Dynamic calibration of tipping-bucket rain gauges and flow meters for precise measurements of rainfall partitioning

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Tipping-bucket rain gauges (TBRGs) and flow meters (TBFMs) are widely applied to measure gross rainfall (*GR*), throughfall (*TF*), stemflow (*SF*) and other water fluxes, including outflow from trenches (e.g., Freer et al., 2002; Liang et al., 2011; Iida et al., 2017). However, it is well known that TBRGs and TBFMs commonly underestimate the inflow of water (e.g., Edwards et al., 1974). Basically, these instruments measure the inflow of water by counting tips of buckets. Thus, if water flow continues during bucket tipping, a certain amount of water is not captured by the bucket, and finally is underestimated (e.g., Iida et al., 2020). To evaluate the inflow of water precisely, calibration of TBRGs and TBFMs is required. We recently tested eleven types of TBRG and TBFM based on the dynamic calibration procedures (Shiraki and Yamato, 2004; Iida et al., 2012), and obtained the calibration curves (Iida et al., 2012; 2018; 2020; Shimizu et al., 2018). In this presentation, we show the simple and handmade equipment necessary to generate constant inflow of water, and the difference in calibration results among various TBRGs and TBFMs. Finally, the effects of applying dynamic calibrations on measurements of rainfall partitioning into interception loss ($I = GR - TF - SF$) are investigated.

We calibrated three TBRGs (0.2 mm tip, type RG-3M [Onset Computer Corp.] and type Rain Collector II [Davis Instruments]; 0.5 mm tip, type OW-34-BP [Ota keiki seisakusho Co., Ltd.]), and eight TBFMs (50 mL tip, type UIZ-TB-50; 100mL tip, type UIZ-TB-100; 200 mL tip, type UIZ-TB-200; 500 mL tip, type UIZ-TB-500 [Uizin Co., Ltd, Tokyo.], 200 mL tip, type TXQ-200; 400mL tip, type TXQ-400 [Ikeda keiki seisakusho Co., Ltd.], and 500 mL tip [Yokogawa Electric Corp.]) (Iida et al., 2012; 2018; 2020; Shimizu et al., 2018). At first, the static amount of one tip (c) was determined. We dripped water into the bucket with an injector until it tips. Then, c was calculated as the difference in mass of injector between initial and final conditions. Constant inflows of water (q) with different intensities were generated by the handmade equipment and applied to various TBRGs and TBFMs. We measured the time interval between tips (t), and obtained the actual amount of one tip (v) as the product of q and t. We derived the scaled amount of tip ($V = v/c$) and inflow ($Q = q/c$) as dividing them by the static amount of tip (c) (e.g., Shiraki and Yamato, 2004).

The relationships between Q and V were fitted reasonably by quadratic equations for all TBRGs and TBFGs (Iida et al., 2012; 2018; 2020; Shimizu et al., 2018). Rain Collector II and UIZ-TB-100 showed the largest underestimation among TBRGs and TBFMs, respectively, and 10% underestimation was detected when $Q > 0.14$ (s^{-1}) and $Q > 0.12$ (s^{-1}), respectively. The calibration curves for 7 of 8 TBFM lay within ±2% of that of TXQ-400 when $Q < 0.2$ (s^{-1}) (e.g., Shimizu et al., 2018; Iida et al., 2020). Thus, there are some possibilities that most types of TBFMs have similar calibration curves with TXQ-400 (Shimizu et al., 2018). By applying the calibrations, effects on the interception loss (I) ranged from -20% to +4% (Iida et al.,

2018). Therefore, to evaluate *I* precisely, the application of dynamic calibrations on *GR*, *TF* and *SF* measured by TBRG and TBFM are highly recommended.

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