PROGRESS REPORT

THROUGH

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VISSR Atmospheric Sounder (VAS)

Development and Performance Evaluation

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Prepared by

Space Science and Engineering Center

The University of Wisconsin

Madison, WI

for

National Aeronautics and Space Adminstration

Goddard Space Flight Center

Greenbelt, MD

I. General

Over the spring and summer, SSEC has acquired and processed the AVE/VAS Special Network data, supported the NOAA VAS Assessment by routinely forwarding VAS data products to Kansas City and Miami, evaluated the total system performance of the VAS system (satellite, SDB, processing system), and evaluated VAS-F prelaunch performance with respect to calibration and noise reduction.

On June 3, 1982 V. Suomi, W. Smith, P. Menzel, G. Wade, and T. Schreiner traveled to Philadelphia, PA to attend the AGU conference held there. Presentations of recent VAS research developments (especially regarding wind field determinations) were made (CO_2 winds, gradient winds, H_2O winds).

On June 16, 1982 V. Suomi, W. Smith, C. Hayden, and P. Menzel attended the VAS Science Workshop held at Greenbelt, MD by GSFC. UW/NESS research results were presented. Also, SDB improvements were planned and future NASA research proposals were discussed.

On August 3, 1982 P. Menzel traveled to Suitland, MD to discuss the VAS calibration with NESS operations personnel. The calibration data, software, and VAS-F results were delivered. Also transparent VAS schedules for hurricane coverage were generated.

On September 7, 1982 W. Smith and P. Menzel attended a briefing to NESS management on the plans for NOAA Operational VAS Assessment. On the following day, J.T. Young joined P. Menzel to hear the SDB Design Review and suggestions for future improved performance were made.

On September 14, 1982 P. Menzel travelled to Santa Barbara, CA to confer with SBRC, NOAA, and GSFC personnel regarding the puzzling behavior of the lower large HgCdTe detector on VAS-F. Recent test results seem to support launch of the VAS-F detector package as is.

On September 30, 1982 W. Smith and P. Menzel travelled to Wallops, VA to brief the NOAA personnel on the VAS accomplishments from the past severe storm and hurricane seasons. The conflict between continued SDB support of transparent VAS operations and VAS-F postlaunch checkout was discussed. It was emphasized that scheduling should strive for minimal interruption in transparent VAS operations during next springs severe storm season.

II. VAS System Performance Study

In an effort to assess the total system performance (VAS satellite, Wallops SDB, and GSFC and UW ground receiving stations), the AVE/VAS Special Network data of March 6, 1982 received at UW was compared with that received at GSFC. Both GSFC and UW generate the VAS radiometric values with the equation:

$$V = (P - Y_z) \times 2^{(F + \Delta F - N)} \text{ ergs/(sec-ster} \cdot \text{cm}^{-1})$$

where

P = N most significant bits of the IR pixel value,

Y_z = N most significant bits of the space view value,

ΔF = line scale factor,

F = channel scale factors which are 8, 8, 8, 8, 8, 4, 8, 8, 7, 7, 4, 2 for bands 1 through 12 respectively, and

N = the number of significant bits.

Single pixel multiscanned calibrated radiometric values at 1730Z were found to be in disagreement. After some investigation the causes for this disagreement were discovered to be:

a) The UW preprocessor was not programmed to subtract of the fractional part (five least significant of the 15 bits) of the space view. As a result the UW single pixel radiometric values were too small by the fractional part of the space view. This was corrected immediately after it was noticed.

b) To ensure efficient ingest of VAS data into the McIDAS, the UW preprocessor averages the 10 bit multiscan data on the fly so that after each spin a 16 bit interim average value is created by the algorithm $new = \frac{1}{n} new + \frac{n-1}{n} old$. The firmware that performs this caluculation creates errors when the fractional multipliers cannot be expressed exactly (e.g. 1/3). The 12 bit average value that is forwarded to the McIDAS is sometimes off by one bit in the least significant bit (LSB). GSFC does the averaging with software; it creates a cumulative total and then divides by the number of spins. Their larger processing system allows it to process the data in this way.

c) The McIDAS receives spin averaged single pixel and space view radiometric values from the UW preprocessor with 12 bit accuracy. The GSFC system uses 16 bits. Twelve bits is adequate so that the spin averaging process does not destroy radiometric information larger than the single sample noise. Additional bits do not add radiometric information.

After correcting the UW problem associated with the fractional part of the space view, the single pixel UW versus GSFC comparison was repeated. Table 1 summarizes the results of that comparison. No deviations greater than .4°C were noticed; the deviations remaining are the result of different preprocessing (12 bits versus 16, different averaging), not errors in preprocessing. A hand calculation of several single pixel values at UW using the GSFC averaging scheme was able to reproduce GSFC radiance values to three significant figures.

The effect of the space view correction in the preprocessor is seen in Figure 1. Brightness temperature fields for several of the spectral bands are shown before and after the correction. The gradients of these temperature fields are clearly unaffected but the absolute values of the derived temperature profiles are changed by as much as one degree. Reprocessing of the March 6 sounding fields has been started and only modest changes in the sounding fields have been seen, even though a general improvement is expected.

The AVE/VAS Special Network data was also investigated to assess how well the available bit stream is utilized by the Synchronizer/Data Buffer (SDB) at Wallops, VA. It was found that of the available 10 bits typically only 6 or 7 bits were turned on (the 3 or 4 MSB's were typically not used) in a scan line of data. This resulted in the LSB representing rather large radiometric values. The truncation error at the SDB equals half the radiometric value of the LSB; multiple scanning cannot reduce the noise below the truncation value. Therefore it is important to keep this value as low as possible. Subsequent SDB improvements in July, 1982 now ensure that 8 to 9 bits are typically used in a scan line of data. The LSB value (hence the truncation error) are now more in accordance with prelaunch specifications. Table 2 summarizes this information.

It should be noted that noise reduction is accomplished in two ways: temporal reduction by multisampling (the spin budget) and spatial reduction by sounding over areas larger than the detector field of view (the improvement factor). What is not gained in one noise reduction mode can be gained in the other.

III. VAS Instrument Support

A noise analysis of the VAS-F thermal vacuum test high speed raw data was completed early this summer. The single sample noise and associated spin budget for the large detectors appears in Table 3. While this performance is within specification, it caused some concern because the lower large HgCdTe detector is noticeably noisier than its upper counterpart. Is this detector subject to intermittent extraneous noise? Is it failing? VAS-D had exhibited a similar noise disprecancy in upper and lower channels before the upper large HgCdTe detector failed. To answer these questions, SBRC conducted some additional tests and concluded that the performance of the lower large HgCdTe detector was stable (it was not deteriorating in the 2 years between tests) and that the popcorn noise detected by UW in its analysis is probably inherent in the detector surface (where the electrical leads are connected). Therefore VAS-F will be launched with the present detectors and a spin budget of roughly 60 is anticipated.

The calibration coefficients were also determined by UW from vacuum test data with the same analysis of covariance used for VAS-E. Only the secondary mirror shield and baffle forward coefficients were allowed to change. Table 4 summarizes the results; the relative error is somewhat improved over VAS-E.

IV. Development of VAS Data Processing Techniques

The moisture retrieval algorithm has received considerable attention. Moisture retrieval is currently updated after the temperature retrieval using a direct solution for the moisture lapse rates within the three atmospheric layers; (1) surface-700 mb, (2) 700-500 mb, and (3) 500-100 mb. Greatly improved vertical structure is achieved with the new moisture retrieval algorithms. An updated first guess procedure whereby the previous dwell sound is used to form the guess for the current retrieval was also implemented in order to improve the temporal consistency of the results.

The AVE/VAS Special Network data of March 6 has been used to investigate vertical resolution and temporal continuity in the retrievals. Results are reasonably successful in both areas, although there are indications that the former could be improved by sharpening the weighting functions used in the physical retrieval solution. The data have also been used to experiment with updating the skin temperature estimate (initially obtained statistically) during the temperature retrieval. The success of the update seems to be dependent on the accuracy of the initial temperature guess.

The available special radiosonde data for March 6 provided a high resolution standard to check the isallobaric wind computations made from consecutive VAS dwell soundings. Simple analyses and analyses adjusted by potential vorticity conservation were investigated. Reasonable fields of divergence were obtained, but the amount of careful editing required to maintain stability precludes the use of this technique in the semi-operational VAS processing. A better method for calculation of divergence is under investigation.

A CO_2 cloud tracking technique to determine simultaneous heights and velocities of cloud motion winds has been developed. Using animated CO_2 channel imagery from VAS, multi-level cloud situations are separated into high, middle, and low level cloud motion wind vectors by the CO_2 slicing method. The VAS CO_2 channel radiometric values are used in the CO_2 absorption method to assign quantitative heights to the cloud vectors; cloud top pressures are determined from the ratio of the deviations in cloud produced radiances and the corresponding clear air values for three CO_2 channels in a radiative transfer equation formulation. Two case studies showed that CO_2 cloud motion wind vectors are in good agreement with radiosonde wind observations and CO_2 cloud heights are within a 50 mb root mean square deviation of radiosonde, bi-spectral and stereo height determinations.

V. VAS Assessment

The AVE/VAS Special Network data collection was conducted on five days this spring (February 6, March 6, March 27, April 24, and May 1 of 1982). UW archived the VAS data and viewed the AVE/VAS data sets in real time jointly with Marshall Space Flight Center. These data are now being processed to determine the accuracy of the VAS temperature and moisture profiles by comparisons between VAS, TIROS, and RAOB soundings.

Soundings from March 6 have been transferred to MSFC and the ground-based data has been transferred to SSEC. March 6 has received the most attention to date because the AVE/VAS network documented, with three hourly measurements, a mesoscale event consisting of a rapidly moving temperature perturbation with strong horizontal wind shear but shallow vertical extent. The event occurred behind a cold frontal cloud band in clear conditions and thus allows testing of the retrieval algorithms without cloud contamination and with good ground truth. VAS was found to be able to delineate this mesoscale event. It was shown that the nominal retrieval resolution (75 km) over-smoothed the thermal gradients in this case. Single pixel soundings provided much closer agreement with the special network observations. The sensitivity of VAS retrievals to the surface skin temperature and the first guess were also investigated. Improvements in the skin temperature estimate within the retrieval using radiative transfer are under investigation.

The remaining AVE/VAS days are now receiving attention; from working with March 6, it is obvious that a superior data set is available which will enable research of more reliable techniques.

VI. Technology Transfer into the Operational Arena

During the end of March, seven-hour transparent VAS mode of operation was successfully begun. For seven weekdays during that period on which data was sent, 26 retrieval data sets covering areas of potential severe weather were processed on McIDAS and sent to Kansas City in near-real time (about 1½ to 2 hours after receiption). Since then, numerous data sets have been generated and edited for both Kansas City (SFSS/NSSFC) and Miami (SFSS/NHC) as listed in Table 5.

By the end of May, the schedule of transparent VAS operations was expanded to 16 hours. During June and July, processing with emphasis on the hurricane environment was begun; during August, the priority for real time data was shifted from Kansas City to Miami.

For Kansas City, a regional scale area (about 20° of latitude by 24° of longitude) centered on the severe outlook issued at NSSFC and was covered with retrievals about 75 to 150 km (5 to 10 FOV) apart. To observe the temporal changes in the atmospheric state, usually four time periods separated by three hours were processed. Starting in early May, the initial LFM first guess (usually a 12-hour forecast) was updated, as the day progressed, with the most recent VAS retrievals (previously, interpolation between forecasts had been used). Once the interactive editing was completed, a standard set of products (a file of edited retrievals and objective analyses of selected parometers) was sent via the McIDAS remote terminal. See Table 6.

Data sent to Miami typically covers a larger area (30° of latitude by 70° of longitude), with retrievals about 150-300 km (10-20 FOV) apart. The time scale is larger also. The primary interest of the SFSS/NHC is in data near 1200 GMT, followed by data near 00 GMT, and on days with active tropical weather data near 1800 GMT. Products which are delivered include analyses of the 1000-100, 500-300 thickness, three-layer relative humidities, precipitable water, gradient winds at standard levels. See Table 7. For the hurricane situation, determination of the wind field was emphasized. Interaction with Miami-SFSS personnel pointed out both good and bad examples of VAS gradient wind patterns. Since the gradient wind was inconsistent near cloudly areas, we are attempting to blend the gradient winds and cloud drift winds to form a more complete specification of the flow. The cloud drift winds include tracking window image tracers (with heights calculated from VAS tropospheric CO_2 channels), and water vapor tracers.

Although the hurricane season in the Atlantic has been rather quiet this year, Hurricane Debby, on 15-16 September is especially interesting. Both VAS and polar orbiter data were processed. Intensities derived from the microwave data on NOAA-7 agree well with NHC estimates. The NOAA dropwindsondes launched during that period will be especially interesting; initial temperature comparisons between the dropsondes and VAS retrievals (available every three hours) look good.

Table 1. March 6, 1982 Radiance Comparisons

Band	Mean Difference[A] (erg/etc)	(°C)
1	.0	.0
2	-.33	-.3
3	-.05	.0
4	.01	.0
5	-.19	-.2
6	.0019	.0
7	.0	.0
8	.0	.0
9	-.018	.0
10	.0	.0
11	-.0056	-.4
12	.0	.0

[A] for 5 single pixel comparisons GSFC-UW

Table 2. Truncation Errors at the SDB

Band	Truncation Error March 6	Sept 22	Single Sample Noise	Noise Reduction
		(all values in ergs/etc)		
1	.5	.25	2.0	.25
2	1.0	.25	1.4	.25
3	.5	.125	1.2	.25
4	.5	.25	1.0	.25
5	.5	.5	.8	.25
6	.0078	.004	.026	.004
7	.25	.25	.64	.25
9	.125	.0625	.61	.15
8	.25	.25	.09	.25
10	.0625	.03125	.15	.10
11	.0078	N/A	.026	.004
12	.002	.002	.007	.004

Table 3. VAS-F Prelaunch Noise Analysis

Band	Detector	Single Sample Noise (ergs/etc)		Spin Budget	
		Upper	Lower	Upper	Lower
1	HgCdTe	3.14	3.97	1	2
2	HgCdTe	1.82	2.19	9	12
3	HgCdTe	1.52	2.05	6	10
4	HgCdTe	1.24	1.81	5	8
5	HgCdTe	.86	1.13	2	3
6	InSb	.021	.021	5	5
7	HgCdTe	.82	1.06	2	3
8	HgCdTe	.10	.13	1	1
9	HgCdTe	.71	.89	4	6
10	HgCdTe	.18	.25	1	1
11	InSb	.024	.023	6	6
12	InSb	.010	.010	1	1
				43	58

Table 4. VAS-F Radiometric Calibration Algorithm Coefficients

From Ray Tracing (for all spectral bands)

Secondary Mirror	.041
Primary Mirror	.032
Scan Mirror	.031
Shutter Cavity	-.031
Primary Mirror Mask	.060
Baffle Aft	.095

From Analysis of Covariance (for spectral bands 1→12 respectively)

Baffle Forward	.148	.066	.162	.165	.130	.137	.153	.134	.171	.164	.132	.188
Secondary Mirror Shield	.192	.209	.170	.160	.202	.149	.213	.231	.245	.238	.217	.219

Absolute/Relative Errors* (for spectral band 1→12 respectively)

Relative	.65	.38	.45	.53	.27	.016	.35	.27	.13	.12	.015	.005 ergs/etc.
Absolute	.02	-.89	-.65	-1.04	-1.10	-.072	-.95	-1.68	-.34	-.39	-.062	-.024 ergs/etc.

* for 28 thermal gradients

Table 5. Record of Data Sets Processed

		(late) MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Data Received On: (Days)		7	17 1/2	11	20	18	21	19	113 1/2
Retrieval Data Sets Sent to:	Kansas City:	26	70	41	70	61	50	4	322
	Miami:	-	-	-	7	16	26	26	75

Table 6. Desired Operational VAS Products for Kansas City

A. SELS Outlooks including VAS derived

moisture changes
shortwaves
vertical motion fields
jets

— from MSI at 14Z

and

upper/lower RH
total precipitable water
850-500 ΔZ/850-200 ΔZ
gradient/thermal winds
stability fields
selected change fields
selected advective fields

— from DS at 11 and 14Z

12Z Raob analysis will be compared with VAS information before and after

B. SELS Watches including VAS monitoring of

jet location wrt moisture axes
moisture changes
dry intrusions
surface heating patterns
stability changes

C. Nowcast Guidance and SIGMET Support

D. Aviation Forecasts will benefit from VAS reports on

winds aloft
turbulence
time rate of change of thermal winds/temperatures

E. Synoptic Scale Information

general patterns noted in 6.7 μ
time rate changes in moisture
large scale circulation patterns

Table 7. Desired Operational VAS Products for NHC

A. Large Scale at Synoptic Times (00Z and 12Z)

thickness
(1000-100mb, 500-300 mb)
height fields
(1000 mb, 500 mb)
precipitable moisture
sea surface temperature

→ from DS at synoptic times

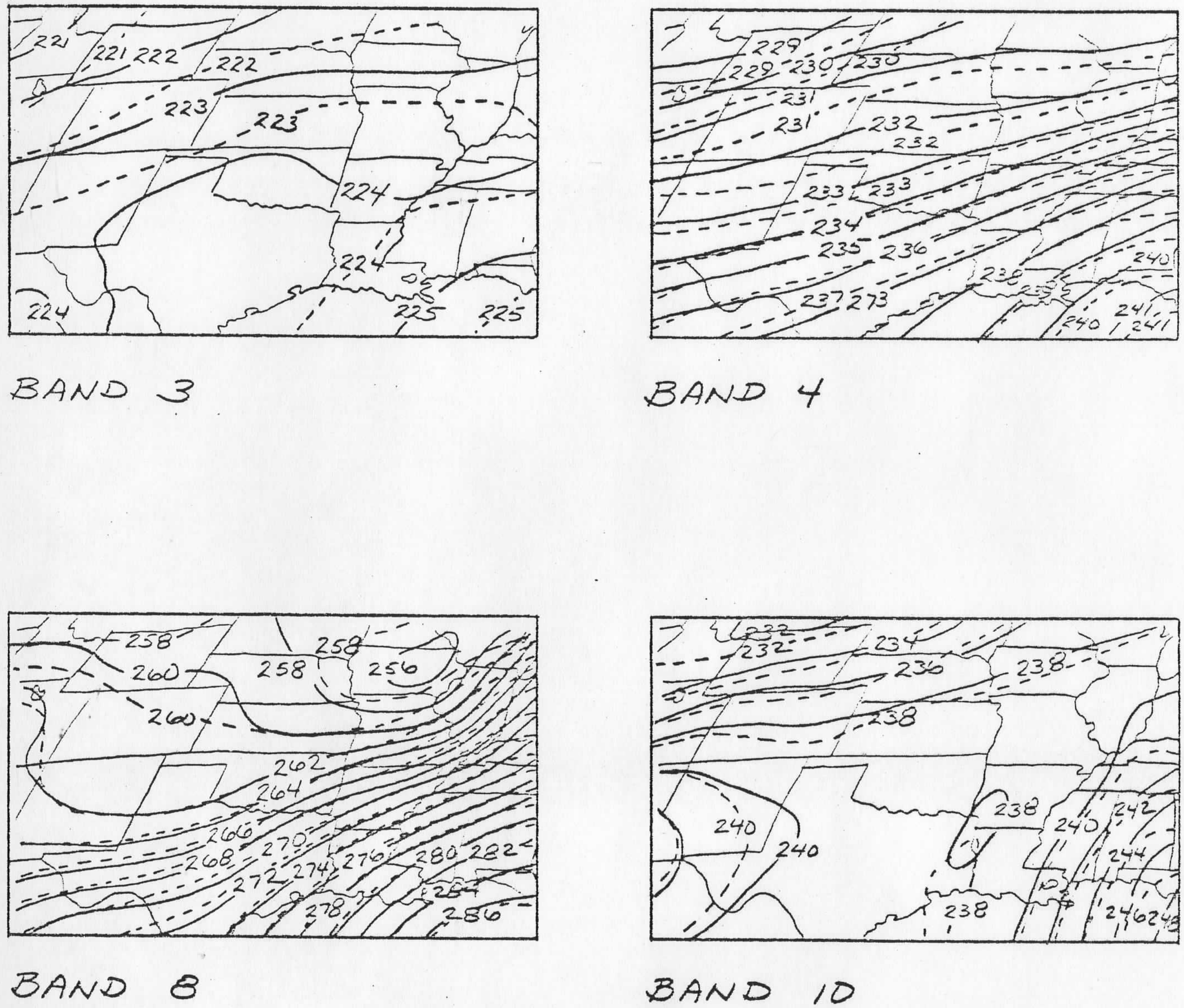
coverage at 5° resolution of 0 to 50°N, 25 to 125°W from 1 June to 30 November, 1982

B. Selected Tropical/Sub-Tropical Weather Systems

precipitable moisture
moisture
low (ch 7)
middle (ch 9)
high (ch 10)
geostrophic winds
deep layer mean
upper level
thickness
(1000 mb - 100 mb, 500-300 mb)
two hourly changes of above
analysis of above

→ from two hourly DS or DI

coverage at 30 km resolution of 0° to 50°N, 25 to 125°N, during lifetime of weather system



——— CORRECTED BRIGHTNESS TEMPERATURES
- - - - - PREVIOUS BRIGHTNESS TEMPERATURES

FIGURE 1. EFFECT OF SPACE VIEW CORRECTION

SPACE SCIENCE AND ENGINEERING CENTER

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October 15, 1982

Ms. Vanessa Scott
Code 269, Bldg. 16
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Greenbelt, MD 20771

Dear Ms. Scott:

In accordance with Article III of Contract NAS5-21965, I am submitting the required Progress Report for activities through September, 1982.

If you have any questions or desire further information, please contact me at (608) 262-6361.

Sincerely yours,

Paul Menzel

Paul Menzel
Program Manager

cc: Jim Greaves, (8 copies)

PM:jr