Improving the Prediction of Inflow into the Major Reservoirs over the Headwater Basins of the Salt and Verde Rivers Using Noah-MP and RAPID

Sadaf Moghisi[1], Ali Behrangi[1], Mohammad A. Farmani[1], Aniket Gupta[1], Bo M Svoma[2], and Guo-Yue Niu[1]

[1] Department of Hydrology and Atmospheric Sciences, University of Arizona

[2] Salt River Project (SRP), Phoenix, Arizona

1. Introduction & Objectives

Importance: Improved the predictions of snow accumulation, snowmelt infiltration, runoff, and inflow to reservoirs is essential for effective Forecast-Informed Reservoir Operations (FIRO).

Study Area: The Salt and Verde river basins in the central Arizona.

Modeling Approach:
- Utilizes the Noah-MP land surface model with a dynamic vegetation model.
- Implements the RAPID streamflow routing model for streamflow predictions.

Model Evaluation:
- Compared model results against SMAP-derived soil moisture and freeze-thaw states.
- Validated against UA Snow Water Equivalent (SWE), USGS streamflow data, and MODIS-based Leaf Area Index (LAI).
- Used Kling-Gupta Efficiency (KGE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Pearson Correlation, and Nash-Sutcliffe Efficiency (NSE) to assess model performance.

Objectives:
- Validate Model Performance: Assess Noah-MP simulations using SMAP soil moisture, UA SWE, USGS streamflow, and MODIS LAI, with RMSE, Bias, MAE, Pearson Correlation, NSE, and KGE as evaluation metrics.
- Support Water Management: Improve FIRO for over 2 million people in the central Arizona through more reliable snow and streamflow predictions.

2. Methodology

- **Forcing Data:** The AORC dataset provides hourly near-surface atmospheric forcing, including precipitation, radiation, temperature, pressure, humidity, and wind speed, from dynamically and statistically downscaled sources (1980–2022).
- **Land Surface Model:** The Noah-MP land surface model with a dynamic vegetation model was used to simulate Snow Water Equivalent (SWE), Leaf Area Index (LAI), soil moisture, and other land surface components.
- **Streamflow Routing:** The RAPID model (David et al., 2011) routes daily streamflow across the watershed.

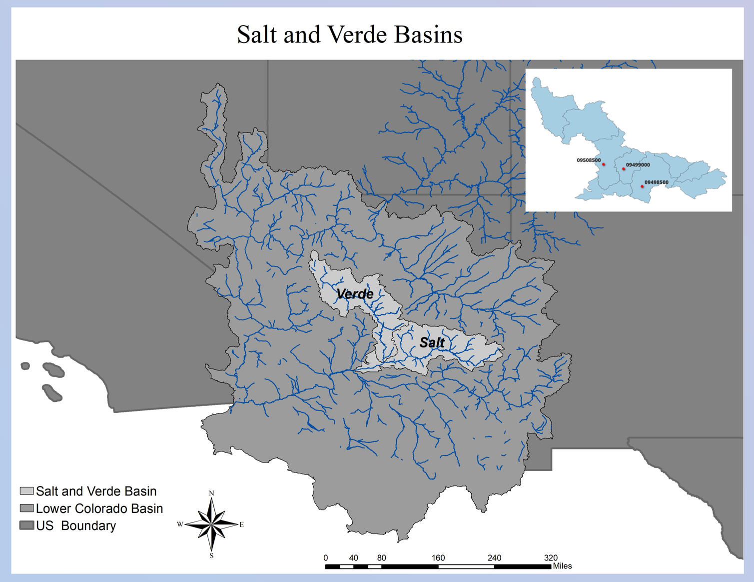

Fig. 1. Salt and Verde River Basins in central Arizona with streamflow gauge locations.

3. Results

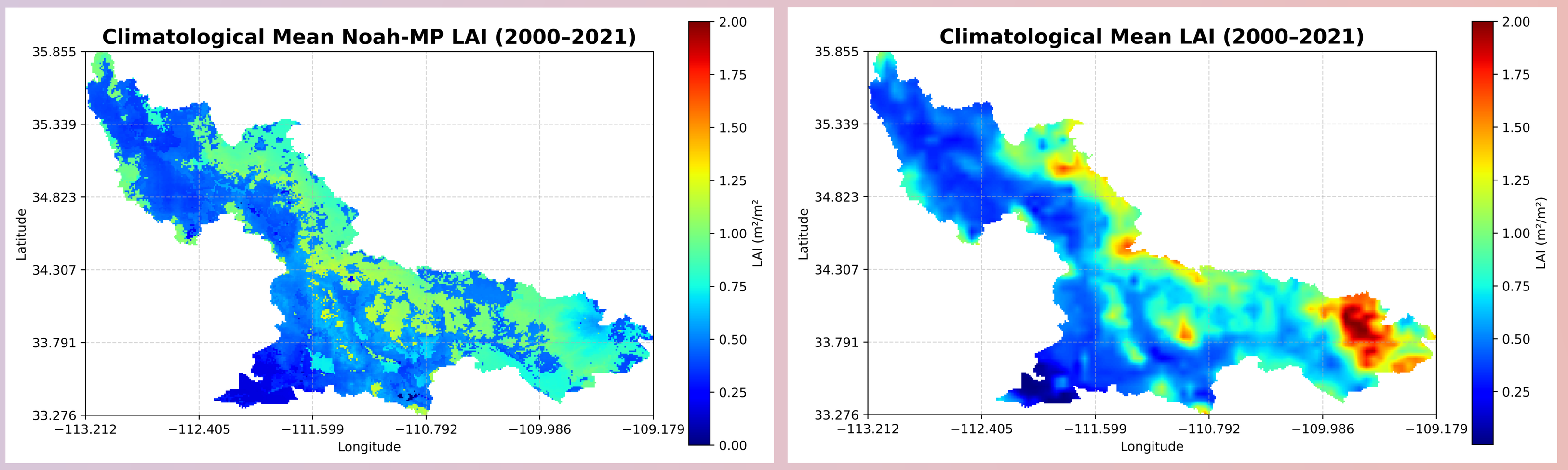

Fig. 2. Climatological mean Leaf Area Index (LAI): MODIS-based (right) and Noah-MP simulated (left).

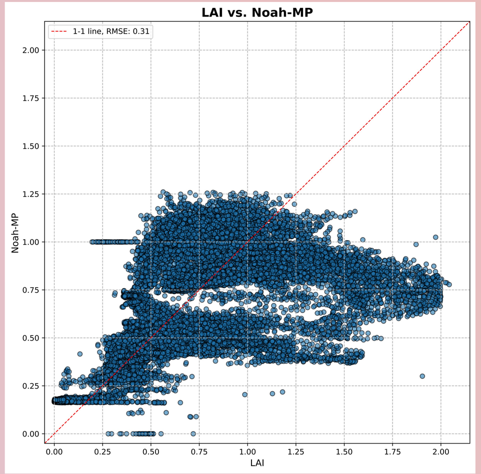

Fig. 3. Scatter plot of MODIS-based vs. Noah-MP simulated Leaf Area Index (LAI) with the 1:1 reference line and RMSE value.

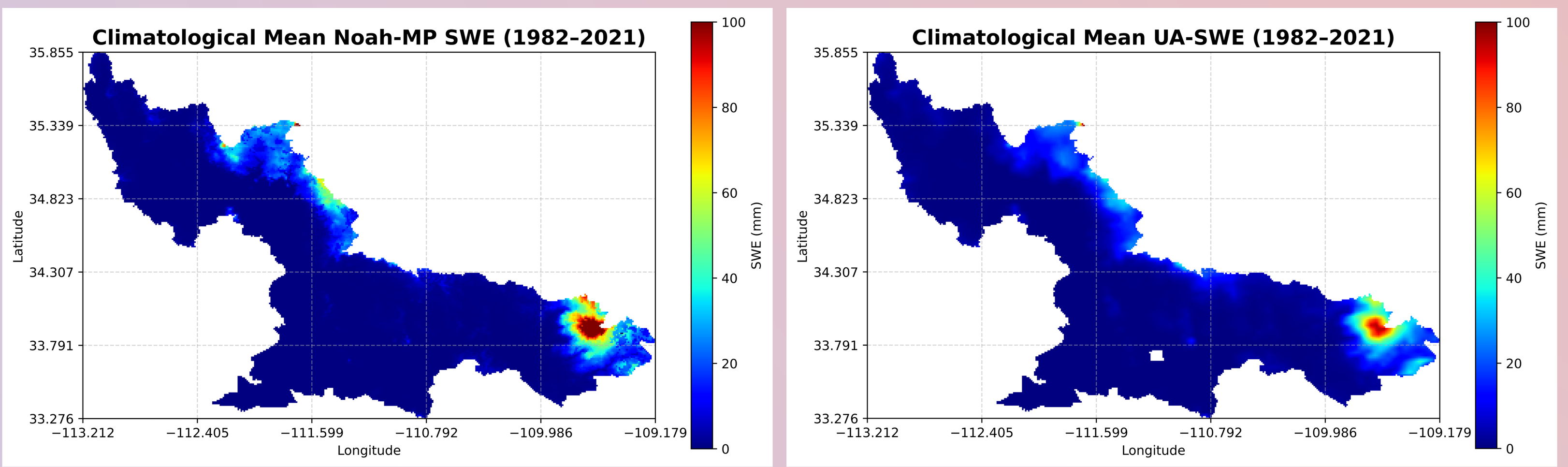

Fig. 4. Climatological mean Snow Water Equivalent (SWE): UA_SWE (right) and Noah-MP simulated (left).

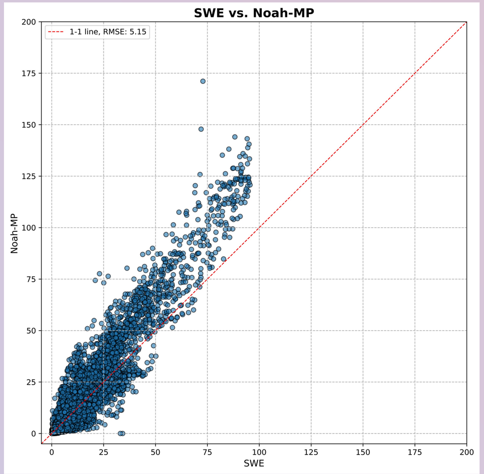

Fig. 5. Scatter plot of UA_SWE vs. Noah-MP simulated Snow Water Equivalent (SWE) with the 1:1 reference line and RMSE value.

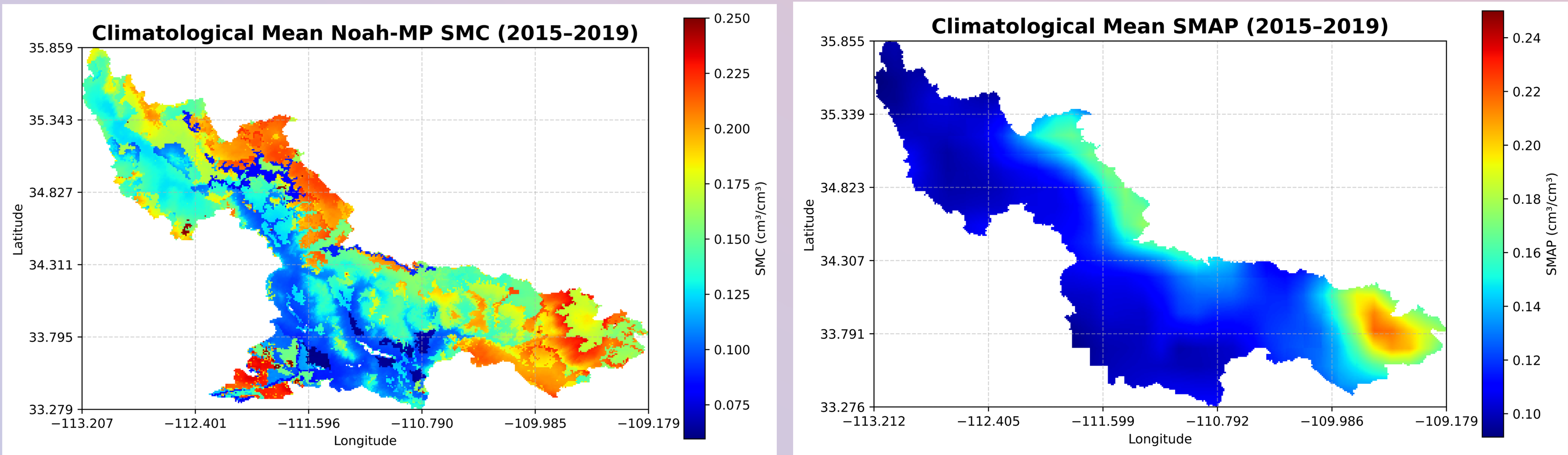

Fig. 6. Climatological mean Soil Moisture Content (SMC): SMAP (right) and Noah-MP simulated (left).

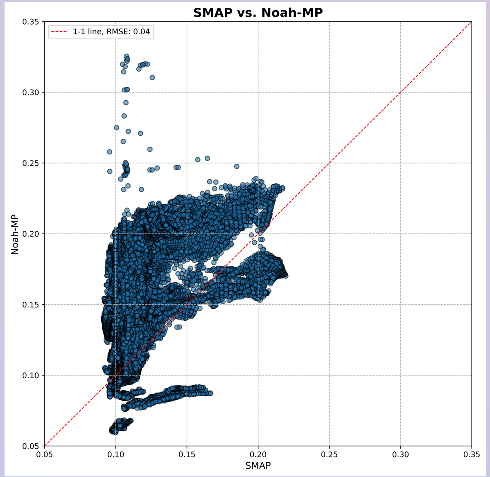

Fig. 7. Scatter plot of SMAP vs. Noah-MP simulated Soil Moisture Content (SMC) with the 1:1 reference line and RMSE value.

3. Results

Table 1. Evaluation metrics.

Metric	SWE	LAI	SMC
RMSE	5.1475	0.3103	0.0435
MAE	1.815	0.2069	0.0353
Correlation	0.9534	0.5437	0.5709
NSE	0.7569	0.239	-1.4726

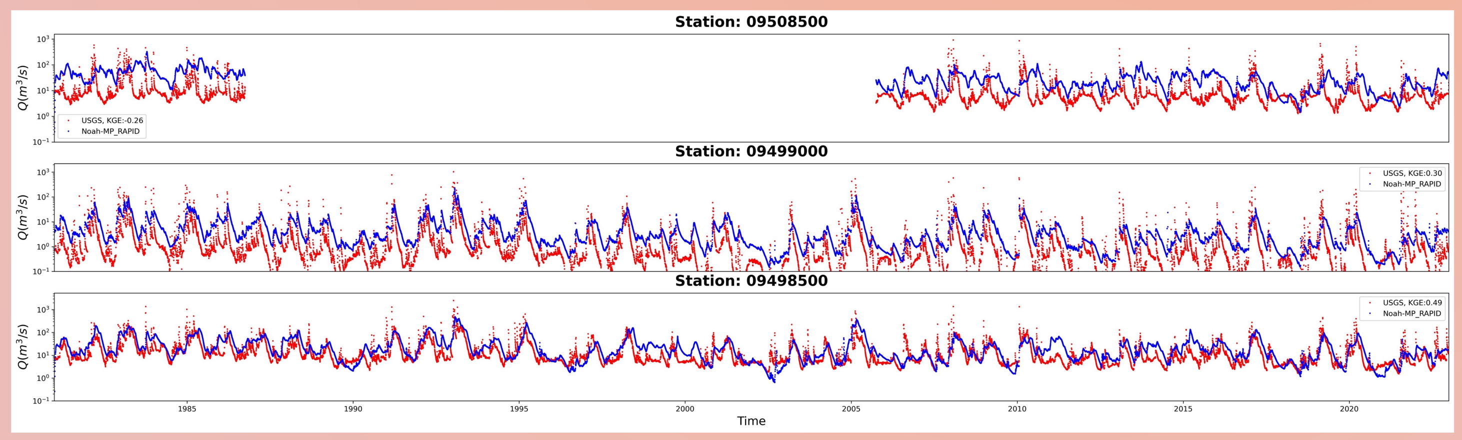

Fig. 8. The model predicted daily streamflow vs. USGS gauge measurements from 1981 – 2022

4. Conclusion

- The overall pattern in model streamflow and USGS streamflow time series is similar, indicating that the model captures the general trend of the observed streamflow.
- The spatial patterns of Leaf Area Index (LAI), Snow Water Equivalent (SWE), and Soil Moisture Content (SMC) are consistent between the datasets, reinforcing the model's ability to replicate large-scale distributions.
- Among the variables analyzed, SWE is the best-performing variable, exhibiting high correlation and Nash-Sutcliffe Efficiency (NSE), indicating strong predictive skill.
- The Noah-MP model tends to overestimate SMC, runoff generation, and streamflow.
- Conversely, Noah-MP underestimates LAI, which results in the model allocating more precipitation to runoff rather than evapotranspiration, ultimately contributing to overestimated streamflow.
- At gauge 09498500, the model produces the highest KGE, indicating the best model performance. The selected gauges are minimally affected by upstream dams, ensuring streamflow reflects natural hydrological processes.

5. Future Work

- Apply a differential, learnable, parsimonious version of Noah-MP that facilitates differentiable parameter learning (dPL).
- Enhancing snow, runoff, and streamflow predictions using machine learning-based differentiable parameter learning (dPL).
- Optimizing spatially-varying parameters to improve the model performance.
- Evaluating the model performance on snow, ET, and streamflow predictions and overall hydrological modeling accuracy.

Acknowledge: This study is funded by the Salt River Project (SRP).