Typhoon Committee Roving Seminar 2019
CMA Headquarters, Beijing, 11-13 November 2019

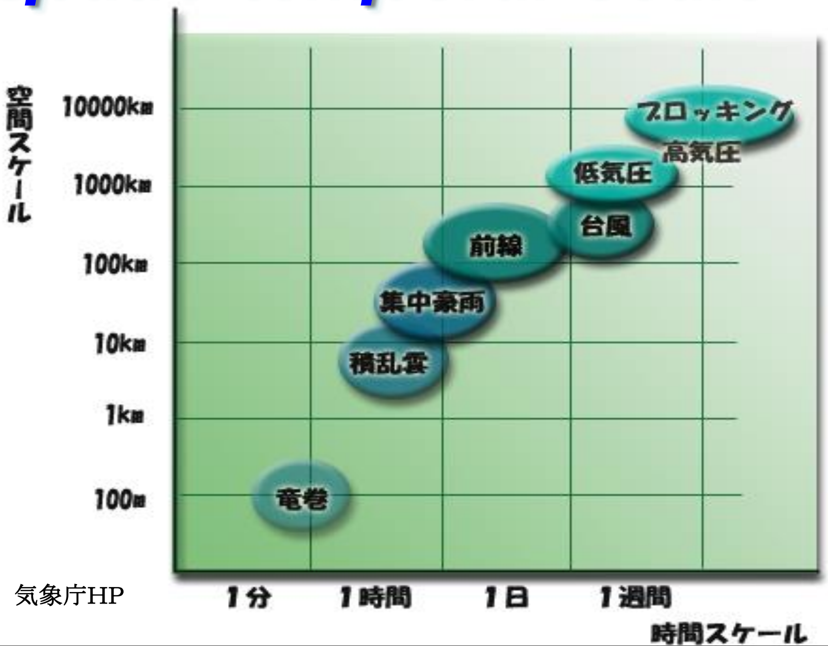
Hybrid Ensemble Forecast of Typhoon Related Rainfall and Its Applications into Flood Forecast

Wansik YU
Water Resources Research Center, K-water Convergence Institute
Korea

Eiichi NAKAKITA
Disaster Prevention Research Institute, Kyoto University
Japan

Contents

Spatio-temporal Scale

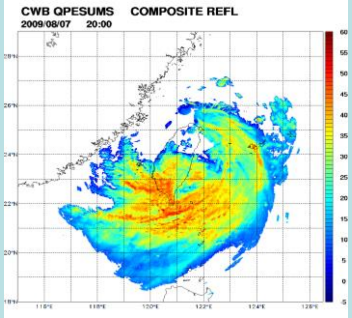


気象庁HP

Typhoon

Range: 1000km
Duration: 1day to a few days

大河川での洪水、大規模水害、土砂災害
2009/08/08 in 台湾

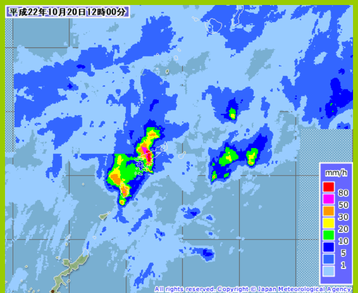


台湾中央気象局、台湾国家災害防救科技中心

Localized heavy rainfall (Baiu season)

Range: 100km
Duration: 6 hours to half a day

中・小河川での洪水、内水氾濫、土砂災害
2010/10/20 in奄美



南日本新聞　OFFICIAL SITE

Shower or Torrential rainfall

Range: 10km
Duration: about half an hour

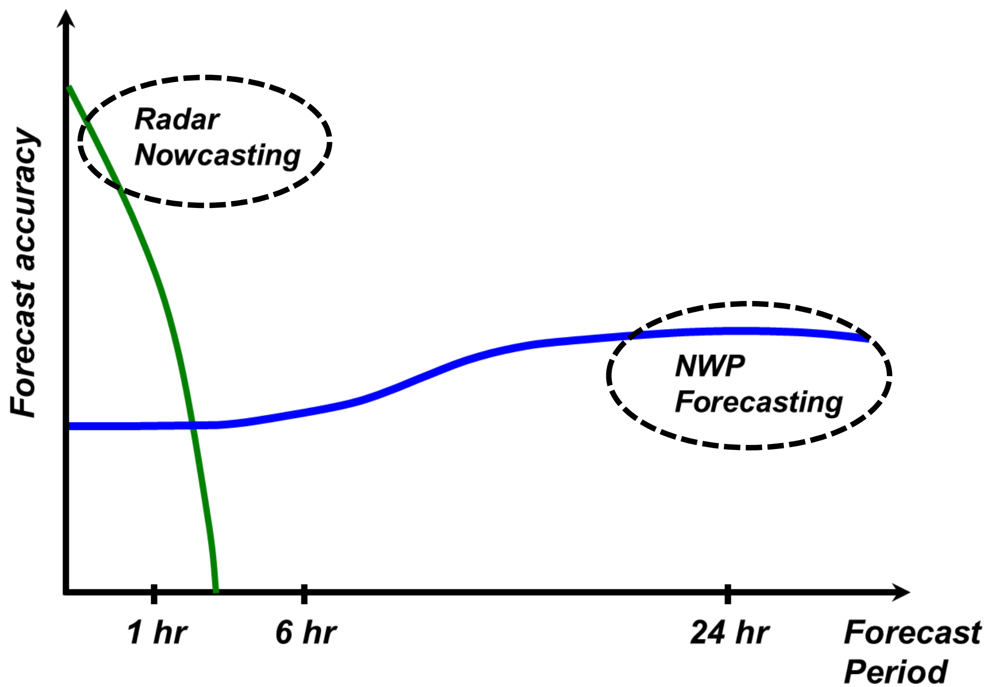
小河川や下水道内での鉄砲水、都市内水氾濫
2008/07/28 at 都賀川　2008/08/05 at 雑司ヶ谷

都賀川モニタリング映像

共同通信

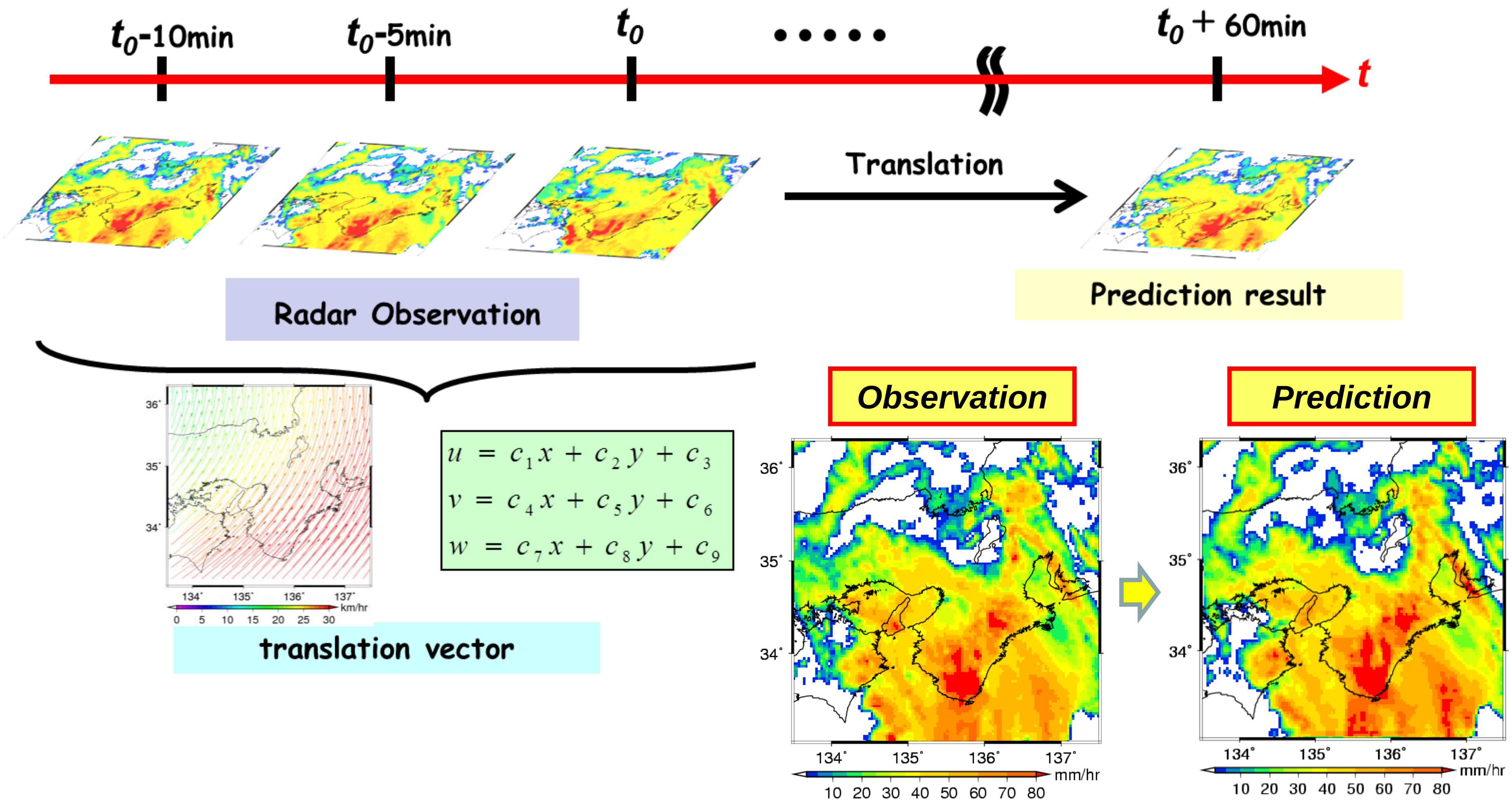
Background on Rainfall Forecast

- ***Rainfall Forecasts can be achieved from radar prediction or Numerical Weather Prediction (NWP) models.***
- ***For very short lead time (0–3 h), radar prediction performs best, whereas for longer lead times, forecasts based on numerical models is better than radar prediction.***



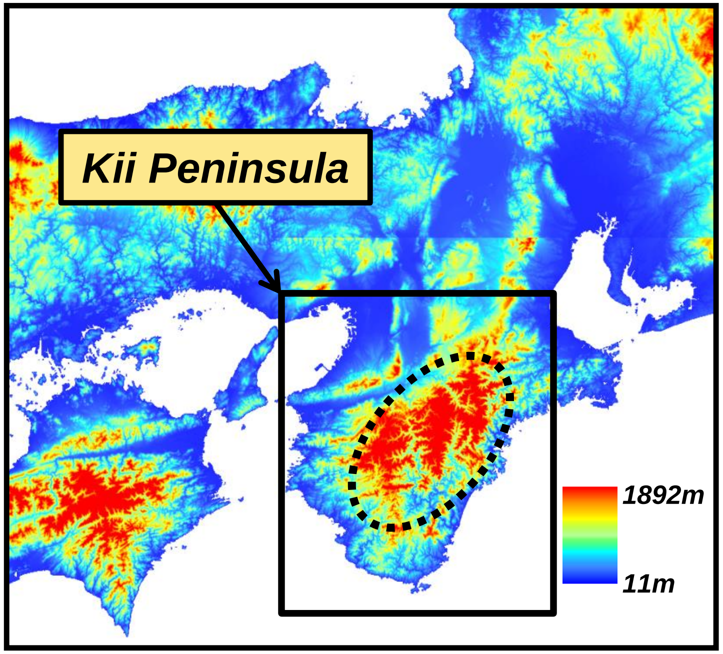
Radar Prediction with Translation Model

- *Translation model (Shiiba,Takasao and Nakakita, 1984)*

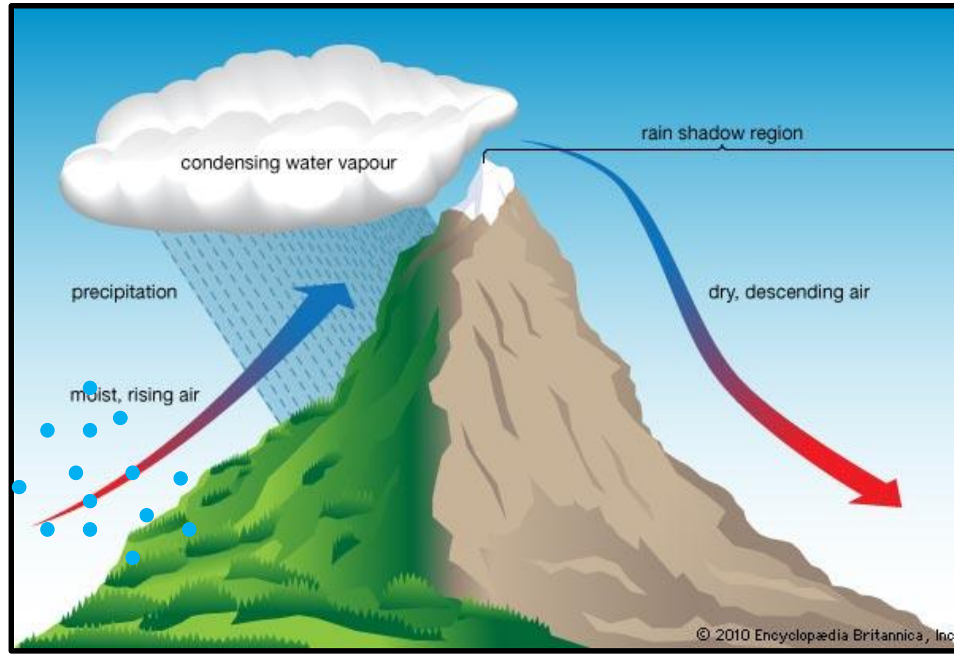


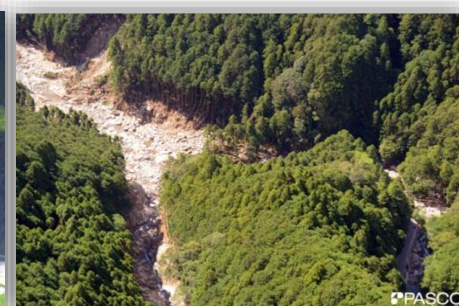
What is the Orographic rainfall?

Topography in Kii peninsula



Orographic Rainfall

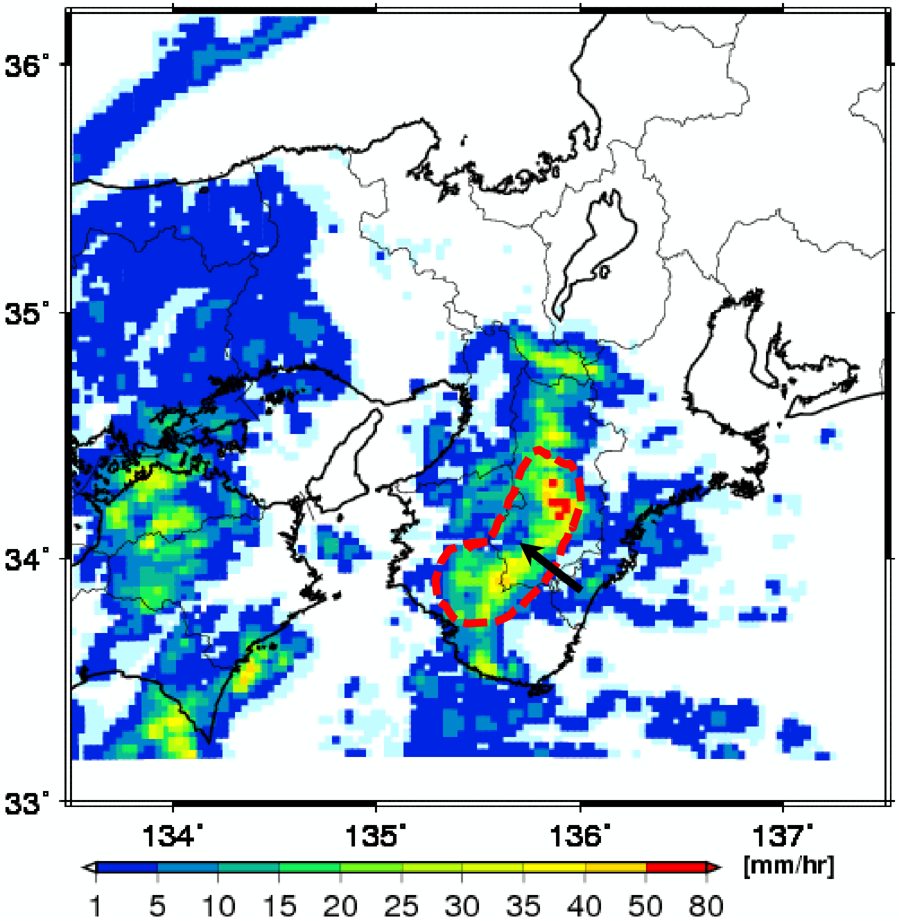




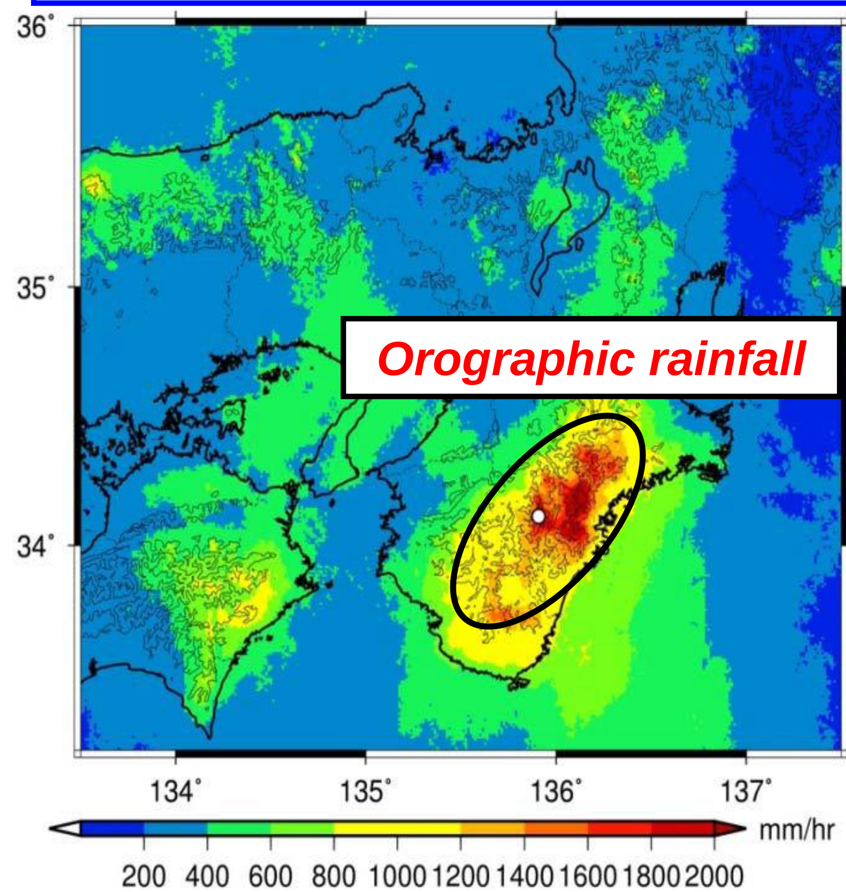
What is the Orographic rainfall?

Typhoon No.12, 2011

Observed Radar Rainfall
2011/09/01/09:00 ~ 09/05/09:00

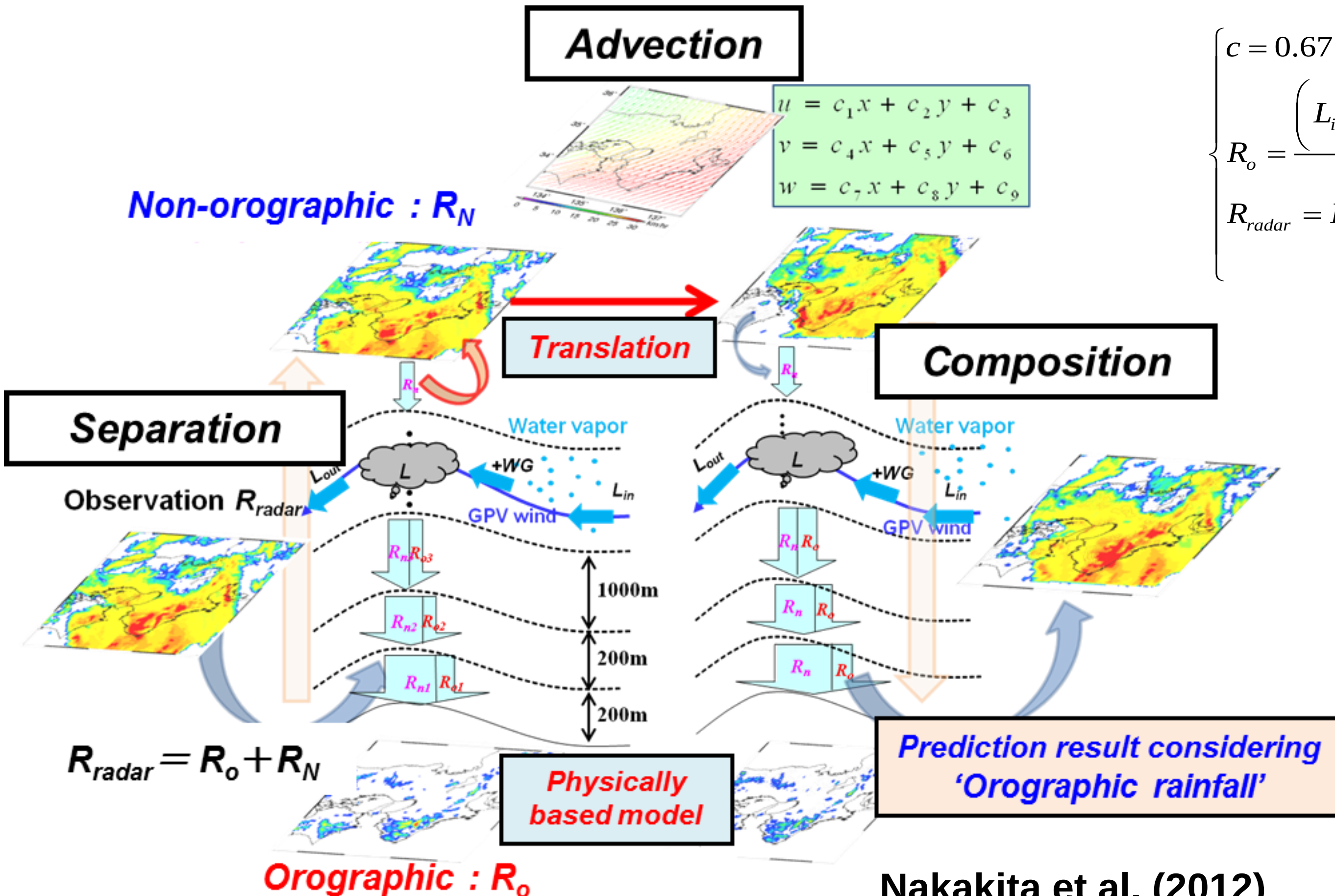


Accumulated Rainfall
2011/09/01/09:00 ~ 09/05/09:00



Improved Radar Rainfall Prediction

Orographic rainfall identification scheme



Nakakita et al. (2012)

Seeder-Feeder Mechanism

$$
\begin{cases}
c = 0.6778 R_N^{\ 0.731} \times 10^{-3} \\
R_o = \dfrac{\left(L_{in} - \dfrac{WG}{c}\right)\left(1 - e^{-(c\Delta t)}\right) + WG\Delta t}{\Delta t} \times 3.6 \times H \\
R_{radar} = R_0 + R_N
\end{cases}
$$

Procedure

1. Separation
2. Advection
3. Composition

Improved Radar Rainfall Prediction

Physically-based Method for Orographic Rainfall

Cloud Water Content

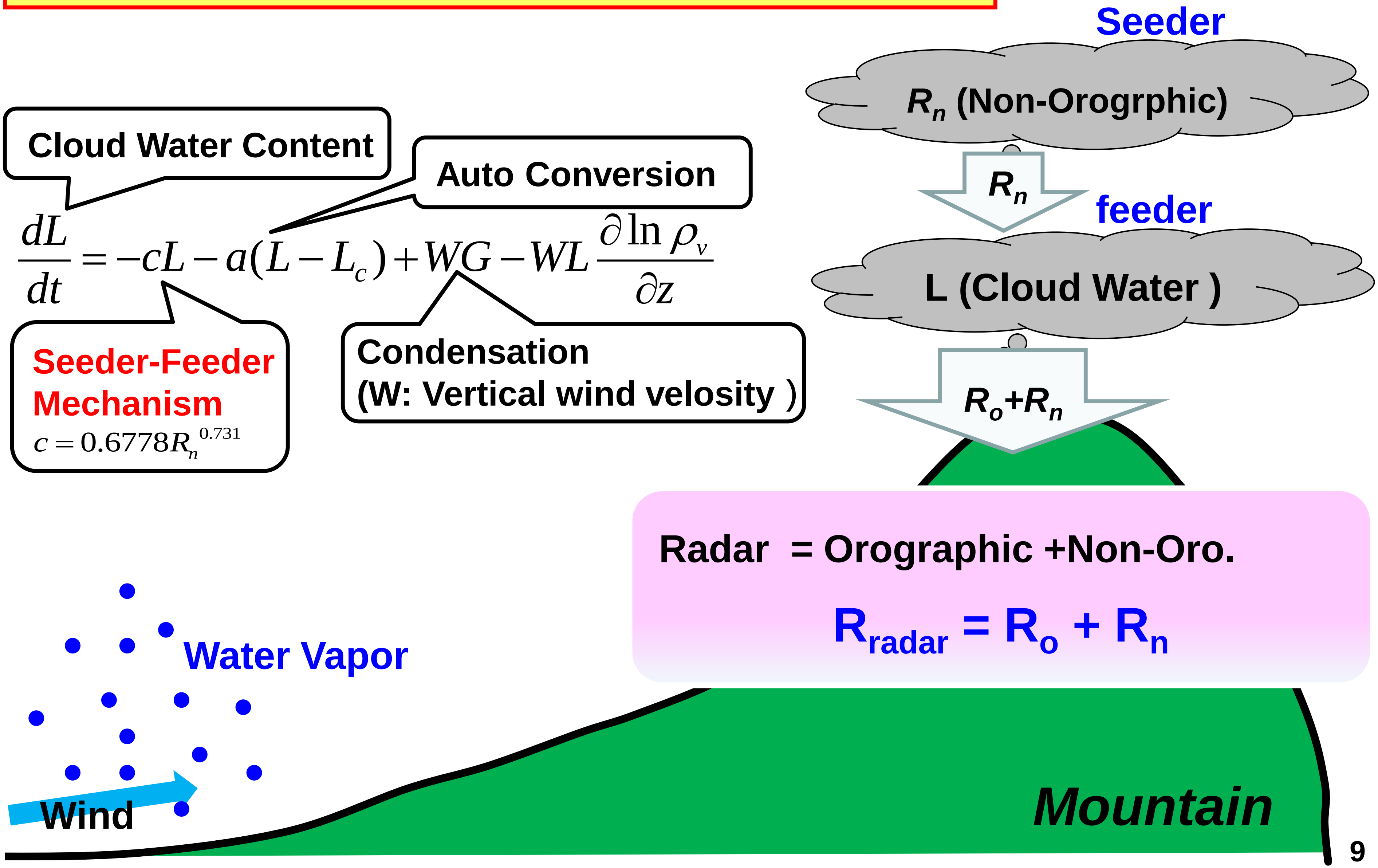
Auto Conversion

$$\frac{dL}{dt} = -cL - a(L - L_c) + WG - WL\frac{\partial \ln \rho_v}{\partial z}$$

Seeder-Feeder Mechanism

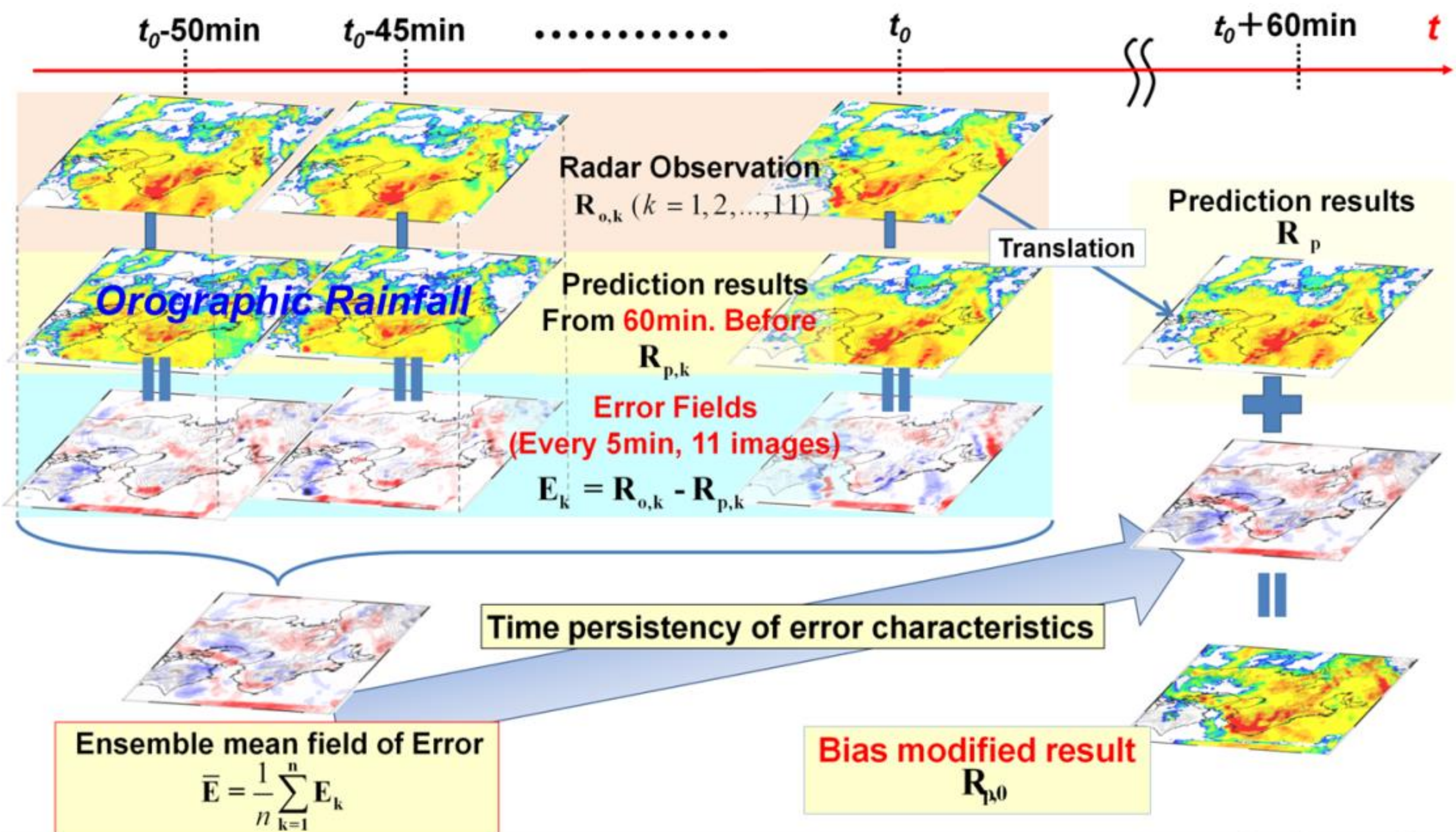
$c = 0.6778 R_n^{0.731}$

Condensation
(W: Vertical wind velosity)



Improved Radar Rainfall Prediction

Error-field scheme considering error structure



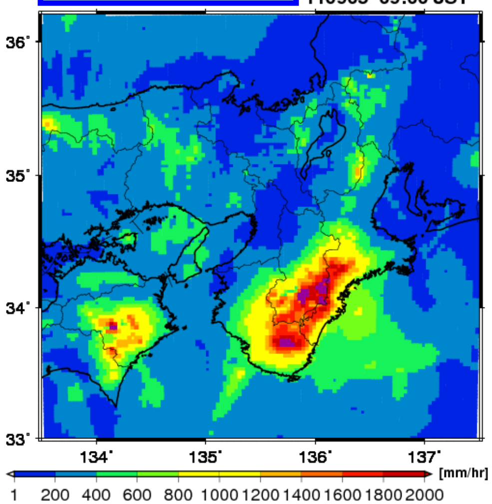
Kim et al. (2009)

Improved Radar Rainfall Prediction

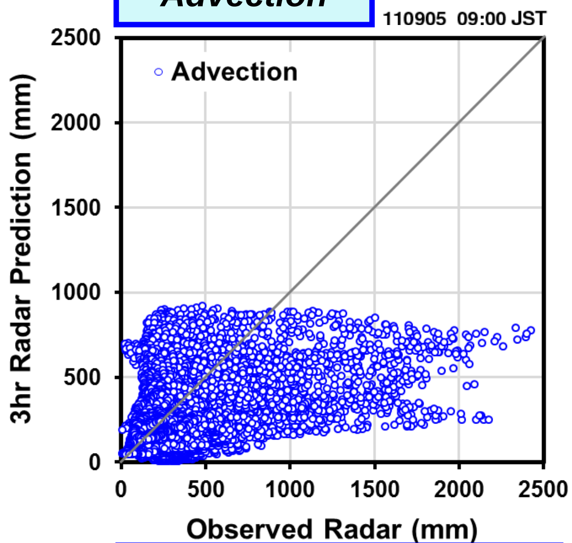
Accumulated Rainfall

2011/09/01/09:00 ~ 09/05/09:00 JST

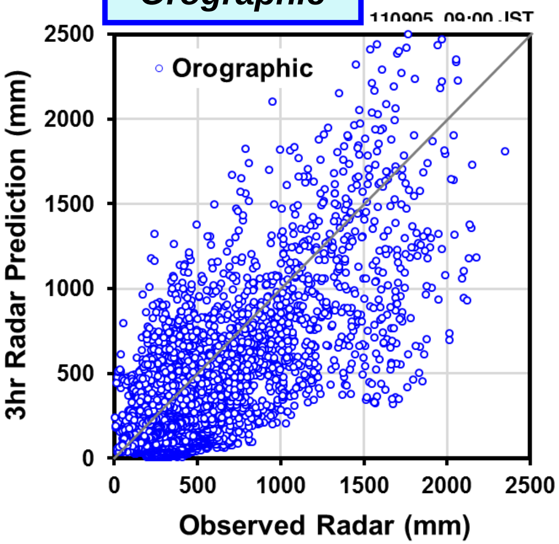
Obs_Radar



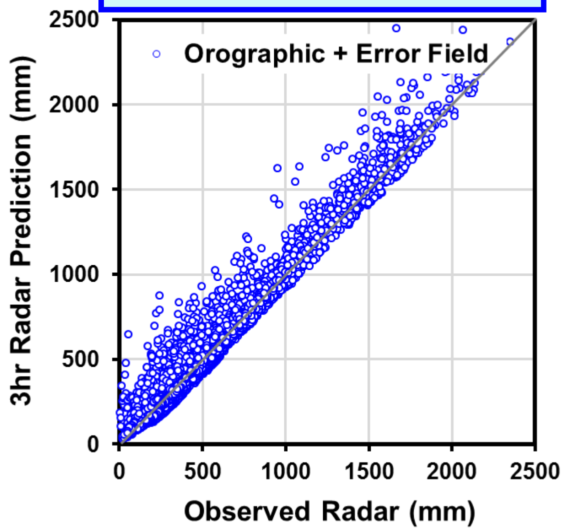
Advection



Orographic



Orographic + Error Field



Numerical Weather Prediction (NWP)

- ***NWP models solve the dynamics and physics of the atmosphere to predict the weather based on current weather conditions.***

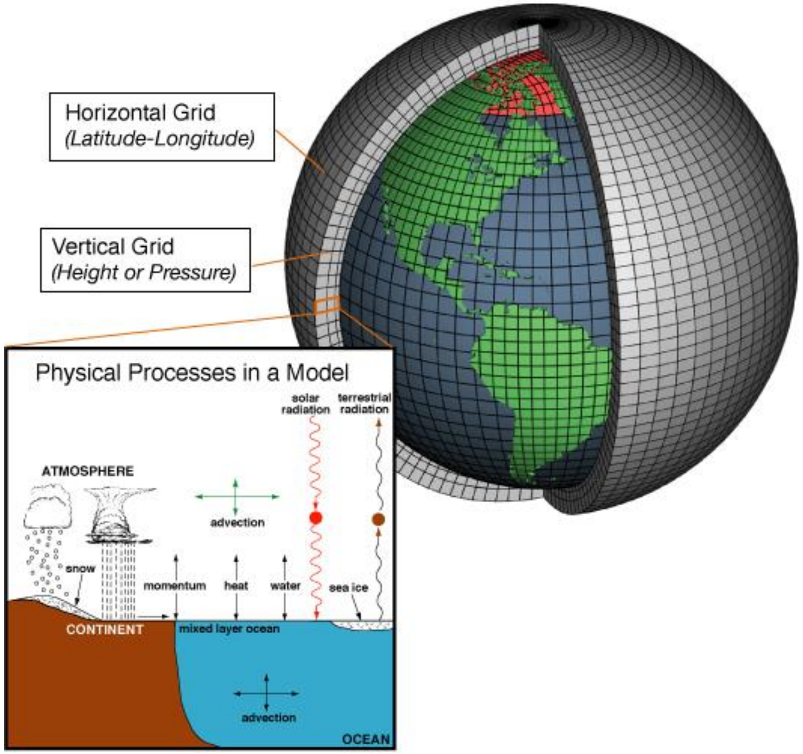
- ***At longer lead times, higher accuracy QPF can be produced by NWP models.***

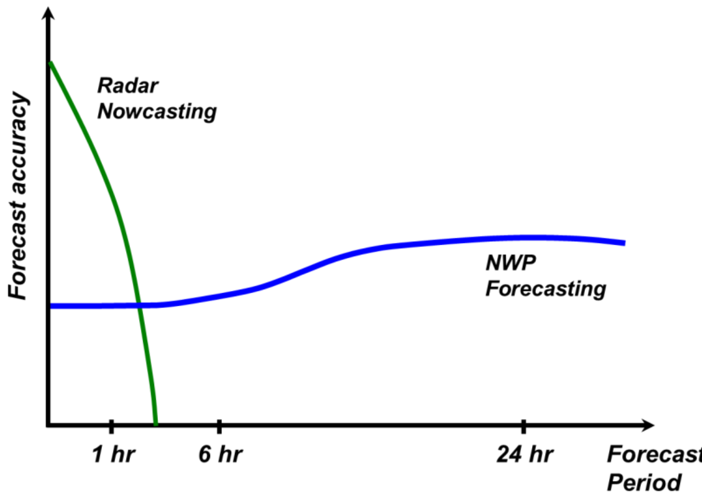
- ***The Operational NWP model at JMA in Japan***

  - Meso-Scale Model (MSM)

  - Global Spectral Model (GSM)

  - One-week EPS



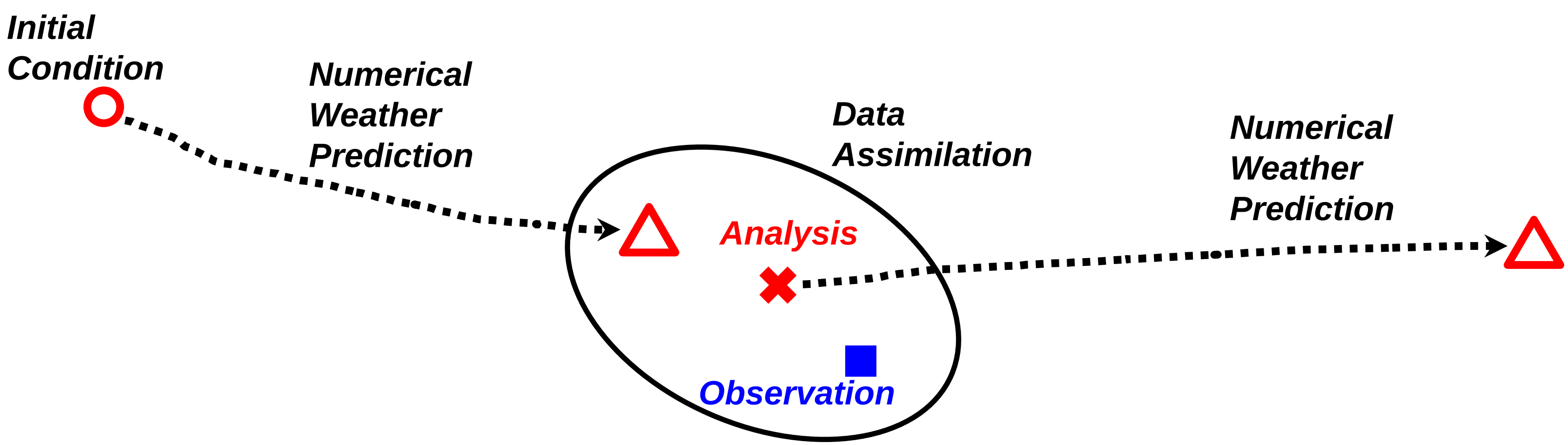


Numerical Weather Prediction (NWP)

Gather Observations → *Data Assimilation* → *Numerical Weather Predictions*

1. Deterministic Forecast

2. Ensemble Forecast



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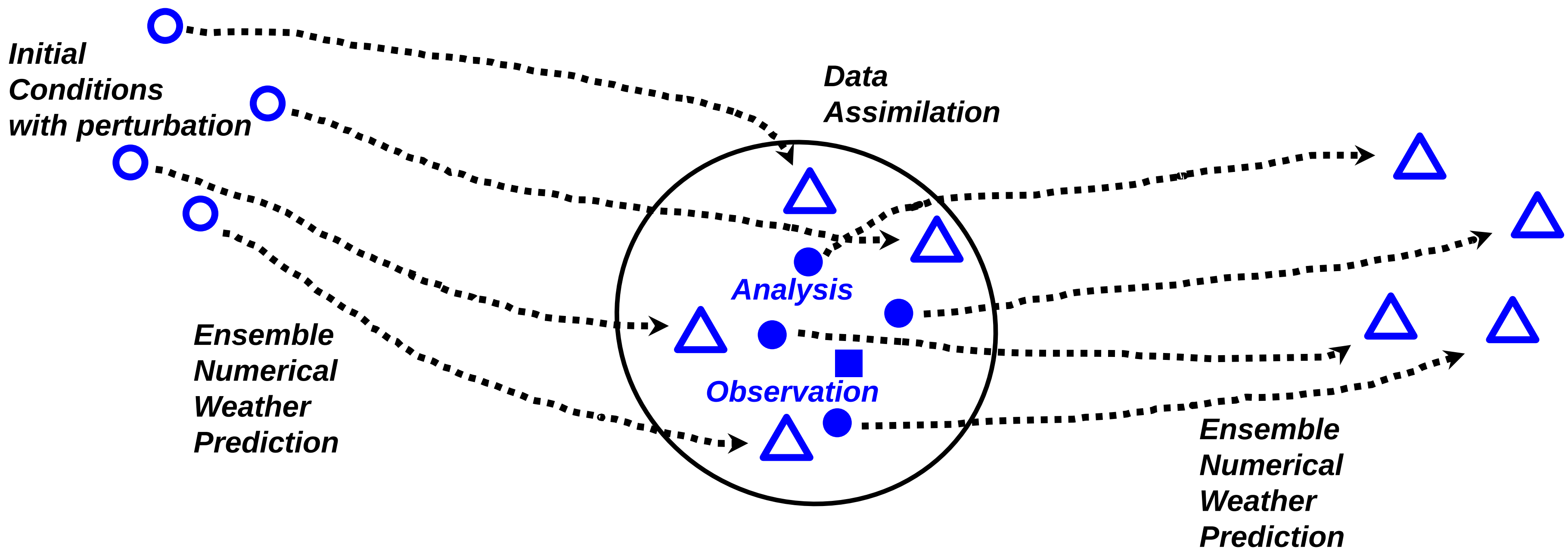
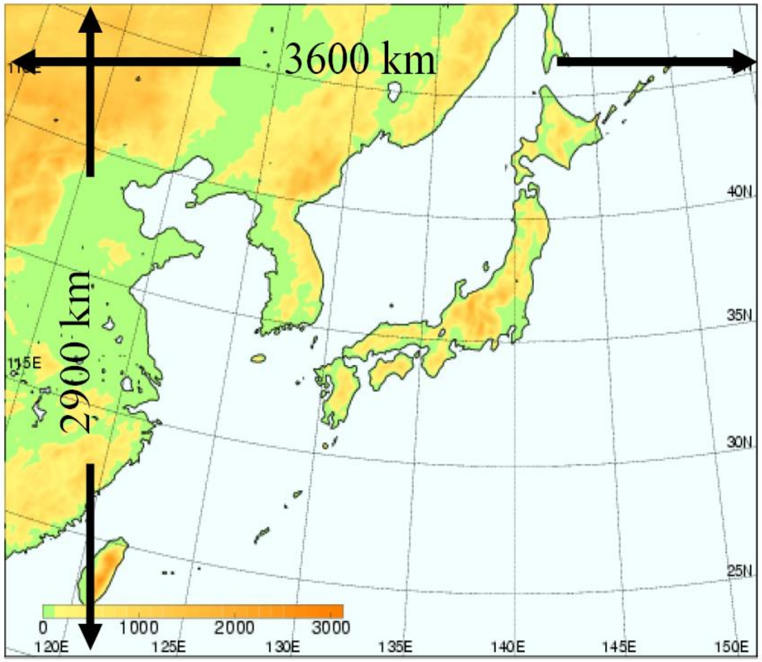


The Operational NWP model at JMA in Japan

Meso-Scale Model (MSM)

- **Objectives of Meso-scale NWP System**
  - **Disaster Prevention**
    - **Prediction of severe weather such as heavy rainfall is one of the main targets for mitigation and reduction of damage to property and loss of life.**
    - **Input to short-range precipitation forecast system**
    - **Input to storm surge model**
  - **Aviation Weather Forecast**
    - **Enrichment of the weather information for aviation safety**
    - **Terminal Area Forecast (TAF) Guidance and so on.**

Forecast Domain



- Horizontal resolution : 5km
- Domain : 3600 km x 2900 km
- Forecast term
  - + 00, 06, 12, 18 UTC ➔ 15 hours
  - + 03, 09, 15, 21 UTC ➔ 33hours

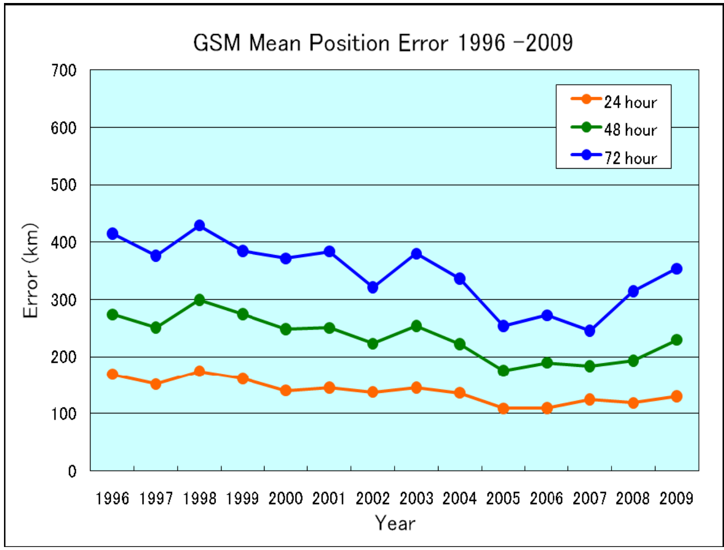
The Operational NWP model at JMA in Japan

Global Spectral Model (GSM)

Forecast Domain

- The GSM provides a primary basis of official typhoon forecast
- Typhoon forecast skill in the GSM is improving year-by-year
- The Types of GSM
  - Deterministic
    - support the track and Intensity forecast
    - Horizontal Resolution : 20km
    - Forecast Term : 00, 06, 18 UTC ➔ 84hours

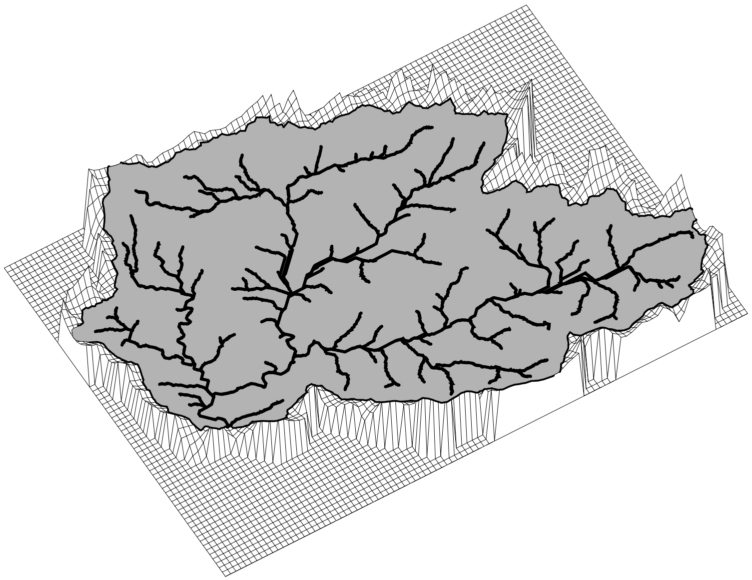
      12 UTC ➔ 216 hours
  - One Week Ensemble Prediction System (WEPS)
    - support track forecast and provide probabilistic information.
    - Horizontal Resolution : 60km
    - 12 UTC ➔ 216 hours, 51Ensemble members

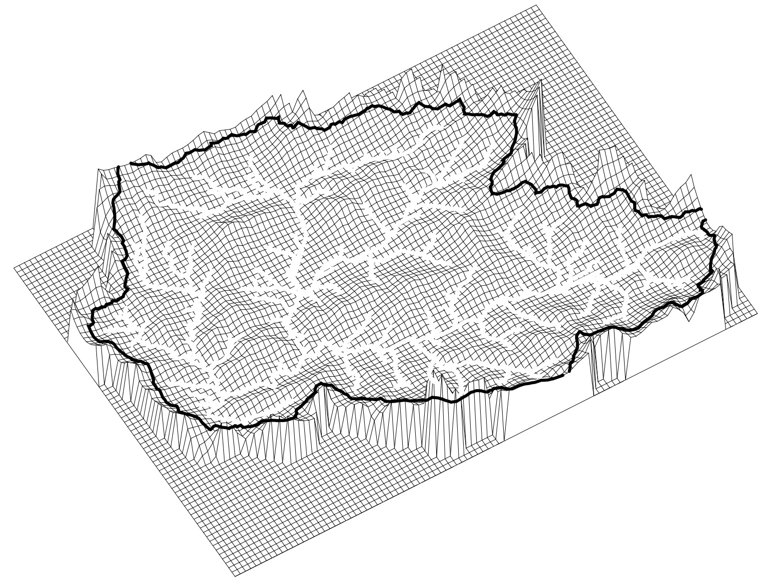


(from JMA)

Flood Forecasting using Hydrologic Model

- ***Lumped Model***
- ***Distributed Model***





Classification	*Lumped*	*Distributed*
Catchment	• *Single unit*	• *A number of smaller subareas or elements, such as a grid-cell*
Parameter	• *Same parameter values*	• *Distributed parameter or lumped parameter value*
Accuracy	• *tend to produce lower model performance*	• *leads to improve model performance*

Hydrological Application of High-Resolution Ensemble NWP Rainfall and Distributed Hydrologic Model

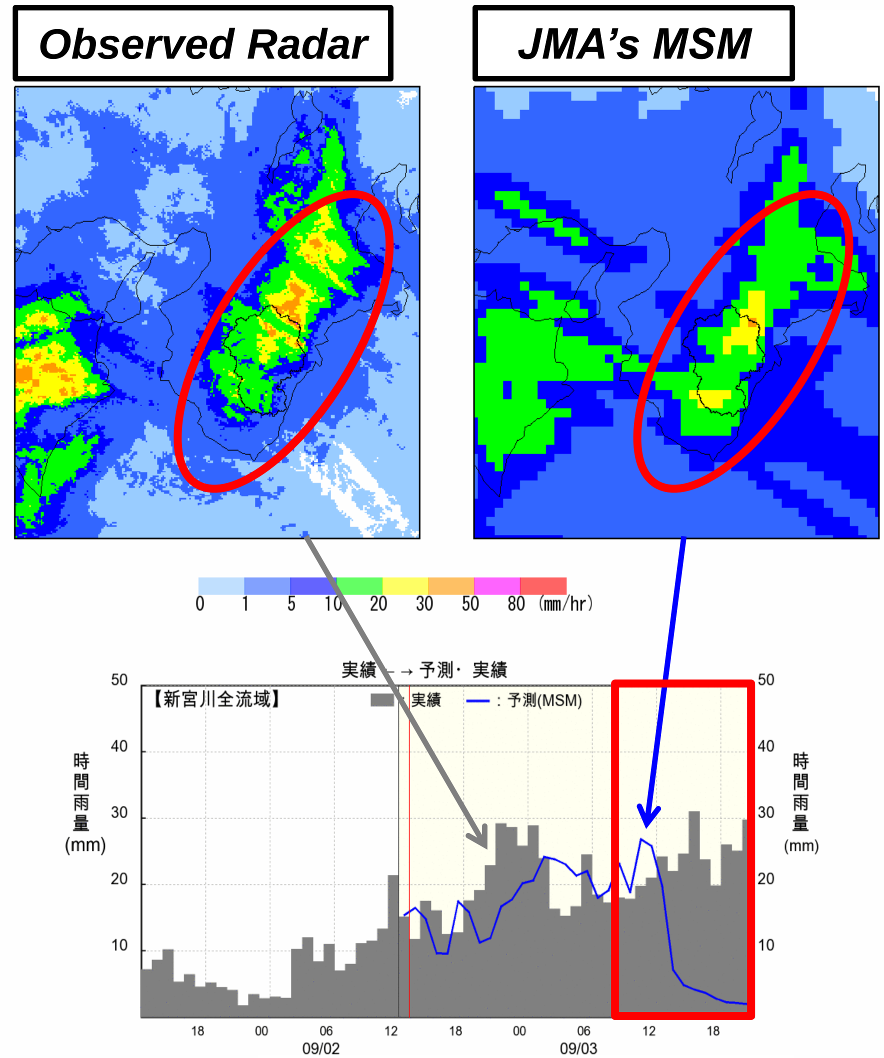
(CASE STUDY : Typhoon No.12, 2011)

Flood Event: Typhoon 'Talas', 2011 (T1112)

- *On Sep. 2 to 4, 2011 Typhoon No.12 (Talas) caused local heavy rainfalls across Japan.*
- *It caused enormous flooding and landslide disasters, and many roads were damaged as well as electricity, communication lines and water supply.*

Meso-Scale Model Prediction in Japan

- ***The JMA's operational mesoscale NWP model (MSM) generally well predicted the typhoon track.***
- ***However, the rainfall intensity was weaker compared with observed radar rainfall.***
- ***And, the movement of MSM was also faster as lead time is longer.***
- ***So, pattern moved to the North-Eastern part of Kii peninsula quickly.***

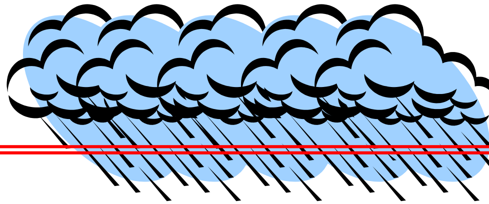


09/02/12:00 ~ 09/03/20:00 JST

From J-POWER

Meso-Scale Model Prediction in Japan

One-week EPS



216h ensemble forecast, Medium range, 51 members, 60km resolution

MSM

Short-term

33h deterministic forecasting, short range, 5km resolution

We want to know the informarion of

High-resolution and short-term ensemble prediction.

Ensemble NWP rainfall of Typhoon 'Talas', 2011

Design of meteorological experiment

Simulated by Meteorological Research Institute (MRI) of JMA

Kazuo SAITO, Hiromu SEKO and Seiji ORIGUCHI (2011)

- ***Forecast Model***

  - JMA Non-hydrostatic Model (JMA-NHM)

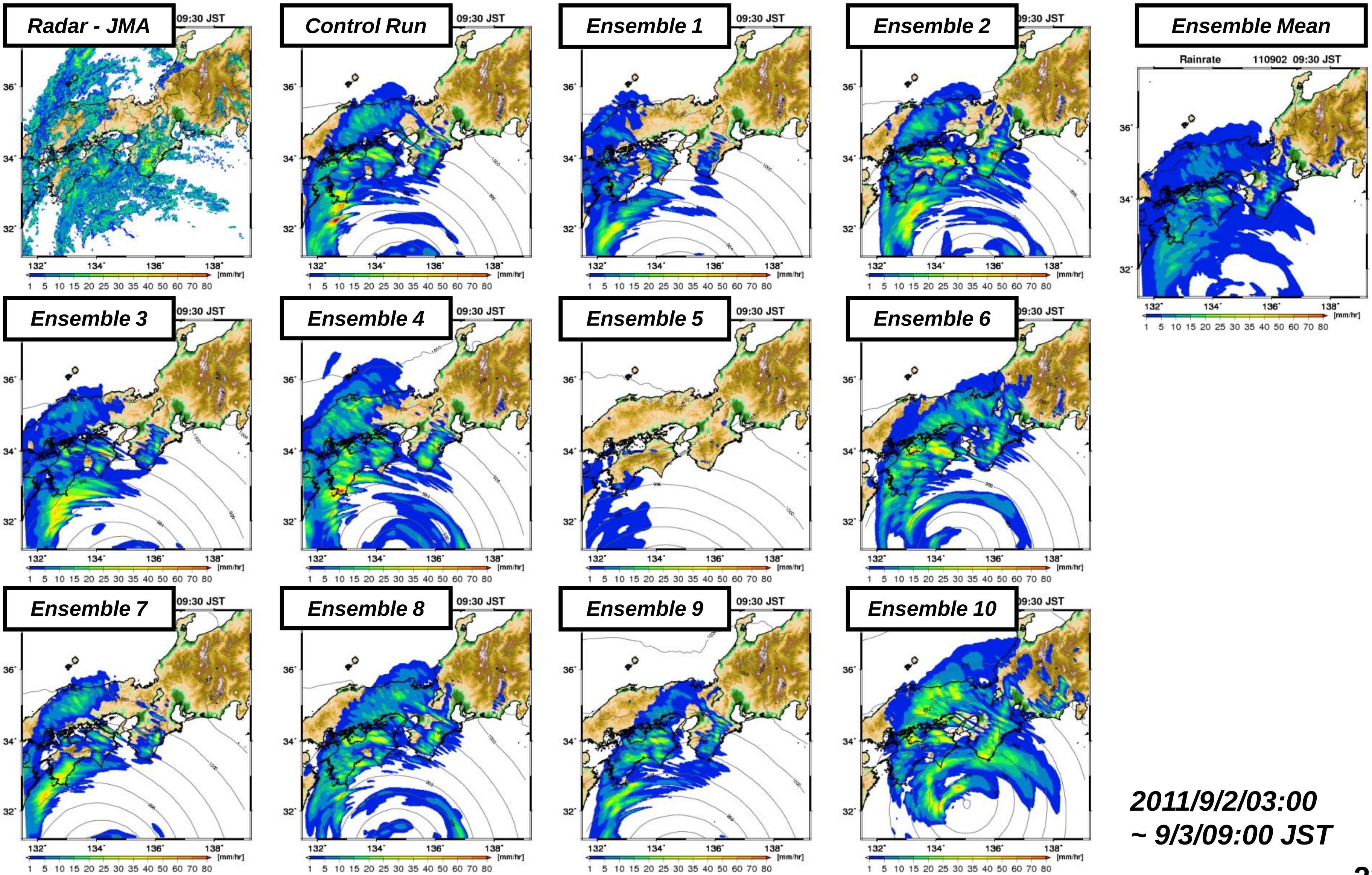
- ***Designed Ensemble NWP Data***

  - 10 km resolution: 11 members (1 unperturbed + 10 perturbed), 36 hours forecast time

  - 2km resolution: 11 members (1 unperturbed + 10 perturbed), 30 hours forecast time

Ensemble NWP rainfall of Typhoon 'Talas', 2011

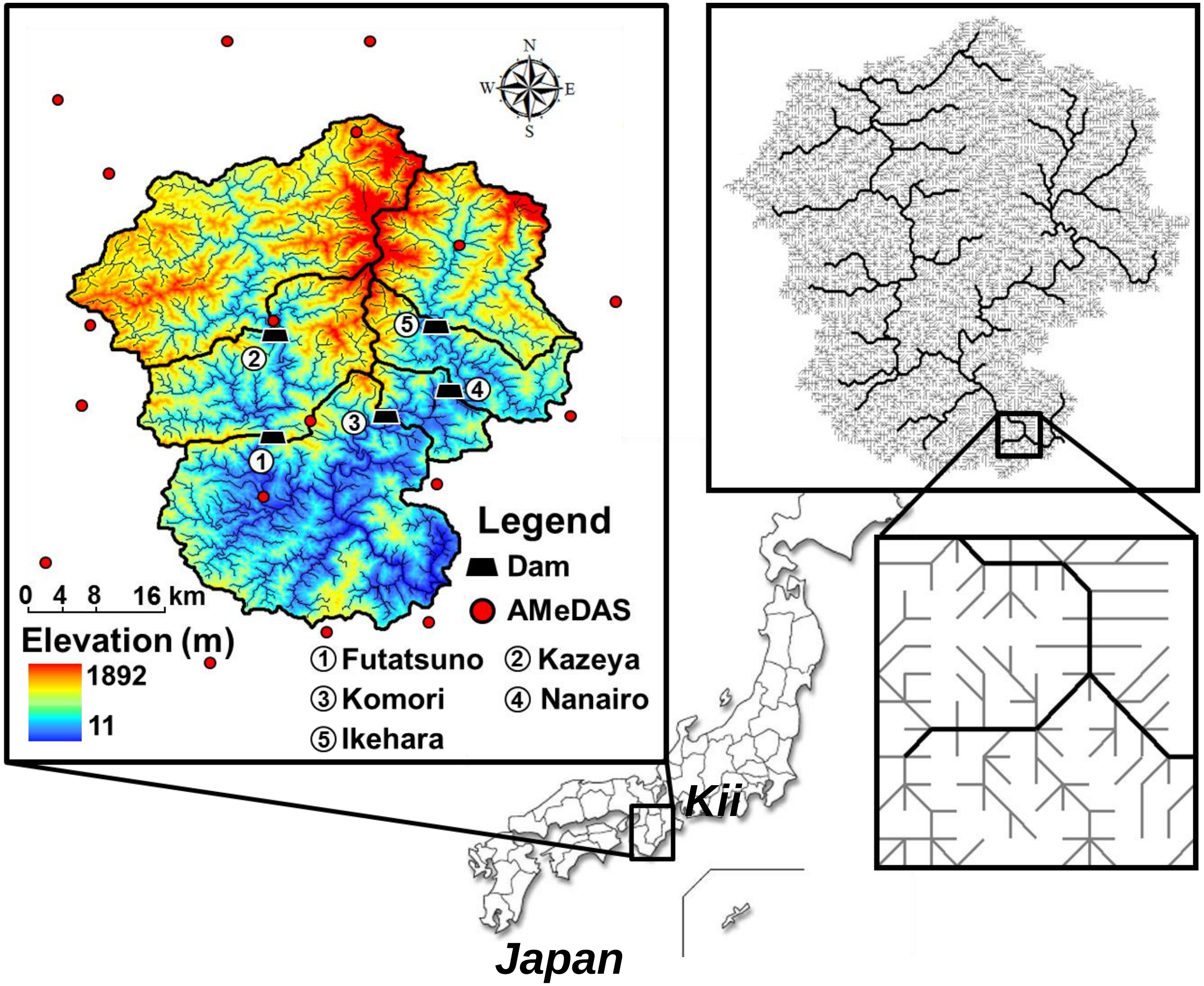
Ensemble Forecast with 30hr forecast time and 2km resolution



2011/9/2/03:00
~ 9/3/09:00 JST

Target Area

Shingu River Basin (2,360 km^2)



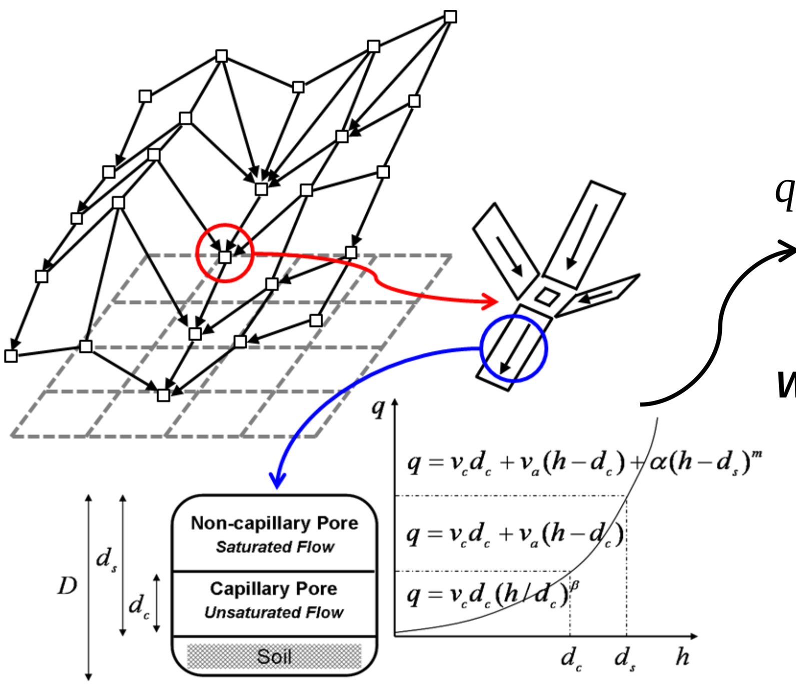
① Futatsuno Dam

④ Nanairo Dam

Dam Obs. Data
: From J-Power

Distributed Hydrologic Model: KWMSS

- ***Distributed hydrologic model based on "Object-oriented Hydrological Modelling System (OHyMoS) is used for flood forecasting.***
- ***One dimensional kinematic wave method for subsurface and surface (KWMSS) flow simulation is applied to each grid-cell.***
- ***Governing equation and rainfall-runoff process***



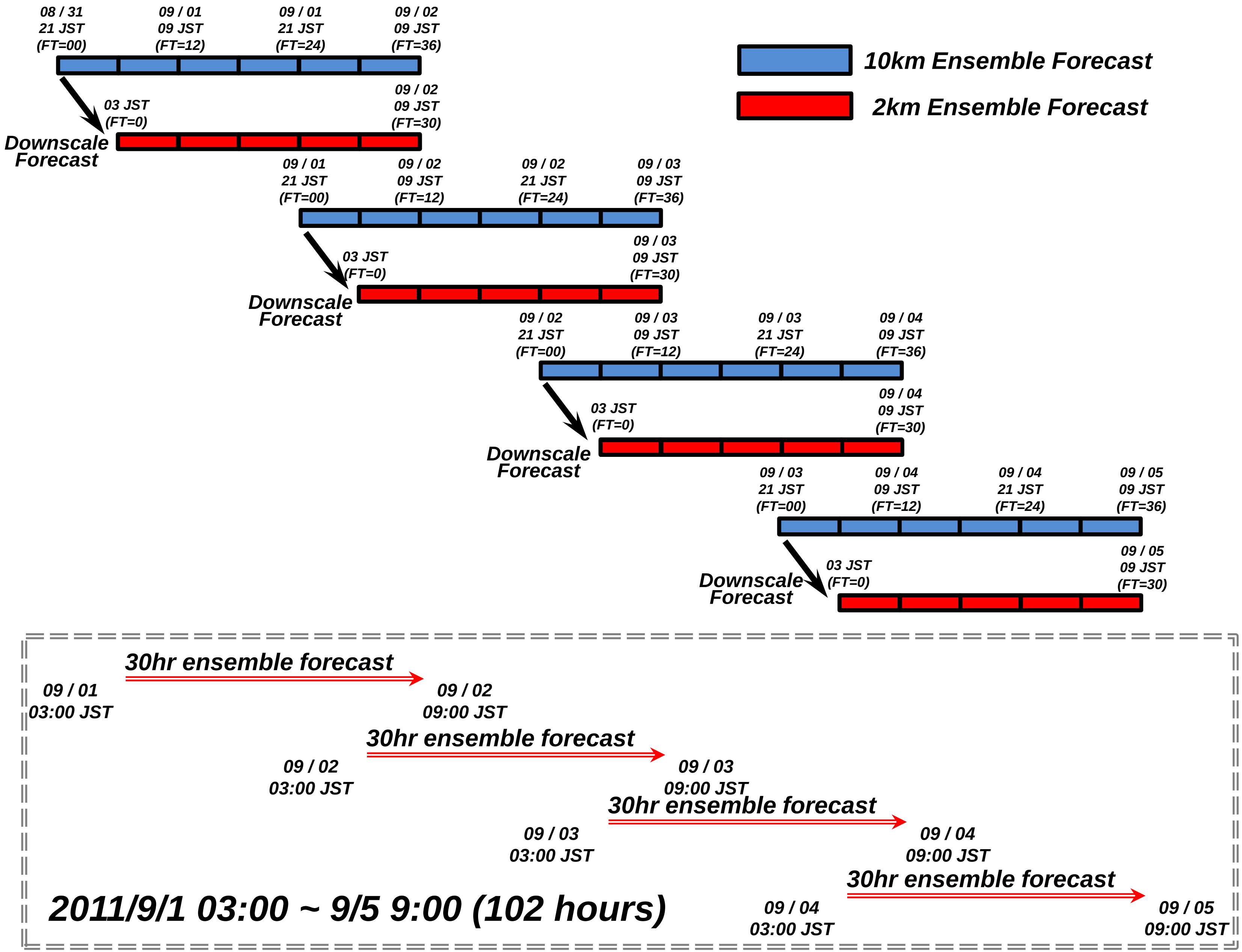
Tachikawa et al. (2004)

$$q = \begin{cases} v_m d_m (h/d_m)^\beta & : 0 < h \le d_m \\ v_m d_m + v_a(h-d_m) & : d_m < h \le d_a \\ v_m d_m + v_a(h-d_m) + \alpha(h-d_a)^m & : d_a < h \end{cases}$$

Where, $v_m = k_m i$, $v_a = k_a i$, $k_m = k_a/\beta$, $\alpha = \sqrt{i}/n$, $m = 5/3$

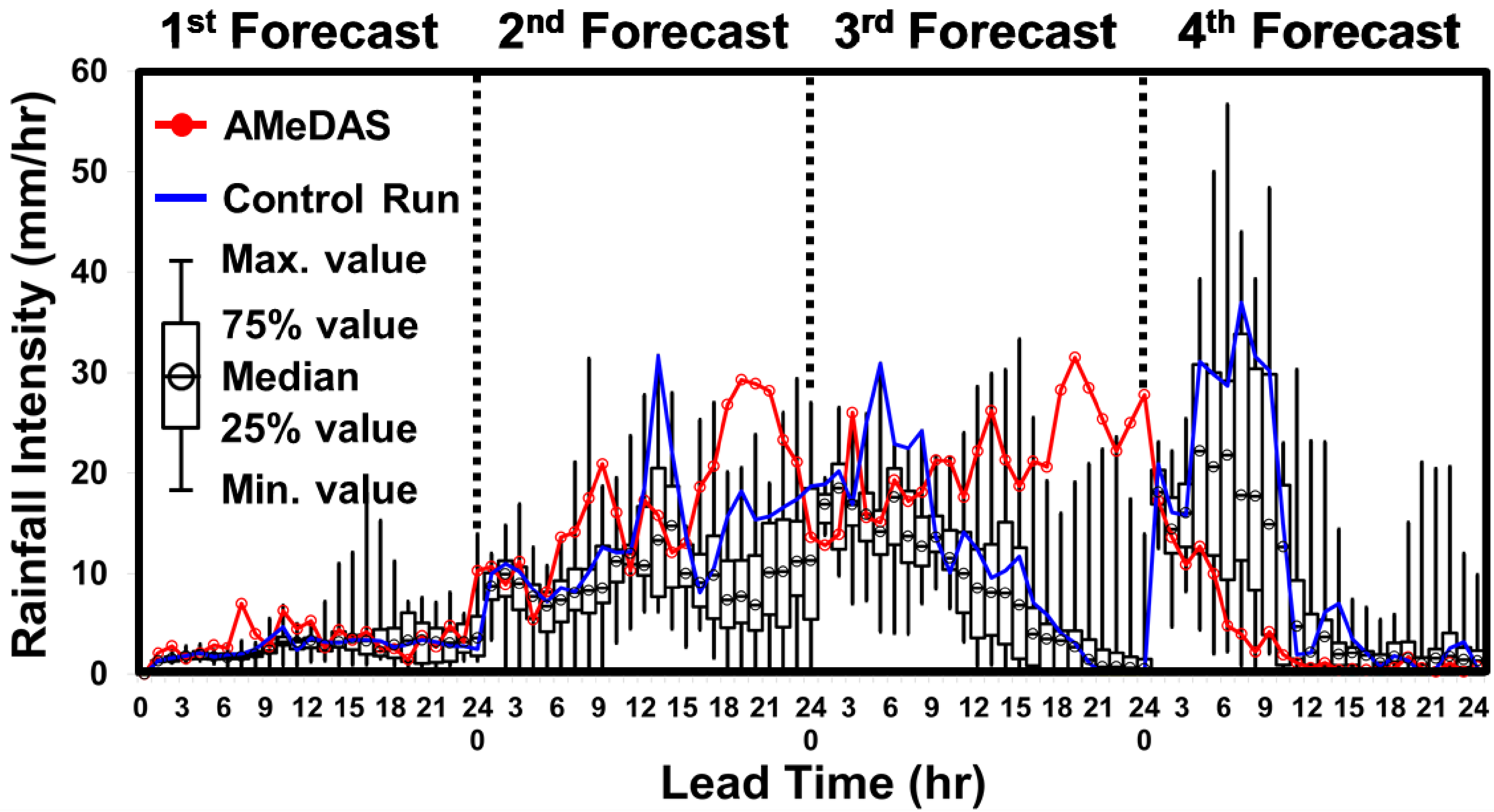
$$\frac{\partial h}{\partial t} + \frac{\partial q}{\partial x} = r(x,t)$$

A schematic of four sets of forecast runs



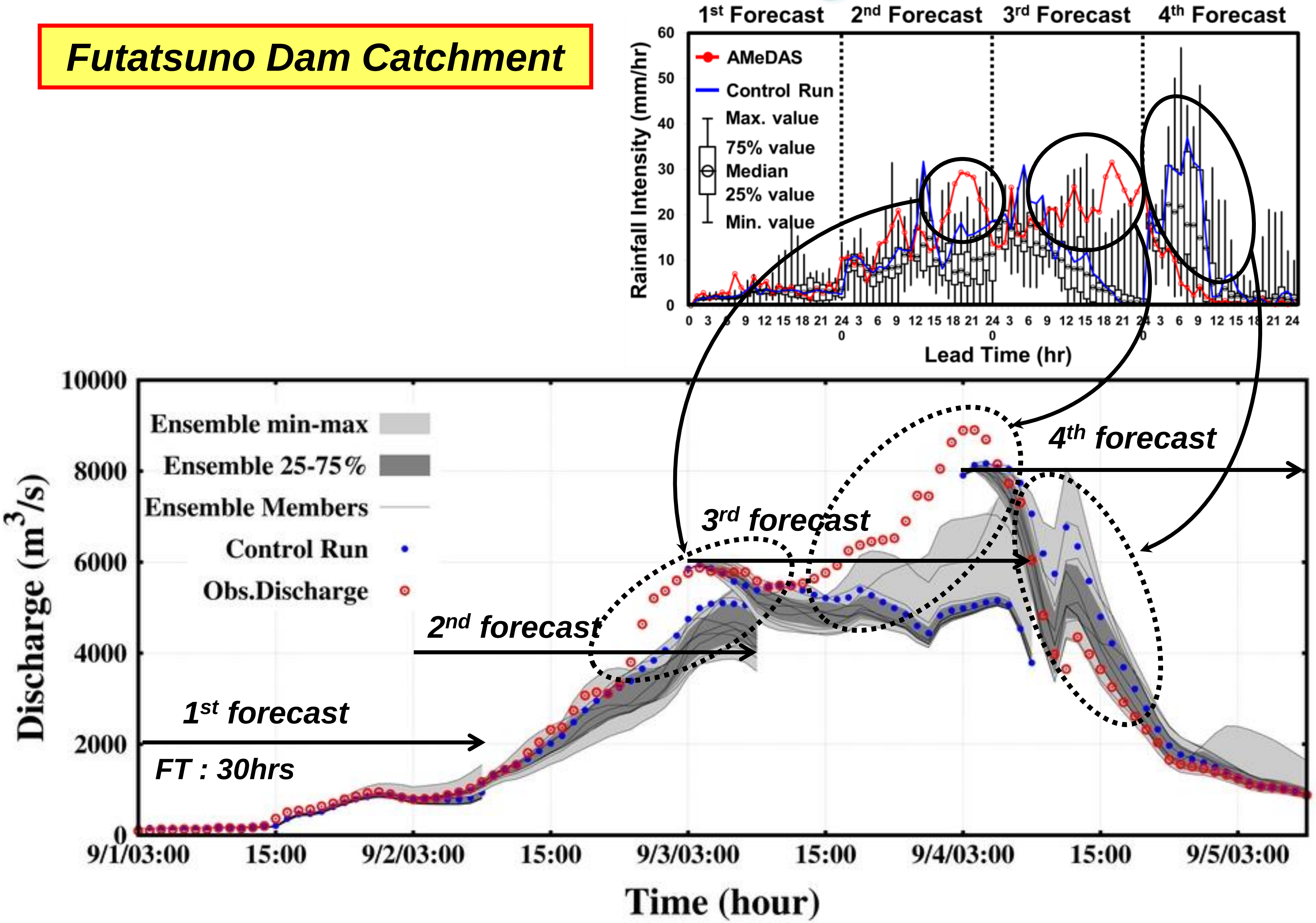
Forecasted Ensemble Rainfall in T1112

Areal rainfall (Shingu river basin)



Ensemble Flood Forecasting

Futatsuno Dam Catchment



Summary

1. ***Although ensemble forecast could produce more suitable results compared with deterministic control run in terms of quantitative precipitation forecast (QPF), <u>the uncertainty of ensemble NWP rainfall was also significant at longer lead times.</u>***

2. ***Flood forecasts driven by ensemble outputs showed that in general <u>it has a large proportion of under and over predictions at short lead times and exhibited a negative bias at longer lead times.</u>***

3. ***Despite the deficient performance for longer lead times, it was shown that the <u>ensemble flood forecast provides additional information to the deterministic forecast.</u>***

Improvement of rainfall and flood forecasts by blending ensemble NWP rainfall with radar prediction considering orographic rainfall

Objective

- ***The aim of this study is to <u>blend the advantages of ensemble information of NWP rainfall forecast and radar-based prediction</u> for the accuracy improvement of rainfall and flood forecasting in viewpoint of the hybrid forecast.***

  (i) Radar-based prediction

  - considering orographic rainfall and error field scheme

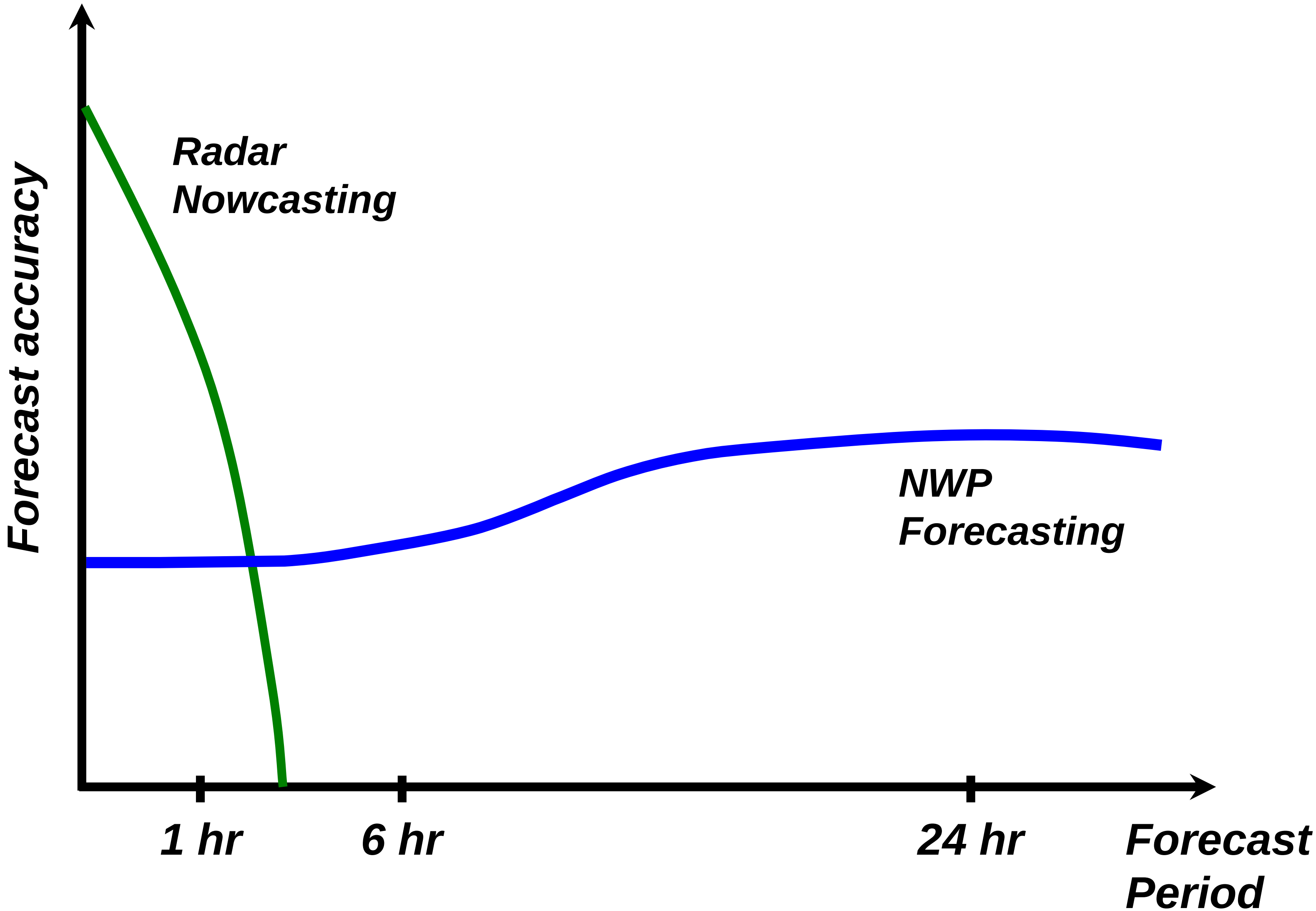
  (ii) Ensemble NWP rainfall updating

  - Error Field Scheme

  (iii) Blending of the radar prediction and ensemble NWP rainfall

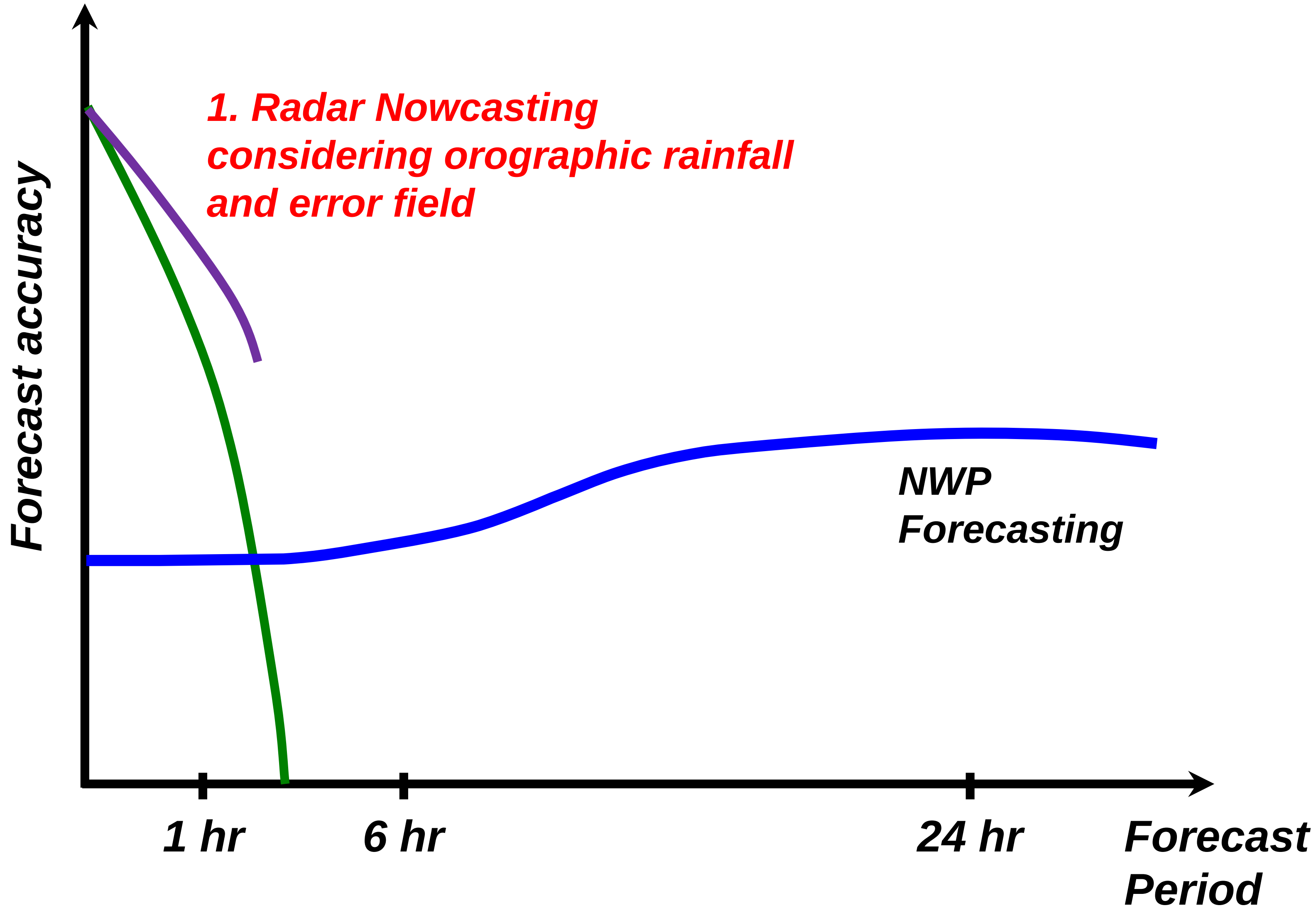
Background & Purpose

- ***Procedure of Blending of the radar and NWP forecast***



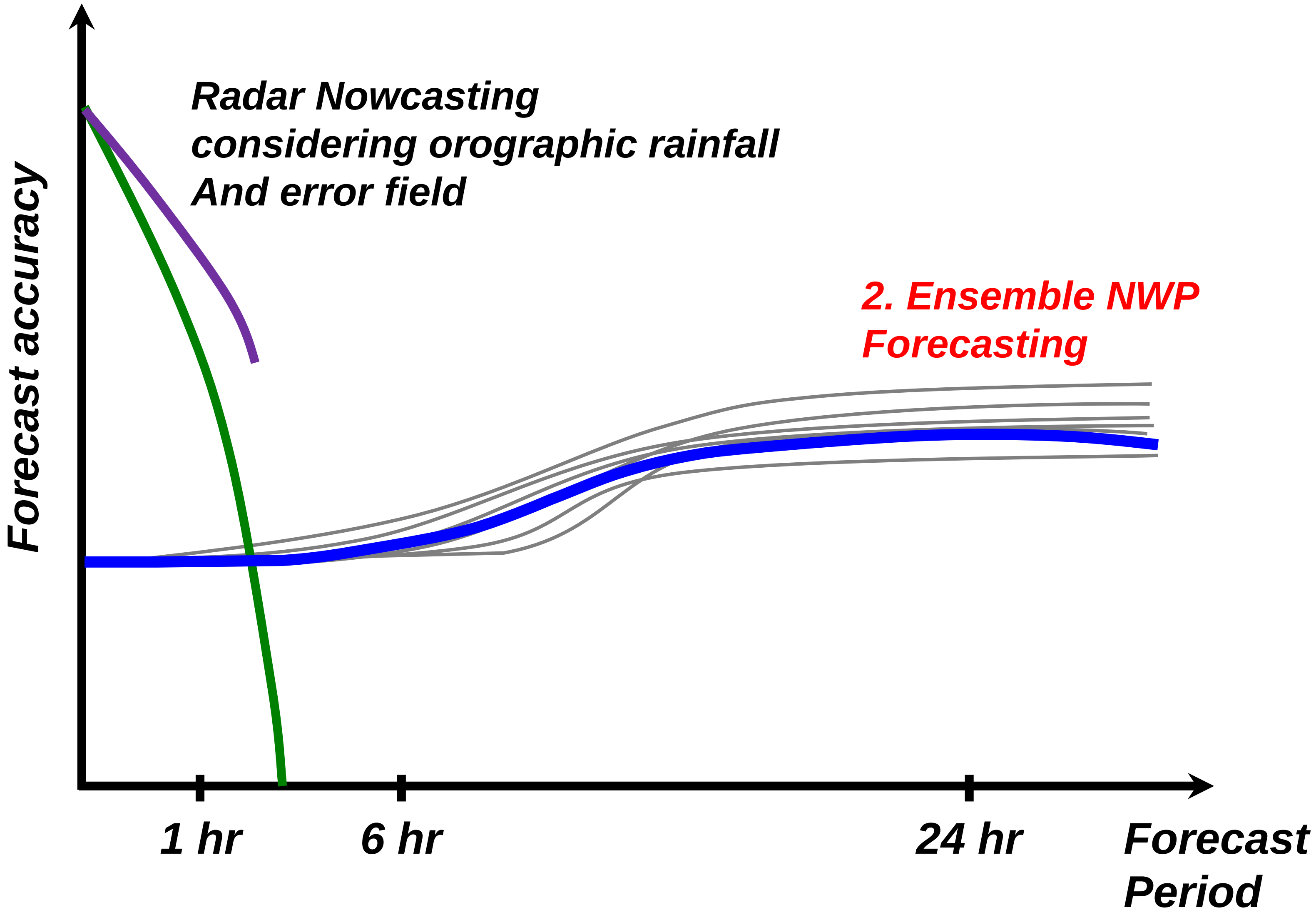
Background & Purpose

➢ ***Procedure of Blending of the radar and NWP forecast***



Background & Purpose

➢ ***Procedure of Blending of the radar and NWP forecast***



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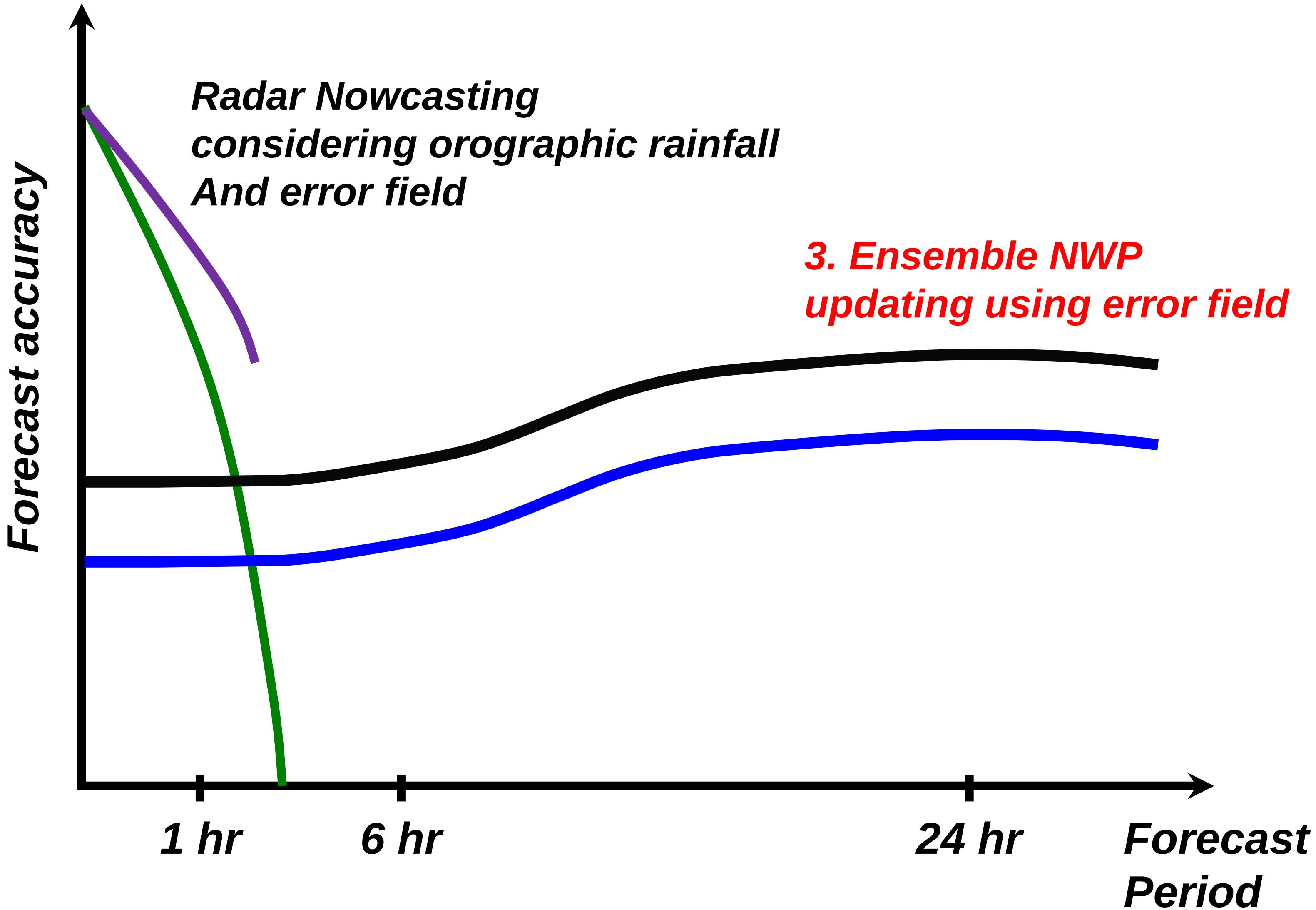

Background & Purpose

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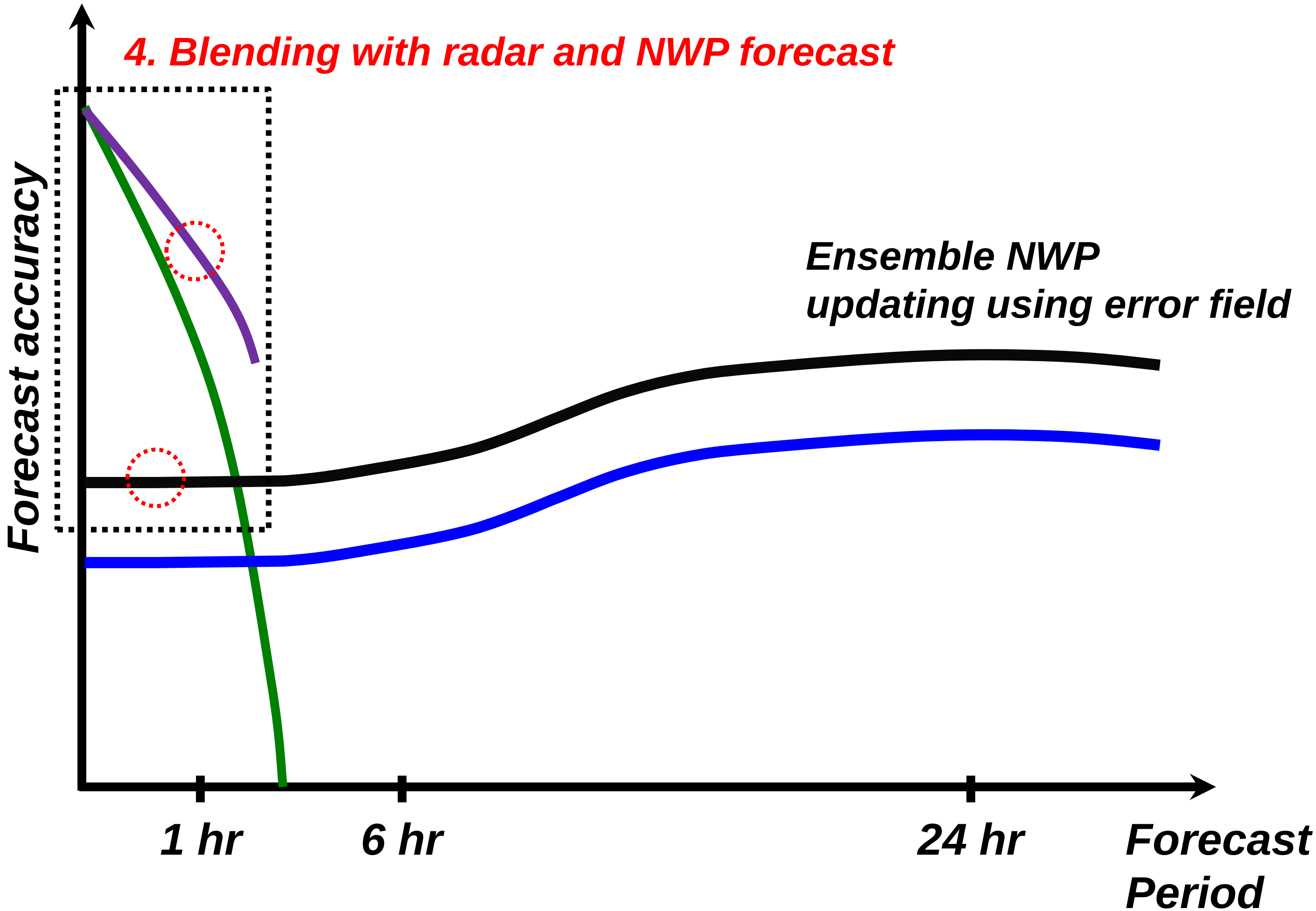
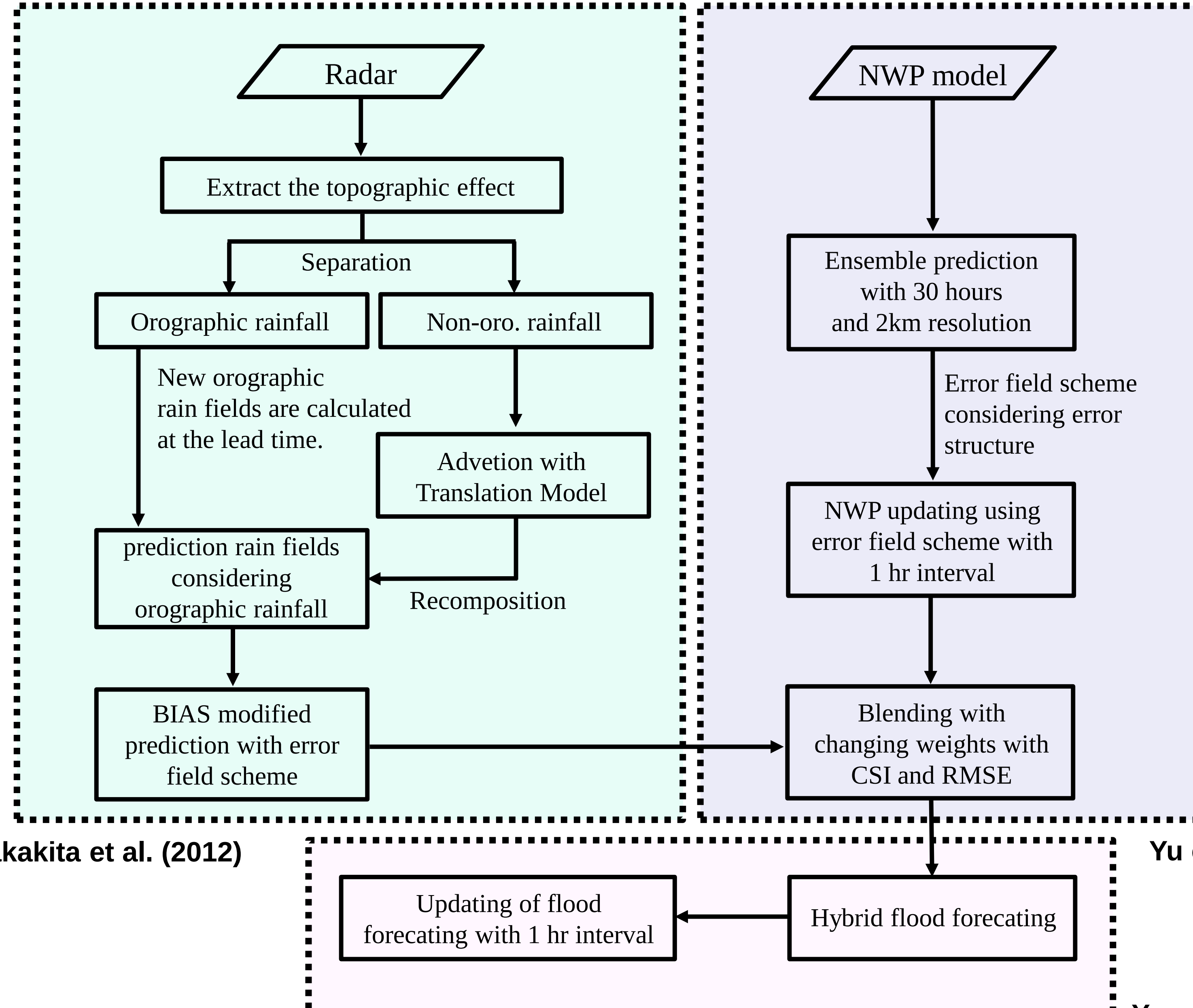


Flowchart for Hybrid flood forecating



Nakakita et al. (2012)

Yu et al. (2014)

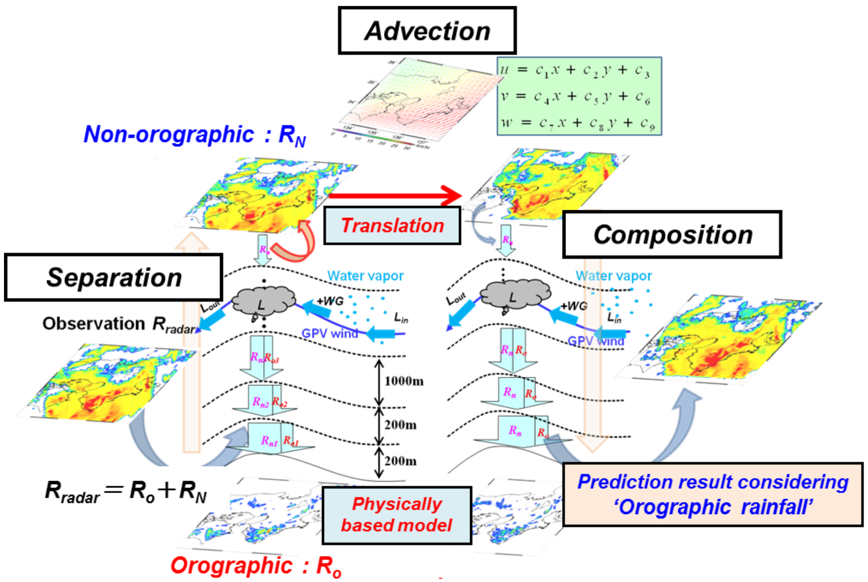
Yu and Nakakita (2015)

Radar-based Prediction

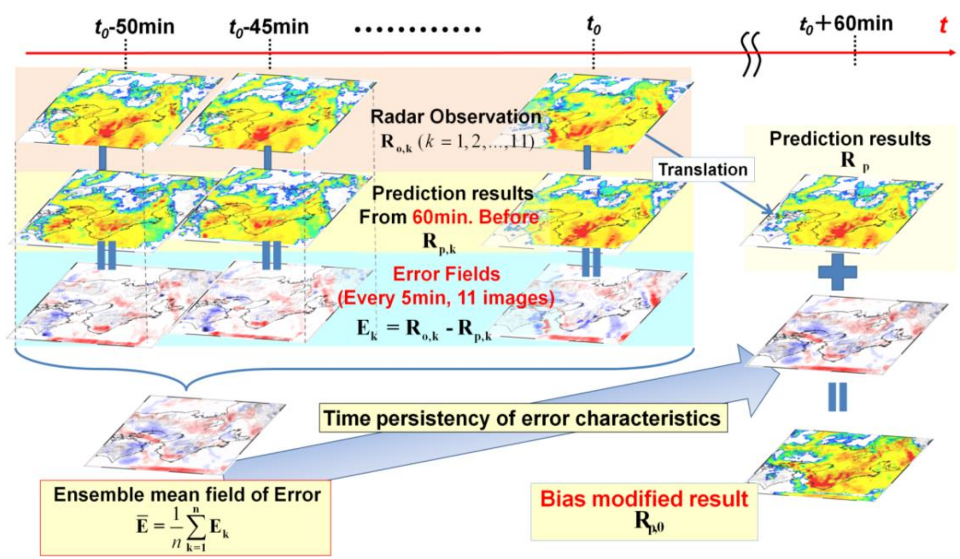
Improved Radar image extrapolation method *Nakakita et al. (2012)*

- *Combining* *orographic rainfall* *identification scheme and the* *error field scheme considering error structure (3hr lead time).*

1. Orographic rainfall identification scheme



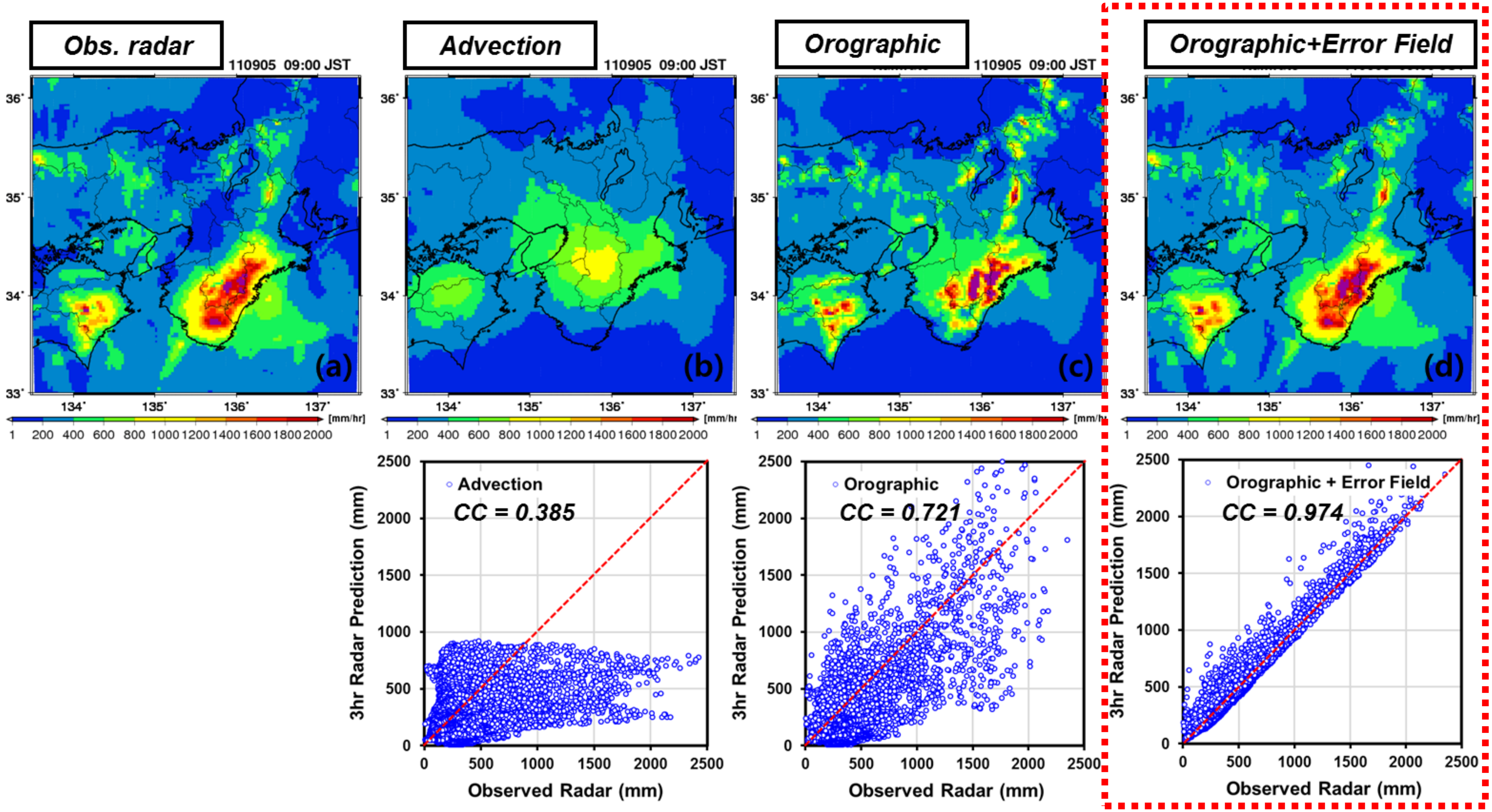
2. Error field scheme considering error structure



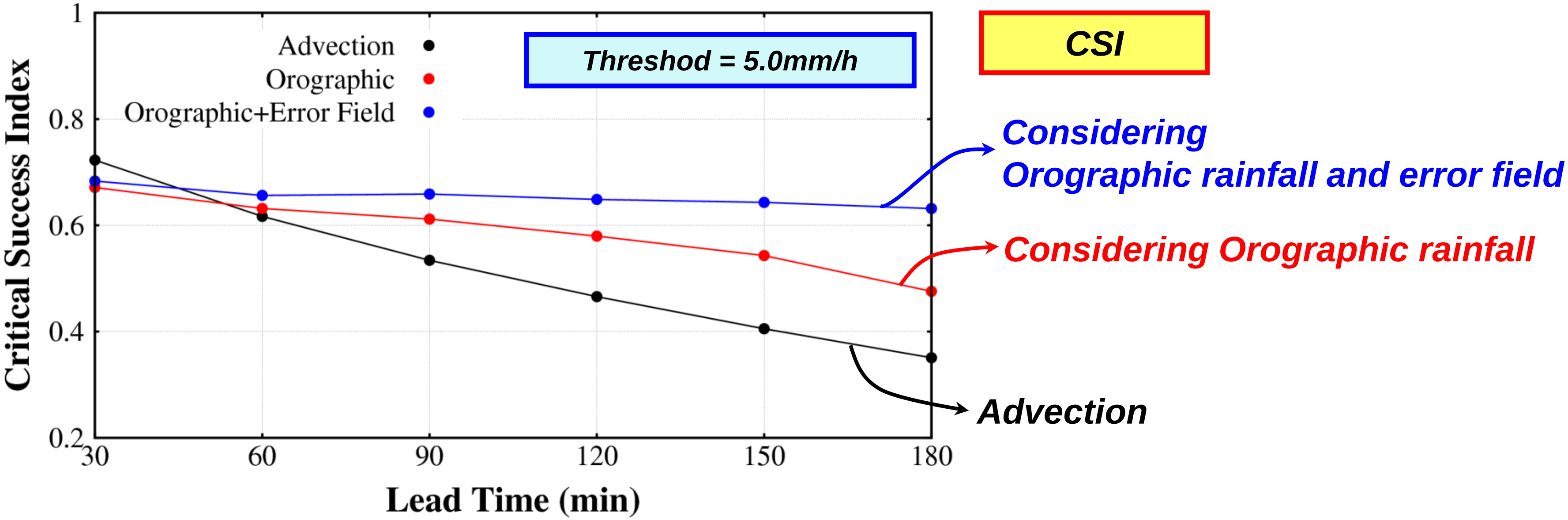
$$
\begin{cases}
c = 0.6778 R_N^{\ 0.731} \times 10^{-3} \\
R_o = \dfrac{\left(L_{in} - \dfrac{WG}{c}\right)\left(1 - e^{-(c\Delta t)}\right) + WG\Delta t}{\Delta t} \times 3.6 \times H \\
R_{radar} = R_0 + R_N
\end{cases}
$$

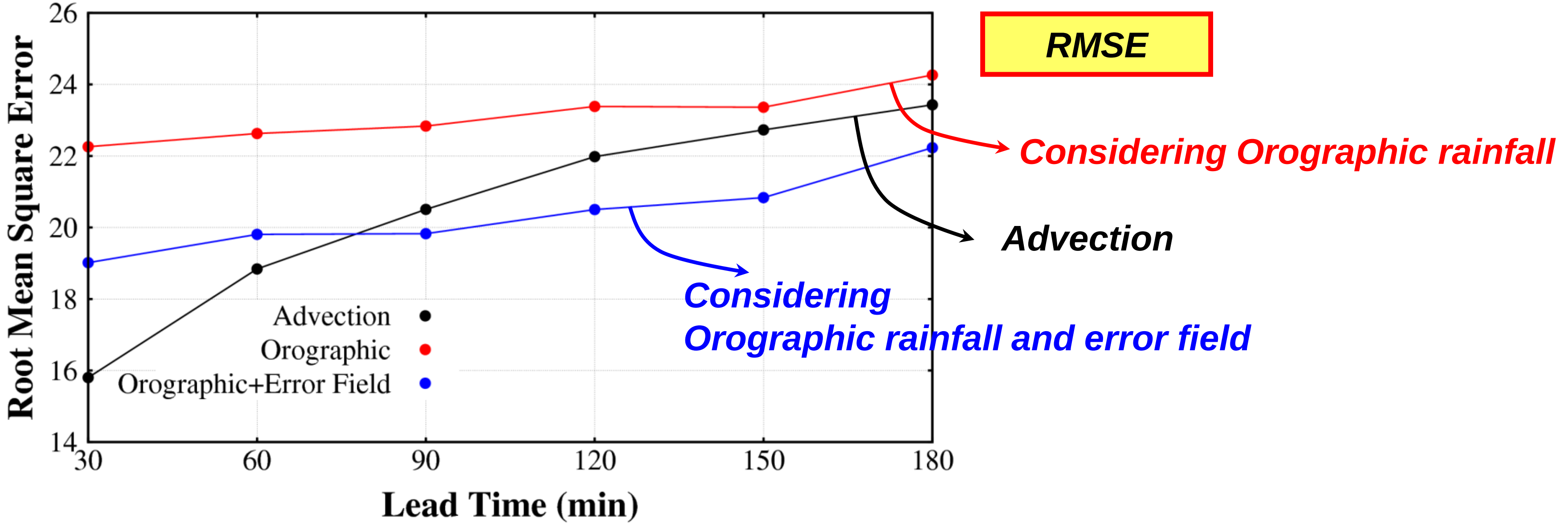
Radar-based Prediction

Accumulated Rainfall *2011/09/01/09:00 ~ 09/05/09:00 JST*

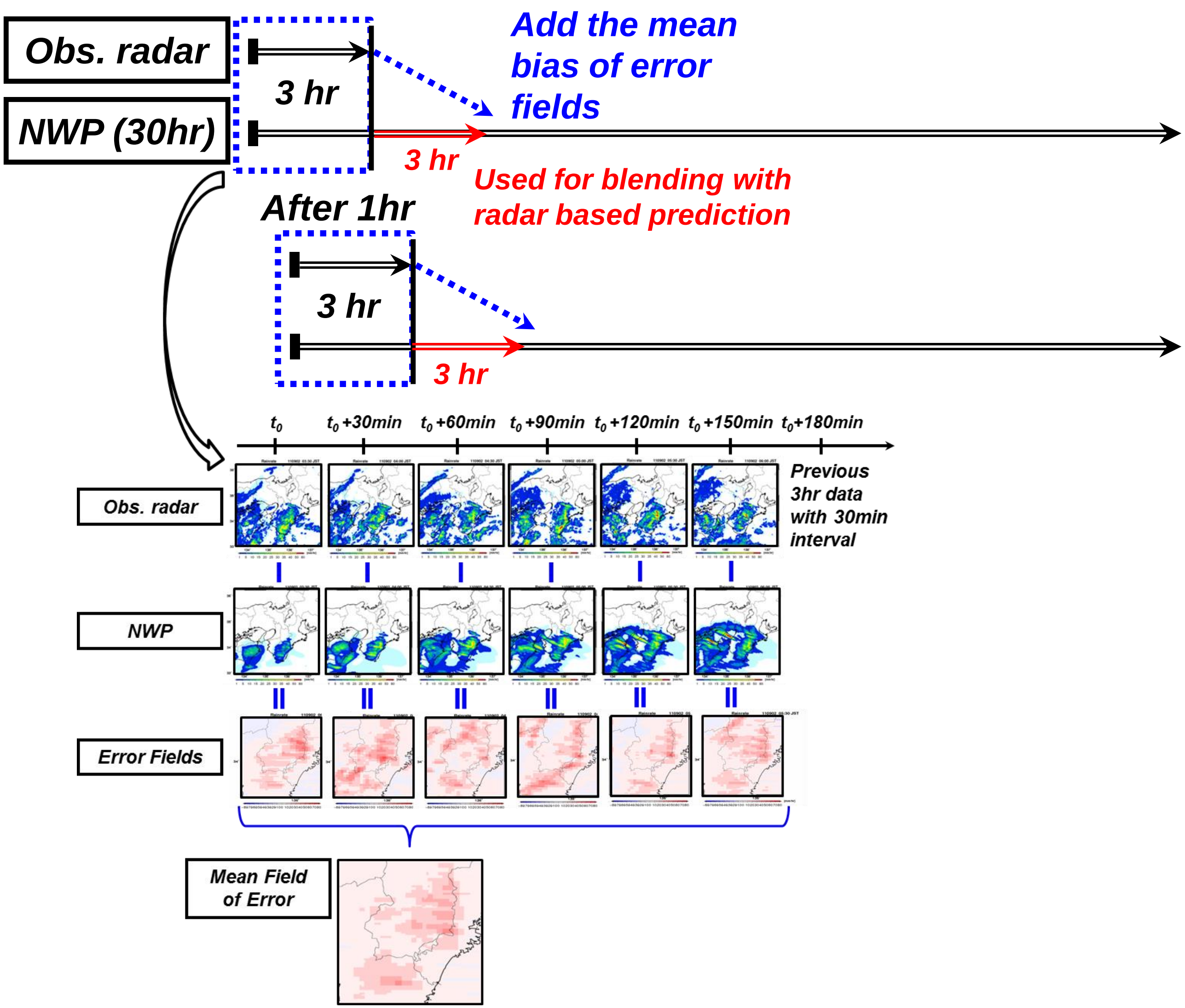


Rainfall Verification





NWP Updating with Error Field Scheme



Blending of the radar and NWP

$$R_{blend,i} = C_{radar,i} \times R_{radar} + C_{nwp,i} \times R_{nwp,i}$$

$$C_{radar,i} + C_{nwp,i} = 1$$

$$\begin{bmatrix} R_{blend,1} \\ R_{blend,2} \\ R_{blend,3} \\ \cdot \\ \cdot \\ R_{blend,10} \\ R_{blend,11} \end{bmatrix} = \begin{bmatrix} C_{radar,1} \\ C_{radar,2} \\ C_{radar,3} \\ \cdot \\ \cdot \\ C_{radar,10} \\ \boxed{C_{radar,11}} \end{bmatrix} \times R_{radar} + \begin{bmatrix} \boxed{C_{nwp,1}} \\ C_{nwp,2} \\ C_{nwp,3} \\ \cdot \\ \cdot \\ C_{nwp,10} \\ C_{nwp,11} \end{bmatrix} \times \begin{bmatrix} R_{nwp,1} \\ R_{nwp,2} \\ R_{nwp,3} \\ \cdot \\ \cdot \\ R_{nwp,10} \\ R_{nwp,11} \end{bmatrix}$$

$$C_{nwp,i} = \frac{w_{nwp,i,1} + w_{nwp,i,2}}{2}$$

$$w_{nwp,i,1} = \frac{CSI^2_{nwp,i}}{CSI^2_{radar} + CSI^2_{nwp,i}}$$

$$w_{nwp,i,2} = 1 - \frac{RMSE^2_{nwp,i}}{RMSE^2_{radar} + RMSE^2_{nwp,i}}$$

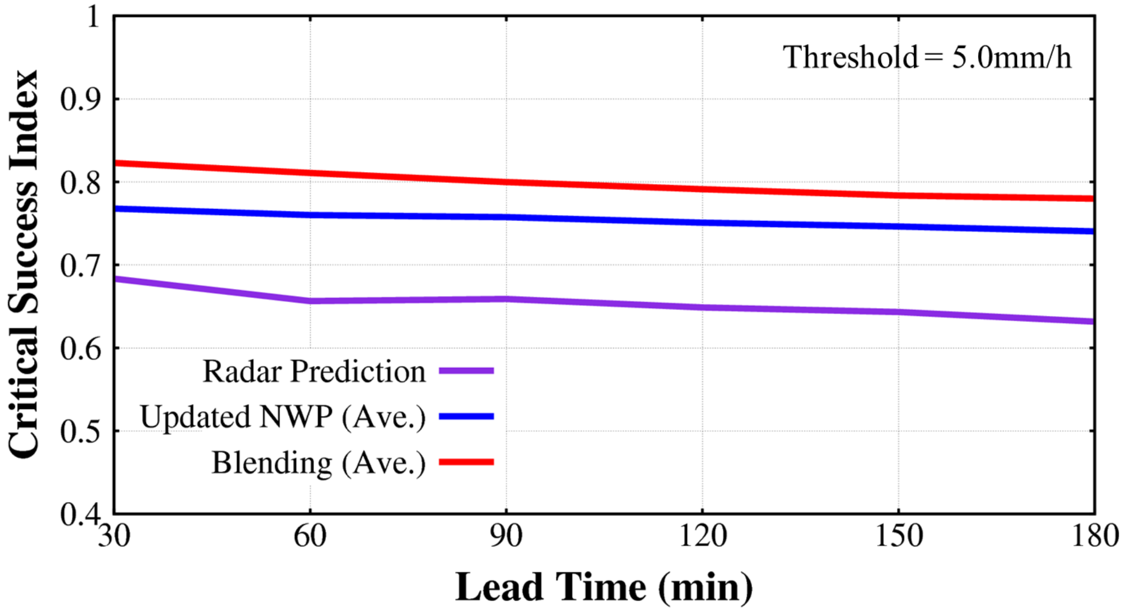
Threshold : 5 mm/h

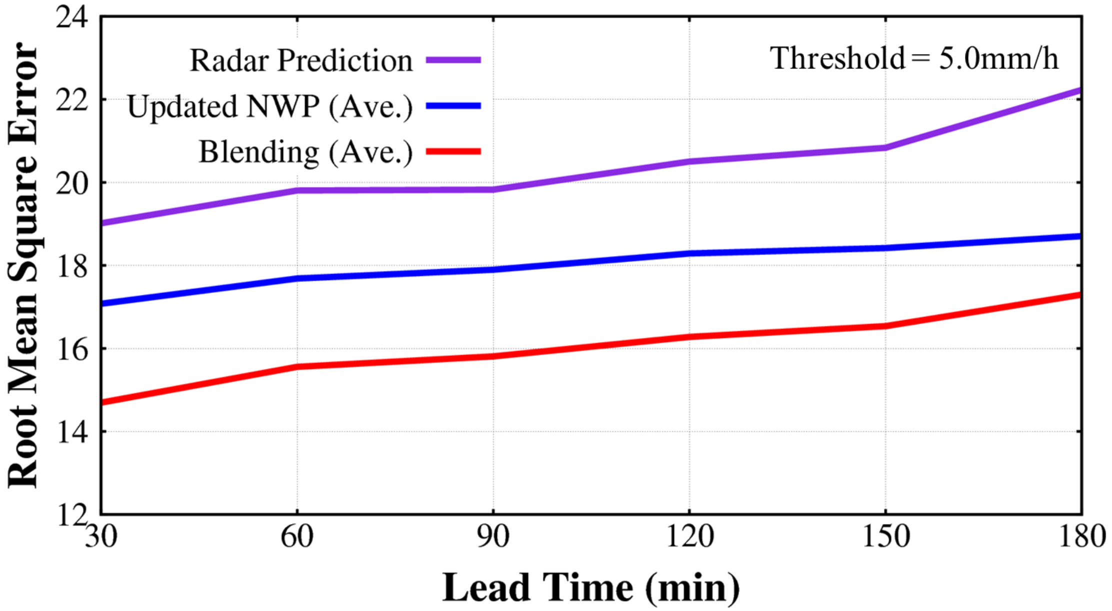
$$C_{radar,i} = \frac{w_{radar,i,1} + w_{radar,i,2}}{2}$$

$$w_{radar,i,1} = \frac{CSI^2_{radar}}{CSI^2_{radar} + CSI^2_{nwp,i}}$$

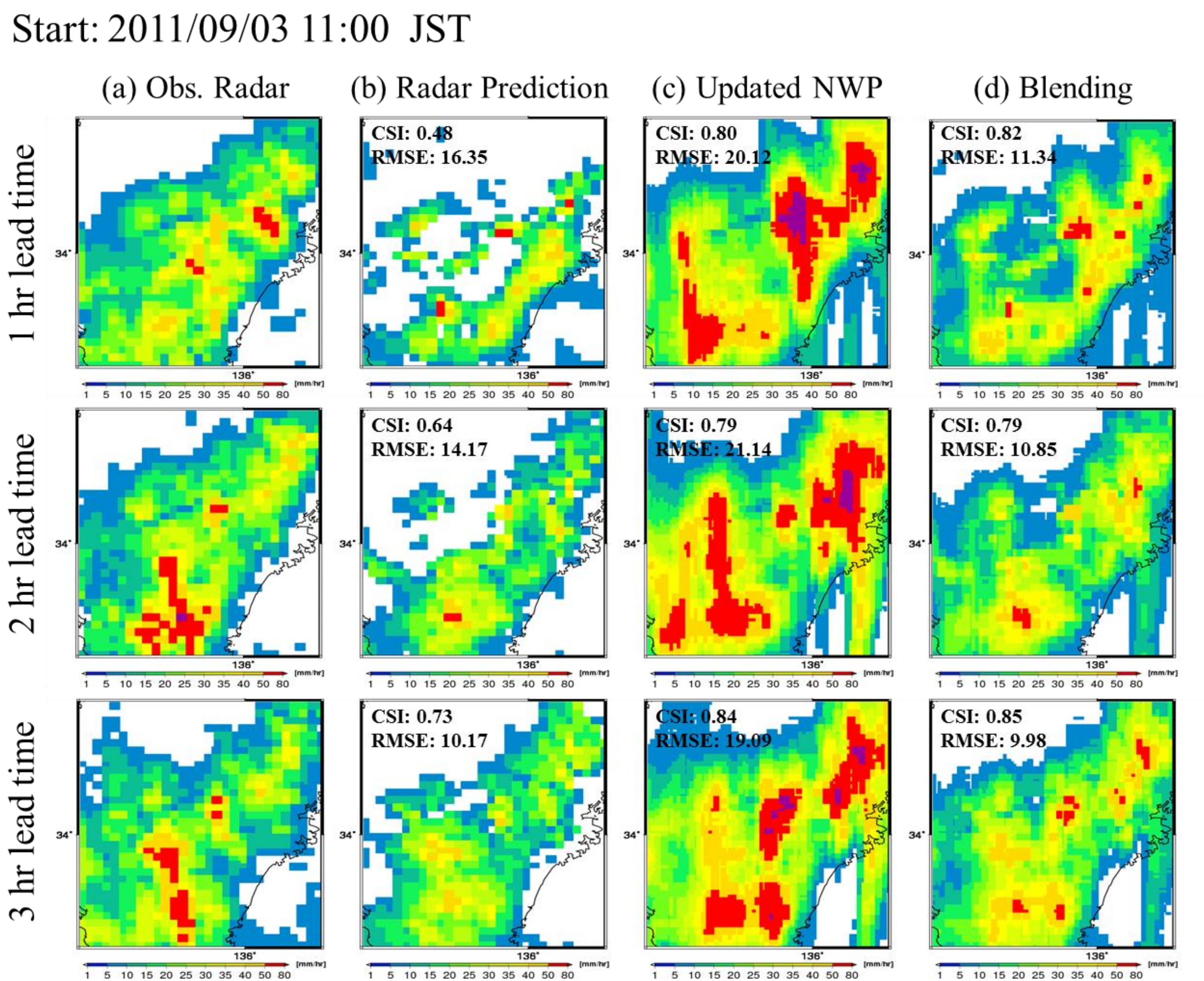
$$w_{radar,i,2} = 1 - \frac{RMSE^2_{radar}}{RMSE^2_{radar} + RMSE^2_{nwp,i}}$$

Rainfall Verification





Rainfall Verification



Rainfall Verification

CSI

Lead Time	Type	Thresholds (mm)					
		0.1	0.5	1.0	5.0	10.0	20.0
60min	Radar	0.81	0.79	0.78	0.66	0.55	0.38
	NWP	0.94	0.92	0.90	0.76	0.65	0.45
	Blend	**0.97**	**0.95**	**0.93**	**0.81**	**0.71**	**0.51**
120min	Radar	0.80	0.78	0.77	0.65	0.54	0.38
	NWP	0.94	0.91	0.89	0.75	0.64	0.44
	Blend	**0.96**	**0.94**	**0.93**	**0.79**	**0.69**	**0.49**
180min	Radar	0.80	0.78	0.77	0.63	0.52	0.36
	NWP	0.94	0.91	0.89	0.74	0.63	0.42
	Blend	**0.96**	**0.94**	**0.92**	**0.78**	**0.68**	**0.47**

Rainfall Verification

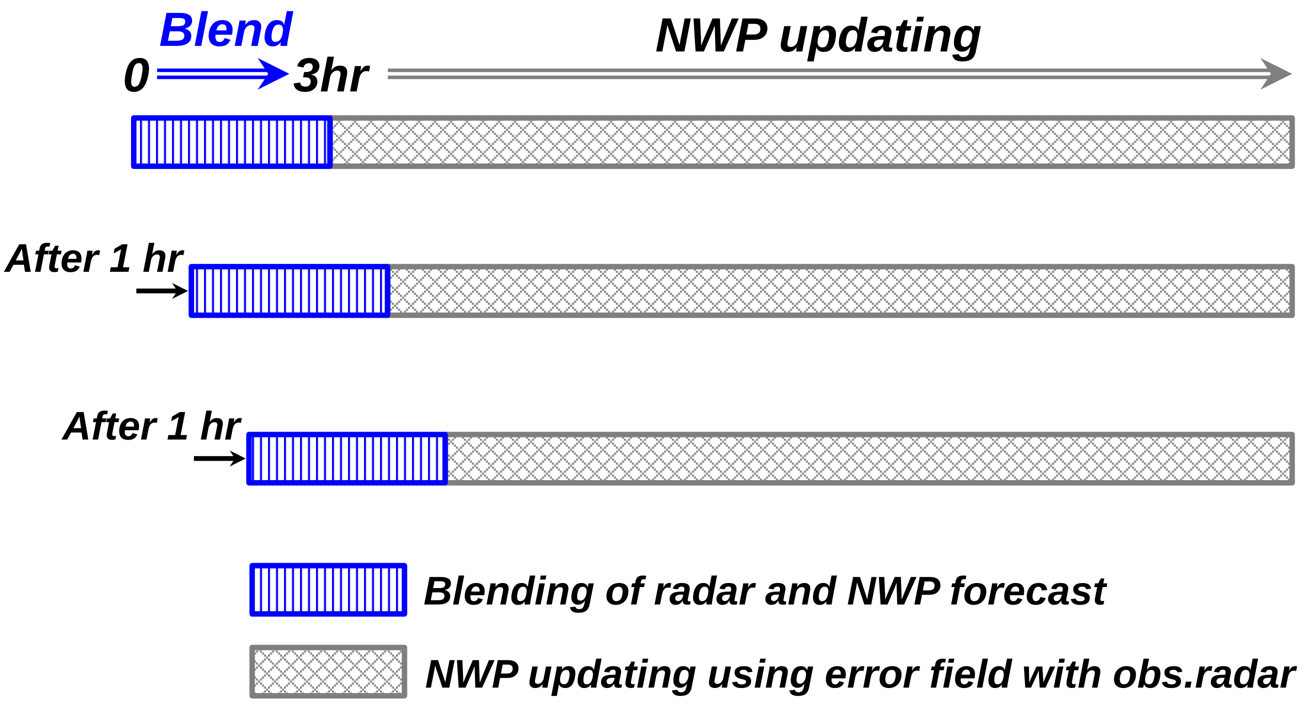
RMSE

Lead Time	Type	Thresholds (mm)					
		0.1	0.5	1.0	5.0	10.0	20.0
60min	Radar	17.92	18.02	18.10	19.81	23.07	31.65
	NWP	16.17	16.21	16.27	17.8	20.56	28.58
	Blend	**14.41**	**14.43**	**14.46**	**15.56**	**18.08**	**25.90**
120min	Radar	18.63	18.72	18.79	20.50	23.84	32.30
	NWP	16.79	16.83	16.88	18.29	21.18	29.26
	Blend	**15.15**	**15.17**	**15.20**	**16.28**	**18.84**	**26.77**
180min	Radar	20.28	20.37	20.44	22.23	25.77	35.26
	NWP	17.25	17.29	17.33	18.71	21.56	29.73
	Blend	**16.14**	**16.16**	**16.19**	**17.30**	**19.94**	**28.01**

Application into hybrid flood forecasting

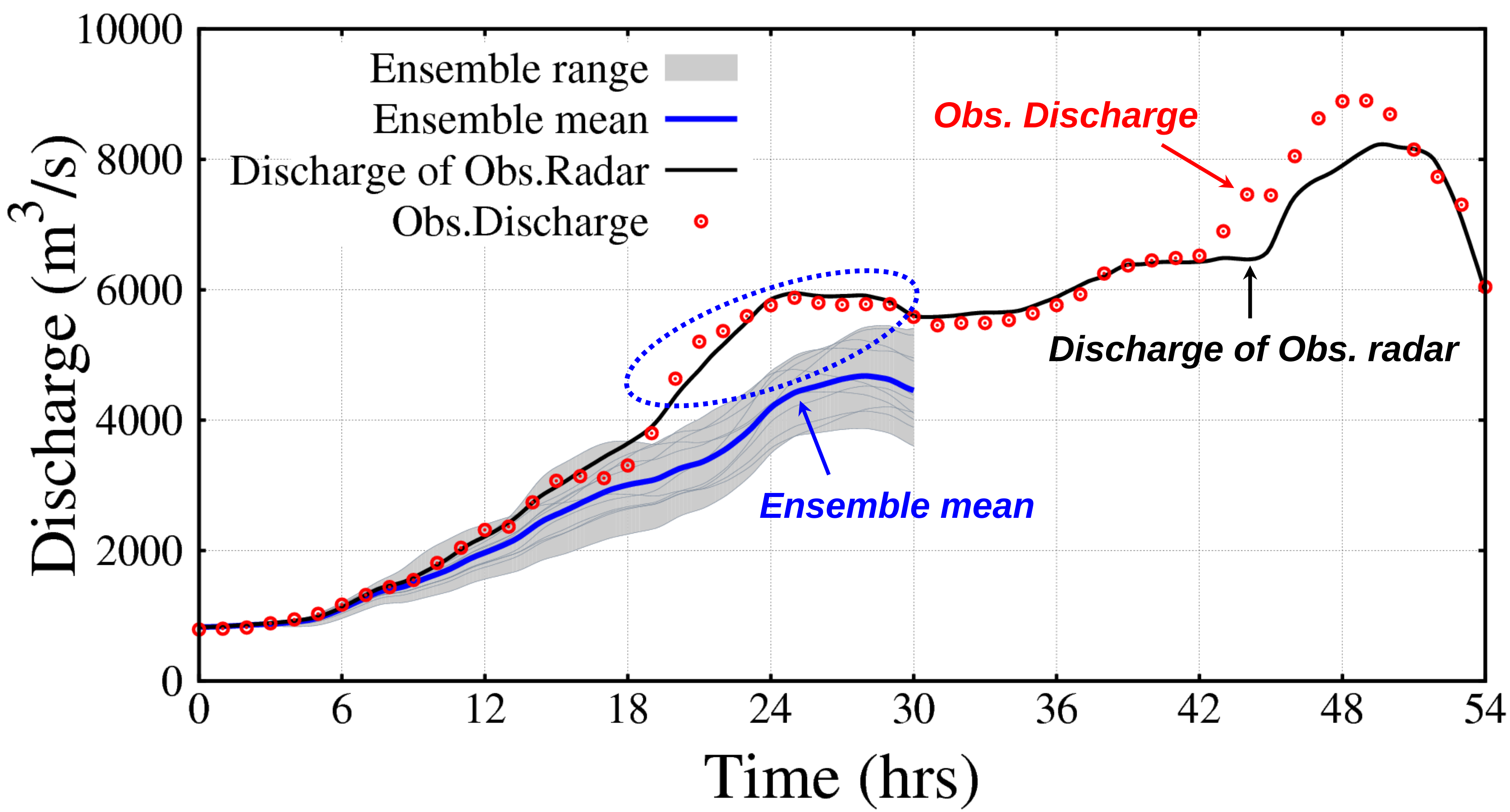
Strategy for hybrid flood forecasting

- *0 ~ 3 hr: blending results of radar and NWP*
- *3 hr ~ : NWP updating using error field with obs.radar*



Application into hybrid flood forecasting

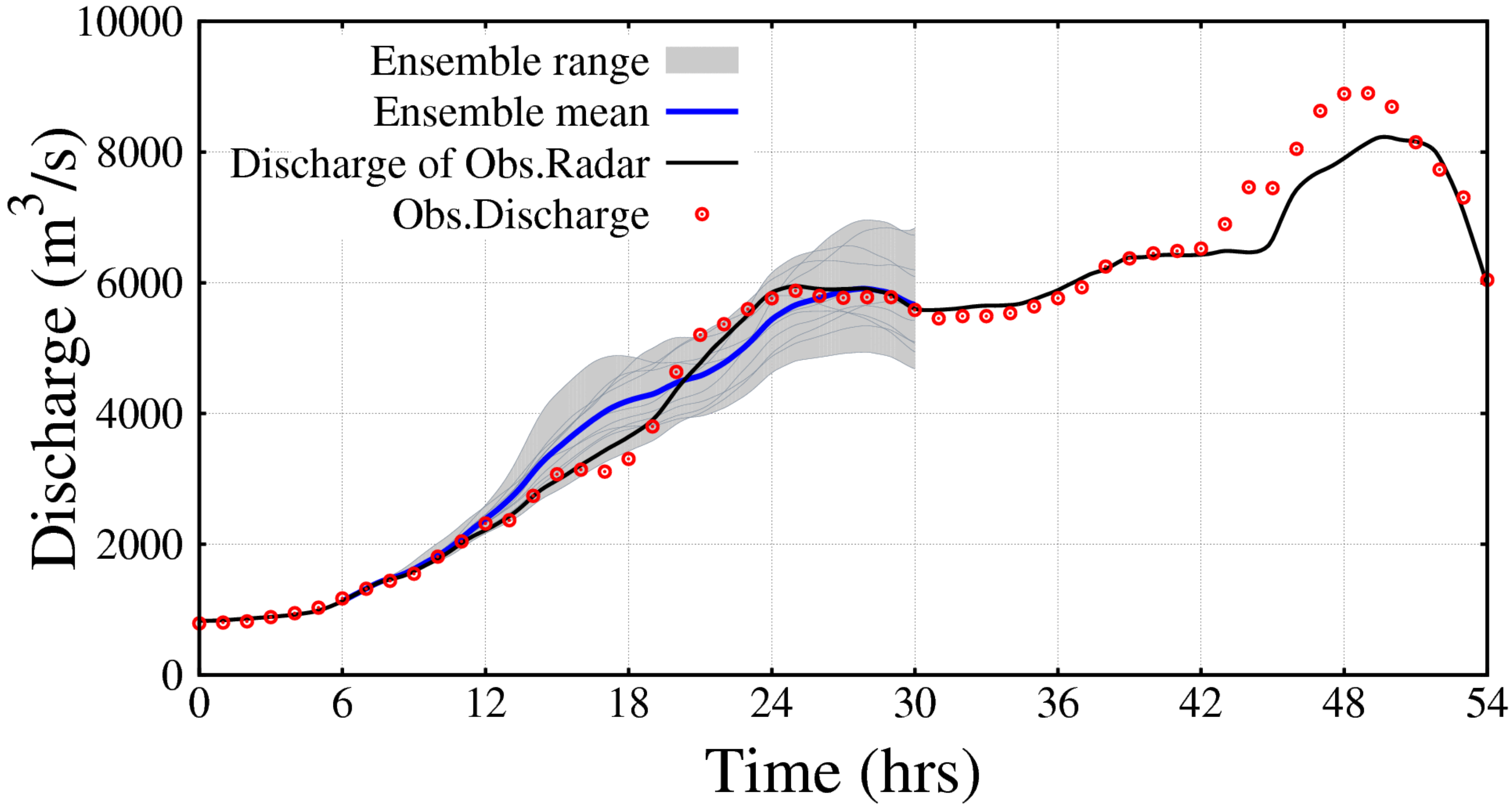
Futatsuno Dam Catchment ***2011/09/02/18:00 ~ 09/03/00:00 UTC (30 hours)***



Application into hybrid flood forecasting

Futatsuno Dam Catchment

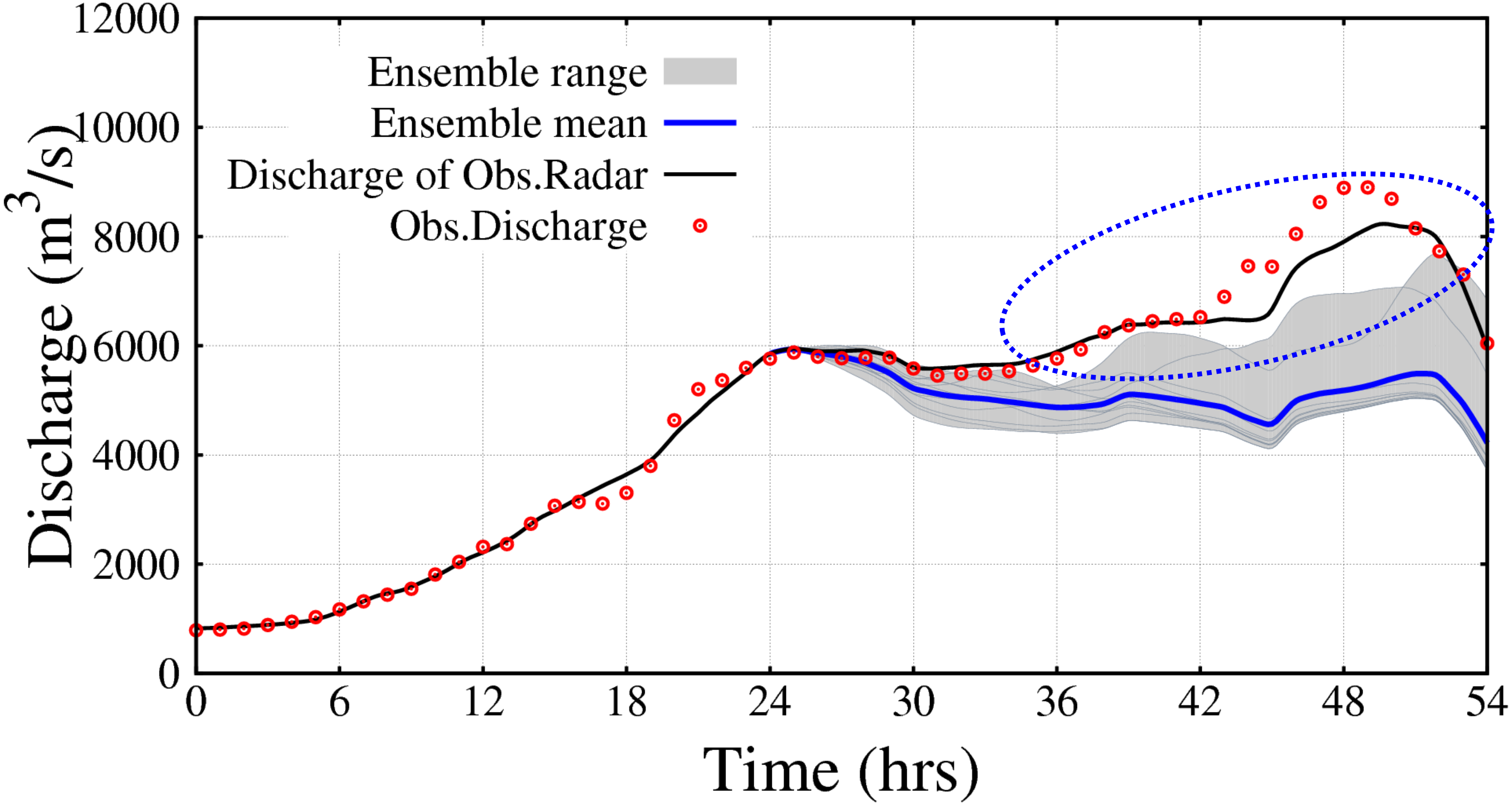
2011/09/02/18:00 ~ 09/03/00:00 UTC (30 hours)



Application into hybrid flood forecasting

Futatsuno Dam Catchment

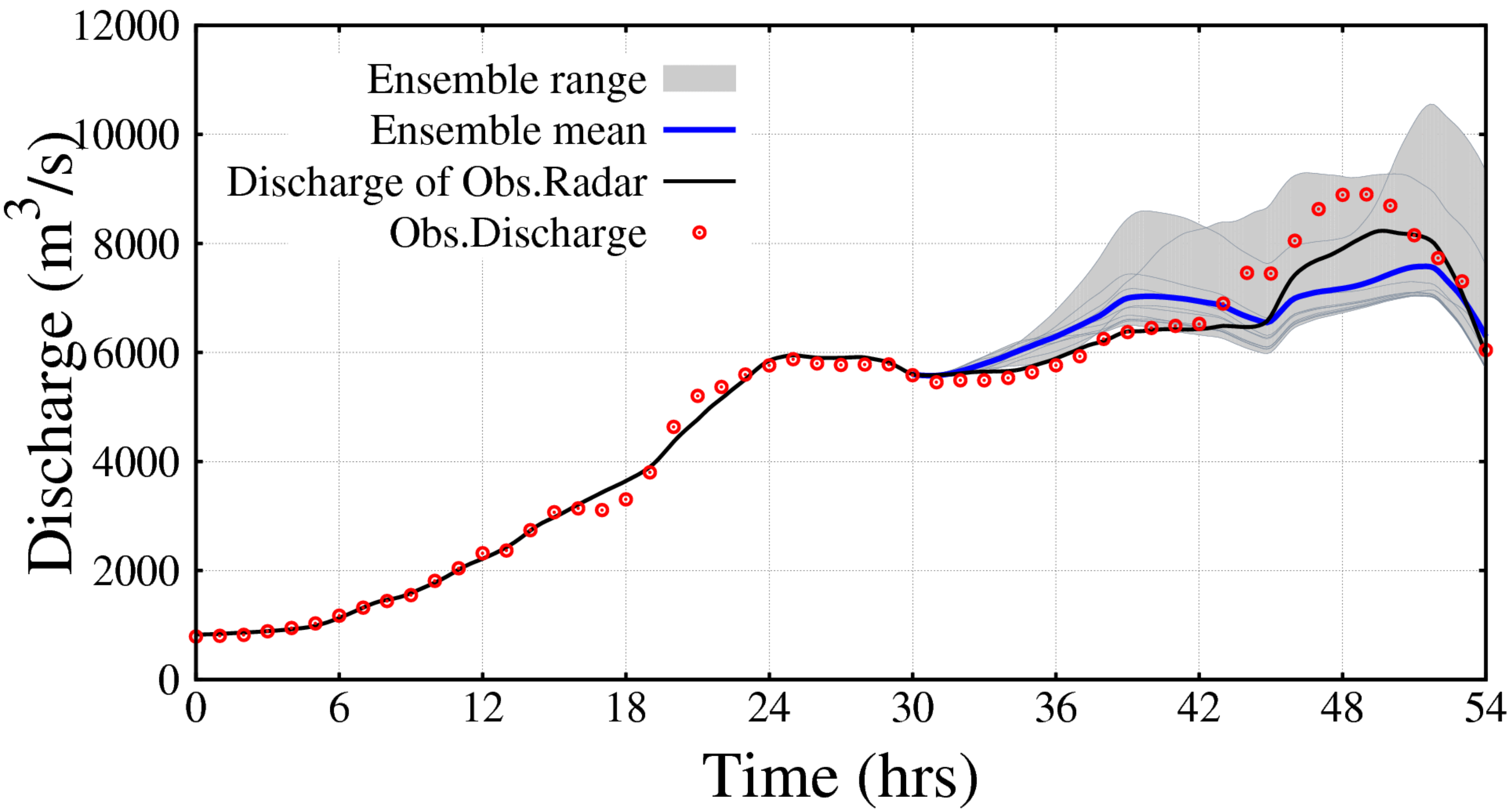
2011/09/03/18:00 ~ 09/04/00:00 UTC (30 hours)



Application into hybrid flood forecasting

Futatsuno Dam Catchment

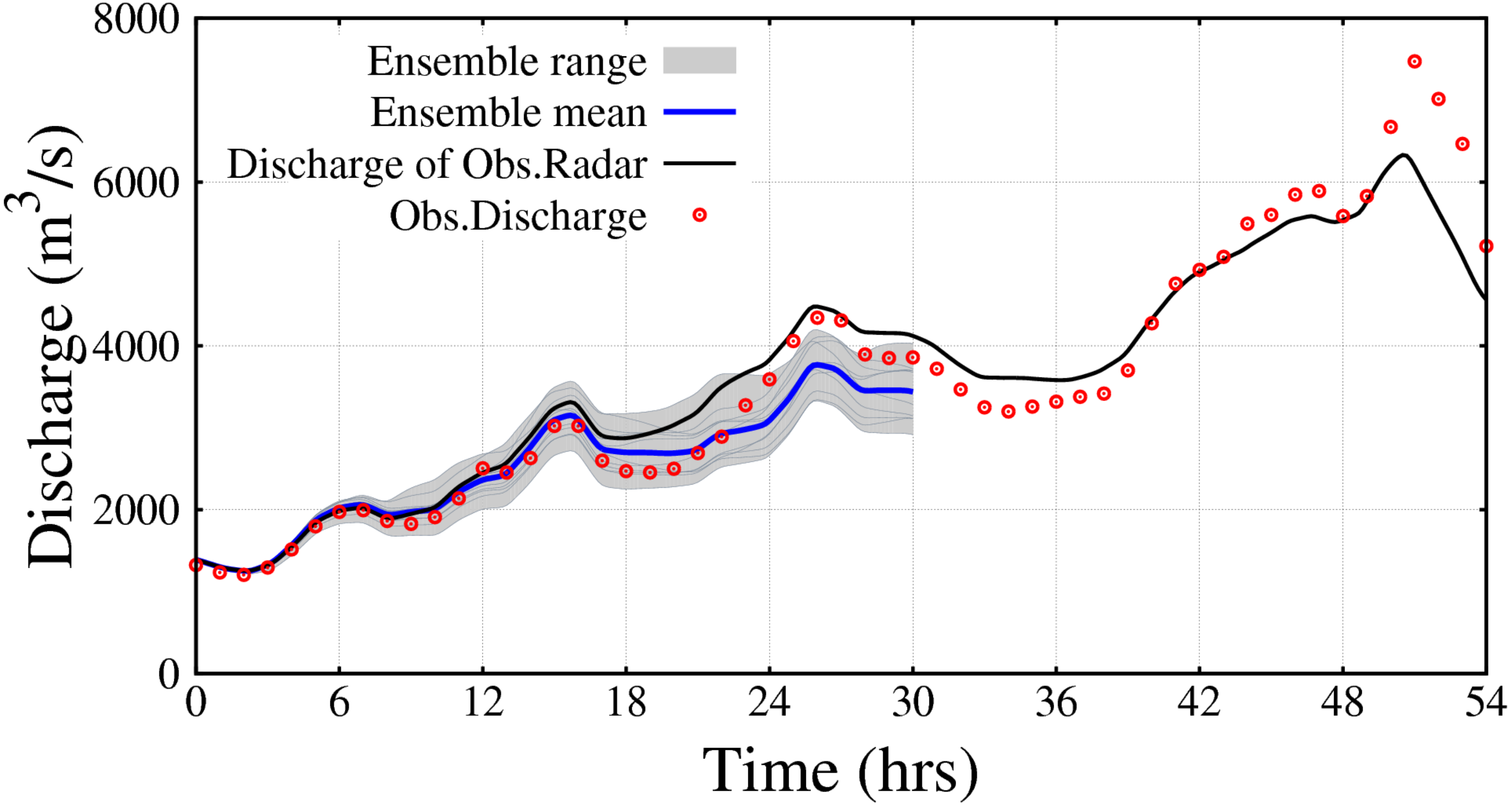
2011/09/03/18:00 ~ 09/04/00:00 UTC (30 hours)



Application into hybrid flood forecasting

Nanairo Dam Catchment

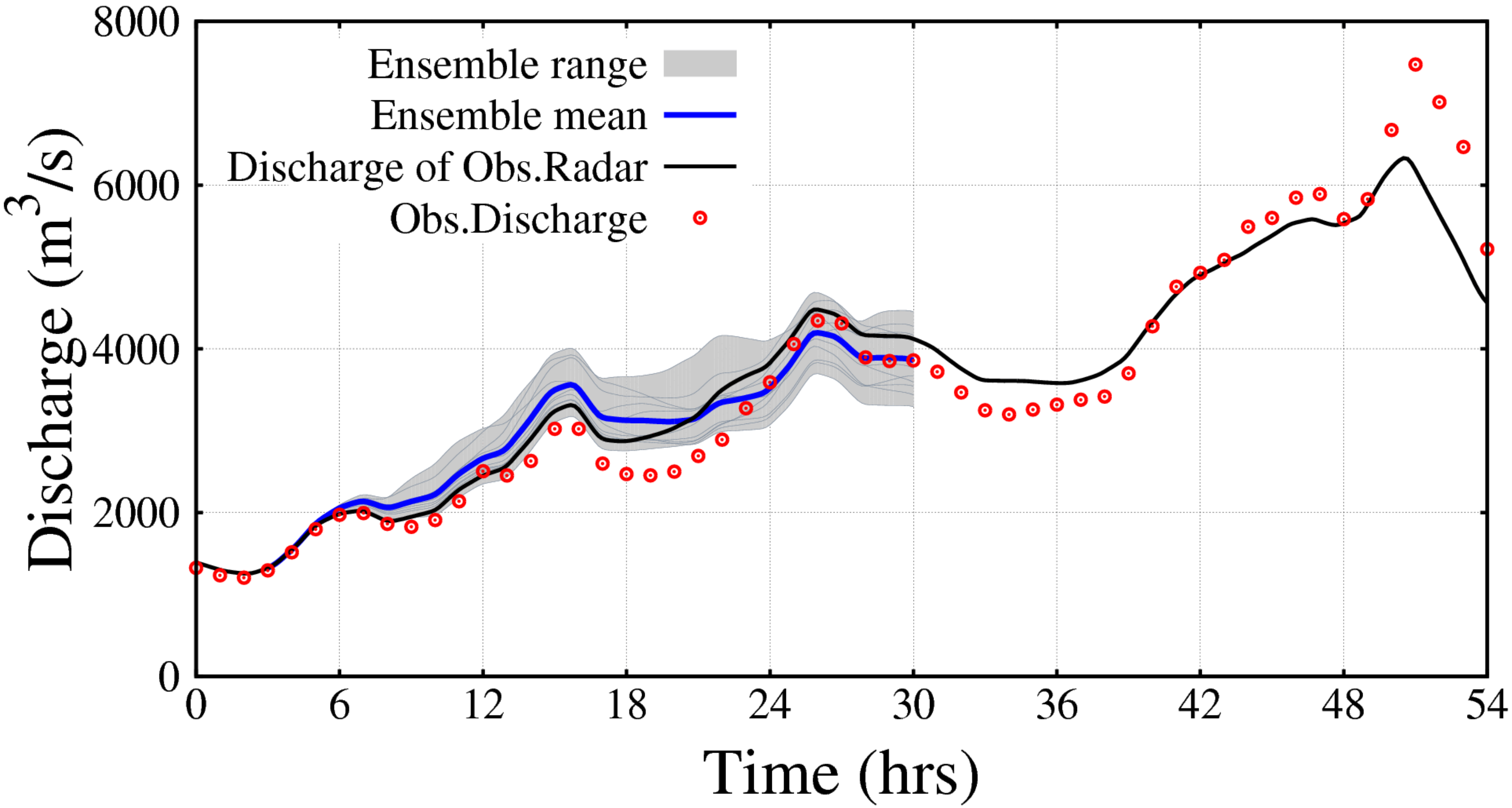
2011/09/02/18:00 ~ 09/03/00:00 UTC (30 hours)



Application into hybrid flood forecasting

Nanairo Dam Catchment

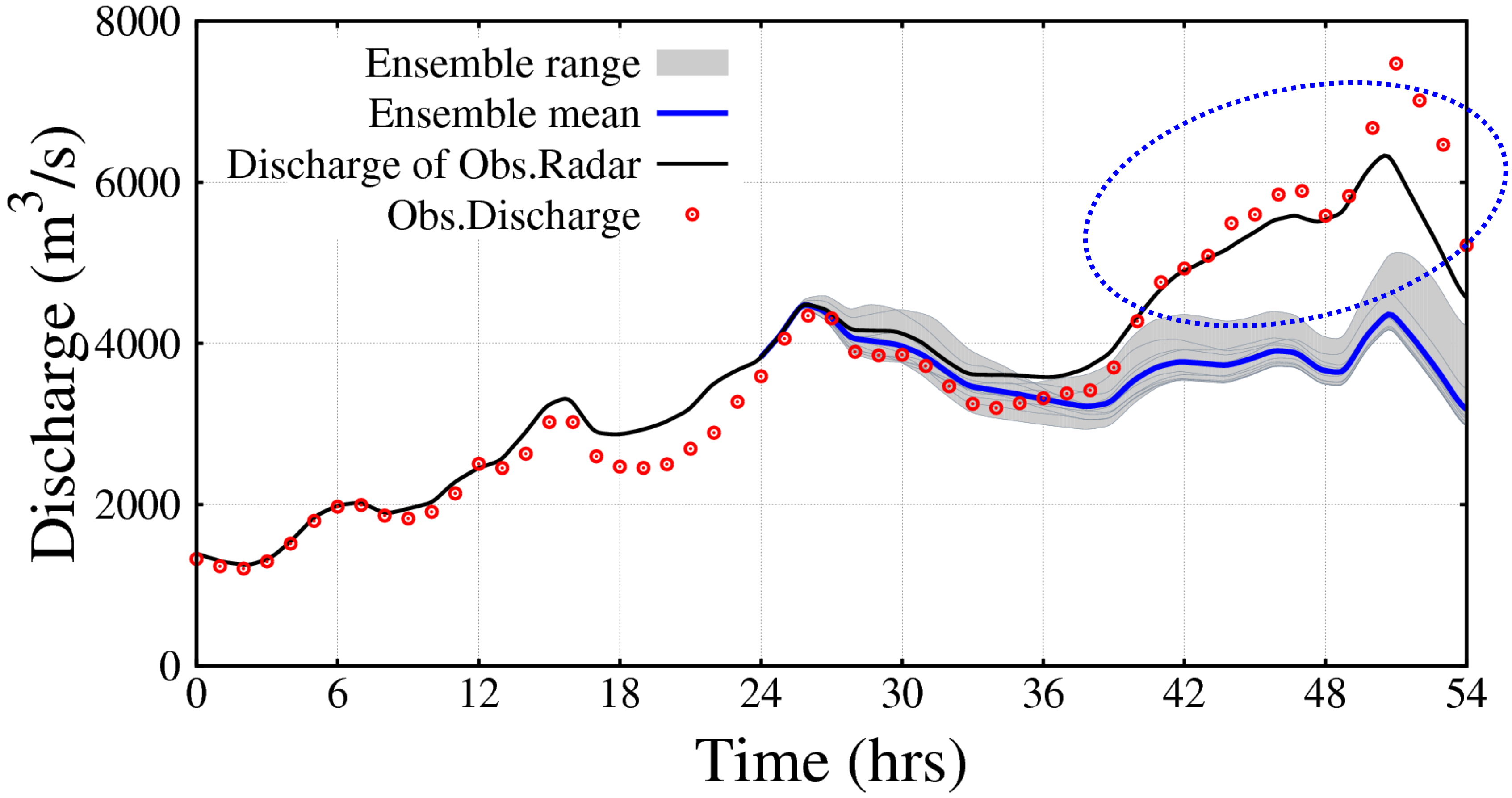
2011/09/02/18:00 ~ 09/03/00:00 UTC (30 hours)



Application into hybrid flood forecasting

Nanairo Dam Catchment

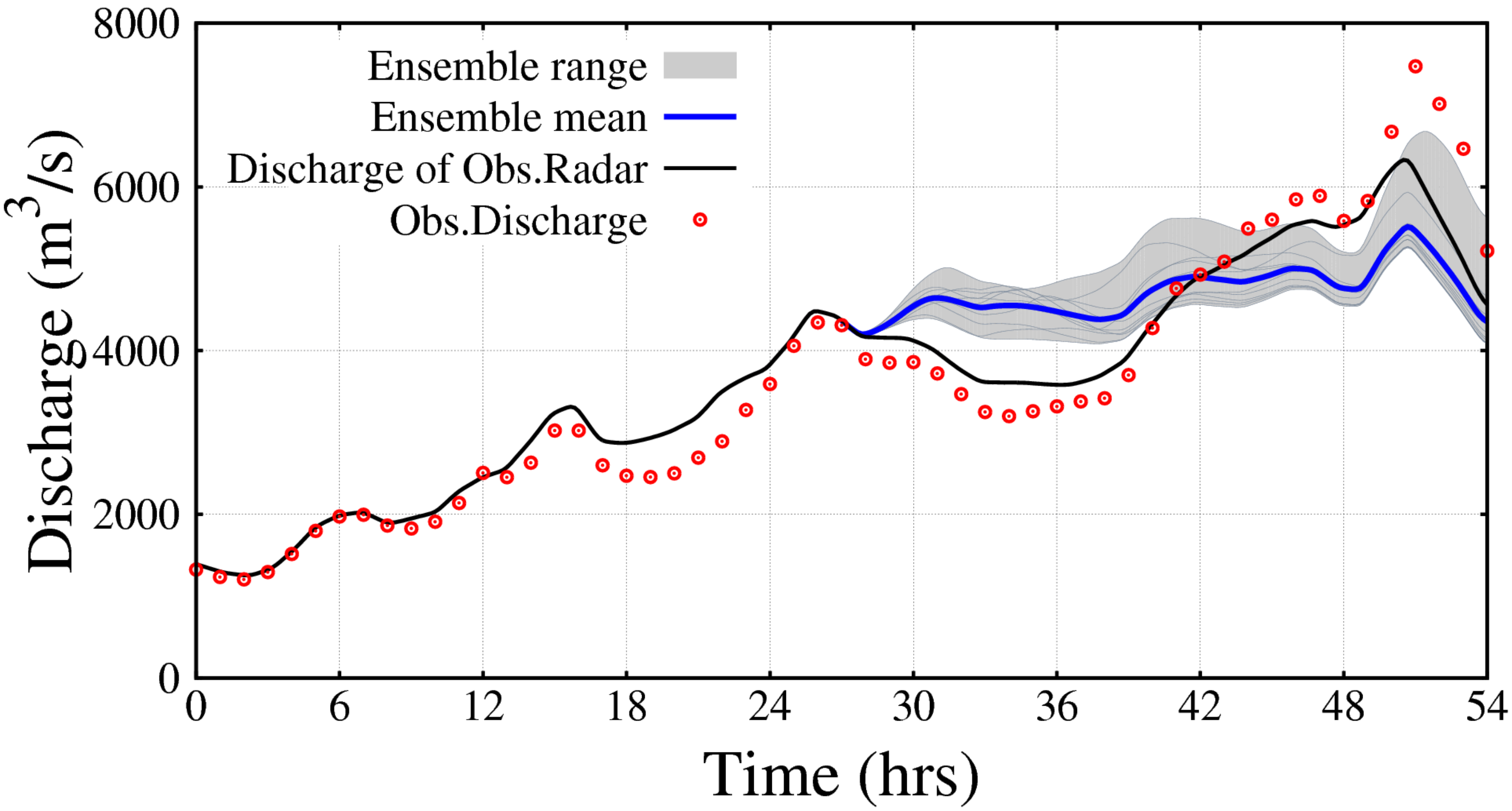
2011/09/03/18:00 ~ 09/04/00:00 UTC (30 hours)



Application into hybrid flood forecasting

Nanairo Dam Catchment

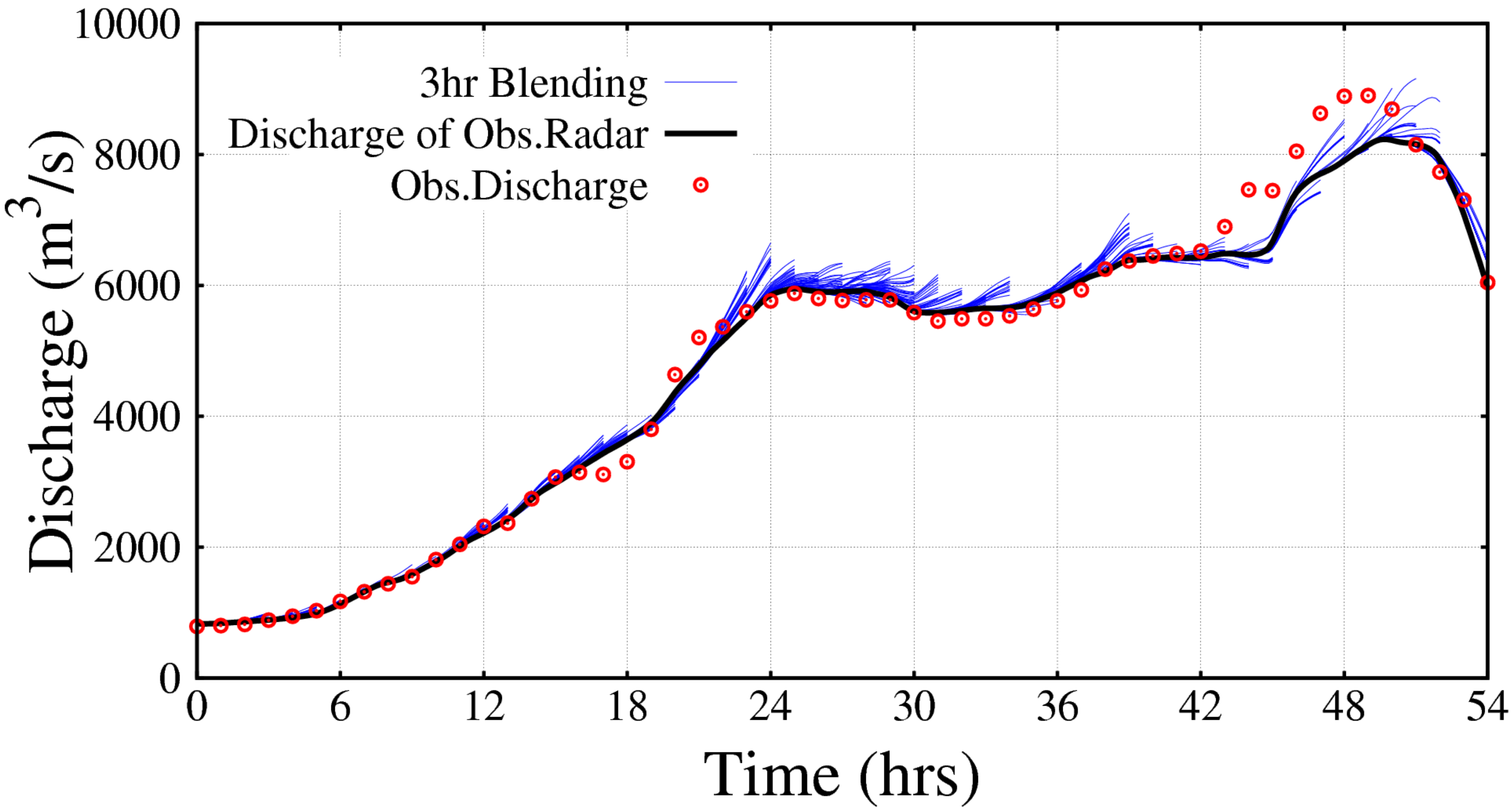
2011/09/03/18:00 ~ 09/04/00:00 UTC (30 hours)



Application into hybrid flood forecasting

Futatsuno Dam Catchment ***2011/09/02/18:00 ~ 09/04/00:00 UTC (54 hours)***

- ***3hr blending results***



Summary

1. ***Hybrid system merging radar prediction and NWP forecast was carried out to improve the accuracy of rainfall and flood forecasts during the Typhoon No.12 event.***

2. ***<u>Blending produced more skillful prediction</u> in rainfall verification than either NWP forecast or radar prediction alone.***

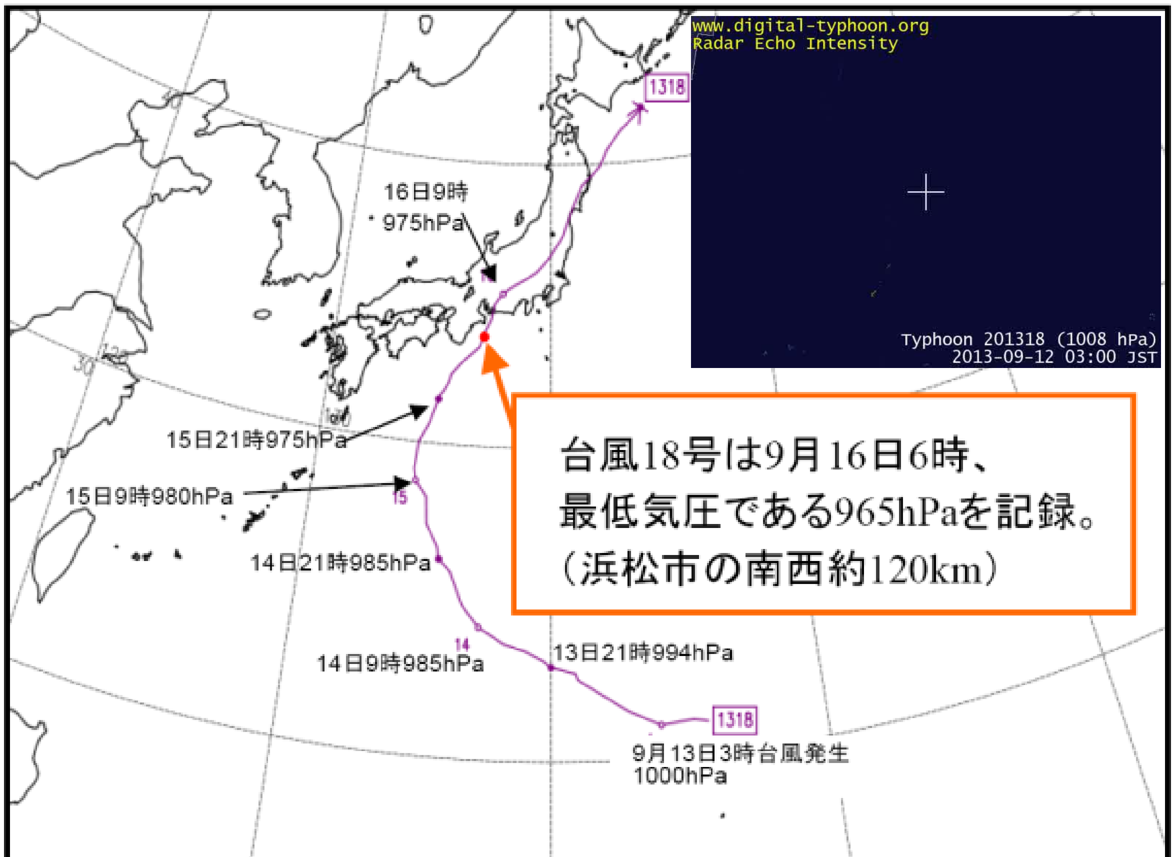
3. ***Hybrid system with blending radar prediction and updated NWP forecast <u>could improve the under-predicted part</u> of original ensemble NWP forecasts in rising limb and peak discharge period.***

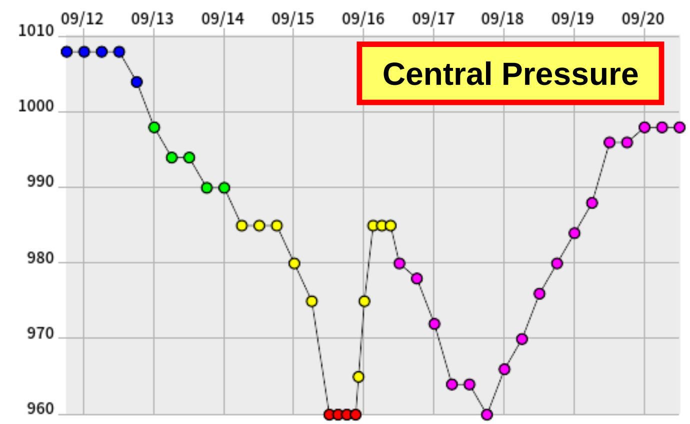
4. ***Later, Hybrid system could be applied the hydrological application such as Dam operation and real-time flood forecasting.***

Application of Flood Early Warning Using High-Resolution Ensemble Rainfall from NWP Model: Case Study of the 2013 Largest Flood Event

Typhoon No. 18 ‘Man-Yi’, 2013 (T1318)

- ***On mid-Sep. 2013 heavy rainfalls happened over Japan due to the season's 18th typhoon (T1318), ‘Man-yi’, which caused large flooding and enormous landslide disasters over Japan's Kinki region.***





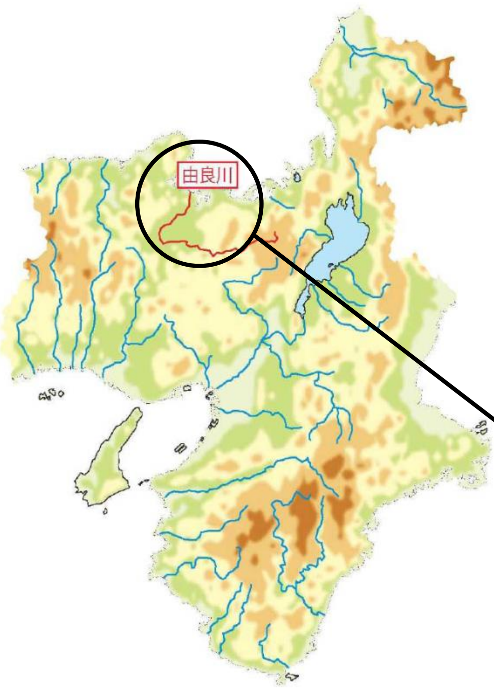
台風18号9月16日6時時点の状況
- 位置: 浜松市の南西約120km
- 大きさ階級: 大型
- 中心気圧: 965hpa
- 最大風速: 中心付近で30m/s, 最大瞬間風速は45m/s
- 進行方向: 北北東
- 進行速度: 40km/h

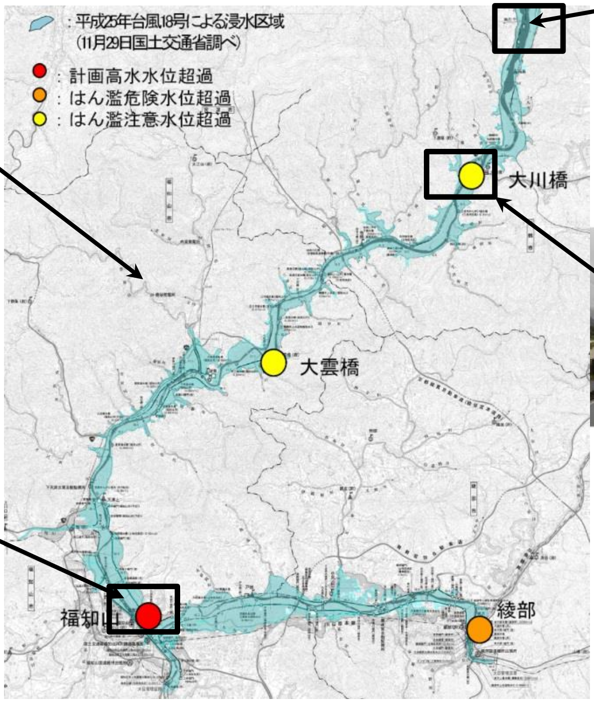
Typhoon No. 18 ‘Man-Yi’, 2013 (T1318)

YuraGawa

■福知山で観測史上最高水位を記録。

■由良川沿川の4市（福知山市、舞鶴市、綾部市、宮津市）では、浸水家屋約1,600戸、浸水面積約2,500haに及ぶ被害が発生した。





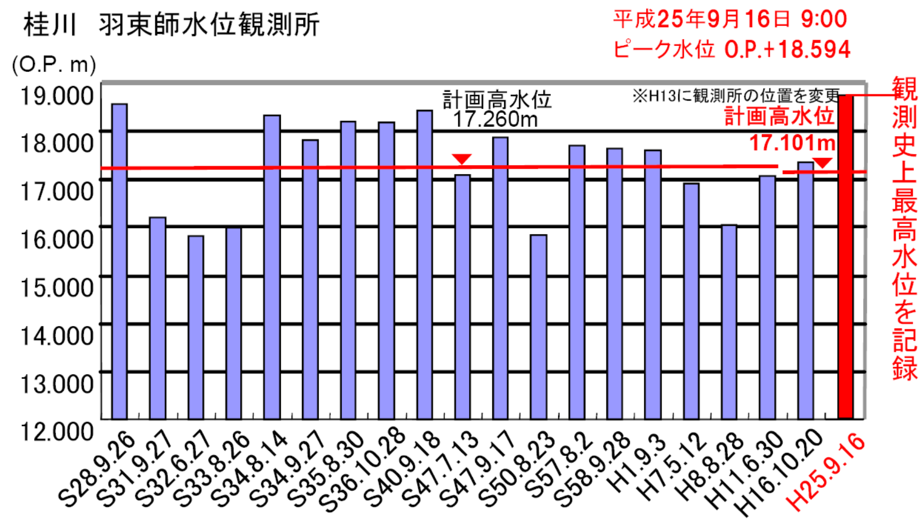
出典：国土交通省 近畿地方整備局 河川部

Typhoon No. 18 ‘Man-Yi’, 2013 (T1318)

KatsuraGawa

■京都市嵐山地区が浸水

■台風18号に伴う豪雨により、桂川の嵐山地区では、溢水により浸水家屋93戸、浸水面積約10haに達する被害を受け、周辺の旅館等も甚大な被害となった。ピーク時には渡月橋の橋面を洪水が乗り越えた。

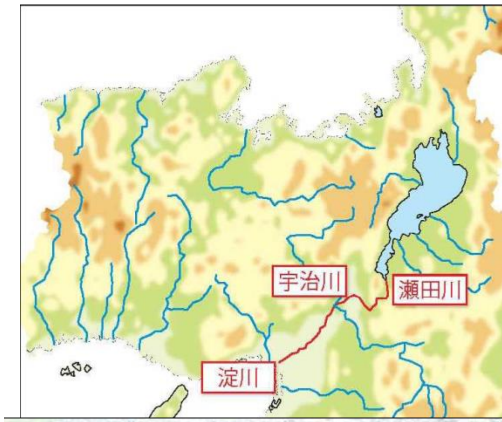


出典：国土交通省　近畿地方整備局　河川部

Typhoon No. 18 ‘Man-Yi’, 2013 (T1318)

UjiGawa

■宇治川では、向島地点において計画高水位を超過する洪水となり、危険な状態となった。



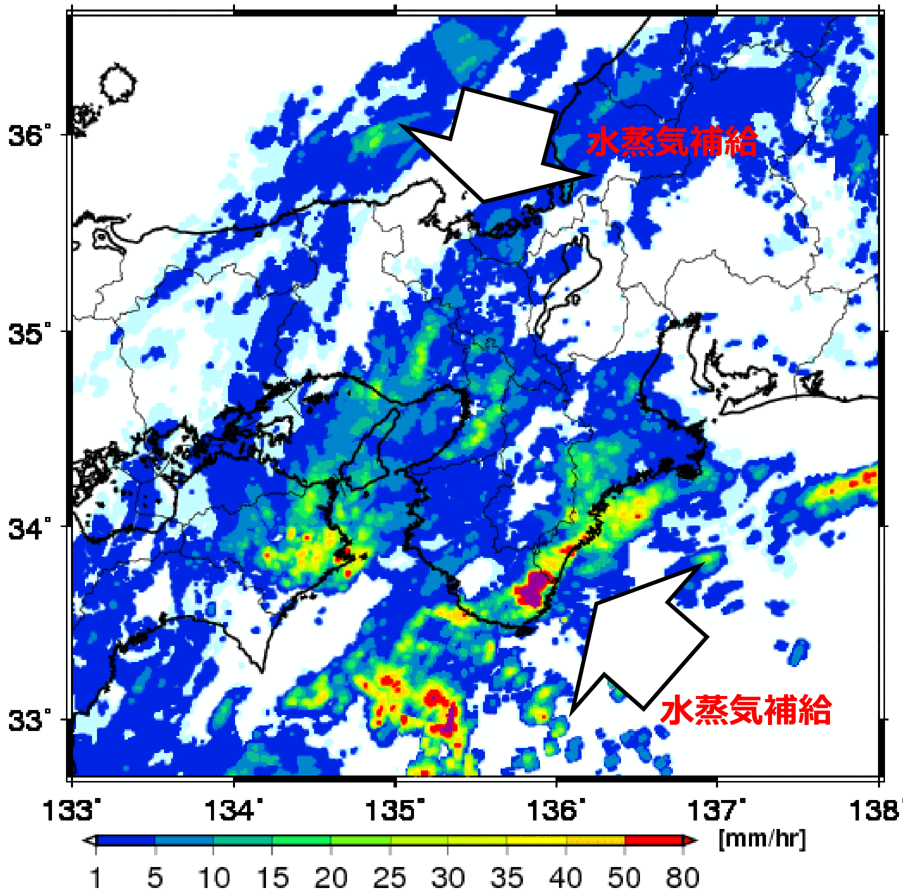
出典：国土交通省 近畿地方整備局 河川部

Background & Objective

- *One of the reasons why it was seriously damaged is due to orographic rainfall.*

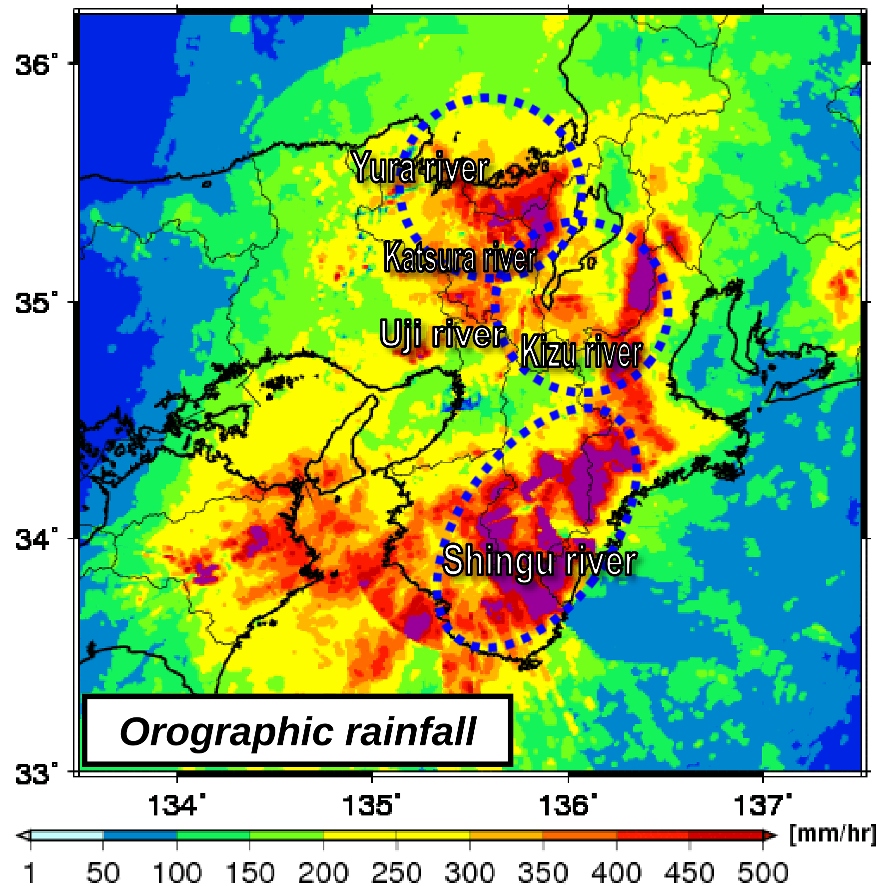
MLIT Obs. Radar

2013/09/15/03:00 ~ 09/16/23:00



Accumulated Rainfall

2013/09/15/03:00 ~ 09/16/23:00



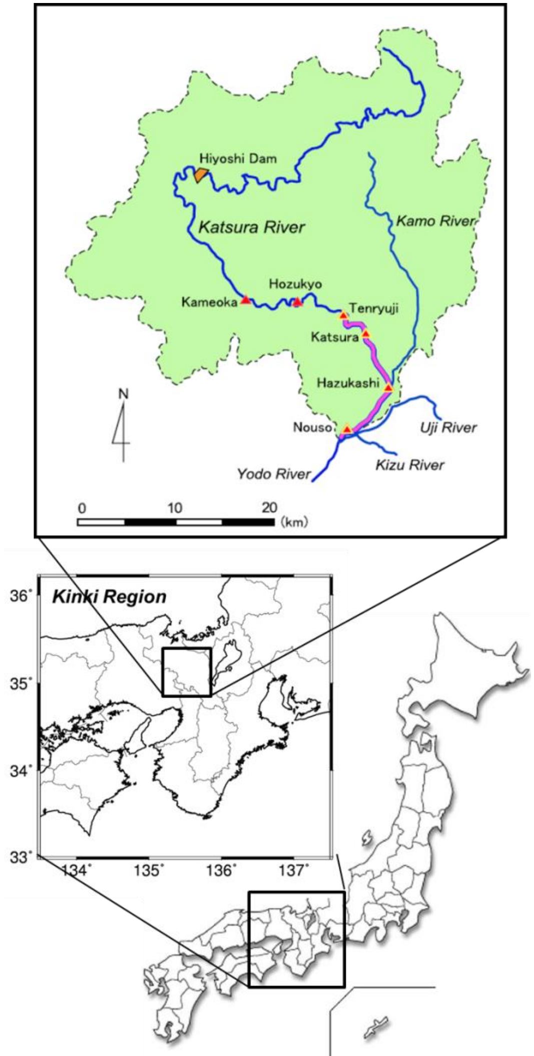
Background & Objective

➢ ***Assessment of ensemble rainfall from NWP model that whether it can predict the heavy rainfall or not in the Kinki region.***

1. How much did the downscaled forecast improve the location and magnitude of rainfall in the Kinki region?

2. How much did the downscaled NWP improve the reliability of the discharge for the Hiyoshi dam operation?

3. How can apply the downscaled NWP for flood early warning in the Katsura river basin?



Ensemble Rainfall Forecast from NWP model

- ***Forecast Model***

  - JMA Non-hydrostatic Model (JMA-NHM)

- ***Designed Ensemble NWP Data***

  - 10 km and 2km resolution, 48 hr forecast time with 30min time step

  - 51 ensemble members

  - Newly ensemble forecast with 6 hour interval (Total 7 forecast data)

- ***Initial and boundary conditions for ensemble forecast***

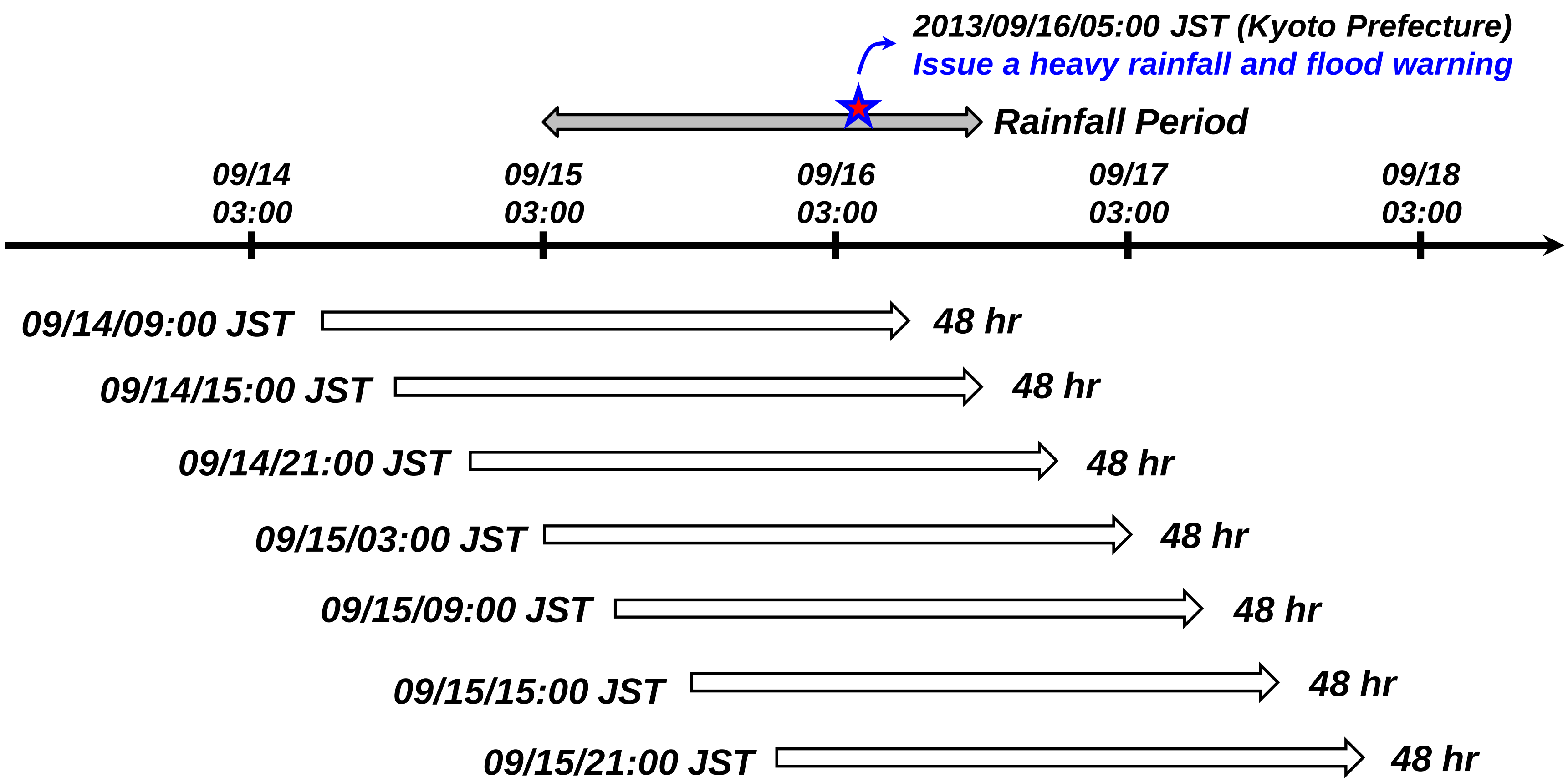
  - 10km : JMA's one week global Ensemble Predicion System (WEP)

  - 2km : from 10km output

Collaborative research result by HPCI program (Nakakita, Yamaguchi, Yu, Kunii, Oizumi (2014))

Ensemble Rainfall Forecast from NWP model

The design of ensemble forecast with 6 hour interval



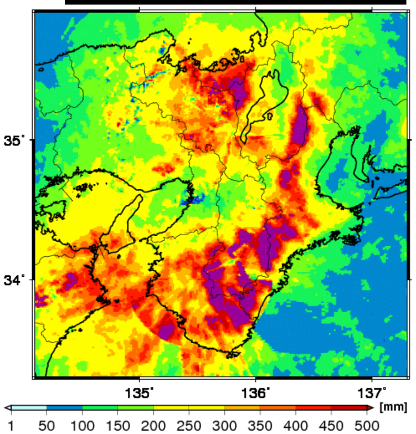
1. 2013 / 09 / 14 / 09:00 ~ 09/16/09:00 JST (48 hours)
2. 2013 / 09 / 14 / 15:00 ~ 09/16/15:00 JST (48 hours)
3. 2013 / 09 / 14 / 21:00 ~ 09/16/21:00 JST (48 hours)
4. 2013 / 09 / 15 / 03:00 ~ 09/17/03:00 JST (48 hours)
5. 2013 / 09 / 15 / 09:00 ~ 09/17/09:00 JST (48 hours)
6. 2013 / 09 / 15 / 15:00 ~ 09/17/15:00 JST (48 hours)
7. 2013 / 09 / 15 / 21:00 ~ 09/17/21:00 JST (48 hours)

Spatial Rainfall Verification

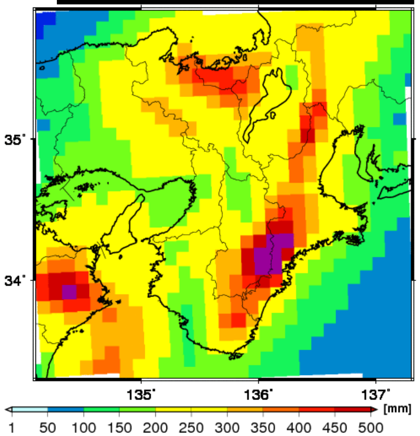
10 km resolution: 2013/09/15/03:00 ~ 09/17/03:00 (48 hours)

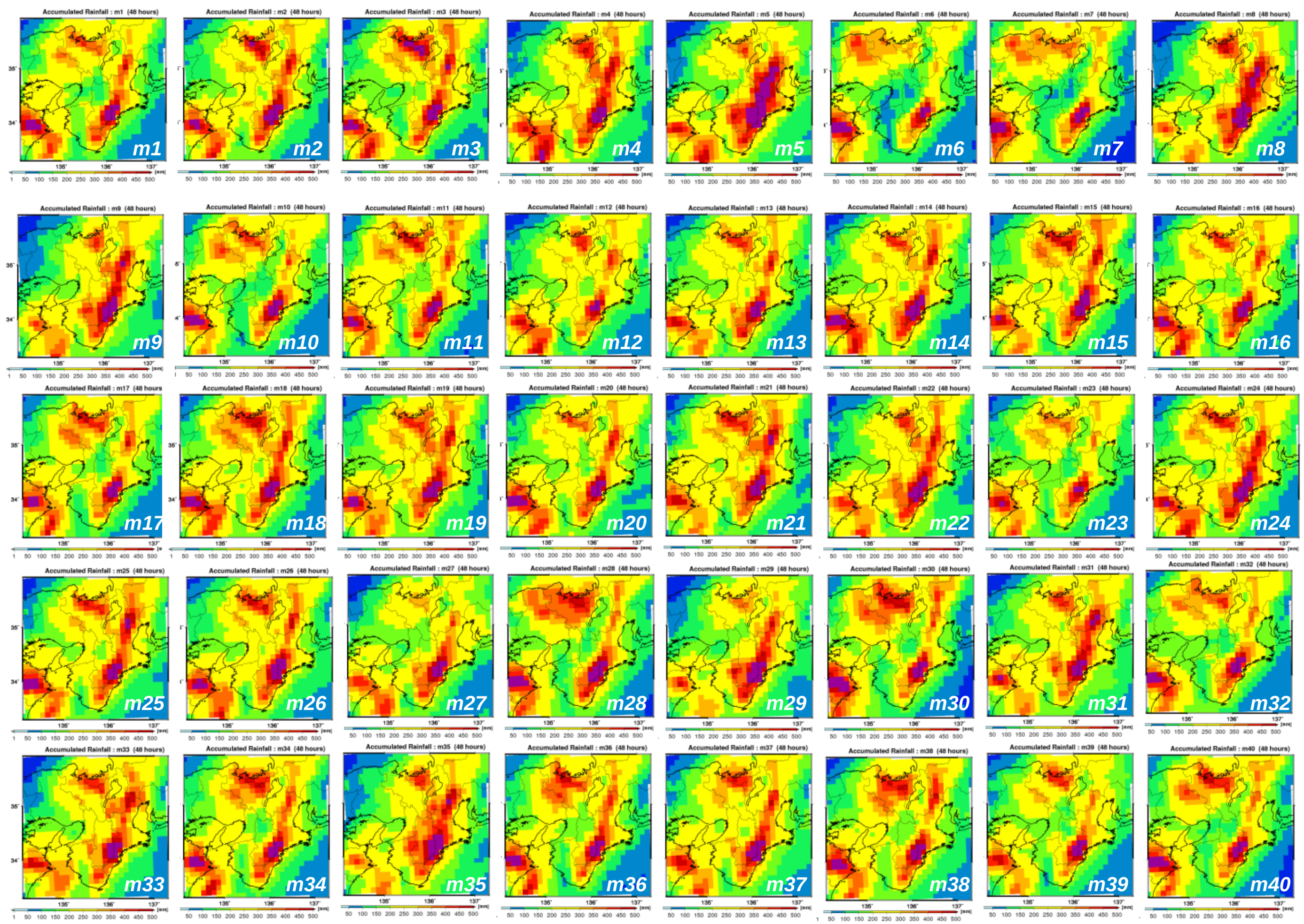
Accumulated Rainfall

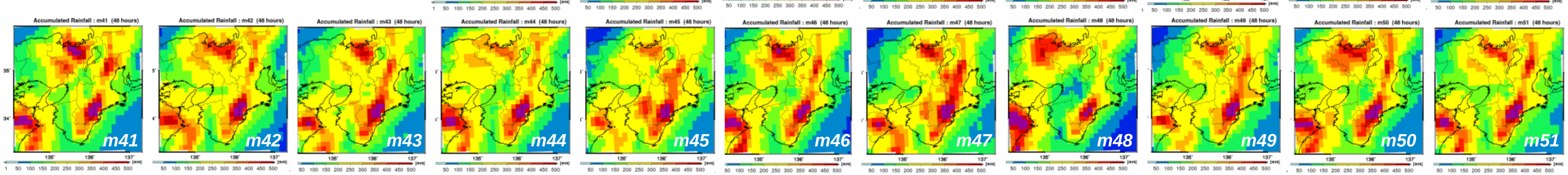
MLIT Obs. Radar



Ensemble Mean





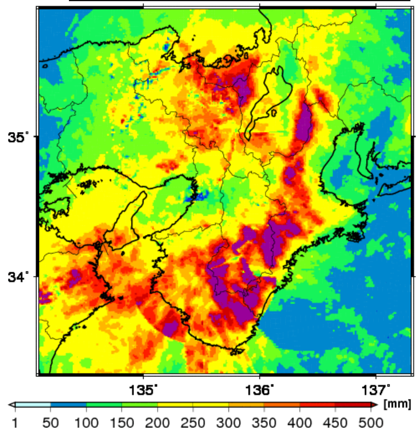


Spatial Rainfall Verification

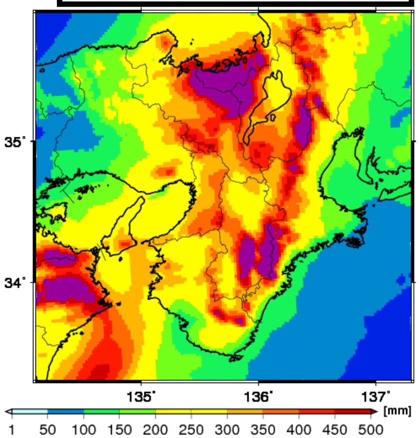
2 km resolution: 2013/09/15/03:00 ~ 09/17/03:00 (48 hours)

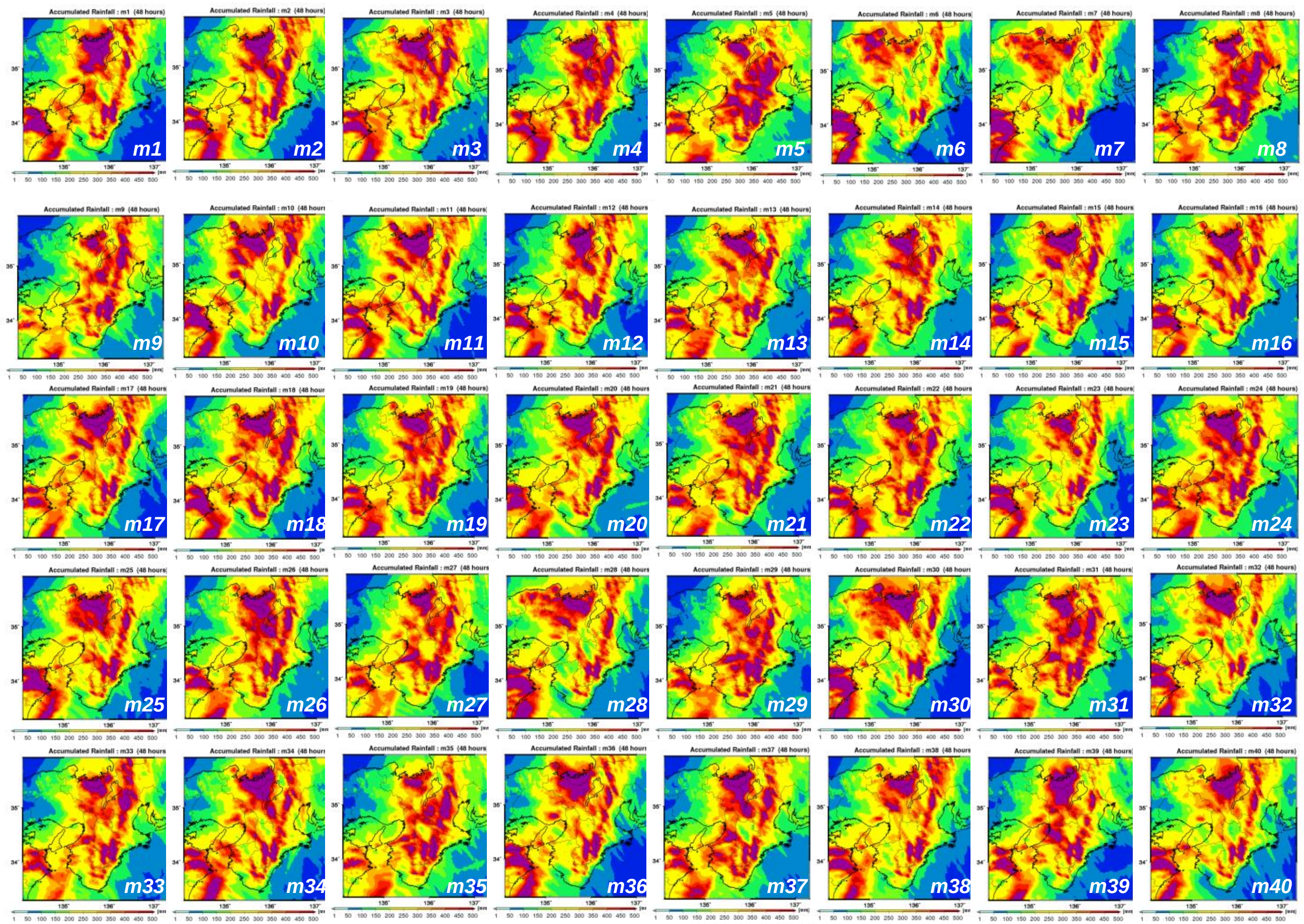
Accumulated Rainfall

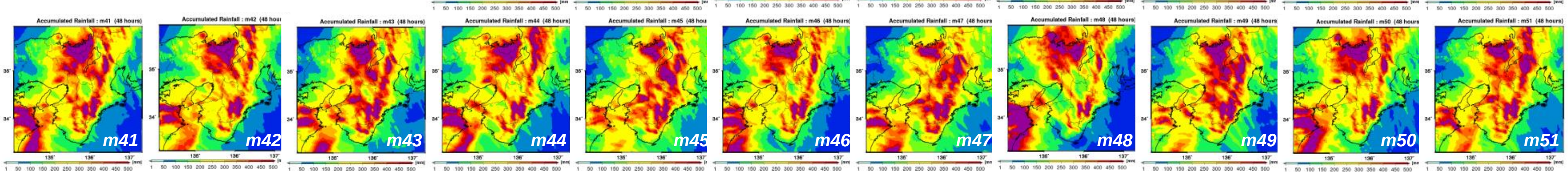
MLIT Obs. Radar



Ensemble Mean



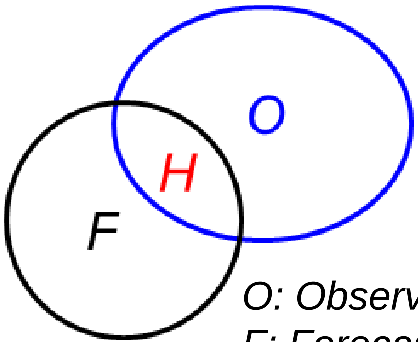




Spatial Rainfall Verification

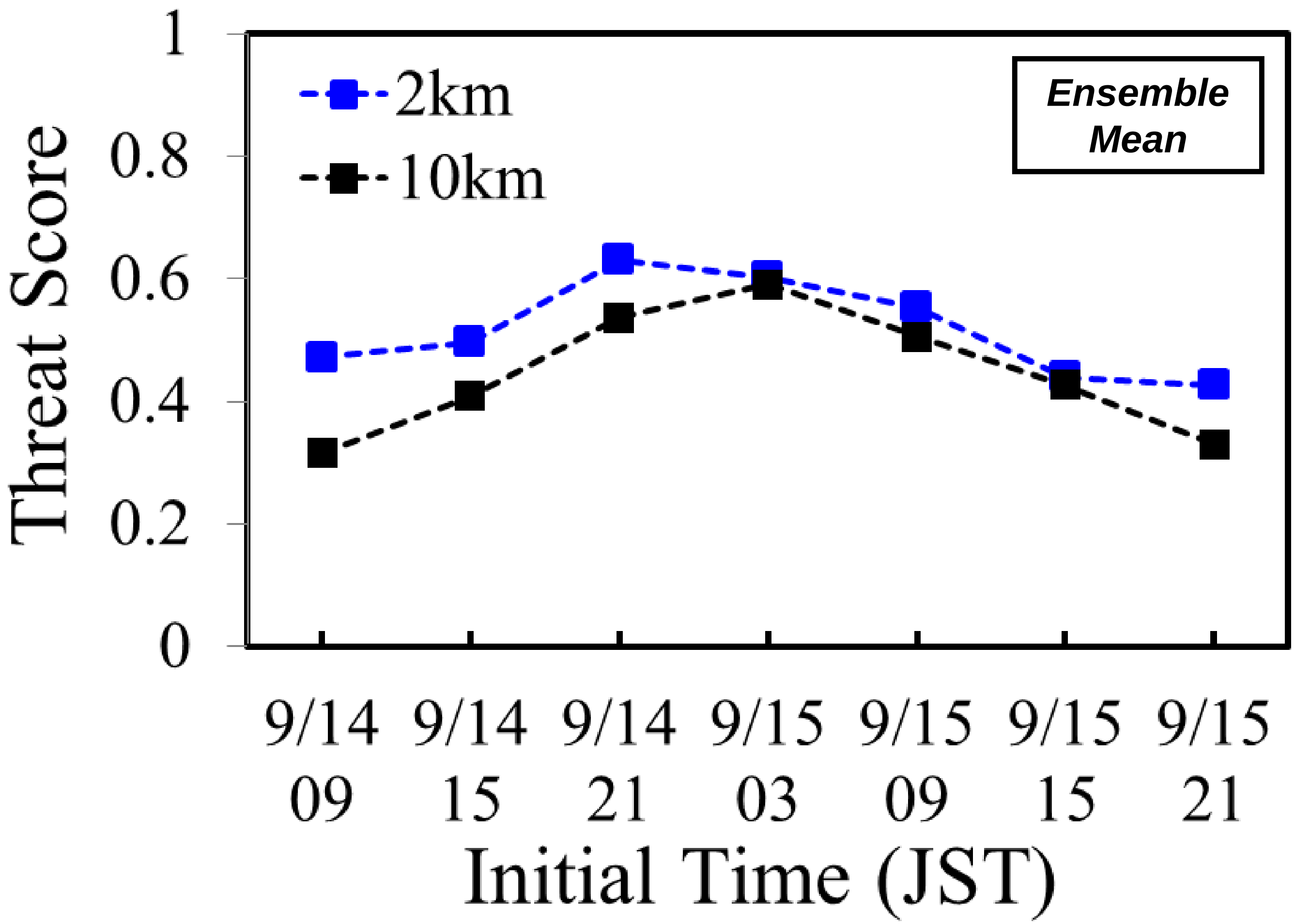
- ***How much did the downscaled forecasts improve the location and magnitude of rainfall?***

$$TS\,(CSI) = \frac{H}{F + O - H}$$



O: Observe
F: Forecast
H: Hit

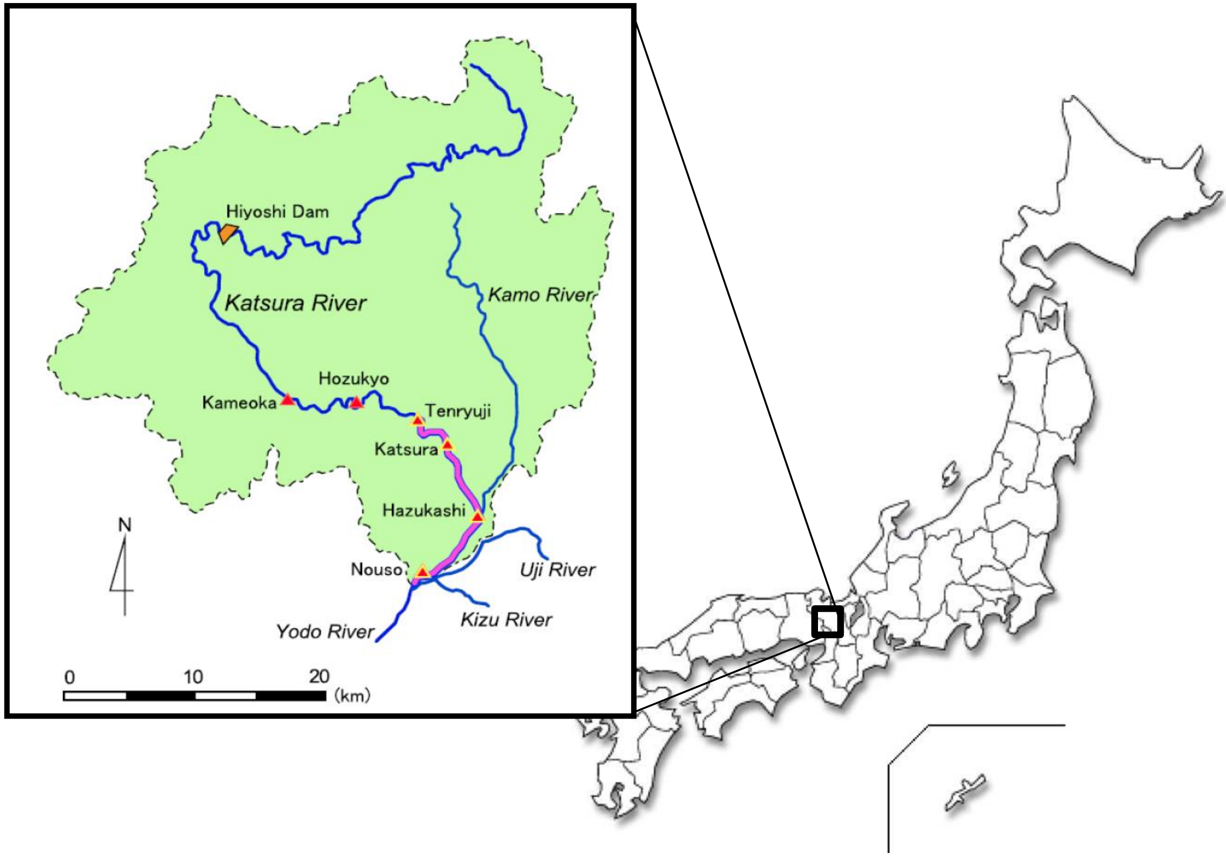
- Threshold: 5 mm/hr
(0 ~ 48 hrs ➔ 240 mm)



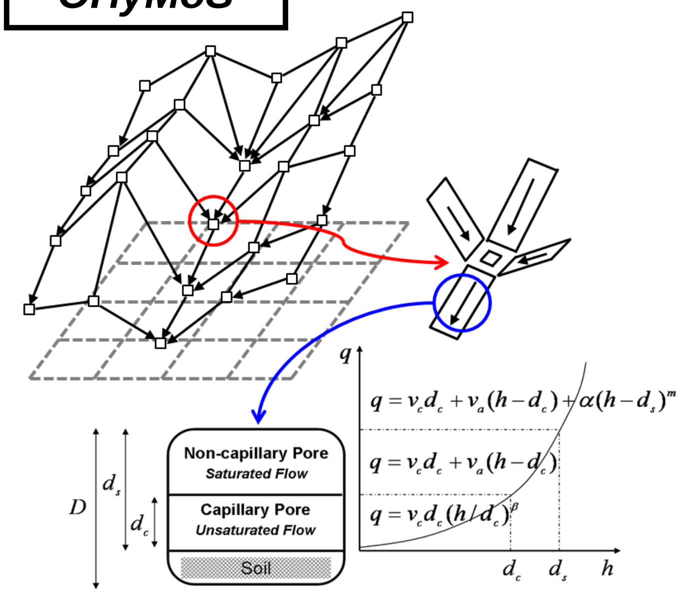
Ensemble Flood Forecasting

- **How much did the *downscaled NWP improve the reliability of the discharge* for the Hiyoshi dam operation?**

  - ***Katsura river basin***
    1. *Hiyoshi dam (290 km²)*
    2. *Katsura station (887 km²)*



OHyMoS



Tachikawa et al. (2004)

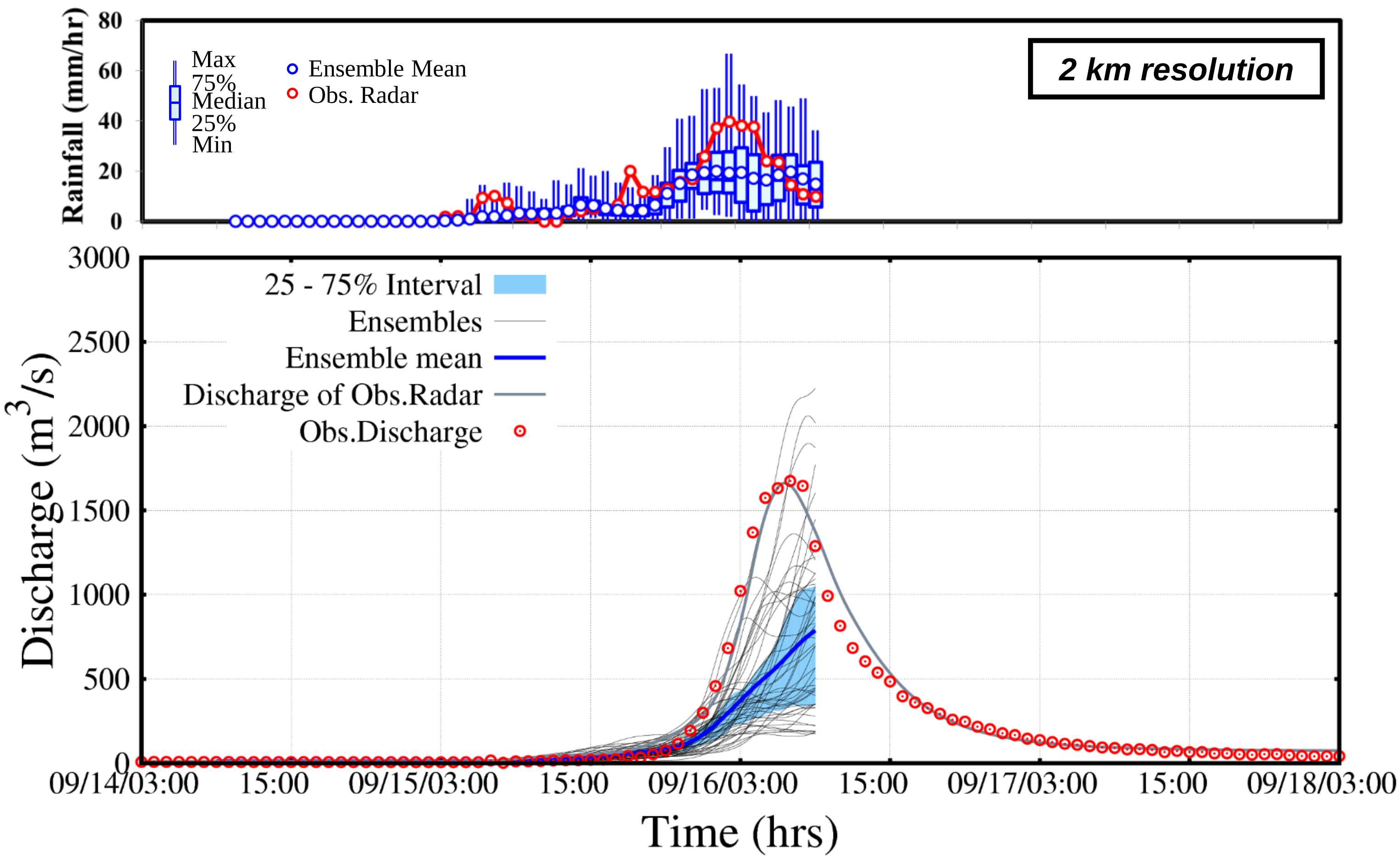
- ***Kinematic wave method for subsurface and surface (KWMSS) flow simulation is applied to each grid-cell.***

Ensemble Flood Forecasting

- ➢ ***How much did the downscaled NWP improve the reliability of the discharge for the Hiyoshi dam operation?***

Hiyoshi dam

2013/09/14/09:00 ~ 09/16/09:00 JST (48 hours)

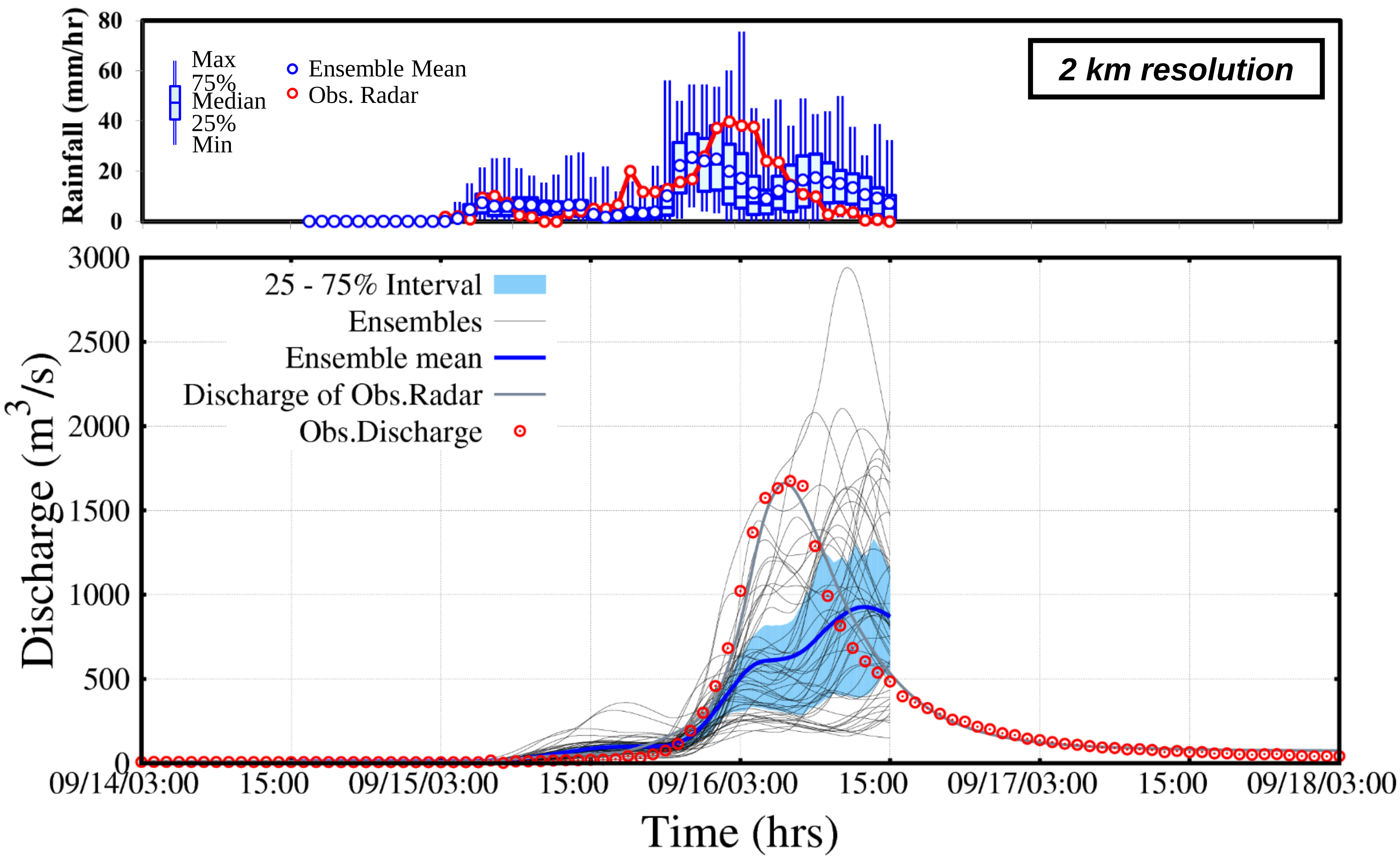


Ensemble Flood Forecasting

➢ ***How much did the downscaled NWP improve the reliability of the discharge for the Hiyoshi dam operation?***

Hiyoshi dam

2013/09/14/15:00 ~ 09/16/15:00 JST (48 hours)

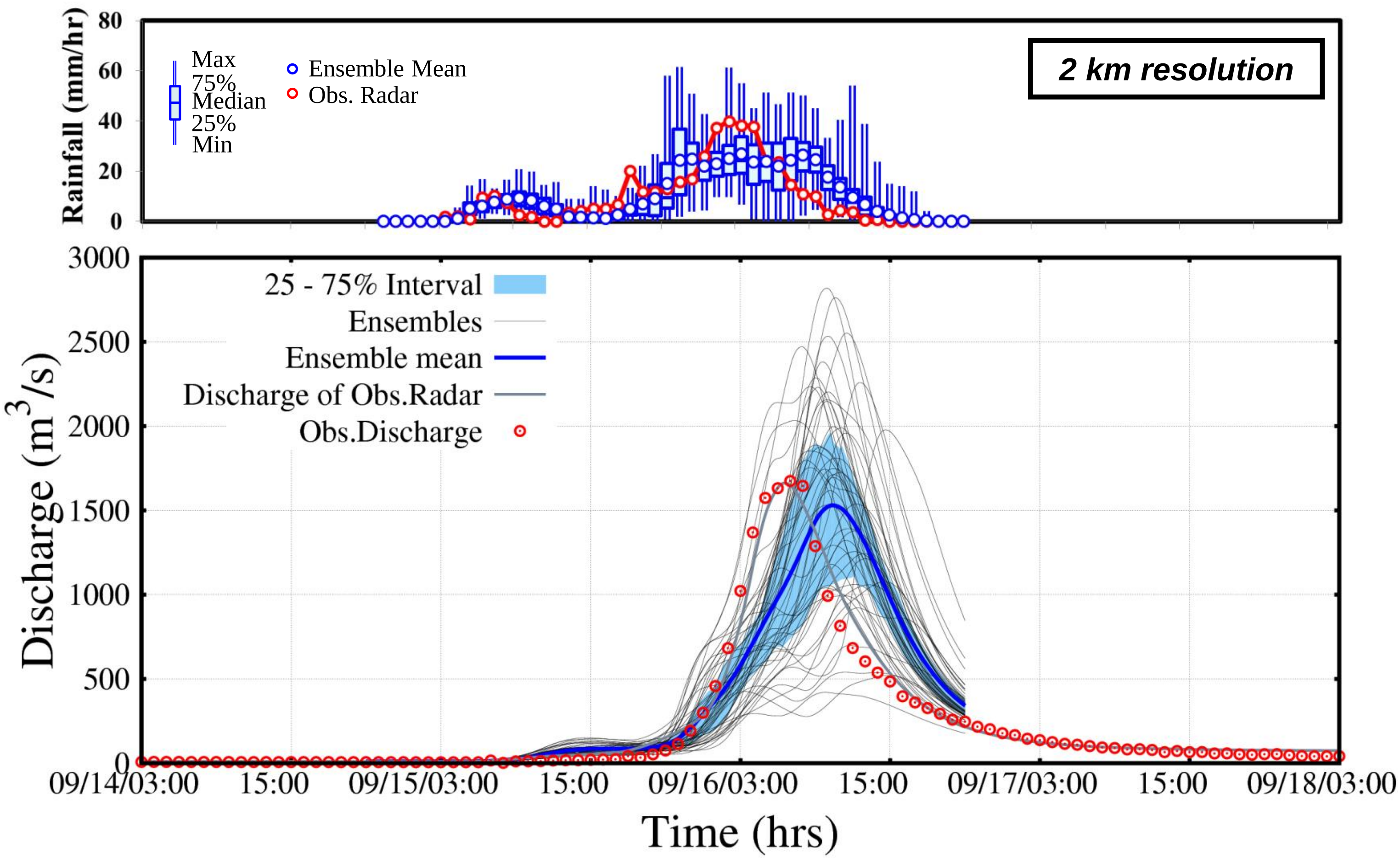


Ensemble Flood Forecasting

➢ ***How much did the downscaled NWP improve the reliability of the discharge for the Hiyoshi dam operation?***

Hiyoshi dam

2013/09/14/21:00 ~ 09/16/21:00 JST (48 hours)

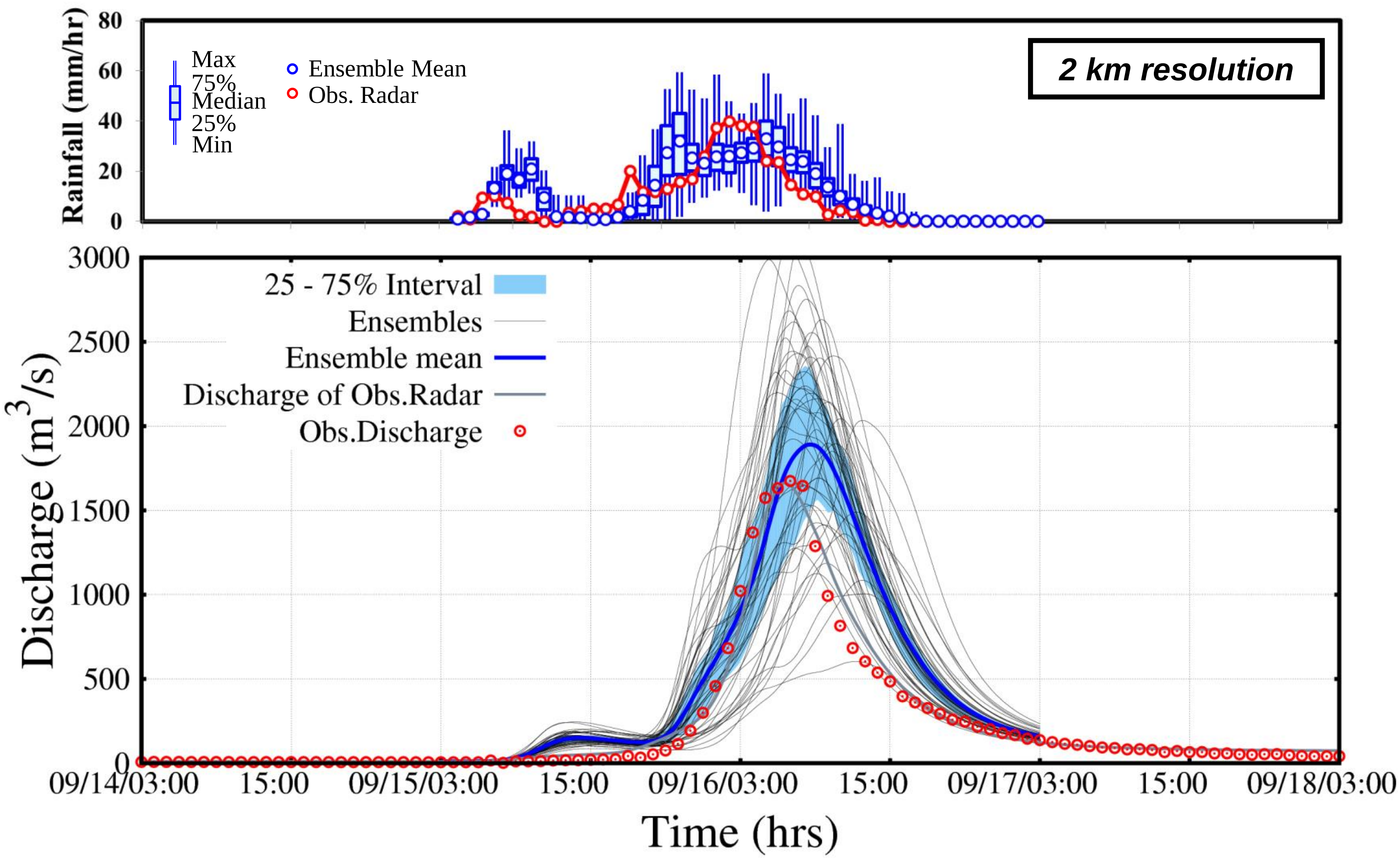


Ensemble Flood Forecasting

➢ ***How much did the downscaled NWP improve the reliability of the discharge for the Hiyoshi dam operation?***

Hiyoshi dam

2013/09/15/03:00 ~ 09/17/03:00 JST (48 hours)

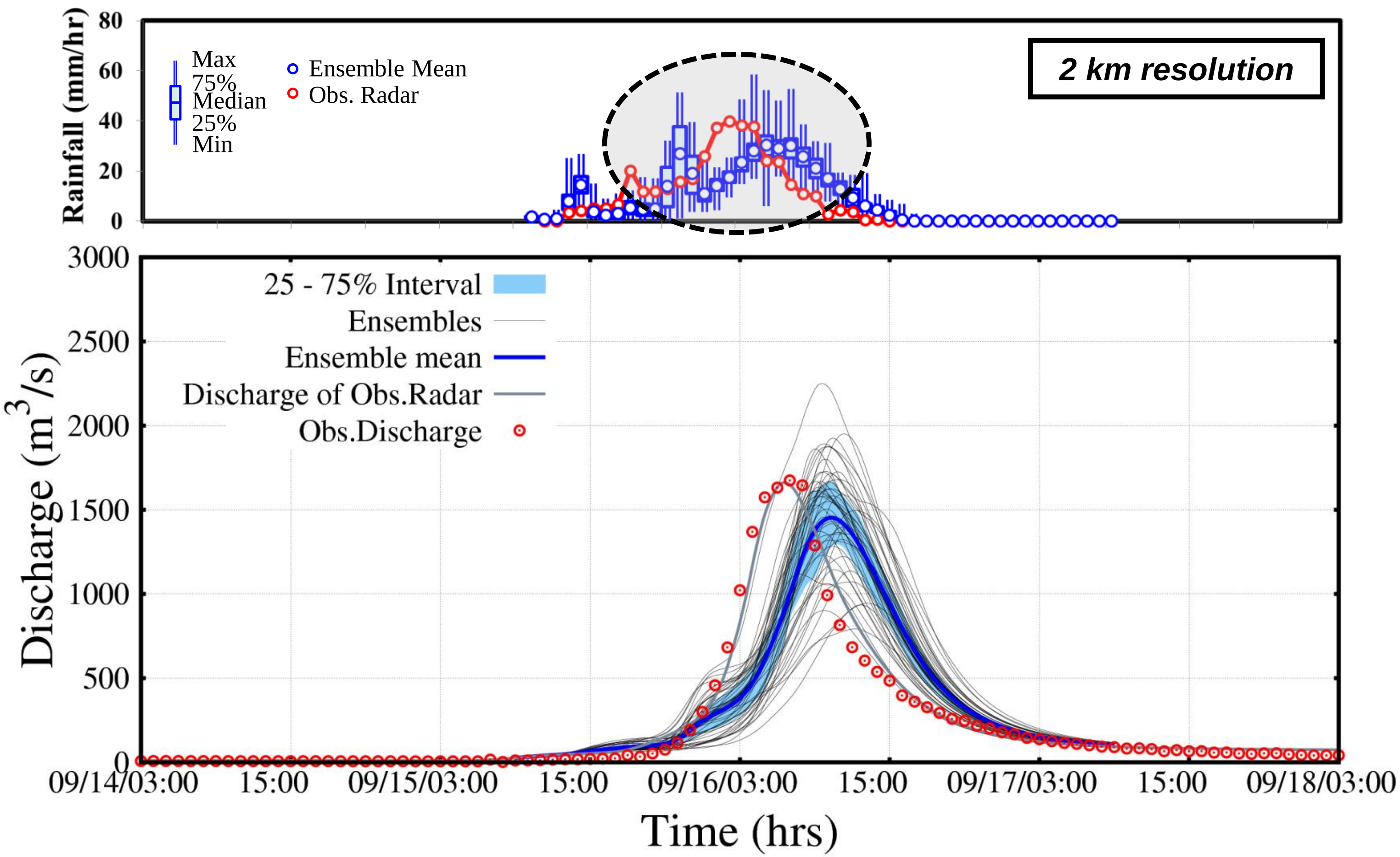


Ensemble Flood Forecasting

➢ ***How much did the downscaled NWP improve the reliability of the discharge for the Hiyoshi dam operation?***

Hiyoshi dam

2013/09/15/09:00 ~ 09/17/09:00 JST (48 hours)

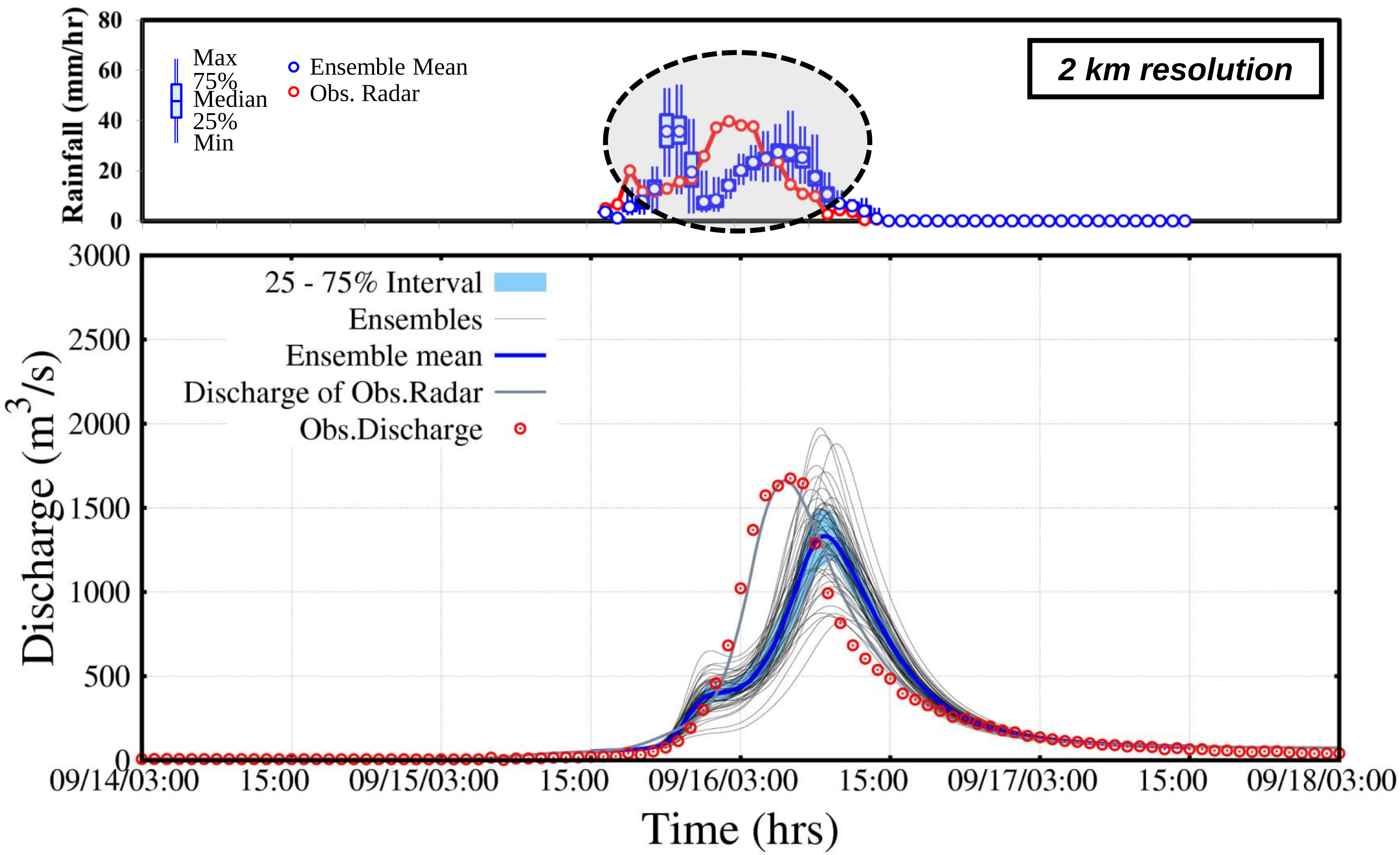


Ensemble Flood Forecasting

➢ ***How much did the downscaled NWP improve the reliability of the discharge for the Hiyoshi dam operation?***

Hiyoshi dam

2013/09/15/15:00 ~ 09/17/15:00 JST (48 hours)

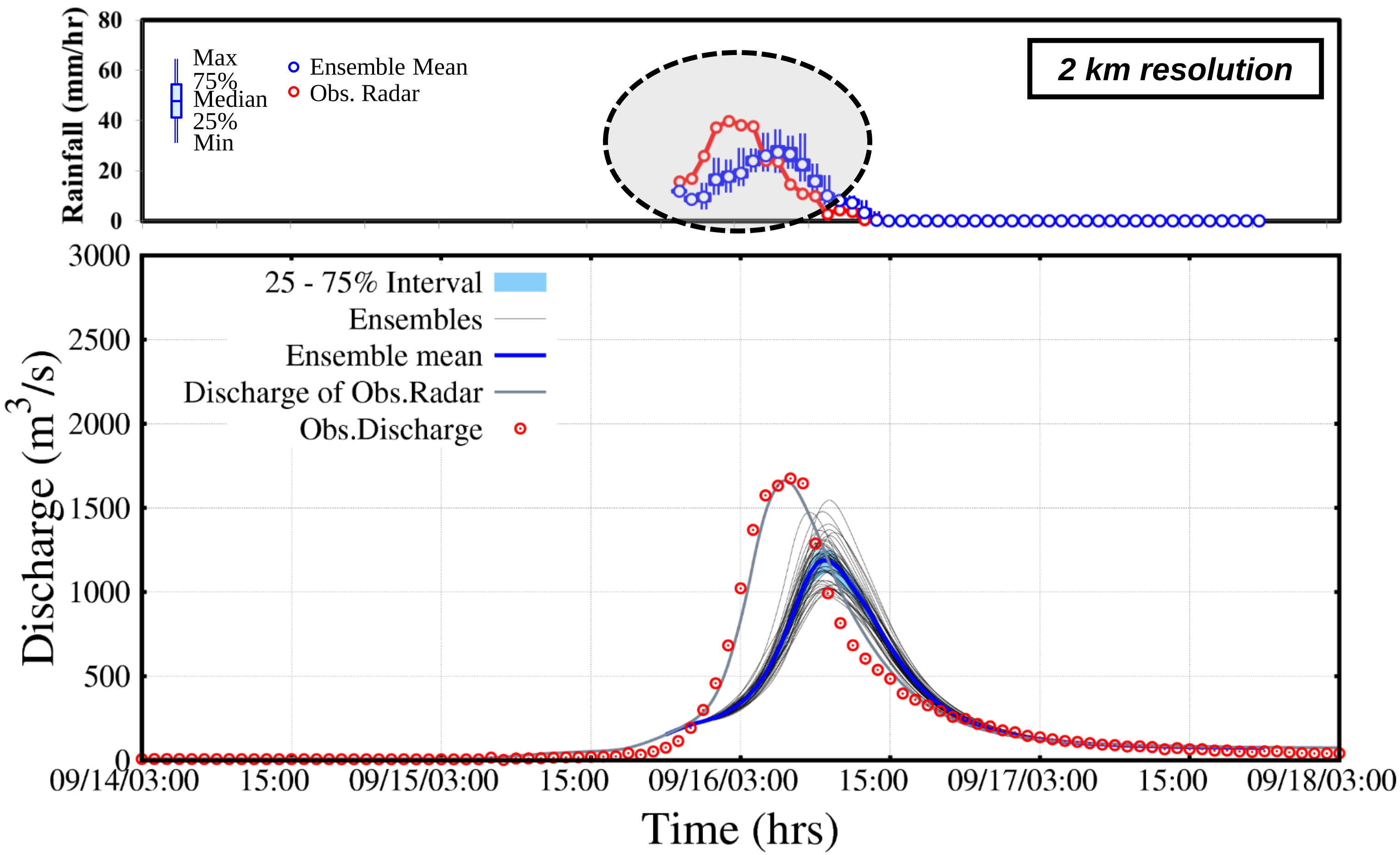


Ensemble Flood Forecasting

- ➢ ***How much did the downscaled NWP improve the reliability of the discharge for the Hiyoshi dam operation?***

Hiyoshi dam

2013/09/15/21:00 ~ 09/17/21:00 JST (48 hours)



Rainfall and Flood Forecast Verification

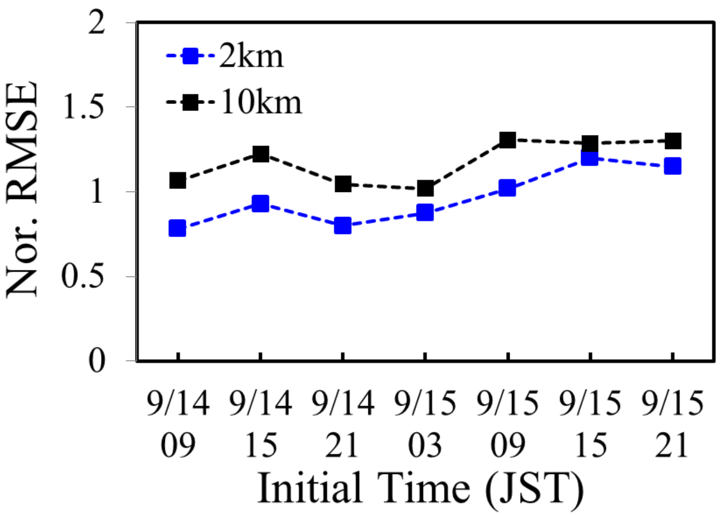
Hiyoshi dam

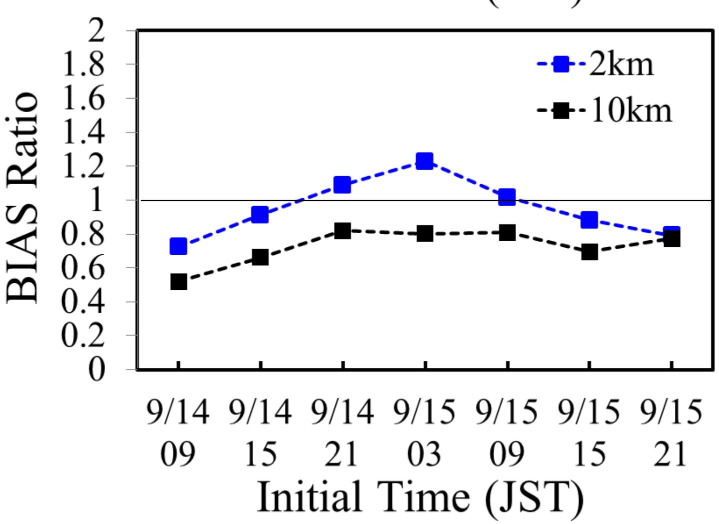
1. $Nor.\ RMSE = \dfrac{\sqrt{\frac{1}{N}\sum_{t=1}^{N}(O_t - F_t)^2}}{\frac{1}{N}\sum_{t=1}^{N}O_t}$

2. $\text{BIAS Ratio} = \dfrac{\sum_{t=1}^{N}F_t}{\sum_{t=1}^{N}O_t}$

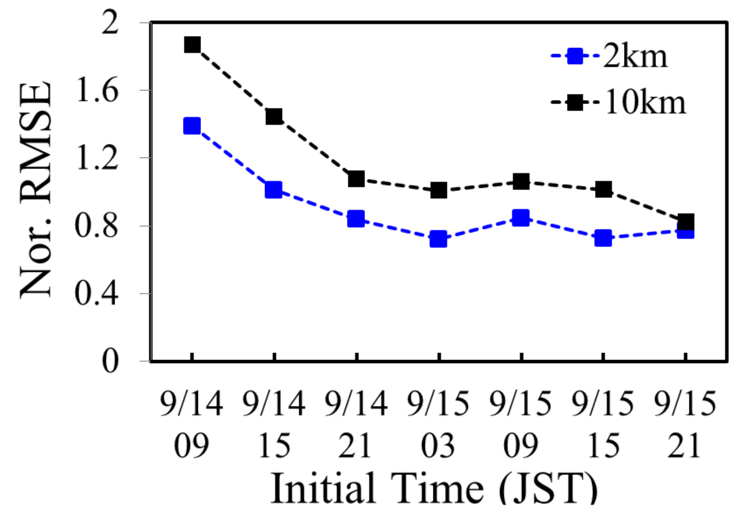
3. $\text{Relative Error (\%)} = \dfrac{O^{peak} - F^{peak}}{O^{peak}} \times 100$

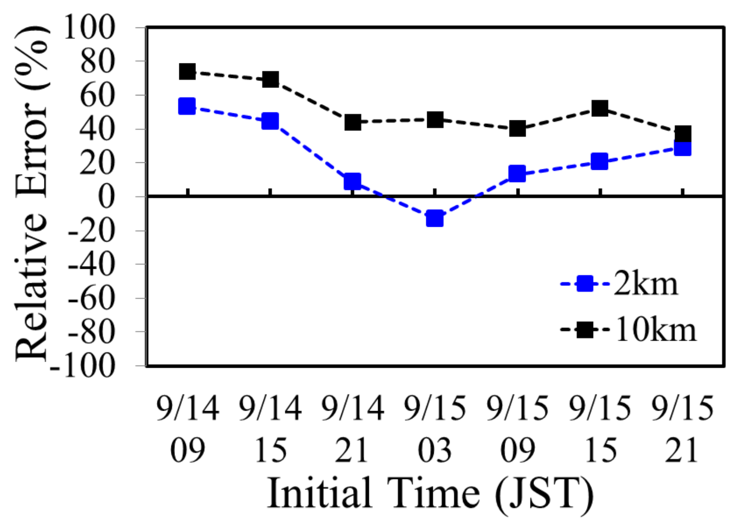
Rainfall Verification





Discharge Verification





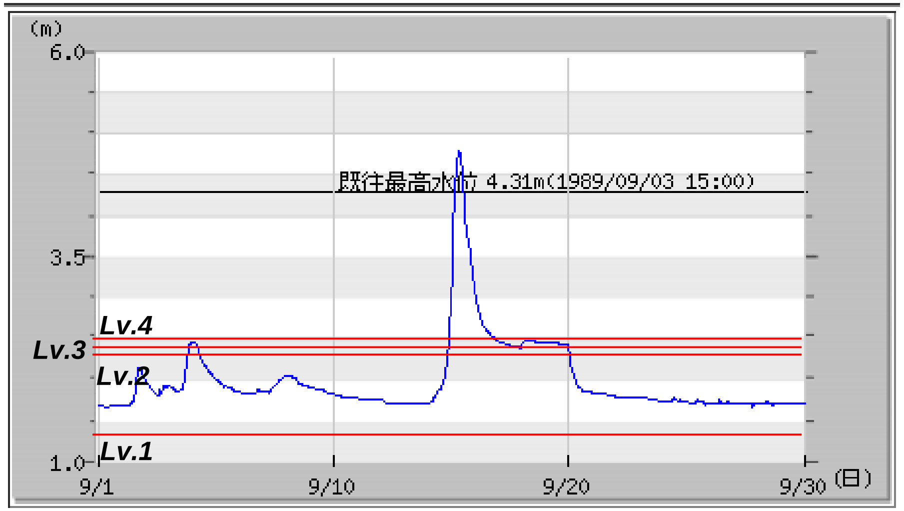
Application to Flood Early Warning

- ***How can apply the downscaled NWP for flood early warning in the Katsura river basin?***

Katsura station

観測所記号	観測所名	水系名	河川名
306041286606330	桂(かつら)	淀川	桂川

年月	2013年9月



Katsura station data: http://www1.river.go.jp/
(国土交通省 水文水質データベース)

観測所詳細諸元情報

観測所名		桂（かつら）
観測項目		水位流量
観測所記号		306041286606330
水系名		淀川
河川名		桂川
観測所管理者名		国土交通省淀川河川事務所
観測所種別		第1種
観測所諸元	流域面積	887.00km2
	零点高	19.391m
	水防団待機水位	2.80m
	はん濫注意水位	3.80m
	避難判断水位	3.90m
	はん濫危険水位	4.00m
	計画高水位	5.06m
	計画高水流量	:m3/s

Warning Lv.1（水防団待機水位）*: 2.80m*

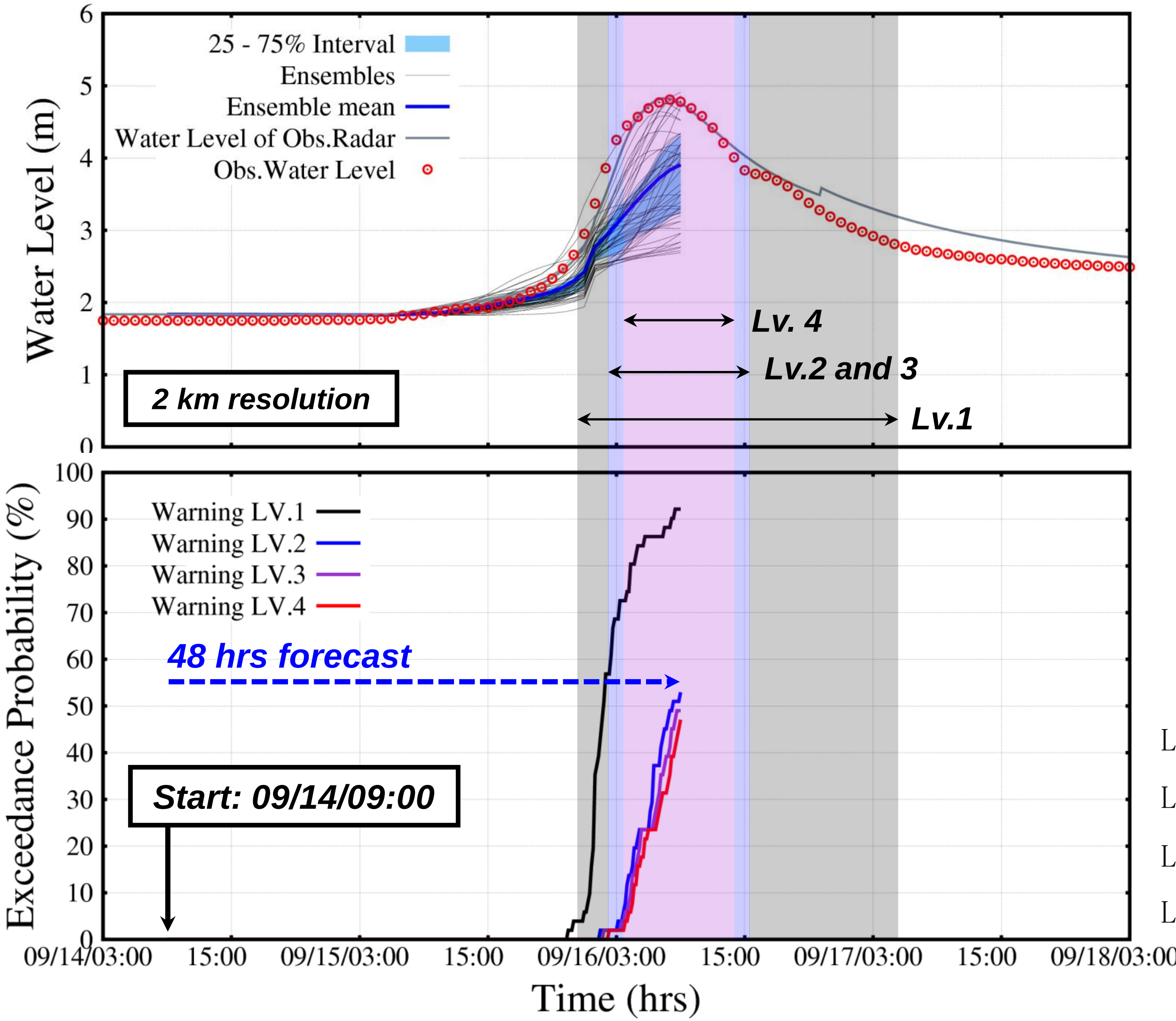
Warning Lv.2（氾濫注意水位）*: 3.80m*

Warning Lv.3（避難判断水位）*: 3.90m*

Warning Lv.4（氾濫危険水位）*: 4.00m*

Application to Flood Early Warning

Katsura station



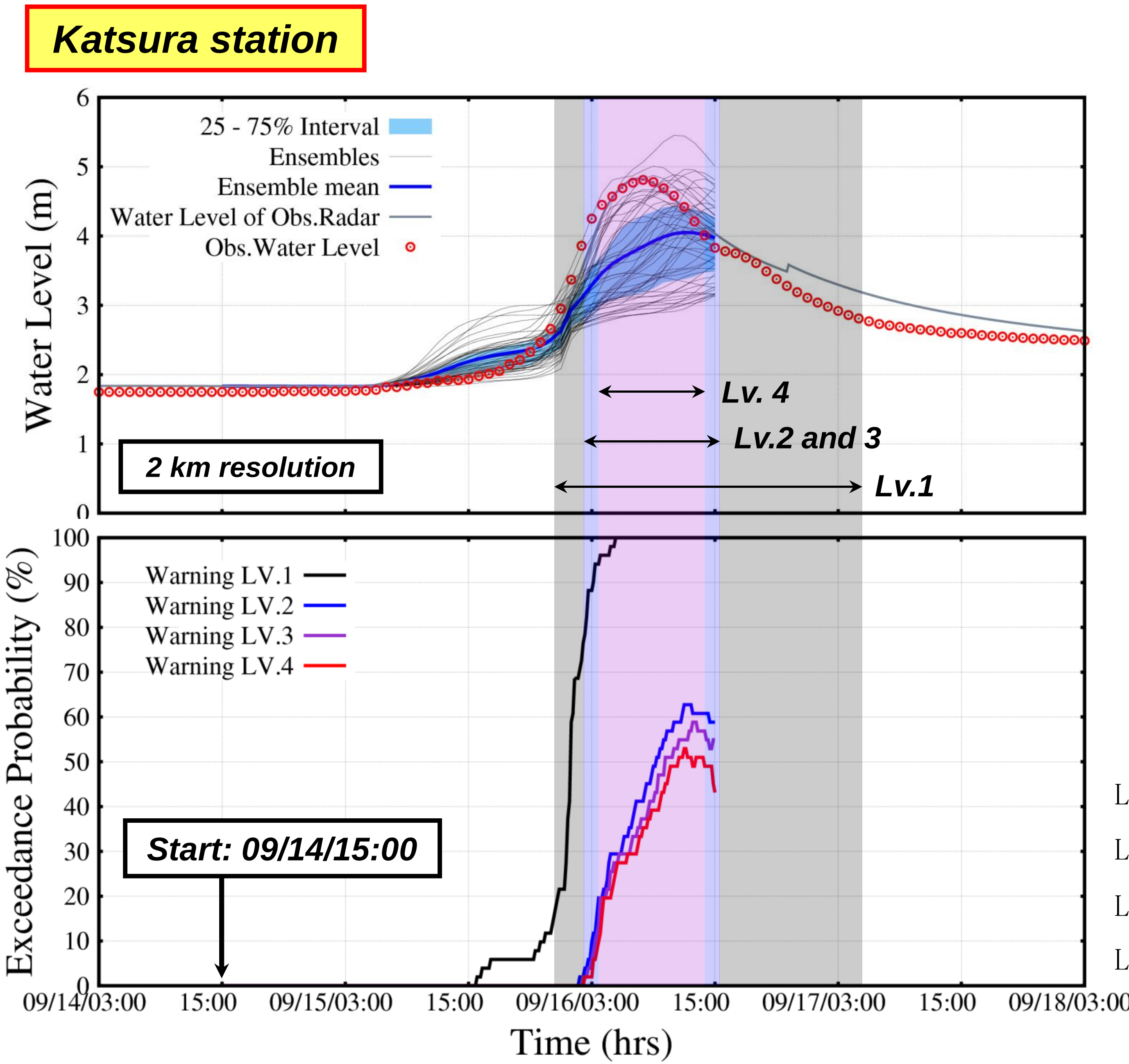
Lv. 1　水防団待機水位(2. 8m)

Lv. 2　氾濫注意水位(3. 8m)

Lv. 3　避難判断水位(3. 9m)

Lv. 4　氾濫危険水位(4. 0m)

Application to Flood Early Warning



Lv. 1 水防団待機水位(2.8m)

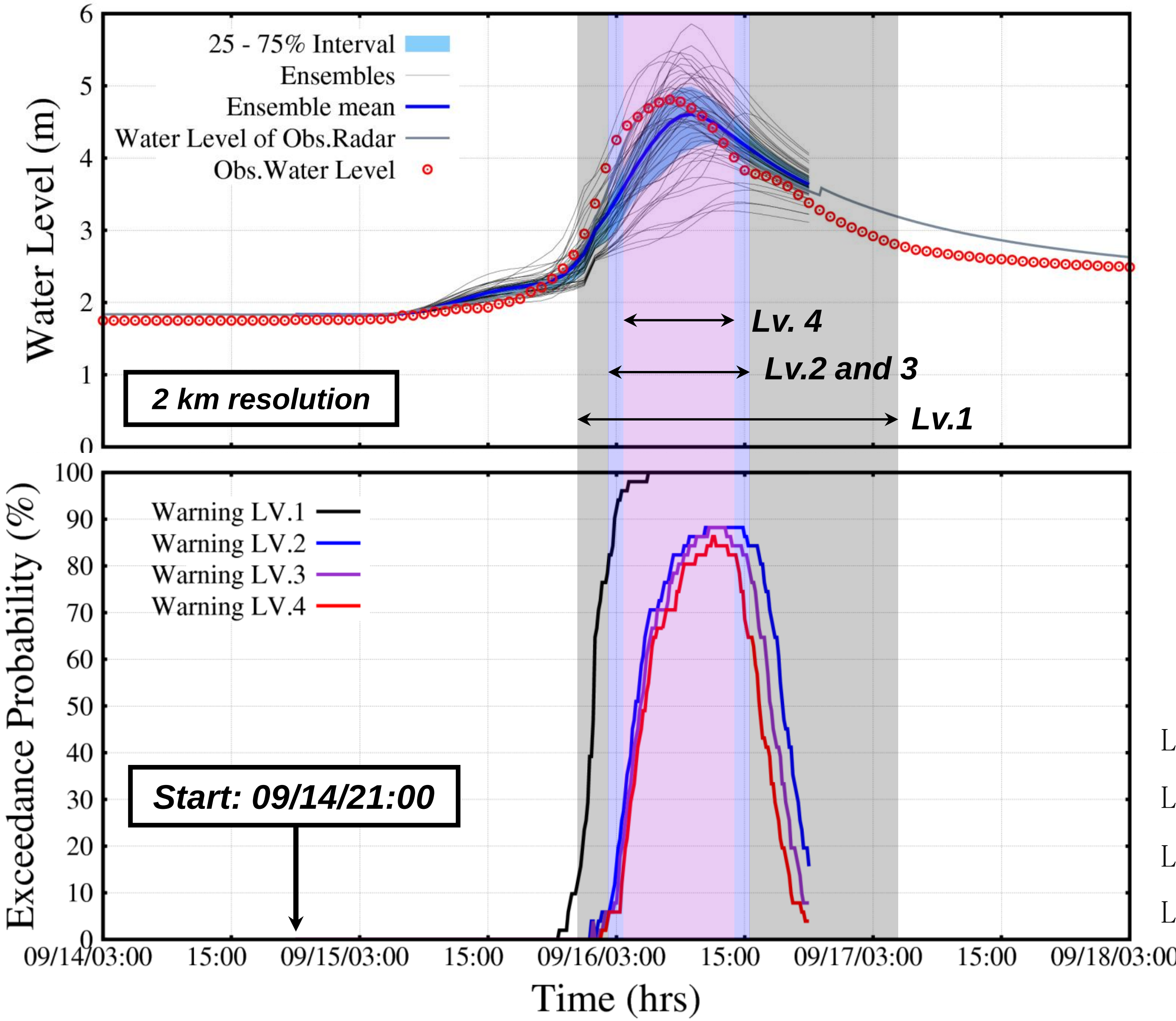
Lv. 2 氾濫注意水位(3.8m)

Lv. 3 避難判断水位(3.9m)

Lv. 4 氾濫危険水位(4.0m)

Application to Flood Early Warning

Katsura station



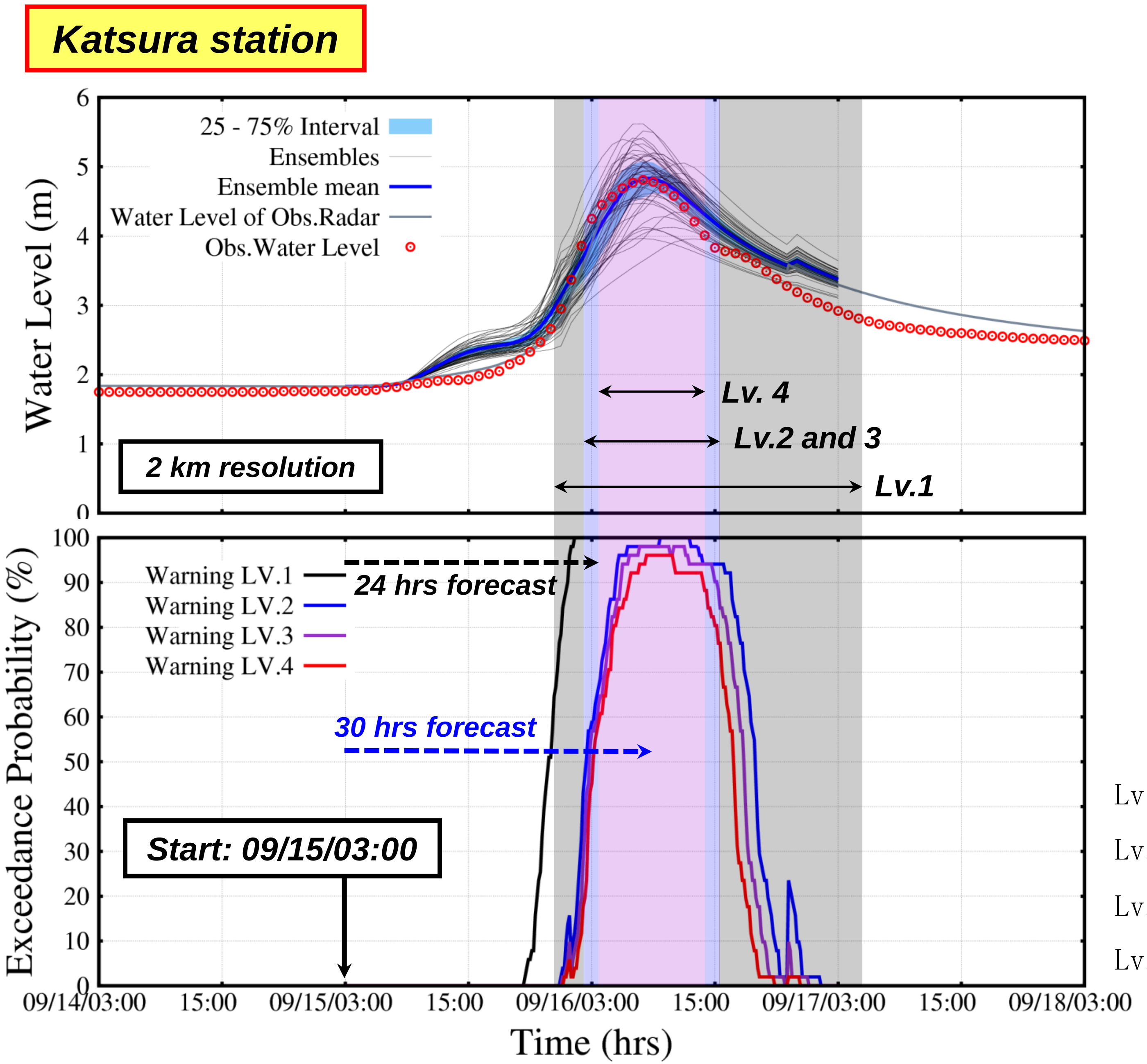
Lv. 1 水防団待機水位(2.8m)

Lv. 2 氾濫注意水位(3.8m)

Lv. 3 避難判断水位(3.9m)

Lv. 4 氾濫危険水位(4.0m)

Application to Flood Early Warning



Lv. 1　水防団待機水位(2.8m)

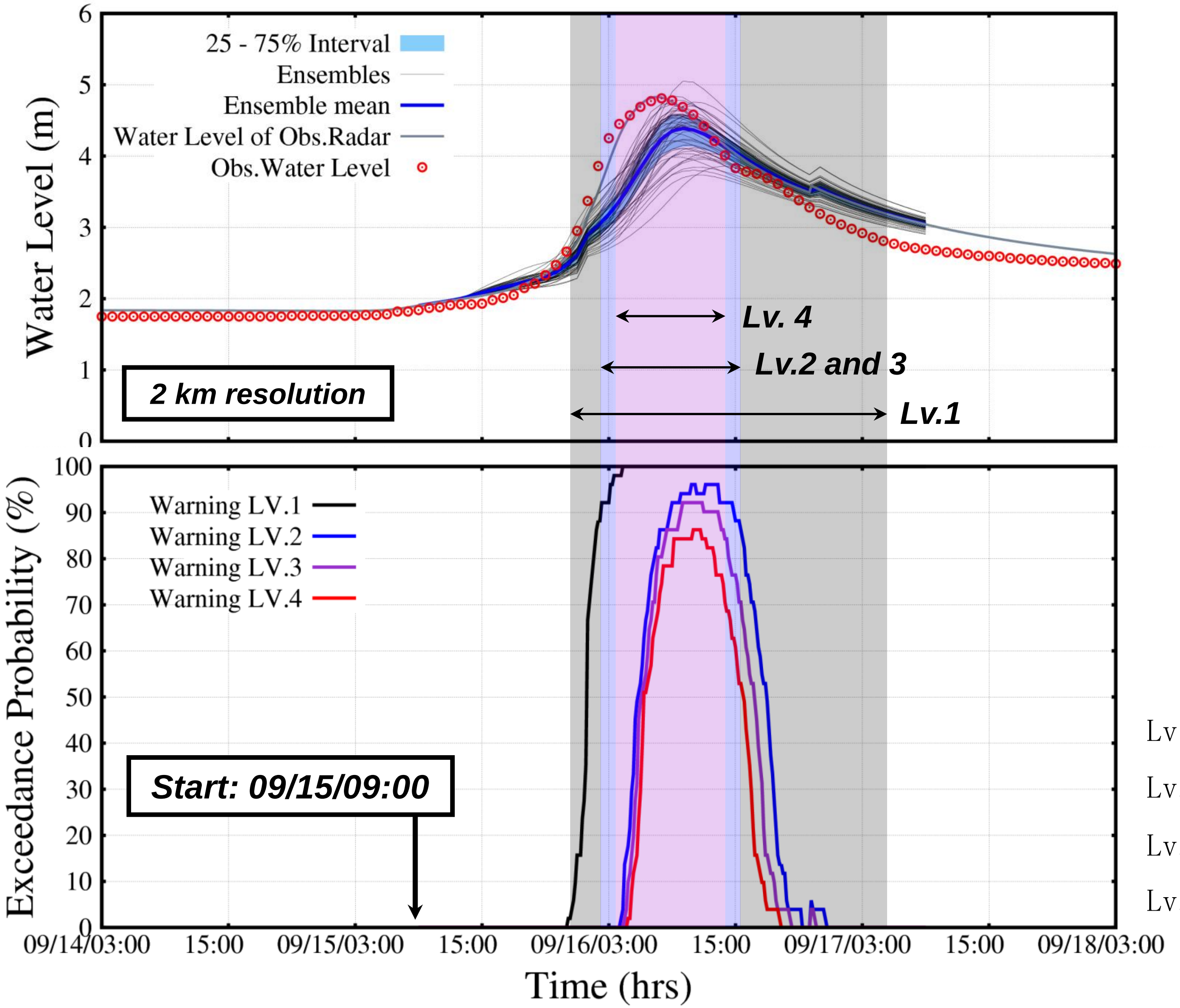
Lv. 2　氾濫注意水位(3.8m)

Lv. 3　避難判断水位(3.9m)

Lv. 4　氾濫危険水位(4.0m)

Application to Flood Early Warning

Katsura station



Lv. 1 水防団待機水位(2.8m)

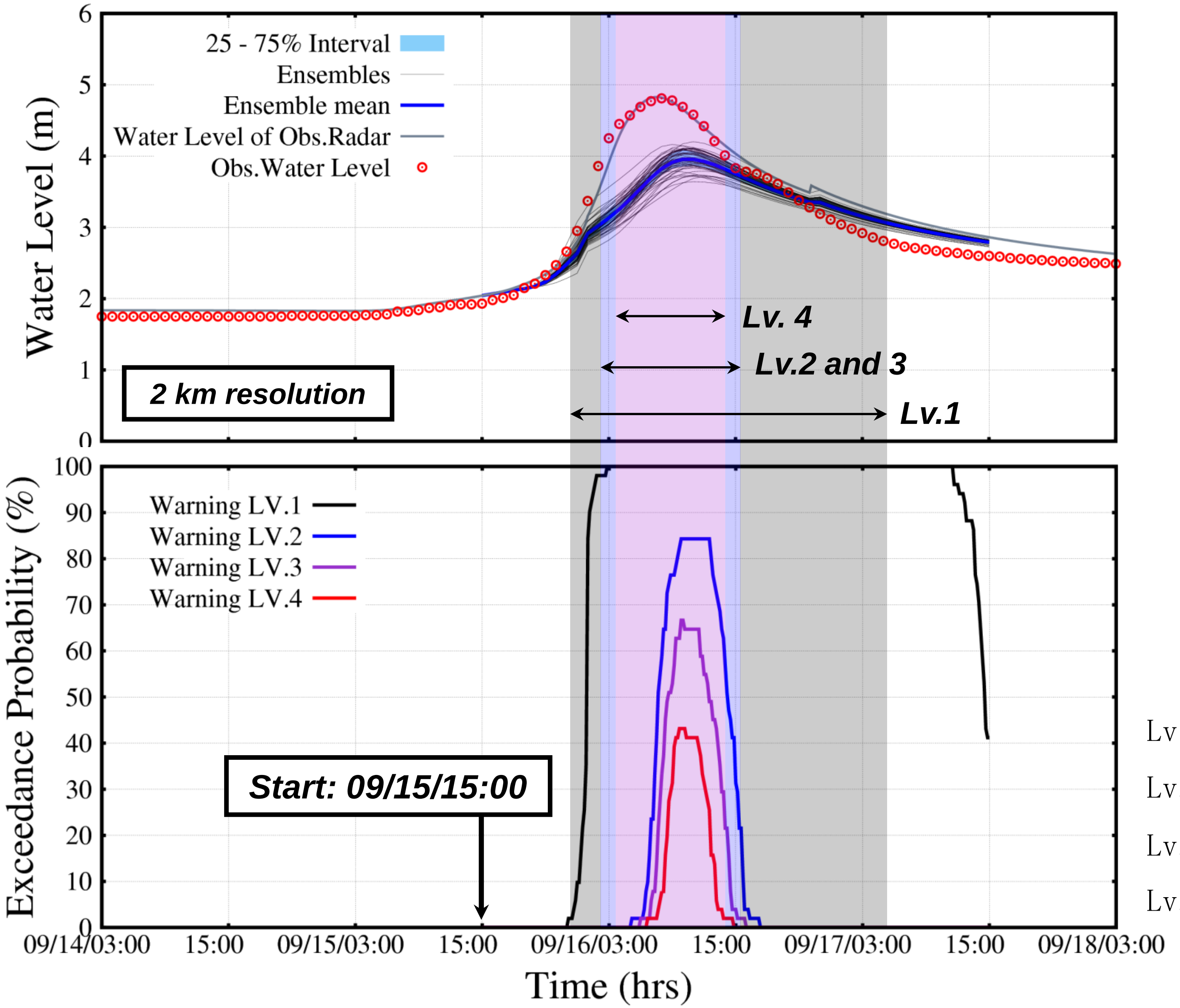
Lv. 2 氾濫注意水位(3.8m)

Lv. 3 避難判断水位(3.9m)

Lv. 4 氾濫危険水位(4.0m)

Application to Flood Early Warning

Katsura station



Lv. 1　水防団待機水位(2. 8m)

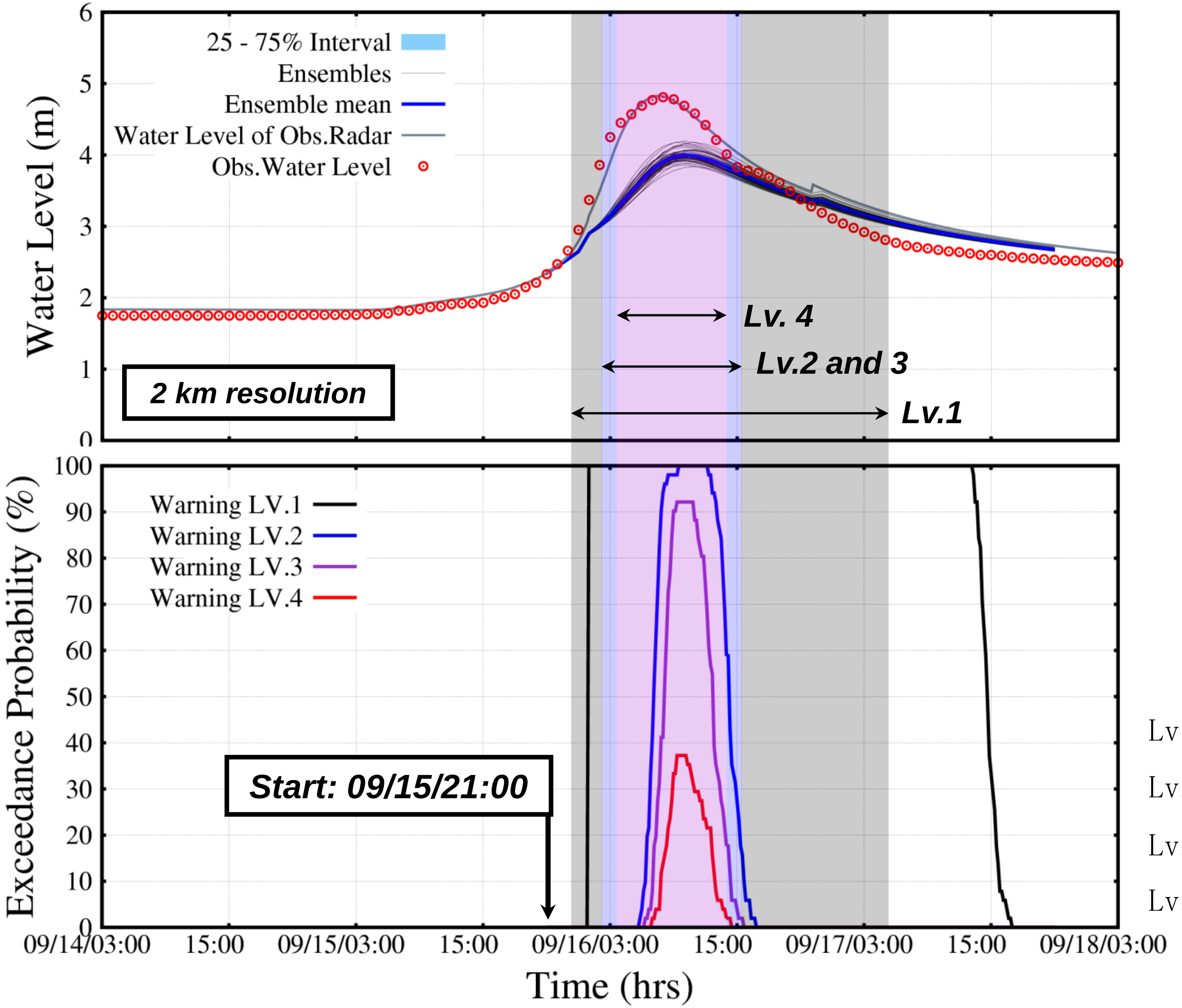
Lv. 2　氾濫注意水位(3. 8m)

Lv. 3　避難判断水位(3. 9m)

Lv. 4　氾濫危険水位(4. 0m)

Application to Flood Early Warning

Katsura station



Lv. 1　水防団待機水位(2. 8m)

Lv. 2　氾濫注意水位(3. 8m)

Lv. 3　避難判断水位(3. 9m)

Lv. 4　氾濫危険水位(4. 0m)

Conclusion

- ***Downscaled NWP result had more specific distribution than 10 km resolution and was more well matched compared with obs. radar rainfall distribution.***

- ***Downscaled NWP improved the reliability of the discharge for the Hiyoshi dam operation.***

- ***NWP predicted well the water level for flood early warning in the Katsura river basin.***

Thank You for your attention !

Related papers

- Nakakita, Eiichi, Tomohiro Yoshikai, and Sunmin Kim, Application of Error-Ensemble prediction method to a short-term rainfall prediction model considering orographic rainfall, Weather Radar and Hydrology (Proceedings of a symposium held in Exeter, UK, April 2011) (IAHS Publ., 351, 2012), pp.317-322, 2012.
- Yu, Wansik, Eiichi Nakakita, and Kosei Yamaguchi, Assessment of probabilistic flood forecasting using ensemble NWP rainfall with 30hr forecast time during typhoon events, Advances in River Engineering, JSCE, Vol.19, pp. 235-240 ,2013, June.
- Yu, Wansik, Eiichi Nakakita, Sunmin Kim, and Kosei Yamaguchi, Accuracy improvement of flood forecasting using pre-processing of ensemble numerical weather prediction rainfall fields, Journal of Japan Society of Civil Engineers, B1 (Hydraulic Engineering), JSCE, Vol.70, No.4, pp.151-156, 2014.
- Yu, Wansik, Eiichi Nakakita, Sunmin Kim, and Kosei Yamaguchi, Improvement of rainfall and flood forecasts by blending ensemble NWP rainfall with radar prediction considering orographic rainfall, Journal of Hydrology, Vol.531, pp.494-507, doi:10.1061/jhydrol.2015.04.055, 2015.
- Yu, Wansik, Eiichi Nakakita, Sunmin Kim, and Kosei Yamaguchi, Assessment of Uncertainty Propagation of Ensemble NWP Rainfall to Flood Forecasting with Catchment Scale, Advances in Meteorology, 2015.
- Yu Wansik, E. Nakakita, S. Kim, and K. Yamaguchi, Assessment of ensemble flood forecasting with numerical weather prediction by considering spatial shift of rainfall fields, Water Resources and Hydrologic Engineering, KSCE Journal of Civil Engineering, Vol.22, pp.3686-3696, 2018.09.