Multi-Sensor Assessment of Changes in Seasonal Snow Cover Persistence in the Columbia River Basin Using Cloud Computing Platforms

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Abstract

It is now widely understood that seasonal snow cover in the Western United States is melting earlier than in past decades. This could have significant consequences for human populations and ecosystems dependent on regularity in timing and magnitude of downstream flows that originate as snow. However, while earlier melt is well established, less is known about intra-annual changes in the spatial and temporal distribution of accumulation and ablation (melt) cycles in the core winter months and spring months, i.e. the 'persistence' of seasonal snow cover. This is significant because changes to the persistence of seasonal snow in the winter and spring could have important implications for other snow cover characteristics such as albedo, as well as ancillary hydrologic factors such as soil moisture and runoff. To understand these changes in persistence, this project focuses on study basins in different climatic zones of the Columbia river basin, capturing the shift from maritime snowpack in the west to alpine snowpack in the east. The research relies on a combination of time series analysis of NRCS SNOTEL stations and snow courses and use of an optical remote sensing product which is based on the MODIS MOD10A1 dataset. To compensate for significant winter and spring cloud cover, particularly in the Pacific Northwest, a temporal and spatial gap filling approach utilizing higher spatial resolution products (e.g. Landsat and Sentinel 2) is implemented primarily in Google Earth Engine. The seasonal snow persistence from the MODIS-based product is evaluated using additional Landsat, Sentinel 2 and Planet Labs data, as well as data from the in situ monitoring stations. Finally, changes in intra-annual seasonal snow cover persistence are characterized for core winter, spring and early summer months along an elevational gradient and across study sub-basins.

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1. Introduction

Background:

- Snow is melting earlier than in previous decades[1] and is particularly susceptible at low-mid elevations and in warmer (e.g. maritime) snowpacks
- Less work has been done on the spatial and temporal distribution of changes across a water year

Primary Research Objective:

- Build on existing work[2] to identify areas of decreasing snow persistence in the Columbia River Basin and Pacific Northwest

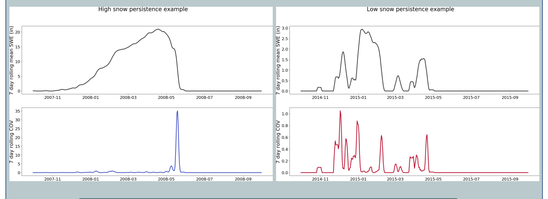
Definition of Snow Persistence:

- Distribution of accumulation/ablation (melt) cycles in space and time

2. Methods

Conducted in Google Earth Engine

- Remote sensing data (MODIS/VIIRS)
- In Situ data (SNOTEL)
- Cloud corrections, gap filling, combine datasets
- Access data via API, clean and organize
- ID snow covered vs non snow-covered areas
- Classify time series types (examples below)
- Quantify snow persistence in space and time
- Identify snow persistence in space and time

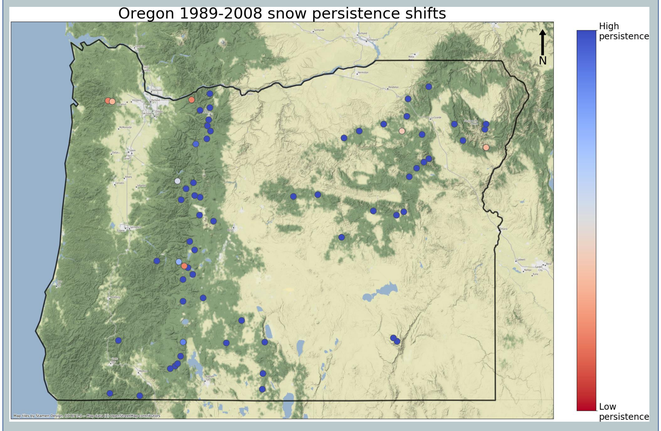


Integrate and analyze findings

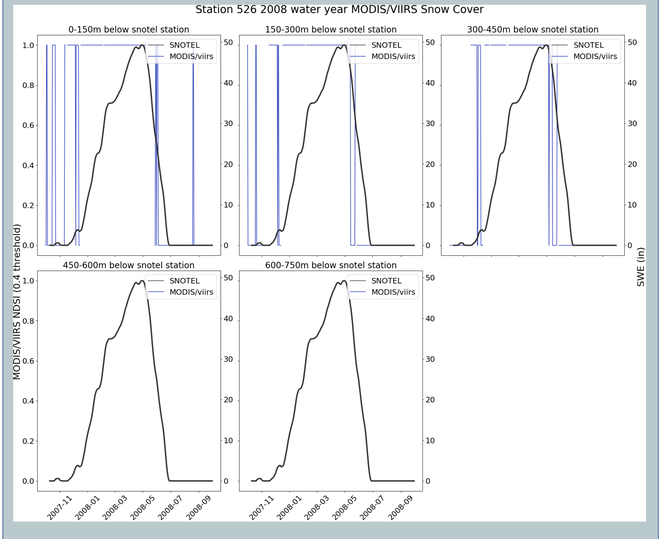
3. Results

- SNOTEL data shows decreases in persistence across the winter season when comparing wetter/cooler to warmer/drier years. This is particularly evident in the Cascades.
- The weather/climate factors matter year to year as well as the geographic location of the station
- Snow cover persistence does not seem to show a long-term linear trend
- MODIS/VIIRS remote sensing product shows a similar signal but is limited in temporal resolution by clouds

High water years comparison

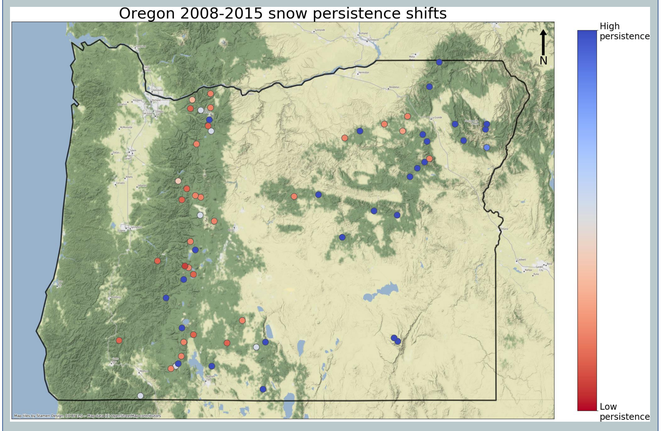


Widespread high snow persistence

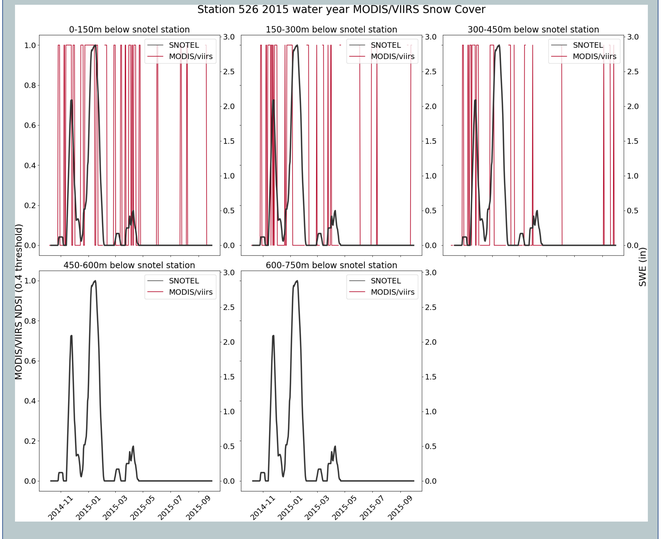


Higher duration of snow cover, especially at higher elevations (Central Oregon Cascades)

High and low water years comparison



High snow persistence remains in Eastern Oregon but goes down in the Cascades



Lower duration of snow cover (higher frequency of accumulation/melt) (Central Oregon Cascades)

4. Conclusion

- Changes in snow persistence have important implications for human and ecosystem water use/availability
- Persistence is lower to much lower in warmer/drier years, conditions which could become more frequent or extreme in the future
- Additional stations and years show similar trends
- More work is required to better understand trends across space using remote sensing and modeled data

5. References

1 non exhaustive)

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