Seasonal evolution of subgrid snow variability in mountainous terrain

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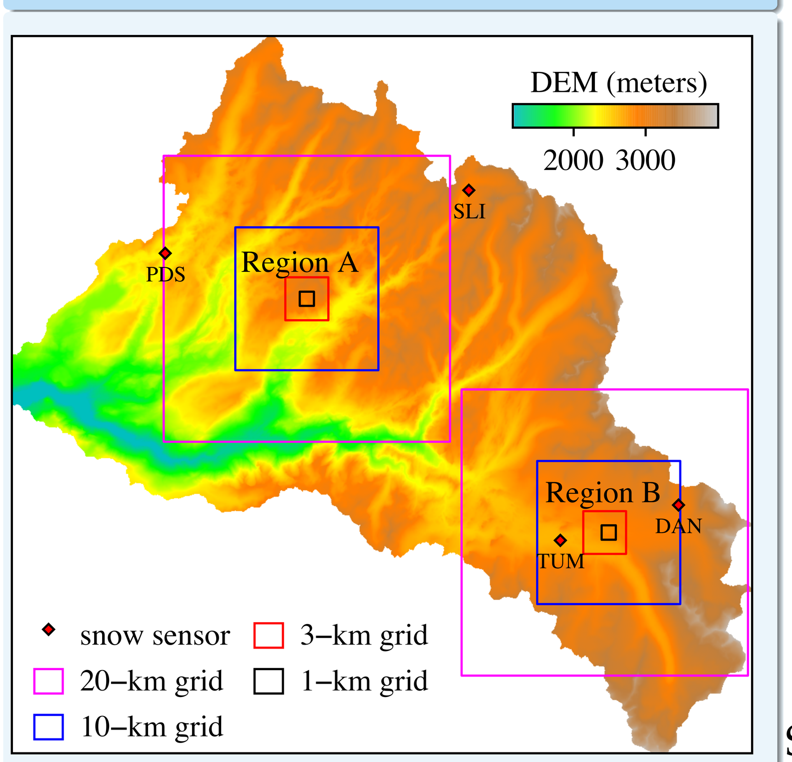
Overview

This study investigates the seasonal evolution of snow subgrid variability at different scales based on continuous high-resolution ASO snow water equivalent (SWE) data and modeled SWE data (daily, 50-m) with periodic assimilation of ASO SWE for the Tuolumne River Basin in California. The time series of descriptive statistics of subgrid variability within 20-km, 10-km, 3-km, and 1-km squares were calculated and analyzed from this data. The results reveal characteristics of the seasonal evolution of snow subgrid variability and provide knowledge for the development of improved large-scale snow models that consider small-scale snow processes.

Study Area



▲ Tuolumne River Basin above Hetch Hetchy Reservoir. Two regions (A and B) with eight nested squares are shown.

Acknowledgements

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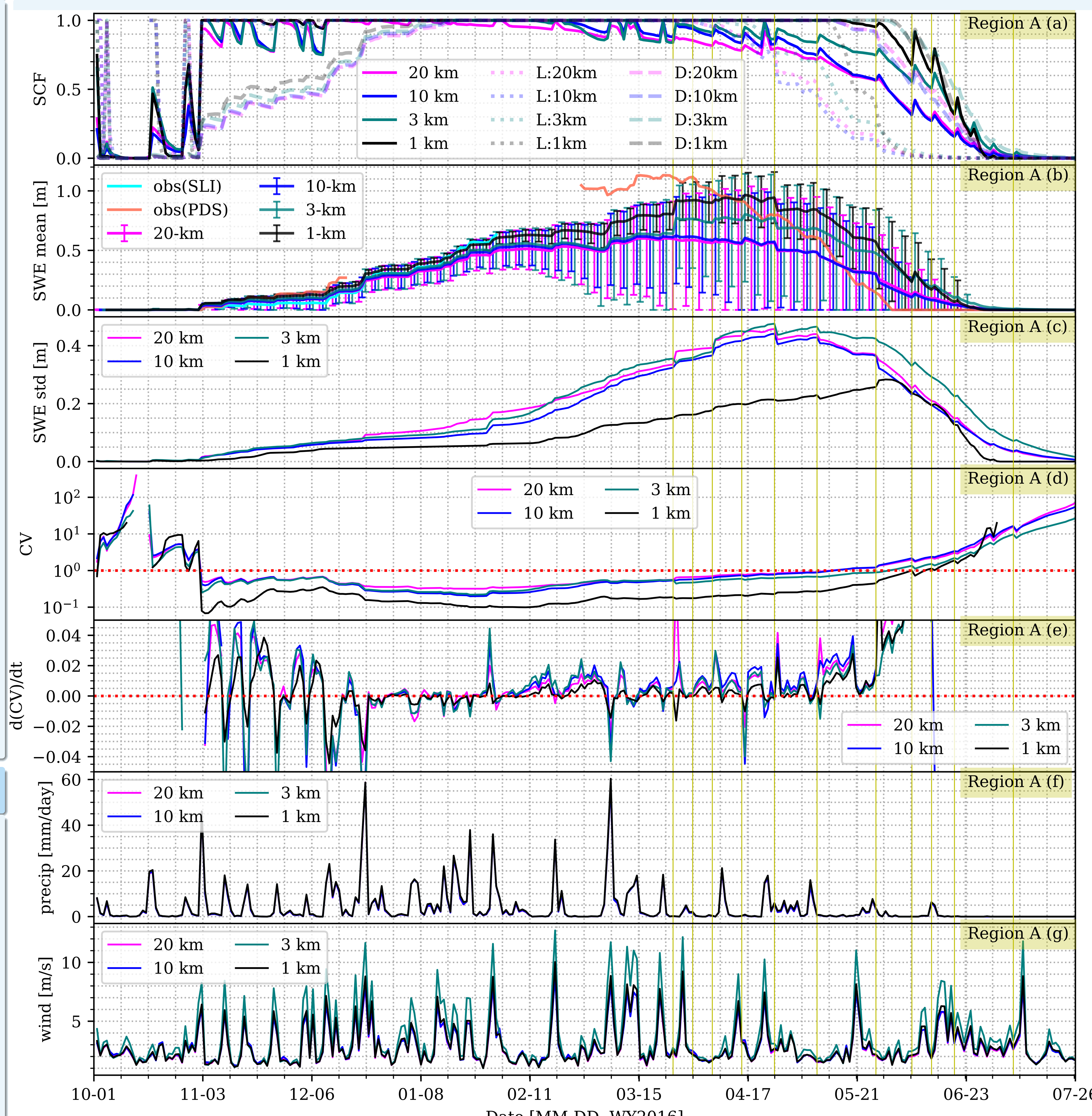
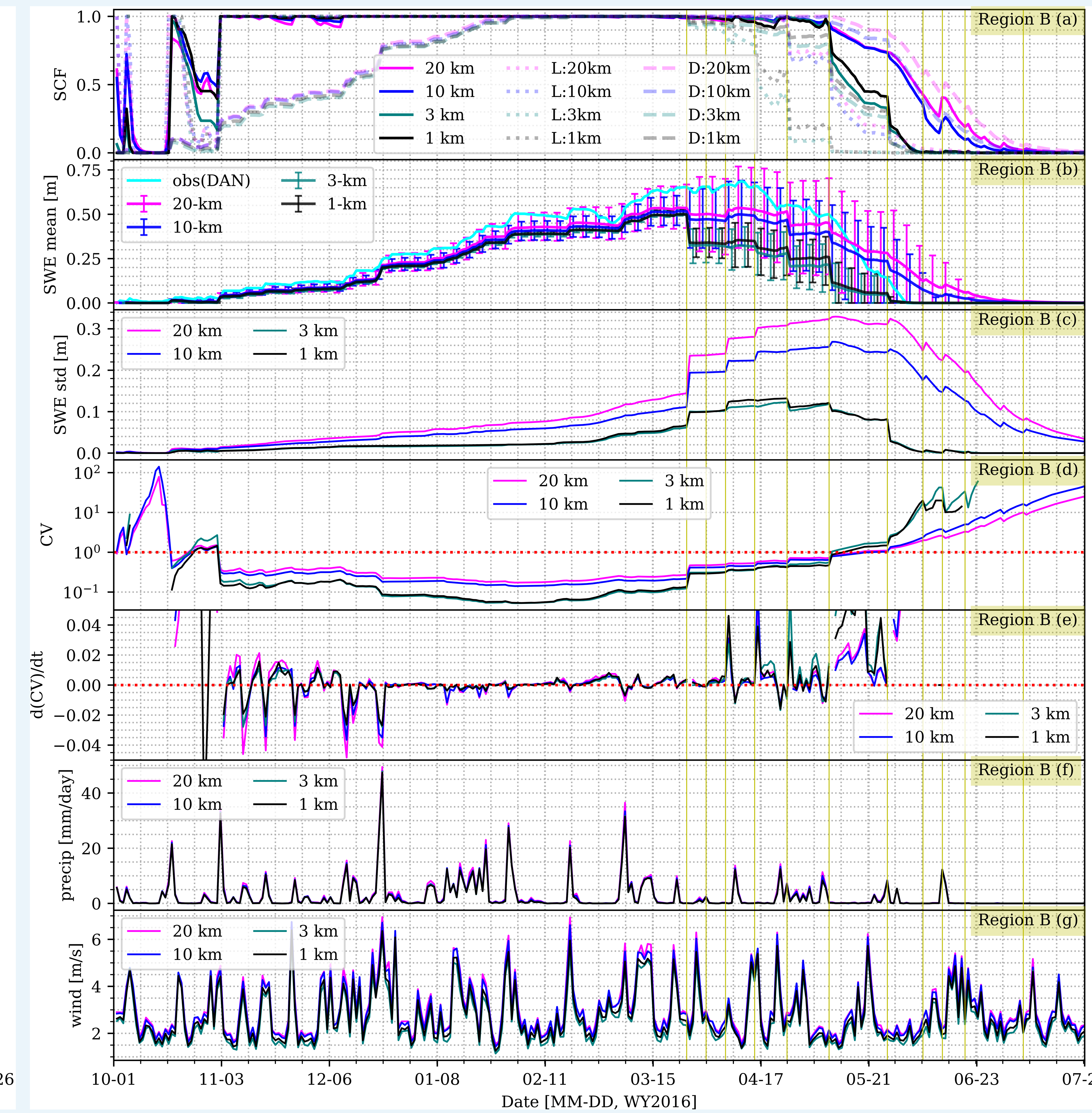
Results



▲ Time series for Regions A of (a) snow-cover fraction (L means lognormal distribution, and D means depletion curve), (b) mean of SWE, (c) standard deviation of SWE, (d) coefficient of variation of SWE, (e) time gradient of SWE mean, (f) time gradient of SWE standard deviation, (g) mean of wind speed, and (h) mean of precipitation at different scales (i.e., 20 km, 10 km, 3 km, and 1 km). In the subplot (b), 15th and 85th percentiles of SWE, snow depth measurements from in-situ sensors were also added. The vertical solid yellow lines are the dates for insertion of ASO measurements.



▲ Time series for Regions B of (a) snow-cover fraction (L means lognormal distribution, and D means depletion curve), (b) mean of SWE, (c) standard deviation of SWE, (d) coefficient of variation of SWE, (e) time gradient of SWE mean, (f) time gradient of SWE standard deviation, (g) mean of wind speed, and (h) mean of precipitation at different scales (i.e., 20 km, 10 km, 3 km, and 1 km). In the subplot (b), 15th and 85th percentiles of SWE, snow depth measurements from in-situ sensors were also added. The vertical solid yellow lines are the dates for insertion of ASO measurements.

Snow cover fraction methods

1. Liston (2004)

$$SCF = \frac{1}{2}\mathrm{erfc}\left(\frac{Z_{D_m}}{\sqrt{2}}\right) \quad (1)$$

$$Z_{D_m} = \frac{\ln(D_m) - \lambda}{\zeta}, \quad \lambda = \ln\mu - \frac{1}{2}\zeta^2, \quad \zeta^2 = \ln(1 + CV^2)$$

The required inputs are mean SWE, μ, coefficient of variation, CV, and accumulated snow melt, D_m.

2. Barlage (2010)

$$f = 1 - \left[\exp\left(-2.6\frac{\mu}{\mu_{max}}\right) - \frac{\mu}{\mu_{max}}\exp\left(-2.6\right)\right] \quad (2)$$

The required input is SWE, μ. μ_{max} is 40 cm for grass, crop, shrub and is 80 cm for forest.

Findings

1. Snow was distributed more uniformly during the accumulation stage than melting stage.
2. During the whole snow season, the evolutions of mean and standard deviation of SWE had similar trends but with different time lags.
3. The coefficient of variation is generally less than one when a square is fully snow-covered. When snow cover fraction of a square is smaller than 0.7, the coefficient of variation of SWE is generally larger than one.
4. Snow cover fraction of a square is highly related to the subgrid variability of SWE.
5. Spatial variability of snow depends on scale.

Conclusions

1. In mountainous areas, the partially snow-covered period can last for 50 days to 180 days depending on grid cell resolution and the topographic features within that grid cell.
2. When a grid cell is fully covered with snow, the coefficient of variation of SWE is generally stable (usually less than 1.0). However, when a grid cell is partially covered with snow, the coefficient of variation of SWE can be quite large.
3. Subgrid variability of snow is generally larger in the coarsest grid cells than the finest grid cells, but there is no absolute rule on this as variability of topography is also important.