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## Spectral analysis of a forced turbulent bubbly flow

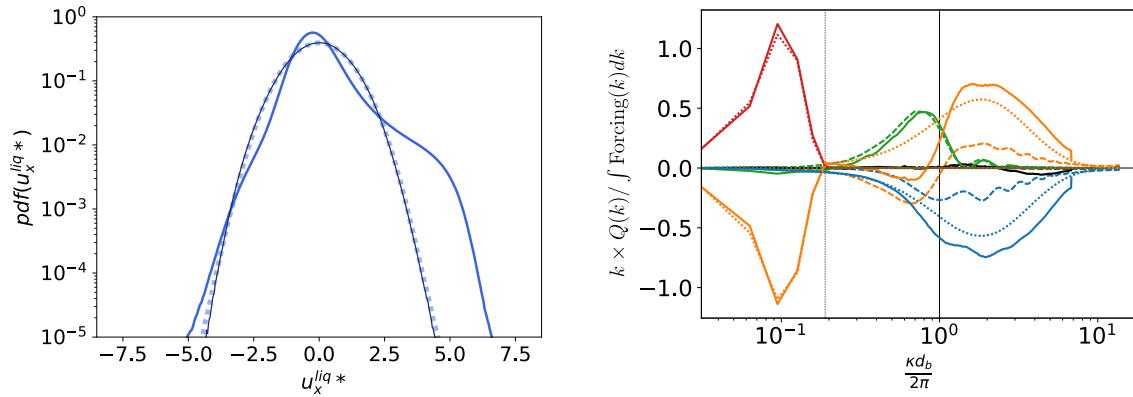
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A close look at the interaction between bubble-induced agitation and a turbulent flow forced at large scales is necessary to identify the key mechanism at play in the kinetic energy budget<sup>1</sup>. It is of an especially strong interest for the Euler-Euler two-fluid RANS modeling to correctly capture the level of turbulent kinetic energy in the flow as its value is used as an input in other models. Several models with more or less complexity have been proposed with, for instance, an additional source terms in two-equations models<sup>2</sup> or Reynolds-stress-based models<sup>3</sup>. However, all these models still lack a proper breakdown of the mechanisms by which fluctuations are produced.

To disentangle the origin and effect of those fluctuations and improve modeling, we performed numerical simulations of bubbly flows using a one-fluid Navier-Stokes solver and a front-tracking method in a triple-periodic domain. To produce turbulent bubbly flow, a large-scale forcing is added to the swarm simulations. Our objective is to characterise the scale-by-scale interaction between fluctuations. Three volume fractions are studied ([3, 6, 12]%) with a forcing equivalent to a  $Re_\lambda = 150$  flow. A precise parametrisation allows to place the bubble diameter at the bottom of the inertial range of the single-phase flow enabling a direct interaction.

The probability density function (PDF) of vertical velocity on Figure 1a shows that liquid velocity fluctuations in the coupled simulation (HIT, 3 %) is almost identical to the single phase forced simulation (HIT). The significant asymmetry of the bubbles-only simulation (3 %) is wiped by the forcing. But on Figure 1b, the scale-by-scale budget shows that the spectral signature of the bubbles still plays a major role in the dynamics of the fluctuations.

After detailing the simulation definition and post-processing procedure<sup>4</sup>, those results will be discussed with an emphasis on the RANS modeling consequences.



(a) PDF of the vertical velocity for the forcing-only (dotted), bubbles-only (plain large) and coupled (plain thin) simulations. The volume fraction is 3 %.

(b) Scale-by-scale spectral budget of the forced single-phase, the bubbles-only and coupled simulations. Red: production by the forcing term, green: production by buoyancy, orange: total transfer between scales, blue: dissipation term.

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<sup>1</sup>F. Risso, *Annual Review of Fluid Mechanics* **50** (2018).

<sup>2</sup>M. Colombo et al., *Nuclear Engineering and Design* **375** (2021).

<sup>3</sup>A. du Cluzeau et al., *Physical Review Fluids* **7** (2022).

<sup>4</sup>G. Ramirez et al., *International Journal of Multiphase Flow* **submitted** (2024)