U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
OFFICE OF SYSTEMS DEVELOPMENT
TECHNIQUES DEVELOPMENT LABORATORY

TDL OFFICE NOTE 91-1

VERIFICATION OF 1-6 HOUR STATISTICAL WEATHER FORECASTS

Robert G. Miller and Joseph Lang

January 1991

VERIFICATION OF 1-6 HOUR STATISTICAL WEATHER FORECASTS

Robert G. Miller and Joseph Lang

I. INTRODUCTION

The aviation industry wants skillful 1-6 h airfield terminal weather forecasts because of their importance in making safe landings and takeoffs of commercial and private aircraft. Lives can be lost if conditions change unexpectedly. Furthermore, deciding when to depart and where to land, with consideration to appropriate alternate landing facilities, depends directly on present and future weather conditions. To our knowledge, there are no operational objective guidance products that satisfy this need of short-range weather forecasts at the present time.

This paper compares the results of a statistical weather forecasting procedure against the tough competition presented by persistence. The verification analysis covers 415 U.S. stations for all 24 hours of the day in the period from September 1, 1989 to August 31, 1990--a total of almost 2 million test sample predictions. Visibility and ceiling conditions of Low Instrument Flight Rules (LIFR), Instrument Flight Rules (IFR), Marginal Visual Flight Rules (MVFR), and Visual Flight Rules (VFR) are studied to measure the skill in the forecasting of 1, 2, 3, 4, 5, and 6-h changes--situations for which persistence gives no assistance.

The verification of all elements contained in a Standard Airways Observation (SAO) are included in this study--pressure, temperature, dewpoint depression, visibility, lowest cloud height and amount, second cloud height and amount, ceiling, total cloud cover, wind, precipitation types and intensities, obstructions to vision, and thunderstorms (both regular and severe). The analysis includes a comparison of the statistically predicted probabilities versus conditional persistence probabilities. Categorical forecasts are directly compared to those of persistence in terms of Percentage Correct, Heidke Skill Score, and Critical Success Index or Threat Score (see Appendix for definitions of these scores), computed from contingency tables. Section II entitled Data Analysis contains a complete description of the sources of data utilized in this study and the statistical methodology employed.

A full treatment of the comparative verification can be found in section III Results.

Specific details leading to the conclusions drawn and possible ways to improve the statistical method are contained in Section IV Summary and Possible Improvements.

II. DATA ANALYSIS

The statistical method for which comparisons are made against persistence is known under the acronym GEM, for Generalized Exponential Markov, and will be described by means of an example (for a comprehensive discussion of GEM see Miller, 1981). The philosophy, underlying the development of a statistical procedure such as GEM, is that of the late MIT Professor of Mathematics,

Norbert Wiener, and is contained in his book "Cybernetics" and in a Berkeley Symposium paper (Wiener, 1948 and 1956).

GEM's methodology consists of a system of regression equations where each of 290 dependent variables (predictands) employs a set of 290 independent variables (predictors). The specific equations for making a 1-h forecast of the predictands CLEAR, SCATTERED, BROKEN, and OVERCAST--of the weather element Total Cloud Cover--are contained in the last four columns of Table 1. Column 1 identifies the predictor variable whose regression coefficients appear to the right for CLEAR, SCATTERED, BROKEN, and OVERCAST, respectively.

A set of 220 predictor variables constitutes a representation of all the weather elements contained in a Standard Airways Observation. An additional 70 selected interactive terms are also in the predictor set making the total 290. Since some of the SAO's elements are qualitative, such as rain (e.g., none, light rain, moderate rain, and heavy rain), which are not conducive to any numerical assignment, all the original weather elements of an SAO plus the 70 interactive predictors were transformed into categories. For example, pressure is broken into 13 categories, each separated by 5-millibar intervals, such that in any particular SAO the observation of pressure falls into one and only one category. For the sake of mathematical convenience, each observation is represented by a 0-1 vector with a 1 in that element's observed category and a 0 in all its remaining categories. The unity predictor in column 1 of Table 1 is a 1 in every observation.

To make an estimate of the probability that CLEAR will be observed 1 hour hence we accumulate the product between the 0-1 observation vector and the 290 regression coefficients in column 2 of Table 1 marked CLEAR. Obviously, the same estimated probability will result if we merely add the coefficients for all the predictors that are 1's in the observation vector; this amounts to a useful labor saving device. Furthermore, the sum of the estimated probabilities of the mutually exclusive and exhaustive events CLEAR, SCATTERED, BROKEN, and OVERCAST is equal to unity.

What is important to appreciate is that an appraisal can be made of the effect a predictor has on the forecast by noting the magnitude of its regression coefficient--disregarding for the moment the issue of correlation among the predictors. This is possible because that coefficient constitutes an addition or subtraction (depending upon the sign of that coefficient) to the estimated probability density, when that weather element's category is observed to have occurred--that is, has a value of 1.

For example, when there is an overcast condition in Total Cloud Cover of the input observation the quantity 0.37256 is added to the estimated probability that OVERCAST will be the condition at 1 hour, irrespective of what the rest of the initial observed conditions are at the time. It is easy to see that under the right circumstances the estimated probability of OVERCAST at 1 hour could reach a sizeable positive value making that event very likely to occur in 1 hour. The same could be said of each and every one of the predictand categories. Conversely, a low probability estimate would suggest an event that is unlikely to occur in 1 hour.

Altogether there are 63 individual elements in this study: Unity, Month of the year, Hour of the day, Pressure, etc. The full list is represented in column 1 of Table 1. As was stated before, each is partitioned into a set of

categories amounting to a total of 290. For example, Total Cloud Cover is one of the 63. It possesses 4 categories.

Regression equations for making 1-h forecasts were derived for each of the 290 predictand categories, each equation having 290 predictors. All of the equations could be arranged in a manner similar to those of Total Cloud Cover in Table 1. However, it would be impractical to display all 63 sets here. Obviously computer files exist containing their values. They also reside on microfiche in the original GEM report (Miller, 1981). Suffice it to say, they make interesting reading and help one to appreciate why skillful predictions might be forthcoming using the GEM procedure.

GEM utilizes the entire set of 290 equations with their 290 regression coefficients to make a 1-h forecast. The scheme proceeds, in its estimation of the probability at hours 2-6, by replacing the 0-1 observation vector in the accumulated-product calculation with the vector of estimated probabilities from the previous projection--starting with the 2-h forecast. An exponential weighting is then applied to the series of iterated forecasts--just as the theory of Markov Chains requires when dealing with changes that can occur at any time and not just at discrete times, say, on the hour. This issue is covered in the original documentation of GEM (Miller, 1981).

Notice that specific equations to predict for 2, 3, 4, 5, and 6 hours were not created nor were they necessary in GEM. The iteration scheme just mentioned precludes the need for their development. The basis for this approach is the assumption that our original 1-h equation-set could be iterated, as covered in the theory of Markov Chains (Howard, 1960).

Categorical forecasts were determined on the basis of the magnitude of the predicted probabilities within each weather element. An inflation procedure, found to be successful in converting probability forecasts to categorical forecasts, in an FAA sponsored effort involving automated observations, was employed here (Miller, 1988). That technique is a variation of a procedure proposed by Klein, Lewis, and Enger (1959).

A slight change to the FAA inflation method was employed here after finding that a highly significant change had occurred between the climatology in the years of GEM's development sample, 1954-1965, and the climatology in the verification year of data, 1989-1990. The change in the inflation procedure amounted to a relaxation of the dampening imposed by the exponential weighting scheme. Specifically, the predicted probability for any projection hour H was multiplied by 0.8 and a value of 0.2 was added to the probability of the category in which persistence resided. The motivation for this variation was to help account for the change in climatology through persistence since persistence "knows" what the current climatology is.

A final variation was made in the procedure of making categorical predictions in GEM. That is, Pressure, Temperature, and Dewpoint Depression were derived from an expected value computation between their predicted probabilities and midvalues of the intervals for which they are estimates.

In the development of GEM, about 100,000 observations were sampled from 40 stations from around the country making a full data sample of nearly 4,000,000 from the years 1954-1965. Figure 1. depicts the location of each of the 40 stations.

In the regression analysis, calculations were made by computing anomalies. That is, station averages for each of the 290 variables were extracted from that station's contribution to the full data sample. The final equations were then made "generalized" by employing the 40 station's overall averages--representing an estimate of the 40 station's climatology--in arriving at the equations' additive constants. This is tantamount to not stratifying the sample into 40 individual equation sets, one for each station, but creating an equation set that is applicable anywhere. Individual station's climatologies could be reinstated for purposes of making the prediction more station specific. Surprisingly, experimental evidence has show this "refinement" to be more harmful than helpful, perhaps because of the change in climatology noticed between the development and test samples mentioned above.

A generalized set of equations was employed in this verification, meaning that the same equation set was used to predict at each and every one of the 415 stations in the test sample. The reader can judge for himself/ herself as to whether this practice produced respectable results. Remember, if single station equations had been used, the 290 x 290 = 84,100 regression coefficients would need to be developed for each of the 415 stations. This practice would require a very large developmental sample.

An attempt to "explain" this fact--since it does go against our meteorological intuition--goes as follows:

The input observation represents the set of covariates which help account for the obvious differences we observe among the 40 stations' climatologies. Visualize this, we wouldn't expect a Miami, Florida input observation when making a Caribou, Maine forecast or visa versa. If such a situation happened to arise, Caribou's forecast might logically be expected to look Miami-ish and visa versa.

Test sample predictions were performed on observations contained in the National Meteorological Center's operational hourly SAO data base. The period covered is from September 1, 1989 to August 31, 1990 including all 24 hours of the day. Figure 2 shows a map depicting the location of the 415 stations that were included in this verification.

A gross editing was performed on the data. No attempt was made to correct any of the elements in the observation if it were deemed questionable--they were rejected for fear that any attempt to estimate an observation's value could taint that observation. It was noticed almost immediately that a small number of garbled or erroneous messages caused pressure values to be sent as 4 digits instead of the usual 3 digits. This would cause 1-h pressure changes that indicated unacceptable values. The policy was to eliminate the observations involved. This practice rejected about 100 cases in the almost 2,000,000 test sample, a number thought be sufficiently insignificant to have created any sampling problems.

A very noticeable difference between the development sample of 1955-1965 and the 1989-1990 year of test sample data occurs in Ground Fog. That is, there were 70,241 cases of Ground Fog in the 3,964,513 development sample (1.77%) versus 650 in the 1,895,300 test sample (0.03%) or a factor difference of over 50. It is clear, from the "climatological change" of this element, that a modification in its definition or usage was instituted during the

interval of time between samples thus providing a legitimate reason, albeit arbitrary, for omitting Ground Fog as an element to be verified here.

III. RESULTS

The presentation of the results obtained in this study begins with a discussion of the ability of GEM to predict changes in Ceiling at 1-, 2-, 3-, 4-, 5-, and 6-h projections. Table 2 shows the number of times each operationally important change, between LIFR, IFR, MVFR, and VFR conditions, occurred and/or was predicted to occur. The precise definitions of the LIFR, IFR, MVFR, and VFR terms for ceiling are:

CEILING

LIFR (Low Instrument Flight Rules)	0 - < 500 feet
IFR (Instrument Flight Rule)	500 - < 1000 feet
MVFR (Marginal Visual Flight Rules)	1000 - < 3000 feet
VFR (Visual Flight Rules)	3000 feet or above

The first three columns of Table 2 identify the GEM statistical forecast (G), persistence (P), and the verifying observation (O). For example, the line having the combination G = LIFR, P = VFR, and O = LIFR for all 6 projection hours appears as follows:

G	P	O	1-h	2-h	3-h	4-h	5-h	6-h
LIFR	VFR	LIFR	0	1	4	36	278	547

These figures show that GEM predicted the lowering of ceiling from 3000 feet or above to 0 - < 500 feet, 6 hours in advance successfully 547 times. For 5 hours in advance it did this 278 times. 36 correct forecasts were made at 4 hours. There were 4 instances when it succeeded doing this 3 hours in advance and 1 time when it did this 2 hours in advance. No correct predictions of this change were made by GEM at 1 hour. Conversely, of the times GEM predicted the same change it was incorrect 2,150 times, from 338 + 514 + 1,298 = 2,150 in the 6 hour forecast, from the three rows:

G	P	O	1-h	2-h	3-h	4-h	5-h	6-h
LIFR	VFR	IFR	0	1	6	14	140	338
LIFR	VFR	MVFR	0	1	5	30	194	514
LIFR	VFR	VFR	0	0	4	72	535	1298

For the same situations in which GEM was correct 547 times and incorrect 2,150 times, Persistence was incorrect 547 + 338 + 514 = 1,399 times and, of course, did not correctly forecast any VFR to LIFR changes. Of the 2,697 times that GEM forecast LIFR from an initial condition of VFR, the ceiling actually lowered 1,399 times or about 52%. The net result shows that GEM had 547/(547 + 338 + 514 + 1,298) = 20.3% correct for an event that occurred less than 1 percent of the time, specifically, 13,167 LIFR events following 1,490,387 VFR events. Another interesting fact about GEM's capabilities, in this instance, is that it succeeded in improving 547 of persistence's 13,167 misses, 4.2%, of these operationally important VFR to LIFR changes. These latter figures were extracted from the full ceiling contingency tables of persistence and GEM which follow:

CEILING (PERSISTENCE) projection time: 6 hours

		OBSERVED CONDITION				
		LIFR	IFR	MVFR	VFR	TOTAL
PERSISTENCE CONDITION	LIFR	14178	8316	7260	11912	41666
	IFR	8672	19008	19397	18383	65460
	MVFR	6011	17364	62718	81754	167847
	VFR	13167	20665	76514	1380041	1490387
	TOTAL	42028	65353	165889	1492090	1765360

CEILING (GEM) projection time: 6 hours

		OBSERVED CONDITION				
		LIFR	IFR	MVFR	VFR	TOTAL
GEM FORECAST	LIFR	16296	10493	9170	14527	50486
	IFR	6539	14723	13407	11969	46638
	MVFR	6182	18643	57552	60867	143244
	VFR	13011	21494	85760	1404727	1524992
	TOTAL	42028	65353	165889	1492090	1765360

The two forecast-versus-observed contingency tables for ceiling afford additional opportunities for interpretations. The numerous scores computed in the study (contained in Tables 4 through 9 later on in this report) reflect the kinds of features expected to be found in the complete contingency tables. Unfortunately, the contingency tables are too voluminous for us to do more than what is shown here and in the 6-h visibility comparisons which follow. Suffice it to say, a comparison between GEM's 16,296 correct predictions of LIFR are decidedly greater than the 14,178 that persistence achieved (16,296 - 14,178 = 2,118 more). GEM predicted LIFR 8,820 more times than persistence with a correct forecast percentage of 2,118/8,820 = 24.0%. This high percentage, for an event that has a climatology of 42,028/1,765,360 = 2.4% seems quite respectable.

In forecasting Visibility, Table 3 shows the number of times each operationally important change, between LIFR, IFR, MVFR, and VFR conditions, occurred and/or was predicted to occur. The precise definitions of the LIFR, IFR, MVFR, and VFR terms for visibility are:

VISIBILITY	
LIFR (Low Instrument Flight Rules)	0 - < 1 miles
IFR (Instrument Flight Rules)	1 - < 3 miles
MVFR (Marginal Visual Flight Rules)	3 - < 6 miles
VFR (Visual Flight Rules)	6 miles or greater

For example, the line having the combination G = VFR, P = IFR, and O = VFR is:

G	P	O	1-h	2-h	3-h	4-h	5-h	6-h
VFR	IFR	VFR	1	40	92	203	358	658

GEM was successful 658 times in predicting the lifting of the visibility from 1 - < 3 miles to 6 miles or greater, 6 hours in advance. 358 times it did so at 5 hours, 203 times it was successful at 4 hours, 92 times it was successful at 3 hours, 40 times at 2 hours, and 1 time at 1 hour. Conversely, of the times GEM predicted the same change it was incorrect 232 times in 6 hours, namely, 7 + 50 + 175 = 232 from:

G	P	O	1-h	2-h	3-h	4-h	5-h	6-h
VFR	IFR	LIFR	0	0	1	1	3	7
VFR	IFR	IFR	0	4	4	15	27	50
VFR	IFR	MVFR	0	12	13	47	93	175

While GEM was incorrect 232 times, persistence was incorrect 658 + 7 + 175 = 840 times and, of course, did not correctly forecast any changes. Of the 890 times that GEM forecast VFR from an initial condition of IFR, the visibility lifted 833 times or about 94%. The net result is that GEM had 658/(658 + 7 + 50 + 175) = 73.9% correct for an event that occurred 26,177 times out of 60,093 initial conditions of IFR, or 43.6% of the time. These latter figures were extracted from the full contingency tables of visibility for persistence and GEM, namely:

VISIBILITY (PERSISTENCE) projection time: 6 hours

		OBSERVED CONDITION				
		LIFR	IFR	MVFR	VFR	TOTAL
PERSISTENCE CONDITION	LIFR	7761	5007	4744	11758	29270
	IFR	5225	13859	14832	26177	60093
	MVFR	4950	15551	38751	70343	129595
	VFR	11082	25116	71788	1438416	1546402
	TOTAL	29018	59533	130115	1546694	1765360

VISIBILITY (GEM) projection time: 6 hours

		OBSERVED CONDITION				
		LIFR	IFR	MVFR	VFR	TOTAL
GEM FORECAST	LIFR	7767	4994	4721	11645	29127
	IFR	5209	13808	14649	25517	59183
	MVFR	4861	15165	37520	63013	120559
	VFR	11181	25566	73225	1446519	1556491
	TOTAL	29018	59533	130115	1546694	1765360

GEM's skill over persistence can be appraised by comparing corresponding cells of persistence's contingency table with GEM's contingency table. They show that GEM achieves 6 more correct predictions of LIFR while making 143

fewer forecasts of LIFR. The bulk of GEM's superiority over persistence, however, is accomplished in predicting improving visibility conditions successfully.

Rain and Rain Shower are also weather elements whose change conditions are of interest. From a set of tables similar to those of ceiling and visibility we display Rain Shower and its observed and predicted change over the 1-6 hour period. The figures which follow show how many times a no rain shower condition (NONE) remained NONE or changed to RW-, RW, or RW+. Included in the figures are the frequencies of GEM's forecasting of these events. There were 39 cases where GEM initiated RW- at 2 hours and was successful. It did this erroneously 141 times. However, the event RW- was observed to start 24,184 out of 1,816,928 (source figures not shown) situations where NONE was the initial condition. GEM's 39/(39 + 141) = 21.67% compares favorably with the conditional climatological percentage 24,184/1,816,928 = 1.33% for a 2-h forecast.

G	P	O	1-h	2-h	3-h	4-h	5-h	6-h
RW-	NONE	NONE	0	141	316	645	462	224
RW-	NONE	RW-	0	39	72	116	58	27
RW-	NONE	RW	0	14	14	13	10	1
RW-	NONE	RW+	0	2	4	3	2	1

Finally, we show the frequencies of changes in Fog in a similar manner. All considerations pertain to the initial hour being 0600 local time. N signifies a no fog event and F signifies the occurrence of a fog event. Note that 3,773 times GEM successfully "turned fog off" in its 6-h forecast. It successfully "turned fog on" 28 times in its 6-h forecast. Gleaned from these figures is the interesting fact that there were 2,863 + 123 = 2,986 instances when fog did not "burn off" by noon.

Initial hour	GPO	1-h	2-h	3-h	4-h	5-h	6-h
0600	NNN	59247	57299	56396	55286	54824	55327
0600	NNF	1986	2580	2380	1973	1783	1580
0600	NFN	0	1	28	1305	2757	3773
0600	NFF	0	0	1	41	92	123
0600	FNN	0	0	2	16	28	39
0600	FNF	0	2	6	23	27	28
0600	FFN	2668	5866	8296	8694	8328	8045
0600	FFF	12552	9667	6898	4640	3619	2863

A full set of comparative scores between GEM and persistence can be found in Tables 4 for the 1-h projection. The predictand weather elements are listed in the first column of Table 4 less, of course , Unity, Month of the year, Hour of the day, and the Interactive terms. Subsequent projections, hours 2 to 6, follow in Tables 5-9, respectively. Definitions of each of the scores presented in Tables 4-9 are given in the Appendix.

The reader wishing to possess an MS-DOS/PC-DOS file containing all of the verification contingency tables can obtain a copy from the authors upon request, along with an accompanying file for studying the frequency of all

forecast and observed changes for Rain, Rain Shower, Thunderstorm (regular or severe), and Fog classified according to all 24 initial hours of the day.

IV. SUMMARY AND POSSIBLE IMPROVEMENTS

The following is a brief summarization of the contents of Tables 4-9 on the skill or lack of skill demonstrated by this test sample verification between the statistical weather forecasting method GEM and that of Persistence. Each element will be addressed according to how its categorical forecasts and its probabilistic forecasts compared:

- Pressure
  Gem's categorical forecasts at 2-h are worse than persistence but superior at 3-h and beyond, probabilities are always better.

- Temperature
  GEM's categorical forecasts at 1-h and beyond are better than persistence, probabilities are always better.

- Dewpoint Depression
  GEM's categorical forecasts are worse than persistence at 1-h but beyond that projection are better. Probabilities are always better.

- Lowest Cloud Amount
  GEM is worse than persistence at 1-h but better at 2-h and beyond, probabilities are always better.

- Visibility
  GEM is better than persistence on all scores and at all projections except the LIFR Threat at 1-h. Probabilities were always quite a bit better than conditional persistence.

- Weather
  GEM is better than persistence on all scores and at all projection except for the 6-h Threat. Probabilities were always better than conditional persistence.

- Fog
  Fog is forecast by GEM with more skill than persistence starting at 2-h. Probabilities are always better.

- Haze
  GEM ties with persistence in all categorical forecasts. Its probabilities are worse at 1-h and better from 2-h to 6-h.

- Blowing
  GEM never deviated from persistence categorically but had better probabilities.

- Drizzle
  GEM begins to depart successfully from persistence at 5-h. Its Threat Score at 6-h is not better but other scores are. GEM's probabilities are always better than persistence.

- Rain
  GEM departs from persistence starting at 2-h and except for Threat at 5-h is better. Probabilities are better.

- Rain Showers
  Rain showers can be turned off as early as 1-h by GEM. Its ability to initiate RW- begins as early as 2-h and continues to 6-h. Occasionally falls to persistence but is better most of the time. GEM's probabilities are always better.

- Snow
  GEM departs from persistence successfully at hour 3 and beyond. GEM occasionally has a Threat score that is not as good as persistence. Probabilities are always better.

- Snow Showers
  GEM does not deviate from persistence until the 5-h projection and is successful, probabilities are better.

- Freezing Drizzle
  GEM never deviates from persistence categorically, Probabilities are better.

- Freezing Rain
  GEM never deviates from persistence categorically, Probabilities are better.

- Thunderstorm
  GEM betters persistence on most score comparisons except on percentage of hits by a small margin. Probabilities are better suggesting they could be useful if spatially mapped.

- Thunderstorm (Heavy)
  GEM stays with persistence throughout the 6 projections categorically. Probabilities are better.

- Lowest Cloud Height
  GEM is worse than persistence at 1-h. GEM does better between 2-6 hours. Probabilities are always better than conditional persistence.

- Second Cloud Amount
  GEM is worse than persistence at 1-h but better after that. Probabilities are better.

- Second Cloud Height
  GEM has better Heidke and probabilities (Brier scores) than Persistence throughout 1-6 hour. Its Hit percentage is worse from 1-3 hours but better from 4-6 hours. GEM has poorer Threat scores from 4-6 hours.

- Total Cloud Cover
  GEM is uniformly superior to persistence at all projection times.

- Ceiling
  GEM has mixed comparative scores against persistence at 2 and 3 hours. At 4 hours and beyond it forecasts rising and falling ceiling conditions successfully. Probabilities are better by quite a bit.

- Wind
  GEM and persistence have mixed successes both categorically and in probabilities at all hours. This appears to be one of GEM's least competitive predictands when pitted against persistence even though it does no worse than persistence overall.

The final conclusion is that GEM provides 1-6 hour probabilities which are, for all intents and purposes, uniformly superior to conditional persistence at all projection times. When comparing the aggregate of all forecast scores, the statistical method bettered persistence by a factor of about 8 to 1. The crucial issue of demonstrating skill in predicting visibility and ceiling LIFR, IFR, MVFR, and VFR changes is positive--the objective statistical procedure successfully predicted lifting and lowering conditions in both visibility and ceiling. There were 547 correct forecasts of the lowering of ceiling from VFR conditions to LIFR conditions--a very important and difficult fete to accomplish--at the 6-h projection time. Such a performance had previously been thought impossible for any statistical procedure, commonly characterized as, "yielding nothing but predictions that gravitate toward the most likely conditions."

Even at the hard-to-predict first hour the probabilities are an improvement over conditional persistence by 12.8% and 16.9% in the Brier Score for visibility and ceiling, respectively. This suggests that an application of decision-theoretic methods could be of practical usefulness (see Miller, 1962 on this subject).

In successfully predicting conditions important to aviation, GEM shows a capability in situations where persistence can only hold on to the present conditions for its contribution. Fog along with Rain Shower changes can be anticipated successfully by the statistical prediction procedure.

The majority of the remaining elements demonstrate enough integrity to be worthy companions to ceiling, visibility, fog, and rain showers for the statistical method to be accepted as automated objective guidance in the time frame of 1-6 hours. The method at times seems reluctant to break from persistence; however, this is a point in its favor since false alarms rates need to be kept as small as possible.

Statistical weather forecasting procedures are objective. Their predictions are determined in a systematic manner usually by computers and without the need of human intervention or interpretation by its users. This suggests that modifications could make the procedure better. From work performed for the Federal Aviation Administration (FAA) on the Automated Weather Observing System (AWOS), experiments have revealed that improvements will be forthcoming in the method employed here if interactive predictors are uncovered in a systematic manner (Miller, 1988).

A logical set of interactive terms potentially beneficial are those combining hour of the day with temperature and month of the year with temperature. A redevelopment of GEM would be required to make these modifications.

A logical set of interactive terms potentially beneficial are those combining hour of the day with temperature and month of the year with temperature. A redevelopment of GEM would be required to make these modifications.

The inclusion of a station's latitude, longitude, altitude, closeness to bodies of water, ground cover (sand, snow, ice, dirt, etc.) would seem to have a role to play as additional predictors. Remarks in the observation could be organized into a predictor set as well. All of these suggestions would require a redevelopment of GEM.

Finally, we give a partial list of attributes, features, and/or characteristics of GEM that justified the making of this verification study:

- o Instantaneous forecasts from:
  - Record observation
  - Special observation
  - Automated observation
  - Anywhere in the U.S.
- o Instantaneous forecasts for:
  - Pilot briefing for departing location and for destination
  - Telephone dial-up and quick response system
  - Anywhere in the U.S.
- o Mapping of probabilities for analysis or feedback
- o Anytime--any hour, any season
- o Portable
- o No communication lines necessary, under most circumstances
- o No model output required thus avoiding delays
- o No spatial information needed (no grid point interpolations)
- o No SAO past history required (needs no "memory")
- o Simple to use, no expertise necessary
- o Requires nothing more than a Personal Computer

Appendix

Definition of Verification Scores

For all the following scores, these definitions apply:

N = sample size (number of cases),
f_i = the ith forecast, and
o_i = the ith matching observation.

The following score is appropriate for variables in probabilistic form:

Brier score (BS)--The Brier score measures the mean square error. Lower values are better. The Brier score is relevant when f_1 is a probability forecast of an event in the range zero to one and o_i is one if the event occurred and zero if it did not occur. In this context, an "event" is defined to be one of two or more exhaustive and mutually exclusive categories of a weather element. It is customary, when the weather element is divided into more than two categories, to compute a Brier score over all categories.

$$BS = \frac{1}{N} \sum_{i=1}^{N} \sum_{j=1}^{k} (f_{ij} - o_{ij})^2$$

where j refers to the k categories of the weather element.

Brier Scores for persistence are computed from the conditional probability given persistence's observed category at time = 0. The 1-h calculation comes from the developmental sample's conditional probabilities while 2-6 hour values come from estimates resulting from a set of exponentially weighted powers of Markov transition-probability matrices.

The following scores are appropriate when the forecasts and observations each naturally occur in, or are put into, one of m mutually exclusive and exhaustive categories.

Contingency table--not a score as such, but contains all verification information for the discrete variables (see Table A.1). The element X_{ij} in the table is the number of times the forecast was in the jth category and the observation was the ith category. The row and column totals are also shown here with the subscript p. Various scores can be computed from these elements.

Table A.1 Contingency table.

Observed Category	Forecast Categories 1	2	...	m	Total
1	X_{11}	X_{12}	...	X_{1m}	X_{1p}
2	X_{21}	X_{22}	...	X_{2m}	X_{2p}
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
m	X_{m1}	X_{m2}	...	X_{mm}	X_{mp}
Total	X_{p1}	X_{p2}	...	X_{pm}	X_{pp}

Percent Correct (PC)--the fraction of the time a correct forecast was made, regardless of the category, expressed in percent. Larger values are better.

$$PC = \frac{\sum_{i=1}^{m} X_{ii}}{X_{pp}} \times 100.$$

Bias by category (BIAS)--measures the tendency to overforecast (BIAS > 1) or underforecast (BIAS < 1) a particular category. A bias of one indicates no overforecasting or underforecasting. The bias for the ith category is:

$$BIAS_i = \frac{X_{pi}}{X_{ip}} .$$

Heidke skill score (SS)--the skill score measures the fraction of possible improvement afforded by the forecasts over a test set of forecasts. The test

forecasts are values expected by chance computed on the marginal totals of the contingency table. Larger values are better. The Heidke skill score is highly influenced by the "balance" in the contingency table from which it is measured since it is based upon the expectation of chance.

$$SS = \frac{NC - E}{T - E} \quad \text{where number correct (NC)} = \sum_{i=1}^{m} X_{ii},$$

$$T = X_{pp}, \quad E = \sum_{i=1}^{m} (X_{ip} \cdot X_{pi})/T$$

Critical Success Index (CSI) or Threat Score (TS)--the fraction of the time the threat event was correctly forecast when there was indeed a threat. This is computed from a contingency table when there are only two categories (m = 2), the first of which is for a "threat" event, such as low ceilings or low visibilities. A threat, for this purpose, is defined as a situation where either the threat event occurred, or was forecast, or both.

$$CSI = \frac{X_{11}}{X_{11} + X_{12} + X_{21}}$$

References

Howard, R., 1960: Dynamic Programming and Markov Processes. The Technology Press, MIT, John Wiley and Sons, New York, 136 pp.

Klein, W. H., B. M. Lewis, and I. Enger, 1959: Objective prediction of five-day mean temperature during winter. J. Meteor., 16, 672-681.

Miller, R. G., 1962: Statistical prediction by discriminant analysis. Meteorological Monographs, Vol. 4, No. 25, Amer. Meteor. Soc., Boston, Massachusetts, 54 pp.

_____, 1981: GEM: A statistical weather forecasting procedure. NOAA Technical NWS 28, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 103 pp.

_____, 1988: Very short range statistical forecasting of automated weather observations. Federal Aviation Administration, Final Report DOT/FAA/PM-88/3, U.S. Department of Transportation, 236 pp.

Wiener, N., 1948: Cybernetics. The Technology Press, MIT, John Wiley and Sons, New York, 194 pp.

_____, 1956: Nonlinear prediction and dynamics. Proceeding of the Third Berkeley Symposium, Ed., J. Neyman, University of California Press, Berkeley, 247-252.

Table 1. GEM equations for predicting the four categories of Total Cloud Cover, CLEAR, SCATTERED, BROKEN, and OVERCAST, at 1 hour.

	PREDICTAND			
PREDICTOR	CLEAR	SCATTERED	BROKEN	OVERCAST
UNITY	0.28252	0.19713	0.18220	0.33814
MONTH OF YEAR				
JANUARY	-0.01815	-0.00005	-0.00056	0.01877
FEBRUARY	-0.01607	0.00062	0.00225	0.01320
MARCH	-0.01699	0.00362	0.00525	0.00812
APRIL	-0.00383	-0.00354	-0.00264	0.01001
MAY	-0.00016	0.00093	0.00128	-0.00204
JUNE	0.00933	0.00417	-0.00050	-0.01300
JULY	0.01386	0.00417	0.00164	-0.01967
AUGUST	0.01802	0.00368	-0.00380	-0.01789
SEPTEMBER	0.02426	-0.00838	-0.00644	-0.00945
OCTOBER	0.01110	-0.00232	-0.00062	-0.00816
NOVEMBER	-0.00652	-0.00177	0.00305	0.00524
DECEMBER	-0.01497	-0.00128	0.00103	0.01522
HOUR OF DAY (LOCAL STANDARD TIME)				
0000	0.02530	-0.01236	-0.05513	0.04219
0100	0.01863	-0.00862	-0.05177	0.04176
0200	0.01618	-0.00715	-0.04932	0.04029
0300	0.00131	0.00319	-0.04173	0.03723
0400	-0.02348	0.01488	-0.02961	0.03821
0500	-0.02874	0.01292	-0.02129	0.03711
0600	-0.01919	0.01004	-0.02141	0.03056
0700	-0.00077	-0.01284	0.04848	-0.03486
0800	-0.00322	-0.00366	0.04903	-0.04215
0900	-0.01619	0.00558	0.05503	-0.04441
1000	-0.02592	0.00992	0.05827	-0.04227
1100	-0.02898	0.00735	0.06133	-0.03970
1200	-0.02831	0.00423	0.06084	-0.03676
1300	-0.02421	0.00527	0.05717	-0.03823
1400	-0.01993	0.00478	0.04903	-0.03389
1500	-0.01448	0.00166	0.04450	-0.03168
1600	-0.00316	-0.00207	0.03710	-0.03187
1700	0.01055	-0.00948	0.03085	-0.03193
1800	0.02089	-0.01168	0.02345	-0.03266
1900	0.02683	0.00350	-0.05929	0.02897
2000	0.03362	0.00013	-0.06345	0.02970
2100	0.03154	-0.00464	-0.06223	0.03533
2200	0.02444	-0.00354	-0.05831	0.03741
2300	0.02628	-0.00728	-0.05593	0.03692
SEA LEVEL PRESSURE (MILLIBARS)				
800.0-985.0	-0.00414	-0.01341	-0.00134	0.01889

985.1-990.0	-0.00310	-0.01261	-0.00311	0.01883
990.1-995.0	-0.00690	-0.00043	-0.00617	0.01350
995.1-1000.0	-0.00776	-0.00129	-0.00409	0.01313
1000.1-1005.0	-0.00922	-0.00239	-0.00054	0.01215
1005.1-1010.0	-0.00837	-0.00215	0.00019	0.01032
1010.1-1015.0	-0.00457	-0.00135	-0.00023	0.00616
1015.1-1020.0	0.00038	0.00134	-0.00023	-0.00149
1020.1-1025.0	0.00608	0.00061	0.00044	-0.00712
1025.1-1030.0	0.00944	0.00134	0.00007	-0.01086
1030.1-1035.0	0.01140	0.00098	0.00276	-0.01514
1035.1-1040.0	0.01532	0.00226	0.00411	-0.02169
1040.1-1090.0	0.02407	-0.00380	-0.00005	-0.02022

DRY BULB TEMPERATURE (DEGREES F)

-140 TO -31	0.03499	-0.07086	0.04043	-0.00456
-30 TO -26	0.01394	-0.02833	-0.01037	0.02476
-25 TO -21	0.04539	-0.00764	-0.03552	-0.00223
-20 TO -16	0.03389	-0.01505	-0.01643	-0.00241
-15 TO -11	0.02820	-0.02147	-0.01624	0.00952
-10 TO -6	0.02875	-0.01621	-0.01459	0.00205
-5 TO -1	0.02960	-0.01419	-0.01961	0.00420
0 TO 4	0.02611	-0.01199	-0.01178	-0.00235
5 TO 9	0.02403	-0.01138	-0.00908	-0.00358
10 TO 14	0.02416	-0.01058	-0.01379	0.00022
15 TO 19	0.02195	-0.01156	-0.01477	0.00438
20 TO 24	0.02354	-0.01450	-0.01618	0.00713
25 TO 29	0.02232	-0.01388	-0.01765	0.00921
30 TO 34	0.02189	-0.01456	-0.01790	0.01056
35 TO 39	0.01987	-0.01468	-0.01435	0.00915
40 TO 44	0.01596	-0.01223	-0.01116	0.00744
45 TO 49	0.01216	-0.01040	-0.00994	0.00817
50 TO 54	0.00745	-0.00929	-0.00559	0.00744
55 TO 59	0.00335	-0.00727	-0.00364	0.00756
60 TO 64	-0.00026	-0.00458	0.00004	0.00481
65 TO 69	-0.00467	0.00062	0.00548	-0.00143
70 TO 74	-0.01116	0.00803	0.01240	-0.00927
75 TO 79	-0.02040	0.01610	0.02403	-0.01973
80 TO 84	-0.03178	0.02534	0.02635	-0.01992
85 TO 89	-0.04892	0.04297	0.02574	-0.01979
90 TO 94	-0.06434	0.07192	0.01136	-0.01894
95 TO 99	-0.06764	0.08673	0.00199	-0.02108
100 TO 104	-0.07003	0.07326	0.00891	-0.01214
105 TO 109	-0.10277	0.08391	0.02807	-0.00921
110 TO 140	-0.08741	0.03587	0.05475	-0.00321

DEW POINT DEPRESSION (DEGREES F)

0	-0.03380	-0.00567	-0.01902	0.05849
1	-0.03466	-0.00347	-0.02024	0.05837
2 TO 4	-0.02371	-0.00555	-0.02324	0.05250
5 TO 7	-0.00945	0.00804	0.01011	-0.00870
8 TO 11	-0.00094	0.00492	0.01164	-0.01562
12 TO 15	0.00659	0.00198	0.01201	-0.02058
16 TO 19	0.01130	0.00345	0.00865	-0.02339

20 TO 25	0.01644	0.00528	0.00363	-0.02535
26 TO 35	0.02874	-0.00292	-0.00298	-0.02284
36 TO 50	0.04551	-0.02446	-0.00427	-0.01678
51 TO 99	0.06975	-0.05469	-0.00561	-0.00944
LOWEST CLOUD AMOUNT				
CLEAR	0.21128	-0.10670	-0.05572	-0.04886
SCATTERED	-0.07042	0.06350	0.00426	0.00267
BROKEN	-0.08101	0.04459	0.03339	0.00303
OVERCAST	-0.11278	-0.00566	0.04692	0.07152
TOTAL OBSCURATION	-0.10757	-0.00431	0.04618	0.06570
VISIBILITY (MILES)				
.00 TO .49	-0.00429	-0.01293	-0.01171	0.02893
.50 TO .74	-0.00509	-0.01164	-0.01955	0.03628
.75 TO .99	-0.00937	-0.00417	-0.02444	0.03799
1.00 TO 1.49	-0.00882	-0.00283	-0.02775	0.03940
1.50 TO 1.99	-0.00882	0.00390	-0.02977	0.03469
2.00 TO 2.49	-0.00735	0.00109	-0.02793	0.03420
2.50 TO 2.99	-0.00319	0.00268	-0.03509	0.03560
3.00 TO 3.99	-0.00319	0.00072	-0.02897	0.03144
4.00 TO 4.99	0.00066	-0.00301	-0.02983	0.03218
5.00 TO 5.99	0.00391	-0.00558	-0.02995	0.03163
6.00 TO 6.99	0.00238	-0.00711	-0.02585	0.03058
7.00 TO 100.0	0.00030	0.00066	0.00512	-0.00607
WEATHER				
NO WEATHER	0.00052	0.00273	0.00273	-0.00598
WEATHER	-0.00205	-0.01079	-0.01079	0.02364
FOG				
NO FOG	-0.00031	-0.00012	0.00043	0.00000
FOG	0.00465	0.00184	-0.00642	-0.00006
GROUND FOG				
NO GROUND FOG	0.00020	-0.00024	-0.00037	0.00041
GROUND FOG	-0.01130	0.01347	0.02056	-0.02272
HAZE				
NO HAZE OR SMOKE	-0.00034	-0.00065	0.00004	0.00095
HAZE OR SMOKE	0.00492	0.00933	-0.00057	-0.01368
BLOWING				
NO BLOWING	0.00003	-0.00004	-0.00006	0.00006
BLOWING	-0.01062	0.01324	0.02069	-0.02332

DRIZZLE				
NO DRIZZLE	0.00006	0.00024	0.00024	-0.00054
LIGHT DRIZZLE	-0.00587	-0.02215	-0.02137	0.04939
MOD OR HEAVY DRIZZLE	-0.00538	-0.02142	-0.01910	0.04591
RAIN				
NO RAIN	0.00005	0.00084	0.00149	-0.00237
LIGHT RAIN	-0.00148	-0.02174	-0.03848	0.06171
MODERATE RAIN	0.00329	-0.01936	-0.03481	0.05087
HEAVY RAIN	0.00788	-0.02174	-0.03346	0.04732
RAIN SHOWERS				
NO RAIN SHOWERS	-0.00002	0.00041	0.00002	-0.00041
LIGHT RAIN SHOWERS	0.00096	-0.01655	-0.00089	0.01649
MODERATE RAIN SHOWERS	0.00016	-0.00969	-0.00750	0.01704
HEAVY RAIN SHOWERS	0.00065	-0.00480	0.01190	-0.00775
SNOW				
NO SNOW	0.00002	0.00041	0.00016	-0.00059
LIGHT SNOW	-0.00090	-0.02107	-0.00713	0.02910
MODERATE SNOW	0.00161	-0.01611	-0.02426	0.03876
HEAVY SNOW	0.00191	-0.01886	-0.02230	0.03925
SNOW SHOWERS				
NO SNOW SHOWERS	0.00003	0.00009	-0.00028	0.00016
LIGHT SNOW SHOWERS	-0.00327	-0.00940	0.03026	-0.01758
MODERATE SNOW SHOWERS	-0.00028	0.00058	0.03338	-0.03368
HEAVY SNOW SHOWERS	-0.00230	-0.02225	0.05566	-0.03111
FREEZING DRIZZLE				
NO FREEZING DRIZZLE	0.00001	0.00003	0.00002	-0.00005
FREEZING DRIZZLE	-0.00929	-0.02348	-0.01443	0.04720
FREEZING RAIN				
NO FREEZING RAIN	0.00000	0.00001	0.00003	-0.00004
FREEZING RAIN	-0.00251	-0.01883	-0.03394	0.05528
THUNDERSTORM				
NO THUNDERSTORM	0.00001	0.00027	-0.00012	-0.00016
THUNDERSTORM	-0.00109	-0.03553	0.01616	0.02047
THUNDERSTORM (HEAVY)				
NO HEAVY THUNDERSTORM	0.00000	-0.00000	-0.00000	0.00000
HEAVY THUNDERSTORM	-0.00337	0.01053	0.04327	-0.05043

LOWEST CLOUD HEIGHT (HUNDREDS OF FEET)

0	TO	1	0.06073	-0.03358	-0.04611	0.01896
2	TO	4	0.04409	-0.05139	-0.03063	0.03793
5	TO	6	0.03656	0.09457	-0.02316	-0.10797
7	TO	9	0.02995	-0.05959	-0.01735	0.04699
10	TO	14	0.02597	-0.05298	-0.00945	0.03646
15	TO	19	0.02175	-0.04313	-0.00560	0.02698
20	TO	24	0.01826	-0.03303	-0.00174	0.01651
25	TO	29	0.01275	-0.02569	0.00383	0.00911
30	TO	39	0.00651	-0.01014	0.00328	0.00036
40	TO	49	0.00327	0.00430	-0.00609	-0.00148
50	TO	59	0.00688	0.00669	-0.01147	-0.00209
60	TO	75	0.00792	0.00443	-0.00945	-0.00289
76	TO	99	0.00571	-0.00616	0.00095	-0.00050
100	TO	150	0.00008	-0.00788	0.00603	0.00176
151	TO	UNLIMITED	-0.02048	0.01966	0.00946	-0.00864
PARTIAL OBSCURATION			0.04451	-0.00910	-0.04256	0.00715

SECOND CLOUD AMOUNT

CLEAR	0.01576	0.01459	-0.01763	-0.01272
SCATTERED	-0.08045	-0.00371	0.07295	0.01120
BROKEN	-0.02047	-0.05022	0.04131	0.02938
OVERCAST	-0.02843	-0.03443	0.02472	0.03813

SECOND CLOUD HEIGHT (HUNDREDS OF FEET)

0	TO	1	0.03368	-0.02384	-0.02687	0.01703
2	TO	4	0.01263	-0.03596	0.00061	0.02272
5	TO	6	0.00363	-0.02507	0.00312	0.01832
7	TO	9	0.00094	-0.02054	-0.00166	0.02126
10	TO	14	0.00302	-0.01056	-0.00723	0.01477
15	TO	19	0.00223	-0.00634	-0.00974	0.01385
20	TO	24	0.00241	-0.00548	-0.00882	0.01189
25	TO	29	0.00168	-0.00377	-0.00900	0.01110
30	TO	39	0.00015	0.00009	-0.01200	0.01177
40	TO	49	0.00168	-0.00096	-0.01543	0.01471
50	TO	59	0.00627	-0.00781	-0.01016	0.01171
60	TO	75	0.00761	-0.01356	-0.01010	0.01605
76	TO	99	0.00969	-0.01987	-0.00912	0.01930
100	TO	150	0.00761	-0.02397	-0.00043	0.01679
151	TO	UNLIMITED	-0.00132	0.00351	0.00146	-0.00365

TOTAL CLOUD COVER

CLEAR	0.36600	-0.00626	-0.15703	-0.20272
SCATTERED	-0.04251	0.35556	-0.07557	-0.23748
BROKEN	-0.18119	-0.03729	0.33863	-0.12016
OVERCAST	-0.18339	-0.18196	-0.00721	0.37256

CEILING

0	TO	1	-0.03332	0.05379	-0.08215	0.06169
2	TO	4	-0.01870	0.06541	-0.10020	0.05349
5	TO	6	-0.01545	0.06609	-0.10755	0.05691
7	TO	9	-0.01246	0.06896	-0.11030	0.05379
10	TO	14	-0.00878	0.06468	-0.10945	0.05355
15	TO	19	-0.00389	0.05929	-0.09978	0.04437
20	TO	24	-0.00175	0.05507	-0.09145	0.03813
25	TO	29	0.00168	0.04761	-0.08509	0.03580
30	TO	39	0.00499	0.03922	-0.07756	0.03335
40	TO	49	0.00480	0.03610	-0.06722	0.02631
50	TO	59	-0.00077	0.03983	-0.06428	0.02521
60	TO	75	-0.00285	0.04032	-0.06642	0.02895
76	TO	99	-0.00107	0.03806	-0.06899	0.03201
100	TO	150	0.00076	0.02863	-0.06012	0.03072
151	TO	UNLIMITED	0.00211	-0.02847	0.04967	-0.02332

WIND (SPEED IN KNOTS)

CALM	0.00012	0.00330	-0.00449	0.00108
NNE-NE <10	0.00207	-0.00637	0.01619	-0.01190
NNE-NE 10-19	-0.00362	-0.00876	0.01374	-0.00137
ENE-NE <10	-0.00184	-0.00802	0.01797	-0.00810
ENE-NE 10-19	-0.00533	-0.01316	0.01019	0.00830
ESE-SE <10	-0.00282	0.00067	-0.00768	0.00983
ESE-SE 10-19	-0.00882	-0.00588	-0.01208	0.02678
SSE-S <10	-0.00245	-0.00031	-0.00388	0.00665
SSE-S 10-19	-0.00637	-0.00490	-0.00572	0.01699
SSW-SW <10	0.00091	0.00263	-0.00272	-0.00082
SSW-SW 10-19	-0.00276	-0.00257	-0.00027	0.00561
WSW-W <10	0.00452	0.00263	-0.00070	-0.00645
WSW-W 10-19	0.00483	0.00397	0.00652	-0.01532
WNW-NW <10	0.00630	0.00287	-0.00327	-0.00590
WNW-NW 10-19	0.00783	0.01046	0.00273	-0.02102
NNW-N <10	0.00067	0.00122	-0.00737	0.00548
NNW-N 10-19	0.00220	0.00403	-0.01092	0.00469
NNE-E >19	-0.00423	-0.01169	0.00983	0.00610
ESE-S >19	-0.00992	-0.00515	-0.00914	0.02421
SSW-W >19	-0.00637	0.00942	0.00567	-0.00872
WNW-N >19	0.00085	0.01836	0.00083	-0.02004

INTERACTIVE PREDICTORS

NOT ((AUT OR WINT) AND DAY)	0.00960	-0.00243	-0.00786	0.00069
((AUT OR WINT) AND DAY)	-0.00319	0.00081	0.00261	-0.00023
NOT ((AUT OR WINT) AND HUMID)	0.00766	-0.00655	0.00317	-0.00428
((AUT OR WINT) AND HUMID)	-0.00121	0.00104	-0.00050	0.00068
NOT ((AUT OR WINT) AND SOUTH WIND)	-0.00481	0.00193	0.00043	0.00245
((AUT OR WINT) AND SOUTH WIND)	0.00131	-0.00052	-0.00012	-0.00067
NOT ((AUT OR WINT) AND EAST WIND)	-0.00669	0.00036	0.00010	0.00623
((AUT OR WINT) AND EAST WIND)	0.00132	-0.00007	-0.00002	-0.00123
NOT ((AUT OR WINT) AND OVERCAST)	-0.00524	0.00896	-0.00098	-0.00274
((AUT OR WINT) AND OVERCAST)	0.00131	-0.00224	0.00024	0.00068
NOT ((AUT OR WINT) AND UNLIM CEIL)	0.00777	-0.01711	0.03827	-0.02893

((AUT OR WINT) AND UNLIM CEIL)	-0.00318	0.00700	-0.01565	0.01183
NOT ((AUT OR WINT) AND UNLIM VIS)	0.00585	-0.00156	-0.00360	-0.00069
((AUT OR WINT) AND UNLIM VIS)	-0.00400	0.00107	0.00246	0.00047
NOT ((AUT OR WINT) AND NO PRECIP)	-0.00370	0.00325	-0.01904	0.01949
((AUT OR WINT) AND NO PRECIP)	0.00285	-0.00250	0.01468	-0.01502
NOT (DAY AND HUMID)	0.00407	0.00593	-0.01119	0.00119
(DAY AND HUMID)	-0.00034	-0.00049	0.00093	-0.00010
NOT (DAY AND SOUTH WIND)	0.00435	-0.00648	0.00236	-0.00024
(DAY AND SOUTH WIND)	-0.00128	0.00191	-0.00070	0.00007
NOT (DAY AND EAST WIND)	0.00319	0.00111	-0.00299	-0.00132
(DAY AND EAST WIND)	-0.00067	-0.00023	0.00062	0.00027
NOT (DAY AND OVERCAST)	0.00909	-0.00605	-0.05365	0.05060
(DAY AND OVERCAST)	-0.00186	0.00124	0.01098	-0.01036
NOT (DAY AND UNLIM CEIL)	-0.01573	0.03220	-0.06546	0.04900
(DAY AND UNLIM CEIL)	0.00679	-0.01389	0.02824	-0.02114
NOT (DAY AND UNLIM VIS)	-0.00735	-0.00407	0.00371	0.00771
(DAY AND UNLIM VIS)	0.00525	0.00291	-0.00265	-0.00551
NOT (DAY AND NO PRECIP)	0.00376	-0.00051	0.00643	-0.00968
(DAY AND NO PRECIP)	-0.00304	0.00041	-0.00520	0.00782
NOT (HUMID AND SOUTH WIND)	-0.00082	-0.00186	0.00819	-0.00551
(HUMID AND SOUTH WIND)	0.00010	0.00022	-0.00099	0.00067
NOT (HUMID AND EAST WIND)	-0.00470	-0.00022	0.00509	-0.00017
(HUMID AND EAST WIND)	0.00050	0.00002	-0.00054	0.00002
NOT (HUMID AND OVERCAST)	0.00727	0.01088	0.01967	-0.03783
(HUMID AND OVERCAST)	-0.00123	-0.00185	-0.00334	0.00642
NOT (HUMID AND UNLIM CEIL)	-0.02454	0.01255	0.03065	-0.01866
(HUMID AND UNLIM CEIL)	0.00251	-0.00128	-0.00313	0.00191
NOT (HUMID AND UNLIM VIS)	0.00415	0.00189	0.00252	-0.00856
(HUMID AND UNLIM VIS)	-0.00069	-0.00031	-0.00042	0.00142
NOT (HUMID AND NO PRECIP)	0.00497	0.00613	0.00186	-0.01296
(HUMID AND NO PRECIP)	-0.00109	-0.00134	-0.00041	0.00283
NOT (SOUTH WIND AND EAST WIND)	0.00452	-0.00691	0.02011	-0.01773
(SOUTH WIND AND EAST WIND)	-0.00093	0.00142	-0.00412	0.00363
NOT (SOUTH WIND AND OVERCAST)	0.00802	0.00667	-0.00972	-0.00497
(SOUTH WIND AND OVERCAST)	-0.00147	-0.00122	0.00178	0.00091
NOT (SOUTH WIND AND UNLIM CEIL)	-0.00833	0.01056	0.00039	-0.00262
(SOUTH WIND AND UNLIM CEIL)	0.00336	-0.00425	-0.00016	0.00105
NOT (SOUTH WIND AND UNLIM VIS)	-0.00100	-0.00300	-0.00052	0.00452
(SOUTH WIND AND UNLIM VIS)	0.00065	0.00196	0.00034	-0.00295
NOT (SOUTH WIND AND NO PRECIP)	0.00214	-0.00350	0.00104	0.00032
(SOUTH WIND AND NO PRECIP)	-0.00153	0.00250	-0.00074	-0.00023
NOT (EAST WIND AND OVERCAST)	0.00563	0.00195	-0.02888	0.02131
(EAST WIND AND OVERCAST)	-0.00092	-0.00032	0.00472	-0.00348
NOT (EAST WIND AND UNLIM CEIL)	-0.00381	0.01426	0.00322	-0.01368
(EAST WIND AND UNLIM CEIL)	0.00096	-0.00361	-0.00082	0.00346
NOT (EAST WIND AND UNLIM VIS)	-0.00127	-0.00009	-0.00428	0.00563
(EAST WIND AND UNLIM VIS)	0.00051	0.00004	0.00172	-0.00227
NOT (EAST WIND AND NO PRECIP)	-0.00318	-0.00403	-0.00941	0.01662
(EAST WIND AND NO PRECIP)	0.00141	0.00179	0.00418	-0.00737
NOT (OVERCAST AND UNLIM CEIL)	0.00530	0.00775	-0.03937	0.02633
(OVERCAST AND UNLIM CEIL)	-0.00027	-0.00039	0.00200	-0.00134
NOT (OVERCAST AND UNLIM VIS)	-0.00211	0.00226	-0.02335	0.02321
(OVERCAST AND UNLIM VIS)	0.00064	-0.00068	0.00706	-0.00702
NOT (OVERCAST AND NO PRECIP)	-0.00469	-0.01379	0.02921	-0.01073
(OVERCAST AND NO PRECIP)	0.00149	0.00438	-0.00928	0.00341

NOT (UNLIM CEIL AND UNLIM VIS)	0.00624	-0.00162	-0.01588	0.01126
(UNLIM CEIL AND UNLIM VIS)	-0.00838	0.00218	0.02133	-0.01512
NOT (UNLIM CEIL AND NO PRECIP)	0.00435	0.00065	0.00643	-0.01143
(UNLIM CEIL AND NO PRECIP)	-0.00704	-0.00106	-0.01040	0.01850

Legend

WEATHER--The occurrence of any hydrometer or obstruction to vision.

AUT OR WINT--Any of the months January, February, March, October, November, or December.

UNLIM--Unlimited ceiling or unlimited visibility.

DAY--Daylight hours of 0600-1800.

HUMID--Dewpoint depression of 3 degrees or less.

EAST WIND--Wind having an easterly component.

SOUTH WIND--Wind having a southerly component.

PRECIP--Precipitation falling.

OVERCAST--Total sky cover has 10 tenths coverage.

Table 2. Frequencies of GEM (G), Persistence (P), and Verifying Observation (O) for Ceiling change forecasts of LIFR, IFR, MVFR, and VFR for hours 1, 2, 3, 4, 5, and 6.

CEILING

G	P	O	1-h	2-h	3-h	4-h	5-h	6-h
LIFR	LIFR	LIFR	33563	26748	22329	18901	16244	14141
LIFR	LIFR	IFR	6354	8345	8977	8896	8640	8286
LIFR	LIFR	MVFR	1941	3550	4927	5941	6704	7191
LIFR	LIFR	VFR	2640	4676	6542	8403	10069	11811
LIFR	IFR	LIFR	0	0	1	84	441	1182
LIFR	IFR	IFR	0	2	2	64	431	1394
LIFR	IFR	MVFR	0	0	0	19	220	819
LIFR	IFR	VFR	0	1	2	40	253	802
LIFR	MVFR	LIFR	0	0	0	66	249	426
LIFR	MVFR	IFR	0	0	0	62	262	475
LIFR	MVFR	MVFR	0	0	1	81	345	646
LIFR	MVFR	VFR	0	0	0	55	311	616
LIFR	VFR	LIFR	0	1	4	36	278	547
LIFR	VFR	IFR	0	1	6	14	140	338
LIFR	VFR	MVFR	0	1	5	30	194	514
LIFR	VFR	VFR	0	0	4	72	535	1298
IFR	LIFR	LIFR	0	0	0	0	0	7
IFR	LIFR	IFR	0	0	0	0	0	14
IFR	LIFR	MVFR	0	0	0	0	6	29
IFR	LIFR	VFR	0	0	0	0	2	13
IFR	IFR	LIFR	5918	7960	8744	8754	8125	6190
IFR	IFR	IFR	46884	35622	29055	24415	20151	13940
IFR	IFR	MVFR	12407	17005	19005	19611	17905	12414
IFR	IFR	VFR	5038	8079	10881	13463	14303	10834
IFR	MVFR	LIFR	0	0	0	3	118	203
IFR	MVFR	IFR	0	0	0	15	283	468
IFR	MVFR	MVFR	0	0	0	15	336	551
IFR	MVFR	VFR	0	0	0	3	251	461
IFR	VFR	LIFR	0	0	1	4	54	139
IFR	VFR	IFR	0	0	5	12	112	301
IFR	VFR	MVFR	0	0	2	14	154	413
IFR	VFR	VFR	0	0	1	12	188	661
MVFR	LIFR	LIFR	0	0	0	0	5	15
MVFR	LIFR	IFR	0	0	0	1	3	14
MVFR	LIFR	MVFR	0	0	0	0	5	31
MVFR	LIFR	VFR	0	0	0	1	3	12
MVFR	IFR	LIFR	0	0	0	0	176	1226
MVFR	IFR	IFR	0	0	0	1	698	3505
MVFR	IFR	MVFR	0	0	0	1	1453	6038
MVFR	IFR	VFR	0	0	0	2	1163	6127
MVFR	MVFR	LIFR	1781	2921	3919	4676	4917	4813
MVFR	MVFR	IFR	11152	15103	16688	17126	16417	14743
MVFR	MVFR	MVFR	130101	104555	88956	77294	65426	50827
MVFR	MVFR	VFR	36021	52944	63786	70216	65266	53353
MVFR	VFR	LIFR	0	0	0	0	7	128
MVFR	VFR	IFR	0	0	1	4	38	301

MVFR	VFR	MVFR	0	0	6	16	83	656
MVFR	VFR	VFR	0	1	8	27	184	1375
VFR	LIFR	LIFR	0	0	0	0	5	15
VFR	LIFR	IFR	0	0	0	0	1	2
VFR	LIFR	MVFR	0	0	0	1	3	9
VFR	LIFR	VFR	0	0	0	1	25	76
VFR	IFR	LIFR	0	0	0	6	46	74
VFR	IFR	IFR	0	0	0	6	43	89
VFR	IFR	MVFR	0	0	0	0	63	126
VFR	IFR	VFR	0	0	0	52	320	620
VFR	MVFR	LIFR	0	0	0	2	130	569
VFR	MVFR	IFR	0	0	0	6	361	1678
VFR	MVFR	MVFR	0	0	1	119	3082	10694
VFR	MVFR	VFR	0	0	0	1048	11271	27324
VFR	VFR	LIFR	3188	5613	7747	9589	11175	12353
VFR	VFR	IFR	5751	9449	12704	15642	17972	19725
VFR	VFR	MVFR	34437	50070	59702	66437	71329	74931
VFR	VFR	VFR	1558124	1504415	1465729	1430187	1401293	1376707

Table 3. Frequencies of GEM (G), Persistence (P), and Verifying Observation (O) for Visibility change forecasts of LIFR, IFR, MVFR, and VFR for hours 1,2, 3, 4, 5, and 6.

VISIBILITY

G	P	O	1-h	2-h	3-h	4-h	5-h	6-h
LIFR	LIFR	LIFR	21508	16545	13539	10870	9037	7754
LIFR	LIFR	IFR	5409	6288	6347	5779	5310	4991
LIFR	LIFR	MVFR	1835	3284	4123	4509	4633	4711
LIFR	LIFR	VFR	1333	3416	5713	7897	9835	11639
LIFR	IFR	LIFR	0	0	0	0	5	13
LIFR	IFR	IFR	0	0	0	0	2	2
LIFR	IFR	MVFR	0	0	0	0	0	10
LIFR	IFR	VFR	0	0	0	0	2	6
LIFR	VFR	IFR	0	0	0	0	1	1
IFR	LIFR	LIFR	0	0	0	0	13	4
IFR	LIFR	IFR	0	0	0	0	13	1
IFR	LIFR	MVFR	0	0	0	0	6	1
IFR	LIFR	VFR	0	0	0	0	5	2
IFR	IFR	LIFR	4931	5871	6100	5744	5425	5205
IFR	IFR	IFR	37625	27403	22182	18253	15599	13807
IFR	IFR	MVFR	14048	16741	16879	16102	15331	14647
IFR	IFR	VFR	5640	11245	16095	19961	23063	25513
IFR	VFR	MVFR	0	0	0	0	0	1
IFR	VFR	VFR	0	0	0	0	0	2
MVFR	MVFR	LIFR	1902	3278	4155	4564	4862	4858
MVFR	MVFR	IFR	12668	15890	16856	16484	15867	15157
MVFR	MVFR	MVFR	92272	69734	57123	48154	41997	37514
MVFR	MVFR	VFR	32695	47057	55844	60986	62562	63007
MVFR	VFR	LIFR	0	0	0	0	0	3
MVFR	VFR	IFR	0	0	0	0	1	8
MVFR	VFR	MVFR	0	0	0	0	1	6
MVFR	VFR	VFR	0	0	0	0	1	6
VFR	LIFR	LIFR	1	0	0	1	0	3
VFR	LIFR	IFR	0	3	2	6	12	15
VFR	LIFR	MVFR	0	6	15	17	25	32
VFR	LIFR	VFR	1	13	25	77	100	117
VFR	IFR	LIFR	0	0	1	1	3	7
VFR	IFR	IFR	0	4	4	15	27	50
VFR	IFR	MVFR	0	12	13	47	93	175
VFR	IFR	VFR	1	40	92	203	358	658
VFR	MVFR	LIFR	0	0	2	12	46	92
VFR	MVFR	IFR	0	1	6	63	203	394
VFR	MVFR	MVFR	0	7	16	206	661	1237
VFR	MVFR	VFR	0	53	200	1237	4124	7336
VFR	VFR	LIFR	1656	3663	5635	7593	9362	11079
VFR	VFR	IFR	6162	11146	15335	18992	22264	25107
VFR	VFR	MVFR	31196	45895	55563	62365	67582	71781
VFR	VFR	VFR	1624417	1569467	1527876	1491416	1461836	1438408

Table 4. Comparative verification scores for 1-h forecasts between GEM and Persistence. A "+" appears to the right of the persistence score when GEM betters persistence. A "-" appears if persistence betters GEM. An "=" appears when there is a tie between GEM and Persistence. A final tally of +'s and -'s appears at the end of the table.

Predictand Element and Score	GEM	Persistence
SEA LEVEL PRESSURE 1		
hits :	1714472	1714472
percent correct:	0.904591	0.904591 =
heidke :	0.880175	0.880175 =
BRIER SCORES :	0.087969	0.088155 +
TEMPERATURE 1		
hits :	1261621	1250987
percent correct:	0.665658	0.660047 +
heidke :	0.641724	0.635822 +
BRIER SCORES :	0.254938	0.255611 +
DEW POINT DEPRESSION 1		
hits :	1098669	1101938
percent correct:	0.579681	0.581406 -
heidke :	0.522221	0.523618 -
BRIER SCORES :	0.285944	0.289960 +
LOWEST CLOUD AMOUNT 1		
hits :	1364009	1364111
percent correct:	0.719680	0.719734 -
heidke :	0.600920	0.600976 -
BRIER SCORES :	0.206008	0.211922 +
VISIBILITY 1		
hits :	1775824	1775823
percent correct:	0.936962	0.936961 +
heidke :	0.716899	0.716898 +
BRIER SCORES :	0.048685	0.055852 +
threat :	0.557563	0.557575 -
threat (IFR) :	0.605598	0.605596 +
WEATHER 1		
hits :	1778977	1777877
percent correct:	0.938626	0.938045 +
heidke :	0.801619	0.800446 +
BRIER SCORES :	0.050668	0.055817 +
threat :	0.723489	0.722344 +

FOG 1

hits :	1834001	1834001
percent correct:	0.967657	0.967657 =
heidke :	0.829003	0.829003 =
BRIER SCORES :	0.028216	0.029590 +
threat :	0.734736	0.734736 =

HAZE 1

hits :	1868667	1868667
percent correct:	0.985948	0.985948 =
heidke :	0.822963	0.822963 =
BRIER SCORES :	0.012911	0.012825 -
threat :	0.709830	0.709830 =

BLOWING 1

hits :	1893018	1893018
percent correct:	0.998796	0.998796 =
heidke :	0.721781	0.721781 =
BRIER SCORES :	0.001024	0.001198 +
threat :	0.565416	0.565416 =

DRIZZLE 1

hits :	1879896	1879896
percent correct:	0.991873	0.991873 =
heidke :	0.547179	0.547179 =
BRIER SCORES :	0.006182	0.006335 +
threat :	0.383459	0.383459 =

RAIN 1

hits :	1857182	1857182
percent correct:	0.979888	0.979888 =
heidke :	0.664855	0.664855 =
BRIER SCORES :	0.016040	0.016435 +
threat :	0.541802	0.541802 =

RAIN SHOWERS 1

hits :	1851019	1849933
percent correct:	0.976636	0.976063 +
heidke :	0.448856	0.435954 +
BRIER SCORES :	0.016430	0.016870 +
threat :	0.322009	0.321984 +

SNOW 1

hits :	1878842	1878842
percent correct:	0.991316	0.991316 =
heidke :	0.772924	0.772924 =
BRIER SCORES :	0.007382	0.007606 +
threat :	0.666494	0.666494 =

SNOW SHOWERS 1

hits :	1884947	1884947
percent correct:	0.994538	0.994538 =
heidke :	0.634932	0.634932 =
BRIER SCORES :	0.004383	0.004437 +
threat :	0.479799	0.479799 =

FREEZING DRIZZLE 1

hits :	1893776	1893776
percent correct:	0.999196	0.999196 =
heidke :	0.655113	0.655113 =
BRIER SCORES :	0.000663	0.000670 +
threat :	0.487559	0.487559 =

FREEZING RAIN 1

hits :	1893960	1893960
percent correct:	0.999293	0.999293 =
heidke :	0.665148	0.665148 =
BRIER SCORES :	0.000587	0.000592 +
threat :	0.498691	0.498691 =

THUNDERSTORM 1

hits :	1877330	1877334
percent correct:	0.990519	0.990521 -
heidke :	0.453071	0.452865 +
BRIER SCORES :	0.006819	0.006904 +
threat :	0.296893	0.296720 +

THUNDERSTORM (HEAVY) 1

hits :	1895190	1895190
percent correct:	0.999942	0.999942 =
heidke :	0.017828	0.017828 =
BRIER SCORES :	0.000029	0.000029 =
threat :	0.009009	0.009009 =

LOWEST CLOUD HEIGHT 1

hits :	1342613	1342632
percent correct:	0.708391	0.708401 -
heidke :	0.640646	0.640659 -
BRIER SCORES :	0.221483	0.226443 +
threat :	0.558625	0.558676 -

SECOND CLOUD AMOUNT 1

hits :	1420449	1420712
percent correct:	0.749459	0.749597 -
heidke :	0.554268	0.554333 -
BRIER SCORES :	0.178938	0.187698 +

SECOND CLOUD HEIGHT 1

hits	:	1547114	1547119
percent correct	:	0.816290	0.816292 -
heidke	:	0.533838	0.533817 +
BRIER SCORES	:	0.131254	0.135981 +
threat	:	0.254846	0.254846 =

TOTAL CLOUD COVER 1

hits	:	1457783	1457680
percent correct	:	0.769157	0.769103 +
heidke	:	0.688880	0.688825 +
BRIER SCORES	:	0.179228	0.182622 +

CEILING 1

hits	:	1768672	1768672
percent correct	:	0.933188	0.933188 =
heidke	:	0.757064	0.757064 =
BRIER SCORES	:	0.053070	0.063859 +
threat	:	0.605994	0.605994 =
threat (IFR)	:	0.678678	0.678678 =

WIND 1

hits	:	913487	913487
percent correct	:	0.481975	0.481975 =
heidke	:	0.445076	0.445076 =
BRIER SCORES	:	0.358899	0.358331 -

Projection Time: 1 Gem(+'s): 37 Persistence(-'s): 14 72.54902%

Table 5. Same as Table 4. except for 2-h.

Predictand Element and Score	GEM	Persistence
SEA LEVEL PRESSURE 2		
hits :	1540294	1540304
percent correct:	0.829425	0.829431 -
heidke :	0.785775	0.785783 -
BRIER SCORES :	0.146838	0.155160 +
TEMPERATURE 2		
hits :	991923	885177
percent correct:	0.534136	0.476655 +
heidke :	0.500487	0.439409 +
BRIER SCORES :	0.340251	0.375225 +
DEW POINT DEPRESSION 2		
hits :	854710	789892
percent correct:	0.460249	0.425345 +
heidke :	0.385442	0.346179 +
BRIER SCORES :	0.347173	0.393178 +
LOWEST CLOUD AMOUNT 2		
hits :	1149332	1148270
percent correct:	0.618898	0.618326 +
heidke :	0.457640	0.456345 +
BRIER SCORES :	0.251579	0.300490 +
VISIBILITY 2		
hits :	1683255	1683160
percent correct:	0.906408	0.906356 +
heidke :	0.578703	0.578591 +
BRIER SCORES :	0.065349	0.073234 +
threat :	0.390719	0.390516 +
threat (IFR) :	0.449655	0.449455 +
WEATHER 2		
hits :	1683075	1679538
percent correct:	0.906311	0.904406 +
heidke :	0.694869	0.691703 +
BRIER SCORES :	0.072369	0.088290 +
threat :	0.603396	0.601083 +

FOG 2

hits	1753542	1753258
percent correct:	0.944256	0.944103 +
heidke	0.704048	0.703412 +
BRIER SCORES	0.043975	0.051702 +
threat	0.581276	0.580592 +

HAZE 2

hits	1812986	1812986
percent correct:	0.976266	0.976266 =
heidke	0.701338	0.701338 =
BRIER SCORES	0.019936	0.021988 +
threat	0.554869	0.554869 =

BLOWING 2

hits	1853629	1853629
percent correct:	0.998151	0.998151 =
heidke	0.572455	0.572455 =
BRIER SCORES	0.001430	0.001949 +
threat	0.401916	0.401916 =

DRIZZLE 2

hits	1836542	1836542
percent correct:	0.988950	0.988950 =
heidke	0.383668	0.383668 =
BRIER SCORES	0.007486	0.009326 +
threat	0.244130	0.244130 =

RAIN 2

hits	1805543	1805365
percent correct:	0.972258	0.972162 +
heidke	0.537067	0.535555 +
BRIER SCORES	0.020430	0.024146 +
threat	0.406857	0.406857 =

RAIN SHOWERS 2

hits	1802009	1801159
percent correct:	0.970355	0.969897 +
heidke	0.302315	0.290985 +
BRIER SCORES	0.018842	0.024303 +
threat	0.201847	0.201470 +

SNOW 2

hits	1832599	1832599
percent correct:	0.986827	0.986827 =
heidke	0.655959	0.655959 =
BRIER SCORES	0.010343	0.011774 +
threat	0.527226	0.527226 =

SNOW SHOWERS 2

hits	:	1843202	1843202
percent correct	:	0.992537	0.992537 =
heidke	:	0.500770	0.500770 =
BRIER SCORES	:	0.005503	0.006524 +
threat	:	0.345910	0.345910 =

FREEZING DRIZZLE 2

hits	:	1854930	1854930
percent correct	:	0.998852	0.998852 =
heidke	:	0.501760	0.501760 =
BRIER SCORES	:	0.000866	0.001015 +
threat	:	0.335411	0.335411 =

FREEZING RAIN 2

hits	:	1855130	1855130
percent correct	:	0.998960	0.998960 =
heidke	:	0.510118	0.510118 =
BRIER SCORES	:	0.000787	0.000925 +
threat	:	0.342857	0.342857 =

THUNDERSTORM 2

hits	:	1832742	1832745
percent correct	:	0.986904	0.986906 -
heidke	:	0.247016	0.246811 +
BRIER SCORES	:	0.008085	0.010643 +
threat	:	0.145227	0.145092 +

THUNDERSTORM (HEAVY) 2

hits	:	1856957	1856957
percent correct	:	0.999943	0.999943 =
heidke	:	-0.000028	-0.000028 =
BRIER SCORES	:	0.000028	0.000042 +
threat	:	0.000000	0.000000 =

LOWEST CLOUD HEIGHT 2

hits	:	1076601	1076556
percent correct	:	0.579733	0.579709 +
heidke	:	0.482246	0.482223 +
BRIER SCORES	:	0.282446	0.309593 +
threat	:	0.405370	0.405231 +

SECOND CLOUD AMOUNT 2

hits	:	1251147	1250018
percent correct	:	0.673724	0.673116 +
heidke	:	0.422048	0.418713 +
BRIER SCORES	:	0.210850	0.252750 +

SECOND CLOUD HEIGHT 2

hits	:	1410254	1410424
percent correct	:	0.759401	0.759492 -
heidke	:	0.390692	0.390412 +
BRIER SCORES	:	0.154044	0.179455 +
threat	:	0.142200	0.142200 =

TOTAL CLOUD COVER 2

hits	:	1241285	1240076
percent correct	:	0.668413	0.667762 +
heidke	:	0.552962	0.552278 +
BRIER SCORES	:	0.231692	0.265588 +

CEILING 2

hits	:	1671341	1671343
percent correct	:	0.899992	0.899993 -
heidke	:	0.635795	0.635797 -
BRIER SCORES	:	0.071665	0.085157 +
threat	:	0.447166	0.447186 -
threat (IFR)	:	0.542326	0.542316 +

WIND 2

hits	:	734768	734768
percent correct	:	0.395662	0.395662 =
heidke	:	0.352662	0.352662 =
BRIER SCORES	:	0.393361	0.428064 +

Projection Time: 2 Gem(+'s): 56 Persistence(-'s): 7 89.8000%

Table 6. Same as Table 4. except for 3-h.

Predictand Element and Score	GEM	Persistence
SEA LEVEL PRESSURE 3		
hits :	1394685	1393777
percent correct:	0.762231	0.761735 +
heidke :	0.701295	0.700745 +
BRIER SCORES :	0.193015	0.209069 +
TEMPERATURE 3		
hits :	817322	669354
percent correct:	0.446687	0.365819 +
heidke :	0.406455	0.320729 +
BRIER SCORES :	0.385691	0.431290 +
DEW POINT DEPRESSION 3		
hits :	707752	609809
percent correct:	0.386804	0.333276 +
heidke :	0.301611	0.241588 +
BRIER SCORES :	0.380227	0.444366 +
LOWEST CLOUD AMOUNT 3		
hits :	1033618	1026915
percent correct:	0.564899	0.561235 +
heidke :	0.380427	0.374782 +
BRIER SCORES :	0.273782	0.356509 +
VISIBILITY 3		
hits :	1621037	1620740
percent correct:	0.885938	0.885776 +
heidke :	0.489749	0.489408 +
BRIER SCORES :	0.075550	0.083809 +
threat :	0.296810	0.296537 +
threat (IFR) :	0.362236	0.361894 +
WEATHER 3		
hits :	1616718	1609952
percent correct:	0.883578	0.879880 +
heidke :	0.619476	0.613754 +
BRIER SCORES :	0.086745	0.111137 +
threat :	0.528084	0.524552 +

FOG 3

hits	:	1698256	1693813
percent correct	:	0.928140	0.925712 +
heidke	:	0.616139	0.607590 +
BRIER SCORES	:	0.054683	0.067147 +
threat	:	0.488381	0.480529 +

HAZE 3

hits	:	1773318	1773318
percent correct	:	0.969163	0.969163 =
heidke	:	0.613976	0.613976 =
BRIER SCORES	:	0.024343	0.028128 +
threat	:	0.459922	0.459922 =

BLOWING 3

hits	:	1825479	1825479
percent correct	:	0.997671	0.997671 =
heidke	:	0.464346	0.464346 =
BRIER SCORES	:	0.001675	0.002676 +
threat	:	0.303367	0.303367 =

DRIZZLE 3

hits	:	1806707	1806707
percent correct	:	0.987411	0.987411 =
heidke	:	0.299006	0.299006 =
BRIER SCORES	:	0.008006	0.010415 +
threat	:	0.181906	0.181906 =

RAIN 3

hits	:	1769888	1769605
percent correct	:	0.967289	0.967134 +
heidke	:	0.454793	0.452364 +
BRIER SCORES	:	0.022858	0.028224 +
threat	:	0.330170	0.330170 =

RAIN SHOWERS 3

hits	:	1769417	1768916
percent correct	:	0.967031	0.966758 +
heidke	:	0.225709	0.216763 +
BRIER SCORES	:	0.019775	0.026753 +
threat	:	0.147339	0.146720 +

SNOW 3

hits	:	1799830	1799824
percent correct	:	0.983653	0.983650 +
heidke	:	0.576733	0.576649 +
BRIER SCORES	:	0.012214	0.014409 +
threat	:	0.440824	0.440824 =

SNOW SHOWERS 3

hits :	1813895	1813895
percent correct:	0.991340	0.991340 =
heidke :	0.421679	0.421679 =
BRIER SCORES :	0.006046	0.007492 +
threat :	0.276853	0.276853 =

FREEZING DRIZZLE 3

hits :	1827242	1827242
percent correct:	0.998634	0.998634 =
heidke :	0.405589	0.405589 =
BRIER SCORES :	0.000968	0.001181 +
threat :	0.254919	0.254919 =

FREEZING RAIN 3

hits :	1827458	1827458
percent correct:	0.998752	0.998752 =
heidke :	0.414141	0.414141 =
BRIER SCORES :	0.000887	0.001087 +
threat :	0.261643	0.261643 =

THUNDERSTORM 3

hits :	1802946	1802952
percent correct:	0.985356	0.985359 -
heidke :	0.158165	0.157937 +
BRIER SCORES :	0.008467	0.011640 +
threat :	0.090245	0.090109 +

THUNDERSTORM (HEAVY) 3

hits :	1829638	1829638
percent correct:	0.999944	0.999944 =
heidke :	0.019019	0.019019 =
BRIER SCORES :	0.000029	0.000042 +
threat :	0.009615	0.009615 =

LOWEST CLOUD HEIGHT 3

hits :	921289	921080
percent correct:	0.503508	0.503394 +
heidke :	0.388726	0.388629 +
BRIER SCORES :	0.312819	0.350715 +
threat :	0.319607	0.319207 +

SECOND CLOUD AMOUNT 3

hits :	1159523	1155729
percent correct:	0.633709	0.631635 +
heidke :	0.352485	0.345374 +
BRIER SCORES :	0.225860	0.287353 +

SECOND CLOUD HEIGHT 3

hits :	1334760	1334899
percent correct:	0.729480	0.729556 -
heidke :	0.316451	0.315491 +
BRIER SCORES :	0.164283	0.199009 +
threat :	0.104387	0.104387 =

TOTAL CLOUD COVER 3

hits :	1110856	1108669
percent correct:	0.607111	0.605916 +
heidke :	0.470147	0.468932 +
BRIER SCORES :	0.259769	0.315793 +

CEILING 3

hits :	1606085	1606086
percent correct:	0.877766	0.877767 -
heidke :	0.555291	0.555263 +
BRIER SCORES :	0.082681	0.098033 +
threat :	0.353325	0.353357 -
threat (IFR) :	0.456104	0.456038 +

WIND 3

hits :	622534	622537
percent correct:	0.340231	0.340232 -
heidke :	0.293284	0.293286 -
BRIER SCORES :	0.411774	0.464980 +

Projection Time: 3 Gem(+'s): 61 Persistence(-'s): 6 91.04478%

Table 7. Same as Table 4. except for 4-h.

Predictand Element and Score	GEM	Persistence
SEA LEVEL PRESSURE 4		
hits :	1274888	1266960
percent correct:	0.707660	0.703260 +
heidke :	0.632253	0.627309 +
BRIER SCORES :	0.227843	0.251718 +
TEMPERATURE 4		
hits :	693799	529594
percent correct:	0.385111	0.293965 +
heidke :	0.340095	0.243795 +
BRIER SCORES :	0.410357	0.458404 +
DEW POINT DEPRESSION 4		
hits :	597788	490839
percent correct:	0.331818	0.272453 +
heidke :	0.239406	0.172452 +
BRIER SCORES :	0.397719	0.468651 +
LOWEST CLOUD AMOUNT 4		
hits :	963384	941474
percent correct:	0.534752	0.522590 +
heidke :	0.338386	0.319809 +
BRIER SCORES :	0.287549	0.392809 +
VISIBILITY 4		
hits :	1570210	1568915
percent correct:	0.871586	0.870868 +
heidke :	0.422189	0.421172 +
BRIER SCORES :	0.082211	0.090577 +
threat :	0.231424	0.230954 +
threat (IFR) :	0.297020	0.296443 +
WEATHER 4		
hits :	1561085	1549356
percent correct:	0.866521	0.860011 +
heidke :	0.556656	0.549204 +
BRIER SCORES :	0.097591	0.129723 +
threat :	0.468787	0.466119 +

FOG 4

hits :	1652208	1640649
percent correct:	0.917102	0.910685 +
heidke :	0.545371	0.527546 +
BRIER SCORES :	0.062503	0.079092 +
threat :	0.419867	0.405956 +

HAZE 4

hits :	1736469	1736469
percent correct:	0.963873	0.963873 =
heidke :	0.544490	0.544490 =
BRIER SCORES :	0.027272	0.032605 +
threat :	0.392110	0.392110 =

BLOWING 4

hits :	1796789	1796789
percent correct:	0.997355	0.997355 =
heidke :	0.384549	0.384549 =
BRIER SCORES :	0.001789	0.003396 +
threat :	0.239061	0.239061 =

DRIZZLE 4

hits :	1776945	1776945
percent correct:	0.986340	0.986340 =
heidke :	0.241954	0.241954 =
BRIER SCORES :	0.008296	0.011164 +
threat :	0.143585	0.143585 =

RAIN 4

hits :	1736498	1735538
percent correct:	0.963889	0.963356 +
heidke :	0.397722	0.389305 +
BRIER SCORES :	0.024478	0.031279 +
threat :	0.276636	0.276636 =

RAIN SHOWERS 4

hits :	1738824	1737849
percent correct:	0.965180	0.964639 +
heidke :	0.175196	0.167960 +
BRIER SCORES :	0.020287	0.028465 +
threat :	0.112927	0.112935 -

SNOW 4

hits :	1767825	1767396
percent correct:	0.981278	0.981040 +
heidke :	0.514614	0.508589 +
BRIER SCORES :	0.013533	0.016477 +

threat	:	0.374774	0.374774 =
SNOW SHOWERS 4			
hits	:	1784333	1784333
percent correct	:	0.990441	0.990441 =
heidke	:	0.362459	0.362459 =
BRIER SCORES	:	0.006407	0.008193 +
threat	:	0.230032	0.230032 =
FREEZING DRIZZLE 4			
hits	:	1798808	1798808
percent correct	:	0.998476	0.998476 =
heidke	:	0.330786	0.330786 =
BRIER SCORES	:	0.001035	0.001299 +
threat	:	0.198716	0.198716 =
FREEZING RAIN 4			
hits	:	1799011	1799011
percent correct	:	0.998588	0.998588 =
heidke	:	0.339288	0.339288 =
BRIER SCORES	:	0.000948	0.001203 +
threat	:	0.204816	0.204816 =
THUNDERSTORM 4			
hits	:	1773476	1773486
percent correct	:	0.984415	0.984420 -
heidke	:	0.106342	0.106269 +
BRIER SCORES	:	0.008631	0.012224 +
threat	:	0.060559	0.060517 +
THUNDERSTORM (HEAVY) 4			
hits	:	1801450	1801450
percent correct	:	0.999942	0.999942 =
heidke	:	-0.000029	-0.000029 =
BRIER SCORES	:	0.000028	0.000043 +
threat	:	0.000000	0.000000 =
LOWEST CLOUD HEIGHT 4			
hits	:	814168	811977
percent correct	:	0.451925	0.450709 +
heidke	:	0.324579	0.323672 +
BRIER SCORES	:	0.330527	0.375647 +
threat	:	0.262906	0.261693 +
SECOND CLOUD AMOUNT 4			
hits	:	1106737	1086233
percent correct	:	0.614324	0.602942 +
heidke	:	0.312489	0.294340 +

BRIER SCORES :	0.235266	0.309790 +

SECOND CLOUD HEIGHT 4

hits :	1285283	1278908
percent correct:	0.713430	0.709892 +
heidke :	0.269740	0.265660 +
BRIER SCORES :	0.170231	0.213074 +
threat :	0.072329	0.072473 -

TOTAL CLOUD COVER 4

hits :	1016425	1012461
percent correct:	0.564193	0.561993 +
heidke :	0.411838	0.409727 +
BRIER SCORES :	0.277893	0.348722 +

CEILING 4

hits :	1552128	1551194
percent correct:	0.861550	0.861031 +
heidke :	0.495167	0.494020 +
BRIER SCORES :	0.090460	0.106878 +
threat :	0.290085	0.289161 +
threat (IFR) :	0.392753	0.392027 +

WIND 4

hits :	537568	537570
percent correct:	0.298391	0.298392 -
heidke :	0.248505	0.248507 -
BRIER SCORES :	0.424840	0.482870 +

Projection Time: 4 Gem(+'s): 63 Persistence(-'s): 5 92.64706%

Table 8. Same as Table 4. except for 5-h.

Predictand Element and Score	GEM	Persistence
SEA LEVEL PRESSURE 5		
hits :	1185031	1166195
percent correct:	0.665648	0.655067 +
heidke :	0.578402	0.566759 +
BRIER SCORES :	0.253406	0.284499 +
TEMPERATURE 5		
hits :	607347	437076
percent correct:	0.341155	0.245511 +
heidke :	0.292549	0.191883 +
BRIER SCORES :	0.426038	0.473523 +
DEW POINT DEPRESSION 5		
hits :	517491	409481
percent correct:	0.290682	0.230011 +
heidke :	0.193062	0.124135 +
BRIER SCORES :	0.408927	0.481536 +
LOWEST CLOUD AMOUNT 5		
hits :	914168	879836
percent correct:	0.513501	0.494216 +
heidke :	0.309561	0.279506 +
BRIER SCORES :	0.297225	0.418111 +
VISIBILITY 5		
hits :	1533070	1529173
percent correct:	0.861146	0.858957 +
heidke :	0.372812	0.370226 +
BRIER SCORES :	0.087573	0.095815 +
threat :	0.186295	0.185862 +
threat (IFR) :	0.251229	0.250496 +
WEATHER 5		
hits :	1516974	1502444
percent correct:	0.852105	0.843943 +
heidke :	0.504245	0.498394 +
BRIER SCORES :	0.106046	0.145660 +
threat :	0.422793	0.423534 -

FOG 5

hits :	1615580	1598273
percent correct:	0.907493	0.897772 +
heidke :	0.481890	0.461648 +
BRIER SCORES :	0.068810	0.089044 +
threat :	0.363260	0.350291 +

HAZE 5

hits :	1708414	1708414
percent correct:	0.959639	0.959639 =
heidke :	0.491187	0.491187 =
BRIER SCORES :	0.029454	0.036300 +
threat :	0.344299	0.344299 =

BLOWING 5

hits :	1775118	1775118
percent correct:	0.997108	0.997108 =
heidke :	0.326270	0.326270 =
BRIER SCORES :	0.001861	0.004198 +
threat :	0.195971	0.195971 =

DRIZZLE 5

hits :	1754680	1754677
percent correct:	0.985627	0.985626 +
heidke :	0.203671	0.203580 +
BRIER SCORES :	0.008484	0.011679 +
threat :	0.119076	0.119076 =

RAIN 5

hits :	1710635	1709723
percent correct:	0.960887	0.960374 +
heidke :	0.347612	0.339494 +
BRIER SCORES :	0.025649	0.033706 +
threat :	0.236698	0.236705 -

RAIN SHOWERS 5

hits :	1717703	1715148
percent correct:	0.964857	0.963422 +
heidke :	0.141019	0.139097 +
BRIER SCORES :	0.020579	0.029708 +
threat :	0.091039	0.093978 -

SNOW 5

hits :	1743426	1742808
percent correct:	0.979306	0.978959 +
heidke :	0.465330	0.456606 +
BRIER SCORES :	0.014502	0.018124 +
threat :	0.327342	0.327360 -

SNOW SHOWERS 5

hits :	1762074	1762073
percent correct:	0.989781	0.989780 +
heidke :	0.319441	0.319403 +
BRIER SCORES :	0.006639	0.008697 +
threat :	0.198425	0.198425 =

FREEZING DRIZZLE 5

hits :	1777322	1777322
percent correct:	0.998346	0.998346 =
heidke :	0.278596	0.278596 =
BRIER SCORES :	0.001081	0.001390 +
threat :	0.162400	0.162400 =

FREEZING RAIN 5

hits :	1777510	1777510
percent correct:	0.998451	0.998451 =
heidke :	0.276172	0.276172 =
BRIER SCORES :	0.000996	0.001294 +
threat :	0.160731	0.160731 =

THUNDERSTORM 5

hits :	1751658	1751663
percent correct:	0.983930	0.983933 -
heidke :	0.076907	0.076805 +
BRIER SCORES :	0.008716	0.012551 +
threat :	0.044392	0.044335 +

THUNDERSTORM (HEAVY) 5

hits :	1780165	1780165
percent correct:	0.999943	0.999943 =
heidke :	-0.000029	-0.000029 =
BRIER SCORES :	0.000028	0.000043 +
threat :	0.000000	0.000000 =

LOWEST CLOUD HEIGHT 5

hits :	742312	734652
percent correct:	0.416967	0.412664 +
heidke :	0.279776	0.276906 +
BRIER SCORES :	0.342625	0.392849 +
threat :	0.220495	0.218919 +

SECOND CLOUD AMOUNT 5

hits :	1073442	1035469
percent correct:	0.602967	0.581637 +
heidke :	0.282497	0.256339 +
BRIER SCORES :	0.242013	0.327194 +

hits :	1257429	1238705
percent correct:	0.706315	0.695797 +
heidke :	0.235591	0.229995 +
BRIER SCORES :	0.174441	0.225402 +
threat :	0.055762	0.055951 -

TOTAL CLOUD COVER 5

hits :	947530	941030
percent correct:	0.532240	0.528589 +
heidke :	0.368589	0.364681 +
BRIER SCORES :	0.291020	0.372872 +

CEILING 5

hits :	1517634	1508966
percent correct:	0.852475	0.847607 +
heidke :	0.452114	0.445624 +
BRIER SCORES :	0.096549	0.113508 +
threat :	0.245626	0.241046 +
threat (IFR) :	0.348579	0.343765 +

WIND 5

hits :	473438	473446
percent correct:	0.265937	0.265941 -
heidke :	0.213725	0.213713 +
BRIER SCORES :	0.433719	0.491564 +

Projection Time: 5 Gem(+'s): 67 Persistence(-'s): 7 90.54054%

Table 9. Same as Table 4. except for 6-h.

Predictand Element and Score	GEM	Persistence
SEA LEVEL PRESSURE 6		
hits :	1117180	1089789
percent correct:	0.632834	0.617318 +
heidke :	0.535711	0.519276 +
BRIER SCORES :	0.271596	0.309036 +
TEMPERATURE 6		
hits :	543823	374089
percent correct:	0.308052	0.211905 +
heidke :	0.256588	0.155845 +
BRIER SCORES :	0.436412	0.482653 +
DEW POINT DEPRESSION 6		
hits :	459621	352090
percent correct:	0.260355	0.199444 +
heidke :	0.158945	0.089273 +
BRIER SCORES :	0.416453	0.488827 +
LOWEST CLOUD AMOUNT 6		
hits :	876963	834176
percent correct:	0.496762	0.472525 +
heidke :	0.286798	0.248724 +
BRIER SCORES :	0.304450	0.436231 +
VISIBILITY 6		
hits :	1505614	1498787
percent correct:	0.852865	0.848998 +
heidke :	0.334502	0.330964 +
BRIER SCORES :	0.092074	0.100065 +
threat :	0.154174	0.153601 +
threat (IFR) :	0.219033	0.218072 +
WEATHER 6		
hits :	1482454	1465855
percent correct:	0.839746	0.830343 +
heidke :	0.461852	0.456790 +
BRIER SCORES :	0.113051	0.160023 +
threat :	0.388167	0.390813 -

FOG 6

hits :	1587819	1565127
percent correct:	0.899431	0.886577 +
heidke :	0.430528	0.407628 +
BRIER SCORES :	0.074036	0.097477 +
threat :	0.320719	0.308174 +

HAZE 6

hits :	1687771	1687771
percent correct:	0.956049	0.956049 =
heidke :	0.448110	0.448110 =
BRIER SCORES :	0.031169	0.039552 +
threat :	0.308075	0.308075 =

BLOWING 6

hits :	1759866	1759866
percent correct:	0.996888	0.996888 =
heidke :	0.272298	0.272298 =
BRIER SCORES :	0.001923	0.005110 +
threat :	0.158652	0.158652 =

DRIZZLE 6

hits :	1738817	1738805
percent correct:	0.984965	0.984958 +
heidke :	0.169841	0.169651 +
BRIER SCORES :	0.008623	0.012135 +
threat :	0.098383	0.098397 -

RAIN 6

hits :	1691979	1691076
percent correct:	0.958433	0.957921 +
heidke :	0.306808	0.298739 +
BRIER SCORES :	0.026547	0.035729 +
threat :	0.206078	0.205957 +

RAIN SHOWERS 6

hits :	1703555	1699070
percent correct:	0.964990	0.962450 +
heidke :	0.115605	0.116732 -
BRIER SCORES :	0.020770	0.030900 +
threat :	0.075274	0.079700 -

SNOW 6

hits :	1725794	1725170
percent correct:	0.977588	0.977234 +
heidke :	0.423209	0.414267 +
BRIER SCORES :	0.015263	0.019490 +
threat :	0.290063	0.290152 -

SNOW SHOWERS 6

hits	:	1746400	1746399
percent correct	:	0.989260	0.989259 +
heidke	:	0.284295	0.284257 +
BRIER SCORES	:	0.006786	0.009077 +
threat	:	0.173408	0.173408 =

FREEZING DRIZZLE 6

hits	:	1762290	1762290
percent correct	:	0.998261	0.998261 =
heidke	:	0.245942	0.245942 =
BRIER SCORES	:	0.001111	0.001449 +
threat	:	0.140778	0.140778 =

FREEZING RAIN 6

hits	:	1762444	1762444
percent correct	:	0.998348	0.998348 =
heidke	:	0.231805	0.231805 =
BRIER SCORES	:	0.001029	0.001361 +
threat	:	0.131626	0.131626 =

THUNDERSTORM 6

hits	:	1736525	1736447
percent correct	:	0.983666	0.983622 +
heidke	:	0.060735	0.060777 -
BRIER SCORES	:	0.008792	0.012800 +
threat	:	0.035715	0.035751 -

THUNDERSTORM (HEAVY) 6

hits	:	1765257	1765257
percent correct	:	0.999942	0.999942 =
heidke	:	-0.000029	-0.000029 =
BRIER SCORES	:	0.000030	0.000044 +
threat	:	0.000000	0.000000 =

LOWEST CLOUD HEIGHT 6

hits	:	692995	678471
percent correct	:	0.392552	0.384324 +
heidke	:	0.247377	0.242125 +
BRIER SCORES	:	0.351486	0.405707 +
threat	:	0.186568	0.185210 +

SECOND CLOUD AMOUNT 6

hits	:	1049703	996457
percent correct	:	0.594611	0.564450 +
heidke	:	0.257515	0.225556 +
BRIER SCORES	:	0.247231	0.342166 +

SECOND CLOUD HEIGHT 6

hits :	1240090	1208820
percent correct:	0.702457	0.684744 +
heidke :	0.207787	0.202052 +
BRIER SCORES :	0.177704	0.237084 +
threat :	0.042681	0.044142 -

TOTAL CLOUD COVER 6

hits :	898131	886466
percent correct:	0.508752	0.502145 +
heidke :	0.336710	0.328985 +
BRIER SCORES :	0.301109	0.391588 +

CEILING 6

hits :	1493298	1475945
percent correct:	0.845889	0.836059 +
heidke :	0.408614	0.405097 +
BRIER SCORES :	0.101638	0.118823 +
threat :	0.213808	0.203953 +
threat (IFR) :	0.307125	0.305319 +

WIND 6

hits :	422356	422410
percent correct:	0.239246	0.239277 -
heidke :	0.185124	0.185081 +
BRIER SCORES :	0.440014	0.495810 +

Projection Time: 6 Gem(+'s): 67 Persistence(-'s): 9 88.15790%

The aggregated tally for all six projection times resulted in Gem(+'s) = 351 Persistence(-'s) = 48 or 87.96992%.

Figure 1. A map showing the locations of the 40 stations used in the development of GEM, each station contributing about 100,000 sample observations.

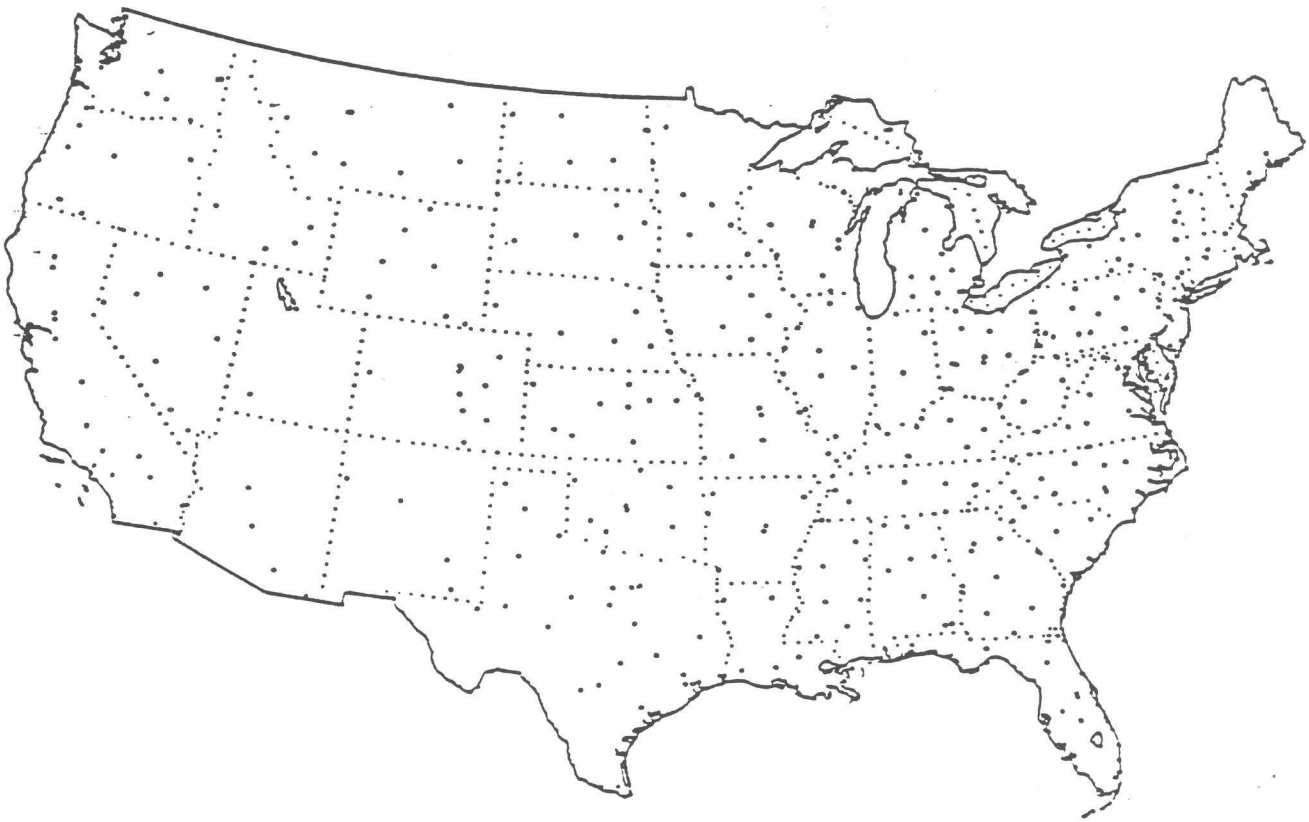

Figure 2. Map showing the location of the 415 stations for which comparative verifications were performed between GEM and Persistence from September 1, 1989 to August 31, 1990.


DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA