Characterisation of seismogenic zones and gas hydrates accumulation regions in the South Caribbean margin using 3D lithospheric-scale thermal and rheological models

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Active continental margins are potentially exposed to geohazards of different nature, including earthquakes and gas hydrate destabilisation, which may result in submarine landslides and devastating tsunamis. The northern margin of the South American plate is characterised by two flat-slab subductions: the Nazca plate from the west, and the Caribbean plate from the north. This defines a complex and poorly understood tectonic setting which poses a risk for the inhabitants of the region.

Gaining insight into the physical conditions (such as rock strength and temperature) at which earthquakes nucleate in this region requires building an improved lithospheric model, and determining the thermal and rheological states of the tectonic plates involved in this subduction system.

Combining 3D lithospheric-scale thermal and rheological modelling is a novel approach to establish the spatial variation of seismogenic zones, both at shallow and intermediate depths, thus providing crucial information about the range of conditions at which earthquakes may occur. This method is especially useful in regions like the South Caribbean where more classical approaches are limited because seismic records do not extend far back in time and the frequency of megathrust earthquakes is low.

Furthermore, in river-dominated continental margins, such as the South Caribbean, the destabilisation of gas hydrates deposits has been recently recognised as one of the most important triggering factors of submarine landslides. Gas hydrates are stable in low-temperature and high-pressure environments, normally found in marine sediments within continental slopes, with dominant temperatures ranging from 5°C to 10°C, at depths greater than 400 m. However, the gas hydrate stability zone is mainly controlled by the local geothermal gradient and the bottom water temperature, being both parameters influenced by the particular setting of each region.

Our research aims to evaluate the physical state of the seismogenic zones in the northern margin
of the South American plate and Panama microplate, and to identify the locations of potential gas hydrates accumulation in the South Caribbean margin.

Here we present the complete workflow of this analysis, starting from the definition of an up-to-date 3D lithospheric-scale model which has been validated with the forward modelling of gravity anomalies. This model is the main input for calculating the 3D steady-state thermal field and the 3D pressure field, using the software LYNX. Based on our modelled results, we evaluate the rheological behaviour of the present-day lithospheric configuration, considering the locations of the earthquakes from the Bulletin of the International Seismological Centre. Finally, by modelling the temperature and pressure within the marine sediments, we constrain the spatial distribution of the potential gas hydrate stability zone.

With this work we exemplify how 3D lithospheric-scale thermal and rheological models may contribute to the assessment of geohazards in a region such as the Caribbean Sea, where hundreds of thousands of coastal inhabitants, tourists and infrastructures are potentially at risk.