We thank Anonymous Reviewer #1 for their careful and thorough review of our long paper. The main critique is that the paper lacks the clear presentation of the problem in the introduction and statistical tests for the validity of the 'truth' of the results.

However, AR#1 states "4. *Scientific Significance*: Due to my background, I don't know whether the manuscript represents a substantial contribution to the scientific progress within the scope of Ocean Science. But, I think the authors bring in some new data and new information to the topic".

Fundamental shift of global warming studies to the top 2m ocean

This is the fourth in a series of four papers on our new ground truth verification data that shifts the emphasis of the anthropogenic global warming debate from climatology to the oceans. In particular, to the top 2m that is of pivotal importance but is almost completely un-studied until our unique ground truth verifications

The first two papers show that global models of anthropogenic global warming have been underestimated by wrong assumptions of the so-called ocean mixed layer that is highly stratified (Matthews, 2013, Matthews and Matthews, 2013).

The third (a companion paper unpublished due to change of Topic Editor) presents the first in-situ direct measurement of tropical evaporation free of precipitation, of ocean heat sequestration, and shows surface dynamics of the top 2m depend on salinity as well as temperature, and on logarithmic wind-driven Lagrangian currents as well as standard Ekman wind-drift.

The fourth reviewed paper confirms from century-long observations that tropical heat travels poleward, melts basal Arctic ice that has buffered ocean warming until 1986. Decreasing ice led to rapid global warming, and greenhouse gas heat imbalance now outweighs all other signals suggesting strong positive feedbacks resulting in serious impacts such as extreme weather, storms and sea level rise not shown by atmospheric assumptions.

All four papers therefore, offer important new scientific ground truth verification for accelerating global warming that concerns the majority 93% of AGW in the oceans over 70% of earth's surface including the 8.5% of shelf seas (<200m) where the largest impacts strike.

Why the authors are uniquely well-equipped tackle these big problems

The authors are uniquely well equipped to use basic physics and scientific method of verification ground truth experiments to investigate why successive iterations of climate models consistently underestimate observed global warming, Arctic icemelt, sea level rise and extreme weather events. Both are qualified and experienced sailors, navigators and deep-sea SCUBA divers

The father and son authors have scientific careers spanning 50 years. JBM is an experimental physicist who showed that changing physical forces determine that flat-bottomed freely falling raindrops broke asymmetrically for potential thunderstorm electrification (Matthews and Mason, 1964). His mentor co-author went on to become Director General of UK Met Office. JBM had a career in geophysics and marine science with peer-reviewed publications from instrument design field, lab and numerical research. He had special interests in coastal and estuarine research and modelling where sea surface processes, stratification of buoyant surface water over saline cooler water and impacts of tides, storm surge and pollution are of paramount importance. He is subject to neither "publish or perish" career pressure, nor bias from funding agencies since the research is funded from solely from personal pension income, savings and loans.

JBRM is a student with lifetime interest and curiosity in the scientific ground truth of geophysical problems especially of actual climate change and ocean acidification. He has a first class degree in Geophysics and climate change from UEA that has the widest range of field verification courses to complement all relevant classroom sciences, field and modelling studies including social, economic and financial aspects. It is supplemented by the comprehensive SEA Semester (www.sea.edu) that encompasses historical and classroom work with sea experience that surpasses that of most professional ocean scientists. Few ocean scientists can safely navigate a large sailing vessel to make accurate landfall on Hawaii solely by Polynesian methods of observations without any navigational aids as SEA semester students accomplished.

Supplementary Introduction

A review of the four papers should provide a supplementary introduction that would help the reviewer and readers understand the full context of the reviewed paper.

The first paper arose from a SEA Semester observational experiment in response to a problem revealed by Vecchi et al (2008) in EOS, our weekly AGU geophysics newspaper. As a result, student author JBRM reported that errors were likely due to changes in sea surface temperature (SST) measurement methods from buckets to sub-surface engine intake to modern satellite measurement (Matthews, 2012). The author, on his first peer-reviewed publication, was surprised to receive a personal communication from an ‘anonymous reviewer’, a climatologist statistician with whom he had been in correspondence, apologising for recommending the paper not be published. Fortunately, the paper was published with minor revisions (Matthews, 2013).

The second paper showed, from the SEA Pacific data and other ground truth, using unique hourly meridional sampling, that unaltered bucket, satellite and CTD data were in good agreement (Matthews and Matthews, 2013). From basic physics it was shown that engine room intake samples taken from unknown depths by unsupervised non-scientists were the source of errors in datasets and hence in the models that used them. Evaporative cooling of bucket samples was unlikely on physics of the short sampling time, high latent heat of evaporation of seawater, and buoyancy of surface water. We recommended datasets be corrected by removing all subsurface data because the climatological assumption the ocean mixed-layer, uniform to 10m, is demonstrably wrong. It is a dynamic slowly mixing layer. Substantial gradients, continually varying through diurnal cycles are present in all oceans due to buoyant fresh warm water floating over cooler salty water. In addition, we recommended removal of all alterations to bucket samples made according to unproven statistical assumptions of evaporative cooling.

JBRM created a revised dataset and applied it to ocean acidification, sensitive to temperature, for his PhD in carbonate chemistry and ocean acidification (Matthews, 2013).

Third paper: Field verification of tropical evaporation and heat sequestration

The third paper, first author JBM, presents the first in-situ measurement of evaporation at sea free from precipitation and of ocean heat sequestration (ocean warming). It determined the surface dynamic and thermodynamic physics of the upper 2m ocean in a tropical Pacific meridional transect between Tahiti and Hawaii. Evaporation minus precipitation is normally used because of the difficulty in measuring evaporation. Indeed, as recently as October 2012, it was speculated that ocean evaporation measurement would be solved only by large groups of people applying a range of methods including satellite and buoy data and large computer models (Lippsett, 2012). Our 3m hourly datasets are a simple direct experiment to measure evaporative brine and heat transport free from precipitation and strong surface winds.

Three distinct temperature regions were found. They were warm >28ºC, saline water from Tahiti to the equator, ~27ºC from the equator to an abrupt front~12km wide at 11ºN, and at ~25ºC from the front to Hawaii. (Matthews and Matthews, 2013). Figure 1 shows hourly evaporative cycle for the southern hemisphere (SH) from 10-day means of real surface and 3m temperatures along with the air temperature. Heat passing through the surface and 3m layer (shaded orange) is in $MJm^{-2}day^{-1}$. Atmospheric heat cycled is negligibly small by comparison. Heat can be lost from the surface for example to nocturnal radiative loss. However, there is no radiative back radiation from 3m. Ocean heat is trapped by downward thermal diffusion in the morning, and by downward evaporative brine settlement over the diurnal cycle. There is no room here for details in the paper such as, correlation tests and computations of physical processes etc. That is why it was presented as a companion paper.

Daily brine enhancement passing through 3m is shown shaded in green. We calculated from this the volume of water needed to produce the total brine enhancement, and determined the daily evaporation rate and heat loss. The curves are shown without error bars because these are small due the 10-day means. It is clear that a single figure for SST on this timescale is meaningless. Salinity decreases from south to north as shown on the plot outside the diurnal cycle.

Data from the other two northern hemisphere regions (NH) have lower evaporation due to lower temperature regimes clear from the physics of evaporation. Evaporation depends only on sea temperature (T°C) that controls the equilibrium or saturation vapor pressure, $e_{s,}$ (hPa) expressed as the Clausius-Clapeyron relation,

$$e_s = 6.1094\exp\left(\frac{17.625T}{T+243.04}\right).$$

In practical terms, this equation determines that water vapor in air increases by about 7%°C^{-1} of sea temperature rise as stated in the reviewed paper. Precipitation increases by ~2-3%°C^{-1}).

The surprise finding was that surface salinity is critically important in determining heat sequestration and evaporation. SH hypersaline water (defined as >35.5‰, Andutta et al., 2011) at 28°C is underlain by water >36‰ to 200m. (We use Adrian Gill's near-surface density approximation that depends only on temperature and salinity in ‰, parts per thousand, instead of deep-sea psu). Nocturnal cooling is limited in its ability to cause brine sinking in the high salinity layer. Sinking is observed only to 2300 hours local time. In the less saline (<35‰) NH (not shown here) thermohaline vertical brine settlement goes on almost till dawn, the beginning of the next cycle. The result is that NH Pacific traps twice as much ocean heat as SH tropical Pacific.

Further meridional analysis confirmed the equatorial meridional tropical cells (MTCs) of Perez et al. (2010). Figure 2a shows as summary schematic meridional dynamics and thermodynamic processes observed superimposed on the CTD temperature profile to 200m. Equatorial upwelling either side of the equator and the Equatorial Undercurrent (EUC) isolates NH and SH waters to 200m depth. The top 5m is shown exaggerated on isopycnals to show convergent downwelling (red) and divergent upwelling (blue). There are many more details in the paper. It is only summarised here.

Figure 2b shows eleven interconnected, counter-rotating, divergent cyclonic (blue) /convergent anticyclonic (red), Lagrangian wind-divergent surface gyres on an equal area projection (after Ebbesmeyer and Scigliano, (2009). In the upper 2m wind-driven gyres obey a log rule that means in practice that currents are ~3% of windspeed and 3-4º to right (NH) of wind direction, as found for oil spills and surface drifter ground truth verification experiments. We adopt the Ebbesmeyer nomenclature because it specifically refers to field verified Lagrangian coherent surface currents in the upper 2m as stated in the reviewed paper. These are the jet streams of the ocean as we state in the reviewed article. Speeds are nautical miles per day (1 nm is a minute of latitude).

The dependence of heat sequestration and evaporation on surface salinity was a surprise finding from the ground truth verification data. Heat is transported poleward under a buoyant freshwater layer as in Carmack's (2007) alpha/beta ocean system. Our thesis is that this suggests a direct connection between equatorial heat sequestration and polar basal icemelt.

We suggested that our experimental worked needed repeating using modern techniques such as seal sensors as in Greenland (Straneo et al. 2010) and Antarctica (Årthun et al., 2012) and subsurface unmanned drones. Innovative model techniques such as variable boundary models to take advantage of uneven data scatter (e.g. Matthews and Laevastu, 1978), and research adaptively managed through ecosystem process studies as the 1978 offshore Arctic oilfields (Matthews, 2013), and extended to fisheries and renewable resources generally (Walters, 2002).

Objectives of the reviewed paper

The fourth, reviewed paper objective is to examine century-long ground truth surface timeseries to test the hypothesis that equatorial heat sequestration, poleward heat transport, basal icemelt and extreme weather are all part of the dynamic and thermodynamic processes in the ocean top 2m and dominate the 93% of AGW long-term processes.

Methodology for finding trend boundaries

The reviewer particularly asks how we arrive at trend boundaries. We could have used successive iterations to obtain a least squares best fit to a boundary such as the Gauss-Seidel method for finding and refining tidal harmonic starting values (Matthews, 1968). However, in this case we determine boundaries immediately using the Newtonian method of inspection. Transition points are usually clearly visible after a seasonal extreme low. In any case, revised transition points can be tried and easily recomputed in case of uncertainty. The post-1986 boundary is well documented for the north Atlantic region.

Test of the methodology

We subsequently tested the methodology on the Scripps Pier (32ºN) surface and 5m records that run from 1916 (http://shorestation.ucsd.edu/index.html, last access 10 March 2014). This is on the southbound Turtle convergent gyre California Current. The same three warming, cooling, warming regimes are found but with different transition boundaries. The transition to rapid warming is 1976/77, some ten years before the Atlantic transition. Moreover, the other boundary had best fit at 1941/2. This is 2 years later than the comparable transition in the north Atlantic.

The different transition boundaries are consistent with different surface properties of the almost land-locked north Pacific and the north Atlantic/Arctic ocean system. It is consistent with Scripps lower salinity (33.6±0.2‰) water i.e. dominant thermohaline convection.

However, there is a prominent warm peak in the record in 1959 at the time of maximum sunspot numbers and solar irradiance. This is at the same date of solar sunspot maximum irradiance peak in the Port Erin record. However, there is no a matching cold water event. That is consistent with the lack of Arctic surface water off Scripps Pier..

We suggest this is experimental ground truth evidence that supports our hypothesis of Arctic basal icemelt as the cause of observed North Atlantic cooling in the Manx record form unusual warming 3½ years earlier. Moreover, Scripps Pier record shows the same dominance of AGW over solar heat variations. It is confirmed by data for the month of June. The post-

1976 June warming trend is 0.037ºCyr^{-1}. That is exactly the same rate observed in the Manx record from 1986. Moreover, there is a persistent temperature gradient in the top 4.5m of 0.6±1.0ºC, confirming the validity of our rejecting subsurface data (Matthews and Matthews, 2013).

Scripps long-term salinity mean is 33.6±0.2‰ at the surface and 33.7±0.2‰ at 5m. This is well within the thermohaline evaporative zone we reported. It is much lower even than the Isle of Man mean salinity 34.1±0.1‰ from 1982 to 2006. Moreover, recently reported tropical water through Florida Strait at 26ºN shows Gulf Stream water at 36‰ at 500m (Smeed et al., 2004). The Labrador Sea shows temperatures ~4C and salinity 34.9ppt (Yashayaev et al., 2008). Therefore, high salinity water at Port Erin is consistent with both water sources. Indeed, water of 35.5‰ was reported off the Rhine delta at Dutch monitoring stations in the early 1980s. These are among the monitoring stations abandoned from the mid 1980s. Saltwater at the surface is most likely from tropical brine that overlays colder Arctic brine.

Our ground truth experiments and equations show surface seawater density at 35‰ varies linearly with temperature, >35‰ it is equally and oppositely dependent on temperature and salinity, and <35‰ it subject to temperature dominated thermohaline convection.

Thus, there is a sound basis in physics for these findings founded on high quality observational field verification data. Statistical analyses cannot improve this. Only repeat experiments and comparisons with other relevant observational data will do that. For example, SEA has run tropical meridional cruises for many years and there is likely a trove of existing real ocean data to test our hypothesis from buoys and research vessels timeseries.

Long-term solar variation and AGW

The relationship between sunspot numbers (proxy for total solar irradiance) and Central England temperatures (CET) is best seen graphically (Figure 3). CET and trends are in Table 6 from 1659-2011. The Maunder minimum from 1630-1721 coincides with medieval cold period (blue). From post-1750 industrial revolution onwards, air temperature shows a gradually rising trend consistent with AGW consistently rising heat imbalance. The mid-century maximum appears in both as short peaks (red).

The key point of this plot is that post 1986 (green). A marked falling trend in solar irradiance coincides with a marked air temperature rising trend. This is strong ground truth evidence that solar irradiance variations are far smaller than CO_2 greenhouse gas heat trapping as the

Berkeley physicists found. All the heating comes from the sun. However, the greenhouse gas component now outweighs the signals from volcanism or variations in the solar cycle. We noted that the 11-year sunspot cycle accounts for all major ocean indices including the North Atlantic Ocean (NAO) decadal index and ENSO (El Niño/La Niña) index. Moreover, we noted, in paper three, that the 21st century weakening of El Niño suggests likelihood of permanent La Niña warm conditions (e.g.. McPhaden et al. 2010). Therefore, statistically derived forecasts based on fixed statistical assumptions from before the industrial revolution are likely to be both misleading and wrong.

Coincidence not Correlation

We take Kinsman's (1957) suggestion further to suggest the correlation coefficient be renamed the coincidence coefficient. This puts experimental field verification back as the nearest arbiter of scientific truth. Experimental observations cannot be improved by statistics. Ground truth may or may not be consistent with original theories, hypotheses or assumptions. Indeed, field observations often throw up unexpected results as we found in the mid-Pacific.

An example of Real Correlation – density with temperature and salinity

Seawater density increases with increasing salinity but decreasing temperature. We noted that Port Erin data from 1982-2007 shows salinity as high as 36‰. In fact, there are 57 days between 30 October 1993 and 20 May 2001 with salinity >35‰ with temperature range 6.5-7.4ºC usually in spring.

The correlation coefficients between density, and respectively, temperature and salinity were –0.7 and 0.7. This is a real mathematical relationship and shows the temperature and salinity have equal and opposite effects on density for salinity >35‰. Both these figures would be considered low on usual statistical assumptions. However, these are real mathematical relationships and are real mathematical correlation not coincidence.

Moreover, for the full period 1982-2007 with salinity 34.1±0.1‰, the corresponding figures were –0.7 and 0.4. This is consistent with thermohaline convection occurring at low salinity (<35‰), and salt being important at high salinity. It again confirms Carmack's (2007) alpha/beta ocean circulation system. Statisticians would consider 0.4 very low and not significant. Nevertheless, this again is mathematical relationship not coincidence.

We feel this justifies our suggestion for change of name to Coincidence Coefficient in all cases without known mathematical relationships or known causality.

Surface salinity and ocean warming

It also demonstrates the importance of making accurate salinity and temperature measurements in the top few metres on an hourly and daily basis to understand ocean surface dynamics. No climate models incorporate real observational surface temperature and salinity in the top few metres or Lagrangian logarithmic 2m surface drift. Until data are routinely collected and models revised to incorporate them, we shall have underestimates of global warming, ocean heat sequestration, precipitation, extreme storms and basal ice melt. Climatologists speak of sensitivity i.e. the air temperature rise from doubled CO_2. This is particularly meaningless when 97% of trapped heat is in the ocean and increasing at over 1ºC. Each increment in CO_2, currently about 3ppmyr^{-1} is like adding another blanket to the global heat trap. We already have, at ~400ppm, 6.3% above the long-term mean.

Thus, our analysis using basic physics suggests that only a reduction below the long-term stable value mean of 280ppm will create global cooling. Stabilising fossil fuel contributions at some existing level will not reduce the heat imbalance as expected based on the 7% air data. Ocean heat has built over centuries. Using ground truth verified ocean surface processes should produce new and sobering estimates of likely outcomes.

How close to scientific experimental truth are our findings?

The reviewer asks this very important question and rightly suggests that the word ‘possible’ in the title suggest some doubt. We are aware that many authors have attempted to relate solar variation to global warming, therefore introduced the element of doubt.

We firmly that our results are the nearest to scientific truth we can get based on experimental, testable ground truth observations and basic physics.

Scientific method demands that theories, models and statistical assumptions be verified by experiments. We have done this through rare high quality sea surface ground truth timeseries.

AGW in top of ocean has been ignored for trivial atmospheric warming

AGW heat imbalance is caused by greenhouse gases at the top of the atmosphere. It ha been shown from 250 years of land air data to depend only on log of CO_2 concentration and volcanism rather than solar irradiance variations. This implies a 6.3% increase from the long-term stable 280ppm CO_2 (800k years of Antarctic ice cores) to the present 400ppm.

Over 70% of earth' surface is ocean, including the 8.5% in shelf seas (<200m), and 93% of AGW is in the ocean. The upper 2m of ocean controls the dynamics and thermodynamics of the ocean heat trap.

Our Conclusion

On the basis of real observations of the upper 2m ocean, we conclude that ocean warming is due to continuous rising concentration of greenhouse gas top-of-the-atmosphere heat

Trap sequestered below 2m, buffered by basal icemelt until 1986, and now rapidly accelerating at a rate of about 0.037ºCyr^{-1}. That is more than 1ºC in 20 years.

There is no comforting lull. There are many possibilities for positive feedback to make things worse. Doing nothing will ensure they happen. The only optimistic conclusion is that there are now well-trained multidisciplinary scientists skilled in real at=sea ocean science with techniques to tackle the problems. Efforts should be switched away from trivial atmospheric warming to the ocean surface. The tail has been wagging the dot for too long.

"A simple idea underpins science: 'trust, but verify'. Results should always be subject to challenge from experiment", "Modern scientists are doing too much trusting and not enough verifying" (*Economist*, 19 Oct. 2013). This is our attempt to redeem trust in scientists.

Acknowledgements

We are grateful for publication of this discussion paper but regret the stressful withdrawal of the fee waiver agreed at initial submission. Manx residents are specifically excluded from receipt of UK or EU research grants. We are grateful for continued Manx government and Scripps Pier volunteers collection of their unique timeseries and making them freely available online.

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FIGURES

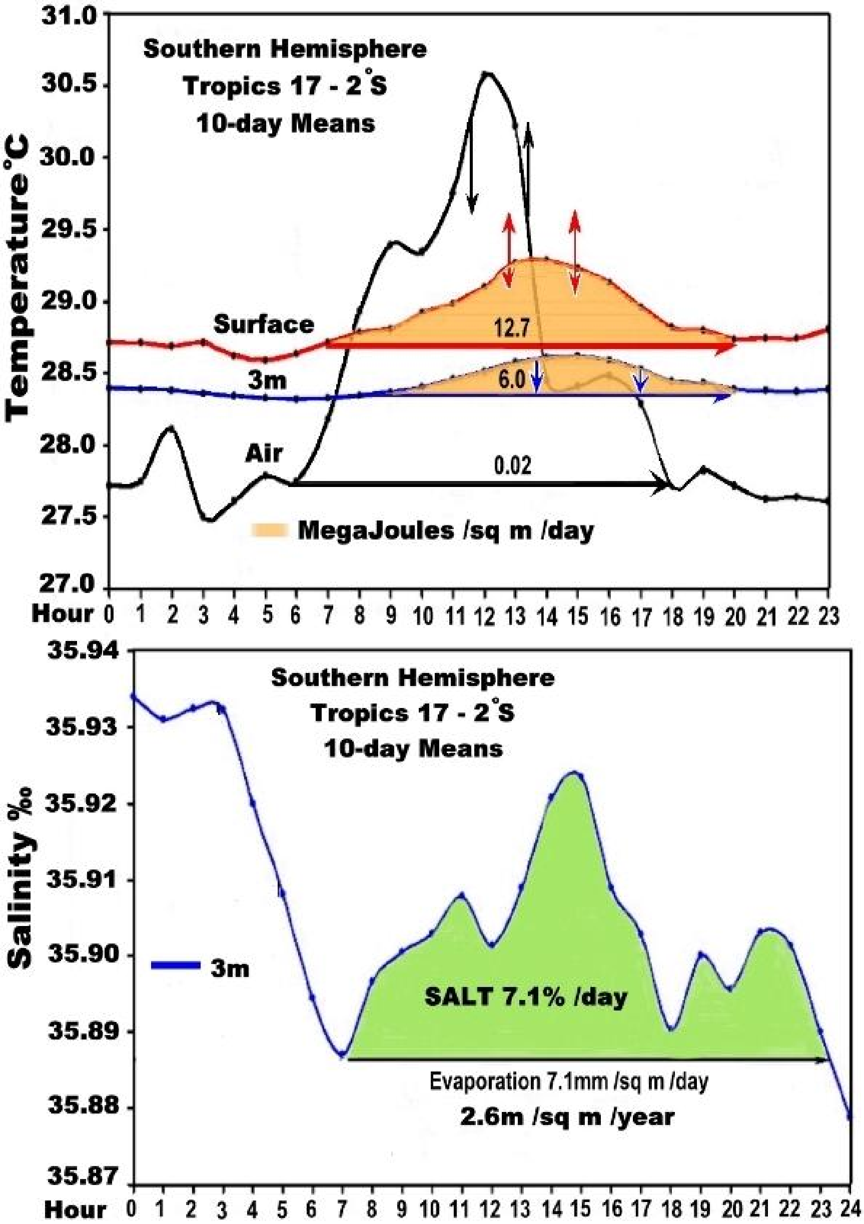

Fig 1. Southern Hemisphere mean equatorial evaporation and heat sequestration from Nino 3.4 area ~140ºW from hourly ground truth data. Salinity decreases from south to the north outside the diurnal evaporative brine cycle.

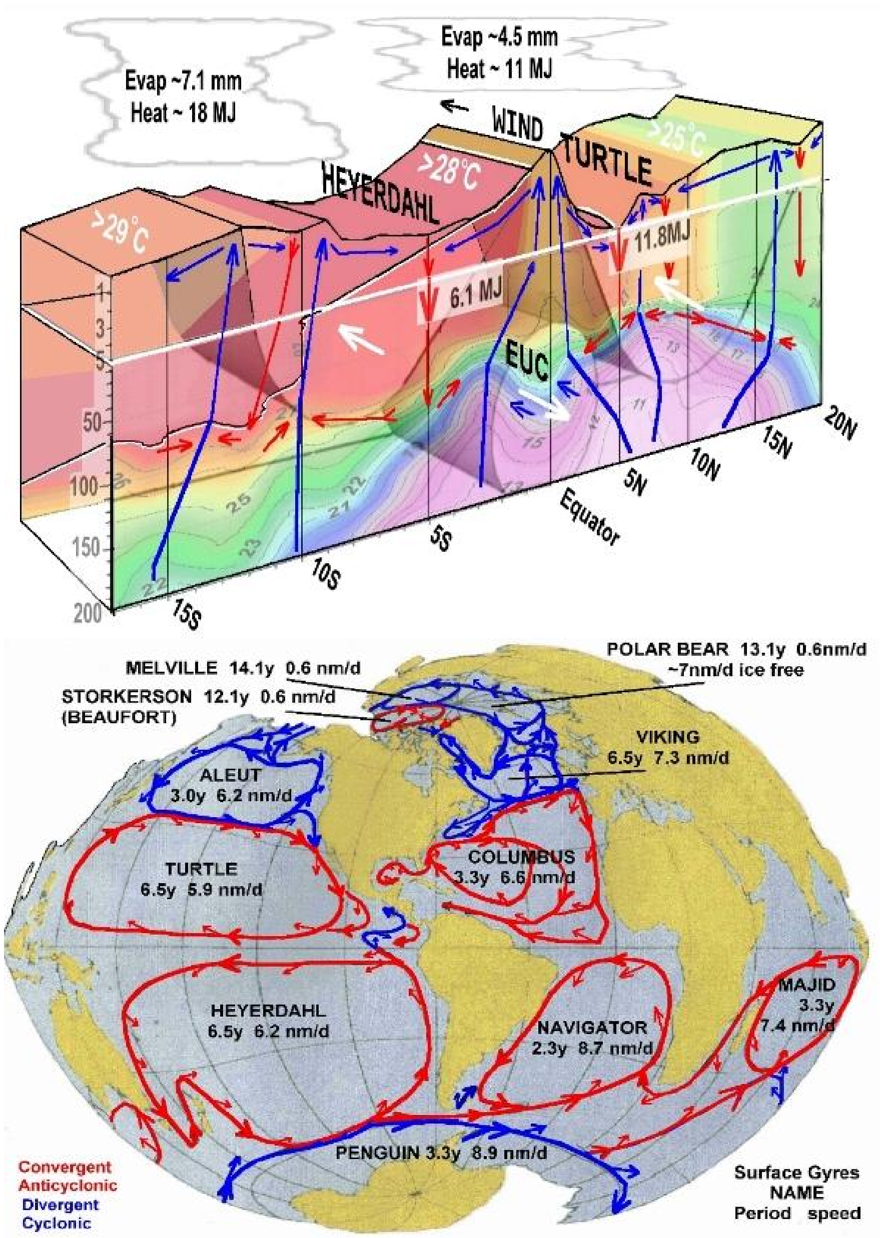

Figure 2 a) Schematic of meridional vertical tropical cells, evaporation and heat sequestration in mid-Pacific at ~140ºW. Arrows show upwelling (blue) and downwelling (red) cells, eastbound Equatorial Undercurrent (EUC) and westbound surface gyres b) Ebbesmeyer eleven named interconnected counter-rotating divergent (blue)/convergent (red) Lagrangian surface gyres on an equal area projection. Speeds are nautical miles per day (1 nm is a minute of latitude).

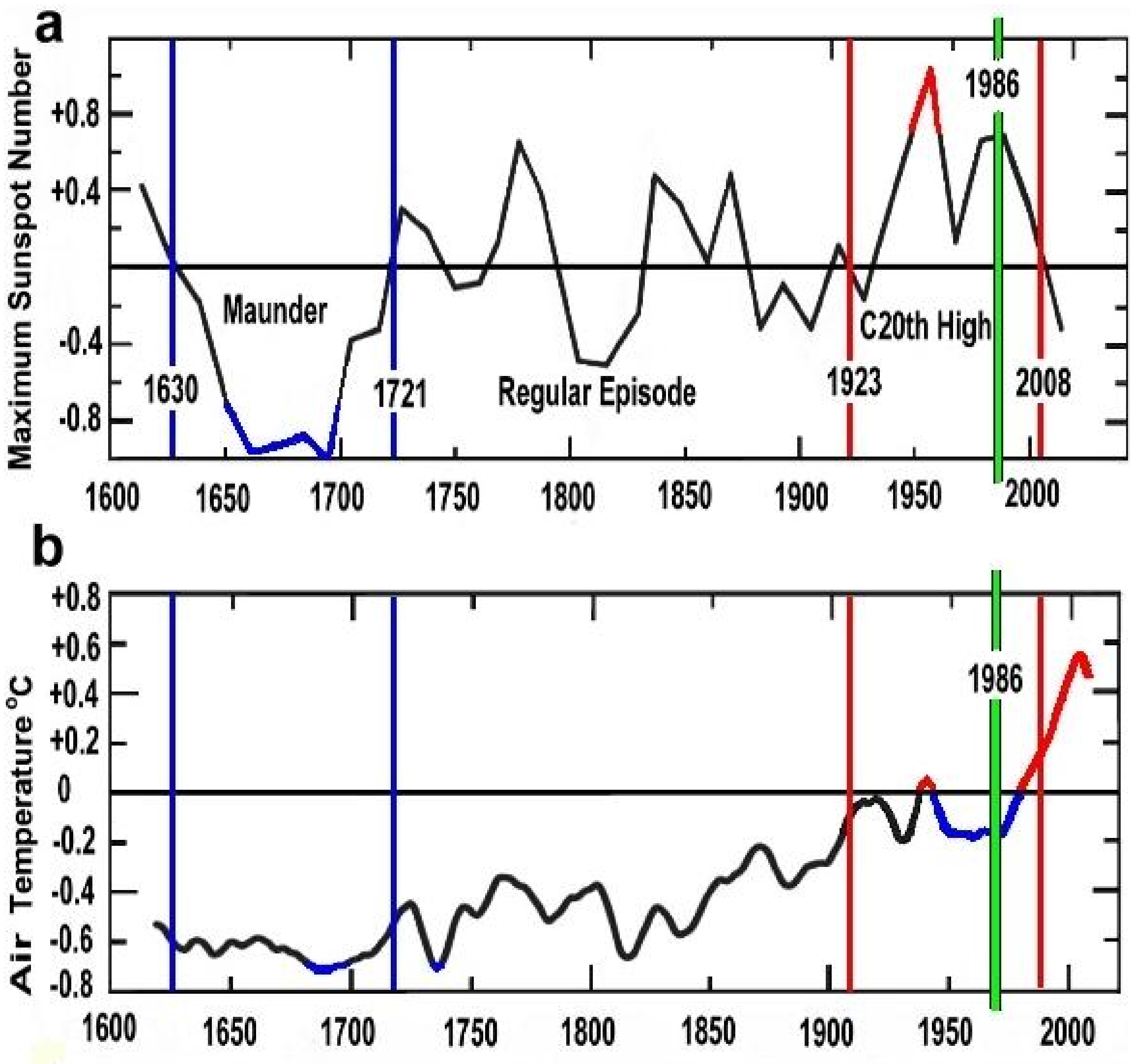

Figure 3. From 1600-2008 a) Maximum sunspot from Maunder Minimum 1630-1721 to modern 20th century high 1923-2008 (red boundaries), b) Land air temperature. 1986 (green) marks transition to rapid solar irradiance decline and rapid temperature rise. Extremes are marked high (red) and low (blue).