Snowpack Ablation and Ditch Irrigation in the the Skalkaho Creek Subbasin, Bitterroot Valley, MT

Introduction, Materials, and Methods

Skalkaho Creek rises high in the Sapphire mountain range of far western Montana. It drains approximately 134 square miles from east to west before feeding into the much larger Bitterroot River just south of Hamilton, Montana. Because of the varied topography through which the creek flows, distinct public and private ownership mosaic, and consistent yearly snowpack, it has acted as a dependable source of irrigation water for Daly Ditches Irrigation District (DDID) in the downstream flats and as a stronghold for native salmonids in the upper reaches. However, that balance is potentially tenuous. Reports list Skalkaho Creek as critically dewatered, suffering from elevated pollutants due to nearby agricultural and irrigation activity, and yet still supporting a vibrant fishery (Northwest Power and Conservation Council, 2009; Clark Fork Coalition, 2017). Looking into the future, the predicted effects of global warming and climatic change, the governance reality of overallocated Skalkaho Creek meltwater, and competing demands for that water potentially contribute to future climate vulnerabilities to both the dependent human and ecological systems.

To better understand this potential problem and conflict regarding water, I employed a GIS to investigate snowpack retention over time. I utilized Daymet data from 1980 - 2018 to look for temporal trends. Daymet was chosen due to it being the only gridded climate product with a fine enough scale (1km x 1km) to compare Skalkaho Creek, a HUC 10 sub basin, to other Bitterroot watershed sub basins. It is also the only product I am aware of to spatially interpolate Snow Water Equivalent (SWE). I looked at the Bitterroot basin at-large to compare the various HUC 10 sub basins to each other based strictly on snowpack retention over time. To calculate this sub basin retention, I calculated mean SWE for April 1 and June 1 for each watershed polygon for each year from 1980 - 2018. Snowpack retention to changing climatic conditions was then estimated by \[
\frac{(\text{June 1 mean SWE}/\text{HUC 10 sub basin})}{(\text{April 1 mean SWE}/\text{HUC 10 sub basin})} \times 100
\] to yield a snowpack retention metric (% retention).

Importantly, Daymet calculates SWE by requiring inputs: Tmin, Tmax, and precipitation. Daymet temperature observations come from two sources: National Climate Data Center and SNOTEL (Thornton et al., 2016). Recently, Oyler et al. (2015) found that SNOTEL temperature sensors significantly bias both Tmin and Tmax. This bias is more pronounced during the relatively colder winter months, but it is also present during the spring snowmelt season. Because of this sensor bias, a field campaign was launched from the mid-1990s to the mid-2000s to replace these sensors. However, the new sensors appear to be biasing Tmin towards warmer readings.

Due to the above findings, I also sought out to validate SWE derived from Daymet with SWE as measured at the five Bitterroot Watershed SNOTEL sites: Skalkaho Summit, Daly Creek, Twin Lakes, Twelvemile Creek, and Nez Perce Camp. This validation was performed by converting SWE (in.) to SWE (kg/m²). First, SWE (in.) was converted to a snowload (lbs/ft²)
estimate by multiplying SWE (in.) by 5.2 (Natural Resource Conservation Service, n.d). After converting to snowload, I converted snowload to the metric equivalent through multiplying lbs/ft² by 4.88. This resulted in a comparable value to Daymet, which calculates SWE as kg/m². However, Daymet is a gridded raster mosaic with individual pixels measuring 1km x 1km. To find a comparable value to SNOTEL, I decided to divide the 1km x 1km pixel by 1000 to yield an kg/m² estimate. This value was then compared to Daymet SWE derivations for model fit and consistency.

**Results and Discussion**

First and foremost, the analysis of Daymet data at the HUC 10 sub basin level indicates an overall decline in SWE retention from April 1 – June 1 (see figure 1). Figure 2 geospatially displays the mean retention percentage distribution across the 16 Bitterroot Watershed sub basins for the years 1980 – 2018 and breaks them down into four quartiles. Additionally, two SNOTEL sites which regularly record snowpack on June 1, Twin Lakes and Skalkaho Summit, have also seen a decline in amount since 1989 (see figures 3 and 6, respectively). Interestingly, some sites have recorded an increase in April 1 SWE values, which could align with predictions made by O’Gorman (2014) regarding at or near freezing temperatures having an outsized effect on precipitation regimes. Even with this increase in April 1 SNOTEL SWE values, observed declines in June 1 SNOTEL SWE values lends credibility to conclusions that snowpack ablation is in fact increasing. This is further corroborated by the upward temperature trends observed at the two Skalkaho Creek SNOTEL sites, albeit considering sensor bias noted by Oyler et al. (2015).

Figures 3, 4, 5, 6, and 7 below display the results from the Daymet validation exercise. For the five SNOTEL sites investigated, April measurements do not line up well at all. For instance, the index of agreement calculated for April 1 values at Daly Creek SNOTEL site were >0.5, which indicates paltry agreement between the observed and predicted values. This trend of low agreement was noted for all April 1 values with Nez Perce Camp and Twelvemile Creek faring a bit better with index of agreements of 0.57 and 0.53, respectively. June 1 values, on the other hand, revealed more varied results. The three lower elevation SNOTEL sites: Daly Creek (figure 7), Twelvemile Creek (figure 4), and Nez Perce Camp (figure 5) revealed almost zero agreement between the observed and predicted values. However, June 1 measurements line up much better at the two relatively higher elevation sites: Twin Lakes (figure 3) and Skalkaho Summit (figure 6) with index of agreement values at 0.72 and 0.84, respectively. Overall, this lack of model validation and inconsistent correlations point to Daymet being able to only do so much for managers looking to leverage it to make recommendations at the HUC 10 sub basin level.

Both Daymet and SNOTEL sites corroborate to show a steady decline in June 1 SWE values. This observation comes at the same time a precipitous temperature increase is also observed for the entire months of March and May at both Skalkaho Summit and Daly Creek SNOTEL sites, albeit with the abovementioned sensor bias. Furthermore, the general decline
observed in June 1 SWE values for both observational data collected at SNOTEL sites and Daymet interpolations combined with an interesting upward trend in April 1 SNOTEL SWE values lend credibility to the conclusion that snowmelt timing is become earlier and overall ablation rates becoming higher. This combination validates findings that indeed snowmelt dominated watersheds should expect to see lower than average late season flows in the near future. When factoring anthropogenic forcings into this equation, it is reasonable to conclude this trend of temperature increase and ablation rates resulting in lower late-season flows is likely to continue along its current trajectory. This reality is likely to contribute challenges to both the human social systems and naturally occurring ecosystems dependent and accustomed to predictable and consistent year-to-year hydrologic fluctuations.
Figure 1. Retention percentages over time for the 16 HUC 10 sub basins of the Bitterroot River watershed as calculated via Daymet data.
Figure 2. Mean retention percentage (1980 – 2018) for all HUC 10 sub basins ranked and displayed as quartiles.
Figure 3. A visualization of how consistent Daymet is at predicting SWE values when comparing them to SWE values as observed at Twin Lakes SNOTEL station.

Figure 4. A visualization of how consistent Daymet is at predicting SWE values when comparing them to SWE values as observed at Twelvemile Creek SNOTEL station.
Figure 5. A visualization of how consistent Daymet is at predicting SWE values when comparing them to SWE values as observed at Nez Perce Camp SNOTEL station.

Figure 6. A visualization of how consistent Daymet is at predicting SWE values when comparing them to SWE values as observed at Skalkaho Summit SNOTEL station.
**Figure 7.** A visualization of how consistent Daymet is at predicting SWE values when comparing them to SWE values as observed at Daly Creek SNOTEL station.
References


