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A review on the sensitivity of primary sonic booms to atmospheric conditions

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Sonic boom is the acoustical trace at the ground level of the aerodynamical shock flow pattern of a supersonic body. Two types of sonic booms are generally considered. Primary booms are emitted below the aircraft and propagate over a few tens of kilometers directly down to the ground. Secondary booms are emitted above the aircraft and are reflected in the stratosphere or the thermosphere (depending on the wind orientation) back to the ground. Reflected primary booms that propagate in the upper atmosphere before returning to the ground are also considered as secondary booms. The main frequency of a primary boom is of the order of a few Hz, closely linked to the aircraft size. However, because of relatively short propagation distances and strong nonlinear effects, primary booms have a higher frequency content, with audible shocks. Primary booms are known to be quite sensitive to the atmospheric conditions. Roughly speaking, three types of dependance can be distinguished : large scale variations due to various climates on the earth surface, medium scale variations due to day-to-day meteorological conditions, and small scale variations due to local turbulence within the planetary boundary layer. After about half a century of studies, some better understanding of these effects is now available, although many aspects are beyond today's knowledge. The present works aims at synthesizing the present knowledge, based on various recent research programmes performed for various aircraft, for Mach numbers very close to one up to six. For almost transonic Mach numbers (less than 1.2), acoustical rays carrying out the acoustical field may or may not reach the ground, depending on Mach number, wind orientation and latitude. For higher Mach numbers (1.6 to 2) the amplitude of the pressure field below the aircraft in cruise conditions varies relatively little. Variability is much higher for the focused boom, or superboom, that occurs when the aircraft is accelerating before reaching its cruise speed. The rise time that characterizes the high frequency content may vary with days on one given point by about one magnitude order. As it is strongly governed by atmospheric temerature and humidity, it may also differ significantly, depending on the local climate. Also, the local turbulence, that is randomly scattering and focusing the shock fronts, makes this quantity highly variable. The width of the geographical extent at the ground level of the impact zone of rays also shows some specific features. Its variability and dependance with winds is much larger for lower Mach numbers (1.6) than higher one (2 or more). Variability is also larger at latitudes with oceanic or subpolar climates, than at lower ones with tropical conditions.