THE UNIVERSITY OF MICHIGAN

INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

WEATHER FOR INDUSTRIAL PROFIT

George W. Reynolds

Research Associate
The University of Michigan

April, 1958

IP-283

WEATHER FOR INDUSTRIAL PROFIT

George W. Reynolds

Research Associate
The University of Michigan

Although many industries are already making profitable use of weather information, the tremendous profit potential from applying weather information to business problems has only begun to be realized.

In the retail domestic heating oil industry, at least some of the retailers keep a record of the accumulation of degree days* since each customer's tank was last filled. They can tell approximately how fast the oil is being used by watching the number of degree days. Consequently, they know when each tank needs re-filling, and can keep the tank filled without any effort on the customer's part. This office control is good customer relations and it cuts expenses by eliminating tank checking trips to customers' houses.

The retailer profits in several ways.

1. The number of trips he makes is kept to a minimum. His records help him to combine deliveries. He avoids filling only half-empty tanks.

2. He avoids many emergency calls from people who would forget to reorder. These calls often come at night.

3. His customers are happier because there is no effort on their part. They don't even have to let anyone in to check the oil level in the tanks. As a result they are less likely to change to gas or

* It is considered that the amount of heat required for a house is proportional to the amount by which the average temperature of the day is less than 65°F. Thus, 65 minus the average temperature of the day gives the number of degree days accumulated during that day. For example, suppose the average temperature at Detroit on January 15 was 30°. The number of degree days accumulated on January 15 would be 65 minus 30 or 35 degree days.

to another company.

Of course not all industries can take the weather information which is regularly available and apply it directly for a more efficient business operation. However working with a meteorologist many industries can make far more profitable use of weather knowledge than has been made in the past.

For instance, road contractors can cut costs through the thoughtful use of properly interpreted weather information. Low temperatures can be fatal to certain asphaltic mixtures. As a matter of fact, Michigan State Highway Department specifications for "hot plant mix" require that "Bituminous aggregate mixture shall not be produced or placed during rainy or threatening weather ---, or when the air temperature is less than 40°F, except by the approval of the engineer"(1). If the contractor could be advised 6 to 12 hours before 40° is reached, or before it starts raining, he could postpone delivery of the asphalt. The savings in a single day could run into the hundreds of dollars.

On the other hand, without properly available weather information, there might be an unnecessary cancellation of the order, resulting in lost time. This is costly in terms of equipment rental and payment for unused skilled labor. It also delays starting on the next job.

A reliable 6 to 12 hour weather forecast service can be obtained. It would be better than the free public service which is already available. The cost for several months would be less than the unnecessary waste of a single day.

The ultimate savings and earnings of weather information for business as a whole could easily run into millions of dollars annually. But this financial advantage is not going to come for nothing. It is going to require solid thinking and research effort in order to understand clearly and quantitatively

the best ways of using weather as a industrial tool.

When we speak of applying weather information to industrial planning, our first thoughts go to weather forecasts. Long range weather forecasts and seasonal outlooks are especially attractive. Mr. W. J. Sweeney, Vice President of the Esso Research and Engineering Company, recently told a meeting of the American Petroleum Institute that a seasonal forecast which is 50 per cent better than a climatic average would save the heating oil industry more than a hundred million dollars a year.(2) This estimate includes savings in tankage costs and unnecessary oil inventory. In addition, "costly, extraordinary refinery operations to provide 'last minute' adjustments for the actual winter severity" would be somewhat reduced. Further, the risk of running out of heating oil during an extra cold winter would be lessened.

But at the present time, according to Dr. H. C. Willett of the Massachusetts Institute of Technology, this type of forecast is correct only about 60 per cent of the time.(3) This is about 20 per cent better than chance. Unfortunately, the heating oil industry cannot afford to take a 40 per cent operational risk of being caught short.

Requirements for Successful Use

Several conditions are necessary for the successful application of weather knowledge to industrial problems.

1. The specific business activity must be sensitive to changes in weather conditions.

2. There must be some understanding of which of the weather factors are important, and the degree of their importance. If the understanding of the weather relationship is precisely expressed, in terms

of dollars, number of units, per cent, etc., more effective application of weather knowledge is likely. Except for obvious relationships this requires study.

3. Planning on the basis of a knowledge of this industry-weather relationship must be a practical possibility. If there is nothing you can do with it, any knowledge of the effects of weather on industrial operations is academic, rather than practical.

4. The application of dependable weather information must result in profit. The weather information must be sufficiently dependable so that the profits from successful applications exceed the losses accrued when incorrect weather information is supplied.

5. Unless the weather information is 100 per cent reliable, the effects of applying incorrect information must not be calamitous. Weather information is usually not 100 per cent reliable.

Weather affects almost all human activity in one way or another. The way we build our houses, the food we eat, the clothes we wear, the kind of car we drive, our vacation habits, our health, and our buying habits are all at least partially controlled by weather conditions. However, industrial activity is also affected by many other factors, such as farm income, advertising, styling, war, strikes, etc., which may in themselves be weather dependent. Frequently, the effects of these variables may be so great that they mask any effects that the weather has directly upon the activity.

Operations-Weather Categories

Perhaps one of the most difficult obstacles to industrial applications of weather information is the lack of a clear and precise understanding

of the uses to which this weather knowledge might be put. Operationally, weather considerations can be placed in three categories.

1. The effects of weather are obvious and understood, and sufficiently dependable weather information is available. An estimation of the amount to be gained by including weather considerations in business planning is possible.

For example, the Pacific Gas and Electric Company knows that below 65°F, a fall of one degree in the average temperature will increase the daily customer demand by 28 million cubic feet of gas.(4)

Consequently, they employ a meteorological staff to assist in gas load dispatching.

2. Weather conditions have a considerable and perhaps even obvious effect on industrial activity, but the magnitude of this effect is not understood. This may be the result of:

   a. the complexity of weather effect,
   b. the linkage with other weather sensitive conditions which also affect the operations,
   c. the independent variability of other factors which are operationally important, and
   d. the lack of thoughful effort being directed toward understanding this relationship.

For example, the trend in the weather influences the trend in the sales of clothing, but we don't know the quantitative relationships. Bad weather may reduce the attendance at a football game, or at an auction, or the number of down-town shoppers, but

again, we don't know the magnitude of the effect. For that matter, we don't even know just how to define "bad weather". However, these are not insurmountable problems. By the application of appropriate statistical techniques it should be possible to isolate many of the effects of weather from the effects of other influences.

3. The relationships between weather and business problems are sufficiently understood, but weather information which is reliable enough to use in planning is not available. The actual dependability of the weather data itself may be very high; but the industrial situation may be such that a single mistake costs more than all of the successes gain. Perhaps a single mistake could cause the company to become bankrupt or suffer a permanent loss of publis prestige. It maight even result in a public disaster.

Hurricane Threat

The Dow Chemical Company has taken steps toward correcting a situation in which thepossibility of disaster prevented the application of moderately reliable weather information.(5) Freeport is frequently under the threat of a hurricane. It used to be that any time a hurricane was forecast to pass anywhere near Freeport, the plant had to be closed down. Hurricane damage to a chemical plant in full operation could very well result in public disaster. Even a six-hour hurricane forecast is not totally dependable. Because of communication and weather analysis problems a forecast is already several hours old before the public receives it.

The Dow Company now has this problem pretty well in hand. They have their own weather department which is equipped with a radar weather set.

Whenever a hurricane is a potential threat, this weather section keeps an almost minute by minute track of its progress and development. The minute it heads for Freeport, they know it. The company is informed of significant changes in direction of movement and intensity as they occur, rather than according to a rigid time schedule.

As a consequence, their hurricane information is current rather than several hours behind actual hurricane progress. They now wait until the hurricane is much closer to Freeport before shutting down. Sometimes they do not shut down at all, even though the conditions would have required a shut down of several hours under the old system. A company spokesman has stated that the savings from avoiding one unnecessary shut down have paid for the cost of the entire weather installation, plus the meteorologist's salary for life.

Personalized Weather Service

In this case, a personalized weather service was the answer to the problem. The public agencies cannot consider the specific problems of each industry and must maintain a schedule of communications and announcements. The scheduling often delays the flow of information to the public, and the older information is, the less it is likely to apply to our current problems.

Furthermore, the communicated information must be somewhat general in nature. Otherwise, it would become too bulky to meet transmission schedules and broadcasting and newspaper requirements. A personalized service can usually increase the dependability of the information, and can attend to the detail which is significant to the particular industry which it serves.

Calling the Weather Bureau is not the answer. In one 24 hour period there were 374,000 telephone calls for weather forecasts in the New York City area alone. How much time could have been spent in understanding each individual problem?

Unfortunately, this specialized weather service is not available in all communities. Meteorological consultants are available in several of the metropolitan areas. These agencies act as advisers for industrial groups and business firms. There are not enough of these organizations to supply all of industry, if industry were suddenly to decide that it wanted to fully exploit the weather profit potential. The supply of industrial meteorologists will no doubt grow with industry's recognition of the profit to be derived from the thoughful application of weather information.

Types of Weather Services

Actually, although we so often think of "weather service" and "weather forecasting" as being synonomous, this need not be the case. The weather forecast is our least reliable weather information, and the longer the forecast period, the less reliable it is. There are four different phases of weather services for industry:

1. the application of current weather information,
2. the application of weather forecasts,
3. the application of climatological information, and
4. physical research.

Current Weather Information

Current weather information is among our most dependable weather knowledge. But in order to apply this knowledge we must be able to delineate

the effect that existing weather is having on the activity. This effect may be immediate or it may lag behind the weather events. Some study may be required in order to arrive at a dependable estimate of the magnitude of this effect.

The spectacular use of degree days in planning insecticide operations in Iowa is an example of the application of current weather information. Based upon the accumulation of degree days an onslaught of grasshoppers was forecast one week in advance. In this case the operational event lagged one week behind the weather event. As a consequence, the application of insecticide was timely. The damage to crops was considerably reduced. There was a savings of insecticide by applying it when it would do the most good.

Power companies use observed information to decide where to send repair crews after wind and ice storms. The Bear Hybrid Seed Corn Farms of Illinois plant when the soil temperature reaches 60°F for two days in a row. A fuel moisture measurement is used in determining the fire hazard in forest areas. Airplane pilots make their final landing and take-off decisions on the basis of existing weather. Decisions concerning crop dusting and spray fertilizing from aircraft depend upon conditions at the time of operation.

Another application of knowledge of the concurrent relationships between weather and sales activities can be made by the producer or the distributor. By knowing the present weather he can anticipate the flow of replacement orders. For example, if a could wave is being experienced, he may anticipate that dealers will be ordering heavily to replenish their battery inventory. Following a snowy period dealers are likely to be

restocking snow tires.

Actually, it is difficult to separate current weather information from very short range forecasts. It is often assumed that the observed conditions will continue to exist until the operation takes place.

Weather conditions frequently vary significantly over a matter of a few yards distance. Since conditions observed at one point may not be representative of conditions at the point of operations, the judgment of an experienced meteorologist is usually required in assessing the usefulness of a set of meteorological data.

Weather Forecasts

Weather forecasts may be classified into three groups: short range forecasts, long range forecasts, and weather outlooks. Short range forecasts are for periods up to 48 hours, long range forecasts are for three to five days, and weather outlooks, are for a month or a season.

Obviously, the farther we can see into the future, the more useful the information is likely to become, provided that it is reliable. But, unfortunately, the farther we try to see into the future, the more difficult is the seeing. Here is the catch. The dependability of a forecast decreases as the length of the forecast period increases.

Since the weather isn't as likely to change in a short period, forecasts for two or three hours in advance are bound to be more accurate than forecasts for two or three days in advance. Furthermore, it is possible to attain a reasonable degree of accuracy for a specific location when the forecasts are only for short periods.

For long range forecasts and weather outlooks it is only possible to indicate the general weather trend over a general area. Even these general

indications are right only about three-fifth of the time. Sometimes this is all the accuracy that is needed. Usually people are interested in specific locations and need a greater degree of reliability.

The possible applications of reliable, specific, long range forecasts and weather outlooks are almost infinite. The grain broker who knew the weather, day by day, for a month in advance would be at a tremendous advantage. Advertising can be gauged to expected weather conditions. Advertise rain-wear on wet days, snow tires on snowy and icy days, or air conditioners on hot, humid days. The farmer would know when to cut his hay. Dollar Day sales could be planned for a good day.

But all of this is idle dreaming. Accurate, precise long range forecasts and outlooks are for the some-distant future. However, useful long range forecasts and outlooks of a general nature are slowly improving. Reliable "above and below normal" forecasts may be a reality in 10 years or so.

Applications of short range weather forecasts are often underestimated. Utilities use short range forecasts in spotting emergency crews to repair damage done by ice and wind storms. They also use forecast and observed information in scheduling their power load. Cities use such short range forecasts to schedule snow plowing. Bakeries have found that people tend to buy different kind of goods during different weather conditions. Furthermore, they have found that a larger percentage of the bakery goods are sold downtown during bad weather. Consequently, they apply short range forecasts as well as current weather in programming their baking and the distribution of their products.

Citrus and other fruit growers use short range forecasts in deciding whether they are going to have to use their frost protection devices. They

then follow through by keeping constant observations of the temperature trend. Some New England trucking concerns base their decisions about which routes to use on short range weather forecasts. Off-shore drilling companies use long and short range forecasts and observations in regulating their activities.(6)

Ships take the "least time track," rather than shortest distance, between two points.(7) Airplanes do the same thing. The forecast of winds and waves is the main basis for selecting a "least time track" which is different from the shortest distance track. The ships get long range forecasts before they leave port. This is followed by radioed short range forecasts which help them to change their courses as conditions dictate. Not only do they avoid storms, but they also navigate to get the most favorable, or the least unfavorable, winds and waves.

Climatology

Climatology is the study of the weather of the past for whatever purpose. The Applied Climatologist applies weather history for practical benefit. The benefits from applied climatology are based on:

1. the assumption that the past will be reflected in the future, and
2. the discovery of relationships between weather and contemporary or subsequent operational activity.

For example, like many other retail operations the department store depends upon the physical presence of its customers. This physical presence is affected by weather conditions. Further, the customer's interests in different types of merchandise are weather sensitive.

Professor A. Thornton Steele of Western Reserve University made an applied climatology study in cooperation with the Younkers Department Store of Des Moines, Iowa.(8) As a result, Professor Steele obtained a "Weather Sales Expectancy Index" for an early Easter season. He obtained another for a late Easter season. The season was defined as the seven weeks period preceding Easter. A precise quantitative relationship was obtained. The index for a given day depended upon the temperature, wind velocity, snow depth, and the amount of sunshine during the day. This index ranged from 70 to 110 per cent. Now, how was it useful?

The department store industry has a method of estimating the expected volume of sales for each day of the year. This can be adjusted by applying the "Weather Sales Expectancy Index".

For example, suppose that non-weather factors indicated that tomorrow's sales would total $100,000. Let the forecast "Weather Sales Expectancy Index" be 109 per cent. Then management would anticipate handling an extra $9,000 worth of business. This might require the utilization of extra help. Perhaps help might be obtained temporarily from one of the "non-sales" departments.

If the forecast "Weather Sales Expectancy Index" were only 70 per cent, then management would plan on $30,000 less business. Perhaps sales help would be utilized in some other capacity. Or perhaps this is the time to arrange displays.

This index is also highly useful in evaluating a day's sales. Suppose the planned sales totaled $100,000 and the actual sales were only $75,000. The first thought might be that advertising was ineffective. Now if the "Weather Sales Expectancy Index" was only 70 per cent, sales

were actually $5,000 higher than might have been expected. The advertising manager should be applauded rather than censured. What is more important, apparently his advertising techniques were good ones and worth repeating.

Of course, this index will help should the reverse be true. That is, if sales were actually lower than should have been expected, weather-wise, the sales techniques should be examined.

This is a case of using weather history, climatology, to provide a basis for making operational judgments from current or forecast weather information. The relationships study is a phase of applied climatology.

A Michigan relailer reports that if, in June or July, there are four days in a row with temperatures above 90°F people rush to buy air conditioning equipment. A three day hot period brings no such rush. Only two or three days are necessary for a similar surge in fan buying. An applied climatology study would reveal the validity of this opinion.

Is four the magic number of days? Is 90 the significant temperature? These are the questions the applied climatologist would try to answer.

Climatology would also show such things as the earliest date such a period has ever occurred, the latest date of occurrence, and the calculated risk in assuming that the first of these periods would be after a certain date. There could be an estimate of the probability of such a sales-significant hot period after any selected date, or the probability of having at least so many a summer.

The store manager would then decide what calculated risk he wished to take in scheduling his fan and air conditioning inventory. And, of course, if this applies to an individual store, it would apply even more

to a distributor's problems.

Applied climotology is the research direction through which we (1) learn the usable relations between weather and business, and (2) obtain estimates of the probability of operationally significant weather occurring at a particular place and time.

Most climatological studies require considerable effort and can be afforded only by large industries, or by the pooling of resources of several small businesses. There is one bright spot in the picture for small businesses. Once the weather information is collected, it often can be used for a number of different unrelated purposes. This, of course, makes the information cheaper and may put it within the reach of the small, home-owned industry.

Need for Marketing Information

The biggest difficulty in relating weather to marketing is the unavailability of specific marketing information. We can get very reliable weather observations which can be interpreted by a professional weatherman. We can do a good job of short range forecasting. We can make climatic summaries of past weather conditions. But we can't always get the specific information on sales.

It has long been recognized that more rain protection gear is sold during rainy periods. How much more? A daily record of sales is necessary in order to relate weather conditions to the sales of rainwear. Such information is usually not available for a specific item. If it is, the information is hidden from the researcher because of competition instincts.

Suppose your weather consultant tells you that it is going to rain hard tomorrow for sure, and probably on the day after tomorrow, too. Will it

pay you to make a special rainwear display? How much rainwear should you bring out of the warehouse? Should you call up the distributor and try to get an additional supply? Should you put on an "extra" in the rainwear department? This additional effort costs you money. Will the additional volume of rainwear sales justify the extra effort? You can't get answers to these questions unless you have detailed figures showing the past relationships between rain and the sales of rainwear.

Physical Research

The final way in which meteorology may be useful to industry is through research, other than climatology. The air pollution problem is an important example of this.

Suppose that in the operation of a plant a certain amount of smoke is discharged into the atmosphere. This, of course, pollutes the air. Frequently, the pollution from a single plant may be irritating, but not dangerous. However, when a group of plants or a large plant system is considered, the combined effect can become serious. In October, 1948, 20 persons died and hundreds became ill during conditions of pollution around Donora, Pennsylvania. (9)

Occasionally, the citizens feel that a certain industry is polluting their air and demand that steps be taken to eliminate the pollution. Then the problem arises as to whether the stack effluents are really settling on the community, and, if they are, which chemicals are involved.

Obviously, when a new plant is built, its air pollution potential to a community should be considered. Just such a problem is presently being studied by a research group at The University of Michigan. They have set up

a model of a plant, with its stacks, and the surrounding area. Then smoke is emitted from the stacks and a wind of various speeds and directions is blown across the area. In this way they can study the problem and decide where the smoke and its chemicals are going to go. This becomes a special problem when atomic energy is involved.

Physical research is not, of course, limited to air pollution problems. Major contributions can be made to construction, architectrual, heating, ventilating, medical, fire hazard, agricultural, forestry, aging, drying, solar energy, and many other problems through the careful application of meteorological physics and model analogy.

Expensive Investigation Not Always Necessary

Very often the problem can be solved without extensive research. It is sometimes possible to reason through physical understanding, analogy with similar circumstances, and an understanding of climatology as to whether or not a particular operation will be successful as far as the weather is concerned. For example, an industry needing a supply of water, or a chocolate candy factory, does not locate in the desert for obvious reasons.

How to Make Weather Show a Profit

Now what can industry do to make weather show a profit? First, it must answer three questions:

1. How does weather affect operations? This must be reduced to specific considerations, such as the production, distribution, and storage of specific items, the behavior of specific machines, the behavior and absenteeism of personnel, scheduling of forces, inventory, buying, selling, etc. This can best be done with the

cooperation of a professional weatherman who is interested specifically in the application of weather knowledge to the problems of the specific business he is serving.

2. Would increased knowledge of weather conditions, past, present, or future, help in planning? Could it be used to prevent waste, or to make any operations more profitable, or perhaps make some new undertaking feasible? How far in advance must this information be made available in order to be usable?

3. Is this kind of weather information dependably available? How much is gained by using it, if it is right? How much is lost if it is wrong? What is the future effect on activities if the wrong decision is made? In other words, how does the ledger balance? These questions must be answered by the combined effort of the industry and the meteorologist. Any by-passing of either will result in an incomplete, and perhaps misleading solution.

After these three questions are answered, and not until they are answered, an industry is ready to make the decision about whether or not it would be profitable to apply weather information to its planning problems. If the answer is "yes" the meteorologist should then be able to suggest the most efficient method of getting the weather information.

A final remark. The lack of availability of proper weather information does not necessarily mean that it could not be made available. It probably means that specific effort has not been spent on developing that particular knowledge. Long range forecasts are not very dependable, but if 6, 12, or even 24 hour forecasts, or calculated risk information would be useful, then weather information can be applied for profit.

REFERENCES

1. "Standard Specifications for Road and Bridge Construction." Michigan State Highway Department, Lansing, Michigan. May 1957. p. 158.

2. Sweeney, W. J. "Importance and Need of Degree-Day Forecasting for the Petroleum Industry. Session on Weather Forecasting, 36th Annual Meeting, American Petroleum Institute. November 1956. pp. 3-7.

3. Willett, H. C. "Prospects for Reliability in Long-Range Forecasting." Session on Weather Forecasting, 36th Annual Meeting, American Petroleum Institute. November 1956. pp. 39-43.

4. Smith, C. P. "Meteorology in a Public Utility." Weatherwise, Vol. 6, No. 2 April 1953. pp. 49-50.

5. Jorgenson, R. C. and W. F. Gerdes. "The Dow Chemical Company Leads Industry in Using Radar for Hurricane Detection." Bulletin, American Meteorological Society, Vol. 32, No. 6, June 1951. pp. 221-224.

6. Glenn, A. H. "Weather and Oil." Weatherwise, Vol. 6, No. 2, April 1953. pp. 39 and 58.

7. Hartnett, W. J. "Weathermen for Industry." Bulletin, American Meteorological Society, Vol. 37, No. 10, December 1956. pp. 530-532.

8. Steele A. T. "A Department Store Uses Weather." Weatherwise, Vol. 6, No. 2, April 1953. pp. 42-43.

9. Schrenk, H. H. and others. "Air Pollution in Donora, Pa; Eqidemiology of the Unusual Smog Episode of October 1948." Public Health Bulletin No. 306. 1949. Page II.