XVIII
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Evaluation of the water security indices of multi-purpose dams in Korea based on climate stress scenarios

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Background

- Climate change is the biggest risk factor in water management, and there is an increasing demand to reflect the impact of climate change and countermeasures in the process of establishing a water management plan.
- Vulnerability of dam infrastructure due to climate change is being evaluated, but there is a limit to considering future climate change uncertainty and using decision-making tools.
- A new methodology is needed to assess the vulnerability of dam inflows to climate change without relying on historical hydrologic data, specific carbon emission scenarios, or projections of climate models.

Goals

Analysis of discharge from multi-purpose dam watersheds in South Korea under climate stress scenarios

Background

[Necessity of research]

- Although research to analyze changes in water resources due to climate change is continuously being conducted, in general GCM(Global Climate Models), which simulate climate based on greenhouse gas emission scenarios such as IPCC's RCP (Representative Concentration Pathways) contains many uncertainties(Maurer 2007).
- To supplement this, Brown et al. (2012) proposed a Decision-Scaling (DS) method.
- Decision-Scaling (DS), a procedure for identifying climate-related risks by priority using structured multi-dimensional sensitivity analysis with the establishment of a decision analysis framework.
- This is not a top-down impact assessment based on a prediction of climate change scenarios, but a bottom-up assessment of vulnerability to climate change based on sensitivity analysis for a wide range of climate conditions through pre-selected evaluation indicators.

➡ Therefore, after creating a climate stress test scenario considering changes in rainfall and temperature in a multi-purpose dam basin, we will use it as input data for a long-term runoff model to evaluate which factors each dam is more sensitive to.

Study area and dataset

[Study area]

- There are four water systems in Korea. Accordingly, one dam for each water system was selected.

→ Han river : Chungju Dam, Geum river : Yongdam Dam
Nakdong river : Hapcheon Dam, Seomjin river : Seomjingang dam

[Dataset]

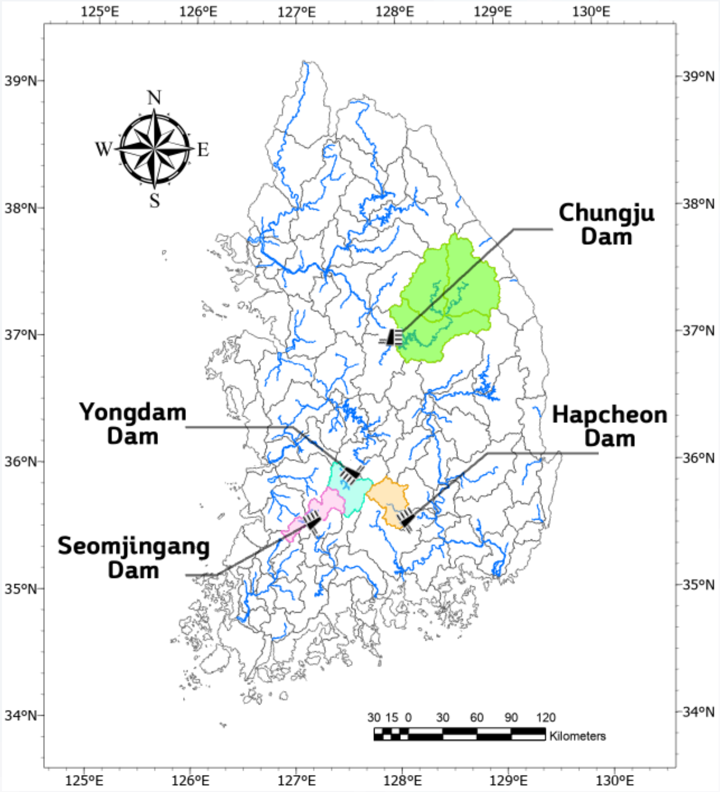
- Meteorological data(daily)

✓ rainfall(mm/day)

✓ Temperature(℃)

✓ Discharge(m^3/sec)

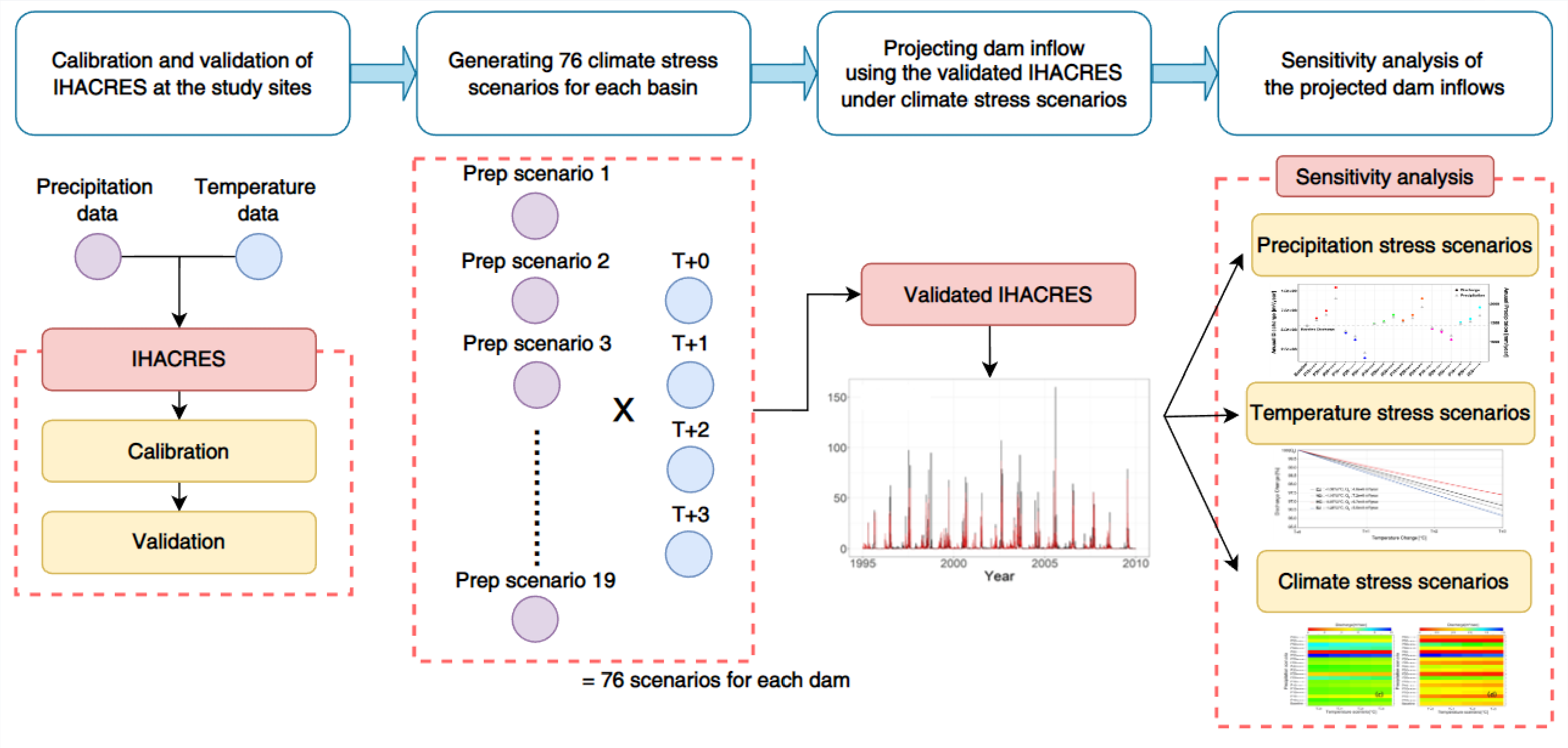
- Data for 20 years from 1995 to 2014 were used. In the case of Yongdam Dam, data from 2001 after the completion of construction were used.
- Rainfall and temperature data were used by averaging the space with the Thiessen network of the target basin.



<Study sites used in this study>

Methodology

[Overall Procedure]

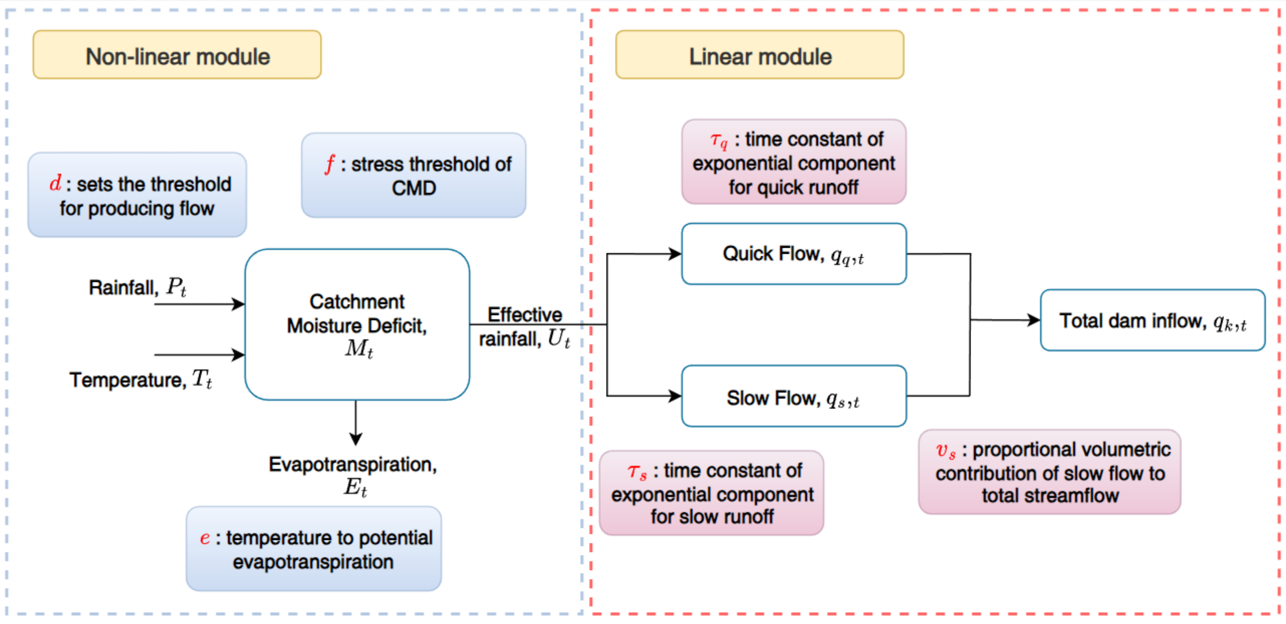


<Scheme for DS(Decision-Scaling) procedures used in this study>

Methodology

[Long term runoff models]

- The IHACRES (Identification of unit Hydrographs And Component flows from precipitation) model, which was first presented by Jakeman (1990), was used to simulate the dam inflow.
- It is a model designed to have the advantages of a physical model and a conceptual model that requires a small amount of input and has the advantage of testing multiple scenarios with open-source code.



<Schematic diagram of IHACRES and 6 parameters used in this study (Modified from Evans 2003>

Methodology

[Climate stress scenarios generation method]

- Changes in monthly precipitation in each precipitation scenario were calculated by dividing the 4 quartiles according to the rank, and the change in dam inflow was analyzed by preparing seven scenarios including the baseline by setting the rainfall increase and decrease rates for each quartile to 10/20/50%.

Scenarios	Quantile Rank				Symbolic expression
	UH(Upper High)	MH(Middle High)	ML(Middle Low)	LL(Lower Low)	
Baseline	-	-	-	-	P××××
1	+10/20/50%	+10/20/50%	+10/20/50%	+10/20/50%	P++++
2	-10/20/50%	-10/20/50%	-10/20/50%	-10/20/50%	P----
3	-	+10/20/50%	+10/20/50%	-	P×++×
4	+10/20/50%	-	-	+10/20/50%	P+××+
5	-10/20/50%	+10/20/50%	+10/20/50%	-10/20/50%	P-++-
6	+10/20/50%	-10/20/50%	-10/20/50%	+10/20/50%	P+--+

- Temperature change was changed at 1°C intervals from +0°C to 3°C

Temperature change	+0°C	+1°C	+2°C	+3°C
Symbolic expression	T+0 (Baseline)	T+1	T+2	T+3

Result

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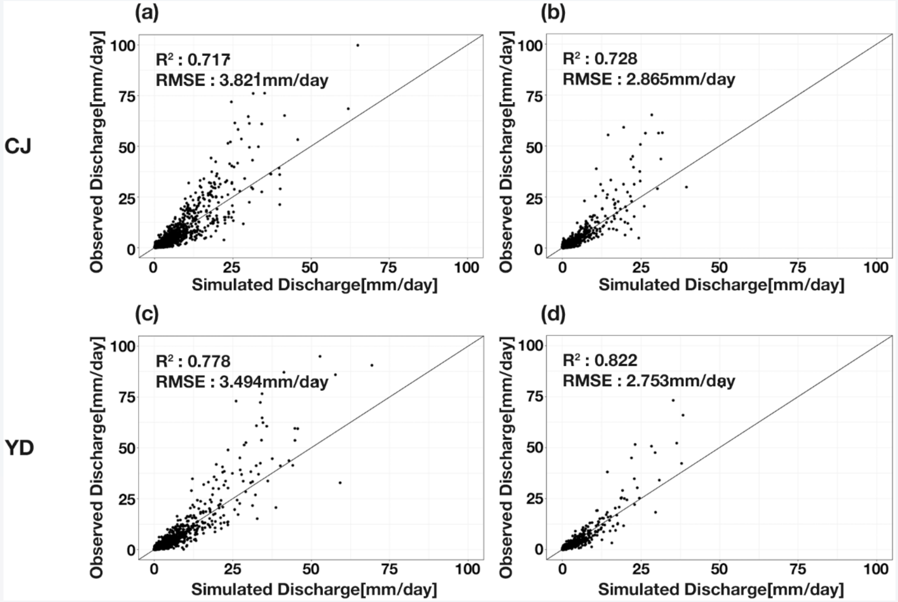
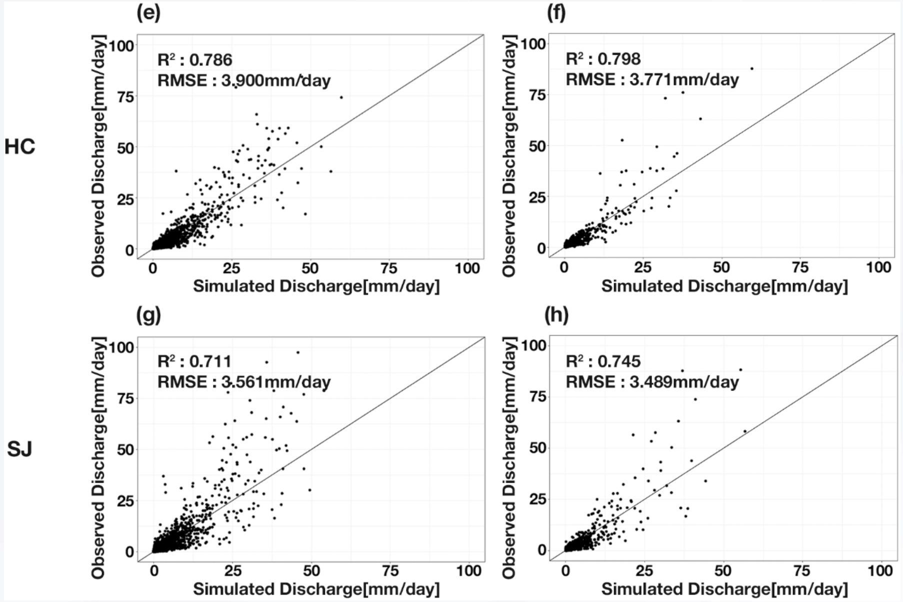
[Calibration and validation of IHACRES at the study sites]



- In the base year (1995~2014), the calibration period and the validation period are divided by 7:3, 1995~2009 as the model calibration period and 2010~2014 as the model validation period.
- In the case of Yongdam Dam, which was completed in 2000, 2001~2010 was the model calibration period and 2011~2014 was the model validation period

- The graph shows the inflow of observed /simulated values for each dam as a 1:1 graph.
- In all dams, the R^2 of the calibration period is 0.71 to 0.82, and the RMSE has a good evaluation index between 2.7 and 3.9 mm/day.



Result

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[Inflow analysis based on the rainfall stress scenario]

- Table shows rate of change in dam inflow with respect to baseline scenario
- Notably, the rate of inflow increase was found to exceed the rate of rainfall increase and this pattern was observed consistently across all basins, with minimal variation between them.
- UH quantile rainfall have a more prevailing effect on the total inflow of dams and overall range of flow-durations.
- The increase or decrease in rainfall during the monsoon season emerges as a significant factor influencing the overall inflow change due to the concentrated nature of rainfall in Korea during this period.

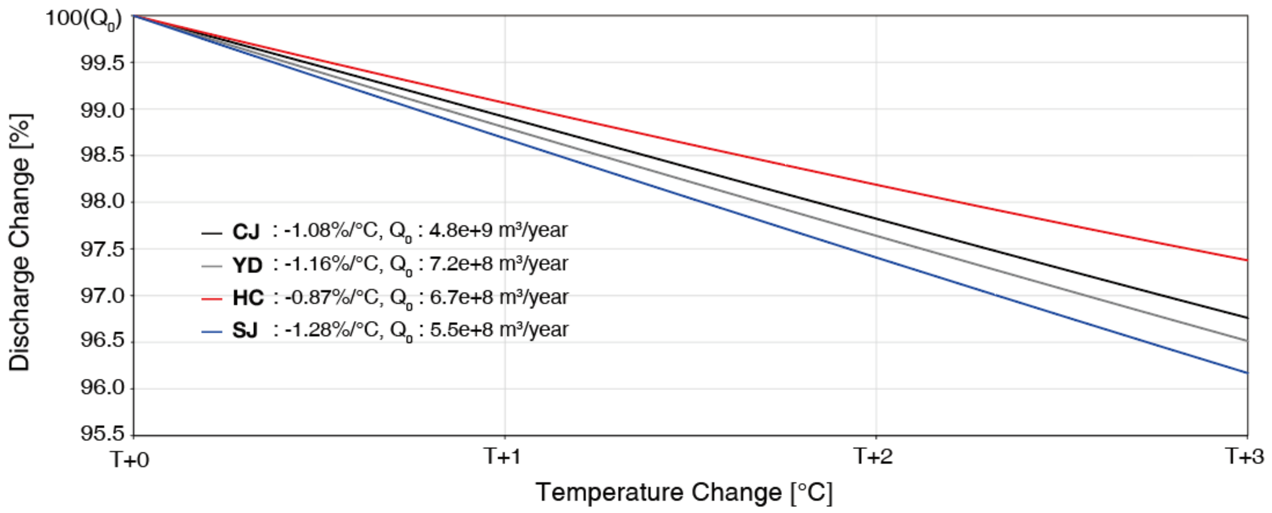
<Rate of change in dam inflow with respect to baseline scenario>

	Rate of Change (%)							
	Chungju		Yongdam		Hapcheon		Seomjingang	
Scenario	±10%	±20%	±10%	±20%	±10%	±20%	±10%	±20%
P++++	17.5	35.2	16.5	33.3	17.2	34.7	17.3	35.0
P----	-17.2	-34.0	-16.1	-31.7	-16.8	-33.0	-16.8	-33.1
P×++×	5.4	10.9	4.8	9.6	4.9	9.9	4.8	9.8
P+××+	12.1	24.2	11.7	23.5	12.3	24.6	12.5	25.1
P-++-	-6.6	-13.1	-6.8	-13.3	-7.2	-14.2	-7.5	-14.6
P+--+	6.8	13.8	7.1	14.5	7.5	15.2	7.9	16.1

Result

[Inflow analysis based on the temperature stress scenario]

- Figure shows the average annual inflow rate change rate of each dam when the reference scenario is increased at 1°C intervals from temperature 0°C to 3°C.
- Although the difference between the research areas was small, the HC showed the smallest and the SJ showed the highest rate of change.
- In SJ, which has the smallest dam inflow compared to rainfall, the change in dam inflow according to temperature change is the largest.
- However, compared to the results of the rainfall stress scenario conducted in this study, the change in inflow to temperature was relatively insignificant in terms of absolute quantity.

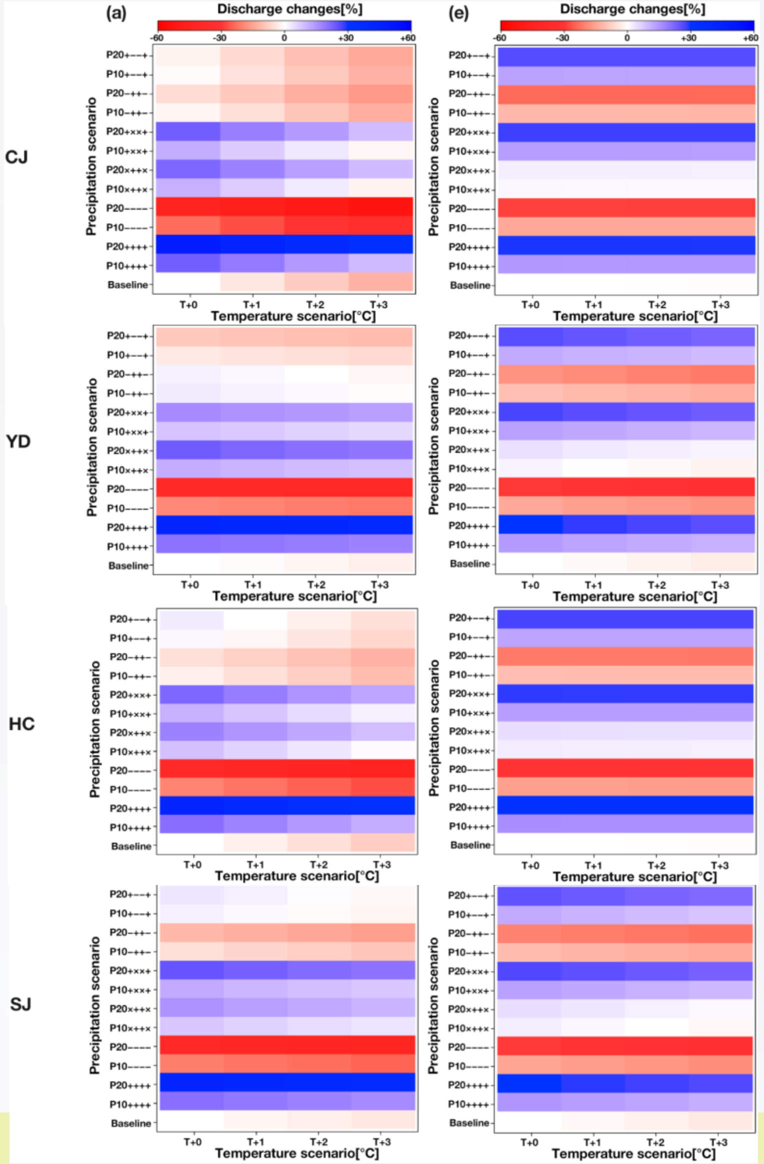


<Percentage changes in discharges under temperature stress scenarios compared to the baseline scenario>

*** Q0 represents mean annual discharge under the baseline scenario.**

Result

[Inflow analysis based on the climate stress scenario]



- Figure shows the change in runoff according to the climate stress scenario considering composite changes in rainfall and temperature. Left part shows the rate of change in low flow regime among the flow regime analysis results for the runoff, and right part shows the rate of change in flood flow regime compared to the reference scenario.
- Compared to YD and SJ, CJ and HC show a relatively large variation in low and flood flow regime depending on temperature, suggesting that the sensitivity to climate stress may be different for each dam when it is low and high flow regimes.

➡ Therefore, it is judged that measures for problems that may arise due to future climate change should be individually established in other dams through sensitivity analysis to climate stress.

Conclusion and follow-up research plan

- ✓ As a follow-up study, we aim to evaluate the stability and vulnerability of dams through a data analysis program based on HEC-ResSim for outflow to which climate stress scenarios are applied.
- ✓ It is believed that through the dam stability index, the impact and changes in water supply due to climate stress will be periodically evaluated to ensure sustainable dam management and smooth evaluation.
- ✓ Through this analysis, the inflow of multi-purpose dams can be evaluated to be more sensitive to changes in climate change factors such as rainfall and temperature depending on the season, which can help establish seasonal countermeasures against future climate changes.
- ✓ In the future, the DS technique can be used as one of the tools that can be used to individually establish countermeasures against possible future climate changes in accordance with the watershed characteristics of each dam and the conditions for continuing to achieve the successful operation of the dam.

Thank you.