THE NEED FOR ACTION TO CONFRONT POTENTIAL CONSEQUENCES OF GLOBAL CLIMATE CHANGE ON A REGIONAL BASIS

(U.S. South Atlantic Coastal Areas of Florida, Georgia, North Carolina, South Carolina plus Puerto Rico and the U.S. Virgin Islands)

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Abstract: The natural record present in air trapped in ice cores, in types of pollen content in peat bogs or in the fluctuating count of windblown diatoms found in deep ocean cores, confirms that the Earth's climate has been oscillating between ice age and warmer climates for millions of years. The time-scales of such repeated advance and retreat of glacial ice point to a 23,000 year cycle, a clear link to the so-called *Milankovitch cycles*. Orbital forces do not however explain all of the oscillations between warm and cold climates, so other factors need to be taken into account. Of these other factors *variations in solar output, plate tectonics* and the resulting alteration of land/ocean distribution patterns and changes in ocean circulation, but principally *atmospheric carbon dioxide forcing*, are considered contributors to climate oscillations.

Although gaps of critical knowledge in the understanding of complex interaction of natural forces driving climate change remain, it is uncontestable that a causal link between atmospheric carbon dioxide and global warming exists. It is also indisputable that natural cataclysmic events, such as volcanic eruptions and meteor/comet impacts, have punctuated these natural oscillations in climate with "peaks" from time to time.

A question under current debate is the role of *anthropogenic factors* in global warming and consequentially in global climate change and in altering the natural time-scales of climate oscillations. That human activity has the capability of altering the atmosphere and consequentially climate, on a micro or regional scale, is generally accepted. The *urban heat island effect* links *urbanization* to altered temperature, humidity, visibility, cloud cover, wind and sunshine and even rain over cities. There are empirical data showing that human activity is a net contributor of *greenhouse gases* including CO_2 and *chlorofluorocarbons* [CFCs] which have an adverse effect on *stratospheric ozone*.

The international community and our federal government have by way of treaties, such as the IPCC[1] and FCCC[2] and laws such as the one creating the USGCRP[3], adopted a *precautionary principle* calling for action now to reduce the consequences of global climate change, rather than waiting until solid scientific proof of causal links is obtained.

The U.S. Congress has mandated a *National Assessment* [NA] on the potential consequences of climate change be made public by January 1, 2000. The NA will compile information from *Regional Assessments* [RAs] throughout the country. RAs will be based on *regional workshops* where regional *stakeholders* will come together with representatives from the federal, state and local government, from the scientific research community and from NGOs and business, to discuss such potential consequences and to recommend actions.

Results of simulations and models are inconclusive in linking global warming to an increase in the number and intensity of extreme weather events. However initial simulation results and empirical data show some intensification of extreme events may result from global warming. To focus on this possibility and to discuss potential regional consequences of climate change, on *U.S. South Atlantic Coastal Areas, Puerto Rico and the U.S. Virgin Islands*, the *International Hurricane Center* will hold a *Climate Change and Extreme Events Workshop* in July 21-23, 1998 at Florida International University's Kovens Conference Center in North Miami, Florida.

[1] IPCC: Intergovernmental Panel on Climate Change; established by the UN and the WMO in 1988
[2] FCCC: Framework Convention on Climate Change: international treaty ratified by the senate in 1992
[3] USGCRP: U.S. Global Change Research Program established by U.S. law in 1989.

INTRODUCTION

Change is Inherent to Planet Earth

Change whether imperceptibly slow or punctuated by cataclysmic events, but always present and inexorably permanent, is inherent to planet Earth and the whole universe. Change, like gravity, is a universal constant.

One element of change that holds a great deal of interest for humankind, because of its potential effects on all fields of human activity, is Climate Change.

Natural Climate Change

The scientific community has continuously uncovered natural records that help document, and some times explain, the history of climate change on Earth. Most of these natural archives describe a history of cycles, or oscillations, in the natural processes of the planet that continue even today. Pollen contents in peat bogs around the world, such as *La Grande Pile*[4] and *Les Echets* in France or the *Tenaghi Phillipon* in Greece, hold records of major vegetation inversions that go back 1 million years. Such vegetation inversions reflect changes in climatic habitats resulting from significant shifts in precipitation.

Different natural markers of climate change cycles show a clear linkage to astronomical processes. For example, fluctuations in the abundance of windblown diatoms present in deep ocean cores, and the presence of *sapropels*[5] in cores from the eastern Mediterranean Sea, constitute independent markers of climate change over Tropical Africa that point to a 23,000 year cycle[6] that coincide with the precession in the orbit of the Earth.

Some natural markers identify purely geological processes, including plate tectonics and the formation of mountains as well as the zigzag of greenhouse gases, as main contributors to climate change. Yet others such as those coming from ice cores and measurements of the ratios of oxygen isotopes over time, also serve to confirm these climate cycles and to show that the Earth's climate is naturally oscillating between Ice Ages and warmer climates.

Stating that Earth's climate is oscillating between Ice Ages and global warming is an oversimplification. On the other hand scientific knowledge derived from available information still has significant gaps. For example, the combination of factors interacting to drive the Earth's climate system is not yet fully understood.

Also sudden cataclysmic events, including volcanic eruption and meteor/comet impacts, have undoubtedly punctuated these oscillations with contributors to climate change over the ages.

[4] Richard B. Potts 1996 – *Humanity's Descent: The Consequences of Ecological Instability*
[5] Martine Rossignol-Strick 1985
[6] Milutin Milankovitch 1935 – *Milankovitch cycles*

The gaps of critical knowledge in the science of climate change are made more complex, because as each glacial/warming oscillation is completed the habitats and the biosphere itself entering a new cycle are different than those which initiated the preceding cycle. As a result of new rounds of change being applied to already-changed environments, the baselines also change making it more difficult to develop predictive models for natural climate change.

Anthropogenic Climate Change

A clear example of the effect of human activity on climate can be found in and around the ever-expanding urban environments of today.

Weather service and meteorological stations have consistently recorded noticeable differences between data readings collected around cities and those from rural sites. These observations show that levels of temperature, humidity, wind, cloud cover, rain and even sunshine are different between urban and rural environments.

Urbanization, a clear and undeniable representation of human activity on this planet, provides important examples of climate modification resulting from anthropogenic causes.

Because of the disruption of surface soils and natural vegetation, in addition to the increased emission of greenhouse gases and atmospheric pollutants, city environments are better stores of heat and poorer stores of water. Urbanization – human activity – changes the cycling of heat and water creating local climates with distinct surface temperatures and humidity levels.

Thus urbanization offers a solid empirical record supporting climate change that results from human intervention, although at a micro and near-surface scales. Is human activity capable of significantly contributing to climate change on a global scale?

After years of analysis, in 1995 the United Nations sponsored *Intergovernmental Panel on Climate Change* [IPCC] offered the following findings "…evidence suggests that there is a discernible human influence on global climate." The IPCC noted however that the amount of that influence is unknown due to "uncertainties in key factors."

While ambiguities about the specific consequences of human activity on the global climate remain, the capability of humankind to alter the atmosphere is generally accepted.

One significant element in human contributions to atmospheric changes is that they are by and large unidirectional. While nature continuously employs feedback mechanisms to balance numerous elements interacting in the atmosphere, and driving the global climate, human activity continues to insert byproducts into the atmosphere without elements to interactively counteract their impact.

The *greenhouse effect*, a key factor in *global warming*, is a clear example of the above. Of the various gases that are part of the process called the greenhouse effect, human activity is a net contributor of *carbon dioxide* as a result of burning fossil fuels. CO_2 concentration in the atmosphere is now 30% higher than before the industrial revolution, and it continues to increase at a rate of 0.3% a year mainly from human activity emissions.

Human activity is also a net contributor of other greenhouse gases such as *methane* and *nitrous oxide,* as well as *chlorofluorocarbons* [CFCs] that have damaged the ozone layer.

Average global surface air temperatures have risen by 0.5° Celsius in the past 100 years. The IPCC projects average surface air temperatures rising by 1° to 3.5° Celsius in the next 100 years. Most of this warming is attributable to the emission of greenhouse gases resulting from human activity.

A NEED FOR ACTION

That the global climate has oscillated between extremes of cold and warm temperatures over the course of million of years is uncontested. That the rate of climate change has accelerated since the Industrial Revolution is also generally accepted. Thirteen of the warmest years over the last century have occurred since 1980, with 1997 been the hottest on record.

That shifts in climate have shaped and defined the course of human destiny over the past several hundred thousand years is also accepted. That climate change will continue to affect human activity is a fact.

Thus here stands humanity, at the threshold of a new millenium, accepting that global climate has changed human beings in the past and that it will continue to do so in the future. This certainty however is now linked to a still debated near-certainty that humankind seems to be changing the global climate.

Scientific Proof of Cause and Effect is Needed

The global scientific community has yet to show direct causal links between aspects of human activity and atmospheric alteration leading to global climate change. As the scientific process of identifying such cause and effect continues, it is generally accepted that human activity contributes to processes that are changing the way solar energy interacts with the Earth's atmosphere. This anthropogenic change in interaction may lead to alteration of the global climate. This knowledge will, in turn, allow humankind to control, change or even stop activities that result in such contributions possibly leading to a reduction of their adverse effects on the global climate.

How Will Humankind be Affected?

Far more important than resolving the uncertainties that remain about anthropogenic causes of global climate change, is the need to understand and predict what ramifications climate change will have and how these, in turn, will affect humankind.

Finding answers is difficult due to the multiple interactive variables that constitute the global climate system.

Some effects of climate change have been identified already, and attempts at predicting future behavior of these have been made. Global warming and sea-level rise are two such indicators of climate change.

What consequences will this rise in global temperature bring about? Will prevailing wind and precipitation patterns change in a significant manner? What effects may these significant changes bring about? Will these changes alter agricultural output or growing seasons?

Will these changes bring about more frequent and intense extreme climatological events such as hurricanes, tornadoes, flooding and storm surges? Will the prevailing tracks of extreme events shift thereby changing the vulnerability of previously "safe" communities? Will cyclic phenomena, capable of altering global climate patterns, become more frequent, more intense or long lasting?

This line of questioning may easily grow, by piling question upon question, adding to this chain of uncertainties. Yet, the main question would still remain: how will this effects impact the lives of millions of people who may depend on the predictability of prevailing rainfall and wind patterns for their own survival?

It must be stated however that while significant uncertainties and ambiguities about cause and effect remain, the fact that climate change is in progress today and that the rate of change has accelerated in historical times, are both uncontestable.

Action Must Be Taken Now

In view of these certainties, and of the potential for significant impact on human activity, it is proposed that the only prudent course is to explore and implement alternatives for action to reduce the adverse effects of global climate change, and to do it now.

An International Worldwide Framework for Action

One important response to this call for action now is the United Nations Framework Convention on Climate Change that was proposed in 1992. The Convention was negotiated and ratified by 165 countries taking effect as a World Treaty on March 21, 1994. The Convention faced with the question of what to do when the consequences of a problem are uncertain, has proposed action be taken now rather than waiting until the consequences and adversely affected *stakeholders* have been identified.

In taking this proactive stance the Convention has broken new ground by adopting the *precautionary principle,* a recent development in international law. Under such precautionary principle, activities that have the potential for adverse or irreversible damage, such as those that may contribute to climate change, can be restricted or prohibited before there is absolute scientific certainty about their effects.

This precautionary principle is founded on the understanding that the ability of humankind to combat the adverse effects of certain environmental problems may be seriously compromised, or be

taken away altogether, if final scientific proof of cause and effect is required before actions can be taken. In other words, to wait for such final proof might be too late.

The Convention, as an international treaty, has the potential of changing the status-quo or, at the very least, of motivating individual countries into recognizing the need to act now. This positive outlook must be however sobered by the recognition that the road ahead is difficult and fraught with the potential for failure. Inequalities between developed and developing countries are at the root of such perils.

The need for many countries to improve the standard of living for the vast majority of their population, through industrialization and urbanization and improved public services, is a process that could exacerbate anthropogenic contributions to climate change.

This need of developing countries clashes with the interest of already developed nations that have been, and continue to be, some of the largest contributors of greenhouse gases. The international community must find the will to put the common good above the interests of individual states. The United Nations Framework Convention on Climate Change is a positive step in that direction.

THE UNITED STATES BLUEPRINT FOR ACTION

The United States has taken a pragmatic approach to tackling the potential national consequences of climate change and variability. First it recognizes there is an existing, evolving and long-term problem. It also recognizes the need for setting objectives and for taking action sooner rather than later, even though actual effects from climate change may not be fully recognizable for some time.

The United States Global Change Research Program

The United States Global Change Research Program [USGCRP] was established by the Global Change Research Act [7] in 1990. The same Congressional act also mandates that the Federal government shall prepare and submit to the President and the Congress a *National Assessment* on the potential consequences of climate variability and change.

This National Assessment [NA] must meet the following objectives:

1) *"integrates, evaluates and interprets the findings of the Program* [the USCGRP] *and discusses the scientific uncertainties associated with such findings;*

2) *analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and*

3) *analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years."*

[7] Public Law 101-606

Completion of the NA will be based on the involvement of a wide cross section of *stakeholders* from representative sectors from all corners of the nation. These stakeholders will come from the government sector [Federal, state, tribal and local], from business and industry, from academia, non-profit organizations and from the general public.

The assessment will provide a matrix of scientific research findings and stakeholders needs and objectives to be used by planners, legislators, managers and the general public to make decisions and to take actions to mitigate the potential for adverse impacts from climate variability and change.

The National Assessment Process

This multidisciplinary and comprehensive NA process will incorporate three main components:

1) National synthesis: this will collate findings from the regional and sectoral analyses on the potential national consequences of climate change. This may also include new analyses as needed.

2) Sectoral analyses: these will discuss potential consequences from climate change of important economic sectors across the nation, with emphasis on the following five:

    a) Agriculture

    b) Coastal regions

    c) Forestry

    d) Human health

    e) Water resources and management

3) Regional analyses: these will identify potential consequences from climate change on specific geographic regions. The work will be based on a series of regional workshops that has been underway for a year and is nearing completion.

THE NEED FOR REGIONAL ACTION

For the purposes of this workshop our region includes the Atlantic coastal regions of Florida, North Carolina, South Carolina and Georgia, plus the U.S. Virgin Islands and Puerto Rico.

This region has a permanent population of 15.5 million (1997), a seasonal population of 5.0 million and a floating tourist short-term population averaging 30 million yearly. This means that as of 1997 some 20.0 – 24.0 million people inhabit this vulnerable region.

This region has the highest level of vulnerability to climatological hazards in the United States and the Caribbean. The two costliest hurricanes on record [Hugo in 1989 and Andrew in 1992] hit this regional coastline in the past ten years. One of only two category 5 hurricanes to make landfall in the continental U.S. hit here [Florida Keys in September 1935].

In addition to hurricanes the region is vulnerable to sea level rise, storm surges, tornadoes, coastal and riverine flooding, flash floods, lightning and wild fires and drought.

More than 26% of the total barrier island acreage in the U.S. is located along the coastline of this region. In addition the Florida Keys, Puerto Rico and the U.S. Virgin Islands constitute important island environments especially vulnerable to the consequences of climate change.

The vulnerability of the region includes important and fragile coral reefs already subjected to severe anthropogenic and natural stresses. These reefs are an essential component in a complex ecological environment which would sustain irreparable damage should climate change intensify coral reef bleaching.

When the special vulnerability of this coastal/islands region is taken in conjunction with global warming and sea level rise, both existing indicators of climate change, it could be concluded that conditions may arise that would result in more frequent or intense hurricanes affecting the region.

In view of this, it was thought appropriate to designate this as the Climate Change and Extreme Events Workshop.

Purpose and Objectives of the Workshop

The overall purpose of this regional workshop will be to debate the state of our current knowledge on the issues of climate variability and climate change, to draw conclusions as to what this means in terms of impact to life and the environment, and to examine the vulnerability of our region to the adverse effects that may result.

Another important purpose of this workshop will be to provide key regional information that can be collated with that from other regions in order to create a national assessment of vulnerability to climate-related impacts.

A key objective of this workshop is to make an effective contribution to the mitigation of climate related impacts, by identifying potential mitigation measures and by offering specific recommendations for action on regional and national scales. It is expected that this process will be facilitated by bringing together regional stakeholders with academics and representatives from the public and private sectors under a format and agenda emphasizing and promoting the need to convert scientific analysis into long term policy and day-to-day actions.

Main Workshop Themes

To maintain consistency with the many similar workshops that have taken place already or are just being organized across our nation, this regional workshop will focus its dialog and debate on the following themes:

Trends and Impacts – Existing Stresses and Issues

Current knowledge has already identified key indicators that point to potential adverse impacts that may be brought about by climate variability or change.

On the other hand, there exist regional stresses and issues that may be affected even more by climate change or an increase in the magnitude of climate variability.
These climate change trends and potential impacts need to be integrated with existing regional stresses and issues into an overall picture to create a foundation for meaningful debate on climate change related vulnerability and mitigation on a regional basis.

Interaction of Climate Change with Existing Stresses

Existing stresses already tax regional infrastructures, often to their limits, and already require most of the time of regional policymakers.

The questions to be asked include:

- Are current stresses magnified or dampened when climate change or magnified climate variability affect a given region?

- How might climate change interact with existing regional stresses?

Types of Information Needed to Understand Climate Change

The effects of climate change need to be understood by stakeholders and decision-makers, both in the private and public sectors, to assess the regional vulnerability to potential adverse impact.

This understanding may only come from knowledge that is based on information mainly provided by the scientific and academic communities.

The questions to be asked are:

- What information is needed and how can it be converted to knowledge?
- Is the essential information available and, if so, is it accessible to those that could use it to make decisions and to establish policy?
- How is this information communicated to stakeholders and decision-makers? Is it passed on as data or is it transferred via an educational process, to promote the acquisition of knowledge for effective policy and decision making?
- What areas of research need to be pursued to provide answers for questions posed by regional stakeholders?
- How can the gap between information providers and knowledge users be bridged?

Coping Mechanisms

Information, knowledge and understanding of the processes driving climate change, the potential impacts and the effects of the interaction with existing regional stresses and issues, will only be meaningful if they result in coping mechanisms being adopted that may, in turn, lead to mitigation measures.

The questions then become:

- What are some of these coping mechanisms?
- Can these coping mechanisms minimize stress while also addressing regional climate change issues and concerns?
- How will these coping mechanisms be adopted by regional stakeholders and decision-makers?

What is the Cost? What can done?

All discussions of issues and findings and the debate on strategies and positions, will make an effective contribution only within the context of what climate change means in terms of cost and of actions that may be needed. In that sense, these questions of cost and needed actions constitute the underlying theme or common thread of this workshop.

The issue of cost must be viewed as the price tag, in human, economic, environmental and political terms that will be paid as a result of actions taken or not relative to climate change and its potential impacts on this region and elsewhere.

The issue of needed action has to be viewed from the perspective of anthropogenic forces driving the processes leading to climate change. Actions need to be based on the ability of humankind to effectively manage its influences on climate, especially those with deleterious consequences. In this respect, identifying such manageable human influences must become a priority in order to fuel the debate that may lead to effective mitigation actions being taken.

The International Hurricane Center

The International Hurricane Center [IHC], a Type 1 research center at Florida International University [FIU], in collaboration with NOAA Office of Global Programs [OGP], the U.S. Global Change Research Program [USGCRS] and the White House Office of Science and Technology Policy [OSTP], will hold the regional workshop on climate change in July 21-23, 1998 at FIU's Kovens Conference Center in North Miami, Florida. Additionally the IHC is working with The Climate Institute to host an international Climate Change Conference the first week of December, 1998.

The Stakeholders

This workshop will be most effective if it addresses the concerns of regional stakeholders while also providing a foundation to discuss how and when to take action to better prepare for what seems as a present reality to some or a distant future to others.

Who are these regional stakeholders?

Stakeholders are defined as those who have a vested interest in the region and its future. In that sense, all sectors of society are stakeholders. This includes local authorities, industry and business, all sorts of local organizations and the public at large.

It would be impractical and overwhelming to try to address the concerns of all sectors of society relative to the issue of climate change. Thus for the purposes of this workshop, stakeholders are defined as those sectors that are keystone components of the region. This means sectors that have the potential for affecting the region in a significant manner, in human, environmental, economic or political terms, when and if adversely affected by climate change.

It is recognized that these stakeholders, even under this narrower definition, may still represent too many sectors to achieve productive dialog during the workshop, however the following regional stakeholder sectors have been identified:

- Tourism
- Insurance
- Banking

- Agriculture
- Water Resources
- The Everglades
- The Coastal/Marine Environment
- The Health Sector

The potential effects of climate change and variability on regional stakeholders are best identified through the analysis of likely scenarios in the region under study.

CLIMATE CHANGE AND HURRICANES

Background: There is incontrovertible scientific evidence that global average temperatures are raising both over land and ocean surfaces. Combined land/ocean observations show that average surface temperatures have increased by 0.3° – 0.6° C over the last century.

The rise in average surface temperature has not been uniform. Subtropical areas have experienced higher increases than tropical areas. Also, there are some sub-areas within warming areas that have actually cooled or not warmed at the same rate. Empirical evidence suggests that this is the result of regions that are downwind of major sources of sulfur dioxide emissions. Sulfate aerosols present in such emissions reflect sunlight back into space partially compensating for global warming.

With regard to this cooling effect, it should be stated however that: a) the net effect over the past century is a warming trend, b) sulfate aerosols remain in the atmosphere for relatively short times as they are washed away by precipitation, usually in the form of acid rain, and c) government policy, such as the United States Clean Air Act require significant reductions of this type of industrially-generated emissions. In summary, except for natural emissions of sulfate aerosols such as volcanic eruptions, these cooling agents should not be expected to have a major compensating effect on global warning.

Regarding this component of global climate change, it is important to notice that satellite and balloon atmospheric studies are still inconclusive as to the existence of global warming and may, in some cases, even suggest that a cooling trend may exist. On the other hand, middle atmosphere aeronomy confirms the increase in carbon dioxide concentration that provides a cooling mechanism for the stratosphere, but keeps the warming trend in the troposphere, the region where much of earth's weather takes place.

Based on the above it could be concluded that the coupled ocean-atmosphere heat-transfer engine has been warming over the past century and will continue to warm by about 2° C by the year 2100, even when the cooling effect of aerosols is taken into account[8].

[8] IPCC Report 1996

This global warming is a causal effect of increased greenhouse gases as the atmosphere tries to keep the balance between incoming and outgoing solar energy[9]. Yet other climatic changes may take place to compensate for the continued global warming. Some of these changes may include altered wind patterns and ocean currents.

Current global warming promotes and sustains environmental factors that favor cyclogenesis, such as high sea-surface temperature [SST] exceeding 26° C and a deep thermocline, high relative humidity in the lower/middle troposphere as the capacity of the air to hold moisture increases with warming. Warming of the troposphere also promotes atmospheric conditional instability, which in turns promotes tropical cyclones (TCs)[10].

There are empirical data indicating that hurricanes formation, cyclogenesis, will encounter more favorable environmental physical parameters as global warming continues. However, empirical data alone such as SSTs or the combination of other environmental factors are not sufficient to establish how hurricane frequency might respond to continued global warming. Although these empirical observations should not be ignored, they cannot be used to project tropical cyclone variability on interannual or interdecadal time-scales.

Several tools including modeling, theoretical simulation, analysis of geological records and instrumental observations have been used to ascertain hurricane variability and to try to understand how environmental factors favoring cyclogenesis may change in response to climate change
Models[11] have simulated increases in hurricane intensities in a global climate warmed by CO_2 increases resulting in hurricane wind speeds that were higher by a factor of 5% to 12% (3-7 m/s) and central pressures that were lower (more intense hurricanes) by 7 to 20 mb[12]. Some of the same models have been used by others to investigate possible changes in hurricane activity under higher CO_2 induced climate change, but with mixed result[13]. So it is apparent that uncertainties remain and that model refinement is needed to improve the reliability of the results.

A significant problem is the lack of extensive and accurate instrumental records. Aircraft reconnaissance provides a continuous record of more than 50 years for the North Atlantic Hurricane Basin (North Atlantic, Caribbean Sea and Gulf of Mexico), and for the Western North Pacific. For the remaining tropical cyclone areas most of the reliable instrumental records are based on satellite observations extending over the last 25 years. Such a short and limited record is not adequate to making conclusive analyses of tropical cyclone variability.

Complementing these short records, studies have been initiated to quantify tropical cyclone activity over the last 10,000 years (back to the origins of the present interglacial period) by studying polar ice cores, coral reef cores and other records. While initial results show the potential of this methodology there is insufficient information at this time.

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[9] IPCC Report 1995
[10] W. M. Gray 1968
[11] OAGCM: *Ocean-atmosphere General Circulation Model;* AGCM ; *Atmosphere General Circulation Model;* Also Mesocale models.
[12] T. R. Knutson, R. E. Tuleya, Y. Kurihara 1997
[13] Broccoli and Manabe, 1990, 1992

Current Stresses: a) Against this background of empirical data and tentative, but still inconclusive scientific evidence on the issue of TC variability, the population and development of the coastal and island components of this region continue to grow thereby increasing the vulnerability to extreme events, and the stresses on the regional environment; **b) T**he totality or this regions falls within the path of the largest number of tropical cyclones, and hurricanes, based on the historical record. The region has also received more hurricane landfalls than any other region in the United States; **c)** The very low degree of accuracy in predicting landfall with sufficient advanced warning to allow the emergency management community and the population at large to take effective protective action, while minimizing the costs of such actions, creates another current stress factor.

Potential Consequences of Climate Change: a) An increase in the frequency and/or intensity of hurricanes traveling through, or making landfall in, this region may have a high degree of probability, based on the results of simulations and modeling, and on empirical data; **b)** Just one impact from a major hurricane on one of the highly developed areas in the region, the probability of which would increase from climate change, could create so severe a socio-economic impact as to make it impossible for said area to fully recover (i.e. Homestead, Florida) ; **c)** More frequent or intense hurricanes could so severely alter the physical and ecological structures of coastal systems, as to make beach renourishment, commercial or recreational fishing, and tourism in general unsustainable at its current levels.

CLIMATE CHANGE AND WATER RESOURCES

A critical factor in coastal development, from North Carolina through Florida, is water. Although this coastal region is in the drainage basin for the Appalachian mountains and it contains several rivers and lakes including Lake Okeechobee in Florida, the second largest freshwater lake entirely within the lower 48 states, competing demands for water have placed stresses on the region's water resources.

Underneath Florida is the Floridian Aquifer, one of several enormous limestone reservoirs of underground water, estimated to contain $1x10^{14}$ gallons of fresh water. The Atlantic coastal region of Florida receives from 53 to 60 inches of rain a year or a range of $1x10^{8}$ to $1.13x10^{9}$ gallons of water per day.

An integral component of this fresh water inventory is the Kissimmee-Okeechobee-Everglades system that provides storage, water transport and purifying/filtering functions. Of this system the better known element is *the Everglades*, a lifeline for the ecology of a whole region.

Current Stresses: a) Despite all this water, its availability for residential consumption, agriculture, industry, recreation and for ecosystems such as the Everglades, is already compromised as a result of the decreased capability of the natural system for storing and cleansing freshwater; **b)** The principal stress on water resources in Southeast Florida comes from development and urbanization of the area. This has been made possible by 1,800 miles of drainage canals and flood gates built by the U.S. Army Corps of Engineers as the *Central and Southern Florida Flood Control Project,* going back to 1948, and now maintained by the South Florida Water Management District [SFWMD]; **c) T**he Central and Southern Florida Flood Control Project was designed to provide

drainage and water supply protection for a population of 2.0 million people by the year 2000, but it is already meeting the needs of almost 6.0 million people in mid 1998[14], severely taxing its capacity and its management requirements; **d)** Drainage has been instrumental in reducing the area of the Everglades, by two million acres to half their size, over the last 50 years, and presently drain $652x10^5$ gallons of fresh water per year into the sea. This upsets the water balance [salinity] of estuaries affecting complete ecosystems. This drainage has lowered the water table to accommodate urban growth, siphoning water eastward from the Everglades instead of allowing it to replenish the aquifer. Although the example of Southeast Florida may be extreme, similar situations of human intervention placing stresses on natural waters systems are found in the Atlantic coastal areas of Georgia and the Carolinas; **e)** Island communities are especially vulnerable to stresses on their freshwater supplies. Most of the smaller islands lack natural sources of freshwater and must depend on piped water or on collected/stored rainwater. In the case of Puerto Rico, limited freshwater supplies are compromised by high population density and continued urban/industrial development in the island. In the U.S. Virgin Islands collected rainfall, desalinization plants and barged water from Puerto Rico provide most of the supply; **f)** This is a region where water resources and freshwater systems are already under severe stress. Where there is abundant supply, systems are in place that basically throw away large volumes of freshwater. Other parts of the region have limited or no freshwater sources except for rainfall.

Potential Consequences of Climate Change: a) An increase in extreme events brought about by climate change or variability that leads to increased risk of flooding would, in turn, increase the conflicting needs of a human habitant that depends on flood control measures that clash with the needs of the natural habitat; **b)** The Everglades could continue to deteriorate should there be a need to increase measures that lower the water table, to protect the human habitat, or drain millions of fresh water per day into the ocean; **c)** A combination of flood control measures and continued sea level rise would further compromise the supply of ground water for human use affecting development and/or the cost of living; **d)** Alteration of precipitation patterns could seriously affect the availability of fresh water in certain islands environments in the region, increasing their dependency on remote sources [barged or piped water] or on desalinization, reverse osmosis or other technologies thus the cost of their water supply; **e)** Adverse effects on surface and/or ground water resources would have negative consequences on agriculture, the natural habitat of several flora and fauna species, on biodiversity and on many coastal and marine systems.

CLIMATE CHANGE: SEA LEVEL RISE AND COASTAL IMPACT

Background: The ocean as a major force in the system that drives the Earth's climate is expected to react to climate changes and viceversa. This means the ocean itself could provide positive feedback to specific components of climate change.

Changes in ocean behavior in response to climate change will first be felt by the coastal regions. Higher population density and growth and related development makes coastal regions increasingly vulnerable to ocean-side hazards.

[14] South Florida water Management District 1997

There is a consensus among the scientific community, and other sectors of society, that sea level rise is and will continue to be one of the most likely effects of global climate change as a result of global warming.

Sea level has been rising for centuries in response to glacier and polar ice melting, and from expansion resulting from higher temperatures. It should be noted however that while sea level rise is real on a global scale, on a site-specific basis there are coastal areas around the world where sea level has risen faster due to land subsidence. In other areas sea level is actually dropping as a result of land moving up due to geological forces. Global sea level has risen between 10 cm and 25 cm over the past 100 years and much of this rise may be related to the increase in global mean temperatures[15]. The rate of sea-level rise however went from 0.2-0.4 mm/yr over the past 2,000 years to about 1.8 mm/yr over the past 100 years[16], signaling acceleration. Projected sea-level rise, based on climate models, may be at a rate of 6.0 mm/yr to 9.0 mm/yr over the next 100 years[17].

Current stresses: Coastal region development has created significant stresses on coastal systems such as biodiversity, commercial and recreational fishing, hydrology, wetlands, estuaries, beaches, barrier islands and coral reefs. These stresses add to the vulnerability of coastal areas because some of the natural defense mechanisms have been weakened by them.

Some of these stresses are: **a)** Human intervention and development have in many cases modified the geomorphic and ecological components of coastal systems, significantly reducing their capabilities to resist or to interact with natural processes. This non-sustainable development has increased the vulnerability to natural hazards; **b)** The combination of sea-level rise and very low topography prevalent in most of this region, except for most of Puerto Rico and the U.S. Virgin Islands, has resulted in loss of land and salt-water infiltration. The slope of some coastal areas is so small that a rise of one unit in sea-level translates into 200 horizontal units, i.e.: the average sea-level rise of 2 mm/yr in this region results in a net horizontal land loss of 400 mm/year along the length on the coastline. If instead we use the projected average of 7.5 mm/yr over the next 100 years, this would translate of a net loss of approximately 2,400 km² of land by the year 2100 from North Carolina to South Florida; **c)** Loss of agricultural land due to sea-level rise and salt-water infiltration resulting in economic loss as well; **d)** Implementation of flood control measures and related public works projects have altered natural drainage and runoff. This in turn has adversely affected fresh water resources, and irreplaceable ecosystems such as the Florida Everglades, estuaries and bays, and coastal flora through siltation, alteration of salinity or depletion of fresh water; **e) A**nother significant stress comes from the net deficit of protective measures/structures to assist the emergency management community, and the public at large, in combating the impact of hurricanes, surge and coastal flooding; **f)** This region is also subject to wild fires resulting from a combination of alterations in precipitation patterns, drought, higher temperatures and a high incidence of lightning. The occurrence of wild fires seems to be worst when said conditions follow a season of abnormally high precipitation which promotes increased growth of underbrush that then dries-up and ignites.

[15] IPCC 1995: *The Science of Climate Change* (New York, Cambridge University Press, 1996)
[16] Douglas: *Global Sea Level Change*; Fleming and Webb: *Tectonic and Eustatic Coastal Changes.*
[17] S. Leatherman, R. Chalfont, E.C. Pendleton, T.L. McCandless, S. Funderburk: *Vanishing Lands 1995*

Potential Consequences of Climate Change: Given current trends and human activity possible consequences may be: **a)** Increased human, physical, structural, ecological and economic damages from hurricanes and other natural hazards impacting the region; **b)** A reversal in the trend toward lower loss of life from hurricane and coastal flooding that has been reported by The National Hurricane center [NHC] of NOAA. Development is in a collision course with hurricanes and other natural hazards, that could be made worse as a result of global climate change; **c)** Significant adverse socio-economic impact would result from loss of agricultural land, reduced or altered economic activity, storm damages, loss of jobs, permanent displacement of population and other related consequences; **d)** Potential loss of tourism market as more visitors become aware of the increased vulnerability of the area and start to prefer other destinations.

CLIMATE CHANGE AND HEALTH ISSUES

Background: Climate change and associated higher temperatures will have adverse effects on human health in this region. Other factors, such as the existing vulnerability to extreme climatological events, such as hurricanes and coastal flooding, also have the potential for adverse consequences in the health sector.

Current Stresses: a) The potential for health damage is higher in this coastal/island regions because of the large number of people 65 year or older that have continuously come to reside here. These individuals are generally more susceptible to illness or to the effects of climate change or variability. Paradoxically these elderly residents have moved to coastal areas because of their milder climate compared to the extremes found in more northerly latitudes; **b)** Heat waves are particularly dangerous to the elderly, specially those living alone, and to those who have cardiovascular diseases. Recent research in Florida shows that 28 individuals die every year in Tampa as a result of heat-related causes during the summer.[18] Similar numbers could be found elsewhere in the region;
c) Higher surface temperatures already bring conditions favoring higher concentrations of ground-level ozone which is associated with aggravated respiratory conditions, such as allergies, asthma, emphysema and others. Asides from its adverse effects on human health, low tropospheric ozone affects ecosystem health and agricultural crops; **d)** Wild fires often result from climatological conditions in the region bringing not only the possibility of physical harm, and economic loss, but also increased occurrences of respiratory and cardiovascular illnesses; **e)** The region is already fertile ground for malaria, encephalitis, dengue fever and other mosquito-carried diseases; **f) T**he impact of extreme events in the region, specially hurricanes and flooding, have resulted in outbreaks of vectors such as rats and roaches, while continuously increasing the incidence of human pathogens and other contaminants in regional fresh and saline water sources.

Potential Consequences of Climate Change: a) Some of the worst effects on human health may come from expansion of the mosquito-breeding habitat to more northerly latitudes, making such diseases as malaria, encephalitis, dengue fever and similar ones more common in the region.[19]
b) An increase in the incidence of respiratory and cardiovascular diseases as well as heat stroke could result from heat waves, and continued warming and its associated promotion of low level ozone; **c)** A higher occurrence of wild fires would also result in higher incidences of allergies and

[18] U.S. EPA: Study on Climate Change and Florida 1997
[19] IPCC: Climate Time Bomb – Reports 1990, 1994

other respiratory and cardiovascular diseases; **d)** There is a possibility of increased instances of skin cancer resulting from solar radiation and the effect of greenhouse emissions on the atmosphere; **e)** More frequent extreme events and the associated disruption of water supplies or the contamination of the same, and the resulting impaired sanitation and hygiene conditions, would reflect in potentially adverse health consequences; **f)** The possibility of post-traumatic stress syndrome and other mental illnesses could also be expected as a result of this region experiencing more damaging or more frequent extreme events; **g)** The ultimate potential health consequence from climate change would be increased injuries and loss of life resulting from extreme events.

CLIMATE CHANGE AND ISLANDS

Background: Islands, especially small island states, are perhaps the most vulnerable of all coastal areas to the consequences of global climate change[20] such as accelerated sea-level rise.
This region includes a veritable archipelago of more than 250 islands and coral reefs that (except for Puerto Rico at 9,104 km²) have land areas of less than 150 km². Puerto Rico and its islands of Viequez, Culebra and several smaller ones, the U.S. Virgin Islands [St. Thomas, St. John, St. Croix and 50 smaller islands], the Florida Keys and more than 26% of barrier island acreage in the U.S., are part of this region.

Topographically this sub-region includes two types of islands: those that have mountain ranges or peaks and those that are practically flat. Puerto Rico has mountains ranging from 750 meters to 1,340 meters in height within a few kilometers of the coastline. In the U.S. Virgin Islands hilly terrain is punctuated by elevations higher than 350 meters in St. Thomas [474 m], in St. John [392 m] and in St. Croix [355 m]. The vast majority of the remaining islands including the Florida Keys and the barrier islands along the Carolinas, Georgia and Florida may have ridges or high points reaching to 3 meters above present mean sea level.

Permanent population of these islands is estimated at 4.6 million [1997], with more than 90% of them residing in Puerto Rico and the U.S. Virgin Islands. There is however a seasonal or floating population that may average at least an equal number on a yearly basis. This seasonal population represents an important economic contributor to these islands.

A significant portion of infrastructure development in these islands has been undertaken to support tourism. From beachfront hotels and condominium buildings, marinas and piers, to roadways, airports and ocean ports, a large investment has been made to support tourism as a major component of the islands' economies.

Current Stresses: the most important stresses on these island communities include: **a)** Existing and increasing vulnerability to hurricanes, specially in view of the high rate of urbanization and population growth; **b)** Sea level rise; **c)** Limited fresh water resources, some islands depend of water being piped or barged from remote sources or on desalinization; **d)** Tourism as an important economic asset is also a source of environmental degradation; **e)** Demographics that include a higher population density than the national average, and a percentage of elderly [65 years and above] population that is also higher that the national average, resulting in higher vulnerability and

[20] S.P. Leatherman, N. Beller-Simms: Journal of Coastal Research, Special Issue No. 24, 1997

demand for emergency services; **f)** Ecosystems and biodiversity which are degrading and under attack.

Potential Consequences of Climate Change: Existing stresses in these islands could be aggravated by the following: **a)** Sea level rise would bring about a worsening of existing stresses. In view of the extensive coastal development, an increase in sea-level would bring storm surge closer to buildings and infrastructure; **c)** An intensification of hurricanes, whether in number or in magnitude, would increase the amount of damage inflicted on these islands. Some particularly severe consequences would be upon those islands where topography [i.e.: Puerto Rico, the U.S. Virgin Islands] contributes to stronger hurricane winds and flash floods, thus more structural/physical damages; **d)** Sea level rise, combined or not with land submergence, would erode and degrade beaches. In most of these islands beaches, which are seldom more than 30 meters wide, are the main natural attraction for tourism. This would result in severe economic damage to the region; **e)** Changes in predictable historical patterns of precipitation, that may include drought, would adversely affect water freshwater resources specially in those islands that lack their own reliable natural sources; **f)** Sensitive ecosystems, such as coral reefs, oyster beds and fisheries, which already suffer considerable and mostly anthropogenic stress, could be degraded further as a result of any intensification of hurricanes or changes in precipitation brought about by global climate change; **g)** Continued global warming could bring about increased illnesses aggravated by heat waves, in regions with high humidity and high population density.

CLIMATE CHANGE AND INSURANCE ISSUES

Background: Extreme events such as hurricanes, floods and other natural hazards must be viewed as sources of potential damage or loss. Knowing that an extreme event may cause a loss is not enough to measure the amount, timing and extent of a given loss. The amount, timing and extent of a loss, or whether a loss occurs at all, depend on the interaction of multiple variables. It is generally accepted that with respect to extreme events there is an *uncertainty of loss*. Such uncertainty of loss is the *risk* associated with an extreme event. Because an extreme event only allows the option of *loss* vs *no loss* the associated risk is considered to be a *pure risk* rather than a *speculative risk* (one that holds the potential for benefit as well as loss).

Insurance is a mechanism that allows potential victims of an extreme event to distribute the associated pure risk among a very large number of entities and individuals. Insurance in effect transfers *most* of the uncertainty of loss to others.

Insurance that indemnifies *insured* individuals for losses from extreme events is known as *property-casualty insurance*. This type of insurance is a *promise to pay* by the *insurer* to the insured and, as such, it is based on financial strength of the insurance companies that depends to some degree on other factors including state regulations, and the *reinsurance* market.

The financial strength of many insurance companies, both large and small, has been continuously tested in recent years by the occurrence of numerous extreme events in this country and abroad. In fact, Hurricane Andrew brought total direct losses of $30.0 billion to South Florida in 1992, of these approximately $16.0 billion were *insured losses* that resulted in several insurance companies going broke and in the State of Florida going into the insurance business through the *Florida Joint*

Underwriting Association [JUA]. Many other insurance companies, including some of the largest in the country, cancelled many policies in the area or stopped insuring for *wind peril* in addition to raising premiums.

In a sense Hurricane Andrew woke up a whole industry, including regulatory agencies and the public at large, to the uncertainties and realities on insurance when confronted with extreme events. Other major disasters have continued to highlight the need for new approaches to property casualty insurance.

One interesting contrast comes from the *National Flood Insurance Program* [NFIP] which makes flood insurance available to property owners and occupants in *NFIP participating communities*, but ties such availability of *affordable* insurance to conditions for receipt of federal financial assistance for purchase or construction of structures in special flood hazard areas. The NFIP is now linked to federally funded hazard mitigation programs requiring the implementation of measures to *reduce the potential for damage* from extreme events as a condition for disaster assistance funding.

Current Stresses: a) The continued development of coastal areas and population growth are contributing to increased vulnerability and a higher probability of loss in the event of impact from a natural hazard; **b)** There are conflicting interests on the issue of insurance. While the home and business owners expect the insurance industry to offer economic incentives to help them pay for mitigation measures to the reduce the potential for damage from hazard events, and regulators push for lower rates to maintain the *availability* and *affordability* on insurance, many insurers insist that *"rates are lower than they need to be"*[21]; **c)** Some insurers have increased their premiums on homeowner, renters and condo-unit policies, and continue to apply for further increases. For example: one of the largest property insurers in this region was granted a rate increase of 13.1% in Florida in 1996, and a new increase of 22.6% also in Florida in 1997, for a compounded rate increase of 38.7% in two years; **d)** Some insurers claim present rates cannot generate the level of revenue needed to cover expected losses and expenses plus a reasonable rate of return for their business. Should these assertions be true, a critical point has been reached inasmuch as the *promise to pay* by insurers is as good as their financial strength; **e)** Building and housing construction in most of the region continues, by and large, to exclude mitigation measures that could reduce the potential for damage from extreme events.

Potential Consequences of Climate Change: a) Climate change and variability could alter the *mix* of extreme events in the region increasing, as a result, the risk to insurers. For example the region could experience more wild fires, due to altered rain patterns, drought, higher temperatures and lightning, while the threat of hurricanes remains the same; **b)** An alteration of the mix of extreme events in the region, or an increase in the frequency or intensity of extreme events, would result in increased damage to property and higher losses to insurers. This could precipitate an insurance crisis with only difficult and painful alternatives for resolution; **c)** An insurance crisis would critically affect the availability and affordability of property insurance. This could also adversely affect the construction industry and home ownership; **d)** It is also possible that the potential for higher risk and losses could result in a higher degree of cooperation between all parties leading to incentives from insurers leading to mitigation measures being incorporated in the

[21] The Miami Herald, Saturday,July 11, 1998: *State Farm spurns Nelson's Order*

design/construction of housing and buildings and a reduced potential for damage from extreme events.

CLIMATE CHANGE: SOCIO-ECONOMIC AND POLITICAL IMPACT

Background: The characteristics of this region as defined by its population trends and demographics, the extent and value of its development and infrastructure, and the type of economic activities combined with past and current government actions, have set the foundation for significant socio-economic and political consequences of global climate change. Of equal importance for such potential consequences is the interaction of human activity with existing ecosystems in the region.

The description of stresses and potential consequences already given herein with respect to other regional elements already includes identification of socio-economic impacts. The itemization of current stresses and potential consequences that follows complements these previously identified impacts.

Current Stresses: a) The magnitude of the *value at risk* resulting not only from the *replacement value* of all human infrastructure and possessions in the region, but also from the *irreplaceable value* of numerous and unique ecosystems and, above all, by the value of human life at risk, is perhaps the most important stressor affecting this region; **b)** Damages brought about by past extreme events, such as Hurricanes Andrew, Hugo, Luis, Marylyn, David and Gilbert, to mention some of the most recent only, are still affecting most of this region. The area of Homestead continues to be economically depressed as a result of damage from hurricane Andrew (1992); **c)** Beach erosion, salt water infiltration, sea level rise and other impacts to the biosphere that are now occurring, carry a socio-economic cost; **d)** Competition for limited resources, specially financial, by numerous regions trying to recover from the impact of climatological hazards, has created a type of *political* stress factor; **e)** A similar type of stressor results from international actions or decisions relative to global climate change. Although important agreements have been reached in the international arena, significant areas of dispute remain; **f)** The lack of a significant industrial base and the reliance of the service sector and tourism as the main economic engines for the region, creates a higher risk of adverse economic and social impact; **g)** Competition between the special interests of certain economic sectors and the need to mitigate and reduce the potential for damage is another current stress in this region; **h)** The high vulnerability to hurricanes and other climate induced extreme events combined with the general lack of protective measures places the emergency management community in the region under continuous, and severe stress.

Potential Consequences of Climate Change: a) More frequent or more intense extreme events could result in significant increments in the amount of damage, resulting in larger economic losses in the region; **b)** Physical and structural damages could in turn result in loss of businesses and ecosystems, leading to loss of jobs, population displacement and adverse socio-economic impact on the region; **c)** Climate change may result not only in more intense or frequent extreme events, but in an alteration of the physical coastal attributes, such as beaches and mild climate, that have attracted tourists and seasonal residents to the region. This could lead to diminishing tourist visits with consequential economic losses that could be permanent or very difficult to overturn or compensate for.

CLIMATE CHANGE: SUGGESTIONS FOR FUTURE ACTION

Background: The scenarios described above have identified the vulnerability of stakeholders and natural ecosystems to a range of stresses and natural hazards, some of which could be exacerbated by the potential regional consequences of climate change and variability.

Causal links between natural and anthropogenic contributors and specific trends in climate change have been identified in some cases, while in others there are only empirical data or inconclusive results from simulations, modeling and research.

While it may take yet some time to arrive at conclusive evidence of cause-effect with respect to anthropogenic contributors to climate change, it is uncontestable that climate has and will continue to change is response to natural triggers and cycles. Also, significant natural trends in global climate change have been identified, but important uncertainties remain with respect to regional trends resulting from such change.

As important as the need to continue work in resolving existing uncertainties, is the need to take action on the basis of the accepted and recognized trends of global climate change and the potential regional consequences of such change.

Possible Actions: in order to cope with the possible aggravation of existing stresses by the potential regional consequences of climate change, actions that could be taken may include the following:

a) Education of all sectors and levels of society in the region to contribute to the creation of a *culture of mitigation* that will help the population at large understand the vulnerabilities of our natural and human systems to the potential effects of present trends in climate change, the types and consequences of potential changes, and the measures humankind must start taking and continue to take to reduce the potential for damages;

b) Implementation of physical/structural mitigation measures through the incorporation of the same in the design, construction and retrofitting of buildings, facilities and infrastructure. Some of these measures include design/construction elements that will reduce the potential for damage from storm surges, coastal flooding, severe wind loads and the impact of wind carried debris, to coastal infrastructure and buildings;

c) Continued research of building behavior under climatic hazards such as hurricanes, storm surges and coastal flooding. This research should focus on identifying *damage functions* reflecting the type of design and construction of a building under specific hazard conditions. While this research needs to incorporate modeling, simulation using wind and water tunnels and testing of materials, more emphasis should be placed on empirical data derived from actual climatological hazard events;

d) Implementation of mitigation measures through the legislative/institutional process including *regional building codes* that recognize and effectively address the vulnerabilities of this coastal and island region. *Land-use codes and ordinances* that guide coastal and island development to reduce potential damages from climatological extreme events while also reducing the ecological costs, should be encouraged;

e) Strengthening and wider application, of management practices and programs such as *The National Flood Insurance Program, The Coastal Management Act; the Local Mitigation Strategy; the Residential Construction Mitigation Program,* and others;

f) Recognition and support of needed action by the Federal Government through legislation that will include in the national budget funding that is commensurate with the objective of reducing damages from hurricanes and other consequences of climate change on this and other regions of the country;

g) Creation and funding of coastal research/education centers that will continuously assess trends in climate change, the potential regional consequences of such trends, and the role of both natural and anthropogenic contributors to such trends. One of the main areas of research at these centers could be in the area of instrumentation, such as the airborne laser terrain mapper, which would considerably improve the capability for data acquisition, and the time needed for such data collection, in order to provide more comprehensive and effective data sets for climate modeling. Improved data acquisition is important in the areas of: i) coastal/island topography and geomorphology, ii) trends in beach erosion/accretion patterns, iii) sea level changes with respect to a specific regional datum, iii) hydrological and meteorological characteristics, iv) ecosystem characteristics, v) demographic and development characteristics;

h) Increased interdisciplinary, interagency and intersectoral cooperation in the fields of research and implementation of mitigation measures to confront the potential regional consequences of climate change. This type of effort would emphasize not only the collaboration between academic institutions and government agencies at all levels [federal, state and local], but also between the academic and public sector and the private business and industrial sectors. While supporting these multiple partnerships, such an effort should make paramount the development of individual institution's capabilities to ensure the level of excellence that will be required to meet difficult and aggressive objectives. Increased cooperation between the emergency management community and the building design and construction sector [*practitioners*] with the research and academic sectors should be one of the objectives of this type of initiative;

i) Promotion of research into and usage of renewable energy sources specially those which are "clean" in the sense that they eliminate or considerable reduce the emission of gases that contribute to global warming;

j) Development and implementation of regional, national and international incentives to encourage different regions and countries to practice mitigation to reduce potential adverse consequences of climate change, especially those resulting from anthropogenic contributors. These incentives could include political, economic and technological components allowing both developed and developing countries to meet global objectives as well as their own national and regional goals for improved standards of living, environmental health and sustainable development.