Easy method to establish the dispersion relation of capillary waves on water jets - Supplementary Material B.

Wout M. Goesaert Bsc.* and Dr.ir. Paul S.W.M. Logman†

Leiden Institute of Physics, Niels Bohrweg 2, 2333 CA Leiden, The Netherlands

(Dated: September 25, 2023)

I. ACCURACY OF TWO ALTERNATIVE (SIMPLER) METHODS FOR STUDENTS

To produce the results in this article, code was written to perform precise image analysis. This Python code can also be found in the online supplementary material.

However, undergraduate students may not have the skills to automatically process the images and distill the radius and wavelength of the capillary wave automatically from those images.

Students may instead use an easier way to measure the radius of the jet wave to calculate the stream velocity v_{stream} via the second equation in the paper. It does not matter whether students measure the radius of the jet wave via the mean of the minimum and the maximum of the wave or via the mean of the sinusoidal wave for most wavelengths (see the red markings on the second figure in the paper for a visualization of both methods). However, for long wavelengths, a deviation is introduced of maximally 4% at $\lambda = 3.57 \pm 0.06$ mm (see Fig. 1).

Students may also choose to determine the wavelength of the capillary waves by means of directly analyzing digital photographs instead of writing a program to do this for them. This way, an error of up to 30 % may be introduced for the shortest wavelengths (see Fig. 2). The errors for both the radius and the wavelength would however not account for the observed deviation from the theoretical dispersion relation in this article, since that deviation is larger. The easier measurements by directly analyzing digital photographs are found to result in smaller uncertainties. However, they are also more susceptible to biases.

* w.m.goesaert@umail.leidenuniv.nl

† logman@physics.leidenuniv.nl

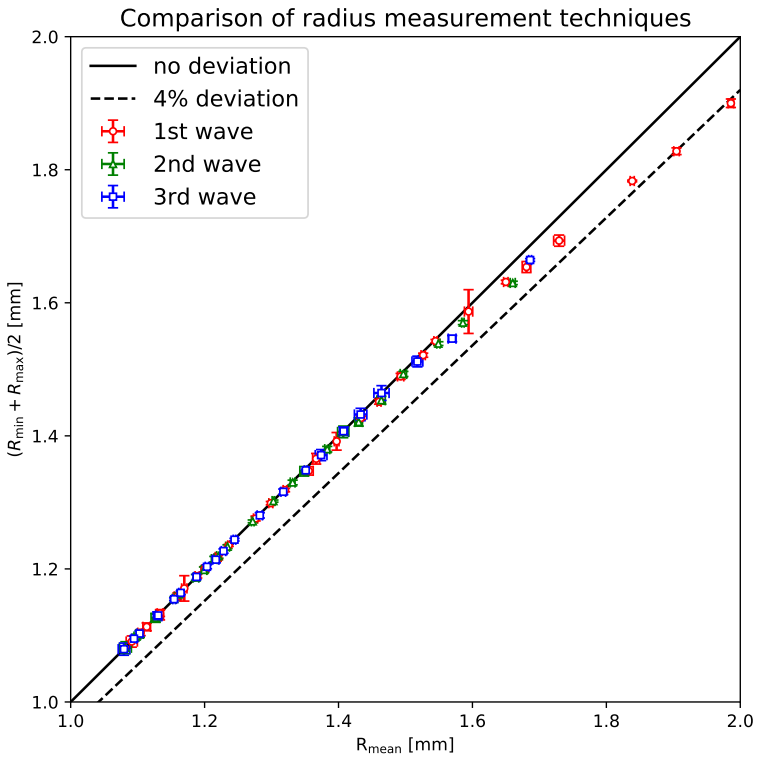

FIG. 1. Comparison of two methods for measuring the radius of the water stream over a wavelength. Each data point consists of 9 radius measurements. The small size of the introduced systematic error shows that students can use the easier to perform minimum-maximum method instead of taking the mean over the whole wave.

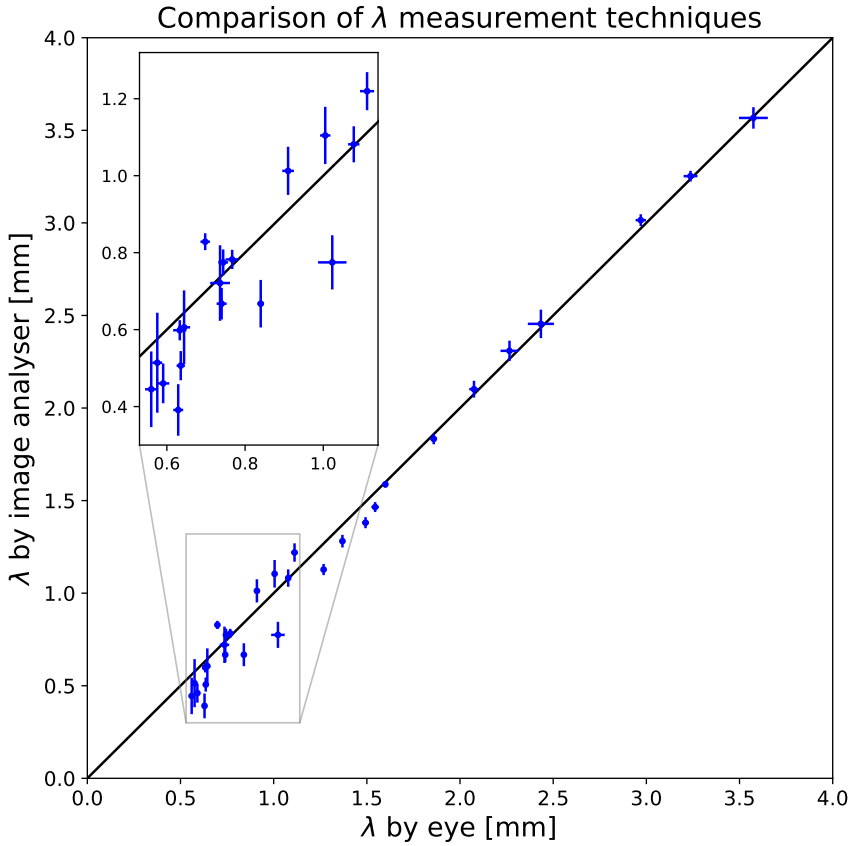

FIG. 2. Comparison of two methods for measuring the wavelength. Each data point consists of 18 measurements. A deviation is observed at the shortest wavelengths that is weakly significant.