

GLOBAL CHANGE

October 1990

This special section discusses potential Impact and Implications for the NPS

The greenhouse effect is real – a natural function of various constituent gases in the atmosphere that limit the radiation of heat energy from the Earth to outer space. Without the greenhouse effect, the Earth's surface would be about 60 degrees C cooler.

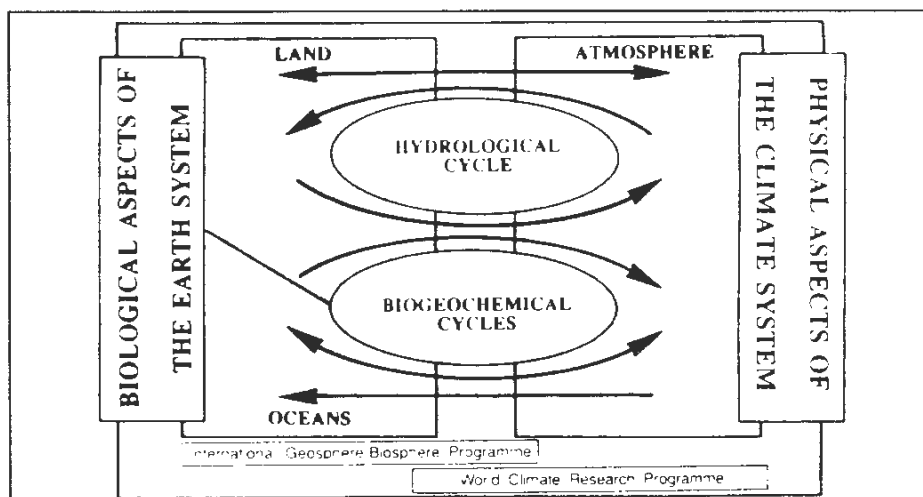
The overarching indicator of global change is a persistent trend toward worldwide climate change that goes beyond so-called normal variation and that seems likely to lead to intensified and unpredictable events in nature.

The concern of the world's governments and the scientific community is manifest in unprecedented basic research initiatives to detect, understand, and predict global change. These initiatives involve an expanding network for cooperation in setting research priorities and objectives and gathering, sharing, storing, retrieving, and utilizing relevant data. U.S. participation in these initiatives is backed by a substantial budget for global change research (see Table 1).

The greenhouse effect has become an issue of global concern because

- the cumulative effects of human (anthropogenic) influences in increasing the concentration of greenhouse gases appears to be either causing climate change or accelerating natural cycles and trends, and
- these changes seem to be occurring at a rate 10 to 60 times faster than any known previous climate change.

The evidence so far shows the Earth to have warmed about 0.5 degree C (about 1 degree F) in the past 100 years. Although a number of periods of both



Linkages among biological, chemical and physical processes critical to our understanding of global change on a decade-to-century time scale. Arrows refer to the seven first research priority questions as described in *The IGBP Global Change Report*, #12, 1990.

cooling and warming took place during that time, the six warmest years on record all have occurred within the past decade. The Earth now is warmer than at any time in recorded history.

If global warming is in fact occurring, the actual mean temperature increase involved will not be the primary focus of concern for natural resource managers.

Rather, it will be the magnitude, frequency, geographic extent, and duration of the climatic "events" – the episodic events of wildfire, hurricanes, drought, etc. – that could accompany even a modest overall warming. These are the kinds of events that are known to cause significant changes in ecosystems. These changes, if

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Table 1: FY 1990-1991 U.S. Global Change Research Program Focused Budget

(Dollars in Millions)

Focused Program	Total Budget		Climate & Hydro-logic Systems		Biogeochemical Dynamics		Ecological and Systems Dynamics		Earth System History		Human Interactions		Solid Earth Processes		Solar Influences	
	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91
Agency Totals	659.3	1034.1	291.7	461.5	198.7	265.8	90.2	178.6	7.7	19.1	4.8	15.0	57.4	80.9	8.8	13.2
DOC/NOAA	18.0	87.0	14.2	67.6	3.3	13.5	0.0	4.9	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0
DOE	50.0	66.0	32.0	44.0	7.0	9.0	9.0	10.0	0.0	0.0	2.0	3.0	0.0	0.0	0.0	0.0
DOI	13.3	43.7	4.9	12.2	0.8	2.0	0.9	10.3	2.4	8.0	0.9	5.3	3.4	5.9	0.0	0.0
EPA	13.2	26.0	1.0	3.3	2.5	3.1	9.7	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NASA	488.6	661.0	221.4	302.5	162.2	198.3	51.0	90.0	0.0	0.0	0.0	0.0	47.7	63.0	6.3	7.2
NSF	55.0	103.0	16.8	29.8	20.2	32.2	3.5	8.5	4.5	9.0	1.2	5.5	6.3	12.0	2.5	6.0
USDA	21.2	47.4	1.4	2.1	2.7	7.7	16.1	35.3	0.3	1.1	0.7	1.2	0.0	0.0	0.0	0.0
Scientific Objective																
Observations	137.2	255.0	89.1	148.9	17.2	38.9	14.1	39.6	0.0	0.2	0.0	2.2	13.1	20.8	3.7	4.4
Data Management	65.2	129.4	32.9	64.0	21.2	34.7	5.5	17.7	0.5	2.2	0.4	1.0	3.8	8.8	0.9	1.0
Understanding	409.7	560.0	143.1	200.3	148.1	176.2	65.5	103.2	6.1	13.1	2.9	10.6	40.5	50.1	3.5	6.5
Prediction	47.2	89.7	26.6	48.3	12.2	16.0	5.1	18.1	1.1	3.6	1.5	1.2	0.0	1.2	0.7	1.3

The Assistant Secretary of the Interior for Fish, Wildlife, and Parks is the Departmental overseer of the NPS Global Change Program, which is headed by NPS Assistant Director for Natural Resources Eugene Hester. The Global Change Program organizational chart is available from the Regional Chief Scientists and from the new Washington Office Global Change Program Coordinator, Pete Comanor. (See bio, page 8.) (Table: From USGC Research Program Report for FY 1991, pp. 18-19.)

and when they occur, will define the new limits within which resource managers will have to operate.

Circumstantial Evidence

The evidence on the climatological effects of anthropogenic increases in carbon dioxide, methane, nitrous oxide, chlorofluorocarbons (CFCs), and several minor greenhouse gases is circumstantial. But most global circulation models (GCMs) indicate that, with an equivalent doubling of CO₂ levels by mid-21st Century, the average global temperature can be expected to increase by 3 to 5 degrees C (5 to 9 degrees F) (*Intergovernmental Panel on Climate Change*, May 2, 1990). The probability of an increase of this magnitude is subject to considerable debate, although even conservative authorities concede it at least a 50-50 chance – a probability level that, from a policy perspective, warrants significant concern.

In addition to the direct effects of climate change, an accelerated rise in sea level is expected as a result of warming-induced expansion of the oceans and potential melting of polar ice. According to the IPCC Report (referenced above):

"By 2030, even if greenhouse forcing increased no further, there would still be a commitment to a continuing sea level rise for many decades and even centuries, due to delays in climate, ocean, and ice mass responses. Sea level would go on rising from 2030 to 2100 by as much again as from 1990 to 2030, due to the effects of pre-2030 greenhouse gas increases alone." (See Figures, p. 7)

Changes much larger than those suggested by the GCMs have occurred many times in the Earth's geologic history and no doubt are likely to occur naturally sometime in the planetary future. However, never in human recorded history have such global climatic and related changes occurred at the rate projected and with the degree of human involvement that is now being investigated.

Uncertainties Abound

Many uncertainties cloud our predictions, particularly with regard to the timing, magnitude, and regional patterns of climate change. These uncertainties stem particularly from our incomplete understanding of:

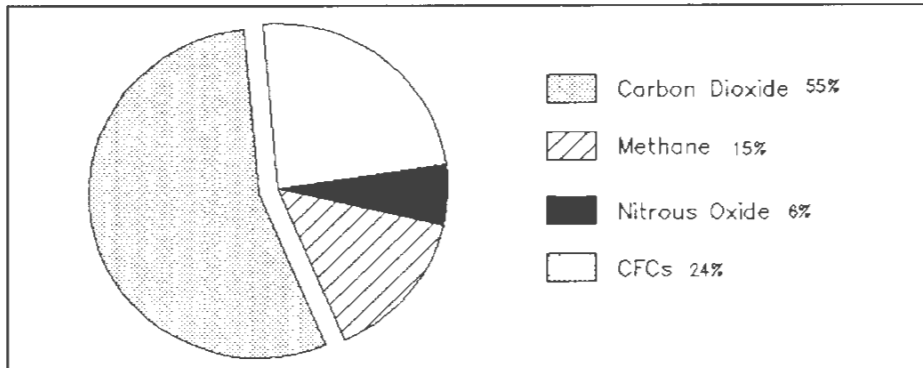
- the sources and sinks of greenhouse gases, which affect predictions of future concentrations;
- the role of clouds, which strongly influence the magnitude of climate changes;
- the role of the oceans, which influence the timing and patterns of climate change;
- the role of polar ice sheets, which affect predictions of sea-level rise.

These dynamic earth system processes are partially understood. Proposed research will reduce the uncertainties, but the complexity of the overall system means that surprises cannot be ruled out, particularly with regard to natural systems.

Potential Management Problems

The potential ecological effects of a 3 to 5 degree C annual global warming projected to occur by mid-21st Century were discussed in the Conference on Consequences of the Greenhouse Effect for Biological Diversity, organized by the World Wildlife Fund and cosponsored by the NPS and other agencies in October, 1988. The Conference provided a valuable summary of the kinds of effects likely to be of special interest to natural resource managers.

Some notable examples include changes in timing and rates of snowmelt, and associated effects such as acid pulse; and changes in the frequency of hurricanes, with reduced productivity of mangroves and



The contribution from each of the man-made greenhouse gases to the change in radiative forcing from 1980 to 1990. The contribution from tropospheric ozone may also be significant but it is difficult to quantify.

GLOBAL WARMING POTENTIALS OF GREENHOUSE GASES RELATIVE TO CO₂

Time Horizon

	20 yr.	100 yr.	500 yr.
Carbon dioxide	1	1	1
Methane	63	21	9
Nitrous oxide	270	290	190
Chloro-fluorocarbons	4100-7100	1500-7300	510-4500

(Figures are best estimates calculated on basis of present day atmosphere.)

other hurricane-influenced ecosystems. For some plant species, the direct effects of rising levels of CO₂ in increasing the rate of photosynthesis (the so-called "CO₂ fertilization" effect) and reducing evapotranspiration could be significant, with potential ramifications at the ecosystem, biome, and biosphere levels. Robin Graham, Monica Turner, and Virginia Dale have provided an excellent overview of the state of knowledge of the effects of CO₂ and climate change on forests in the September 1990 issue of *BioScience*.

There may be major shifts in distribution of common forest trees. Preliminary research indicates that the range of such important deciduous forest species as sugar maple, beech, yellow birch, and eastern hemlock might have to shift 500 km northward under global warming, with accompanying extinction throughout much of their existing ranges. Failure of reproduction in areas outside a species' climatological limits is likely to be an early sign of change.

Targets of Heat Stress

Animals that require multiple habitats for completing their life cycles, such as amphibians and migratory birds, could experience significant stress. Heat stress could affect the survival of embryos of ground-nesting birds, animals such as pocket mice that burrow underground to reduce heat loads, and cold-blooded species, such as many desert lizards, with distributions determined by temperature. It also could encourage increased aggression, competition, and other behavioral impacts on many animals. Natural shifts in ranges may be especially difficult for animals with low fecundity or low natural rates of dispersal. Animals known to be subject to temperature-induced switching of sex ratios, such as some turtles and geckos, could be at a

particular disadvantage.

Species relationships, such as plant-herbivore interactions, and the distribution and abundance of parasites could change. The possibility of rapid proliferation of species, including disease organisms, able to invade habitats affected by climatic stress and related disturbances, such as wildfire, is a major concern.

A Letter To The Parks

The list of ecological resources and regions likely to be especially vulnerable to the effects of climate change reads like a letter to the National Park System: Arctic tundra, and boreal forests; alpine, subalpine and relict communities; western forests; coastal lagoons, marshes, and coastal barriers; coral reefs; and many populations of endangered, threatened, rare, and endemic species. GCMs are in general agreement that the magnitude of global warming is likely to be greater at high latitudes and in mid-continental areas. In North America, these are areas where the National Park System is particularly well represented.

A large inventory of the nation's cultural resources also is potentially at risk from the effects of global change. Sea level rise could threaten lighthouses, coastal fortifications, archaeological sites, and other cultural resources in coastal areas. Rising groundwater levels could result in structural damage to foundations of historic structures in affected areas. Increased precipitation in arid areas would adversely affect adobe and other climate-sensitive materials.

Overall, the ecological and cultural heritage included in the National Park System, by any measure, ranks high on the list of resources at risk from the effects of global change.

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The following section provides thumbnail sketches of global change research concepts being considered for inclusion in the NPS Global Change Research Program. A twelfth description is included for the coastal barriers thematic initiative.

Colorado Rockies. (core park: Rocky Mountain NP) The proposed program will follow an hierarchical approach, ranging from the study of global and regional effects of global change to those on the landscape and local levels. This global change research will utilize regional climate models to determine possible scenarios; these scenarios will then be used to predict ecological effects. An analysis of precipitation amounts, seasonalities, and intensities will be undertaken. A paleoecology component includes a study of historical records of debris flows. Additional studies will cover the impacts on lakes and streams, and vegetation changes due to changing characteristics and loss of soil.

Florida Keys. (core parks: Biscayne NP, Everglades NP, Fort Jefferson NM) The proposed program centers on the 200-mile-long Florida Keys coral reef track from Biscayne NP to Fort Jefferson NM. This program includes a study of the sensitivity of the corals themselves to factors associated with global change, such as temperature change and sea level rise, and will investigate the possibility of a drowning of the coral reef system due to sea level rise and potential adverse effects of increased water temperature. This research program will correlate the reconstruction of paleoclimates based upon records contained in coral, such as changes in salinity and deep water upwelling, with contemporary monitoring of regional sea water temperature, currents, and salinity. Studies of the effects of storm intensity on seagrass and coral reef productivity also have been proposed.

Glacier. (core park: Glacier NP) The proposed program has four primary components. Investigators plan to conduct a landscape analysis, with an emphasis on ecotones and shifting landscape patterns, and will study the diversity of topography and the possibility of rapidly shifting ecological boundaries. The alpine zone will also be studied; researchers anticipate that this

zone may change dramatically, but are not certain yet how dramatic the change will be. A third component is watershed analysis, and a study of the links between weather patterns. A paleoecology component also is planned, including lake sediment analysis, tree ring coring, pollen profile analysis, and glacier coring, with the possibility of as much as a 12,000 year history.

Great Basin. (core park: Great Basin NP) The proposed program is primarily comprised of baseline monitoring studies. It will utilize a system of remote weather stations and an upgraded, Class I air quality monitoring station. Paleoecological studies (particularly dendrochronology) will be used as a tool for understanding the past and as clues to the future. The program will investigate relict species and biogeography, as well as plant community fluctuations, with respect to elevational gradients and Great Basin's location at the convergence of three weather systems. In addition, the Great Basin program will examine the chemical and biological sensitivity of small watersheds.

Northwest Alaska. (core parks: Bering Land Bridge NP, Cape Krusenstern NM, Noatak NP) The proposed program focuses on comparison of the impact of climatic change with other forces (e.g., herbivores, fire) on the sensitive resources of the Arctic regions. The program will include studies on response of the tree line to temperature change. The impact of global change on aquatics also will be investigated. With 27 percent of the world's soil carbon stored in Arctic peat soil and permafrost, the potential for mass release of carbon dioxide and methane into the water is significant. The program will monitor and study changes in this soil and permafrost. In addition, the potential implications of global change for native people will be studied.

Olympic Peninsula. (core park: Olympic NP) The proposed program concentrates primarily on sub-alpine and alpine environments. As the Olympic Peninsula has, within a relatively small area, some of the wettest and driest areas in the United States, changes in precipitation patterns and quantities and their relation to global change could have significant effects. Of particular interest is the physiological response of

trees and other vegetation at high elevations and in old-growth forests to the effects of global change. The program includes research on global change effects on stream hydrology and chemistry. In addition, the program will examine the effects of changing environmental conditions on the physical and ecological processes associated with disturbances such as fire, avalanches, and glaciation.

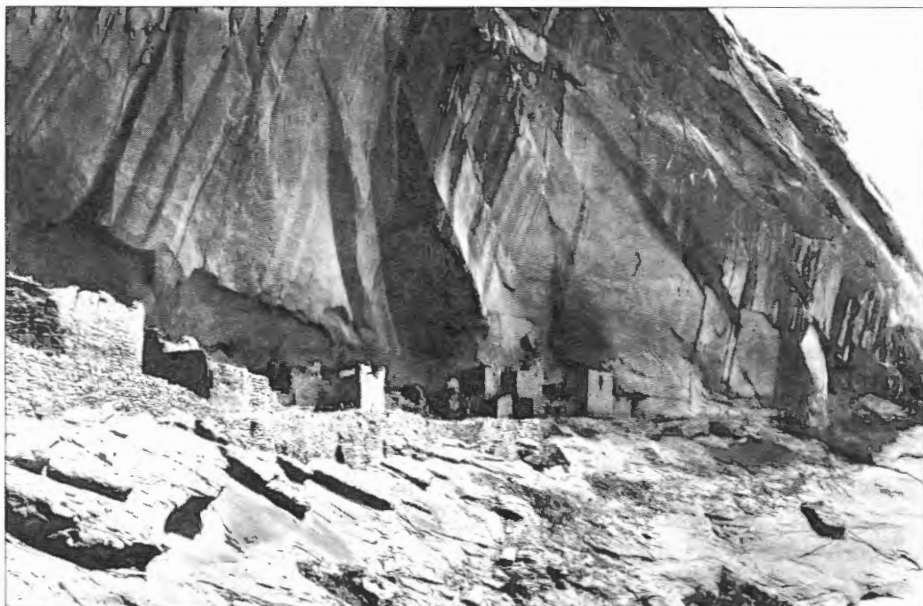
Ozark Highlands. (core parks: Buffalo NSR, Ozark NSR) The proposed program concentrates primarily on aquatic resources. The effects of global change on the spring-fed aquatic systems of Ozark NSR will be compared with the effects on the precipitation-fed systems of Buffalo NSR. The correlation of red cedar chronology and stream flow regimes will be investigated, and the current records will be expanded to develop a model of the predicted effects of global change. The plants and animals of the Ozark springs, and the distribution and abundance of fish, will be studied to determine their sensitivity to global change. Social scientists will study potential effects on recreational uses, and construct correlative models using the "dust bowl" records of the 1930s.

Sonoran Desert. (core park: Organ Pipe Cactus NM) The proposed program studies how climate affects species distribution and structure in the desert environment. The investigators will integrate existing primary data sets into a geographic information system designed for the global change program. Specific activities include monitoring soil moisture and temperature and relating these properties to sensitive animal species such as the desert tortoise, and comparing remote Organ Pipe Cactus NM and urban impacted Saguaro NM for differences in ecosystem response to climatic change effects in an effort to factor out anthropogenic factors. In addition, researchers plan to experiment with environmental manipulation (e.g., "rain-out shelters") for modeling purposes.

Southern and Central Sierra Nevada. (core park: Sequoia-Kings Canyon NP) The proposed program focuses primarily on disturbance regimes in forested ecosystems, changes in the tree line ecotone, and global change effects on species such as the giant Sequoia that might ensue. This program will also study the tree line ecotone. Models will be developed to predict the types of changes that could be expected under varying climatic conditions. Investigators also plan to monitor what is happening today, such as studying reproductive modes and dispersal, so that climate change could be detected as it occurs. In addition, the study will focus on paleohistorical studies to provide data to test models of climate, disturbance, and biotic change.

Southern Blue Ridge. (core park: Great Smoky Mountains NP) The proposed program includes a characterization of selected sensitive ecological communities and species and their microclimates, and will attempt to correlate soil temperature and moisture regimes with the population dynamics of potentially sensitive species in old-growth forested watersheds. Also planned is a model to predict ecosystem destabilization associated with climate change, development of models of community distribution, watershed processes and response, and application of these models in Shenandoah NP and Great Smoky Mountains NP. The investigators plan to cooperate with the Southern Appalachian Man and the Biosphere Cooperative in studying human influences pertaining to global change.

Western Lake Superior. (core parks: Isle Royale NP, Voyageurs NP) The proposed program focuses on the fringe boreal forest of the Western Lake Forest



Paleoarcheology in relation to the Global Change program involves not only the saving and studying of prehistoric ruins but the investigation of how the inhabitants adapted to environmental conditions (and how, in some cases, they seem to have given up in the face of these changed conditions.) This is Inscription House Ruin at Navajo NM in Arizona.



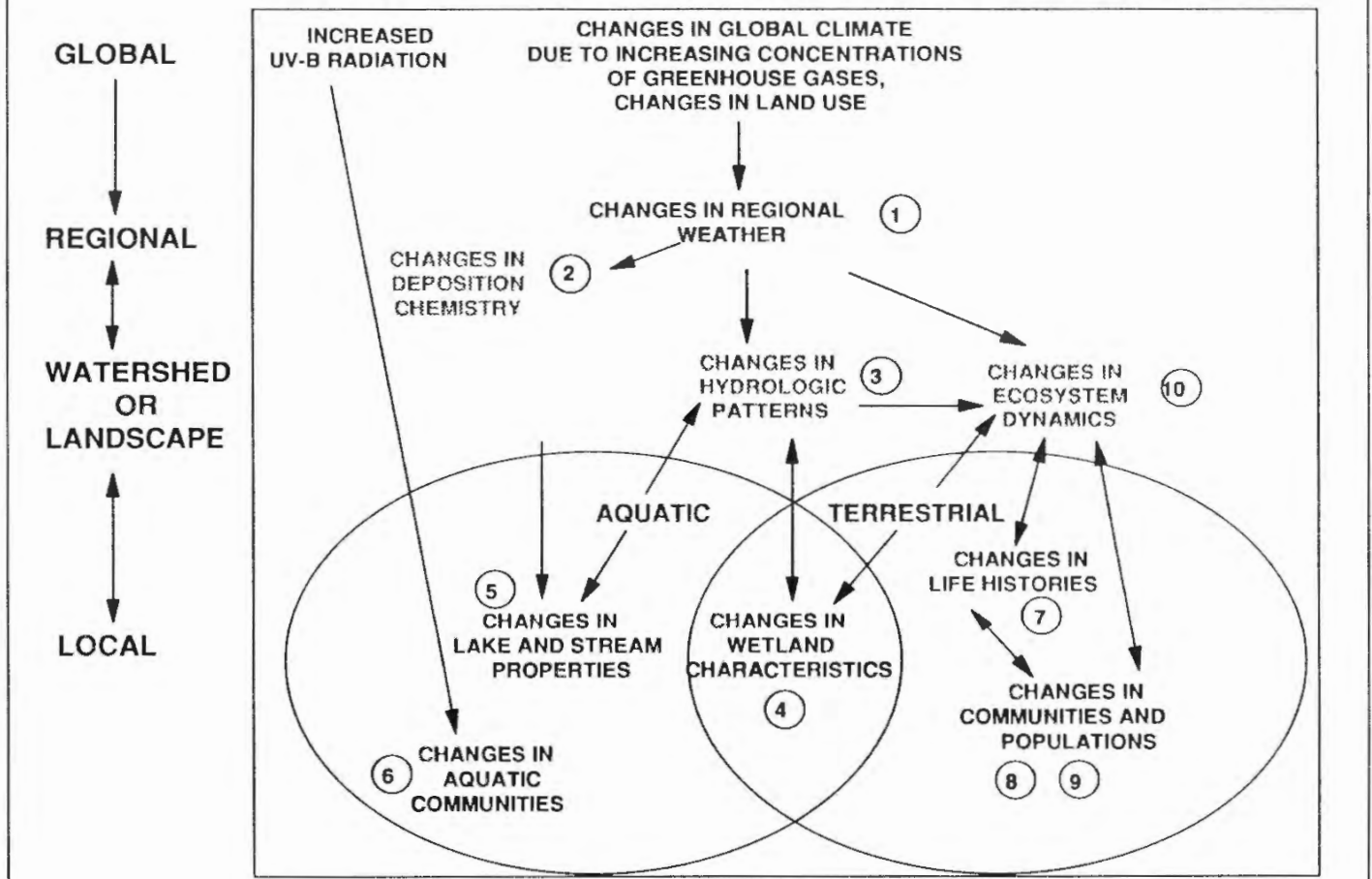
This erosion scene (Cape Hatteras, March, 1973) will be repeated with increasing frequency up and down the nation's coastlines if ocean levels continue to rise and storm events intensify in numbers and strength.

province, with emphasis on change in the nitrogen cycle as an early indicator of climate change. The program will involve contributing sites to the north and west of the core research areas to study the vegetation that may replace the boreal forest. Investigators plan to contribute to a multi-agency university study of the climate of Lake Superior, as well as to collaborate with the Canadian Park Service on boreal forest monitoring studies. The program also plans to institute studies on subsistence and small-scale economic fishing in Lake Superior and Canadian border lakes.

Coastal Barriers. The coastal barrier islands constitute one of the most dynamic natural systems within the National Park System. This thematic research program, which in FY 91 will focus primarily on the Mid-Atlantic NPS units, will be expanded in the out-years to include NPS units on the entire Atlantic and Gulf seaboard. The monitoring and research program will investigate the processes that are directly linked with the physical and biological systems that will respond to a change in climate; sea level, storm frequency and magnitude, air and water temperature, precipitation, and tidal wetland dynamics. Modeling and state-of-the-art GIS will be the foundation of this thematic research program.

An example of the global change research concepts that will be considered for inclusion in the NPS Global Change Research Program is shown below.

COLORADO ROCKIES GLOBAL CHANGE PROGRAM



Numbers in circles are hypothesis numbers which were discussed in the proposal.