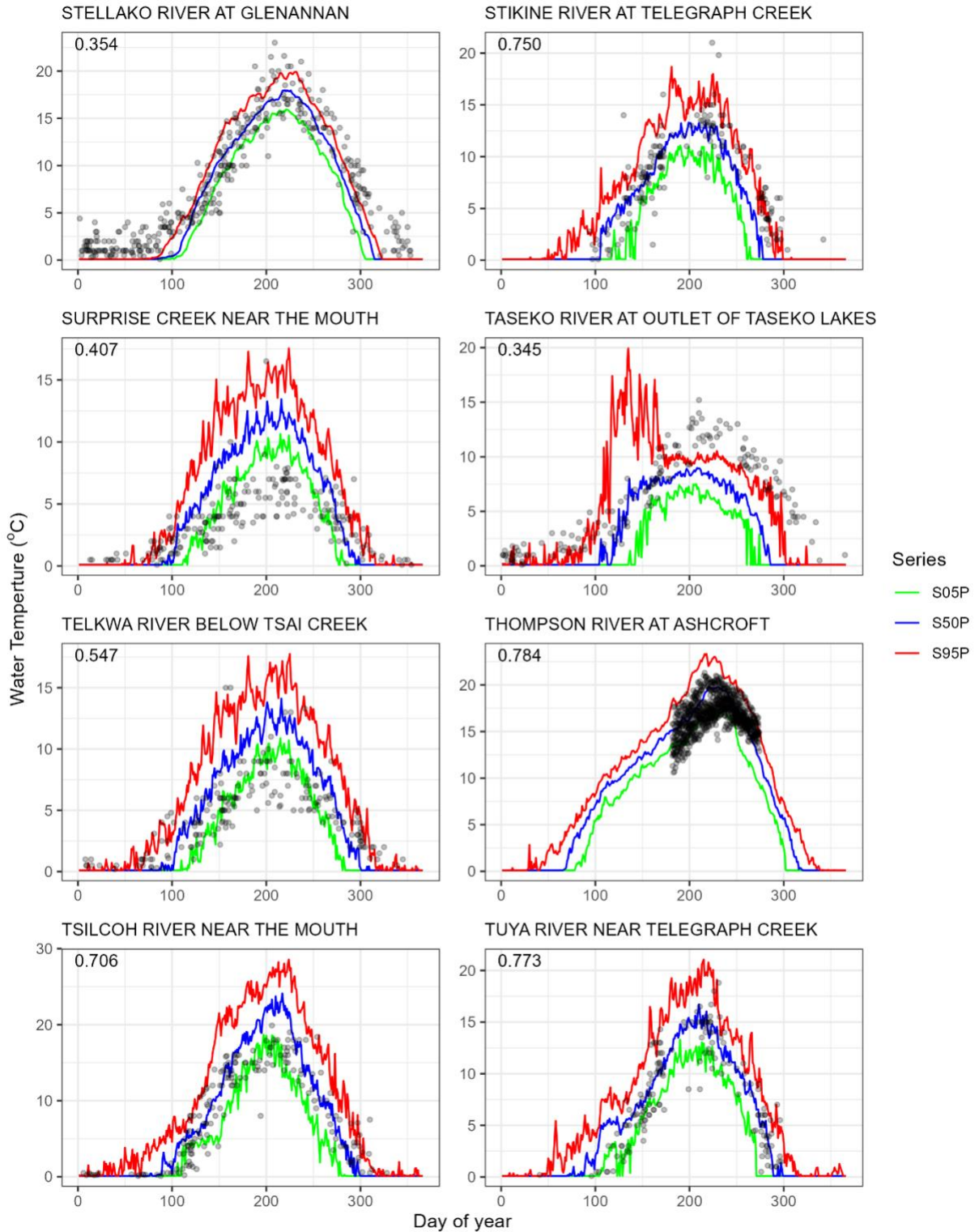


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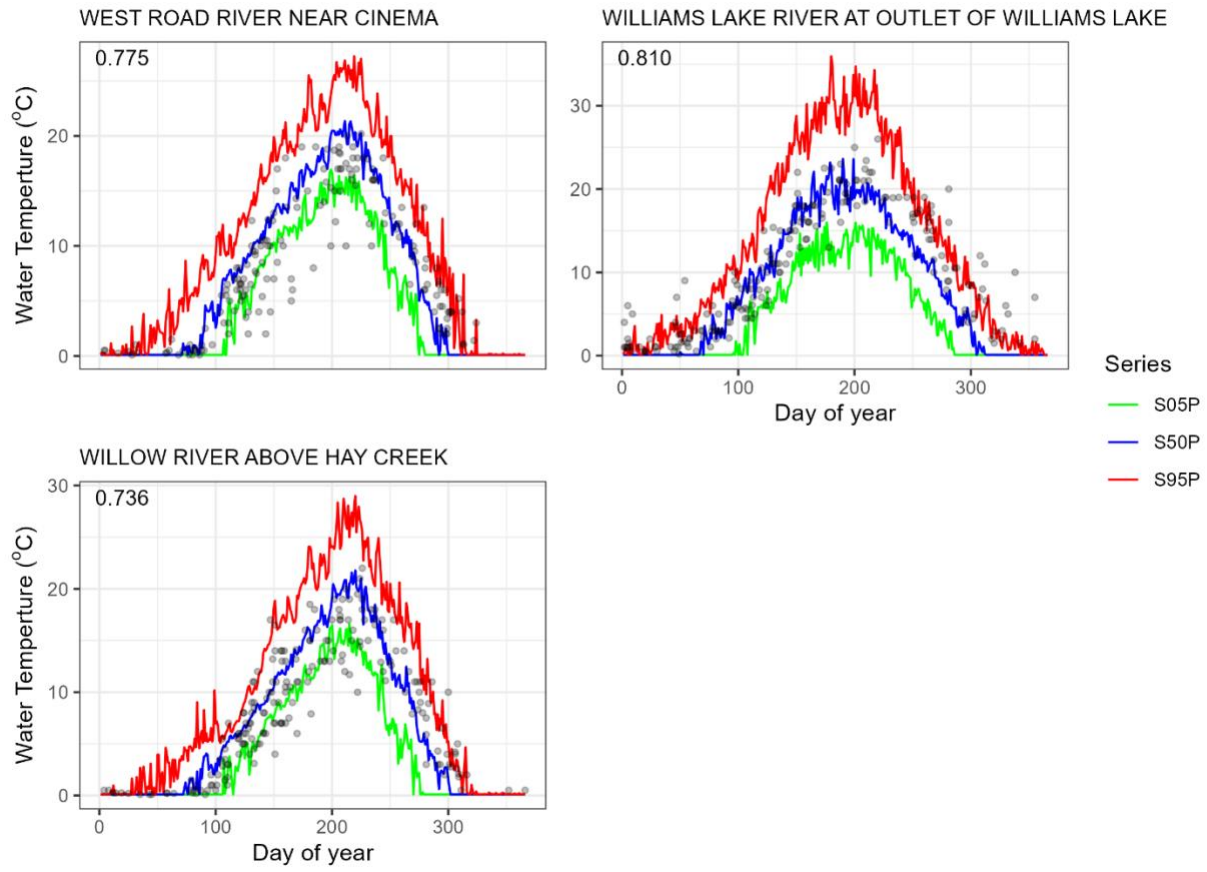


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