Ph.D. in Scienza e Tecnologie per l'industria chimica, farmaceutica e alimentare (XI Cycle-New Series)

FOREST FIRE MODELLING

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Adstract

Wildland fires have always been undesired and dangerous events. The danger includes the destruction of a renewable natural resource, damage of the atmospheric environment through the emissions of pollutant gases, which contribute to the greenhouse effect, and threat to the lives of people living in the areas surrounding the place where fire occurs and of the members of firefighting teams. To cope with all this, it is necessary to know the behaviour of the fire in order to be able to make adequate and proper decisions that will assist activities implemented in fire suppression and prevention. In this context, fire behaviour modelling is utilized to determine these characteristics and to simulate fire propagation in a variety of vegetations, under diverse climatic and topographic conditions.
In this context, the aim of the thesis work was to study and describe the fire propagation under different fuel features and boundary conditions with particular attention to terrain configurations where fire propagation may be characterized by abrupt variations in intensity and propagation rate. These areas include double-slope domain and canyons where such a phenomena (commonly identified as eruptive behaviour) occurs without any change in the main factors governing the fire propagation (i.e. atmospheric condition, vegetative fuel, domain topography). This work aims to provide an increase of knowledge in the fire spreading, currently still limited, thanks to the adoption of a physically-based code (WFDS) to model flame propagation; in fact, through the numerical resolution of the fundamental balance equation describing the fire phenomenon, it offers a way to analyze the fire behaviour on a scientific basis. To purse this target different aspects, reported in different chapters, were considered in this work.
The first part examines shortly the social, economical and ecological impact of wildland fires on a global scale and for the countries of the Euro–Mediterranean region. The role of fire behaviour modelling as a tool for fire fighting activities and prevention management is put in evidence and discussed.
The second part endeavours a short review of the main surface fire spread models developed since 1990 with particular attention to physically-based codes. These models are alternative to empirical or quasi-empirical models, which do not have physical basis and are only statistical in nature or make use of some form of physical framework upon which to base the statistical modelling chosen. A comparison between the most frequently used simulation codes is accomplished and the advantages to consider a physical code - for instance *WFDS* - rather than an empirical or quasi-empirical one is highlighted.
The subsequent section presents an outline of the physical mechanisms and length scales governing the propagation of wildfires, which have to be considered when a physical modelling approach is employed. In this context, the literature highlights two regimes in the propagation of surface fires,

i.e. wind-driven fires and plume-dominated fires, which are governed by radiation and convective heat transfer, respectively. In this part a short outline of the mathematical background, which is used to describe the physical and chemical aspects involved in the fire phenomena along with its numerical implications, is also provided.
The fourth chapter discuss about the way by which the wind and the terrain inclination affect the fire propagation across a homogeneous fuel; in this case also the possibility for the occurrence of a transient regime even under constant geometric and ambient conditions is also addressed. Furthermore, the role played by the understorey vegetation on the development of a crown fire is investigated by considering a domain made of a heterogeneous surface fuel under a linear stand of trees.
The fifth part deals with the description of fire behaviour across double-slope terrains and canyon configuration. Simulations, performed by the WFDS code, help, in the first case, to understand the main parameters affecting the variation of fire propagation in correspondence of the domain slope change. In the second case, the numerical approach provides insights in the understanding and description of the so-called eruptive behaviour, characterized by an exponential increase in the fire propagation rate, promoted by the particular domain configuration.
In the sixth section the numerical code WFDS is used to study the behaviour of a fire propagating over a relatively large area with a real surface configuration. In particular, the code provides information to deduce the fire front shape profiles and terrain area burned in time.
Finally, part seven discusses the findings of this thesis and summarizes the main conclusions. The potentiality of the numerical code in providing reliable and detailed predictions of the behaviour and effects of fire over a wide range of conditions is highlighted. However information about the limitations of the code is also provided.