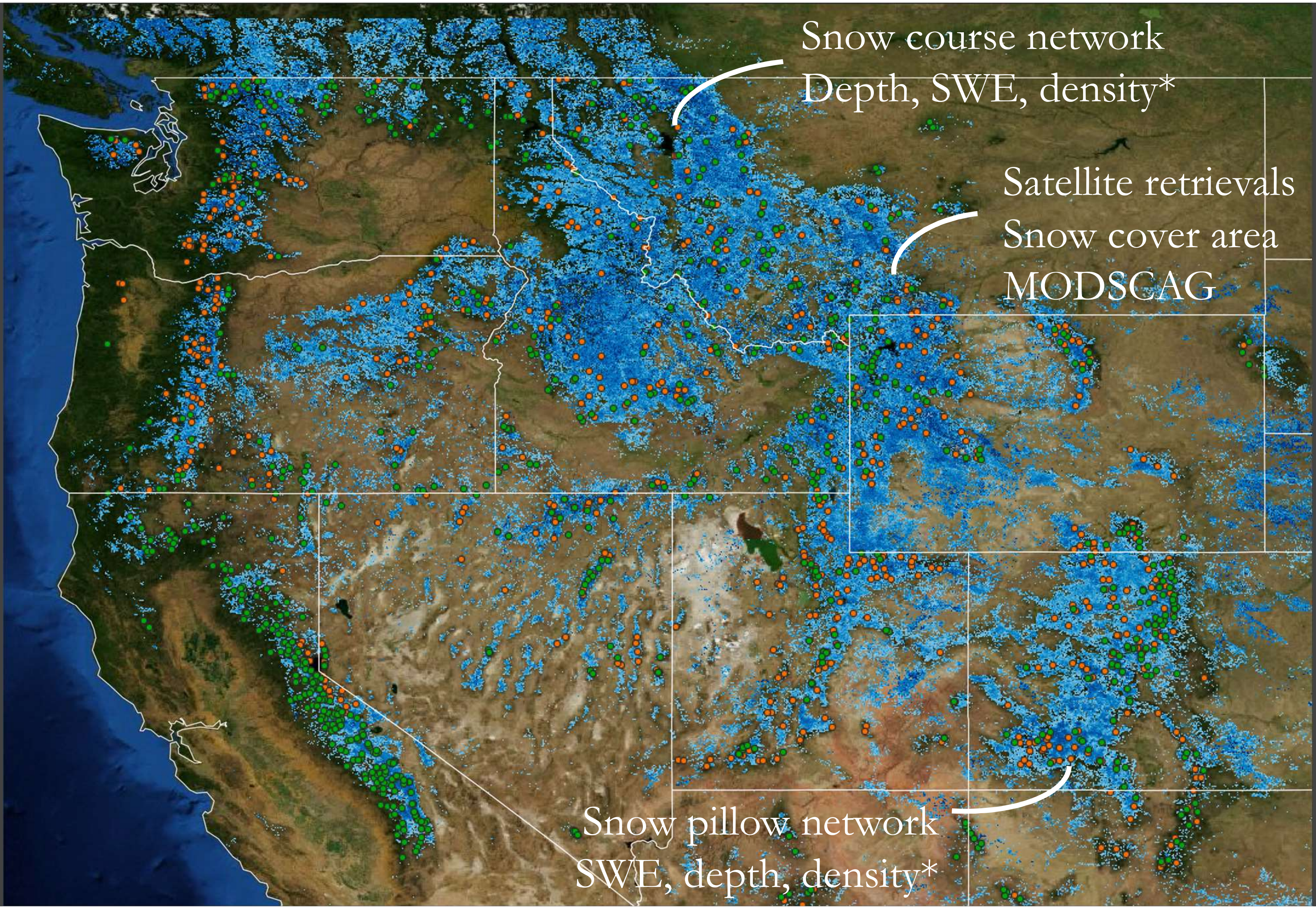
The Airborne Snow Observatory

current state-of-the-art for instantaneous SWE mapping in the mountains

Overview

- State of observations of the snow pack in the Western US
- Use of observations in operational forecasts
- The Airborne Snow Observatory for SWE mapping
- Improvement in operational forecasts


Snow course network
Depth, SWE, density*
Satellite retrievals
Snow cover area
MODSCAG
Snow pillow network
SWE, depth, density*

Voids in our observations

- Snowmelt dominates runoff signal across much of the Western US
- Sparse in-situ networks (few per watershed)
- Poor representation of high and low elevation conditions
- Point measurements of SWE, spatial measurement of snow cover
- Clouds obscure satellite view
- Need models/relationships to use these obs. for runoff forecasting

These observations drive our Operational forecasts

Statistical streamflow forecast

- Regression relates spring SWE to spring/summer flows

Temperature index runoff forecast

- Calibrated air temperature/snowmelt relationship

Snow water resources & forecasts affected by:

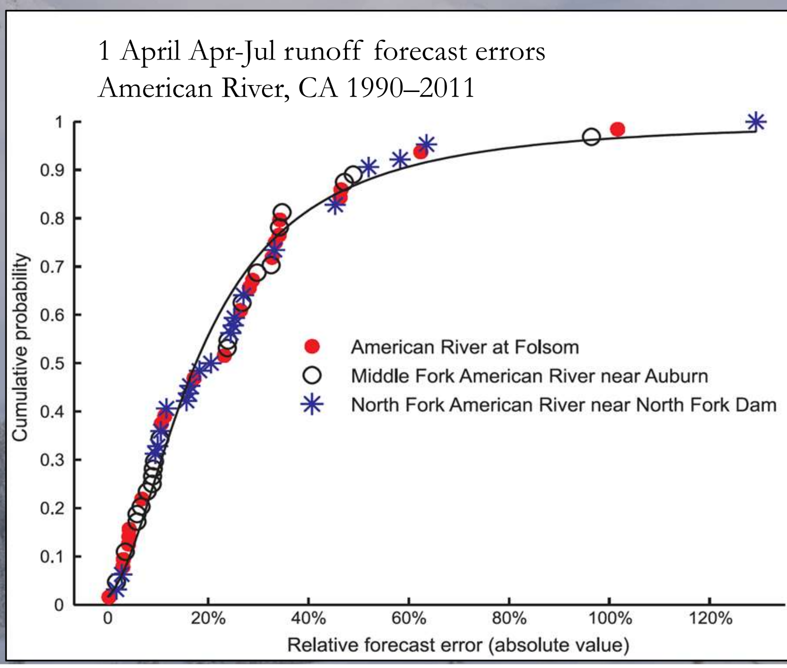
Warming temperatures
Snow season duration
Rain/snow fraction
Mid-winter melt
Rain-on-snow
Forest change
Dust on snow

Operational forecasts are therefore vulnerable to unusual conditions…

…*and conditions are changing*

Operational forecasts

- Subject to non-negligible error when conditions that impact the snow pack deviate from "average"
- To improve forecasts at the watershed scale, we need to improve our SWE monitoring at the watershed scale
- Along with our use of observations in runoff models



Blue River, CO

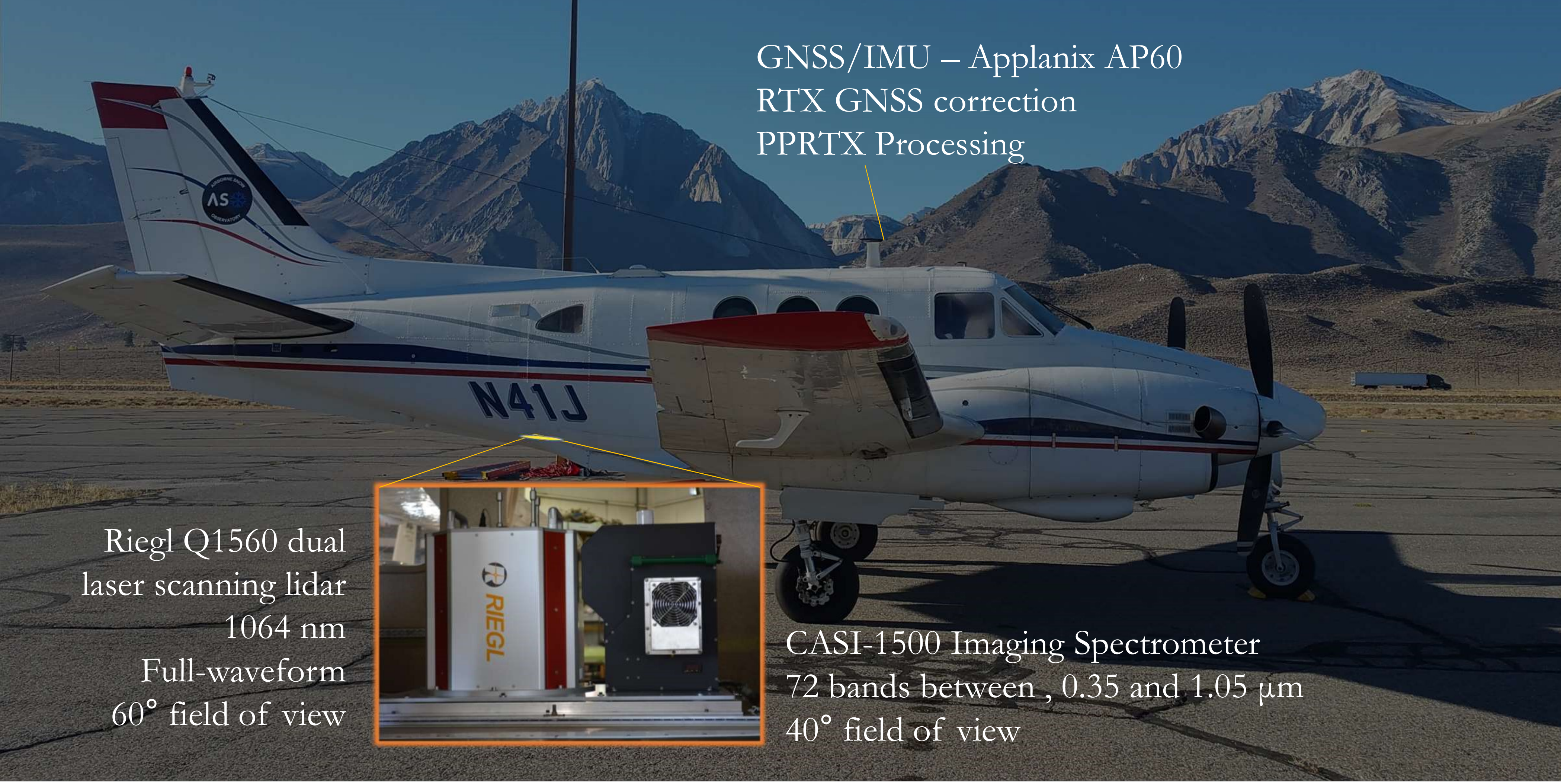
	April Forecast	Obs Inflow	% Difference
1999	120	197	-39%
2000	155	159	-2%
2001	150	146	3%
2002	59	57	4%
2003	170	173	-2%
2004	100	78	28%
2005	125	120	4%
2006	210	176	19%
2007	150	177	-15%
2008	200	195	2%
2009	180	192	-6%
2010	120	142	-15%
2011	225	272	-17%
2012	100	64	56%
2013	100	134	-25%
2014	250	242	3%
2015	166	202	-18%
2016	167	157	7%
2017	195	184	6%
2018	137	117	17%

Forecast > 10% Low

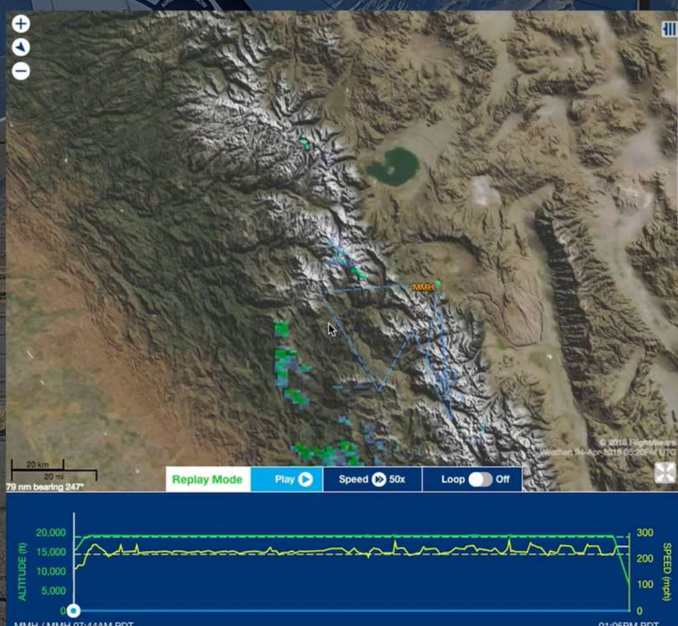
Forecast > 10% High

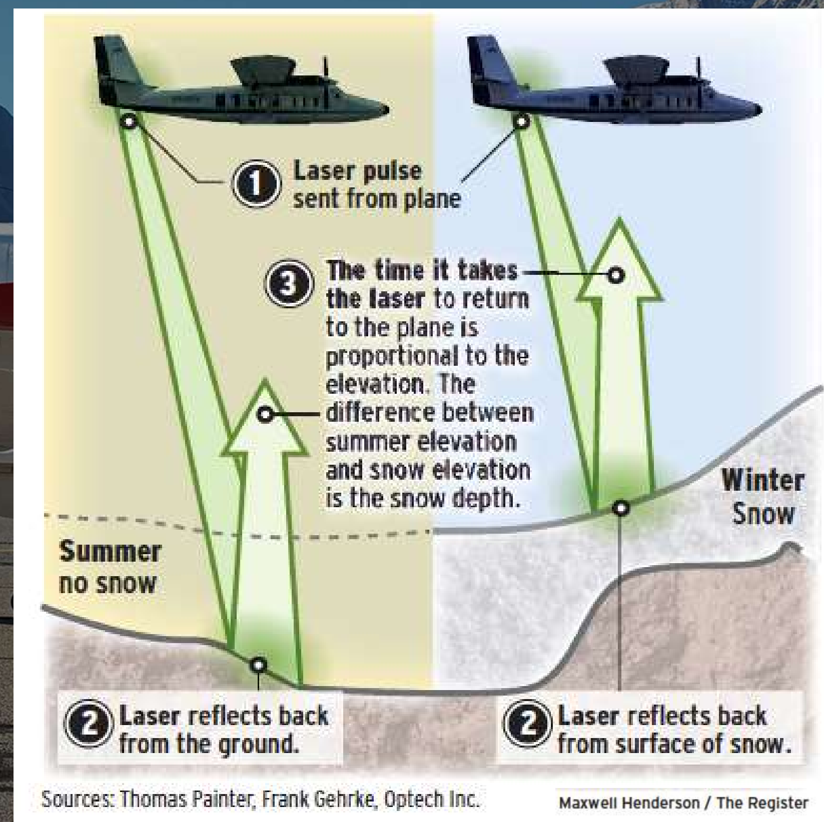
Data courtesy Nathan Elder, Denver Water

Pathfinder: The Airborne Snow Observatory

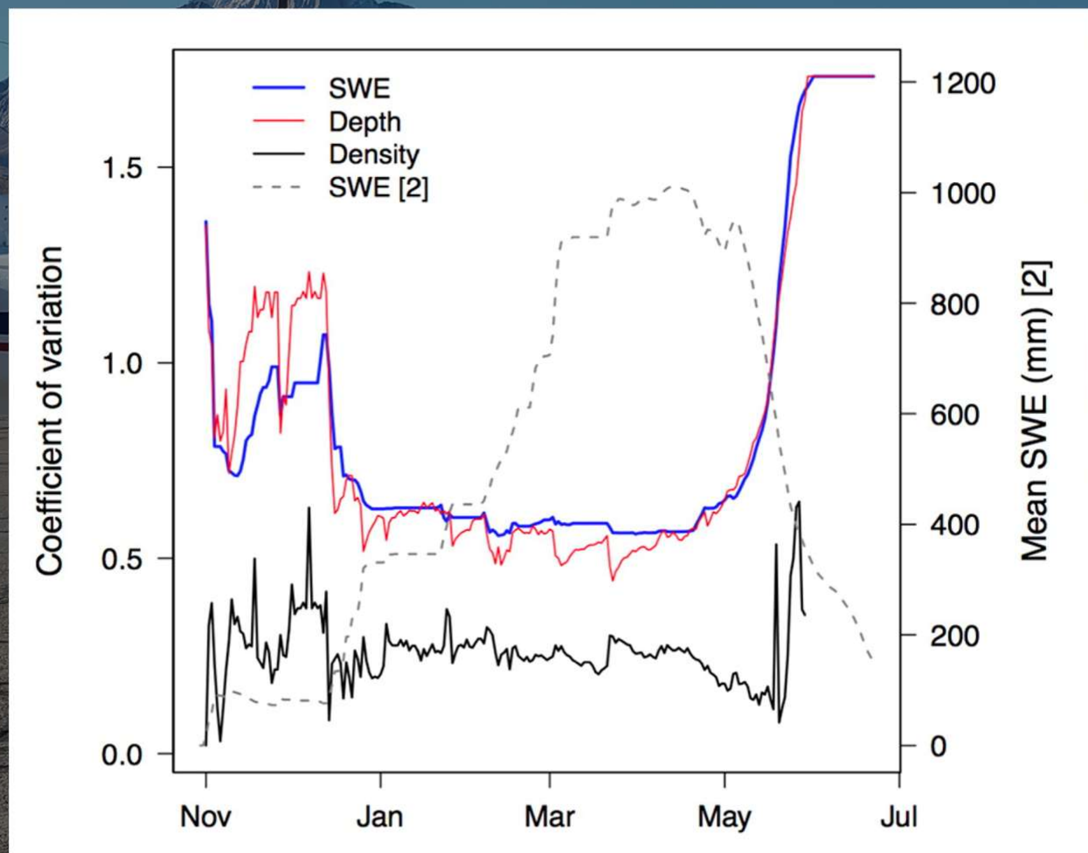


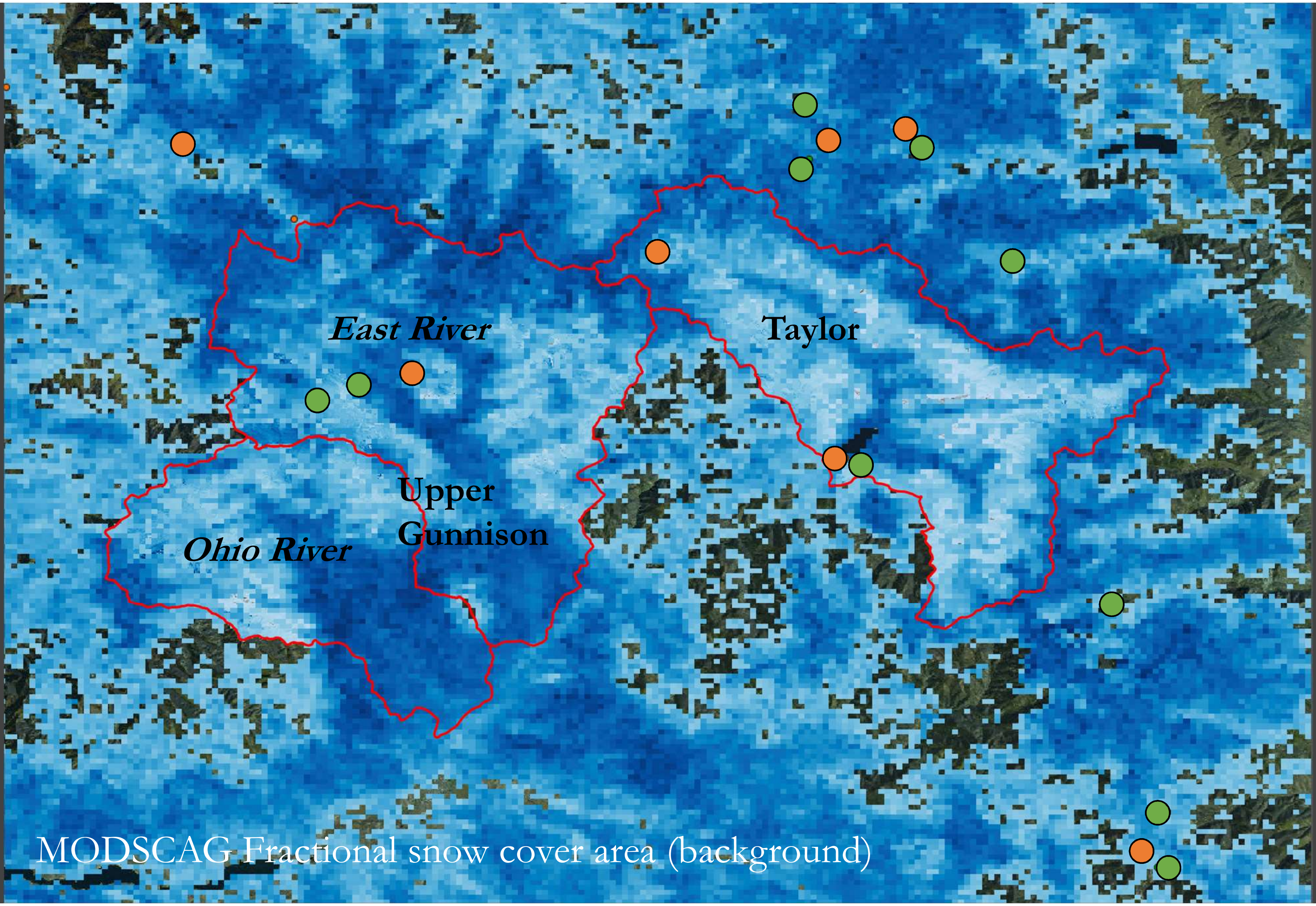
- Spatially-distributed snow depth observations
- Snow depth maps at 3 m spatial resolution

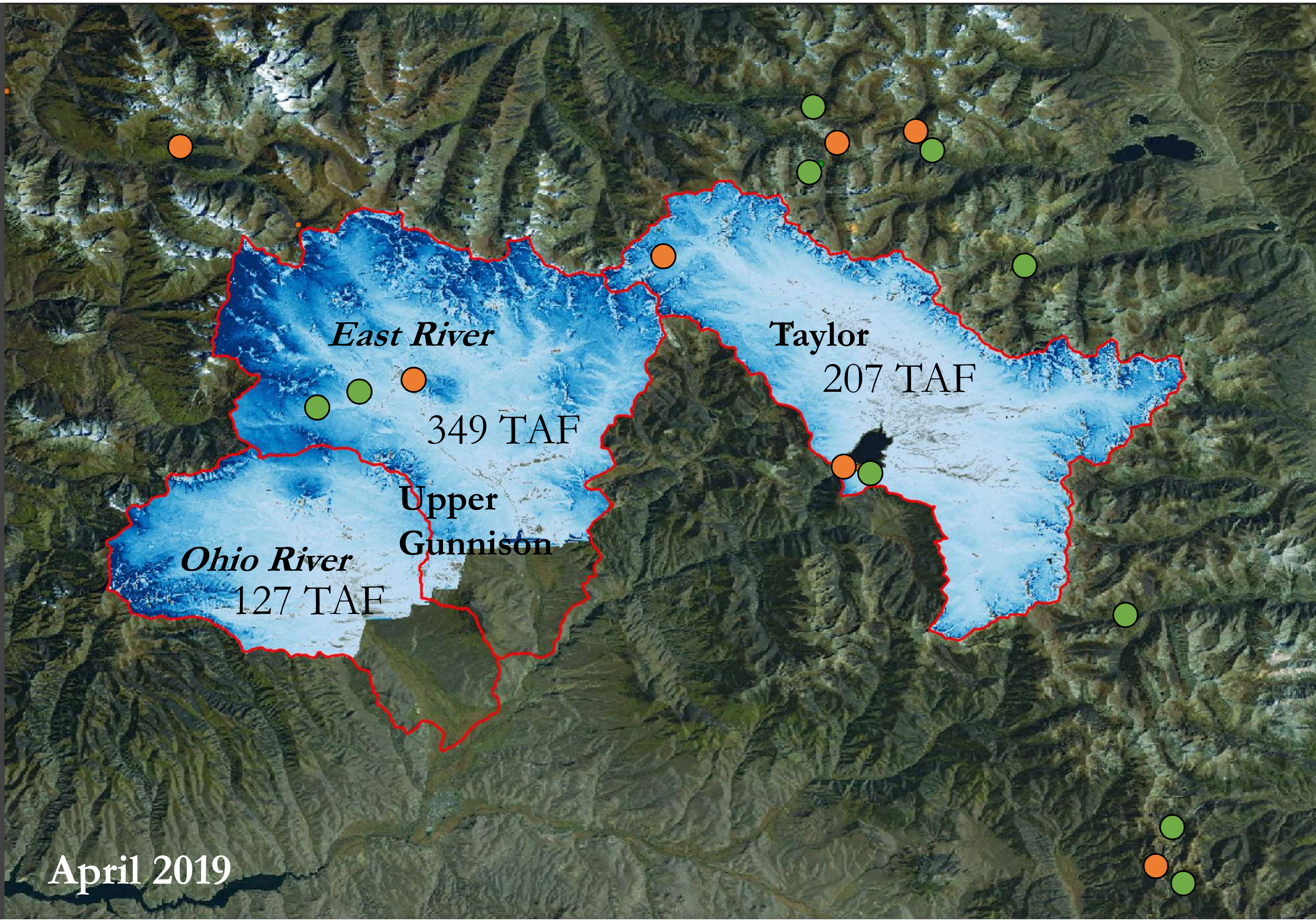


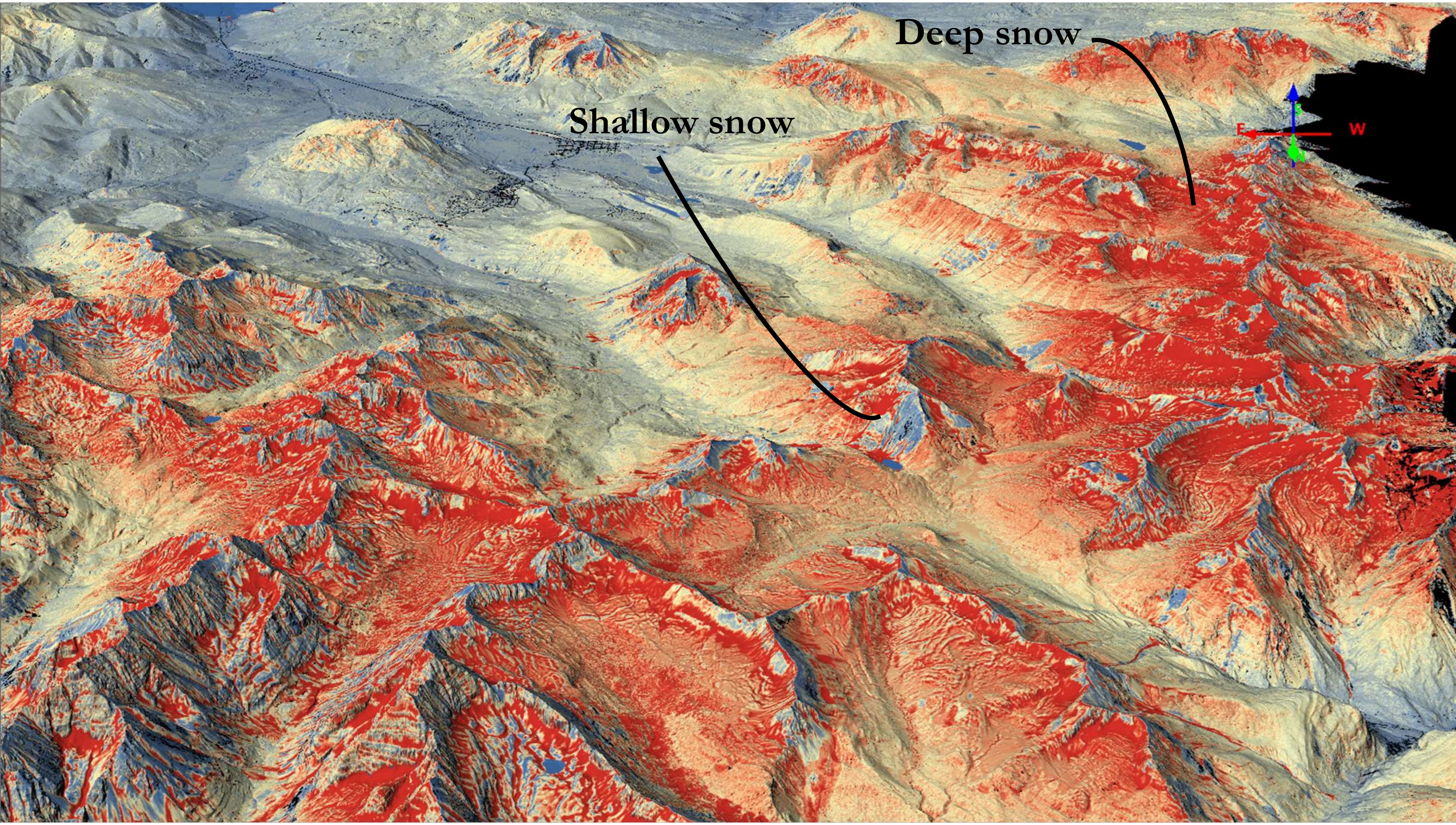


- Snow depth observations are converted to SWE using snow density maps from a physically-based model
- SWE maps at 50 m spatial resolution

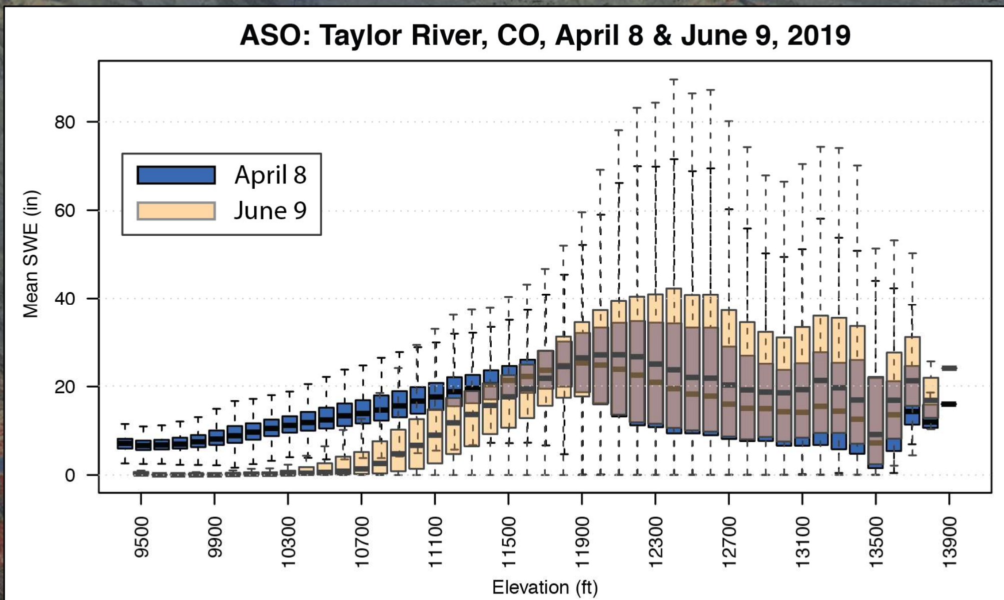



East River
Taylor
Upper Gunnison
Ohio River
MODSCAG Fractional snow cover area (background)


East River
349 TAF
Taylor
207 TAF
Upper
Gunnison
Ohio River
127 TAF
April 2019


Deep snow
Shallow snow
E
W
S
N

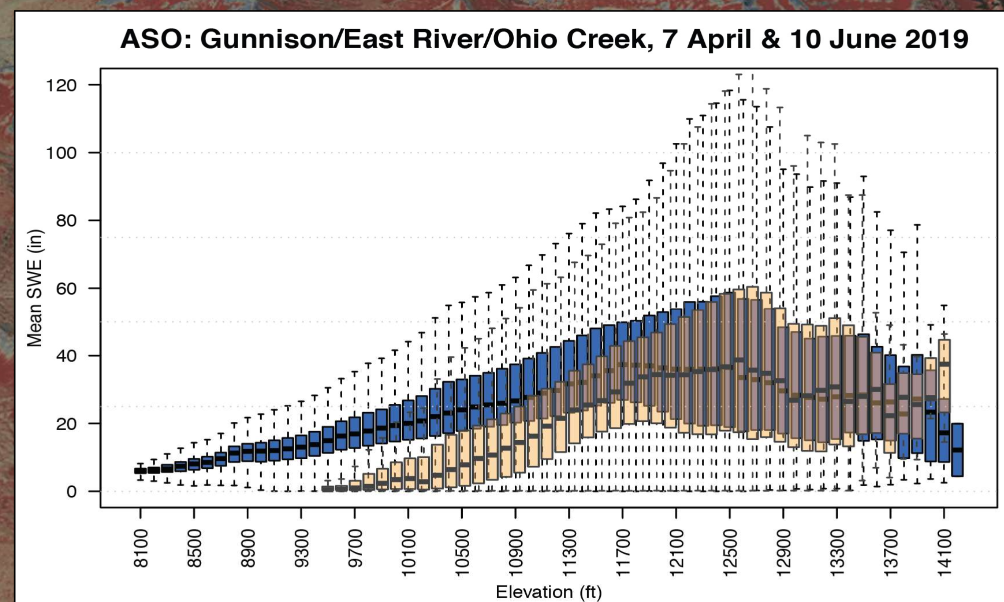
East River, 2019



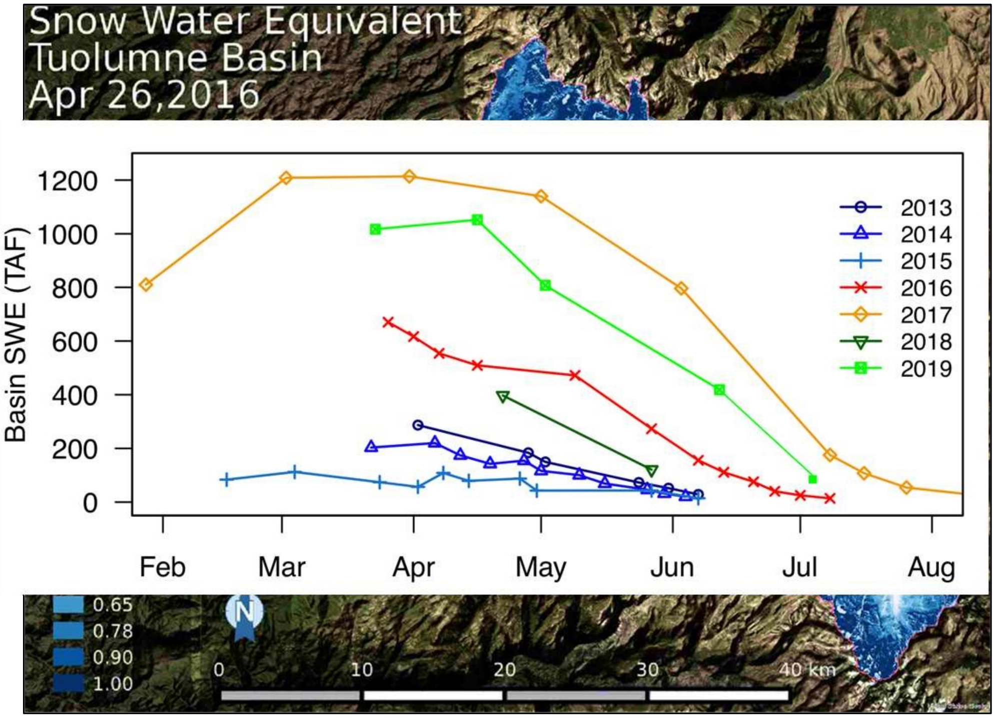
Not just watershed SWE

Derived metrics:

- Distribution with elevation
- Distribution with time
- Distribution per sub basin



Building a legacy in the southern Sierra Nevada



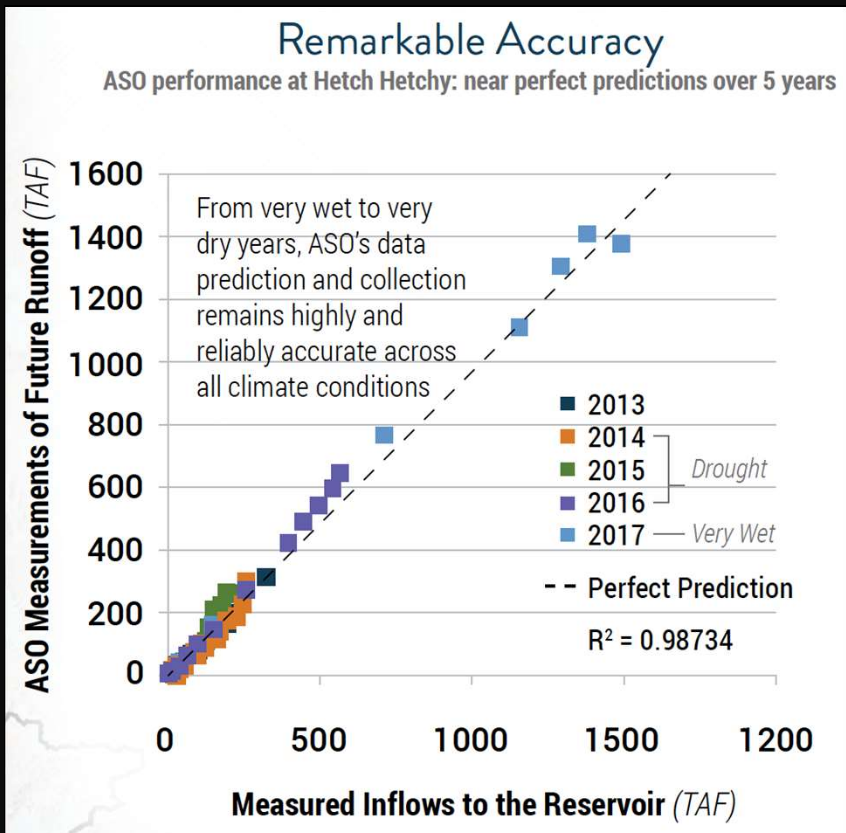
Example: Tuolumne River Basin

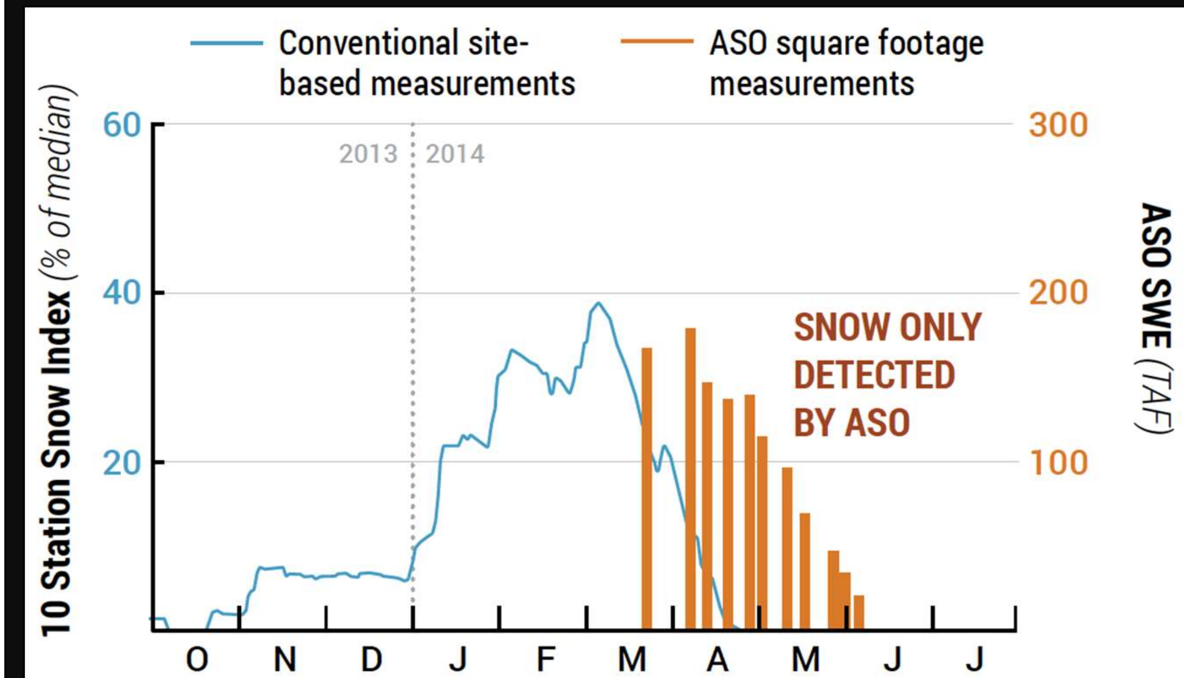
utility to operations in a wide range of conditions

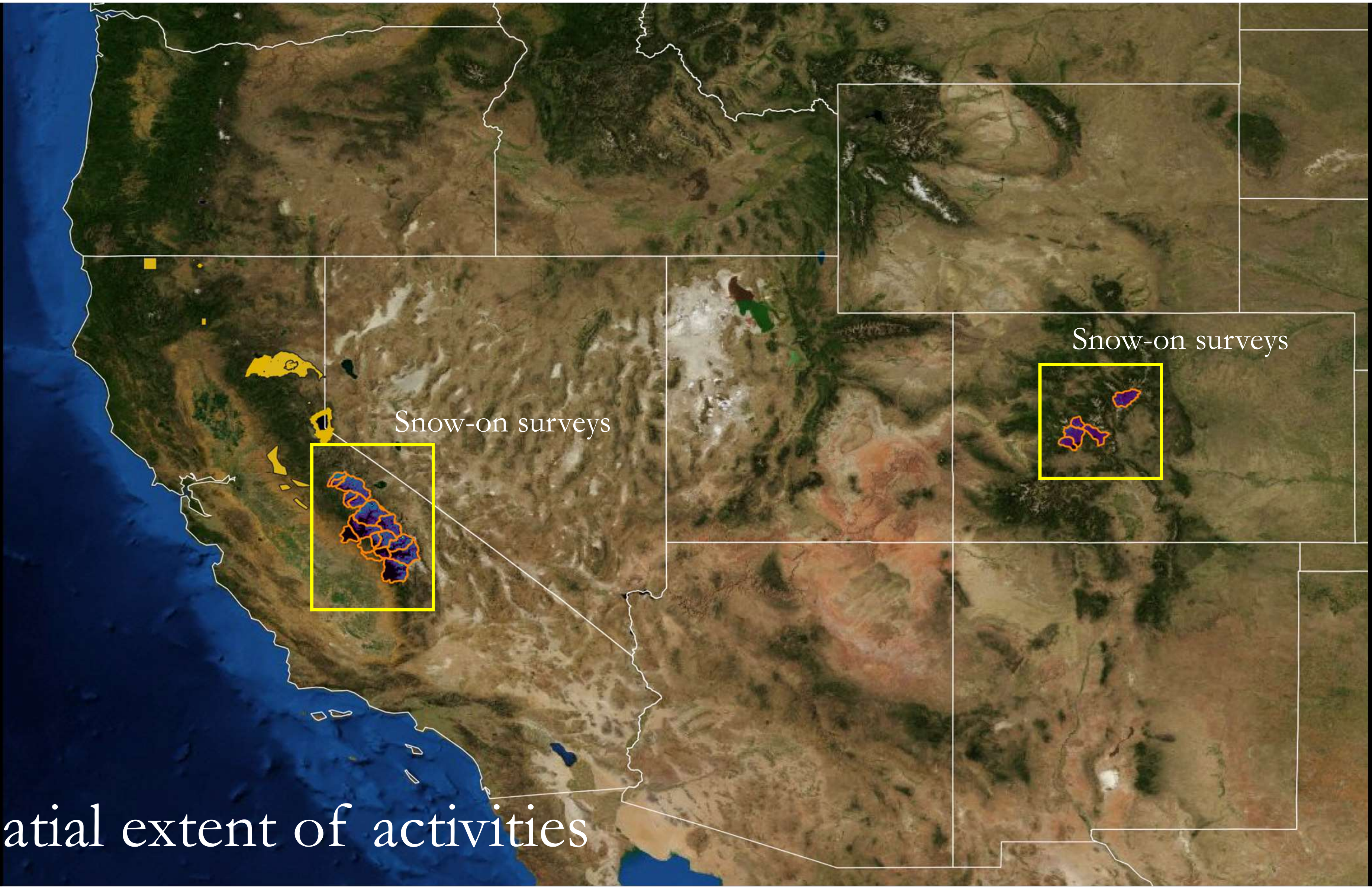
refined data processing for fast data turnaround

bridge to partnerships in neighboring basins

Improvement brings impact …

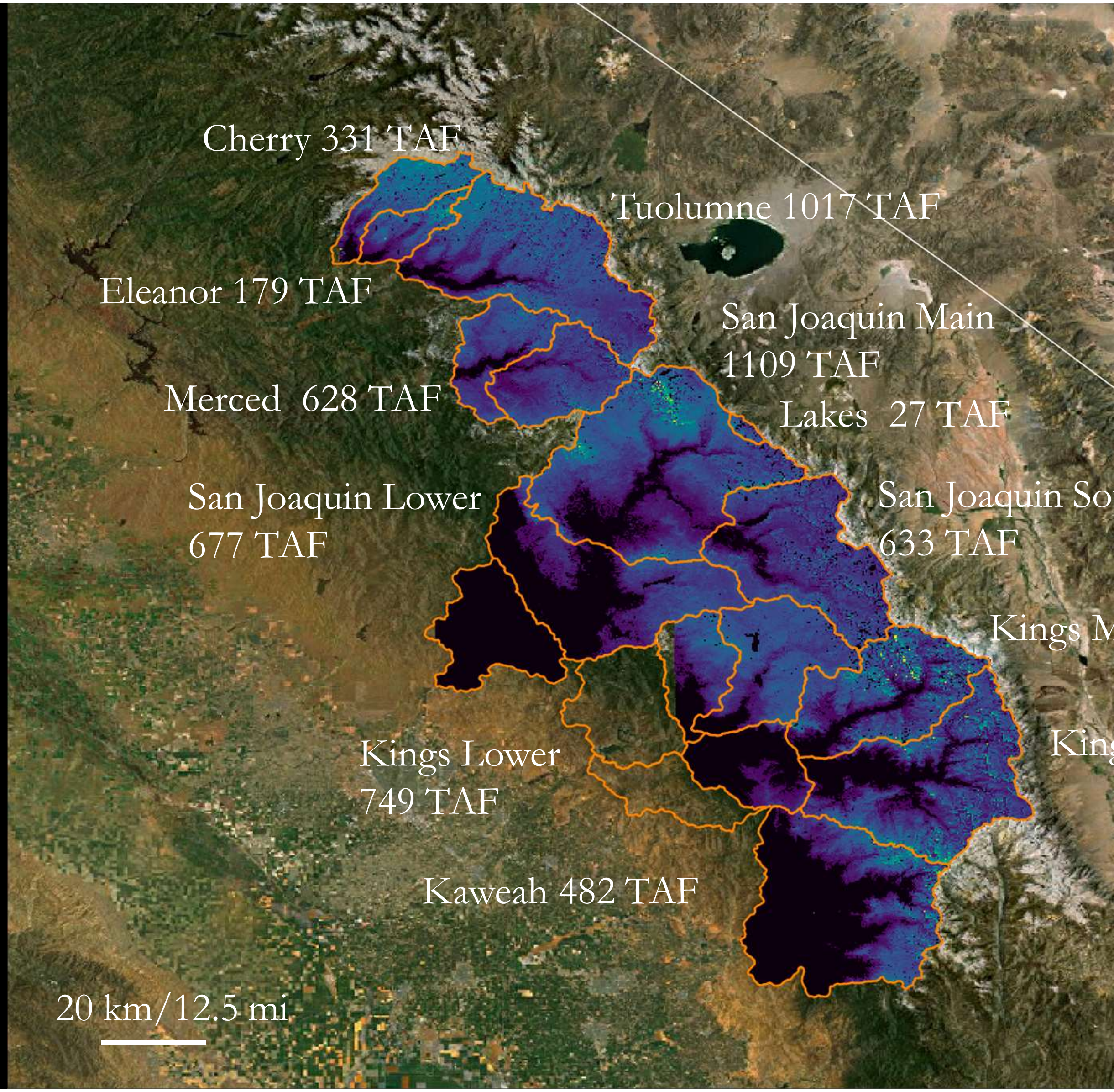






Spatial extent of activities

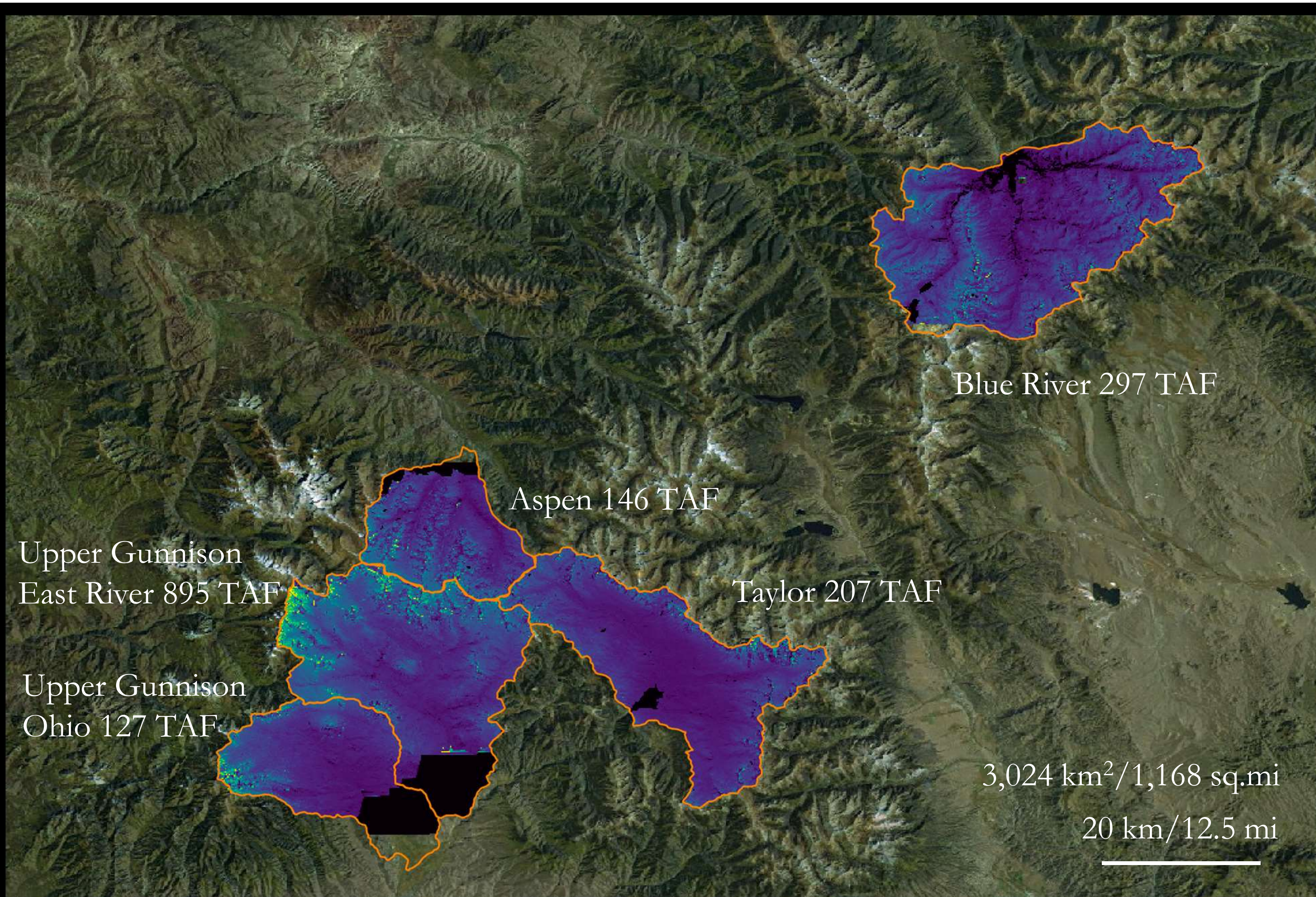
April 2019
SWE



11,084 km^2/4,280 sq.mi

California

April 2019
SWE



Colorado

Outlook to the future

- ASO started at the NASA Jet Propulsion Laboratory in 2012, first as a demonstration mission and then starting in 2016, mostly funded by operational entities

- These operations will be transitioning out of JPL at the end of the year

- A private company will be taking over the ASO tech transfer, with lidar, spectrometer and modeling surveys for water management entities in both California and Colorado, starting in 2020

- Contact at California Cooperative Snow Survey Program

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The Airborne Snow Observatory

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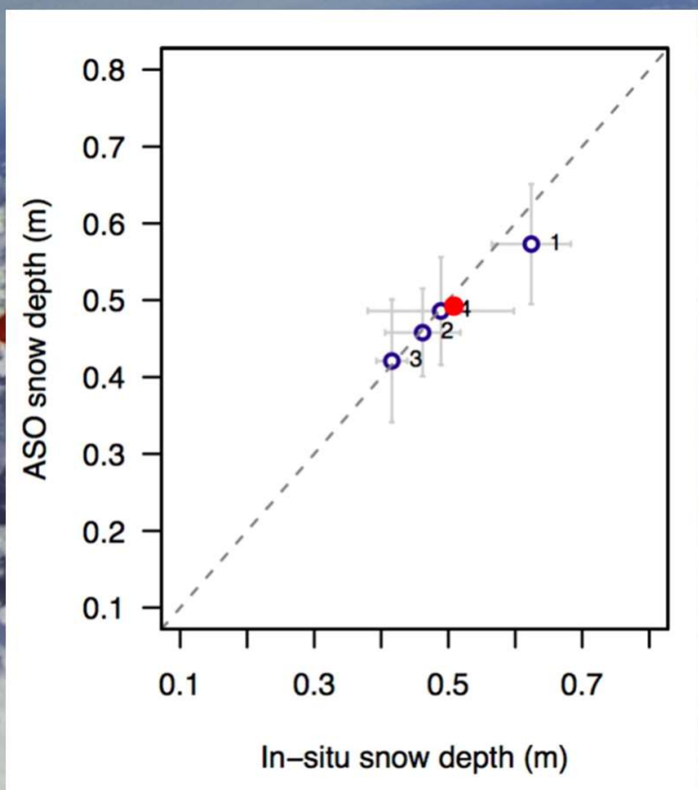
What is the accuracy?

Snow depths in exposed areas are within
1-2 cm at the 50 m scale



Currier et al., 2019