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VISSR Atmospheric Sounder (VAS) Research Review

A summary of a research review held at
Goddard Space Flight Center
Greenbelt, Maryland
June 16-17, 1982

NASA

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VISSR Atmospheric Sounder (VAS) Research Review

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PREFACE

A major advance in geosynchronous weather observation occurred in September 1980 with the launch of the first Visible/Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS). The VAS, an experimental instrument flown onboard the National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES), is capable of achieving multispectral imagery of atmospheric temperature, water vapor, and cloudiness patterns over short time intervals. In addition, this instrument provides for the first time an atmospheric sounding capability from geosynchronous orbit. A second VAS instrument was launched in May 1981. At present (September 1982), the first VAS instrument continues to function on GOES-4 (135°W) and the second instrument operates on GOES-5 (75°W). The GOES-F satellite, scheduled for launch in April 1983, will also carry a VAS instrument.

The VAS Demonstration is an effort funded by the National Aeronautics and Space Administration (NASA) for evaluating the VAS instrument's performance, and for demonstrating the capabilities of a VAS prototype system to provide useful geosynchronous satellite data for supporting weather forecasts and atmospheric research. The specific objectives of the Demonstration are:

- To evaluate the performance of the VAS Instruments on GOES-4, -5, and -6
- To develop research-oriented and prototype/operational VAS data processing systems at the Goddard Space Flight Center (GSFC) and the University of Wisconsin, respectively
- To determine the accuracy of certain basic and derived meteorological parameters that can be obtained from the VAS instrument
- To assess the utility of VAS-derived information in analyzing severe weather situations

GSFC is primarily responsible for carrying out the Demonstration. Members of the VAS Demonstrations Team include scientists from the University of Wisconsin's Space Science and Engineering Center, the NOAA/NESS Development Laboratory in Wisconsin, and NASA's Marshall Space Flight Center (MSFC).

A crucial activity necessary for achieving the objectives of the VAS Demonstration has been the performance of a "ground-truth" field experiment to provide the detailed data sets needed for validating and assessing the VAS measurements. This field program, known as the Atmospheric Variability Experiment (AVE) for VAS, or more simply, the Special Network Experiment, provided 4 days of simultaneous ground-based and satellite data during March, April, and May 1982. Acquisition of the groundbased data was organized by NASA/MSFC through their contractor, Texas A&M University. The VAS Demonstration Team will use these acquired data sets to conduct research directed toward achieving the VAS Project objectives.

At present, the work accomplished by the Demonstration Team has shown the VAS to be a potentially revolutionary instrument with possible applications far beyond the severe local weather discipline. Some of these additional areas include hurricane and extratropical cyclone research, cloud climatology, determination of sea-surface temperatures, numerical modelling, and diagnosis of moisture patterns and upper-air circulations.

Because there is now a reasonable basis for assuming that VAS could improve their weather forecast and service programs, NOAA has initiated an Operational VAS Assessment (NOVA) Program. The program's purpose is to assess the possible improvements to NOAA's weather/environmental analysis and forecasting services if the capabilities of the VAS were put into operational use.

A VAS Research Review was held at GSFC on June 16 and 17, 1982. (See the VAS Research Review Agenda shown in Appendix A). Our intention was to provide a forum for the exchange of information among scientists currently working with VAS data and to inform interested members of the meteorological community of the potential capabilities of the VAS instrument. The Review included a summary of the work performed by the VAS Demonstration Team, the preliminary results from the NOVA Program, and a look at the future plans in both of these areas.

This document summarizes the findings, conclusions, and recommendations presented at the VAS Research Review in June 1982. Each speaker contributed a brief document outlining the message he or she wished to convey, which did not necessarily include a recapitulation of all the materials presented. The main goal has been to produce a document that could be easily read in order to learn who is currently working with VAS data, the results to date, and potential areas for additional research.

James R. Greaves
Conference Chairman

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SYSTEM DESCRIPTION

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The elements of the VAS Demonstration Data Acquisition and Command Network, shown in Figure 1, consists of the following:

- Geostationary Operational Environmental Satellite (GOES)/VAS Instrument
- National Oceanic and Atmospheric Administration (NOAA) Command and Data Acquisition (CDA) station
- Goddard Space Flight Center (GSFC) Data Acquisition and Processing System
- University of Wisconsin Data Acquisition and Processing System

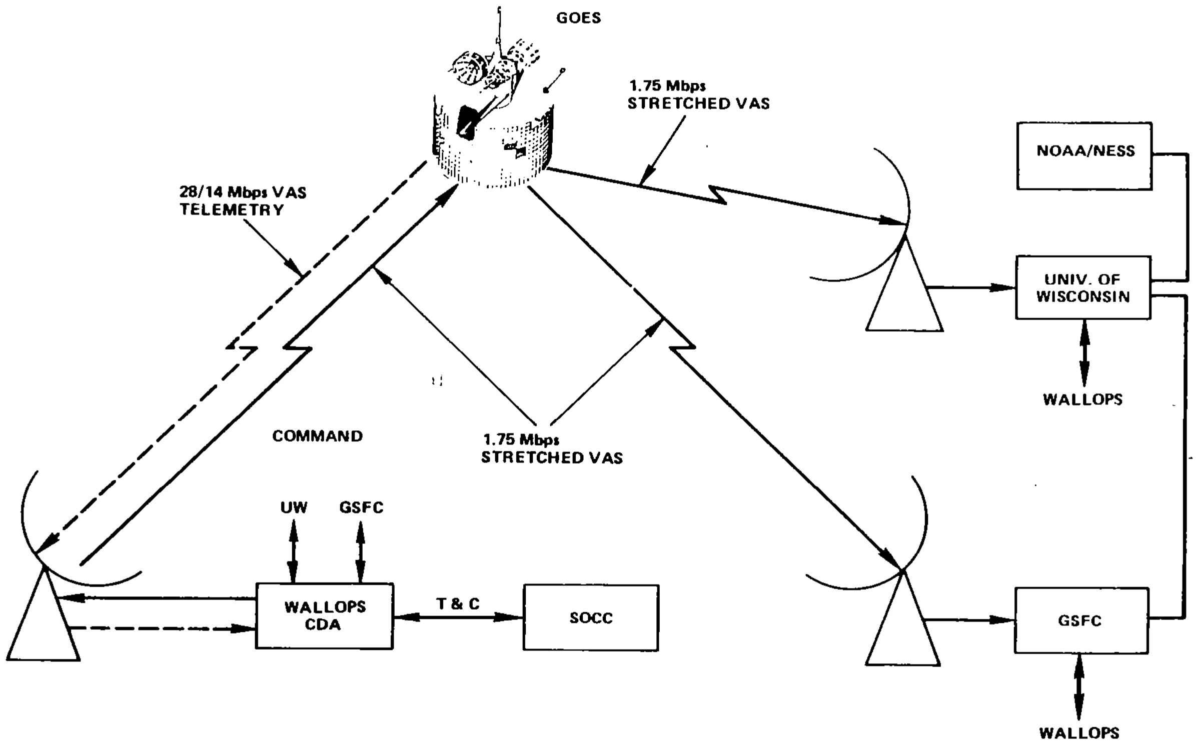

Figure 1. VAS demonstration system.

The VAS, carried onboard the GOES-4 and -5 satellites, is a radiometer with 8 visible channel detectors and 6 thermal detectors that detect infrared radiation in 12 spectral bands. A filter wheel in front of the detector is used to achieve the spectral selection. The spatial resolution is 0.9 kilometer in the visible and 7 or 14 kilometers in the infrared depending on the detector used. Full Earth-disk coverage is accomplished by spinning in the west to east direction at 100 rpm and by stepping a scan mirror from north to south. Additional VAS instrument characteristics are summarized in Table 1.

Table 1
VAS Instrument Characteristics

Spectral Channel	Central Wavelength (μm)	Central Wavenumber (cm^{-1})	Weighting Function Peak (mb)	Absorbing Constituent	Typical Spin Budget*
1	14.7	678	70	CO_2	2
2	14.5	691	125	CO_2	4
3	14.3	699	200	CO_2	7
4	14.0	713	500	CO_2	7
5	13.3	750	920	CO_2	4
6	4.5	2209	850	CO_2	7
7	12.7	787	surface	H_2O	3
8	11.2	892	surface	window	1
9	7.3	1370	600	H_2O	9
10	6.8	1467	400	H_2O	2
11	4.4	2254	300	CO_2	7
12	3.9	2540	surface	window	1

*Number of spins sensed by the same detector with filter and mirror positions fixed.

The VAS has three operating modes: the operational VISSR mode, the multispectral imaging (MSI) mode, and the dwell sounding (DS) mode. The operational VISSR mode is used by NOAA/NESS for its operational products, which include a visible picture and an 11-micrometer infrared (channel 8) picture at half-hour intervals. The other modes are VAS unique. The MSI mode combines the operational VISSR capability (visible plus infrared window) with two additional spectral channels to provide half hourly full Earth disk imagery of atmospheric water vapor, temperature, and cloud distribution. The DS mode is used primarily for sounding to obtain the temperature and moisture profiles. In this mode, multiple spins on the same scan line in a given spectral band are averaged to obtain the required signal-to-noise ratio for sounding.

The DS mode cannot be used simultaneously with either the VISSR or MSI modes. At present, a transparent VAS mode (TVM) is used by NOAA/NESS to provide their operational users with a 15 minute VISSR image every half hour, 24 hours per day, and to provide research users with approximately 15 minutes of MSI data and 11 minutes of DS data every half hour, 16 hours per day. VAS-unique MSI and DS data are relayed through a separate geosynchronous spacecraft to the research users. The operational users receive the VISSR imagery directly from GOES-4 or -5.

The satellite transmits data to the CDA station at 28 Mbps. These data are brought into a computer called the Synchronizer/Data Buffer (S/DB) where they are reformatted, calibrated, quality checked, and merged with telemetry, operations schedules, and navigation parameters. The data are then retransmitted to the spacecraft at 1.75 Mbps. The CDA station commands the GOES and transmits processor data loads (PDLs) to the VAS. The PDL is a command sent to the spacecraft for configuring the VAS instrument. This command selects operational VISSR, MSI, or DS modes and defines the north to south extent of the image, the spectral bands, number of spins per band (when in the DS mode), and detector size.

At GSFC, VAS data are received by an 8-meter dish and microwaved to a preprocessor. These data are then received, reformatted, quality checked, and archived at the preprocessor which then passes the data to the VAS sounding processor through a shared, dual-ported disk. Temperature and moisture extraction can be performed on the sounding processor. These parameters are then passed to the VAS assessment processor which is used to perform meteorological research.

VAS data are also received by an 8-meter dish on the roof of the Space Science and Engineering Center at the University of Wisconsin in Madison, Wisconsin. The data are brought into the Data Base Manager (DBM) where they are reformatted, quality checked, archived, and passed on to the Applications Processor upon request from the scientist. In addition, the DBM receives and archives VISSR, TIROS-N, and other ancillary data. The scientist performs parameter extraction and meteorological research on the Applications Processor through interactive user terminals. The processed data is then archived in the DBM where it and other stored data are available to researchers.

LOW-LEVEL WATER VAPOR FIELDS FROM THE VAS "SPLIT-WINDOW" CHANNELS AT 11 AND 12 MICRONS

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Originally, the VAS "split window" channels were designed to use the differential water vapor absorption between 11 and 12 μm to estimate sea-surface temperature by correcting for the radiometric losses caused by atmospheric moisture. This study shows that it is possible to reverse the procedure in order to estimate the vertically integrated low-level moisture content with the background surface (skin) temperature removed, even over the bright, complex background of the land. Because the lower troposphere's water vapor content is an important factor in convective instability, the derived fields are of considerable value to mesoscale meteorology. Moisture patterns are available as quantitative fields (centimeters of precipitable water) at full VAS resolution (as fine as 7 kilometers horizontal resolution every 15 minutes), and are readily converted to image format for false color movies.

The technique, demonstrated with GOES-5 data from July 13, 1981, uses a sequence of "split-window" radiances taken once every 3 hours from dawn to dusk over the Eastern and Central United States. The algorithm is calibrated with the morning radiosonde sites embedded within the first VAS radiance field; then, entire moisture fields are calculated at all five observation times. Cloud contamination is removed by rejecting any pixel having a radiance less than the atmospheric brightness determined at the radiosonde sites. Independent verification with the evening radiosonde sites showed agreement over a wide range of water content. The most striking demonstration of the relative accuracy of the fields is the space-time continuity of many vivid subsynoptic and mesoscale moisture features that developed over the Midwest. Dry areas noticeably change because of advection and subsidence, and wet areas evolve convective clouds and scattered rainfall, all of which correspond to the lower resolution features in the conventional meteorological data. Indeed, during the afternoon of the case study, thunderstorms broke out within Iowa following the development of a very moist clear area.

This algorithm produces real time, quantitative, mesoscale moisture fields at high resolution with relatively modest computing effort. The image fields are an informative background for displaying

the contours of other key parameters retrieved from VAS dwell soundings. At present, the VAS "split-window" channels are available from GOES-5, so that regional low-level moisture images could be distributed along with operational VISSR pictures.

DIAGNOSING CONVECTIVE INSTABILITY USING VAS DATA

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This presentation shows the utility of combining visible and various infrared images from the VAS to produce a forecasting tool, that can be available on a near real-time basis, to predict severe weather development. Areas where dry air in the midtroposphere overlays substantial moisture at low levels are used to diagnose mesoscale regions that have the potential for being convectively unstable before the onset of severe convection. Specifically, 6.7 micron water vapor imagery, used for isolating regions of substantial midlevel dryness, are combined with images of low-level clouds or with "split-window" low-level moisture images described earlier to delineate regions that have the potential for convective instability. In areas where scattered low-level clouds are present, computer-generated, color image combinations are used to isolate those warm, low-level clouds that are in potential convectively unstable environments from clouds that exist under a deeply moist atmosphere. In clear regions, the "split-window" technique is used for delineating areas of substantial boundary-layer moisture. These images are again computer overlayed by the midlevel dryness to produce a color-coded image of potential convective instability.

Results from several cases were presented, including January 20, July 13, and July 20, 1981. In all cases, convection develops in the convectively unstable air, usually along the edges of the bands of upper-level dryness or in the presence of some form of a low-level lifting mechanism. Although the primary changes affecting the midlevel dryness patterns appear to result from advective processes, substantial enhancements and deformations of the mesoscale dryness patterns do occur at space and time scales that cannot be resolved by using conventional radiosonde data only. These translations and modifications, combined with the dramatic increases of low-level moisture noted in the previous paper, can cause isolated regions to become convectively unstable over a period of only a few hours. The time evolution of these convectively unstable regimes indicates that VAS can provide subjective, mesoscale information on a real-time basis before the onset of convection. As indicated in the following paper, the subjective results shown here have been independently verified using quantitative sounding procedures.

USE OF THE VAS FOR ANALYSIS OF A PRETHUNDERSTORM ENVIRONMENT

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The two previous presentations showed images of low- to upper-level moisture fields derived from the VAS split window and 6.7-μm channels, respectively. For several cases, the image sequences revealed that the mesoscale moisture distribution can be derived with VAS radiances. This presentation's purpose is to demonstrate that the information content of the VAS radiances can be converted to meteorological parameters useful for analyzing a severe weather environment. The method by which the VAS radiances are converted to vertical profiles of temperature, dewpoints, and equivalent potential temperature involves a basic regression technique using the most local radiosonde data available for establishing a correlation matrix (Chesters et al., 1982).* The results indicate that mesoscale features apparent within images of the radiances can be converted to usable temperature and moisture fields using regression when surface temperature and dewpoint observations (available from National Weather Service (NWS) and Federal Aviation Administration (FAA) stations) are included within the total data base. In addition, our results indicate that surface data are very important for better defining lower tropospheric structure that the VAS radiances alone cannot properly resolve.

Analyses of these retrievals distinctly show mesoscale structure in the temperature and moisture fields derived with VAS radiances collected every 3 hours between 1200 GMT 13 July and 0000 GMT 14 July 1981. The retrievals capture the moisture structure mentioned in the previous papers. More important, convective instability (as defined by a negative $\partial\theta_e/\partial Z$) is clearly detected in Iowa immediately before the onset of convection. The results indicate that the VAS is capable of providing valuable mesoscale information suitable for analyzing a preconvective environment that is generally clear. Toward this end, the VAS is successful in filling in data gaps that exist in the present operational network—both in space, and more critically, in time.

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*D. Chesters, L.W. Uccellini, and A. Mostek, 1982, "VISSR Atmospheric Sounder (VAS) Simulation Experiment for a Severe Storm Environment," *Monthly Weather Review*, **110**, pp. 198-216.

ANALYSIS OF MULTISPECTRAL DATA USING AN UNSUPERVISED CLASSIFICATION TECHNIQUE–APPLICATION TO VAS

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A statistical classification method based on clustering of multidimensional histograms has been applied to several channels of the VAS multispectral imagery.

The objective of the method is to automatically discriminate and classify atmospheric and ground features such as cloud types, atmospheric moisture patterns, ocean, or ground. Such a clustering method has the advantage of forming natural data groupings, without *a priori* classification. Clusters are not limited by straight lines or plane surfaces as is the case in threshold methods. A similar technique has been previously used on European Space Agency Meteorological Satellite (Meteosat) data and details can be found in Desbois et al., 1982.*

The method has been applied to simultaneous full resolution images from channels 8 (11.2 micron), 10 (6.7 micron), and 12 (3.9 micron) from June 22, 1981 at 1932 GMT. Twenty image segments of 64 by 64, 12 image segments of 128 by 128, and 4 image segments of 254 by 254 picture elements were analyzed. In addition, normal VISSR mode images at 1800, 1830, and 2000 GMT were used to identify the classes.

Figure 1 shows the promising results that were obtained during this preliminary study. This figure details the gray levels measured along a scan line and the result of the classification scheme (dashed curves) for the three channels investigated. Each point of the image is affected to a class. Each class is identified by a center of gravity ($\vec{G}$) that is represented by a vector in the three-dimensional space of gray levels. $\vec{G}$ has three components, one for each channel and the values of these components are represented on the dashed lines. Figure 1 indicates the class number in parenthesis and the associated physical feature.

The dynamic clusters method appears to be useful for extracting objective information for cloud classification from the three channels investigated in this study. *In-situ* data, however, are needed for validating the classification method. An effort should be made to reduce the computer time used by the current method.

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*M. Desbois, G. Seze, and G. Szejwach, 1982, "Automatic Classification of Clouds on Meteosat Imagery: Application to High-Level Clouds," *J. Appl. Met.*, 21, pp. 401-412.

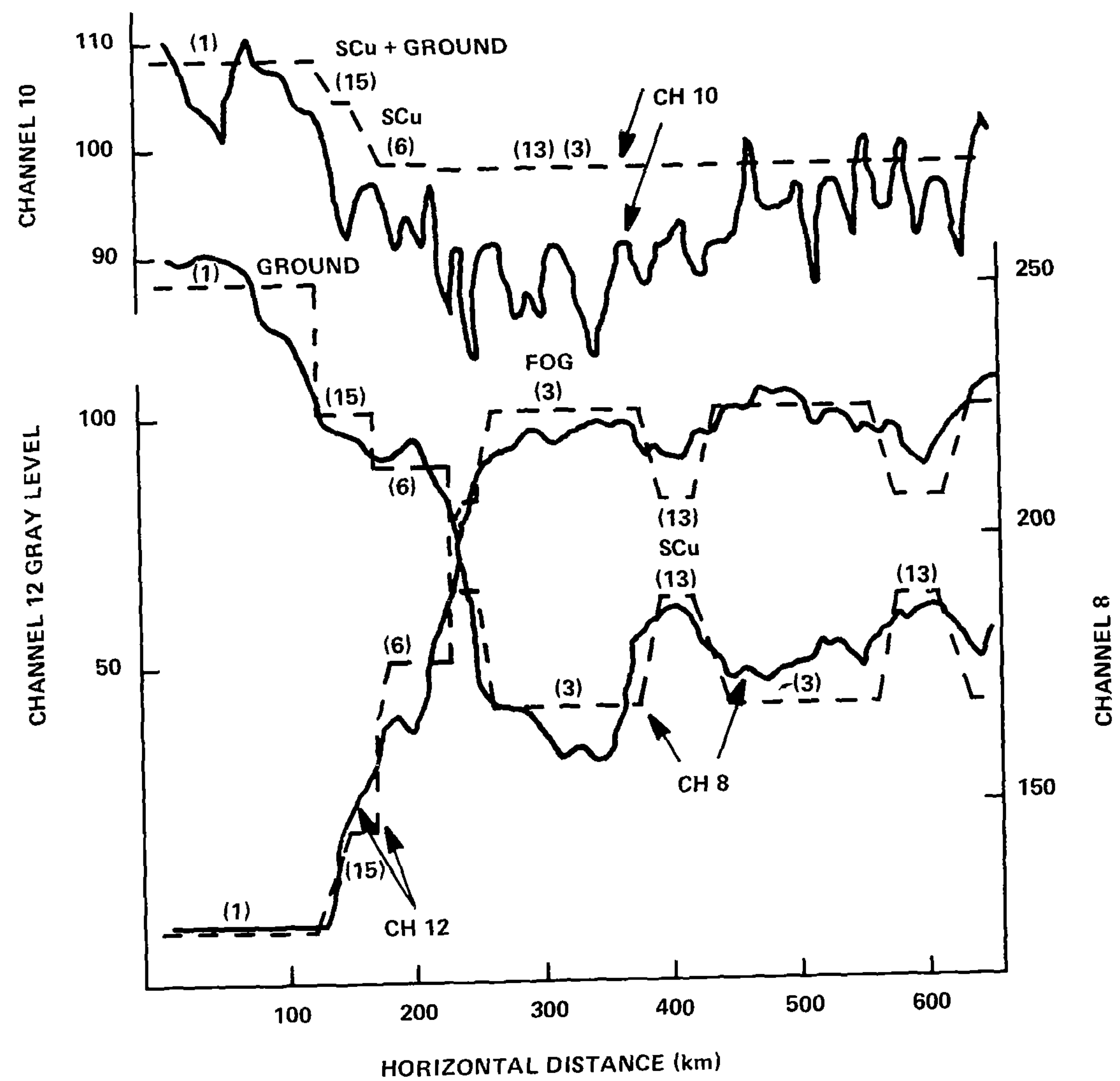

Figure 1. Gray levels observed along a scan line and results of the classification scheme.

THE INFERENCE OF TROPICAL CYCLONE DYNAMICS USING GOES VISSR/VAS DATA

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Arnold (1977) theorized that tropical cyclone formation and intensification may occur in regions where a lower tropospheric cyclone vortex is superimposed under a limited area of (~radius 200 kilometers) dynamically forced upper tropospheric subsidence. This subsidence is caused by the upper tropospheric convergence of outflows from adjacent deep convective cells or between convective cells and the environmental flow. The subsiding air produces warming aloft through adiabatic compression. This in turn causes a thickness increase aloft that creates a circulation favorable for evacuating mass from the subsidence column, thereby causing pressure to fall below the level of warming. The lower pressure enhances lower tropospheric mass and moisture convergence, which increases the enthalpy of the column through both adiabatic warming and latent heat release from the enhanced convection. This enhanced convection, if it exists long enough, initiates the release of Conditional Instability of the Second Kind (CISK) which is needed for further development. This phenomenon was also hypothesized by Fritsch and Chappell (1980) for mesocyclogenesis.

This sequence of events was observed on 2 September 1981 during tropical cyclone Emily, and was suggested as a possible mechanism for cyclogenesis. Geostationary Operational Environmental Satellite (GOES) East VISSR/VAS sensors were used. The VISSR visible imagery obtained every 15 minutes was used to define the low tropospheric cyclonic vortex and upper tropospheric horizontal convergence. The VAS water vapor (channels 9 and 10) and carbon dioxide (channels 3 and 4) channels were used to infer upper and middle tropospheric subsidence by monitoring the adiabatic compressional drying and warming, respectively, occurring within this layer.

Evidence of an existing lower tropospheric cyclonic vortex is seen in Figure 1. The figure shows the satellite-derived wind vectors (length of vector is proportional to wind velocity, where the strongest winds were approximately 35 knots) superimposed on the GOES visible image of tropical storm Emily at 20 GMT 2 September 1981. Vectors and low-level clouds depict the center of the cyclonic vortex immediately south of the large convective cell in the center of the image. Upper tropospheric cloud tracers and rawinsonde reports along the Eastern United States suggest that the southwesterly environmental upper tropospheric flow is converging with the outflow from the convective cell north of the vortex.

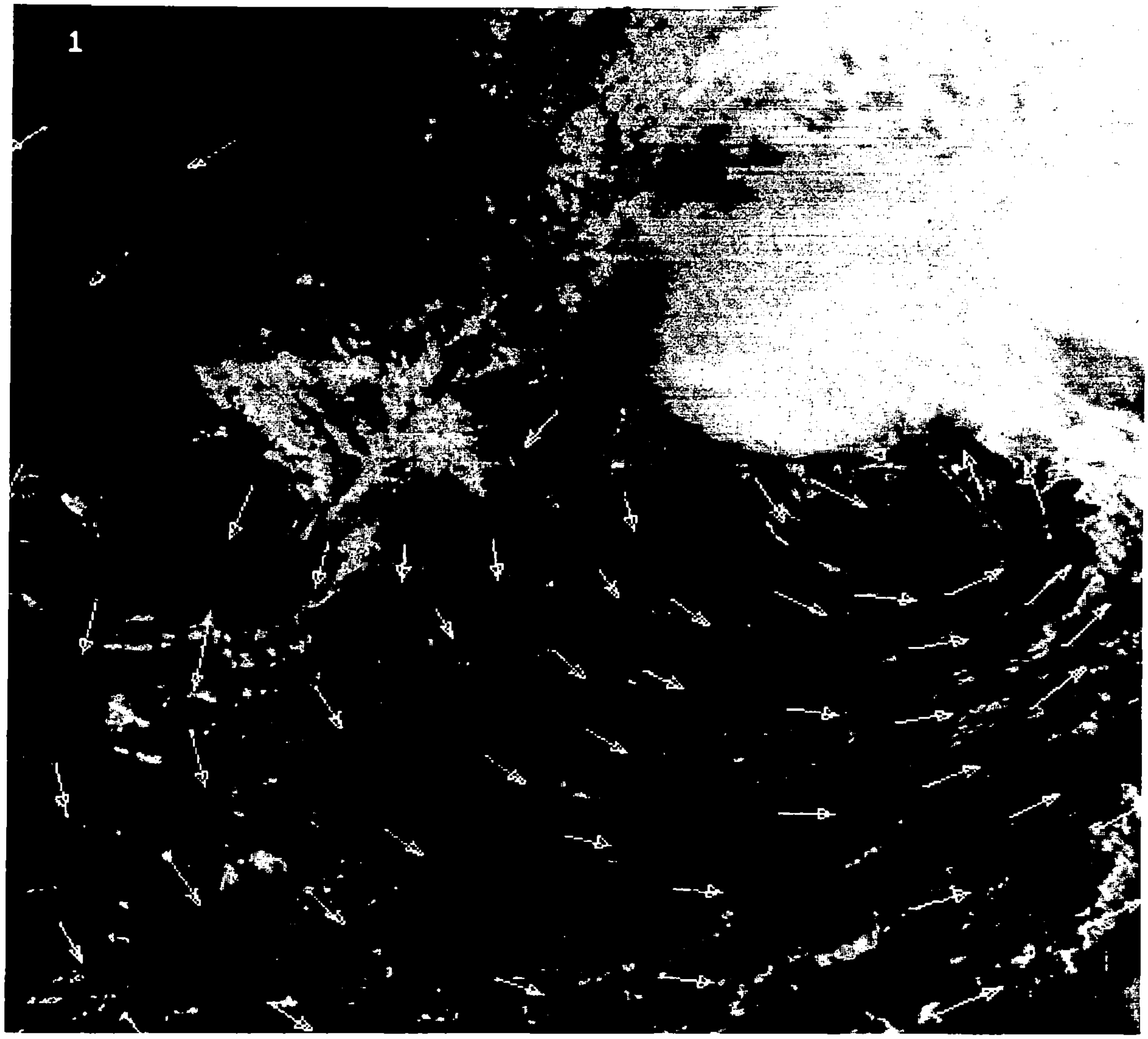

Figure 1. Satellite-derived wind vectors superimposed on GOES visible image of tropical storm Emily at 20 GMT 2 September 1981.

Inference that this upper tropospheric convergence is causing localized subsidence above the lower tropospheric cyclonic vortex is seen in Figure 2. This figure, which shows the radiance information from VAS channel 10 (6.7-μm water vapor channel) of tropical storm Emily at 11, 14, 17, and 23 GMT 2 September 1981, suggests that the area above the lower tropospheric vortex is drying during the 12-hour period as delineated from the increased clear column brightness temperatures (T_B). Since there is no source of dry upper tropospheric air surrounding Emily, the drying that is being inferred from this VAS channel in the clear column above the vortex was most likely caused by subsidence. This subsidence caused an approximate temperature increase in the upper troposphere within a 200-kilometer radius area superimposed above the vortex of 0.5°C during the

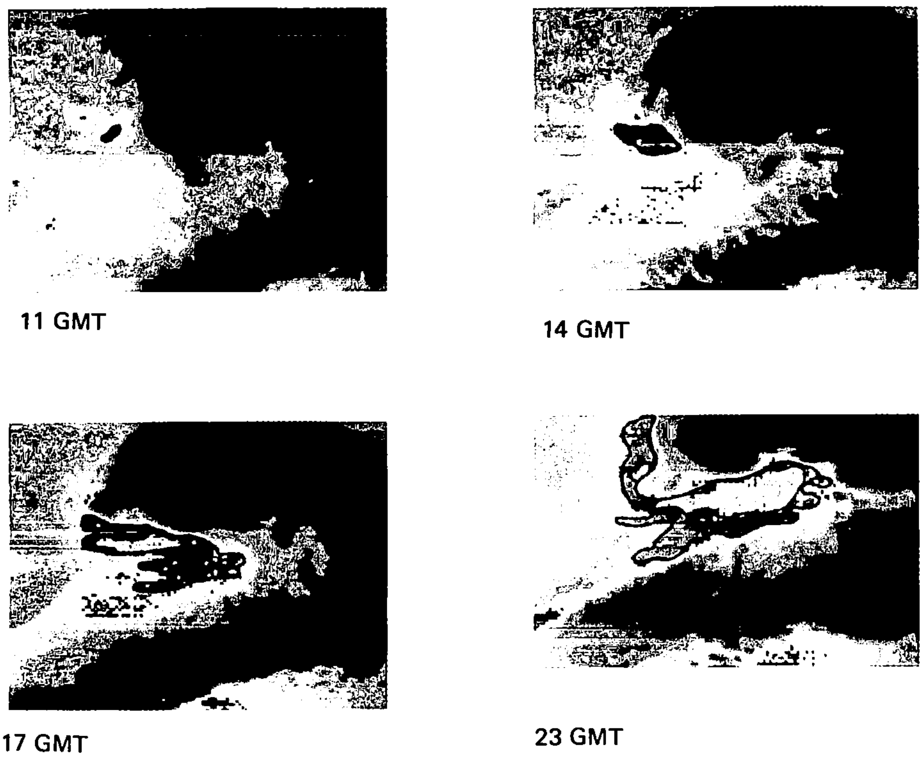

Figure 2. VAS water vapor (channel 10) radiances for tropical storm Emily on 2 September 1981. Contours are the 251 K and (in 1700 and 2300 GMT only) 254 K equivalent blackbody temperature lines.

12-hour period. Gray (1975) showed that a warming of 0.5°C over a layer 200 to 500 mb within an area of 200-kilometer radius would cause a minimum surface pressure decrease of 1.5 mb in order to satisfy the gradient wind balance.

Although there were no aircraft observations of Emily at this time, GOES images revealed that the convection within the vortex increased with an eye at the center. These images suggest that Emily continued to intensify during the time period after the VAS observations.

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Fritsch, J. M. and C. F. Chappell, 1980, "Numerical Prediction of Convectively Driven Mesoscale Pressure Systems. Part II: Mesoscale Model," *J. Atmos. Sci.*, **37**, pp. 1734-1762.

Gray, W. M., 1975, "Tropical Cyclone Genesis," Colorado State University, Department of Atmospheric Science, Paper No. 234, 121 pp.

VAS ASSESSMENT STATUS AND PRELIMINARY RESULTS

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The following major points were presented at the VAS Research Review:

a. Despite the fact that the National Oceanic and Atmospheric Administration (NOAA) did not prepare for routine VAS operations before 1985 and because of the unprecedented level of interest in the early application of this new VAS weather observing tool, NOAA, the National Aeronautics and Space Administration (NASA), and the University of Wisconsin (UW) pooled their equipment and manpower resources to enable routine VAS operations to be successfully accomplished as a result of a highly cooperative and motivated effort.

b. VAS soundings, produced in real time on an hourly basis, consistently delineate the areas of the country where intense convective weather will occur several hours in advance of the severe weather developments. This conclusion is based on the daily experience gained at UW as a result of the NOAA/UW VAS "Nowcasting" program. An objective method of forecasting the "Probability of Severe Weather" for 100-kilometer square areas of the United States from the VAS soundings was presented. Figure 1 is an example sequence of these probability forecasts and the subsequent observed severe weather.

c. There are several limitations of the VAS for mesoscale applications:

   - Because it operates in the infrared, the VAS is not effective in regions of extensive cloud cover. Therefore, the VAS is not expected to be useful for delineating weather associated with winter frontal systems.

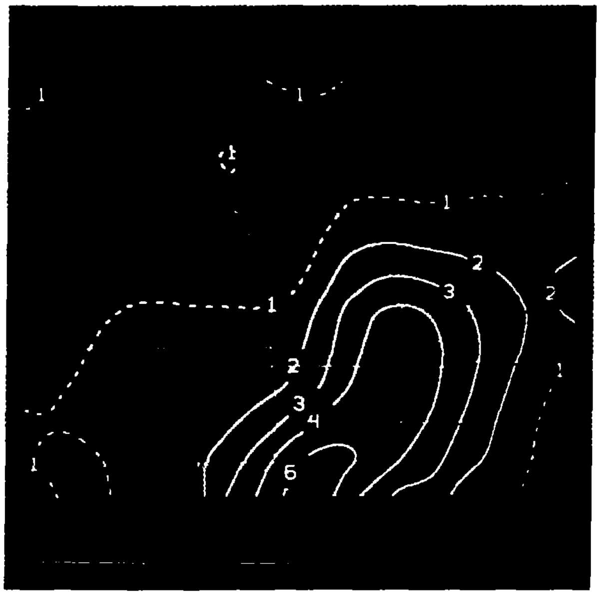
   - The relatively low-spectral resolution of the sounding radiance measurements limits the vertical resolution of the VAS instrument.

   These limitations can be overcome by adding a microwave sounding capability and by using high-spectral resolution interferometric techniques on future geostationary weather satellites.

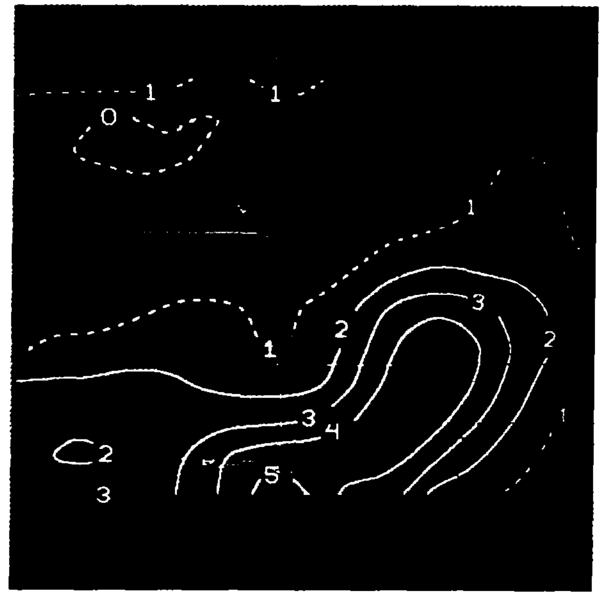
d. Basic limitations of the current "real-time" processing system at the University of Wisconsin are:

   - Use of a relatively slow (0.2 MIPS) Harris computer for data processing

   - Research scientists performing the routine VAS data processing operation

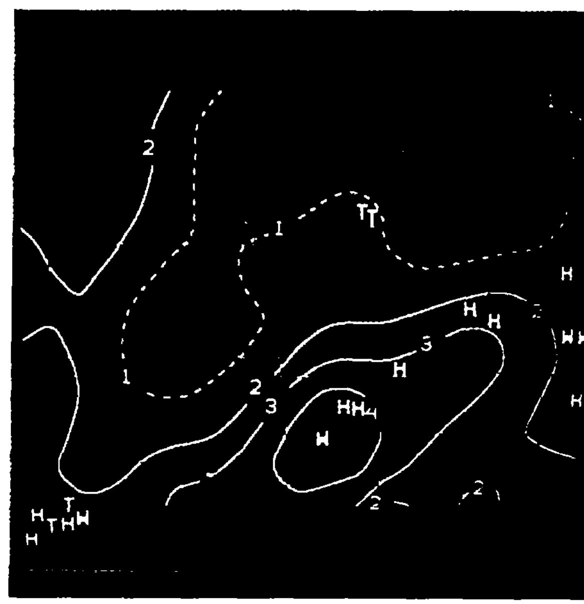


1400 GMT



1500 GMT

1600 GMT



1900 GMT

Figure 1. Probability of severe weather (%/10) forecast from VAS sounding on May 21, 1982. The forecasts are valid 3 to 9 hours after the VAS observation time. (Plotted on the 19 GMT analysis are symbols for the actual severe weather (W-wind, H-hail, and T-tornado) which occurred after 2200 GMT.

In the future, these limitations should be alleviated by using a much more powerful IBM-4341 computer (1.2 MIPS speed) and by hiring and specifically training personnel for routine VAS data processing operations.

VAS OPERATIONAL PROCEDURES AND RESULTS AT THE KANSAS CITY SATELLITE FIELD SERVICES STATION

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The Kansas City Satellite Field Services Station (SFSS) is participating in an operational assessment of VAS data by using a Man-computer Interactive Data Access System (McIDAS) terminal linked with the University of Wisconsin by a 9600-baud telephone line. The terminal is located within the National Oceanic and Atmospheric Administration (NOAA) complex of the National Severe Storms Forecast Center (NSSFC) and the SFSS. During the period March through May, 7 hours of VAS data were processed and edited daily by Dr. Smith's group at the University. Since mid-May, data have been scheduled 16 hours a day, 7 days a week; however, during this time period there have been very few days with 16 hours of data to evaluate.

Our McIDAS terminal, which has 10 display frames and 5 graphics, provides access to the sounding data processed. These data are processed using two procedures. The dwell sounding (DS) data are generated by using all 12 spectral channels with a spin budget of 39. To provide coverage for most of the United States, soundings are made starting at 18 minutes after the hour from approximately 49°N to 36°N and at 48 minutes after the hour from 36°N to 26°N. The dwell imaging (DI) mode uses 11 channels but the spin budget is 17. With the reduced spin budget, retrievals can be made at 18 or 48 minutes after the hour for approximately 44°N to 27°N. With these constraints we proposed a schedule of data sets to use and how they might best be employed operationally. Table 1 shows the schedule and how the data set could be used.

Table 1
Schedule of Data Sets

Start Time		Received	Purpose
(1048/1118)	DS	1230	RAOB Comp.
1248	DI	1400	1530 Outlook
(1348/1418)	DS	1530	Trends
1548	DI	1700	Trends
(1648/1718)	DS	1830	1930 Outlook
1848	DI	2000	Watches
(1948/2018)	DS	2130	Watches
2148	DI	2300	Watches

During our near real-time evaluation, the following characteristics of each parameter were focussed on: gradients, axes, and trends or changes. The parameters that much of our working time has been devoted to are: low-mid-upper level relative humidity, precipitable water, stability indices (LI, TOT, K), temperature, dewpoint for 850-700-500 mb, and winds for 850-300 mb.

Thus far experience has shown the schedule (Table 1) to be rather ambitious. By trying to evaluate the data operationally the following problem areas were identified.

Data Voids

The major problems are associated with cloudiness. In addition, because these voids move, continuity from one set to the next is obscured. At any given time these voids may be quite large and prevent us from creating realistic analyses or change fields from the analyses.

Uncertainty in Absolute Values

The range of absolute values for many of the satellite-derived parameters exceeds the range of those derived from conventional RAOB data. This characteristic has hampered our effort to involve other meteorologists in the evaluation.

Time Lag

Use of these sounding data can be improved by ensuring that processing and editing is limited to less than 1 hour. At present, the delay averages at least 2 hours and frequently more.

Inadequate Vertical Resolution

When comparing VAS and radiosonde soundings, it became readily apparent that VAS had inadequate resolution of the lower tropospheric temperature and moisture profiles.

Sometimes Inadequate Horizontal Resolution

Under special cases (e.g., when the dry line location is desirable), VAS provides no more detail than the surface station dew points.

Data Compete with RISOP/RRSD Mode

The current ground system configuration prevents multimode satellite operations—so VAS is terminated if RISOP or RRSD is called. As a result, VAS is estimated to have been terminated by late afternoon at least 70 percent of the time. In fact there have been very few cases where we have seen afternoon-processed VAS data.

VAS OPERATIONAL PROCEDURES AND RESULTS AT THE KANSAS CITY SATELLITE FIELD SERVICES STATION

Differences Between DS and DI Data

Before early June, VAS DI data were derived using only nine channels and a spin budget of 19. During this period, significant fluctuations were noted from hour to hour between the two types of data. DI data have tended to be more unstable and more moist. Since early June, however, when the process was changed to include 11 channels with a spin budget of 17, only minor fluctuations in differences between DS and DI data were noticed.

Limited Hard-copy Ability

Lack of a hard-copy device has severely limited our ability to document many of the parameters operationally reviewed. Because our only way to save data is to get a printout, we have routinely received printouts for each set of lifted indices, total totals, and precipitable water.

The following observations summarize our experience with VAS data thus far. Many of these observations are based on material that was learned while working with VAS data during April.

- Axes of VAS parameters correlate well with conventional fields but maxima and gradients are frequently underestimated.
- 500- and 300-mb level winds are consistent with conventional radiosonde winds but 850-mb winds are frequently underestimated.
- Lower level vertical wind shear is underestimated with strong synoptic weather situations.
- 600- and 400-mb level relative humidity values provide good continuity and correlate well with radiosonde data.
- Low level relative humidity (800 mb) is much less consistent and difficult to assess.
- Precipitable water used in combination with stability indices (lifted index) often points to strongest convective development.
- VAS data improve horizontal resolution of some parameters.
- Subtle trends are often masked by biased maxima or minima.
- Extreme stability trends are well identified but the degree of instability may not correlate with RAOB data over the area of interest.
- VAS- and RAOB-derived stability indices can not be realistically compared.

Based on these findings, we have the following recommendations:

- Improve the algorithms incorporating conventional surface data to improve lower tropospheric profiles.
- Minimize differences between DS and DI data (this problem has already been addressed and reduced significantly).
- Develop a VAS threat index from retrieved temperature, moisture, thicknesses, precipitable water, and stability indices, or the raw radiances.
- Consider reducing the 5 by 5 (field of view) spatial matrix to improve horizontal detail.

In addition to the tremendous potential of VAS sounding data, the multispectral imagery (especially the moisture channel) has also provided several operational benefits. These data allow us to monitor the evolution of upper-circulation systems and their significant features such as deformation zones and upper level vorticity centers or lobes. The imagery provides better continuity of the cutting-off or coming-out process of upperlows and improves our ability to observe the interaction between the polar jet and low latitude circulation systems. VAS data also allow identification of upper-air conditions that are favorable for the outbreak of deep convection over land areas during the afternoon heating or nighttime cooling. In summary, it is obvious that the VAS's multispectral imagery and sounding data have tremendous potential, but we have only scratched the surface in recognizing its potential use.

SPECIFYING HEIGHTS AND VELOCITIES OF CLOUD MOTION FROM GEOSTATIONARY SOUNDING DATA

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Data from the geostationary Visible/Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS) has been processed for assigning simultaneous heights and velocities of cloud-motion winds. Two techniques are discussed: the first technique delivers qualitative height assignments from imagery and the second technique uses the radiometric information contained in the VAS data to calculate quantitative heights.

Qualitative height assignments and quantitative velocities are achieved with the carbon dioxide (CO_2) slicing method. This technique uses sequences of half hourly CO_2 channel images (spectral bands 3, 4, and 5 at 703, 715, and 751 cm^{-1}) for tracking clouds at high (351 to 100 mb), middle (651 to 350 mb), and lower (sfc to 650 mb) levels. This CO_2 slicing improves cloud-vector determinations (because the individual cloud elements are tracked at a given altitude) and it indicates the height assignment of the cloud-wind vector. Good agreement with radiosonde wind observations at 200, 400, and 700 mb was found. Errors in the cloud-motion wind velocity are expected to be minimized because apparent motions caused by higher level clouds overlaying lower level clouds are not observed.

The second technique uses sequences of half hourly visible and infrared window channel images for specifying cloud-motion winds and radiances from CO_2 spectral bands 3, 4, and 5 to specify cloud-top pressures. The CO_2 absorption method determines cloud-top pressures from the ratio of differences in cloud-produced radiances and corresponding clear-air values for the CO_2 absorption spectral bands. The method, which does not depend on fractional cloud cover or cloud emissivity (in fact the effective cloud amount is a byproduct of the calculations), becomes unreliable when the difference of cloud-produced radiance and corresponding clear-air value falls within the sensing instrument noise level. Several comparisons of cloud heights, determined by using different techniques, were randomly made over several different cloud types. Comparisons of CO_2 heights with 15 radiosonde observations on April 8, 1982 at 12 GMT were within 50-mb rms with no discernible bias; comparisons with 12 stereo cloud-height determinations were within 30-mb rms with no discernible bias; and comparisons with 20 bispectral cloud heights were within 100-mb rms with the bispectral heights biased about 30 mb too low in altitude. This last comparison indicates the difficulty the bispectral technique has with cirrus clouds. Cloud heights are estimated too low because the infrared window senses radiation from within and below the thin clouds, thus the brightness temperature is an overestimate of the cloud temperature.

This work was accomplished on the Man-computer Interactive Data Access System (McIDAS) at the University of Wisconsin where man interaction enabled selection of cloud elements, checking for consistency of cloud height and wind fields, and editing of erroneous results. Both CO_2 slicing and CO_2 absorption heights can be calculated by using multispectral imaging data from spectral bands 3, 4, 5, and 8. Therefore, by employing the VAS on GOES-5, the heights and velocities of cloud-motion winds could be specified on a daily basis over large regions of the globe or the Western Hemisphere.

EVALUATION OF THE EFFECT OF VAS DATA ON SOME NMC ANALYSES AND FORECASTS

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VAS data have been studied at the National Meteorological Center (NMC) since early 1981. This paper summarizes the results of an experiment, conducted between October 1981 and January 1982, that was designed to examine the effect of VAS data on the limited-area fine-mesh model (LFM) analysis-forecast system. VAS data obtained from the Pacific geostationary satellite would be especially valuable for LFM analysis because temperatures from the polar-orbiting satellite over the east Pacific are received too late for 1200 GMT LFM analysis. Because the VISSR has only infrared channels, retrievals are possible only in regions with little or no cloudiness.

Six cases were randomly chosen for the current evaluation, by requiring that, barring computer problems, each case would fall on Tuesday of each week, beginning in November 1981. Each set of VAS observations consisted of 50 to 100 mandatory level soundings made in the dwell sounding (DS) mode (Smith et al., 1981a, b). The soundings, produced at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), Madison, Wisconsin, used the LFM 12-hour forecast (FM12) valid at the time of the data for a first guess in processing the VAS radiances. CIMSS routinely uses the FM12 1000-mb height field as the reference level from which to build mandatory level soundings from the radiance-derived thicknesses.

The corresponding FM12 1000-mb temperatures serve as the 1000-mb temperatures over water in the VAS soundings. At NMC the 1000 mb first-guess heights were subtracted from each sounding at all levels in these tests. The thicknesses thus derived were added to the 1000-mb height analysis for the particular case under consideration during the subsequent analysis, which also included all routinely available conventional data (O'Lenic, 1982). These analyses are herein referred to as "VAS" analyses. Analyses using only the available conventional data are referrred to as "NOVAS" analyses. Likewise, forecasts prepared from these analyses are called "VAS" and "NOVAS" forecasts, respectively.

At 500 mb, the VAS analyses exhibited a considerable (30 to 60 meter) difference from NOVAS analyses. Usually VAS soundings are colder in the 1000 to 500-mb layer by up to 1.5°C, and warmer by about the same margin between 500 and 200 mb than the original LFM analyses. The longitudinal variance of the 500-mb analyses is less than those without VAS, to the south of 44°N, but is larger, by up to $0.4 \times 10^4 \, m^2$, to the north of this latitude. A comparison of VAS and NOAA-7 analyses was made for one case in which a large phase difference was observed between the SAT (VAS and NOAA-7) and the NOSAT analyses. The NOAA-7 analysis reproduced the essential, high-amplitude features of the VAS analysis, although the NOAA-7 analysis differences exhibited a somewhat higher amplitude at 500 mb and lower amplitude at 250 mb than their VAS counterparts. Two out of six of the VAS forecasts were improved by 60 to 90 meters at 500 mb over the NOVAS forecasts. In one case, VAS data introduced large and complex changes to the NOVAS analysis, yet the VAS forecast showed little significant improvement to a forecast, which in the NOVAS mode was already satisfactory. There were two cases in which VAS did little to improve poor forecasts, and one, in which the small observed improvement was far overshadowed by the low quality of the forecast. In summary, using VAS data improved two of the six forecasts studied, and, although the remaining VAS forecasts showed little significant improvement, neither did any forecasts exhibit reduced accuracy.

The analysis method used for the LFM system (Cressman, 1959) has the feature that independent analyses are made first at 1000 and 300 mb. In the absence of data between these levels, the temperature lapse rate in the first guess is preserved in the analysis. When a 1000-mb report (e.g., a surface ship) deepens a trough or low center–and no other data exist–the typical result is the appearance of excessively warm temperatures at low levels in the analysis above the area of lowered 1000-mb heights. This situation occurs because, under the stated conditions, the analysis reduces the effect of such a height change from a maximum value at 1000 mb to no change at 300 mb. A 1000 to 300 bias of opposite sign would be expected when a 1000-mb ridge or high center is amplified by surface ship data. As a rule, lows have more concentrated centers than highs and they are more likely to require correction of the first guess by surface data, which will lead to the falsely-analyzed lower tropospheric previously mentioned. Such a bias might not occur in another, truly three-dimensional analysis system. Even if the VAS thicknesses were identical to those in the first-guess, the successive correction analyses scheme would produce another problematic effect. Under this condition, the 1000-mb height change would be transmitted undiminished with height, upward throughout the atmospheric column, and would correct the excessively warm (or cold) thicknesses back to the first-guess thicknesses, producing a marked reflection of 1000-mb features at all levels up to and including 300 mb. The effect of this process would be to produce either an apparent cold or warm bias, respectively, even though the VAS temperatures agree with the first guess. Therefore, it is suggested that further tests using VAS data use an up-to-date three-dimensional analysis system for eliminating such complications.

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USE OF THE VAS WATER VAPOR IMAGERY TO ANALYZE UPPER-LEVEL FLOW PATTERNS

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Imagery from the present geostationary operational environmental satellites (GOES) provides forecasters with the means by which weather systems of all scales can be monitored every half hour on a 24-hour basis. Since 1974, operational geostationary satellites have provided users with only visible and infrared (IR) imagery in the 11.5-μm window. Now, additional IR channels are available that are being developed for operational use.

In November 1980, GOES-4 was launched with a new instrument called the Visible Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS). This instrument has a radiometer consisting of the standard visible channel detectors and six thermal detectors that detect IR radiation in 12 spectral bands. Any one of the 11 new IR channels can be substituted for the standard 11.5-μm window channel when the satellite is operating in the standard VISSR mode to provide data in image form to operational users through the current GOES distribution system.

In October 1981, the National Earth Satellite Service (NESS) began providing users of GOES-West imagery with two pictures a day from the 6.7-μm IR moisture channel, one at 0015 GMT and one at 1215 GMT. In February 1982, the number was increased to four per day, once every 6 hours. The resolution of the VAS sensor can be either 7 or 14 kilometers, depending on the detector used. The 6.7-μm data currently being sent to users from GOES-West is 14 kilometers; the standard 11.5-μm IR from this satellite is 7 kilometers.

The 6.7-μm moisture channel imagery of VAS was chosen for initial operational evaluation, because it directly augments the standard 11.5-μm window channel IR by providing the operational meteorologist with additional information for diagnosing and monitoring upper-tropospheric flow.

Energy that is measured by the detector at 6.7 μm represents the integrated radiant energy emitted by water vapor through a deep layer of atmosphere. The amount of energy detected by the satellite sensor depends on the temperature and moisture profile of the column of atmosphere being sensed. Low-radiation levels (cold) appear white in the imagery and high-radiation levels (warm) appear dark gray. The precise height of the water vapor being observed cannot be determined since the amount of radiation received by the satellite is a function of both the atmosphere's water-vapor content and its temperature. For a standard atmosphere, the maximum return at 6.7 μm is centered at 400 mb with 80 percent of the energy coming from a layer bounded by 620 and 240 mb.

Moisture channel imagery helps to define the large-scale, upper-level flow better than IR in areas devoid of wind reports and cirrus-cloud motion vectors. This type of imagery also helps to more precisely locate and diagnose upper-level circulation features such as wind maxima, circulation centers, and deformation zones. A great deal can be inferred about the upper-level flow patterns from the motions of cirrus and the evolution of large-scale cloud formations as they appear in the IR window channel. The IR moisture channel makes this process easier because it shows the spatial continuity of upper-level moisture and cloud fields that are related to circulation features. Moisture patterns that are present even when clouds are absent provide clues to the upper-level flow.

Moist and dry areas appearing in the imagery result from a combination of both vertical motion and moisture advection. Moisture patterns in different areas of the image usually will relate to flow at different altitudes. The white (colder) portions of the image will represent flow in a higher layer than adjacent patterns in darker gray (warmer) portions of the image. Analysts should keep in mind how the height of upper-level moisture will be controlled by the height of the tropopause as it varies between troughs and ridges and across the jet.

Moisture patterns combined with cloud patterns can be used to more precisely locate the position of the jet stream axis over the oceans. A strong jet can be located by the sharp, well-defined poleward cloud edge of an associated cirrus cloud shield. The stronger the jet, the better defined the edge and the less ambiguity in interpretation. These jet indicators predominantly occur in southwesterly, upper-level flow. In northwesterly flow, in advance of ridges, cirrus clouds are usually not present to locate the jet axis. A dark zone that parallels the jet axis, however, often appears in the moisture channel imagery. The dark band, which is not always well defined, is believed to represent sinking and drying associated with the jet circulation. Other dark bands, that are similar, are often present and usually represent advection patterns of drier air aloft. The analyst needs to carefully follow the continuity of pattern evolution for correctly diagnosing their origin and for identifying the feature likely to be jet associated. Because of such ambiguities, analysis of animated, frequent-interval moisture imagery is preferred. Experience shows that 12-hour intervals are unsatisfactory and 6-hour intervals still leave some question as to interpretation. Tests with 2-hour frequencies show this interval to be preferable.

CORRELATION OF 3 HOUR RADIOSONDE DATA WITH COINCIDENT NIMBUS-7 TOTAL OZONE MEASUREMENTS

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During Spring 1982 a special network exercise supporting the VAS Demonstration, another special processing activity was also underway. This was the second near-real time total ozone mapping spectrometer (TOMS) activity involving out-of-sequence processing of Nimbus-7 data over the United States and Europe. The ozone data maps were used by Northwest Airlines to search for regions of clear-air turbulence and by the ALPEX team, an aircraft data gathering program, for synoptic upper air and tropopause height analyses.

The Nimbus-7 polar-orbiting satellite crosses the Central United States at 12:00 a.m. (noon) local standard time (1800 GMT). For the four VAS Saturdays March 6 and 27, April 24, and May 1, total ozone maps were generated from the TOMS instrument. On the latter two dates coverage was completed; however, on March 6 the two western orbits were missing (three orbits cover the United States) and on March 27 the center orbit was missing. An effort is being made to recover the March 27 missing orbit.

Usually the National Weather Service (NWS) radiosonde network takes data at 1200 and 0000 GMT, so that the 1800 GMT Nimbus data are 6 hours away from being coincident over the United States. During the VAS Demonstration Special Network Experiment, NWS stations took readings on Saturday at 1200, 1500, 1800, and 2100 and on Sunday at 0300 and 0600 GMT. Therefore, the TOMS total ozone levels can be directly correlated with radiosonde tropopause height for testing the ability of TOMS data to give an independent satellite measurement of tropopause height.

Such a data regression has been done for two European areas by M. J. Munteanu in February 1979 and over the United States by Northwest Airlines during the Spring 1981 real-time TOMS program. Neither of these data sets had coincident temperature sounding radiances and time interpolation had to be used in the Northwest Airlines study. The combination of the VAS/TOMS special network data set is unqiue. The regression analysis at 1800 GMT can be used for determining the relationship between total ozone and tropopause height over the NWS stations. The impact of this independent measure on temperature profiling accuracy can be assessed for the full area of VAS soundings at 1800 GMT.

My team proposes to do the correlation study for March 27, April 24, and May 1 as soon as radiosonde data from the NWS stations are available. The analysis, in draft publication form, would then be made available to VAS sounding teams at Goddard Space Flight Center and University of Wisconsin for additional analysis.

VAS TEMPERATURE RETRIEVALS FOR NASA SPECIAL NETWORK OBSERVATIONS OF 6 MARCH 1982

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There are at least four reasons why March 6, 1982 offers a relatively unique opportunity for an in-depth study of VAS retrieval capability. First, a mesoscale event consisting of a rapidly moving temperature perturbation with strong horizontal wind shear but shallow vertical extent occurred over Texas. Second, the mesoscale event passed through the National Aeronautics and Space Administration (NASA) special radiosonde network and was well documented with three-hourly measurements. Third, the event occurred behind a cold frontal cloud band during clear conditions. Fourth, the event was accompanied by large skin temperature changes as the day progressed. This fortunate combination allows us to test two important aspects of the retrieval algorithms with minimal cloud contamination and good ground truth. The first aspect concerns the horizontal and vertical resolving power of the retrievals and the second aspect concerns sensitivity to the boundary term (the skin temperature).

The resolving power of the VAS system for temperature determination is to some degree a function of the first guess profile and convergence criteria which are required for fitting "calculated" to "observed" brightness temperatures. These enter through the iterative algorithm used in the NESS/Wisconsin processing.

$$T^{n+1}(p_j) = T^n(p_j) + \sum_{i=1}^{m} \frac{W^*(\upsilon_i,p_j)\left\{T_o(\upsilon_i) - T_c^{\,n}(\upsilon_i)\right\}}{\sum_{i=1}^{m} W^x(\upsilon_i,p_j)}$$

where $T^n(p)$ is the temperature profile at the n^{th} iteration (n=0 the first guess); $T_o\ (\upsilon_i)$ is the brightness temperature observed at frequency (ν_i); $T_c\ (\upsilon_i)$ is the brightness temperature calculated at frequency (υ_i); and W is the weighting function appropriate to level j and frequency i.

$$W(\upsilon_i,p_j) = \left(\frac{\partial Tc\ (\upsilon_i)}{\partial B\ (\upsilon_i)}\right)\left(\frac{\partial B\ (\upsilon_i)}{\partial T(p_j)}\right)\ \frac{\partial \Upsilon(\upsilon_i,p_j)}{\partial \ln p}$$

$$W^* = W/\epsilon(\upsilon_i)$$

where B represents the planet radiance, Υ is the transmittance, and ϵ is an estimate of the noise associated with the measurement at frequency υ_i. The ϵ are assigned dynamically according to the spin budget of the measurement and the horizontal averaging imposed in the processing (usually a 5 by 5 field of view).

An initial evaluation of the VAS temperature retrievals after the receipt of the special network data was somewhat disappointing. Whereas VAS data depict the larger scale evolution of the frontal passage, the intensity of the system was seriously underestimated. Most disturbing was the observation that the radiance measurements were not fitted as closely as desired, leaving residuals that had the same sense as the error in the retrieval temperature profile. This evaluation led to a series of experiments that attempted to sensitize the solution, some of which are summarized in Table 1.

Table 1
Changes Relative to Initial Guess Temperature Profile for
Six Experimental Retrievals and Collocated Radiosonde
(Brownwood, Texas) 2000 GMT 6 March 1982

		Ex1	Ex2 (WF)	Ex3	Ex4	Ex5 (WF)	Ex6	RAOB
	975	6.0	6.0	6.0	6.0	6.0	6.0	5.5
P	850	1.5	2.0	2.5	2.7	3.8	4.7	-1.2
R	700	1.4	1.7	1.9	1.3	3.5	4.2	-0.5
E	500	1.5	1.5	1.3	0.7	-0.2	-2.0	-3.3
S	400	1.6	1.6	1.4	0.7	-0.8	-2.6	0.5
S	300	1.4	1.4	1.3	1.8	1.8	1.8	1.7
U	250	1.2	1.0	0.9	2.6	3.7	4.9	3.8
R	200	0.9	0.5	0.2	2.6	4.0	5.8	6.1
E	150	0.7	0.2	0.1	1.9	2.8	4.0	3.3
	100	0.8	0.4	0.1	-0.7	-2.6	-4.1	-0.1
Iter.		2	5	9	4	9	15	

The right-hand column of Table 1 gives the error of the first guess (a profile interpolated from National Weather Service limited-area, fine-mesh model (LFM) analysis and 12 hour forecast fields) indicated by the 2000 GMT radiosonde at Brownwood, Texas. The first guess did not represent the mesoscale feature well. Note that the 500-mb guess is more than 3 degrees too warm (the 500-mb temperature at Brownwood cooled by 5.4 degrees between 1700 and 2000 GMT) whereas the 200-mb guess is more than 6 degrees too cold (the 200-mb temperature warmed by 3.8 degrees between 1700 and 2000 GMT). The column under Ex1 shows the result for the "normal" retrieval's adjustment to the guess. Note that the profile has been warmed throughout and there is no indication of the lower tropospheric cooling and upper tropospheric warming. The sensitization experiments consisted of two technqiues. First, the convergence criteria were tightened and second the shape of the weighting functions were altered by raising them a power. Given the usual shape of the weighting function the latter modification has the effect of reducing the overlap of the different frequencies while "sharpening" the peaks. In essence, the smoothing is reduced. Results of the sensitizing are shown in Table 1 as Ex2 through Ex6. Ex2 and Ex3 show that for the normal weighting function the increased convergence had a relatively minor effect. Results are far more dramatic for Ex4 through Ex6 with the weighting function cubed. In Ex6 cooling and warming of the middle and upper troposphere is captured, although an error appears to remain in the lower troposphere where the surface heating has too large an effect. The important conclusion to be noted is that the "normal" retrieval procedure is apparently too smooth in this case, and better results can be obtained by modifying the procedure. One must remember, however, that sensitizing the algorithm makes it more susceptible to noise and in partly cloudy situations the sensitization might not be advantageous.

Table 1 shows that the VAS radiances are capable of capturing the sense of the mesoscale change in the vertical. Table 2 indicates that the same is true in the horizontal. The table contains results for eight retrievals centered within a 70-by-70 kilometer square. Mean and standard deviation statistics are given for the first guess and retrieval profiles. Note that cooling and warming of the lower and upper troposphere is shown by the averaged retrieval, but equally important the first guess horizontal variance, as indicated by the standard deviation at each level, has been greatly enhanced. This situation is especially true in the middle and upper troposphere where the intense gradients were observed.

Table 2
Mean Temperature Profiles and Level Standard Deviations for Initial Guess and Retrievals at Eight Locations Within 70-by-70 Kilometer Square. Sample Taken Over NASA Special Network
2000 GMT 6 March 1982

P	T_R	T_g	σ_R	σ_g
965	280.8	247.6	0.1	0.4
850	271.1	271.2	0.5	0.7
700	265.4	265.6	0.5	0.5
500	250.3	251.4	1.0	0.4
400	239.6	239.4	2.0	0.4
300	227.7	225.7	1.7	0.4
250	222.9	219.8	1.2	0.2
200	222.4	219.0	0.7	0.4
150	220.6	217.6	0.6	0.2
100	214.5	213.8	1.3	0.1

For VAS, like all preceding passive-sounding instruments, retrievals are sensitive to the first guess. The results shown in Table 1 and Table 2 were obtained using initial profiles based on LFM analyses and forecasts. The sensitivity experiments were also performed on climatological initial profiles. Under this constraint the sensitization was not successful in delineating the mesoscale event although brightness temperature residuals were at least as small as with the LFM guess. Several other initial profiles were used including the 1200 GMT LFM analysis (i.e., no forecast updating) and a "best" guess using the special network observations at 2000 GMT. In general, the quality of the retrievals improved with the quality of the initial guess. Thus our experience continues to show that the best retrievals are made with the best first guess, especially when the number of radiance measurements is limited as with the VAS instrument.

The sensitivity of VAS retrievals to the surface-skin temperature estimate continues to be a major problem. The large changes shown in Table 1 Ex6 at low levels are in all probability associated with an incorrect boundary temperature. Experiments have shown that small changes in the skin temperature affect the retrieval up to 300 mb, with nearly one-to-one correspondence at 850 mb. In VAS processing, the skin temperature is estimated by regression using the three window channels. The method is known to work well over the ocean; however, it appears to work only reasonably well over land. Some preliminary attempts have been made to update the skin temperature estimate within the retrieval using radiative transfer. Whether or not this is beneficial depends on the quality of the initial temperature/moisture profile.

In conclusion, the NASA special network radiosonde coverage for 6 March 1982 has already proved to be extremely useful. We have been able to demonstrate that the VAS is capable, with tender loving care, of delineating a mesoscale event. We have demonstrated that our "normal" retrieval procedure has the deficiency of oversmoothing, but this can be corrected. We have been able to document our "first guess" dependence; and finally we have a superior data set to evolve better techniques for treating the surface boundary problem.

AVE/VAS EXPERIMENT: GROUND TRUTH NETWORK

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INTRODUCTION

The Visible/Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS) rawinsonde field program was discussed. Specific items that were covered include: planning, personnel requirements and training, operational requirements and procedures, sounding times and dates, methods of data processing, data inventory, and status of data processing.

Special Soundings

Special soundings were made at the 12 locations specified in the Operations Plan with the National Weather Service station at Stephenville, Texas at the center of the network. Sounding times were 12, 15, 18, 21, 00, 03, and 06 GMT. Table 1 shows the dates and numbers of special soundings.

Table 1
Dates and Numbers of Special Soundings

Date	Number	Percentage of Soundings
February 6, 1982	22 of 36	61
March 6, 1982	80 of 84	95
March 27, 1982	74 of 84	88
April 24, 1982	82 of 84	98
May 1, 1982	80 of 84	95
Total	338 of 372	91

Data Processing and Projected Dates for Data Availability

Data processing is proceeding smoothly at Texas A&M University. No significant problems have been encountered and the data appear to be of the highest quality obtainable from the GMD sounding systems. Established procedures are being used to process AVE data. All soundings are processed for each pressure contact and interpolated to 25-mb intervals. Both forms of data will be available on magnetic tape.

The projected dates for data availability (final form) are:

Operational Date (1982)	Availability Date (1982)
February 6	July
March 6	July
March 27	September or October
April 24	August
May 1	September or October

More detailed summaries of the available data base and the data themselves may be obtained from the Chief, Environmental Applications Branch, ES84, NASA, Marshall Space Flight Center, Alabama 35812.

AVE/VAS EXPERIMENT: SYNOPTIC SUMMARY AND PRELIMINARY RESULTS

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The AVE/VAS Ground Truth Field Experiment was conducted during the Spring of 1982 under the National Aeronautics and Space Administration (NASA) Severe Storms and Weather Research Program and managed by Marshall Space Flight Center (MSFC). The experiment consisted of acquiring correlative ground truth measurements (rawinsonde data) corresponding to the time and space resolutions of VAS sounding data. The objectives of the AVE/VAS Experiment are:

- To acquire four-dimensional data sets of the "actual" atmospheric structure down to the mesoscale
- To provide measurements for quantitative comparisons between ground-based and VAS-derived atmospheric parameters
- To evaluate the impact of VAS data on diagnostic analysis of structural features and dynamical processes important to the development of mesoscale phenomena
- To evaluate the impact of VAS data on numerical model simulations, nowcasting, and other mesoscale forecasting systems

The first objective has been accomplished by collecting rawinsonde and VAS data over a regional network in the central United States and a mesoscale network in central Texas. At present, the other objectives require many detailed studies which are just beginning.

The data collection period consisted of 4 formal days and a "shakedown" day in which both rawinsonde and VAS data were collected. Table 1 summarizes the collection periods, cloud cover, and weather conditions for the 5 days. Figure 1 shows the 24 National Weather Service (NWS) stations that participated in the experiment and the area in central Texas covered by the 12 mesoscale stations. The average station spacing of the NWS regional network is 400 kilometers and the mesoscale spacing is 125 kilometers.

All of the experiment periods are of great value for evaluating the performance of VAS and VAS sounding retrieval algorithms because of the varying weather conditions that occurred. VAS with its 12 infrared channels is not transparent to clouds and several of the experiment days included significant cloud cover. Soundings that used data from gaps between clouds and radiance data from above the clouds must be considered in addition to clear air retrievals. The most useful experiment periods are the 6 to 7 March and the 24 to 25 April cases. The 6 to 7 March period is ideal for evaluating VAS-derived soundings because most of the regional and mesoscale network is cloud free for a long time. Strong temperature and moisture gradients existed at all levels which will push

Table 1
Data Collection Periods

Observation Period	Rawinsonde Data	General Cloud Cover	Synoptic Conditions
6 to 7 February 1982: "Shakedown" Day AVE/VAS I	Special Network plus Stephenville, Texas (NWS) at 12Z, 18Z, 00Z.	Regional network: Mostly clear over Texas and Oklahoma, clouds and snow cover north. Mesoscale network: Clear early, increasing high clouds in pm.	High pressure over regional network with stationary front off the Gulf Coast.
6 to 7 March 1982: AVE/VAS II	Special Network and 24 NWS stations 12Z, 15Z, 18Z, 21Z, 00Z, 03Z, 06Z.	Regional network: Clear except for east Texas and Louisiana, snow cover Oklahoma panhandle. Clearing with time. Mesoscale network: Low clouds east, clear by 2300Z.	High pressure over the Rocky Mountains with a surface front off the Gulf Coast. Large amplitude upper level trough over plains with jet streak propagating around base.
27 to 28 March 1982: AVE/VAS III	Special Network and 24 NWS stations 12Z, 15Z, 18Z, 21Z, 00Z, 03Z, 06Z.	Regional network: Overcast over central region, clear on fringes. Little change with time. Mesoscale region: Overcast middle and low clouds early, overcast to broken low clouds by 0600Z.	Weak surface trough connecting low pressure center over Wyoming and southwest Texas. High pressure over Great Lakes area with a warm front off the Gulf Coast. Weak upper level trough with closed low over Colorado.
24 to 25 April 1982: AVE/VAS IV	Special Network and 24 NWS stations 12Z, 15Z, 18Z, 21Z, 00Z, 03Z, 06Z.	Regional network: Mostly cloudy in middle of region, clear SW and NE, clearing in south late. Mesoscale network: Low overcast early, partly clear later with clouds moving in.	Surface trough running south from a double low in Kansas and northwest Texas. Weak frontal system off Gulf Coast with upper level closed low over Colorado.
1 to 2 May 1982: AVE/VAS V	Special Network and 24 NWS stations 12Z, 15Z, 18Z, 21Z, 00Z, 03Z, 06Z.	Regional network: Partly cloudy north and west, cloudy in center. Partly cloudy over region late. Mesoscale network: Cloudy early, broken to partly cloudy low clouds by 2300Z.	High pressure over Great Lakes region with a weak trough over east Texas and Louisiana. Upper level ridge over mountains with small perturbation in flow which is undercutting the ridge.

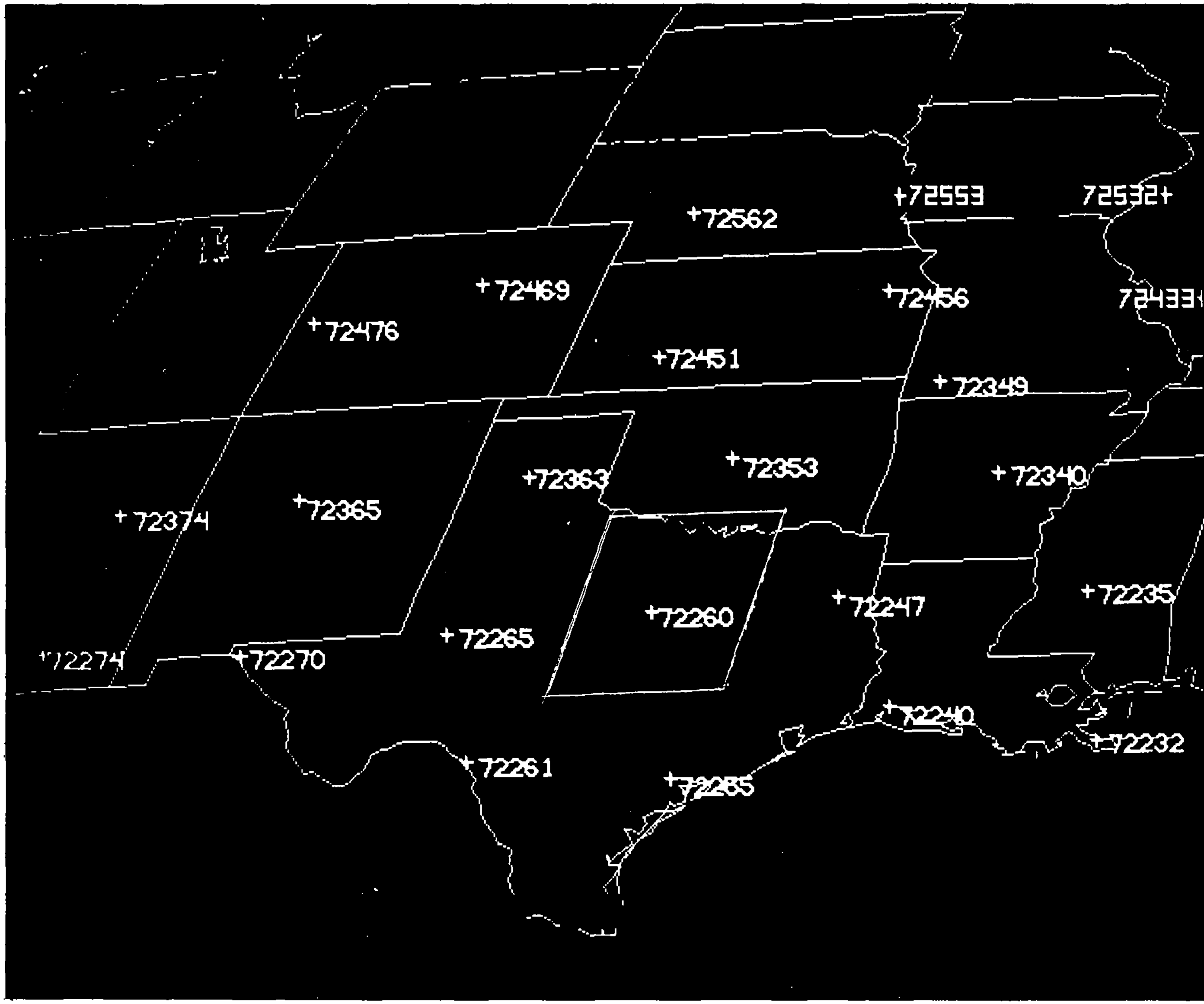

Figure 1. AVE/VAS regional rawinsonde network and box encompassing the 12 special network stations in central Texas.

VAS to its limit of horizontal resolution. Strong horizontal wind shear existed in the upper levels as a strong wind maximum associated with a baroclinic wave moves through the mesoscale region. This will surely be an optimum situation to evaluate thermally derived winds from VAS sounding data. An example of the mesoscale variability at this time is shown in Figure 2. The 24 to 25 April case provides a situation typical of severe storm cases although no severe weather was reported. Intense convection developed by mid-day on 24 April in a relatively cloud-free area of northwest Texas. During the evening hours, the storms intensified and moved through Oklahoma and central Texas. The potential use of VAS is great in such situations to sample changes in the prestorm environment critical to severe storm development.

The mesoscale data obtained during the AVE/VAS Ground Truth Field Experiment is crucial to the VAS evaluation. In the VAS Demonstration, MSFC is responsible for managing the field experiment and for independently evaluating VAS sounding products produced by a physical iterative method and a statistical regression method. Sounding data retrieved by each method will be provided to MSFC by scientists at National Environmental Satellite Service and NASA's Goddard Space Flight Center, respectively.

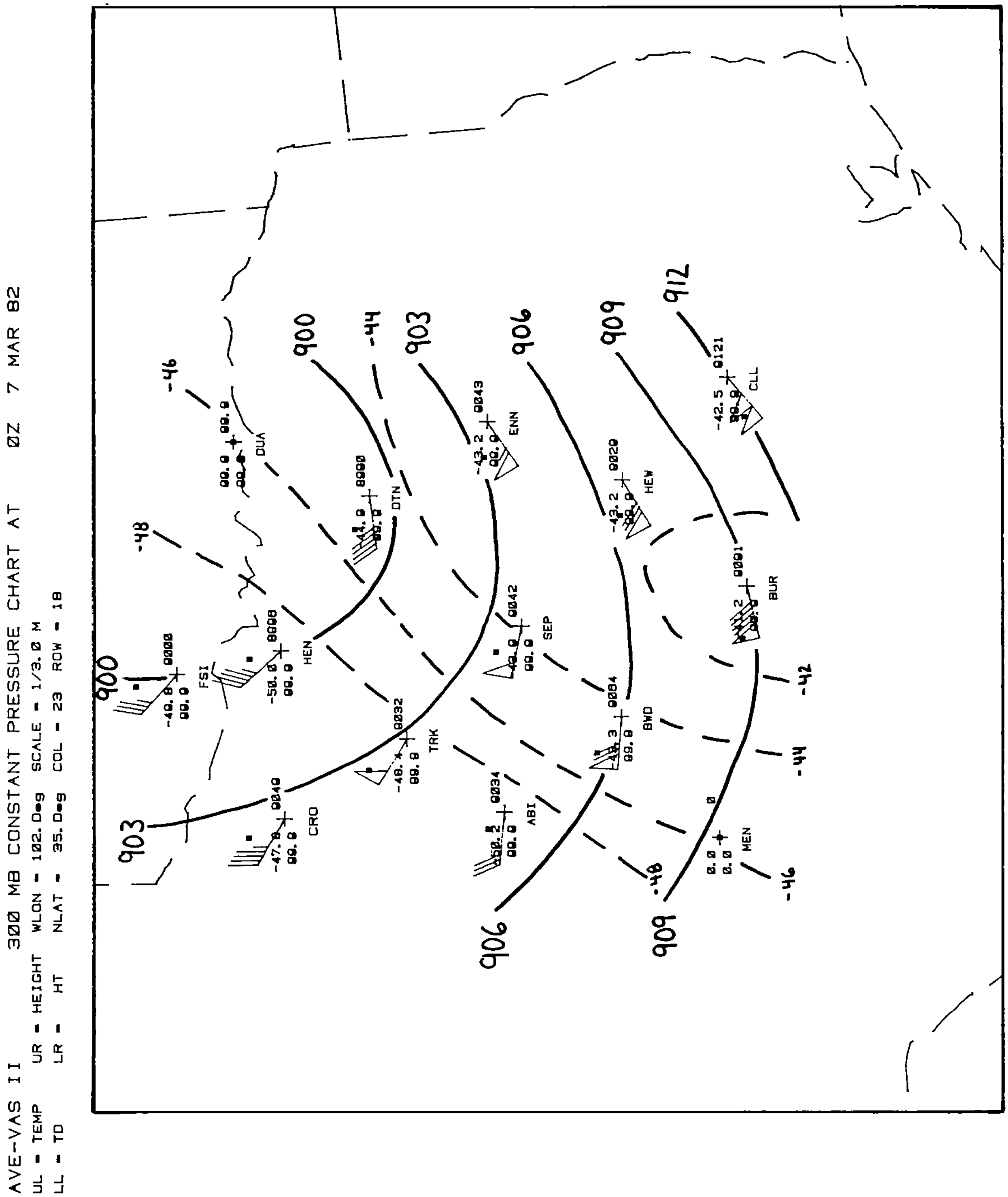

Figure 2. 300-mb pressure chart for 7 March 1982 (AVE/VASII) at 0000 GMT. Height contours (solid) are in decameters and temperature contours (dashed) are every 2°C.

VAS APPLICATIONS AT COLORADO STATE UNIVERSITY

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The development and evaluation effort dedicated to the NOAA/NASA VAS Program has been extremely rewarding for the agencies directly involved. Their success encourages other research institutions to apply VAS information to a wide array of tropospheric studies. The initial assessments of VAS radiometer and satellite performance (Menzel, 1981) were satisfactory; and VAS operations were smoothly carried out by the NESS SOCC and associated processing and retransmission facilities. The application of VAS data has proceeded rapidly within the sponsoring agencies (Anderson et al., 1982 and Chesters et al., 1982). This work was aided by the availability of advanced image processing systems and by previous studies with the geosynchronous European Space Agency Meteorological Satellite (Meteosat) and the polar-orbiter multichannel radiance data.

Colorado State University (CSU) has pursued the acquisition and use of VAS data through the Geostationary Operational Environmental Satellite (GOES) Direct Readout Earthstation Facility and Interactive Research Imaging System (IRIS) within the Department of Atmospheric Science. (See Green and Kruidenier, 1982 for a description of these systems). Researchers in the department and the CSU/NOAA Cooperative Institute for Research in the Atmosphere (CIRA) implement VAS data as these data are received in the real-time VISSR mode (e.g., channel 10 imagery), and as dwell sounding (DS) and multispectral imaging (MSI) radiances on magnetic tapes produced by the Space Science and Engineering Center. In addition, during the next year CSU plans to complete system development to allow direct reception and archiving capability for transparent mode VAS transmissions. CSU will apply VAS data to support individual research projects, to address Colorado's needs concerning water, air, and energy resource planning, and to provide graduate student and professional training in satellite meteorological remote sensing.

The extensive image processing capabilities of the Atmospheric Science IRIS Facility are being used for specific multispectral image analysis methods. MSI data are being brought into the mesoscale and synoptic forecast process through image enhancement and compositing. To help offset the problem of a relatively high signal-to-noise ratio, a logarithmic enhancement function based on the actual image brightness histogram is applied to the water vapor (WV) channel data during display. Preprocessing software for VAS tapes received from SSEC allows the system user at CSU to navigate each channel's image (Saufley, 1982) and to specify how the raw 10-bit infrared radiances will be scaled during display on the 8-bit resolution video monitor. Smoothing algorithms for MSI imagery are also being tested.

Some examples of combinations of co-located GOES image sectors that are produced are as follows:

- Visible (VIS) and WV images displayed side by side on a video monitor can be looped to reveal diurnal evolution in the cloud and moisture fields

- A WV pixel brightness threshold is assumed to indicate cloud, and all portions of a displayed WV sector above that threshold are replaced in the displayed image by the higher resolution VIS pixels (usually VIS points are color tinted to help discriminate between the two data types)

- A VIS sector is displayed with transparent color graphics of various WV brightness contours

At least one sounding retrieval scheme for VAS DS data will be in use by the end of the current year, with plans for adapting these retrievals to the mountainous Colorado region. A substantial portion of the radiance channel weighting function curves for certain DS channels lies below ground level in the Colorado Rockies (approximately 650 mb). Mesoscale data sets collected during recent winter and summer field programs in Colorado will provide verification of the satellite soundings. The "ground truth" and descriptive data sources are surface mesonetwork and aircraft observations, ground-based radiometric and frequent balloon soundings, and three-dimensional radar. Methods for initialization of the retrieval schemes will be explored through CSU's growing mesoclimatology data base for Colorado and GOES DCP *in-situ* observations and vertically-pointing radiometers.

Individual applications planned for VAS data at CSU in the near future include:

- The study of mass and moisture flux and associated orographic effects in summer and winter storms

- The operational support of field programs such as aircraft flight planning, cloud-seeding decisions, and scheduling of Research Rapid Scan Days

- The investigation of mesoscale and synoptic scale interactions

- The use of mesoscale moisture fields for improving the estimation of surface solar insolation, forest fire hazards, and 1 to 2 day precipitation forecasts.

The methods and theory of VAS data reduction and analysis will be more fully incorporated into graduate course work on satellite applications. Hands-on training will include VAS image analysis techniques for students and other system users. In addition, a video monitor will provide real-time satellite pictures during noon forecast discussions, and the VAS soundings and images will be available as supporting data in the departmental weather forecast contests. Already VAS verification has proceeded far enough that all of the previously mentioned activities can be confidently pursued. The potential value of VAS information will be emphasized in CSU's educational role, the research effort, and the proposals.

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FUTURE RESEARCH CONTRIBUTIONS OF THE VAS

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As seen from the previous summaries, VAS data are used for studying and predicting numerous meteorological phenomena. These phenomena include severe local storm antecedent conditions, the formative stages of tropical cyclones, the definition of upper tropospheric circulation features, and as input to synoptic scale prediction models. Further refinements in these areas will certainly result in even better products and interpretations. Nevertheless, there remains an impressive list of additional areas where VAS data should be examined.

For regional and mesoscale phenomena, this list includes severe local storms once the storms have formed, the later stages of tropical cyclones, extratropical cyclones, orographically induced events, fog, frost and freeze conditions, and dust storms. Concerning the last three phenomena, the VAS can be most beneficial by defining temperature, moisture, and cloud conditions before the onset of events (e.g., the actual formation of the fog). VAS data should be contained in analyses of any meteorological event where significant diurnal variability occurs—including some large-scale events such as the Intertropical Convergence Zone where the convective process is important.

In addition, the VAS should be used for studies of cloud climatology. Numerous studies show that the channels used for temperature and water vapor profiles can contribute to a better specification of cloud type and cloud-top height. If these parameters are known, then cloud amount estimates can be improved.

Oceanographic investigations is another research area for the application of VAS data. The most productive applications may be associated with locating and tracing the evolution of current boundaries and detecting upwelling regions. Other applications would be appropriate where knowledge of the absolute and relative sea-surface temperatures, accurate to $\leq 1.0^\circ$ and $\leq 0.5^\circ C$, respectively, is required.

There are several advantages, that should be explored, for acquiring profiles from a geosynchronous satellite instead of from low orbit. First, there is a consistent viewing geometry to any given location—meaning that the spatial resolution and the atmospheric slant path do not vary, so excellent interpretations can be made of spatial and temporal gradients. It is possible to attain nearly synoptic coverage over a large area. Data are coming from a single sensor which simplifies calibration corrections. There can nearly always be a near-perfect pairing of data with measurements from other sources because geosynchronous data can be taken at frequent intervals. Time compositing may be used for effectively improving spatial resolution and coverage because clouds move and change between successive surveys. Finally, geosynchronous soundings can be made with space and time scales that are commensurate with rapidly changing events.

VAS RESEARCH REVIEW

A number of interesting possibilities occur with the simultaneous measurements from two VAS instruments or from a VAS and a polar-orbiting sounder. With two window channel measurements at different angles, the two radiance measurements can be used for estimating the radiance that would be present if there were no moisture—thus the true skin-surface temperature can be determined. (This technique has been successfully used for determining sea-surface temperature with the window channels from the Meteosat imager and the TIROS AVHRR.) Because the weighting functions for the temperature channels shift vertically with the changing slant path, combining the data from two sensors might improve the vertical resolution of the profiles. Precise relative calibration of the two VAS sensors is possible where the viewing angle is the same (which is anywhere along 105°W longitude with the satellites at their present locations).

Probably the greatest weakness of satellite soundings is their coarse vertical resolution, which is about 6 kilometers for the VAS. There are a number of ways, however, that other data can be combined with satellite soundings to possibly improve the vertical resolution and accuracy of the profiles. Over land the temperature and moisture boundary conditions at the surface can be determined by the surface network. Sea-surface temperature can be used for the lower temperature boundary condition over water. Usually, ground-based soundings have better vertical resolution near the bottom of the sounding which could help the satellite-based profiling in the lower and middle troposphere. One possible way of locating the top of the boundary-layer temperature and moisture inversion is to measure the heights of cumulus that form in the boundary layer. Stereo measurements from the geosynchronous satellites would be especially effective for performing the height calculation. Cloud heights of any layer would be useful for locating moisture zones. An interesting possibility for improving the vertical resolution of the temperature profiles in the upper troposphere and lower stratosphere is by using a tropopause height estimate from ozone measurements which was suggested in an earlier paper of this document.

For a number of important mesoscale products and processes the VAS and VISSR data need to be combined. Some of the best examples are when wind and cloud growth information (from the VISSR) can be joined with VAS temperature and moisture data. Moisture convergence in the lower troposphere is a product where the winds can be measured from the split-window techniques described in another contribution to this summary report. Other products and processes that could substantially benefit include jet-stream position and strength, storm-environment interactions, and inputs for numerical models (i.e., temperature, moisture, winds, and surface temperature).

SOME POTENTIAL RESEARCH APPLICATIONS OF GOES/VAS DATA IN METEOROLOGY

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The understanding and utilization of radiance data from the VAS instrument for meteorological purposes requires an extensive and organized research plan whose ultimate goal is to provide quantitative measurements of the structure/dynamics of the atmosphere. The unique multispectral VAS data are potentially useful in almost all aspects of meteorology but have immediate applications in the mesoscale and severe-storm research area since measurements are available over regional areas at time intervals of less than 1 hour. This brief outline is intended to overview some of the higher priority research applications of VAS data pertaining to the interpretation and utilization of the passive VAS radiance measurements for mesoscale and severe-storm research.

Research Areas and Objectives

- Statistical Structure Function Analysis of VAS Imagery and Sounding Data—To quantitatively assess the ability of VAS to capture mesoscale atmospheric structure and variability.

- Defining Mesoscale System Environments Using VAS Data—To assess the use of VAS measurements in determining the dynamics and structure of mesoscale circulation systems.

- The Role of Ageostrophic Accelerations in the Representativeness of Mass-Derived Flow Fields—To determine the dynamical nature of ageostrophic flow as it pertains to winds potentially derived from mass fields measured by VAS.

- An Integrated Satellite and Surface Evaluation of Precipitation Characteristics—To examine the structure and dynamics of the immediate mesoscale environment of precipitation systems.

- Diagnosing the Interaction of Cumulus Convection with Its Environment—To determine the usefulness of VAS data in examining the momentum and heat exchanges between convective systems and their mesoscale environment.

- Evaluation of Model Ageostrophic Motions and Their Sensitivity to VAS Moisture and Temperature Fields—To evaluate the impact of high-resolution moisture and temperature fields from VAS on numerically simulated flow structure and evolution.

- Mesoscale Initiation of Cumulus Convection Using VAP Data—To assess the usefulness of VAS soundings and imagery in defining the three-dimensional structure of the atmosphere that initiates convection.

- Nowcasting with VAS for Severe Storms—To determine the short-range predictive capability of VAS soundings and imagery for severe-storm development.

- Mesoscale Winds Determined from GOES Satellite Imagery and VAS Data—To provide a method by which VAS imagery can be used to improve cloud-winds through quantitative height assignment and water-vapor "feature" tracking where clouds are absent.

APPENDIX A

VAS RESEARCH REVIEW AGENDA

National Aeronautics and Space Administration
Goddard Space Flight Center
June 16 and 17, 1982

Wednesday, June 16 (Building 26, Room 205)

9:00	J. Greaves, V. Suomi	Introduction
9:15	H. Montgomery	System Description
9:30	D. Chesters	Low-Level Moisture Measured from VAS "Split-Window"
10:00	R. Petersen	Diagnosing Convective Instability Using VAS Data
10:30	BREAK	
10:45	L. Uccellini	VAS Sounding Analyses for Preconvective Environments
11:15	G. Szejwach	Automated Cloud Classification Schemes Using VAS
11:35	E. Rodgers	Detection of Tropical Cyclone Formation Using VAS
12:00	LUNCH	
1:15	H. Schmidt	Operational Implementation of VAS
1:30	W. Smith	Processing Methods and Preliminary NOVA Results
2:00	B. Heckman, R. Anthony	Cloud Motion/Height Fields from VAS Data
2:30	P. Menzel	VAS Operational Procedures and Results at SFSS
3:00	BREAK	
3:15	E. O'Lenic, N. Phillips	Effects of VAS Data on NMC Analyses and Forecasts
3:45	R. Anderson	Upper-Level Flow Patterns from VAS Water Vapor Imagery
4:00	M. Kruidenier	VAS Applications at Colorado State University

Thursday, June 17 (Building 22, Room 365)

9:00	J. Greaves	Introduction
9:15	H. Montgomery	AVE/VAS Experiment: VAS Data Acquisition
9:30	J. Gatlin	TOMS Ozone Data During Special Network
9:45	C. Hayden	Review of Special Network Data Sets
10:15	J. Scoggins	AVE/VAS Experiment: Ground Truth Network
10:35	BREAK	
10:50	G. Jedlovec	AVE/VAS Experiment: Synoptic Summary
11:10	G. Wilson	Future VAS Research at MSFC
11:30	W. Shenk	Future VAS Research at GSFC
11:50	R. Arnold, J. Dodge	Concluding Remarks
12:00	LUNCH	
1:00	VAS/MET System Demonstrations (Building 28)	

BIBLIOGRAPHIC DATA SHEET

1. Report No. NASA CP-2253	2. Government Accession No.	3. Recipient's Catalog No.
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7. Author(s) James R. Greaves		8. Performing Organization Report No. 83F0188
9. Performing Organization Name and Address Goddard Space Flight Center Greenbelt, Maryland 20771		10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Conference Publication 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The VAS is an experimental instrument flown onboard the NOAA GOES that achieves multispectral imagery of atmospheric temperature, water vapor, and cloudiness patterns. In addition, this instrument provides atmospheric sounding from geosynchronous orbit. The VAS Demonstration was funded by NASA for evaluating the VAS instrument's performance and for demonstrating the capabilities of a VAS prototype system. A VAS Reseach Review was held at GSFC on June 16 and 17, 1982. This conference provided scientists and members of the meteorological community with information about the potential capabilities of the VAS instrument.

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VISSR atmospheric sounder, multispectral imaging, dwell sounding, operational VISSR, and "split-window" channel	Unclassified - Unlimited Subject Category 47

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