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Simulation of airborne radar observations of precipitating systems at different frequency bands

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The accident of the Rio-Paris flight (June 2009) has dramatically recalled to atmosphere scientists the necessity to understand as well as possible the physics of precipitating systems, in particular on the context of civil aviation. An airborne radar is the appropriate tool to provide to pilots an estimation of meteorological hazard associated to intense precipitations.

Currently, airborne radar of civil aviation operates at X band ($f = 10\,\mathrm{GHz}$, $\lambda_0 \approx 3.2\,\mathrm{cm}$), f being the central frequency and λ_0 the wavelength in vacuum, since it permits to use small antenna ($D \sim 80\,\mathrm{cm}$). However, many other frequency bands, used jointly or not, could be utilized. Because measured reflectivity Z_m is modified by changing f, different physical information about precipitating systems are expected to be obtained. Herein, comparison of different $Z_m -$ fields measured by airborne radar of civil aviation at different frequency bands is presented. For that, simulations of an airborne radar observations of modeled nimbostratus and cumulonimbus are performed. The case of mesoscale convective system is also presented in order to illustrate the flexibility of the model developed.

The airborne radar is at $10\,\mathrm{km}$ of altitude, in a static mode, and operates at the most common frequency bands: S ($f \approx 3\,\mathrm{GHz}$, $\lambda_0 \approx 10.7\,\mathrm{cm}$), C ($f \approx 5.5\,\mathrm{GHz}$, $\lambda_0 \approx 5.5\,\mathrm{cm}$), X, K_u ($f \approx 15\,\mathrm{GHz}$, $\lambda_0 \approx 2\,\mathrm{cm}$), K_a ($f \approx 35\,\mathrm{GHz}$, $\lambda_0 \approx 0.86\,\mathrm{cm}$) and W ($f \approx 94\,\mathrm{GHz}$, $\lambda_0 \approx 0.32\,\mathrm{cm}$). The first band ($S$) is the least attenuated, so that it is considered as the reference one.

Simulated $Z_m -$ fields are clearly degraded as f increases because of Mie effects and microwave attenuation. At S, C and X bands, attenuation is weak and Mie effects slightly increase the backscattered signal. At K_u band, microwave attenuation is compensated by Mie effects. At K_a and W bands, a very strong attenuation and significative Mie effects degrade seriously $Z_m -$ fields. Degradation is such that for a squall line, the closer convective tower hides the farther ones which is dramatic for a pilot to estimate hazard at long distance. Moreover, because hail is the main meteorological hazard for civil aviation, hail-rain discrimination is discussed and clarified for convective systems. It appears S and C bands be the best ones, but the important size of the antenna used are prohibitive. X band allows to distinguish hail and rain if hail rate is high enough ($R_h > 16\,\mathrm{mm\,h^{-1}}$). Higher frequencies are more difficult to used on civil aviation due to high ambiguities and a too strongly attenuated microwave signal.

Such a comparative study has never been made for an airborne radar in the context of civil aviation.