CRHM Modelling of Mountain Hydrological Processes in Marmot Creek during the Flood

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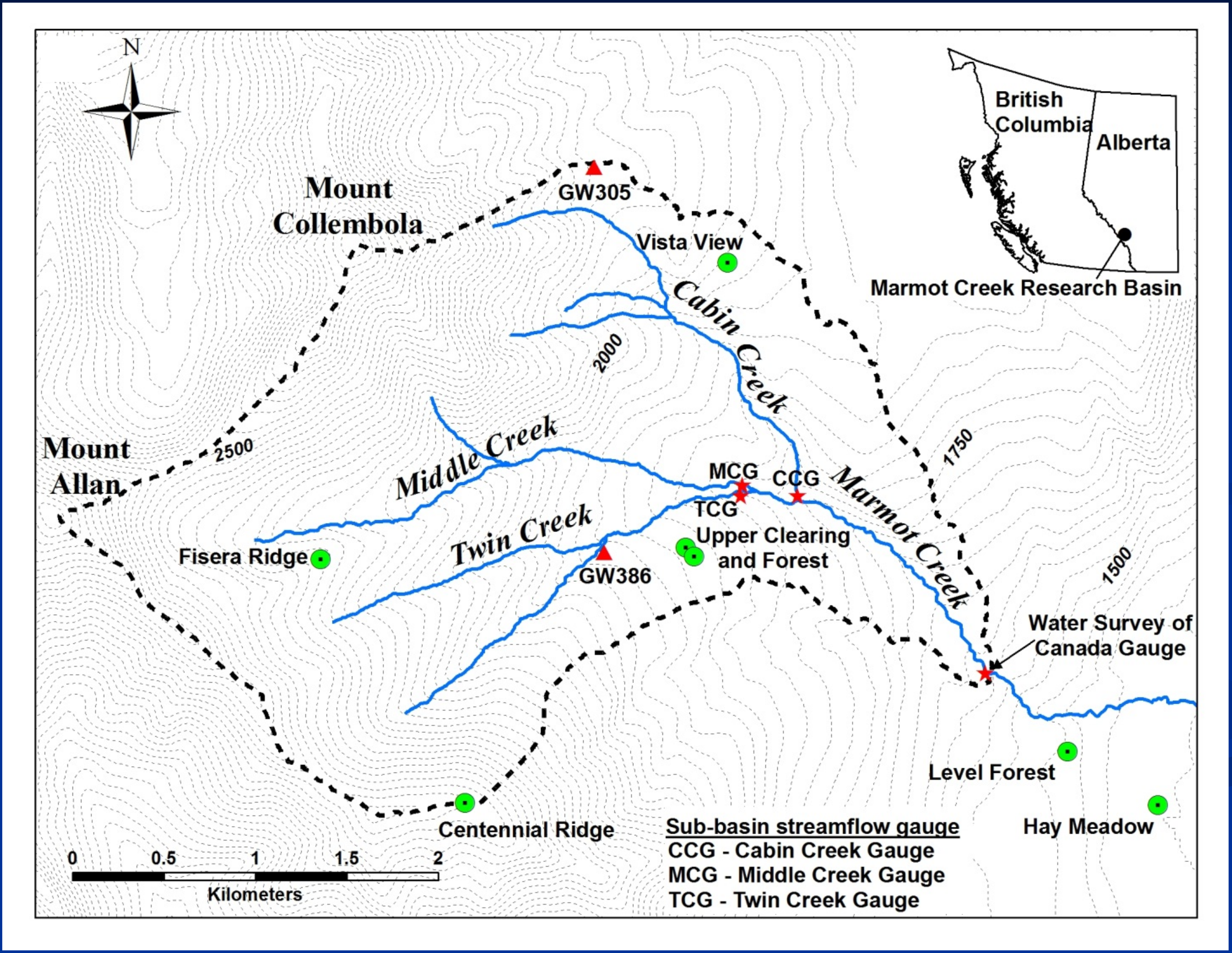
Purpose

- Set up a hydrological model for mountain watershed from physical principles rather than using calibration.
- Use the model to diagnose hydrological process behaviour during a flood under varying antecedent conditions.
- Learn from the model simulation of flooding to suggest where improved understanding of physical principles can guide the next phase of model development.

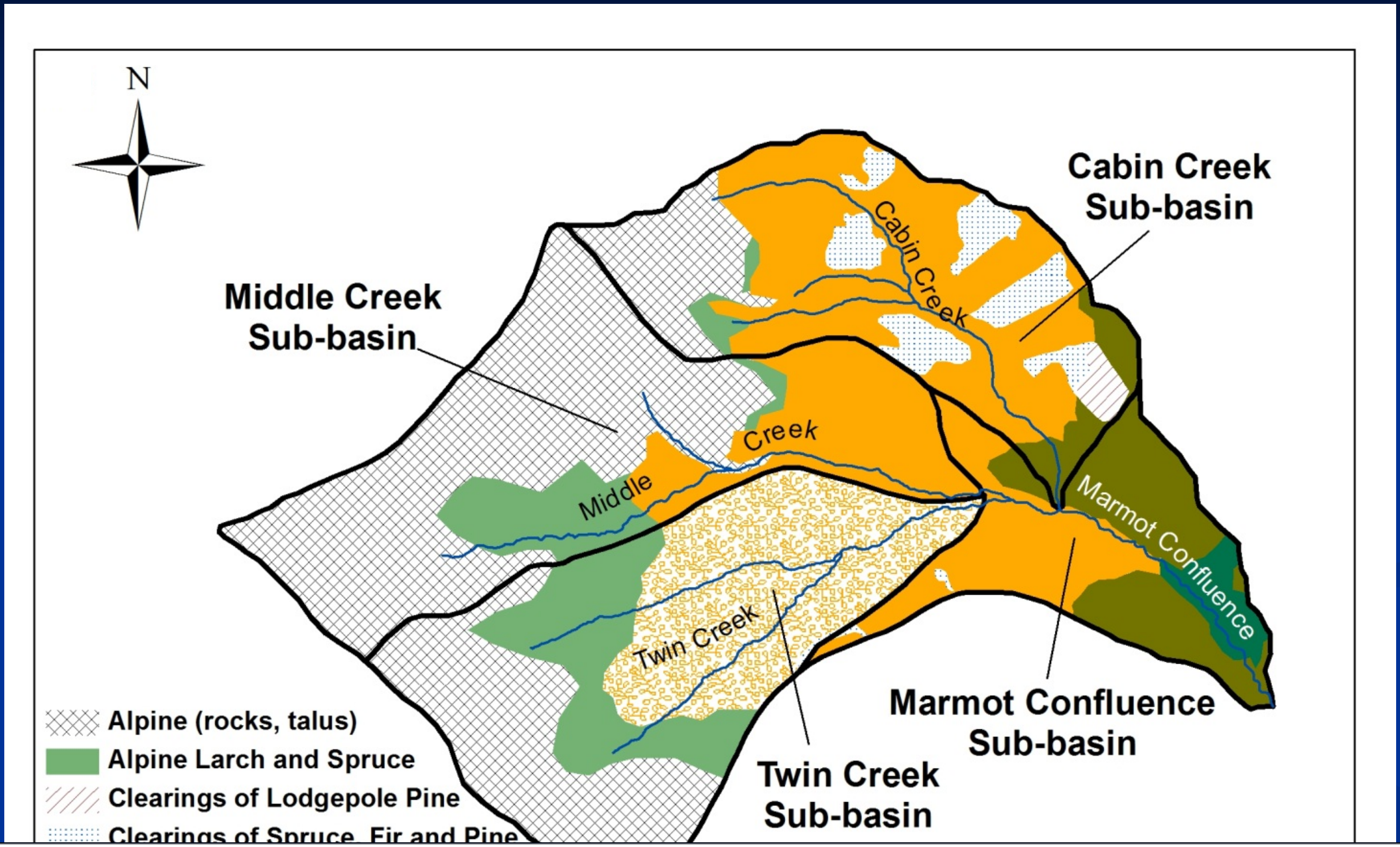
Cold Regions Hydrological Modelling platform: CRHM

- Objected-oriented, modular and flexible platform for assembling hydrological models (Pomeroy et al., 2007, Hydrol. Process.)
- Modules from about 50 years of hydrology research at University of Saskatchewan and Environment Canada in prairie, mountain, boreal, arctic environments
- Purpose-built model by user from basin spatial configurations, spatial resolutions, and dominant hydrological processes in the basin.
- Hydrological Response Units (HRUs) based simulation
  - Landscape units with characteristic hydrological processes
  - Single parameter set
  - Number of nature depending on variability of basin attributes and level of physical complexity chosen for model
- Sub-basins structure – a series of “representative basins” with same physical process modules and HRUs but varying parameter values

Marmot Creek Research Basin (~9.4 km^2)



Marmot Creek Research Basin - Landcovers



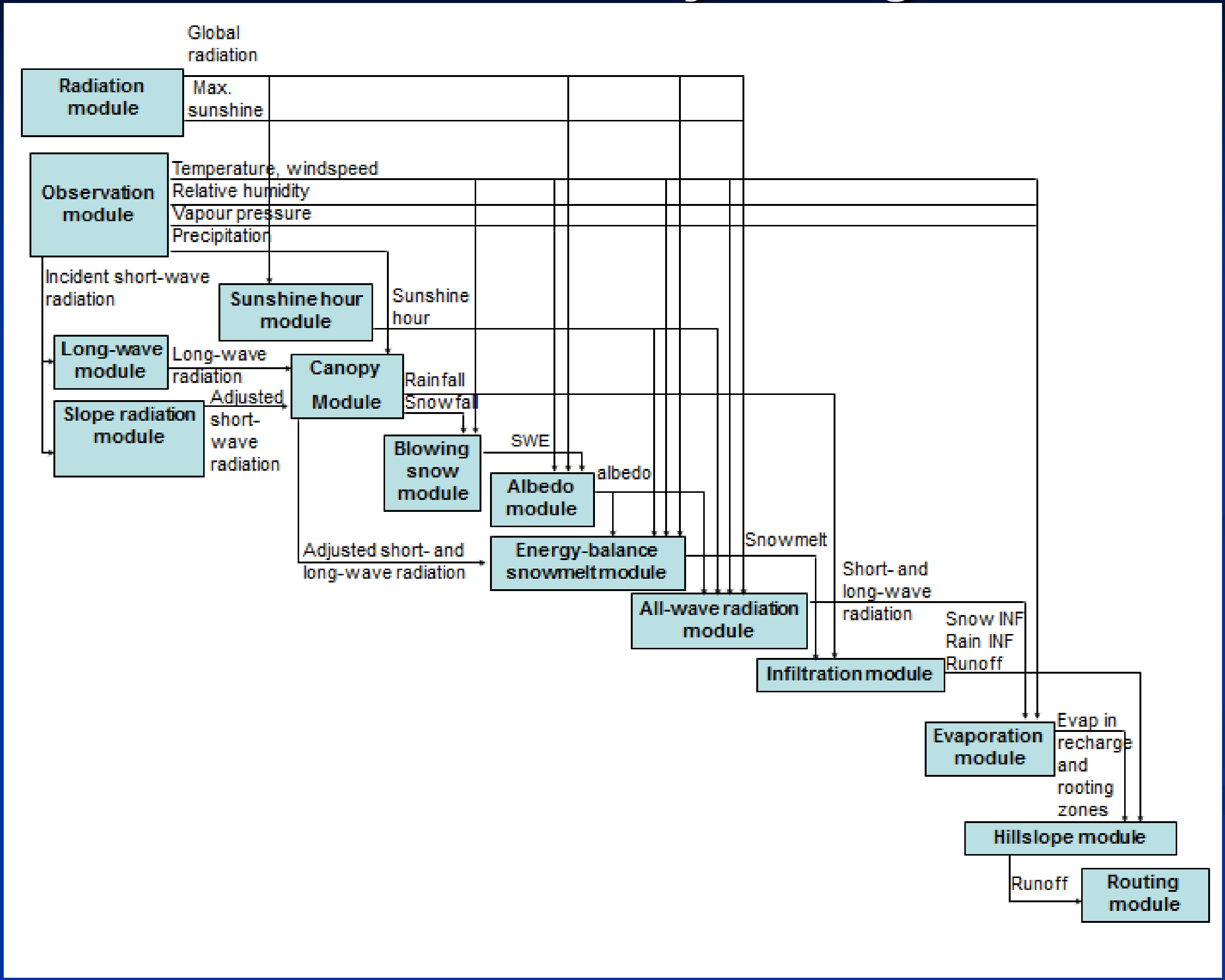
	Alpine Environment (AE)	Treeline Environment (TE)	Middle to Upper Elevation Forest (MUF)	Cabin Forest Clearing Blocks (CFC_SE)	Twin Forest Clearing_North-facing (TFC_N)	Twin Forest Clearing_South-facing (TFC_S)	Lower Elevation Forest (LF)
Area (km^2)	3.23	0.93	2.75	0.40	0.26	0.24	1.42
Area (% of basin)	34.5	10.0	29.3	4.3	2.7	2.6	15.2
Elevation (m)	2413	2217	1983	1927	1966	2014	1756
Aspect (˚)	110	91	108	140	34	113	113
Slope (˚)	30	22	20	11	17	21	14

Alpine Talus/Forest

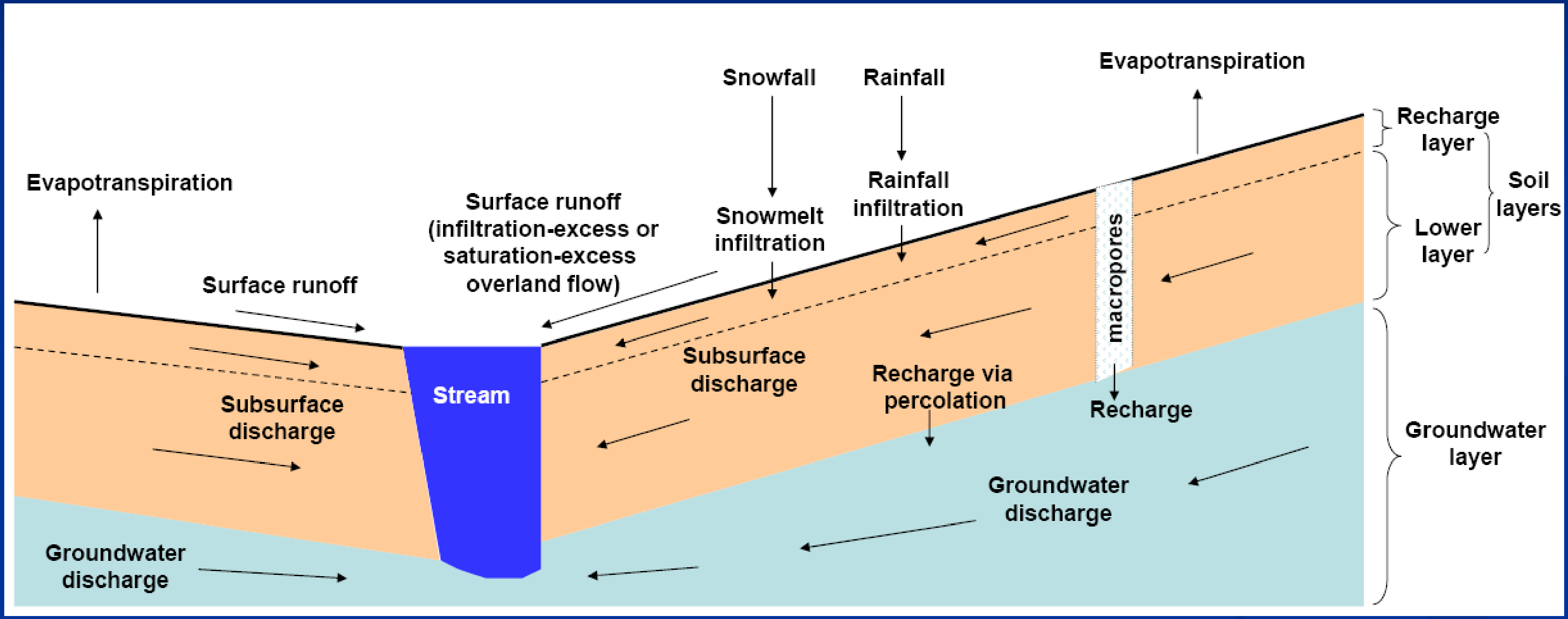



Sub-alpine Coniferous Forest

Marmot Creek Basin Hydrological Model

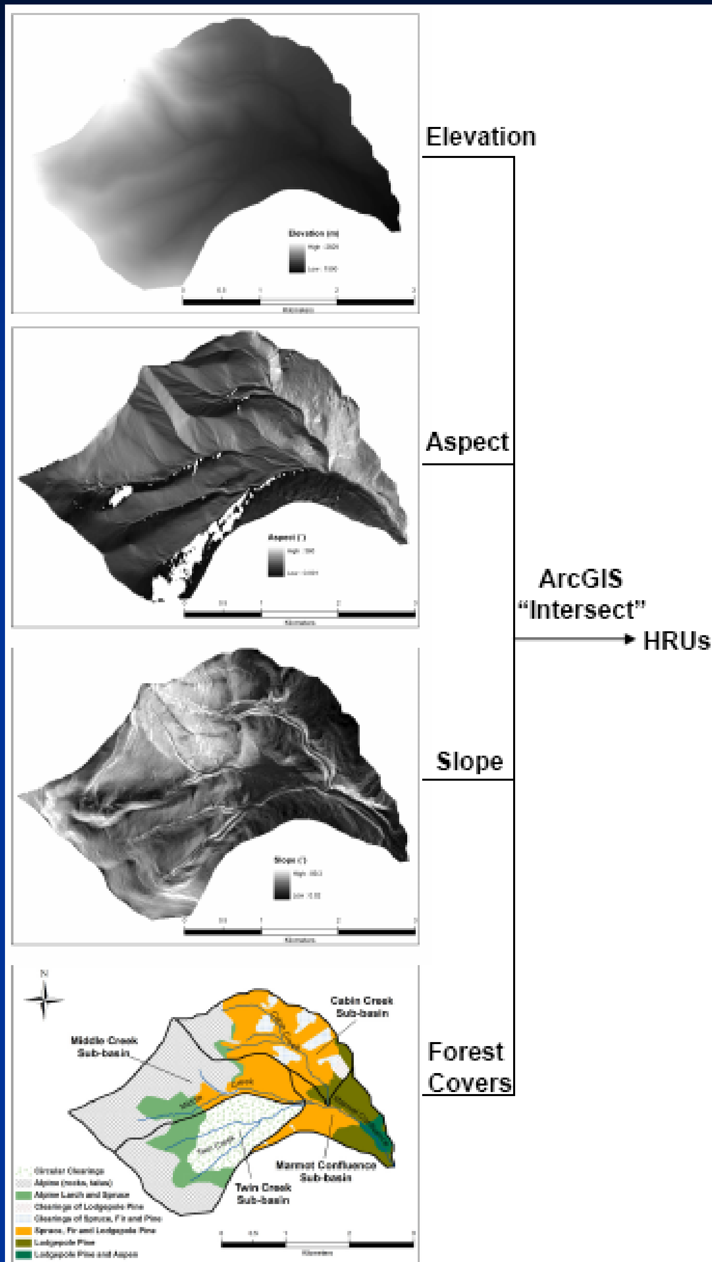


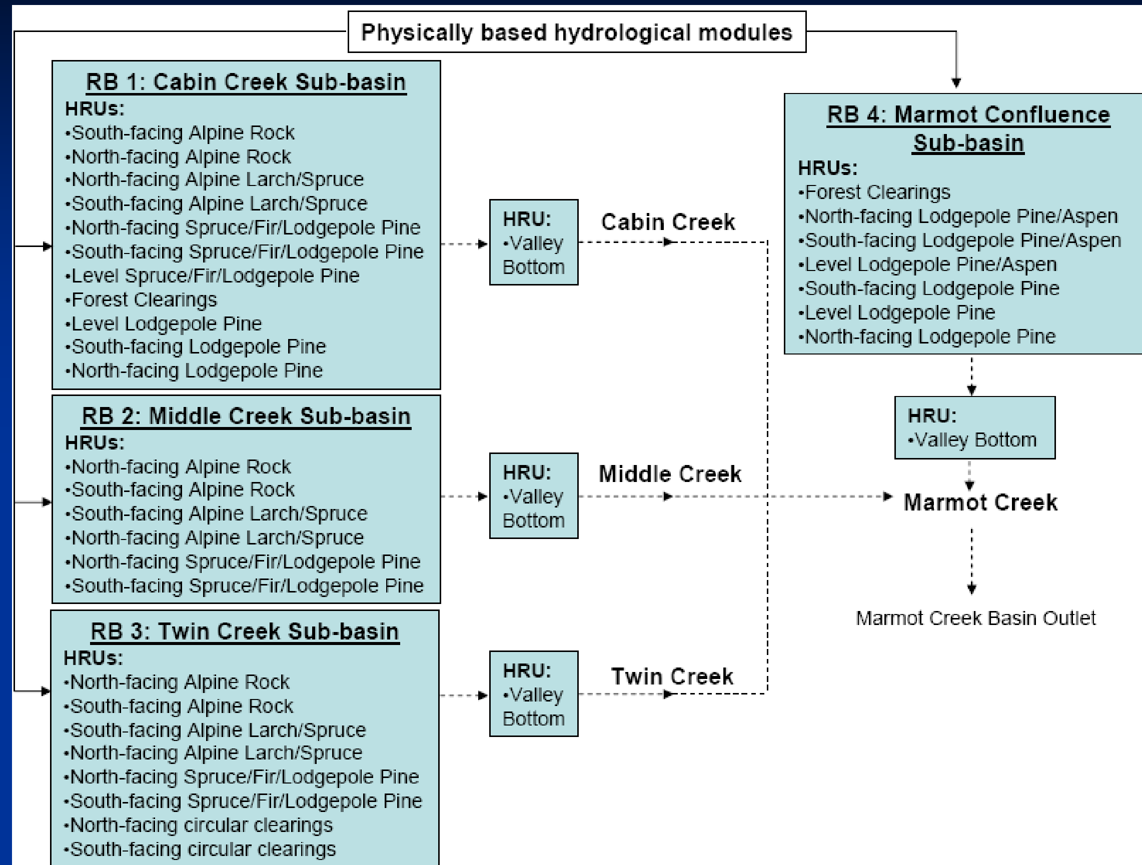
Hillslope Module



(Fang et al., 2013, Hydrol. Earth Syst. Sci.)

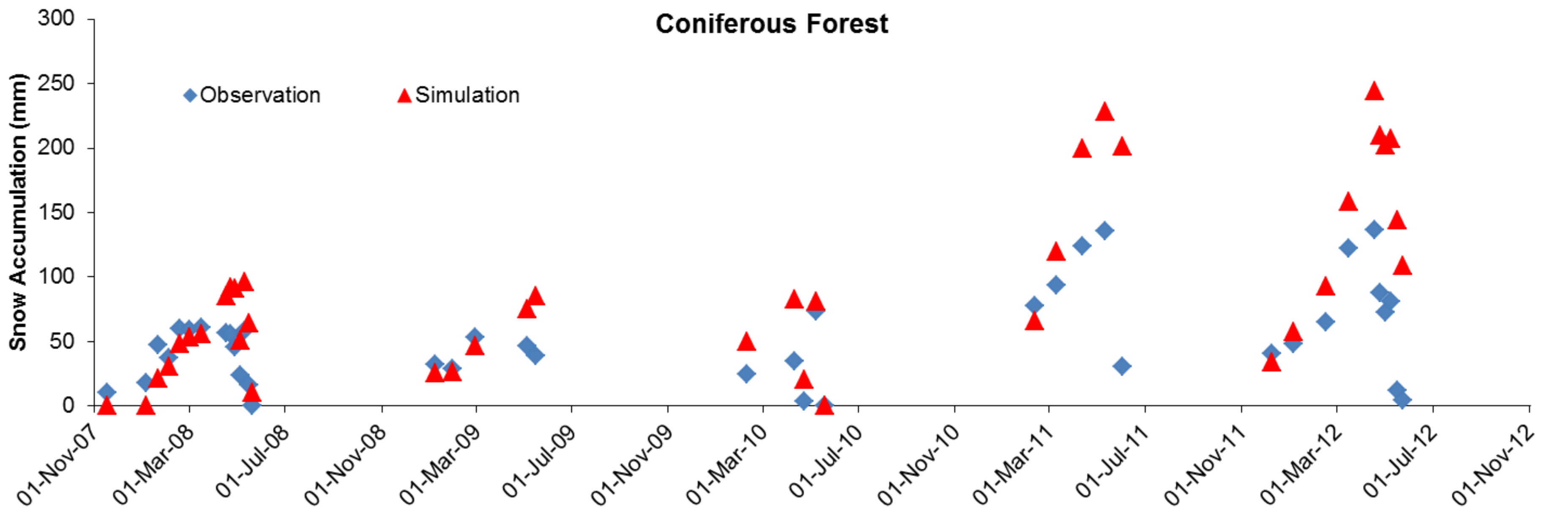
HRU Delineation and Model Structure

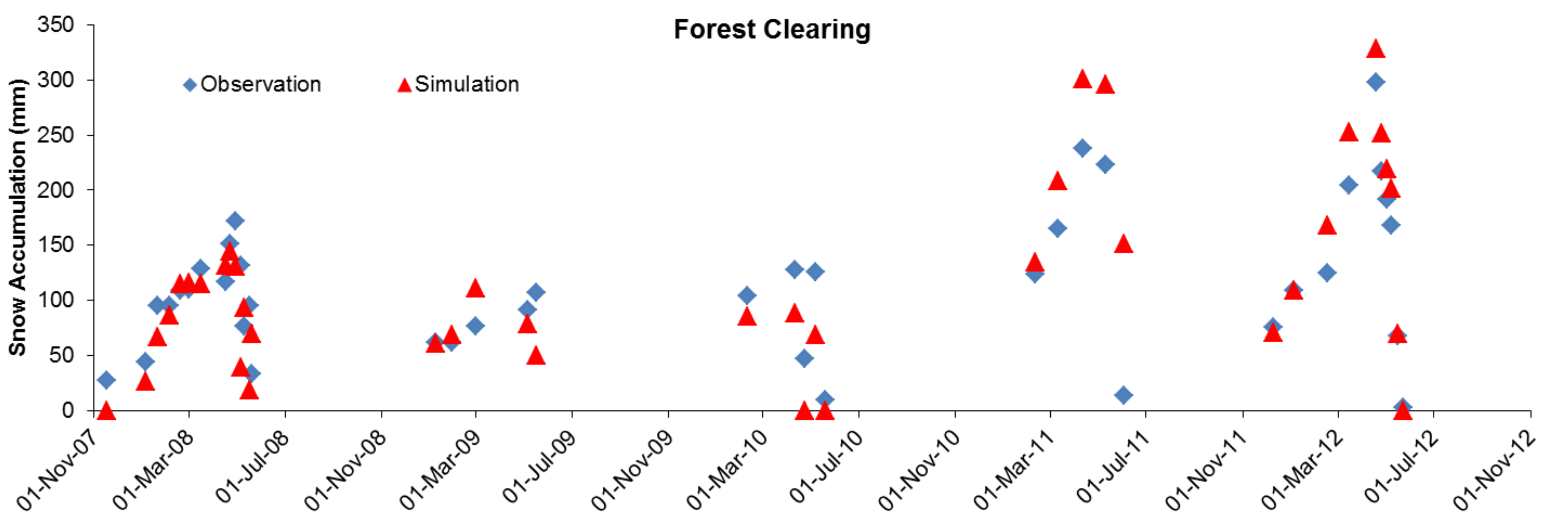




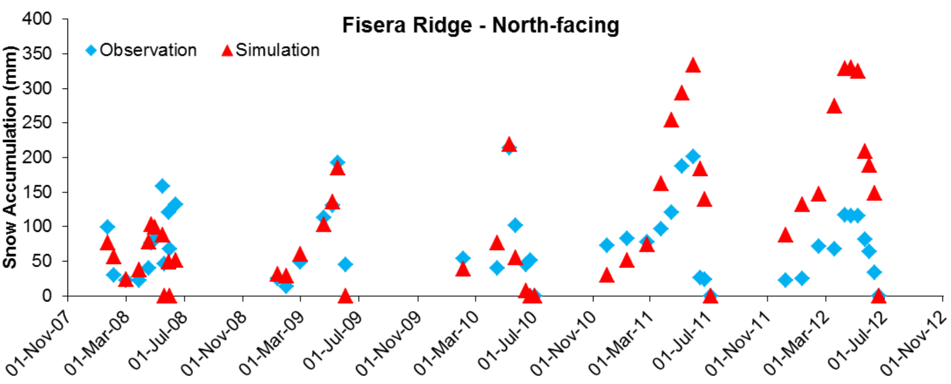
(Fang et al., 2013, Hydrol. Earth Syst. Sci.)

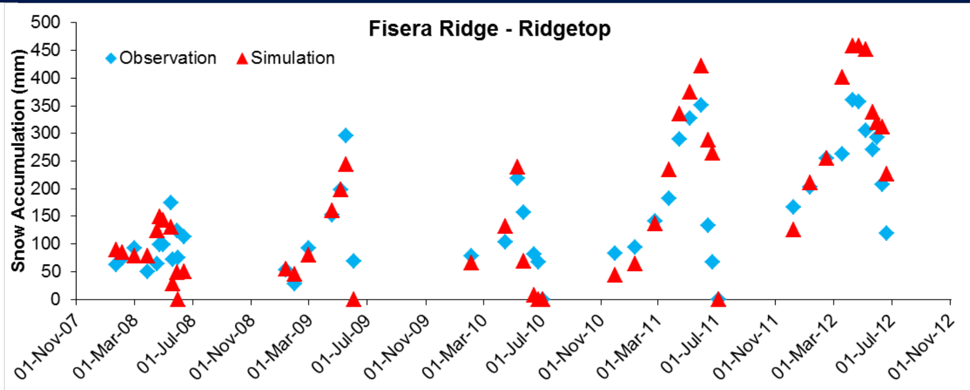
SWE Test (Forest Environment)

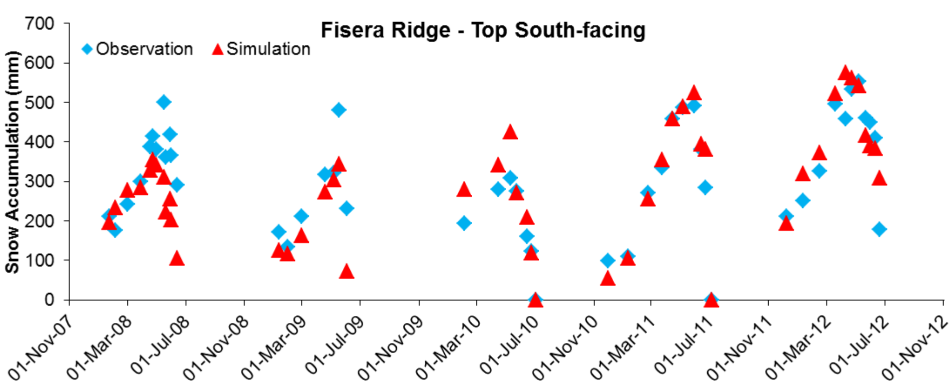


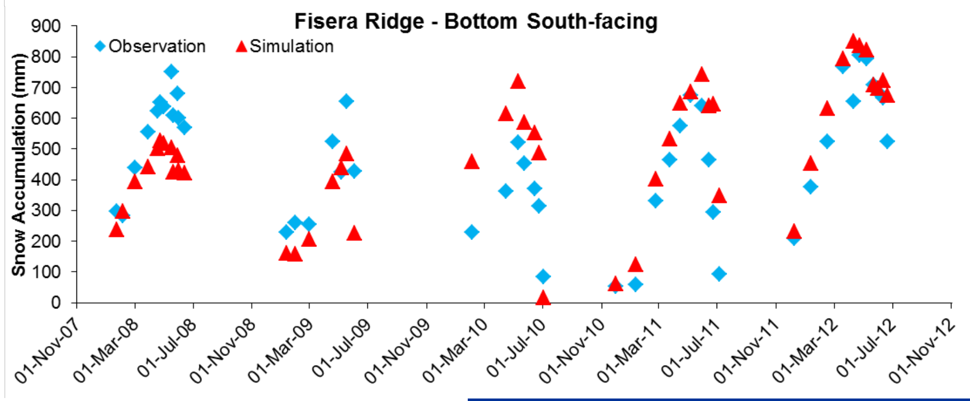


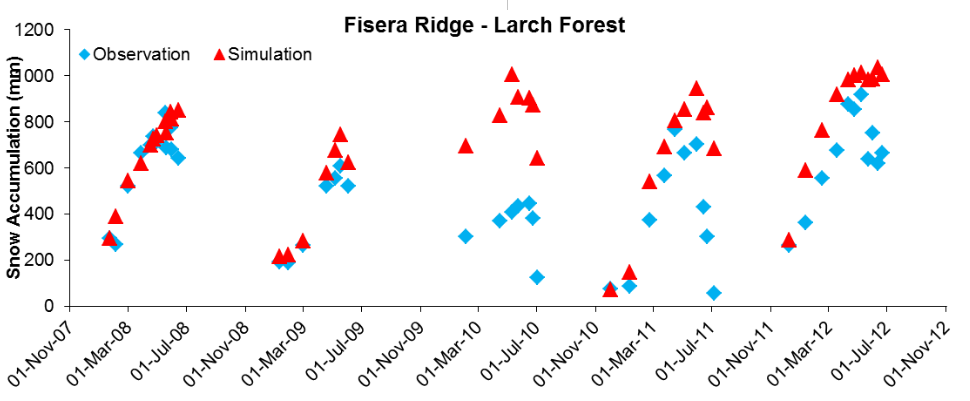
SWE Test (Alpine Environment)







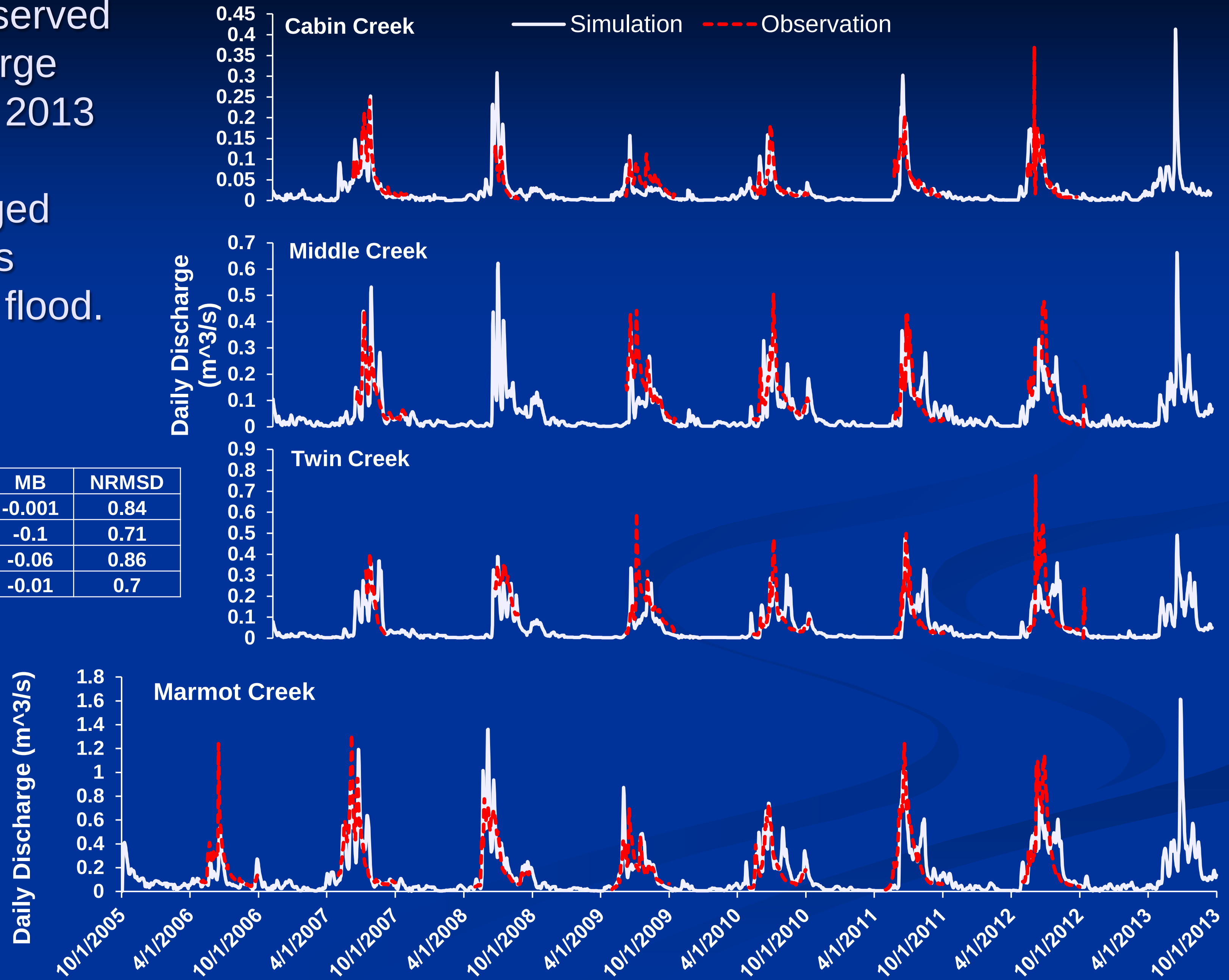




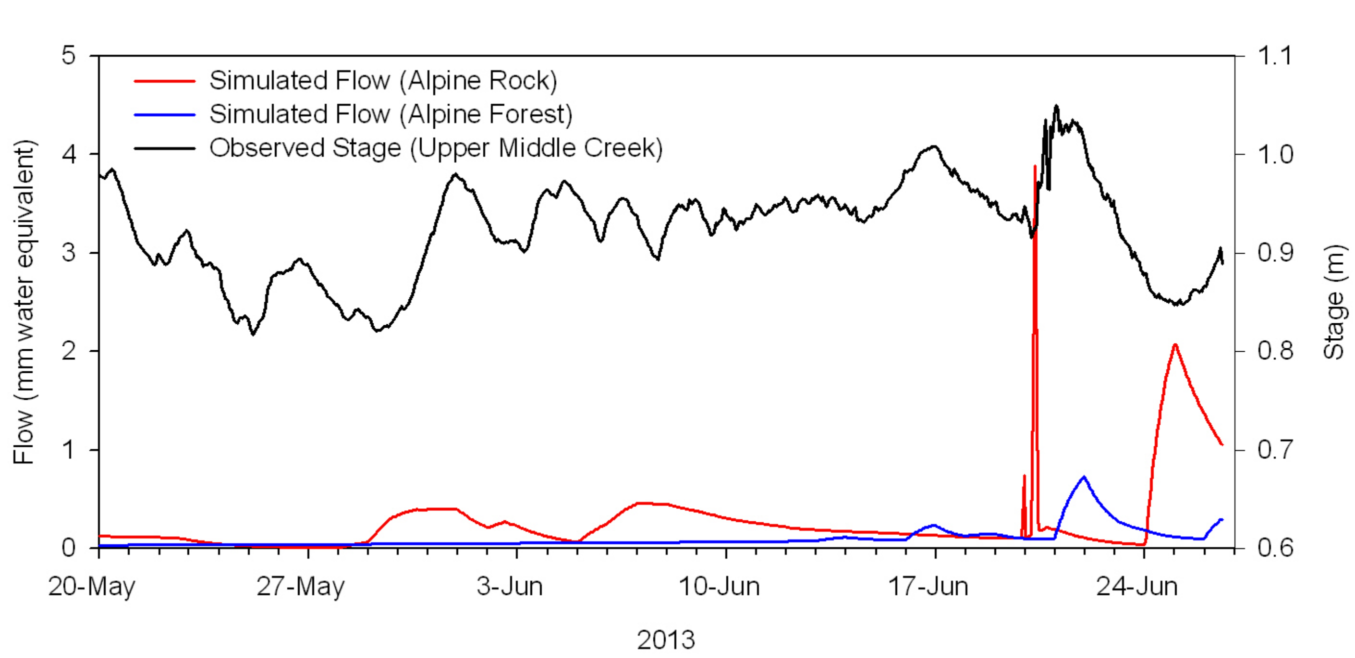
Streamflow Test

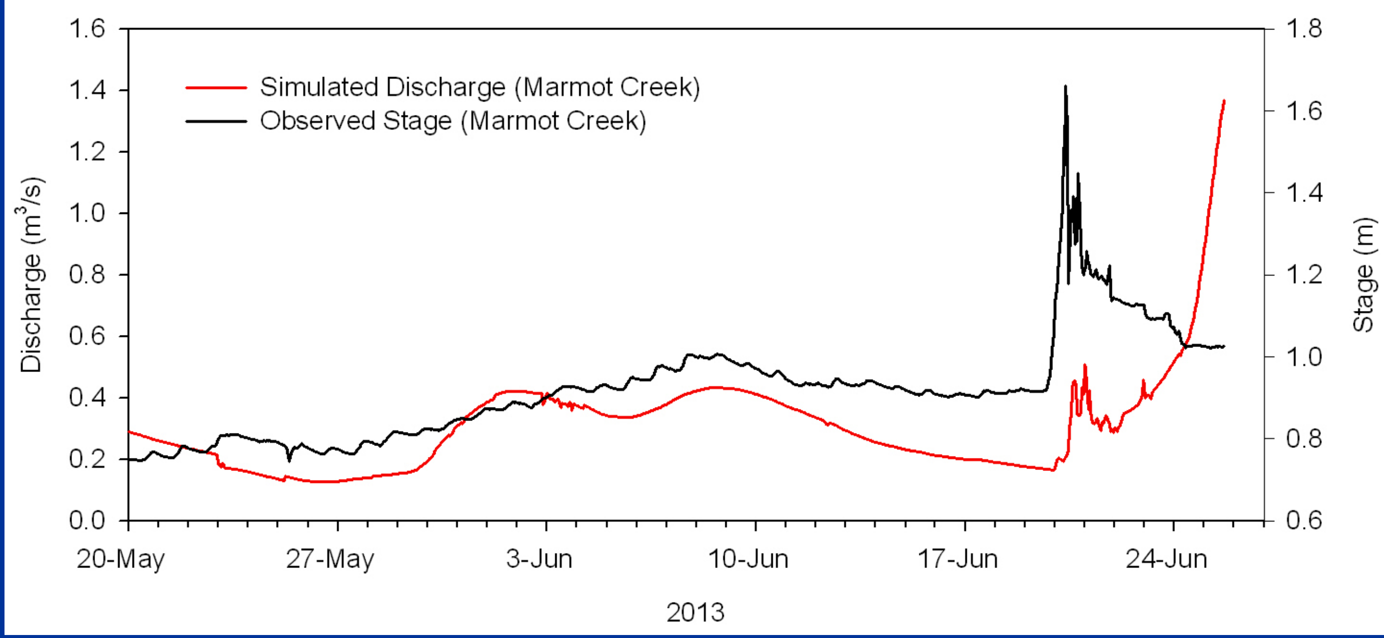
- No observed discharge during 2013 due to damaged gauges during flood.

	NSE	MB	NRMSD
Cabin	0.17	-0.001	0.84
Middle	0.32	-0.1	0.71
Twin	0.1	-0.06	0.86
Marmot	0.47	-0.01	0.7

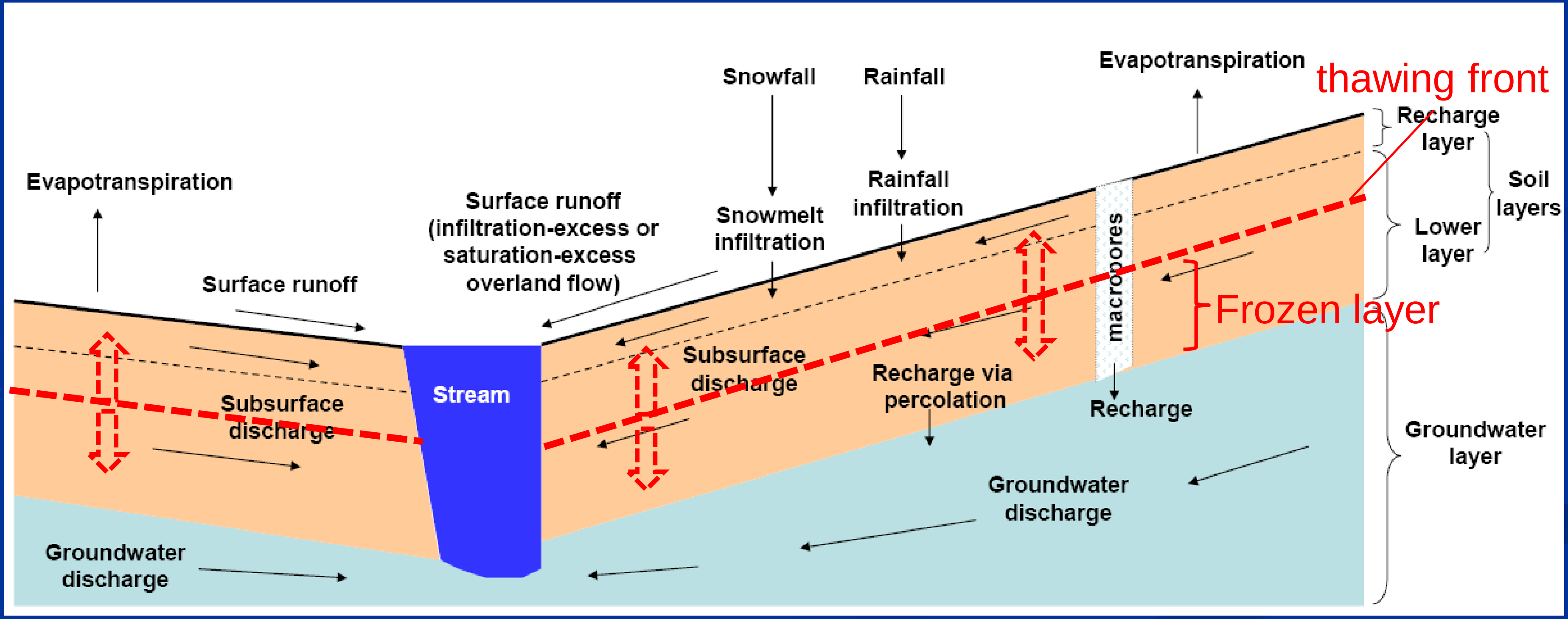


2013 Streamflow Evaluation





- Current model estimates hydraulic conductivities in soil layers but does not consider the impact of freezing on sub-surface water flow.
- Field observations of a thawing front in the sub-surface suggest ground frost restricted soil moisture storage and percolation to groundwater during the flood.
- What's next – revised hillslope module incorporating thaw-freeze algorithm and frost depth dynamics.



Flood Simulations

- Use meteorology of 17-24 June 2013 to carry on “virtual” flood simulations.
- Impose the flood meteorology in the same period in other years: 2006 to 2012 and in different months of 2013 from May to July.

17-24 June 2013
flood meteorology

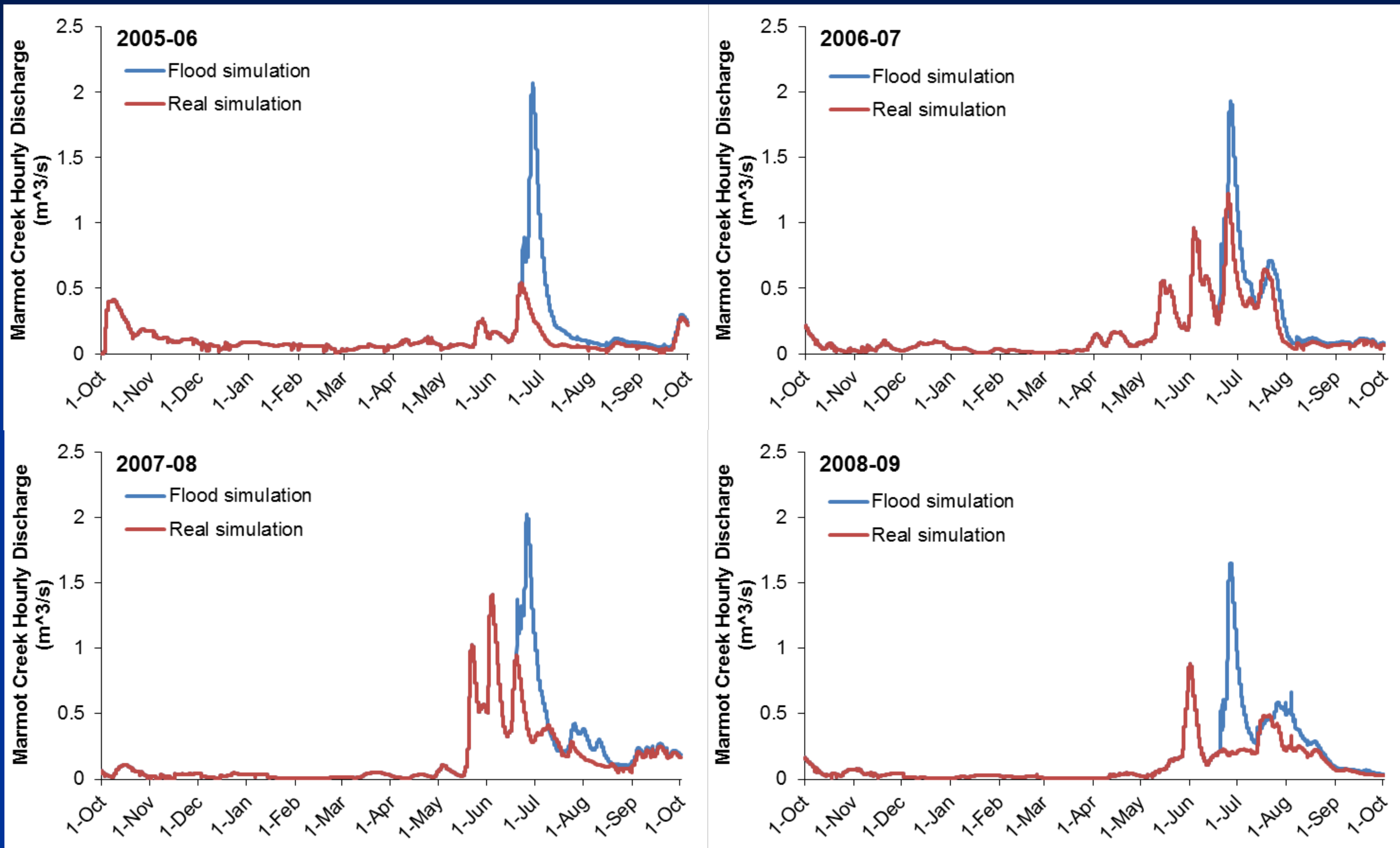
17-24 June
meteorology in

2006
2007
2008
2009
2010
2011
2012

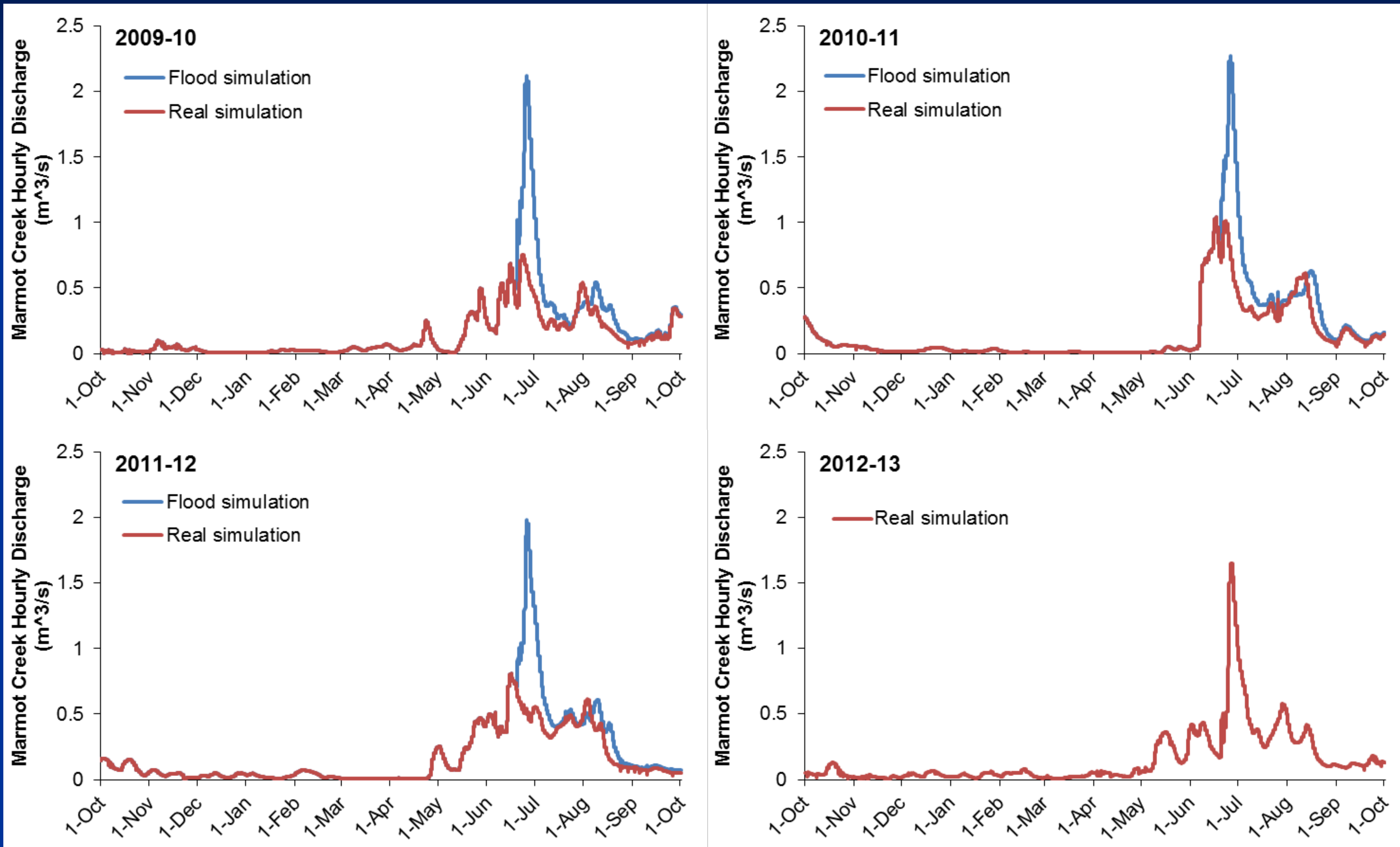
meteorology in

Early May: 6-13 May 2013
Late May: 20-27 May 2013
Early June: 3-10 June 2013
Early July: 8-15 July 2013
Late July: 22-29 July 2013

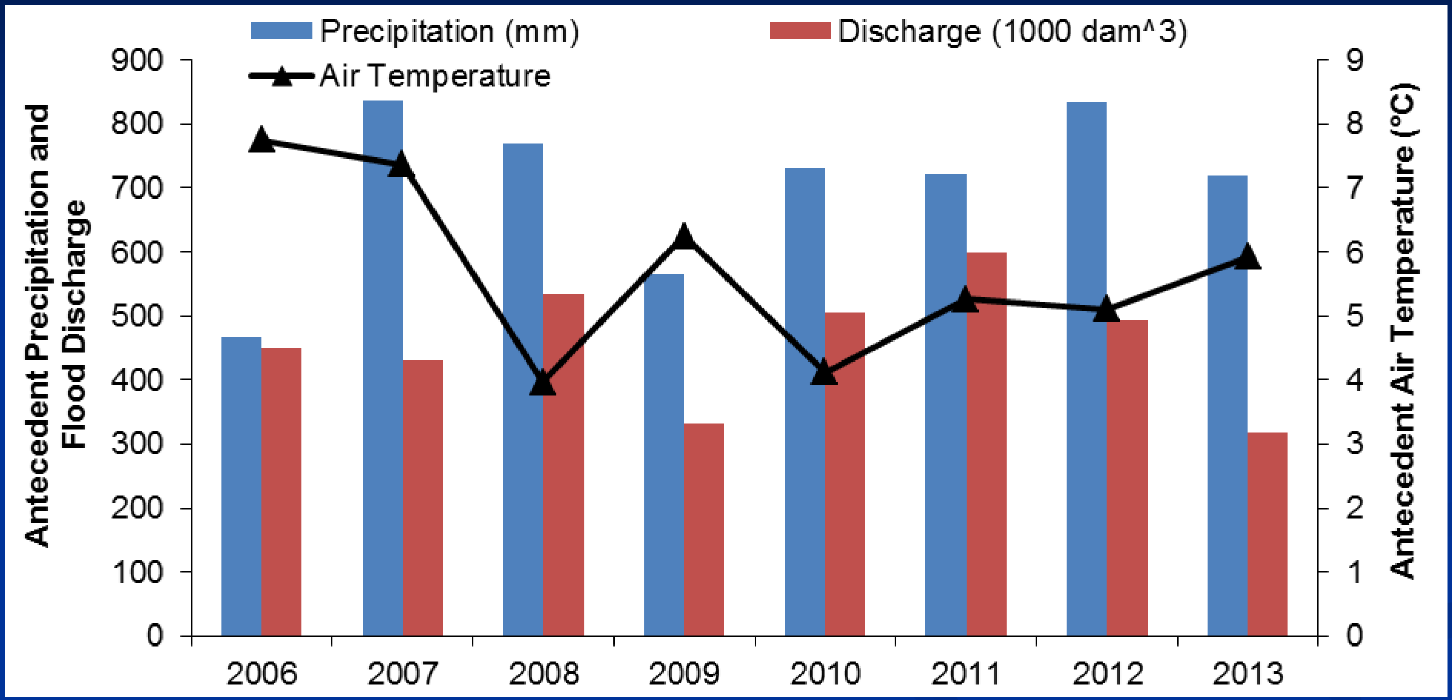
Flood Simulations – same time, different years



Flood Simulations – same time, different years

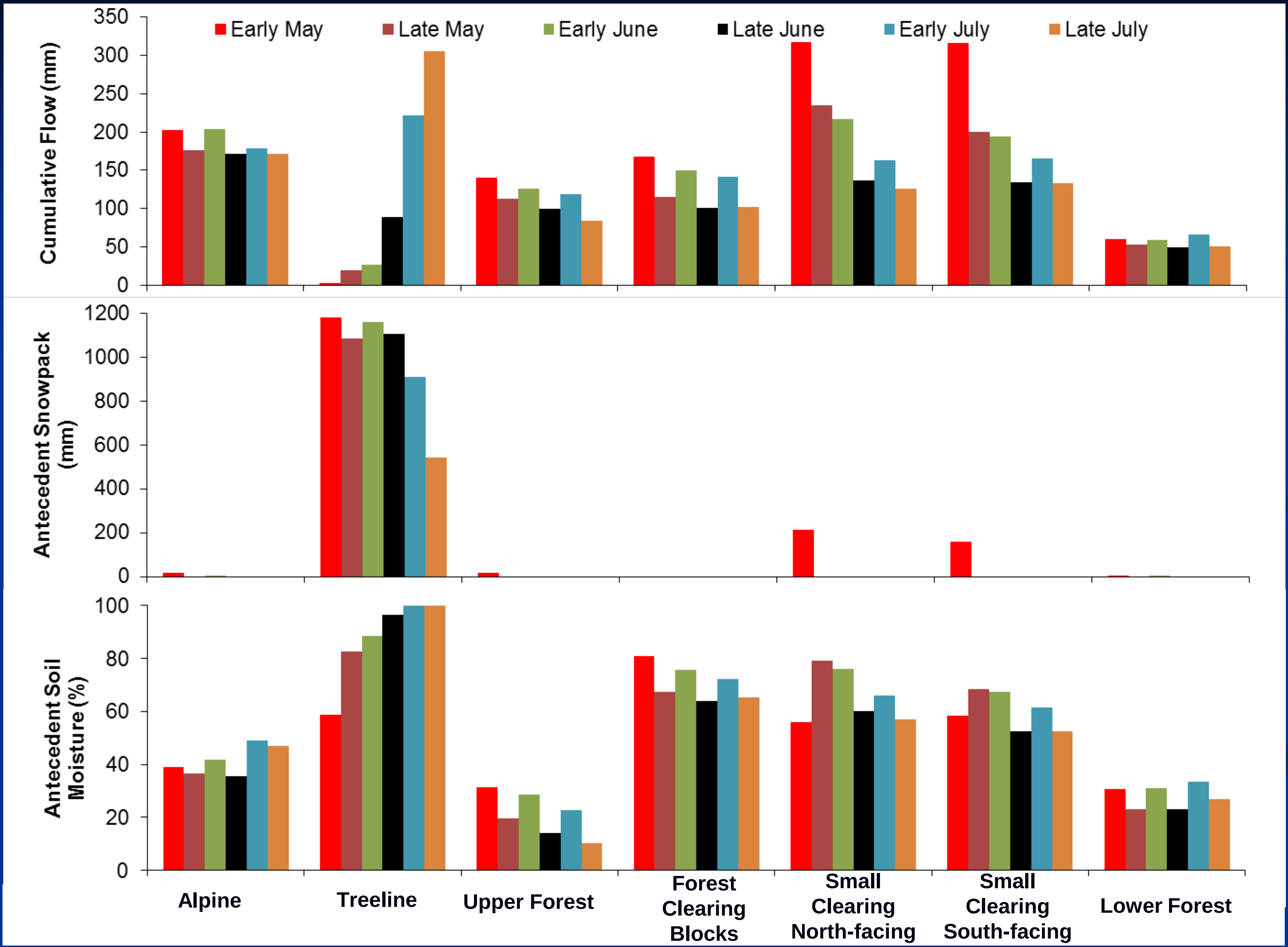


Flood Simulations – antecedent conditions

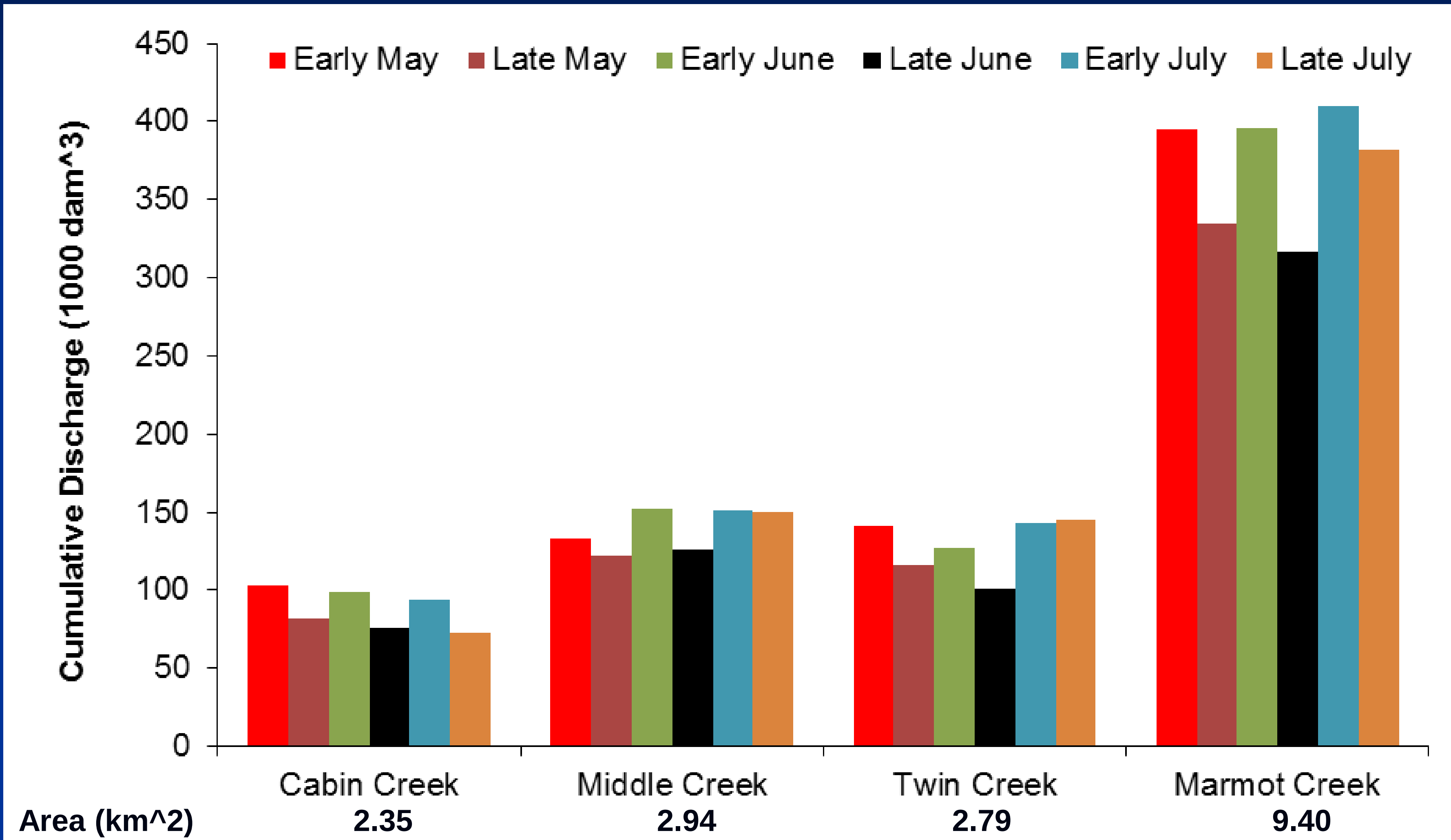


- Antecedent precipitation: total precipitation from beginning of hydrological year to onset of flood, i.e. 1 October to 16 June
- Antecedent air temperature: average temperature in June to onset of flood, i.e. 1 June to 16 June
- Flood discharge: total discharge as result of the flood meteorology of 17-24 June 2013

Flood Simulations – different months in 2013



Flood Simulations – different months in 2013



Conclusions

- A hydrological model was set up without calibration in CRHM to simulate the hydrological cycle at Marmot Creek Research Basin in the Canadian Rockies.
- Model showed relatively good performance for snow accumulation and streamflow for non-flooding years; no direct comparison during flooding year but records of stage suggest modelled peak streamflow was lagged behind actual flows.
- Current hillslope module needs to incorporate thermal conditions of soil and thaw-freeze dynamics to improve subsurface flow and basin streamflow simulations.
- “Virtual flood” simulations show modelled streamflow is sensitive to antecedent conditions of snowpack, soil moisture and forest covers at various elevations.
- Runoff generation “hotspots” develop early in summer in forest clearings and later in summer at treelines when large rainfall volumes are imposed on the basin.
- Model simulations suggest that late June is a relatively inefficient time of year to generate high streamflow from Marmot Creek.

Acknowledgements

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