CSQ-36 Summary

Question	Knowledge Advancement Objectives	Geophysical Observables	Measurement Requirements	Tools & Models	Policies / Benefits
Can we observe, model and forecast the deformation processes during the seismic cycle at plate boundaries, from pre- to post-seismic phases and during the inter-seismic phase ?	A) Identify and delineate the locked versus the creeping segments of plate boundaries, and monitor inter-seismic strain accumulation, by accurately measuring the surface deformations of the plates around major boundaries.	. Surface displacements on land by GNSS and satellite imagery • Seafloor displacements • Gravity to constrain mass changes	• Long-term trends • High accuracy over all spatial scales • Multi-satellite missions with orbit inclination choice can help to improve the gravity recovery (this point is valid for all the Objectives here).	Models of surface deformations and gravity changes associated with slip at the plates interface (back-slip models)	Seismic hazard assessment and risk mitigation Emergency planning and response
	B) Document the spatio-temporal characteristics of transient aseismic events in subduction systems.	. Surface displacements on land by GNSS and satellite imagery • Seafloor displacements • Gravity to constrain mass changes • Ground geophysical dataset: seismicity	• Timescales from ~1 day to 2 years • High accuracy over all spatial scales. Mw 6 event: ~10x10km fault plane. Mw 7: ~30x30km plane. Mw 8: 100’s km.	Models of surface deformations and gravity changes associated with slip on faults (see below).	
	C) Document the possible existence of a short-term preparatory phase for earthquakes.	• Surface displacements on land by GNSS and satellite imagery • Seafloor displacements • Gravity to constrain mass changes • Ground geophysical dataset: seismicity	• Timescales from ~1 day to decadal • High accuracy over all spatial scales, including medium scales (100’s of km) to	Models of surface deformations and gravity changes associated with slip on faults and slab deformation.	

			monitor deep deformations	Calculation of stress redistribution	
	D) Quantify the co-seismic slip distribution and discriminate between early rupture models.	. Surface displacements on land by GNSS and satellite imagery • Seafloor displacements • Gravity to constrain mass changes ● Ground geophysical dataset: seismology, tsunami records from near-coastal pressure gauges and sea bottom pressure measurements	● High accuracy over all spatial scales. M_w 5 event: ~3x3km fault plane. M_w 6: ~10x10km fault plane. M_w 7: ~30x30km plane. M_w 8: 100's km. ● Coverage on both sides of the plate boundaries and over epicentral areas. ● Gravity: 1cm EWH@200km resolution, monthly = detection of Mw > 7.4 earthquakes.	Models of surface deformations and gravity changes associated with slip on faults. Need to develop models able to account for the 3D structure of plate boundary zones (not only a radial stratification, also a lateral structuration of the Earth's physical parameters). Calculation of stress redistribution	
	E) Assess the relative contributions of localized vs distributed deformations at depth along the plates interface and in the surrounding mantle during the post-seismic phase, in order to quantify the stress redistribution along plate boundaries after an earthquake.	• Surface displacements on land by GNSS and satellite imagery • Seafloor displacements • Gravity to constrain mass changes	● Time scales from weeks to decades ● Coverage on both sides of the plate boundaries and over epicentral areas. ● High accuracy over a range of spatial scales to separate different spatio-	Models: same challenge as above to take into account the 3D structure of the Earth, also including models of visco-elastic relaxation of the mantle after a co-seismic rupture, and coupled models combining slow slip	

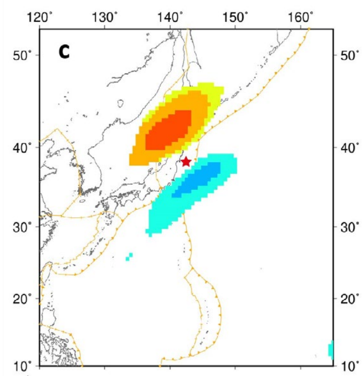
			temporal signatures of deep aseismic slip (more local) and mantle relaxation (involves larger scales)	and visco-elastic relaxation. Calculation of stress redistribution	

CSQ-36 Narrative

Constraining the mechanisms of stress accumulation and stress release at plate boundaries during the seismic cycle remains a major challenge of Earth's sciences. We need to identify the processes leading up to the initiation of a rupture, to accurately quantify the spatio-temporal distribution of the co-seismic slip and decipher the post-seismic deformation mechanisms, which contribute to the stress redistribution near the faults, thus the assessment of the seismic hazard.

At subduction zones, space geodetic observations of crustal displacements have shown that the plate boundaries include freely slipping sections and locked zones, where the interface between the plates cannot slip and the continental plate progressively deforms, until the stresses applied to the faults become too large and the rupture occurs. Finely monitoring this progressive strain accumulation in the continental plate remains essential in order to map the areas prone to a seismic rupture. Until now, it has however not been sufficient to anticipate a rupture over the short term. Geodetic and seismic data have also revealed a variety of transient motions at different time scales at the shallower depths of the plate interface, from tenths of second for tremors, to years during slow slip events (Schwartz & Rokosky, 2007). Their interactions with seismic ruptures is still not well understood. At greater depths, these transient motions are less well documented because they have not produced measurable crustal displacements, but they are reflected in observations of deep seismic activity, and more recently, in anomalous gravity signals observed 1-2 months before two great ruptures from GRACE (Panet et al., 2022). Retrospective analyses have evidenced a variety of such transient signals before large ruptures, suggesting the existence of interactions between deep and shallow deformation processes at different time scales prior to large subduction earthquakes (see references in Panet et al., 2022).

Today, our understanding of ruptures initiation is still based on a partial image of the movements near the plate boundaries, missing a large part of the motions at depth. The oceanic domain is also not well covered, yet subduction boundaries are located in coastal oceanic areas. To progress in the modelling, and possibly forecasting, of seismic cycle processes, it is essential to monitor deformation at all depths, over a broad range of spatial and temporal scales, on both sides of the plate boundaries. At subduction zones, this could allow us to understand the role of deeper slab dynamics in the initiation of a rupture. Combined with ground deformation and seismological data, a homogeneous coverage of mass changes all over oceanic epicentral areas as obtained by satellite gravity would provide a better description of the spatial extent of the co-seismic slip and enable us to assess the relative role of different post-seismic deformation processes, such as localized slip or mantle visco-elastic relaxation.



Anomalous gravity gradient signal in February 2011, before the March 2011 Tohoku earthquake, attributed to slab extension (Panet et al., 2022). Colors : -0.075 to 0.075 mEötvös.

References

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