THUNDERSTORM DOWNBURSTS: MONITORING, MODELLING, SIMULATION AND LOADING OF STRUCTURES

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Abstract: Thunderstorms are frequent phenomena that cause wind speeds and wind-induced damage often greater than those due to extra-tropical cyclones. This new paradigm of wind engineering gave rise to a recent burst of research despite which there is not yet a model of thunderstorm outflows and their loading of structures like that developed for cyclones in the early 1960s and still in use in the engineering practice. In a planetary phase of climatic evolutions, this shortcoming is exalting the excessive safety and cost of high-rise buildings with respect to the apparent unsafety of low- and medium-rise structures in thunderstorm days. This paper describes the research carried out at the University of Genova on this problem, the results it is producing and their perspectives.

Keywords: Aerodynamic actions, Dynamic response, Non-synoptic wind, Outflow.

1. Introduction

Wind actions are crucial for safety and sustainability of structures. The wind climatology of Europe and of many parts of the world is dominated by synoptic extra-tropical cyclones and mesoscale thunderstorms. Thunderstorms are frequent phenomena that cause wind speeds and wind-induced damage often greater than those of extra-tropical cyclones [1]. This gave rise to an impressive amount of research despite which there is not yet a model for thunderstorm outflows and their loading on structures like the one developed for cyclones in the early 1960s [2]. This happens because the complexity of thunderstorms makes it difficult to formulate realistic and simple models, their short duration and small size make available a limited data, there is a persisting gap between research in wind engineering and atmospheric sciences.

This shortcoming leads to unsafe and expensive structures. The insufficient safety of low- and medium-rise structures is testified by frequent damage and collapse in thunderstorm days. The excessive cost of tall buildings is apparent due to the absence of critical situations caused by the wind. Both these aspects derive from the fact that thunderstorm outflows intensify close to the terrain and reduce their speed on increasing the height whereas traditional wind speed and loading increase with height.

2. Wind & Ports and Wind, Ports & Sea Projects

The research carried out at the University of Genoa on thunderstorms originated from two European projects, Wind & Ports (WP) [3] and Wind, Ports & Sea (WPS) [4], financed by the European Cross-border program Italy–France Maritime 2007-2013. They handled the wind safe management and risk assessment of the High Tyrrhenian Ports. This aim was pursued through an integrated set of tools including an extensive monitoring network, multi-scale numerical models, medium- and short-term forecast algorithms, statistical analyses.

In particular, the WP and WPS Projects created a network of 28 ultrasonic anemometers, 3 LiDAR (Light Detection And Ranging) profilers and 3 weather stations, each one including another ultrasonic anemometer, a barometer, a thermometer and a hygrometer. Realized in a geographic area well-known for the intense convective activity and its dramatic effects, this monitoring network produced an unprecedented amount of non-stationary wind speed records due to gust fronts potentially associated to thunderstorm outflows [5].

3. The THUNDERR Project

THUNDERR (www.thunderr.eu) is a Horizon 2020 ERC project leaded by author that started from the above premises to pursue three main objectives: 1) using full-scale monitoring [6], laboratory tests [7], CFD simulations, and weather surveys [8] to formulate a unitary and interdisciplinary model of the thunderstorm outflows, with the prospect of being itself a novel scientific result and a robust basis for engineering analyses; 2) developing a triad of wind loading models based on the response spectrum technique [9, 10], time-domain simulations [11] and non-stationary stochastic dynamics [12], robustly supported by measured data; and encapsulating the classic method for cyclones and the new method for thunderstorms into a novel wind loading format easily transferable to engineering practice and codes; 3) spreading results throughout international community to strengthen and support a renewed culture on thunderstorm phenomena and their actions on structures.

5. Conclusions

This paper provides the general framework of the THUNDERR project, illustrates the results obtained up to this phase of the ongoing research, describes the perspectives of the studies undertaken and their potential impact on civil, structural and wind engineering as well as their consequences on building safety and sustainability.

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