Combining regional climate models and satellite measurements improves SWE accuracy and spatial resolution

Merging regional climate models and remote sensing datasets to estimate mountain snow water equivalent: Proof-of concept in the Tuolumne watershed

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INTRODUCTION

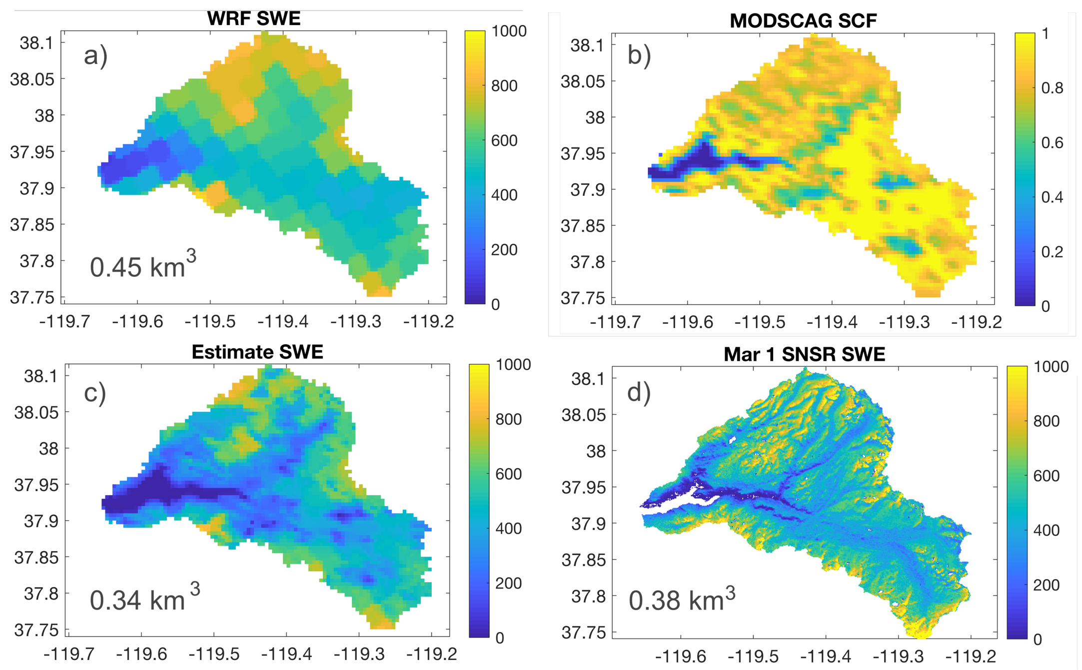
- No viable strategy for direct observation of global mountain snow
- Mountain regional climate model (RCM) **accuracy**: snowfall > energy balance

METHODS

1. Mass-and-energy constrained optimization (MECO) estimates daily precipitation, SWE, snow cover fraction (SCF) and melt at 500 m resolution.
2. MECO minimizes difference between estimates, WRF and MODIS SCF; constrain melt based on energy balance using CERES Syn and WRF
3. Test: Tuolumne, Sierra Nevada (775 km^2).

RESULTS

- In situ snow pillows and courses: RMSE WRF 99 mm. MECO: 48 mm
- Diff. from SNSR: WRF 18%. **MECO: 10%.**



DISCUSSION

- ~4 km RCMs constrained by energy balance could be deployed globally
- This would produce a new estimate of global mountain SWE at 500 m resolution
- Caveat: this algorithm still needs to be adapted to treat forest effects

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Photo taken looking down at Tuolumne Meadows on December 23, 2014 (with Unicorn Peak in the background) by Laura and Rob Pilewski (the Tuolumne Winter Rangers).

PROBLEM FORMULATION

We used the HPC language Julia to solve the following mass-and-energy constrained optimization problem:

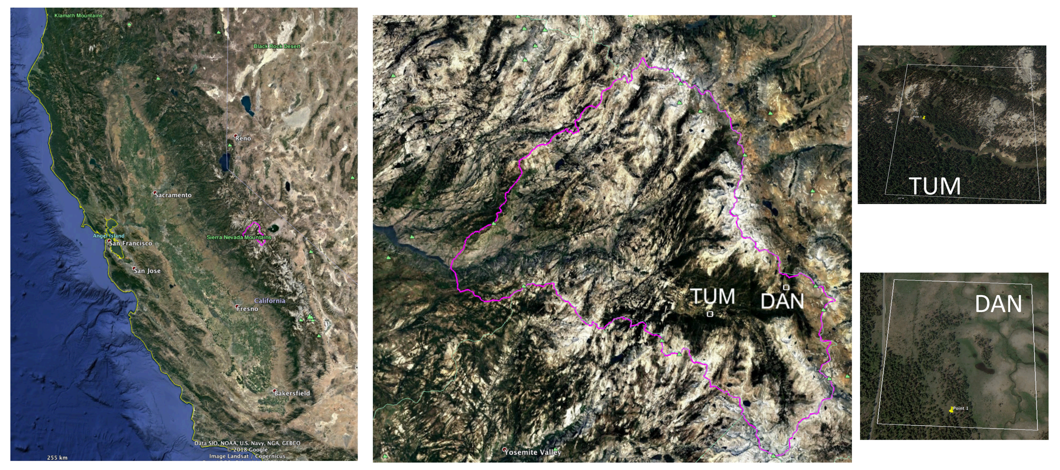
$$\min_x \sum \left(\frac{x_i - \overline{x_i}}{\sigma_i}\right)^2$$

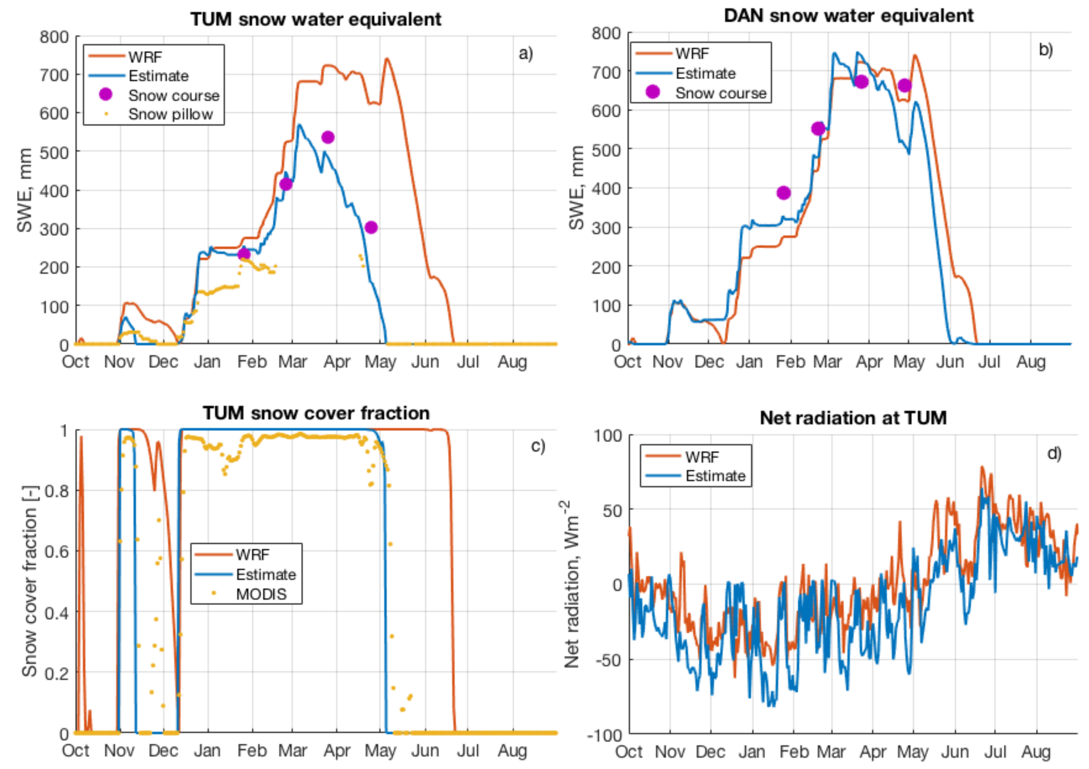
subject to: $$\frac{dSWE}{dt} = P - M$$

$$M = \left[R_s^{\downarrow}(1-\alpha) + R_l^{\downarrow} - R_l^{\uparrow} - H - LE\right]SCF$$

where $R_s^{\downarrow}$, $R_l^{\downarrow}$, and $R_l^{\uparrow}$ are the (surface) downwelling shortwave, upwelling longwave and downwelling longwave respectively, α is albedo, ρ is water density, L is latent heat of vaporization, LE is latent heat flux, H is sensible heat flux, P is precipitation, and Q is runoff; the vector x represents the MECO estimate of SWE, SCF, P, $R_l^{\uparrow}$, H, and E, σ represents uncertainty, and the overline denotes either WRF or observed estimate, respectively. CERES $R_s^{\downarrow}$ and $R_l^{\downarrow}$ and WRF α are taken as given. Forest impacts will be considered in future versions.

IN SITU COMPARISON





DATASETS USED

- WRFv4 with Noah-MP model simulations: 3 km resolution, forced by NARR at boundary conditions
- SCF: MODIS Snow Covered Area and Grain Size (MODSCAG)
- $R_s^{\downarrow}$ and $R_l^{\downarrow}$: CERES Synoptic: hourly, 1° resolution
- In situ data: the CA DWR snow surveys and snow pillows, after QA/QC by UW
- 90 m SWE estimates from UCLA Margulis group Sierra Nevada Snow Reanalysis (SNSR)

Details, references and links in the paper draft

Terrestrial Hydrology: 80NSSC17K0200

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