

N72-17558

EXAMETNET

Experimental InterAmerican
Meteorological
Rocket
Network

CASE FILE
COPY



THE FIRST FIVE YEARS, 1966-1970

Sponsored by the EXAMETNET Executive Committee
of the participating National Scientific Organizations

ARGENTINA Comisión Nacional de Investigaciones Espaciales

BRAZIL Comissão Nacional de Atividades Espaciais

UNITED STATES National Aeronautics and Space Administration



EXAMETNET: THE FIRST FIVE YEARS, 1966-1970



Scientific and Technical Information Office

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C.

1972

FOREWORD

Meteorological sounding rockets were first utilized in significant numbers in the late 1950's and the coordinated launching of these sounding rockets was essentially confined to the Northern Hemisphere. In the mid-1960's, Argentina, Brazil, and the United States established a cooperative program of coordinated launches to overcome this obvious inequity in our knowledge of the upper atmospheric structure and behavior with regard to the Southern Hemisphere. The purpose of the program was to provide synoptic information of stratospheric and lower mesospheric winds and temperatures up to an altitude of about 60 km in both hemispheres. These data, when combined with those from other observational techniques, would form a base for the study of various meteorological phenomena such as mid- and high-latitude warmings, tropical oscillations, interrelations between different regions of the atmosphere, large scale circulation patterns, and inter-hemispheric relations in the upper atmosphere.

After planning and organizational meetings in 1965, the Experimental Inter-American Meteorological Rocket Network (EXAMETNET) began launching meteorological sounding rockets in January 1966 and has continued on a coordinated schedule. Each year representatives of each country convene to review the activities of the past year and plan for the coming year. At the last meeting in Rio de Janeiro, Brazil, in October 1970, it was felt that the completion of five years of operation was a milestone at which it would be appropriate to assess the efforts of a half decade and that the assessment might assist in the formation of future plans.

This document is a report of this assessment. It describes the formation of the network, international and national relations, technology, data procedures and techniques, and their improvements and the research that has been accomplished as a result of this international cooperative effort.

While this is a self-assessment and an internally prepared document, there was a deliberate effort to maintain objectivity as the various aspects were reviewed. It is hoped that this

goal was achieved and that this report may be of some interest and utility to other organizations and groups engaged in or planning meteorological sounding rocket observations and the coordination of such activities with others to enhance the scientific utility of the information.

Conrado Estol
Comisión Nacional de
Investigaciones Espaciales,
Argentina

Fernando de Mendonca
Comissão Nacional de
Atividades Espaciais,
Brazil

Morris Tepper
National Aeronautics and
Space Administration
United States

CONTENTS

FOREWORD	iii
INTRODUCTION	1
FORMATION OF NETWORK	3
INTERNATIONAL AND NATIONAL RELATIONS	9
TECHNOLOGY	12
DATA PROCEDURES AND TECHNIQUES	18
RESEARCH RESULTS	21
SUMMARY	43
RECOMMENDATIONS	47
REFERENCES	49
SUPPLEMENTAL REFERENCES	53

INTRODUCTION

The meteorological rocket, first utilized in significant numbers in the late 1950's, is now recognized as a standard means of gathering atmospheric data above the upper limit of the balloon-borne radiosonde (about 30 km). Indeed, much valuable information has become available from rocketsonde observations for use in a variety of research studies, as well as for the derivation of high-altitude climatological and model atmospheres. Typical of the research studies are those concerned with winter-time stratospheric warmings, which predominantly occur over the middle and polar latitudes. No complete explanations have yet emerged with regard to the cause and the full effect of this phenomenon. Also of prime importance are studies concerning the less dramatic quasi-biennial and semi-annual oscillations at low latitudes.

Once the explanations for these phenomena are forthcoming, more study will be required to determine the interactions between warmings and tropical oscillations, as well as in defining the coupling mechanism between various layers of the troposphere and stratosphere. This general problem area has long interested meteorologists, since some feel it may be possible to gain insight into tropospheric conditions, especially large-scale relatively long-range changes, from close inspection of stratospheric conditions and changes.

Until the middle 1960's, rawinsonde and rocketsonde observations provided only a limited amount of high-altitude data and these were concentrated mainly in the Northern Hemisphere. Most of the rocketsonde observations came from the cooperative organization of launching sites called the Meteorological Rocket Network (MRN). Although much was being learned about the Northern Hemisphere stratosphere, some researchers felt that the full meteorological significance of its behavior would also require Southern Hemisphere data. Before this time the most popular assumption was to consider the Southern Hemisphere stratospheric circulation a mirror image of that of the Northern Hemisphere.

Clear evidence of differences between the hemispheres began to emerge after analysis of stratospheric rawinsonde data in the Southern Hemisphere became a reality during the International Years of the Quiet Sun (IQSY), 1964-1965. Hemispheric dissimilarities in circulation patterns were most apparent over polar regions during the winter season, but differences could also be perceived at the lower latitudes.

There was, therefore, ample motivation for acquiring more meteorological information on the stratosphere in the Southern Hemisphere. Cooperative scientific efforts utilizing observational data extending to the highest possible altitude could be initiated to gain knowledge of the hemispheric circulation in the stratosphere and, consequently, to determine similarities and differences between the two hemispheres.

Any observational program involving rockets must be limited in scope. The planners of the Experimental Inter-American Meteorological Rocket Network (EXAMETNET) representing the governments of Argentina, Brazil and the United States, fully realizing the limitations, decided that a meridional-type network would provide valuable information for many types of research. Thus, the original EXAMETNET of three rocketsonde stations in the Americas between 40°N and 40°S was formed. The principle objective of the network was to provide information on stratospheric temperature and wind up to about 60 km, so that comparisons could be made of the measured parameters in both hemispheres and the tropics and the results related to the structure and dynamics of the upper atmosphere. The present sites are Mar Chiquita, Argentina (37.8°S), Natal, Brazil (5.9°S) and Wallops Island, Virginia (37.8°N).

Because of the limited number of launch sites, EXAMETNET cannot provide the large volume of observations needed spatially to delineate the high-level circulation. It is, therefore, logical that network data must be combined with other observations in order to carry out many studies. The network was formed with this point in mind. Additionally, it is extremely important that a high degree of cooperation, on a national level as well as international, be maintained, especially in terms of coordination of launch schedules between network and other stations. This philosophy of cooperation takes full account of the number of observations available from the world-wide rawinsonde network as well as from other rocket stations, and more recently, thermodynamic data from the satellite-borne atmospheric sounding instrumentation.

FORMATION OF NETWORK

A. Organization

Establishment of the EXAMETNET resulted from a suggestion made by Argentina in 1965 to set up, on an experimental basis, a number of launch sites in South America with the capability of growing into a coordinated network of launching facilities in the Western Hemisphere extending from the Arctic to the Antarctic [Ref. 1]. To initiate this research network, Memoranda of Understanding for cooperative projects were concluded by the Argentine and Brazilian space agencies with the U.S. space agency. These agencies are: the Comisión Nacional de Investigaciones Espaciales (CNIE-Argentina), the Comissão Nacional de Atividades Espaciais (CNAE-Brazil), and the National Aeronautics and Space Administration (NASA-United States). The memoranda established project responsibility of each country.

In August 1965, a meeting took place at Wallops Island, Virginia, U.S.A., bringing together representatives from various countries interested in participating in the EXAMETNET. Views were exchanged on the overall objectives and conduct of the network. To achieve success in all phases of this experimental program, each participating country designated personnel to be responsible for the technical and scientific aspects; namely, a Project Manager to assure project implementation and coordination, a Scientific Coordinator to review the data and provide for the analysis, and an Experimenter to conduct research with the data.

In addition, an organization was established within which these designated personnel can carry out their assigned functions and responsibilities. The basic organization (Fig. 1) consists of an EXAMETNET Executive Committee (EEC) for providing guidance and advice. This Committee is served by two working groups: the Technical Working Group (TWG) coordinates and implements the experimental program and the Scientific Working Group (SWG) provides the scientific plans, recommendations, launch schedules and data procedures.

The Executive Committee, consisting of a representative from each national participating organization, has the overall responsibility for the implementation of the program. It provides guidance and advice to the Technical and Scientific Working Groups on its own initiative or when consulted by those groups. It approves plans and recommendations of the Scientific and Technical Working Groups for launch schedules for synoptic observations and commits its individual national organizations to this support.

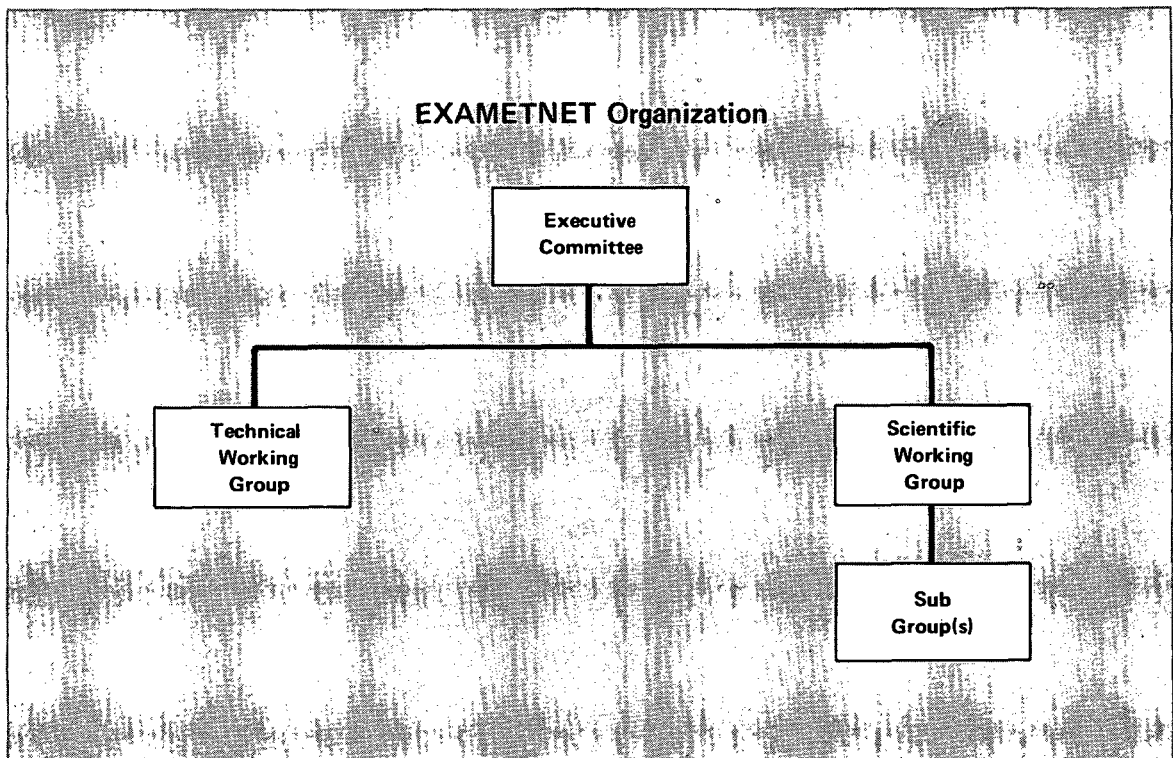


Figure 1. — Basic EXAMETNET organization.

The Technical Working Group provides technical recommendations and plans to the national scientific organizations participating in the EXAMETNET. Under the direction of the Executive Committee, the TWG plans, coordinates, reviews and implements facility and operational requirements necessary for carrying out the established scientific needs of the network.

The Scientific Working Group provides the scientific recommendations and plans to the national scientific organizations participating in the EXAMETNET. Under the direction of the Executive Committee the SWG determines and reviews requirements, network schedules, data dissemination, exchange, and utilization, and recommends scientific analysis and research areas associated with EXAMETNET.

Implementation of EXAMETNET has involved the major areas of observational scheduling (Fig. 2), facilities and equipment preparation, training, launch site preparation, and finally the logistics and operation of the network (Fig. 3), including data processing. Initial operations began in early 1966.

The systems and facilities used by the EXAMETNET participants (Fig. 4) are generally defined by the Memoranda of Understanding between each country and the United States. Argentina and Brazil provided the range facilities, within their respective countries, including launcher foundations, blockhouses, support buildings, utilities, safety devices, etc., and the personnel for conducting the network launches. The United States provided the procurement, construction, rehabilitation and modification of meteorological rocket training and data acquisition systems on loan to or for training of.

B. Criteria for Membership

Agencies from other countries may be considered for regular membership in EXAMETNET provided the following primary criteria are met:

- (1) The proposed member agency should have the sponsorship of, or be a part of an appropriate civilian scientific central governmental agency (or governmental designated agency) within its home country.
- (2) The proposed member agency must have a demonstrated scientific and technical capability as determined by the EXAMETNET Executive Committee (EEC). The details of this requirement can be made known to prospective member agencies during the exchange of correspondence with the EEC.

No. of rockets	Jan												Feb												Mar												Apr												May												Jun												Jul												Aug												Sep												Oct												Nov												Dec												No. of remaining rockets	Percentage of remaining rockets																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															</											

Flexible matrix launching schedule

Figure 2. —Suggested launching schedule for EXAMETNET stations based on number of available rocketsondes for yearly use.

Estimated implementation schedule for planned meteorological rocket facility

Task	Number of months required to complete									
	1	2	3	4	5	6	7	8	9	10
1. Radar systems procurement, rehabilitation, and modification	→	→	→	→						
2. Meteorological ground support systems procurement	→	→	→	→						
3. Launcher construction	→	→								
4. Instrumented and training rocket procurement	→	→	→	→	→	→				
5. Classroom training				→	→	→				
6. Practical training						→	→			
7. Preparation of facility for shipment							→			
8. Shipment								→		
9. Site activation									→	

Figure 3. —Time schedule in months to activate new rocket launch facilities.

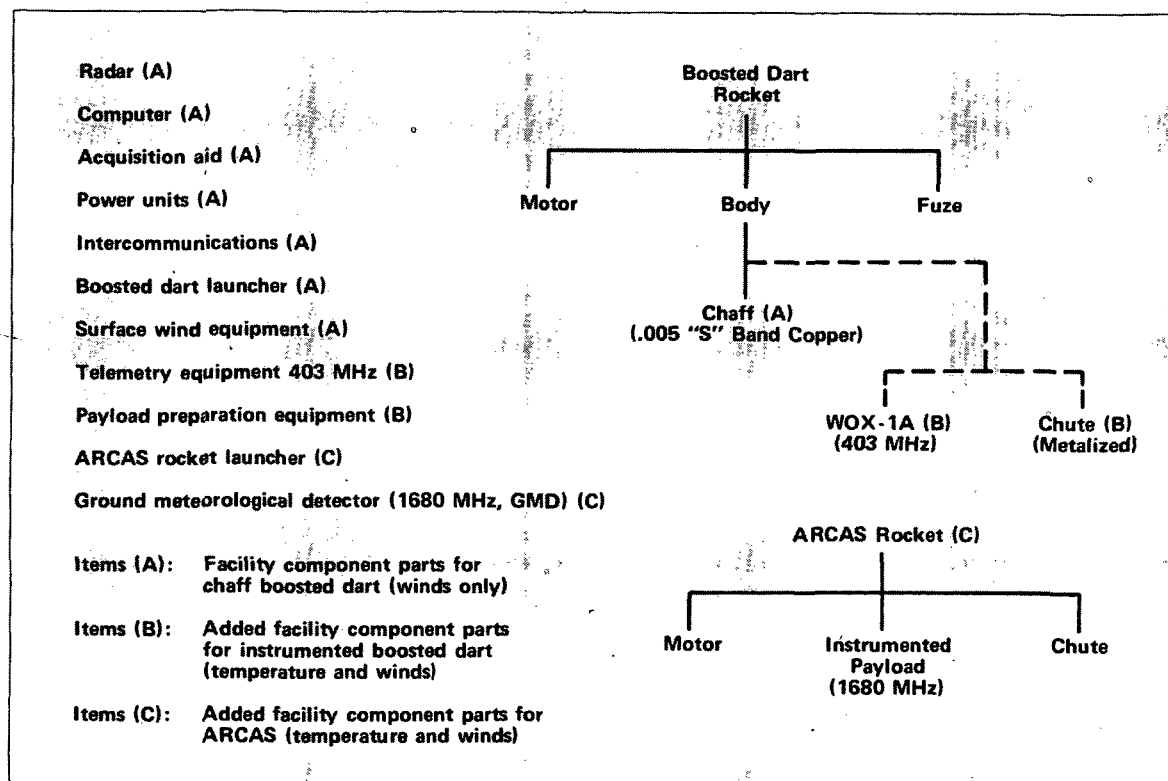


Figure 4. —Equipment used at EXAMETNET launch sites.

- (3) The proposed member agency should be from the Americas, or have facilities located in the Americas.

However, upon meeting criteria (1) and (2), a country could be accepted into the network as an Adjunct Member.¹ This Adjunct Member could participate in EXAMETNET activities such as: coordination of rocket launching schedules, exchange of data in accepted format and other activities. Adjunct Members participate in the activities of the Scientific Working Group and the Technical Working Group at the Annual EXAMETNET Meetings.

At the 6th Annual Meeting held in Rio de Janeiro, Brazil, October 1970, Spain was affirmed by the EEC to become the first Adjunct Member of EXAMETNET. This was a natural consequence of several years of cooperation between Spain and regular EXAMETNET members. For example, a cooperative program of small meteorological rocket launchings by Spain (Comisión Nacional de Investigaciones de Espacio, CONIE) was agreed upon via a Memorandum of Understanding with the United States (NASA) in 1966. EXAMETNET implementation procedures were utilized for providing the rocket tracking and data acquisition systems on loan to and for training of the Spanish team. Spain provided the range facilities, including launcher foundations, blockhouses, 403 MHz telemetry, equipment, support buildings, utilities, safety devices, etc., and the personnel for conducting their launches.

¹The concept and criteria for Adjunct Membership were established during the 5th Annual EXAMETNET Meeting at Mar del Plata, Argentina in 1969.

INTERNATIONAL AND NATIONAL RELATIONS

A. International

While EXAMETNET is a regional international endeavor with its activities generally confined to the Americas, it has become part of the world-wide community with its relations and activities spreading outside the Western Hemisphere.

The EXAMETNET participation in the international community has had a number of aspects. One was in the establishment of an international format for reporting data from meteorological sounding rocket launchings. The Committee on Space Research (COSPAR) recognized the need for a common standard data format and formed an ad hoc working group for its development. The EXAMETNET representatives were part of this ad hoc working group which incorporated many of the features and procedures of the previously adopted EXAMETNET format. Subsequently, the World Meteorological Organization (WMO) adopted the format. The World Data Center-A (WDC-A) was asked to issue instructions for preparing the format and requested that all countries adhere to them.

EXAMETNET, using this standard international format, now submits data to World Data Center-A for inclusion in the publication of meteorological sounding data along with those of the other organizations and countries for use by the scientific community.

The EXAMETNET participants are members of Panel C (Meteorological Rocket Observations and Networks) of COSPAR Working Group 6 so that network activities are a part of this international group's deliberations. At the COSPAR Meeting XIII in Leningrad, USSR, during May 1970, Panel C stressed the very considerable advantage derived from coordinated soundings and urged every possible effort be made to secure such coordination, especially in neighboring regions. Coordinated launches have always been a basic premise in EXAMETNET operations.

The EXAMETNET sites, at present, form a meridional chain or network of stations. At the XIII Meeting of COSPAR, the USSR discussed a proposal that two meridional chains be organized, one in the Eastern Hemisphere and one in the Western and that EXAMETNET might serve as the basis for the Western Hemisphere meridional network. The data from these two networks would be exchanged for studies of the stratospheric circulation, the semi-annual, annual, and biennial oscillations in the atmosphere and related atmospheric research.

The WMO has recognized the increased use of sounding rockets, the different types launched, and the need to determine the comparability of the data from these different systems in order to enhance the scientific utility of measurements. To fulfill the need for comparability, the WMO is organizing a program of intercomparison of rocketsondes at the Indian range at Thumba during 1972. The EXAMETNET members are considering participation in this program, although several intercomparison, reliability, and repeatability of measurement tests have already been accomplished. These include comparisons of the Arcasonde system with two types of Boosted-Dart systems (i.e., WOX-1A and the PWN-8B), as well as individual reliability and repeatability tests of the three systems.

EXAMETNET data are disseminated to over 200 recipients in the international scientific community. In addition, member countries have responded to requests for special launches and for compilation of their sounding rocket data. For example, the organization honored a request from India for launches from as many EXAMETNET sites as possible in coordination with Indian launches scheduled for certain days in March 1970. Also for use in upper atmosphere research, EXAMETNET provides data from its network to the Free University of Berlin.

B. National

(1) Argentina

The EXAMETNET program in Argentina is under the responsibility of CNIE. The evaluation of the data as well as that of the scientific correlations and results is performed by the National Meteorological Service (Servicio Meteorológico Nacional), and the operations are carried out by Argentine Air Force personnel. In addition to submitting data to WDC-A, the processed data are made available to universities and scientific organizations.

(2) Brazil

CNAE is the national agency responsible for the Brazilian participation in EXAMETNET. A portion of the operations is executed by the Grupo Executivo de Trabalhos e Estudos de Projetos Espaciais (GETEPE) of the Ministry of Aeronautics for CNAE under an agreement between these organizations. Other agencies make use of the data and are kept informed of the plans. Among those are the Meteorological Office of the Ministry of Agriculture and the Meteorology Laboratory of the Aeronautics Technical Center. Contact has also been established with the WMO sponsored meteorological project in northeastern Brazil.

(3) United States

While NASA is the national agency directly charged with fulfilling the United States commitment to the EXAMETNET Program, other national organizations are directly and indirectly involved. At NASA request, the Upper Air Branch, National Meteorological Center, National Oceanic and Atmospheric Administration (formerly the Environmental Science Services Administration) accepted the function of the U. S. Experimenter to carry out research with the EXAMETNET measurements and other related data.

Since the coordination of meteorological rocket soundings and the enhancement of the utility of the data is one of the goals of EXAMETNET, it was appropriate to maintain contact with the activities of the cooperative Meteorological Rocket Network. This is accomplished through the NASA membership in an organization which has the function of reviewing the total plans of the U. S. Government agencies for meteorological research and services. This is the Office of the Federal Coordinator for Meteorological Services and Research (OFCM). OFCM is divided into a number of committees and groups staffed mainly by members of various government agencies. Meteorological sounding rocket activities are assigned to the Scientific Advisory Group (SAG) of the Interagency Committee for Applied Meteorological Research (ICAMR). EXAMETNET is represented through the NASA member on SAG. The SAG, which reports to ICAMR, is kept informed of the EXAMETNET plans and accomplishments and reviews how these plans merge with those of the other agencies.

Additionally, the Meteorological Working Group of the Inter-Range Instrumentation Group (IRIG/MWG) initiates and coordinates the cooperative activities of the various national ranges. It is through this medium that the IRIG/MWG and national ranges are kept informed of the improvements, developments, procedures and accomplishments of EXAMETNET.

TECHNOLOGY

A. Introduction

The following general requirements help to insure that EXAMETNET data meet the highest possible standards called for by the research community: (1) the use of uniform equipment and procedures at the various stations, (2) the use of qualified flight systems to meet launch schedules, (3) the continual development of reliable communications so that data are distributed in the most efficient manner, and (4) the maintenance of a high level of proficiency of operations personnel.

B. Training

The participants of EXAMETNET carried out a program of technical and operational training before network operations began (Fig. 5). Included were the areas of radar operation and maintenance, rocket preparation and launching, payload preparation, data reduction, and telemetry equipment maintenance. In addition to insuring the development of uniform procedures throughout EXAMETNET, the training provided the basis for each participating agency to conduct such programs of their own, to maintain proficiency in the event of personnel changes and for future growth.

C. Developments and Improvements

Shortly after the formation of the network, both Argentina and Brazil integrated the Arcas meteorological rocket (Fig. 6) into their facilities. Recently, Argentina has added the Space Data Corporation Datasonde system (Fig. 7) to its inventory. Brazil also plans procurement and initial use of this system during the late 1970 - early 1971 period. Consistent with the concept of cooperation between EXAMETNET members, Argentina will provide assistance to Brazil in familiarizing personnel with this new system.

Spain has included in its inventory the SKUA meteorological rocket system developed by the United Kingdom [Ref. 2]. This system, which provides temperature data as well as wind data, is used in addition to a number of chaff rockets.

Development of new systems as well as reliability testing and modification of operational rockets has been carried out by member countries. Pertinent results include:

Training phase ➤	Classroom								Practical							
Period ➤	Week number								Week number							
Elements	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 – MPS-19 radar and OA-626 computer systems 4 radar technicians																
2 – Meteorological payload and ground equipment theory, maintenance, and operation 1 meteorological electronics technician																
3 – Ground safety, vehicle preparation, and launch techniques 1 electronics and/or VP&L technician, plus 1 technician to be trained in element 2																
4 – Meteorological rocket and associated data reduction, coding, packaging, etc. 1 meteorologist																
5 – Range operations and flight safety 1 meteorologist (same as in element 4)																
6 – Total facility integration and final set up All trainees																
7 – Practical training in all above areas, including the launching, tracking, and data handling of chaff and instrumented rockets All trainees																

Figure 5.—General training schedule for EXAMETNET.

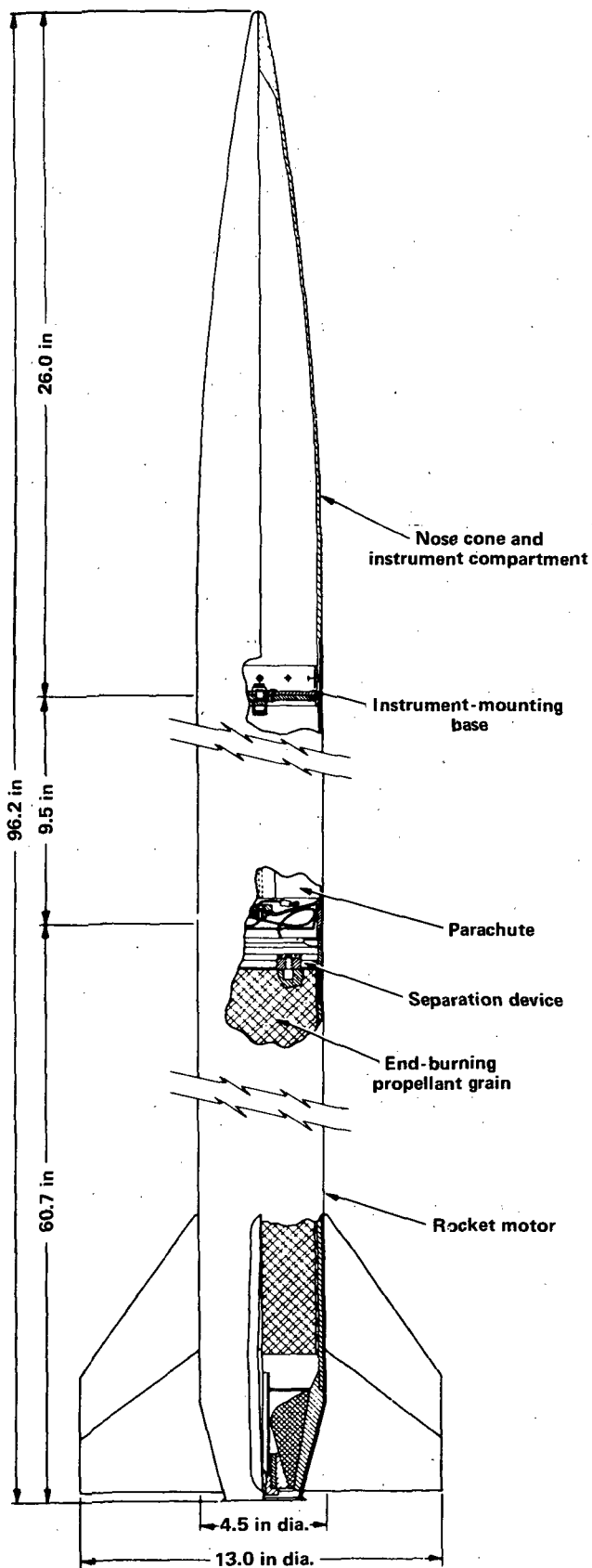


Figure 6. —Arcas rocket.

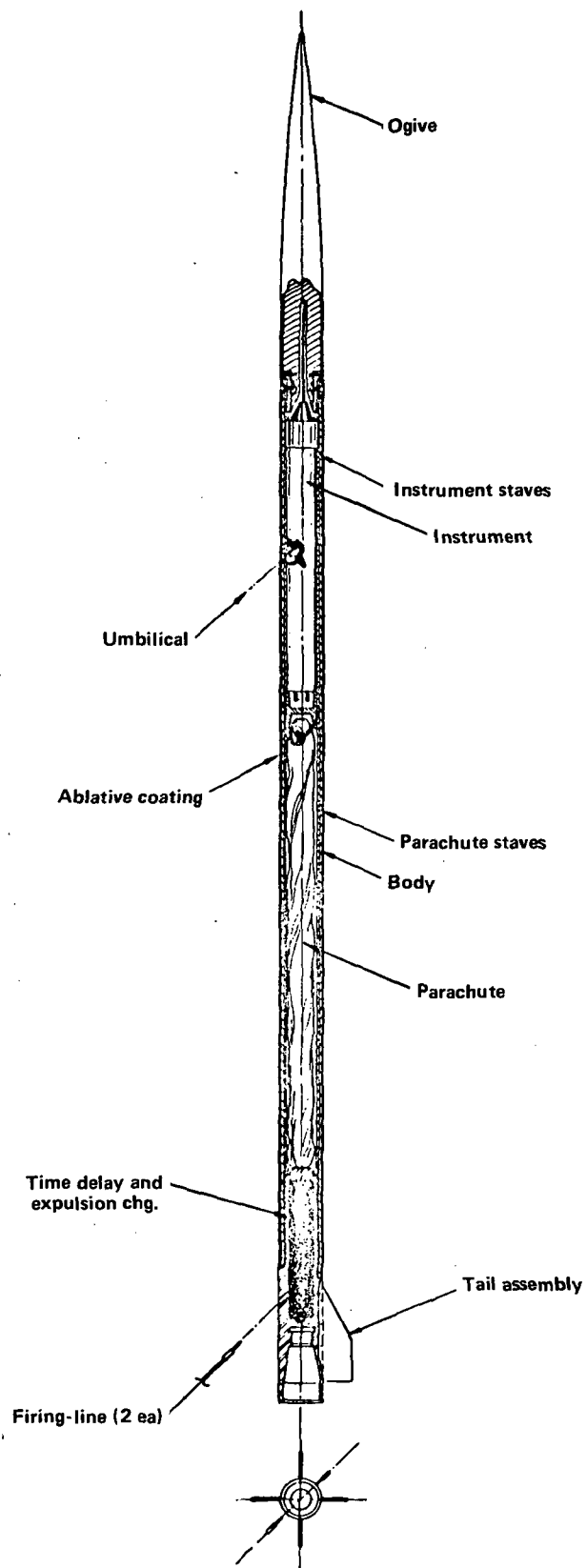


Figure 7. —Datasonde system (dart only).

(1) Argentina

At the request of CNIE, several years ago, IIAE (Instituto de Investigación Aeronáutica y Espacial) of Argentina started designing a meteorological rocket system. The result of this effort is the DIM (Dardo de Investigación Meteorológica) which is a boosted dart system equipped with a chaff payload. Several operational launchings have already been carried out from Mar Chiquita and it is expected that the system will be officially put into operation in 1971.

(2) Brazil

At the request of GETEPE of the Ministry of Aeronautics, a new meteorological sounding rocket system is being developed in Brazil by private companies specifically to conform to EXAMETNET requirements. This system is called the SONDA-1. The rocket motor has already been developed and work on the payload is continuing. The entire system is expected to be ready for testing during 1971.

Some of the modifications mentioned in the U. S. section (see next section) have also been implemented at the Natal range, namely those contained in items b, c, and d.

(3) United States

In the United States, availability and reliability of performance of various flight systems, such as the WOX-1A, Arcasonde, and SDC Datasonde, are constantly monitored. In addition, as new systems are developed they are tested and studied to determine their usefulness in terms of the EXAMETNET objectives. In particular, the Datasonde system was found to be an effective and relatively inexpensive tool for EXAMETNET. It has replaced the Arcasonde for many operations.

Other improvements have been made to ground and flight equipment. Some of these are:

- (a) Addition of improved Boosted-dart motor to the flight hardware.
- (b) Changing of the 403-MHz telemetry recorder speed from 1/2 inch per minute to 5 inches per minute to improve the resolution of the analog data.
- (c) Addition of a helical antenna to the 403-MHz receiving system to improve the received signal.
- (d) Addition of an AGC recorder to the mobile MPS-19 radars to monitor radar signal strength.
- (e) Addition of digital computer methods to the data reduction techniques.

D. Tests

Numerous tests and comparisons have been conducted to determine the reliability of various rocket systems. Included were:

- (1) A determination of the WOX-1A system's reliability for routine utilization. Results were disappointing as only 22 percent of the systems tested by EXAMETNET provided temperature.
- (2) Comparisons of Datasonde payloads to determine their repeatability [Ref. 3], as well as the quality of the thermistors and thermistor mounts [Ref. 4]. Results showed an average root-mean-square temperature difference of about 1°C for 5 pairs. The importance of quality control for each individual instrument was highlighted as one pair, containing an instrument with a cracked glass thermistor coating, exhibited an RMS difference of 2.8°C.
- (3) Comparisons of data gathered by meteorological rockets with temperature and geopotential height information derived from satellites [Ref. 5]. These comparisons have just been started, and it is hoped that much information can eventually be gained regarding the accuracy of rocketsondes as well as the utility of satellite data at stratospheric levels.
- (4) Determination of quality control techniques for application to rocket wind [Ref. 6] and temperature data. Real-time quality control methods are feasible and worthwhile (for example, through radar plot-board monitoring of fall rates just after parachute ejection) and through their use, faulty hardware or erratic sensor behavior can be distinguished. These methods have been established by determining realistic limits for fall rates, as well as the altitude of first usable data after ejection. Rocketsonde temperature measurements can also be evaluated by noting rocketsonde-radio-sonde temperature differences in the region of data overlap.

DATA PROCEDURES AND TECHNIQUES

The value of the EXAMETNET data is highly dependent on the success and efficiency of launch site operations as well as the rapid dissemination of the observational information in a suitable format. With regard to launch site operations, it was recognized that uniform procedures had to be established before network operations began. Thus, standardized data reduction methods were developed, resulting in compatible data presentation from all stations. Standardization is extremely important in reduction of rocketsonde data since it is possible to make many subjective decisions in deriving data from the various instruments tracking any given flight system.

A manual of the EXAMETNET data reduction procedures has been published and this technical report is continually updated by the network participants as necessary [Ref. 7]. It should be noted that uniform procedures have not been developed for all other non-network launch sites. Quite possibly these varied reduction procedures could inject a significant bias in the final data presentations.

Additionally, a centralized data checking technique was developed at Wallops Station where network observations are examined for accuracy. The information is then processed by electronic computer and placed on magnetic tapes which are then submitted to WDC-A for international distribution.

Also developed within the EXAMETNET was a new technique for wind determination from the radar information. The procedure, though simple, yields a wind measurement at every whole kilometer of height, providing a definite advantage for climatological calculations. Additionally a new smoothing technique for the wind data has yielded more consistent results than the method formerly used [Ref. 8].

At the inception of the network, it was recognized that the rocketsonde data reduction procedures, as well as the format for data publication used at that time, did not completely satisfy the needs of the scientific community. To correct obvious deficiencies, the EXAMETNET revised the existing data publication format and the revised format was used for EXAMETNET annual reports. Although this new format allowed the presentation of data in a form which provided much information to the user, a less desirable result was the addition of a new data format considerably different from that used for the monthly publications. Two different formats were impractical since World Data Center-A was to assume the responsibility of publishing all rocket observations on a monthly basis. This problem stimulated requests for a common rocketsonde data format which was mentioned earlier. The resulting format is indicated in Fig. 8. While this new data presentation

SOUNDING CONSTANT PRESSURE LEVELS (HGT IN GEOPOTENTIAL DECATRS)

POLAR COMPONENT									
DEG	MPS	N-S	E-W	MPS	DEGC	MB	G M ⁻³	MPS	A B
05110	071	000	071	-034		5.000-1	5.511-1	010	

05413	271	071	-002	071	-020	4,000-1	3,511-1	318
04992	263	074	009	073	-015	7,000-1	9,434-1	322
04724	261	063	011	063	-018	1,000+0	1,366+0	320

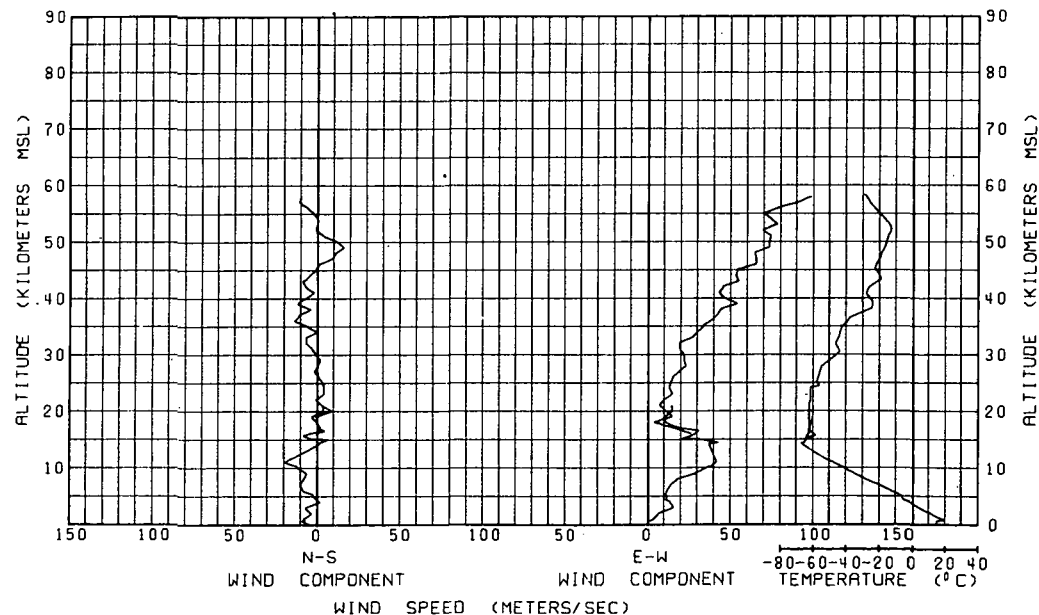
[illegible]

Figure 8. — Example of World Data Center-A high-altitude data format.

has been in publication only a short time, response from the scientific community indicates that the value of the rocketsonde data publications has been considerably enhanced.

RESEARCH RESULTS

A. Introduction

It has been shown clearly within the last decade that the stratospheric layer is one in which dramatic meteorological changes can occur, and there is evidence that some of the changes may be linked to the tropospheric circulation. These fundamental findings, coupled with recently derived requirements for meteorological support of supersonic transport and space shuttle operations, will demand a comprehensive knowledge of the stratosphere (15 to 55 km) and perhaps even the mesosphere (55 to 80 km). This knowledge would include, among countless other items: (1) the behavior of the circulation regimes at all altitudes in both the Northern and Southern Hemispheres and the differences that may, for example, be brought on by the different land-sea distributions; (2) the possible interactions between the circulation patterns in both hemispheres; and perhaps most important, (3) the interactions between the upper and lower layers of the atmosphere.

Complete information on the above-mentioned items would normally require a vast system of high-altitude observing stations capable of obtaining temperature and wind data from the surface to above 60 km. However, the expense of such a system, designed for in situ measurements, is completely prohibitive, and thus the planning of such a network would be only an academic exercise. This is especially true in the Southern Hemisphere, where ocean areas would further restrict the distribution of observational sites.

Since we cannot hope for the large volume of data needed to describe the entire atmosphere, we must find other less costly ways for acquiring the necessary information. It is important to reemphasize that EXAMETNET was formed with the expectancy of maximum data acquisition from a minimal rocket network. This philosophy dictated the establishment of carefully derived firing schedules at rocket stations oriented in a general north-south line. However, the philosophy also takes full account of the number of observations available from the worldwide rawinsonde network as well as from other rocket stations, and more recently, thermodynamic data from the satellite atmospheric sounding instrumentation.

It is the purpose here to review the salient contributions of the EXAMETNET to the meteorological community. In doing so, we shall attempt to evaluate the scientific usefulness of the line of meridional type of network, extending across the equator into both hemispheres, so that judgements can be made as to the need for additional networks.

Experience has shown that the difficult task of sounding the atmosphere with meteorological rockets must be complemented by a parallel effort to evaluate the accuracy of the measured data. This evaluation is a basic function of the EXAMETNET research. We will first review the results of these data accuracy studies, which, as mentioned earlier, included comparisons between observations by different types of rocketsonde data and between rocketsonde measurements and temperatures derived from satellite radiance measurements.

B. Data Accuracy Studies

(1) Separation of diurnal variation from instrumental errors

The determination of the diurnal tide in the stratosphere (from 30 to 60 km) is closely linked to the evaluation of instrumental errors. In fact, in many cases it is nearly impossible to separate the two, although many attempts have been made [Refs. 9, 10]. As a result, there are still considerable differences of opinion as to the true amplitude and phase of the tide. Before the formal establishment of EXAMETNET, experiments were sponsored in order to gain insight on this problem. One was carried out in September 1965 at Wallops Island [Ref. 11]. The results of the data analysis, which involved a comparison of the temperature variation inferred geostrophically from the tidal wind data with the temperature variation measured directly by the rocketsondes, was by no means conclusive. There was a suggestion, however, that the rocketsonde observations contained error due to direct solar radiation affecting the sensors or some critical portion of the instrument package. Thus, it became mandatory that future tests be conducted with the objective of determining the accuracy of rocketsonde measurements.

(2) Small-scale variability

As is the case for any observational series, if the data points are sufficiently close together in space and/or time, then the validity of any individual observation can be "verified" by comparing it against the surrounding values. On the other hand, when the observations are in a region generally void of other data points, then each report must be accepted at its face value and the need for utmost accuracy is relatively increased.

In view of certain inherent difficulties in the measurement of atmospheric temperature with rocketsonde instrumentation (i.e., aerodynamic heating, etc.), an extensive program of testing and evaluation has been in progress to insure that the most reliable systems possible are being employed by the EXAMETNET participants. The use of such equipment in sparse data areas (for example, in the Southern Hemisphere) is especially desirable, since comparisons with measurements made close by in space and/or time cannot be as readily accomplished as in areas where observational data are relatively plentiful.

Several experiments have been carried out to determine the compatibility of both wind and temperature profiles measured with different types of rocketsondes launched within periods of several minutes to several hours of each other, and placed in nearly the same spatial positions [Refs. 3, 12, 13]. Results generally indicate that the small-scale structure of the wind and temperature fields can be repeatedly discriminated. A good example of the small-scale repeatability between the zonal wind component as measured by the Arcasonde 1A and the Japanese Mt-135 is shown in Fig. 9. However, these early experiments did raise some questions. For example, although the small-scale perturbations of the temperature profiles were repeatable, in some cases the smoothed temperatures were as much as 5-8° at variance over a period of a few hours especially at the higher altitudes. The question arises as to whether these large-scale differences are a function of instrumental bias or real atmospheric variation.

In response to the questions raised above, the EXAMETNET has sponsored two additional experiments. The first entailed a concentrated series of launchings of the Datasonde instrument [Ref. 3], while the second involved a comparison of several rocketsonde instrument types with each other and against measurements obtained by the various temperature-profile-radiometer instruments aboard the Nimbus III and IV experimental satellites [Ref. 5].

The results of the first experiment conducted on June 20, 1969 indicate that temperatures measured by the Datasonde instrument are generally repeatable to within 2°C, but that substantial large-scale variability (variability in the mean temperature throughout a given layer) can exist, apparently as a result of a real atmospheric change. For example, a temperature change of over 7°C within 2 hours at about the stratopause was verified by several soundings. These results are important since they indicate an increasing meso-scale stratospheric variability which probably peaks at the stratopause. More investigation should indicate whether the amplitude of this variability increases during the winter season.

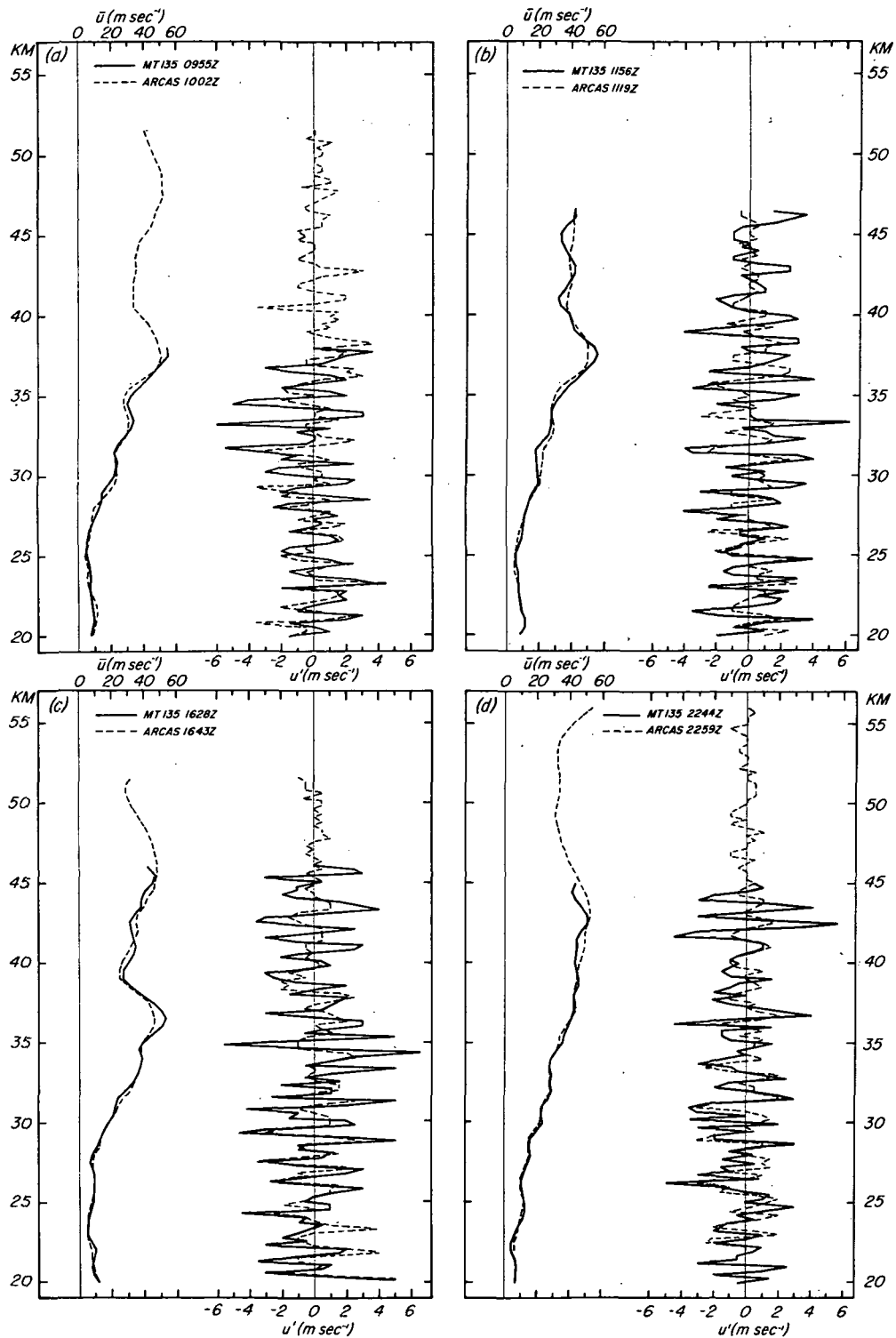


Figure 9.—Smoothed (U) and perturbation (U') zonal wind profiles for United States-Japan comparison tests on April 4, 1967 [Ref. 12].

(3) Rocketsonde-satellite sounder comparisons

The rocketsonde-satellite sounder experiment was recommended at the Fifth Annual Meeting of EXAMETNET. In accordance with these recommendations, NASA conducted the experiment at Wallops Station. Essentially this is a comparison between satellite derived temperatures from the temperature-profile-radiometer or spectrometer instruments and those measured by rocketsondes. This comparison is afforded by scheduling rocketsonde observations at the approximate time of satellite overflight. A significant amount of data has already been obtained at Wallops Island. Although no firm conclusions have yet been reached, there are indications that several of the transmittance functions used for deriving the satellite temperature profiles may not be correct. These results may provide an important method of adjusting the transmittances which were originally derived in a theoretical manner.

Another preliminary indication from the rocketsonde-satellite comparison is that in certain configurations of thermistor placement, the Datasonde rocketsonde instrument (used for a portion of the comparisons) yields temperatures that are biased toward the warm side. This bias was also suggested in earlier comparisons with other instruments.

C. Circulation Studies

There were several attempts to obtain high-level information for cross-sectional type analysis of the Southern Hemisphere before the actual start of the EXAMETNET launch operations. Perhaps the most prominent was the NASA Mobile Launch Expedition aboard the USNS Croatan [Refs. 14, 15] which provided an outstanding amount of data up to 60 km while the ship cruised a route southward across the equator and along the west coast of South America. Examples of how such data can be used are shown in Figs. 10 and 11. A north-south cross section of wind and temperatures along 78°W in the Southern Hemisphere is shown in Fig. 10. Although the observations were taken during a period of about two weeks, they were combined to show the general features of the circulation.

Another method of presenting cross-sectional type data is shown in Fig. 11. These segments of analyses up to 0.4 mb can be used for limited comparisons of circulation regimes during analogous seasons of the Northern and Southern Hemispheres. The Northern Hemisphere segments here were taken from synoptic analyses [Ref. 16], and those of the Southern Hemisphere were again derived from data taken from the Croatan over a period of about 2 weeks.

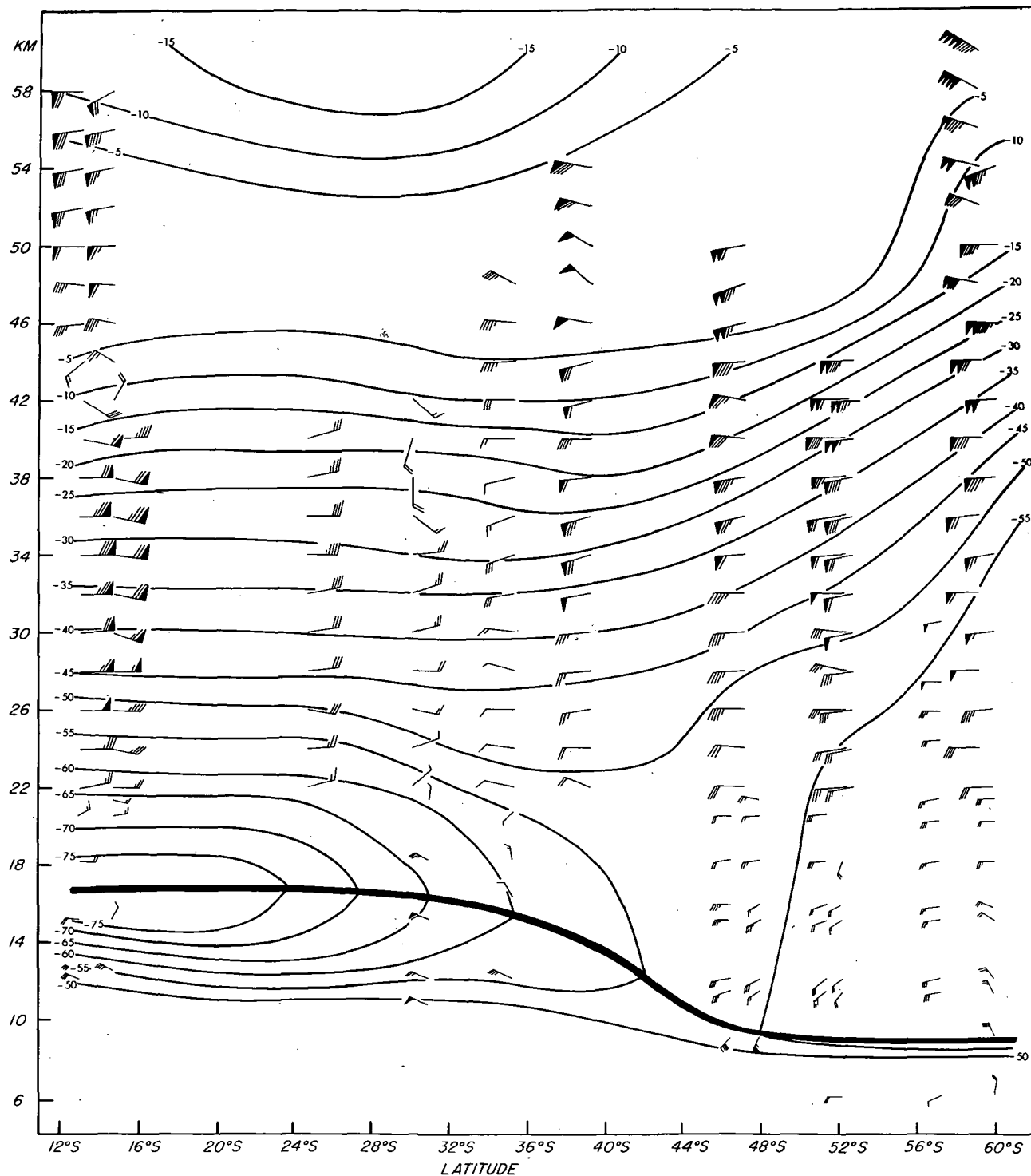
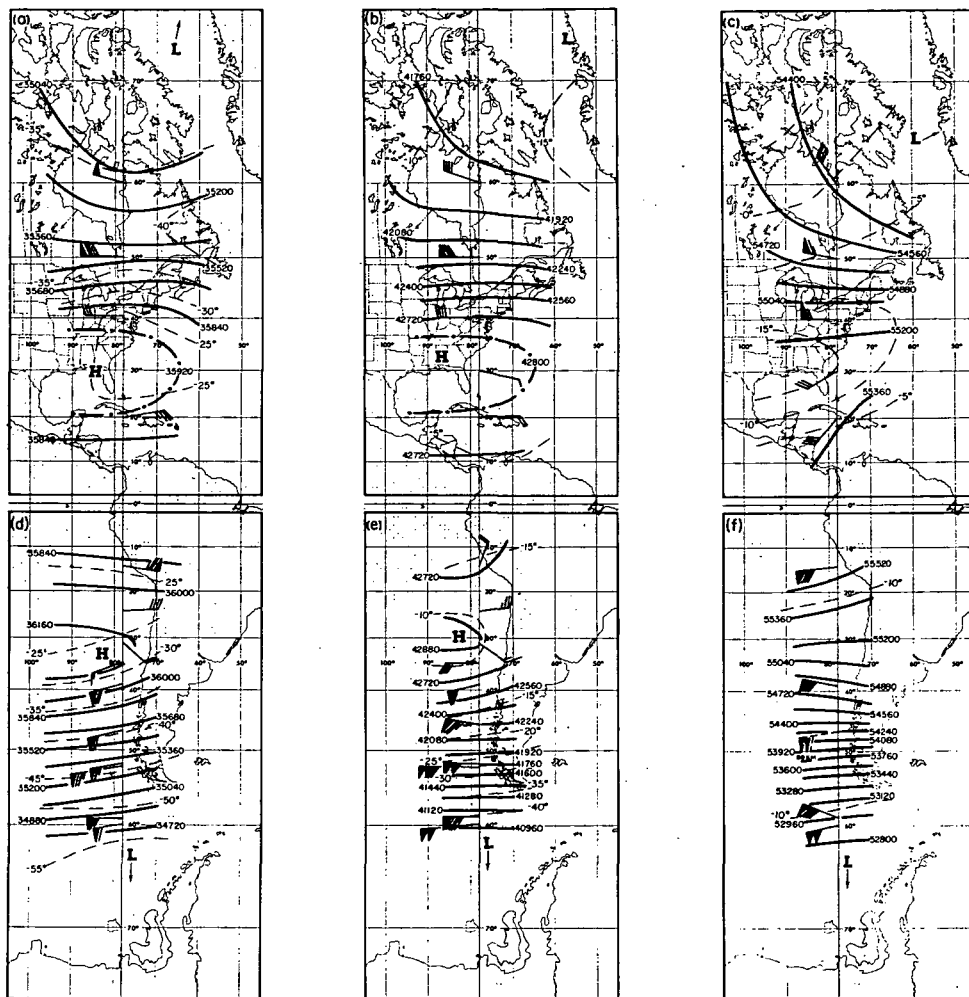


Figure 10. —Space-time cross-section of wind and temperature from 12°S to 60°S along 78°W for March and April 1965 [Ref. 14]. Rocketsonde winds (kt) are denoted by large symbols, temperature (°C) by upright numerals, and support rawinsonde data by small wind symbols; isotherms at 5°C intervals.

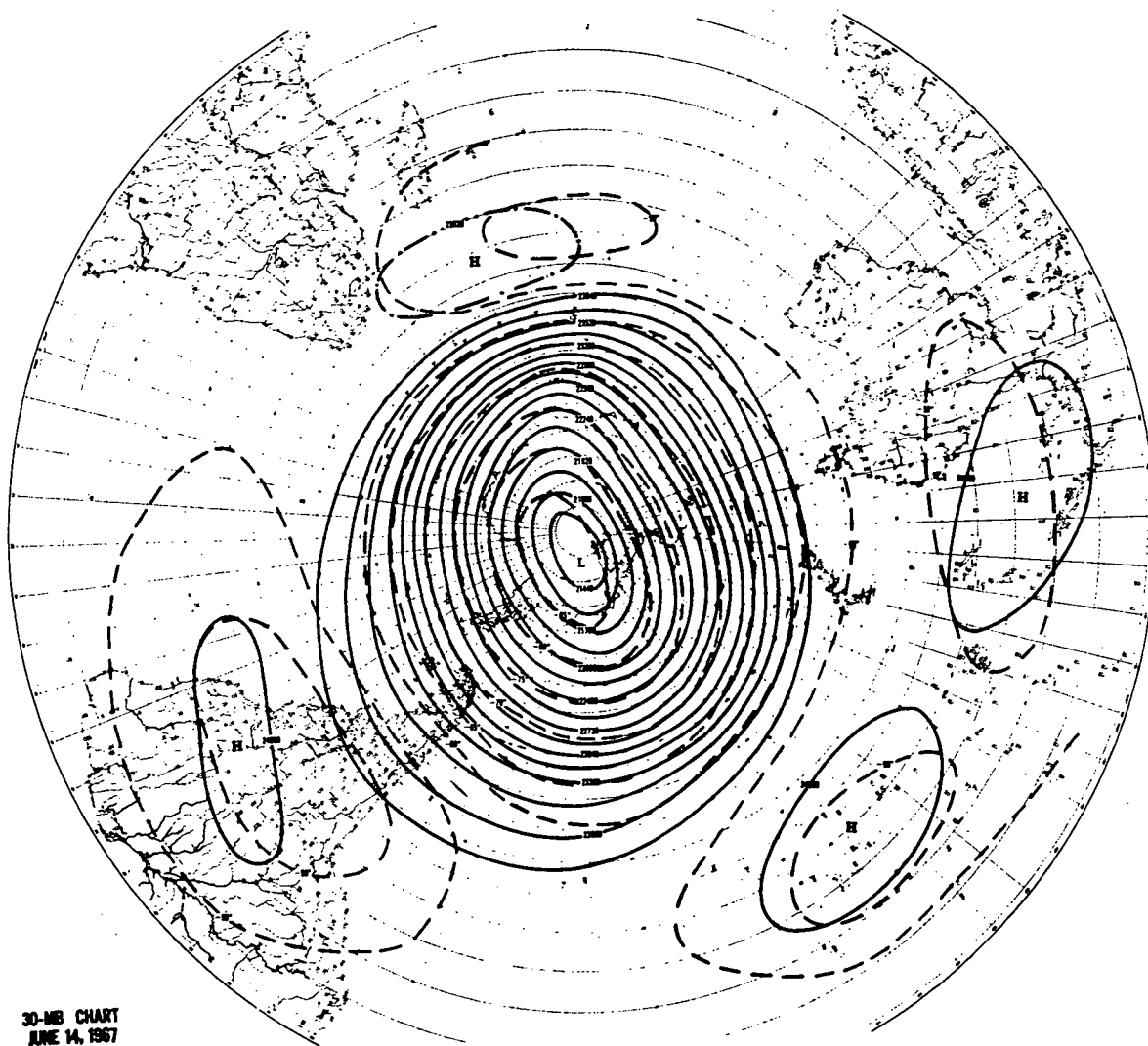


Because of the generally large scale of the synoptic systems in the stratosphere and the fact that they very likely slope with height, it has long been considered that the optimum way of studying the stratospheric circulation at rocketsonde heights is to construct a map analysis at lower altitudes (height and temperature at a constant-pressure level) utilizing all information available (rawinsonde, rocketsonde, constant-level balloon, satellite). That map can then be utilized as a base chart into which the relatively few higher-altitude rocket observations can be meaningfully integrated to at least infer the circulation at higher levels.

For the initial attempt at this type of analysis in the Southern Hemisphere [Ref. 17], rawinsonde data and constant-level balloon information were used to construct weekly analyses for the 30-mb level for the month of June 1967 (the analysis for June 14 is shown in Fig. 12). Rocketsonde information from Chamical,² Argentina; Natal, Brazil; and Ascension Island indicated (rocket reports from Chamical and Natal also for June 14 are shown in Fig. 13) that a subtropical ridge, present in the lower stratosphere, diminished with height. In addition, the data suggested that the polar westerlies extended equatorward with increasing height. These results are consistent with those which had been derived previously from Northern Hemisphere data.

More recently [Ref. 18], research efforts have concentrated on the question of whether stratospheric warmings occur with the same frequency and intensity in the Southern Hemisphere as they do in the Northern Hemisphere. The Southern Hemisphere winter of 1969 was notable in that several warming pulses occurred throughout the season, although these warmings could not be classified as strong by Northern Hemisphere standards and were not accompanied by major circulation changes. An example of the circulation pattern during such a warming in mid-August is shown in Fig. 14. The available rocket reports and high-level radiosonde reports (a time section of temperature and wind showing the effect of the warming at Mirny, A USSR station in the Antarctic, is shown in Fig. 15) suggest that the warming was somewhat more pronounced in the higher portions of the stratosphere. However, the results strengthen the concept that the polar regions of the hemispheres react quite differently during warming periods. Increasing evidence indicates, for example, that mid-winter stratosphere circulation breakdowns (i.e., wind reversals), may never occur in the Southern Hemisphere at least at the lower levels because the strength of the winter-time polar cyclone is significantly greater than that of the Northern Hemisphere.

²Earlier site of Argentine rocket station, before the move to Mar Chiquita.



30-MB CHART
JUNE 14, 1967

Figure 12. —Southern Hemisphere 30-mb analysis for the week of June 14, 1967. Units: geopotential meters and degrees Celsius. Contour intervals: 160 gpm, 5°C [Ref. 17].

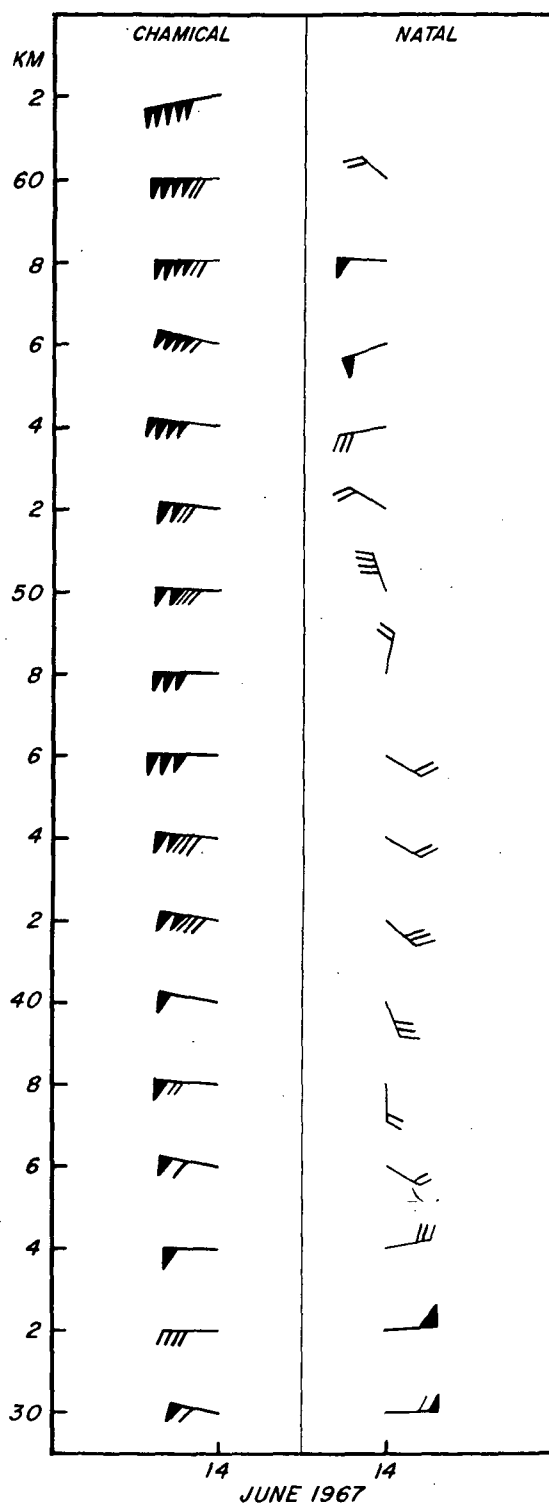


Figure 13.—Observed rocketsonde winds (knots) for Chamental, Argentina, 30°22'S-66°17'W, and Natal, Brazil 5°55'S-35°10'W; June 14, 1967. A full barb represents 10 knots; a pennant, 50 knots [Ref. 17].

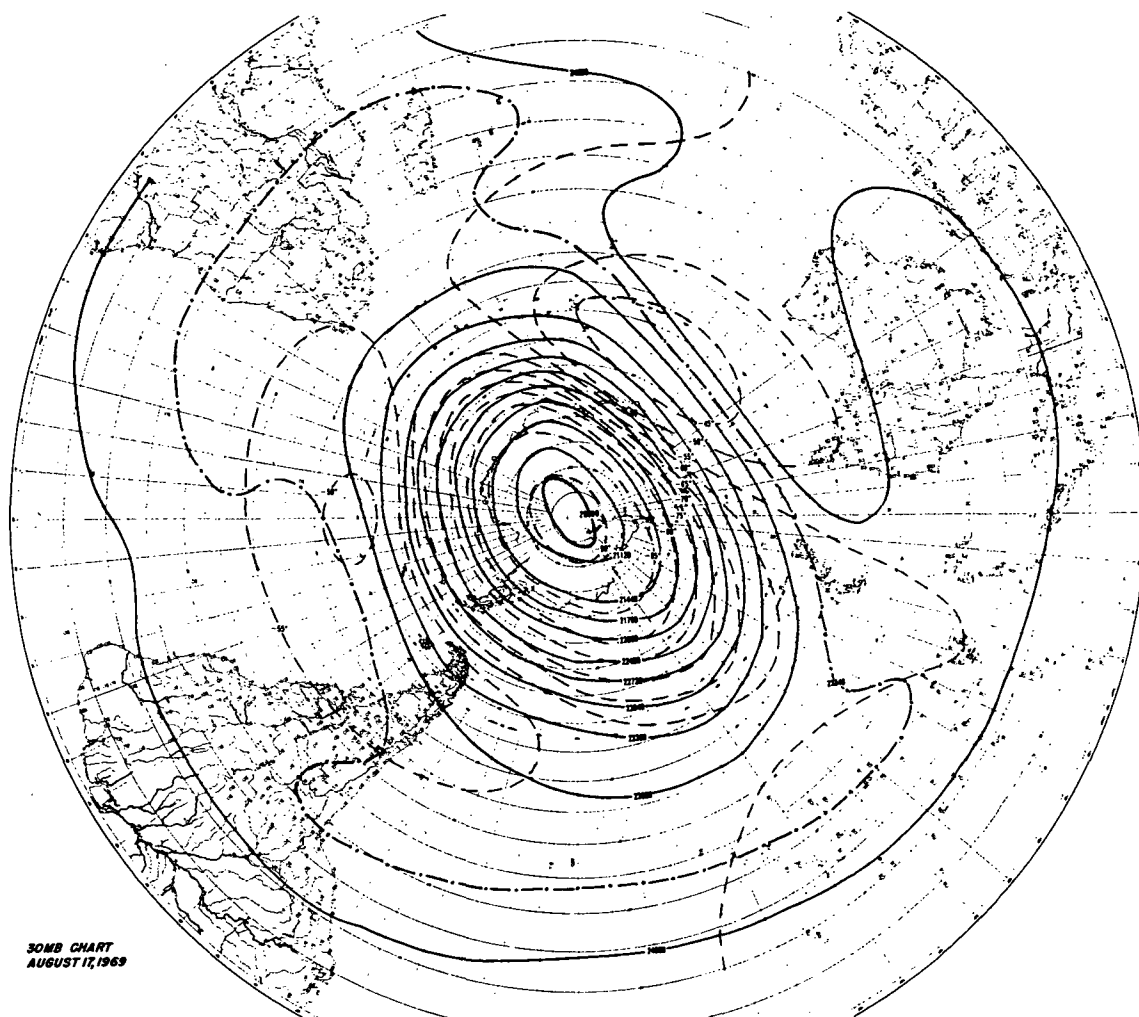


Figure 14. —Southern Hemisphere 30-mb analysis for August 17, 1969. Units: geopotential meters and degrees Celsius. Contour intervals: 320 gpm, 5°C [Ref. 18].

MIRNY 566-E93

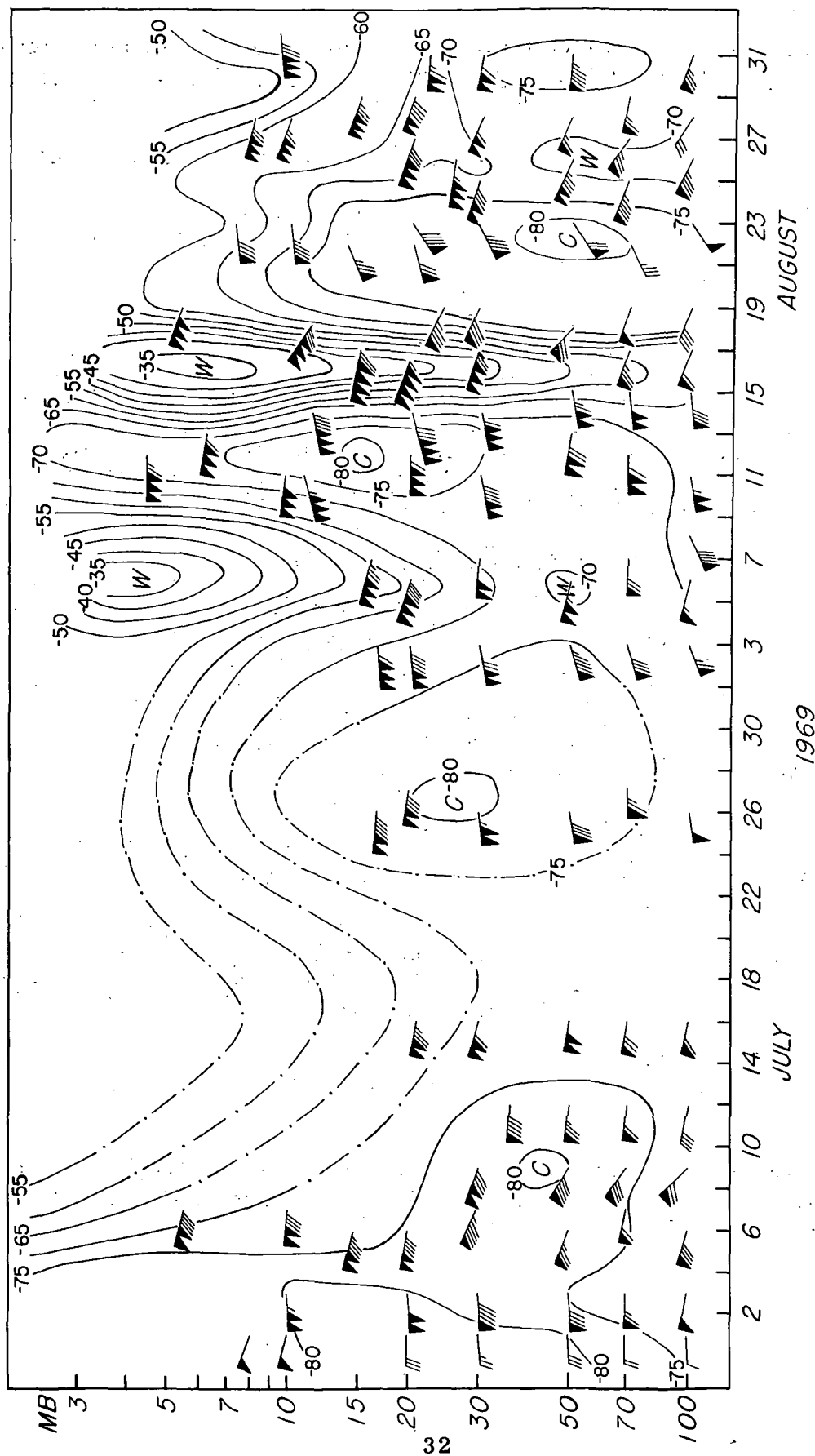


Figure 15.—Time-height section of radiosonde observations at Mirny, Antarctica (66° 33'S, 93° 01'E). Temperature units: °C. The broken portion of the analysis (---) reflects a period where data were sparse and resulted in a decreased confidence level in the analysis. Wind units: knots [Ref. 18].

It is recognized, however, that the major effects of a mid-winter warming event in the Southern Hemisphere may occur at altitudes higher than those portrayed by the current radiosonde analyses. For example, it is noted that the results of several studies [Refs. 19, 20, 21] as well as recent satellite data from the Selective Chopper Radiometer (SCR) instrument on board Nimbus IV (private communication) support the concept of a mid-winter warming in the Southern Hemisphere that is principally confined to the upper stratosphere. A similar phenomenon has been observed in the Northern Hemisphere [e.g., Ref. 22].

Some hemispheric comparisons have also been accomplished for the lower latitudes. For example, the circulation at Chamical, Argentina (30°S) was compared with that of White Sands, New Mexico (32°N) [Ref. 20] utilizing the SCI (Stratospheric Circulation Index). The zonal wind components at the two stations were found to be similar. However, differences between the meridional components of the two stations were found. The reason for the observed differences remains to be determined.

The data available during the 1969 Southern Hemisphere winter, in conjunction with maps of the Northern Hemisphere summer, allowed a very general approximation of the world-wide circulation pattern, as was attempted with the earlier "Croatan" data. One important aspect of the pattern was the complex differences that may occur from year to year (Fig. 16) according to the phase of the so-called quasi-biennial cycle. As can be seen, the biennial cycle may influence the circulation pattern, even at middle latitudes and up to 50 km.

A special effort to obtain all possible Southern Hemisphere data, which involved the cooperation of EXAMETNET member states, allowed a series of synoptic charts to be drawn for a portion of the springtime stratospheric circulation change. Again, certain phases of this annual event appeared to take place in a different manner from the Northern Hemisphere [e.g., Ref. 19]. For example, the reversal of the temperature field at 30 mb appeared more orderly in the Southern Hemisphere. In addition, it is rather remarkable that the circulation at higher latitudes remained westerly several weeks after the temperature reversal had been fully completed. Rocket winds from Mar Chiquita indicate that even at higher levels the summertime circulation was not yet established by the middle of November, although the temperature reversal had been completed. This again points to the extreme intensity of the wintertime polar cyclone which, of course, is partially regulated by very cold Antarctic air below the stratosphere.

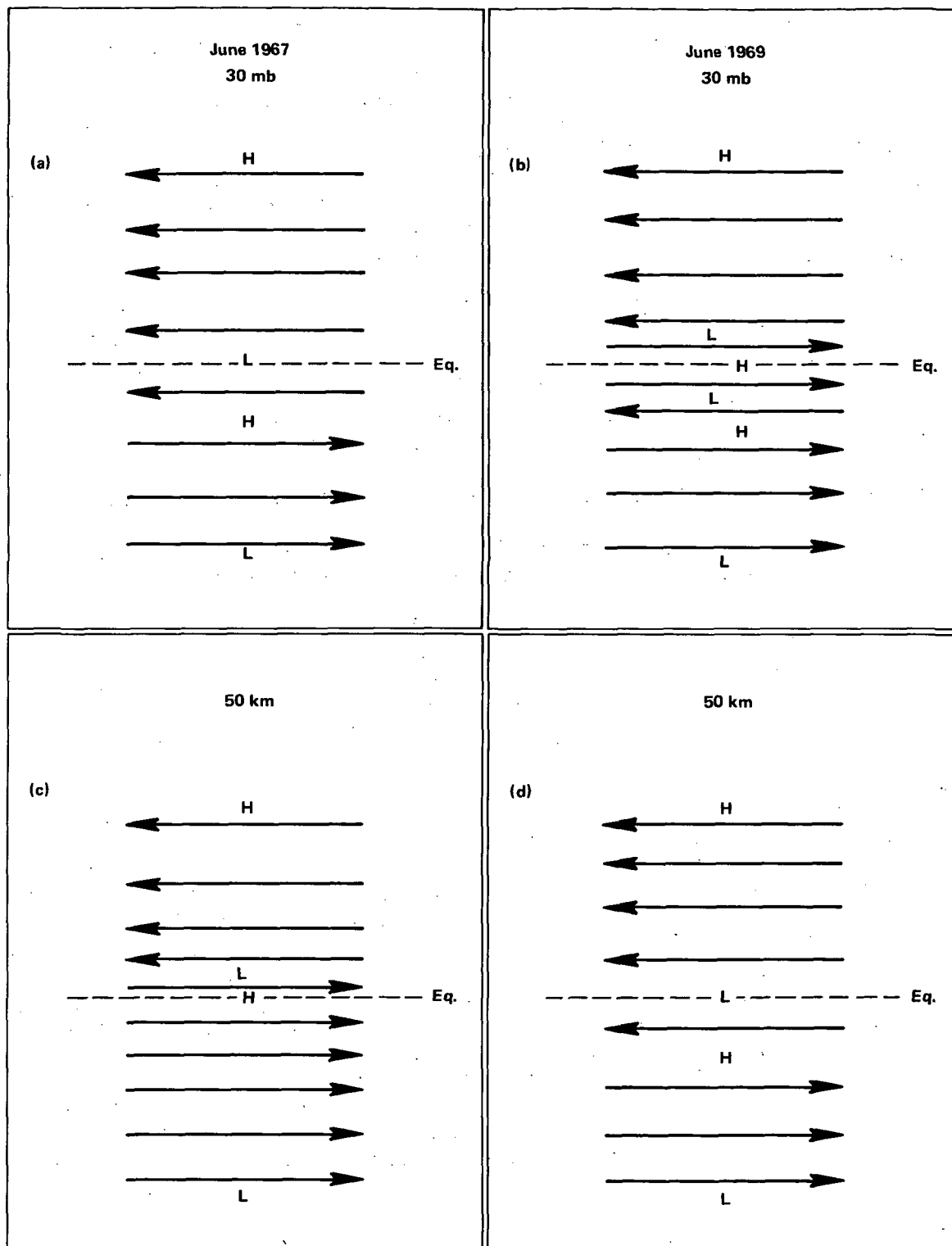


Figure 16.—Schematic diagram of general synoptic pattern at 30 mb (a,b) and 50 km (c,d) for June 1967 (left side) and June 1969 (right side). North Pole is at top and South Pole is at bottom in all diagrams [Ref. 18].

D. Tropical Circulations

As shown above, networks such as the EXAMETNET can provide valuable data for use in studying high-level hemispheric circulations and also to study differences between the patterns in each hemisphere. An additional basic function of the EXAMETNET is to increase our knowledge of the stratospheric behavior within the tropical regions, paying special attention to the possible relationships between phenomena of tropical and middle latitudes. Analysis of the tropical regions of both hemispheres is valuable, not only for solving purely meteorological problems, but also for providing information to those concerned with problems such as tracing radioactivity introduced into the atmosphere.

Major aspects of the low-latitude circulation are the quasi-biennial oscillation, known to be most pronounced in the middle stratosphere, and the semiannual variation, which peaks near the stratopause. With the aid of rocketsonde observations from stations near the equator (including information from the EXAMETNET station at Natal) together with data from other longitudes north and south of the equator, it was possible for the first time to establish that the semi-annual cycle occurs at low latitudes around the entire globe [Refs. 23, 24]. For example, the time sections of Ascension Island and Natal, Brazil (Figs. 17, 18) show quite comparable wind variations with time. The components of the quasi-biennial cycle may be subtracted, leaving variations that are probably a consequence of the double passage of the sun between latitudes 23.5N and 23.5S. Subsequent analyses [Refs. 25, 26, 27], have provided further information on the amplitude of the semiannual cycle as a function of latitude.

The results of the low latitude studies suggest a link between these circulations and the basic annual cycle of high latitudes. The full importance of the semi-annual variation, which is significantly stronger than the quasi-biennial oscillation, is not yet known. A possible influence of the semiannual cycle on semiannual variations encountered at higher altitudes, even to satellite orbiting levels, merits investigation. It may well be that these tropical variations have an important role in the triggering of stratospheric warmings.

Yet another use of EXAMETNET data has been directed toward the improvement of standard atmospheres. The Natal data, in particular, have been used by a working group of the Committee on Extension of the Standard Atmosphere, as a check on the adequacy of the existing "supplemental" atmosphere for the tropics. Significant departures from the CIRA 1965 model atmosphere have been found [Refs. 24, 28, 29, 30].

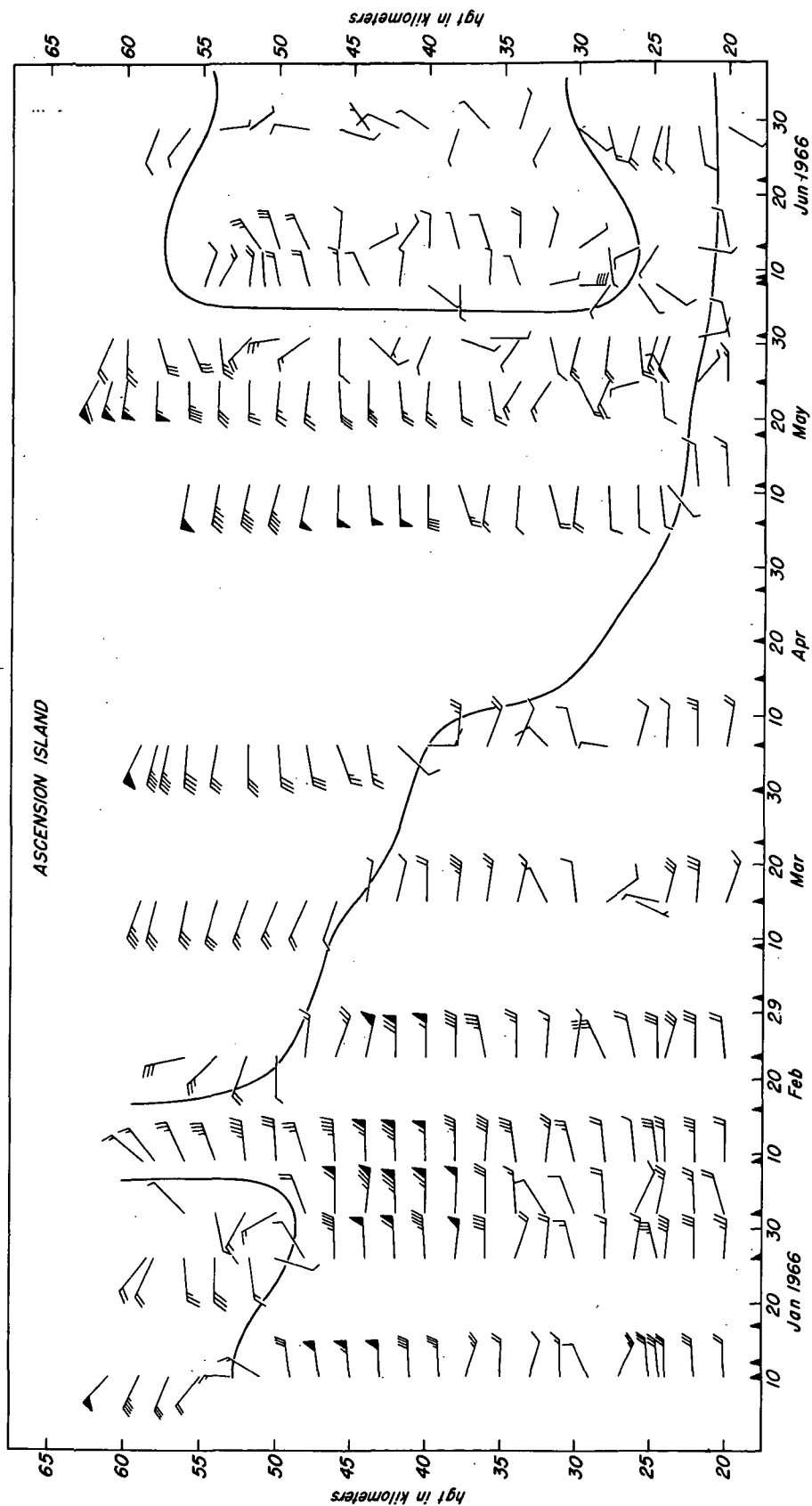


Figure 17a.—Time section of observed rocketsonde winds (m. sec.^{-1}) for Ascension Island: January - June 1966. The heavy black lines generally separate winds with easterly components from those with westerly components. Indentations from bottom scale indicate all days for which observational data were used. A full barb represents 10 m. sec.^{-1} ; a pennant, 50 m. sec.^{-1} [Ref. 23].

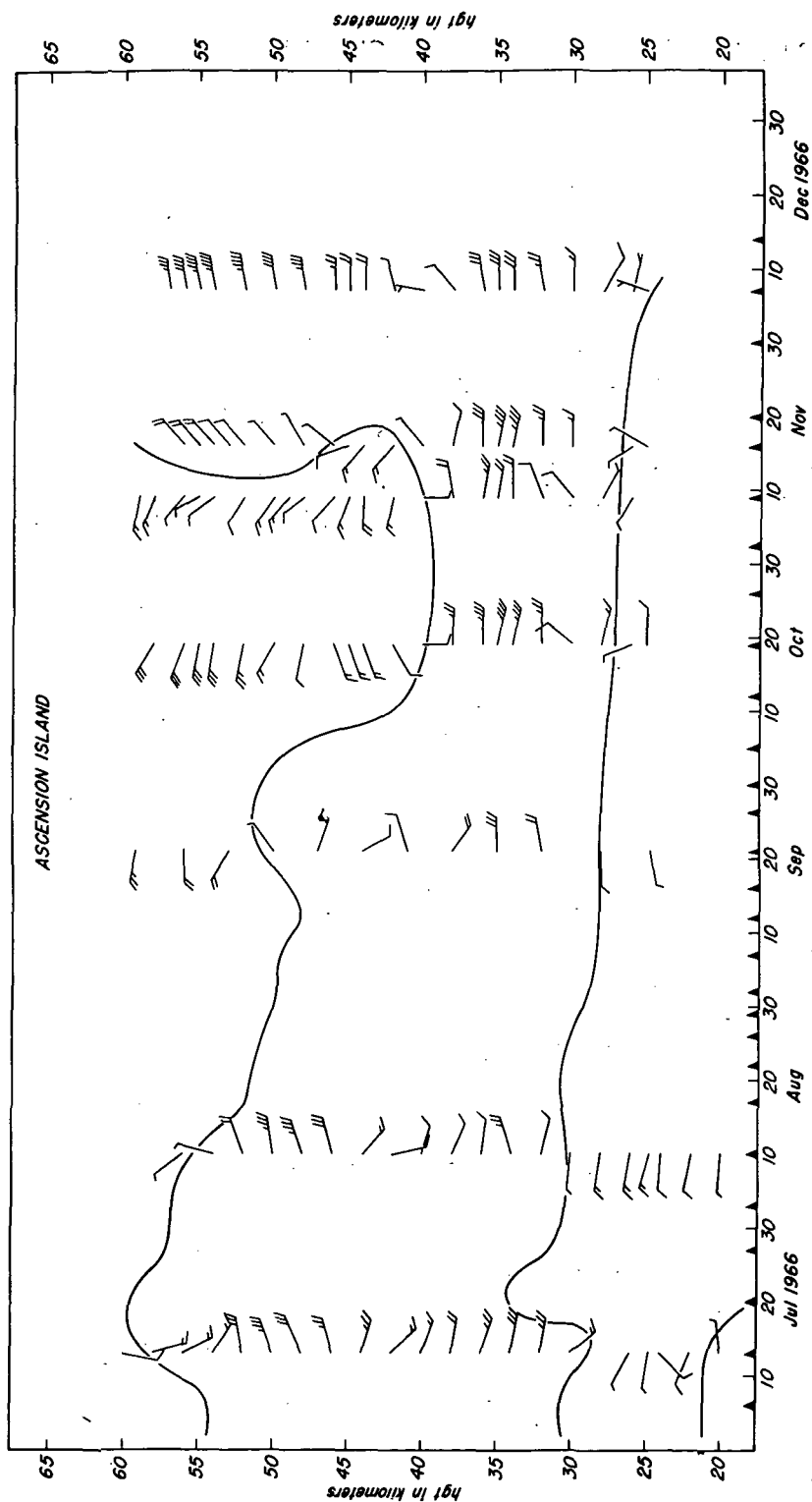


Figure 17b. —Time section of observed rocketsonde winds (m. sec. -1) for Ascension Island: July - December 1966. The heavy black lines generally separate winds with easterly components from those with westerly components. Indentations from bottom scale indicate all days for which observational data were used. A full barb represents 10 m. sec. -1 ; a pennant, 50 m. sec. -1 [Ref. 23].

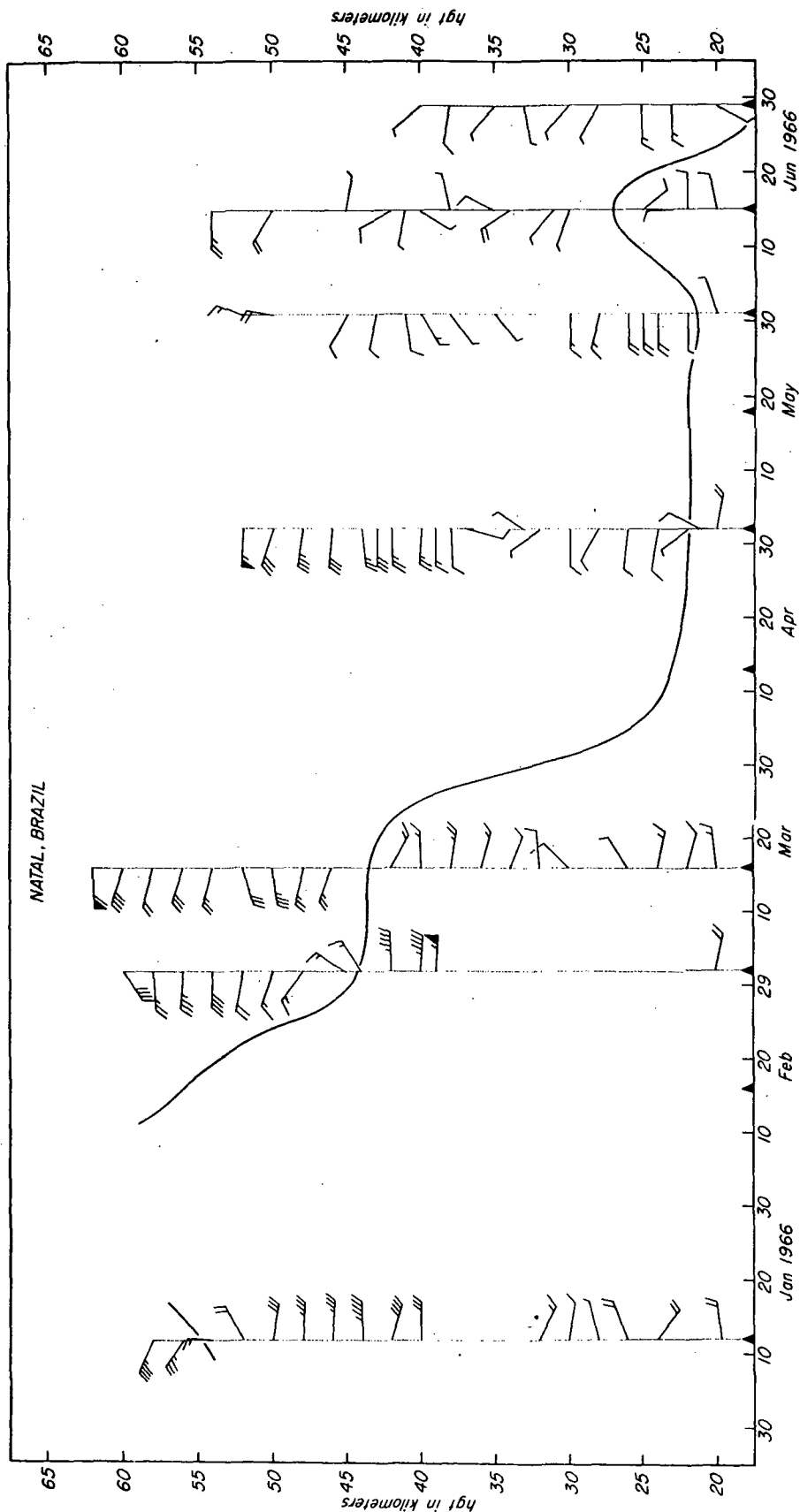


Figure 18a. — Time section of rocketsonde winds (m. sec.^{-1}) for Natal, Brazil: January - June 1966. The heavy black lines generally separate winds with easterly components from those with westerly components. Indentations from bottom scale indicate all days for which observational data were used. A full barb represents 10 m. sec.^{-1} ; a pennant, 50 m. sec.^{-1} [Ref. 23].

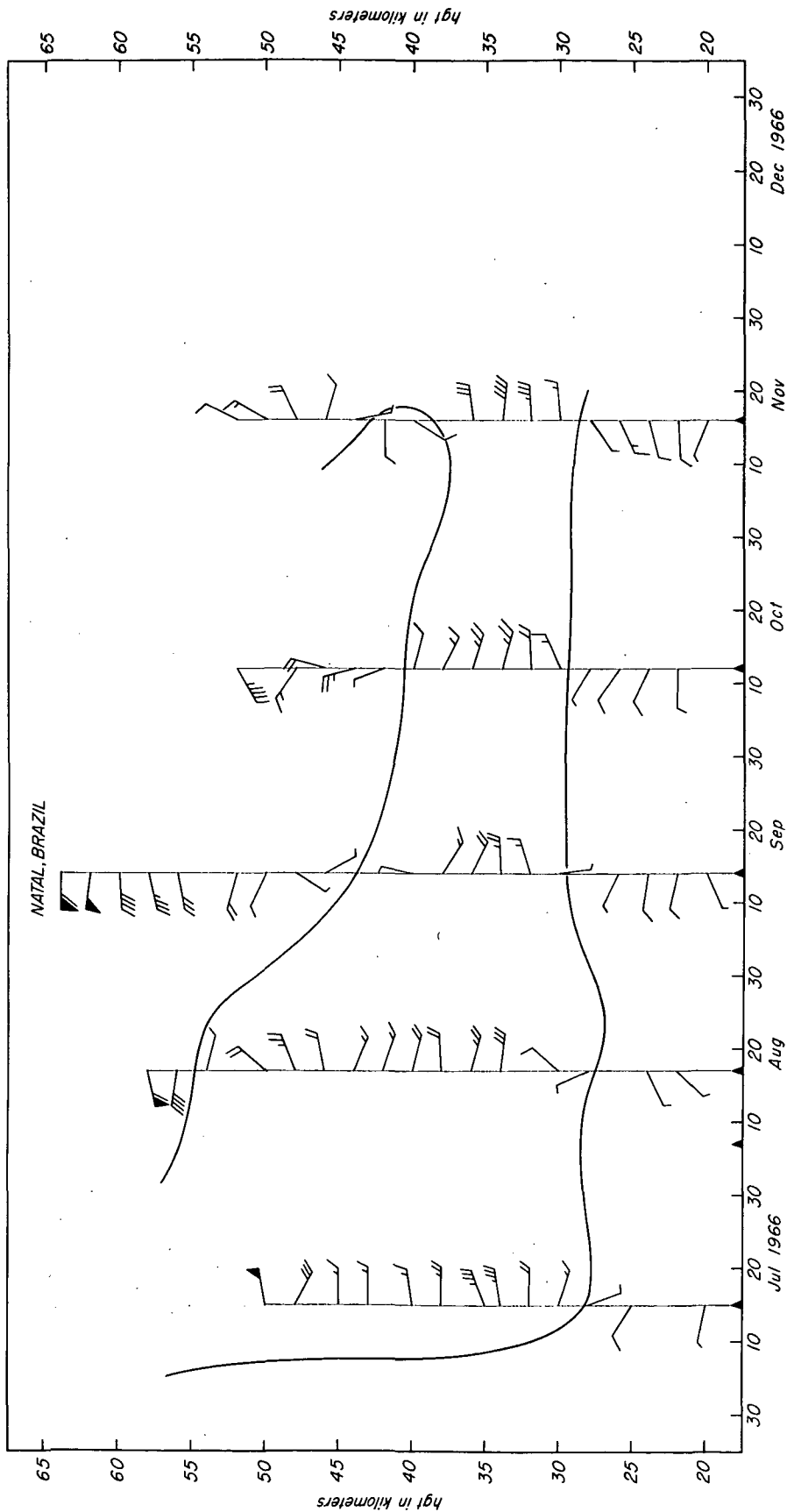


Figure 18b. —Time section of rocketsonde winds (m. sec. ⁻¹) for Natal, Brazil: July - December 1966. The heavy black lines generally separate winds with easterly components from those with westerly components. Indentations from bottom scale indicate all days for which observational data were used. A full barb represents 10 m. sec. ⁻¹; a pennant, 50 m. sec. ⁻¹ [Ref. 23].

E. Stratospheric-Tropospheric Interactions

As described above, the essential purpose of the EXAMETNET as an observational network is to offer coordinated rocketsonde launchings that, when utilized with all other available data, allow the maximum information to be obtained concerning the structure and circulation of the Northern and Southern Hemisphere stratospheres. Delineation of the general synoptic patterns and depiction of the differences and similarities between the two hemispheres as described in the previous sections, however, inevitably raises the question of why the events occur as they do. For example, why is the Southern Hemisphere wintertime stratospheric circulation more symmetric about the pole than the Northern Hemisphere? Is this circulation difference related to the observed differences in the mid-winter warmings or even to the cause of the quasi-biennial oscillation?

While a complete report of the many studies that seek to answer these questions is beyond the scope of this brief review, a few words should be stated on one aspect of research that may prove to be fundamental to a host of aerological problems. It has long been recognized by theory [e.g., Ref. 31] and observation [e.g., Refs. 32, 33, 34, 35] that the troposphere is a major source of kinetic energy for the stratosphere by means of the mechanical coupling at the tropopause; that is, the troposphere does work at the stratospheric boundary, thereby providing kinetic energy to the stratospheric flow.

While computations of the energy flux have been made only in the lower stratosphere, it has been shown that this exchange can be directly related to the mid-winter warming events and the quasi-biennial oscillation [e.g., Refs. 35, 36]. In comparing an estimate of the energy flux [Ref. 35] with a 10-mb circulation index [Ref. 37], it was concluded that an increase in the vertical energy transfer precedes an observed effect in the circulation at 10 mb by 2-4 days and that the existence of the well-known Aleutian anticyclone is related to an energy flux at that scale-length. Unfortunately, at this time it is not possible to extend this type of correlation analysis to the upper stratosphere as the data are rather restricted both spatially and temporally. Vertical motion analyses for the upper stratosphere, however, have been constructed for limited geographical areas [Ref. 22]. It is hoped that these calculations can be extended in the near future to include the entire hemisphere, so that the energy flux computations can be accomplished for this region.

Furthermore, it is noted that because the atmospheric density decreases so rapidly with height, a relatively small transmission of the energy through the lower stratosphere can have a profound effect at higher levels. Indeed, several investigators are presently studying anomalous ionospheric situations that may be related to energy transfer.

F. Eclipse Studies

The EXAMETNET has cooperated in two experiments oriented toward determining structural and circulation changes during a solar eclipse. The first experiment took place at Tartagal, Argentina (23°S) on November 12, 1966. Observational data indicated a temperature drop exceeding 10°C near 50 km in the eclipse, and an increase of about 20°C at 60 km from before totality to an observation time in mid-afternoon. Clearly, these large changes required clarification. Since temperature errors in rocketsondes tend to increase with height there is a question as to whether these changes reflected those of the real atmosphere.

Fortunately, a total solar eclipse also occurred at Wallops Island during March 7, 1970. Preliminary results from meteorological rocketsonde observations taken during the period of this phenomenon [Ref. 38] also indicated significant temperature changes. However, there were some rather startling differences. For example, the analyzed Wallops data show the maximum changes (Fig. 19) occurring in the 40-55 km layer instead of higher as shown by the Tartagal data. It is noteworthy that the amplitude of temperature change decreases above about 55 km. This result suggests that instrumental error due to solar radiation was not a prime factor in this experiment, since the radiational error would be expected to increase with height.

The observed temperature variation at Wallops Island is more nearly in accord with the prediction from tidal theory, which suggests that maximum amplitude of the day-night variation, due to ozone heating and cooling, should occur below the stratopause. A more detailed investigation is being made of the March 7 eclipse temperature data and of the relationship between the wind and thermodynamic changes.

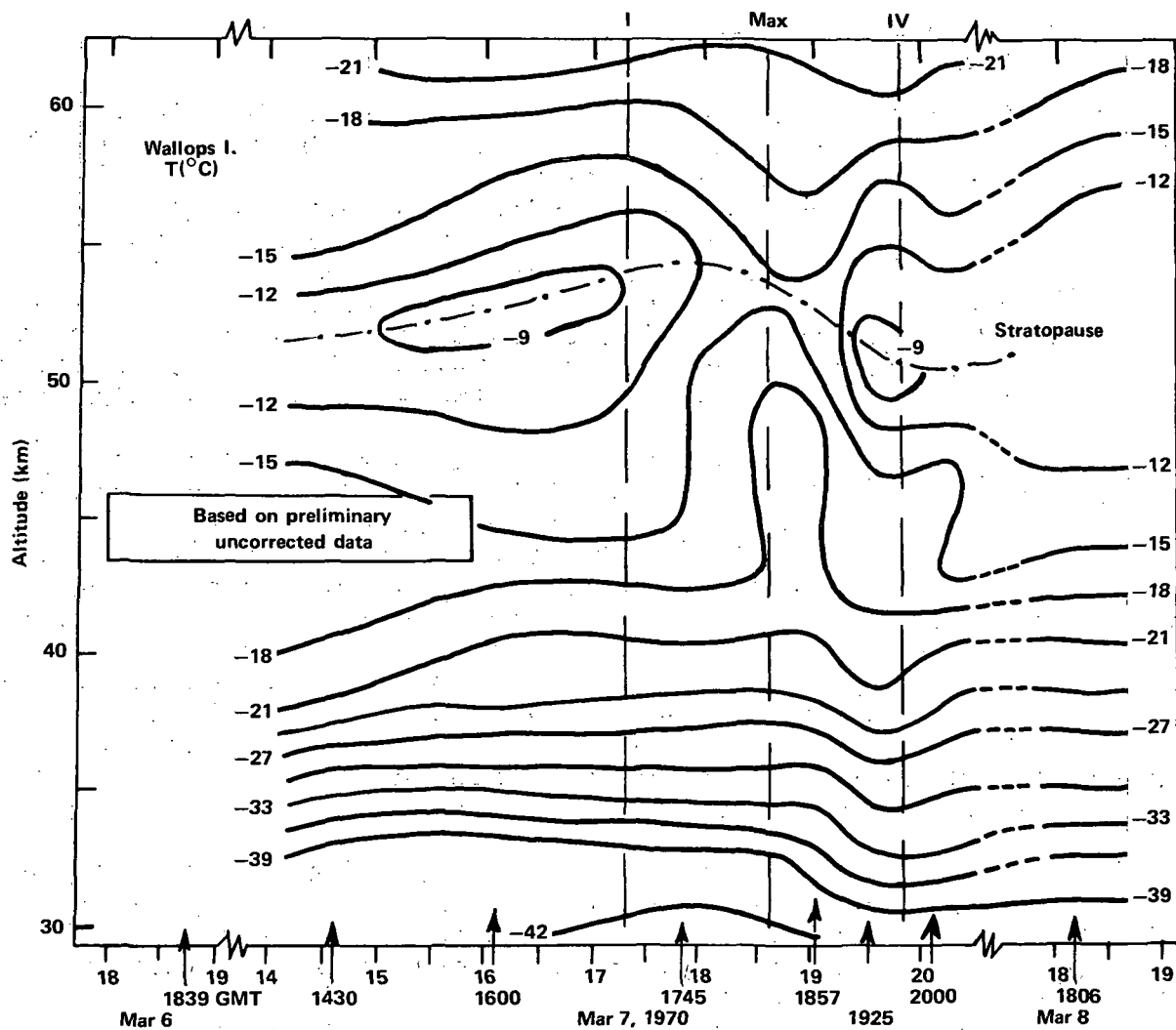


Figure 19.—Preliminary analysis of smoothed rocketsonde temperatures for Wallops Island, Virginia, for the solar eclipse of March 7, 1970, indicating a temperature decrease by as much as 7 degrees within the layer 40 to 60 km [Ref. 38].

SUMMARY

The Experimental Inter-American Meteorological Rocket Network (EXAMETNET) was established to fill a gap in the knowledge of the stratosphere, especially in the Southern Hemisphere.³ The goal is the organization of an inter-hemispheric network of sounding rocket stations which would coordinate their operations and combine their resources and scientific capabilities to expand the knowledge of the structure and dynamics of the atmosphere to about 60 km. It is recognized that this endeavor requires a high degree of cooperation, as well as the utilization of other sources of atmospheric measurements such as from rawinsonde and satellite soundings.

In August 1965, personnel of the space agencies, representing Argentina, Brazil and the United States met at Wallops Island, Virginia to organize the network. The result is a basically meridional line of stations within the Americas, one in each country, and extending between 40°S and 40°N. It is hoped that the network can be expanded to a line from pole to pole and to as high an altitude as possible, although at present the altitude capability is about 60 km. The cooperative agreements among the participating countries involves training, loan of equipment, procurement of rocket systems and related hardware, ground-range facilities, station personnel, and so forth. In terms of the organizational structure created for conducting the network, the activity consists of an Executive Committee to guide and advise the operation and two Working Groups, scientific and technical. The Working Groups contain project managers, scientific coordinators, experimenters and other personnel necessary to the operations. Each country is represented on the Committee and Working Groups.

While the original membership of the network was confined to countries having sounding rocket facilities in the Americas, it was realized that the utility of the data would be enhanced if sounding rocket activities in other regions were coordinated with those of EXAMETNET. To do this an adjunct membership was established for those countries with launch sites outside the Americas. It is a procedure through which these countries can participate in the deliberations, plans and activities of EXAMETNET. Spain is the first country to become such a member.

³The important contribution of rocket-grenade and falling sphere programs conducted in Australia is fully recognized. The EXAMETNET program, however, provided for the first coordinated inter-hemispheric rocket network.

Although EXAMETNET is an international regional network (i.e., in the region of the Americas), it soon became a recognized part of the international community. For example, the organization is represented in the WMO and COSPAR through the national representatives of the participating countries. Another aspect is coordinated launchings. India requested and received the coordination of EXAMETNET launches with launches in India. Furthermore, the USSR has proposed coordinated launchings from an Eastern and a Western Hemisphere meridional chain or network of stations to study various aspects of stratospheric circulation, and has further proposed that EXAMETNET form the basis of the Western Hemisphere chain.

Nationally the EXAMETNET program is related to activities within each participating country. In Argentina, the evaluation and scientific study of the sounding rocket data are performed by the National Meteorological Service, and the data are made available to universities and scientific organizations as well. In Brazil, there is cooperation between CNAE and the Ministry of Aeronautics to perform the EXAMETNET operations. Other agencies are informed of the EXAMETNET plans and make use of the data, such as the Ministry of Agriculture and the Meteorology Laboratory of the Aeronautics Technical Center. In the United States, close contact is maintained with the advisory groups which coordinate the efforts of the Meteorological Rocket Network of the United States. EXAMETNET is also represented in the committees and working groups of the Office of the Federal Coordinator for Meteorological Services and Research through the NASA members of this organization. The National Weather Service of the National Oceanic and Atmospheric Administration (NOAA) cooperates with NASA in fulfillment of the United States commitment for scientific research.

Improvement and standardization of operations are aspects important to the success of the network. In addition continued advances in technology are essential. To this end Argentina and Brazil have each developed sounding rocket systems which are to be used in the EXAMETNET observing program. The Argentine rocket system (named DIM) and the Brazilian rocket system (named SONDA-1) are expected to be available in 1971 and will be used for meteorological and aeronomic investigations. EXAMETNET has incorporated also in its operations the use of the Data-sonde rocket system for wind and temperature measurements. Other technological improvements include modification of a 403 MHz telemetry recorder to yield high-resolution temperature data and improve the signal reception, the introduction of digital computer methods in the data reduction and radar modifications for improved tracking and location resolution.

Network stations conduct special tests on a continuing basis to determine the reliability of rocket systems, especially in terms of the repeatability and accuracy of their atmospheric measurements. These tests include the intercomparison of data from the various rocket systems. Allied to these tests is the project for comparing rocket and satellite soundings. Proof of compatibility will allow the use of satellite data along with regular radiosonde and rocketsonde information to greatly increase our upper atmosphere data sample.

At the inception of the network, it was recognized that uniform reduction procedures and publication formats were a prerequisite to the efficient exchange and scientific application of the data. The EXAMETNET participants, after a review of existing methods, developed improved reduction techniques and formats now described in a data preparation and procedures manual. This accomplishment permitted significant contributions to the development of a uniform international rocketsonde format for the exchange and publication of rocket data, which was adopted by WMO and COSPAR for international use and for archiving and data dissemination by WDC-A.

Research studies conducted by the EXAMETNET participants cover a wide range of interests. Basically, they might be summarized under several major subjects including, a) diurnal variations, b) data accuracy (including comparisons with other instruments and methods of observations such as satellites), c) circulation studies, and d) stratospheric-tropospheric interactions.

Although rocket observations provide extremely valuable data in the layer from about 30 to 60 km, the inherent design problems of some systems can result in errors of measured parameters, especially temperature. Error possibilities were clearly brought out by careful analysis of data gathered during experiments designed to determine the diurnal variation of wind and temperature. Recognition of the error problem and subsequent investigations led to the realization that the separation of errors from true variabilities is indeed a difficult task. Therefore, it has become mandatory to conduct instrumented intercomparison tests. Although one could not expect precise corrections to emerge from such tests, certainly they have resulted in meteorologists being able to use the data with higher confidence than before.

Closely related to the determination of instrumental error is the question of the reality of small-scale atmospheric motions and temperature variations, in contrast to apparent variation due to instrumental or tracking error. Conclusions from rocketsonde experiments clearly point to the existence of real perturbations of temperature at stratospheric levels, with characteristic time scales of several hours and a magnitude exceeding 5°C.

Wind variations are also noteworthy. Experiments performed during solar eclipses using rockets of all sizes tend to reinforce the concept of true small-scale perturbations at stratospheric levels.

One of the main uses of EXAMETNET data is in research directed toward determining the stratospheric circulations of both the Southern and Northern Hemispheres. To this end, as well as for other problems, the network data are used with all other available reports. The combined information indicates that the Southern Hemisphere stratosphere, at least during the past few years, has exhibited significant mid-winter warming trends, but these did not result in the chaotic circulation breakdowns known to occur in the Northern Hemisphere. Unfortunately most of the observations were restricted to the lower stratosphere and it is not clear if a similar statement can be made for the higher altitudes. Differences in the regular springtime circulation transitions have also been noted between the two hemispheres.

Stratospheric circulation features of the tropics historically have been treated separately from those of higher latitudes. However, it has become increasingly evident that some of the phenomena can be found at nearly all latitudes, although with varying degrees of intensity. One reason for separate treatment, of course, has been that the usual method of synoptic analysis is not readily applicable in very low latitudes, where the geostrophic approximation is no longer valid.

The basic meridional configuration of the EXAMETNET is highly conducive to research directed toward a determination of the possible linkages between the high and low latitudes of each hemisphere, as well as between the hemispheres themselves. Background for these studies is the information published on the quasi-biennial cycle, which is dominant in the tropical stratosphere up to about 30 km. Above about 30 km a semi-annual component becomes more important, with a peak amplitude at about 45 km. Significantly, the EXAMETNET data have helped to confirm the global extent of the latter mentioned phenomenon.

Because of the obvious impact of satellite-derived temperature-height profiles as a new data source, EXAMETNET recommended an experiment to compare these data with those obtained from rocketsonde and radiosonde observations. In response to this, NASA conducted such an experiment at Wallops Station. Comparison observations are now available in significant numbers and analysis is proceeding.

RECOMMENDATIONS

The recommendations that follow are oriented toward improvements in the scientific, technological and organizational areas of EXAMETNET:

1. Efforts should be continued by each participant to maintain the planned coordinated schedule of launches so as to provide the greatest scientific utility of the network data.
2. Efforts should be continued by the scientists in the analysis of both single station and network rocketsonde data and such other atmospheric measurements that will enhance the scientific utility of the upper atmosphere research.
3. Consideration should be given to the desirability (need) to add launch sites near the latitudes of 25°S, 50°S, 6°N and 50°N. A site at 25°S would provide continuity of measurements between Natal (6°S) and Mar Chiquita (38°S) while sites at 50°S and 50°N would help extend coverage into the higher latitudes. Data from a site at about 6°N, such as Kourou, French Guiana with those from Natal would provide greater information on the structure of the equatorial atmosphere and inter-hemispheric relations.
4. Consideration should be given to gaining cooperative launchings with other countries and agencies who have the capability of operating within the polar regions, such as the Japanese station at Showa and the USSR station at Molodeznaja in the Antarctic. Prime areas in Canada where very useful information could be obtained are Newfoundland and Resolute Bay.
5. Consideration should be given to an increased frequency of launchings. Assurances of at least two meteorological rocket observations per week increases the level of confidence by the scientists using the data. Where possible, a launch schedule which provides more than two launches per week is recommended so that synoptic features of the stratosphere may be followed and studied. Additionally, launch schedules should be provided which, within the capabilities of each participant, will allow phenomenological features to be studied, e.g., stratwarms, quasi-biennial and semi-annual oscillations.

6. Strong consideration should be given to a continuing effort to improve and develop reliable sensors as well as integrated ground, flight, and data systems, along with the particular procedures and techniques to meet the technical and scientific demands of EXAMETNET. These demands include higher accuracy, reliability, and altitude of the flight systems. Efforts should also be directed toward uniformity of standards, lower equipment costs, and improved utilization of manpower.
7. Consideration should be given to assisting the expansion of international meteorological sounding rocket activities. This could take many forms such as exchange of information on observational procedures and techniques, cooperative and coordinated launch campaigns, and representation on committees of international organizations and planning groups.
8. Consideration should be given to the participation in programs for the intercomparison of sounding rocket systems, such as that planned at Thumba, India, as well as to the broad dissemination of the results to the scientific and technical committees.
9. Efforts should be continued to obtain the comparison of satellite temperature sounder data with those from rocketsondes and radiosondes. These comparisons should use the "best" (that being derived by what is considered the best of perhaps several different methods) satellite derived temperatures, along with radiosonde and satellite information gathered at the time of satellite passage over the particular station. In addition, development of the optimum method for merging the satellite data with the in situ observations in an appropriate synoptic analysis technique should be initiated.
10. Consideration should be given to the full utilization of present (Nimbus III and IV) and future data from satellite temperature sounder experiments combined with rocketsonde data in the construction of global stratospheric analysis.
11. Consideration should be given to the utilization of measurements in the fields of Atmospheric Chemistry and Electricity. Preliminary research should, therefore, be oriented toward determining possible phenomenological interactions using data from EXAMETNET and other meteorological rocketsonde observations and parameters associated with chemistry and electricity, such as minor constituents.

Plans should also be formulated for extension of EXAMETNET soundings to include such parameters if the preliminary studies yield optimistic results.

REFERENCES

1. Bettle, J. F., J. F. Spurling, and F. J. Schmidlin:
The establishment of the Experimental Inter-American
Meteorological Rocket Network (EXAMETNET), presented
at American Institute of Aeronautics and Astronautics
(AIAA) Sounding Rocket Vehicle Technology Specialist
Conference, Williamsburg, Va., February 27-March 1, 1967.
2. Clark, D. D., 1965: A meteorological rocketsonde. J. Sci.
Inst., 42, 733-736.
3. Miller, A. J. and F. J. Schmidlin, 1970: Rocketsonde
repeatability and stratospheric variability. J.
Appl. Meteor. (In press.)
4. Schmidlin, F. J. and A. J. Miller, 1971: Rocketsonde
manufacturers and calibration variabilities and their
relationship to temperature measurements. NASA TM
(to be published).
5. Spurling, J. F. and A. J. Miller, 1969: Rocketsonde
satellite comparison experiment. Paper presented at
the 6th annual EXAMETNET meeting, Rio de Janeiro,
Brazil, Oct. 1969.
6. Schmidlin, F. J., 1968: A preliminary quality control
technique with application toward checking rocket
winds. (Unpublished manuscript.)
7. EXAMETNET, 1968: EXAMETNET data preparation and guidance
procedures manual. Available from Meteorology Section,
NASA, Wallops Station, Wallops Island, Va., 45 pp.
8. Miller, A. J., 1969: Response characteristics of meteor-
ological rocket wind reduction techniques. J. Geoph.
Res., 74, 6853-6858.
9. Ballard, H. N., 1967: A review of seven papers concerning
the measurement of temperature in the stratosphere and
mesosphere. ECOM-5125, Atmos. Sci. Lab., White Sands
Missile Range, 67 pp.
10. Beyers, N. J., B. T. Miers and R. J. Reed, 1966:
Diurnal tidal motions near the stratopause during 48
hours at White Sands Missile Range. J. Atmos. Sci.,
23, 325-333.

11. Finger, F. G. and H. M. Woolf, 1967: Diurnal variation of temperature in the upper stratosphere as indicated by a meteorological rocket experiment. J. Atmos. Sci., 24, 230-239.
12. Miller, A. J., H. M. Woolf and F. G. Finger, 1968: Small-scale wind and temperature structure as evidenced by meteorological rocket systems. J. Appl. Meteor., 7, 390-399.
13. Miller, A. J., 1969: A note on the variability of temperature as indicated by rocketsonde thermistors. J. Appl. Meteor., 8, 172-174.
14. Finger, F. G. and H. M. Woolf, 1967: Southern Hemisphere stratospheric circulation as indicated by shipboard meteorological rocket observations. J. Atmos. Sci., 24, 387-395.
15. Manning, J. C. and F. W. Chamberlain, 1966: Shipboard rocket measurements of wind and temperature up to 65 km in the Southern Hemisphere, Minutes of AMS Conference on Dynamic Structure on the Free Atmosphere, Nov. 1966.
16. Staff, Upper Air Branch, 1967: Weekly Synoptic Analyses, 5-, 2-, and 0.4-mb surfaces for 1964 (based on observation of the Meteorological Rocket Network during the IQSY). ESSA Technical Report WB-2, Silver Spring, Md., 176 pp.
17. Miller, A. J. and F. G. Finger, 1969: Synoptic analysis of the Southern Hemisphere stratosphere. NASA TM X-1814, 23 pp.
18. Miller, A. J., F. G. Finger and M. E. Gelman, 1970a: 30-mb synoptic analyses for the 1969 Southern Hemisphere winter derived with the aid of Nimbus III (SIRS) data. NASA TM X-2109, 27 pp.
19. Lichtenstein, E. R., V. R. Barros and M. W. Vargas, 1967: The reversal of the stratospheric circulation over Chamical during the Spring of 1966. CNIE Report - PE-12, 6 pp.
20. Brynsztejn, S. M., 1970: Two years of meteorological rocket soundings at Chamical. (Unpublished manuscript.)
21. Quiroz, R. S., 1965: Mid-winter stratospheric warming in the Antarctica revealed by rocket data. J. Appl. Meteor., 5, 126-128.
22. Miller, A. J., 1970: A note on vertical motion analyses for the upper stratosphere. Mo. Wea. Rev., 98, 616-620.

23. Quiroz, R. S. and A. J. Miller, 1967: Note on the semi-annual wind variation in the equatorial stratosphere. Mo. Wea. Rev., 95, 635-641.
24. Laboratorio de Fisica Espacial (LAFE) report - 95, 1969: Brazilian participation in the EXAMETNET program.
25. Angell, J. K. and J. Korshover, 1970: Quasi-biennial, annual and semiannual zonal wind and temperature harmonic amplitudes and phases in the stratosphere and low mesosphere of the Northern Hemisphere. J. Geoph. Res., 75, 543-550.
26. Belmont, A. D. and D. G. Dartt, 1970: The variability of tropical stratospheric winds. J. Geoph. Res., 75, 3133-3145.
27. Raja Rao, K. S. and K. T. Joseph, 1969: Stratospheric and lower mesospheric wind systems in the Equatorial region. Indian J. Met. and Geoph., 20, 213-220.
28. Laboratorio de Fisica Espacial (LAFE) report - 137, 1970: Brazilian participation in the EXAMETNET program.
29. Salgado, J. A. M., U. Belculfine, C. Girardi, M. Del Tedesco and F. de Mendonca, 1967: Meteorological sounding rocket program at Natal. LAFE report - 62, 93 pp.
30. Salgado, J. A. M., U. Belculfine, M. Del Tedesco and F. de Mendonca, 1966: Meteorological sounding rocket program at Natal. LAFE report - 47.
31. Eliassen, A. and E. Palm, 1960: On the transfer of energy in stationary mountain waves. Geofys. Publ., 22, 1-23.
32. Muench, H. S., 1965: On the dynamics of the wintertime stratospheric circulation. J. Atmos. Sci., 22, 349-360.
33. Newell, R. E. and M. E. Richards, 1969: Energy flux and convergence patterns in the lower and middle stratosphere during the IQSY. Quart. J. Roy. Met. Soc., 95, 310-327.
34. Miller, A. J. and K. W. Johnson, 1970b: On the interaction between the stratosphere and troposphere during the warming of Dec. 1967-Jan. 1968. Quart. J. Roy. Met. Soc., 96, 24-31.

35. Miller, A. J., 1970: The transfer of kinetic energy from the troposphere to the stratosphere. J. Atmos. Sci., 27, 388-393.
36. Perry, J. S., 1967: Long wave energy processes in the 1963 sudden stratospheric warming. J. Atmos. Sci., 24, 539-550.
37. Johnson, K. W., A. J. Miller and M. E. Gelman, 1969: Proposed indices characterizing stratospheric circulation and temperature fields. Mo. Wea. Rev., 97, 565-570.
38. Henry, R. M. and R. S. Quiroz, 1970: Preliminary results from a meteorological rocket experiment. Nature, 226, 1108-1110.

SUPPLEMENTAL REFERENCES

1. EXAMETNET Executive Committee: EXAMETNET Data Report Series, 1966, 1967, and 1968 Quarter Reports, Numbers 66-101, 66-102, 66-103, 66-104, 67-101, 67-102, 67-103, 67-104, 68-101, 68-102, 68-103, and 68-104; Annual Report, 1968; Annual Report, 1967.
2. Johnson, K. W. and M. E. Gelman, 1968: Temperature and height variability in the middle and upper stratosphere during 1964-1966 as determined from constant pressure charts. Mo. Wea. Rev., 96, 371-382.
3. Miller, A. J. and H. M. Woolf, 1967: An extrapolation procedure for determining the height of a meteorological rocket instrument in the event of tracking-radar failure, published as Appendix in EXAMETNET Data Report Series No. 67-102, 28 pp.
4. Quiroz, R. S., and A. J. Miller, 1968: Height-lag correlations of density with pressure and temperature at rocket altitudes of the stratosphere. J. Atmos. Sci., 25, 104-112.
5. Schmidlin, F. J., 1966: Graphical method for determining atmospheric pressure from rocketsonde observations. Mo. Wea. Rev., 94, 529-533.
6. Spurling, J. F. and N. Arizumi, 1967: The Japan-United States meteorological rocket project, presented at the Seventh International Symposium on Space Technology and Science, Tokyo, Japan.
7. Staff, Upper Air Branch, 1969: Weekly synoptic analysis, 5-, 2-, and 0.4-millibar surfaces for 1966 (based on meteorological rocketsonde and high-level rawinsonde observations). ESSA Technical Report WB 9, 169 pp.
8. Staff, Upper Air Branch, 1969: Stratospheric synoptic density maps for 1964-1965 and for the warming event of December 1967. NASA TM X-1903, 49 pp.
9. Woolf, H. M., 1968: On the computation of solar elevation angles and the determination of sunrise and sunset times. NASA TM X-1646, 19 pp.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE \$300

FIRST CLASS MAIL

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION



POSTMASTER: If Undeliverable (Section 158
Postal Manual) Do Not Return

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546