Summary

The goal of this Thesis is to combine results from high-resolution numerical simulations with novel analysis methodologies to shed light on the characterizing processes of wall-bounded turbulence and transition. By exploiting large quantities of data and designing analysis frameworks that are able to leverage such data, new insights are gained on several aspects of wall-bounded turbulence. Among these methods, a particular relevance will be occupied by graph-based approaches, which we use to model certain fluid features as sets of interactions.

The results presented hereafter include mainly contributions from the Lagrangian viewpoint of fluid dynamics, *i.e.*, the viewpoint where the observer moves with the fluid. We used this approach to study the dispersion of tracers in channel flow at varying Reynolds number, which we analysed by means of a discretized representation of their motion which was in turn translated into a network. By doing so, the role of near-wall coherent structures and their influence on particle dispersion was quantified. Moreover, Reynolds scaling properties were measured and a Reynolds independence was found in the outer flow.

The mixing of inertial particles was also studied in channel flow. In this case, mixing was quantified by measuring close encounters of particle pairs. In particular, the relation between the spatially heterogeneous timescales of the flow and the inertia of particles was explored, showing that clustering phenomena do not appear at the same locations for different particles, but instead are dependent on the position inside the channel.

Finally, the deformation of puffs in a transitional channel flow was studied. The numerical simulation of transition involves a spatially evolving flow, which is laminar with wave-like perturbations at the inlet and turbulent at the outlet. Puff deformation is measured by computing the principal axes of the particle cloud, which provides simplified measures regarding their size and elongation. We characterized the interplay between the flow scales and the puff deformation, which are mainly ruled by the puff size. In particular, we found that small puffs are more stretched than larger ones, and that this effect is heightened in the transitional region. By measuring other flow features, we link this behaviour to the intermittency typical of transition.

From the Eulerian perspective, we employed a network-based approach, the visibility graph, to study boundary layer transition. We transform fixed-point time-series into a graph by means of a convexity criterion. Similarly to other studies in this work, a methodological innovation is used here with the aim of shedding light on particular aspects of a known fluid problem, namely identification of turbulent regions in transitional flows. The properties of the resulting graph are able to describe the geometric features of the time-series, which we in turn relate to the properties of the underlying flow. In particular, we found that the visibility approach is particularly sensitive to the transition from an intermittent state to a fully turbulent one. We use this feature to provide a characterization of the turbulent-non turbulent interface starting from spatially coarse data.

All these approaches are characterized by the necessity of treating very large quantities of data, which are significantly extensive in time and space. The key challenges in this case lie in the generation of the data itself, which will be covered in the following with particular regard to the numerical simulation of channel flows, and in the interpretation of the results. The analysis frameworks include network-based approaches, which are powerful tools in fluid dynamics as they enable the uncovering of several key interactions taking place in turbulent flows.