Vector-Based MESH Model Setup for Yukon River Basin

Supplement #1 to Centre for Hydrology Report No. 16,
Yukon River Basin Streamflow Forecasting System

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Executive summary

The Yukon River Basin the second largest river in the Arctic region of North America and is shared between Canada and the US. The Canadian part covers almost half of the Yukon Territory in addition to a small portion of the province of British Columbia, while the US part falls totally within the state of Alaska. This study is concerned with Canadian part of the Yukon River with its outlet at Eagle, Alaska - just downstream of the international boundary (288,000 km^2). The southern part of the Yukon River basin is characterized by extensive icefields and snowfields at high elevations (up to 4700 m above sea level) with steep slopes, and thus generates considerable runoff. There are also mountain ranges on the eastern and northern boundaries of the basin, while the western areas are milder in slope and partially forested. Snow redistribution by wind, snowmelt, glacier melt and frozen soil processes in winter and spring along with summertime rainfall-runoff and evapotranspiration processes are thus key to the simulation of streamflow in the basin.

This supplement shows the development of a vector-based MESH setup for the Canadian portion of the Yukon River Basin at Eagle. Without additional calibration, the vector-based model performance was compared to the previously generated grid-based MESH model whose development was documented in Centre for Hydrology Report #16. MESH was driven by the Environment and Climate Change Canada Global Multiscale Model (GEM) weather model forecasts with precipitation replaced with the Canadian Precipitation Analysis (CaPA) which assimilates local precipitation observations where they exist, collectively referred to as GEM-CaPA. Additionally, the models were run, without additional calibration using the newly developed Regional Deterministic Reforecast System v2 (RDRS v2) forcing. RDRS v2 forcing is being extended as a hindcast by ECCC to approx. 1980 and so will permit 40 year runs of MESH from which streamflow exceedance return periods can be calculated. Model performance was slightly inferior for the vector-based setup compared to the original grid-based one. This may be due to the full calibration applied to the grid-based model and parameter transfer to the vector-based model without recalibration. Model performance also deteriorated when the RDRS v2 was used as forcing data, as the model was originally calibrated to GEM-CaPA. It is expected that model performance will improve once it is fully calibrated using the RDRS v2 forcing data.

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1. Introduction

The Yukon River Basin is the fifth largest basin in North America with an area of more than 850,000 km^2, about 324,000 km^2 of which lies in Canada. It is second largest river basin in the Arctic region of North America. The river originates from the Llewellyn Glacier, BC and flows northwest along a 3,185 km course to discharge into the Bering Sea. The Canadian portion is mostly within the Yukon Territory in addition to a small portion in the north of British Columbia while the US part falls totally within the state of Alaska. MESH was previously set up on the YRB on a fixed grid at 5 and 10 km resolution, depending on the sub-basin. The objective of this work is to set up a vector-based MESH model for the Canadian portion of the Yukon River Basin (with Eagle as the outlet). In the vector-based approach, the actual geometries of river reaches and basins are used for spatial discretization rather than a regular lat-lon grids that were used for the grid-based setups documented in the main report.

2. Spatial Datasets and Model Development

This MESH application has used the MERIT Hydro global hydrography datasets, developed using the MERIT Hydro DEM and multiple inland water maps to characterize sub-basins and define the model spatial structure and routing (Yamazaki et al., 2019). The drainage database information file for the Main Yukon River Basin, which includes the geophysical parameters of the river network such as river order, channel length, slope and basin areas, was created by processing the MERIT Hydro rivers and basins using in-house scripts. This yielded 6057 modelling subbasins for the entire basin (~289,100 km^2) (Figure 1), to the outlet at the Yukon River at Eagle (09ED001) as shown in Figure 1. The grid-based model has 3448 grid-cells which means that the vector-based setup is generally higher in resolution, especially in the mountain headwaters. The vector-based model setup includes the same important lakes (Figure 1) used in the grid-based setup, of which the outflow relationship parameters were transferred from the grid-based MESH setup of the Yukon River Basin to this vector-based setup (Elshamy et al., 2020). Unlike the grid-based setup, the vector-based setup does not require any corrections of flow directions which is a huge advantage in terms of model development time and its accuracy.

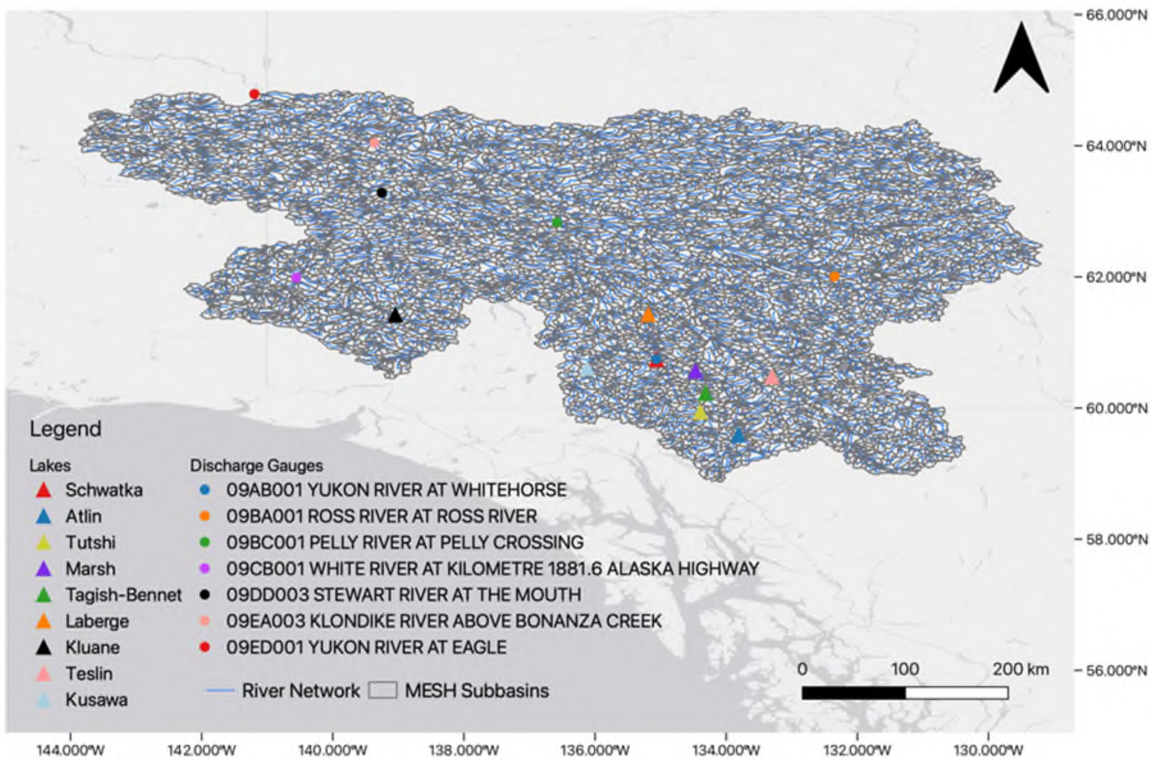

Figure 1: Main Yukon River Basin vector-based MESH model subbasins and rivers, outlets of important lakes and discharge gauges

The 30 m LANDSAT version of the 2010 NALC dataset (CCRS et al., 2017), and MERIT Hydro DEM (Yamazaki et al., 2019) were used to create MESH grouped response units (GRUs). Following the methodology used for the grid-based MESH model setup of the Main Yukon River Basin, GRU discretization was performed based on the land cover types and slope and aspect categories, which yielded 12 GRUs (Figure 2) which is the same number as for the grid-based setup. The model parameters for each of these GRUs (Figure 2) and river routing parameters were transferred from the grid-based MESH setup of the Yukon River Basin (Elshamy et al., 2020). This was done to make the models comparable and to facilitate the transfer of parameters.

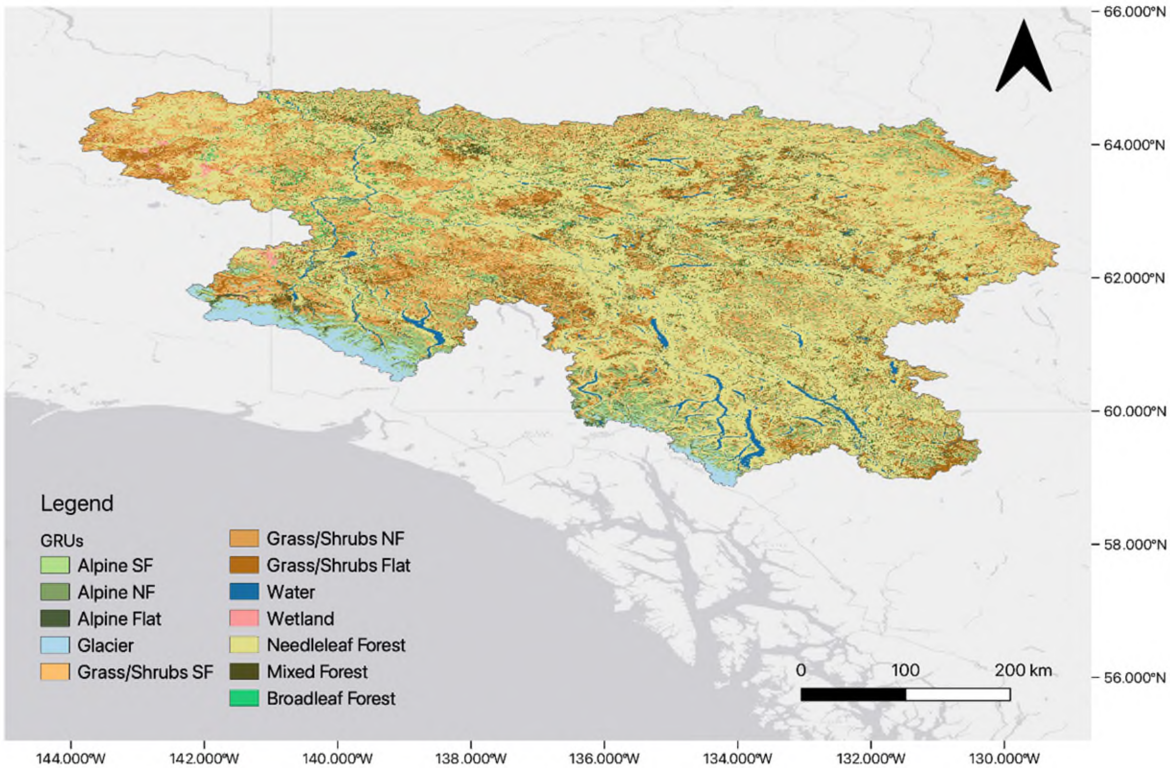

Figure 2: GRU discretization by combining land cover and slope & aspect

The meteorological variables to run MESH, namely incoming shortwave radiation, incoming longwave radiation, total precipitation rate, air temperature, wind speed, barometric pressure and specific humidity were obtained from two datasets: Global Multiscale Model (GEM) with precipitation replaced by the Canadian Precipitation Analysis (CaPA) (GEM-CaPA; Côté et al., 1998; Mahfouf et al. 2007) and the Regional Deterministic Reforecast System v2 (RDRS_v2; Gasset et al., 2021). The meteorological inputs are available for 2004-2017 and 2000-2017 from GEM-CaPA (GC) and RDRS_v2, respectively. The gridded meteorological variables were remapped over the MESH model subbasins (Figure 1). Hereon, GEM-CaPA forced MESH is referred to as GC-MESH and RDRS v2 forced MESH is referred to as RDRS-MESH.

3. Simulation Results and Performance

The GC-MESH and RDRS-MESH model simulations were initialized on Sep 1, 2004 and run to Dec 31, 2015. The period between Sep 1, 2004 and Dec 31, 2005 was considered as a spinning period. Although RDRS forcing is current available from 2000, this period was selected as a common period to compare model performance under the different forcing datasets. The streamflow observations at the discharge gauges of interest (Figure 1) over the 2006-2015 period were compared against the simulations from the GC-MESH (Figure 3) and RDRS-MESH (Figure 4).

Table 1 compares the performance of the vector-based setup under both forcing datasets.

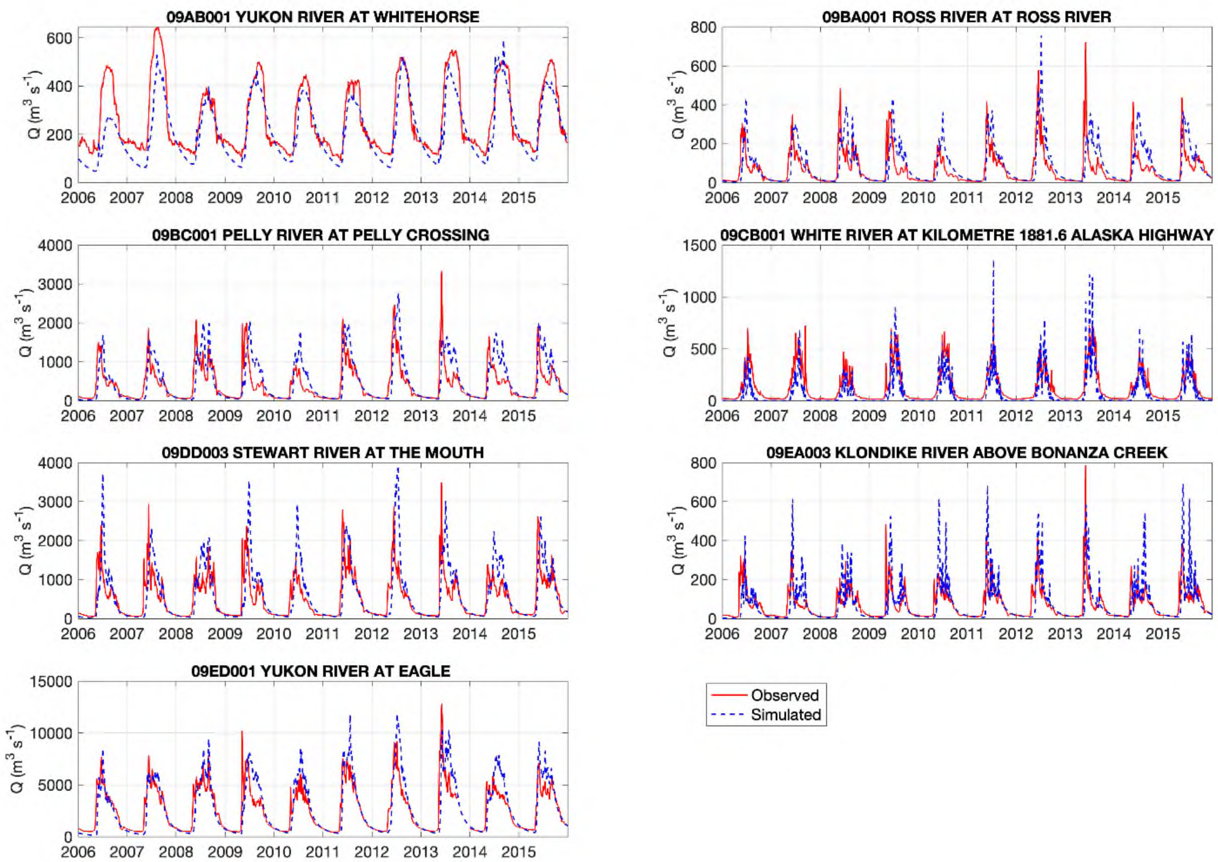

Figure 3: Comparison of GC-MESH vector-based model simulations against the observations from the discharge gauges of interest (Figure 1)

Figure 3 & 4 and the KGE values on

Table 1, show that the vector-based MESH model performance is reasonable for most stations without additional calibration, particularly at Whitehorse (09AB001) and the basin outlet, Eagle, (09ED001). The performance of GC-MESH for simulating streamflow was better than RDRS-MESH since the model parameters were transferred from the grid-based MESH model that was calibrated using the GEM-CaPA forcings. The vector-based MESH models will need to be calibrated in order to decrease the percent bias

(PBIAS) values and this will automatically improve KGE values. The routing parameters will possibly require special attention as it is now vector-based rather than grid-based.

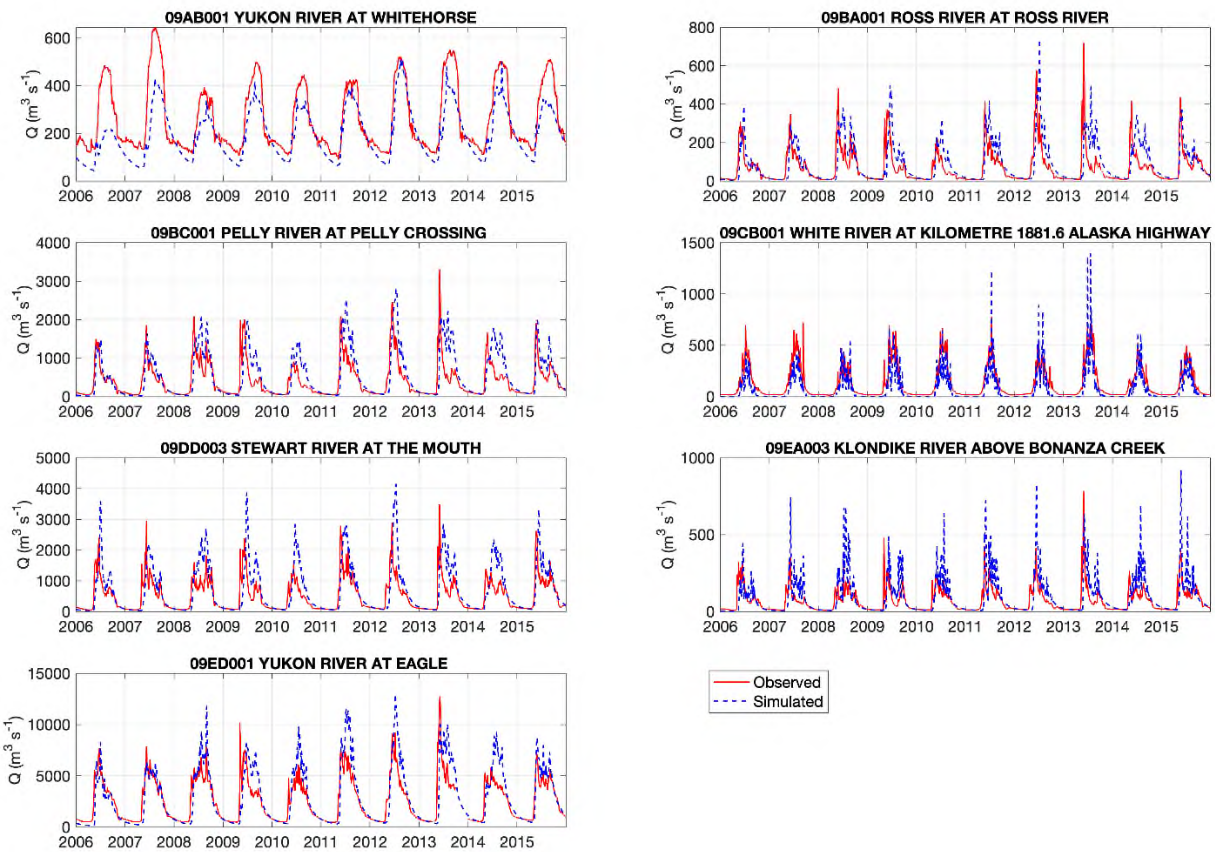

Figure 4: Comparison of RDRS-MESH vector-based model simulations against the observations from the discharge gauges of interest (Figure 1)

Table 1: GC-MESH and RDRS-MESH model performance of the vector-based model at the discharge gauges of interest (Figure 1)

Gauge	GC-MESH-Vector		RDRS-MESH-Vector	
	KGE (2006-2015)	PBIAS (2006-2015)	KGE (2006-2015)	PBIAS (2006-2015)
09AB001	0.77	-17%	0.63	-25%
09BA001	0.54	27%	0.54	29%
09BC001	0.60	20%	0.51	28%
09CB001	0.59	-39%	0.57	-40%
09DD003	0.52	17%	0.35	34%
09EA003	0.57	8%	0.23	37%
09ED001	0.72	7%	0.62	12%

4. Comparisons to the grid-based model

Results of the grid-based setup, as presented in the main Centre for Hydrology Report #16 (Elshamy et al., 2020), were plotted against those from the vector-based setup in Figure 5 for GEM forcings. Additionally, the grid-based setup was run using RDRS v2 forcing data and results were compared to those of the vector-based setup and observations in Figure 6. Table 2 summarizes the results of the grid-based model for both forcing datasets.

Table 2: GC-MESH and RDRS-MESH model performance of the grid-based model at the discharge gauges of interest (Figure 1)

Gauge	GC-MESH-Grid		RDRS-MESH-Grid	
	KGE (2006-2015)	PBIAS (2006-2015)	KGE (2006-2015)	PBIAS (2006-2015)
09AB001	0.92	3%	0.57	-26%
09BA001	0.79	15%	0.82	9%
09BC001	0.89	4%	0.81	9%
09CB001	0.44	3%	0.53	-41%
09DD003	0.83	-3%	0.62	20%
09EA003	0.77	-16%	0.64	15%
09ED001	0.93	-3%	0.91	6%

As the grid-based model was calibrated to GEM-CaPA, it has better overall performance compared to the vector-based model. As well, the performance generally deteriorates when RDRS v2 is used (further calibration may improve that) except for a few stations. Comparisons of the two forcing datasets needs to be done to explain these differences in performance which are persistent for both model setups.

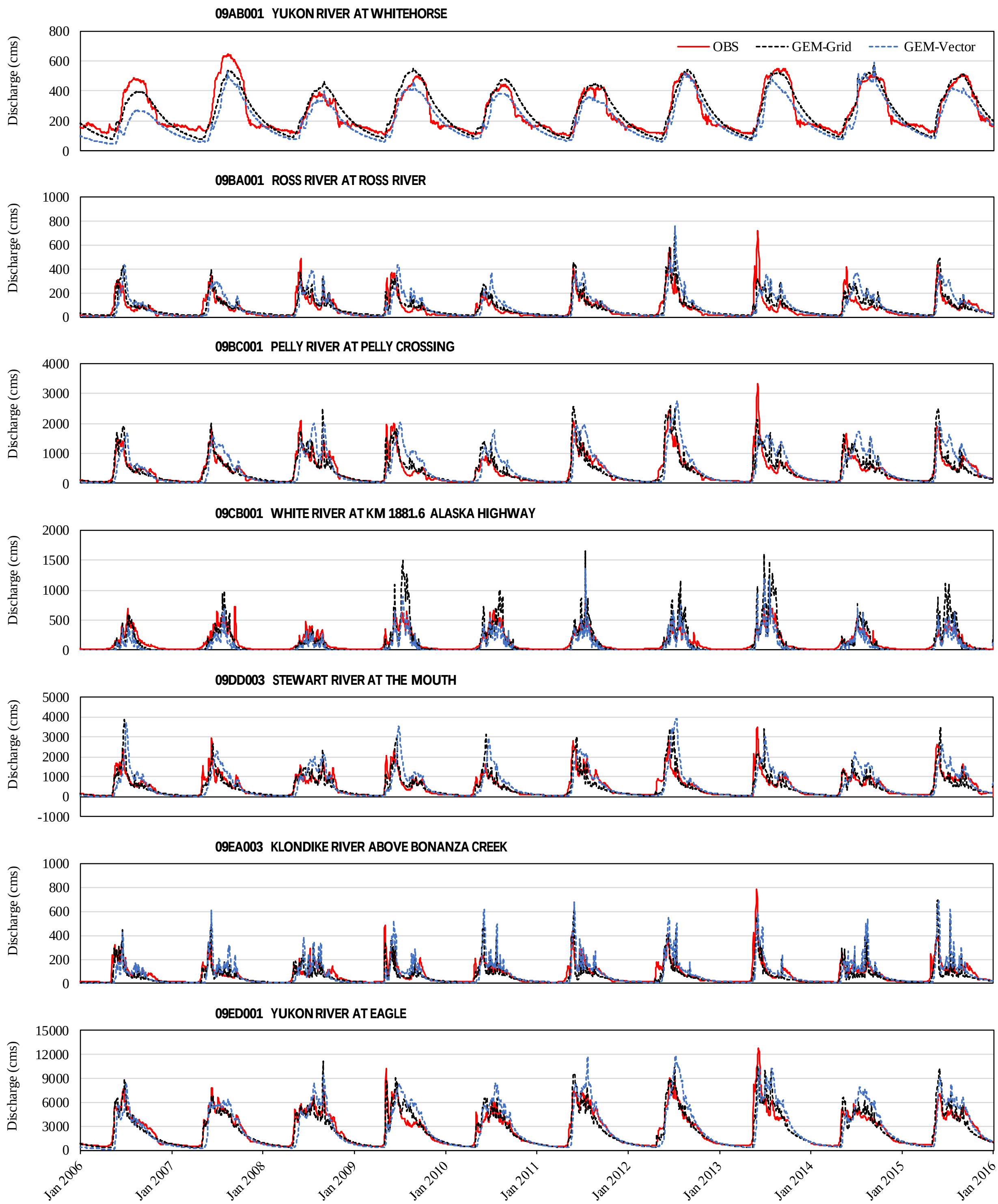

Figure 5: Comparison of GC-MESH vector-based and grid-based model simulations against observations from the discharge gauges of interest

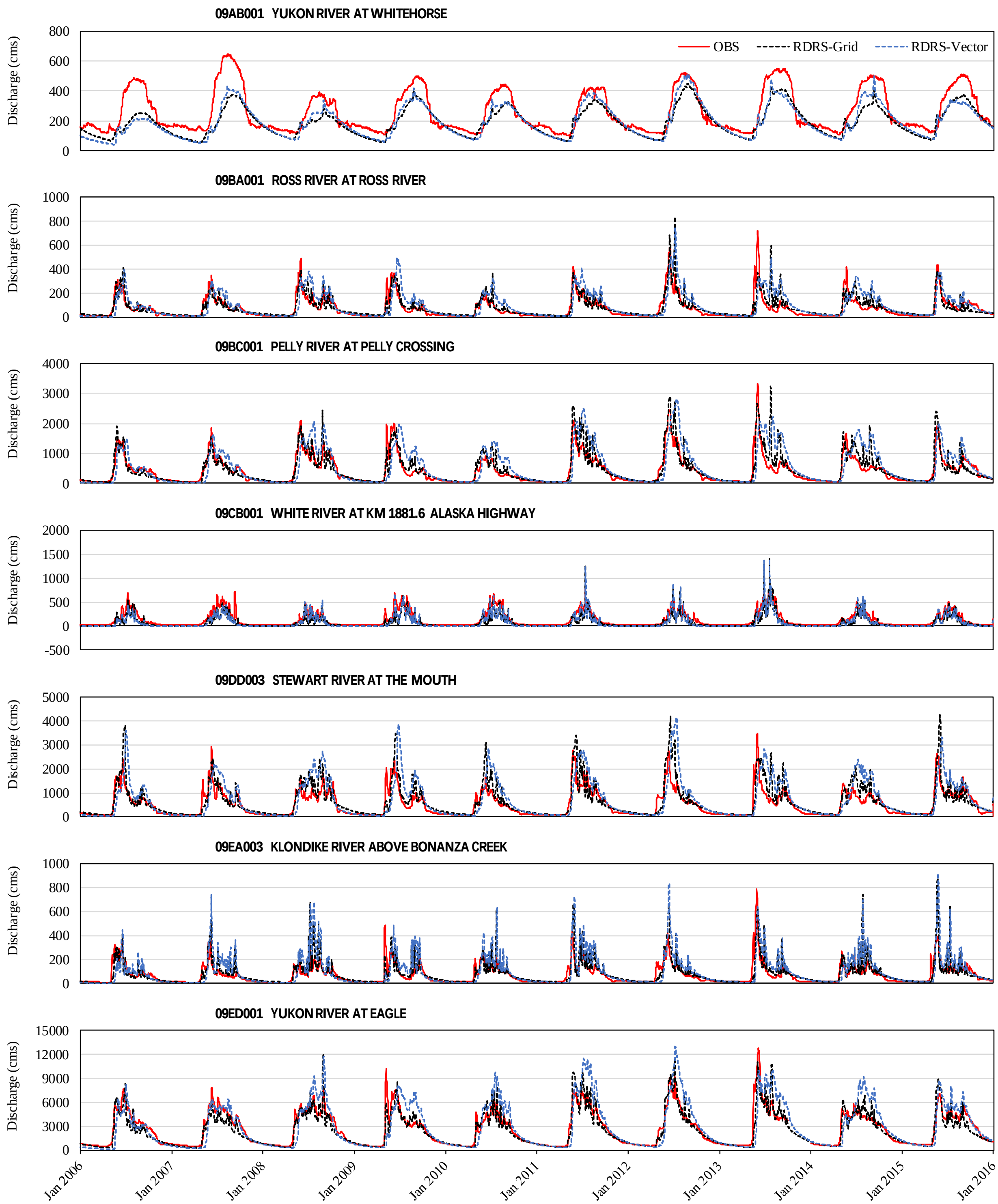

Figure 6: Comparison of RDRS-MESH vector-based and grid-based model simulations against observations from the discharge gauges of interest

5. Conclusions and Recommendation

A vector-based model discretization and routing setup for the MESH model of the Yukon River basin has been developed. Parameters were successfully transferred from the grid-based MESH model setup and the vector-based model has produced reasonable results when compared to streamflow observations. Vector-based MESH performance is slightly inferior to those of the grid-based discretization, but this is likely to improve with further calibration. Both setups were forced with meteorology from the newly released RDRS v2, which is available for a longer period (2000-2017), but GEM-CaPA remains the operational meteorological forcing to use for forecasting. RDRS is being extended backwards by ECCC to start in 1980 but this is not yet available. Both the vector-based and the grid-based setups showed lower performance under RDRS v2 as it was calibrated to GEM-CaPA. It is recommended that the vector-based MESH formulation be calibrated with GEM-CaPA forcings if it is to be applied for forecasting purposes and that it be calibrated with RDRS v2 forcings if applied for hindcasting and streamflow probability calculations. These calculations should be possible once RDRS v2 is fully extended to 1980 and that would provide 40 years for calculation of flow duration curves for the various sub-basin outlets and main outlet of the YRB.

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