CSQ-51 Summary

Question	Knowledge Advancement Objectives	Observables	Measurement Requirements	Tools & Models	Policies / Benefits
How we can improve the understanding of lithosphere-atmosphere-ionosphere coupling mechanisms?	A) high spatial resolution measurements of the total electron content of the ionosphere	• **Gravity waves** • **Acoustic waves** • **Ionosphere density**	measurements at frequency of higher than ~3.3 mHz measurements every 1min	GNSS receivers, Ionosonde networks and airglow cameras Gravimeters	Support the emergency plans during large earthquake and tsunami And major Volcanic eruption Improve the knowledge of interactions between lithosphere-atmosphere-ionosphere
	B) improve the measurements of Atmospheric anomalies (short term)	• Atmospheric temperatures • Clouds shapes	Atmospheric profiles from different sources	Atmospheric profiles Polar and Geostationary meteorological satellites	
	C) Measure short term atmospheric pressure waves triggered by earthquakes, explosions, volcanic eruptions, tsunamis,	• Atmospheric pressure	Atmospheric profiles from different sources		

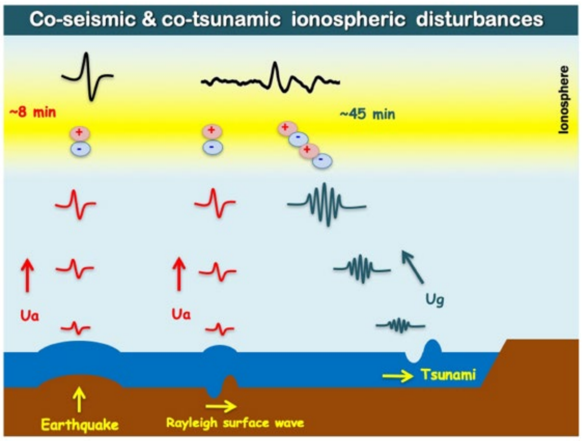
CSQ-51 Narrative

Tsunami Early Warning System for the Indian Ocean (https://www. gitews.org/; Falck et al., 2010), and so forth. These systems largely rely on “classic” geophysical data sets. However, despite numerous efforts, the classic methods still fail to correctly estimate the magnitude of large earthquakes (Mw > 8) in real time, and therefore, they also fail to correctly estimate the tsunami potential. In response to this need, it has recently been suggested that the ionosphere-based technique could, in future, present a novel approach for Natural Hazard-detection in near-real time (e.g., Savastano et al., 2017).

The ionosphere can be strongly perturbed by disturbances in the geomagnetic field, such as geomagnetic storms and substorms. In addition, the magnetic field plays an important role in the propagation of plasma perturbations. The ionized particles are not free to move horizontally, as they are confined by the Earth's magnetic field. As a result, any movement of the neutral air in the meridional direction will blow ionization along the magnetic field.

Impulsive forcing from the Earth's surface occurring due to earthquakes, explosions, volcanic eruptions, tsunamis, and so forth triggers atmospheric pressure waves. Depending on their frequencies, these atmospheric waves can be distinguished as acoustic and gravity waves. The acoustic waves are characterized by frequencies higher than the acoustic cutoff frequency (ωa), that is, higher than ~3.3 mHz. The acoustic waves are longitudinal waves in which particle moves in the direction of the wave propagation.

During earthquakes, vertical displacements of the ground or of the ocean floor induce perturbations in the atmosphere and ionosphere (Figure). The ionospheric perturbations, called coseismic ionospheric disturbances (CSID), are usually detected ~8–9 min after an earthquake. The Rayleigh surface waves generated by earthquakes propagate along the Earth's surface and induce acoustic waves that ~8–9 min later can be registered in the ionosphere, similarly to CSID generated by the coseismic crustal piston-like motion (Figure).



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