Call for Application - PhD Fellowship in Space Research

Modeling and inversion of tsunami waves based on their ionospheric GPS/GNSS signature

Géoazur Laboratory, Sophia-Antipolis, France

3 years full-time contract with CNES (French national space agency)

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*CNES PhD application due **31 March, 2020** at:*
https://recrutement.cnes.fr/en/annonce/898720-71-modelisationinversion-des-tsunamis-a-partir-de-signature-ionospherique-gnss-06560-valbonne

Scientific Background:

Too often, tsunami warning systems do not provide a reliable estimate of the wave size in time to efficiently warn threatened coastal populations. This lack is especially critical in regions with little or no dedicated instrumentation. Therefore, despite the experience gained after the destructive Sumatra-Andaman tsunami in 2004, the Sulawesi-Palu tsunami in December 2018 lead Indonesia's tsunami early-warning system to a false estimate. Despite a lack of sensors on the ground or in the water, many coastal regions are constantly being monitored by radio signals emitted by GNSS (Global Navigation Satellite Systems such as GPS, GLONASS, and Galileo). Although originally designed for precise positioning, navigation, and timing, it was proposed a couple decades ago that the signals recorded from these satellite constellations could be used for large-scale natural hazard monitoring, and might in particular contribute to a rapid and accurate assessment of tsunami threats.

Tsunamis remain extremely difficult to observe before they arrive at a coast, which can be nearby or far away from the actual tsunami source location (e.g. an underwater earthquake, a landslide, or a meteorite impact). This difficulty is due to the low amplitude of the tsunami wave in the open ocean (on the order of a meter for the largest and most destructive) and the long wavelengths of these oceanic gravity waves (on the order of a hundred kilometers). Important to this project, these gravity waves efficiently couple energy into the atmosphere, which eventually perturbs the ionosphere, the ionized part of Earth's upper atmosphere. The ionospheric footprint of tsunamis can now be probed using GPS/GNSS tools, capable of measuring fluctuations in ionization. The ionospheric response intensity depends on, among other parameters, the size of the tsunami (Rolland et al., 2010; Lovett, 2010). Because the quantity used by tsunami warning centers is the variation in water height at ocean level, physical modelling must be implemented to relate the ionospheric measurement to the water height variation.

The objective of the thesis is therefore to consolidate and develop a methodology for tsunami height inversion using ionospheric data extracted from GNSS measurements. Initiated by Rakoto et al. 2017 and Rakoto et al. 2018, the method is based on a generalized spherical harmonic summation formalism (Lognonné et al., 1998). This method has been successfully used to model a wide variety of atmospheric and ionospheric disturbances excited by earthquakes and tsunamis.

Proposed work plan:

In order to improve the reconstruction of the main tsunami wavefront, the PhD student's work will first consider the effects of 3D bathymetry, as well as reflections along the coasts adjacent to the tsunami generation zone. The student will be in charge of evaluating how uncertainties in the model parameters and measurement noise affect the inversion. A realistic noise model could thus include environmental parameters such as geomagnetic activity or local time (e.g. the ionosphere is more agitated at noon than at midnight local time), geometrical parameters such as the configuration of GNSS satellites, and realistic instrumental noise estimated from experimental measurements at sea. The ionospheric signature of several past tsunamis will allow to set up a robust inversion chain and even provide quality indicators on the estimated tsunami wave height. Finally, in the perspective of future tsunami warning operations, the PhD student will contribute to a real-time implementation of the method based on observations acquired during measurement campaigns conducted on the Mediterranean sea and the Pacific Ocean in which he/she will be able to participate.

Working environment:

The host laboratory, Géoazur, is a multidisciplinary research unit of the Observatoire de la Côte d'Azur and is located in the Sophia-Antipolis technology park near Nice, in Côte d'Azur, South of France. The PhD degree will be awarded by Université de la Côte d'Azur (UCA), one of the top ten French universities.

This PhD fellowship, supported by the French space agency CNES, will take place in the context of the ITEC (Ionospheric Total Electron Content tsunamimeter) project funded by the French national research agency ANR (2020-2023) and labelled by the SAFE cluster. The project coordinator, Lucie Rolland, will be the main supervisor of the PhD candidate. In addition, the student will work closely with the ionospheric seismology group of the Institut de Physique du Globe de Paris (IPGP). The theoretical aspects of the thesis will be co-advised by Philippe Lognonné. The collaborative environment and the skills gained during this thesis project will offer opportunities both in academic research and in research and development, especially in companies specializing in the exploitation of data from the space sector.

Application requirements and procedure:

This thesis is open to any interested candidate with a strong background in theoretical and applied physics (geophysics, astrophysics, remote sensing). A specialization in numerical modeling is highly appreciated. The person recruited must hold a Master's degree or an equivalent diploma obtained by 2020 at the latest (see the requirements for application to the fundamental science doctoral school here). Prior to submitting the formal grant application on the CNES website here, prospective applicants are invited to send a resume and a motivation letter to Lucie Rolland (Géoazur Laboratory) no later than **24 March 2020**. Interviews will be conducted as soon as a relevant application is received.

For any question regarding this application please contact:

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References:

Rolland et al. (2010). Ionospheric gravity waves detected offshore Hawaii after tsunamis. *Geophysical Research Letters* 37.17.

Lovett (2010). Tsunamis leave ionosphere all shook up. In: *Nature*. https://www.nature.com/news/2010/100914/full/news.2010.467.html.

Lognonné, P., Clévédé, E., & Kanamori, H. (1998). Computation of seismograms and atmospheric oscillations by normal-mode summation for a spherical earth model with realistic atmosphere. *Geophysical Journal International*, *135*(2), 388-406.

Rakoto et al. (2017). "Tsunami modeling with solid Earth-ocean-atmosphere coupled normal modes". In: *Geophysical Journal International* 211.2, pp. 1119–1138. issn: 0956-540X.

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