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Infrasound absorption by atmospheric clouds

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A model is developed for the absorption of infrasound by atmospheric clouds made of a suspension of liquid water droplets within a gaseous mixture of water vapor and air. The model is based on the work of D.A. Gubaidullin and R.I. Nigmatulin [Int. J. Multiphase Flow, 26, 207-228, 2000], which is applied to atmospheric clouds. Three physical mechanisms are included : unsteady viscous drag associated with momentum transfers due to the translation of water droplets, unsteady thermal transfers between the liquid and gaseous phases, and mass transfers due to the evaporation or condensation of the water phase. For clouds, in the infrasonic frequency range, phase changes are the dominant mechanisms (around 1 Hz), while viscous and heat transfers become significant only around 100 Hz. Mass transfers involve two physical effects : evaporation and condensation of the water phase at the droplet surface, and diffusion of the water vapor within the gaseous phase. The first one is described through the Hertz-Knudsen-Langmuir theory based on kinetic theory. It involves a little known coefficient known as coefficient of accommodation. The second one is the classical Fick diffusion. For clouds, and unless the coefficient of accommodation is very small (far from the generally recommended value is close to one), diffusion is the main limiting effects for mass transfers.

In a second stage, the sound and infrasound absorption is evaluated for various typical clouds up to about 4 km altitude. Above this altitude, the ice content of clouds is dominant compared to their water content, and the present model is not applicable. Cloud thickness, water content, and droplets size distribution are shown to be the major factors influencing the infrasound absorption. A variety of clouds have been analyzed. In most cases, it is shown that infrasound absorption within clouds is several orders larger than classical absorption (due to molecular relaxation of nitrogen and oxygen molecules in presence of water vapor). Examples of the numerical simulation of a primary sonic boom nonlinear propagation through clouds will be presented. For a thick cloud like a cumulo-nimbus, cloud absorption will be shown to lead to a large amplitude decay. Moreover, the shock fronts can be completely smeared out, which explain some observations during flight tests. [Work performed through a research contract between Airbus France and University Pierre et Marie Curie - Paris 6 / d'Alembert / INSP].