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PREDICTING CEILING AND VISIBILITY WITH BOOLEAN PREDICTORS

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16. Abstract

Predictors were developed for Seattle 3-hour ceiling and visibility prediction which were Boolean combinations of the simple weather elements observed at a network of stations. These Boolean predictors were intended to provide a more complete formulation of the conditions which precede specified categories of ceiling and visibility than was possible with the simple predictors used in previous experiments. Better definition of the antecedent conditions should lead to improved probability forecasts of terminal weather. A test of one set of Boolean predictors was completed, and the verification results were examined. The forecasts made with these predictors were not as good as forecasts based on simple predictors. For reasons discussed in the report, the results of this test should not be considered as final; however, it does appear that the development and application of Boolean predictors of this type for a large number of terminals would be much more costly than the use of simple predictors.

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INTRODUCTION

The ceiling and visibility prediction techniques developed under Tasks 1 and 2 of the Federal Aviation Administration/Weather Bureau Agreement FA67WAI-131 were based on binary predictors defined in terms of the individual weather elements observed at a network of stations. Thus, a predictor would take the value 1 or 0 depending on whether the observed initial element (ceiling, visibility, wind, or humidity, etc) was or was not within a specified range. Meteorological theory and experience both indicate that the weather processes governing variations in ceiling and visibility are generally too complicated to be represented by such simple variables. Predictors representing combinations of several initial conditions may be more successful in forecasting significant changes in ceiling or visibility.

Task 4 of the Agreement provides for experiments with such combination predictors. Specifically, Task 4 reads in part as follows: "The Weather Bureau shall develop equations in which the variables represent the physical processes associated with cloud base height, cloud amount, fog, and other obstructions to vision. This task shall be a first step in that direction by using predictors in the REEP equations which are physically meaningful combinations of direct observations." Event 1 of the Work Statement reads, "A first set of derived predictors shall be prepared to enable a test of the approach to be made. --- predictors for ceiling and visibility shall be prepared for two projections, 3 and 8 hours, at each of three terminals, Seattle (SEA), San Francisco (SFO), and Los Angeles (LAX).

"The derived predictors shall be selected from surface data to represent the physical processes of warm advection, moisture advection, weather translation, non-adiabatic heating and cooling, and others.---"

"Other predictors shall be developed and tested to represent Boolean combinations of either simple or derived predictors, defined so as to indicate specific---conditions which have been determined from forecaster experience or from physical considerations to be related to the subsequent occurrence of significant ceiling or visibility variations."

Events 4 and 5 state, "REEP screening or other statistical regression programs shall be applied to the sets of derived predictors to develop prediction equations. --- The derived prediction equations shall be applied to independent data samples for test. The verification shall be compared with the verification previously computed---to determine whether any improvement has been achieved."

Thus, the intent of Task 4 was to test the effectiveness of more complex and more meaningful predictors and to compare the forecast verification with that of simple surface predictors. This report describes the results of the tests which were completed and discusses further tests which are desirable but were not conducted for reasons to be explained.

PREDICTOR DEVELOPMENT

The Statement of Work calls for the development of predictors to represent certain specific physical processes (e.g. advection of moisture), and other predictors based upon forecaster experience. These two kinds of predictors tend to be similar although not identical. Predictors to represent moisture advection, for example, might be constructed by taking the product of a pressure gradient (to represent the air flow) and the moisture gradient along the direction of flow. In practice, forecasters learn to identify situations in which, for example, the air reaching the terminal is becoming more moist by observing the wind direction at certain key stations together with the presence of clouds or precipitation at other stations. Attempts were made to define physical predictors in terms of the observations at network stations, but it was clear that station locations were not ideal for this purpose and a large amount of experimenting would be required to obtain the best predictors. Furthermore, new computer programs would be required for computing these predictors from large samples of data, and manpower for this work was not available. It was decided, therefore, that this approach should be taken only after developing and testing predictors based on forecaster experience.

Accordingly, the assistance of the Weather Bureau forecast staffs at the Los Angeles, San Francisco, and Seattle offices was obtained in developing predictors. Experienced forecasters in the Scientific Services Division of Weather Bureau Western Region Headquarters at Salt Lake City provided additional suggestions. A list of simple predictors which had already been computed from a large sample of hourly aviation weather observations in connection with Task 1 [1] was made available to the forecasters with a request to specify combinations of these which, in their experience, would tend to be followed by a single one of the five predictand categories of ceiling or visibility. These predictand categories are defined in Table I.

TABLE I. DEFINITION OF THE CEILING AND VISIBILITY PREDICTAND CATEGORIES

CATEGORY	CEILING Feet	VISIBILITY Miles
1	≤ 100	≤ 3/8
2	200 - 400	½ - 1 3/8
3	500 - 900	1½ - 2½
4	1000 - 2900	3 - 4
5	≥ 3000	≥ 5

The weather elements from which predictors were defined for all three terminals are given in Table II.

TABLE II. METEOROLOGICAL VARIABLES FROM WHICH DUMMY PREDICTOR VARIABLES WERE DEFINED

Predictor Variables and Units		
CIG	Ceiling Height	Feet
VIS	Prevailing Visibility	Miles
WDR	Wind Direction	Degrees from North
WSD	Wind Speed	Knots
WEA	Weather	12 Classes
DBT	Dry Bulb Temperature	°F
DPT	Dew Point Temperature	°F
SLP	Sea Level Pressure	Mb
TCA	Total Cloud Amount	Tenths
RLH	Relative Humidity	%
SCL	Lower Sky Cover	8 Classes
TOD	Time of Day	Local Standard
DOY	Day of Year	Days counting from Jan. 1.

Table III lists the stations in the networks for SEA, SFO, and LAX. The networks for SFO and LAX are tentative because the data samples for these stations have been only partially processed and some stations may not have adequate data for the period of record used in this study.

TABLE III. PREDICTOR STATION NETWORKS USED IN DEVELOPING BOOLEAN PREDICTORS FOR SEATTLE, SAN FRANCISCO, AND LOS ANGELES

SEATTLE

AST	Astoria, Ore.	OTH	North Bend, Ore.
BFI	Boeing Field, Seattle, Wash.	PAE	Paine Field AFB, Everett, Wash.
BLI	Bellingham, Wash.	PDX	Portland, Ore.
HQM	Hoquiam, Wash.	SEA	Seattle, Wash.
NEJ	Seattle NAS, Wash.	SMP	Stampede Pass, Wash.
NUW	Whidbey Island NAS, Wash.	TCM	McChord AFB, Tacoma, Wash.
OLM	Olympia, Wash.	TTI	Tatoosh Island, Wash.
		YKM	Yakima, Wash.

SAN FRANCISCO

ACV	Arcata, Calif.	RBL	Red Bluff, Calif.
FAT	Fresno, Calif.	RNO	Reno, Nev.
MER	Castle AFB, Merced, Calif.	SAC	Sacramento, Calif.
NGZ	Alameda NAS, Calif.	SFO	San Francisco, Calif.
NUQ	Moffet Field NAS, Calif.	SRF	Hamilton AFB, San Rafael, Calif.
OAK	Oakland, Calif.	SUU	Travis AFB, Fairfield, Calif.
PDX	Portland, Ore.		

LOS ANGELES

BFL	Bakersfield, Calif.	NTB	Los Alamitos NAS, Calif.
BUR	Burbank, Calif.	NTD	Point Mugu, Calif.
DAG	Daggett, Calif.	NZJ	El Toro MCAS, Calif.
EDW	Edwards AFB, Calif.	NZY	San Diego NAS, Calif.
LAX	Los Angeles, Calif.	SAN	San Diego, Calif.
LGB	Long Beach, Calif.	SBD	San Bernardino, Calif.

Definition of Boolean predictors from these variables is a two-step process. First, each variable is converted into a set of "dummy variables," that is, zero-one variables each of which represents a specified range of the original variable. A few of the dummy variables for SEA are given in Table IV for purposes of illustration. The complete set for SEA consists of 601 variables similar to these.

TABLE IV. A FEW OF THE DUMMY VARIABLES FOR SEATTLE. THE COMPLETE SET INCLUDES 601 VARIABLES OF THIS TYPE

VARIABLE NUMBER	DEFINITION
1	DOY 1 - 15
2	DOY 16 - 31
25	TOD 0100 - 0200 PST
26	TOD 0300 - 0400 PST
37	SEA CIG $\leq$ 100
38	SEA CIG 200
51	SEA VIS $\leq$ 3/8
63	SEA WDR NE - ESE
94	SEA RLH 91 - 96
95	SEA RLH $\geq$ 97
193	HQM WEA R-, R, R+
194	HQM WEA RW-, RW, RW-
299	TCM VIS ½ - 1 3/8
388	OLM CIG 200 - 400
584	SEA 3 Δ SLP $\leq$ -3.05
585	SEA 3 Δ SLP -3.05 to -2.05

The second step is the combining of these dummy variables into groups of two or more by means of the connectives "AND" or "OR". Table V shows four examples, two designed to predict ceiling and two designed for visibility. Number 1 for ceiling is intended to specify a weather situation occurring between the hours of 9:00 p.m. and 5:00 a.m. inclusive and during the period September 16 (DOY = 259) to November 15. The situation is characterized by low ceiling and low visibility at one or more of the stations SEA, PAE, and TCM or by RLH $\geq$ 90% or drizzle at SEA, and also by a pressure gradient which indicates weak flow from the north across Seattle. In the experience of the forecast staff, this situation would tend to be followed in 3 hours by ceilings of 100 feet or below at SEA, and a preliminary summary of the data indicated that this was the case 12% of the time. However, this set of conditions was satisfied (i.e., the value of this predictor was 1) only 69 times in the 10,000-case data sample. (Note that the DOY and TOD restrictions limit the predictor to only about 6% of the sample).

The other predictors shown in Table V define other situations described by forecasters. Number 36 for ceiling represents a persistent low ceiling situation. Number 8 for visibility was designed to aid in forecasting Category 4 visibility but was found to be useful for Categories 1 and 2 as well. Number 36 for visibility was selected for its inverse relationship to Category 5 as well as its direct relationship to Category 1 visibility.

TABLE V. DESCRIPTION OF TWO BOOLEAN PREDICTORS DEVELOPED FOR SEATTLE 3-HOUR CEILING FORECAST EQUATIONS AND TWO PREDICTORS FOR VISIBILITY FORECAST EQUATIONS. THE "AND" AND "OR" OPERATORS ARE INDICATED BY * AND + RESPECTIVELY. PARENTHESES DEFINE THE ORDER IN WHICH OPERATIONS ARE PERFORMED.

CEILING PREDICTORS

1. DOY 259-319 * TOD 2100-0500
   * ((SEA CIG ≤ 400 * SEA VIS ≤ 2½)
   + (PAE CIG ≤ 400 * PAE VIS ≤ 1 3/8)
   + (TCM CIG ≤ 400 * TCM VIS ≤ 1 3/8)
   + SEA RLH ≥ 90 + SEA WEA L)
   * ((AST SLP - BLI SLP) -2.0 to + 0.9)
   * SEA SLP ≥ 1020.0

36. (SEA CIG ≤ 100 + TCM CIG ≤ 200)
   * (SEA VIS ≤ 3/8 + NUW CIG ≤ 100
   + BFI CIG 200 - 1900)

VISIBILITY PREDICTORS

8. TOD 2100-0500 * SEA WSD ≤ 10
   * SEA WEA None, F, GF, H, K, or BD
   * (SEA VIS 4 - 7 + TCM VIS ≤ 5 + PAE VIS ≤ 5)

36. DOY 259-366 * (NUW SLP - PDX SLP) ≥ 0.0
   * ((SEA RLH ≥ 91 * (PAE VIS ≥ 5 + PAE VIS ≤ 1 3/8))
   + (SEA RLH 77-90 * (TOD 1900-0200
   + PAE VIS ≤ 1 3/8)))

For ceiling prediction, 62 predictors were defined including 5 predictors representing unconditional persistence of the initial ceiling and 18 representing persistence stratified by time of day and day of year. 43 predictors were defined for visibility, including 5 for persistence and 8 for stratified persistence. All predictors screened for SEA 3-hour ceiling prediction are listed in Appendix A and those for visibility are listed in Appendix B.

The persistence predictors in Appendix A are Numbers 49 to 54, inclusive, and in Appendix B are Numbers 37 to 41. The predictors which represent persistence stratified by day of year or time of day are Numbers 27 to 35 and Numbers 41 to 48 in Appendix A and Numbers 18 to 25 in Appendix B.

Under an earlier Weather Bureau contract, predictors were developed for these same three terminals (SEA, SFO, LAX) by investigators at San Jose State College, San Jose, California [2, 3]. These predictors were based on discussions with forecasters combined with investigations of the relationships of ceiling and visibility to dewpoint and changes in dewpoint, pressure differences across the network of stations, and pressure tendencies. Some of the predictors found by San Jose State to be most promising are included in Appendices A and B.

Similar sets of predictors were developed for San Francisco and Los Angeles, again in collaboration with the Weather Bureau staff forecasters at those two locations and by San Jose State College. The predictors which were completed are listed in Appendices C, D, and E and in the reports from San Jose State College [2, 3].

DATA PROCESSING

The new predictors developed for Seattle and San Francisco were based on networks of stations which were somewhat different from the networks used in previous studies. In earlier work it had been necessary to omit several stations because the 1949-1958 data sample was not readily available, but some of these stations were essential for representing pressure gradients and advective processes which the forecasters now urged for inclusion in the new list of predictors.

Data for six new stations for the Seattle network for the period 1949-1958 were acquired from the National Weather Records Center and surveyed for completeness. Five of these were sufficiently complete and were included in the development sample. Table III lists the stations in the new network.

It was decided to assemble data for the San Francisco network for a more recent period in order to facilitate the development of equations based on the new Boolean predictors, upper air data, and the output of numerical prediction models. Upper air data were available from another project for the period November 1961 through April 1968, therefore surface hourly observations were acquired from the National Weather Records Center for this period for the stations listed in Table III for San Francisco.

Data for the Seattle network were processed to produce four samples of 10,000 randomly selected cases each. The REEP screening program was modified to accept up to 40,000 cases as input, and preliminary screening runs for Seattle 3-hour ceiling prediction were attempted with 30,000 cases. However, the available forecast verification program could not be used to verify this many forecasts, and the screening output was found to contain some errors due to an erroneous weather variable.

Due to the short time remaining, further screening runs were limited to a 10,000-case sample. A portion of this sample (1800 cases) was withheld for testing, and screening runs were made on a sample of 8172 cases for both 3-hour ceiling and 3-hour visibility.

The Boolean predictors defined for Seattle included 23 persistence-type predictors for ceiling and 13 for visibility. Persistence tends to be the strongest predictor for short projections such as 3 hours, and it was desired to examine the effectiveness of the Boolean predictors alone without the direct effect of persistence in the equations. Screening runs for ceiling were made, therefore, on 62 predictors including persistence and 39 Boolean predictors excluding persistence. Similar runs for visibility were made on 43 predictors including persistence and 30 without persistence.

The resulting equations were used to make forecasts on both the development data and test data, and the forecasts were verified. The equations for SEA are listed in Appendices F and G.

Although a number of Boolean predictors were developed for San Francisco and Los Angeles (Appendices C, D, and E), the time and resources available for this Task were not adequate to permit data samples to be processed and screening runs to be made. The procedure was found to be much more difficult than had been planned, and steps were being taken to close the entire project at the time these predictors had been developed.

VERIFICATION

The objective of the verification subtask was to compare the effectiveness of prediction equations based on Boolean predictors with equations for the same terminals based on simple predictors. Both types of equations produce forecasts in probability terms; hence, the comparison was based on verification scores appropriate to probability forecasts. It is desirable that statements of the probability of a weather event be <u>reliable</u>; that is, over a period of time the event should actually occur with the frequency implied by the probability forecast. It is also desirable that the probabilities be as close to zero or to 100 percent as possible when the event does not occur, or does occur, respectively. These two characteristics of probability forecasts are measured by a single score called the P-score or the "Brier Score" [4]. The P-Score is the squared difference between the forecast probability and the so-called "observed probability" which is 1.0 for the predictand category which occurs and is 0.0 for all other categories. The P-Score for a given occasion (one forecast) is the sum of these squared differences for the five categories of ceiling or of visibility. The P-Score for a number of forecasts is the sum of all such squared differences divided by the number of forecasts, and is given by

$$P = \frac{\Sigma(F - D)^2}{N}$$

where F is the forecast probability,

D is the observed probability and is 1 if the event occurs and 0 if it does not occur,

N is the total number of forecasts.

P can be computed in this way for each predictand category, then the P-Score for all forecasts is the sum of the five P-Scores for the individual categories (see Table VI).

The P-Score is a measure of forecast error, therefore smaller P-Scores are better. It has a range of 0 to 2.

If the climatological frequencies of the ceiling and visibility predictand categories are known, these can be used as climatological probability forecasts, in which case the same forecast would be made every time, and no forecast skill is implied beyond the knowledge of climatology. Such forecasts can be verified to provide a control or base level of accuracy. Comparison of real forecasts with the climatological base is desirable because of the relationship between the P-Score and the frequency of the event being forecast. For a given forecast technique, P-Scores tend to be smaller (better) the lower the proportion of occurrences of the predictand event in the sample being verified.

To make this comparison with climatology, a P-Score is computed called the "climatological P-Score." This is the verification score that would be obtained if climatological forecasts were actually made and verified, but it can be computed directly from a knowledge of the frequency of occurrence of the event in the set of cases being verified. It is given by

$$P_c = \frac{n}{N} \left(1 - \frac{n}{N} \right)$$

where n is the number of occurrences of the event being forecast, and N is the number of forecasts.

The comparison of P and P_c was summarized by computing the percentage improvement of the actual forecasts over climatological forecasts,

$$\% \text{ Improvement} = \frac{P_c - P}{P_c} \times 100$$

This figure is negative if the actual forecasts are worse than climatological forecasts.

The forecasts made for SEA on both development data and test data were verified by means of the P-Score and were compared with the climatological P-Score. The results are given in Table VI, and the summary in terms of improvement over climatology is in Table VII.

The verification scores for forecasts made from simple predictors were computed during earlier experiments under a contract with Travelers Research Center [5]. At that time, the P-Scores were not computed on the test data for individual predictand categories. This accounts for the missing scores in Table VI.

TABLE VI. VERIFICATION OF SEATTLE 3-HOUR CEILING AND VISIBILITY FORECASTS ON DEVELOPMENT DATA AND TEST DATA. THE VERIFICATION STATISTIC IS THE P-SCORE. THE RESULTS OF THREE TESTS ARE SHOWN: (1) EQUATIONS DERIVED FROM SIMPLE PREDICTORS BASED ON SURFACE WEATHER DATA, (2) EQUATIONS DERIVED FROM BOOLEAN PREDICTORS PLUS PERSISTENCE PREDICTORS, AND (3) EQUATIONS DERIVED FROM BOOLEAN PREDICTORS ALONE.

CEILING P-SCORE	Category of Predictand					
DEVELOPMENT DATA	1	2	3	4	5	Total
1. Simple Predictors	.0113	.0173	.0341	.1091	.1192	.2910
Climat	.0184	.0193	.0396	.1526	.1960	.4259
2. Boolean + Persistence	.0119	.0199	.0379	.1133	.1215	.3044
Climat	.0191	.0225	.0438	.1517	.1993	.4364
3. Boolean only	.0134	.0206	.0398	.1181	.1315	.3234
Climat	.0191	.0225	.0438	.1517	.1993	.4364
TEST DATA						
1. Simple Predictors	*N.A.	N.A.	N.A.	N.A.	N.A.	.3039
Climat	"	"	"	"	"	-----
2. Boolean + Persistence	.0102	.0185	.0244	.0991	.1114	.2635
Climat	.0153	.0228	.0270	.1344	.1753	.3748
3. Boolean only	.0111	.0197	.0252	.1014	.1171	.2746
Climat	.0153	.0228	.0270	.1344	.1753	.3748
VISIBILITY P-SCORE						
DEVELOPMENT DATA						
1. Simple Predictors	.0152	.0185	.0258	.0389	.0611	.1595
Climat	.0257	.0210	.0287	.0444	.1086	.2285
2. Boolean + Persistence	.0168	.0201	.0265	.0428	.0695	.1757
Climat	.0272	.0226	.0289	.0463	.1128	.2378
3. Boolean only	.0190	.0204	.0267	.0442	.0733	.1835
Climat	.0272	.0226	.0289	.0463	.1128	.2378
TEST DATA						
1. Simple Predictors	N.A.	N.A.	N.A.	N.A.	N.A.	.1402
Climat	"	"	"	"	"	-----
2. Boolean + Persistence	.0145	.0143	.0242	.0330	.0624	.1483
Climat	.0275	.0148	.0254	.0353	.0949	.1979
3. Boolean only	.0183	.0149	.0244	.0340	.0651	.1566
Climat	.0275	.0148	.0254	.0353	.0949	.1979

* Not Available

TABLE VII. VERIFICATION OF BOOLEAN PREDICTION EQUATIONS IN TERMS OF THE PERCENTAGE BY WHICH THE EQUATIONS IMPROVE OVER CLIMATOLOGICAL FORECASTS.

	PERCENT IMPROVEMENT OVER CLIMATOLOGY					
	Category of Predictand					
	1	2	3	4	5	Total
CIG						
DEVELOPMENT DATA						
Simple Predictors	39	10	14	29	39	32
Boolean + Persistence	38	12	14	25	39	30
Boolean only	30	8	9	22	34	26
TEST DATA						
Boolean + Persistence	33	19	10	26	37	30
Boolean only	27	14	7	25	33	27
VIS						
DEVELOPMENT DATA						
Simple Predictors	41	12	10	12	44	30
Boolean + Persistence	38	11	8	8	38	26
Boolean only	30	10	8	5	35	23
TEST DATA						
Boolean + Persistence	47	3	5	7	34	25
Boolean only	34	-1	4	4	31	21

DISCUSSION

Three types of forecasts are compared in Table VI. P-scores are given for forecasts based on simple predictors (including persistence), on Boolean predictors including persistence, and on Boolean predictors alone. In each case, the P-score for "no-skill" climatological forecasts is listed for reference. These comparisons are incomplete in several ways. No verification of simple predictors without persistence was conducted to provide a direct comparison of simple and Boolean predictors. However, such a comparison is of minor interest because the inclusion of persistence predictors has always improved the quality of the forecasts.

The best forecasts of all might be expected from equations based on all three types of predictors--persistence, simple, and Boolean. Because of unexpected data processing difficulties, the resources available for this task were exhausted before such equations could be developed, and the comparatively poor performance of Boolean predictors as indicated in Tables VI and VII seemed to be sufficient reason not to divert resources from other tasks or to delay progress on other tasks in order to pursue this approach.

Furthermore, it would have been desirable to compute and verify forecasts using the simple predictor equations on the identical data samples used for the Boolean predictors. Both types of equations were derived from 10,000 cases drawn from the same 10-year period, but the older data samples were no longer available and new samples had to be drawn for the Boolean predictor test.

In summary, the simple predictors performed slightly better than the Boolean predictors. Specifically, the comparison of Boolean equations including persistence with simple predictors including persistence on development data (Table VII) in terms of percentage improvement over climatology was as follows:

	Simple	Boolean
CIG	32	30
VIS	30	26

Examination of the scores for individual categories of ceiling and visibility indicates that the Boolean predictors performed much better on categories 1 and 5, corresponding to the lowest and to the highest ceilings and visibilities, than on the intermediate ranges. Most of the Boolean predictors were designed by the forecasters to represent bad weather situations, and it is encouraging to note that verification scores reflect this.

Tests of this kind on longer projections and at other stations would have been desirable, but there is no obvious reason to expect different results. More than 20 man-days of effort on the part of the forecast staff at Seattle, plus a similar effort by others involved in the project were required to develop the Boolean predictors for three-hour ceiling and visibility for this one terminal. This does not include the labor of editing, coding, and screening these predictors. To a great extent all terminals are different, and a similar effort would be required for each terminal. Although the procedure could be somewhat streamlined, it is, nevertheless, impracticable to expend an effort of this magnitude for each of several hundred terminals.

The computational effort presumably could be reduced to a reasonable level. The difficulties in this test were of two principal kinds:

1. Because the predictors were very complex, they were difficult to code and punch without error for entry into computer programs,

2. the computer programs themselves were difficult to write and to check.

Note that the only successful computer runs were those with only 10,000 case samples. Although the program was revised to screen 30,000 cases, it was not used successfully on this task.

Perhaps the strongest argument against further pursuit of this approach is that the physical processes which are presumed to be represented by these Boolean predictors based on network observations are better represented and more accurately forecast by the products of numerical weather prediction. Numerical prediction of fields of atmospheric moisture, vertical stratification of temperature, and wind fields, all in the lower troposphere, are beginning to appear in sufficient detail and accuracy to use in ceiling and visibility forecasting.

SUMMARY

Comparison of 3-hour ceiling and visibility forecasts for Seattle based upon Boolean predictors with forecasts based upon simple predictors and on Boolean predictors plus persistence indicates that the Boolean predictors alone were not as effective as Boolean predictors plus persistence, and that the simple predictors produced the best forecasts. Conclusions from this test must be drawn with caution since forecasts for only one projection for one terminal were tested.

The possibility remains, also, that equations derived by screening all three types of predictors simultaneously, simple, Boolean, and persistence, would produce the best forecasts of all.

Time did not permit the computation and verification of simple predictor forecasts on the same sample of test data as that used to test the Boolean equations. The simple predictor equations were available only in the form of computer printed output, and the labor involved in preparing these equations for a test on a new data sample did not seem to be justified by the results shown in Tables IV and V.

CONCLUSIONS

The results of this limited test of the application of the Boolean predictor approach to terminal forecasting were not encouraging. A great many difficulties were encountered in obtaining predictor screening runs on the computer and in deriving the prediction equations. Even under the assumption that computational difficulties could be eliminated, the amount of labor involved in defining Boolean predictors for each of the hundreds of terminals for which forecasts are required makes this approach impractical.

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APPENDIX A

BOOLEAN PREDICTORS FOR SEATTLE 3-HOUR CEILING PREDICTION

The 62 predictors in this list are two-valued variables. Each variable has the value 1 if all the conditions specified in its definition are satisfied, otherwise it has the value 0. Prediction equations are derived by regression screening applied to these predictors. The definitions of the abbreviations for weather element and station used in this list are given in Tables II and III, respectively. The Boolean operators "AND" and "OR" are represented in these predictors by * and +, respectively. The symbol $3\Delta P$ refers to the sea level pressure change over the last three hours.

1. DOY 259-319 * TOD 2100-0500 * ((SEA CIG ≤ 400 * SEA VIS ≤ 2½)
   + (PAE CIG ≤ 400 * PAE VIS ≤ 1 3/8) + (TCM CIG ≤ 400 * TCM VIS ≤ 1 3/8)
   + SEA RLH ≥ 91 + SEA WEA L) * (AST SLP - BLI SLP) -2.0 to +0.9
   * SEA SLP ≥ 1020.0

2. DOY 320-074 * SEA CIG ≤ 2900 * SEA DBT ≤ 39 * SEA DPT ≤ 32
   * (BLI SLP - PDX SLP) ≥ 3.0 * (SEA SLP ≤ 999.9 + SEA 3ΔP ≤ -2.1)
   * (SEA WEA S,SW + PAE WEA S,SW + TCM WEA S,SW + NEJ WEA S,SW)

3. DOY 259-074 * TOD 2100-0500
   * ((SEA CIG ≤ 900 * SEA VIS ≤ 4)
   + (PAE CIG ≤ 900 * PAE VIS ≤ 4)
   + (TCM CIG ≤ 900 * TCM VIS ≤ 4)
   + SEA RLH ≥ 91 + SEA WEA L,ZL)

4. DOY 259-074 * TOD 2100-0500
   * ((SEA CIG 200-900 * SEA VIS ≤ 4)
   + (PAE CIG ≤ 900 * PAE VIS ≤ 4)
   + (TCM CIG ≤ 900 * TCM VIS ≤ 4)
   + (SEA RLH ≥ 91 * SEA WSD 5 - 9)
   + SEA WEA L,ZL)

5. DOY 075-166 * TOD 2100-0500
   * (SEA CIG 500-900 + SEA TCA ≤ 3/10)
   * SEA VIS ≤ 4 * (OLM SLP - BLI SLP) 0.7 to 2.0
   * (SEA WEA L,ZL + OLM CIG ≤ 800 + TCM CIG ≤ 700)

APPENDIX A (Continued)

6. DOY 167-258 * TOD 2200-0500
   * (SEA CIG 500-900 + SEA TCA $\leq$ 3/10)
   * SEA VIS $\leq$ 4 * (OLM SLP - BLI SLP) 0.7 to 2.0
   * (SEA WEA L,ZL + OLM CIG $\leq$ 800 + TCM CIG $\leq$ 700)

7. DOY 259-074 * TOD 1900-0600
   * (SEA CIG 500-900 + SEA TCA $\leq$ 3/10)
   * SEA VIS $\leq$ 4 * (OLM SLP - BLI SLP) 0.7 to 2.0
   * (OLM CIG $\leq$ 800 + TCM CIG $\leq$ 700)

8. DOY 259-074 * SEA CIG 500-900
   * SEA WEA L,ZL

9. DOY 121-258 * TOD 2300-0500
   * SEA CIG $\leq$ 1400 * ((OTH SLP - SEA SLP) $\geq$ 2.0
   + (SEA WDR S - W * SEA WSD $\geq$ 4)
   + (OLM SLP - BLI SLP) $\geq$ 1.0)

10. DOY 121-258 * TOD 2100-0500
   * ((OTH SLP - SEA SLP) 1.0 to 3.0
   + (SEA WDR S-W * SEA WSD 4 - 12)
   + (OLM SLP - BLI SLP) $\geq$ 1.0
   + (AST SLP - BLI SLP) $\geq$ 1.5)
   * (HQM CIG 800-1400 + AST CIG 800-1400)

11. (DOY 244-166 + (DOY 167-243 * TOD 2100 0500))
   * (SEA CIG 500-1900 + SEA TCA 1/10 - 4/10)
   * (OLM CIG $\leq$ 900 + TCM CIG $\leq$ 900)
   * (OLM SLP - BLI SLP) $\geq$ 1.0

12. DOY 121-258 * TOD 0500-1000
   * SEA CIG $\leq$ 900 * SEA VIS $\geq$ 3

13. SEA CIG $\leq$ 4900 * SEA TCA $\geq$ 7/10
   * (SEA WEA R,RW + HQM WEA R,RW
   + OLM WEA R,RW + TCM WEA R,RW)
   * ((SEA WDR SSE-SW * SEA WSD $\geq$ 4)
   + SEA SLP $\leq$ 999.9 + SEA 3ΔP $\leq$ -2.1)

14. DOY 121-258 * TOD 1900-1000
* SEA CIG $\leq$ 2900 * SEA WSD $\geq$ 6
* SEA TCA $\geq$ 9/10 * (SEA WDR S-WSW
+ (OTH SLP - SEA SLP) $\geq$ 2.0 + (OLM SLP - BLI SLP) $\geq$ 1.0)

15. DOY 121-258 * TOD 0000-0600 * HQM CIG $\leq$ 1400
* (OLM CIG $\leq$ 2900 + TCM CIG $\leq$ 2900)
* ((SEA WDR S-WSW * SEA WSD $\geq$ 4)
+ (OTH SLP - SEA SLP) $\geq$ 4.0 + (OLM SLP - BLI SLP) $\geq$ 1.0
+ (AST SLP - BLI SLP) $\geq$ 2.0)

16. TOD 1700-0600 * SEA CIG $\geq$ 3000 * HQM CIG $\leq$ 1900
* ((HQM SLP - SEA SLP) $\geq$ 3.0 + (OTH SLP - SEA SLP) $\geq$ 4.0)

17. TOD 0700-1600 * SEA CIG $\geq$ 3000 * HQM CIG $\leq$ 1900
* ((HQM SLP - SEA SLP) $\geq$ 3.0
+ (OTH SLP - SEA SLP) $\geq$ 4.0)

18. TOD 0700-1600 * SEA CIG 1000-2900
* (OTH SLP - SEA SLP) $\geq$ 2.0

19. TOD 1700-0600 * SEA CIG 1000-2900
* (OTH SLP - SEA SLP) $\geq$ 2.0

20. SEA CIG $\geq$ 3000 * SEA RLH $\leq$ 79
* (YKM SLP - SEA SLP) $\geq$ 4.0

21. SEA CIG $\geq$ 3000 * SEA RLH $\leq$ 79
* ((YKM SLP - SEA SLP) $\geq$ 4.0 + (SEA WDR N-E
* SEA WSD $\geq$ 5))

22. SEA CIG $\geq$ 3000 * SEA WDR NNW-E
* SEA WSD $\geq$ 4

23. SEA CIG $\geq$ 3000 * SEA VIS $\geq$ 6 * SEA TCA $\geq$ 6/10
* (SEA WEA None, F,GF,H,K
+ OLM WEA None, F,GF,H,K
+ TCM WEA None, F,GF,H,K)

APPENDIX A (Continued)

24. SEA CIG $\geq$ 3000 * SEA VIS $\geq$ 7 * SEA TCA $\geq$ 6/10
* ((YKM SLP - SEA SLP) $\geq$ 4.0 + (OTH SLP - SEA SLP) $\leq$ 0.0)

25. DOY 152-273 * TOD 0700-1200
* SEA CIG 1000-2900 * (SEA WEA None, F,GF,H,K
+ OLM WEA None, F,GF,H,K + TCM WEA None, F,GF,H,K)

26. DOY 001-090 * (SEA RLH $\leq$ 76 + ((NUW SLP - PDX SLP) $\geq$ 0.00
* (TTI SLP - YKM SLP) $\leq$ -0.1 * OLM CIG $\geq$ 3000)
+ (SEA RLH 77-90 * TOD 1100-1800))

27. DOY 320-090 * TOD 0000-0500 * SEA CIG $\leq$ 100

28. DOY 320-090 * TOD 2300-0500 * SEA CIG 200-400

29. DOY 001-090 * TOD 2300-0500 * SEA CIG 500-900

30. DOY 001-090 * TOD 2300-0500 * SEA CIG 1000-2900

31. DOY 320-090 * TOD 0800-1600 * SEA CIG 500-1900

32. DOY 001-090 * TOD 0800-1600 * SEA CIG 1000-2900

33. DOY 320-090 * TOD 1700-2200 * SEA CIG $\leq$ 400

34. DOY 259-090 * TOD 1700-0500 * SEA CIG $\leq$ 100

35. DOY 259-090 * TOD 2300-0600 * SEA CIG 1000-2900

36. (SEA CIG $\leq$ 100 + TCM CIG $\leq$ 200) * (SEA VIS $\leq$ 3/8
+ NUW CIG $\leq$ 100 + BFI CIG 200-1900)

37. DOY 001-090 * ((SEA RLH $\geq$ 77 * OLM CIG $\leq$ 900
* (NUW SLP - PDX SLP) $\geq$ 0.0 * (TTI SLP - YKM SLP) $\leq$ -0.1)
+ (SEA RLH $\geq$ 91 * (((NUW SLP - PDX SLP) $\leq$ -0.1
* (TTI SLP - YKM SLP) $\leq$ -0.1) + (TOD 1900-1000
* (NUW SLP - PDX SLP) $\leq$ -0.1 * (TTI SLP - YKM SLP) $\geq$ 0.0)
+ (OLM CIG $\leq$ 2900 * (NUW SLP - PDX SLP) $\geq$ 0.0
* (TTI SLP - YKM SLP) $\geq$ 0.0)))
+ (TOD 1900-1000 * SEA RLH 77-90
* (NUW SLP - PDX SLP) $\geq$ 0.0 * (TTI SLP - YKM SLP) $\geq$ 0.0))

APPENDIX A (Continued)

38. DOY 091-151 * TOD 1900-1000 * SEA RLH ≥ 91
* (TTI SLP - YKM SLP) ≥ 2.0
* ((TTI SLP - YKM SLP) - (NUW SLP - PDX SLP)) ≥ 0.0
* ((TTI SLP - YKM SLP) + (NUW SLP - PDX SLP)) ≥ 0.0

39. DOY 152-258 * ((SEA RLH ≥ 91 * ((TOD 1900-0200
* (NUW SLP - PDX SLP) ≤ -1.1 * (TTI SLP - YKM SLP) ≥ + 2.0)
+ (OLM CIG ≤ 900 * ((NUW SLP - PDX SLP) ≥ + 1.0
+ (TTI SLP - YKM SLP) ≤ +1.9)) + (OLM CIG ≤ 2900
* (NUW SLP - PDX SLP) - 1.0 to+0.9
* (TTI SLP - YKM SLP) ≥ + 2.0))) + (SEA RLH 77-90
* TOD 1900-0200 * (NUW SLP - PDX SLP) -1.0 to +0.9
* (TTI SLP - YKM SLP) ≥ 2.0))

40. DOY 259-366 * ((SEA RLH ≥ 91 * OLM CIG ≥ 3000
* ((TTI SLP - YKM SLP) - 3(NUW SLP - PDX SLP)) ≤-0.1)
+ (((TTI SLP - YKM SLP) - 3(NUW SLP - PDX SLP)) ≥ 0.0
* ((SEA RLH ≥ 91 * (OLM CIG ≥ 3000 + OLM CIG ≤ 900))
+ (TOD 1100-1800 * SEA RLH 77-90 * OLM CIG ≤ 2900))))

41. DOY 274-059 * SEA CIG ≤ 100

42. DOY 274-059 * SEA CIG 200-400

43. DOY 244-059 * SEA CIG 500-900

44. DOY 091-273 * SEA CIG ≥ 3000

45. DOY 274-059 * TOD 0000-0500 * SEA CIG ≤ 100

46. DOY 182-304 * TOD 0200-0500 * SEA CIG ≤ 400

47. DOY 091-273 * TOD 1000-1600 * SEA CIG ≥ 3000

48. DOY 121-273 * TOD 1000-2000 * SEA CIG ≥ 3000

49. SEA CIG ≤ 100

50. SEA CIG 200-400

51. SEA CIG 500-900

52. SEA CIG 1000-2900

APPENDIX A (Continued)

53. SEA CIG ≥ 3000

54. SEA CIG ≤ 400

55. DOY 001-090 * (SEA RLH ≤ 76 + (OLM CIG ≥ 3000
* (NUW SLP - PDX SLP) ≥ 0.0 * (TTI SLP - YKM SLP) ≤ -0.1)
+ (TOD 1100-1800 * SEA RLH 77-90
* (((NUW SLP - PDX SLP) ≥ 0.0 * (TTI SLP - YKM SLP) ≥ 0.0)
+ ((NUW SLP - PDX SLP) ≤ -0.1 * (TTI SLP - YKM SLP) ≤ -0.1)
+ ((NUW SLP - PDX SLP) ≤ -0.1 * (TTI SLP - YKM SLP) ≥ 0.0)))
+ (SEA RLH ≥ 91 * ((TOD 1100-1800
* (NUW SLP - PDX SLP) ≤ -0.1 (TTI SLP - YKM SLP) ≥ 0.0)
+ (OLM CIG ≥ 3000 * (NUW SLP - PDX SLP) ≥ 0.0
* (TTI SLP - YKM SLP) ≥ 0.0))))

56. DOY 091-151 * (((TTI SLP - YKM SLP) ≤ +1.9
+ ((TTI SLP - YKM SLP) - (NUW SLP - PDX SLP)) ≤ -0.1
+ ((TTI SLP - YKM SLP) + (NUW SLP - PDX SLP)) ≤ -0.1)
+ (SEA RLH ≤ 76 * (TTI SLP - YKM SLP) ≥ 2.0
* ((TTI SLP - YKM SLP) - (NUW SLP - PDX SLP)) ≥ 0.0
* ((TTI SLP - YKM SLP) + (NUW SLP - PDX SLP)) ≥ 0.0))

57. DOY 152-258 * (SEA RLH ≤ 76 + (((NUW SLP - PDX SLP) ≥ 1.0
+ (TTI SLP - YKM SLP) ≤ +1.9) * (SEA RLH 77-90
+ (SEA RLH ≥ 91 * OLM CIG ≥ 3000))
+ (TOD 1900-1000 * SEA RLH 77-90
* (NUW SLP - PDX SLP) - 1.0 to +0.9
* (TTI SLP - YKM SLP) ≥ 2.0))

58. DOY 259-366 * ((((TTI SLP - YKM SLP)
- 3(NUW SLP - PDX SLP)) ≤ -0.1 * (SEA RLH ≤ 90
+ (SEA RLH ≥ 91 * OLM CIG ≥ 3000)))
+ (((TTI SLP - YKM SLP) - 3(NUW SLP - PDX SLP)) ≥ 0.0
* ((SEA RLH ≤ 76 * (OLM CIG ≥ 3000 + OLM CIG ≤ 900))
+ (SEA RLH 77-90 * (TOD 1900-0200 + (TOD 1100-1800
* OLM CIG ≥ 3000)))))

APPENDIX A (Continued)

59. DOY 001-090 * (((NUW SLP - PDX SLP) ≥ 0.0
* (TTI SLP - YKM SLP) ≤ -0.1 * SEA RLH ≥ 77
* OLM CIG 1000-2900) + (TOD 1900-1000
* SEA RLH 77-90 * (((NUW SLP - PDX SLP) ≤ -0.1
* (TTI SLP - YKM SLP) ≤ -0.1) + ((NUW SLP - PDX SLP) ≤ -0.1
* (TTI SLP - YKM SLP) ≥ 0.0))))

60. DOY 091-151 * (TTI SLP - YKM SLP) ≥ 2.0
* ((TTI SLP - YKM SLP) - (NUW SLP - PDX SLP)) ≥ 0.0
* ((TTI SLP - YKM SLP) + (NUW SLP - PDX SLP)) ≥ 0.0
* (SEA RLH 77-90 + (TOD 1100-1800 * SEA RLH ≥ 91))

61. DOY 152-258 * ((SEA RLH ≥ 91 * ((TOD 0300-1800
* (NUW SLP - PDX SLP) ≤ -1.1 * (TTI SLP - YKM SLP) ≥ 2.0)
+ (OLM CIG 1000-2900 * ((NUW SLP - PDX SLP) ≥ 1.0
+ (TTI SLP - YKM SLP) ≤ +1.9)) + (OLM CIG ≥ 3000
* (NUW SLP - PDX SLP) -1.0 to +0.9
* (TTI SLP - YKM SLP) ≥ 2.0))) + (SEA RLH 77-90
* (NUW SLP - PDX SLP) ≤ -1.1 * (TTI SLP - YKM SLP) ≥ 2.0))

62. DOY 259-366 * ((SEA RLH ≥ 91 * OLM CIG 1000-2900
* ((TTI SLP - YKM SLP) - 3(NUW SLP - PDX SLP)) ≤ -0.1)
+ (((TTI SLP - YKM SLP) - 3(NUW SLP - PDX SLP)) ≥ 0.0
* ((OLM CIG 1000-2900 * (SEA RLH ≥ 91 + SEA RLH ≤ 76))
+ (TOD 0300-1000 * SEA RLH 77-90))))

APPENDIX B

BOOLEAN PREDICTORS FOR SEATTLE 3-HOUR VISIBILITY PREDICTION

1. DOY 259-319 * TOD 2100-0500 * (SEA VIS ≤ 2½ + TCM VIS ≤ 1 3/8 + PAEVIS ≤ 1 3/8 + SEA RLH ≥ 91 + SEA WEA L, ZL) * SEA WSD ≤ 5 * SEA SLP ≥ 1019.95

2. DOY 259-319 * TOD 2100-0500 * (SEA VIS ≤ 2½ + TCM VIS ≤ 1 3/8 + PAE VIS ≤ 1 3/8 + SEA RLH ≥ 91 + SEA WEA L, ZL) * SEA TCA ≤ 5 * SEA WSD ≤ 5 * SEA SLP ≥ 1019.95

3. DOY 259-319 * TOD 2100-0500 * SEA VIS ≤ 3/8 * SEA WSD ≤ 5

4. DOY 320-074 * SEA CIG ≤ 2900 * SEA DBT ≤ 39 * SEA DPT ≤ 32 * (BLI SLP - PDX SLP) ≥ 3.0 * SEA SLP ≤ 999.95 * (SEA WEA S, SW + PAE WEA S, SW + TCM WEA S, SW + NEJ WEA S, SW)

5. DOY 259-319 * TOD 2100-0500 * (SEA VIS 2½ - 4 + TCM VIS 2½ - 4 + PAE VIS 2½ - 4 + SEA RLH ≥ 91 + SEA WEA L, ZL) * SEA WSD ≤ 5 * SEA SLP ≥ 1019.95

6. DOY 259-319 * TOD 2100-0500 * (SEA VIS 2½ - 4 + TCM VIS 2½ - 4 + PAE VIS 2½ - 4 + SEA RLH ≥ 91) * SEA WSD ≤ 5 * SEA TCA ≤ 5 * SEA SLP ≥ 1019.95

7. DOY 259-319 * TOD 2300-0600 * SEA VIS ≤ 1 3/8 * (SEA WSD 5-10 + (YKM SLP - SEA SLP) ≥ 6.0)

8. TOD 2100-0500 * SEA WSD ≤ 10 * SEA WEA None, F,GF,H,K * (SEA VIS 4 - 7 + TCM VIS ≤ 5 + PAE VIS ≤ 5)

9. TOD 0600 - 1200 * SEA WEA None, F,GF,H,K * SEA VIS ≤ 2½

10. DOY 259 - 319 * TOD 2200 - 0600 * SEA TCA ≤ 5

APPENDIX B (Continued)

11. DOY 259-074 * TOD 2200-0600 * SEA TCA ≤ 5
* (OLM SLP-BLI SLP) ≥ + 0.1

12. DOY 305-090 * TOD 0600-1000 * SEA VIS ≤ 2½
* (SEA WSD ≥ 6 + (YKM SLP - SEA SLP) ≥ 4.0)

13. DOY 091-304 * TOD 0300-0700 * SEA VIS ≤ 2½
* (SEA WSD ≥ 6 + (YKM SLP - SEA SLP) ≥ 4.0)

14. TOD 2100-0500 * SEA VIS ≤ 3 * SEA WSD ≥ 8
* (PDX SLP-BLI SLP) ≥ 4.0

15. TOD 0600-2000 * SEA VIS ≤ 3 * SEA WSD ≥ 8
* (PDX SLP-BLI SLP) ≥ 2.0

16. SEA VIS ≥ 5 * TCM VIS ≥ 5 * PAE VIS ≥ 5
* SEA WSD ≥ 11

17. SEA VIS ≥ 5 * ((OLM SLP-BLI SLP) ≥ 3.0
+ (BLI SLP-OLM SLP) ≥ 3.0)

18. DOY 001-090 * TOD 0800-1600 * SEA VIS ≥ 5

19. DOY 001-090 * TOD 1700-0200 * SEA VIS ≤ 3/8

20. DOY 091-151 * TOD 0800-1600 * SEA VIS ≥ 5

21. DOY 091-151 * SEA VIS ≥ 5

22. DOY 152-258 * TOD 0800-1600 * SEA VIS ≥ 1½

23. DOY 152-258 * TOD 1700-0700 * SEA VIS ≥ 3

24. DOY 259-366 * TOD 1700-0400 * SEA VIS ≤ 3/8

25. DOY 259-366 * TOD 0700-1600 * SEA VIS ≥ 5

26. DOY 001-090 * (SEA RLH ≤ 90 + (SEA RLH ≥ 91
* (((NUW SLP-PDX SLP) ≥ -2.0 * (TTI SLP-YKM SLP) -2.0 to + 0.9
* PAE VIS ≥ 5) + (TOD 1900-1000 * ((NUW SLP-PDX SLP) ≤ -2.1
+ ((NUW SLP-PDX SLP) ≥ -2.0 * ((TTI SLP-YKM SLP) ≥ 1.0
+ (TTI SLP-YKM SLP) ≤ -2.1)))))))

APPENDIX B (Continued)

27. DOY 091-151 * ((TTI SLP - YKM SLP) ≤ + 1.9
+ (SEA RLH ≤ 90 * (TTI SLP - YKM SLP) ≥ 2.0))

28. DOY 152-258 * (((TTI SLP - YKM SLP) ≤ + 1.9
+ (NUW SLP - PDX SLP) ≥ + 2.0 + (NUW SLP - PDX SLP) ≤ -2.1)
+ (SEA RLH ≤ 90 * (NUW SLP - PDX SLP) -2.0 to + 1.9
* (TTI SLP - YKM SLP) ≥ + 2.0))

29. DOY 259-366 * (((NUW SLP - PDX SLP) ≤ -0.1
* (TTI SLP-YKM SLP) ≥ 0.0) + ((NUW SLP - PDX SLP) ≤ -0.1
* (TTI SLP-YKM SLP) ≤ -0.1 * ((SEA RLH ≤ 76
* (TOD 1900-1000 + PAE VIS ≤ 4)) + SEA RLH 77-90
+ (TOD 1900-0200 * SEA RLH ≥ 91)))
+ ((NUW SLP-PDX SLP) ≥ 0.0 * (SEA RLH ≤ 76
+ (TOD 0300-1800 * SEA RLH 77-90 * PAE VIS ≥ 1½)
+ (SEA RLH ≥ 91 * PAE VIS 1½ - 4))))

30. DOY 001-090 * TOD 1100 - 1800 * SEA RLH ≥ 91
* (NUW SLP-PDX SLP) ≥ -2.0 * ((TTI SLP - YKM SLP) ≥ + 1.0
+ (TTI SLP-YKM SLP) ≤-2.1)

31. DOY 091-151 * SEA RLH ≥ 91 * (TTI SLP - YKM SLP) ≥ + 2.0

32. DOY 152-258 * TOD 1100 - 1800 * SEA RLH ≥ 91
* (NUW SLP-PDX SLP) -2.0 to + 1.9 * (TTI SLP-YKM SLP) ≥ + 2.0

33. DOY 259-366 * (NUW SLP - PDX SLP) ≤ -0.1
* (TTI SLP-YKM SLP) ≤ -0.1 * ((TOD 0300 - 1800
* SEA RLH ≥ 91) + (TOD 1100 - 1800 * SEA RLH ≤ 76
* PAE VIS ≥ 5))

34. DOY 001-090 * SEA RLH ≥ 91 * PAE VIS ≤ 4
* (NUW SLP-PDX SLP) ≥ -2.0 * (TTI SLP - YKM SLP) -2.0 to + 0.9

35. DOY 152-258 * TOD 1900-1000 * SEA RLH ≥ 91
* (NUW SLP-PDX SLP) -2.0 to + 1.9 * (TTI SLP - YKM SLP) ≥ 2.0

APPENDIX B (Continued)

36. DOY 259-366 * (NUW SLP - PDX SLP) $\geq$ 0.0
* ((SEA RLH $\geq$ 91 * (PAE VIS $\geq$ 5 + PAE VIS $\leq$ 1 3/8))
+ (SEA RLH 77-90 * (TOD 1900 - 0200 + PAE VIS $\leq$ 1 3/8)))

37. SEA VIS $\leq$ 3/8

38. SEA VIS ½ - 1 3/8

39. SEA VIS 1½ - 2½

40. SEA VIS 3 - 4

41. SEA VIS $\geq$ 5

42. SEA VIS $\leq$ 1 3/8

43. SEA VIS $\leq$ 2½

APPENDIX C

BOOLEAN PREDICTORS FOR SAN FRANCISCO 3-HOUR CEILING PREDICTION

1. DOY 305-059 * TOD 2300-0400 * SFO CIG ≤ 100

2. DOY 305-059 * TOD 2300-0400 * SFO CIG 1000 - 2900

3. DOY 305-059 * TOD 1100-1500 * SFO CIG ≥ 3000

4. DOY 060-135 * TOD 2300-1000 * SFO CIG 1000 - 2900

5. DOY 305-059 * TOD 1600-2200 * SFO CIG ≤ 100

6. DOY 060-135 * TOD 1100-1500 * SFO CIG ≥ 3000

7. DOY 136-236 * TOD 2300-0400 * SFO CIG 500 - 900

8. DOY 136-236 * TOD 0500-1500 * SFO CIG ≥ 3000

9. DOY 237-304 * TOD 0500-1500 * SFO CIG ≥ 3000

10. DOY 237-304 * TOD 2300-0400 * SFO CIG 1000 - 2900

11. DOY 152-243 * TOD 1200-2200 * SFO CIG ≤ 900
    * SFO WSD ≤ 11

12. DOY 152-243 * TOD 1200-1600 * SFO CIG ≥ 3000
    * (SAC SLP-SFO SLP) ≥ -0.5 * $(\text{SAC SLP - SFO SLP})^{\Phi}_{-3}$
    - (SAC SLP-SFO SLP) ≥ 0.0

13. DOY 152-243 * TOD 1200-1600 * SFO ≥ 3000
    * SUU WSD ≤ 8 * (RBL SLP - SAC SLP) ≥ 1.5

14. DOY 136-258 * TOD 1200-1600 * SFO SCL 2 - 3
    * SFO TCA 2-4 * MFR SLP ≤ 1011.0
    * (SFO SLP-SAC SLP) ≥ 2.0 * (SAC SLP - RNO SLP) ≥ - 4.0
    * PDX 24ΔP ≥ + 4.0 * RNO 24ΔP ≤ -2.0
    * SFO 24ΔP ≥ -1.0

Φ $(\text{SAC SLP-SFO SLP})_{-3}$ means this variable 3 hours earlier.

15. DOY 136-258 * TOD 1200-1400 * SFO CIG 1000 - 2900
* SFO SCL ≥ 6 * (SFO SLP - RNO SLP) ≥ + 2.0
* (SFO 24ΔP - SAC 24ΔP) ≥ + 1.5

16. TOD 1900-0300 * ((ACV SLP - SFO SLP) ≥ + 5.0
+ (SFO SLP-SMX SLP) ≥ + 3.0
+ (ACV SLP plus RBL SLP minus (SFO SLP plus SAC SLP)) ≥ + 2.0

17. NUQ CIG 1000-2900 + (SFO CIG ≤ 9500
* ((NGZ WDR ESE-SSW * NGZ WSD ≥ 4)
+ SFO CIG ≤ 400 + NGZ CIG 1000 - 2900))

18. SFO CIG 500 - 900 + (OAK CIG 500 - 900
* (TOD 0600 - 1700 + SFO CIG ≤ 300 + SFO RLH ≥ 88))

19. SFO CIG ≤ 400 + (NGZ VIS ≤ 3/8 * (NGZ CIG 500 - 900
+ OAK CIG 200 - 400))

20. (NGZ VIS ≤ 3/8 * (SFO CIG ≤ 400 + OAK CIG 200 - 400))
+ (NUQ CIG ≤ 100 * (SFO CIG ≤ 100 + NUQ VIS ≤ 3/8
+ SRF CIG ≤ 100 + OAK CIG 200 - 400))

21. SFO CIG ≥ 3000 * (OAK CIG ≥ 3000 + OAK WSD ≤ 5
+ TOD 0600 - 1700)

22. SRF CIG 1000-2900 + (SFO CIG ≤ 900 * (OAK CIG 1000 - 2900
+ NUQ CIG 1000-2900 + RBL CIG ≥ 10,000))

23. SFO CIG ≤ 900 * (SFO RLH ≥ 88 + TOD 0600 - 1700
+ OAK CIG 1000 - 2900)

24. SFO CIG ≤ 400 * (OAK CIG 200 - 900 + OAK VIS ≤ 3/8
+ NUQ CIG 200 - 400)

25. DOY 305-059 * TOD 2200-0400 * SFO TCA ≤ 4
* SFO VIS ≤ 1 * SFO WDR N-E * SFO WSD ≤ 5
* SFO DBT 45-50 * SFO DPT 40-46 * SAC VIS ≤ 1
* FAT VIS ≤ 1 * (RNO SLP - SFO SLP) ≥ 0.1

APPENDIX C (Continued)

26. DOY 136-243 * TOD 0500-0900 * SFO RLH $\geq$ 88
* OAK CIG 200 - 900

27. DOY 136-243 * SUU WDR SW - WSW * SUU WSD $\geq$ 11

28. DOY 136-243 * SFO SLP $\geq$ 1014.0

APPENDIX D

BOOLEAN PREDICTORS FOR SAN FRANCISCO 3-HOUR VISIBILITY PREDICTION

Some of the predictors listed in Appendix C for SFO ceiling prediction were proposed also for visibility prediction. This is particularly true for winter predictors. The following are additional predictors.

1. DOY 172-262 * TOD 1600-2200 * SFO WDR WNW - NNW
   * SFO WSD ≥ 10 * SFO TCA ≤ 1/10 * SFO DBT 62-68
   * SFO DPT ≤ 57 * SRF WDR SSE-SSW
   * SRF WSD ≤ 8 * SRF TCA ≤ 1/10

2. DOY 152-243 * TOD 2300-0300 * SFO TCA ≥ 7/10
   * SFO SCL ≥ 5/10 * SFO WDR WNW-NW * SFO WSD ≤ 9
   * SUU WDR SW-W * SUU WSD ≥ 10 * SFO DBT 48-54
   * SFO DPT 46-53 * (SFO SLP - SAC SLP) ≥ 0.1
   * (ACV SLP - SFO SLP) ≥ 0.1

3. DOY 121-212 * TOD 2300-0300 * SFO TCA ≥ 8/10
   * SFO SCL ≥ 7/10 * SFO DBT 50-56 * SFO DPT 45-50
   * SFO WDR SW-W * SFO WSD 6-15
   * SFO 3ΔP ≥ + 0.1 * (SFO SLP - RNO SLP) ≥ + 0.1

4. DOY 335-059 * TOD 1700-2200 * SFO VIS 1-3
   * SFO TCA ≤ 5/10 * SFO WDR N-E * SFO WSD ≤ 7
   * (SFO SLP - CEC SLP) ≥ + 0.1 * (SAC SLP - CEC SLP) ≥ + 0.1
   * SFO RLH ≥ 70

5. DOY 305-031 * TOD 1000-1600 * SFO CIG 200-400
   * SFO VIS ≤ 1 * SFO WDR N - E * SFO WSD ≤ 5
   * SFO DBT 42-48 * SFO DPT 40-46
   * (ACV SLP - SAC SLP) ≥ + 0.1 * (SAC SLP - SFO SLP) ≥ + 0.1
   * SAC VIS ≤ 1½ * FAT VIS ≤ 1½

APPENDIX E

BOOLEAN PREDICTORS FOR LOS ANGELES 3-HOUR CEILING AND VISIBILITY PREDICTION

These predictors are in an early stage of development and not all of them have been designed specifically for either ceiling or visibility prediction. Many weather situations which these predictors are designed to forecast are associated with both low ceiling and low visibility, therefore in this listing, the two kinds of predictors are not separated nor identified. The first 20 predictors are intended to represent persistence stratified by season and time of day.

1. DOY 244-120 * TOD 0000-0300 * LAX CIG ≤ 100
2. DOY 305-059 * TOD 1700-0300 * LAX CIG ≤ 100
3. DOY 305-366 * TOD 1300-0300 * LAX CIG ≤ 100
4. DOY 121-304 * TOD 0000-0300 * LAX CIG 200-400
5. DOY 121-181 * TOD 2100-0300 * LAX CIG 200-400
6. DOY 060-120 * TOD 1700-2300 * LAX CIG 200-400
7. DOY 121-304 * TOD 2100-0300 * LAX CIG 500-900
8. DOY 182-243 * TOD 1300-0300 * LAX CIG 500-900
9. DOY 060-304 * TOD 2100 0700 * LAX CIG 1000-2900
10. DOY 121-243 * TOD 1700-0700 * LAX CIG 1000-2900
11. DOY 305-059 * TOD 0000-1600 * LAX CIG ≥ 3000
12. DOY 305-181 * TOD 0800-1200 * LAX CIG ≥ 3000
13. DOY 305-059 * TOD 1700-0700 * LAX VIS ≤ 3/8
14. DOY 121-181 * TOD 2100-0300 * LAX VIS ≤ 3/8
15. DOY 244-059 * TOD 0400-0700 * LAX VIS ½ - 1 3/8
16. DOY 121-243 * TOD 2100-0300 * LAX VIS ½ - 1 3/8
17. DOY 001-059 * TOD 2100-0300 * LAX VIS 1½ - 2½
18. DOY 001-304 * TOD 2100-2300 * LAX VIS 1½ - 2½

APPENDIX E (Continued)

19. DOY 121-243 * TOD 0400-0700 * LAX VIS 3-4

20. DOY 121-243 * TOD 2100-2300 * LAX VIS 3-4

21. DOY 091-304 * TOD 1300-1600 * NTD CIG $\leq$ 200
    * LAX WDR WSW-W

22. DOY 213-090 * TOD 1300-1600 * LAX WDR WSW-W
    * (NTD CIG $\leq$ 500 + (NTD VIS $\leq$ 2½ * NTD WEA F, G, F, H, K))

23. TOD 1300-0500 * NZY WDR E-SW * NZY WSD $\geq$ 5
    * NZJ WDR ESE-SSW * NTB WDR E-SW
    * LGB WDR E-SW * BUR WDR E-S
    * (LGB CIG $\leq$ 400 + LGB VIS $\leq$ 7/8 + NTB CIG $\leq$ 400
    + NTB VIS $\leq$ 7/8)

24. TOD 1300-0500 * NZY WDR E-SW
    * (NZJ WDR ESE-SSW + LGB WDR E-SW
    + NTB WDR E-SW) * (LGB CIG $\leq$ 400
    + LGB VIS $\leq$ 7/8 + NTB CIG $\leq$ 400 + NTB VIS $\leq$ 7/8)

25. TOD 1300-0500 * NZY WDR E-SW
    * (NZJ WDR ESE-SSW + LGB WDR E-SW
    + NTB WDR E-SW) * (LGB CIG 500-900
    + NTB CIG 500-900 + LAX CIG $\leq$ 900)

26. DOY 121-334 * TOD 1300-1800 * LAX WDR WSW-W
    * LAX WSD 8-16 * BUR RLH $\geq$ 70 * BUR WDR E-S

27. DOY 274-151 * LAX CIG 2000-4900
    * LAX WEA None, F, H, K * (NTD WEA R, RW, L
    + BFL WEA R, RW)

28. LAX WEA None, R, RW * LAX SLP $\leq$ 1005.5
    * (LAX SLP - DAG SLP) $\geq$ + 2.0

APPENDIX E (Continued)

29. ((LAX RLH ≤ 59 * LAX SLP ≥ 1020.5)
+ ((BFL SLP - LAX SLP) ≥ 5.6 * (DAG SLP - LAX SLP) ≥ 3.1)
* LAX WEA None

30. TOD 0200-0700 * LAX VIS 5-14 * LAX RLH ≤ 79
* LAX SCL ≤ 4 * LAX WSD ≤ 7

31. (LAX CIG ≤ 600 + LAX VIS ≤ 1 3/8) * ((NTD WDR N-E
* NTD WSD ≥ 8) + (SBD WDR NW-SE * SBD WSD ≥ 13)
+ (BUR WDR N-ENE * BUR WSD ≥ 8) + (NZJ WDR N-E
* NZJ WSD ≥ 14) + (LGB WDR N-ENE * LGB WSD ≥ 8))

32. DOY 305-090 * TOD 1300-1500 * LAX DPT ≤ 44

33. DOY 152-273 * TOD 1300-1500 * LAX DPT ≤ 54

34. DOY 274-120 * TOD 2300-0400 * (LAX RLH ≥ 90
+ (LAX VIS ≤ 2½ * LAX WEA F, GF, H, K) + (LGB VIS ≤ 2½
* LGB WEA F, GF, H, K)) * BUR RLH ≤ 49

35. LAX TCA ≥ 6/10 * BUR CIG ≤ 600

36. (LAX CIG ≤ 600 + LAX VIS ≤ 1 3/8) * ((BUR DBT-LAX DBT) ≥ 16
+ (LAX RLH - BUR RLH) ≥ 30 + (NTD DBT-LAX DBT) ≥ 10
+ (LAX RLH - NTD RLH) ≥ 30 + ((LAX RLH-SBD RLH) ≥ 30
* SBD WSD ≥ 13) + (BUR WDR WNW-ENE * BUR WSD ≥ 8))

37. LAX CIG 500-900 * ((NTD CIG ≤ 900 * NTD WEA L)
+ (LGB CIG ≤ 900 * LGB WEA L))

38. LAX CIG 1000-2900 * BUR CIG ≤ 600 * BUR WEA R, L

39. LAX CIG 500-900 * BUR CIG ≤ 600 * BUR WEA R, L

40. (LAX VIS ½ - 1 3/8 + BUR VIS ≤ 3/8) * (NTB VIS ½ - 2½
+ NTB CIG 300-500 + NTB RLH ≥ 90)

41. TOD 1800-0400 * (LGB CIG $\leq$ 100 + LGB VIS $\leq$ 7/8
+ NTB CIG $\leq$ 100 + NTB VIS $\leq$ 7/8) * (LGB WDR E-SSE
+ LGB WSD $\leq$ 3 + NTB WDR E-S + NTB WSD $\leq$ 3)

42. DOY 305-120 * TOD 0200-2100 * LAX RLH $\geq$ 71
* (NZY WSD $\leq$ 5 + (NZY WDR WNW-E * NZY WSD $\geq$ 6))
* (LAX SLP-BFL SLP) $\geq$ - 4.0 * (LAX SLP-DAG SLP) $\geq$ + 1.0

43. DOY 121-304 * TOD 0200-1400 * LAX RLH 71-89
* (NZY WSD $\leq$ 5 + (NZY WDR WNW-E * NZY WSD $\geq$ 6))
* (LAX SLP-BFL SLP) $\geq$ 0.0

44. DOY 305-120 * TOD 0200-1000 * LAX RLH $\geq$ 71
* (LAX SLP-DAG SLP) $\leq$ -0.1

APPENDIX F

PREDICTION EQUATIONS FOR SEATTLE 3-HOUR CEILING

Five equations are listed, one for each ceiling predictand category. Only the coefficients differ among equations; the predictor variables are the same for all equations. The Ceiling Predictand Categories are defined in Table I, and the Predictors are defined in Appendix A. All 62 Boolean predictors listed in Appendix A were screened to derive these equations.

PREDICTOR COEFFICIENTS

CEILING PREDICTAND CATEGORY

TERM	PREDICTOR	1	2	3	4	5
CONSTANT		-.0072	.0824	.2221	.3743	.3284
1	53	.0195	-.0646	-.1920	-.2143	.4514
2	49	.0231	-.0372	-.0363	-.0999	.1503
3	52	.0078	-.0627	-.1595	.1018	.1125
4	34	.1593	-.2083	.0677	.0307	-.0494
5	13	-.0029	-.0037	.0173	.0984	-.1092
6	36	.1367	.1368	.0198	-.0633	-.2300
7	9	-.0135	.0171	.1475	-.0326	-.1185
8	33	.2809	.0100	-.1919	-.0551	-.0439
9	57	-.0128	-.0257	-.0207	-.0380	.0973
10	4	.0136	.0412	-.0040	-.0012	-.0496
11	39	.0105	.0331	.0631	.1230	-.2297
12	22	-.0013	-.0018	-.0086	-.0370	.0486
13	27	.1484	-.0514	-.1254	.0186	.0098
14	19	-.0032	-.0057	-.0151	.1353	-.1113
15	54	.0491	.0828	-.0408	-.1048	.0137
16	12	-.1003	-.0392	.0332	-.0595	.1658
17	61	.0145	.0120	.0488	.0904	-.1656
18	56	-.0086	-.0176	-.0157	-.0805	.1223
19	58	.0044	-.0076	-.0170	-.1048	.1231
20	55	-.0071	-.0064	-.0168	-.0875	.1178
21	15	.0322	.0965	-.0071	-.0130	-.1086
22	11	.0060	-.0371	.1033	.0287	-.1009
23	10	.0073	.0149	-.0027	-.0880	.0685
24	46	.1890	.1071	-.1016	-.0775	-.1170
25	41	.1828	.0168	-.0846	-.0793	-.0357
26	16	-.0075	-.0030	-.0125	.1521	-.1291
27	24	.0001	-.0003	-.0077	-.0790	.0868
28	23	-.0120	-.0113	-.0031	.0765	-.0495
29	28	-.0372	.1544	-.1061	.0582	-.0693
30	42	.0708	-.0788	.1782	-.1591	-.0111
31	14	.0028	-.0433	-.0171	.0502	.0074
32	25	-.0026	.0070	-.0336	-.1060	.1353
33	35	-.0089	-.0066	.0485	-.0381	.0052
34	1	-.0766	.0634	.0011	-.0680	.0801
35	3	.0293	.0062	.0109	-.0131	-.0333
36	38	.0003	.0126	.0575	.0666	-.1371

APPENDIX G

PREDICTION EQUATIONS FOR SEATTLE 3-HOUR VISIBILITY

These equations are arranged in the same format as that used in Appendix F. These Predictor Variables are defined in Appendix B. All 43 predictors were screened in deriving these equations.

		PREDICTOR COEFFICIENTS				
		VISIBILITY PREDICTAND CATEGORY				
TERM	PREDICTOR	1	2	3	4	5
CONSTANT		.0196	.0502	.0710	.2164	.6429
1	37	.3908	.0548	-.0598	-.1545	-.2313
2	41	-.0171	-.0434	-.0486	-.1738	.2829
3	8	.0723	.0496	-.0010	.0657	-.1865
4	24	.2630	-.1990	-.1150	-.0358	.0868
5	43	.0760	.1051	.1169	-.0773	-.2207
6	36	.0678	.0581	.0416	.0193	-.1868
7	9	-.1523	-.0879	.0098	.1142	.1162
8	30	-.0297	.0768	.1453	-.0144	-.1780
9	16	-.0027	-.0031	-.0135	-.0240	.0433
10	1	-.0908	.1457	-.0560	.0632	-.0621
11	12	.1284	-.0306	-.0049	-.0379	-.0550
12	34	.0896	.0377	.1002	-.0184	-.2091
13	19	.0562	-.1367	.0484	.0378	-.0057
14	35	.0379	.0323	.0101	-.0091	-.0712
15	38	.0580	.0449	-.0527	-.0112	-.0390
16	15	-.0661	-.0344	.0046	-.0116	.1075
17	22	-.0018	-.0059	-.0186	-.0212	.0475
18	21	-.0001	-.0063	-.0144	-.0217	.0425