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A Study on the Case of Global Warming and Climate Change

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ABSTRACT: *Global warming has become familiar to many people as one of the most important environmental issues of our day. Associated with this warming are changes of climate. The basic science of the greenhouse effect that leads to the warming is well understood. Global warming is a phrase that refers to the effect on the climate of human activities, in particular the burning of fossil fuels (coal, oil and gas) and large scale deforestation, which cause emissions to the atmosphere of large amounts of greenhouse gases of which the most important is carbon dioxide. Such gases absorb infrared radiation emitted by the earth's surface and act as blankets over the surface keeping it warmer than it would otherwise be. Climate is the average weather conditions experienced in a particular place over a long period. Turkey is one of the sensitive areas to climate variation in the world. Many of the likely characteristics of the resulting changes in climate (such as more frequent heat waves, increases in rainfall, increase in frequency and intensity of many extreme climate events) can be identified. Adaptation to the inevitable impacts and mitigation to reduce their magnitude are both necessary. International action is being taken by the world's scientific and political communities. Because of the need for urgent action, the greatest challenge is to move rapidly to much increased energy efficiency and to non fossil fuel energy sources.*

Keywords: *Global warming, Climate change, Adaptation, Environmental, Weather conditions*

I. INTRODUCTION

The basic principle of global warming can be understood by considering the radiation energy from the sun that warms the earth's surface and the thermal radiation from the earth and the atmosphere that is radiated out to space. As commonly understood, global warming refers to the effect on the climate of human activities, in particular the burning of fossil fuels (coal, oil and gas) and large scale deforestation activities that have grown enormously since the industrial revolution, and are currently leading to the release of about seven billion tonnes of carbon as carbon dioxide into the atmosphere each year together with substantial quantities of methane, nitrous oxide and chlorofluorocarbons. These gases are known as greenhouse gases.

For the last 150 years, direct instrumental data have been available that enable a construction to be made of changes in the global near surface air temperature. The increase in temperature over the 20th century is particularly striking. The 1990s are very likely to have been the warmest decade during this period and the year 1998 the warmest year. A more striking statistic is that each of the first eight months of 1998 was the warmest of those months in the record. Although there is a distinct overall trend, the increase is by no means uniform. In fact, some periods of cooling as well as warming have occurred and an obvious feature of the record is the degree of variability from year to year and from decade to decade. An obvious question to ask is whether the effects of human activities are significant against the background of natural variability [1, 2].

We have seen that climate change is complex and variable both in space and time. The likely impacts on human communities and ecosystems will also be complex. There is also much variability in important factors relevant to climate change such as sensitivity (i.e. the degree to which a system is affected either adversely or beneficially), adaptive capacity (i.e. the ability of a system to adjust) and vulnerability (i.e. the degree to which a system is susceptible to or unable to cope with adverse effects). Different ecosystems, for instance, will respond very differently to changes in temperature, precipitation or other climate variables. For humans, it is the least developed countries that in general are most vulnerable; they are likely to experience more of the damaging climate extremes and also have less capacity to adapt.

A few impacts of climate change will be positive so far as humans and ecosystem productivity are concerned. For instance, in parts of Siberia or Northern Canada increased temperature will tend to lengthen the growing season with the possibility of growing a greater variety of crops. In some areas, increased carbon dioxide will aid the growth of some types of plants leading to increased crop yields. However, because over centuries human communities have adapted their lives and activities to the present climate, most changes in climate will tend to produce adverse impacts. If changes occur rapidly, urgent and possibly costly adaptation to a new climate will be required by the affected community. An alternative might be for that community to migrate to a region where less adaptation would be needed a solution that has become increasingly difficult or, in some cases, impossible in the modern crowded world [3]. Further, adverse impacts are likely to lead to insecurity and conflicts particularly due to increased competition for scarce resources.

The assessment of climate change impacts, adaptations and vulnerabilities draws on a wide range of physical, biological and social science disciplines and consequently employs a large variety of methods and tools. It is, therefore, necessary to integrate information and knowledge from these diverse disciplines. Such a process is often known as Integrated Assessment. Assessment of the impacts of global warming is also made more complex because global warming is not the only human induced environmental problem. Loss of soil and its impoverishment (through poor agricultural practice), over extraction of groundwater and damage due to acid rain are examples of environmental degradations on local or regional scales that are having a substantial impact now [4].

The global water cycle is a fundamental component of the climate system. Water is cycled between the oceans, the atmosphere and the land surface. Water is also an essential resource for humans and for ecosytems. During the last 60 years water use has grown over threefold [5]; it now amounts to about 10% of the estimated global total of river and groundwater flow from land to sea. Increasingly, water is used for irrigation. In Turkey about 75% of available water is so used. Water from major rivers is often shared between nations; its growing scarcity is a potential source of conflict. In many areas, groundwater extraction greatly exceeds its replenishment a situation that cannot continue indefinitely. With global warming, there will be substantial changes in water availability, quality and flow. On average, some areas will become wetter and others drier. Substantial changes in variations of flow during the year will also occur as glaciers and snow cover diminishes leading to less spring melt. Much of these changes will exacerbate the current vulnerability regarding water availability and use. Especially vulnerable will be continental areas where decreased summer rainfall and increased temperature result in a substantial loss in soil moisture and increased likelihood of drought [6].

Impacts of climate change on fresh water resources are likely to be exacerbated by other pressures, e.g. population growth, land use change, pollution and economic growth. Some of the adverse impact on water supplies can be reduced by taking appropriate alleviating action, by introducing more careful and integrated water management [3] and by introducing more effective disaster preparedness in the most vulnerable areas. Substantial uncertainties remain in knowledge of some of the feedbacks within the climate system (that affect the overall magnitude of change) and in much of the detail of likely regional change. Because of its negative impacts on human communities (including for instance substantial sea-level rise) and on ecosystems, global warming is the most important environmental problem the world faces. The largest contribution to sea-level rise in the 21st century is expected to be from the thermal expansion of ocean water as it warms. Calculation of the precise amount of expansion is complex because it depends critically on the water temperature and also because of the long time taken (decades to centuries) for warming at the surface to penetrate to lower ocean levels [7].

About 10% of the world’s land area is under cultivation. The rest is to a greater or lesser extent unmanaged by humans, of this about 30% is natural forest. Within this area climate is the dominant factor determining the distribution of biomes. Large changes in this distribution have occurred during the relatively slow climate changes in the past. It is the very rapid rate of change of climate that will cause excessive stress on many systems. How much it matters depends on the species and the degree of climate change (e.g. temperature increase or water availability). Two particularly vulnerable types of species are trees and coral. The viability of some large areas of tropical forests under climate change is of especial concern. Many corals are already suffering from bleaching caused by increased ocean temperatures. Further, as large quantities of extra carbon dioxide are dissolved in the oceans, their acidity increases posing a serious threat to living systems in the oceans especially to corals [4].

The Intergovernmental Panel on Climate Change (IPCC) was formed jointly by two United Nations bodies, the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) with a remit to prepare thorough assessments of climate change, its causes and effects. The panel established three working groups, one to deal with the science of climate change, one with impacts and a third with policy responses. The IPCC has produced three main comprehensive reports, in 1990, 1995 and 2001 together with a number of special reports covering particular issues. Three important factors have contributed to the authority and success of the IPCC’s reports [8-10]. The first is the emphasis on delineating between what is known with reasonable certainty and what is uncertain differentiating so far as possible between degrees of uncertainty. The second is the involvement in the writing and reviewing of the reports of as many as possible of the world’s climate scientists, especially those leading the field. For the third assessment report in 2001, those taking part had grown to 123 lead authors and 516 contributing authors, together with 21 review editors and 420 expert reviewers involved in the review process. The thorough debate by scientists during the assessment process ensures that the scientific community is well informed on a broad front. No previous scientific assessments on this or any other subject have involved so many scientists so widely distributed both as regards their countries and their scientific disciplines. A third factor arises because the IPCC is an intergovernmental body and governments are involved in its work [4].

Despite the fact that the terms global warming, climate change and greenhouse effect are related to one another, climate change is predominantly on the agenda today, overwhelmingly. The details of human interaction with the environment, and especially with the atmospheric environment, have become clearer in the last 30-40 years. These details include future droughts and low flows, wetness and high (flood) currents, global cooling and warming. There are countless benefits for every society, country and region in various national and international meetings about the rational and participatory solutions of climate change, as well as the study of climate change from the scientific, political, social, economic and sustainability perspectives. The assessment considers new evidence of past, present and projected future climate change based on many independent scientific analyses from observations of the climate system, paleoclimate archives, theoretical studies of climate processes and simulations using climate models. This paper will describe the basic science of global warming, its likely impacts both on human communities and on natural ecosystems and the actions that can be taken to mitigate or to adapt to it.

II. GLOBAL CHALLENGES: CLIMATE CHANGE

Observations of the climate system are based on direct measurements and remote sensing from satellites and other platforms. Global scale observations from the instrumental era began in the mid 19th century for temperature and other variables, with more comprehensive and diverse sets of observations available for the period 1950 onwards. Paleoclimate reconstructions extend some records back hundreds to millions of years. Together, they provide a comprehensive view of the variability and long-term changes in the atmosphere, the ocean, the cryosphere, and the land surface. Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (high confidence). It is virtually certain that the upper ocean (0-700 m) warmed from 1971 to 2010, and it likely warmed between the 1870s and 1971. Proxy and instrumental sea-level data indicate a transition in the late 19th to the early 20th century from relatively low mean rates of rise over the previous two millennia to higher rates of rise (high confidence). It is likely that the rate of global mean sea-level rise has continued to increase since the early 20th century.

Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system (Figure 1). The long-term climate model simulations show a trend in global mean surface temperature from 1951 to 2012 that agrees with the observed trend (very high confidence). There are, however, differences between simulated and observed trends over periods as short as 10 to 15 years (e.g., 1998 to 2012). Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions. Climate change will affect carbon cycle processes in a way that will exacerbate the increase of carbon dioxide in the atmosphere (high confidence). Further uptake of carbon by the ocean will increase ocean acidification [11].

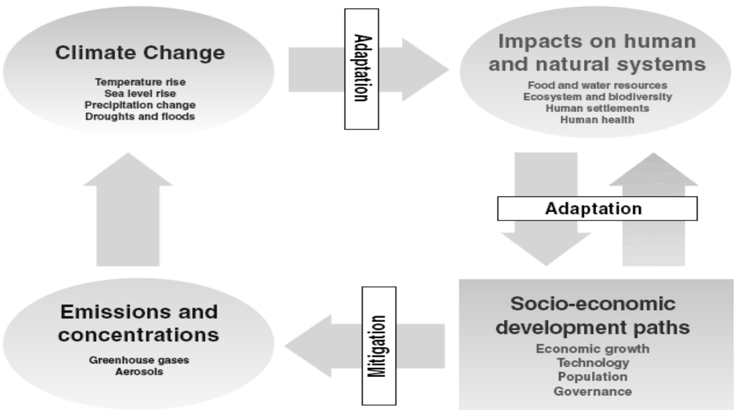

Figure 1. Climate change system in the world

The observed reduction in surface warming trend over the period 1998 to 2012 as compared to the period 1951 to 2012, is due in roughly equal measure to a reduced trend in radiative forcing and a cooling contribution from natural internal variability, which includes a possible redistribution of heat within the ocean (medium confidence). However, there is low confidence in quantifying the role of changes in radiative forcing in causing the reduced warming trend. The global ocean will continue to warm during the 21st century. Heat will penetrate from the surface to the deep ocean and affect ocean circulation. There is medium confidence that natural internal decadal variability causes to a substantial degree the difference between observations and the simulations; the latter are not expected to reproduce the timing of natural internal variability [12]. There may also be a contribution from forcing inadequacies and, in some models, an overestimate of the response to increasing greenhouse gas and other anthropogenic forcing (dominated by the effects of aerosols).

The rate and magnitude of global climate change is determined by radiative forcing, climate feedbacks and the storage of energy by the climate system. Estimates of these quantities for recent decades are consistent with the assessed likely range of the equilibrium climate sensitivity to within assessed uncertainties, providing strong evidence for our understanding of anthropogenic climate change. Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions [13].

Cumulative emissions of carbon dioxide largely determine global mean surface warming by the late 21st century and beyond. Most aspects of climate change will persist for many centuries even if emissions of carbon dioxide are stopped. Cumulative total emissions of carbon dioxide and global mean surface temperature response are approximately linearly related. Any given level of warming is associated with a range of cumulative carbon dioxide emissions, and therefore, e.g., higher emissions in earlier decades imply lower emissions later. A lower warming target, or a higher likelihood of remaining below a specific warming target, will require lower cumulative carbon dioxide emissions [12]. Accounting for warming effects of increases in non-carbon dioxide greenhouse gases, reductions in aerosols, or the release of greenhouse gases from permafrost will also lower the cumulative carbon dioxide emissions for a specific warming target.

The water cycle describes the continuous movement of water through the climate system in its liquid, solid and vapour forms, and storage in the reservoirs of ocean, cryosphere, land surface and atmosphere. In the atmosphere, water occurs primarily as a gas, water vapour, but it also occurs as ice and liquid water in clouds. The ocean is primarily liquid water, but the ocean is partly covered by ice in polar regions. Terrestrial water in liquid form appears as surface water (lakes, rivers), soil moisture and groundwater. Solid terrestrial water occurs in ice sheets, glaciers, snow and ice on the surface and permafrost. The movement of water in the climate system is essential to life on land, as much of the water that falls on land as precipitation and supplies the soil moisture and river flow has been evaporated from the ocean and transported to land by the atmosphere. Water that falls as snow in winter can provide soil moisture in springtime and river flow in summer and is essential to both natural and human systems [14]. The movement of fresh water between the atmosphere and the ocean can also influence oceanic salinity, which is an important driver of the density and circulation of the ocean. The latent heat contained in water vapour in the atmosphere is critical to driving the circulation of the atmosphere on scales ranging from individual thunderstorms to the global circulation of the atmosphere.

2.1 Global Challenges: Energy

Energy is one of the most strategic resources and basic commodities necessary to support a modern industrialized society. Since the industrial revolution, access to commercial energy has enabled not only a better quality of life but also economic prosperity demonstrated by an increasing living standard. Abundant energy has spurred major technological and industrial development on our globe and has brought about great paradigm shifts, for example, in the way we travel. Societal development by and large has a close link to energy too. For example, the prosperous western way of life rests on almost unlimited access to energy supplies. Similarly, in the developing world, material scarcity is often connected to energy shortage.

Although energy may appear as a symbol for progress in a historical perspective, it is increasingly interlinked to the most serious global challenges of our time or even to the whole existence of the present societal structure. Energy is connected with key challenges such as climate change, environmental degradation, security, poverty, health, food production, agriculture, and water resources. Thus, when searching for better and more sustainable energy solutions, energy needs to be dealt with in a broader multidisciplinary framework considering these interconnections [15].

The best publicized negative effect from energy is climate change associated with greenhouse gas emissions from the extensive use of fossil fuels, which still constitute the bulk of our energy production and on which many emerging growing economies in Asia and elsewhere rely. These emissions increase the global temperature, which in turn may damage our ecosystems and may lead to draughts, famine, extinction of species, humanmigration, and so on. Limiting these adverse effects to a tolerable level would require more than halving the global energy related emissions by the middle of this century. The challenge to build a sustainable path towards a low carbon society encompasses amajor socio-technical transition, which requires better understanding of the influence of social, technical, and economic factors, and their interactions [16].

2.2 Global Challenges: Food, Agriculture and Nutrition

The broad complex of food, agriculture, and nutrition presents some of the greatest challenges facing the world today, not only in terms of their scale and consequences but also the difficulties faced in defining and implementing sustainable solutions. Furthermore, much of the research in this area fails to contend adequately with the complexity of the challenges presented by the global agri-food system, reflecting an inability and/or unwillingness to work across disciplinary, epistemological, and/or methodological boundaries. If achieving nutritionally adequate diets for all in the world today was not challenging enough, looking to the future there is the specter of ensuring that nine billion or more people have enough to eat while meeting growing demand for animal based foods as more and more people are lifted out of poverty. There is much debate over how to achieve this while not undermining the natural resource base and threatening environmental sustainability at the local and global levels, especially in the context of climate change.

2.3 Global Challenges: Health

Global health is a relatively new field and area of practice. For centuries, people have worried about disease and medical misfortune coming from afar, inspiring numerous international health and tropical medicine initiatives. But with hyper globalization of the last few decades, we have begun to think of health as truly global. Health is increasingly recognized as something requiring collaboration and solidarity across traditional boundaries. The good news is that global population health is improving. The past 25 years have witnessed a particularly golden era of unprecedented health achievements. Successfully addressing these global health challenges requires more than just new technology, or more medical care, or better trained health workers. It requires new knowledge and social innovations for how we govern our global society, how we finance health interventions, and how we deliver on the promise of what we already know. Such interdisciplinary perspectives on global health challenges that cross anthropology, biology, economics, engineering, epidemiology, geography, law, management, philosophy, politics, sociology, statistics and virology, and many more need a home where they will be welcomed, celebrated, criticized, and conveyed in whatever way will amplify their potential impact.

2.4 Global Challenges: Water

Water is by its very nature paradoxical. On the one hand, it is an abundant global resource at over 1400 million km^3; on the other hand, it is a scarce commodity with just 0.001% being readily available for human consumption with huge geographical variations even of that small fraction. Perhaps the most important global water challenge of all still remains: ensuring access to adequate and equitable drinking water and sanitation for all. Significant progress has been made since the Millennium Declaration in 2000. The importance of water goes beyond its links even with health and climate change. Water is intimately intertwined with other key global resources such as food and energy.

The influence of global climate change is perhaps felt most keenly by water. Both observational records and climate projections show that freshwater resources are particularly vulnerable and have the potential to be strongly impacted. Climate change also has the potential to increase intense rainfall and raise sea levels, both of which increase the risk of flooding. It has been estimated that flood damage across Europe could increase by 200% by the end of the century. The traditional stationarity concept that past hydrological experience provides a good guide to the future no longer holds, and this brings with it enormous challenges to managing water into the future [17].

III. GLOBAL WARMING

We have been familiar for a long time with problems of air quality caused by the emissions of pollutants such as the oxides of nitrogen or sulfur into the atmosphere from local sources. That is local pollution. Measures to reduce such pollution especially in major cities are actively being pursued. Global warming is an example of global pollution. Because of the long life time in the atmosphere of many greenhouse gases such as carbon dioxide, their effects impact on everyone in the world. Global pollution can only be countered by global solutions. The greenhouse effect arises because of the presence of greenhouse gases in the atmosphere that absorb thermal radiation emitted by the earth's surface and, therefore, act as a blanket over the surface (Figure 2). It is known as the greenhouse effect because the glass in a greenhouse possesses similar properties to the greenhouse gases in that it absorbs infrared radiation while being transparent to radiation in the visible part of the spectrum. If the amounts of greenhouse gases increase due to human activities, the basic radiation balance is altered.

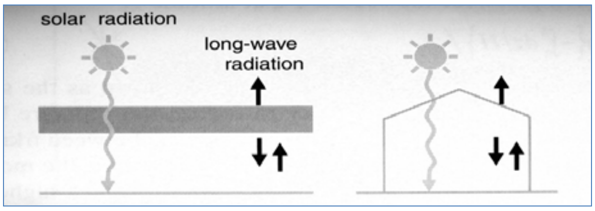

Figure 2. A greenhouse has a similar effect to the atmosphere on the incoming solar radiation

A greenhouse is a structure where protected farming is carried out and it is partly separated from its surroundings. The roof's transparency is a link between the internal microclimate and outdoor atmospheric conditions. The air exchange between the inside and outside establishes the microclimate and atmospheric conditions. A microclimate is the local modification of the general climate that is imposed by the special configuration of a small area. It is influenced by topography, the ground surface and plant cover and man made forms such as greenhouse, houses and wind breaks [18]. The basic goal of farmers that use greenhouse is to strive to provide environmental conditions which allow photosynthesis and respiration to occur so that plants grow, and that the quality is good and are marketable. Air exchange rate is one of the most important parameters of ventilation systems in a greenhouse. The ventilation systems serves the purpose of optimum control of greenhouse climatic conditions for plant growth through supply of sufficient and uniform air exchange rate, between the inside and the outside of greenhouse environments. A better air exchange rate helps reduce the greenhouse air temperature and improves the evapo-transpiration processes for crops. Ventilation and leakage rates are influenced by environmental factors such as wind speed, wind direction, temperature difference between inside and outside and ventilator aperture [19].

The thermal environment of the greenhouse arises from the complicated mass and heat exchanges between the various components of the greenhouse and the fluctuating weather conditions which present a dynamically changing greenhouse microclimate [20]. The conditions which define the microclimate of the greenhouse are the inflows and outflows and production of energy and mass as result of interactions between the external and internal of the greenhouse.The radiation balance of earth and atmosphere is illustrated in Figure 3, which shows the components of the radiation that on average enter or leave the earth's atmosphere and make up its radiation budget. The incoming solar radiation must, on average, be balanced by thermal radiation leaving the atmosphere or the surface. Incident at the top of the atmosphere on a surface of one square metre directly facing the sun is about 1370 W. The average over the whole earth's surface is one quarter of this or 342 Wm^{-2}. About 30% of the incoming solar radiation on average is reflected or scattered back to space from the earth's surface, from clouds, small particles (known as aerosols) or by Rayleigh scattering from molecules.

The gases nitrogen and oxygen that make up the bulk of the atmosphere neither absorb nor emit thermal radiation. If they were the only atmospheric constituents there would be no clouds and no greenhouse effect. In this case, to realize radiative balance, the average earth's surface temperature would be about -6 °C. In fact the average surface temperature is about 15 °C. The difference between these two figures of about 20 °C is because of the natural greenhouse effect due to the natural abundances of the greenhouse gases, water vapour, carbon dioxide, ozone, methane and nitrous oxide. Of these gases, the largest greenhouse effect is due to water vapour and the second largest to carbon dioxide. The natural greenhouse effect is clearly vital in maintaining the earth's climate as we know it, with its suitability for human life to flourish.

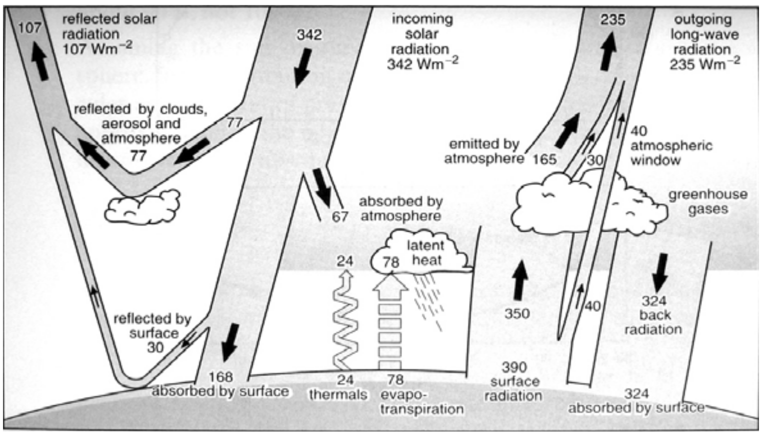

Figure 3. The earth's radiation and energy balance

Climate change is a long-term challenge, but one that requires urgent action given the pace and the scale by which greenhouse gases are accumulating in the atmosphere and the risks of a more than 2 °C temperature rise. Today we need to focus on the fundamentals and on the actions otherwise the risks we run will get higher with every year. Bayesian methods to constrain equilibrium climate sensitivity or transient climate response are sensitive to the assumed prior distributions. That can in principle yield narrower estimates by combining constraints from the observed warming trend, volcanic eruptions, model climatology and paleoclimate, and that has been done in some studies, but there is no consensus on how this should be done robustly. This approach is sensitive to the assumptions regarding the independence of the various lines of evidence, the possibility of shared biases in models or feedback estimates and the assumption that each individual line of evidence is unbiased. The combination of different estimates in this assessment is based on expert judgement. Accounting for short-term variability in simple models remains challenging, and it is important not to give undue weight to any short time period which might be strongly affected by internal variability.

The estimates from the observed warming, paleoclimate, and from climate models are consistent within their uncertainties, each is supported by many studies and multiple data sets, and in combination they provide high confidence for the assessed likely range. Even though this assessed range is similar to previous reports, confidence today is much higher as a result of high quality and longer observational records with a clearer anthropogenic signal, better process understanding, more and better understood evidence from paleoclimate reconstructions, and better climate models with higher resolution that capture many more processes more realistically [21]. Near-term decadal climate prediction provides information not available from existing seasonal to interannual (months to a year or two) predictions or from long-term (mid 21st century and beyond) climate change projections. Prediction efforts on seasonal to interannual time scales require accurate estimates of the initial climate state with less focus extended to changes in external forcing12, whereas long-term climate projections rely more heavily on estimations of external forcing with little reliance on the initial state of internal variability. Estimates of near-term climate depend on the committed warming (caused by the inertia of the oceans as they respond to historical external forcing) the time evolution of internally generated climate variability, and the future path of external forcing. Near-term predictions out to about a decade (Figure 4) depend more heavily on an accurate depiction of the internally generated climate variability.

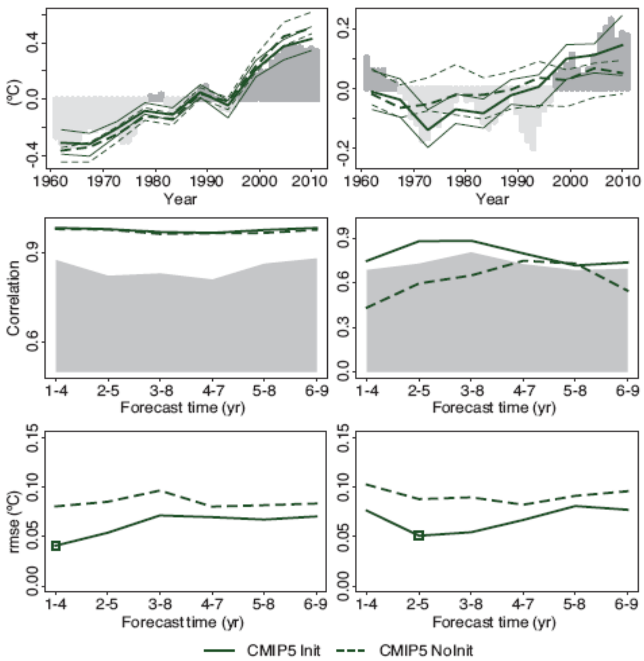

Figure 4. Decadal prediction forecast quality of several climate indices, CMIP5: Coupled Model Intercomparison Project Phase 5 [1]

In the near-term, it is likely that the frequency and intensity of heavy precipitation events will increase over land. These changes are primarily driven by increases in atmospheric water vapour content, but also affected by changes in atmospheric circulation. The impact of anthropogenic forcing at regional scales is less obvious, as regional scale changes are strongly affected by natural variability and also depend on the course of future aerosol emissions, volcanic forcing and land use changes. There are various mechanisms that could lead to changes in global or regional climate that are abrupt by comparison with rates experienced in recent decades. The likelihood of such changes is generally lower for the near-term than for the long term. It is virtually certain that, in most places, there will be more hot and fewer cold temperature extremes as global mean temperatures increase. These changes are expected for events defined as extremes on both daily and seasonal time scales. Increases in the frequency, duration and magnitude of hot extremes along with heat stress are expected; however, occasional cold winter extremes will continue to occur. Twenty-year return values of low temperature events are projected to increase at a rate greater than winter mean temperatures in most regions, with the largest changes in the return values of low temperatures at high latitudes. Twenty-year return values for high temperature events are projected to increase at a rate similar to or greater than the rate of increase of summer mean temperatures in most regions.

The earth's climate system is powered by solar radiation (Figure 5). Approximately half of the energy from the Sun is supplied in the visible part of the electromagnetic spectrum. As the earth's temperature has been relatively constant over many centuries, the incoming solar energy must be nearly in balance with outgoing radiation. The dominant energy loss of the infrared radiation from the earth is from higher layers of the troposphere. The sun provides its energy to the earth primarily in the tropics and the subtropics; this energy is then partially redistributed to middle and high latitudes by atmospheric and oceanic transport processes.

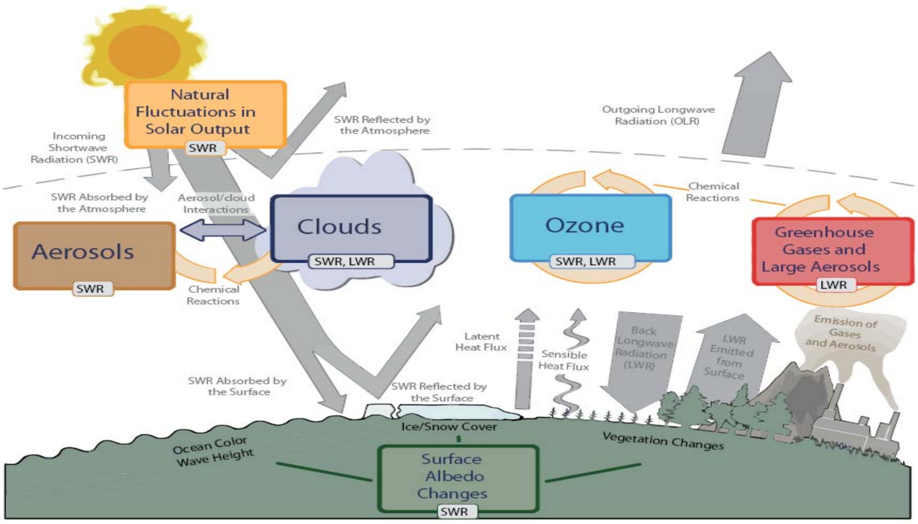

Figure 5. Main drivers of climate change: The radiative balance between incoming solar shortwave radiation (SWR) and outgoing longwave radiation (OLR) is influenced by global climate drivers, longwave radiation (LWR). Natural fluctuations in solar output (solar cycles) can cause changes in the energy balance (through fluctuations in the amount of incoming SWR) [3]

Changes in the global energy budget derive from either changes in the net incoming solar radiation or changes in the outgoing longwave radiation. Changes in the net incoming solar radiation derive from changes in the sun's output of energy or changes in the earth's albedo. Changes in the outgoing longwave radiation can result from changes in the temperature of the earth's surface or atmosphere or changes in the emissivity (measure of emission efficiency) of longwave radiation from either the atmosphere or the earth's surface. For the atmosphere, these changes in emissivity are due predominantly to changes in cloud cover and cloud properties [22].

In addition, some aerosols increase atmospheric reflectivity, whereas others (e.g., particulate black carbon) are strong absorbers and also modify shortwave radiation. Indirectly, aerosols also affect cloud albedo, because many aerosols serve as cloud condensation nuclei or ice nuclei. This means that changes in aerosol types and distribution can result in small but important changes in cloud albedo and lifetime. Clouds play a critical role in climate because they not only can increase albedo, thereby cooling the planet, but also because of their warming effects through infrared radiative transfer. Whether the net radiative effect of a cloud is one of cooling or of warming depends on its physical properties (level of occurrence, vertical extent, water path and effective cloud particle size) as well as on the nature of the cloud condensation nuclei population [3, 4, 22]. Because anthropogenic emission sources simultaneously can emit some chemicals that affect climate and others that affect air pollution, including some that affect both, atmospheric chemistry and climate science are intrinsically linked.

IV. FUTURE DIRECTIONS FOR THE WORLD CLIMATE RESEARCH

Research and assessment communities meet: in the absence of an internationally agreed-upon and funded climate research strategy, the World Climate Research Programme (WCRP), on behalf of the WMO, the International Council for Science, and the Intergovernmental Oceanographic Commission, assumes the daunting tasks of planning and coordinating international efforts on climate research. The WCRP, a multinational consortium established in 1980, has undergone internal refreshment and refocusing since 2011. Following extensive engagement with the research community, WCRP identified five climate science "grand challenges". These call for community focus and rapid progress on the following topics: clouds and atmospheric circulation, regional sea level, climate extremes, water availability, and rapid cryosphere changes. The WCRP seeks to understand and predict present and future flows of heat, water, and carbon in atmospheric, land, oceanic, and ice systems through skillful use, intercomparison, and sharing of models and observations. WCRP presently focuses its efforts through grand challenges (hexagons) (Figure 6). We recognize the need to increasingly ensure continuity and fidelity from global climate data to socially useful regionally focused information.

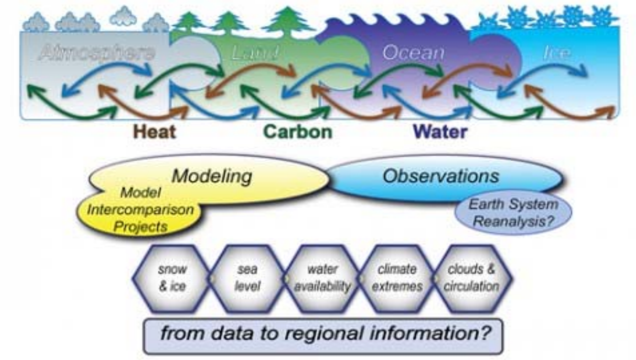

Figure 6. Focus and efforts through grand challenges in hexagons

Challenges ahead; as WCRP pursues new directions, we confront four interlinked obstacles: (I) funding is decreasing generally, and it is increasingly earmarked and allocated for purposes other than fundamental climate research, (II) despite confirmation of the validity, indeed urgency, of the WCRP grand challenges, we have only a mixed record of implementation and a weak record of public engagement, (III) our tendency across WCRP is to overload and overwork a few key individuals, especially female individuals, and (IV) our most careful and creative products continually and increasingly clash with social or political comfort and convenience [17, 23]. WCRP has developed through the accretion of good ideas and worthy plans, reflecting the emerging complexity and expanding facets inherent in analysis and prediction of a rapidly evolving climate system. Although we describe here the recent and necessary reassessment of the WCRP activities, we see a need for additional and continual refinement in light of priorities and resources. With a small number of staff serving management and coordination roles at the center and across the projects, WCRP always and increasingly relies on enthusiastic volunteers who build and sustain the international science community. We observe an optimistic sense of urgency and possibility within that community, the collective overt determination to not simply repeat past steps or continue past processes emerging from the "Lesson Learnt" meeting confirms their motivation. If we as representatives and leaders fail to confront funding, implementation, capacity, and messaging issues, we risk a serious and disabling loss of confidence and commitment within and across this most valuable climate resource.

V. CONCLUSION

A spectrum of models is used to project quantitatively the climate response to forcings. The simplest energy balance models use one box to represent the earth system and solve the global energy balance to deduce globally averaged surface air temperature. At the other extreme, full complexity three dimensional climate models include the explicit solution of energy, momentum and mass conservation equations at millions of points on the earth in the atmosphere, land, ocean and cryosphere. Climate change commitment is defined as the future change to which the climate system is committed by virtue of past or current forcings. The components of the climate system respond on a large range of timescales, from the essentially rapid responses that characterise some radiative feedbacks to millennial scale responses such as those associated with the behaviour of the carbon cycle and ice sheets [24-26]. Because of the slow response time of some components of the climate system, equilibrium conditions will not be reached for many centuries. Slow processes can sometimes be constrained only by data collected over long periods, giving a particular salience to paleoclimate data for understanding equilibrium processes. Climate change commitment is indicative of aspects of inertia in the climate system because it captures the ongoing nature of some aspects of change [27]. These actions require clear policies, commitment and resolve on the part of governments, industries and individual consumers. Urgent action is required for three reasons. The first is scientific. Because the oceans take time to warm, there is a lag in the response of climate to the increase of greenhouse gases. A commitment to substantial climate change already exists, much of which will not be realized for several decades. The second reason is economic. Energy infrastructure, for instance, in power stations, lasts typically for 30 to 50 years. It is much more cost effective to begin now to phase in the required infrastructure changes rather than having to make them much more rapidly later. The third reason is political. Countries like China and India are industrializing very rapidly. They need to do so in ways that are much more efficient and with much smaller greenhouse gas emissions than has been done in the developed world.

Dynamic and intensified changes in the global ecosystem result in significant disruptions to the natural environment. One of the most prominent examples of this is climate change and the resulting natural disasters. As firms are embedded within the natural environment, they need to adapt to any environmental disruptions that transpire. Climate knowledge absorption as an essential information generating and internalizing capability, climate related operational flexibility as a short-term adjustment capability, and strategic climate integration as a long-term, innovation-focused capability. The water demand management and cleaner production initiatives could help reduce the strength and volume of industrial effluents and probably eliminate the use of toxic substances through substitution. The benefits do not accrue only to the industry but to the local authority through reduced costs of conveying and treating industrial effluents. Subsequently, the quality of effluent discharged from municipal sewage treatment works to the environment would improve, thereby limiting environmental damage and social costs leading to sustainable development.

However, the intensification of disruptions caused by global climate change requires organizations to start adapting to them immediately. Consequently, it is important that organizations acknowledge the strategic relevance of ecological issues such as climate change and accelerate their efforts to develop and deploy capabilities required for the adaptation process. Notably, it is vital to emphasize that specific knowledge is required regarding both the sources of a changing natural environment and their consequences for business. As such, an organization's absorptive capacity regarding knowledge about global warming, corresponding effects on the business environment, and related corporate response options has to be viewed as an essential component of a successful long-term strategy in terms of the organization's climate change exposure as well as in terms of its sustained competitiveness.

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