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ANALYSES IN THE FIELD OF SATELLITE METEOROLOGY

WILLIAM K. WIDGER, JR.

ARACON GEOPHYSICS COMPANY
CONCORD, MASSACHUSETTS
A DIVISION OF ALLIED RESEARCH ASSOCIATES, INC

31 JULY 1963

PART I
(SUMMARY)
FINAL REPORT
UNDER
CONTRACT NO. AF 19(628)-320
PROJECT 6698
TASK 669802

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AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE BEDFORD, MASSACHUSETTS

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ANALYSES IN THE FIELD OF SATELLITE METEOROLOGY

1. Introduction

1.1 This constitutes the Final Report with regard to Analyses in the Field of Satellite Meteorology under Contract No. AF 19(628)-320.

1.2 Under the terms of the contract, it was specified that research and development studies were to be performed in the following areas:

1. Analyses of the results of various studies of satellite meteorological data to determine what methods have been discovered, and evaluation of those methods.

2. Feasibility and pilot diagnostic studies of satellite meteorological techniques, as directed by the contracting officer.

3. Literature surveys and the conduct of seminars as directed by the Satellite Meteorology Branch of AFCRL.

4. Studies of the use of satellite data for tropical operations and, in particular, a study of techniques to determine the eye or center of tropical storms and hurricanes and some qualitative estimation of their circulation intensity from satellite photographs.

5. Development of simplified techniques for geographic location and orientation of satellite photographs, and for data extraction, for use by meteorological personnel, world-wide and at remote read-out sites.

A further originally specified area of work, pertaining to preparation of materials for exposition and training, was deleted under the terms of modification 1.

1.3 From the viewpoint of specific technical topics and approaches, the research and development work under Contract No. AF 19(628)-320 can best be divided into the following areas, which will be used as the basis for discussion in the remainder of this report. The correlation between this division of areas of work, and that as specified in the Statement of Work and summarized just above, will be presented in Section 1.4.

- A. Analysis of terrestrial features as seen by TIROS, for the area of the continental United States (excluding Alaska), and initiation of the construction of a landmark map portraying these features.

B. Development of a modification and improvement of the Fujita method of TIROS picture location and rectification, which was suggested from use of the Fujita technique during the work under "A".

C. Investigation of the characteristics of the Nimbus Automatic Picture Transmission (APT) System as they apply to the nature and utilization of the data to be expected from the APT System, and preliminary development of techniques for the geographic referencing and use of such data.

D. Partial compilation, from the technical literature, of operationally applicable techniques for the utilization of meteorological satellite data.

E. Initial studies toward a tropical storm development model based on TIROS photographs.

F. Analyses of stratiform cloud patterns in the Canary Islands area and development of a possible explanation for an anomolous "doughnut"-shaped cloud pattern photographed there by TIROS I on May 8, 1960.

1.4 Table I indicates the correlation between the topics specified in the Statement of Work as listed in Section 1.2, and the technical organization of the studies as listed in Section 1.3.

2. Analyses of Terrestrial Features and Initiation of the Construction of a Landmark Map

2.1 Under Contract No. AF 19(628)-320 the analysis of terrestrial features within the continental United States (excluding Alaska) was completed and work was begun on the landmark map which would portray these features. It was not, however, possible to complete this work, or even to bring it to a point justifying the preparation of a scientific report, prior to suspension of work under the satellite meteorology portion of the contract.

2.2 Accordingly, the completion of the maps and the preparation of a suitable descriptive report was transferred to Contract No. AF 19(628)-2471; and the maps and report have been issued under that contract. The landmark map consists of two sections, each covering approximately one-half of the United States, at a scale of 1:3,000,000. The maps and studies leading to them

are described in Scientific Report No. 2 under Contract No. AF 19(628)-2471 entitled Terrestrial Features of the United States as Viewed from TIROS. As that report indicates, the photography of the TIROS meteorological satellite series is providing the first continuous view, from outside the atmosphere, of the earth's surface and its cloud masses. To assist in the problems of identification, due to the similarity of many clouds to certain terrestrial features, a map has been compiled portraying the United States as its surface features appear in TIROS photography. The ground patterns are those of late winter and early spring (February - April). The report, which is to accompany the map, is a compilation of photographs illustrating selected geographical features as shown on the map or noted during its preparation, with descriptive comments on the nature of these features and why they are visible in the TIROS pictures.

3. Development of Modified Fujita Technique for TIROS Picture Location

3.1 During the course of the identification and study of terrestrial features as viewed by TIROS, extensive use was made of the techniques developed by Dr. Fujita¹ for precise location and rectification of TIROS photographs. It became apparent to the investigator, Mr. Cronin, that certain modifications which might expedite the application of the basic technique were possible.

3.2 The technique as amended by Mr. Cronin and Mr. Abreu of W. E. Howell Associates, Inc., has been published as Scientific Report No. 1 of this contract with the title: A Modification of the Fujita Method for TIROS Photograph Rectification.

3.3 The technique is a manual one which permits the portrayal of a latitude-longitude grid on the satellite photography with maximum accuracy; consistent results with errors no greater than one-fifth of a degree of great circle arc have been attained. As described in the report, use of the procedures has been accelerated by the incorporation of primary points and nadir angles as published by NASA; in the original Fujita technique, this information is obtained by several additional steps which require an earth horizon on at least one or two photographs of each orbit for which picture location is to be determined. As a consequent further advantage, the modified technique can be applied to

Technical Organization
Of The Studies

TABLE I

Topics Specified In The Statement of Work

	1	2	3	4	5
	Analysis Of Various Studies	Feasibility and Pilot Diagnostic Studies	Literature Surveys	Tropical Studies	Geographic Location Techniques
A. Terrestrial Feature Analysis	X	X	X		
B. Modification of Fujita Method	X	X			
C. APT System	X	X	X		X
D. Compilation of Operational Techniques	X		X		
E. Tropical Storm Development Model	X	X		X	
F. Stratiform Cloud Patterns				X	

graphic rectification of any orbit, whether or not horizons are present. No loss in accuracy is introduced by this abbreviated method.

3.4 It is expected that the ease with which one can acquire the basic data, and the rapidity, accuracy, and simplicity of this technique, should encourage a greater research use of TIROS photography, particularly among those who do not have ready access to computer-drawn geographic grids.

4. Investigation of the Characteristics of the Nimbus Automatic Picture Transmission (APT) System and Preliminary Development of Data Location Techniques

4.1 The Nimbus APT System has been designed to automatically photograph the area under the satellite, at intervals of about 208 seconds, and to immediately relay the picture to relatively inexpensive ground receiving and presentation equipment located at weather stations within radio range of the satellite transmitter. During the course of this part of the work under the contract, it was learned that the APT system might also be test flown in later TIROS satellites, and it was necessary to use significant resources to devise methods of coping with the TIROS spin-stabilized attitude.

4.2 The objective of this study was to develop a system whereby the receiving weather stations could readily and with reasonable accuracy geographically locate the various cloud features visible in the APT pictures.

4.3 The work in this area, prior to its transfer to Contract No. AF 19(628)-2471, has been reported in the following four Technical Notes under Contract No. AF 19(628)-320:

4.3.1 Technical Note No. 1, Notes of Nimbus System "A" Meeting, 14-15 August 1962. Subjects discussed at the meeting and in this Technical Note included: APT System Characteristics, Map Projections and Errors, Ground Station Operations (including Antenna Tracking, Picture Timing, and Picture Gridding), Communications, and Pre-launch Phasing of the Program.

4.3.2 Technical Note No. 2, Recommendations for System "A" Operational Data Dissemination. In this note, recommendations for the contents of a daily and weekly message were proposed to provide personnel at direct readout facilities with a means for coping with data handling tasks associated with the envisioned TIROS and NIMBUS System "A" operations. A

minimum data content daily message format was suggested to comply with restrictions on available teletype transmission time. Data contained in the daily message are of such form as to permit the user to extrapolate information, on-site, with minimum difficulty should communication lines be temporarily interrupted. Data requirements necessary to keep a read-out facility operational during extended communications failures were also mentioned. Data of the latter type are apt to be voluminous and would not be well suited for dissemination on crowded teletype circuits.

4.3.3 Technical Note No. 3, Notes of Nimbus System "A" Data Utilization Meeting, November 8, 1962. Subjects discussed at this meeting and in this Technical Note included: Communications to Remote Sites; Orbital Specifications, Tolerances and Accuracies; and Tracking and Geographical Charts (including accuracy, techniques, formats, backup procedures, and training).

4.3.4 Technical Note No. 4, Recommendation for Nimbus System "A" Maps and Station Procedures. This note described proposed manual techniques for the geographic referencing of APT pictures, including such topics as satellite tracking, determination of satellite position at picture time, and picture location and referencing using both projection and overlay techniques.

4.4 The detailed procedures adopted for the use of the APT ground stations, as further developed under Contract No. AF 19(628)-2471, have been reported in Scientific Report No. 1, APT Users' Guide, under that contract.

5. Compilation of Operationally Applicable Techniques for the Utilization of Meteorological Satellite Data

5.1 Only extremely limited studies had been possible in this area before. Because of the higher priority indicated by the Contract Monitor, it was necessary to divert available personnel and resources to the work on terrestrial landmark features and the APT geographical referencing techniques. The results to that point do not permit a meaningful technical report or even a worthwhile summary at this time. It is hoped that work in this area can later be resumed and brought to fruition under Contract No. AF 19(628)-2471 or a successor thereto.

6. Initial Studies towards a Tropical Storm Development Model

6.1 During the studies of TIROS data for tropical areas, especially with regard to estimations of circulation intensity, it became apparent that a tropical storm development model (essentially analogous to the development model proposed by Boucher and Newcomb² of ARACON Geophysics Co., for extratropical vortices) was feasible.

6.2 Although considerable progress was made in both the initial formulation and the implementation of the concept, it was not possible to carry the studies to completion, or even to a stage justifying preparation of a technical report, because of diversion of resources to work on terrestrial landmark features and the APT geographical referencing techniques after the Contract Monitor requested that these be given priority. It is intended that the studies will be brought to completion, and that a scientific report covering this work will be submitted, under Contract No. AF 19(628)-2471.

6.3 The work carried out under Contract No. AF 19(628)-320 has clearly demonstrated that, from analyses of satellite-observed cloud patterns relating to tropical cyclone developments, a composite model can be, and (to a major degree) has been, developed. Each stage in the development can be illustrated by an appropriate TIROS example. A progression from an initial convergent band is apparent, with the vortex stages just prior to the establishment of a vigorous surface circulation having a banded and a clearly defined cyclonic appearance. The initial appearance of cirriform clouds seems to signal the onset of hurricane force surface winds beneath the cirriform cloud deck. The cloud structures illustrating the more mature stages of development possess characteristic patterns which permit reasonable estimates of the changes of surface and low-level wind intensities.

7. Analyses of Stratiform Cloud Patterns near the Canary Islands

7.1 This study, a by-product of work on tropical vortex-shaped cloud patterns in the eastern Atlantic, has been separately reported as Scientific Report No. 2 under Contract No. AF 19(628)-320 entitled: An Analysis of Stratiform Cloud Patterns in the Canary Island Region.

7.2 TIROS-observed stratiform cloud patterns of the Canary Islands region were analysed during two different synoptic situations. The results of these analyses suggested that the variations in cloud distribution in these cases are related to variations in the direction of the low level wind. Application of this hypothesis provides a possible explanation for the "doughnut" cloud which appeared on May 8, 1960, in TIROS photographs of this area; the annular shaped cloud is believed due to a heat-produced thinning of the stratus, carried down-wind from the islands and possibly intensified by circulations associated with a weak low pressure system in the area.

8. Summary Listing of Reports Covering Work under Contract No. AF 19(628)-320.

8.1 Quarterly Progress Reports under the contract:

1. First, covering period 1 January through 31 March 1962; dated 2 April 1962.
2. Second, covering period 1 April through 30 June 1962; dated 3 July 1962.
3. Third, covering period 1 July through 30 September 1962; dated 10 October 1962.
4. Fourth, covering period 1 October through 31 December 1962; dated 14 January 1963.

8.2 Technical Notes under the contract:

1. No. 1, Glaser, A. H., and L. Goldshlak: Notes on System "A" Meeting 14-15 August 1962, dated 27 August 1962.
2. No. 2, Goldshlak, L.: Recommendations for System "A" Operational Data Dissemination, dated 14 November 1962.
3. No. 3, Brooks, E. M.: Notes of Nimbus System "A" Data Utilization Meeting, 8 November 1962, dated 26 November 1962.
4. No. 4, Brooks, E. M.: Recommendations for Nimbus System "A" Maps and Station Procedures, dated 28 December 1962.

8.3 Scientific Reports under the contract:

1. No. 1, Cronin, J. F., and L. W. Abreu, 1963: A Modification of the Fujita Method for TIROS Photograph Rectification.

2. No. 2, Merritt, E. S., 1963: An Analysis of Stratiform Cloud Patterns in the Canary Islands Region.

8.4 Reports under other contracts:

1. Goldshlak, L., 1963: APT Users' Guide, Scientific Report No. 1, Contract No. AF 19(628)-2471.
2. Cronin, J. F., 1963: Terrestrial Features of the United States as Viewed from TIROS, Scientific Report No. 2, Contract No. AF 19(628)-2471.

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1. Fujita, T., 1963: A Technique for Precise Analysis for Satellite Data; Volume I-Photogrammetry, USWB Meteorological Satellite Laboratory Report No. 14.
2. Boucher, R. J., and R. J. Newcomb, 1962: "Synoptic Interpretation of Some TIROS Vortex Patterns: A Preliminary Cyclone Model, "J. Applied Meteorology, 1 (2), pp. 127-136.

AF Cambridge Research Laboratories, Bedford, Mass. ANALYSES IN THE FIELD OF SATELLITE METEOROLOGY, PART I, (SUMMARY) FINAL REPORT, by W. K. Widger, Jr., July 1963 pp. AFCRL-63-843 Unclassified report A summary of research and development analyses in the field of satellite meteorology is presented. Topics discussed include: Analysis of terrestrial features as seen by TIROS, and construction of ○	UNCLASSIFIED 1. Meteorological Satellites 2. Terrestrial Features 3. Rectification (Photography) 4. Nephanalysis I. Widger, W. K. Jr.	AF Cambridge Research Laboratories, Bedford, Mass. ANALYSES IN THE FIELD OF SATELLITE METEOROLOGY, PART I, (SUMMARY) FINAL REPORT, by W. K. Widger, Jr., July 1963 pp. AFCRL-63-843 Unclassified report A summary of research and development analyses in the field of satellite meteorology is presented. Topics discussed include: Analysis of terrestrial features as seen by TIROS, and construction of ○	UNCLASSIFIED 1. Meteorological Satellites 2. Terrestrial Features 3. Rectification (Photography) 4. Nephanalysis I. Widger, W. K. Jr.
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