Process-oriented SWMM Real-time Correction and Urban Flood Dynamic Simulation

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Objectives

In order to dynamically simulate urban flooding during the flood process, it is essential to implement real-time correction of SWMM model parameters.

Significance

Equipping urban flood models with the capability of dynamic calibration, not only enhances the accuracy of flood process simulation but also holds significant fundamental significance in enabling more effective and precise urban flood forecasting and early warning systems.

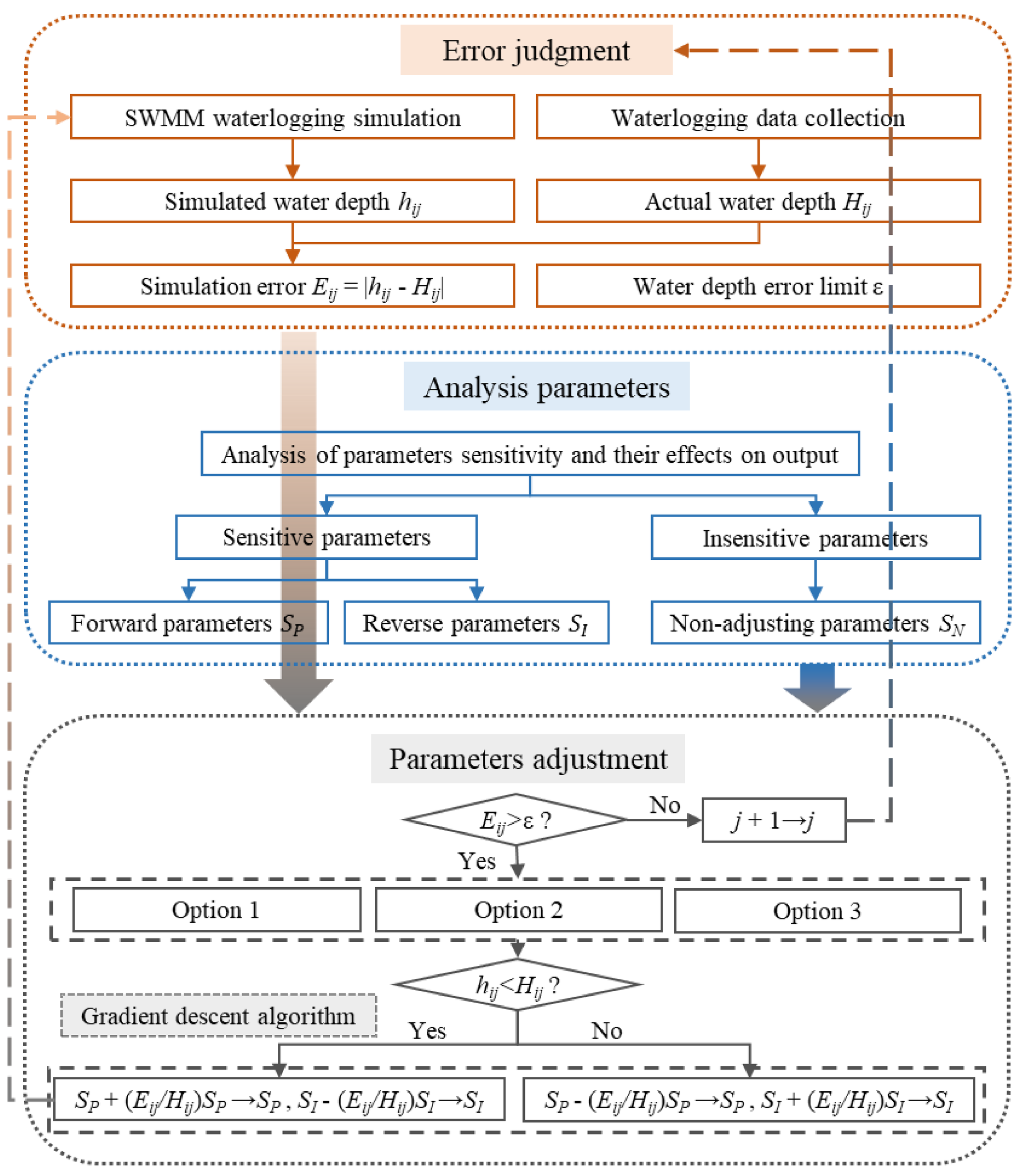

Figure 1 Technical roadmap.

● Error judgment

Determine whether the simulation error of water depth at the node exceeds the error threshold.

● Parameters analysis

Conduct an analysis on the sensitivity of parameters and designate the sensitive parameters as calibration targets.

● Parameters adjustment

Adjust the parameters and update the simulation results with the gradient descent algorithm.

Methods

Parameters sensitivity analysis

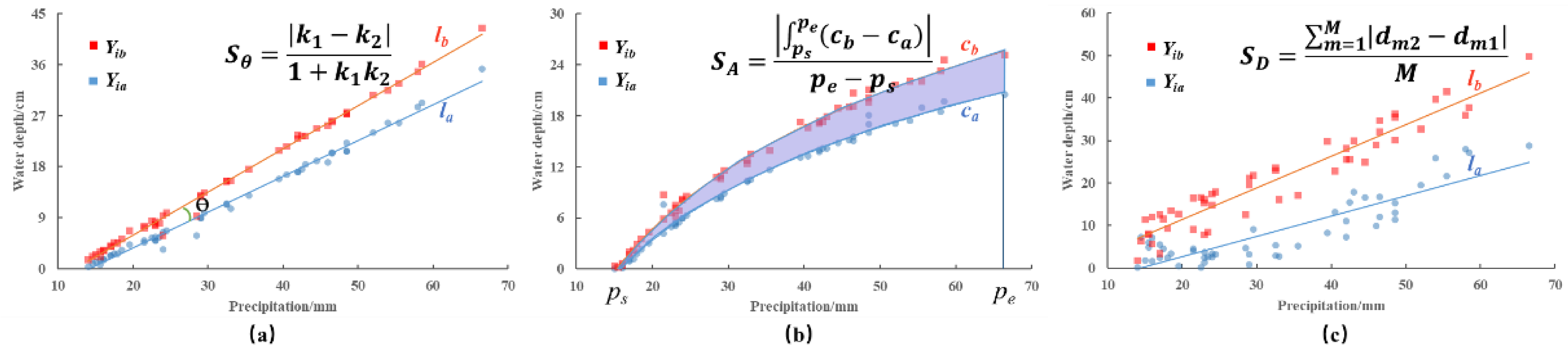

Figure 2 Schematic diagram of the improved Morris method. Parameter sensitivity is represented by the scatter plot of dispersion.

Parameters optimization algorithm

$$S_P^* = \begin{cases} S_P^+ = \begin{cases} S_P^U, & \left(h_{ij} < H_{ij},\ S_P + \frac{H_{ij} - h_{ij}}{H_{ij}} S_P \geq S_P^U\right) \\ S_P + \frac{H_{ij} - h_{ij}}{H_{ij}} S_P, & \left(h_{ij} < H_{ij},\ S_P + \frac{H_{ij} - h_{ij}}{H_{ij}} S_P < S_P^U\right) \end{cases} \\ S_P^- = \begin{cases} S_P^L, & \left(h_{ij} > H_{ij},\ S_P - \frac{h_{ij} - H_{ij}}{H_{ij}} S_P \leq S_P^L\right) \\ S_P - \frac{h_{ij} - H_{ij}}{H_{ij}} S_P, & \left(h_{ij} > H_{ij},\ S_P - \frac{h_{ij} - H_{ij}}{H_{ij}} S_P > S_P^L\right) \end{cases} \end{cases}$$

$$S_I^* = \begin{cases} S_I^+ = \begin{cases} S_I^U, & \left(h_{ij} > H_{ij},\ S_I + \frac{h_{ij} - H_{ij}}{H_{ij}} S_I \geq S_I^U\right) \\ S_I + \frac{h_{ij} - H_{ij}}{H_{ij}} S_I, & \left(h_{ij} > H_{ij},\ S_I + \frac{h_{ij} - H_{ij}}{H_{ij}} S_I < S_I^U\right) \end{cases} \\ S_I^- = \begin{cases} S_I^L, & \left(h_{ij} < H_{ij},\ S_I - \frac{H_{ij} - h_{ij}}{H_{ij}} S_I \leq S_I^L\right) \\ S_I - \frac{H_{ij} - h_{ij}}{H_{ij}} S_I, & \left(h_{ij} < H_{ij},\ S_I - \frac{H_{ij} - h_{ij}}{H_{ij}} S_I > S_I^L\right) \end{cases} \end{cases}$$

Results

The final NSE values for all three scenarios exceeded 0.8. Overall, Scenario 3 achieved the highest level of fit with the least number of parameter adjustments, making it the most effective option. The dynamic correction model does not require calibration of all runoff parameters during the rainfall-flood process. However, calibrating only the most sensitive parameters often requires more adjustments and results in poorer fitting performance.

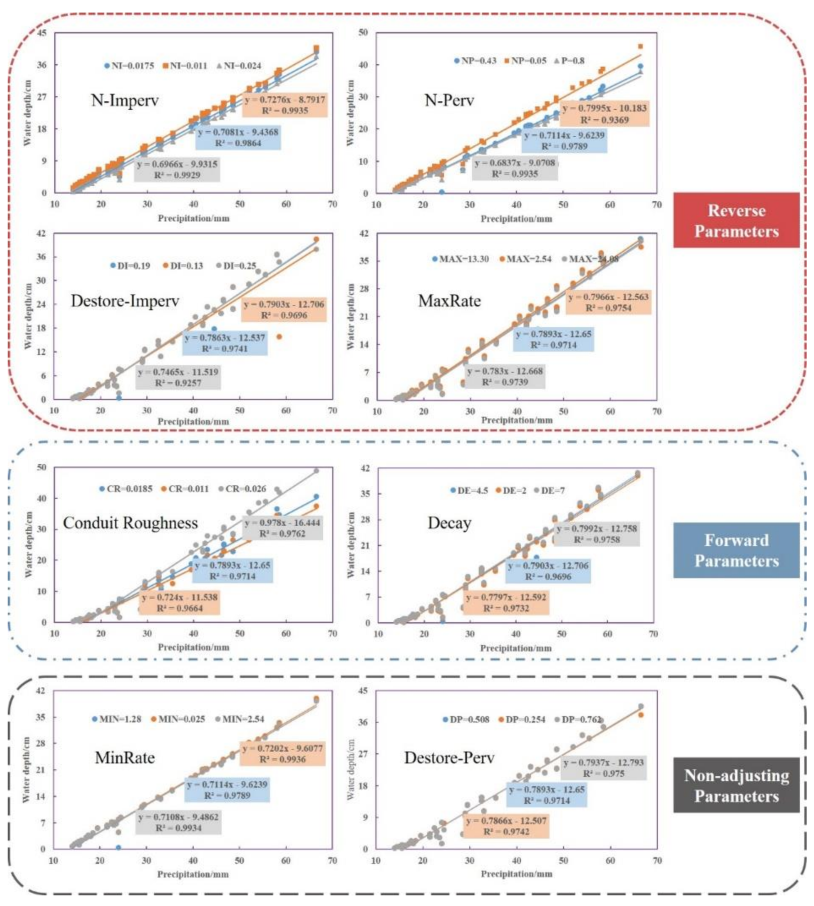

Figure 3 The results of parameter sensitivity analysis show that the angle of the fitting line increases as parameter sensitivity increases.

Conclusions

In contrast to the outcome-oriented parameter calibration, the process-oriented parameter calibration focuses on making adjustments to the model at each time step during the rainfall-flood process, rather than fitting and calibrating the entire flood process after it has concluded. This approach reduces the computational space needed for parameter optimization and enhances the efficiency of parameter calibration. When applied to urban flood simulation, this method enables real-time adjustments to the simulation results as time progresses, thereby improving the accuracy of the simulation.

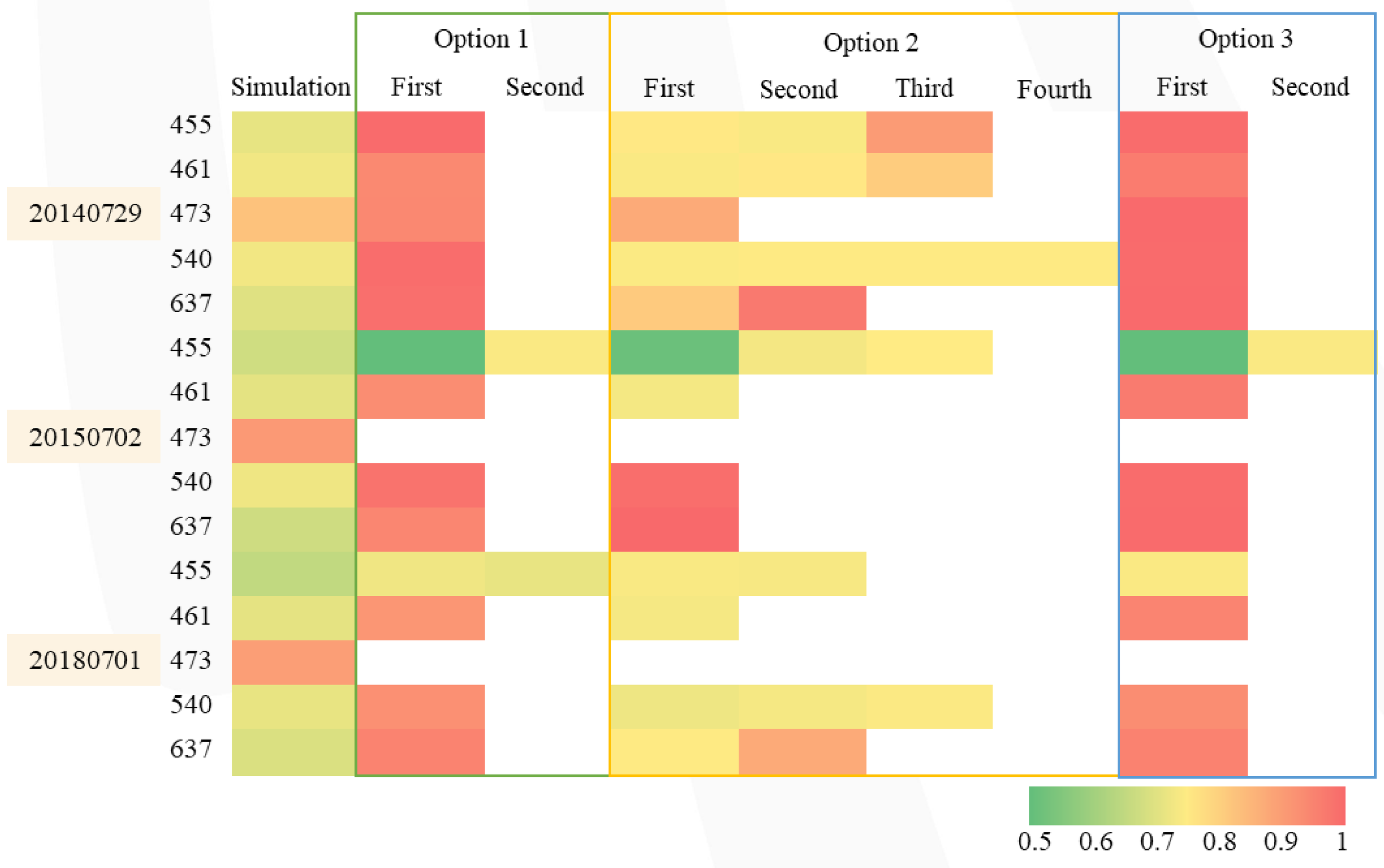

Figure 4 The NSE heat map of simulated flood results after real-time parameter calibration, with colors tending towards red indicating higher levels of fitness.

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