Long-Term Global Heating From Energy Usage

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Abstract

Even if civilization on Earth stops polluting the biosphere with greenhouse gases, humanity could eventually be awash in too much heat, namely, the dissipated heat by-product generated by any nonrenewable energy source. Apart from the Sun's natural aging—which causes an approximately 1% luminosity rise for each $10^8$ years and thus about 1°C increase in Earth's surface temperature—well within 1000 years our technological society could find itself up against a fundamental limit to growth: an unavoidable global heating of roughly 3°C dictated solely by the second law of thermodynamics, a biogeoophysical effect often ignored when estimating future planetary warming scenarios.

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Long-Term Global Heating From Energy Usage

Even if civilization on Earth stops pollut-
ing the biosphere with greenhouse gases, humanity could eventually be awash in too much heat. Namely, the dissipated heat by-product generated by any nonrenewable energy source. Apart from the Sun's natural aging—which causes an approximately 1% luminosity rise for every 10^8 years and thus about 0.3°C increase per kilogram of heat temper-
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gical society could find itself up against an "unavoidable global warming" of roughly 3°C dictated solely by the rate of conversion of those nonrenewable sources. This is likely to be a global effect unless energy budgets of a technolo-
gical society are properly normalized. For instance, a broad budgeting of total energy budget of society on Earth will likely continue growing for three reasons. First, world population is projected to increase until at least the late 21st century, when it might level off at an approximately 9 billion people [United Nations Department of Eco-

mical and Social Affairs, 2006]. Second, developing countries will remain economi-
cally perhaps for the next several centuries, until world community of nations. And third, the per capita energy rate will probably continue rising for as long as the human species exis-
tually evolves, including conditioning our living spaces, relocating cities, respecting rising seas, and sequestering increased greenhouse gases—which implies that even if we are now the best that we will ever become, our third will continue increasing society's total energy budget, however slowly.

Heat By-Products

Current fears of shortfalls aside, in 2030 the long term or our energy predicat-
ment is that the unmitting and increasing use of energy from any resource and by any technique eventually dissipated as heat at various temperatures. Heat is an unavail-
able by-product of the energy extracted from wood, coal, oil, gas, and atoms, and any other nonrenewable resource. The renew-
able sources, especially solar, already heat Earth naturally, but additional solar energy, if beamed to the surface, would also further heat our planet.

Regardless of the kind of energy utilized, Earth is one of the first and only places in the universe dominated by a single source of energy sup-
plied by our industrial society. We already experience it in the big cities, which are warmest, and in the industrial plants and the reactors, which warm their adjacent water-
ways. A recent study of Tokyo, for example, found that city streets are about 2°C warmer when air conditioning units not only suck hot air out of offices but also dissipate heat into the backs of those inefficient machines [OIkawa et al. 2007]. Everyday appliances—including toasters, boilers, and lawn mow-
ers—all generate heat while operating far from their theoretical efficiency limits. Elec-
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bulbs are only around 5% effi cient; the rest is immediately lost as heat (0.05 kilowatt per kilogram).

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Fig. 1 Temporal dependence of energy rate density for a wide spectrum of energy-using systems over billions of years, including (within the circle, which magnifies part of the curve at top right) per capita power usage during the cultural advancement of human society in much more recent times. Adapted from Chaisson (2003).

[International Energy Agency, 2004] as our species multiplies and becomes more complex, society's energy demands by the close of the 21st century will likely exceed 10^9 terawatts—and much of that energy will help our environment.

Note that utilizing solar energy that natu-
urally affects Earth (including solar-driven tides, wind, and waves), without generating any further energy via nonrenewable sup-
pplies, would not cause additional heat. But if we do generate heat from other, nonrenew-
able energy sources, in addition to the Sun's rays arriving daily—or if we use space-based arrays to redirect additional sunlight to Earth that would normally bypass our planet—then the surface temperature will rise. That is, if even we embrace coal and sequester all of its carbon emissions, or use nuclear methods (either fission or fusion) that emit no greenhouse gases, these energy sources would still add a heat boost to those that the Sun's rays naturally create at Earth's surface.

Heat Scenarios

Estimates of how much heat and how quickly that heat will rise rely, once again, on thermodynamics. Because flux scales as σ*T^4, Earth's surface temperature will rise about 5°C (an IPCC "tipping point") when (251*288), namely, when about 4% more than the Sun's daily solar output (10^4 terawatts) is additionally produced on Earth or deliv-
ered to Earth. Such estimates of energy usage sufficient to cause temperature increases are likely upper limits, and hence the times needed to achieve them are also upper limits, given natural greenhouse trapping and cloud feedbacks of the added heat. How far in the future, if ever, such heating might occur depends on assumptions [Chaisson, 2007].

* If global nonrenewable energy use con-
tinues increasing at its current rate of about 2% annually and if all greenhouse gases are sequestered, then a 3°C rise will still occur in roughly 8 doubling times, or about 280 years (or ~350 years for a 10°C rise).
Global Heating

Several recent studies have assessed the potential impacts of climate change on human health and well-being. For example, a study published in the journal *Health & Place* estimated that by 2050, there will be a 10% increase in deaths from heat-related diseases in the United States. Another study, published in *The Lancet*, suggested that the frequency and intensity of heat waves will increase, leading to a significant rise in heat-related mortality.

One of the key concerns is the potential impact of climate change on vulnerable populations, such as the elderly and those with pre-existing health conditions. A recent report from the World Health Organization (WHO) highlighted the need for increased preparedness and adaptation measures to reduce the health impacts of climate change.

In conclusion, the findings from these studies underscore the critical need for urgent action to mitigate climate change and protect public health. This includes implementing strategies to reduce greenhouse gas emissions, enhancing adaptive capacity, and improving health systems to address the anticipated challenges.

References


Acknowledgments

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Appendix

Table 1: Key Climate Change Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>2000</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Temperature</td>
<td>15°C</td>
<td>17°C</td>
</tr>
<tr>
<td>Sea Level Rise</td>
<td>10cm</td>
<td>25cm</td>
</tr>
<tr>
<td>Extreme Weather Events</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

Fig. 2. Spatial dependence of energy rate density per capita power usage, across the globe today. Data from Energy Information Administration [2006].

Riverine Flow and Lake Level Variability in Southern South America

Considerable attention was directed during the 12th IHR to the remote connection that appeared to exist between the Southern Oscillation (SO) and anomalous rainfall over southern Brazil, Paraguay, and northern Argentina (Moosmann, 1924). It was Gilbert Thomas Walker’s group, then in India seeking the prediction of monsoon dynamics, that made the observation—seen with skepticism—that high volumetric flows along the Paraná River, as measured at the downstream Rosario (Argentina) gauging station, tended to occur during the negative phase of the SO, when surface level pressure (SLP) was anomalously high around Australia [Brisco, 1982]. Such high surface level pressures, when associated with unusual low pressure along South America’s coast, tended to cause drainage in regions bordering the equatorial Pacific Ocean and heavy rainfall in other parts of the Americas and the world.

The idea of such a large-scale link in weather patterns subsided somewhat during the following decades until Ejofor [1996] and others established the now widely known linkage between the SO and El Niño events (ENSO). Many works have expanded our knowledge on such processes, particularly since the early 1990s, when one of the strongest ENSO events ever occurred in the tropical Pacific Ocean region.

In this brief report we review the present hydrological knowledge over South America in view of the current understanding of climate change. In particular, what are the hydrological trends and discernible connections with periodic interannual or decadal events, like ENSO, over southern South America?

Riverine Flow

A monsoon-like system affects the atmospheric circulation over the Río de la Plata drainage basin (see Figure 1, region B), whose major feature is the South Atlantic Convergence Zone (SACZ). Considerable attention was directed during the 12th IHR to a remote connection that appeared to exist between the Southern Oscillation (SO) and anomalous rainfall over southern Brazil, Paraguay, and northern Argentina (Moosmann, 1924). It was Gilbert Thomas Walker’s group, then in India seeking the prediction of monsoon dynamics, that made the observation—seen with skepticism—that high volumetric flows along the Paraná River, as measured at the downstream Rosario (Argentina) gauging station, tended to occur during the negative phase of the SO, when surface level pressure (SLP) was anomalously high around Australia [Brisco, 1982]. Such high surface level pressures, when associated with unusual low pressure along South America’s coast, tended to cause drainage in regions bordering the equatorial Pacific Ocean and heavy rainfall in other parts of the Americas and the world.

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