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Discussion

Comment on "Thermal pollution causes global warming", by B. Nordell [Global Planet. Change 38 (2003), 305–312]

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Nordell (2003) discusses contributions of various energy sources to the temperature of the Earth's surface. This paper is seriously flawed and contradicts basic principles of physics. The paper contributes wrong and misleading arguments to the important discussion about human impact on the Earth's climate.

The Earth is heated by several sources. The dominant source is the solar irradiance, about 342 W m^{-2} as a global average. A part of this flow is directly reflected back to space, a part is absorbed in the atmosphere and the largest part is absorbed by the Earth's surface. Flow of geothermal heat from the Earth's interior amounts to about 0.087 W m^{-2}. Human activity releases additional heat ("thermal pollution"), on average 0.02 W m^{-2}. The latter two numbers are given by Nordell.

At any given temperature, the surface emits thermal radiation according to Stefan-Boltzmann's law. Most of this thermal radiation is not directly emitted to space, but is absorbed by (natural and anthropogenic) greenhouse gases in the atmosphere. The additional heat flux from the atmosphere back to the surface resulting from anthropogenic greenhouse gases has been estimated by IPCC (2001) to about 2.5 W m^{-2}. The thermal pollution (0.02 W m^{-2}) is thus about a hundred times smaller than the anthropogenic climate forcing due to greenhouse gases.

A complete analysis of the Earth's energy balance needs to take into account the detailed energy exchange between surface and atmosphere as well as the radiative transfer of thermal radiation through the atmosphere towards space. We agree with Nordell on this point. However, the further discussion is simply wrong. He states that "During the day, [short wave radiation] heats the ground surface, which is later cooled off by the same amount of [outgoing long-wave radiation]. When all incoming radiation has been emitted, the only remaining energy sources are the geothermal heat flow and thermal pollution. This constant heat flow is radiated layer by layer through the atmosphere".

This is in contradiction to Stefan-Boltzmann's law. The Earth's surface emits thermal radiation continuously in accordance with its temperature. It is against the laws of physics to split up the thermal emission from the surface into a "temporary outgoing flux" that compensates incoming radiation and a "constant background heat flow" that transports geothermal heat

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and heat pollution towards space. Rather, the surface is emitting according to its temperature at any given moment and this temperature is essentially unaffected by heat pollution.

Another important point, which 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. This is because there are large fluxes of sensible and latent heat that contribute to a redistribution of energy between different locations and seasons.

As these basic assumptions by the author are in error, all subsequent conclusions are also in error.

We would also like to comment on the atmospheric model used by the author to obtain his radiative results. This model is based on simplistic assumptions that make it inappropriate for any quantitative calculations. Among the flawed assumptions are an atmosphere consisting of completely absorbing layers, the lack of any spectral dependence of atmospheric radiative properties, a vertically constant net radiative heat flux and the complete neglect of non-radiative energy transport. The mathematical derivations are also in error. The formalism developed in the appendix is not consistent with the text. While the step towards the last equation in the appendix seems to be crucial for Nordell's argument ("It can be shown that..."), we do not see how it can be justified.

Nordell is right in stating that thermal pollution can contribute significantly to the energy budget at specific locations. He gives the extreme example of Tokyo with an additional heat production of 140 W m^{-2}. Such local addition of heat contributes to the well-known urban heat island effect. An issue worth considering is whether thermal pollution might influence surface temperatures over larger areas in heavily industrialised regions.

References

IPCC, B., 2001. Climate change 2001: the scientific basis. In: Houghton, J.T., et al., (Eds.), Contributions of Working Group I to the Third Assessment Report of the IPCC. Cambridge University Press.

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