Trends in Sierra Nevada snowmelt based on 10 years of MODIS fractional snow covered area data: the apparent and the missing

Roger Bales\textsuperscript{a}, Robert Rice\textsuperscript{a}, Karl Rittger\textsuperscript{b}, Thomas Painter\textsuperscript{c}

\textsuperscript{a}Sierra Nevada Research Institute, UC Merced
\textsuperscript{b}Bren School, UC Santa Barbara
\textsuperscript{c}Geography, U. Utah

This talk is more about data than modeling!
Sierra Nevada fractional snow covered area (SCA) from MODIS

MODSCAG algorithm – Painter et al., 2008

SCA at left is binned into 4 classes for ease of viewing

Pixel size: 500 m

Data available for 2000-2009

Despite differences in elevation, latitude & accumulation, there is a remarkable consistency to rate & extent of snowmelt with elevation & latitude – Eastern Sierra Nevada example
Apr 10, 2008

Bishop Creek

Cottonwood Creek

Fraction SCA

Day of year

Elevation, m

0

0 - 0.25

0.25 - 0.5

0.5 - 0.75

0.75 - 1
SCA in each elevation band increases with latitude.
For 2000-08, winter SCA at 1800-3900 m elevation shows a consistent increase with latitude.

Precipitation increases about 30% per degree latitude.

At a given latitude, SCA increases about 0.15 per 300 m elevation.

Fraction SCA in winter

Latitude, degrees
Consider also rate of SCA depletion during snowmelt, with elevation & latitude.
Each 300-m elevation band melts out ~3 weeks later than the next lower band. Inter-annual differences are about 6 weeks.

Rate of SCA depletion during snowmelt with elevation & latitude

Graphs showing the rate of SCA depletion with elevation and latitude for Bishop and Cottonwood with data points for different years.
Estimating SWE from SCA & snowmelt calculation

Validation remains a challenge because of no ground truth data.
How much of the snowcover does MODIS detect?

Glacier Point, April 2009

MODIS: 26% SCA
Survey: 38% SCA
LANDSAT: 19% SCA
Glacier Point, May 2009

MODIS: 0% SCA  Survey: 20% SCA
Comparison of MODSCAG snow detection

13 May, 2002

Central/southern Sierra Nevada
Summary

SCA varies consistently across elevation & latitude, with both SCA amount & rate of depletion showing similar patterns in both wet and dry years.

Estimation of SWE from SCA and snowmelt calculations is very sensitive to SCA fraction

For quantitative hydrologic modeling, and particularly in small basins, MODIS SCA products require bias corrections of 10-50%, depending on forest cover & time of year

These biases much less important for basin-scale hydrologic modeling, i.e. 100’s to 1,000’s of km², at lighter forest cover