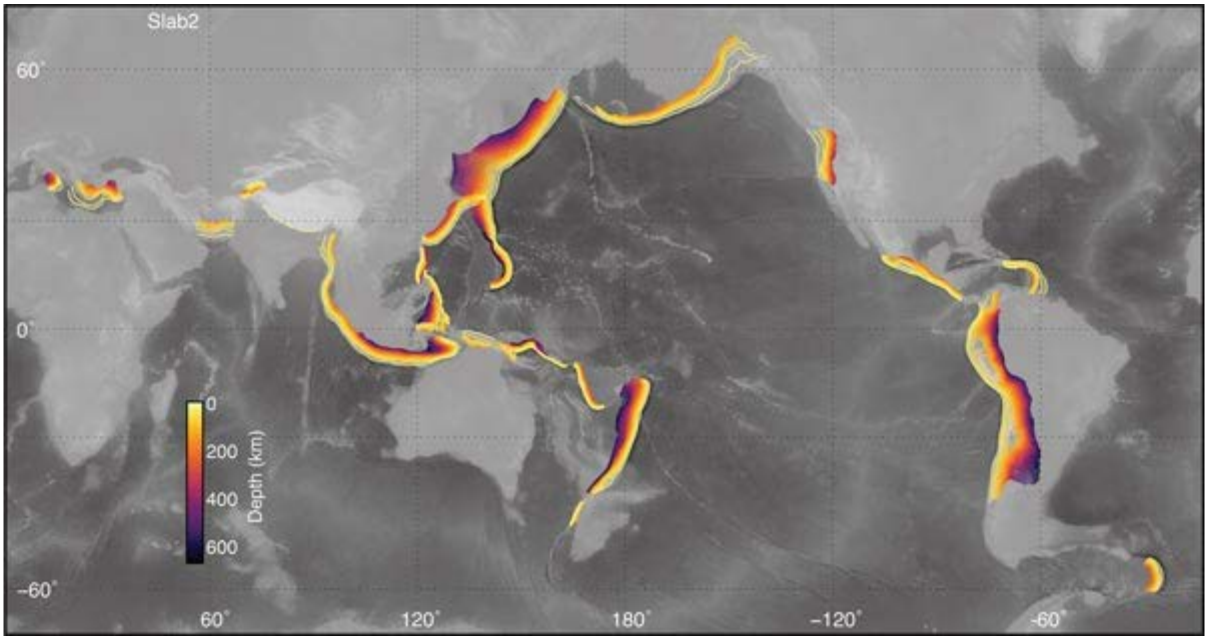
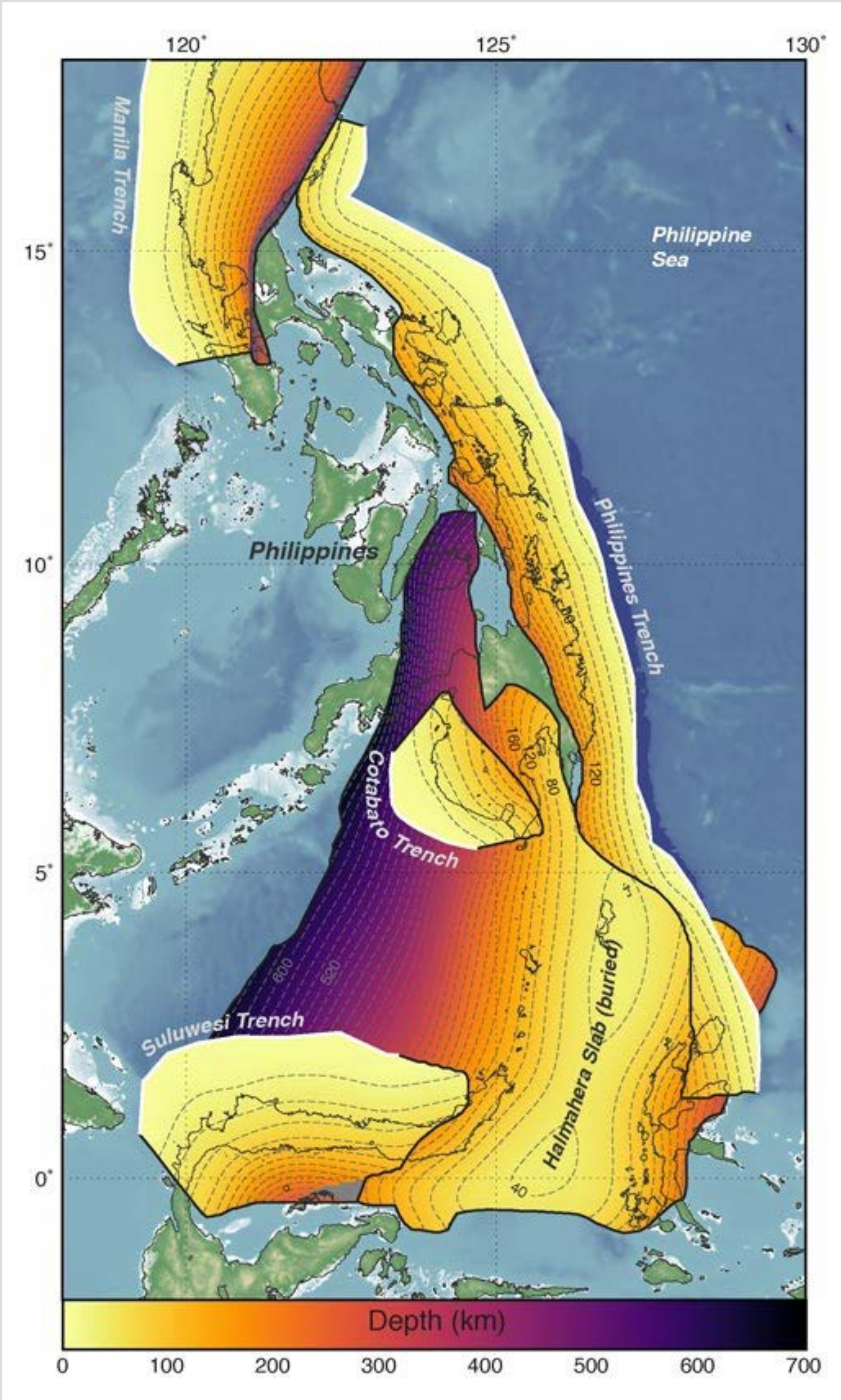
U.S. Geological Survey - Earthquake Hazards Program

Collection of 3D Geometries for Global Subduction Zones



The global distribution of models included in Slab2.

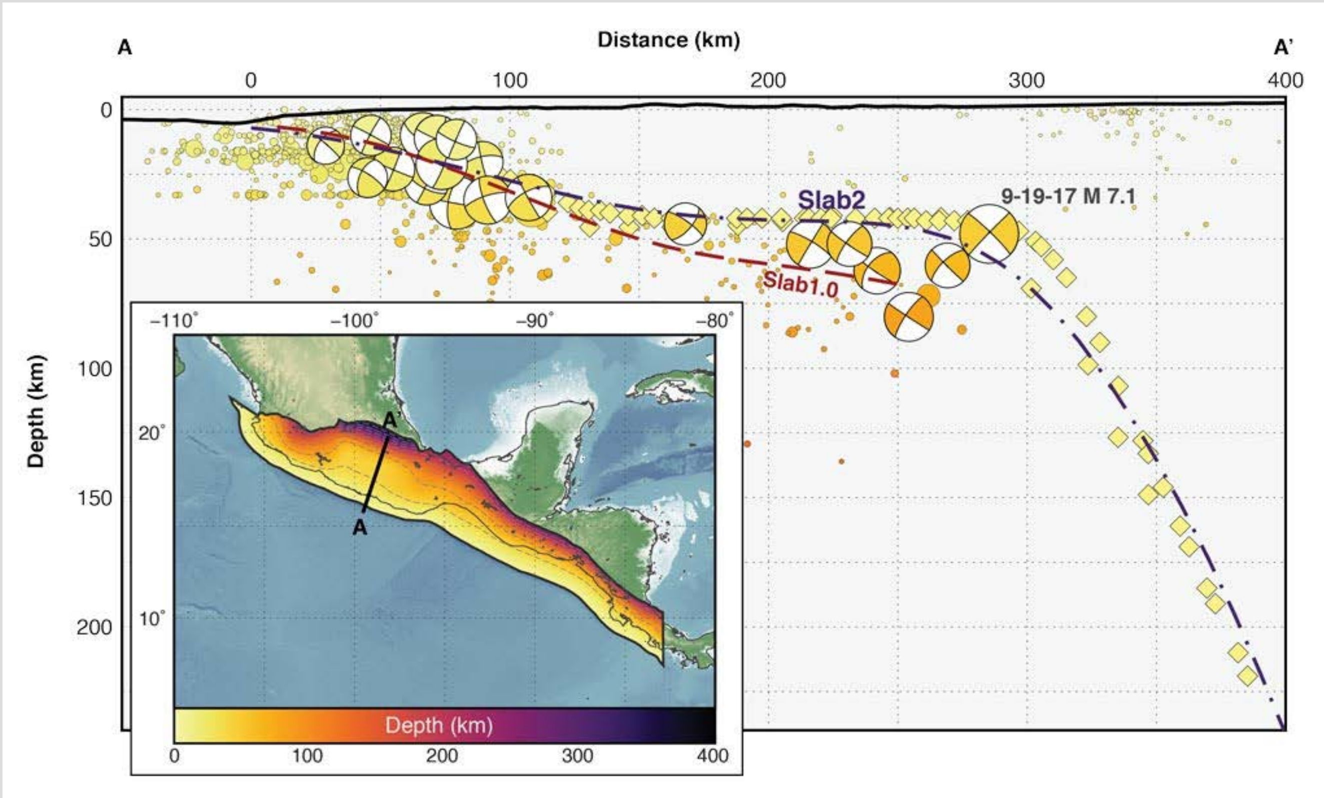
The world's largest earthquakes (magnitude 9+) occur in subduction zones, places on the planet where one tectonic plate is sliding under another. In fact, 90% of all the energy released in all the historical earthquakes are from the uppermost area of subduction zones where the two brittle plates are in contact. We know these areas are capable of generating enormous earthquakes, but just how large depends on the geometry of the slabs and their areas of contact with the upper (overlying) tectonic plate. Although subduction zones extend from the surface to as deep as ~700 km, the most hazardous area is the shallowest ~50 km where the large ("megathrust") earthquakes are generated. This is also the part of the slab that can produce tsunamis when an earthquake occurs.



Here, five slabs (the Manila, Philippine, Cotabato, Halmahera, and Sulawesi slabs, from north to south) interact with one another. The Halmahera slab is an inverted U-shaped subduction zone that is completely buried and has no surface expression. It underlies the Cotabato and Sulawesi slabs on its western limb and abuts or overlies the Philippine slab on its eastern limb.

Knowledge of the geometry of subducting slabs is a critical requirement for many types of seismic analyses, and is used as input into many types of seismological analyses. A previous model of worldwide subduction zones called Slab1.0 has been heavily used by seismology researchers. Slab1.0 was ripe for updates because of new information about subduction zone structure and the need for an improved approach to the modeling procedure that would create a better picture of the most important shallowest portion of the slab. The new model, Slab 2.0, includes more and different types of data that constrain slab geometry, including data for subduction zones not covered in the initial release. The new model also employs an improved modeling approach applied consistently for all subduction zones. The result is a 3D picture of all known active subduction zones globally from the near surface to the deepest part of the Earth's upper mantle, covering over 24 million square kilometers of the Earth.

This comprehensive analysis revealed that the down-dip limit of the seismogenic zone (where the slab is brittle and can produce earthquakes) varies from a depth of about 37 km to 54 km. The width (measured along the fault surface in the direction of subduction) varies from about 70 km (Manila slab) to 195 km (Alaska slab), averaging about 115 km. Taken together, these length and width estimates combine to yield an area estimate for the seismogenic portion of subduction zones that is approximately 30% larger than the older estimate. This has important implications for seismic hazard around the world: the greater the area capable of generating large earthquakes, the greater the overall hazard.



Slab2 model for the Middle America slab in Mexico. Main panel shows a cross-section of Slab2 (blue dot-dashed) vs Slab1.0 in this region (red dashed). The Slab2 model shows a more northeasterly extent to the flat slab than is imaged by earthquake data and focal mechanisms (circles and beachball symbols). Earthquakes and focal mechanisms are colored by depth, according to the scale used in the inset. The location and focal mechanism solution of the September 19, 2017, M7.1 intraplate earthquake near Mexico City is highlighted. The projection width of the cross-section is +/- 50 km.

If the extensive use of SLAB1.0 is any indication, this new collection will be used as a reference for, or starting point for:

- earthquake source characterization - defining the type of earthquake likely at each subduction zone site;
- global hazard analysis – estimating the detailed hazard at each site around the world;
- modeling megathrust behavior – puzzling out the complex motions of the large plate interactions at subduction zones;
- analyzing slow slip – figuring out when and how large plates slip slowly without causing a large earthquake;
- seismic anisotropy – estimating the structures in subduction zones that affect seismic wave propagation;
- volcano petrology – determining what type of geologic content may be in volcanic magma associated with the subducting slabs at each location;

- tsunami hazard – what subduction zones are most likely to cause a damaging tsunami; and
- mantle flow – the motion of the viscous mantle material directly beneath the earth's crust.

- written by Lisa Wald, USGS, September 2018

For More Information

- This Dynamic Earth: The Story of Plate Tectonics
- Slab2, a comprehensive subduction zone geometry model - replace with citation and final link
- Hayes, G., 2018, Slab2 - A Comprehensive Subduction Zone Geometry Model: U.S. Geological Survey data release.

The Scientist Behind the Science

Gavin Hayes with his children, Azalea, Winston and Calliope.

Gavin Hayes has worked at the USGS NEIC for 11 years. In his research, he attempts to use seismology to address key questions like "Why do earthquakes occur where they do, how big can they be, and how often do the largest events (re)occur?". He is also heavily involved in earthquake response, working on earthquakes in real-time to improve our knowledge of their size, slip distributions, tectonic settings, and their impact. When he's not working, Gavin loves to spend time with his wife, Vanessa, and their three children, Azalea, Winston and Calliope.