SY22A-04t

Creating a Program to Provide Highly Accurate Snow Water Equivalent Data in Colorado: Colorado Airborne Snow Observatory (CASO)

Presenter: Page Weil, PE, Lynker, lynker-intel.com

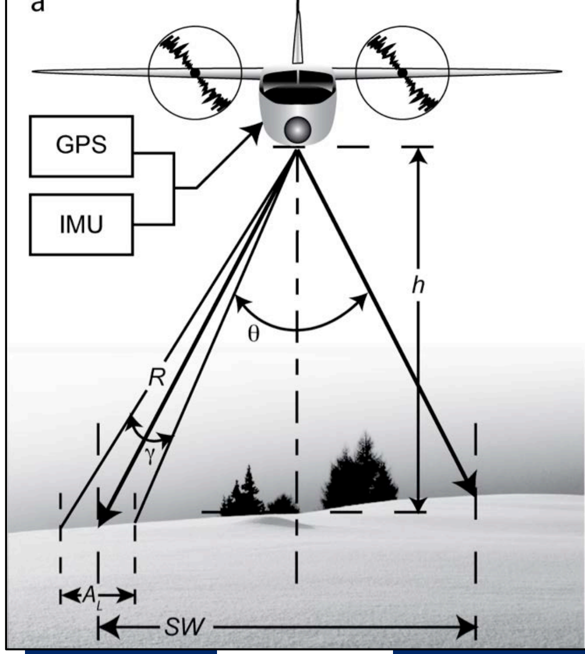
Co-Authors:

Jeffrey S Deems, ASO, Inc

Laurna Kaatz, Denver Water

Taylor Winchell, Denver Water

ASO is an Operational SWE Monitoring Tool



measure snow depth via differential altimetry *(constrained by spectrometer)*

lidar can provide the accuracy in rough terrain & forest

monitor & model snow density

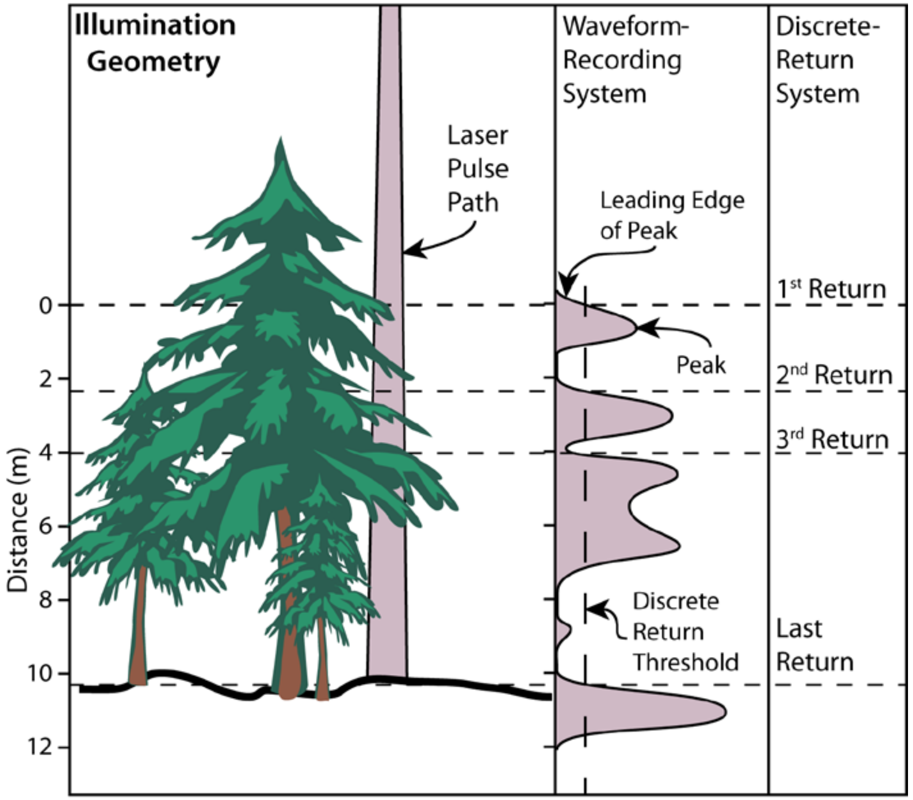
snow depth variation dominates SWE pattern

measure albedo *(constrained by lidar)*

imaging spectrometer retrieves albedo
& surface properties

ASO airborne program advantages

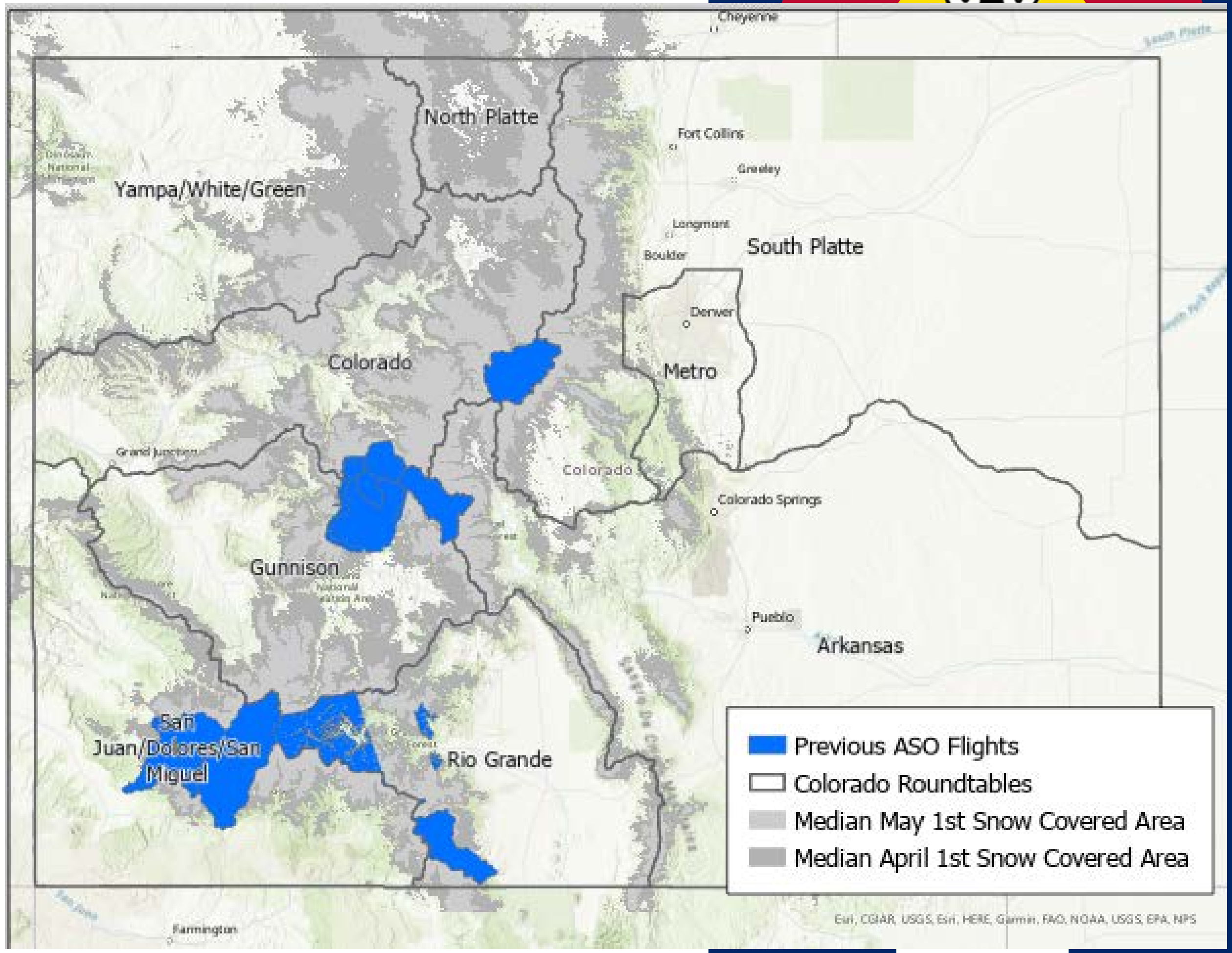
- time-nimble, targetable, commercial technology



Deems et al., 2013

Airborne Snow Observatory Flights in Colorado

- **Current State:**
- ~30 flights have been conducted in targeted areas for specific agencies
- Scattered and Lacking Consistency
- No effort to make them useful for a broader group

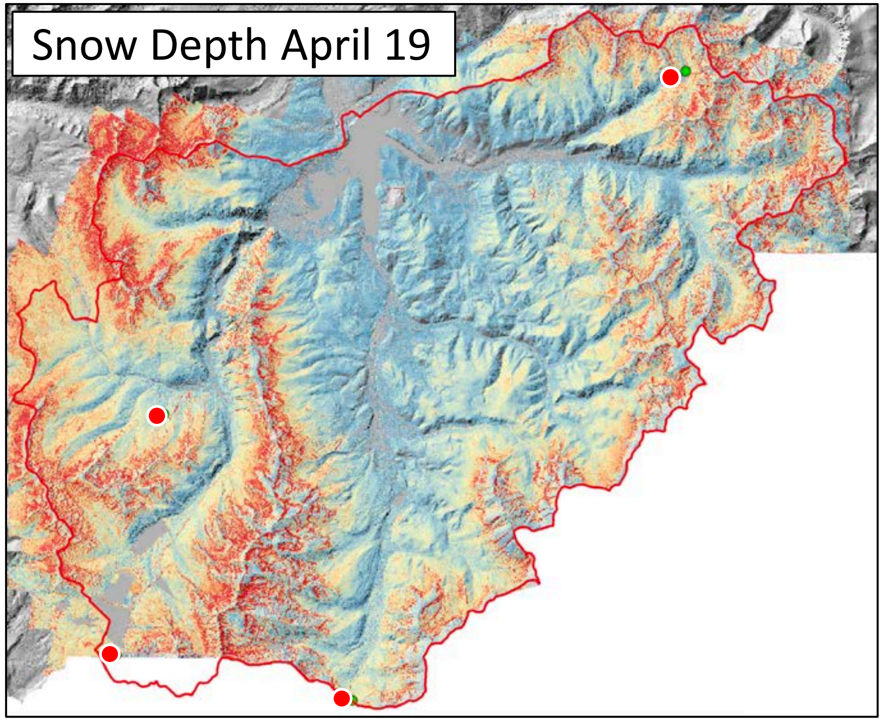


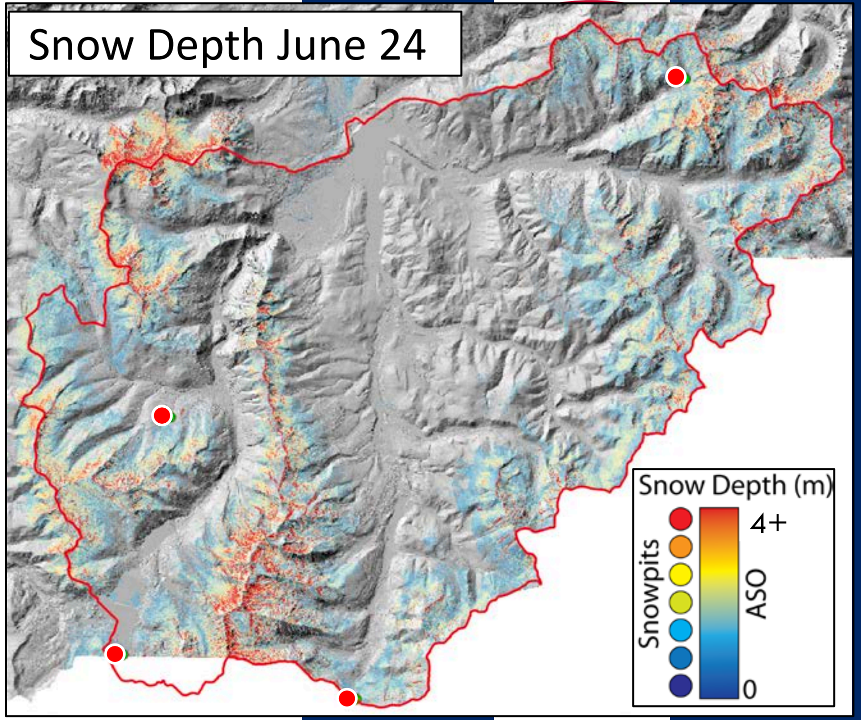
CASO Project Goal:

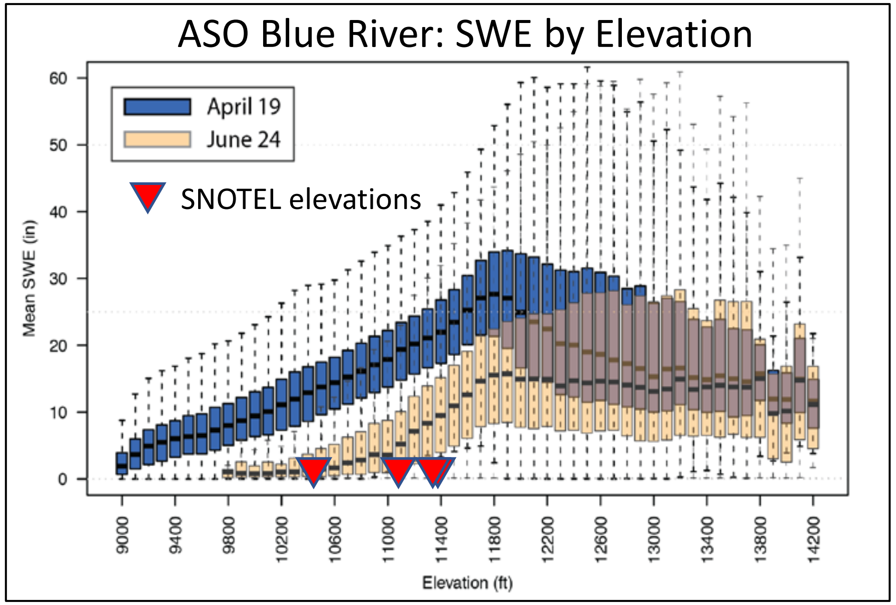
- Develop and communicate a roadmap for creating an equitable and sustainable ASO flight program in Colorado that would ultimately benefit multiple basins and a diverse group of water stakeholders.

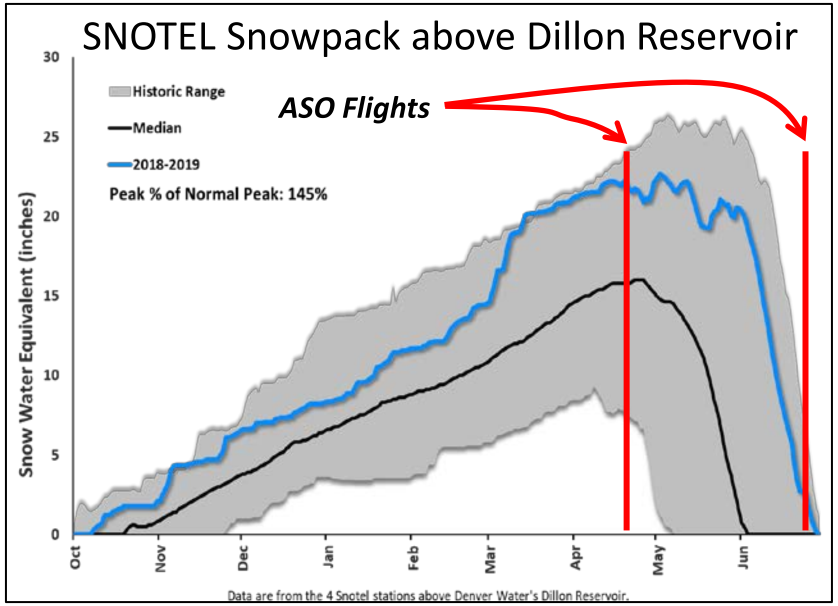
How Can ASO Improve Snow Monitoring in Colorado?

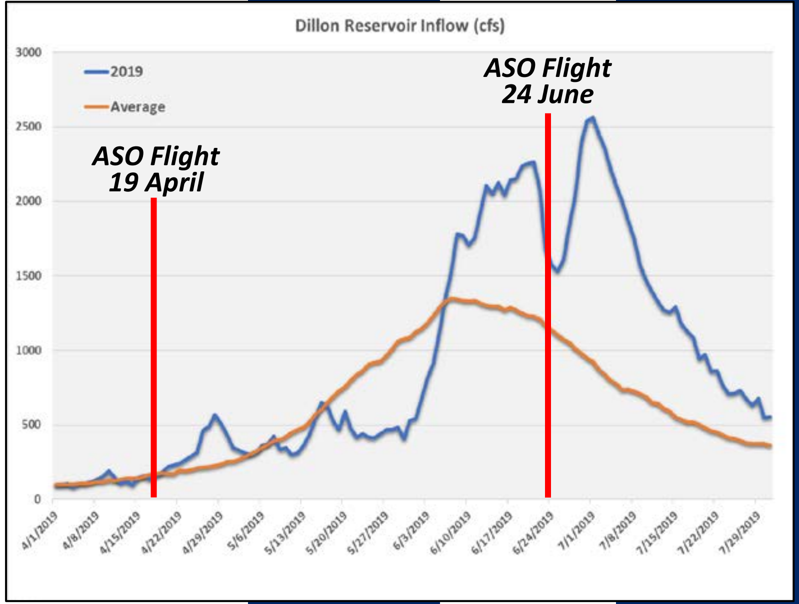
- >80% of annual runoff in CO is directly from snowmelt
- Existing monitoring networks (SNOTEL) are sparse
- Improved data can lead to improved forecasts and water management





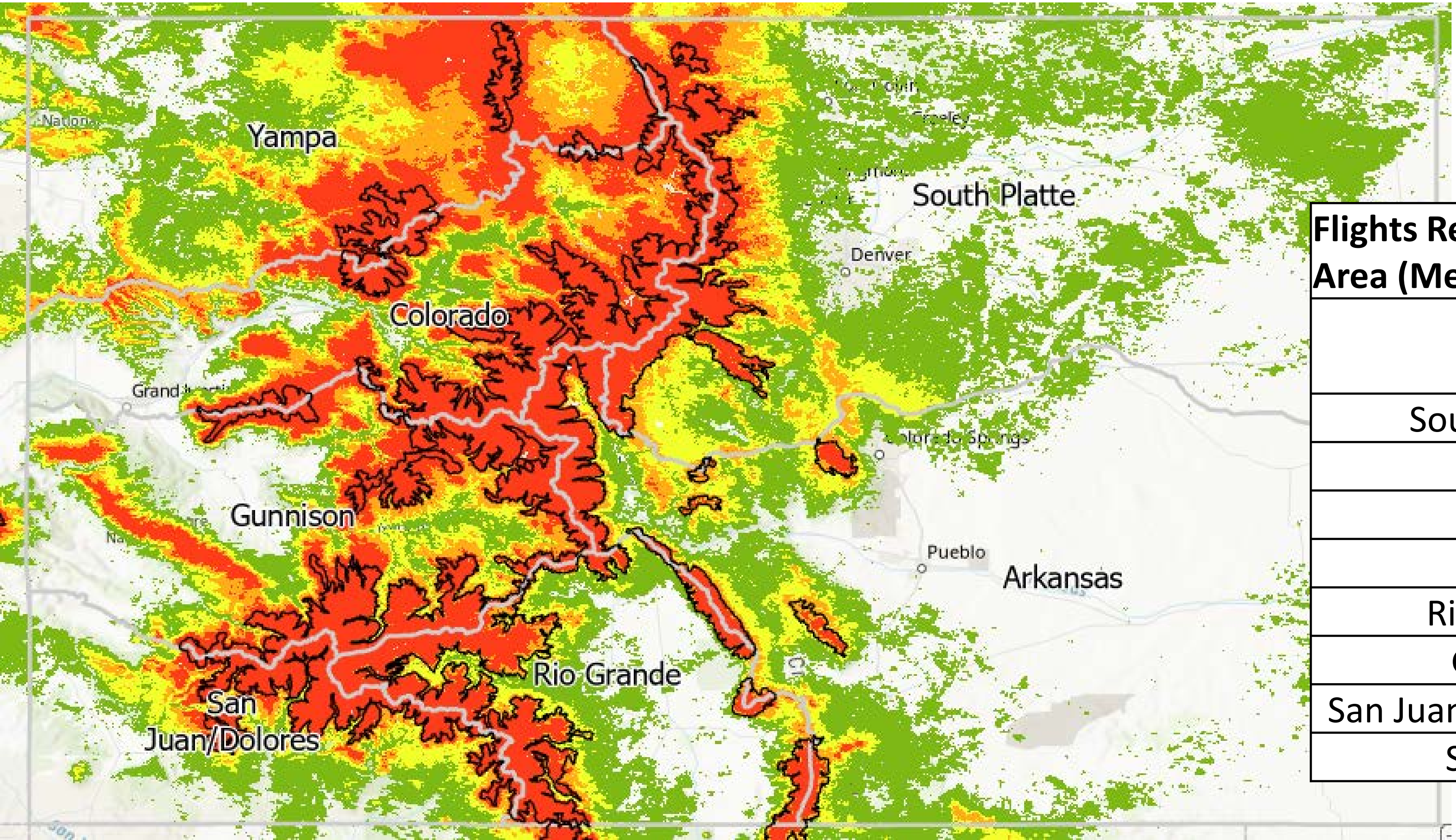






Ultimate Goal to Have Regular ASO coverage on April 1st

Yellow is the coverage in the median year (Green-yellow-orange-red are 25-50-75-99th %iles)
Black is the 10,000’ contour line



Flights Required for April 1st Snow Covered Area (Median Snow Year)

Basin	Sq.Mi	Approx. # of flights
South Platte	3,444	2.5
Arkansas	2,207	1.6
Colorado	6,214	4.6
Yampa	5,490	4.1
Rio Grande	2,706	2.0
Gunnison	5,409	4.0
San Juan/Dolores	2,274	1.7
Statewide	27,743	20.5

Upcoming Activities and Program Vision

Build a Program to promote this vision:

V1 – Funding

State/Federal Partnership

V2 - Governance and Structure

Managed at the State Level to encourage equity in flights

V3- Hydroclimate Science

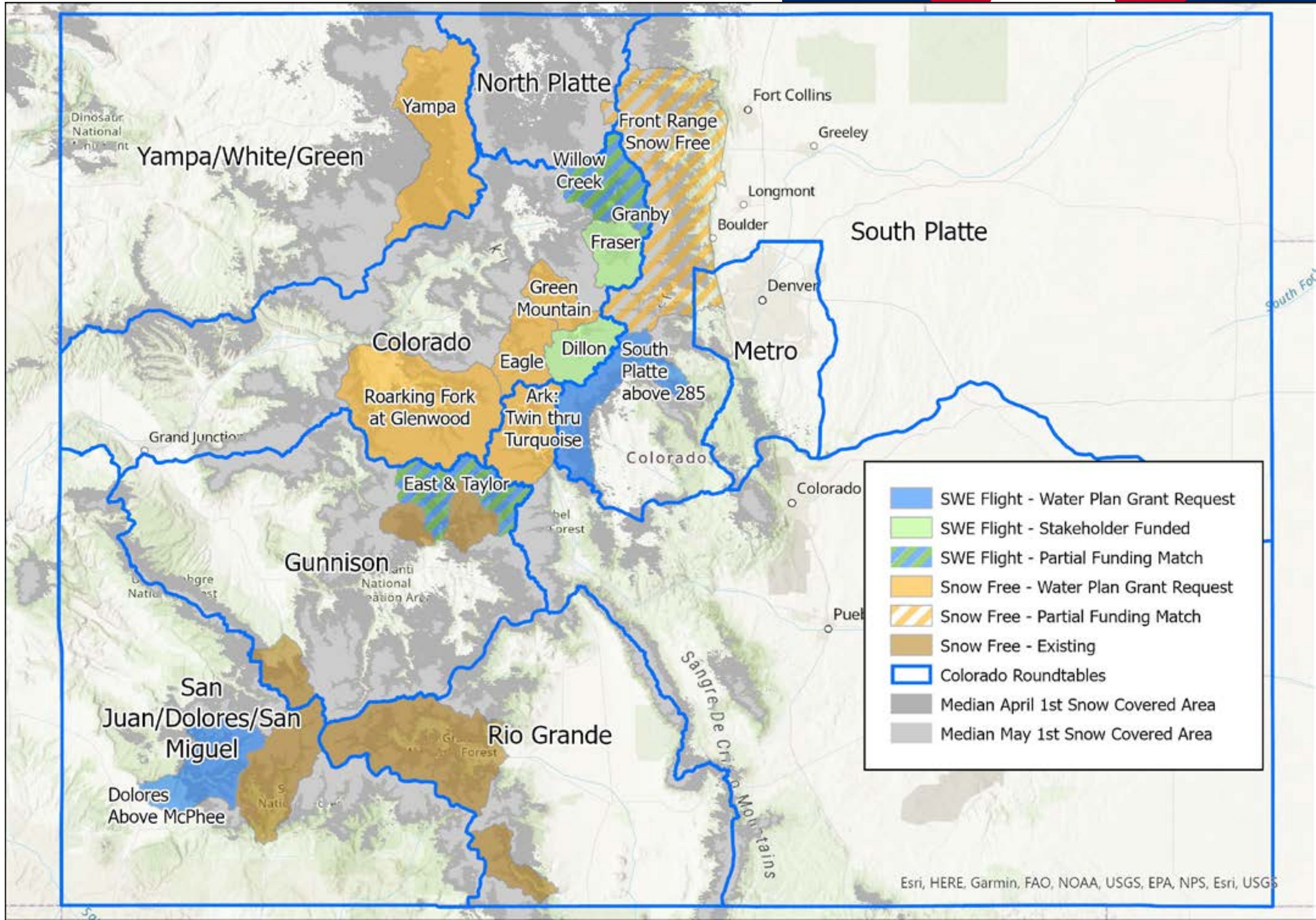
Improve knowledge of snowpack, water supply forecasts and climate impacts

V4 - Water Management and Decision-Support Applications

Improve water management decision making on short (yearly) and long (decadal) timescales.

2022 Flight Activities

- *Snow measurement*
- *Data prep*
- *Modeling*



AGU Slides

Andy Wood

Water Supply Forecasting

- Baseline forecast methods, datasets
  - model-based ESP hindcasting (SUMMA/mizuRoute)
  - statistical prediction if scope allows
  - verification workflow

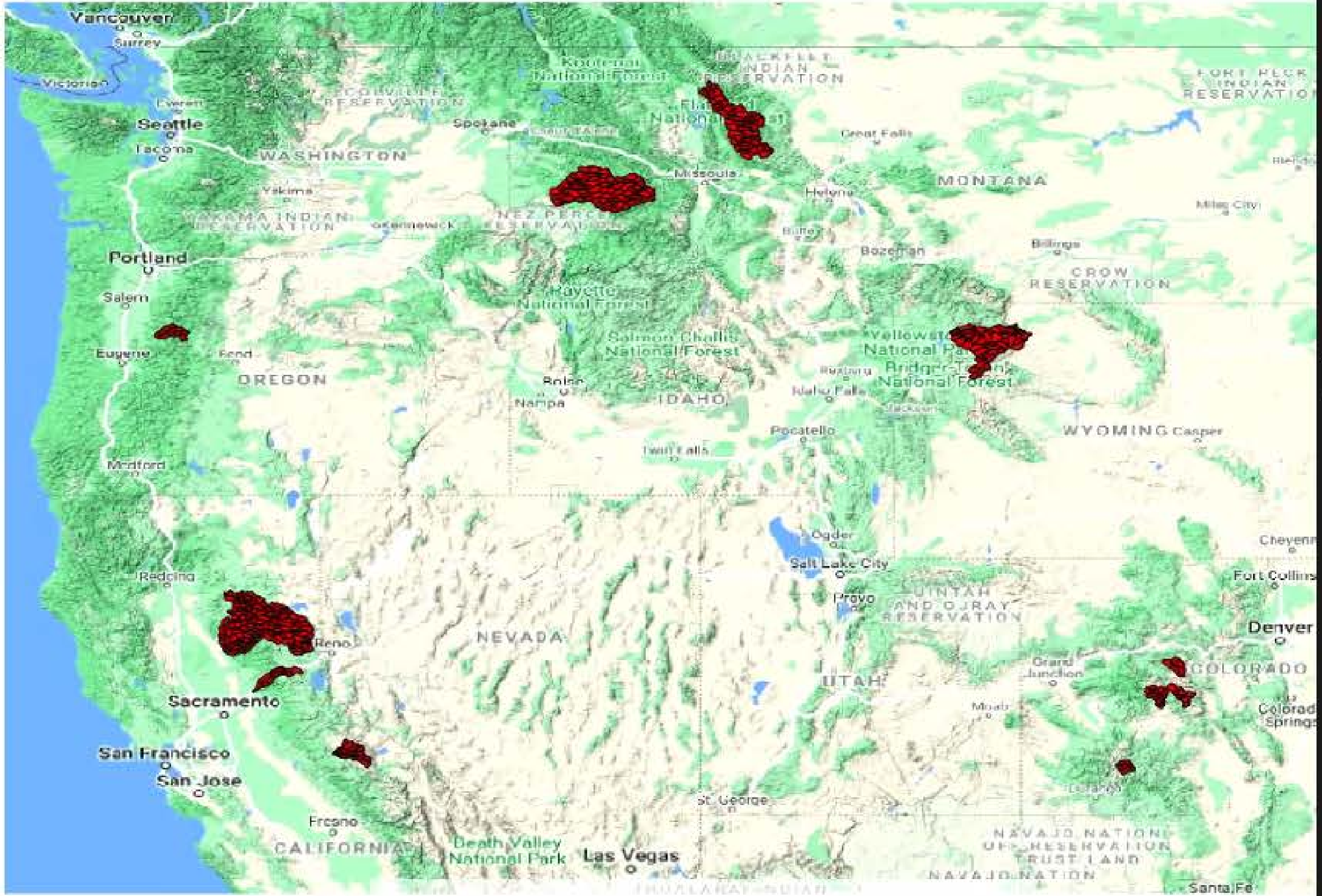
Snow Monitoring

- Intercomparison of snow observations
  - SNOTEL / CDEC
  - ASO, Stereo-optic SWE, SNODAS, SWANN, …
- Use SHREAD tool (for snow data processing)

Alternative modeling

- CTSM, other?
- Compare with operational results

Testbed on 12-20 small-to-medium scale watersheds in the western US



current list is in development

Baseline hydrology modeling/forecasting solutions

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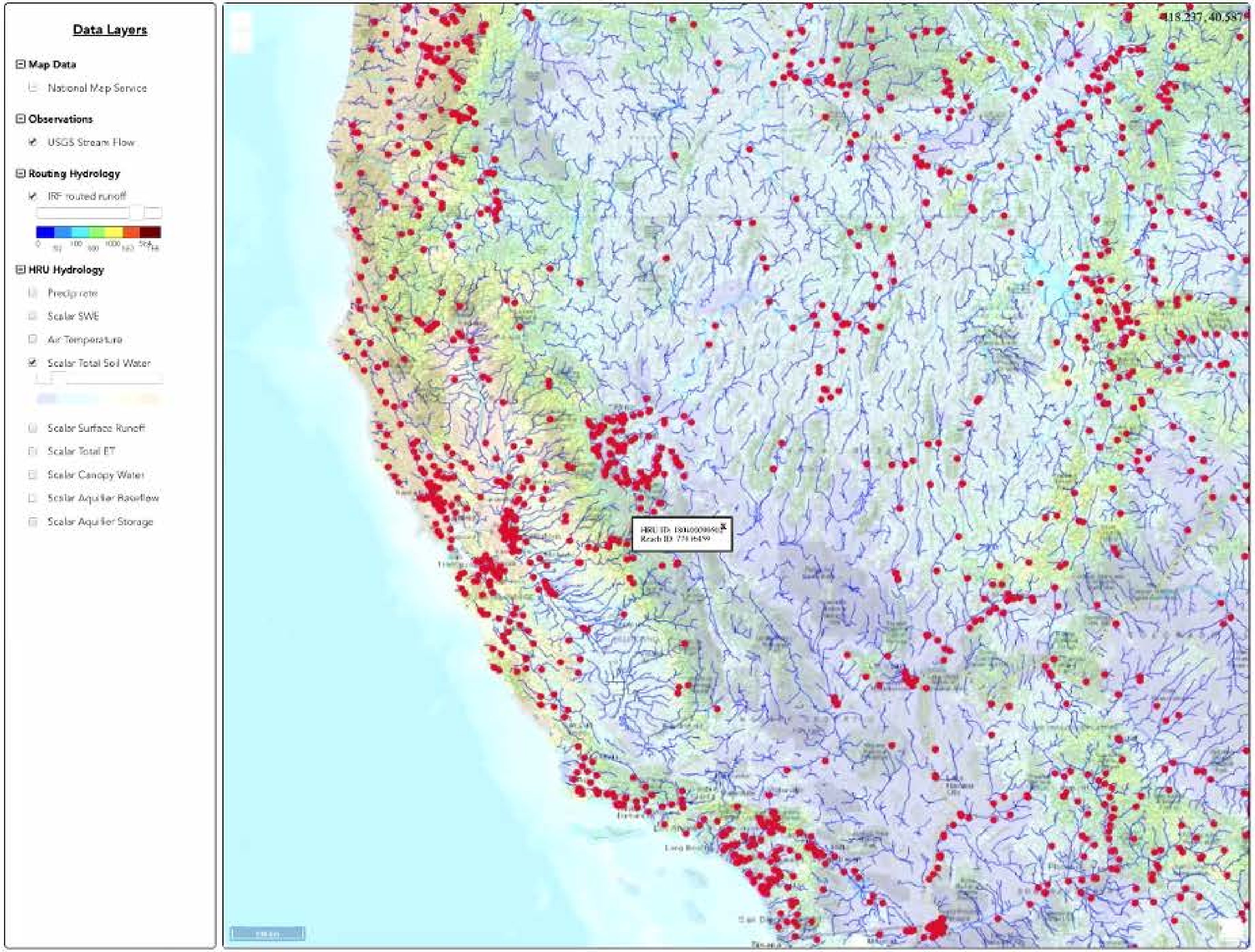
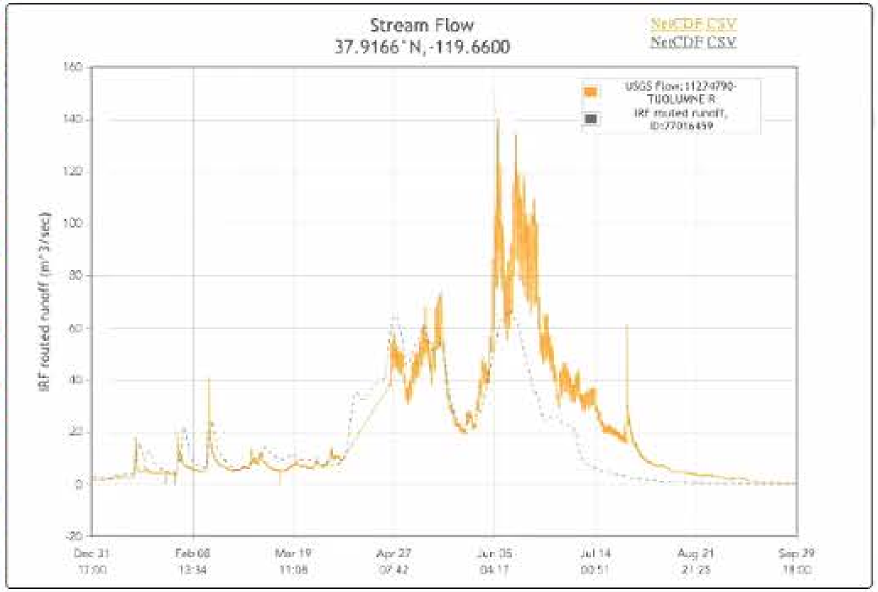
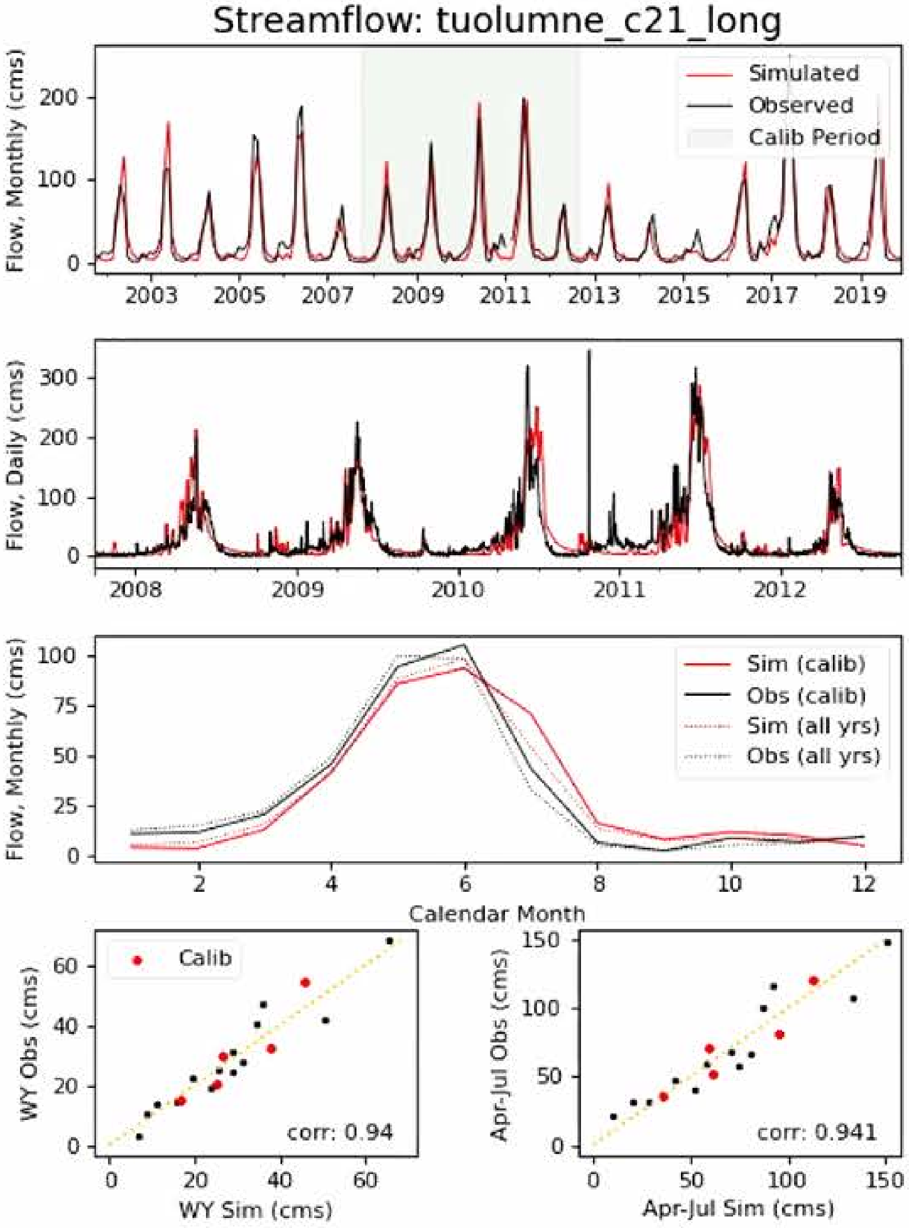
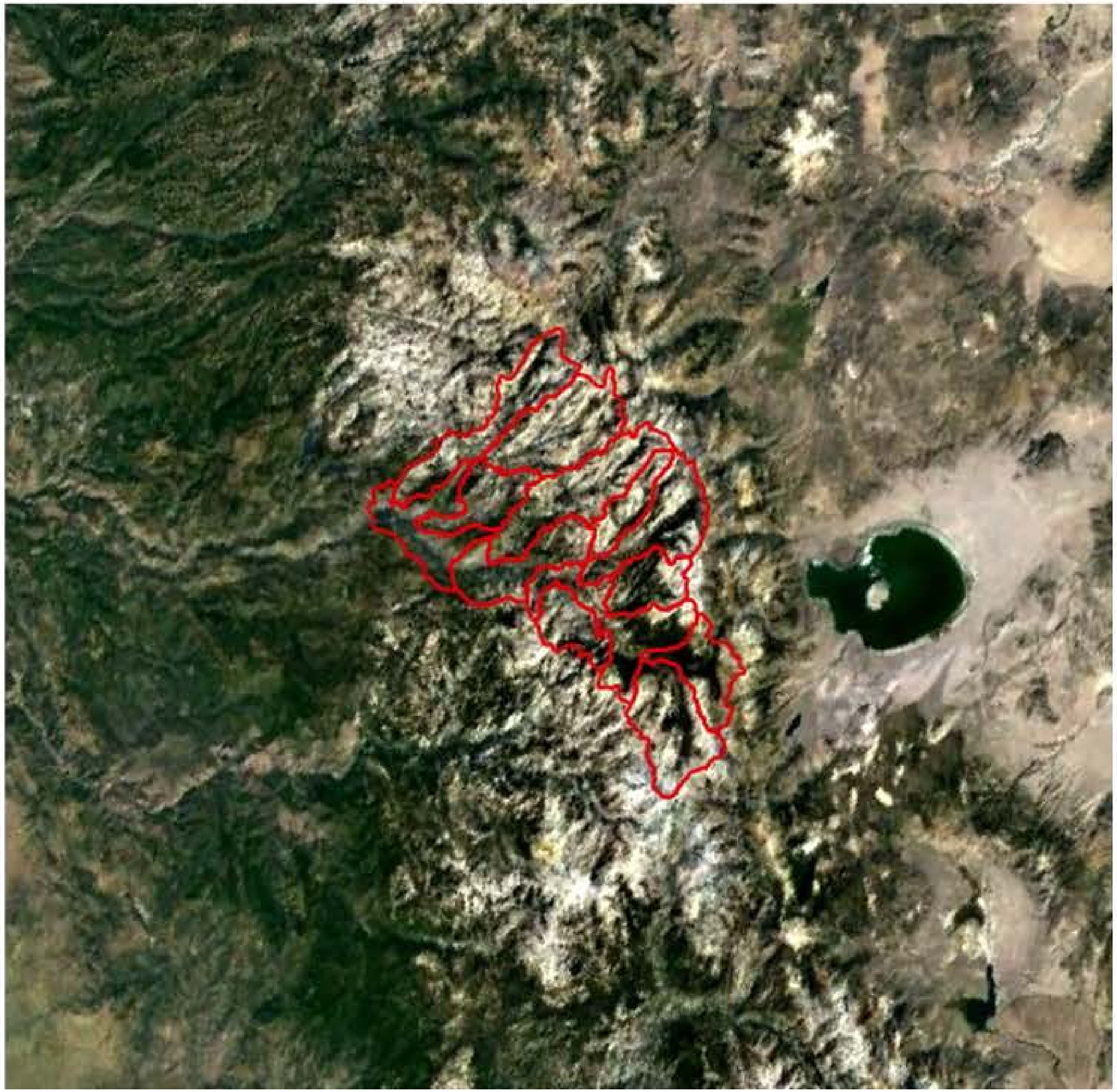




- **SUMMA:** Structure for Unifying Multiple Modeling Alternatives *(Clark et al., 2015)*
  - Process-oriented hydrologic model
- **MizuRoute** *(Mizukami et al., 2016)*
  - River network routing tool
  - Post-processor of SUMMA runoff
- **GMET** *(Newman et al, 2015)*
  - Ensemble forcing tool

Example: Tuolumne Basin with ASO / water supply forecasting assessment





Assessing modeled versus ASO-based snow water equivalent (SWE)

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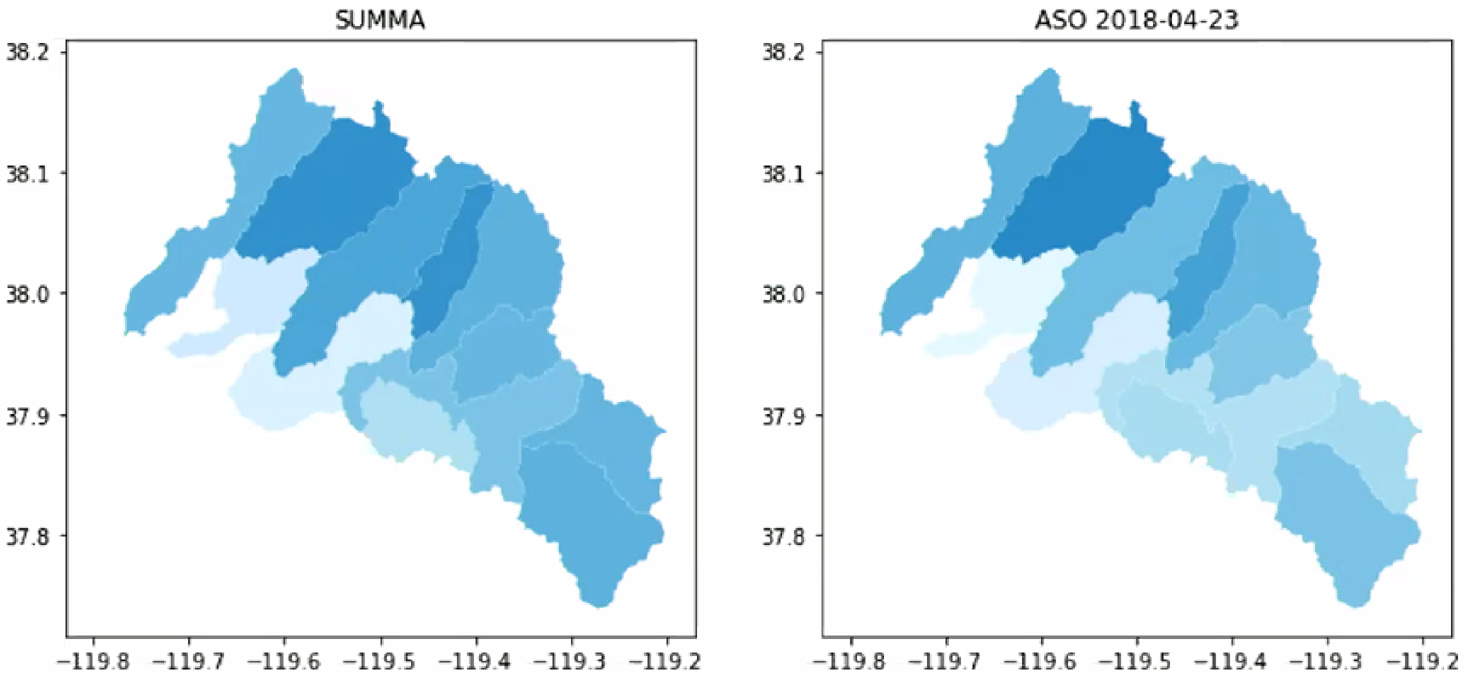
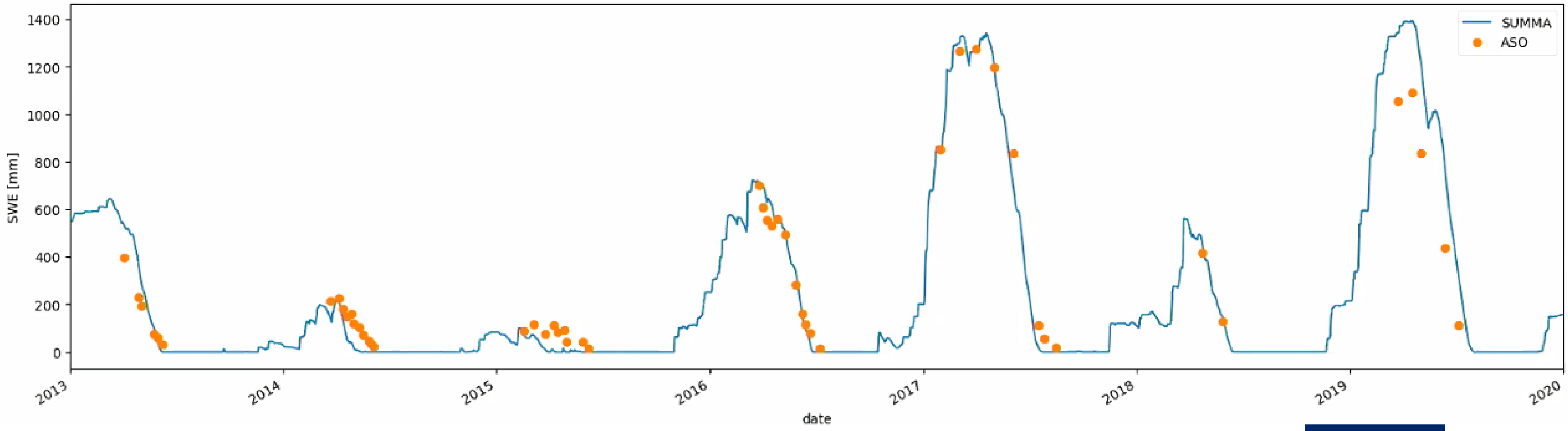
- SUMMA is calibrated for streamflow -- but simulates snow (SWE) well
- Spatial patterns are realistic (though coarse)
- Year to year variability is discriminated well





Snow Data Assimilation Results

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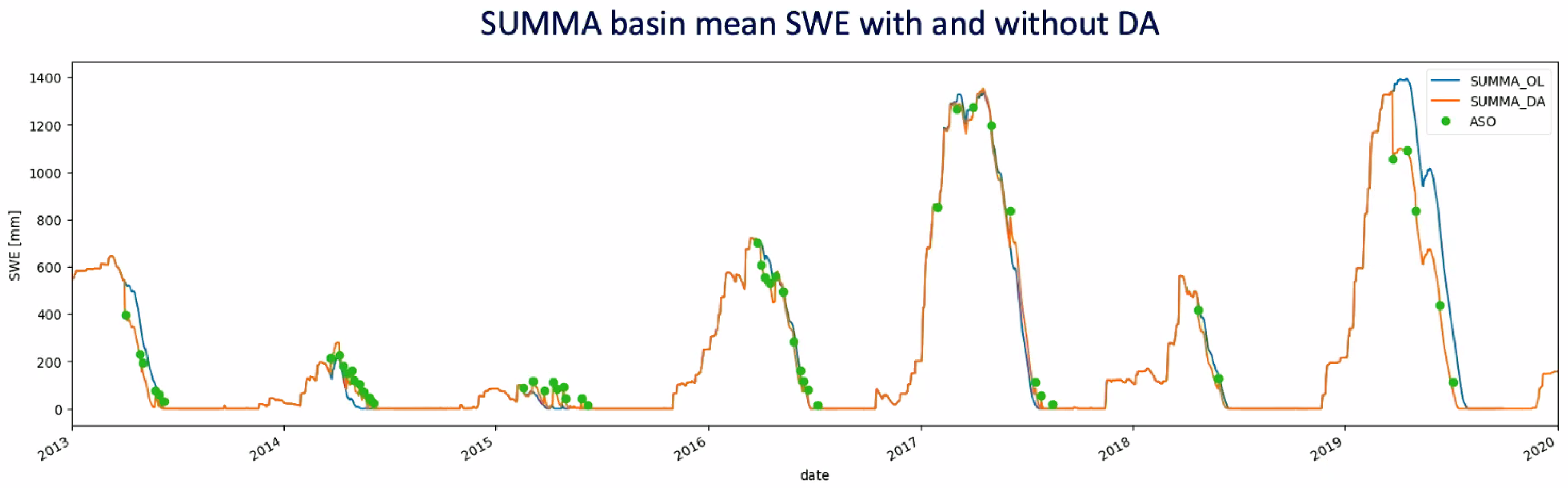

- DA run sometimes has lower SWE (2013, 2019)
- DA run sometimes has more SWE (2014, 2015 and late season)
- After first DA update (near peak), subsequent cycles have less effect (see 2013, 2019)

ESP Forecast Results with sequential DA

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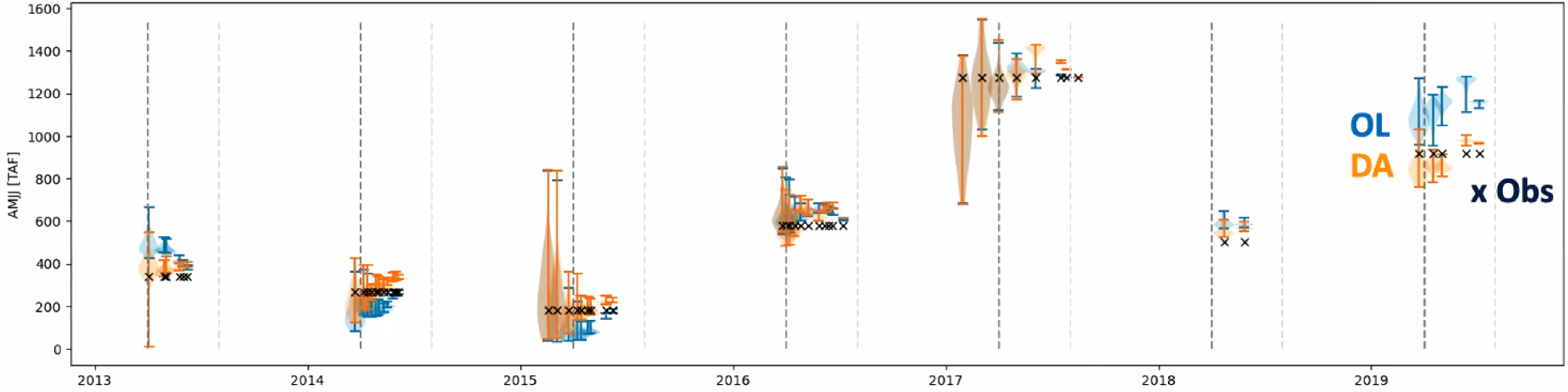
ESP water supply volume (Apr-Jul) forecasts on ASO flight dates

Hetch Hetchy Reservoir inflows



- SUMMA run with observed forcing to forecast date (ASO flight dates)
- Assimilating all available ASO flight data (orange violins)
- Forecast with ensemble of historical weather sequences

CASO