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Towards Tsunami Early-Warning with Distributed Acoustic Sensing (DAS)

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Although Tsunami Early Warning Systems (TEWS) are in operation, they are yet to become the norm, mainly due to the high cost of installation and operation of offshore instrumentation with sufficient spatial coverage and spatial density of instruments. Tsunami observations are made mostly by coastal tide gauges, fixed moorings located offshore such as DART, or cabled observatories such as S-NET or NEPTUNE. While S-NET is capable of near-field warnings, many systems rely on seismic data, an effective TEWS should rely on direct measurements of the wave to avoid errors in the extrapolation of seismic information, and allow detection of tsunami from other sources (volcanic eruptions and submarine landslides).

To maximize evacuation time for coastal communities, tsunami warning systems should be based on sensors deployed as close as possible to the offshore source areas such as subduction earthquakes. With the advent of seafloor Distributed Acoustic Sensing (DAS), such deployments are becoming feasible at a relatively low cost and can deliver upon other key requirements for early-warning systems: Delivering real-time data from a dense array of strain sensors. DAS is capable of converting the already existing seafloor telecom fiber links into a dense linear array of strain sensors over spans of up to 100 km. With such attributes, DAS is becoming a sensor package to consider in the design of future TEWS, as a cost-effective means of deploying instrumentation directly at offshore locations such as active plate margins and subduction zones where the most destructive tsunamis are generated. Providing several measurements per tsunami wavelength, in real-time would allow faster forecasting of a tsunami.

Despite the aforementioned attributes, there are some aspects of DAS that need to be addressed towards integrating these sensors into future early-warning systems: 1) DAS measures 1D horizontal strain when vertical pressure is the usual means to detect tsunami, and 2) DAS usually has lower performance at long periods typical of a tsunami (a few 100s). In this work, we investigate both aspects. For the former, we present an analysis based on a 3-D full physics simulation which couple the dynamic rupture to the tsunami wave generation and propagation; upon which we estimate the expected strain observable on a submarine cable due to two effects induced by the hydrostatic pressure perturbations arising from tsunami waves: the Poisson's effect of the submarine cable and the compliance effect of the seafloor. We also consider the

effect of seafloor shear stresses induced by the horizontal fluid flow arising from tsunami waves. For the latter point, we review the low-frequency limit of DAS and present recently reported improvements in low-frequency sensitivity of a DAS system using linearly chirped pulses (cp-DAS); attained by suppressing the 1/f noise from the instrument. Tsunamis are expected to be observable with high signal-to-noise ratio, within a few minutes of the source onset, on seafloor cables located above or near the source area.