

# **A NATURAL BRAKE ON GLOBAL WARMING?**

**v1.0**

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## **ABSTRACT**

It is possible that a negative feedback cycle is responsible for the recent global warming 'pause' and will delay further warming for centuries.

The only necessary assumption is that organisms with access to a free source of energy will take advantage of it. These are poikilothermic animals which migrate vertically across the ocean thermocline. The change in body temperature which results can be used to generate energy for the animal's use, using internal chemical mechanisms whose efficiency is limited by the Carnot cycle.

Even a small rise in surface temperature greatly increases the energy available to such animals, and will tend to increase their numbers and activity. A thermodynamically inevitable consequence is that increasing quantities of heat energy will be pumped down into the mid-depths, as is already observed to be happening.<sup>[1]</sup>

Confirmation of the effect would support Jeremy England's hypothesis<sup>[2]</sup> that life tends to dissipate energy available from the environment at the highest possible rate. At the ecosystem level, an event such as a jellyfish bloom could be described as the available biomass reorganising itself from forms which perform modest vertical transport of heat, fish which carry ~2 kg of water per kg dry weight as they migrate, to forms which perform far more: jellyfish which carry up to 20 kg of water per kg dry weight internally, and can drag even larger quantities externally.

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There is a highly plausible mechanism whereby any poikilothermic animal which regularly transitions between different temperature environments can harvest energy as its body warms and cools, using the Carnot cycle. Since this energy is effectively free, it would be surprising if evolution did not harness it.

Irrespective of the precise chemical mechanism used, likely one of the known ATP interactions, the maximum achievable efficiency is  $\Delta T/T$ , where  $\Delta T$  is the difference in temperature between the 'hot' and 'cold' reservoirs available and  $T$  is the upper absolute temperature. Because this efficiency is fairly low, the organism will transfer far more thermal energy between the two environments than it extracts as work.

My previous paper<sup>[3]</sup> discusses specific possible examples. Marine animals which pass through the thermocline during diel vertical migration are obvious candidates, as they transit a temperature range up to 20°C. I found that mesopelagic fish could obtain  $\sim 10\times$  more energy by thermal harvesting than used to perform the migration. However from Kleiber's law, only a very large or lethargic fish could obtain all the energy it needs from a single daily migration.

By contrast gelatinous organisms such as jellyfish and salps can swim slowly with high efficiency.<sup>[4]</sup> Such organisms could easily obtain all the energy they need by thermal harvesting. Almost all food eaten can then be used to generate dry body mass of offspring, for a formidable reproductive rate. Spectacular rapidly multiplying blooms of jellyfish and salps are indeed observed.

Quantitative estimates are difficult. Sonar can track only fish with air-filled swim bladders: it is salutary that the recent Malaspina cruise<sup>[5]</sup> discovered that the total mass of fish in the sea may have been underestimated by at least a factor of 10. Gelatinous organisms without swim bladders are

currently very difficult to track except with attached tags, practical only for larger jellyfish. Jellyfish and salps are 90-95% water, and it has recently been discovered that they tend to draw an additional mass of external water with them as they travel; a further interesting possibility is that groups of small zooplankton in proximity to one another drag large masses of water with them when they migrate vertically. In both cases the ratio of thermal energy to dry body mass transported can be very large. The total mixing work done on the ocean by marine animals is estimated to be of the order of 1 TW or greater.<sup>[6]</sup>

This can result in the transport of a vastly greater quantity of thermal energy. To push one litre of water at constant temperature down from the thermocline top to the thermocline base against increasing buoyancy, allow it to cool to ambient, then raise it to its original position against increasing negative buoyancy, requires work and transfers heat as shown in Table 1.

**Table 1**

Depth		Tropics	Mid-latitude
100 m	Temp °C	20	13
	Density g/L	1024.79	1026.42
700 m	Temp °C	9	
	Density g/L	1027.14	
Work to cycle 1 kg water J		14.1	4.32
Thermal energy transported kJ		46	16.74
Ratio		3,262	3,875

The ratio is over 3,000 in each case: 1 TW mixing work could in principle draw over 3 PW heat energy from the ocean mixed layer to the mid-

depths. Current net anthropogenic greenhouse solar forcing is only  $1.5 \text{ W/m}^2 = 0.75 \text{ PW}$ .

Not all mixing work acts to transport heat across the thermocline; a vertical salinity gradient will often increase the work needed relative to the above figures; and the 1 TW work rate estimate is anyway highly approximate. However the key point is that if thermal harvesting is taking place, the incentive to perform mixing work will increase as the temperature across the thermocline rises, providing negative feedback to counter surface warming. For example an increase of 2 degrees at the top of an initial 11 degree thermocline increases the thermal harvest available by 18%, selectively favouring organisms which obtain a large proportion of their energy in this way. The expected result, an increasing fraction of the available biomass reallocated from hard-bodied organisms to gelatinous ones which transport large amounts of heat vertically, is exactly what is seen in jellyfish blooms.

What specific harvesting mechanisms should we look for? It is straightforward for a migrating organism to transfer itself while temporarily preserving its temperature, so that we achieve a reservoir of warm water surrounded by cold after downward thermocline transit, and cold water surrounded by warm after upward transit. But how is useful work to be extracted? There are two basic choices.

First, from a spatial temperature gradient. Any creature which respire using gills or lungs has the capacity to circulate internal fluid (blood) in close proximity to external fluid (water or air) with a barrier as little as a single cell thick between them, and a large surface area involved. Energy can readily be harvested from such a steep temperature gradient, e.g. in human engineering by the Peltier effect.

Second, using a system whose state changes as the temperature changes. This method does not require a spatial temperature gradient, nor that the temperature change be rapid. In human engineering, the familiar example is a piston driven by gas expansion, but a chemical reaction will also serve: the stable point of almost any chemical equilibrium changes with temperature. The result in a biological system will likely be the

manufacture of ATP, probably within the mesoglea in the case of jellyfish. A much more speculative alternative is the thermogalvanic effect, currently being investigated for waste heat recovery in human engineering: decreasing the temperature of a battery increases its voltage, so by charging a battery at a higher temperature, then discharging it at a lower one, more energy emerges on discharge than is input during charging.<sup>[7]</sup> While there is no necessity for a biological harvesting mechanism to be electrical, it is intriguing that we have recently discovered both bacteria which can harvest electricity directly<sup>[8]</sup> and bacterial nanowires which can be many centimetres long and conduct electricity well<sup>[9]</sup>.

The oceanic vertical interchange may well take place 'under the radar' of the method conventionally used to detect vertical water mixing: monitoring the concentration at a given depth of recently human-produced substances not found in nature, such as tritium and chlorofluorocarbons, as tracers. If a packet of water is taken repeatedly up and down, with heat exchange but little or no physical mixing at each end of the journey, such tracers will not detect the process. Some thermal harvesting organisms may also be difficult to observe directly, potentially comprising no more than a fragile transparent sac with a wall one to a few cells thick, perhaps with a sponge-like ability to reform after fragmentation.

The thermal capacity of the oceans is enormous. They contain sufficient water to cover the Earth's entire surface in a layer 3 km deep. To heat this water by 2°C requires  $2.5 \times 10^{10}$  J/m<sup>2</sup>. At 1.5 W/m<sup>2</sup>, the current net anthropogenic solar forcing, this would take  $1.7 \times 10^{10}$  seconds = 500 years.

Net anthropogenic forcing may well increase by a factor of two or more. Nevertheless a modest increase in the rate at which heat is taken down into the ocean mid-depths can reduce surface warming to a negligible rate. There are indications that this has already been happening for over a decade.<sup>[10]</sup>

If the feedback hypothesis outlined in this paper is correct, much of the money and effort currently being spent to minimize and adapt to the anthropogenic greenhouse effect is being wasted. Local climate variation will happen, especially over the largest land masses, but a significant further rise in global surface temperature will not, for the currently foreseeable future.

The hypothesis outlined in this paper can be tested independently at the biochemical, behavioural and ecological levels, using experiments and observations that are not difficult to perform. This work should be done urgently.

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