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CLIMATE CHANGE IN THE RECENT GEOLOGICAL PAST AND THE NEAR FUTURE. PREDICTING ITS IMPACTS: A REVIEW

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Abstract

The climate changes are necessarily related to the increase of the Earth's temperature, resulting in a sea level rise. Such continuous events, were taking place with minor and greater intensity, during the alternation of warm and cool periods in the Earth during the Late Quaternary and the Holocene periods. However, a particularly significant awareness has taken place in the scientific community, and consequently in the greater public, in the last decades: that a climatic change will take place soon, or it is on-going, and that therefore it is important to undertake drastic actions. However, such a climatic change has not been recorded yet, and hence the necessary actions are not required, for the time being.

Keywords: *Climate change, impacts, Late Quaternary, natural hazards, sea level rise*

Περίληψη

Οι κλιματικές αλλαγές σχετίζονται με την αύξηση της θερμοκρασίας της γης, η οποία έχει σαν αποτέλεσμα την άνοδο της στάθμης της θάλασσας. Αυτές οι αλλαγές συνέβαιναν, με μικρότερη ή μεγαλύτερη ένταση, κατά τις εναλλαγές θερμών και ψυχρών περιόδων στη γη, στη διάρκεια του Τεταρτογενούς και της Ολοκαίνου περιόδου. Τις τελευταίες δεκαετίες έως και σήμερα, υπάρχει ιδιαίτερα στην επιστημονική κοινότητα και κατά συνέπεια, στο ευρύτερο κοινό, μία σαφής ανησυχία εάν η κλιματική αλλαγή θα αρχίσει σύντομα και θα συνεχιστεί στο μέλλον, οπότε θα πρέπει να ληφθούν άμεσα δραστικά μέτρα. Όμως, επειδή μεγάλης έντασης και συνεχούς διάρκειας κλιματική αλλαγή δεν έχει ακόμη καταγραφεί, προς το παρόν δεν κρίνονται απαραίτητες οι ενέργειες για την αντιμετώπισή της.

Λέξεις κλειδιά : *Κλιματική αλλαγή, συνέπειες, Ανώτερο Τεταρτογενές, φυσικές καταστροφές, άνοδος της στάθμης της θάλασσας*

1. INTRODUCTION

The history of our Planet has been examined and studied through sciences such as the Earth Sciences. However, in the last years the impacts of the climate change are repeatedly discussed and /or analyzed in either daily news or scientific presentations. Therefore, we have examined the changes that are expected to take place, today or in the near future.

At present we have some reliable data on the past through the historical studies of the climate. They cannot, however, be easily projected towards the future. On the other hand, the mass media declare of any occasion about extreme weather events. The climatic change process though is an ongoing process and not a sudden event. Among the news of greater impact and as a major worry for the population is certainly the expected increase of sea level. This has been an easy way for many experts to predict future events, usually either for the next years or a few decades later, without examining the events in the past.

In general, taking into account the greater and specific experience on the climate issue from the last 30 years, we can think with reasonable thoughts and suggestions, on how we will meet the eventual impacts of climatic changes in the near future. This is the main focus of this paper.

2. QUATERNARY – HOLOCENE COLD / WARM CLIMATE PERIODS

2.1. Regional Setting

The Earth has undergone in the last about 500.000 years four significant climate changes, known as *Milankovich* periods or cycles, (name after a Serbian geoscientist and astronomer who described them first in 1920). This time includes three cold periods, lasting about 100.000 years each, with warm periods between them, lasting about 12.000 years (Petit J.R.et al., 1999).

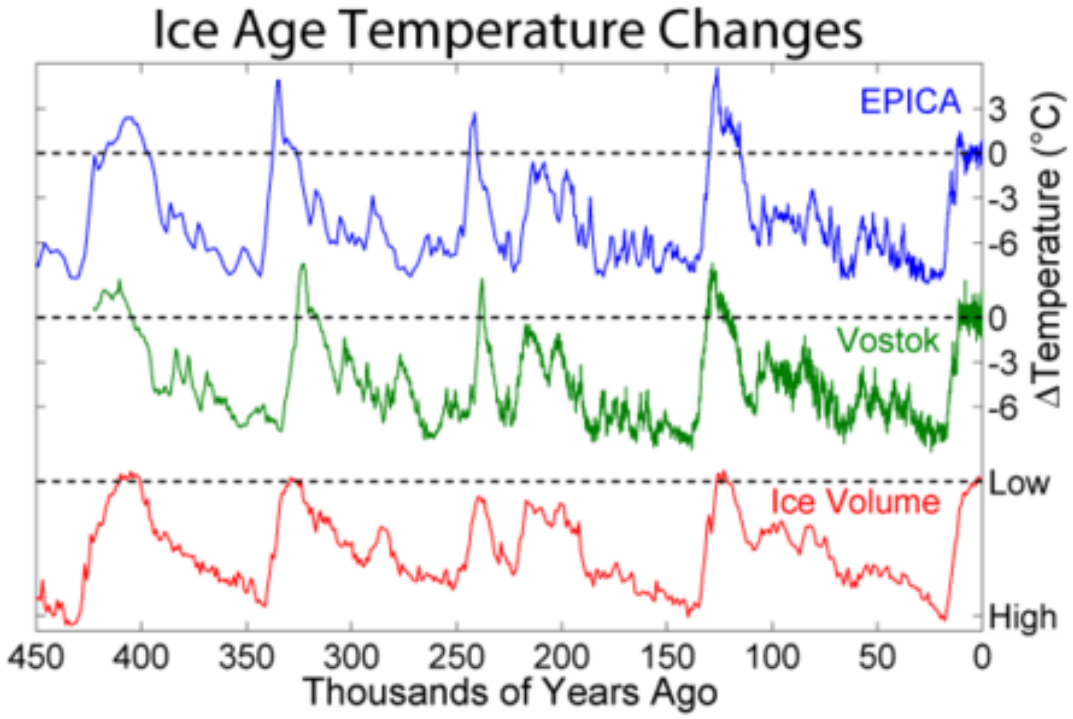

Fig. 1: Ice temperature changes during the last glacial – interglacial cycles and comparison to changes in global ice volumes. The temperature changes in the upper two plots are from ice cores from Epica and Vostok sites in Antarctica. The bottom plot shows ice volume from globally distributed marine sediment cores. During several earlier-interglacial periods the temperature was higher than present interglacial period. (*After Petit J.R.et al, Nature, 399, 429-436*).

Today we are living in the last warm period that started about 12.000 years ago and is expected to end in about 2.000 years from now (Fairbanks, 1989, Fig. 2a), when the next cool period will start again. The cause of these cycles is the variability of the solar radiation reaching the Earth.

From detailed marine sedimentological researches, we know now that during the end of the cool phases of these cycles, the sea surface was worldwide at about 120 m below today's level, decreasing the temperature of the Earth. Gradually the Earth's temperature reached to-days value. The increase in the sea level was continuous at variable rates, as high as 37 mm/yr and as low as to 5 mm/yr (Bard, et.al., 1990, Fig. 3b).

The above description of the earlier climate changes serves to indicate that the climate change is not a sudden phenomenon, since the temperature and the sea level changes are ongoing events of variable intensity.

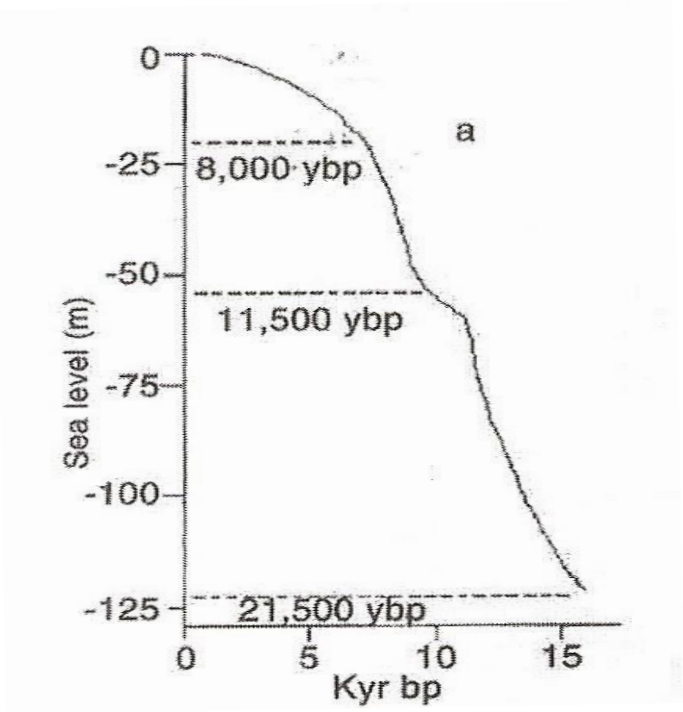

Fig. 2: Sea level curve, defining stages of increase (21.500 years BP and 11.500 years BP) and delays (8.000 years BP) in sea level rises (Fairbanks, 1989).

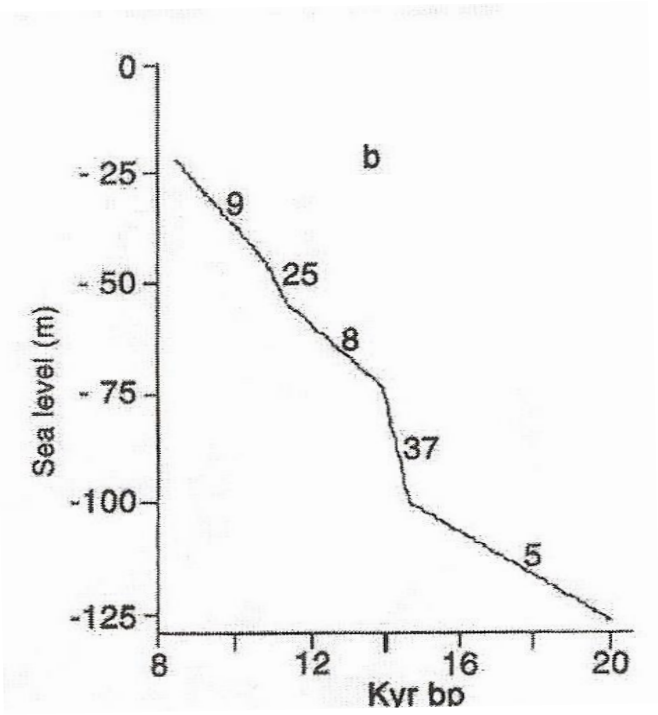

Fig. 3: Rates in sea level rises in mm/yr, alternating increase and delays stages (Bard, et.al. 1990).

2.2. Case studies and suggestions of meeting eventual impacts

During the beginning of the 1980s the various discussions were focused in the CO_2 production of the industry in the developing countries and the expected impacts, such as the possibility of a considerable temperature increase and a sea level rise. For this purpose, a group of specialized weather scientists was asked to evaluate the impacts that the CO_2 increase in the atmosphere would have an increase in temperature and sea level rise.

Based on this, many international groups, among them UNEP (United Nations Environmental Program) organized and funded research programs in coastal countries in areas with large population, in order to predict the impacts of the forthcoming climate changes there. The research teams used the expected climatic scenarios, both in global scale and, more specifically, in Southern Europe cases (IPCC, 1991, Table 1).

One of the first districts to be studied was the Mediterranean Sea that included two areas in Greece: The greater city of Thessaloniki, in Thermaikos Gulf, northwestern Aegean Sea, as an-estuarine area, (Georgas and Perissoratis, 1989), and Rhodes Island, in southeastern Aegean, (Perissoratis, et al., 1996).

According to the expected impacts, a series of actions were proposed, described and presented to the local and regional organizations. The main suggestions were referring to the impacts expected from two scenarios, as depicted by the IPCC working Group for southern Europe mentioned above. In the first scenario, by the year 2030, it is expected a temperature increase of 1.8°C and sea level rise by 18 cm (+/- 10 cm); in the second scenario, by the year 2100, the estimations were respectively increased to 3°C and sea level rise to 65 cm(+/- 35 cm), (Table 1).

The study for the Thermaikos Gulf and the city of Thessaloniki suggested that, even in the low scenario, by the year 2030, the expected sea level rise would gradually increase by 30 to 40 cm. In that case the sea would cover the intertidal zone greatly affecting the city's exposed seawall pavement.

SCENARIOS		TIME HORIZON			
		2030		2100	
IPCC GLOBAL (Business as usual)					
Temperature		+ 1.8 °C (?)		3 °C	
Sea level		+ 18 cm +/- 10 cm		+ 65 cm +/- 35 cm	
IPCC Southern Europe (Business as usual)					
Temperature		+ 2 °C winter + 2 - 3 °C summer		-	
Precipitations		+ 0 to 10 % winter - 5 to (-15 %) summer		-	
Soil moisture		- 15 to - 25 % summer		-	
Univ. East Anglia NE Med		°C global	for 1.8 °C global	°C global	for 3 °C global
Temperature	Winter	0.5-1.8	0.9-3.24	0.5-1.8	1.5-5.4
	Spring	0.6-1.4	1.08-2.52	0.6-1.4	1.8-4.2
	Summer	0.6.1.6	1.08-2.88	0.6-1.6	1.8-4.8
	Autumn	0.7.1.6	1.26-2.88	0.7-1.6	2.1-4.8
	Annual	0.7-1.5	1.26-2.7	0.7-1.5	2.1-4.5
Precipitations	Winter	-15 -6			
	Spring	-7 -15			
	Summer	-22 -26			
	Autumn	-18 -15			
	Annual	-6 -6			
Univ. East Anglia for Rhodes		°C per global °C	for +1.8°C global	°C per global °C	for 3 °C global
Temperature	Winter	0.5-0.8	0.9-1.44	0.5-1.8	1.5-2.4
	Spring	0.6-0.8	1.08-1.44	0.6-0.8	1.8-2.4
	Summer	1.0-1.1	1.8-1.98	1.0-1.1	3.0-3.3
	Autumn	0.7-0.8	1.26-1.44	0.7-0.8	2.1-2.4
	Annual	0.7-0.8	1.26-1.44	0.7-0.8	2.1-2.4
		% per global °C	mm	% per global °C	mm
Precipitations	Winter	0-2	0-13	9-4.8	0-21
	Spring	4-6	5-10	7.2-14.4	10-17
	Summer	4-12	0.2-0.75	12-39.6	0.38-1.26
	Autumn	0-2	0-3.8	4.2-9.6	6.3-14.5
	Annual	-2-0	?(-21)-0	(-4.2)-0	(-30)-0

Table 1. Climatic scenarios used for Southern Europe areas (IPCC,1991)

The effects were estimated as more disastrous by the year 2100 in a foreseen 1 m sea level increase scenario in the coastal sector of the Thessaloniki. To diminish and even eliminate these impacts, the study suggested the construction of a buffer zone of the Thessaloniki Bay, as the sea depth in the suggested area is suitable for the construction of a dam (Fig. 4, Georgas and Perissoratis 1989, p 531). In respect to the study for the island of Rhodes, adopting the same IPCC scenarios, the study examined in detail the coastal zone of the island defining four impact zones, with special attention to the city of Rhodes. The study concluded that in the coastal-zone areas, the impact of an eventual 30 cm sea level rise scenario in the next 30-40 years would be minor in the city of Rhodes as well as in other nearby urban areas, because this island sector is characterized by active tectonic uplift. For the same reason in the case of the second scenario, of about 1m sea level rise, the impacts would be noticeable but easily confronted (Perissoratis et al, 1996, p132-133; 138- 139).

Fig. 4: Bathymetric map of Thermaikos Gulf and location of the proposed dam (arrow). The upper right square, indicates the location of the two areas studied, Thermaikos Gulf (Macedonia, Northern Greece) and Rhodes island (Dodecanese, SE Aegean).

A series of suggestions and the required actions were proposed for both studied areas. The needed actions, except of the cases of expected climatic changes, were the necessary activities for the better protection of the natural environment (Table 2, Perissoratis and Georgas, 1994).

However, it is important to note that, up to now (2019), no climatic change has been observed and no sea level rise has been recorded in the Aegean and Eastern Mediterranean.

Suggested actions recommendations.

Estuarine (Thermaikos Gulf)	Insular (Rhodes Island)
Short term	
• Identification of high risk areas & vulnerability assessment study • Development of coastal strategy for protection, accommodation or defend after cost/benefit analysis • Implementation of water management plan • Ecosystem protection • Barrier construction at the inner bay entrance	
• Pollution control • Increase pumping capabilities	• Change of coastal landuse • Upgrade coastal legislation & building standards • Recycling of biologically treated water • Development of a ground water management plan • Reforestation • Introduce drip irrigation in agriculture
Long term	
• Detailed mapping of vulnerable areas • Provision of setback zones (retreat option) in landuse planning • Study and monitoring of physical parameters • Update the local climatic scenario	

Table 2. Suggestions and Recommendations for future actions in the inner Thermaikos Gulf and Rhodes Island (Perissoratis and Georgas, 1994).

3. EXPECTED IMPACTS FROM EVENTUAL CLIMATE CHANGES

3 .1. Predictions of future increases in Earth's temperature and sea level rise

The sea level increase that would result from a future temperature increase, was and has been in research continuously by many researchers. At the same time the study of the sea level rise, especially in the last two hundred years and earlier, and also up to the last two thousand years has been carried out. Thus, according to Jevrejeva et al (2006, Fig.5) during the period from year 1850 to year 2000 BP the global sea level rise was of the order of 20 mm/year, while, according to Grinsted et al (2009,) in the last 2000 years the minimum sea level rise was about 15mm/year and the maximum about 23mm/year. These estimates are within the known estimations for the Holocene period (Fig. 3b).

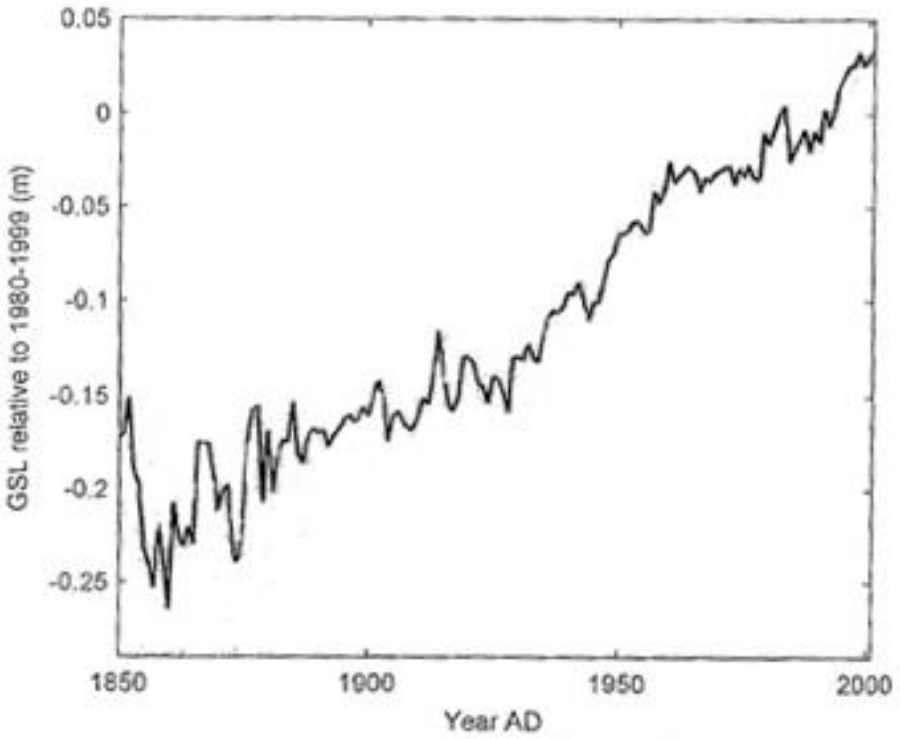

Fig. 5: Reconstructed Global sea level rise for the period between years 1850 and 2000 (modified after Jevrejeva et al. 2006).

On the other hand, the IPCC in its evaluation in the global warming report (IPCC, 2007) estimates a sea level rise between 18 and 59 cm by 2100; that is a rate of about 3 to 7 mm/year. As for the final, 2016 IPCC report approved in the 2017 and 2018 sessions, it is stated that : … *it is agreed to a Global Warming of 1.5°C, above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change…..*:. In these reports, the 1991 model with the relevant sea level and temperature estimations (Table 1) were not mentioned. For the future estimates for the year 2100, both ideas are different as it is shown in Fig 6. The IPCC model considers a rise of 35 cm, that is a rate of 35 mm/year while Grinsted et al. (2009) give, as expected, rise about 1.2 m that is 120 mm /year, an increase of about 3.5 times.

3.2. The implications of using the future predictions and the suggested actions

The above overestimations of sea level rise are based on hypotheses that are not related to an actual *on-going* event, taking place in this period. However, these overestimations have been used by many research groups that deal with the expected future impacts. As a consequence, they usually suggest the carrying out of the necessary actions very soon.

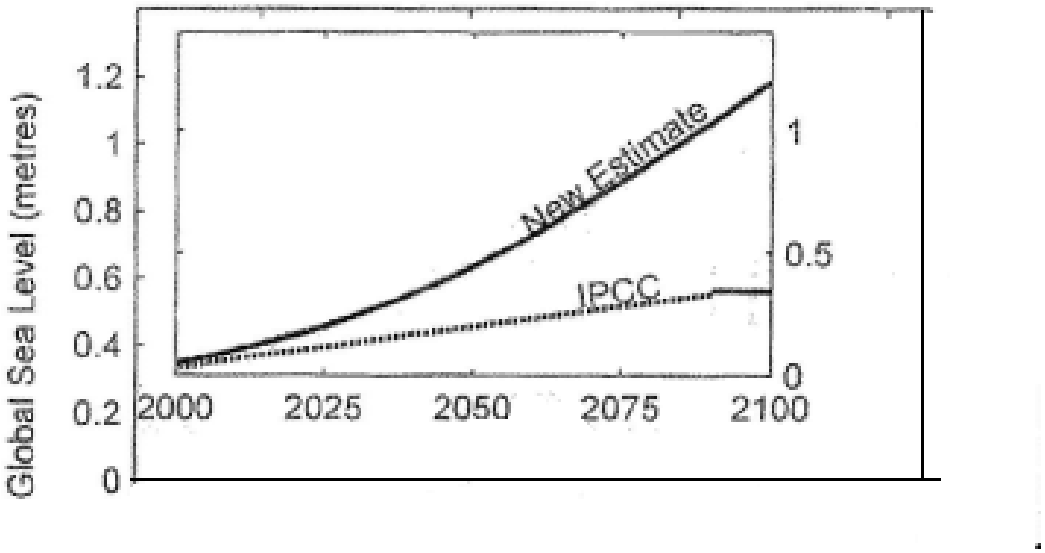

Fig. 6: Global sea level depicting the change between years 2000 to 2100, (modified from Grinsted et al 2009, New Estimate, and IPCC 2007).

On the other hand, these "predictions" have been presented to the greater public and not in scientific fora where they would be under scientific consideration and discussion. This is mainly because the qualitative predictions and the impacts of published data are suitable for impressing the greater public, via the various media, especially in western counties.

In Greece particular two extensive considerations / studies on the forthcoming impacts of the expected climatic change were carried out and their outcomes have been recently published and presented to daily news. In 2009, the National Bank of Greece established and funded the Committee on Impacts of the Expected Climate Change in Greece, that presented its reports in 2015 (CCISC, report 2015, 465 pages). The conclusions and suggestions of that committee was based, among other impacts, on an expected 1 m sea level by the year 2100, as stated by the researchers that studied the considerable future rise, without accepting the IPCC evaluations. Actually, it is considered as an *on-going* event that is expected to start now with an average of 1.2 cm sea level rise per year. That Committee examined all areas and all aspects of activity in Greece, from coastal areas to tourism, and from water systems to forests. The report also lists the immediate necessary actions to defend Greece from the coming impacts, suggesting to start the actions as soon as possible. These include plans for saving, among others, the coastlines, building all hotels farther inland, and even taking steps for saving the ancient archaeological buildings from the impacts. Furthermore, the committee evaluated that if the necessary actions would start later, near the year 2100, the cost will be on the order of 700 billion euro. If the necessary work would start now, the cost would be 30% less.

It is interesting to note that by the year 2100 that is 80 years from now, very few people will remember the outcome of this report, as was the case with the 1991 IPCC estimations.

Similar ideas in Greece were also presented by *diaNEOsis*, a non-profit research organization that studied, among other things, the impacts of climate change in the Greek economy (Georgakopoulos, 2017). The study, partly presented in daily newspapers and available to the public, considers the IPCC 2007 report and the sea level rise values from 20 to 59 cm by the year 2100 as very moderate and accepts a sea level rise from 0.80 m to 2.0 meters. The study, focuses and describe the impacts between the years 2048 to 2065, when today's infant population of Greece that will face phase the impacts, will be from 40 to 60 years old. Again, climate change is considered as an *on-going* process that would affect 90% of the touristic infrastructure that lies within a distance of about 2 km from today's coastal line, as well as the agriculture. The study also suggests the necessary actions by the Greek State, such as a transition by 2050s to the low carbon economy, organizing meetings for the future impacts, but, mainly, within the next four years, special plans for the tourism and agricultural sectors. No evaluation of costs for these actions were presented.

On the other hand, it is well accepted that one of the main economic sources of Greece and other Mediterranean countries is tourism. Therefore, the predictions of studies that eventual impacts of an eventual climatic change will take place soon in Greece, support a very negative and pessimistic impression to the ordinary people. Moreover, as many physical events have been taking place in Greece, all are related to consequences of the climate change without any scientific explanation, confusing again the public at-large. This was initially the case for the disastrous fire it the *Mati* area nearby Athens (23 July, 2018,) in which 100 people died.

4. CLIMATIC CHANGE, DISASTER AMENDMENT AND MITIGATION POLICIES

Earths processes and disaster events therefore are ongoing regardless of any climatic change that certainly has not up to now been taken place so far. In all cases, the key scientists that can deal with the environmental changes and its impacts on land are the Earth scientists. The assessment of the disaster requires considerable experience and work based mainly on the earlier historical records of the disasters and the transfer of the relevant experience from similar areas. The required actions include also preparation of the main steps to meet the impacts and then carry out the mitigation

policies. The human environment is destroyed from natural processes: these are mainly Coastal Erosion, Earthquakes, Tsunamis, Floods, and Seismic Activity (Active Faults). Earth scientists have the background, knowledge and experience to deal with the impacts of these natural events regardless of the eventual climate change. At the same time, the high population density of the modern coastal zones and the related planning usually degrade the area.

5. CONCLUSIONS

The discussion about the climatic changes has been taking place for about 30 years and continues. However, the forthcoming increase of the Earth temperature and the sea level rise has not been recorded yet, in order to proceed with the necessary actions to meet the impacts. As expected, the IPCC initial models (1991) have been changed to more realistic suggestions for a temperature and sea level increase (2007, 2016 and forward).

On the other hand, from studies on the sea level changes, concerning both the last 150 years, and the near future, indicate that the sea level rise in the past was similar to that during the late Holocene period. Therefore, the assessment that the sea level in the next 100 years is expected to be at least 3 times higher than those estimated by the IPPC, is not reasonable. They also suggest that this process will be starting soon. These estimations are then used by other research groups to support the necessary actions for meeting the impacts. The final result is the causing of a great negative feeling and pessimism in the ordinary people that use the coastal areas extensively now. Therefore, it is necessary for all scientific teams, concerned with the issue of climatic changes, to engage more discussions and to develop realistic estimates of the expected future impacts when the latter will start to take place.

6. ACKNOWLEDGMENTS

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