Developing the next generation of water supply forecasting tools:
Model updates and automation

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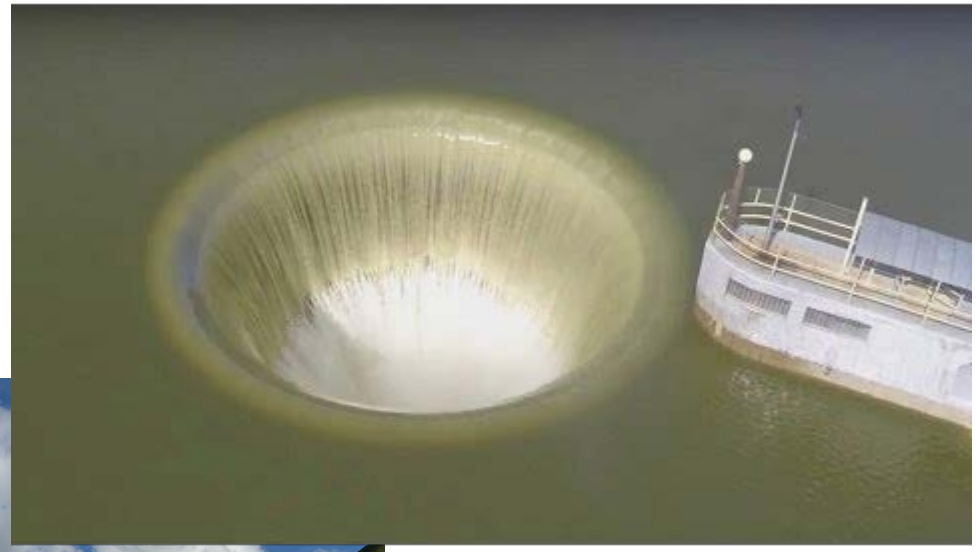
USDA Agricultural Research Service and NASA Jet Propulsion Lab Partnership

CA Cooperative Snow Survey 11/9/2017

Snowpocalypse in Idaho

Lucky Peak rooster tail

Arrowrock spillway
Last used 2006

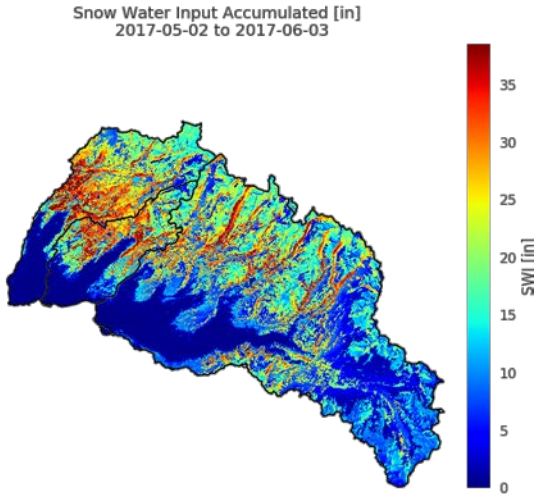


Owyhee Reservoir glory hole
Last used 2011

Water Supply Forecasting

- The spatial revolution
  - New approaches in science and operations
  - Why ARS leads the way
- Model and workflow overview
  - Automation and reproducibility
  - Automated Water Supply Snow Model
- Water supply forecasts
  - Short term and seasonal products
  - ESP like forecast results
- WY 2018 plans
  - Basins and forecasts

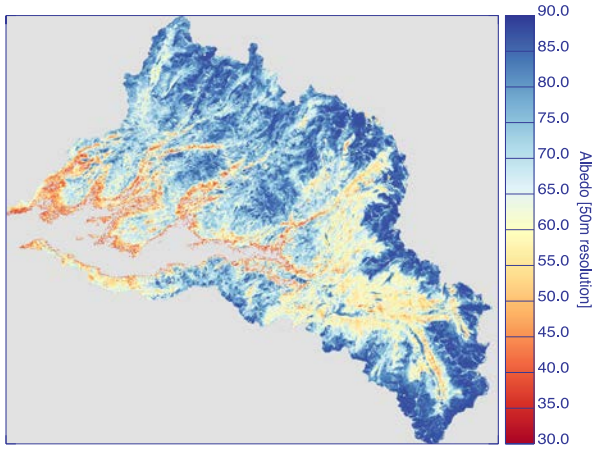
We have come a long way



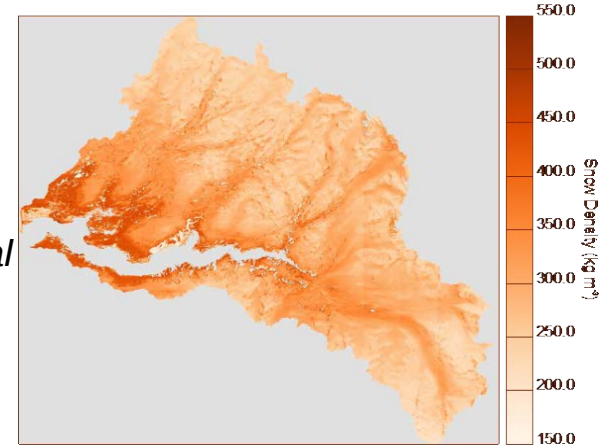
New approaches to science and operations

- How do we use spatial data?
- How should we modify our existing
  - Measurement strategy?
  - Models?
  - Forecasting approach?

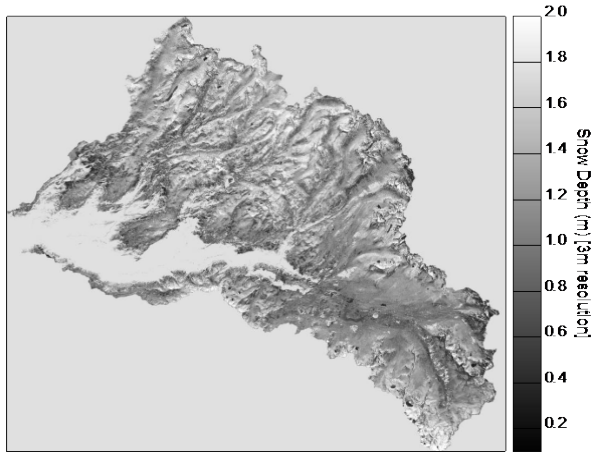
Snow Albedo (3 & 50 meter)



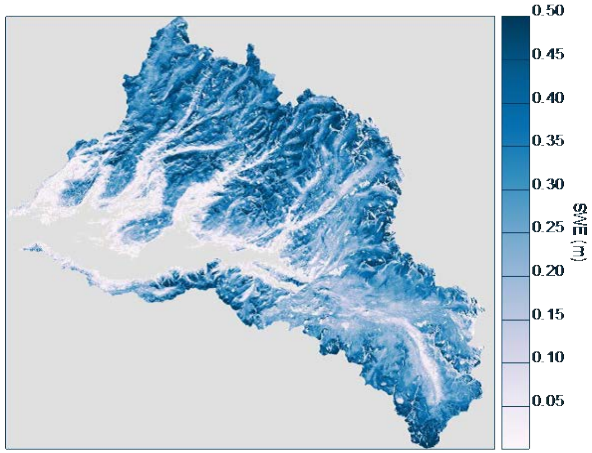
Snow Density from *iSnobal* (*50 meter*)



Snow Depth (3 & 50 meter)



Snow Water Equivalent (*50 meter*)



Water Supply Forecasting: Why ARS?

<u>No other federally funded snow research/modeling program</u>

- NOAA – flood forecasting of large systems
- NRCS – seasonal water supply forecasting
- USGS – stream flow, research hydrology, no snow research
- USBR – operational management, very limited research
- Universities – 1-3 year research efforts
- USDA-ARS NWRC
  - Long term commitment to research
  - Snow, water supply, and modeling since the 1960's

ARS has recognized the importance of projects in CA and are allocating resources (i.e. computing)

Water Supply Implications

Need:

Lower uncertainty (risk) in water supply forecast using spatial data

Solution:

Technology transfer of iSnobal with ASO updates for operational water supply forecast over the next 3-5 years

Value:

Optimized flood and power releases, increased skill for short term and seasonal volume inflows

The modeling workflow must support the need and show value

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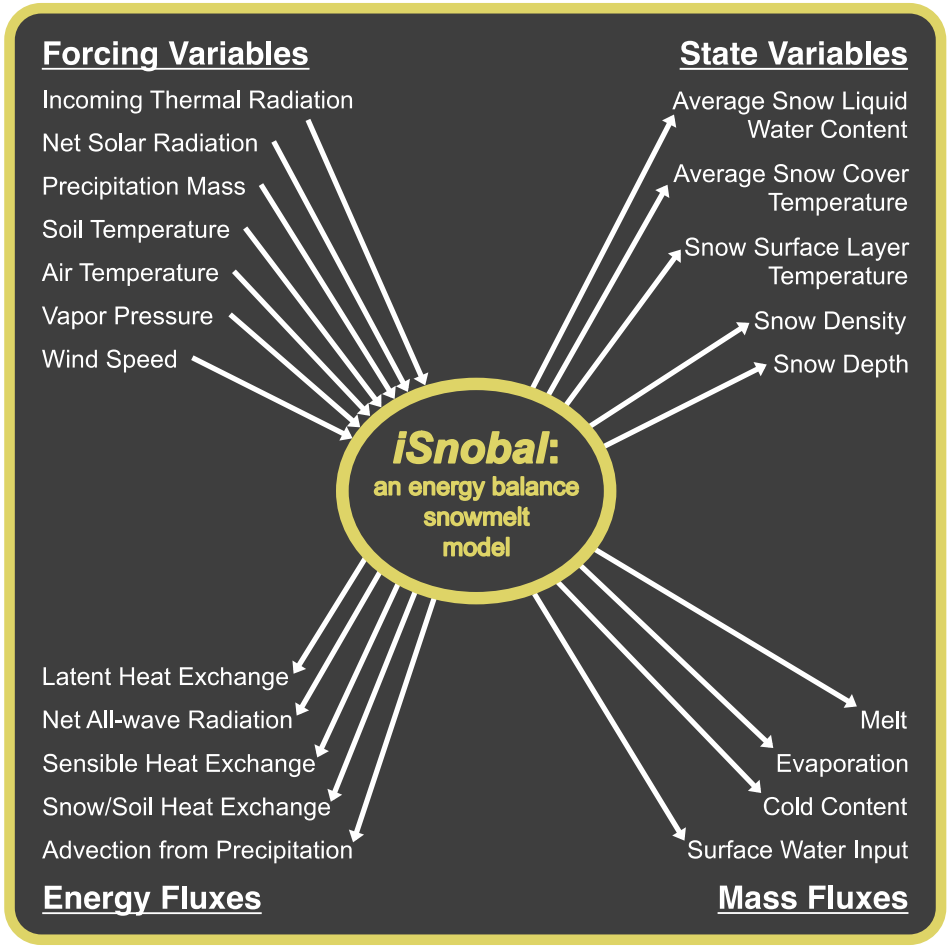
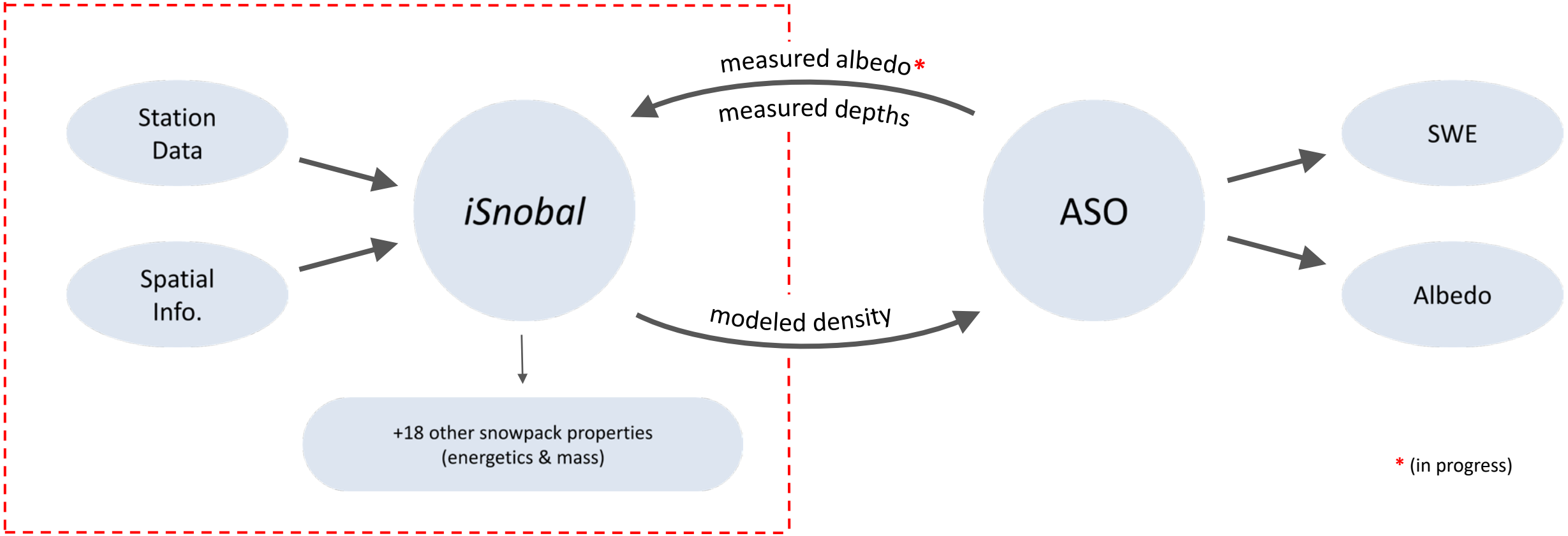
iSnobal Overview

- Physically based snow model (Marks et al., 1999)
- Varying spatial and temporal resolution
- Easily handles rain and rain on snow events
  - Important for flood forecasting
  - Risk management and mitigation
- Input data
  - Cooperative measurement network is the backbone of the modeling in CA
  - Air temp, RH, precipitation, wind, solar radiation



Modeling Overview

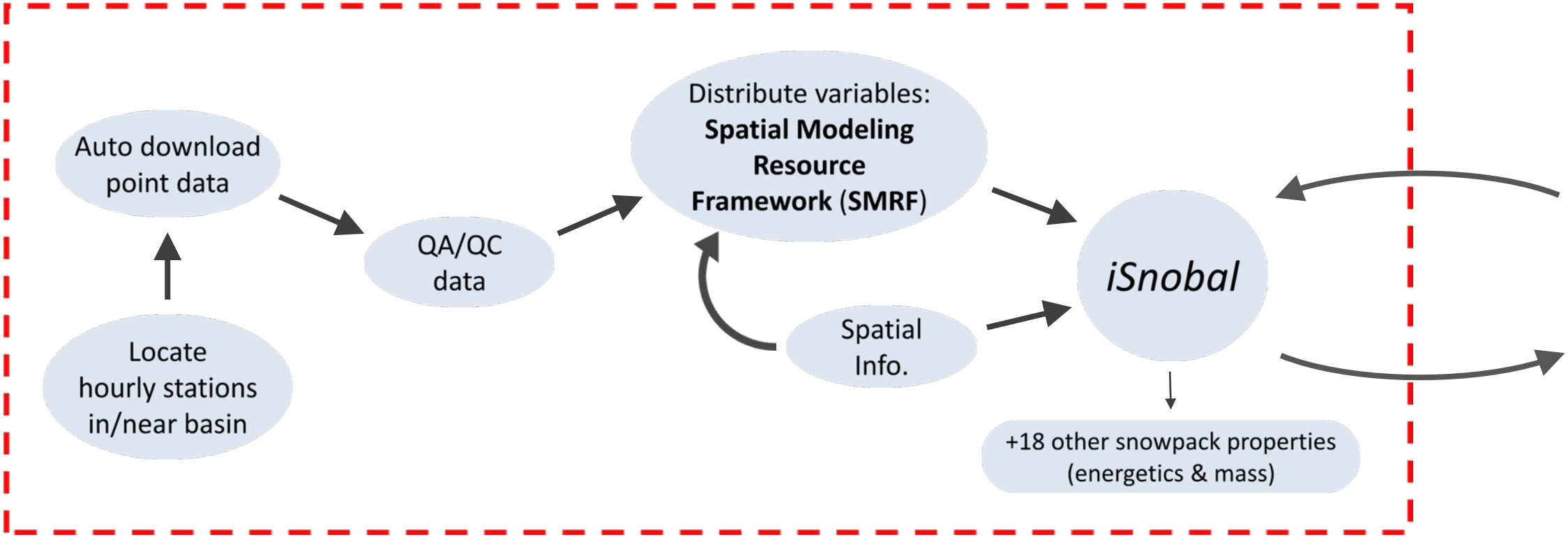


- Conversely, ASO lidar provides spatial snow *depth* information to force *iSnobal* model (direct insertion).

Modeling Overview

- 95% of effort is creating forcing data fields.
- Model results only as good as measurement quality and data interpolation schemes.
  - Directly affect the products delivered to water managers and ASO

The *iSnobal* modeling procedure



Goals for workflow

- Reproducibility, reproducibility, reproducibility
  - Unlimited ways to run the models, how to ensure repeatability
  - Software is being designed with this as a priority
  - Allows us to give data, configuration, and reproduce results exactly
  - Operational and research implications, coordination

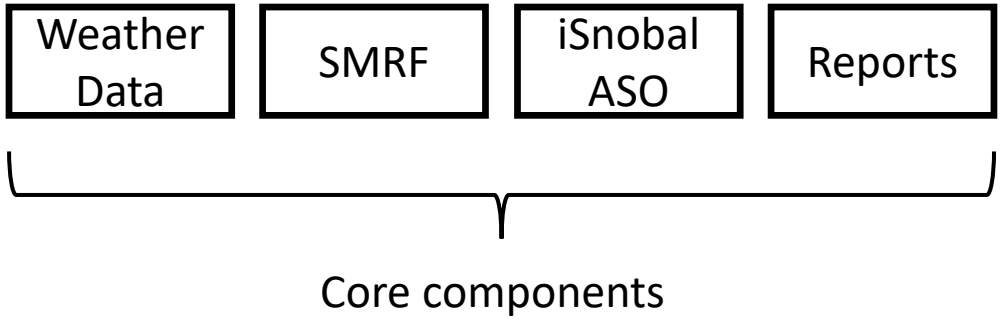
- Extensive testing
  - Ensure nothing is breaking
  - Producing results that we expect
  - Means running the workflow multiple times

- Technology transfer
  - Must be an easy to follow workflow or automated

Any sufficiently advanced technology is indistinguishable from magic. –Arthur C. Clarke

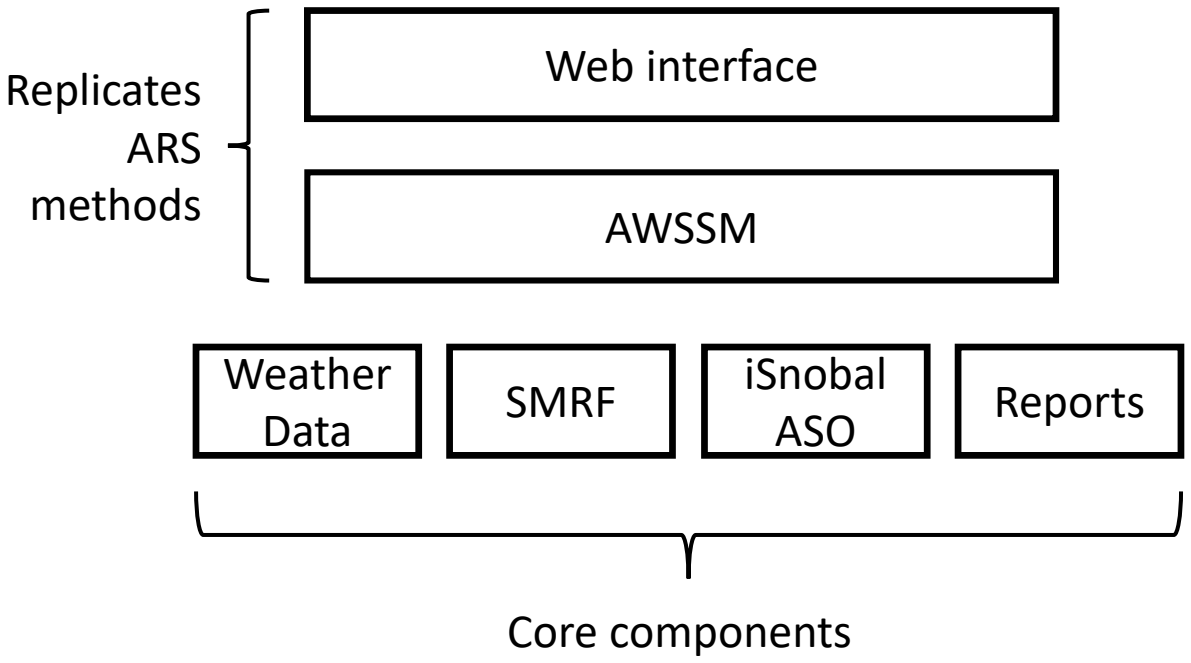
Core components

- Weather database
  - MySQL, automatic downloads
  - Simple cleaning, audit logs
- SMRF
  - Reads station or gridded forecast data
  - Distributes for iSnobal
- Models
  - Takes distributed forcing
  - Runs models, iSnobal (+ PRMS)
- Reports
  - Process model results to pass along to stakeholders

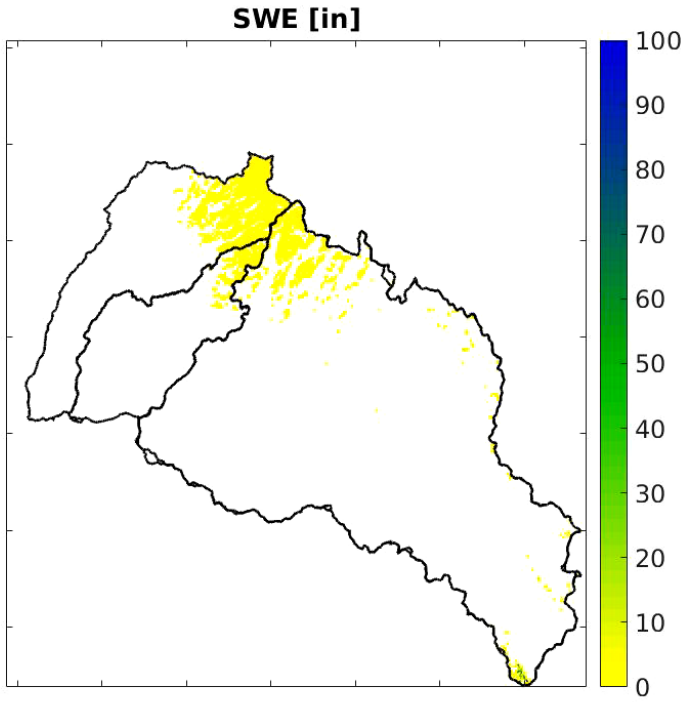


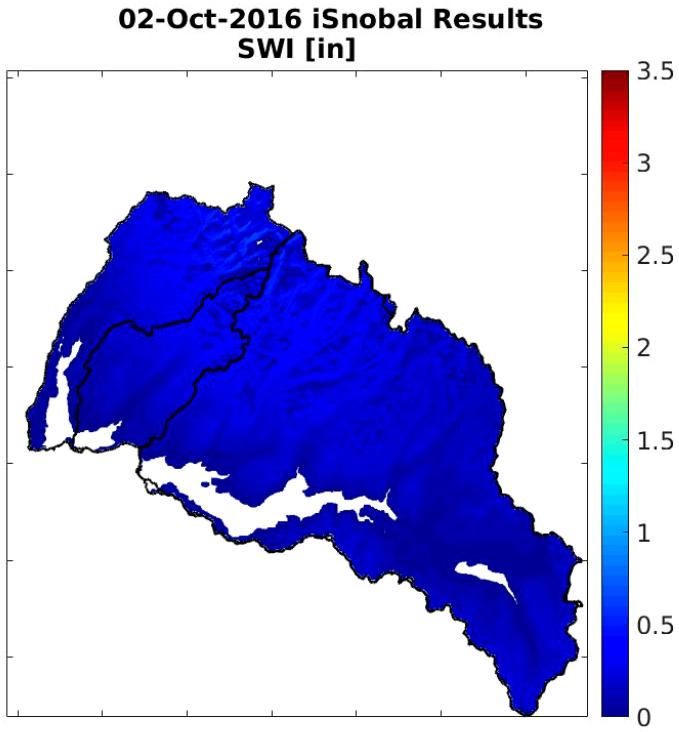
Tying it all together - AWSSM

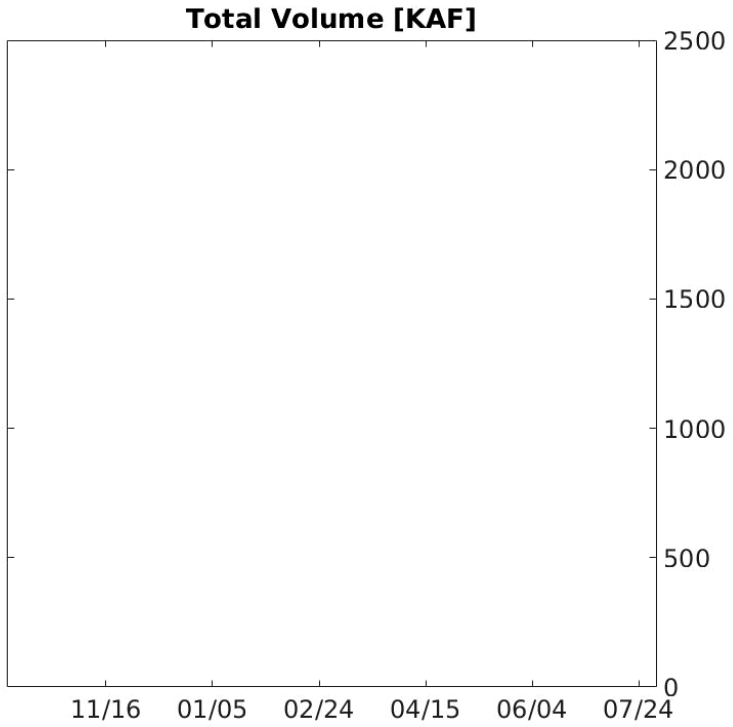
- AWSSM
  - Automated Water Supply Snow Model
  - Modeling magic
- Tool that manages the core components for data processing, SMRF, and modeling so you don't have to
- Automated procedures for
  - WRF forecast ingestion (BSU)
  - Running iSnobal
  - Updating with ASO
- Replicates what ARS modelers do
- Designed around scalability and reproducibility
  - Can regenerate model results easily



WY 2017







Major events on new years and mid June
Both captured in modeled melt

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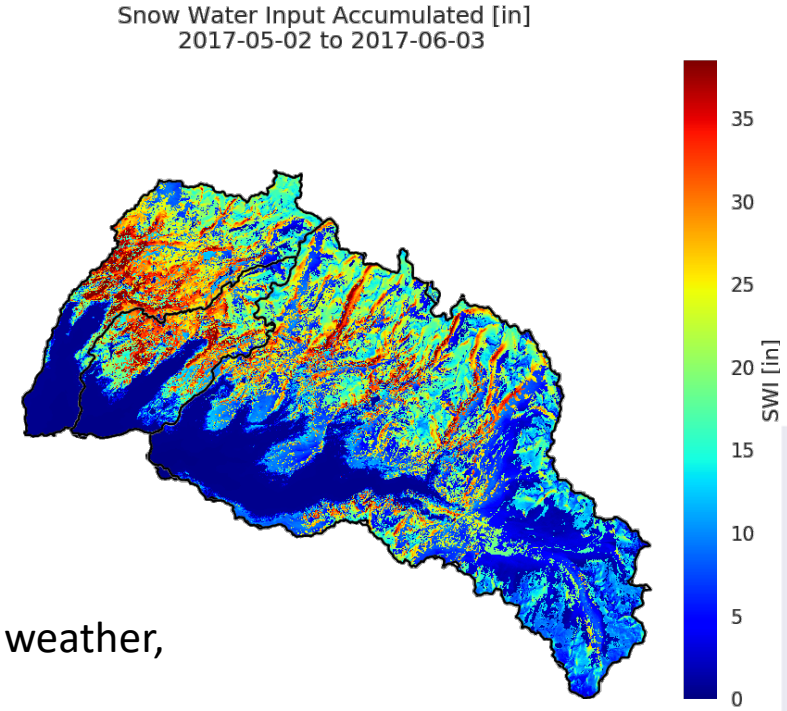
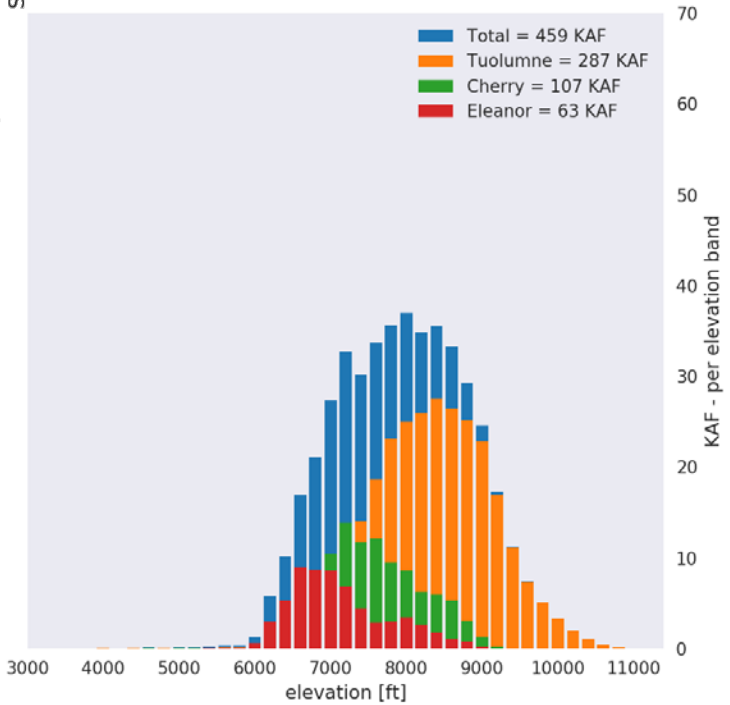
Short term forecast

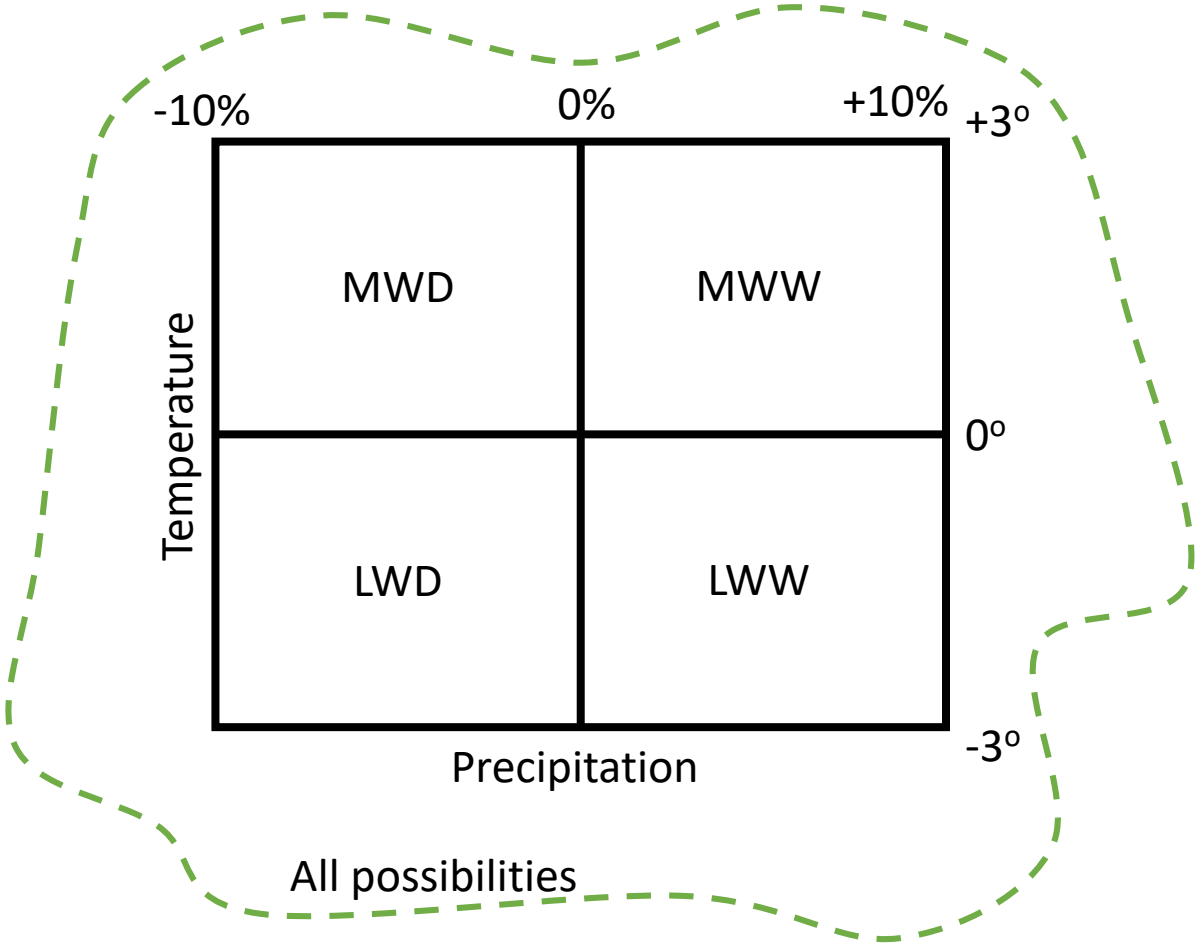
- Products
  - Snow water input and SWE
  - Maps and by elevation
- WRF
  - 3 km 10 day forecast, physically based
  - Based on the GCM forecast
- Statistical
  - Generate stochastic weather from past weather, 10-30 day
  - Mimics current RFC Ensemble Streamflow Prediction (ESP) methods
  - Attempt to capture all possibile senarios
  - Run AWSSM in esemble mode a couple thousands of times





ESP like forecast

- **Goal: Capture potential scenarios**
- Generate random but coherent weather scenario
  - Resample past observed data to build random scenario
  - Past 5 years of met data in Tuolumne
- Further perturb temperature and precipitation
  - More warming wet (MWW)
  - More warming dry (MWD)
  - Less warming wet (LWW)
  - Less warming dry (LWD)
- All performed in AWSSM



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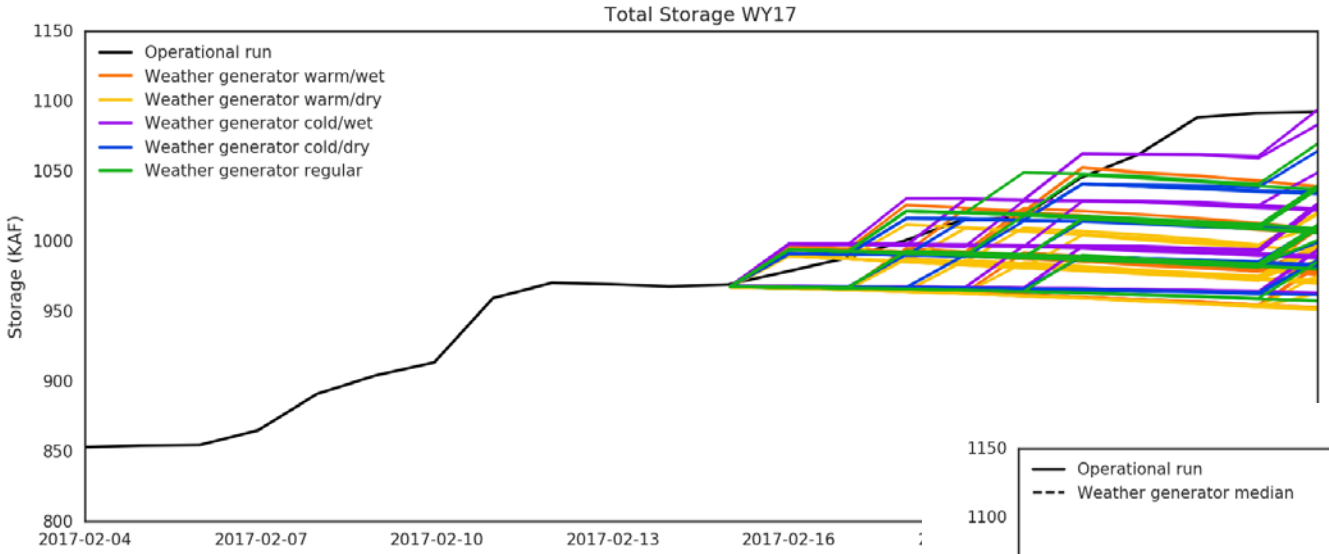
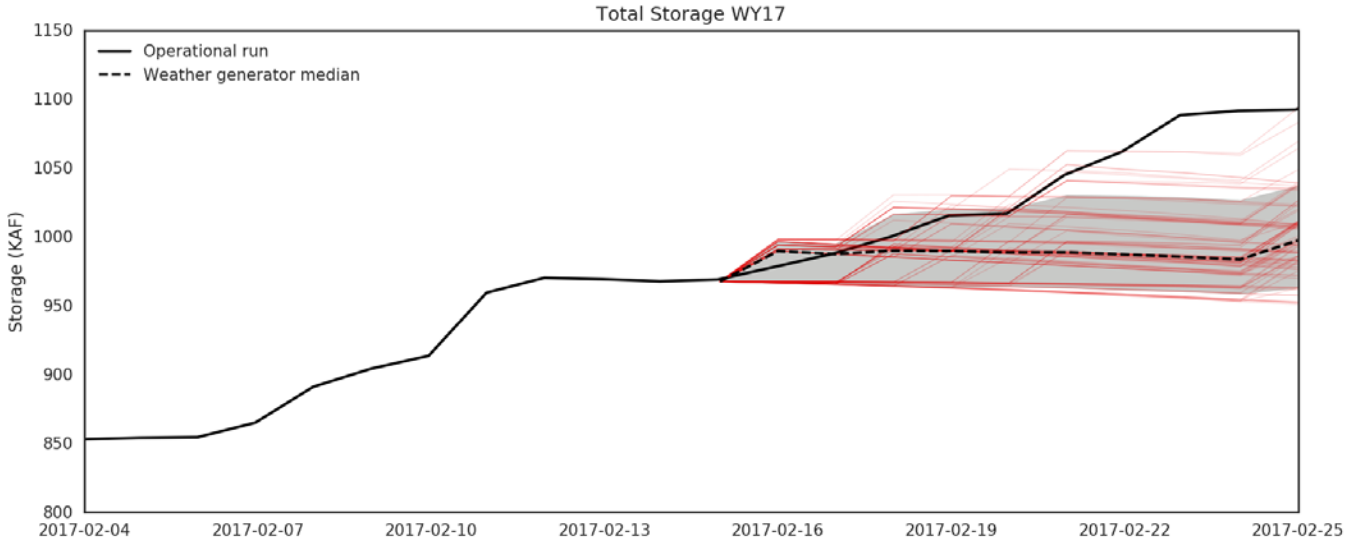
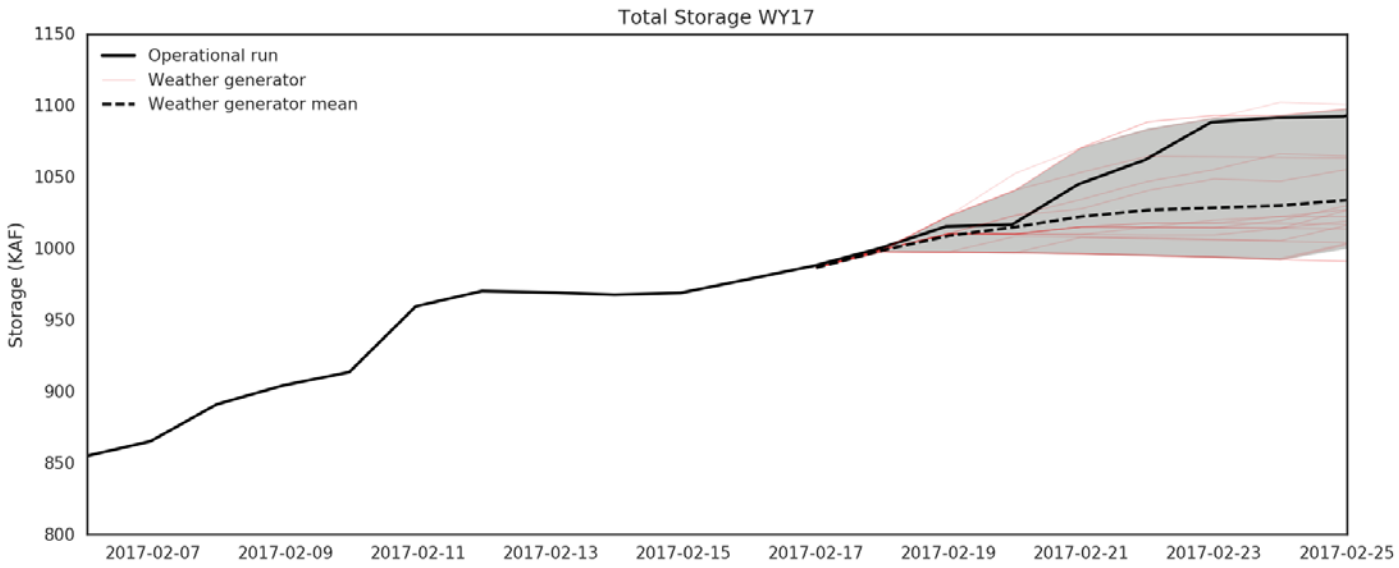




ESP like forecast

- How the basin will react to a potential future
  - Using the knowledge of the snowpack
- Weather generators have been used to generate long term climate scenarios
  - Could produce seasonal ESP forecasts
  - Run 1,000+ times instead of the past 40 years
  - Potential for multi year runs



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Operational plans

- Basins
  - Tuolumne
  - San Joaquin
    - Lakes
  - Boise River Basin
  - Kings (load permitting)
- 10 day WRF forecast
- Update model with ASO
- Testing scenario's
- Weekly reports

	Initial Snowpack	Snow Accum	Rain Accum	Evap	Water Inputs (snow melt + rain)	Natural River	Watershed Yield
Week 1							
Week 2							
Week 3							
Week 4							
Week 5							
Week 6							
Week 7							
Week 8							

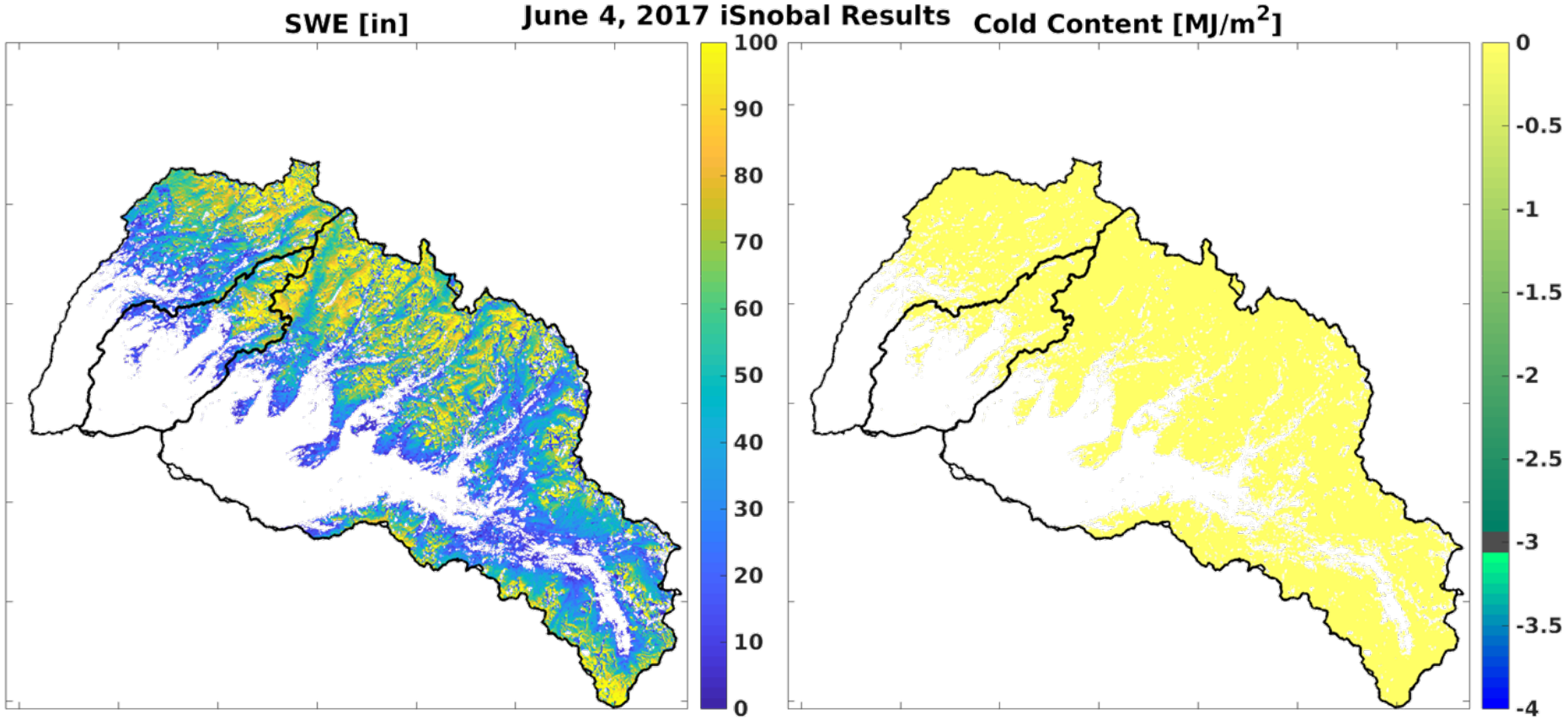
- Weekly summary of input and model state
- What else would be useful?
- Output on CDEC?

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.



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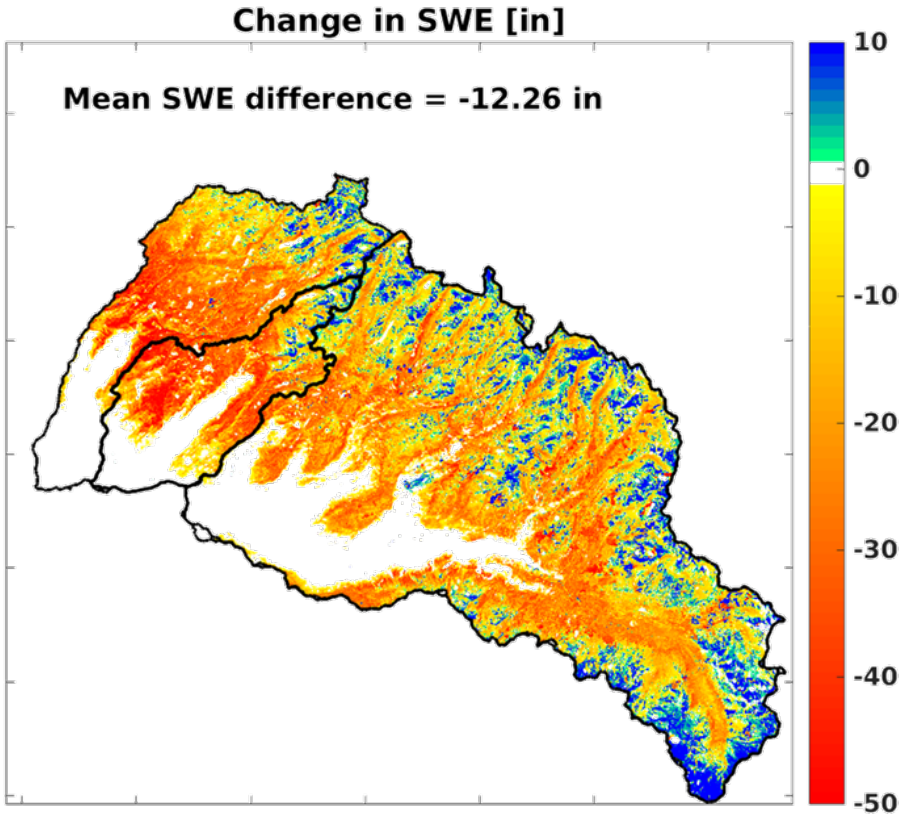
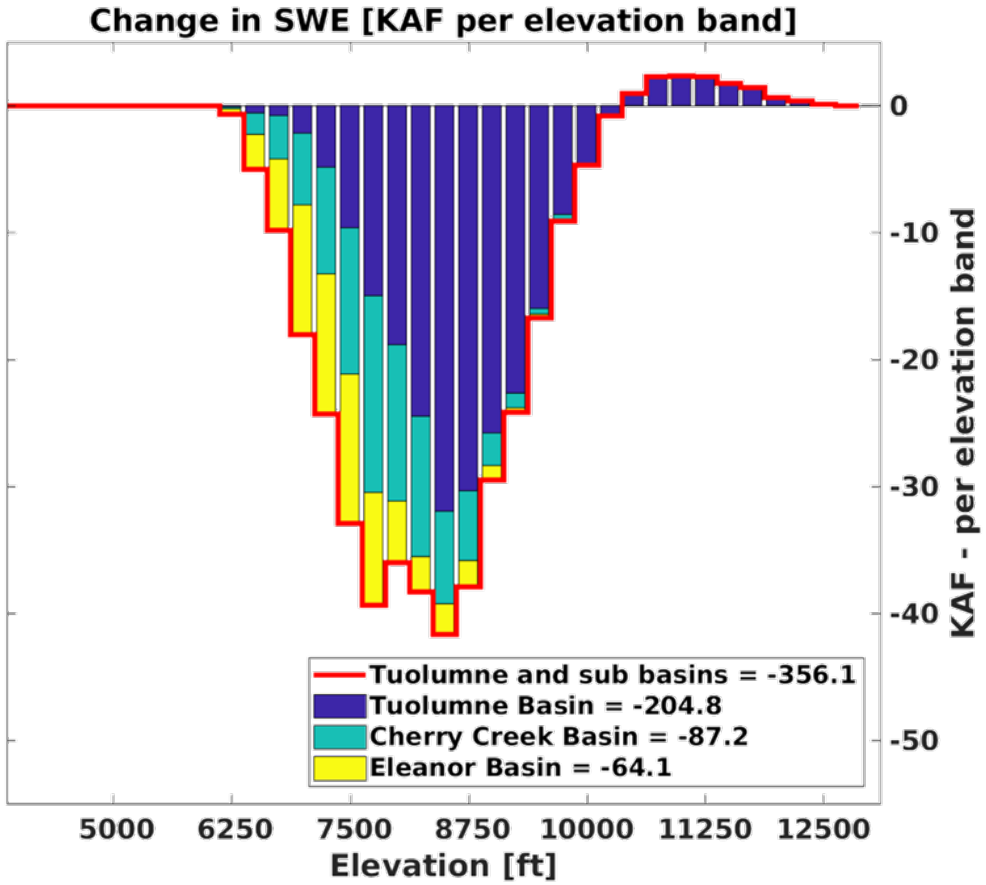
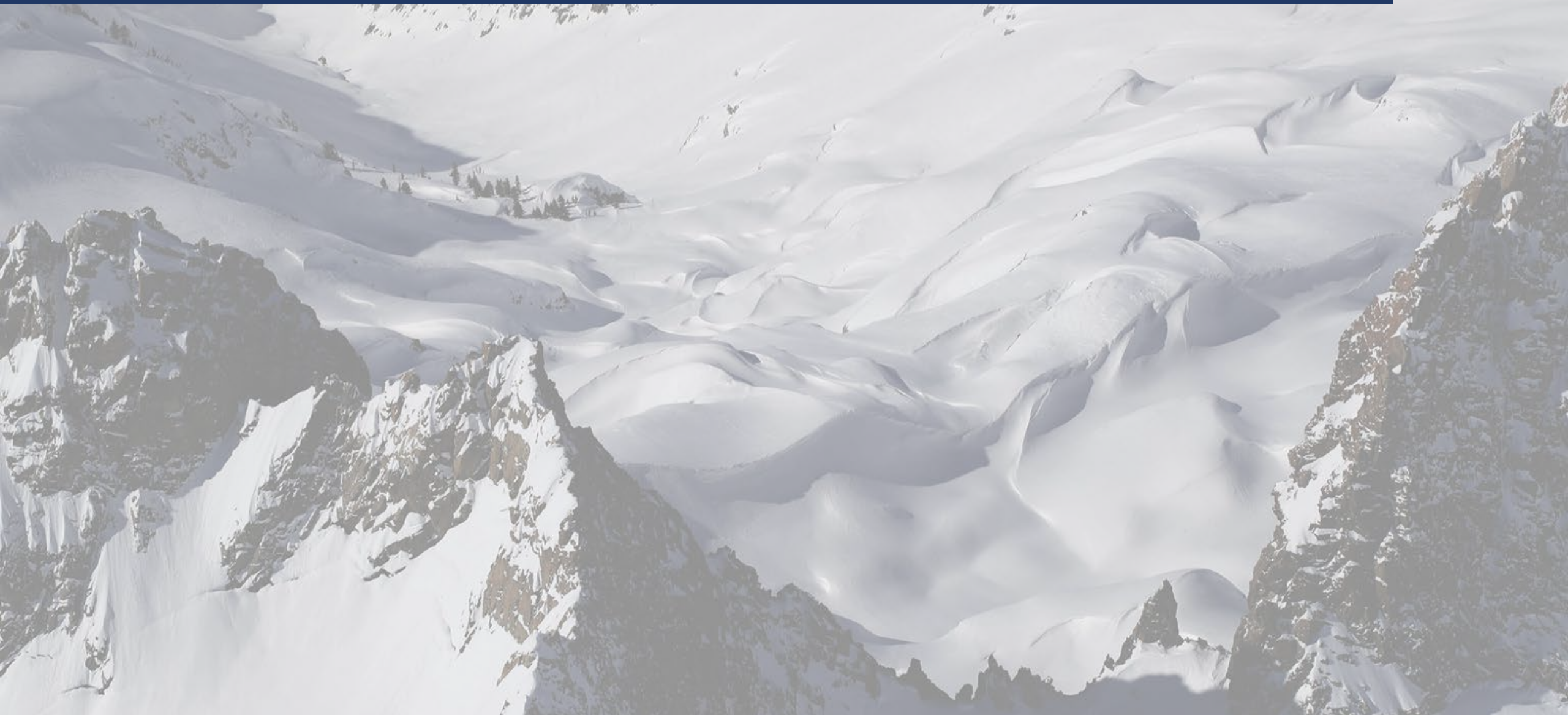


(May 3 – Jun 4)

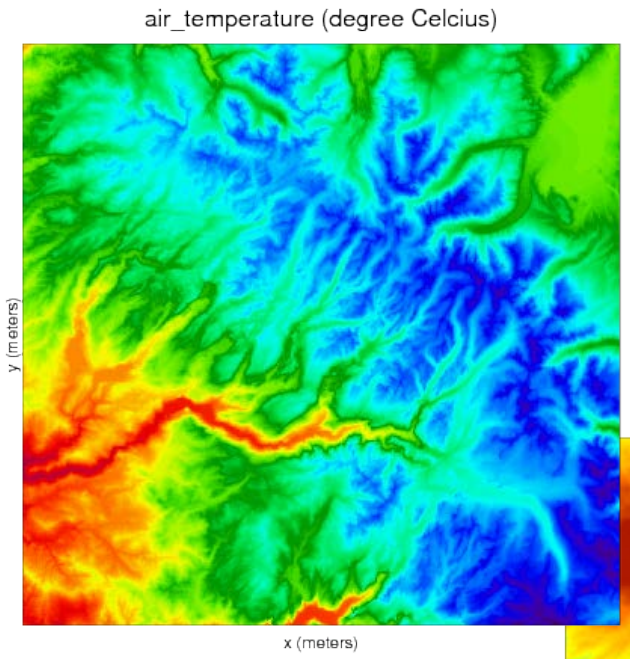


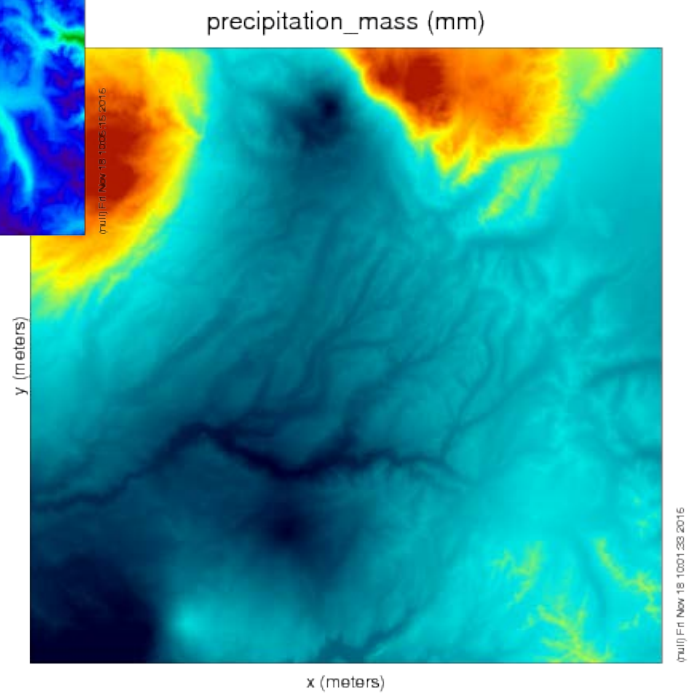
Questions?



Spatial Modeling for Resources Framework

- Peer reviewed software, Havens et al, 2017
  - Extensive and up to date doc's at smrf.readthedocs.io
- Distributes everything required to run iSnobal
  - Aimed at both operational and research users
  - Standardizes data development
- Two years of testing
  - Operational, real time modeling in CA and Idaho
  - Historic modeling over Tuolumne

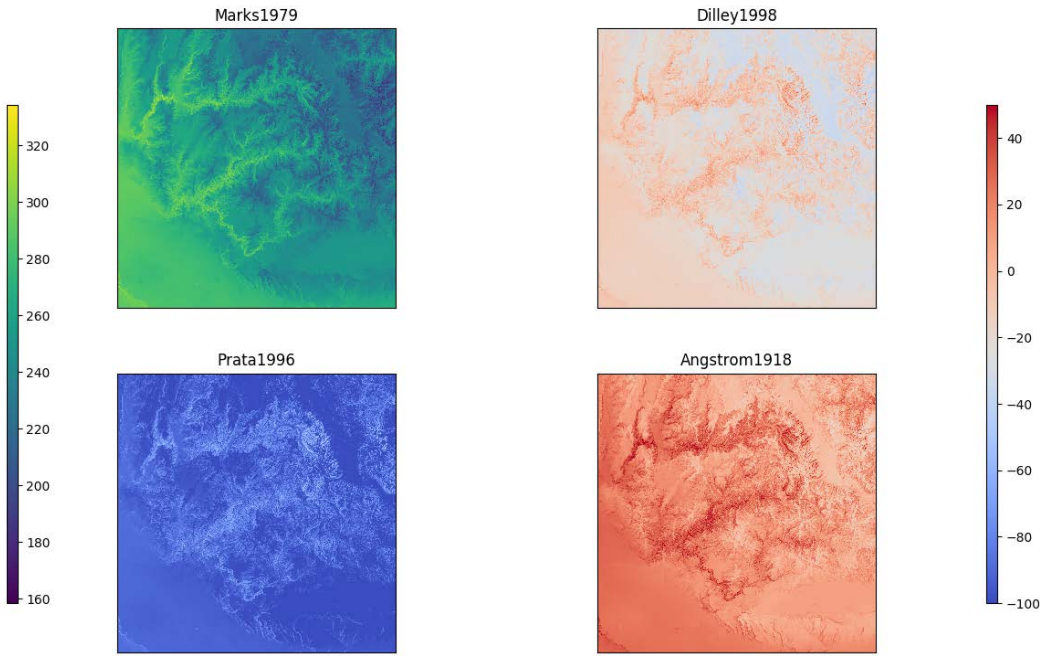




Spatial Modeling for Resources Framework

Key features:

- Open source (github.com/usda-ars-nwrc/smrf)
  - Active development
  - Continuing to add more features
- Data reproducibility
  - Can easily regenerate the output data given a few small files
- Point data or gridded forecast
- Flexible for testing different methods
  - Extensive doc's explaining features
  - Examples showing different uses



Evaluating different thermal (longwave) radiation methods

Forecasting products

Short term

- Short term forecast from numerical weather prediction model, 3-10 day typically
  - BSU Leaf Lab running 10 day forecast over **all** Sierras
- Use WRF to run iSnobal to produce a melt forecast
- Basin response to water input

Seasonal

- Relating historical model results to measured streamflow
- Requires multiple years of model runs
  - One data point per year
- Provides possible inflow volume
- Future forecast dependent on seeing a similar year in the past