TELEDYNE MARINE TECHNOLOGY WORKSHOP San Diego 2019

国立研究開発法人 土木研究所 PWRI PUBLIC WORKS RESEARCH INSTITUTE

HSD 株式会社ハイドロシステム開発 Hydro Systems Development,Inc.

Estimation of actual uncertainty of ADCP measurement in a river

October, 2019

Teledyne Marine Technology Workshop

ICHARM, PWRI, Japan

Atsuhiro Yorozuya

Hydro Systems Development, Inc., Japan

Takashi Kitsuda

Table 1. Type A Error Sources Tested with *QUant*, Including the Default Standard Deviation of the PDF for Each Term

Input quantity	Definition	Standard deviation
Left edge velocity	Mean velocity in the left edge ensembles	Standard deviation of velocities in the left edge ensembles
Right edge velocity	Mean velocity in the right edge ensembles	Standard deviation of velocities in the right edge ensembles
Water velocity	Velocity measured in each bin	Standard deviation of the water-track error velocities
Bottom-track velocity	Velocity of the boat relative to the riverbed for each ensemble	Standard deviation of the bottom-track error velocities
Water depth	Distance from the water surface to the riverbed for each ensemble	Standard deviation of the water depth from the four beams for each ensemble
Missing ensembles	Ensembles for which no data were acquired	Absolute value of the difference between the missing ensemble discharge calculated two ways (see text)

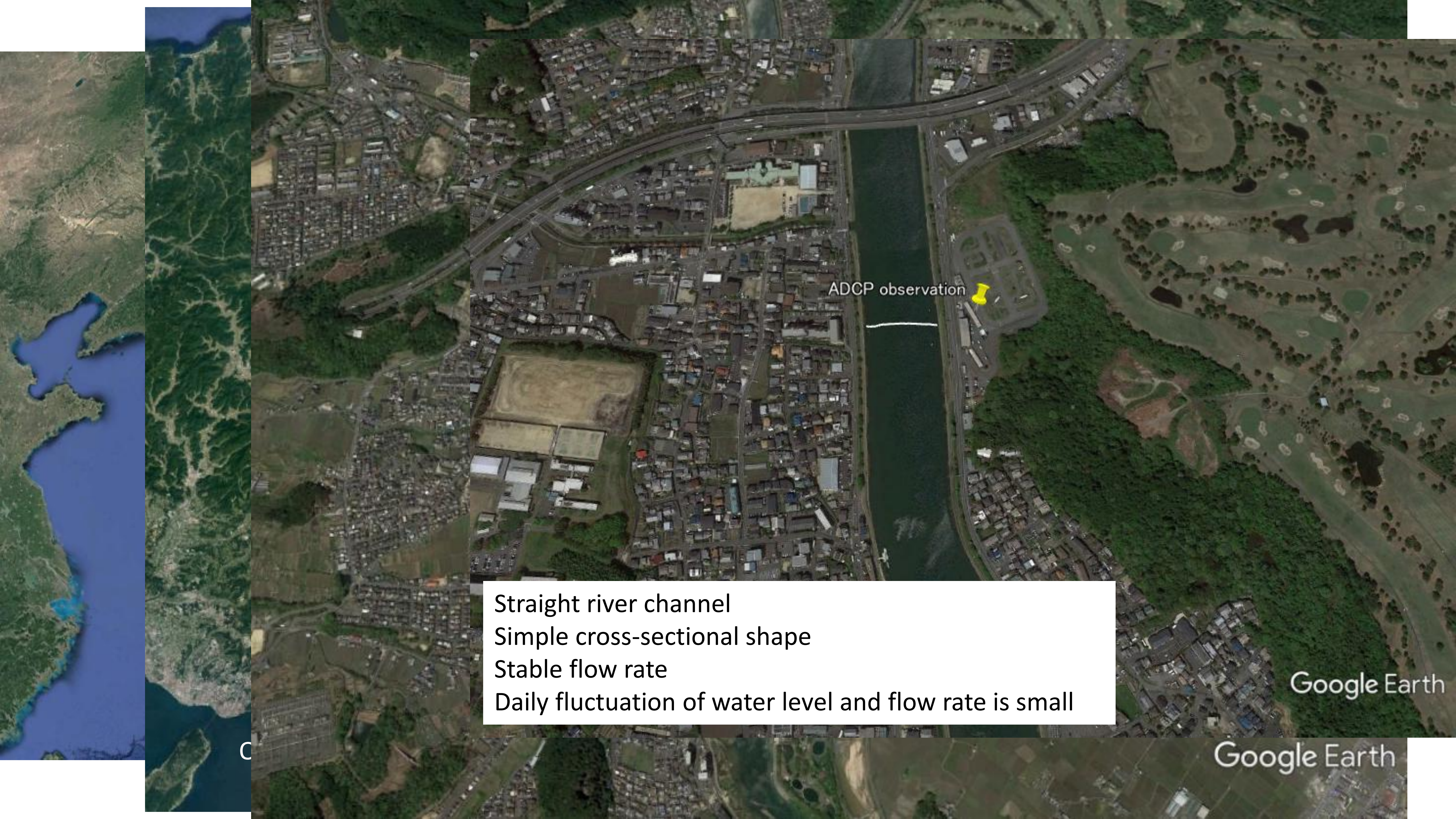
Table 2. Type B Error Sources Tested with *QUant*, Including the Default Standard Deviation of the PDF for Each Term

Input quantity	Definition	Standard deviation
ADCP draft	Distance from water surface to transducer face	0.05 m
Heading	Angle between the instrument reference frame and the magnetic north	2°
Magnetic variation	Angle between magnetic north and true north	2°
Temperature	Water temperature measured by the instrument	2°C
Salinity	Water salinity	2 ppt
Extrapolation at top and bottom	Discharge computed for the unmeasured areas at the top (near the water surface) and bottom (near the bed)	Percent deviati[illegible] power law an[illegible]
Left edge coefficient	Value that is multiplied by the mean velocity of edge ensembles, the distance to bank, and average depth of edge ensembles to obtain the left edge discharge	[illegible]
Right edge coefficient	Value that is multiplied by the mean velocity of edge ensembles, the distance to bank, and average depth of edge ensembles to obtain the right edge discharge	[illegible]
Distance to left bank	Distance between the left bank and the point where edge ensembles were collected	[illegible]
Distance to right bank	Distance between the right bank and the point where edge ensembles were collected	30% of the edge distance

Note: These values can be modified by the user.

We like to discuss only about this part.
Not Type B and others.
Exactly same set up, same measurement section

Cited from Stephanie A. Moore; Elizabeth C. Jamieson; Francois Rainville; Colin D. Rennie, M.ASCE; and David S. Mueller, Monte Carlo Approach for Uncertainty Analysis of Acoustic Doppler Current Profiler Discharge Measurement by Moving Boat, J. Hydraul. Eng., 2017, 143(3): 04016088



Straight river channel
Simple cross-sectional shape
Stable flow rate
Daily fluctuation of water level and flow rate is small

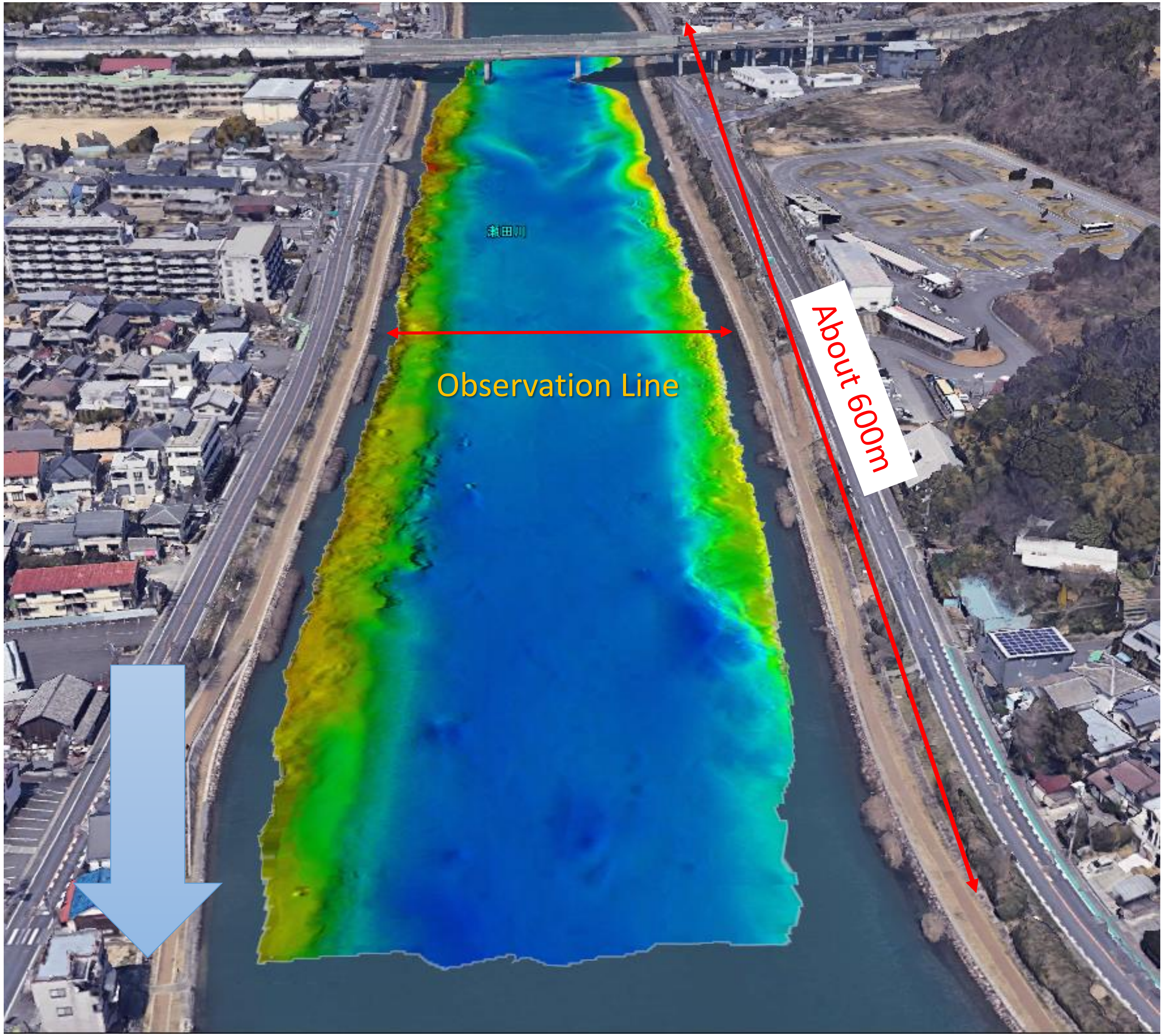
Contents Observation

Type of instrumentation	Some comments	etc
1.H-ADCP	1min	1755data（5/8　11:58～5/9　17:17）
2.WH ADCP RioGrande (1200kHz)	1.5min～2min RTK-GNSS-compass	tota 209 transect （5/9　07:15～5/9 16:57） Valid data N=177
3.Water Level RT100 draft of boat　RT100	Water level：1min draft：1second	Fixed in steel pipe for ADCP（as gauge） Fixed at tethered boat (for ADCP draft) Fixed out side of water (for atmospheric pressure measurement)
4.UAV	Aerial photo	Range of 100m×500m
5. MB2	3D bathymetry	Range of 100m×500m

Photo

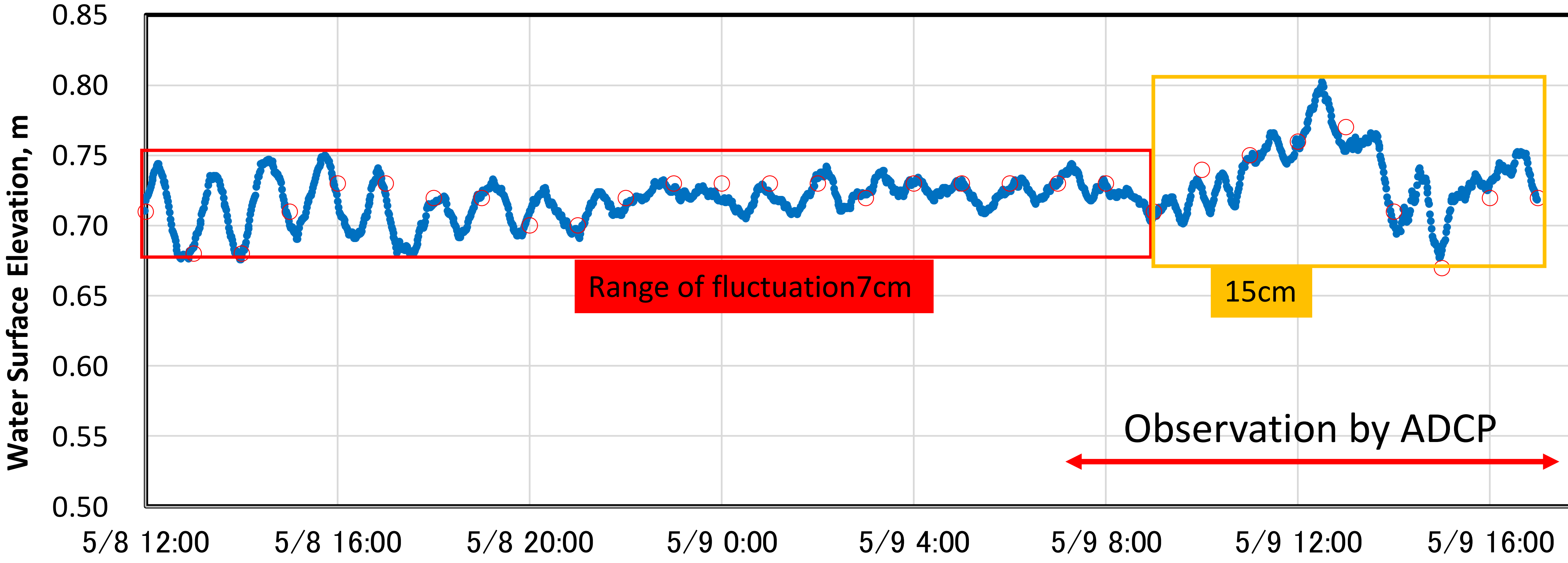
Results of multi-beam sonar

River bed is flat and good rectangular shape



Water Level

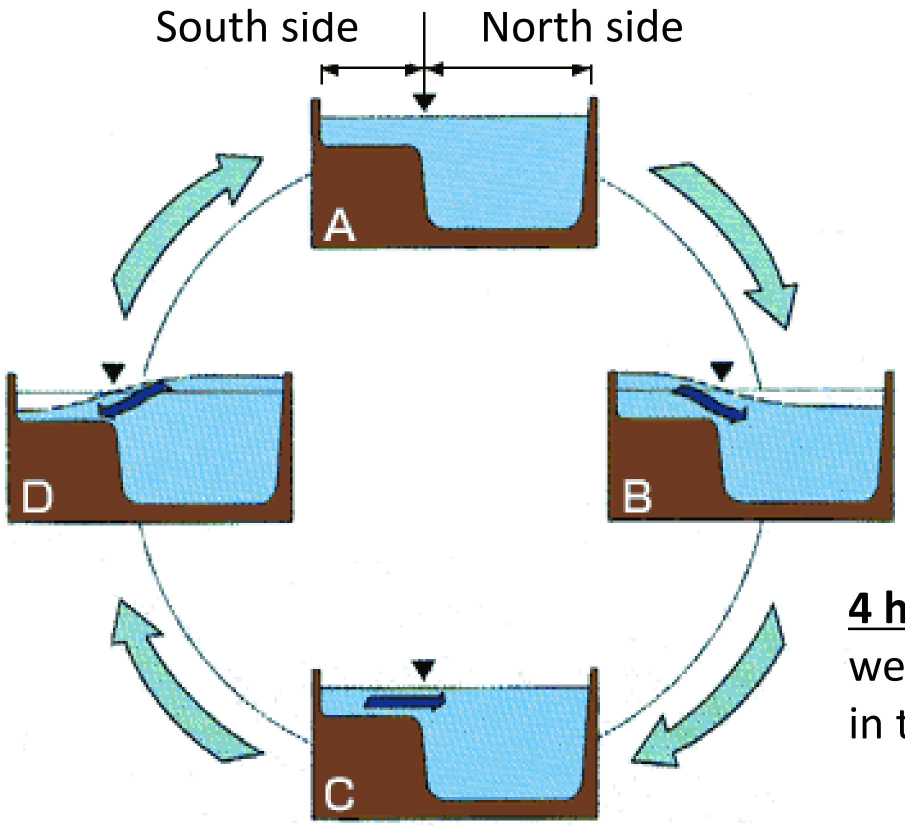
MLIT (measurement/hour) and our observation (measurement/minutes)



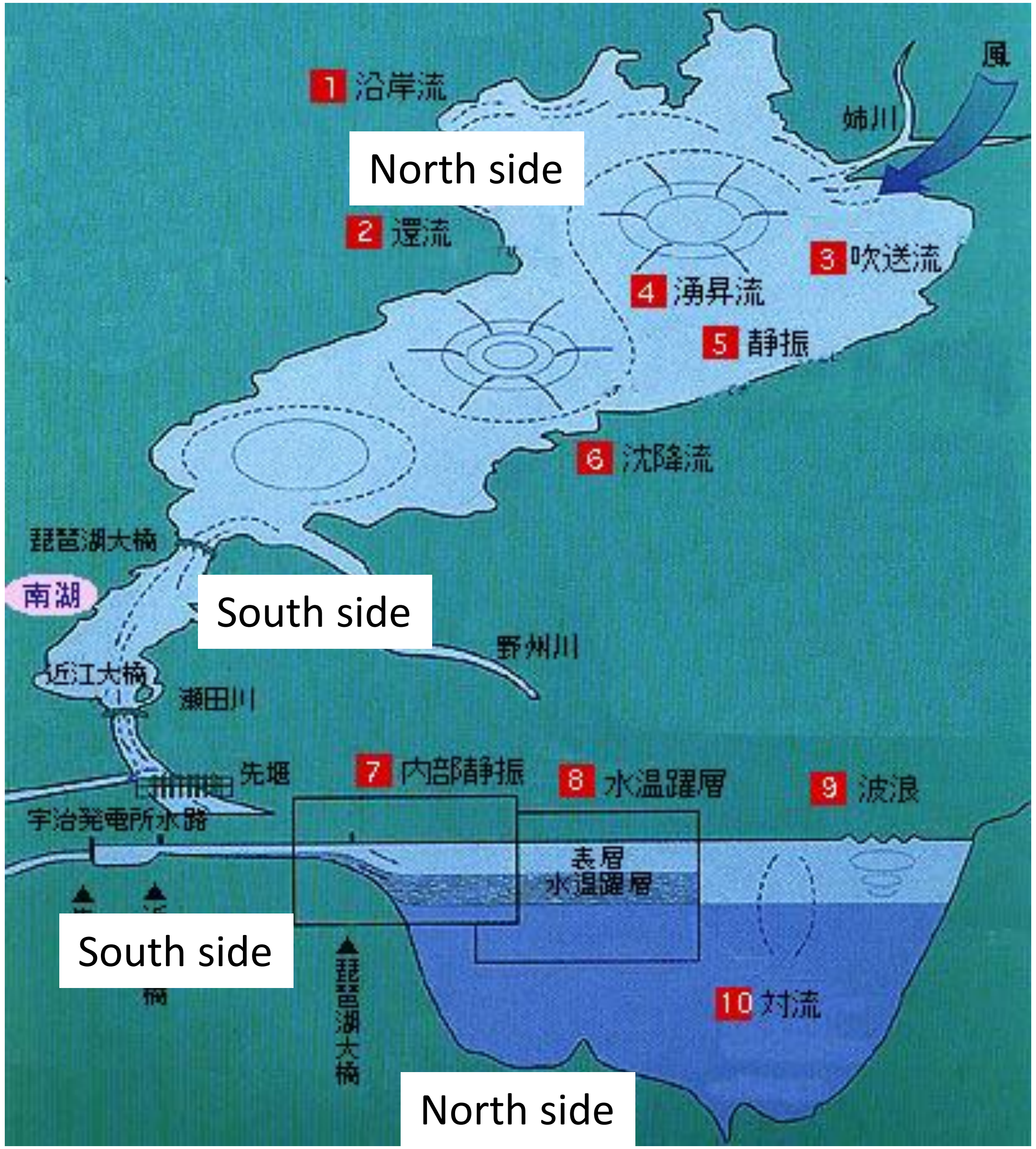
※ Short period fluctuation was observed

Seiche-related phenomena?

A seiche (/ˈseɪʃ/ SAYSH) is a standing wave in an enclosed or partially enclosed body of water. Seiches and seiche-related phenomena have been observed on lakes, reservoirs, swimming pools, bays, harbors and seas.
By wiki pedia

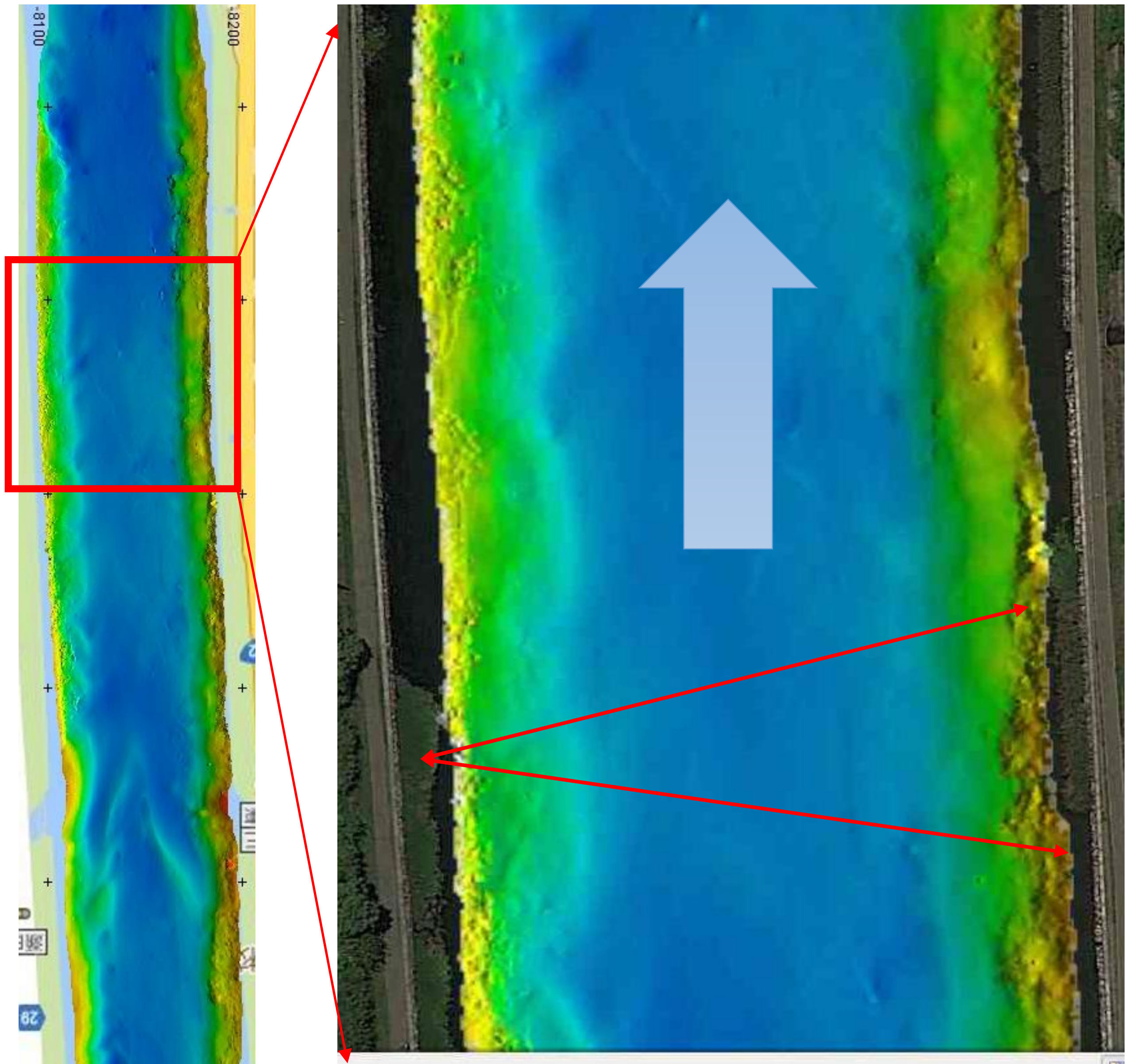


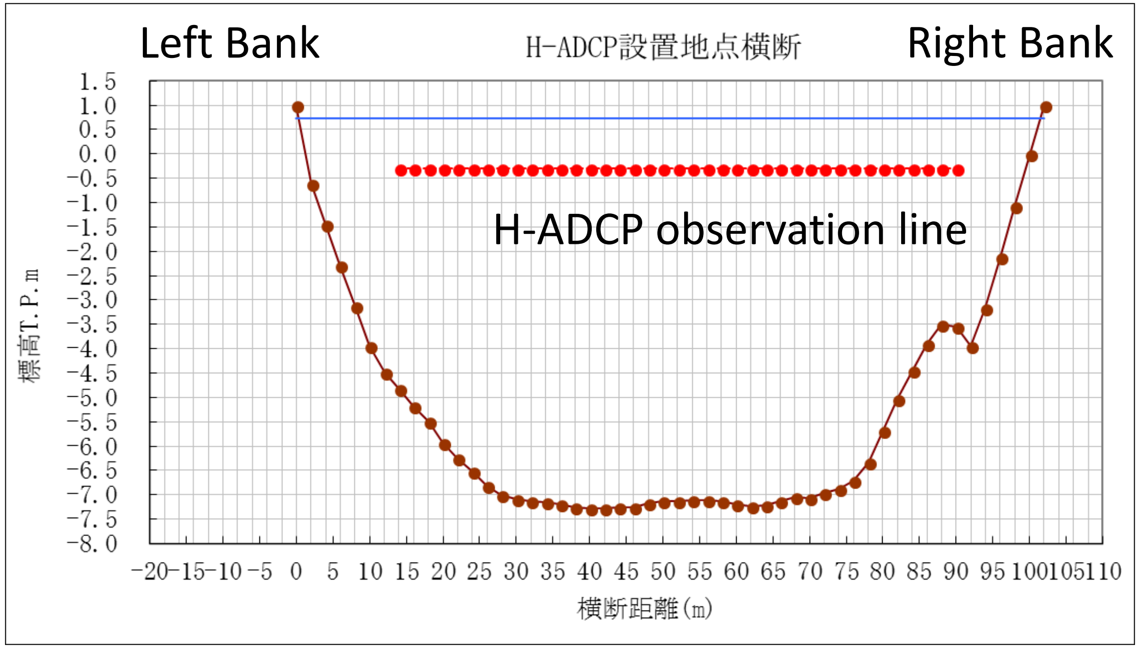
4 hours cycle were recognized in this lake



https://www.kkr.mlit.go.jp/biwako/aquabiwa/aqua/lake-pheno.html

H-ADCP mounting Line

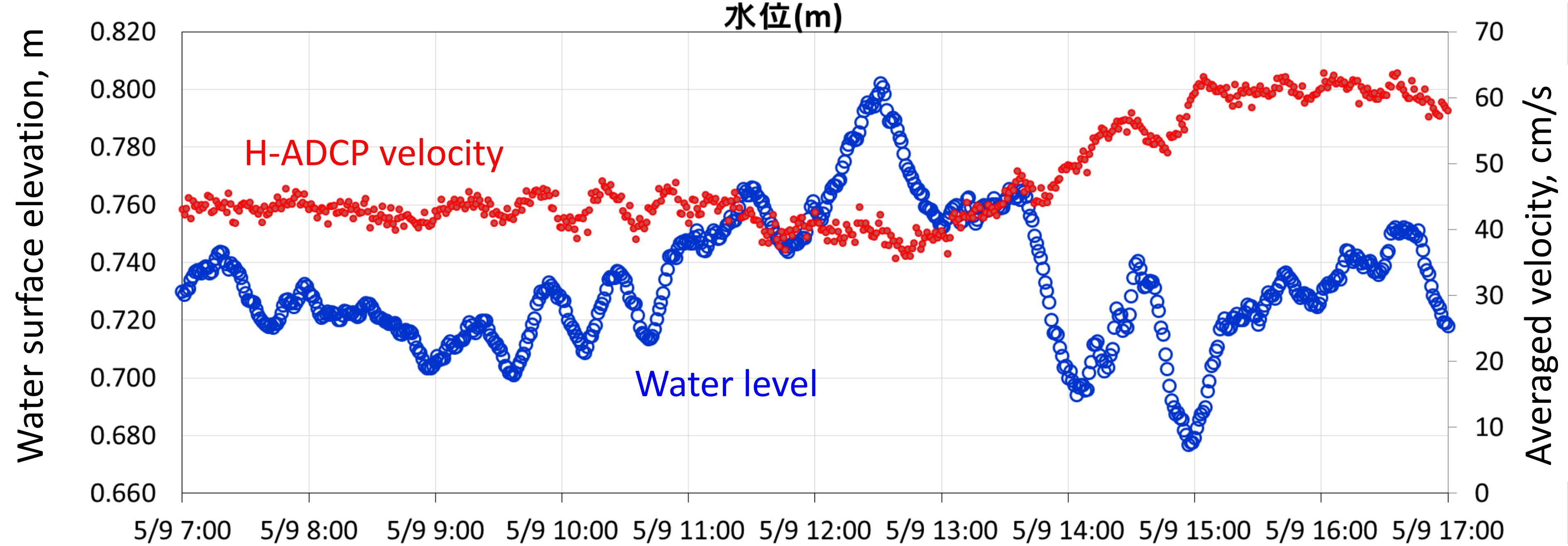




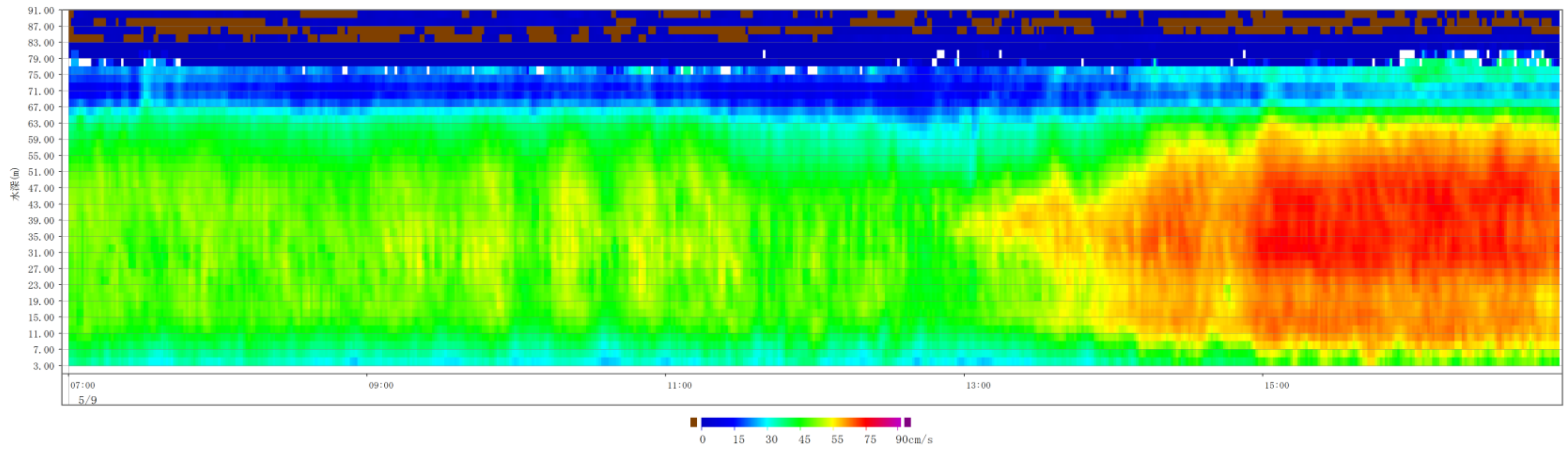
Maximum Depth is 7.2m

Maximum Water level fluctuation is 15cm

H-ADCP velocity(average of horizontal)

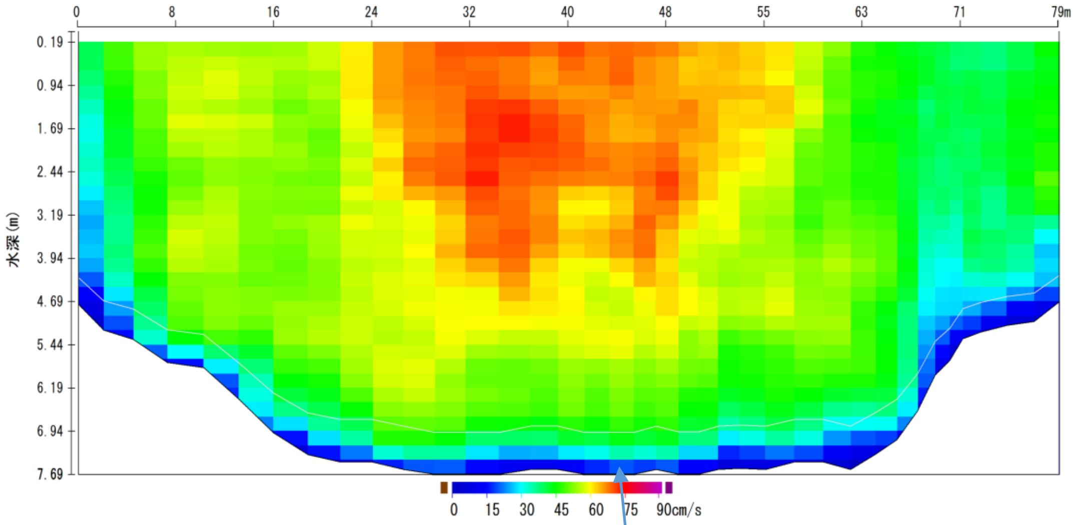


Horizontal distribution of velocity obtained by ADCP

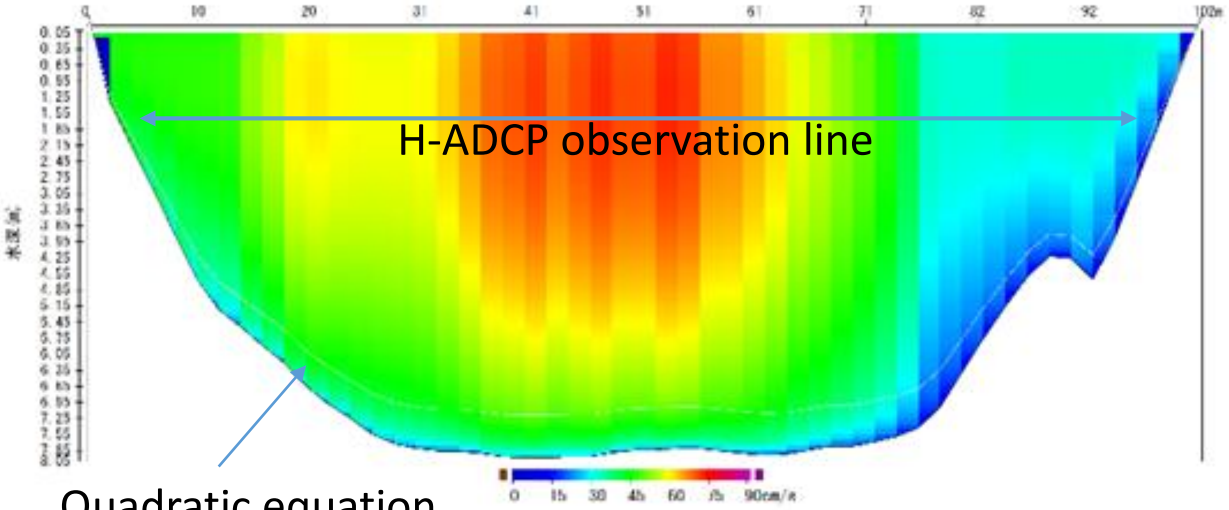


H-ADCP calculation method

ADCP transect



Calculation result of flow distribution from H-ADCP single observation line



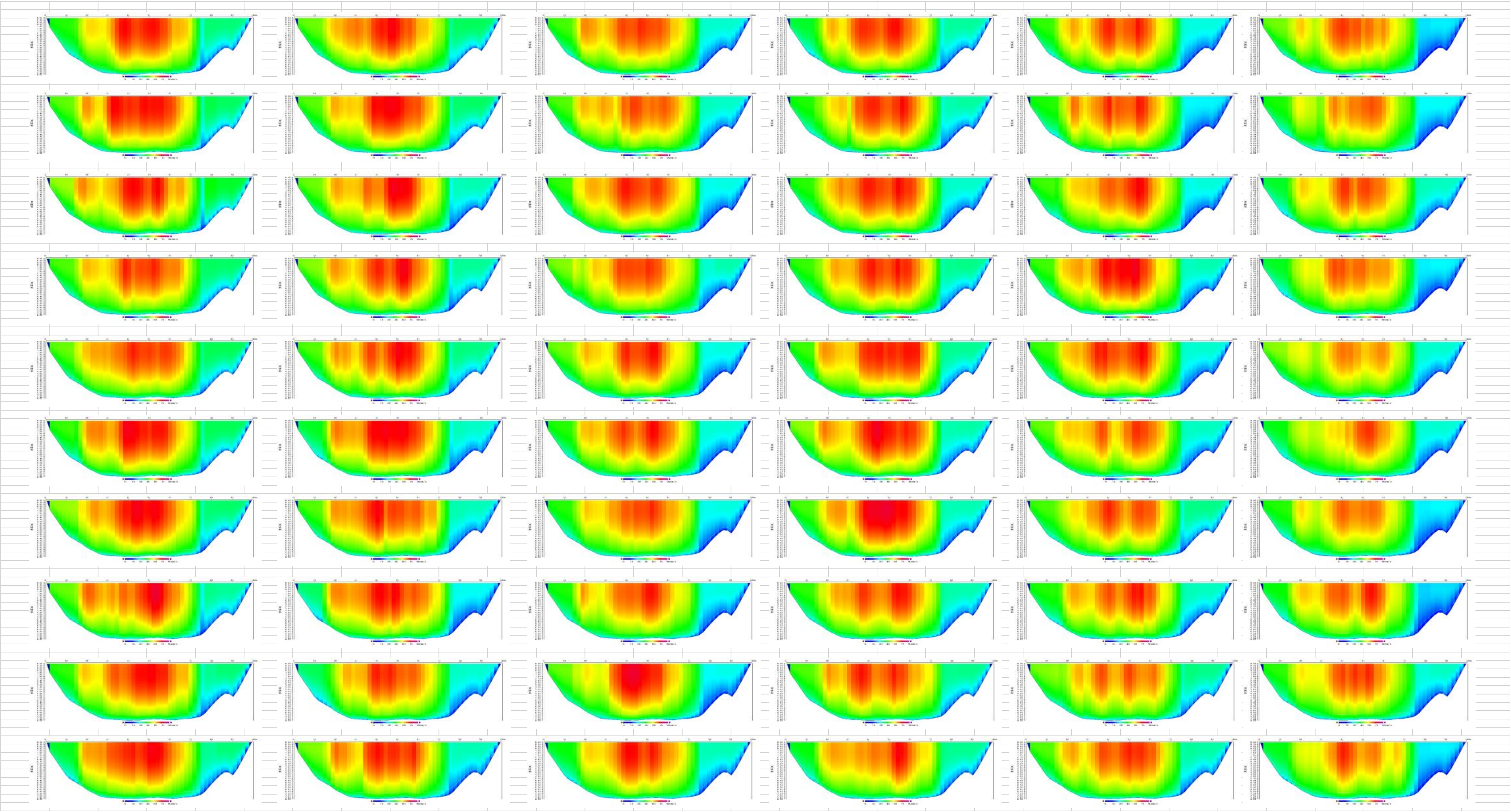
Quadratic equation

Calculation discharge

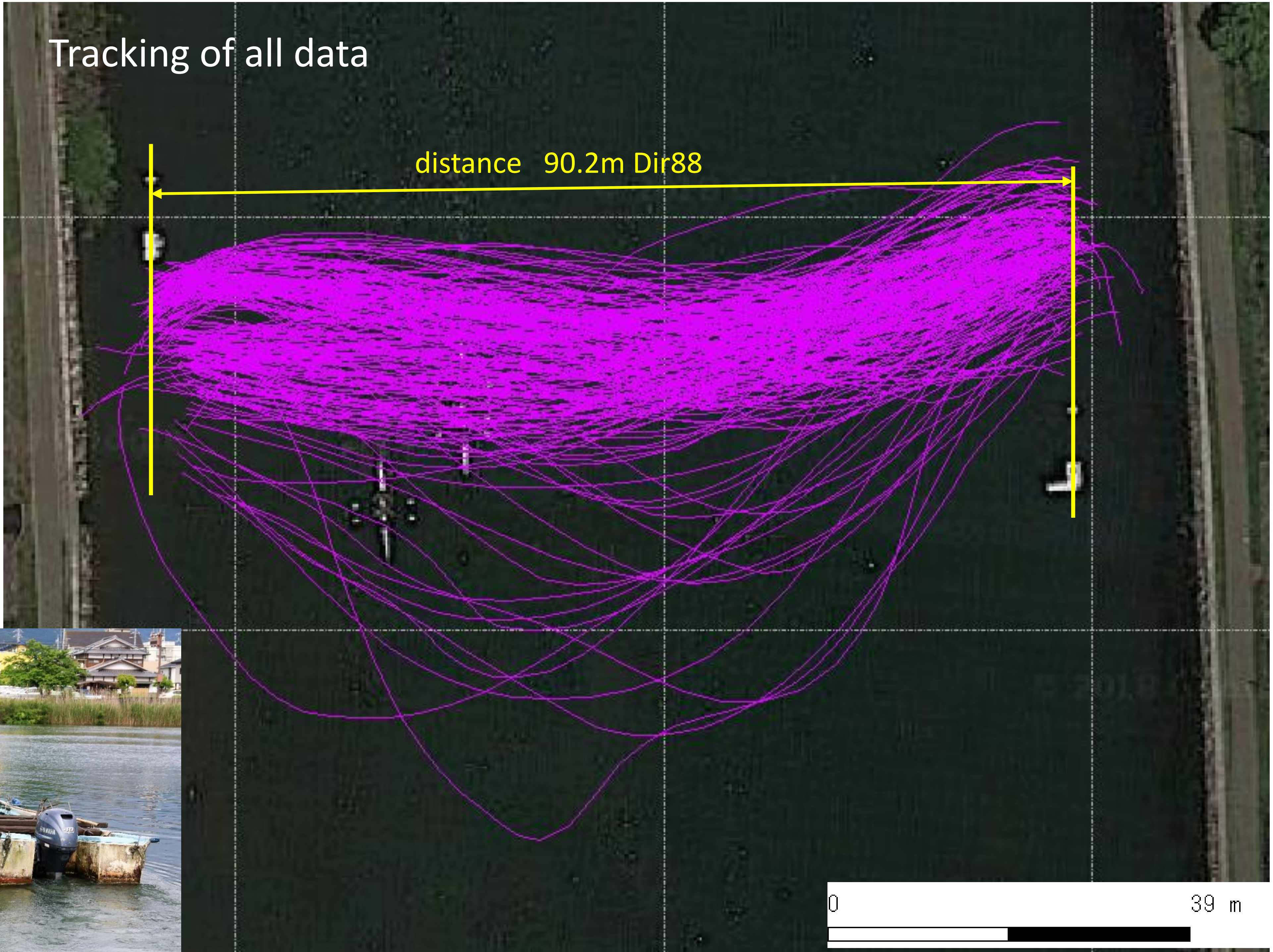
Bin size: 25cm

bottom10%:outer polation by Log

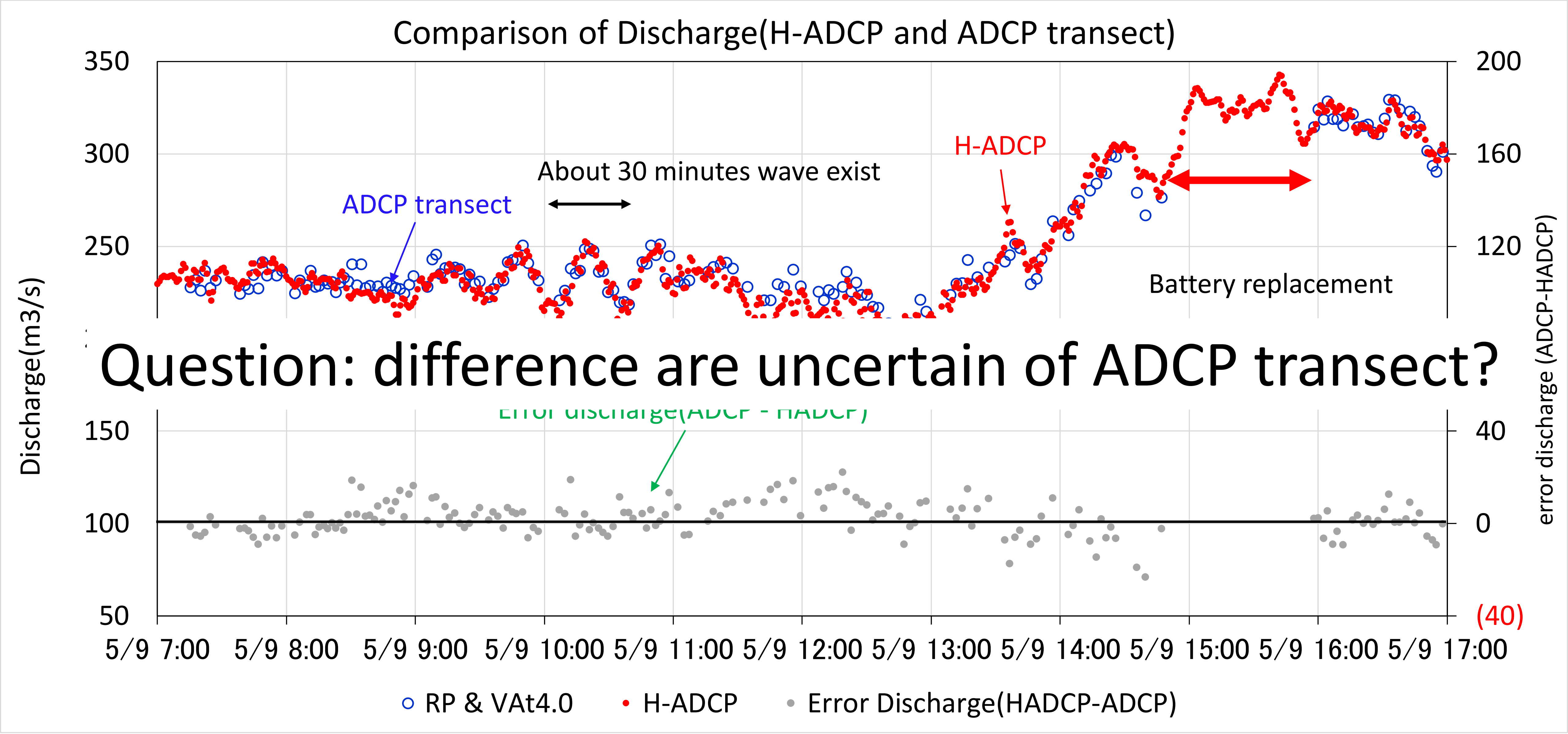
H-ADCP calculation result



Condition?



Discharge comparison of H-ADCP and VAt4.0



Question: difference are uncertain of ADCP transect?

How to determine uncertainty of ADCP using this kind of data?

1. Determine uncertainty of H-ADCP
   - Implement “High-pass filter” in order to subtract random noise.
   - Fourier Transform is applied.
2. Subtract ADCP transect from H-ADCP’s
3. Compare the results with Q-view

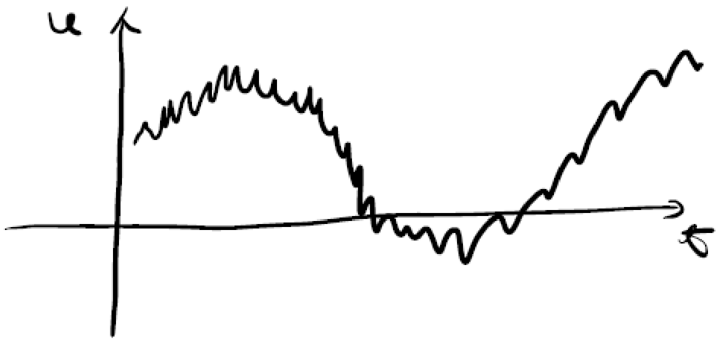
1. Determine uncertainty of H-ADCP

- Implement “High-pass filter” in order to subtract random noise.
- Fourier Transform is applied.

$$a_n = \frac{2}{T}\int_0^T Q(t)\cos\frac{2n\pi t}{T}\,dt$$

$$b_n = \frac{2}{T}\int_o^T Q(t)\sin\frac{2n\pi t}{T}\,dt$$

$$Q(t) = \frac{a_0}{2} + \sum_{n=1}^{N}\left(a_n\cos\frac{2n\pi t}{T} + b_n\sin\frac{2n\pi t}{T}\right)$$



Raw data or when N = ∞

=

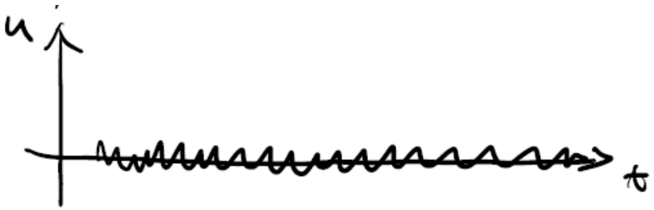
Natural pattern

Good N1 is needed to determine

$$Q(t) = \frac{a_0}{2} + \sum_{n=1}^{N1}\left(a_n\cos\frac{2n\pi t}{T} + b_n\sin\frac{2n\pi t}{T}\right)$$

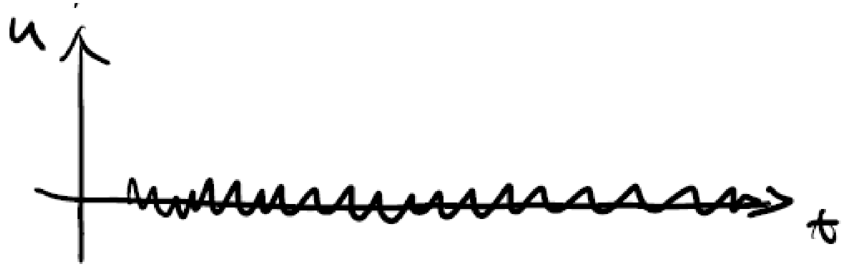
+

Random noise or uncertainty



$$uQ(t) = \sum_{n=N1+1}^{N}\left(a_n\cos\frac{2n\pi t}{T} + b_n\sin\frac{2n\pi t}{T}\right)$$

Random noise or uncertainty



$$uQ(t) = \sum_{n=N1+1}^{N} \left(a_n \cos \frac{2n\pi t}{T} + b_n \sin \frac{2n\pi t}{T} \right)$$

Now there are two unknown.

1. Uncertainty of H-ADCP discharge
2. N1

Finding two unknown is impossible.

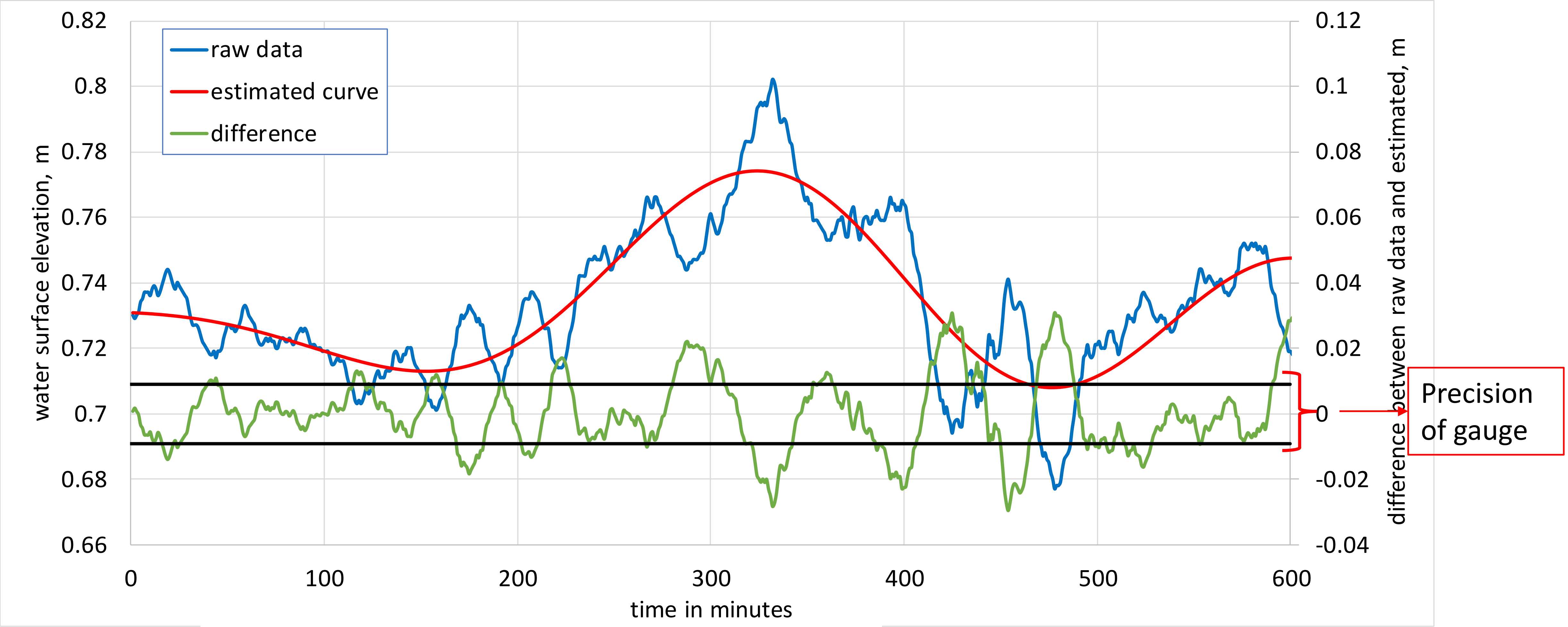
Finding N1 with known uncertainty, and apply same N1 to H-ADCP discharge

Known uncertainty?

Uncertainty of Gauges are known!!

RuggedTROLL100
precision; ±0.1%F.S.
F.S. is set as 9m
→ Precision is **±0.009m**

One of the **bad example** of selection of N1

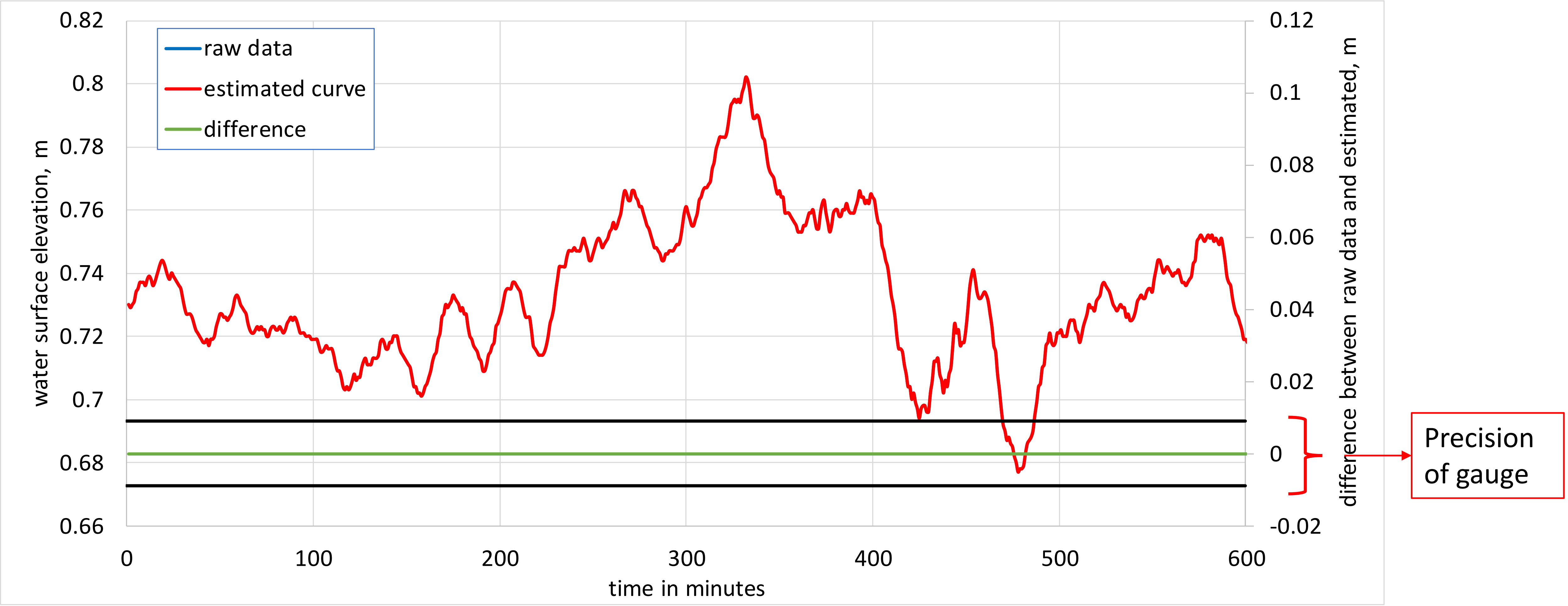


$$uQ(t) = \sum_{n=N1+1}^{N} \left(a_n \cos \frac{2n\pi t}{T} + b_n \sin \frac{2n\pi t}{T} \right)$$

When N1 = 10, corresponding to that of **4 hours**. (Seiche)

Difference is more than precision

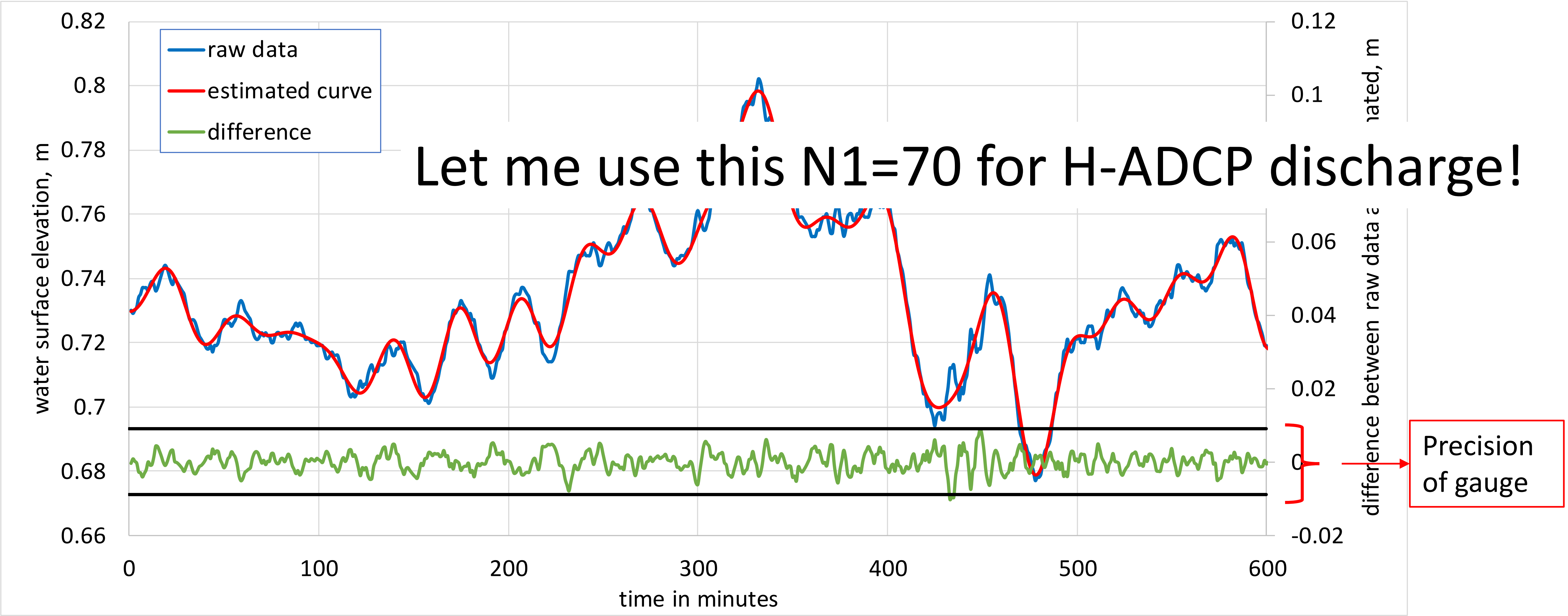
One of the **bad example** of selection of N1



$$uQ(t) = \sum_{n=N1+1}^{N} \left(a_n \cos \frac{2n\pi t}{T} + b_n \sin \frac{2n\pi t}{T} \right)$$

When N1 = ∞, corresponding to that of mathematically true, but **practically untrue**. Error is too small.

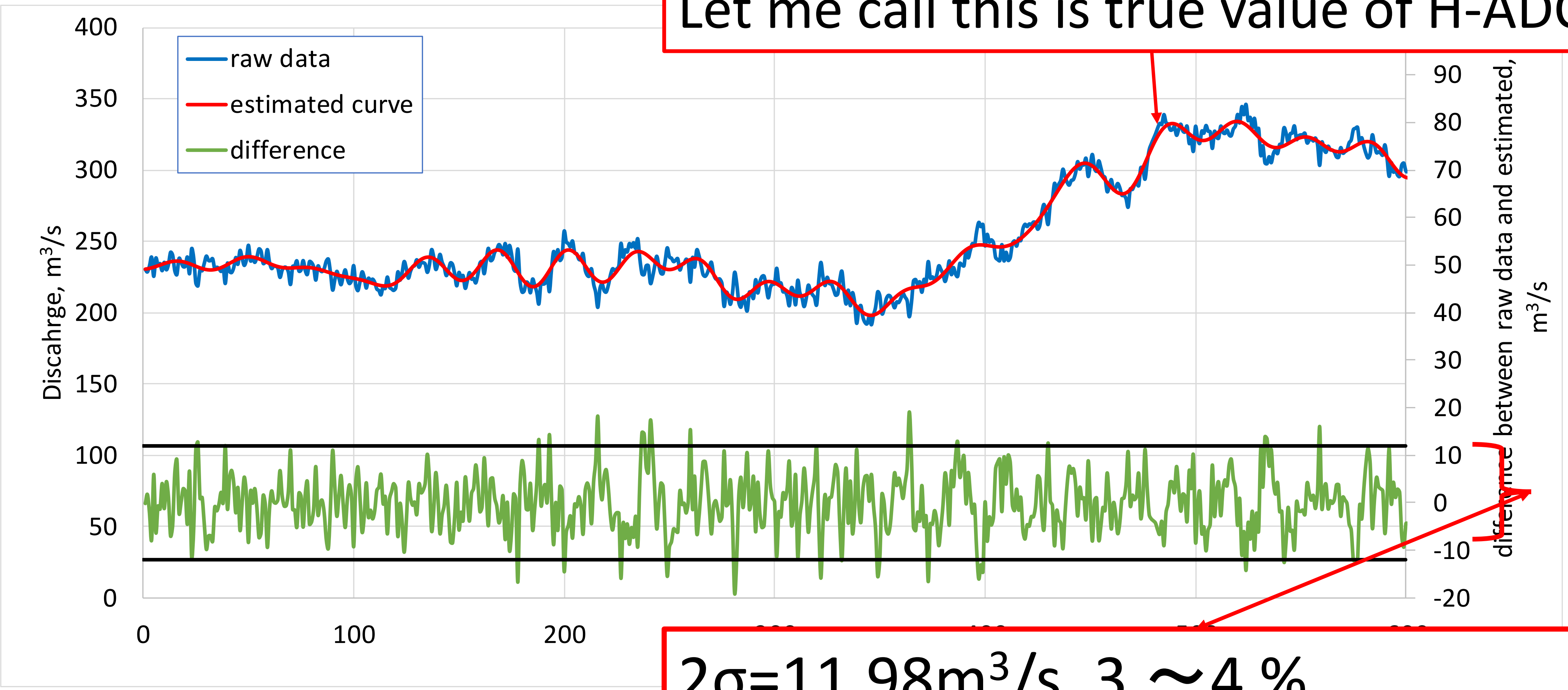
One of the appropriate example of selection of N1



$$uQ(t) = \sum_{n=N1+1}^{N} \left(a_n \cos \frac{2n\pi t}{T} + b_n \sin \frac{2n\pi t}{T} \right)$$

When N1 = 70, corresponding to that of 30 m.
Precision is acceptable range.
30 minutes are selected from wave pattern.

Uncertainty of H-ADCP discharge



Let me call this is true value of H-ADCP

2σ=11.98m³/s, 3 ～4 %

This number is uncertainty of H-ADCP

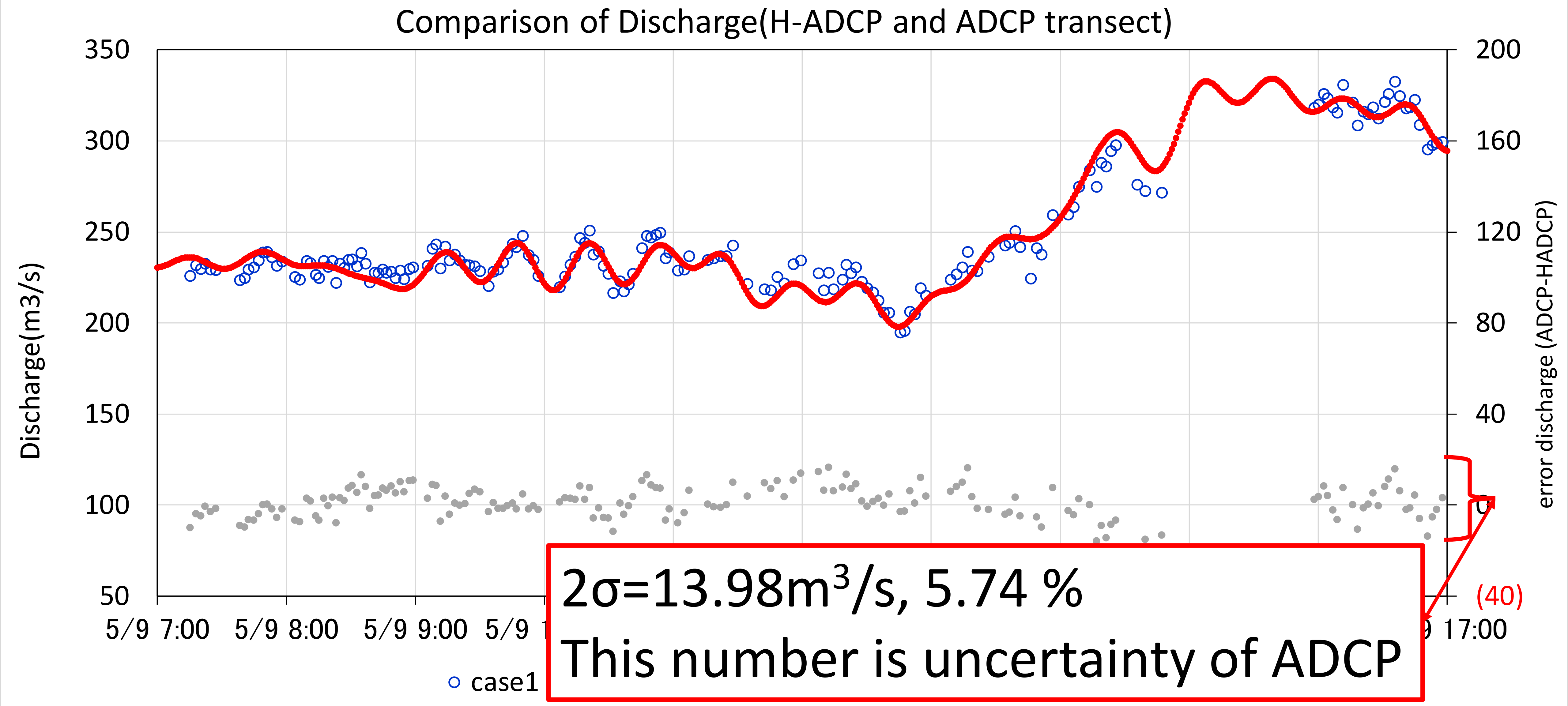
$$uQ(t)=\sum_{n=N1+1}^{N}\left(a_n\cos\frac{2n\pi t}{T}+b_n\sin\frac{\cdots}{T}\right)$$

30 minutes are selected from wave pattern.

Discharge values with different set up

	case1	case2
Reference for velocity	Bottom track	External GPS
Reference for track	Bottom track	External GPS
compass	internal	external

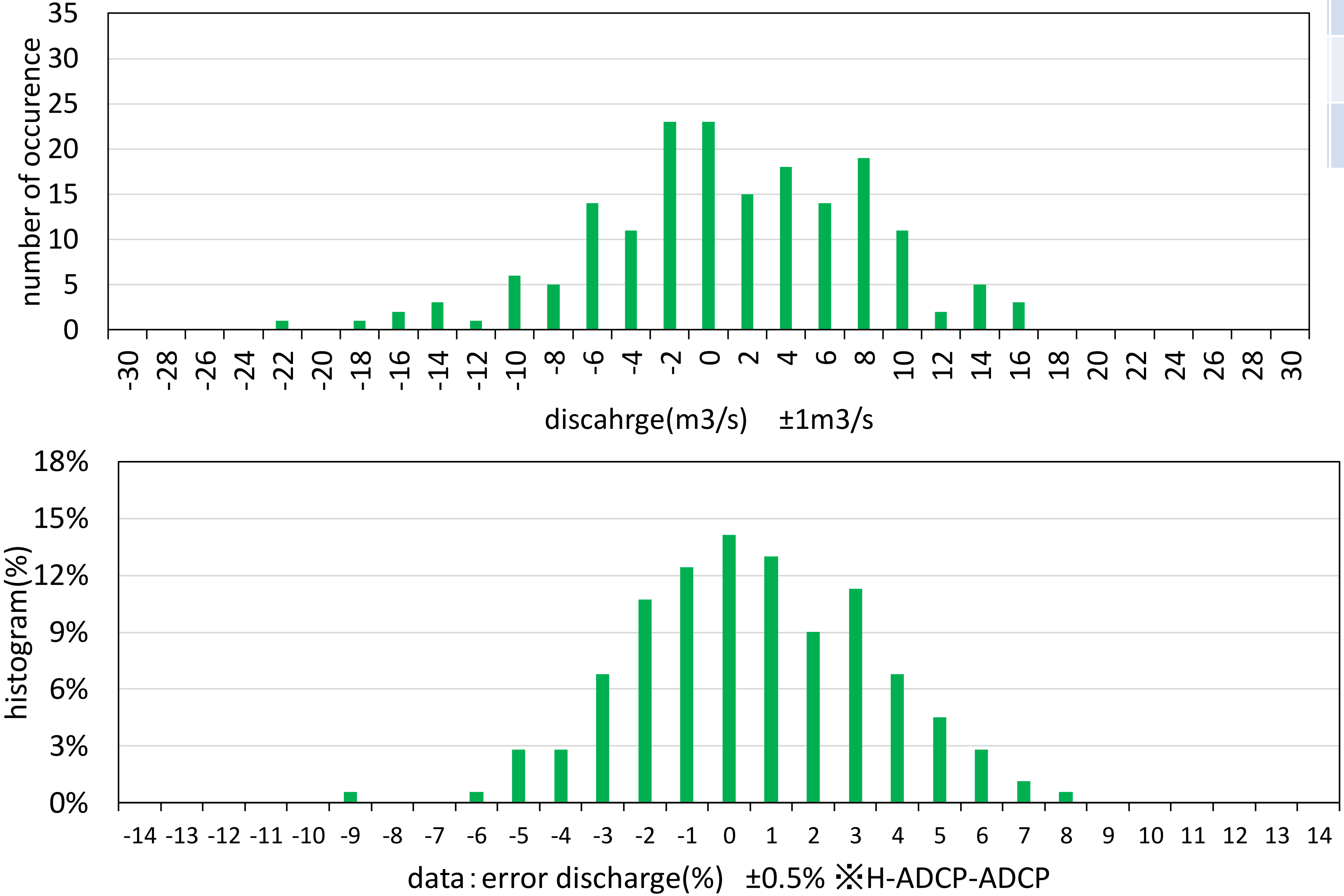
	case1
Reference for velocity	Bottom track
Reference for track	Bottom track
compass	internal



2σ=13.98m³/s, 5.74 %

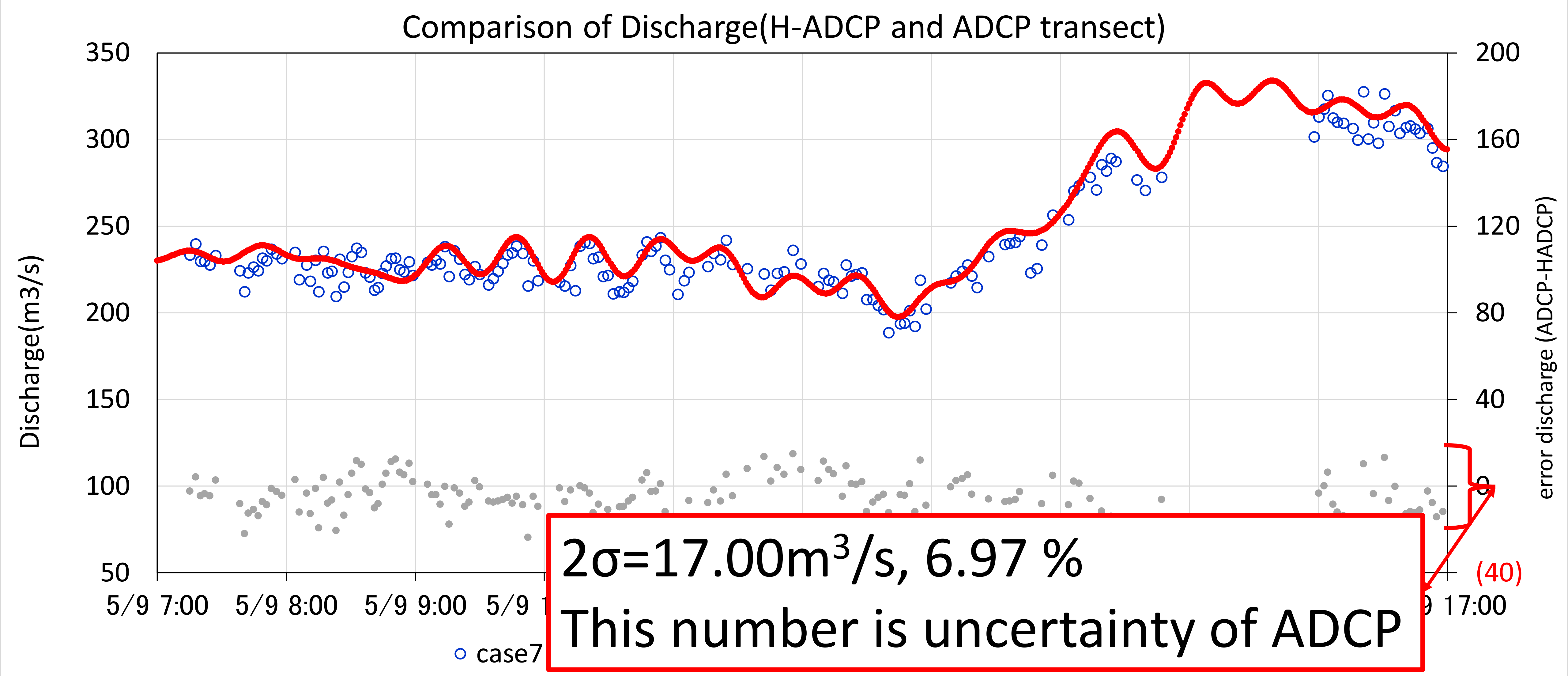
This number is uncertainty of ADCP

Histogram of error discharge between H-ADCP and ADCP



case1
Bottom track
Bottom track
internal

	case2
Reference for velocity	External GPS
Reference for track	External GPS
compass	external

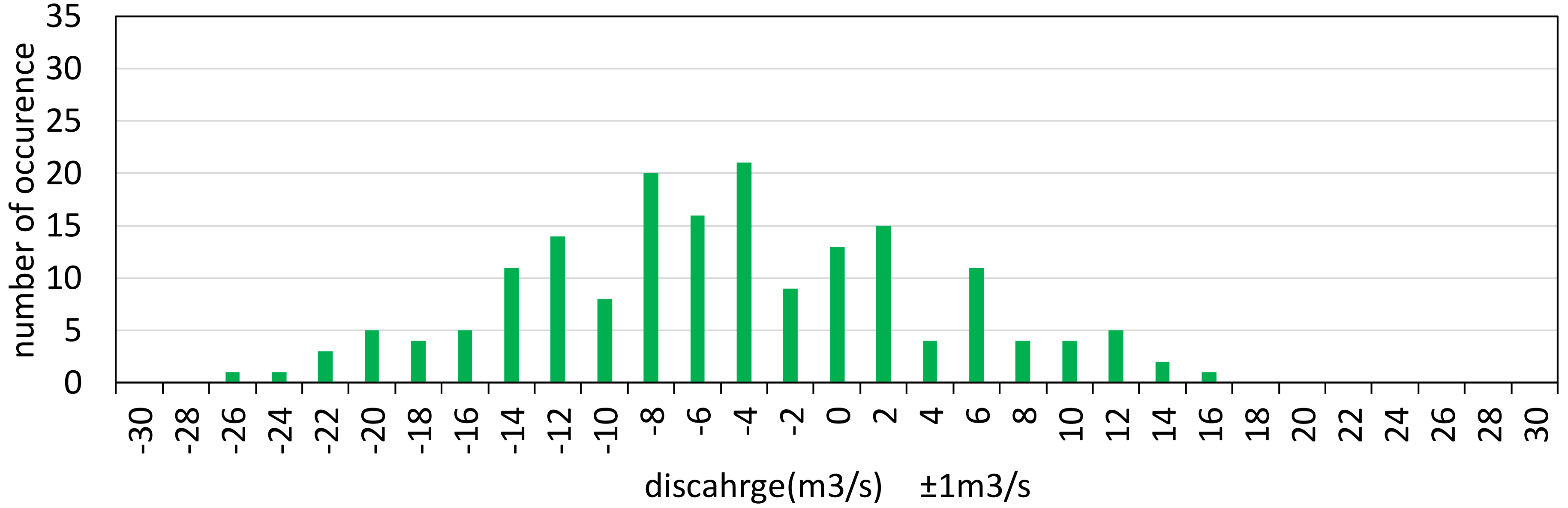


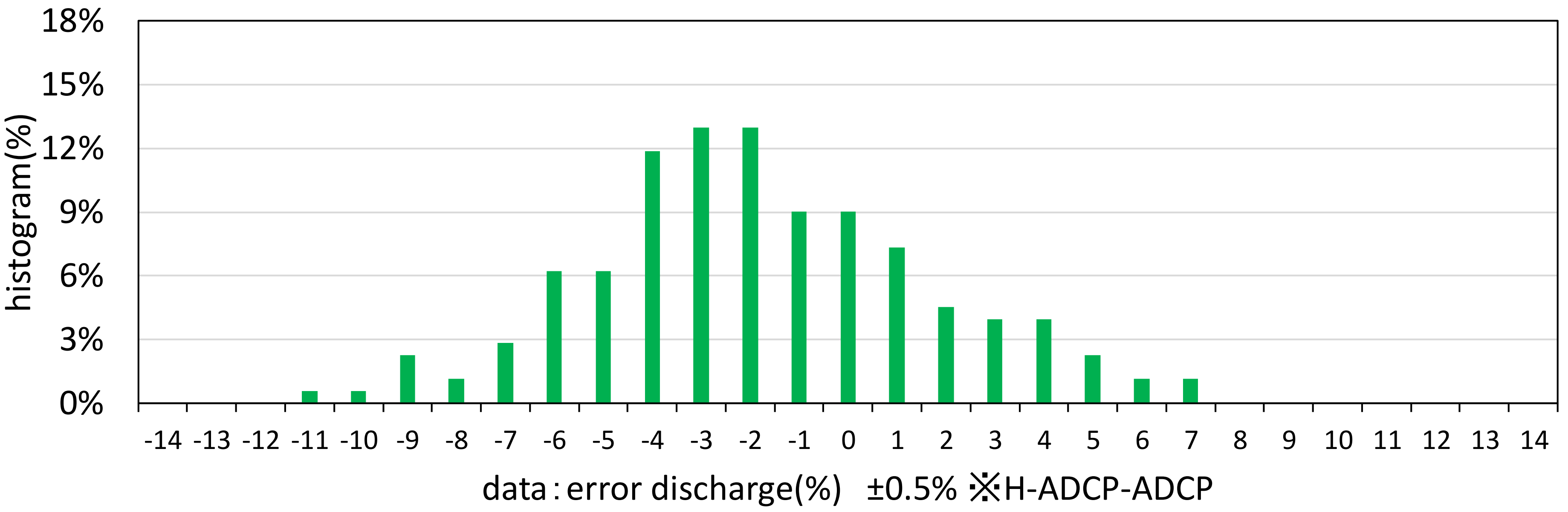
2σ=17.00m^3/s, 6.97 %

This number is uncertainty of ADCP

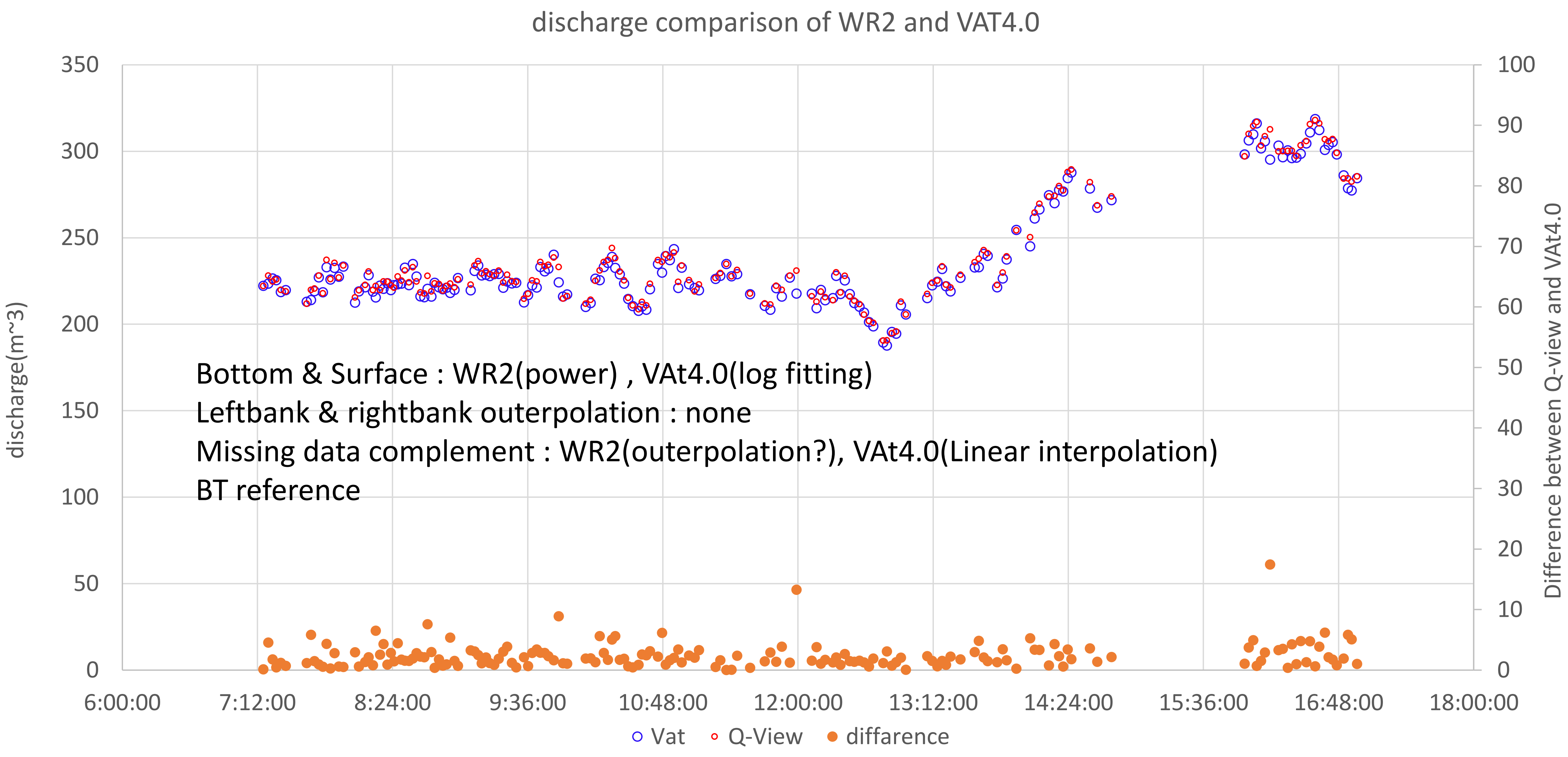
Histogram of error discharge between H-ADCP and ADCP

case2
External GPS
External GPS
external

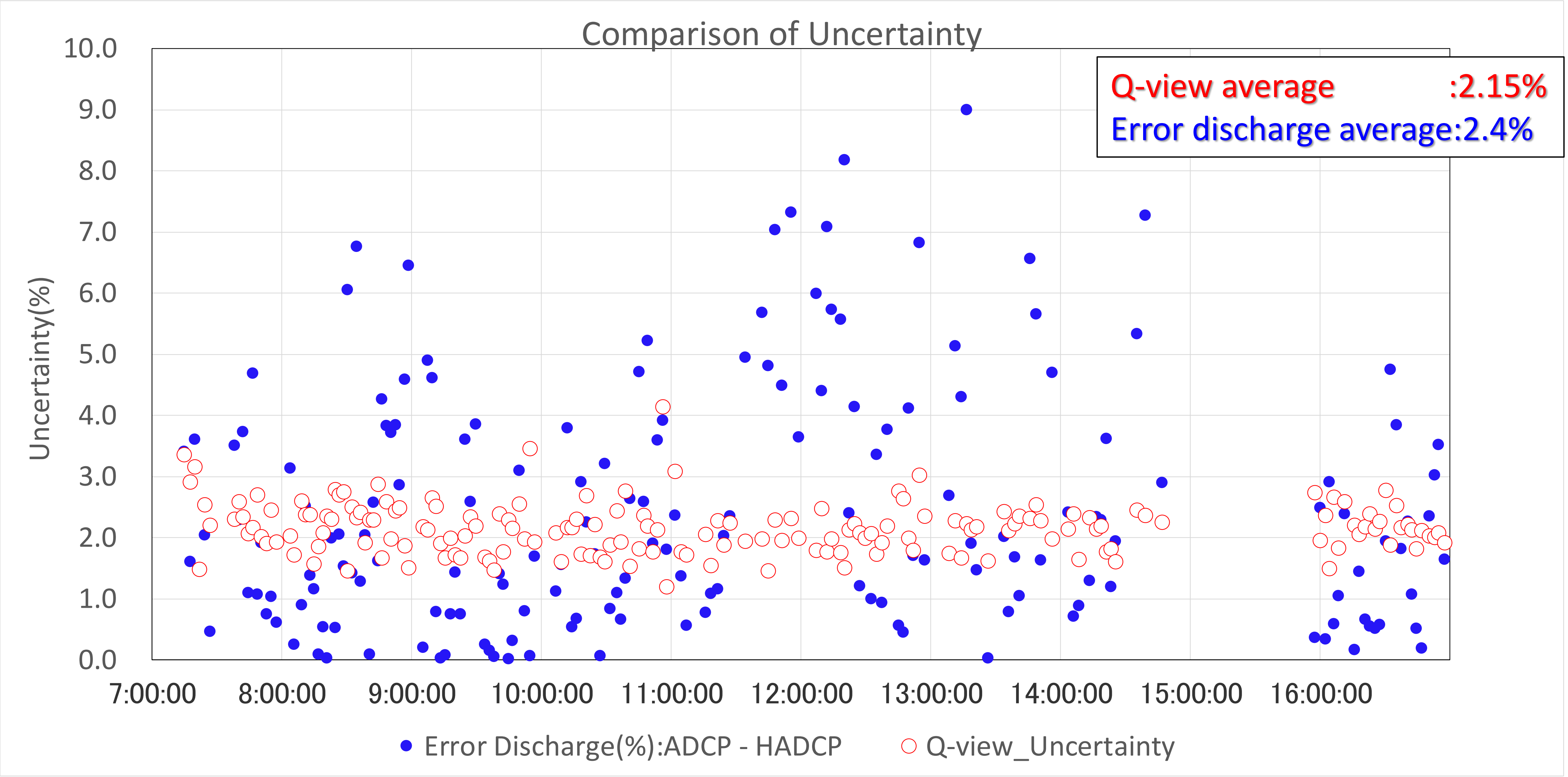




Discharge comparison of Q-view and VAT4.0(BT)



Comparison of Q-view uncertainty and error discharge between H-ADCP and ADCP(BT)



conclusion

- 209 transects were measured in an actual river
- Fluctuation with the period of 4 hours and 30 minutes are recognized.
- Uncertainty of H-ADCP were about 3 to 4 %
- Uncertainty of ADCP with bottom track is about 6%
- While, uncertainty of ADCP with GPS is about 7%