Teledyne Marine Technology Workshop (TMTW) 2019,

October 8, 2019 San Diego, USA

Comprehensive measurement techniques of water flow, bedload and suspended sediment using ADCP

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Shoji Okada

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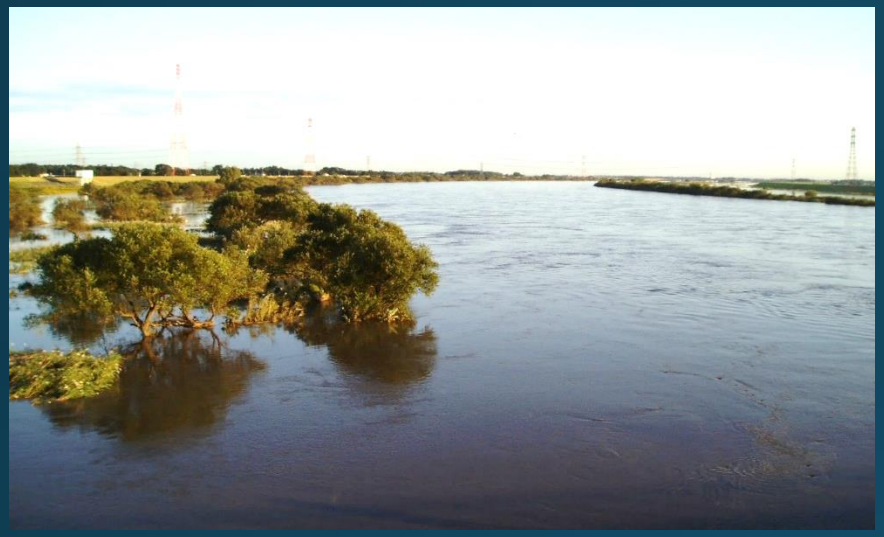
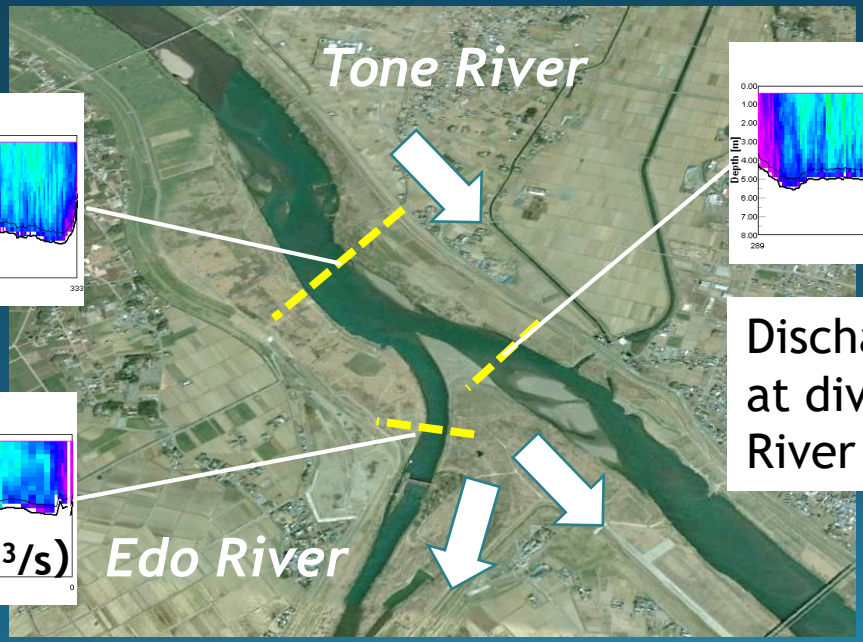
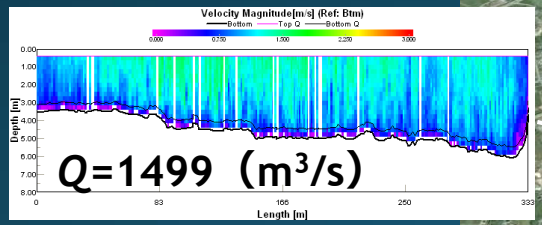
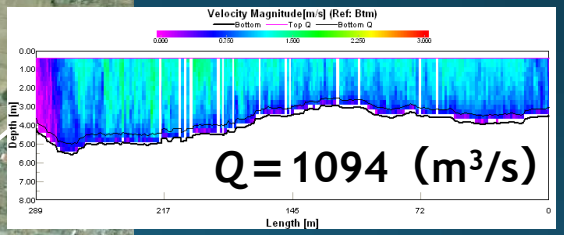
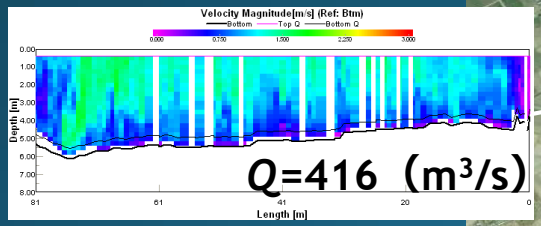
Flood observation at Tone River in October 2004





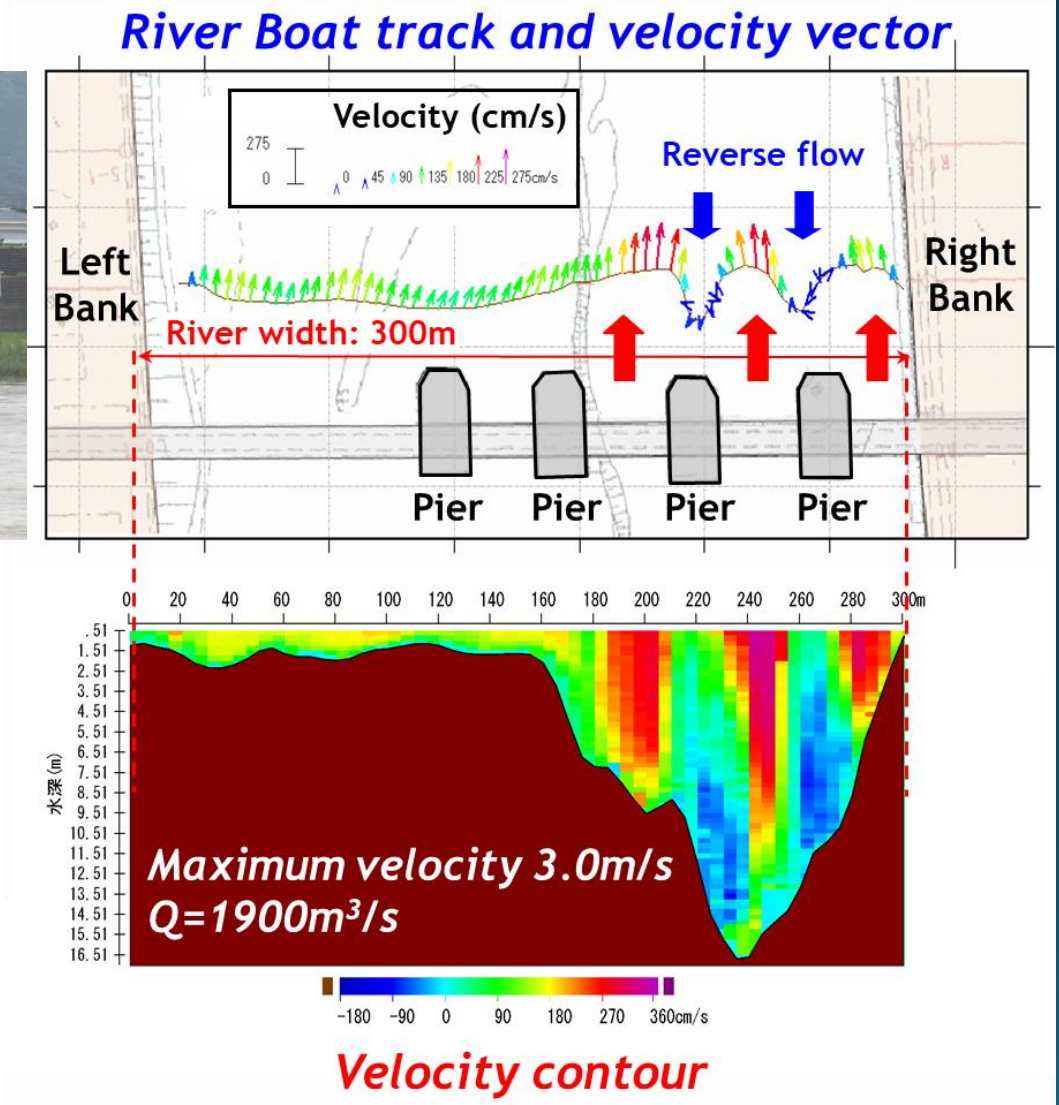




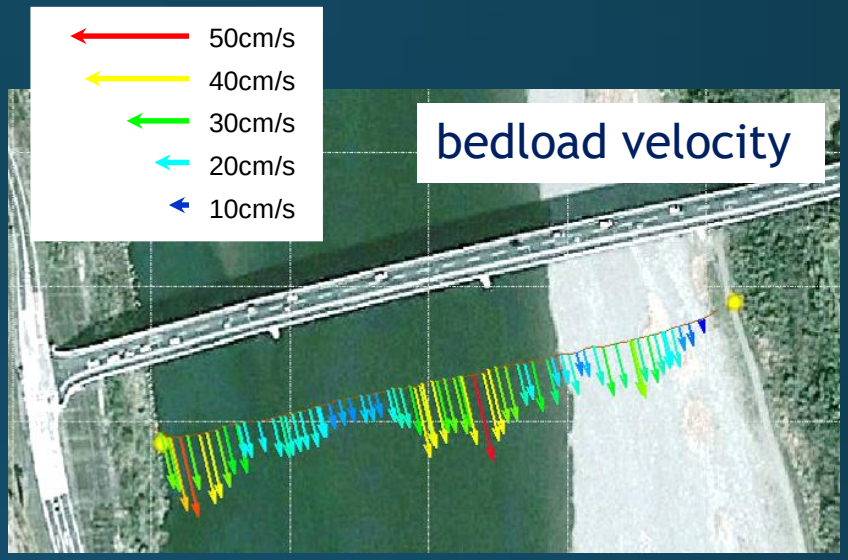


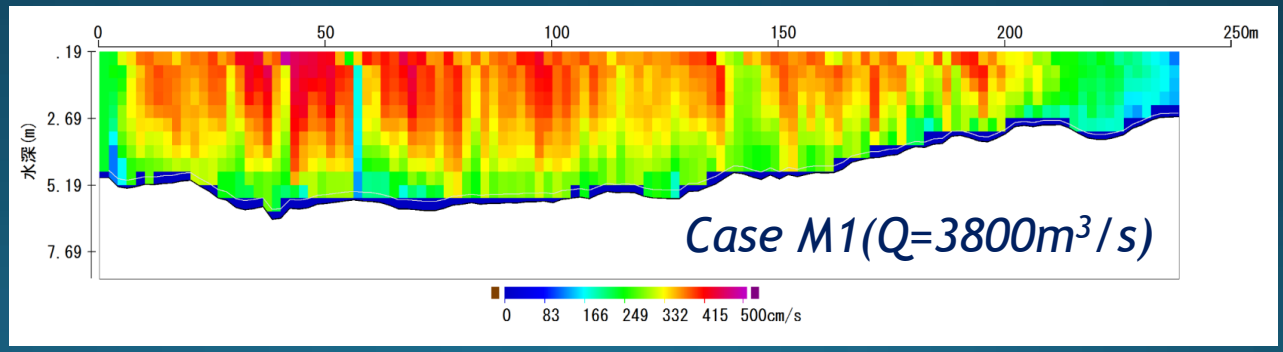
Discharge measurement at diversion point of Tone River and Edo River

Flood observation in Shimanto River using Riverboat (Okada & Kitsuda, 2007)



Flood observation in Niyodo River using High-speead Riverboat (Okada & Kitsuda, 2012)





By the introduction of ADCP for flood observation, the flow observation technique in Japan has made significant progress.

Technical issuess for flow and sediment measurement

Bedload measurement :

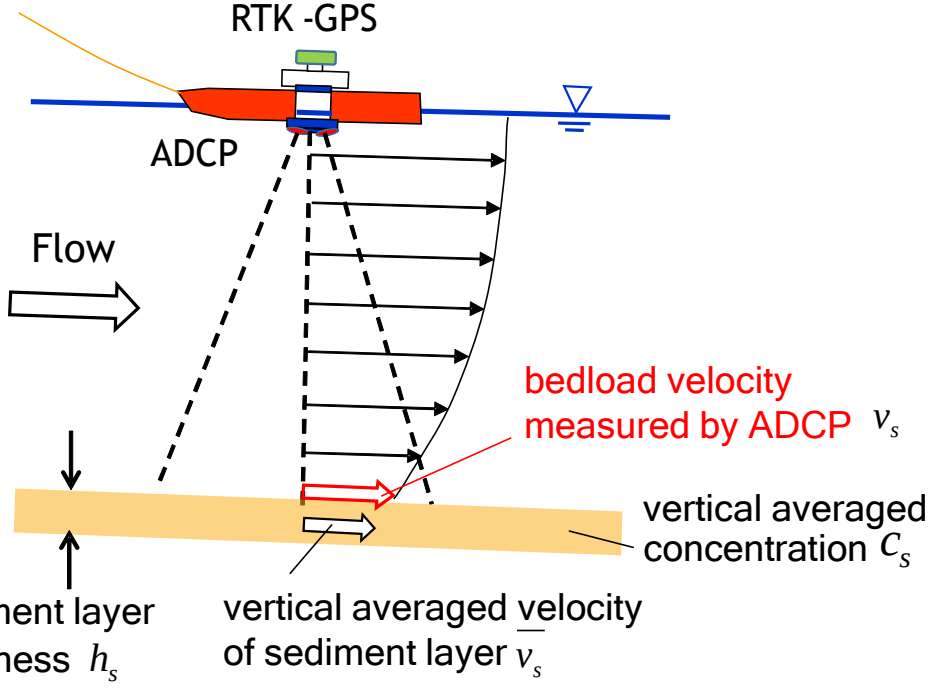
- Data acquisition techniques to verify our proposed method

Suspended sediment measurement :

- Data acquisition techniques to calibrate the coefficients of our proposed method

2. Verification of bedload measurement method using ADCP

Application to measurement of bedload discharge using ADCP+RTK-GNSS



Egashira et. al. (1997)

$$\frac{h_s}{d} = \frac{1}{c_* \cdot K_1}\tau_*$$

$$K_1 = \frac{1}{\cos\theta \cdot \{\tan\phi_s/(1+\alpha) - \tan\theta\}}$$

$$\frac{\overline{v_s}}{u_*} = \frac{4}{15}\frac{K_1 K_2}{\sqrt{f_d + f_f}}\tau_*$$

$$K_2 = \frac{1}{c_s}\left[1 - \frac{h_s}{h_t}\right]^{1/2}$$

$$f_d = k_d(1-e^2)(\sigma/\rho)c_s^{1/3}$$

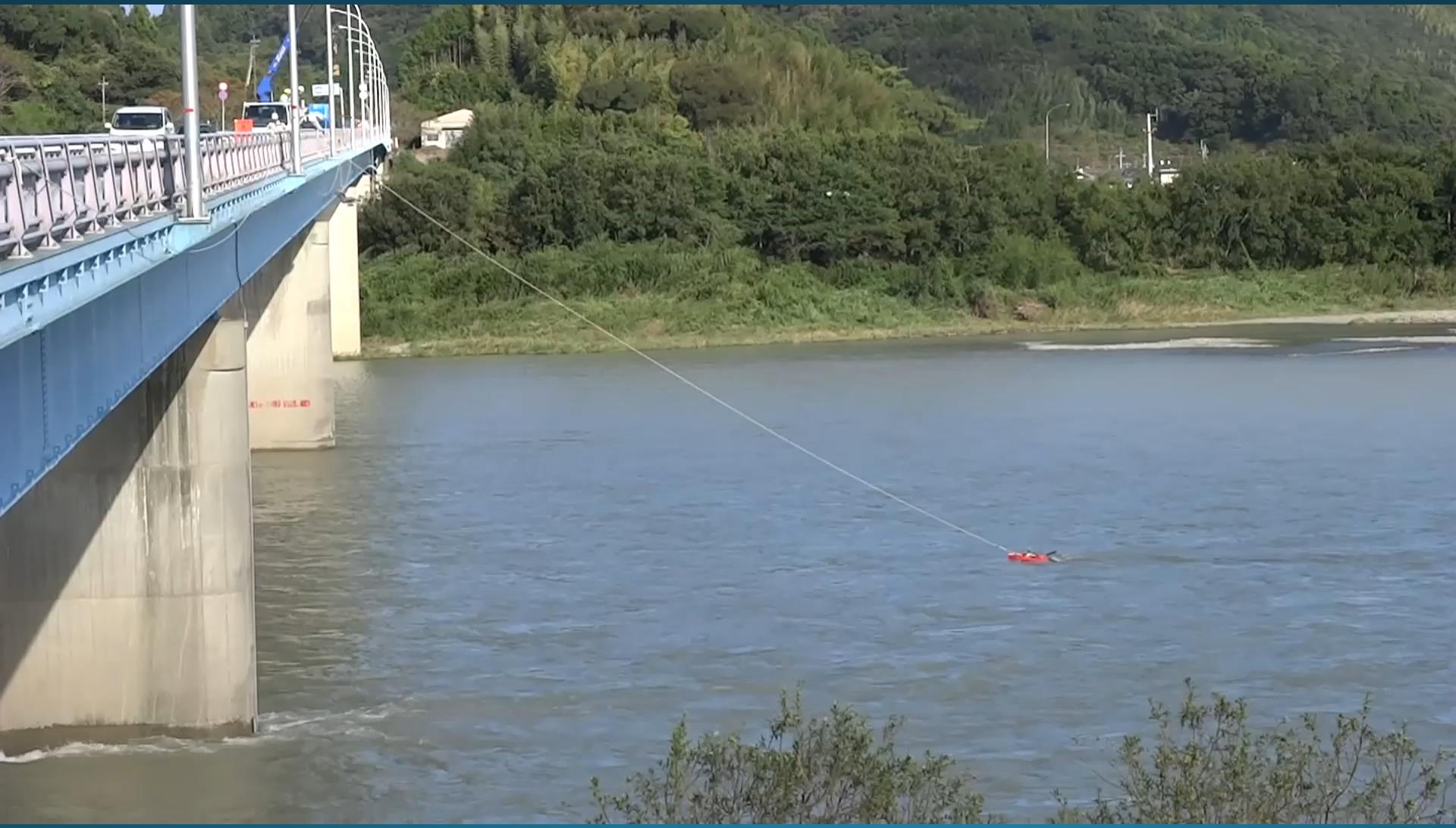
$$f_f = k_f(1-c_s)^{5/3}c_s^{-2/3}$$

bedload discharge

$$q_B = \int_0^{h_s} c \cdot u \cdot dz \cong \overline{v_s} \cdot h_s \cdot c_s$$

$$\overline{v_s} = 0.65\ v_s$$

Flow and sediment observation at Niyodo River (October,2014 Okada & Kitsuda)

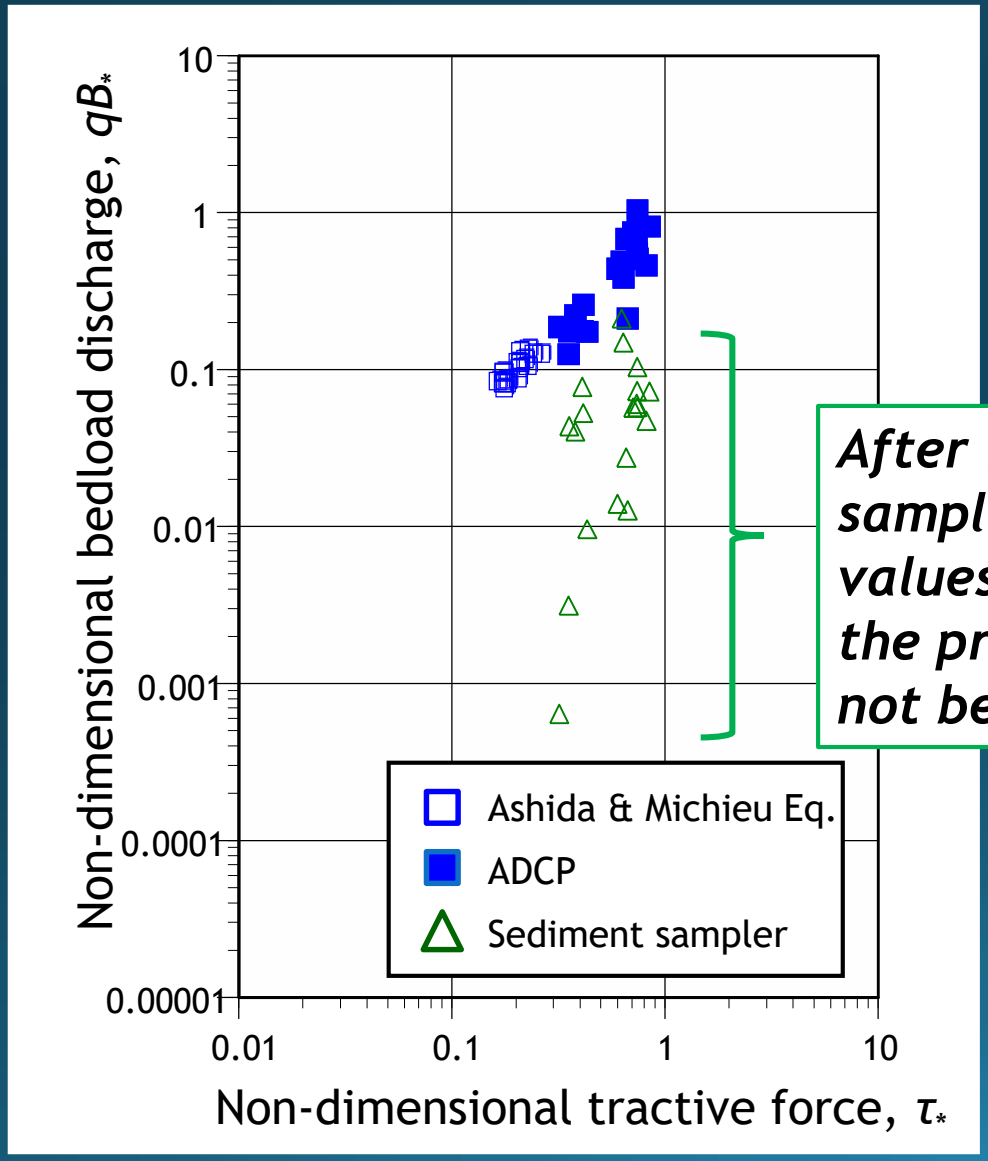


2. Verification of bedload measurement method using ADCP

Flow and sediment observation at Niyodo River (October,2014 Okada & Kitsuda)

By setting a pressure gauge at the side of the sampler, we can measure the actual time that was settled on the riverbed.

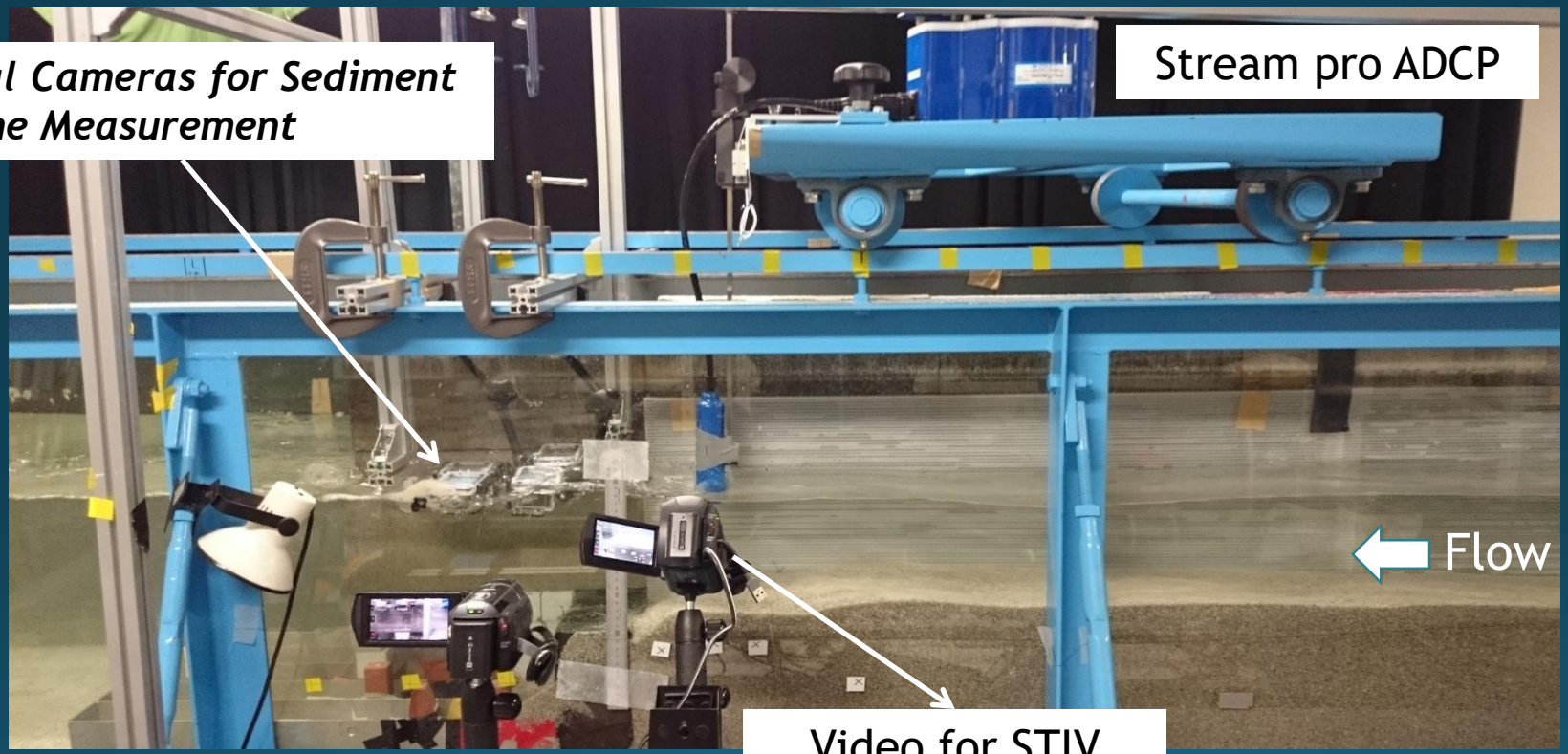
Comparison of bedload discharge between ADCP and sampler



After improving the sediment sampler, the measured values varied greatly, and the proposed method could not be verified.

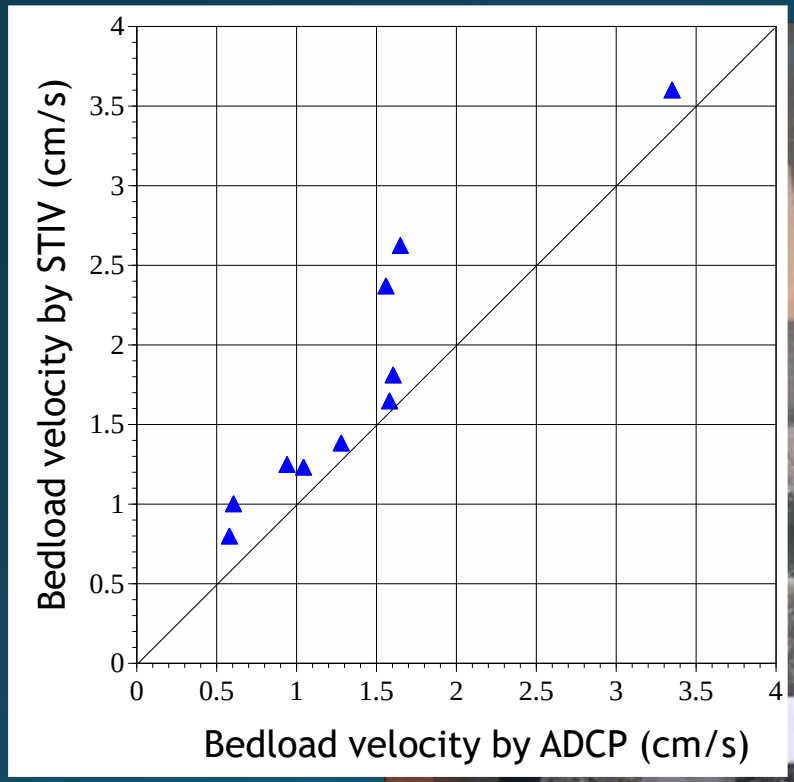
2. Verification of bedload measurement method using ADCP

Verification of the proposed method by experiments using a movable bed channel



2. Verification of bedload measurement method using ADCP

Measurement of sediment layer velocity using STIV (Space-Time Image Velocimetry) method

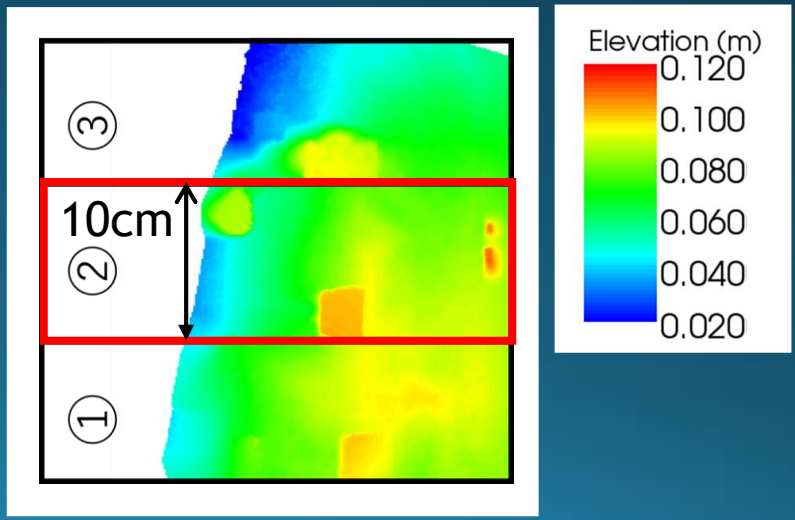


As a result, it was confirmed that both values showed almost the same value.

Measurement of sediment volume change using SfM (Structure from Motion) method

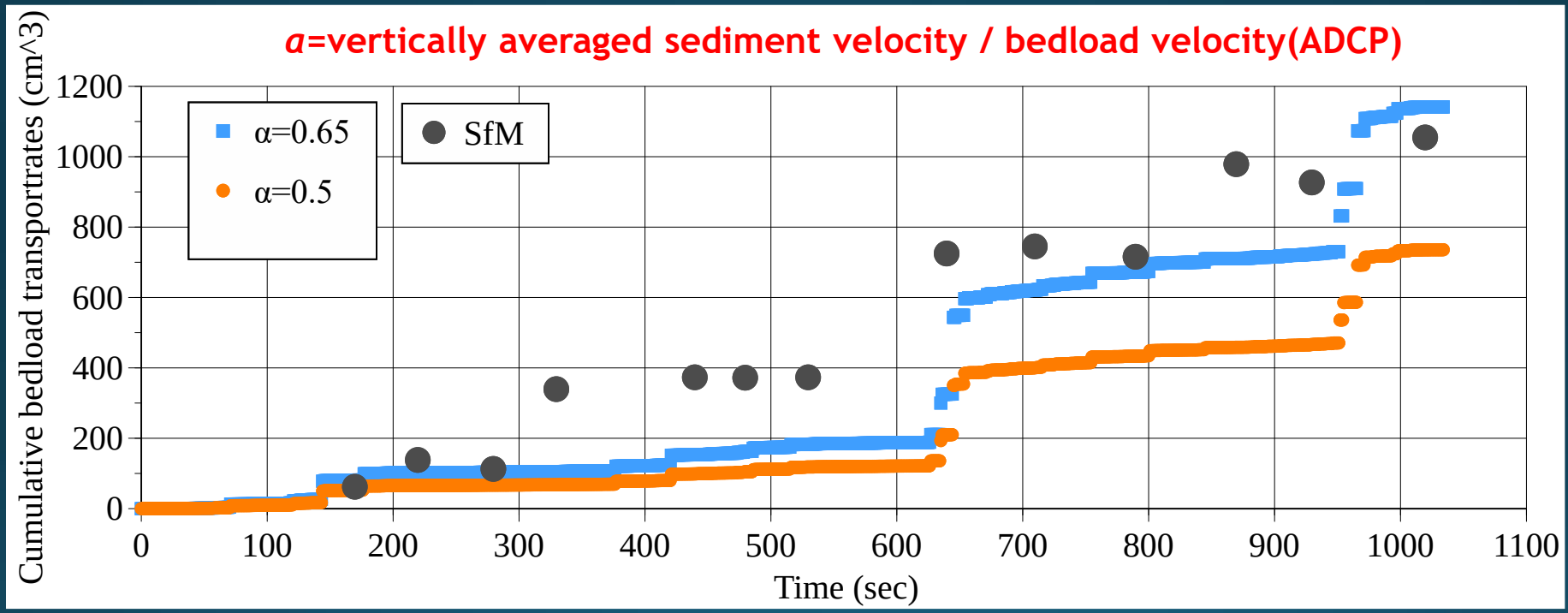
The volume change of the sediment deposited at the downstream was measured by the SfM method from the time-lapse images of four digital cameras and compared with the value calculated by the proposed method.

SfM (Structure from Motion) Method



2. Verification of bedload measurement method using ADCP

Comparison of sediment volume change at downstream (the SfM method and ADCP bottom track velocity method)

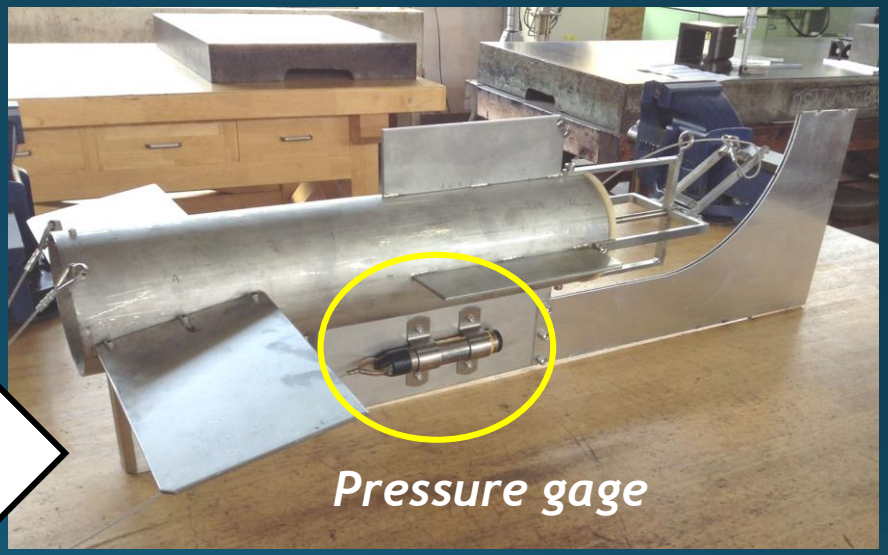


From this result, it is clear that the proposed method is effective when the calibration coefficient a is 0.65.

3. Examination of techniques necessary for suspended sediment measurement during flood

Improvement of the water sampler for flood flow measurement

Van Dorn Water Sampler for calm flow



Improved water sampler for flood flow

We made a steel horizontal Van Dorn water sampler and installed a pressure gauge so that water could be collected at any depth.

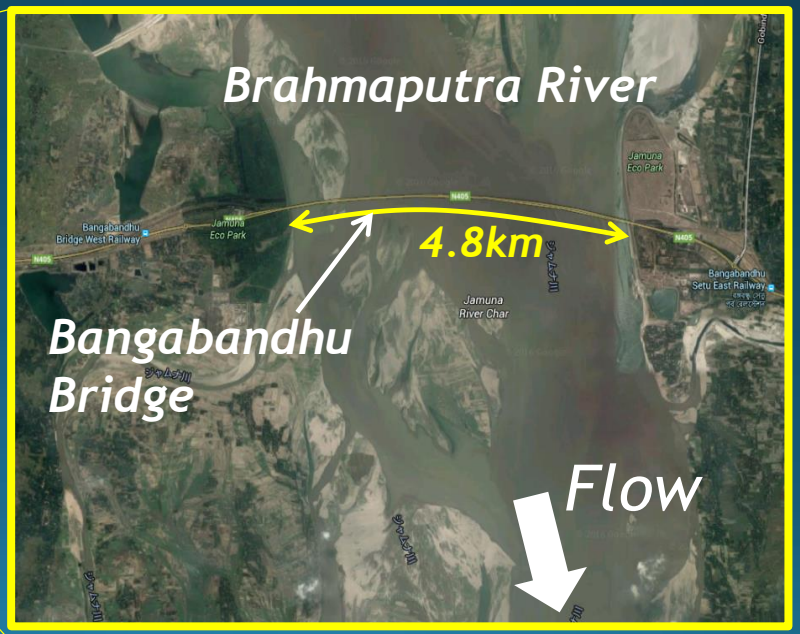
3. Examination of techniques necessary for suspended sediment measurement during flood

Water sampling test using the improved sampler

Sampling is successful under high-velocity conditions, but if the ship heading is directed in the opposite direction to the flow, it will be difficult to sample near the riverbed.
Therefore, we changed the direction of the ship heading in the same direction as the flow during turbidity measurement and sampling.

4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

Flood observation in Brahmaputra River



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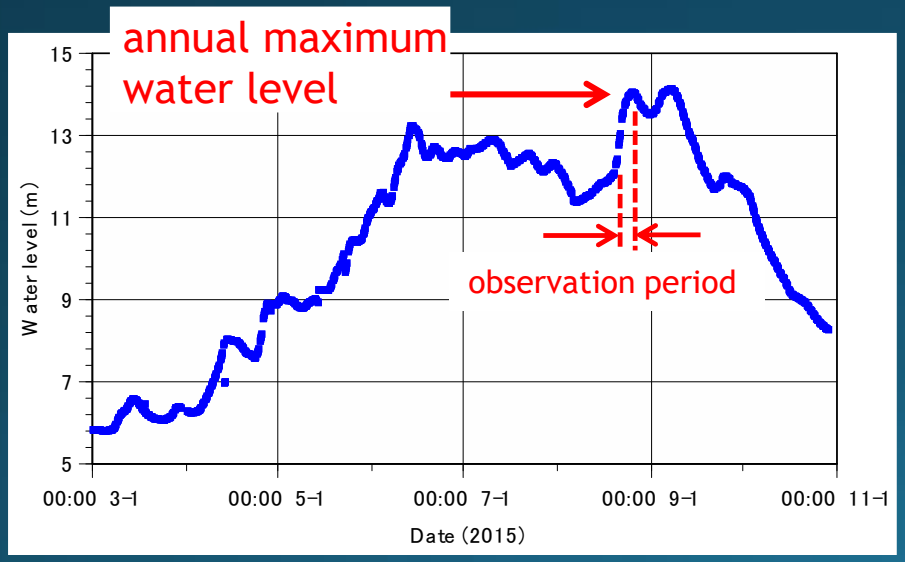
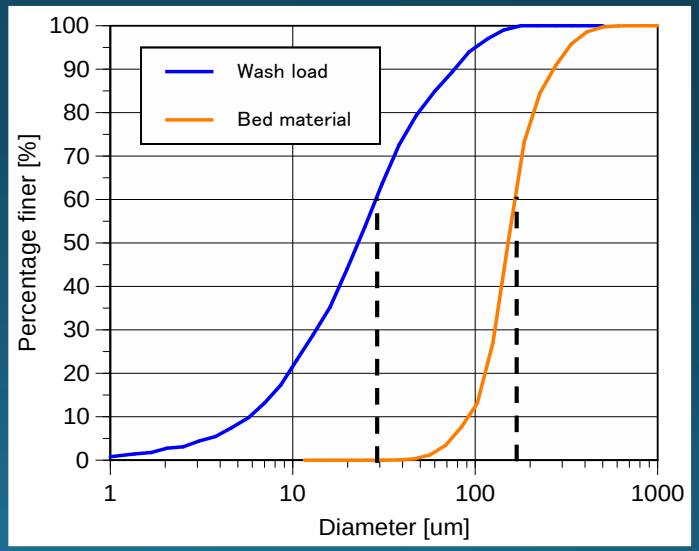
Flood observation in Brahmaputra River



Hydrograph of water level at the Serajgang Gauging Station (BWDB)



Grain size distribution of wash load and Bed material

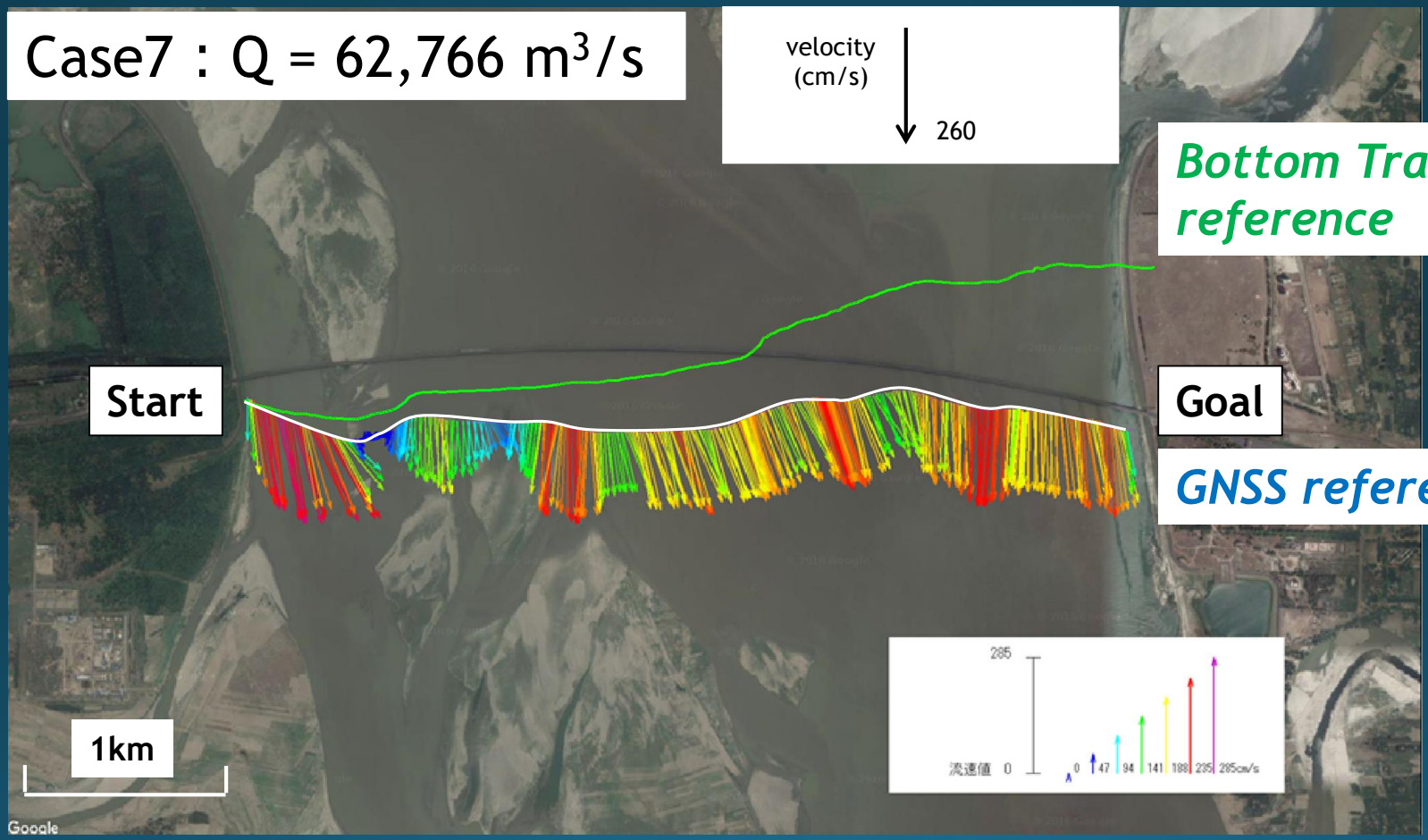
4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

Measurement results of discharge

	August 2015	Discharge (m^3/s)
Case 1	21, 10:41	38,574
Case 2	21, 17:00	40,756
Case 3	22, 8:42	43,480
Case 4	23, 8:54	56,000
Case 5	23, 18:12	59,211
Case 6	24, 8:40	59,690
Case 7	24, 17:20	62,766
Case 8	25, 8:57	61,942

4. Flood observation in Brahmaputra River, Bangladesh

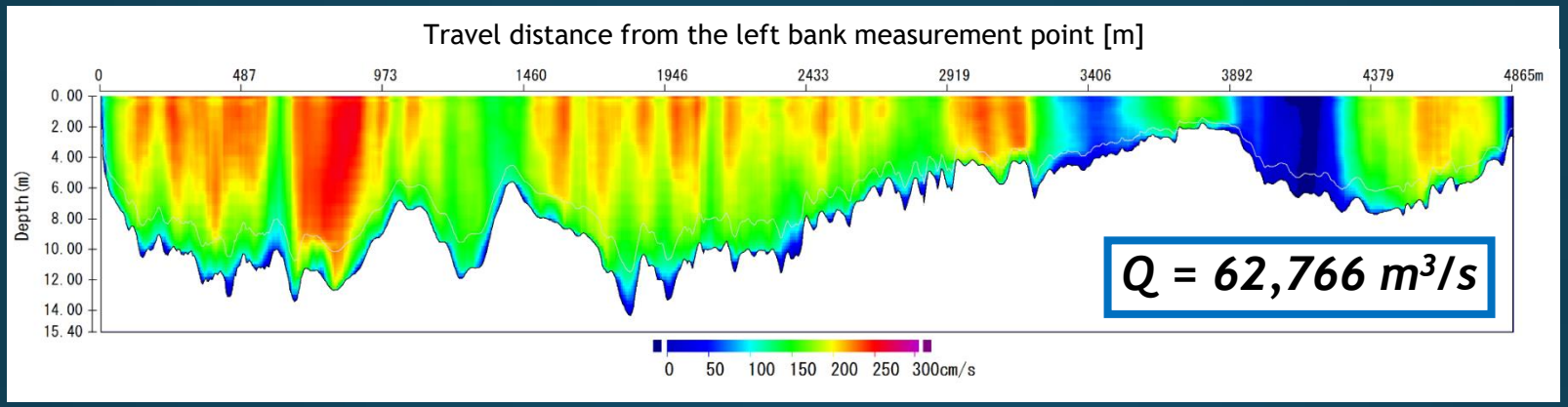
Cross-sectional distribution of depth-averaged velocity vector and boat track



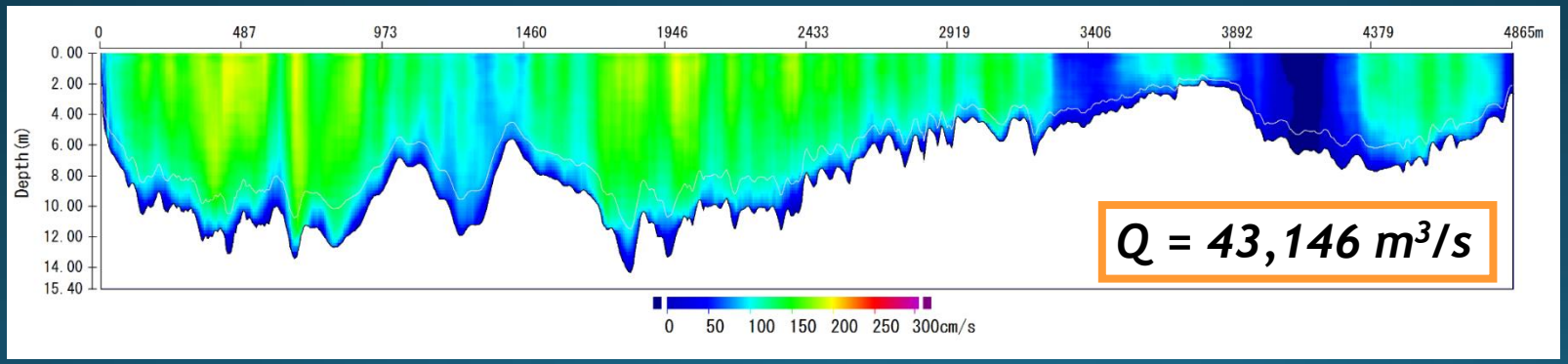
From this figure, it can be seen that the bedload velocity is large and the flow discharge by the bottom track reference is considerably smaller than the actual value.

4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

Effect on the discharge value due to moving-bed



(a) Velocity distribution (GPS reference)

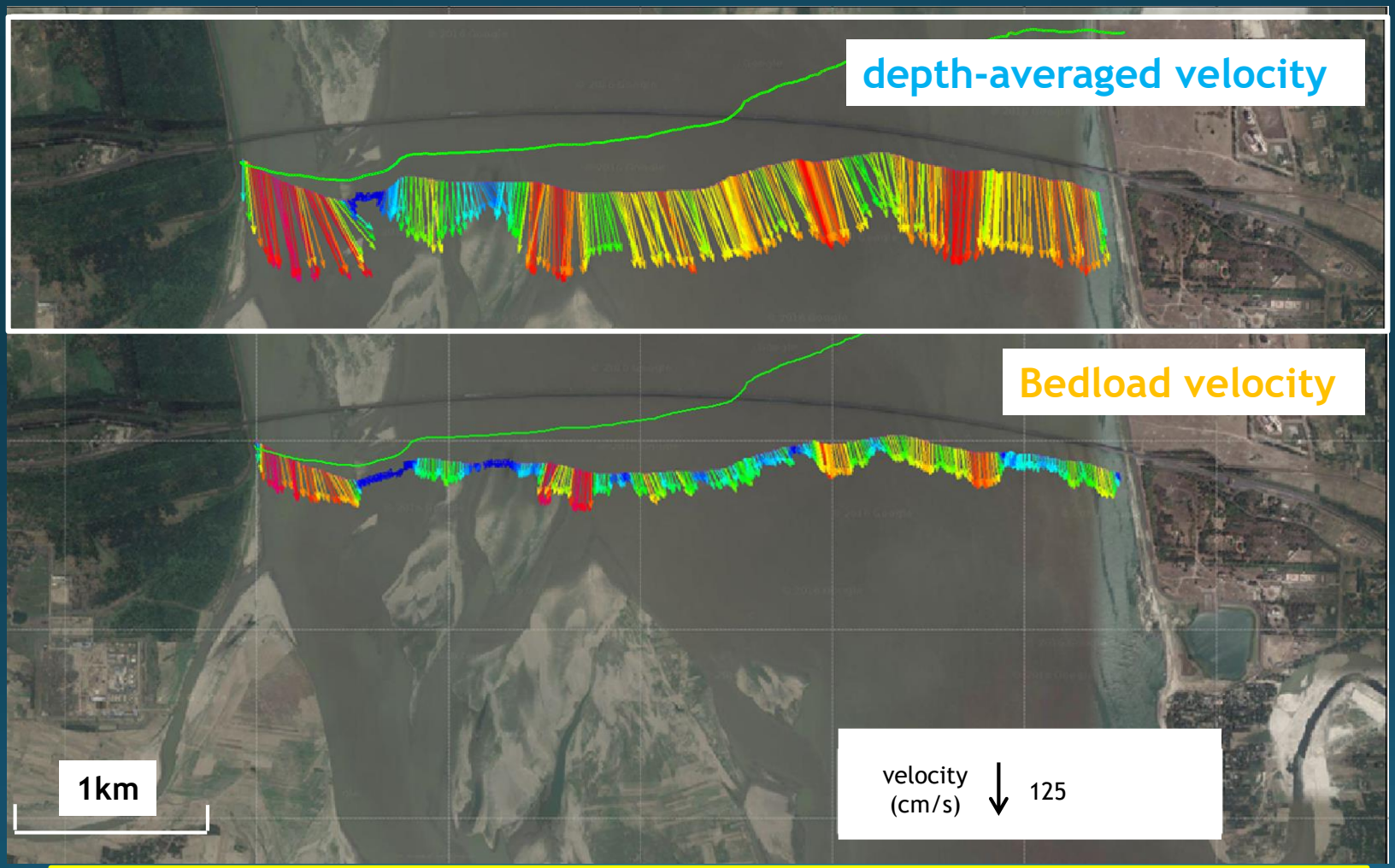


(b) Velocity distribution (Bottom track reference)

Discharge difference of about 30% occurs for the actual value.

4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

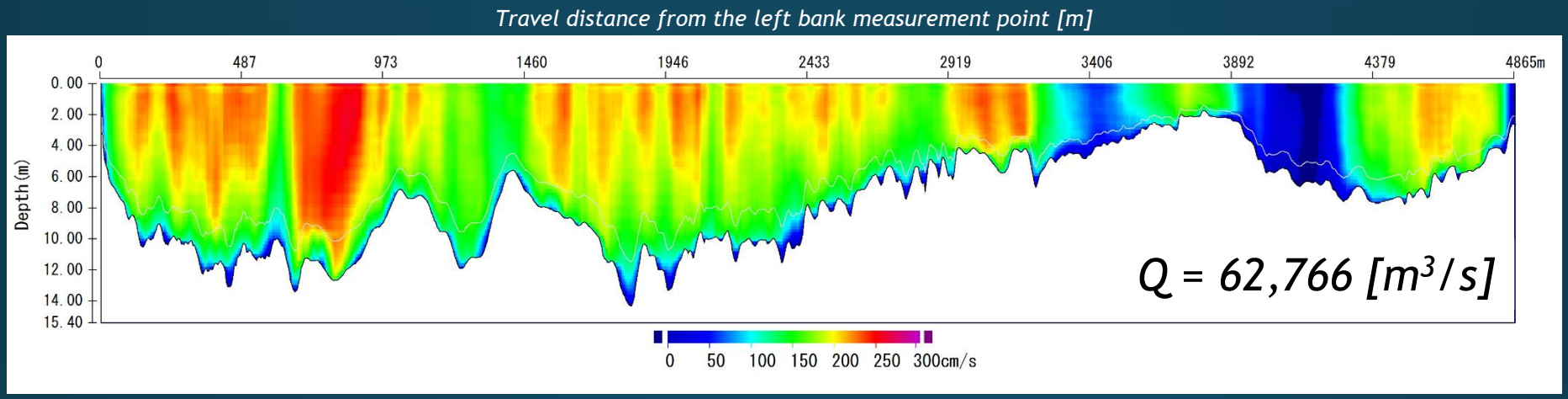
Cross-sectional distribution of bedload velocity vector



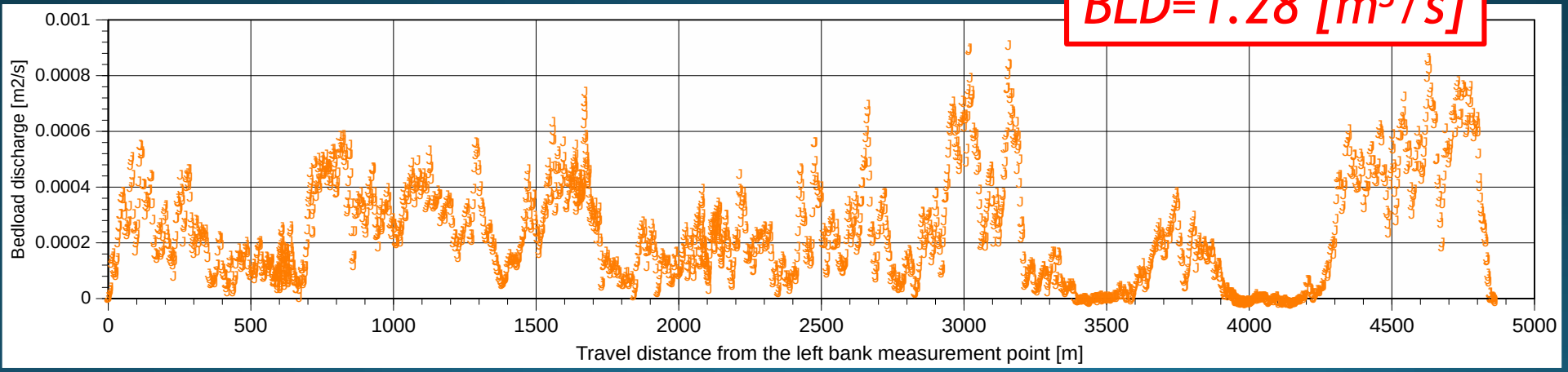
Bedload velocity is proportional to the depth-averaged velocity

4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

Cross-sectional distribution of bed load discharge (Case 7)



(a) Velocity (GPS reference)



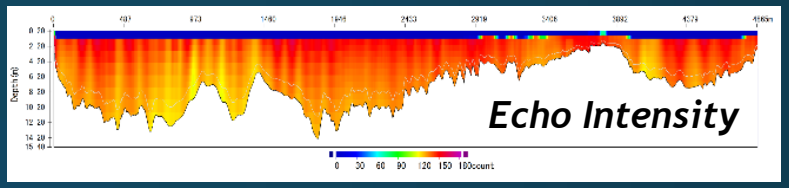
(b) Bed load discharge

4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

Application to measurement of suspended sediment discharge using Echo intensity of ADCP

Calibration data

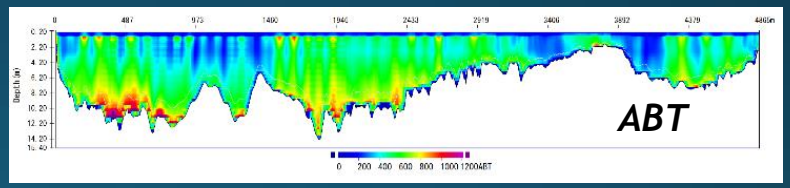
- Vertical distribution of echo intensity (ADCP)
- Turbidity and water temperature (Turbidity Meter)
- SSC and Grain size by water sampling



Estimation formula (Kitsuda et al., 2006)

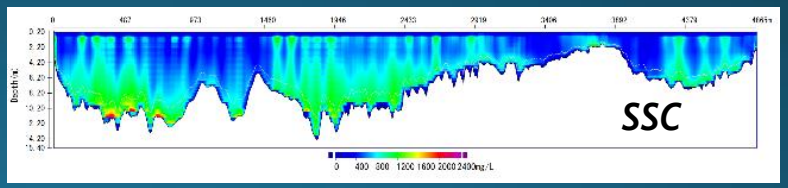
$$\log M(r) = S\{dB + 2r(\alpha_w + \alpha_s)\} + K_s$$

Acoustic Backscatter Turbidity

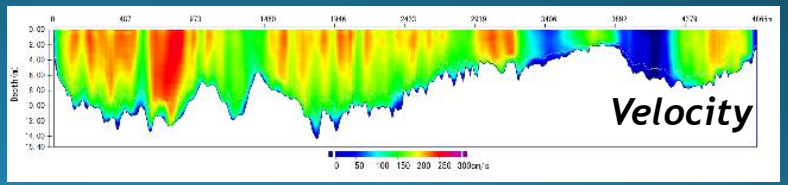


Turbidity - SSC relation

SSC (Suspended sediment Concentration) at each point



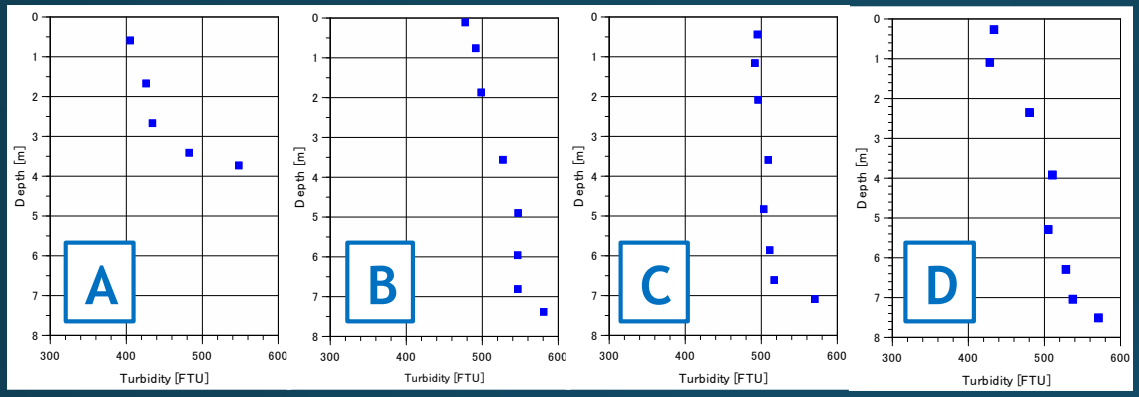
× velocity distribution

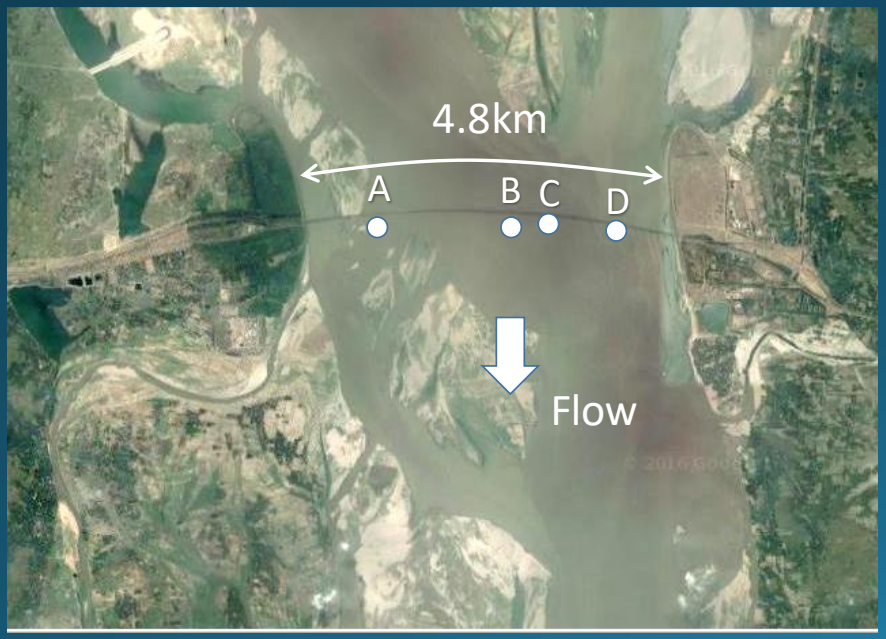


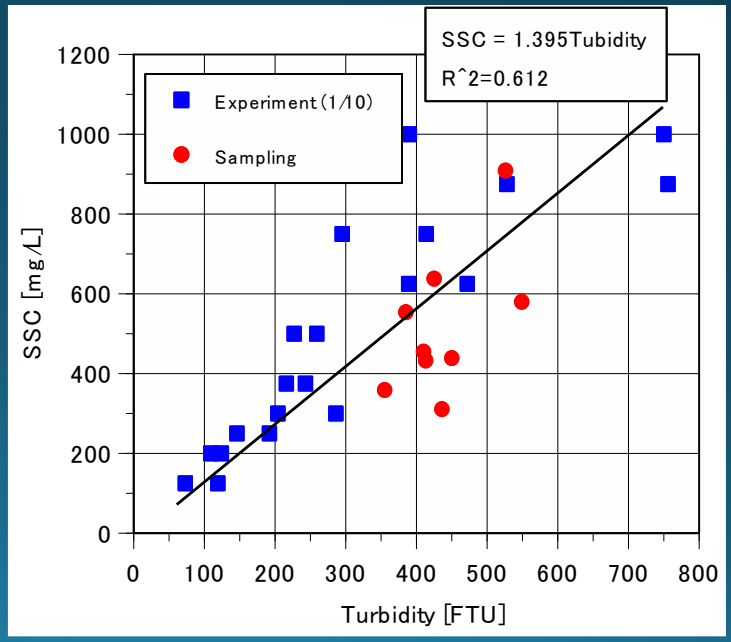
SSD (Suspended sediment Discharge)

4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

Vertical distribution of Turbidity & Relationship between Turbidity and SSC

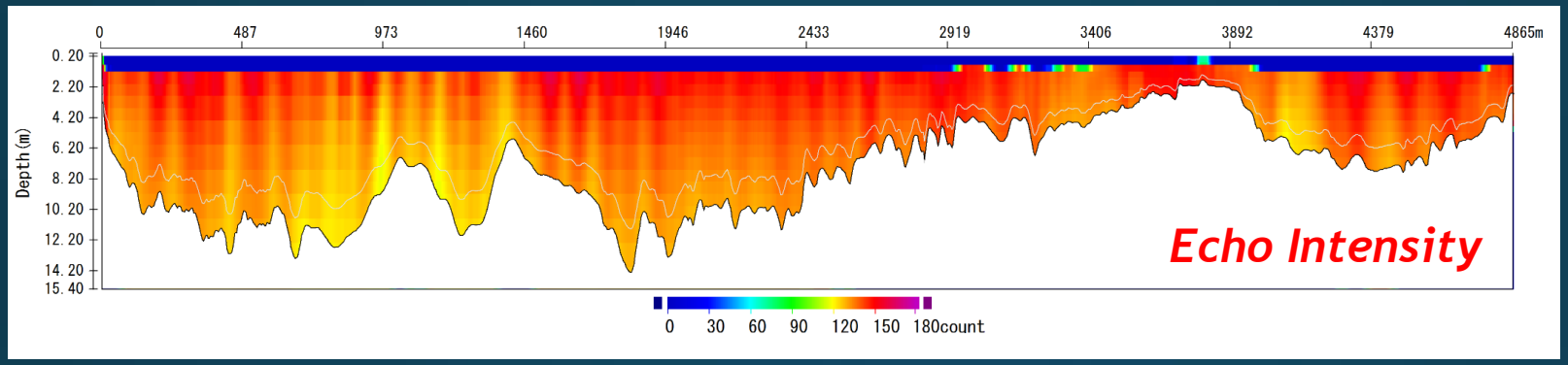


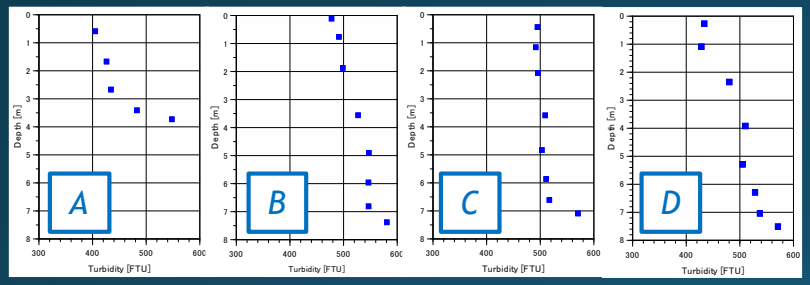




4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

Estimated ABT using the Echo Intensity

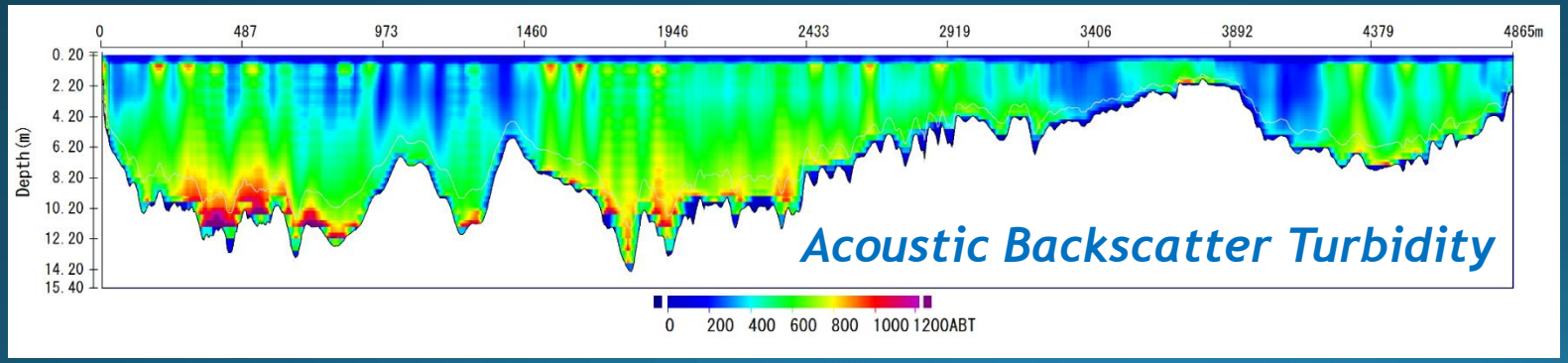




Vertical distribution of Turbidity

Estimation formula (Kitsuda et al., 2006)

$$\log M(r) = S\{dB + 2r(\alpha_w + \alpha_s)\} + K_s$$



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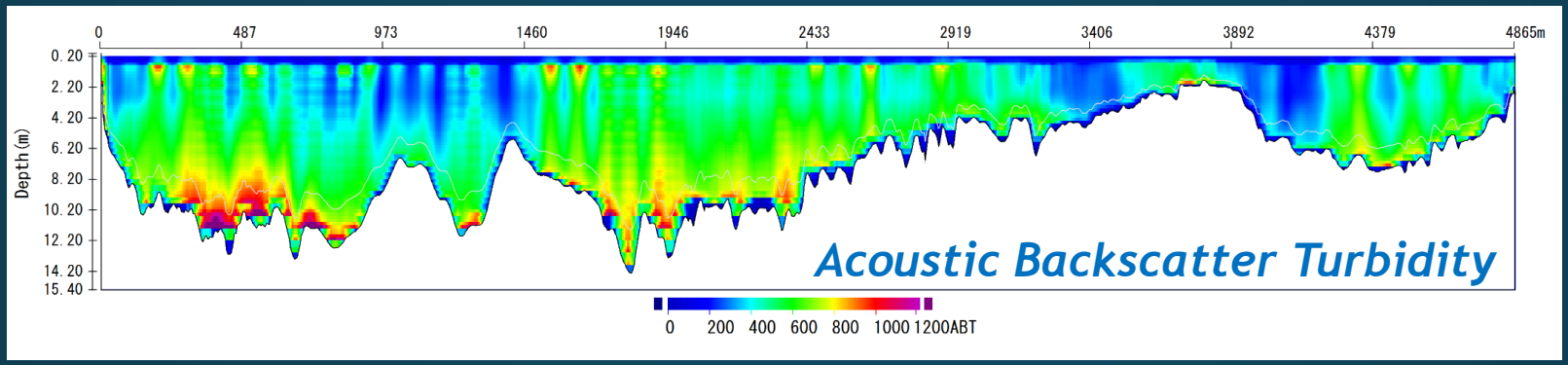
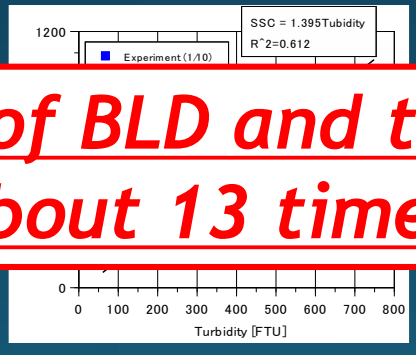
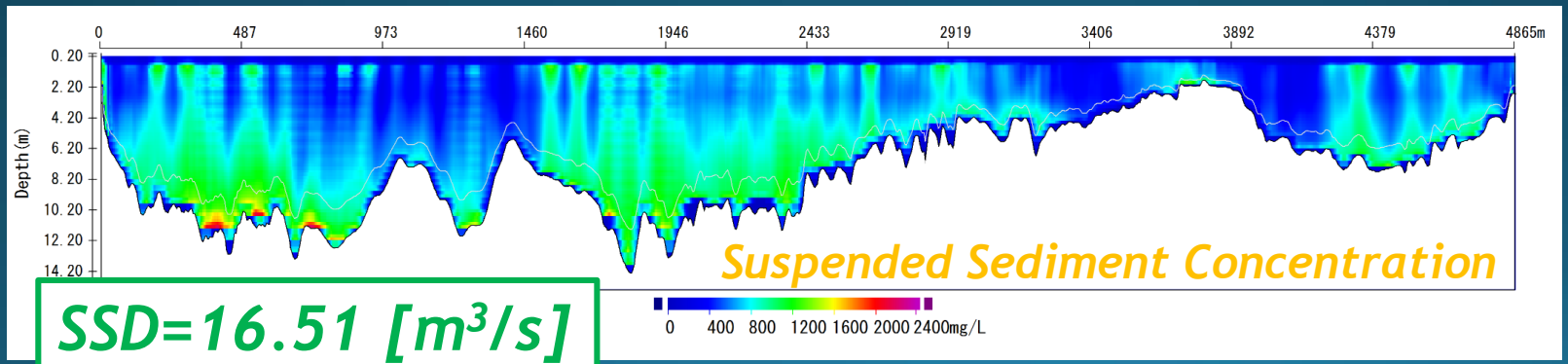




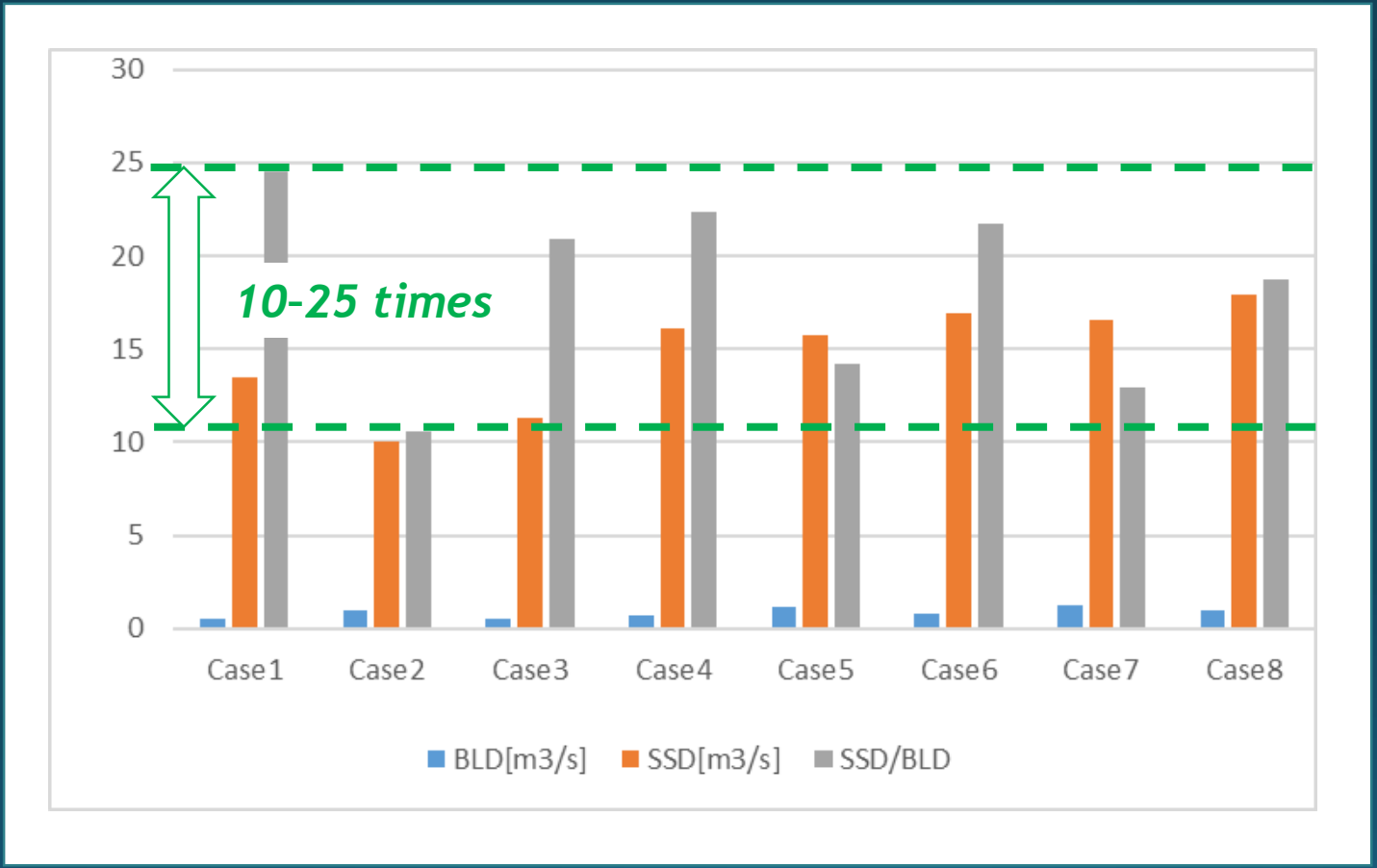
The ratio of BLD and the SSD was about 13 times.



SSD=16.51 [m³/s]

4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

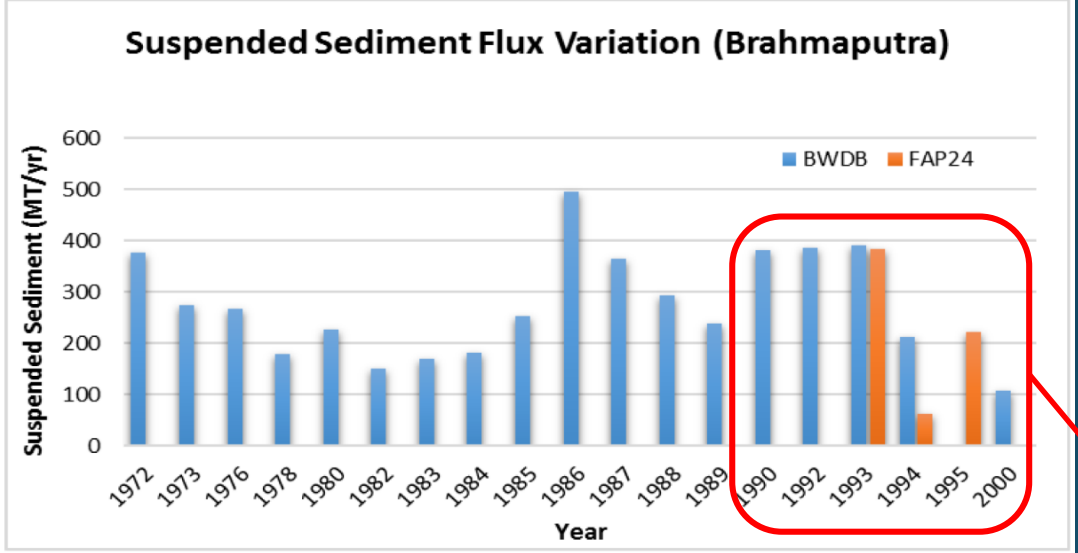
Ratio of bedload discharge and suspended sediment discharge

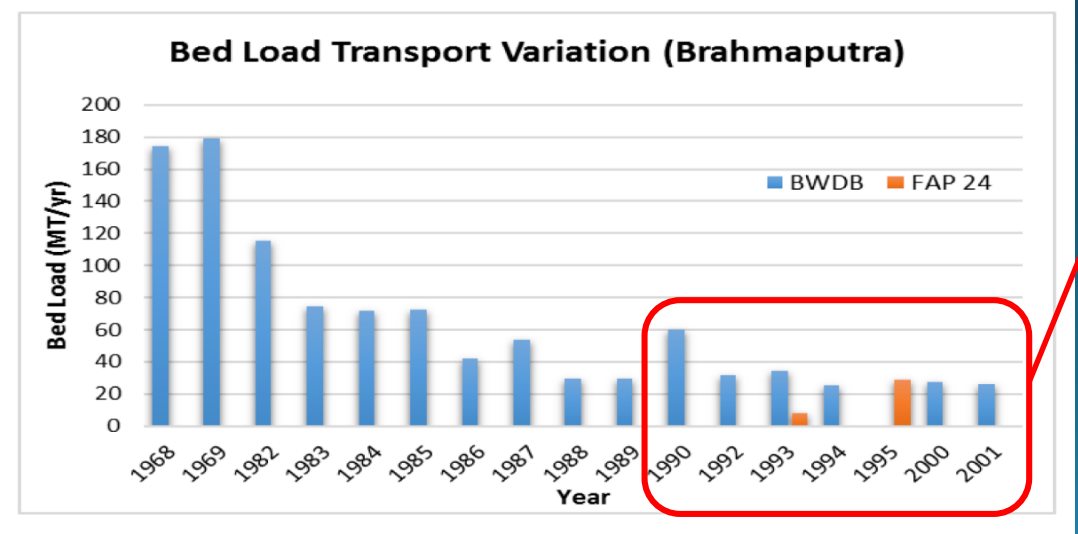


Including the other cases, the ratio fell within the range of 10-25 times. Certainly, we found that SSD was dominant compared to the BLD.

4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

Comparison with other research results





Md. Munsur Rahman et al. : Sediment Flux to Ganges-Brahmaputra-Meghna Delta, International Symposium jointly organized by JpGU and AGU, 2016.

The ratio of suspended sediment and Bedload discharge represents the range of 5-20 times.

Main results :

- Validated our proposed bedload measurement method by experiments using movable bed channel
- Improved the water sampler and sampling method for flood flow measurement
- From the results of field observation at the Brahmaputra River in Bangladesh where suspended sediment dominant, we could confirm the effectiveness of the proposed method

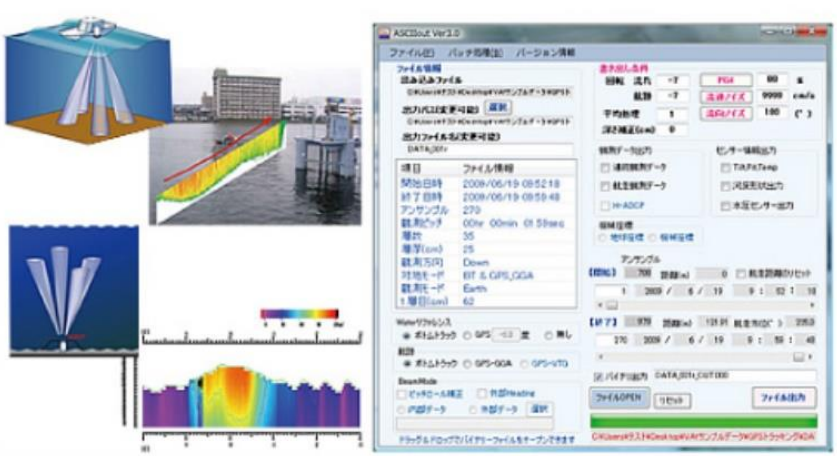
5. Summary

NEW RELEASE!!

Visual ADCP tools ver.4.0

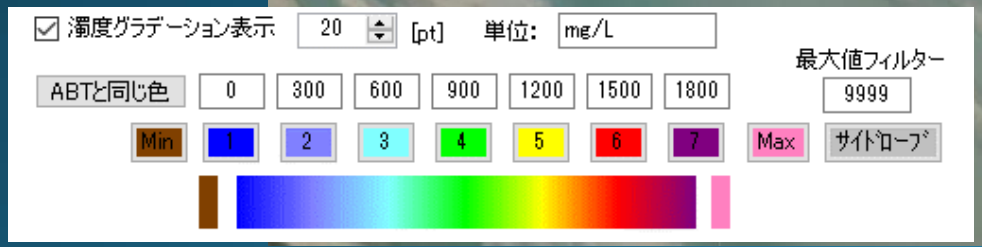
(produced by Hydro Systems Development, Inc.)

ADCP data processing / drawing software



→ water velocity

→ bedload velocity




Thank you for your attention!!

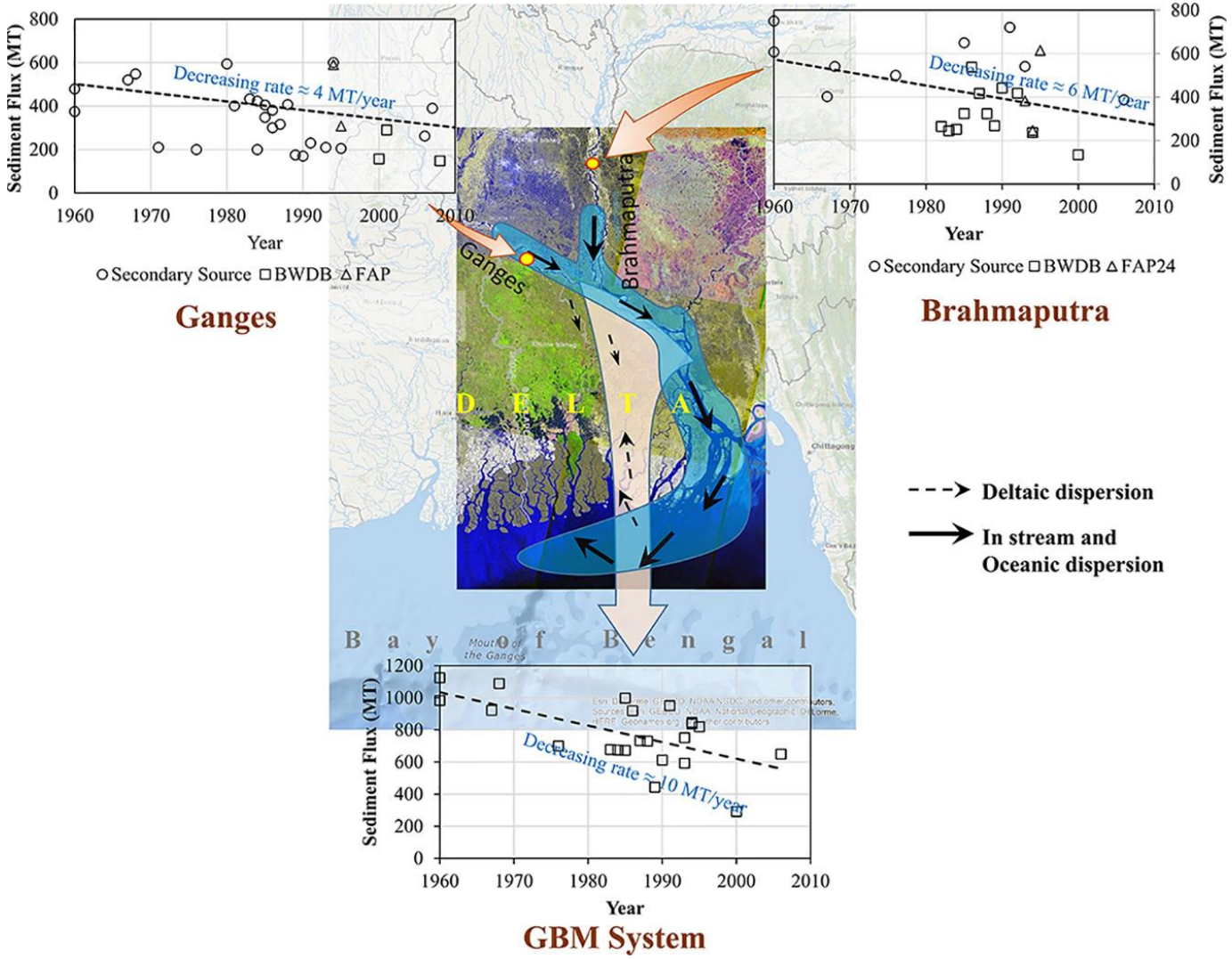
Requests to RD from a heavy user in Japan :

To further improve the accuracy and efficiency of our measurement (especially for suspended sediment measurement),

Please upgrade the firmware of River Ray and River Pro to output the background noise information. (Add the WQ command)

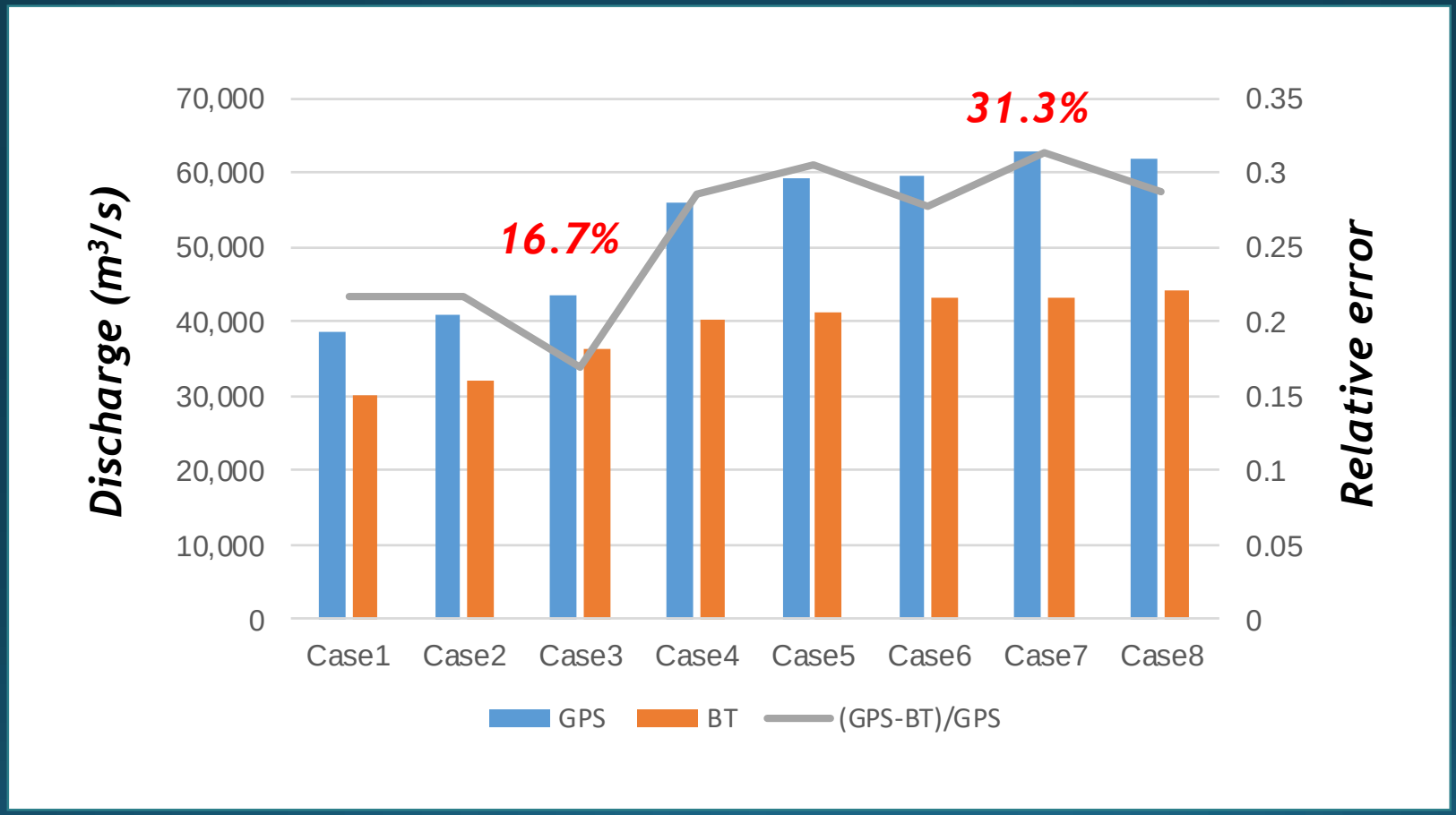
Please develop a new ADCP that can output transmit power information.

Munsur Rahman et.al (2018) : Recent sediment flux to the Ganges-Brahmaputra-Meghna delta system, Science of The Total Environment, Vol. 643, 1 December 2018, pp.1054-1064.



4. Comprehensive measurements of flood flow, bedload and suspended sediment using ADCP

Effect on the discharge difference due to the moving-bed



Against the discharge of 38,000-63,000 m³/s, as the amount of discharge increased, the difference increased up to a maximum of 31.3%.