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Mitigate or Adapt?

Graham T Reader*
Department of Mechanical, Automotive and Materials Engineering, University of Windsor
401 Sunset Ave, Windsor, ON, Canada

Abstract
Any changes in climate prior to the 19th century are attributed to natural causes, largely due to external factors. However, since 1992 such natural climate changes have been defined as climate variabilities by the United Nations Framework Convention on Climate Change (UNFCCC). Modern changes in climate, using the same framework, are presumed to be caused by human activities, especially from the emissions of Greenhouse Gases (GHG) generated from the combustion of fossil fuels. Subsequently, instead of humans finding ways to adapt to changes in climate by such measures as migration, precipitation harvesting, flood prevention, and irrigation, mitigation has become the approach to reducing the harmful effects of climate change with the main focus being on reducing Carbon Dioxide emissions by energy use transitions to renewable and sustainable sources such as solar, wind, and water. The overall aim of mitigation being, not only to reduce anthropogenic impacts on climate, but also to eventually end them and, maybe, even reverse their effects. But can mitigation eradicate non-human climate variabilities? If GHG emissions are removed from the atmosphere will that prevent volcanic activity, earthquakes, cryosphere melting, extreme weather events, sea-level rise, and the orbital effects of Milankovitch cycles? The probability of mitigation counteracting the natural effects of volcanoes, earthquakes, and orbital causes, range from unrealistic to impossible. However, climate models suggest that mitigation inhibits ice melts, reduces the number and severity of weather events, restricts, or eliminates, sea-level rises, and limits increases in land and ocean surface temperatures. But how long will it take for mitigation to fulfil its promise? In the meantime, should adaptation measures be encouraged to constrain the harmful effects of both natural and anthropogenic climate drivers? In this short paper, a background discussion about whether mitigation or adaption should be pursued separately, or in an efficacious combination, is introduced.

1. Introductory Comments

The appropriation of the term ‘Climate Change’ by the UNFCCC has likely caused confusion among the general population and prompted some of the disagreement in the scientific community debates. Those who have commented that changes in the climate have always occurred are often vilified and disparagingly labelled *deniers*. This situation is regrettable, but the confusion and the scientific challenges has roots in the assertion that climate change is due to human activities alone as pronounced in the initial reports of the UN’s main scientific source, the Intergovernmental Panel on Climate Change (IPCC), and in the stated ‘green’ policies of the political governments of the associated UN countries. Providing, an example of what could be described as a *humpty-dumpty* definition [1], i.e.,

> “*When I use a word,” Humpty Dumpty said in rather a scornful tone, “it means just what I choose it to mean — neither more nor less”. “The question is,” said Alice, “whether you can make words mean so many different things*”.

Can it then be assumed that, prior to the arrival of humans, the Earth experienced no changes in climate? Palaeoclimatological studies, i.e., the what, when, and why of the Earth’s climate since its formation about 4.6 billion years ago, have shown many changes in climate [2,3]. The studies have identified several factors as climate ‘influencers’ which continue to contribute to these changes and some scientists have concluded that the ‘greenhouse-effect’ has always been the main climate ‘controller’, mainly the variations in the levels of atmospheric Carbon Dioxide (CO_2). Other influencers, such as deviations in solar irradiance and cosmic rays are said to have only a small effect on climate, except in a few extreme cases, which are rare and temporary [2]. Not all scientists agree [4,5]. Perhaps such disagreements are an inherent characteristic of the ubiquitous *scientific method*, compounded by the need for more hypothesis testing data. Despite the age of the Earth, methodical measurements of atmospheric CO_2 concentrations, using scientific instruments, did not start until the middle of the last century. Comparable quality surface temperature measurements have a slightly longer history, being available from the 1850s. How then can there be definitive statements about past climates and their changing nature? The answer is, by using ‘proxies’ such as ice cores, tree-rings, and geological analyses. Subsequently, by using climate models, efforts can be made to replicate the proxy and measured data by finding possible causes for changing climates and assessing their impact on the quality of the model replication. This parametric-type approach has led to CO_2 atmospheric concentrations being considered the main cause of historical, and current, changes in climate; albeit that by volume CO_2 only accounts for 0.0407% of the current atmosphere [6]. Nevertheless, this miniscule proportion, and tiny changes in its level, are believed to be the main influence on anthropogenic climate change and the key disrupter of climate stabilization.

A certain amount of atmospheric CO_2 is a necessary contributor to the *greenhouse-effect* which keeps the Earth at habitable and ecologically beneficial temperatures. But what are these temperatures, i.e., is there an ideal average surface temperature? There appears to be no definitive answer in the available encyclopedic scale literature on *global warming*, especially since the pre-industrial period[i] prior to 1750 CE[ii]. what is the Earth's ideal surface temperature? There appears to be no definitive answer in the available encyclopedic scale literature on *global warming*, especially since the pre-industrial period[iii] prior to 1750 CE. At that time, according to the *proxy* data, the global surface temperature was 13.42^0C [7], but in the 20th century the measured global average land and ocean surface temperate was only 12.7^0C, which, by 2020, had risen to 13.86^0C [8]. However, others suggest that the average temperature over the last century was 13.9^0C, which, by 2019, had increased to 14.85^0C [9]. Such differences could be construed as unhelpful, but illustrate the difficulties encountered when attempting to be definitive about average absolute[iv] temperatures and probably explains why climate scientists prefer to use temperature anomalies i.e., differences between average temperatures over a given period of time, compared to a baseline average computed over another specific time span. Defining a baseline is therefore important when defining temperature anomalies, so when the members of the UNFCC formulated the 2015 Paris Agreement on climate change the chosen baseline was the *pre-industrial* period and the goal was to limit global warming in this century by achieving a temperature anomaly "*to well below 2, preferably to 1.5^{0}C*" compared to this period [10].

So, why not add this targeted anomaly to the actual average temperature of the chosen baseline to provide the public with a definitive and understandable mean global temperature limit? Is this because the strength of messaging on climate change would be diluted by saying the temperature must be limited by 2100 to less than 1% higher than 1750, using the Kelvin temperature scale? The most likely answer is yes, but, in general, the Kelvin scale is only regularly used by engineers and scientists. A stronger message could be communicated if the Celsius (centigrade) scale was used as 15.42/13.42 would yield a 14% higher temperature limit; albeit, the difference between a Celsius and Kelvin increase being a quirk of definition. Perhaps then the temperature anomaly approach is more efficacious, provided the baseline is clearly stated? But here again there can be problems, since there are contradictions in exactly *what is the pre-industrial period*. The IPCC and UNFCC have chosen the 51-year period, 1850-1900, as defining the pre-industrial period, almost a century later than the acknowledged start of the 1st Industrial Revolution [11] and the preferred 1.5^0C increase limit is based on this baseline. However, the NASA global temperature website bases their anomaly charts from 1880 onwards on a baseline of 1951-1980 [12].

Furthermore, despite the Paris Agreement baseline choice, the IPCC's *Special Report on Global Warming of 1.5^{0}C* adopted a more detailed working definition of the target anomaly, i.e., a limiting increase of 1.5^0C warmer than 1851-1900 period **or** 0.87^0C more than 1986-2005 **or** 0.67^0C above the 2006-2015 average [13]. Therefore, in assessing how much mitigation is needed, there is no target average global temperature, but only temperature anomaly targets based on differing baselines, which are probably not known or taken cognisance of by the public. Given that it can be somewhat tricky to measure mitigation success using surface and ocean temperatures, actual or anomalous, is there a more convincing yardstick? There is global acceptance of the CO_2 concentration data from the Mauna Loa observatory in Hawaii [14], and as there are frequently published correlations between average surface temperatures and atmospheric CO_2 levels, then reductions in GHG levels should be followed by temperature declines. Would CO_2 measurements then supply a better benchmark for mitigation success? Maybe, but it is also true that there are regional and historic instances where temperature rises happen before CO_2 concentration growth, but, even in these circumstances, the higher CO_2 levels can eventually amplify the temperature increases [15]. So, what does all this mean? If mitigation is the strategy to combat UNFCCC climate change then authoritative measures of strategic success will be tenuous until universally accepted data becomes available. But can we wait until the end of the century? Perhaps the best that can be done is to use the continually improving hundred or so climate change models to predict the impacts of mitigation under various what-if scenarios? However, the accuracy of models' predictions to-date have not been very encouraging.

Regardless of the scale of success that particular mitigation strategies achieve there is measurable proof that changes in climate are taking place in many global regions especially as measured by sea-level rises, albeit that *sea-*

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[i] There appears to be some disagreement about the exact date.
[ii] A google scholar search of global warming articles yields 2,360,000 references and citations
[iii] There appears to be some disagreement about the exact date.
[iv] Not in the thermodynamic sense using the Kelvin scale.

level is an surprisingly difficult concept to define. If the trends in such rises are well documented and substantiated, then it would be remiss not to construct suitable and proper sea-wall defences around the impacted population centres. Such an approach would be an obvious example of adaptation. But, if eventually mitigation were to prove successful, would immediate or short-term adaptation be necessary solely as a *band-aid* solution until ample mitigation successes are achieved. Conceivably, a parallel modern context could be whether face masks, social distancing, and lock-downs will suffice until efficacious vaccines for all become available in combating a global pandemic. In both cases the nuances are likely to be *costs*, human, societal, and economic.

2. Mitigation and Adaptation

As the climate debates began in earnest with the UNFCCC declarations of the 1990s, and the subsequent IPCC Assessment Reports (ARs) which underpin the Paris Agreement, in any discussion of mitigation and adaptation it is arguably valuable to consider how these strategies are defined in these documents. It also needs to be emphasised, especially for post-secondary students, that IPCC reports incorporate a wealth of information and encyclopedic literature reviews and that individual chapters are multi-authored. It would be neglectful for any scholar or researcher to take no account of these publications in their climate studies. Unfortunately, the sections known as *Summaries for Policymakers* (SPM) do not always fully reflect the content of the individual chapters and this can lead to cavalier and misleading quotations in the media. In the author's opinion, SPMs tend to be as much political and agenda-driven as scientific, but the peer reviewed main chapters present high-calibre, scientific, studies, even if, at times, the stated confidence and certainty levels may be revealed, ultimately, as somewhat inflated. The scale of the recent AR studies on adaptation and mitigation can be gauged by the details of AR5 as summarized in Table 1. It would be sensible for post-secondary students, their teachers, and researchers not to ignore such a comprehensive collection of peer-reviewed material.

Table 1. IPCC AR5 [16], Working Group Main Report Statistics

AR5 Working Group Number	Description	Number of Pages of Main Report	Lead & Contributing Authors	Number of References/Citations	Reviewers
1	Physical Science Basis	1,552	809 (209 Lead/600+ Contributing)	>9,200	1,089
2	Impacts, Adaption, Vulnerability	1,846 (1150-Part A; 696 Part B)	678 (242 Lead/436 Contributing)	>12,000	1,729
3	Mitigation of Climate Change	1,454	411 (235 Lead/176 Contributing)	~10,000	1,046
	Synthesis*	169			
All		5,021	1,898	~31,000	3,864

*Distils and Integrates the findings of AR5 Working Groups 1-3 and incorporates the findings of IPCC Special Reports (a) *Renewable Energy Sources and Climate Change Mitigation* and (b) *Managing the Risks of Extreme Events and Disasters to Advanced Climate Change Adaptation*.

The precise wording of the definitions of Mitigation and Adaptation has changed since the first UNFCCC and IPCC statements, almost 3 decades ago. In AR5 the reason for the amendments to adaptation is *progress in science* while for Mitigation, substances other than GHGs are included in the definition [17]. These added substances have long been named as criteria air pollutants by many countries. Shortened forms of these definitions are,

> "Adaptation: *The process of adjustment to actual or expected climate and its effects*".
> "Mitigation: *A human intervention to reduce the sources or enhance the sinks of greenhouse gases….*{including}*….human interventions to reduce the sources of other substances which may contribute directly or indirectly to limiting climate change.*"

Although the AR5 report has emphasized the virtues of both Adaptation and Mitigation, global finance investments and strategies have, almost without exception, focused on mitigation activities. These activities attracted $537 Billion US (93%) of total finance in both 2017 and 2018, which represents over 50% more, in US $ terms, than in 2010/11, but with a slightly smaller proportion, 93% v 96% [18,19]. This level of financial investment is a discernible demonstration, perhaps, of the '*prevention is better than cure*'[v] approach, which underpins the medical and health sciences approach to disease control, as embedded in many national government policies [e.g., 20]. One dictionary explanation of the phrase is, "*It is better to stop something bad from happening than it is to deal with it after it has happened*" [21]. Could this philosophy be used to clarify the differences between mitigation and adaption? The answer is both yes and no. Mitigation is aimed at preventing something bad from happening i.e., anthropogenic climate change, but many climate scientists assert that something bad has already happened and the situation is likely to get worse. If this is the case, then, arguably, any mitigation measures could be viewed as a form of adaptation, at least until the anthropogenic climate change situation stabilizes. But, how will it be known when this condition is achieved? As already noted, there are uncertainties surrounding global mean surface temperature estimates and precise CO_2 correlations. Indeed, a targeted CO_2 concentration level does not necessarily create a specific mean global temperature, or temperature anomaly, which can be used by politicians as a measure of mitigation success [22]. For now, there is only general political agreement that the average global temperature rise *should be* limited to no more than 2^0C, and preferably lower, by 2100. Any increase above 2^0C is depicted as being climatically dangerous. Yet, by some estimates the global temperature had already increased 1.1^0C by 2020 [23].

Whether the *should-be* limit can be achieved is a matter of intense discussion and analysis. If the use of fossil fuels were to be banned, it is hypothesised that global warming would continue and it would take at least four decades for the global temperature to stabilize, but at a higher level than experienced at the time of the prohibition [24]. As cutting fossil fuels is a cornerstone of mitigation strategies, then the consequent time-lags palpably reinforces the need to adapt to continually rising temperatures. Whatever the issues associated with defining targets and benchmarks it is obvious that both mitigation and adaptation strategies will be necessary to address the Paris Agreement goals. It can also be argued that adaptation improvements will need to be continual, even after mitigation is believed to be a success, so that adverse, albeit relatively temporary, natural changes in climate, floods, droughts and so on, can be tackled as the need arises. The challenge will be how to fund these improvements to account for all eventualities. But what if the *eventuality* is an annual, or a *10-year*, or a *100-year*, or even a *500-year occurrence?* The likelihood of these occurrences, and their impact, should be a key element of adaptation.

The USGS (United States Geological Survey) suggest that the term *recurrence interval* is a better description than the sometimes-misleading use of remarks such a 100-year flood. Moreover, it could be that two comparable events, e.g., heavy floods, occur at the same location only a few years apart rather than say a gap of 100 years. To address such issues, "the USGS and other agencies" use a factor called the *Annual Exceedance Probability* (AEP) in conjunction with a recurrence interval, so if a 100-year occurrence has an AEP of 0.1(10%) it means there is a 10% chance of occurrence in any given year [25]. It has been seen that uncontrolled Anthropogenic climate change is causing more frequent and intense weather events [26, 27], then factors such as AEP and recurrence interval, and their impacts, should be a key element of adaptation.

3. Concluding Remarks

Adaptation, while lessening the impact of climate variability on some local and regional populations, will likely make little immediate impression on the Paris Agreement emission targets, unless used to complement Mitigation, and in some manner, help moderate the possible societal severity of the necessary anthropogenic climate change actions. Likewise, Mitigation could be accompanied by non-climate change benefits positively affecting adaptation [28] Alone Mitigation or Adaptation will be insufficient to address both the climate change and climate variability concerns as expressed in the Paris Agreement and in the IPCC's AR5. How then can they be used together in a sustainable synergistic matter to achieve all the desired outcomes? These matters will be addressed at the *2021 Thriving Through Climate Change and Pandemic*, Symposium, and Industrial Summit to be held at the University of Windsor, Windsor, Ontario, Canada 24-25 June [29]. Consequently, this paper should be regarded has an *extended abstract* for a keynote

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[v] A tenet attributed to the Dutch philosopher Desiderius Erasmus at the start of the 16th century.

presentation to be given at the Symposium and Summit. A longer and more inclusive paper will be the subject of a chapter '*Defeating the impacts of changing climates*' in a future Springer book [30]. This chapter will include consideration of some aspects of the mitigation and adaptation strategies and scenarios comprehensively reviewed in the technical summaries of AR5 [31,32] with a focus on energy transitions and CO_2 sequestration. The use of *climate indices*, such as AEP, to measure and assess the possible impacts of changing climates on concerns such as regional water scarcity will be explained. Brief comments on national plans for a zero-carbon future by 2050 will be made using the recent publication by the UK's Climate Change Committee as the exemplar [33].

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