Coupling the National Water Model with A Reservoir Operation Simulation Model

Russian River Basin Case Study

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U.S. Department of Commerce

CIRA
Connecting Models and Observations

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

SONOMA COUNTY WATER AGENCY

US Army Corps of Engineers

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- Integrated Water Management Model, NWM-ResSim
- Experiments of the NWM-ResSim
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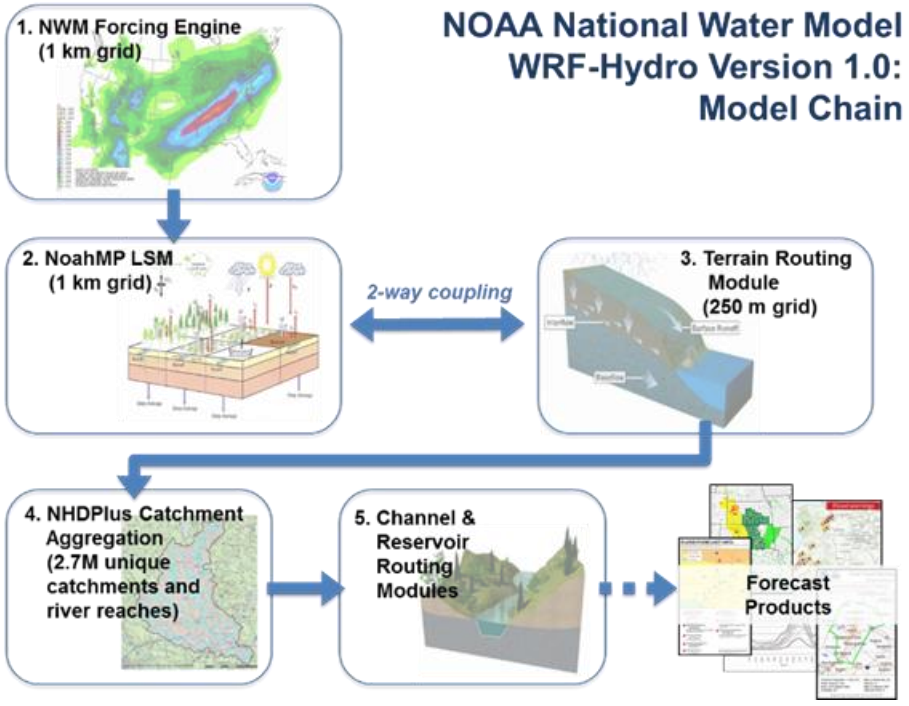
1. Introduction

Current Status and Challenges

Current Status



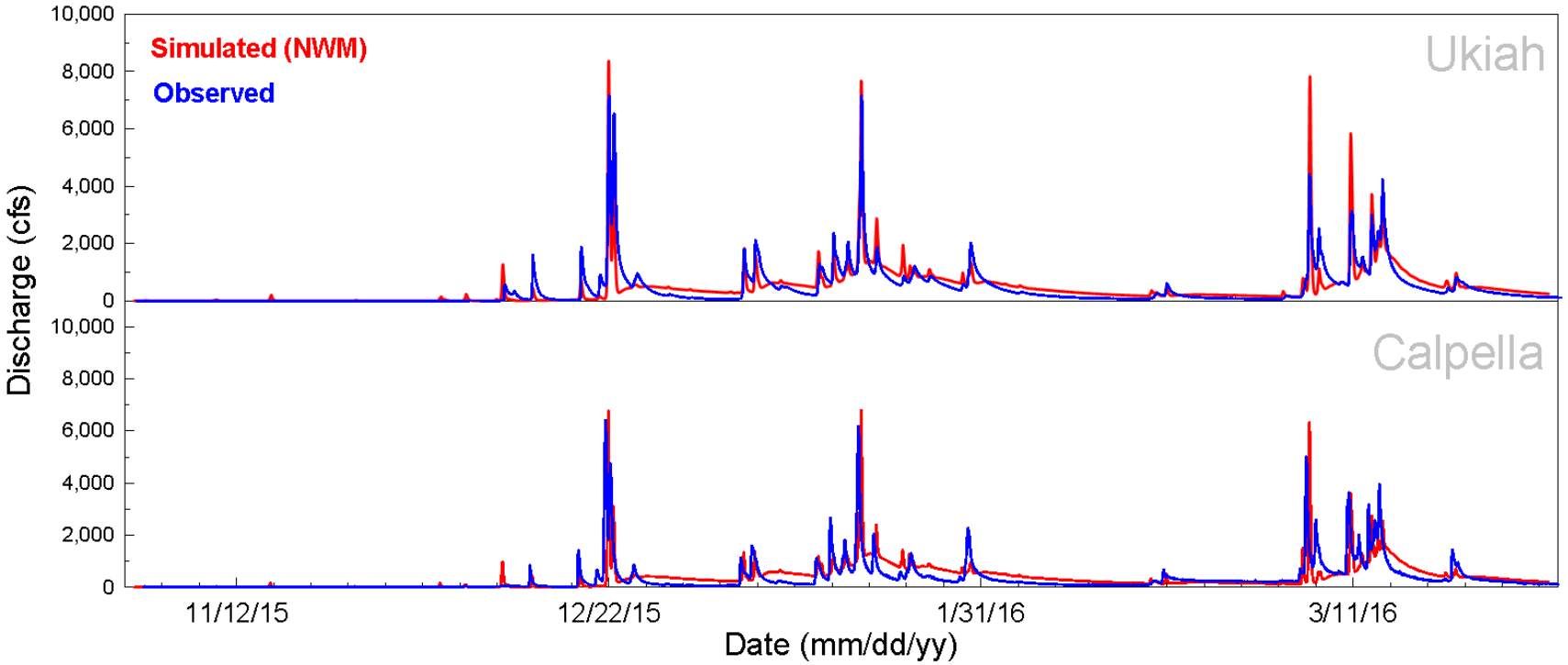
[Conceptual diagram of the NWM component]

Natural Flows

Reservoir Operations and Regulated Flows

Flood Forecasting

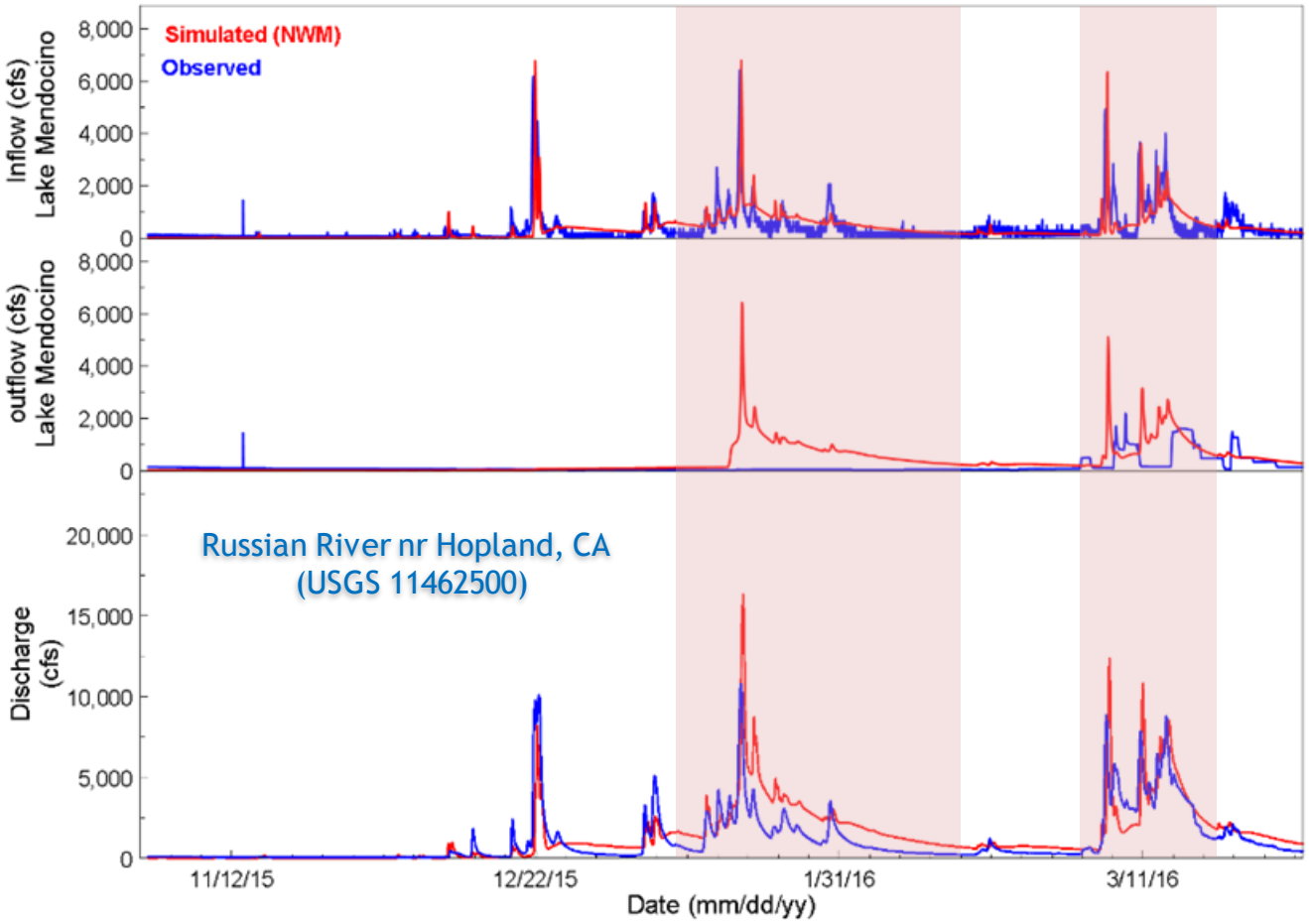
Current Status



Comparison of USGS gages and NWM simulated streamflows,
a) Russian River nr Ukiah (USGS 11461000) and b) E. Fk. Russian River at Capella (USGS 11461500)
Both gages are located upstream of Lake Mendocino

NWM performance for natural flows is considered adequate to be used as inflows into Lake Mendocino. Especially, peak flow and time to peak.

Challenges we are faced with



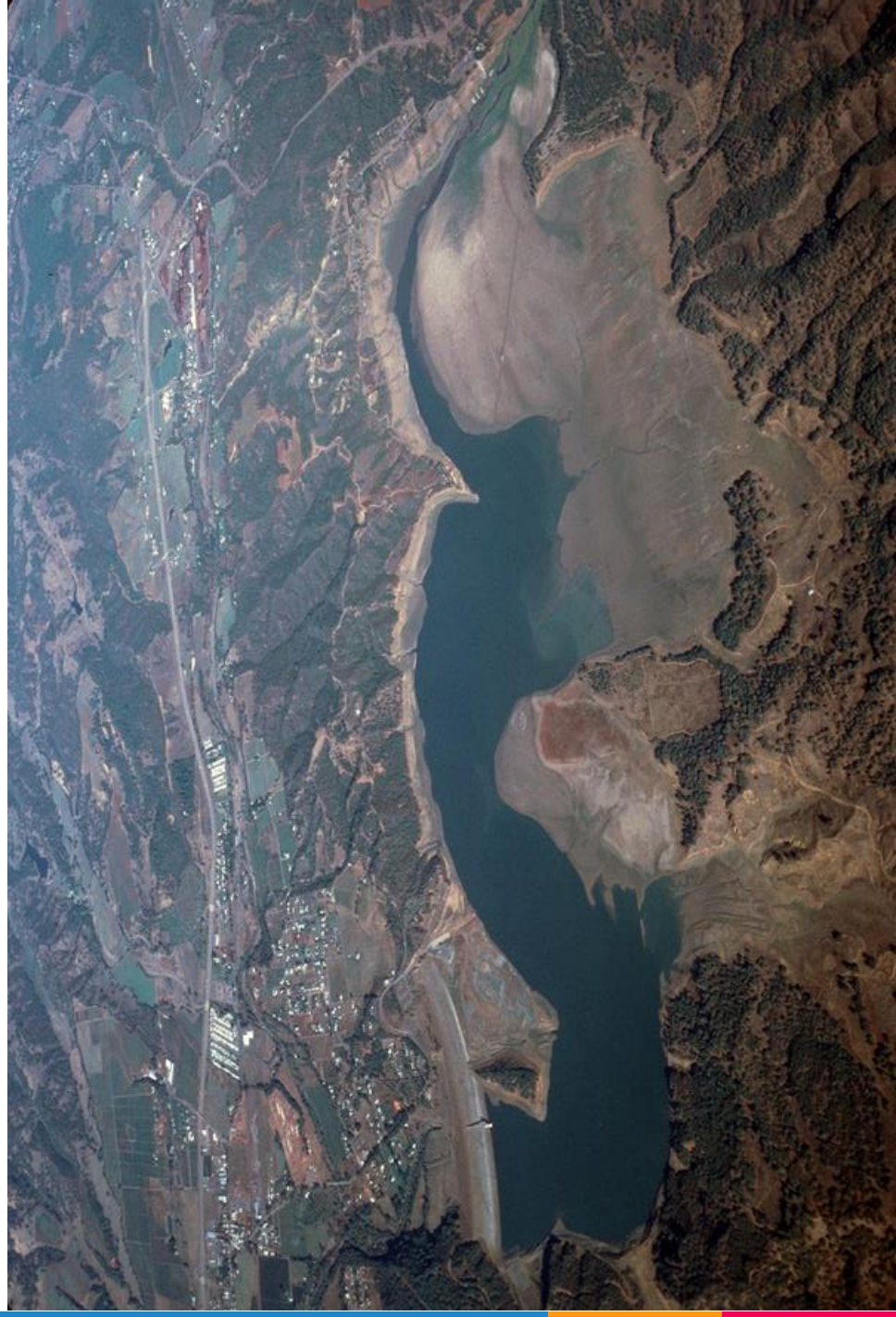
[Evaluation of natural and regulated flow in the upper Russian River basin]

5 Approaches for Representing Reservoirs

1) Assimilation of gaged release flows
2) Level-pool routing
3) Machine learning to derive operations guidance
4) Integration of NWM flows into river basin water management models
5) Retrieval of scheduled releases provided by reservoir operators

Experiments of the 5 Approaches

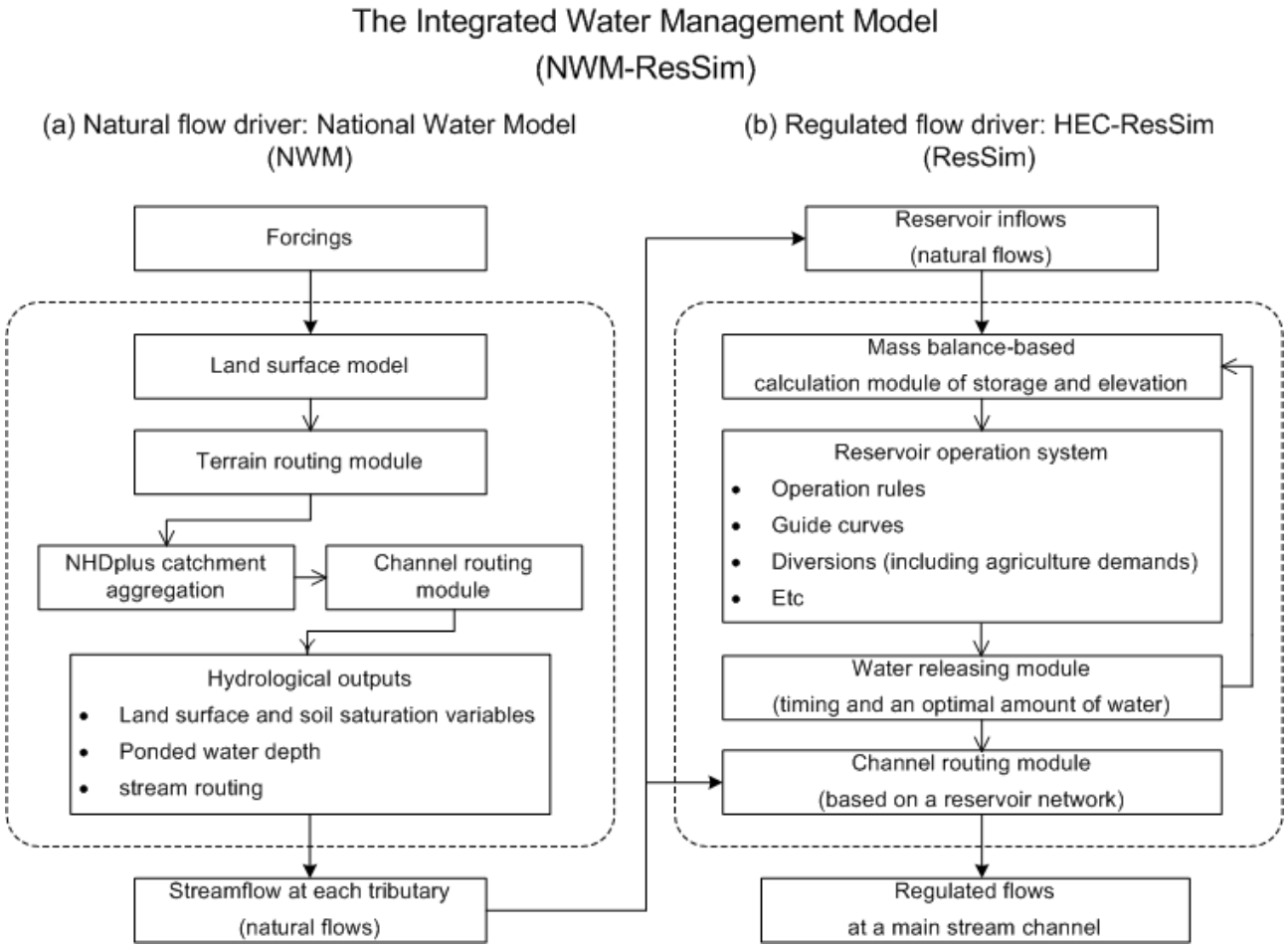
- Integrated Water Management Model (NWM-ResSim)
- Evaluation of the NWM-ResSim



2. NWM-ResSim

Integrated Water Management Model through a coupling of a reservoir operation simulation model with the NWM.

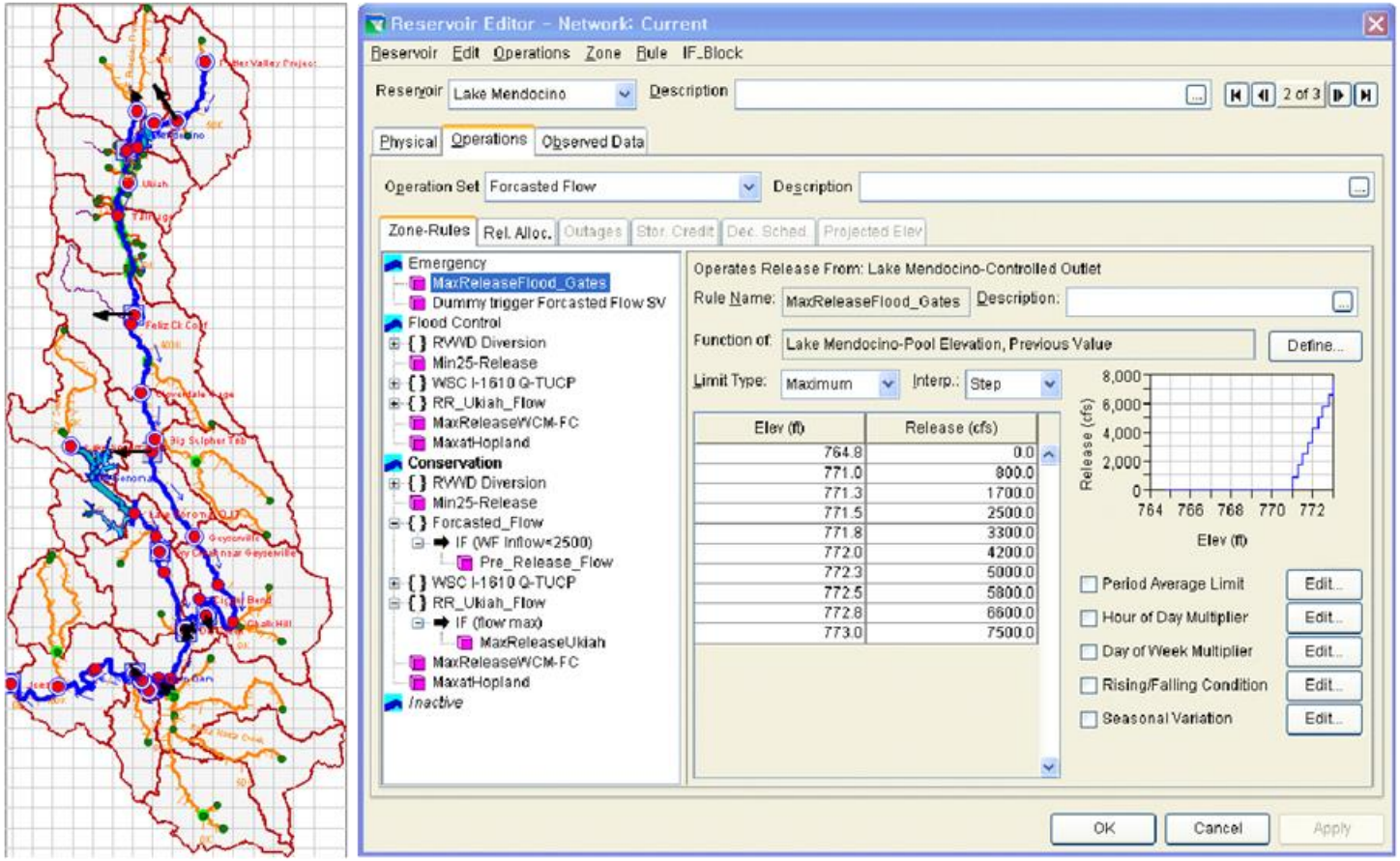
Structure of the NWM-ResSim



[Conceptual diagram of the NWM-ResSim]

HEC-ResSim

Reservoir Operation Simulation Model

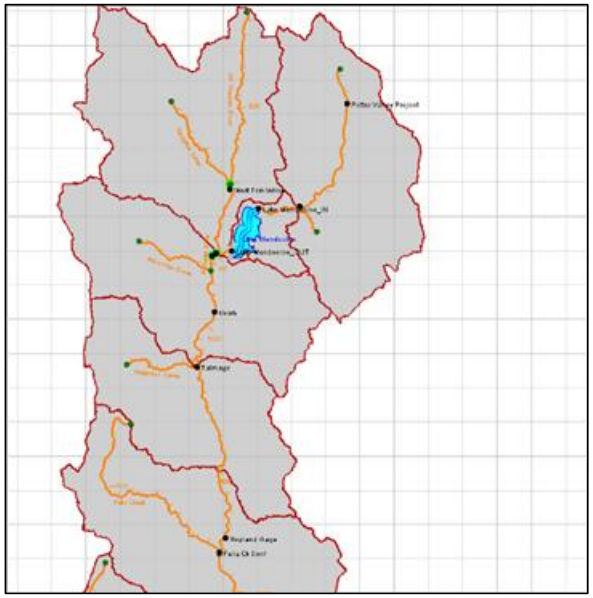


[Sonoma County Water Agency HEC-ResSim for the Russian River basin]

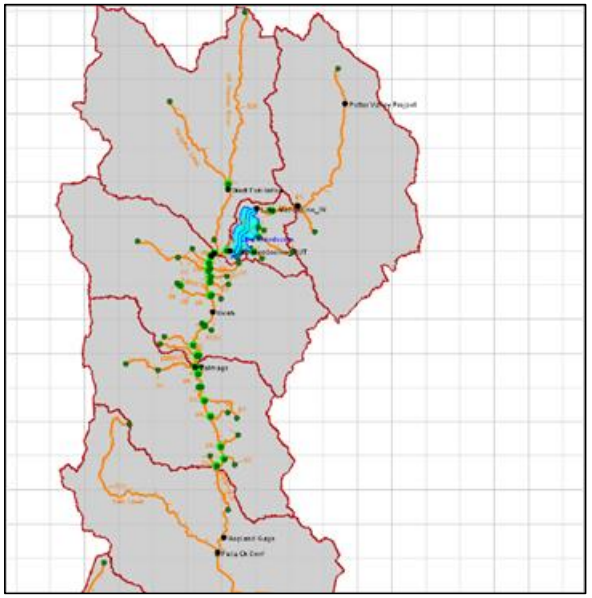
NWM-ResSim

for Lake Mendocino

- Reconfigured ResSim using the NHDplus stream reaches
  NWM has higher resolution, so new nodes required for local inflows
- Importing channel lengths of the NHDplus – for ResSim channel routing
- Importing NWM routing parameters – alternate ResSim choices
- Applied current operation guide curves and rules for Lake Mendocino



(A) Original channel network from SCWA

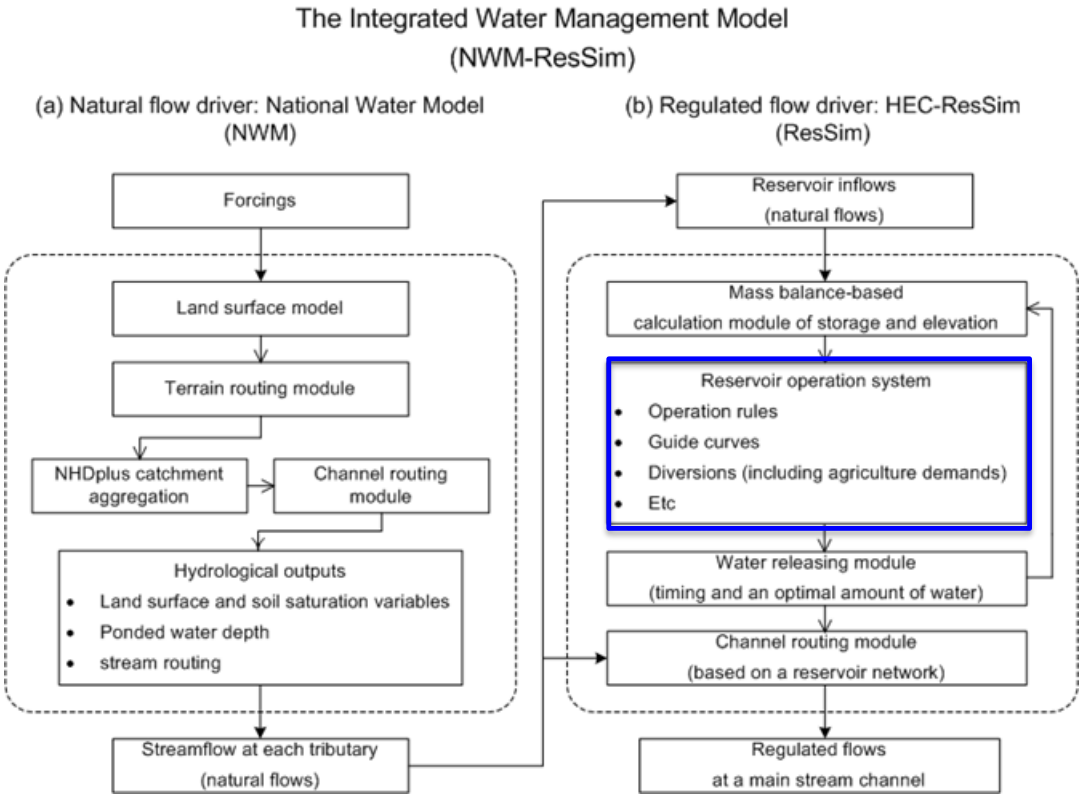


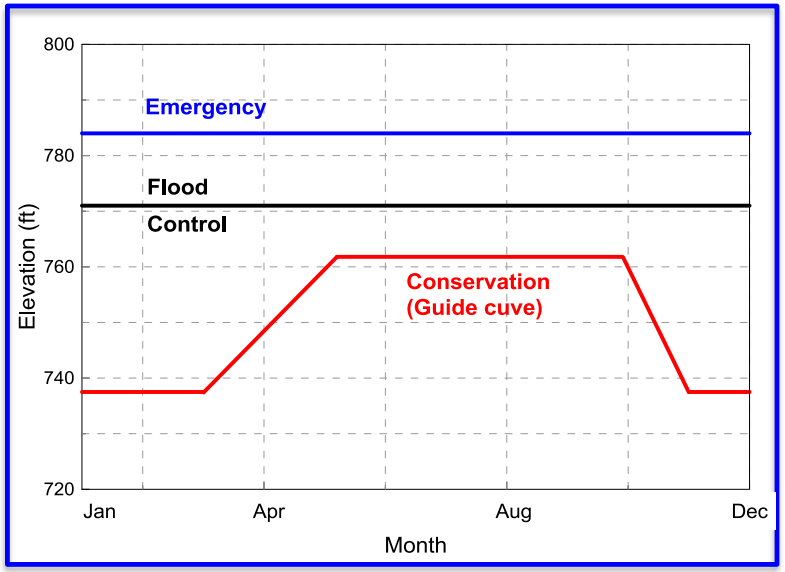
(B) New channel network (NHDplus)

[Comparison the existing ResSim channel network and the revised ResSim channel network]

IDD

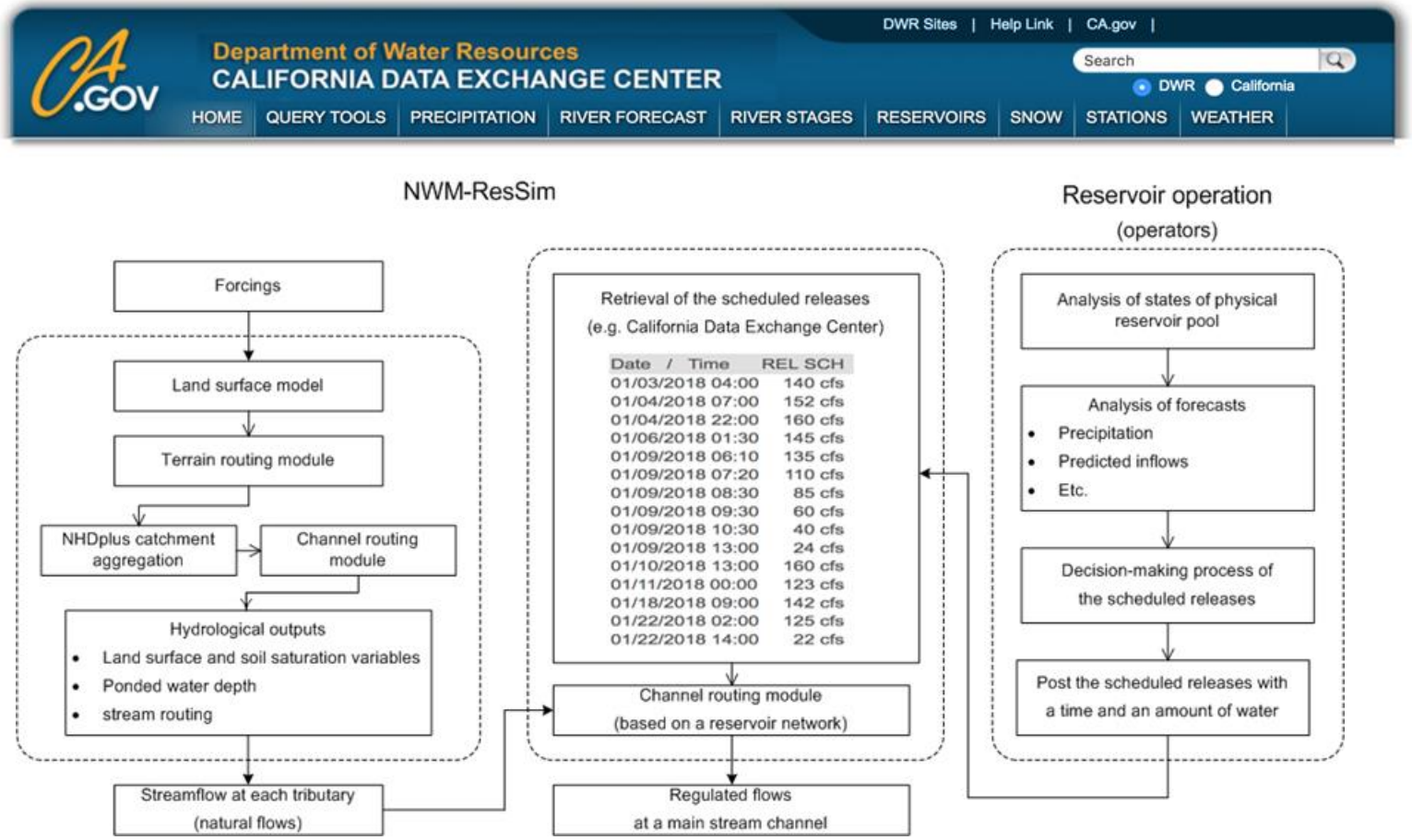
Integration of natural flow Driver and regulated flow Driver





RSO

Retrieval of Scheduled Operations



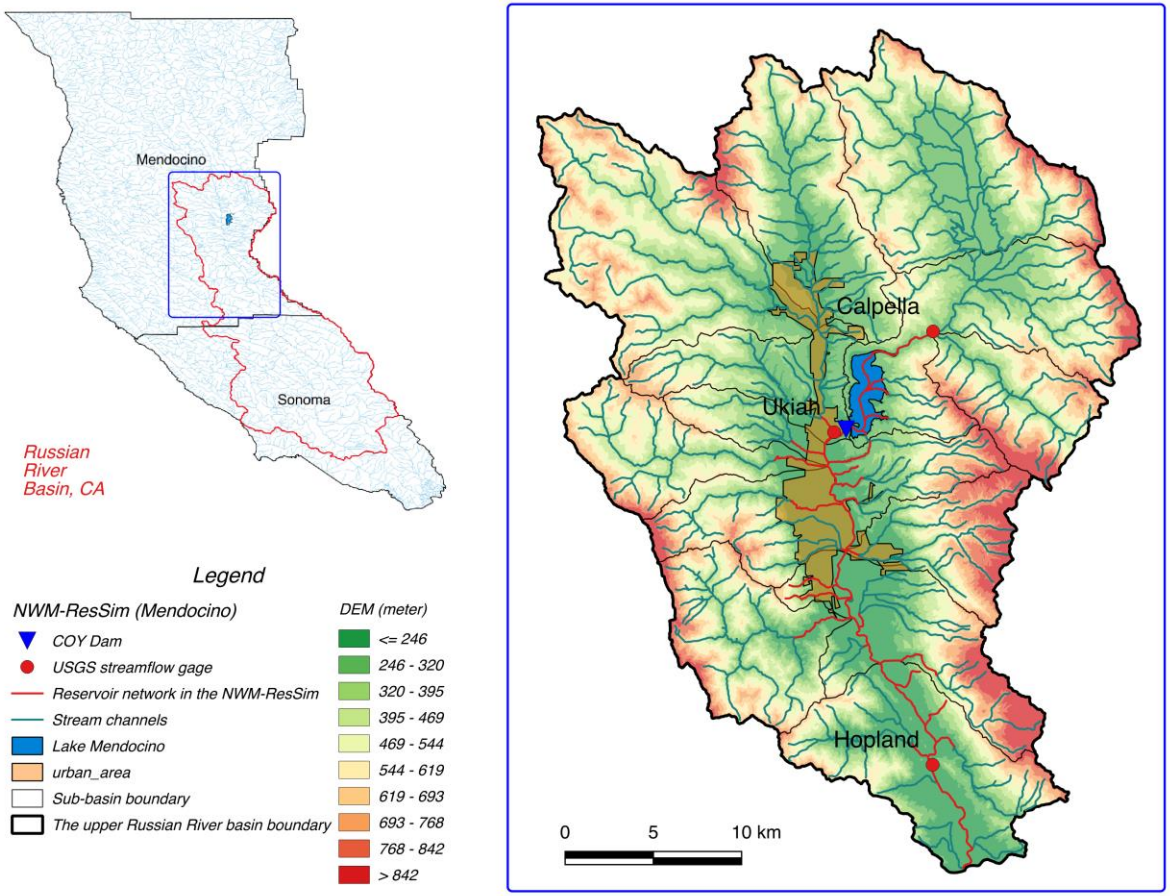
[Flowchart of the RSO in the NWM-ResSim]

3. Experiments of the NWM-ResSim

In terms of
natural flows, channel routing, and reservoir operations

Application Basin

The upper Russian River basin with Lake Mendocino

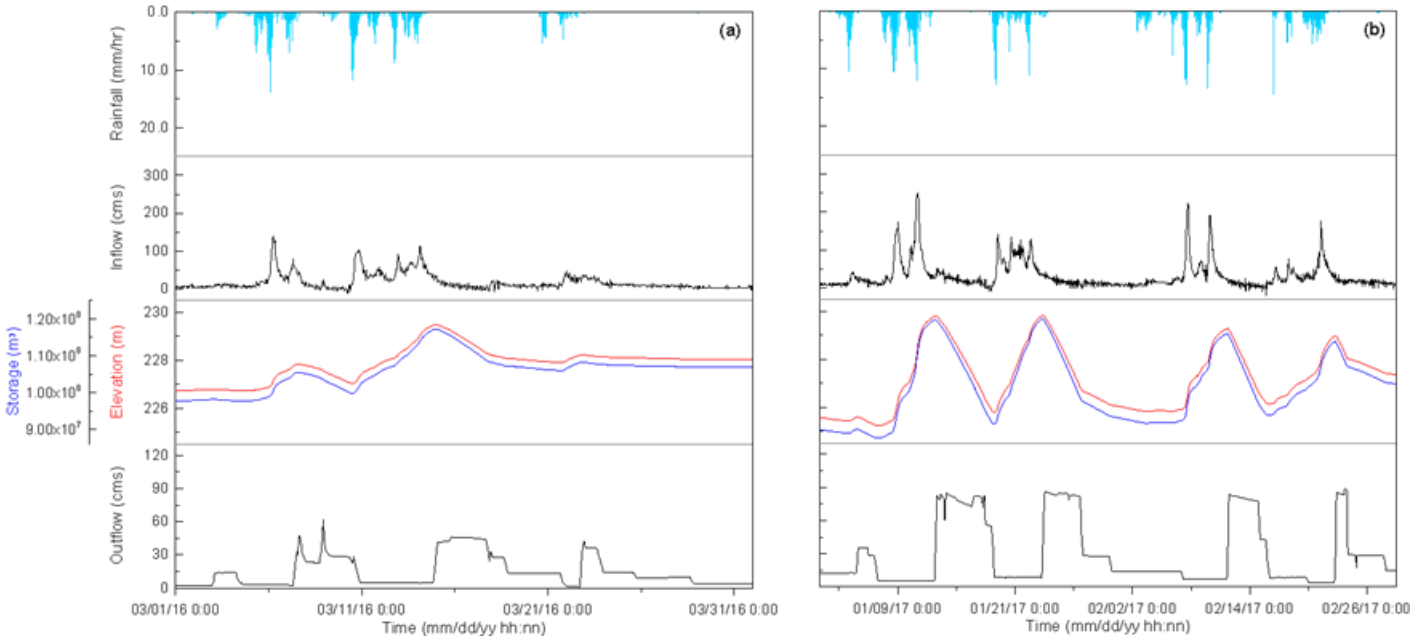


[The upper Russian River basin with three main USGS gages used in this study]

Application Data

Rainfall and state variables of reservoir storage

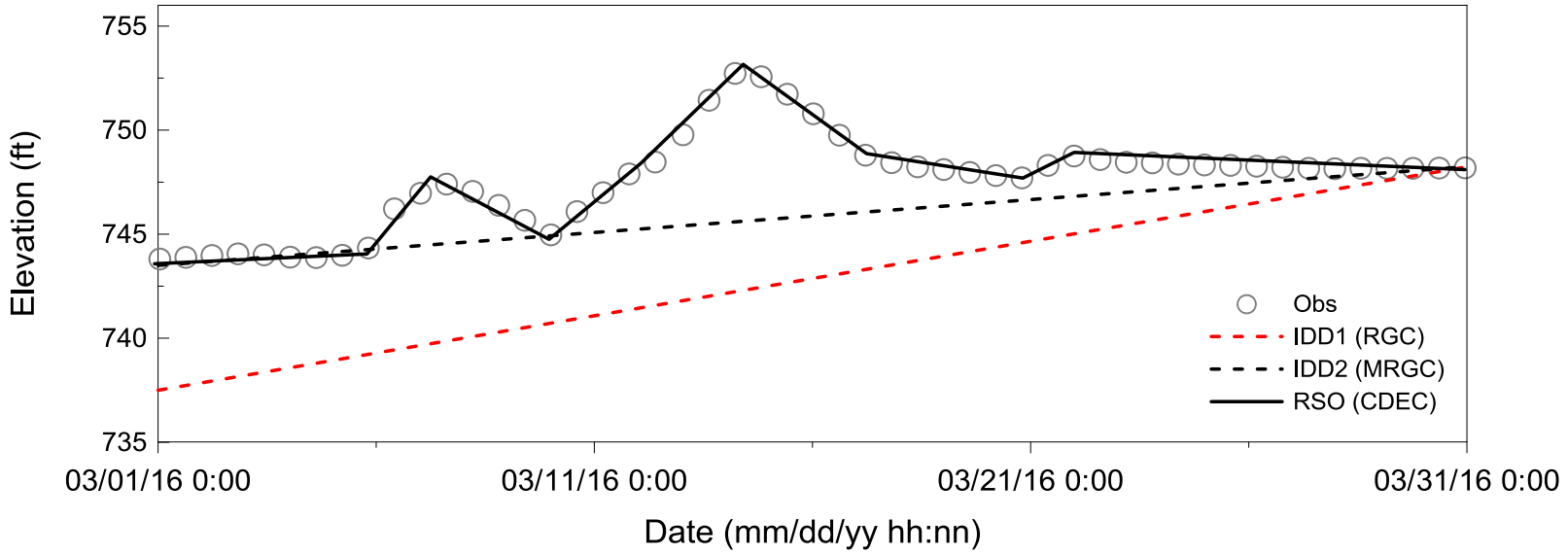
- Time series of state variables of Lake Mendocino-pool (rainfall, inflow, elevation, storage, and outflow) during the application periods. In this figure, the left panel and the right panel represent March, 2016 and December, 2016-March, 2017 representatively



[Application data: state variables of the reservoir storage]

Analysis

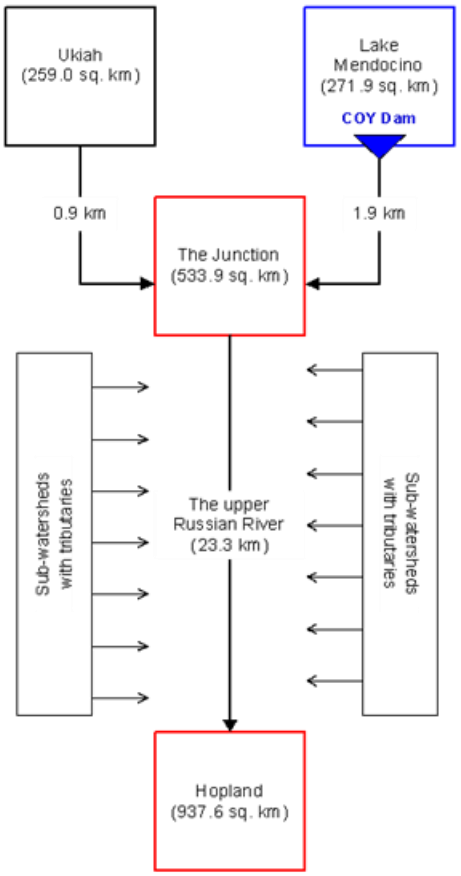
Guide curves

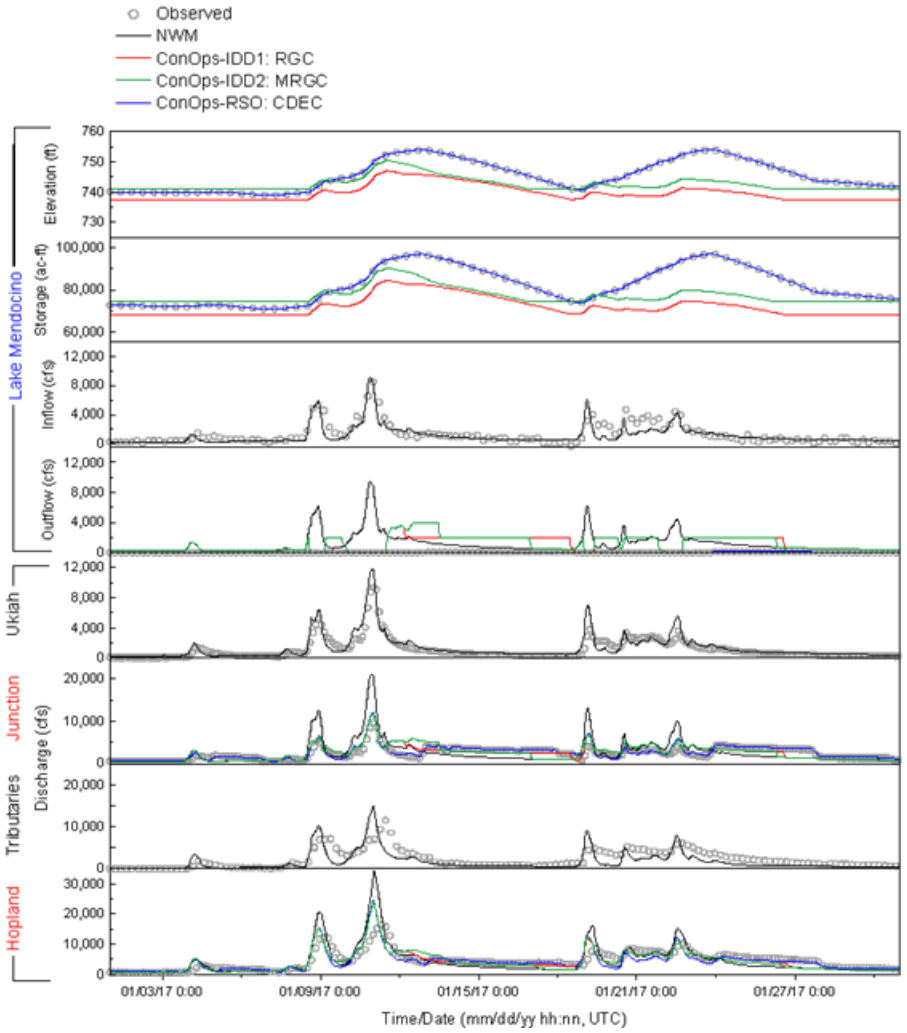


- Comparison results of the guide curves. In this figure, Obs, IDD1 (RGC), IDD2 (MRGC) and RSO (CDEC) indicate the observed elevation state, the actual guide curve used in the operation, the reference guide curve from USACE (2012), and the modified RGC respectively.

Results

Jan. 2017





[Jan. 2017 simulation results from two approaches and the NWM]

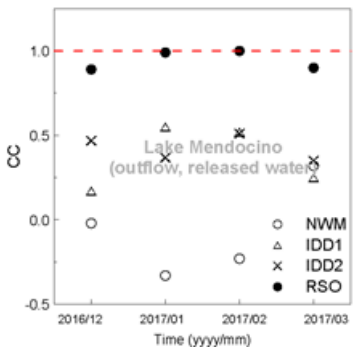
Statistics

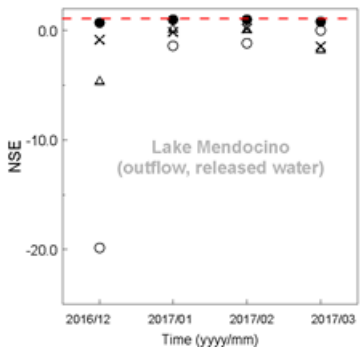
For four month (Dec. 2016-Jan. 2017)

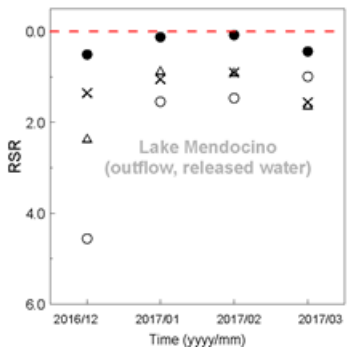
- Correlation Coefficient (CC)
- Nash-Sutcliffe Efficiency (NSE)
- RMSE-observation Standard deviation Ratio (RSR)
- Percent-BIAS (PBIAS)
- Bias
- Difference (%) of peak flow
- Difference (hr) of time to peak

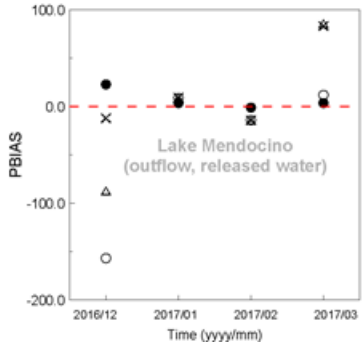
Daily-based Statistics results

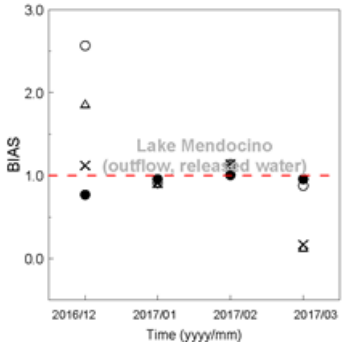
For four month (Dec. 2016-Jan. 2017)

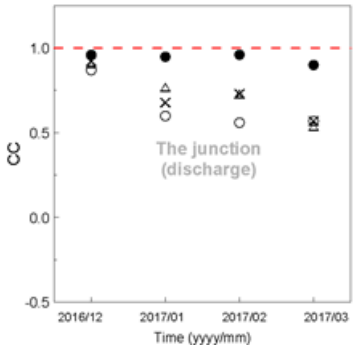


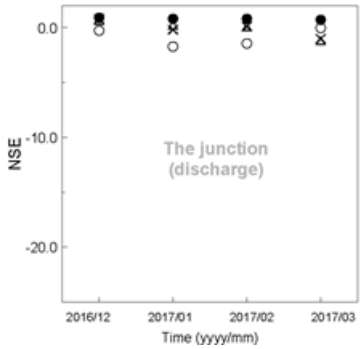


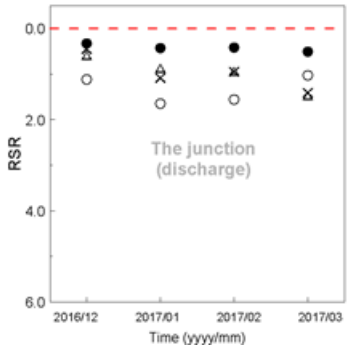


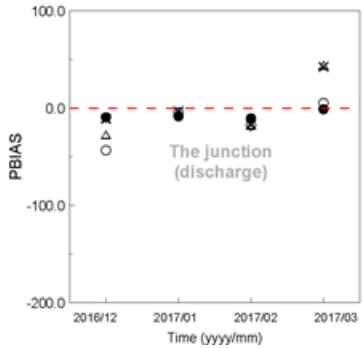


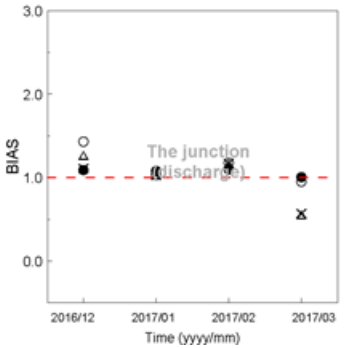


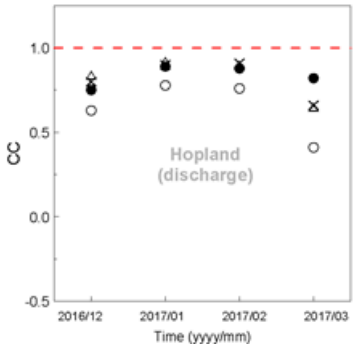


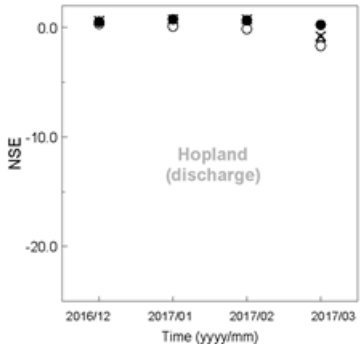


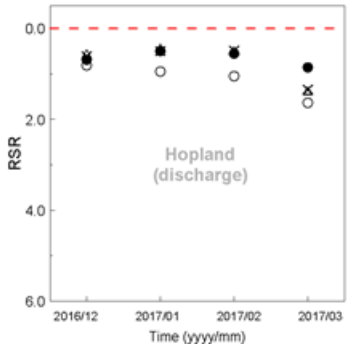


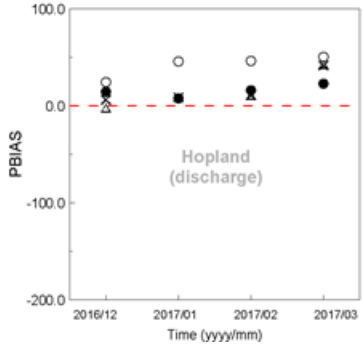


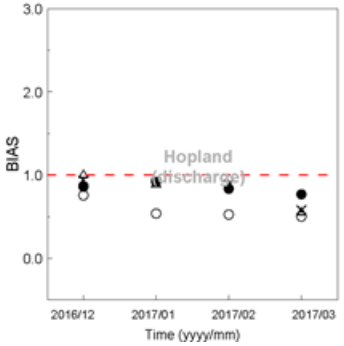






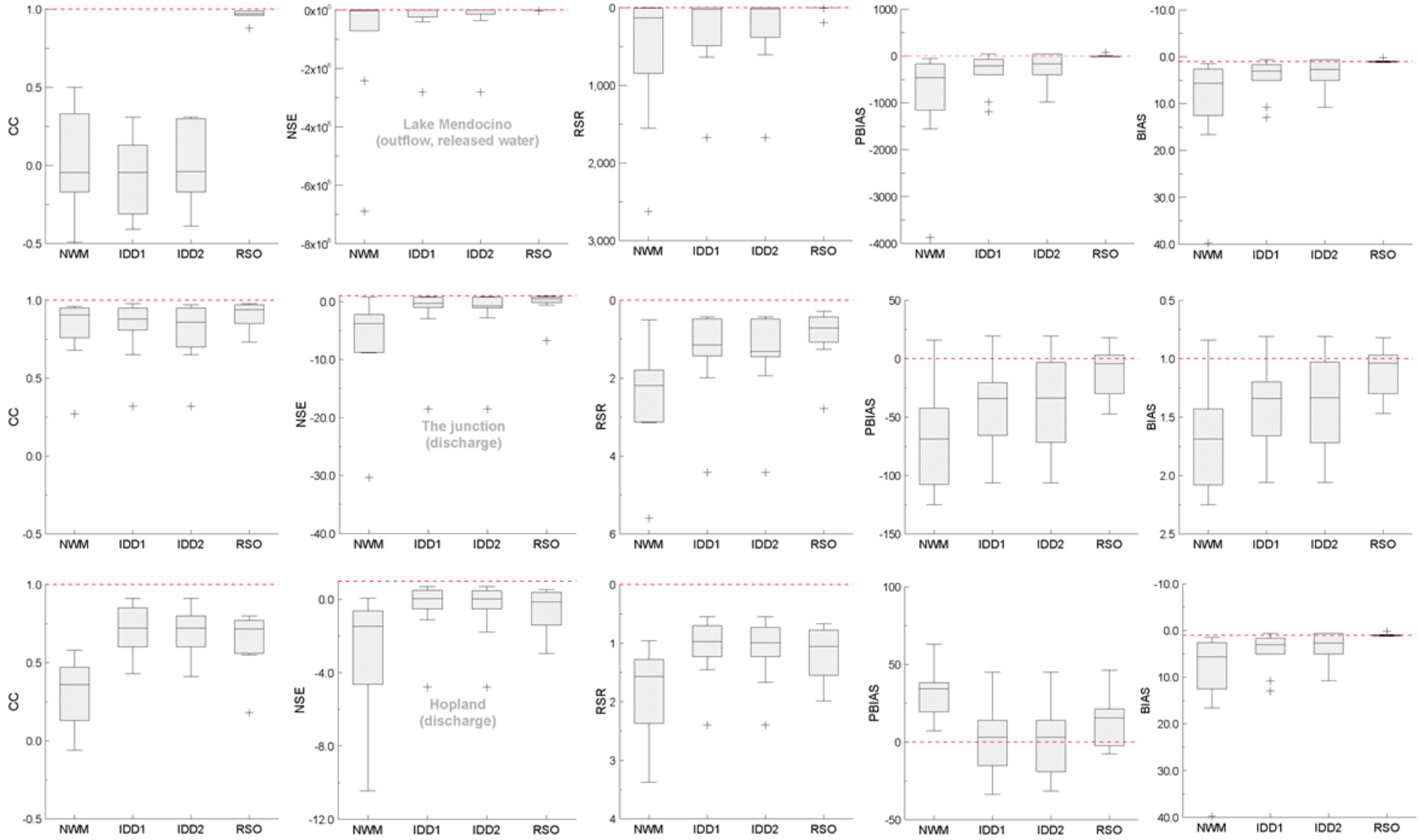






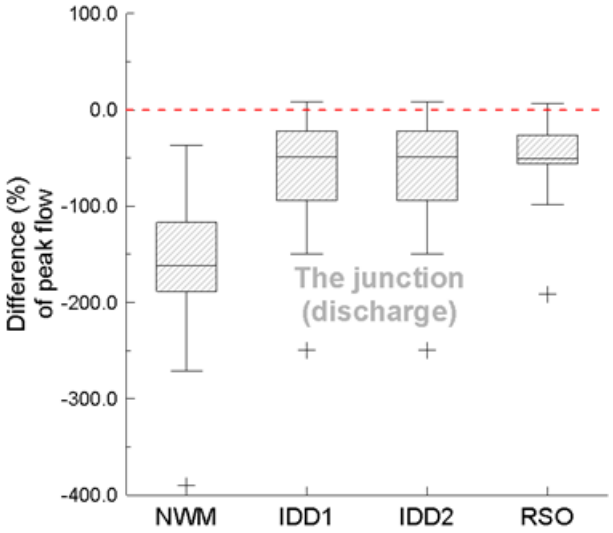
Event-based Statistics results

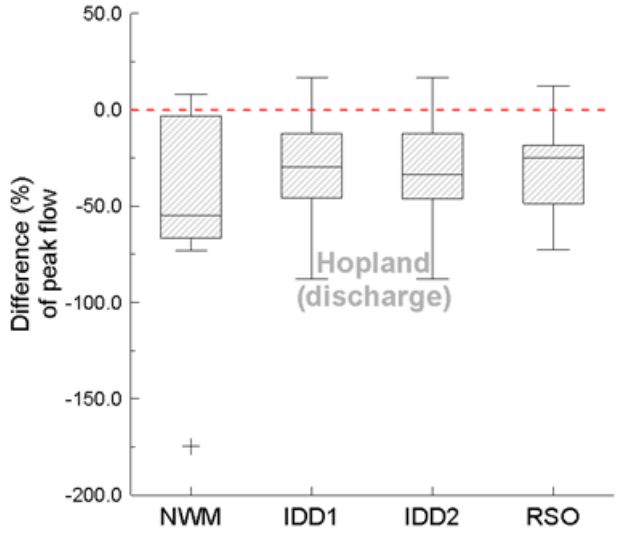
For four month (Dec. 2016-Jan. 2017)

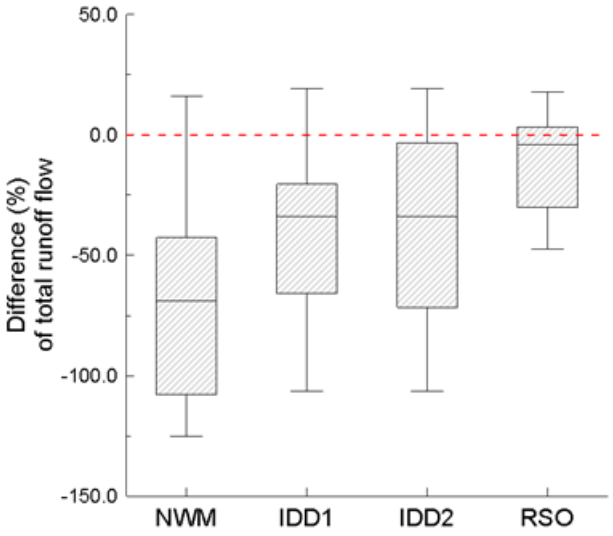


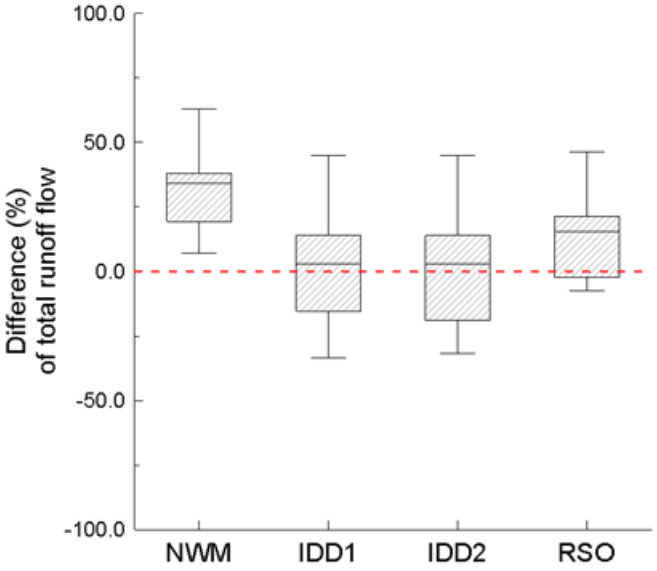
Event-based Statistics results

For four month (Dec. 2016-Jan. 2017)









Conclusions

- This study coupled the HEC-ResSim with the NWM to represent the influence of regulated flows and assessed the default operational guide curve and found that reservoir operations deviated significantly for the simulated runoff event.
- Incorporation of NWM upstream and downstream tributary inflows, and reservoir operations guide curves (derived from actual performance) greatly improved downstream flow estimates for one simulation period. For another period, poor NWM performance impacted simulated flow accuracy for reservoir inflows and downstream.
- Downstream main-stem channel routing was conducted using the ResSim model using parameters derived from a) the original ResSim model, b) NHD-Plus reach data, and c) NWM channel routing.
- The influence of Lake Mendocino releases on downstream flows is attenuated as one proceeds further downstream.
- There is a cascade of possible approaches for coupling reservoir operations into the NWM and this study experimented two approaches.
  - Integration of NWM flows into river basin water management models
    - Many operating agencies have sophisticated management models
    - Customize inputs to accept NWM inflows required
  - Retrieval of scheduled releases provided by reservoir operators
    - Many operating agencies post scheduled releases to CDEC

Thanks!

Any questions?

You can find me at:

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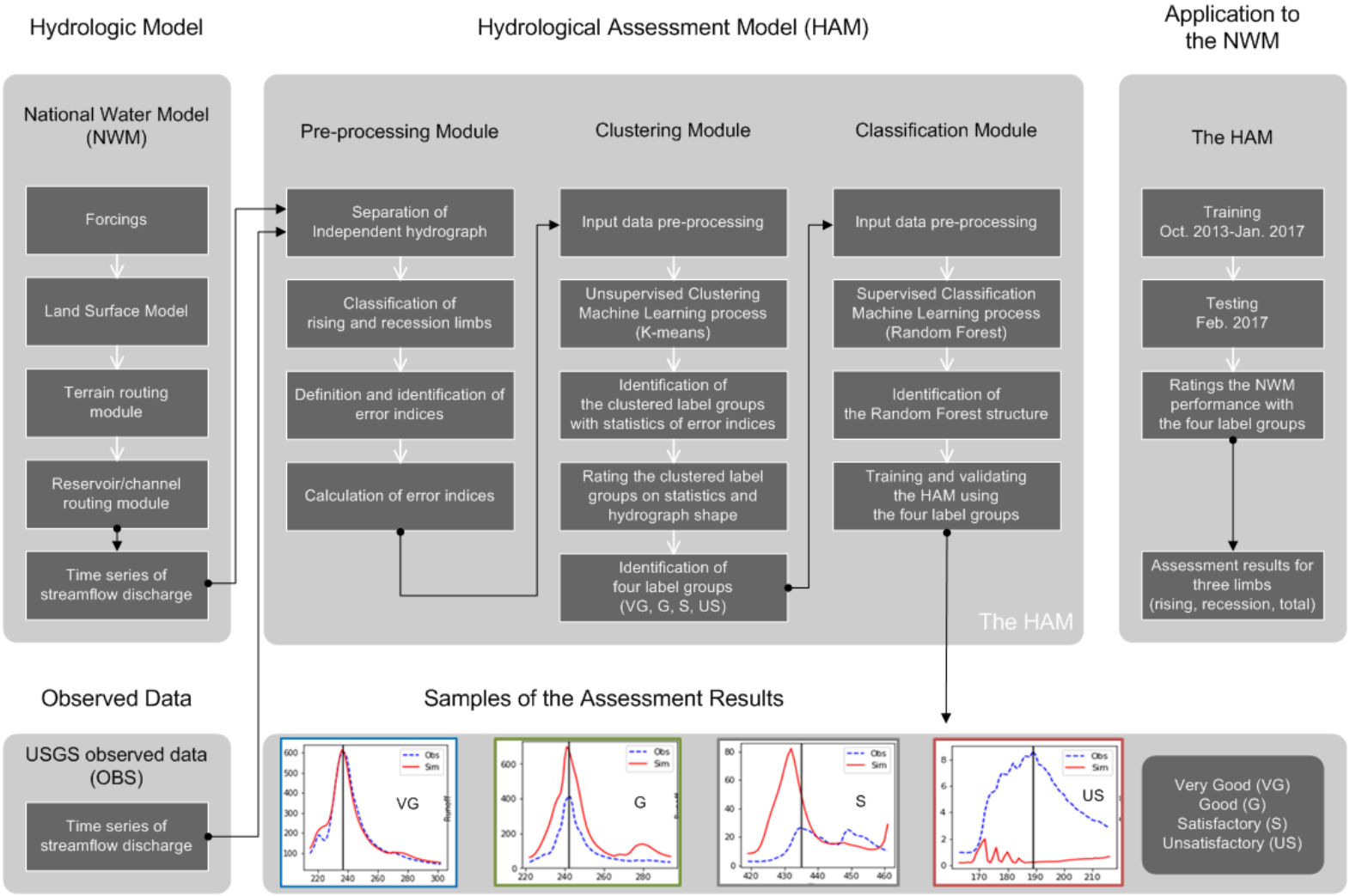
Back-up slides

Current Status



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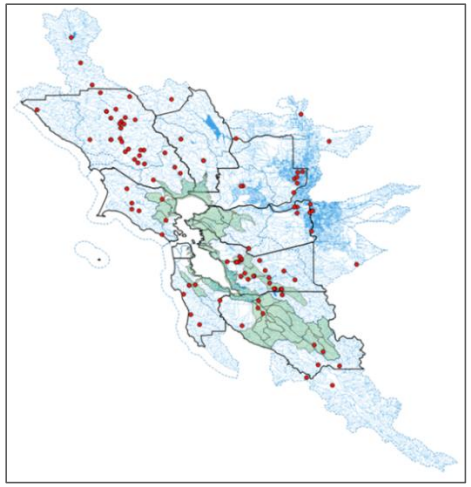
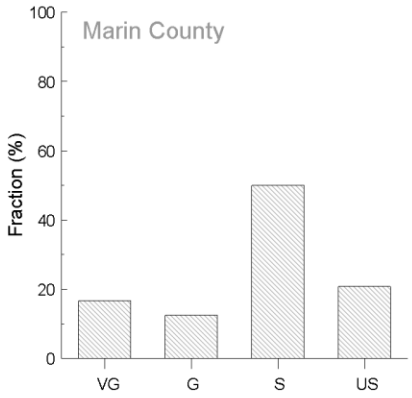
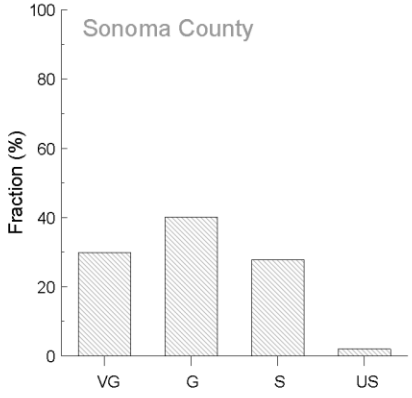
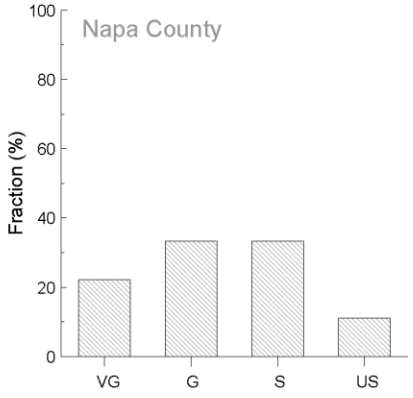
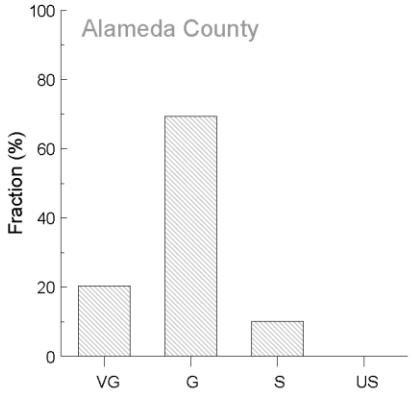
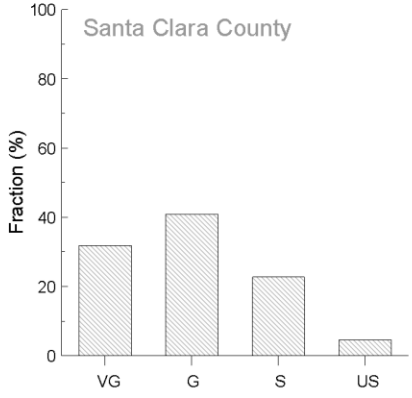


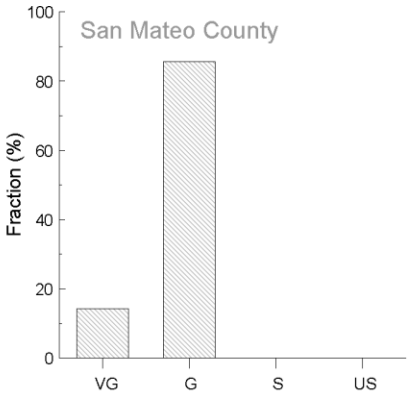






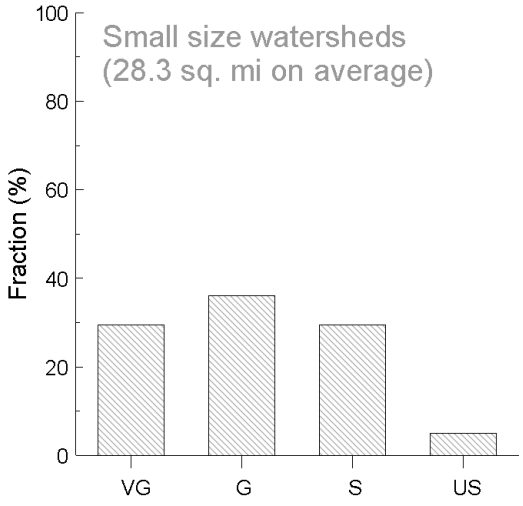


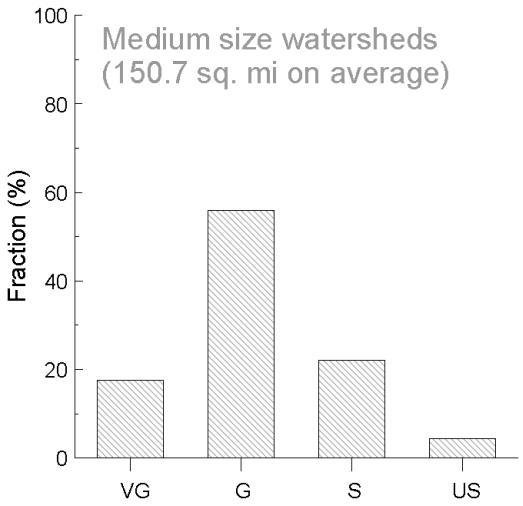


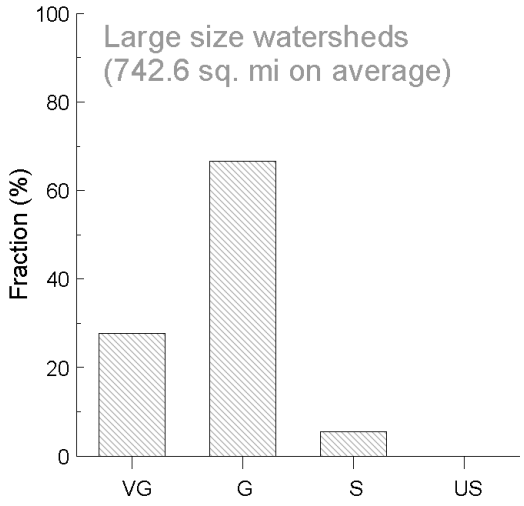


Very Good (VG)
Good (G)
Satisfactory (S)
Unsatisfactory (US)

Current Status





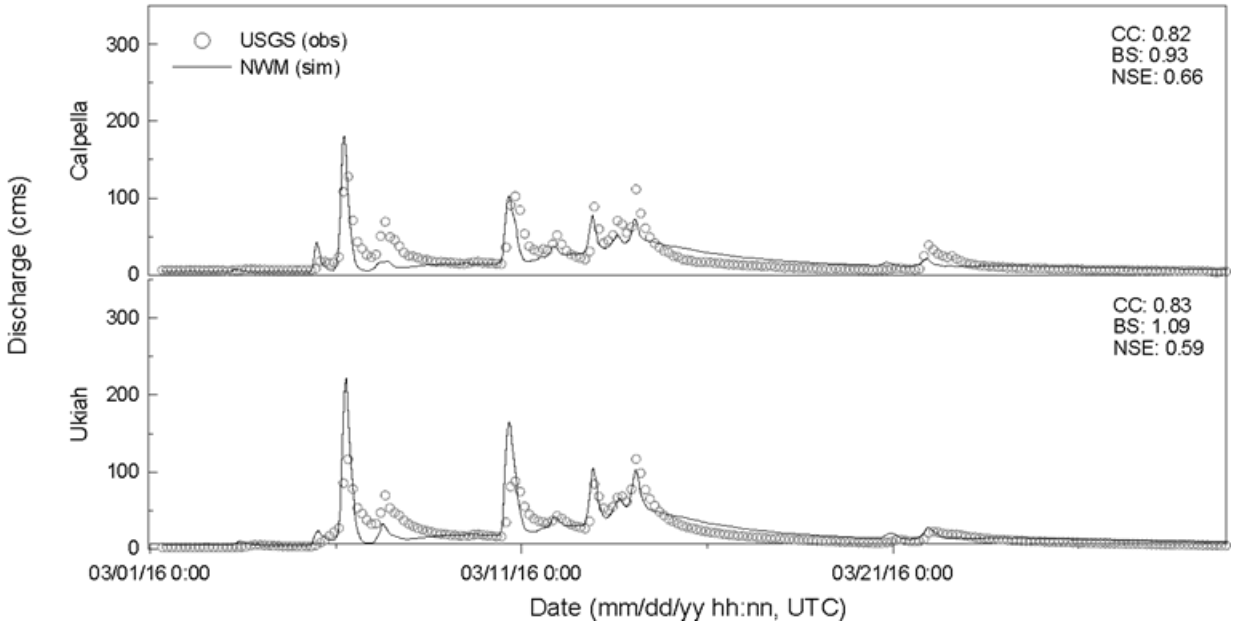


- The HAM is a hydrological assessment model to evaluate the performance of hydrologic models in an objective manner. This study applied the HAM to results of the NWM in San Francisco Bay area.
- The four ratings (Very Good, Good, Satisfactory, Unsatisfactory) are considered a reasonable approach to evaluation of the NWM performance. For example, for small watersheds 67% of events were rated as good or very good; 97% were rated satisfactory or better. For large watersheds, 97% events of were rated as good or very good.

Evaluation

Natural Flows

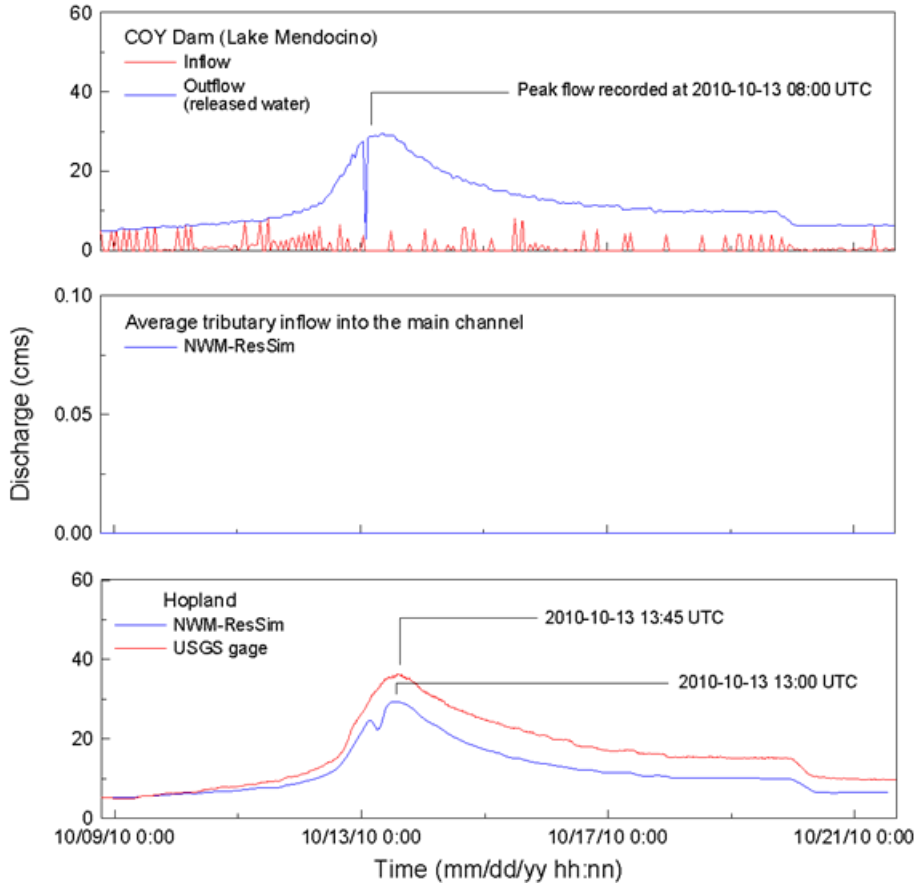
- Time series Comparison results of the observed and the simulated streamflows by the NWM for Mar. 2016. In the figure, correlation coefficient (CC), bias (BS), and Nash-Sutcliffe efficiency coefficient (NSE) are used as the error indices to evaluate the NWM performance.



[Evaluation results of the natural flows using error indices]

Evaluation

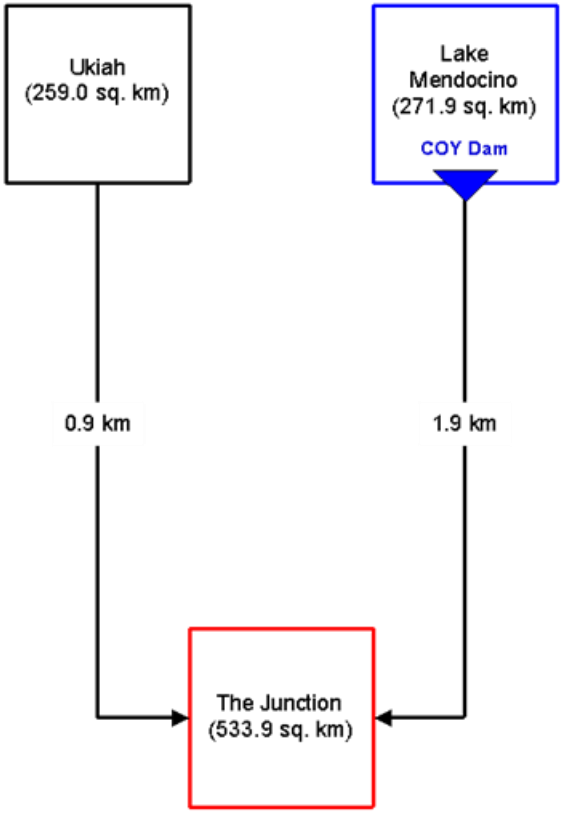
Channel Routing

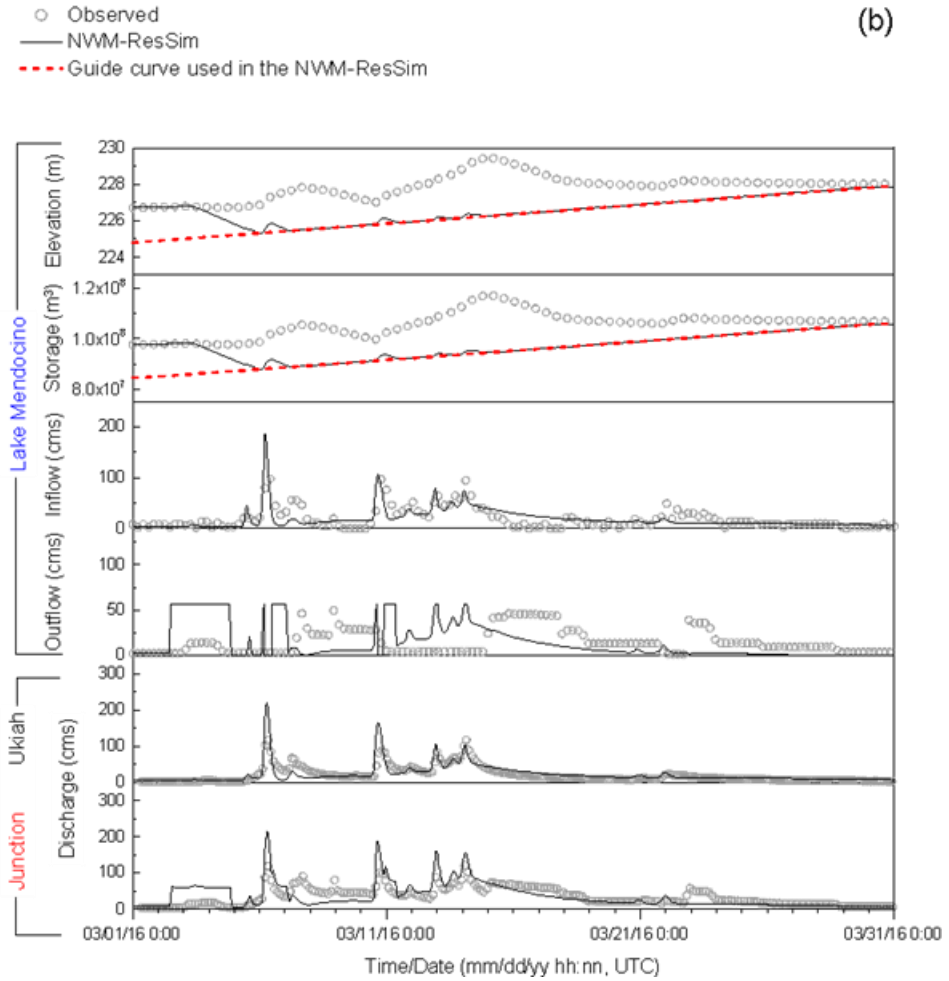


[Evaluation of the channel routing performance of the NWM-ResSim]

Evaluation

Reservoir Operations Simulation

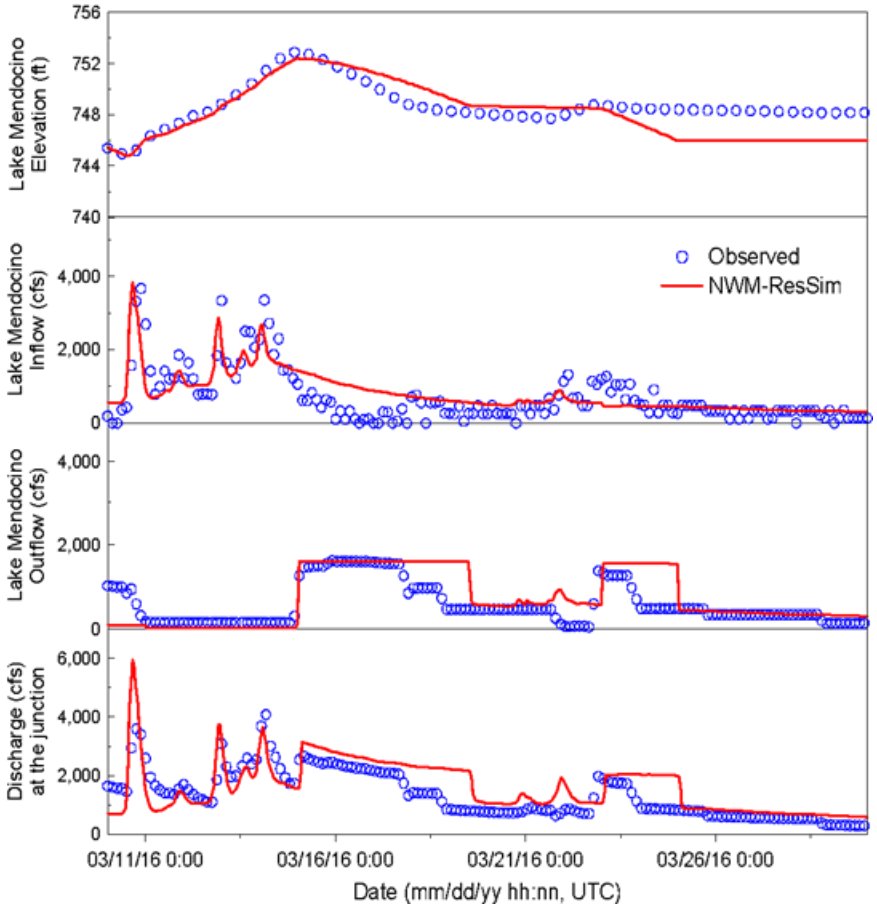




[Evaluation of the NWM-ResSim]

Evaluation

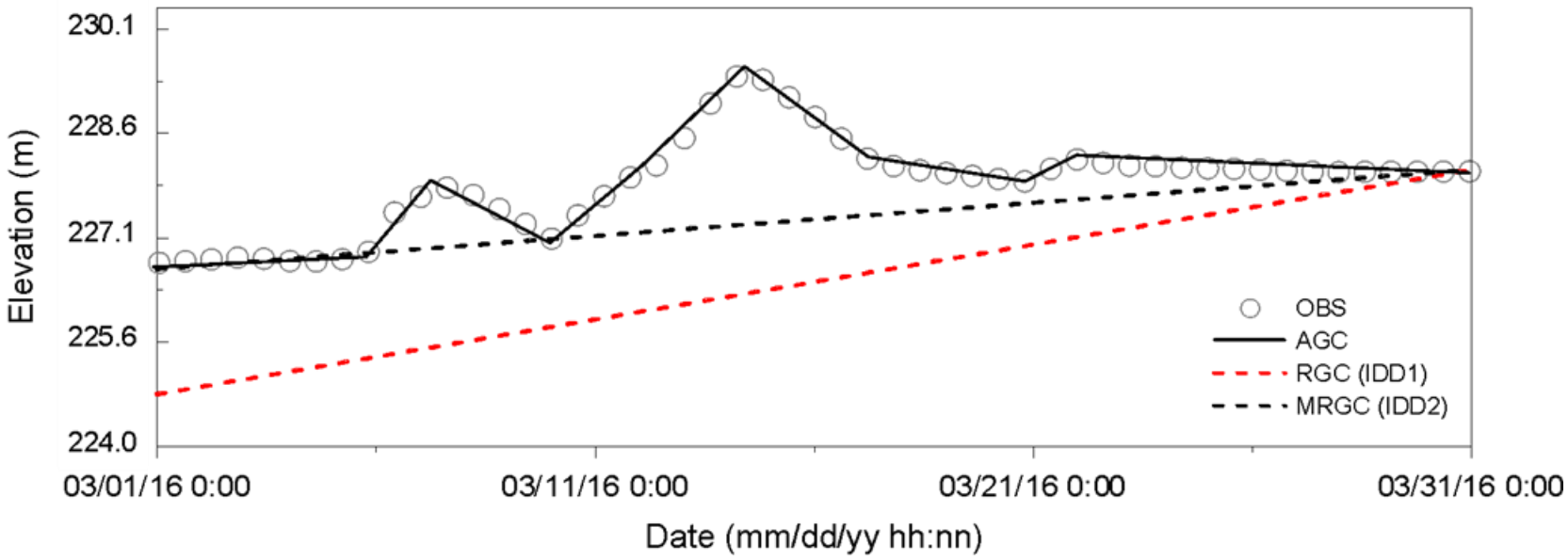
Reservoir Operations Simulation



[Evaluation of the reservoir operations simulation of the NWM-ResSim]

Applied the Approaches

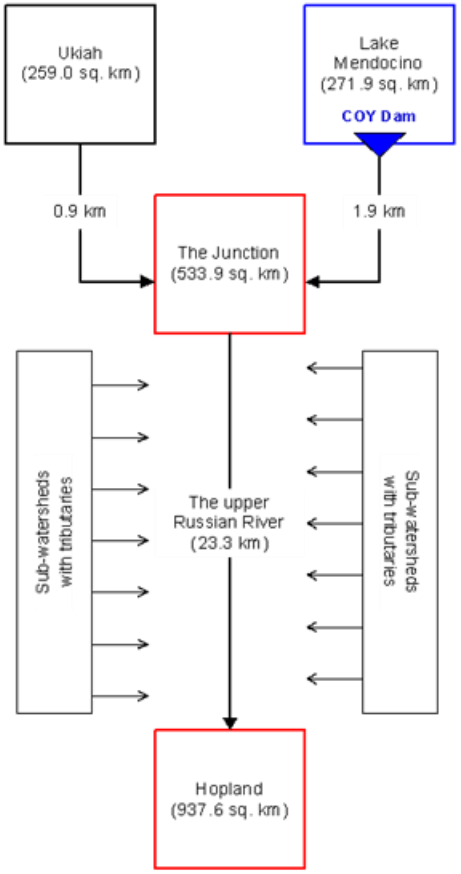
Three guide curves

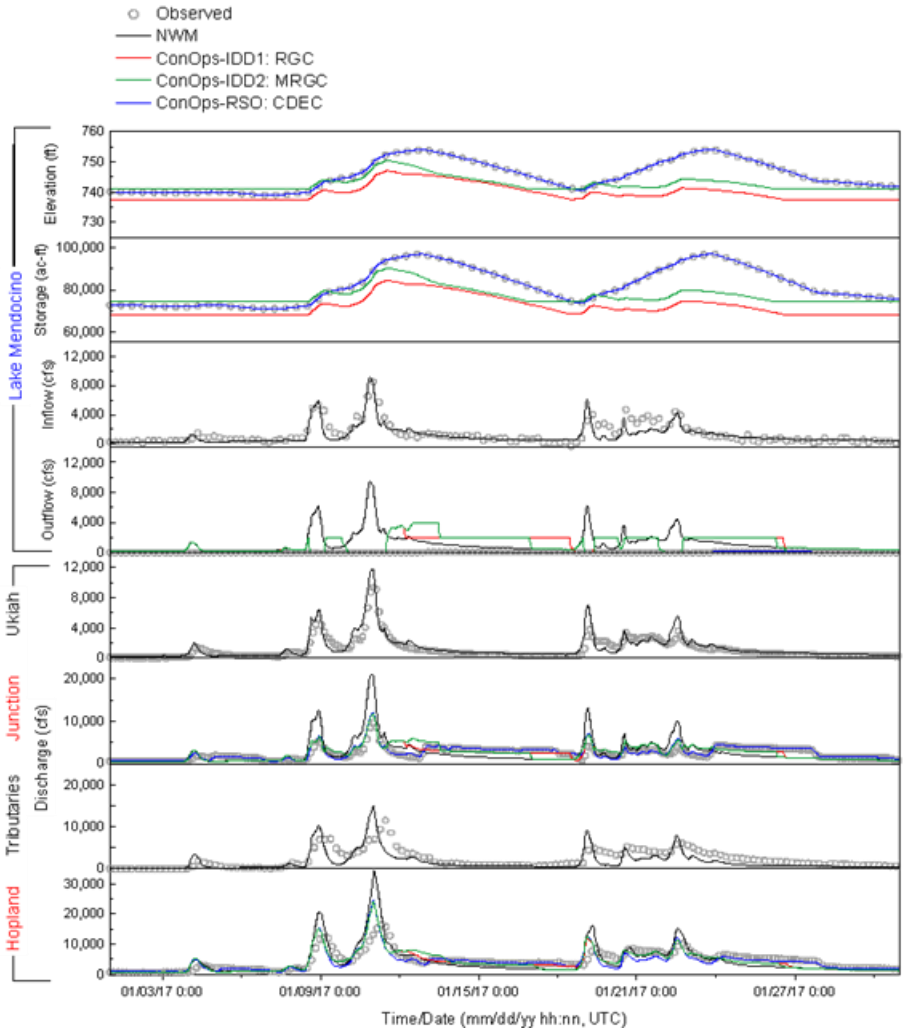


- Comparison results of the guide curves. In this figure, OBS, IDD1, IDD2, and RSO indicate the observed elevation state, the reference guide curve (RGC) from USACE (2012), the modified RGC, and the retrieval of scheduled releases (RSO).

Results

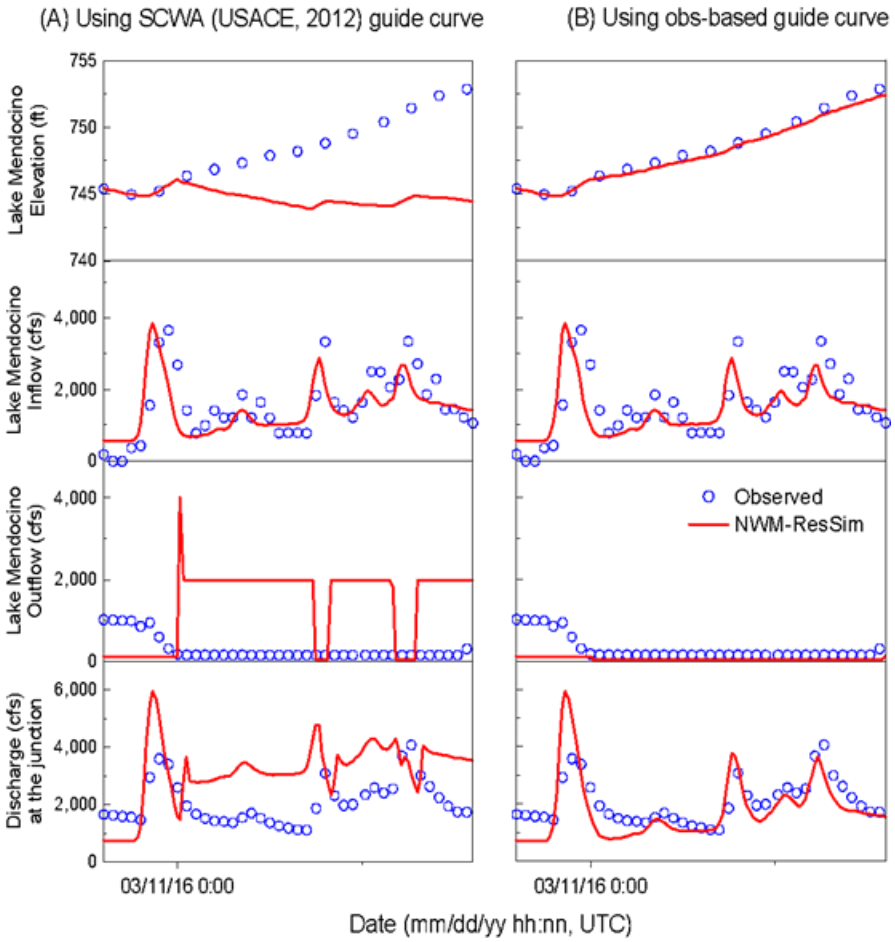
Jan. 2017



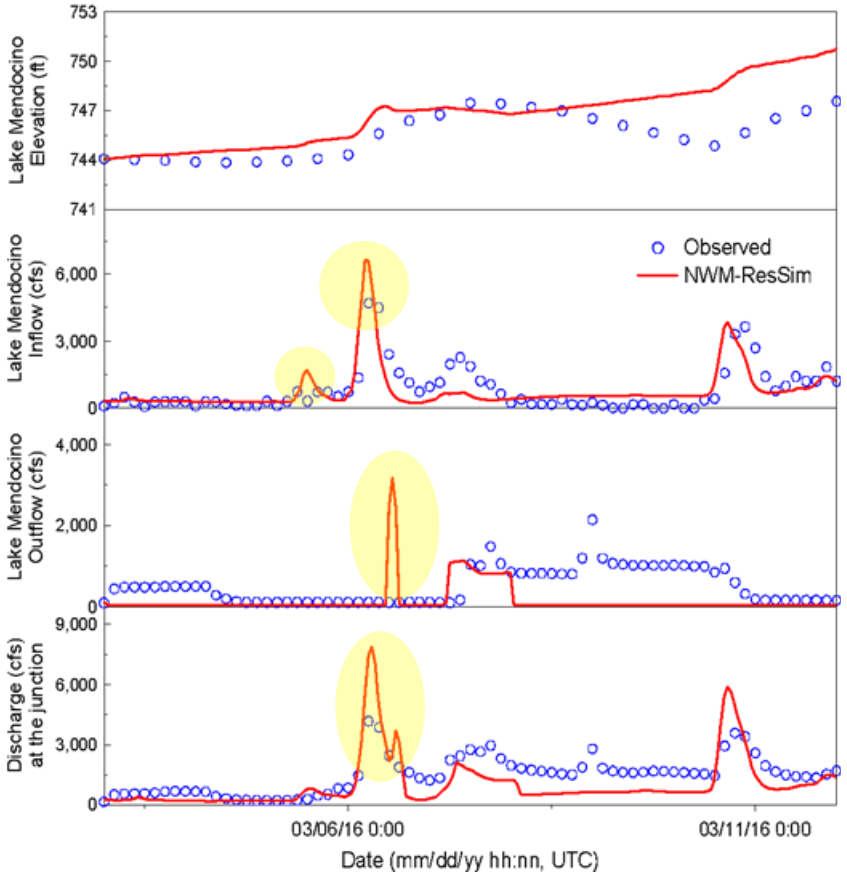


[Jan. 2017 simulation results from two approaches and the NWM]

Discussion on Uncertainty



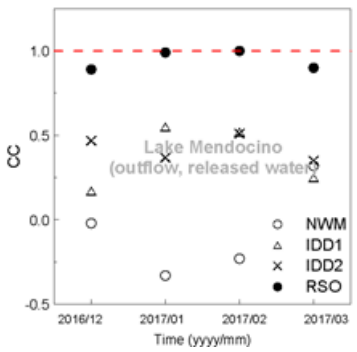
[By a guide curve]

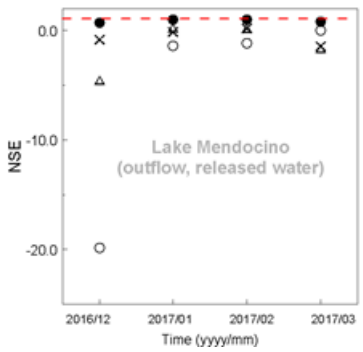


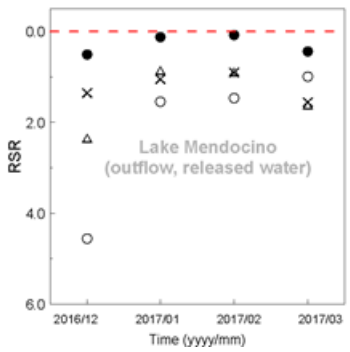
[By the accuracy of inflow]

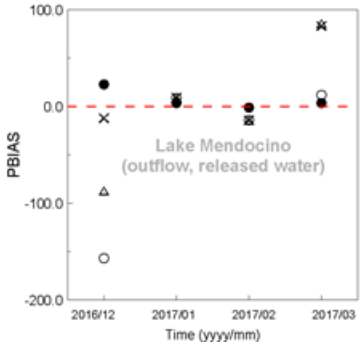
Daily-based Statistics results

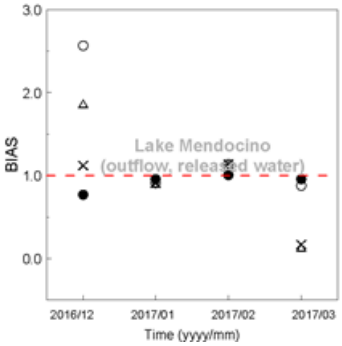
For four month (Dec. 2016-Jan. 2017)

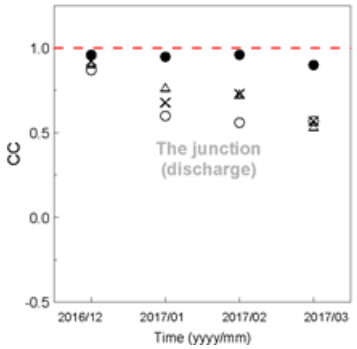


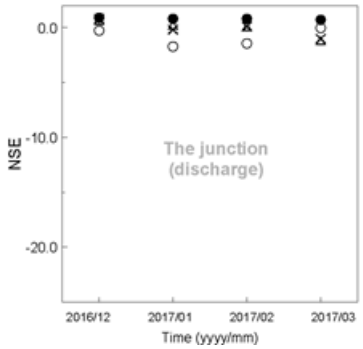


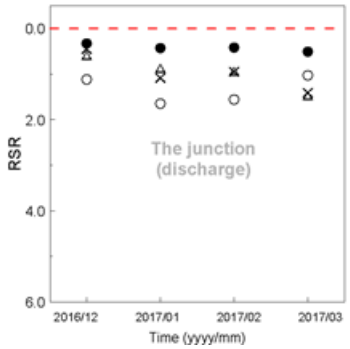


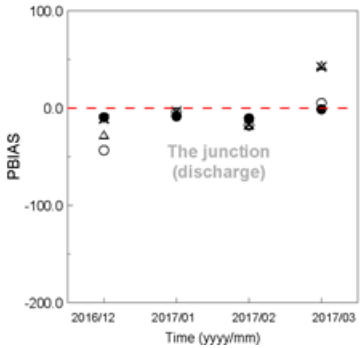


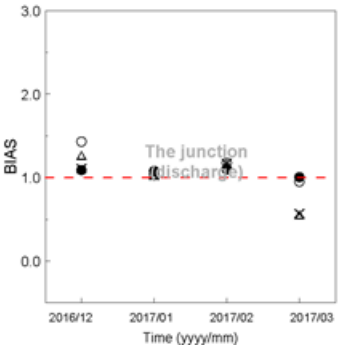


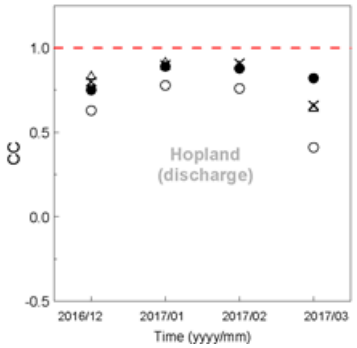


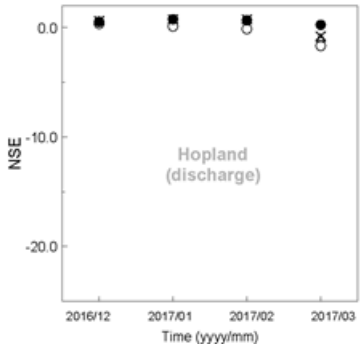


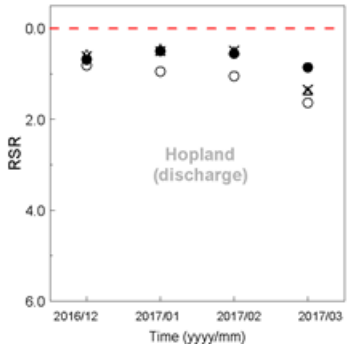


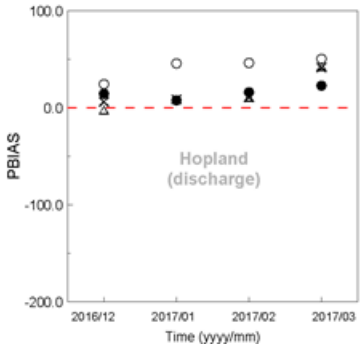


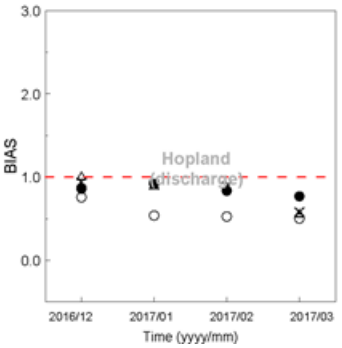






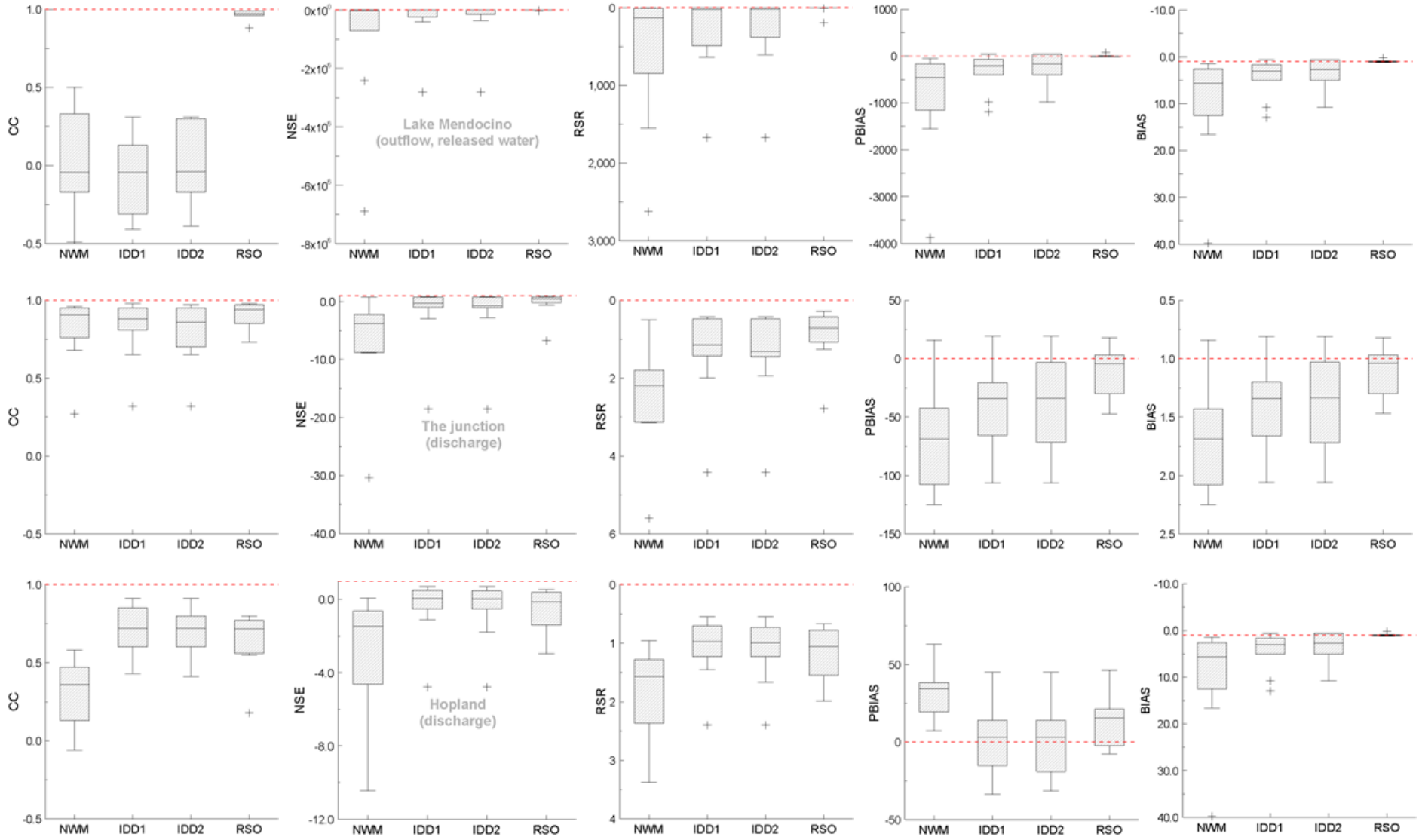






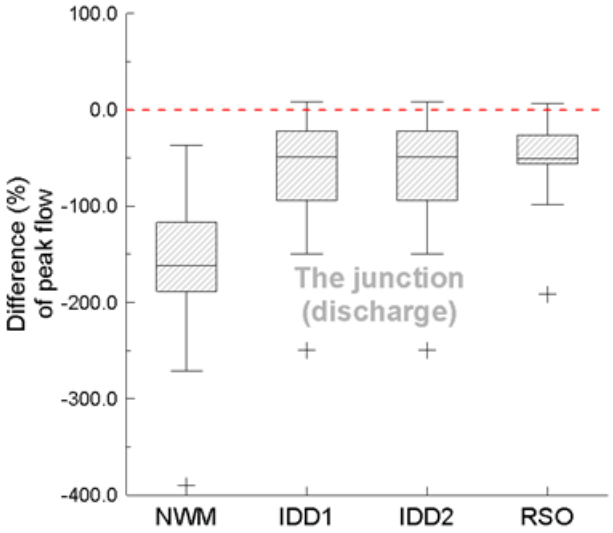
Event-based Statistics results

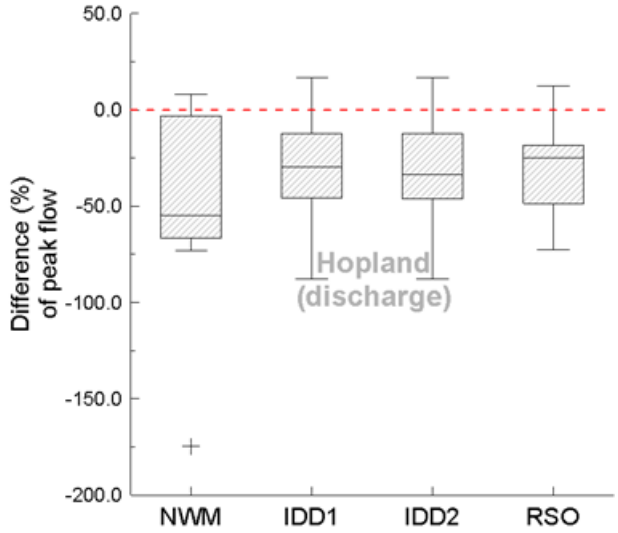
For four month (Dec. 2016-Jan. 2017)

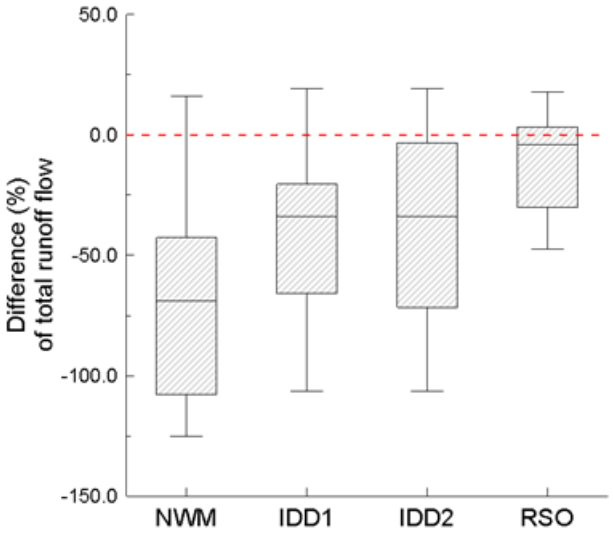


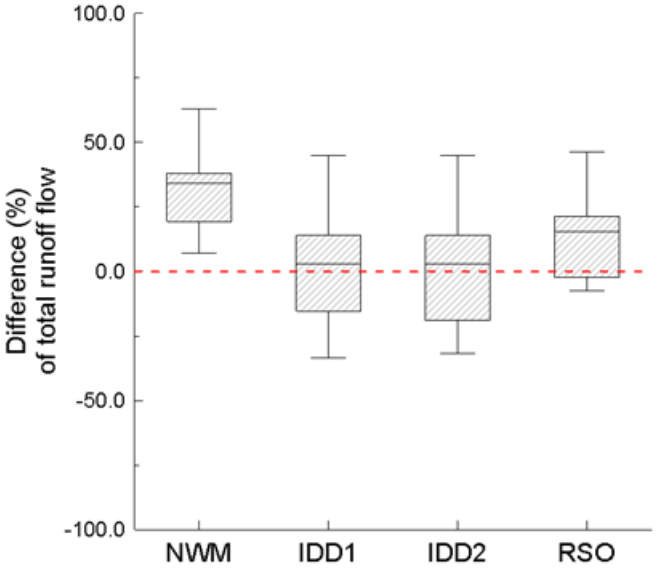
Event-based Statistics results

For four month (Dec. 2016-Jan. 2017)









Discussion on cancellation effect

- The numerical values in the table indicate the differences of total runoff volumes [(Obs – Sim)/Obs X 100 (%)] between the observed and simulated discharges. The table consists of Case A (IDD > RSO in performance) and B (IDD < RSO). In overall, it is found that there is a cancellation effect depending on the accuracy of natural flows at the tributaries.

Location	Case A				Case B			
	Event7		Event11		Event5		Event10	
	IDD	RSO	IDD	RSO	IDD	RSO	IDD	RSO
Lake Mendocino	-67.0	-4.2	-977.0	0.5	-508.8	-15.2	-219.3	0.0
Ukiah	-0.1		3.2		-37.2		-64.5	
Junction	-20.5	0.5	-50.8	3.2	-80.4	-33.0	-106.3	-47.4
Tributaries	37.2		21.1		14.7		24.0	
Hopland	9.6	21.3	-3.0	14.5	-19.0	-2.4	-31.6	-7.6

[Difference (%) of total runoff volumes between the observed and simulated]

Conclusions

The 5 Approaches

1) Assimilation of gaged release flows
   - Current NWM approach
2) Level-pool routing
   - Incorporate reservoir Elevation-Area-Storage characteristics
3) Machine learning to derive operations guidance
   - Our project showed deviations from “official” operations guides
   - Manual approach used to infer operations rules
4) Integration of NWM flows into river basin water management models
   - Many operating agencies have sophisticated management models
   - Customize inputs to accept NWM inflows required
5) Retrieval of scheduled releases provided by reservoir operators
   - Many operating agencies post scheduled releases to CDEC