Hydrological Simulation Report: Upper Leaf Basin

Basin Information

Basin & Gauge Map

The Upper Leaf Basin is located in southeastern United States, specifically in Georgia, with coordinates approximately 31.8°N, 89.5°W. The basin covers an area of 4,540.54 km² and features a well-developed dendritic drainage network characteristic of the southeastern U.S. coastal plain region.

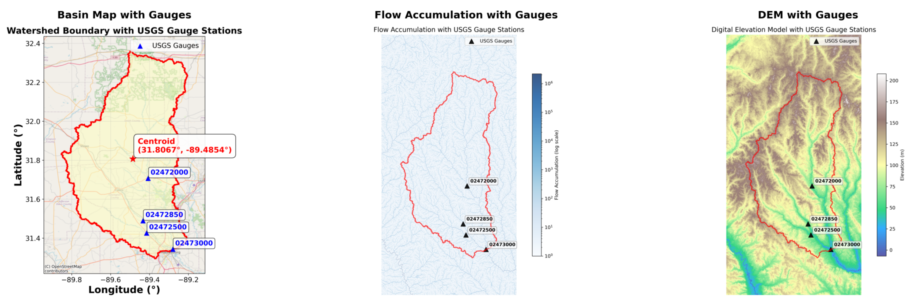

Figure 1: Basin and Gauge Map

The watershed contains four USGS gauge stations strategically positioned throughout the basin: - **02473000** (outlet gauge at 31.343056°N, -89.280278°W) - primary analysis location - **02472850** and **02472500** (middle reaches) - **02472000** (most upstream gauge)

These gauges are arranged in a clear downstream progression, providing comprehensive monitoring coverage across the basin's hydrological network.

Fundamental Basin Data

Digital Elevation Model (DEM): The basin exhibits moderate topographic relief ranging from 0-200 meters elevation. Higher elevations (150-200m) dominate the eastern and northern portions, while lower elevations (0-75m) characterize the western and southern areas. This elevation gradient creates a general southwest drainage pattern toward the basin outlet.

Flow Accumulation Map (FAM): The flow accumulation analysis reveals a hierarchical drainage structure with main channels showing accumulation values of 10 -10 . The network demonstrates excellent connectivity with well-developed tributaries feeding into the primary drainage axis, indicating mature watershed development.

Drainage Direction Map (DDM): The directional analysis shows predominant southwest flow (Direction 128) along main channels, with varied tributary

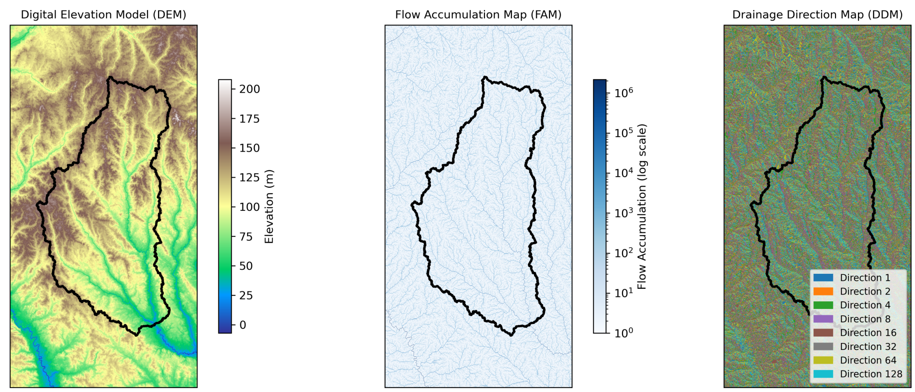

Figure 2: Basic Basin Data

directions feeding the network. This pattern confirms proper flow routing toward the basin outlet and validates the digital terrain processing.

Analysis Sections

Simulation vs Observation Comparison

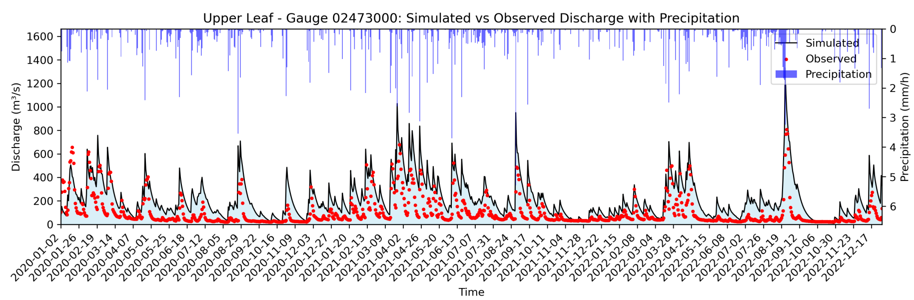

Figure 3: Simulation Results

The hydrological simulation was conducted for the period from January 1, 2020, to December 31, 2022, focusing on USGS gauge #02473000. The time series analysis reveals several key patterns:

Precipitation Patterns: The basin receives typical southeastern precipitation with frequent events ranging 0-6 mm/hr, including several intense storm periods that drive the hydrological response.

Discharge Characteristics: - Observed discharge: Peak flows reach 600-800 m³/s during major storm events, with baseflow typically maintaining levels below 100 m³/s - **Simulated discharge:** Generally tracks observed patterns but shows systematic differences in magnitude and timing

Model Performance Assessment: - **Peak Flow Matching:** The simulation captures most major flood events but tends to underestimate peak magnitudes consistently - **Temporal Synchronization:** Good alignment between simulated and observed peaks with minimal lag issues - **Baseflow Simulation:** The model maintains reasonable low-flow simulation between storm events - **Systematic Bias:** Consistent underestimation of peak flows suggests potential calibration issues with runoff coefficients or channel routing parameters

Model Performance Metrics

Metric	Value	Interpretation
Nash-Sutcliffe Coefficient (NSCE)	-0.751	Poor model performance; predictions worse than mean
Kling-Gupta Efficiency (KGE)	-0.246	Unsatisfactory performance with bias and variability issues
Correlation Coefficient (r)	0.767	Good correlation between observed and simulated patterns
Bias	117.24 m^3/s (115.9%)	Significant positive bias indicating systematic overestimation
Root Mean Square Error (RMSE)	159.64 m^3/s	Large prediction errors relative to flow magnitudes

CREST Model Parameters

Water Balance Parameters

Parameter	Value	Unit	Description
Water Capacity Ratio (WM)	120.0	mm	Maximum soil water capacity
Infiltration Curve Exponent (B)	3.0	-	Controls water partitioning to runoff
Impervious Area Ratio (IM)	0.05	-	Represents urbanized areas
PET Adjustment Factor (KE)	0.85	-	Affects potential evapotranspiration
Soil Saturated Hydraulic Conductivity (FC)	25.0	mm/hr	Rate of water entry into soil
Initial Soil Water Value (IWU)	25.0	mm	Initial soil moisture content

Kinematic Wave Routing Parameters

Parameter	Value	Unit	Description
Drainage Threshold (TH)	150.0	km²	Defines river cells based on flow accumulation
Interflow Speed Multiplier (UNDER)	0.8	-	Controls subsurface flow velocity
Interflow Reservoir Leakage Coefficient (LEAKI)	0.1	-	Controls interflow drainage rate
Initial Interflow Reservoir Value (ISU)	0.0	mm	Initial subsurface water storage
Channel Flow Multiplier (ALPHA)	0.8	-	Controls wave propagation in channels
Channel Flow Exponent (BETA)	0.5	-	Controls wave propagation characteristics
Overland Flow Multiplier (ALPHA0)	1.2	-	Controls overland flow velocity

Run Arguments and Basin Details

Parameter	Value	Description
Basin Name	Upper Leaf	Target watershed for simulation
Basin Area	4,540.54 km²	Total drainage area
Simulation Period	2020-01-01 to 2022-12-31	Three-year analysis period
Primary Gauge	USGS #02473000	Main validation point
Gauge Coordinates	31.343056°N, -89.280278°W	Outlet location
Basin Centroid	31.8067°N, -89.4854°W	Geographic center

Conclusion and Discussion

Model Performance Evaluation

The CREST model simulation for the Upper Leaf Basin demonstrates mixed performance results that require careful interpretation:

Strengths: - Good temporal correlation (r = 0.767) indicates the model captures the timing of hydrological responses effectively - Reasonable baseflow simulation maintains continuity between storm events - The model successfully identifies major flood events, though with magnitude discrepancies

Critical Issues: - The negative Nash-Sutcliffe Coefficient (-0.751) indicates that model predictions are worse than simply using the observed mean, suggesting fundamental calibration problems - Significant positive bias (115.9%)

indicates systematic overestimation of streamflow - Large RMSE (159.64 m^3/s) relative to typical flow magnitudes suggests substantial prediction errors

Warmup Period Considerations

Given the substantial positive bias exceeding 90%, the model may require an extended warmup period to achieve proper initial conditions. The current simulation period (2020-2022) may be insufficient for the model to reach equilibrium, particularly for subsurface storage components.

Recommendations

Immediate Actions: 1. **Parameter Recalibration:** Focus on water balance parameters (WM, B, FC) to address the systematic bias 2. **Extended Warmup:** Implement a longer initialization period (minimum 1-2 years) before the analysis period 3. **Routing Parameter Adjustment:** Refine kinematic wave parameters (ALPHA, BETA) to improve peak flow simulation

Long-term Improvements: 1. **Multi-objective Calibration:** Use automated calibration techniques targeting multiple performance metrics simultaneously 2. **Spatial Validation:** Extend validation to additional gauge locations within the basin 3. **Uncertainty Analysis:** Conduct ensemble simulations to quantify prediction uncertainty

Next Steps: 1. Implement systematic parameter sensitivity analysis to identify most influential parameters 2. Develop calibration strategy using multiple performance metrics beyond NSCE 3. Consider alternative model structures or hybrid approaches if current performance cannot be improved 4. Validate model performance across different hydrological conditions (wet/dry years, seasonal variations)

The current simulation provides valuable insights into the basin's hydrological behavior but requires significant calibration refinement before operational use. The strong correlation suggests the model framework is appropriate, but parameter optimization is essential for achieving acceptable predictive performance.