Abstract

The widely studied topic of *thermal convection* has attracted the interest of the scientific community for centuries. In particular, the exploration of convective heat transfer in the field of environmental fluid dynamics is of key relevance for our Planet and humanity, due to the current critical times which are strongly affected by climate changes. Extreme and undesired events continue to influence our lives and risk to alter significantly the natural environment. Such phenomena are approached from multiple viewpoints, like numerical weather prediction and climate models, field campaigns and exploration of long climatic datasets. Actually, convective phenomena represent key processes which need to be better understood and sometimes better parameterized in numerical models. In this context, a remarkable and non-negligible aspect concerns the boundary conditions affecting such convective dynamics e.g., the geometrical and thermal complexity of an urban agglomeration or the different properties characterizing land and oceans.

Within a wide range of possible boundaries, this work focuses on a subset of particular boundary conditions involved in convection: thermal anomalies.

Cities represent a notable example of this situation. Actually, urban areas are characterized by different thermal properties with respect to the surrounding natural landscapes, due to their materials, geometry and human activities. The mutual action of those peculiarities make any city a thermal heterogeneity affecting the temperatures occurring in the area. Particularly, the urban air temperatures are warmer than the rural ones and this effect is known as Urban Heat Island (UHI). *Part I* of this thesis focuses on the definition, analysis and characterization of the UHI effect. One crucial existing gap in literature regards the identification of "urban" and "rural" meteorological sites to be used for UHI quantification, a problem which is still an open question. We develop a novel and as much as possible objective approach to face this problem. After establishing the definition, we capitalize the findings for a dual purpose. First, to fully characterize the effects produced by urban thermal heterogeneities with respect to their surrounding areas, in the specific case of the city of Turin, from a ground-level point of view and considering vertical atmospheric profile. Second, to validate a numerical weather prediction model which adopts a new urban parameterization, capable of capturing the UHI effect.

Part II of this work investigates what can be considered as an idealization of the subject of *Part I*: thermal anomalies applied on the boundaries of a Rayleigh-Bénard (RB) problem. Historically, its conceptual clearness has allowed scholars to widely explore its dynamics so far. Still, several issues remain open, e.g., the effects produced on the heat fluxes by non-homogeneous boundary conditions. Furthermore, the reduction of computational times in recent years has favoured the development of various modifications of the classical scheme, in which a fluid is confined between two plates kept at different temperatures. Our investigation on this topic is associated with the possibility to idealize hot spots like cities in a numerical system where ideally any configuration can be imposed at the boundaries. Thus, we evaluate the effects produced on convection by thermal heterogeneities, which we model through sinusoidal patterns set (i) in phase and (ii) in counter-phase between the top and the bottom plates. In the first case, the convection patterning results strongly affected by the boundary anomalies unless the scale of the perturbations is comparable to the natural scale of the system (i.e., under thermally-uniform boundaries). In the second case, the convection develops even if the two plates are characterized by a global null temperature difference. This counter-intuitive result is due to the alternation of purely convective zones and stable zones, where the bottom surface is cold while the top one is hot.