The estimation of river bankfull depth by the use of satellite altimetry dataset and the river routing model

2019 July 3rd

The University of Tokyo (Dai Yamazaki Lab.)
Master 2nd Takuto Shiozawa

Self Introduction

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Master 2nd
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2014-2018 UTokyo Civil Engineering
Bachelor thesis: Data assimilation of river model

2018- UTokyo master Civil Engineering

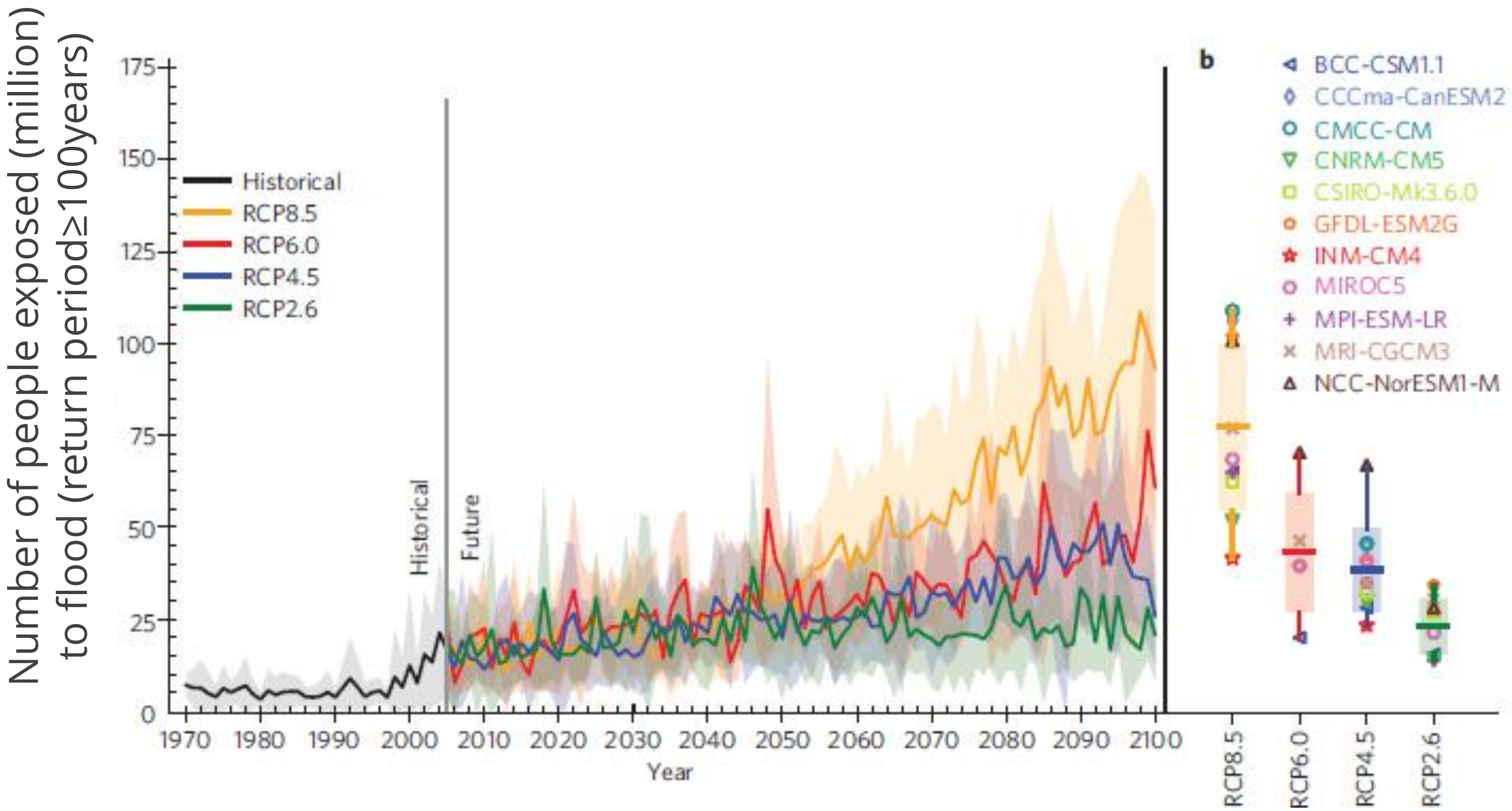
Today's topic !!

Master thesis: Estimation of river bankfull depth

Currently, I'm researching as an intern in LEGOS (Dr.Biancamaria)

Background

The estimation of flooded area by global river routing model is important for the impact of flood on the society 【e.g., Hirabayashi et al., 2013, Philip et al., 2017】



【Hirabayashi et al.,2013, *Nature Climate Change*】

Background

There is still large discrepancy of the inundation between the model output and observations

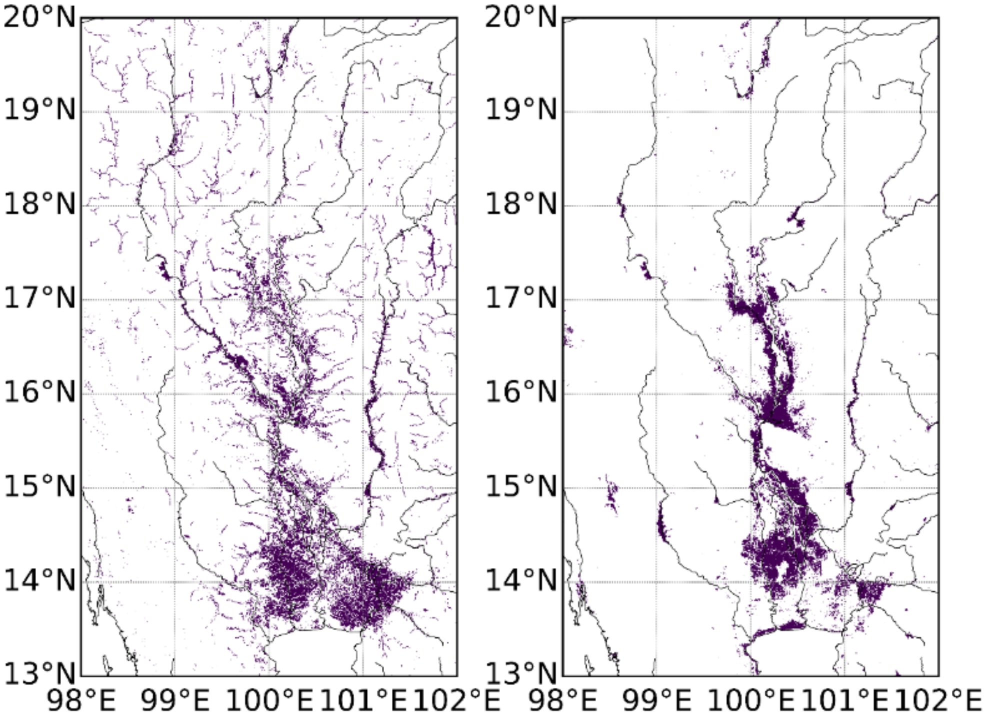
e.g. 2011 Thailand flood

https://www.jiji.com

Inundation Comparison

River routing model, CaMa-Flood

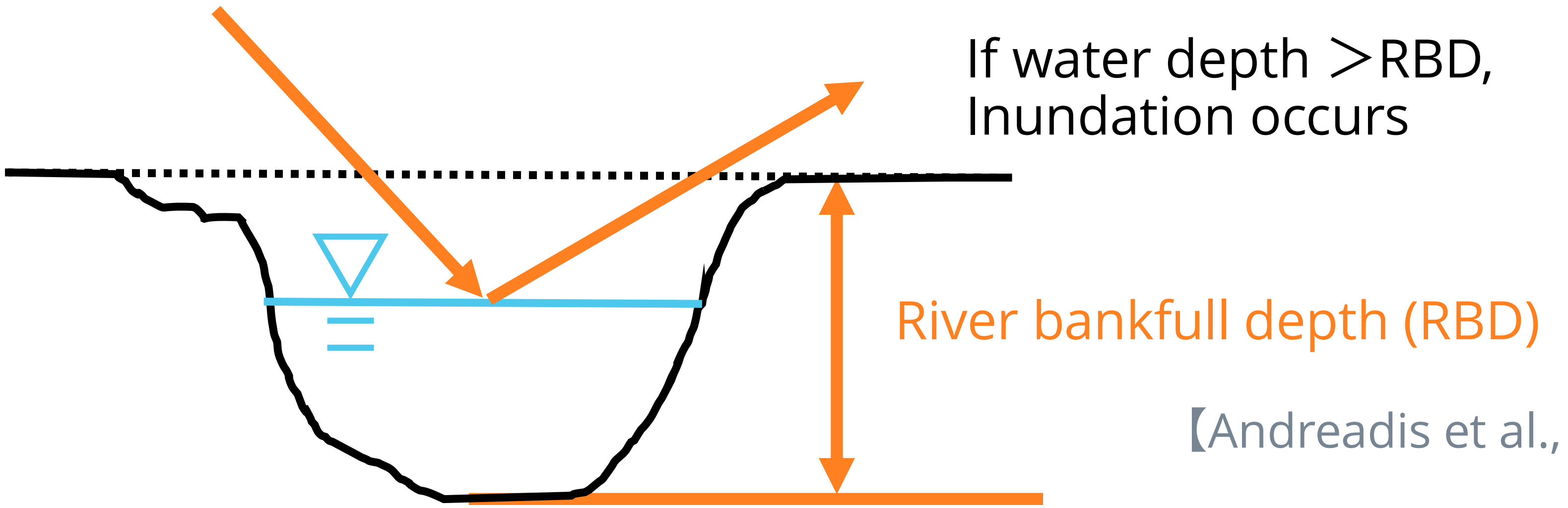
MODIS obs.



Background

River bankfull depth(RBD) is defined in the model

RBD = channel top elevation－riverbed elevation

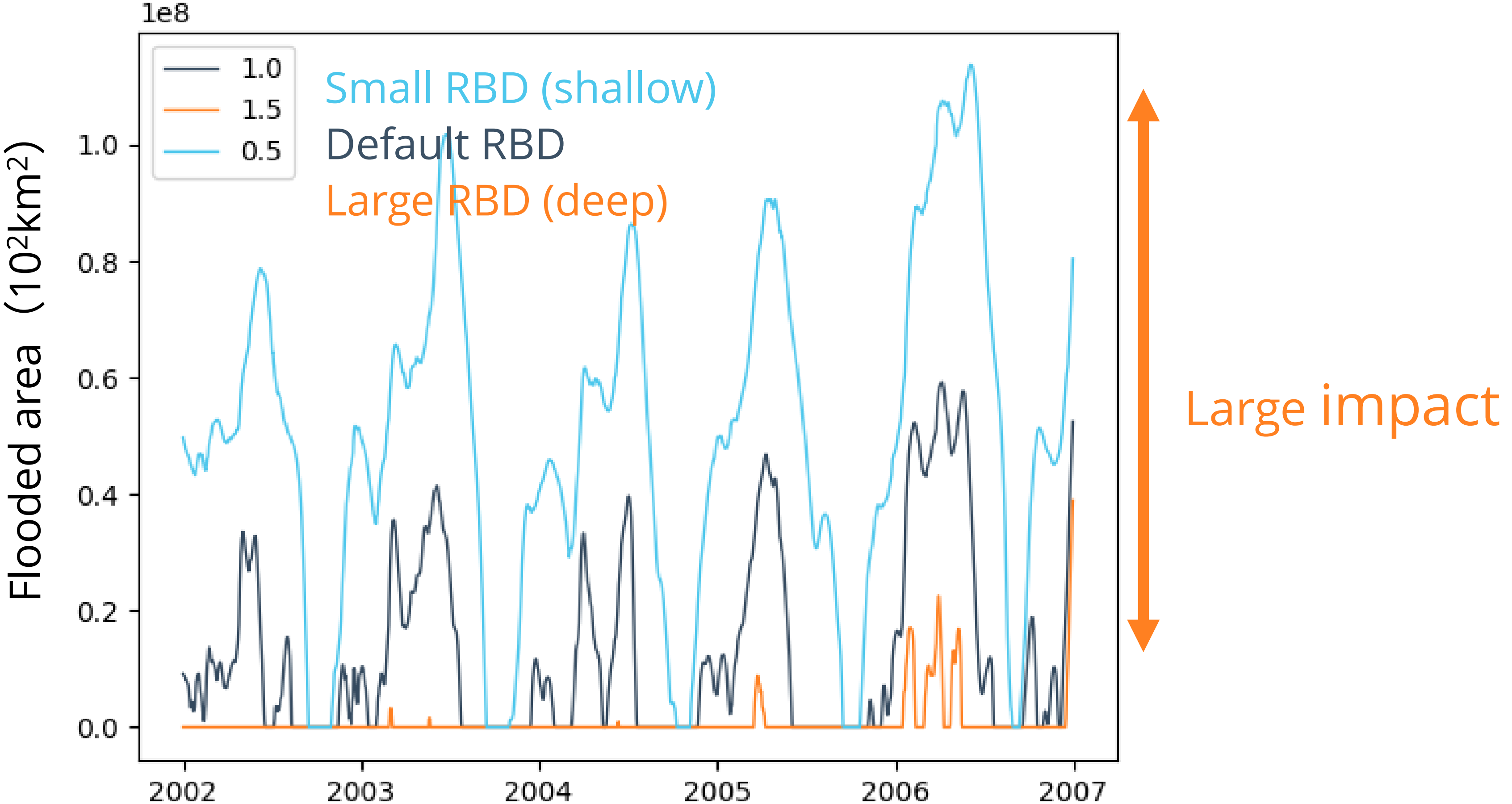


【Andreadis et al., 2013】

Satellites wave tend to reflect on the water surface, which make it difficult to measure RBD directly

RBD value strongly affects the flood inundation estimation, because it changes channel capacity

The effect of RBD value on the flooded area estimation in the Amazon river



Previous researches

The recent RBD dataset is produced by the simple empirical equation and parameters tuned globally

$$H = a \times R^b$$

【Yamazaki et al., 2011】

$$H = a \times A^b$$

【Andreadis et al., 2013】

H:RBD,R:Upstream runoff, A:Drainage area, a,b: global parameter

this equation can't consider local characteristics (e.g. topography and geology) and make a large error

【Andreadis et al., 2013】

Can I reverse-estimate RBD efficiently on a global scale by using the river model and satellite altimetry dataset?

Methodology

Development

1. Construct a method
2. Validate it with a virtual test (OSSE)

Application

3. Apply it to the Amazon river basin

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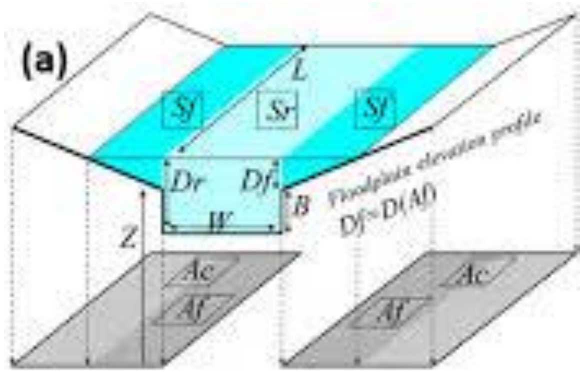
Model and dataset

CaMa-Flood (global routing model) 【Yamazaki et al., 2012】

- Spatial resolution of main calculation is 0.1deg (about 10km)
- ELSE_GPCC as forcing runoff data 【Kim et al., 2009】
- River channels are modeled like the right figure.

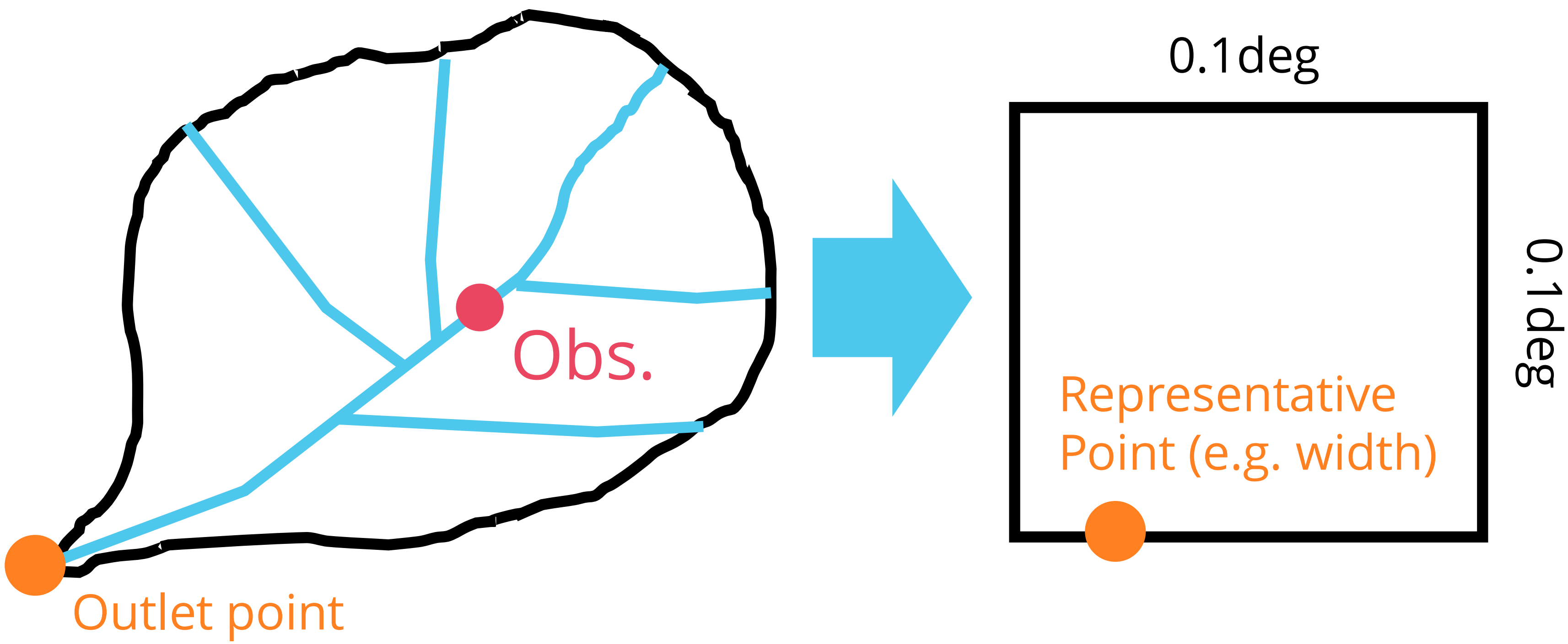


【Yamazaki et al., 2012】

Hydroweb (satellite altimetry dataset)【e.g. Da Silva et al., 2010】

- Data from 2002 to 2010 (Envisat and Jason-2) used in my method

Concept of comparison



✓ The effective width and water surface elevation is decided based on those values of an outlet point

✓ Observations within a grid are compared with the model

Method of estimation

Hypothesis:

WSE difference is mainly caused by RBD error

⇒The difference

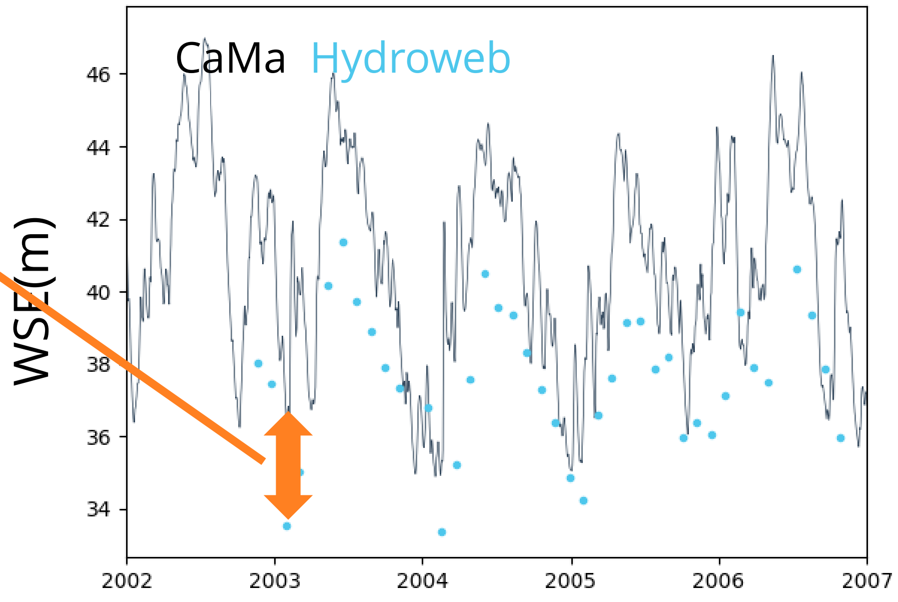
= updated RBD – original RBD

✓ River width and DEM were improved by satellite observation

-MERIT-DEM (Yamazaki et.al, 2017)

-GRWL (Allen and Pavelsky, 2018)

WSE from CaMa and HydroWeb



Original

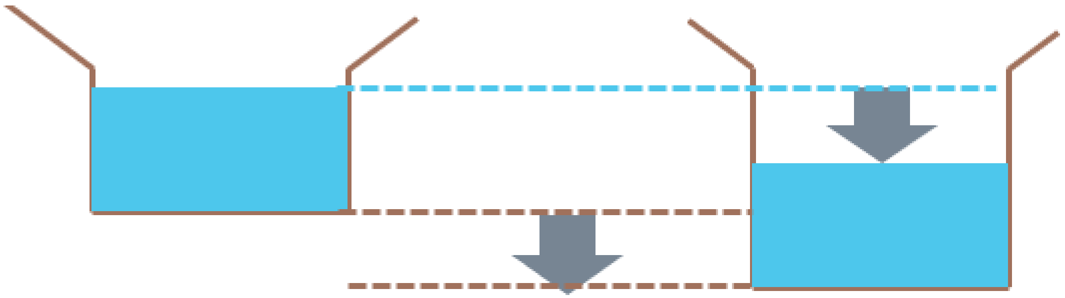
$$h_{x,y} = aR^{b}_{x,y}$$

Updated

$$h'_{x,y} = h_{x,y} + d_{x,y}$$

CaMa Hydroweb

$$d_{x,y} = \frac{1}{s}\sum_{t=1}^{s}\left(e^{m}_{x,y,t} - e^{o}_{x,y,t}\right)$$



Riverbed elevation is changed

If RBD increases,

WSE will decrease

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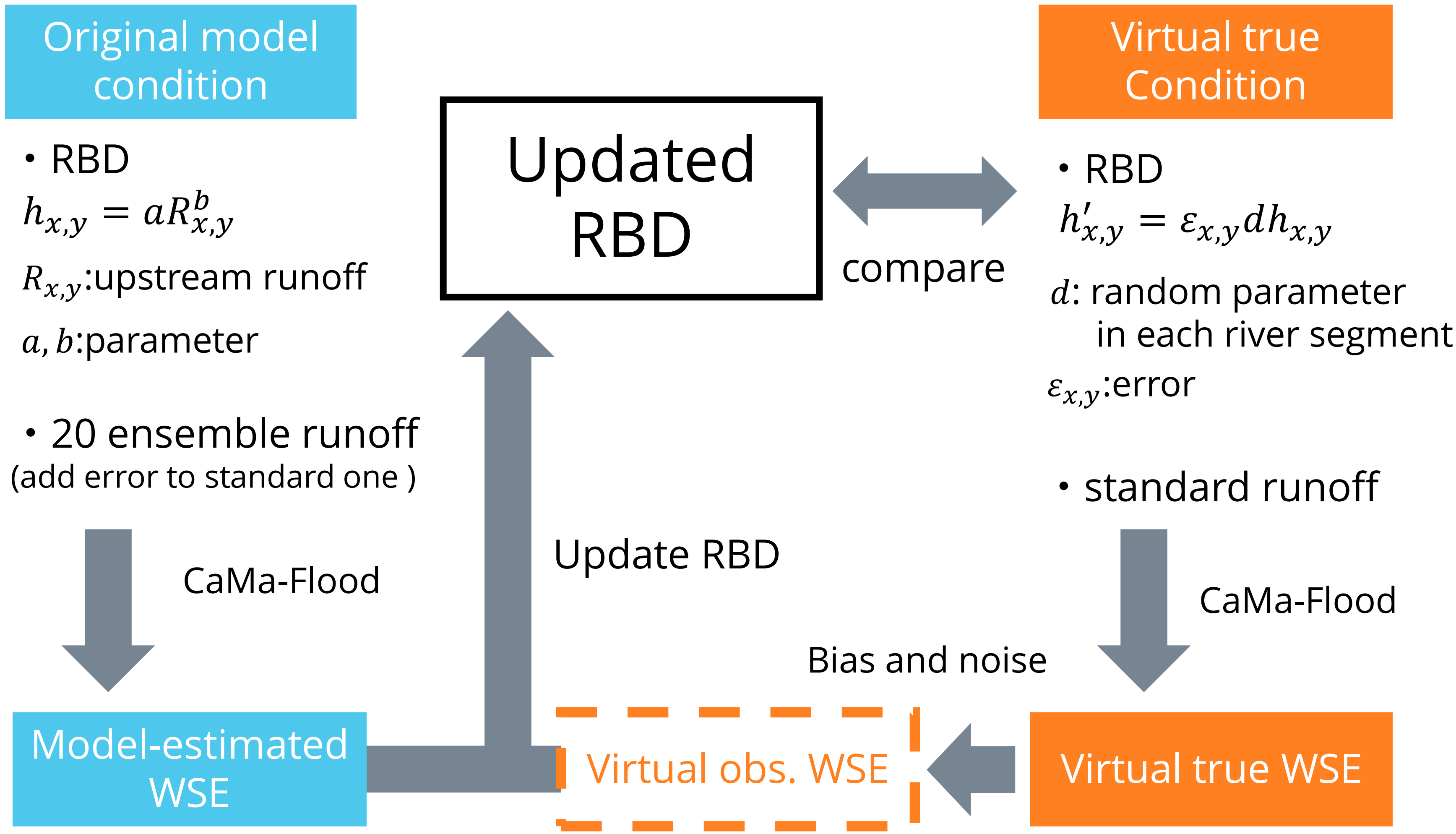
Virtual test scheme

make a virtual true RBD to validate
the performance of method in an ideal situation



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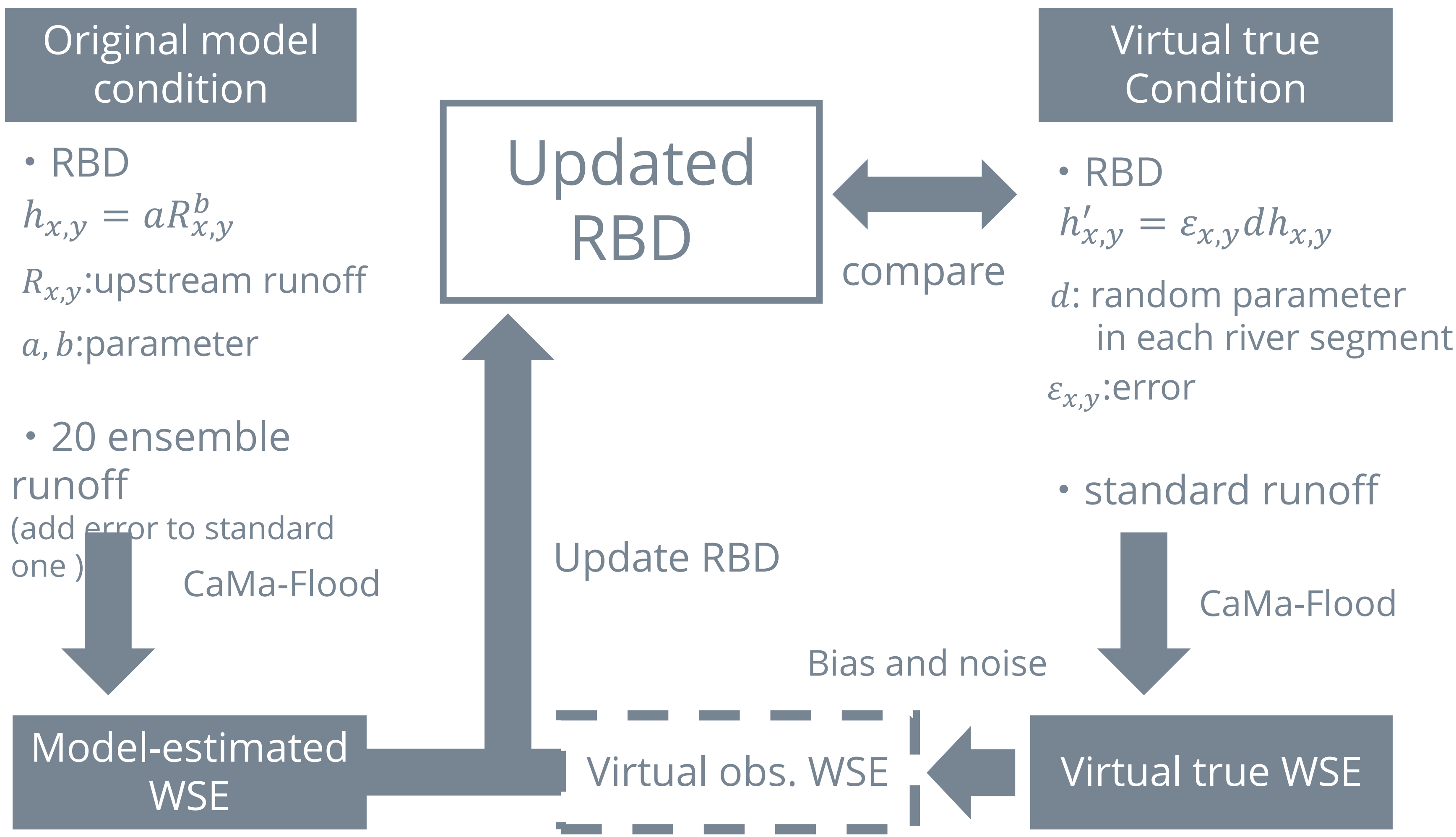

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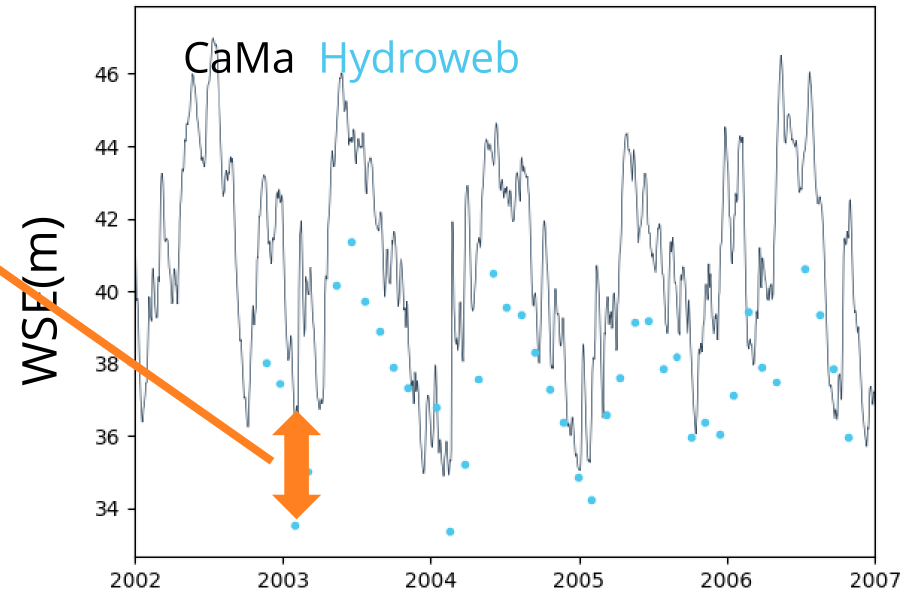

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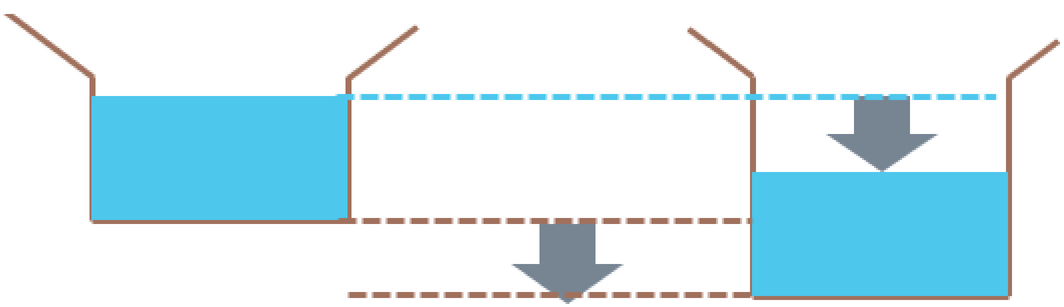
$$d_{x,y} = \frac{1}{s}\sum_{t=1}^{s}\left(e_{x,y,t}^{m} - e_{x,y,t}^{o}\right)$$



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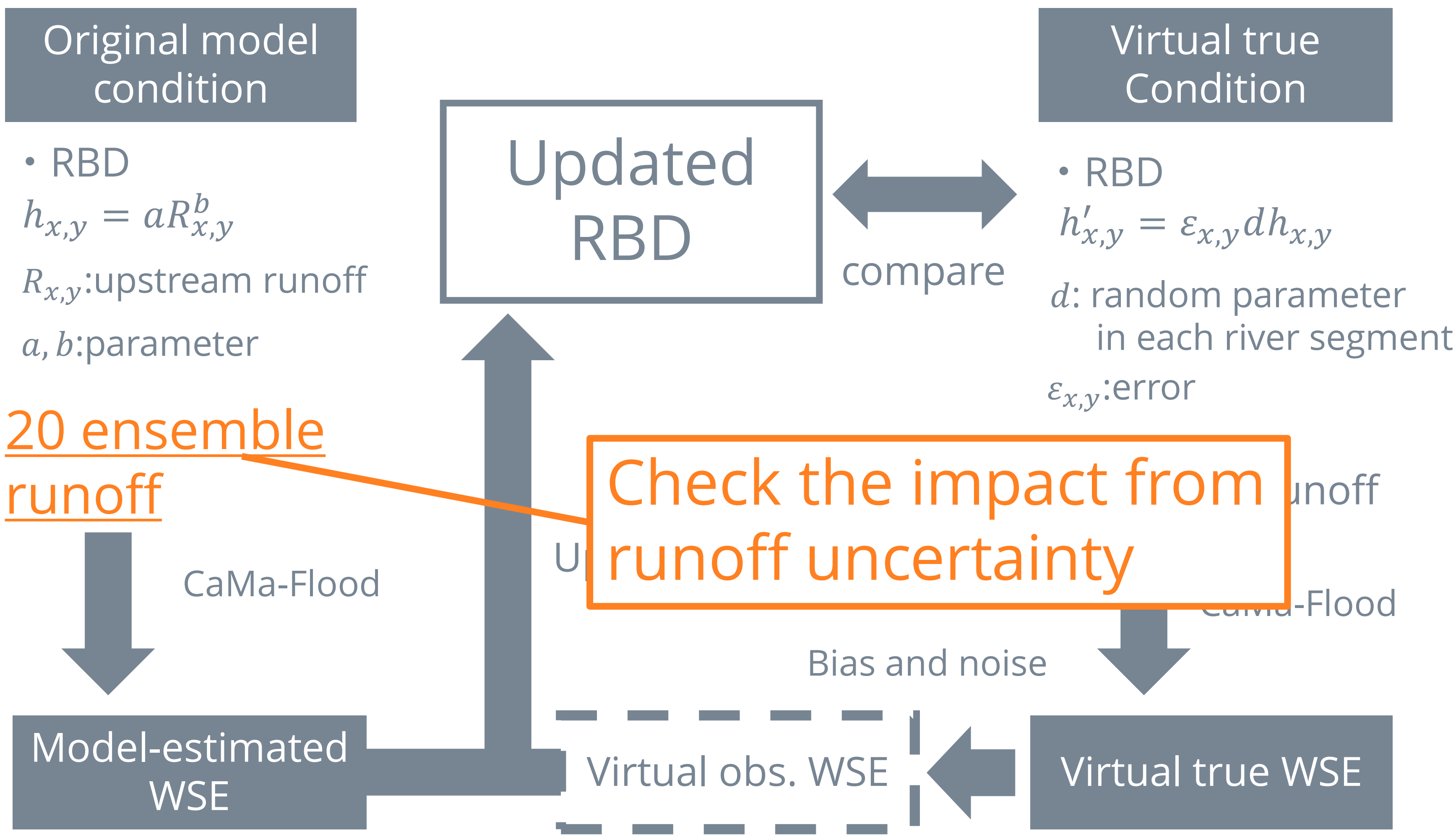
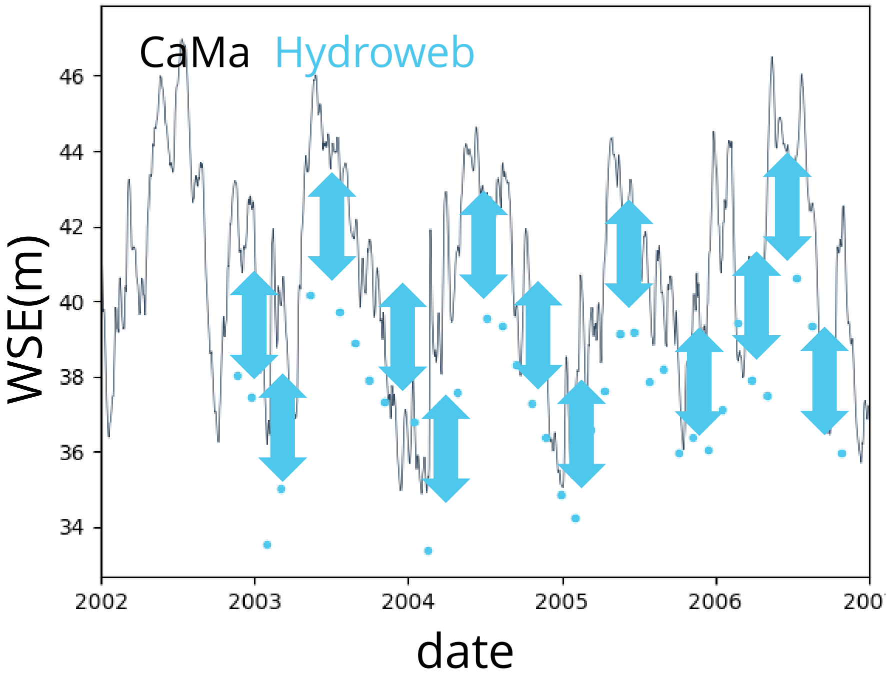


Two cases for OSSE

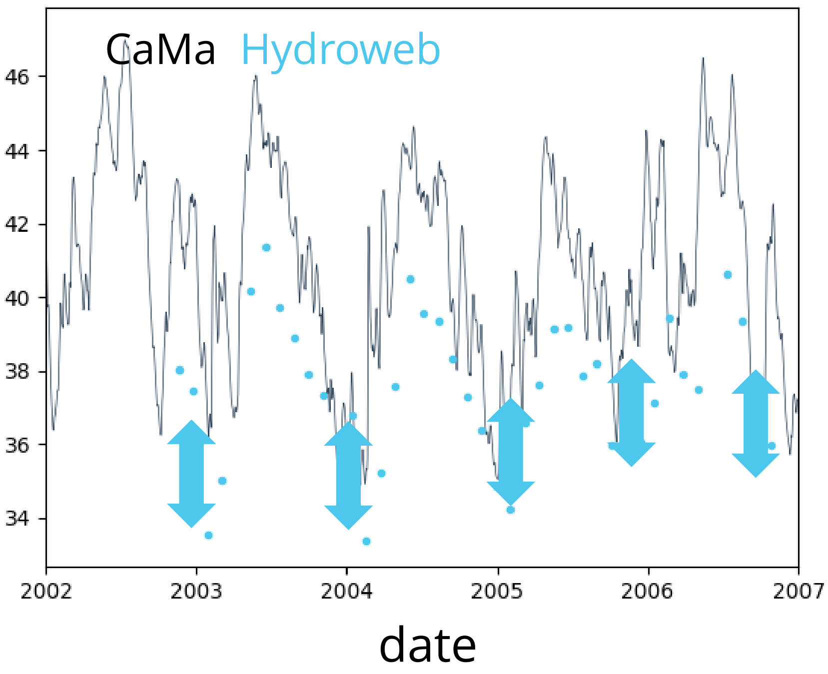
Try two cases with different "*s*" to find a way of reducing runoff impact

$$d_{x,y} = \frac{1}{s}\sum_{t=1}^{s}(e^{m}_{x,y,t} - e^{o}_{x,y,t})$$

1. All Obs. case



2. Only low flow Obs. case



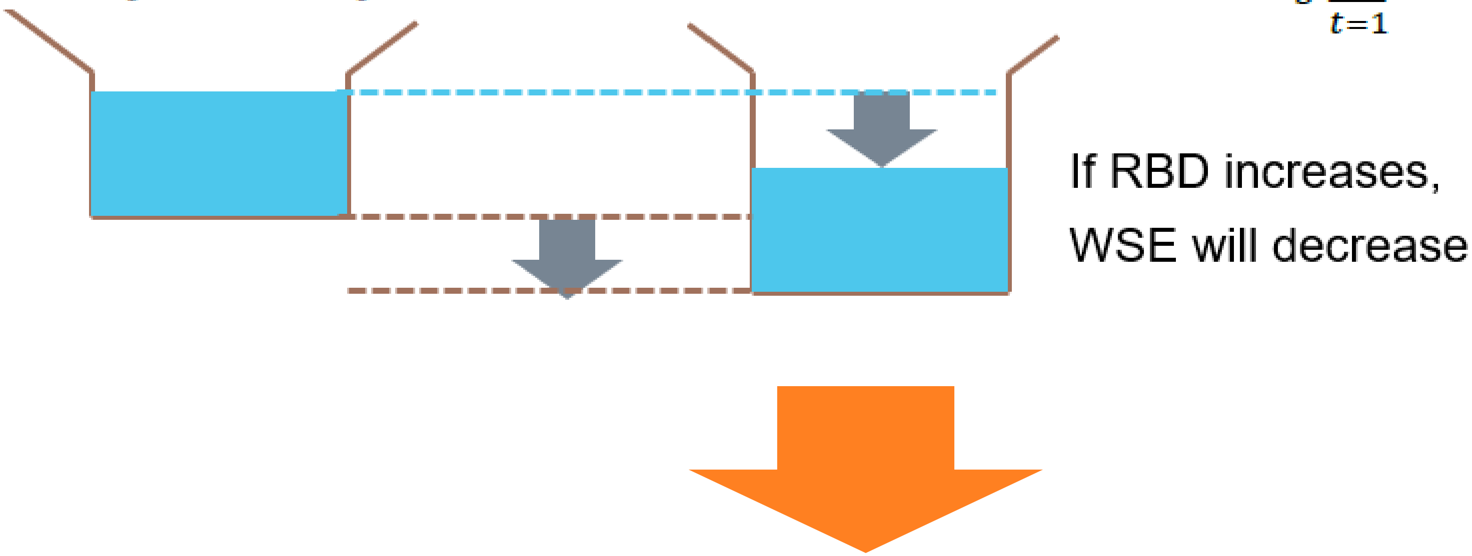
Which is better estimation?

Two cases for OSSE

In the method, the runoff uncertainty is directly reflected on the RBD uncertainty

$$h_{x,y} = aR_{x,y}^{b}$$

$$h'_{x,y} = h_{x,y} + d_{x,y} \qquad d_{x,y} = \frac{1}{s}\sum_{t=1}^{s}(e_{x,y,t}^{m} - e_{x,y,t}^{o})$$



If the relative uncertainty of runoff is constant 20%,

2m WSE ⇒ Estimated RBD has ±0.4m range

10m WSE ⇒ Estimated RBD has ±2m range

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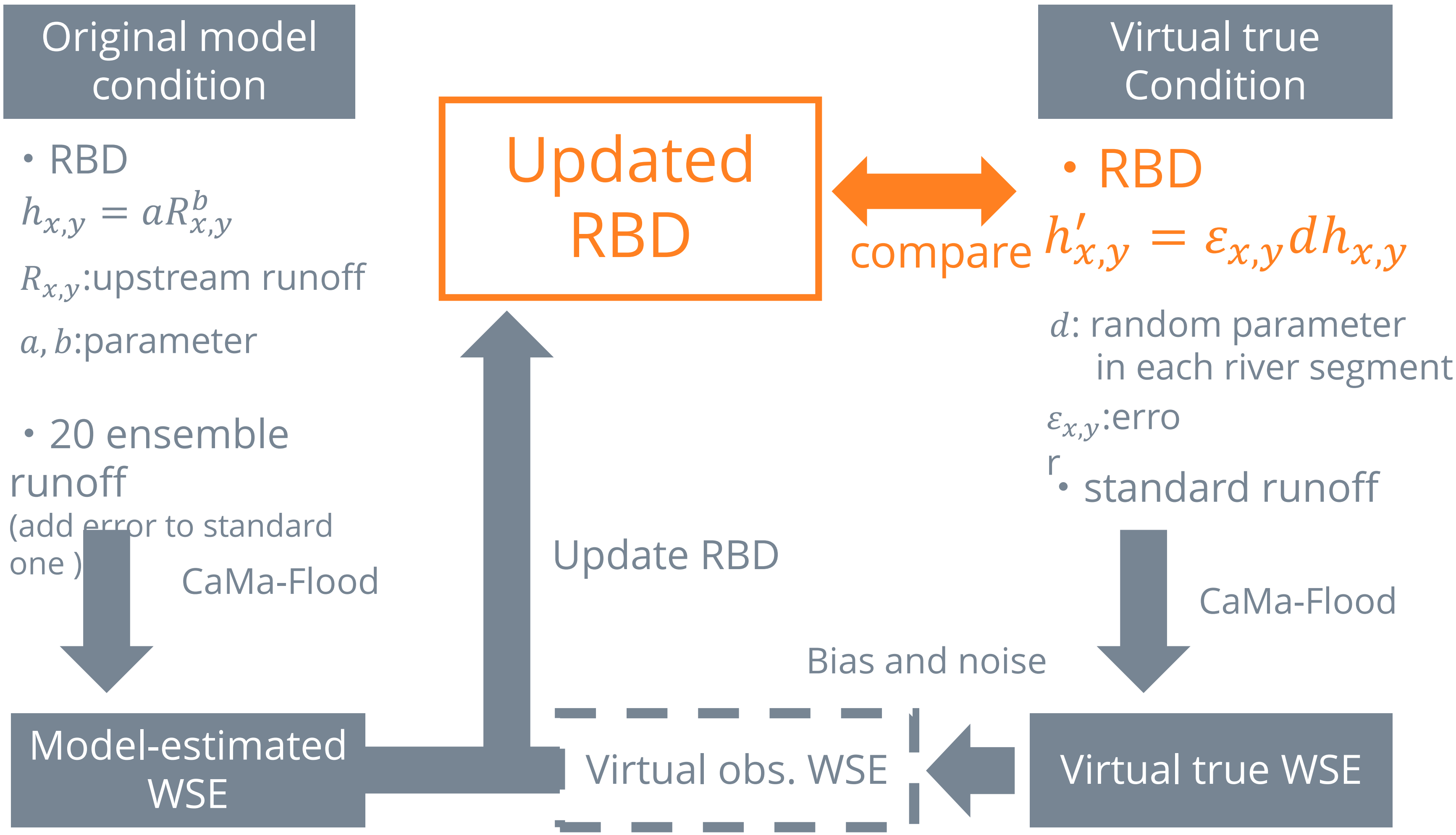
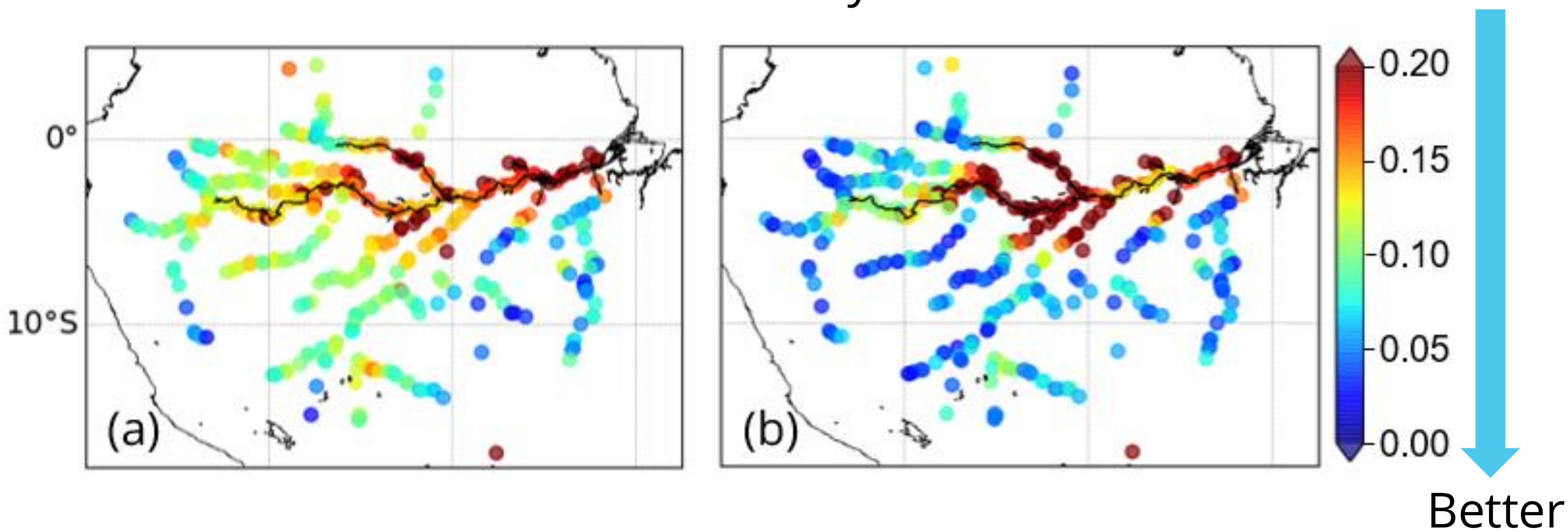


Relative mean bias between "true" RBD and updated RBD

Relative mean value comparison

1. All Obs. case
2. Only low flow Obs. case



✓ Mean bias is less than the original RBD

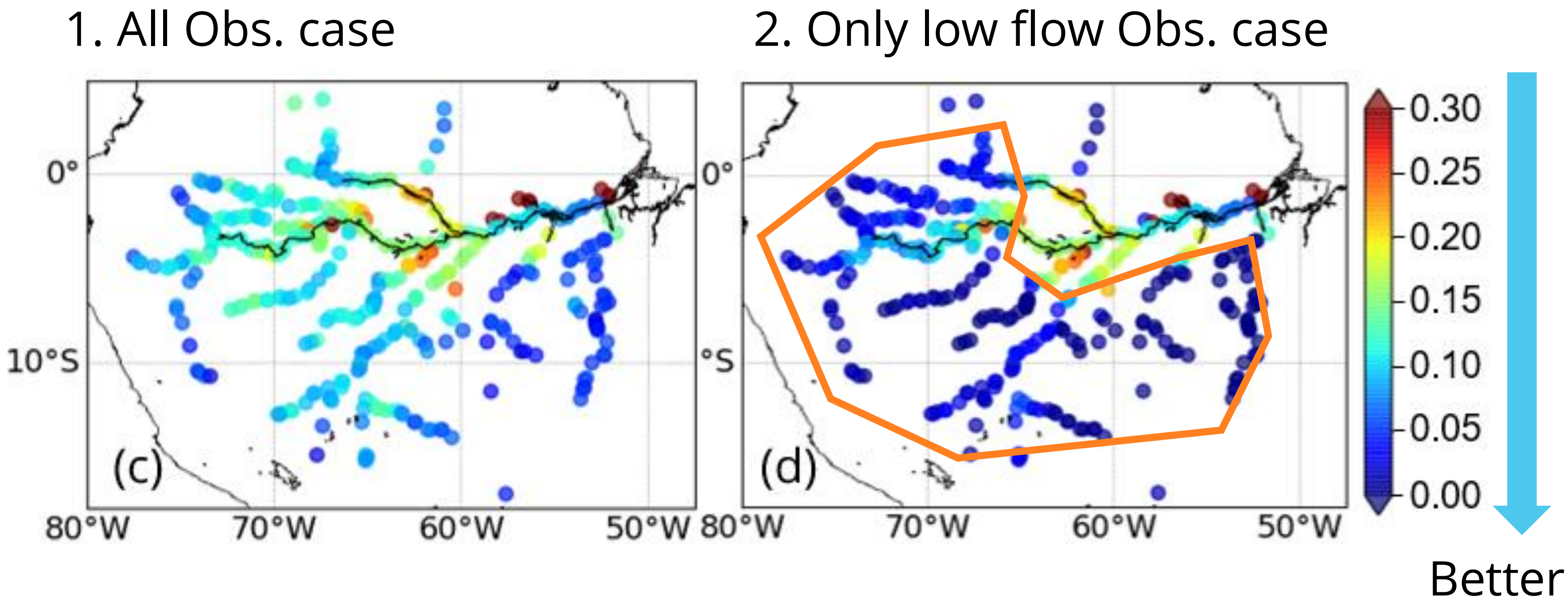
- In original case, 63% is over 0.3, but in the updated case 75% is below 0.15

✓ Abs. difference is smaller in upstream areas

- almost below 10%, especially low in Only low flow Obs. case

Relative standard deviation of updated RBD

Standard deviation of 20 case (with different runoff)



At low flow, the accuracy of the estimation is less affected by the uncertainty of runoff

⇒Because the absolute value of uncertainty of runoff is smaller at low flow

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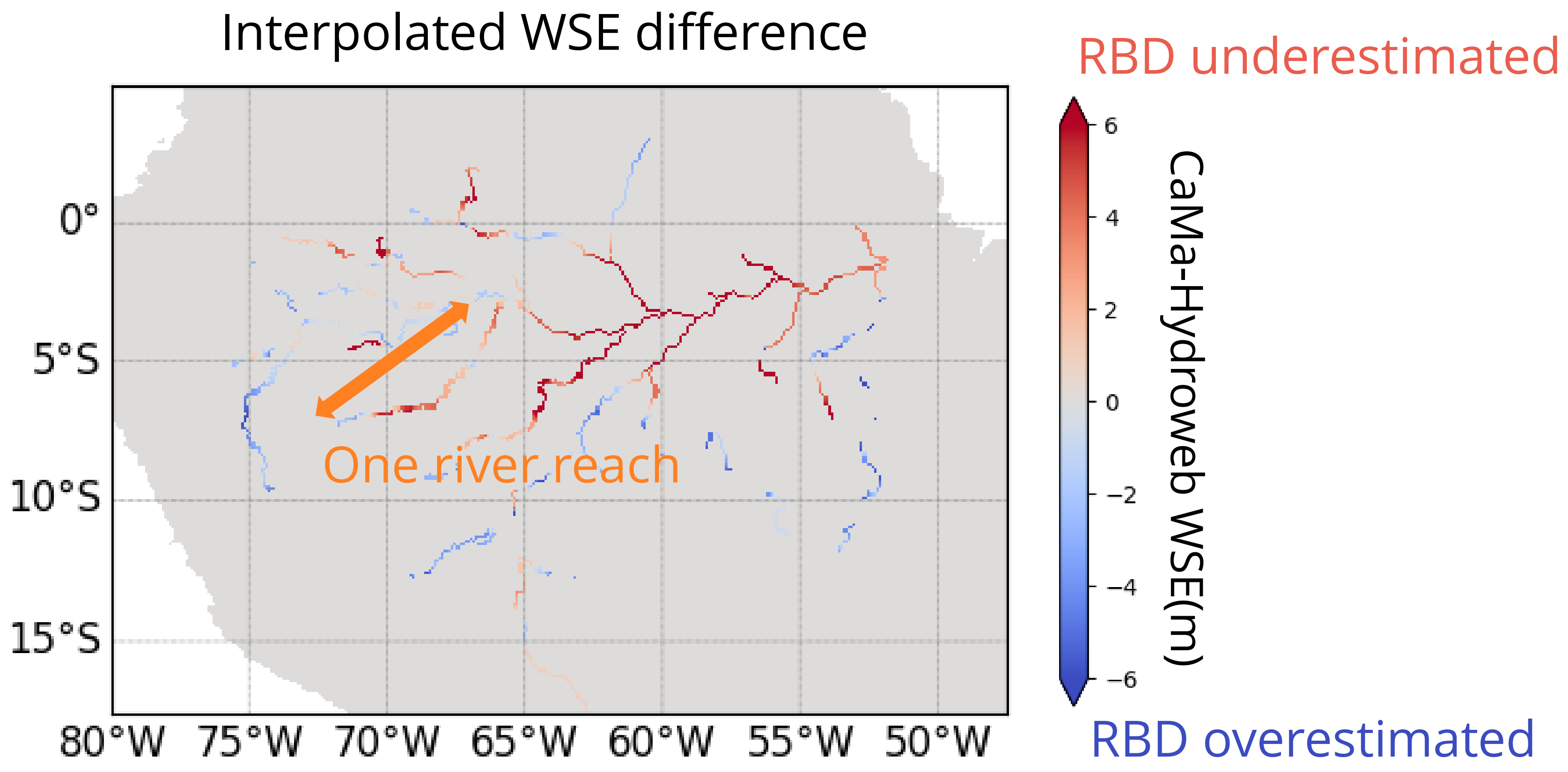
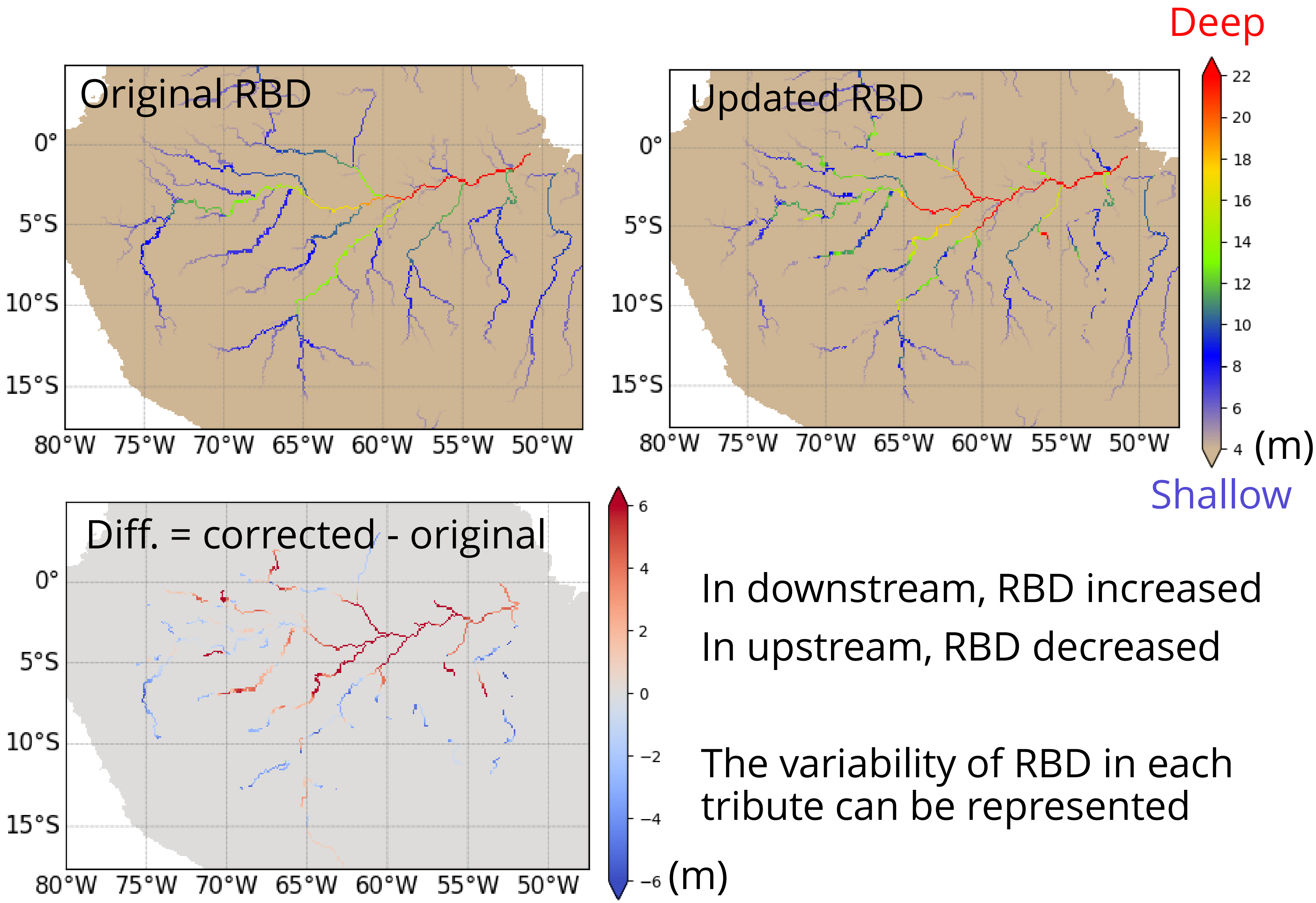
Procedures for the test with real Hydroweb

1. WSE difference at low flow is calculated at observed coordinates
2. Interpolated it in each river reach

-River reach: part between confluence points



Comparison of original and updated RBD

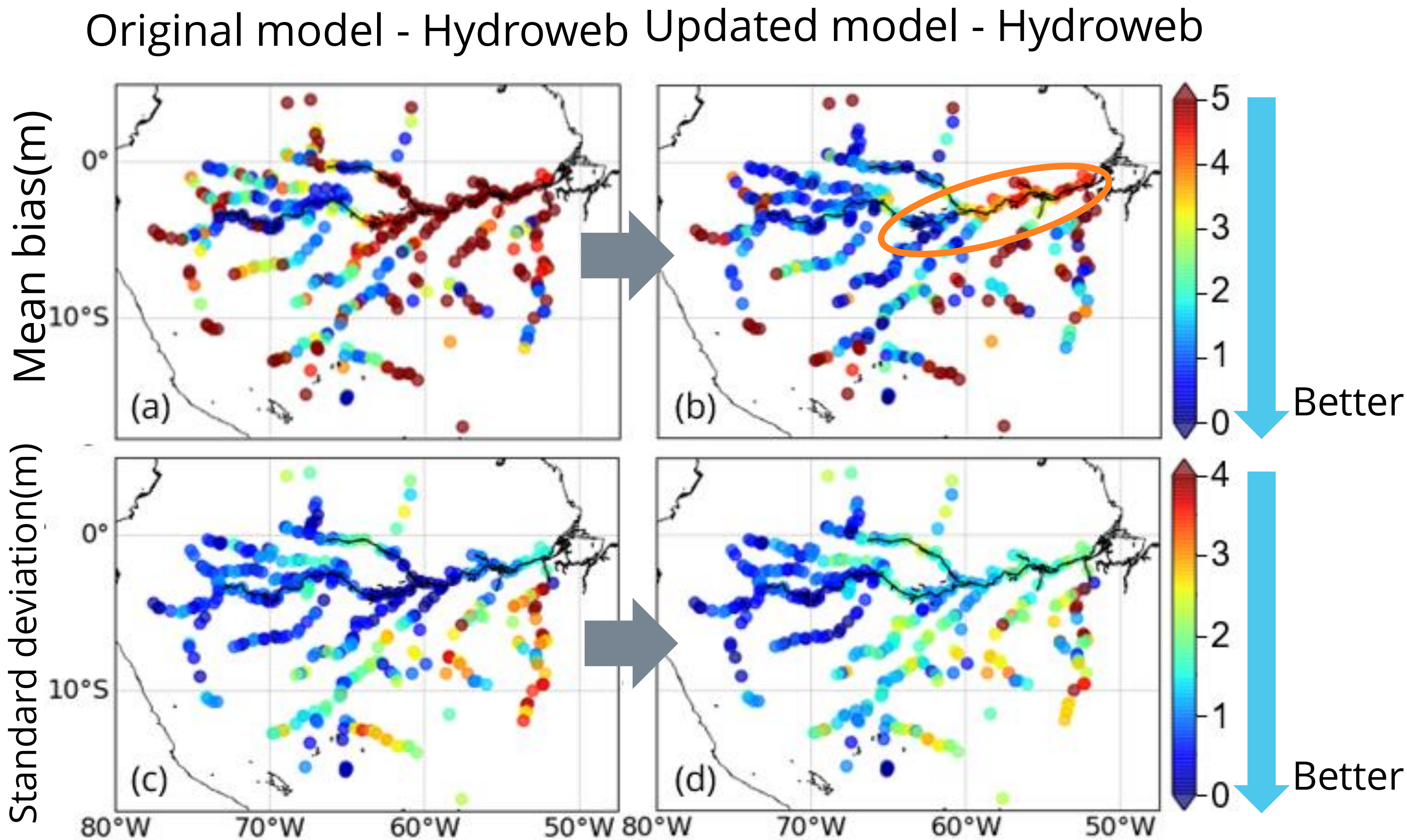


In downstream, RBD increased

In upstream, RBD decreased

The variability of RBD in each tribute can be represented

Mean bias and absolute std. difference with Hydroweb

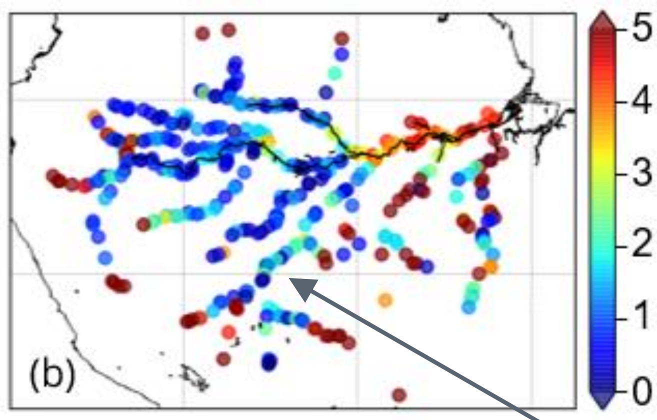


Mean bias was improved, but Std. not necessarily

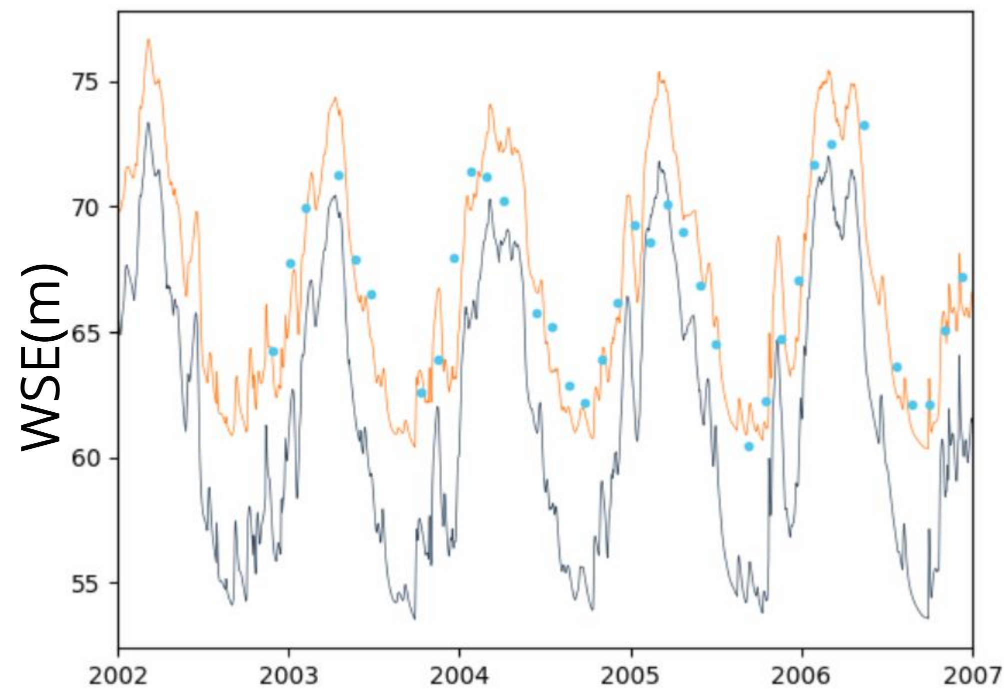
⇒ Especially bad at the main midstream points

A sample of improved points

Mean bias(m)

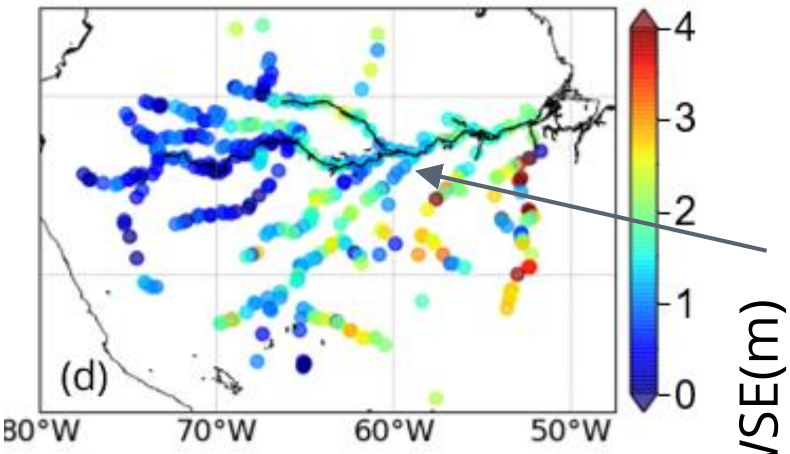


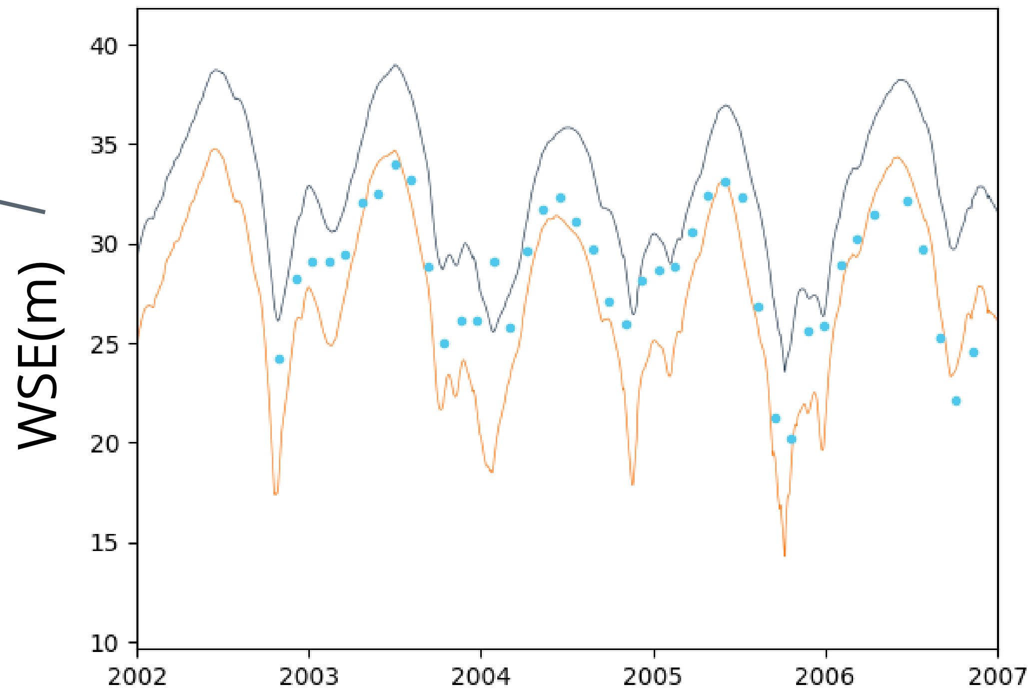
Hydroweb Original model
Updated model



Not only the mean bias, but also amplitude was improved

Bad std. value in the midstream

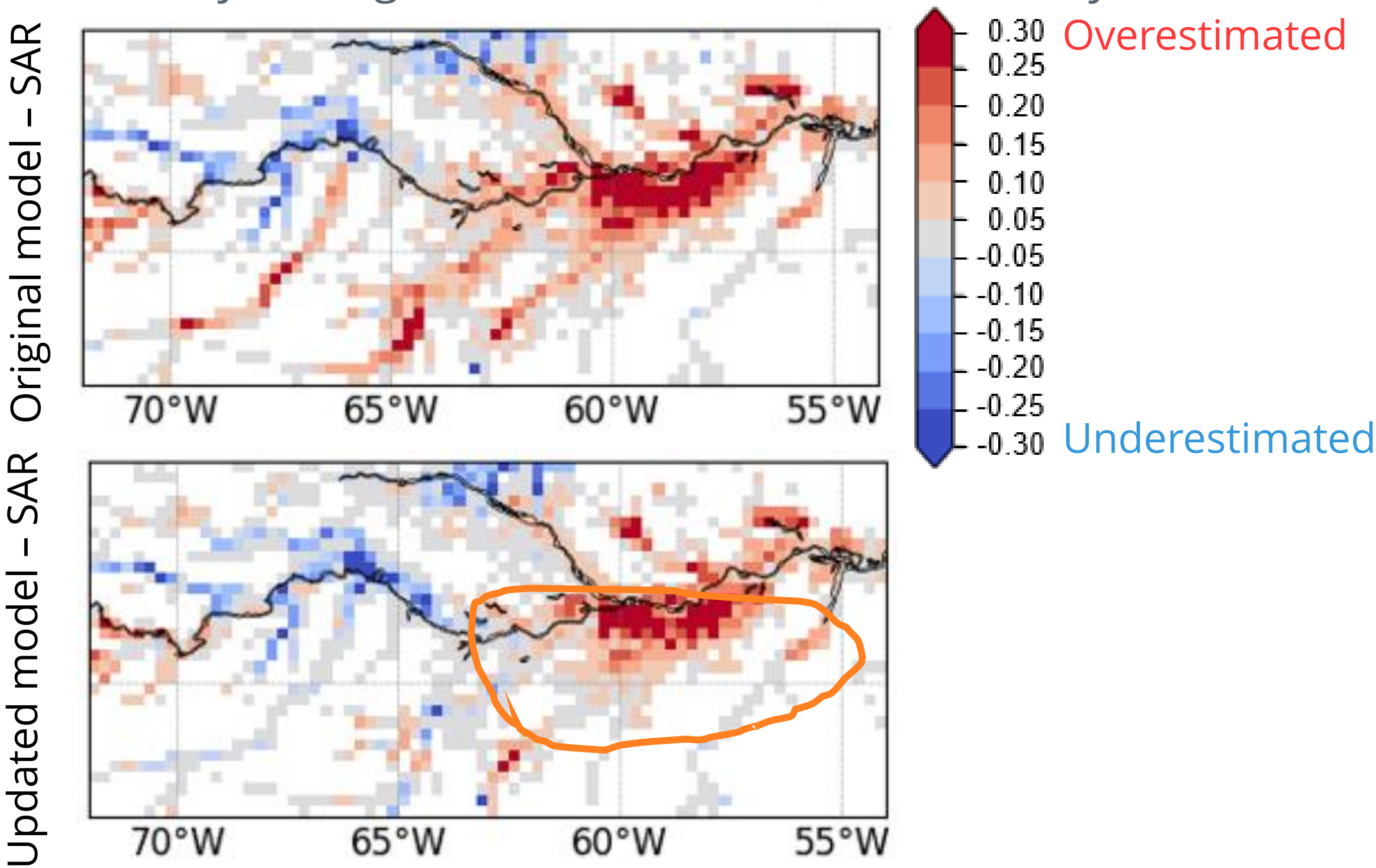




In the sharp low flow, it is difficult that the model and observation have the same low-flow timings

Comparison with SAR imagery (Hess et al., 2003)

The monthly-averaged inundation rate (0-1.0) in rainy seasons in 1996



Increase of RBD made the difference of the model results and SAR estimate smaller

Conclusion & Next Challenge

Conclusion

✓ Constructed the simple method to tune the RBD by using the satellite altimetry dataset

- Flood inundation ratio was improved in upstream areas

✓ Check the runoff impact by OSSE, a virtual test

- Upstream isn't affected much by runoff uncertainty

Next challenges

✓ Validate the result by using in-situ measurement

- Really important

✓ Consider other factors which have error

- @LEGOS