Evidence of Climate Change (Global Warming) and Temperature Increases in Arctic Areas

Eric Kojo Wu Aikins

***Abstract*—**This paper contributes to the debate on the proximate causes of climate change. Also, it discusses the impact of the global temperature increases since the beginning of the twentieth century and the effectiveness of climate change models in isolating the primary cause (anthropogenic influences or natural variability in temperature) of the observed temperature increases that occurred within this period. The paper argues that if climate scientist and policymakers ignore the anthropogenic influence (greenhouse gases) on global warming on the pretense of lack of agreement among various climate models and their inability to account for all the necessary factors of global warming at all levels the current efforts of greenhouse emissions control and global warming as a whole could be exacerbated.

***Keywords*—**Anthropogenic Effects, Arctic, Climate Change, Natural Variability.

I. Introduction

GLOBAL climatic conditions have largely changed in recent past decades in favor of increases in temperature. This change that mainly manifests in increases in temperature is becoming more pronounced in arctic areas of the world. Climate change as defined by the 1992 United Nations Framework Convention on Climate Change (UNFCCC) represents a change "which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere" [1], [2]. This definition is premise on the role of humans in creating the observable dynamics in global climatic conditions. Notwithstanding the recognition of human impact on climate change, this definition largely does not spell out specifically the various ways in which humans are contributing to global climate change. On the other hand, the Intergovernmental Panel on Climate Change (IPCC) defines climate change to mean "a statistically significant variation in either the mean state of the climate or its variability". The IPCC intimated that climate change could result from natural internal processes or external forcing, or persistent anthropogenic changes that largely affect the composition of the earth's atmosphere or changes in land use [1], [3]. Consequently, the IPCC largely recognizes the importance of humans in shaping their terrestrial environment as well as the atmosphere. The mention of land use change in this definition largely connotes the bi-directional nature of anthropogenic effects, which the UNFCCC definition does not state explicitly. Nonetheless, these definitions largely agree that the recent climate change are primarily due to changes in humans use of resources that produces greenhouse gases that leads to or stimulates changes in the global atmospheric composition and climate [1], [4]-[10]. Additionally, the IPCC definition states the role of natural internal processes or external forcing in providing the most encompassing assessment of climate change. Inherent in this definition is the impact of natural internal processes like the Arctic Oscillation/North Atlantic Oscillation (AO/NAO) and El Nino/Southern Oscillation on global and arctic climate change. For instance, reference [6] indicated that the global temperature increases of the early part of this century (1920s-1930s) was primarily due to natural processes other than external forcing or anthropogenic forcing. The authors argued that the extent of the climate warming in this period could not be attributed to anthropogenic forcing because anthropogenic forcing was weak during that period and accounted for only 20 percent of the global warming. In terms of high latitude warming within the same period the authors of reference [6] overly cited reference [11] as lending credence to their observation that natural variability other than any other climatic change factor accounts for the high latitude warming of the early 20th century. Contrary, the authors of reference [11] argued that anthropogenic effects through greenhouse and sulfate emissions coupled with natural atmospheric variability offer a plausible explanation for the increase temperature trend observed in the early part of the 20th century (1925-1944). They explained that the model trend depicting temperature increasing in the early 20th century, which did not take into consideration the effects of volcanism and solar irradiance, was similar to a pattern derived from an observed record. Furthermore, the authors of reference [11] intimated that the early 20th century had some greenhouse gases fingerprint.

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II. Causal Factors of Global Temperature Increases

The early 20th century temperature increases may be attributed to differences in temporal resolution, differences in the predictive power of the models for measuring and predicting global temperature increases, and the interpretation of the results of these studies.

First, temporal difference: 1920s-1930s [6] versus 1925-1944 [11] exits between the two periods as depicted by the most commonly used temperature models within the two time periods. Also, the interpretation of the effects of the integration of sulfate with greenhouse gases in these models largely influenced their ability in isolating the real cause of the

warming period of the early part of the past century. This observation is made particularly in view of reference [6] that did not state categorically the impact of greenhouse gases and sulfate on the 1920s-1930s global warming though they presented a graph that portray this relationship. Perhaps, they considered this to be less significant in explaining the early 20th century global and Northern Hemisphere warming phenomena. Rather they base their argument mainly on the proportion of variability in temperature change due to greenhouse gases emissions without sulfate effect. Although they attributed 20 percent of the temperature variability to greenhouse gases it could be argued that if the influence of sulfate was accounted for, a different trend would have been observed. If they did that then their claim that "we strongly support the contention of reference [11] that this high latitude warming represents primarily natural variability within the climate system rather than being caused by external forcing whether solar forcing alone [12] or a combination of increasing solar radiance, increasing anthropogenic trace gases, and decreasing volcanic aerosols, as suggested from the analysis of 400 year of temperature proxy data from the Arctic [13] would not have been as conclusive as it stands.

Secondly, differences in and some inherent weaknesses of some of the models for measuring and predicting global temperature increases mainly accounted for the increases in temperature that were recorded in the early 20th century. As a result, temperature increases recorded within this period could be described as accidental and largely due to measurement errors and not mainly due to observed or measured increases in temperature. Although the authors of reference [11] gave credence to the possibility of physical processes stimulating the warming of higher latitudes of Northern Hemisphere they also noted that part of the warming observed in this period occurred at other times with regards to the late 1800s pattern. In examining the local difference in Northern Hemisphere temperature over this period they noted that enhanced Thermohaline Circulation (THC) partially attributed to positive phase of modeled NOA (1910-1950 with peak at 1920s) largely accounts for the Northern Hemisphere temperature variation. However, in relating their results to the basic assumptions underlying their models, which is cold bias, they stated a caveat that implied that the result of the Northern Hemisphere temperature variability needs to interpreted with caution because of its susceptibility to over estimating ice-albedo feedbacks that influence Northern Hemisphere climate system. Additionally, authors of reference [11] observed that part of the 1920s and 1930s warming occurred in the 1800s implying that the observed warming of this period could not be attributed mainly to climatic changing factors observed only within this period. They intimated that experiments of several past decades indicated that a more general warming that occurred during that period suggest a robust forcing response of the climate system linked to the increasing concentration of greenhouse gases. They concluded that "if the simulated variability and model response to relative forcing are realistic, our results demonstrate that the combination of greenhouse gases forcing, sulfate aerosols, and internal variability could have produced the early 20th century warming, although to do so would take unusual large realization of internal variability".

Thirdly, authors of reference [14] attributed the warming of the earlier part of the 20th century to solar forcing but noted that combined influence of greenhouse gases and internal variability could represent this change. They added that solar irradiance changes could have contributed significantly if their model assumed little error in the relative amplitude of greenhouse gases and sulfate. Authors of reference [15] put the impact of global radiative forcing on global climate change to the last ice age rather than the current interglacial period. Changes in ice sheet and vegetation were the main drivers of this change [15]. However he noted in his 1998 study: 'climate forcing in the industrial era' that solar forcing of 0.4 W/m^2 represented a substantial proportion of climate change during that era. Reference [16] described small temperature variation between 1854 and 1922 as being of solar origin. Also, Authors of reference [12] explained that total energy output of the sun led to long term variation in temperature variation between 1861 and 1989.

The possible sensitivity of models that incorporate greenhouse gases and sulfate emissions into measuring climate change, notwithstanding, the review of the literature largely indicates that solar activity and increasing emission of greenhouse gases and sulfate into the atmosphere are the main forces that underpinned the early 20th century global warming. This assertion is made with respect to the possible influence of the industrial revolution, particularly in the Northern Hemisphere that peeked in the United States between 1888 and 1920 characterized as the *Electric Street Car Era* [17]. This period was largely associated with increase sulfate emissions into the atmosphere that coupled with greenhouse gases offer plausible explanation for global warming during this period.

For instance reference [18] reports that anthropogenic aerosols emissions into the atmosphere from transportation and industry were so darkened that they both absorbed and reflected sunlight in almost equal proportions. In respect of this observation Authors of reference [15] noted that relative cooling of eastern United States, southwest Europe, and the Far East (1950-1995) could be attributed to anthropogenic sulfate production that characterizes these regions. Furthermore authors of reference [15] citing reference [19] noted that spatial correlation exists between source region cooling and regions of anthropogenic aerosols. They intimated that this relationship creates positive feedback 'fingerprints' for transient climate simulations that incorporate greenhouse gases and sulfate aerosols than those that use only greenhouse gases.

In regard of the recent (post 1930s to present) climate changes author of reference [20] found that AO accounts for more than half of the temperature increases in eastern arctic and less than half of temperature change in western arctic including Alaska. On the other hand, authors of reference [4],

for example, contend that the increasing summer warmth cannot be fully explained in terms of atmospheric circulation, sea ice, or cloud changes that largely represent natural forcing of atmospheric changes. They noted that changes in AO and NAO influence Eurasia winter warming. In comparing the impact of PNAT, PDO, El Nino-Southern Oscillation they argued that these natural atmospheric forcing elements have strong impacts on Alaska winter temperature whiles their impact on Alaska summer temperature is weak. In his review; ' a new force in high latitude climate' author of reference [21] noted that AO and NAO account for 42 and 32 percents wintertime variations respectively of recent past decades. This observation supports the assertion made by the authors of reference [4] indicated above. Also, the review intimated that AO is largely responsible for Northern Hemisphere warming with anthropogenic underpinnings. This is largely premise on the fact that increasing greenhouse gases emission into the atmosphere generate positive trend in AO that result in Eurasia and Northern Hemisphere winter warming. This observation is consistent with other studies that indicate that anthropogenic forcing through increasing emission of greenhouse gases into the atmosphere explains a large proportion of Northern Hemisphere, arctic, and global warming (increases in temperature) in recent years [1], [6], [11], [14], [18], [19], [21],[22],[24]-[27].

The increase atmospheric carbon dioxide is primarily caused by increase burning of fossil fuel for both domestic and industrial purposes and secondarily by changes in land use [28], [29]. Authors of reference [30] report of annual atmospheric carbon dioxide increase of 1.5 percent from pre-industrial level of 250-280 ppm (per part molecule) to post industrial level of about 360 ppm. In assessing their CLIMER 2 model authors of reference [31] indicated that carbon dioxide was the dominant climate forcing since 1900. Their model determined that carbon dioxide warmed effect of 0.5 ^{0}C during the period 1900-1990 with solar irradiance yielding 0.2 ^{0}C within the same period. According to [23] the causal relationship between greenhouse emissions and global climate change and temperature increases is an established fact. He indicated the present carbon dioxide concentration of 372 ppm is higher than any period within the past 420,000 years. Though his observation is global in nature yet its local consequences are obvious that require careful mitigation measures with respect to the already built greenhouse gases momentum, especially carbon dioxide emissions into the atmosphere over the years.

The author of reference [26] in his article 'Global temperature hits record again' cited James Hansen's (Greenhouse expert) remark that the green house warming is here. Hansen based his conclusion on three climatic models that simulated global increasing temperature trend for the 1990s. Also, he attributed the 1990s increasing temperature to increasing greenhouse gases emission into the atmosphere. In a related study the authors of reference [22] indicated that in all 1990, 1991, 1997, and 2000 were the four most hottest years on record with a tie for the 1991 and 2000 periods. Though the author of reference [26] intimated that other Climatologist are not in complete synch with Hansen's assertion the findings and observations of other studies reported by references [1], [6], [11], [13]-[16], [18], [19], [21], [22]-[27], [32] attest to the increasing influence of greenhouse gases on global warming. For instance, greenhouse gases emissions in the atmosphere, particularly carbon dioxide emissions was attributed to the warming of the past century of about 0.5-0.6 ^{0}C [23], [22], [31], [14], [13], [29], [16], [27], [33]. Prior to Hansen's 'declaration' of the onset of the greenhouse effect as major contributing factor of global warming [28], Damon and Kunen [33] stated in their study 'global cooling?' that "if the carbon dioxide greenhouse effect causes global warming trend, it will most probably become apparent first in Antarctica".

The authors of reference [33] observed warming trends in five out of six Antarctica weather stations used in their study. They postulated that increase in solar energy and carbon dioxide driven greenhouse effect were expected to create increase temperature in Southern Hemisphere between 1960 and 1964 relative to Northern Hemisphere cooling due to changing albedo underpin by manmade pollution and intensity of volcanism. This assertion has largely been confirmed over about 40 years span typified by recent melting of Antarctica ice, especially along the Antarctic peninsula, which provides an observable evidence of the effect of greenhouses gases driven global warming [34]-[38]. Average temperature of Antarctic peninsula has increase over the years to about –5 ^{0}C above that of the whole continent mean temperature of –37 ^{0}C where in about two months of the year this area experience temperatures above freezing point (0 ^{0}C) [39]. In relation to the influence of greenhouse gases on global temperature change the author of reference [24] based on the results of 1, 000 year temperature analysis concluded that natural variability is subsidiary to anthropogenic increases in greenhouse gases. He asserted that anthropogenic increases in greenhouse gases offer a more parsimonious explanation for the 20th century warming. Also, he confirmed that the greenhouse effect is already here and that it accounted for about 25 percent of temperature variability of the Northern Hemisphere for the 20th century. Authors of reference [32] found that gradual increases in atmospheric carbon dioxide is associated with arctic warming with relative increases in late fall and winter maximum and summer minimum air temperatures over the arctic ocean and its surrounding areas. The author of reference [16] observed a global warming pattern consistent with the logarithm of atmospheric carbon dioxide concentration whose effect he noted could be worse than previously thought. Additionally, the authors of reference [14] largely attributed anthropogenic components to the global warming that occurred between 1946 and 1996. The authors of reference [25] used sea ice data, one of the important proxies for climate change to examine the impact of anthropogenic influence on global warming. They found that the observed warming of Northern Hemisphere sea ice extent is associated with greenhouse-warming.

Related to greenhouse gases is global radiative forcing, which exerts considerable impact on global climate change. The authors of references [15], [28] confirmed that global climate is very sensitive to global radiative forcing. They mention that for the past 20 years the growth rate of greenhouse gases climate forcing declined to about $0.3W/m^2$/year due to the reduction in carbon dioxide and the dipping of chlorofluorocarbons and methane growth rates. Furthermore, they mentioned the rapid increasing influence of cumulative greenhouse gases. In examining the global warming trend since the industrial revolution the authors of reference [15], [28] concluded that anthropogenic aerosols alone yielded very little forcing. The authors of reference [12] recounted that based on the approximately 11 year solar cycle mean land air temperature of the Northern Hemisphere could be related to the long term variability in solar activity prior to 1990. Using more data since 1990 they found that this assertion cannot be fully substantiated giving the observed changes since 1990. Rather solar activity with decadal smoothing accounted for about two-thirds of the climate change 1861 to 1989 though its explanatory power has waned. Instead, it accounts for about half of the variance of Northern Hemisphere land air temperature change since 1990. They admitted the application of smoothing technique in their analyses for both pre and post 1990 largely improved their results. The authors of reference [40] found that long term changes in solar activity influence terrestrial activity. Their model which used suitable parameters of terrestrial climate mainly Northern Hemisphere land air temperature and possibly more direct measure of solar activity such as solar cycle length produced a model with better goodness of fit. Their model was an improvement of that stated in reference [41] that employed one dimensional ocean thermal model of the work of the authors of reference [42]. They underscored the fact that traditionally sun and weather association has been criticized for lack of physical mechanisms that account for this relationship and the poor statistical significance of the correlation between them. To conclude their 1991 study the authors of reference [40] argued that if the result of their study that argue in favor of solar activity as the one of the primary forces of global temperature change could be related to real physical mechanism then it is probable for a better assessment of greenhouse warming signals and long term climate changes to be achieved through appropriate modeling of the sun's dynamics. In achieving this would allow for firm conclusions to be made in respect of the full impact of anthropogenic changes on climate change [12], [40].

In examining the arctic environmental change for the last four centuries the authors of reference [13] also cautioned that natural climate forcing mechanisms needs to be accounted for before any firm conclusions about anthropogenic influence of recent arctic warming can be made. They added that an analysis of both 18^{th} and 20^{th} century arctic temperature increases indicate that solar forcing played a role. Findings of these studies largely confirm that global warming is real and the role of anthropogenic forcing cannot be ignored in creating and sustaining the current trend. Further increase in greenhouse gases has the potential for compounding the current impact of solar irradiance on global warming.

Conversely, other climate change researchers view the claim that greenhouse forcing is the principal factor responsible for the increases in temperature over the past decades as inconclusive basing on the premise that these studies do not control for all other important factors that create global temperature increases [43]. For instance, authors of reference [40] reported that model simulations driven by their basic assumptions do not present long term time series of fundamental quantities. This assertion was based on the reliance of the scientific community on model simulations due to the seemingly lack of realistic global scale experiments that effectively assess and elucidate the effect of increasing release of carbon dioxide emissions into the atmosphere. In relation to the limitations of simulated models and the apparent lack of global experiments on carbon dioxide driven greenhouse effects on global warming, the author of reference [43] in reporting the proceedings of the 2004 IPCC workshop on climate sensitivity questioned the severity of greenhouse gases emissions in determining global warming and how would the world be as result of this effect? He lamented that about 25 years of climate research and estimating global warming trends has not produced any conclusive results but have only confirmed Charney's subjective 1.5 to 4.5 0C temperature sensitivity range based on Manabe and Hansens' model predictions. He blamed the status quo (hand-waving climate models) that could not provide conclusive and agreed upon climate sensitivity model range. He cited for example the disagreement between two basic climate models: NCAR and GEDL in respect of the differential simulation of cloud effects by making two opposing assumptions. For instance, he noted that the NCAR model assumes increase in the amount of low level cloud whiles the reverse holds for the GEDL model. As a result, whiles the NCAR model predicts wet conditions over the conterminous United States the GEDL model predicts dry conditions.

Nonetheless, the authors of reference [15] argued that climate analyses offer appropriate and flexible means of differentiating climate forcing from climate feedbacks as they reflect the time scale considered and the intended use. They explained that when quantities that are normally considered as fixed boundary conditions are represented as forcings into current global climate models, the empirical climate sensitivity is comparable to the model sensitivity. This largely suggests that irrespective of the differences in the basic assumptions and the time period within which climate change forcings are derived due to data limitations, their results often portray similar general trend of climate change. So far as empirical climate sensitivity measurement of climate change is still in its incipient stages or perhaps in the youthful stage, climate models that are based on reasonable assumptions will remain a viable option for the early part of this century. The application of sophisticated climate models and subsequently improved versions of such models based on the help of more

powerful computers in addition to the improved understanding of atmospheric processes would improve the explanatory and predictive power of climate models as indicated by reference [43]. This suggestion considers the need for more empirical climate change sensitivity analysis to complement the results of the improved model sensitivity analysis so as to help provide realistic models that offer better explanations for climate change over the years.

III. Conclusion

To conclude, the present study argues that if climate scientist and policymakers ignore the anthropogenic influence (greenhouse gases) on global warming on the pretense of lack of agreement among various climate models and their inability to account for all the necessary factors of global warming at all levels the current efforts of greenhouse emissions control and global warming as a whole could be exacerbated.

Observable ecological and environmental impacts of global warming on Arctic and Antarctic land cover change, one of the world's most stable ecological zones supports this argument. Furthermore, the present study suggests that attempts to mitigate the impact of greenhouse effect would require the intensification of programs, project, bilateral, and international protocols that aim at lowering the current rate of greenhouse gas emission and other atmospheric forcing factor that positively influence global warming beyond the acceptable range in order to help create suitable ecological and atmospheric conditions and the interrelationships between them.

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