Improving the Estimation of Discharge in Permafrost Simulations by Coupled ATS-MOSART

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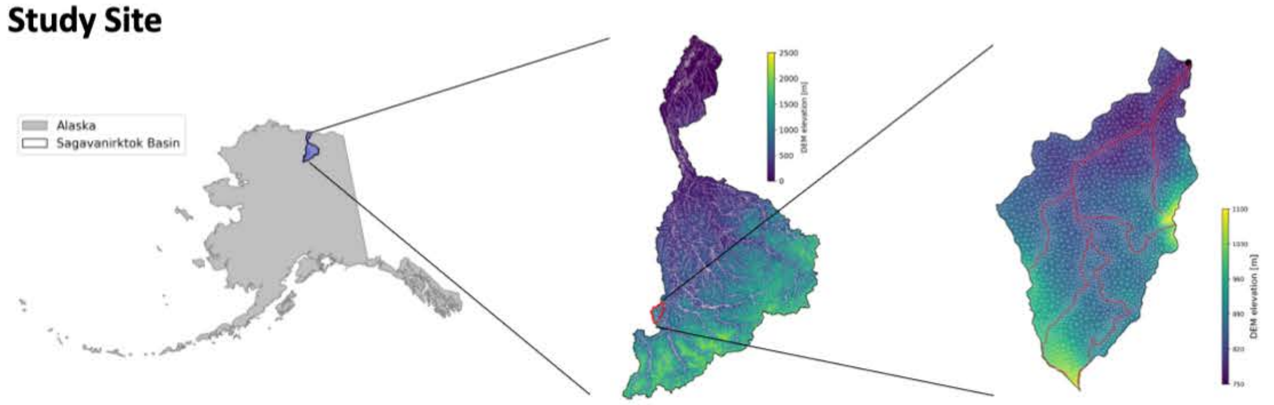
Motivations

- Follow-on work based on All-Hands meeting, 2022.
- Proposed a novel model conceptualization for watershed-scale permafrost simulations and applied to a small catchment in Sagavanirktok (Sag) River basin.
  - Watershed decomposition to subcatchments
  - Parameterization of subcatchments to 2D hillslopes
  - Hillslope-scale simulations of freezing-thaw cycles by ATS (Advanced Terrestrial Simulator)
  - External river routing using hillslopes discharges by MOSART (Model for Scale Adaptive River Transport)
- Issues: significant bias in simulated discharge compared to gauge observations.
  - Overestimated discharge peaks during snowmelt dominated period.
  - Underestimated discharge (keeps zero) during spring after snow melt.
  - Inappropriate representation of infiltration-runoff partitioning.
- Solutions:
  - Used rainfall data from a weather station of the neighbor catchment (Imnavait).
  - Improved the relative permeability model.
  - Modified aerodynamic resistance term.

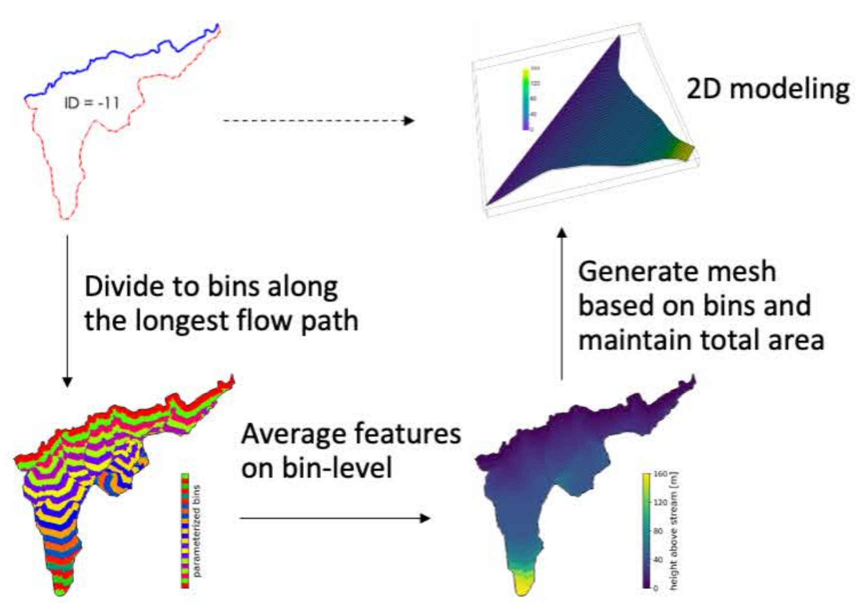
Study Site



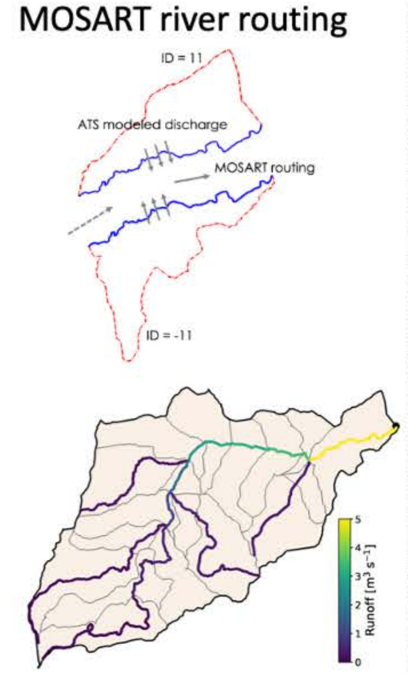
Model Conceptualization

Catchment decomposition

Hillslope parameterization and ATS simulation

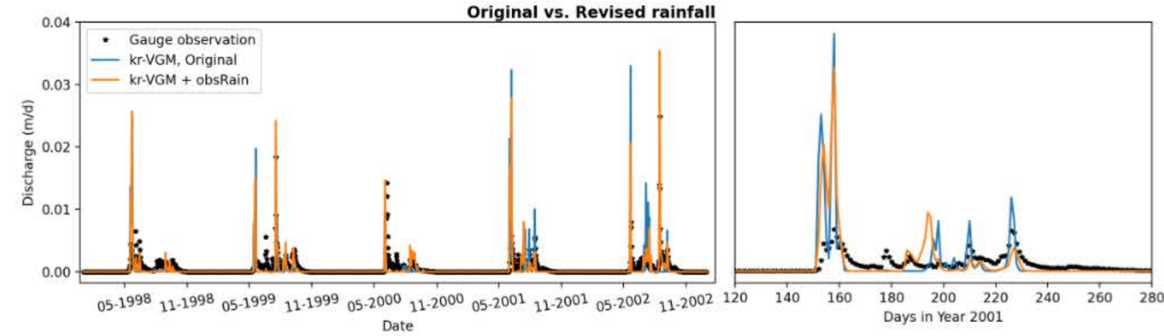


MOSART river routing



Discharge Improving Progress

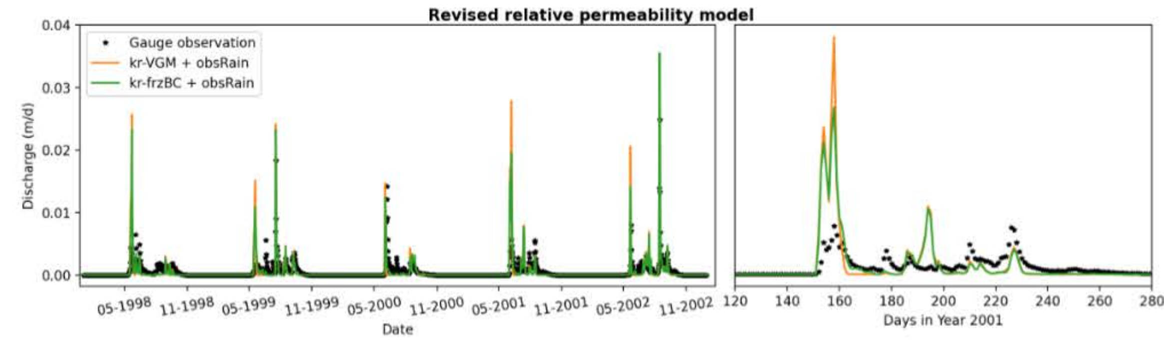
1. Use rainfall data collected from a neighbor weather station.



Equilibrium assumption of homogeneous porous media does not perform well for permafrost simulations in these area due to macropores.

- To introduce non-equilibrium dual-permeability model;
- To modify relative permeability model to allow water moving deeper instead of keeping at very shallow surface.

2. Replace van Genuchten Mualem based kr to a model proposed by Niu & Yang (2006).



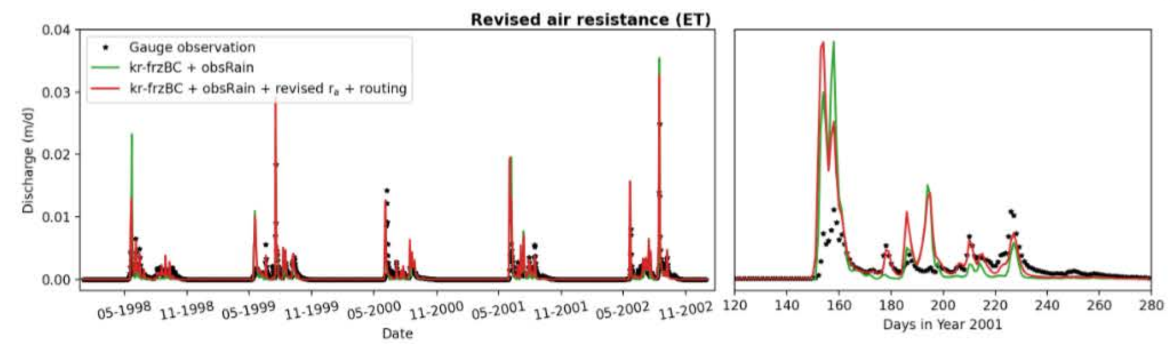
$$kr_{\mathrm{VGM}} = \left(\frac{\theta_{\mathrm{liq}} - \theta_{\mathrm{r}}}{\theta_{\mathrm{sat}} - \theta_{\mathrm{r}}}\right)^{l} \left\{1 - \left[1 - \left(\frac{\theta_{\mathrm{liq}} - \theta_{\mathrm{r}}}{\theta_{\mathrm{sat}} - \theta_{\mathrm{r}}}\right)^{1/m}\right]^{m}\right\}^{2}$$

Let water move deeper.

$$kr_{\mathrm{frzBC}} = (1 - F_{\mathrm{frz}})\left(\frac{\theta}{\theta_{\mathrm{ice}} + \theta_{\mathrm{liq}}}\right)^{(2b+3)}$$

$$F_{\mathrm{frz}} = e^{-\omega(1 - \theta_{\mathrm{ice}}/\theta_{\mathrm{sat}})} - e^{-\omega}$$

3. Revise air resistance term to include microtopography effect [$E = \Delta q / (r_a + r_s)$]



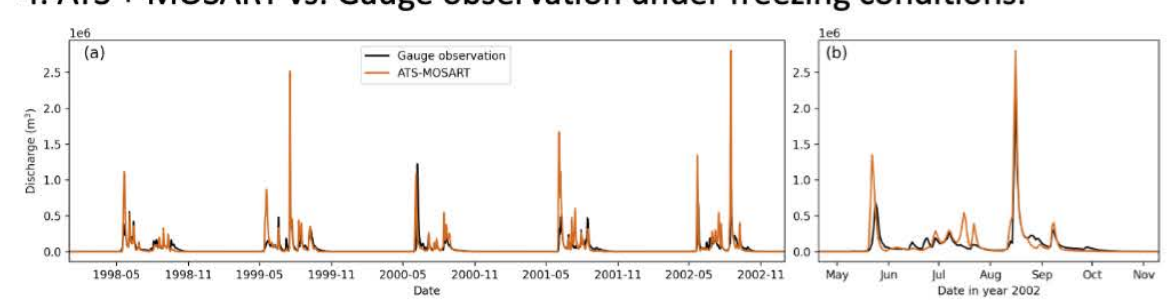
$$r_{\mathrm{a}} = \frac{1}{\kappa^2 u} \ln\left(\frac{z_{\mathrm{ref}}}{z_{0\mathrm{v}}}\right) \ln\left(\frac{z_{\mathrm{ref}}}{z_{0\mathrm{m}}}\right)$$

Hold water in soil

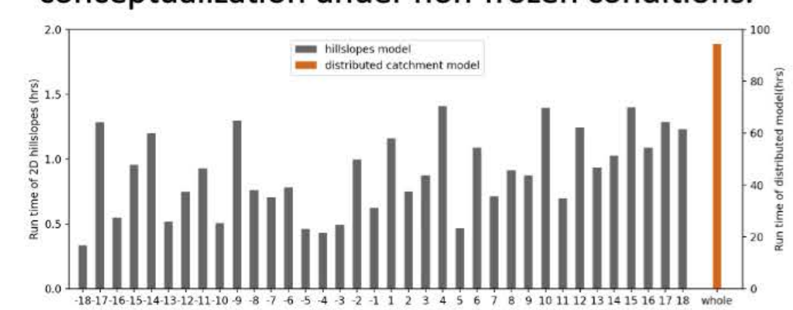
$$z_{0\mathrm{v}} = z_{0\mathrm{m}} \longrightarrow \ln\left(\frac{z_{0\mathrm{v}}}{z_{0\mathrm{m}}}\right) = -\kappa\left\{a\left(\frac{u_* z_{0\mathrm{m}}}{\nu}\right)^{b} - \left[m \ln\left(\frac{u_* z_{0\mathrm{m}}}{\nu}\right) + n\right]\right\}$$

testing

4. ATS + MOSART vs. Gauge observation under freezing conditions.



Runtime: 3D distributed model vs. model conceptualization under non-frozen conditions.



Work in progress

1. Parameterization of 6498 hillslopes of Sag river basin.
2. ATS simulation of the 6498 hillslopes.