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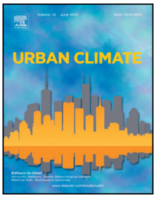

Interaction of severe convective gusts with a street canyon☆

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ABSTRACT

Severe convective gusts lead to wind conditions that differ from those of atmospheric boundary layer (ABL) flows. Main differences are high velocities at ground level and transient flow conditions. Their interaction with inner-city areas has only rarely been examined and is the aim of the present work. In the experimental study the convective gusts were simulated by a jet, imbedded in an ABL flow generated by a wind-tunnel. The gust impinged on a street canyon model. Both steady experiments (continuous jet) and non-steady experiments (pulsed jet) were conducted. Flow fields within the street canyon were measured by means of a 2D/2C TR-PIV system.

Comparisons of the steady flow field within a street canyon model and for a gust propagation on open terrain revealed an average increase of the maximum horizontal velocity of 50% within the canyon, an increase of the outflow's height, and a conservation of high velocities over a distance more than 3 times larger compared to open terrain conditions. Further experiments with a transient gust included the generation of a ring vortex. This vortex propagates above the street canyon and results in an additional increase of peak velocities.

1. Introduction

Convective down-gusts are downdrafts which often occur during severe thunderstorms and can be regarded as a falling air parcel with higher density than the surroundings. After the impingement of a downdraft, the air is accelerated outwards from a high pressure region close to the impingement center. As reported

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in literature, wind speeds of over 200 km/h can be reached in thunderstorm outflows at ground level (Fujita, 1990). These wind speeds can exceed those related to synoptic-scale winter storms.

In order to understand the formation of convective downdrafts, research projects have been performed, for example NIMROD 1978, JAWS 1982 and MIST 1986 (Dodge et al., 1986; Fujita, 1981; McCarthy et al., 1982). In these campaigns, detailed information about the characteristics of downbursts, like the mean velocity profile of the outflow resembling the one of a wall jet (Hjelmfelt, 1988), could be obtained. Further studies revealed that maximum horizontal velocities occur at a height of about 5% of the initial downburst diameter (Kim and Hangan, 2007).

Pistotnik et al. (2011) observed that a perfect interaction of processes on various scales – from synoptic to convective scale – led to a steady state of extreme intensity for the downburst investigated in their study. This emphasized the complex organization of thunderstorms. Since these processes are not yet fully understood and also to obtain statistical information, further full scale measurements were performed and are still in progress. Recent projects include, e.g., SCOUT, "Wind and Ports" and "Wind, Ports and Sea" (De Gaetano et al., 2014; Gunter and Schroeder, 2015; Solari et al., 2012).

According to Fujita (1990), a downburst can be regarded as a column of descending air impacting on the ground and bursting out radially. In some cases a ring vortex is generated in the shear layer between the falling air parcel and the surrounding air and precedes the outflow. The generated gust front causes a sudden drop of temperature and a sudden increase of the wind speed at ground level. The size of convective gusts or downdrafts varies from a few tens of meters to several kilometers. Small events have a shorter life time compared to larger events. So called macrobursts show a horizontal extension of >4 km. Microbursts are events with a horizontal extension of up to 4 km and have an average lifetime of 5 to 15 min. Fujita also postulated the existence of smaller structures that he called *burst swath* with an average extent of 100 m (Fujita, 1981). During low-level flights, he took photos of wind damages in forests with a path width of 40 m, which he attributed to these swaths. However, according to the authors' knowledge there has been no scientific evidence for those swaths to this day.

Buildings and structures are designed to withstand wind loads on the basis of national or international wind loading codes (e.g. EUROCODE, DIN EN 1991-1-4, ASCE7). These codes are based on certain lay-out wind velocities at given reference heights, which result from a statistical analysis of weather station data. However, as convective events are very localized and of short duration, they are only poorly represented in the statistics.

Wind loading codes presume a horizontal wind and do not consider a vertical wind component of the approaching flow. In case of down-gusts, momentum is transported vertically and, thus, can introduce high velocities into inner-city regions. It is apparent that buildings or other engineering structures exposed to such outflows will experience wind loadings that differ from those in a steady atmospheric boundary layer (ABL). In spite of this knowledge, only a few investigations have been performed on the impact on structures, like single buildings or lattice transmission towers (e.g. Chay and Letchford, 2002; Jesson et al., 2015; Letchford and Chay, 2002; Savory et al., 2001). The two-part work of Chay and Letchford revealed that both the specific velocity profile of the outflow as well as the transient characteristics cause pressure distributions on single buildings that differ from the conventional assumptions. Jesson et al. (2015) conducted experiments with a pulsed jet including the occurrence of a ring vortex. From comparisons between pulsed jet, steady jet and ABL experiments he suggested that a localized separation at the building and a following reattachment is not present in the ring vortex driven pressure field in contrast to steady flows. In addition to the experimental or numerical simulation of the thunderstorm wind field to determine the structural loading, a recent approach is to apply the spectrum response technique to thunderstorm events. This method is known from earthquakes and was adapted to thunderstorm outflows (Solari, 2016; Solari et al., 2015).

All these investigations were focused on the impact of downdrafts on single structures. The interaction of the outflow with built-up areas has only rarely been investigated. Only two recent studies on this topic are known to the authors. A numerical simulation was performed by Sim et al. (2016) who investigated the flow characteristics of a convective outflow passing through an array structure. In this study, the outflow has already developed into a purely horizontal flow, i.e., a strong vertical wind component was not considered. A laboratory experiment is planned by Romanic et al. (2016a). However, at the moment no information is available about the flow situation in the impinging region within the built environment. Additional effects, like channelization or funneling effects within street canyons or around inner-city places, are expected to occur. The aim of the research project ConWinG is to identify

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