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

gram. Proc. Fla. State Hort. Soc. 92:22-25.

4. ———. 1980a. An improved satellite frost warning system. Proc. Fla. State Hort. Soc. 93:41-44.
5. ———. 1980b. Evolution in frost protection. Amer. Fruit Growers 100(2):12, 92-94.
6. ———. 1980c. Frost protection. The Citrus Industry Magazine 61(9):17-26.
7. Shaw, Roger H. 1981. Comments on "A short-range objective nocturnal temperature forecasting model." J. Appl. Meteor. 20:95.
8. Sutherland, Robert A. 1980. A short range objective nocturnal temperature forecasting model. J. Appl. Meteor. 19:247-265.
9. ———. 1981. Reply. J. Appl. Meteor. 20:96-97.

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

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

THOMAS W. OSWALT
University of Florida, IFAS,
Cooperative Extension Service, Polk County,
1702 Hwy 17 South, Bartow, FL 33830

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).

Programs designed to provide rapid review of current weather events—"nowcasts"—could provide growers with valuable information in arriving at decisions to initiate cold protection activities.

For such a system to be useful, it would be necessary to determine the relationship between the SFFS thermal temperatures and conventionally observed surface temperatures.

Materials and Methods

Infra-red thermal images were collected over the experimental SFFS link on seven nights. Nights selected for study were January 10-11, 11-12, and 12-13, 1981. Copies of the symbols maps were requested from the Climatology section of the Fruit Crops Department, IFAS for 8:00 p.m., 1:00 a.m. and 6:00 a.m. The 2:00 a.m. map for January 13 was used because the 1:00 a.m. map was not received.

Copies of the thermograms for 19 government thermograph stations located in Polk County were provided through the Federal-State Frost Warning Service, a cooperative effort between IFAS Extension and the National Weather Service at Ruskin. The stations and their locations are listed in Fig. 1.

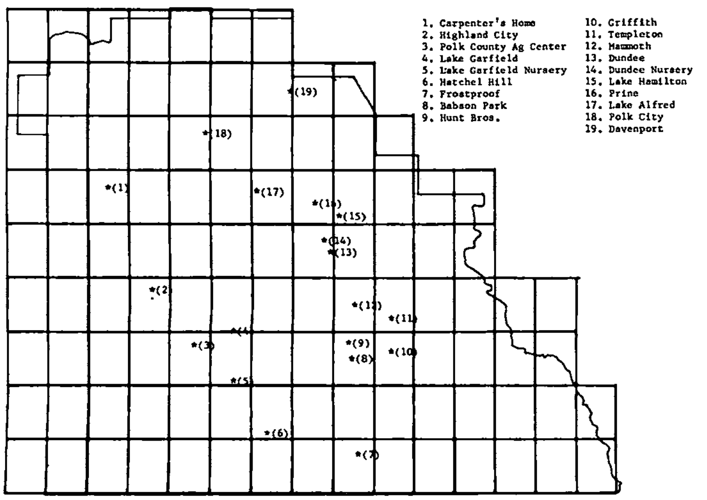

Fig. 1. Names and relative locations of 19 thermograph stations in Polk County used to compare with SFFS maps.

A map of Polk County was divided into sectors equivalent to a picture cell—(pixel—smallest element of resolution as provided by the GOES satellite). The apparent size of each pixel was about 4 miles (East to West) by about 5 miles (North to South). Using these estimates, approximately 13.9 pixels covered the distance of 55.7 miles along the southern border of the county. Nine pixels covered the distance in a north to south direction.

Large lakes provided the landmarks necessary to align a template to mark the Florida coastline. These lakes were Okeechobee, Istopoga, Kissimmee and Apopka (Fig. 2).

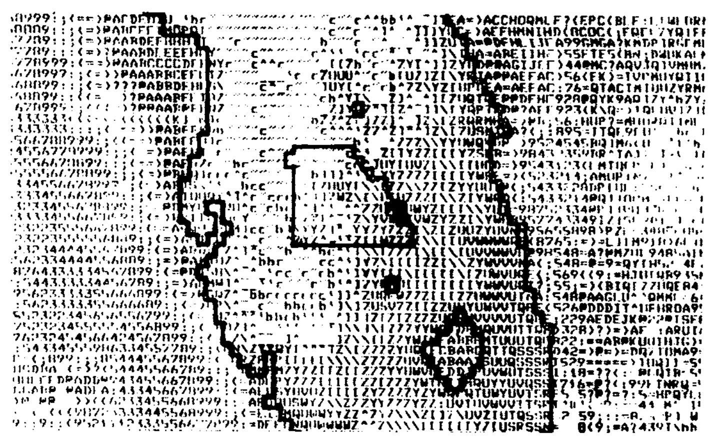

Fig. 2. SFFS symbols map for 6:00 a.m. January 13, 1981. Landmarks used to align a template are from Lake Apopka, north of Polk County, Lake Kissimmee, eastern Polk County, Lake Istopoga, south of Polk County and Lake Okeechobee. The temperature in each pixel is represented by a letter or other symbol.

Results and Discussion

A detailed study of the printed SFFS symbols maps uncovered some useful temperature patterns.

The warmest pixel in Polk County was Lake Kissimmee which consisted of one to three pixels depending upon the satellite alignment as it scanned across the state. The coldest pixels were in the Green Swamp area of northwest Polk County.

SFFS would be most useful if the pixel temperatures were closely related to selected field stations. Charts from 19 government stations were used to "ground-truth" the temperatures observed from the SFFS thermal maps.

The poorest correlations were caused by a large difference between ground and SFFS readings on January 11, 1981 at 6:00 a.m. The extremely low readings by the SFFS methods was attributed to a cirrus cloud cover or at least enough moisture aloft to attenuate the radiation emitting from the earth's surface. The radiometer in the GOES satellite probably scanned areas of moisture (or ice crystals) aloft and adjacent land surfaces collectively. The results would likely be an integrated temperature considerably lower than adjacent pixels. Often the pixel in question exhibited a more normal relationship with the ground-truth sites either the hour before or after the time of the observed anomaly. Additional SFFS symbols maps at 5:00 and 7:00 a.m., January 11, were obtained to compare pixels in the same relative position. The extremely low temperatures (mid teens) did not usually carry over to the next hour's map. The locations of the pixels with the low temperatures did vary indicating motion as one would expect with a cloud. Hourly observations aid in the detection of such occurrences; however, it is important to remember that the attenuation of radiation has a very practical effect of warmer surface temperatures.

Plotting the SFFS temperatures against thermograph temperatures for each location generally revealed higher thermograph temperatures. By way of possible explanation the satellite measured radiative surfaces while thermographs were measuring free air temperatures 4.5 feet above the radiating surface. Such a consistent relationship would allow accurate temperature estimates for those areas in which thermograph stations were located.

The correlation coefficients for the 19 thermograph stations identified a number of sites with a value approaching one. A correlation coefficient of one represents a perfect fit where a unit change of the independent variable (SFFS temperatures) resulted in a unit change in the dependent variable (thermograph temperature).

Lake Alfred, Davenport and the Polk Ag Center had the highest correlations. The temperatures recorded from SFFS and thermographs were plotted against time for Lake Alfred. The differences for the 3 observations on January 11-12, 1981, ranged from a low of 1.8°F to a high of 3.0°F. In Fig. 3 the data for Lake Alfred is plotted for 9 observations taken over the 3 dates and 3 times. The correlation is quite good at 0.966; hence the scatter of observation points is small.

The stations with the lowest correlations were Hunt,

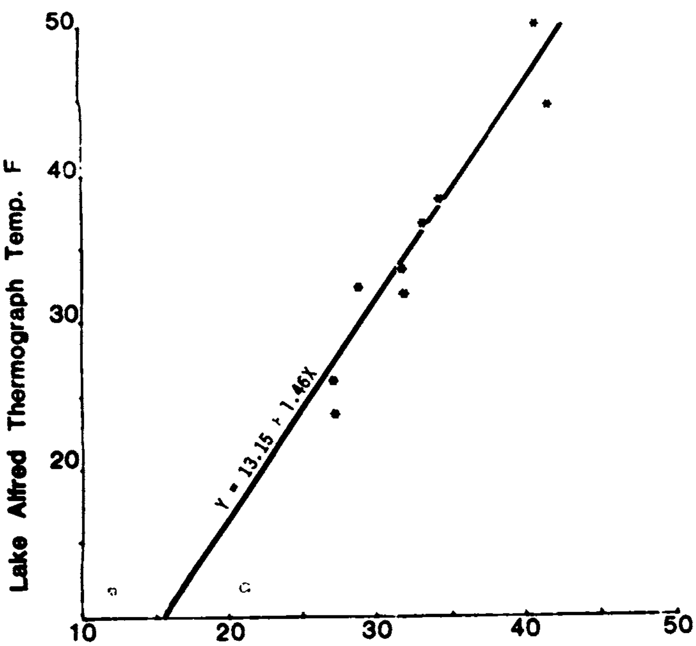

Fig. 3. Line of best fit giving a correlation coefficient of 0.97 for 9 observations taken at 8:00 p.m., 1:00 a.m. and 6:00 a.m. on January 10-11, 11-12 and 12-13, 1981, Lake Alfred thermograph station.

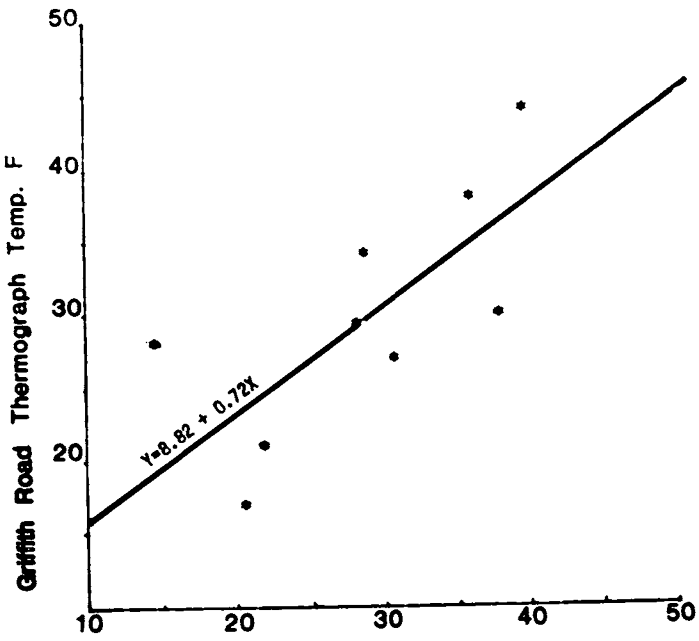

Fig. 4. Line of best fit giving a correlation coefficient of 0.82 for 9 observations taken at 8:00 p.m., 1:00 a.m. and 6:00 a.m. on January 10-11, 11-12 and 12-13, 1981, Griffith Road thermograph station. Note scatter of observation points around line of best fit.

Griffith Road and Lake Hamilton. On January 11-12 the Griffith Road station thermogram and SFFS temperatures were plotted against time. As was expected the SFFS temperature was lower than the thermograph temperature at 8:00 p.m. and 6:00 a.m.: however at 1:00 a.m. SFFS temperature was higher for some unexplained reason. This type of variation was evident in Fig. 4 where the temperature plots were widely scattered on either side of the curve. The removal of the January 11, 6:00 a.m. temperature did not noticeably improve the correlation coefficient of 0.82 because of the random scatter of the remaining 8 observations.

In summary, comparisons of SFFS and thermogram temperatures showed a very strong correlation in 9 of the 19 stations observed. Seven stations showed strong correlations. It appears that SFFS has the potential of being a rapid and accurate means of determining surface temperatures during clear nights (Table 1).

Knowledge of the relationships of the thermograph temperatures to that of the SFFS temperatures makes SFFS maps more convincing. It seems advisable to monitor SFFS temperatures from hour to hour to determine rates of fall and to provide rapid determination of the coldest areas in the county. SFFS offers a unique "nowcast" of weather events which should provide growers with valuable inputs to cold protection activities and other management decisions.

Table 1. Correlation coefficients for the 19 Polk County Thermograph stations.

Station	Correlation coeficient	Station	Correlation coefficient	Station	Correlation coefficient
1	0.98	7	0.61	13	0.93
2	0.91	8	0.73	14	0.94
3	0.90	9	0.82	15	0.83
4	0.95	10	0.95	16	0.97
5	0.85	11	0.95	17	0.90
6	0.70	12	0.91	18	0.98
				19	0.95

As subtle as it is revolutionary, SFFS products present temperatures as a continuum as compared to weather stations consisting of a finite number of discrete points.

Literature Cited

1. Bartholic, J. F. and R. A. Sutherland. 1978. Future freeze forecasting. Proc. Fla. State Hort. Soc. 91:334-336.
2. Martsolf, J. David. 1979. Frost protection: A rapidly changing program. Proc. Fla. State Hort. Soc. 92:22-25.
3. ———. 1980. An improved satellite frost warning system. Proc. Fla. State Hort. Soc. 93:41-44.