USDA Agricultural Research Service: Snow Water Supply Forecasting Program

Dr. Fred Pierson[1], Dr. Scott Havens[1], Dr. Danny Marks[1], Dr. Ernesto Trujillo[2,1], Dr. Andrew Hedrick[1], Mark Robertson[1], Micah Johnson[2,1]

[1] *Northwest Watershed Research Center, USDA Agricultural Research Service, Boise, Idaho*
[2] *Sierra Nevada Research Institute, University of California, Merced, California*

Idaho Water Users Association, January 22, 2019

USDA-ARS Snow Water Supply Forecasting Program

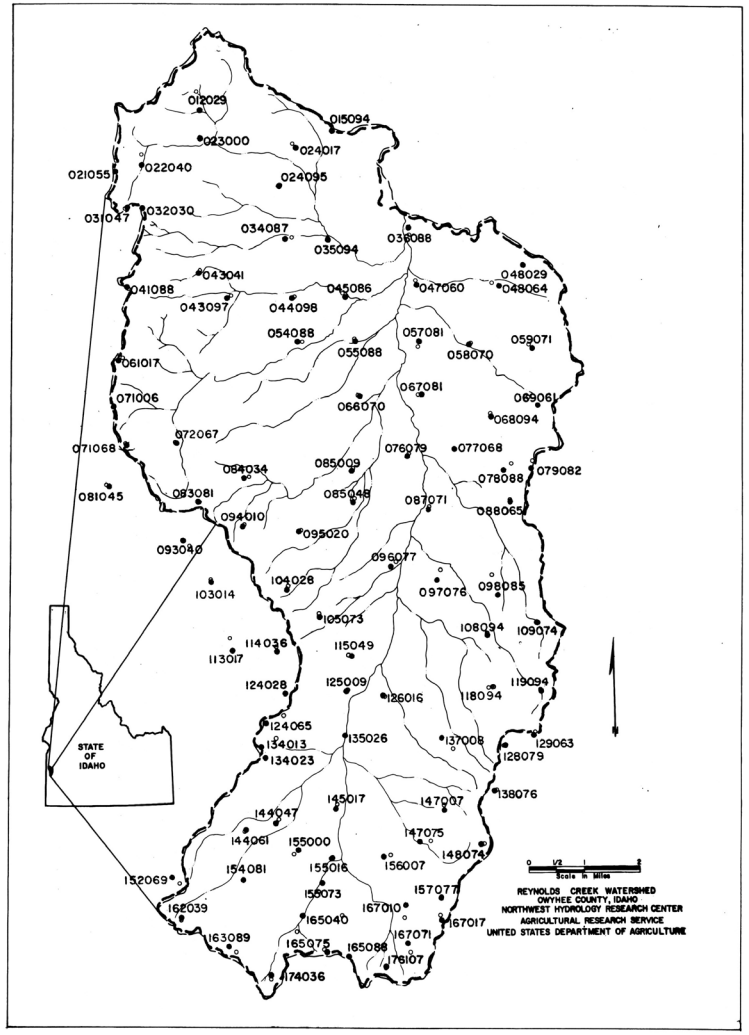
- Introduction to USDA-ARS?
- Program Overview
- Past and Current Impact
  - Boise River Basin, ID
  - San Joaquin, CA
- 2020 and Beyond
  - Technology transfer
  - Scientific advancements

Who is ARS?

- USDA's chief scientific in-house research agency
- Focused on finding applied solutions to agricultural problems
- 2,000+ scientists and post-docs at 90+ locations
- Only 2 locations for watershed research in the west
- Boise is the only unit that has a dedicated snow hydrology group

Reynolds Creek Experimental Watershed (RCEW)

- Started in 1960 for long term monitoring and research
- 239 km^2 or 90 mi^2
- 81 precipitation stations to start
- Currently:
  - 32 climate stations
  - 36 precipitation stations
  - 7 eddy-covariance towers
  - 14 stream gauges
  - 10 soil microclimate stations
  - 3 instrumented headwater basins
  - 8 long term snow courses



RCEW History: SNOTEL

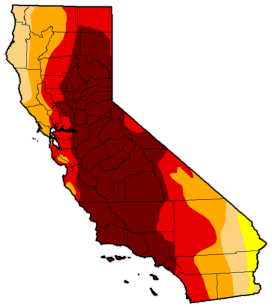
Improving Western Snow Water Supply Forecasting

NASA-JPL

USDA Agricultural Research Service

Stakeholders:

California Department of Water Resources
Natural Resources Conservation Service
United States Bureau of Reclamation
Many CA water management agencies



Variable climate lead to historic 4 year drought, followed by record snowfall

Agriculture and irrigation

Power generation

Municipal conservation

Unique Program: Scientists and Stakeholders

Stakeholder Input

- Set common project goals
- Continuous direct real time feedback
- The connection to the users has enhanced operational application of the work

Local Scientific Team

- Dr. Fred Pierson
- Dr. Danny Marks
- Dr. Scott Havens
  - Computational modeling and big data
- Dr. Andrew Hedrick
  - Remote sensing applications
- Dr. Ernesto Trujillo
  - Streamflow and snow modeling

USDA-ARS Snow Water Supply Forecasting Program

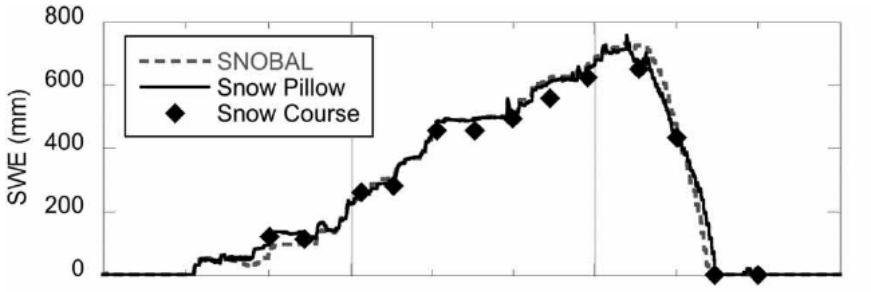
- Introduction to ARS?
- **Program Overview**
- Past and Current Impact
  - Boise River Basin, ID
  - San Joaquin, CA
- 2020 and Beyond
  - Technology transfer
  - Scientific advancements

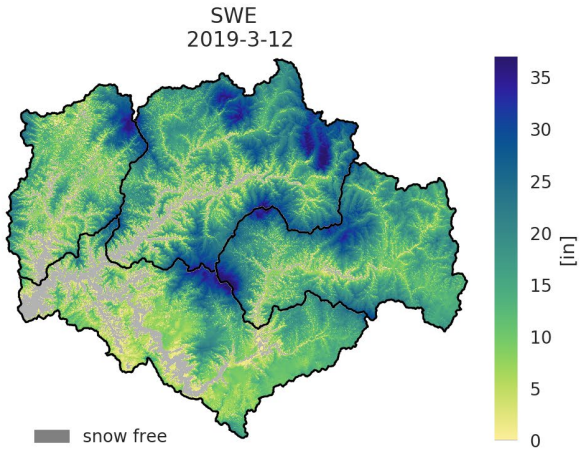
Snow science has come a long way

Measurement and modeling spatial revolution

From 10's of points to million's

Areal lidar for snow depth
NASA-JPL Airborne Snow Observatory (ASO)





USDA-ARS modeling
Boise River Basin

Integration of Modeling and Remote Sensing

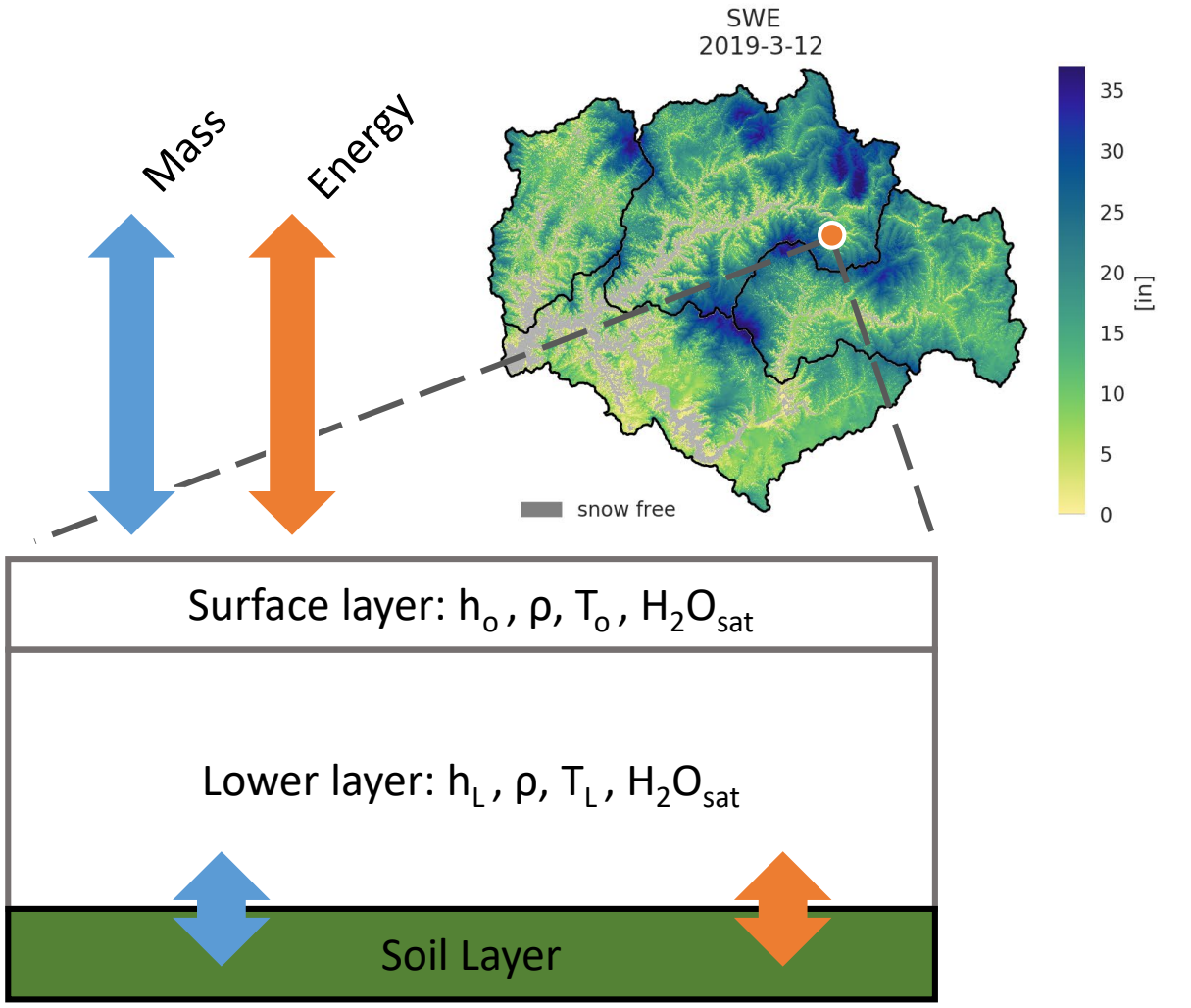
Snow Water Equivalent (SWE) = *depth x density*

ASO measures snow depth

iSnobal models density

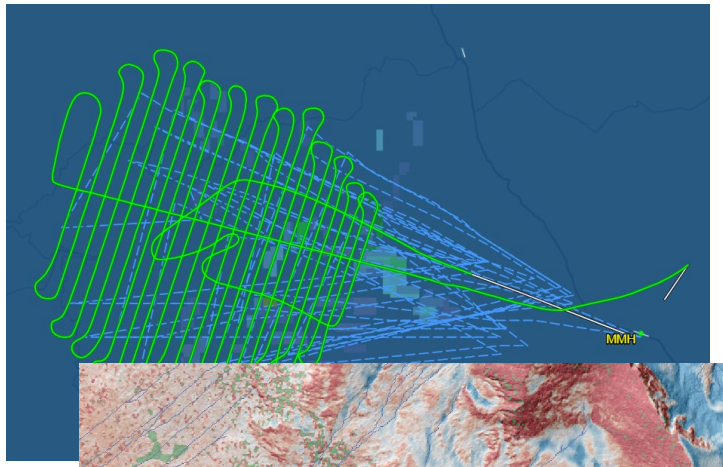
iSnobal
Snow Model Overview

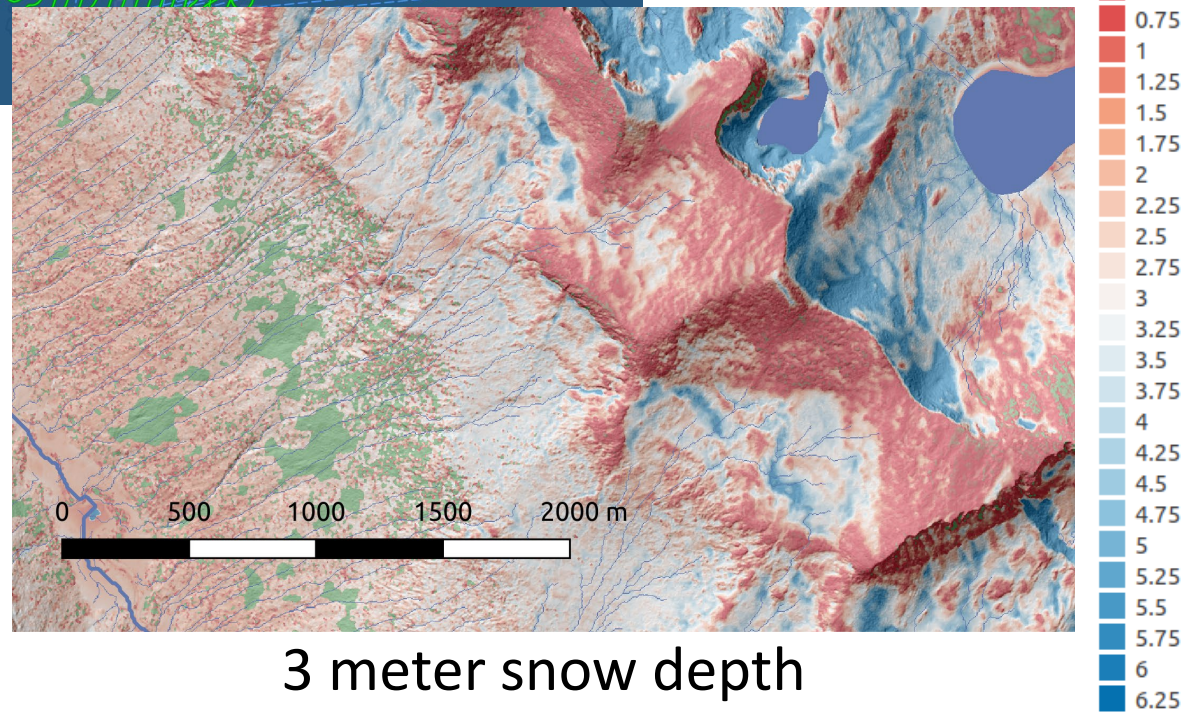
- USDA-ARS developed model
- Physically based snow model (Marks et al., 1999)
  - Mass and energy balance of the snowpack
- Varying spatial and temporal resolution
- Input data
  - Cooperative measurement network
  - Using atmospheric model (HRRR) since WY2018



Remote Sensing
Airborne Snow Observatory flights

- Started by NASA JPL in 2013
- “Mow” full or part of a watershed to obtain lidar point cloud
- snow depth = snow on – snow off
- Turn around time of 2-5 days
- **Producing gridded snow depth measurements at 3 meters (~10 ft) over entire watersheds**

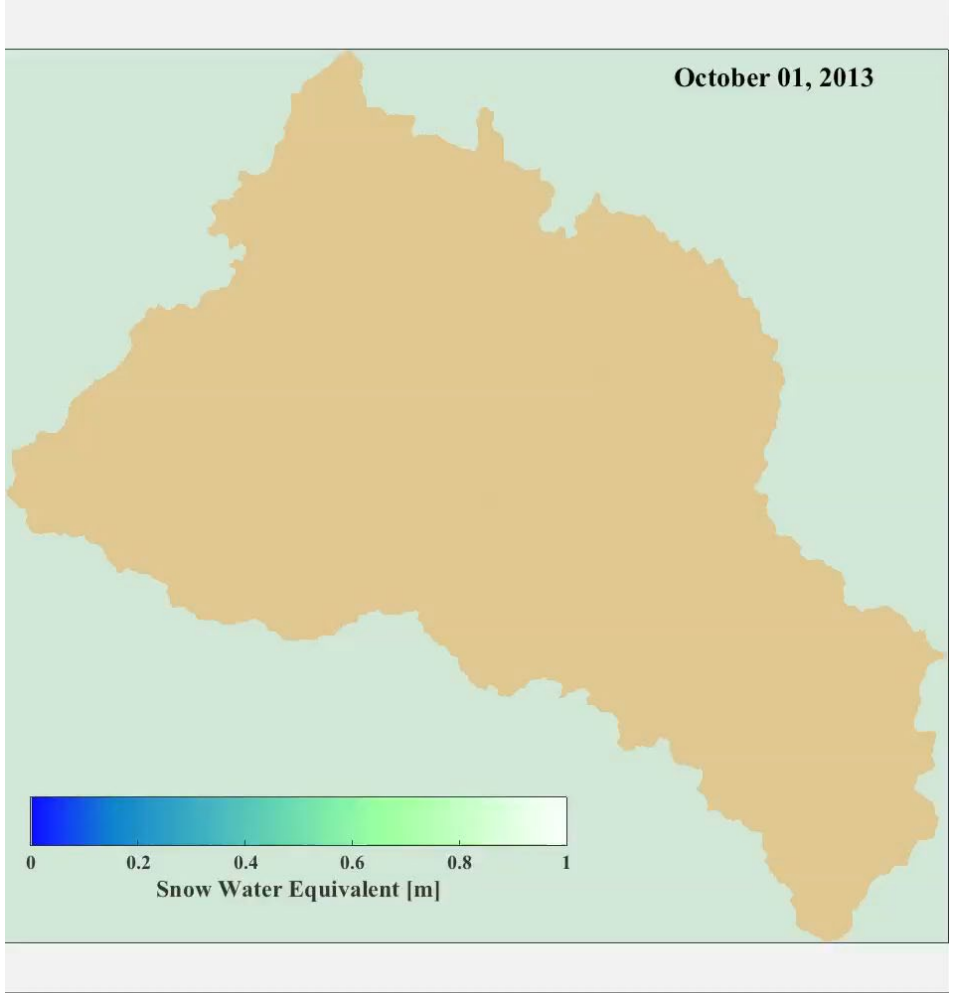




3 meter snow depth

Power of ASO + iSnobal

- ASO defines the snow distribution
  - **Snapshot** of what is on the ground
- iSnobal
  - **Continuous** results between flights
  - Update model with measurements
  - Model can provide more information than just SWE
- Spatial revolution in water supply forecasting
  - **Moving from information at a few point to millions in real time**

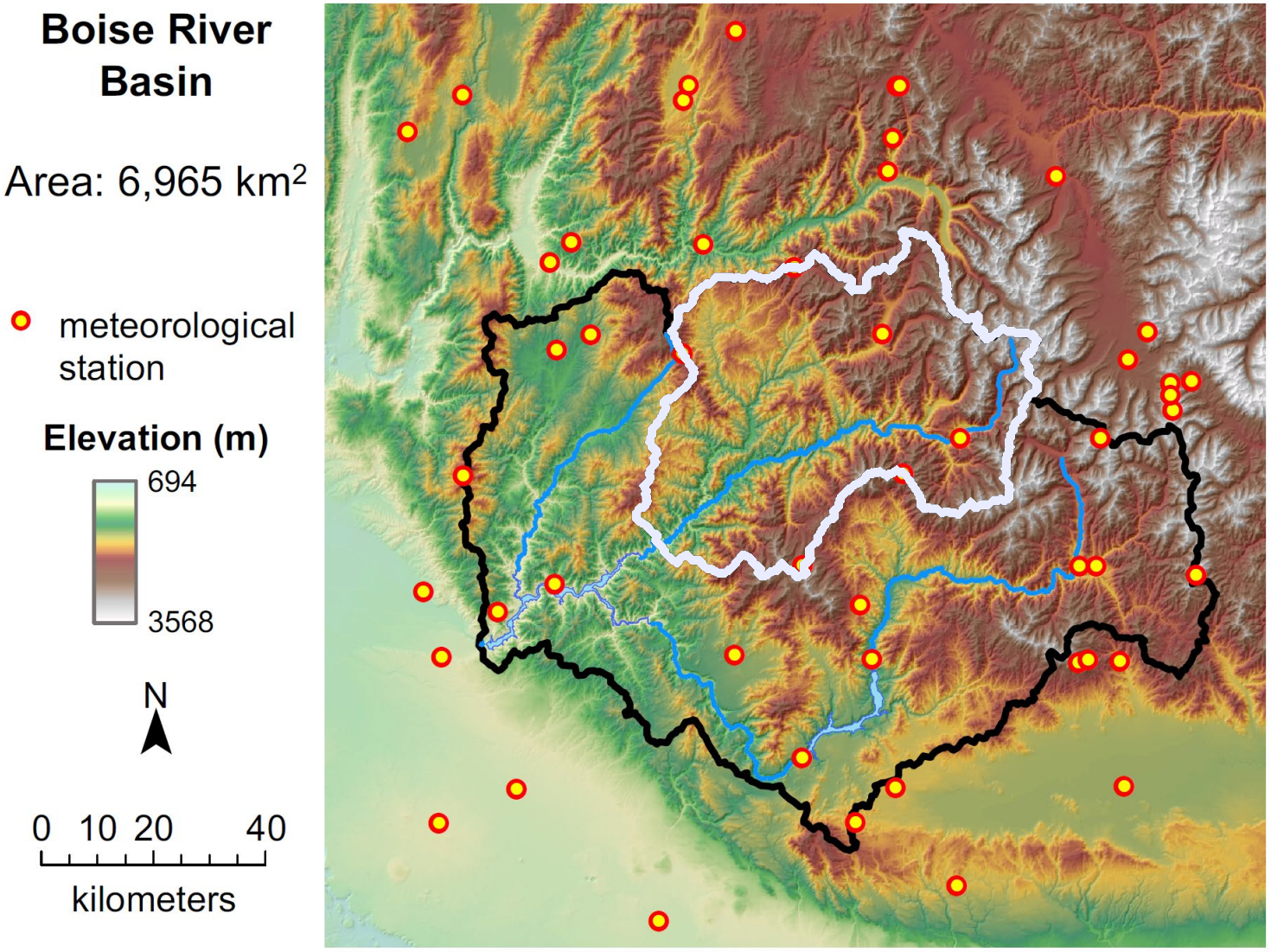


Daily model results, Tuolumne River, WY2014

USDA-ARS Snow Water Supply Forecasting Program

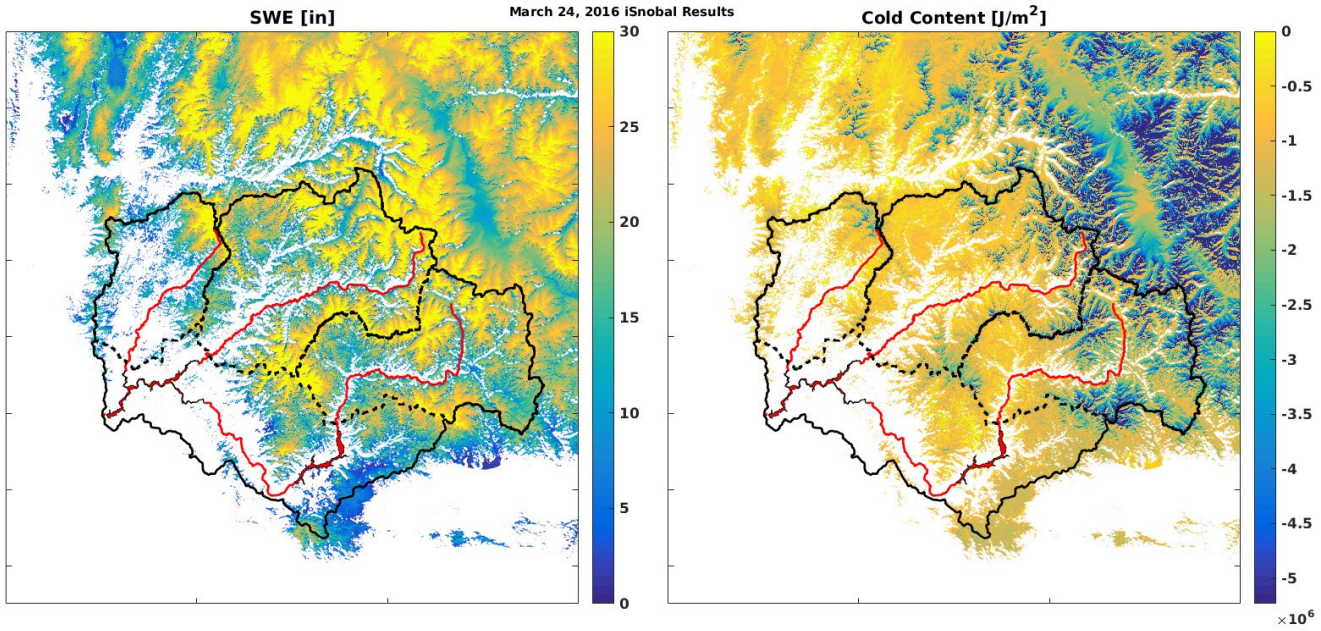
- Introduction to ARS?
- Program Overview
- **Past and Current Impact**
  - **Boise River Basin, ID**
  - **San Joaquin, CA**
- 2020 and Beyond
  - Technology transfer
  - Scientific advancements

Boise River Basin beginnings



- Long term research at RCEW facilitated moving to a larger area
- Initially started modeling Twin Springs in 1998
  - Collaboration with the NRCS National Water and Climate Center
- Led to installation of new sensors at Snotel sites still in operation today

Boise River Basin beginnings



Sample from weekly report
Left: spatial Snow Water Equivalent (SWE)
Right: Cold content or ripeness

- US Bureau of Reclamation, PN Region Project
  - Ran iSnobal in support of reservoir operations and water management
  - WY 2013 to 2016
- Produced weekly reports summarizing model results
  - With iSnobal, confirmed that runoff was over predicted in 2013 and 2014

Idaho projects proved that the model could run operationally

California's Historic Drought

4 below average years

to the 2nd wettest

- CA was in the height of the 2012-2015 drought
- ASO had been operating since 2013 and provided a lower bound to the amount of water left in a basin

- Historically wet 2017
- iSnobal and measurements could provide operational information for flood control
- Modeling 6 large primary basins by 2019 – entire Southern Sierras

Example: San Joaquin River

- Friant Dam, Millerton reservoir
  - Located near Fresno, CA
  - Operated by USBR Mid Pacific
  - Small capacity of 520,500 AF
- Supplies 2 large canals
  - 34 water districts and municipalities
  - 15,000 family farms with more that 1 million acres of highly productive farmland
- San Joaquin River Restoration Program
  - Restore flows for self-sustaining Chinook salmon fishery

Friant Dam and Millerton Lake
from Friant Water Authority

Current Water Supply Forecasts in CA

California Department of Water Resources

- California Cooperative Snow Surveys
  - The NRCS of California
- Bulletin 120
  - Statistical relationship between point measurements of snow pillows/courses to streamflow

California Nevada River Forecast Center

- Ensemble Streamflow Prediction
  - Using last 50 years as proxy for future weather
- SNOW-17 temperature index snowmelt model
- Various hydrologic models like Sacramento soil moisture model

San Joaquin WY 2019
May 15th water management decision

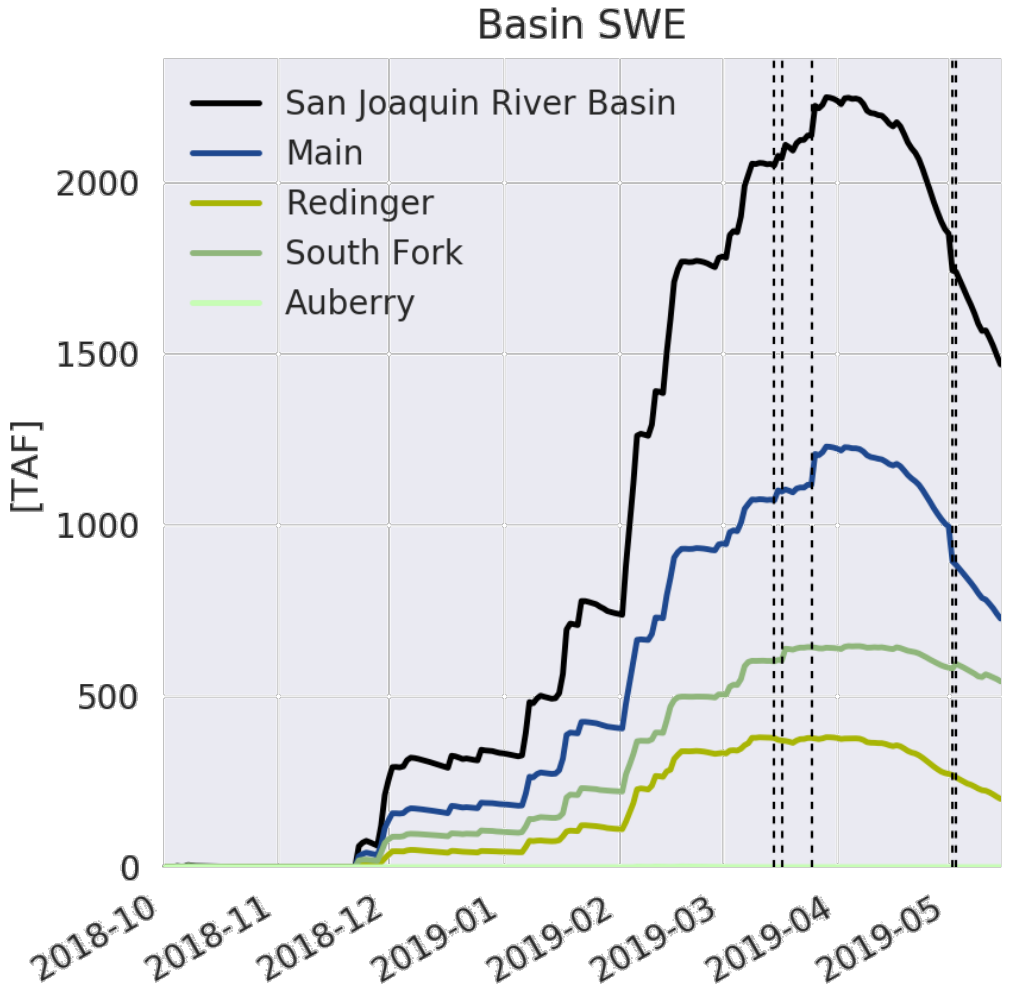
- 90% chance of inflow exceeding 1,550 TAF or 1,970 TAF
  - Which one is more reliable when there is 420 TAF difference?
- Extremely significant because active storage is only **385 TAF**!
  - Rely on personnel expertise to make informed decision

May 15th	CDWR	CNRFC	Difference
50%	1,770	2,060	**290**
90%	1,550	1,970	**420**

Total inflow was in 2019 was 2,750 TAF or 7 times the active storage

San Joaquin Forecast Accuracy

- Reclamation's blended forecast
  - Blending traditional forecasts with snow volume estimates
  - Important in unusual years or periods of high uncertainty
  - Leaned heavily on USDA-ARS modeling in 2019
  - iSnobal results showed ~1.5 MAF of snow volume
- Average forecast accuracy of **1.6% (-41 TAF)** after peak SWE



The Water Manager's Dilemma

Segal's Law

"A man with a watch knows what time it is.
A man with two watches is never sure."

"With snowpack measurement and modeling we have a powerful way to determine which watch is more accurate."

USDA-ARS Snow Water Supply Forecasting Program

- Introduction to ARS?
- Program Overview
- Past and Current Impact
  - Boise River Basin, ID
  - San Joaquin, CA
- **2020 and Beyond**
  - **Technology transfer**
  - **Scientific advancements**

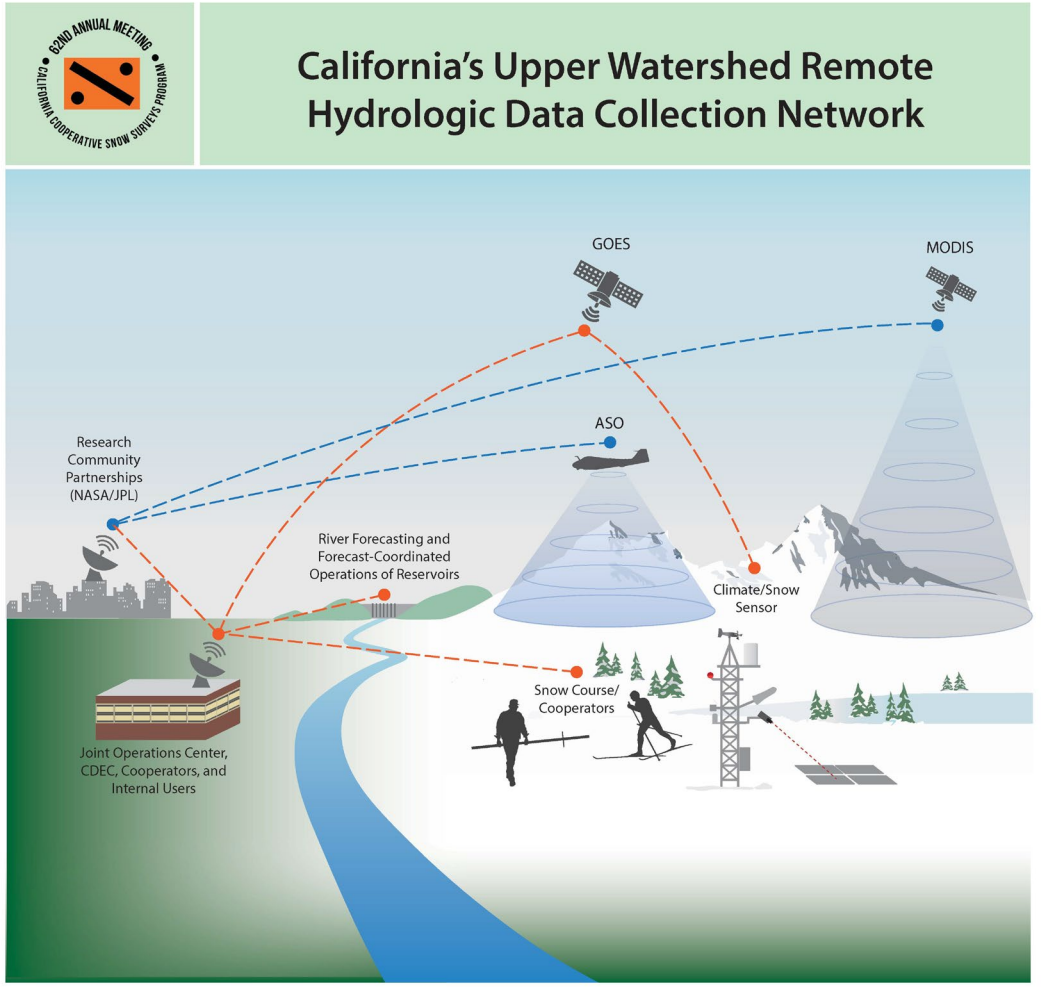
Current State of Forecast Tools

- Have overcome the limits of remote sensing and computational ability
- USDA-ARS does technology transfer
  - Stakeholder attainable cloud-based technology
  - Transferability for easy model setup with anyone
  - Training
- Direct interaction with stakeholders on how they see utilizing the model

30+ water managers and scientists learning about iSnobal

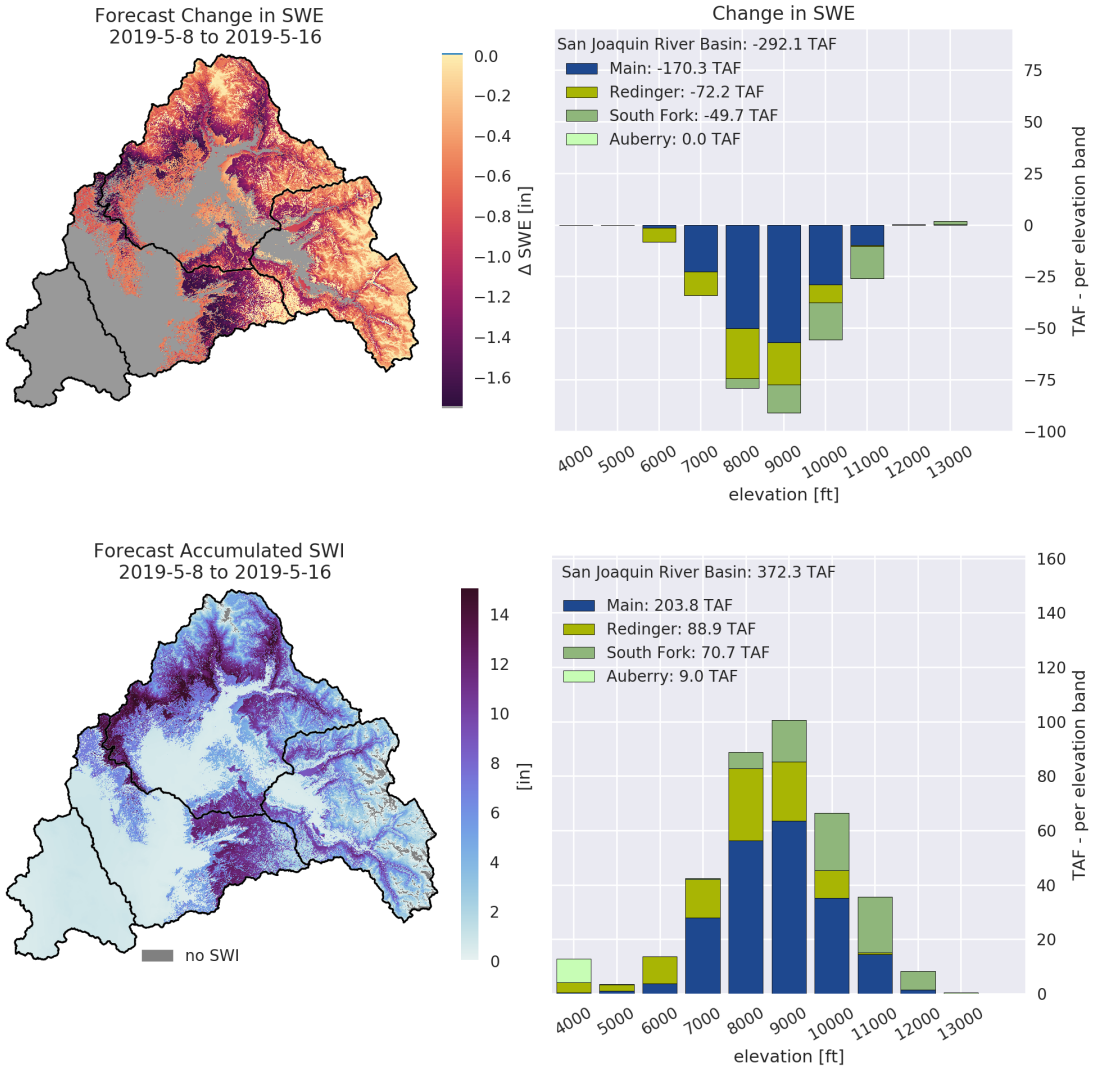
State of Technology Transfer in CA

- CA Senate Bill authorizing CDWR to take on ASO
  - 10 year bill, awaiting funding
- NASA transitioned ASO (flights) to private contractor
  - Contractor will use USDA-ARS modeling
- USDA-ARS will continually support and further develop the operational model
  - Advancing scientific research will transition to the operational model



Moving Forward 2020

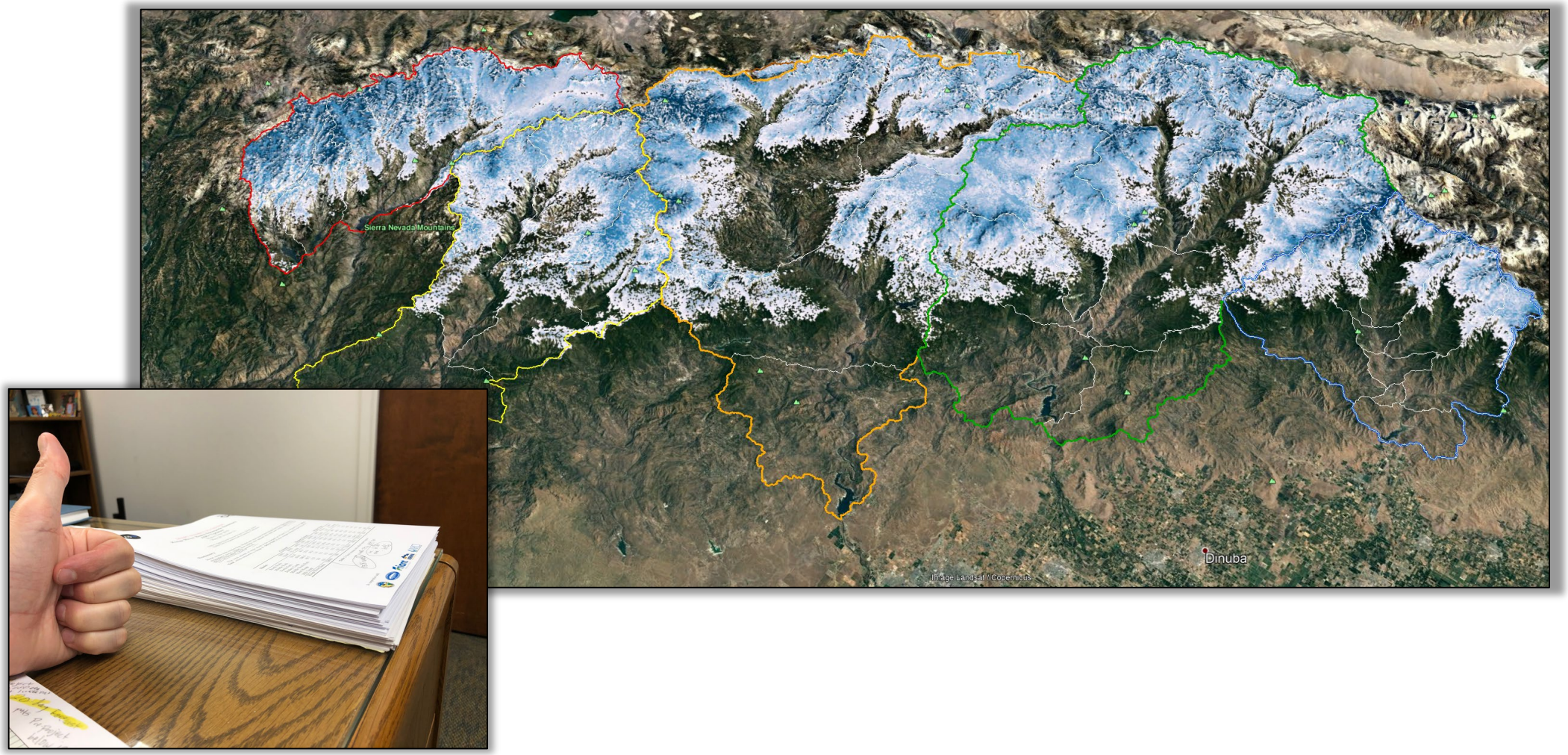
- Last 5 years have been heavily focused on real time application
  - Research model to applied model
- Now USDA-ARS can focus on the science to improve modeling
  - 10 day forecasts
  - Flight optimization
  - Long term model runs
  - Streamflow modeling
  - Software improvements
  - etc…



Summary

- Primary goal is more accurate estimates of reservoir inflow
- The model has been successfully used in CA and ID to help inform operational decisions
- USDA-ARS is committed to integration of modeling and remote sensing to develop an enhanced water supply forecasting tool
- While the first phase of the technology is being implemented in CA, there are still more scientific advancements to continually improve operational forecasting

Questions?



Courtesy of Matt Meadows, Kings River Water Association