Enhancing snowpack physics in Noah-MP land model to improve S2S prediction of precipitation and droughts

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With contributions from

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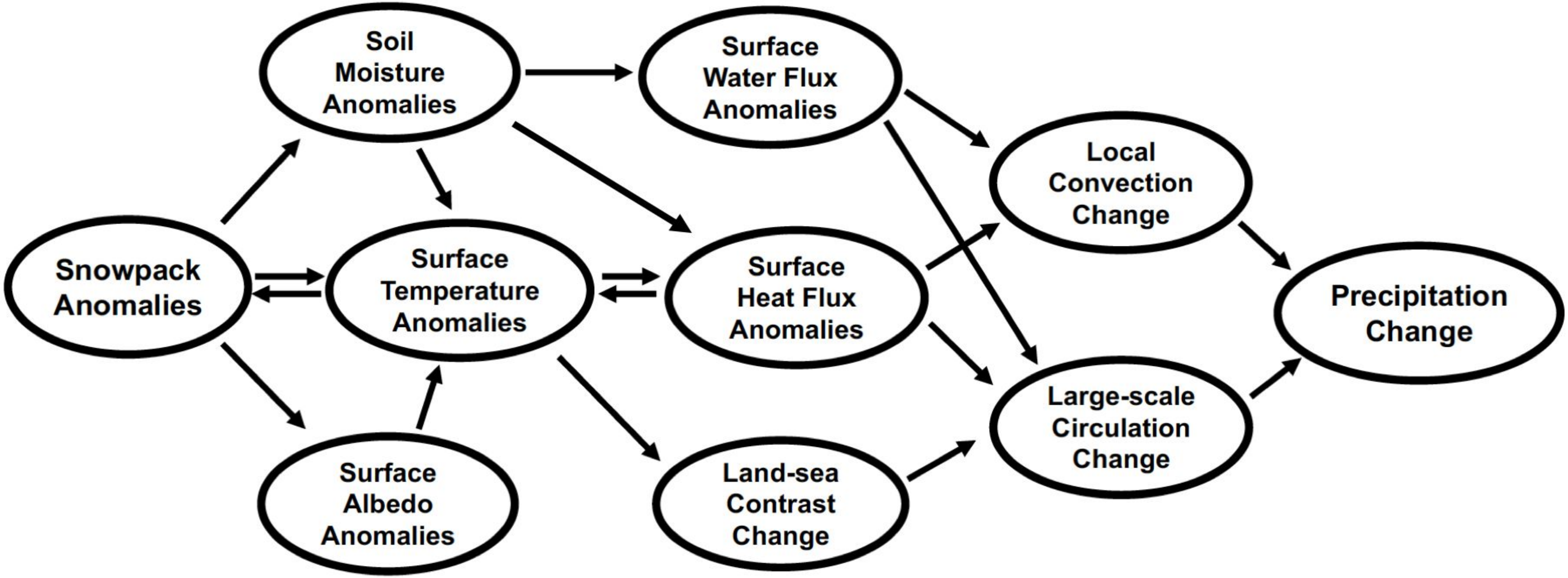
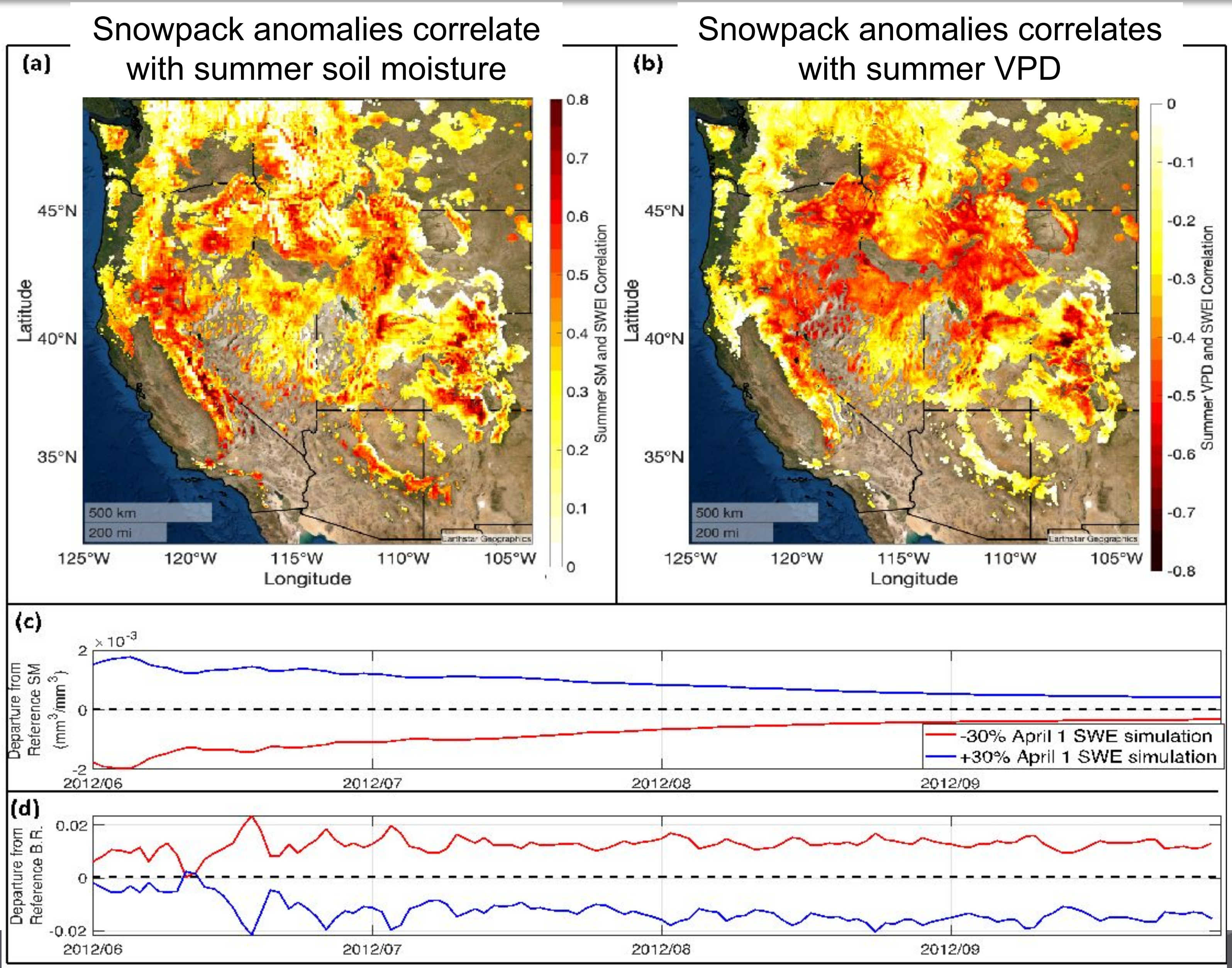
June 6, 2024 *@S2S Community Workshop*

Snowpack-precipitation interaction and feedback



Spring snowpack connection with summer soil moisture

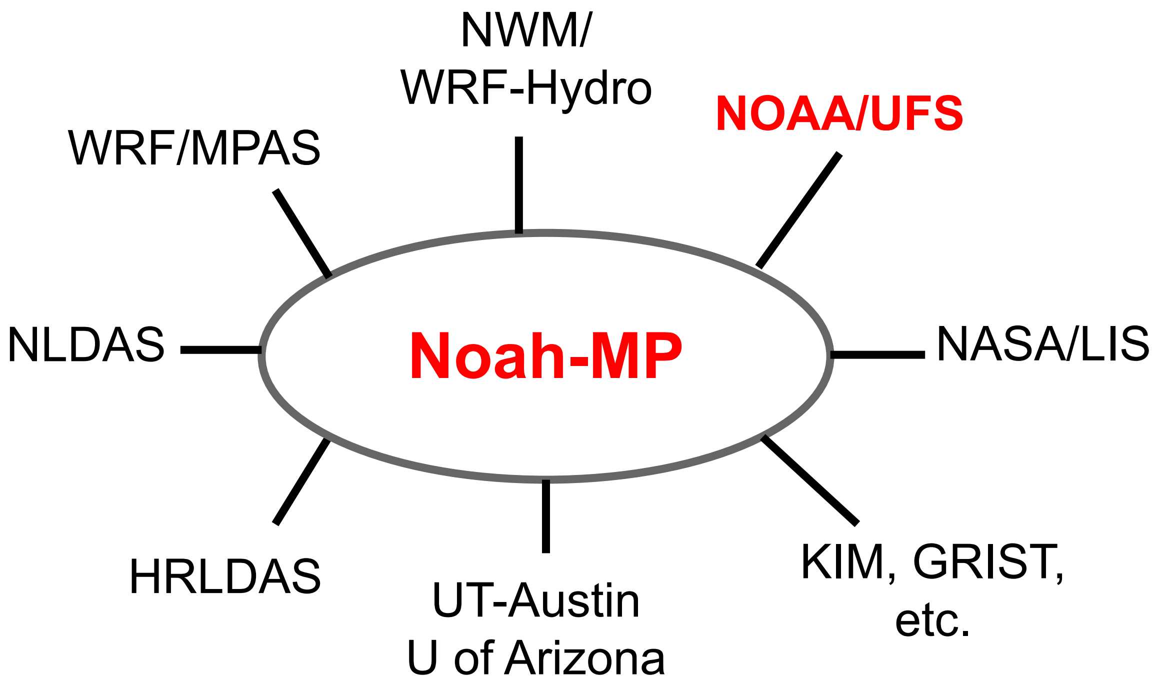


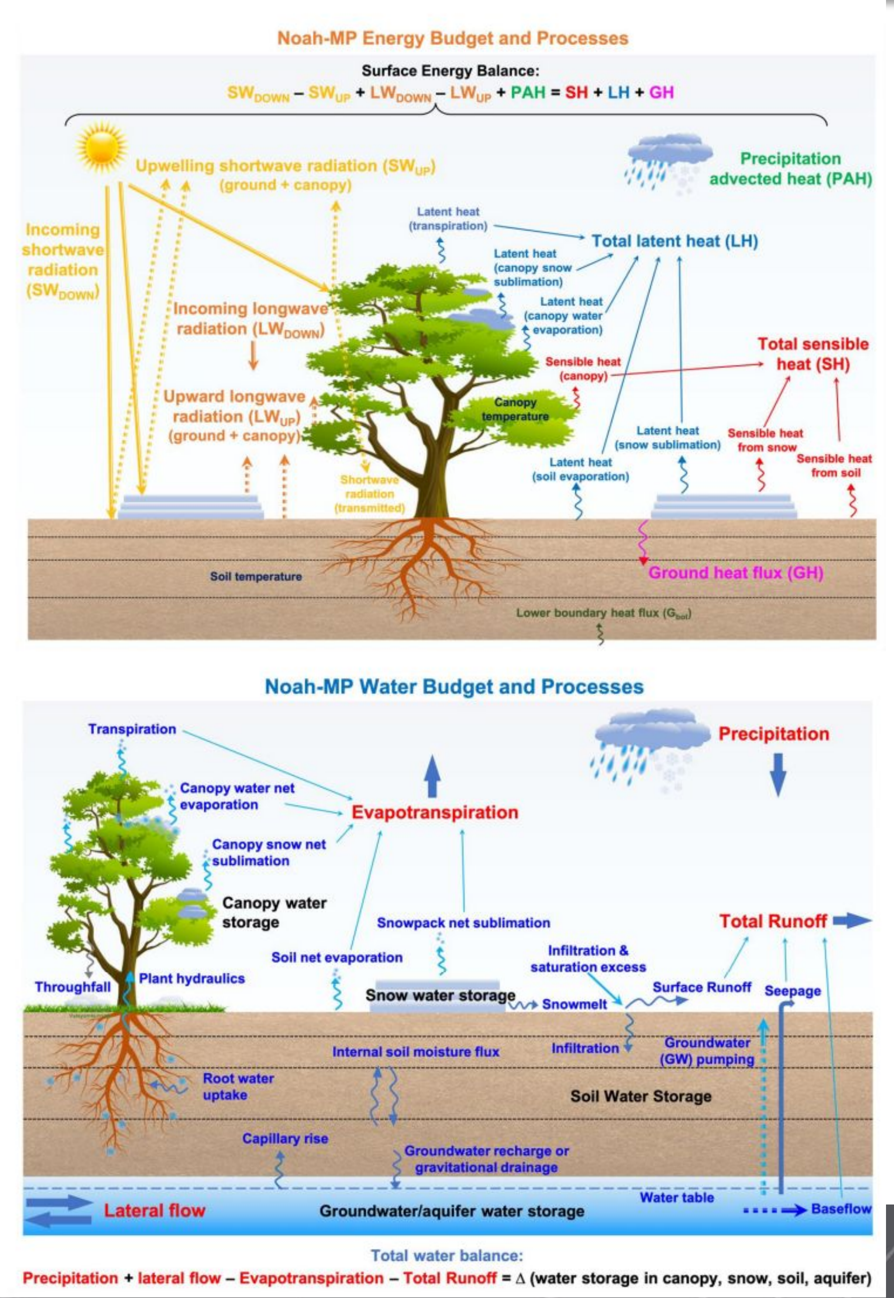
Observed snowpack anomalies are significantly correlated ($p < 0.05$) with summer soil moisture and VPD over 71% of the domain.

Low spring SWE leads to low soil moisture and high VPD in summer via soil moisture memory based on physical land surface model simulations.

Abolafia-Rosenzweig, He, et al., 2022 *ERL*

Community Noah-MP land surface model (LSM)





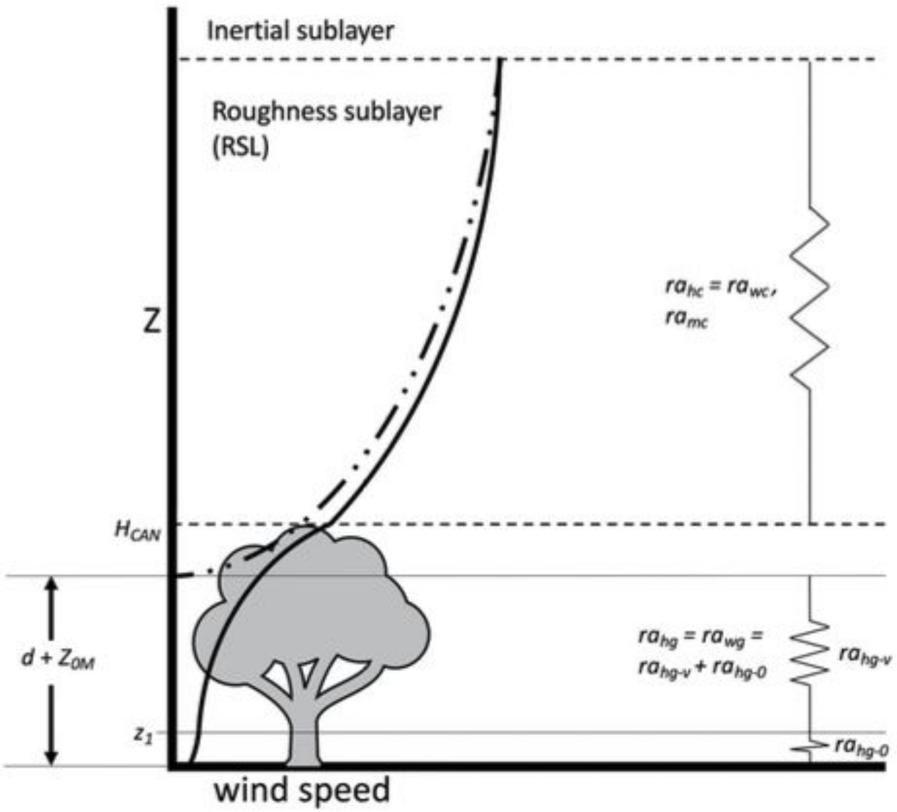
He et al. (2023)

Process-level snowpack physics improvements in Noah-MP LSM

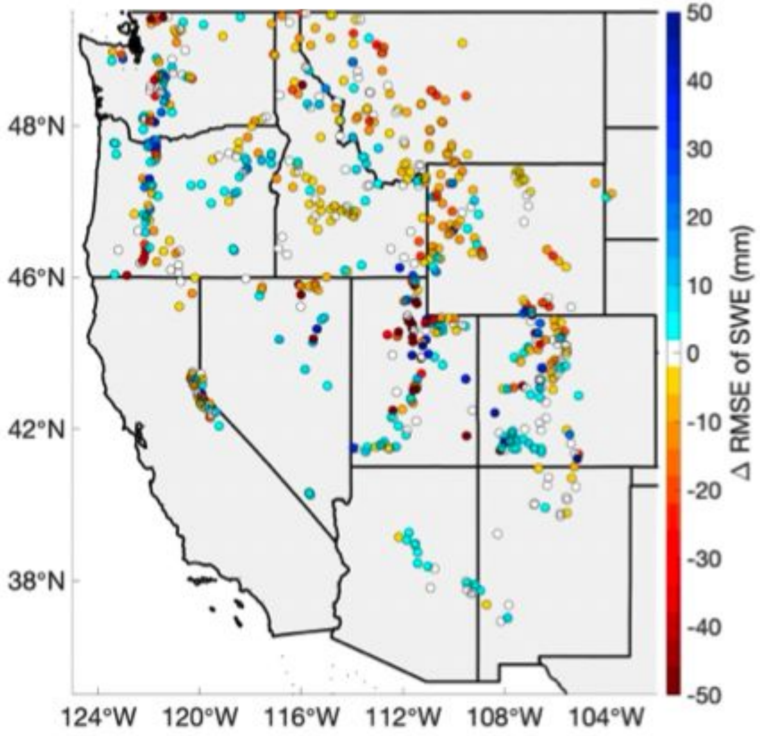
1. **Improve canopy turbulence scheme above snowpack:** *Abolafia-Rosenzweig, He, et al. 2021 JAMES*
2. **Improve snow compaction/densification:** *Abolafia-Rosenzweig, He, et al. 2024 JAMES*
3. **Improve snow albedo scheme:** *Lin, He, et al., 2024 JGR-Atmos in review*
4. **Improve snow cover parameterization:** *Abolafia-Rosenzweig, He, et al. 2024 in preparation*
5. **Improve canopy snow interception:** *next-step work*

Implementing a Unified Turbulence Parameterization Throughout the Canopy and Roughness Sublayer

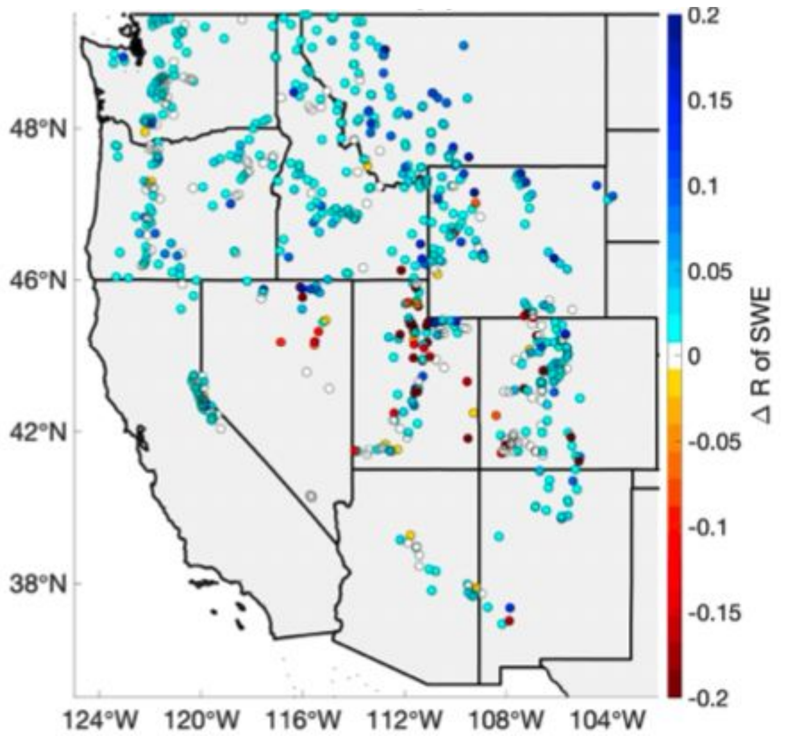
- Noah-MP uses the Monin-Obukhov (M-O) Similarity Theory (MOST) to calculate land-atmosphere exchanges of fluxes.
- The MOST flux-profile relationships are known to fail within and above rough surfaces (particularly in the RSL).
- Previous work concluded that simulated snow water equivalent (SWE) is sensitive to different surface turbulence parameterizations.
- We integrate a RSL turbulence parameterization (Bonan et al., 2018) within Noah-MP



Reduced RMSE of SWE

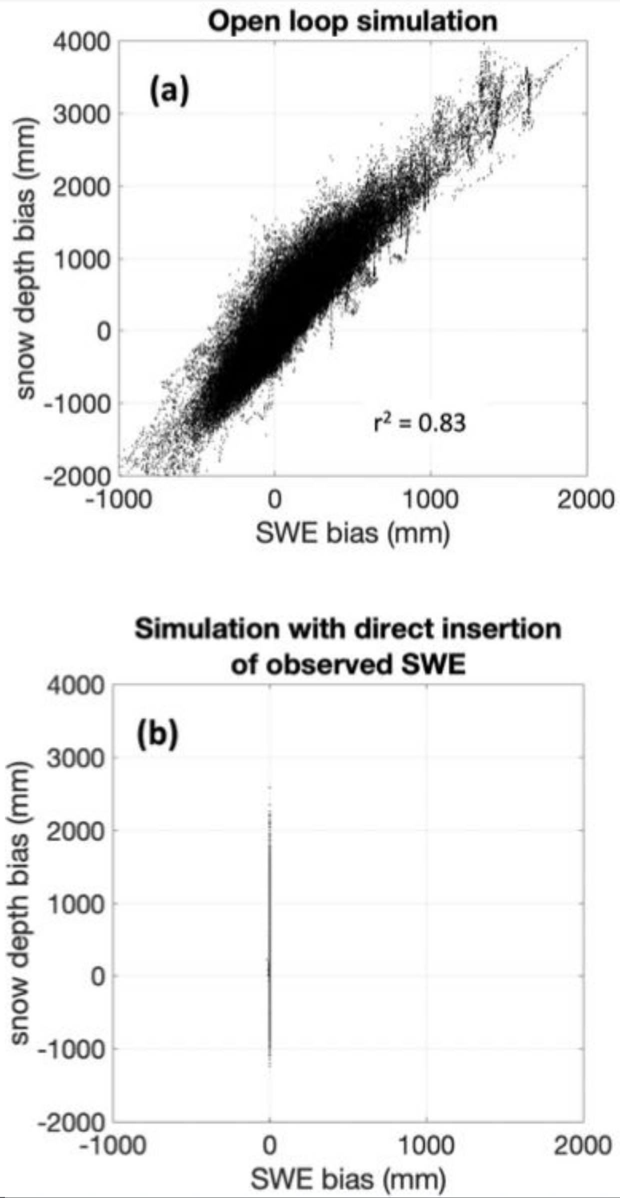


Increased Correlation of SWE



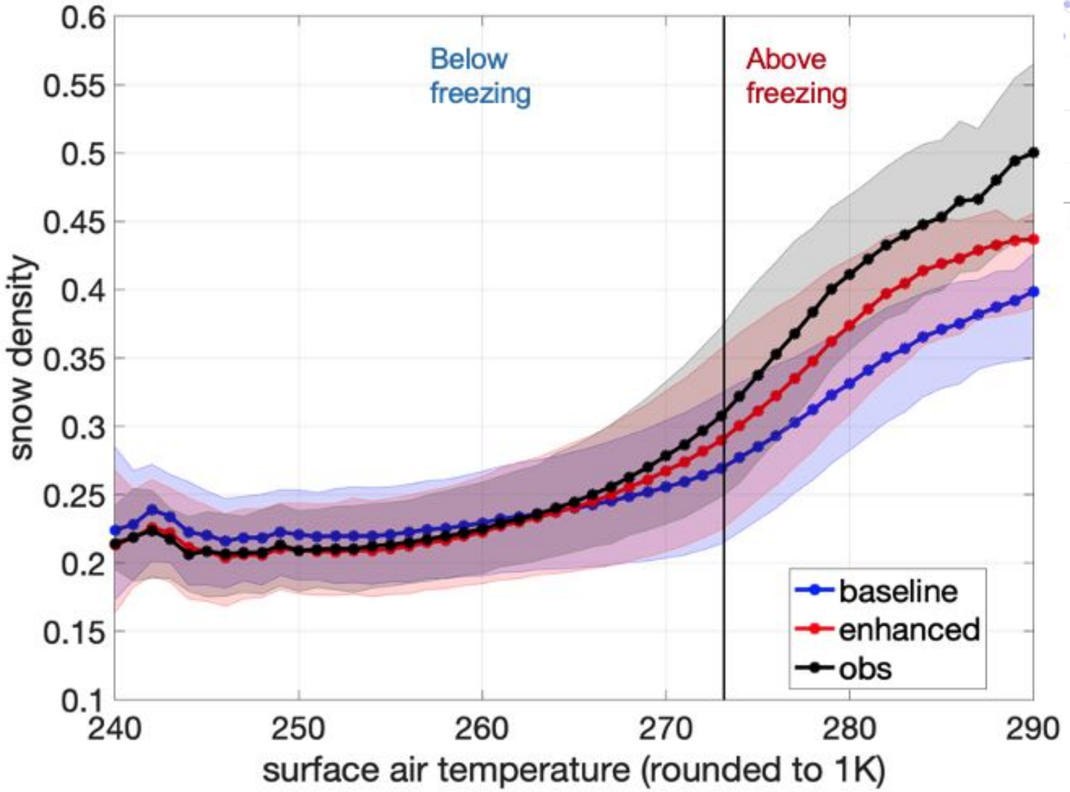
Abolafia-Rosenzweig, R., He, C., Burns, S. P., & Chen, F. (2021). Implementation and evaluation of a unified turbulence parameterization throughout the canopy and roughness sublayer in Noah-MP snow simulations. *Journal of Advances in Modeling Earth Systems*, 13, e2021MS002665.

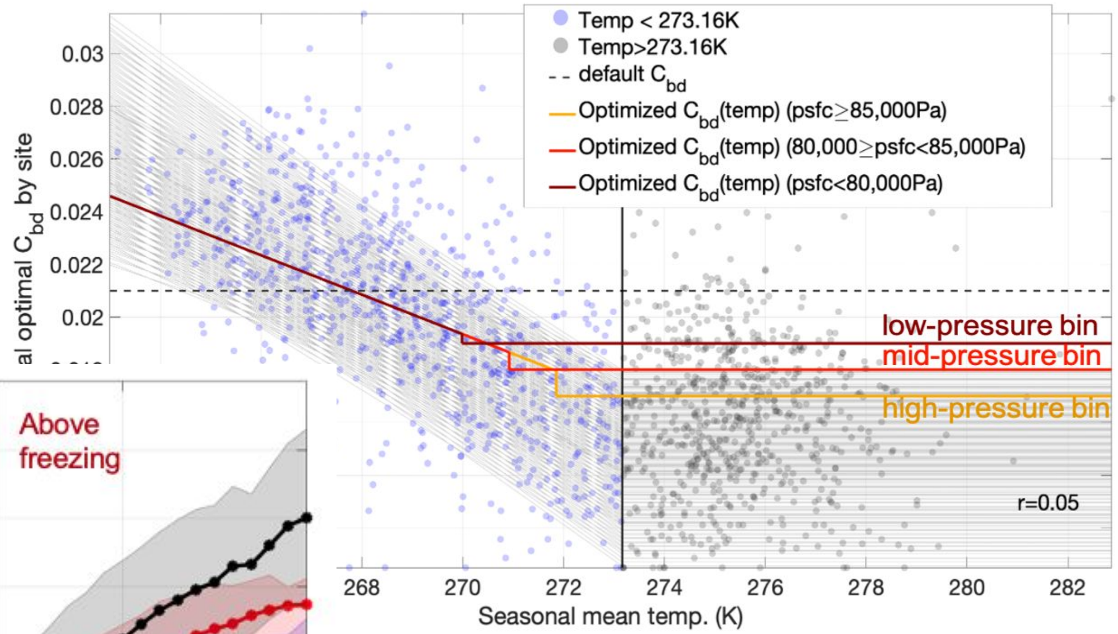
Improved Noah-MP snowpack compaction parameterization constrained by SNOTEL in-situ observations



Noah-MP **snow compaction processes**:

- destructive metamorphism
- Overburden
- melt metamorphism



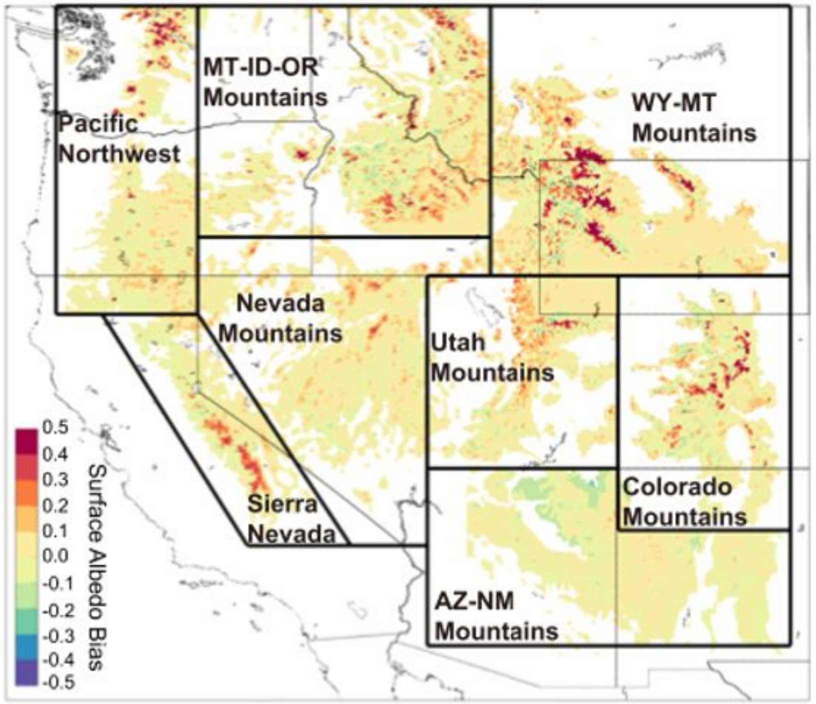


Abolafia-Rosenzweig, R., He, C., Chen, F., & Barlage, M. (2024). Evaluating and enhancing snow compaction process in the Noah-MP land surface model. *Journal of Advances in Modeling Earth Systems*, 16, e2023MS003869

Improved snow albedo modeling in Noah-MP coupled with a physical snowpack radiative transfer scheme

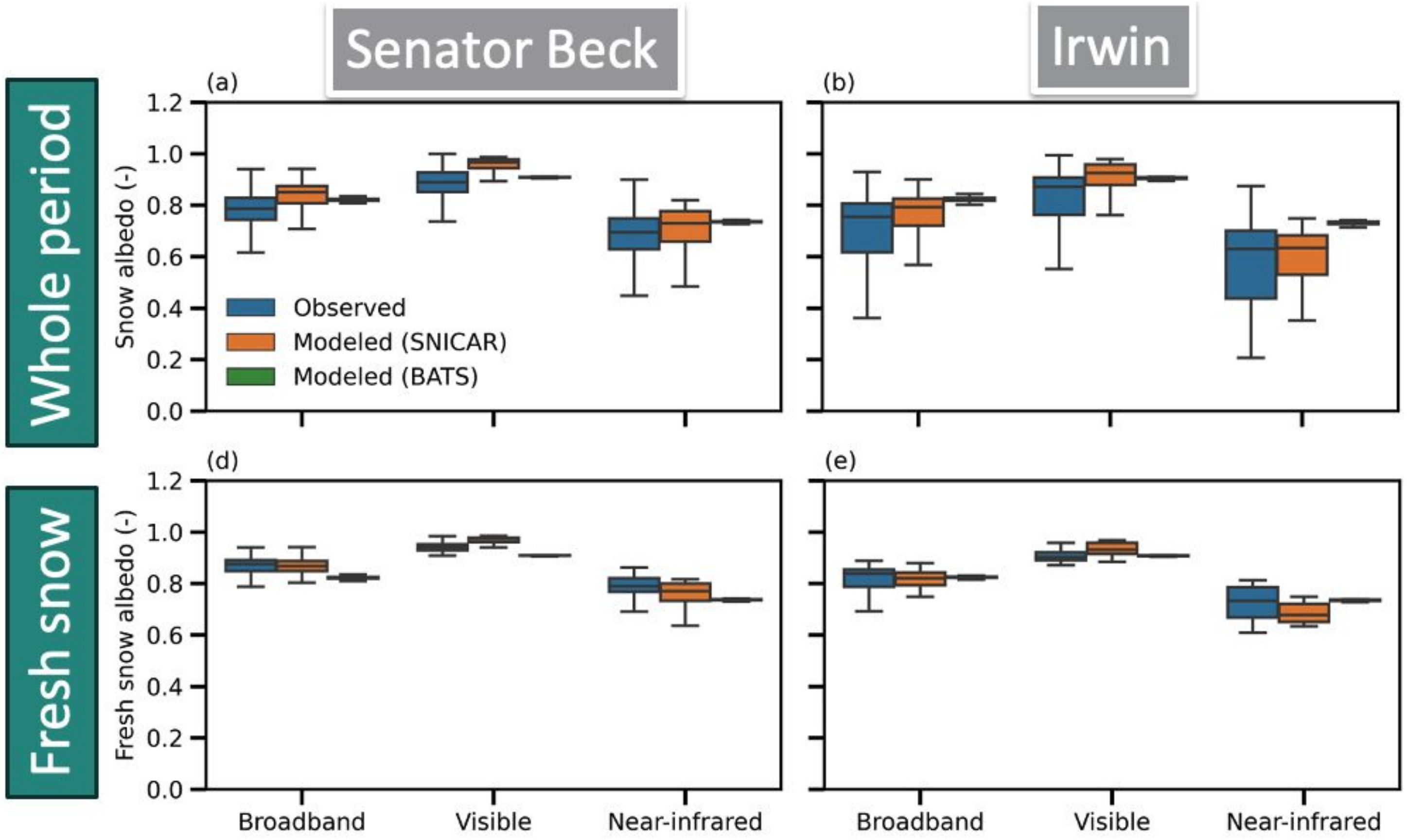
- Default Noah-MP snow albedo schemes (e.g., BATS & CLASS) are semi-empirical, showing systematic biases.
- SNICAR is a physical radiative transfer model that resolves snow-aerosol-radiation interactions.
- NoahMP-SNICAR significantly improves the magnitude and variability of snow albedo modeling.

Snow albedo bias using default Noah-MP snow albedo scheme



He et al., 2019

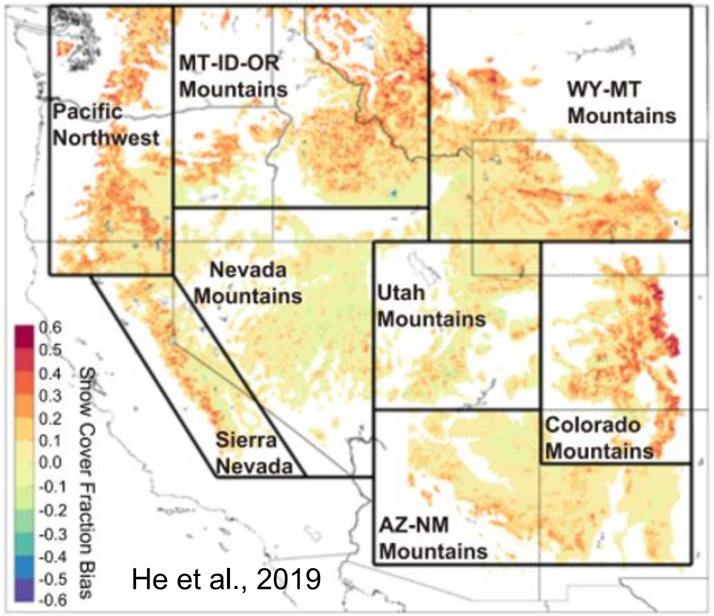
NoahMP-SNICAR comparison with in-situ measured snow albedo



Tzu-Shun Lin, Cenlin He, Ronnie Abolafia-Rosenzweig, et al. Implementation and evaluation of SNICAR snow albedo scheme in Noah-MP (version 5.0) land surface model. ESS Open Archive . January 24, 2024. DOI: 10.22541/essoar.170612215.54848315/v1

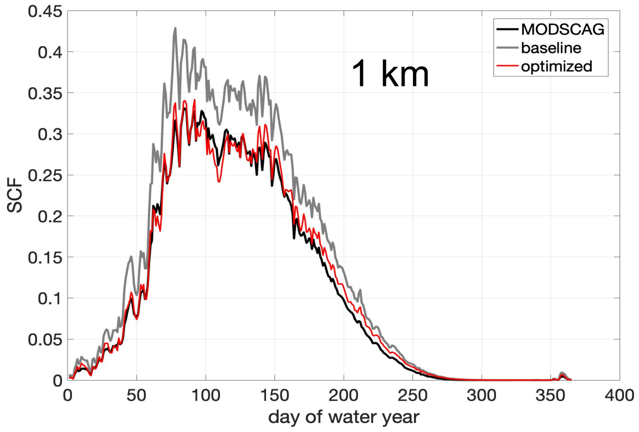
Developing an observation-constrained scale-aware snow cover parameterization in Noah-MP

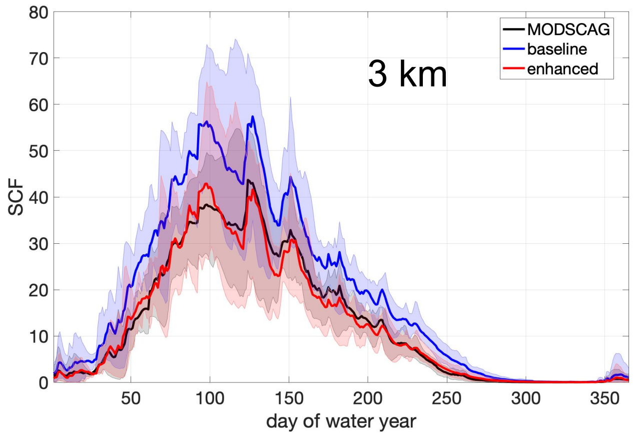
- Default Noah-MP snow cover parameterization tends to systematically overestimate snow cover.
- Developing a scale-aware snow cover parameterization using observation-based data (MODSCAG SCF, SNODAS SWE & SD)

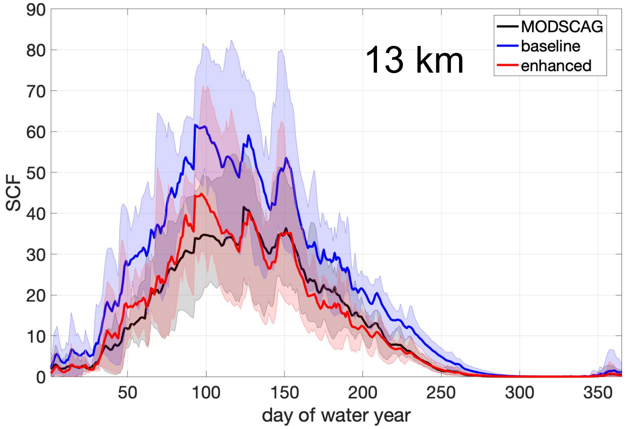


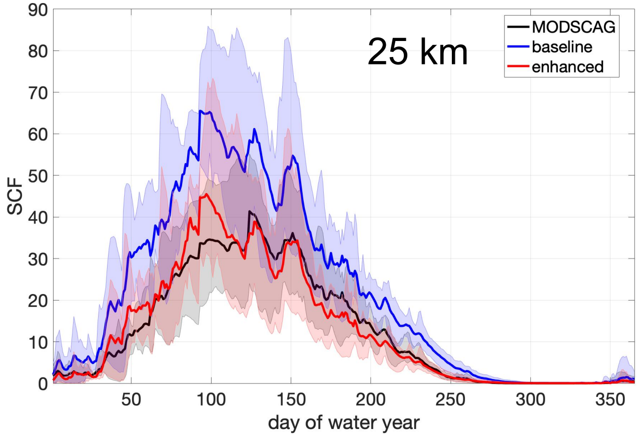
Snow cover bias using default Noah-MP

Snow cover evaluation with MODSCAG observations at UFS-relevant scale



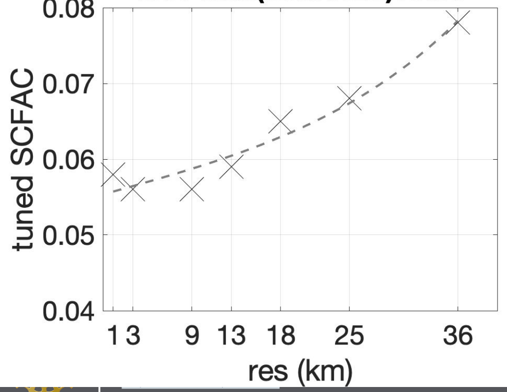




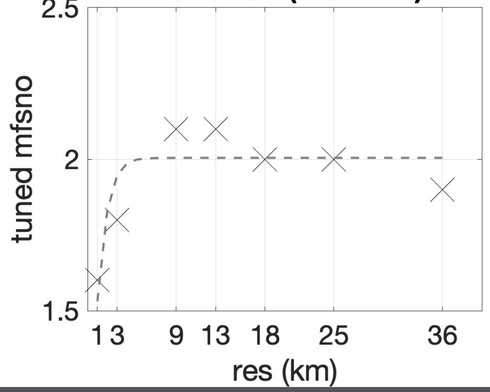


Optimized snow cover parameter vs spatial scale

0.01*sinh(0.05xRES)+0.06



1.00 + tanh(0.59*RES)



Abolafia-Rosenzweig, R., He, C., et al. (2024) *In preparation*

Thank you!

If you are interested in our work, please email me: cenlinhe@ucar.edu