Decision Support for Preliminary Release of Reservoir for Flood Control using ECMWF Medium-range Ensemble Rainfall Forecast

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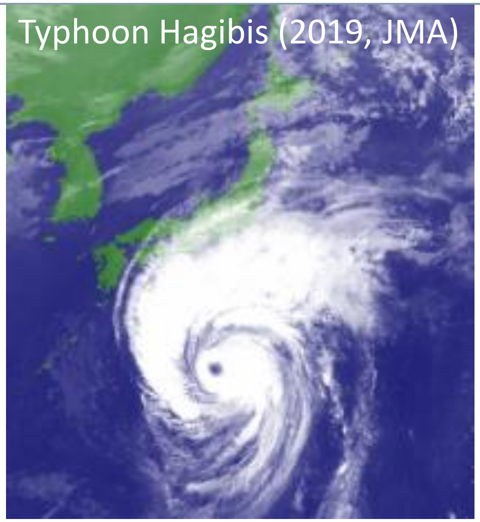
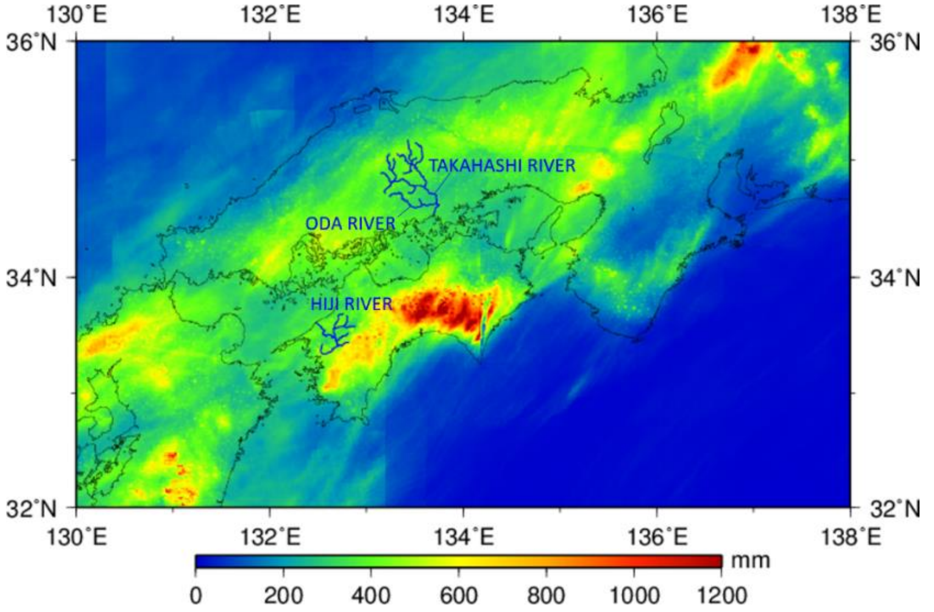
MANAGEMENT OF LARGE-SCALE FLOODS BY RESERVOIRS

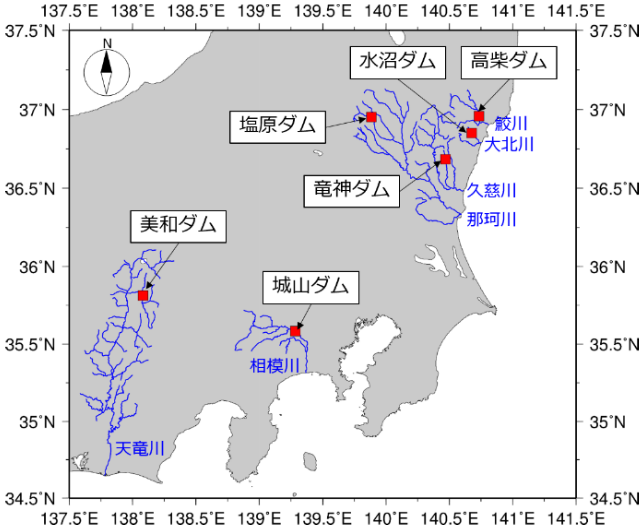


- Occurrence of extreme floods getting more frequently and widely
- Needs for enhanced capability of flood control by reservoirs



Total rainfall observed in floods in July, 2018 (West Japan Floods)

Wide Inundation in Takahashi River basin (Source: Japan MLIT)

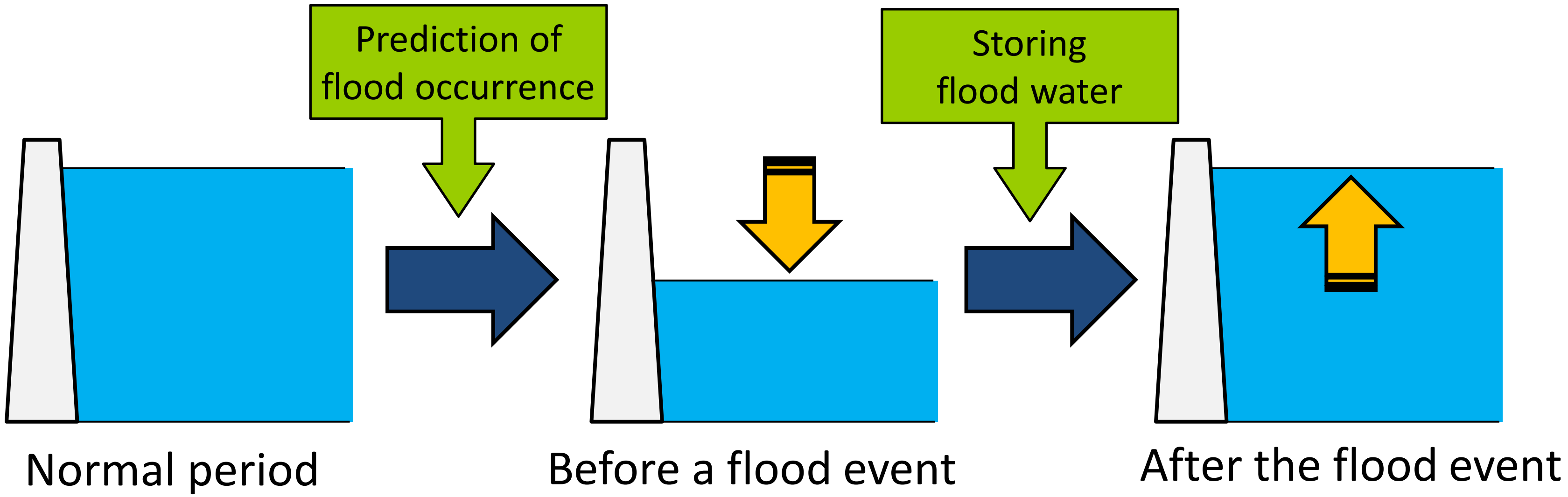


Reservoirs that conducted ESGRO during Typhoon Hagibis hit in 2019

PRELIMINARY RELEASE OPERATION

Preliminary release (pre-release, PR) operation for enhancement of flood management

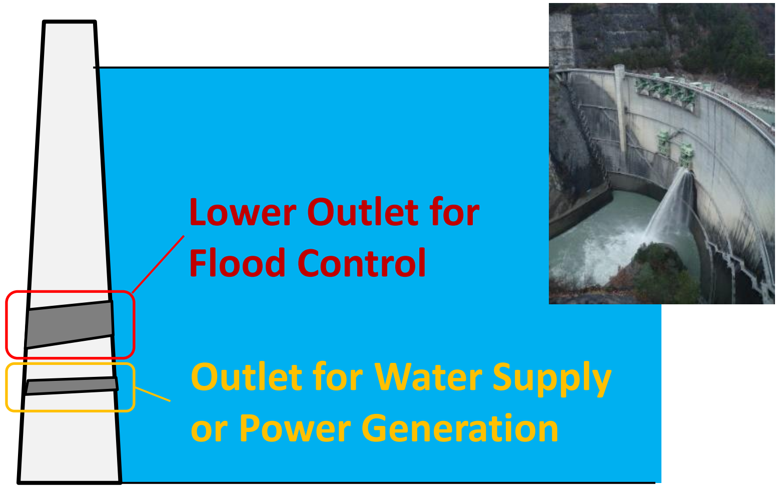
Keeping water level as high as possible, at the same time as safely decreasing water level in advance of flood events so as to secure storage capacity for flood control (enables integrated management)



→ Consideration of hydrological prediction is important.

ISSUES IN PRELIMINARY RELEASE OPERATION

- Prediction uncertainty
- Secure drawdown and water recovery
- Compensation for insufficient water recovery in case of false alarm
- Small discharge capacity for PR
- Insufficient PR when short-range prediction considered

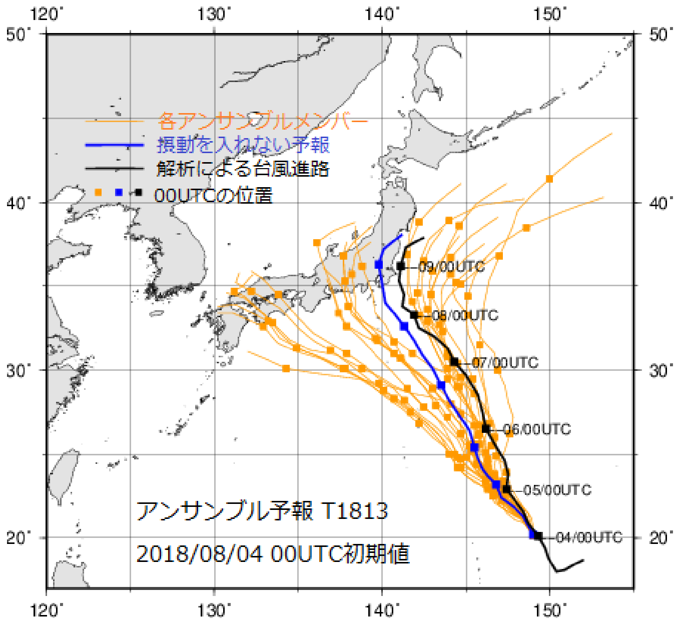


Multi-purpose Reservoirs

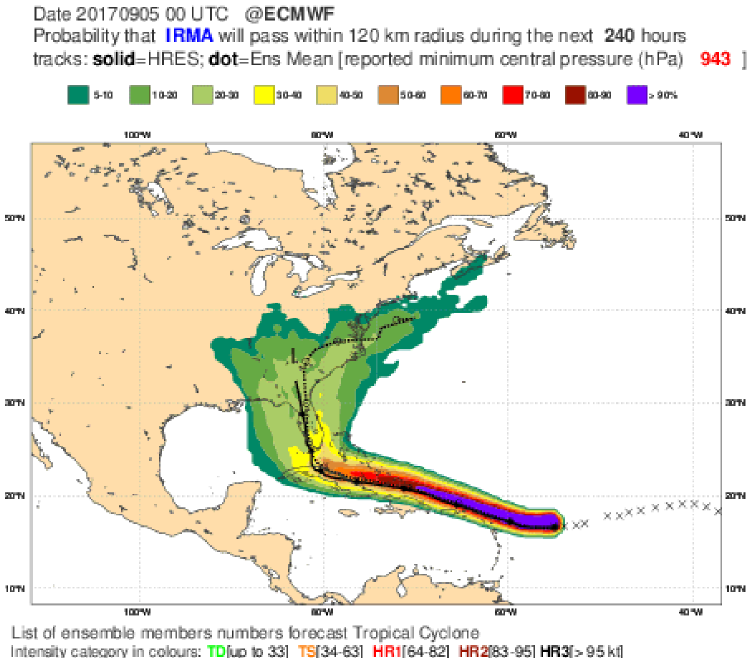
Reservoirs Dedicated for Water Supply or Power Generation

LONG-RANGE ENSEMBLE RAINFALL FORECAST

- Long-range (medium-range) ensemble forecast
- Prediction with lead time of one week to a half month
- Multiple possible prediction scenarios which contributes to better uncertainty handling and robust decision making



Ensemble Typhoon Track Forecast (JMA)



Medium-Range Ensemble Forecast (ECMWF)

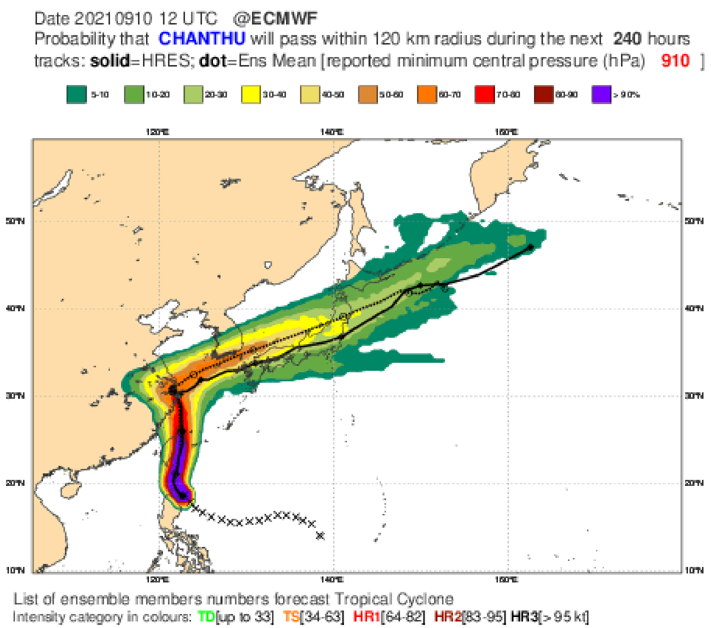
STUDY OBJECTIVE

- Consideration of **long-range operational ensemble rainfall forecast** in PR operation of reservoirs
- Development of an effective method to conduct PR from **hydropower dam reservoirs** (please see the contribution by **Kido et al.** in the symposium proceedings for application to **PR operation by multi-purpose reservoirs**)
- Assessment on the effectiveness of the proposed approach over other PR methods for a hydropower dam reservoir

ENSEMBLE RAINFALL FORECAST

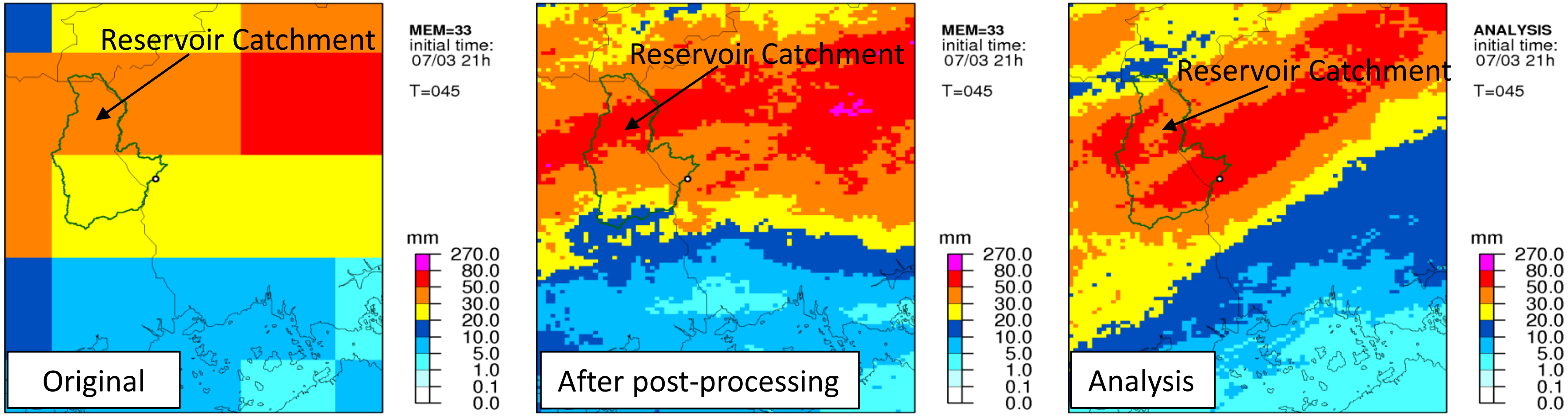
- ECMWF Medium-range Ensemble Rainfall Forecast for the coming 15 days
- Advantage in spatial and temporal resolutions as well as its long forecast range
- Further refined by JWA using BC and DS algorithms (called **JWA Ensemble Forecast**)

Items	ECMWF 15-Day Ensemble (Original)	JWA Ensemble (After BC and DS)
Forecast Range	360 hours (15 days)	360 hours (15 days)
Spatial Coverage	Global	Japan Area
Spatial Resolution	0.25 degrees grid	1 km
Temporal Resolution	3 hours (until 144 hours ahead) 6 hours (after 145 hours ahead)	3 hours (until 144 hours ahead) 6 hours (after 145 hours ahead)
Frequency of Prediction	Twice a day	Once a day
Number of Members	51	51



JWA ENSEMBLE RAINFALL FORECAST

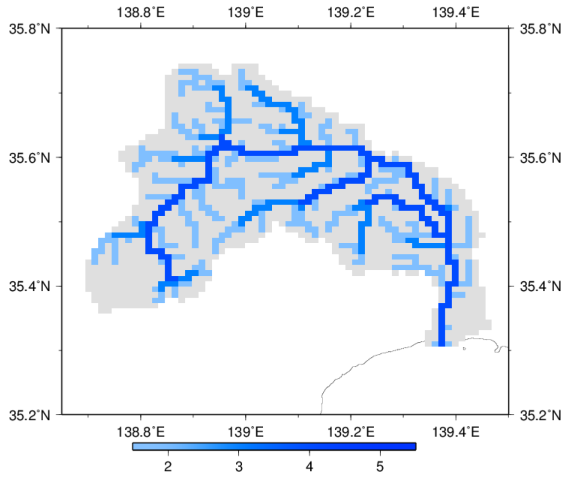
- Derived from ECMWF Medium-range Forecast using a post-processing method developed by JWA
- **Correction of model bias (frequency bias)** to remove systematic errors
- **Downscaling from 25km grid to 1km** by use of statistical downscaling based on the constructed analogues method (Hidalgo et al., 2008)



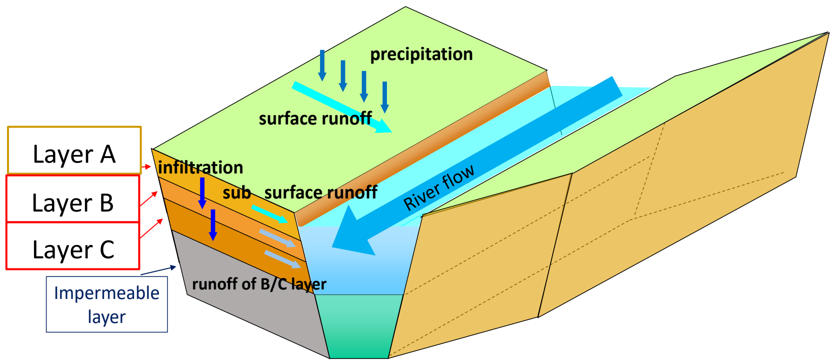
ECMWF original | JWA Ensemble Forecast | Analysis

ESTIMATION OF ENSEMBLE INFLOW PREDICTION

Hydro-BEAM (Hydrological River Basin Environment Assessment Model)



Run-off routing of river basin



Structure of each mesh cell

- A cell grid type rainfall-runoff model developed by *Kojiri et al.* (1998)
- Each mesh cell consists of one river channel and two slopes interposing the river
- Each slope has three vertical layers named Layers A, B and C from the top
- Kinematic wave model for Layer A and surface flow
- Storage function model for Layers B and C
- Squared mesh of 1km by 1km, calculated with time resolution of 10 min

DECISION MAKING METHOD FOR PR

- PR is initiated based on an ensemble member with **the third greatest value of the maximum inflow rate** predicted.

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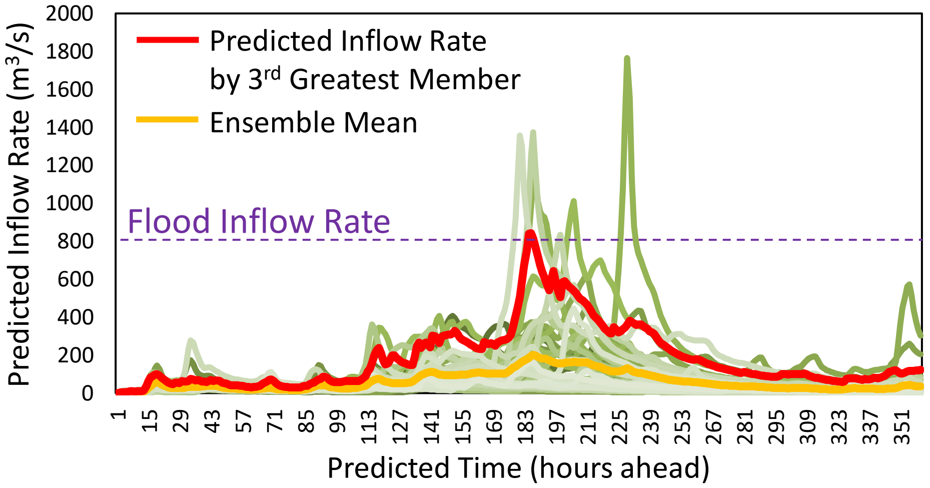
Reducing the number of misses to conduct PR before large floods



- The amount to release water is determined by ensemble members with **5 smallest values of total inflow volume** predicted.

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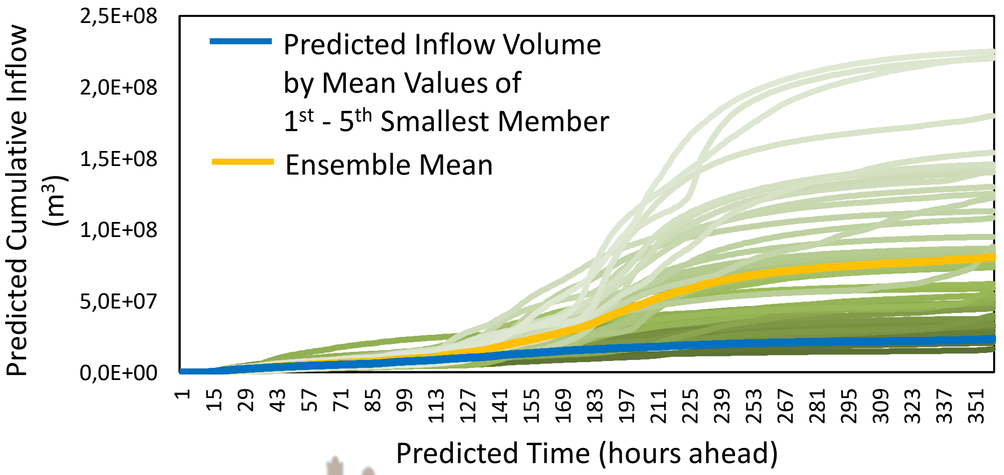
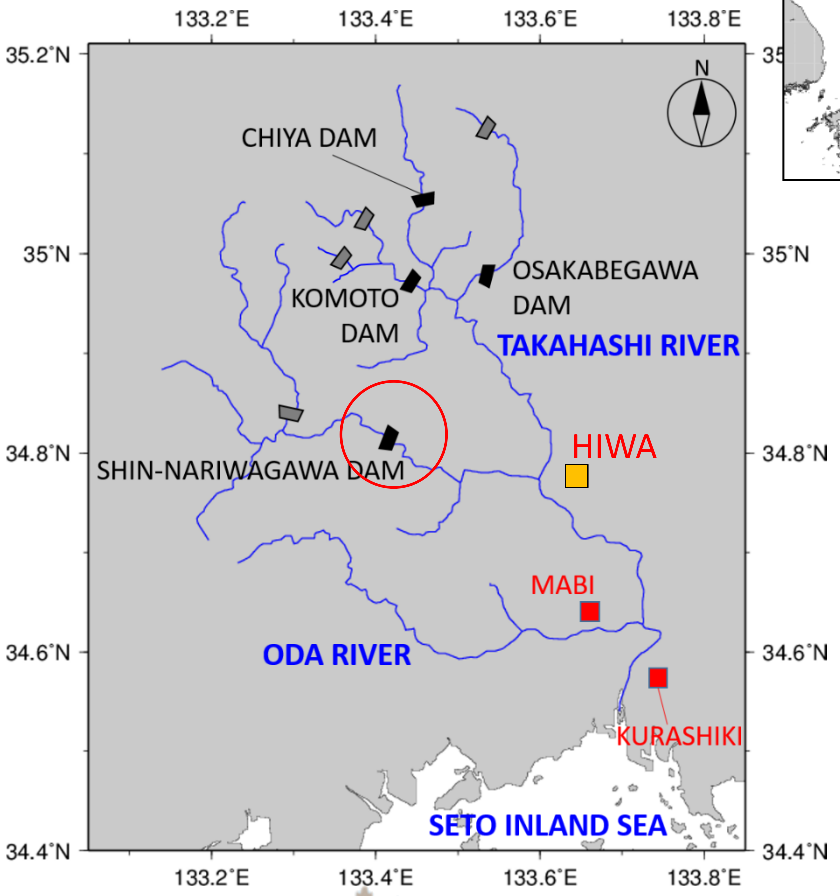
Securing water storage recovery after floods



TARGET RESERVOIR

Hypothetical reservoir whose hydrological data are derived from Shin-Nariwagawa Dam Reservoir, Takahashi River basin

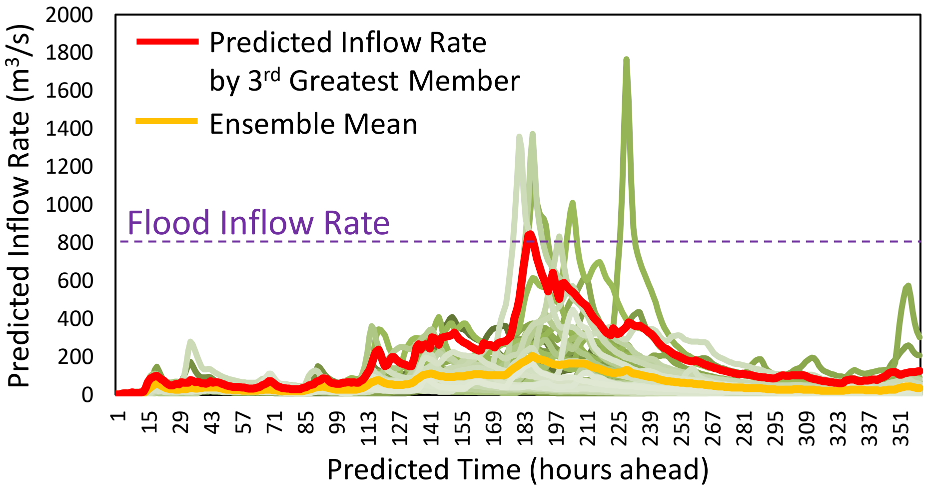
Effective Storage Capacity	80.5 MCM
Catchment Area	625 km^2
Flood Inflow	800 m^3/s
Max. Release Rate for Power Generation	400 m^3/s
Flood Control Rule	Delayed Release

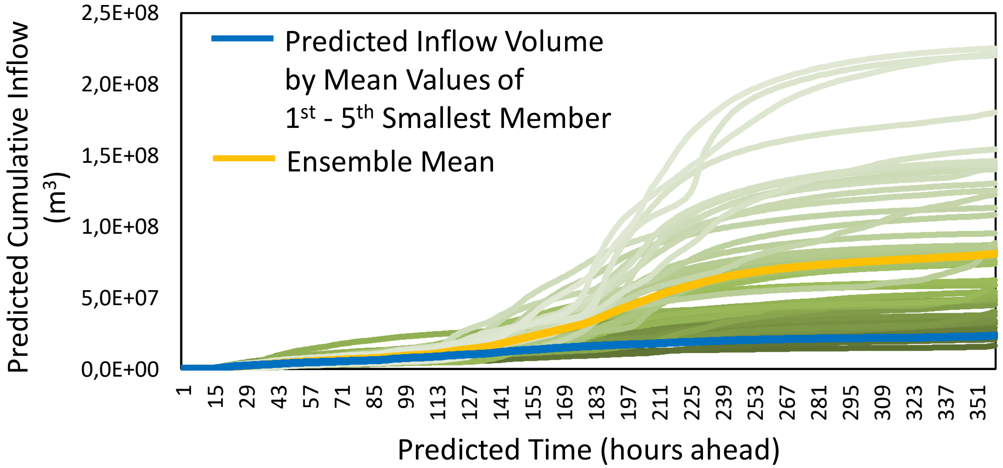


SIMULATION CASES

The following cases were considered to see effects of difference in ways to determine PR operation considering hydrological forecasts (ENS: ensemble, CTRL: control run = member 1)

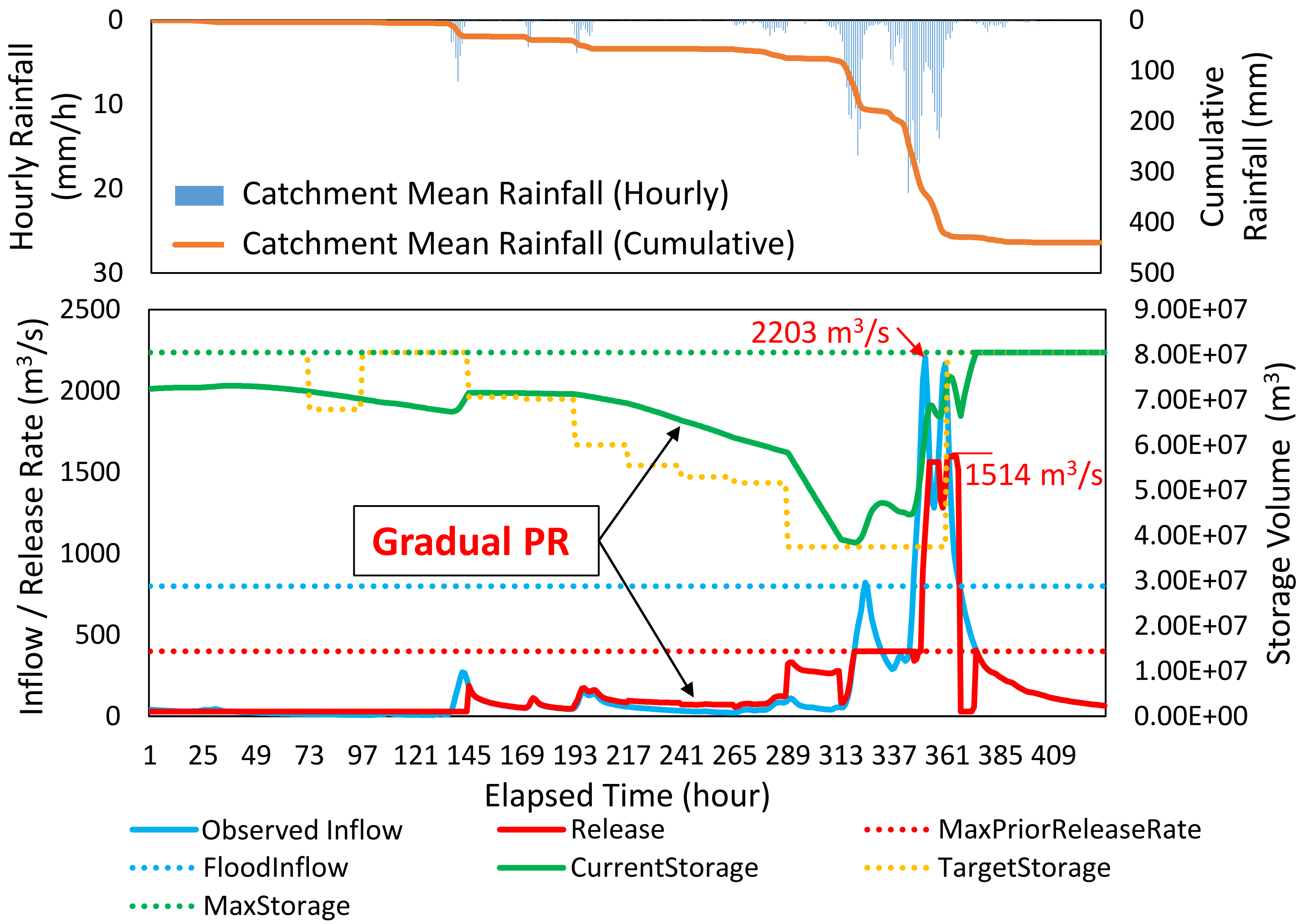
Cases	Criteria to Start PR	Criteria for PR Amount	Lead Time of Prediction	Remarks
1	ENS-greater	ENS-smaller	15 days	Proposed method
2	ENS-mean	ENS-mean	15 days	Deterministic (ensemble mean)
3	CTRL	CTRL	15 days	Deterministic single prediction
4	ENS-greater	ENS-smaller	3 days	Long-range forecast not available





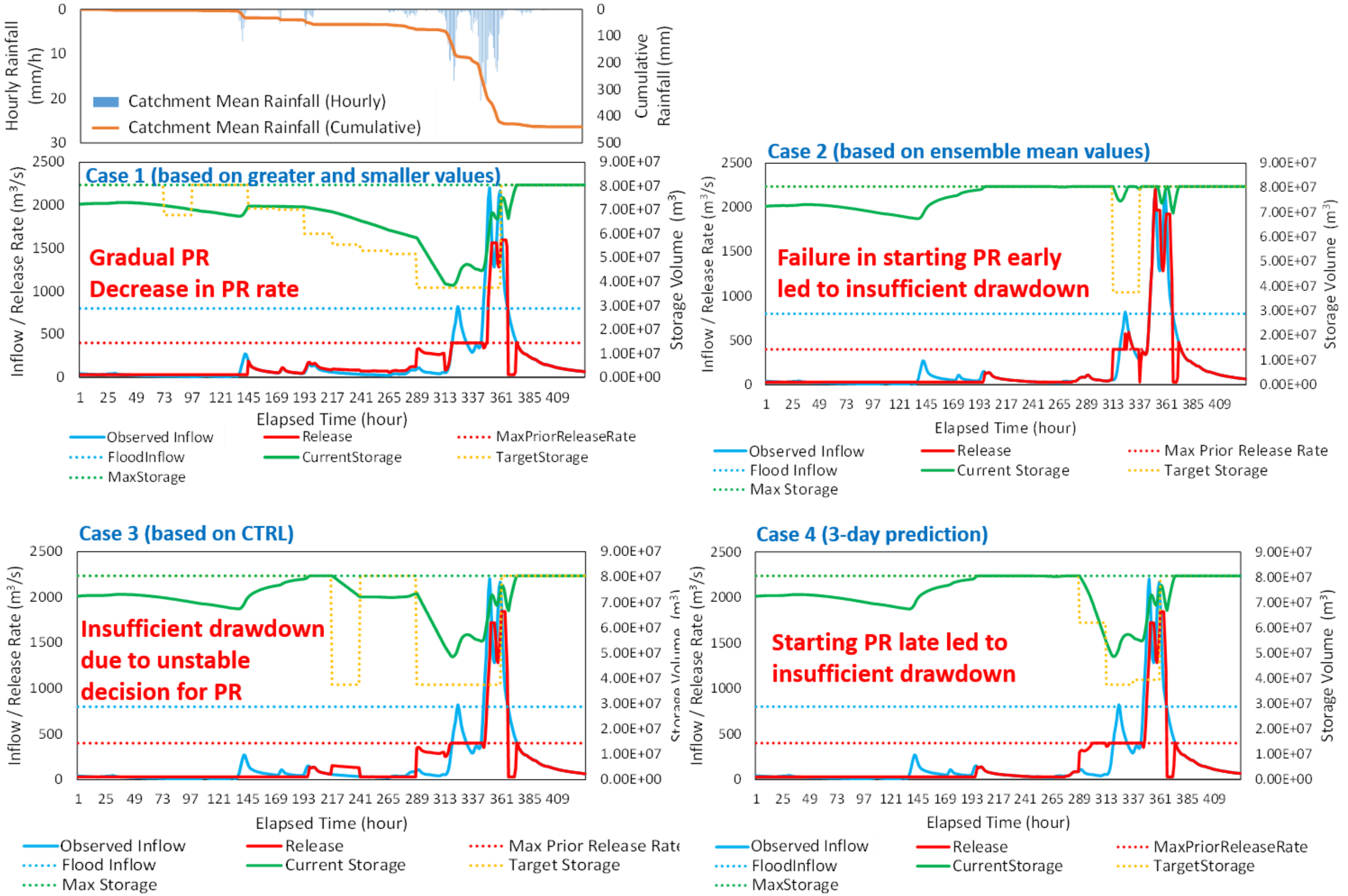
SIMULATION RESULTS (FLOOD EVENT 1, CASE 1)

- PR was conducted gradually from 11 days before the flood event
- Maximum release rate was decreased by 489 m^3/s



SIMULATION RESULTS (FLOOD EVENT 1)

PR was conducted most effectively in Case 1.



SUMMARY OF SIMULATION RESULTS (6 FLOOD EVENTS)

Indices for Flood Control

Cases	Decrease in max. release rate (m^3/s)	PR amount (MCM)	Rate to Effective Storage Capacity	Timing of starting PR (hrs ahead)	Mean PR rate (m^3/s)	Rate of Misses
1. 15+ENS	417.5	31.06	0.39	275.5	126.5	0.33
2. 15+EM	116.2	13.44	0.17	33.5	389.8	0.33
3. 15+CTRL	324.2	29.04	0.36	204.4	186.1	0.33
4. 3+ENS	324.2	28.07	0.35	49.3	297.1	0.33

Indices for Water Supply and Power Generation

Cases	Rate of false PR	Mean volume of drawdown in false PR (MCM)	Rate to Effective Storage Capacity	Rate of storage recovery	Difference in generated electric power (kWh)	Difference in values of generated power[1)] (10^3 JPY)
1. 15+ENS	0.67	27.64	0.34	1	+411,404	+8,228
2. 15+EM	0	-	-	1	-49,981	-1,000
3. 15+CTRL	1	29.64	0.37	1	+33,797	+676
4. 3+ENS	0.67	23.96	0.3	1	0	0

[1)] Estimated assuming 20 JPY/kWh for unit price of electric power

CONCLUDING REMARKS

- A method for PR considering long-range ensemble rainfall forecast was developed.
- Proposed PR operation method based on both greater and smaller ensemble members in long-range forecast **(Case 1) showed balanced performance, deriving an increased FC capability in large flood events without sacrificing water use purposes by securing water storage recovery**.
- Conducting PR **can even increase hydropower generation by decreasing water release unavailable for power generation** in large flood events, which can become a prospective measure to increase renewable energy towards carbon neutral society.
- **Further investigation is needed considering reservoirs with smaller catchment (<200 km^2)** as water storage can be recovered more easily in the Shin-Nariwagawa Reservoir thanks to its large catchment area (625 km^2).

Thank you for your kind attention!

Merci pour votre attention!

Acknowledgement

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