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Numerical simulations of acoustic and infrasound waves in the coupled ground-atmosphere system: sensitivity study to atmospheric conditions, synergy between balloon and ground sensors

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The presented work consists in 1) the full-wave modelling of waves in a coupled solid-atmosphere medium, and in 2) the analysis of planetary applications. A software modelling the coupled system between full Navier-Stokes (or compressible Euler) and elastodynamic equations is used as a starting point (see in particular [1], [2]). The numerical techniques as well as the latest developments are detailed. Thanks to the full Navier-Stokes implementation, the solver can take into account wind, viscosity and atmospheric attenuation, and enables modelling of gravity waves. Moreover, contrast of speed and impedance between the solid and atmospheric parts is high, highlighting the need of a coupled system solver considering both at the same time.

Three cases of applications are studied. Firstly, a ground impact is modelled in order to highlight coupling between the ground and the atmosphere. Secondly, ground explosions, atmospheric explosions, and microbaroms are simulated in various atmospheric conditions. Thirdly, a seismic event under mountains is envisaged.

A recent experiment involved a seismic hammer being shot several times in a flat topography frame. The hammer blows releasing enough energy in the ground and both its acoustic bang and seismic effects can be observed. The presented 2D simulations are set up to match the experiment's parameters. Simulations not only corroborate expected data, but also show low amplitude infrasound propagating ahead of the hammer's bang. Synergy between ground sensors and balloon platforms is highlighted.

Propagation of waves under different atmospheric conditions is simulated and analysed. The atmospheric models are generated using MSISE, for different times of the day (midday, midnight), at different dates (seasons), and for different climates (different latitudes and/or longitudes). The considered sources are ground explosions, atmospheric explosions (reentry of meteoritic bodies or of artificial spacecraft), and microbaroms. Simulated recorders play the role either of ground barometers or stratospheric balloon stations. Synergy between ground sensors and balloon platforms is again highlighted.

The effect of an earthquake occurring under non-flat topography (mountain range) on the atmosphere is studied, in particular as function of the roughness of the terrain.

[1] Brissaud, Q. (2017). Modélisation numérique des ondes atmosphériques issues des couplages solide/océan/atmosphère et applications. PhD thesis.

[2] Brissaud, Q., Martin, R., Garcia, R. F., and Komatitsch, D. (2017). Hybrid Galerkin numerical modelling of elastodynamics and compressible Navier-Stokes couplings: applications to seismo-gravito acoustic waves. Geophysical Journal International, 210(2):1047–1069.