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A SUBSIDIARY OF LOCKHEED CORPORATION
1830 NASA Road 1, Houston, Texas 77058
Tel. 713-333-5411

TL
CR 160108
JSC-14588
JAN 2 2 1979

Ref: 642-7203
Job Order 73-705-02
Contract NAS 9-15200

(NASA-CR-160108) FEASIBILITY OF ESTIMATION OF SURFACE AIR TEMPERATURE FROM METEOROLOGICAL SATELLITE DATA TEST PLAN (Lockheed Electronics Co.) 17 p HC A02/MF A01 CSCL 04B G3/47

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TECHNICAL MEMORANDUM

FEASIBILITY OF ESTIMATION OF SURFACE AIR TEMPERATURE FROM METEOROLOGICAL SATELLITE DATA TEST PLAN

By

D. E. Phinney

Approved By: B L Carroll
B. L. Carroll, Manager
Earth Observations Development and Evaluation Department

November 1978

LEC-12899

1. BACKGROUND

The utility of crop growth and yield models such as those employed in the Large Area Crop Inventory Experiment can be sharply increased by using available meteorological data. Meteorological satellites provide a valuable source of data which may be used to supplement the network of surface meteorological observations.

Originally envisioned as being required in data-sparse areas, meteorological satellites provide a means of gathering data which allows the application of growth and yield models to areas of only a few square kilometers. Developing yield technology will use selected spectral features from the visible and near-infrared wavelengths along with meteorological observations to make estimates of crop yield on a relatively small area scale. Future large-scale crop monitoring systems may well sample yield on a statistical basis much like that currently used for acreage.

Meteorological satellites may make an immediate contribution to the crop growth model or crop calendar. Operating from maximum and minimum air temperatures, crop calendars are used extensively by both yield modelers and image analysts. Based upon experience gained by processing radiometric data in order to make air temperature estimates using the Screwworm Eradication Data System (ref. 1), it is possible to begin developmental work on a system designed to drive crop calendar models.

The data processing system advanced here is designed to supplement the existing global network of synoptic meteorological observations. Cast against an operational background, the system is designed to provide estimates of daily maximum and minimum air temperatures on a standardized computational grid. To ensure continued worldwide coverage, only the polar orbiting meteorological satellite will be considered as a source of radiometric data.

2. SYSTEM DESCRIPTION

A system for processing radiometric data from meteorological satellites is presented in some detail in this section; an overview is shown in figure 1. The broad outlines of the processing will be retained, but probably individual components and their interactions will be modified as a result of studies during development. A summary of the processing flow precedes a detailed breakdown which follows the numbering of components as shown in figure 1.

The Surface Air Temperature Estimation System (SATES) is designed to provide air temperature estimates on a standardized grid system using both satellite radiometric data and surface synoptic observations. Since radiometric estimates of temperature can be made in only cloud-free areas, a methodology is needed to provide reliable estimates in areas covered by cloud.

An algorithm was developed during the screwworm study (ref. 2) to provide estimates for cloudy areas. In that algorithm, a smoothed temperature difference field referenced to a ground control station was used. The daily difference between the air temperature at the control station and radiometric estimates of air temperature produced from cloud-free data at the grid point was smoothed, using a low pass filter. When cloud cover was encountered, the daily temperature estimate was made by adding the observed air temperature at the control station to the value of the temperature difference field that was valid for the cloudy grid point. As might be expected, the reliability of the temperature estimate was dependent upon the distance between the control station and the grid point. A modification of that procedure is planned for SATES.

The SATES approach would first interpolate the first-order synoptic observations to the grid network, using an objective analysis technique. The temperature difference field would then be calculated as the smoothed difference between cloud-free radiometric estimates and the interpolated surface data for each grid point. For cloud-covered grid points, the

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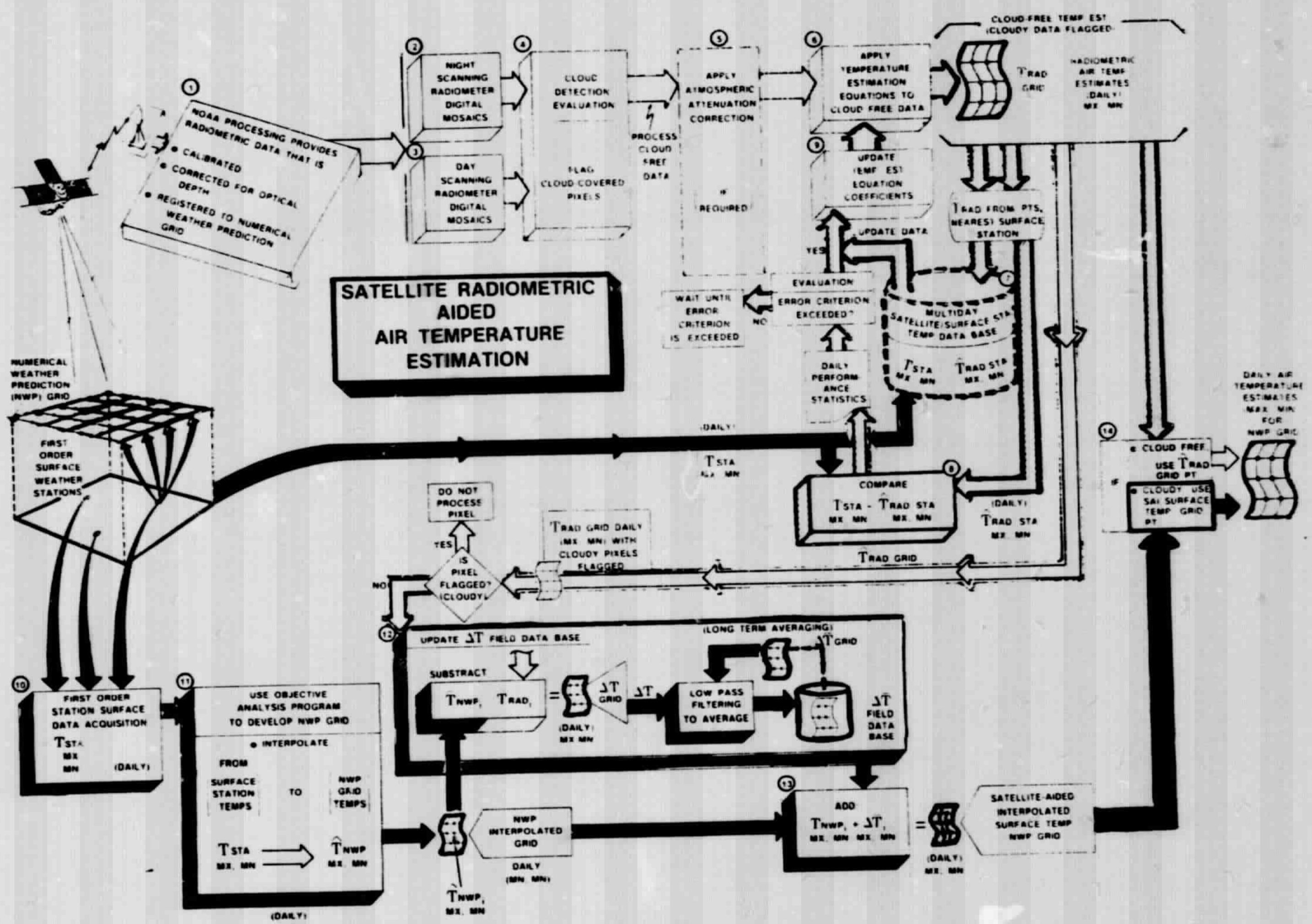

Figure 1.– Radiometric data processing system.

temperature estimate would result from the addition of the interpolated surface data and the value of the temperature difference field at the grid point.

The overall structure of SATES is discussed in the following paragraphs by component: the radiometric data processing, analysis of the surface data, the construction of the temperature difference field, and the temperature estimate. The data flow applies for estimation of any temperature parameter such as maximum, minimum, or mean air temperature; in fact, all estimates would be made in parallel.

Numbers in the following paragraph headings are keyed to figure 1.

2.1 PREPROCESSED RADIOMETRIC DATA (1)(2)(3)

The basic data will be obtained from the scanning radiometer on the National Oceanic and Atmospheric Administration (NOAA) series of operational meteorological satellites. The data are available from the National Environmental Satellite Service for real-time data or from the National Climatic Center for retrospective orders. The data, provided on magnetic tape in digital form, have been calibrated, corrected for limb darkening, and registered to the Numerical Weather Prediction (NWP) grid. Visible and blackbody radiometric temperature for all day-pass orbits and blackbody radiometric temperatures for all night-pass orbits for each day are mosaicked on the NWP grid. Six data sets are available for each day, three each for the Northern and Southern Hemispheres.

2.2 CLOUD DETECTION (4)

The first step of processing the radiometric data in SATES is cloud detection; the exact algorithm used will be determined during the developmental study. Detection and flagging of all cloud-contaminated pixels are the objectives. Simple histogram thresholds will be evaluated but the most promising lines of study appear to be with setting limits on differences between the radiometric temperatures and the interpolated surface temperature, or on the difference between the temperature estimates resulting from the radiometric value and that resulting from application of the temperature difference field.

2.3 ATMOSPHERIC ATTENUATION CORRECTION (5)

Initially, no correction for atmospheric attenuation will be applied beyond the simple limb-darkening correction inherent in the NOAA data. If an error analysis indicates the need, additional corrections will be evaluated. A preliminary correction could be based on the estimation of precipitable water from interpolated surface dewpoint. The use of radiosonde data would be attempted only if this approach failed.

2.4 ESTIMATION OF AIR TEMPERATURE (6)(7)(8)(9)

The temperature estimation algorithms will be functional relationships based on day and night radiometric temperatures, altitude, interpolated day and night dewpoint temperatures, and day length. The goal is to estimate maximum, minimum, and mean air temperature for each cloud-free grid point. The objective can be obtained through reliable estimates of two of the following parameters: maximum air temperature, minimum air temperature, mean air temperature, and daily temperature range. The prediction parameters and the predictive variables will be selected during the developmental study.

The coefficients for the predictive equations will be developed through analysis of radiometric and appropriate ancillary data at a preselected set of calibration grid points which correspond to the location of surface synoptic observations. The SATES algorithms will provide for a daily evaluation of the accuracy of the estimates at each calibration point and collect statistics for the updating of the predictive equation coefficients. The predictive equation can be updated either daily or only when evaluation indicates that the reliability of the predictions has exceeded a prespecified error criterion.

The results of the processing of radiometric data will be a gridded set of temperature estimates for cloud-free areas; cloudy areas would be flagged. This temperature field would also be used to update the temperature difference field.

2.5 DAILY SURFACE DATA PROCESSING (10) (11)

The daily synoptic data available on a station-by-station basis from the National Meteorological Center would be interpolated to the NWP grid, using objective analysis techniques. The required temperatures including dewpoints are available internationally through the meteorological data transmissions sponsored by the World Meteorological Organization. However, the station density varies widely over the world and evaluation of the impact of this variation on SATES performance will be required.

2.6 TEMPERATURE DIFFERENCE FIELD (12)

The temperature difference (ΔT) field initially advanced during the screwworm project proved to be extremely powerful. It is expected that, as implemented in SATES, the ΔT field will be improved and indeed be the heart of the system. It will be the fundamental tool for providing temperature estimates in areas covered by cloud. Additionally, one potential method for making the final temperature estimates uses the radiometric data only to update the ΔT field.

The ΔT field is based on the difference between the interpolated surface temperature and the radiometric temperature estimate. The difference is calculated daily for each grid point having cloud-free data. The daily differences are used to update the reference ΔT field using a low-pass filter. The resulting ΔT field is then the expected difference at each grid point between the interpolated surface temperature and the radiometric temperature estimate.

The choice of initialization values, proper filter constant, and length of time that the field requires to stabilize will be evaluated during the development studies.

2.7 SATELLITE-AIDED INTERPOLATION OF SURFACE OBSERVATIONS (13)

The ΔT field and the interpolated daily surface observation are added at each grid point, resulting in a temperature field that is essentially a satellite-aided interpolation of the surface observations. One of the strengths of the proposed SATES methodology lies in the fact that temperature estimates can be made even in the total absence of radiometric data. The length of time that such estimates would be reliable will be evaluated since the stability of the ΔT field over time dictates the frequency with which radiometric data must be processed. It is conceivable that the radiometric data could be processed only every second or third day without significant loss of accuracy.

2.8 DAILY AIR TEMPERATURE ESTIMATES (14)

The SATES processing to this point has resulted in two daily gridded temperature fields. The first is derived solely from day radiometric temperatures and is valid only for cloud-free areas. The second field is derived from the day synoptic meteorological data and the reference ΔT field and is valid at all grid points. On the assumption that the cloud-free radiometric-based temperature estimates are the best possible, the fields are merged, using the satellite-aided interpolation field in cloudy areas. This assumption will be tested in the evaluation described in section 3.

3. EVALUATION OF AIR TEMPERATURE ESTIMATES

Many of the design alternatives can be evaluated during the development of SATES. However, an evaluation of the total system will be needed both for validation purposes and for a final determination of the system configuration. Two major issues must be addressed, (1) for SATES to be useful for temperature estimation, it must show skill over simple interpolation of the surface synoptic meteorological network, and (2) a determination must be made of the accuracy of the system under two alternative modes of operation.

In the first mode, the radiometric data would be used only to update the ΔT field. In that case, the satellite-aided interpolation of the surface observations would provide the temperature estimates.

In the second mode, the radiometric data would supply the temperature estimates in cloud-free areas with the ΔT field used to fill in cloudy regions.

The overall flow of data in the SATES evaluation system is shown in figure 2. Numbers in the following paragraph headings are keyed to figure 2.

3.1 PREPARATION OF GROUND TRUTH (15) (16)

High-density meteorological observations from the class C cooperative station network will be used as ground truth. The daily observations from these stations will be interpolated to the NWP grid system using objective analysis techniques. The resulting gridded results will be called the NWP cooperative grid.

3.2 EVALUATION METHODOLOGY (17)

Validation of temperature estimates are desired on a point-by-point basis and for larger area averages up to and including the area of a typical climatological district. Each of three temperature estimates will be

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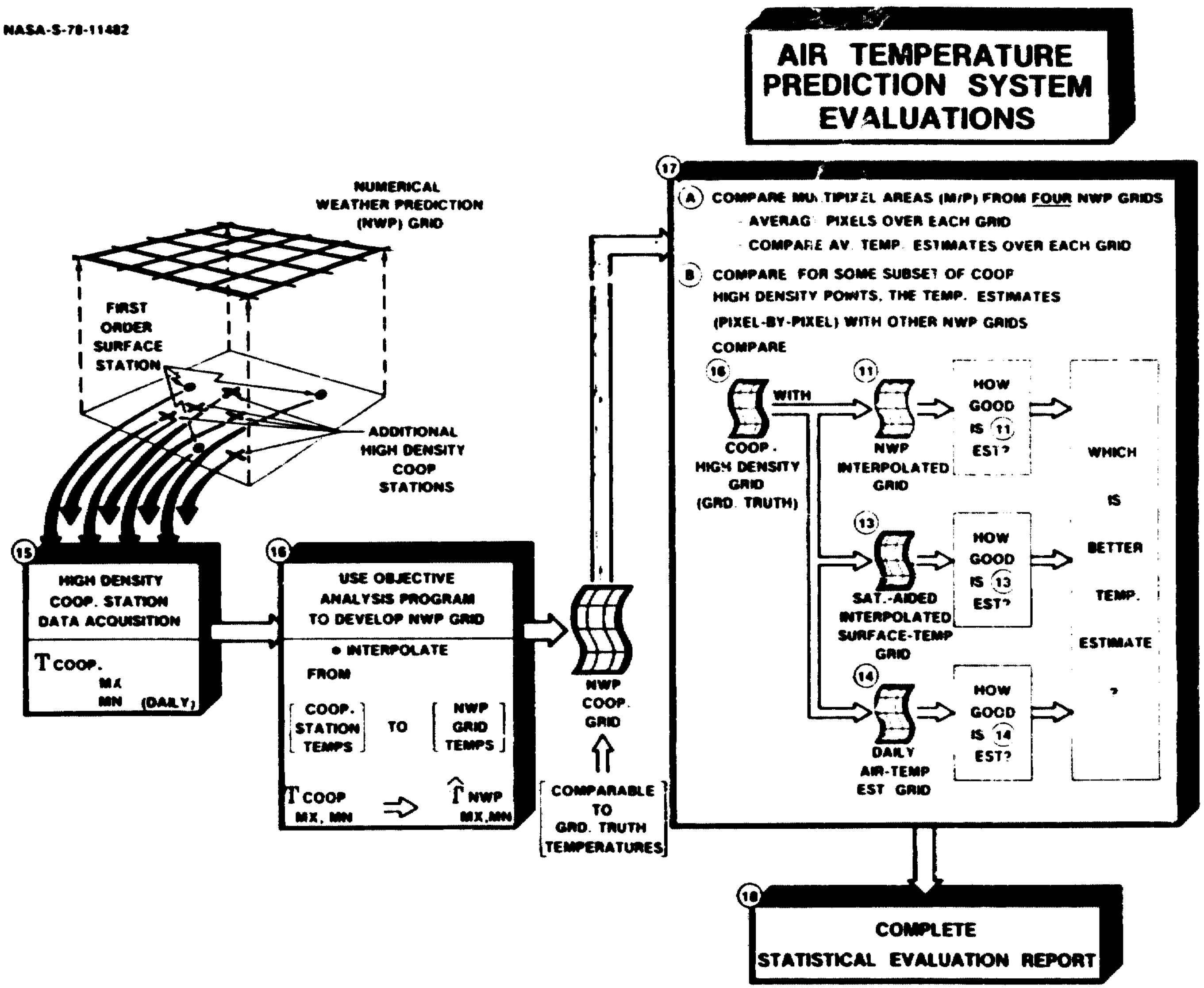

Figure 2.— Air temperature prediction system evaluations.

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compared, both for area averages and for those points which correspond to the locations of the cooperative stations.

The NWP cooperative grid will be compared to the grid resulting from interpolation of the synoptic meteorological observations. This will provide baseline statistics on the capability of simple interpolation of surface observations. For any of the radiometric products to be of use, they must show increased skill in comparison with this baseline.

The NWP cooperative grid will be compared to the grid resulting from the satellite-aided interpolation of the surface data ((13), fig. 1) and with the daily air temperature estimate grid ((14), fig. 1).

3.3 STATISTICAL ANALYSIS (18)

A statistical analysis of the comparisons will determine in what configuration (if at all) the use of radiometric data provides increased accuracy over interpolation of the surface observations. Both daily and overall statistics including bias and root mean square errors will be calculated on both a daily and overall basis. Additional statistical analyses will be performed as needed to identify major sources of error in the system.

4. PRELIMINARY FEASIBILITY STUDY

A preliminary feasibility study using radiometric and surface data gathered during the screwworm project is proposed to conserve resources. Data for 16 first-order synoptic stations and for 23 cooperative stations shown in table 1 are available for the March 29 to June 13, 1975 and the October 4 to October 31, 1975 time periods. The data locations for Texas are shown in figure 3. The data are similar to that proposed for use in SATES except that the radiometric data were taken from the very high resolution radiometer on the NOAA satellites.

The use of these data will allow low-cost studies of the major developmental steps leading to SATES. Specifically, the exact form of the predictive equations relating radiometric and ancillary data to surface air temperature, the nature of the cloud detection algorithm, and the initialization and stability characteristics of the ΔT field can be studied. In addition, the overall predictive ability of the system can be evaluated in the spring, early summer, and fall.

TABLE 1.— SELECTED STATIONS FOR PRELIMINARY FEASIBILITY STUDY

(a) Synoptic stations

Name	Latitude, N	Longitude, W	Name	Latitude, N	Longitude, W
El Paso	31°48'	106°24'	Abilene	32°25'	99°41'
Marfa	30°22'	104°01'	San Antonio	29°32'	98°28'
Del Rio	29°22'	100°55'	Austin	30°18'	97°42'
Cotulla	28°27'	99°13'	Waco	31°37'	97°13'
McAllen	26°11'	98°14'	Corpus Christi	27°46'	97°30'
Brownsville	25°54'	97°26'	Victoria	28°51'	96°55'
Midland-Odessa	31°57'	102°11'	Houston	29°58'	95°12'
San Angelo	31°22'	100°30'	Port Arthur	29°57'	94°01'

(b) Cooperative stations

Name	Latitude, N	Longitude, W	Name	Latitude, N	Longitude, W
Sierra Blanca	31°11'	105°21'	Nixon	29°16'	97°45'
Red Bluff Dam	31°54'	103°55'	Columbus	29°43'	96°32'
Presidio	29°34'	104°23'	El Campo	29°12'	96°17'
Chisos Basin	29°16'	103°18'	Conroe	30°19'	95°27'
Marathon	30°12'	103°14	Liberty	30°03'	94°49'
Sanderson	30°09'	102°24'	Temple	31°06'	97°21'
Bakersfield	30°53'	102°18'	Beeville	28°27'	97°42'
Juno	30°09'	101°07'	Laredo	27°30'	99°28'
Sterling City	31°51'	100°59'	Hebbronville	27°18'	98°40'
Brownwood	31°43'	98°59'	Armstrong	26°56'	97°48'
Mason	30°44'	99°13'	Harlingen	26°12'	97°40'
Eagle Pass	28°42'	100°29'			

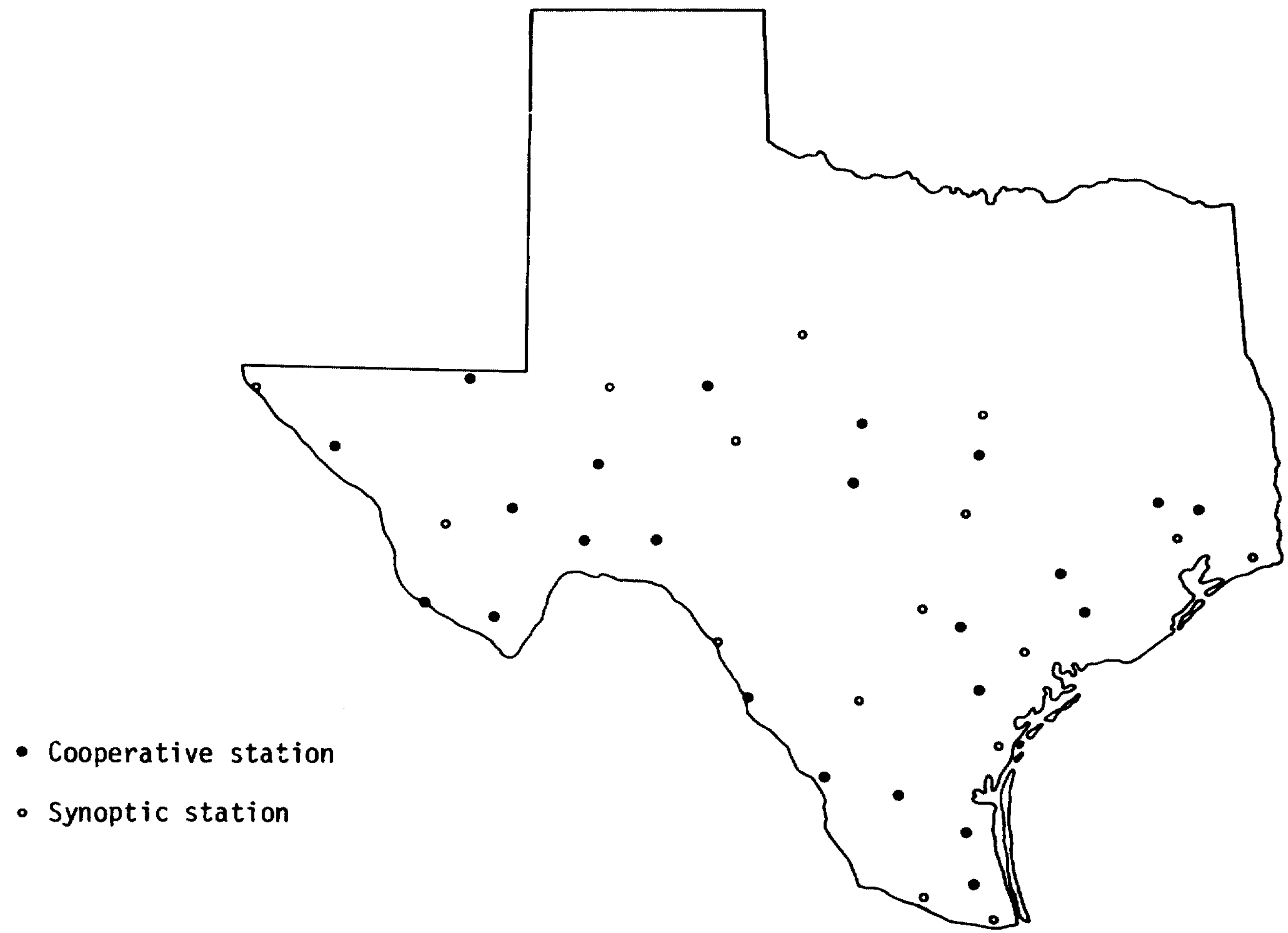

Figure 3.— Synoptic and cooperative stations in Texas.

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2. Arp, G. K., F. C. Forsberg, L. E. Giddings, and D. E. Phinney: System Development of the Screwworm Eradication Data System (SEDS) Algorithm. JSC-10965, 1976, 67 pp.

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