P47

Global-Scale Drought Risk Assessment: Application of the Surface Water-Groundwater Integrated Analysis Simulator GETFLOWS

○Souki Fukazawa, Kazuhiro Tada // sfukazawa@getc.co.jp // Geosphere Environmental Technology Corp.

Introduction

- ✓ Water risk assessment tools like Aqueduct are being user worldwide.
- ✓ Global assessment tools have limitations in quantifying risks for specific scenarios, especially the risk associated with the increase in **local** water demand.
- ✓ By extending the watershed scale approach to a global scale, this study attempts a global drought risk assessment using GETFLOWS (Tosaka et al., 2000)
- ✓ GETFLOWS is a simulator developed for analyzing the Geo-Hydrological cycle system at a watershed scale (Fig.1).

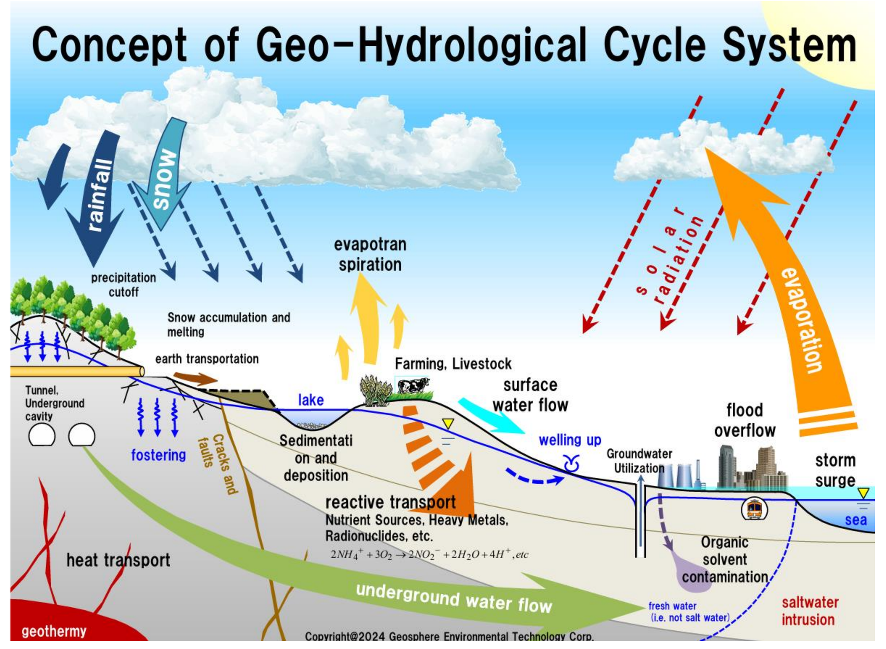

Fig.1 Concept of Geo-Hydrological Cycle System

Model Concept / Dataset

Concept

- ✓ Separating the Global dataset and Japan dataset.
- ✓ Using Open data on meteorology, topography, river network, land use, and geology.
- ✓ Aggregating and Reclassifying the geology into a number that is realistically feasible for parameter matching.
- ✓ Validating the model with river flow and dam inflow on a daily basis.
- ✓ Quickly creating a 3D water circulation model anywhere in the world by specifying the target area

Dataset

Classification	Data	Domestic Data	Overseas Data
Meteorology	Precipitation	Analytical rainfall (JMBSC/JMA)	The WFDEI Meteorological Forcing Data (Weedon et al., 2018)
	Evapotranspiration	WFDEI temperature (Calculated by Hamon method)	Synthesis of Global Actual Evapotranspiration from 1982 to 2019 (Abdelrazek et al., 2020)
Topography	Land	AALOS World 3D - 30m (JAXA/EORC)	GEBCO2022 (NOC)
	Ocean	J-EGG500(JMDC)	GEBCO2022 (NOC)
River Network		MERIT Hydro (Yamazaki et al. ,2019)	MERIT Hydro (Yamazaki et al. ,2019)
Land Use and Land Cover		AVNIR-2 High Resolution Land Use Land Cover Map (JAXA)	GLCLU_2019 (Hansen et al., 2021)
Geology		Seamless Geological Map of Japan at 1:200,000 (AIST)	World Geologic Maps (USGS)
Monitoring	river discharge	Water Information System (MLIT)	GRDC(Global Runoff Data Centre)
	dam	Database of Dams(MLIT)	GRanD v1.3 (GDW)

Calibration and Validation

Settings (about Japan Models)

Targets

- ✓ 119 river discharge or dam inflow in Hokkaido on a daily basis (8/1/2007 – 7/31/2009)
- ✓ Selected sites without dams upstream to avoid water use impacts
- ✓ Create one model per observation point
- ✓ space resolution : 500 m / time resolution : 1 day
- ✓ Within the 33 models that were engineering-judged to be explanatory in the analysis with the initial settings, 11 were used for training models and the rest for test models

Tuning parameters

- ✓ Following **12 common coefficients** for 119 models are optimized.
  - ➢ 6 permeability coefficients and 6 porosity coefficients for geological classification
  - ➢ The geological classification is divided into 6 categories based on topsoil, Quaternary, and 4 Tertiary layers, determined by calculated weathering looseness from surrounding terrain data.

Objective Function

- ✓ The commonly used indicators (MAE, NSE, KGE...) could not reproduce low water.
- ✓ non-parametric KGE (Sandra Pool, Marc Vis & Jan Seibert, 2018)
- ✓ The mean value of non-parametric KGE calculated using the flowrate(Q) and its inverse(1/Q)
- ✓ Snow accumulation and snowmelt are weighted with the weight of other periods due to the large uncertainty of weather data.
- ✓ Objective value is sum of objective functions of training models.

Optimization Methods

- ✓ Optimization Tool : Optuna (T.Akiba, et al., 2019)
- ✓ one of Bayes' theorem called Tree-Structured Parzen Estimator

Results

- ✓ Objective function : training/test models ≅ 0.60, other models ≅ 0.32.(Fig.2)
- ✓ Good reproducibility of transient analysis(Fig.3)
- ✓ Parameters at topsoil and shallow geology are dominant.

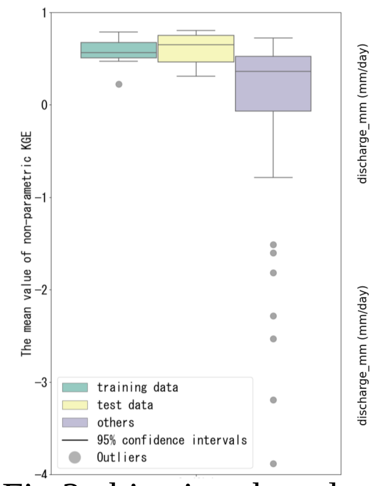

Fig.2 objectives boxplot

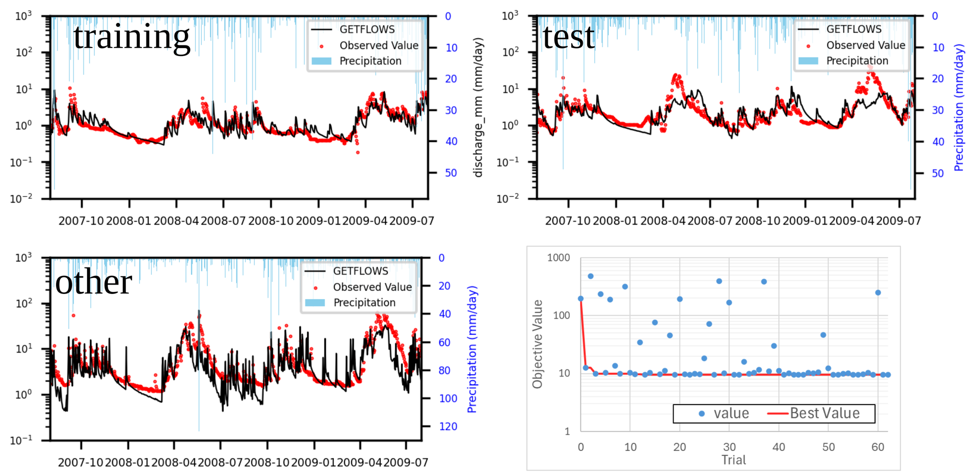

Fig.3 Examples compared with observed / optimization history

Drought Risk Assessment

Purpose

- ✓ Drought risk assessment that reflects **local** conditions
- ✓ Evaluation including dam operations to give a stable water supply throughout the year
- ✓ Future risk assessment in scenario analysis

Proposal for Dam Operation Formulation

- ✓ Variables :
  - S : Storage Volume
  - C : Storage Capacity
  - S_t : Target Storage Volume
  - I : Inflow
  - Q : Outflow
  - Q_{max} : Maximum Outflow
  - D : Demand
- ✓ Governing Equations :

$$\Delta S = I^n - Q^n = S^n - S^{n-1}$$
$$0 \le S^n \le C$$
$$D^n \le Q^n \le Q_{max}$$
$$minimize: (S^n - S_t^n)^2$$

input : C, S_t, I, Q_{max} and D
output : S and Q

Target Station and Dam

- ✓ Dam Operation : Satsunaigawa Dam in Tokachi Riv watershed(Fig.4)
- ✓ Demand : 70m³/s (0.74 mm/day) at Moiwa station(Fig.5)
- ✓ The shortfall at Moiwa is adjusted by the discharge of Satsunaigawa Dam. Based on observed values, a discharge of 2.8 m³/s is assumed in normal periods.
- ✓ Reproducibility of Satsunaigawa Dam (Fig.6).
  - ➢ NSE=0.723, KGE=0.592, npKGE=0.820, logNSE=0.711

Scenario Condition :

- ✓ All forests in the watershed(Fig. 4) are devastated, topsoil is washed away, and bedrock areas are outcropped.
- ✓ Forest topsoil permeability and Manning's roughness are modified, with all other conditions remaining the same.

Results

- ✓ The Formulation of the dam operation worked well compared to the actual data.(Fig.7)
- ✓ The reproducibility of the existing conditions analysis has a significant impact on the evaluation of dam operations.(Fig.8)
- ✓ In the existing conditions analysis, the operation of Satsunaigawa Dam ensured the required flow rate at Moiwa.
- ✓ But in the scenario, the dam storage was depleted and the required flow rate could not be secured.(Fig.9)
- ✓ Proposal of water risk index for dam operation
  - ✓ Shortage Days = 204, Total Shortage Volume=3.4x10⁸ m³

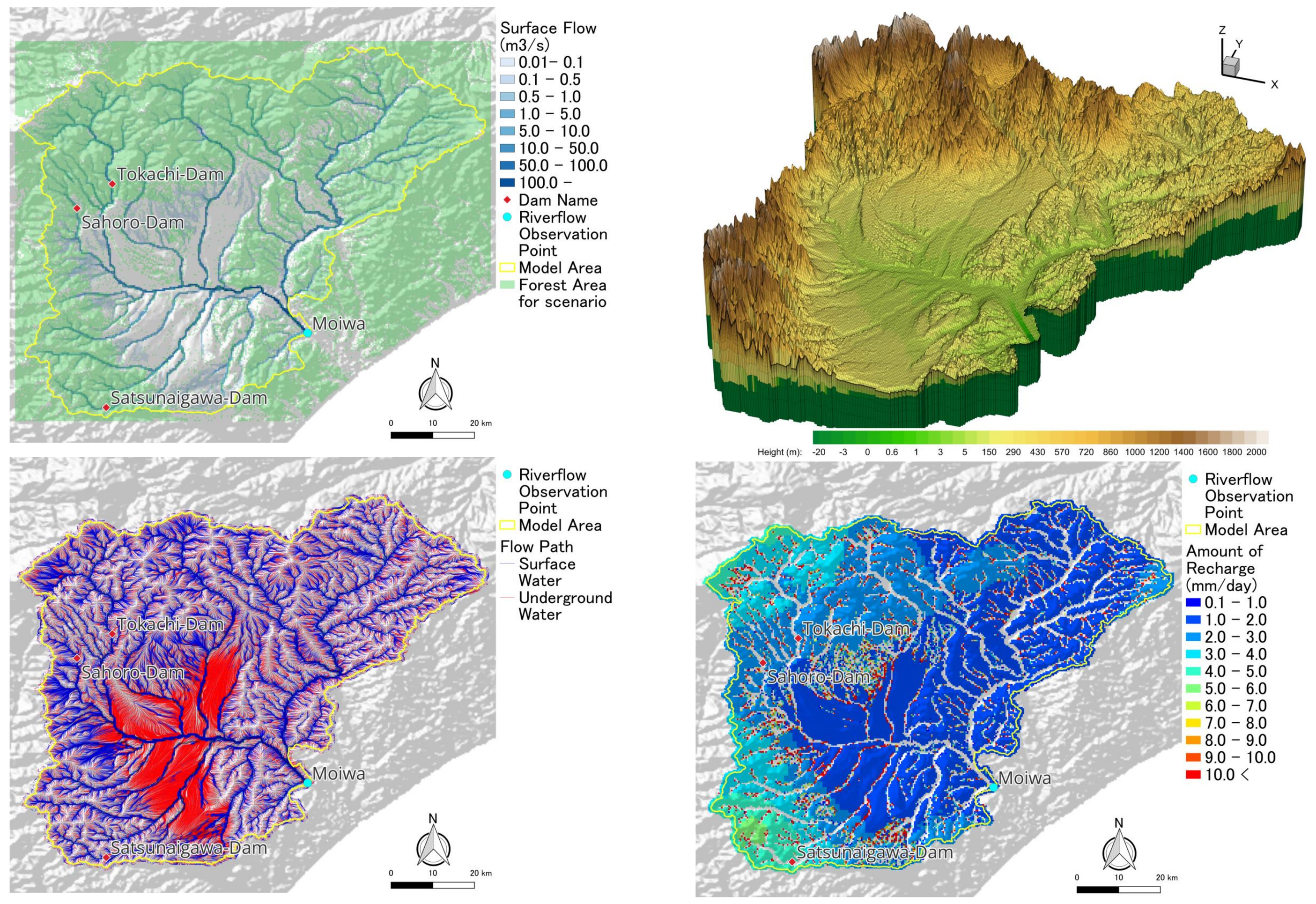

Fig.4 3D model and Results for the Tokachi River watershed using optimized parameters

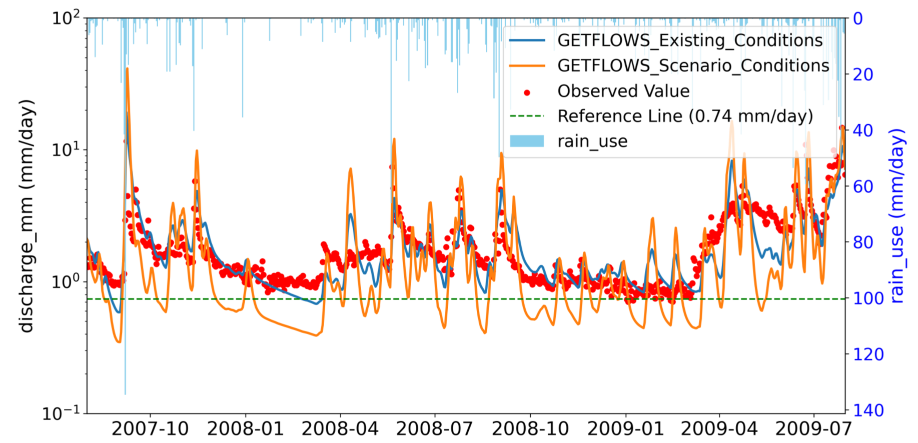

Fig.5 Discharge at Moiwa station: observed, Reproduced and Scenario Analysis

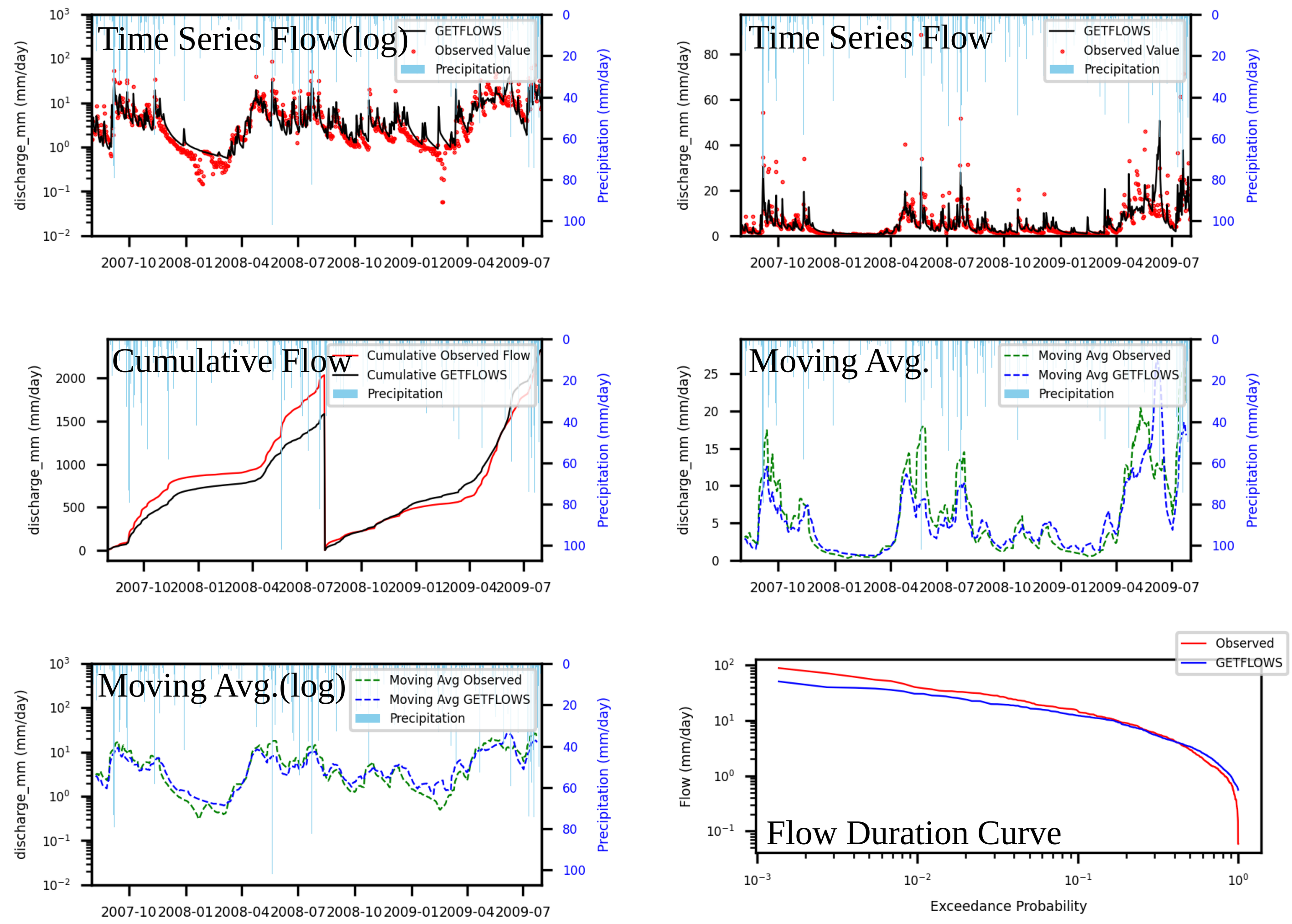

Fig.6 Comparison graphs of inflow into Satsunaigawa Dam (one of test model)

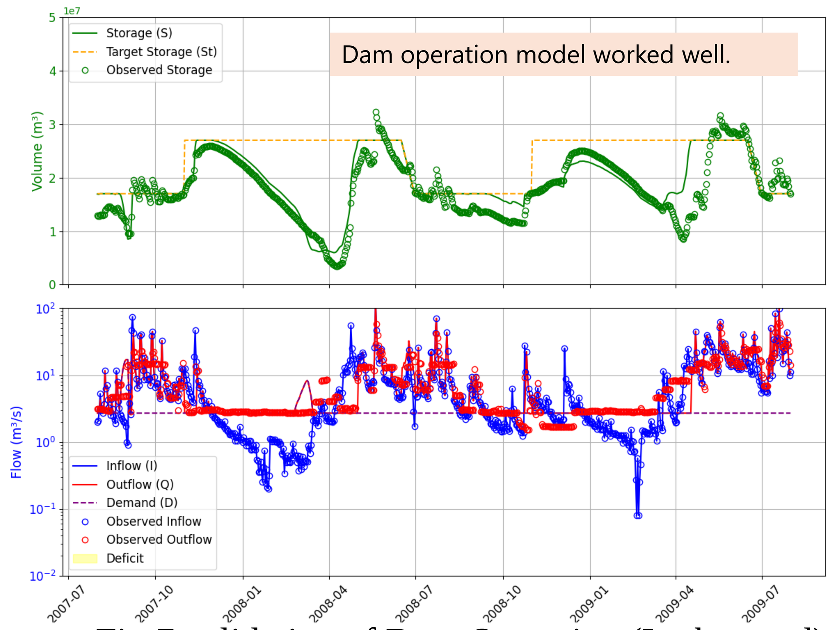

Fig.7 validation of Dam Operation (I=observed)

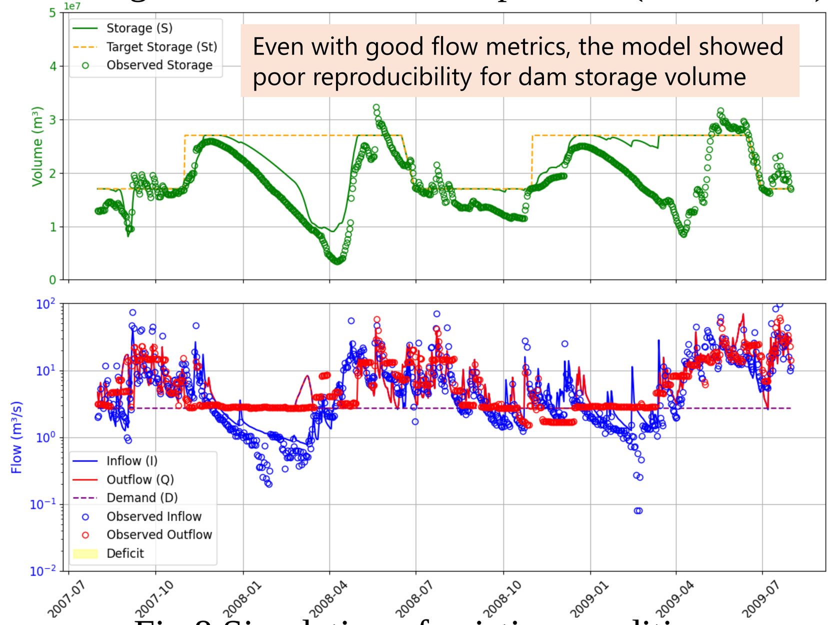

Fig.8 Simulation of existing conditions

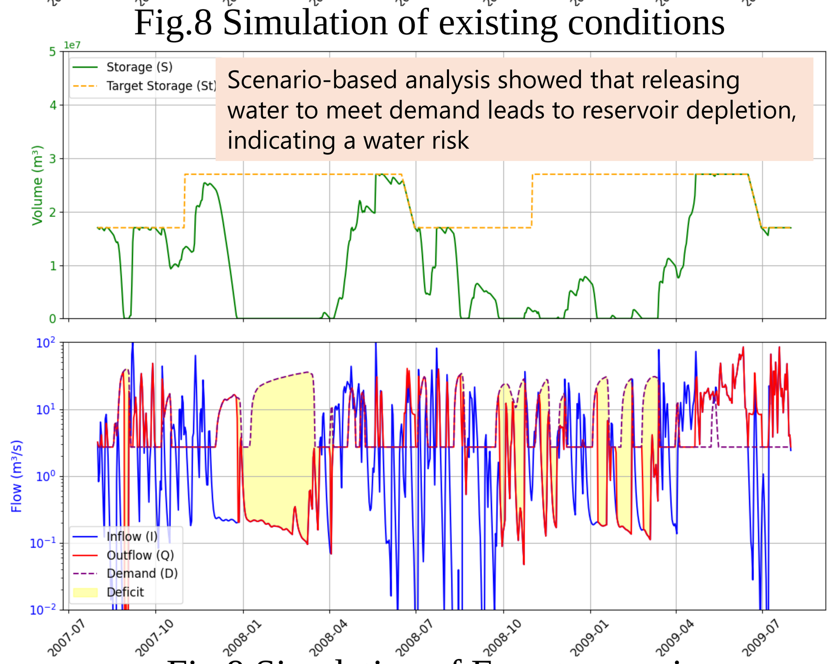

Fig.9 Simulation of Forest scenario

Conclusions

- ✓ Developed a system that can quickly create a valid 3D model of the entire globe when a region is specified.
- ✓ Proposed and validated Dam Operation Formulation.
- ✓ Established drought risk assessment methodology incorporating local information.
- ✓ Improving the accuracy of the 3D model is crucial as it can affect drought risk assessment values.

Future Plans

- ✓ Water resource assessment for multiple dams
- ✓ Water risk assessment under climate change scenarios
- ✓ Development of drought risk assessment methods through stakeholder interviews and alternative approaches

Acknowledgements : This study was implemented based on "Building a Smart Disaster Prevention Network" in Cross-ministerial Strategic Innovation Promotion Program(SIP3) by Council for Science, Technology and Innovation(CSTI).