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Gravitational stresses and tectonic loading near shore: insights from the Gulf of Cadiz.

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The state of stress in coastal regions near plate boundaries is commonly dominated by plate tectonic driving forces. Other sources of stress such as crustal thickness heterogeneities and water loading are unlikely to perceptibly alter the stress build up on major plate boundary faults. They may however significantly change the stress on secondary coastal fault systems, altering the accumulated tectonic stress needed for these faults to rupture. Although many studies demonstrate the impact of topographic and bending stresses on seismicity, particularly at shallow depths, this relation has been underestimated in coastal regions. And yet such stresses are especially relevant when fault systems associated with a plate boundary are close to the coastline. In the Gulf of Cadiz previous 2D modeling along a vertical section of the lithosphere, running approximately perpendicular to the Africa-Eurasia convergence, showed that flexural stresses exert a significant control on the seismicity pattern (Neves and Neves, 2009). Nonetheless a full 3D model was needed to address the effect of the coastline shape and to properly evaluate the gravitational stresses associated with topography, both of the surface and of the Moho. Here we present 3D finite element models that predict the elastic-strain energy that arises from the combined result of gravitational stresses, bending stresses associated with local deviations from isostasy and regional compression associated with the Africa-Eurasia convergence. The numerical finite element analysis was conducted using the ABAQUS/Standard software. The models are validated against the undulations of the geoid, which reflect variations in the gravitational potential energy in the lithosphere, the WSM stress indicators and the observed seismicity distribution. The modelling comprises two steps: step 1 simulates a geostatic state of stress induced by crustal thickness variations and water loading; step 2 simulates the NW regional compression caused by the Africa-Eurasia convergence. In step 1 the stress pattern is determined by the balance of vertical loads modulated by the distinct isostatic restoring forces applied on oceanic and continental regions. Near the surface topography plays a major role on focussing the strain-energy in the region of the Horseshoe Abyssal Plain. At the bottom of the elastic plate the region of high strain-energy is widely distributed along the coast following the continental margin. This pattern is produced by flexure and confirms the previous 2D models showing that the bending stresses are focused along the continental slope and are mainly supported by the mantle. When the convergence is superimposed on step 2 the stress builds up by elastic straining of the whole plate. Its more notorious effect at shallow depths is to displace the regions of high-strain energy against the major topographic features. Considering that motion along faults is stick-slip the balance between gravitational and tectonic loading depends on the length of the interseismic period. For long periods of tectonic stress build up the gravitational stress are negligible whereas for short periods they can be significant. We model both hypothesis and use the predicted stress field to compute the perturbation of the background stress caused by the presence of faults using a method based on the elastic dislocation theory. For some selected fault planes the Coulomb stress perturbations between step 1 and step 2 are calculated. In this way we discriminate the relative contribution of local sources of stress and regional tectonic forces to the seismic hazard in this region.