SUMMARY OF VAS SYSTEM DEFINITION

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The purpose of this paper is to summarize the VAS System Definition which was organized by SSEC for NASA review on November 9, 1976. The system definition emphasizes what should be done; subsequent efforts to design the system will determine what can be done.

The basic outline of this paper contains (a) an explanation of the meteorological utility of VAS; (b) an overview of the system elements and the role of man interactive feedback; (c) a brief discussion of data collection, (d) data analysis, and (e) data synthesis.

The goals of VAS sounding research as outlined in the OSIP (Operational Satellite Improvement Program) Plan for the VAS Demonstration are (1) to increase our understanding of short lived weather phenomena, and (2) to increase the ability to predict the behavior of short lived weather phenomena. Short lived weather (also referred to as mesoscale) phenomena include tropical storms, mid-latitude tornadoes and thunderstorms, frost and freeze, dust storms, fog, etc. To achieve these goals of sounding research a complete and consistent four dimensional description of the atmospheric state during mesoscale phenomena must be accumulated. Here four dimensional description implies a coordinated horizontal, vertical, and temporal description. Complete and consistent indicates that there are no data gaps and that the data is internally consistent (eg. rainfall areas should have clouds present).

The anticipated sources of meteorological observations include VAS, VISSR images from the SMS series, polar orbiting satellite images and soundings from TIROS-N and the satellites of the DMSP (Defense Meteorological Satellite Program), Conventional Weather Data (NMC, AFOS, or Kansas City Satellite

Field Service Station Information), and digital radar information. If other sources of information prove meteorologically valuable then we will try to incorporate them also. The data set should be as useful as possible to meteorologists.

It should be noted that such a variety of sources of meteorological observations is needed because different sources satisfy different mesoscale knowledge requirements. In a 1971 SEOS feasibility study conducted at SSEC, different knowledge requirements for mesoscale study were listed in order of importance. Table 1 shows them and indicates the respective sources of information.

The most important knowledge requirement is the boundary layer motion field. The boundary layer is considered to be the lower 10% of the atmosphere where the vertical viscous force is comparable in magnitude to the pressure gradient and Coriolis forces. The turbulent stresses of the boundary layer are both mechanical (such as friction) and thermal (such as solar heating) and are strongly dependent on topography, ground cover, and moisture content of the air. The evaporation of water is a major source of energy for baroclinic disturbances. From VAS we expect information on the low level moisture fields and conventional weather data should relate ground cover and winds. The wind magnitude and direction is a key indicator of developing activity because it shows where convergent and divergent regions are.

Vertical Stability is an important indicator of mesoscale weather. Relieving stresses caused by unstable layering in the vertical direction in the atmosphere implies large vertical motions and energy releases. Information on the time rate of change of the temperature field and moisture field in 3 directions are the keys to vertical instability. VAS and polar orbiting soundings and conventional weather radiosonde will provide this information.

KNOWLEDGE REQUIREMENTS (listed in order of importance)	SOURCE VAS	Polar Orbiter	VISSR	Conventional Weather	Radar
1. Boundary Layer Motion Field	X			X	
2. Vertical Stability	X	X		X	
3. Surface Temperature	X	X	X	X	
4. Temperature Lapse Rate	X	X		X	
5. Regions of Strong Convective Activity	X		X	X	X
6. Middle and Upper Tropospheric Motion	X		X	X	
7. Pressure Field in Boundary Layer				X	
8. Moisture Field	X	X		X	
9. Convergence and Divergence	X		X	X	
10. Wind Shear and Jet Stream	X		X	X	

Table 1

Surface temperature is derived from blackbody temperatures of window channel radiances on VAS, VISSR, and polar orbiters and from ground observations at weather stations. Temperature lapse rates come from soundings and radiosondes. Regions of strong convective activity are found from time sequence imaging on VAS and VISSR, ground observations, and hydrometeor (i.e., rain) detection by radar. If convective activity is strong enough, it will be raining. And so on down the list. The pressure field in the boundary layer comes from only conventional weather data.

It should be noted that these knowledge requirements were ranked for a large number of mesoscale phenomena. Priorities for severe storms (i.e. wind and moisture) would be different from those of frost watches (i.e. temperature field). This table should be viewed with that in mind.

Not only is this table inadequate in presenting specific priorities; it also fails to indicate what VAS offers that the other sources don't. It seems to indicate that all knowledge requirements can be satisfied without VAS. What this table omits is the interaction of space and time scales. Much of conventional weather is obtained on the synoptic scale from weather stations separated by 300-400 km. Much of polar orbiter information under-samples some areas, over-samples others and does so every 4 to 6 hours. These time and space scales are adequate for describing larger scale weather phenomena but they are inadequate by themselves to describe mesoscale phenomena. To see this more clearly consider Table 2. Clearly desired mesoscale space and time resolution varies with the atmospheric condition (stable, active, or severe) and it requires much more information than non-VAS data can provide.

VAS will fill the observation time and space gaps. As complete as possible a four dimensional data set will rely heavily on VAS to provide information where non-VAS coverage is weak and/or untimely.

Mesoscale Phenomena

Space and Time Resolution

Atmospheric Condition	Resolution Desired	
	Space	Time
Stable	200-400 Km	1-2 Hr
Active	20-50 Km	1-2 Hr
Severe	20-50 Km	5-15 Min

note: Synoptic scale phenomena are adequately parameterized by observations separated by 300-400 Km at 4-6 hour intervals.

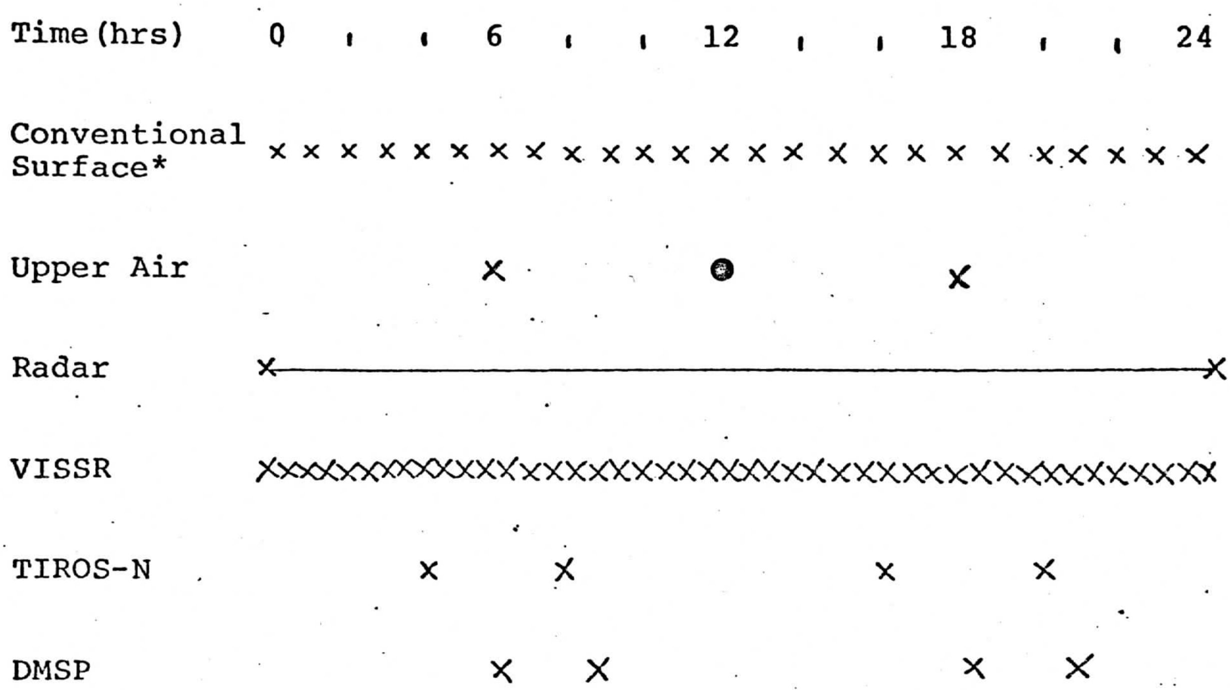
Table 2

Table 3 indicates roughly the timeliness of the non-VAS data. Surface data from weather stations is updated every hour. The capability to incorporate special observations is very important--if a front crosses over a weather station and interesting weather occurs (i.e. rainfall) more frequent reports are to be received. Upper air data from radiosondes and aircraft is available every 12 hours. In between information is derived from the NMC model predictions. Departures from these predictions (evaluated assuming a balanced state of the atmosphere) indicate possible areas of interest for further VAS and VISSR observations. Examples of departures would include winds being in opposite directions and fronts occurring where they shouldn't. Digital radar will be nearly continuous. VISSR updates occur every 20-30 minutes. TIROS-N morning and evening satellites have overpasses at 4, 8, 16 and 20 hours LST. DMSP provides 12 hour interval coverage. Since it has been observed that the maximum severe weather occurs at 3 or 4 in the afternoon, when non-VAS observations are sparse, it readily becomes evident that VAS filling of time and space gaps is crucial.

Now, to indicate more completely the importance of the non-VAS ancillary data, Table 4 indicates from the SEOS report the location of the mesoscale knowledge requirements as described by the observable physical fields (mass, motion, thermal, moisture, hydrometeor, ...). Almost half of the knowledge requirements are satisfied by observations at the earth surface and the boundary layer. Conventional weather data provides most of this information. Clearly VAS data by itself would be incomplete.

Ancillary data then provides the backdrop upon which VAS data will build. It will provide a description of the boundary layer, provide ground truth and reference data, and provide microwave sounding information which allows soundings where there are clouds. The polar orbiting satellites are

Timeliness of Ancillary Data



* Capability to incorporate Special Observations

⊙ Information here is derived from NMC Model (departures from balance then indicate possible areas of interest)

Table 3

Location of Mesoscale Knowledge Requirements

Location / Physical Field	Mass	Motion	Thermal	Moisture	Hydrometeor	Other
Earth Surface and Boundary Layer	X	XX	XX	X	X	XX
Middle Troposphere		XX	X	X		X
Upper Troposphere		X				
General Atmosphere						XX

Table 4

equipped with microwave units, and are deemed essential to description of severe storms where clouds obscure much of the turbulence.

To summarize, achieving the goal of understanding short lived weather phenomena requires atmospheric data with a spatial scale fine enough to resolve severe weather activity (several tens of kilometers) as well as observations frequent enough to determine rates of change in relevant atmospheric parameters (half hourly). This points to a system centered around soundings from a geosynchronous platform which incorporates ancillary data from the meteorologically active areas.

It is now appropriate to identify the system elements and to explain the man interactive feedback. As indicated in the previous statements, the data inputs will be voluminous and from several sources. The situation may be likened to the data matrix in figure 1. Raw data enters at the upper left with high volume and low information density. The matrix operates with either digital or analog techniques, whichever are most appropriate at any given stage, and yields output at the lower right of low data volume and high information density. The most efficient path may pass anywhere through the matrix, guided by the human operator who remains outside the matrix and communicates through high information density channels. This approach to continuous flow data processing has been successfully implemented by SSEC on McIDAS (Man-computer Interactive Data Access System). We anticipate that it will be applied to the VAS program also to produce the four dimensional data set. The man interaction is a key ingredient in this approach. Much of our effort at SSEC will be to define the man's role better and to insure that he remains outside of the system and does not become a bottleneck.

THE MCIDAS APPROACH

TO CONTINUOUS FLOW

DATA PROCESSING

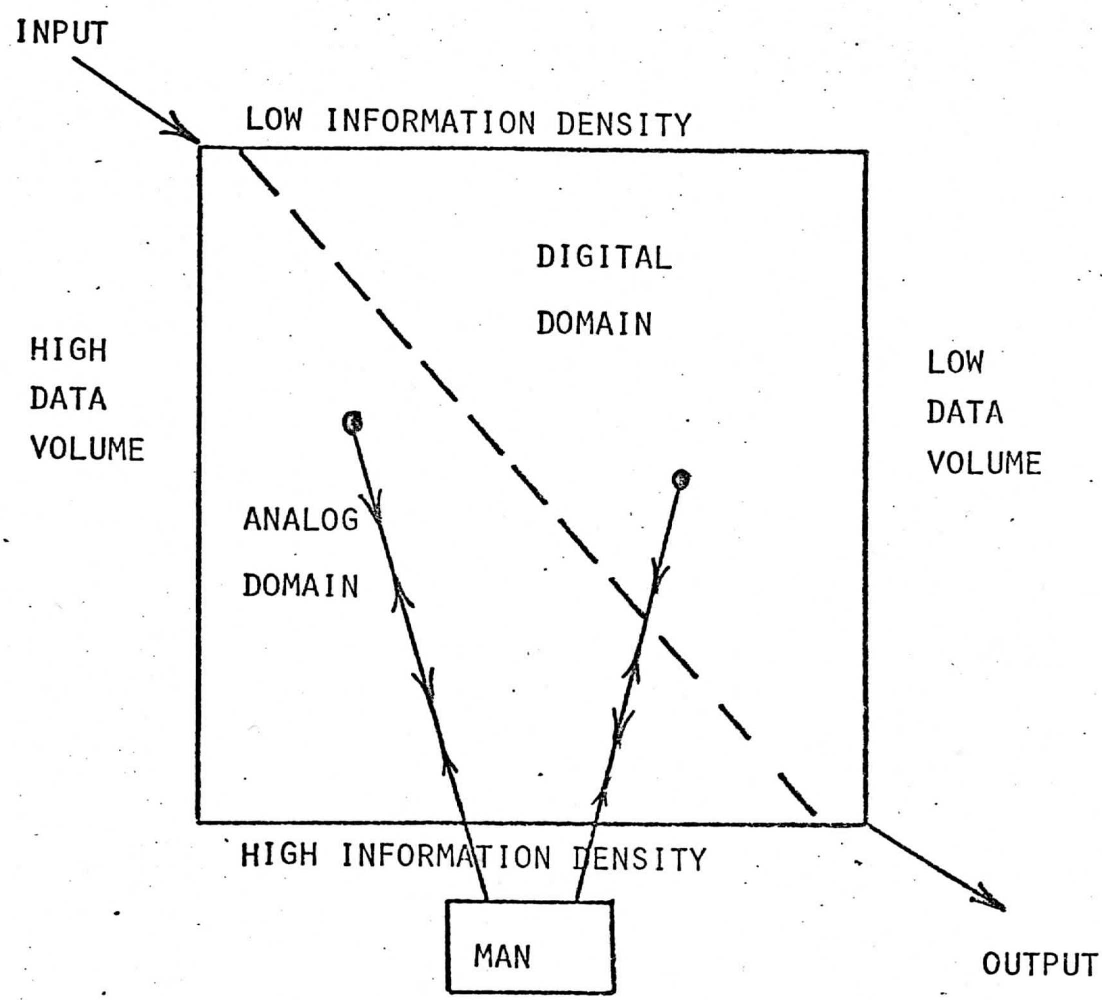


Figure 1

The next figure indicates a general definition of the four system elements - collection, analysis, synthesis, and modelling. Collection involves receiving raw data, preprocessing it to obtain physical observables (eg. raw radiances from VAS, conventional weather ground temperature) and then filing those observables. Analysis processes the observables to derive meteorological parameters (such as temperature profiles, winds, ...). Synthesis produces a complete and consistent four dimensional data set of atmospheric state parameters. Modelling predicts the future state of the atmosphere and determines auxiliary descriptors (eg. rainfall areas).

Successful development of the VAS system will require evaluation of all the system elements at each stage of development. Output of each element will be compared against reference standards (eg. winds inferred from time sequence images of clouds compared to ground station observations). Processes and/or data inputs will be modified to determine effects on comparison. Based on results of process modification tests, problem areas will be identified and modified processes will be rated. Wherever possible tested improvements will be implemented. Figure 3 is a schematic diagram indicating the role of feedback.

We now will talk more explicitly about each of the first three system elements. In the data collection element, we will review the sources of ancillary data and what information each provides. Surface data yields surface T, P, velocity, visibility, etc. Upper air yields profiles. Radar yields liquid water content. VISSR yields time sequence images allowing description of motion fields and identification of cloud types. Polar orbiters provide stratospheric soundings (the slowly varying stratosphere is adequately sampled by polar orbiters and helps pin down upper tropospheric determinations), soundings in cloudy regions (as mentioned before), and

GENERAL DEFINITION OF SYSTEM ELEMENTS.

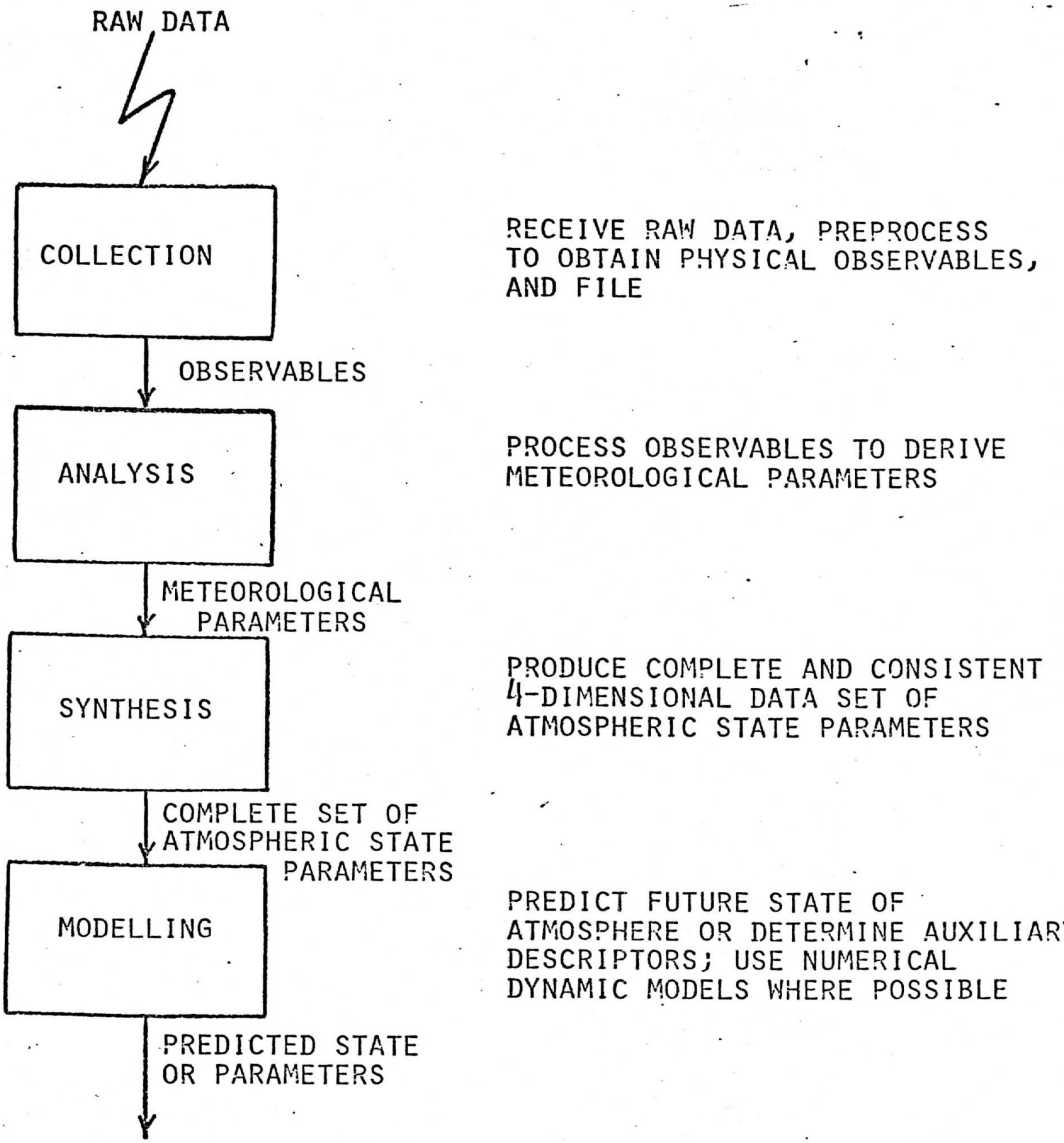
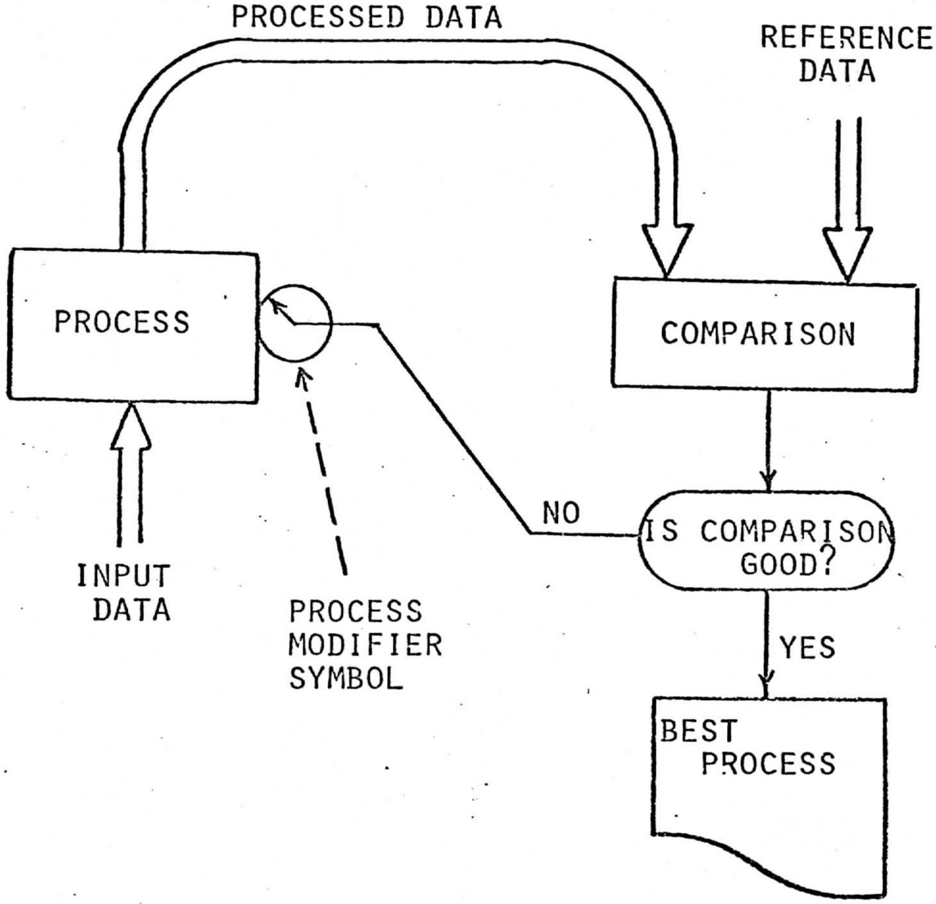


Figure 2

ROLE OF FEEDBACK

EXAMPLE OF FEEDBACK LEARNING:



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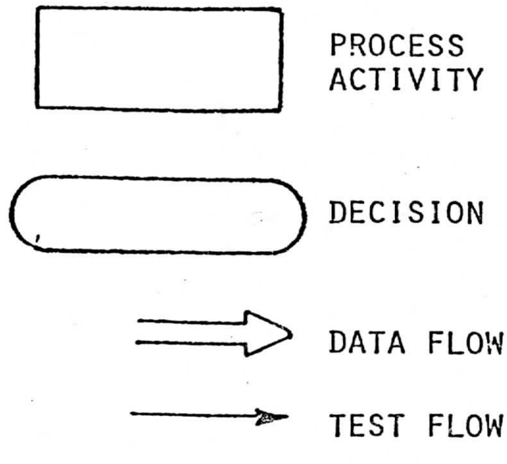

Figure 3

intercomparison soundings with VAS. In addition they also offer a different viewing angle than VISSR (or VAS) that helps with cloud height determinations. It should be pointed out that often observations from different sources are combined to produce inferred data. For example, if a weather station observes ground temperature of 20°C and the VISSR window channel blackbody temperature of the same area reads a lower temperature 10°C, then it can be inferred that the FOV is cloudy. This would be an example of auxiliary data for clear column retrieval. All this is briefly summarized in Table 5.

We now turn our attention (see Figure 4) to how VAS will be programmed in a typical day of severe storm observation. Early in the day the NMC prediction indicates 10 to 20 possible danger areas deserving attention. Often a strong correlation exists between morning conditions and afternoon severe weather (such as tornadoes). Coordinating the NMC prediction with the latest mesoscale analysis and synthesis and with early morning VAS and VISSR images, the man in the loop can direct the VAS to an area of possible severe weather and program the instrument for sounding or imaging and use this new VAS data interactively to update his selection of VAS operating mode and target. This concept for VAS operation clearly indicates the VAS advantage of watching for a storm and following it once it develops. It allows the operator to control the instrument so that VAS data contains information that cannot be gotten from other sources - the hard to get soundings around active weather and the strong gradients which are real and not noise.

Analysis is that system element which takes observations into derived meteorological parameters. For the VAS there are two types of observables - sounding data and imaging data. The characteristics of the sounding data are twelve channel radiances that give complete vertical coverage to an accuracy of 1 Wark (.25 erg/etc for the 15μ window channel) after time and

Ancillary Data Collection

SOURCE	DATA TYPE	REMARKS
Conventional Weather Data		
- surface	T_s, P_s, v_s, cloud hts. visibility	Description of Boundary Layer, Ground Truth Information Auxiliary Data for Clear Column Retrieval
- upper air	T(P, Q(P), v(P)	Vertical Resolution of Temperature and Humidity Fields
- radar	radar	Liquid Water Content
VISSR	high resolution visible images, IR window images	Description of Motion Fields, Cloud Types
Polar Orbiting Satellites		
- TIROS-N		
BSU	14 channel IR sounding	Intercomparison Soundings with VAS
SSU	3 channel IR sounding	Stratospheric Soundings
MSU	4 channel Microwave sounding	Soundings in Cloudy Regions
AVHRR	high res. visible images	Different Viewing Angle than VISSR helps with Cloud Height Determination
- DMSP	high res. visible images IR channel soundings Microwave soundings	More Complete Data Base, Better Cloud Height Determinations

Table 5

Concept for Selection of VAS Operating Mode

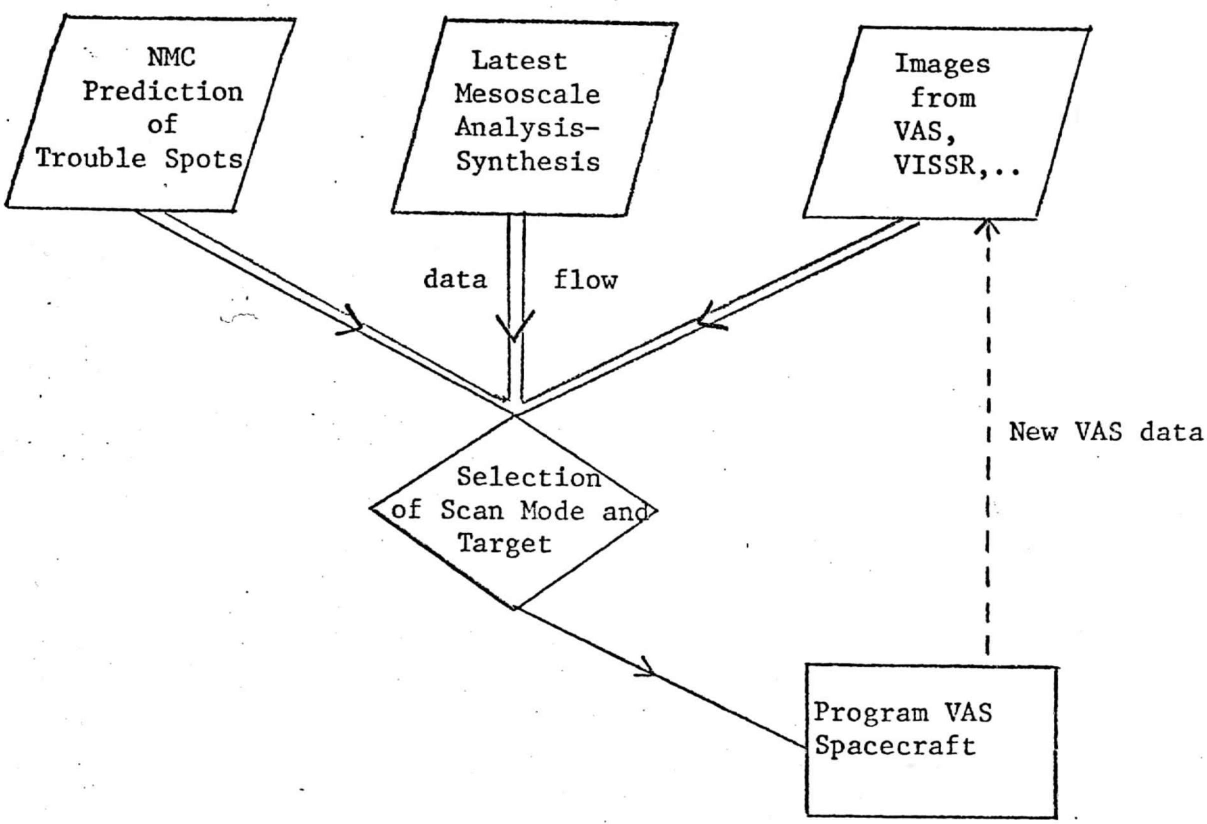

Figure 4

space smoothing. It has been indicated that this accuracy will allow successful temperature profile determination. The imaging data emphasizes horizontal coverage leaving vertical coverage incomplete. Spectral radiances here are chosen for specific applications (eg. the 4μ window channel would be used to evaluate sea surface temperatures over broad areas) and the sampling accuracy required also varies with application.

The derived meteorological parameter outputs can be classified by clear and cloudy areas. From clear areas one gets water vapor fields, winds from water vapor tracking (time sequence H_2O channel images), temperature fields, and surface temperatures (blackbody temperature determinations from window channel radiances). From the cloudy areas one determines winds from cloud tracking, cloud heights, liquid water content, and cloud types.

Table 6 indicates an overview of the status of the techniques used in analysis of the observables. For sounding analysis, existing polar orbiting sounder techniques need adaptation to account for characteristics of geosynchronous soundings and the interactive small machine environment. For imaging analysis, McIDAS techniques are directly applicable for retrieving cloud motion winds and polar orbiter techniques are applicable for determining cloud heights. Techniques for water vapor motion winds, surface temperature, cloud type, ... need development.

Synthesis takes the derived meteorological parameters and produces the four dimensional data set. The basic object of synthesis is to create a complete meal for the model. Every box in the mesoscale volume is full of numbers that describe the atmospheric state (T, P, Q, $\vec{V}$, liq H_2O, ..). Since the synoptic scale phenomena such as highs, lows, and fronts are often the driving force behind mesoscale weather they must be incorporated into the data as boundary conditions. A secondary objective is to make the meal

OVERVIEW OF TECHNIQUE STATUS

	Input Sources	Outputs	Status of Analysis Techniques
Sounding Analysis	Primary sources: VAS TIROS-N Auxilliary sources: Assimilated data Historical data VISSR images	q(P) T(P) Pcloud Tsurface	Existing polar orbiting sounder techniques need adaptation to interactive small machine environment.
Imaging Analysis	Primary sources: VAS VISSR Auxilliary sources: Assimilated data	- Cloud motion winds - Pcloud - Water vapor motion winds Liquid water content Tsurface Water vapor distribution Lower tropospheric temperature Cloud type	- McIDAS techniques directly applicable - Existing polar orbiter techniques applicable - Need development

Table 6

BASIC OBJECT OF SYNTHESIS

(A COMPLETE MEAL FOR THE MODEL)

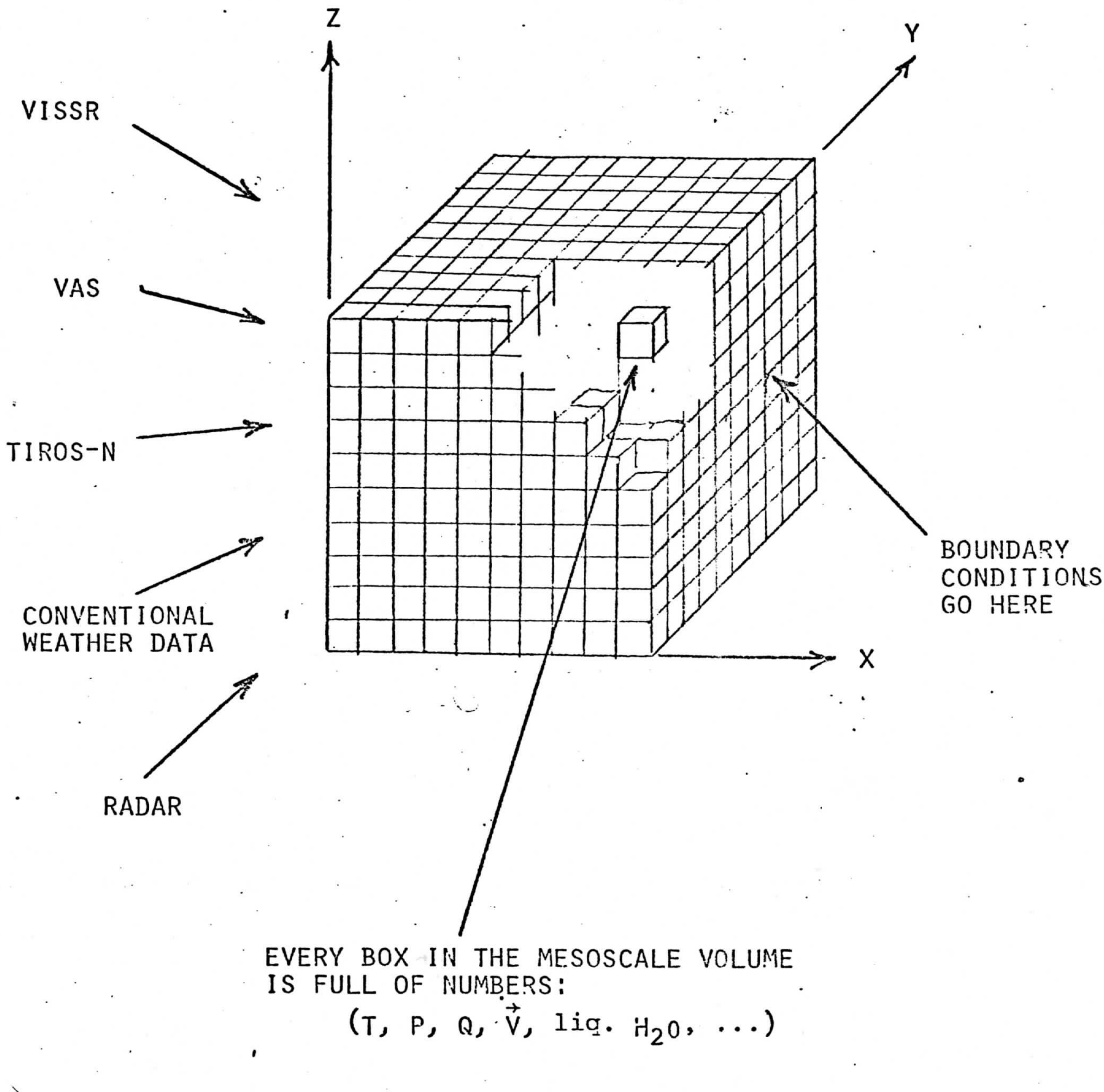

Figure 5

digestible for the model - the data set must be conditioned to mesh with the model. The model must be scaled temporally and spatially to provide useful short term forecasting. And as the resolution of the data set increases, more physics must be incorporated to power the model. All these considerations must be kept in mind to insure a smooth clock like functioning of the system.

To assimilate everything into a consistent four dimensional depiction of the state of the atmosphere will require different synthesis functions. These functions must eliminate data gaps and discontinuities that would cause predictive models to blow up and put heavy clouds and thunderstorms in the middle of high pressure areas. Interpolation, correlation, smoothing, deconvolution, extrapolation, uniform weighting, and quality control are all methods that will be used to transform incomplete, uneven, and irregular spatial and temporal coverage into a uniform, complete, and consistent data set. See Figure 6.

Many of these synthesis functions are incorporated in various models. An interpolation model determines values on a uniform grid from measurements made on a nonuniform grid. A diagnostic model derives secondary parameters (eg. rain areas) from primary parameters (eg. T, P, Q) to check consistency of derived and observed secondary parameters. An initialization model prepares data for predictive models by filtering data to eliminate scales and processes inappropriate to the model. Predictive models predict future values of primary parameters from initial conditions. An extrapolation model (eg. kinetic model) is characterized by simplicity and is useful only for very short times.

Once a proper and fully consistent description of the past and present

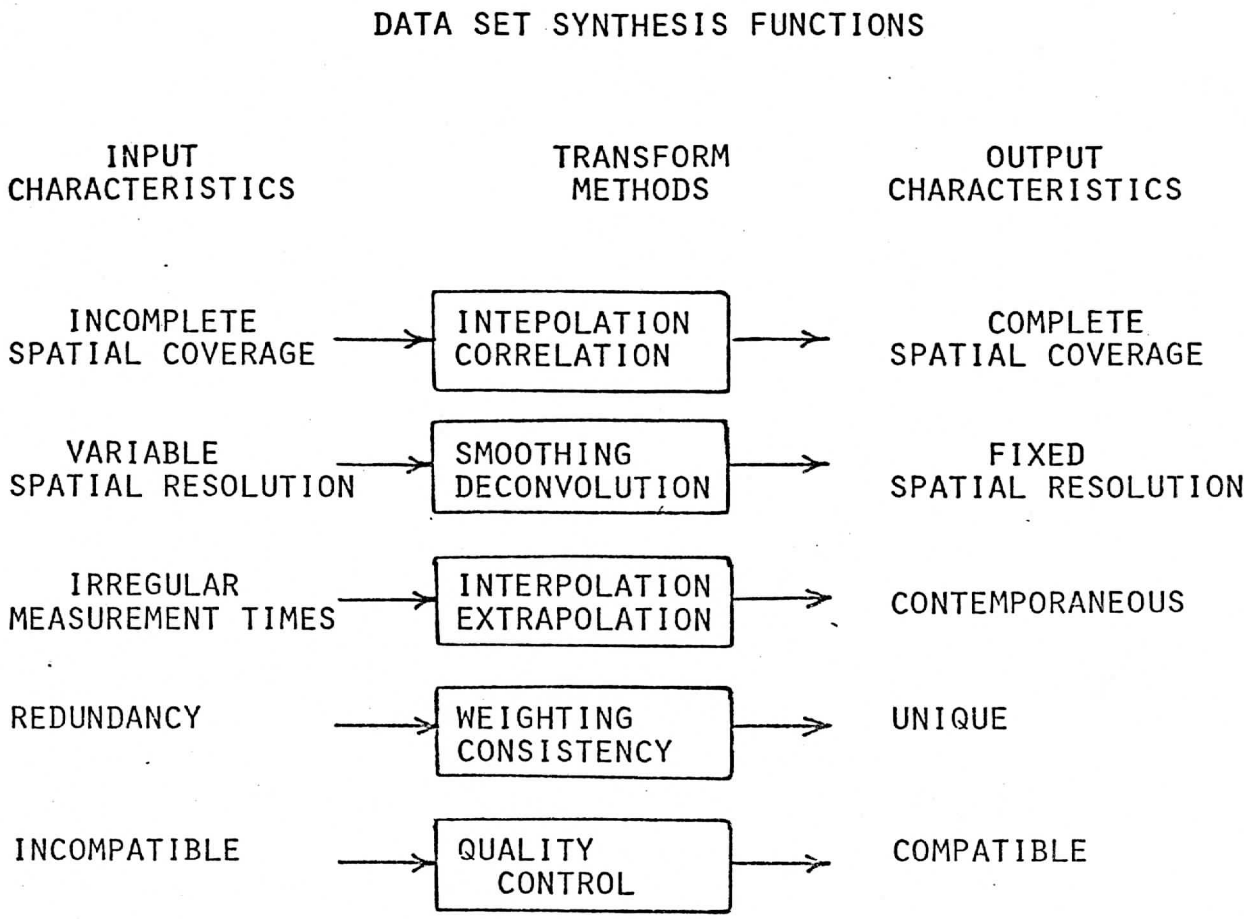
DATA SET SYNTHESIS FUNCTIONS
INPUT CHARACTERISTICS
TRANSFORM METHODS
OUTPUT CHARACTERISTICS
INCOMPLETE SPATIAL COVERAGE
INTEPOLATION CORRELATION
COMPLETE SPATIAL COVERAGE
VARIABLE SPATIAL RESOLUTION
SMOOTHING DECONVOLUTION
FIXED SPATIAL RESOLUTION
IRREGULAR MEASUREMENT TIMES
INTERPOLATION EXTRAPOLATION
CONTEMPORANEOUS
REDUNDANCY
WEIGHTING CONSISTENCY
UNIQUE
INCOMPATIBLE
QUALITY CONTROL
COMPATIBLE

Figure 6

states of the atmosphere is produced, then it will be made available to scientists in the meteorological community who can perform the modelling which extends the present into the future. This is the last system element and its successful development will rest heavily upon people and resources beyond SSEC.

Such a complete system as just described will accomplish the primary objective of the VAS mission - to better understand and improve prediction of mesoscale weather phenomena.