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Parameterizing the gains in earthquake monitoring using submarine optical fiber telecom cables

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The need for submarine observatories to monitor offshore tectonic sources that can generate destructive earthquakes and tsunamis is widely recognized but the requirements of real-time communications and cost has hindered its Implementation. Only very few dedicated cables with sensors are in operation today. If the dozens of commercial telecommunication submarine cables that are deployed every year were instrumented, they could revolutionize the offshore earthquake monitoring. These cables, named as SMART (Science Monitoring And Reliable) have been advocated by the JTF of United Nations (Joint Task Force) for nearly a decade but none has been deployed today. However, there are several identified projects that should become the first pilots worldwide.

Fiber optic research have shown that the cable itself can be used as strain meters and useful for seismic monitoring.

One technology is DAS, Distributed Acoustic Sensing. DAS uses a single dedicated portion of (dark) fiber on a submarine cable, with a length about ~100 km. It can be modelled as a distributed strain sensor, with localization ability of a few meters. The DAS signal using OTDR (optical time domain reflectometry) and signal phase detection measures the fiber strain and record earthquakes with a resolution like broadband seismic sensors.

Another technology is LI (Laser Interferometry). LI may use a dark fiber or a single telecom wavelength channel in an optical fiber pair with commercial traffic, thousands km long. It relies on frequency stable laser sources and coherent detection. LI detects the changes of fiber optical transmission parameters over the whole cable. Using recording instruments on both ends, the arrival point of the first seismic waves is determined, and the azimuth to the epicenter estimated.

This work proposes and applies one methodology to assess the gain in earthquake source information using any of the three cable sensor technologies mentioned, against a background

scenario that includes only land stations. We use a Monte-Carlo simulation to allow for picking uncertainties, local and regional variations of propagation velocity models. We parametrize the gain in information by measuring the epicenter uncertainty ellipse and the focal depth variability.

The proposed methodology is applied to the NE Atlantic domain, SW Iberia and the Azores archipelago, an area where the relative motion of the Nubia, Eurasia and North America plates can generate large and destructive earthquakes and tsunamis.

While the inclusion in the monitoring network of SMART observatories, placed inside cable repeaters, spaced every ±70 km, is straightforward, the use of DAS and LI is not. For DAS and LI we consider that observations can be decimated to virtual seismic stations every 5 km and 1 km respectively. To avoid using a set of very close stations, we implement different station selection algorithms.

The investigation presented in this work was conducted by LEA, Listening to the Earth under the Atlantic, a partnership between IT, IPMA and IDL. One of the main objectives of LEA is to promote research, development, training and outreach on geophysical and oceanographic phenomena using submarine cables, fostering its applications to Science and Civil Protection.