ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT ET PHYSIQUE DE L'UNIVERS, PARIS

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Subject title: Near-real-time detection and assessment of trans-oceanic tsunamis from space

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Presentation of the subject:

A tsunami (from Japanese "harbor wave") is an unusually large wave occurring in a result of the displacement of a large volume of water. Tsunamis are usually generated by submarine earthquakes, but can also be caused by landslides or underwater volcanic eruptions. Tsunamis are one of the deadliest natural hazards and remain difficult or even impossible to predict. Therefore, their rapid and timely detection becomes the only way to prevent or to reduce the human loss.

The near-real-time (NRT) monitoring of tsunami propagation in both near-field (<500 km from the source) and far-field (>500 km away from the source and trans-oceanic propagation) remains very challenging. It can be done by using seafloor pressure sensors, deep-ocean assessment and reporting of tsunamis (DART) and tide gauges. However, most of the tsunamigenic areas of our Planet are not equipped with necessary instruments. Besides, systems like DART are very expensive, difficult in maintenance, and often go out of order. Therefore, it is of highest importance to develop new and more accessible methods that will enable to monitor tsunami propagation and to assess the risk of tsunamis of any origin.

One of the new and innovative approaches is the use of ionospheric measurements. The ionosphere is a part the Earth's atmosphere with the maximum of ionization located at 200-400 km of altitude. However, despite being high above the surface, the ionosphere is sensible to natural hazards and man-made events (e.g, explosions, rocket launches, nuclear tests). Tsunamis generate gravity waves that propagate upward and trigger atmospheric/ionospheric perturbations.

The main aim of this PhD thesis is to develop methods allowing for tsunami detection and assessment in NRT, by using ionospheric GNSS data. The final idea is to contribute in the improvement of the existing tsunami early warning systems.

This work will involve 1) development of novel NRT-compatible methods of automatic detection of ionospheric disturbances generated by tsunamis, including that of seismic and volcanic origin; 2) development and application of machine learning techniques for tsunami detection and separation from other ionospheric disturbances (i.e., travelling ionospheric disturbances, TIDs); 3) development of empirical and rapid semi-numerical NRT methods of inversion of tsunami parameters (wave height and propagation speed) from the ionosphere;

The main instrument to be used is Global Navigation Satellite System (GNSS) that allows to measure total electron content (TEC) above the receiver and up to 500-600 km of away from it, including over the water. Each modern GNSS receiver can capture up to 35-50 GNSS satellites, providing up to numerous observation points at each moment of time. Using data of GNSS satellites on islands opens new possibilities for ionosphere-based monitoring of tsunamis propagation.