ACPS 2021: ARCHITECTURE, CITY, PEOPLE, STRUCTURE

THE INTERNATIONAL SCIENTIFIC ONLINE VIDEO-CONFERENCE

ANALYSIS OF AERODYNAMIC PHENOMENA IN THE CENTER OF WARSAW NEAR ZŁOTA 44 STREET BUILDING IN THE CONTEXT OF AIR POLLUTION AND THE SAFETY OF UNMANNED AERIAL VEHICLE

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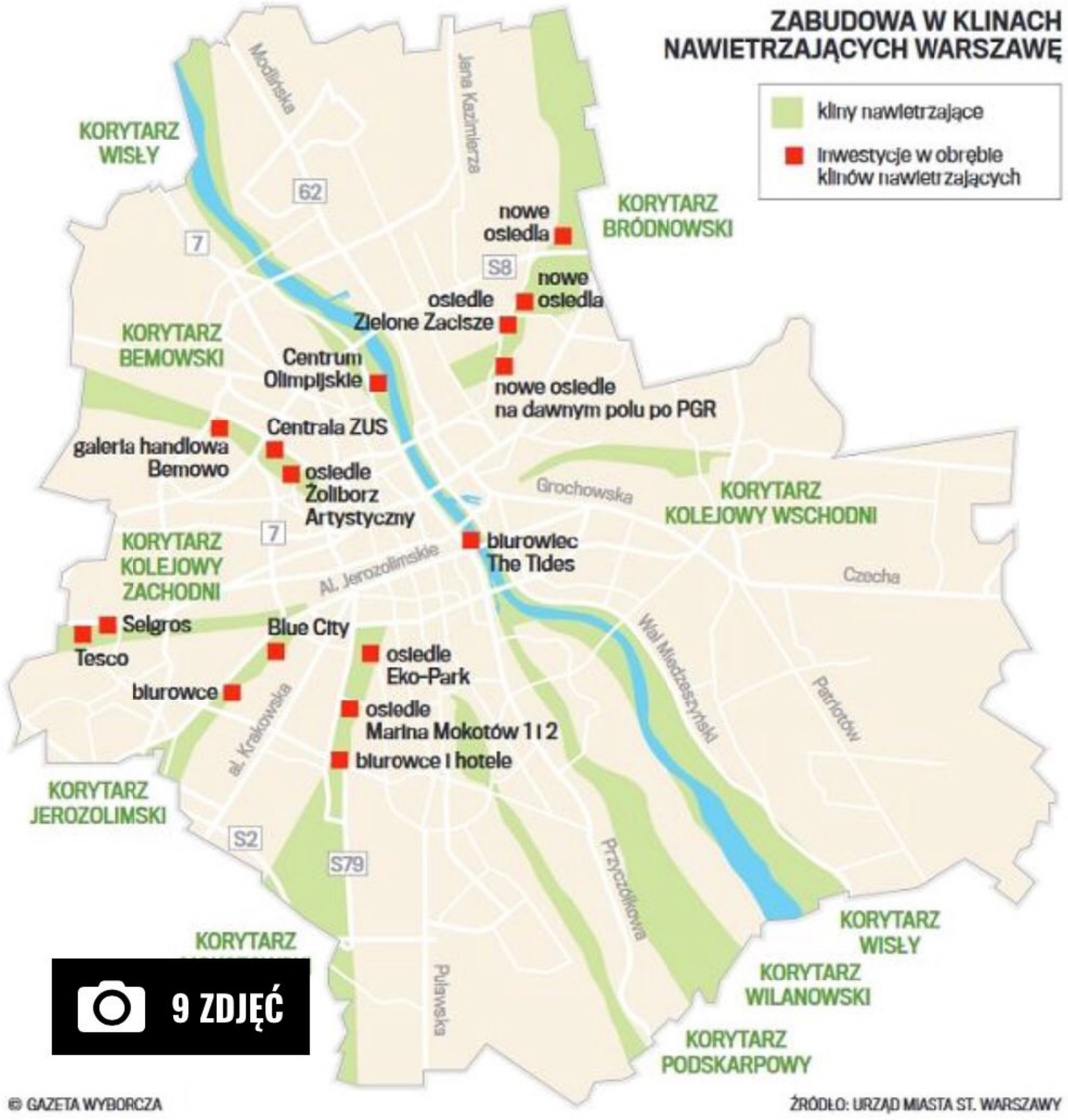
The study investigates the possibility of using unmanned aerial vehicles (UAVs) to investigate air pollution in the vicinity of tall buildings in the center of Warsaw at Zlota 44. Based on the analysis of experimental tests on a model of the building in a wind tunnel and numerical tests in the Fluent computer program, locations where air pollution accumulates due to aerodynamic phenomena will be determined, and locations safe for drone flights will be identified. Particular attention will be paid to the most popular wind directions for Warsaw - west and southwest.

https://www.f5.pl/ekologia/jeden-domek-jednorodzinny-opalany-kopciuchem-jest-w-stanie-wytworzyc-wiecej-smogu-niz-budynek-mieszkalny-zasilany-ogrzewany-z-sieci

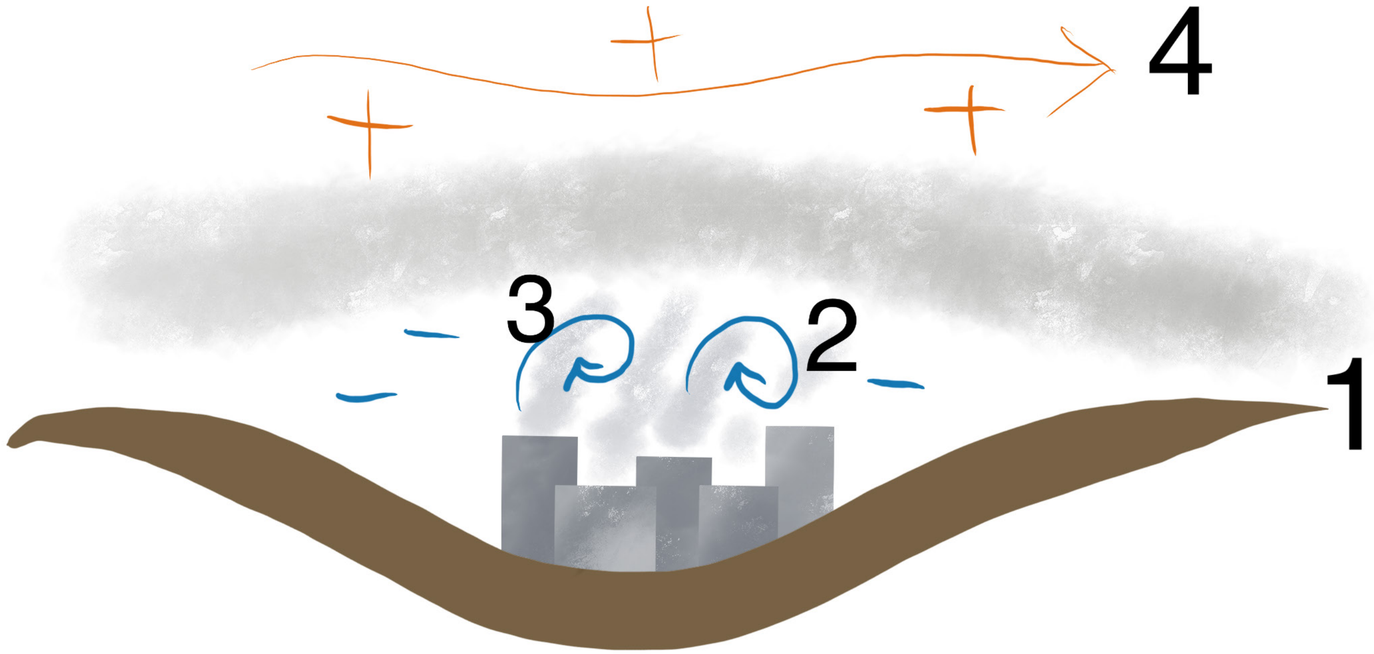
One of the important issues in the context of city planning is the possibility of its natural ventilation through aeration wedges and planning housing developments in such a way that they are ventilated by the flowing air. Unfortunately, aeration wedges are developed under capital pressure and housing estates are usually designed in such a way as to maximally use the available area for development. The problem of smog and accumulation of pollution occurs in densely built-up city centers, adjacent districts and also in neighbouring towns. Currently in Poland, more and more actions are being taken to reduce the scale of air pollution, especially in large urban agglomerations.



https://twitter.com/OzdobaJacek/status/1070287946438377472/photo/1

The occurrence of smog is directly related to the lay of the land. It occurs much more often in cities located in mountain basins and valleys, and the main factors of its formation are high emissions of pollutants connected with the heating season, mainly from households equipped with old-type boilers, for which poor quality fuels are used; high pressure and windless weather, which prevents ventilation of the city and leads to thermal inversion. Pollutants are then blocked from above by masses of warm air. A so-called „smog cap" is formed, preventing vertical air exchange.

1. Terrain - cities located in basins or mountain valleys.
2. High pollutant emissions associated with the heating season, primarily from households equipped with old-type boilers and using poor quality fuel.
3. High atmospheric pressure and windless weather, which prevents ventilation of the city and leads to:
4. Thermal inversion, i.e. blocking of pollutants from the top by masses of warm air, resulting in the formation of a „smog cap" and preventing vertical air exchange.



Air pollution is a problem that affects many countries in the world. When examining methods to reduce smog, they can be categorized into several aspects:

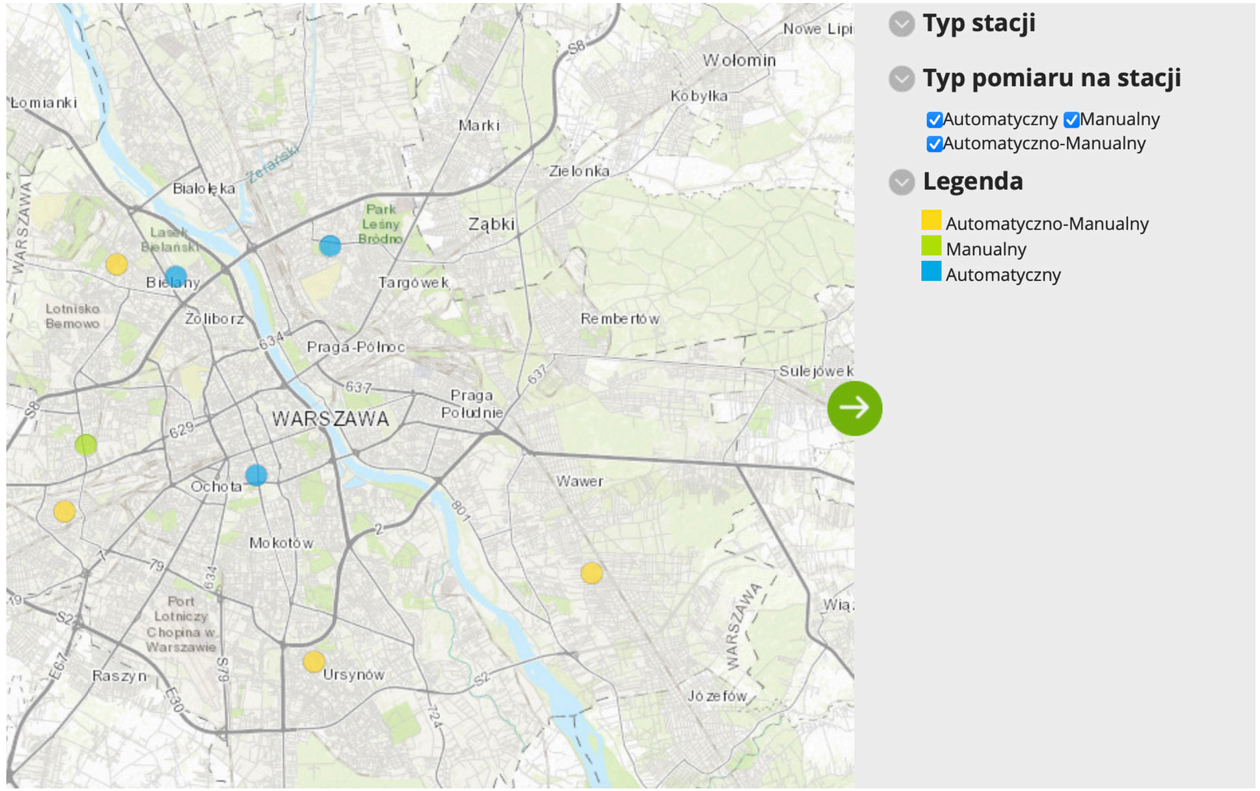
- REDUCTION AT SOURCE
  Reduction of emissions in the municipal and industrial sectors
  Legislation, ecological design
  Reduction of emissions in the transport sector
- INDIRECT REDUCTION
  Mechanical and chemical cleaning - textures, smog absorbing materials
  Small architecture and air-purifying elements
  Public education
- SMOG REMOVAL AT THE FINAL PHASE OF THE SMOG CYCLE
  Urban ventilation

REDUCTION AT THE SOURCE

INDIRECT REDUCTION

REMOVING THE SMOG IN THE FINAL PHASE OF THE SMOG CYCLE

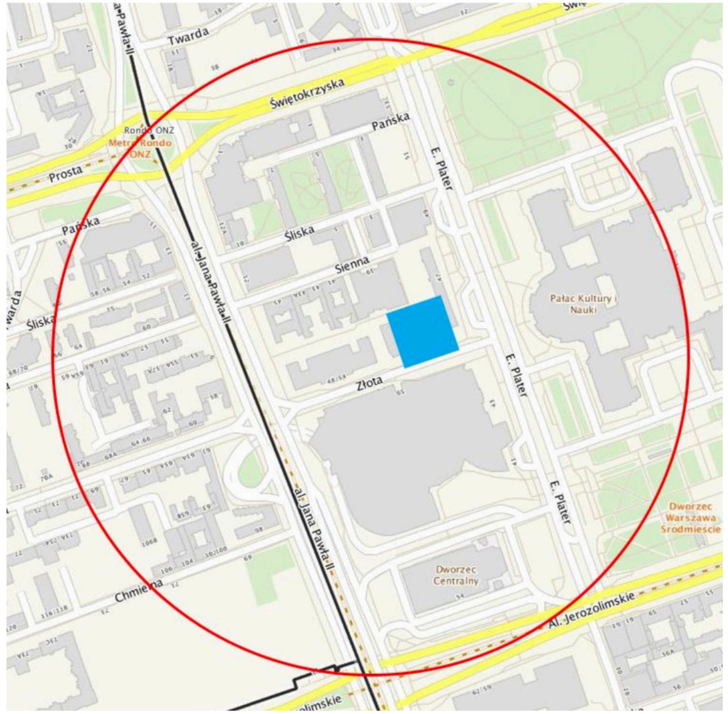
Unfortunately, the phenomenon of smog is not thoroughly researched. In Poland there are large gaps in the location of measuring stations, which results in a large lack of information. There are about 260 stations, out of which only 8 in Warsaw: 4 automatic, 3 automatic-manual and 1 manual. Smog measurements allow to examine the state of pollution but only at the place of measuring station, which is near the ground level. Composition and intensity of air pollution changes with height and vicinity of the place of survey. It will be different in case of high building at the height of 10th floor, different at the height of first floor, different in case of scattered buildings in suburban areas. Many factors influence the state of air, including the type and intensity of aerodynamic phenomena. In order to more accurately predict pollution, it is necessary to study aerodynamic phenomena in the context of the built-up area and to measure them by a denser network of measuring stations located at different heights.



http://powietrze.gios.gov.pl/pjp/current/station_details/info/552

Drones can be used to measure pollution. Components such as sensors for smog, chemical and radiological contamination can be attached to such a device. Drones can also be used to monitor dust and gas levels, collect weather data, or diagnose high-voltage power lines. The key to identifying sites that are particularly dangerous for drone flight is to designate zones with potentially significant flow velocity gradients and high turbulence. Vortices with diameters larger than the overall dimensions of the unmanned aircraft pose the greatest risk to flight.

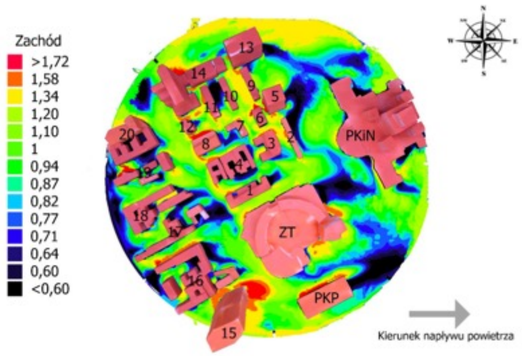
The aim of this study was to identify potential zones of pollutant accumulation in a densely built-up section of the city marked with a red circle (the radius of the circle has a dimension of 300m), as well as to investigate the impact of the introduction of a high-rise building (up to 200m), highlighted in blue on the map below) on the ventilation conditions in its vicinity. A tall building usually intensifies the flow, so it may improve ventilation conditions in the immediate vicinity, although at higher wind speeds it may be a source of discomfort for drones.



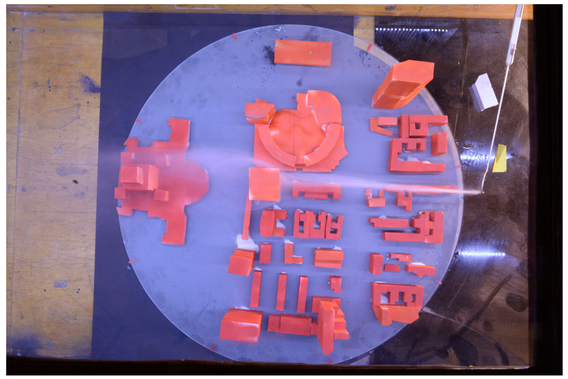
https://wlkp24.info/dron-bedzie-sprawdzal-jakosc-dymu-rusza-program-antysmogowy/

Experimental tests were carried out in the wind tunnel on a model made of styrodur and numerical tests in the Fluent program.In both cases the influence on the geometry of the development was studied in the case of leaving the high-rise building on the site of the Zlota 44 skyscraper and in the case of removing it from examined layout.

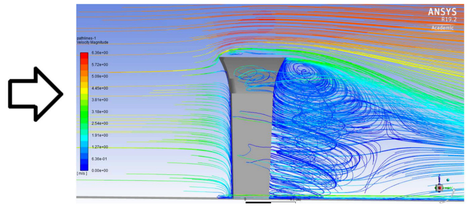
Tunnel testing on a mockup: saltation and oil visualization

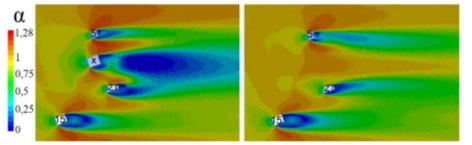


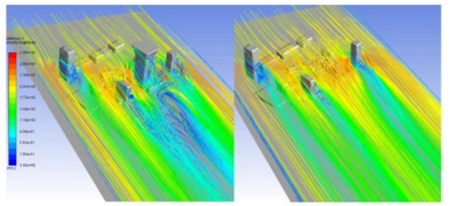
Experimental studies using smoke in a wind tunnel



Visualization of streamlines after calculations in ANSYS Fluent





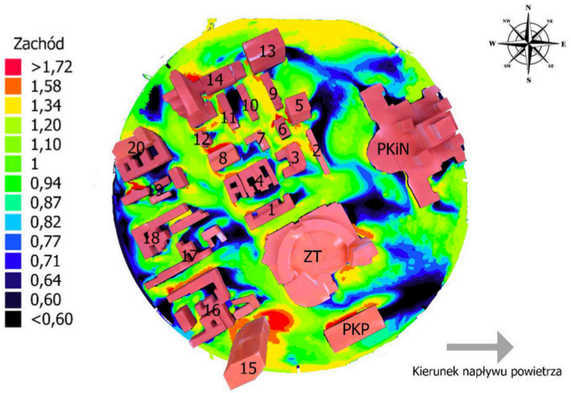


The research led to the conclusion that for most of the analyzed planes the presence of the conceptual building causes turbulence and increases velocity gradients. On the other hand, in the ground zone it blocks rather than intensifies the flow, i.e. it does not improve or improves at a minimal level for certain directions of the air inflow, the ventilation between buildings. Despite the negative effects of placing the building among other buildings, thanks to the flow analyses it is possible to determine the zones with reduced risk for the safety of unmanned aircraft flight - these are the areas with velocity enhancement coefficients in the range of 0.8 - 1.2 with the exception of zones near the windward walls of buildings. It is also possible to define higher-risk spaces - these are primarily located in close proximity to tall structures and in their footprint.

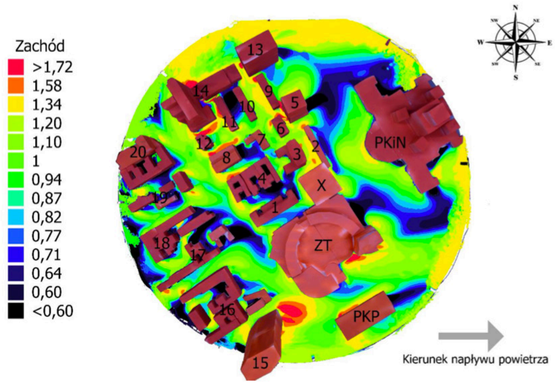
STAGNATIONS
-danger for drones
-place of accumulation of pollutants

The presence of a building intensifies the flow slightly

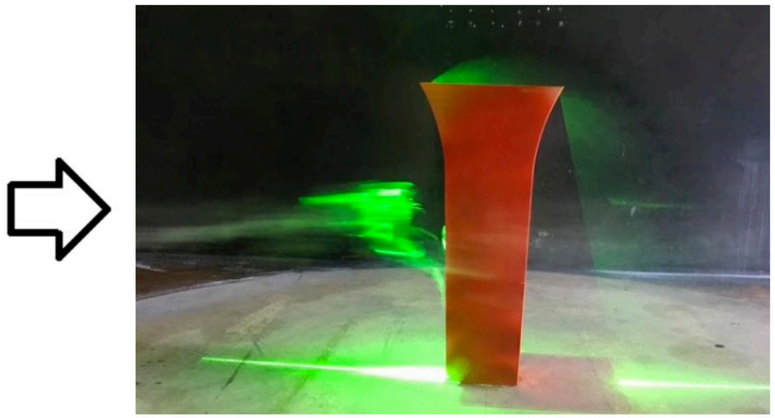
Saltation map and oil visualisation for west direction without building



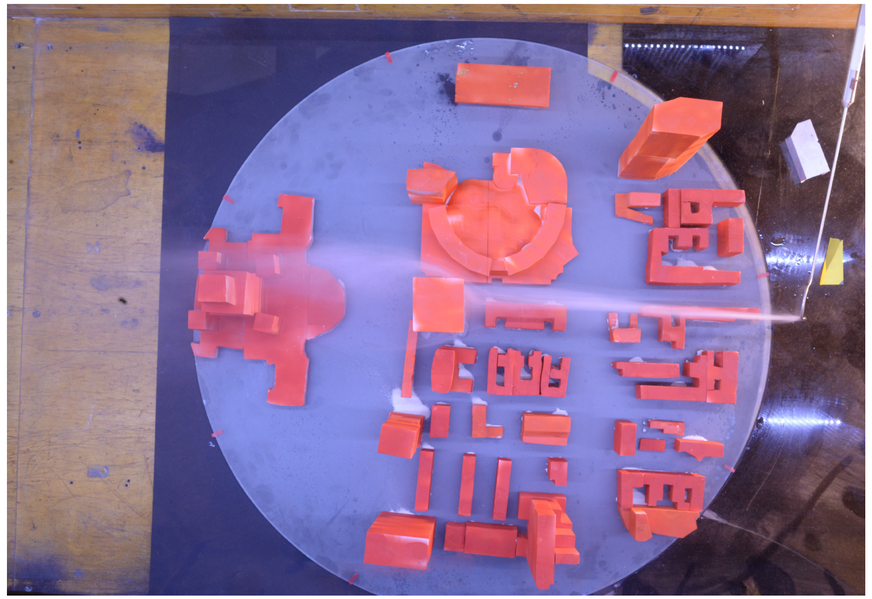
Saltation map and oil visualisation for west direction with building



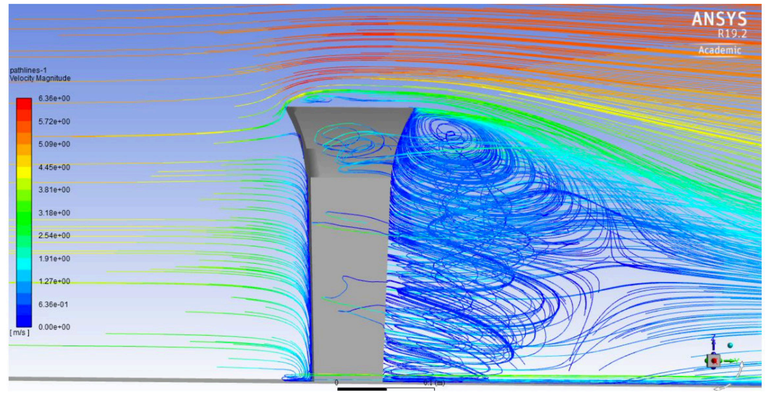
The image shows the model during a test using smoke. The air is coming in from the left side. The curvature of the airflow with smoke particles towards the base of the building can be seen.
This fact suggests that the shape of the building may have an effect on the enlargement of the horseshoe vortex as well as a significant degradation of wind conditions with respect to the safety of drones flying nearby.

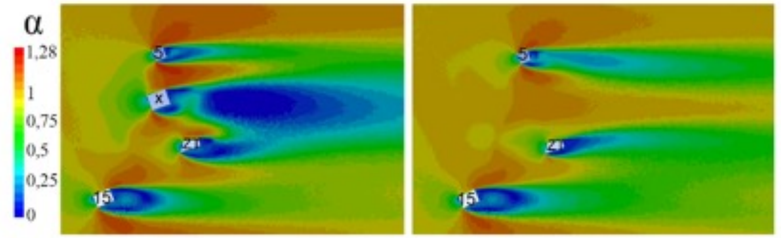


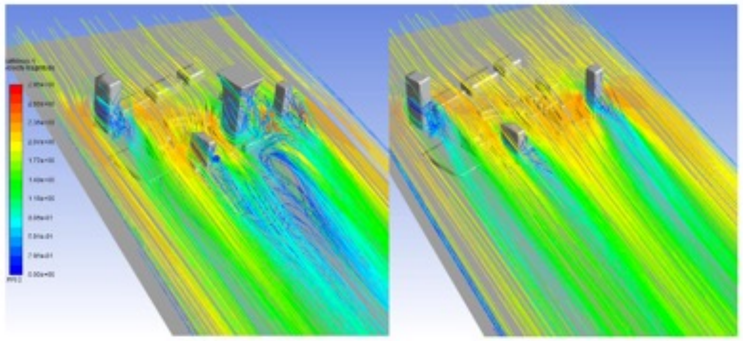
Smoke testing of a building with a tapering shape (the direction of air inflow is marked with an arrow)



An identical model was also investigated numerically. The illustration shows a visualization of the current lines in the plane of the building, and their color depends on the velocity value at each point through which the curves pass. As in the case of the study illustrated above, the descent of air currents towards the ground is visible. Very high turbulence can be observed in the building footprint, which was not as apparent in the smoke study.







It has been investigated that the building is likely to fulfill the intended purpose of bringing some of the flow from higher layers, with higher velocities, to those located below and intensify the velocity, thus better ventilating the area in its vicinity at the pedestrian level.

In contrast, with respect to UAVs, the area near the building is unfavorable for flight safety. Additionally, its height compounds the aforementioned effect.

It can be particularly difficult for the operator to control the trajectory of the model or aircraft in the near footprint behind the building due to turbulence and at the edges of the windward wall by the large velocity gradient.

a:CDS 2021

THANK YOU FOR YOUR ATTENTION

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