CO_2 and climate change

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Abstract

It is shown that tropical Pacific sea surface temperature anomalies are closely congruent to global temperature anomalies, and that over more than a century. When we understand the cooling mechanism over the tropical Pacific, and especially its CO_2 dependency, we can draw conclusions for the global CO_2 climate sensitivity.

It is shown that the cooling of the tropics, or trade wind belt, is by deep convection, i.e. by a few thousand concentrated tropical thunderstorms that carry all the sensible and latent heat swept up by the trade winds all the way on to the tropopause. The physics of deep convection have been formulated since 1958 and are based on sound thermodynamics and measurements on location.

The trends of the temperature in the high atmosphere in the last half century are very negative, starting on this height where the convection reaches. That means that more CO_2 has a cooling effect rather than a warming effect. Cloud tops radiate much more intense than the thin air on this height. This is the cause behind the cooling, as much as the CO_2 increase.

The cooling trend is quite in discrepancy with the “greenhouse-gas-induced-global-warming” theory, but is quite in accord with increasing deep convection. The adjustment of these temperature measurements to bring them more in line with the climate models leads to unphysical conditions and processes.

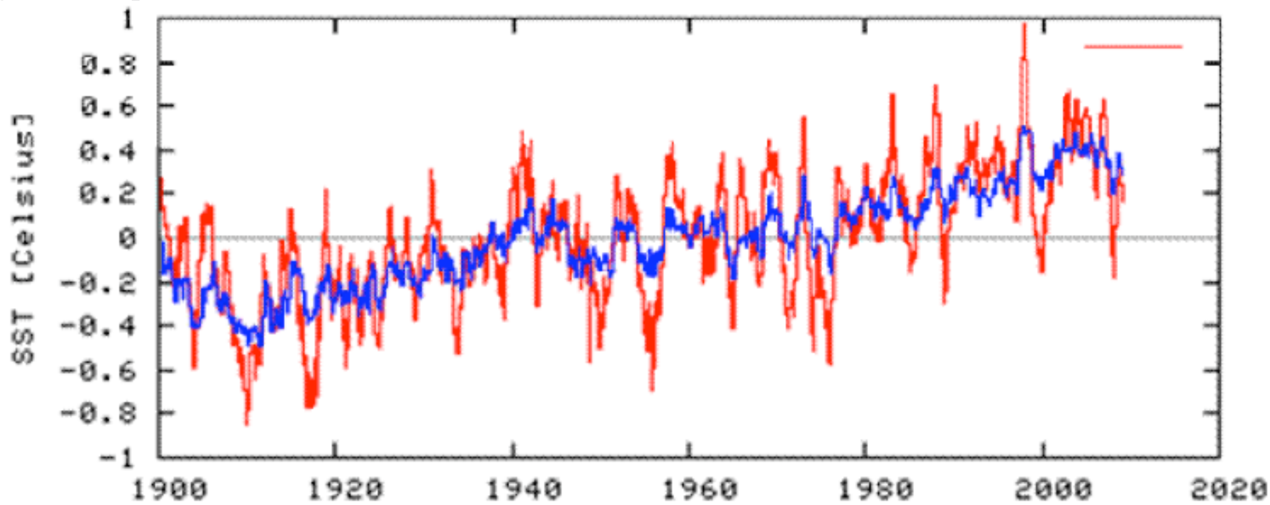
The response of the upper atmosphere temperature on volcanic eruptions also fits in the deep convection theory, but not in the mainstream theory.

Not CO_2 increase, but two other parameters are the cause of climate change: ENSO or El Niño Southern Oscillation, a large change in the cold water upwelling along the coast of South America correlates well to short term climate change, and change in the intensity of hard, deeply penetrating Galactic Cosmic Radiation, well documented by ^{10}Be deposits and ^{14}C levels, correlates very well with long-term climate change including ice ages.

My conclusion is that climate changes are not caused by greenhouse gases.

Tropical Pacific SST- and global temperature anomalies

Data from KNMI climate explorer show that the tropical Pacific not only drives the world's climate, but that the Sea Surface Temperatures [SST] anomalies there closely match the anomalies of the global temperature:



Red: SST anomalies Pacific 20°N-20°S; blue: global temperature anomaly.

We see that the noise amplitude in the Pacific SST is larger, but that it faithfully indicates global values. When we understand the heat transfer in the tropical Pacific, we can extrapolate to global values. The same is true for the climate sensitivity due to CO_2 increase. This makes our physical treatment much simpler. We do not need complicated climate models, but can treat the cooling mechanism with closed algebraic formulas from the classic meteorology and compare the results directly with measurements.

Mechanism of tropical Pacific cooling.

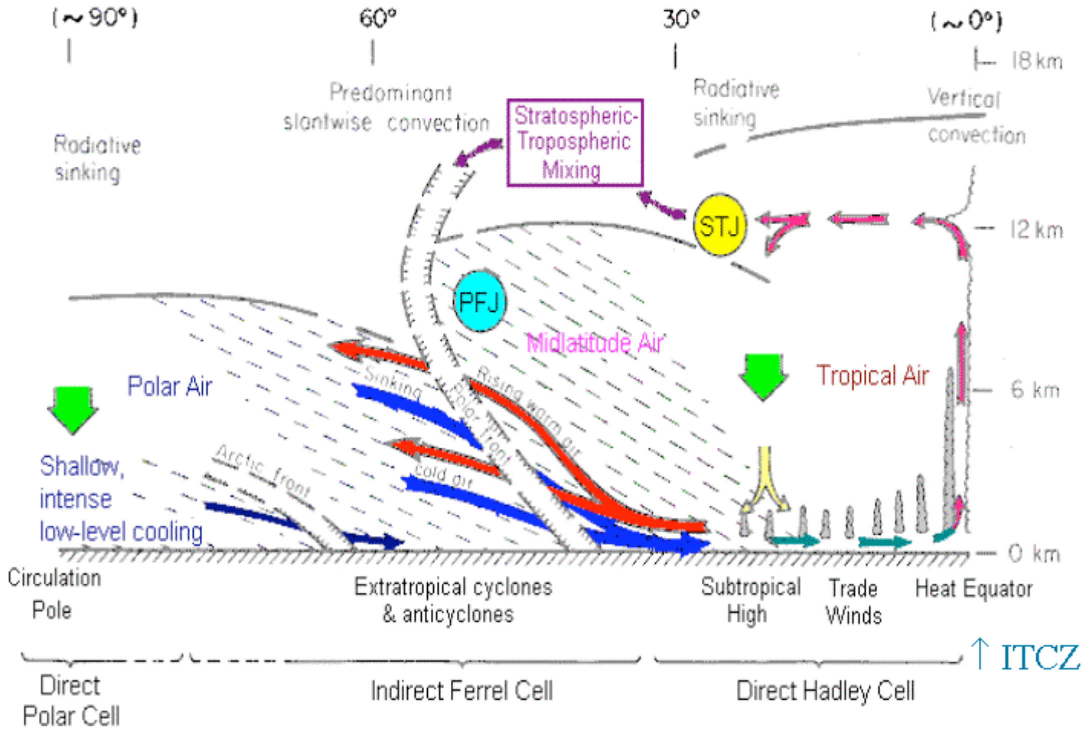
The cooling of the Pacific takes place in the Hadley cycle. Trade winds carry heat & moisture from the sea to the Intertropical Convergence Zone [ITCZ], where a series of rainstorms or deep convection towers convert this heat, mostly latent heat, to expansion until the tropopause is reached. The deep convection towers have dimensions large enough that mixing between convection chimney and environment is small. All potential height, stored in sensible & latent heat, is converted into real convection height. The tropopause height is the same as that what follows from temperature & humidity at sea level. There is no radiative heat transfer from SST to atmosphere. There is however a direct transfer from SST to space via the Infrared Window, that is the collection of all wavelengths where nor water, nor CO_2 have molecular absorption.
Deep convection transports heat from the surface to the tropopause at the location of rainstorms, especially at the intertropical convergence zone. A few thousand tropical thunderstorms are enough to get rid of all the heat that is taken by evaporation from the sea surface in the trade wind zone, from 20º N to 20º S. [Riehl & Malkus, 1958]. It is not complicated to quantify this deep convection. We have no need of climate models, but use instead straightforward physics, since long part of classical meteorology: http://en.wikipedia.org/wiki/Equivalent_potential_temperature:

$$\theta_e = T_e \left(\frac{p_0}{p}\right)^{\frac{R_d}{c_p}} \approx \left(T + \frac{L_v}{c_p} r\right) \left(\frac{p_0}{p}\right)^{\frac{R_d}{c_p}}$$

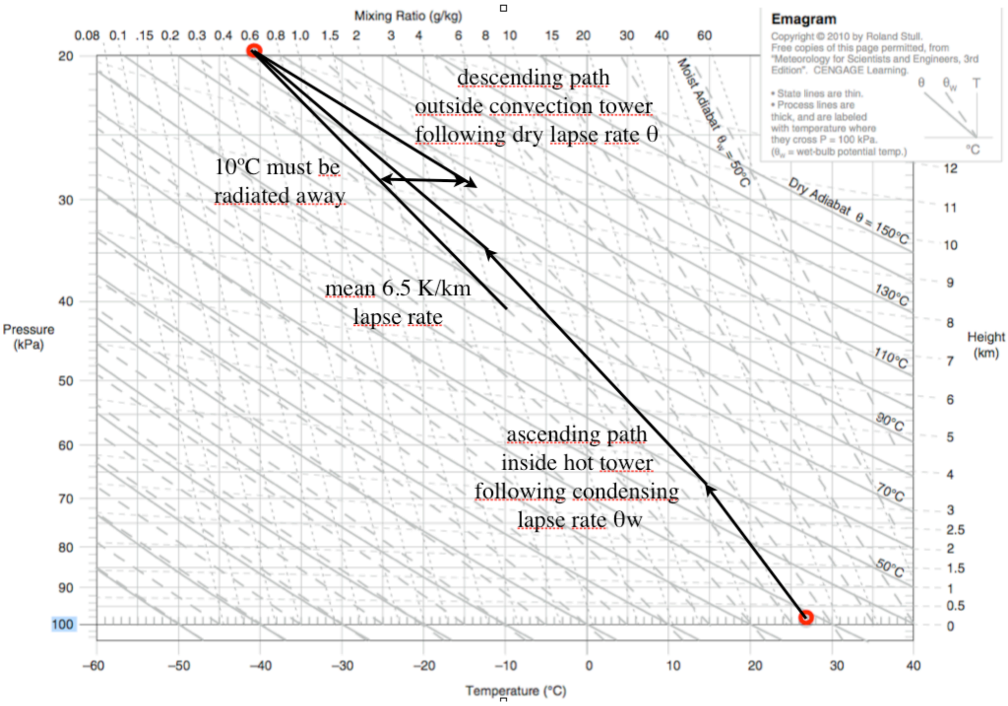
where T is the air temperature, Lv the latent heat of water, Cp the heat capacity of air at constant pressure, Rd the gas constant, p0 the pressure at sea level, p the air pressure, r the specific humidity. As long as θe in the convection column is larger than the θe in the environment, buoyancy is positive and convection continues. If the deep convection tower diameter is large enough and mixing at the chimney boundary can be neglected, all heat collected at the surface will be converted to expansion and thus to upward movement.
Now Rd/Cp=2/7 for a two-atomic gas like air, Lv/Cp=2500 K, r= rH.qsat=rH.exp[13.8-5291/T], an approximation of the Clausius Clapeyron equation that describes water saturation qsat as function of temperature, here SST. Let us take the low-atmospheric relative humidity as rH=0.85. Then we get for θe at 1000 kPa as a function of T or SST: θe=T+2500*0.85*exp[13.8-5291/T], and for tropical SST values from 299 K to 303 K we get θe values from 340 to 354 K: for every ºC of SST rise we see a 3 to 4 K rise in θe. This large effect is due to the uptake of water vapor from the sea surface with rising SST. θe is the temperature we would get if all water vapor condensed and the air parcel would be adiabatically brought to 100 kPa pressure.
What is the maximum convection height we can reach with those surface values of θe? Let us assume that at the top of the cloud, because of the low temperature, the specific humidity r=0, so $\theta e=T(100kPa/p)^{2/7}$. T decreases with height along the lapse rate LR; T=SST-LR.h and $\theta e=[SST-LR.h].(100kPa/p)^{2/7}$ determines the maximum height to which the moist surface air can be convected. 100kPa/p can be approximated by exp[1.274e-4.h], so that outside the convective column θe=[SST-LRh].(exp[1.274e-4.h)2/7, and the maximum convective height is that h whereby [T-LR.h].(exp[1.274e-4.h)2/7 = T+2500*0.85*exp[13.8-5291/T], the right-hand term being the θe inside the convective column. The maximum height can be solved from this equation. This h is very sensitive to the lapse rate and to SST; we see that at a lower lapse rate the maximum convective height becomes lower and we see that for every K increase of SST the maximum convective height is 0.7 to 3.3 km more, for a rise in sea level relative humidity of 5% the height increases 0.7 to 3.3 km, for an increase in lapse rate outside the convective chimney the height increases 0.4 to 2.9 km, all these sensitivities increase strongly with SST. Over sea with SST at 302 K or 29 ºC, the tropopause height is indeed around 14 to 16 km.

lapse rate	6.5 K/km	6.5 K/km	6.4 K/km	6.4 K/km
rel. hum	85%	80%	85%	80%
SST	h_max	h_max	h_max	h_max
296 K	10000 m	9260	9530	8840
297	10700	9860	10100	9390
298	11400	10500	10800	9990
299	12300	11200	11500	10600
300	13200	12000	12300	11300
301	14300	12900	13200	12100
302	15700	13900	14200	12900
303	18400	15100	15500	13900

A couple of schematic drawings taken from http://www-das.uwyo.edu/~geerts/cwx/notes/chap01/tropo.html might illustrate the cooling mechanism. Going with the trade winds towards the ITCZ the trade wind cumulus eventually develops into large deep convection towers that reach into the troposphere / stratosphere inversion. Then the air spreads out and cools by radiation into space, until it is cold enough to sink in the descending branch of the Hadley cell and reaches sea level again at about 20° latitude.



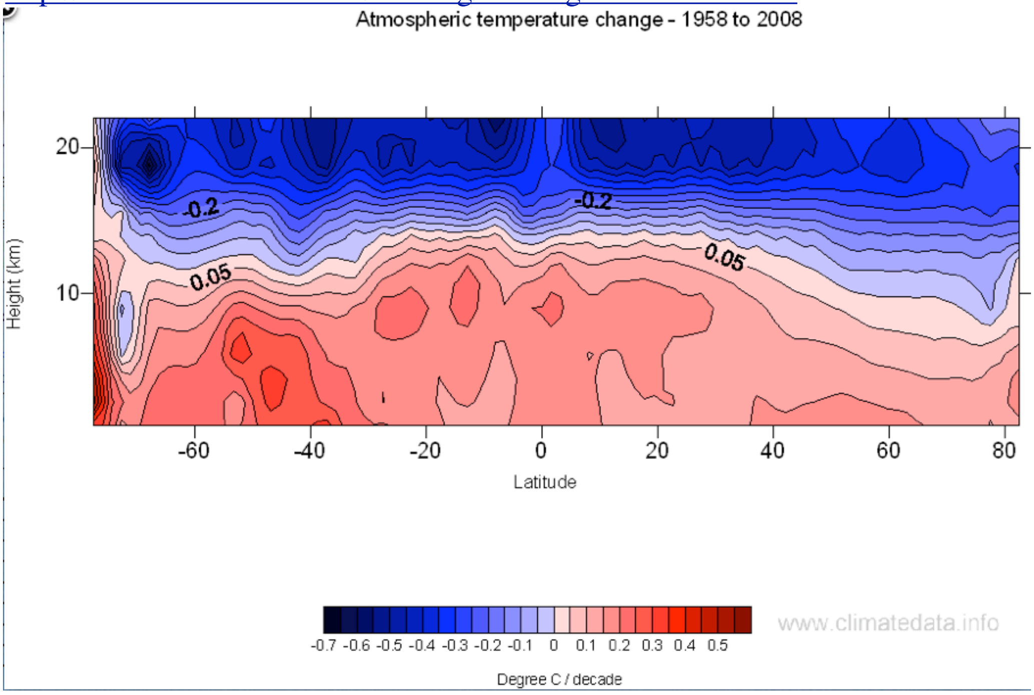
We see that the system between -20° and +20° latitude is much simpler and easier to describe than that at higher latitudes, because at low latitude there is no [anti]cyclonic behavior. Deep convection pushes up the tropopause to 16 km, i.e. the height that follows from SST, local lapse rate and sea level humidity, combined in the equivalent potential temperature θe.
We can illustrate this deep convection mechanism is a so-called emagram, a p / t thermodynamic diagram of the atmosphere:



We follow an air parcel from the sea surface at 27 ºC and 85% relative humidity, rising unmixed along the saturated lapse rate θ_w to 12 km height. Water content is reduced from 73 g/kg to 0.6 g/kg, and has precipitated, because at -40 ºC the water droplets have solidified into ice and have coalesced. In this emagram the freezing heat is not taken into account, however, which makes our treatment conservative. Let us assume that at this 12 km height the convective energy is used up, the cloud spreads its anvil of ice crystals, radiating into space over a large surface until the air is cold enough to begin its descent along the dry adiabat. In the emagram it is shown that for a descent of 2 km already a 10 ºC radiative cooling is necessary, the local lapse rate being 6.5 K/km. This will take a day or so, the radiation from an ice cloud being much stronger than from air at this height. Tropical rainstorm cloud tops are the coldest spots in our atmosphere, sometimes cooling to -80 ºC. The intenser the tropical convective cooling, the colder the air in the upper troposphere becomes. A higher level to which heat is convected increases strongly the ease of radiation into space. Both lapse rate and SST are contained, or regulated, by this ITCZ convective heat transfer. The deep convective heat transfer system is stable, because stronger radiative cooling of the upper troposphere increases the lapse rate and therefor the convection height and heat transfer and higher SST increases heat transfer, because **1]** the higher convective height increases, **2]** the mass transfer driving force [1-rH] at the surface increases, **3]** wind speed increase also; all trade wind is driven by this OTCZ deep convection. This results in about 40 W/m2 flux increase per K SST increase, see my paper "tropical rainstorm feedback", ENERGY & ENVIRONMENT 21, #4, 2010, p.217. This is a "negative feedback" so large that the "climate sensitivity" of doubled CO2 becomes very small as a result. ***The 40 W/m²K has to be compared to the 3.6 W/m²K radiation feedback in the IPCC models, which is then brought back by very unphysical positive feedbacks, among which "water vapor feedback", to 1.5 W/m²K , to obtain an alarming 3 to 5 K global temperature increase as a result of CO_2 doubling.***

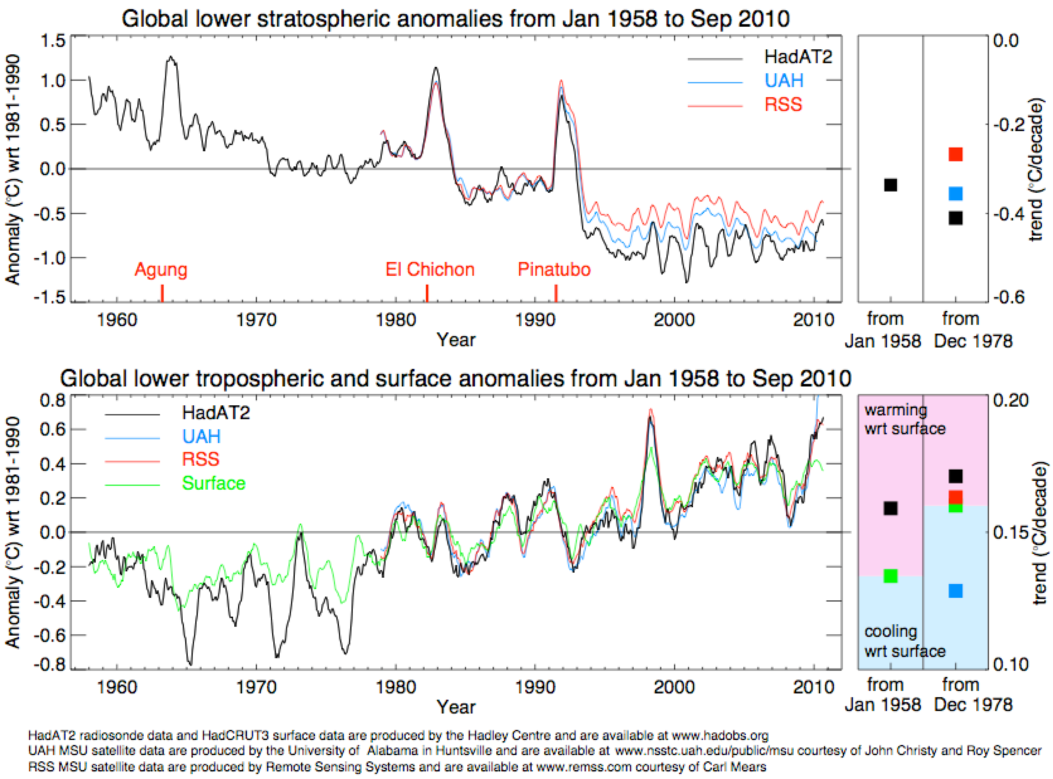
Real world - Model discrepancies

There is a large discrepancy between the observed upper tropospheric temperatures [negative trend] and the temperatures expected by climate models that start from the greenhouse warming hypothesis [positive trend]. Greenhouse models expect as a consequence of the 35% rise in CO2 that the temperature rise in the tropical troposphere, for example during the 1979-2009 warming period, is much larger [0.3 K/10y] than the 0.15 K/10y surface warming trend. Let us first look to the measured trends as a function of height and latitude: From the official Hadley Center web page http://www.climatedata.info/Forcing/Forcing/radiosonde.html we take the following graph:



We see that the anomaly in the tropics is indeed a good measure for the global anomaly, not only at the surface, but also up to 20 km in height. We see also that above ca. 12 km there is a cooling trend, which is at 15 km the same as the warming trend at the surface, an at higher altitudes even 5 times as large [-.7 K/10y] as the surface trend. Clearly the rising CO_2 concentration, which is larger that the water concentration at these heights, is the cause of this strong cooling trend. Not much is published of this strong cooling trend due to CO_2. It is the only clear effect of CO_2 that can be measured, however.

Another quite unexpected behavior of the higher atmospheric temperature is the reaction to large volcanic eruptions, the data sources are indicated in the legend:



We see that as a trend, the surface warms and the upper atmosphere cools. The years after a large volcanic eruption, the upper atmospheric temperature increases a full ºC. This reaction is much more clear than the surface temperature response. Clearly the volcanic aerosols that are brought far in the stratosphere have a life time over there much longer that in the troposphere, where they are rained out. They absorb solar radiation, and heat the atmosphere. This solar radiation does not reach the surface, therefor the convection slows down, and the upper atmosphere is cooled less.

From AIRS satellite measurements we als clearly learn that convection means cooling near the convection column top, 100 hPa in this case, brought about by strong radiative cooling: *Observations of convective cooling in the tropical tropopause layer in AIRS data, H. Kim and A. E. Dessler, Atmos. Chem. Phys. Discuss., 4, 7615–7629, 2004* : For each AIRS temperature profile, they looked within ±3 h of the profiles' measurement time and determine the time history of convection in the 1° 1° box around the measurement. Stage 0: No convection within ±3 h, Stage 1: No convection in the previous 3 h, convection starts in the next 3 h, Stage 2: Convection star ted in the previous 3 h and continues for the next 3 h, Stage 3: On-going C208 >10% for the entire 6-h period, Stage 4: Convection on-going during previous 3 h, convection stops in the next 3 h, Stage 5: Convection stopped in the previous 3 h, no convection in the next 3 h

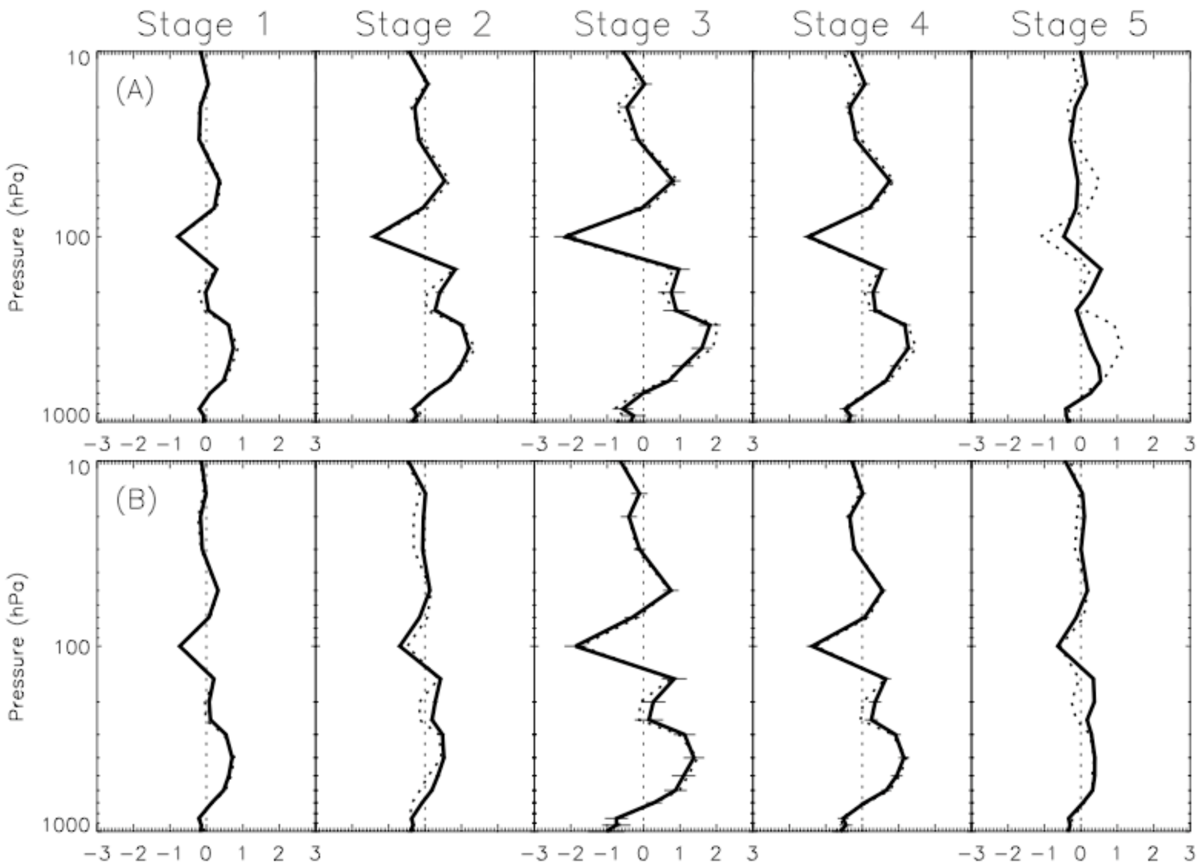
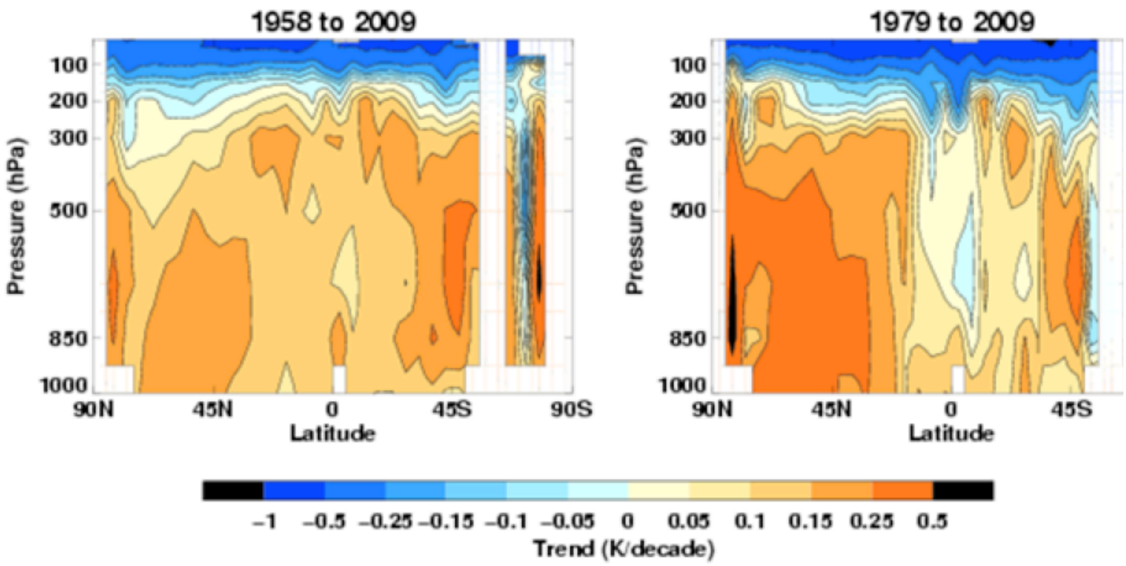


Fig. 1. Mean temperature anomaly over convective stages for **(a)** February 2003 and **(b)** July 2003. Dotted lines indicate values from nighttime only. Horizontal bars at each pressure level mean the 95% confidence interval for mean of the temperature anomaly.

Warming & cooling trends in different recent periods.
Let us see how these trends differ in warming and in longer periods; again from Hadley center sources: http://www.metoffice.gov.uk/climatechange/science/monitoring/hadat.html



The global warming started in 1976 with the “big climate shift”, the trend stopped in 1999 but the climate stayed warm until 2010. We see that in the warming period 1079-2009 not only the warming trend at the surface is higher, but the cooling trend in the high tropical troposphere is more clearly enhanced. We see even a cooling trend 1979-2009 replacing a warming trend 1958-2009 at the tropical 500-800 hPa height. We could even conclude that more CO_2 cools the climate, because it cools the upper regions where th edeep convection reaches, increasing the effective lapse rate over the whole height with 0.35 K/decade, over 2 decades and 12 km that means 0.07*2/12=0.012 K/km, not much, but we see in the table that a 0.1 K/km lapse rate increase at SST -302K increases the convection top 1.5 km. So this CO_2 cooling trend over 2 decades brings the convection top 1.5 km/0.1*0.012=180 m higher, which is not negligeable.
This behavior has been a problem for many, as it contradicts the global-warming-by-greenhouse-gases theory. So there has been a large activity to bring models and observations into agreement, strangely only **by adjusting the measurements instead of adjusting the models**.
From: *Toward Elimination of the Warm Bias in Historic Radiosonde Temperature Records—Some New Results from a Comprehensive Intercomparison of Upper-Air Data, LEOPOLD HAIMBERGER et al, JOURNAL OF CLIMATE, VOLUME 21, 4587)* we take the following figure:

15 SEPTEMBER 2008 HAIMBERGER ET AL. 4601

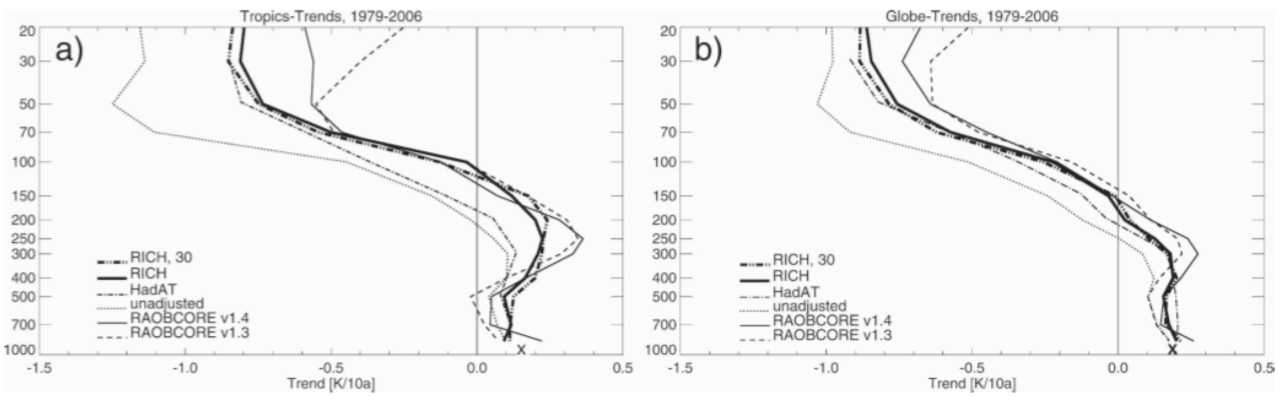


FIG. 11. Vertical temperature trend profiles (a) for the tropics (20°S–20°N) and (b) for the global mean. Thick solid curve is standard RICH estimate using standard eight reference stations. Thick dashed–double dotted curve is RICH estimate using 30 reference stations. Thin solid curve is RAOBCORE, version 1.4, estimate, thin dashed is RAOBCORE, version 1.3, and dotted is from unadjusted radiosonde data. HadAT2 profiles (thin dashed–dotted) are estimated from less available radiosondes and are included for reference. Corresponding surface temperature trends from HadCRUT, version 3.0 are denoted with x symbols.

We see that the unadjusted 1979-2006 tropical temperature profile trends in the tropics, left graph, dotted line, shows a constant 0.1 K/decade warming with height until 200 Pa [11 km in the tropics], and above this height a substantial cooling trend, with a minimum of -1.2 K/decade [twelve times

the surface warming trend] at 70 Pa. This behavior is does not agree with the accepted theory of Greenhouse-gas induced global warming, that implies a **decrease** of the convection activity with rising SST, because the temperature and moisture at 500-100 hPa in theory both rise, and the rising θe than prevents convection. This is the main *"positive feedback"* assumed by the models to get the high climate sensitivity to be able to attribute the warming 1976-2010 to the CO_2 increase. This is the reason that so many corrections or adjustments have been proposed to the radiosonde measurements; the maximum adjustment [see left graph] reaching 0.9 K/10y, or 10ºC/decade from 1979 to 2009, that makes an adjustment of **2.7 ºC** between the HadAT temperature reanalysis and the unadjusted radiosonde measurement. Radiosonde sensors normally have a precision of **0.1 ºC**! Physically it is impossible that convection decreases while the driving force for convection increases. Riehl & Malkus measured and quantified this deep convection in 1958 for the first time by flying into thunderstorms and derived the θe mathematics, which are soundly and simply founded in atmospheric thermodynamics. Thunderstorms are very local phenomena, they cannot and are not well parameterized in climate models. Clearly frequency and intensity of these storms is increasing fast with SST. Any CO_2 in the atmosphere, if it would increase SST, is regulated back by this deep convective cooling mechanism.
The main error in the climate models is that they suppose heating and moistening, and thus higher θe, of the upper troposphere by CO_2, in contradiction with radiosonde measurements. This assumed heating & moistening leads the model to assume an increase of θ_e at this height, which makes deep convection *decrease* as a result of increasing SST, very unphysical as we see here above.
On the contrary, the upper troposphere will cool and thus dry out as a result of stronger deep convection, because cloud top temperature goes down and condensation efficiency increases with deep convection intensity. In the region that the air spreads from the ITCZ and subsides, radiation into space is therefore enhanced. The lowest temperatures in the troposphere are to be found in the deep convection cumulonimbus tops, sometimes -80 ºC. All water is then in solid form, which coalesces easier and snows [rains] out more efficiently.

Another discrepancy is the large underestimation of precipitation trends by the models:
In the global warming period from 1980 to 2007, we see that the precipitation in the ascending branch of the Hadley cycle increases, that means that the tropical thunderstorms increase in number & strength, and the precipitation in the descending branch decreases, that means that the air in this branch becomes drier, because the deep convection condensation ends at a higher and thus colder level in the atmosphere: R. P. *Allan*, B. J. *Soden*, Geophys. Res. Lett. 34, L18705 (*2007*).

Current changes in tropical precipitation 3

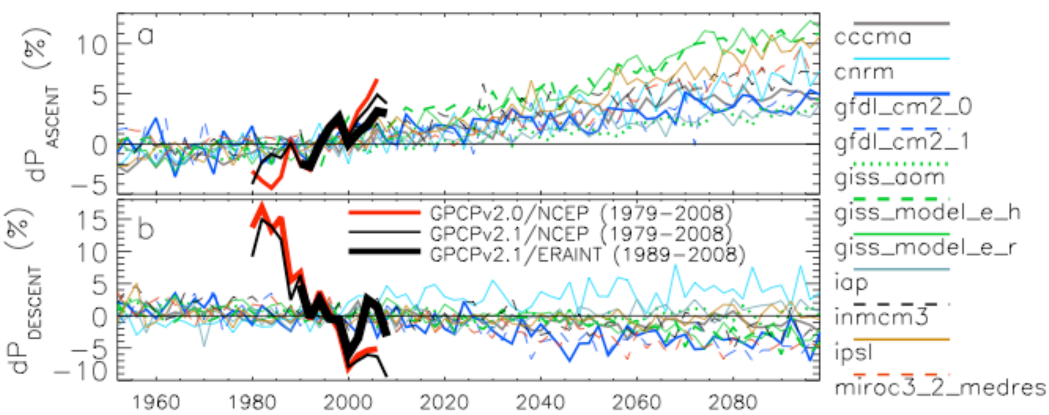


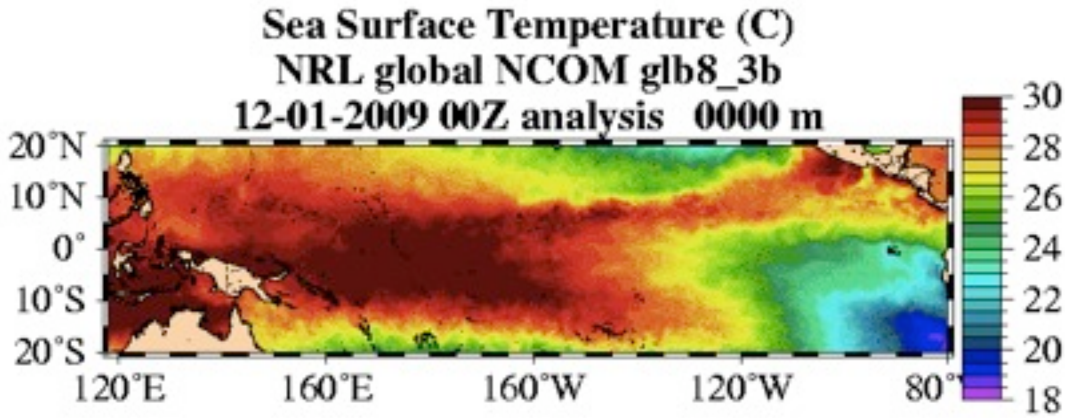
Figure 1. Precipitation anomalies (2-year averages) over (a) ascending and (b) descending branches of the tropical circulation for CMIP3 models and versions 2.0 and 2.1 GPCP observations applying NCEP or ERA Interim reanalysis vertical motion fields. Updated from Allan & Soden (2007).

We see that 11 climate models underestimate strongly the observed precipitation anomalies, both in the ascending [factor 3 underestimation] as in the descending [factor 5 underestimation] mode. The models just cannot follow the increase of the hydrological cycle. If they would do that correctly, the resulting climate sensitivity would be much lower. It looks as if the models are made artificially so, that the resulting climate sensitivity is alarmingly high. It looks as if the observations are adjusted, when they do not fit the models.

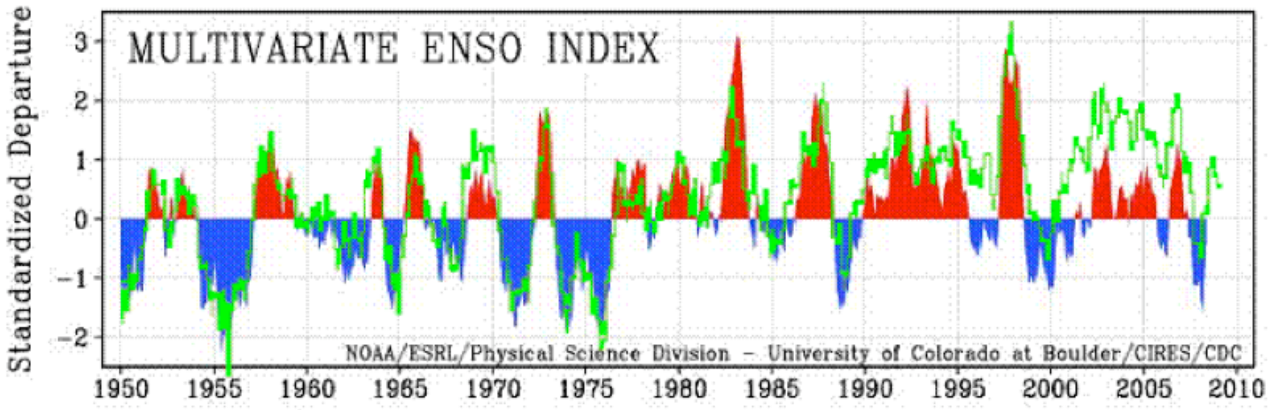
Resuming we have three climate stabilizing processes here when SST rises: **1]** heat take-up from the ocean rises with 40 W/m^{2}K, **2]** convection height rises with 1.5 km/K SST, and **3]** the spreading air from the ITCZ will contain less water enhancing OLR from the lower latitudes.
All these effects are physically founded, and clearly measured by numerous independent sources.

Alternative causes for the global warming

Now we have to find the cause for the global warming between 1976 and 1998. When it cannot be the CO_2 increase, it must have another cause. This cause must lie in the tropical Pacific, and indeed it does. http://www7320.nrlssc.navy.mil/global_ncom/anims/eqp/sst12m.gif gives an animation of the tropical Pacific SST as a function of time December 2009-December 2010:



Please click on the link to see the animation, it is very instructive indeed!
We see in December 2009, until April 2010, a high temperature [El Niño] along most of the region, only at the Southeast corner of the region we see somewhat lower temperatures. In April the sea is the warmest. Then in May 2010 we see the beginning of a cold tongue of deep upwelling cold water [La Niña] growing from East to West, reaching almost as far as 160ºE longitude in November 2010. The difference or range in SST is large: from 30 ºC maximal to 18 ºC minimal. The extension of the effect is also very large, about a million square kilometers. We see also a very fast change, in a few days, in this time frame seen as a flickering of SST between 30 and 29 ºC in the warm regions. Here is the mechanism of cooling: As soon as rising SST reaches a certain value, deep convection sets in and in a matter of days the temperature is brought back a few ºC. In the cold tongue, nothing of this kind can be seen. The “thermostat” works only above 27 ºC.
This effect with sometimes a duration of many years, large as well in geographic as in SST dimension, is called ENSO or or El Niño Southern Oscillation. It has a major influence on the global temperature as we see in the following ENSO and SST history:



The green curve, tropical Pacific SST anomaly, is the same as the red curve in the first graph. The red positive and blue negative excursions are the standardized ENSO index or SOI values as a function of time. We see that the tropical Pacific SST closely follows the ENSO index. In the period of global warming, the red El Niño events were more frequent than the blue La Niña events, the latter being upwelling of deep cold water before the coast of Peru. **We see that the period of global warming between 1976 and 1999 is simply a period with frequent positive excursions of the ENSO index.** The period before 1976, many blue excursions, was one of falling global temperature. In 1976 the “big climate shift”, many red warm excursions. After 1999 there was no global warming anymore, but it stayed warm. CO_2 in the atmosphere rises steadily however during these three different periods. The correlation is clearly with ocean currents, not with CO_2.

Galactic Cosmic Rays

For explaining the larger and longer-duration climate excursions, such as the Little Ice Age, or real ice ages for that matter, ENSO-like oscillations will not suffice.

Another, this time external, variable in our climate is the variability in hard Galactic Cosmic Rays [GCR], originating from Galactic supernovae, that are more or less screened off by Solar magnetic fields. GCR, together with very low concentrations of sulphuric acid that are always present, increase the number of cloud condensation nuclei. Most cosmic rays come from the sun, but their energy is in the order of MeV, and therefore they cannot penetrate down to the height where cloud nucleation is important. GCR with energies >13 GeV penetrate down to surface level, leaving thousands of ionized air molecules in their tracks. Variable cloud condensation of course has an immediate effect on temperature, through condensation and rain-out efficiency, through cloud life time [Albrecht effect], cloud whiteness [Twomey effect], cloud cover and resulting absorbed solar radiation.

From Henrik Svensmark, Torsten Bondo, and Jacob Svensmark, GEOPHYSICAL RESEARCH LETTERS, 36, 2009 we take the following five graphs, data from five different satellites measuring aerosols, cloud water content, liquid water cloud fraction and low infrared sensed cloud cover fraction, just at the time of a Forbush [red broken curve] event:

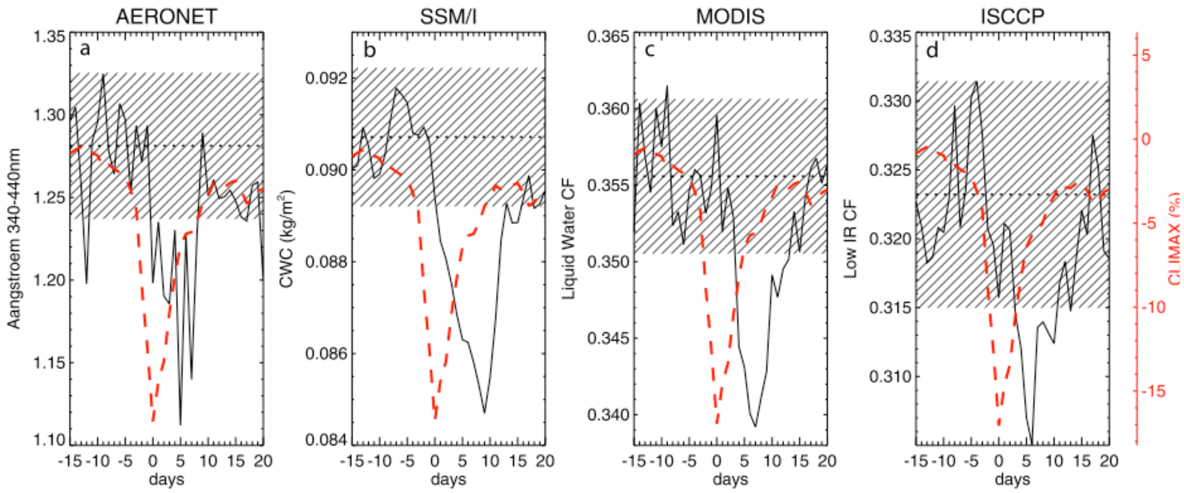


Figure 1. The evolution of (b) cloud water content (SSM/I), (c) liquid water cloud fraction (MODIS), and (d) low IR-detected clouds (ISCCP) is here averaged for the 5 strongest Forbush decreases that their data sets have in common (order numbers 1, 3, 4, 6, and 7 in Table 1) and is compared with (a) the corresponding evolution of fine aerosol particles in the lower atmosphere (AERONET). In (a) each data point is the daily mean from about 40 AERONET stations world-wide, using stations with more than 20 measurements a day. Red curves show % changes in GCR neutron counts at Climax. The broken horizontal lines denote the mean for the first 15 days before the Forbush minimum, and the hatched zones show $\pm 1\sigma$ for the data, estimated from the average variance of a large number of randomly chosen periods of 36 days of each of the four data sets. The effects on clouds and aerosols are not dominated by any single event among the 5 averaged. Examples of SSM/I data for several individual events are shown in the auxiliary material.

A Forbush event is a sudden decrease in Galactic Cosmic Rays [GCR] due to a large plasma outbreak from the Solar Corona. GCR are protons and He nuclei with 10...30 GeV energy, and therefore they can penetrate our atmosphere all the way to the surface, creating large showers of charged muon particles on their way, 10Be and 14C isotopes from 14N and 16O air atoms, as well as neutrons that can be counted with Earth-based instruments. We see, about 5 to 10 days after the sudden 17% decrease of the GCR, that the aerosol concentration decreases with 12.5% after 5 days, the global cloud water content decreases with 6.5% after 9 days, the liquid water cloud fraction decreases with 4.5% after 7 days and the low IR sensed cloud fraction decreases with 5.6% after 6 days.

The mechanism is currently a subject for study at CERN, Genève. First results, see CERN-SPSC-2010-013 SPSC-SR-061, April 7, 2010, from CERN's "CLOUD" experiment confirm the hypothesis: Charged particles from GCR are instrumental in transforming very small but ubiquitous 30 nm H_2SO_4 particles into 100 nm cloud condensation nuclei. During a period of high Solar magnetic activity, Sun spots are more frequent, GCR intensity is less and cloud condensation nuclei are less frequent. Clouds then have larger droplets, are less white or reflective, the condensation efficiency increases, the clouds rain out easier, the cloud cover decreases, and the Earth's albedo decreases and as a result the amount of sunlight absorbed at the surface increases. This causes global warming; a 2% cloud cover decrease raises the global temperature with 1ºC.

In the graph here under we see that the period of global warming, 1976-1998, is also a period of less GCR intensity:

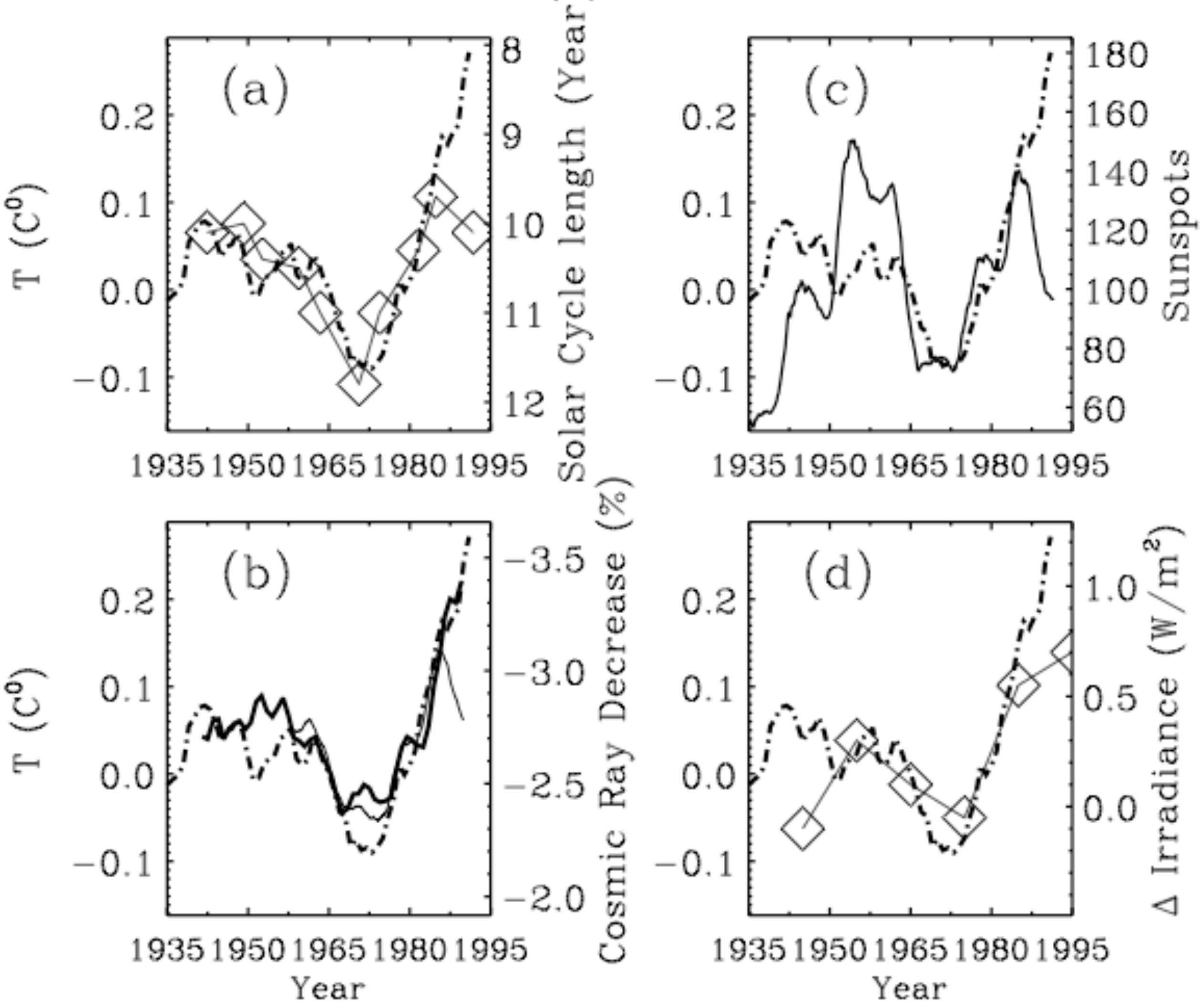


FIG. 3. 11 year average of Northern Hemispheric marine and land temperatures (broken line) compared with, a) unfiltered solar cycle length. b) 11 year average of cosmic ray flux (from ion chambers 1937–1994, normalized to 1965), thick solid line), the thin solid line is cosmic ray flux from Climax, Colorado neutron monitor (arbitrarily scale), c) 11 year average of relative sunspot number, d) decade variation in reconstructed solar irradiance (zero level correspond to 1367 W/m^2, adapted from Lean et al. [6]). Note the 11 year average has removed the solar cycle in b) and c).

Clearly the global temperature anomaly correlates with GCR level and [much] less with Solar irradiance, sunspots and solar cycle length.
It is a question if GCR intensity decreases, bringing less clouds and more sunshine, could influence the ENSO. A stronger heating of the sea surface might impede cold water upwelling, called La Niña.
In any case the correlation of the warming [until 1950] cooling [1950-1976] warming again [1976-1995] correlates much stronger with GCR intensity than with CO_2 in the atmosphere, the latter being monotonically rising.

COSMIC RAYS, PARTICLE FORMATION, NATURAL VARIABILITY OF GLOBAL CLOUDINESS, AND CLIMATE IMPLICATIONS Fangqun Yu, Atmospheric Sciences Research Center, State University of New York, Albany, New York, USA gives us the following three graphs:

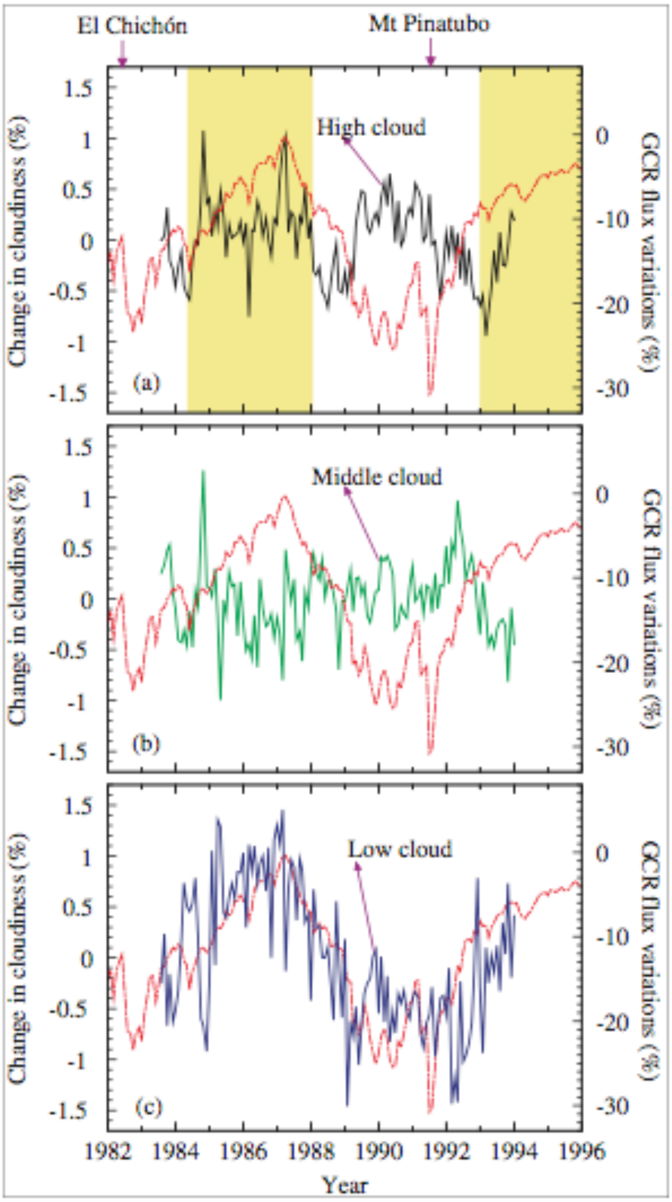


Figure 5. The global average monthly mean anomalies of (a) high, (b) middle, and (c) low IR cloud cover during last solar cycle. The variations of galactic cosmic ray (GCR) fluxes as measured from CLIMAX (normalized to May, 1965) are also indicated in each panel (dot-dashed lines). The shaded areas in Figure 2(a) corresponding to the years that global high cloudiness might have been affected by volcano eruptions and El Niño event.

We see that the low clouds, which have a cooling effect on the climate, are correlated with GCR, not the middle and the high clouds. Indeed, the period with decreasing low clouds, 1986-1992, is one of rising temperatures. Cloud condensation nuclei due to ionizing radiation are abundant in the higher atmosphere, because lower energetic solar protons can penetrate to this height. Only GCR of energies of >13 GeV penetrate as far as the surface. The correlation with climate is not without hiatus however, but it is in any case better than the correlation with CO_2.

Manley G (1974) Central England temperatures: Monthly means 1659–1973. Q J R Met Soc 100:389–405 gives central England temperatures, *10Be as an indicator of solar variability and climate, J. Beeret al, Swiss Federal Institute for Environmental Science and Technology (EAWAG),* compare with ^{10}Be values.

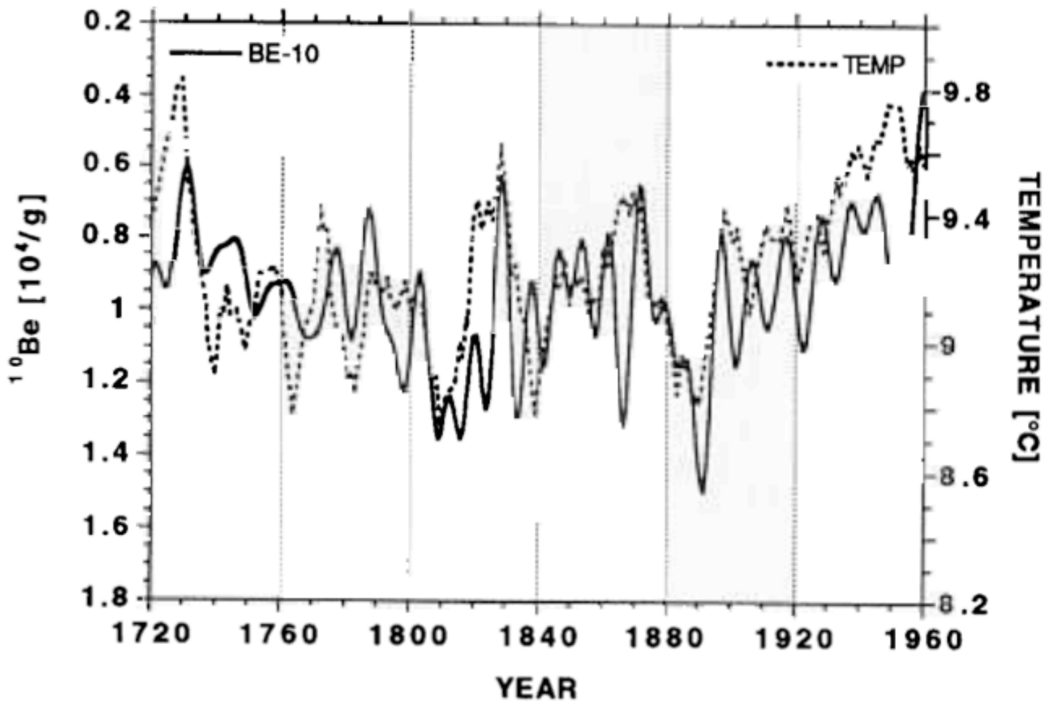


Fig. 8: Comparison of the low-pass filtered ^{10}Be data from Dye 3 (Fig. 2) with the temperature record from central England (Manley 1974).

We see on all scales a clear correlation of GCR intensity, for which the ^{10}Be isotope in well-dated sediments is witness, and cold periods. Note the inverted scale for ^{10}Be. Dye3 is a Greenland ice core. Central England is our oldest instrumental temperature record. More ^{10}Be, stronger GCR, more cloud condensation nuclei, more and whiter clouds, higher albedo, lower temperature.
One might ask why the Greenland GCR should correlate with Central England temperatures, but we have to realize that the GCR intensity has a solar-system-wide extension, so that all local temperatures on earth should feel the impact.
There is no possibility that the CO_2 amount in the atmosphere would be the cause of these climate changes from 1720 until 1960: it has known no period of decreasing.

Before the age of temperature measurement we have to resort to other variables that are a measure of climate, such as grain prices that rise after cold and bad growing seasons: We see a persistent correlation of ^{10}Be and grain prices. High ^{10}Be means strong GCR's, more and whiter clouds, lower sunshine, lower temperatures, shorter growing seasons, and higher grain prices:

INFLUENCE OF SOLAR ACTIVITY ON STATE OF WHEAT MARKET IN MEDIEVAL ENGLAND, Lev A. Pustilnik, Gregory Yom Din. They conclude:
a) The coincidence between the statistical properties of the distributions of intervals between wheat price bursts in medieval England (1259-1702) and intervals between minimums of solar cycles (1700-2000);
b) The existence of 100% sign correlation between high wheat prices and states of minimal solar activity established on the basis of 10Be data for Greenland ice measurements for the period 1600-1700.

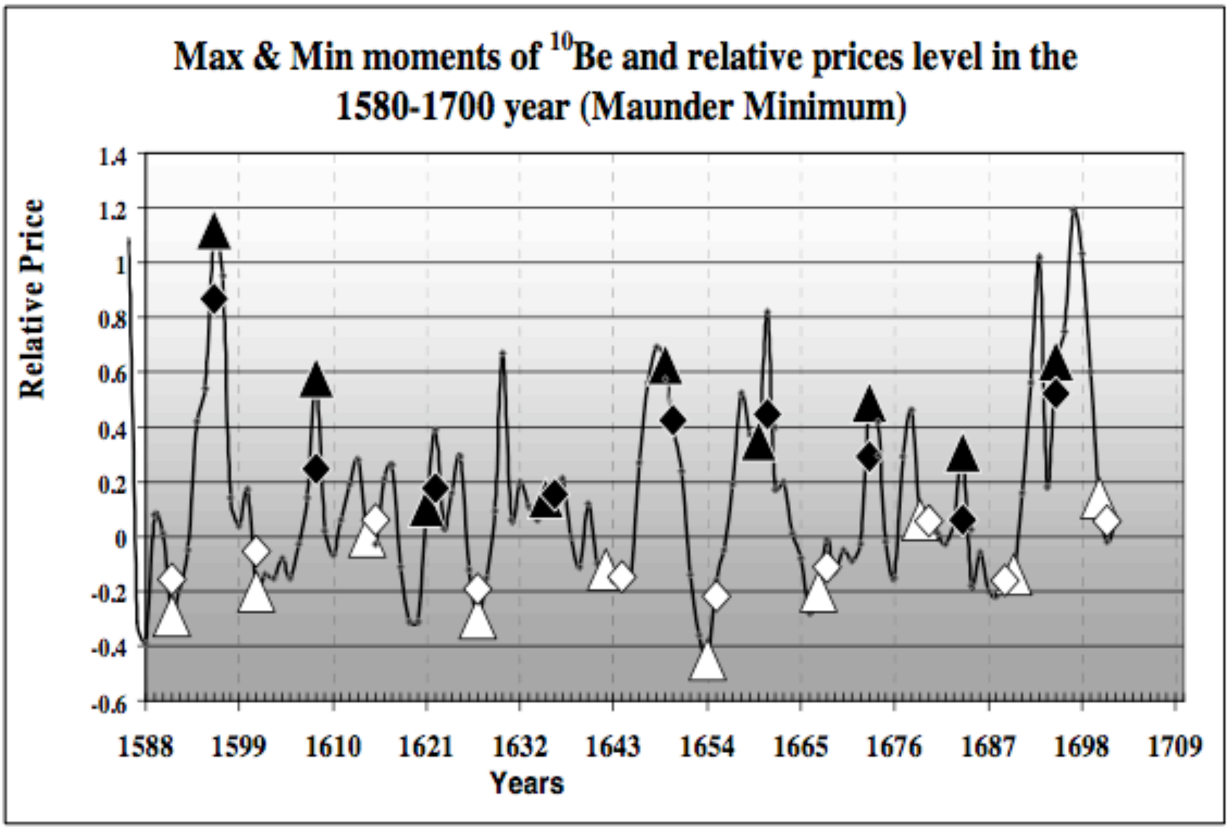
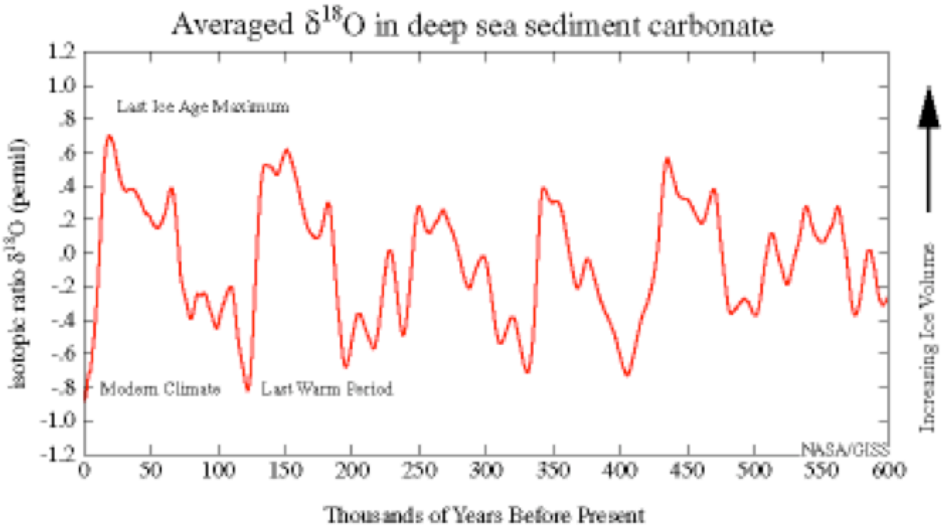


Figure 9. Consistent differences in prices at moments of maximum and minimum states of solar activity (1600-1700). White and black rectangles are prices averaged for 3-years intervals centered on moments of maximum and minimum of solar activity, white and black triangles are prices in the moment of the maximum and minimum.

The recovery from the penultimate ice age [termination II] begins tens of thousands of years before the peak in the June insolation [Milanković cycle]. This has been known a long time as "the causation problem" and has been a mystery until the ^{10}Be deposition rate had been correlated with the temperature proxy and the ice volume proxy; the Specmap time scale given below:



The specmap is the standard proxy for the global temperature history. http://www.giss.nasa.gov/research/briefs/schmidt_01/specmap.GIF gives the specmap time series, a $^{18}O/^{16}O$ isotope abundance as a proxy for the amount of ice volume. Ice, coming from evaporated sea water, is enriched in light water $H_2{}^{16}O$, and the remaining sea is enriched in heavy $H_2{}^{18}O$, as is the carbonate that originates in the sea and incorporated in the sediment.

CERN–PH–EP/2004–027, 18 June 2004, THE GLACIAL CYCLES AND COSMIC RAYS, J. Kirkby, A. Mangini, R.A. Muller; give the following set of time histories:

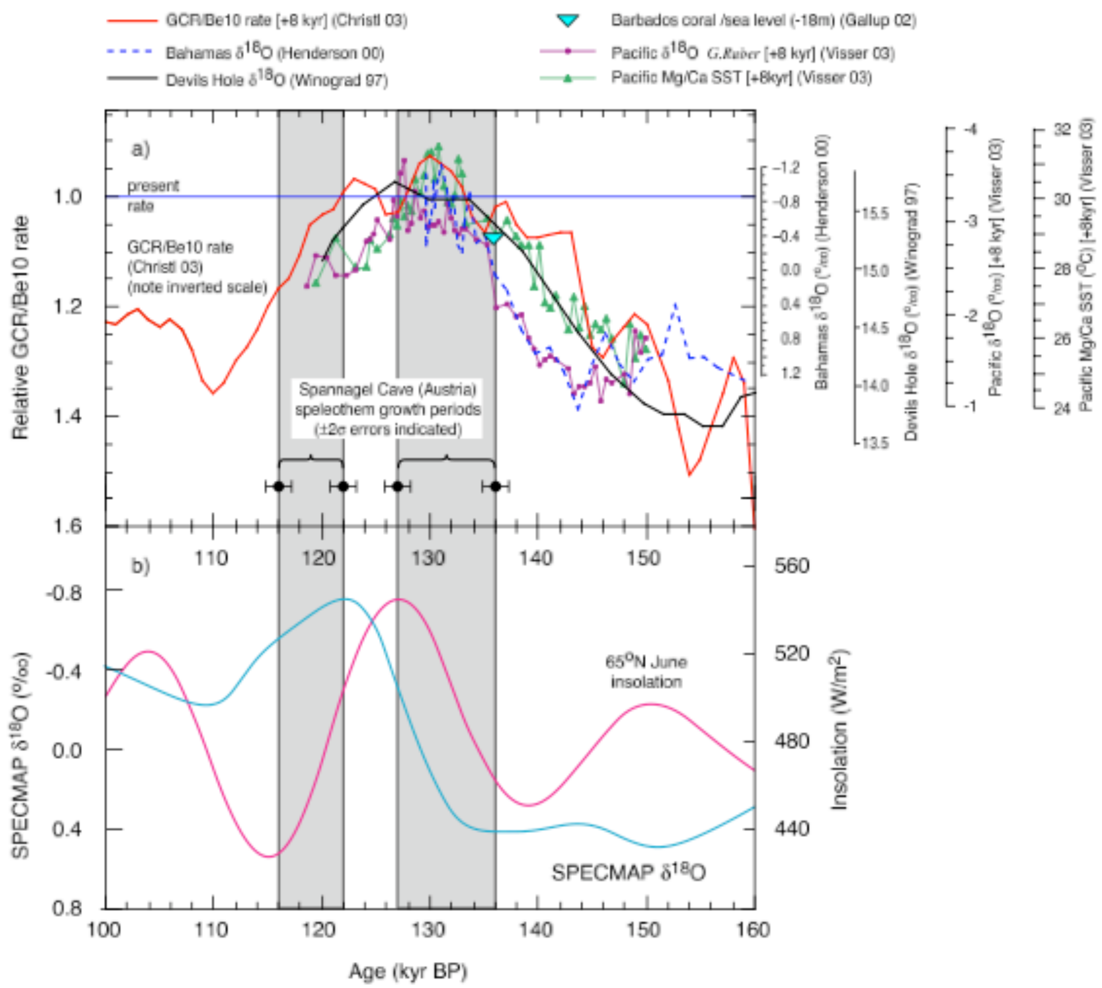


Fig. 3: Timing of glacial Termination II. a) The GCR rate together with the Bahamian δ^{18}O record [41], the date when the Barbados sea level was within 18 m of its present value [42], the δ^{18}O temperature record from Devils Hole cave, Nevada [43], and the Visser *et al.* measurements [44] of the Indo-Pacific Ocean surface temperature and δ^{18}O records. The GCR rate and the Visser *et al.* data are shifted earlier by 8kyr in order to correct for estimated systematic errors in the SPECMAP timescale, on which they are based. The growth periods of stalagmite SPA 52 from Spannagel Cave, Austria, are indicated by grey bands and black points. b) The 65°N June insolation and the SPECMAP δ^{18}O record [34].

It is clear that a steady decrease, mind the inverted scale of 10Be [GCR rate], from 1.5 to 0.9 times the current rate over a period of 30000 years, has been the driver for termination II, not the 65° June insolation, which comes 8000 years later, and not the world's temperature rise as seen in the specmap, which comes 12000 years later.

Conclusion

Our present climate is due to an increased length of the last interglacial period, more than 10000 years, due to a low level of GCR that maintains a low cloud cover, a low albedo, more absorbed sunshine and a pleasant climate. In the very long run, we need not mind about CO_2 or global warming, but instead about higher GCR activity and global cooling. There is no way we can influence GCR activity, originating in active black holes and imploding supernovae.