2024_7_Aero_OB: The effects of turbulence intermittency on accelerating the formation of nascent raindrops in warm cumulus clouds

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Warm cumulus are the fluffy clouds onto which people project shapes of familiar objects. They are aerosols of liquid water droplets contained within a turbulent body of air and sometimes yield rain, although this is an intermittent process with only around one in a million droplets becoming big enough to trigger the raindrop-formation process. Cloud droplets form at small sizes and grow through condensation of water vapour, however this growth rate is too slow to explain the observation that rainfall can develop within approximately 30 minutes of a cloud's formation. It is increasingly clear that turbulence within the cloud is a vital factor in accelerating this droplet-growth since it causes collisions between droplets, which then coalesce. Current estimates suggest that turbulence increases the rate of collisions two- to three-fold. However, the physics behind this turbulence-enhanced collision and coalescence are not well understood meaning that they are not well parameterised for weather/climate modelling.

Droplets within turbulence are exposed to aerodynamic and gravitational forces which determine their trajectories, and hence likelihood of colliding/coalescing. An exact equation (Maxey & Riley 1983, MR83) exists to describe the motion of a very small droplet in turbulence. However, this equation is only formulated for idealised point particles which do not influence the cloud turbulence (a one-way coupling). This is typically a reasonable assumption within the bulk of a warm cumulus cloud, however cloud-turbulence is intermittent, meaning that there are patches of clouds that are significantly more turbulent than average. In these patches the assumption behind MR83 that cloud droplets can be treated as point particles does not hold and a two-way coupling between the droplet dynamics and the cloud turbulence exists. Our research will focus on understanding these intermittent turbulent physics.

We will conduct simulations with our state-of-the-art CFD solver on the UK national supercomputer. We will identify features of intermittent cloud-turbulence that induce this two-way coupling between turbulence and droplets and try to learn the physics behind droplet motion under these conditions. Our final objective is to take these newly-discovered physics and parameterise them into a form that will be useful for numerical weather prediction (NWP). We are partnering with the Met Office and the successful student will spend time there learning their cloud microphysics models and implementing an updated version to account for our newly discovered intermittent turbulent physics. As NWP becomes ever higher-fidelity accounting for the effects of cloud-turbulence becomes increasingly important to improving forecasting accuracy, especially as climate change is expected to increase levels of atmospheric turbulence. Cloud/precipitation formation/decay are key uncertainties in global climate modelling and our research will help to reduce these uncertainties.