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FROM GEOSTATIONARY SATELLITES"

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16. Abstract This is the first Quarterly Report on "Studies of Soundings and Imaging Measurements from Geostationary Satellites." The report covers work performed during the quarter on five related studies.					
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Preface

This is the first quarterly report on Contract NAS5-21798, "Studies of Soundings and Imaging Measurements from Geostationary Satellites." The studies supported by this contract are a continuation of work on applications of satellite data, especially meteorological data collected from geosynchronous orbit. This work was begun with the launch of the ATS-1 satellite and among many other results, has lead directly to the development of methods to measure cloud motions with high accuracy and at operational rates. The technique is being implemented by NASA under separate contract and will be used extensively to support the GARP Atlantic Tropical Experiment (GATE) scientific and operational efforts. The Man-Computer Interactive Data Access System (McIDAS) is the equipment and software set needed to implement the cloud motion measuring technique; however, McIDAS also can be used to access, display, and process data to achieve many other important objectives. This year's studies are directed largely at exploring these other applications for McIDAS. The prototype equipment used to demonstrate the McIDAS concept is being used to support the studies, and we have experienced considerable difficulty in forcing this prototype equipment to operate over long periods and to process large volumes of data with precision. Nevertheless, if we are to be prepared to use the complete McIDAS with the efficiency necessary to support GATE; we must pursue the present studies despite prototype hardware maintenance problems. This first quarterly report covers our difficulties as well as our progress, and explains our actions to overcome our problems.

Introduction

The work proposed by SSEC for the period 1 August 1972 to 31 July 1973 was organized into several individual tasks each with specific objectives. It was necessary to reduce the overall scope of the contract to conform to NASA funding limitations, and three of the proposed tasks were eliminated and the others replanned. To avoid confusion, each of the original tasks is described briefly here and the action taken in reorganizing the work is indicated.

Task A. Investigations of Meteorological Data Processing Techniques

The objective of this task is to explore use of the McIDAS concept in accessing synchronous orbit satellite data to obtain information other than cloud motion. This task, which is a major effort under the contract, was reduced by 20 percent from the original proposal; however, the importance of this effort in developing applications of satellite data continues to increase and, by reprogramming within the contract, the original scope of the task has been restored.

Task B. Sun Glitter

The objective of this task is to explore techniques of using the specular reflection of the sun on the ocean surface to determine sea surface conditions from which surface wind speed and direction can be inferred. The effort was reduced 25% from the original proposal.

Task C. Particulates

This task was intended to develop further the techniques originated by Dr. McLellan for quantitative measurement of atmospheric

particulates from ATS data. This task was deleted from the original proposal.

Task D. Cloud Growth Rate Study

Under this task we expect to develop techniques for using McIDAS to produce quantitative information on storm cloud intensity in tropical and temperate weather systems. This task was severely reduced including dropping support to one graduate student entirely. However, to prepare to support GATE with McIDAS we have reprogrammed some funds back into this study since the results promise to be of considerable value.

Task E. Comparative Studies in Satellite Stability

Under this task we have continued support to Mr. Aniruddha Das, a Ph. D. candidate in the Engineering Mechanics Department. Das is completing an advanced computer model capable of comparing performance of satellites using spin stabilization versus inertia-wheel or gas reaction motors. Funds on this task were reduced by finding other support for most computer costs and the savings were reprogrammed to Task D.

Task F. High Resolution from Geostationary Orbit

The need to view small areas at high resolution at will and with short delays between images has been recognized for some time. This study was intended to develop feasible design alternatives. The task was deleted.

Task G. Rainfall by RAKE Radar

This task was to be a continuation of the study being performed last year by Collins Radio Co. on the feasibility of using RAKE radar techniques, which were developed jointly by Collins and the University, to the measurement of precipitation amounts from satellites. The work performed last year did not support system feasibility sufficiently to justify continuing the study at this time. Therefore, only a small in-house effort has been conducted under this contract and the remaining funds have been reprogrammed within the contract.

During this quarter our ability to use the prototype McIDAS equipment was limited by two severe maintenance problems:

(1) We depend upon the Raytheon 440 computer to digitize all of our data and for most prototype McIDAS data processing functions. The 440 system has, until this year, given us outstanding service with an "up-time" record over 98%. However, when first installed four years ago, the tape units were operated with soft oxide tapes for a short period of time which resulted in greatly accelerated head wear. In August, the tape units began to malfunction so badly that McIDAS operation was impossible. Since the heads were well within their normal working lifetime and because these units are now a discontinued model, we experienced great difficulty in diagnosing the trouble correctly and in obtaining new heads.

(2) The McIDAS video disk recorder, Ampex Model 10, failed twice while under warranty and was repaired by Ampex at no cost. It failed the third time, still under warranty, and with Ampex agreement it has been sent to their laboratories for repair and reconfiguration to a new model 10 A. Upon close examination, it was found that the disk shaft was not true and

that the unit was in that respect faulty. The new model will use floating heads rather than contact heads and the shaft will be replaced.

The cost to us of these equipment problems has been relatively small in dollars, but has seriously delayed the work which we had planned to perform under this contract. Meanwhile, necessary software modifications have been completed and some portions of the studies have been pursued using hard copy data. We anticipate being able to make up all of the lost time during the remainder of the contract period.

Task Progress

Task A. Investigations of Meteorological Data Processing Techniques

I. Correction of ATS Line Start Jitters:

Precision display ATS images frequently show obvious line start timing errors. The corresponding digital data cannot be navigated accurately and cloud displacement measurements are not possible. The characteristics of this jitter are quite variable. Visual inspection of the imaged earth edges shows small amplitude line to line jitter (not a serious problem because of the averaging done), pseudo - regular deviations of varying amplitude, and discrete large amplitude shifts. The latter two can cause serious problems and occur frequently enough to cause a significant reduction in the fraction of ATS data useable for wind determination. When they are discovered at the time of navigation a substantial waste of time results.

We are currently studying the feasibility of using earth edge detection for two purposes

- 1) early screening of data
- 2) correction of data by "aligning" each scan line with a smooth curve approximating the apparent shape of the earth.

As an example of the second use, assume the earth's curve is a circle; then, even in the presence of skew, frame compression, and rotation, the apparent curve should be an ellipse. By fitting a general ellipse to the measured earth edge positions the smoothed (elliptical) earth edge can be obtained. The next process is to note the displacement of each line of interest from this smoothed edge so that subsequent corrections can be made in the data processing. "Line of interest" would be those covering the area containing the landmark used for navigation, and also those covering the target area for wind determination.

We are currently investigating a case of five digitized ATS images which were brought to the point of Navigation and then rejected because of inconsistencies in apparent landmark motion in the frame. Detailed visual inspection of the corresponding precision display images also revealed irregularities in the earth edge position. Our object is to determine the following:

- 1) To what accuracy can the earth edge be determined for each line.
[How can noise be compensated.]
- 2) Can the smoothed earth edge be determined cheaply and unambiguously?
For example, is it possible to use the analog error signal available in the line start log as a means of automatic line start jitter correction?
- 3) Can the line shifts from the smoothed curve be used to correct the discrepancies in the apparent landmark motion?
- 4) How does visual inspection of earth edge appearance correlate with the computer analysis of the digital data; i.e., how big an error can be determined visually?

II. Bi-Spectral Cloud Height Determination

Radiometric measurements in a single IR window channel can be used to determine cloud altitude only if the following conditions are satisfied;

- 1) The radiometer field of view is small compared to the observed cloud;
- 2) the observed cloud has a known emissivity;
- 3) only a single cloud level is present in the radiometer field of view; and
- 4) the atmospheric temperature profile is known.

Radiometer and cloud simulation tests conducted by SSEC during the performance of NASA contract NAS5-21607 (SMS SOUNDER SPECIFICATION) indicate that these conditions are frequently violated when the radiometer field of view is of the order of 10 to 20 km or larger. For the specific cases tested conditions (1) and (2) were most troublesome.

An additional high resolution (say 1 km IFOV) visible channel (as would be available from SMS) could reduce the uncertainty in condition (2) and especially in condition (1). However, the visible channel essentially responds to the product of the fractional cloud amount N and the albedo a , while the IR channel responds to $N\epsilon$ where ϵ is the cloud emissivity. Since a and ϵ are not simply or even uniquely related, the visible channel can only provide a limited degree of correction when conditions (1) or (2) are violated.

A more promising approach, one which does not require that conditions (1) or (2) be satisfied, is to use two infrared channels with wavelengths sufficiently close together so that cloud emissivity is the same at both wavelengths, although it may exhibit spatial variations over the IFOV or cloud

to cloud differences. At first glance it would appear that two such channels would be redundant and not independent sources of cloud height information. However, by choosing these channels in the 15μ CO_2 absorption band it is possible to obtain large differences in pressure weighting of the channels with only a small difference in wavelength. This approach is currently under investigation by Bill Smith at NESS.

SSEC has also had some experience in bispectral cloud level discrimination in the CO_2 band as a result of work on SMS sounder specification. The approach was not pursued very far because signal to noise ratios for the proposed sounding channels (with narrow spectral bandpass) were generally too high to permit adequate discrimination on a field by field basis. However, the programs for radiance calculation and cloud distribution simulation which were developed in the earlier study provide us with a capability to pursue this approach in significant detail.

The mathematical description of the cloud level determinations follows that given by Smith.¹ The following definitions are required

I_{ν} = observed spectral radiance in channel ν

$I_{\nu, \text{cloud}}$ = spectral radiance of the cloud in channel ν

ϵ_{ν} = cloud emissivity in channel ν

ν = wavenumber of spectral channel

$I_{\nu, \text{clear}}$ = spectral radiance under cloudless conditions (the clear column radiance)

$I_{\nu, B}$ = spectral radiance at ν by a black body at the cloud level

N = fractional cloud cover in the radiometer IFOV

N_{ν}^* = $N\epsilon_{\nu}$ = effective cloud cover for channel ν

The observed spectral radiance in the presence of clouds is given by

$$I_{\nu} = N I_{\nu, \text{cloud}} + (1 - N) I_{\nu, \text{clear}} \quad (1)$$

where

$$I_{\nu, \text{cloud}} = \epsilon_{\nu} I_{\nu, B} + (1 - \epsilon_{\nu}) I_{\nu, \text{clear}} \quad (2)$$

Combining these two equations yields

$$I_{\nu_1} = N_{\nu_1}^* I_{\nu_1, B} + (1 - N_{\nu_1}^*) I_{\nu_1, \text{clear}} \quad (3)$$

$$I_{\nu_2} = N_{\nu_2}^* I_{\nu_2, B} + (1 - N_{\nu_2}^*) I_{\nu_2, \text{clear}} \quad (4)$$

where the subscripts 1 and 2 refer to the two spectral channels. Since cloud emissivity is a slowly varying function of γ the close proximity of ν_1 and ν_2 implies that $N_{\nu_2}^* = N_{\nu_1}^* = N^*$. Thus N^* can be eliminated from the equations to obtain

$$\frac{I_{\nu_1} - I_{\nu_1, \text{clear}}}{I_{\nu_2} - I_{\nu_2, \text{clear}}} = \frac{I_{\nu_1, B} - I_{\nu_1, \text{clear}}}{I_{\nu_2, B} - I_{\nu_2, \text{clear}}} \quad (5)$$

For a given temperature profile the RHS (right hand side) is a function of cloud pressure only. According to Smith, it is also a weak function of temperature profile variations. We shall use a special notation for this ratio, namely

$$F_{1,2}(p) = \frac{I_{\nu_1, B} - I_{\nu_1, \text{clear}}}{I_{\nu_2, B} - I_{\nu_2, \text{clear}}} \quad (6)$$

The LHS (left hand side) of (5) is just the slope of a cloud line in the $I_{\nu_1} - I_{\nu_2}$ plane i.e. if N^* is varied from zero to one and I_{ν_1} is plotted as a function of I_{ν_2} , the resultant curve is a straight line with a slope

given by the LHS of equation (5). This is shown in Figure 1. Note that the slope can also be determined by two pairs of (I_{v_1}, I_{v_2}) measurements at different N^* values i.e., in different IFOV's. In this case knowledge of the clear column radiances would not be needed to determine the slope of the cloud line. Denoting the cloud line slope by dI_{v_1}/dI_{v_2} equation (5) can be rewritten in the form

$$\frac{dI_{v_1}}{dI_{v_2}} = F_{1,2}(p) \quad (7)$$

which states, in essence, that the cloud line slope is uniquely determined by the cloud pressure. The procedure for cloud level determination is to measure (I_{v_1}, I_{v_2}) pairs, determine the cloud line slope, and read off the appropriate pressure from the known function $F_{1,2}(p)$. This process is illustrated in Figure 2.

We are currently beginning to use radiance calculation programs developed under NAS5-21607 to optimize the choice of channels and bandwidths so that $F_{1,2}(p)$ has a strong pressure dependence, and so that radiometer noise is minimized. We are also considering the use of a broad band CO_2 channel coupled with a nearby IR window channel which would allow the high spatial resolution required to minimize the number of condition (3) violations.

We are also considering the feasibility of including one or more additional channels for this purpose on a future SMS; these estimates will make use of the extensive work already done by SSEC in specification of a temperature sounder for SMS. This extended capability for cloud height determination could be extremely important in the tropics, where temperature profile

variations are only slightly greater than the errors inherent in remote sounding. In this case wind determinations at known levels could provide a much better description of the dynamical state of the atmosphere.

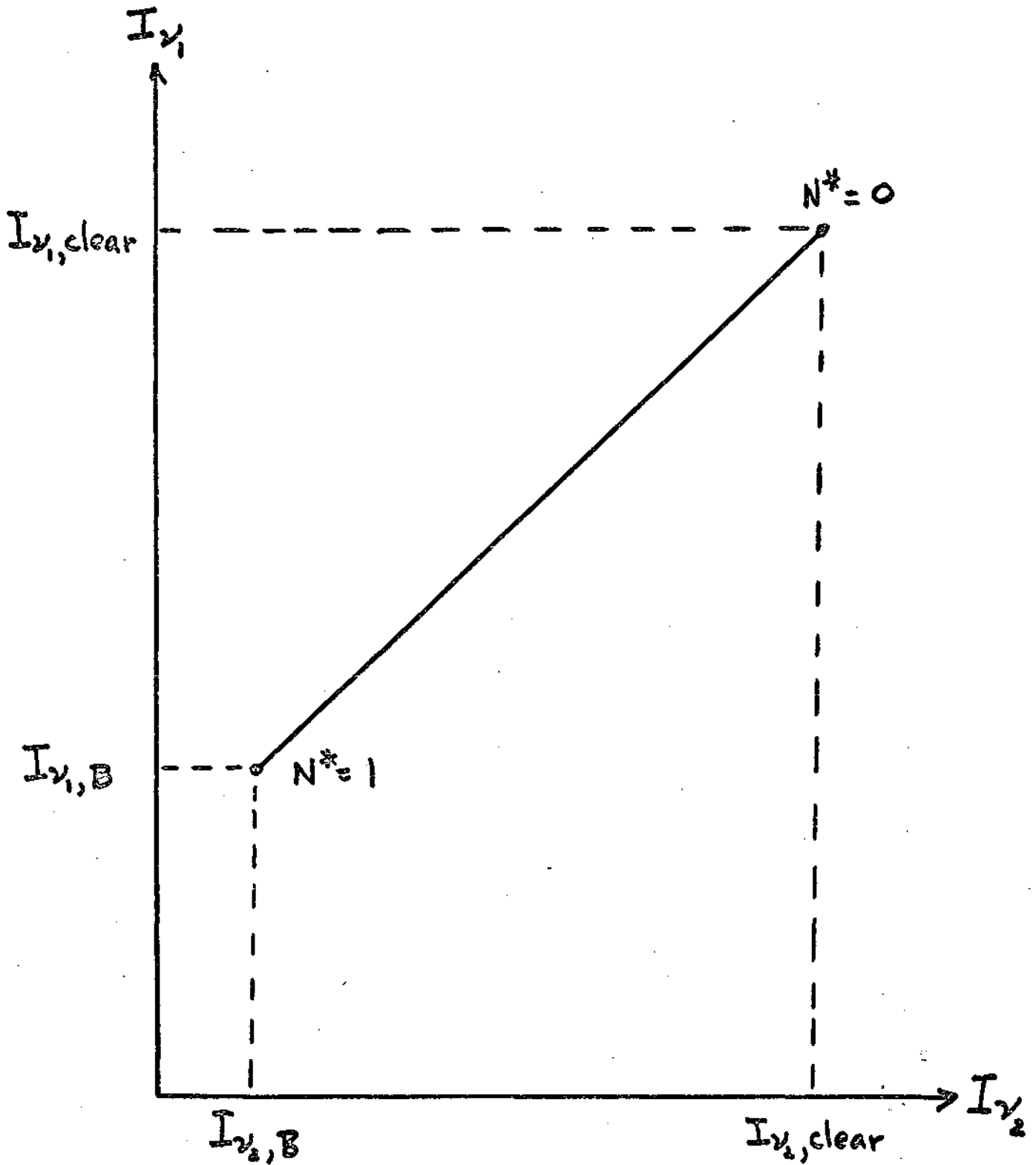


Figure 1. For a single cloud level I_{ν_1} and I_{ν_2} are linearly related. The cloud line slope is determined by cloud pressure.

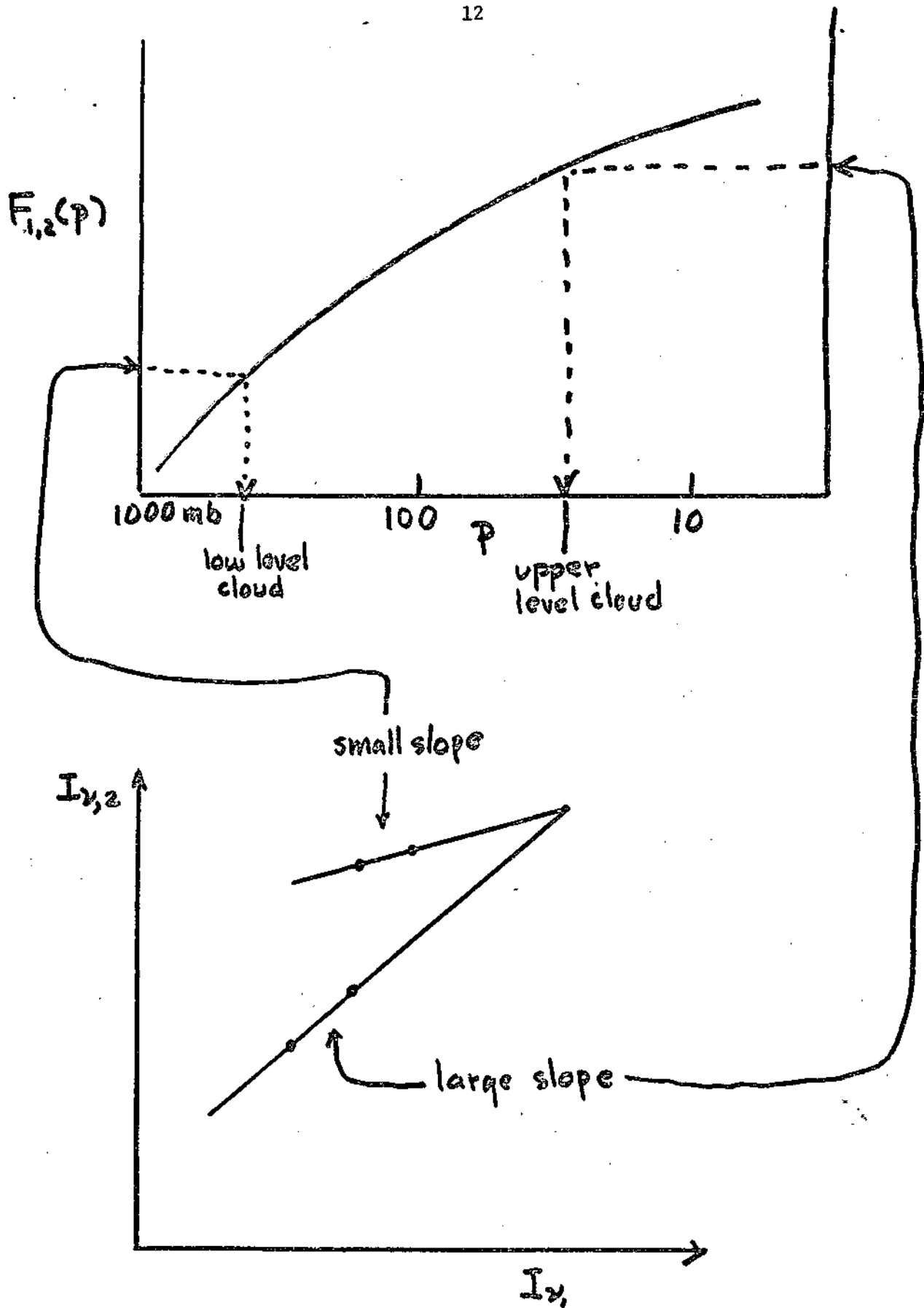


Figure 2. Procedure for cloud level determination.

NOTES

1. William L. Smith, private communication.

Task B. Sun Glitter

Feasibility of sun glitter observations from near earth polar orbiters for surface wind determination is being investigated. A graduate student has been assigned to this project, but little in the way of hard results have been obtained so far. This is due to a necessary interval of familiarization with the main literature on the subject. Current subtopics under investigation include

- 1) Polar orbiter sun glitter geometry; position and size of sun-glitter pattern, pointing requirements, etc.
- 2) Observation requirements: no. of different angles of observation required, sensor resolution acceptable, radiance measurement accuracy required, feasibility of wind direction as well as magnitude measurements.
- 3) Optimum spectral band for minimizing background affects and maximizing signal sources. (Near IR appears desirable at this time).

Task D. Cloud Growth Rate

A few severe storm situations in mid-latitude frontal zones have been selected and digital tapes for several ATS images have been processed for display on McIDAS. Some difficulties have since been experienced in navigating a few of these selected pictures for noise and line jitter in the data. Techniques to eliminate or atleast minimize such problems are being investigated under Task A. In the mean time brightness gradient analyses of a severe storm complex from those tapes already navigated continue with a view to estimating volume flux directly at cirrus outflow levels. The procedure involves in measuring cloud anvil growth-rate atop the severe storm complex and change

in slope of the brightness field from the successive brightness normalized digital displays.

As of today, this research is in the experimental stage and has yielded hardly any significant results for this progress report.

Task E. Comparative Studies in Satellite Stability

The progress report prepared by Mr. Das is technically complex and quite lengthy. It is being proofread by Professor T. C. Huang at this time, but Professor Huang's schedule has not permitted him to complete this work in time to meet the deadline for this report. We will include the quarterly progress report for this task in the next monthly report.

Task G. Rainfall Measurement by RAKE Radar

Work on this task has been terminated because the feasibility of measuring rainfall by RAKE radar from synchronous orbit does not appear sufficiently high at this time. Work during this quarter was limited to critical review of the Collins study performed under the previous year's contract and an overall feasibility analysis. The Collins report, our evaluation and conclusions are included in full in the final report for last year's contract which is now being printed.

It should be noted that the feasibility of using the RAKE technique is only marginally discouraging. It is quite possible that the work performed last year has identified the problem areas sufficiently well so that they can be overcome in the near future.

New Technology

No items of new technology have been developed under this contract during this quarter.

Program for Next Reporting Interval

The prototype McIDAS equipment will be operating by the fourth week in November. After it has been checked out, we will use the system to pursue the objectives of the several tasks as outlined above.

Conclusions and Recommendations

None at this time.