Ocean Surface Temperature Limit

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Summary

This four-part paper analyses the role of atmospheric water in regulating Earth's thermal balance.

Part 1 is an analysis of the temperature of tropical ocean warm pools with observations of the annual temperature limit of thirty degrees Celsius including charts showing the actual temperature limiting process using hourly data observed at moored buoys in three tropical oceans when warm pools occurred at the buoys. Open ocean surface temperature is observed to limit below 32C and annual average for the warmest open ocean water is 30C. The Persian Gulf is also discussed as it is one of the few large bodies of water where the surface temperature can exceed 32C during an annual cycle.

Part 2 discusses the mechanism of deep convection concluding with the persistency of clouds over ocean warm pools preventing further heat uptake once the sea surface reaches 32C. Once the open ocean surface reaches 32C, the oceans have sustained cloud cover, often referred to as monsoon due to the common occurrence across all tropical water but taking the name from the seasonal change in the Arabian Sea.

Part 3 examines the global ocean energy balance over an annual cycle month-by-month to quantify the role of atmospheric water in regulating the global energy balance. The concept of Atmospheric Water Cooling Coefficient is introduced and this factor is observed to range from negative to positive over a twelve month cycle with the annual average being positive thereby showing that atmospheric water is a net cooling agent.

Part 4 combines aspects of deep convection covered in Part 2 with the measured atmospheric water response presented in Part 3 to identify 45mm of total atmospheric water as the level where the atmosphere shifts into sustained deep convection. Above this level, the atmospheric water becomes a net cooling agent with reduction in surface insolation due to cloud reflection being greater than the reduction in outgoing long wave radiation due to the low radiating temperature of high-altitude cloud.

Conclusions.

- Current climate models assume the oceans keep absorbing heat through the surface without end. Until they can replicate the physics of deep convection tightly linked to surface temperature rather than the naive parameterisation of clouds, they will remain nothing more than extended weather models with useful predictive ability of a few days.
- It is near impossible to get heat into oceans through the surface. It takes thousands of years. The warm surface water is only meters deep and the surface warms and cools rapidly. Further, the warm pools move about and have a fleeting presence at any particular location. The feedback loop is that the warmest water forms the most cloud which rapidly results in cooling.
- Observations of the attributes of water in the atmosphere contradict the heat trapping assumption of atmospheric water described by the "Greenhouse Effect". Water in the atmosphere is not heat trapping but rather a temperature regulating component that increases radiating power (the sum of reflected short wave radiation and emitted long wave radiation) when the surface warms and reduces radiating power when the surface cools through reduced cloud cover enabling more surface insolation.

List of abbreviations and units

AWCC – Atmospheric Water Cooling Coefficient, is the gradient of the regression line for the total EMR radiating power of Earth as a function of total precipitable water in the atmosphere. Unit is Watts per square metre per centimetre of total precipitable water.

Atmospheric pressure measured in millibars (mb)

BoM – Australian Bureau of Meteorology

C – Degrees Celsius, is a temperature scale ranged from 0C at the freezing point of water and 100C at the boiling point of water at standard atmospheric pressure. 0C equals 273.15K.

CAPE – Convective Available Potential Energy, the energy manifested as the buoyancy of moist air that fuels cloudburst in the atmosphere. Units are Joules per Kilogram. Updraft velocity in metres per second (m/s) is a function of CAPE determined as SQRT(CAPE*2).

CSIRO – Australian Commonwealth Scientific and Industrial Research Organisation

Density – Mass per unit volume usually kilograms per cubic metre (kg/Cu.m) or grams per cubic metre (g/cu.m)

EMR – Electro-Magnetic Radiation, is the apparent energy present in the electro-magnetic field at any fixed point in space and time. Unit is power flux in Watts per square metre (W/sq.m).

LFC – Level of Free Convection, the altitude where the atmosphere partitions to form a surface vertical convecting zone and an upper dehumidifying zone not involved in the surface convection. Altitude measured in metres (m) or kilometres (km).

K – Degrees Kelvin, is a temperature scale where 0K is absolute zero.

Precipitation has the units of millimetres per day (mm/day)

NOAA - USA National Oceanic and Atmospheric Administration

NASA – USA National Aeronautics and Space Administration

OLR – Outgoing Longwave Radiation, is the long wave power flux measured by satellites at the notional top of the atmosphere. Unit is a power flux of Watts per square metre (W/sq.m).

SWR – Short Wave Radiation, is the short wave radiation directly from the sun or reflected from objects such as Earth. Unit is power flux in Watts per square metre (W/sq.m)

TPW – Total Precipitable Water, is the amount of atmospheric water in the total air column from surface to top of the atmosphere. Units can be kilograms per square metre (kg/sq.m) or an equivalent total depth of liquid water in millimetres (mm) or centimetres (cm) as the density of liquid water is 1000kg/Cu.m so 1mm TWP is the same as 1kg/sq.m.

ToA – Top of the Atmosphere, in the context of this analysis is taken as the orbiting altitude of the various satellites used to collect the data.

Part 1: Observed Ocean Surface Temperature Regulation – Upper Limit

Ocean surface temperature observations show that less than 10% of open ocean surface water exceeds an annual average surface temperature of 30C. Also less than 1% of the ocean surface exceeds 32C for more than a few days. The thermostatic upper limit of 30C for ocean warm pools has been observed scientifically since at least the 1970s and is easily observed globally in the current era using satellite measurements. Each year, warm pools reach their maximum extent of around 9% of the ocean water surface area in April as both Tropical Western Pacific and Indian Ocean reach peak heat uptake. This is observed with reference to Figure 1.

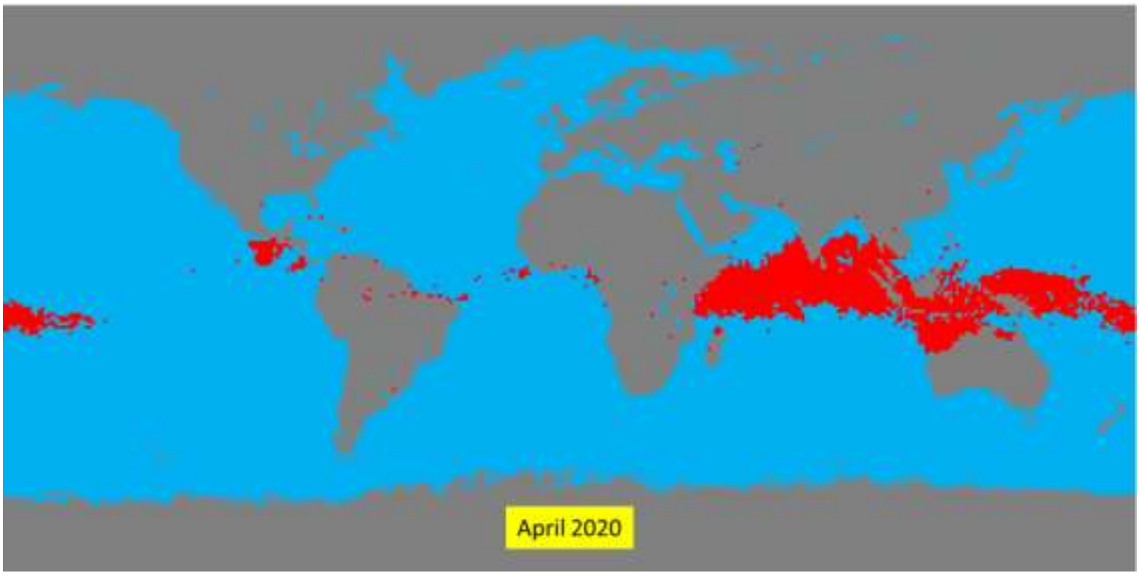


Figure 1: Global map highlighting tropical warm pools at or above30C shown in red – April 2020.

The Northern Hemisphere continues to warm from April through to August. The Pacific warm pools contract as they advance northward and the Indian Ocean warm pools dissipate as the northern monsoon sets in over the Arabian Sea and Bay of Bengal while the Gulf of Mexico becomes a temperature regulating warm pool and the Persian Gulf becomes the warmest ocean surface on the globe. Figure 2 highlights this transition by comparison with Figure 1.

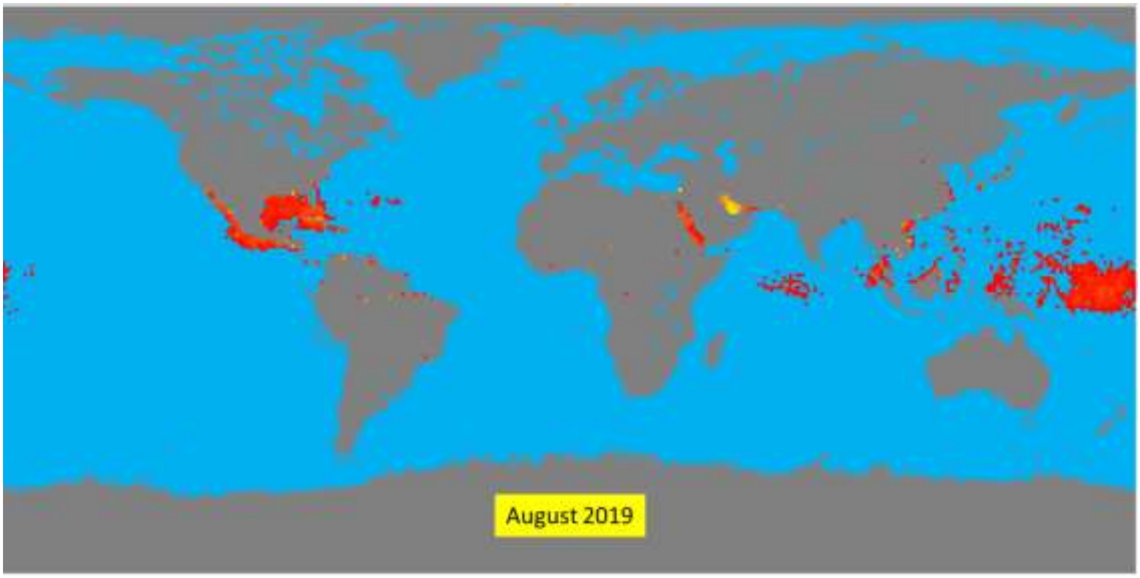


Figure 2: Extent of warm pools in August 2019 – red above 30C, yellow at and above 34C.

By January, the solar zenith has moved south and the global oceans are at the start of their warming phase. The Gulf of Mexico and Persian Gulf have cooled. Ocean warm pools reduce to their minimum extent in January with only 3.9% of the ocean water surface at or above 30C as depicted in Figure 3.

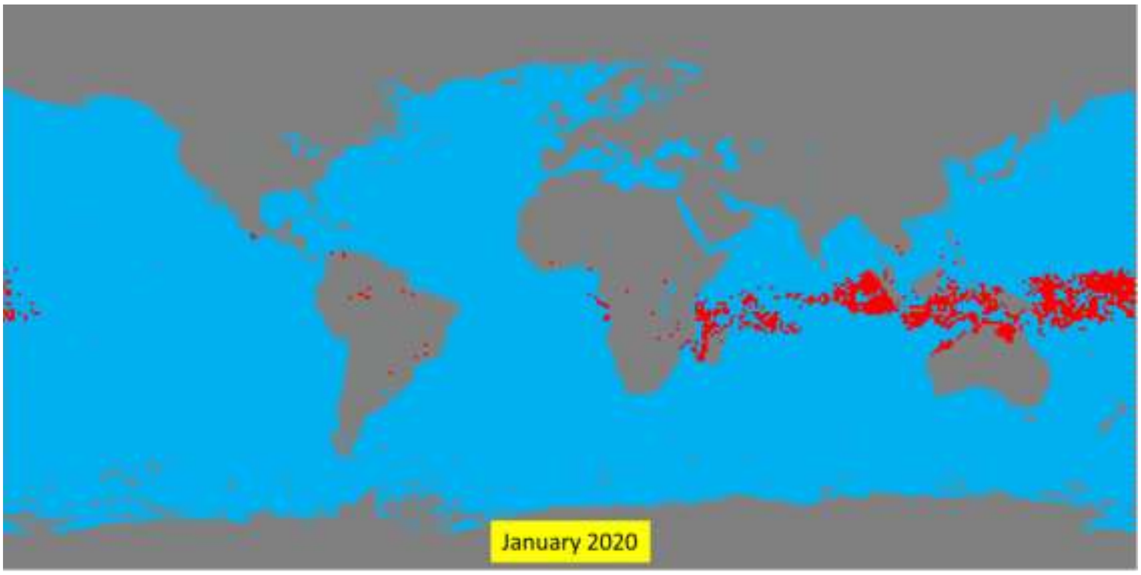


Figure 3: Warm pool minimum annual extent occurs in January – January 2020.

The surface temperature upper limit of 32C becomes more apparent when the proportion of ocean surface area at any given temperature is charted as shown in Figure 4.

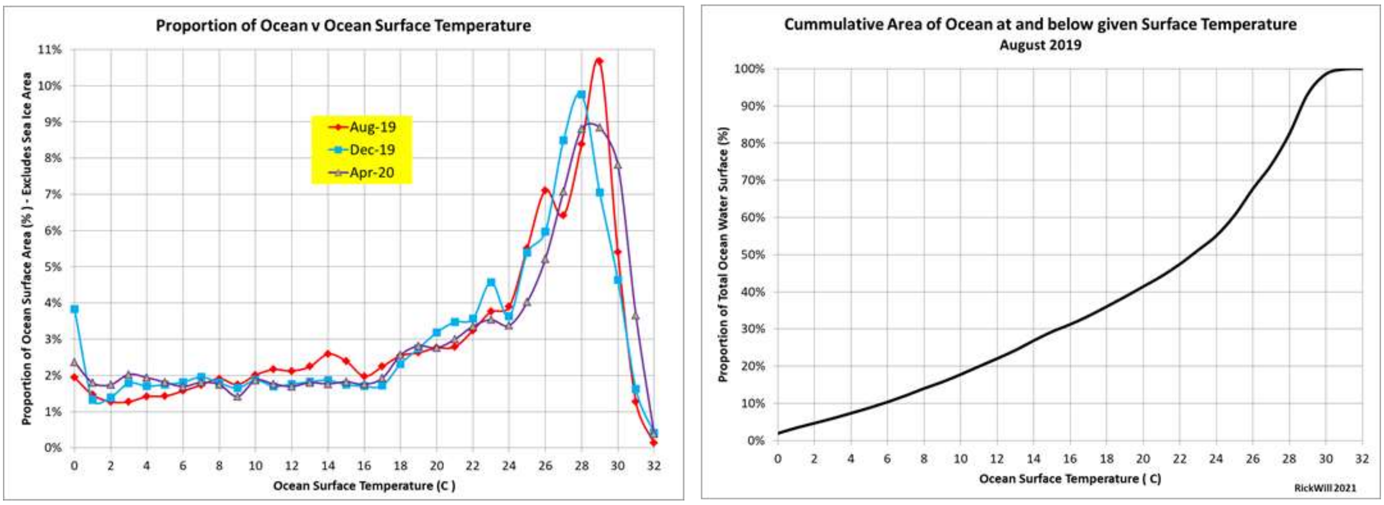


Figure 4: Area of ocean surface at a specific temperature as a proportion of the total ocean surface area and cumulative proportion by area at or below given surface temperature.

More than 50% of the ocean water surface exceeds 22C as shown in Figure 4 right panel while the peak proportion of ocean area is in the range 28C to 29C but falls off sharply above 29C such that there is less than 1% of the ocean surface area warmer than 32C, left panel.

Warm Pool Temperature Limiting Process

The response of the temperature limiting process over tropical warm pools can be observed in hourly intervals when the warm pools exist at the tropical moored buoys. The same temperature limiting process is observed across the three tropical oceans as set out in the series of ocean surface temperature limiting charts in Figure 5.

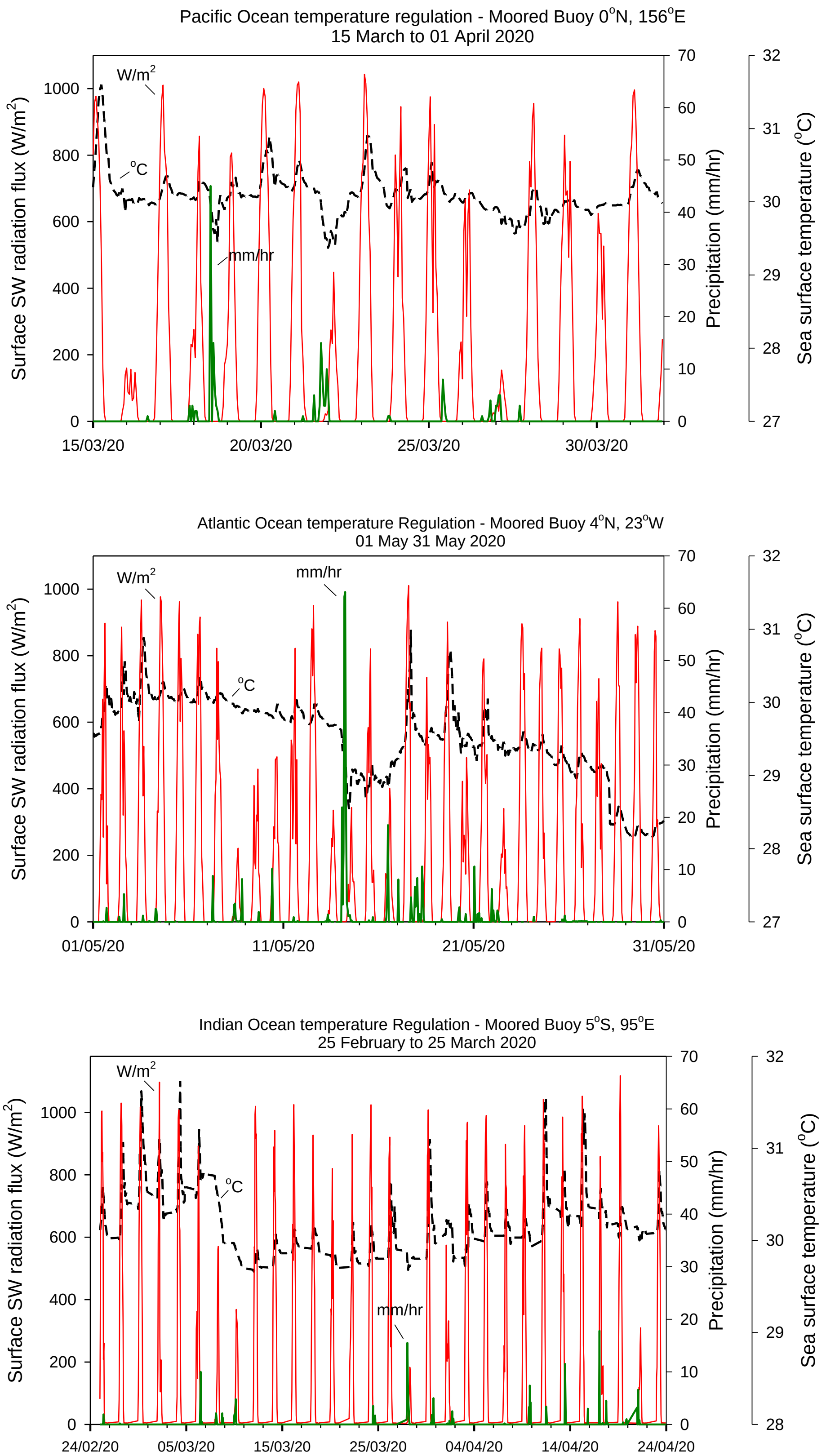


Figure 5: Temperature limiting processes in the tropical warm pools; top Pacific, middle Atlantic and bottom Indian. THINK ABOUT THAT – three ocean buoys separated by thousands of kilometres all limiting to 30C by the same process.

With reference to the surface temperature limiting charts in Figure 5, the temperature limiting process begins when the surface temperature rises above 30C in clear sky conditions before the local convective cycle sets in. The cycle starts with cloudburst followed by persistent cloud that reduces surface insolation to slow the rate of rise in temperature. Moist air diverges from cooler adjacent zones to the warm pool resulting in heavy precipitation that increases the cooling rate in the warm pool. The high level moist air has been cooled over water at 28C to 29C that is absorbing heat at the surface due to predominantly clear sky conditions above. Convergence of moist air to the warm pool continues until it is no longer the warm pool. This is particularly apparent in the middle image where the Atlantic warm pool cools below 30C from 14 May and the precipitation drops to zero as the warm pool moves on. The following Table 1 provides averages for all variables and peak insolation for the charts in Figure 5.

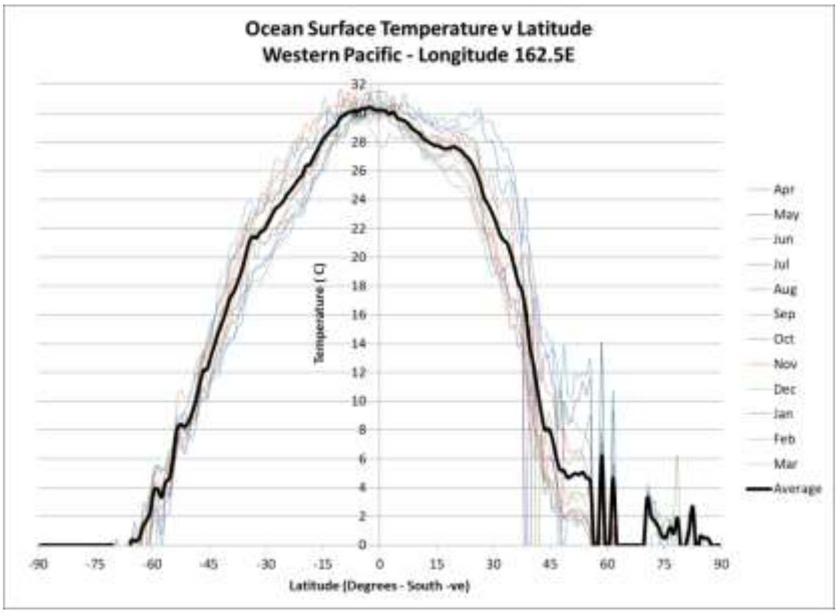
Ocean	Electro-Magnetic Radiation (W/sq.m)				Precipitation (mm/day)
	Surface Insolation		ToA OLR	Column Net EMR Warming	
	Peak	Average			
Pacific	1042	202	216	-14	10.5
Atlantic	1011	184	235	-51	11.9
Indian	1116	223	215	8	6

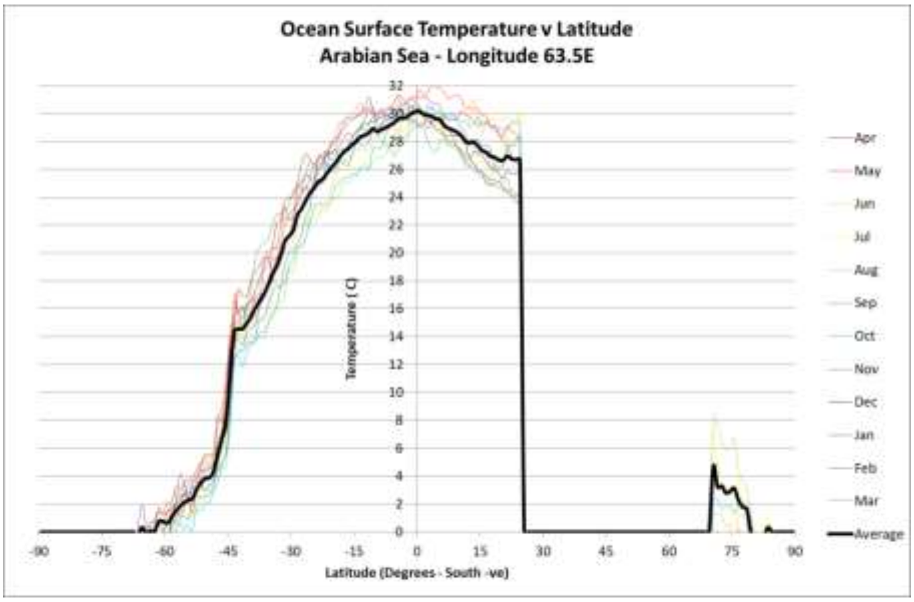
Table 1: Average of all variables from temperature limiting charts and top of atmosphere OLR above the respective buoys during the observation period

The conditions are different at the three locations. Both Pacific and Atlantic are experiencing net EMR cooling while the Indian has mild net warming. Both Pacific and Atlantic are experiencing net convergence while the Indian is still in a divergence zone. The high peak insolation for the Indian indicates that there were likely clear sky conditions for at least one day. The high net EMR cooling combined with the high precipitation rate for the Atlantic is consistent with a reduction in the surface temperature at the buoy during the period as observed in Figure 5 middle panel.

The Annual Cycle of Warm Pools

As previously observed the warmest regions of the tropical oceans can move appreciably throughout the year but the Equator usually observes the highest annual average surface temperature; always close to 30C in all warm pools as observed in the series of south to north transects through warm pools displayed in Figure 6.





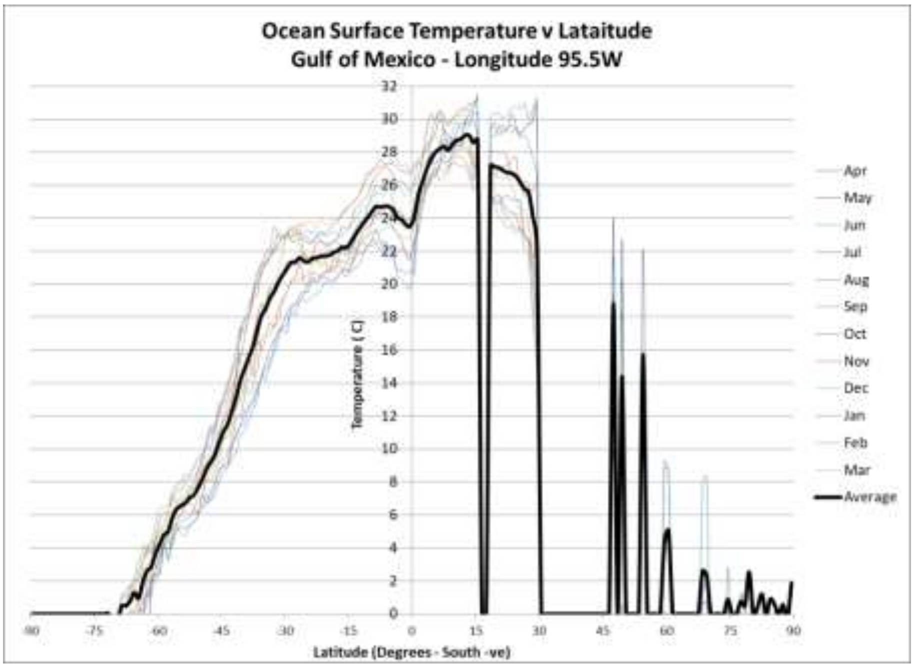


Figure 6: Monthly and annual average sea surface temperature south to north transects – top Western Pacific, middle Indian Ocean through the Arabian Sea, bottom Gulf of Mexico and Eastern Pacific

The Persian Gulf becomes the warmest ocean surface in August each year. It is the only ocean surface that regularly exceeds 34C in any year. This unique deviation from the temperature regulating feature of the tropical oceans is highlighted in Figure 7.

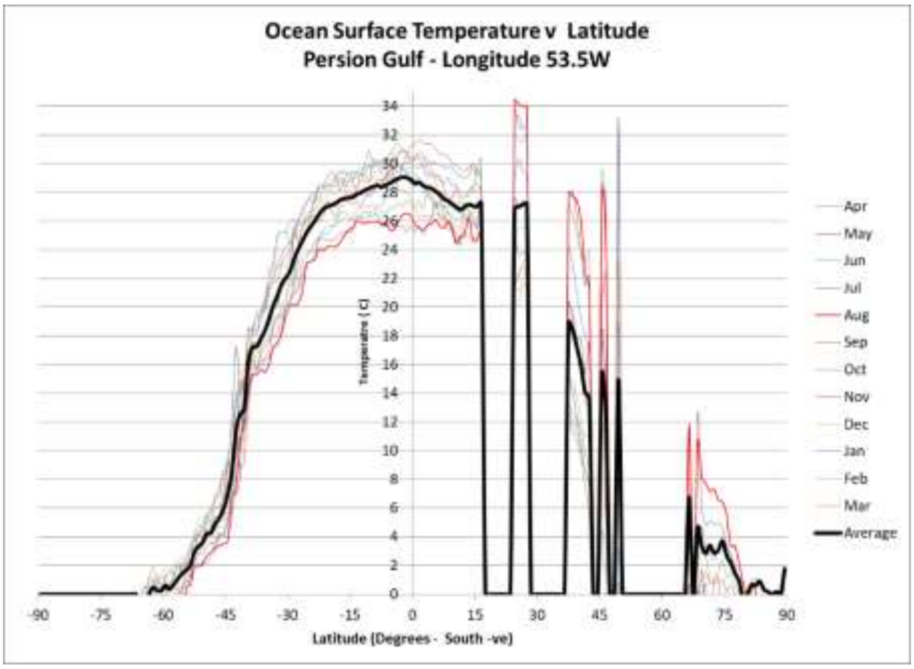


Figure 7: Monthly and annual average sea surface temperature south to north transects centred on 53.5W through the Persian Gulf and Indian Ocean – August highlighted with red curve.

Performance of Climate Models in predicting Ocean Surface Temperature

The tropical warm pools present a challenge for climate models because the models rely on cloud parameterisation rather than the actual physics of convective instability that limits the maximum ocean surface temperature. NOAA provides a high quality data set for sea surface temperature in the tropical Pacific that combines ocean water temperature measurements observed at the tropical moored buoys interpolated between buoys using satellite imagery. Figure 8 demonstrates the poor performance of the CSIRO and BoM, Australian Community Climate and Earth Systems (ACCESS) climate model over the Nino34 region in the tropical Pacific. The Nino34 region is located between latitudes 5N and 5S from longitudes 120W to 170W. This region is recognised as an important indicator of global weather and particularly the Pacific El Nino and La Nina modes that influence weather conditions across the eastern States of Australia.

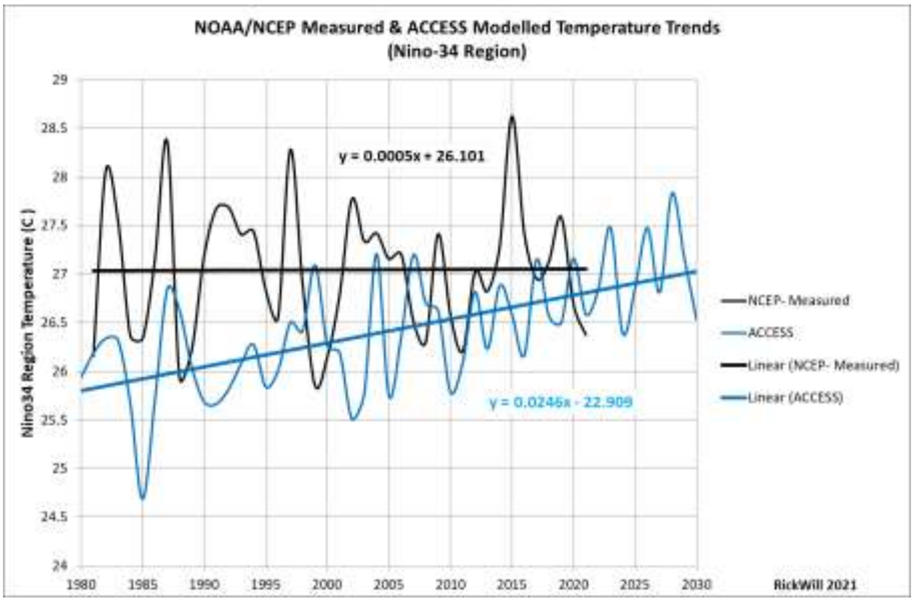


Figure 8: Comparison of ACCESS climate model prediction and hindcast over five decades with the actual observed ocean surface temperature over four decades.

It is quite apparent that the model has cooled the past to an extreme degree to maintain its warming trend. According to the ACCESS hindcast, the well-known 1997/98 El Nino in Australia could not have possibly occurred because the temperature in this region is observed to exceed 28C for El Nino conditions to form as shown in Figure 8 in the measured data. The model output clearly demonstrates its poor performance over this important weather influencing region.

It is noted here that the Nino34 region is most commonly a high divergence zone with high net evaporation rates (evaporation less precipitation). More than 50% of the net EMR absorbed by the oceans enters in the narrow temperature range 27.5 to 28.5C. This results in the mixed layer in the region being constantly shoaled and the ocean surface temperature, measured at nominally 1m depth, is identical to the air temperature at nominally 2m above the surface.

The uniqueness of the Persian Gulf provides another example of the poor performance of the ACCESS model over this region in a comparison with measured data in Figure 9.

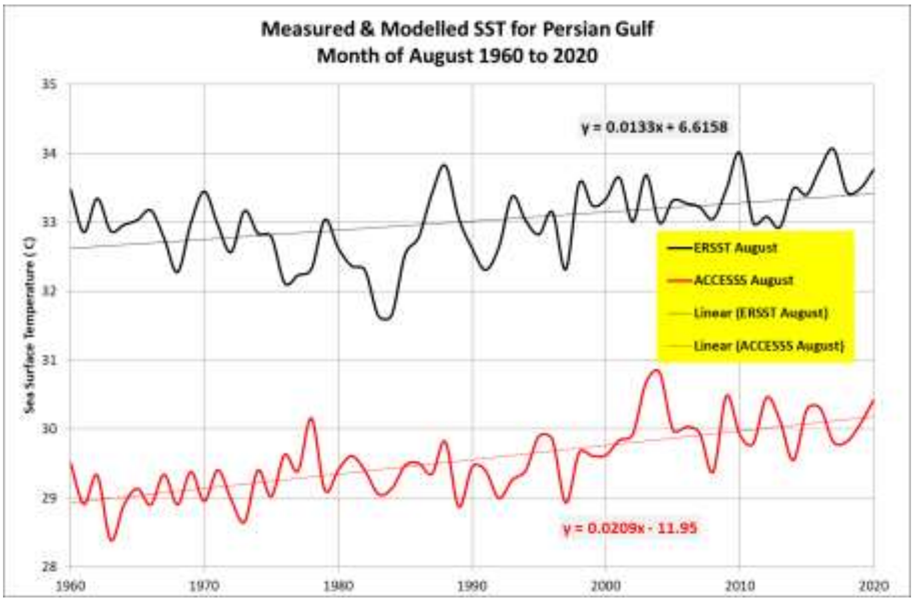


Figure 9: Comparing measured and modelled surface temperature in the Persian Gulf for the month of August 1960 to 2020.

In August each year, the Persian Gulf becomes the warmest ocean surface on the globe. The unique conditions of low mid-level moisture prevents the formation of convective instability and the surface temperature regulating phenomena associated with high level convective cloud. Here the ACCESS model again produces a poor result but in this case up to four degrees Centigrade cooler than the measured data.

Part 2: Deep Convection and Development of Convective Potential Energy

Water in the atmosphere behaves differently to the other components. Water vapour has the lowest density of the common constituent gasses. Water exists in the atmosphere as a gas, liquid and solid. All three phases are effective emitters of long wave radiation and ice in the atmosphere forms highly reflective cloud.

The unique properties of water in the atmosphere create convective instability that is observed to limit the ocean surface temperature in tropical warm pools to an annual average of 30C, detailed in Part 1 above. The primary cause of convective instability that drives deep convection is the buoyancy of water vapour. The development of convective potential relies on the ability of atmospheric water, in all phases, to cool by radiated heat transfer.

Level of Free Convection

Convective instability can only occur when the mass of water vapour in the atmosphere exceeds 30kg/sq.m; equivalent to 30mm TPW. Once the level of water exceeds 30mm, the atmosphere can partition into a zone of free convection in contact with the surface and an upper zone that is not involved in the surface vertical convection currents. The upper altitude of the surface mixing zone is termed the Level of Free Convection (LFC).

To better appreciate how the LFC develops, it is useful to examine the conditions of a saturated air column over a surface at 300K (27C) with 1010mb surface pressure based on the August-Magnus-Roche approximation for water vapour pressure. Such conditions are observed over ocean surfaces at the onset of the deep convective cycle. Figure 10 compares the density of air with altitude and the density of water vapour with altitude.

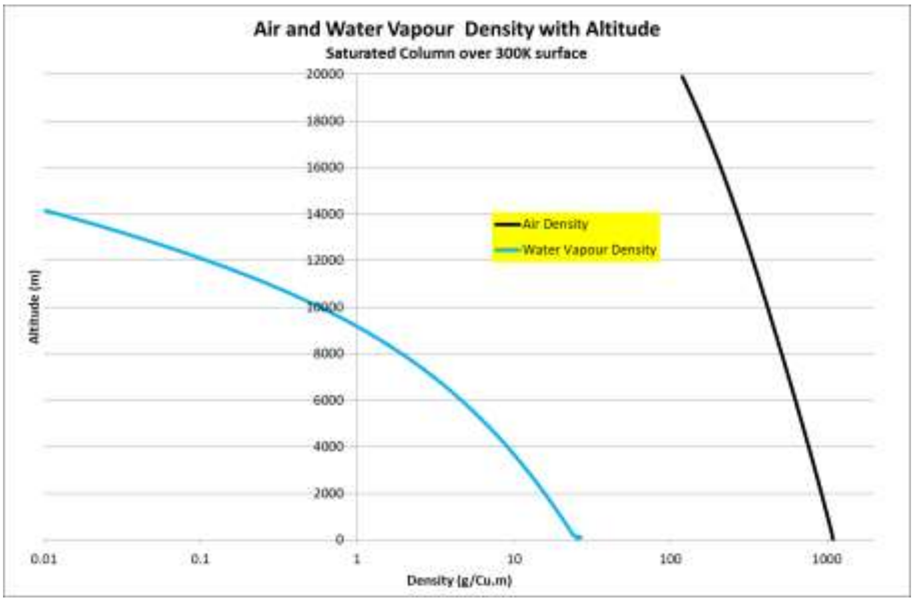


Figure 10: Variation of moist air density with altitude and water vapour density with altitude in saturated column above 300K surface at 1010mb surface pressure

With reference to Figure 10, it is observed that the density of the water only makes a small contribution to total air density and falls off rapidly with altitude such that water has negligible mass above 14,000m. Moreover, this is for a saturated column but water vapour can be present over a wide range of relative humidity at any altitude from zero up to the saturated level. Figure 11 compares the density change of moist air with altitude and the density contribution of water in saturated air.

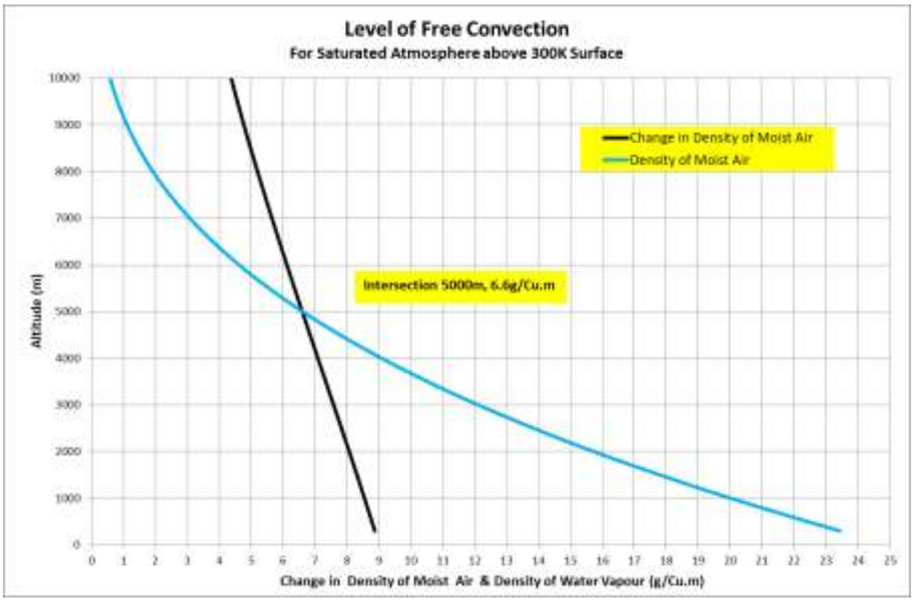


Figure 11: Formation of level of free convection in saturated air column above 300K surface and 1010mb surface pressure

With reference to Figure 11, it is observed that the density of water with elevation is greater at ground level than the change in density of air with elevation. At 5000m and 6g/Cu.m, the density of the water vapour reduces faster than the density change of the total mixture with altitude. That transition creates the condition where dry air will be supported by a moist air column below. In other words, dehumidifying air above the LFC through condensing the water vapour will not result in that parcel of air sinking into the moist region below the LFC. Similarly, rising moist air parcel, under thermal equilibrium, will not have sufficient buoyancy to rise above the LFC; the contribution of water to the buoyancy is unable to elevate the moist parcel into the dry zone.

An LFC can exist in any air column where the total water column exceeds 30mm irrespective of relative humidity. The free convection zone below the LFC will increase in water vapour above a warming ocean surface while the water vapour above the LFC is solidifying or condensing as it cools via radiated heat loss. Given sufficient time, the water vapour above the LFC solidifies and condenses to leave dry air while the zone below the LFC becomes saturated. This condition can be better appreciated with reference to Figure 12 for the atmospheric conditions above a 303K (29.9C) surface; typical of tropical warm pools.

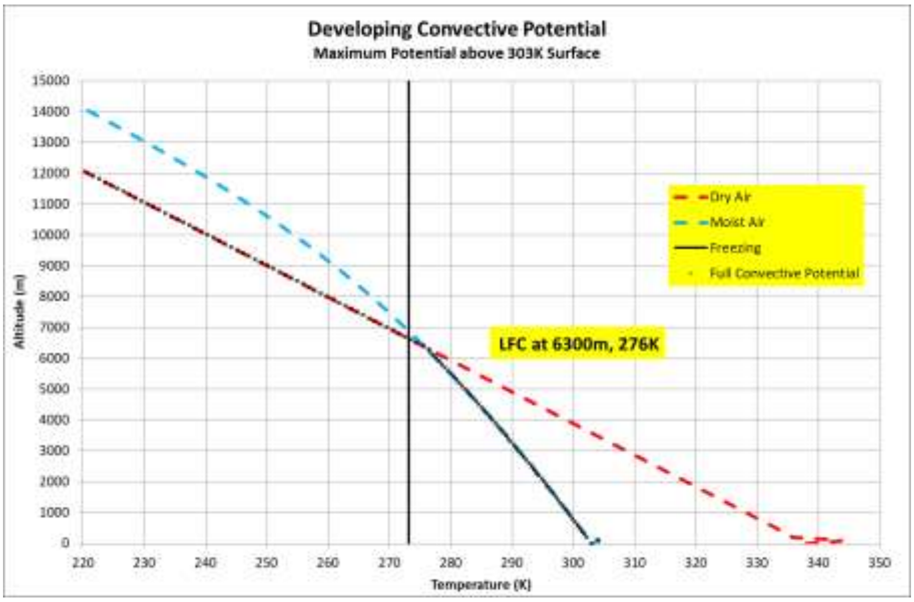


Figure 12: Developing convective potential over a 303K ocean surface and 1010mb surface pressure

The atmospheric temperature profile will follow a saturated adiabat from the surface to the LFC then progress upward along the dry adiabat that passes through the LFC. Under these surface conditions and relative humidity, the LFC is at 6300m where the temperature is just above freezing at 276K.

Convective Available Potential Energy

The partitioning of the atmosphere above and below the LFC can exist while the column is in thermal equilibrium. If there is a disturbance that causes a small parcel of moist air to penetrate into the dry zone, its lower density and, therefore, buoyancy will cause it to rise and it will be followed by more moist air until the zone above the LFC becomes supersaturated. This is the process of cloudburst whereby moist buoyant air bursts into the upper dry zone once the thermal equilibrium is upset and convective instability ensues. The supersaturated air above the LFC gives rise to local precipitation that can grow to intense rain if moist air converges laterally from more stable zones.

With reference to Figure 12, the work done by the rising moist air during cloudburst is determined by the area on the chart between the moist adiabat and the dry adiabat above the LFC. The low level of moisture above 14,000m or 220K means this condition limits the development of convective potential to below this altitude above ocean warm pools limiting at 303K. The maximum possible Convective Available Potential Energy (CAPE) above a surface at 303K is 6000J/kg. This requires the CAPE to be fully developed before instability occurs. Observations above tropical warm pools indicate the convective potential rarely exceeds 4000J/kg in these regions. The maximum updraft velocity during cloudburst is the square root of the CAPE*2. A CAPE of 4000J/kg would consequently create a maximum updraft velocity of 89m/s (320kph).

Convective Instability and Cloud Cover

The atmospheric column becomes supersaturated during cloudburst. Water vapour can extend to at least 14,000m during cloudburst and produces high level cumulus cloud that effectively blocks surface insolation at the onset of the convective cycle and each subsequent cloudburst. The outgoing long wave radiation is absorbed by the water vapour, water condensate and, finally, the ice high in the atmosphere that will have a radiating temperature as low as 220K with a corresponding OLR radiating power of just 130W/sq.m with average outgoing long wave power of 210W/sq.m over 30C warm pools. By contrast, the peak reflective power can be as high as 1000W/sq.m in peak insolation as observed at the tropical moored buoys.

The precipitation following cloudburst subsides leaving the zone above the LFC saturated but set to again develop convective potential. During this stage, most long wave radiation from tropical warm pools exits above the freezing altitude to solidify the water vapour thus forming persistent cirrus cloud that deepens during the CAPE development phase.

In essence, the atmosphere over tropical warm pools acts as a heat engine of enormous power absorbing heat at typically 210W/sq.m at the ocean surface to produce water vapour that increases the humidity of the air column below the LFC. The region above the LFC goes through a water condensing/solidifying phase by releasing heat as OLR at 210W/sq.m above the LFC. At some point convective instability is inevitably triggered and the moist air enters the dehumidified zone then bursts upwards due to its buoyancy. The supersaturated water condenses or solidifies during the cloudburst forming cumulus cloud and some of the moisture precipitates. The zone above the LFC is now saturated and primed to repeat the condensing/solidification phase during which persistent cumulus cloud thickens then likely thins before the next cloudburst.

The surface heat input and emitted heat at altitude are both near 210W/sq.m, which is consistent with cycling 7.3mm of water through the atmosphere each day. The ocean advection eventually transports the high altitude water vapour to higher latitudes where the moisture gradually solidifies/condenses to play a further role in the global energy balance away from the warm pools. The ocean air currents have TPW as high as 70mm over the warm pools and it is reduced to below 10mm at high latitudes.

The persistency of the cirrus cloud is better appreciated with reference to distribution of water vapour above the LFC and the level of freezing for stated surface temperature as set out in the following Table 2.

Surface Pressure 1010mb							
Surface Temperature (K)	300	301	302	303	304	305	306
Wv Above LFC (mm)	15.9	15.5	14.6	13.8	13.1	12.6	11.6
Wv Above Freezing (mm)	10	10.2	10.3	10.5	10.5	10.5	11.1
Cloud Persistency (% Wv above 273K)	63%	66%	71%	76%	80%	83%	96%

Table 2: Distribution of water vapour above the LFC and the level of freezing under saturated conditions for nominated surface temperature

The table established the cloud persistency during the CAPE development phase when cirrus cloud deepens and then thins before the cloudburst cycle repeats. At 300K, the clear sky conditions can persist for approximately 37% of the CAPE development period if the divergence does not disrupt the cycle. The ice forming the cirrus cloud melts as it descends somewhere in the region of the freezing altitude and continues to descend below the LFC as water condensate and revaporises as it mixes below the LFC. The cirrus cloud dissipates while the exiting OLR is condensing the water vapour below the level of freezing but above the LFC. Usually the air above 300K (27C) water surface diverges to air over warmer water and this disrupts the regular convective cycle such that clear sky persists for longer than 37% of the time. On the other hand, convergence of moist air to warm pools at 303K (30C), where clear sky would be expected 24% of the CAPE development stage, reduces the proportion of clear sky to a level where the surface heat fluxes, including cooling precipitate, are balanced and 303K is the upper temperature limit. The net warming value in Table 1 from the moored buoy data supports this conclusion. Without convergence playing a role, the radiated heat fluxes balance when the surface reaches 305K with clear skies 17% of the CAPE development stage. A surface temperature of 306K (32.85C) has not been observed in open ocean warm pools. At this temperature, the sky above the ocean would maintain persistent cloud, cycling from cumulus to thickening cirrus then thinning cirrus but no clear sky before the next cloudburst.

The location of the warmest pool experiences convergence of mid-level moist air and cooler adjacent zones experience corresponding divergence. This results in the warmest pool experiencing precipitation of up to 15mm/day, twice the daily rate of condensate production, while adjacent locations typically 2.5mm/day, under half the daily condensate production.

Typical long wave radiating power over a tropical warm pool is 210W/sq.m. This corresponds to water vapour solidification/condensing rate of 7.3mm/day. Hence, above a warm pool of 303K (30C), it takes a maximum of 45 hours for a convective cycle to solidify/condense 13.8mm of water vapour if it is not disrupted by divergence of moist air and shorter if it reaches instability before the CAPE reaches full potential. Observed convective cycles rarely run to full potential.

The Persian Gulf

The surface temperature in the Persian Gulf has been observed to exceed 307K (34C) in August but examining the atmospheric profile shows the mid-level moisture content is too low to create the LFC needed before deep convection can develop despite high surface level relative humidity. The Persian Gulf experiences high rates of evaporation but the prevailing dry north-westerly winds, so-called Shamal, transport the high level moisture laterally to the Arabian Sea. Cloudbursts are rare events in the Persian Gulf.

Warm Pool Temperature Sensitivity to Surface Pressure

The temperature limit in warm pools has some sensitivity to the surface pressure. For example, there are atmospheric oxygen proxies that indicate the partial pressure of oxygen in the atmosphere has been 50% higher than present. Table 2A has been prepared to compare the likely surface temperature during the Cretaceous period on the basis that the nitrogen mass has not changed significantly.

Surface Pressure 1100mb							
Surface Temperature (K)	303	304	305	306	307	308	309
Wv Above LFC (mm)	16.2	15.3	14.5	13.8	13.3	12.3	11.5
Wv Above Freezing (mm)	10	10.2	10.3	10.5	10.6	10.7	11
Cloud Persistency (% Wv above 273K)	62%	67%	71%	76%	80%	87%	96%

Table 2A: Cloud persistency as a function of ocean surface temperature at 1100mb – possible surface pressure during the Cretaceous period

Table 2A indicates similar cloud persistency to present day conditions would occur at ocean warm pools with temperature limit three degrees Kelvin higher at 1100mb surface pressure than the present day surface pressure of typically 1010mb.

Part 3: On the role of Atmospheric Water - Albedo trumps Long Wave Absorption and Re-emission

A study of the top of atmosphere electro-magnetic radiated power flux over the global oceans covering a twelve month period from August 2019 to July 2020 reveals that water in the atmosphere provided net radiated energy loss over the annual cycle.

The cooling or heating effect of atmospheric water is found to respond to the ocean surface temperature with slightly less than one month time lag. The gradient of the radiated power loss with respect to the atmospheric water quantity varies from month-to-month and is introduced here as the Atmospheric Water Cooling Coefficient (AWCC).

Water in Earth's Atmosphere

Water is a small but key constituent of Earth's atmosphere. In the tropics, the total water mass distributed throughout the entire atmospheric column can be as high as 70kg/sq.m. That corresponds to 70mm or 7cm above any given surface area. At the poles, the atmosphere contains negligible water.

The water in the atmosphere can exist in three phases - gas, liquid and solid. When water evaporates from a surface, it enters the atmosphere as a gas commonly referred to as water vapour. When water vapour cools it will form a liquid condensate or solid ice depending on the atmospheric temperature where the phase change occurs. If the temperature is higher than 0C then the water vapour condenses to liquid water. If the temperature is lower than 0C then the water vapour solidifies to solid ice. Liquid water and solid ice in the atmosphere are the fundamental constituents of clouds.

Water in its three phases in the atmosphere has a profound effect on the global energy balance. All phases absorb and emit long wave electro-magnetic radiation (OLR) emitted from the surface of the earth and the atmosphere. The solid phase dominates the reflection of short wave electro-magnetic radiation (SWR) thereby reducing the insolation reaching the surface and absorbed by the oceans.

Atmospheric Water & Radiating Power

There are three electro-magnetic radiated power fluxes observed at the top of Earth's atmosphere:

- Incoming short wave solar radiation
- Reflected short wave radiation
- Outgoing long wave radiation

The incoming insolation varies from 1317W/sq.m to 1415W/sq.m over an annual cycle due to the eccentricity in Earth's orbit. The peak insolation occurs in early January in the present era. The area average over the spherical surface ranges accordingly from 329W/sq.m up to 354W/sq.m.

For the Earth to have a stable temperature, the incoming SWR from the sun must be balanced at the top of the atmosphere by reflected SWR and the OLR. However the insolation arriving is varying over a year resulting in energy being stored in the oceans when the insolation is high and then released when the insolation is lower. The high thermal inertia of the oceans dampens the surface temperature variation. An additional heat storage factor results from the distribution of water over the surface of the globe with the peak insolation occurring when the southern hemisphere, with its high proportion of surface water, has the highest exposure to the sun due to axis obliquity. Due to the variation in heat stored, variation in atmospheric water and global distribution of atmospheric water, it is possible to examine how atmospheric water alters Earth's total radiated power flux (the sum of reflected SWR and OLR) throughout the year.

For convenience of analysis the year was considered in monthly intervals. The specific twelve months examined were August 2019 to July 2020. Over the twelve months, it was observed that the radiated power flux peaked in July 2020 at 360W/sq.m. in locations where atmospheric water ranged from 2cm to 3cm as displayed in Figure 13. For July 2020, there was a strong upward trend in radiating power with atmospheric water averaging 8.42W/sq.m/cm. This gives rise to the herein named coefficient, Atmospheric Water Cooling Coefficient (AWCC).

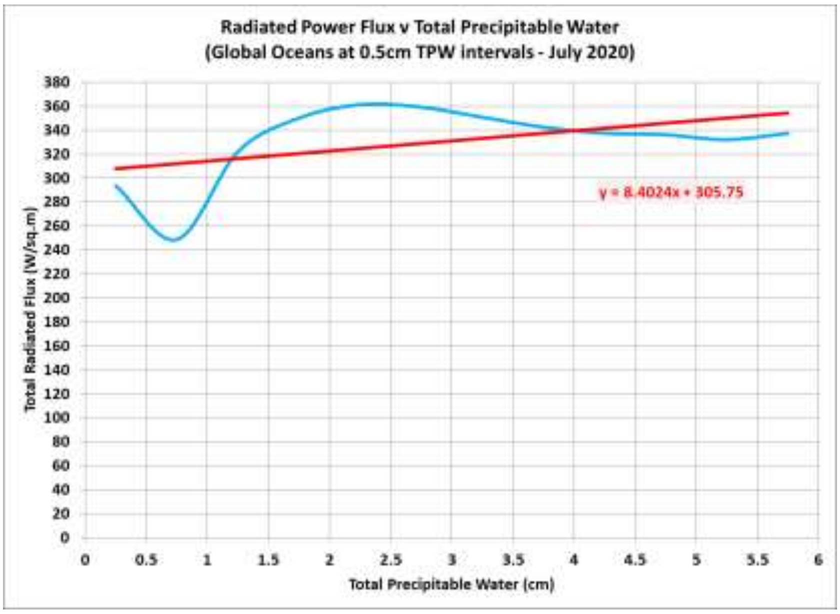


Figure 13: Radiated power flux above ocean surface as a function of atmospheric water content - July 2020.

December 2019 also had peak radiated power flux of 360W/sq.m but the peak occurred in locations where atmospheric water was less than 1cm per Figure 14.

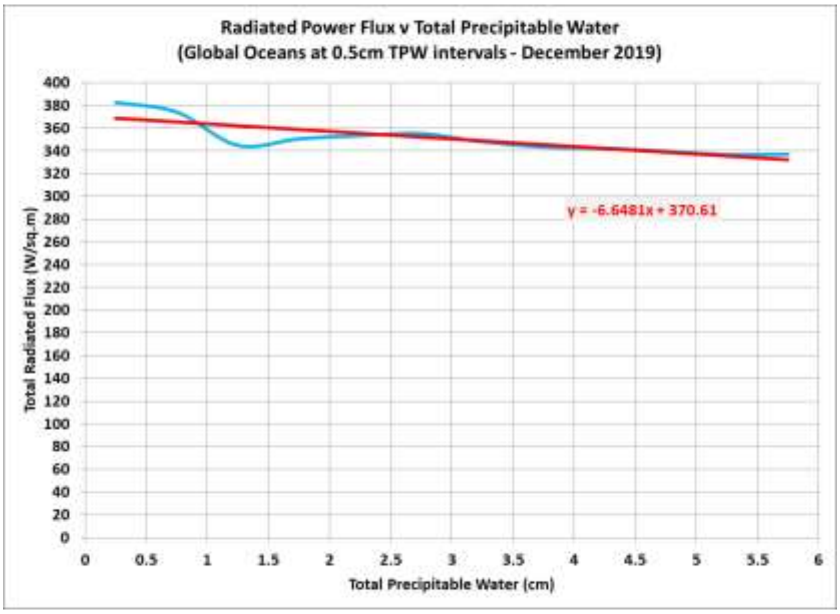


Figure 14: Radiated power flux above ocean surface as a function of atmospheric water content – December 2019.

As shown in Figure 14, for December2019 the AWCC was minus 6.6W/sq.m/cm. Of the twelve months, nine had a positive cooling coefficient and three had a negative cooling coefficient; meaning atmospheric water contributed to net warming for three months. The average AWCC over the twelve months examined was 2.78W/sq.m/cm as displayed in Figure 15. The positive AWCC over the annual cycle demonstrates that atmospheric water was a net cooling agent over the period but is able to warm and cool the surface.

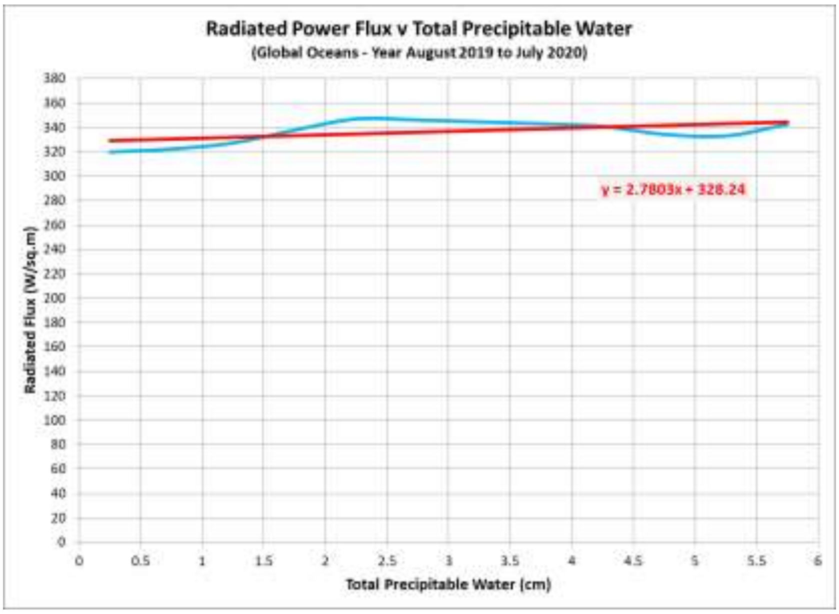


Figure 15: Radiated power flux above ocean surface as a function of atmospheric water content – combined twelve months August 2019 to July 2020 (Excludes areas with sea ice)

AWCC Response to Ocean Surface Temperature

Examining the way the AWCC varied over the twelve months, it became apparent that the AWCC is responsive to the ocean surface temperature and actually provided a regulating function through negative feedback for both warming and cooling. This was tested as observed in Figure 16.

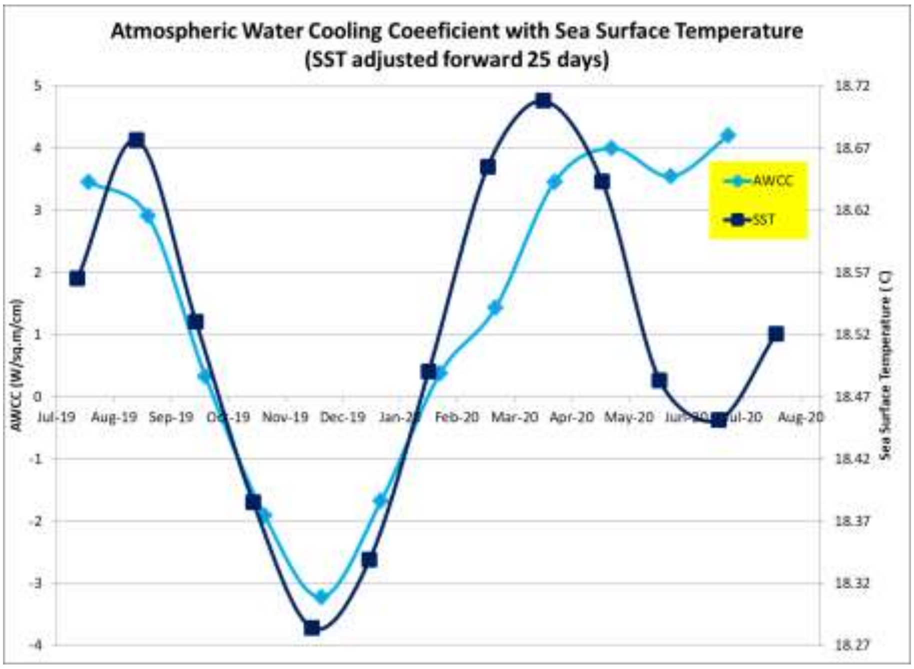


Figure 16: Atmospheric Water Cooling Coefficient charted with average Ocean Surface Temperature over twelve months – August 2019 to July 2020 for AWCC and July 2019 to July 2020 for SST advanced 25 days

In Figure 16 the temperature has been advanced 25 days to time adjust the lagged response of the AWCC to SST. There is a delay between the ocean surface temperature increasing and the increase in the AWCC of around 25 days so advancing the temperature by this period gives better alignment of the curves. Likewise a fall in ocean surface temperature leads to a delayed reduction in the AWCC.

AWCC and “Greenhouse Effect”

NASA provides the following description for the “Greenhouse Effect”:

The greenhouse effect is a process that occurs when gases in Earth's atmosphere trap the Sun's heat. This process makes Earth much warmer than it would be without an atmosphere. The greenhouse effect is one of the things that makes Earth a comfortable place to live.

The main greenhouse gases are:

- *Water vapor*
- *Carbon dioxide*
- *Methane*
- *Ozone*
- *Nitrous oxide*
- *Chlorofluorocarbons*

During the day, the Sun shines through the atmosphere. Earth's surface warms up in the sunlight. At night, Earth's surface cools, releasing heat back into the air. But some of the heat is trapped by the greenhouse gases in the atmosphere. That's what keeps our Earth a warm and cozy 58 degrees Fahrenheit (14 degrees Celsius), on average.

Actual observed data shows that total ocean radiated power flux, the sum of OLR and reflected SWR, is positively correlated with water in the atmosphere over the twelve months examined. In fact the atmospheric water exhibits a regulating response to ocean surface temperature when area average temperature is near 18.5C with the AWCC positive above this value and negative below.

It is further noted that, like the twelve-month total chart in Figure 15 and July chart in Figure 13, ten of the twelve individual months examined exhibited an increasing radiating power at areas where atmospheric water exceeded 5cm. That is the result of convective instability over tropical oceans.

Actual observations of the attributes of water in the atmosphere contradict the heat trapping assumption of atmospheric water described by the “Greenhouse Effect”. Water in the atmosphere is not heat trapping but rather a temperature regulating component that increases radiating power when the surface warms and reduces radiating power when the surface cools. Overall, atmospheric water was a cooling agent for the period analysed. Without atmospheric water, the surface of Earth’s oceans may well be warmer than the current temperature, not cooler. Notably, atmospheric water is an open ocean surface temperature limiting agent with some precision at 30C (303K).

The concept of the “Greenhouse Effect” demonstrates a misunderstanding of how Earth’s average surface temperature is achieved. The energy balance of the oceans, and consequently the entire earth, are related primarily to the upper and lower thermostatic limits on ocean surface temperature. The area of 30C warm pools expand and contract in response to variation in the top of atmosphere insolation due to the orbital eccentricity combined with the extent of water surface exposed more directly to the sun due to water distribution and rotational axis obliquity. Sea ice expands and contracts in reverse to the warm pools but to reduce heat loss from water below the ice due to the low thermal conductivity of the sea ice. The temperature of the ocean water surface ranges from minus 2C (271K) to 30C (303K). It should be no surprise that the average surface temperature of the globe is 14C (574/2=287K) given the distribution of water having equatorial dominance over polar extent causing average ocean surface temperature higher than 14C and average elevation of land at 800m with more land at higher latitudes than equatorial resulting in average land temperature being slightly less than 14C.

Climate models are based on a flawed assumption. Until they can replicate the actual physics of deep convection tightly linked to surface temperature rather than the naive parameterisation of clouds they will remain nothing more than extended weather models with useful predictive ability of a few days.

Part 4: The Atmospheric Gear Change

Total Precipitable Water & Level of Free Convection

In Part 2 of this analysis it was briefly mentioned that the atmosphere cannot form a Level of Free Convection (LFC) unless the Total Precipitable Water (TPW) exceeds 30mm. The listed conditions below all create an LFC at 500m, the lowest altitude considered stable enough to enable the LFC to form:

- Surface temperature 298K, relative humidity 52% and TPW 3.1cm
- Surface temperature 293K, relative humidity 71% and TPW 3.1cm
- Surface temperature 288K, saturated and TPW 3.2cm

This demonstrates that an LFC can form under widely varying surface temperature and relative humidity but TPW remains consistent close to 3.1cm for an LFC 500m above surface level; the lowest likely altitude to avoid surface disturbances.

Part 2 also quantified the rate of condensation at 7.3mm/day if all OLR exists via the atmospheric column. This condition certainly holds once the TPW reaches 3.1cm due to the high long-wave absorption of water vapour, water condensate and ice. With the LFC at 500m and TPW of 3.1cm, there is 2.3cm (23mm) of water above the LFC. It would therefore take 75 hours for the column to develop full CAPE. It is likely that divergence or other disturbance would disrupt the full development such that any cloudburst is weak.

It is observed that cloudburst cycles become established once the TPW reaches 4.5cm. Typical surface conditions for onset of occasional cloudburst are 296K and 80% humidity. This results in the LFC being at 2000m with 10mm of water vapour above the LFC and 7mm of water above the level of freezing if the relative humidity is constant. The full CAPE can be recharged in 33 hours and the cirrus cloud persistency is nominally 70% of the full CAPE development phase.

Atmospheric Water in Cooling Mode

An interesting observation results when combining an understanding of deep convection as discussed in Part 2 and above in this Part with the actual ToA outgoing EMR data analysed in Part 3. Figure 17 displays the twelve monthly regression lines for the ToA EMR emitted power versus TPW for the full year established in Part 3.

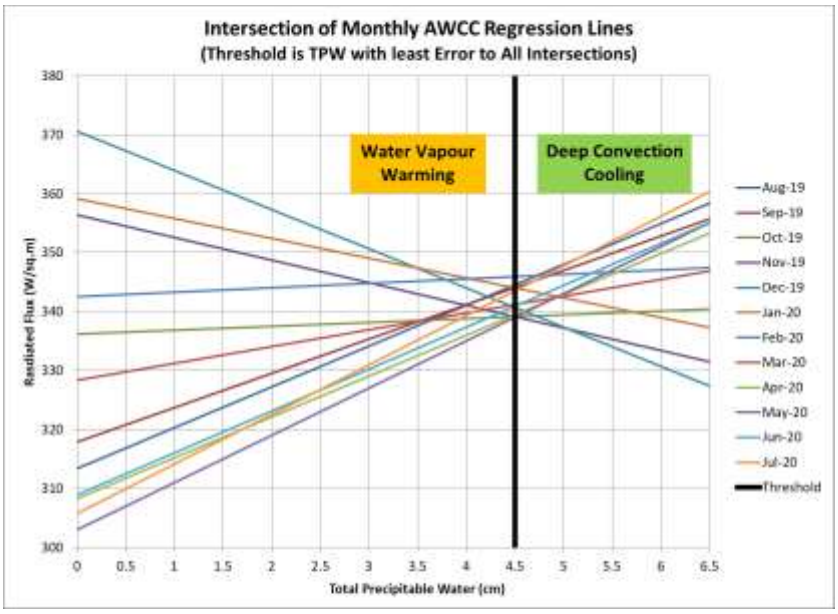


Figure 17: Regression lines for twelve monthly plots of ToA outgoing EMR flux versus TPW

With reference to Figure 17, there is a vertical line shown at 4.5cm, termed “Threshold” that gives the least squares error to the points of intersection. This is the TPW where the atmosphere goes into cooling mode when deep convection sets in. Above the Threshold, the atmospheric water provides cooling principally by regular cloudbursts catapulting water vapour above the LFC to form highly reflective cumulus cloud and then persistent cirrus cloud while the CAPE is recharging. Once deep convection sets in, the increased reflection of ToA insolation trumps the reduction in OLR so ToA radiating power increases.

Below the Threshold, the water vapour acts as a warming agent by reducing the radiating temperature of the atmospheric column thereby reducing ToA OLR without producing high level reflective cloud.

When the surface temperature is cooling, the slope of the regression lines or AWCC, introduced in Part 3, is negative. It is evident that there is a reduction in the radiating power of the atmosphere above the Threshold compared with the months where the surface was warming and the AWCC is positive.

Atmospheric water imbues the atmosphere with the ability to change mode in response to changes in the surface temperature. The warming mode and cooling mode are distinct around the Threshold TPW of 4.5cm. In warming mode, the atmospheric water is a warming agent and in cooling mode atmospheric water is a cooling agent. It is certainly not causing a "Greenhouse Effect" that is solely warming the planet. Atmospheric water is able to stabilise the surface temperature by allowing more surface insolation and reducing OLR power when the ocean surface is cool and restricting surface insolation more than reduction in OLR with reflective cloud when the surface is warm. Deep convection provides a precise regulating annual average temperature limit of 30C over open ocean warm pools.

Current climate models parameterise clouds and atmospheric water is treated as a "Greenhouse Gas" when it exists in the atmosphere as gas, liquid and solid. The solid phase is a key factor in the formation of reflective clouds. These phases are all responsive to surface temperature at the base of the atmospheric column and surface pressure to a much lesser degree. The atmospheric mode change around 45mm TPW is not a simple process that can be emulated with a few cloud parameters.

Acknowledgement

The author appreciates the availability of the data referenced for this analysis from the following sources:

- *NASA's Earth Observations satellite data sets*
- *NOAA Pacific Marine Environment Laboratory Tropical Moored Buoys portal*
- *KNMI Climate Explorer*

Date Links for the Referenced Data

https://neo.sci.gsfc.nasa.gov/view.php?datasetId=CERES_LWFLUX_M

https://neo.sci.gsfc.nasa.gov/view.php?datasetId=CERES_SWFLUX_M

https://neo.sci.gsfc.nasa.gov/view.php?datasetId=MYD28M

https://neo.sci.gsfc.nasa.gov/view.php?datasetId=MYDAL2_M_SKY_WV&date=2021-04-01

https://www.pmel.noaa.gov/tao/drupal/disdel/

Note that the data was sourced for various time intervals, usually monthly, from these locations.

The Author

Richard Willoughby graduated from the University of Queensland with a degree in electrical engineering. Working in the Australian mining industry, he was instrumental in the early engineering development of Australia's high value port operations at Dampier, WA, shipping iron ore and Dalrymple Bay, Queensland, shipping coal. He specialised in heavy machinery automation; mobile and fixed plant structural integrity and computerised maintenance systems. This skillset later led to him leading development of novel hard rock mining equipment. He was design manager for the Century Mine Project, Queensland where economic viability depended on fine grinding technology, developed for the paper industry, to be applied to large scale mining as well as development of the world's longest concentrate pipeline from Lawn Hill to the port at Karumba. Richard also developed an acute appreciation of the significance of natural perils in the design process and the impact on project costs and operational safety and reliability. He spent the last decade of his working career as an engineering risk consultant for the insurance industry, aiding underwriters and industry clients to assess engineering risks in large construction projects and operations over a broad industry spectrum and wide geographic spread. His enduring interest in climate stems from the engineering imperative to quantify risk as well as the mitigating measures to maximise overall value. Richard has recognised a long overdue need to apply such rigour to climate models that are making physically impossible predictions. Climate modellers are disconnected from the consequence of the false predictions coming from their inept models and unaccountable for the waste of resources linked to government policy inspired by dire yet impossible predictions.

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http://www.bomwatch.com.au/ 22 pp.