EGU2012-3743 CRUST1.0: An Updated Global Model of Earth's Crust

Gabi Laske[(1)], Guy Masters[(1)], Zhitu Ma[(1)] and Michael E. Pasyanos[(2)]

[(1)] *IGPP, Scripps Institution of Oceanography, UCSD*
[(2)] *Lawrence Livermore National Laboratory*

visit us at http://igppweb.ucsd.edu/~gabi/crust1.html
RELEASE of CRUST1.0 is expected by August 2012

This project was funded by NSF, DoD

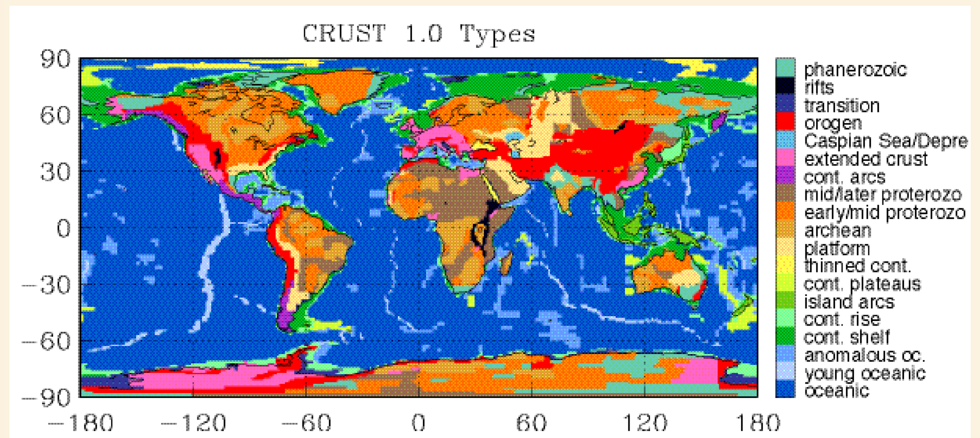
Abstract

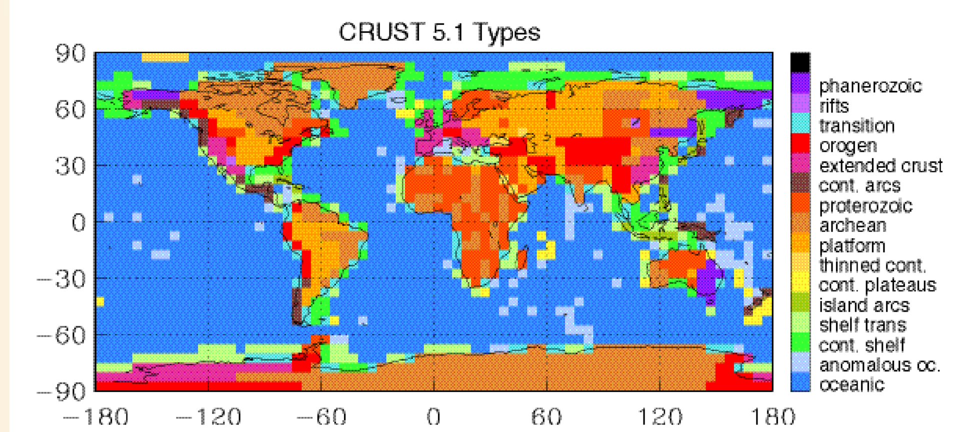
We present an updated global model of Earth's crustal structure. The new model, CRUST1.0, serves as starting model in a more comprehensive effort to compile a global model of Earth's crust and lithosphere, LITHO1.0. CRUST1.0 is defined on a 1-degree grid and is based on a new database of crustal thickness data from active source seismic studies as well as from receiver function studies. In areas where such constraints are still missing, for example in Antarctica, crustal thicknesses are estimated using gravity constraints.

The compilation of the new crustal model initially follows the philosophy of the widely used crustal model CRUST2.0 (Bassin et al., 2000; http://igppweb.ucsd.edu/~gabi/crust2.html). Crustal types representing properties in the crystalline crust are assigned according to basement age or tectonic setting. The classification of the latter loosely follows that of an updated map by Artemieva and Mooney (2001) (http://www.lithosphere.info). Statistical averages of crustal properties in each of these crustal types are extrapolated to areas with no local seismic or gravity constraint. In each 1-degree cell, boundary depth, compressional and shear velocity as well as density is given for 8 layers: water, ice, 3-layer sediment cover and upper, middle and lower crystalline crust.

Topography, bathymetry and ice cover are taken from ETOPO1. The sediment cover is essentially that of our sediment model (Laske and Masters, 1997; http://igppweb.ucsd.edu/~sediment.html), with several near-coastal updates. In the sediment cover and the crystalline crust, updated scaling relationships are used to assign compressional and shear velocity as well as density. In an initial step toward LITHO1.0, the model is then validated against our new global group velocity maps for Rayleigh and Love waves, particularly at frequencies between 30 and 40 mHz. CRUST1.0 is then adjusted in areas of extreme misfit where we suspect deficiencies in the crustal model. These currently include some near-coastal areas with thick sediment cover and several larger orogenic belts. Some remaining discrepancies, such as in backarc basins, may result from variations in the deeper uppermost mantle and remain unchanged in CRUST1.0 but will likely be modified in LITHO1.0. CRUST1.0 will be available for download.

A: Crustal Types in CRUST1.0





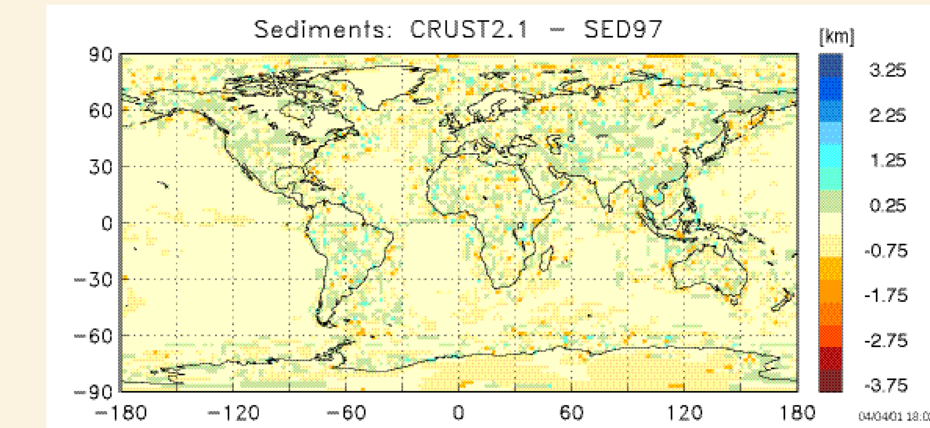
D- 01: Platform
E- 02: slow thin Platform
F- 03: Archean (Antarctica)
G1 04: early Archean
G2 05: late Archean
H1 06: early/mid Proterozoic
I1 07: late Proterozoic
I2 08: slow late Proterozoic
J- 09: island arc
K- 10: forearc
L1 11: continental arc
H2 12: early/mid Proterozoic (Antarctica, Greenland, S. America)
M- 13: extended crust
N- 14: fast extended crust (Antarctica)
O- 15: Orogen (Antarctica), very thick upper crust, very thin lower crust
P- 16: orogen, thick upper crust, very thin lower crust
Q- 17: orogen, thick upper crust
R- 18: orogen
T- 19: Margin-continent/shield transition
U- 20: Margin/Shield
X- 21: Rift
Z1 22: Phanerozoic
A1 23: normal oceanic
B- 24: melt affected o.c. and oceanic plateaus
C- 25: continental shelf
S- 26: continental slope, margin, transition
V1 27: inactive ridge, Alpha Ridge
V2 28: thinned cont. crust, Red Sea
W- 29: oceanic plateau with cont. crust
Y1 30: Caspian depression
Y2 31: intermed. cont./oc. crust, Black Sea
Y3 32: Caspian Sea oceanic
A0 33: oceans 3 Myrs and younger
Z2 34: Phanerozoic (Antarctica, Greenland)
L2 35: slow continental arc

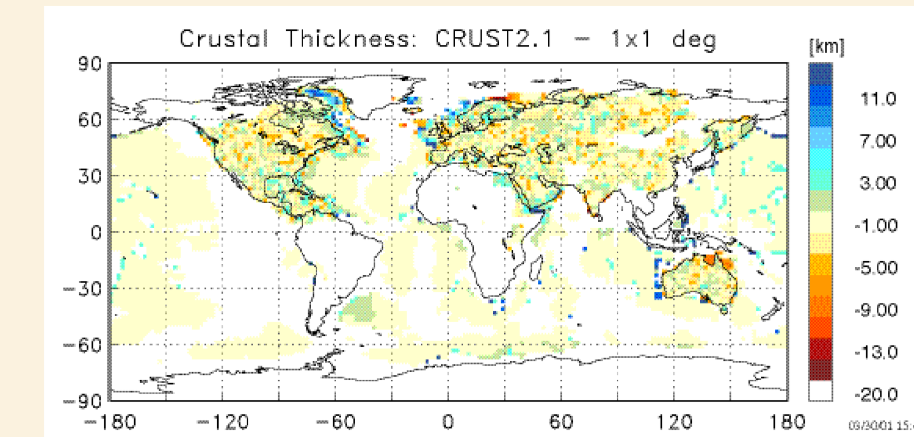
	CRUST 1.0	CRUST2.0	CRUST5.1
crustal types			
# crustal types	35	360	139
ice	-	binned	binned
		Brit. Ant. Serv.	Drewry, 83/Weidick 92
sediments	-	binned	binned
		closer L&M 97	loosely L&M 97
Moho depth	-	binned map	binned database
Vp, Vs, ρ	scaled	scaled	scaled
	validated		
layer thickness	relative	absolute	absolute
Vpn	in progress	CRUST5.1	estimated
basement age	Artemieva	loosely USGS	loosely USGS
type-independent			
topography	ETOPO1	ETOPO5	ETOPO5
ice thickness	NGDC/ETOPO1	-	-
sediments	updated L&M 97[(1)]	-	-
Moho depth	new model[(1)]	-	-
Vpn	LLNL+UCSD[(1)]	-	-

[(1)] work in progress

The role of crustal types has changed and now plays a minor role to only assign properties of the crystalline crust. The crustal types were completely reassigned to resemble the basement age of Artemieva and Mooney (2001). The scaling of the crustal elastic parameters were carefully validated in a similar fashion as sediment velocities. Some new crustal types where introduced to better match velocity anomalies in certain regions, such as the Himalayan orogenic belt and very young oceans.

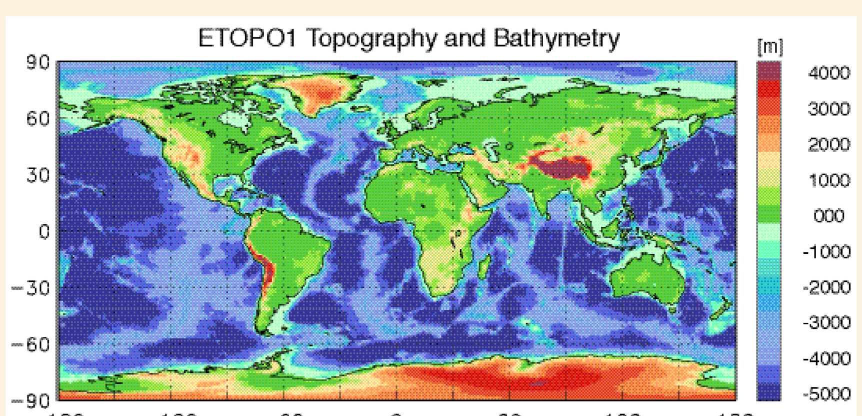
C: CRUST2.0: The Disadvantage of Tying Crustal Types to Sediment and Crustal Thickness



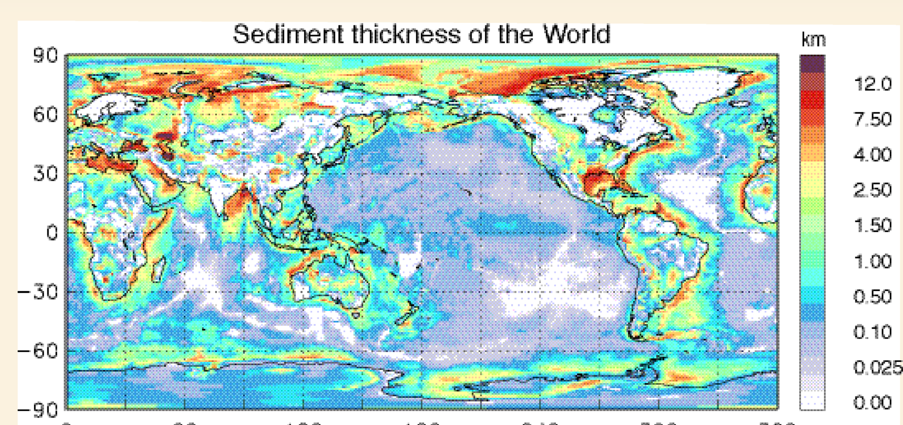


The manual assignment of crustal types is cumbersome. Many types are needed to accommodate variations in sediment and crustal thickness. This is the main reason why the number of crustal types jumped from 139 in CRUST 5.1 to 360 in CRUST2.0. CRUST2.0 tried to represent crustal thickness to within ± 5 km, sediment thickness to within 1.0 km and ice thickness to within 0.25 km of true values. Nevertheless, CRUST2.0 did not succeed everywhere to stay within these boundaries.

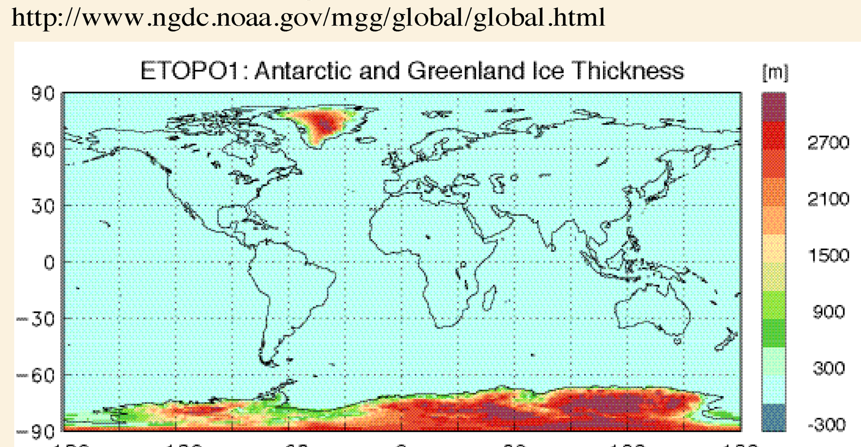
B: Independent Models Binned Into 1x1° Cells



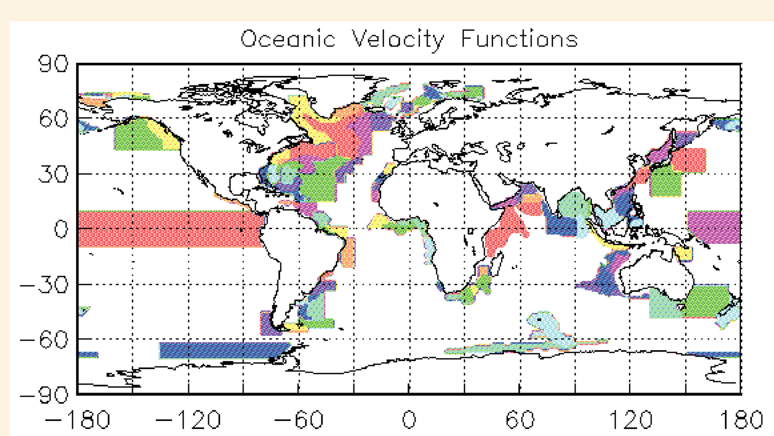
ETOPO1 bathymetry and topography were downloaded from the NGDC website and binned/averaged into 1° cells. Source:
http://www.ngdc.noaa.gov/mgg/global/global.html



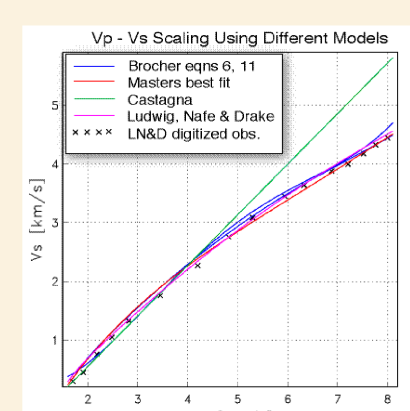
The Laske and Masters (1997) sediment model is now an independent part of CRUST1.0 in its entirety. It consists of three layers. In CRUST5.1 and CRUST2.0, the sediment cover was divided into unconsolidated and consolidated sediments.
The sediment model was updated in about 20 regions to fit surface wave group velocities.

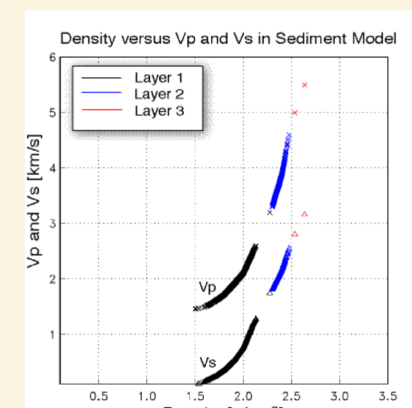


Ice surface and bedrock data are also part of the ETOPO1 dataset. They were downloaded from the NGDC website and binned/averaged into 1° cells. The raw data come from various sources, incl. Antarctic Digital Database, European Icesheet Modeling Initiative, Scientific Committee on Antarctic Research, NASA and the National Snow and Ice Data Center.



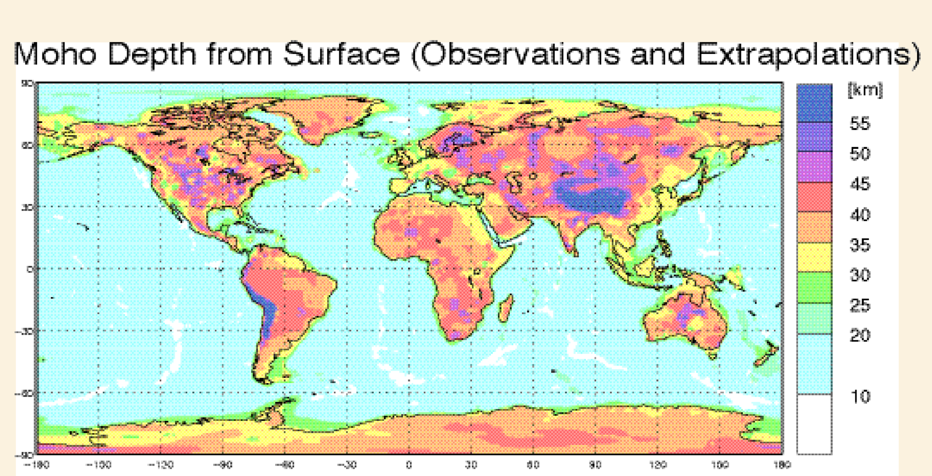
We use 170 distinct published and unpublished velocity functions to assign Vp as function of depth. The majority of these, 140, are in the oceans, while 20 distinct functions are assumed for continents. Discrepancies between observed and predicted 40-mHz group velocities (part D) may result from erroneous velocity functions and adjustments are in order.

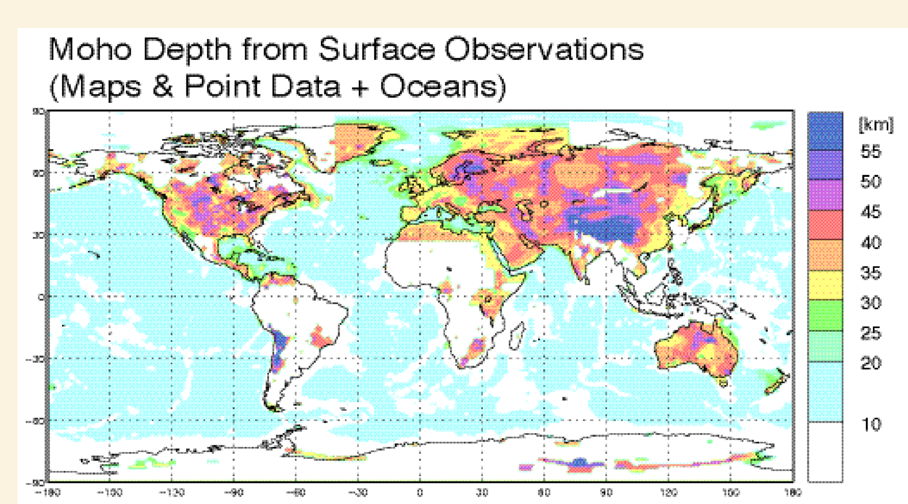




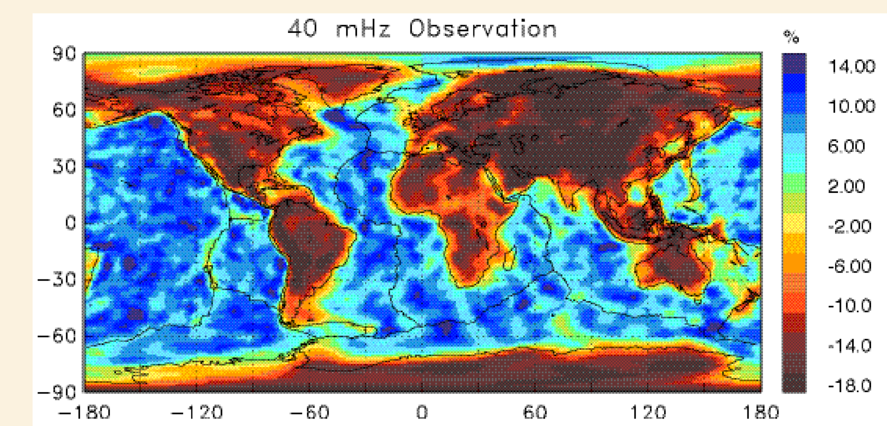
Left: The scaling of Vp, Vs and ρ was validated against Brocher, 2005, and other references. Right: Vp, Vs and density as actually used in the sediment model.

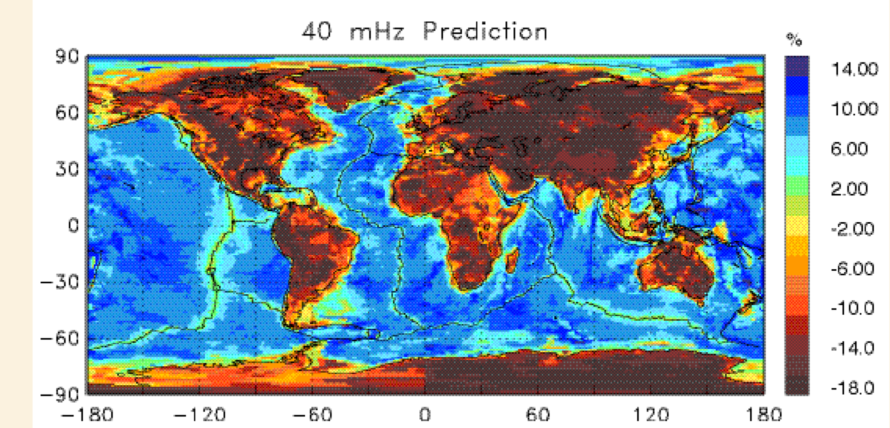
We compiled a new crustal thickness model from a combination of active source experiments, receiver functions and published Moho maps. A weighting scheme was applied in areas of data overlap.
In areas of no data coverage, crustal thicknesses were adopted from CRUST2.0. In areas with no data in the oceans, a standard crustal thickness was assumed.

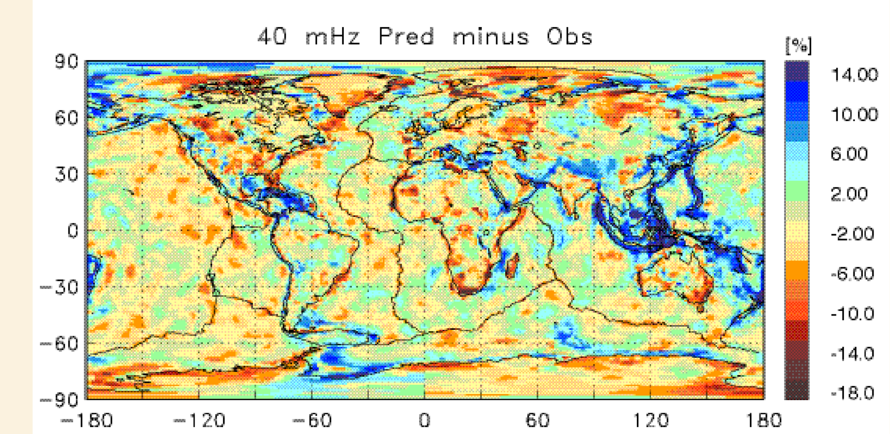




D: Validation against Rayleigh wave group velocities





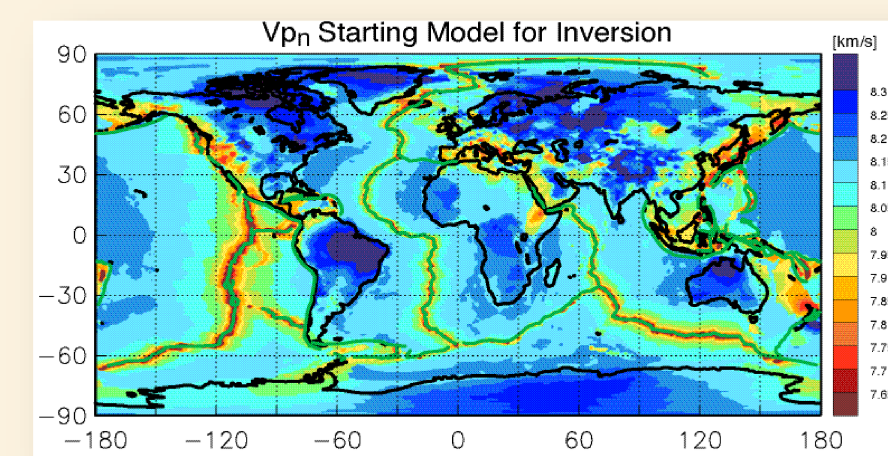


We validate our new crustal model against Rayleigh wave group velocity maps. That 40 mHz, group velocity is sensitive primarily to crustal structure, but also uppermost mantle structure. Validation therefore has to take into account that some discrepancies between observations and predictions can result from mantle structure that was not accounted for. The largest unexplained signal is found along subduction zones where the crustal model currently only accounts for the crust in the overriding plate but ignores anomalous deeper structure. Backarc basins also exhibit a significant mismatch.

Our highest priority before the release, however, is to remove some of the still existing discrepancies in some sedimetary basins.Our suspicion is that either sediment thickness is wrong by a 1km or the applied velocity function does not correctly prepresent Vp as function of depth.

E: To-Do List before Release

- Check sediment velocity functions (any unreliable functions??)
- Finish validation of sediment thickness, then adjust velocity functions to better fit surface wave data.
- Rerun predictions against surface wave maps and make final adjustments to sediments, Moho depth, elastic parameters.
- Add realistic Vpn model.



Our current "best-estimate" Vpn model, modified from LLNL Vpn model G3Dv3. In the oceans, a cooling halfspace model was assumed.

References

Artemieva, I.M. and Mooney, W.D., Thermal thickness and evolution of Precambrian lithosphere: A global study, J. Geophys. Res., 106, 16,387-16,414, 2001.

Bassin, C., Laske, G. and Masters, G., The Current Limits of Resolution for Surface Wave Tomography in North America, EOS Trans AGU, 81, F897, 2000.

Brocher, T.M., Empirical Relations between Elastic Wavespeeds and Density in the Earth's Crust, Bull. Seismol. Soc. Am., 95, 2081-2092, 2005.

Laske, G. and Masters, G., A Global Digital Map of Sediment Thickness, EOS Trans. AGU, 78, F483, 1997.