

Regional patterns of evolving glacio-hydrologic processes in the Pacific Northwest

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Acknowledgements

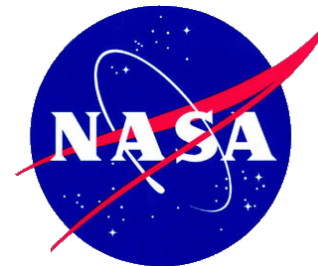
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Dennis Lettenmaier (UW, UCLA)



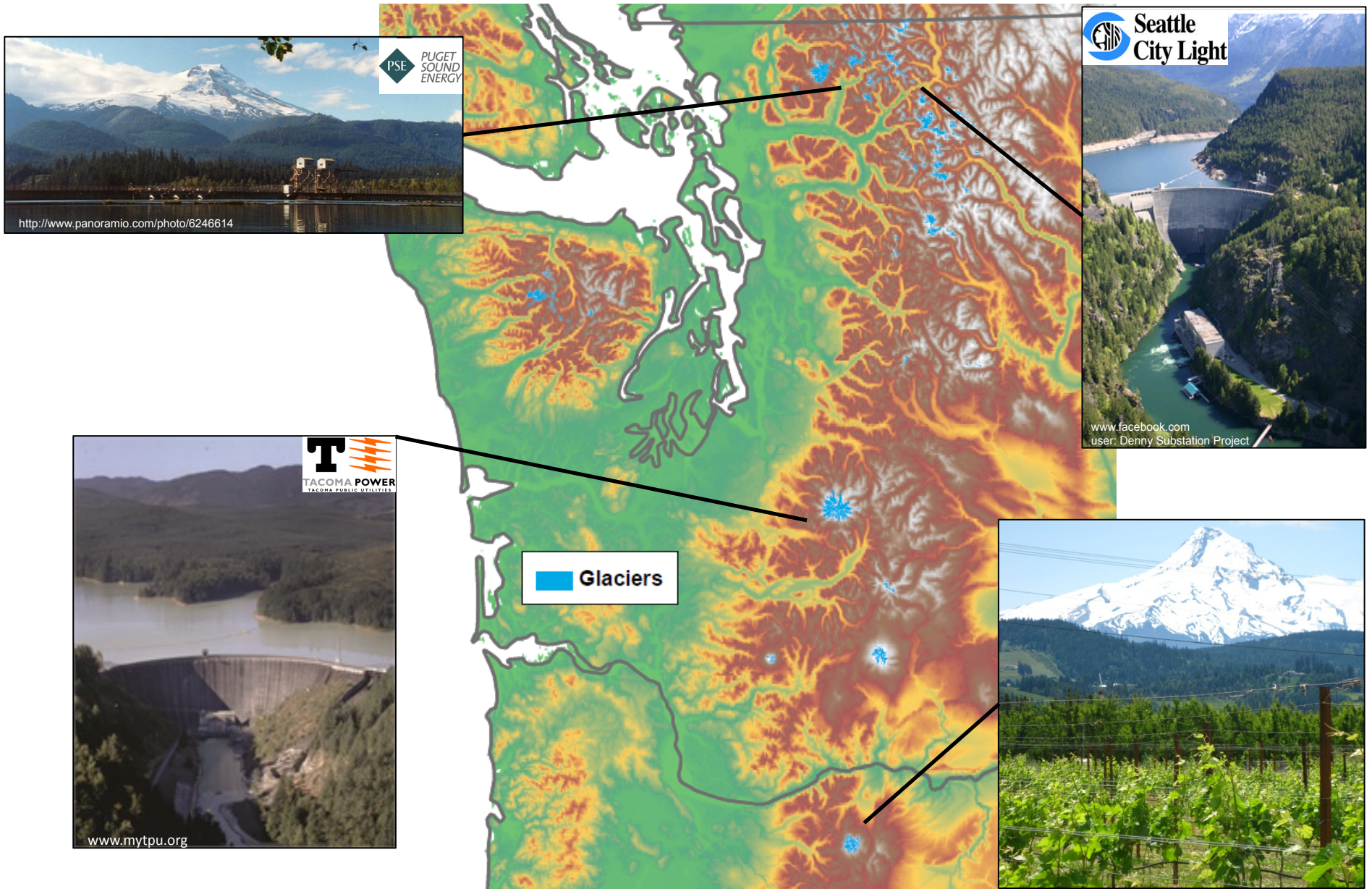
Garry Clarke (UBC)
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Christina Bandaragoda (UW)
Andrew Fountain (PSU)
Matthew Bachmann (USGS)
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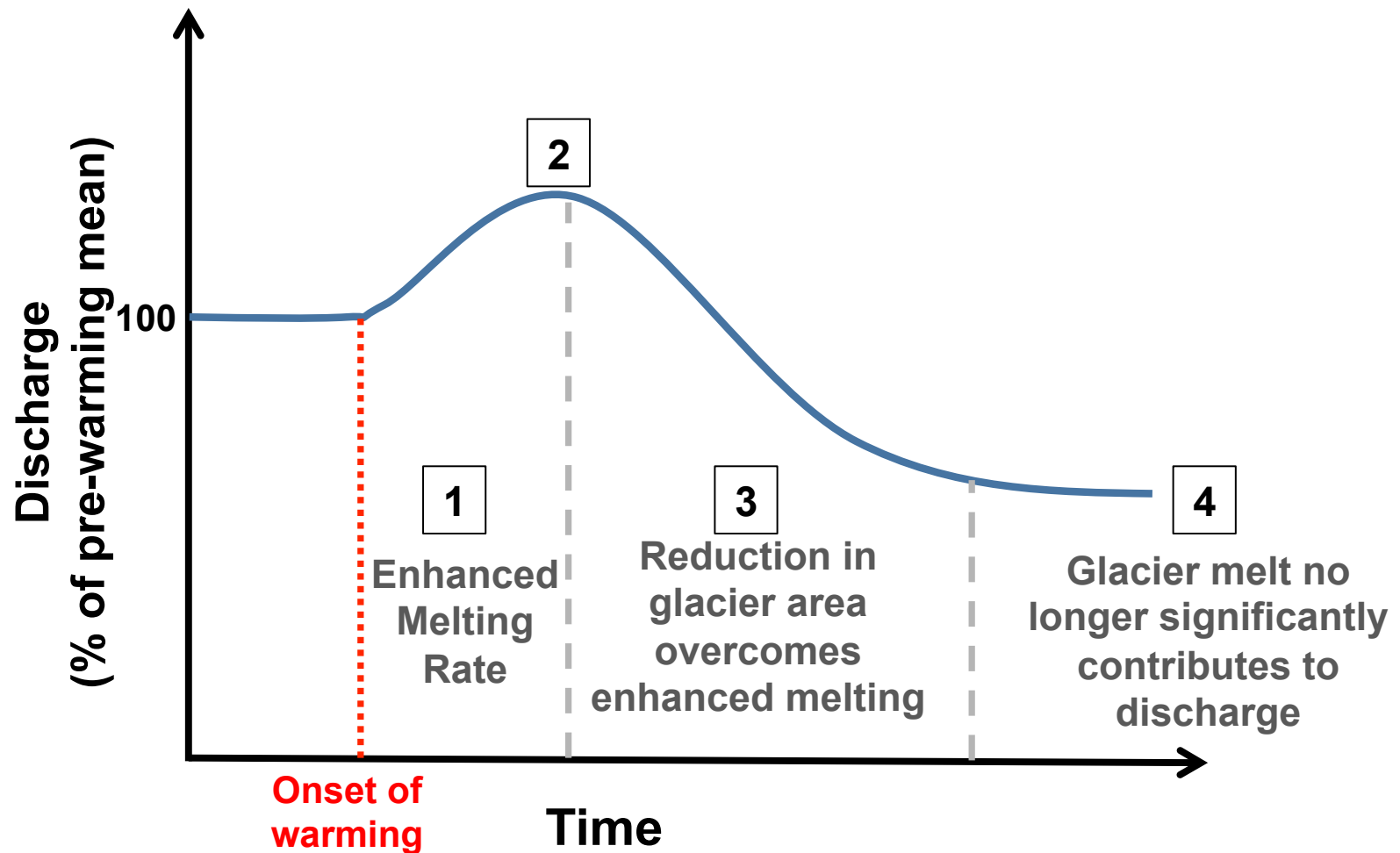
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Glacier Recssion and Downstream Risks: Water Management

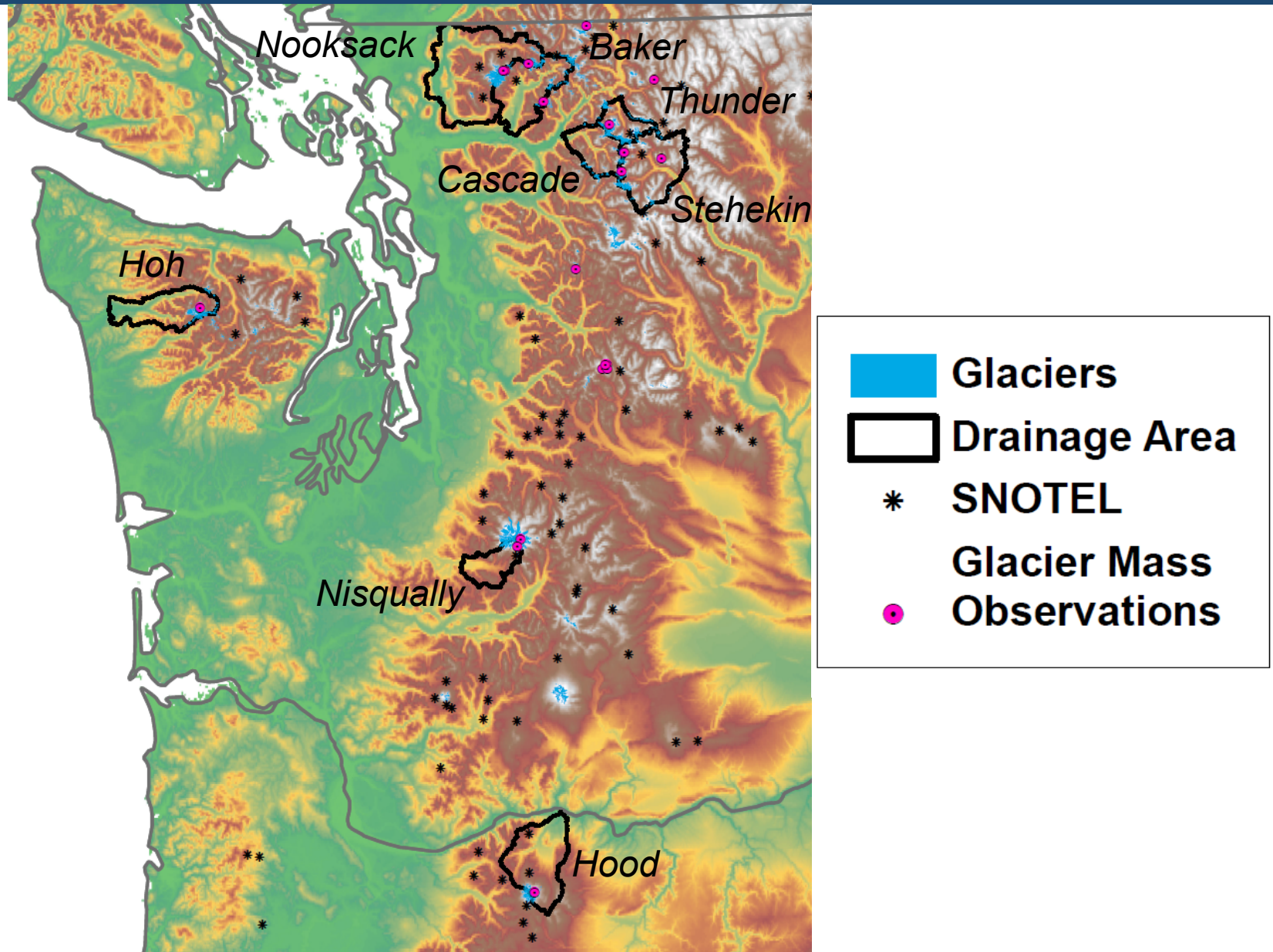


Hydrologic Response to Glacier Recession



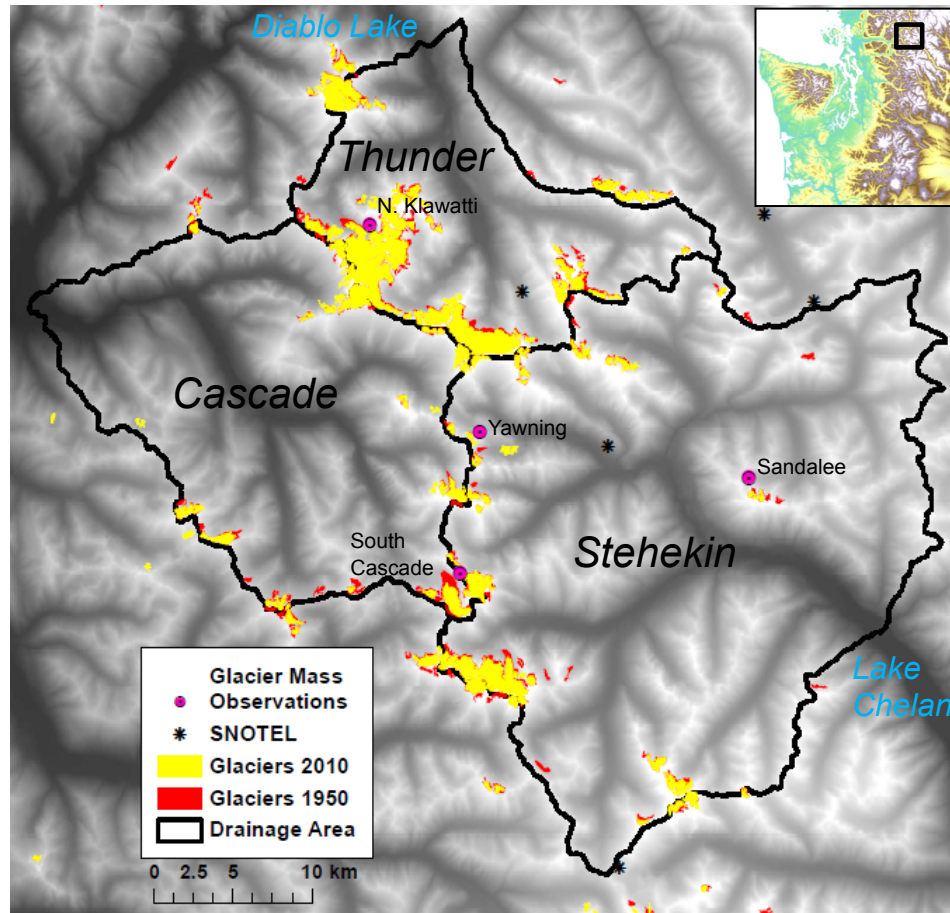
Phases of Hydrologic Response to persistent glacier recession

Sample of Partially Glacierized PNW Watersheds

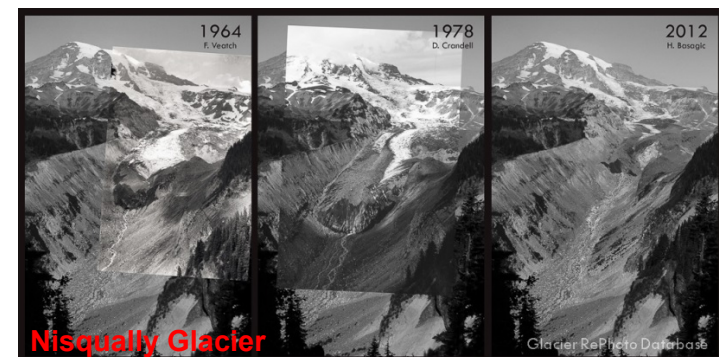
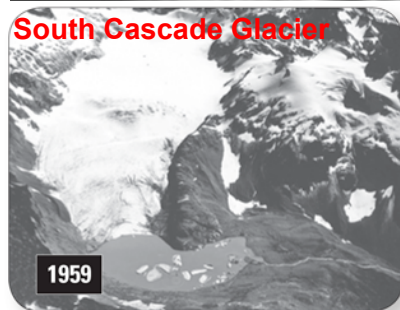
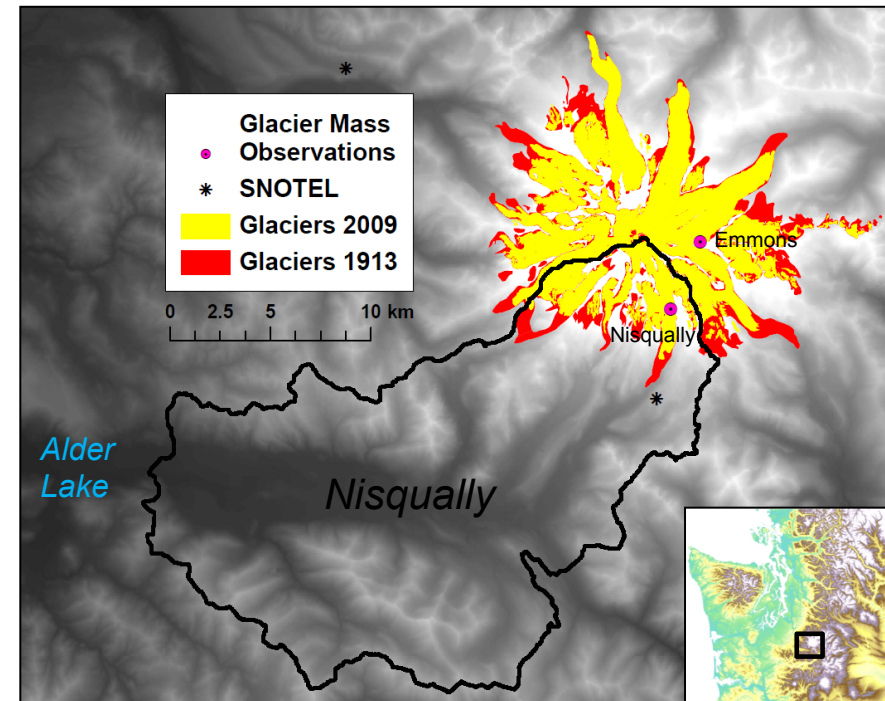


Partially Glacierized PNW Watersheds

North Cascades



Mount Rainier

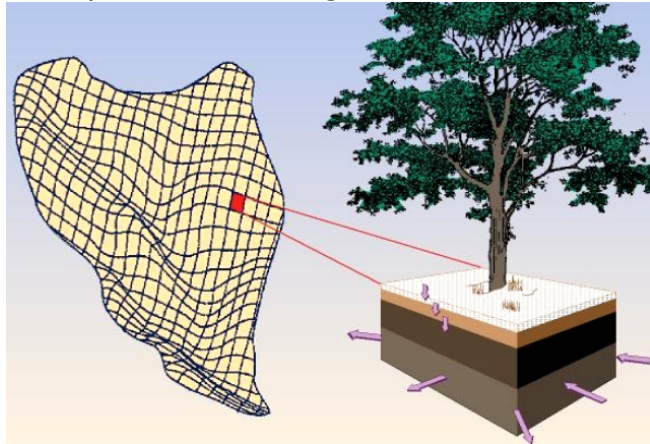


Glacier Extent Data Sources: North Cascades ~1950, Andrew Fountain; North Cascades 2010, Landsat Imagery; Mount Rainier 1913/2009, Andrew Fountain

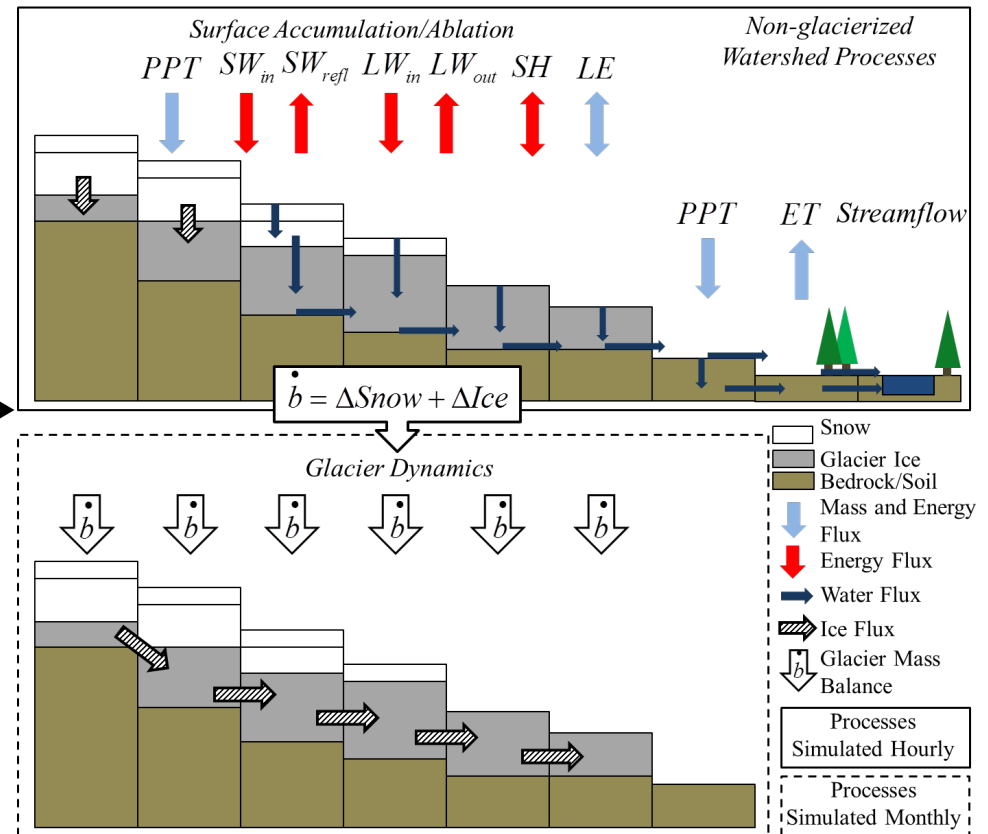
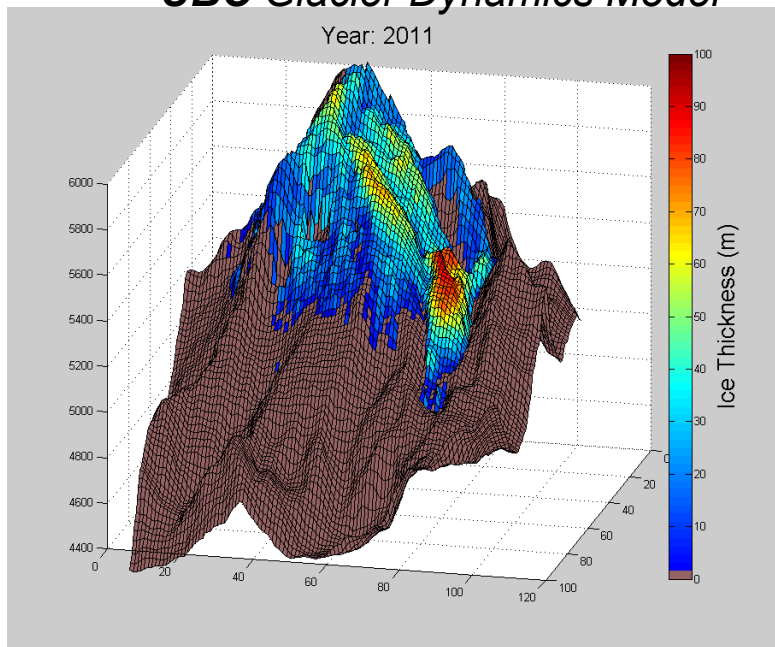
<http://pubs.usgs.gov/fs/2009/3046/>

Coupled Glacio-Hydrological Modeling [Naz et al. 2014]

Distributed Hydrology Soil Vegetation Model (DHSVM, Wigmosta et al. 1994)



UBC Glacier Dynamics Model

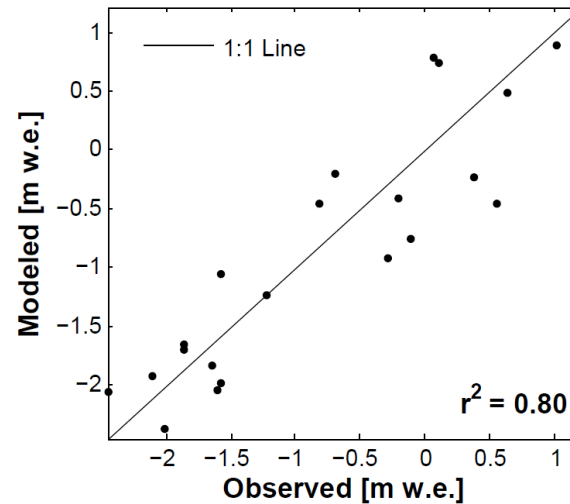


Representation of ice flow is required to evolve glacier area over long time scales which is essential for the projection of low flows in partially glacierized watersheds

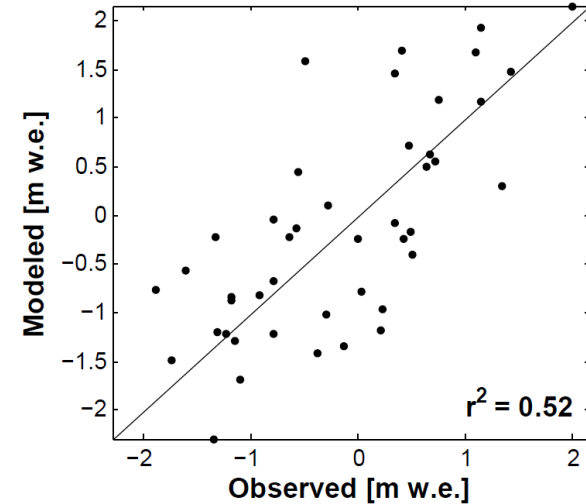
Constraining Modeling with Observations

Glacier Mass

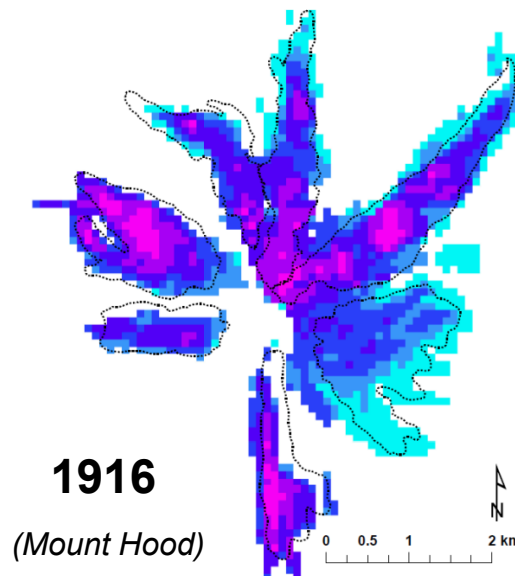
South Cascade Glacier (Cascade):
Annual Net Balance 1991–2011



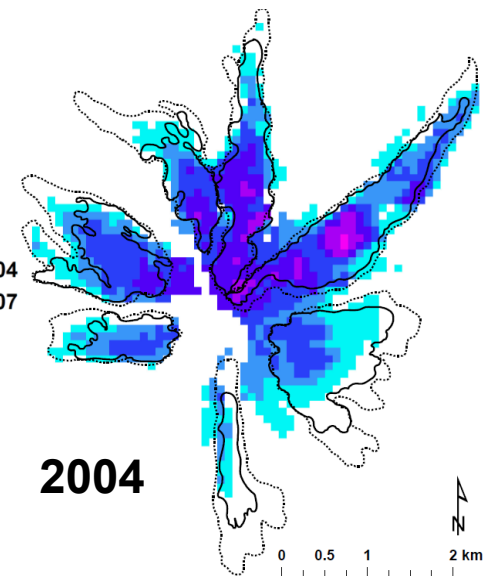
Blue Glacier (Hoh):
Annual Net Balance 1956–1999



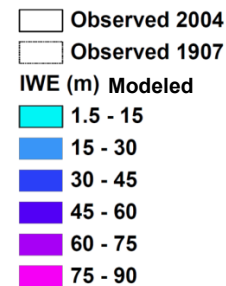
Glacier Area



1916
(Mount Hood)

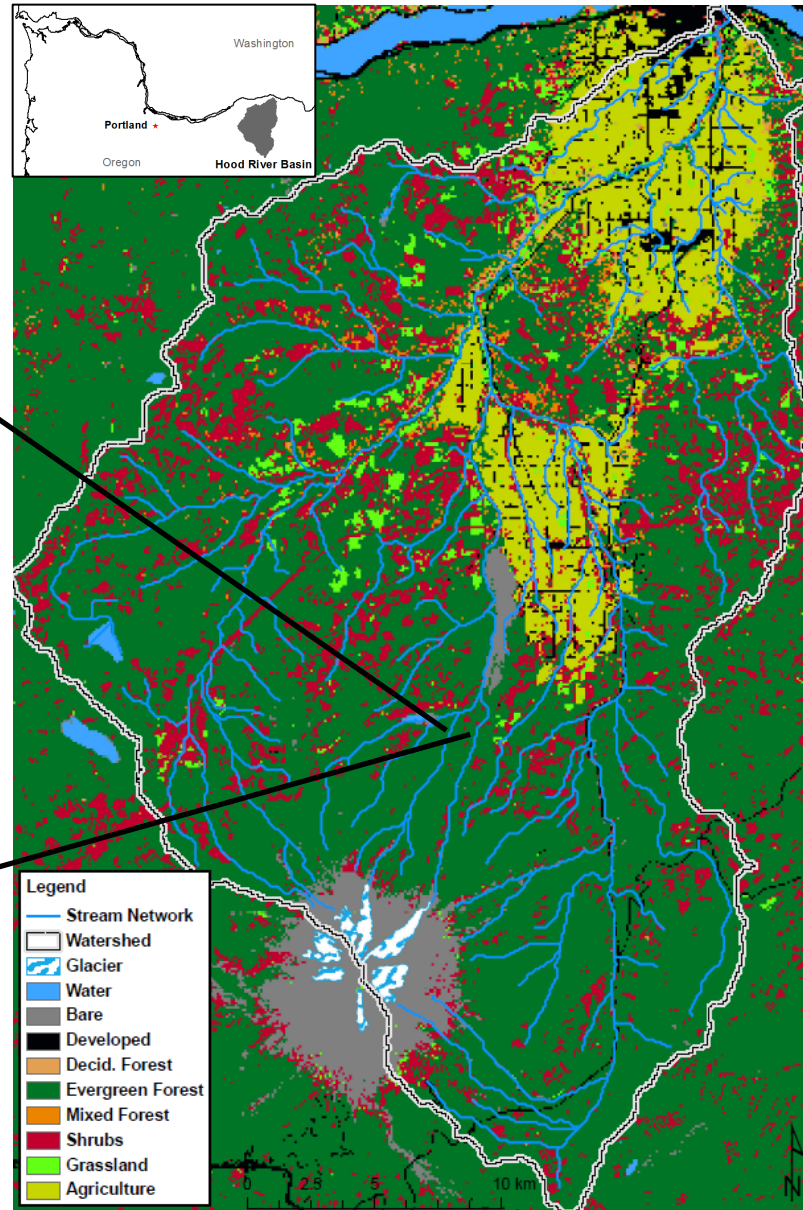
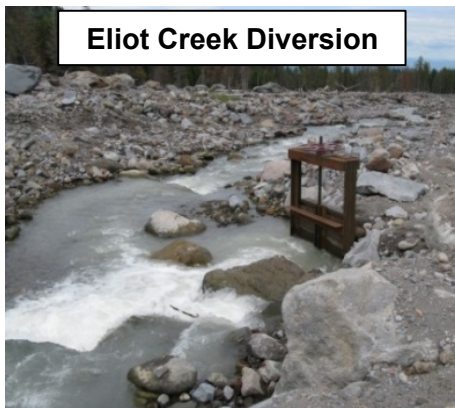


2004

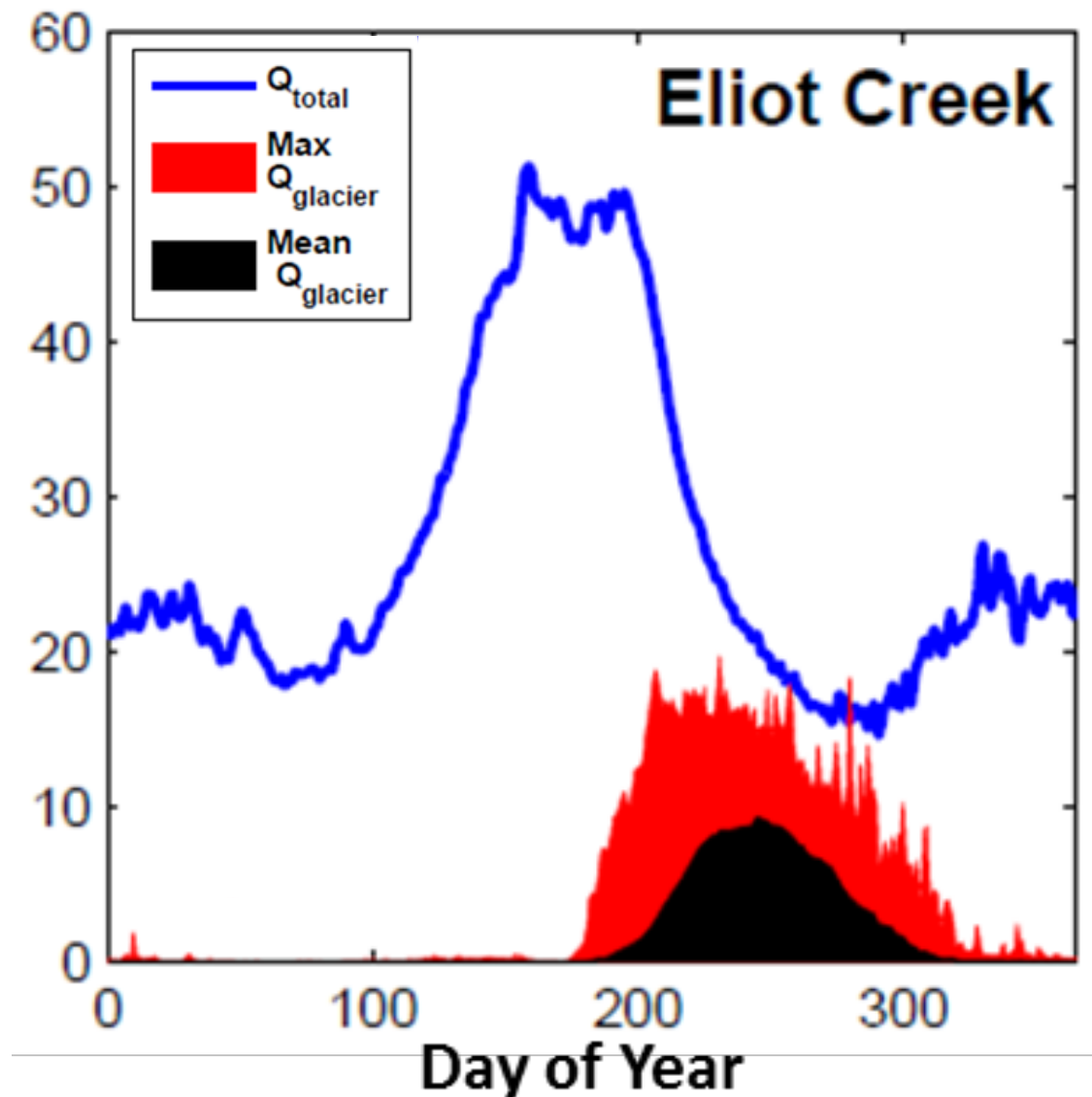


Data Sources: South Cascade Glacier, USGS; Blue Glacier, UW ESS; Mount Hood, Jackson and Fountain (2007)

Model Application: Hood River, Oregon



Hood River: Historical Analysis (1916-2010)

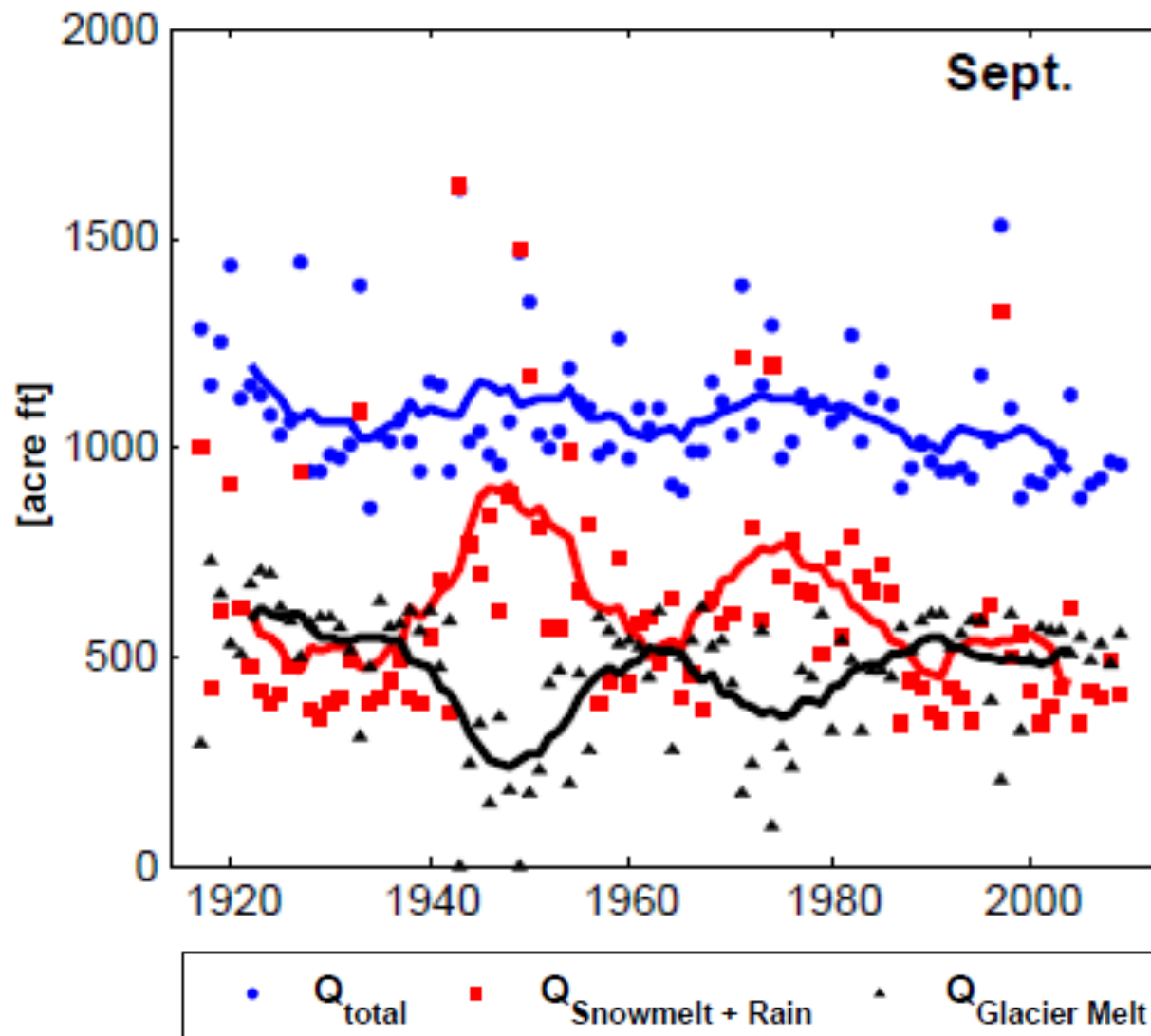


**Mean Annual Daily
Maximum Contribution:
49%**

**Maximum Daily
Contribution:
77%**

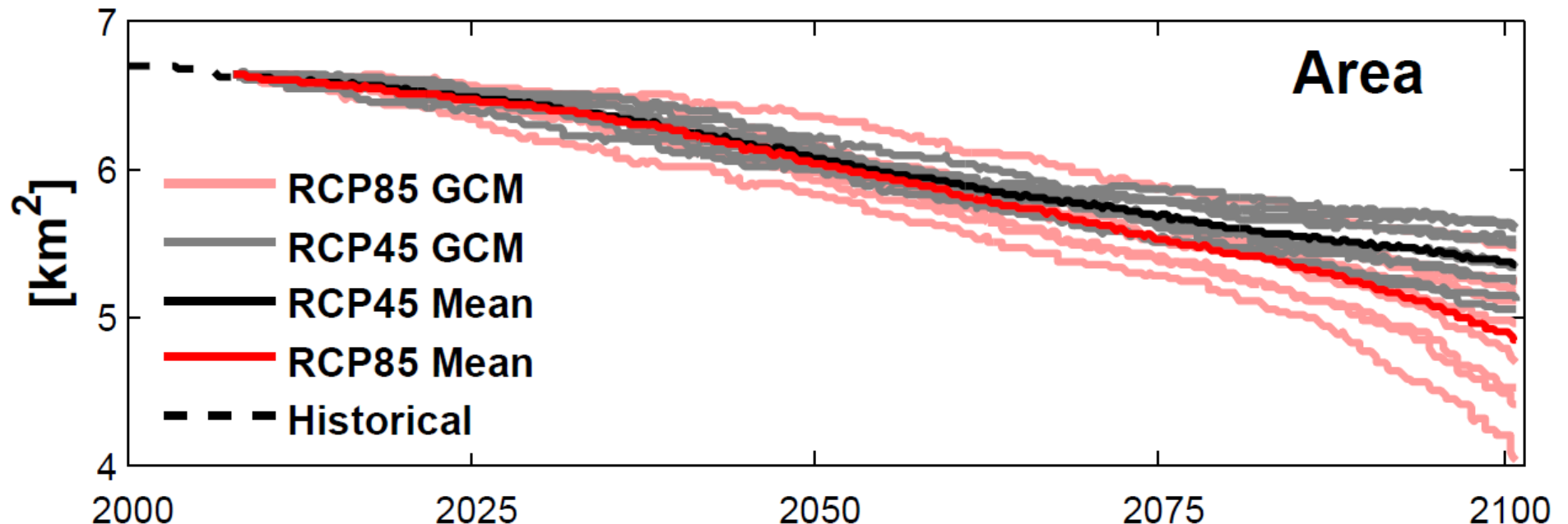
Hood River: Historical Analysis (1916-2010)

Modeled Eliot Creek September Discharge Volume



Hood River: Future Projections

Future simulations are forced with projections of 10 GCMs for two emissions scenarios (RCP4.5, RCP8.5) downscaled using the MACA methodology as part of the *Integrated Scenarios of the Future Northwest Environment* project (NWCSC, CIRC).

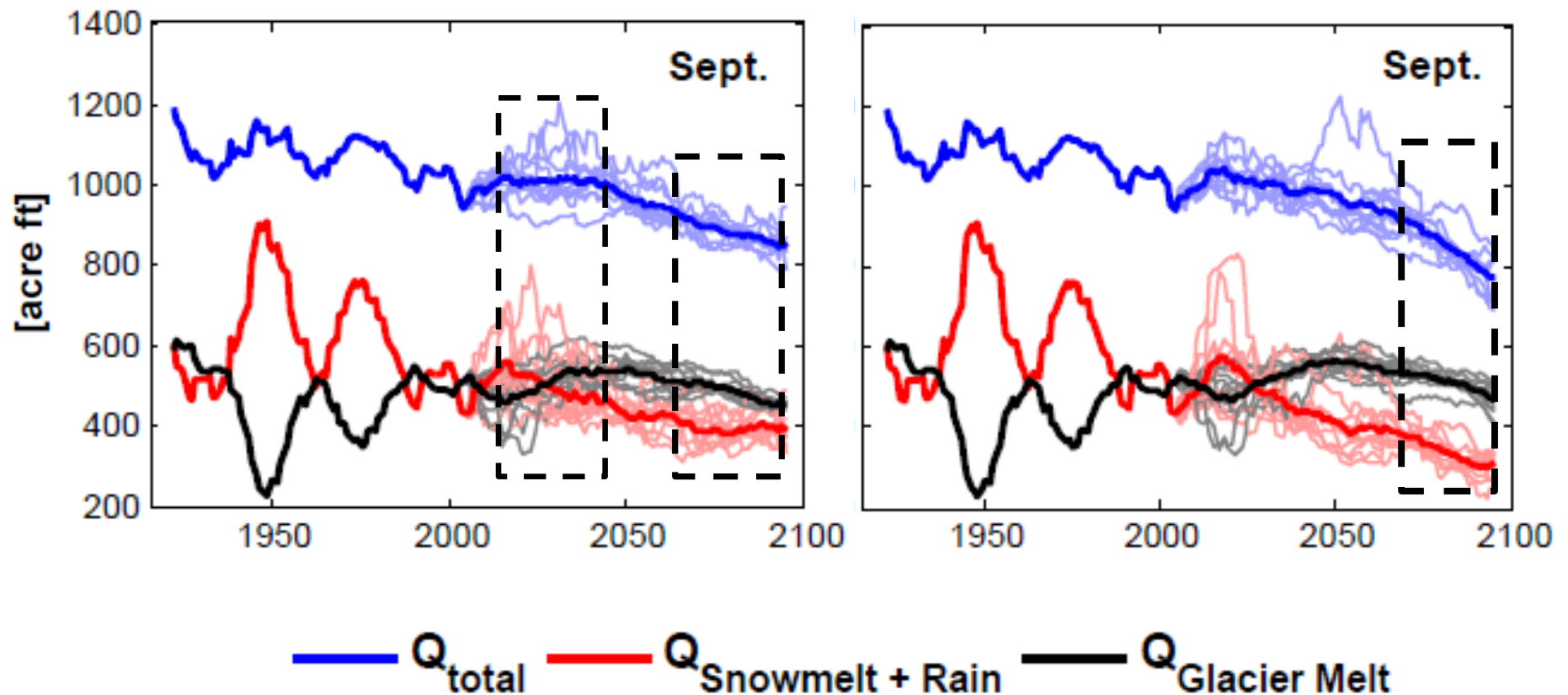


$\Delta Area$: 15-24% (RCP4.5) 18-40% (RCP8.5)

Hood River: Future Projections

RCP4.5

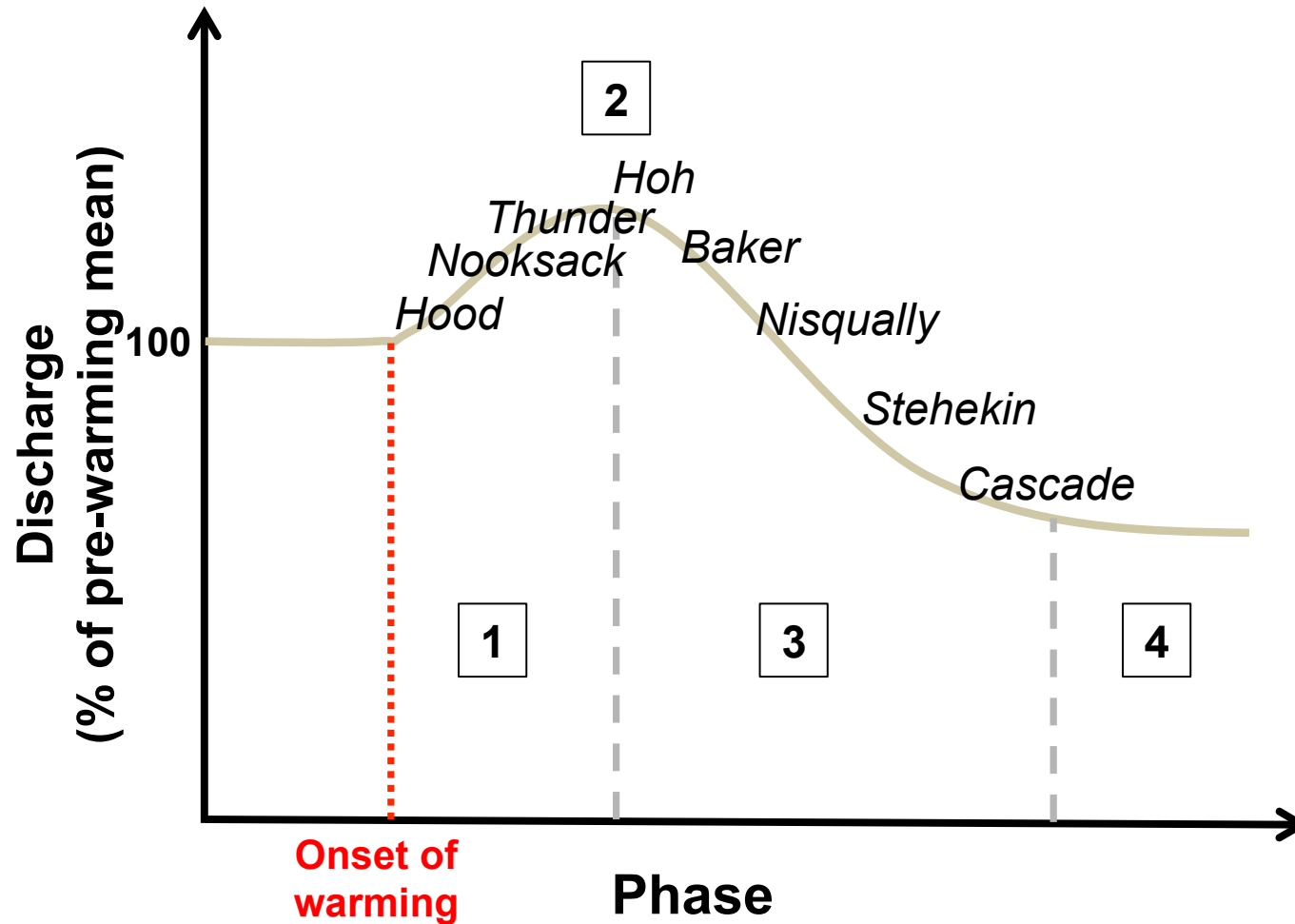
RCP8.5



*Individual GCM data represents 10-yr running mean

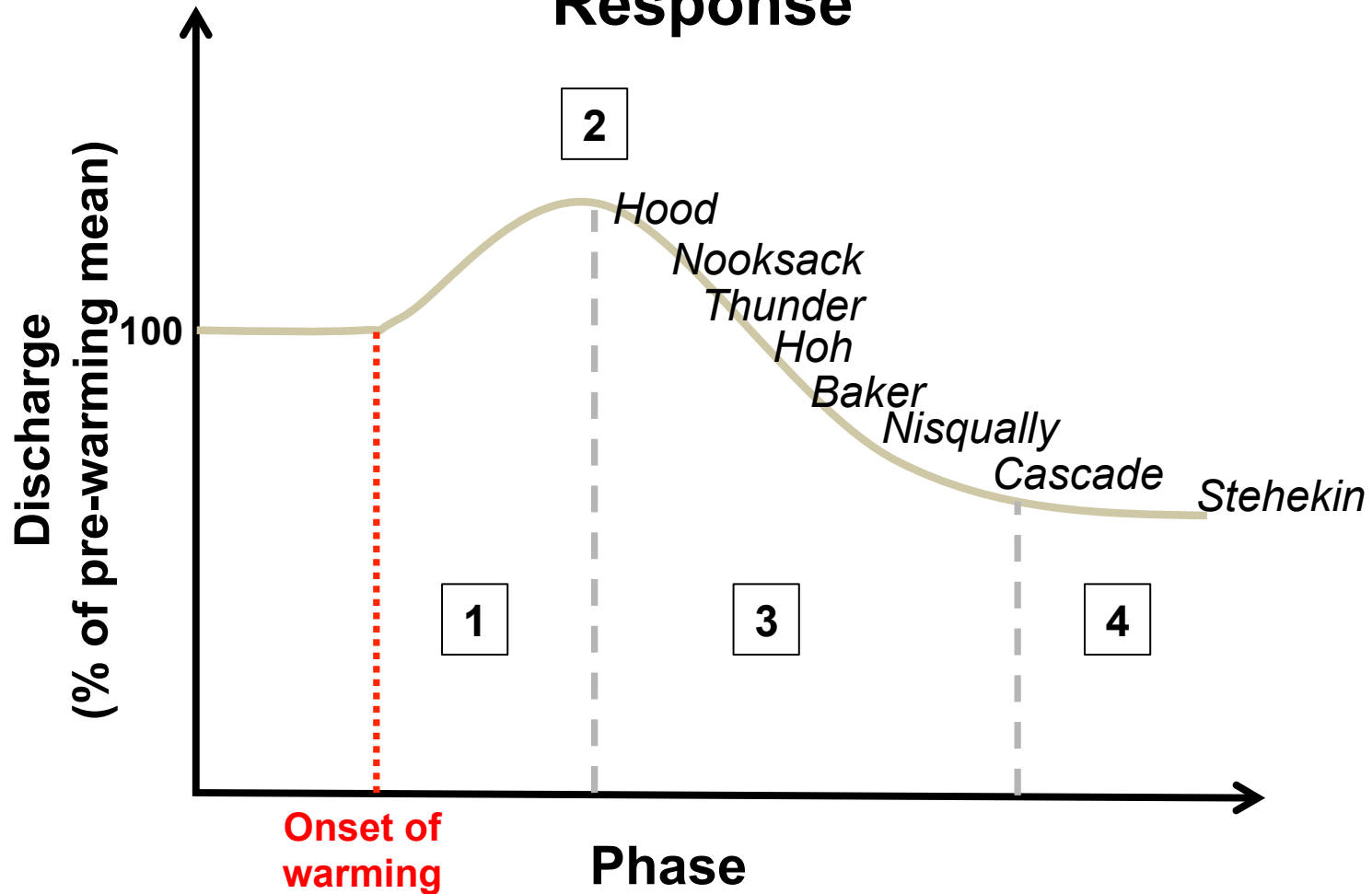
Hydrologic Response to Glacier Recession

Diagnosing *Present* Phase of Hydrologic Response



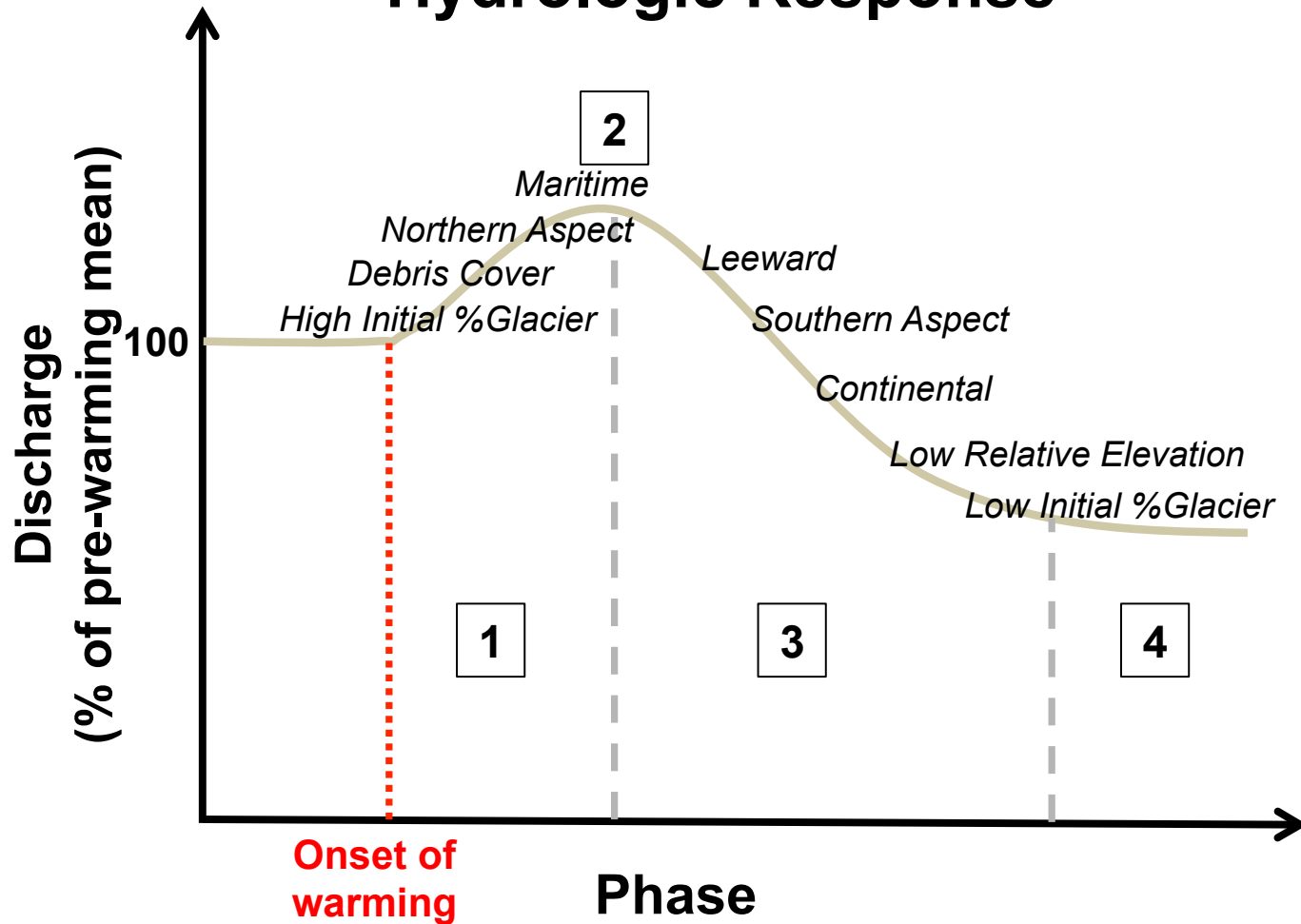
Hydrologic Response to Glacier Recession

Projecting *Future (20XX)* Phase of Hydrologic Response



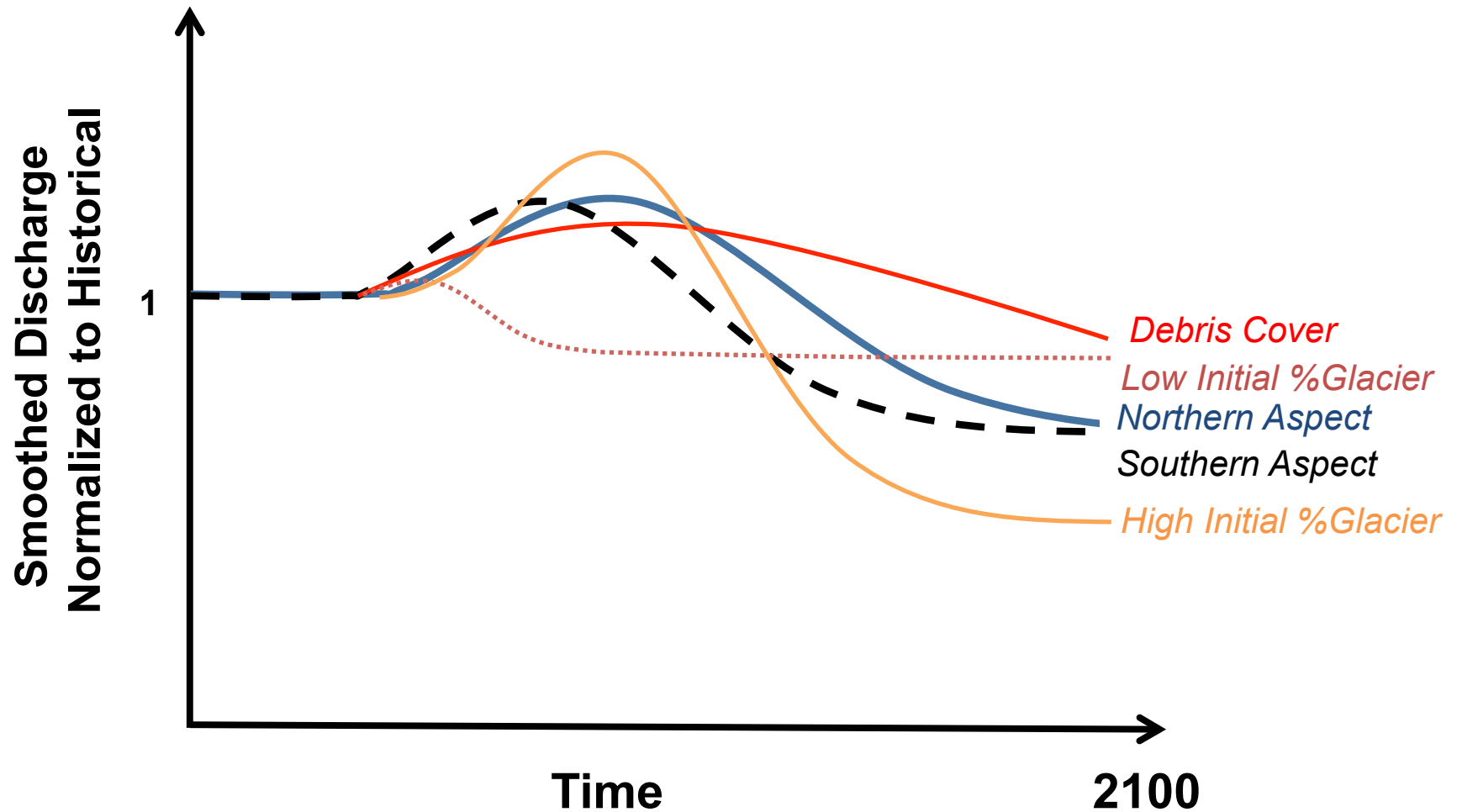
Hydrologic Response to Glacier Recession

Describing Mechanism behind ***Present*** Phase of Hydrologic Response



Hydrologic Response to Glacier Recession

Generalizing the *Pathway* of Hydrologic Response



Conclusions

- **A framework for describing glacio-hydrologic change across the Pacific Northwest region is outlined**
- **An example model application in the Hood River basin demonstrates the glacier contribution to late summer streamflow has risen steadily over the last ~40 years, during a time when the non-glacier contribution has been steadily decreasing**
- **A consensus over climate models indicates that this glacier melt contribution will continue to increase until midcentury (Sept.)**
- **Ongoing data analysis and model applications in 8 river basins are being used to characterize glacio-hydrologic change across the PNW**

Thank you!

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References

Jackson, K. M., & Fountain, A. G. (2007). Spatial and morphological change on Eliot Glacier, Mount Hood, Oregon, USA. *Annals of Glaciology*, 46(1), 222-226.

Jarosch, A. H., Schoof, C. G., & Anslow, F. S. (2013). Restoring mass conservation to shallow ice flow models over complex terrain. *The Cryosphere*, 7(1).

Naz, B. S., Frans, C. D., Clarke, G. K. C., Burns, P., & Lettenmaier, D. P. (2014). Modeling the effect of glacier recession on streamflow response using a coupled glacio-hydrological model. *Hydrology & Earth System Sciences*, 10(4).

Wigmosta, M. S., Vail, L. W., & Lettenmaier, D. P. (1994). A distributed hydrology-vegetation model for complex terrain. *Water Resources Research*, 30(6), 1665-1679.