GLOBAL CHANGE RESEARCH IN U.S. NATIONAL PARKS

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ABSTRACT

The U.S. National Park Service has selected 20 biogeographic areas (BGAs) for its global change research program. Each contains many biological populations arrayed along a series of ecological gradients. The BGAs (each with a core of one or more parks) represent an optimal scale for research and predictive modelling relating to the hypothesized effects of global change on biodiversity and ecosystem integrity. Many of these parks are units of the International Network of Biosphere Reserves, and provide excellent opportunities to study global change on a comparative, cooperative, and international basis. The program is designed to utilize the expertise of the academic community and other Federal agencies, as well as resident park scientists and resource managers. Ongoing research focuses on such topics as paleoclimates, hydrology and ecosystem processes in small watersheds, regional climatic modeling, forest dynamics and ecotone shifts, climate and fire history, and the effects of sea level rise on coastal barriers. Most results will be incorporated into existing or developing GIS's. Early results are discussed. We are working to share data among NPS BGAs and with other participants in the interagency U.S. Global Change Research Program being developed by the Committee on Earth and Environmental Sciences. Using highly visible national park sites will provide long-term baseline data for detecting, assessing, and predicting global change effects on terrestrial ecosystems.

INTRODUCTION

During the 1980s, major advances in remote sensing, geographic information system (GIS), and computer system technologies substantially improved environmental assessment at scales from local to global. The technologies have become the cornerstone of predictive modelling of the global earth system in general and climatic change in particular. They are also fast becoming operational tools of policy makers, planners, managers, and scientists concerned with managing natural and human systems on local to regional scales. Each application reflects the particular scale of the science, management, and policy issues involved.

Toward the end of the 1980s, world attention focused increasingly on sustainability as an integrating concept linking natural and human systems. "Sustainable development" has come to be regarded as the process for ensuring that the development needs of present generations do not compromise the ability of future generations to meet their own needs (World Commission on Environment and Development 1987). This process depends upon predictive modelling across many temporal and spatial scales. As the 1990s begin, sustainability is providing the umbrella for integrating the capabilities of the physical, biological, and social sciences in developing these models (Lubchenco et al 1991).

Biological diversity is an important consideration in sustainable development, especially in geographic areas containing national parks and equivalent reserves. Sustaining natural biological diversity is the ultimate challenge facing managers of national parks and protected areas. Meeting the challenge will require the effective use of scientific information to support policies and management practices at the ecosystem, species, and genetic levels. It will also require development of capabilities to adaptively manage biological diversity under unprecedented rates of environmental change.

In the next century, the status of biological diversity is likely to depend on whether the interacting effects of human-caused fragmentation of natural habitats (a local and regional influence on biological diversity) and global climatic change (a worldwide influence) can be successfully addressed. A major concern is that, under rapid climatic change, species comprising ecological communities will dissociate as their habitat conditions become unfavorable, and that, for many species, rapid migration to favorable habitats elsewhere across natural barriers and fragmented landscapes will be impossible. The capability to identify newly favorable habitats, and the management skills to establish viable species populations in such habitats, are presently limited. In a recent report on the policy implications of global warming, the National Academy of Sciences concluded that adaptive management of global change effects on biological diversity is problematic in view of the complexity of natural ecological systems (National Academy of Sciences 1991)

IMPORTANCE OF BIOGEOGRAPHIC AREA SCALE

Global change research involves many agencies and organizations, both in the U.S. and elsewhere, working in many fields and at appropriate scales. Studies range from global in scale, e.g., the Joint Global Ocean Flux Study (International Geosphere-Biosphere Programme 1990), through all intermediate levels, to research on individual species populations at individual sites and in the laboratory. The National Park Service (NPS) has elected to focus primarily at the biogeographic area (BGA) scale.

A BGA is defined as an area having a special combination of physiography, climate, vegetation, characteristic species, natural processes, human populations and resource uses. Each BGA is part of a terrestrial biogeographical province (sensu Udvardy 1975) or coastal region (sensu Ray 1975). Because human systems are explicitly included, it may be also be considered a biogeocultural region (sensu U.S. MAB 1989). In the NPS Global Change (GC) program, a BGA comprises one or more protected national park units and the surrounding ecologically associated area. The BGA provides a suitable scale for sustaining most components of the natural biological diversity of the national park unit(s). It provides, or could provide with appropriate management, sufficient redundancy of favorable habitat to assure the survival of these components under the inevitable occurrence of stochastic catastrophic events, such as fire, storms, drought, disease outbreaks, and pest infestations--i.e., the kinds of events that are likely to increase in frequency and intensity under climatic change (Parsons 1991). Because of their wide range, migratory birds and certain insect species may require research and management coordination among multiple BGAs, but the BGA scale is still appropriate for sustaining adequate habitat for these species. The BGA is an appropriate scale for integrating natural and social sciences which is required for modelling the relationships between global change, biodiversity, and land uses (Long-term Ecological Research Network 1989). Finally, it is a management-relevant scale for the broad inter-institutional cooperation that will be needed to address the hypothesized consequences of global change (Comanor and Gregg in press).

ROLE OF BIOSPHERE RESERVES

Biosphere reserves (BR) provide the conceptual basis for NPS global change research, and are beginning to provide an operational framework as well. BRs are internationally designated by UNESCO on the basis of nominations from the countries participating in the Man and the Biosphere Program (MAB) (UNESCO 1987). Brs are selected on the basis of their capability to implement several roles:

o **Conservation**, focused on sustaining representative examples of minimally disturbed, naturally functioning ecosystems of a terrestrial or coastal/marine biogeographical province;

o **Research and Monitoring**, focused on integrating the natural and social sciences to support conservation of ecosystem processes and biological diversity within the context of sustainable human uses;

o **Sustainable development**, focused on developing the theory and demonstrating the practice of sustainable human uses of ecosystems; and

o **Outreach**, focused on education, communication, and participation. This includes establishment of cooperative frameworks for sharing information, especially within a biogeographical area, and utilization of national and international networks for technology development and comparative studies.

A hypothetical BR typically includes one or more strictly protected core natural areas for conservation, ecosystem monitoring, and education ("core areas"); one or more zones of managed uses ("buffer zones") for experimental research and demonstrating sustainable types and patterns of ecosystem uses; and a transition area of multiple uses for implementing cooperative programs involving local communities and regional institutions to promote sustainability in the surrounding biogeographical area (UNESCO 1984, U.S. MAB 1989). Core areas and zones of managed use are legally established management units designated as BR components by UNESCO on the

basis of national nominations. The transition area is open-ended and usually not included as a designated component of the biosphere reserve. The functional boundaries of the transition area may vary in space and time depending on the cooperative activities underway. In some BRs, these functional boundaries may eventually encompass an entire BGA.

Since UNESCO made the first BR designations in 1976, the international network has expanded to 300 BRs in 75 countries. In the U.S. and many other countries, BRs provide a framework for linking complementary management units in the same BGA (Figure 1). The 47 U.S. BRs -- the world's largest domestic network -- include 91 management units, of which the NPS administers 30. Because the linkages are voluntary and BR designation does not constrain management prerogatives, additional management units participating in cooperative BR programs can be readily nominated for UNESCO designation as BR units. The interplay of program development and the opportunistic designation of BR component units helps foster commitment among stakeholders in BR research, educational, and demonstration programs. Cooperative regional MAB organizations, involving different levels of government and the private sector, have been established in five BGAs (i.e., the Champlain-Adirondack area, Southern Appalachians, Mammoth Cave Area, Land-between-the-Lakes area of Tennessee and Kentucky, and the Central California Coast) and are under discussion in about 15 others. These organizations plan and implement cooperative biosphere reserve programs.

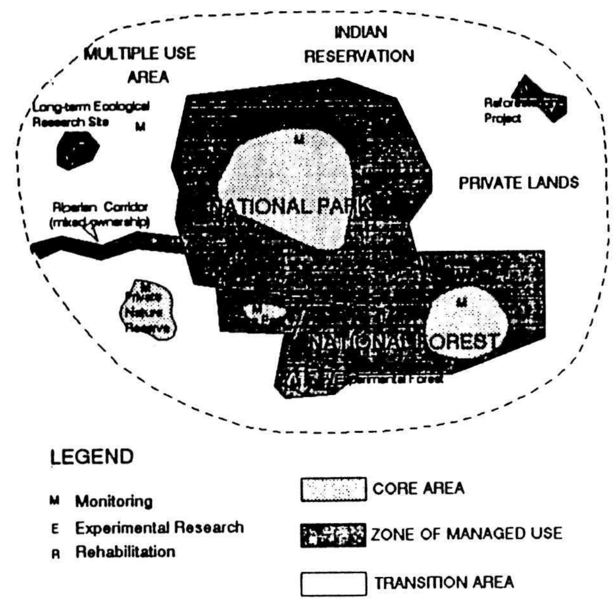


Figure 1.
Hypothetical biosphere reserve showing zonation and types of potentially included management units

Biosphere reserves provide a suitable framework for linking research at different ecological scales (Dyer and Holland 1991). Research in a fully operational biosphere reserve will usually include the development and linkage of spatial databases at the plot, landscape patch, small watershed, and whole landscape scales (Figure 2). Research at each scale may, in turn, be linked to complementary activities in cooperating sites within the BGA, the larger biogeographical province, or, in some cases, internationally with sites elsewhere in the biome or with biospheric studies of earth system processes.

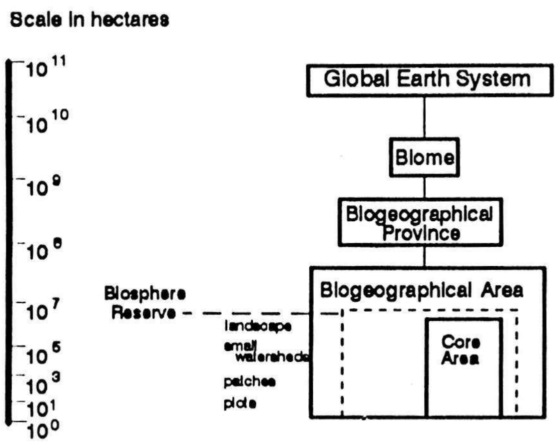


Figure 2. The relationship of scale to the National Park Service Global Change Program

Because of their scientific and network functions, large size, and potential to involve many stakeholders, BRs are logical standard-bearers for research on sustainable development, biodiversity, and global change. During the past two years, the U.S. MAB Program has initiated major interdisciplinary research projects involving five U.S. BRs to improve understanding of interactions of natural and human systems at the BGA scale (U.S. MAB 1990, 1991). The projects rely substantially on integration of spatial databases in predictive modelling to improve the scientific basis for addressing these broad research and management issues.

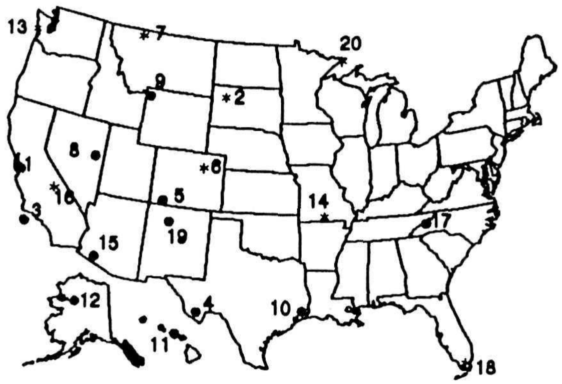
At the international level, North American and European National MAB Committees have formed the EuroMAB organization,

which last year initiated planning of the Biosphere Reserves Integrated Monitoring Program (BRIM). The program is developing metadatabases on inventory (including spatial databases), monitoring, research, facilities, and staff in the 166 EuroMAB BRs to facilitate identification of opportunities for cooperation. Cooperative activities will emphasize GC-related monitoring in biomes having large numbers of Brs, especially temperate broad-leaf forests (58 Brs), complex mountain systems (46), and evergreen sclerophyllous woodlands or "Mediterranean ecosystems" (22).

The NPS GC Research Program currently supports research in eight NPS BGAs. Each of these BGAs includes one or two core park research areas, which are either existing or potential BR units, and as many as six additional cooperating parks within the BGA or the larger biogeographical province (Table 1). The BR status of the core park research areas varies. Some were designated as BR in the 1970s. Others are being considered for inclusion in BR nominations. These areas can play catalytic roles in building cooperative biosphere reserve programs involving multiple research sites in their respective BGAs. Several areas are exploring these opportunities. In the Southern Sierra BGA (Mixed Mountain Systems Biome, Sierra-Cascade Biogeographical Province), Sequoia National Park, designated as a BR in 1976, is the core park research area for NPS global change research. Yosemite National Park is a cooperating park, but presently not a BR unit. The possibility of establishing a Southern Sierra BR linking the two parks and potentially other cooperating sites is under consideration. In the Ozark Highlands BGA (Temperate Broad-leaf Forest Biome, Eastern Forest Biogeographical Province), Buffalo National River and Ozark National Scenic Riverways are core global change research areas. A feasibility study, sponsored by U.S. MAB and various agencies in the BGA, has recommended further consideration of the two parks and several other sites for nomination as the Ozark Highlands BR.

THE NPS GLOBAL CHANGE RESEARCH PROGRAM

The fundamental goal of NPS global change research is to develop predictive understanding of global change effects on natural ecosystems in BGAs of exceptional importance for conservation.
The NPS has selected 20 BGAs for its Global Change (GC) Research Program (Figure 3). When fully implemented, this network will include representative BGAs in all of the biomes and most of the biogeographic provinces in North America north of Mexico, along the major cold-to-hot and wet-to-dry climatic gradients of the U.S. Ongoing and planned research focuses on tundra (Alaska parks, Olympic Peninsula, and the Rocky Mountains); deserts (Great Basin, Chihuahuan, and Sonoran); montane coniferous forests (Rocky Mountains, Sierra Nevada, and Olympic Peninsula); temperate deciduous forests (Gulf Coast [Texas], Appalachians, Lake Superior Basin), coral reefs, and subtropical mangrove forest.



1 Central California Coast
2 Central Grasslands
3 Channel Islands
4 Chihuahuan Desert
5 Colorado Plateau
6 Colorado Rockies
7 Glacier National Park Area
8 Great Basin
9 Greater Yellowstone
10 Gulf Coastal Plain

11 Hawaiian Islands
12 North West Alaska
13 Olympic Peninsula
14 Ozark Highlands
15 Sonoran Desert
16 Sierra Nevada
17 Southern Blue Ridge
18 South Florida
19 Upper Rio Grande
20 Western Great Lakes

* Sites funded in FY 1992

Figure 3.
Biogeographic areas in the NPS Global Change Research Program

BGAs were selected competitively, using a multistage external peer review process. Selection required evidence of resource sensitivity to GC, capability to conduct GC research, an effective research plan, and a group of related research projects contributing to predictive understanding of GC effects on the BGA (National Park Service 1991). Research projects were selected according to criteria used by the interagency U.S. Global Change Research Program (Committee on Earth and Environmental Sciences 1990): relevance/contribution, scientific merit, readiness, linkages, costs, enhancement to existing U.S. global change research programs, and agency approval.

BGA programs include various research combinations linking past and future: paleostudies to provide evidence of past climatic changes and provide long-term trend data, baseline studies which may detect GC signals, and hydrological and ecosystem process research to help us understand effects within an integrated unit. Paleostudies include dendrochronology to help understand the shifting forest-alpine tundra boundary (Olympic Peninsula), the influence of fire on redwoods (Sierras), and climatic effects on water flow (Ozark

Highlands). Process studies focus on nutrient dynamics (Colorado Rockies and Western Lake Superior). The data from paleostudies, long-term observations, and process studies will be used to develop models to predict GC effects in the BGA and provide the basis for research and development on opportunities for adaptive management. The utility of these models will depend on refinements in General Circulation Models (GCMs), which presently do not enable reliable assessments of potential climate changes at regional and subregional scales. Nevertheless, we are utilizing the GCM output and GIS technology to develop regional-scale (i.e., biogeographical province) models of climate change, using BGA data from sites in the Colorado Rockies and the Central Grasslands, soon to be augmented by data from the Ozark Highlands and -- in cooperation with Canadian colleagues -- from Alberta's Elk Island National Park. We are also using GCM output to parameterize watershed-scale models in the Colorado Rockies, Glacier National Park Area, Ozark Highlands, and Western Great Lakes BGAs. At a still more local scale, we will soon be using forest stand models to simulate and predict forest dynamics at several of our study sites. By linking models at the several scales discussed, we hope eventually to develop predictive assessments of GC effects at scales relevant to sustainable management of ecosystems and biological diversity.

Inter-institutional linkages are vital. At present, more than 90% of NPS research project funds support park-based research by non-NPS researchers in 13 universities and several cooperating federal agencies. These researchers work closely with NPS scientists and natural resource specialists in a multidisplinary, cooperative way, reflecting many research interests (Comanor and Dennis 1992). Each BGA has its own NPS program coordinator. The BGA-based interdisciplinary "team" approach gives park managers access to expertise not available within the NPS, and enjoys strong field-level support.

All NPS BGA programs plan to use remote sensing and GIS technology. Planned applications and themes vary in complexity and scale. Rapid relocation of research sites for long-term monitoring will rely on Global Positioning System. Actual mapping of resource features, including species assemblages or ranges, will involve traditional field mapping or remote sensing. GIS applications will build upon and utilize a nominal data base, containing standard themes. This data base is being developed according to policy and standards established through a central office GIS Division. Nominal database themes include vegetation, land use, topography and hydrography, transportation/infrastructure, administrative boundaries, soils, geology, and cultural resources.

For GIS, NPS uses the Geographic Resource Analysis Support System (GRASS). However, cooperators will also use other systems such as ARC/INFO. By coordinating our research with the research of other agencies, we seek ultimately to develop integrated models of natural and human systems that improve the basis for sustaining biological diversity as conditions in the BGA change. GIS will be a basic tool in developing BGA models, and for linking them with models of earth system processes at regional and global scales. Eventually, we envision a reciprocal interaction in which data from national parks contribute to progressive refinement of earth system models, and the refinements in earth system models facilitate progressive improvement in prediction of the global change effects on ecosystem sustainability and biological diversity at management-relevant scales. In order to consider appropriate policy and management responses, as well as to design future research and monitoring studies, we will need to predict changes in climate as well as resource responses, such as changes in species distributions, at appropriate scales of interest (Kelmelis and Ragone 1992). GIS will be essential for these activities because it can provide a common spatial framework for combining GC data, provide a means to establish spatio-temporal relations between disparate data sets, and support predictive modelling (Consortium for International Earth Science Information Network 1991).

CONCLUSION

GIS technology is now widely used as a tool for creative integration of spatial databases (Frank et al 1991). The NPS Global Change Research Program will link databases at scales from local to global to model the effects of global change in biogeographic areas representative of most of the major biogeographical provinces occurring in the United States, and suitable for addressing both scientific and practical management issues.

Within the BGAs, the NPS Global Change Research Program is using biosphere reserves as the organizing framework for global change research, to encourage cooperative research with others in the BGA, to link research with public education, and, in the longer term, to develop adaptive management strategies for biological diversity under conditions of global change. As the program develops, the international BR network can be utilized for comparative studies to detect global change signals, provide data for improving the reliability of predictive models of GC effects, and support the broad cooperation required to demonstrate these linkages.

The logistical challenges of developing and linking databases at various spatial and temporal scales to meet both scientific and management needs are formidable and long-term. By providing a GIS-based focus within the U.S. Global Change Research Program for research at the BGA scale, the NPS is doing its part to address these challenges.

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TABLE 1. Funded NPS global change sites categorized according to major biogeographical classification units. (Core park research areas indicated in boldface; cooperating parks indicated by asterisk (*). Biosphere reserve status is noted in parentheses)

- Grasslands Biome
  - Grasslands Biogeographical Province
    - *Homestead National Monument, Nebraska
    - *Indiana Dunes National Lakeshore, Indiana
    - *Pipestone National Monument, Minnesota
    - *Scotts Bluff National Historic Site, Nebraska
    - Central Grasslands Biogeographic Area
      - *Badlands National Park, South Dakota
      - **Theodore Roosevelt National Park, North Dakota**
      - **Wind Cave National Park, South Dakota**

- Mixed Mountain Systems with Complex Zonation Biome
  - Rocky Mountains Biogeographical Province
    - Colorado Rockies Biogeographic Area
      - **Rocky Mountain National Park, Colorado (1)**
    - Glacier National Park Area Biogeographic Area
      - **Glacier National Park, Montana (1)**
  - Sierra-Cascade Biogeographical Province
    - Southern Sierra Biogeographic Area
      - **Sequoia National Park, California (1)**
      - *Yosemite National Park, California (4)

- Temperate Broad-leaf Forest Biome
  - Eastern Forest Biogeographical Province
    - Ozark Highlands Biogeographic Area
      - **Buffalo National River, Arkansas (2)**
      - **Ozark National Scenic Riverways, Missouri (2)**

- Temperate Needle-leaf Forest/Temperate Broad-leaf Forest Biomes
  - Lake Forest Biogeographical Province
    - *St. Croix National Scenic Riverways, Wisconsin and Minnesota.
    - Western Great Lakes Biogeographic Area
      - *Apostle Islands National Lakeshore, Wisconsin (4)
      - **Isle Royale National Park, Michigan (1)**
      - *Pictured Rocks National Lakeshore, Michigan (4)
      - *Sleeping Bear Dunes National Lakeshore, Michigan (4)
      - **Voyageurs National Park, Minnesota (3)**

- Temperate Rainforest Biome
  - Oregonian Biogeographical Province
    - Olympic Peninsula Biogeographic Area
      - **Olympic National Park, Washington (1) 1/**
- Tropical Monsoon Forest Biome
  - Everglades Biogeographical Province
    - South Florida Biogeographic Area
      - *Big Cypress National Monument, Florida (4)
      - **Everglades National Park, Florida (1)**

<u>Biosphere Reserve Status</u>
1 = designated
2 = proposed unit, active consideration
3 = proposed unit, inactive
4 = under discussion

1/ cooperating sites in different biogeographical provinces not identified (i.e., Crater Lake National Park, Mount Rainier National Park, and North Cascades National Park with Olympic National Park).

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FOREWORD

The theme for this year's ASPRS/ACSM/RT 92 Convention -- ***Mapping and Monitoring Global Change*** -- is particularly timely. 1992 marks the 500th anniversary of the landing of Columbus in America, the **International Space Year,** and the **International Earth Summit** in Rio de Janerio. These events focus our attention on the fantastic changes that have taken place in our world over the past five centuries, changes that promise to continue at an increasingly rapid pace. The global mapping and monitoring sciences were in their nascent form in 1492, but they were essential to guide Columbus on his voyage across the Atlantic. Today, these technologies are combining with earth, biological, atmospheric and other sciences to provide critical information about the current and future state of our global environment. A major goal of the ASPRS/ACSM/RT 92 Convention is to provide a forum for the examination, discussion and debate of the scientific, technological and social challenges represented by the urgent need for ***mapping and monitoring global change***!

Many first-time events will take place during this ASPRS/ACSM/RT 92 Convention. Never before have our societies held their major annual convention in conjunction with an ISPRS Congress, and we are delighted that the XVII ISPRS Congress is being hosted by ASPRS in the United States this year! The combination of the ISPRS Congress and the ASPRS/ACSM/RT 92 Convention will make this the largest gathering ever held of remote sensing, GIS and mapping specialists, photogrammetrists, cartographers, surveyors, educators, resource managers, technicians, scientists, and engineers from around the world. This is the first time that ASPRS and ACSM have combined forces with Resource Technology to host an examination and discussion of the various technological and scientific issues in the mapping, monitoring and management of the world's forest, range, water, air and other natural resources. This Convention also represents the first time that several technical plenary sessions have been held to high-light the theme of the convention. In addition, there are more technical papers over (400) and sessions (112) than at any previous ASPRS/ACSM Convention! This is indeed a premiere event!

The papers presented at this 1992 ASPRS/ACSM/RT 92 Convention on "Mapping and Monitoring Global Change" are contained in five volumes of proceedings. Volume 1 contains the papers for the technical sessions on Global Change and Education; Volume 2 -- Photogrammetry and Surveying; Volume 3 -- GIS and Cartography; Volume 4 -- Remote Sensing and Data Acquisition; and Volume 5 -- Resource Technology 92 papers. Only papers or abstracts received in time for publication are contained in these proceedings.

ASPRS/ACSM/RT 92
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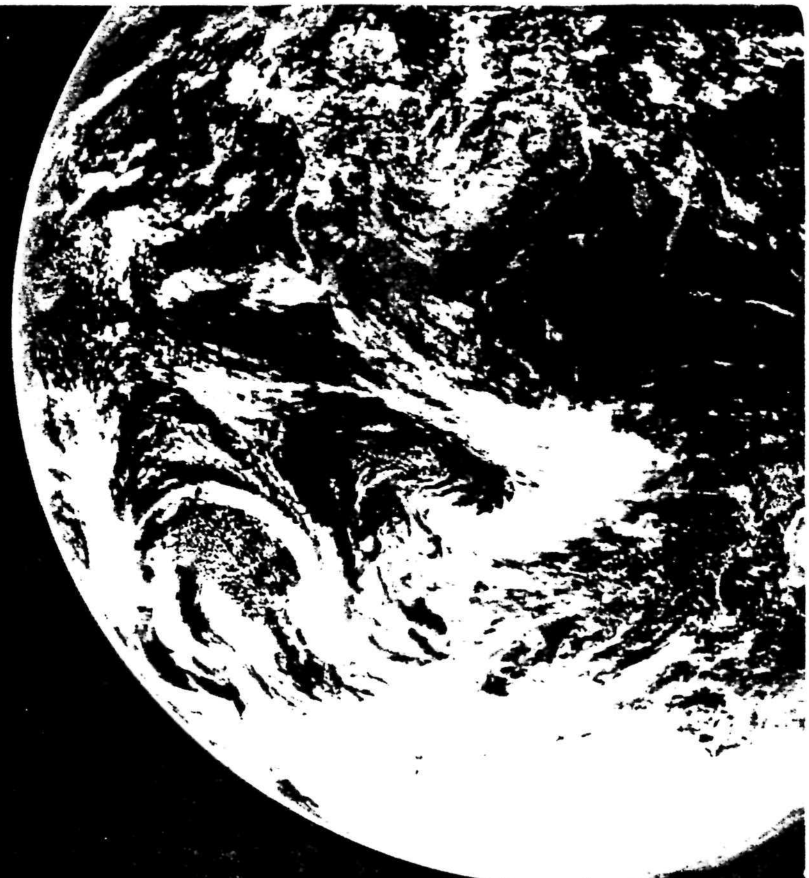

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