What resolution snow model is necessary to simulate streamflow timing and volume?

Anna K. D. Pfohl[1], William Ryan Currier[1], Elijah Boardman[2], Justin Pflug[3], Ning Sun[4], Mimi Hughes[1], Rob Cifelli[1]

[1]NOAA, Earth System Research Lab, Physical Sciences Lab, Boulder, CO; [2]University of Nevada, Reno, Department of Natural Resources and Environmental Science, Reno, NV; [3]NASA Goddard Hydrological Sciences Laboratory, Greenbelt, MD; [4]Energy and Environment Directorate, Pacific Northwest National Laboratory, Richland, WA

Motivations

- Fine spatial resolution snow data are important for capturing snowpack processes (e.g., wind redistribution and avalanches) at ridge (100 to 1000 m) and slope scales (1 to 100 m) (Clark et al., 2011; Mott et al., 2018)
- Such datasets are not used for streamflow modeling; River Forecasting Centers rely on lumped models with limited elevation bands

Do fine-resolution snow datasets that resolve snowpack processes improve modeled streamflow timing and volume compared with coarse-resolution datasets?

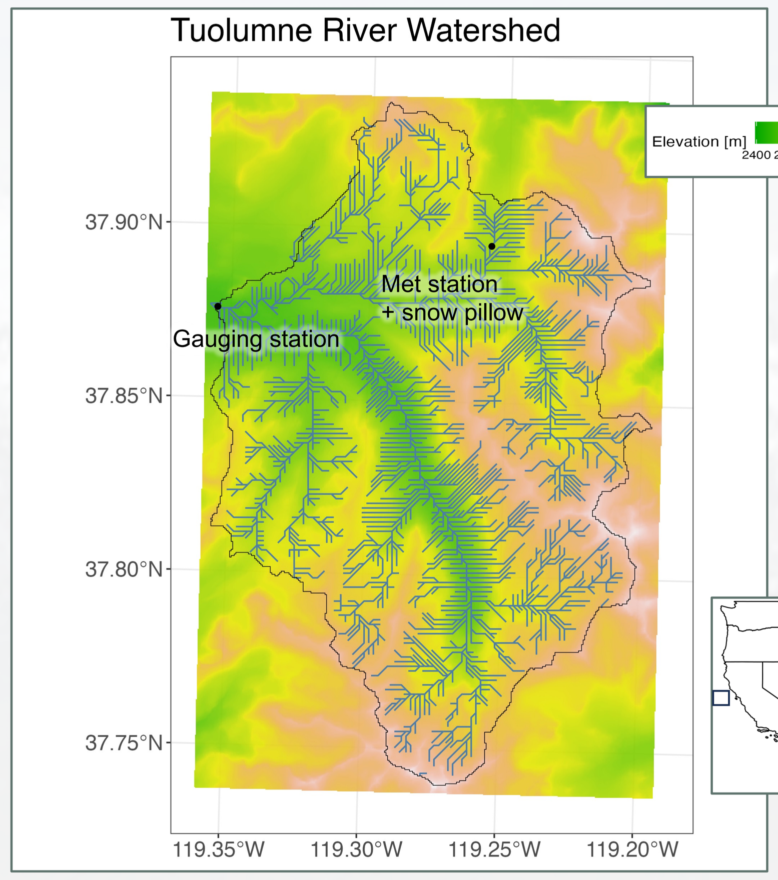


Figure 1. Tuolumne River Watershed with stream network used for model runs.

Methods

- Distributed Hydrology Soil Vegetation Model (DHSVM) (Wigmosta et al., 1994; Wigmosta et al., 2002)
  - Used grid spacing of 50 m in Tuolumne River, CA (Fig. 1) (Currier et al., 2022)
  - Topographic routing of streamflow
  - Two layer (surface and snowpack) mass- and energy-balance models snow
  - Forcing data from Dana Meadows meteorological station (Lundquist et al., 2016)
- Direct insertion (DI) of SWE
  - Airborne Snow Observatory (ASO) SWE data from near peak (April 16, 2016) at 50 m (Fig. 2)
  - Resampled to grid spacings of 1 km and basin mean (Fig. 3)

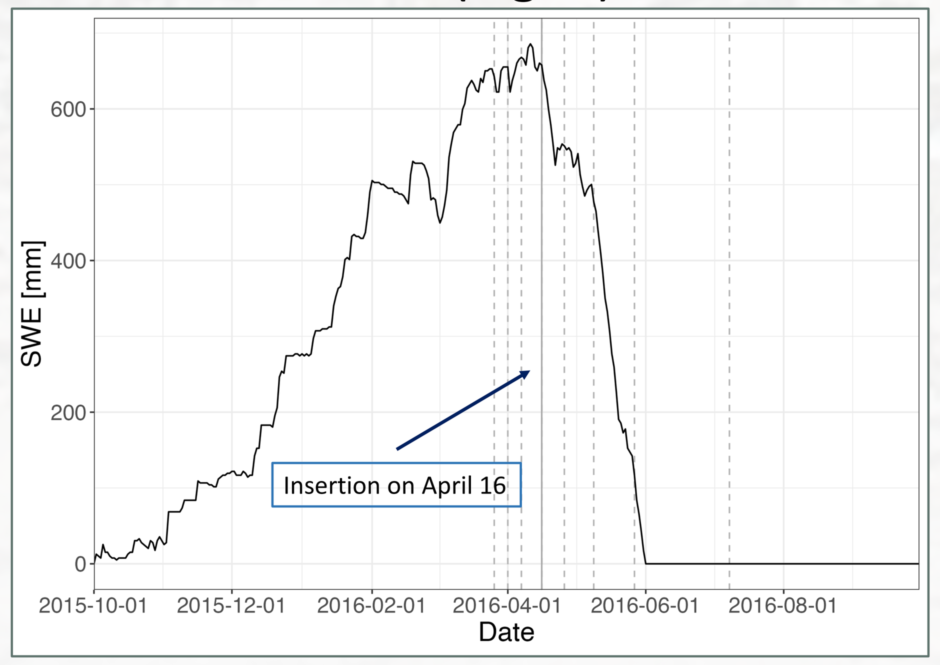


Figure 2. Observed SWE from Dana Meadows snow pillow and ASO flights (dotted gray lines) with date of direct insertion (solid gray line)

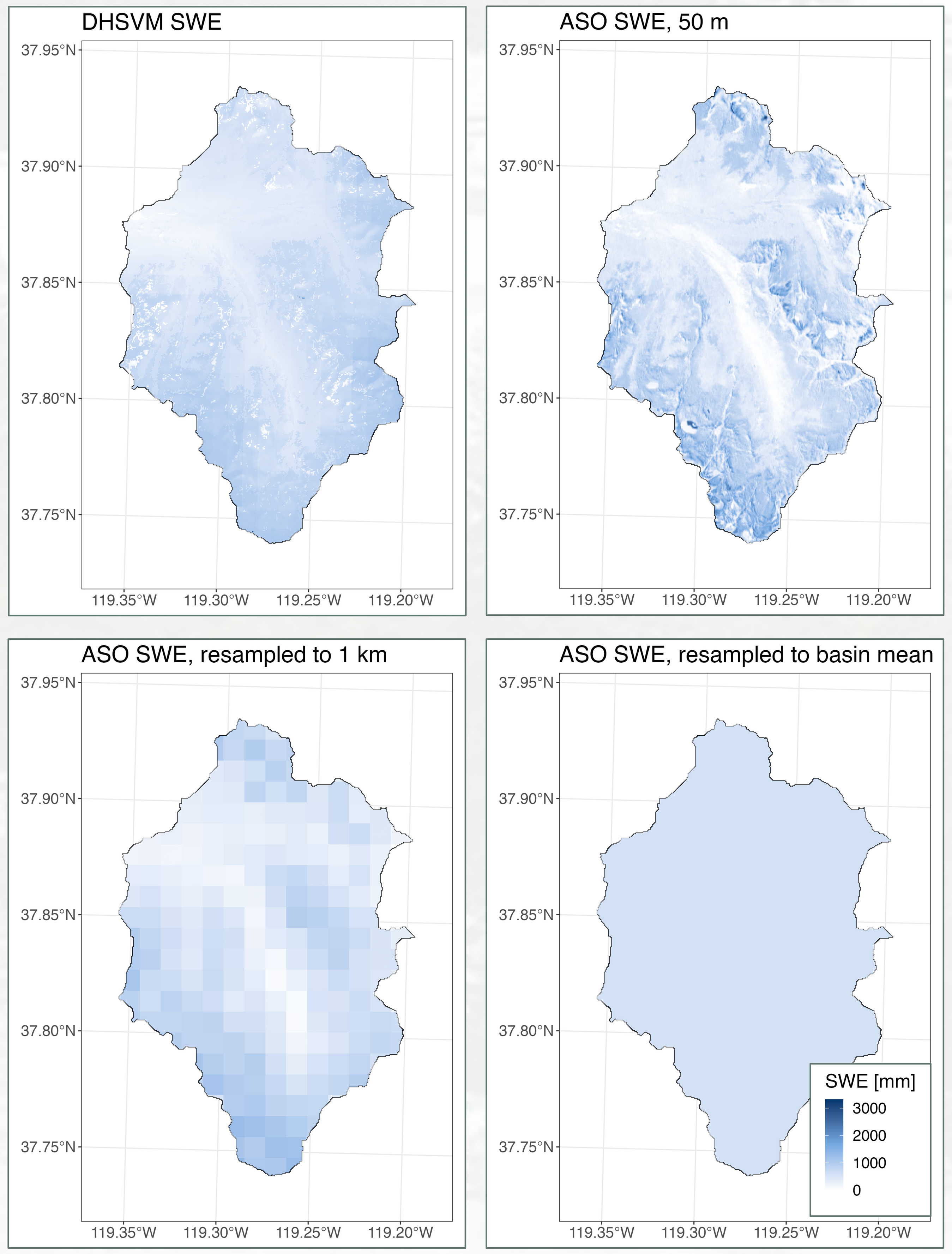
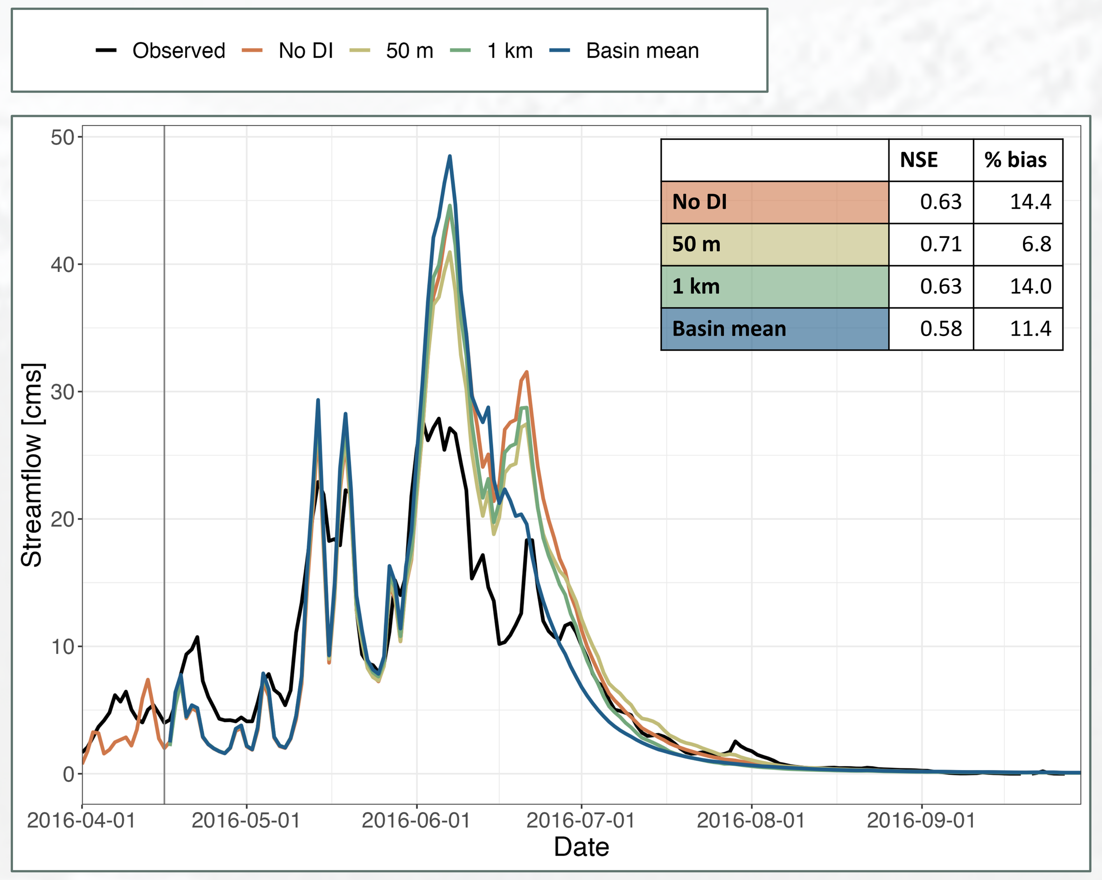


Figure 3. DHSVM modeled SWE at 50 m (upper left), ASO SWE used for April 16 direct insertion into model at 50 m (upper right), 1 km (lower left), and basin mean (lower right).

Results and conclusions

Increased snow heterogeneity impacts the timing and magnitude of modeled streamflow



	NSE	% bias
No DI	0.63	14.4
50 m	0.71	6.8
1 km	0.63	14.0
Basin mean	0.58	11.4

Figure 4. Observed and modeled, including with direction insertion, streamflow.

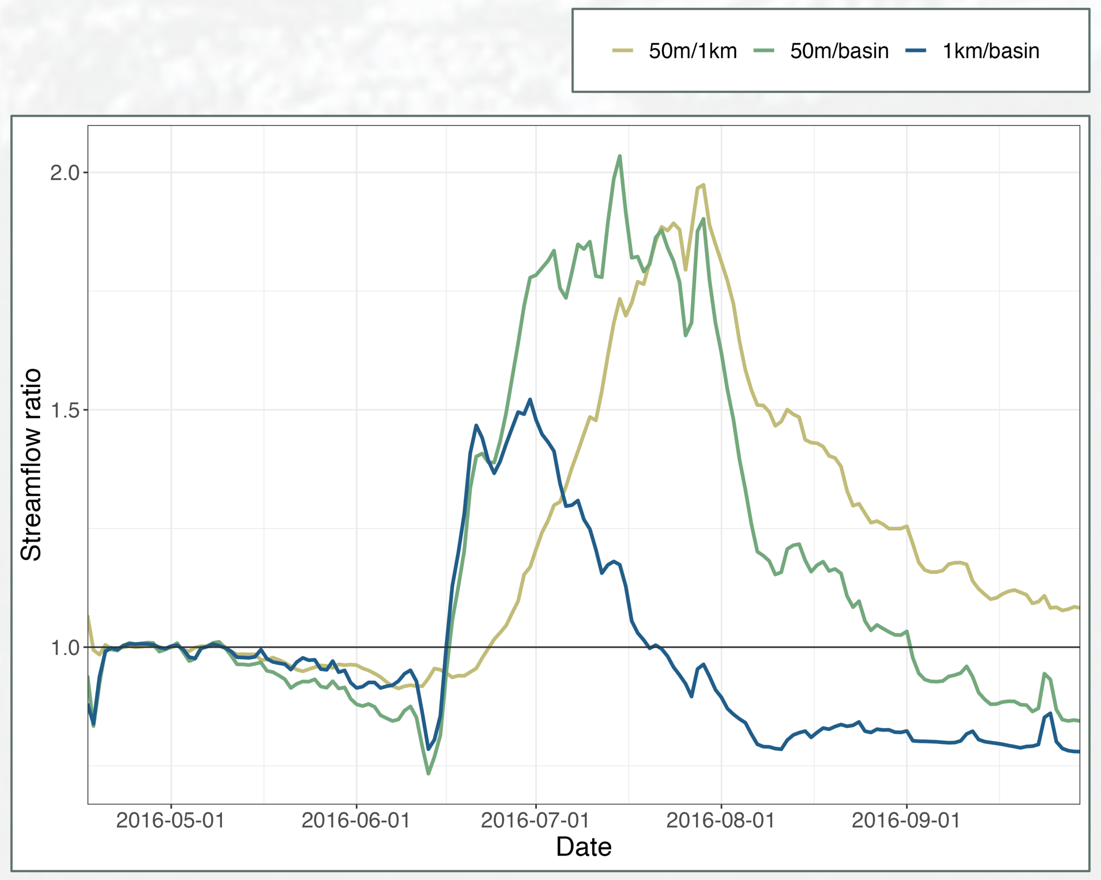


Figure 5. Ratio of modeled streamflow with direction insertion of SWE at different grid spacings.

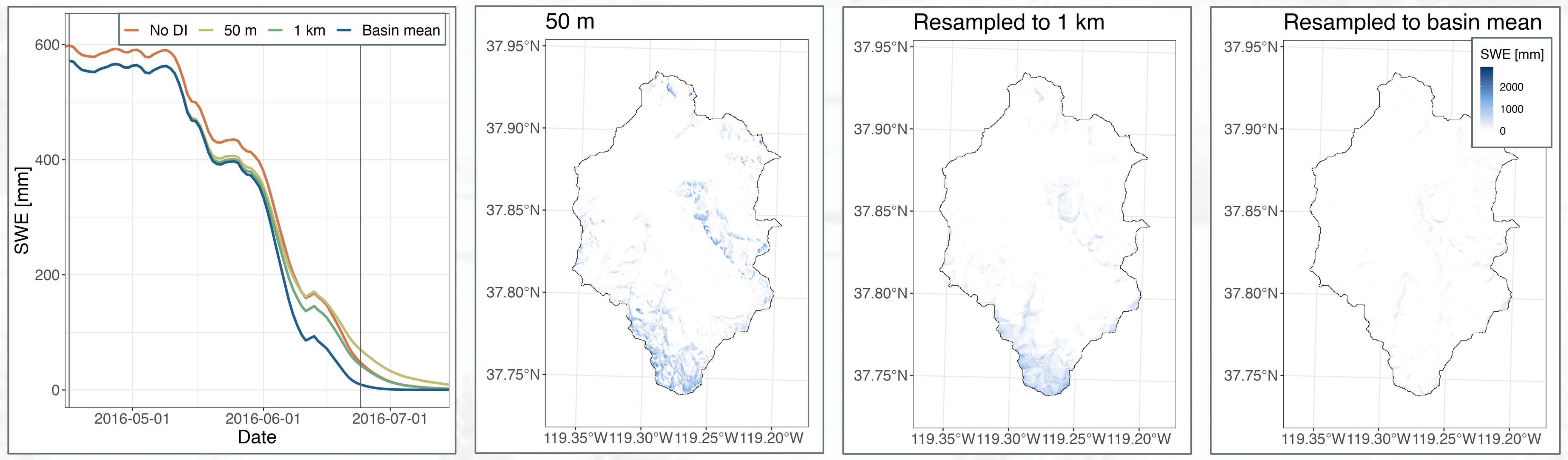
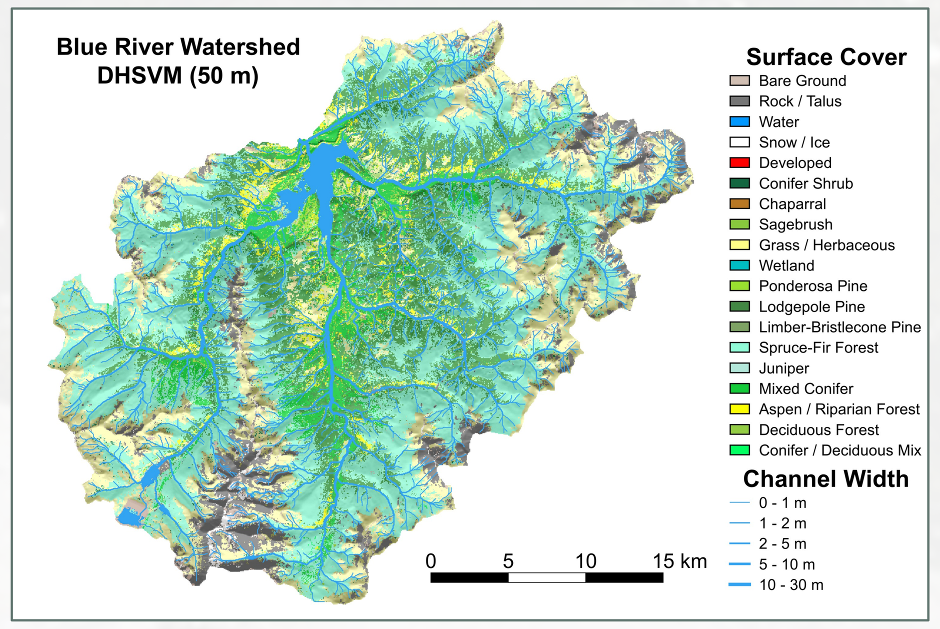


Figure 6. Modeled basin mean SWE for different grid spacings (far left) and SWE maps from DHSVM on June 24 from 50 m, 1 km, and basin mean grid spacings.

- Fine-resolution (50 m) SWE improved model performance and reduced magnitude of peak compared with simulations that had a coarsened snowpack (Fig. 4)
- Increased late-season flows from snow melting at high elevations in mid- to late June are capture at 50-m and 1-km grid spacings but not in the basin mean (Fig. 4 and Fig. 5) since these areas are snow free by early June (Fig. 6)
- Cumulative ET from time of insertion to end of WY was 205 mm, 207 mm, and 216 mm for 50-m, 1-km, and basin-mean resolutions, respectively
- Soil moisture in June and July was greater at high elevations with 50-m and 1-km insertions

Future work

- Incorporate additional spatial resolutions between 50 m and 1 km
- Explore the impact that radiation variability has on streamflow timing and magnitude
- Repeat experiments during high and low snow years
- Expand study area to Hetch Hetchy Reservoir in the Tuolumne and to the Blue River Watershed in Colorado



References:

Clark, M. P., Hendrikx, J., Slater, A. G., Kavetski, D., Anderson, B., Cullen, N. J., et al. (2011). Representing spatial variability of snow water equivalent in hydrologic and land-surface models: A review. *Water Resources Research, 47*(7); Currier, W. R., Sun, N., Wigmosta, M., Cristea, N., & Lundquist, J. D. (2022). The impact of forest-controlled snow variability on late-season streamflow varies by climatic region and forest structure. *Hydrological Processes, 36*(6); Lundquist, J. D., Roche, J. W., Forrester, H., Moore, C., Keenan, E., Perry, G., et al. (2016). Yosemite Hydroclimate Network: Distributed stream and atmospheric data for the Tuolumne River watershed and surroundings. *Water Resources Research, 52*(9), 7478-7489; Mott, R., Daniels, M., & Lehning, M. (2015). Atmospheric Flow Development and Associated Changes in Turbulent Sensible Heat Flux over a Patchy Mountain Snow Cover. *Journal of Hydrometeorology, 16*(3), 1315-1340; Wigmosta, M. S., Nijssen, B., & Storck, P. (2002). The distributed hydrology soil vegetation model. *Mathematical Models of Small Watershed Hydrology and applications*, 7-42; 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.