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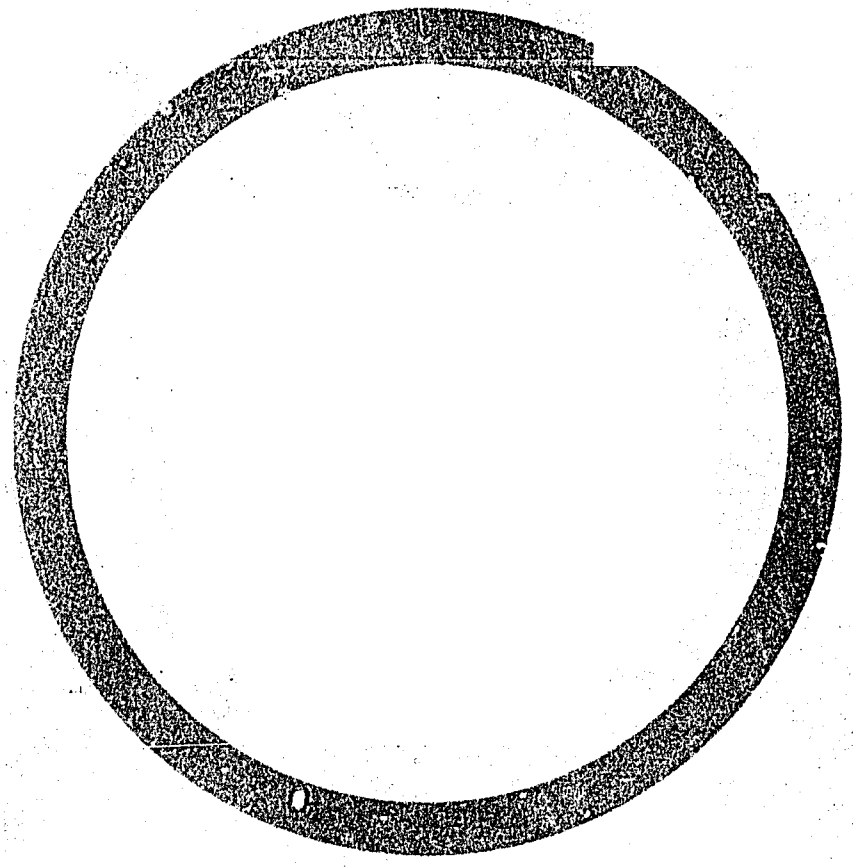

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FINAL REPORT

SOLAR DATA COLLECTION IN CENTRAL AMERICA

- Survey of existing solar radiation data
- Evaluation of systems, institutions, personnel
- Plan for improving solar radiation data collection in each country, throughout the region

CONTRACT NO. AID/LAC-80-1
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ABSTRACT

A review of the existing solar radiation data base and instrumentation currently in use in the Central American countries indicates that the existing data may be highly inaccurate. In order to provide data useful in the design of solar energy systems and in increasing agricultural productivity, it is recommended that the existing data base be checked and rehabilitated if necessary and if possible, by installing new and properly calibrated instruments and by training and coordinating personnel in the six Central American countries. It is also recommended that the existing network of solar radiation data acquisition stations be upgraded and expanded to provide information that will prove valuable in the future as food and energy prices increase and shortages become more severe.

I. INTRODUCTION

Solar America, Inc., was contracted by the Agency for International Development (AID/Washington) during July 1979 to assist the Regional Office of Central American Programs (ROCAP) in designing a fuelwood and alternative energy sources project. Solar America Inc., was asked to (a) identify alternative energy sources that could substitute for fuelwood in domestic and small industrial applications and (b) design a preliminary cost-effective solar data collection plan for Central America, including Panama. The solar data plan was to include recommendations for hardware, work plans, and delineations of responsibilities of cooperating institutions in Central America. Preliminary recommendations were presented to ROCAP in the intial project paper.

After a temporary suspension of work on the solar data aspect of the contract, the scope of this part was modified to include the following activities:

(1) Personnel from Solar America, Inc., would travel to Central America to evaluate present solar data and existing instrumentation and to understand better how national agencies interpret data they are now collecting. Meetings would be held by Solar America with representatives of host countries and USAID personnel.

(2) After assessing the collected information, Solar America would design a preliminary plan to improve data quality and reliability that could include (a) calibration of existing recording equipment, (b) expansion of the data collection system, if needed, (c) suggested routines for periodic recalibration and maintenance of recording equipment, and (d) suggestions for

cooperation in program operations and servicing of equipment. Brief cost estimates would be prepared as part of this phase of work.

(3) A conference of involved institutions would be held at technical and program direction levels to consider the proposal and recommended improvements.

As the demand and prices of energy and food increase, alternative energy sources need to be developed and agricultural productivity improved.

Solar energy technologies are being considered for many appropriate energy applications in the near future; several solar applications are already commercially successful or are in advanced development stages. To yield the greatest benefit-to-cost ratio, solar energy systems will have to be designed according to the known availability of solar radiation and other local climatological characteristics in any specific area.

Agricultural production can be greatly increased by use of accurate climatological data, including patterns of solar radiation availability and rainfall.[1] An improvement in agricultural productivity can not only increase local food supplies, but it can also allow the possibility of some production of synthetic fuels from biomass. This biomass could consist strictly of agricultural wastes, or it could include grains that are grown specifically for fuel production.

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[1]Hargreaves, G.A., Ministerio de Recursos Naturales, Honduras

Increases in agricultural productivity are an immediately desirable goal. The production of energy from solar radiation may be a near-term necessity. To meet these goals, an accurate data base of solar radiation availability is needed.

The existing data base for Central America may or may not be reliable. Solar America, Inc., on recent trips to Central America, noted that (a) the number of data collection stations there are limited; (b) the instrumentation in use there for collecting solar data has not been calibrated; and (c) the instruments may not be functioning properly as a result of degradation and peeling of black coatings on radiation-measuring parts, and condensation within the instrument casings. For these reasons, Solar America recommends that the existing data be correlated with properly calibrated instruments that are operated under properly controlled environmental conditions. It is possible that error factors can be developed statistically that will allow rehabilitation of some or all of the existing data. Therefore, in as short a time as six months a reliable body of data may be developed. On the other hand, it may be necessary to collect new data for a longer period of time in order to obtain sufficiently accurate data for use in designing cost-effective solar energy systems and for improvements in agricultural productivity based on knowledge of precipitation, solar radiation, and temperature patterns for specific areas.

By 1985, the use of earth satellite observations for estimating solar radiation availability will probably be generally available. However, these observations will need to be verified and calibrated by reliable data acquired at ground stations. Meteorologists consider a 30-year period to be the standard length of time needed to develop an accurate data base. In order to determine whether the existing data can be rehabilitated, or

whether an entirely new body of data will have to be developed, a network of properly calibrated and maintained meteorological data collection stations is needed in Central America as soon as possible.

Two basic types of measurements are currently taken at ground-based sites. These are measurement of the total solar radiation falling on a horizontal surface from the entire sky dome, and measurement of the solar beam that comes directly from the sun. This is recorded by pyranometers and pyrheliometers, respectively. It is possible to develop mathematical models that show the long-term average relationships between these two measurements in a given climatic area. Thus, once a relationship is established, the measurement of only one to these paramenters may be sufficient for many purposes.

II. THE SURVEY OF EXISTING DATA

A number of international repositories of solar radiation data records were contacted in an attempt to obtain data for Central America. These included the U.S. National Climatic Center in Asheville, N.C., and the World Meteorological Organization (WMO) in Switzerland. No useful data were obtained from those organizations, largely because they report monthly averages, not the daily information necessary for a thorough analysis.

The local meteorological agencies in the Central American countries were contacted to identify what measured solar radiation data existed there. A large amount of data was identified. Initially, Solar America attempted to obtain all the historic data; it soon became clear, however, that the current project had insufficient resources, both in funding and time, to collect and analyze this data. Only a representative sample was collected and reviewed.

A listing of the data collection stations is contained in Appendix C.

A large data base of solar radiation data measurements for Central America does exist. However, there appears to be a number of significant problems with that data base relative to reliability, including a lack of calibration, and degradation and malfunctions of the measuring instruments.

The current data base comes primarily from measuring instruments installed in the early 1970s. These instruments are of two types--actinografos and heliografos.

The actinografo (actinometer) is an instrument designed to measure total global solar radiation on a horizontal surface, the same as a pyranometer. This instrument is designated a Class 3 instrument in the WMO classification system (where 1 is the highest quality). All the instruments examined were made by a German firm, Feuss. These instruments rely on the differential expansion of three bimetallic strips, two white and one black, for the sensing of solar radiation. These differential expansions move a pen that indicates the amount of solar radiation on a chart. The chart is driven mechanically by a spring. These charts must be read and manually integrated to obtain daily total values. These types of instruments have been in wide use for many years around the world. The accuracy of the data from this instrument can vary widely depending upon the care with which it is maintained and calibrated, while the accuracy of a well-maintained instrument could vary from $\pm 20\%$ to $\pm 50\%$. This type of instrument suffers from the following problems:

a) The calibration constant is a function of ambient temperature and probably of wind as well.

b) These instruments are nonlinear, and calibration is a function of the solar elevation and azimuth.

c.) The mechanical movement of the strips often causes flaking of the white and black paints, which thus alters the instrument's response.

d) The instrument is not well sealed, and conditions of high humidity can cause deterioration of the painted surfaces and corrosion of parts, affecting operation and accuracy.

Because of these problems, these instruments are not relied upon today by those who are seriously planning solar energy programs. Despite these problems, historical data from a well-maintained network of these instruments may be better than no data. A careful examination of the existing data should be made to identify those data which are useful and those which are unusable. In addition, a careful calibration of all instruments should be done to determine their current conditions, calibration factors, and other characteristics.

The heliografo (interim reference sunshine recorder) measures a parameter similar to beam radiation. Little is known about the relationship between the heliografo measurements and the pyrheliometer measurements. It should be possible to develop a model showing a relationship between those instruments when sufficient data become available.

Heliografo and actinografo measurements were collected from a number of countries. These data were computerized, and a method that had been developed previously for eval-

uating instrument calibration change was applied to the actinografo data. A sample of the data was reviewed, and a representative analysis is included in Appendix F. The general conclusions from this review are:

1) The calibration of most of the actinografos reviewed has changed significantly since the instruments were installed.
2) From the data collected, it appears impractical to predict which instruments will change or by how much.
3) These problems place doubt on the quality of the data base available, mostly because of the actinografo itself.
4) A careful analysis of the data and comparison of existing instruments with pyranometers should establish the quality of the existing data base and provide data which can be used until results are obtainable from a network of newer instruments.

Data from the heliografo were not examined in as much detail, because this instrument is not prone to changes in calibration.

Brief visits were made to a number of observing stations. It was judged that the personnel were competent and generally performed their current tasks well.

A significant effort in specialized retraining will be required for installation, maintenance, and operation of modern instruments. This is particularly true if electronic data logging systems are to be used.

The average tenure in any given job is 1.4 years[2] for positions of this type. The conclusion is that a continuous training program is mandatory for maintaining adequate operation of stations. It was suggested that a cassette tape and slide presentation method be used and that a series of course-lecture programs be prepared. This appears to be an ideal method because of its moderate cost and reproduceability, and because projector facilities in most cases already exist.

III. TYPES OF SOLAR RADIATION DATA NEEDED

A. Solar data needed for the design and evaluation of simple solar systems (water heaters, dryers, stills, etc.) and for agricultural uses.

In order to design and evaluate the performance of simple solar systems such as solar water heaters, solar dryers, and solar stills, one needs to know the following information:

1) Total hemispheric solar radiation (pyranometer)
2) Dry-bulb temperature
3) Dew-point temperature
4) Wind velocity and direction

A pyranometer, together with standard meteorological instrumentation systems, can provide all the above-mentioned data. It is necessary that the pryanometer be

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[2]This statistic was provided by Mr. Robert McCollough of ROCAP office in San Jose, Costa Rica.

calibrated periodically (at least once a year) against a standard pyranometer to ensure accuracy of measured data.

B. Solar data needed for design and evaluation of complex systems and for simple concentrating collector systems.

It is necessary to have reliable hourly direct-normal and total-hemispheric values of solar radiation. The design of complex solar and meteorological data should consist of the following:

1) Direct-normal solar radiation (pyrheliometer)
2) Total-hemispheric solar radiation (pyranometer)
3) Meteorological data (dry-bulb temperature, dew point, wind data)

IV. PRELIMINARY PLAN FOR IMPROVING THE DATA BASE

The optimum form of a data collection system will depend on the technical progress made in a number of areas, including the use of satellite data and mathematical models for estimating solar radiation availability. It will also depend on the ability of organizations to maintain high-quality stations at operational status.

The recommended plan is phased, with decision points at the end of each phase to allow accommodation of lessons learned or new developments in the technology.

This plan may be appropriately applied in any single country, and thus will succeed whether or not all countries work together. Regional cooperation, however, will provide additional benefits to all.

The recommendations in this plan are prioritized. Those within each priority group are of equal priority: thus, the first-priority items should be undertaken before those of second priority, and so forth.

Priority 1:

New instrumentation with necessary training and management changes for one category A station[3] in each country.

Development of training programs that can be used to maintain desired levels of competence.

Development of statistical models for estimating solar radiation in the Central American climates.

Priority 2:

Additional instrumentation for research facilities such as universities.

Rehabilitation, wherever possible, of existing data.

Calibration facility.

Research on using data from satellites.

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[3]Category A, B, and C stations are defined in Appendix A

Electronic data-logging systems.

Additional Category C stations in each country.

Additional Category A stations in locations experiencing climatic extremes (sunny, cloudy).

Priority 3:

Use of satellite data.

Development of coordinated regional publications on solar data acquisition and evaluation.

Automated central-station data reduction in each country.

Management and Administration: The most important factors in any network are management and administration. It is recommended that at least one full-time person at a level of Ingeniero (college graduate or technical-school graduate) be assigned to network administration in each country.

Calibration: It is recommended that all instruments be calibrated at six-month intervals for the first two years, and thereafter annually, or as experience dictates.

It will be important to establish a calibration facility that can provide high-quality calibration services to a large number of instruments. One facility would satisfy

the needs for a number of countries. Such a facility should have two or three full-time personnel, at least one of which has a college degree in science.

Until this facility is established, secondary standards for each country can be calibrated at the U. S. National Oceanographic Administration Agency Solar Radiation Facility at Boulder, Colorado.

Maintenance: Routine checking of all instruments should be done daily by a trained person familiar with the instruments and their operation. Initially, instruments should be checked by a trained technician weekly or monthly, and then quarterly or as experience dictates.

Instrumentation: It is recommended that the existing actinometers be phased out as soon as practical, but they should not be discarded. The actinometers now in use should be compared with a pyranometer for at least one year at each site in order to establish calibration factors that can be used to rehabilitate the existing data base; after one year, these actinometers can be recalibrated.

The new instrumentation recommended is of three levels of sophistication. These are named here, Category A (the best), Category B, and Category C. Category A stations provide hourly data and are equivalent to the best stations in any network. Category A data stations give the data needed for design and evaluation of complex systems. Category B stations allow the use of sampling to create models for extrapolating the data measured at Category A and B stations elsewhere. The equipment configurations for each category are given in Table I (See Appendix A). It is also necessary that spare instruments be purchased for each network.

It is recommended that each country have at least one Category A station as a minimum (See Appendix B). Then, as funds permit, Category C stations should be located wherever actinometers have been located, and, as funding permits, these stations should be upgraded to Category B. Category A stations are important where any sophisticated solar power facility or any facility using concentrating collectors is planned.

Approximately five years of data is required to establish the solar radiation climate at a given location. The current shortages of fossil fuel and the urgency of developing alternative energy systems as soon as possible suggest that progress be rapid. Therefore, it is recommended, that an attempt first be made to validate and/or rehabilitate data that has already been collected.

When changes of the magnitude discussed here are planned, the option of creating a completely new data collection system, including personnel and organizations, should be considered. Based on the evaluation of the existing organizations, it is best to improve the instrumentation in the existing organizations and to provide necessary training to existing personnel.

New data collection locations should be selected based on the following criteria:

1) Any location that is a potential site for a solar energy or agricultural project that will require a history of data to measure performance of systems.

2) Any area that experiences an abrupt climatic change over a short geographic distance; this often occurs near mountain ranges and seacoasts.

3) The feasibility of maintaining and operating a data collection system at any site.

Potential problems are foreseen in two areas:

1) Lack of familiarity of personnel with the equipment--particularly, the electronics and microcomputer data-logging systems.

2) The effects of tropical climates on the performance of the instrumentation, plus the selection of data recording systems that will be most reliable and what environmental conditioning is needed for them.

3) Short tenure of technical personnel in jobs.

A phased program is recommended to minimize these potential problems. This includes: local training of personnel with hands-on experience of equipment, testing a variety of equipment in the environment in which it will be used prior to large-scale purchases of equipment, and use of consultants, on a regular basis, who have specific experience in solving the problems encountered. It is also recommended that self-paced training programs be developed using 35-mm slides and cassette tapes.

V. RECOMMENDED PROGRAM FOR A DATA COLLECTION NETWORK

Recommendations for Proceeding on a Solar Data Base Project for Central America

1. It is recommended that ICAITI and CRRH jointly submit a proposal to U.S. AID for a three-year solar data base collection project as follows:

   a. Solar America, Inc., will be contracted by AID to perform an in-depth study for all the data presently available from each country in Central America. The data will be entered into a computer analysis system, reliability and accuracy will be determined, and a data base will be established by validation and rehabilitation.

   b. After the data reliability project is underway, Solar America, Inc., will assist in the design of an organizaional management technical team involving the CRRH group and the ICAITI group.

2. The U.S. AID grant should be administered by ICAITI, because they have demonstrated stability, have had prior U.S. AID assistance, and have established proper fiscal and management control capabilities. The CRRH group would manage the project.

3. The Regional Office of Central American Programs (ROCAP), located in Guatemala City, should be the U.S. AID funding agent.

4. As in-kind contributions, each country will purchase all the equipment necessary to establish the solar data collection network through the CRRH group.

5. Solar America, Inc., will assist in the selection and purchase of U.S. equipment required for the project. Solar America, Inc., will also assist in the first year of equipment set-up and operation and train Central American personnel on use, maintenance, and calibration.

6. The data collection project should consider wind and other climatological data as essential elements of this project.

7. Solar America, Inc., in conjunction with equipment suppliers, will be responsible for developing a comprehensive training program including slide shows and cassette tapes for in-country training, and will also be responsible for continuous upgrading of the training program over the entire three-year project period.

8. Each country, through the CRRH group, should send one (1) individual to the United States to attend comprehensive courses in both solar and wind data collection.

9. Solar America, Inc., in conjunction with equipment suppliers and individuals who have been trained in the United States, will conduct training and upgrade in-country seminars for all individuals involved in the program.

10. The core data base program will run approximately three (3) years, with two to five years of follow-up

programs in training and in data verification and instrumentation calibration. The total budget figure should be approximately $1.75 million for three (3) years and $0.8 million for the following two to five years.

Planning, Contractual Arrangements, and Organization (See Abstract Proposal to Develop Project Plan)

1. Prepare a detailed plan that can be used on a country-by-country basis.

2. Work out a complete budget, including participating funds from each country (local governments.)

3. Work out contractual arrangements on a country-by-country basis.

4. Define responsibilities in this program as a whole and within each country on a regional basis.

Initial Installation, Training, and Equipment Evaluation

1. Purchase of complete equipment for one station, including at least one set of spare equipment for each country.

2. Training of technicians in the installation and operation of equipment.

3. Evaluation and testing of equipment upon arrival. Setups in laboratory environment with sensors outside for initial checkout (2 weeks to 2 months of operation) and daily experimentation.

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4. Initial installation of equipment at one site near an existing main facility.

5. Evaluation of system performance throughout 12-18 months of operation. Declaration of operational status of system should occur during this period.

6. Begin collection of data from new system and establish data reduction procedures and archival procedures and programs.

7. Establishment of initial performance goals for systems. Suggested targets for the first year of operation are less than 20% of total hours with missing or invalid data in the first year after the station has been declared operational. Greater than 50% missing data in the first operational year would be cause for considerable concern and should initiate reevaluation of the program. Later years should have targets of less than 10% missing data, and 5% or less should be the ultimate goal.

8. Develop a plan for funding and management of a regional calibration facility. Contract with a facility manager.

9. Revision of the plan: The plan should be revised at the end of Phase 1, based on experience gained.

<u>Expansion of Network (following Solar Data Base Project)</u>

1. The decision to expand (include additional stations into the new network) should be based on system per-

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formance after the first installation has been declared operational. This decision may come as soon as 6 months after the first station is operational or as long as 24 months from that time. The decision should be made by those managing the data collection networks.

2. New stations added to the network: New stations should be added, on-site personnel trained, and data collection begun, one station at a time. Established sites in the new network should be maintained at a high level of reliability. Additional new stations should not be added unless the exisitng ones can be maintained at a high level of performance.

3. The ultimate number of stations envisioned at this point is one for each location where an actinografo is now installed. Future expansion beyond this number of stations should be based on:
   - future technological developments in solar radiation resource assessment, particularly the use of satellite data.
   - perceived needs for data in a particular area.

The existing instruments at sites should be maintained and data collected for at least one year after the new system is declared operational. A degradation curve can then be developed for the old instruments, which will provide the opportunity to develop correlations between the old instruments and the new, which may lead to rehabilitation of the old data. Additional correlation with other climatological data can also contribute to possible rehabilitation of the existing data.

The establishment of a solar data base network is not sufficient for the development of a solar energy program, because solar resource data is used to predict the performance of solar systems, whose performance is measured by testing under carefully measured conditions. Research and testing facilities for system performance evaluation must have equipment for measurement of the solar radiation similar to those used for resource measurement.

It is recommended that solar system research facilities be equipped with the same solar sensors used for resource measurement and with comparable data-recording equipment.

VI. SPECIFIC RECOMMENDATIONS FOR EACH COUNTRY

The foregoing recommendations give a picture of the solar data collection network as it should appear in each country; however, some specific problems were observed that should require individual attention in each country. these are given here on a country-by-country basis.

COSTA RICA

The first visit to Costa Rica consisted of a trip to the U. S. Embassy office of USAID/CR, where Mr. David Straley, USAID engineer, assisted Solar America in locating all agencies in Costa Rica with meteorological interests or activities. His office set up appointments with such institutions as the Instituto Tecnologico in Cartago, both of the universities, and the Central Office of the Instituto Meteorologico in San Jose. At the latter we met with engineer Patricia Ramirez and were given a comprehensive description and background on solar radiation instrumentation and data collection in Costa Rica. Historic data records were made available to Solar America for all stations in the country, and samples of this data were collected at this time. During the subsequent visit, engineers Hugo Herrera and Eladio Zarate made available additional requested data for further study and evaluation. An on-site visit was also provided so that the typical data collection systems could be observed and evaluated with respect to the project. Engineers Herrera and Zarate provided time for discussion of instrumentation experience, maintenance, operations, and problems related to each.

It was the consensus of the Solar America engineers that the Instituto Meteorologico is a well organized and operated organization. The personnel are highly capable and seem to have excellent technical expertise and experience. Their records were well docu-

mented, easily retrieved, and up to date. The personnel were very cooperative in assisting Solar America in obtaining all the requested data. They also gave excellent assistance in data interpretation. The San Jose station typifies those of Costa Rica, having old equipment that is now considered obsolete. The stations appear to be well maintained, but no calibration equipment is available.

Costa Rica would profit greatly by the implementation of high-quality instrumentation and equipment for collecting reliable solar radiation data. The personnel are of high technical quality and exhibit a diversity of expertise. Although they do not seem to be in need of outside assistance in operating techniques for the solar radiation stations, assistance in the areas of setting up new equipment, learning calibration techniques, and implementing solar data collection programs would be very beneficial.

All the institutions contacted in Costa Rica were aware of the Instituto Meteorologico, and most were acquainted with one or more of the personnel at the Instituto. It is recommended that a formal link of coordination between I.C.E. (the electrical utility division of Costa Rica) and the Instituto Meteorologico be established in order to give more useful sharing of data and calibration access, including sharing of data and common archival methods. Data publication would therefore be through one channel.

The three universities are each pursuing courses of research in solar energy system development. These three programs should be coordinated so that there will be minimum duplicaton of research. In addition, it was noted that there was a significant lack of measuring instrumentation at the universities. It is suggested that an important element in the program will be the obtaining of adequate solar radiation measurement instrumentation for researchers at these universitites.

EL SALVADOR

The USAID office in San Salvador introduced Solar America to CEL, the electrical utility division of the government, where initial contact was made with Dr. Alberto Chiquillo, superintendent of scientific investigation and special projects. Dr. Chiquillo is in direct contact with the meteorological institute and is a key person in its relation with CEL. Successive visits were made to the Servicio Meteorologico Nacional at Santa Tecla, where discussions were held with Dr. Gelio T. Guzman and the meteorological personnel, including Lic. Rolando Martinez and Lic. Jose Caceres.

We found highly capable people involved with the solar radiation data collection process in El Salvador. It is unfortunate they do not have modern or adequate equipment with which to collect and record the solar data; they are well aware of the inadequacy of their present instrumentation and have expressed a desire to upgrade the present systems with new equipment as soon as possible. There was mention of unavailability of certain parts for the present equipment, namely batteries and other small items that are necessary to keep all the instruments in operation. The manual system of data currently in use is well organized, and current and historic data were made readily available upon request.

The meteorological personnel are well aware of the efforts of other countries in upgrading and improving solar radiation data collection systems. From the Santa Tecla office we were able to obtain the names of respected solar data researchers in other countries, such as Dr. Ignacio Galindo of Mexico.

El Salvador's experience with solar data instruments has been with units manufactured by a European firm by the name of Robitzsch, whereas all the other countries of Central America had chosen Feuss,

another European unit. Both the Robitzsch and Feuss instruments are Class 3 units, and both appear to have similar problems in operating properly. Neither instrument is sealed against water penetration through condensation, and both have problems with the black absorber plates losing their pigmentation through flaking and peeling. The result is that the absorption rate changes and the instrument does not collect and log uniformly over a period of time.

The El Salvador meteorological group definitely needs new and adequate solar data collection and recording equipment in order to bring their solar data system up to acceptable levels of reliability and accuracy. The personnel are fully capable of handling the operations of any solar data collection system if given the proper equipment and materials. They will need outside assistance in setting up solar data programs, and over a period of time they would be able to develop their own continuing solar systems programs. From satellite data (four years' accumulation) and from historic solar data collected from the ten listed stations, it appears that El Salvador receives a great deal of solar radiation annually, probably more per unit of land area than any of the other Central American countries. Further data collection with proper instrumentaton, will be needed to verify this fact.

It is also recommended that more direct cooperation be instituted between CEL and the Servicio Meteorologico Nacional to ensure a maximum sharing of data and of calibration resources. This would definitely benefit both of the institutions and enable the highly qualified personnel within each to make their most effective contributions.

HONDURAS

The Central station, located in the Tegucigalpa airport terminal, was first visited during July of 1979. Engineer Pedro Cortez provided all the requested data and described the solar data collection process very adequately at that time. Sample data appeared to be consistent with respect to observed solar radiation for the area, although no calibration or other confirmation techniques were available at that time. Later visits with other meteorological personnel indicated that the meteorological staff has good capability from the standpoint of management and technical ability. The staff was very helpful in providing information, and it appeared that their manual methods of recording the daily data and information were efficient and current.

The Honduras solar data collection instruments and equipment, which are old and obsolete in comparison to modern equipment, do not have the capability of making accurate measurements and recording adequate and reliable data. Although few stations currently exist, their capabilities would greatly be enhanced by complete replacement of the equipment now in use. Honduras, being a relatively large country, would also benefit from the addition of stations in remote areas in which solar radiation is not now being measured.

Besides the very capable meteorological personnel, Honduras also has some great resources through the CRRH (Comite Regional de Recursos Hidraulicos) and their associated personnel. Sr. Nabil Kawas, a CRRH staff member, is a tremendous asset to both Honduras and Central America. He is actively involved in the improvement plans for both local and regional solar data collection systems. He is knowledgeable and enthusiastic in regard to adequate solar data coverage, and he has regional cooperation and communication and possesses leadership qualities that can be of great benefit to Honduras and Central America.

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Another individual who is invaluable to both Honduras and the region is Dr. George Hargreaves, who is associated with CRRH and with the Ministry of Natural Resources (Ministerio de Recursos Naturales). Dr. Hargreaves is also a special representative for Utah State University, an institution of exceptional quality in the agricultural sciences. Most persons with whom we visited informed us that Dr. Hargreaves is the top agricultural expert in Central America at this time. His services as consultant, instructor, special program developer, and so forth are in constant demand. As of this writing, he is just finishing a one-week program in Nicaragua and is starting a two-week program in Panama that is especially tailored to technical government personnel and deals with the relationships of seasonal solar radiation availability, rainfall quantity, temperature ranges, and seed spacing, for the optimal production of corn by small farmers. Dr. Hargreaves's abilities in solar data collection and interpretation make him a valuable resource to any solar data collecion system that is ultimately chosen, whether for Honduras or for the entire region.

It is recommended that any future implementation of solar radiation equipment should involve all parties mentioned above. It is further recommended that the northeastern flatland of Honduras be equipped with at least a Class C station because of the potential for developing solar energy and agricultural economies in that area. The potential at this time is unknown, but according to all indicators it could be very large.

PANAMA

The primary visit to Panama included consultation with engineers Lynn Sheldon and Eric Zallman of USAID/Panama, followed by a meeting with IRHE engineer Teresa De Bryson and others. The subsequent visit with IRHE involved site visits to both Tocumen Station and Canal Zone

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to see the actual operations of typical stations and to visit with the station personnel regarding the equipment and data gathering process. Because the instruments and equipment at these sites undergo extremes of rainfall and humidity almost year-round, the types of instruments used and the frequency of their calibration can be expected to greatly affect the reliability of data provided. The Canal Zone Station, operated by the Smithsonian Institute, is well maintained. The data from this station can be considered extremely reliable on the basis of equipment capability, calibration, and personnel in charge of that station.

The IRHE group (which runs all the stations except for the Canal Zone Station) has a considerable amount of expertise in the area of meteorology and technical capability, but its equipment is of the older, class III type instrumentation. In addition, the group had no local capabilities for regular instrument calibration, and therefore the data reported may not be sufficiently reliable because of measurement inaccuracies. The IRHE people recognize the inadequacy of their present equipment and are looking ahead toward quality solar collection capability in the future. The IRHE solar radiation records were well kept, and the personnel were most helpful in assisting Solar America in gathering the requested information.

Solar America noted that an unusually good rapport exists between IRHE and USAID/Panama, and that excellent lines of communication are always open between these two institutions. They should be encouraged to continue this cooperative relationship in order to bring the maximum benefit to both institutions and to the Republic of Panama.

The cost-effective use of solar energy in Panama will rely on the ability of a solar radiation data base to provide accurate information on which solar designs and decisions may be made. The present equipment is old, has exceeded its useful life, and should be replaced with modern, high-quality equipment. The IRHE personnel would benefit from

technical assistance in the form of training and guidance in certain areas of the solar data program. However, it is felt that the IRHE personnel are technically well enough prepared to handle the solar data station operation and maintenance without outside assistance. Various individuals were noted to be very advanced in specific areas, such as electronics, solar theory, mechanics, and data evaluation and interpretation, and several individuals hold university degrees in related areas.

Because the Panama meteorological data collection is handled by IRHE, it is recommended that IRHE establish coordination with the Smithsonian Radiation Biology Laboratory. This same coordination should be established between the universities and technical institutions, and between IRHE and the Smithsonian Laboratory. This type of coordination will provide Panama with direct communication with one of the world's best technical resources with respect to not only solar data collection, but also other meteorological areas such as wind, etc...

GUATEMALA

Three on-site visits were made to the Observatoric Nacional at Guatemala City. The observatory administers the meteorological service for all of Guatemala. Engineer Claudio Urrutia, the director, was most helpful in assisting Solar America with these visits and in providing personnel in each of the areas of interest. Guatemala has ten stations that collect and record solar radiation data. All records for these stations, both historic and current, are well documented and easily retrievable for use when needed. The personnel were able to provide the requested solar radiation data for the entire country. They were also helpful in describing in detail how the solar radiation data processes are carried out, both in Guatemala City and

across the country. It was at this central station that we were able to see detailed meteorological mapping of the country and of Central America, including temperatures, rainfall, winds, and solar radiation.

The instruments used in Guatemala are of the older, obsolete type, and a European Feuss instrument appeared to be used exclusively for solar radiation measurements. An older, unnamed instrument was seen at the central station, indicating that solar radiation measurements were being taken at some time previous to the documented station data included in Appendix C. Except for the Panama Canal Zone, it is probable that Guatemala was the first Central American country to take solar radiation measurements.

The solar radiation personnel at the central station in Guatemala are capable people with good technical abilities. It is obvious that they fully understand how to operate and maintain a solar radiation station, for their station is among the best we have seen in Latin America. Their radiation data is kept current at all times and is undoubtedly as good as the instruments that provided the data. It is evident that new solar instruments and equipment are needed in order to update and improve the data collection system so that the information is more reliable and accurate. The personnel are quite capable of handling and operating a modern station and should need no assistance in this regard. They would, however, need outside assistance in setting up solar radiation programming for future application.

It is recommended that the meteorological institute, the Universidad de San Carlos (Guatemala), and ICAITI (the regional technical institution) establish cooperation and communication for the purpose of working together in the area of solar radiation data collection. This would place the various technical personnel in positions of interchanging information and assistance, and it would ensure that there would not be simultaneous duplication of efforts in the pursuit of solar radiation data. All data from each source would then be included in the national data archives.

NICARAGUA

During the time of this contract is was not possible for Solar America to make on-site visits to the meteorological stations because of political and associated barriers. It has only recently become possible to make such visits.

Nicaragua was able to send three of their technical people to the Solar Data Seminar in Guatemala during February, and from these people we were able to get some information on the country's solar radiation data status. Telephone follow-up also assisted in obtaining the information listed in Appendix C.

Lic. Leon Olivarez is the director of the Servicio Meteorologico Nacional, located in Managua, the capital. The meteorological institute is administered by Nicaragua's department of defense. The three people who attended the seminar, Engineers Jaime Lopez, Mirna Navarro, and Cesar Garcia, are capable technical persons who can operate and maintain solar radiation instruments without outside assistance. These people would probably need little or no outside assistance for implementing new equipment and instruments. They would, however, need outside assistance in setting up new solar radiation programs and systems for future use.

Nicaragua would benefit greatly from new instrumentation systems for solar radiation data collecting and recording. Their present systems are obsolete or nonexistent, and all indications are that solar energy exists in abundant quantities over large portions of Nicaragua during much of the year. The country has just come through a crisis and is in need of all available assistance during the rebuilding phases. Solar energy use is of vital importance during this period, for it can offset some of the direct costs of conventional energy sources.

It is quite probable that training will be needed for numerous personnel, for the abovementioned core does not constitute a sufficient group to handle all the meteorological tasks for the entire country.

It is recommended that the meteorological people establish a cooperative program with the universities and other institutions in order to share information and technical expertise throughout the community and country. This level of operation will ensure that the maximum use will be made of solar radiation data and that there will be a minimum duplication of effort between all parties.

It is also recommended that some special study be planned for the country. Past situations have contributed to intermittent operation of some, if not all, meteorological sites, and it is likely that there is not now a workable solar radiation data collection process in existence. Nicaragua constitutes a large, central area within Central America, and some kind of data base is urgently needed there in order to build a regional solar data network. This void needs to be filled immediately.

VII. JUSTIFICATIONS FOR REGIONALIZATION OF SOLAR DATA ACQUISITION AND ANALYSIS PROGRAMS

1. Regionally organized planned programs

   a. cut costs because plans do not need to be completely redeveloped on a country-by-country basis;

   b. allow researchers in various countries to learn from one another and to help solve each other's problems; mistakes need not be repeated;

   c. involve easier dissemination of funds and easier management of programs; and

   d. can present regionally organized training sessions that cost less and can cover more trainees with more talent.

2. Regionally archived and/or published data is more accessible to researchers; also, much agricultural productivity research and energy-oriented research is being done by regional laboratories (such as IICA, ICAITI, etc.)

   Note: This does not mean we should eliminate any archives in each country. Each country must have immediate access to its own data. Development of local archives in each country should take priority over regional archival programs.

3. Despite the benefits of regionality, each country must be able to operate its own system or network independently.

4. A regional supply and repair center would eliminate the time-consuming practice of ordering supplies from overseas and the high costs of shipping broken instruments long distances for repair.

APPENDICES

APPENDIX A

TABLE I

SOLAR DATA INSTRUMENTATION

Instrumentation recommended for Category A, B, and C Stations

Category A*	Jan. 1980 ($ US)
Pyrheliometer (Eppley NIP with Tracker)	$ 1,700
Pyranometer (Eppley PSP)	1,090
Temperature and Humidity Sensors	1,500
Wind Velocity Sensor	1,000
Digital Data Logging System w/Intergrating Cap	12,000
2 Strip Chart Readers for Backup	6,000
Equipment Racks & Instrument Mountings	3,000
TOTAL COST	$26,290

Category B*	
Pyranometer (Eppley PSP)	$ 1,090
Strip Chart Recorder	3,000
Equipment Racks & Instrument Mountings	500
TOTAL COST	$ 4,590

Category C*	
Heliografo, Integrating Sol-A-Meter that does not require external power	$ 900
Max/Min Thermometer and Standard Instrument Shelter **	500
Instrument Mounting, etc.	600
TOTAL COST	$ 2,000

*These equipment lists assume stable 110V or 220V AC power is available and that equipment can be housed in an existing climate-controlled building. Where these facilities are not available, the costs of providing them should be added to the above costs.

**These items are optional, depending on the need for data.

APPENDIX B

Minimum Instrumentation For Each Country

Item	Installed	Spares	Total
Eppley PSP pyranometer	1	1	2
Eppley NIP pyrheliometer	1	1	2
Eppley solar tracker	1	0	1
Strip chart recorders	2	1	3
Misc. associated equipment, Mountings, etc.			

The choice of an electronic data collection system is a significant effort and is not covered under the current contract. A number of location-specific conditions must be considered, including:

- availability of spare parts and maintenance
- performance in the tropical climate
- effects of available power supplies.

It is suggested that the selection of one or two specific data-collection systems be made during the initial portion of Phase 1 and that this be done in conjunction with those who will operate and maintain the new systems.

Preliminary Specifications for Electronic Data Collection System:

1) Local availability of parts, spares, and maintenance.
2) Reliability of local power systems.
3) Reliable operation in the local climate or in a specified climate that can be maintained in a local building.
4) Initial availability of instruments with a minimum of 4 dc input channels and a resolution of 10 microvolts.
5) Easy expandability to 16 channels.
6) Capability of recording hourly integrated total values as well as instantaneous values.
7) Paper-tape printed output and magnetic-tape cassette-recorded output.

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8 An integral 24-hour clock.

9) On-site programmability.

10) Input impedances of 100,000 ohms or greater.

11) High level of noise rejection at 60 Hz, or at 50 Hz if that is the frequency of the power supply.

12) Accuracy of at least $\pm 0.1\%$.

These specifications are preliminary only and should be developed in more detail before purchases are made, but they should give enough information at this time to estimate costs.

APPENDIX C

COUNTRY COSTA RICA: STATIONS MAKING SOLAR RADIATION MEASUREMENTS

Location	Lat	Long	History	Actino	Helio
San Jose	9°56'	84°05'	1971-pres.	*	*
Puntarenas	9°58'	85°50'	1970-pres.	*	*
Nicoya	10°09'	85°27'	1971-pres.	*	*
Limon	10°00'	83°03'	1971-pres.	*	*
Puriscal	9°51'	84°19'	1975-pres.	*	*
Volcan Irazu	9°59'	83°42'	1970-pres.	*	*
Palmar Sur	8°57'	83°28'	1973-pres.	*	*
Taboga	10°21'	85°09'	1971-pres.	*	*
Turrialba (IICA)	9°53'	83°38'	1966-74	*	*
Cobal	10°15'	83°40'	1970-77	*	*
La Pinera	9°11'	83°20'	1970-77	*	*
Central	10°01'	84°16'	1963-75	*	*

INSTITUTION CONTACTED: Instituto Meteorologico Nacional
San Jose, Costa Rica

PERSONNEL CONTACTED: Ing. Patricia Ramirez
Lic. Eladio Zarate
Ing. Hugo Herrera

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APPENDIX C

COUNTRY El Salvador: STATIONS MAKING SOLAR RADIATION MEASUREMENTS

Location	Lat	Long	History	Actino	Helio
Planes de Montecristo	14°33'	89°22'	1976-pres.	*	*
Ahuachapan	13°56'	89°52'	1970-pres.	*	*
San Salvador (ITIC)	13°43'	89°13'	1969-pres.	*	*
Estacion Matriz			1973-pres.	*	*
Nueva Concepcion	14°08'	89°18'	1969-pres.	*	*
Apastepeque	13°42'	89°45'	1972-pres.	*	*
La Carrera	13°20'	88°32'	1972-pres.	*	*
La Union Beneficio	13°20'	87°53'	1970-pres.	*	*
La Galera	14°03'	88°06'	1976-pres.	*	*
Las Pilas	14°22'	89°05'	1977-pres.	*	

INSTITUTION CONTACTED: Servicio Meteorologico Nacional
Santa Tecla, El Salvador

PERSONNEL CONTACTED: Dr. Gelio Tomas Guzman L.
Lic. Rolando Martinez
Lic. Jose Jimenez Caceres

APPENDIX C

COUNTRY Guatemala: STATIONS MAKING SOLAR RADIATION MEASUREMENTS

Location	Lat	Long	History	Actino	Helio
Cd. Guatemala	14°35'	90°32'	1972-pres.	*	*
El Porvenir	14°57'	91°55'	1972-pres.	*	*
Labor Ovalle	14°52'	91°30	1971-pres.	*	*
Huehuetenango	15°19'	91°28'	1969-prs.	*	*
Coban	15°26'	90°22'	1971-pres.	*	*
Panzos	15°24'	89°39'	1971-pres.	*	*
Pto. Barrios	15°42'	88°35'	? -pres.	*	*
La Fragua	14°57'	89°33'	1971-pres.	*	*
Esquipulas	14°34'	89°27'	1974-pres.	*	*
Montufar	13°49'	90°09'	? -pres.	*	*

INSTITUTION CONTACTED: Observatorio Nacional
Cd. Guatemala, Guatemala

PERSONNEL CONTACTED: Ing. Claudio Urrutia and
Technical Assistants

APPENDIX C

COUNTRY Honduras: STATIONS MAKING SOLAR RADIATION MEASUREMENTS

Location	Lat	Long	History	Actino	Helio
Tegucigalpa	14°04'	87°13'	1969-pres.	*	
San Pedro Sula	15°30'	87°55'	1970-pres.	*	
(and others, ? ?)					

INSTITUTION CONTACTED: Servicio Meteorologico Nacional
Tegucigalpa, Honduras

PERSONNEL CONTACTED: Ing. Pedro Cortez Q. and Others

APPENDIX C

COUNTRY Honduras: STATIONS MAKING SOLAR RADIATION MEASUREMENTS

Location	Lat	Long	History	Actino	Helio
Tegucigalpa	14°04'	87°13'	1969-pres.	*	
San Pedro Sula	15°30'	87°55'	1970-pres.	*	
(and others, ? ?)					

INSTITUTION CONTACTED: Servicio Meteorologico Nacional
Tegucigalpa, Honduras

PERSONNEL CONTACTED: Ing. Pedro Cortez Q. and Others

APPENDIX C

COUNTRY Nicaragua: STATIONS MAKING SOLAR RADIATION MEASUREMENTS

Location	Lat	Long	History	Actino	Helio
Managua	12°08'	86°10'	(intermit.)		
Chinandega	12°37'	87°06'	(intermit.)		
Rivas	11°25'	85°50'	(intermit.)		
Juigalpa	12°05'	85°21'	(intermit.)		
Dulces	(miss.)	(miss.)	(intermit.)		
Puerto Cabezas	14°03'	83°22'	(intermit.)		

INSTITUTION CONTACTED: Servicio Meteorologico Nacional
Dept. de Defensa, Managua, Nicaragua

PERSONNEL CONTACTED: Ing. Jaime H. Lopez (por telefono)
(Lic. Leon Olivarez, Director)

APPENDIX C

COUNTRY Panama: STATIONS MAKING SOLAR RADIATION MEASUREMENTS

Location	Lat	Long	History	Actino	Helio
David	8°25'	82°25'	1971-pres.	*	
Anton	8°23'	80°16'	1971-pres.	*	*
Tocumen	9°03'	79°22'	1971-pres.	*	*
Real			1974,75,77	*	*
Los Santos	7°57'	80°25'	1974-pres.	*	*
La Raya	8°08'	80°48'	1971-75		*
Santa Rosa	8°11'	80°40'	1973-pres.		*

INSTITUTION CONTACTED: Instituto de Recursos Hidraulicos y Electrificacion
Panama, Panama

PERSONNEL CONTACTED: Ing. Luque
Ing. Jaime Leon
Ing. Jose, and others

SEMINARIO CENTROAMERICANO

COLECCION, INTERPRETACION Y UTILIZACION DEL DATO SOLAR

PROGRAMA

Miércoles 13 de febrero

9:00	Inauguración, Director del ICAITI, Lic. Fancisco Aguirre; ROCAP, Dr. José Chacon Comité Regional de Recursos Hidráulicos, Ing. Nabil Kawas
10:00	Fundamentos de la radiación solar, SOLAR AMERICA, INC.
11:00	Descripción de los instrumentos básicos
12:00	Tiempo para almuerzo
14:00	Principios de operación de los instrumentos termoeléctricos
15:00	Introducción a la calibración de los documentos

Jueves 14 de febrero

8:30	Selección del lugar e instalación de los instrumentos
9:00	Mantenimiento de los instrumentos
10:00	Métodos de grabación de la data
10:30	Demonstración de la calibración de los instrumentos
12:00	Tiempo para almuerzo
14:00	Usos de satélites para obtención de data solar
15:00	Usos de la información solar para la agricultura
16:00	Recomendaciones

Viernes 15 de febrero

8:30	Discusión programas
12:00	Clausura

APPENDIX D-2
LIST OF PARTICIPANTS
SOLAR ENERGY SEMINAR

CENTRAL AMERICA

GUATEMALA

Noemi Gonzalez Merida
Consejo Nacional de Planificacion Economica

David Isai Revolorio Molina
Instituto Geografica Nacional

Edgar Ramiro Bucaro Rosales
Desarrollo Petrolero y Energetica
Naciones Unidas/Plan. Econ

Luis Alberto Pas
Consejo Nacional de Planificacion Economica

Mario Hernandez Herrera
INSIVUMEH

Alfred Ramirez
INSIVUMEH

J. Joaquin Bayer S.
ICAITI

Ramona Villalon Donoso
ICAITI

Jaime Valladares L.
ICAITI

Edwin Bracamonto Orozco
Facultad de Ingenieria
Universidad de San Carlos, Guat.

NICARAGUA

Mirna Jerez Navarro
Servicio Meteorologica Nacional

Cesar Lopez Garcia
Servicio Meteorologica Nacional

Jaime Hernandez Lopez
Servicio Meteorologica Nacional

EL SALVADOR

Jose Hernandez Salguero
Servicio Meteorologico

Jose Ovidio Alvarenga Sosa
Servicio Meteorologico

Jose Miguel Hernandez
Comision Ejecutiva Hidroelectrica del Rio Lempa (CEL)

HONDURAS

Luis Alonso Ponce Aguilar
UNAH

Luis Alberto Medina V.
Recursos Hidricos-Hidrologia y Meteorologia

Pablo Hernandez E.
Direccion de Recursos Hidricos

George Hargreaves
Recursos Hidricos
Ministerio de Recursos Naturales

COSTA RICA

Luis Felipe Rivera Rivera
Instituto Meteorologico Nacional

Ricardo Chaves Garro
Instituto Meteorologico Nacional

Jose Miguel Paez Jimenez
Universidad de Costa Rica

Marco Antonio Vasquez Esquivel
Universidad de Costa Rica

PANAMA

Jose C. Perez J.
IRHE

Alfonso Liao Lee
IRHE

APPENDIX D-3

SUMMARY OF

FIRST REGIONAL CENTRAL AMERICAN SOLAR DATA SEMINAR, FEB. 13-15, 1980

GUATEMALA, C.A.

I. Objectives

1. To recognize the existence of solar energy data in Central America and Panama and to plan for improvement over the short and long terms

2. Awareness of each participant of the importance of this type of activity

3. Analysis, interpretation, evaluation and inventory of all the existing data

4. Identification of solar energy data sources

5. To recognize the existing situation as to equipment, personnel, organization, and method of data acquisition at the institutions presently operating in Central America

II. Problems Encountered

1. Deficiency in equipment

2. Lack of maintenance facilities for:

   a) apparatus maintenance
   b) calibration

3. Shortage of trained personnel

4. Difficulty in collection of information

5. Lack of adequate economic resources

6. Lack of coordination in acquisition of adequate equipment and achievement uniformity of instrumentation for the region

III. Recommendations

1. To hold seminars, concentrating on the necessities of these activities at the levels of

   a) government
   b) executive bodies
   c) users, etc.

2. Setting up courses for training

   a) foreign programs
   b) local programs

3. Participation of local experts in the acquisition of equipment

4. Arranging financing for access to satellite data

5. Creation of a calibration center for the region, with adequate personnel and equipment

CRITIQUES FROM CONFERENCE PARTICIPANTS

I. CRITICA

Se cumplió con la parte a) y b) del programa del seminario, no así con la c) "utilización de la data solar". Si señado´ algo con respecto a la agricultura per nada con respecto a la transformación de esta energía; por ejemplo: en electricidad.

II. PONENCIA PARA UN PROXIMO SEMINARIO

Que se trate únicamente de utilización de la energía solar y que se presenten películas hacerca de las fases de proyectos de este tipo ya realizados, señalaudo el costo de los mismos y los aparatos empleados. Un pocando todas las conferencias hacia proyectos necesarios en el área centroamericana. Necesarioamente los participantes deben tener conocimiento anticipado de los temas a tratar en el seminario.

Agradezco la invitación que me hiciera para participar en este primer seminario.

****

El seminario en general me parecio adecuado, sin embargo se detecto bastante desorfanizacion en la exposicion de la materia seria ideal que ha profesores elaboraran un programa detallado de los temas que expondran en cada sesion de esta manera se les facilitaria a ellos la exposicion del tema y a los alumnae la compaension del mismo. Hubo conceptos que no fueron explicados a su debido tiempo sino que fueron expuestos en el momento que el profesor se recordo de ellos ..... en el piranometro, este lleva a confusion al alumno. De todas maneras fraciar puet a pesar de la falta de seguencia en las exposiciones pude aprender bastante.

****

Consideraría en base a lo discutido, se fijarán varios proyectos en donde fuda tracerse uso de la energía solar y en concordancia con ello recolectar los datos ya con un objetivo que sería la realización un fin determinado entonces seria bueno realizar un seminario en donde enfosaran proyectos que sería viable tuvieran su aplicación a nuestros paises, aprovechando la energia solar como un paliativo que ayudara a afrontar la actual crisis energifica.

Respecto al curso per descinocimiento de varios de los aparatos mostrados, no puedo hacer ninguna critica pues mas bien fue una experiencia en la cual obtuve conociemiento de instrumentos. Esto debido a mi trabajo que representa mas que todo una acción de planificación.

Es en ello que considero el lineamiento de varios proyectos en donde se aplique su energía solar como un medio para ser que debido a la importancia que presenten puedan tomarse en cuenta en los planes de desarrollo nacionales en el unglón especifico del sector energetico.

SUGERENCIAS DEL SEMINARIO

-- Tratar que el seminario proximo sea mas amplio en tiempo (1 Semana) para profundo un mas en los topicon

-- Que los proximos seminarios sean individuales

1) calibración, instalación y mantenimiento del equipo
2) recolección de datos
   a) auspelación
   b) ordenación
   c) evaluación
   d) publicación

SUGERENCIAS GENERALES

-- Grater de crear un fondo para la traducción de manuales, falletos que reparten en los seminarios congresos y otros reuniones.
-- Confeccionar un manual de meteorologia en general (observación estadistien y otros) para estandariz los criterion del personal involverado en estudios proyectos del area C.A.
-- Sugerir la standarización de todo el equipo que recoge datos ya que la marjoria de los paises del area estan comprando aparatos nuevos.

****

OBSERVACIONES

-- Considero que los seminarios o actividades similares deberán de ser de mas dias de duración, una semana, por ejemplo

-- Tal vez sería necesario hacer actividades más académicas orientadas para personas que no trabajan en meteorología, pero que tengan alguna relación con la energía solar, por ejemplo los interesados en proyectos de utilización de energía solar. Como sustituto de algyna otra forma de energía.

****

SUGERENCIAS PARA FUTUROS SEMINARIOS

1. Realizar un seminario a nivel de jefaturas de los Institutos Meteorológiocos del area Centroamericana con el fin de conocerlos objetivos y programas de cada Instituto relativos al uso que se le da a la información recolectada y aparte de ese seminario secar conclusiones y nuevos objetivos para el uso de la informacion como podia ser: la agricultura uso de fuentes no convencionales de energía, meteorología, etc.

De este seminario podrian salir a flote las necesidades y limiticiones de cada pais y pudrian esbozar un futuro plan de seminarios y cooperacion, los paises del área, donde se tratarian los problemas comunidades. Estos futuros seminarios seran el .... para los objetivos programas a definidos por las autoridades del area.

2. Realizar un curso practico para tecnicos, en medición sobre calibración, medición, lectura y processamiento de informacion con objetivos concretos que le permitan a este personal ruejorar la calidad de su trabajo.

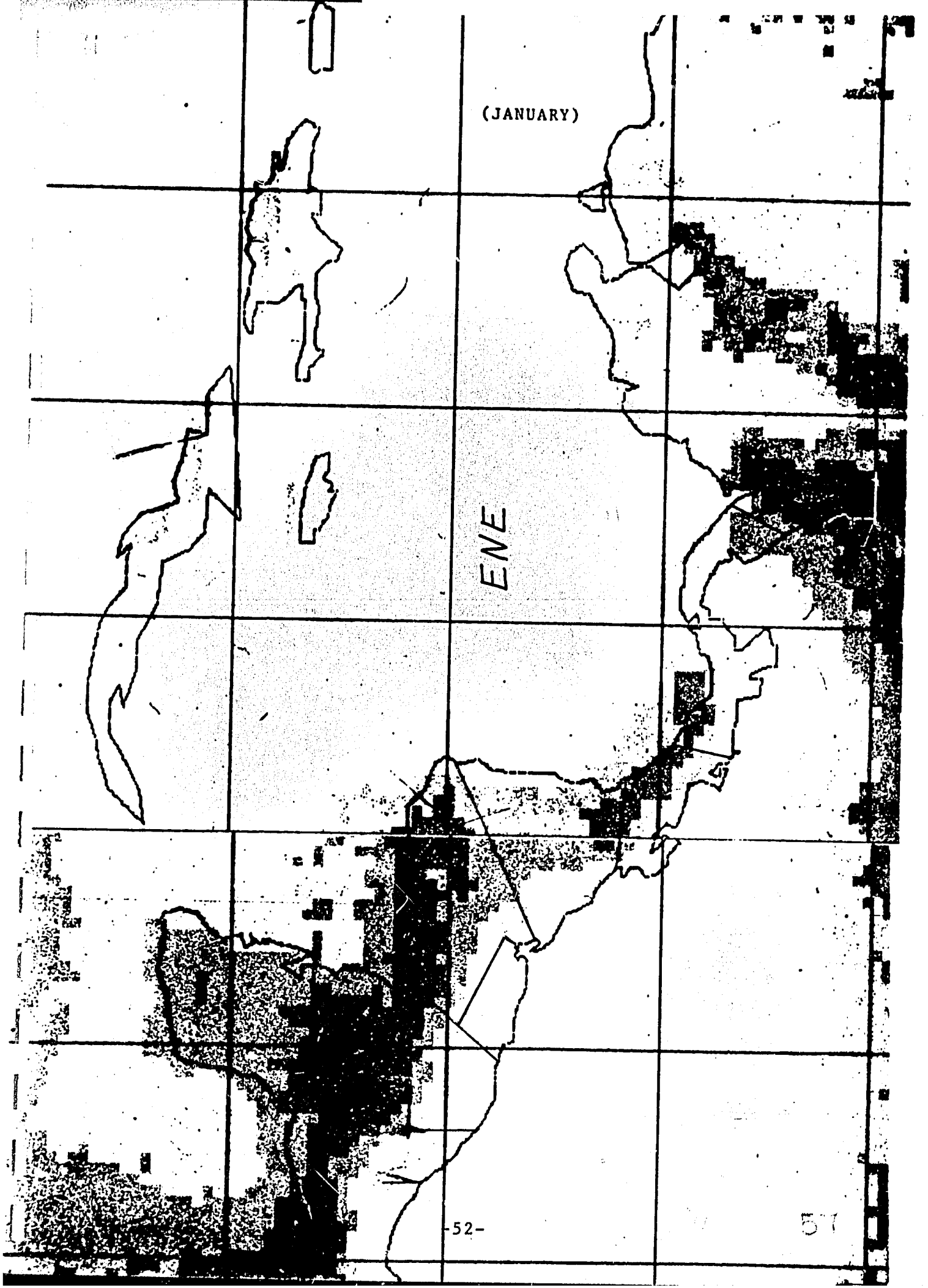
APPENDIX E

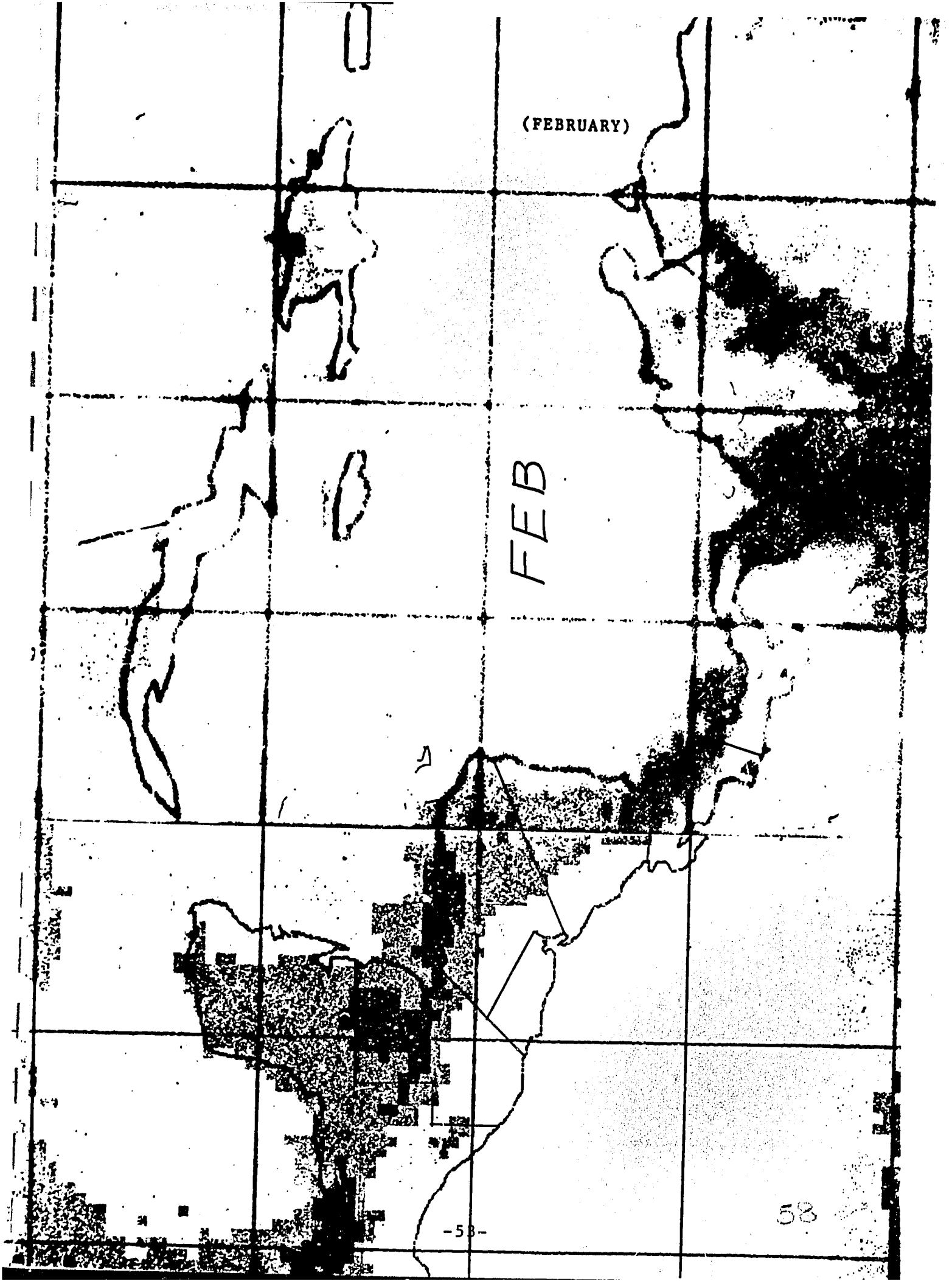
SATELLITE REPRESENTATION

The following 12 pages are monthly satellite representations of solar radiation patterns for Central America. These "pictures" are monthly reproductions taken from four years of satellite monitoring, during which cloudy and clear conditions were photographed daily. The dark areas indicate high cloud cover (low solar radiation to ground sites); the gray indicates medium cloud cover, and the white indicates low cloud cover.

The resolution of the satellite camera is noted by the printout of small "blocks" (areas). The seasonal differences between sunny skies and cloudy skies, and differences between mountain and lowland sky conditions, are very evident in these reproductions.

Future improvements in satellite monitoring, data recording, and reduction and interpretation will make it possible to obtain more precise solar radiation patterns for specific regions and sites.


(JANUARY)
ENE


(FEBRUARY)
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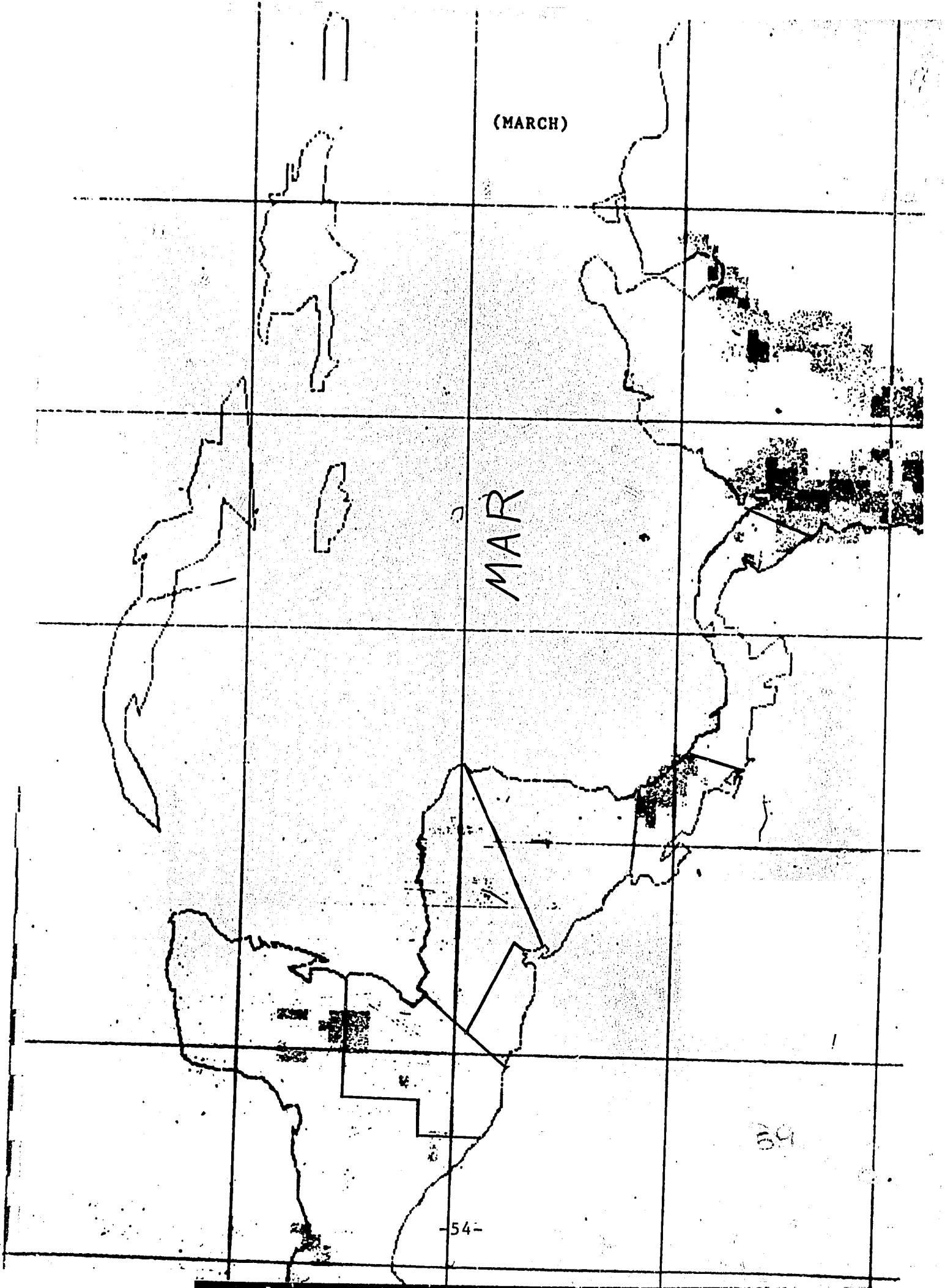
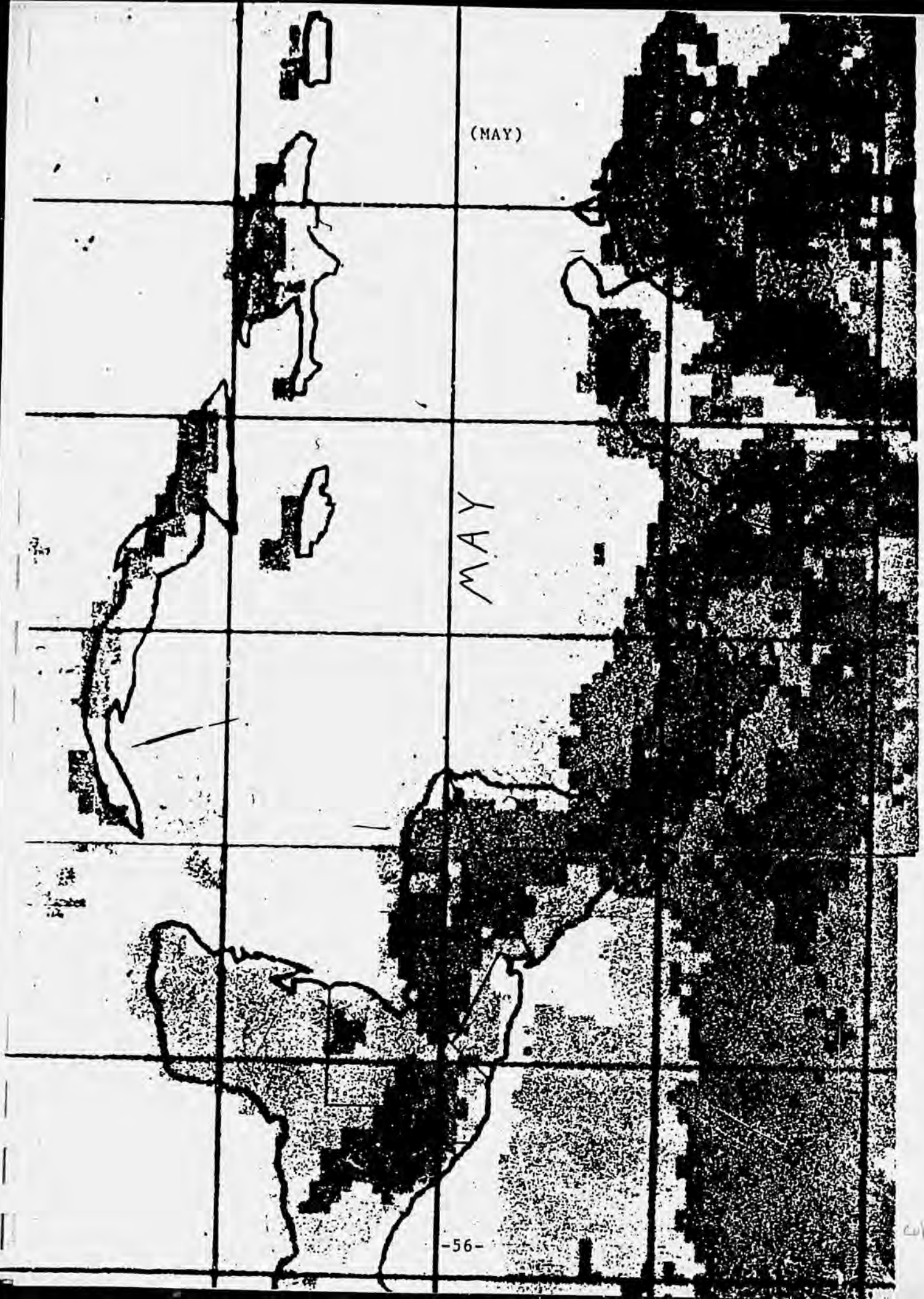
58


(MARCH)
MAR

(APRIL)


(MAY)
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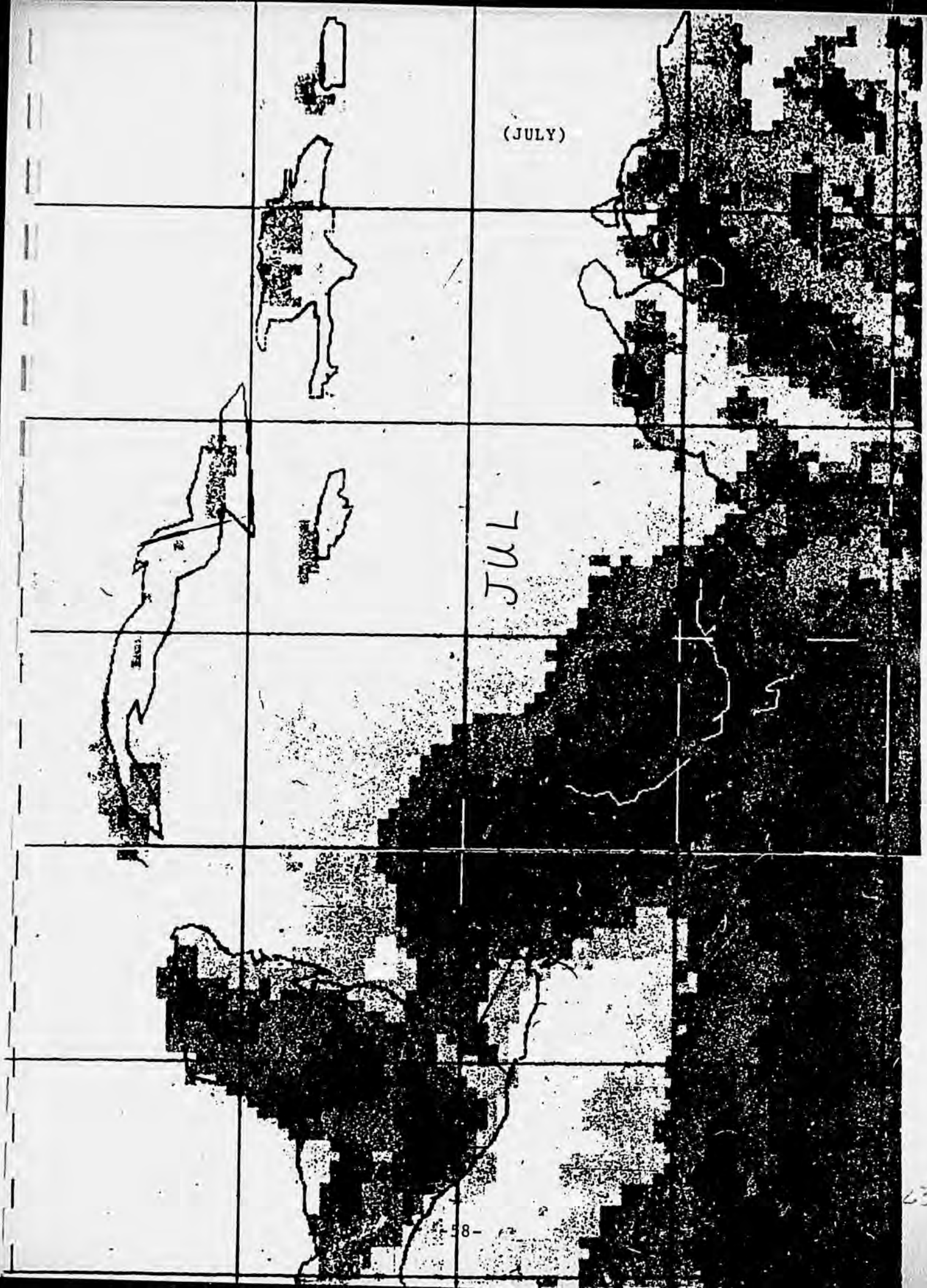
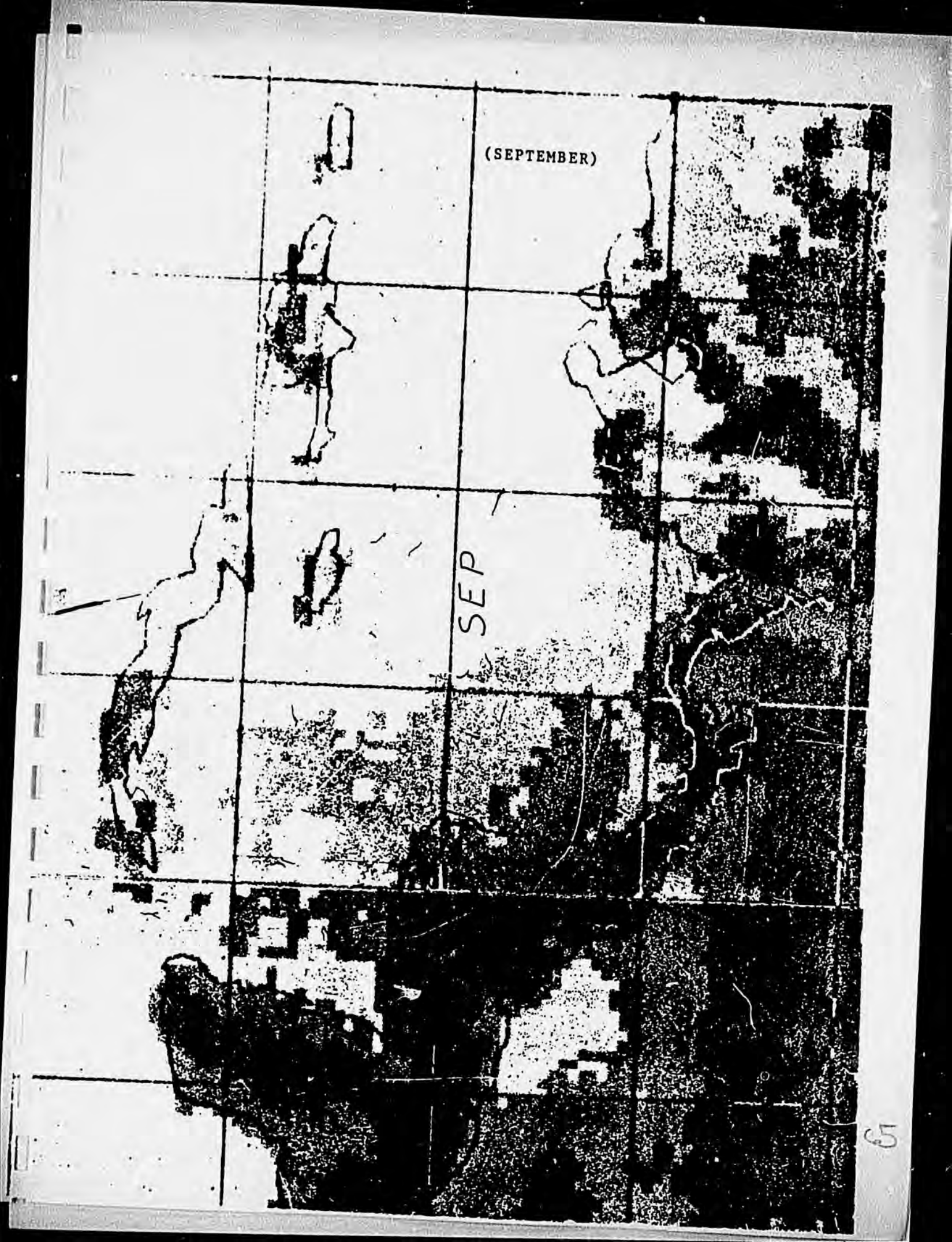
(JUNE)
JUN

(JULY)



23

AUG
(JULY)



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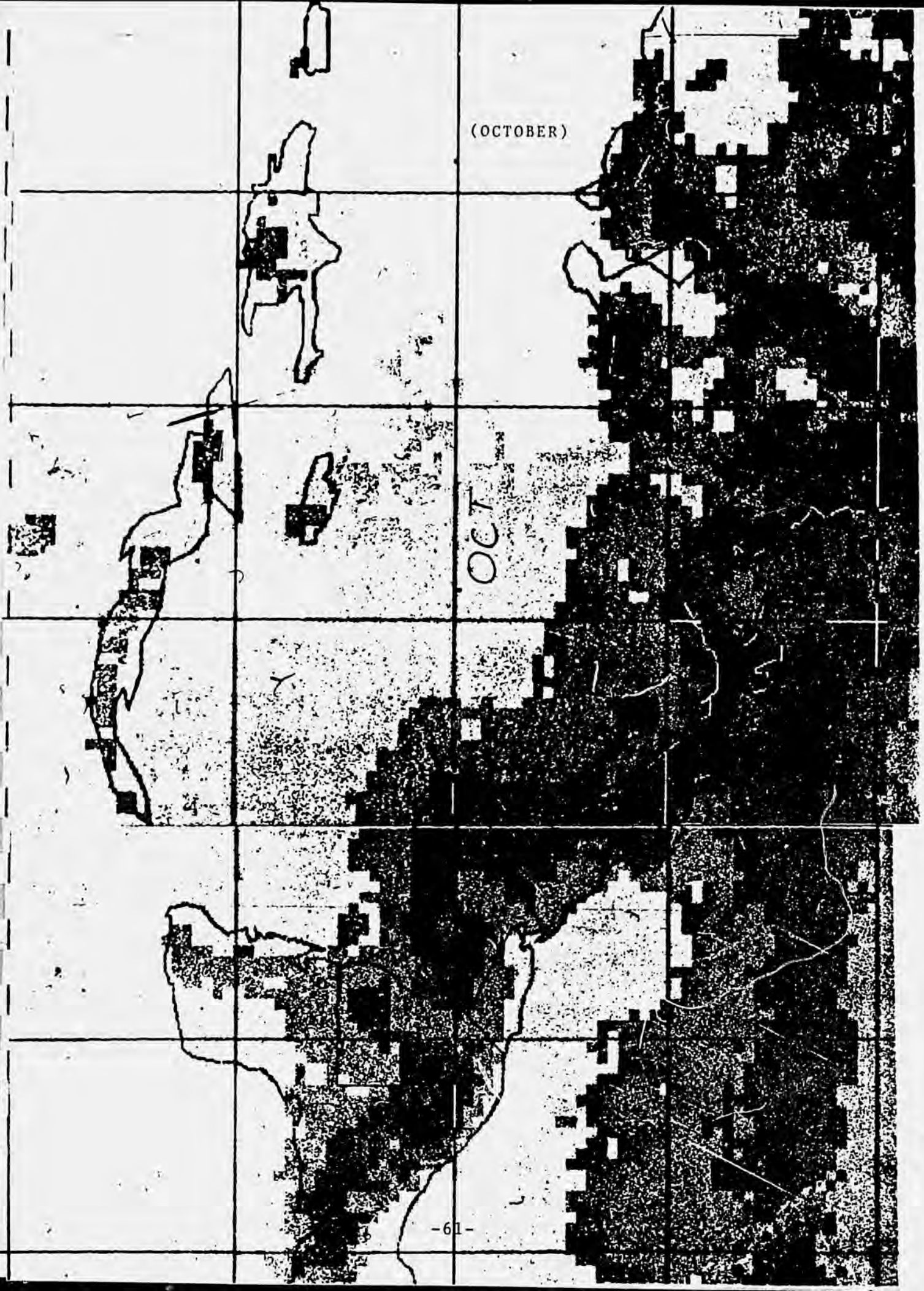
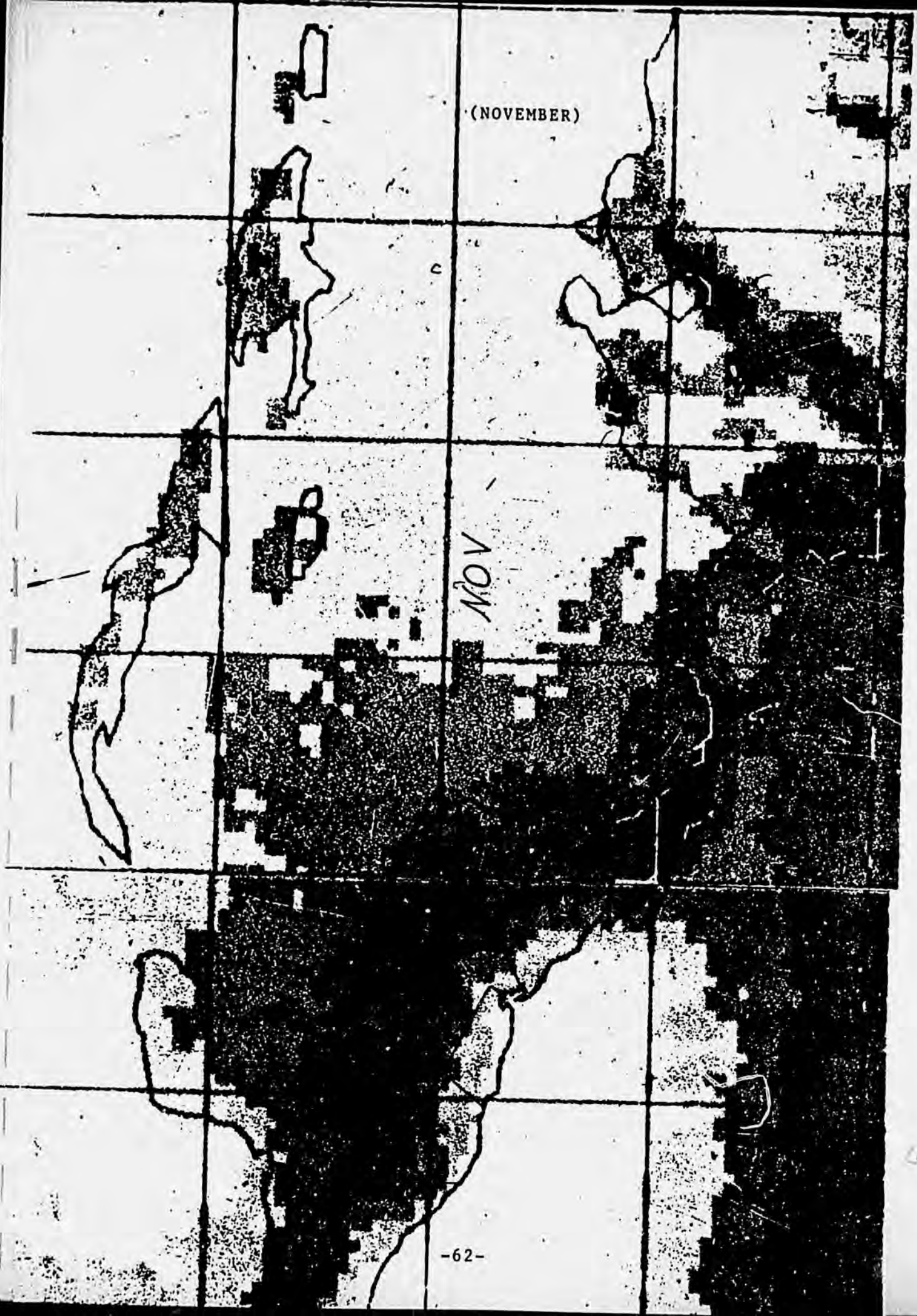
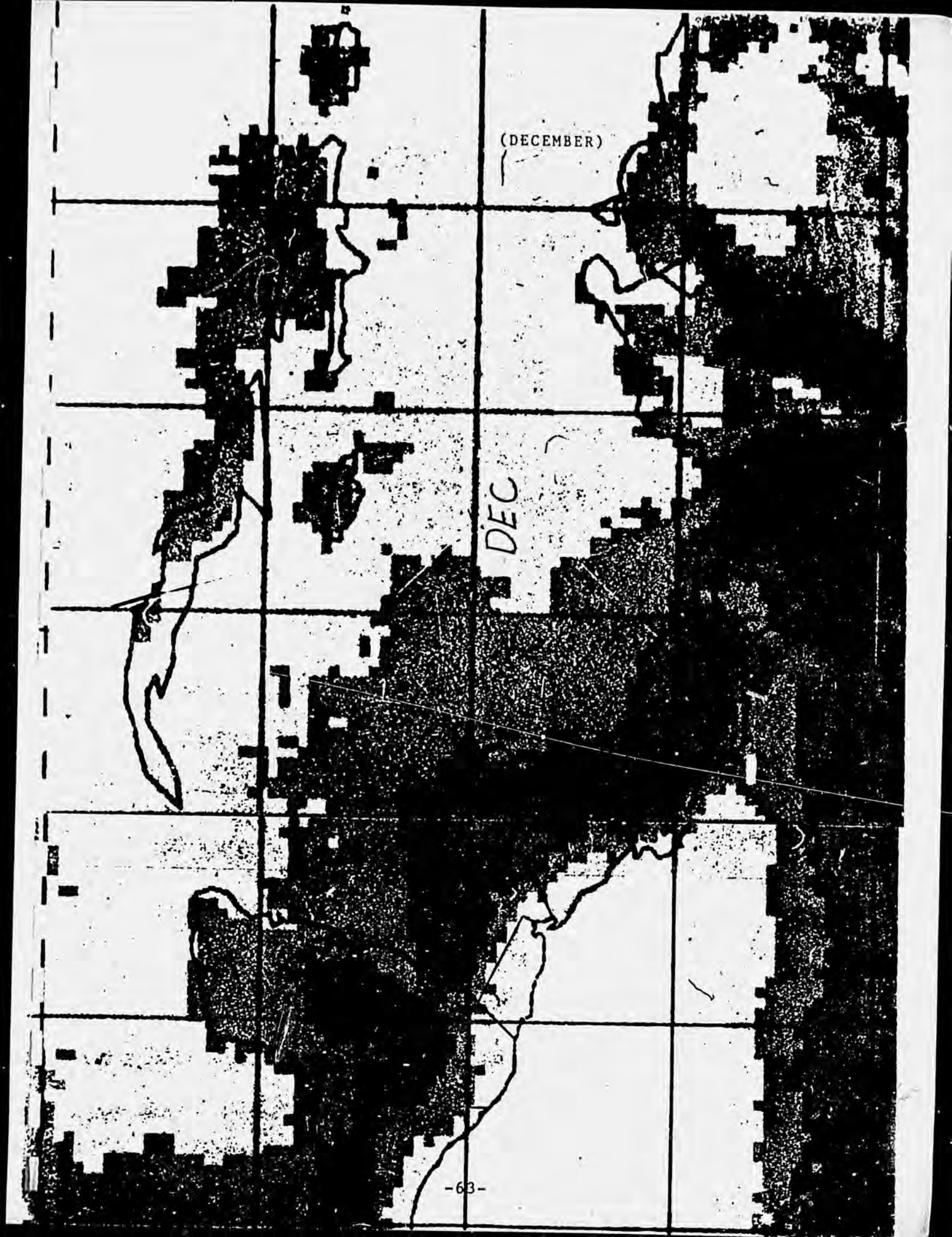

(OCTOBER)
OCT

(NOVEMBER)




(DECEMBER)
DEC

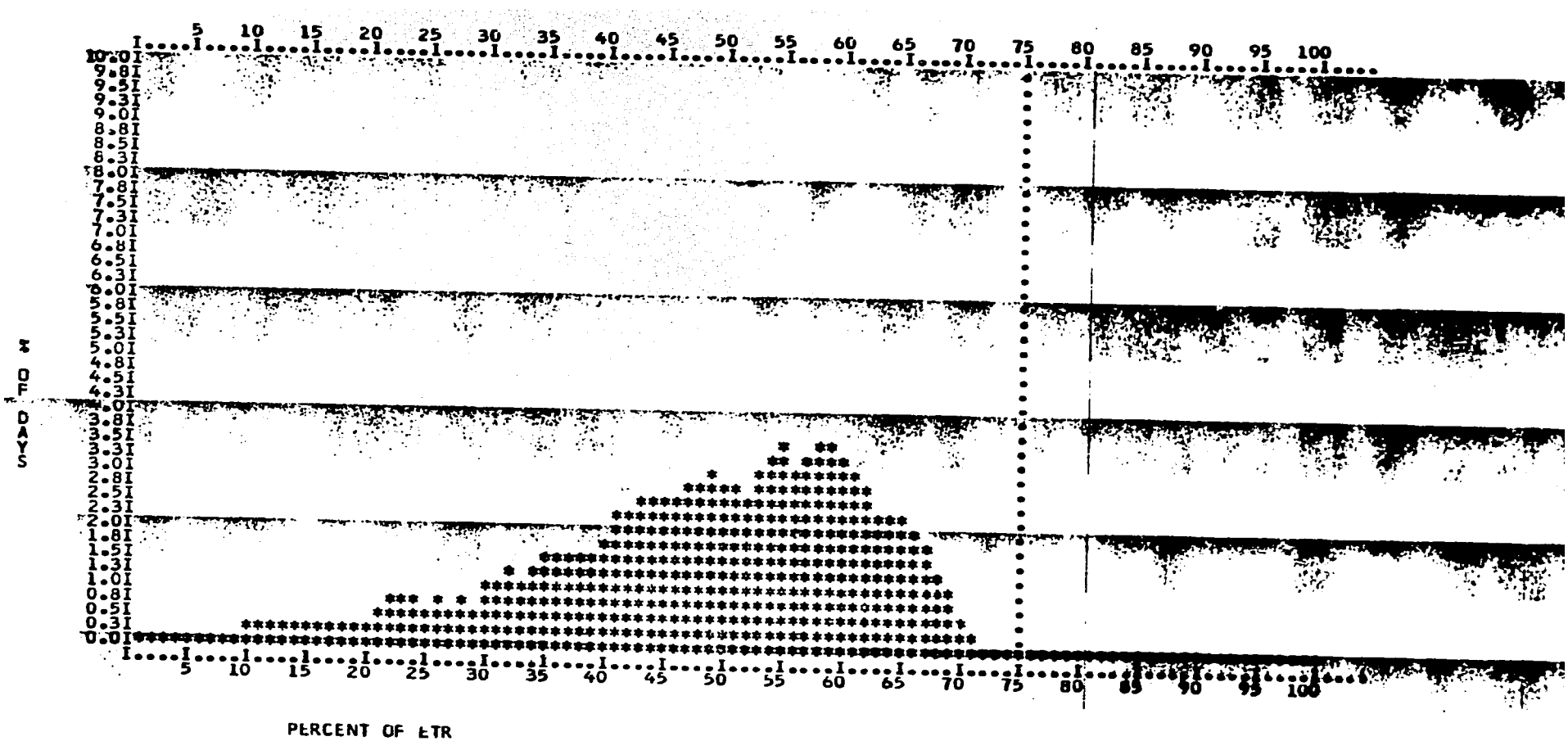
APPENDIX F

COMPARATIVE COMPUTER PRINT-OUTS OF TWO DIFFERENT SOLAR DATA STATIONS

The following two pages are graphical representations of solar data profiles from two different collection stations, one at Balboa, Panama, the other at Taboga, Costa Rica. These profiles were printed by computer from several years of continuous, daily solar radiation raw data.

The daily solar radiation accumulation through two-week periods was checked against the calculated extraterrestrial radiation (ETR), and only the daily %-age exceeding 50% of possible ETR was printed by the computer. From this print-out, in two week increments, the profile was printed to indicate graphically the %-age of days versus the %-age of ETR across the range.

The profile for Balboa, Panama gives a picture of a well maintained station. The shape of the print-out curve is not highly dissimilar from the known ETR curve. This station is maintained by the Smithsonian Institute and is known to be kept in good calibration through regular attention. The other profile is from Taboga, Costa Rica, a remotely located station. The bi-modal, irregular curve of this graph is indicative of changes occurring from time to time through the data period, probably due to drift from calibration, exchange of recording instrument, or other problems due to less than adequate maintenance of the sensor.



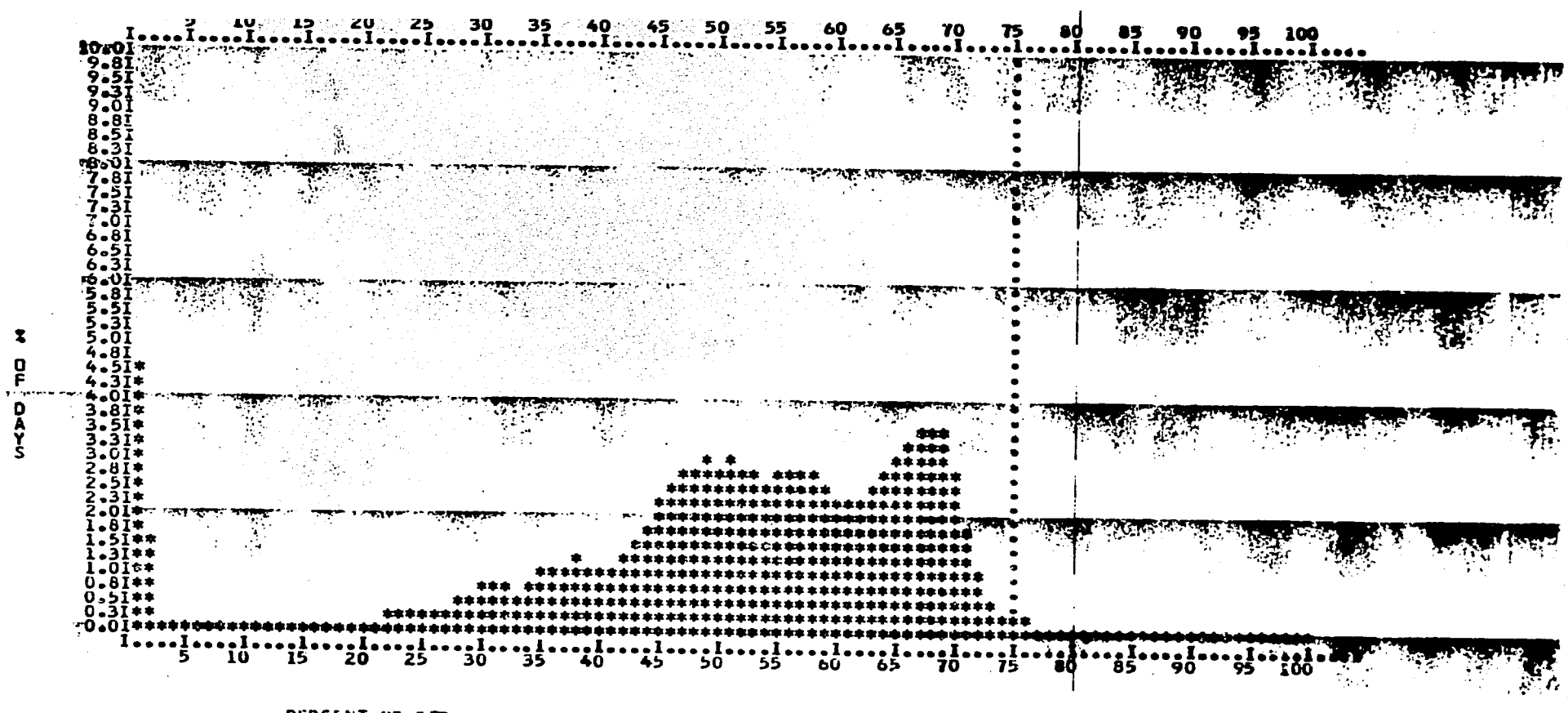
PERCENT OF DAYS VERSUS PERCENT OF ETR (SMOOTHED DATA)

1 BALLOA (SMITHSONIAN) PAN.

LAT: 9.00 LONG: 79.50 ELEV: 10

HISTOGRAM FOR ENTIRE DATA SET

1707 DATA POINTS.



PERCENT OF DAYS VERSUS PERCENT OF ETR (SMOOTHED DATA)

48 TABOGA C.R.

LAT: 10.35 LONG: 85.15 ELEV: 40

HISTOGRAM FOR ENTIRE DATA SET

2169 DATA POINTS.

APPENDIX G

SUPPORTIVE CORRESPONDENCE

SECRETARIA DE ESTADO EN EL DESPACHO
DE
RECURSOS NATURALES
REPUBLICA DE HONDURAS

Tegucigalpa, D.C.
November 16, 1979

Mr. Robert Maushammer
LAC/DR 2252 NS
U.S. Agency for International Development
Washington, D.C. 20523
U.S.A.

Dear Mr. Maushammer:

Lic. Kawas forwarded a copy of his letter to you in Spanish.

In view of the possibility that you may not read Spanish and would like to have an English copy as your action copy I am forwarding a translation of his letter.

Sincerely yours,

George H. Hargreaves

ENG. GEORGE H. HARGREAVES
Asesor Técnico del
Ministerio de Recursos Naturales

Enclosure: Translation
cc: Executive Director, R.H.
cc: Files (2)
GHH*AMAW

SECRETARIA DE ESTADO EN EL DESPACHO
DE
RECURSOS NATURALES
REPUBLICA DE HONDURAS

TRANSLATION

November 14, 1979

Dear Mr. Maushammer:

I am writing in reference to my visit to the offices of AID in Guatemala, where we talked with Eng. Alejandro Sundermann and Eng. José A. Chacón of ROCAP. We discussed the possibility of developing a Solar Radiation Project on the Central American Isthmus.

I would like to indicate that El Comité Regional de Recursos Hidráulicos (CRRH) is an Intergovernmental organism, created by the countries in 1967, for the coordination and development of programs in the field of Water Resources in the region. To date we have colaborated and developed projects with OMM, UNESCO, PIADIC,etc. Various Projects, Courses and Seminars have been executed for the training of personal at different levels. Also we have produced a series of 148 Technical Publications.

On October 15, 1979 we undertook the introductory part of Proyecto de Previsión de Caudales e Inundaciones en el Istmo Centro Americano (Project for Flood Flows and Flooding in the Central American Isthmus). The principal objective is to serve as a Pilot Project for the instalation of a net-work of automatic stations on a chosen river basin in each country and a Hydrological Center that will process information using the mathematical models to estimate flood flows and water levels in storage, etc.

At the same time the Committee in its XIII Ordinary Meeting held in San José, Costa Rica, July 16-20, 1979 decided to start activities within the field of unconventional sources of energy, under a plan that promotes the obtaining of basic information, in this field and its storage and use for development studies.

One of the most important fields is solar radiation, and at the present time very few stations distributed in some countries of the area for this purpose. They have 1 Heliograph and 1 Actinograph and are not well equipped for the study of solar radiation.

Because of this, CRRH has consider convenient to formulate a program

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SECRETARIA DE ESTADO EN EL DESPACHO
DE
RECURSOS NATURALES
REPUBLICA DE HONDURAS

that will have two main parts:

a. Elaboration of a Solar Radiation Atlas, using Satellite Data, for all the Central American Isthmus, using mathematical models, because adequate information does not exist.

b. Installation of a net-work of Solar Radiation Stations in each country so as to have the necessary observed information.

In each country all the Institutions that work in Hydrology and Meteorology are members of CRRH, through Law Decrees, so they will be the Institutions encharged of the Operation and Maintance of these net-works by the respective countries after their instalation.

For the above reasons I am asking for your cooperation so that AID/ROCAP will study the possibility of financing a Project of this type which I believe will be of much benefit to the countries that are members of CRRH.

Sincerely yours,

NABIL KAWAS
Executive Secretary

Mr.
Robert Maushammer
LAC/DR 2252 NS
U.S. Agency for International Development
Washington, D.C. 20523
U.S.A.

cc: Director Ejecutivo de Recursos Hídricos
cc: Files (2)
/AMAW

CABLE: "CORREH"

Comité Regional de Recursos Hidráulicos
APARTADO POSTAL 718
TEL. 32-38-04
TEGUCIGALPA, D. C., HONDURAS, C. A.

S-CRRH/385/79

14 de Noviembre de 1979.

Estimado Señor Maushammer:

Por la presente, tengo el agrado de escribirle referente a mi visita a las Oficinas del AID en Guatemala, donde conversamos con el Ing. Alejandro Sunderman y el Ing. José A. Chacón de la Oficina de ROCAP, donde se discutió la posibilidad de desarrollar un Proyecto sobre Radiación Solar en el Istmo Centroamericano.

Deseo señalar que el Comité Regional de Recursos Hidráulicos (CRRH), es un Organismo Intergubernamental, creado por los países desde 1967, para la coordinación y desarrollo de programas en el campo de los Recursos Hídricos en la región. Al momento han colaborado y desarrollado Proyectos con la OMM, UNESCO, PIAHC, etc. y se han ejecutado varios Proyectos en el área, Cursos y Seminarios para el Entrenamiento de Personal en los distintos niveles, así como la producción de una serie de 148 Publicaciones Técnicas.

El 15 de Octubre del presente año, se inició la etapa preparatoria del Proyecto de Previsión de Caudales e Inundaciones en el Istmo Centroamericano, con el objetivo principal de servir como Proyecto Piloto para la instalación de una red de estaciones automáticas en una cuenca escogida por cada país, y un Centro Hidrológico que procese la información y a través de modelos matemáticos, generar, caudales, niveles de embalse,etc.

Al mismo tiempo el Comité en su XIII Reunión Ordinaria, celebrada en San José de Costa Rica, del 16 al 20 de Julio de 1979, resolvió iniciar actividades dentro del campo de las fuentes no convencionales de energía, bajo un plan que promueve en primera prioridad la obtención de la información básica, en este campo, su procesamiento archivo y utilización para estudios a desarrollar.

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Comité Regional de Recursos Hidráulicos

CABLE: "CORREH"

APARTADO POSTAL 718

TEL. 32-38-04

TEGUCIGALPA, D. C., HONDURAS, C. A.

Uno de los campos más importantes es el de Radiación Solar y al momento, muy pocas estaciones distribuidas en algunos países del área se refieren a ese campo y constan de 1 Heliógrafo y un Actinógrafo, los cuales no son suficientes para el estudio de la Radiación Solar.

Por tal motivo el CRRH, ha creído conveniente la formulación de un programa que consta de 2 partes esenciales:

a.- Elaboración de un Atlas de Radiación Solar, utilizando Datos de Satélite, para todo el Istmo Centroamericano, por medio de modelos matemáticos, ya que no existe la información adecuada al respecto.

b.- La instalación de una Red de Estaciones de Radiación Solar en cada uno de los países, para poder tener la información necesaria observable en este campo.

En cada uno de los países todas las Instituciones que trabajan en Hidrología y Meteorología son Miembros del (CRRH), por Decretos Ley, y por lo tanto serían estas las Instituciones por país encargadas de la Operación y Mantenimiento de estas redes, después de su instalación.

Por tal motivo solicito a Usted su colaboración para interponer sus buenos oficios, para que AID/ROCAP, estudie la posibilidad de financiar un Proyecto de este tipo, el cual a no dudarlo será de mucho beneficio para los países miembros del CRRH.

Esperando su contestación a la presente y poniéndome a sus gratas órdenes, me suscribo.

Atentamente,

ABEL PAZAS
SECRETARIO EJECUTIVO

SECRETARIA EJECUTIVA DEL COMITE REGIONAL DE RECURSOS HIDRAULICOS Tegucigalpa, D.C. Honduras, C.A.

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October 2, 1979

Dr. George Hargroves
Dirección de Recursos Hídricos,
Tegucigalpa, D.C.
Honduras

Dear Dr. Hargroves:

This is in response to your letter of August 8, 1979 to Mr. Donald Fiester of our office, regarding your proposal for a project to determine and map solar radiation for the Central American region.

At the time of Frank Marquez' visit with you, ROCAP was planning to include a solar data collection element in a Fuelwood and Alternative Energy Sources project that was being developed with CATIE and ICAITI. During review in Washington, for financial and administrative reasons, the solar data collection element of the project was deleted. We understand that AID is reconsidering the matter and that a cable will be sent to the USAID offices in Central America soliciting their interest in a possible AID assisted coordinated regional solar data collection system. AID Panama and AID Costa Rica already have approved projects which include some solar data gathering.

The major difference I see in what you propose and what we had originally considered under our project is the accuracy of data to be collected. Your proposal states that errors of 10-15 percent are acceptable for most agricultural uses of solar radiation; Solar America, Inc. recommended that for energy uses a figure of ± 2% was necessary, especially for complex energy systems. I would appreciate any information you might have about data already on hand and the amount of cloud-free coverage of satellite data available for the isthmus.

Since your proposal closely parallels what our Washington offices are considering, I am taking the liberty of forwarding a copy of your letter to Mr. Robert Maushammer who is handling the matter. You might want to contact him directly. His address is: IAC/LR 2252 NE, U.S. Agency for International Development, Washington, D.C. 20523.

Sincerely,

Alejandro Sundermann, P.E.
Chief Engineer

bcc: Robert Maushammer
Penny Farley

SECRETARIA DE ESTADO
EN EL DESPACHO DE
RECURSOS NATURALES

REPUBLICA DE HONDURAS, C. A.

Nota No. CE-07-79

Tegucigalpa, DC.
August 8, 1979

Mr. Don Fiester
Agricultural Officer ROCAP
c/o American Embassy
Guatemala City, Guatemala

Dear Mr. Fiester:

Recently Mr. Frank Marquez of Solar American Corporation stopped in Honduras. He indicated that ROCAP might have some money for regional projects.

We are in the process of developing a proposal for determining incident solar radiation from GOES-2 satellite data. I would like to propose a 5 year project of radiation determination and mapping for the Central American Isthmus. The project should include some training of Central American technicians in the methodology. I estimate that a 5 year project would cost about $150,000 or about $30,000 per year.
Although I recommend the full project it could be started with only the first years financing as after it is started its value would probably bring additional financing.

The Comité Regional de Recursos Hidráulicos of Central America wishes to sponsor this proposed project. A copy of CRRH resolution is forwarded. Also I am forwarding a copy of a brief description of the methodology.

If you are interested, would you consider financing a trip to Guatemala for me so that we could consider this proposed project in greater detail?

Sincerely yours,

DR. GEORGE H. HARGRAVES

GHH:AMAW
cc:files

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PROYECTOS EN COLABORACION CON EL PIADIC

214 (CRRH) Resolución aprobada el 19 de julio de 1979

EL COMITE REGIONAL DE RECURSOS HIDRAULICOS

CONSIDERANDO:

La información presentada por la Secretaría Ejecutiva, relativa a las posibilidades y perspectivas para llevar a cabo un programa en colaboración con el PIADIC;

RESUELVE:

1. Solicitar al PIADIC que explore la posibilidad de realizar un proyecto en colaboración con el CRRH, el cual consta de las actividades siguientes:

   a) Proporcionar dos técnicos para realizar un curso itinerante el el Istmo Centroamericano, en la programación de computadoras para el mejoramiento de los bancos de datos y el uso de la información climatológica en el planeamiento agrícola y desarrollo de los sistemas de cultivos;

   b) Proporcionar uno o más técnicos para realizar un curso itinerante en el Istmo Centroamericano, en el uso de los datos climáticos para el planeamiento y producción agrícolas, incluyendo el uso de la información proporcionada por el satélite GOES para la preparación de mapas regionales de radiación solar incidente;

   c) Proveer asistencia en la elaboración de un proyecto regional de mapas de radiación solar incidente, usando los datos del satélite GOES y en la búsqueda del financiamiento para el

d) Financiar el entrenamiento en el exterior de uno o dos técnicos del Istmo Centroamericano, en el uso de los datos del satélite GOES para el mapeo de la radiación solar incidente, para la elaboración de modelos de precipitaciones convectivas y para otros usos Meteorológicos e Hidrológicos;

2. Encargar a la Secretaría Ejecutiva efectuar las gestiones ante el PIADIC para las actividades anteriores;

3. Encargar a la Secretaría Ejecutiva la elaboración del proyecto, incluyendo el presupuesto respectivo, para su presentación al PIADIC previa aprobación del Comité; y

4. Encargar a la Secretaría Ejecutiva las gestiones ante los organismos correspondientes, para el financiamiento del Proyecto.

SOLAR RADIATION FROM SATELLITE DATA

Solar radiation largely determines the potential growth rates of crops. It is used in the reliable methods for estimating the potential water use of crops or for calculating actual and potential crop evapotranspiration.

In the Central American Isthmus there are few ground-based measurements of solar insolation. Attempts to infer radiation from sunshine hours or the percentage of possible sunshine have met with considerable success. However, the networks of sunshine recorders is too sparse to produce accurate estimates at all locations of interest. The only economical and practical source of high resolution data is meteorological satellites.

The incident visible solar radiation flux that arrives at the top of the atmosphere is depleted by absorption and scattering. The major absorbers are water vapor and aerosols. In the presence of clouds there is a large increase in scattering, some increase in absorption and less incoming radiation at the surface.

Data available from satellites include mean target brightness, cloud amount and cloud brightness. The mean target brightness measures the reflected radiation due to all causes. The cloud amount and brightness yield information on the radiation component scattered by clouds.

Tarpley (1) presents equations for estimating solar radiation. Visible clear brightness of the target is calculated by regression analysis. For this estimations the local solar zenith angle, X, and the azmuth angle between sun and satellite are used. Cloud fraction is determined from the satellite data. Cos X is proportional to extraterrestial radiation. Equations are presented with Cos X as the dominent term and including use of fractional cloud amount, n, mean target brightness, predicted clear brightness, mean cloud brightness and normalized clear brightness.

(1) Tarpley, J.D. "Estimating Incident Solar Radiation at the Surface from Geostationary Satellite Data", National Environmental Satellite Service, NOAA, Washington, D.C., 1979, 22 p plus tables and figures. (Paper submitted to Amer. J. of Applied Meteorology).

An evaluation of satellite estimates of radiation was made by comparing with radiation measured by 22 well standarized pyranometers. The use of two pictures per day at 0900 and 1500 hours local time to make daily estimates resulted in a good correlation with a coefficient of correlation equal to 0.88 and a standard deviation equal to 58.5 Langleys per day. Daily errors of in the order of 10 to 15 percent are acceptable for most agricultural and other uses of solar radiation.

The procedure given by Tarpley provides satisfactory results. The equation can be applied for use in any area or region. However, it seems probable that other procedures may be developed that will give as good or better estimates. From 6 years of daily measurements from Davis California, five day sums were used in a regression analysis. Solar radiation, RS, was calculated from extraterrestial radiation, RA, and percentage of possible sunshine, S., The equation can be written:

$$RS = 0.075\ RA \times S^{1/2} \qquad (1)$$

This procedure predicted 98 percent of the variance for 5-day means. Extraterrestial radiation can be calculated from latitude for any given location. A good correlation between percent of possible sunshine and equations using mean target brightness, cloud amount and cloud brightness can be anticipated.

Although Tarpley presents usable and adequate equations, the procedures are new and it can be anticipated that as more data are processed the methodology will be improved. It is hoped that both improved accuracy and greater simplicity will be possible.

The GOES-2 satellite is stationed above the equator at 75°W longitude. Data coverage is from 25°W to 125°W and from 50°N to 50°S latitude. The data sample or pixel is about 8 Km. at the satellite subpoint. For analysis Tarpley divided the area into targets approximately 50 Km. on a side, each made up of 7 X 6 arrays of 8 Km pixels. The targets were centered at the intersections of 0.5° interval latitude and longitude lines beginning at the area boundaries.

...../.....

Readings are stored and magnetic tapes produced and sold to user agencies. The GOES digital data can be obtained on 9 track 1600 bpi tapes at a cost of $60.00 per tape. The price is reduced for large orders. The satellite data sets can be obtained from:

Mr. J. Emmett Bragg
Environmental Products Group, S 132
NESS, World Weather Building
5200 Auth Road
Camp Springs, Maryland 20233

INCREMENTO DE LA PRODUCCION AGRICOLA EN CENTRO AMERICA UTILIZANDO INFORMACION CLIMATICA

El creciente interés sobre el abastecimiento futuro de alimento y las necesidades urgentes para aumentar la exportación agrícola, han conducido a la formulación de varias propuestas para llevar a cabo un inventario de los recursos climáticos y de suelos de diferentes áreas geográficas. Históricamente alrededor de una tercera parte del incremento de la producción alimenticia proviene de una aplicación de tecnología mejorada en las tierras agrícolas existentes, y dos terceras de incorporar nuevas tierras bajo cultivo. Mucha información adicional es necesaria para tomar decisiones razonables con respecto a cuales tierras y bajo que condiciones se deberán poner bajo cultivo. Probablemente es de mayor importancia, la necesidad de utilizar en mucho más alto grado la información existente que pueda obtenerse.

Un estudio hecho en Honduras por el Consorcio para el Desarrollo Internacional (CID)[1] señala que el sector agrícola debe hacer dos contribuciones para el desarrollo nacional.

(a) Tiene que producir una cantidad adecuada de alimentos y fibra para cumplir con las necesidades domésticas.
(b) Deberá hacer una adecuada contribución a la balanza comercial.

Los cálculos de un análisis macro-económico presentado en el Informe indica que en base al intercambio comercial, hay que regar antes de 1990 un área adicional de 64,000 hectáreas. Tomando en cuenta ambos objetivos, 122,000 hectáreas deberían ponerse bajo riego entre

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1. Van de Wetering, H. y Hargreaves, George H., " Programa de los Recursos Hídricos Propuesto para el Ministerio de Recursos Naturales". Consorcio para el Desarrollo Internacional, Julio 1978. 243 p.

1970 y 1990. Si se pretende un sostenido e capital a rangos aceptables, será requerido más personal calificado y una mayor disponibilidad y uso de la información solicitada.

Los incrementos requeridos en la producción pueden ser realizados mediante una combinación de varios actividades diferentes o tecnologías básicas. Estas incluyen lo siguiente:

(a) Aumento del área de riego
(b) Mejoramiento del control de inundaciones y drenaje
(c) Mejoramiento del proceso de almacenaje y mercadeo a través del mejoramiento del transporte y expansión de la electrificación rural.
(d) Expansión del uso de fertilizantes.
(e) Promoviendo alta tecnología de la agricultura de secano, cuando los suelos y el clima son favorables.
(f) Promoción del uso amplio de leguminosas tropicales para mejorar la producción y fertilidad.

Para asignar prioridades a las varias actividades y a los diferentes tipos de desarrollo, se necesitan más conocimientos con respecto a los suelos, clima y recursos de agua. Se dá aquí un énfasis predominante al clima y a la descripción depropuestas y programas para la mejor recolección y uso de la información.

EVALUACION DE RECURSOS DE LA TIERRA PARA AMERICA TROPICAL

Cochrane[2] propone un estudio de reconocimiento de América Latina. La evaluación de computadora se realizaría vía satélite y por medio de la imagen del radar, además de la información convencional disponible. El procedimiento requiere el mapeo o la clasificación de las áreas que tienen condiciones similares de topografía, suelo, vegetación y clima. Se evalúa el clima por la estimación del balance hídrico utilizando el método descrito por Hargreaves [3].

Los métodos propuestos han sido desarrollados y utilizados en algunos

2. Cochrane, Tom T."Land Resources Evaluation for Tropical America", Centro Internac. de Agricultura Tropical, (CIAT) Cali, Colombia, Personal Communication October 1979, 11 p. 3. Hargreaves, George H., "World Water for Agriculture", Agency for International Development, 1977, 177 p.