

Title: The Turbulent Flight Environment Close to the Ground

Watkins S., Thompson M., Ravi S. and Fisher A.

RMIT University, Australia

## Abstract

The last few metres of the Earth's surface is the flight domain and home of the vast majority of nature's flyers and increasingly man-made replica's (micro air vehicles, or MAVs). It is also traversed by larger craft whilst taking off and landing. The atmospheric boundary layer (ABL) generally exists from the ground up to 400-1000m and when any appreciable wind is present is highly turbulent. Relatively low speed flight through the ABL results in significant turbulence intensities relative to the flying craft. This is in contrast to high speed flight above the ABL, where (aside from clean air turbulence) the flight domain is essentially smooth. To-date the vast majority of tests associated with aircraft have been in smooth flow replications.

In order to further understand the flight domain through the lower levels of the ABL, measurements are described from banks of highly responsive probes which give insight into the temporal and spatial distributions of turbulence. Parameters varied include the lateral probe spacing (thus enabling insight into the effect of the span on any craft on the turbulence characteristic), altitude, wind speed and relative flight speed. These insights are then used to understand the typical turbulent flight domain for replication in wind tunnels or CFD.

An overview is then provided of experiments and results on airfoils and instrumented MAVs (both fixed wing and flapping) which illustrate the effects of replicated ABL turbulence on time-averaged and time-varying pressures and forces. Turbulence was generated by grids in several wind tunnels, resulting in a variety of intensities and scales. From measurements in smooth and turbulent flows it is demonstrated that turbulence can generally enhance the time-averaged performance of airfoils at low Reynolds number but provides significant control challenges as spans and speeds reduce.

The results have implications both for low speed flight of MAVs and also aircraft take-off and landing flight conditions.