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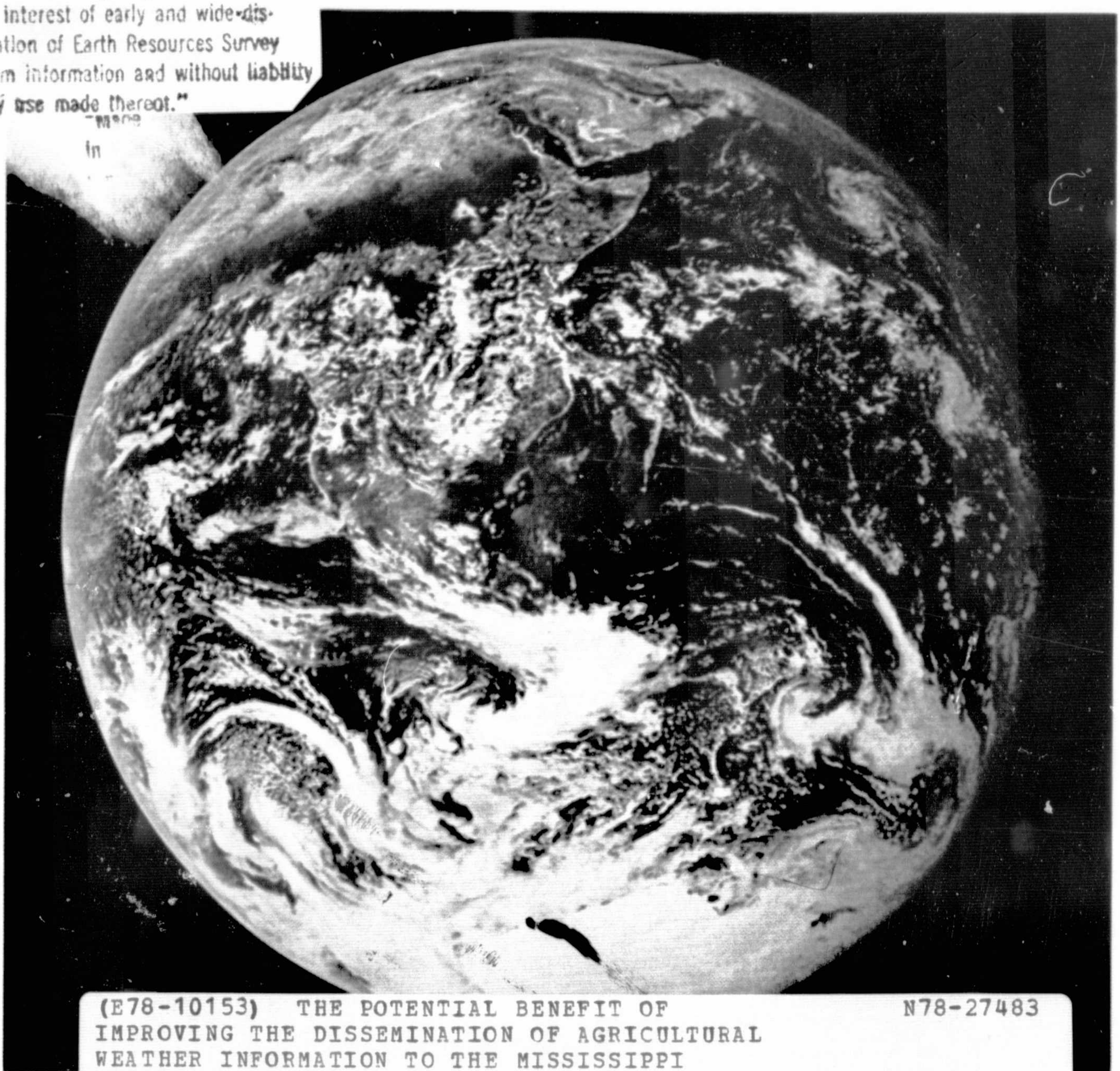

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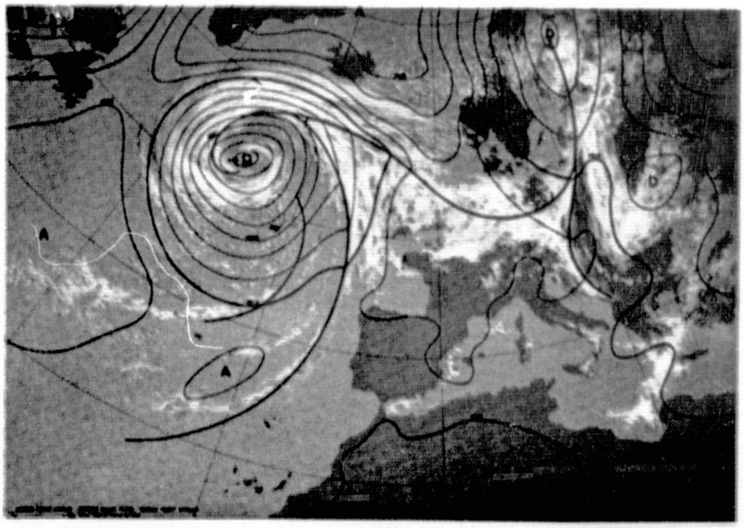

Photo of map courtesy French National Weather Bureau.
Apollo 17 photo courtesy NASA.

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THE POTENTIAL BENEFIT OF IMPROVING THE DISSEMINATION OF AGRICULTURAL WEATHER INFORMATION TO THE MISSISSIPPI COTTON FARMER

FINAL REPORT
JUNE 1978

THE POTENTIAL BENEFIT OF IMPROVING THE DISSEMINATION OF AGRICULTURAL WEATHER INFORMATION TO THE MISSISSIPPI COTTON FARMER

Final Report
Grant No. NSG 5073
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

By

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June 1978

ABSTRACT

Inadequate dissemination of agricultural weather information is costing the Mississippi cotton farmer thousands of dollars annually. There exists a large potential benefit to the individual cotton farmer in reduced time and money if the dissemination of agricultural weather information was improved. This paper discusses the weather related problems associated with specific farm operations used in cotton production, a newly proposed system of disseminating agricultural weather information to reduce these problems, and a brief discussion of the potential benefit to the Mississippi cotton farmer if this system were used.

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INTRODUCTION

Since man first turned the soil to plant a crop, he did so with great uncertainty. One of the greatest concerns has always been the weather. To date, he has been able to control, to some extent, all other variables (i.e. weeds, insects, soil fertility, water) important in farm production. Even though amazing accomplishments have taken place in the science of meteorology, today's farmers of America cannot be expected to continue to feed a world with increasing populations, rapidly decreasing world food supplies and continuing uncertainties in weather predictions (46). If the individual American farmer is to continue to feed and clothe 50 to 55 people, increase his output, and make a profit, the uncertainty of weather must be reduced.

The Purpose of This Report

This paper summarizes a study of the potential benefits resulting from improved dissemination of weather information (specifically short-range and current information) to one sector of the agricultural community. The study was limited to a monocultural cropping system (cotton) requiring very weather-sensitive farm operations and was further restricted to the analysis of cotton production in one state (Mississippi). This report will discuss the potential benefits of a new agricultural weather dissemination service that will reduce the short-term, weather-related risks involved in Mississippi cotton production.

Specific questions addressed in the study were:

1. What are the detailed agricultural problems of Mississippi cotton which have a meteorological factor?

2. What are the meteorological parameters required to help solve these problems; the accuracy and timeliness requirements of these parameters?
3. What are the space systems or sensors that could provide observations of these parameters?
4. How will these observations be used?
5. What are the practical benefits?

To conduct the research necessary to complete this study, information was obtained from Mississippi State University, Cooperative Extension Service personnel, cotton growers in the state and local National Weather Service (NWS) personnel. From this research, it was determined that the following critical farm operations should be considered:

1. Land preparation (subsoiling/chisel plowing)
2. Preplant (with respect to herbicides)
3. Planting (with respect to pesticides)
4. Pest management (insect and weed control)
5. Harvest (including application of harvest-aid chemicals)

Role of the National Weather Service and News Media in Weather Information

The National Weather Service (then called the U. S. Weather Bureau) was created in 1870 to satisfy the general public's needs for weather information. This has been accomplished, in part, by establishing weather offices throughout the United States. Tremendous amounts of both general and special weather information and data are sent via teletype daily to television and radio stations. Once the information reaches the news media, it is disseminated to the public. Although sound in theory, this method of disseminating weather information is not completely satisfactory to those having weather sensitive activities. When the information is needed only to determine whether to wear a winter coat or a light jacket, or if an umbrella might be required, the weather report given by the local news station is usually sufficient. Many sectors of the public, however, require more specialized information than is currently provided.

In the late 1950's and early 1960's, the U. S. Weather Bureau attempted to meet the farmer's needs for more pertinent weather information and specialized forecasts. At that time, a network of agricultural weather offices was established in selected areas to disseminate agricultural weather information and farm advisories over teletype to television and radio stations. Unfortunately, the television and radio media have not been able to meet agricultural needs in this area. The primary role of these two media is entertainment of the general public. The lack of time and knowledge of television and radio announcers (and in too many cases, television meteorologists) about either agricultural meteorology or farming requirements has resulted in dissemination techniques which have not kept pace with the amount of weather information available.

Recently, the National Oceanic and Atmospheric Administration (NOAA) has attempted to provide agriculture with better weather information and advisories. Only a few states presently receive this information. Supporters maintain that the NOAA Weather Wire will provide satisfactory information to the public until the NOAA Weather Radio is country-wide. Adequate weather forecasts and descriptions are not always provided, especially during bad weather events, a time when the user needs the most detailed and frequently updated information (34).

Some of the more difficult problems with both NOAA's Weather Radio and Weather Wire are:

1. limited range and use of the NOAA Weather Radio,
2. expense to radio and television stations and other potential users of connecting to the NOAA Weather Wire or purchasing Weather Radio,
3. rigid structure of forecasts and limited text of weather descriptions,
4. lack of education, on the part of media and user, on how to use and interpret weather information.

During the last 20 years, dissemination of weather information has changed very little, even though improvements in weather prediction and technology have advanced tremendously. Information now available within the National Weather Service, if made available to the farmers in a timely manner, would reduce many risks and uncertainties in farm production.

Past and Present State of Weather Forecasting and Previous Studies

The basic tool used in early forecasting, and an important tool today, is the synoptic weather map. In the mid-19th Century these maps served little value in forecasting weather because they were assembled long after the time of observation. The telegraph created a means for rapid communication to collect data and prepare current weather maps. Forecasting weather events from these synoptic maps was difficult because very little was known about the physical and mathematical laws governing the atmosphere. The lack of regular upper air measurements made three-dimensional atmospheric analysis impossible. Even with these limitations, forecasting was becoming an art. Soon after the turn of the century, meteorology and weather prediction advanced rapdily. In 1918, Vilhelm

Bjerknes and Jacob Bjerknes published classical papers on physical and dynamic meteorology. Bjerknes' work on the polar front theory is widely accepted today (38).

Between 1920 and 1950 many more advances in meteorology and weather forecasting occurred. The development of the radiosonde provided for regular upper air observations. This increase in knowledge of upper air analysis produced the concepts of long and short-wave disturbance and jet stream. Also, during this time period (1920-1950) the teletypewriter and facsimile advanced the means of communications.

With the combination of physical-numerical methods and the invention of the high speed electronic computer (early 1950's), meteorology and weather prediction became more an exact science than an art. Before the digital computer, predictions on even simple weather variables took days to calculate manually; now these same equations require only fractions of seconds on a high speed computer.

Despite the tremendous advancement in weather prediction in the past 20 years, there are still major limitations in numerical prediction. The accuracies heralded by the proponents of numerical weather prediction are not yet possible. Some current limitations can be summarized as follows (34):

1. Progress in forecasting precipitation and other small scale weather elements has been very slow.
2. Important problems remain to be solved in the application of numerical techniques to the forecasting of smaller scale weather phenomena such as thunderstorms and heavy precipitation on a scale of major importance to individual farms.

According to Sanders' "Skill in Forecasting Daily Temperature and Precipitation: Some Experimental Results,"

> I feel obliged to point out that NMC's accomplishments, however praiseworthy and valuable they may be, do not necessarily imply an improvement in forecast accuracy on the bottom line -- at the level of the public forecast for a particular location. We did not find such improvements in forecasts of daily temperature and precipitation at Boston. (45)

Another factor that provided a significant improvement in weather forecasting capability was the development of the meteorological satellite in 1960. Satellite imagery allows surveillance of both large scale weather systems and small scale, short lived weather phenomena (i.e. fog, thunderstorms, etc.) throughout the day and night. Geostationary satellites positioned over the equator produce imagery every half hour. Although many experts believe satellite meteorology is still in the early stages of development, use of this imagery in weather prediction is already very large.

At a recent annual meeting of the American Meteorological Society, the chairman of the Committee on Weather Forecasting and Analysis, Roger A. Pielke, presented a paper on, "An Overview of Recent Works in Weather Forecasting and Suggestions for Future Work" (34). In this presentation, Pielke commented on the usefulness of providing medium, short-range (one to 12 hours) information and current weather to specific users. Pielke stated that, "little useful information on these time-scales currently reaches the user." It was emphasized that more effort is needed to improve the presentation of medium (12 to 48 hours) range information. On the subject of short-range and current weather information, Dr. Pielke stated:

> The preparation of "nowcasts" (not to be necessarily confused with Project NOWCAST) as part of an operational program, in conjunction with the improved dissemination of short-range forecasts, would be a valuable service to the users.
>
> The potential exists for a major improvement in short-range and in current weather descriptions. Machinery needs to be optimized to disseminate this information to users quickly and effectively. (34)

In a study, "The Potential Economic Benefits of Improvements in Weather Forecasting," Thompson (51) estimated a potential annual savings in the United States of greater than $12 billion due to operational improvements (better use of forecasts) and scientific advances (more accurate forecasts). The operational improvements of weather dissemination to agriculture alone was valued at $250 million (Table 1) with a total benefit to agriculture of $567 million. Thompson also stated:

> It will be observed that summer precipitation in the southeast United States is associated with large potential economic gains. Here, not only is the precipitation a frequent phenomenon, but it occurs primarily in the form of random showers and thunderstorms. Such precipitation is difficult to predict 24 hours in advance and, accordingly, there exists a considerable potential for economic improvement.

The Agricultural Research Institute (ARI) has stated that for every one dollar invested to improve weather information (and forecasting) there would be a return of at least $50 to U. S. agricultural income (1). In this same report, the ARI estimated food and fiber loss in excess of one billion dollars occurs annually in the United States due to adverse weather conditions.

A System to Improve the Dissemination of Agricultural Weather Information

Colorado State University, in conjunction with the National Aeronautic and Space Administration (NASA), has developed a new system that will

Table 1. Summary, as a function of economic activity, of potential annual savings due to operational improvements, scientific advances and total gains due to improvements in weather forecasting in the United States. Figures are in millions of dollars.

Activity	Operational Improvements	Scientific Advances	Total Gains*
Agriculture	250.3	316.7	567.0
Aviation (commercial)	1.4	2.2	3.6
Construction	13.1	18.4	31.5
Communications	0.3	0.4	0.6
Electric Power	0.5	0.8	1.3
Energy (e.g. fossil) Fuels	#	0.1	0.1
Manufacturing	8.1	11.9	20.0
Transportation (rail, highway & water)	1.3	1.9	3.2
Other (gen. public, government, etc.)	47.3	64.5	111.8
Totals*	322.2	416.9	739.1

* All sums may not balance due to rounding off.

\# Less than 0.05.

(After Thompson, 1972)

improve the dissemination of agricultural weather information. This system, called Project NOWCAST, places particular importance on the following factors:

1. Providing current and short-range weather information to the agricultural community.
2. Disseminating this information hourly over Educational Television.

3. Tailoring the weather information to the agricultural community.
4. Providing pertinent weather information usually only available to meteorologists.

Project NOWCAST, by combining satellite imagery of clouds, radar, weather maps and surface weather data, mini-computers, specially trained agricultural weather interpreters, and educational television, can provide hourly weather briefings essential to improve farm production (Figure 1).

The primary equipment which makes the NOWCAST possible (in addition to the SMS-GOES satellite) is the Agricultural Weather Collection and Dissemination System (AWCDS) (Figure 2).

The AWCDS provides the capability for collection of satellite imagery from the National Environmental Satellite Service (NESS), radar imagery from NOAA and the Federal Aviation Administration (FAA), facsimile maps and teletyped weather information from NWS and sensor data from special agricultural weather stations, storing the information in the computer, adding information to the maps and sending the packaged weather briefing to the user community via educational television link.

The NOWCAST station will provide the following daily services to the agricultural community:

0600: A ten-minute live show by the NOWCAST station director. Emphasis placed on the present weather conditions over the region; the probable weather changes during the day; their influence on farming activities; and the outlook. Discussions may include items such as soil moisture, evapotranspiration rates, dew and frost, wind and growing degree days.

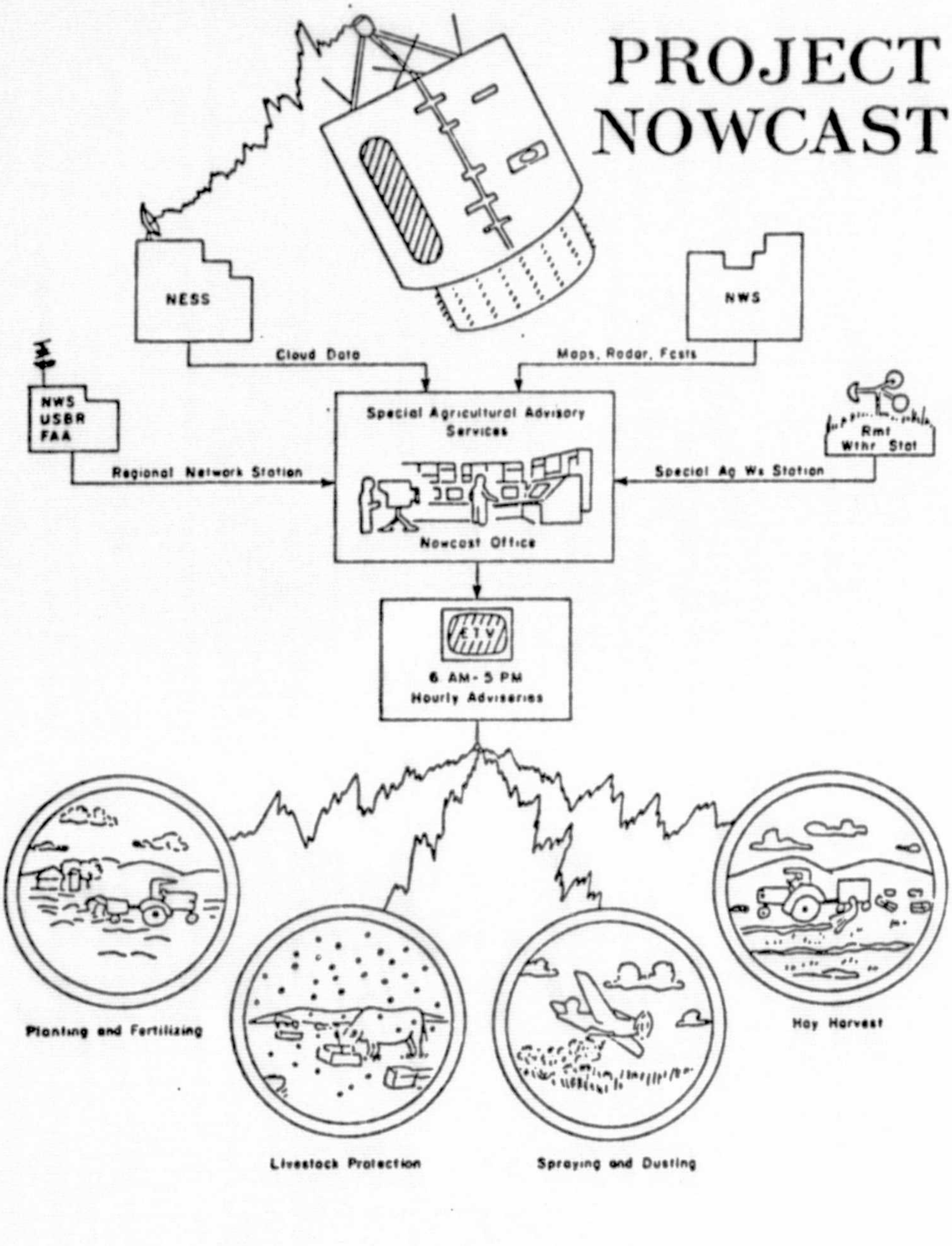

Figure 1

The NOWCAST System

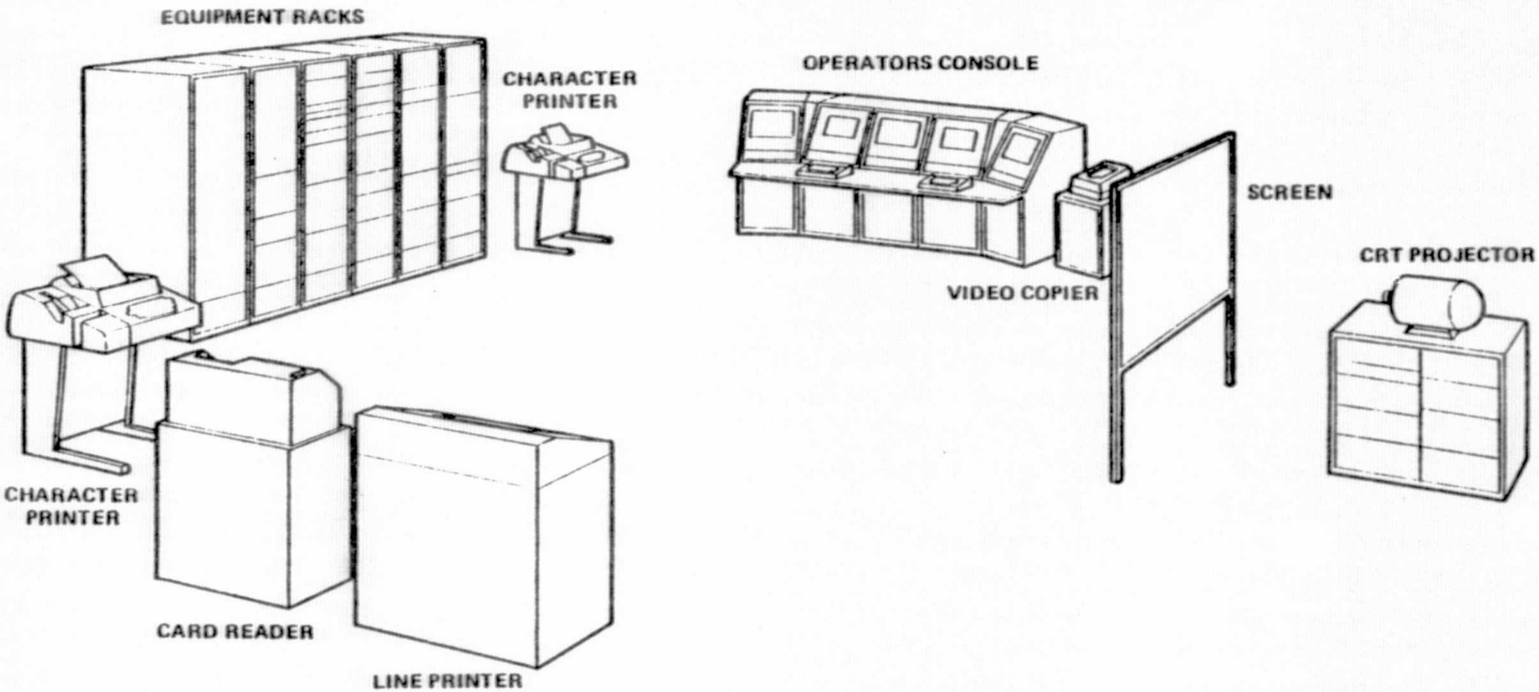

Figure 2. AWCDS Equipment Layout.

0700 - 1100: Four-minute shows including the following information.

(a) SMS two mile resolution U. S. coverage (Figure 3)

(b) SMS movie loope of (a)

(c) SMS one-half mile resolution, local area (500 miles) radar overlay to show areas of precipitation last hour and at present (figure 4)

(d) Surface weather map

(e) Surface weather map, six and 12 hour prognostic charts

(f) Surface wind map (Figure 5)

(g) Present air temperature (Figure 6)

(h) Maximum air temperature prognostic charts (Figure 7)

(i) Surface temperature from SMS

(j) Soil temperature, two inch bare soil (Figure 8)

(k) Relative humidity maps (Figure 9)

(l) One or more special maps such as:

dew/frost prognostic charts (Figures 10 and 11)

growing degree days

drying conditions for haying

spraying advisories

solar radiation

stability index (Figure 12)

thunderstorm probability (Figure 13)

The maps will be shown in logical sequence with audio interpretation.

1200: A second ten-minute live show; updated version of 0600 program.

1300 - 1700: Several four-minute shows as per the morning schedule.

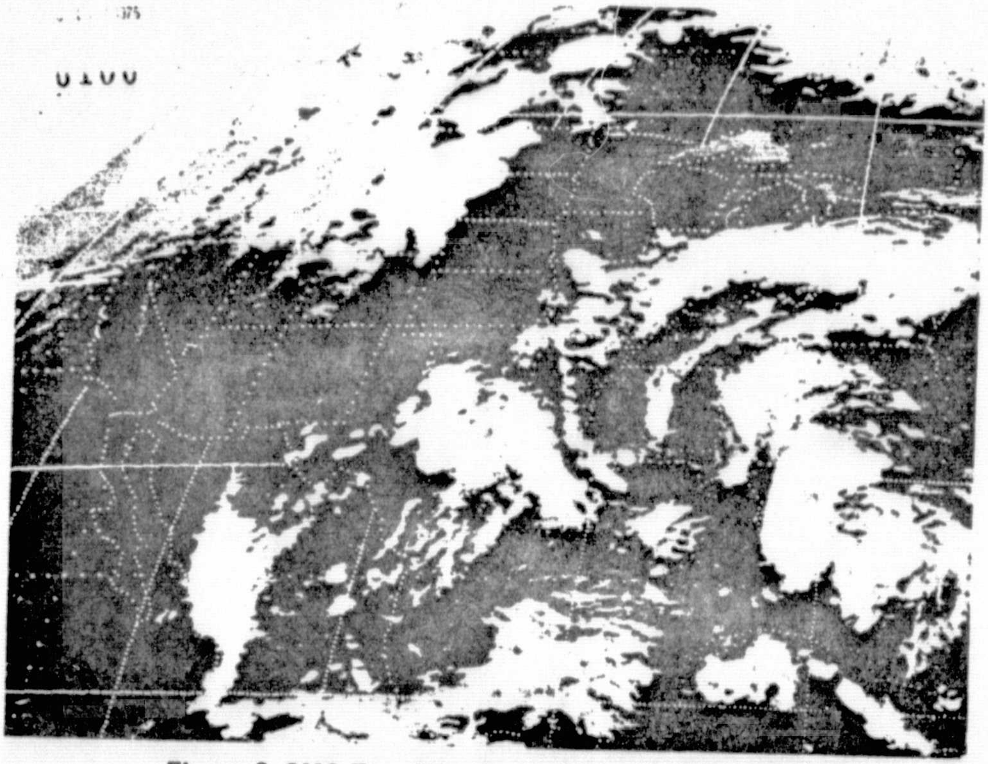

Figure 3. SMS Two-Mile Resolution U.S. Coverage.

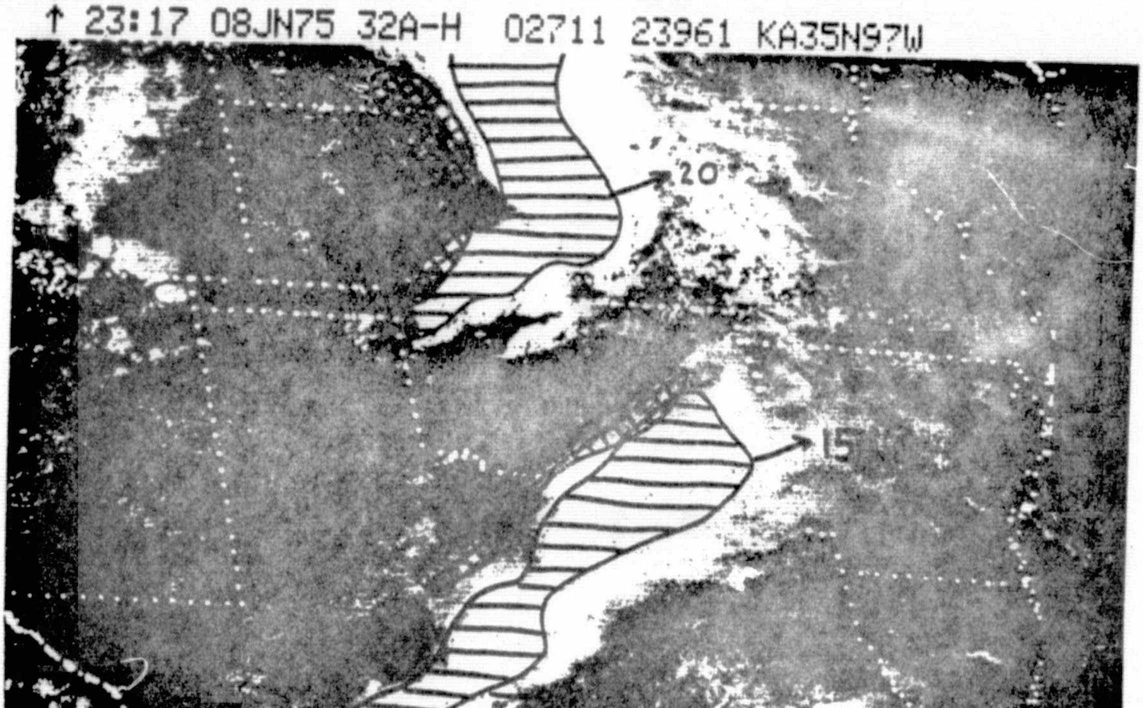

Figure 4. SMS One-Half Mile Resolution, Local Area (500 Miles) Radar Overlay To Show Areas Of Precipitation Last Hour And At Present.

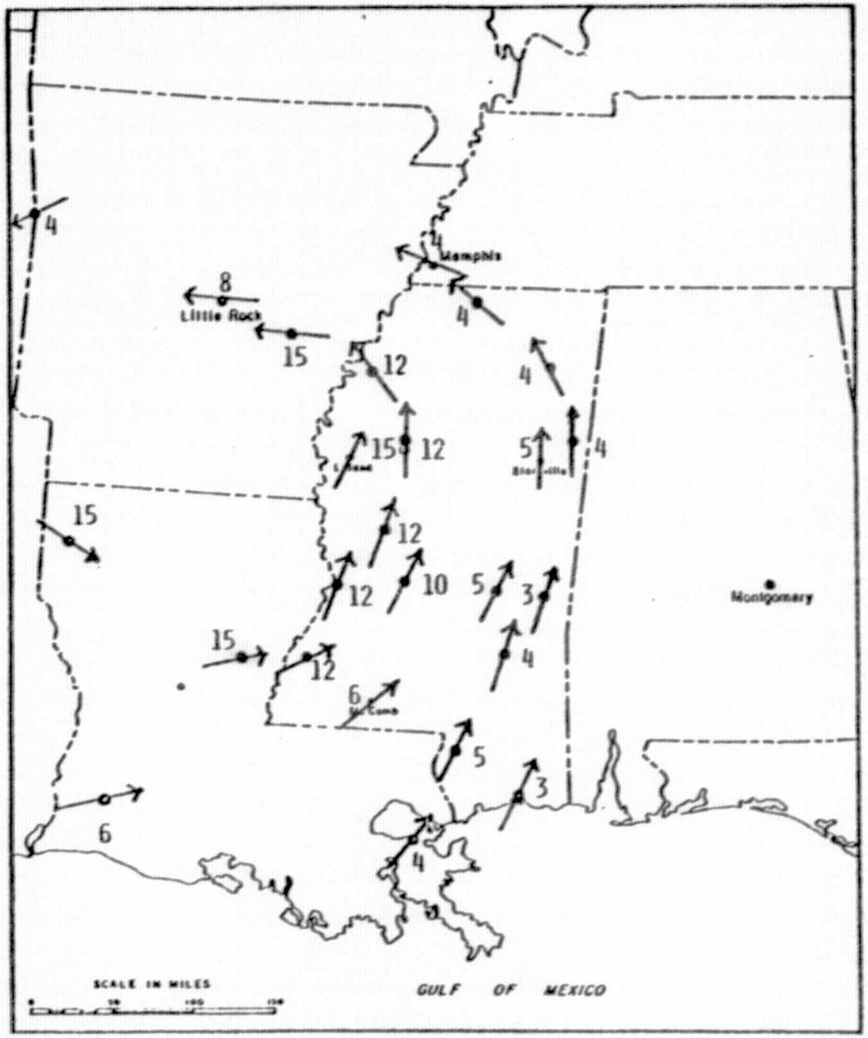

Figure 5. Present Surface Wind.

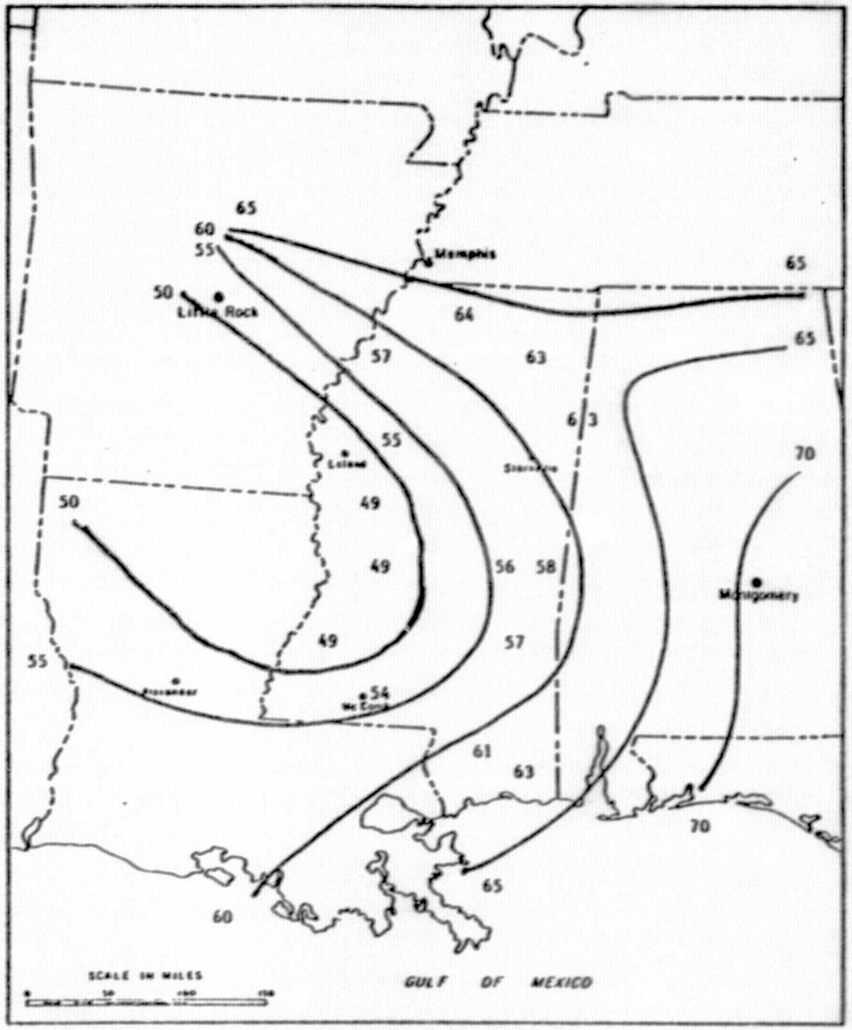

Figure 6. Present Air Temperature.

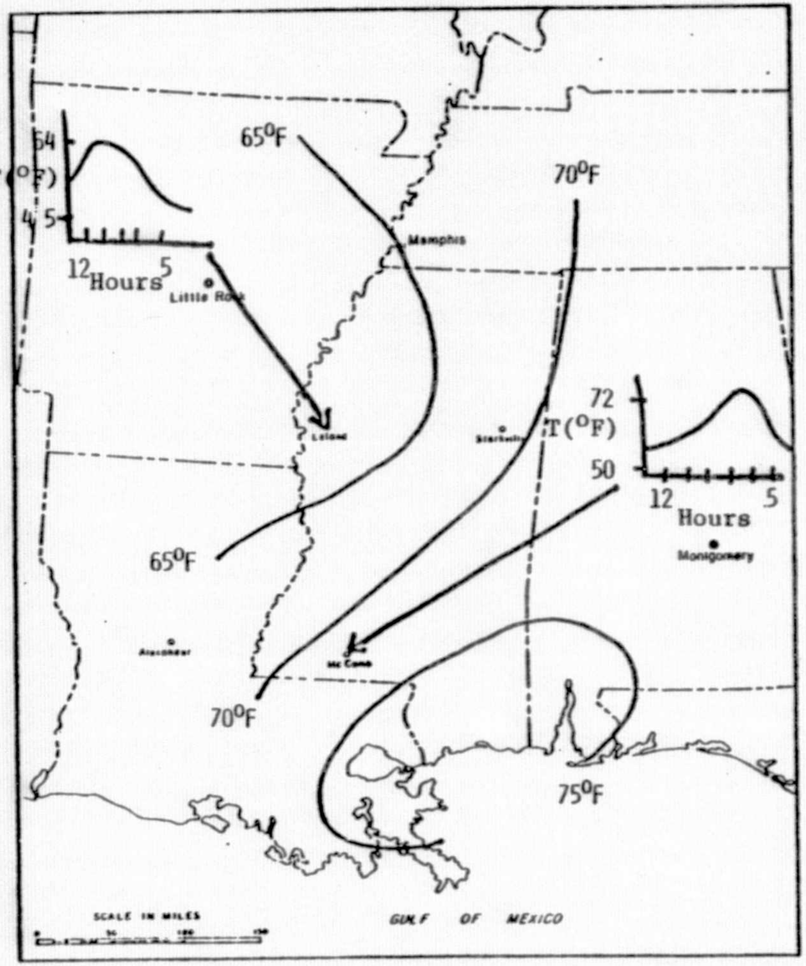

Figure 7. Expected Maximum Air Temperature.

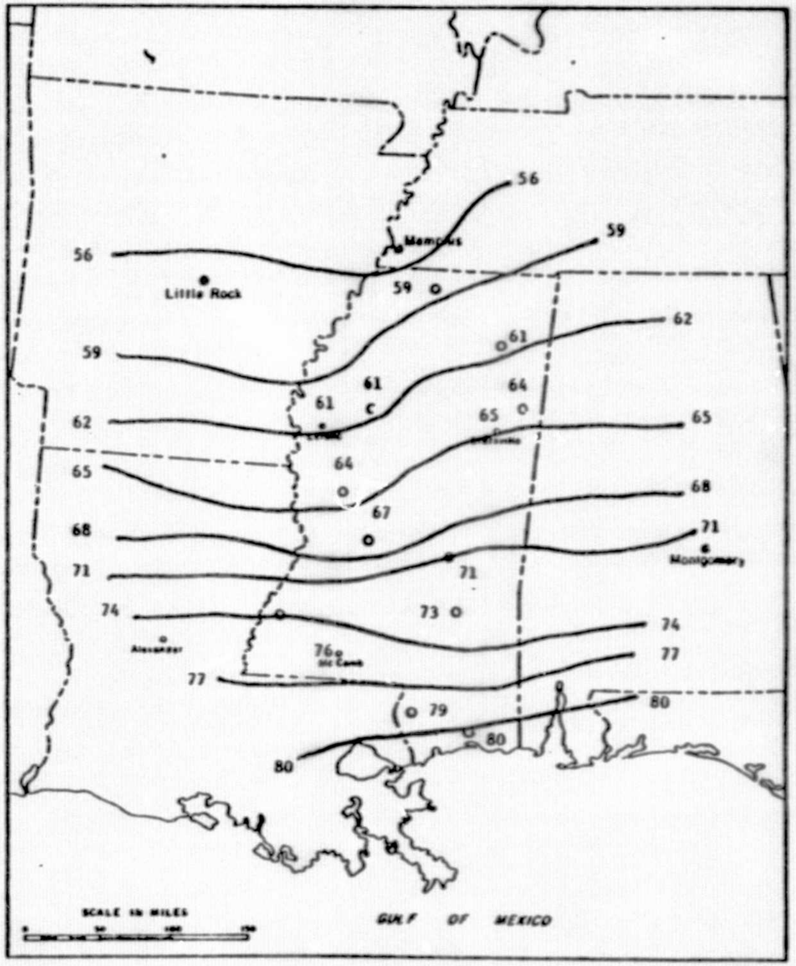

Figure 8. Soil Temperature - 2" Bare Soil.

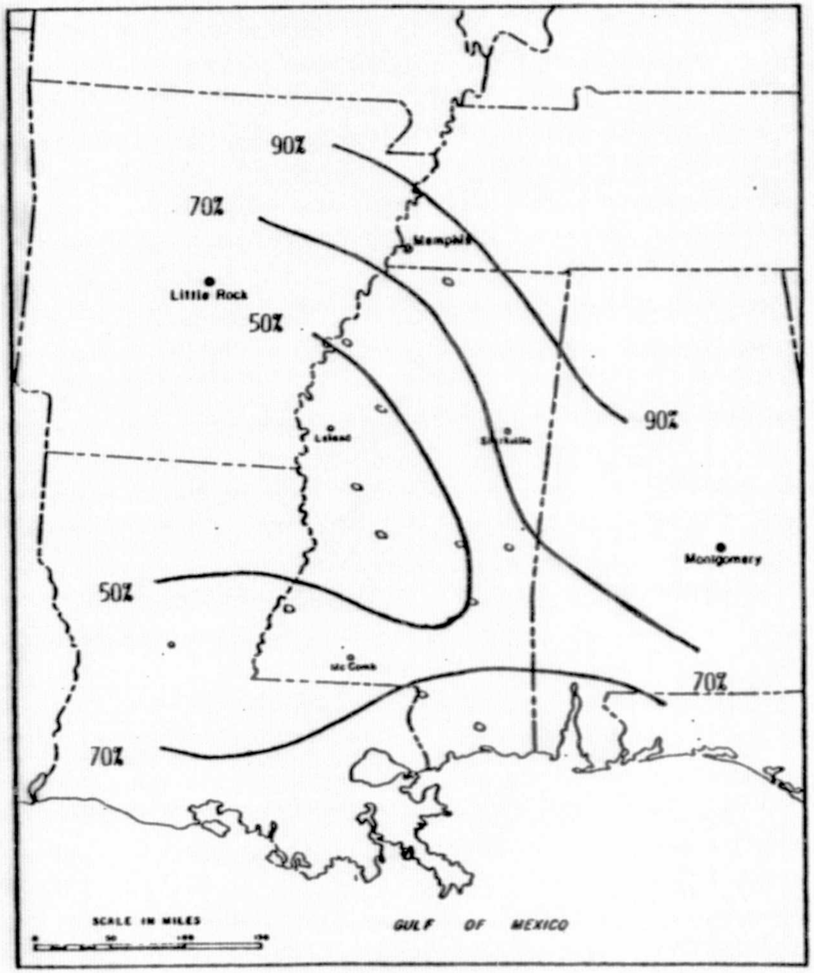

Figure 9. Hourly Relative Humidity.

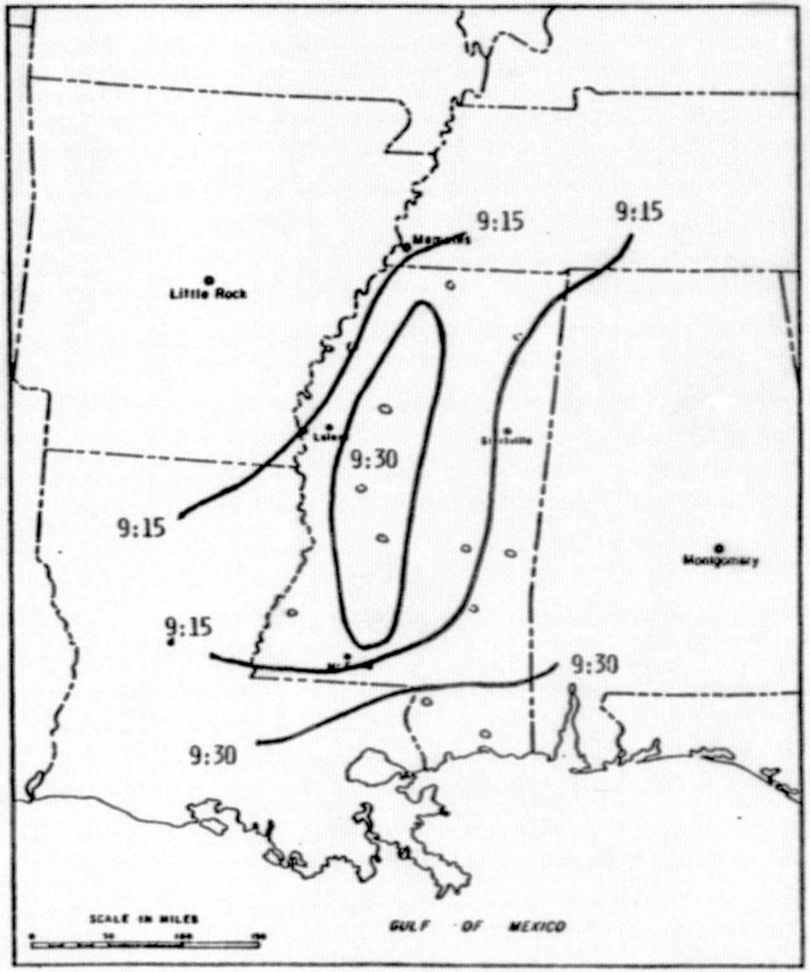

Figure 10. Dew Dry Off - Morning - ± 10 Minutes.

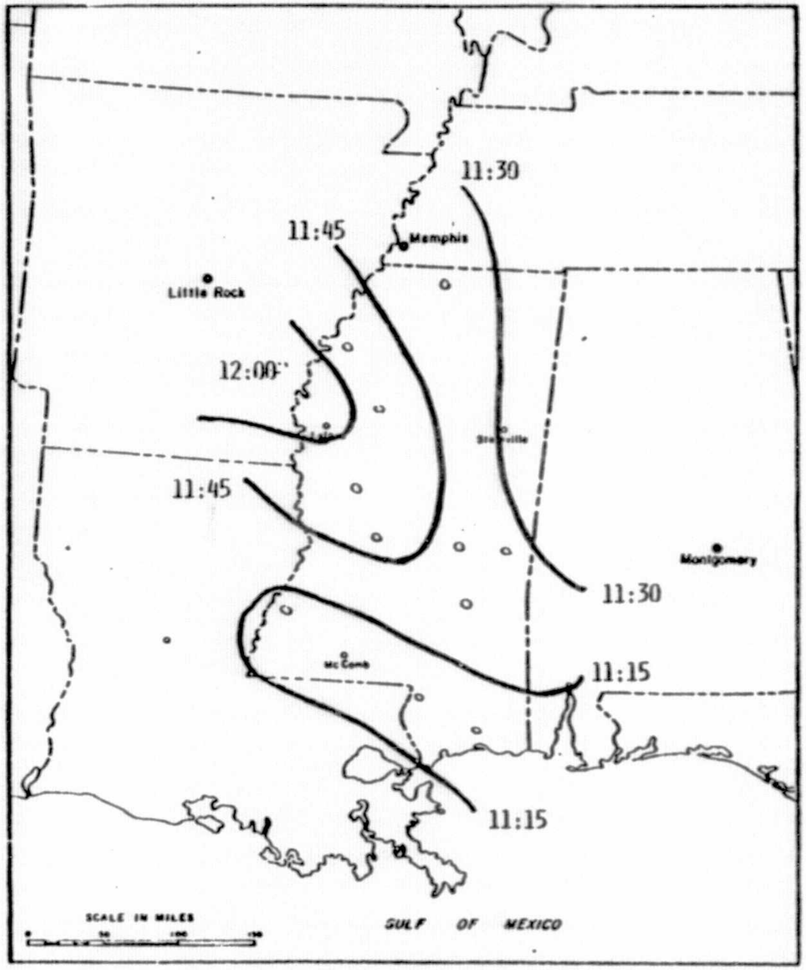

Figure 11. Dew Fall - Evening - ± 10 Minutes.

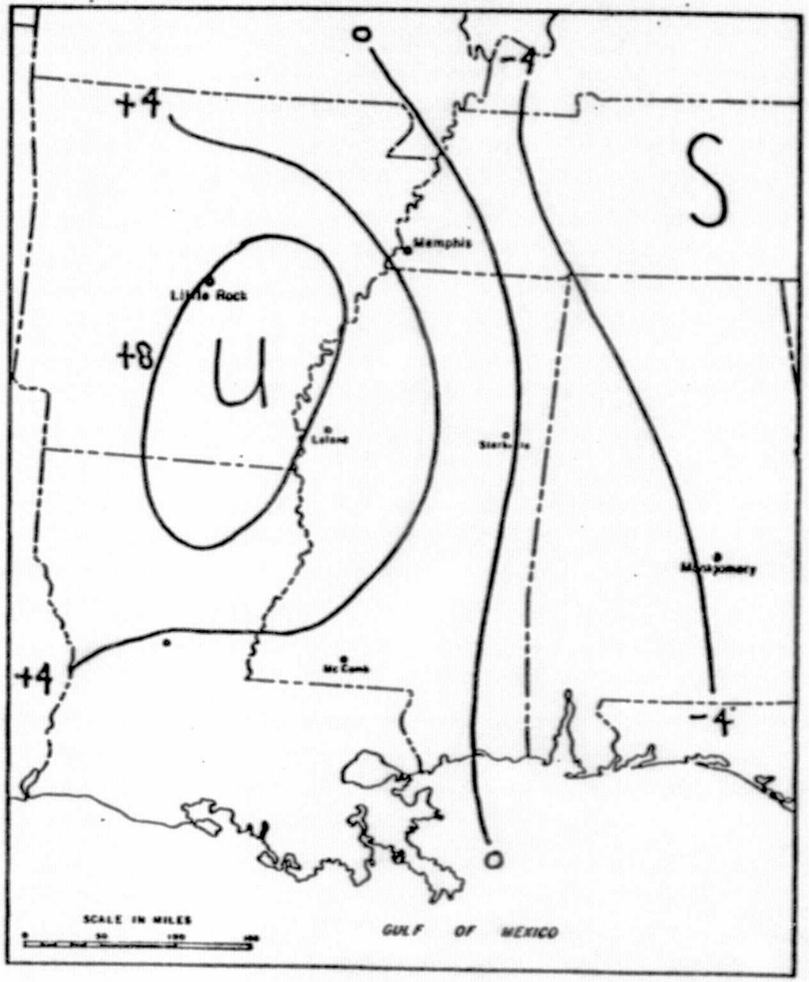

Figure 12. Stability Index.

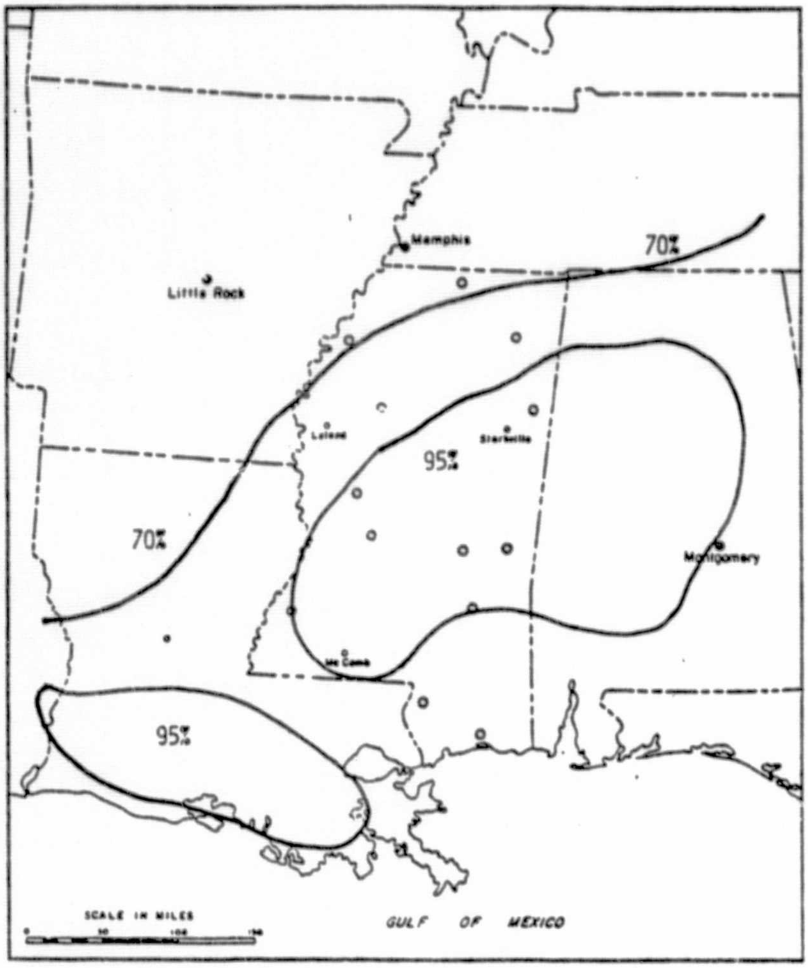

Figure 13. Thunderstorm Probability - $\geq$ .01".

Figures 3 through 13 are examples of some of the visual materials that might be used in the NOWCAST briefings on various days.

The above program was developed through discussions with farm operators and ETV program directors. It will undoubtedly change as the program is demonstrated and the needs of the user and capabilities of the AWCDS become more familiar to the NOWCAST staff. At certain times during the growing season, the ten-minute show will be modified (particularly on days when weather conditions are generally favorable for farm activities) to bring special messages from the agricultural extension services of the state.

Project NOWCAST was created to reduce weather related risks to the individual farmer. In actuality, there will be very little affect on world food prices derived from providing any given area with Project NOWCAST. The same is true for the American consumer; prices will not change because one sector of the agricultural community receives weather information from Project NOWCAST. What will occur is, farmers will receive current and short-range information in a timely manner which will cause less replanting, less washoff of pesticides, and in general, a more efficient farm production.

The potential benefits of Project NOWCAST differ between agricultural regions. For example, farmers in the Willamette Valley of Oregon would receive greater benefit from Project NOWCAST than would farmers in the San Joaquin Valley of California. Agriculture is very diversified in the Willamette Valley, with a high frequency of frontal activity entering this area from a region of low weather observation sites, the Pacific Ocean. The San Joaquin Valley is generally a fair weather area.

The benefits derived from providing current and short-range information to the farmer is very dependent on response time. Response time is the amount of time it takes the farmer to complete the integration of weather information into a farm operation. Response time varies according to many factors, two of which are, the difficulty of the farm operation and the type of equipment used. For example, it takes more time to subsoil a given number of acres than to apply a pesticide to those same acres.

Pesticide application by airplane takes considerably less time than does application by ground equipment. In this report, response time will be considered relative to the difficulty of the farm operation and the type of equipment used.

Background Information

Cotton is King in Mississippi, but not because of tradition. Surprisingly, more acres were planted in soybeans in 1976 than in cotton (Figure 14). Cotton farming is popular in Mississippi because of the large potential for profit if favorable weather occurs or if the farmer can use weather information to his advantage. Cotton is one of the few crops that costs as much as $200 to $250 per acre to produce (31) (Table 2). If above average yields are obtained, profits may exceed two to three times the cost of production. Most farmers, to guard against possible adverse weather, plant part of their acreages to less weather sensitive crops such as rice and/or soybeans. Cotton growing is a year-round operation (Table 3). As soon as the harvest operation is completed, operations must begin for the next season's crop. Most chemicals needed to produce cotton (herbicides, insecticides and harvest-aid chemicals) are applied by airplane and/or ground equipment. Application of these chemicals and the chemicals themselves are very weather sensitive and are greatly affected by air temperature, wind speed, precipitation and other weather variables. The potential savings of reducing washoff of pesticides, reducing the amount of replanting and in other operations is tremendous. Today's cotton farm is, at best, a multi-structured business with hundreds of thousands of dollars invested in land and equipment.

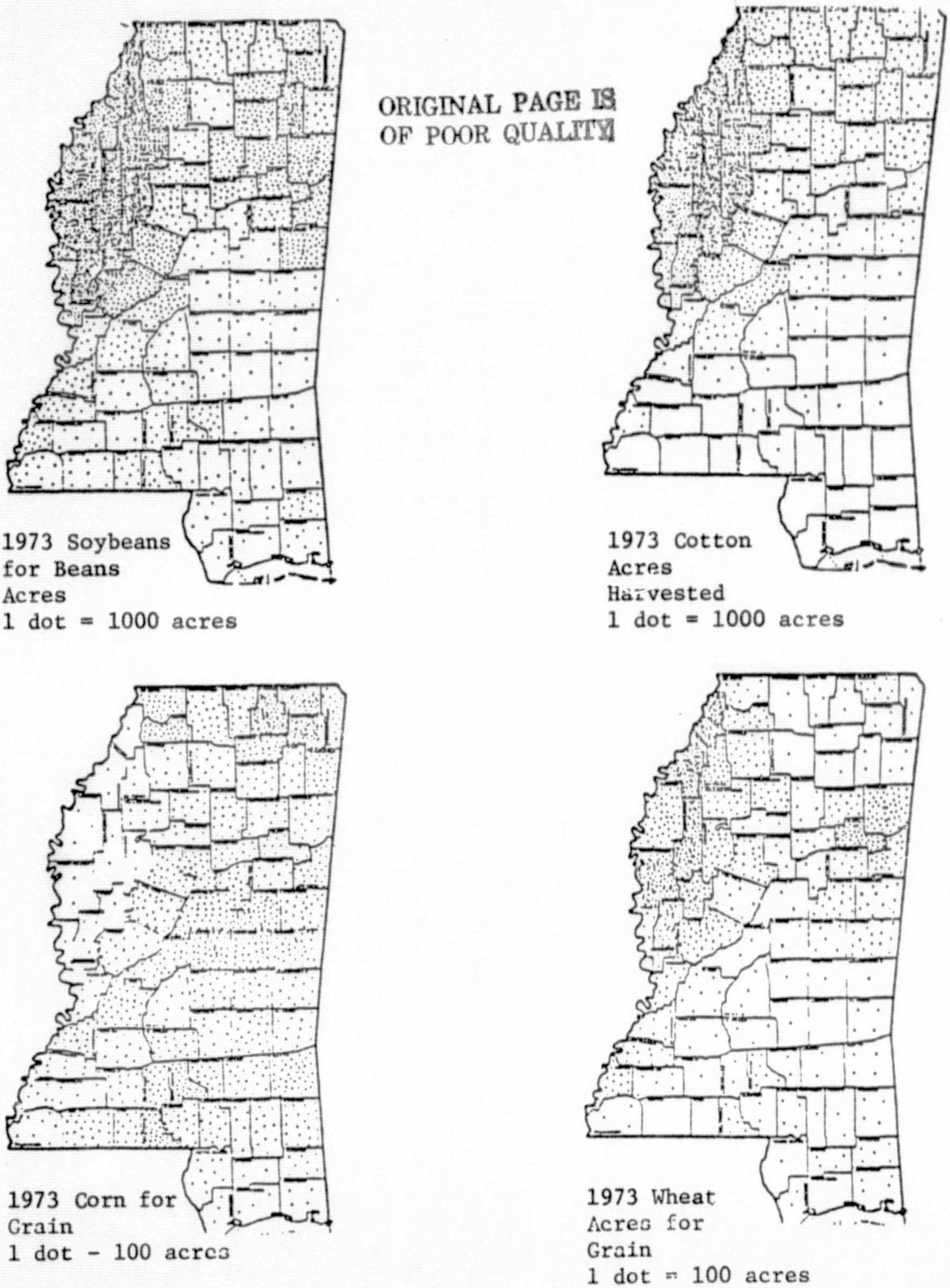

Figure 14. Distribution of Soybean, Cotton, Corn and Wheat in Mississippi.

Table 2. Estimated Cost Per Acre, 2 X 1 Cotton, Land Basis, Sandy Soil, Usual Input Practices, 8 Row Equipment, Mississippi Delta, 1976.

Operation Description	Month	Tractor Direct Cost	Tractor Fixed Cost	Equipment Direct Cost	Equipment Fixed Cost	Labor Cost	Material Cost	Misc Cost	Total Cost
		----------	----------	----------	----------	Dollars	----------	----------	----------
Apply Lime X1/6	11	.00	.00	.00	.00	.00	.00	6.22	6.22
Stalk Shredder 2 Row	11	.47	.53	.03	.13	.46	.00	.00	1.62
Chisel Plow 16 ft.	3	.63	.74	.15	.33	.51	.00	.00	2.35
Chisel Plow 16 ft.	3	.63	.74	.15	.33	.51	.00	.00	2.35
Disk and Incorp. 21 ft.	3	.51	.60	.52	.96	.41	3.47	.00	6.47
Disk Harrow 21 ft.	3	.40	.47	.34	.62	.32	.00	.00	2.15
Field Cult. 21 ft.	3	.28	.33	.14	.31	.23	.00	.00	1.30
Disk Bed	4	.28	.33	.16	.27	.23	.00	.00	1.28
Disk Bed and Fert.	4	.34	.40	.23	.39	.28	5.00	.00	6.64
Row Condition	5	.30	.36	.37	.72	.25	.00	.00	2.00
Plant and Pre.	5	.34	.39	.32	.72	.54	10.02	.00	12.33
Trailer	5	.05	.05	.04	.08	.41	.00	.00	.63
Cultivate Early	5	.41	.48	.21	.40	.33	.00	.00	1.82
Apply Ins. Ground	5	.00	.00	.25	.32	.17	.54	.00	1.28
Cult and Post Early	5	.46	.54	.29	.57	.37	.76	.00	2.98
Cult and Post Early	6	.46	.54	.29	.57	.37	2.44	.00	4.67
Hand Weed Control	6	.00	.00	.00	.00	3.08	.00	.00	3.08
Cult and Post Late	6	.33	.39	.21	.41	.27	2.44	.00	4.05
Cult and Post Late	6	.33	.39	.21	.41	.27	1.17	.00	2.78
Hand Weed Control	7	.00	.00	.00	.00	3.08	.00	.00	3.08
Cult and Post Late	7	.33	.39	.21	.41	.27	7.10	.00	8.71
Insect Scouting	7	.00	.00	.00	.00	.00	.00	1.50	1.50
Apply Ins Air X2	7	.00	.00	.00	.00	.05	7.27	1.60	8.91
Apply Ins Air X4	8	.00	.00	.00	.00	.09	14.53	3.20	17.82
Apply Ins Air X2	9	.00	.00	.00	.00	.05	5.23	1.60	6.88
App Defoliate - Air	9	.00	.00	.00	.00	.00	2.62	1.65	4.27
1st Pick 2 Row	10	.00	.00	9.35	15.90	2.55	.00	.00	27.79
Haul	10	.00	.00	.00	.00	.00	.00	5.83	5.83
2nd Pick 2 Row	10	.00	.00	4.82	8.19	1.32	.00	.00	14.32
Haul	10	.00	.00	.00	.00	.00	.00	1.46	1.46
Gin	10	.00	.00	.00	.00	.00	.00	51.44	51.44
TOTAL SPECIFIED COSTS		6.54	7.67	18.31	32.03	16.40	62.60	74.51	218.06
INTEREST ON OPERATING CAPITAL									4.51
TOTAL SPECIFIED COSTS INCLUDING INTEREST ON OPERATING CAPITAL									222.57

(After Parvin, 1976)

Table 3. Mississippi Cotton Calendar.

January	Financial arrangements for next crop. In recent years, still harvesting. Attending meetings on production changes for upcoming year. Some land preparation begun. Make equipment changes and repairs.
February	Begin land preparation and complete harvest (subsoil, chisel plow, etc.). Spread lime, phosphate, and potash fertilizer. Equipment changes and repairs.
March	Hopefully continue with land preparation. Apply fertilizer and lime. Apply and incorporate preplant herbicides on those fields where needed.
April	Continue land preparation, fertilizer application, rowing up, preplant herbicide application, etc. About mid-April begin to plant. Fungicides and insecticides applied at planting. Apply pre-emergence herbicides.
May	Finish planting (by mid-May). Begin cultivations for weed control. Control of early season insects. Apply postdirected herbicides for weed control. Cultivate middles and skip.
June	Begin insect management program checking for plantbugs, fleahoppers, boll weevils, and bollworms. Cultivate and apply postdirected herbicides. Apply sidedress application of nitrogen if needed.
July	Continue insect management program. Cultivate and apply postdirected herbicides. Layby cotton with layby herbicides, if needed. Begin spot treatment weed control. Intensify insect management.
August	Complete layby of crop. Insect control. Spot treatment for grass and weed control. Begin to prepare fields for harvest.
September	Continue insect control. Spot treat for weeds. Intensify preparations for harvest.
October	Continue insect control. Defoliate cotton that is mature. Begin harvest.

Table 3. - continued

<u>November</u>	Complete defoliation by early November. Continue harvest. Late November - cut stalks, soil sample, deep plow, apply lime, etc.
<u>December</u>	Continue harvest. Cut stalks, subsoil, chisel plow, soil sample, apply lime. Bed up heavy soils. Leave sandy and silt soils flat.

Saving even small percentages of money on various farming operations adds up to more efficient, financially productive farm operations.

LAND PREPARATION

Introduction

Preparation of the land for the next growing season begins immediately after the cotton is harvested. This operation consists of subsoil plowing and/or chiseling the subsurface compacted layer(s). The subsoil operation, commonly called subsoiling, consists of running a three or four prong implement eight to 24 inches into the soil. Normally, the chisels are pulled through the soil perpendicular to the previous year's crop rows. The purpose of subsoiling is to break up any compacted soil layers which mechanically impede root development of the cotton plant, increase the intake storage and transmission of water into the subsurface, and increase the depth of aerated soils (35).

Agricultural Problems Associated with the Subsoiling Operation

Most soil compaction is the result of the previous growing season's farm operations. Factors such as the number of times an implement passed over the soil, the percentage of organic matter, the moisture content of the soil and the soil type determine the depth and thickness of the compacted layer. Not all farmers in Mississippi prepare their fields by subsoiling, however, subsoiling is becoming common on all soil types (29). Grisson found that the Buckshot series soils usually receive less benefit from the subsoiling or chiseling operation than do other soils (16). Rainey (35) showed that crops responded to subsoiling on sandy soils more frequently than on clay soils. He concluded that this was the result primarily of the heaving effect of clay in the soil which tends to break up compacted layers even without the subsoiling operation.

Research at the Delta Branch Experiment Station of the Mississippi State University in 1954 indicated that cotton yields were more than doubled when compacted soils were chisel plowed (34). Rainey concluded from his research that the effect of subsoiling apparently lasted only one growing season. On the other hand, research by Grisson indicated that approximately one-half of the beneficial effect of deep tillage on a silt loam in 1953 was carried over to the 1954 crop (16). Whether the effect does or does not last more than a year, the importance and benefits of this operation have been well documented. The effectiveness and permanency of the subsoiling, however, is influenced greatly by soil moisture content (13); the compacted layer is more completely shattered and more likely to remain in a shattered condition when the subsoil is relatively dry (14). When the subsoil is relatively wet, the operation is often less beneficial.

Under certain conditions, chisel plowing can even reduce crop yields. If adequate rainfall or irrigation is not available during a growing season, water loss in the lower layers by deep percolation will reduce subsequent crop yields (14). Optimally, the chisel plow operation should be undertaken as soon after harvest as possible when soils are dry but when rainfall is expected to occur soon in order to replenish moisture in the lower soil layers.

Meteorological Significance in the Land Preparation Operation

To date, farmers in Mississippi have not had adequate agricultural weather information to schedule the subsoiling operation at a time when their efforts would reap the greatest benefits. For example, assuming a forecast for fair weather conditions, the farmer also needs information about the soil moisture condition in the subsoil layer of each soil type on his farm before deciding if he should undertake the chiseling operation. If he chisel plows when there is too much subsoil moisture, he may increase the depth of the compacted layer (14). Not only has he wasted his time and efforts, but the results of the operation have increased the probability of crop damage during the dry part of the summer. On the other hand, assuming that adverse weather is forecast, the farmer could still accomplish this operation to his greatest benefit if he knew: (a) if the rainfall were going to occur over his farm; (b) the time that it would occur; (c) how long it would rain; and (d) the probable amount of precipitation that would be received (29). For the chisel plow operation, he also needs to know the present soil moisture content of the soils that will be chiseled (this undoubtedly will be different for the light, medium and heavy soils).

It has been established that the heavy (clay) soils benefit less from subsoiling, not because less compaction occurs on these soils, but due to the freezing and thawing effect of breaking a compacted layer. Through soil temperature measurements, the farmer has a better understanding of the extent of heaving occurring on the clay soils. As an example, suppose a mild winter occurs in Mississippi. If the heavy soils are not freezing, chisel plowing these soils would be beneficial. By not having adequate soil temperature information, the farmer may not perform this operation on his heavy soils, thereby causing subsequent problems with water drainage and root establishment later in the growing season. The combination of adequate weather, soil moisture, and soil temperature information will allow him to make the most beneficial, short-term decision for his chisel plow operation.

The response time in the subsoiling operation is rather long in comparison to the average number of days of suitable field work possible during this time of year (late October to December). As can be seen from Table 4, as January approaches, the average days suitable for field work (for 1973-1976) decreases drastically. The farmer, to complete the subsoiling operation on all of his land, must have information on the frequency and location of frontal activity so he can plan this operation between the frontal activity.

Application of NOWCAST to Land Preparation of Cotton

In considering the applicability of the NOWCAST weather information system to the land preparation operation, as well as for other operations discussed in this report, only the 1976 growing season will be considered. Due to adverse weather during the 1975 harvest period, cotton farmers in Mississippi were unable to complete harvest operations until late January or early February 1976. As a result, only ten percent of soils having a compacted layer were subsoiled or chiseled (29). Instead, most farmers went directly to the preplant operation after harvest on the assumption that late spring subsoiling would, in this case, not be economically beneficial and furthermore, would probably be too time consuming.

As mid-summer of 1976 approached, much of the cotton-growing region of Mississippi entered a serious drought period which laster two months. As a result, the average cotton yield for the entire state of Mississippi was reduced to only 374 pounds, compared to a ten year average of 550 pounds per acre (see Table 5) -- a loss of nearly 50 percent of the average cotton crop (29). Had the other 90 percent of the compacted soils in the cotton fields been subsoiled, it is believed by several cotton

Table 4. Average Days Suitable for Fieldwork, Mississippi, 1973, 1974, 1975, and 1976.

Week Ending	1973	1974	1975	1976	Average
Jan. 4	0.5	0.2	0.3	0.8	0.5
11	0.1	0.1	0.6	0.8	0.4
18	3.0	0.4	1.1	1.0	1.4
25	2.0	0.1	1.3	2.6	1.5
Feb. 1	0.9	0.5	2.1	2.5	1.5
8	2.2	0.4	0.9	2.8	1.6
15	0.8	2.0	1.9	3.5	2.1
22	3.2	0.9	0.8	3.1	2.0
Mar. 1	4.4	3.1	1.9	3.8	3.3
8	1.5	5.7	2.5	4.9	3.7
15	0.9	4.1	1.3	1.0	1.8
22	1.8	2.6	1.0	1.5	1.7
29	0.6	2.1	3.0	1.4	1.8
Apr. 5	2.5	2.5	1.7	0.6	1.8
12	3.1	4.1	1.5	5.3	3.5
19	0.3	2.6	1.8	5.8	2.6
26	0.4	2.5	4.2	6.1	3.3
May 3	2.2	5.0	1.5	4.5	3.3
10	2.8	4.9	0.6	4.7	3.3
17	5.2	3.3	1.9		
24	4.1	2.2	5.1	4.3	3.9
31	3.8	3.5	2.8	3.3	3.4
June 7	4.9	2.2	4.9	2.8	3.7
14	4.6	2.2	1.1	5.8	3.4
21	4.9	3.3	4.0	3.8	4.0
28	5.5	4.8	5.2	4.2	4.9
July 5	5.2	5.7	5.0	4.7	5.2
12	5.1	5.1	3.5		
19	4.7	5.7	5.5	5.3	5.3
26	4.8	3.7	4.7	6.1	4.8
Aug. 2	4.2	5.0	2.0	5.3	4.1
9	5.5	5.3	1.8	5.7	4.6
16	4.7	4.1	4.5	6.2	4.9
23	6.0	5.6	4.2	6.2	5.5
30	5.3	4.0	5.4	6.1	5.2
Sept. 6	2.8	3.0	5.9	5.4	4.3
13	3.7	2.7	4.4	3.1	3.5
20	5.9	5.1	3.9	6.0	5.2
27	5.5	2.5	3.8	6.1	4.5
Oct. 4	5.0	5.4	4.0	4.8	4.8
11	4.9	6.1	4.8	4.4	5.1
18	3.7	4.0	3.4	6.1	4.3
25	6.1	6.1	4.8		
Nov. 1	3.8	4.1	4.6		
8	1.6	4.0	2.3	5.4	3.3
15	4.7	3.3	3.2	4.3	3.9
22	1.9	2.4	3.9	4.1	3.1
29	1.1	3.1	3.1	5.0	3.1
Dec. 6	2.7	3.6	4.1	2.8	3.3
13	5.0	1.6	4.6	2.6	3.5
20	2.5	1.9	2.8	2.4	2.4
27	0.4	0.2	3.3		

Table 5. Mississippi Cotton Information 1950-76.

Year	Acres Planted	Acres Harvested	Yield Per Acre	Production	Season Ave. Price	Value of Prod.
	1,000 Ac.	1,000 Ac.	Lbs.	1,000 Bales	Cents	1,000 Doll.
1950	2,084	2,030	3,4	1,332	40.25	268,116
1951	2,463	2,340	329	1,608	39.34	316,371
1952	2,440	2,416	378	1,906	35.36	336,992
1953	2,554	2,490	410	2,129	33.80	359,800
1954	2,010	1,960	384	1,571	34.48	270,868
1955	1,755	1,700	570	2,023	33.63	340,175
1956	1,655	1,595	483	1,609	32.86	264,374
1957	1,400	1,335	388	1,081	28.37	153,311
1958	1,185	1,125	409	961	34.23	164,440
1959	1,535	1,475	509	1,568	33.21	260,407
1960	1,580	1,520	486	1,542	31.00	239,000
1961	1,665	1,580	493	1,625	33.89	275,447
1962	1,635	1,585	512	1,696	33.18	281,393
1963	1,485	1,438	709	2,129	33.25	353,989
1964	1,498	1,460	732	2,226	31.88	340,543
1965	1,471	1,430	678	2,020	30.47	295,474
1966	1,032	993	653	1,350	22.73	147,312
1967	955	890	567	1,051	29.65	149,565
1968	1,155	1,105	660	1,519	23.93	174,401
1969	1,225	1,185	534	1,319	23.15	146,555
1970	1,235	1,190	658	1,613	21.94	179,275
1971	1,355	1,325	613	1,693	27.64	224,573
1972	1,664	1,606	599	2,007	29.20	281,310
1973	1,370	1,340	651	1,816	37.90	330,384
1974	1,825	1,715	448	1,595	47.00	359,832
1975	1,175	1,100	448	1,070	55.40	276,591
1976	1,600	1,470	343	1,050	65.00	317,520

experts of the state that the improved root development would have enabled the cotton plant to have survived the drought period and the yields would have been sharply increased (29). Dr. James Brown of the National Cotton Council conducted a survey for the 1975 cotton crop to determine which of the tillage operations were of the greatest importance to the cotton yield

(7). Results of his study showed that farmers that completed the subsoiling or chisel plowing operations obtained significantly higher yields than did those farmers who did not include subsoiling in the land preparation.

Benefits to Land Preparation Resulting from NOWCAST

Three types of information provided by the NOWCAST office should be of major benefit to farmers involved in land preparation. First, it is planned that calculated soil moisture budgets on a 50 mile grid system will be provided for each of the three soil types at various depths. In addition, actual soil moisture measurements at selected locations on specific soils across the state will be provided. The farmers will receive the soil moisture budget information daily, together with precipitation, pan evaporation and calculated evaporation for each soil type. Second, soil temperature measurements from the surface to a depth of 36 inches on major soil types (most important on heavy soils for this operation) will provide input on heaving of clay soils. This will aid in deciding the need for subsoiling the heaving soils in spring. Third, NOWCAST will be most beneficial in providing current information about precipitation. By superimposing the radar overlay over the latest satellite picture, the farmer will be able to see where rain is presently occurring with respect to his land. He will also be able to see where it has been raining during the past hour and the speed and direction of the precipitation area. This type of information, when provided each hour, will keep the farmer updated on the probabilities of rainfall amounts and time of occurrence on his farm.

To illustrate a specific application of NOWCAST to land preparation activity, a hypothetical example of a farmer in Washington County, Mississippi will be discussed. At 6:00 a.m. Farmer Jones views the ten minute NOWCAST presentation. A soil moisture map of western Mississippi indicates that both heavy and light soils are dry at all levels. Farmer Jones has completed his cotton harvest on the heavier soils and knows that if he conducts the chisel plow operation at this time, he should obtain maximum benefits in breaking the compacted layer that developed over the previous growing season. The NOWCAST program indicates that rainfall is occurring in a broad band approximately 50 miles west of his farm and the probability of rainfall late in the afternoon is approximately 70 percent. As a result, Farmer Jones decides to chisel plow his clay soils that day and to chisel plow his medium and lighter textured soils tomorrow.

No doubt, this example is oversimplified, but basic agricultural weather information of this type is needed for making maximum use of the farmer's time and energies. This basic weather information is currently available. It is not, however, being disseminated to the farm operator.

Considering the average 1976 market price of 63 cents per pound cotton lint (currently the highest price on record (Table 5)), and a potential increase of 240 pounds per acre of cotton for soils that have been subsoiled or chisel plowed (remembering that 50 percent of the heavy soils do not necessarily benefit from subsoiling), NOWCAST could have an effect on approximately 40 percent of the total cotton acreage in the state. The potential increase in profit resulting from land preparation using the NOWCAST briefing program would be:

$ .63 X 240 lb. increase per acre X 640,000 acres = $96 million.

To the individual farmer with 100 acres of land, assuming he is able to complete this operation on all of his land due to Project NOWCAST, his potential increase in profit would be:

$ .63 X 240 lb. increase per acre X 100 acres = $15,100.

PREPLANT

Introduction

In this study, the preplant operation is defined as occurring from January through early April. The preplant operation prepares the seedbed, creating a favorable environment for germination of the cotton seed and emergence of the seedling. One of the most important components of this operation is freeing the seedbed of weeds.

Cotton farmers in Mississippi have serious problems in keeping the fields weed-free during the entire growing season. Since cotton is a tropical plant not native to latitudes of the United States, weeds commonly grow better in the cotton fields of Mississippi than do the cotton plant (14). Early season weed control is very important because competition between weeds and cotton seedlings depletes necessary nutrients, moisture and sunlight necessary to establish and maintain a good stand of cotton plants.

Weed control in the preplant operation is normally accomplished by mechanical means and/or by applying a preplant incorporated herbicide (generally referred to as PPI). Preplant incorporated herbicides were applied on 95 percent of Mississippi's cotton crop acreage in 1976 and were used in the preplant operation on other crops such as soybeans.

There are three methods of applying a preplant incorporated herbicide. The first method involves applying the herbicide using tractor-drawn equipment and incorporating the herbicide into the soil one to three inches deep using some type of mixing implement (disk harrow, etc.). A second application is generally made by all farmers to insure uniform distribution of the herbicide into the soil (29).

The second method of applying a PPI is to aerially spray and use ground equipment to incorporate twice. This method costs more but reduces the amount of time to complete the spraying part of the operation. It still takes as much time to incorporate the PPI as in the first method.

The third method is to ground-apply or aerially spray but not incorporate manually. Instead, precipitation is depended upon to incorporate the PPI into the soil (29). This method is obviously less time consuming since it consists only of spraying the PPI (no incorporation).

Agricultural Problems Associated with the Preplant Operation

In completing this operation, farmers using methods one or two have problems not associated with using method three. Since methods one and two demand two incorporations to better distribute the herbicide into the soil, the number of trips into the field is increased. This causes two problems the farmer would like to minimize. First, increased trips into the field causes greater compaction of the soil. Second, increased times over the field increases production costs. Method three reduces these problems because of the reduction in number of trips into the field. This would provide a considerable savings to the farmer.

Meteorological Significance in the Preplant Operation

Method three, although most beneficial to the farmer, is not widely used in Mississippi. Most PPI's could be incorporated into the soil by rainfall if the farmer knew that rainfall would occur within an acceptable amount of time (12). This "acceptable amount of time" depends upon the herbicide used (Table 6). As can be seen from Table 6, the permissible delay of time, when the herbicide reaches the surface until it is lost to

Table 6. Preplant Incorporated Herbicides.

Herbicide	Permissible Delay Incorporation	Relative Length of Control
Amex	Several	Intermediate
Cobex	24 Hours	Shortest
Tolban	4 Hours	Intermediate
Treflan	8 Hours	Longest
Prowl	7 Days	Intermediate

the atmosphere, ranges generally from two to eight hours. For example, if Farmer Jones uses Treflan as a PPI spray, he has eight hours to incorporate the herbicide into the soil. The probabilities of the PPI being incorporated by rainfall is very small, simply because Farmer Jones does not know exactly where, when, or how much rainfall is expected on his land. In other words, there is just too much uncertainty to permit reliance of rainfall to incorporate the PPI using present-day weather information.

Recently, a new PPI on the market is advertised as requiring only one-fourth inch of rain within seven days to be incorporated three inches into the soil. Therefore, a farmer, after considering the amount of control his fields need and by knowing when rainfall activity will hit his land, could ground apply or aerially spray the PPI and thus save one or two trips into the field.

Wind speed must also be considered when applying a PPI. Wind speed of less than seven miles per hour at the surface is considered acceptable for spraying. Wind speeds of seven to 12 miles per hour are considered fair for spraying, but other factors must be considered such as what other drops in the area may be affected by a drifting PPI. Wind speeds of greater than 12 miles per hour are considered normally unacceptable for spraying (22).

For this operation, response time is very dependent on the method of application. It takes approximately ten hours to spray and incorporate (method 2) a PPI on 100 acres of land. In an hour, this same acreage can be sprayed by an airplane. Using current weather dissemination techniques, if rainfall was expected in four to five hours, it would be impossible to complete this operation, using method one, before rainfall started. On the other hand, using method three, there would be sufficient time for the farmer to call his pilot and have the PPI applied before rainfall commenced. This would save the farmer the cost of two extra trips into the field to incorporate the PPI.

Application of NOWCAST to the Preplant Operation

In the preplant operation, NOWCAST would benefit farmers presenting small time/space scale information on rainfall and wind speeds. Hourly, state-wide surface wind speed information would allow the farmer to estimate the amount of herbicide drift. After viewing the surface wind map, the farmer may decide to undertake some farm activity less sensitive to wind speed than herbicide spraying.

Precipitation information would come from satellite and radar data with the satellite imagery used in two ways. A slow speed, high resolution film loop of the past 24 hours of pictures would be televised and updated hourly, and the latest satellite picture would be superimposed with the latest radar picture. In addition, NOWCAST will provide locations of pressure systems, fronts and their movement. With the use of radar, the farmer would also be advised of rainfall activity and its proximity to his land.

By combining the current NOWCAST information on wind speed, pressure systems, rainfall location and movement, the farmer can expect to decrease soil compaction and, most importantly, the cost of production in the preplant operation.

Benefits to the Preplant Operation Resulting from NOWCAST

In evaluating the potential savings in the preplant operation it was found that for approximately 55 percent of the cotton acreage, farmers use method one (ground apply and two incorporations) (Table 7). Method two is used on about 35 percent of the cotton acreage (Table 7). About ten percent of the Mississippi cotton acreage was not considered in the potential savings estimate because: 1) about five percent of the state's cotton acreage does not have a preplant incorporated herbicide applied on it; and 2) about five percent already use method three to incorporate the herbicide.

As can be seen from Table 7, the cost of the PPI depends on soil type, therefore, the cost of application varies with soil type. This cost is fixed regardless of how the PPI is applied. Of major importance is the cost of incorporating the PPI (mixing the herbicide into the soil once applied). This cost of incorporation represents one trip into the field. The savings comes from elimination of a second trip. The potential savings derived from method one might be as great as $3.8 million. In method two, if, after spraying the PPI by airplane, both incorporations were not necessary, due to timely incorporation by rainfall, this would be considered potential savings. The total potential savings in

Table 7. NOWCAST Economic Impact on Preplant Operations for Cotton.

METHOD 1 ≈ 55% ≈ 900,000 Total Mississippi Acres

	Light	Medium	Heavy
PPI/A	3.47	5.23	6.97
Apply and Incorporate	6.47	8.20	9.94
Incorporate	2.15	2.15	2.15
	8.62	10.35	12.09

Light 20% X 900,000 X $8.62	=	$1,551,600
Medium 25% X 900,000 X $10.35	=	2,328,750
Heavy 55% X 900,000 X $12.09	=	5,984,550
Subtotal		$9,864,900

Save One Trip $1,935,000 Two Trips $3,870,000

METHOD 2 ≈ 550,000 ≈ 35% Total Mississippi Acres

	Light	Medium	Heavy
PPI/A	3.47	5.23	6.97
Aerial Spray	1.50	1.50	1.50
Two Incorporations	4.30	4.30	4.30
	9.27	11.03	12.77

Light 20% X 550,000 X $9.27	=	$1,019,700
Medium 25% X 550,000 X $11.03	=	1,516,625
Heavy 55% X 550,000 X $12.77	=	3,862,925
Subtotal		$6,399,250
Save		$2,365,000

Total Cost =	$ 9,864,900	Total Savings =	$2,365,000
	6,399,250		3,870,000
	$16,264,150		$6,235,000

this operation is approximately \$6 million. Assuming the farmer used method two or three and had information on when, where and how much rainfall is expected, Mississippi cotton farmers have the potential of saving from four to six million dollars on this operation.

Assuming Farmer Jones had to apply a PPI on 1,000 acres of medium soil using ground equipment, the potential savings of using rainfall to incorporate the herbicide would be as follows (in other words, saving the cost of using an implement twice for incorporating the PPI);

(The cost of two incorporations not needed) X (acres) =

(\$4.30) X (1,000) = \$4,300 .

PLANTING

Introduction

In Mississippi the cotton planting season occurs between mid-April and mid-May as shown in Table 3. Any planting occurring after May 20 is unusual because the cotton plants normally would not have enough mature bolls before the first frost to make harvest profitable. Planting before mid-April usually results in replanting due to inadequate soil temperatures. Therefore, the purpose of this operation is to place the seed in the ground at the proper time to minimize replanting and maximize the length of the growing season. The entire cotton production process depends on the success of planting and on obtaining a uniform stand of cotton plants in the field. This is all too often easier said than done. A good example is the 1976 planting season. That year, 35 percent of the total cotton acreage in Mississippi was replanted three and four times due, in part, to adverse weather at planting time (28). The farmer monitors the weather very closely during the planting season, however, pest control is also very important at this time.

There are primarily three methods of planting cotton in Mississippi (with respect to pesticides) (5, 6, 13, 29). Method one consists of planting seed pretreated with two fungicides and one insecticide. This method is used on nearly 50 percent of Mississippi's cotton acreage but provides only short-term (one to two weeks) control of certain insects. One such insect, called thrips, damages the cotton seedlings' terminal leaves. Since the terminal leaf is also the growing point of the plant, many experts believe controlling thrips early in the growing season is of extreme importance to later cotton growth.

The most widely used method of gaining control over weeds and insects in the planting operation is by placing pesticides and herbicides in the furrow during seed placement (method two). Specific insecticides for controlling thrips, plant bugs and fleahoppers, along with a pre-emergence herbicide for controlling teaweed, Johnson-grass and other grasses and broadleaf weeds are used. As the insecticides used in this method are taken up into the seedling (systemic action), insects feeding on the plant are killed. Thus, beneficial insects (spiders, flower bugs, etc.) that prey on more harmful cotton insects later in the growing season (tobacco budworm and cotton bollworm) are also destroyed. These systemic insecticides also cause slow plant growth early in the growing season.

Method three, which is recommended by some Mississippi Extension experts, is to plant without any of the usual insecticides. Some experts believe it is more important to establish the stand of cotton plants before applying insecticides that may slow plant growth (13). Many farmers and agricultural consultants in Mississippi, however, belive the opposite, insect control must be maintained during the entire growing season.

Agricultural Problems Associated with Planting

In the planting operation, obtaining a uniform stand of plants is of maximum importance. Any cotton seedlings which fail to emerge (break the surface) by May 20 are of little or no value for making cotton lint by harvest time. The farmer must consider many factors before he plants if he is to get a uniform stand of plants. Seed quality is one of the most important considerations. Cotton seed with poor vigor will have a smaller percentage of germination and emergence. Obtaining top quality seed is usually difficult. Farmers compensate for this problem by overplanting. Instead of planting the optimum number of plants per unit area, they plant 50 to 100 percent more seeds than necessary (29).

Another problem in obtaining a uniform stand is poor soil temperature. Germination of the seed and emergence of the seedling are functions of soil temperature. For average seed vigor, the planting depth soil temperature should be equal to or greater than 68°F for seven to ten days to obtain proper germination and emergence (14) (Figure 15).

Soil moisture at seed depth is yet another problem associated with getting a good stand of plants. Too much moisture deprives the seedling of necessary gas exchange; too little moisture at seed depth delays germination of the seed. Therefore, regardless of seed quality, the farmer must consider soil moisture and soil temperature during and after planting time to obtain a uniform, healthy stand of cotton plants. On the average, 15 percent of Mississippi's cotton acreage is replanted yearly (29). This is a high percentage for any crop. Under very unfavorable weather conditions at planting time, such as during 1976, an even larger percentage of Mississippi's cotton acreage requires replanting.

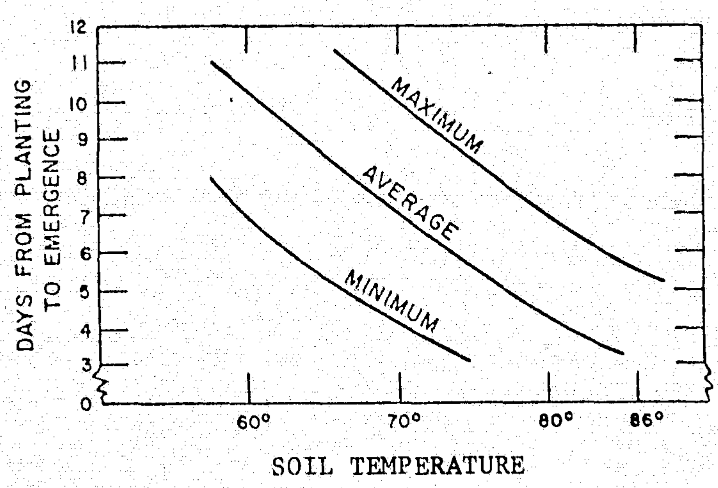

Figure 15. Relation of Maximum, Minimum and Average Soil Temperature to the Number of Days Required from Planting to Emergence for Cotton (Mississippi). (After Elliott, 1968)

Meteorological Significance in the Planting Operation

Rainfall affects the planting operation in several ways. First is its effect on germination and emergence, in terms of soil moisture. Rainfall amounts during springtime in the Mississippi Delta area averages 14 inches (24). While this amount of rainfall is sufficient for good growth, it is important that the rain be distributed throughout the time period to insure sufficient soil moisture for proper germination and emergence of the cotton stand. Often however, too much rain and cool weather occurs during (and soon after) planting (23). This causes poor germination and emergence, thus, replanting is required. Assuming soil moisture is adequate and rainfall of perhaps one-half inch occurs the day before the farmer plans to plant, soil moisture in his heavy soils will be in excess for several days. If fair weather occurs the next day, he may still be able to plant his lighter (sandy) soils without worrying about excess soil moisture. On the other hand, if one-half inch of intense rainfall (thunderstorm activity) occurs immediately after planting, the seed can be washed out of the ground and resultant cool nighttime air temperatures can cause improper germination. Rainfall occurring any time after planting, but before emergence of the seedling, causes soil crusting. Soil crusting inhibits emergence of the seedling by solidifying the soil surface, forcing the farmer to break the surface crust to allow emergence of the seedling to occur (14).

Although rainfall is needed to keep moisture in the soil, soil moisture also affects soil temperature. Damp weather causes soil moisture to increase and soil temperature to decrease. Energy used to raise the soil temperature is, instead, used to evaporate soil moisture. During planting season this tends to reduce germination of the seed and slow growth of the seedling (40). At the same time, the probability of replanting is increased.

Most farmers cannot determine the magnitude of the weather variables by looking at his fields. He must have accurate, current information on soil temperature, soil moisture and rainfall to minimize the need for replanting. Relative to the other operations discussed in this report, the response time of the planting operation is large and nearly equal to the subsoiling operation. At four miles per hour a farmer can plant 50 to 80 acres in ten hours (this considers six to 12 row planter pulled by one tractor). Replanting costs valuable time and money.

Application of NOWCAST to the Planting Operation

Getting the information to the farmer becomes extremely important for the successful completion of the planting operation. At present, the dissemination of specialized weather information is almost totally inadequate. Riley (44), an agricultural meteorologist for the (then) Weather Bureau, stated, "It's often a result of ineffective communcation between (weather) advisor and the user, rather than incorrect information." At present it has come to the point that timely weather information must be considered the limiting factor in production and quality potential of cotton in Mississippi.

In Project NOWCAST, current weather information will be automatically fed into the computer system from sources already established. Satellite information from the GOES-1 satellite will be made into a film loop (24 hours of information), updated every 25 minutes and televised every hour. This visual information will inform the farmer of the frequency of frontal movement through Mississippi and the position of current storm tracks.

The state-wide radar picture (available on real-time basis), and the latest satellite picture with a computer technique for superimposing the two images, will enable the farmer to see where rainfall is occurring in relation to his farm. The technique of superimposing the latest satellite and radar pictures will give new meaning to present percent probability of occurrence method used for precipitation forecasting.

Many weather variables important for completing the planting operation are not presently being collected within the State of Mississippi (40). Weather variables such as soil moisture and soil temperature will be collected by NOWCAST instrumentation on a real-time basis throughout the state and televised hourly during planting season. It is believed a visual presentation of agricultural weather information directed to the planting operation will reduce the large amount of required replanting of cotton which occurs each year in Mississippi.

Benefits to the Planting Operation Resulting from Project NOWCAST

It is believed that half of the replanting that occurred in 1976 (30 to 35 percent) would not have been needed had Project NOWCAST been available to the Mississippi cotton farmers. For the 1976 growing season, as an example, the following emphasizes the potential savings to the Mississippi cotton farmers. In this analysis, two methods of planting (methods one and two) each equal to one-fourth of the 30 to 35 percent total acreage replanted are assumed.

Method 1:	Ground Equipment Cost/A	= \$ 3.49
	Triple-Treated Seed/A	= 7.42
		\$10.91
	480,000A X 1/4 X \$10.91	= \$1,309,200

Method 2: Cost of Planting and Pesticides/A = $ 18.42

480,000A X 1/4 X $18.42 = $2,210,400

Potential Saving for Operation = $3,500,000

(Although recommended, Method Three is not widely used and, therefore, not considered in the potential saving estimate.)

If this analysis is realistic, the savings from this operation would nearly pay for the four year proposed Project NOWCAST in one year.

Let us consider the potential savings to an individual farmer. If, in 1976, Farmer Jones used method one on 1,000 acres of cotton land, the cost of planting would be approximately $10,900. Replanting 15 percent of his land would cost $10.91 per acre X 150 acres = $1,636.50. If, by using NOWCAST weather information, he did not have to replant this acreage, this amount could be considered potential savings with greater profit potential at harvest time.

PEST MANAGEMENT OPERATION

Introduction

For the purpose of this paper, control of both weeds and insects is included in the pest management operation. The period of the growing season considered here will be from emergence of the seedling to the start of cotton harvest. The purpose of the operation is economical weed and insect control. Economics are very important in this operation because the cost of controlling these pests is very large. If a farmer can save one trip into the field in this operation, a significant monetary savings is effected.

Insect Control

Primarily, there are three methods used to control insects during this period: 1) cultural; 2) biological; and 3) chemical. Each includes both preventive and after infestation applications (14). The cultural method includes all agronomic practices to control insects. The greatest benefit when using the cultural method results when the overwintering populations of harmful insects are reduced. Examples of agronomic practices for pest management in cotton currently used are: 1) defoliation or desiccation; 2) rapid harvesting; and 3) elimination of crop residues after harvest. Defoliation or desiccation of the cotton plant removes squares and premature bolls that the cotton boll weevil would normally feed on before overwintering. Eighty percent of the insect damage to cotton plants occurs in the fruit (14). Rapid harvest rids a food source (the boll) from the field. If the farmer can get the cotton harvested early, the food source is decreased which decreases the insect population. Stalk shredding and deep plowing also remove food supplies from the field, reducing the overwintering population of insects (14).

The biological method, although sound in theory, is not widely used. This method consists of introducing parasites and predator insects in the field to control cotton pests.

Chemical control of cotton insects is the most common method of control. Insecticides can be applied by ground equipment or by aerially spraying. Insecticide spraying is done either on a necessary basis (when the insect population approaches crop damaging levels) or on a preventive basis (scheduled spraying before damaging levels are reached). The amount of insecticides used on cotton is staggering. One-half of all insecticides used in the United States is sprayed on cotton (29). One agricultural consultant estimated, during heavy insect pressure periods in Sunflower County, Mississippi, chemical applications in his client-farmer's cotton acreage (12,000 acres) reached $75,000 per week (4).

Agricultural Problems Associated with Controlling Insects

Insecticides were, at one time, considered to be the answer to all problems associated with controlling insect damage to cotton plants. As the use of insecticides increased, however, these harmful insects became resistant to the insecticides used. Today, farmers continue to have the problem of applying increasing amounts of insecticides and obtaining less and less pest control. Currently, annual cotton crop damage in Mississippi averages 15 to 20 percent. What really troubles the farmer is, as one Mississippi cotton grower put it, "70 to 80 percent of the cotton crop pays for expenses, the insects only eat my profits." This is easily understood when a farmer with 1,000 acres of cotton has to apply insecticide costing \$30,000 to \$50,000 in a three month period (29).

As a result of recent Environmental Protection Agency restrictions, certain insecticides have been removed from the market. One of these is the ovicide called Fundal. This ovicide was extensively used to control both the cotton bollworm and tobacco budworm in the egg stage. This is the best stage to control these insects because in this stage of insect development, no feeding occurs on the plant. The moths of these two insects lay 200 to 400 eggs which hatch in approximately three days (14). To control these insects in the egg stage, it is necessary to apply the ovicide ten to 13 times during the growing season. With all ovicides taken off the market in 1977, Mississippi cotton farmers were forced to spray alternative chemicals at increased frequencies, heavier rates and at higher costs (4).

Insect control on cotton is presently so difficult that many farmers hire consultants for pest management. The agricultural consultant's role in pest management is directed toward keeping the farmer informed on current and predicted insect populations in his fields. Recommendations are made to the farmer as to when he should spray for insects and the type of chemical to use. Using the agricultural consultants can be very profitable to the farmer in terms of keeping the farmer from wasting time and chemicals when he should not be spraying. The use of agricultural consultants has become very popular in Mississippi. These consultants made recommendations on 80 percent of Mississippi's cotton acreage in 1976 (13).

Weed Control

The purpose of weed control in the pest management operation is to keep unwanted plants out of the cotton field at an economical cost. If certain weeds, such as bermuda grass, infest the cotton field the farmer may have to plow under the crop and let the field lie fallow until next year. Weed problems in cotton production are caused by both annual and perennial grasses and by broadleaf plants. They reduce quality of cotton lint and yield by competing with cotton plants for soil moisture, sunlight and plant nutrients (14). Weeds not only cause problems in establishing a stand of cotton plants, but also in the harvesting operation. For these reasons, the farmer fights weeds the entire growing season.

There are several methods the farmer may use to control weeds. The most practical methods are: herbicides (ground and aerially applied), flame, cultural, mechanical, hand labor and biological method (14). This section of the report will consider the methods used most extensively in Mississippi, the herbicide and mechanical methods.

The favored method of controlling weeds is by spraying herbicides, however, the chemical and mechanical methods (cultivating) are often completed together (54). The herbicide method can be divided into: 1) preplant treatment, 2) pre-emergence treatment, 3) post-emergence treatment, and 4) layby (which is late season post-emergence treatment). Treatments one and two were discussed earlier in the sections on preplant and planting operations.

Post-emergence weed control (after the stand of plants has emerged) is accomplished by directing a spray under the cotton leaves and branches onto the weeds. This is called post-directed spraying. Normally, the farmer will use a post-directed spray four times during the period mid-June to late-July. After late-July, the "layby" method of weed control is used. Layby consists of a final heavy application of herbicide the last time the farmer can still get into the field with a cultivator without damaging the cotton plants with his equipment. The use of high rates of certain herbicides to control late season weeds and grasses from layby to harvest has become a widely accepted practice in Mississippi. This part of weed control is not profitable if there is no weed infestation when layby starts. For this reason, not all cotton acreage receives this high rate of herbicides at "layby".

Agricultural Problems Associated with Controlling Weeds

The farmer's decision on when to spray for weeds is, as in most of his operations, dependent on many factors. The severity of the weed infestation is probably his first consideration. The farmer does not have definite guidelines indicating when weeds are damaging his cotton crop. The farmer must ask himself, "does the field have enough weeds in it to justify the cost of an application of herbicide?" If his cotton is well developed, he may delay spraying.

The stage of development of the plants is another factor involved in weed control. Early in the growing season, if soil moisture is low, cotton seeds may be slow to germinate and emerge from the soil. Weeds, which develop and grow faster than does cotton can easily establish themselves faster than a field of cotton plants. If the weeds become as tall or taller than the cotton plants, replanting may be necessary. Later in the growing season, when the cotton plants are in the later stages of development, weeds are less of a problem in competing with cotton for light, water and nutrients. The taproot system of the cotton plants allows for deep penetration into the soil decreasing weed competition (14).

If the farmer cannot get into the field to cultivate or spray herbicides, he cannot control weeds. After the farmer has decided spraying for weeds is necessary, soil moisture conditions and adverse weather may keep him from completing this operation. If soil moisture is too high to allow ground equipment into the field, the herbicides may be applied using aerial equipment but; adverse weather is still a limiting factor.

A heavy weed infestation at harvest time slows the harvesting operation, making it less efficient. The equipment must be stopped to be unclogged of weeds that get into the picker. Weeds also add moisture to the cotton lint after it has been harvested. This reduces the quality of cotton by lowering the grade and, thereby, directly lowering the farmer's profit. With short-term weather information, the problem of adverse weather would be reduced as the limiting factor in timing this farm operation.

Meteorological Significance in the Pest Management Operation

In both weed and insect control operations, the question faced by the farmer and agricultural consultant is: "To spray or not spray?" Many variables are involved in finalizing this decision, but weather is the only factor the farmer has no control over. The weather-related problems for both weed and insect control are very similar. For this reason, these components of pest management are combined in this section.

Weather vs. Weed and Insect Control. The most important weather variables involved in these operations are: precipitation, air temperature and wind speed (precipitation and wind speed are the most important).

The effect of air temperature on pesticides is mainly a disassociation problem. As afternoon temperatures reach the maximum, the pesticides become less effective. To give an example, methel parathion is used when immediate control of bollworms and budworms is necessary. The optimum temperature for methel parathion is 76^{o}F (4). In July, the average maximum temperature is 93.5^{o}F (24). For maximum efficiency this insecticide should not be used in the daytime before the maximum temperature is approached.

The farmer must consider wind speed in this operation. Wind speeds of less than seven miles per hour are considered favorable for spraying because little or no drifting of the spray occurs. Wind speeds between seven and 12 miles per hour often present a problem due to increased drifting of the pesticide. When the wind speed is in this range, the farmer must consider the kind of crops located in the field downwind of the spraying operation. He could kill beneficial insects in the crop downwind (or in the case of herbicide drift, the entire crop could be damaged or destroyed). He must also consider the expected wind conditions over the next two to six hours. If the winds are in the marginal zone now, but are expected to slow down within one or two hours, he may decide to wait a while before starting these operations. If the wind speed is expected to remain in the marginal zone and immediate control is crucial, he may choose to go ahead and spray anyway. Wind speeds greater than 12 miles per hour can cause drifting of the pesticide to the point that control is greatly reduced (23). Time and money are wasted if spraying is undertaken when these conditions exist.

The third weather variable important in the pest control operation is precipitation. One-quarter to one-half inch of rainfall will usually wash the pesticide off the cotton plant thereby reducing necessary control. Differential heating resulting in turbulence and frequent convective cloud development in Mississippi increases the problem of "showery" type rainfall. Large amounts of surface heating from solar radiation combined with the Gulf of Mexico as a moisture source creates a high probability of thunderstorm activity on a daily basis. Since the pest control operation is a cyclic process (farmers must spray every five to seven days to achieve insect control), isolated or widespread thunderstorm activity can interrupt a farmer's spray schedule. This not only reduces profits but increases the problem of maintaining necessary control of weeds and insects.

Rainfall plays a very important role in the type of pesticide the farmers use in insect control. The residual effect (the amount of time the insecticide remains active) of a pesticide must be considered in terms of rainfall frequency, amount and duration (4).

The farmer's choice in terms of residual effect is either: a) quick acting, low residual; or b) slow acting, long residual (28). Obviously, a persistant type pesticide should not be used if thunderstorm activity is imminent. Amazingly, even though weather information is potentially available, extension personnel recommend spraying even if thunderstorm probability is high. The thinking is, since the weather can be very unpredictable at times, especially in the South, and current information is lacking, the farmer should not worry about rainfall. If control is necessary, go ahead and spray. With adequate weather information dissemination, this uncertainty would be eliminated.

A very beneficial consideration in this operation is response time. Aerial application of pesticides is very fast. Within minutes after the farmer decides to spray, a plane can be in his fields applying a pesticide.

Accuracy of Weather Information for Weed and Insect Control. Accuracy of weather variables for weed and insect control operations is not well defined. This is best shown in a recent survey conducted by Dr. Eugene Rench, Director of the Environmental Study Service Center, Located at the Stoneville Research Center in Mississippi. Dr. Rench questioned 35 agricultural consultants in the Mississippi area (included are a few out-of-state consultants). The survey was not random, but according to Dr. Rench, those consultants surveyed represent the highest quality and the majority of the cotton specialists in the Delta area (39).

A sample of the questions asked and comments on what the answers tend to indicate are listed in the Appendix.

Application of Project NOWCAST to the Pest Management Operation

By satisfying the needs of the cotton farmer on three weather variables, the pest management operation would be much more effective. To complete this operation successfully and with less uncertainty, the farmer must have short-term (one to six hours) weather information on air temperature, wind speed and, most importantly, rainfall. Project NOWCAST would provide this information using analysis technology already available to meteorologists in the National Weather Service.

NOWCAST would provide the most current (updated every 25 minutes and televised every hour) Geostationary Observational Environmental Satellite (GOES) cloud pictures to the farmer. This information would be used in two ways to satisfy the two important needs for rainfall information. First, the most recent 24 hours of satellite pictures would be reproduced into a slow speed film loop for hourly display. Hourly satellite pictures would show the farmer the present location of pressure systems and current storm track movement. Also, frontal location and movement would be portrayed in a satellite picture film loop.

The second way the satellite pictures would be used is with the most current radar picture, as discussed in earlier sections. From the early morning telecast through the entire day, the farmer would know where rainfall was occurring and whether the activity was frontal or air mass induced. The farmer could thus time his pesticide spraying operations around the weather with an improved probability of completing the operation successfully.

Less waste of pesticides would occur if the farmer could monitor regional maps of wind speed and air temperature on an hourly basis. NOWCAST would provide this information from data generated by the National Weather Service and NOWCAST's automated weather data collection instruments positioned around the state. This system would allow a variety of other weather maps of importance to the farmer to be viewed throughout the working day.

Benefits to the Pest Management Operation Resulting from NOWCAST

Successful pest management is critical if the cotton farmer expects to make any profit at harvest time. Low profit is easily understood when the cost of each spraying application of an insecticide or herbicide is considered. Depending on the severity of the pest and the agronomic practice used, cost of pesticides (applied after emergence) averages from $1 to $5 per acre. Later in the growing season, when insect populations are larger and weeds have re-established themselves (after layby), the cost of pesticides averages \$8 to \$12 per acre (29).

This in itself may not seem excessively expensive, but considering the farmer makes, on the average, seven and one-half applications of insecticides and four applications of herbicides (not to mention the number of times he cultivates), profits are easily and very quickly reduced.

General opinion of the experts in Mississippi with whom we consulted during the course of this study indicated that in both insecticide and herbicide spraying at least one spraying could be saved on these operations over the entire state for one growing season (generally believed a very conservative estimate). Assuming the average cost of the spray material, cost of labor, equipment, etc., of \$5 per acre (again very conservative) (29):

2 X \$5 X 1.6 million acres of cotton = \$16,000,000 in one season.

Using the same estimates on 1,000 acres, the potential savings to an individual farmer might be:

2 X \$5 X 1,000 acres of cotton = \$10,000.

HARVEST OPERATION

Introduction

The efforts of all operations during the growing season are reflected in the harvest operation. If any operation previous to harvest was not completely successful, the results will show in an overall reduction in yield. At the same time, if the harvest operation is not timely with respect to plant (boll) maturity and weather, quality and yield of cotton lint will be reduced. The farmer must have an efficient harvest operation to make a profit.

Since the cotton varieties used in Mississippi are an indeterminate type, the individual plant blooms and fruits the entire season (14). The first cotton bolls open weeks before the crop can be harvested. For this reason, the farmer's decision on when to plan his harvest operation is based on many factors. Some factors involved are: what harvest method (equipment) to use, weather, when (and if) to apply a harvest-aid chemical, and where to store or gin the cotton.

Hand picking cotton lint was once the common harvesting method. As labor costs increased, profits decreased and hand picking lost its popularity. The mechanization of agriculture has produced numerous machines designed to mechanically harvest cotton. To date only two types of mechanical harvesters are used to pick cotton lint. They are the spindle picker and the stripper picker. Both machines have advantages and disadvantages the farmer must consider long before and also during harvest season.

The spindle picker, a very expensive equipment investment, makes two trips into a given field to complete harvesting. The first picking starts after 60 percent of the cotton bolls have opened (14). The spindle picker only harvests open cotton bolls. As the majority of the remaining bolls open, the final picking is made.

The stripper picker is used only once in the harvest operation. The stripper removes all the cotton bolls from the plants, whether the bolls are open or not. For this reason, this machine is not used until 85 to 90 percent of the cotton bolls are open (14).

The advantages and disadvantages of these machines center around the time of harvesting. The spindle picker can be used earlier in the harvest season, but is limited to picking only part of the crop each trip into the field. The stripper picker, although considered the faster of the two types of pickers, cannot be used until later in the harvest season. The cotton bolls that opened long before harvest must "weather" in the field until 90 percent of the bolls have opened. Research in picker efficiency indicated the stripper picker harvests as much as 25 percent more cotton per acre than does the spindle picker (29). Once the stripper is used, the harvest operation is complete. No bolls remain in the field for later picking.

Greater than 90 percent of the cotton harvested in Mississippi in 1976 and 1977 was harvested by spindle pickers. Stripper picking, however, is expected to increase in the future (20). Some extension experts believe the cotton farmer will use both machines for harvesting. After 60 percent of the cotton bolls open, the spindle picker, as usual, would be used to harvest. Instead of using the spindle picker on the second picking, the stripper would be used.

Whether the spindle picker or the stripper picker is used to harvest cotton lint (or a combination of the two machines), mechanical harvesting requires that the stand of cotton plants be defoliated (using a harvest-aid chemical) before picking can be undertaken. The harvest-aid chemicals used to defoliate cotton fields in Mississippi are of two types, defoliants and desiccants (14). Defoliants are used to induce shedding of the leaves but not necessarily to destroy the plant. When using a defoliant, the plant must be actively metabolizing in order for the leaf drop process to occur. The desiccants are used mainly for stripper picking. Since the stripper removes all the cotton bolls in one trip, large amounts of moisture in the unopened bolls must be removed before harvesting. The desiccant removes this moisture by killing the plant which then drys to equilibrium with the environmental moisture level (relative humidity of the air). Other benefits of harvest-aid chemicals are (14):

1. Makes cotton bolls open and dry out faster.
2. Picking can start earlier in the day and sooner after rains.
3. Lowers cotton seed moisture (less heat required during ginning which improves seed and lint quality).
4. No green leaves in trailer (reduces chance of heat damage to seed).
5. After leaf drop, picker operator can see rows better.
6. Can be ground or aerially sprayed.

Since these chemicals stop plant growth, fiber development in the immature bolls is also terminated. Depending on the weather conditions, this can reduce yield. In fact, many of the disadvantages in using harvest-aid chemicals are weather related. Some of these disadvantages are (14):

1. If growing conditions are poor, leaf drop is slow to occur (seven to 14 days).

2. Under high moisture conditions, second growth may occur before completing harvest.
3. The added cost of production for material and application.
4. Residues may be hazardous to other plants and animals.
5. Poor leaf drop can add trash (moisture) to cotton lint.
6. May reduce the rate of opening of immature cotton bolls.

Agricultural Problems Associated with Harvesting Cotton

Optimum quality cotton lint and yield are very important to obtain the highest possible profit for the Mississippi cotton grower (2). However, in many years, considering all the problems associated with growing cotton, the farmer is fortunate to break even. When the farmer begins the harvest operation, his greatest concern is to get the crop out of the field as soon as possible without reducing his profits. Even in this stage of the growing season, many things can keep the farmer from harvesting a profitable crop. Any factor that keeps the farmer out of the field during harvest season will reduce profits. Poor leaf drop, wet soils and wet weather, in general are examples of such factors.

As mentioned previously, a harvest-aid chemical is usually necessary to harvest cotton. Even though modern ginning methods can remove most of the trash (i.e. leaves and weeds) found in harvested cotton lint, the moisture added by this trash decreases the cotton quality. Research by the United States Department of Agriculture at the Stoneville Research Center in Mississippi found that machine-picked defoliated cotton has higher quality and less foreign matter content than does undefoliated cotton (11).

After the cotton is harvested, it must be stored or ginned as soon as possible to keep quality of seed cotton at the optimum. The farmer usually has made prior arrangements with a gin to process his cotton. Even with prior arrangements completed, the harvested cotton may be forced to remain in the trailer for 12 to 24 hours. The ginning process is probably the most serious bottleneck in the harvesting operation (29). In-the-field storage, although sometimes necessary, has the problem of the cotton being exposed to possible adverse weather elements before being ginned. Most farmers favor this over not getting the cotton harvested.

Meteorological Significance in Harvesting

Harvest-Aid Chemicals - Defoliation. Leaf abscission (leaf drop) is a natural occurrence of most plants in the fall. It can also occur during extremes of moisture (such as a drought or flood) and extremes of temperature (hot, dry weather or a frost). If, and when, leaf abscission occurs, cotton growth stops. As mentioned earlier, this can have both advantages and disadvantages. Premature leaf abscission can seriously reduce yield (14). Research has shown that applying a defoliant before 60 percent of the bolls are open usually reduces yield and quality (5). As harvest time approaches (with its normally unstable weather), the farmer must make the decision of when and whether to defoliate (after 60 percent of the bolls have opened), based primarily on the current and expected weather outlook. Precipitation probability must be considered before application of the defoliant chemical. Thunderstorm activity (1/4 inch) within 48 hours of application will wash off or reduce the effectiveness of the defoliant chemical (4). Wind speeds greater than 12 miles per hour will cause drifting of the defoliant (23). This is wasteful, ineffective and can cause damage to adjacent crops. In addition, the longer term outlook must be considered since the leaf drop process from an application of a defoliant takes seven to 14 days (14).

A heavy frost or freeze ($\leq 28^{\circ}F$ for one to two hours) has a negative effect on cotton, depending on the type of picker used (14). The immature bolls, with high moisture content, are very sensitive to freezing temperatures. The frosted boll rots and produces no cotton (29). The Extension Service recommends defoliation prior to a hard freeze.

The best defoliation occurs when the daytime temperatures are in the $80^{\circ}F$ to $90^{\circ}F$ range and nighttime temperatures are greater than $60^{\circ}F$ (14). When applying a defoliant under less than optimum air temperatures, defoliation is slow, ineffective and, consequently, timing of harvest becomes difficult. Adequate sunshine is also important. Cloudy, cool weather from the time of application to three to five days after application can seriously reduce the effect of the chemical. This results in no or poor leaf drop and added trash and moisture in the lint and picker. The cotton plant should be mature and actively growing (photosynthesizing) for the defoliant to be effective.

Harvest-Aid Chemicals - Desiccation. As mentioned earlier, farmers that use stripper harvesters must apply a desiccant to the field prior to harvest. Since the stripper cleans the entire plant of cotton bolls, the added moisture from the leaves and immature bolls threatens the quality of the cotton. The desiccant reduces this problem by causing rapid loss of moisture over the entire plant (reduces moisture to 6.5 percent) (14).

The environmental requirements for a desiccant are as big a problem as for a defoliant. However, the time from application to harvest is less (three to five days) for a desiccant. At the same time, the necessity for favorable short-term weather is more important in applying a desiccant.

Weather and Harvesting. Moisture, both from precipitation and humidity, has its greatest effect on cotton prior to and during harvest. Not only can it keep the farmer out of the field, it can also reduce cotton quality and yield. Relative humidity and dew formation cause several unique problems in harvesting cotton. Research at Stoneville, Mississippi (U.S.D.A.) found that relative humidity is the greatest single influence on moisture content in seed cotton (30). The problem occurs between picking efficiency and maintaining cotton quality. High quality cotton (dry enough to pick) favors relative humidities below 50 percent. However, the spindle picker is more efficient at relative humidities of greater than about 50 percent. As the relative humidity increases, spindle clogging from weeds and trash increases.

Dew formation dictates when daily picking can start and when it should stop. If the farmer picks wet cotton lint, the quality of the lint will be reduced and the chance of mold or rot occurring before the cotton lint is ginned is increased.

Any weather variable related to moisture is important during the harvest season. The farmer needs to know wind speeds, expected air temperature, cloud cover and daily evaporation in order to start daily picking as early as possible, without losing any quality in his cotton.

Application of NOWCAST to the Harvest Operation

As noted, the most important weather variables in applying harvest-aid chemicals (and until leaf drop occurs) are rainfall and wind speed.

Many of the NOWCAST weather briefing techniques discussed for other farming operations will apply to the harvest time decision-making. (Information on dew will be of particular importance at this time.)

Project NOWCAST will also be beneficial in the harvest operation by disseminating short-term weather information that will allow the farmer to either pick his cotton or plan less weather sensitive tasks. If the farmer knew in advance that rainfall was going to halt his daily picking operation, alternative operations (e.g. maintenance on pickers) could be planned. By providing information on wind speed, percent sunshine, relative humidity, soil moisture conditions, evaporation and general drying conditions, the farmer could make plans on when to start picking again. Most of this information is available now, but never reaches the farmer. During the harvest season, NOWCAST personnel would tailor weather briefings specifically for the harvest operations.

Benefits to the Harvest Operation Resulting from NOWCAST

Determining a dollar value for potential savings in applying harvest-aid chemicals and in the picking of cotton is difficult, even more so than for the other operations. Also, since cotton harvesting is very slow the response time for this operation is also slow. For this reason, the potential saving for this operation is smaller in relation to the other operations. In terms of picking cotton, the farmer is going to pick if he can get his machines into the field. Much can be said about planning less weather sensitive tasks. To put a monetary value on these is beyond the scope of the study.

An example can be used to indicate potential savings in applying harvest-aid chemicals. During the period in 1976 when the majority of the farmers were applying defoliants, a light frost occurred that would have caused leaf drop for a large portion of the state. According to one agricultural extension expert at Mississippi State University, had the farmer been updated on front and pressure system location and movement, the majority of the defoliant already sprayed would have been saved. Unfortunately, actual values are not available, but if 25 percent of the total cotton acreage had been spared this operation due to timely NOWCAST information (considering 12½ percent for ground and 12½ percent for aerial application), the saving would have been as follows (31):

12½% X 1.4 million acres X (\$2.62 + \$ .80) =		\$ 598,500
12½% X 1.4 million acres X (\$2.62 + \$1.50) =		721,000
	Total	\$1,319,500

where \$2.62 is the approximate cost of chemicals,

\$ .80 is the cost of ground application, and

\$1.50 is the cost of aerial application.

Of course, this potential savings would not occur every year. One in 15 years may be a more realistic estimate.

SUMMARY AND CONCLUSION

The potential benefit resulting from improved dissemination of agricultural weather information is evident, especially considering increased farm production costs. The farmer must have the complete weather picture (current, short and long range) to reduce weather-related risks. Project NOWCAST was developed to provide this information and is shown to have the potential of substantially reducing costs and risks in the production of a monocultural cropping system -- cotton. It is realized, any weather briefing system cannot be 100 percent effective, however, current weather dissemination methods are far from satisfying agricultural needs.

Considering the critical farm operations discussed in this report -- land preparation, preplant, planting, pest management, and harvest operation -- improved dissemination of four specific weather variables would reduce much of the weather-related cost and risk. Those weather variables are:

1. rainfall
2. air temperature
3. soil temperature
4. wind speed.

Using educational television, NOWCAST would provide these variables and other weather information in a more timely manner. This information would be provided using satellite and radar imagery, pertinent weather maps and computer techniques to visually disseminate this information.

The purpose of this paper was not purely to derive the economic benefits. However, the benefits derived from Project NOWCAST and improved weather dissemination are easily reflected by discussing potential savings.

The values stated as savings are not absolute. These values represent a conservative estimate of the savings to the Mississippi cotton farmer, given timely weather information related to agricultural production.

If we consider the total potential savings to the individual farmer for the critical farm operations on 1,000 acres of cotton land, this value is very realistic. The individual farmer could save over $36,000, which is 16 percent of the 1976 cost of producing 1,000 acres of cotton. On a statewide basis, the total potential savings exceeds 100 million dollars. If only ten percent of this value was saved due to timely weather information, Project NOWCAST would be worth undertaking.

Most phases of agricultural production are weather dependent. Either by reducing washed-off chemicals or energy consumption, proper utilization of accurate and timely weather information can add to overall individual farm production and efficiency.

Chart of Operations

Operation	Time	Weather Variables	Accuracy
1. Land preparation a. Land prepared when dry with precipitation soon after. b. Purpose is to breakup compacted layers to promote good root growth.	End of harvest Approximately December to Mid-April	A. Soil Moisture 1. Subsoil must be dry to break compacted layers. B. When precipitation is expected 1. Direct farmer to work heavier soils before precipitation since they dry slowest. C. Amount of precipitation expected 1. Direct farmer to work heavy soils first	½" - 1.0"
2. Preplant a. Condition soils and at same time apply herbicides then incorporate herbicides.	March to Mid-April	A. Precipitation 1. If precipitation comes, will incorporate herbicide. a. ¼" within X hours will incorporate b. Save cost of machinery to fields and prevent compaction of soil by machines. 2. If no precipitation coming, incorporate by machines. B. Wind speed effect on spray application of herbicides (X - Time depends on herbicide used. Varies from 2 hours to 7 days.)	¼" - ½" <7 mph-good 7-12 mph-fair >12 mph - poor
3. Planting a. Purpose is to get uniform stand as early as possible in growing season.	Mid-April to Mid-May	A. Precipitation 1. Occur on day before planting, plant light soils first since they are workable sooner. 2. Occur on planting day could wash out seeds. 3. Occur on day after planting could cause crusting which slows or prevents emergence. B. Soil temperature 1. Soil temperature needs to be 68°F for 10 days to germinate.	¼" - ½" ± 2°F
4. Weed Control	After emergence to harvest. Approximately May to October	A. Precipitation 1. Precipitation within 1-6 hours after application reduces control of post-direct herbicide. 2. "Lay-by" application needs precipitation within a week on approximately 50% of acreage to leach into soil. B. Wind speed 1. Spraying C. Air temperature 1. Needs to be hot and dry. 2. Depends on herbicide used.	¼" - ½" >7 mph reduces control >12 mph, do not spray 70° - 90°F
5. Insect Control a. Insects eat profits.	Growing season May-October	A. Precipitation 1. Time precipitation will start and stop. 2. Spraying is cyclic and precipitation may interrupt cycle. 3. Some need for forecast of amount of precipitation. 4. Radar reports showing location and movement of precipitation. B. Temperature 1. Max and min air temperature. 2. Forecast of air temperature. C. Wind 1. Spraying D. Dew 1. Some need for forecast of times when dew forms and dries off. E. Bad weather costs farmer from $4 to $30 per acre.	¼" - ½" >7 mph hampers aerial application of pesticides. Depends on herbicide used.
6. Defoliation or desiccation	October to November	A. Temperature 1. Hot days 2. Mild nights 3. Light freeze does the same as defoliation process. B. Precipitation 1. Precipitation will wash off chemicals C. Wind 1. Spraying	≥80°F day ≥60°F Night ≥28°F for 1-2 hours ¼" - ½" ≤7 mph-good 7-12 mph-fair >12 mph-poor
7. Harvest	October to December (In recent years, harvest has gone into January)	A. Humidity 1. Picking machines more efficient when RH < 50% B. Dew 1. Time dew forms* a. Picking can go until that time 2. Duration* 3. Time dew burns off* a. Begin picking at that time *Cotton lint and cotton seed favor RH < 50%	

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REFERENCES

1. Agricultural Meteorology Study Panel, Agricultural Research Institute, 1976.

2. Baker, G. L., et al. 1974. Effects of Field Weathering on Cotton Fiber Quality. Cotton Production Research, MAFES.

3. Baker, R. S. and G. M. Roberts. 1975. Herbicides Evaluated Pre-emergence on Cotton at Branch Stations. Information Sheet 1251, Volume 37, #5, MAFES.

4. Black, Russell. 1976. Executive Secretary, Mississippi Agricultural Consultants. Private Communication.

5. Bridge, R. R., et al. 1971. The Influence of Planting Date on Agronomic and Fiber Properties of Cotton. Bulletin 786, MAFES.

6. Bridge, R. R., et al. 1973. Influence of Planting Method and Plant Population on Cotton. Bulletin 804, MAFES.

7. Brown, James. 1977. National Cotton Council, Private Communication.

8. Coats, G. E. 1967. Effects of Growth Regulors on Germinating Cotton. Bulletin 752, MAFES.

9. Colwick, R. F., et al. 1972. Stripper-Type Cotton Harvest Study. Information Sheet 1199, MAFES.

10. Cooperative Extension Service. 1976. Agronomy Handbook. Bicentennial Edition.

11. Crowe, G. B. 1955. The Economics of Cotton Defoliation. Bulletin #552, Mississippi State University Agricultural Experiment Station.

12. Deems, B. 1977. Director Pesticides Division, American Cyanamide Company. Private Communication.

13. Delta Agricultural Digest, Inc. 1976. (Information supplied to this publication by Mississippi Extension personnel.)

14. Elliott, F., et al. 1968. Advances in Production and Utilization of Quality Cotton: Principles and Practices. The Iowa State University Press, Press Bldg., Ames, Iowa, pp. 102-104.

15. Fawlett, E. B. 1977. Current Capabilities in Predicting at the National Weather Service's National Meteorological Center. Bull. Amer. Meteor. Soc. 58, 143-149.

16. Grisson, P., et al. 1955. The Influence of Deep Tillage on Cotton Production in the Yazoo-Mississippi Delta. Information Sheet #507, Mississippi State Univeristy Agricultural Experiment Station.

17. Harris, V. C. 1964. Production of Cotton Without Pre-emergence Cultivation or Hand Hoeing. Bulletin 685, MAFES.

18. Johannessen, Karl R. Associate Director, Meteorology and Oceanography. Private Communication (Letter), 12/15/76.

19. Jordan, R. N. and R. S. Baker. 1975. Control of Bermudagrass in Cotton. Research Report #20, Vol. 1, MAFES.

20. Kimbrough, E. A. and J. F. O'Kelly. 1955. 1954 Cotton Variety and Irrigation. Bulletin 525, MAFES.

21. Lindsey, M. M. 1964. Effect of Harvesting Conditions on Cotton Quality in the Yazoo-Mississippi Delta. Bulletin 695, MAFES.

22. Lindsey, M. M. 1969. Mechanical Cleaning and Ginning of Ground-Loss Cotton in the Yazoo-Mississippi Delta. Bulletin 775, MAFES.

23. McWhorter, C. G. 1975. Wind and Herbicide Movement. Research Report #3, Vol. 1, MAFES.

24. McWhorter, J. C. 1962. Climatic Patterns of Mississippi. Bulletin 650, Mississippi State University Agricultural Experiment Station.

25. Meyer, G., Editor. Mississippi Weather and Crop Report, Mississippi Crop and Livestock Reporting Services.

26. Mississippi Agricultural Statistics, 1954-1973. 1975. USDA Statistical Reporting Service, Compiled by James P. Liles.

27. Mississippi Cooperative Extension Service. 1976. Cotton Insect Control Guide. Mississippi State University.

28. Mississippi Cooperative Extension Service. 1977. NEWS (Progress of "III by '83"), Released 1:00 p.m. or later, January 27, 1977.

29. Mullendore, George. 1976. Agronomist in Cotton, Mississippi Extension Service, Mississippi State University, 12/10/76 - 12/13/76. Private Communication.

30. Parker, R. E. and W. P. Caldwell. 1967. Behavior of Seed Cotton Exposed to Certain Atmospheric Conditions. Bulletin 746, MAFES.

31. Parvin, D. W., Jr. 1976. Cost of Production Estimates for Major Crops, Mississippi Delta, 1976. Bulletin 843, Mississippi Agricultural and Forestry Experiment Station (MAFES).

32. Pettiet, J. V. 1973. Soil Factors that Limit Crop Production on Certain Yazoo-Mississippi Delta Soils. Bulletin 64, MAFES.

33. Pettiet, J. V. 1974. An Interpretive Evaluation of Soils in the Yazoo-Mississippi Delta Area for Crop Production. Bulletin 808, MAFES.

34. Pielke, R. A. 1977. An Overview of Recent Work in Weather Forecasting and Suggestions for the Future. Bull. Amer. Meteor. Soc. 58, 506-520.

35. Raney, W. A., et al. 1954. The Effects of Deep Breaking on Mississippi Soils. Information Sheet #492, Mississippi State University Agricultural Experiment Station.

36. Ranney, C. D. 1961. Fusarium Wilt of Cotton Can be Controlled with Resistant Varieties or Soil Fumigation. Bulletin #615, Mississippi State University Agricultural Experiment Station.

37. Ranney, C. D., et al. 1968. Studies of Interactions Among Chemicals Applied to Cotton at Planting, 1965-66. Bulletin #762, MAFES.

38. Reed, B. J. 1977. Bjerknes Memorial Lecture. Presented at the 57th Annual Meeting of the American Meteorological Society.

39. Rench, E. 1976. Survey of 35 Mississippi Agricultural Consultants on Weather.

40. Rench, E. Agricultural Meteorology, NOAA, Director, ESSC, Stoneville Research Center, Stoneville, Mississippi. Private Communication, 1976.

41. Riley, D. H., et al. 1964. Soil Temperatures and Cotton Planting in the Mid-South. Bulletin #678, MAFES.

42. Riley, J. A. 1959. Relative Humidity in Cotton Fields at Harvest Time. Bulletin #581, Mississippi State University Agricultural Experiment Station.

43. Riley, J. A. 1960. Climate of the Delta Area of Mississippi, U.S. Weather Bureau Bulletin #605, Mississippi State University Agricultural Experiment Station.

44. Riley, J. A. 1963. Farm Weather Advisories - On a Modern Scale. Prepared for: 5th National Conference on Agricultural Meteorology, Lakeland, Florida.

45. Sander, F. 1973. Skill in Forecasting Daily Temperature and Precipitation.

46. Schneider, Stephen H. and Lynne E. Mesirow. 1976. Genesis Strategy: Climate and Global Survival. Plenum Press, New York.

47. Schweizer, E. E. 1967. Effects of Residue of DSMA in Soils on Cotton, Soybeans and Cereal Crops. Bulletin #736, Mississippi State University Agricultural Experiment Station.

48. Spurgeon, W. I. and J. S. Hursh. 1969. Influence of Row Direction on Microclimate and Yield of Skip Row Cotton. Bulletin #772, Mississippi State University Agricultural Experiment Station.

49. Spurgeon, W. I., et al. 1974. Limited Seedbed Preparation for Cotton. Bulletin #813, MAFES.

50. Thompson, A. C., et al. 1976. Nitrogen Concentrations of Cotton Leaves, Buds, and Boll in Relation to Age and Nitrogen Fertilization. Reprinted from Agronomy Journal, Vol. 69, July 1976, pp. 617-621.

51. Thompson, J. C. 1972. The Potential Economic Benefits of Improvements in Weather Forecasting. Under NASA Grant NGR 05-046-005, Final Report.

52. Tupper, G. R. and J. M. Anderson. 1974. Harvesting Cotton With an Experimental Combine. Information Sheet 1250, Vol. 37, No. 7, MAFES.

53. United States Department of Commerce. 1973. Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days, 1941-70. NOAA, EDS. Mississippi.

54. Weed Control Handbook of Mississippi. 1961. Bulletin #612, Mississippi State University Agricultural Experiment Station.

55. Wooten, O. B. 1959. Special Equipment for Chemical Weed Control. Bulletin #576, MAFES.

56. Wooten, O. B., et al. 1966. One Trip Planting Equipment for Cotton. Bulletin #738, MAFES.

57. Wooten, O. B., et al. 1975. Development of Optimum Seedbed Preparation Techniques for Cotton. Vol. 4, MAFES.

APPENDIX

Survey of Agricultural Consultants

The question: "What are the accuracies needed on the weather variables important in cotton production?" can best be answered by presenting the results of a survey conducted by the Director of the Environmental Studies Service Center located at Stoneville, Mississippi. Dr. Eugene Rench surveyed 35 Agricultural Consultants in the Mississippi Delta area on the subject of weather variables important in cotton production. These consultants represent the majority of the cotton acreage in the Delta. After personally talking with some of these consultants, it was found that much of the research needed to document the answers on the survey has not been conducted. Many of the consultants said their answers resulted from direct observation and from the experience of working as an Agricultural Consultant. The consultants either have a degree in the agricultural sciences or have passed a rigorous examination pertaining to pesticides and plant physiology.

After each question, Dr. Rench commented on the results. They show a very diverse need on weather information and the accuracies required of this information. The following information indicates: 1) that short-term weather information is vital to agriculture; 2) the accuracies to fulfill those needs are quite diverse; and 3) in the past, weather information has not been adequate to satisfy agricultural needs.

1) What is the relative importance of the following weather parameters to your business? (Range of importance 1-3, where 1 is most important.)

	Rating	Range
Rain	1.00	0
Air Temperature	1.44	1-3
Soil Temperature	1.65	1-3
Wind	1.97	1-3
Sunshine	1.97	1-3
Dry Conditions	2.47	1-3
Dew	2.53	1-3
Dew Point	2.74	1-3

According to these consultants, the first four variables are very important to their operation with rainfall undoubtedly the most important.

2) Usually, how close do you need to know when it is going to start or stop raining?

			# of Responses
The Results:	≤ 1 hour	=	9
	2 hours	=	6
	3 hours	=	3
	4 hours	=	5
	5 hours	=	2
	6 hours	=	7
	24 hours	=	2

Approximately 50 percent of the consultants said they needed this information within two hours.

3) Does duration of rainfall need to be forecasted?

The Results: Yes = 100%

4) How many days does it take to interrupt your spraying schedules?

			# of Responses
The Results:	≤ 1 day	=	19
	1-2 days	=	3
	2 days	=	7
	2-3 days	=	1
	3 days	=	1
	4 days	=	2

Approximately 50 percent of the consultants said one days rain interrupted their spraying schedules.

5) How accurate do rainfall amounts forecasted need to be in order to be of practical value?

The Results:

Inches	# of Responses
1/10	3
1/4	10
1/4-1/2	1
1/2	7
1	7
2	1

According to Dr. Rench, the consultants interpreted this to mean how much rain does it take to wash off pesticides. Fifty percent said 1/10 to 1/2 inch would reduce control. The other 50 percent said 1/2 to two inches.

6) How accurate do radar reports and forecasts of locations of showers have to be to be of significant aid to you?

The Results:

Distance	# of Responses
1-10 miles	17
11-20 miles	5
21-30 miles	5
31-40 miles	2
>50 miles	4

7) What percent of your recommendation is based on current rain or weather? Less than six hours, next 24 hours, next three to five days?

The Results:

	Average %	Range %
Current Weather	63	0 - 100
< 6 Hours	58	0 - 100
< 24 Hours	51	0 - 80
3 - 5 Days	49	0 - 100

Indications are that many of the consultants use the total rain outlook, from present weather to five days ahead.

AIR TEMPERATURE

8) How accurate do forecasts of maximum and minimum air temperatures have to be to make your recommendations work?

The Results:

^{o}F	# of Responses
$\pm$ 0-5	16
$\pm$ 6-10	12
$\pm$ 11-20	1

The results indicate forecasts of air temperatures are adequate for the consultants. Several did take the extra step to point out that it became more critical to forecast air temperatures when they get below 70^{o}F. One cited that best control of cotton pests was obtained when temperatures were between 70^{o} and 90^{o}F.

9) How far in advance do air temperatures need to be forecast?

The Results:

Days	# of Responses
1	4
2	10
2-3	1
3	9
3-4	1
3-5	4
4-5	1
5	2
5-6	1
7	1

The results indicate diverse needs.

WINDS

10) Do winds above seven miles per hour hamper aerial application of pesticides?

The Results: Yes = 97%

11) Are you using wind speed and direction to make spraying recommendations?

The Results: Yes = 97%

From comments made, the question was poor. Speeds and not direction are important for insecticide application. Direction was mentioned for herbicides.

DEW

12) Does dew impact your recommendations?

The Results: Yes = 49%
No = 51%

This depended mainly on the type of chemicals they normally used. Dew aids some mixtures and dilutes others.

MISCELLANEOUS

13) What percent of your weather information comes from radio, TV and newspapers?

The Results: Radio = 51%
TV = 45%
Other = 4%

The results were interesting. Some used newspapers and the FAA Service at Greenville, Mississippi. None used the National Weather Service Agricultural Weather Information at Stoneville, Mississippi. They were given the telephone number of the Stoneville office.

14) How much does bad weather contribute to the pest management costs? (Dollars or Percent)

The Results: The ranges were $4.00 to $30.00 per acre. Percentages ranged from five to 100. Considerable numbers of those responding said the costs and percentages varied greatly. Many were in the 25 to 50 percent range. One estimated weather cost his customers around $600,000 last year (1975) on 20,000 acres.