The Yukon River Basin Forecasting System: A script-based, cloud-based prototype for a data-sparse basin

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GWF Open Science Meeting 2021

Introduction

The Yukon River Basin is a major circumpolar river that is shared between Canada and the US. The Canadian headwaters comprise glaciated high mountains, alpine tundra, boreal forest and a system of mountain lakes, underlain partly by permafrost. Snowmelt is a primary driver of runoff. The Yukon River Basin Forecasting System was developed for the basin draining to Eagle (288,000 km^2), Alaska near the Canada-US border. The river basin is characterized by an extremely low-density of unevenly distributed meteorological stations, with about 1 station per 3000 km^2.

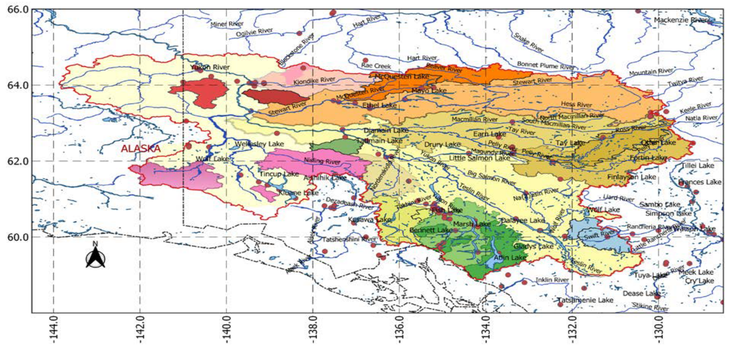

Fig 1: *Main Sub-basins of the Yukon and Location of Meteorological Stations (Red Dots)*

Objectives

1. To set-up, calibrate and validate a GEM-MESH forecasting model for the Yukon River Basin (Yukon) and its main sub-basins
2. To operationalize a discharge forecasting system to inform the Yukon Environment flood forecasters on the hydrological state of the basin and anticipated changes to streamflow.

MESH Setups for the Yukon River Basin

- MESH (Fig 2) was set-up for the YRB@Eagle using topographic and land use data at 0.125° resolution → 3,448 Cells, and for 4 main sub-basins at 0.0625°.
- MESH uses grouped response units (GRUs) to characterize sub-grid heterogeneity. YRB GRUs were defined based on land cover classes and terrain slope and aspect.
- Flow routing (RTE) is a based in the WATROUTE kinematic wave model.
- The routing includes 9 lakes that use a storage discharge relationship for lake-routing
- The domain was calibrated and validated using observations from Water Survey of Canada gauges and was driven by GEM-CaPA analysis.

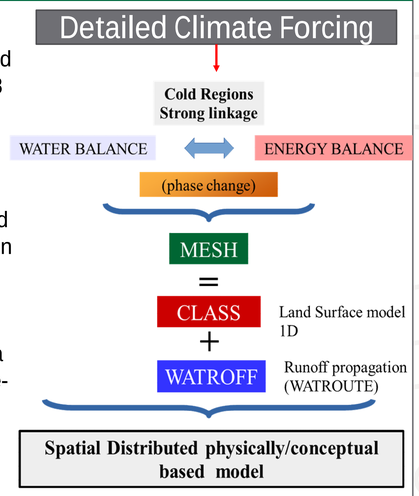

Fig 2: *MESH Schematic*

Forecast System Setup

Fig 3: *Forecast Timeline Example for May 30*

- The Yukon Forecasting System consists of a set of scripts to download and prepare meteorological forcing data (from ECCC Regional and Global Deterministic Prediction Systems - RDPS and GDPS), run MESH for a set of model setups, and post-process MESH outputs.
- Static (model setups) and dynamic (met forecasts) data are organized in separate folders.
- The forecast system runs a 1-day hindcast to update the initial conditions using RDPA (CaPA) and RDPS, then it runs two series of forecasts (5 km, 10 km grids) based on RDPS and GDPS.
- The system runs daily and automatically on the Amazon Cloud to insure reliability.

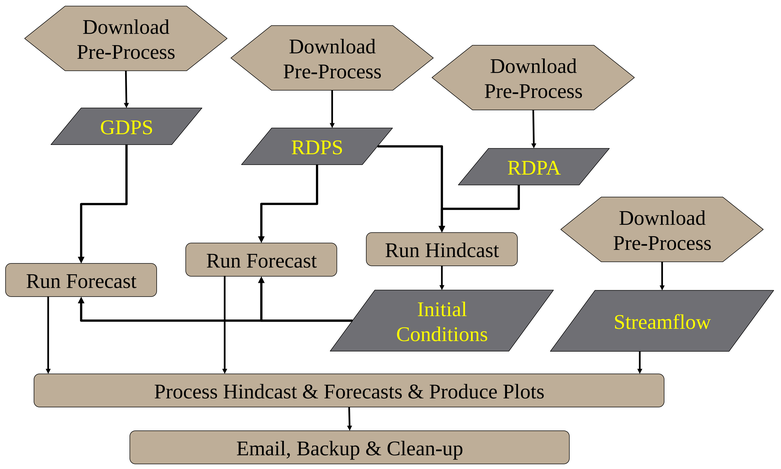

Fig 4: *Overall Workflow of the Forecast System*

Forecast System Performance & Robustness

- Forecast reports were improved based on user feedback.
- For the flood season of 2020 (April 20 till Oct 1) – there were 9 failures over 165 days (6%)
- Failures were analyzed and they mainly resulted from failing to download met forecasts (8 GDPS, 1 RDPS)
- Each occurrence was debugged until the system worked and measures were taken to increase robustness of the system:
  - High level log
  - Alternative download links for GDPS and RDPS
  - Following ECCC datamart newsletter to anticipate changes & production issues
  - Daily backup and removal of unnecessary data

Sample Forecast for a station

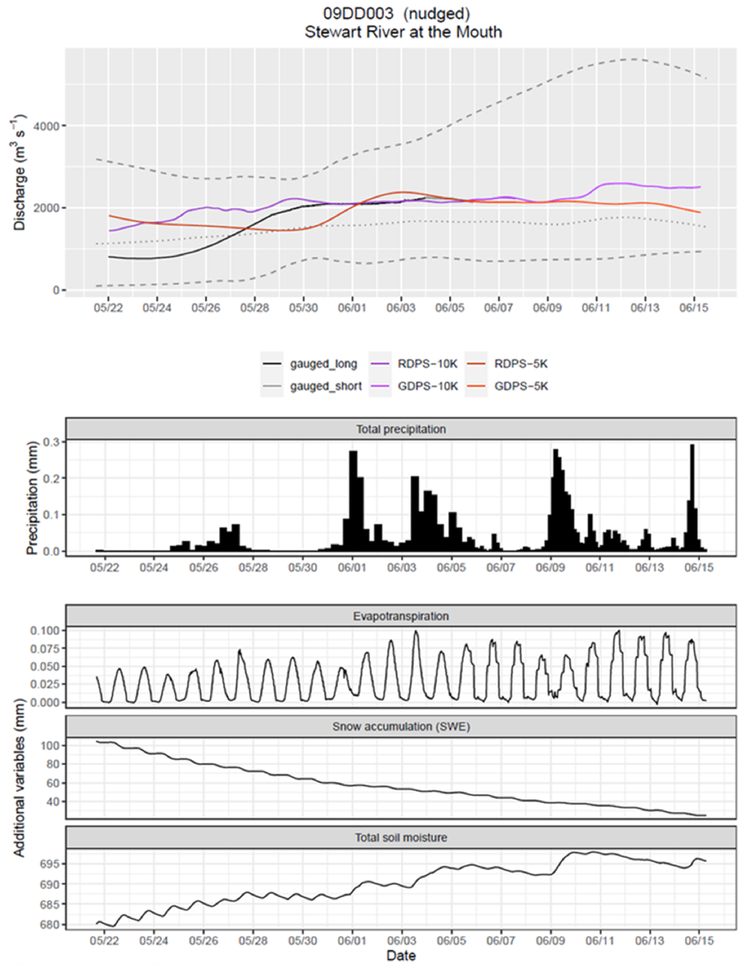

Fig 5: *Sample Forecast for the Stewart River at the Mouth issued June 5, 2020 - includes hydrographs, and water Balance components*

Conclusions & Next Steps

- The Yukon represents a grand challenge for forecasting and prediction – complex terrain, cold regions processes, mountains, sparse weather and hydrometric networks and big rivers.
- The system performed well for most of the season, giving guidance on major events occurring on the Klondike and the White rivers
- Over the course of this first year, system robustness to failures and efficiency in processing and space utilization has been improved.
- Human interpretation and judgement by provincial/territorial forecasters is essential – this system aids forecasters, and is NOT a public system
- The system is running again for 2021 and new results will be evaluated further. The system is an important part of GWF's knowledge mobilisation.

References

Elshamy, M., Loukili, Y., Princz, D., Richard, D., Tesemma, Z. and Pomeroy, J. W.: Yukon River Basin Streamflow Forecasting System, Center for Hydrology Report 16, University of Saskatchewan, Saskatoon, 2020. www.usask.ca/hydrology