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Interferometric imaging for the characterization of ice particles and droplets in the atmosphere

Marc BRUNEL

Rouen Normandy University, France, Korea, E-mail:brunel@coria.fr

Abstract

The entacement of water droplets or ice particles in the atmosphere is important for aircraft safety and meteorology. Interferometric out-of-focus imaging offers an interesting solution: The technique allows indeed size measurements of both kinds of particles, leading to a possible estimation of Ice Water Content and Liquid Water Content. In this technique, liquid droplets generate two-wave interference motifs whose frequency gives the droplet's diameter.
In this talk, we'll go over how the device was built and how the first aerial photographs of liquid droplets were taken. After that, we'll show how the methodology could be used to ice particle characterisation. We'll talk about how an irregular rough particle's speckle-like out-of-focus image can reveal some information about its morphology. We'll illustrate how the size of such particles can be estimated based on the size of the light speck in their speckle-like defocused image. In order to adapt these observations made with salt or sand particles to the case of ice particles, it has been necessary to develop laboratory characterization experiments involving real ice. We created a chilly chamber for this purpose. Droplets of liquid fall into the chamber and freeze. A second well-calibrated technique (in our case, digital in-line holography) has been added to the setup to quantitatively validate the measurements acquired. The interferometric out-of-focus image and the digital in-line hologram of the frozen droplets are thus recorded at the same time.

We present the experimental results obtained. We show that the particle's sizes deduced from the size of the speck of light of the speckle-like patterns is corroborated quantitatively by the numerical reconstruction of the hologram recorded simultaneously for the same particle, and that the description proposed to evaluate the size of irregular rough particles is adapted to frozen droplets. The quasi-real-time algorithms created to distinguish liquid droplets and ice particles, measure their sizes, and evaluate the ice water contents and liquid water contents will next be presented.

Ice crystal characterization is based on the analysis of speckle patterns. Prototypes based on interferometric particle imaging have thus been developed and tested in flight. In this lecture, the instrumentation developed to perform accurate size measurements will be described. The presentation will address: (i) the principle of the analysis of speckle patterns for ice crystal sizing, (ii) the development of laboratory instrumentation around a freezing chamber, (iv) their combination to ice crystal growth simulation using phase field modelling, (v) the generation of programmable pseudo-particles using a Digital Micromirrors Device and (vi) pattern considerations for the realization of an airborne instrument

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