The Current and Future State of Snowpack in the Colorado Rocky Mountains

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Introduction

- The life cycle of snow links Earth's climate system with atmospheric, hydrologic, and ecological processes that provide critical resources to humans and wildlife around the world.
- The snow properties, distributions, and evolutions associated with various environmental factors are strongly controlled by physics
- Changes in snow phenology in a future climate will likely affect water availability and wildlife ecology processes

★ Use a high-resolution regional climate model to drive a detailed snowpack model ★

CONUS Simulations

- V3.4.1 WRF model; 4-km spacing; CONUS domain (Fig. 1)
- Physics parameterizations: Thompson aerosol-aware microphysics, Noah-MP LSM, YSU PBL, RRTMG radiation

PSEUDO-GLOBAL WARMING APPROACH

- Compute 30-year CMIP5 19 model ensemble monthly mean Historical period : 1976-2005; Future period (RCP8.5): 2071-2100
- Compute perturbation: Difference between two climates
- Add perturbation to the 6-hourly ERA-I data

TWO EXPERIMENTS

- **Control run (CTRL):** Forced with ERA-I reanalysis, 13-year continuous integration, 1 October 2000 – 1 October 2013
- **Pseudo-Global Warming run (PGW):** Forced with ERA-I plus climate delta

$$D_{RCP8.5} = CMIP5_{2071\text{-}2100} - CMIP5_{1976\text{-}2005}$$

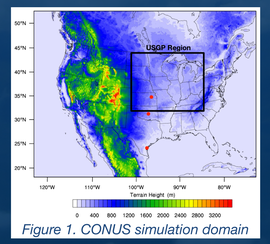


Figure 1. CONUS simulation domain

SnowModel description

- SnowModel is a suite of snow-distribution and snow-evolution modeling tools that are flexible in spatial and temporal domains (Liston and Elder 2006)
- Used widely for studies on climate, hydrology, remote sensing, wildlife, vegetation, avalanche, glacier and ice mass balance, etc.

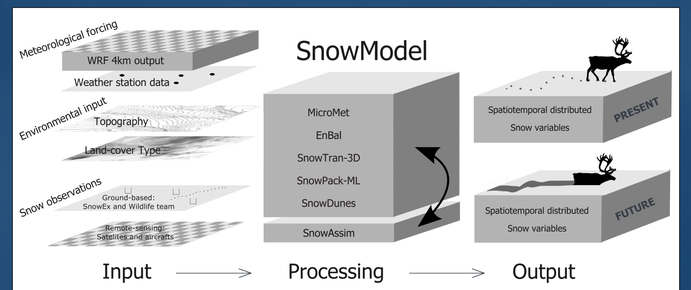


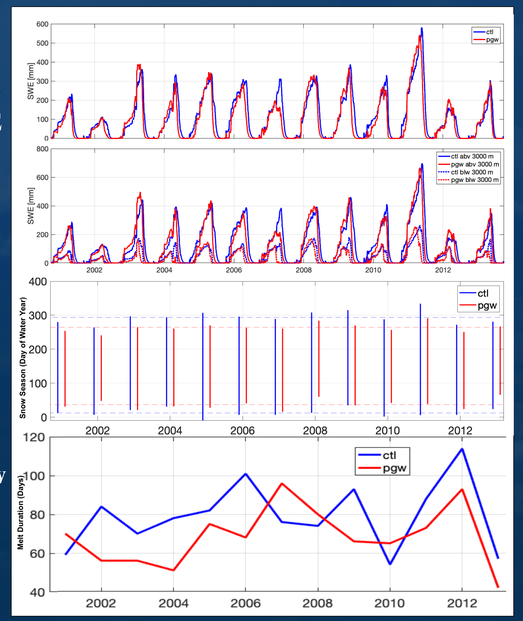
Figure 2. SnowModel schematic showing model inputs, processing modules, and outputs.

SnowModel runs - Colorado Rocky Mountains

- Downscale WRF CONUS simulations to a domain centered on the Colorado Rocky Mountains for input conditions to SnowModel
- SnowModel model resolution of 100 m to capture detailed snowpack dynamics

Snowpack Changes in a Future Climate

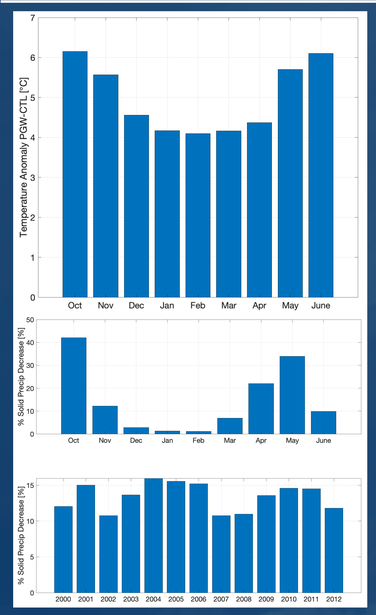
- Shorter snowpack duration in a future climate → less SWE
- Similar behavior above and below 3000m, but significant annual variability is clear
- Earlier and faster melting of SWE, especially clear at upper elevations
- Future climate snow season is ~30-75 days shorter than the current climate

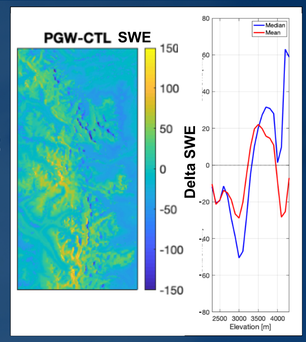


★ Shorter snowpack seasons in a future climate ★

- Mean SWE decreases at lowest and highest elevations, increases at middle elevations

ENVIRONMENTAL CONDITIONS





- Greatest future temperature changes in the fall and spring → reason for shortening snowpack duration
- Decrease in the percentage of solid precipitation is greatest in the fall and spring as a result
- Minimal annual variability of the decrease in solid precipitation → does not explain full variability of the signal (e.g., 2007)

★ Notable increase in temperature and decrease in solid precipitation in the fall and spring → shorter seasonal snowpack ★

Conclusions

Snowpack dynamics simulated at 100-m over the Colorado Rocky Mountains in a future climate show:

1. Shorter snowpack duration (~30-75 days) and less overall SWE
2. Mean SWE decreases at the lowest and highest elevations, increases at middle elevations
3. Greatest future temperature changes in fall and spring → explains shorter snowpack durations
4. Decrease in the percentage of solid precipitation also peaks in the fall and spring, with minimal annual variability

Acknowledgements

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