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Discussion

Reply to the comment of J. Gumbel and H. Rodhe on “Thermal pollution causes global warming”, by B. Nordell [Global Planet. Change 38 (2003), 305–312]

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To understand complex problems like the energy balance of Earth, we should not look at the details without having a more large-scale understanding of the problem. My approach (Nordell, 2003) is therefore axiomatic.

Over longer time scales (years), the Earth is a net heat source in space to which it emits its heat. Consequently, the periodic heating and cooling that occur during much shorter time scales are of no interest for this long-term energy balance. These periodic energy flows are zero sum events that add no heat to the planet, which also answers most of the comments made by Gumbel and Rodhe (G&R). One example, which G&R say that the author “does not seem to appreciate, is that the radiative fluxes at the surface, at any given location and time, do not necessarily balance out”. The author understands this, but in my much longer time scale, they do balance out.

By considering the long-term energy balance of the planet (Fig. 1), the net heat of the planet (e.g., geothermal heat flow) must be emitted. Earth’s

thermal equilibrium is maintained by this net outgoing long-wave radiation (OLR). The driving force of the net OLR is the difference between the Earth’s surface temperature and the effective temperature of its atmosphere.

Before global warming, the major net heat source was the geothermal heat flow. Calculations based on my approach, and preglobal warming temperature data, should therefore result in a net OLR equal to the geothermal heat flow.

Performed net OLR calculations were simplified by using one land temperature and one sea surface temperature for each month. The resulting global net OLR for 1880 temperature data was slightly lower than the estimated geothermal heat flow. However, by dividing land and sea surface in several areas of colder and higher temperatures, a more accurate and greater net OLR (geothermal heat flow) would be obtained.

The increasing global temperature since 1880 must result in an increasing net OLR (i.e., greater than the geothermal heat flow). This required a new heat source. The only new heat source identified was from heat dissipation of the global use of non-renewable energy sources (thermal pollution).

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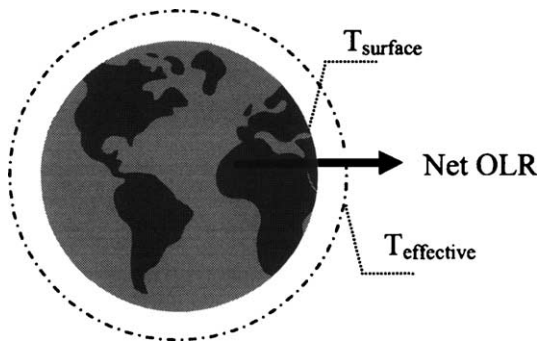


Fig. 1. Earth's long term energy balance.

Calculations based on the global temperatures in 1999 showed that in addition to the geothermal heat flow, one third of the thermal pollution was also emitted to space (i.e., two thirds was not emitted). This remaining heat must contribute to global warming. Further, calculations showed that the global mean temperature had to increase by another $1.8\text{ }^{\circ}\text{C}$ before all net heat was emitted.

I agree with Gumbel and Rodhe that, my writing: "During the day, short wave radiation heats the ground surface, which is later cooled off by the same amount of outgoing long-wave radiation," is inaccurate. It is more confusing than enlightening, and I should rather have said that: during a global mean day, the global mean temperature is constant.

About my simplistic assumptions of "an atmospheric consisting of completely absorbing layers, a

vertically constant net radiative heat flux, and the complete neglect of non-radiative energy transport," I would like to give the following comments.

With my approach and year long time scale:

- there must be a "vertical constant net radiative heat flux" equal to the net OLR
- there can be no mass convection in the vertical direction (unless mass leaves our planet)
- no energy convection occurs due to the small temperature gradient.

It is true that my model does not consider "any spectral dependence of atmospheric radiative properties" and assumes "an atmosphere consisting of completely absorbing layers."

The layers do not have to be completely absorbing, but based on the assumptions that they are, and that the net OLR is known, performed calculations give the effective radiation through the atmosphere independent of its radiative properties.

I cannot find any errors in my mathematical derivations.

Reference

- Nordell, B., 2003. Thermal pollution causes global warming. *Global and Planetary Change* 38, 305–312.