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The Accidental Geo-Engineering of the Intertropical Convergence Zone

Key words: Intertropical Convergence Zone, Atlantic Equatorial Mode, Sea Surface Temperature, Mediterranean, Sahel, Precipitation, River Nile, Aswan.

Abstract: *There have been many studies which examine the effects of sea surface temperature (SST) upon the Sub Saharan climate, but few that demonstrate how events on the Sub Saharan continent may affect SST. The Atlantic Equatorial Mode (AEM) is a region of the Atlantic which exhibits a warming trend consistent with an increase in applied solar energy. The probable cause of this is by a reduction in the Intertropical Convergence Zone's (ITCZ) cloud mass above, which previously had been absorbing, scattering and reflecting away incoming solar energy. As the ITCZ's general cloud mass and African Easterly Waves (AEW) drift, form and re-form westward from Sub Saharan Africa (SSA), they would dissipate and rain-out as they cross the Equatorial Atlantic. Thus a net reduction in this cloud mass would produce a corresponding increase in sea surface insolation thus temperature, in a pattern which would have followed the characteristics of the previous cloud mass. Scrutiny of historic SST data as well as precipitation and river flow in SSA suggest that there exists a sequence of previously unrecognised climatic events originating in the Eastern Mediterranean, which are partly responsible for altering the ITCZ precipitation and cloud mass, causing both the Sub Saharan droughts and the AEM increased SST. That variability in the evapotransportation from the Eastern Mediterranean and Nile Delta southward late summer is causing a general degradation within the ITCZ. Human efforts to control the annual Nile flood since 1902, by the introduction of a dam complex at Aswan on the River Nile is the principle means that has caused this change to the East Mediterranean evapotransportation factor. That a failure to recognise the existence of this event may partly explain the inaccurate conclusions of so many climate models.*

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Introduction: For as long as there have been oceans on this planet, they will have been absorbing solar energy and distributing that energy towards the poles, due to the Coriolis Effect (Herweijer et al 2004; Trenbeth & Caron 2001). Adding to this effect is evaporation, where moisture from the oceans and continents inhabits the atmosphere. This atmospheric moisture can form clouds, which have the dual capacity of trapping heat in the atmosphere and reflecting away incoming solar energy from the planet's surface (Ramanathan V et al 1995; Raschke et al, 2005; Y. Liu, 2011). Although a number of studies have been applied to researching the various climate issues in the Sahel over the passed century (Yongkang et al 1993; Ahlcrona 1988; Nicholson et al 1998), refinement of the relevant data [Nicholson's African Precipitation Dataset, NCAR] demonstrates that what happens there, is part of a larger scaled degradation in the precipitation patterns over a much broader swathe of latitudes on the Sub Saharan continent. Concurrently any reduction in this continental rain/cloud mass may provide knock-on effects westward within the ITCZ over the Equatorial Atlantic, by increasing insolation and SSTs. From this there follows a feed back, where Atlantic SST partly affect continental African precipitation, thus cloud formation. By refining historic data it becomes possible to measure the effects of cloud variability upon the ocean surface at some specific locations, by factoring in our understanding of existing ocean currents (S. G. Philander 2001; A Hernandez-Guerra et al 2005) and their heat transport. Like a radiographer using X Ray; being able to produce an image on a reactive photosensitise plate, of that which has come between the plate and the radiation source. We are in a position to replicate this process using the sun as

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the radiation source and the sea surface temperature data as the reactive plate. This provides a recognisable and quantifiable image of that which has affected the amount of solar radiation (heat) being absorbed by the reactive plate - the sea surface. From this we can derive a confident understanding of the relative cloud mass/density that had come between the ocean surface and the sun at particular locations within particular timeframes. Refinement of SST data [HadISST1] for the equatorial Atlantic reveals an 'abnormal' (figure 1) seasonally migrating zone that extends from the West African coast, diminishing westwards. Taking all other factors into account, it is prudent to consider that this event (here from referred to as the 'Atlantic Equatorial Mode' ~ AEM) is principally the result of the increased insolation due to the reduced cloud mass – the same reduced cloud mass responsible for the Sub Saharan droughts upwind. Using River Niger flow in West Africa as a proxy for the cloud mass/density or their precursors that drift and form within the AEM, we have to confront the possibility that the AEM cloud density may have reduced by as much as 35% since the start of the last century – producing the corresponding increase in sea surface insolation.

It is commonly stated that the Atlantic and Indian Ocean SSTs, ENSO and human emissions present the dominant forcing for the negative Sub Saharan precipitation variance (M Biasutti et al 2007; P Lamb 1978; D Ackerley et al 2011; M Biasutti 2008; Jian Lu, T Delworth 2005**)**. These perspectives fail to appreciate that the Mediterranean, independently or as a direct result of the larger oceans influence, provides evapotransportation to the northern fringes of the ITCZ on the African Continent during the latter part of the rainy season, July – October (D Rowell, 2002; F Raicich et al, 2003; Fontaine, Bernard et al, 2010; B Fontaine et al, 2011). Consequently factors affecting Mediterranean SST and salinity (thus evaporation) can have an insidious positive or negative effect upon, not just the Sub Saharan moisture budget and subsequent recycling, but also the length of the rainy season. Enough to encourage a positive or negative Charney Effect, thus precipitation and overall cloud mass within the ITCZ over Africa, then later over the AEM downwind. Although this moisture flux may be a minor contribution to the larger ITCZ, it appears to have been providing a significant fraction of this end-of-season ITCZ northern fringe moisture flux. Adding the sensitivity of the biomass in SSA combined with the varying moisture budget and the passage of time, may have all contributed to the ITCZs equivalent of a slow puncture; nether dramatic nor obvious, but recognisable over an extended period of time.

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There exists in the north Equatorial Atlantic a region of elevated sea surface temperatures (SST) with a number of distinct features. By comparing existing SSTs (source: HadISST1) to historic data from the same region, we are able to view and quantify how the SST has changed. This resultant AEM embodies a number of features:

- The elevated SST is highest in the east near the African Coast then diminishes westward.
- It migrates seasonally.
- It does not strictly conform to known movements of the prevailing ocean currents at that location.
- The elevated temperature warm zone remains largely consistent, even though it straddles both the northern and southern equatorial Atlantic currents.

Figure 1

Equatorial Atlantic SST anomaly (AEM): 1990 to 1999 against 1870 to 1929

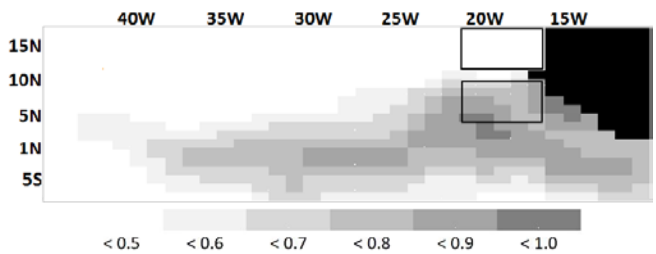


Figure 1 demonstrates the elevated temperature zone refered to as the AEM. This chart showing the mean August, September, October effect by degrees centegrade from 1990 to 99, relative to a base period 1870 to 1929. The two ocean surface blocks shown in this image are used later as a means to quantify and refine the trends in AEM variability.

Figure 1 is a snapshot from a series of SST anomalies of the Equatorial Atlantic, which demonstrates a cohesive warm zone which migrates northward then southward throughout the year, but is most pronounced in the late summer months. Unlike ENSO, which provides for warm and cold phases, the AEM since the mid 1960s exhibits a near consistent elevated temperature trend.

Figure 2

AEM absolute and anomaly temperature gradients

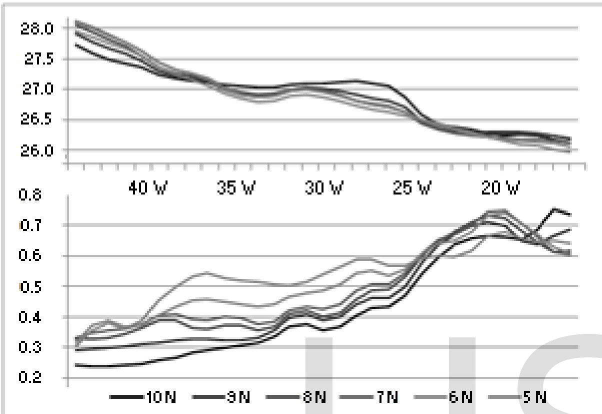


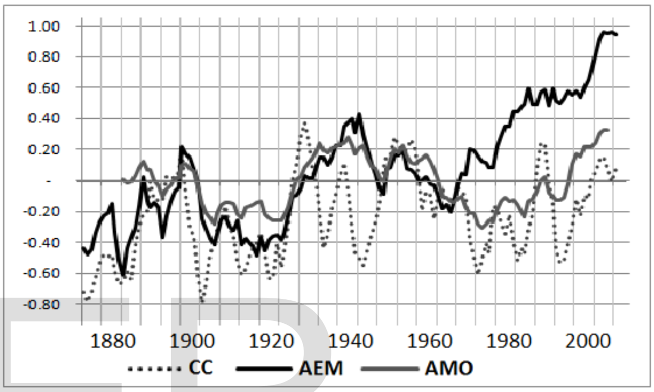
Figure 2 comparison of ocean surface temperature features within a block of the equatorial Atlantic 1990/99 (5N to 10N, 17W to 45W), used here to compare the mean temperature (upper graph) and anomaly temperature (lower graph) against 1870 to 1929 base values.

Figure 2 (upper gradient) demonstrates an increase in absolute SST as one moves westward across the Equatorial Atlantic, due to the ocean surface constantly absorbing solar energy, becoming warmer. The western sector being exposed to the equatorial sun for longer, achieving a higher temperature than the eastern sector. The lower gradient shows that there has developed a distinct bias in how much additional heat is being absorbed and/or carried in the eastern sector of this zone compared to the western end, despite the fact that the western portion has been in the equatorial region for longer.

Figure 3 shows a chart of how the SST of the inflow to this AEM (J García-Serrano et al, 2011) compares to temperatures within the zone itself, by refining the ocean blocks shown in figure 1. Scrutiny of the temperature of the sea currents inflowing from the North East Atlantic down the coast of West Africa into the AEM (refereed to here as the Canary Current or CC) demonstrates a marked difference to the SST gradient of the water in the AEM itself, despite these two blocks of the ocean being essentially the same body of water. The divergence of the AEM towards a constant incline since the mid 1960s is not mirrored here with the CC inflow temperature.

Figure 3

AEM compared to Canary Current 'Inflow' (CC) and Atlantic Multidecal Oscillation (AMO).



Mean SST gradients for two specimen blocks of the equatorial Atlantic shown in figure 1 are compared in figure 3. The distinction is of how each block exhibits surface temperature variability over the passed 140 years compared to the AMO.

The first 45 years of this timeline (figure 3) shows a confident relationship between the CC inflow, AMO and AEM SST variability. It should be considered that this is the 'normal' course of events in this region; minor changes in Atlantic SSTs produce minor changes in the ITCZ cloud mass (thus insolation of the AEM) and visa versa. Since the sun has been the principle agent for warming the CC surface as it flows into the AEM region, it should be considered that some outside factor has been responsible for the change in the amount of that solar energy reaching the ocean surface. This same factor would be relevant in altering the constituent data which contributes to the overall AMO figures. To assess the viability of this insolation variability hypothesis, the change in the temperature of the inflow to the AEM is compared to historical data for river flow and rainfall upwind on the West African Continent. The river and rain data being

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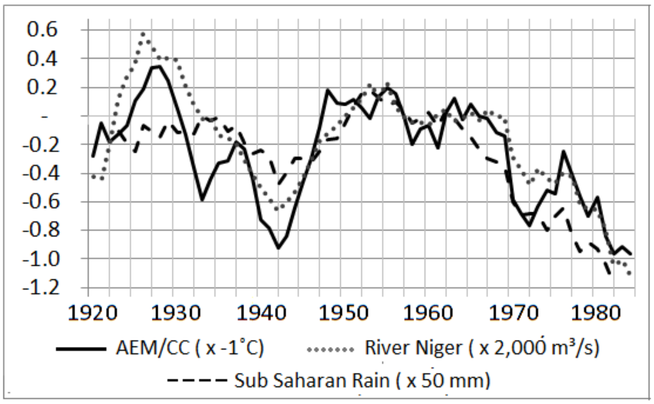
indicative of the overall cloud mass thus AEM insolation and temperature i.e. less cloud means more insolation. To produce the true AEM/CC insolation variability, the CC figure is subtracted from the AEM figure then inverted: x -1.

Figure 4

AEM surface warming compared to Sub Saharan Rainfall and River Flow



The AEM/CC variability is compared in figure 4 to other ITCZ cloud mass indicators in West Africa: rainfall and river flow. [Source: GRDC: River Niger at Koulikoro, Nicolson's African Precipitation Dataset and HadISST1]

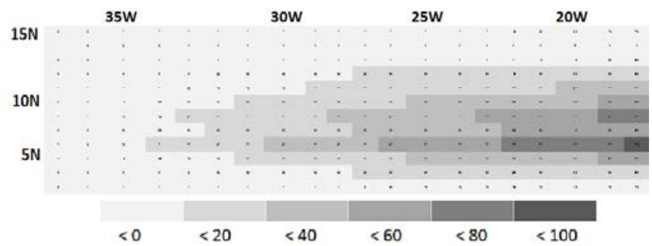
If we are to achieve any degree of confidence in establishing the nature of the agents which produced the AEM ΔSST/insolation variability, it is necessary to make best use of what scarce information is available. The Historic land based climate and precipitation records across Sub Saharan Africa vary in timescale and quality, so too does the number of weather stations and their locations. But since this information is indicative of climatic conditions 'upwind' of the AEM, it is prudent to examine them to see if there are any consistent features which may help explain the AEM event. The river flow, indicative of generalised precipitation in the Upper Niger basin upstream from Koulikoro (12˚51'N 7˚33'W) in west Sub Saharan Africa, has been used as a proxy for cloud mass or their precursors, heading westwards from the Sub Saharan continent towards the equatorial Atlantic. As can be seen in figure 4, there is a high degree of compatibility between these cloud mass indicators and the (inverted) AEM/CC variability.

Given that the sun has been the principle agent for warming the equatorial oceans surface for the passed 3.5 billion years, and that cloud density above would have an effect upon the net SST variability in respect to determining how much solar energy reaches the ocean surface, the strong corelation as shown in figure 4 should be of no surprize.

The Complex nature of ocean currents, wind driven surface currents and surface mixing make it difficult to find a 'true' base temperature which can be applied to all of the gridded temperature readings as shown in figure 1. To circumvent this obsticle an 'idealised' downwelling irridesence effect has been produced based upon the information for rain/cloud deficit for August (as shown later in figures 7 and 8) Assuming [1] 90% cloud cover at peak. [2] 10% sea surface albedo. [3] straight line reduction in cloud cover to zero, over 20˚ of longitude westward. [4] wind direction due west. [5] no substantive change in the nature of the sea currents at that location. [6] downwelling irridesence affect reducing at 47% per meter. [7] no evaporative or radiative cooling.

Figure 5

Idealised AEM irridesence downwelling (watts) from West African Coast based on 1965 to 84 rainfall deficit, compared to the previous 20 years rainfall (August).

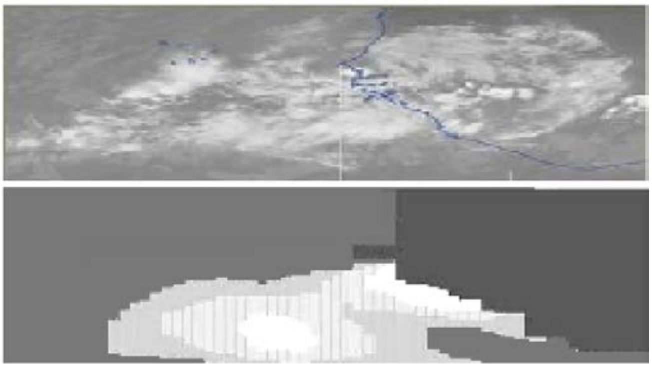


The figure 5 chart is a rendetion of sea surface irridesence downwelling based upon increased insolation due to reduced cloud cover. The latitudinal rainfall reductions for a given period is used to determin the possible reduction in cloud cover.

On the basis of the aforesaid conditions, the peak insolation value would achieve a 1˚C SST increase for the top 1 meter in less than 2 days. It is concluded that applying the cloud cover reduction rule is more than sufficient to produce the sea surface warming effect as demonstrated in figure 1.

Figure 6

Satellite and SST data image of the AEM region

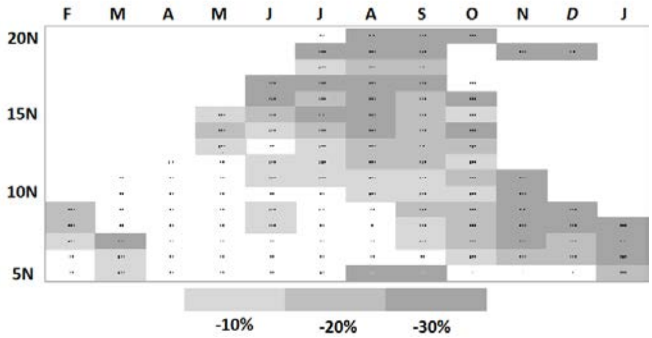


The figure 6 upper image is a satellite photograph of an Easterly Wave cloud formation extending from the West African coast. It is compared to the lower image of sea surface temperature anomaly for the same location and timeframe.

Further credence to the hypothesis of insolation being the principle factor in producing the AEM can be made by comparison of the most prominent meteorological system operation at this location and timeframe. African Easterly Wave (also known as Easterly Wave, Tropical Wave) is a trough of low pressure orientated north to south with a westward vector. These events provide a significant portion of the Sub Saharan precipitation and cloud formations; they vary in frequency and intensity. Although the figure 6 comparison does not provide any actual proof that cloud (AEW) variability is the cause of the AEM, the consistent timeframe/location factor of these two events does demonstrate that a reduction in the cloud formation would cause a corresponding increase in insolation of the nature shown in the lower image.

Figure 7

Percentage rainfall deficit 1965 to 84 compared to previous 20 years.



By means of showing the precipitation deficit by month and latitude, chart 7 demonstrates the effects of the seasonal movement of the Intertropical Convergence Zone as it migrates north then south across the 15 degrees of latitude form the Gulf of Guinea (5N) to the southern border of the Sahara desert (20N). Important features are not just that the rainfall by magnitude diminishes towards the north, but also the length of the 'rainy season' reduces by latitude northwards. [Source: Nicolson's African Precipitation Dataset, NCAR]

Figure 7 demonstrates the percentage rainfall reduction across the 15 degrees of latitude in SSA, 1965 to 84 compared to the previous 20 years. Although the Sahelian droughts have been highlighted over the past century, they are in reality part of a much larger system that encompasses over 7.5 million square kilometres. Percentage rainfall rather than actual rainfall is in many respects a more useful means of demonstrating the precipitation variability, especially when used as a measure of the attrition applied to the vegetation in the region.

The objective of producing such a presentation is that it provides some understanding of the nature of, or precursors too, the cloud formations that eventually provide cloud cover above the AEM. These two items, SST and continental rain, though appearing to be differing in their nature, are in many respects symptomatic of a consistent trend within the ITCZ.

There are a number of factors that help define the eventual cloud mass that provided the AEM sun-block. Although mid summer in the northern hemisphere is 21^{st} of June, when the earth axis has achieved its maximum northern tilt towards the sun, it should follow that the ITCZ and its accompanying precipitation should also be greatest at this time, like the monsoon in India which manages to peaks in July-August even though it covers the same latitudes as the Sahel. As demonstrated In figure 7 this delayed peak ITCZ/precipitation factor may be due to a trinity of [A] the interval between when the Sahelian vegetation matures sufficiently during the early rainy season to the point where it is able to produce the surface albedo/aerosol conditions more favourable to cloud formation and rain. [B] That the evapotransportation from the Mediterranean arena representing a 'supplementary' moisture flux to the ITCZ, without which the rainy season would have peaked much earlier and would not have extended so far north. [C] From mid July, increased evapotransportation from the Eastern Mediterranean.

Organic Factors

The Charney Effect (Charney et al 1975, Charney et al 1977) is an understanding of how vegetation on the ground affects cloud formation above. But changing rainfall regimes also affect the type of vegetation which will grow in any given region (scrub, savannah, forest), thus earth surface albedo. The vegetation type also affects the production of aerosols which act as cloud condensation nuclei (CCN).

If we are presented with the year on year reduction in rainfall as demonstrated by figure 4 since the mid 1960s, it will become necessary for each species of vegetation to 'migrate' to a latitude further south, to an area with a rainfall regime that is compatible with the their own individual resistance time: the genetic timeframe from which a plant flourishes at the start of the rainy season, to producing viable seeds or growth for the following season. This ever decreasing length of the rainy season northward extends to the point where there are few or no plant species that are able to produce viable growth and seeds within the timeframe stipulated by the length of the rains. In addition to the plant life in any latitude being burdened by a reduced water supply and associated increase in insolation / evaporation / transpiration, they are also preyed upon by fauna (mammals, birds and insects). Thus a lesser vegetation mass is having to feed a fauna population that is initially disproportionately larger than under 'normal' conditions. Further attrition is produced by an invasion of migrant flora due to the changing rainfall regime into latitudes occupied by various other species of plant life. This particular aspect of the flora shuffle does provide the opportunity for the southward migrating vegetation to plant itself into what is generally more fertile ground. Thus it can flourish in this new environment, sufficient to help encourage a positive Charney Effect, thus the previous flora species in that latitude can begin to re-establish itself. This particular scenario may be the redeeming factor to explain the tendency towards organic recovery in this region under 'normal' circumstances.

The sensitivity of vegetation to the magnitude and length of the rainy season, insolation, aerosols and recycling all have the ability to exacerbate any alteration in the nature of the prevailing weather systems. Under normal circumstances there will be a variation in the moisture, rainfall, biomass relationship above and below a certain mean on an annual basis. But we are presented with the effects of a near constant 'minus factor' since the mid 1960s (fig 4) which has ensured that this equation results in a near year on year degradation in those conditions, which partly contribute to the formation of the ITCZ cloud mass. A relatively normal and minor change in one particular subsystem having no real effect on a continental scale, but should this minor change at a key location and timeframe be repeated year on year over this continent, it may affect the flora/biomass, which inturn may profoundly exacerbate the changes in the larger meteorological events. Although human intervention in the Sahel has often been described as the guilty party in the large scale degradation of the region, this may be true on local levels, but it does not provide an explanation as to why the majority of the rainfall deficit occurs towards the end of the rainy season (figure 7).

Effects of Mediterranean SST and Salinity on Sahelian Rainfall

Another item of importance which is displayed in chart 7 is the factor of the most significant rainfall deficit being towards the latter half of the rainy season. As the ITCZ migrates northward (following the thermal equator), it draws in air and moisture from up to 3,000 km north (the northern Hadley Cell – G

Hadley 1735). In the earlier part of the year this action ensures the Sahara region is effectively sucked dry of all moisture (without there being any other moisture source to replenish the supply), helping to create the desert. From May onwards this 3,000 km inward avection begins to draw from the southern Mediterranean arena (D Rowell, 2002; F Raicich et al, 2003; Fontaine, Bernard et al, 2010; B Fontaine et al, 2011). The moisture budget or evapotransportation to the northern fringe of the ITCZ begins to increase, since this would be the first port of call for any transportation of the Mediterranean moisture within the northern summer timeframe. A dearth of flora species that can cope with the duopoly of a short resistance time and high insolation, ensures the Sahara has a very high surface albedo (35%), sufficient to inhibit cloud formation and rain during this Mediterranean/ITCZ moisture transport. As the ITCZ begins its southward migration from late summer, if it is combined with a reduced moisture budget, there results in a lessening in the rainfall in each latitude in which the northern fringes of the ITCZ happens to occupy at that time, thus attrition to the latter stages of the development of seeds and growth of the flora in each successive latitude, encouraging the previously mentioned negative Charney Effects. From this late summer precipitation there would have followed recycling, where up to 90% of groundwater evaporates, contributing to further cloud formation and rain (H Savenije 1995, C Risi 2010). Conversely less Mediterranean evapotransportation would mean less rain, means less recycling. Means that even when the ITCZ or northern Hadley Cell is no longer drawing directly from the Mediterranean arena, the effects of such a moisture deficit are still being exhibited throughout the latter rainy season in those latitudes further south, due to reduced recycling. Such a downward trend in rainfall and arrested development of the flora in the late season will have a corresponding effect upon the new growth in the early part of the following season, thus encouraging a further negative Charney Effect at the start of the following year. Thus what might be originally viewed as an irrelevant and seemingly obscure climatic event in the Mediterranean, due to a resultant year on year negative balance on the moisture budget, can be compounded over time by the degradation of the Sub Saharan biomass, to produce a significant reduction in the ITCZ cloud mass which had previously acted as a sun block above the AEM.

Figure 8

Representation of rainfall magnitude and deficit

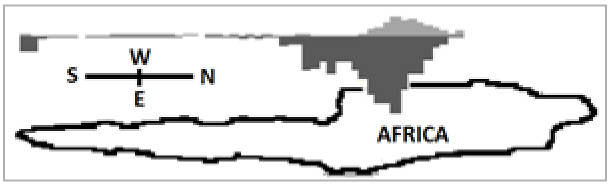
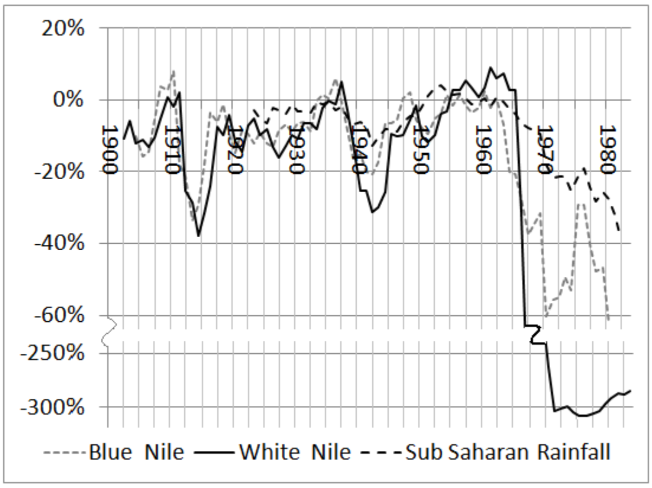


Figure 8 provides a representation of the relative magnitude and location of the rainfall on the African Continent whilst the ITCZ is at its northern most migration in August, for the years 1945 to 64 (dark grey bars). The light grey bars represent the relative reduction and location of the rainfall deficit in the following 20 years.

To this factor of the Mediterranean evapotransportation role in the Sub Saharan climate can be added the formation of African Easterly Waves (AEW). The precipitation deficit formation as shown in figure 8 is suggestive that AEWs may be playing a disproportionate role in producing this effect. Although it is known that these AEWs predominantly form towards the centre of the Sub Saharan Continent (Leroux and Hall 2009, G Berry and C Thorncroft 2005), it has been demonstrated that the genesis or precursors to these events can be backtracked to the Ethiopian Highlands (A Mekonnen, W Rossow 2011). In figure 9, where Blue Nile flow at Khartoum is used as a proxy for precipitation over the Ethiopian Highlands, there is a strong correlation with that of rainfall across Sub Saharan Africa. Such a relationship should be of no surprise since the aforesaid genesis of AEWs plus recycling from the Highlands westward with the trade winds would both affect conditions in SSA.

Figure 9

Sub Saharan Rainfall compared to Blue Nile flow from the Ethiopian Highlands and White Nile flow.



Given that the river flow is dependent to a large extent on rainfall, it should follow that river flow records can in many cases provide a useful record of rain variability, as shown in figure 9. [Source GRDC, NCAR. 1945 to 64 mean values, 5 year smoothing]

The River Nile had been to a large extent a feedback mechanism. Condensed moisture, predominantly over the Ethiopian Highlands, falls as rain then flows along the Blue Nile and Atbara, then White Nile into the Egyptian Delta and Eastern Mediterranean. This Egyptian flood started in mid July and lasted till October/November. In the delta it formed what was in real terms a warm, shallow, fresh water lake of up to 26,000 km² surface area, depending upon the magnitude of the flood from the Ethiopian Highlands. The stream of flood water then floated upon the denser, saline eastern Mediterranean (S. H. Sharaf El Din 1975), which could sometimes be detected as far north as Southern Turkey (S El-Sayed and G van Dijken 2006). The White Nile from Southern Africa, though portraying some seasonal variability, actually increased its flow during the timeframe inwhich the Blue Nile diminished, yet this White Nile increase represented in magnitude only 12% of the Blue Nile decrease.

To reiterate B Fontaine et al, (2011) *'...warm SST anomalies positively affect the Sahelian precipitation in JAS in reinforcing the moisture transport from the Mediterranean across the Sahara and hence the moisture flux convergence over the Sahel'.* The question which then arises is, to what extend did the historic flooding of the Nile Delta and the associated desalination of the Eastern Mediterranean surface contribute to this Sahelian moisture flux?

Figure 10

Nile Delta and east Mediterranean Moisture Flux

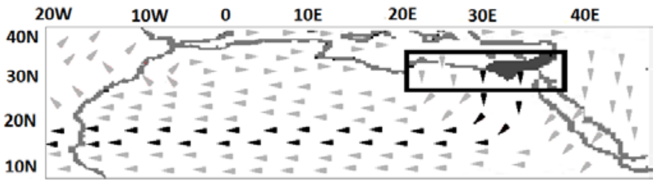


Figure 10 (which is a rendering of D Rowell, 2003) demonstrates that the region of the Eastern Mediterranean and Nile Delta affected by the annual flood. Though representing a minor fraction of the Mediterranean Sea, would still have contributed significantly to the overall moisture budget from that region, to the northern fringe of the ITCZ. This is with consideration that the majority of the *Mediterranean / Sahelian moisture flux crosses the North African shore east of 20E, and would be enhanced by the down draft of hot dry air from the northerly avection of the Hadley cell. As this northern boundary of the Hadley cell migrates south, the Nile flood effect provides an ever increasing proportion of the total Mediterranean evapotransportation in the late rainy season.*

If it is accepted that the Mediterranean is an important contributor to the Sahelian moisture budget late summer due to evapotransportation, or as defined earlier '*contributing to the northern fringe of the ITCZ*', it would follow that variance in the Nile flood would have an affect upon the Mediterranean / Sahelian moisture flux. This might be checked by comparing the downstream White Nile flow to that of precipitation in the Sahel and on the Ethiopian Highlands. *It is unknown whether or not the Delta/E. Mediterranean flood created a high pressure zone at this time. But it is prudent to examine how such an air pressure difference would affect the Mediterranean / Indian Ocean interface as mentioned in ~ (D Rowell, 2002; F Raicich et al, 2003; B Fontaine et al, 2011)***.** *An event which pushes the Med/Indian interphase south east may allow for the ITCZ/Nile flood evaporation to be pushed higher up the Ethiopian Highlands, with the higher altitude*

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providing the conditions more favourable to cloud formation and rain; a sequence contributing to the precursors to AEWs.

The succession of events relating to AEM, Sahelian rainfall, AEWs and Ethiopian Highland rainfall and river flow present a consistent theme within the 'African ITCZ', but in figure 9 a significant factor is introduced. The White Nile flow figure is taken from Aswan in Egypt.

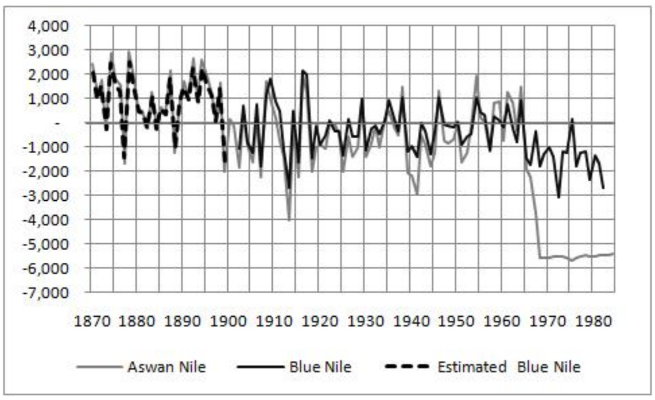
Man made efforts to partially control and benefit from the River Nile has involved a number of large river management projects**:** Aswan l (1902), Assiut Barrage (1903), Isna Barrage (1909), Aswan Dam II (1912), Sennar Dam (1925), Nag Hammadi Dam (1930), Aswan Dam lll (1933), Jebel Aulia Dam (1937), Owen Falls Dam (1954), Aswan High Dam IV (1964), Roseires Dam (1966). The Nile flood had been altered, particularly by the Aswan Dam complex, in two ways.

1 With the first Aswan Dam, the flood was allowed to proceed as normal, then the dam began to close so that the latter part of the flood was stored in the dam reservoir. This shortened the timeframe that the lower Nile was flooded – altering the gross evaporation during what had been the normal flood season.

2 Slowing the flow of water once the dam closed ensured the heavier silt particles sank in the reservoir, thus altering the flood waters downwelling iridescence factor, thus again altering evaporation.

Figure 11

Estimated and Actual Blue Nile flow anomaly compared to Nile flow at Aswan



The relationship between the river flow/rainfall on the Ethiopian Highlands and the man made alteration to the Nile flood as demonstrated here, undergo the same variability. This should not be happening, unless the mass of water allowed to flow from the dam complex is having an effect upon the rainfall on the Ethiopian Highlands. [Source: GRDC. ASO, 1945 to 64 mean values. 5 year smoothing, m^3/s]

Large dams for the purpose of river management or irrigation or energy have been built on the Nile and its tributaries since the start of the last century. The operation of these structures has affected the mass of water flowing towards the Nile Delta and Eastern Mediterranean – thus evapotransportation southward towards SSA. This can be viewed by looking at how the very large Aswan operation, in its four stages of development (1902, 1912, 1933, 1964), has ensured some measure of control of the up to 12,000 m^3/s of river flow which inundated the Lower Nile. The majority of this flood water came from the Ethiopian Highlands. It can be seen that the Blue Nile flow/Ethiopian rainfall correlates strongly with the White Nile flow at Aswan – despite the latter figures being significantly affected by human intervention. Examining the 'character' of these rivers flow pre the introduction of the dams compared to after (1902) demonstrate a significant alteration in their general flow rates. This is again repeated after 1964, when the total control of the Lower Nile was produced by the introduction of the Aswan High Dam. Although it may be convenient to dispose of this correlation as being coincidental, one has to consider that the equivalent of multi billion dollar investments had been produced with the singular purpose of containing much of the Ethiopian (Blue Nile) flood in the Aswan Dam reservoir (Lake Nasser). For both these river systems to maintain the same flow characteristics, despite the successful human efforts to alter one of them, is of paramount importance, given the relationship of the Ethiopian event being a precursor to both Sub Saharan precipitation and Equatorial Atlantic Insolation.

The 'estimated' Blue Nile flow pre 1900 is produced on the basis that the White Nile form Southern Africa was flowing in the region of 1,500 m^3/s. This figure was subtracted from the Aswan flow pre 1900 to determine the contribution from the Ethiopian Highlands.

Discussion: Atlantic Ocean SSTs have an effect upon the SSA climate, yet varying cloud mass from or due to events on the SSA continent will have an effect upon Atlantic SSTs. There is also to be considered that events in the Atlantic will impact in the Mediterranean, which will inturn affects SSA, and events in the Mediterranean independent of the larger oceans will also have an affect in SSA. Of particular concern is the introduction of large scale river management, irrigation and land usage projects in the last century, which have a direct effect upon sea surface salinity and temperature of the Eastern Mediterranean as well as the nature of the Nile Delta, during the late summer Nile flood, sufficient to alter evapotransportation from the Eastern Mediterranean region to SSA.

This research highlights three main areas of contention:

[1] The existence of the AEM and the factors affecting the SST increase of the Canary Current as it flows along the Western coast of the Sahara and Sahel.

[2] The reduction in the Sub Saharan precipitation in the period 1965 to 84 being predominant in the most northerly latitudes and towards the end of the rainy season.

[3] The relationship between precipitation on the Ethiopian Highlands and the dam operation at Aswan.

There is sufficient information contained here to demonstrate that there is real cause for concern that human adventures affecting the annual Nile flood have provided an insidious, unrecognised but significant effect upon large scale meteorological systems. It is not possible to achieve any useful understanding of planetary climate dynamics, without understanding those factors which are affecting the planets largest weather system – the ITCZ.

A significant portion of this moisture budget which had been contributing to the biomass in the southern border of the Sahara towards the end of the growing season had been the result of a feedback mechanism, where the midsummer rains form a large shallow lake in the north eastern Sahara, as well as altered the surface salinity and temperature of the east Mediterranean. Thus our predecessors may have been impressed with the Nile flood moving northward at 12,000 tons per second, without appreciating that there was a similar river, of far less density, yet of a mass of 6,000 tons per second moving southward over their heads – as a direct result of the northern flow. The human effort to restrict the north-flowing flood has thus affected the south flowing moisture contribution ---- and the rest is history!

It has not been the intention for this research to provide all of the right answers - but to allow us to start asking some of the right questions.

Conclusion: There is a significant increase in Equatorial Atlantic sea surface temperatures due to an apparent increased insolation, as a result of reduced cloud cover within the ITCZ. Confidence in such an ascertain comes from it requiring in the region of a net 2.6 hours of additional clear sky to produce the warm trend (fig 1) relative to the pre 1900 mean. This is a figure easily within the margin demonstrated by the reduction in cloud cover indicators as mentioned here.

The chain of events from human intervention in the Mediterranean Sea and Nile Delta, to Sub Saharan Africa, to the Equatorial Atlantic, is a specific subject area which requires more resources and attention, to ensure that these events are fully understood. Cloud densities or general cloud mass at the thermal equator, in respect to their effects upon sea surface insolation and temperature, is a subject area that again requires greater resources and scrutiny.

It may be the case that river management operations are having an insidious effect upon seasonal regional evapotransportation from delta and estuaries. The Nile problem as demonstrated here, presents a special case in this respect due to its location and the associated prevailing climate systems. There is as yet no evidence to suggest that any other factor is responsible for the large scale degradation of the African ITCZ.

With consideration to all of the information contained here, it is the understanding of the author that further human intervention can be emplaced, to provide the circumstances inwhich some measure of control to the precursors to AEWs may be produced. Such an adventure would be within known engineering constraints, relatively cheap when measured against the negative effects of climate variability within the ITCZ, acceptable to all parties and provide a greater degree of stability across much of Sub Saharan Africa, sufficient to promote an optimistic future.

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