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A parametric heat flow model in the spherical earth

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Abstract

In this paper, we model the temperature profile of the Earth with two heat sources: the first is the interior source, generally understood by geophysicists as the primary, if not only, source; the second is a source closer to the surface, explained herein. The model temperature profiles with our chosen *best-fit* parameters are compared with data from the Preliminary Reference Earth Model (PREM) to examine the relative sizes of the two sources; the near-surface source is found to be much larger than the interior source. If correct, the near-surface source could explain a number of paradoxes involving the heat coming from the Earth that have until now not been resolved.

Keywords: Earth's heat sources; *Tresinos*

1. Introduction

In a recent paper (Mayer and Reitz, 2014), we proposed a new source of thermal energy generation in the Earth after detailing the numerous internal conflicts of geophysical observations and the "Standard Earth Energy Paradigm" (SEEP). The proposed "new" source is powered by the release of energy produced during the formation (and later nuclear reactions) of a particle composed of two electrons and one proton held together by electromagnetic forces that we call a *tresino* (Mayer and Reitz, 2012), which occurs fairly close to the surface of the Earth. Most geophysicists believe the primary internal source of energy in the earth results from radioactive decay mostly of Uranium and Thorium somewhere inside the Earth. In fact, it is commonly believed that radioactive decay is the *only* source of energy from the Earth's interior. In this paper, we present a simple parametric heat flow model that suggests that the new energy source close to the surface is the dominant component of the Earth's net heat release.

2. The power sources

We assume a spherically symmetric Earth that contains (i) a centrally-peaked internal heat source, and (ii) a thin zone located close to the surface. The internal heat source is assumed to be either radioactive decay from the heavy elements U and Th or residual primordial heat, or some combination of the two. We take the internal source to be distributed as,

$$P_{int} = P_0\left(1-(r/R)^2\right) \quad (1)$$

where P_0 is the source power per cm^3 at the center and $R = 6.8 \times 10^8$ cm is the radius of the Earth. If continued through out the volume, the total interior power would be $(8/15)\pi P_0 R^3$.

The second power source is a thin source placed at a radius ηR where $\eta \leq 1$ and is taken to be a Dirac delta function as,

$$P_{edge} = (P_e/R)\,\delta(r-\eta R) \quad (2)$$

where P_e is the power per unit area in the thin layer.

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[1] My mentor, colleague, and friend, Dr. John Reitz, passed away two years before this work was completed.

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3. Heat conduction

In this simple model, heat is assumed to be carried only by conduction. In spherical geometry, the heat conduction equation can be written

$$\frac{1}{r^2}\frac{\partial[r^2 T'(r)]}{\partial r} = -\left(P_{int} + P_{edge}\right)/\kappa_0 \quad (3)$$

where $T'(r) = \partial T(r)/\partial r$ and we've taken the thermal conductivity coefficient κ_0 to be a constant everywhere throughout the Earth.

4. The solution

Formulated in this way, the heat conduction equation is easily directly integrated from $0 \le r \le \eta R$ for the interior source and $\eta R \le r \le R$ for the near-surface source. In simplified notation, the solution can be written as

$$T(x) = T_0 + \phi\left[-x^2/6 + x^4/20 + \alpha\left(-\eta + \eta^2/x\right)H(x-\eta)\right] \quad (4)$$

where $x = r/R$, T_0 is the temperature at the center, $\phi = P_0 R^2/\kappa_0$, $\alpha = P_e/(P_0 R)$, is the ratio of the heat source amplitudes, and H is the Heaviside step function. Notice that after setting the temperature at the center (typically $\approx 5000^o$K) that there are only three parameters (ϕ, α, and η) that determine the temperature profile.

5. Fits to PREM

Plotting the temperature profile function from Eq. (4) allows an easy comparison to the standard Earth model - the well-known Preliminary Reference Earth Model (Dziewonski and Anderson, 1981). In Fig. 1, we plot a best “eyeball-fit” of Eq. (4) and the PREM data. The parameters were taken to be: $T_0 = 5200\ ^o$K, $\alpha = 10$, $\phi = 32000$, and $\eta = 0.995$.

In Fig. 2, we plot the same comparison on a finer scale close to the surface.

Our model is clearly not a perfect fit, although overall it does reasonably well given the simplicity of the model. The slope change at $\eta \approx 0.995$ should be noted as this is the location of the near-surface source. Also, notice in this plot, the inner core is located between $0 \le x \le 0.2$, the outer core between $0.2 \le x \le 0.6$, the lower mantle from between $0.6 \le x \le 0.9$ and the upper mantle and the crust between $0.9 \le x \le 1$; with the largest deviation from the model and PREM in the mantle. Most importantly, our model presents a fair-fit to the rapid temperature decrease near the surface, actually quite close, as $\eta = 0.995$ which means that the surface source is only about 35 km below the Earth's surface. Of course, in reality, there will be substantial deviations from spherical-symmetry making the depths different at different radii. Also, the differences might contribute to tectonic motion and volcanic activity. Finally, this model allows easy parameter adjustments for examining how they would affect the *fit* to PREM.

6. Relative source strengths

Integrating the interior power from $0 \le r \le \eta R$ gives,

$$P_{int} = P_0\, V\left(\eta^3 - 3\eta^5/5\right)$$

where V is the Earth's volume. And integrating the surface source $\eta R \le r \le R$ gives the surface power as

$$P_{edge} = P_0\, V\left(3\,\alpha\,\eta^2\right)$$

So, the total power is $P_0\, V(\eta^3 - 3\eta^5/5 + 3\alpha\eta^2)$ and the surface source fraction of the total power is simply,

$$3\,\alpha\,\eta^2 / \left(\eta^3 - 3\,\eta^5/5 + 3\,\alpha\,\eta^2\right).$$

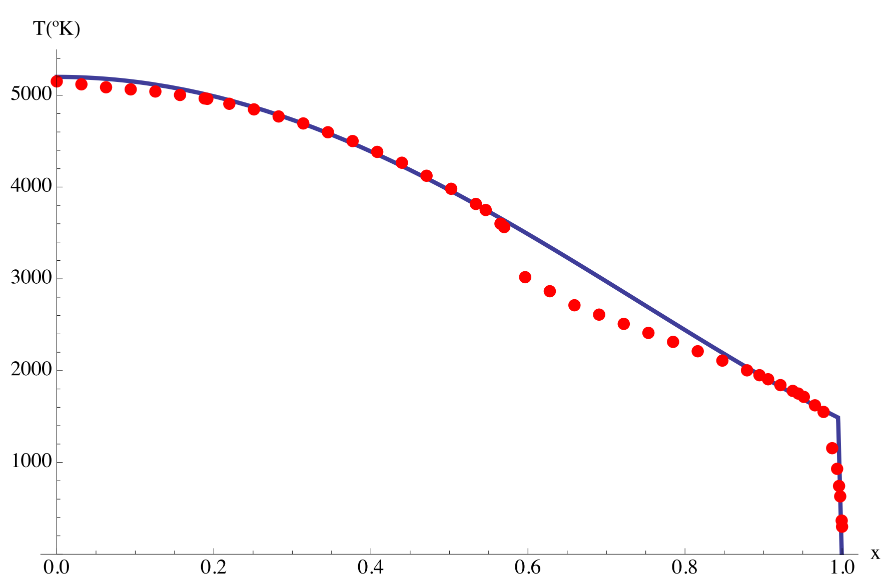

Fig. 1. Plot comparing our model (the blue curve) and the PREM data (red dots) taking $T_0 = 5200\ ^o$K, $\alpha = 10$, $\phi = 32000$, and $\eta = 0.995$.

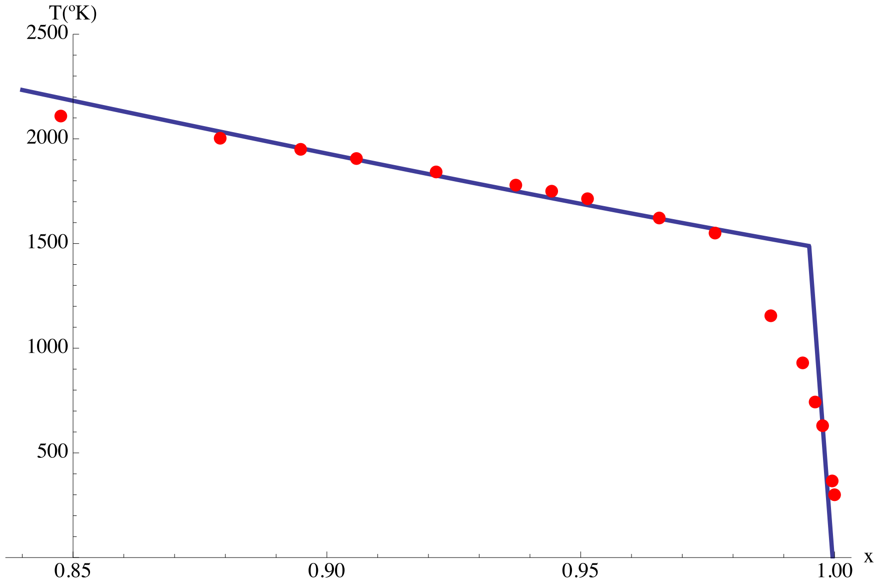

Fig. 2. The same parameters as in Fig. 1 but on a finer-scale closer to the surface.

Using our "best-fit" values from above, this shows that the near-surface power source is about 99% of the total power and that almost all of the thermal power from the Earth originates near the surface with only a very small amount coming from the interior.

7. Discussion

The standard geophysical picture of the Earth's heat has changed over many decades starting from Kelvin's calculation of the age of the Earth (see the discussion in the classic text of (Carslaw and Jaeger, 1959) evolving early in the last century as the importance of radioactive decay was recognized, and still further in recent decades when various authors have found that radioactive heating of the Earth had substantial problems (see (Mayer and Reitz, 2014) for details). Radioactive decay appeared to be the primary source of the Earth's heat mostly because ^{4}He is released in alpha decay of U and Th and helium from the Earth had already been experimentally observed. However, as we show in (Mayer and Reitz, 2014), there is another basic physical process for generating both heat and helium (specifically ^{4}He but more *remarkably* ^{3}He, for which there is no radioactive-decay source).

It is interesting that there would have been a considerably larger amount of U and Th in the Earth than is now estimated to be the case. Geophysicists have measured the total power from the Earth to be about 47 TW (Davies and Davies, 2010) but extending the densities of U and Th (see (McDonough, 2001)) throughout the Earth, the total power generated would have been less than 20 TW. Furthermore, according to (McDonough, 2001), there is no U and Th in the Earth's core; this would in fact reduce the total radioactive decay power to less than 13 TW. Clearly, there is big problem except if there is much more radioactive materials deep in the Earth. But large amounts of power from the deep interior conflicts with the heat flow estimates presented in this paper. Note as well that choosing a nominal κ_0 in the crust, and the $\approx 500^o$K drop at $\eta = 0.995$ results in a total surface heat flow close to the observed 47 TW, though with poor accuracy. Could the radioactive decay of U and Th located at this depth still be the heat source? Of course it could be the case for the observed ^{4}He but can not account for all the similarly observed ^{3}He, as we have previously shown (Mayer and Reitz, 2014).

In conclusion, the assumption that the heat from the Earth has arisen from radioactive decay appears to be wrong even if all the radionuclides are located at a shallow depth of about 35 km. We think this idea (the *SEEP*) may have led to considerable confusion and controversy in geophysics for many decades.

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