



This is the print version of the [Skeptical Science](http://sks.to/thermostat) article '[Tropical thermostat limits sea surface temperature to 30°C](http://sks.to/thermostat)', which can be found at <http://sks.to/thermostat>.

## Tropical thermostat and sea surface temperatures

### What The Science Says:

If the troposphere warms, then the sea surface temperature threshold to kick in convection (and related cloud feedbacks) must also increase. In other words, it is the threshold for deep convection that promotes the skewed plot seen in the first figure, not any universal demand for a maximum ocean temperature.

### Climate Myth: Tropical thermostat limits sea surface temperature to 30°C

"It has been known for some time that the "Pacific Warm Pool", the area just northeast of Australia, has a maximum temperature. It never gets much warmer than around 30 – 31°C. This has been borne out by the Argo floats."

"...this thermostatic mechanism...is regulated by temperature, and not by forcing. It is insensitive to excess incoming radiation, whether from CO<sub>2</sub> or from the sun. During the part of the year when the incoming radiation would be enough to increase the temperature over ~ 30°, the temperature simply stops rising at 30°. It is no longer a function of the forcing." ([Willis Eschenbach](#))

A [post](#) at Watts Up With That (WUWT) by Willis Eschenbach, [embraced by](#) Roger Pielke Sr., goes into detail concerning a purported "tropical thermostat" that sets an upper limit on the ocean temperature. This thermostat could presumably help regulate the response to radiative forcing in a higher CO<sub>2</sub> world, constraining ocean temperatures to be no greater than the threshold value.

The underlying hypothesis is actually not of WUWT-origin and has some roots that were discussed in the literature dating back a couple decades. WUWT presents a histogram of observed ocean temperatures, which shows a sharp cut off at ~31 °C (diagram reproduced below). The figure indicates that no measurements in the worlds oceans show temperatures much higher than that value. Based on this data, WUWT (as well as several older scientific papers based on similar data) suggested this is a theoretical 'maximum ocean temperature' and is independent of solar or greenhouse forcing. [Kleypas et al 2008](#), for example, based a study on corals on the premise that such data support a maximum ocean temperature.

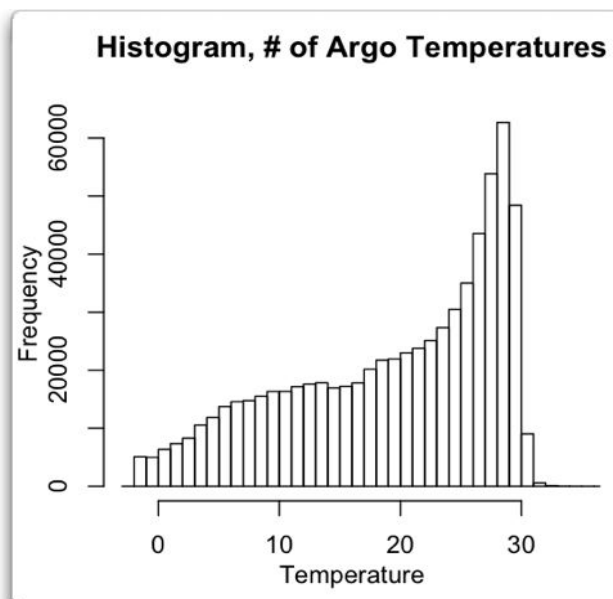


Figure 1. A "histogram" shows how many data points fall in each of the 1°C intervals shown along the bottom axis. The maximum is in the interval 28°-29°C. **Figure and Caption reproduced from WUWT article.**

In another example, in a paper on mass extinctions, [Veron, 2008](#) mentioned that:

*"...the surface temperature of the largest oceans would have been limited by the Thermal Cap of ~31C, widely believed to be the highest temperature large oceans can reach."*

Based on the premise of a maximum ocean temperature, there have been several proposed 'thermostat' mechanisms to explain why tropical sea surface temperatures (SSTs) don't get much greater than ~31°C. Proposals involve negative feedback cloud responses (ex. [Ramanathan and Collins 1991](#)) or enhanced evaporation that keeps the SSTs down (ex. [Newell, 1979](#) or [Hartmann and Michelsen, 1993](#)).

But is this actually "widely believed" as Veron, 2008 state? It turns out the answer is no.

Several older papers rebutted the cloud thermostat hypothesis of Ramanathan and Collins (ex. [Fu et al., 1992](#) and later observational papers) and related thermostat arguments have also been refuted a number of times ([Wallace, 1992](#)). [Pierrehumbert, 1995](#) discussed the regulation of tropical SSTs and showed that there is no physical basis for an upper temperature bound. More recent papers ([Sud et al., 2008](#); [Williams et al., 2009](#)) came to similar conclusions.

Before I explain the discrepancies, it is worth reviewing some basic tropical meteorology:

- The Tropics, loosely ~30 N-30 S latitude (though a number of definitions exist) receive the substantial bulk of Earth's incoming solar radiation, and in fact receive more incoming energy than outgoing infrared radiation to space. This implies that there is a substantial loss of energy by the tropics toward the poles by non-radiative means (atmospheric and ocean transport).
- The tropics are dynamically distinct than the mid-latitude regions that (I assume) many of us are more familiar with. Instead of heat transport being manifest in 'eddies' (cyclones and anticyclones, and associated warm/cold fronts), the tropics instead fall under a giant overturning circulation called the *Hadley cell*.
- Due to the weak Coriolis effect, the tropics have very weak horizontal temperature gradients in the atmosphere. Thus, SSTs vary more than atmospheric temperatures in the horizontal. Furthermore, in the tropics the air very close to the surface always has a similar temperature to the SST. In the vertical (from the surface upward) we typically think of the temperature structure in the tropics as being very close to [moist adiabatic](#), especially over the ocean.

As mentioned before, several papers find no evidence of a 'maximum SST', so how do we reconcile that with the observed data?

## What about the observed Histogram of SSTs?

Answering this question essentially boils down to the question of what SST is required for the onset of deep convection (and thus deep cloud formation). In the modern climate, this value occurs around 28°C. In general, it depends on when air near the surface can become buoyant relative to air in the upper atmosphere and thus have enough energy to rise freely. Because atmospheric temperature gradients in the tropics are small, the threshold temperature for convection depends primarily on the local SST. There is a consequence to this: *If the troposphere warms, then the SST threshold to kick in convection (and related cloud feedbacks) must also increase.* In other words, it is the threshold for deep convection that promotes the skewed plot seen in the first figure, not any universal demand for a maximum ocean temperature.

This concept is shown below. The figure shows a model result for the longwave and shortwave fluxes as clouds form. The threshold for deep convection is readily seen in figure 2a (the longwave flux) and occurs when SSTs exceed 25°C or so. When convection starts, lots of clouds form and the absorbed longwave radiation spikes upwards due to the cloud greenhouse effect. As the climate warms (going from the blue to red line), the SST temperature threshold also rises (i.e., moves to the right).

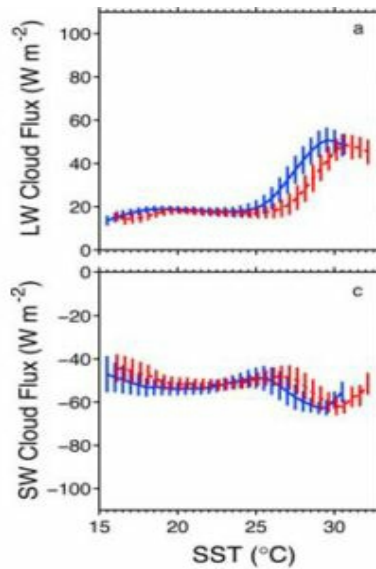


Figure 2. a) TOA cloud LW flux as a function of SST, b) TOA cloud SW flux as a function of SST; Solid blue and dashed red lines correspond to the ensemble median over years 0–20 and 60–80, respectively, from 15 IPCC AR4 coupled ocean-atmosphere models for the 1% per year scenario. Vertical lines indicate the interquartile range. From Willaims et al (2009)

## Faulty Mechanisms

In order to understand why neither clouds nor evaporation act as an inherent buffer in the modern tropical climate, it's worth considering a few more bits of physics:

- It must be kept in mind that in the modern tropical climate, the cloud shortwave (albedo) and cloud longwave (greenhouse) effects nearly cancel each other at the top of the atmosphere - the net effect is close to zero. That doesn't mean clouds are unimportant. If you could remove clouds altogether from the tropics, you could introduce many subtle impacts on the atmospheric heating distribution, circulation, and differences in SST across the tropics. However, the threshold temperature for deep cloud formation increases in a new climate. And because of the cancellation between the albedo/greenhouse effects of clouds, it is not compelling they have some special place in controlling the absolute tropical SST.
- In a new climate it is possible that the albedo effect of clouds could win out over the greenhouse effect. This is a separate argument that cuts into the heart of the climate sensitivity issue. Most studies to date show that the longwave feedback effect is likely to be positive (see ex. [Zelinka and Hartmann, 2010](#); this will also be highly discussed in the IPCC Fifth assessment report, which reserves a whole chapter for cloud and aerosol issues of this sort). Most of the uncertainty in cloud feedback enters into the albedo side of the equation; how the cancellation between the albedo and greenhouse effects of clouds may change in a new climate is a challenging one, but there is no convincing argument as to why this should serve as a strong negative feedback, let alone provide a "thermal cap" on the oceans independent of any large forcing.
- The tropics are partly stabilized by heat transport towards the poles and also by dry regions where infrared radiation more easily escapes to space. Near the equator the large moisture content acts as an infrared 'insulator', but dry regions have a weaker greenhouse effect. Transport of heat into these dry regions lets them act like "radiator fins" (Pierrehumbert, 1995) where energy can more readily leak out into space. If it weren't for this heat escape poleward and out of the dry regions then the bulk of the tropics would, in isolation, collapse into a runaway greenhouse state. This, however, doesn't mean that tropical SSTs cannot increase at all beyond ~31 °C.
- Evaporation does not regulate the absolute value of SST, an argument taken up by Pierrehumbert (1995, cited previously) and shown by a number of papers, one recent being [Miller, 2011](#). Instead, evaporation is such a large factor in the tropics that it wipes out the *differences* between the SST and the overlying air temperature. However, changes in top-of-atmosphere forcing actually impact SST more than changes in the surface forcing, since the whole atmospheric column will regulate its outgoing longwave radiation in response to perturbations. Most longwave radiation escapes in the

high atmosphere, and the troposphere is well-mixed by convection such that it warms and cools as unit in order to balance ingoing and outgoing energy. Evaporation, however, is a buffer that takes up the slack between radiation absorbed at the surface and the flux of energy required to keep the SST close to air temperature.

## The Observed and Past Climate Record

In order to cross-validate whether these results are correct, it would be useful to consult the paleoclimate record, in order to establish whether tropical SSTs were warmer than the modern alleged 'threshold' value. There is abundant palaeoclimate evidence that tropical sea temperatures can rise well above present values. Improved understanding of oxygen proxies and the development of new proxies ('thermometers of the past') such as TEX86 and Mg/Ca have shown that Eocene SST's in the tropics could have been even hotter than 35 °C (see ex, [Huber, 2008](#)).

For modern observations, [Johnson and Xie, 2010](#) find an upward trend in the threshold of deep convection associatd with rising temperatures. This also means that the threshold SST for when hurricanes form will change in a new climate.

## Conclusion

There have been a number of "false thermostats" and incorrect assumptions about a universal and unchanging "convective threshold" that kicks in heavy cloud formation. There's been a long history of refuting thermostats of this sort, but apparently this isn't universally appreciated. Note I have said little of the cloud feedback issue relevant for climate sensitivity; rather, there is no compelling physical justification to suggest that the tropical sea surface temperatures must be pegged at some maximum value independent of the forcing, or that clouds/evaporation must act as some sort of tropical regulation mechanism. As a further example, the figure below shows a simulation by Sud et al (2008) showing 10N-10S latitude tropical SSTs for present day heating versus the extra heating that would happen if CO<sub>2</sub> were doubled:

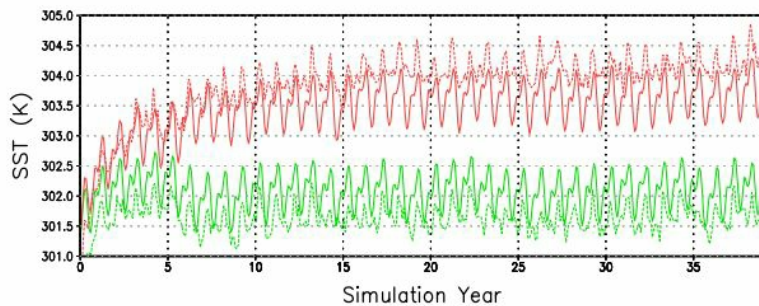


Figure 3. Solid lines show the 10 N- 10 S SST for a present-day (green) and 2xCO<sub>2</sub>.



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