How different are the Sierra Nevada SWE estimates from four land surface models with three forcing datasets?

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Motivation

Despite the popularity of the snowpack products from multiple land surface models (LSMs) with different forcing data for hydrologic and climate researches, quantifying differences in the SWE estimates and identifying dominant sources of errors (LSM physics vs. Forcing) are elusive, especially in mountainous regions.

Research Questions

1. How different are total snowpack estimates from four land surface models (LSM) and three forcing datasets over the Sierra Nevada?

2. Does the LSM physics or forcing data generate the larger errors in SWE estimates?

3. Do the errors depend on dry vs. wet years?
Snow Ensemble Uncertainty Project (SEUP) SWE products (12 combinations; 5 X 5 km²)

Four LSMs
(1) Noah version 2.7.1 (Noah 2.7.1)
(2) Noah-Multi-Parameterization, version 3.6 (Noah-MP)
(3) Catchment version 2.5 (CLSM 2.5)
(4) Joint UK Land Environment Simulator (JULES)

Three Meteorological Forcings
(1) Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA2)
(2) Global Data Assimilation System (GDAS)
(3) European Centre for Medium-Range Weather Forecasts (ECMWF)

Three reference SWE data
(1) Sierra Nevada Reanalysis (SNSR) SWE (90 X 90 m²)
(2) University of Arizona (UA) SWE (4 X 4 km²)
(3) SNODAS SWE (1 X 1 km²)

- Temporal period: 2010 to 2017 (7 years; Spin-up: 2000-2009)
- Spatial extent: California’s Sierra Nevada
Result 1. Total Annual Maximum SWE

Total SWE (in km$^3$) on Annual Maximum dates over the Sierra Nevada
Result 1. Total April 1st SWE

Total SWE (in km³) on 1 April over the Sierra Nevada

Water Year

SWE Volume (km³)


SNSR SWE, UA SWE, SNODAS, NoahMP ECMWF, CLSMF2.5 ECMWF, JULES ECMWF, Noah271 ECMWF, NoahMP GDAS, CLSMF2.5 GDAS, JULES GDAS, JULES MERRA2, NoahMP MERRA2, Noah271 MERRA2
Result 2. Time series of Total SWE Volume (Moderate year)

WY 2010

Total SWE Volume (km³)

O N D J F M A M J A S

UA
SNSR
SNODAS
NoahMP-ECMWF
NoahMP-GDAS
NoahMP-MERRA2
CLSMF2.5-ECMWF
CLSMF2.5-GDAS
CLSMF2.5-MERRA2
JULES-ECMWF
JULES-GDAS
JULES-MERRA2
Noah271-ECMWF
Noah271-GDAS
Noah271-MERRA2
Result 2. Time series of Total SWE Volume (Wet year)
Result 2. Time series of Total SWE Volume (Dry year)

WY 2012

[Graph showing time series of Total SWE Volume for different models and datasets during WY 2012.]
Result 2. Time series of Total SWE Volume (Dry year)

WY 2013
Result 2. Time series of Total SWE Volume (Dry year)

WY 2014

[Graph showing time series of Total SWE Volume for WY 2014]
Result 2. Time series of Total SWE Volume (Dry year)

WY 2015

[Graph showing time series of Total SWE Volume for WY 2015 with different models and years represented.]
Result 2. Time series of Total SWE Volume (Moderate year)

![Time series of Total SWE Volume](image)

WY 2016

Legend:
- UA
- SNSR
- SNODAS
- NoahMP–ECMWF
- NoahMP–GDAS
- NoahMP–MERRA2
- CLSMF2.5–ECMWF
- CLSMF2.5–GDAS
- CLSMF2.5–MERRA2
- JULES–ECMWF
- JULES–GDAS
- JULES–MERRA2
- Noah271–ECMWF
- Noah271–GDAS
- Noah271–MERRA2

Total SWE Volume (km³)
Result 2. Time series of Total SWE Volume (Wet year)

WY 2017

[Graph showing time series of Total SWE Volume for different models and datasets over the year 2017.]
Result 3. Streamflow vs. Total SWE depletion (daily steps)

**USGS Streamflow from Oct-1 to Jun-30**

**Total ΔSWE from Oct-1 to May-31**

\[ \Delta SWE_i = SWE_i - SWE_{i+1}, \text{ when } SWE_i - SWE_{i+1} > 0 \quad (i = \text{date}) \]

**Carson watershed**

[USGS 10308200]

**Kern watershed**

[USGS 1186001]
Result 3. Streamflow vs. Total SWE depletion + Liquid precip.

USGS Streamflow from Oct-1 to Jun-30

Total ΔSWE + Liquid P from Oct-1 to May-31

Carson watershed
[USGS 10308200]

Kern watershed
[USGS 1186001]
Result 3. Streamflow vs. Total SWE depletion (daily steps)

USGS Streamflow from Oct-1 to Jun-30

Total ΔSWE from Oct-1 to May-31

\[ \Delta SWE_i = SWE_i - SWE_{i+1}, \text{ when } SWE_i - SWE_{i+1} > 0 \text{ (i = date)} \]

American watershed

[USGS 11427000]

Mokelumne watershed

[USGS 11335000]
Result 3. Streamflow vs. Total SWE depletion + Liquid precip.

USGS Streamflow from Oct-1 to Jun-30

Total ΔSWE + Liquid P from Oct-1 to May-31

American watershed
[USGS 11427000]

Mokelumne watershed
[USGS 11335000]
Q. How different are total snowpack estimates from four land surface models (LSM) and three forcing datasets over the Sierra Nevada?
A. Noah-MP runs have a snowpack that is closest to the three reference SWE.

Q. Does the LSM physics or forcing data generate the larger variations in SWE estimates?
A. LSM’s differences generate larger SWE uncertainties than forcing difference.

Q. Do the errors depend on dry vs. wet years?
A. Yes, there are even differences in SWE estimates between similar wet years (e.g. 2011 vs. 2017).

✓ The effectiveness of the method using the total streamflow for evaluating total snowpack products may depend on watershed’s water balance.
Thank you.

*If you have any questions or comments, please email me!*

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Supplementary information: low/moderate/high elevations

Total maximum SWE (in km³) at low elevations (0 - 2000 m)
Supplementary information: low/moderate/high elevations

Total maximum SWE (in km$^3$) at moderate elevations (2000 - 3000 m)
Supplementary information: low/moderate/high elevations