USE OF THERMAL INERTIA DETERMINED BY HCMM TO PREDICT NOCTURNAL COLD PRONE AREAS IN FLORIDA

HCMM Data Investigation HFO-002
Contract NAS5-26453

E82-10157
CR-164927

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(E82-10157) USE OF THERMAL INERTIA DETERMINED BY HCMM TO PREDICT NOCTURNAL COLD PRONE AREAS IN FLORIDA Quarterly Report, 16 Jun. - 15 Sep. 1981 (Florida Univ.) 23 p HC A02/MF A01 CSCL 08F G3/43

N82-21681

Unclas 00157

September 15, 1981
Second Quarterly Report for Period June 16-September 15, 1981

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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Preface

The text of this second quarterly report contains the following seven topics as shown in Article XII, Contract NAS5-26453.

1) Problems
2) Accomplishments
3) Significant Results
4) Publications
5) Recommendations
6) Funds Expended
7) Data Utility
8) Program for next reporting interval

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INTRODUCTION

This second quarterly report covers work performed during the period June 16 to September 15, 1981, of a one-year HCMM Data Investigation Contract NAS5-26453 entitled "Use of Thermal Inertia Determined by HCMM to Predict Nocturnal Cold Prone Areas in Florida".

This report documents progress made during the reporting period. The main items of progress were ordering of detailed scenes and CCT's of temperature difference and thermal inertia for the 1978-79 winter. Of the materials that have arrived so far, we were able to depict thermal inertia differences in the south Florida area which included drained organic soils of the Everglades Agricultural Area, undrained organic soils of the managed water conservation areas of the South Florida Water Management District, the urbanized area around Miami, Lake Okeechobee, and the mineral soil west of the Everglades Agricultural Area. Also, we were able to depict the range of wetlands and uplands conditions within the Suwanee River Basin. The day-night scene information from HCMM is well supported by the time-course data of surface temperatures from GOES IR data.

The information available so far shows that the combination of wetlands-uplands surface features of Florida yields a wide range of surface temperatures related to wetness of the surface features.

During the remainder of the work period, we will continue to quantify thermal inertia patterns under a range of surface moisture conditions, and use models to predict surface temperatures from thermal inertia information.

USE OF THERMAL INERTIA DETERMINED BY HCMM TO PREDICT NOCTURNAL COLD PRONE AREAS IN FLORIDA

1. Problems:

A. Lag time in receipt of data products.

Most of the first order of negatives and prints were received in time for evaluation and use in the first quarterly report. However, because of the lack of 12-hour day-night sequency of HCMM satellite overflights, and because of the numerous periods of cloudiness in Florida during the best HCMM winter overflights (1978-79), we delayed ordering CCT's of day and night IR day visible, temperature difference, and apparent thermal inertia until the best choices could be made. However, several items have been received (section 2-A).

2. Accomplishments:

A. Ordered CCT's of day and night IR, day visible, temperature difference, and apparent thermal inertia, as well as transparencies and prints of 1978-79 winter data.

Tables 1 and 2 list the HCMM CCT's and images that were ordered July 10, 1981. During the second quarter, the following products were received.

1. One CCT containing data from January 10, 16, and 18, 1979.
2. Prints containing one each of day and night IR, day visible, temperature difference, and apparent thermal inertia from January 29 and February 1, 1979.
3. Film transparencies and prints containing one each of day and night IR, day visible, temperature difference, and apparent thermal inertia from December 15 and 17, 1978.

3. Significant Results:

A. Thermal properties of organic soils in south Florida.

From Lake Okeechobee southward, the topography of Florida is flat and lies at low elevations. A wide strip from Lake Okeechobee to Florida Bay consists of organic soils (Fig. 5, first quarterly report). An area south of Lake Okeechobee is drained and used for agriculture; it is called the Everglades Agricultural Area. Large canals run from Lake Okeechobee to the southeast coast. Three Water Conservation Areas are located in organic soil to the southeast and south of the Everglades Agricultural Area. The Everglades National Park is located south of these Water Conservation Areas onward to Florida Bay.

A strip of mineral soil is found along the southeast coast of Florida. This mineral soil is also highly drained. It is highly urbanized, with agricultural development at the south end and the north end.

HCMM apparent thermal inertias and temperature differences derived from daytime January 29 data and night time February 1, 1979 data, (Fig. 1) for south Florida showed similar patterns to GOES detected surface temperatures of the same area and for approximately the same time (Fig. 2). The HCMM derived data showed distinct boundaries between the drained organic soil of the Everglades Agricultural Area and the undrained organic soil of the Water Conservation Areas, #1, #2, and #3, managed by the South Florida Water Management District (Fig. 5, from First Quarterly Report), as well as between the Water Conservation Areas and the southeast coastal land area. Differences among the three Water Conservation Areas are present but they are less distinct. The GOES surface pattern for 0100 EST, January 29, 1979, showed a difference of 5-6°C between the Everglades Agricultural Area and the Water Conservation Areas, and a difference of only 1-2°C between the three Water Conservation Areas. Data from February 1, 1979, showed generally equivalent differences (Fig. 2). The HCMM calculated difference in apparent thermal inertia indicates a difference in temperatures and thermal properties of the surface. The region has the same organic soil base, but a different surface water content due to differences in land use and water management. Differences in surface water content contributed to the difference in thermal inertia. Atmospheric conditions would affect the regions equally because of the proximity of the areas. We could not accurately quantify the apparent thermal inertia from the HCMM prints that have been received so far, but the patterns of the HCMM derived apparent thermal inertias for the areas are supported by the GOES surface thermal patterns (Fig. 2) and the GOES diurnal surface temperature wave for different dates (Fig. 3 and Fig. 4).

Diurnal temperatures from GOES for two nights, one each from 1979-80 (wet) and 1980-81 (dry) winter seasons illustrate diurnal amplitudes which resulted from differences in relative surface water content of the areas resulting from wet/dry seasons. Table 3 shows rainfall for periods immediately before February, 1980, and January, 1981. The entire state showed higher than average rainfall for 1979-80 and lower than average rainfall for 1980-81, especially for the latter half of the year (July-December columns). Diurnal temperature amplitudes of the drained Everglades Agricultural Area were larger than those of the three Water Conservation Areas, indicating that the former has a smaller thermal inertia than the latter. Water Conservation Area #1 showed a larger diurnal amplitude than Water Conservation Area #2 wet season, Fig. 3, whereas the difference between the diurnal amplitude was less from data for one day during the dry season, Fig. 4. Average diurnal amplitudes for the Water Conservation Areas were larger for data from January 12-13, 1981 (dry) than for data from February 26-27, 1980 (wet). Diurnal amplitudes from GOES will be used to estimate thermal inertia to compare with those from HCMM apparent thermal inertia.

An equation representing diurnal surface temperatures can be written in a Fourier series as follows,

$$\theta(o,t) = \theta_a + \sum_{k=1}^{\infty} (A_k \cos k\omega t + B_k \sin k\omega t) \qquad (1)$$

where θ is the temperature, t is the time, θ_a is the average temperature at the surface, k is the number of harmonics, A_k and B_k are the Fourier coefficients, $\omega=2\pi/86400\ sec^{-1}$ is the diurnal frequency. Surface temperatures from GOES were used to obtain the coefficients and the equation which describes the diurnal temperature wave. One result is shown in Fig. 5. The equation is,

$$\theta(0,t)=3{\cdot}7-8{\cdot}33\cos(\omega t)-0{\cdot}71\sin(\omega t)+3{\cdot}91\cos(2\omega t)-0{\cdot}51\sin(2\omega t)-0{\cdot}92\cos(3\omega t)+0{\cdot}12\sin(3\omega t)-0{\cdot}45\cos(4\omega t)+0{\cdot}09\sin(4\omega t) \qquad (2)$$

The result will be used to calculate thermal inertia independent of HCMM apparent thermal inertia both as a check and also to be used to fill the HCMM diurnal surface temperature data gap.

B. Thermal properties of mineral soils in the Suwanee River Area of north Florida.

The Suwanee River (Fig. 6) flows through an extensive area of well drained sandy soil in north Florida (Fig. 6, First Quarterly Report). GOES surface temperatures indicated that the area appeared persistently colder than surrounding areas (Fig. 6). The colder areas corresponded well to well drained sandy soils and to LANDSAT identified cleared areas. HCMM apparent thermal inertia for the area (Fig. 7, circled area) showed the same general pattern as GOES and LANDSAT false color imagery. Therefore we decided to examine the thermal properites of the area and to obtain thermal inertias for the region in preparation for construction of a thermal inertia map for Florida. GOES surface temperatures from January 12-13, 1981, were used to obtain a diurnal surface curve for three areas in the Suwanee River Watershed. As an accuracy check for GOES temperature, maximum and minimum temperatures from NOAA cooperative observer stations in the Suwanee River Basin were tabulated in Table 4, approximate location of each site indicated but not individually indentified on Fig. 6. The five areas, shown in Fig. 6, are regions which appeared colder than surrounding areas early in the evening (1900 to 2100 EST). Of the five areas, Area 2 appeared generally the earliest and also the coldest. Their diurnal surface temperatures are shown in Fig. 8. Area 2 has a larger diurnal amplitude than other Areas, which indicated different thermal inertia and thermal properties. All five areas are found in higher well-drained elevations (100 to 150 feet) whereas the warmer areas are found in lower poorly-drained elevations (less than 100 feet).

The diurnal GOES surface temperatures for the Miami urban area is shown in Fig. 3 and Fig. 4. This area shows an urban heat island effect because the midday temperatures are high, but the night time temperatures do not drop as low as the Everglades Agricultural Area.

Fig. 4 also shows the distribution of diurnal surface temperatures for Lake Okeechobee and for a mineral soil area west of Lake Okeechobee.

During the dry conditions (January 12-13, 1981) the diurnal amplitude of surface temperatures of this mineral soil areas was significantly larger than during the wetter conditions (February 26-27, 1980).

Table 5 shows the maximum-minimum temperature differences for these well-defined areas for the February 26-27, 1980 data and the January 12-13, 1981 data. Using assumptions, diurnal heat capacity and thermal inertia were computed according to equation 2 of Price (1980)*.

4. Publications - none

5. Recommendations

No new recommendations for second quarterly report. See recommendations listed in the first quarterly report.

6. Funds expended to date (September 15, 1981) = $17,098.97

7. Data Utility.

Not enough new products received to make new evaluations.

8. Program for next reporting interval.

A. Analyze and evaluate new HCMM temperature difference and thermal inertia data after it arrives.

B. Develop models to utilize HCMM and other satellite derived sources of thermal inertia information for mapping thermal inertia as related to surface conditions and to antecedent soil moisture conditions.

C. Integrate various sources of satellite information and ground-level verification information in order to refine patterns of nocturnal cold-prone and warm-prone areas.

D. Use model(s) to be able to predict patterns of nighttime lows of surface temperature from daytime patterns of maximum surface temperatures and surface thermal inertia information.

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* Price, J. C., 1980: The potential of remotely sensed thermal infrared data to infer soil moisture and evaporation. Water Resources Research, Vol. 16, No. 4, 787-95.

TABLE 1. HCMM transparencies, prints, and CCT's of day visible (DVIS), day IR (DIR), and night IR (NIR) ordered July 10, 1981, that cover the 1978-1979 winter season.

Date	Long.(W)	Lat.(N)	Scene ID	Orbit	Cloud	Quality	Type	Received
(78-79)	deg-min	deg-min	(AAO-)		%			
(Transparencies and Prints -- Day Visible, Day IR, Night IR)								
15 Dec	82-14	28-09	233-07130	3450	60%	G	NIR	
20 Dec	80-11	30-12	238-07060	3524	30%	F	NIR	
20 Dec	81-39	24-04	238-07080	3524	20%	G	NIR	
29 Jan	83-21	31-56	278-18360	4124	40%	G	DVIS	
29 Jan	83-21	31-56	278-18360	4124	40%	G	DIR	
1 Feb	80-49	82-30	281-07040	4161	20%	F	NIR	
3 Feb	80-09	24-09	283-18280	4198	20%	G	DVIS	
3 Feb	80-09	24-09	283-18280	4198	20%	F	DIR	
(CCT's -- Day IR and Night IR)								
15 Dec	82-14	28-09	233-07130	3450	60%	G	NIR	
17 Dec	81-18	27-54	235-18361	3487	20%	G	DIR	
10 Jan	79-03	25-01	259-06570	3835	30%	G	NIR	
13 Jan	81-50	28-26	262-18370	3887	40%	F	DIR	
15 Jan	77-02	25-59	264-06490	3909	40%	G	NIR	
16 Jan	82-07	25-34	265-07070	2095	70%	F	NIR	
18 Jan	79-08	24-59	278-18280	3961	30%	F	DIR	
29 Jan	83-21	31-56	278-18360	4124	40%	G	DIR	
29 Jan	81-52	25-49	278-18350	4124	10%	G	DIR	
1 Feb	80-49	32-30	281-07040	4161	20%	F	NIR	
1 Feb	82-19	26-22	281-07060	4161	30%	F	NIR	
3 Feb	80-09	24-09	283-18280	4198	20%	G	DIR	
3 Feb	81-36	30-17	283-18300	4198	30%	G	DIR	

TABLE 2. HCMM CCT's, prints, and transparencies of temperature differences and apparent thermal inertia, ordered July 10, 1981, that cover the 1978-1979 winter season. Paired rows show the day IR (DIR) and night IR (NIR) scenes combined in each product.

Date	Long.(W)	Lat. (N)	Scene ID	Orbit	Cloud	Quality	Type
(78-79)	(deg-min)	(deg-min)	(AAO-)		%		
17 Dec	81-18	27-54	235-18361	3487	20	G	DIR
15 Dec	82-14	28-09	233-07130	3450	60	G	NIR
13 Jan	81-50	28-26	262-18370	3887	40	F	DIR
10 Jan	79-03	25-01	259-06570	3835	30	G	NIR
13 Jan	81-50	28-26	262-18370	3887	40	F	DIR
15 Jan	77-02	25-59	264-06490	3909	40	G	NIR
18 Jan	79-08	24-59	267-1828	3961	30	F	DIR
16 Jan	82-07	25-34	265-07070	2095	70	F	NIR
29 Jan	81-52	25-49	278-18350	4124	10	G	DIR
1 Feb	82-19	26-22	281-07060	4161	30	F	NIR
29 Jan	83-21	31-56	278-18360	4124	40	G	DIR
1 Feb	80-49	32-30	281-07040	4161	20	F	NIR
3 Feb	80-09	24-09	283-18280	4198	20	F	DIR
1 Feb	82-19	26-22	281-07060	4161	30	F	NIR
3 Feb	81-36	30-17	283-18300	4198	30	G	DIR
1 Feb	80-49	32-30	281-07040	4161	20	F	NIR
3 Feb	81-36	30-17	283-18300	4198	30	G	DIR
1 Feb	82-19	26-22	281-07060	4161	30	F	NIR

TABLE 3. Rainfall and departures from the means from 1979 and for 1980 that determine antecedent surface moisture conditions for periods immediately before the January-February winter period of 1980 and 1981, respectively. Source: Climatological Data, Florida, Annual Summary, National Climatic Center, Asheville, N.C., 83, No. 13, 1979, and 84, No. 13, 1980.

Climatic Zone	1979 Rainfall (inches)				1980 Rainfall (inches)			
	Annual (Jan-Dec)		July-Dec		Annual (Jan-Dec)		July-Dec	
	ppt.	Dep.	ppt.	Dep.	ppt.	Dep.	ppt.	Dep.
Northwest (18)*	72.32	12.47	38.54	10.49	59.99	0.14	24.73	-7.23
North (22)	61.21	6.39	32.51	1.33	51.25	-3.57	23.75	-7.23
North Central (17)	60.72	7.05	34.52	3.18	46.49	-7.19	25.12	-5.24
South Central (29)	59.03	5.85	33.60	2.51	43.90	-9.28	23.70	-7.39
Everglades & Southwest Coast (14)	54.00	0.68	34.18	3.03	45.58	-7.74	26.72	-4.43
Lower East Coast (12)	60.32	0.79	35.15	1.22	57.97	-1.56	33.69	-1.47

*Number of reporting stations in each zone.

ppt. Total rainfall for the zone.

Dep. Departure from long-term means based on periods varying from 10 to 29 years.

TABLE 4. Maximum and minimum temperatures from January 12-13, 1981, for NOAA cooperative observer stations in the Suwanee River basin of North Florida. Approximate location of the cities are indicated in fig. 5 (black circles). Source: Climatological Data, Florida, 85, No. 1, National Climatic Center, Asheville, N.C., 1981.

Station	Temperature (°C) Max.	Min.
Cross City 2 WNW	5.6	-12.2
High Springs	10.0	-7.8
Jasper	5.0	-11.7
Lake City 2 E	4.4	-10.6
Live Oak	10.0	-12.2
Madison 4 N	8.9	-10.0
Mayo	4.4	-11.1
Perry	8.3	-11.7
Steinhatchee 6 ENE	7.2	-11.1
Usher Tower	10.0	-11.7
Average	7.4	-11.0

TABLE 5. GOES maximum and minimum surface temperatures, derived diurnal heat capacity and thermal inertia for two diurnal cycles.1/

Location	Tmax (°C)	Tmin (°C)	ΔT (°C)	D ($W/m^2 \cdot °c$)	P
February 26-27, 1980					
EAA	29	5	24	6.2	730
WCA #1	22	11	11	13.6	1600
WCA #2	21	13	8	18.8	2200
WCA #3	21	12	9	16.7	1950
URBAN	29	10	19	7.9	925
Mineral Soil	23	8	15	10.0	1170
Lake Okeechobee	17	16	1	150.0	17,600
January 12-13, 1981					
EAA	16	-5	21	5.5	650
WCA #1	11	-2	13	8.9	1050
WCA #2	10	-2	12	9.7	1130
URBAN	15	-1	16	7.2	850
Suwanee River #1	6	-12	18	5.7	660
Suwanee River #2	8	-13	21	4.9	570
Suwanee River #3	8	-12	20	5.1	600

1/ $D = \frac{2(\delta S)V(1-\alpha)}{\Delta T}$; $P = \frac{D}{\omega^{\frac{1}{2}}}$

Assume $\delta S = 750\ W/m^2$ for February 26-27, 1980, and assume $\delta S = 580\ W/m^2$ in South Florida and $510\ W/m^2$ for North Florida on January 12-13, 1981. Assume peak net radiation = 0.7 peak solar radiation. Assume $V = 0.75$ and $\alpha = 0.25$. Furthermore, assume that 1/2 of net radiation goes into evaporation.

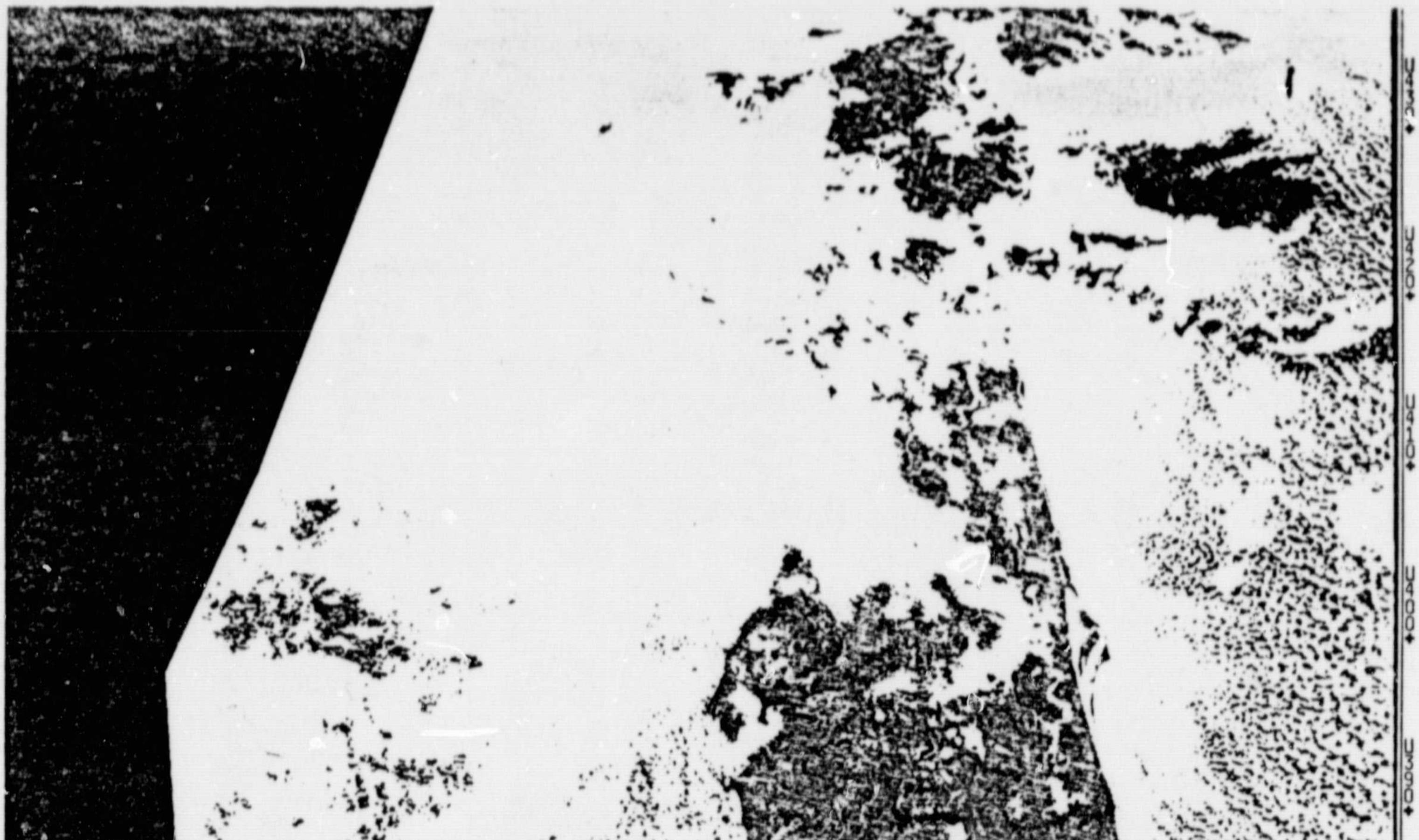


Figure 1. HCMM derived apparent thermal inertia from daytime January 29 and nighttime February 1, 1979, data. Areas in south Florida were clear and were used to compare with GOES images.

+V060 V070+ V080+ V090+ V100+ V110+ V120+ V130+
29JAN79 C N40-33/W085-44 THERMAL-I SUN EL30 A214 5 H CD NASA AEM-A A-A0270-18350-5

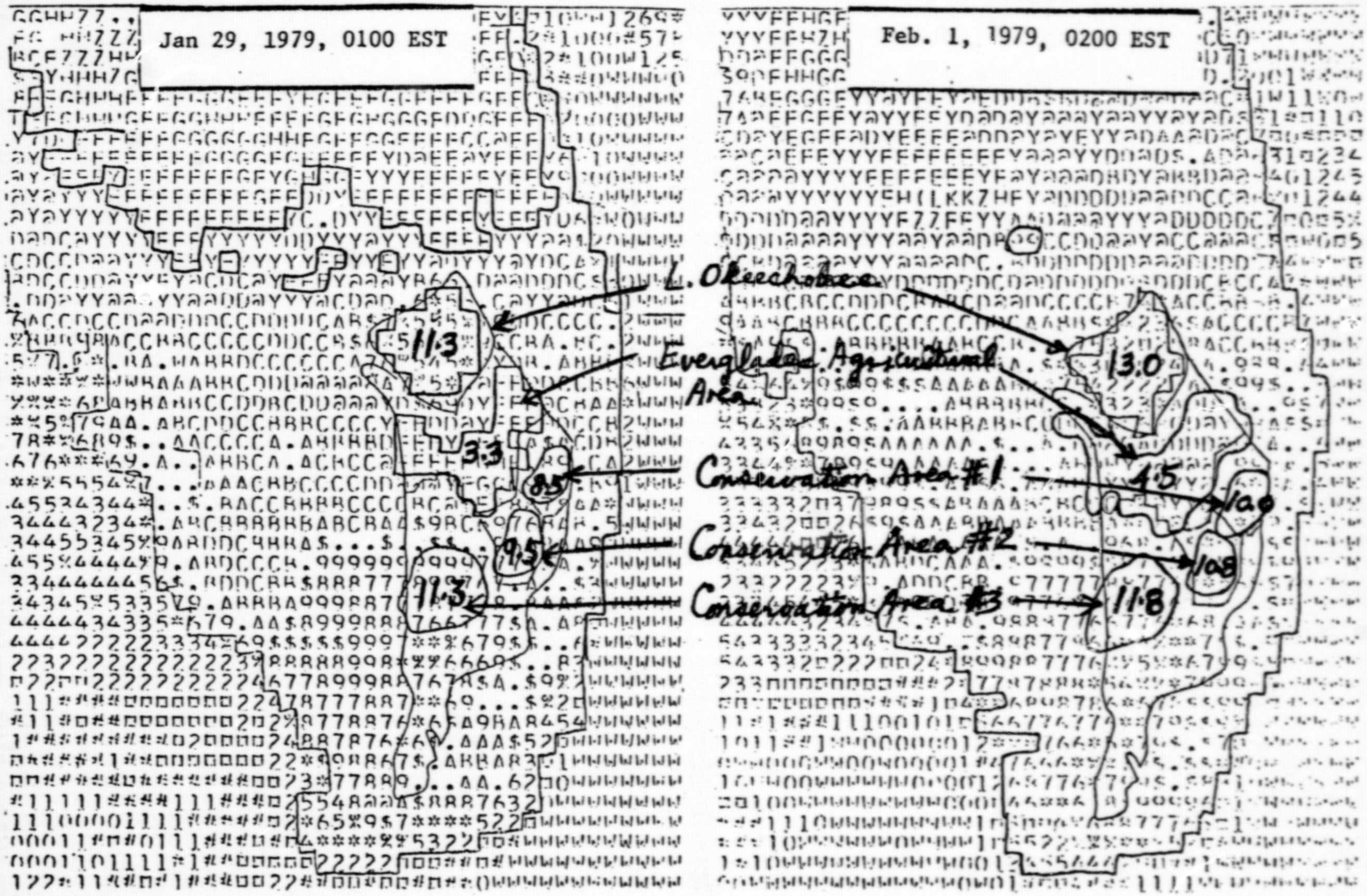


Figure 2. GOES infrared digital data showing average temperatures for Lake Okeechobee, the Everglades Agricultural Area, and Water Conservation Areas #1, #2, and #3 in the early afternoon of January 29 and February 1, 1979.

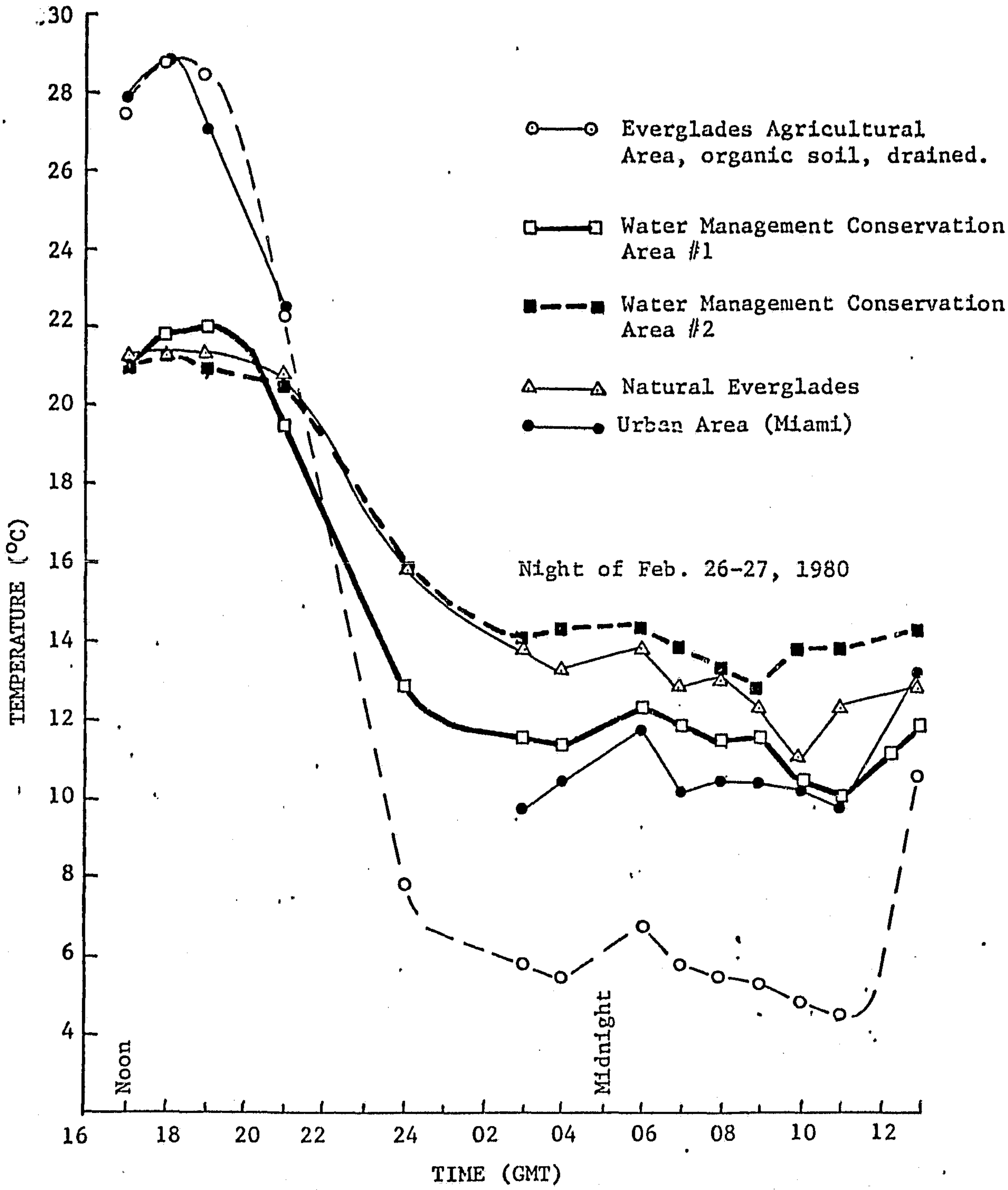


Figure 3. Diurnal surface temperatures obtained from GOES infrared digital data for the night of February 26-27, 1980. The areas are shown in Figure 2.

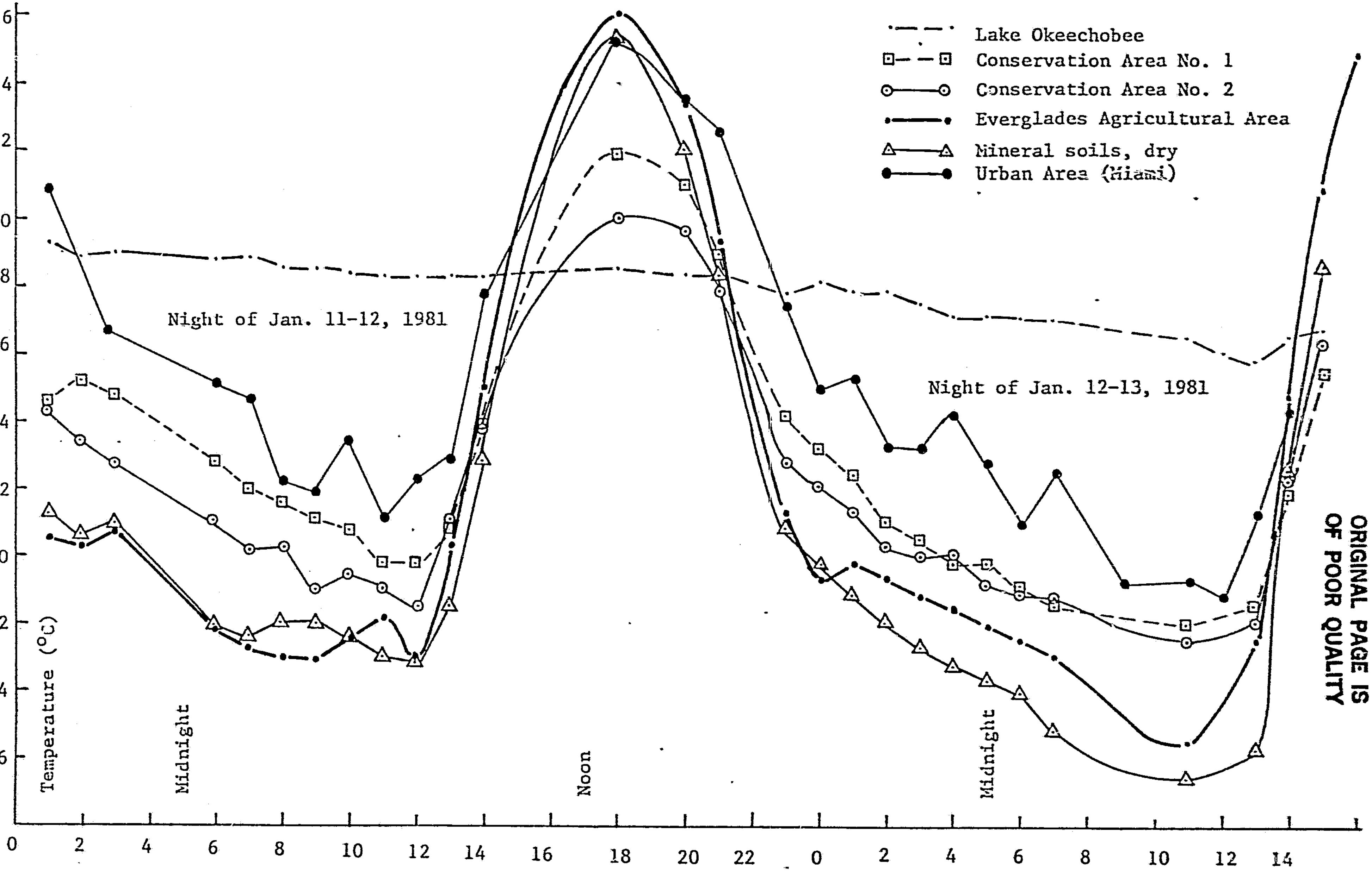


Figure 4. Diurnal surface temperatures obtained from GOES infrared digital data for nights of January 11-12 and 12-13, 1981, during a severe freeze period in Florida.

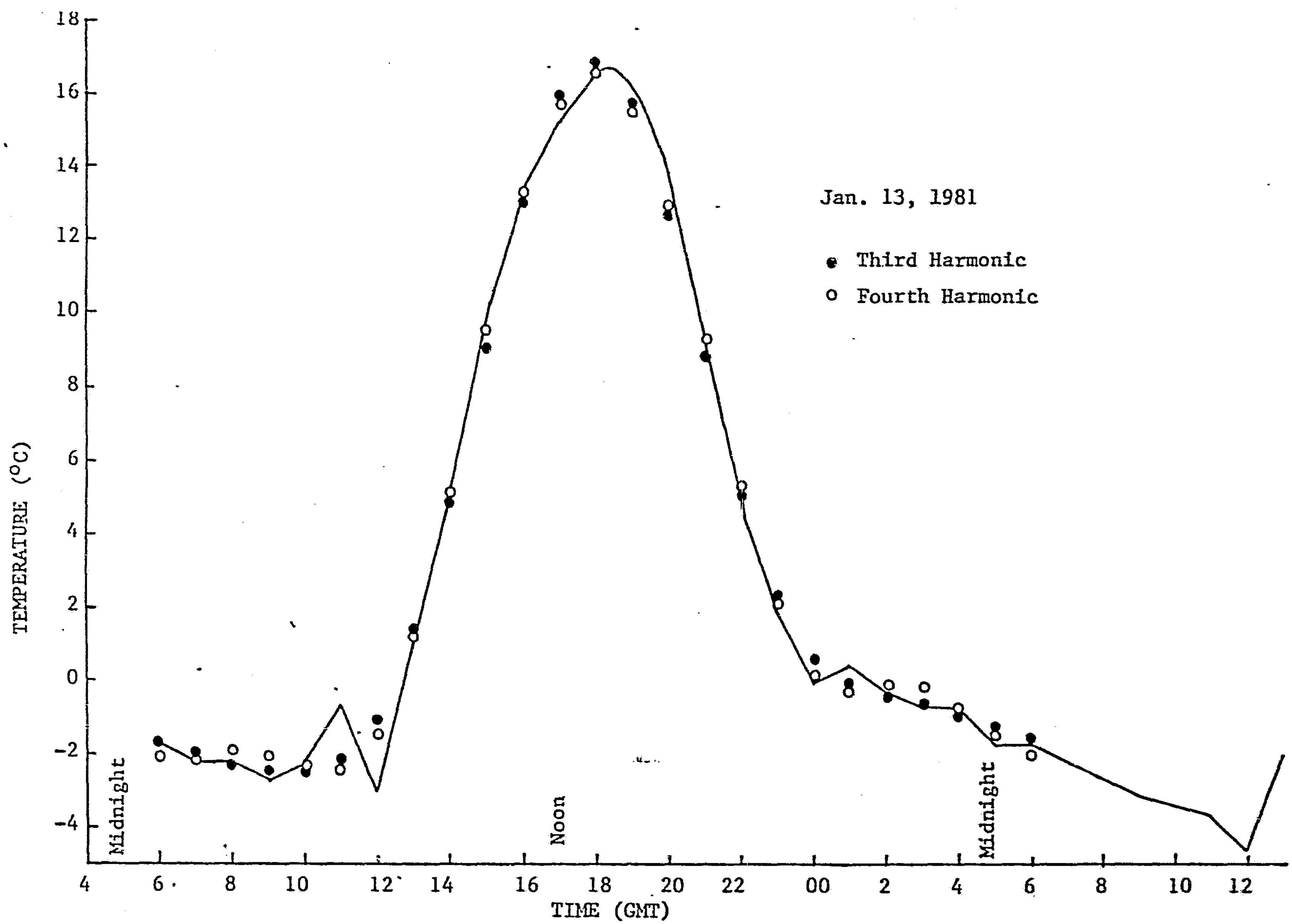


Figure 5. Fourier fit of GOES diurnal temperatures of the Everglades Agricultural Area for data from January 12-13, 1981.

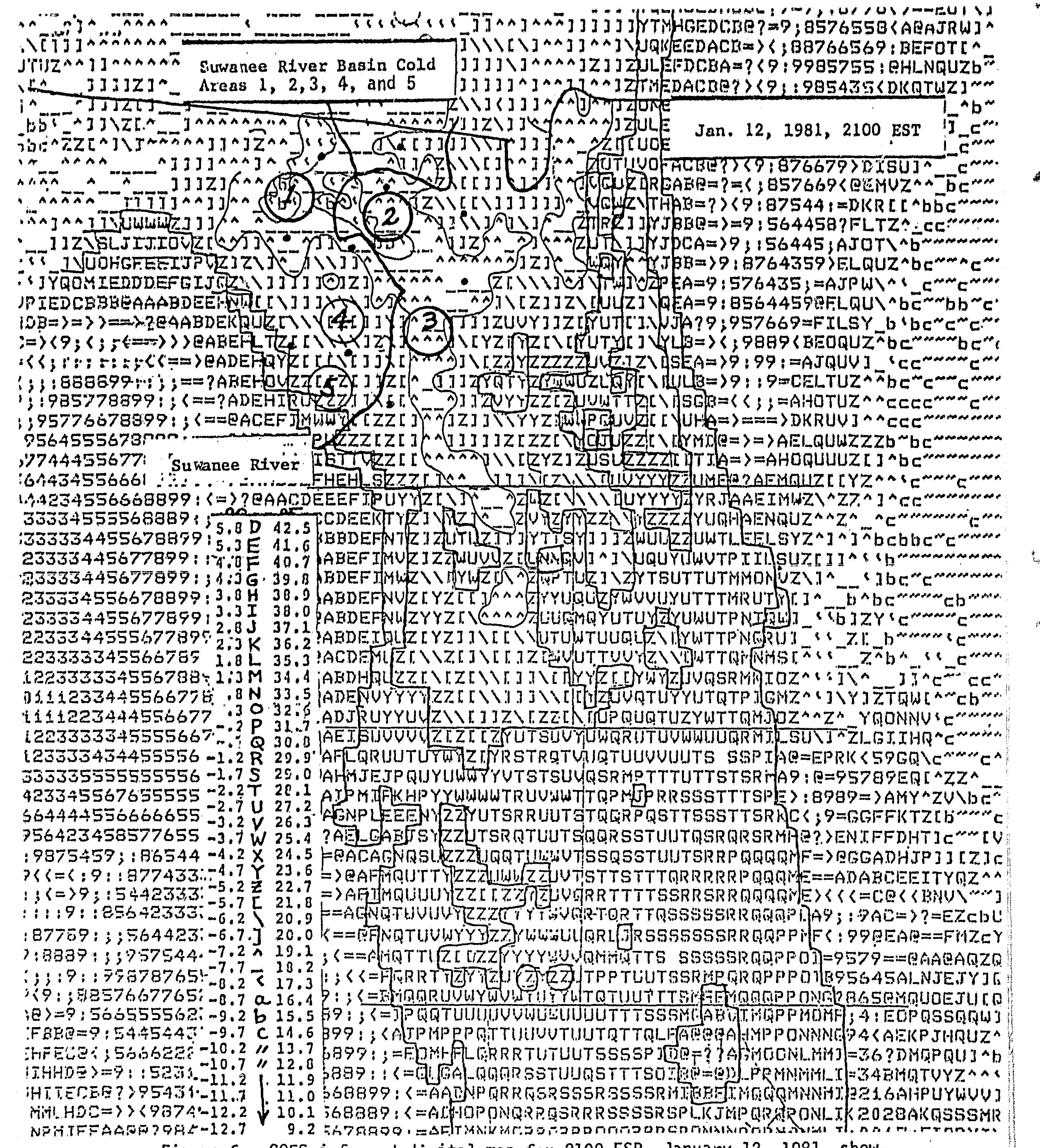


Figure 6. GOES infrared digital map for 2100 ESP, January 12, 1981, showing surface temperatures within the Suwannee River area of north Florida. Coldest areas are outlined. Circles show areas where plotted (Figure 8). A temperature symbol scale is shown on the map.

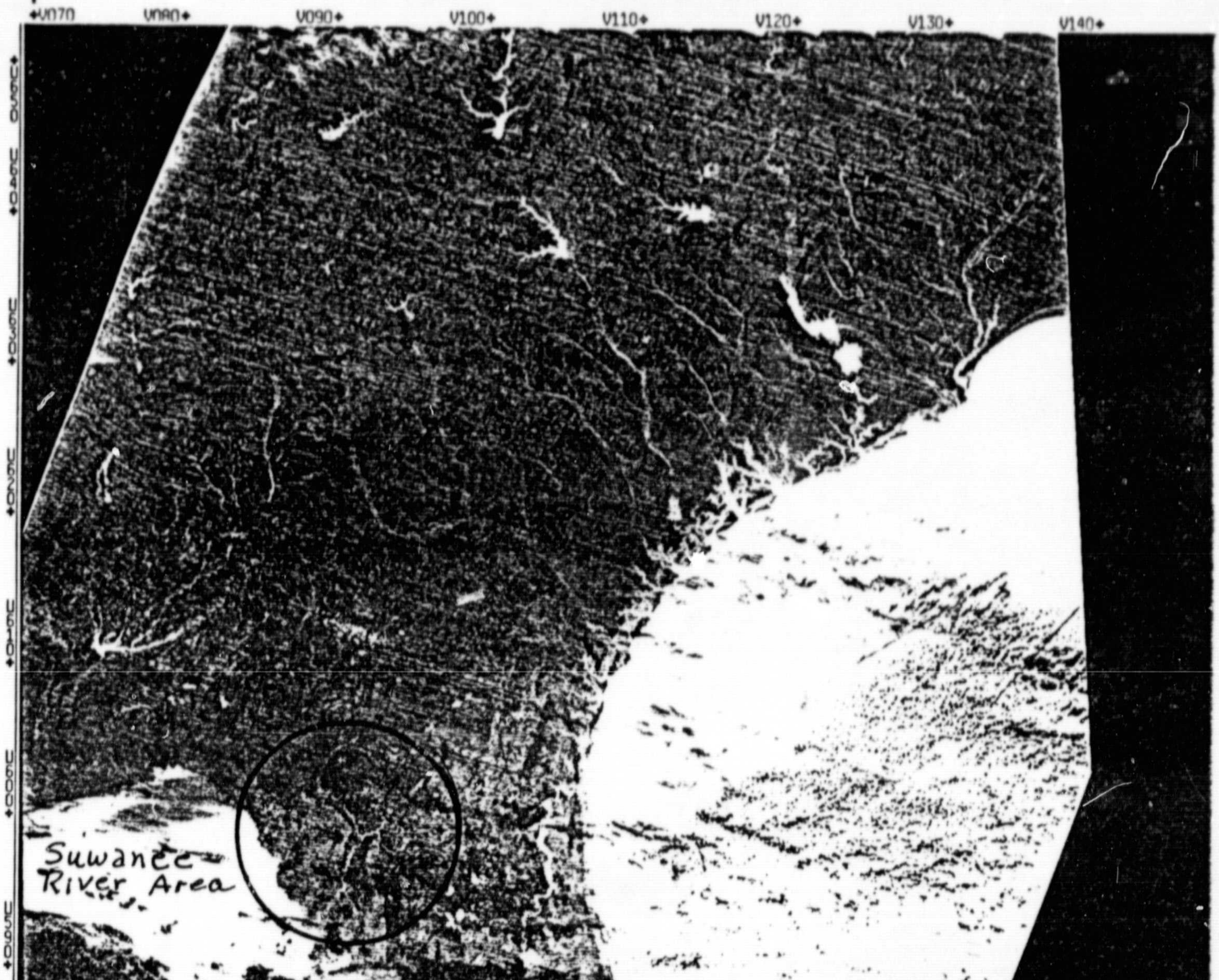
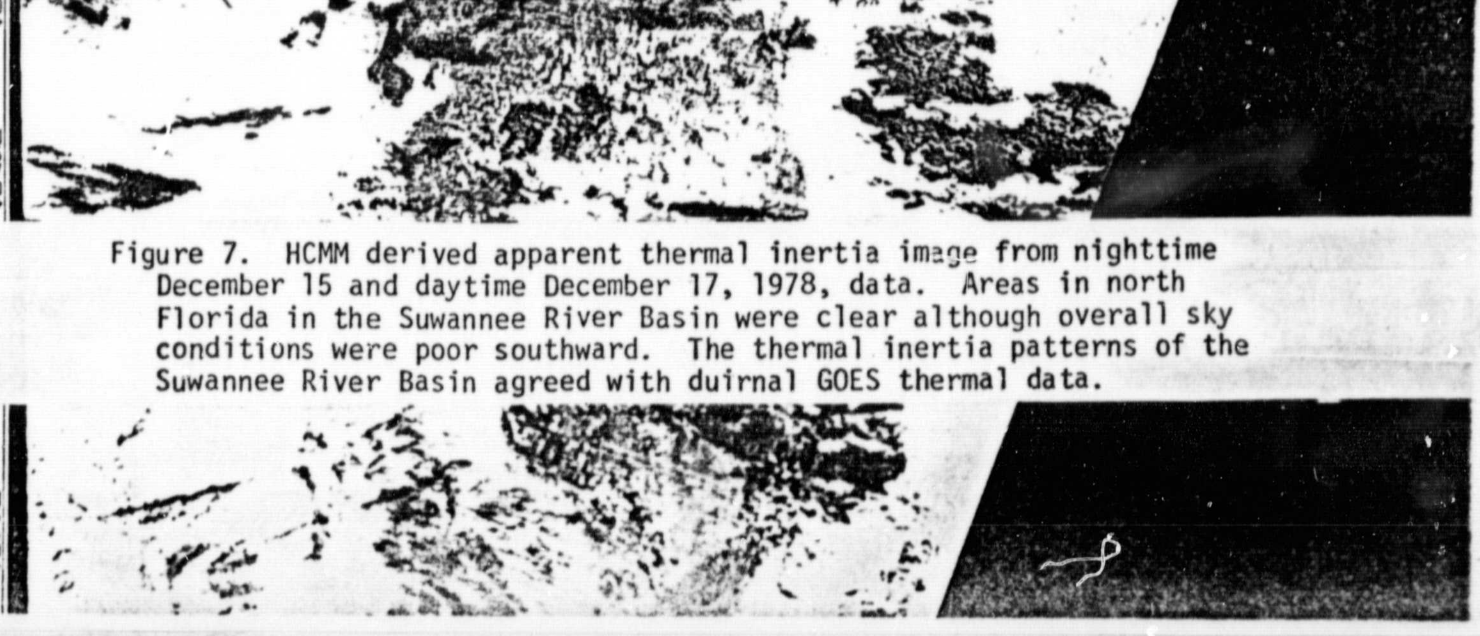


Figure 7. HCMM derived apparent thermal inertia image from nighttime December 15 and daytime December 17, 1978, data. Areas in north Florida in the Suwannee River Basin were clear although overall sky conditions were poor southward. The thermal inertia patterns of the Suwannee River Basin agreed with duirnal GOES thermal data.



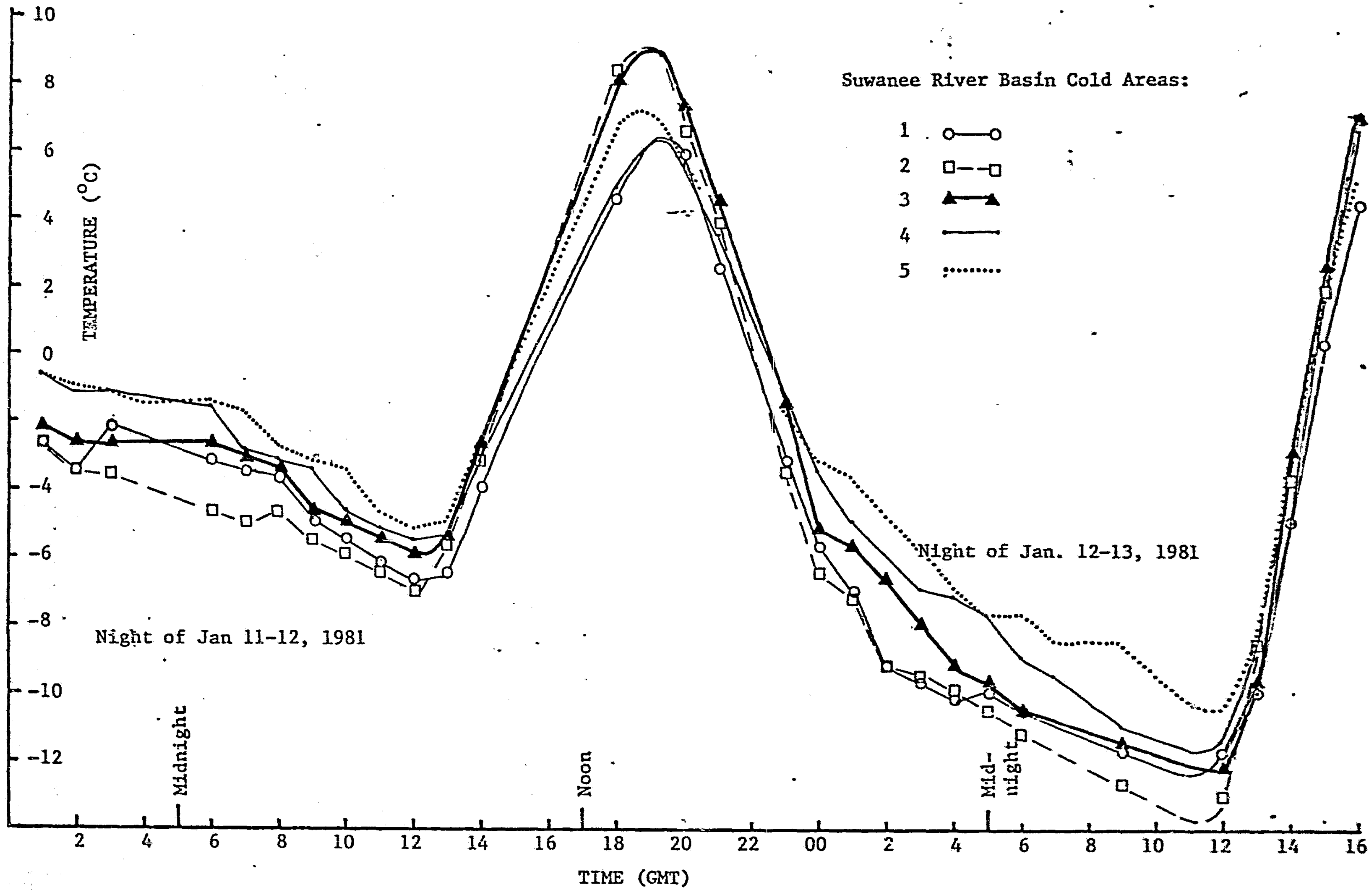


Figure 8. Diurnal surface temperatures with the Suwannee River Basin obtained from GOES infrared digital data for the nights of January 11-12 and 12-13, 1981. The areas are shown in Figure 6.