PhD proposal

Study and characterization of the upper atmosphere by numerical inversion of infrasonic waves recorded on board stratospheric balloons.

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Applicant: Nationality of an EU country, Switzerland or Great Britain only. Must be a student at the time of application.

Keywords: Infrasounds, gravity waves, numerical modeling, inverse problems, atmosphere structure and dynamics.

PhD project :
Measurements of low frequency acoustic waves, as well as atmospheric gravity waves are generally carried out using pressure sensors deployed on the surface. However, during the last decade, a large number of new means of observation have been developed to observe these waves. First, the atmospheric pressure sensors are now deployed on stratospheric balloon platforms and allow these phenomena to be observed from another point of view. Long-term missions (Strateole / CNES, ULDB / NASA) allow in particular to obtain a large spatial coverage. In addition, observations by imaging satellites (AIRS / Aqua, GOLD / SES-14) or in situ (Mission GOCE), as well as ground observations of the ionosphere complete this range of observation means. In addition, new types of sensors providing vector information on atmospheric waves are starting to appear (accelerometers on the envelope of atmospheric balloons, seismometers, etc.) and are used to constrain the direction of arrival of atmospheric waves. Finally, such sensors are now deployed on other planets (INSIGHT mission to Mars, DRAGONGLY mission to Titan).
Our research team has developed, during the last 5 years, tools for numerical modeling of the propagation of acoustic waves, gravity waves and seismic waves in the atmosphere / solid coupled system of planets (Garcia et al., 2017; Brissaud et al ., 2017; Martire et al., 2018). These tools are the state of the art in the field because they allow to mechanically couple the solid and fluid parts, to take into account the attenuation of waves in the atmosphere and winds, and to model both the gravity waves, acoustic waves and shock waves in 3D models.
However, the inversion of the infrasound and seismic data to characterize the source of the waves and the structure of the atmosphere has not been implemented because the observations present a strong non-linearity to the parameters of the atmosphere, in particular to the variations of wind speed.

In this thesis, we propose to use the numerical tools developed and the atmospheric observations to explore various methods of inverting the wave sources and the structure of the atmosphere.
Firstly we will focus on the identification and characterization of wave sources (thunder, atmospheric explosions, earthquakes, infrasound emitted by waves and mountains ...) recorded by stratospheric balloon flights by means of direct simulations in a known atmosphere model. To validate the approach, we will use data from infrasound sensors under balloons acquired during an experiment carried out using explosives. Then we will analyze the various impulsive signals acquired by stratospheric flights.
In a second step we will use the data from long-term flights of stratospheric balloons (Stratéole, ULDB /

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NASA) as well as ocean wave models (WAVEWATCH3) to reverse the atmospheric wind profiles using microbaroms (infrasound emitted by interference constructive oceanic waves). Various parameterizations and inversion methods will be tested on this case study.
Finally, we will also study the potential of new vector observations (accelerometers, seismometers and rotation sensors on the ground or on balloon platforms) for the study of the atmosphere. For this, the sensitivity of these observations to atmospheric parameters and to the source will be determined.
All of these analyzes will identify both the wave sources to be considered, the means of observation (types of sensors and missions) and the inversion methods that will allow imaging of the structure of the atmosphere.

References :

1. Brissaud, Q., Martin, R., Garcia, R. F., & 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.
2. Garcia, R. F., Brissaud, Q., Rolland, L., Martin, R., Komatitsch, D., Spiga, A., ... & Banerdt, B. (2017). Finite-difference modeling of acoustic and gravity wave propagation in Mars atmosphere: application to infrasounds emitted by meteor impacts. *Space Science Reviews*, *211*(1-4), 547-570
3. Martire, L., Brissaud, Q., Lai, V. H., Garcia, R. F., Martin, R., Krishnamoorthy, S., ... & Mimoun, D. (2018). Numerical Simulation of the Atmospheric Signature of Artificial and Natural Seismic Events. *Geophysical Research Letters*, *45*(21), 12-085.