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Integrated Simulation of Wake Turbulence Using Lidar Measurement

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ABSTRACT

The growth of air traffic causes a lack of airport capacity in many of the major airports. Wake turbulence is one of the factors which restricts the airport capacity by the time intervals of landing and takeoff. Numerical investigations of wake vortices have been performed using large eddy simulation (LES) and direct numerical simulation (DNS) [1–3]. Although the numerical simulation could reproduce detailed flow structure of wake vortices, it is difficult to incorporate the effect of actual weather conditions at airport, which significantly affects the decay process of the wake vortices. Usually, the atmospheric effect is considered by atmospheric boundary layer [3] and/or homogeneous turbulence generated based on measured spectrum of the atmosphere, *i.e.*, modified von Karman spectrum [4]. A lidar (light detection and ranging) is effective tool to measure the wake turbulence of an operating aircraft. Real-time measurement and visualization are also possible using the lidar. The Electric Navigation Research Institute (ENRI) set a lidar system for wake turbulence measurements at Sendai Airport in Japan [5]. Form the view point of the understanding of flow structure of wake turbulence, however, there are some drawbacks such as the lack of spatial resolution in the line-of-sight (LOS) direction and the difficulty in tracking tip vortices for long periods due to the disturbance of ambient wind. The lidar measurement at Sendai Airport is averaged every 30 [m] in the LOS direction. This limitation is especially unfavorable because the core diameter of the wake vortex is in the order of several meters.

For the consideration of an actual atmospheric condition in the numerical simulation, the present study attempts to integrate lidar measurements into the numerical simulation using data assimilation technique. Specifically, Four-dimensional variational (4D-Var) method was applied to integrate lidar measurements with the three-dimensional computational fluid dynamics (CFD) simulation, in which actual scanning processes of the lidar was simulated as a measurement operator of the 4D-Var method. And a bogus vortex technique was adopted to ensure the existence of a vortex pair in the flow field [6]. The validation of the method was performed by idealized test cases using “virtual” lidar measurement which was produced by the reference simulation of a vortex pair. Then, the method was applied to actual lidar measurements at Sendai Airport.

Figure 1 shows a schematic of computational domain. Measurement and numerical results are also shown in Fig. 1. The vortex structure is seen in the distribution of vorticity magnitude as in the upper

right of Fig. 1. These results were obtained by integrating the lidar measurements of Boeing 767 that is taking off. Tip vortices were merged to one large vortex when it was flowed by a horizontal wind. The circulation of reproduced vortex was approximately 200 [m^2/s].

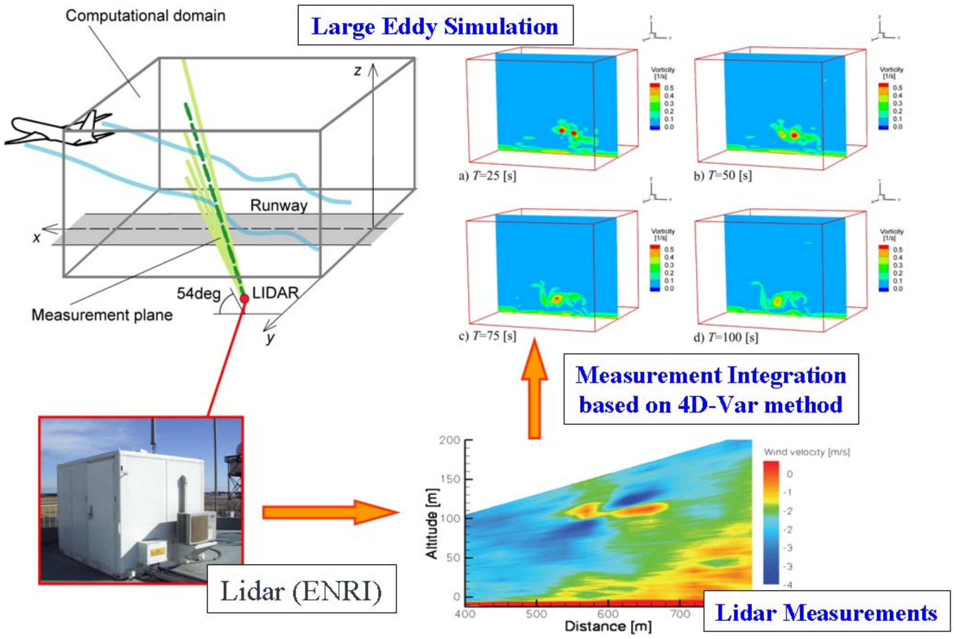

Figure 1: Schematic of the present computation

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