A STUDY OF THE ECONOMIC BENEFITS OF METEOROLOGICAL SATELLITE DATA

FIRST ANNUAL REPORT

A REPORT

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madison, wisconsin

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30 May 1977

The First Annual Report on NASA Contract NAS 5-23706

Acknowledgements

We thank Mr. Ross Bettinger for his assistance in the construction of some of the questionnaires, and Mr. Thomas O. Haig for his contributions in the formulation of the program and for many helpful discussions during the course of the study. The manuscript was reviewed by Mr. Joseph Hilyard.

The staff of Weather Services Corporation, especially Mr. Peter Leavitt and Mr. John Wallace, have been highly cooperative partners in this study, and will be archiving all of their forecasts and verifications for our use.

Most of all, we would like to thank the more than 130 clients of Weather Services who were willing to participate in the program, and without whose cooperation, this study could not succeed.

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I. INTRODUCTION

The tremendous impact of weather and weather related events on American society is dramatically underscored by the events of the past year: An unusually cold winter in the East and Midwest depleted gas supplies, forcing hundreds of thousands temporarily out of work; a freeze in Florida and a drought in the West seriously affected food supplies; heavy snows in the Northeast found many municipalities without sufficient funds to clear streets. While we may find ways to control these abnormal events in the future, the tools with which we can better forecast and prepare for them are available today. This study explores the usefulness of one of these tools - meteorological satellites - in short range forecasting, to benefit many segments of the American economy.

In the era of energy crises and other environmental problems, studies like this are essential to the optimal utilization of America's resources. But the value of any meteorological service is difficult to quantify. David Atlas (1975) described the problem well:[1]

> Another difficulty, when describing atmospheric science and its value, is that so little has been done to appraise the value of present and potential atmospheric science applications. Changnon and others have suggested the need for socio-economic studies of such potential benefits. The importance of such studies cannot be overemphasized, nor should their hazards be minimized ...

In order to accurately appraise the value of satellite data, one must work with potential users and beneficiaries of the augmented services. If we were not operating with real situations in an active marketplace, the results of this study would only fall into the realm of speculation. Such speculative "what if" studies are also discussed by Atlas:[1]

[1] Atlas, David, 1975. Selling Atmospheric Science. Bull. Amer. Meteor. Soc., 56, 688-689.

> ... Unless accompanied by realistic appraisals of what capabilities are realistic to expect, "what if" studies merely give the impression that we are more confident of reaching the capability than we have any right to be. Again, we are raising premature expectations.

Hence, this program, in which we explore the economic benefits of meteorological satellite data to a variety of users, has been undertaken with real beneficiaries in real situations. The problems have been many and varied: How can the weather of one season be compared with that of another? How do we decide on an impartial means of selecting a firm to whom we will supply satellite data? How do we gain confidential information from the beneficiaries of the data? How do we quantify "economic benefits?" Progress has been made on these and other problems, but our future task is still difficult.

The study has been undertaken in a series of steps:

1. Find an established private weather service with a variety of clients, in which meteorological satellite data has not been used, but for whose services it would be valuable.
2. Establish and document the current weather service supplied to the clients and establish a quantitative measure of the value of that service.
3. Develop, jointly with the operators of the private weather service, the facilities and techniques required to supply them with meteorological satellite data in the mode most likely to increase the value of the service to the clients.
4. Install and activate the meteorological satellite data capability in the operator's place of business.

5. After a suitable period, establish a quantitative measure of value of the augmented service.

6. Prepare a series of interim reports on items 1 through 5 to be integrated into a final report which will summarize the study results, approach and procedures.

It is believed that working with a private weather service is the best means of fulfilling the objectives of this program. Such a service deals with an established clientele who see an economic value in specialized weather forecasts. They keep records of both forecasts and their verification, enabling us to determine whether the addition of satellite data will cause any forecast improvement. On a parallel front, clients can be contacted and interviewed to determine how and in what form the forecasts are used. Thus, the economic benefit will be determined by matching forecast, verification and use.

The goals for the first year were: Find the established consulting firm in an impartial manner; contact all their clients to learn how the forecasts are used; begin calculating the current value of the service; and develop the means whereby the weather service can best use the meteorological satellite data to meet its needs. All of these goals have been met, and an elaboration of each item will be found in succeeding sections. At the present time, we are working in three main areas: (1) continued hardware development; (2) documentation of forecast, verification and climatological statistics; and (3) preliminary calculations of the economic benefit attributed to the forecast.

In the following sections, we will discuss the selection of the firm, the methodology, the hardware, the clients and their use of the forecast, and the results to date.

II. SELECTION OF COOPERATING CONSULTING FIRM

One of the earliest hurdles of this study was the selection of a meteorological consulting firm which would be most suitable for our needs. The selection had to be totally impartial because we, a government funded facility, would be working with a firm in the private sector. We also had to avoid giving the chosen firm any undue competitive advantage. A fair balance had to be struck between the benefits to be received from the use of (and experience with) the satellite system, and the expenditures of time and manpower for participation in the study.

Prior to contacting any potential participant, a list of criteria for selection, based on the needs of the program, was drawn up (see Appendix A) to provide an objective basis for selection. The program needs an established and well respected consulting firm with a large and varied clientele. We wanted to work with a firm that offered services of high quality, and we preferred a firm with at least one Certified Consulting Meteorologist on its staff. In addition, we looked for a complete willingness to cooperate in the many facets of the program. The assessment of these criteria could be made only by personal visits and inspection of the interested firms.

From a directory of currently active consulting firms the most promising companies were contacted. The letter of contact included a description of the program plus the selection criteria described above. After contacting several firms on our list, two were chosen for a visit. It was agreed that all information gained from these visits was strictly confidential.

To assure the impartiality of the selection process, two additional precautions were taken. First, a list of the type of information of interest to us was sent to the two interested firms so they could best prepare for our visit (see Appendix A). Second, a detailed list of questions to be asked on both visits was prepared to assure a fair evaluation (see Appendix A). In addition, each visit was to be made by two staff members to minimize personal bias. One staff member made both interview trips so that a more direct comparison between the firms could be made.

The actual interviews paralleled the list of previously prepared questions. The areas discussed were: staff organization and procedures; the nature of in-house quality control; the current and future plans for satellite data usage; actual forecast operations; hardware in use; and reasons for participation in this program. After the visit, each interviewer also recorded his subjective impressions of the operation of the consultant, based upon what he was able to view.

When all the questionnaires were completed and analyzed, the selection was made on the basis of the previously described criteria. Weather Services Corporation of Bedford, Massachusetts met all the needs of the program, and this choice was strengthened by the individual evaluations and subjective impressions formed by the visiting team members. The crucial selection factors were items 2, 4, 6 and 7 on the criteria list in Appendix A.

Weather Service Corporation (WSC) is a highly respected meteorological consultant firm with more than 30 years of experience. They employ about 20 professional meteorologists and four technicians; three staff members are certified Consulting Meteorologists. Their members are active on the National Board of Industrial Meteorologists and in local and national activities of the

American Meteorological Society. Their forecasts and verifications are archived for research as well as quality control. In general, their operations (and client services) are divided into three general areas: daily scheduled forecasts, emergency warnings (snow/ice storms, severe weather) and world-wide climatology. The hardware and techniques they use employ the latest advances in the field of meteorology. Most important, they expressed a strong interest in the study, had a strong desire to incorporate satellite data into their operations, and gave every impression that they would be cooperative partners in the study.

The clients of WSC number over 300 from Maine to Georgia. Many are strongly affected by weather originating in regions where conventional meteorological data is sparse. They include (1) one hundred forty-seven state, county and municipal governments, shopping centers, universities and some private industries interested in snow and ice removal and other emergency weather warnings (e.g., floods, high winds, heavy rains); (2) thirty-three gas utilities interested in temperature forecasts as well as emergency warnings; (4) fifty-nine fuel oil companies who need temperature and heavy snow information; (5) nine commodities clients who use current, long range, and world-wide climate data; and (6) an assortment of construction, blasting, marine and aviation clients. Media clients served by a subsidiary of WSC were not included in this study, to preclude advertising of the satellite data.

Once the selection was official we entered into an agreement with WSC (see letters in Appendix B) which outlined restrictions and responsibilities of both parties. SSEC will develop the means by which WSC will receive satellite data, and will train WSC personnel to use it. WSC will document its forecasts and verifications, and will permit SSEC to contact all WSC clients.

In addition, WSC is restricted from referring to this study in any advertising or promotion to gain new clients, and will not display any reproductions obtained directly from our data installation in any communications media during the period of this study. All records and discussions pertaining to this project will be kept confidential unless otherwise decided by both parties. The selection of Weather Services Corporation in no way constitutes an endorsement of that firm over any other consultant.

III. METHODOLOGY

A. Approaches

Theoretically there are several different ways in which this economic impact study could have been approached. One (which can be rejected almost immediately) would involve working with two different consulting firms, one having a satellite data system, the other not. Comparing the operations of these two firms over a suitable length of time should reveal a difference in forecast accuracy. In addition to the practical problems of getting two firms to cooperate, there are two other obvious obstacles. The operations of any two firms in this field would vary significantly in terms of the size and abilities of the staff and their general forecasting procedures. These differences somehow would have to be "subtracted out" in order to detect a variation due to the use of satellite data. Second, the client groups served by the respective firms would differ substantially in nature and location. To account for such diverse factors in any systematic way would be impossible.

Another approach which initially seems more attractive would involve only one firm. After installation of satellite data hardware, the firm would be responsible for generating two forecasts for every client in every situation; one with knowledge of the satellite data relevant to the forecast, the other without. Differences between the two sets of forecasts over a long period would indicate variations due solely to satellite data input.

Unfortunately, this method is not as feasible as it seems. First, the burden of producing two forecasts for every client would cause a significant, and probably unacceptable, disruption in the operations of the firm. Second, it would be extremely difficult to set up such a procedure in a scientifically valid way. If two different staff members produced the two different forecasts, one would have to account for differences in personal forecast abilities. If the same person did the two forecasts (one without looking at the satellite data, then another revised forecast after seeing satellite data), the first forecast might affect the way he interprets the satellite data. It is also doubtful that later updates or new forecasts could be made without recollection of satellite data.

The methodology chosen for this study is a variation of the one-firm approach just described. The forecast and client operations of a single firm are studied for a control period of one year to obtain base statistics about the forecast and the clients. During this phase researchers would become familiar with clients' operations and their particular vulnerability to the forecasts, and would examine the records of the consulting firm's forecast and their verification to determine the economic impact this year of service had on clients.

This whole procedure would then be repeated after the satellite data hardware was installed and debugged, providing a two-year period in which to study the effects of the new data. Comparison of this set of data with that from the previous year should illustrate any relevant differences due to the use of satellite data, provided certain extraneous influences can be removed. One of these influences stems from the variation in weather from one year to the next. For example, in a year with twice as many snowstorms as usual the total economic benefits due to correct forecasting may be significantly increased. In comparing successive seasons, reference to a climatological mean to normalize the data or provide for a similar sampling of storms from both seasons will be necessary.

Concerning the consulting firm operations, it is important that there be little change in personnel, client base, or operational procedure (other than that associated with the use of satellite data) over the three year study period. WSC is a stable and well established firm and fulfills this requirement very well.

Similarly, clients also must not change operations substantially over the period of the experiment. To some extent, inevitable changes can be taken into account by examining a particular operation that has not changed or by adjusting economic values to some base period (as will be done to adjust for inflation, for instance).

Finally, it is important that the satellite data system installed not produce a major disruption or reorganization in the procedures used by the consulting firm; otherwise, the study might measure the effect of the changed forecast procedures and not of the introduction of the satellite data. This is a difficult goal to achieve. On the one hand, the means must be provided to make the satellite data as useful as possible. For example, combinations of contoured conventional data with satellite images will facilitate the integration of the satellite information into the total forecast product.

On the other hand, the convenience of having conventional data at one's fingertips in a new and useful format may, in itself, have an effect on forecast accuracy. To minimize this problem it is necessary to scrutinize the capability of the equipment given to the consulting firm to assure that nothing really "new" is being made available to the forecaster except the satellite data, itself. Since SSEC would be installing a computer with both satellite and conventional data displays it was highly desirable that the participating consulting firm have some in-house computer capabilities prior to the beginning of the second phase of the experiment. WSC, the chosen firm, does have PDP-11 computer facilities.

B. Defining Economic Benefits

There are many different economic benefits accruing to the clients of meteorological consulting firms, but not all of them are tangible. An attempt will be made here to describe and classify such benefits, especially those with which this study is concerned.

i) Direct and Immediate Benefit to the Client

Forecasts to a client may be improved in one of three ways: by making possible a more accurate forecast; by improving on the frequency and timeliness of the forecast (including updates and emergency warnings); and by allowing the inclusion of more detail or aerial coverage in current forecasts. These improvements may benefit a client in a variety of ways. The most easily measured benefits are those which a client realizes from a single forecast or group of forecasts (for, say, a single storm); the client can point to a specific gain coming directly to him (as opposed to the community of users the client may serve or operate in) over a short period of time (a period of days). Examining in detail the operations of a client, one can ascribe a fairly exact monetary value to some of these benefits. Examples include savings in payroll size, in deployment of equipment costs, and in the use of materials. A major goal of this study is the accurate measurement of this sort of economic value.

Other direct and immediate benefits are not so easily quantified because they involve factors of convenience or efficiency. For instance, it may be of great psychological value to a foreman of a snow and ice crew to know that no storms are expected over the weekend or overnight, since he can, with peace of mind, use his time without the worry of making special plans for handling a plowing situation outside of regular hours. Should a storm occur unexpectedly anyway, he still may be able to handle the situation through last minute efforts in a way no more wasteful of money than he would have used had he known earlier about the storm. But the unpleasant strain placed on him in such a situation is something he would rather avoid by paying for a weather service. In the final analysis, such convenience may have economic ramifications by improving worker morale, efficiency, and turnover rate, and by decreasing the number of errors made in scheduling. Assigning an exact dollar value to such complex factors, however, is not a central objective of this study.

ii) Direct and Long Term Benefits

There are some advantages to a client subscribing to a weather service which, while accruing directly to the client, can only be seen as a gradual ocurrence or as the net result of a long series of forecasts. Again, as with short term benefits, some of these advantages can be measured; others cannot. An example of the former case would be a fuel oil dealer who finds that accurate degree-day forecasting allows him to make fewer refuelings per customer over a winter season. While this kind of benefit can surely be quantified by examination of seasonal statistics (as we plan to do whenever possible), there certainly will be difficulties in determining how satellite data might be contributing to the overall success or failure of the forecasting. If we can isolate several instances during a season where satellite data made a clear contribution, then a case may be made for the positive effect of such data on the long term benefit. Whether this can be done will not be known until the data are in hand.

Other long term benefits are more ambiguous. Through improved forecasting, equipment wear and maintenance may be less over a season, but not in any readily quantifiable amount. The increased accuracy of a forecasting service may encourage a client after a long period of doubt to increase his reliance on the forecast in ways that will ultimately save money, but unless this decision can be specifically connected with satellite data input, it has little meaning to this study.

iii) Indirect Benefits. Indirect benefits are those that accrue to the clients' customers or to the community which they serve. There are many possible examples of this type of benefit. Time is saved by motorists going to work on roads that have been quickly cleared of an early morning snow; lives may be saved and accidents prevented in the same situation. Consumers of agricultural products will save money where prices have been lowered by wise commodities purchasing based on the latest weather information. Certainly there is also an economic value to the better service a utility customer may get through prompt emergency repairs. Although all these benefits could be linked to the improved use of satellite data, quantifying them would be a formidable job, requiring massive public interviewing plus an ability to translate intangibles (e.g., time) into money. For this study, then, these benefits are generally beyond our present powers of quantitative analysis. It should be noted that many of the benefits described are also indirect benefits to the public. This is particularly true where tax money is saved by municipal departments (i.e., the majority of snow and ice forecast clients).

In summary, this study will concentrate on quantifiable short term benefits of direct economic value to the client. Where it is possible to link long term benefits to the introduction of satellite data, these also will be included in our analysis. Important indirect benefits will be pointed out, but not quantified.

Two final comments: There is a certain degree of difficulty in the assignment of an effect to any one cause in a process as complicated as the interaction between a weather forecast and a business decision. In many cases the forecast is only one item among many affecting the decision, for example, to increase energy production or buy commodities. Attention in this study must be concentrated on those decision-making processes where the weather information has a clearly defined role.

Second, we can measure only those benefits the client, himself, chooses to capitalize on. It is often apparent that a client could put a forecast to better use than his procedures currently allow. However, our purpose here is to measure what is actually being done by a cross section of different enterprises, not to specify what could be done under ideal conditions.

C. Methods of Measuring Economic Gain

Since one of the goals in this first year was to understand the operations of each client to see how each eventually would be affected by satellite data, it was first necessary to group clients according to the type of operation they performed. It is important to keep in mind that such groupings do not imply that the clients in each group are by any means homogeneous in their use of and response to the forecast, but only that they all receive the same type of forecast product. Grouping the clients was done merely with the expectation that certain similarities in operation could form the basis of useful generalizations later in the study. Six general groupings were decided upon: snow and ice, electric utilities, gas utilities, fuel oil dealers, commodities dealers and construction clients. In addition, we considered a number of miscellaneous clients (whose unique operations received separate analysis), and a small group of clients concerned with blasting. We decided not to include the latter group in this study. This decision hinged on the fact that blasting operations rely on accurate sounding information to determine how far from the blasting site the noise will penetrate and on other weather data for safety considerations. Though both of these are valuable uses of the forecast products, neither is economically quantifiable. The remaining client groups will be dealt with more thoroughly in Section V.

There are three main approaches possible for measuring economic gain: a study of overall group characteristics and operations; individual studies of a particular client over time; and case studies of particular weather events in relation to a client or set of clients. While it is true that the first approach is the most desirable because it allows a larger, more widely applicable picture to emerge, such an analysis is also the most difficult to perform. One needs a sufficiently large sample in which group characteristics can emerge clearly. Since intuitively we expected there to be significant differences among clients even within the same group, case or individual client studies are needed to bring out the true variation of the data. In addition, the sample size might, in some cases, be too small to allow accurate generalization.

For these reasons, no decision has been made on the approach or set of approaches that will work best with the various clients. Each client group will be treated separately according to the quality and differences of the responses.

Since, at the outset, we knew very little about the operations of WSC clients, a simple attempt at fact finding through the use of questionnaires was first set up. To a certain extent, we intended to see whether we could predict what a client's response would be to a given forecast so that we could calculate an economic impact without having to contact the client about his response in every forecast situation. The questionnaires would give us preliminary information about each firm that could be used to study the client later in more detail. This would be especially important for small client groups (e.g., construction: three firms) for whom generalizations over a wide variety of operations is impossible. Finally, the questionnaire also would give us enough information to judge what weather situations would offer potentially interesting case studies. By checking through weather records for forecasts which were likely to have affected the client signficantly we could follow up to determine the history of the event from the client's point of view.

In summary, our strategy has been one of flexibility. Not knowing in advance which of the three approaches will succeed in delineating the economic impact of satellite data most succinctly, we will use whichever of the methods is most appropriate. Analysis to date indicates that clients, even within single groups, vary widely. Even where there is a large enough sample to allow generalizations, case or client studies will be necessary to carry out a thorough economic analysis.

D. Use of Questionnaires

Questionnaires provide an attractive means of gathering data. They are cheaper than personal visits, and allow the respondent time to carefully think out and research his answers. It would be very difficult to accurately obtain the same quantity of information by phone, so telephone interviews were not considered as a primary means of gathering data. Consequently the use of questionnaires, supplemented by personal contacts where necessary, was chosen as the only practical means of obtaining the vast amount of information required.

The main purpose of the questionnaires was to provide written documentation on the operations of individual clients of Weather Services Corporation, and to ascertain, through the structured questions, the general economic impact of weather forecasts on their operations. This method presupposes that only a discrete number of weather conditions affect each client. If the reactions to and impact of each weather condition are known, we will be able to determine the impact of each situation as it arises during the course of the study without re-contacting the client.

We allowed for several obvious limitations in constructing our questionnaires. Recognizing that we are totally dependent upon the good will and cooperation of the clients, we tried to keep the questions short and to the point, to avoid wasting the respondents' time and trying their patience, and to gather only directly useful information. Because this requires some prior knowledge of each client's operations, we used an "iterative approach."

Except for those clients primarily concerned with snow and ice control or removal, each client was first mailed a one page, two question form and a letter explaining the program. The questions were:

1. In what specific operations do you use weather forecasts from Weather Services Corporation as an aid?

2. If you were asked to place an economic value on the weather forecast you receive, what factors would go into your calculations? (Monetary values are not currently needed, but we're interested in specifics about manpower, equipment, materials, etc.)

Because it was December, and because we wanted responses from "snow and ice" clients for the current season, we attempted to accelerate development of a more specific set of questions for this group. Thus preliminary snow/ice questions were drafted and sent to a sample group. To gain more insight into the impact of the forecast on snow/ice removal, and of determining the utility

The questionnaires, in many situations, had to be followed up by phone calls for a variety of reasons -- misunderstanding of questions, reluctance to put facts into writing which the client considered unpleasant, and a need to translate figures given in one format to some format that we would find useful. In general, however, the questionnaire approach proved satisfactory.

Smaller groups, such as construction companies and commodities dealers, require detailed study and consideration because they do not constitute a statistically valid sample size. The same applies to the one-of-a-kind clients, such as off-shore operations. For these, the questionnaire that gathered background information was also the basis for more detailed case studies.

For all clients, the questionnaires give us documented information on how each client uses the weather forecast in a variety of situations, and how the accuracy of the forecast affects him financially. During the course of this study, these answers will be applied to a variety of weather situations. These answers, along with the forecasts clients received and their verification, will be the basis of the economic benefits calculation.

E. Forecast Verification

An important stage in the process of analysis for both the first and second phases of this study will be the verification of the forecasts made by Weather Services Corporation. If satellite data does in fact improve their forecast, and if this improvement does have impact on the clients, this can best be proven by showing that forecast errors in the control period are "significantly greater" than those in the experiment period. Verification is a notoriously difficult problem, but in this study there are several factors which should make the problem much easier to solve. We should point out first that the verification we are attempting is designed only to catch those errors which have a significant economic effect on the clients, where the individual client is located.

Second, clients, in many cases, can supply the necessary verification data themselves. Utilities, for instance, keep their own observations of temperature and related power requirements. Using such client observations and regular National Weather Service data, Weather Services Corporation has been able to construct maps and tables which, in our estimation, are sufficient to provide the verification needed in all cases. Table I contains a listing of the verification we will need, and which will be supplied by WSC.

A related problem in this study is that of obtaining the climatological statistics necessary to normalize the data for all phases of the study, so that the same basis of comparison is used in analysis. Not a great deal of data is available for this task. With the end of the federally supported State Climatologist System, high density data from many eastern states are sparse. If we attempted to determine accurately the climatology for each client location, we would face an insurmountable problem. However, because we are attempting only to compare data from the two periods, an absolute error in the averages to which we refer will not be of major significance. It is important only that the statistics from the two periods be compared to the <u>same</u> base statistic.

Examination of the available monthly and annual statistical summaries has indicated that these contain the gross kind of averages necessary to accomplish this aim.

TABLE I

FORECAST FORMS AND OTHER DATA TO BE OBTAINED FROM WEATHER SERVICES CORPORATION

A. Snow and Ice
  1. Time of predicted onset of storm
  2. Amount of frozen precipitation predicted, temperature and wind.
  3. Updates
  4. Verification of time and amount, temperature and wind
  5. Cases where no frozen precipitation was predicted but occurred.
  6. Base maps for prediction and verification
  7. Location of client vs. location of prediction and verification
  8. Base maps for State and Turnpike systems

B. Gas Utilities
  1. EHDD forecasts and updates -- up to six days in advance
  2. Verifications
  3. Location of prediction and verification
  4. Same for Weather alerts (cold temperatures, rain, wind, frost)
  5. Time of arrival and amounts
  6. Base maps

C. Electric Utilities
  1. Load Forecast (temperature, humidity, cloud cover, wind), updates
  3. Verification
  3. Location of prediction and verification
  4. Same for weather alerts (cold temperatures, rain, wind, frost, severe weather, lightning)
  5. Base maps

D. Fuel Oil
  1. Total degree days for season
  2. Daily DD forecasts -- up to three days and updates
  3. Weekly (or daily) verifications
  4. Storm warnings (snow and ice) and updates
  5. Location for prediction and verification

E. Marine Forecasting
  1. Forecast sheets

F. Construction
  1. Rain, wind, high and low temperatures, snow prediction and updates
  2. Verification

G. Automobile Association
  1. Temperatures in November and December (10 degree or below)
  2. Rain and temperatures rising into the 40's
  3. Verification

H. Commodities
  1. Forecast sheets

IV. BASIC McIDAS SYSTEM

The system we intend to build for this program is a derivative of the University of Wisconsin's McIDAS, reduced to the essentials for the task at hand. McIDAS systems rely on man for decisions, hence the name, Man-computer Interactive Data Access System. The article by Chatters and Suomi (1975)[2] describes the system's basic capabilities.

Because the same computer is being used for this task as in the developmental McIDAS, all applicable software transfers directly. The consequent savings of time and money provide good system capability at a modest cost. Some modifications will be needed, however, to accommodate different operating configuration and tasks.

Data sources for the McIDAS will be GOES satellite sectorizer lines and conventional Service A and Service C meteorological data. Functional capabilities will include: Storing and viewing up to 130 visible and 130 infrared images; animated loops of these at variable rates; and color and contrast enhancement. There is a joystick controlled movable cursor for location and tracking, with read-out in earth coordinates, and digital read-out for cursor box contents. The satellite data can be gridded and mapped to aid viewing. The graphics which present conventional data in the satellite image projection include T, Td, P, Wind, Cloud Amount/Type, Advection, and time differences of T, Td, W, θ, θ_e, P; and time differences of T, Td, W, θ, θ_e, P. Divergence, vorticity and mixing ratio also will be available. Software for upper air charts, soundings and cross sections is now being developed. All of these can be viewed independently as charts, or overlaid on the satellite images to aid analysis.

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[2] Chatters, G.C. and V.E. Suomi, 1975: The Applications of McIDAS. <u>IEEE Trans. Geosci. Electron GE-13</u>, 137-146.

The system also will be able to derive cloud height from the visible and IR images. There will be no capability to ingest real-time data directly, and no tape reading capability.

The hardware is divided into two sections: Process and Display. (See the block diagram in Figure 1.) The process section is primarily commercial hardware -- a Harris "slash 6" central processor with 24 K bytes of memory and a 10 M byte disk. Software will be brought into the system on removable platters for the disk. The process section also will have custom built facsimile ingest system and input/output controllers.

The display section is directly set up for human interaction. An analog disk stores pictures for display, and these pictures have graphics and a cursor overlaid on them. They are then colored and displayed on a high quality monitor. Character interaction with the CPU, for entering commands, is handled through a standard video terminal.

Before the system is installed at WSC, there will be a break-in period at SSEC to eliminate any "bugs." In addition, we will supply WSC with a service contract for the duration of the experiment.

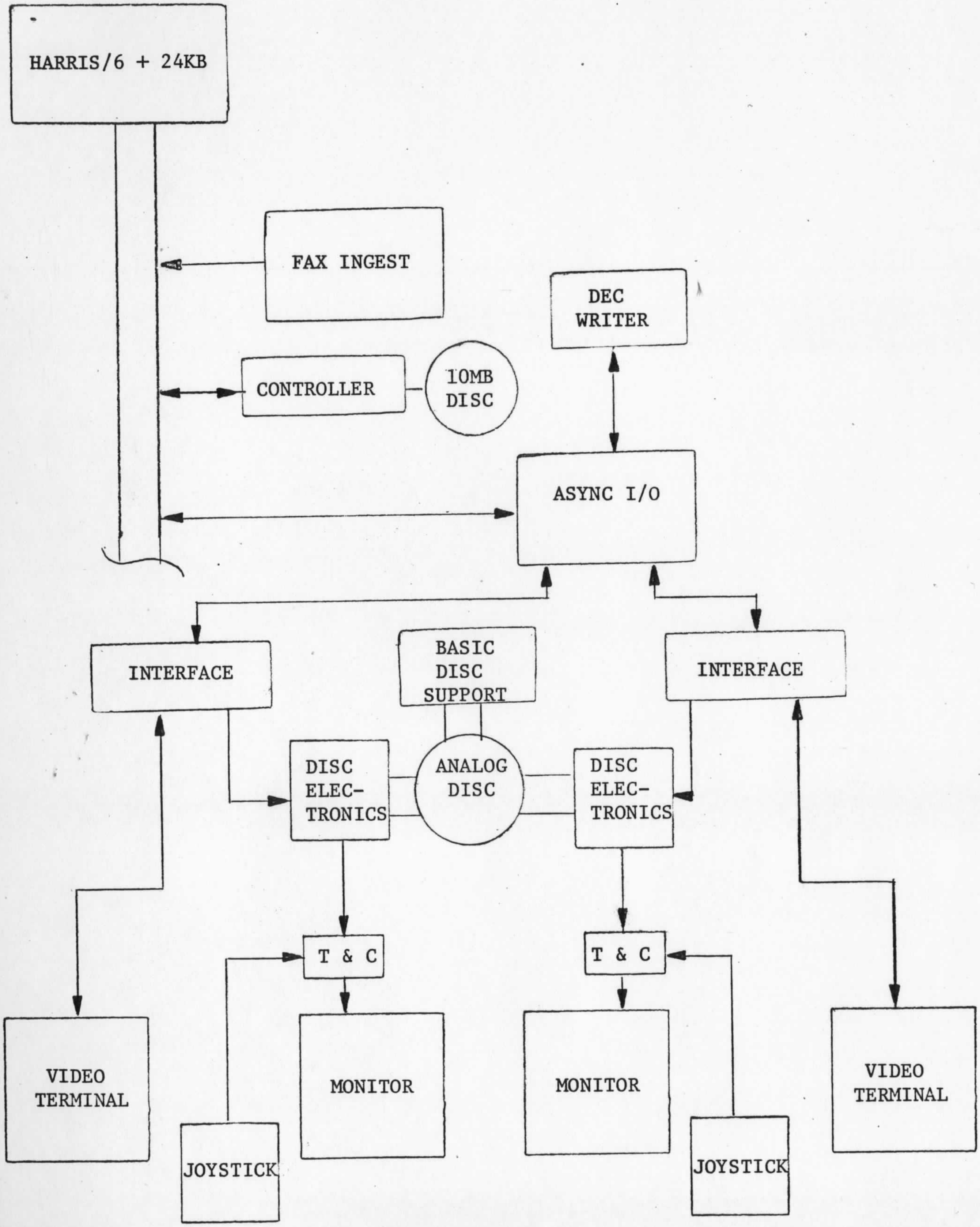

FIGURE 1.
Basic McIDAS System
(T & C: Timing, Cursor and Enhancement)

V. CLIENT GROUP SURVEYS

A primary goal during our first year was to contact all clients of the participating consulting firm to understand their use of the weather service. While a number of client responses have not yet been received, this objective has, for the most part, been achieved. The following sections describe each client group; tell how each group generally uses the forecasts received; present a sample completed questionnaire (in Appendix C); summarize the responses received to date; offer some general comments on those replies; and explain how we will approach the determination of economic impact.

A. Snow and Ice Removal

Clients who receive the snow and ice forecast are concerned with the maintenance of roads and parking lots. These clients were the first group to be contacted, a process which began in December 1976. Since this was the largest and most varied client group (147 subscribers), and because an early start seemed advisable, we contacted this group first. Also, the winter season already had begun -- a time when we could expect these clients to be most aware of their problems and operations.

The questionnaire design effort was followed up by a visit to a number of clients of different types. On the basis of the information so obtained, we were satisfied that the questionnaire was sufficient for our purposes. Questionnaires were mailed in early January 1977. As replies were received, each client was contacted personally by phone for a few additional questions and possible clarification. To date we have received usable replies from 63 out of the 147 clients (about 43%) and expect to receive a few more over the next month.

The makeup of this snow and ice client group can be summarized as follows: Almost all (138 of 147) are government departments in an area ranging from Maine to North Carlina; of these, most (121) are cities ranging from a few thousand to several hundred thousand population. Over half of these cities, however, have populations of less than 30,000. In addition to the cities, there are four state highway divisions, six turnpike authorities, and seven county bodies. The non-governmental bodies among the snow and ice clients are either universities, shopping centers or private corporations, all of whom have large parking areas to clear. Although we have received a good distribution in size and geographic coverage among the 63 clients who have responded, special attempts have been made to get more responses from the larger cities and the state agencies. There are fewer of these in the total sample, and they apparently are more vulnerable to forecast error than the smaller organizations.

A sample questionnaire is included in Appendix C. (For reasons of confidentiality, no client names are included on any of the samples.) The example given is from a city of about 25,000 population. As the questionnaire shows, we were interested not only in how forecast situations were related to decision-making, but also in general characteristics of the entire operation, such as budget size, cost for an average plowing or sanding situation, the size of the highway system, and so forth. Later, in a more detailed analysis of the data received, we will be able to cross-reference economic impact conclusions with some general characteristics of the operation.

The following conclusions have been drawn from a preliminary analysis of the data:

a) A source of loss to nearly all clients were storms which arrived an hour or more later than expected, or which were of significantly less intensity than expected (such that plowing was scheduled, but a sanding operation would have sufficed). These situations can be readily quantified in most cases, although the impact varies widely in dollar loss amounts depending on the client.

b) Other forecast parameters such as wind and temperature were of less importance in influencing the general use of the forecast, but could be important in extreme situations.

c) A significant number of clients were reluctant to admit that they were ever overprepared for a storm, but further questioning did reveal this fact. Follow-up phone calls were useful in eliciting this information, and in clarifying ambiguous responses.

d) Failure to prepare for a storm in time was another significant cause of monetary loss for many clients, but such loss is much harder to measure accurately because of the difficulty in determining time lost in such situations. Some respondents estimated that up to 40% greater costs were incurred in major snow or ice storms.

e) Governmental bodies responsible for road maintenance over large areas respond in a complex way to storm conditions (conditions which can vary widely in the area of their jurisdiction). A case study approach concentrating on one or two counties of a state operation may be the best approach here.

f) For several clients located in erratic weather areas (e.g. near the Great Lakes or right along the coast), case studies also will be the most rewarding and interesting.

g) Clients varied considerably in the quality of the road conditions maintained and thus in the costs incurred. Some cities wait until significant amounts of snow have fallen before calling up removal or sanding crews, to the detriment of their road conditions.

h) Many of the smaller clients (and some of the larger ones) use the forecast for convenience only (i.e., they want to know about approaching storms, although their operations are little affected by the information). There are two reasons for this. First, among smaller clients, the flexibility of a small staff and area of responsibility allow quick mobilization, thus minimizing or eliminating completely the possibility of losses incurred through forecast error. Second, out of mistrust, ignorance, or lack of communication, a number of clients use the forecast product ineffectively. While it is clear to us that the forecast could be used to greater economic advantage, we can only measure what actually happens.

These conclusions suggest that we will be in a good position to evaluate direct immediate benefits to these clients through the verification of the time of storm arrival; verifications of temperature and wind will also be used. While the variation among clients will necessitate some case studies, we expect to be able to document a more general summary as well.

B. Electric Utilities

Eleven large electric utilities from New England to North Carolina receive weather data from Weather Services Corp. Unlike many of the other client groups, most of the electric companies service large areas and have a clientele ranging over a million households. Hence, any slight change in their efficiency would be magnified many times. Weather forecasts are used in three areas of operation: 1) winter load forecasting, in regions where electric heating is prevalent;

2) summer load forecasting, in areas of high air conditioning usage; and 3) storm alerts for maintaining and repairing equipment.

Electric company equipment is very sensitive to weather extremes because much of it is above ground and exposed. In winter, heavy snow, extreme cold, high winds, and (most important) ice storms damage electrical systems; in summer, severe weather, including high winds, hurricanes, and lightning, often disrupt electrical power.

A prime example of a winter crisis is the late spring snow and ice storm that hit New England on March 22-23, 1977. (We are currently working on a case study of this storm.) Tens of thousands of households were without power and much of the area's electrical system was disrupted. Though a forecast cannot prevent disruption, it can allow the utilities to alert their own crews, to catch trouble when it develops, to alert crews from nearby systems, and to restore power at the fastest rate possible.

For routine maintenance, the utilities use the forecasts to make the most efficient use of their manpower. In addition to economic factors, accurate forecasts also have a benefit in the area of safety (such as the safety of crews during electrical storms) and personal comfort.

Load forecasting depends upon a number of meteorological variables: temperature, humidity, wind and cloud cover. Accurate forecasts enable the utilities to better cope with long periods of cold or, for example, by preparing reserve generators which are not economical to maintain during non-peak situations, and which take a long time to be put into operation. A more efficient use of available equipment could minimize down time and reduce "brown-outs."

Of the eleven utilities contacted, we have received complete replies, including follow-up interviews when necessary, from eight. A sample completed questionnaire is included in Appendix C. This company receives forecasts every three hours for temperature, relative humidity, winds and weather for two days in advance, plus a third day outlook. If severe weather occurs, they will also be notified. They are a summer peaking company whose major problems are brought about by heavy air conditioning use and rapid changes in cloud cover. In addition, all their maintenance operations are very sensitive to weather.

Using information from the questionnaires on critical power situations and how they are handled (e.g., extra generators, more manpower), along with forecast, updates and their verification for temperature, humidity, winds and cloud cover, the economic value of the forecasts will be obtained. Other information will include the documentation of additional generator use and cost, and of economic loss suffered by incorrect load forecasts. Maintenance situations (all of which are different) will be treated on a case-by-case basis, using storm information, with actual expenditures often being supplied by the utility. Although personal inconvenience and discomfort also result from incorrect forecasts, such factors are impossible to quantify.

The above example is representative of most of the replies we have received. Some utilities do not use the service for load forecasts, while others in densely populated urban areas are more sensitive to small temperature and cloud cover changes. Maintenance seems to be at least as important as load forecasting for both optimum utilization of manpower and productive system operation.

C. Gas Utilities

Weather Service Corporation provides forecast information to 33 gas utilities from Maine to Georgia. They range from among the largest utilities in the country (Con Edison, Philadelphia Gas) to small municipal systems (Lexington, NC Gas Dept.; Vermont Gas Systems, Inc.). The weather forecasts are used in two major areas: (1) maintenance and service of the system, and (2) forecasting load requirements in order to make optimal use of the available gas supply.

Since most gas mains are underground, weather does not frequently interfere with equipment. Extreme cold, snow and other forms of precipitation do interfere with routine maintenance, and heavy snow plus deep frost penetration often require the call-up of emergency manpower. In emergency situations the forecast is used to minimize the time customers are without service, and to schedule available manpower efficiently. In routine maintenance, forecasts are used to call men into work when the weather permits. For example, if crews are called in and the weather is inclement, they will often have to be paid even if they do not work; if they are not called in during good weather, needed repairs may have to be done on overtime shifts.

Load forecasting is much more variable than service and maintenance scheduling, but has a stronger direct economic impact. Most companies have a fixed amount of gas which they can take from pipelines. This amount is regulated by the Federal Government, and is not enough to meet their total heating season needs. Supplemental gas, either ordered on short notice, or obtained by peak shaving from propane or LNG gas, is much more expensive than pipeline gas. Hence, the companies must know exactly when and how much of their allocated gas is to be used, to avoid sending out expensive supplemental gas unnecessarily, or to avoid pressure drops in their pipelines. In addition, they also must know when "interruptible" customers should be shut off to avoid selling them expensive gas at low prices. Thus, forecast accuracy is crucial to the economic health of many gas utilities.

Of the 33 gas utilities contacted, complete responses have been received from 20; three have declined to participate. Many of the 20 also were contacted by phone to clarify some answers. A sample completed questionnaire is included in Appendix C. This utility (Company S) receives forecasts up to three days in advance for average temperature, maximum and minimum temperature, degree-day, and effective heating degree-day (EHDD, which includes wind). In addition, temperature forecasts are given for every three hours, and wind data every twelve hours. When significant weather is expected that, too, is included in the forecast. Company S explained that since every maintenance situation is different, it would be impossible to give exact monetary figures. On the other hand, it is apparent that when temperatures drop to about 10^{o} F, the exact accuracy of the forecast becomes crucial, with penalties of up to $5.00/million cubic feet for the gas that is "misused."

In studying this gas utility company we will use the forecast EHDD along with their updates, match them with actual conditions and determine how far Company S was from the optimal use of their gas supplies due to the weather forecast. In addition, this past year's conditions will be normalized to other years, to avoid comparing statistics of years with disparate gas use and "critical situations." With the company's cooperation, emergency maintenance cases will be examined as they occur, using storm information.

This gas utility sample is representative, but does not cover every respondent's case. Some larger companies are far more flexible and do not have a clear cut-off point at which peak shaving is used; some are not allowed to have interruptible customers; maintenance problems vary from region to region. In general, however, the dependence of the gas utilities client group on weather forecasts is both significant and quantifiable.

D. Fuel Oil Dealers

Fuel oil dealers generally receive three distinguishable services from the weather consulting firm. One of these, calculated effective heating degree-days, is based on actual weather data and is used with the customer's empirical "K-factor" to estimate the rate of fuel consumption. By keeping track of cumulative effective degree-days since the last fill, the current status of a customer's fuel supply can be determined. The impact of satellite data on knowledge of actual (past) wind and temperature would be slight at best. The potential benefits should be more noticeable in the other two services -- predicted degree-days and storm warnings. These are used to make delivery schedules most efficient.

To date 30 replies and 19 completed questionnaires have been received from the 59 letters sent to fuel oil dealers. The uniformity of response to the principal questions indicates this is an adequate sample. A representative completed questionnaire has been reproduced in Appendix C. The operation described is typical in most respects, though a bit larger than many (more employees, trucks, and volume of business).

From the aggregate replies from all 19 completed forms and other information gained from interviews, the following conclusions have been drawn: The fewer deliveries made per household during each heating season, the lower the cost of the service. There is an optimum "fuel drop per customer," related to the size of the customer's tank and the number of days of reserve for which the dealer aims. For residential customers (who constitute over 90 percent of the business volume) the average optimum fuel drop reported was 192 gallons while aiming for a 4 day reserve under wintertime conditions. On the other hand, the average actual drop was somewhat lower, 182 gallons. In principle, completely accurate forecasts should further reduce the number of deliveries, so dealers are interested in predicted degree days which can aid in scheduling deliveries (including overtime if required).

Deliveries typically are scheduled three days in advance (though sometimes as much as 7 days in advance), but are usually based on an advance four-day forecast. However, adjustments in delivery rates are often made on a 24-hour basis. Because of the reserve in the customer's tank, a degree-day forecast has to be seriously in error (10 DD) to cause delivery schedule problems.

Winter storm warnings play a major role in these short range schedule changes. The response to a prediction of an extended cold snap is to step up the rate of delivery. Similarly, warnings of snow, particularly in excess of 4 inches, will call for stepped up deliveries. This usually means overtime pay for drivers at 1.5 times normal wage rates. Notice, however, that this may be paid even if the forecast is correct. If overtime is scheduled on the basis of a forecast which later proves incorrect, the loss arises because the overtime and premium rate were unnecessary. Similarly, if a storm occurs which was not forecast properly, drivers are unable to make deliveries at difficult "snow stops" and, in an extreme case, have had to hand carry 5-gallon cans of fuel to customers. Snowy conditions also slow down deliveries to normal customers, reserves drop, and the risk of a run-out increases.

Information required to assess the economic impact of weather data on fuel oil dealers will be the disparity between degree-day forecasts and verification, and the disparity between 24 hour winter storm forecasts and verification. Estimates can then be made of the overtime worked at premium rates, for comparison with overtime worked if the actual weather had been forecast correctly. The difference between these numbers, weighted by wage rates and work force size, is a total dollar margin for improvement. This figure can be monitored for change after the introduction of satellite data.

Some notice should also be taken of (and an economic value assigned to) the increased threat of run-out. Otherwise, the erroneous conclusion might be reached that no loss is suffered when an unforecast storm strikes (other than some overtime to "catch up" after the storm). Additional modifications should be made to account for differences in actual weather from year to year. This might be done by estimating total season overtime hours for each year from actual weather data.

E. Commodities Dealers

This is a small, diverse but important group of clients. The discussion below is based on the incomplete information obtained to date. Of the nine members of this group, preliminary information has been received from seven, but detailed questionnaires were received from only four firms. Because of the possible significance of this group two firms were also visited personally.

The activites of the commodities clients fall into four general areas. (1) They may produce and merchandise brand-name products available off the shelf or over the counter to ordinary customers. (2) They may produce, in bulk, a processed commodity to be made into consumer goods by someone else, or possibly by an independent branch of their own comapny. (Examples of bulk products are vegetable oil, sugar, animal feed and flour.) (3) They may buy and resell raw commodities like wheat, soybeans, coffee beans or cocoa beans (possibly supplying storage and transportation). (4) They may engage in commodity futures operations, buying and selling contracts for the future delivery of commodities.

Weather data of greatest interest are climatological statistics (e.g., cumulative rainfall) and alerts about conditions which could cause a sudden change in the supply or price of a given commodity (e.g., Florida citrus freeze or rains that alleviate impending drought damage).

The four activities listed above are dissimilar in several ways. For consumer products, prices are determined by many things unrelated to the cost of the agricultural raw materials -- advertising, labor, and shipping, as well as a desire to maintain a long-term position in the market in competition with interchangeable and alternative products. Changes in costs tend to be absorbed in the short run; major adjustments must tie in with changes in advertising, packaging and other factors.

The price of a raw commodity is a bigger factor for bulk processed commodities. Here, through-put (obtained by balancing supply and demand) has to be kept at a level that permits efficient operation of the plant and labor force. Big markets are associated with this activity, and greater interchangeability is evident. Customers have more bargaining power since the commodity price is less "sticky." To carry on activity in raw commodities, a firm always must be willing to provide a market for both buying and selling. This activity is very sensitive to actual current supply and to future expectations for the current growing cycle. Dealing in "futures" is quite different. In this case, a firm can be "in" or "out" of either buying or selling, or both, at a given moment. Futures prices are highly sensitive, experiencing great short and long-term fluctuations, thus offering more opportunities for short-term gains and losses. These opportunities are dependent upon the state of current stockpiles, the vulnerability of the crop to possible disasters, and expectations in diverse growing areas.

Weather information strongly affects advance planning for production and processing. Actual costs and prices associated with such activity are determined much more directly by "actuals" trading than by weather information or futures prices; that is, to process raw materials or produce products, actual raw materials must be bought. Actuals trading is most directly determined by the prevailing market price. Though an individual or firm may think a market price is too high or too low in some abstract sense, it is the opinions of all buyers or sellers (the market) that determines prices. Weather information is directly valuable in such considerations, affecting decisions to increase actual sales or purchases at a given moment. It is in the futures market that improved actual weather data and weather forecasts would have the greatest direct effect.

In most cases the exact effect of a weather forecast cannot be quantified. Forecast information is so diluted by other weather data, by the actions of other traders, by the current holdings of various companies, and by other external factors that a direct cause-and-effect relationship is often hard to prove. Two or three times a year, however, the reverse is true, and the economic benefits can be substantial. Traders who had advance warnings of either the Florida citrus freeze or the Brazilian coffee freeze made sizable profits, for example.

Since all commodities operations are vastly different the best means of detailed investigation appears to be hindsight case studies of specific commodity situations in the futures market, coupled with an estimate of how they were related to the actuals market.

One final distinction should be made between the commodities group and other client groups. Previously, economic benefits were derived because it was possible to use resources more efficiently. In commodities, profits can be made at the expense of other companies or countries, especially in the futures market. When one firm makes a profit at the expense of its competitor who may not have the same weather data, there is really little economic gain to the economy as a whole. In the long run, if everyone had accurate weather information the market might become more orderly, with the consumer being the beneficiary.

F. Miscellaneous Clients

i. Construction

Only three clients are included in this category. All are involved in concrete pouring and paving operations in the New England or mid-Atlantic region. A questionnaire was first prepared on the basis of preliminary information from these three companies. The answers to these questions were supplemented by detailed interviews by phone to gain better insight into the operations. A sample form is included in Appendix C.

These clients are fairly sophisticated in their use of weather forecasts, and have standard procedures for making decisions. These firms are most affected by heavy all-day rains, strong gusty winds, extreme temperature and snow -- any of which can lead to the cancellation of part or all daily operations. The values of these parameters that provoke cancellation, and the loss due to such cancellation are well specified and should present no serious problem of economic analysis, once verification data is available to us. Because the sample size is so small, conclusions will be presented in the form of client and case studies.

ii. A State Automobile Association

Several phone interviews were conducted with this single client to learn if signficant economic benefits were likely to arise in connection with this study. Conversation revealed that up to 90 employees can be called in for overtime in two types of situations: rain with temperatures rising from the 30's to 40's (causing motor condensation), and temperatures of 10^{o} or below in November and December (causing engine starting problems). Since the association is responsible for servicing members' cars, a large staff is needed to handle early morning service requests. In addition, this association is affiliated with about 100 branches, all of whom are advised by a main office about upcoming demands due to the weather situation.

A director of the association estimated that the forecast causes over-preparation in 15 to 20% of the overtime cases. In our judgment, this client represents an interesting prospect for a case study concentrating on the two situations mentioned above. The client has promised to cooperate in providing data on association decisions regarding overtime call-ups. Verification data will be available from a nearby weather station.

iii. Marine Forecasting

One client firm is engaged in offshore exploration. General marine forecasting would seem to be an attractive application for satellite data, since one of the significant problems in marine forecasting is lack of conventional data. To the extent that one could improve forecasts with satellite data, and to the extent this improvement could be generalized to the maritime industry as a whole, one might be able to attach a significant economic benefit to the eventual widespread application of satellite imagery. Our immediate task concerns only the benefits associated with this one client, however. Even with this limitation, it will be difficult to quantify the total benefits.

The forecast is intended for operations about 200 miles offshore, conducted from a 175 foot research veseel. The ship tows cables bearing sensitive instruments for geophysical sounding. After two weeks at sea, the ship normally returns to port, changes crew and returns to station.

Wind, waves and unusual weather are of interest. The cable-instrument assembly, valued at one-half million dollars, is easily damaged by unfavorable weather. Consequently, weather forecasts are important in planning the orderly conduct of exploration (decisions to deploy or retrieve the equipment). Since the vessel is comparatively small it must return to port in severe weather. This necessitates a 15 to 20 hour warning to insure against loss of the ship, a multi-million dollar investment, and the lives of the crew.

When a storm is forecast (wind or waves) but is late, is less severe than forecast, or does not occur at all, direct economic loss is quantifiable as lost time multiplied by wage rates, plus the cost of maintaining the scientific crew and operating the ship on station ($9K per day). There is an additional cost for fuel, if the ship leaves station unnecessarily to avoid the expected storm.

If a storm occurs but was not forecast, or if it is more severe than forecast, the direct economic loss includes the cost of damage and lost time for repairs, multiplied by the ship operating costs and wage rates. It may not be possible to calculate the indirect economic impact of the lost time on the client; such lost time affects the client's competitive position relative to other companies. (In the opinion of this client, indirect dollar benefits and losses of this kind are far larger than direct costs or benefits.)

We will monitor forecasts for the conditions relevant to this client, and, with the client's continuing cooperation, will obtain verification data and data on unforecast storms from the ship's log. We will also seek data on lost exploration time from the scientific logs. From these, we will calculate the direct economic effects of the forecasts and weather. The number of such "lost time" incidents is expected to be small in a given year, so comparison of one year with another may be difficult. Consequently, a case study basis, rather than a statistical basis, will be used to make the comparison.

VI. SECOND YEAR PLANS

We will continue to assemble the forecasts and their verifications for each weather season through the duration of the control period (fall of 1977). In parallel, we are obtaining climatological statistics for all the areas studied to normalize this year's weather to the 30-year means (mean conditions as well as number of storms, number of freezes, etc.), thus allowing the control period to be directly compared with the experimental period. Using all of the above data, general economic benefits for each client will be obtained, using the responses to our questionnaires plus information gained in personal interviews. Data for storm and severe weather occurrence (other than snow/ice clients) will be evaluated on a case-by-case basis with the cooperation of the firms involved. Within each client group, in-depth case studies will be performed on selected representative and cooperative clients.

Barring unforeseen delays, the hardware system should be assembled and tested by early fall. At about the same time, several employees of Weather Services will be trained on our McIDAS facility, and will be the focal point of the subsequent training in Bedford. Soon thereafter, we expect delivery and installation, with a break-in and non-monitored training period lasting through the 1977-1978 snow/ice season. It is felt that better use and familiarity with the system can be gained in a non-pressure training atmosphere. The control period for the study will end with the system's delivery, and the experimental period (to last for two years) will commence at the end of the snow/ice season.

The training of the entire WSC staff will be done by a combination of our employees plus the WSC members who received prior training. We will concentrate on explaining and demonstrating the optimal use of the satellite data to fit their needs. We will perform no forecasts for them, nor will we compel them to use the satellite data in their forecasts. We believe that the utility of the satellite data will speak for itself.

Once the experimental phase begins, we will re-monitor the economic value of the forecasts, normalize it, and compare it with the value obtained during the control period. The differences will then be attributed to the addition of satellite data.

VII. PERSONNEL

Over the past year, the program has been contributed to by three meteorologists -- Dr. David Suchman, Dr. Barry Hinton, and Mr. Brian Auvine -- and one economist -- Professor Roger Miller. In addition, we have recently hired an undergraduate student to aid with data reduction, and a fourth meteorologist, Mr. David Floyd, who has two years' experience as a forecaster for a private consulting firm. The engineering work is being supervised by Mr. Robert Norton, with Mr. Juris Afanasjevs, Mr. Doyle Ford, Mr. Robert Oehlkers, and Mr. Gary Banta providing the technical expertise.

It is expected that all will continue to contribute to this study for the next year.

VIII. SUMMARY

The purpose of this study is to assess the economic benefit derived from the use of satellite data in short-range weather forecasting. We are working with a private weather service (who does not currently use this data source in any significant way in its forecast procedures) to determine the economic benefits to its clients of the service it currently provides. These client groups include city and state governments, gas and electric utilities, construction companies, commodity and fuel oil dealers, and others.

Once the control period is over, we will install equipment to permit WSC to incorporate satellite data into its forecasts, then re-calculate the benefits of those forecasts to its clients. The difference between the benefits accrued during the control and experimental periods (normalized for year-to-year differences in weather) will form the basis for our conclusions.

The goals for the first year were to determine the feasibility of the study we initially proposed; to select a consulting firm with whom to work; to decide on a method of approach and to begin the control phase while developing the hardware for the experimental phase. All these goals have been reached, and the results from the program's first year show great promise for the successful completion of this study.

APPENDICES

APPENDIX A: THE SELECTION PROCESS

i) CRITERIA FOR SELECTION OF A CONSULTING FIRM

Essential

1. The firm should not be using real time satellite data in any significant way (though should have some knowledge about it) to date, although it should otherwise be a technologically advanced company (make full utilization of "conventional" data).

2. Firm's clients should be a large and stable group containing a mix of public, industrial, and agricultural users (e.g. agriculture, construction, commodity forecasts, municipal services, transport, recreation, utilities).

3. Firm's clients should be located preferably in a region near a meteorologically data sparse area (East Coast), or at least in a relatively meteorologically active region (Midwest).

4. The firm or its clients should have available records over at least a 3 period detailing charges for services, use to which service was put, and ultimate outcome of use. In addition, there must be ready access from both consultant and clients of financial data for performing cost/effectiveness analysis.

5. The firm should be providing several types of services to its clients (e.g. short term forecasts, long term forecasts, emergency warnings, current weather data).

Preferable

6. The firm should preferably have at least one certified consulting meteorologist on its staff.

7. We prefer a firm that has internal quality control--ongoing evaluations of effectiveness of service, documented information on loss of accounts, etc.

Additional Criteria

8. It would be an asset if the firm provided the same service to more than one customer.

9. Firm's staff should be large enough to allow the availability of at least one liaison person who would be available to work with us when needed.

10. A large part of data processing and predicting should be done in-house.

11. Firm must be willing to pay the major portion of the cost of hardware to obtain this data.

ii) THE FOLLOWING INFORMATION SHOULD BE OBTAINED FROM THE CONSULTING FIRM

1. A list of clients who have received services for a year or more. This list should indicate the type of client (i.e. industrial, public, etc.) where this is not obvious, the length of time the firm has been a client, the type and frequency of forecast product(s) received, and the client's location. In addition, we should find out if the firm has a record of the accuracy of their services (outcome of the forecast) or whether such information would be available from the client. Would the various clients be amenable to giving out financial information as to the value of the forecast product to them (and whether this information exists) and the nature of the operation toward which the product was applied?

2. What type of internal quality control does the firm have in regard to effectiveness of service, documented information on the loss of accounts, etc.?

3. A description of the type of hardware being utilized by the firm, and their plans for future modification (NWS TTY circuits, fax machines, computers, software, etc.).

4. A description of their daily and weekly forecast operations. This could best be approached by considering the particular kinds of forecast products (e.g. emergency warnings, short term or long term forecasts) and describing how the firm goes about preparing this product--who does the forecasts and what information he relies upon. How do the forecasts differ from those produces by the NWS?

5. A detailed description of what is currently being done with satellite information (type of satellite information received and how this data is being included in the forecast). In addition, how much the <u>forecasters</u> know about it, how willing they would be to use it, and how much new training must be done.

6. An estimate of what sorts of satellite information, in what format and how frequent a reception of data would be most useful to the firm.

7. An estimate of what financial commitment the firm could make to rent or purchase such a system.

8. The number and professional expertise of the staff: we want to talk to as many staff members as possible; do they know about the program?

9. The name or designation of the person who would be the liaison with us in future work.

10. Why does the firm want to participate?

11. If possible, we would like to contact a few clients, get idea as to how cooperative they would be to participate, give financial data, talk, etc.

12. Accessibility of financial data from both clients and consulting firm.

iii) INTERVIEW QUESTIONNAIRE

STAFF ORGANIZATION AND PROCEDURES

1. Names of people on the staff, their duties and qualifications:

2. How many of these are part time? How many full time? How many hours are put in on an average working day?

3. What sort of professional contacts does the firm have with other meteorologists?

4. Who would be our liason person in the event we were to work with this firm? (Explain what we would expect from such a person).

5. Does the staff generally work alone or in pairs or in some other combination?

6. Pick out the names of two people on the staff and find out what their typical working day activities consist of (e.g. how many forecasts, what order of activities, what responsibilities).

7. Ask to see some typical operations in progress and summarize pertinent observations below:

(If possible, ask the observed staff the following questions)

a) What does the forecaster think of satellite data? Is it useful, and if so, how and when does he use it (be sure to ask when, in the process of forecasting, he decides to look at the satellite data)?

b) What would the forecaster do with an increased capability if he had it (describe the SSEC system).

8. Does the same forecaster always issue the same product? For how long? Are records kept for who does what?

QUALITY CONTROL

1. Does the firm archive its analyses and charts? How far back?

2. Is a record kept of the final product and the actual information conveyed to the client? How far back do these records go?

3. Does the firm keep a record of forecast accuracy or outcome?

4. Would the firm be willing to do any of the above for our records, if they are not doing so already?

5. Does the firm do any sort of quality control on a periodic or on-going basis (loss or gain in clients, effectiveness, speed, accuracy in various areas, etc.)? Describe the procedures used.

   a) Do you analyze these to improve service?

   b) Do you have specific procedures to review compliants by customers? How are they resolved?

6. Does the firm keep a record of fees charged to client which would be available for our inspection?

7. How are charges arrived at?--Flat rate? --Competitive market prices? --Time that goes into forecast?

PRESENT AND FUTURE SATELLITE DATA USAGE

1. What satellite data is currently received?

   a) What form?

   b) How processed?

2. In what types of forecasts is it being used and how? For what clients?

3. How is satellite data incorporated into the forecast (beginning, middle, end)?

4. Is the firm currently anticipating any changes in the above procedures? If so, how? Would it try to gain satellite data anyway?

5. What is your knowledge of the types and uses of satellite data? What types of applications have you seen?

6. Does anyone in firm have experience with satellite data?

   a) Where?

   b) When?

   c) What application?

d) How does he feel about applications to your business?

7. Do you think satellite data would: produce better product? reduce cost? produce more salable product?

8. If you invested in satellite data, would your fees change? How?

9. In what ways do clients benefit from your product? (ask it for clients we personally talk to)

10. How do you sell yourselves to a prospective client?

Daily and Weekly Forecast Operations (To be used as a guide--for each type of forecast)

1. Do you issue emergency warnings?

2. What are these?

3. Which clients receive each of the above?

4. Who is responsible for each?

5. What data are relied upon for each?

6. How or from whom are data obtained?

7. How are data processed or treated?

8. How is information assembled for forecast decisions?

9. Do you issue <u>daily</u> forecasts on regular basis?

10. Do you issue other regular short term forecasts?

11. Do you issue weekly forecasts regularly?

12. Do you issue longer range forecasts or outlooks?

FORECAST OPERATIONS

TYPE OF FORECAST/FREQUENCY

NAMES OF STAFF WHO DO THIS

WHAT EQUIPMENT AND READY-MADE ANALYSES USED (i.e. fax charts)

WHAT IN-HOUSE ANALYSES PERFORMED

WHAT IS FINAL FORM OF SERVICE

HOW CONVEYED TO USER

HOURS SPENT IN PREPARATION

PEOPLE NEEDED IN PREPARATION

STEPS IN PREPARATION OF FORECAST

HOW DO FORECASTS DIFFER FROM/COMPARE WITH THOSE ISSUED BY THE NWS?

HARDWARE DESCRIPTION GUIDE

This is best done by inspecting the equipment room itself and asking the use and function of each machine, what circuit it is wired to etc. Nevertheless a responsible person might be asked to list or recall the following:

(1) Teletypes

(2) Fax machines

(3) Radar Displays

(4) Your own private data sources (describe)

(5) Capabilities of the following:
computers

computer/calculators

plotters

software

(6) Do you use any advanced data storage and or display?
magnetic tapes

microfilm

CRT-terminal

(7) List any future modifications or additions to this equipment that are currently being planned.

(8) Assess the ease with which the hardware interface with our system.

GENERAL QUESTIONS

1. Why do you want to participate?

2. How much does your staff know about project?

3. What type of financial arrangement would you prefer for the hardware? Rental fee? Total monetary investment?

4. What type of turnover of forecasters do you have for a particular forecast product?

GENERAL QUESTIONS

1. Why do you want to participate?

2. How much does your staff know about project?

3. What type of financial arrangement would you prefer for the hardware? Rental fee? Total monetary investment?

4. What type of turnover of forecasters do you have for a particular forecast product?

RATING OF SUBJECTIVE FACTORS

	Excellent	Good	Fair	Poor	Notes
1. Pleasantness of working conditions					
2. Congeniality of head of firm and liaison person					
3. Staff interrelationships (friendliness, frictions, etc.)					
4. Enthusiasm of firm for the proposal					
5. Efficiency of and enthusiasm for the work shown by the staff					
6. Potential adaptability for change					
7. Enthusiasm of staff for proposal					

What impressed you favorably about this visit?

What impressed you unfavorably about this visit?

How would you estimate the willingness of forecasters to use satellite data?

APPENDIX B: LETTERS OF AGREEMENT WITH WEATHER SERVICES CORPORATION

SPACE
SCIENCE AND
ENGINEERING
CENTER

1225 West Dayton Street
Madison, Wisconsin 53706

THE UNIVERSITY OF WISCONSIN

7 December 1976

Mr. John Wallace
Mr. Peter Leavitt
Weather Services Corporation
131 A Great Road
Bedford, MA 01730

Dear Mssrs. Wallace and Leavitt:

This letter is to confirm our intention of working with your firm in a study of the economic benefits of meteorological satellite data, a proposal that has been funded by NASA, and which we expect to continue for a period of four years, from September 1, 1976, to August 31, 1980. In the remainder of this letter we have noted our initial expectations in regard to the goals and methods of this program.

One facet of this study is to establish and document the current weather service you are supplying to your clients and to establish a quantitative measure of the value of that service. Toward this end, we will need a record of the forecast products that you have supplied to your selected clients and their verification.

We will develop, with input from your firm, and within program limitations, the facilities and techniques required to supply you with meteorological satellite data in a form most likely to increase the value of your service to your clients. We do not guarantee, however, that the data actually supplied to you will augment the value of your services. We will be responsible for all costs and manpower associated with the installation and maintenance of any project hardware and software.

After a suitable period we will establish a quantitative measure of the value of the augmented service, again using a record of your forecast products and their verification as well as other information.

As we do not wish to give your firm an undue competitive advantage over other firms through our involvement, we ask that you not refer to this study in any advertising or promotion to gain new clients, and that you not display products obtained directly from our data installation in any communications media during the period of this study. This prohibition should continue until the end of the study or 31 August 1980 whichever is earlier. In addition, we hope that you do not alter your fees as a result of the acquisition of our data during the course of this study. Of course, our involvement with Weather Services Corporation in no way constitutes an endorsement of your firm over other meteorological consulting firms.

We also understand that SSEC will not be involved or responsible in any way in the actual preparation or dissemination of individual forecast products to your clients. The decision to use any or all of the services we provide shall rest with you.

Finally, it is our intention to keep all records confidential which might affect the competitive position of your firm in relation to other firms, or which might affect the relationships between your clients and you. We will view all information obtained from either you or your clients in that light.

Whether or not you have any comments or additions to these points, we would appreciate receiving written acknowledgement of this letter. We look forward to working with you and expect that our cooperation will be fruitful and interesting for both of our organizations.

Sincerely yours,

David Suchman

David Suchman

DS/bm

WEATHER SERVICES CORPORATION
131A GREAT ROAD, BEDFORD, MASSACHUSETTS 01730 • TELEPHONE: (617) 275-8860

December 14, 1976

Mr. David Suchman
Space, Science and Engineering Center
1225 West Dayton Street
Madison, Wisconsin 53706

Dear David:

We were delighted to receive your letter of December 7, 1976, stating your intention of working with Weather Services Corporation in your study of the ecomomic benefits of meteorological satellite data.

We agree to all stipulations and limitations mentioned in your letter, and will strive our utmost to carry this experiment through to a successful conclusion.

Cordially yours,

John E. Wallace

John E. Wallace
President

JEW:ep

APPENDIX C: SAMPLE QUESTIONNAIRES

FIRM: SNOW | ICE

The following are a list of general questions that we will use to try and assess the economic impact of the snow/ice forecasts you receive from Weather Services Corp. They are not intended to cover every possible situation, but if any major part of your operation is neglected by these questions, please indicate.

1. How much does it cost you (per hour) in snow/ice clearing operations for the followi[illegible]

a) salaries - Regular time for snow plowing based on a crew size of 41 men. If the work was done on overtime, the cost would be increased to — $225 per hr. / $340 per hr.
If there was no plowing and work consisted merely of sand and salting, the cost would be approximately 20% of these figures.

b) equipment: sanding - $10 per hr. per sander. The Village generally uses 4 sanders. Therefore, our cost would be $40 per hr.

salting - $12 per hr. per salter. The Village generally uses 2 salt trucks. Therefore, our cost would be $24 per hour.

plowing - $20 per hr. per truck. The Village generally uses 15 trucks. Therefore, our cost would be $300 per hr.

c) materials (e.g. sand, salt)
Salt - $22 per hr. using 2 trucks.

Sand - $ 6 per hr. using 4 trucks.

2. What are your costs to mobilize your equipment for

a) sanding - The sanding equipment is placed on our trucks at the beginning of the season and not taken off until the season is over. Therefore, there is no mobilization cost for each individual storm.

b) salting - The salting equipment is placed on our trucks at the beginning of the season and not taken off until the season is over. Therefore, there is no mobilization cost for each individual storm.

c) plowing - $90 per storm for mounting plows, if done during the regular work day.

Demobilize? - Approximately $50 to remove plows.

3. Are these costs (#1 or #2) affected by the amount and type of snow forecast? Please be specific.

The cost per hour for plowing snow would not be affected by the type or amount of snow. A large snowfall would naturally extend the number of hours that we would have to plow.

4. Are these costs (#1 or #2) affected by the time of day or day of the week? In what way? (Please be specific)

The only effect the time of day or the day of the week has on cost is on the overtime pay for our workers. Any snow removal done before 7 A.M. or after 4 P.M. on a weekday, or on weekends or holidays, would be paid at an overtime rate of 1.5% of regular pay.

5. Under what conditions do you <u>mobilize</u> for

a) sanding - Equipment on trucks during the entire season.

b) salting - Equipment on trucks during entire season.

c) plowing - Prediction of 3 or more inches of snow.

6. When during the course of a storm do your crews actually do

a) sanding - We usually sand and salt during the very beginning of a storm and after plowing has been completed.

b) salting - same as a)

c) plowing - When there is 3 inches of snow on the ground and it appears that the storm will continue, we generally start to plow.

7. Are your costs affected by the amount of snow received aside from having to keep your equipment in operation longer? How? (e.g. call in outside crews, call in backup crews, add more equipment)

Under very severe conditions, we might attempt to hire outside equipment, but this has not been done in the last 5 or 6 years.

8. If a storm strikes earlier than forecast (or if it were not forecast) what additional costs do you incur? (per hour)

None.

9. If a storm strikes later than forecast (or is of less intensity than forecast) what additional costs do you incur? (per hour)

If the storm is less intense than forecast, we may be stuck with a larger work force than actually needed. For example, we might only call in a crew of approximately 10 for salting and sanding; whereas, a full scale plowing operation encompasses approximately 40 people. Therefore, the additional cost per hour could be in the order of $150 to $250 per hour.

NAME OF RESPONDENT:

DATE: January 25, 1977

FIRM:

1. Number of Lane Miles of Road.

148 miles plus 65 acres of municipal lots. Three lots (about 10 acres) are given high priority because they serve basis needs of the city.

2. What was your total 1975-76 snow-ice budget?

CONFIDENTIAL

3. What other services do you receive from WSC?

Hurricane warnings. The forecast was used to get together a crew with front loaders to keep streets clear of limbs during the storm.

4. How often do you mobilize unnecessarily?

This happens occasionally. For example, with 4" on the ground and snow predicted to continue, crews were called in at 3 AM to have street clear by rush hour, but now stopped at 4 AM .
30 menXfour hoursXtime and one-halfX$5.50/hr = $990 lost.

5. How long does it take you to mobilize?

One hour or less. Plows are mounted if the forecast warrants during the normal work day (i.e. if forecast calls for snow during 'overtime hours'. Actual trigger for calling men in is police report of conditions for sanding and salting. Plowable accumulation initiates plowing. There is a tendency to leave plows on unless a period of good weather is definitely forecast.

6. In what ways would you save money through an improved forecast?

Savings in labor costs, especially in overtime (see question 4).

Firm: ELECTRIC UTILITY

This questionnaire is designed to help us assess the economic impact of the weather forecasts that you receive from Weather Services Corporation on your company. The questions were designed along the lines of your responses to our last short questionnaire. Although all the questions may not pertain to your operations or may not be in the format you use, please answer all relevant questions in the best way you know how. Thank you.

General Questions:

1. How many households do you supply with electric power?

CONFIDENTIAL

2. How many square miles do you service?

CONFIDENTIAL

3. What is your client mix (based on power delivered)?

Residential	37.3	%
Commercial	27.6	%
Industrial	25.7	%
Other (Please describe)	9.4	%

4a) What is your maximum peak load capacity?

3844 MW

b) What percentage of maximum peak load capacity is supplied by reserve generators?

Load factor of 0.6

5. What fraction of the power that you distribute is purchased from another source?

10% (1975 figures)

6. Do you sell power to others? -- What fraction of your normal production? _____

Yes

- **Maintenance** (when applicable)

1a) What sorts of weather events cause you to cancel *routine* maintenance or new construction?

Rain, snow etc. and cold weather of $10^{o}F$ or below.

For the following questions, also consider outside contractors if appropriate:

b) What is the minimum advance warning time necessary before such a cancellation that will minimize monetary loss?

On normal working days during scheduled working hours there is no penalty. At all other times, a twenty hour advance cancellation is required to avoid penalty.

c) What is a representative cost to you (in wages, equipment deployment) for failure to cancel in time?

Wages of $15/man plus fringe benefits. Number of men would depend on particular job. Equipment not normally deployed in advance.

d) Suppose that you cancel routine maintenance or construction unnecessarily due to the weather forecast. Do you incur any expenses which would have been avoided had the forecast proven correct? If so, how much?

No extra expense incurred if 20 hour advance notification given.

2a) What sorts of weather events cause you to call up extra crews or hold over crews to do *special emergency repair work* due to damage to the system?

Severe winds, gusting winds - branches and trees cause problems.
Lightning - fuse blowing etc.
Icing conditions - branch and tree problems. Sagging conductors etc.
Heavy rain - branches and trees - washing conditions that cause trees to lean or fall.

b) How far in advance of the occurrence of such a *forecast* event do you engage such crews? (Please include dependence of time of day, or day of week when appropriate.)

Forecasts are tempered by much judgement. Most weather emergencies are handled by local crews and by relocating system crews.

A hurricane, i.e., forecast to pass through the state, rather than on the fringes, would most likely require outside assistance. Additional outside crews would be requested from 4 to 8 hours prior to the predicted storm arrival.

Weekends would require greater advance notice as crew personnel are dispersed widely and require greater time to contact them for assembly.

c) What is the loss to you (in wages, cost of equipment deployment) per hour to engage most or all of your emergency manpower for a storm which is later than forecast or which never materializes at all?

Using premium rates, the cost of one three man line crew including wages, fringes, vehicle, room, meals etc. would be in the vicinity of $75 -$100/hour. This would be the cost of obtaining outside crews in advance. The number of crews requested would depend on an assessment of the path and severity of the forecasted storm; i.e., the last hurricane resulted in an initial request for 50 outside crews.

d) If you fail to engage crews in time to handle emergency work when it is first needed due to a surprise storm, for instance, do you incur extra costs? If so, how much?

-Failure to engage outside crews on time results in a slower restoration of service.

The penalties resulting are: criticism from public and governmental groups, loss of local crews for a longer period due to restoration activities and loss of revenue when service facilities are not in operation.

Load Forecasting (when applicable)

Summer

1. How far in advance do you use weather forecasts?

   12 hours.

2. Is there a *minimum* lead time *after which* a weather forecast update is not useful? What is it?

   Approximately 4 hours.

3a) What combination of weather and load conditions would require extra generators to be brought on-line beyond the spinning reserve, or the purchase of extra power from another source?

   Severe storm alerts, i.e., hurricanes, ice storms. We will anticipate transmission line outages, tidal effects on seashore plants, etc.. Units will be brought on line as security measures for localized areas.

b) How much of a delay is there between the need for and start of extra power production beyond that available from the spinning reserve?

   1. Jet units - 2 minutes
   2. Gas turbines - 15 minutes
   3. Steam - 2-6 hours after brief shutdown
      - 6-12 hours for cold unit

4. Would additional personnel be required to maintain the extra power production capacity? How many people? What would be their average wage rate? What is the minimum number of hours for which they would have to be paid?

   It does not appear that there is a wage penalty here. There would always be enough personnel in the plant to get a unit on the line.

   If additional personnel were required to operate the unit, they would be called in. Extra personnel would always be called in, as required, to meet the increased load no matter what the reason.

5. How much does a 1° change in wet bulb temperature affect your MW load in typical summer temperature ranges?

Not available.

6a) Is there a critical condition (temp, humidity, solar radiation) above which the *accuracy of the forecast* becomes crucial? How?

Temperature - variations of 10° F. or more from forecasts.
Humidity - at summer temperatures of approximately 75° F and an increase of himidity above 60% initiates critical conditions.
Solar radiation - generally has no wind influence and does not produce sustained load increase

b) In what way is this critical accuracy dependent upon the lead time of the forecast (12, 24, 36 hrs)?

12 hours or less.

7. How could a better forecast save you money in a peak load situation?

Peaking units or hydro would be used to shave sharp peaks if weather forecasts would specify temperatures and time of occurrence. This would eliminate the conservative attitude of scheduling units to cover possible longer periods of extreme temperature exposure.

8. How do rapid changes in cloud cover affect your load?

Approximately 2 to 6%

9. Do changes in cloud cover ever cause your load requirements to increase to the point where additional power generation capacity is necessary?

Yes.

Winter

1. Do you use weather forecasts as an aid for load forecasting in the winter?

   Yes.

2. How do the winter weather forecast formats differ from the summer formats?

   Formats are similar.

3. Do you experience "peak-load" problems in the winter? Under what circumstances?

   No.

COMMENTS:

NAME OF RESPONDENT ______

DATE March 10, 1977

Firm: GAS UTILITY

This questionnaire is designed to help us assess the economic impact of the weather forecasts you receive from Weather Services Corporation on your company. The questions were designed along the lines of your responses to our last short questionnaire. Although all the questions may not pertain to your operations or may not be in the format you use, please answer all relevant questions in the best way you know how. Thank you.

General Questions:

1. How many households do you supply with gas for space heating?

CONFIDENTIAL

2. How many square miles do you service?

CONFIDENTIAL

3. What is your client mix (of gas consumed)?

Residential	39.4	%
Commercial	18.7	%
Industrial	39.9	%
Other (Please describe)		%

4. What is your average annual cumulative quantity (ACQ) of gas distributed?

CONFIDENTIAL

5. What is your maximum daily quantity (MDQ) of gas distributed?

CONFIDENTIAL

<u>**Maintenance**</u> (when applicable)

1a) What sorts of weather events cause you to cancel *routine* maintenance **or new** construction?

Snow
Extreme Cold

For the following questions, also consider outside contractors if appropriate:

b) What is the minimum advance warning time necessary before such a cancellation that will minimize monetary loss?

Two Hours

c) What is a representative cost to you (in wages, equipment deployment) **for** failure to cancel in time?

Indeterminate

d) Suppose that you cancel routine maintenance or construction unnecessarily **due** to the weather <u>forecast</u>. Do you incur any expenses which would **have** been avoided had the forecast proven correct? If so, how much?

None

2a) What sorts of weather events cause you to call up extra crews or hold **over** crews to do *special emergency repair work* due to damage to the **system?**

(1) 4" of snow accumulation
(2) Temperatures below 21°F average

b) How far in advance of the occurrence of such a *forecast* event do **you** engage such crews? (Please include dependence of time of day, or **day** of week when appropriate.)

Implement plan based on 7:30 a. m. forecast and 3:30 p. m. forecast.

c) What is the loss to you (in wages, cost of equipment deployment) per **hour** to engage most or all of your emergency manpower for a storm **which** is later than forecast or which never materializes at all?

Indeterminate

d) If you fail to engage crews in time to handle emergency work when it is first needed due to a surprise storm, for instance, do you incur extra costs? If so, how much?

Yes - Indeterminate

<u>Load Forecasting</u> (when applicable)

1. How far in advance do you use weather forecasts?

30 days

2. Is there a *minimum* lead time after which a weather forecast update is not useful? What is it?

Yes - Two Hours

3. How much does a change in Effective Heating Degree Day (per degree) affect your load in typical winter temperature ranges?

1,000 - 1,500 MCF per each DDD

4a) Is there a critical condition (low temperature, high wind velocities, etc.) where the accuracy of the Effective Heating Degree Day forecast becomes more crucial to your operations? Please be specific.

Critical temperature = 10^oF (Avg.)

Critical wind velocity = 7 to 8 MPH

b) **In what way is this critical accuracy dependent upon the lead time of the forecast (24, 48, 72 hrs)?**

24 Hours

5a) **At what point does an unexpected load become so large that you are forced to buy gas from another source?**

At 55 DDD

b) **What is the (additional) cost incurred per cu. ft.?**

$5.00/MCF

c) **How could you have saved money by an accurate forecast?** ***Please be specific.***

Could have curtailed and issued conservation requests.

6a) Suppose that the forecast mistakenly leads you to prepare for a load greater than that which you actually need. What additional cost do you incur, which would not have been present had the forecast been correct?

Additional cost may run as high as \$2.00 - \$3.00 per MCF

b) How great an error has to be made in load forecasting for these costs to be incurred?

Average of 2^{o} - 3^{o} F

7a) At what point (if any) does an unexpected load become so large that you are forced to call up additional manpower?

At 55 DDD

b) What is the additional cost to you to do this over what your costs would have been had you *known in advance* what the exact load would be?

\$2.00 to \$3.00 per MCF

8. If the weather forecast compelled you to erroneously shut off (or not cut off) gas to an interruptible customer, are you hurt financially? In what way? Please be specific.

All gas under contract is on a take-or-pay proposition. If we cannot dump excess gas on interruptible customer once contracted for, we lose abaut $1.00 per MCF for all gas we are stuck with.

9. Do you use Weather Services for summer forecasting? Does this forecast format differ from winter forecasts?

Do not use weather service in summer

COMMENTS:

NAME OF RESPONDENT

DATE ____________

FIRM: FUEL OIL CO.

This questionnaire is designed to help us assess the economic impact of the weather forecasts you receive from Weather Services Corporation on your company. The questions were designed along the lines of your responses to our last short questionnaire. Although all the questions may not pertain to your operations or may not be in the format you use, please answer all relevant questions in the best way you know how. Thank you.

General Questions:

1. How many households do you supply with fuel oil for heating?

CONFIDENTIAL

2. What is your client mix (based on gallons of fuel oil delivered)?

Residential 90 % Commercial 10 %

Industrial — % Other (please describe) — %

3. What is your annual quantity of fuel oil distributed for 1976-1977?

10,000,000 gal

4. During the heating season how many drivers are normally engaged in keeping customers supplied? 16

How many employees/truck? 11 TRUCKS PER DAY 6 DAYS/WK

About how many deliveries does each driver make per day? 30

5. On the average how many hours per week does each driver normally spend delivering fuel oil to customers?

WINTER SEASON. 48-50

SUMMER SEASON. 40

6. How many total miles do your trucks drive per week?

1800 - 2000 MI/WK

7a. What is your average hourly wage paid to drivers?

CONFIDENTIAL

b. What is your hourly overtime rate paid to drivers?

TIME & A HALF

c. Is there a minimum number of hours guaranteed to drivers called up for overtime duty?

NORMALLY 10 HOURS EXCEPT EMERGENCY CALL WITH A 6 HOUR GUARANTEE

Questions Relating to Degree Day Forecasts:

1a. What is your optimum fuel oil drop per household?

200 GAL.

b. What is your average fuel oil drop per household?

185 - 190

2. How many days reserve of fuel do you aim to keep in a customer's tank just before refill?

4 - 5 DAYS.

3. Has any household that you service ever run out of fuel oil due to a bad weather forecast? In such an instance, what penalties did you incur?

No.

4. In planning to meet your optimum fuel oil drop per household, how do the following enter into your planning:

a. Cumulative degree days since the last drop

THIS IS THE MAIN. METHOD OF PROTECTING

b. Forecast degree days
Please explain.

WE USE THE FORCASTED DEGREE DAYS TO ESTIMATE THE NUMBER OF DELVS TO BE MADE & THE NUMBER OF TRUCKS & MANPOWER.

5a. How far in advance do you set up your delivery schedule?

BASIC ROUTES 2 DAYS.

b. What would cause you to modify this present schedule?

WILL CALL ACCTS OR PROTECTED BAD WEATHER

c. What is the minimum forecast lead time that would affect your planning?

1 DAY

6. By how many degree days must a forecast be <u>inaccurate</u> before it costs you money? (degrees 10 DEGREE DAYS. FOR EXTENDED PERIOD between the <u>inaccuracy</u> of the forecast and monetary loss? If so, what is it?

POSSIBLE RUN OUT

7. Do you ever schedule (a) overtime for drivers presently on shift or (b) call up additional drivers because of a predicted number of 'degree days?' If you can, please give a recent example.

IF WEATHER IS PREDICTED TO BE COLD FOR EXTENDED PERIOD WE WILL SCHEDULE DRIVERS ON OVERTIME TO KEEP AHEAD OF THE ACCUM. DEGREE DAYS.

If the prediction proved to be incorrect, how might it cost you money?

BY SCHEDULING DRIVERS ON OVERTIME VS REGULAR TIME.

Emergency Storm Warnings

1a. Do you step up your delivery rate because of a forecast of light snow (less than 4")? If you can, please give a recent example.

No.

If such a prediction proved to be incorrect, how might the accelerated deliveries (which were not necessary) have cost you money?

In overtime wages ____________________

Maintenance and materials ____________________

b. Do you step up your delivery rate because of a forecast of heavy snow (over 4")? If you can, please give a recent example.

YES. WE SCHEDULE TRUCKS ON OVER-TIME BASIS SO WE CAN PULL AHEAD

If such a prediction proved to be incorrect, how might the accelerated deliveries (which were not necessary) have cost you money?

In overtime wages ______$______________

Maintenance and materials ____________________

2. Has it recently happened that an unforecast storm, or one which arrived early, interfered with deliveries? How did it cost you money? Please be specific.

No - Forecasting is presently accurate.

3. How far in advance do you have to receive an emergency storm forecast [as in question (1)] in order to alter your delivery schedule?

4 DAYS.

We appreciate your cooperation. It sometimes happens that key information is not covered adequately by the questions, so please add anything you might think helpful to understand the impact of weather and weather forecasts on your business.

COMMENTS:

C

NAME OF RESPONDENT ____________

DATE 4/11/77

FIRM: CONSTRUCTION

This questionnaire is designed to help us assess the economic impact of the **weather** forecasts you receive from Weather Services Corporation on your **company.** The questions were designed along the lines of your responses **to our** last short questionnaire. Although all the questions may not be in **the** format you use, please answer all relevant questions in the best way **you** know how. Thank you.

1. **To which of the following weather conditions are you sensitive, and what is the threshold value in each to stop work?**

	% Clients Susceptable Summer	Winter		THRESHOLD VALUE
Rain: ("Weather Permitting" Clients')	66	90	Various	70% forecast heavy rain - cut crew by 1/2; 90% " " " cut crew 100%
Wind:	10	0	High Rise	40 to 50 mph gusts
High Temps:	20	0	Same Outdoor	86°F
Low Temps:	20	0	Side walks (April 15 to Nov 15)	35° and steady or falling
Snow:	0	90	All Outdoor	6" or more - operations cancelled on next day.
Not Wx Susceptable (Indoor)	4	10	Indoor Concrete	

2. Do any of the above cause materials loss? Under what conditions?

No, operations are cancelled for any threat of above conditions

3a. How far in advance do you receive forecasts?

4:30 PM each day

b. Is there a minimum lead time after which a forecast update is no longer useful? Please explain.

4:55 PM each day. At 6:30 AM, if forecast proves incorrect, attempt may be made to get workers, but this attempt is usually not successful.

4a. How far in advance do you schedule your operations?

At 5 PM previous day.

b. What is your minimum lead time needed to reschedule?

See (a)

c. When are workers told to report for the next day?

See (a)

They come in at 6 or 7 AM
↑
concrete sidewalks

d. Once called in, do you have to pay your men for a minimum number of hours?

8 hrs.

5a. What is the hourly wage rate paid to workers in weather sensitive areas?

CONFIDENTIAL

b. What is your average crew size in weather sensitive areas?

30 men in winter (Nov 15 to April 15)

55-60 men in summer.

5c. What is the hourly overtime rate paid to workers?

$1\frac{1}{2}$ X

d. Under what conditions are workers put on overtime?

Whenever contracters wants extra work to be done.

6. If a <u>forecast</u> causes you to <u>erroneously</u> cancel work, what penalties do you incur for:

Manpower:

None. They include this factor of forecast error in contract.

Materials:

0

Equipment:

0

7. If you <u>fail to cancel</u> work in inclement weather <u>due to a wrong forecast</u>, what penalties do you incur for:

Manpower:

$96/man.

Materials:

0

Equipment:

0

8. **Are there contract penalties for not finishing on a specific date? If so, have they ever been incurred because of bad weather forecasts?**

Rare.

9. How could your total profitability have been increased by improved weather forecast? Please explain.

Accuracy about 80% in forecast.
Inaccuracy mean loss as in question 7

We appreciate your cooperation. It sometimes happens that key information is not covered adequately by the questions, so please add anything you might think helpful to understand the impact of weather and weather forecasts on your business.

COMMENTS:

NAME OF RESPONDENT ____

DATE 4/26/77