NBC's "10.5" may answer an age-old seismologic question *

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There is a new NBC four-hour miniseries set to air during the May sweeps period (2-3 May), titled simply enough "10.5." No, this is not a sequel to "9 and 1/2 weeks", nor is it a mini-sequel to "10". This number instead refers to a mega-earthquake that rocks the West Coast of the U.S. One may think, that the network writers have done their homework and have consulted a geophysicist or two regarding the realism of their program, let alone the title. This is just a short note to comment on their potential folly. I would like to clarify to the network writers, as well as to the non-seismologists in the earth science community what exactly a magnitude 10.5 earthquake could be, and why, if such were to occur, it may be more than just a West Coast problem. Alternatively, NBC may just soon answer an age-old seismologic question. . .

Magnitudes: What is an earthquake magnitude? The earthquake magnitude scale was first developed by Charles Richter in the 1930s to objectively quantify earthquake size. His magnitude scale was devised such that an incremental increase in magnitude corresponds with a roughly 10 fold increase in ground shaking, hence a magnitude 10.5 earthquake would feel like ten thousand magnitude 6.5 earthquakes (roughly the size of the 1994 Northridge earthquake that rattled L.A. a few years back). In addition to more recent surface and body-wave magnitudes, the Richter magnitude, is an empirical calculation that is dependent on the amplitude of shaking, the frequency at which that amplitude was measured, the distance from the earthquake and any corrections for local geology. These magnitude scales are all calculated from empirical formulae and yield no direct understanding of an individual earthquake's size. Instead, we must look at the moment magnitude.

The moment magnitude, M_w, is a magnitude that is derived from fundamental physical parameters that describe the amount of slip over an earthquake's rupture area. The moment magnitude is defined as

$$M_w = \frac{2}{3}(\log_{10} M_0) - 6.0, \tag{1}$$

where M_0 is the seismic moment of the earthquake. The fraction of 2/3 and the constant of 6.0 are used to correlate this magnitude estimate with current Richter-based magnitudes. The seismic moment, or the force applied to a length, is the same as a torque, but the understanding of why the ground doesn't spin is a bit too complex for this column (it lies in the idea that earthquakes have an equally opposing torque that keeps it from spinning, a double-couple). An earthquake's seismic moment is based on the physical parameters that define the event's rupture area, such that

$$M_0 = \mu \bar{D} A, \tag{2}$$

where μ is rigidity and approximately equals 30 GPa in the crust, $\bar{D}$ is the amount of slip, which scales with magnitude and is usually around 10 m for the largest of known crustal earthquakes, and A is the area that has slipped, which is equal to $l \times w$. The width, w, that is allowed to slip is controlled by the strength of the crust and is certainly limited to the upper 30 km in even the largest strike-slip (Los Angeles-type) earthquakes. It is the length parameter, l, that is the last real unknown and can be calculated based on these other parameters.

How big is a 10.5? Given that $M_w = 10.5$ and using equation 1, then $M_0 = 5.6 \times 10^{24} Nm$. If we assume normal plate rigidity, $\mu = 30$ GPa, and an enormous slip, $\bar{D} = 100$ m (10× larger than seen in the largest crustal earthquakes), we can use equation 2 to find the area, $A = 1.9 \times 10^6\, km^2$. Now, if we assume that the width of the rupture cannot extend more than 30 km into the earth, then the length would need to be just over $60,000$ km. Because the earth's circumference is just about $40,000$ km, a magnitude 10.5 earthquake would have to rupture *one and a half-times around the world*. That is one big earthquake! It is likely that the earth has never seen such an earthquake in it's 4.6 billion year history. The closest thing to come to it was the meteor impact on what is now the Yucatan Peninsula of Mexico, some 65 million years ago, that is hypothesized to have put an end to the dinosaurs. Lets hope that doesn't happen again soon.

Now assume that the slip in such an earthquake was a bit larger, this would allow the rupture length to be proportionally smaller. Doing so, may just answer one of the "great" seismologic questions.

California underwater? When I first moved to California for my postdoc at U.C. Santa Cruz, I was amazed at how many Californians would ask me upon our first meeting "So when is California going to fall off into the ocean?" I would usually respond with something about California most likely ending up in Alaska given enough time. That certainly was not the answer they wanted, nor did it gain me many friends. Well, now I may have an opportunity to change my answer.

To put California underwater we would need to change a couple of the previously mentioned earthquake rupture parameters. California's length, l_{CA}, is roughly 1200 km. The ocean floor off of California is about 5 km below sea-level. If we assumed an earthquake occurred along the California-Nevada boundary and was big enough to put all of California on the ocean floor (completely submerging the Sierras as well), its slip, $\bar{D}_{CA}$ would need to be at least 5 km and it would have a seismic moment,

$$M_{0_{CA}} = \mu \bar{D}_{CA} l_{CA} w \quad = 5.4 \times 10^{24}\, Nm.$$

Using equation 1,

$$M_{W_{CA}} = \frac{2}{3}(\log_{10} M_{0_{CA}}) - 6.0 \quad = 10.5.$$

Too bad I now live in New Mexico, because if I were to be asked the same question today, I think I would simply answer *Sweeps week.*

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