OBSERVING THE ELUSIVE INTERMITTENT SNOW USING TRAFFIC CAMERA IMAGES

Nicholas Wayand[1] and Jessica Lundquist[1]

EXTENDED ABSTRACT

Intermittent snow covers a majority of the western U.S. and is known to have contributed to rain-on-snow type floods. Quantifying the elevational contributions of melt water during such events is hampered from a critical lack of observations of the lowest snow extent. The Moderate Resolution Imaging Spectroradiometer (MODIS) aboard Terra and Aqua offers the best available compromise of sampling and resolution to capture intermittent snow's spatio-temporal snow cover variations over mid-latitudes. However, twice daily images from MODIS are significantly limited by cloud cover that may obscure rapidly melting snowcover; a critical model initialization state for flood forecasting models. In this study, we approach the question of quantifying the snowmelt contribution through an idealized simulation, followed by a comparison of the current available observations of intermittent snowcover.

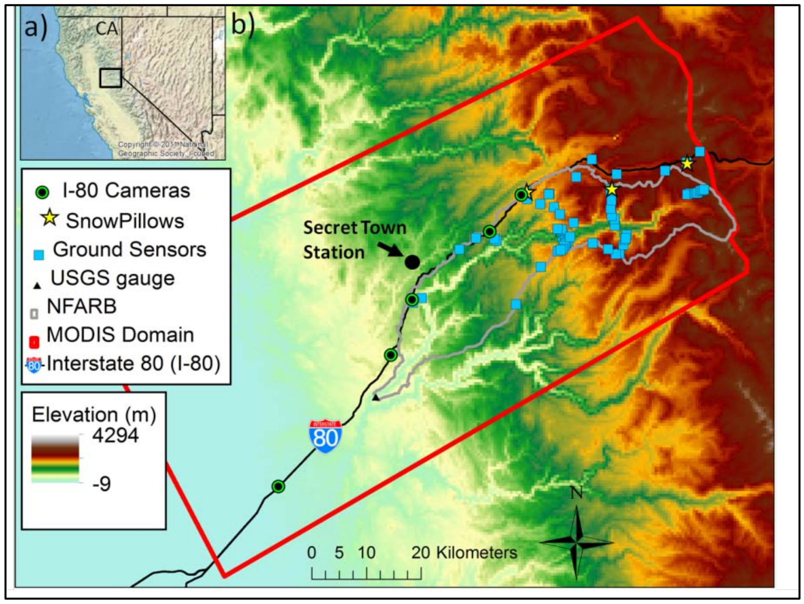

Figure1. (a) Location of study domain in California and (b) map of study domain including the NF American Basin in California (grey outline). Green circles represent locations of traffic cameras along I-80. Blue squares show ground temperature sensor locations. The *red outline* shows extent of MODIS 500 m grid cells included in this study.

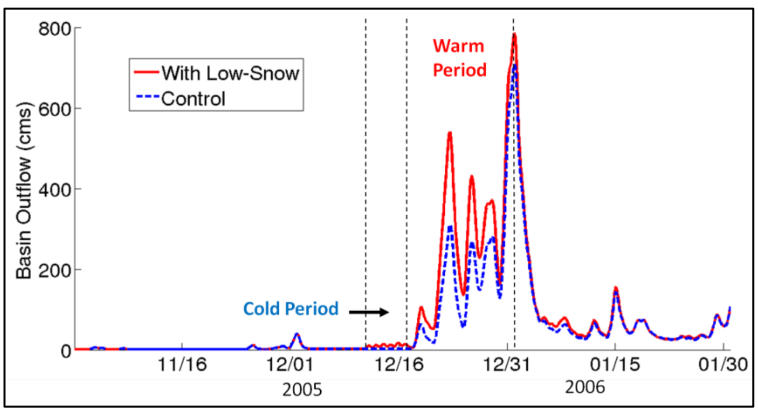

Figure 2. Simulated streamflow at basin outlet for each case.

To estimate the relative importance of snowmelt and rainfall for runoff, we performed two distributed hydrological simulations of an idealized rain-on-snow event over the North Fork of the American River Basin, in California (Figure 1). For the control simulation, meteorological forcing data for the Distributed Hydrological Soil and Vegetation Model (DHSVM, Wigmosta et al. 1994) was obtained from the Secret Town station (California Department of Water Resources, Figure 1) during the December 30th 2006 flooding event, which caused over \$300 million in damages in California (Parrett and Hunriches, U.S. Geological Survey). This control storm had little to no low-elevation snow accumulation. To represent a more typical rain-on-snow storm, we modified the control meteorological forcing data (decreased temperatures by -10 degrees C, and added 2 mm hr^{-1} of precipitation from December 11-17), which resulted an averaged accumulation of 206 mm of snow water equivalent (SWE) below 1500 m (73% of the basin area), prior to the onset of the control storm.

The resulting impact on simulated streamflow is shown in figure 2. During the "warm" period, the total volume of simulated streamflow increases by 41%, predominantly before the peak flow. The total snowmelt during this period was 15% of the total basin averaged input (snowmelt plus precipitation), representing a significant runoff contribution. In addition, snowmelt resulted in earlier saturation of lower elevation soil, which led to increased runoff.

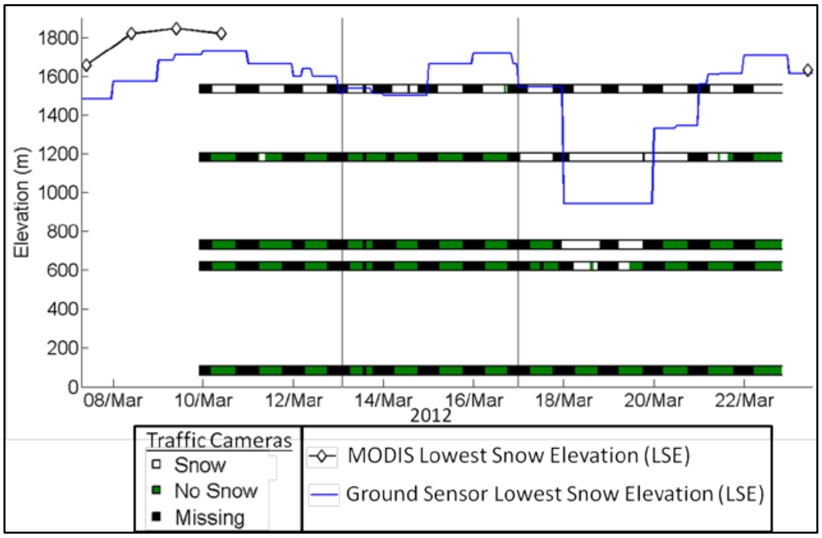

Figure 3. Rows of boxes show snow presence (*white*), absence (*green*), and missing (*black*) from five traffic cameras from the 7-23 March, 2012. The LSE from MODIS is shown as *Black Diamonds* with solid lines (Note: 11-22 March was cloudy). The LSE from ground sensors are shown as *solid blue* lines. Vertical *grey* lines show period of precipitation totaling 560 mm.

Observations of the lowest-snow elevation (LSE) before and during a rain-on-snow event could help reduce uncertainty in the simulated snow extent and melt contribution to runoff. Therefore, for a separate event in 2012, we compared the LSE observed from three available sources: MODIS imagery (MOD10A1 product), ground temperature sensors, and traffic camera imagery (Figure 3). Leading up the onset of precipitation (Mar. 13), the LSE from MODIS and the ground sensors agree with each other to within 200 m, until cloud cover blocks MODIS. On 17-18, the basin wide transition from rain to snow and the drop in snow line is captured by the ground sensors (which reach the lowest sensor at 942 m) and the traffic cameras that show snow presence at 620 m. If the snowline drop had occurred prior to the onset of precipitation, remote sensing products would have missed this important transition for flood forecasting. This case study suggests that MODIS imagery is accurate when available but alone may not be suitable for winter snowcover assimilation within the intermittent snow zone, and highlights two ground-based methods to supplement gaps due to cloud cover.

In summary, the snowmelt contribution from intermittent snow during the idealized rain-on-snow simulation was found to be a significant part of the total basin input (%15). Future work should focus on real events, and examine the sensitivity of the snowmelt contribution to structural errors in the snow model chosen, especially the turbulent heat flux parameterization. Over the same basin, the traffic camera images captured the lowest snowcover during the March 17 2012 event, when MODIS was blocked by cloud cover. These findings suggest the combined use of both MODIS and traffic camera imagery could improve initial conditions for flood forecasting models in maritime environments. (**Keywords**: Intermittent snow, rain-on-snow, traffic cameras, remote sensing)

REFERENCES

Wigmosta, M. S., L. W. Vail, and D. P. Lettenmaier, 1994: A distributed hydrology-vegetation model for complex terrain. *Water Resources Research*, **30**, 1665–1679, doi:10.1029/94WR00436.

Parrett, Charles, and Hunrichs, R.A., 2006, Storms and flooding in California in December 2005 and January 2006—A preliminary assessment: U.S. Geological Survey Open-File Report 2006–1182, 8 p.

Paper presented Western Snow Conference 2013
[1] Nicholas Wayand, Dept. of Civil & Environmental Engineering, University of Washington, 201 More Hall, Box 352700, Seattle, WA 98103, nicway@u.washington.edu.
[1] Jessica Lundquist, Dept. of Civil & Environmental Engineering, University of Washington, 201 More Hall, Box 352700, Seattle, WA 98103, nicway@u.washington.edu.