Simultaneous high-resolution LIF measurements of dissolved gas concentration fields and measurements of wave slope at a wavy free water surface with wind-induced turbulence

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Wind-generated surface roughness is a severe experimental problem for LIF measurements as the illuminating laser light sheet is subjected to focusing and defocusing effects caused by light refraction at the varying curvature of the water surface. Leaving these effects uncorrected leads to wrong estimates of gas concentration, therefore, simultaneous measurement of local gas concentration and local surface orientation is required in turbulence studies at rough water surfaces.

1. Method

In this study we present a significantly improved LIF technique that is suitable for high-resolution measurements of dissolved gas concentration fields in a vertical plane oriented in wind-direction close to a wavy water surface in wind/wave facilities. Our approach extends the earlier work of Münsterer et al. (1998), who used an acid gas (HCl) and a fluorescent pH indicator to visualize the concentration fields of dissolved gases in water.

![Fig. 1 Raw data LIF-image sections; imaged area 35 x 14 mm, pixel resolution 25 micrometer; segmented water surface marked with white-dashed line; the wind blows from right to left, fetch 1.6 m. The distorted image above the water surface is caused by total reflection at the wavy water surface.](image)

2. Advancement

In the present study on wind-induced turbulence, a LIF measurement setup is introduced with three significant improvements: Firstly, the fluorescent pH-indicator 8-hydroxypyrene-1,3,6-trisulfonic acid trisodium salt (HPTS) is used instead of fluorescein. HPTS offers a larger Stokes-shift of 53 nm and higher photo stability as compared to fluorescein, (Falkenroth et al., ISFV 12, Göttingen, 2006). Secondly, the optical resolution is improved by an optimized setup. Aberrations are minimized by observing the vertical illuminated sheet through a tilted side window with the optical axis perpendicular to this window in a Scheimpflug arrangement. Thirdly, the intensity of the vertical light-sheet - illuminating from above - is varied randomly in horizontal direction (Fig. 1) to achieve a non-uniform light sheet. In this way, the horizontal position is coded as a varying structure. These vertically oriented patterns allow to determine the along-wind slope of the short wind waves.

It is also possible to correct for the intensity variations resulting from the above mentioned focusing and defocusing effects. Figure 1 indicates that these distortions are not significant close to the water interface with distances up to about ten times the thickness of the thin mass boundary layer, which is important for determination of fluctuations within the mass boundary layer. Gas concentration gained from LIF profiles in greater depth, however, have to be corrected for these effects. Therefore the additional evaluation of the surface slope, from LIF raw data enables the extraction of reliable gas concentration fields close to the water surface even at a wavy surface with high surface curvature.

A series of measurements was performed in a small linear wind/wave tunnel, which has been constructed for these measurements with the previously described tilted observation windows. The water segment is 4 m long, 32 cm wide and 9 cm deep. It has a gas-tight closed air circulation with a total air volume of 3 m$^3$ and is coated with PTFE for usage of highly reactive species.

Measurements were carried out with wind speeds ranging from 1 to 8 m/s and at fetchs between 0.4 and 2.0 m. The image sequences were recorded with up to 67 frames per second and a resolution of 1400 x 1024 pixels, corresponding to a spatial resolution of 25 μm/pixel. Currently, a detailed analysis of the image sequences is underway.