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Assessing the Seismic Potential of South America with Crustal Deformation Models and Historic Earthquakes

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ABSTRACT

We assess the seismic hazard potential of regions along the 7,500 km long South American (SA) Trench and the active Ecuador-Colombia-Venezuela Plate boundary Zone by examining active tectonic deformation, interplate coupling, crustal strain rates and historic seismicity patterns. The experiments use a continent-wide, two-decade old collection of (pre-Maule) GPS velocity field (1) observations as input to a suite of kinematic models that separately incorporate both fault-block and continuum approaches to quantify tectonic deformation. In parallel, we establish seismic activity rates for 40 seismic source zones all over SA by compiling a catalog of historic earthquakes. We quantify interplate coupling, fault slip-rates, and off-fault rates of strain for the deforming crust to provide geodetic constraints on the long-term patterns of active tectonic deformation. Specifically, we solve for slip and locking patterns along the South American subduction zone to reveal a series of highly coupled patches at offshore locations near the coasts of Ecuador, Colombia, Peru and Chile. These include locked patches that indicate high-friction producing "asperities" along the subduction interface responsible for the 2010 Mw 8.8 Maule and the April 1,2014 Mw 8.2 Iquique earthquakes. Predicted tectonic block motions and fault slip rates reveal that the northern part of South America deforms rapidly, consistent with that expected from a series of multiple tectonic blocks, with the northwestern region behaving as a continuously deforming region with concentrations of elevated strain rates. The fault slip rates and locking patterns predicted by our models reveal that the Oca Ancón-Pilar-Boconó fault system absorbs most of the complex convergence patterns in northeastern Colombia and Venezuela. The Guayaquil-Algeciras and its associated faults in eastern Colombia and Ecuador (e.g., the Romeral and El Tambor fault systems) absorb part of the crustal northeastward transpressional motion due to the Nazca plate convergence. To determine the seismicity rates and equivalent moment release in each seismic region, the spatio-temporal distribution of events were analyzed using information from historical earthquakes. In each source zone region, the moment deficit rates were determined by subtracting the seismic moment release (based on the historical earthquake catalogs) from the calculated tectonic moment accumulation rates. While most of the investigated regions have tectonic moment accumulations that are comparable with seismic moment releases detailed by historical catalogs, we identified zones that have unusually high discrepancies (e.g., the Bucaramanga and Medellín regions) presumably due to the sparse data coverage, inelastic deformation, and complex crust-mantle interactions. Eventually, we use the combined information from moment rates and fault coupling patterns to constrain stochastic seismic hazard models of the region that implement SA trench rupture scenarios. Compared to seismotectonic patterns from other active subduction zones of the world, convergence along the South American trench provides a classic case of a near-orthogonal subduction-orogen system dominated by a periodic, cyclical trench seismic release. In contrast, along the

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continent's active northern plate boundary zone, multi-directional plate convergence results in strain partitioning, with strain distributed along a broad triangular region, predominantly absorbed as slip distributed along fault systems.

Data is from the Global Strain Rate Model (Kreemer et al., in review) compiled mainly from Nocquet et al. 2014; Metois et al. 2012, 2013; Jouanne at al., 2011; Weber et al., 2001, among others.

KeyWords: Crustal Deformation, GPS, Kinematic Models, Subduction, Plate Boundary Zones, Seismic Hazards.