The Development of a Small Unmanned Aircraft for the Sampling of Atmospheric Aerosol and Droplets, Among Other Atmospheric Variables

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Introduction

Small Unmanned Aircraft (SUA), have the potential to perform measurements of atmospheric aerosol which would be impractical otherwise. Typical in-situ measurements are performed using research aircraft or balloon-borne instruments, both of which have limitations regarding manoeuvrability – thus restricting the spatial and temporal sampling abilities. For example, in a highly heterogeneous atmosphere, a small multirotor SUA can be moved around with ease to sample multiple different vertical profiles. However, the use of SUAs in meteorological sampling is in its infancy, and a lengthy validation process must be conducted to ensure any data generated is not being influenced by any artefacts resulting from the SUA itself.

Since the payload of an SUA is much smaller than that of a traditional aircraft measurement platform, aerosol instrumentation is often miniaturised, or adapted from handheld instrumentation. This, however, can cause problems with compatibility between platforms due to differences in aircraft speed and aerodynamics (especially with multi-rotors). To negate these issues, the aerosol instrumentation used for this project has been adapted from the Universal Cloud and Aerosol Sounding System (UCASS) which is an Optical Particle Counter (OPC). The UCASS was designed for use on standard meteorological balloons which travel at similar speeds to the SUA (2-15ms^{-1}), and weighs just 280g. Since the aerodynamics of the SUA is different to a balloon platform, the effect of the SUA aerodynamics needs extensive validation. Furthermore, the UCASS is designed as a single-use instrument and needed mechanical modification for robustness to ensure it can be re-used on an SUA.

The purpose of this project is to therefore create a synergy between an aerosol sampling instrument and an SUA, so that scientifically valid measurements of aerosol and droplets can be performed. Fully exploiting the benefits of the SUA, while not sacrificing the accuracy of traditional atmospheric aerosol measurement on manned aircraft platforms.

Methods

The validation method can be considered a two-tine approach; with Computational Fluid Dynamics (CFD) simulations (with Lagrangian particle tracking) being used as a tool to develop improvements to the SUA, which are then tested against co-located instrumentation (on different platforms). This is in addition to the lab-based instrument calibrations.

A multi-rotor SUA was chosen as the measurement platform for its manoeuvrability and ease of automation. Additionally, multi-rotors are simple to build, maintain, and pilot which makes them more versatile than the fixed-wing alternative (especially in areas where a landing strip would be impossible due to terrain). The SUA has large arms are designed to maximise the distance between the rotors and the UCASS inlet in the centre with the aim of minimising the effect the propeller wash has on the particle flow (this is verified with CFD simulations). Since the UCASS is open path, the SUA is designed to fly directly upwards (parallel with the UCASS inlet) in order to sample a vertical column of air, thus providing vertical profiles of aerosol size distribution, temperature, pressure and humidity. A vertical profile is especially useful for cloud droplet studies, due to the convective processes causing changes in droplet properties in the vertical direction.

Conclusions

Small Unmanned Aircraft (SUA) have the potential to be used as platforms for the measurement of atmospheric particulates. The use of SUA benefits from high manoeuvrability, reusability and low-cost when compared with traditional techniques. However, the complex aerodynamics of an SUA (particularly for multi-rotor airframes), combined with the miniaturisation of particle instruments poses difficulties for accurate and representative sampling of particulates. This project has used CFD simulations to influence the design of a bespoke meteorological sampling system: the AERO-SAM. This consists of a custom built airframe, designed to reduce sampling artefacts due to the rotors, and a purpose built open-path particle counter.