Recent developments in sediment monitoring in Japanese rivers

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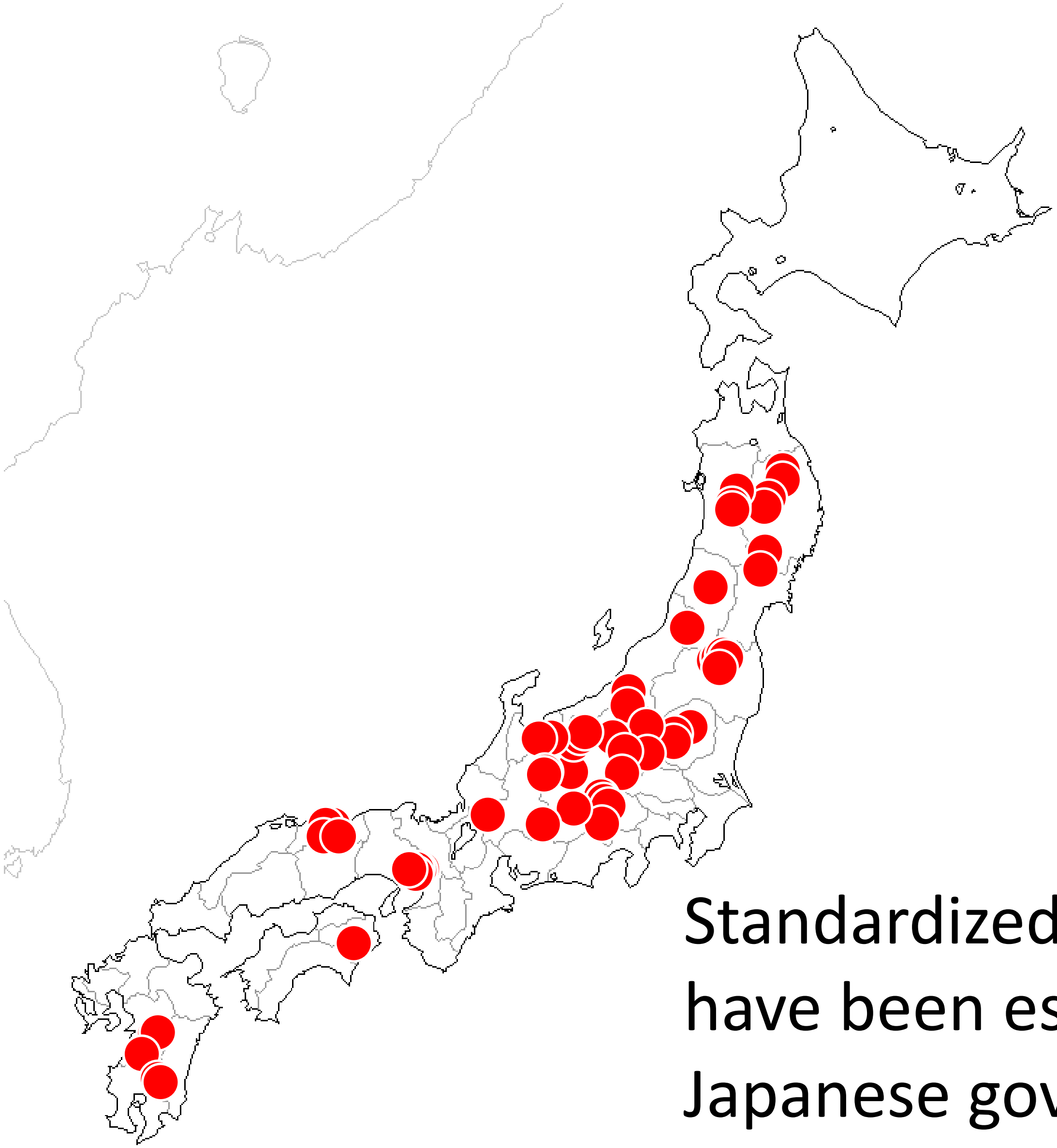
Sediment monitoring in Japanese rivers



Standardized 60 monitoring stations have been established by the Japanese government.

Sediment related issues in mountain areas

Landslide

Disasters

Can we know impacts of mass movement in the upper reach during storm?

Sediment related issues in mountain areas

Watershed management

- Quantity and quality of sediment from mountain streams are critical.
- Even in a basin, tributaries show different characteristics of sediment runoff.

Severe — Sediment runoff — Mild



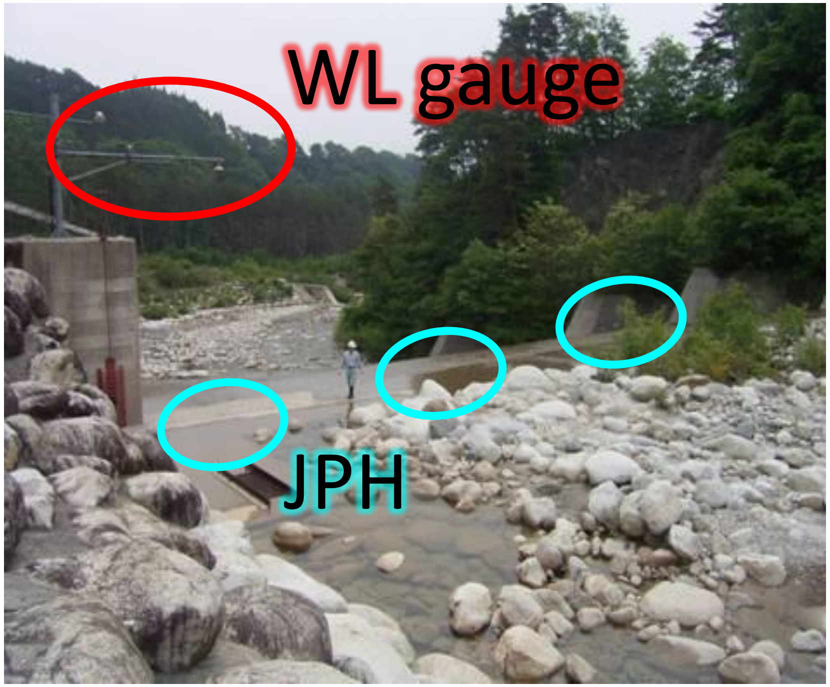
Why sediment monitoring in mountain rivers?

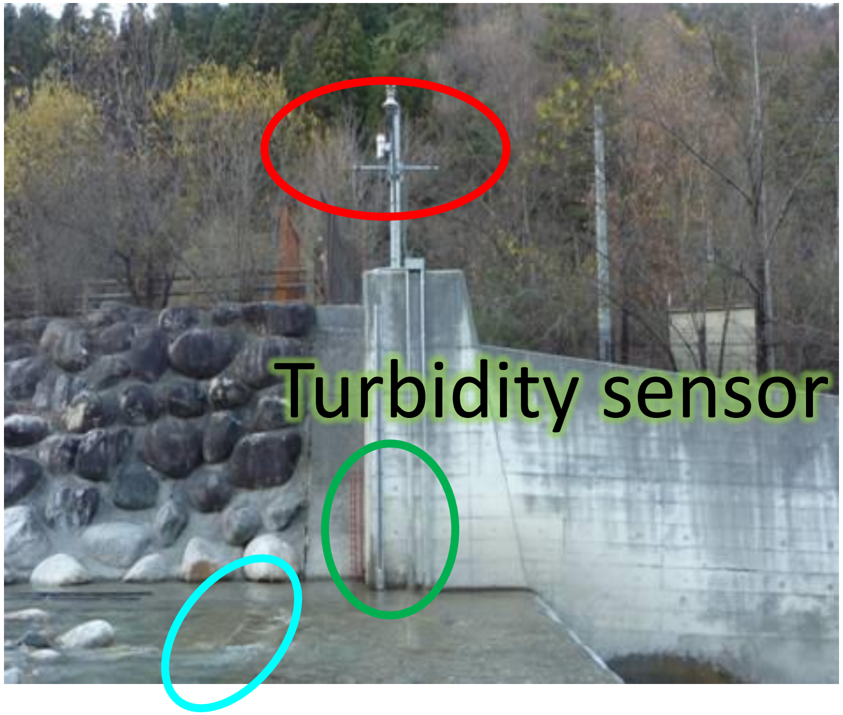
Why not numerical simulations?

- ✓ Mountain rivers include inherent complex geometry.
- ✓ In general, mountain rivers are under supply-limited conditions.
- ✓ Field data is insufficient to validate the simulations.

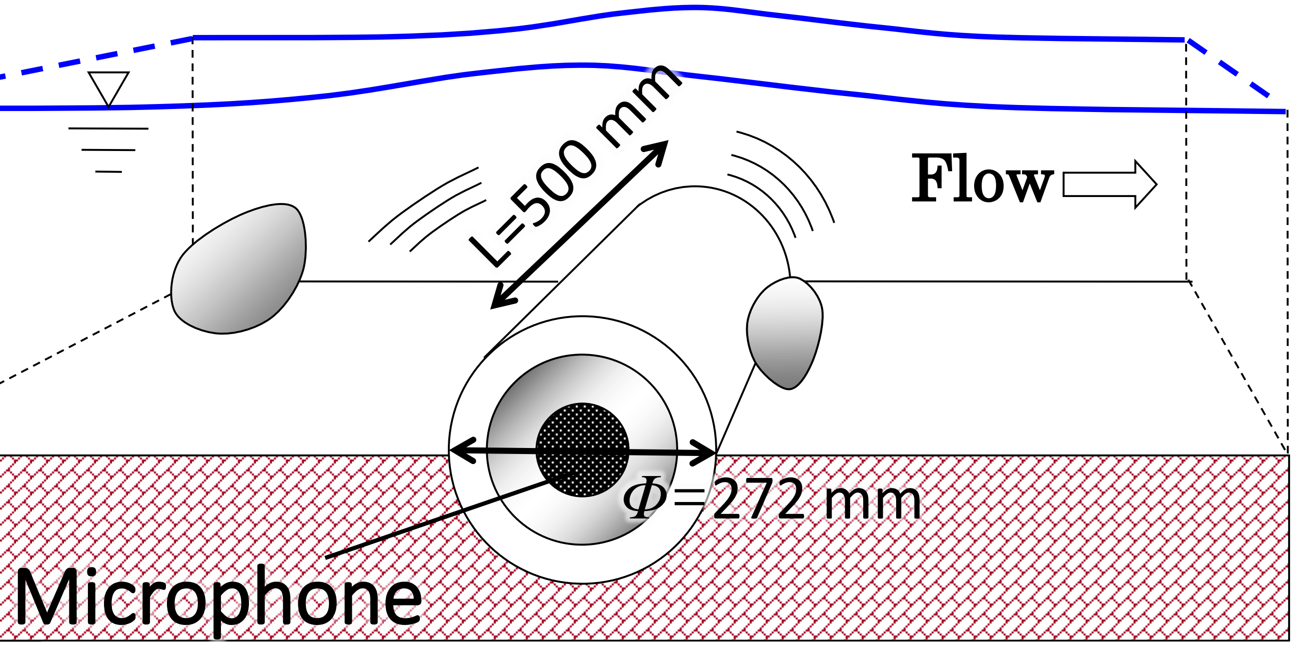
Contents of monitoring

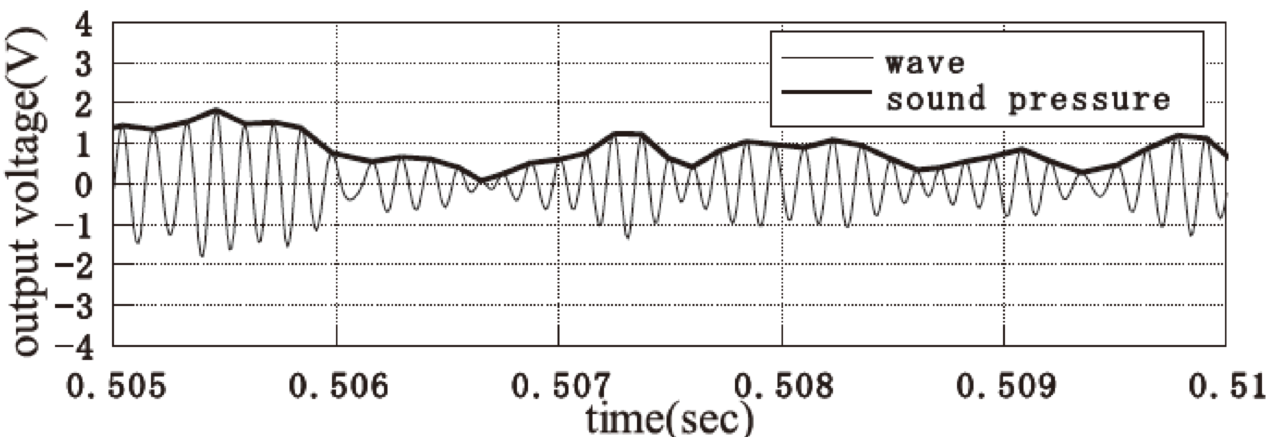
- Water level gauge -> discharge
- Turbidity sensor -> suspended load
- Japanese pipe hydrophone
  (pipe microphone) -> bedload





Bedload transport





Acoustic energy

Suzuki et al. (2010)

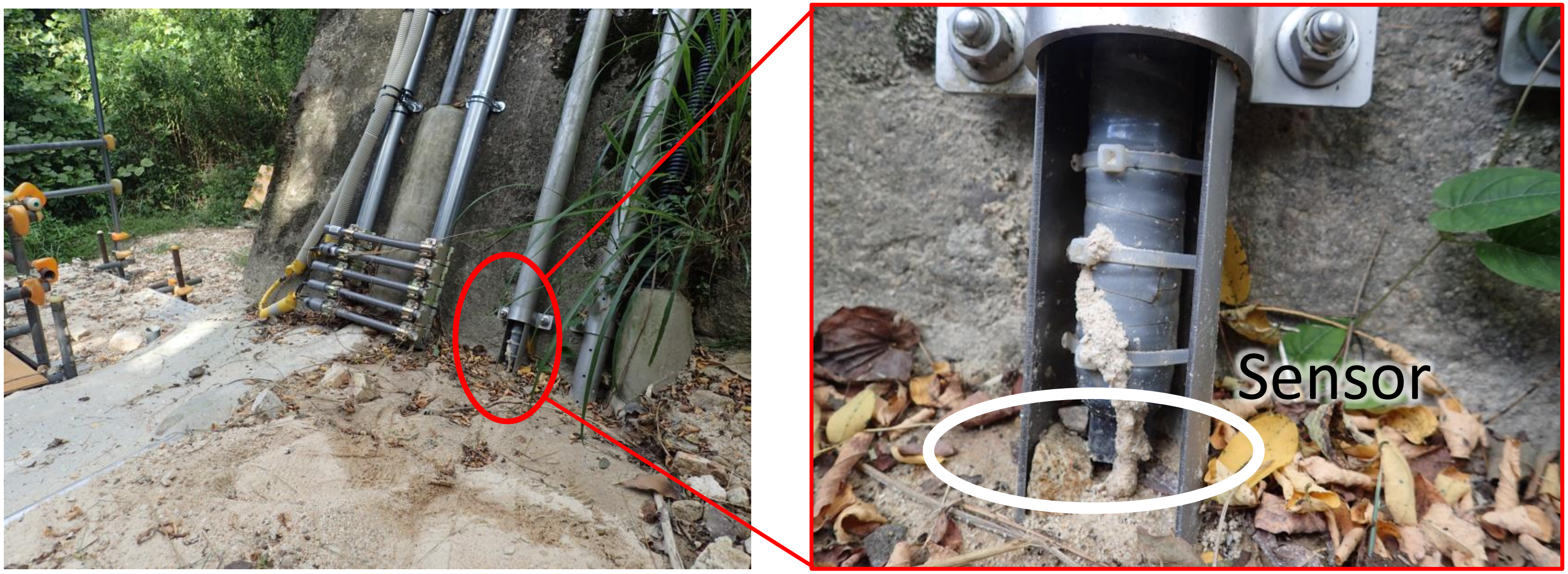
Suspended transport

Optical backscatter type turbidity sensor

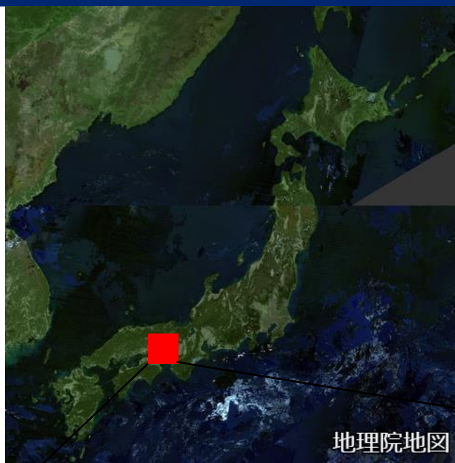
Max measurement: 0 – 4000 NTU

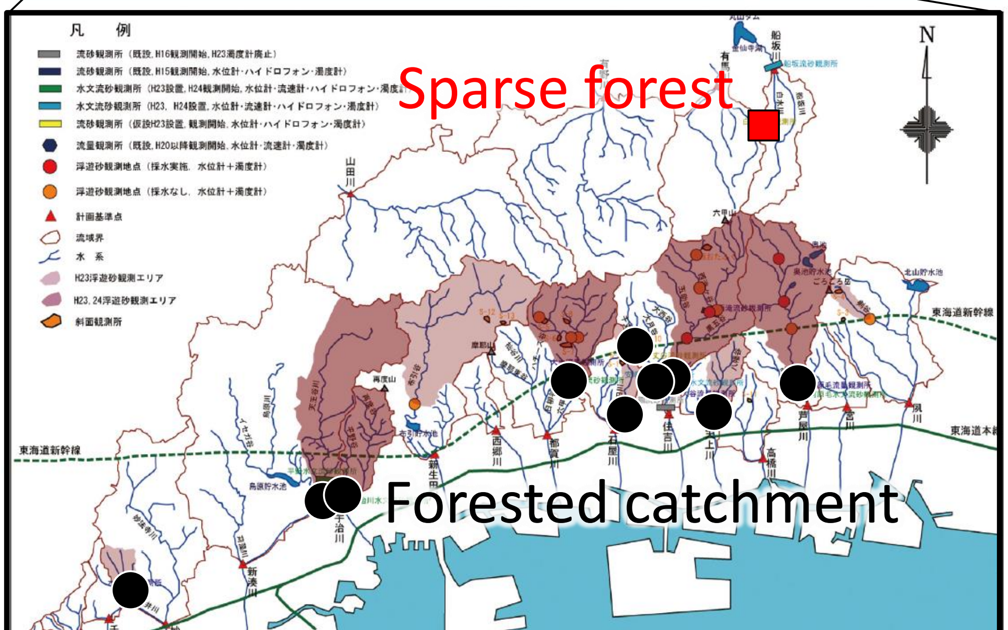
-> 0 – 5 (or 10) g/l for mud

-> 0 – 50 (or 100) g/l for sand

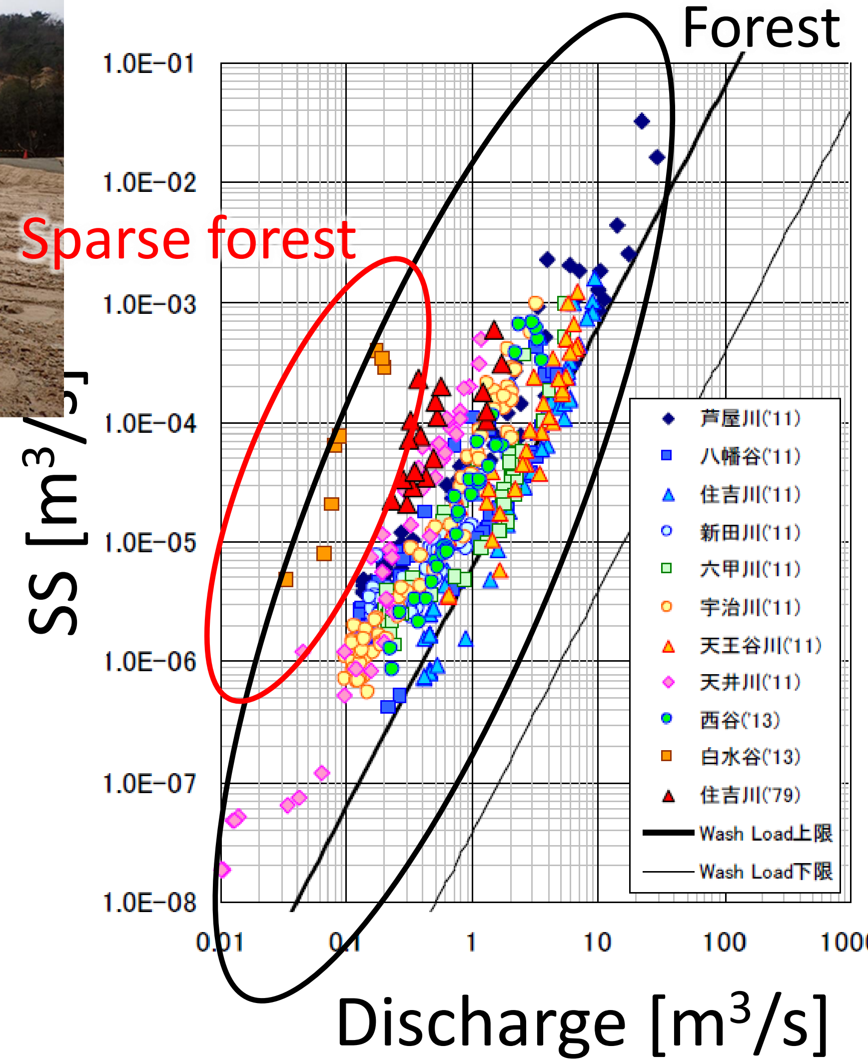


Outcome of standardized monitoring



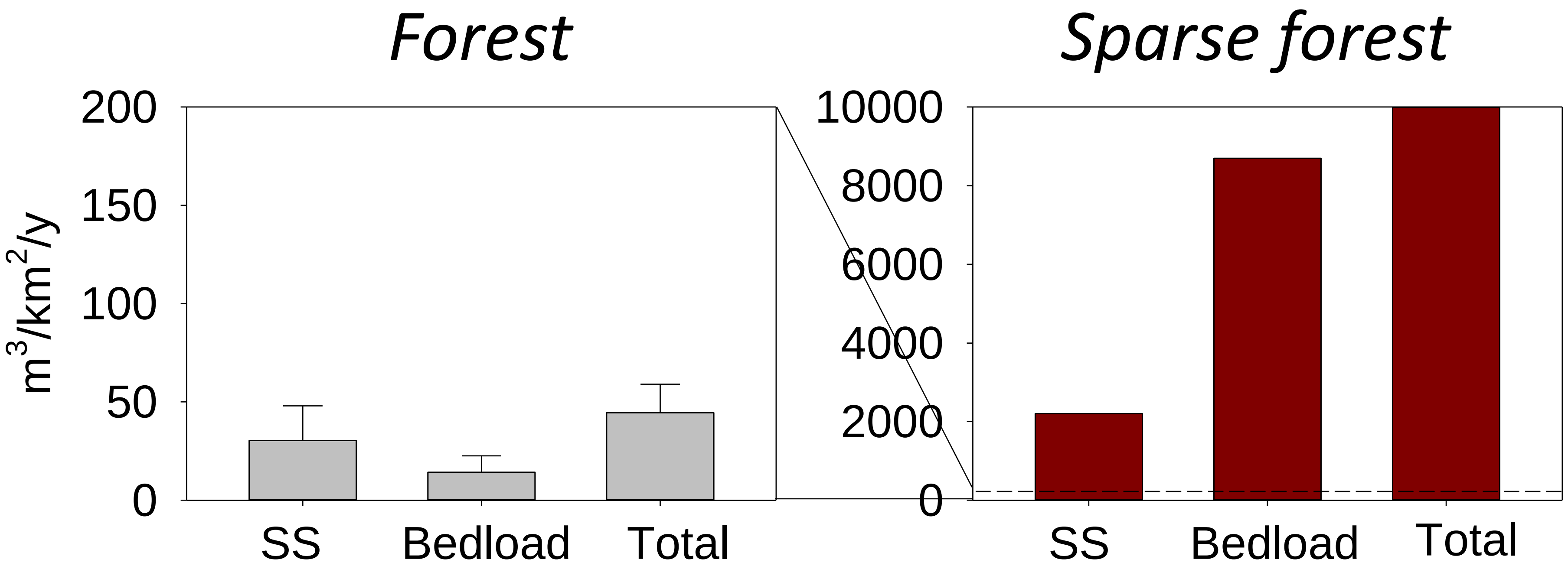


After *Tamura et al*. (2014)



After *Tamura et al*. (2016)

Annual amounts of sediment transport

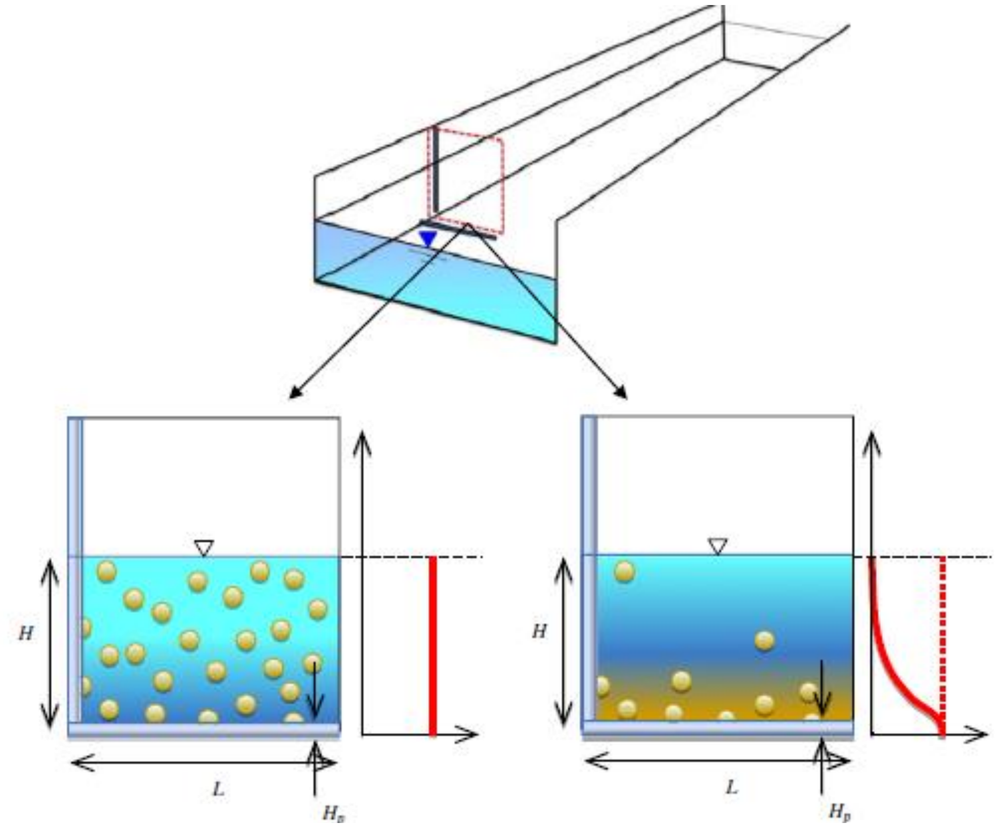


- Monitoring results revealed remarkable impact of plantation and erosion control works.
- Bedload transport was dominant in the sparse forest, while SS was dominant runoff process in the forested catchments.

Problems of monitoring: Bedload

1. Noise of the stream water hides signals of fine particles.
2. Multiple bedload hitting a pipe can cause underestimation of the measured transport rate.
3. Saltating bedload potentially results in underestimation.
4. A single pipe is insufficient to involve cross-sectional distribution of bedload transport.

Combination of vertical and horizontal pipes



Homogeneous distribution

Practical distribution

Tsutsumi et al. (2018)

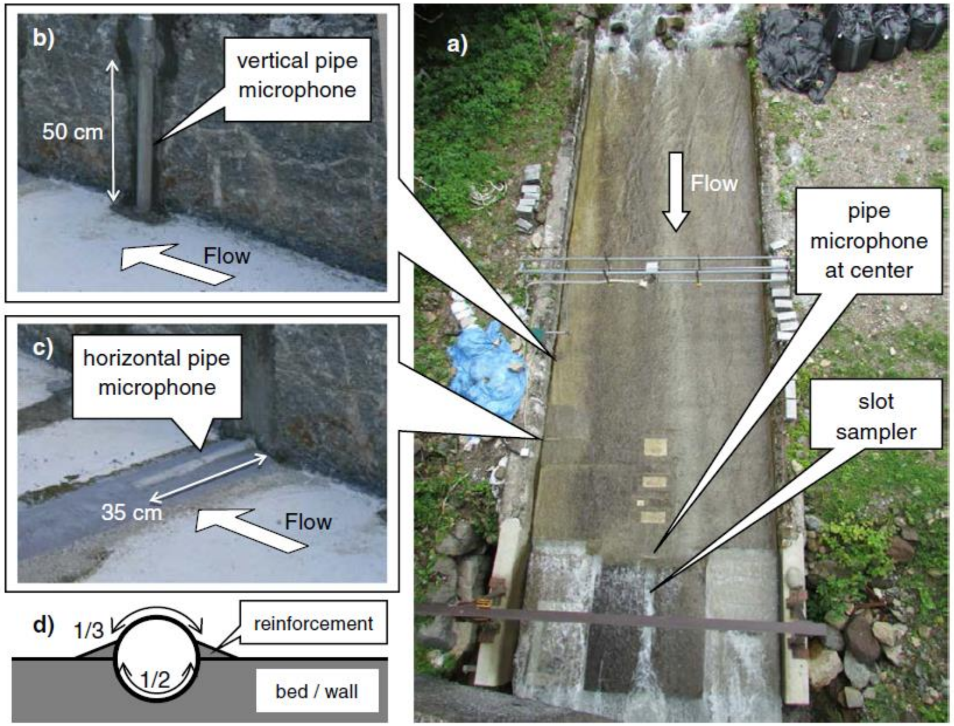
Ratio of Acoustic energy by vertical and horizontal pipes

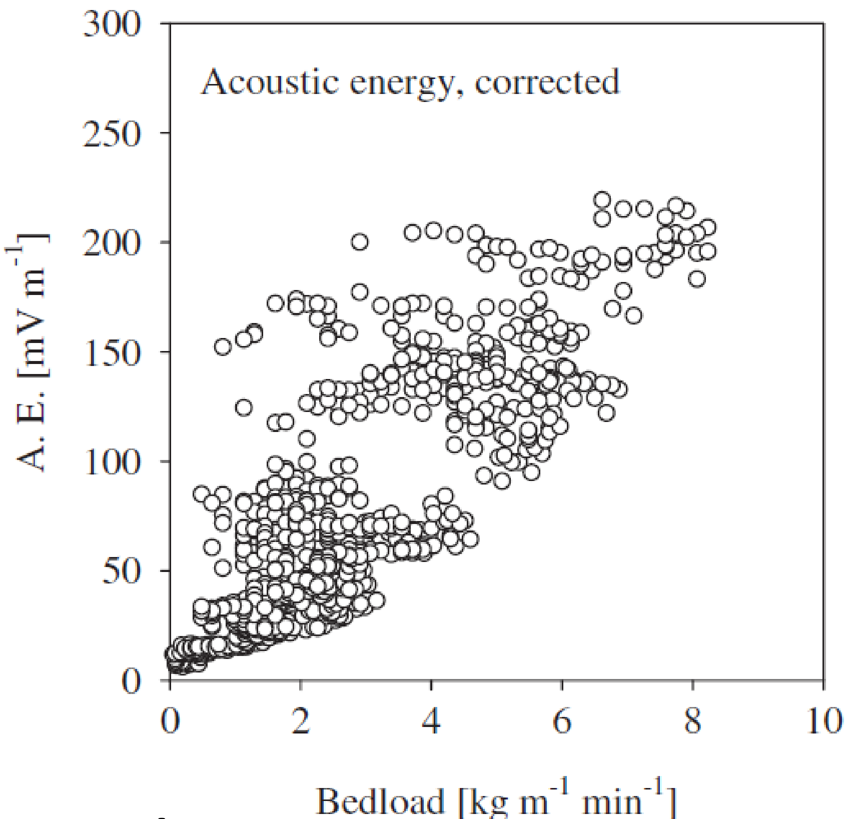
$$R_{hv} = \frac{A_v}{H} \Big/ \frac{A_h}{L}$$

Total acoustic energy through the cross section

$$A_t = R_{hv} \frac{H}{H_p} A_h$$

Effects of the combination





This approach can calculate total acoustic signal by bedload transport including saltating bedload.

Tsutusmi et al. (2018)

Problems of monitoring: Suspended sediment

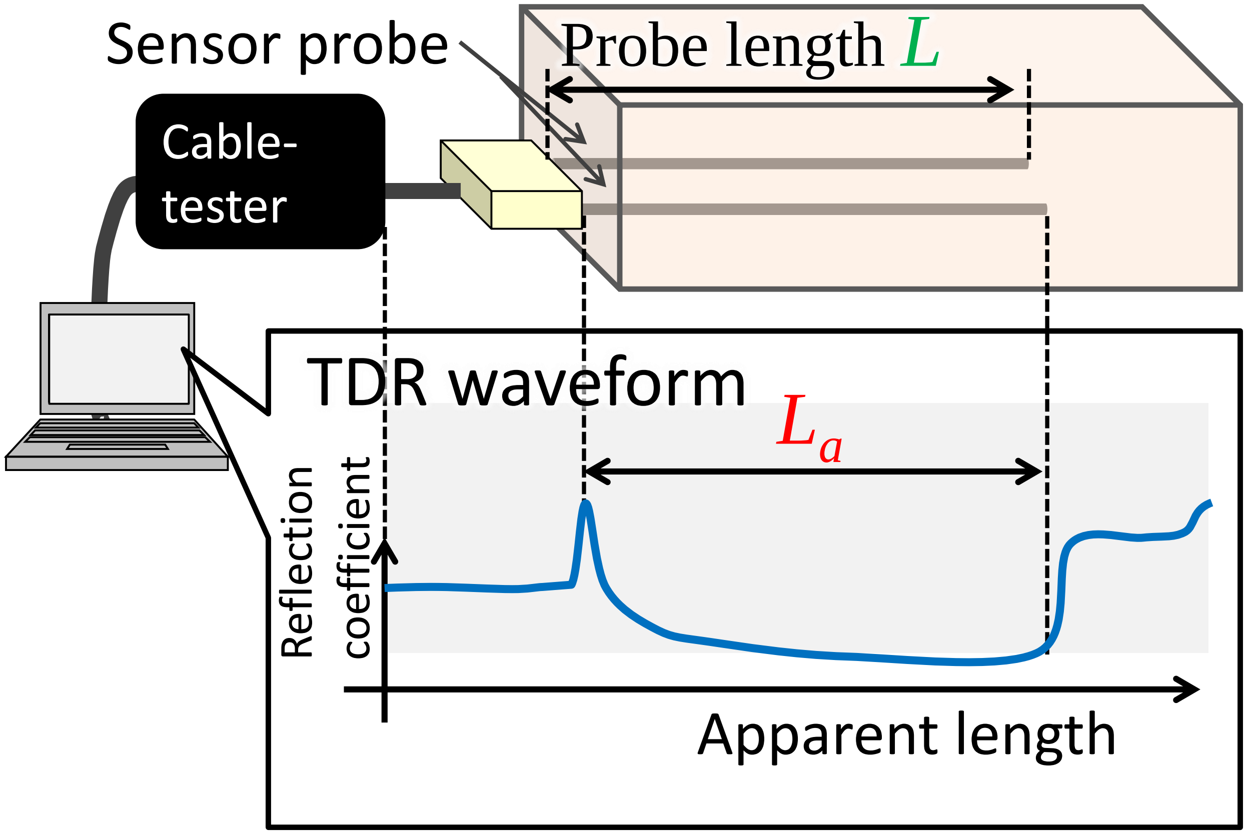
I. Common turbidity sensors are effective to wash-load. Courser suspended load is not reasonably measured by the turbidity.

II. Monitoring of a single turbidity sensor can not catch vertical distributions of concentration.

III. Frequent elevations changes of riverbed and stream surface in mountain rivers may cause malfunction of sensors.

Application of TDR (time domain reflectometry) to sediment concentration measurement

1. Measurement of dielectric constant ε_{obs} using TDR

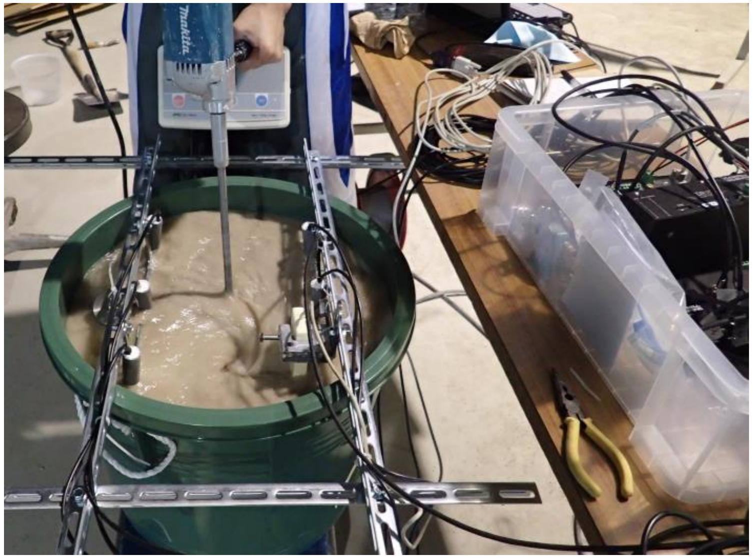


$$\varepsilon_{obs} = \left(\frac{L_a}{L V_p}\right)^2$$

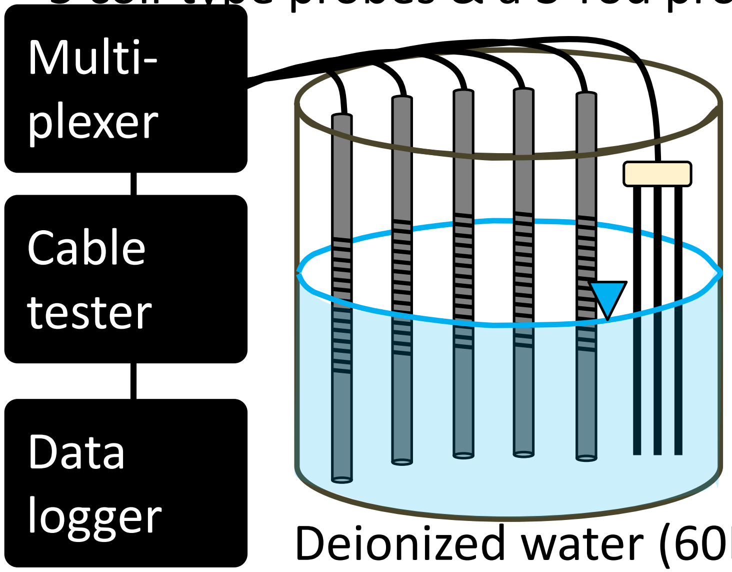
2. Calculation of ratios of water (ε_w=80) and sand (ε_s=3)

$$\sqrt{\varepsilon_{obs}} = (1-\theta)\sqrt{\varepsilon_w} + \theta\sqrt{\varepsilon_s}$$ 〈Dobson et al. (1985)〉

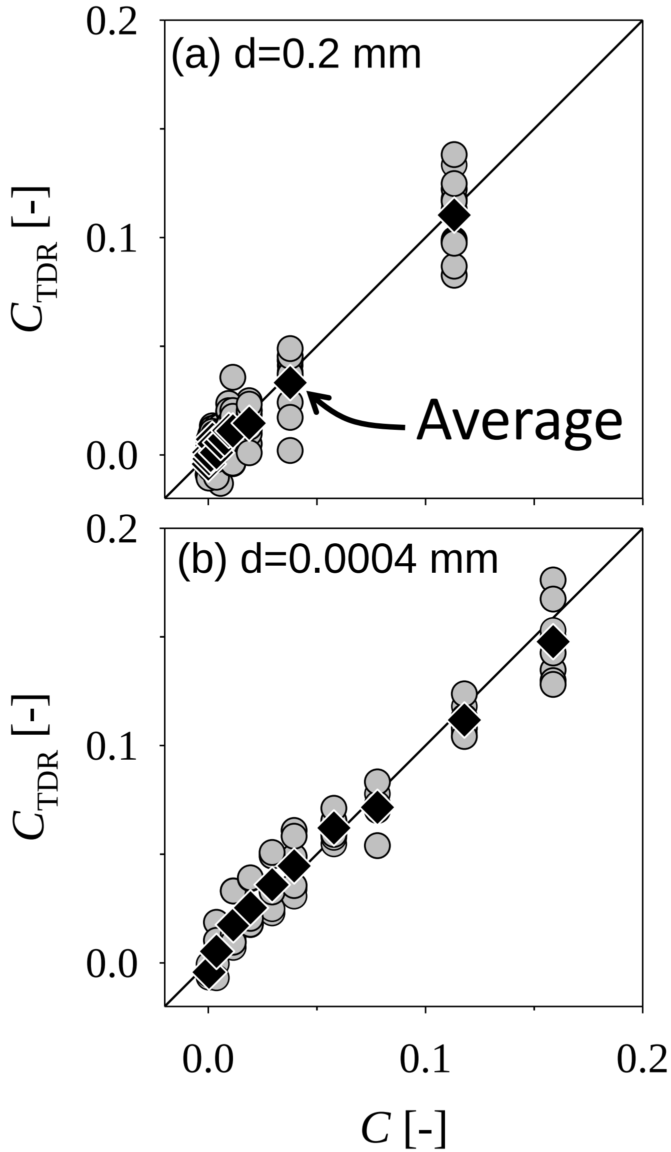
Lab. experiment for validation



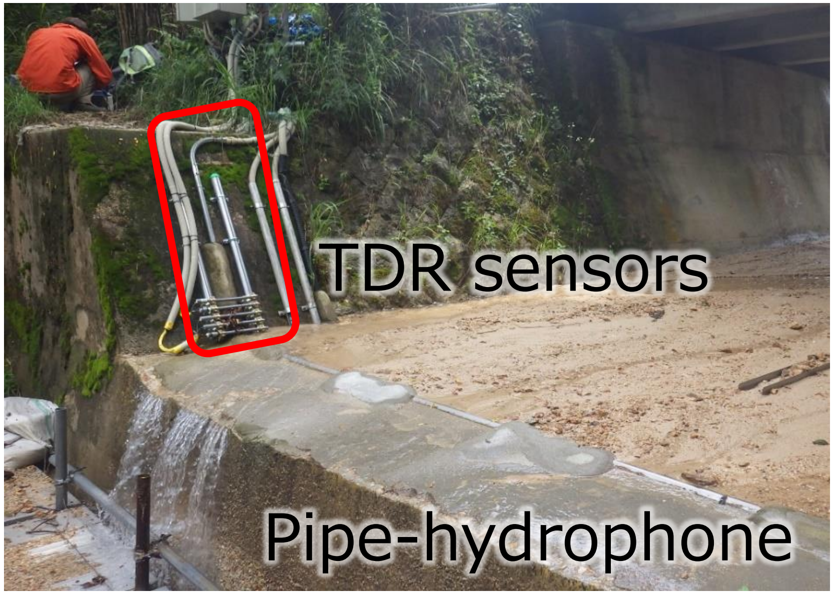
5 coil-type probes & a 3-rod probe



Deionized water (60L)

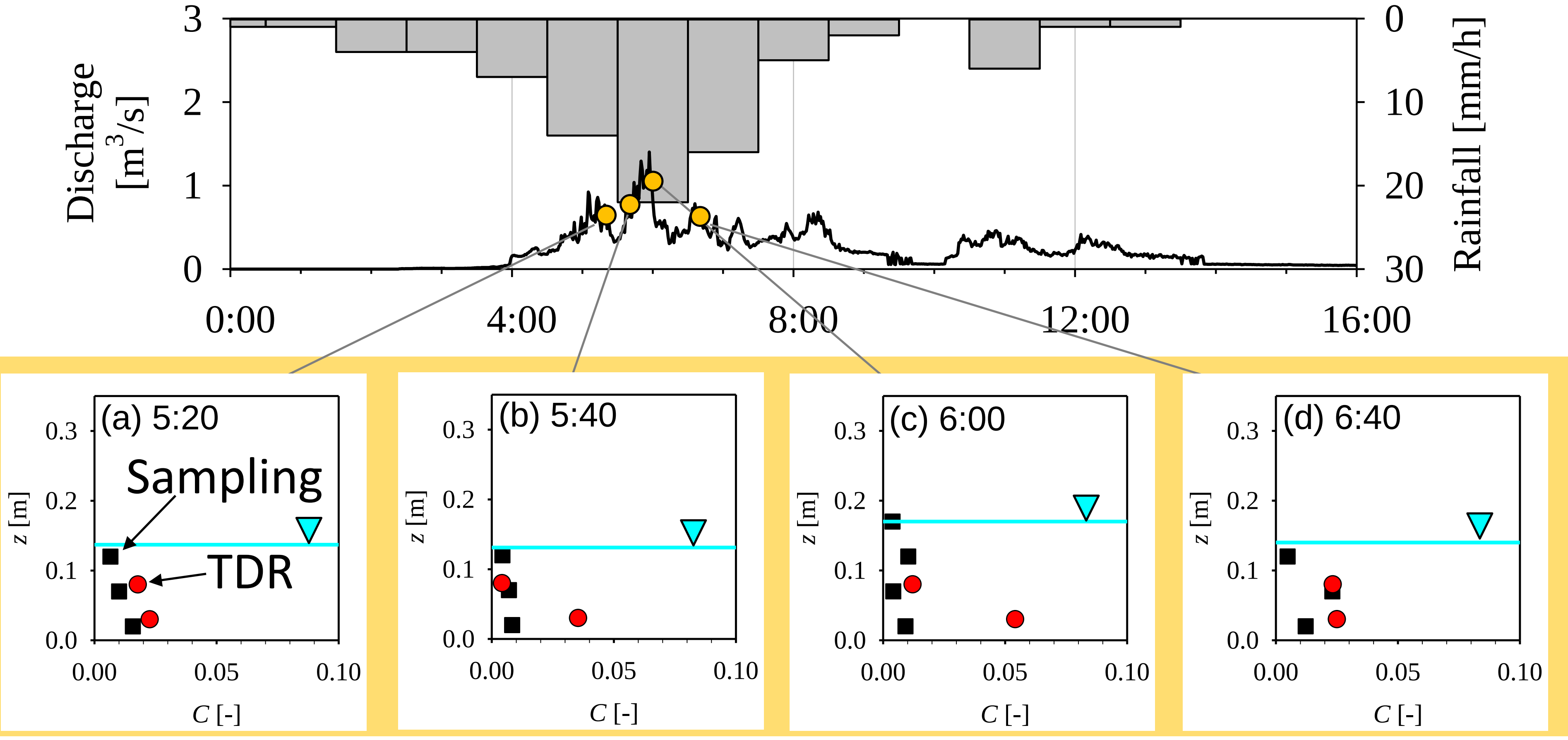


Monitoring at the sparse forest catchment



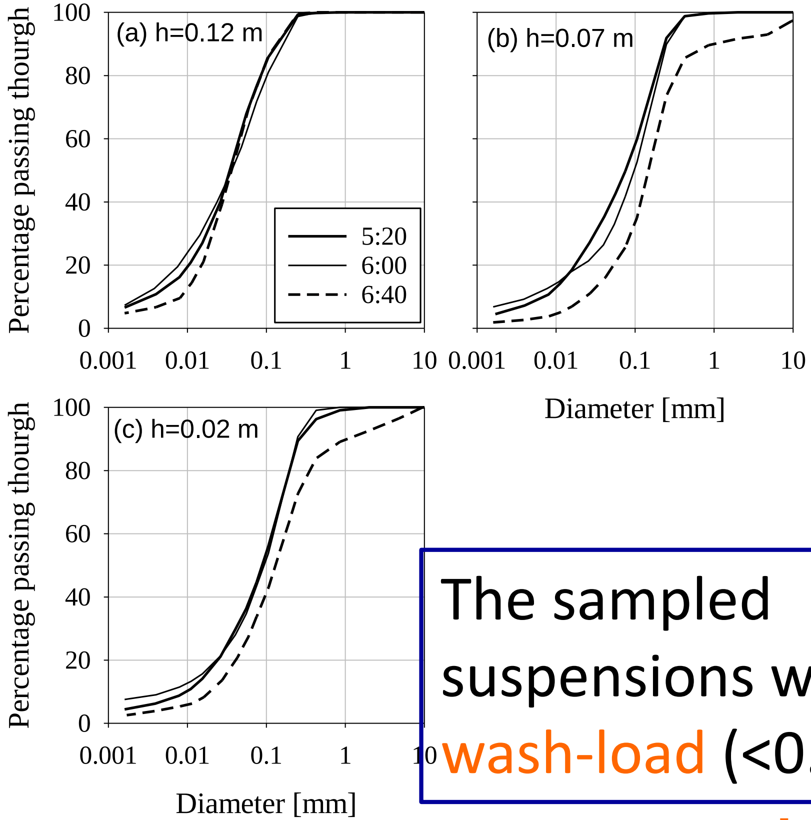
- Sediment concentration by TDR
  Heights of 0.03 - 0.23 m
- Sampling at various heights for suspended load
  Heights of 0.02 - 0.15 m
- Water level, Turbidity

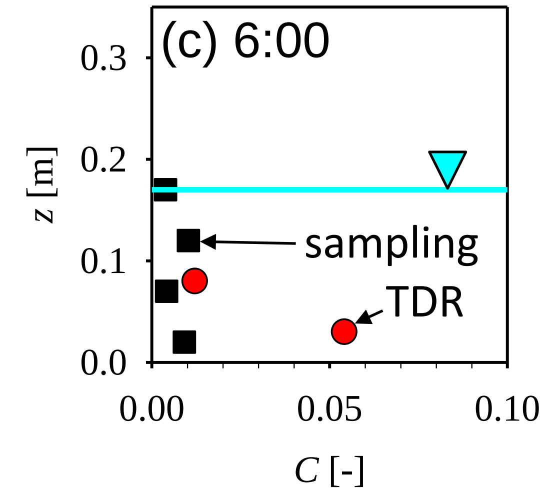
Comparisons between sampling and TDR during a storm in June 2017



- Sediment concentration: TDR > Sampling.
- Vertical profiles (higher at the bottom) were found.

Particle size distributions of sampled suspensions





The sampled suspensions were almost wash-load (<0.1mm).

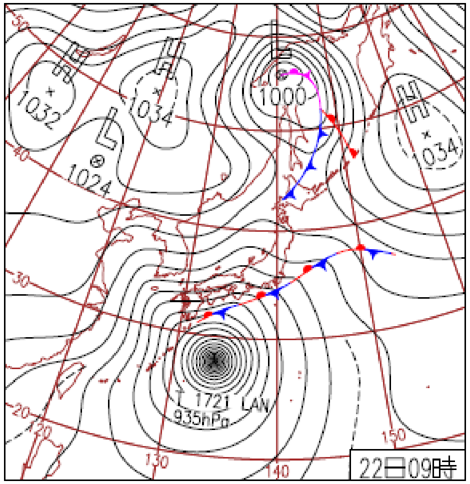
Concentration:

TDR > sampling

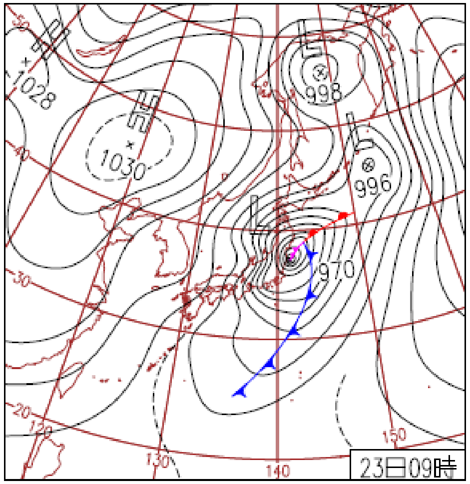
*Remarkable at the bottom.

The sediment concentrations by the TDR method was the sum of wash-load and suspended sediment.

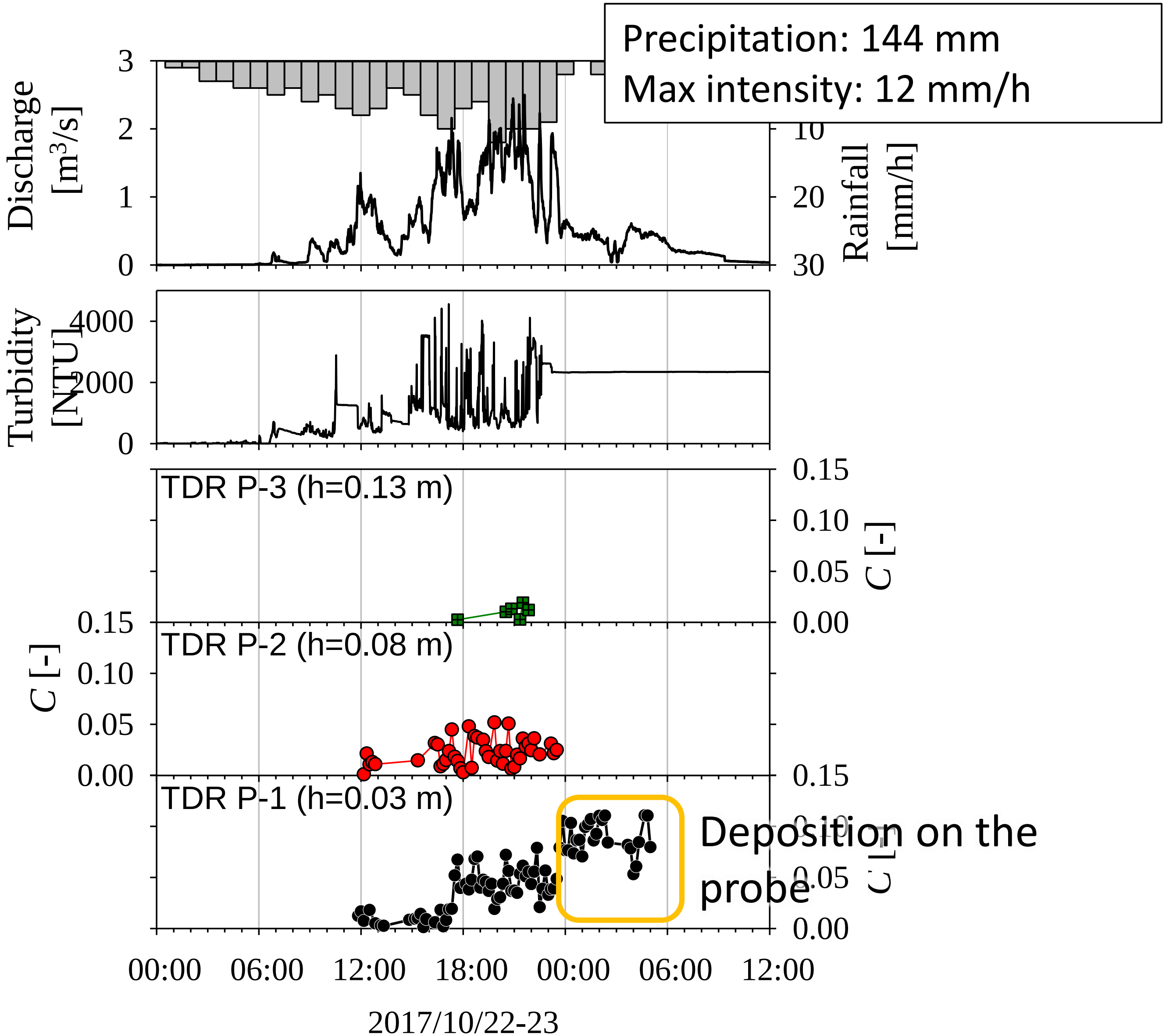
Heavy storm event in Oct. 2017



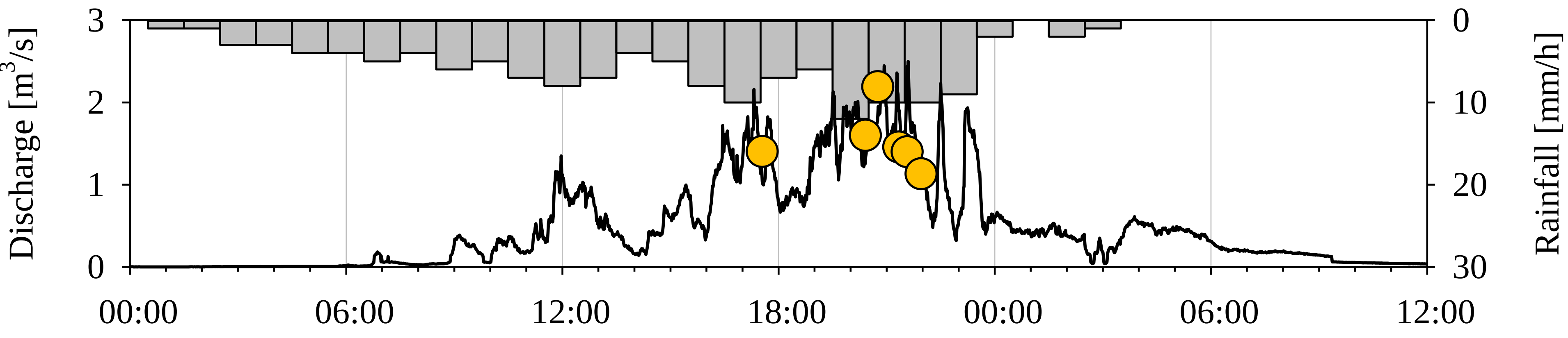
22日(日)台風加速して本州接近

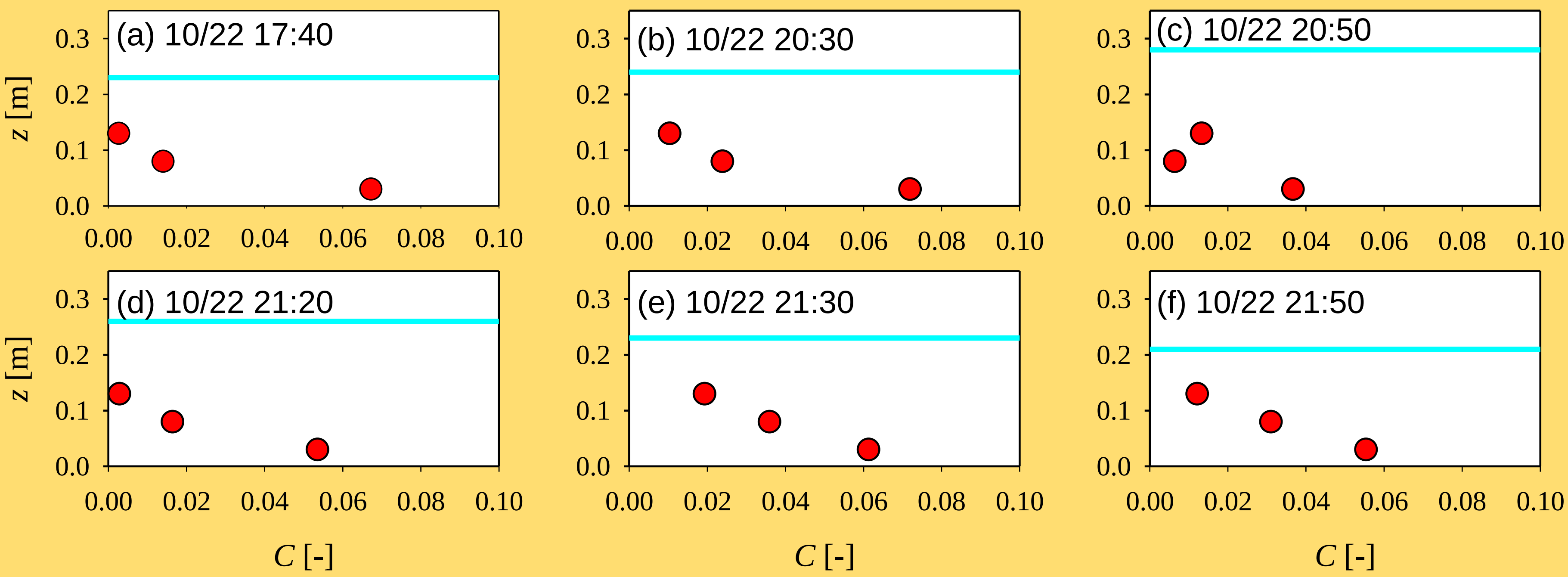


23日(月)台風第21号静岡県上陸

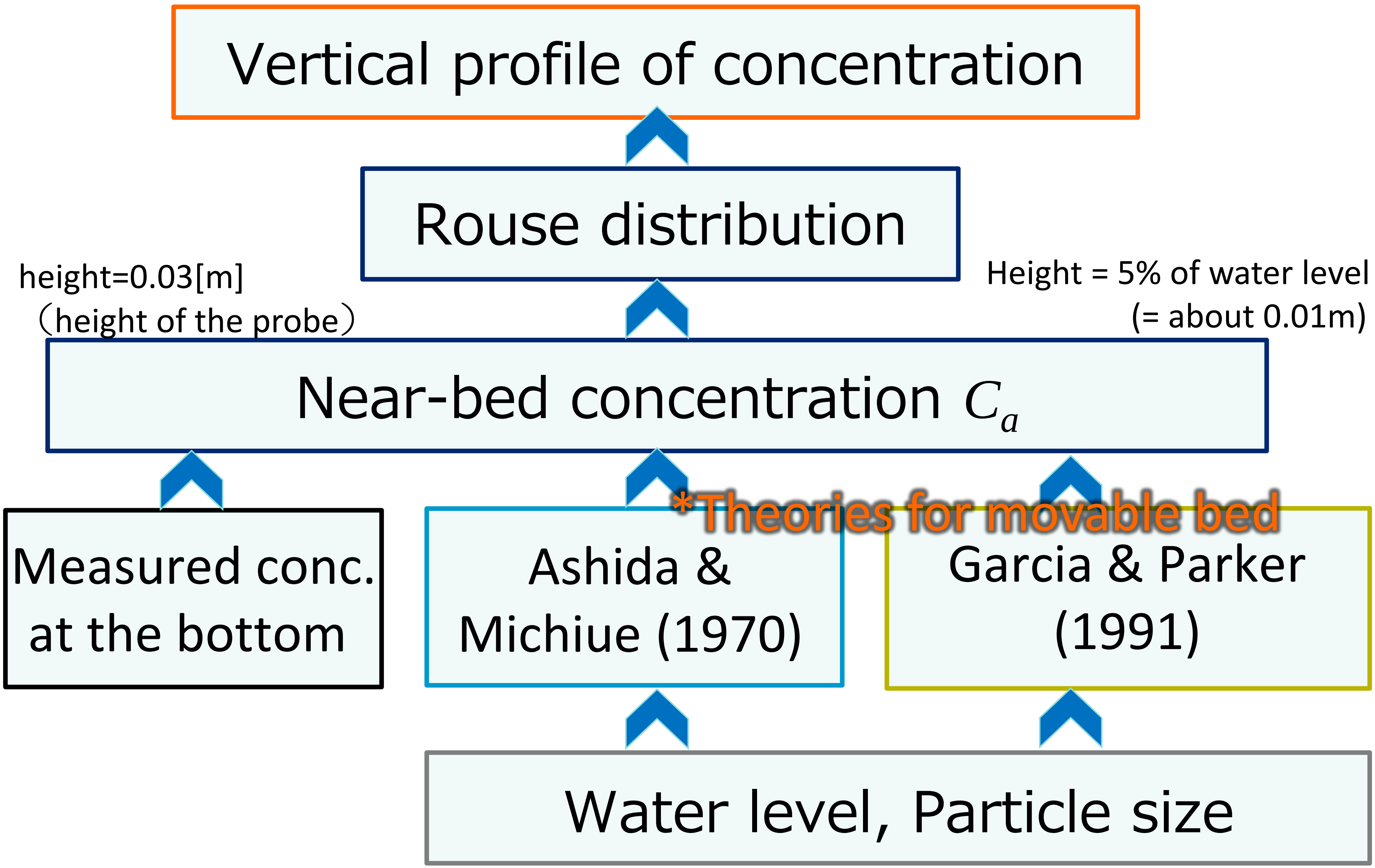


Vertical profiles of concentration

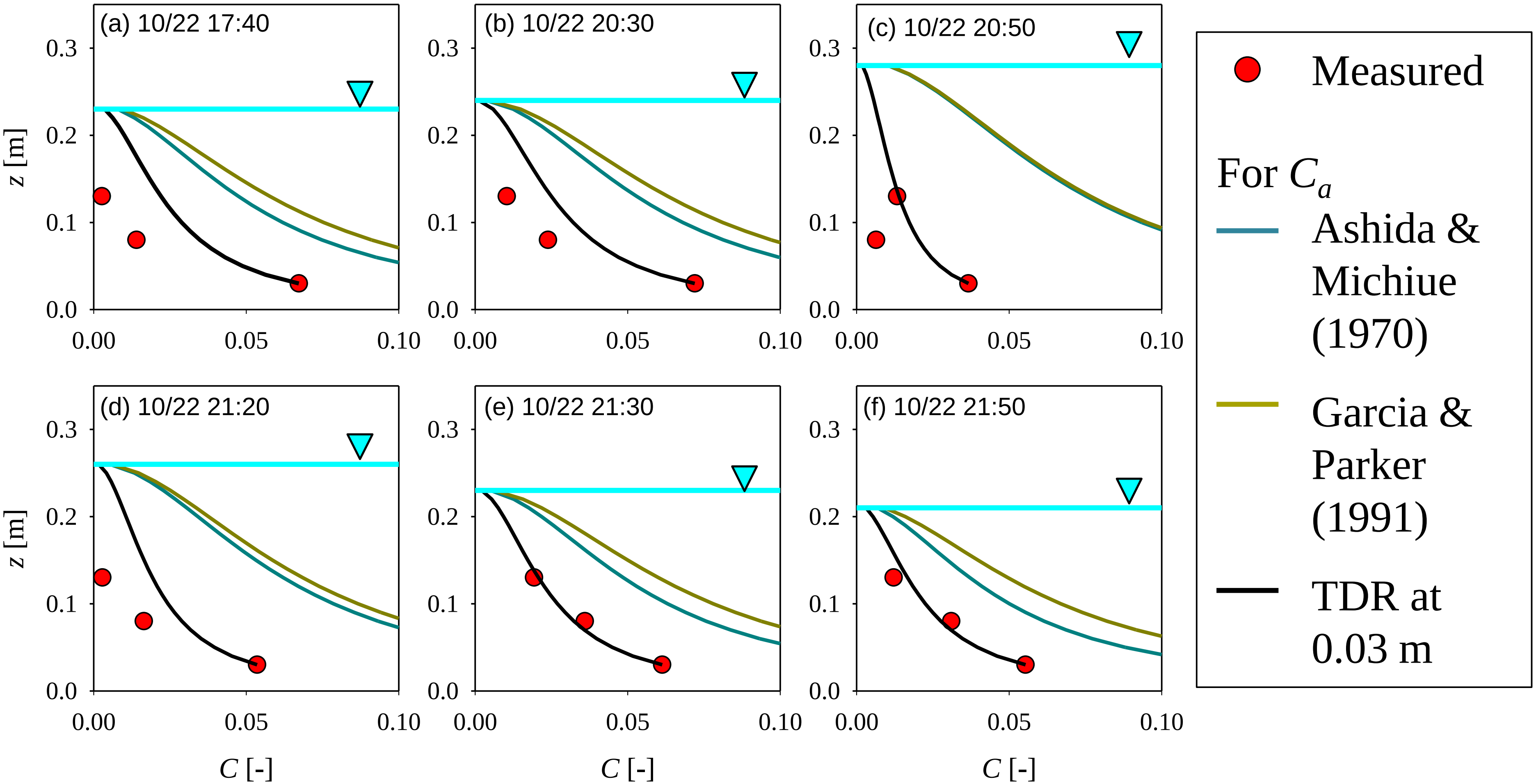




Modelling of concentration profile

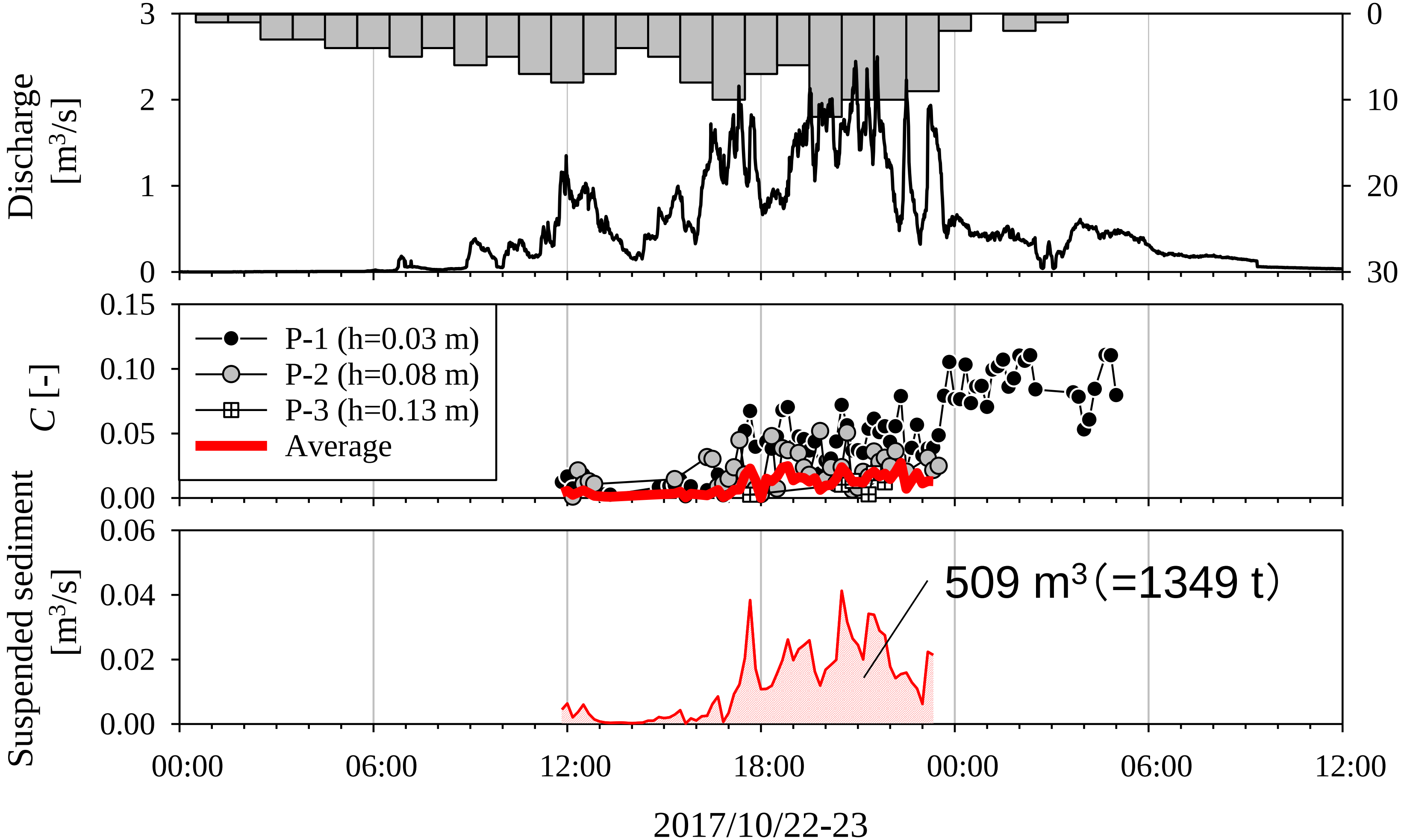


Calculated and measured profiles



Rouse distribution with the measured near-bed concentrations showed better fitting with the observation.

Runoff of suspended sediment during the event

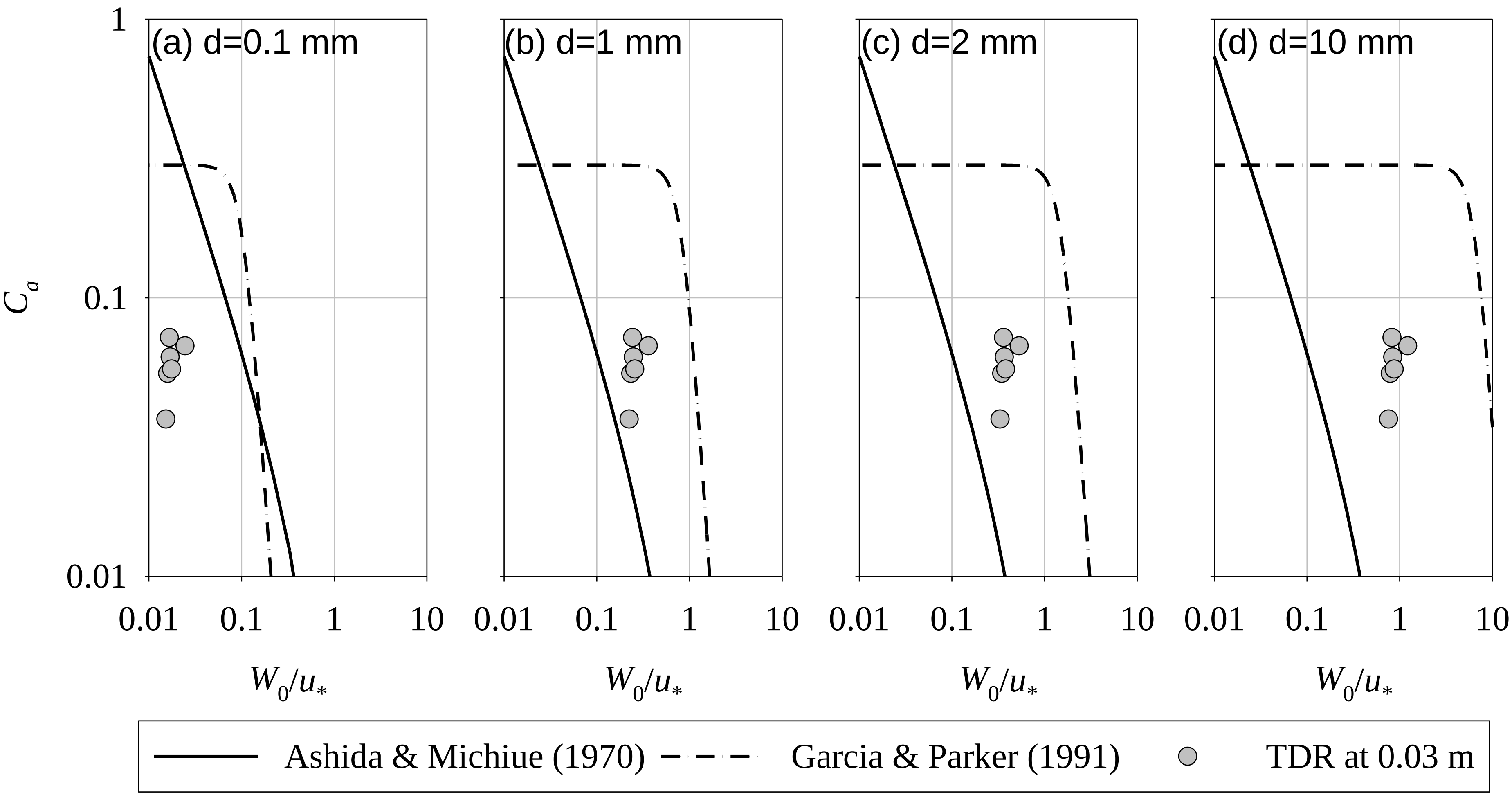


Averaged concentration and SS transport can be calculated when concentrations at the near-bed height were obtained.

Summary

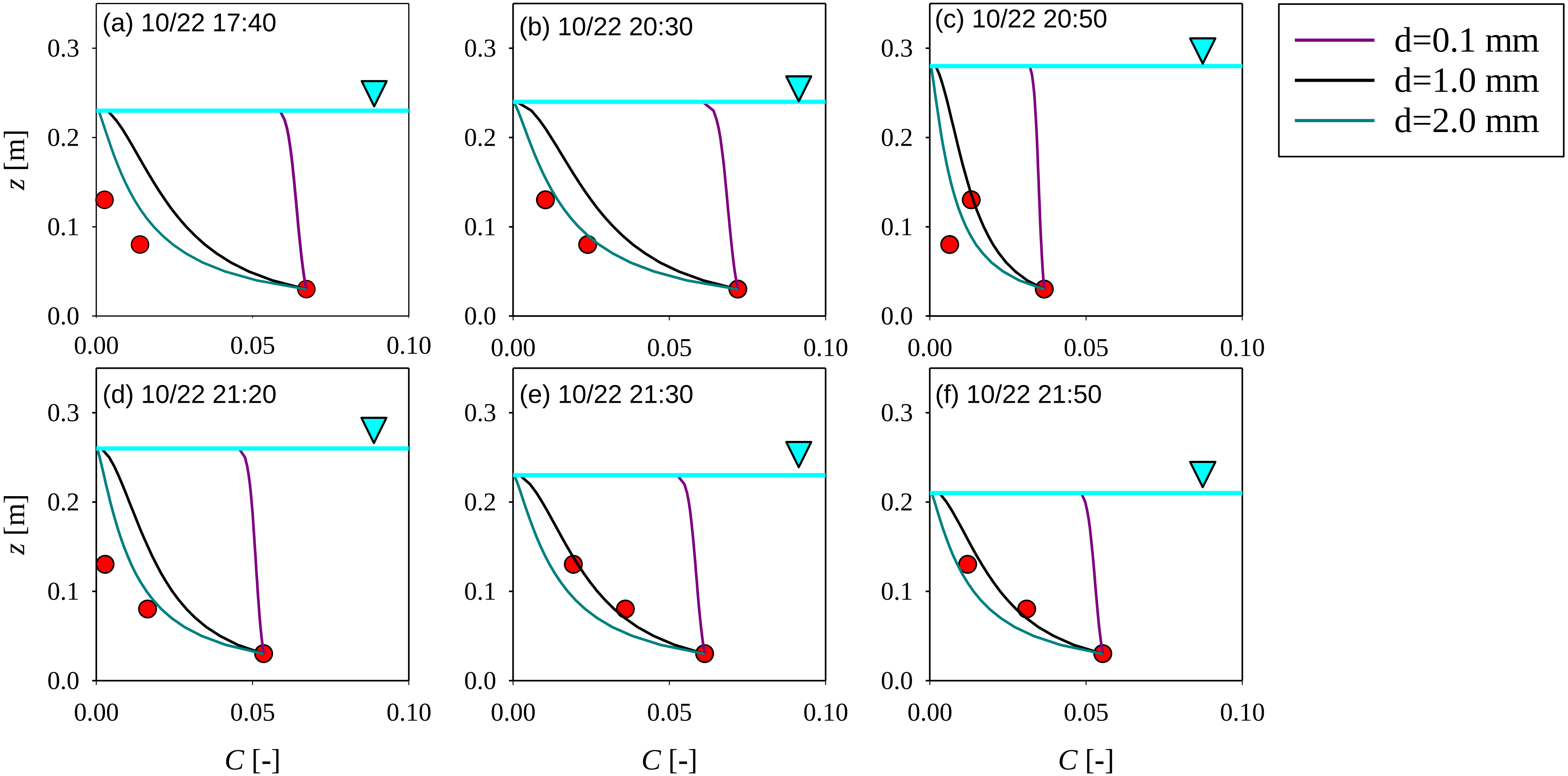
- In Japanese mountain rivers, standardized sediment monitoring systems are established.
- Sediment runoff data in 60 stations have been collected and analyzed to understand characteristics of each catchment and/or detect mass movement in the upper reach.
- Monitoring methods of bedload and suspended load are improved.

Measured (TDR) and calculated C_as



*W_0/u_* was calculated using hydraulic conditions at each time.

Effects of particle size



The profiles during the high discharges were well simulated with d= 1.0 mm.