A Web Application for Modeling Anti-Neutrino Emissions

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Introduction	Going Forward	Acknowledgements & Source Code
Geoneutrinos, neutrinos originating from terrestrial sources, provide clues to the composition and distribution of radiogenic material within the Earth. However, the uncertainties of the current geoneutrino measurements are large enough such that no single earth model has been indicated ^[1] . Our web-based visualization allows quick comparisons between several models and even offers user defined inputs.	 In future versions we hope to have a number of additional features: Update to CRUST 1.0 Inclusion of tomographic mantle models Integration of reactor and earth model pages into a single page Our goal is to implement a useful tool for education as well as the research community. 	This work was supported in part by Lawrence Livermore National Laboratory and National Science Foundation grants through the Cooperative Studies of the Earth's Deep Interior program (EAR 0855838 and EAR 1068097). The source code for the model and website are available on github: https://github.com/docotak/geoneutrinos.org

Methods

The web-based earth model uses several data sources as inputs:

- CRUST 2.0 is used for basic crust parameters ^[2]
- ► PREM provides the basic physical mantle structure ^[3]
- ► A precomputed map of crustal neutrino fluxes ^[4]
- A precomputed map of neutrino fluxes from nuclear reactors
- ► A precomputed map of surface heat fluxes^[6]

Data were converted to JSON using python scripting language.

Real time calculations are performed in the web browser using JavaScript (JS). The following JS libraries are used:

- ► D3 Used to draw the map and colorbar
- ► jQuery Used to handle user input events

The web-based **reactor model** uses the following sources of data as inputs:

- Reactor location, power (thermal), load factors from the IAEA
- Map tiles from OpenStreetMap^[5]
- Data were converted to JSON using python scripting language.

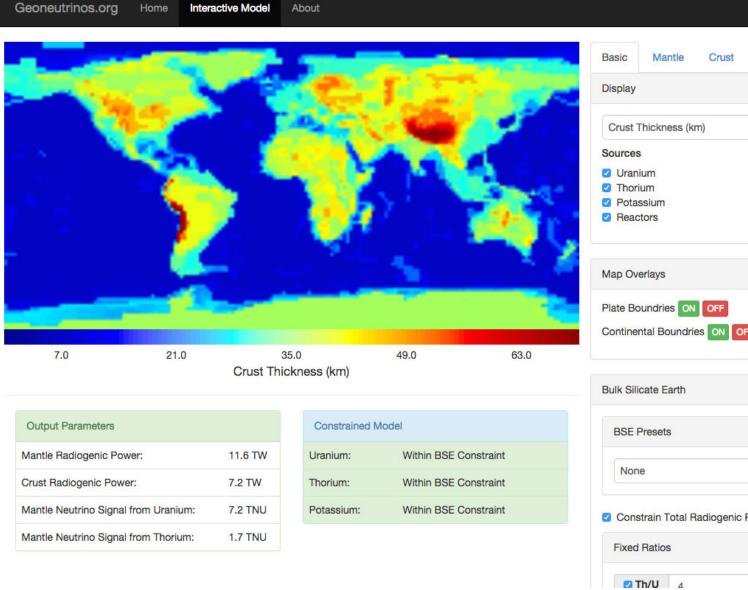
Real time calculations are performed in the web browser using JavaScript (JS). The following JS libraries are used:

- ► D3 Used to draw the spectrum plot
- React UI Abstraction library for the general user interface
- Leaflet Used to draw the map tiles

The webpage uses the Bootstrap library for quick user interface construction and tablet compatibility. Maps are drawn using HTML5 canvas, the overlays (land mass and plate boundaries) and colorbar are drawn using SVG.

Features

Overall Layout

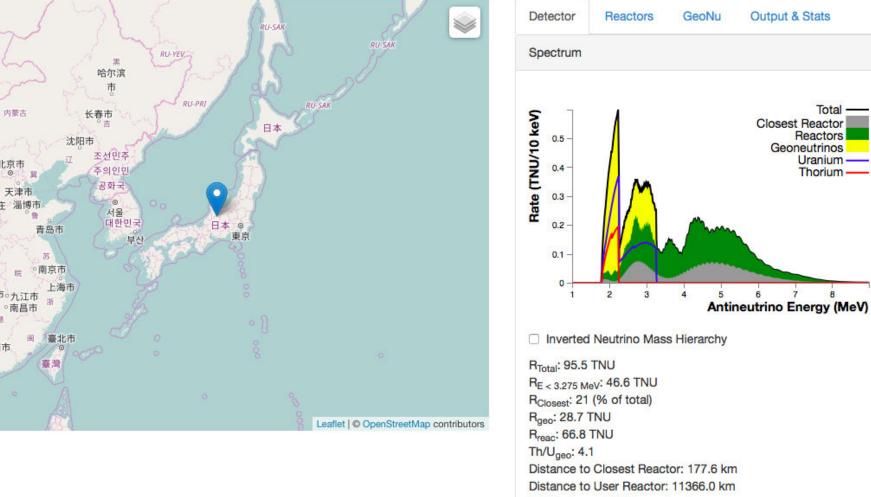


Basic Mantle Crust	_
Display	React
Crust Thickness (km)	+
Sources Uranium Thorium Potassium Reactors	1p
Map Overlays Plate Boundries ON OFF Continental Boundries ON OFF	呼和浩 将市 天 林市 三石家庄 /秦 郑州市 :市 **
Bulk Silicate Earth	判州市。 ^鄂 。武汉市。ታ
BSE Presets	长沙市。南湖
None	職州市 广州市 百宁市 男
Constrain Total Radiogenic Power	y .
Fixed Ratios	

100// in a naw tak

Geoneutrinos.org About Model Reactors

tors



Both earth and reactor pages feature a two column design, with a map on the left and user input on the right. The earth page map displays the results from the selected output as a "heatmap" with a colorbar scale underneath. The reactor page map is zoomable and displays the detector location, and optionally the location of all IAEA registered reactors. Both pages have user controls are organized into categories accessible via labeled tabs. The pages will adjust their layout to best fit the screen size, including devices as small as smartphones.

User Controls

Basic:

Continental Boundries ON OFF

Constrain Total Radiogenic Power

Bulk Silicate Earth

BSE Presets

Fixed Ratios

🗹 Th/U 🛛 4

✓ K/U 12000

None

- Change map display Chan
- Ability to toggle crust layers Adjust the element concentrations in

Crust Presets

None

Note:

heat.

Crust Layers

Soft Sediments Hard Sediments Upper Crust Middle Crust

Lower Crust

Crust Concetrations

Continental

Soft Sediments

Hard Sediments

Param

Upper Crust

Middle Crust

Param Change

Param

Chang

Change

Chang

Param

Oceanic

Value

17.5ng/g

81.0ng/g

183µg/g

Value

17.5ng/g

81.0ng/g

183µg/g

Value

27.0ng/g

232µg/g

105.0ng/g

Value

Crust:

Output: Output for import into RAT-PAC Significance calculator

1 TNU = 1 event/1032 free protons/year

Output Displays



 Change map display Change radiogenic sources Chose BSE preset Adjust BSE element ratios Toggle BSE constraint Adjust BSE element concentrations Toggle map overlays (continents, plate boundaries) 	 Chose mantle layer concentration presets 3 modes of input: homogenous mantle, two layer with adjustable depth boundary, all discrete layers in PREM If BSE constrained, two layer mantle will solve for the layer not being adjusted 			
Basic Mantle Crust	Basic Mantle Crust			
Display	Mantle Presets			
	None \$			
Crust Thickness (km)				
Sources Uranium Thorium 	Uniform Mantle Controls			
 Potassium Reactors 	2 Layer Mantle Controls			
	Param Change Value			
Map Overlays	U 🔍 11.0ng/g			
	Th			
Plate Boundries ON OFF	K 230ua/a			

Mantle

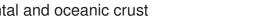
Th	·	-	40.0ng/g
к		-	230µg/g
Boundary Depth			
		06	71KM
Param	Change		Value
\$ U	0	-	11.0ng/g
Th	0	-	40.0ng/g
к		-	230µg/g
Layered	Mantle Controls		

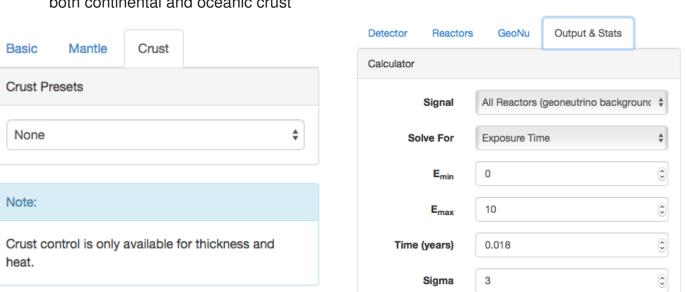
Total Radiogenic Power: 19.5 TW	

Param	Change	Value
U		20.0ng/g
Th		80.0ng/g
к		240µg/g

ntle,	both continental and oceanic

Basic Mantle Crust





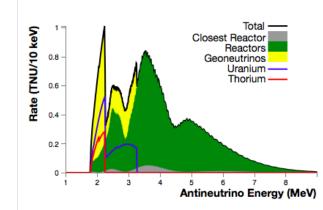
Sigma = Signal * sqrt(Time) / sqrt(Signal + 2 * Background)

RAT-PAC Output	
Total	\$
{ name: "SPECTRUM", index: "total", valid_begin: [0, 0],	

Detector:

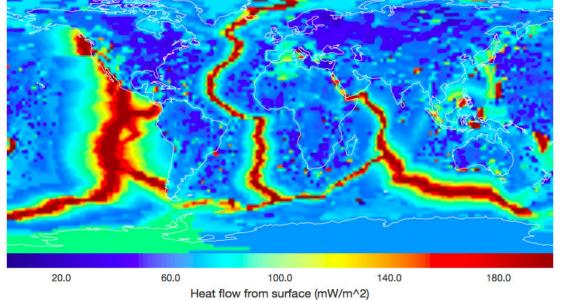
Oscillated neutrino spectrum from reactor and natural sources Many preset detector locations including: Kamioka, Sudbury, Gran Sasso

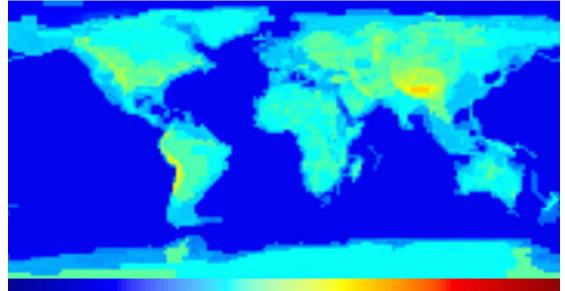
Reactors GeoNu Output & Stats Detector Spectrun



Inverted Neutrino Mass Hierarchy R_{Total}: 221.0 TNU

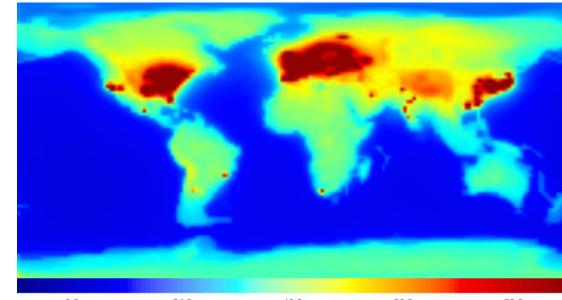
R_{E < 3.275 MeV}: 82.8 TNU R_{Closest}: 4 (% of total) R_{geo}: 40.9 TNU R_{reac}: 180.2 TNU Th/Ugeo: 4.2 Distance to Closest Reactor: 240.5 km Distance to User Reactor: 8522.1 km 1 TNU = 1 event/10³² free protons/year





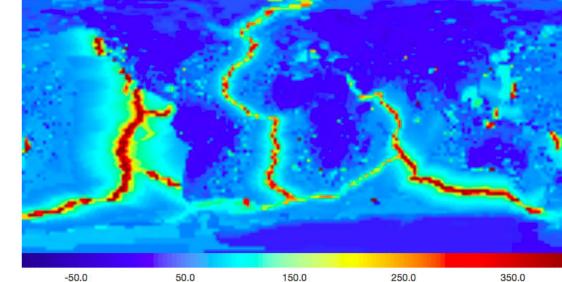
Surface heat flow.

42.0 70.0 98.0 126.0 Crust Heat Intensity (mW/m²) Radiogenic intensity of the crust (not the surface heat flux).

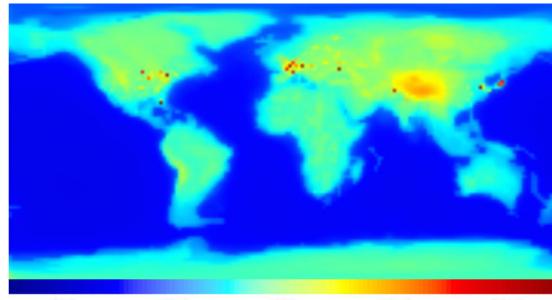


24.0 40.0 56.0 72.0 Geoneutrino Signal (TNU)

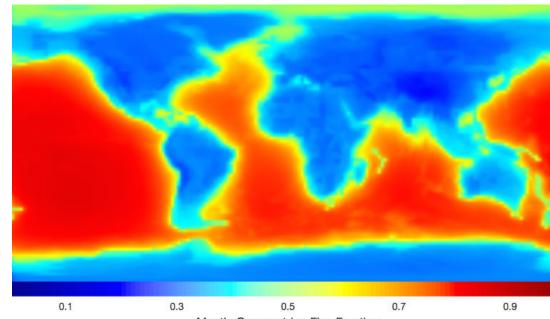
Neutrino signal from all user-selected sources.



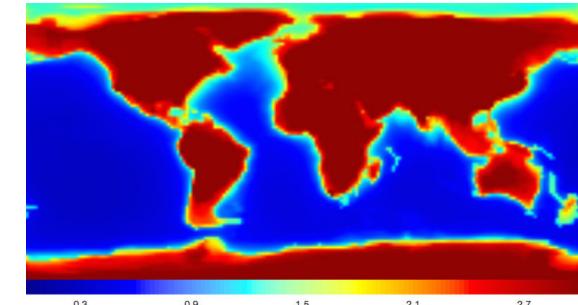
250.0 Heat flow from moho (mW/m^2) Heat flow across Moho.

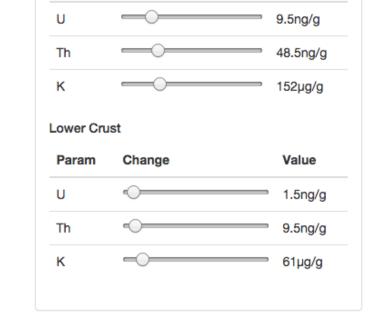


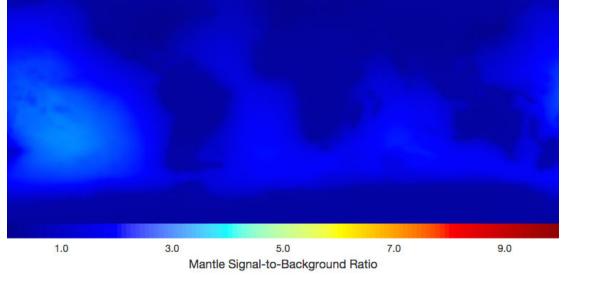
4.2e+7 5.4e+7 3e+7 Geoneutrino Flux (/cm²s) Flux of neutrinos from all user-selected sources.



Mantle Geo-neutrino Flux Fraction Fraction of mantle neutrinos to total surface flux.







Signal ratio of the mantle vs all user-selected sources.

Mantle Signal Fractional Uncertainty Fractional uncertainty of the mantle signal.

References

- [1] S. T. Dye, Huang Y., Lekic V., McDonough W.F., & Sramek, O. (2014) Geo-neutrinos and Earth models. Physics Procedia (in press)
- [2] 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.
- [3] Dziewonski, A.M. and Anderson, D.L., 1981. Preliminary reference Earth model. Phys. Earth Planet. Int., 25, 297-356. [4] Huang, Y. et al. (2013), A reference Earth model for the heat-producing elements and associated geoneutrino flux, Geochem. Geophys. Geosyst., 14, 2003-2029.
- [5] Map data copyrighted OpenStreetMap contributors and available from http://www.openstreetmap.org [6] Davies, J. H. (2013), Global map of solid Earth surface heat flow, Geochem. Geophys. Geosyst., 14, doi:10.1002/ggge.20271.

