

Scalar transport from a point source in flows over wavy walls

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The transport of a passive scalar from a point source in turbulent flows over wavy wall is investigated. The used flow channel facility consists of a train of 72 sinusoidal waves at the bottom surface and a flat top wall. The total length of the test section is 2160mm. A flat entrance section in front of the test section has a length of 2060mm. The wavelength is $\Lambda_w = 30\text{mm}$ and the amplitude-to-wavelength ratio equals 0.05. The height of the channel is $2h = 30\text{mm}$ and the channel has an aspect ratio of 12:1. This aspect ratio ensures measurements undisturbed by the side walls at the measurement location. At the measurement location the turbulent flow is fully developed. A ground level (flush-mounted) low momentum source is used which is located at the crest of the wave profile. Two different Reynolds numbers of $Re_b = 11200$ and $Re_b = 22400$ have been applied, based on the bulk velocity u_b , the total channel height $2h$, and the kinematic viscosity ν . Measurements are performed by using a highly spatial resolving planar laser-induced fluorescence technique for the concentration field and digital particle image velocimetry to assess the velocity field. Rhodamine B is used in aqueous solution as tracer dye. The measurements are performed in three different orthogonal planes, with the normal of the planes in the streamwise, spanwise and wall-normal direction. The area-of-view in all measurement planes covers at least one wavelength in either direction.

An instantaneous realization of the scalar field at a Reynolds number $Re_b = 11200$ is shown in Fig. 1. The scalar distribution is governed by packets of fluid with a high concentration of the tracer in the vicinity of the source at the downslope of the wave profile. Along the wave profile, these packets disintegrate into filament-like structures.

The flow field is characterized by a recirculation zone at the downslope of the wave profile. The flow separates shortly after the wave crest, whereas the point of reattachment depends strongly on the Reynolds number. For increasing values of the Reynolds number the point of reattachment moves from shortly behind the wave trough along the upslope of the wave profile. The large-scale structures prevailing in the flow field meander lateral.

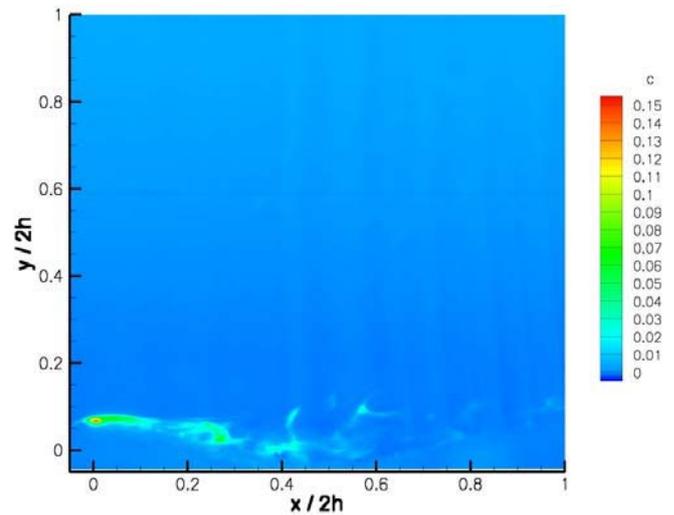


Fig. 1. Instantaneous concentration in the (x,y) -plane at $Re_b = 11200$. The concentration values are normalized with the source concentration c_0 . The point source is located at $x/2h = 0.0$, $y/2h = 0.05$. The image covers the total height of the channel.

For the present case the Schmidt number of the tracer dye is $Sc > 2000$. Therefore, the scalar distribution is mainly governed by the turbulent transport rather than the molecular diffusion. The large-scale structures of the flow field are of main importance for the scalar transport. The lateral meandering of these large-scale structures causes a lateral meandering of the scalar plume. These results in a higher spreading rate compared to a scalar plume in a plane channel flow.

The wavy wall increases the turbulence intensity – characterized by the root-mean-square fluctuations – in the downslope region of the wave profile. Due to the higher turbulence intensity the scalar fluxes in the streamwise and wall-normal direction are also increased compared to a plane channel flow. As a result of the lateral meandering and the higher scalar fluxes induced by the wavy wall, the mixing rate of the scalar is increased.