Hydrologic Modeling Scientific Studies at Lake Mendocino for Forecast Informed Reservoir Operation (FIRO)

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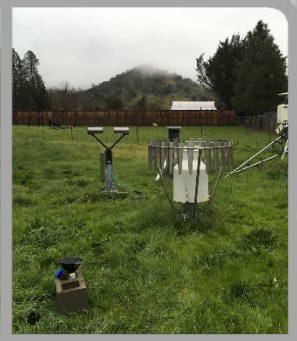


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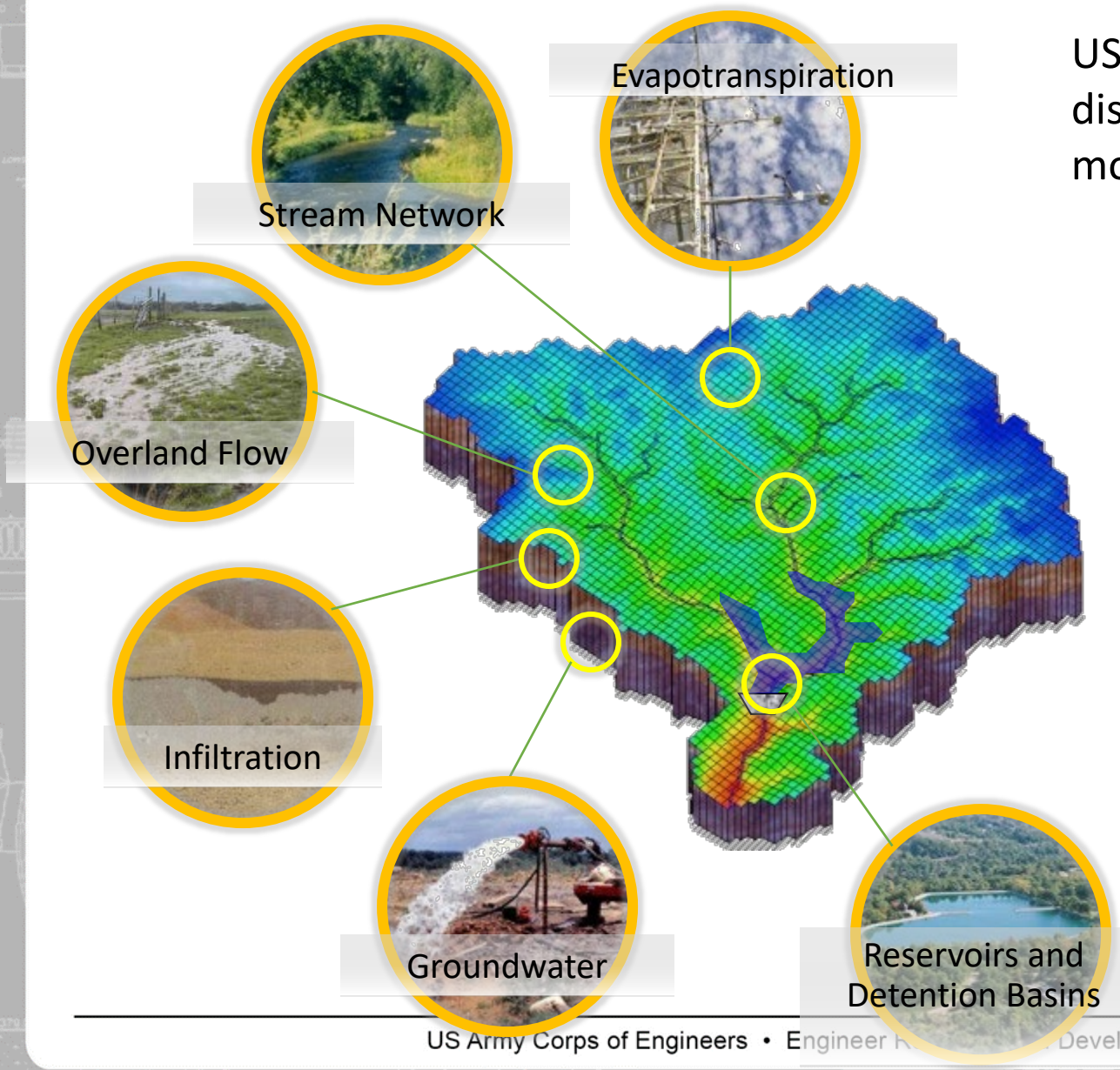
Final Viability Question

- Can research into advanced forecasting tools produce improvements to rainfall, runoff, and reservoir forecast over existing methods currently in use?

What Was Done

- Developed integrated physics based models in the upper Russian River watershed.
- Coupled the hydrologic models to West-WRF, and other rainfall products.
- Simulated the runoff and reservoir response using observed and forecast precipitation.
- Field effort to collect additional model forcing and output calibration/verification data.
- Assessed model outputs: flows, lake levels, soil moistures, in relation to observations and other model results.
- Incorporating the hydrologic model into the NCAR data assimilation framework – Ongoing by NCAR

GSSHA Watershed Modeling in the Russian



USACE physics based distributed watershed model

Model Formulation:

- Multi layer infiltration, ET, and soil moisture accounting
- 2D overland flow
- 1D stream network
- Lake Mendocino Reservoir
- 2D groundwater with exchange between overland, streams, and reservoir.

Effects of Model Resolution

Four models of varying resolution to study effects of model resolution on simulations.

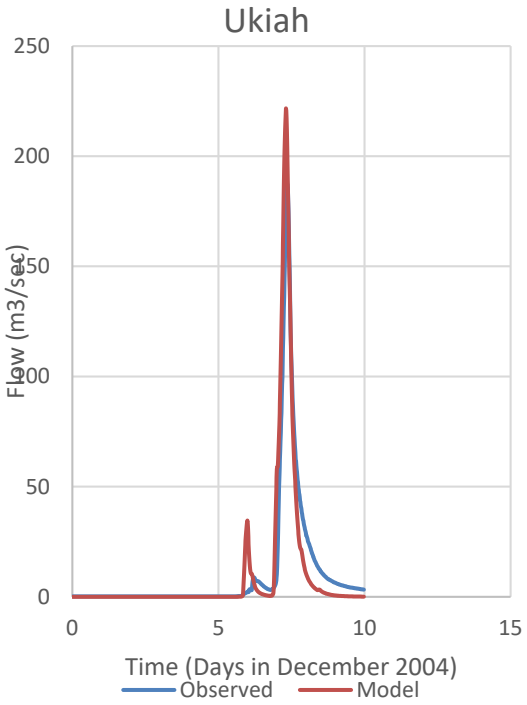
30m grid resolution for watershed above Coyote Dam

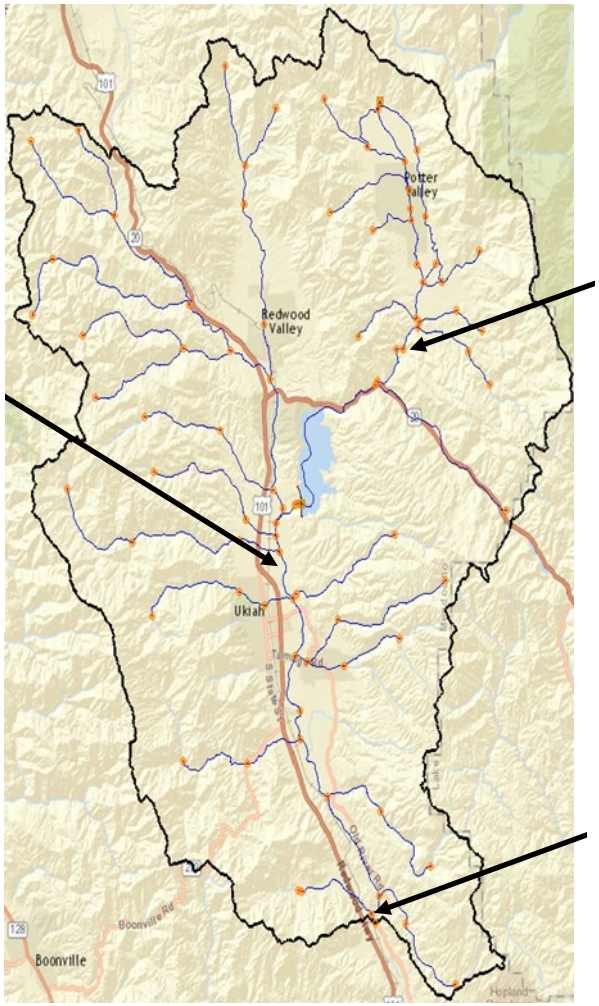
270m, 100m, 50m grid resolution in watershed down to Hopland, CA

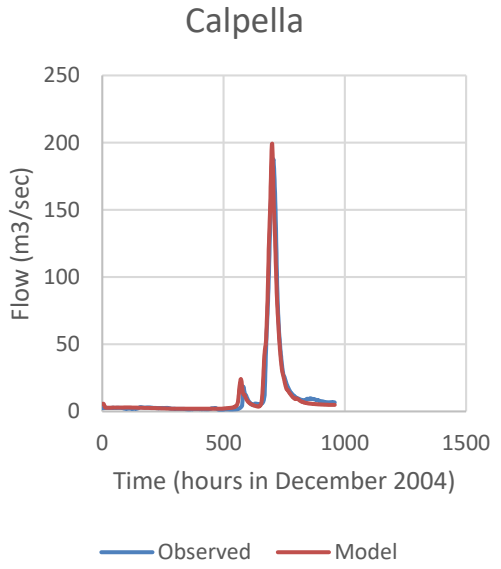
Calibration Strategy

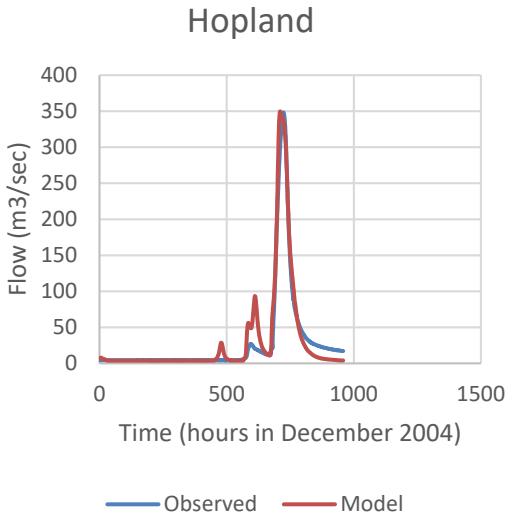
- Single event surface water parameter adjustments, observed data 2004.
- Seasonal surface/subsurface water parameter adjustment
  - ▶ “historic” rainfall data, 2004/2005.
  - ▶ expanded CW3E observed network (RHONET), 2018.
  - ▶ Seasonal calibration to West-WRF 1 day lead time forecast, 2018.
  - ▶ BeoPEST on the DoD Supercomputing Resource Centers (DSRCs) for the 270m and 100m models.

Surface Water Calibration





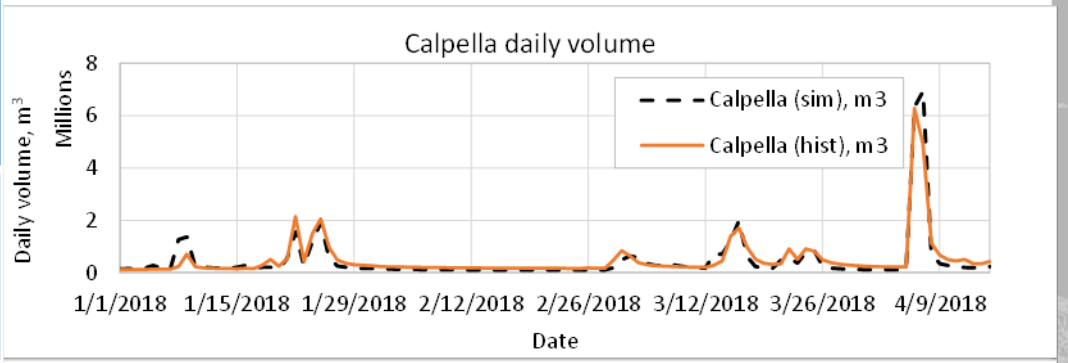


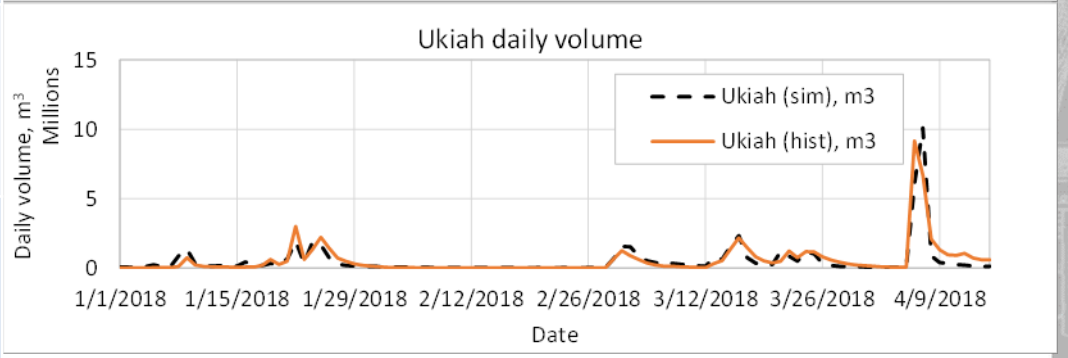


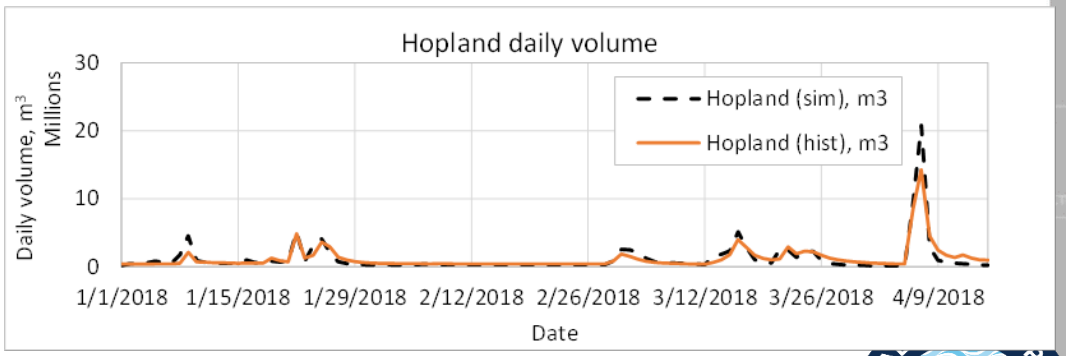
Seasonal (2004/2018) Calibration Results 270m

Gage	NSE 2004 Gage	NSE 2018 Gage	NSE 2018 WWRF
Hopland	0.664 0.812 0.784	0.664 0.558 0.879	0.748 0.865 0.966
Ukiah	0.609 0.908 0.675	0.790 0.911 0.918	0.779 0.934 0.998
Capella	0.729 0.845 0.908	0.772 0.979 0.962	0.879 0.971 0.962

- Good match to daily flows
- Excellent match to event peaks and storm volumes
- Calibration improved with improved gage network
- Calibration improved using West-WRF



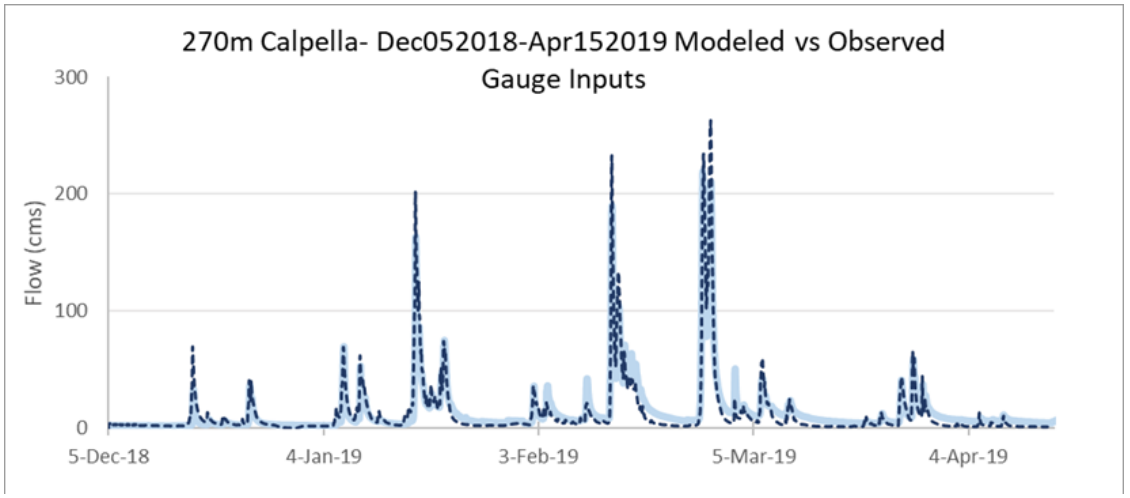


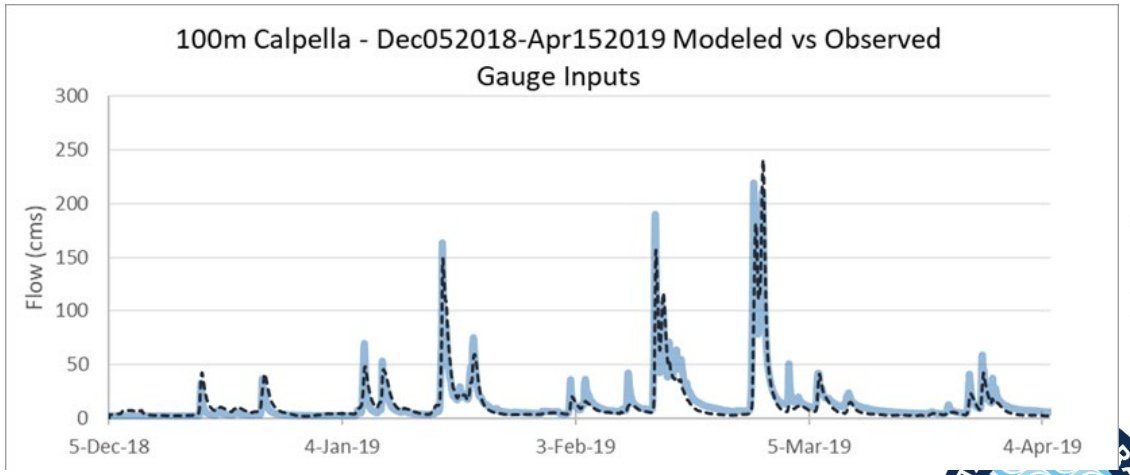


Verification Results Daily Flows (2019) – Gage Network

Gage	NSE 270m Gage	NSE 100m Gage
Hopland	0.875	0.892
Ukiah	0.882	0.854
Capella	0864	0.903

- Excellent match to daily flows
- Better than the calibration
- Higher resolution model slightly better statistics

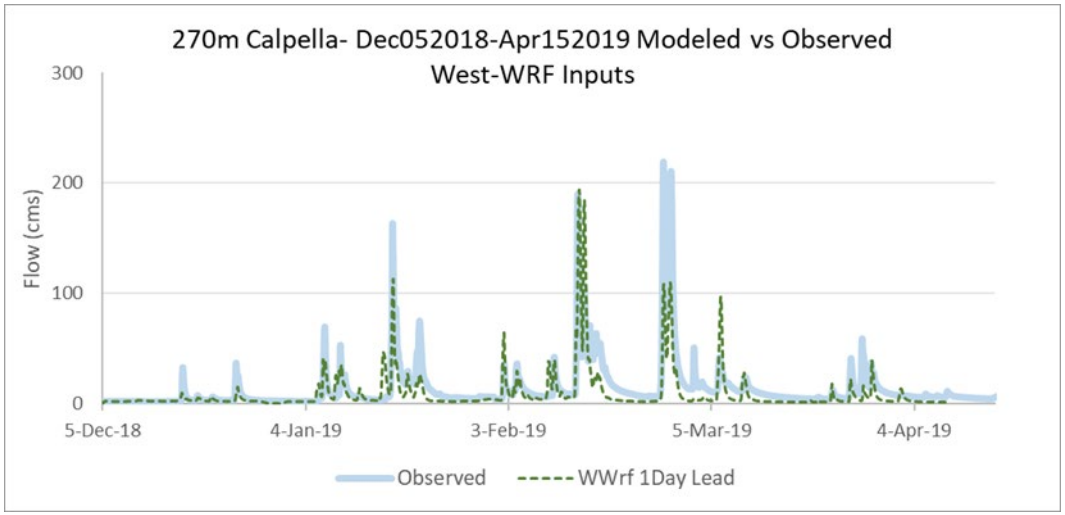


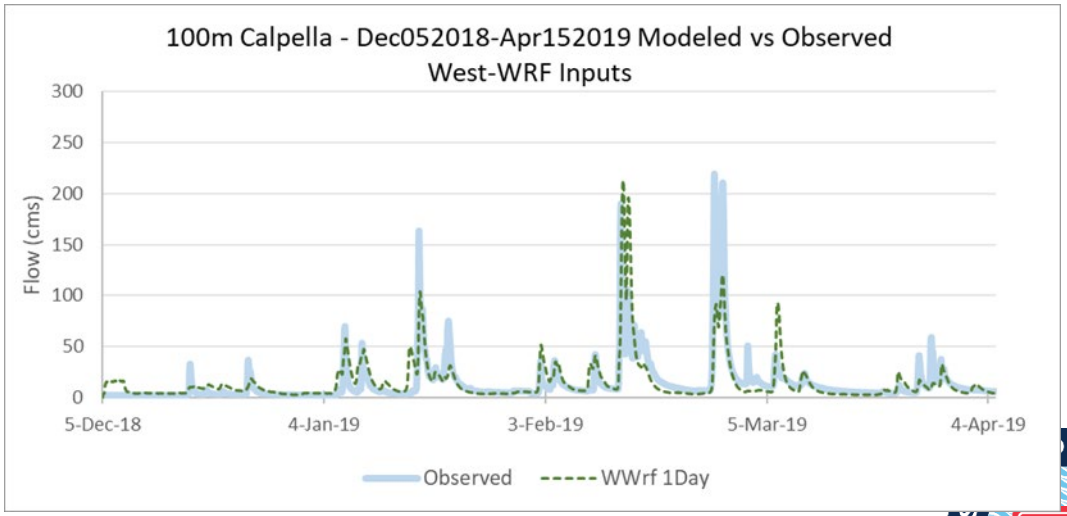


Verification Results Daily Flows (2019) – West-WRF

Gage	NSE 270m WWRF	NSE 100m WWRF
Hopland	0.601	0.562
Ukiah	0.592	0.550
Capella	0.628	0.610

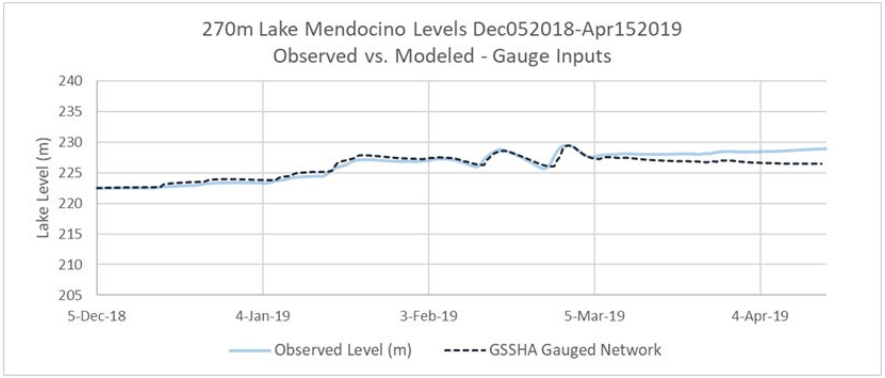
- Good match to daily flows
- Not as good as the calibration
- Not as good as the observed precipitation
- No statistical improvement with higher resolution model

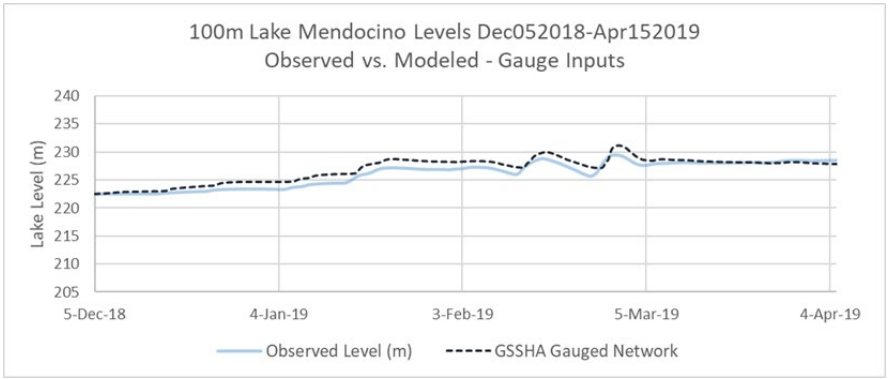




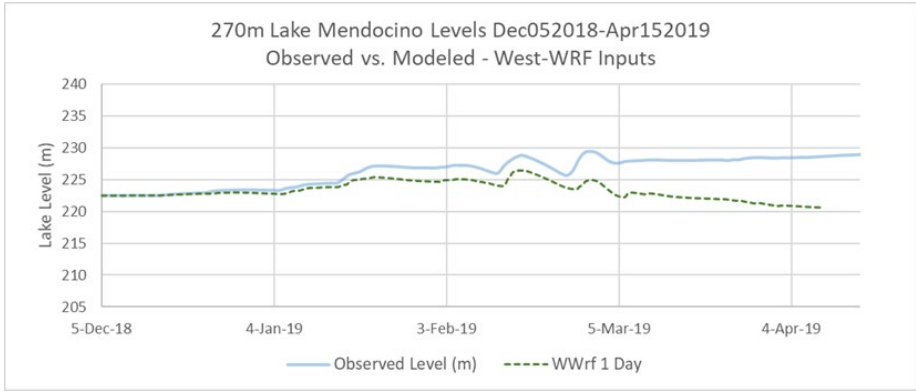
Simulation of Reservoir Levels 2019 Verification Period

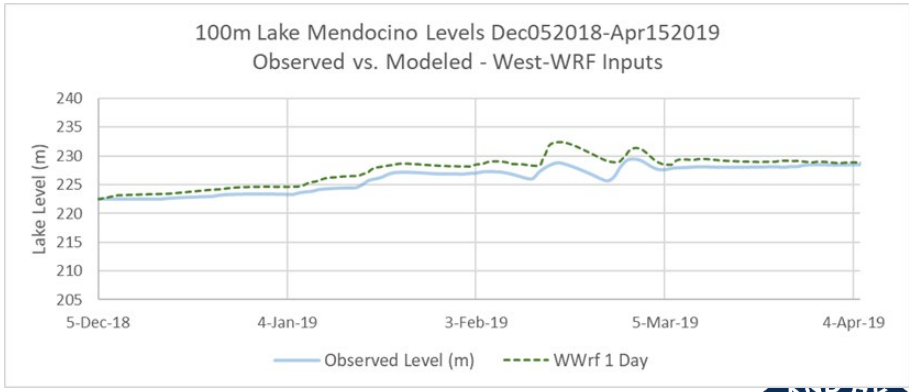
Gage Network





West-WRF

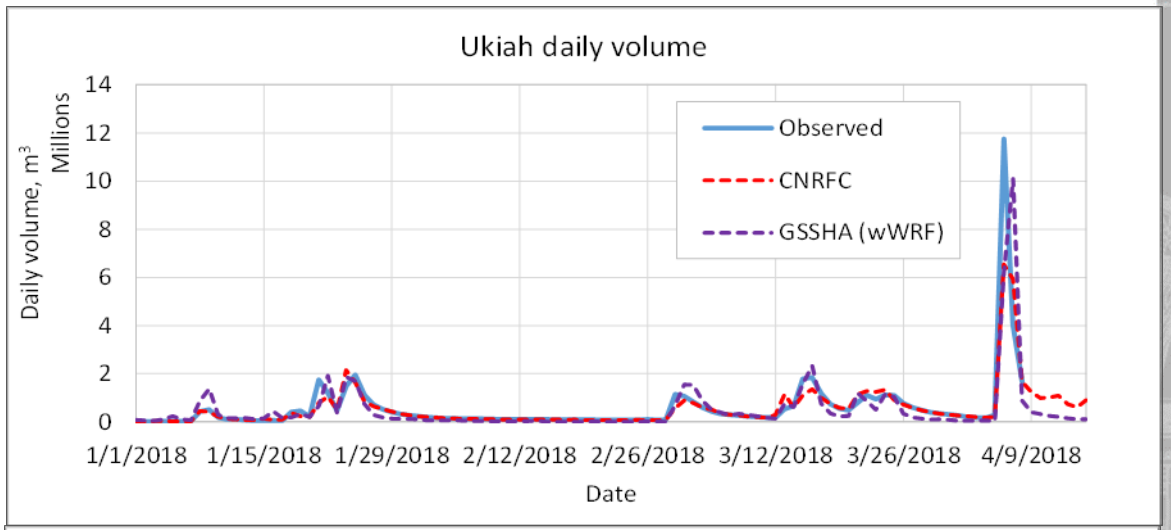


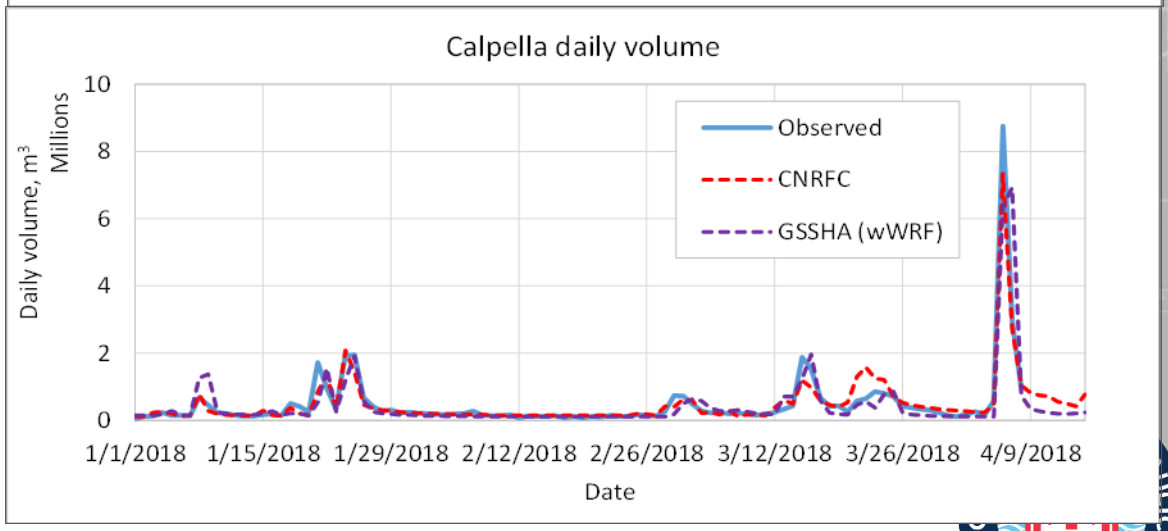


Comparison to CNRFC 1 Day Forecast Calibration Period (2018) Daily Flows

Gage	NSE CNRFC	NSE GSSHA/ WWRF
Ukiah	0.787	0.779
Capella	0.927	0.879

- Good match to daily flows
- Statistics about the same

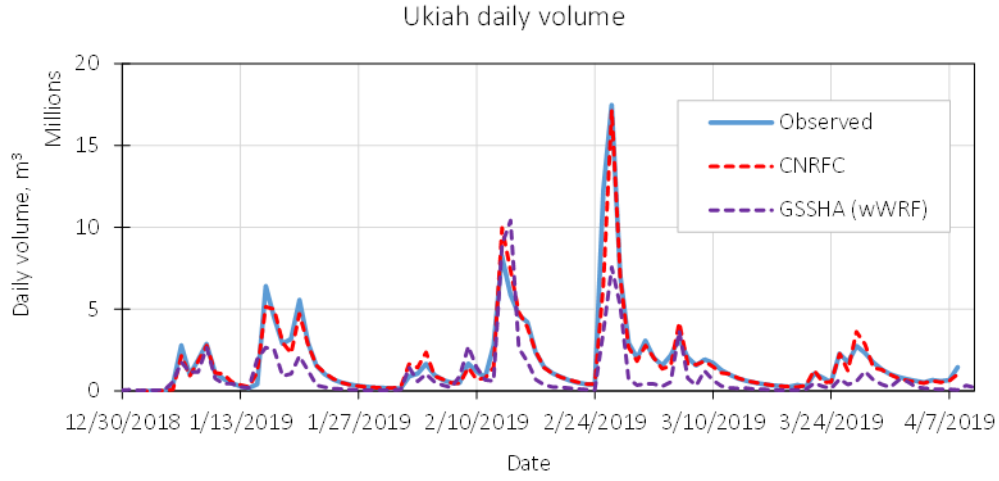


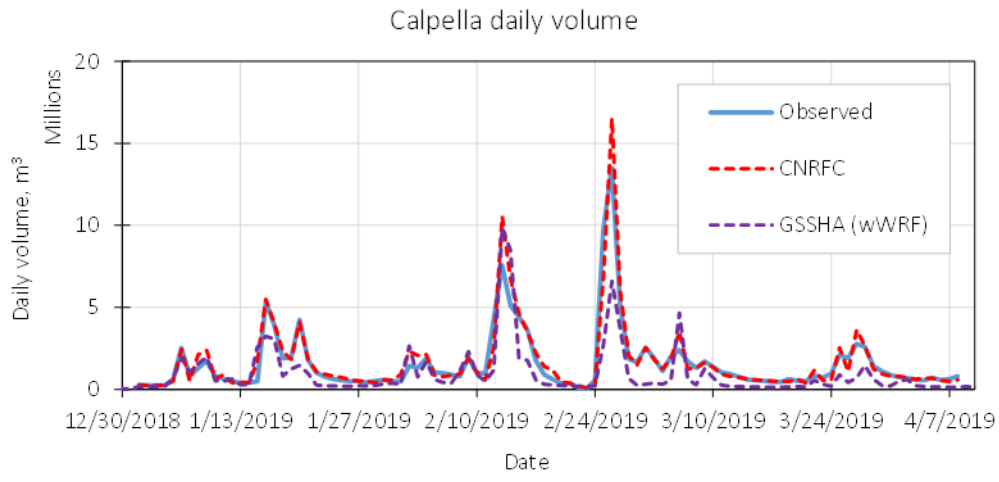


Comparison to CNRFC 1 Day Forecast Verification Period (2019) Daily Flows

Gage	CNRFC	GSSHA /West-WRF	GSSHA Gage
Ukiah	0.917	0.592	0.882
Capella	0.890	0.628	0.864

- CNRFC outperforms for this period
- GSSHA/West-WRF significantly under predicts the largest event using the West-WRF meteorological forecast
- GSSHA performed comparably when driven with the rain gage data

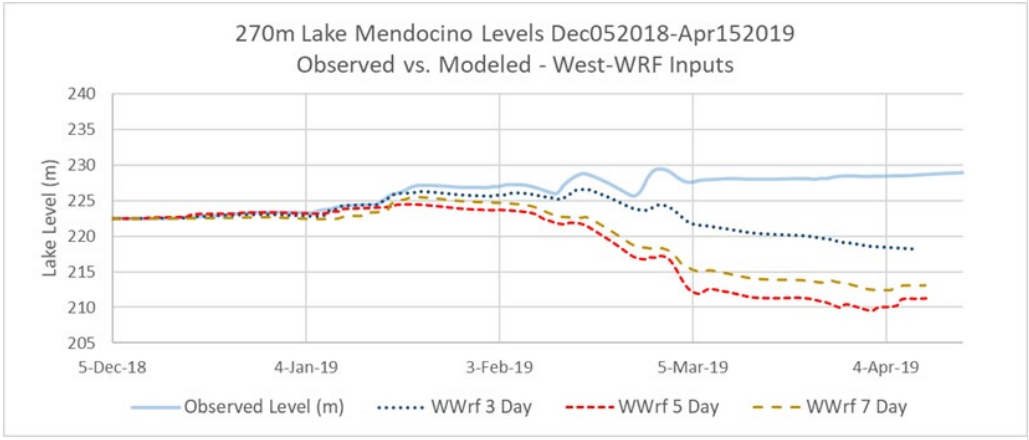


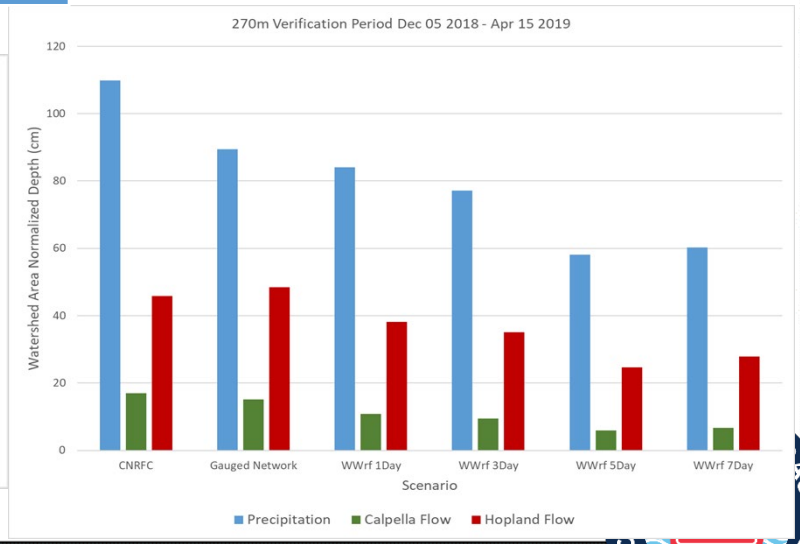


Longer Lead GSSHA/West-WRF Forecast

Gage	NSE 1 d	NSE 3 d	NSF 5 d	NSF 7 d
Hopland	0.601	0.382	0.026	0.029
Capella	**0.628**	**0.398**	**-0.040**	**-0.086**

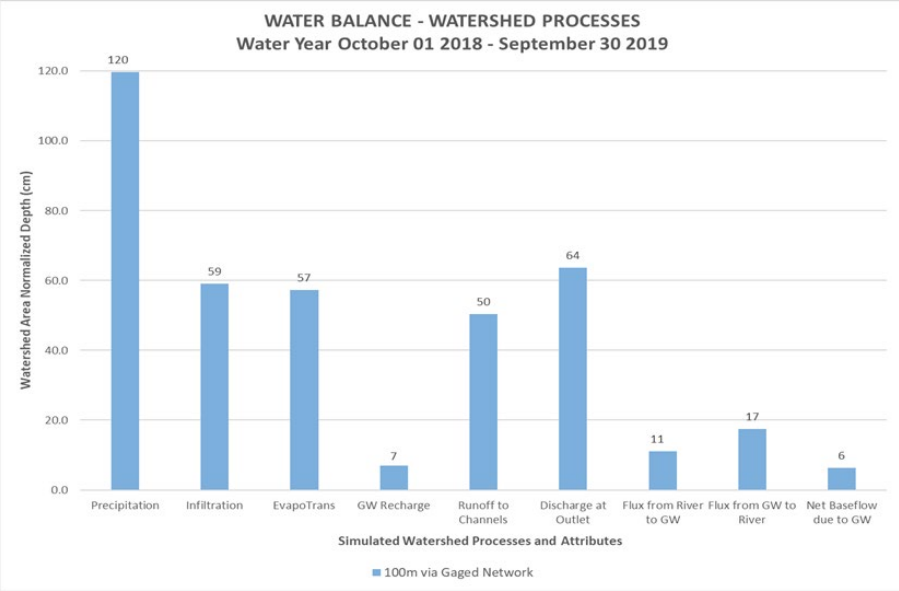
- Predictive value demonstrated at 1 d and 3 d.
- Little predictive value at 5 and 7 days
- Systematic decrease in West-WRF rainfall as forecast lead time increases causes under prediction of flows and reservoir levels.



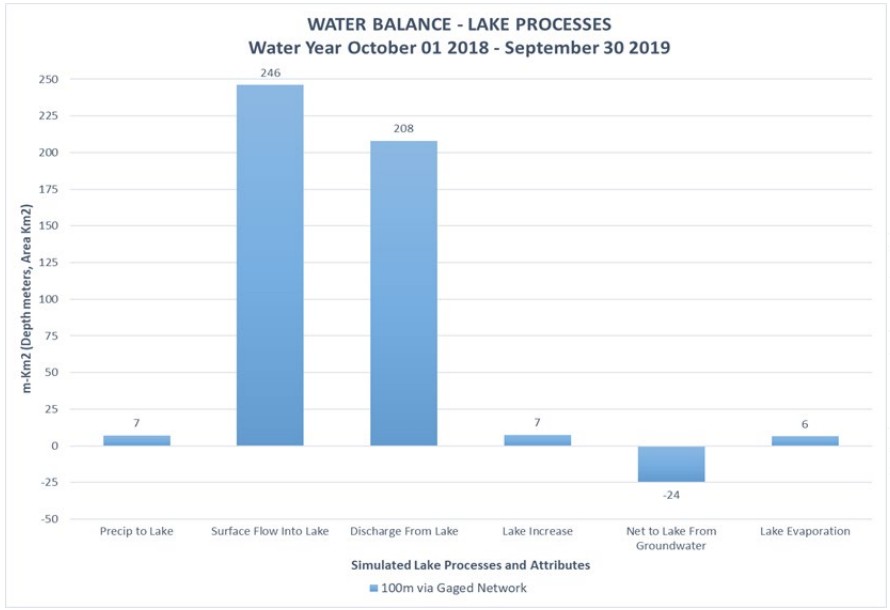


Water Balance

Watershed



Lake



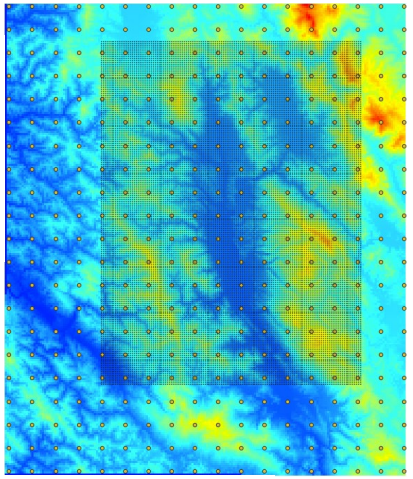
Watershed Process	Totals Normalized by Watershed Depth (cm)
Precipitation	119.8
Infiltration	59.1
Evapo-Transpiration	57.3
GW Recharge	6.9
Runoff to Channels	50.4
Discharge at Outlet	63.7
Flux from River to GW	11.1
Flux from GW to River	17.5
Net Baseflow due to GW	6.3

Lake Process	m-Km2 (Depth m, Area Km²)
Precipitation to Lake	7.0
Surface Flow Into Lake	246.0
Discharge From Lake	207.8
Lake Increase or Decrease	7.3
Net to Lake From Groundwater	-24.5
Lake Evaporation	6.4

Russian River ensemble simulations and soil moisture DA / forecasting

Andy Wood, Hongli Liu, NCAR, with Nawa Pradhan, Clay Lahatte, Chuck Downer

Ensemble forcing generation domain (WRF points and GSSHA grid cells)



Overarching objectives

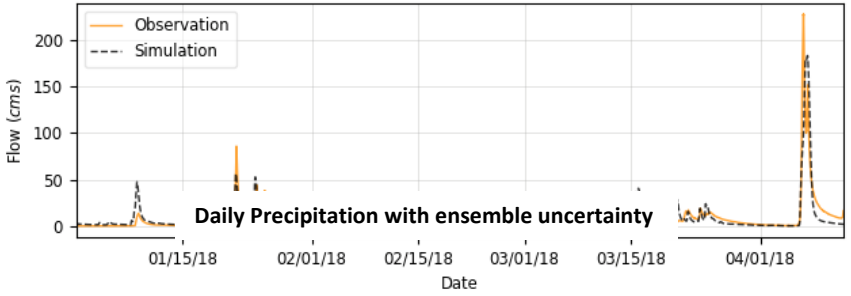
- Use meteorological ensemble forcings to provide for ensemble GSSHA model states
- Use ensemble model states to estimate model uncertainty for assimilating soil moisture measurements
- Use assimilated soil moisture measurements to improve model flow simulations and possibly forecasts

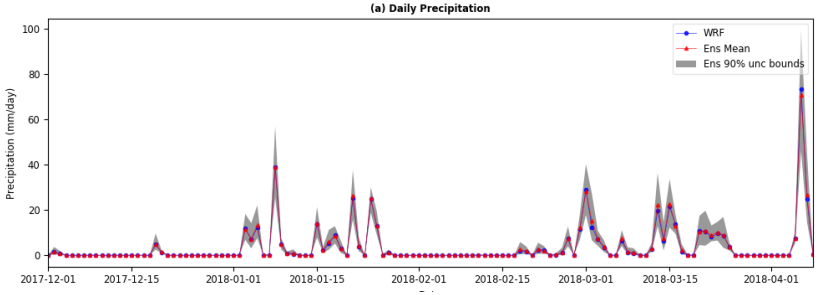
Current progress

- We developed a new strategy for NCAR's GMET to generate uncertainty for existing gridded forcings (westWRF-based input dataset), creating gridded ensemble met. inputs
  - A paper demonstrating the strategy is nearly complete
- We reconciled model simulation performance issues when running GSSHA at NCAR
- Pending generation of one final supporting met input for GSSHA, we will commence ensemble simulations
- Subsequent application of the ensemble particle filter DA will allow the soil moisture observations to influence the flow simulations.

GMET: Gridded Meteorological Ensemble Tool -- https://ncar.github.io

GSSHA model simulation





Key Points

- The GSSHA model was shown capable of reproducing flows and reservoir levels when given sufficient rainfall data.
- The additional precipitation and stream gages in the RHONET network improved calibration results, demonstrating the utility of the field program.
- The GSSHA/West-WRF coupled system was capable of reproducing stream flows at short forecast leads but accuracy diminished as the lead time increased.
- Full report will be included as appendix in FVA.

Final Viability Question

- Can research into advanced forecasting tools produce improvements to rainfall, runoff, and reservoir forecast over existing methods currently in use?

- I guess the verdict is still out. Certainly, the results are encouraging.
- There's a lot that goes into a official forecast, such as from the CNRFC, that is missing from this application.
- Additional studies being conducted at Prada Dam
- Developing an operational version of GSSHA/West-WRF would be good next step.