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**Articles**

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Jeffrey W. Niemitz*

## I. Introduction

Two hundred and nine years ago Benjamin Franklin wrote to a dear friend, "There is nothing you can count on in this world but death and taxes."[1] As astute a scientist as Franklin was, he never could have observed or measured the inexorable change which occurs in the natural world. Given what climatologists and geologists have learned in the past decade about climate changes affecting Earth, one reasonably could add "change" to Franklin's list of certainties. The politics of global warming and the abnormal weather patterns creating the recent strong El Niño are just two examples of climate change. Although climate change is apparent, humans lack a sense of the rates of climate change, both naturally and anthropogenically induced. The time overlap of human land use and the autovariation in the ocean-atmospheric system (see

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1. BENJAMIN FRANKLIN, LETTER TO JEAN BAPTISE LEROY (1789).

figure 1)[2] suggests that humankind should pay more attention to rates of change. A comparison of the rates of global warming change and El Niño evidences the great rate at which the climate changes. The contentiousness of the discussions at the recent Global Warning Conference in Kyoto[3] between developed and developing nations occurred largely because the participants and their special interests could not see the potential of the interaction between long-term climate change and global socioeconomic system.[4] There is no doubt that global warming will occur. What is uncertain is the rate at which this change will proceed.

To illustrate, homeowners in southern California who are so unfortunate as to have their houses slide from the rain-saturated hillsides or ripped from their foundations by storm waves are fully aware of the effects of the present El Niño. The rate of change in this case is rapid but finite. In global warming the change appears to be slow but could have much more profound effects on the ability of the earth's population to feed itself and resist pandemic disease. While all of this could be fodder for science-fiction movies and does have more than its share of speculation, there are several signs that climate change is approaching.[5] This change will have a long-term effect on the most vulnerable and the most populated areas of the continents, the coastlines.[6]

This article will review briefly the most up-to-date scientific evidence on climate change in the recent geologic past and the causes for the change. The article will use that evidence (1) to argue that anthropogenically-induced changes in greenhouse gases in the atmosphere may be moving the globe closer to a major change in climate in the next century; (2) to document the effects of these changes on the coastlines of the United States; and (3) to analyze the North Carolina Coastal Area Management Law of 1974

2. *See* Figure 1 (citing W.L. Gates, PALEOCLIMATIC MODELING—A REVIEW WITH REFERENCE TO PROBLEMS AND PROSPECTS FOR THE PRE-PLEISTOCENE: IN CLIMATE IN EARTH HISTORY: STUDIES IN GEOPHYSICS 8).

3. The Kyoto Conference was a United Nations conference held in Kyoto, Japan, for the discussion of climate change. *See* K. Hasselman, *Climate Change Research After Kyoto*, 390 NATURE 225 (Nov. 20, 1997).

4. *See id.*

5. *See* V. Gornitz and S. Lebedoff, *Global Sea-Level Changes During the Past Century,* SEA LEVEL FLUCTUATION AND COASTAL EVOLUTION (Nummendal, Pilkey, and Howard, eds., SEPM Publications n.41) (1987).

6. *See* Keqi Zhang, *et al., East Coast Storm Surges Provide unique Climate Record,* 78 EOS, TRANSACTIONS, AM. GEOPHYSICAL UNION, 389, 396-97 (Sept. 16, 1997).

("CAMA")[7] and two recent cases[8] tried under CAMA statutes. These cases evidence future problems for those responsible for enacting coastal zone management.

## II. The Evidence of Global Climate Change

It is obvious from geologic time scales[9] that global climate has changed. There is clear evidence of continent-wide glacial activity in the southern continents 400 million years ago and on the super continent of Pangaea 250 million years ago. Both of these events were probably caused by the assembly of the presently dispersed continents into one or two larger entities.[10] This assembly occurred due to deep crustal processes of plate tectonics. This cannot be the sole explanation, however, as there are times in geologic history such as 200 million years ago, when the continents were assembled for which all geologic evidence points to global temperatures warm enough to have an ice-free Earth.

The presently accepted explanation for climate cycling was first suggested in 1875[11] and further refined mathematically in 1941;[12] Imbrie applied the theories to geologic processes in 1980.[13] Focusing on the cause of the ice ages over the last 3 million years, these scientists suggested the ice ages were caused by variations in the distribution of incoming solar radiation due to variations in the earth's orbital geometry.[14] More simply, the distribution of incoming solar radiation changes over known time periods with the phasing of the "wobble" of the earth as it rotates due to the gravitational interaction between the earth, the moon and the sun.[15] Other factors involved include the change in the tilt of the earth on its axis and the eccentricity of the earth's orbit

7. N.C. GEN. STAT. § 133A (1974). The North Carolina Area Management Act was chosen because of its high standards for coastal and wetlands protection along a coastline that is historically one of the hardest hit by storm activity and currently one of the fastest developing coastlines for tourism.

8. Adams v. North Carolina Dep't of Natural and Economic Resources, 249 S.E.2d 402 (N.C. 1992); Everhart & Assoc., Inc. v. Dep't of Env't, Health & Natural Resources, 492 S.E.2d 66 (N.C. Ct. App. 1997), *cert denied*, 347 N.C. 575 (1998).

9. *See* Figure 1 (found in Gates, *supra* note 2).

10. L. FRAKES, CLIMATES THROUGHOUT GEOLOGIC TIME 6 (1979).

11. *See* John Imbrie, *Astronomical Theory of the Pleistocene Ice Ages: A Brief Historical Review*, 50 ICARUS, 408, 415 (1982).

12. *See id.*

13. *See id.*

14. *See id.*

15. *See id.*

around the sun.[16] The frequency of these three geometries is 21,000, 41,000, and 100,000 years, respectively.[17]

Using celestial mechanics and their correlation with global ice volume, it is possible to predict the future trend in ice volume.[18] While many predict that the climate will warm, celestial mechanics predict a cooling trend in the near future.[19] There has been a decrease in ice volume from the end of the last glacial period to the present in the order of 45 million cubic kilometers.[20] If the same volume of ice were to melt today the present eastern shoreline of the United States would migrate westward with the Atlantic Ocean covering all of Cape Cod, Long Island, Delaware, Florida, most of New Jersey, and the eastern parts of Maryland, Virginia, North Carolina, South Carolina, and Georgia. The northern end of the Chesapeake Bay would be just south of Harrisburg, Pennsylvania. Certainly, humans need not worry about a long-term sea level rise of this magnitude. However, some geologic processes concerning climate are relatively rapid, even on human time scales of less than 100 years.[21]

Since 15,000 years ago, the general climate trend has been favorable for human civilization, producing as a consequence exponential population growth.[22] The average global temperature of the earth has risen approximately 4-5 degrees Celsius during this period.[23] There was, however, one critically important setback in this otherwise warming trend, referenced to as Younger Dryas Event (hereinafter "YDE")[24].[25] The suggestion of an almost total return to glacial conditions, about 11,000 years ago first was inferred

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16. *See id.*
17. *See* Imbrie, *supra note 11; see* figure 2.
18. *See generally* A. Berger, *Milkankovitch Theory and Climate,* 26 REVIEWS OF GEOPHYSICS 624 (1988); *see* figure 3.
19. *See id.*
20. *See id.*
21. Geosphere interactions range from days to months. The interactions affect the amount of soil moisture, which in turn influences the level of precipitation. Excessive precipitation may in turn cause flooding. Further, runoff into oceans may affect ocean current circulation and produce hurricanes if other conditions are favorable. *See* U. Cabasch, *Processes and Modelling, in Climate Change: The IPCC Scientific Assessment* 77, 85-86 (World Meteorological Organization/United Nations Environment Programme, Intergovernmental Panel on Climate Change, 1990).
22. *See* Figures 4a,b,c (found in Lamb, *infra* note 26).
23. *See id.* (found in Lamb, *infra* note 26).
24. *See id.* (found in Lamb, *infra* note 26).
25. *See* Figures 4c-4d (found in Lamb *infra* note 26).

from data in northern Europe and Canada.[26] It was clear from pollen records that vegetation in Europe had changed abruptly back to a more alpine assemblage of species.[27] This is indicative of more glacial climates from the heretofore dominant pollen of oak and other deciduous trees common in temperate climate zones.[28] Subsequently, similar evidence was found in ocean cores from the North Atlantic Ocean, which suggested a large increase in icebergs entering the North Atlantic Ocean from the Arctic Ocean and Labrador Sea.[29] At the time it was thought that the YDE was regional in extent. The mechanism for its origin was unknown. In the last decade more detailed research has more accurately delineated the cause and extent of the YDE. Numerous ocean cores from the Caribbean[30] and eastern[31] and western Pacific[32] have established the YDE as a global event.

The cause of the YDE appears to be due to a change in volume and flow direction of glacial meltwater during the transition from glacial to interglacial climate regimes.[33] The ocean core evidence shows that the flow of meltwater before the YDE was from Canada down the ancestral Mississippi River to the Gulf of Mexico.[34] Approximately 11,000 years ago the flow of cold fresh water shifted to the St. Lawrence River system and the north Atlantic.[35] The result of this shift was severe. Because of the arrangement of the continents at the present time, the circulation of the oceans tends to be north-south; warm surface water moves from the equator to the poles, cools at the poles and then sinks. This sinking starts a deep-water circulation which eventually ends

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26. *See* H.H. Lamb, CLIMATE: PRESENT, PAST AND FUTURE 78-80 (1977) (found in W. Broecker *et al.*, *The Routing and Meltwater From the Laurentide Ice-Sheeting During the Younger Dryas Episode,* 341 NATURE 318 (1989)).

27. Alpine assemblage, in this context, refers to the assemblage of vegetation that grows in the alpine environment, including conifers, non-deciduous plants, and some tundra vegetation.

28. *See* Lamb, *supra* note 26.

29. *See id.*

30. *See* B.P. Flower and J.P. Kennett, *The Younger Dryas Cool Episode in the Gulf of Mexico,* 5 PALEOCEANOGRAPHY 949, 950 (1990).

31. *See* L. Keigwin and G. Jones, *Deglacial Climate Oscillations in the Gulf of California,* 5 PALEOCEANOGRAPHY 1009, 1016 (1990).

32. *See* L. Keigwin and S. Gorbarenko, *Sea Level, Surface Salinity of the Japan Sea and the Younger Dryas Event in the NW Pacific Ocean*, 37 QUATERNARY REVIEW 346 (1992).

33. *See* W. Broecker *et al.*, *The Routing and Meltwater From the Laurentide Ice-Sheeting During the Younger Dryas Episode*, 341 NATURE 318 (1989).

34. *See* Flower and Kennett, *supra* note 30.

35. *See* W. Broecker et. al., *supra* note 33.

in the eastern Pacific where the water resurfaces. The warm surface water must lose its heat to the atmosphere in order for it to become more dense and sink. The warmed atmosphere moves with the prevailing westerlies toward Europe, providing a relatively mild climate at higher latitudes than generally is seen in the western hemisphere. A massive influx of cold fresh water from the Great Lakes region to the north Atlantic shut this heat transfer process down, producing a near-glacial climate in Europe for approximately 1000 years.[36] Because of the slow rate of flow of the cold, deep ocean water,[37] it is not possible for the YDE to be manifest in the sediment record simultaneously world wide. The only other explanation is an "atmospheric teleconnection," whereby the atmosphere transfers its heat (or lack thereof) in a matter of days or weeks. Thus, a major climate change event was manifest across the globe in a matter of several years. If such an event were to occur today, the world's much larger population would be defenseless. Evidence from ice cores in Greenland[38] suggest that the change from warm to cold in the YDE was as little as eight years. Simply put, one ramification of such a rapid climate change event would be a similarly rapid decline in world food production resulting in massive famine.

## III. The Last 1000 Years of Climate Change

There have been two major climate excursions in the last millennium (see figures 4a, 4b).[39] During the 12th and 13th centuries, the Medieval Warm Period occurred.[40] This was followed by the "Little Ice Age."[41] On a local geographic scale, these perturbations had some effect on food production and commerce in what was then a mostly agrarian society.[42] The smaller world population, though, was better able to cope with the climate change than one might expect. The explanations for these

36. *See id.*
37. It took 2,000 years for the water to travel from the north Atlantic to the eastern Pacific.
38. *See* W. Dansgaard et. al., *Evidence for General Instability of Past Climate From a 250-kyr Ice-Core Record*, 354 NATURE 218 (1993).
39. *See* Figures 4a-4b (found in Lamb *supra* note 26).
40. *See id.*
41. The "little ice age" occurred between 1450 and 1800. *See Dansgaard,* et al., *supra* note 38.
42. *See* R. Bradley and P. Jones, *"Little Ice Age" Summer Temperature Variations, Their Nature and Relevance to Recent Global Warming Trends*, 3 HOLOCENE 367.

climate excursions are problematic, ranging from excessive volcanism to changes in solar radiation output as well as chaotic, unpredictable ocean-atmosphere interactions.[43]

With the advent of more precise weather monitoring over the last 100 years, the trends in climate change, especially regarding the greenhouse effect and its potential consequences, have become even more difficult to interpret. Despite the undeniable record of measured atmospheric carbon dioxide increase over the last 200 years,[44] there have been decades of cooler than normal global temperatures.[45] What is clear is that there is a high correlation of greenhouse gases with global temperature change over at least the last 160,000 years[46] and probably longer. Thus, with carbon dioxide concentrations higher now than they were at the last major interglacial period[47] higher temperatures in the future seem inevitable.

## IV. The Last One Hundred Fifty Years of Climate Change

One of the clearest trends of climate change over the past 150 years is global temperature change.[48] The 1980s and 1990s in particular have been warm with seven of the eight warmest years occurring in this century.[49] The absolute change in temperature is 0.6 degrees Celsius. While this is significant on a global basis,[50] at this time the rise is not enough above the statistical "noise" to conclusively to say the greenhouse effect has taken hold.[51]

There are, however, distinct effects from even short-term temperature increases which suggest that the greenhouse effect is taking hold. A logical consequence of temperature increase is the melting of more ice. This can be in the form of glacial retreat and/or the shrinkage of polar ice sheets. A decrease in the areal extent of ice will reduce the reflectivity of the earth's surface. With more of the sun's energy being absorbed by the earth's surface, in addition to more greenhouse gases trapping more solar energy, a

43. *See id.*
44. *See* Figure 5a-5b (found in U. Cabasch *supra* note 21).
45. *Id.*
46. *See* Figure 6 (found in U. Cabasch SUPRA note 21).
47. This was 125,000 years ago.
48. *See* Figure 7 (found in D. Raynaud, et al., *The Ice Core Record of Greenland Gasses,* 259 SCIENCE 926 (1993).
49. John Houghton, GLOBAL WARNING: THE COMPLETE BRIEFING (1994), at 11.
50. *See id.*
51. *See id.*

positive feedback mechanism is established. The more the ice melts, the more solar radiation is absorbed by the earth, and the cycle continues. The result of this positive feedback mechanism is the rising of the temperature of the oceans, causing the water mass to expand. For every one degree Celsius increase in global sea surface temperature, sea level will rise one meter.[52] In addition, the meltwater from glaciers and ice sheets adds to the ocean water volume, causing additional sea level rise. Numerous locations along the Atlantic coastline have seen a rise in sea level over the past century.[53] The rates of sea level rise differ slightly from place to place depending on the relative tectonic stability of the continental margin.[54] In all cases, however, the result is sea level rise.

## V. Sea Level Rise and Eastern U. S. Shoreline Erosion

Coastal zones are the first line of defense of the land from the ocean. The notion of the term "barrier island" so frequently used along the eastern U. S. coastline implies just that, a barrier between the land and the sea.[55] Barrier islands are the natural consequence of the interaction between the land and the sea.[56] As sea level rises or falls, the barrier islands respond by migrating toward or away from the mainland respectively. In geologic terms, these narrow strands of sand were ephemeral entities, with most of them being only 6000 to 8000 years old.[57] The barrier islands are the focus of intense development, population migration, and commerce, especially tourism.[58]

It is the coastlines of the eastern U. S. which are experiencing and will continue to experience the exacerbating effects of the rise in sea level associated with the anthropogenic addition of greenhouse gases to the atmosphere. In this decade, we have witnessed

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52. *See id.*

53. *See* Figures 8a, 8b, 8c (found in Working Group on Sea Level Rise and Wetlands Systems, *Conserving Coastal Wetlands Despite Sea Level Rise,* 78 EOS, TRANSACTIONS OF THE AMERICAN GEOPHYSICAL UNION 257 (1997).

54. *See id.* Continent subsiding can produce an apparent sea level rise. Therefore, sea level rise can be faster or slower depending on the negation of the rise by the land subsiding or rising due to long-term tectonic forces.

55. *See* Orrin H. Pilkey, Jr., *et al., From Curritick to Calabash: Living With North Carolina's Barrier Islands* (1978). Dr. Orrin H. Pilkey is a coastal geology professor and director of the Program for the Study of Developing Shorelines at Duke University.

56. *See id.*

57. *See id.*

58. *See id.*

two category 5[59] and numerous category 3 hurricanes[60] along the Atlantic coastline. These hurricanes have caused billions of dollars in damage to property and have caused extensive coastal erosion.

A recent study[61] used storm surge data from tide gauges in Charleston, SC and Atlantic City, NJ, two heavily populated coastal regions, to gauge the effects of sea level rise over the last century. Zhang and others concluded that storms along coastlines produce two kinds of effects: storm tides and storm surge.[62] "Storm tide" is the total water level during the storm due to the astronomical tides, the storm surge, and the mean water level.[63] "Storm surge" is the anomalous increase in water level due to the storm.[64] Storm tides produce coastal damage and flooding. Storm surge gives an indication of the severity of the storm.

In the Zhang study, long-term data were used to produce a picture of the effect of sea level rise on storm surge.[65] The apparent sharp rise in anomalous high water levels in recent years must be corrected for concomitant sea level rise. However, there has been no significant change in the number of storms[66] suggesting that the severity of the storms has increased due to sea level rise over the last century. If this trend continues, damage to coastal development and the economic base underlying that development will increase proportionally.

How will present coastal zone management in the United States deal with this very real climate scenario? Taking a look at one of the most highly regarded coastal zone laws and litigation related to it may help strengthen the environmental policy regarding coastal zone geologic processes and the economic development of that same zone.

## VI. North Carolina Coastal Area Management Law of 1974

Enacted by the General Assembly of North Carolina, the Coastal Area Management Act (CAMA) of 1974[67] was passed to protect coastal areas of environmental concern by requiring permits

59. Hurricane Hugo and Andrew both were category 5 hurricanes.
60. *See id.* In 1996 alone, there were 19 named category 3 storms.
61. Kegi Zhang *et al.*, *supra* note 6 at 389, 396-97 n.37.
62. *See id.*
63. *See id.*
64. *See id.*
65. *See* 9a (found in Zhang, *supra* note 6).
66. *See* 9b (found in Zhang, *supra* note 6).
67. N.C. GEN. STAT. §§ 113A-117 (1974).

for economic development in and around coastal lands and waters.[68] The General Assembly recognized that these coastal lands and waters, particularly the estuaries of North Carolina, were among the most biologically productive in the state, providing fisheries for commercial and recreational purposes.[69] In addition, the coastal lands of North Carolina are some of the most esthetically valuable in the entire nation and consequently are attractive for tourism. CAMA was and is intended to manage the coastline for the benefit of its citizens.[70] There often is conflict, however, as the pressure to develop these resources for economic and recreational purposes is at odds with the preservation and conservation of natural environments. No where is this tension more problematic then on the extensive barrier island-wetlands system[71] stretching along the entire length of the North Carolina coast.

In order to provide optimal and balanced utilization of the natural resources on the coastline, while at the same time preserving and protecting those resources for future generations, the General Assembly legislated the formation of the Coastal Resources Commission (CRC)[72] to develop, adopt, and amend State guidelines regarding the coastal zone.[73] The CRC has jurisdiction over all development in the State's coastal wetlands, not just "significant" development.[74]

One of the most contentious goals of the CAMA is to establish policies, guidelines and standards for the economic "development" of the coastal area.[75] Clearly, this jurisdiction was intended to preserve and protect the beach-dune system. This system acts as a barrier to the onslaught of the ocean, particularly during storms. This, in turn, protects the wetlands and waterways beyond the

68. *See id.* §§ 11A-120 (1974).
69. *See id.* §§ 113A-117 (1974).
70. *See id.* §§ 113A-120.1 (1974).
71. *See id.*
72. A barrier island-wetlands system is defined as the corridor of land from the shoreline to the mouth of the river entering estuaries.
73. Adams v. North Carolina Dep't of Natural and Economic Resources, 249 S.E2d 402 (N.C. 1992).
74. Cobey v. Simpson, 423 S.E.2d 759 (N.C. 1992).
75. N.C. GEN. STAT. § 113-A-102(b)(4)(b) (1997). Specifically, the term "development" refers to "the construction or enlargement of a structure; excavation; dredging; filling; dumping; removal of clay, silt, sand, gravel or minerals; bulkheading, driving of piles; clearing or alteration of land as an adjunct of construction; alteration or removal of sand dunes; alteration of the shore, bank, or bottom of the Atlantic Ocean or any sound, bay, river, creek, stream, lake, or canal; or placement of floating structure in an area of environmental concern identified in G.S. § 113-A-113(b)(2) or (b)(5)." *See* § 113-A-103(5)(a).

dunes, the ecology, and the development which exists in harmony with those natural resources.

In order to provide the expertise for making decisions about the proper balance of development and natural resource preservation, the General Assembly addressed the composition of the CRC.[76] The fifteen appointed members of the CRC have expertise in commercial and sport fishing, marine ecology, coastal agriculture and forestry, coastal development, marine-related business, and coastal engineering.[77] In addition, one member should be from a State or national conservation organization, one should have expertise in financing coastal development, and two more members should be from local government.[78] Three at-large positions are stipulated.[79] The primary function of the CRC is to review plans for land use within the coastal area.[80] These plans serve as a means of assessing the impact of the development on the environment and act as a means by which permits are issued or denied.[81] In the face of such plans, the CRC can designate an "area of environmental concern."[82]

Of particular interest regarding potential climate change and sea level rise is § 113-A-113(b)(6), which refers to "natural hazard areas where uncontrolled and incompatible development could unreasonably endanger life or property, and other areas especially vulnerable to erosion, flooding, or other adverse effects of sand, wind and water."[83] North Carolina was one of the first states to use coastal hazards assessments. Specific coastal beaches were given designations as to the magnitude of potential hazards such as beach erosion, washover during storms, and potential inlet formation.[84] CAMA states that coastal areas which the CRC wishes to designate as an "area of environmental concern"[85] must be submitted to an open hearing process for comment from the private and public sectors of that locality.[86]

CAMA is quite explicit on the role of permits in coastal zone

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76. *See id.* § 113A-104(a) (1997).
77. *See id.* § 113-A-104(b)(1-8).
78. *See id.* § 113-A-104(b)(8).
79. *See id.* § 113-A-104(b)(12).
80. N.C. GEN. STAT. § 113A-107(a).
81. *See id.* § 113A-106.
82. Pilkey *et al., supra* note 55.
83. N.C. GEN. STAT. § 113-A-11(b)(6).
84. *See* Pilkey et al., *supra* note 55.
85. N.C. GEN. STAT. § 113-A-116 to 122 (1974).
86. *See* Pilkey *et al., supra* note 55.

development.[87] Specifically, "every person undertaking any development in any area of environmental concern" must obtain a permit.[88] Minor and major developments are differentiated.[89] "Major developments" consist of developments of 20 acres of more[90] or structures on a single parcel of land which occupy greater than 60,000 square feet.[91] The CRC may designate specific classes of development for general permitting based on criteria. These include size of the development,[92] its impact on areas of environmental concern,[93] how often a specific class of development occurs,[94] and the need for public review and comment of the development plan.[95] Grounds for denial of permits include development in coastal wetland,[96] estuaries,[97] areas of renewable resources,[98] historic areas,[99] areas containing natural hazards,[100] as well as areas where the development would be inconsistent with local land-use plans then in effect.[101]

While these sections of CAMA seem to protect areas of environmental concern, particularly those where there exists a potential loss of life and property, the Act allows for variances to these rules which appear to weaken the legislative resolve of CAMA.[102] Specifically, variances can be obtained from strict application of the guidelines for unnecessary hardships or peculiarities in the property in question,[103] and for conditions which could not reasonably have been anticipated when the guidelines were implemented.[104] The issuance of a variance carries with it the explicit responsibility to make modifications to the property restrictions, however, the intent and purpose of the law must be

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87. N.C. GEN. STAT. § 113-A-116 to 122 (1974).
88. *Id.* § 113A-118(a).
89. *See id.* § 113A-118(d).
90. *Id.* § 113-A-118(d)(1).
91. *See id.*
92. *See* N.C. GEN. STAT. § 113A-118.1(a)(1).
93. *See id.* § 113A-118.1(a)(2).
94. *See id.* § 113-A-118.1(a)(3).
95. *See id.* § 113A-118.1(a)(5).
96. *See id.* § 113-A-120(a)(1).
97. N.C. GEN. STAT. § 113A-120(a)(2).
98. *See id.* § 113A-120(a)(3).
99. *See id.* at § 113A-120(a)(4).
100. *See id.* § 113A-120(a)(6).
101. *See id.* § 113A-120(a)(8).
102. *See* N.C. GEN. STAT. § 113A-120.1 (1989).
103. *See id.*
104. *See id.*

preserved.[105] The CRC may conduct hearings within forty-five days from the receipt of the petition for a variance to publicly discuss the ramifications of that request.[106]

## VII. Two Case Studies

North Carolina's Coastal Area Management Law is more environmentally stringent than the other states laws along the Atlantic coastline. These states are allowing more and more open land developed each year at the expense of fragile wetlands and other sensitive ecosystems. Two recent case studies involving CAMA[107] document the significant tension between the desire to develop land on barrier islands in North Carolina and the relentless changes to the coastline that came from storms as well as normal nearshore, wave-induced sediment transport processes.[108]

### *A. Shell Island Resort v. NC Coastal Resources Commission*

When the Shell Island Resort was built north of Wrightsville Beach, NC in 1986 at a cost of $2.2 million, Mason Inlet was approximately one-half mile to the north.[109] Ten years later, the inlet was 167 feet from the side of the building and closing at a rate of 50 feet per month.[110] To protect their investment, the owners petitioned the CRC to build a "hard" structure or seawall in order to stop the progressive erosion. In addition, Mason Inlet would be dredged every three years at a cost of one to two million dollars to replenish the beach. At the time the resort's developers petitioned for the permit to build, they were informed that the development site was "a hazardous inlet area."[111] This was due to the unpredictable shifting of sand and the position of the inlet by the continuous longshore transport of sand and intermittent, but more damaging, allusive events (nor'easters and hurricanes).[112] The most recent such events, hurricanes Bertha and Fran, which occurred during the summer and fall of 1996, had moved the inlet to its present position, producing concern with respect to the

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105. *See* N.C. GEN. STAT. § 113A-120.1.
106. *See id.*
107. *Id.* § 113A.
108. *See* PILKEY *supra* note 55.
109. *See Beach Hotel's Fate May Turn on Coastal Panel's Ruling,* NEWS & OBSERVER (Raleigh, N.C.) July 25, 1996, at 3A.
110. *See id.*
111. Todd Richissin, *Coastal Panel Reverses Policy, Backs Wall for Shell Island,* NEWS & OBSERVER (Raleigh, N.C.), Sept 21, 1996, at 1A.
112. *See id.*

resort's future structural viability.[113] The CRC allowed the permit when the developers accepted the following terms: "[I]n signing this permit, the permittee acknowledges the risks of erosion associated with developing on this site and recognizes that current state regulations do not allow shore-line erosion control structures."[114] The condominium owners claimed the developers never told them that the area was hazardous.[115] Now they were faced with losing the building and their investment.[116] The CRC, citing the permit provisions, denied a request to erect a steel seawall to protect the property.[117] This was consistent with CRC rules that prohibit such structures because they are detrimental to adjacent beach areas.[118] With the developers no longer involved in the situation, the Resort owners filed suit against the CRC in February of 1996.[119] The alternative, as indicated in a petition to the local country commissioners, was to build a "temporary" 450 foot long by 70 foot wide by 22-foot high pile of sandbags to stop the erosion at a cost of up to $400,000.[120]

The local county commissioners were brought into the situation by being petitioned for federal dredging permits to restore the beach.[121] The commissioners acknowledged that providing public money for this project would have to be justified to other beach property owners who were or might be threatened with increased erosion rates due to the erection of the sandbag seawall.[122] Coastal geologists predicted that the seawall would create enhanced erosion further to the south near Wrightsville Beach.[123] The county potentially faced double financial exposure by losing the tax revenue from the resort if it were destroyed. The county ultimately would be responsible for the cleanup of the debris if the building

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113. *See supra* note 109 at 3A; Todd Richissin, *Coastal Panel Rejects Seawall at Shell Island,* NEWS & OBSERVER (Raleigh, N.C.), Sept. 28, 1996, at 1A.
114. *See* Richissin, *supra* note 111.
115. *See id.*
116. *See* Jim Carter, *Let's Act Quickly to Prevent a Costly Disaster,* NEWS & OBSERVER (Raleigh, N.C.), Sept. 8, 1996, at 1A.
117. *See id.*
118. *See* Todd Reichissin, *Fran Rearranges Not Only Coastline But Also Development Debates,* NEWS & OBSERVER (Raleigh, N.C.), Sept. 22, 1996, at 1A, 20A.
119. *See supra* note 109.
120. *See id.*
121. *See* Bettie Fennell, *County Will Chip in to Help Save Condos,* WILIMINGTON MORNING STAR, April 16, 1996, at 1A.
122. *See* Todd Reichissin, *Even Larger Questions Remain About Repairing Barrier Islands*, NEWS & OBSERVER (Raleigh, N.C.), Sept. 28, 1996, at 1A.
123. *See id.*

collapsed into the ocean. The alternative, moving the resort, was deemed impossible.[124]

In July of 1996, the politically-appointed CRC was caught in an untenable position between its professional staff, who rejected the seawall remedy, and the Resort owners, who favored it.[125] By the end of September, the CRC had granted its first substantial exception to a state policy forbidding "hard" structures for coastal erosion.[126] The exception partially was justified on the grounds that Hurricane Fran had accelerated the erosion of the inlet.[127] Not surprisingly, environmentalists saw the reversal of the CRC as nonsensical in the face of the continuous threat of hurricanes and smaller coastal storms to areas of the coastline, that are especially sensitive to erosion.[128] As Todd Miller, lobbyist for the Sierra Club argued, "the state seems to be violating its own rules because the hazards it warned about came true."[129]

### B. *Everhart & Associates, Inc., and Hettie Tolson Johnson v. NC Department of Environment, Health, and Natural Resources (DEHNR)*

The case of Everhart & Associates v. NC DEHNR,[130] DEHNR appealed a decision by the Hyde County Superior Court's reversing a denial of a permit to Everhart & Associates and Hettie Tolson Johnson (the developers) for the purpose of developing land known as Tolson's Island. The CRC gave three reasons for denying the permit: (1) "the development tract is an island surrounded by water and marsh;"[131] (2) the development would require three 1440 gallon septic tanks to serve nine proposed lots;[132] and (3) approximately half of the development most likely would need to be built over federal Clean Water Act Section 404 wetlands.[133] All three of these conditions violate the Hyde County Land Use

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124. *See* Fennell, *supra* note 121, at 1A.
125. *See generally* Todd Reicissin, *Coastal Panel Reverses Policy, Backs Wall for Shell Island*, NEWS & OBSERVER (Raleigh, N.C.), Sept. 21, 1996, at 1A.
126. *See id.*
127. *See id.*
128. *See id.* at 16A.
129. *Id.*
130. Everhart & Assoc., Inc. v. Department of Env't, Health & Natural Resources, 493 S.E.2d 66, 67 (N.C. Ct. App. 1997), *cert. denied*, 347 N.C. 575 (1998).
131. *Id.*
132. *See id.*
133. *See id.*

Plan.[134]

Following the denial, the developers were granted an administrative hearing before the Administrative Law Judge (ALJ).[135] The ALJ allowed the Developer's motion to disallow testimony concerning the issue of the physiographic status of Tolson's Island.[136] That is, whether Tolson's Island was an island or peninsula.[137] The ALJ based his determination that the Island was a peninsula solely on the Land Use Maps,[138] even though these maps contained specific caveats that they were not surveyed. Instead, their physical features were approximated based on 1987 Hyde County tax records.[139] The ALJ did include in the record an offer of proof from John A. Crew, District Planner for the Development of Coastal Management (DCM).[140] Crew stated that the Land Use Maps were of sufficiently large scale, and because of their lack of detail and accuracy were only useful for planning and informational purposes and not for regulatory purposes as cited on the maps.[141] Crew noted that site inspections were necessary to determine the true conditions of the site in order to grant or deny the permit.[142] In his offer of proof, Terry E. Moore, DCM District Manager stated,

> The development site is a small hummock or island which is separated from the Ocracoke mainland by a regularly flooded ares of coastal wetlands . . . . It is bordered by Southward Creek to the west, and unnamed creek to the east and the Pamlico Sound to the north. There is a wide, low marsh to the east of the development site that separates the site from the main body of Ocracoke. The unnamed creek to the east separates the development site from a similar estuarine island which is part of the Cape Hatteras National Seashore.[143]

In the face of the offers of proof, the ALJ maintained that Tolson's Island was a peninsula based on the Land Use Maps.[144] Furthermore, the ALJ found that the septic tanks did not comply

134. *See Everhart*, 493 S.E.2d at 68.
135. *See id.*
136. *See id.*
137. *See id.*
138. *See id.*
139. *See Everhart*, 493 S.E.2d at 68.
140. *See id.*
141. *See id.*
142. *See id.*
143. *Id.*
144. *See Everhart*, 493 S.E.2d at 68.

with the septic tank regulations of Hyde County because the plan called for three 1400 gallon tanks rather than one tank of 1500 gallons or more.[145] The ALJ upheld the permit denial based on the planned modification of CWA Section 404 wetlands, but offered the Developers the opportunity to modify their development plan to avoid the Section 404 wetlands.[146] The CRC determined that the ALJ had erred by not considering the offers of proof and that the Developers had "failed to meet their burden of coming forward with evidence to rebut the findings."[147] The DCM's permit denial, therefore, was affirmed.[148]

The Developers sought review of the CRC's decision,[149] arguing that the CRC erred in concluding that the Developers had not met their burden of coming forward with evidence to rebut the findings.[150] Finally, the Developers contended that the CRC had erred in concluding that the development plan was "inconsistent with those provisions of the Hyde County Land Use Plan relating to construction on estuarine islands; development in wetlands; and the capacity of new septic systems."[151] The court found that the CRC erred in considering the offers of proof and further, that the CRC arbitrarily had acted in its decision.[152] The court reversed the CRC's denial.[153]

The appeal hinged on the issue of whether the offers of proof were considered "new evidence" or were part of the official record of the administrative review.[154] The Appeals Court concurred that the offers of proof were not "new evidence" and that the CRC acted according to CAMA.[155] The court found that the trial court erred in reversing on this basis.[156]

Though concurring in the result, Judge Mark D. Martin wrote a separate opinion.[157] Judge Martin stated: (1) the evidence indicated that the Hyde County Land Use Maps are public documents, routinely used by landowners, developers, land

145. *See id.*
146. *See id.*
147. *Everhart*, 493 S.E.2d at 69.
148. *See id.*
149. *See id.*
150. *See id.*
151. *See id.* at 68.
152. *See Everhart,* 493 S.E. 2d at 68.
153. *See id.*
154. *See id.* at 68, 69.
155. *See id.* at 69.
156. *See id.*
157. *See Everhart*, 493 S.E.2d at 70 (Martin, J. concurring).

planners, and government agencies,[158] (2) development is prohibited on estuarine islands within one mile of Ocracoke by the Hyde County Land Use Plan,[159] a(nd 3) the Land Use Plan characterizes Tolson's Island as a peninsula.[160] He determined that the CRC "inserted a 'new' shoreline on the Hyde County Land Plan Map to make a 'peninsula' into an 'island'."[161] Judge Martin reiterated the Superior Court's claim that the CRC acted arbitrarily and capriciously because it "relies on the Land Use Plan when it serves it[s] purpose and ignores it when it does not."[162]

The Superior Court concluded as a matter of law from the initial determination of the DCM and the subsequent affirmation of the CRC that the Developer's plan was inconsistent with the Hyde County Land Use Plan and were "ironically and unlawfully" ignoring the Land Use Plan itself.[163]

## VIII. Discussion of the Cases and Policy Recommendations

Given that CAMA is one of the most effective coastal management laws in the United States and that North Carolina is known for the passion with which its coastal scientists fight to protect the people from themselves rather than have their property and lives lost,[164] it is disturbing that these two cases arise at this time. The former case points out the inevitable breakdown of a State-appointed commission when faced with a no-win decision. From 1985 to 1996, the CRC consistently had resisted allowing homeowners to rebuild along the beach after storms had destroyed their property.[165] The Shell Island Resort was built in a coastal area known to be hazardous.[166] The extenuating circumstance in this case was the Resort owners' claims that they never were informed of the hazardous conditions.[167] In an editorial discussing the situation, Jonathan Howes, NC Secretary of Environment, Health, and Natural Resources conceded that CRC did not have the

158. *See id.*
159. *See id.*
160. *See id.*
161. *Everhart*, 493 S.E.2d at 70.
162. *Id.*
163. *Id.*
164. *See generally* Pilkey, Jr., *et al.*, *supra* note 55.
165. Todd Richissin, *Coastal panel rejects seawall at Shell Island,* NEWS & OBSERVER (Raleigh, N.C.) Sept. 28, 1996 at 1A.
166. Jonathan B. Howes, *Shell Island Resort: State can preserve rules protecting beaches and still save building,* NEWS & OBSERVER (Raleigh, N.C.), Sept. 8, 1996, at 41A.
167. *See id.*

authority to post notices of the hazards inherent in this or any similar type of development and the issue should be revisited.[168] However, this issue is tangential to the more important one, the relationship between what is known about long and short-term geologic processes in the coastal zone and development in that coastal zone.

The conventional geologic wisdom about shorelines and inlets is that they migrate uncontrollably and sometimes catastrophically, such as happened in this case. The Resort developers were aware of this possibility but decided to take the risk anyway.[169] Should the CRC have reversed its traditional stance and allowed the "hard" shoreline structures which were known to cause increased beach erosion in other locations along the adjacent coastline? Certainly the granting of the permit to the Shell Island Resort set the course for the controversy. Why was the permit ever granted? The mistake was an inevitable one because of the composition of the CRC as noted in the 113A-104(b) and its ultimate "boss," the Governor of North Carolina.[170] It is noteworthy that the composition of the CRC explicitly does not include a coastal oceanographer or geologist.[171] While ecologic interests are well represented, the geologic interests are not. Much study of coastal sediment dynamics has occurred in North Carolina.[172] While coastal zone dynamics are complex, enough is known to predict which parts of the coastline are prone to long-term erosion, if not catastrophic events such as Hurricane Hugo in 1989. As sea level continues to rise due to climate change, it appears likely that these events will continue apace but with greater intensity. The greater the storm intensity on a regular basis, the greater the probability of extensive property damage and possible loss of life.

Between 1950 and 1980, 499,000 people died in the United States from hurricanes, tornadoes, and cyclones.[173] This was more than any other natural disaster.[174] Property damage estimates have skyrocketed in the past two decades from natural disasters and

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168. *Id.*
169. *Id.*
170. *Id.*
171. *See* Howes, *supra* note 167.
172. *Id.*
173. J. HOUGHTON, GLOBAL WARMING: THE COMPLETE BRIEFING (1994).
174. *Id.*

now approach $1 billion per week in the US.[175] While not all of this is due to coastal disasters, Franklin Nutter, president of the Reinsurance Association of America, recently cited population growth in high-risk areas and climate change as two reasons for the increase in catastrophic losses.[176]

Faced with what appears to be an increase in storm surge activity due to a rise in sea level in the foreseeable future, there needs to be a change in coastal management policy that addresses the scientific evidence for rapid shoreline change and its effects on coastal property. CAMA points us in the right direction, but, as the Shell Island Resort case implies, there is still political pressure to find a remedy which appeases all parties, but frequently at the expense of taxpayers who are totally unaffected. At a minimum, the US Geological Survey should be directed to provide a national coastal hazards assessment using the best and most informed scientific evidence. Included in the equation should be sea level rise over the next fifty years. This assessment should be at the core of a revised Federal Coastal Zone Management Law so that it is incorporated into all state laws. The Shell Island case never would have happened had such provisions been in effect.

Inevitably, the ocean will destroy the property that presently stands in designated hazard zones.[177] When this will happen is not precisely known, but it will occur as barrier islands migrate inland in response to rising sea levels. Structures presently in the coastal zone defined as being between the high tide line and the dunes of barrier islands should not be allowed federal flood insurance and should not be rebuilt after being substantially damaged by coastal storms and/or hurricanes.[178]

A good example of the futility of rebuilding beach houses after coastal storms occurred in North Topsail Beach, North Carolina between July and September of 1996.[179] A glancing blow by Hurricane Bertha in July caused moderate damage to homes along this coastline,[180] which carries a rating for extremely high risk of

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175. Kasey Shewey, *UCAR BRIEFING "Extreme Weather and the Insurance Industry,"* <http://www.agiweb.orgagi/hearings/ucar.html> (visited December 5, 1997).

176. *Id.*

177. *See id.*

178. *See id.*

179. Bernard Thomas, *FEMA Response to Hurricane Fran,* HERALD-SUN (Durham, N.C.), Sept. 15, 1996, at A2.

180. *See id.*

overwash due to little or no dune protection and sparse vegetation.[181] Homes subsequently were rebuilt with funds from insurance policies and FEMA aid.[182] Two months later 115-mph winds from hurricane Fran sent storm surges onto the island,[183] sweeping away most of the houses and depositing the debris off into the ocean.[184]

Are these closely spaced natural events abnormal? Should these houses be rebuilt after years of dune erosion on an island with an extreme risk designation? Should homeowners be given low or no interest loans to rebuild, along with Federal Flood Insurance payouts? The answers are all "no" if one looks at the problem from a scientific point of view and with an eye to economic reality. Would the economic well-being of coastal states be improved if they could wean themselves off the coastal development that intimately interacts with the dynamics of the shoreline? Given the dynamics of expected climate change, sea level fluctuation and continual storms, it would appear prudent for coastal policy to be revised based on economic models which assume systematic removal of all but proven safe development in the coastal zone as measured from the high tide mark to the back of the primary dunes.[185]

*Everhart & Associates* brings up another related problem. It is a problem of semantics, definitions and jurisdictions. Land-use planning usually is successful in the hands of those who are trained to do it; land-use planning used primarily to bolster economic growth or tax bases usually creates more problems than it solves.[186] A case in point is the state of land-use planning in Pennsylvania.[187] Land-use planning is done on the municipal level in Pennsylvania.[188] Most often, however, the formal planning resides with County planning agencies, which have no authority over the decisions of the municipalities.[189] They only can "recommend" changes to development plans submitted for mandatory review.[190] This has lead to significant incompatible zoning across

181. Mark Tosczak, *Building in the Face of Disaster,* HERALD-SUN (Durham, N.C.), Sept. 15, 1996, at A2.
182. *See* Thomas, *supra* note 180.
183. *See id.*
184. *See id.*
185. *See* Shewey, *supra* note 175.
186. *See Everhart supra* note 130.
187. PA. STATE MUNICIPAL PLANNING CODE, 53 P.S. § 10209 *et. seq.*, Act 247, P.L. 805, § 209 (as amended, July 31, 1968).
188. *See id.*
189. *See id.*
190. *See id.*

municipal boundaries[191] and uncontrolled development with, at the very least, esthetic consequences[192] along with potential pollution and health problems.[193]

The *Everhart* case exemplifies the problems of allowing a county agency to produce land-use plans which are at odds with a State statute (CAMA) directly applicable to those plans. The lack of precision in the Land Use Plans of Hyde County appears to leave the terms "peninsula" and "island" open to the most general interpretation by developers.[194] As with incompatible zoning in Pennsylvania, inconsistent Land Use Plans will cause harm. This would have been the case in North Carolina had the appellate court not reversed the decision of the lower court.[195] A remedy would seem to be the use of consistent definitions for topographic/physiographic features of the coastline, as well as minimum regulation for the production of Land Use Plan Maps. There is no apparent reason to produce or use inaccurate maps for land use planning. With the coming rise in sea level, some coastal features will change. A peninsula turning into an island is not an unreasonable expectation. Those who enforce the environmental law must be prepared to be vigilant as these coastal changes occur and must move away from granting any permits in the coastal zone.

## IX. Conclusions

Coastal zones are beginning to feel the effects of a change in global climate. The major effects are a rise in sea level and a concomitant increase in storm surges, particularly along the Atlantic coastal margin. Property and life along the coast have long been exposed to the risk of hurricanes and coastal storms, and global warming will heighten that risk.

Coastal management laws are designed to mitigate this loss by controlling the development of the coastal zone. However, a distinct tension exists between the economic value of the coastline and the potential natural hazards that have been documented by the scientific community. Even with the best intentions, coastal management laws are to some degree driven by politics. Those appointed to make decisions under the law inevitably will find it

191. *See id.*
192. *See* PA. STATE MUNICIPAL PLANNING CODE, 53 P.S. § 10209 *et. seq.*, Act 247m P.L. 805 § 209, as amended, July 31, 1968.
193. *See id.*
194. *Everhart*, *supra* note 130, at 69.
195. *See id.*

more and more difficult to effectuate these laws' intent.

The economic incentive to develop the coastline frequently is irresistible. Yet long-term studies of the dynamics of coastlines are available to those who make those difficult decisions.[196] Frequently, a lack of understanding of time scales and rates of change mislead decision-makers about the interaction with their environment, producing devastating results. Present coastal management laws like North Carolina's are sound, but they need to be revised in the face of the realities of the scientific study and evidence.

The geologic processes that occur in coastal zones are hazardous to property.[197] Future development should not be "grandfathered" in perpetuity[198] but rather should be prohibited after the property has undergone substantial collapse due to storm surge or longer-term beach erosion. Where possible, structures should be moved inland. Allowing the rebuilding of destroyed property or artificially protecting endangered property only prolongs and exacerbates the cycle of erosion and greatly increases the expense to taxpayers. The federal government must be responsible for designating "no-build" zones along coastlines based on the best and most recent scientific evidence. Scientific criteria should be paramount in choosing safe development zones. Such zones exist along the coastlines of most states. State governments should conceive a set of scientifically informed and technologically accurate criteria for land-use planning maps to avoid misinterpretation of legally binding definitions about topographic and physiographic features relevant to coastal development and preservation. If revised coastal management laws break the cycle of coastal development, property destruction by storms, and rebuilding on narrower coastlines immediately, a larger and more stable coastal zone will be evident in the near future for all the public to enjoy.

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196. *See generally*, D. Bush, Orrin Pilkey and W. Neal. LIVING BY THE RULES OF THE SEA: LIVING WITH THE SHORE (Duke University Press, 1996) (as an example of long-term studies and their effect on these decisions).

197. *See id.*

198. *See id.*

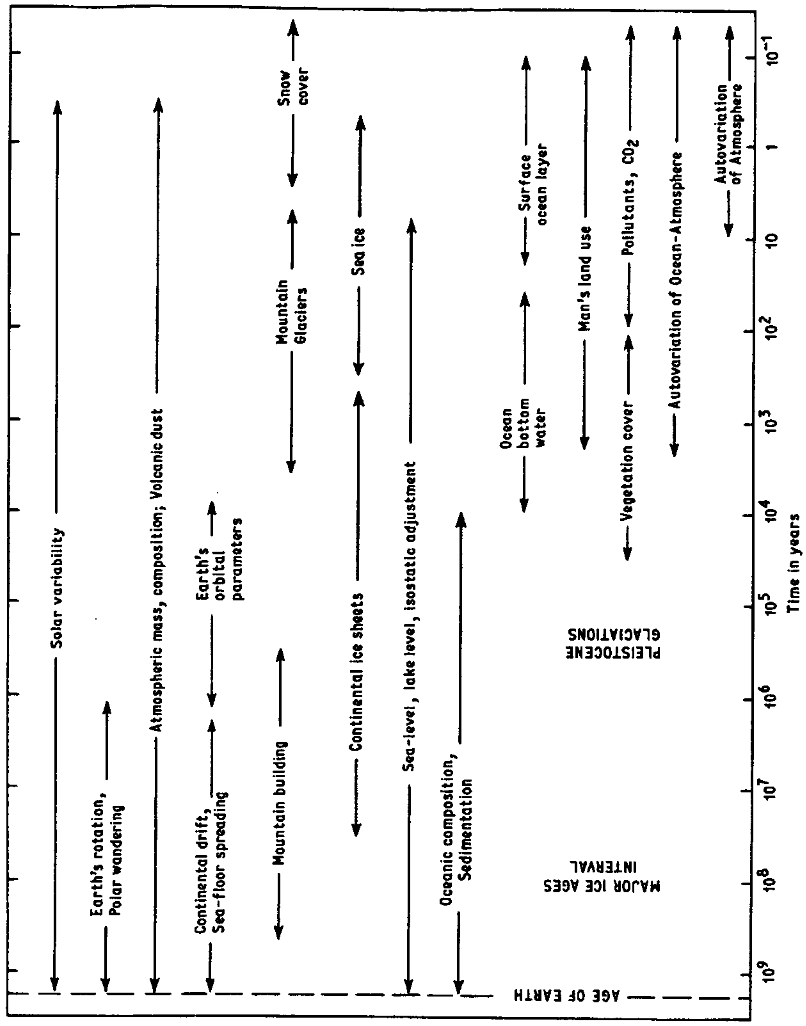


Figure 1. The Characteristic time scales over which possible internal and external causes of climate change take place. Note the coincidence of Man's land use, and autovariation in ocean-atmospheric process (From Gates, 1982)

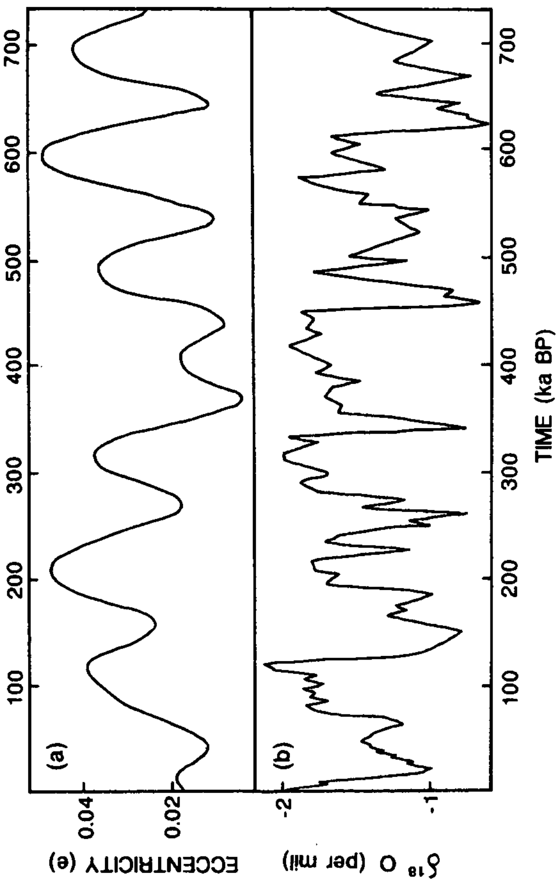


Figure 2. Eccentricity and Global Ice Volume Record for the past 730,000 years (a) Variations in orbital eccentricity, (b) Oxygen isotope curve from deep sea core V28-238. Note decreasing oxygen isotopic data indicates warmer climate and less ice volume After (Imbrie and Imbrie, 1980)

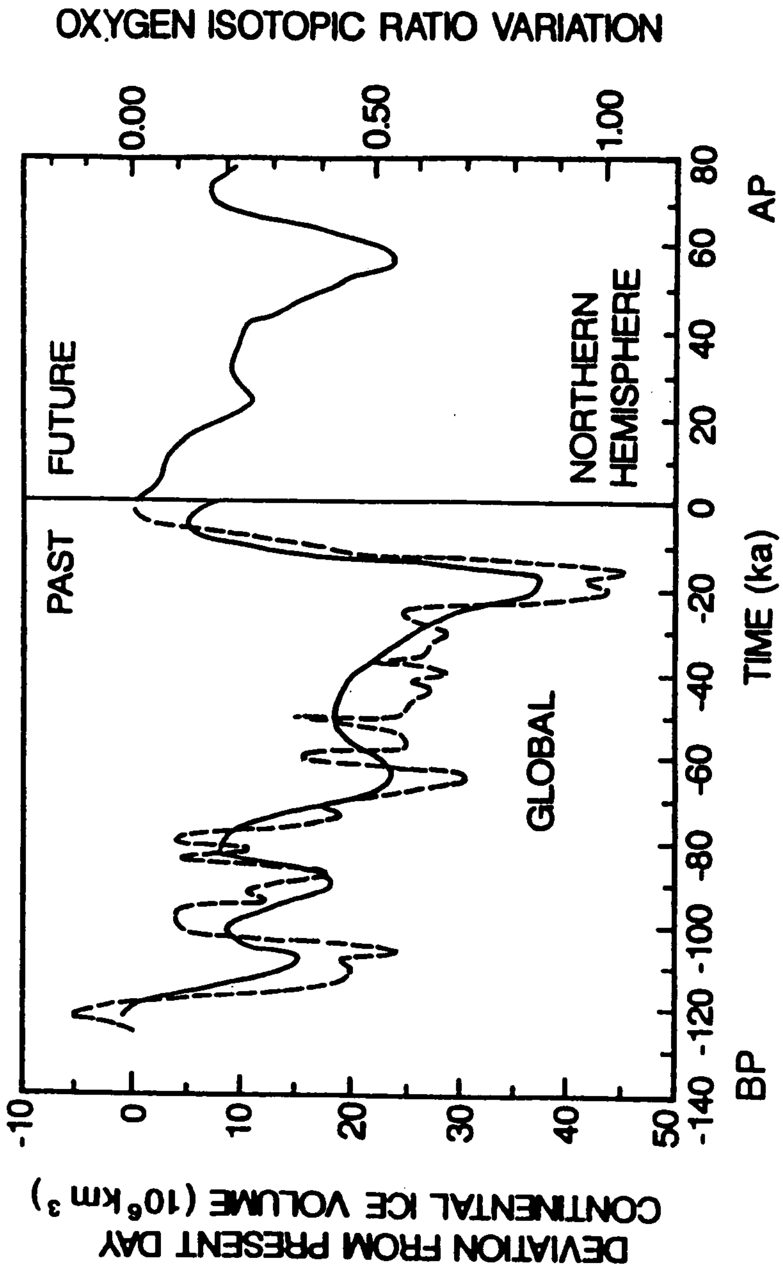


Figure 3. Variations in total continental ice volume, over the Earth from 140,000 years ago to present and over the North Hemisphere from present to 80,000 year in the future. The dashed line represents the variation in oxygen isotope ratios. (After Berger, 1988)

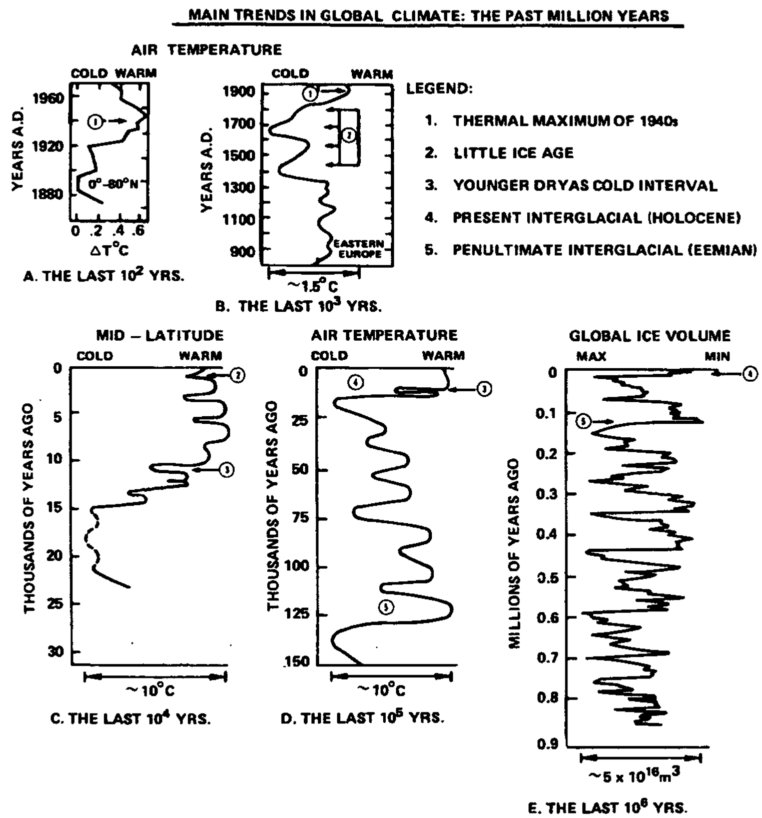


Figure 4. Indicators of global climate change: different time spans compared

a) Successive five-year observed surface air temperature, last 100 years
b) Winter severity index for Europe, last 1000 years
c) Generalized temperature change in middle latitudes form tree-line studies, last 10,000 years
d) Middle latitude air temperature variations from sea temperatures and pollen records, last 100,000 years
e) Global ice volume change from oxygen isotope measurement on plankton, last million years

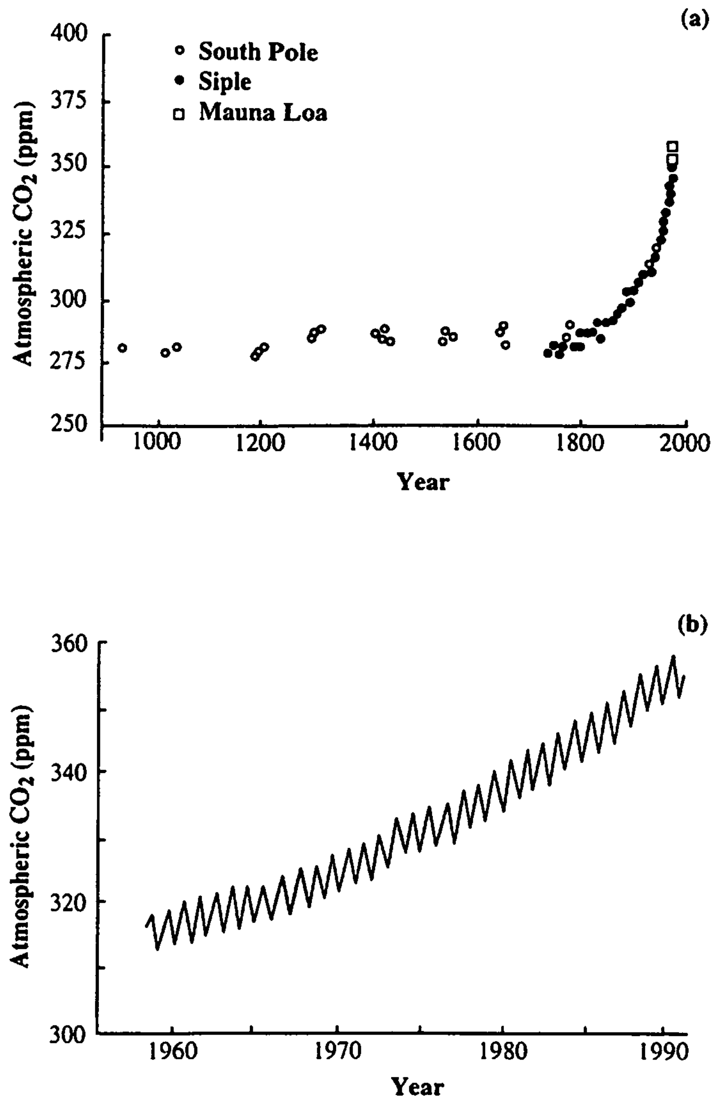


Figure 5. Variation in Carbon Dioxide content of Atmosphere

A) For the last 250 years. Squares are measurement of $CO_2$ in air bubbles in ice Triangles are from Mauna Loa data in B)

B) Direct measurement of air at Mauna Loa, Hawaii.

Seasonal variations are due to withdrawal and production of $CO_2$ by plants

(after IPCC, 1990)

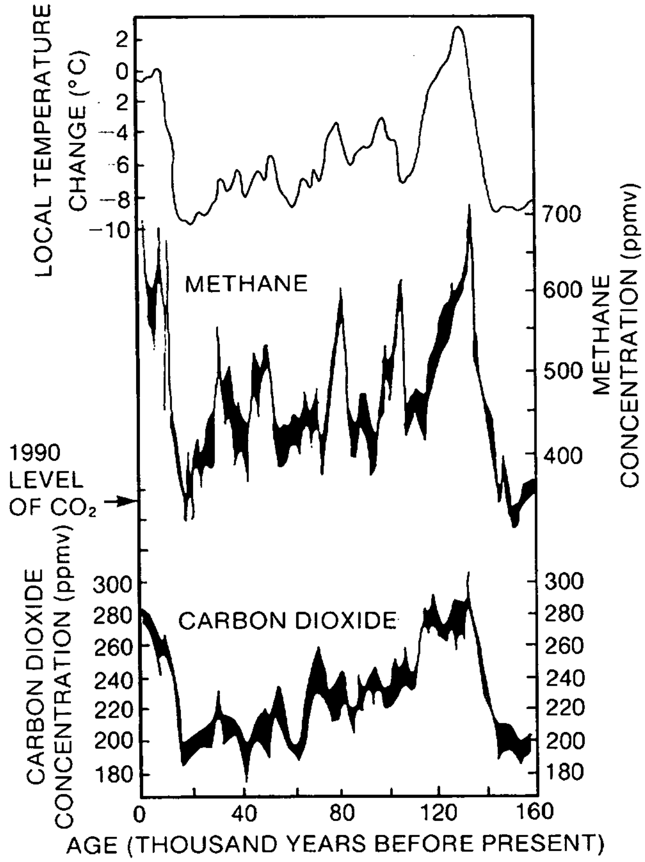


Figure 6. Analysis of air trapped in Antarctic ice cores showing the methane and Carbon Dioxide concentrations highly correlated to local temperature over the past 160,000 years
(after IPCC, 1990)

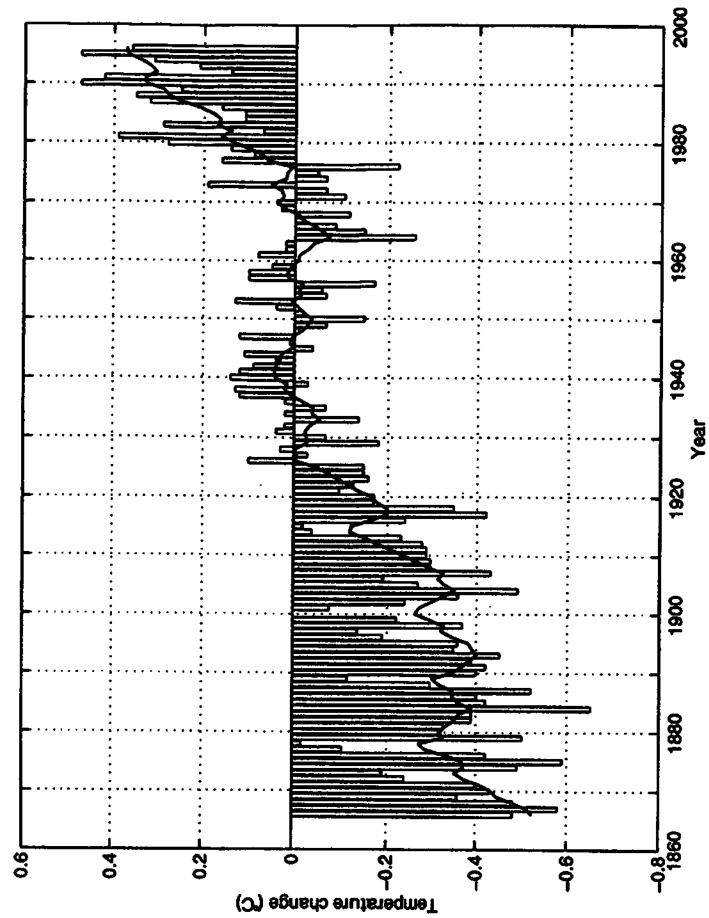


Figure 7. Changes in global average temperature from 1860-1992 relative to the period 1951-1980.

a) over land temperature

b) sea surface temperatures

c) land and sea combined

(After Raynaud and others, 1993)

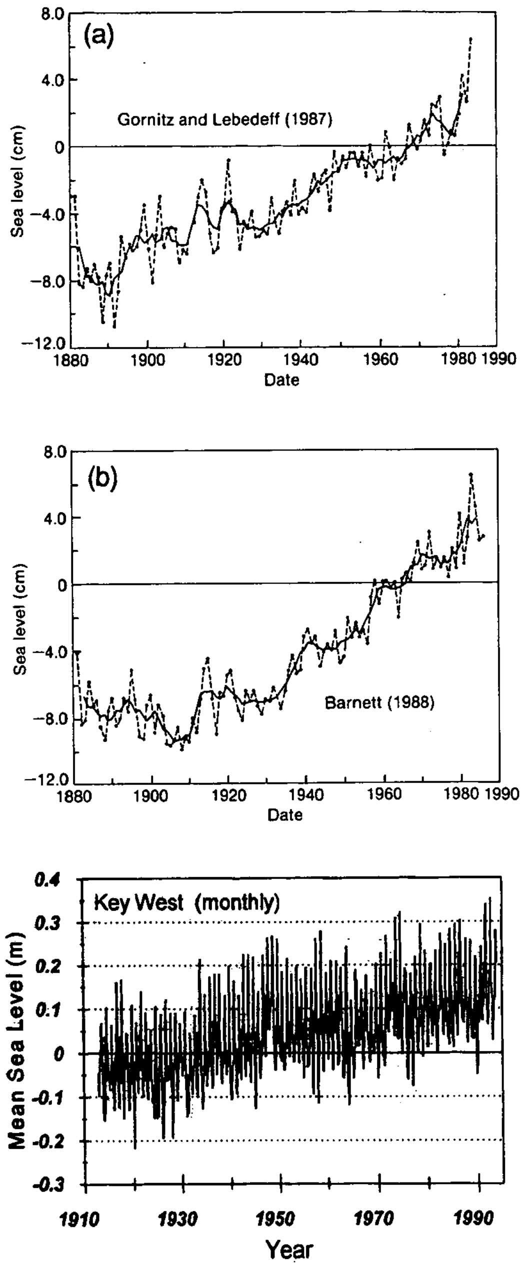


Figure 8. A and B) Global-mean sea level rise over the last century. The Baseline is obtained by setting the average for the period 1951-1970 to zero. The dashed line represents the annual mean; the solid line represents the 5-year running mean C) Sea level rise in Key West, FL (1910-1992). Average is 2 mm/yr with some intermittent rises of over 10 mm/yr.

(after Working Group on Sea Level Rise in Wetland Systems, 1997)

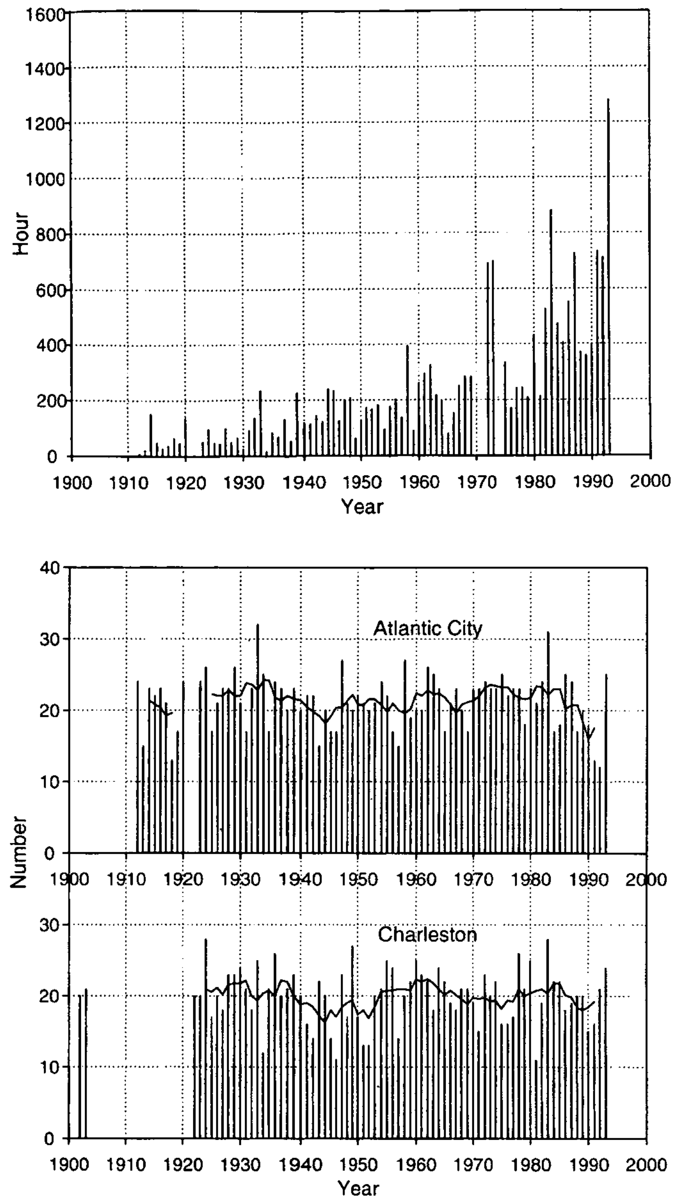


Figure 9. A) Increase in the number of hours of storm surge per year greater than 2 standard deviations from 1912 to 1992 at Atlantic City, NJ. The apparent increase is due to sea level rise during this century. B) Number of storms per year with surge of water level greater than 2 standard deviations at Atlantic City and Charleston, SC. Solid line is 5-year running average. (From Zhang and others, 1997)