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INTEGRATING SNOW MASS ESTIMATES FOR MOUNTAIN AREAS IN THE SNOW CCI+ SWE PRODUCT

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Snow hydrology – Snow water equivalent
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Objectives

- Fill in mountain areas masked out of the Snow CCI SWE product
- Test the feasibility of adapting a proven approach for mountain SWE estimation, a Bayesian Snow Reanalysis Framework (BSRF), to use the Snow CCI SCF product

Outline

- Bayesian Snow Reanalysis Framework overview
- Snow CCI+ MODIS SCFV evaluation
- Prototype configuration
- Preliminary results

BAYESIAN SNOW REANALYSIS FRAMEWORK (BSRF)

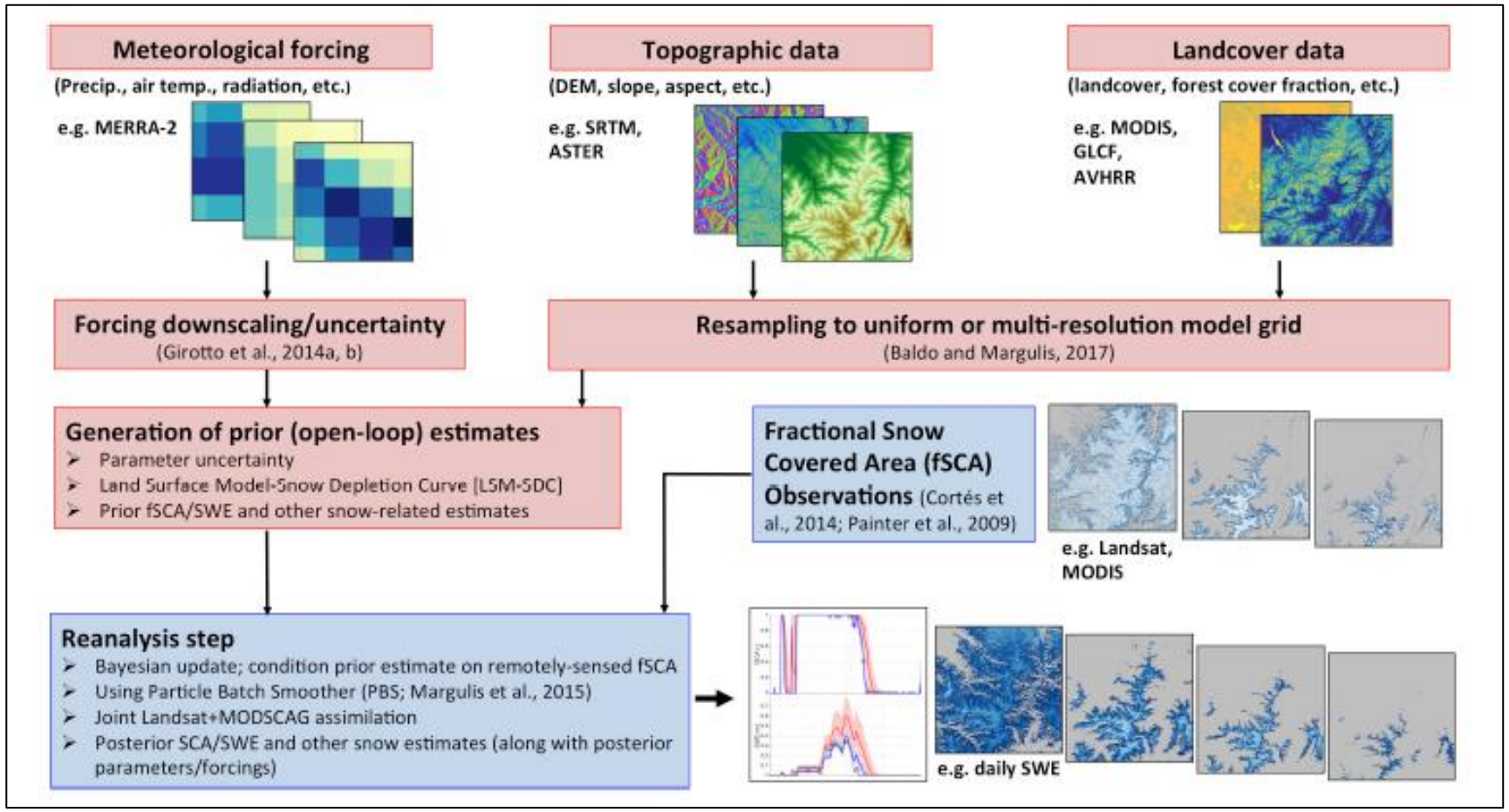


Figure: Margulis et al. 2019

Regional implementations using Landsat and/or MODIS

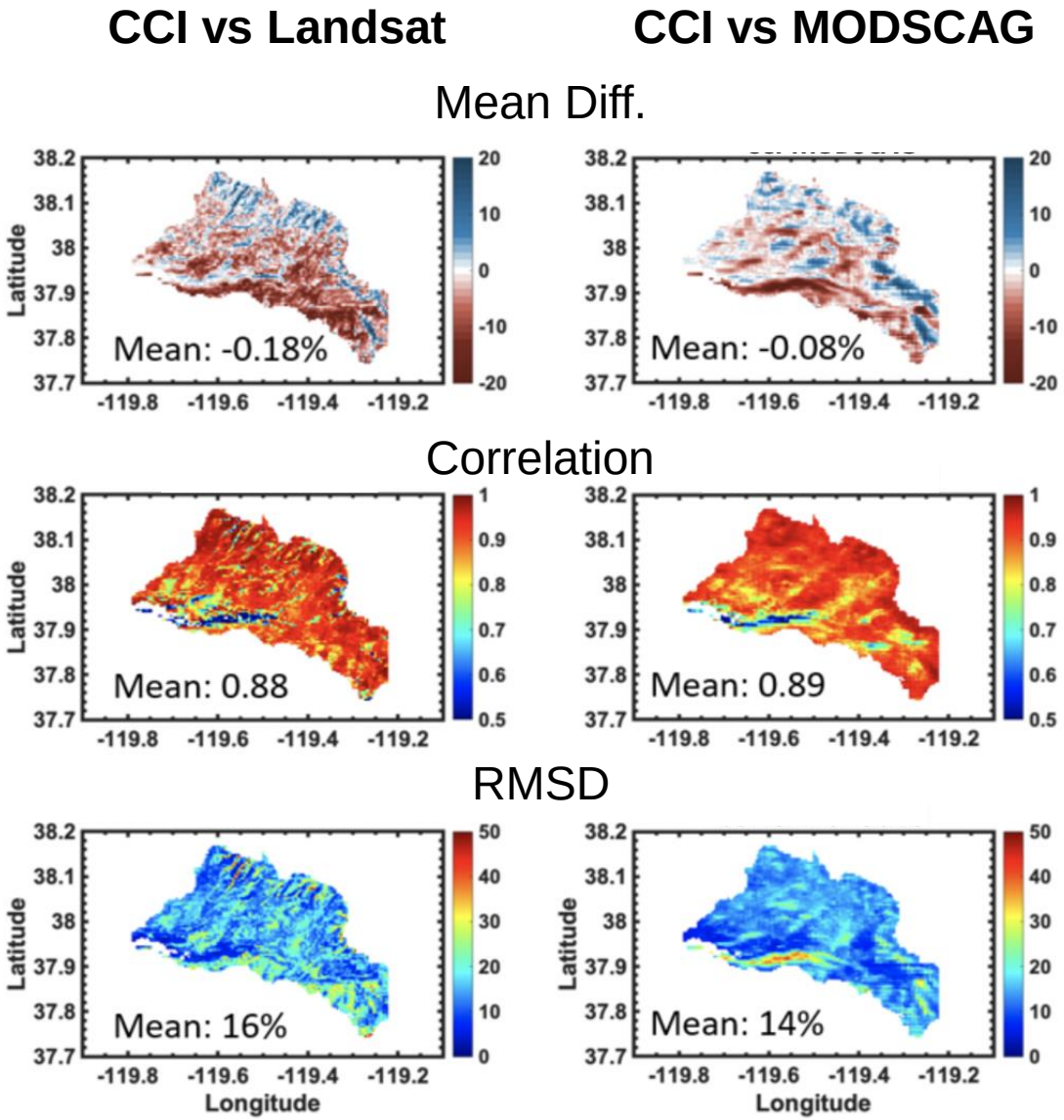
- Western US (Fang et al. 2022)
- High Mountain Asia (Liu et al., 2021)

Snow CCI SCF:

- Hemispheric coverage
- Pixel-wise uncertainty

SNOW CCI+ MODIS SCFV

1. Small differences in SCF compared to Landsat and MODSCAG
2. Saturation at end of accumulation season in some locations.
   - Saturation of fSCA at 100% can lead to overestimation of SWE within BSRF
3. CCI SCF biased low during ablation season
   - Leads to underestimation of SWE in BSRF



Pixel-wise spatial comparison for WY 2016

PROTOTYPE CONFIGURATION

Testing of **Snow CCI SCFV MODIS** conducted for three representative water years – 2015, 2016, 2017 over Tuolumne watershed, California.

1. Measurement error
2. Spatial resolution
3. Viewing angle geometry

Snow CCI+ SCFV MODIS uncertainty layer

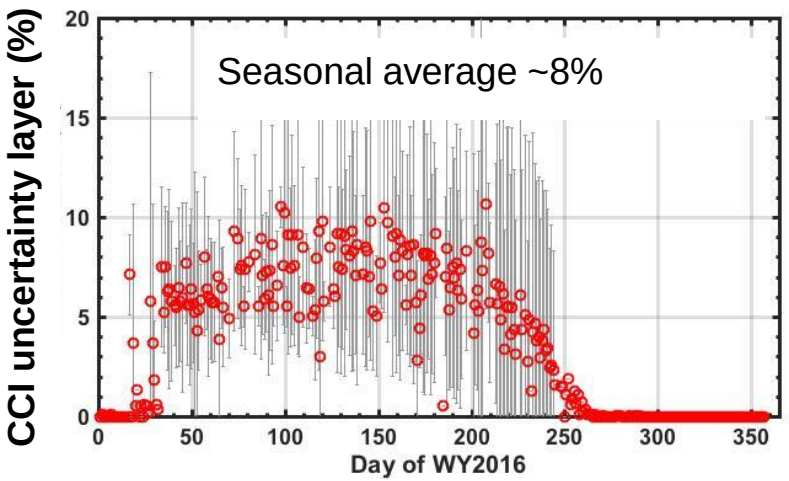
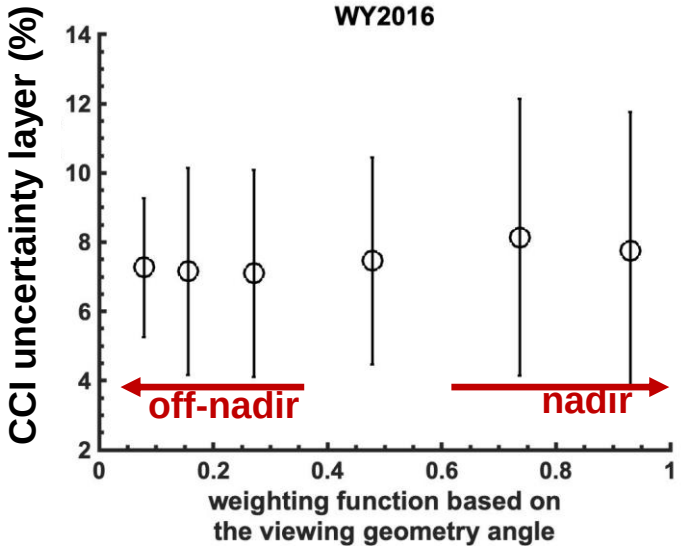


Fig. 2016 Tuolomne basin-averaged CCI SCF uncertainty

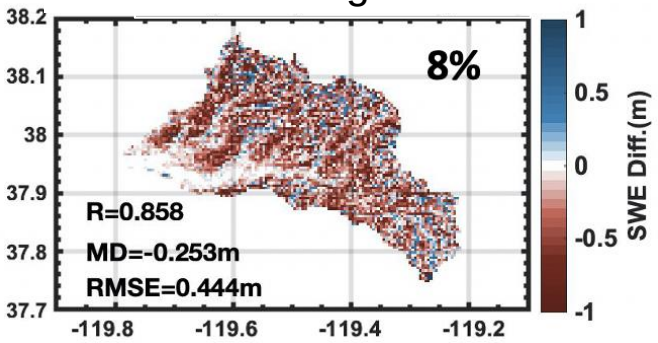


- Snow CCI MODIS SCF uncertainty is the statistical component.
- Limited response of CCI SCF RMSE to changes in fSCA and viewing angle geometry.
- Use of pixel-wise uncertainty not investigated further.

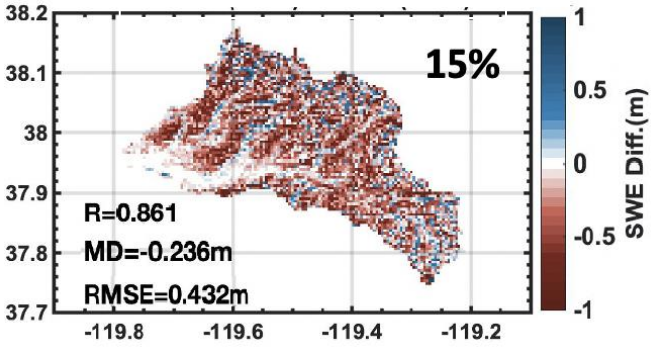
Measurement error

CCI (post) – Landsat (post)

CCI average 8%



MODSCAG 15%

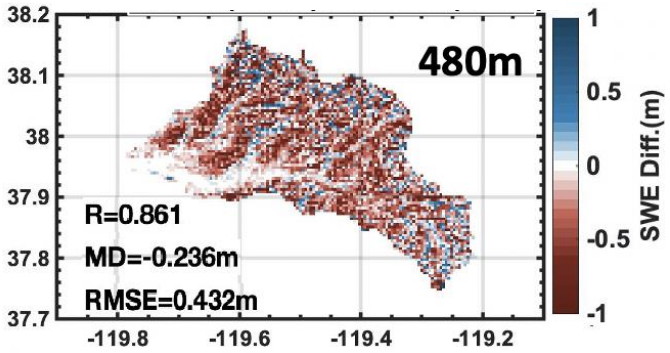


Average CCI SCF RMSE (8%) is too low which overly weights the SCF estimate, degrading performance.

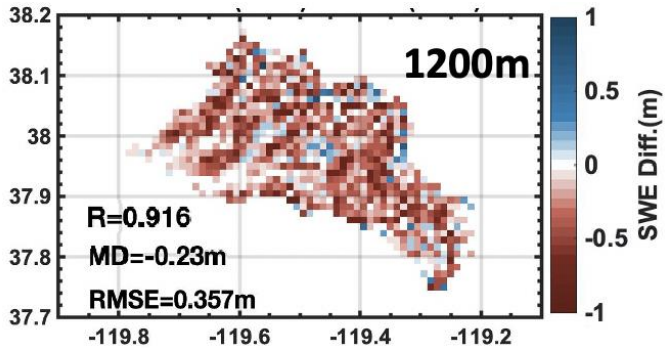
Increasing the error to MODSCAG 15% results in a uniform, but very small, improvement with more realistic fSCA measurement error.

Spatial resolution

Native BSRF 480m

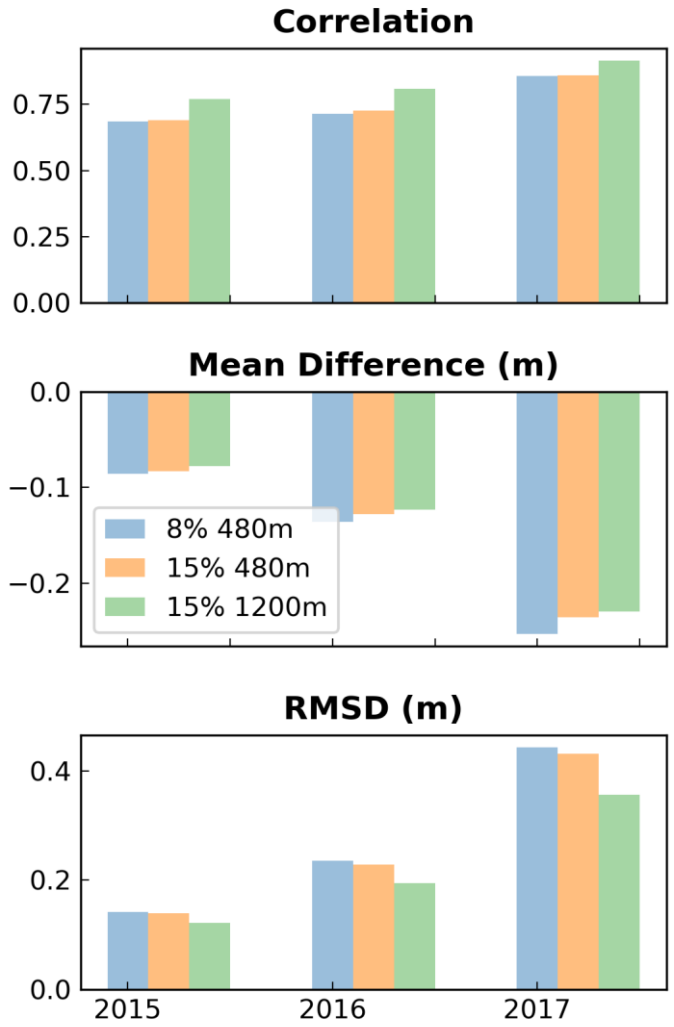


Native CCI 1200m



Nearest neighbour interpolation to 480m resolution overly smooths out spatial variability.

Assimilation of CCI SCF at native CCI SCF resolution shows improvement over prior when compared to Landsat posterior.



- **15% measurement error, native CCI SCF resolution and screen out off-nadir (38.7°) scenes**

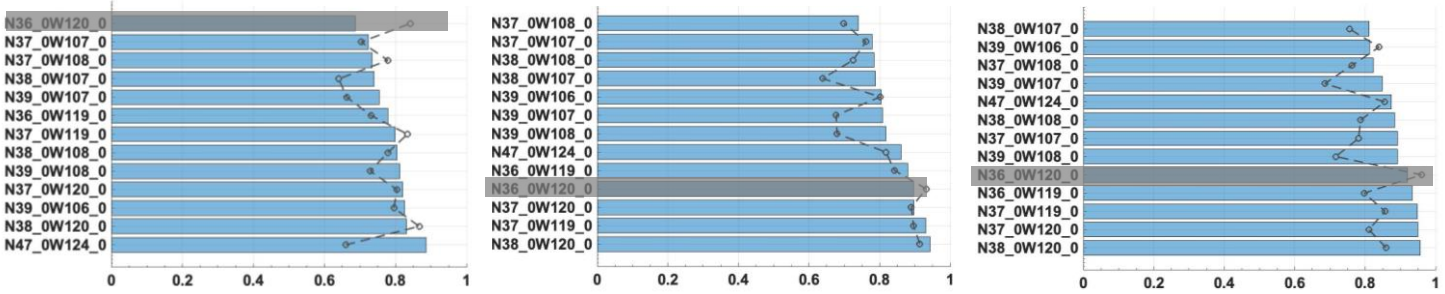
PROTOTYPE CONFIGURATION

- Three typical water years 2015 – 2017
- California and Colorado test areas

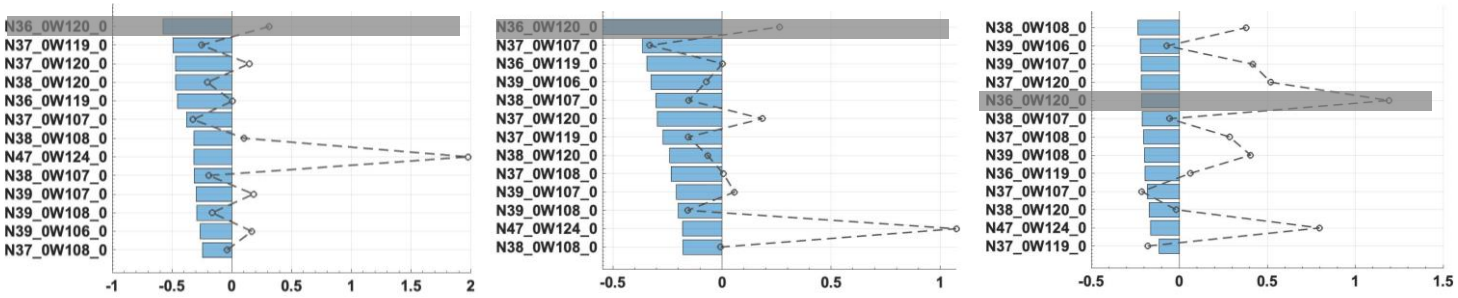
	BSRF-Snow CCI	**BSRF-Landsat Reference**
Assimilation dataset	MODIS CCI SCF	Landsat SCF
Native data resolution	0.01°	30 m
Reanalysis resolution	0.011°/1200 m	0.011°/1200 m
Measurement error	15% (consistent with MODSCAG)	10%
Zenith angle	Off-nadir included up to 38.7°	Nadir only

CCI+ SCFV BSRF PERFORMANCE

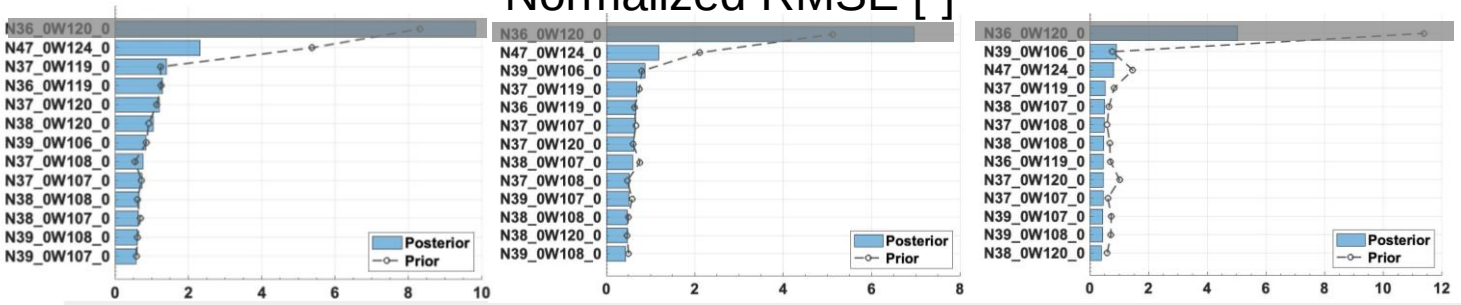
Correlation



Normalized mean difference [-]



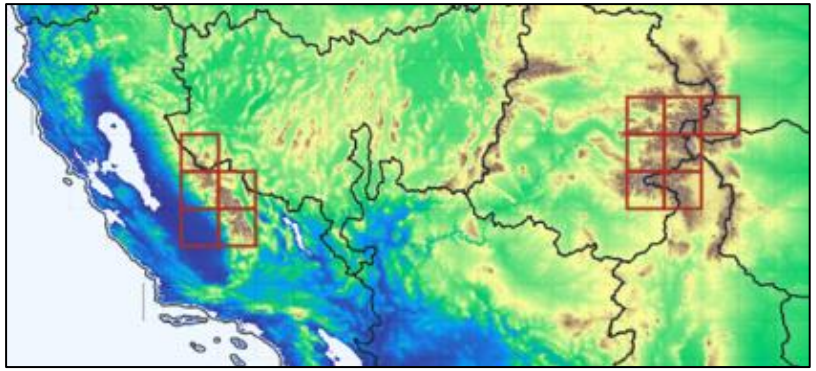
Normalized RMSE [-]



WY 2015 **WY 2016** **WY 2017**

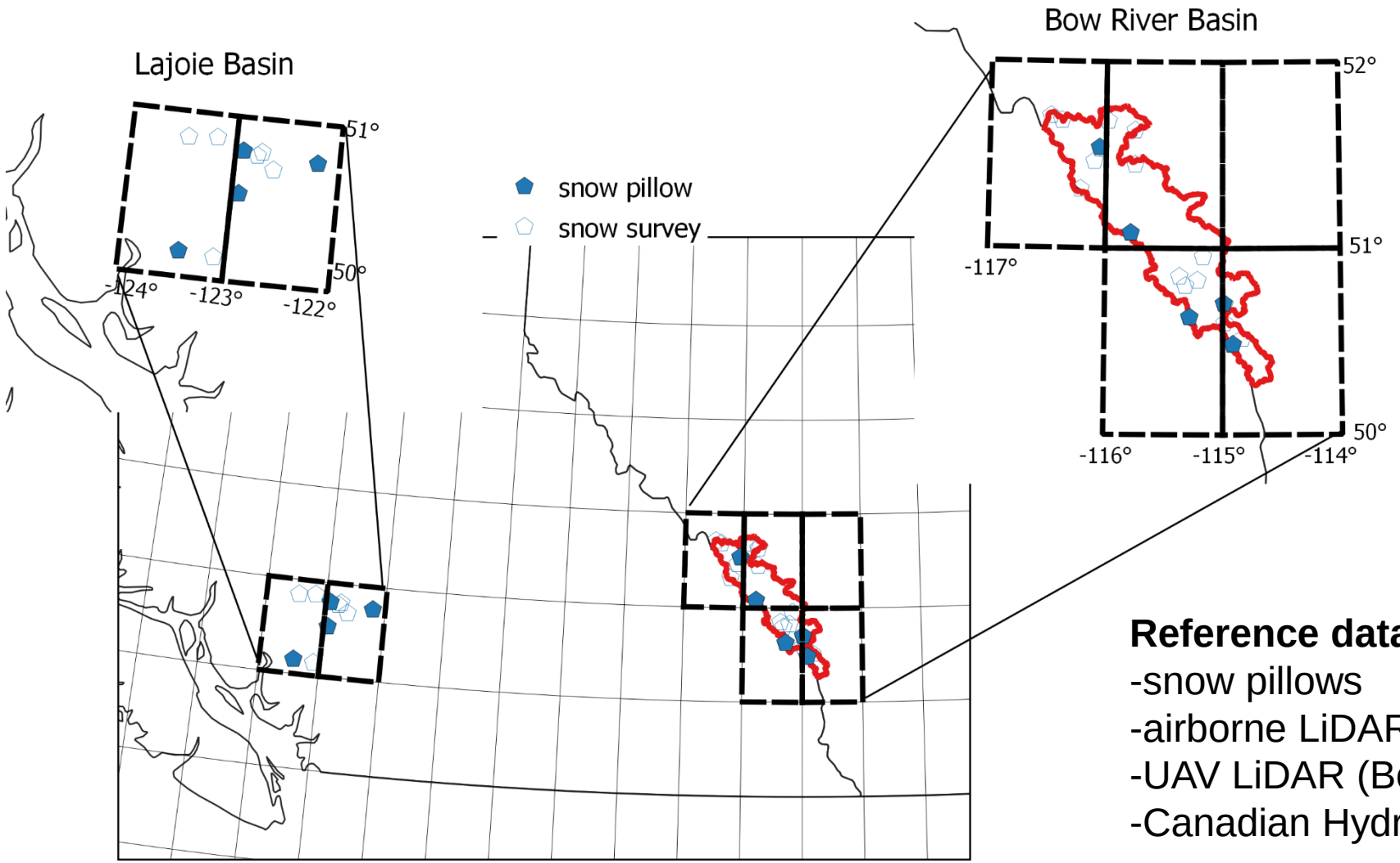
CCI post. vs Landsat post.

CCI posterior vs prior



- CCI-posterior peak SWE outperforms prior (higher correlation, lower RMSE) but magnitude of improvement varies according to tile and WY (wet vs. dry).
- Compared to Landsat-posterior, CCI-posterior has negative bias across all tiles.

NEXT STEP: WESTERN CANADA



- Test water years: 2018 & 2019
- WUS temperature and shortwave radiation uncertainty models
- Static ancillary data files prepared.

Reference data
-snow pillows
-airborne LiDAR (Lajoie 2017-)
-UAV LiDAR (Bow 2019)
-Canadian Hydrological Model (Bow)

SUMMARY

- Successful testing of BSRF with Snow CCI+ MODIS SCFV.
- Optimal configuration determined to be the native resolution of CCI MODIS SCF with a 15% measurement error (consistent with that used for MODSCAG) and screening high zenith angles (>38.7°).
- Snow CCI MODIS SCF BSRF generally improves upon prior but underestimates relative to Landsat-posterior which itself tends to be biased low.
- Reasonable performance provides confidence to extend the assimilation framework into new areas (Canada).
- Snow CCI SCF uncertainty calculations need to be revised in order to introduce spatially and temporally dynamic error estimates into the BSRF.

REFERENCES

Fang, Y., Liu, Y. & Margulis, S.A.: A western United States snow reanalysis dataset over the Landsat era from water years 1985 to 2021. Sci. Data 9, 677, https://doi.org/10.1038/s41597-022-01768-7, 2022

Liu, Y., Fang, Y. and Margulis, S.A.: Spatiotemporal distribution of seasonal snow water equivalent in High Mountain Asia from an 18-year Landsat-MODIS era snow reanalysis dataset, The Crysophere, 15, 5261-5280, https://doi.org/10.5194/tc-15-5261-2021, 2021

Margulis S.A., Liu Y., and Baldo E.: A Joint Landsat and MODIS-Based Reanalysis Approach for Midlatitude Montane Seasonal Snow Characterization. Front. Earth Sci. 7:272. https://doi.org/10.3389/feart.2019.00272, 2019

EXTRAS