

Integration of ASO-derived snow depths to improve snow modeling over mountain regions

Andrew Hedrick¹, Danny Marks¹, Scott Havens¹, Mark Robertson¹,
Hans-Peter Marshall², Kat Bormann³, Tom Painter³

¹ USDA-ARS Northwest Watershed Research Center, Boise, Idaho

² Boise State University, Dept. of Geosciences

³ NASA/Caltech JPL



Research Goal



New advancements allow more informed water resource management.

- + improved measurements of snow energy balance components
- + improvements to existing models
- + airborne/satellite mapping of snow depth, albedo, temperature, etc.
- + high resolution weather forecasts

⇒ integrated **Wx forecasts**, **snow models**, & **hydrologic models** (e.g. WRF-driven iSnobal + PRMS)

Modeling density for ASO

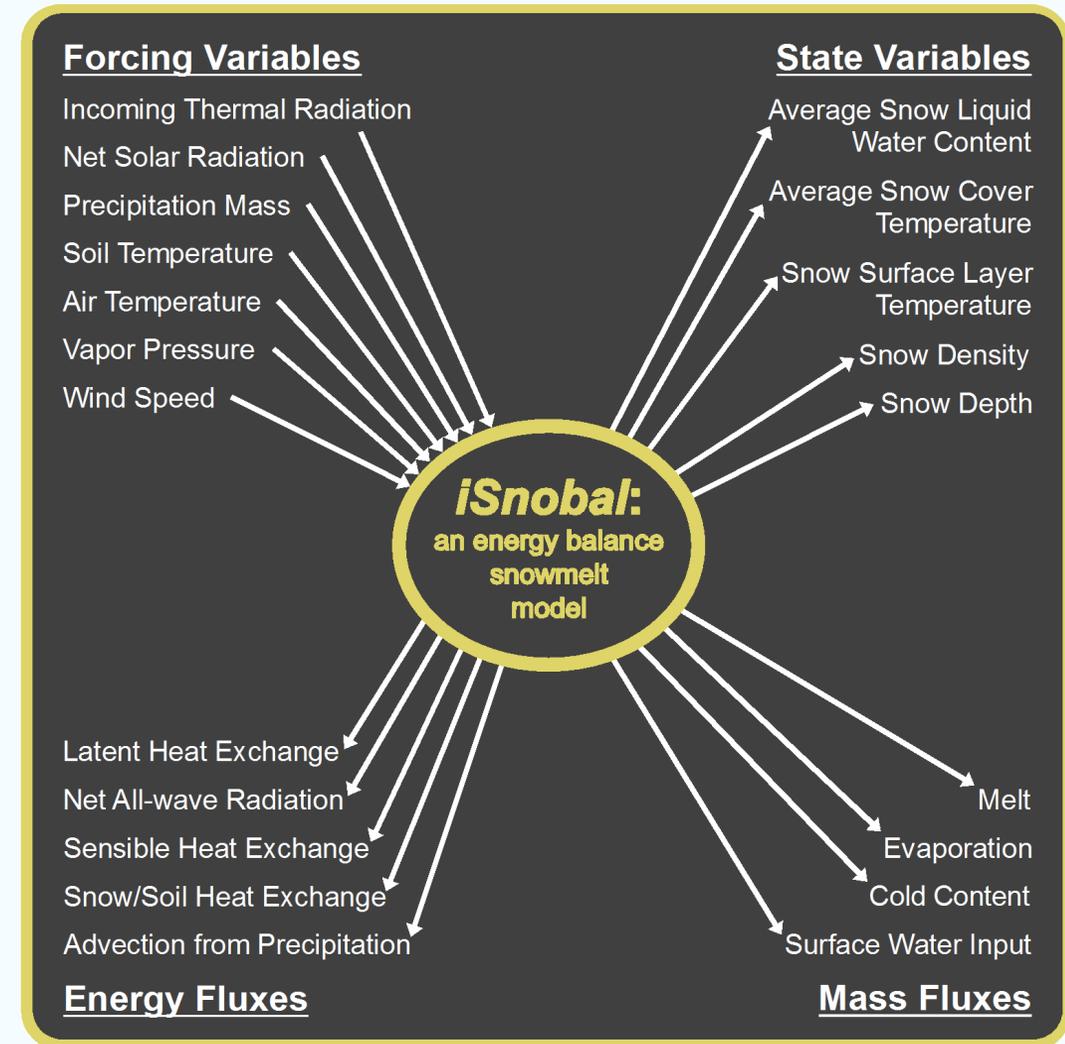


WHY *iSnobal*?

1. Physics-based energy AND mass balance model.
2. Optimized for high resolution (<100m) processes (wind redistribution, canopy shading, etc.).
3. Can be re-initialized when data become available.
4. Computational efficiency permits rapid spin-up
5. 1 to 3 hour forcing data captures diurnal cycle.

LIMITATIONS:

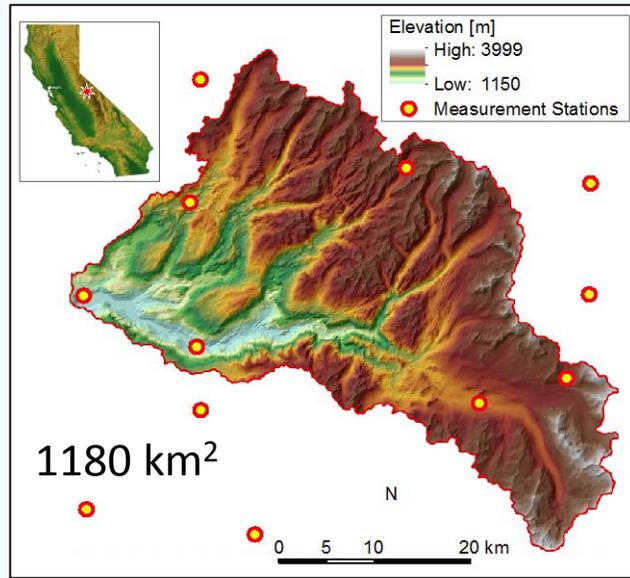
1. 2-layer model - does not track layers through season
2. Previous version did not account for compaction explicitly (new version does)
3. Dated binary file format (requires extra read/write steps)



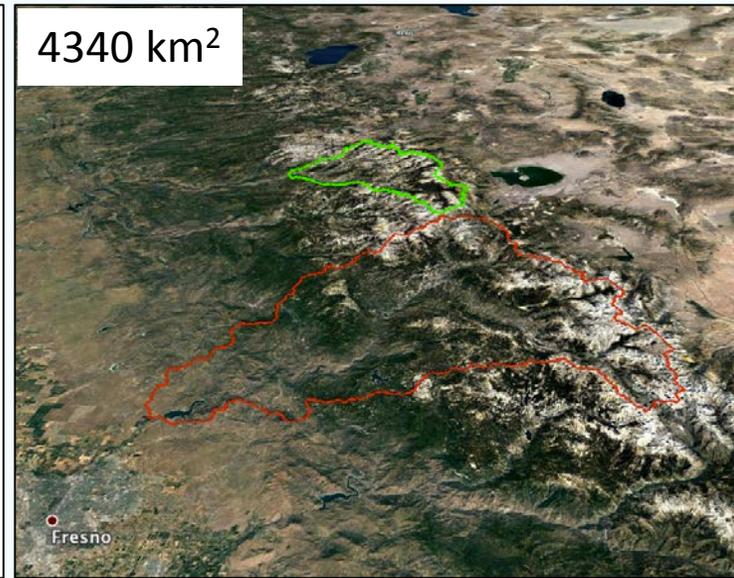
Modeling density for ASO

- NASA-JPL / USDA-ARS partnership since 2013
- ASO measures snow depth snapshots throughout winter/spring.
- Physically based *iSnobal* snow model provides *density* estimates needed for ASO SWE product.

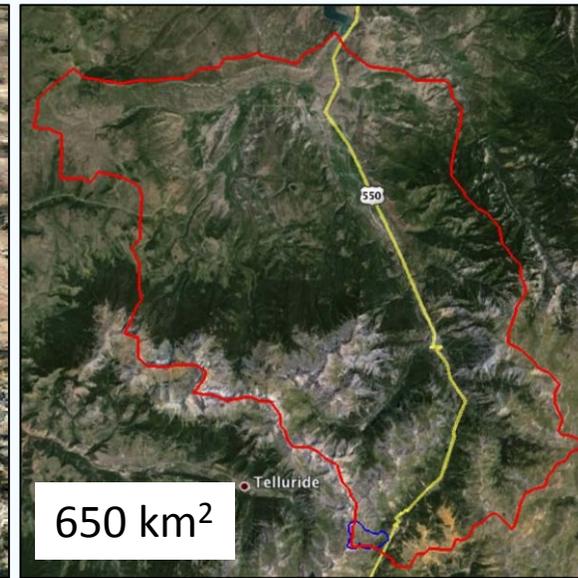
iSnobal + ASO



2013 – present: Tuolumne River Basin, CA (nrt)



2017 (preliminary), 2018 – onward: San Joaquin above Friant Dam, CA (nrt)



2018 (preliminary): Uncompahgre River Basin, CO

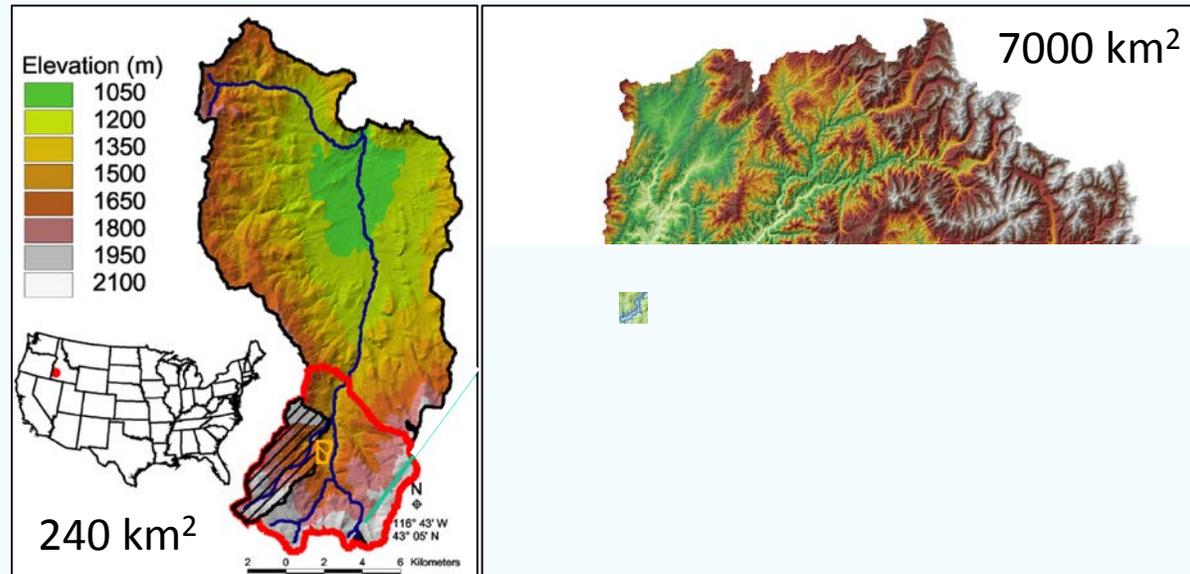
*nrt = near-real time

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iSnobal w/o ASO

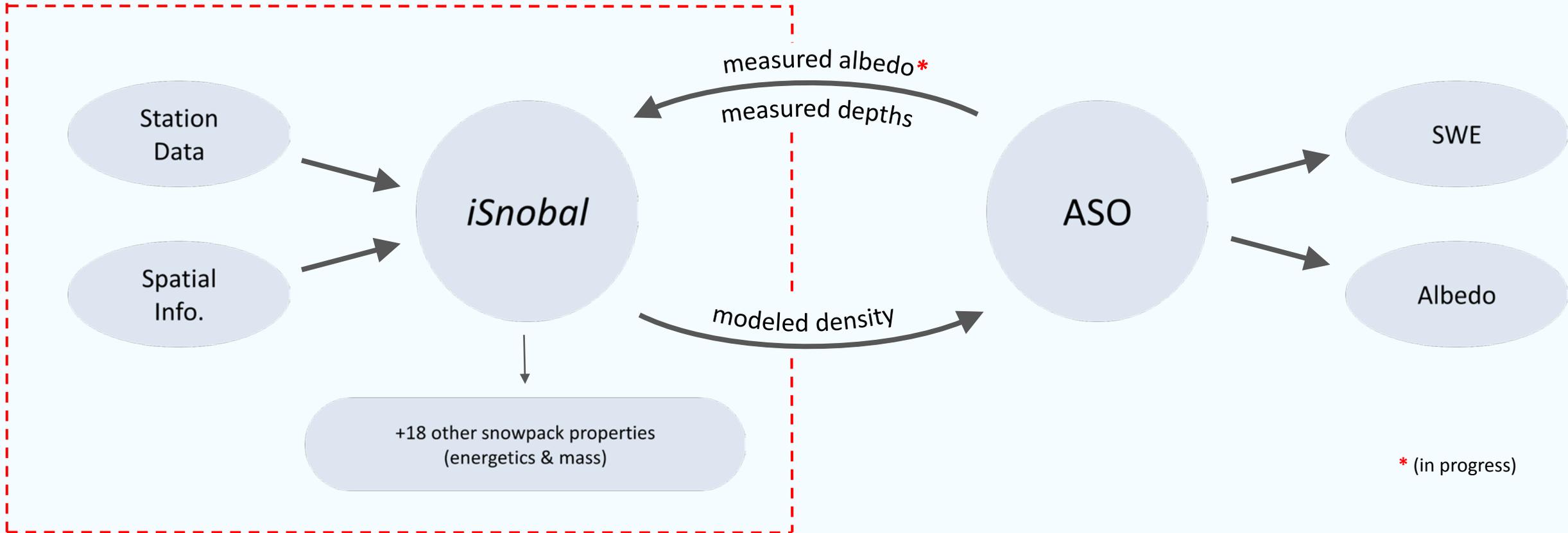


1983 – 2013: Reynolds
Creek Exp. Watershed

2012 – 2017: Boise River Basin, ID (nrt)

*nrt = near-real time

Modeling density for ASO



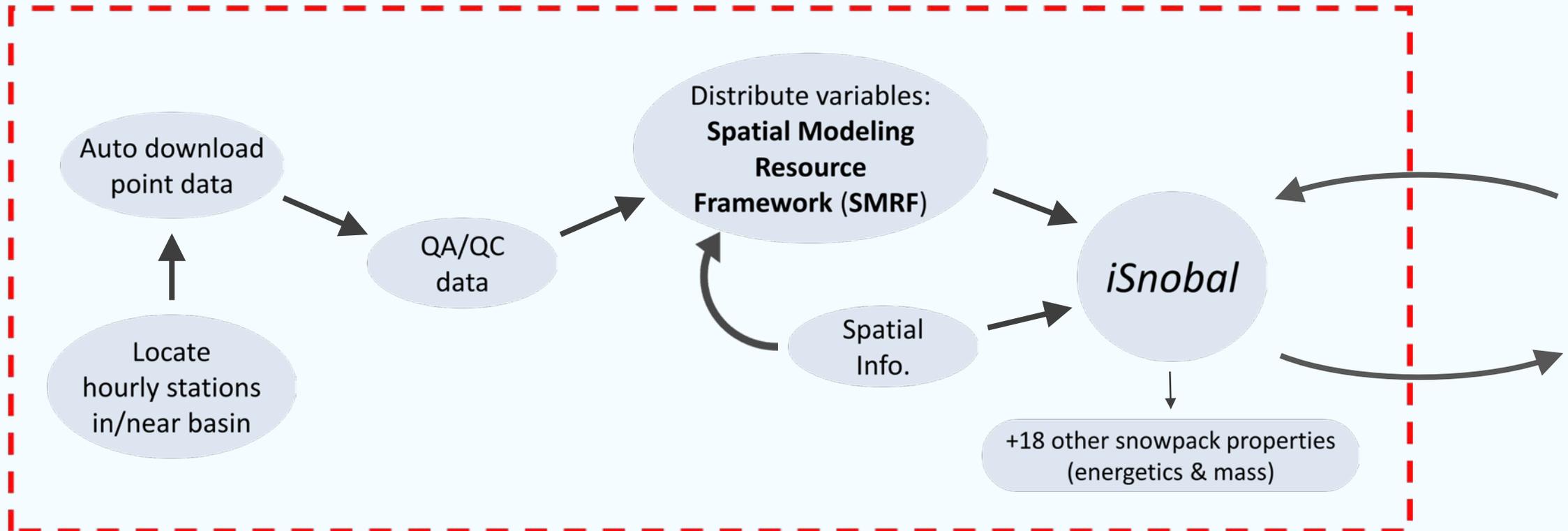
- Conversely, ASO lidar provides spatial snow depth information to force *iSnobal* model (direct insertion).

Model overview



- 95% of effort is creating forcing data fields.
- Model results only as good as measurement quality and data interpolation schemes.

The *iSnobal* modeling procedure



Recent development



- 2017 was a very wet year in the Sierra Nevada
- *iSnobal* density algorithm modified to address compaction
- Model now considers*:
 1. Destructive metamorphism – temperature dependent
 2. Compaction due to overburden
 3. Addition of liquid water (melt or rain)

... see Danny Marks' talk tomorrow morning for more info.

* Each parameterization from Anderson (1976) and Kojima (1967).

Direct insertion of ASO snow depth



- Upscale 3m depths to 50m model resolution
- Create initialization file from last *iSnobal* time step
- Restart model with updated state variables:
 - Depth (from ASO)
 - Bulk density
 - Layer temperatures
 - Liquid H₂O saturation

Cell Scenario 1

ASO measures	iSnobal predicts
$z_s = 0$ mm	$z_s > 0$ mm

easy! → Remove snow conditions from cell (density, snowpack temp., H₂O saturation)

Cell Scenario 2

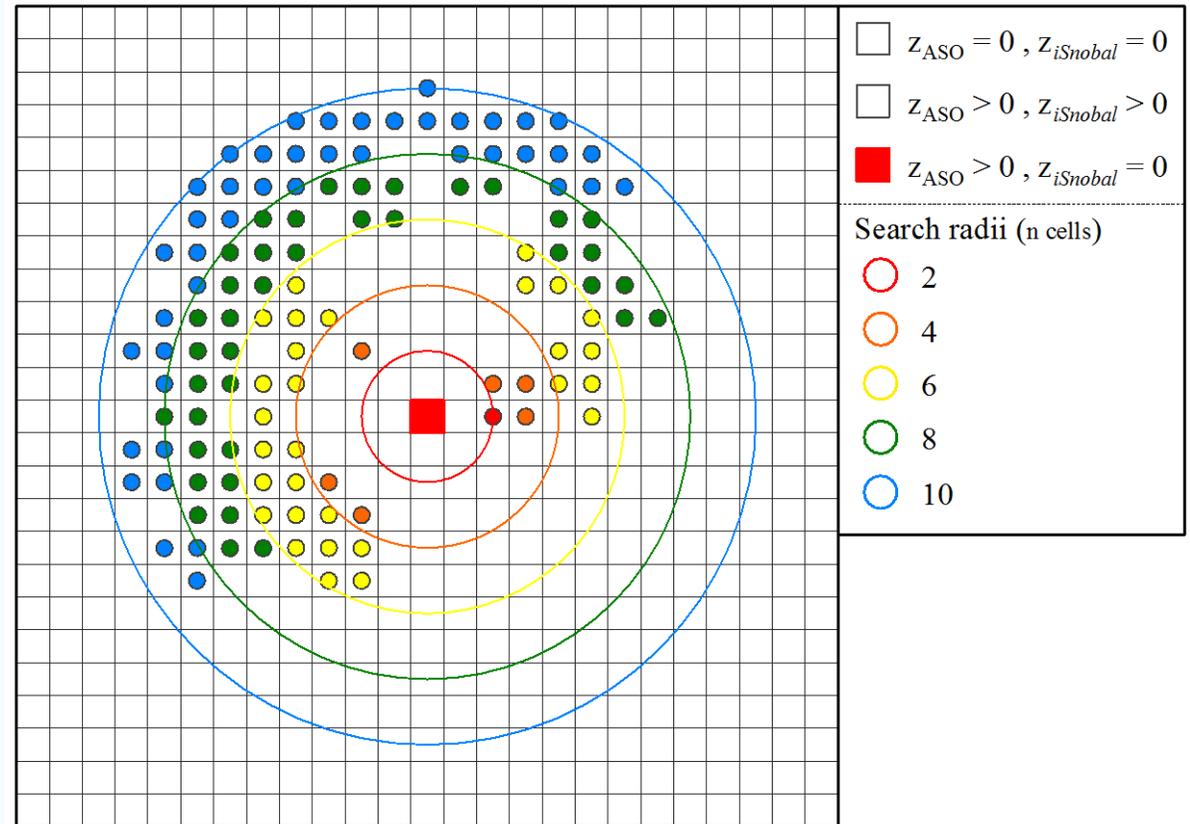
ASO measures	iSnobal predicts
$z_s > 0$ mm	$z_s = 0$ mm

not as easy... → Populate empty model cells with density, snowpack temp., and liquid H₂O saturation (expanding window interp.)

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- Expanding window interpolation –
Grow search window until minimum number of cells obtained for averaging



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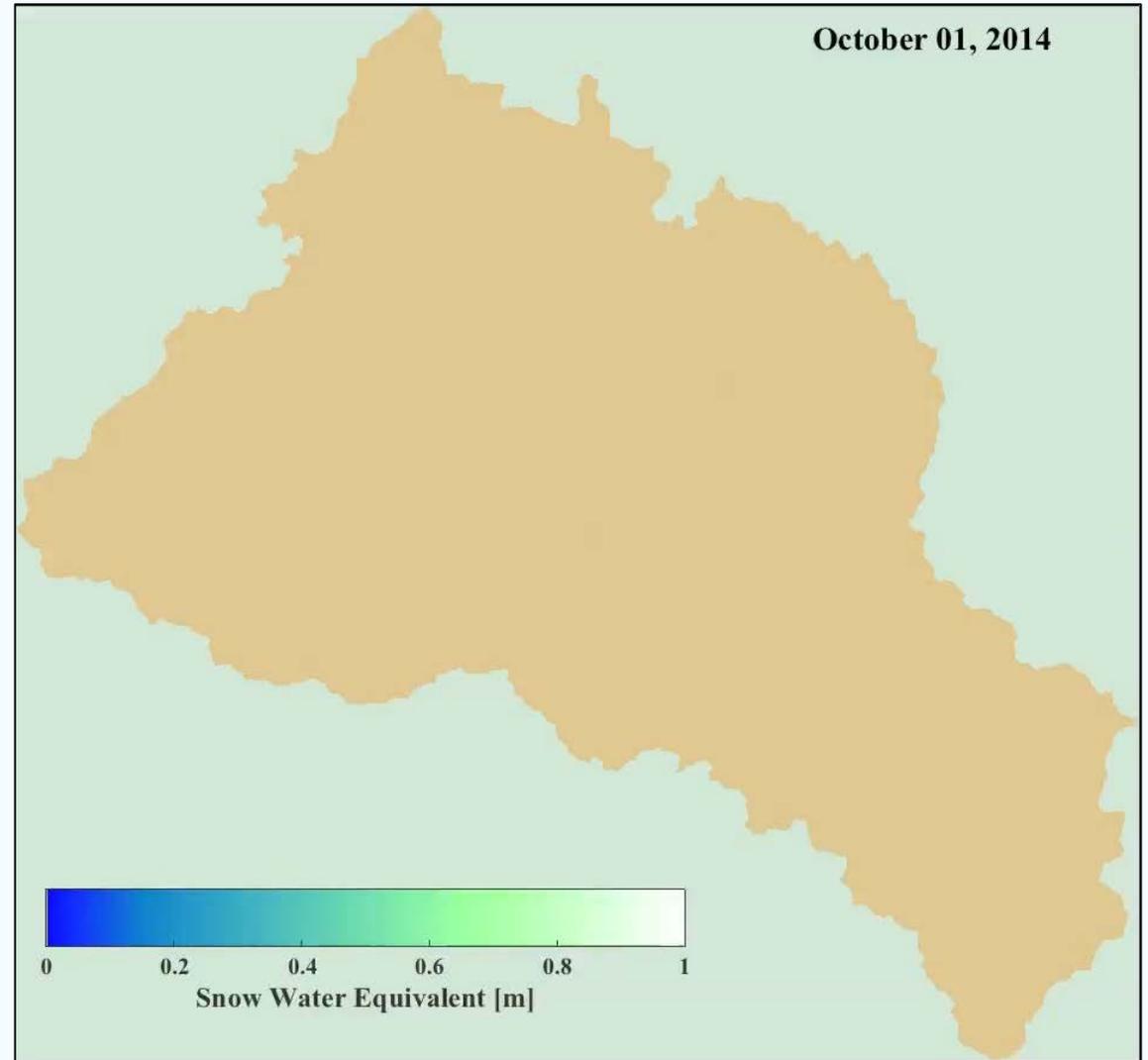
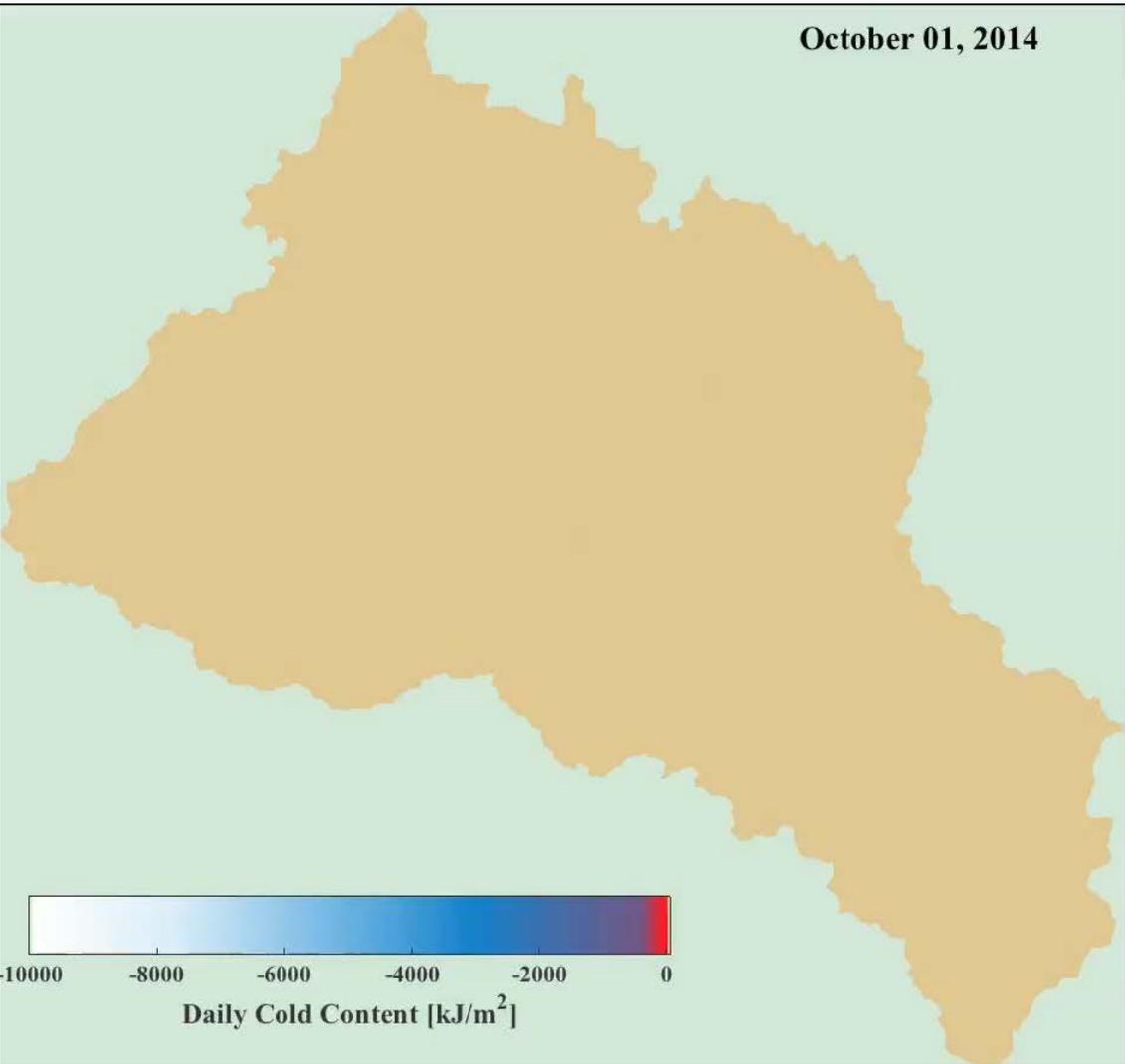
Cell Scenario 3

ASO measures	iSnobal predicts
$z_s > 0 \text{ mm}$	$z_s > 0 \text{ mm}$



Retain model states for density, layer temperature and liquid H₂O content.

Direct insertion of ASO snow depth



Tuolumne River Basin Snowpack Summary

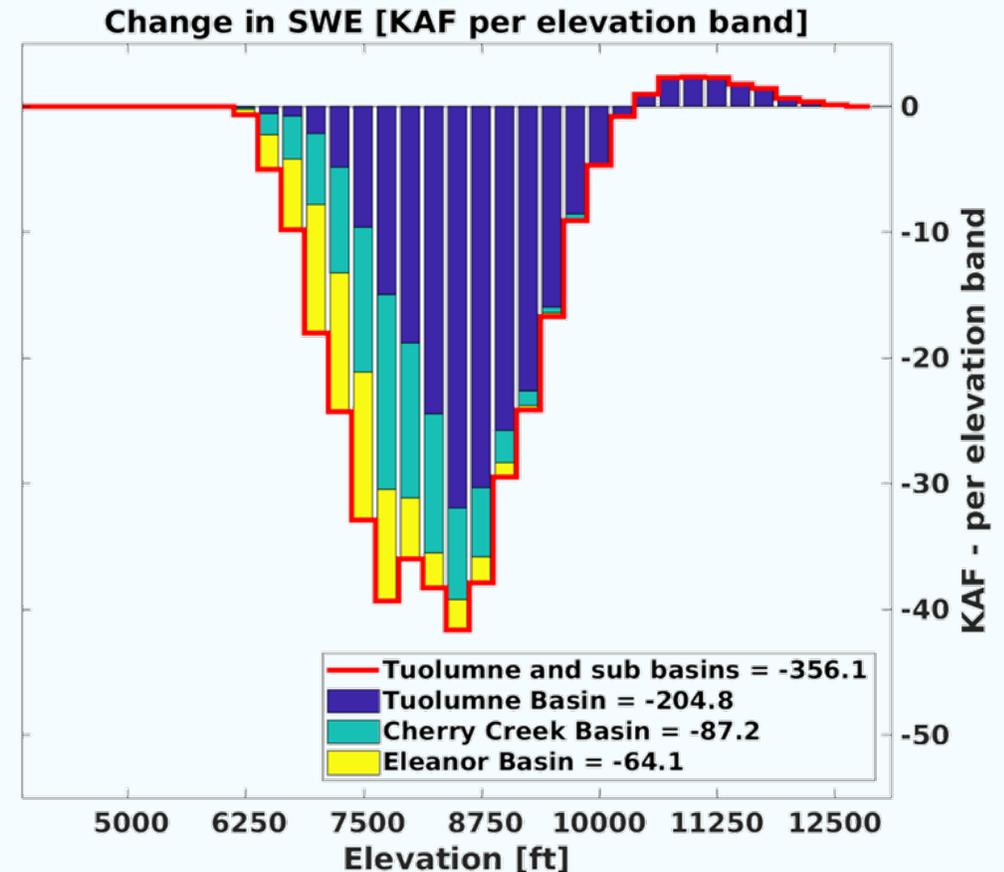
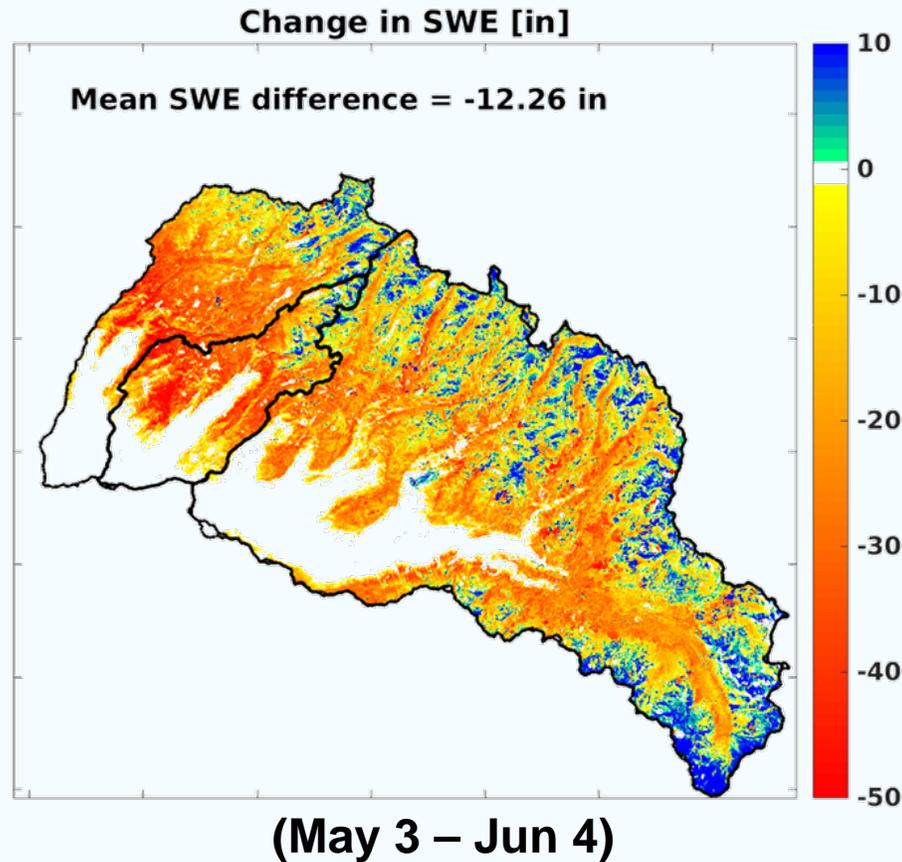
Water Year 2017, June 4

USDA Agricultural Research Service, Boise ID



Tuolumne Snowpack Summary for June 4, 2017

This is the Tuolumne River Basin Summary for the time between May 3 and June 4, 2017. The amount of water stored in the snowpack as of June 4 is estimated at 1106 KAF, which represents a net loss of 356 KAF of snow storage during the reporting period.



Tuolumne River Basin Snowpack Summary

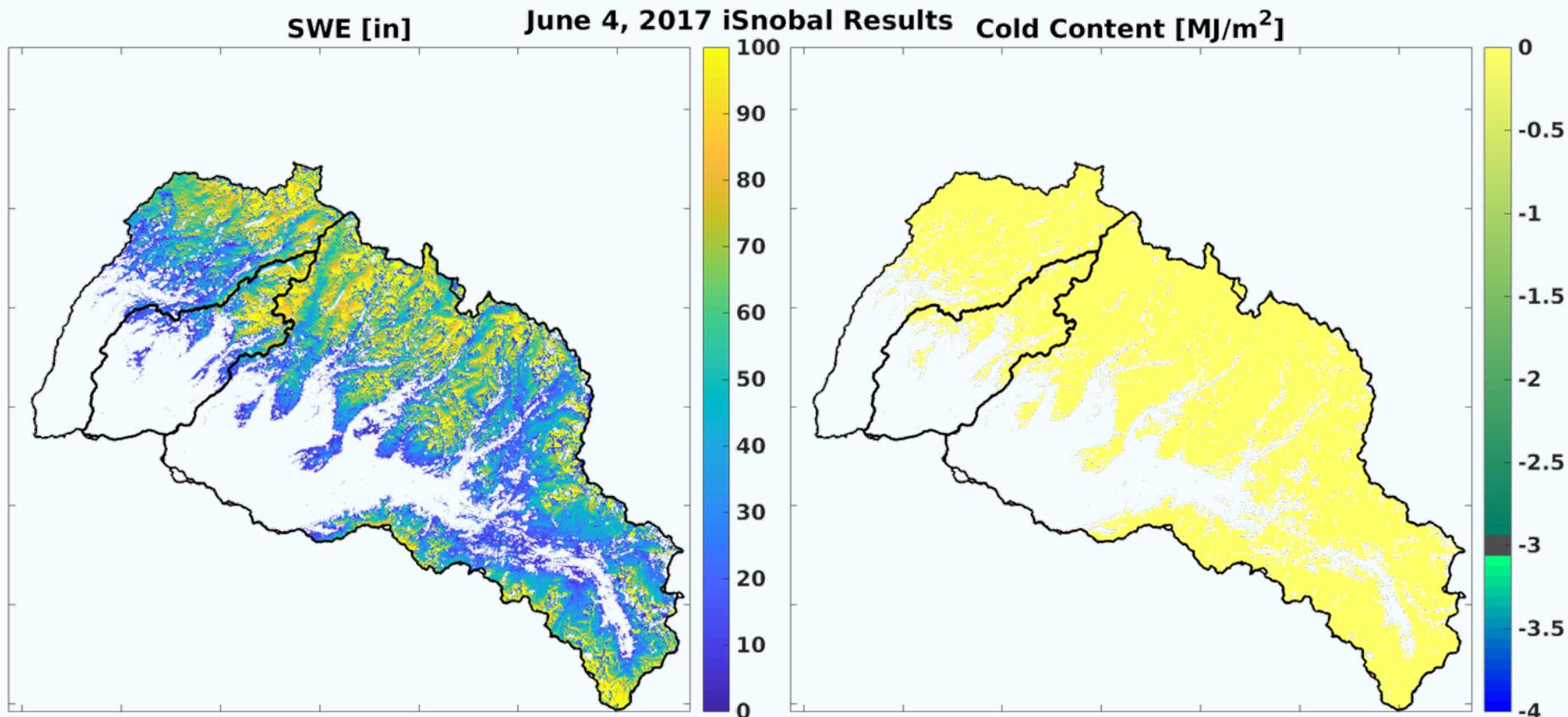
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Currently in development



- More physically based albedo decay
 - Build semi-empirical model from ASO spectrometer reflectances.

— *iSnobal* SWE
- - - *iSnobal* + ASO SWE
— *iSnobal* SWI
- - - *iSnobal* + ASO SWI

Conclusions



- 5 years modeling Tuolumne snowpack
 - Prior density solution did not work in 2017 (400mm storms!).
 - Prior albedo decay curve did not melt snow fast enough in all years.
- How many surveys are necessary?
 - First survey is usually most impactful.
 - Need to perform more testing to determine optimal # of flights.
- Couple to hydrology model (“PRMS-like”).
- Now is the time to expand this modeling to more basins!

THANKS!



Welcome to the Swamp Angel Study Plot

This automated weather station is operated by the Center for Snow and Avalanche Studies, of Silverton, Colorado, under a Special Use Permit administered by the Ouray Ranger District of the Uncompahgre National Forest. Weather, snowpack, soils, radiation, and hydrologic monitoring at this site supports ongoing research regarding alpine snow system processes and the effects of climate change on alpine ecology.

You can help us out. Please do not approach the equipment - you may inadvertently disturb the snow being measured. And, we'd appreciate it if you would avoid the small snow profile plot marked with red stakes.

Every effort is being made to minimize the physical and visual impact of this research, and we hope that your visit to the Senator Beck Basin has not been diminished by encountering this study plot. For further information about this site please call the Center for Snow and Avalanche Studies at (970) 387-5080 or the Ouray District Ranger, Uncompahgre National Forest, at (970) 240-5300.



CSAS

Thanks for your interest!

