Table 3. The effects of the January 18-21, 1977 and the January 13-14, 1981 freezes on Valencia orange trees in a N-K-Irrigation Experiment.

Treatments (Rates)		1977 Leaf drop	1977 Fruit drop	1981 Branch dieback
		%	%	No./tree
Nitrogen:	N-1	27.7	3.5	2.42
	N-2	23.8	2.3	4.24
	N-3	26.5	3.7	4.34
Significance[z]		n.s.	n.s.	**
Potassium:	K-1	25.6	3.3	3.43
	K-2	26.4	3.1	3.90
Significance		n.s.	n.s.	n.s.
Irrigation:	I-1	29.0	5.8	6.34
	I-2	26.5	2.5	3.43
	I-3	22.5	1.2	1.23
Significance		*	**	**

	1977	1981
Temperature (°F) Minimum	23	20
hours below 30°F	32	23

Rainfall (in)		1977 Irrigation (in) I-1	I-2	I-3	1981 Rainfall (in)	1981 Irrigation (in) I-1	I-2	I-3
Sept.	4.46	–	–	–	3.81	–	–	–
Oct.	1.00	–	–	2.00	1.06	–	2.00	2.00
Nov.	2.66	–	2.00	2.00	6.74	–	–	–
Dec.	2.86	–	–	–	.37	–	–	2.00

[z]n.s.—significance, *—significant at 5%, **—significant at 1%.

is shrivelling and dropping or when trees are wilting to the point of leaf loss" (8) seems ill advised. Trees should be irrigated before reaching such an extreme need of water.

Although moderate water stress during the fall can induce cold hardiness under controlled conditions (2, 6, 7), relationship between water status and cold hardiness of field grown citrus trees are difficult to discern because uniform water stress is not easily attained in the field. Data reported in this paper show that mature citrus trees benefited by 4 to 6 inches of supplemented irrigation in the fall and early winter, particularly since below normal rainfall was recorded in the months prior to all 4 freezes. The 4 to 6 inches of supplemental irrigation may have just met the water requirement of the trees. Frequent fall irrigation should be avoided to prevent the dilution of juice solids and to promote cold hardiness. Until more research information becomes available, it seems that temporary leaf wilt for a short time at midday may be used as a guide for fall irrigation for most citrus cultivars.

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FLORIDA SATELLITE FROST FORECAST SYSTEM DOCUMENTS FREEZES OF JANUARY, 1981, AND IS REFINED FOR FUTURE SEASONS[1]

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Additional index words. frost protection, freezes, remote sensing, computer communication, automated weather stations.

Abstract. **Using the weather satellite view of the freezes of January 13 and 18, 1981, the reliability and time delays of the Satellite Frost Forecast System (SFFS) as it acquired data last winter are contrasted with the expected performance this frost season. During the past two winters SFFS has acquired digital satellite data via a 1200 Baud telephone link with a National Weather Service (NWS) facility in Suitland, MD, where stretched VISSR (Visible Infrared Spin-Scan Radiometer) data is received from the GOES weather satellite at 75°W through a 7 m diameter dish antenna. NWS sectorizes the Florida IR (Infrared) data from a hemispherical view stored by the National Earth Satellite Service (NESS) in the VDB (VISSR Data Base) and writes it in a queue that the SFFS computer interrogates hourly. This situation is contrasted with the expected performance of SFFS with a newly procured direct satellite link through a 5 m dish antenna to be located at Gainesville, Florida.**

SFFS products include a black and white map of symbols. These symbols are readily translated to pixel temperature by an included table and have been compared to conventionally measured temperatures in groves. The status of two models that work in series to produce the forecasted thermal maps is described with an indication of the accuracy of the forecasted temperature. Success in acquiring data from 10 automated weather stations to input into these models is described.

[1]Florida Agricultural Experiment Station Journal Series No. 3459. NASA Contracts, NAS10-9168 & NAS10-9892, are acknowledged as providing partial support for SFFS development as administered by Dr. James M. Dodge, Mr. U. Reed Barnett, Mr. Frank W. Horn, Jr., and Mr. Richard A. Withrow, and with cooperation from NOAA/NWS through Dr. Ray E. Jensen and Mr. Frederick C. Crosby. Technical support from Mr. James G. Georg, Dr. Ellen Chen, Mr. Ferris Johnson, Jr., Mr. H. Eugene Hannah, Mr. Michael P. Baker, Mr. Fred D. Stephens, Mr. Robert A. Dillon, Mr. Gary del Valle, Mr. Michael A. Lucido, and Mrs. A. E. Grimes is gratefully acknowledged.

An experimental network of APPLE II+[4] computers was used to transfer SFFS color maps from Gainesville to both Lake and Polk County Extension Centers during the 80-81 frost season. The feasibility of a similar link with six extension offices during the 81-82 frost season has been explored, as well as plans for an interface with an IFAS Computer Network that will link extension and research centers throughout Florida.

The space program provides Florida agriculturists with vivid pictures of the thermal distribution over the peninsula during frosts and freezes. A minicomputer controlled acquisition and prediction system has been developed that produces pictures or maps from satellite and surface observations and predicts what the satellite maps will look like throughout the remainder of the frost night. This system was used experimentally during the frosts and freeze of the 1980-81 winter and the products of the system are used to document those events. There are over 3500 individual temperature sensings (pixels) making up each map, versus a few hundred temperature recording stations that formerly made up the record of freezing temperature distribution over the state during a frost.

SFFS Configuration

SFFS operated experimentally during the 80-81 frost season (Fig. 1). Its evolution has been documented previously (1, 3, 5, 6) and SFFS continues to be refined (2, 4).

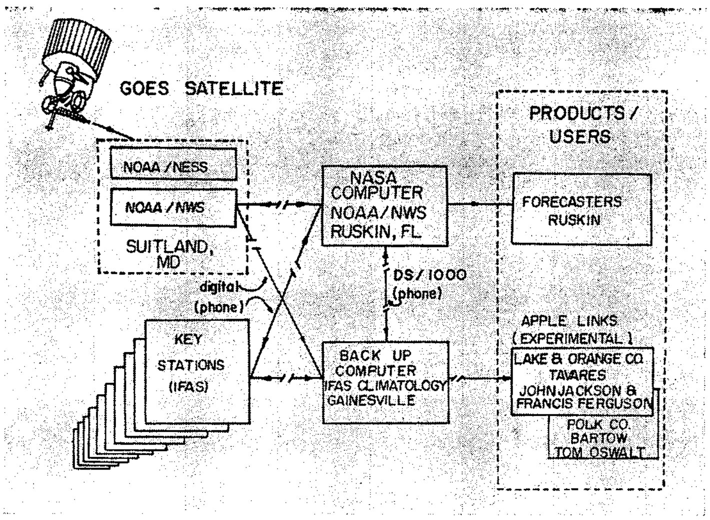

Fig. 1. Block diagram of SFFS as it operated during the 80-81 frost season.

The system is operated by one of two minicomputers which acquire the information necessary to construct the SFFS products automatically. The minicomputers are Hewlett-Packard (HP) Series 1000 machines using a real time operating system (RTE-IVB) and connected as a distributed system (DS/1000). See Figure 1. The link between the machines is currently a 1200 Baud dial-up line, but a dedicated line served by 9600 Baud modems is expected during the early portion of the 81-82 frost season.

The Ruskin minicomputer is an HP 2112 with 192 Kbytes of memory and accessing a 15 Mbyte disc (HP 7905A) as well as being able to produce magnetic tape records (8-track, 800 BPI, HP 7970B). The Gainesville computer is an HP 2113A with 256 Kbytes of memory and similar disc and magnetic tape facilities to the Ruskin system (except the Gainesville system's disc space is located on 3 HP 7900 drives at 5 Mbytes each). Both systems have CRT terminals (HP 2645A) and display the color products on 17 inch Conrac RGB (red-green-blue) monitors. Both systems are able to print hard copy (TI 733 at Ruskin, HP 2635A in Gainesville).

Automated use of telephone connections, both 300 and 1200 Baud is accomplished through a Vadic 1616A multiple chassis housing both auto-dialers and modems (models 801, 305, 3415).

Either computer can acquire data from either or both of the data sources and pass the information or products back and forth on the DS/1000 line but the 1200 Baud dial-up line has been unsatisfactory. During the 80-81 frost season the Ruskin system handled most of the data acquisition and displayed the products for the forecasters. On the major frost nights, the Gainesville system also acquired data from both the sources so that it could in turn pass SFFS products to the two county extension offices that made up the experimental APPLE II network during the season. (See Figure 1.)

Both the method of acquiring satellite data from NWS in Suitland, MD, and the manner in which the automated weather stations are interrogated was described to the FSHS last year (4).

Results and Discussion

Data Acquisition Success. Tables 1 and 2 summarize the success of SFFS in acquiring data from the two data bases used in forming its products. The success rates were analyzed separately for the calling sites since the routing procedures for the phone companies vary and failures to acquire data were due to phone line problems.

Table 1. Success experienced by SFFS in acquiring satellite data by 1200 Baud link to NWS in Suitland, MD, during the 80-81 frost season.

Location of acquiring computer:	Gainesville	Ruskin
Period covered:	Dec 31-Jan 19	Dec 20-Mar 23
Nights of operation:	12	50
Hours of operation per night:	14-15	varied
Total number of maps acquired:	104	351
Highest success rate per night:	93%	100%
Lowest success rate per night:	33%	7%
Average success rate per night:	60%	50%
Standard deviation of average rate:	8%	
Longest average delay per night:	3.4 hrs	7.5 hrs
Shortest average delay per night:	0.8 hrs	1.1 hrs
Average delay, all nights:	1.6 hrs	2.5 hrs
Standard deviation of delays:	0.7 hrs	1.8 hrs

Table 2. Success experienced by SFFS interrogation of automated weather stations during the 80-81 frost season.

Location of interrogating computer:	Gainesville	Ruskin
Period covered:	Jan 9-14	Dec 19-Feb 25
Number of nights of operation:	4	44
Lowest success rate per night:	93%	76%
Highest success rate per night:	99%	100%
Average success rate, all nights:	96%	95.6%
Standard deviation of rates:	2%	4.8%

Acquisition of data from the automated weather stations (Table 2) is satisfactory and demonstrates the effectiveness of a calling program that repeats attempts to make contact with a station and watches for deficiencies in data received.

The success rate for acquisition of the satellite data (Table 1) is unsatisfactory. Most of the delay experienced was in the early portion of the night when SFFS is in need of timely data. Channels through which the satellite data

[4]Use of a trade name or proprietary product does not constitute a guarantee of the product by the University of Florida and does not imply its approval to the exclusion of other products that may also be suitable.

are communicated from the NOAA/NESS antenna to the NOAA/NWS queue in Suitland are what NOAA terms experimental and, as such, communication steps are second priority to those serving an operational task (Fig. 1). Failures to acquire satellite data were the result of finding no current data in the queue at Suitland when SFFS called each hour. A trip by the authors and NASA representatives to Suitland revealed that the channels through which the satellite data were communicated to the Florida queue from the NESS antenna were not designed for such use. There is little likelihood that the reliability and timeliness of the acquisition though NESS-NWS in Suitland can be increased. Consequently, a direct link to the satellite has been investigated and a 5 m dish installation at Gainesville has been recommended. Hopefully the Suitland connection will serve as a backup to the antenna system.

Products. The primary products are the vivid false-color thermal maps of peninsular Florida (4). These are difficult to indicate in black and white. An Extension fact sheet and the October issue of *HortScience* will have a color photo of the output of SFFS. The fact sheet will also contain a copy of the symbols map which was found to be a very sought-after product of the system after the January 12-13 freeze (Fig. 2). The symbols map is a computer printout of the series of symbols used to transmit the maps over telephone lines. These symbols took the place of the original binary data when the Florida sector was read from the VDB in Suitland and placed in the Florida queue. Symbols are the form in which the satellite map data has been archived by SFFS during the past three years of its operation but, the translation schemes vary slightly, complicating recall and comparison of previous year's data.

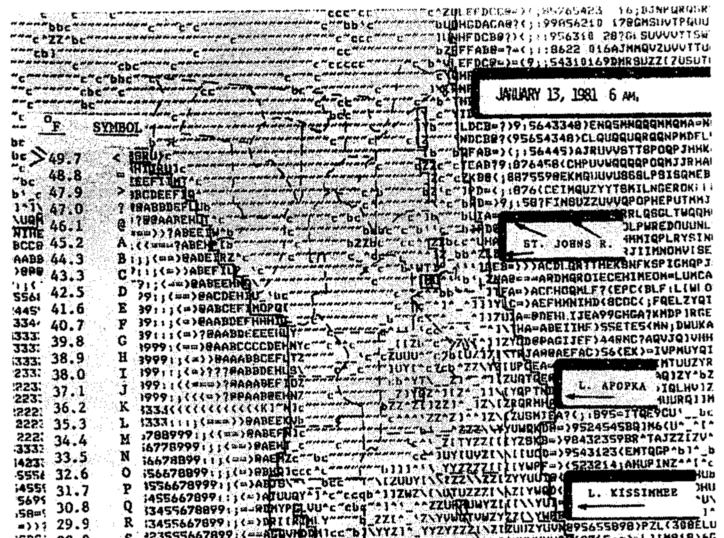

Fig. 2. One of the SFFS products that is reproducable in black and white is the symbols map. The translation table maps temperatures to each pixel. Indications of county lines have been added to this printout of the satellite data in the form that it is communicated over telephone lines.

The symbols map (Fig. 2) served a large audience after the January 13 freeze with detailed information of the severity of the freeze before more conventionally communicated information about the temperatures around the state was available. This product will be retained as an optional output from the system even if binary data through the antenna link to the satellite becomes the primary satellite data acquisition method. For example, Mr. Pete Spyke, Citrus Agent in Indian River County at the time, used the symbols map (Fig. 2) to compare the satellite data with thermograph and thermometer data from growers and NWS thermographs in Indian River County, Florida. Figure 3 is a redrawing of the comparison that he made, indicating a very close agreement between the individual pixel temperatures from the satellite and the temperatures used typically to document the severity of a frost or freeze.

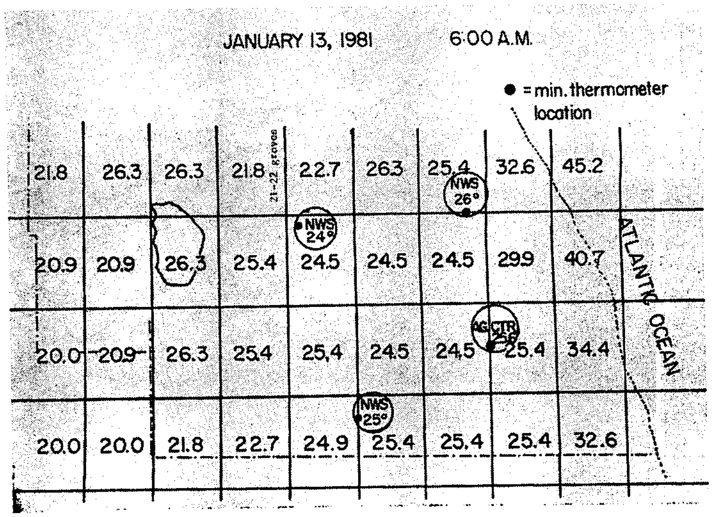

Fig. 3. Comparison of the pixel temperatures, as printed out from the 6AM satellite map, and the minimum temperatures collected by Mr. Pete D. Spyke, Extension Agent in Indian River County, from NWS and growers' thermographs and thermometers revealing excellent agreement between the point source data and the area values on the morning of the big freeze.

The system produces two types of thermal maps: observed maps and predicted maps. The predicted products are the result of two models operating in series. The first, or P-model, uses the automated weather station data to produce forecasts of the future temperature at that station (7, 8, 9). These temperatures are fed to the S-model, along with the current satellite map, to produce the forecasted map. The S-model uses only the rate of change of temperature from the P-model rather than the absolute value of the temperature data, i.e. the change in pixel temperature from the current (observed) thermal map to the predicted map is a function of the change in the predicted temperature at the automated weather stations. Figure 4 describes an output from a tool that SFFS has to evaluate the P-model's forecasting accuracy. On January 12-13, P-model forecasts had a mean error of −0.7°F with a standard deviation of 0.9°F, i.e. the model tended to forecast slightly cold. On January 28-29, the error was less, i.e. −0.4°F but with a much wider dispersion, standard error of 3.1°F (Fig. 4). Grouping the data for all ten weather stations over 2 frosts in 1980 and 5 in 1981, the model had an average error of 1.0°F with a standard deviation of 3.9°F. While there are improvements that can be made in the P-model, its performance is satisfactory. The S-model uses this rather high quality input to predict maps that are too warm, e.g. on January 12-13, the predicted maps had an average error for the approximately 3600 pixels making up the map of just over 1.0°F on the first hour, that steadily degraded to a +5°F error with a standard deviation of close to 7°F by the lengthening of the forecast to 8 hours. However, on January 28-29, the mean error remained less than one degree, regardless of the length of the prediction period, with the standard deviation gradually increasing from about 4°F at one hour to over 5°F at eight hours. The tool that is used to make these analyses is a computer program that subtracts the forecasted map from the observed map for that particular hour and statistically analyzes the differences, i.e. shows their distribution about the mean and computes the standard deviation and variance of the errors.

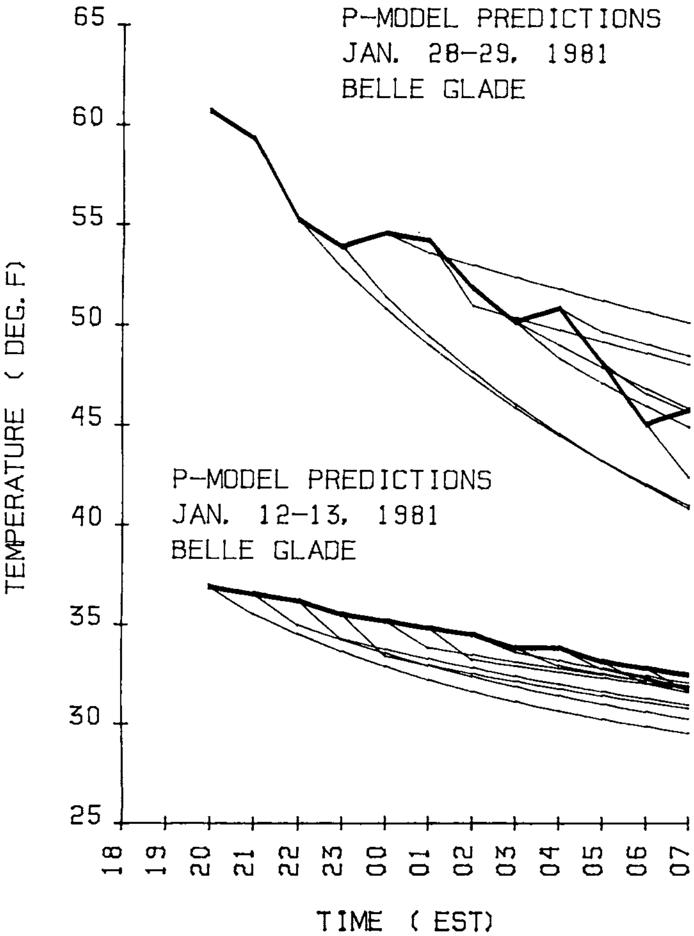

Fig. 4. SFFS tool for evaluation of P-model by comparison of the observed 1.5m temperature trace with the predicted temperatures (the lighter traces) from each hour through the remainder of the night.

Refinements in the method of producing coefficients for the S-model and better orientation of observed pixels with those of previous maps promise to improve the performance of S-model. As S-model is improved, there will be incentive to refine P-model for it may become the weaker link in forecast chain of events, i.e. sensitivity analysis is likely to continue to point a finger at the next element of SFFS that warrants refinement.

Dissemination. Since the conception of the SFFS concept, there have been intentions for the products of the system to be disseminated to a broader audience than just the NWS forecasters (1). Figure 5 indicates the intended configuration of the system during the 81-82 frost season. Notice that, in addition to the satellite data link through NOAA/NWS and NOAA/NESS in Suitland, a direct access system in the form of an antenna system at Gainesville is anticipated. The DS/1000 link between Gainesville is expected to be a dedicated line permitting satellite data to travel down to Ruskin and AFOS and key station data to return to Gainesville at 9600 Baud.

Six county computers (APPLE II+ with 1200 Baud modems) will call either Gainesville or Ruskin to pick up the series of symbols from which they can build thermal maps, both observed and predicted (Fig. 5). The counties that make up the experimental APPLE II network are listed in Table 3. They have equipment shown in Figure 6, i.e. an APPLE II microcomputer, a 19 inch color monitor, two 5 1/4″ floppy disk drives, a calendar clock and a modem capable of 1200 Baud transmission. Software is being developed that will automate each of these systems through the acquisition and the display of SFFS thermal maps each hour of frost nights in 81-82. The possibility exists that some growers with similar equipment may call the county microcomputers and acquire the maps on an experimental basis as well.

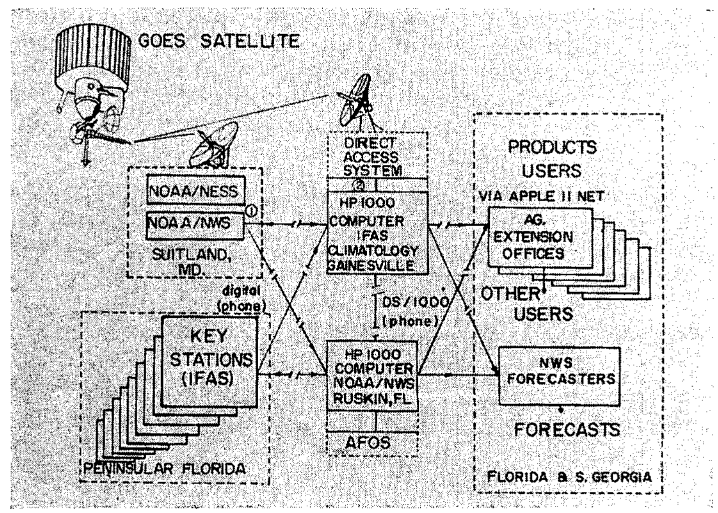

Fig. 5. A block diagram of the Satellite Frost Forecast System (SFFS) indicating the lines of communication of inputs on the left to product dissemination on the right.

Table 3. APPLE II + Network Listing, effective Fall of 1981. This is an experimental network, i.e. neither limiting nor necessarily binding on future networking decisions.

County	City	Agent	Crop(s) Covered
Lake[z] (& Orange)	Tavares	John Jackson (Francis Ferguson)	Citrus, ornamentals
Polk[z]	Bartow	Tom Oswalt	Citrus
Dade	Homestead	Seymour Goldweber	Subtropicals, vegetables
St. Lucie	Ft. Pierce	Pete Spyke	Citrus, Ornamentals
Madison	Madison	Jacque Breman	Peaches
Brooks (GA)	Quitman	Henry Carr	Peaches

[z]Program functional in winter of 80-81 as well.

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Fig. 6. The configuration of the experimental SFFS product receiving stations in each of six county extension offices.

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Proc. Fla. State Hort. Soc. 94:43-45. 1981.

COMPARISON OF SATELLITE FREEZE FORECAST SYSTEM THERMAL MAPS WITH CONVENTIONALLY OBSERVED TEMPERATURES

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Abstract. **During the freeze on January 10-11, 11-12 and 12-13, 1981, Satellite Freeze Forecast System (SFFS) thermal maps, a cooperative effort of NASA, NOAA and IFAS, were received experimentally at two locations in Central Florida—the Lake County Agricultural Center in Tavares and the Polk County Agricultural Center in Bartow. During the night thermal maps of peninsular Florida were received via a computer linkup between the two Agricultural Centers and the Fruit Crops Department, IFAS, University of Florida. The thermal maps are compared with data gathered by the National Weather Service's Minimum Temperature Survey in Polk County. Areas of major damage are ground-truthed against the thermal maps both for the extent of damage and geographic location.**

The winter season of 1980-81 marked the beginning of an experimental link-up to disseminate infra-red thermal images of the Florida peninsula. Data were transmitted over telephone lines from the Fruit Crops Department, IFAS, University of Florida to the county extension offices in both Lake and Polk Counties. The equipment used in the link-up from the Fruit Crops Department to the counties were Apple II micro-computers as described by Martsolf (3). The Polk County "Apple Network" was cooperatively supported by NASA and AREC, Lake Alfred.

Justification for moving towards a system of computerized weather dissemination rests upon several changes facing growers today. Horticulturally, growers need good freeze/frost information to prevent unnecessary losses in energy, fertilizer, pesticide and capital (1). Also, the policies within the federal government indicate a tendency to curtail personnel in NOAA under which NWS operates as a result of increased use of technology, e.g. computers and satellites (2).