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Assessment of Tornado-Induced Building Damage Using a Hybrid Meteorological Model/Engineering LES Method: In Case of Tsukuba Tornado in 2012

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Regarding investigation of detailed mechanisms of actual building damage during a tornado strike, it is critical to accurately estimate transient forces and pressure distribution exerted on buildings. A number of laboratory experiments on wind pressure coefficients on structures have carried out. However, uncertainties still remain in how near-ground strong gust structures are formed and therefore it should be discussed by elucidating dynamics and interaction between more precise tornado structure and high-vorticity vortices generated by buildings and terrain. In the previous study [1], we have shown by numerical simulation, that near-ground part of a tornado significantly changes its structure and motion including speed and direction due to localized pressure drop caused by vortices from inhomogeneous urban geometries and it may cause severer damage at certain locations. We also carried out near-ground flow analysis of an actual tornado in Tsukuba City, Japan in 2012 and revealed that the maximum wind gust distribution fairly corresponds to the damage distribution reported in a field survey report. [2]

In this study, we present analyses of wind forces and damage occurrence mechanisms of severely damaged buildings in Tsukuba Tornado, examining detailed near-ground vortex dynamics in low-rise residential area.
As with the methodology of the previous studies, the tornado was simulated in the meteorological model JMANHM. The data in high-intensity period were taken out for high frequency turbulence regeneration and then introduced to a large parallel large eddy simulation (LES) of the target area. The dimensions of the domain are horizontally 5 km$\times$2.5km and vertically 1.25km. At the bottom, actual buildings and topography were reproduced. We quantitatively estimated surface pressure distribution and rotational moment of a severely damaged mid-rise apartment and wooden houses and it showed a result comparable to observed damage. As for near-ground vortices, we confirmed that multicore vortices near the surface interact with the building configuration. Vortex structures and flow convergence level largely varies during passing over inhomogeneous urban geometries. More detailed analyses will be presented at the conference.

References:
[1] Kawaguchi, M., Tamura, T., et al, LES Method for Generating Broad-Banded Turbulence for Meteorological Events, ETMM12, 2018
[2] Kawaguchi, M., Tamura, T., et al, Tornado Damage Estimation of Cities and Buildings Using Meteorological Model/LES Hybrid Method, 29th Conference on Severe Local Storms, 2018