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CONDITIONAL CLIMATOLOGY GIVEN THE LOCAL OBSERVATION

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GEM

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Editor's Note: Some of the principles that I have followed in selecting articles to be published in the Digest are that they be practical and written so that they appeal to the majority of the readership of the Digest. I have long been familiar with Dr. Miller's work in the Techniques Development Laboratory, NWS, and have often asked Bob to write an article for the Digest because, I felt, his work would greatly add to the advancement of practical meteorology. Dr. Miller's GEMTRIX is a novel, powerful idea, yet easy to understand and can be adapted to a forecasting scheme, particularly when applied to AFOS. The Digest thanks Dr. Miller for his article and invites your comments on it.

Randy Racer
Managing Editor

Brief Biographical Sketch

The author is Chief of the Objective Forecast Branch in the National Weather Service's Techniques Development Laboratory. He has spent almost thirty years developing and applying statistical methods to weather forecasting. His career began as a World War II weather observer serving in India and Burma. Prior to receiving his M.S. in meteorology from New York University he was an observer on ocean station vessels. His research work began at Massachusetts Institute of Technology and continued at the Travelers Research Center, Bell Telephone Laboratories, and the Life Insurance Marketing and Research Association. Prior to joining TDL he was Chief Scientist of the Air Weather Service. He holds a Ph.D. from Harvard in statistics and is the author of numerous technical papers including an AMS Meteorological Monograph entitled "Statistical Prediction by Discriminant Analysis".

INTRODUCTION

Classical climatology gives an average picture of the weather. It can be made more and more specific by conditioning on the basis of time and location. The ultimate conditional climatology would be the one that specifies the probability distribution of all elements everywhere, conditioned on the full state of the atmosphere both past and present. A more practical conditional climatology would be one that takes into account the set of all locally observed meteorological variables to arrive at future conditional probability distributions. This paper will demonstrate the application of such a conditional climatology called GEM, an acronym for Generalized Equivalent Markov model.

METHODOLOGY

The approach will be to estimate the conditional probability distribution of every weather element one hour into the future, given the present condition of those same weather elements. Estimation of the probabilities is performed by multiple linear regression equations. To accomplish this, historical observations are used in the regression analysis. These are schematically represented in Table 1.

The X's and Y's shown in Table 1 represent, for example, month of the year, hour of the day, temperature, ceiling height, visibility, weather, cloud cover, and so forth.

Next, the observations of the X's and Y's are transformed into intervals (or categories). Each is assigned a 1.0 or 0.0 depending, respectively, upon whether that observation is in or out of the interval (or category). This transformation process serves two purposes. First, the regression equations will then actually estimate the desired probabilities (see Miller 1964). Second, the method to extend the conditional probability-distribution estimates beyond one hour is greatly facilitated. Consequently, each column in Table 1 expands into two or more columns which are mutually exclusive and exhaustive. A complete list of the transformations in this paper is given in Table 2.

Table 1. Schematic representation of an historical data sample of N observations, for the initial weather-variable conditions $X_{n,p}$ and the subsequent weather-variable conditions $Y_{n,p}$ where the subscript n denotes the general observation and the subscript p denotes the general variable.

	Initial Weather Variables				Subsequent Weather Variables			
Observation	X_1	X_2		X_p	Y_1	Y_2		Y_p
1	$x_{1,1}$	$x_{1,2}$	...	$x_{1,p}$	$y_{1,2}$	$y_{1,2}$	...	$y_{1,p}$
2	$x_{2,1}$	$x_{2,2}$	...	$x_{2,p}$	$y_{2,1}$	$y_{2,2}$	...	$y_{2,p}$
.								
.								
.								
n	$x_{n,1}$	$x_{n,2}$	...	$x_{n,p}$	$y_{n,1}$	$y_{n,2}$	...	$y_{n,p}$
.								
.								
.								
N	$x_{N,1}$	$x_{N,2}$	...	$x_{N,p}$	$y_{N,1}$	$y_{N,2}$	...	$y_{N,p}$

A 10-year historical sample of data, consisting of 86,782 hourly observations for Washington National Airport (DCA), was organized in the fashion described above. Five years (the odd numbered years) were held aside for subsequent independent tests. The 5 even numbered years became the sample from which the regression equations were developed. The resulting 175 regression equations constitute a matrix of 175 columns and rows. For demonstration purposes, the set of all cloud amount equations is given in Table 3, where the 175 predictors are those identified in Table 2.

To appreciate the effect any variable has on, say, the overcast event, look at the coefficient of that variable. Since the variables are all either 1.0 or 0.0, the coefficient amount is either added (algebraically) or not added. Thus, if the observation is for January (variable number 2), then .02676120 is added to the conditional probability that overcast will be the observed condition one hour hence, all other things held constant. Since one of the other months must be a 1.0 if January is not "on", the situation where it is really August (variable number 9) causes -.01619480 to be added algebraically. This is a swing of .04295600 in the conditional probability of overcast.

Given an observation of all the weather elements at DCA at a particular time, the set of 175 regression equations is then used to estimate the 175 conditional probabilities one hour hence. To arrive at estimates of the 175 conditional probabilities two hours hence the original observation is replaced by the conditional probabilities estimated for one hour. This process of replacing the observation with the previous estimate may be continued ad infinitum. Obviously, the estimates of the conditional probabilities will reflect the fact that only seasonal and diurnal effects are of importance out beyond a certain period of time. The initial observation will eventually lose all of its influence. The process of iteration is referred to as the equivalent Markov process (see Miller 1968 and Whiton 1977).

Another important requirement of a useful conditional climatology is that it be convertible into "best" categorical estimates. This suggests applying a thresholding method that yields certain desired effects, such as producing categorical frequencies that are close to observed frequencies. A method developed by Miller and Best (1979) has been employed here, where the necessary parameters are the readily available multiple correlation coefficients and sample climatologies.

Table 2. Each X and Y in Table 1 has been transformed into the intervals and categories shown in this Table. Each element has been numbered for future reference. The number one element is always unity.

2	MONTH (LOCAL)	JAN	51		13 to 14
3		FEB	52		15 to 17
4		MAR	53		18 to 22
5		APR	54		23 to 27
6		MAY	55		28 to 32
7		JUN	56		33 to 45
8		JUL	57	SLP (MB)	980.1 to 990.0
9		AUG	58		990.1 to 1000.0
10		SEP	59		1000.1 to 1005.0
11		OCT	60		1005.1 to 1010.0
12		NOV	61		1010.1 to 1020.0
13		DEC	62		1020.1 to 1030.0
14	HOUR (LOCAL)	00	63		1030.1 to 1090.0
15		01	64	DB TEMP (DEG F)	-99 to 14
16		02	65		15 to 23
17		03	66		24 to 27
18		04	67		28 to 29
19		05	68		30 to 31
20		06	69		32
21		07	70		33 to 34
22		08	71		35 to 36
23		09	72		37 to 38
24		10	73		39 to 40
25		11	74		41 to 42
26		12	75		43 to 50
27		13	76		51 to 59
28		14	77		60 to 68
29		15	78		69 to 77
30		16	79		78 to 86
31		17	80		87 to 140
32		18	81	DPT DEPRESSION	0
33		19	82	(DEG F)	1
34		20	83		2 to 4
35		21	84		5 to 6
36		22	85		7 to 11
37		23	86		12 to 15
38	WIND DIRECTION	CALM	87		16 to 99
39		NNE to NE	88	SKY COVER	CLR
40		ENE to E	89		SCD
41		ESE to SE	90		BKN
42		SSE to S	91		OVC
43		SSW to SW	92	VISIBILITY	.00 to .49
44		WSW to W	93	(MI)	.50 to .74
45		WNW to NW	94		.75 to .99
46		NNW to N	95		1.0 to 1.49
47	WIND SPEED	0 to 3	96		1.5 to 1.99
48	(KT)	4 to 7	97		2.0 to 2.49
49		8 to 9	98		2.5 to 2.99
50		10 to 12	99		3.0 to 3.99

100	VISIBILITY (CONT)	4.0 to 4.99
101		5.0 to 5.99
102		6.0 to 6.99
103		7.0 to 99.00
104	WEATHER	NO WX
105		WX
106		NO F,IF
107		F,IF
108		NO GF
109		GF
110		NO K,H,D,KH,KD,HD,KHD
111		K,H,D,KH,KD,HD,KHD
112		NO BS,BD,BN,BY
113		BS,BD,BN,BY
114		NO L
115		L-
116		NO R
117		R-
118		R
119		R+
120		NO RW
121		RW-
122		RW
123		RW+
124		NO S,IC
125		S-,IC-
126		S,IC
127		S+,IC+
128		NO SW,IP,SP
129		SW-,IP-,SP-
130		SW,IP,SP
131		NO ZL
132		ZL-
133		NO ZR
134		ZR-
135		NO T,A-
136		T,A-
137	CLOUD COVER	CLR <200 FT
138		OVC <200 FT
139		CLR <500 FT
140		SCD <500 FT
141		BKN <500 FT
142		OVC <500 FT
143		CLR <1000 FT
144		SCD <1000 FT
145		BKN <1000 FT
146		OVC <1000 FT
147		CLR <3000 FT
148		SCD <3000 FT
149		BKN <3000 FT
150		OVC <3000 FT
151	PRES CHG (TENTHS	-900 to -40
152	OF MB)	-39 to -30
153		-29 to -20
154		-19 to -10
155		-9 to 0
156		1 to 9
157		10 to 19
158		20 to 29
159		30 to 39
160		40 to 900
161	CIG (100's FT)	0 to 1
162		2 to 4
163		5 to 6
164		7 to 9
165		10 to 14
166		15 to 19
167		20 to 24
168		25 to 29
169		30 to 39
170		40 to 49
171		50 to 59
172		60 to 74
173		75 to 99
174		100 to 150
175		151 to UNL

Table 3. Regression equations for the four cloud amount categories. The number to the left of each regression coefficient corresponds to the predictor number provided in Table 2.

88. SKY CVR CLR

1	0.252109D+00	2	0.378593D-02	3	-0.150811D-01	4	-0.146293D-02	5	-0.515160D-02	6	-0.916157D-02	7	-0.506491D-02
8	-0.377495D-02	9	0.536705D-02	10	0.899766D-02	11	0.218762D-01	12	0.588490D-02	13	-0.729284D-02	14	0.341956D-01
15	0.303564D-01	16	0.305153D-01	17	0.175048D-01	18	-0.325278D-01	19	-0.318198D-01	20	-0.367038D-01	21	-0.111113D-01
22	-0.154620D-01	23	-0.292261D-01	24	-0.409516D-01	25	-0.411941D-01	26	-0.277684D-01	27	-0.146160D-01	28	-0.820077D-02
29	-0.117323D-01	30	0.400628D-02	31	0.238307D-01	32	0.288505D-01	33	0.273495D-01	34	0.295440D-01	35	0.326888D-01
36	0.181426D-01	37	0.242519D-01	38	0.137467D-01	39	-0.144769D-01	40	-0.160062D-01	41	-0.159432D-01	42	-0.353250D-02
43	0.247586D-02	44	0.424104D-02	45	0.940606D-02	46	0.878859D-02	47	-0.406467D-02	48	0.316474D-02	49	0.236603D-02
50	0.186643D-02	51	-0.485177D-02	52	-0.117122D-01	53	-0.207652D-01	54	0.211336D-01	55	-0.229170D-01	56	-0.406947D-01
57	-0.167098D-02	58	-0.181527D-01	59	-0.148387D-01	60	-0.192419D-01	61	-0.179709D-02	62	0.112783D-01	63	0.422695D-02
64	0.546053D-01	65	0.383433D-01	66	0.287546D-01	67	0.145260D-01	68	0.179192D-01	69	0.148776D-01	70	0.421222D-02
71	0.104761D-01	72	0.105382D-01	73	0.117693D-01	74	0.118857D-01	75	0.103703D-01	76	0.396580D-03	77	0.326554D-02
78	-0.119339D-01	79	-0.261883D-01	80	-0.553747D-01	81	-0.348086D-01	82	-0.271699D-01	83	-0.208527D-01	84	-0.199554D-01
85	-0.523743D-03	86	0.614936D-02	87	0.146153D-01	88	0.568629D+00	89	-0.735732D-01	90	-0.222489D+00	91	-0.242997D+00
92	0.226906D-01	93	0.235873D-01	94	0.218936D-01	95	0.200077D-01	96	0.176277D-01	97	0.257871D-01	98	0.640206D-02
99	0.108725D-01	100	-0.410407D-02	101	0.634015D-02	102	0.159011D-01	103	-0.280710D-02	104	0.946889D-04	105	-0.285518D-03
106	0.737246D-04	107	-0.798925D-03	108	0.529954D-03	109	-0.296885D-01	110	0.371096D-03	111	-0.335734D-02	112	0.611954D-05
113	-0.862736D-02	114	0.121355D-03	115	-0.738565D-02	116	-0.284091D-03	117	0.476052D-02	118	0.940235D-02	119	0.438446D-02
120	-0.112021D-03	121	0.520678D-02	122	0.426018D-02	123	0.150049D-02	124	0.261635D-03	125	-0.191883D-01	126	-0.881312D-02
127	-0.131446D-01	128	-0.931540D-05	129	0.362355D-02	130	-0.831021D-02	131	0.537539D-05	132	-0.156675D-01	133	0.388340D-05
134	-0.339293D-02	135	0.599575D-04	136	-0.165365D-01	137	0.128137D-02	138	-0.503589D+00	139	-0.571240D-03	140	-0.150716D-01
141	0.677816D-01	142	0.356707D-01	143	0.200200D-02	144	0.107227D-01	145	-0.308584D-01	146	-0.304273D-01	147	-0.325066D-02
148	0.173638D-02	149	0.219057D-01	150	0.175728D-01	151	-0.113334D-01	152	-0.113775D-01	153	-0.135989D-01	154	-0.191050D-01
155	-0.128655D-01	156	0.988470D-02	157	0.187773D-01	158	0.254930D-01	159	0.316964D-01	160	0.372222D-01	161	0.476968D+00
162	-0.114197D-01	163	0.342173D-01	164	0.359087D-01	165	-0.504496D-02	166	-0.202040D-02	167	-0.702911D-02	168	-0.992917D-02
169	0.540837D-02	170	-0.242452D-02	171	-0.715649D-02	172	-0.620709D-02	173	-0.524518D-02	174	-0.137195D-03	175	-0.291052D-02

89. SKY CVR SCD

1	0.206654D+00	2	-0.169116D-01	3	0.377228D-02	4	-0.159188D-01	5	0.232646D-02	6	0.195695D-01	7	0.159206D-01
8	0.104096D-01	9	0.169067D-02	10	0.557249D-02	11	-0.778557D-02	12	-0.921293D-02	13	-0.896623D-02	14	-0.232130D-01
15	-0.131860D-01	16	-0.197359D-01	17	-0.165209D-01	18	0.146445D-01	19	-0.179779D-02	20	-0.173700D-02	21	-0.121968D-02
22	0.272648D-02	23	0.173807D-01	24	0.311140D-01	25	0.254180D-01	26	0.178791D-01	27	0.468881D-01	28	0.240397D-01
29	0.177506D-01	30	0.124124D-01	31	-0.136598D-02	32	-0.161868D-01	33	-0.143044D-01	34	-0.179657D-01	35	-0.392597D-01
36	-0.174966D-01	37	-0.263560D-01	38	-0.284623D-02	39	-0.450075D-02	40	-0.176556D-01	41	-0.589848D-03	42	-0.241697D-02
43	-0.187673D-02	44	0.618123D-02	45	0.101731D-01	46	0.281860D-02	47	0.425650D-02	48	-0.831313D-03	49	-0.834944D-02
50	-0.842190D-02	51	0.810619D-02	52	0.189518D-01	53	0.399503D-01	54	0.354328D-02	55	0.149699D-01	56	-0.302696D-01
57	-0.417194D-01	58	0.390244D-03	59	0.359805D-02	60	0.120734D-01	61	-0.273078D-02	62	0.315137D-03	63	0.650353D-02
64	-0.425357D-01	65	-0.257860D-01	66	-0.293237D-01	67	-0.664953D-02	68	-0.197607D-01	69	0.354889D-02	70	0.219032D-02
71	-0.141557D-02	72	-0.392800D-02	73	-0.888269D-02	74	-0.175826D-01	75	-0.137677D-01	76	-0.234802D-02	77	-0.117918D-02
78	0.980849D-02	79	0.267091D-01	80	0.336320D-01	81	0.912018D-02	82	0.455111D-02	83	0.387779D-02	84	0.306187D-02
85	-0.804280D-02	86	-0.324434D-02	87	0.281651D-02	88	-0.680773D-01	89	0.386367D+00	90	0.105544D-01	91	-0.172558D+00
92	0.954024D-02	93	-0.731485D-02	94	-0.209864D-01	95	0.721829D-02	96	0.120775D-01	97	-0.205990D-01	98	0.108165D-01
99	0.770459D-02	100	0.127878D-01	101	0.167774D-01	102	-0.149680D-01	103	-0.100076D-02	104	0.372567D-02	105	-0.112341D-01
106	0.192144D-03	107	-0.194995D-02	108	-0.379197D-03	109	0.212430D-01	110	-0.774512D-03	111	0.700708D-02	112	0.215502D-04
113	-0.303816D-01	114	0.982584D-04	115	-0.598000D-02	116	0.625960D-03	117	-0.110436D-01	118	-0.106962D-01	119	-0.150642D-01
120	0.354862D-03	121	-0.151556D-01	122	-0.186685D-01	123	-0.321224D-01	124	-0.134365D-03	125	0.114836D-01	126	-0.150474D-01
127	-0.902119D-02	128	0.167076D-04	129	-0.605508D-02	130	-0.270476D-02	131	0.635968D-06	132	-0.185363D-02	133	-0.673781D-05
134	0.588683D-02	135	0.963686D-04	136	-0.265788D-01	137	-0.278069D-03	138	0.109284D+00	139	-0.459113D-03	140	0.462042D-01
141	0.428881D-01	142	0.217517D-01	143	0.527039D-02	144	-0.714365D-02	145	-0.755619D-01	146	-0.724022D-01	147	-0.356843D-02
148	-0.438215D-01	149	0.229281D-01	150	0.340092D-01	151	-0.614967D-02	152	-0.318949D-01	153	-0.197483D-01	154	-0.442247D-02
155	0.742979D-02	156	-0.389911D-02	157	0.201394D-02	158	0.157444D-01	159	0.988936D-02	160	-0.806675D-03	161	-0.927017D-01
162	0.177395D-01	163	0.360809D-01	164	0.345927D-01	165	-0.453913D-01	166	-0.390733D-01	167	-0.509810D-01	168	-0.424669D-01
169	0.231729D-02	170	0.174700D-01	171	0.252393D-01	172	0.397561D-01	173	0.405987D-01	174	-0.187238D-02	175	-0.394062D-02

90. SKY CVR BKN

1	0.167715D+00	2	-0.136355D-01	3	-0.951558D-02	4	0.621233D-02	5	0.203480D-02	6	-0.789549D-02	7	0.454469D-02
8	0.751143D-02	9	0.913707D-02	10	-0.248005D-03	11	-0.409173D-02	12	0.872473D-02	13	-0.311860D-02	14	-0.223316D-01
15	-0.196887D-01	16	-0.130378D-01	17	0.496420D-03	18	0.164997D-01	19	0.226511D-01	20	0.289722D-01	21	0.825763D-02
22	0.233419D-03	23	0.987829D-02	24	0.763051D-02	25	0.271203D-01	26	0.276185D-01	27	0.557715D-02	28	0.192422D-01
29	0.137954D-01	30	-0.233527D-02	31	-0.183432D-01	32	-0.217450D-01	33	-0.230960D-01	34	-0.258806D-01	35	-0.223408D-01
36	-0.507015D-02	37	-0.141107D-01	38	-0.286167D-02	39	-0.995881D-02	40	-0.620156D-02	41	-0.509717D-02	42	0.810211D-04
43	0.901393D-02	44	0.153732D-01	45	0.447836D-03	46	-0.585867D-02	47	-0.722552D-03	48	-0.296220D-02	49	0.188979D-02
50	0.747507D-02	51	0.704074D-03	52	-0.435221D-02	53	-0.108589D-01	54	-0.101143D-01	55	0.773726D-01	56	0.171442D+00
57	0.249605D-01	58	0.326419D-01	59	0.115800D-01	60	0.785928D-02	61	0.415686D-02	62	-0.126516D-01	63	-0.492003D-02
64	-0.79[illegible]342D-02	65	-0.329870D-02	66	0.833231D-03	67	-0.291190D-01	68	0.332025D-02	69	-0.146975D-01	70	-0.113096D-01
71	-0.110743D-01	72	-0.132205D-01	73	-0.608881D-02	74	-0.466309D-02	75	-0.551869D-02	76	-0.676183D-02	77	-0.825327D-02
78	0.114835D-01	79	0.201597D-01	80	0.395409D-01	81	0.151545D-01	82	0.161507D-01	83	0.217487D-02	84	0.102622D-01
85	0.197754D-02	86	0.284519D-02	87	-0.749122D-02	88	-0.176615D+00	89	-0.270138D-01	90	0.330753D+00	91	-0.144618D-01
92	-0.207073D-01	93	-0.170441D-01	94	0.896992D-02	95	-0.912537D-01	96	-0.233714D-01	97	0.301982D-02	98	-0.464477D-02
99	-0.46[illegible]951D-02	100	0.657798D-02	101	0.965775D-02	102	0.167818D-01	103	-0.772003D-03	104	0.882438D-02	105	-0.266084D-01
106	0.11[illegible]831D-02	107	-0.117600D-01	108	-0.590306D-03	109	0.330695D-01	110	-0.127924D-02	111	0.115734D-01	112	0.125495D-04
113	-0.17[illegible]924D-01	114	0.330541D-03	115	-0.201167D-01	116	0.234672D-02	117	-0.423936D-01	118	-0.277184D-01	119	-0.296025D-01
120	0.13[illegible]831D-04	121	-0.296753D-02	122	-0.715834D-02	123	0.687897D-01	124	0.289374D-03	125	-0.200513D-01	126	-0.227553D-01
127	-0.29[illegible]532D-01	128	-0.579456D-04	129	0.208770D-01	130	0.142738D-01	131	0.851478D-06	132	-0.248178D-02	133	0.228586D-04
134	-0.19[illegible]716D-01	135	-0.225802D-03	136	0.622771D-01	137	-0.710827D-03	138	0.279361D+00	139	-0.628397D-03	140	0.243152D-01
141	-0.27[illegible]491D-01	142	0.309206D-01	143	-0.126125D-03	144	-0.116526D-01	145	0.709345D-03	146	0.502569D-02	147	0.148070D-01
148	0.23[illegible]925D-01	149	-0.71[illegible]041D-01	150	-0.954869D-01	151	-0.829911D-02	152	-0.883754D-03	153	-0.607388D-02	154	-0.522640D-02
155	-0.32[illegible]138D-03	156	0.699989D-02	157	-0.180623D-03	158	-0.190662D-02	159	0.165159D-02	160	0.161430D-01	161	-0.270100D+00
162	-0.19[illegible]643D-01	163	0.151147D-01	164	.819836D-02	165	0.712166D-02	166	0.247764D-02	167	0.329634D-01	168	0.342615D-01
169	-0.76[illegible]486D-01	170	-0.715735D-01	171	-0.48 283D-01	172	-0.467489D-01	173	-0.419532D-01	174	-0.359235D-01	175	0.174868D-01

91. SKY CVR OVC

1	0.37[illegible]522D+00	2	0.267612D-01	3	0.208244D-01	4	0.111694D-01	5	0.790334D-03	6	-0.251243D-02	7	-0.154004D-01
8	-0.141461D-01	9	-0.161948D-01	10	-0.143221D-01	11	-0.999894D-02	12	-0.539670D-02	13	0.193777D-01	14	0.113490D-01
15	0.25[illegible]837D-02	16	0.225839D-02	17	-0.148036D-02	18	0.138367D-02	19	0.109666D-01	20	0.946865D-02	21	0.407331D-02
22	0.12[illegible]021D-01	23	0.196707D-02	24	0.22[illegible]710D-02	25	-0.113442D-01	26	-0.177292D-01	27	-0.378493D-01	28	-0.350811D-01
29	-0.19[illegible]136D-01	30	-0.140635D-01	31	-0.412143D-02	32	0.908130D-02	33	0.100509D-01	34	0.143023D-01	35	0.289118D-01
36	0.44[illegible]419D-02	37	0.162147D-01	38	-0.803875D-02	39	0.289365D-01	40	0.398633D-01	41	0.216302D-01	42	0.586845D-02
43	-0.961306D-02	44	-0.259955D-01	45	-0.200270D-01	46	-0.574852D-02	47	0.530719D-03	48	0.628770D-03	49	0.409361D-02
50	-0.91[illegible]335D-03	51	-0.395850D-02	52	-0.288734D-02	53	-0.832619D-02	54	-0.145626D-01	55	-0.694256D-01	56	-0.100477D+00
57	0.184298D-01	58	-0.148795D-01	59	-0.339330D-03	60	-0.690724D-03	61	0.371009D-03	62	0.105813D-02	63	-0.581044D-02
64	-0.40[illegible]616D-02	65	-0.925855D-02	66	-0.264120D-03	67	0.212425D-01	68	-0.147876D-02	69	-0.372900D-02	70	0.490702D-02
71	0.201379D-02	72	0.661034D-02	73	0.322221D-02	74	0.103600D-01	75	0.891605D-02	76	0.871327D-02	77	0.616690D-02
78	-0.93[illegible]410D-02	79	-0.206805D-01	80	-0.177932D-01	81	0.105339D-01	82	0.646807D-02	83	0.148000D-01	84	0.663129D-02
85	0.65[illegible]909D-02	86	-0.575021D-02	87	-0.994062D-02	88	-0.323936D+00	89	-0.285779D+00	90	-0.118819D+00	91	0.430017D+00
92	-0.11[illegible]235D-01	93	0.771652D-03	94	-0.987709D-02	95	0.402772D-02	96	-0.633382D-02	97	-0.820795D-02	98	-0.125738D-01
99	-0.139175D-01	100	-0.152617D-01	101	-0.327753D-01	102	-0.177149D-01	103	0.457987D-02	104	-0.126447D-01	105	0.381281D-01
106	-0.14[illegible]968D-02	107	0.145089D-01	108	0.439550D-03	109	-0.246240D-01	110	0.168266D-02	111	-0.152232D-01	112	-0.402193D-04
113	0.367014D-01	114	-0.550155D-03	115	0.334824D-01	116	-0.268858D-02	117	0.486767D-01	118	0.290122D-01	119	0.402822D-01
120	-0.25[illegible]424D-03	121	0.129163D-01	122	0.215672D-01	123	-0.381678D-01	124	-0.416643D-03	125	0.277560D-01	126	0.466157D-01
127	0.517190D-01	128	0.505534D-04	129	-0.184455D-01	130	-0.325883D-02	131	-0.686284D-05	132	0.200029D-01	133	-0.200042D-04
134	0.174777D-01	135	0.694763D-04	136	-0.191618D-01	137	-0.292470D-03	138	0.114944D+00	139	0.165875D-02	140	-0.554479D-01
141	-0.832205D-01	142	-0.963431D-01	143	-0.714626D-02	144	0.807355D-02	145	0.105711D+00	146	0.978038D-01	147	-0.798796D-02
148	0.189927D-01	149	0.266703D-01	150	0.439049D-01	151	0.257822D-01	152	0.441562D-01	153	0.394210D-01	154	0.287539D-01
155	0.575889D-02	156	-0.129855D-01	157	-0.206106D-01	158	-0.393308D-01	159	-0.432374D-01	160	-0.525585D-01	161	-0.114166D+00
162	0.129445D-01	163	-0.664129D-01	164	-0.786997D-01	165	0.433146D-01	166	0.386160D-01	167	0.250466D-01	168	0.181345D-01
169	0.68[illegible]229D-01	170	0.565281D-01	171	0.303460D-01	172	0.131999D-01	173	0.659964D-02	174	0.379331D-01	175	-0.106356D-01

VERIFICATION RESULTS

Applying the methodology described above to the 5 years of independent data produced the verification statistics shown in Table 4 for 1-h conditional-probability estimates.* Additional verification tests have yielded favorable results for GEM at six other locations around the country, for both 1- and 6-h projections (see also Miller, Whiton, and Kelly 1977).

Table 4. Comparative verification for six ceiling and visibility categories between classical climatology, conditional persistence, and the GEM conditional climatology model. Shown are the Brier scores for 43,047 1-h independent projections (lower values are better).

Brier Scores

	Ceiling	Visibility
Classical Climatology	.43709	.36571
Conditional Persistence	.20579	.19006
GEM conditional climatology	.19249	.17240

where the six categories are defined as:

	Ceiling		Visibility
1.	< 200'	1.	< 1/2 mile
2.	200' ≤ to < 500'	2.	1/2 mile ≤ to < 1 mile
3.	500' ≤ to < 1000'	3.	1 mile ≤ to < 3 miles
4.	1000' ≤ to < 3000'	4.	3 miles ≤ to < 5 miles
5.	3000' ≤ to < 7500'	5.	5 miles ≤ to < 7 miles
6.	≥ 7500'	6.	≥ 7 miles

AN EXAMPLE

The derivation of a particular conditional climatology given the local observation will normally be performed automatically in a minicomputer such as an AFOS Eclipse. For demonstration purposes, an application of the methodology described above will now be made for a particular DCA observation. The steps performed are given below and in the flowchart shown in Figure 1.

Step 1: Collect input observation and transform into 1.0's or 0.0's depending upon observed interval or category.

Step 2: Estimate the 1-h conditional probabilities for each element using regression equations. Iterate out hour by hour to twenty-four hours using equivalent Markov principle, thereby creating a GEMTRIX (A Generalized Equivalent Markov Probability Matrix).

Step 3: Convert the probabilities in GEMTRIX into "best" hourly categorical estimates using threshold probabilities, thereby creating a CATRIX (A GEMTRIX converted to a Categorical matrix).

Step 4: Assume hourly categorical estimates to be what will actually be observed and create an FT either subjectively or objectively.

Step 5: Forecaster than accepts or modifies CATRIX through feedback after studying FT and additional current weather information. A final FT is ultimately issued.

*Classical climatology is defined as the dependent sample relative frequencies, and conditional persistence is represented by the dependent sample relative frequencies conditioned on the currently observed ceiling or visibility category.

PERFORMING STEP 1:

The DCA observation chosen for this example is for 1600 local standard time (2100 GMT) on June 17, 1979 and was as follows:

Month : June

Hour : 1600 LST

Wind Direction : 330°

Wind Speed : 10 Kt

Sea Level Pressure : 1011.2 mb

Temperature : 74°F

Dew Point Depression $(T-T_d)$: 1°F

Sky Cover : Overcast

Visibility : 7 mi

Weather : None

Cloud Cover : Overcast under 3000'

Three Hour Pressure Change : -.7 mb

Ceiling : 1100 ft

The corresponding transformed observed values are shown in the first column of the GEMTRIX of Table 5.

PERFORMING STEP 2:

The estimated conditional probability distributions for all weather elements, projected from one to 24 hours, are given in Table 5 in the form of a GEMTRIX. The probabilities have been truncated and renormalized when necessary to have them lie between 0.0 and 1.0 and their sums equal to 1.0. In Table 5 the actual observed interval or category is parenthesized, when not obvious, for purposes of visual verification.

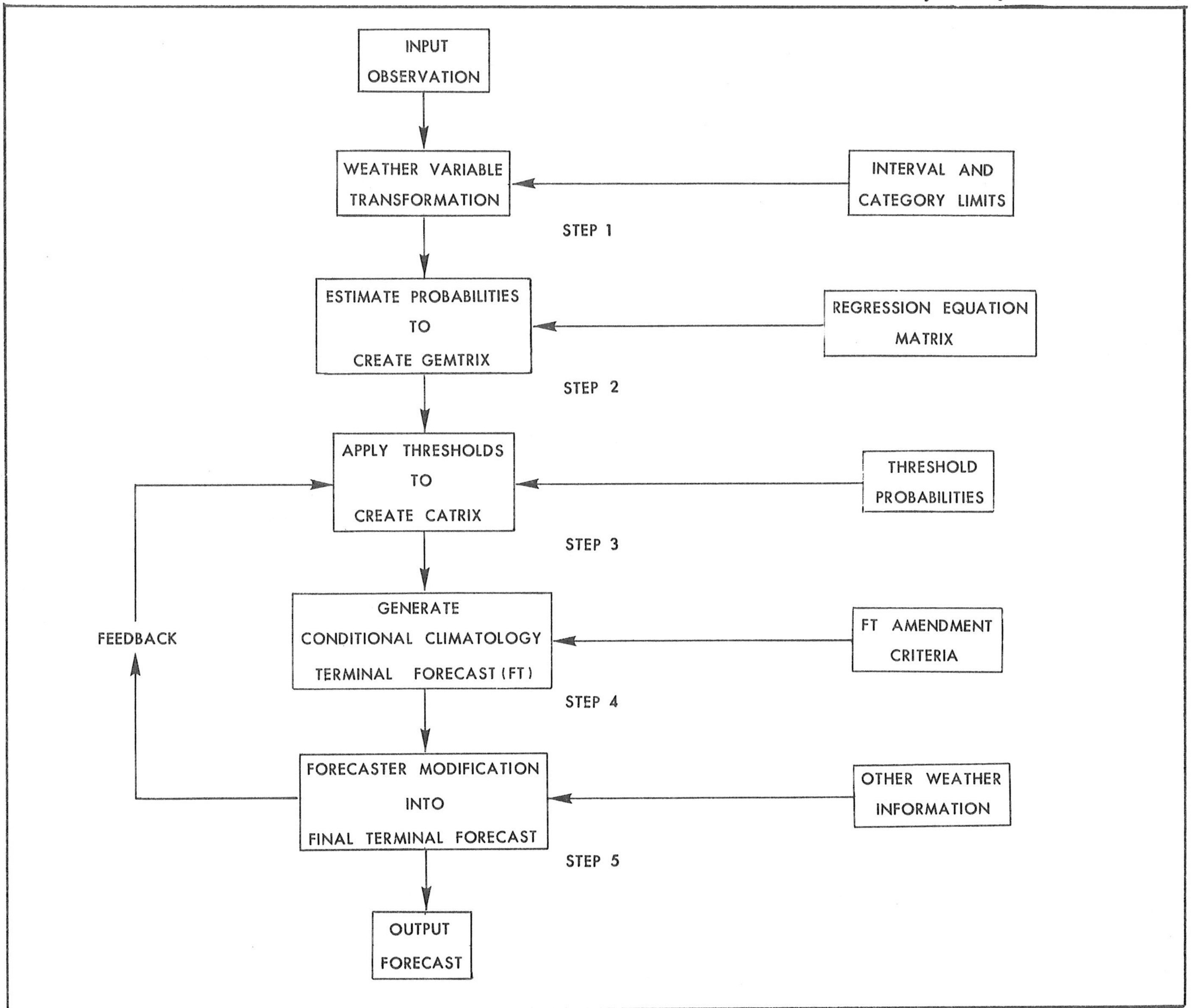

Figure 1. Flowchart of steps to follow in applying GEM to making an aviation terminal forecast.

PERFORMING STEP 3:

Table 6 gives the CATRIX for each weather element, again from one to 24 hours. The numbers in the CATRIX represent the "best" category. These are identified by using Table 2, starting with one if the first category, two if the second category, etc. for each weather element. Thus, a 4 for SKY COVER at hour 23 LST means the fourth category of SKY COVER or OVC.

PERFORMING STEP 4:

Assume the categories shown in the CATRIX will actually occur. A minicomputer algorithm could be written to produce an FT using amendment criteria. However, for this example two experienced forecasters generated the climatological FT shown below from only the information contained in the CATRIX of Table 6.

FORECASTER'S CLIMATOLOGICAL FT

DCA FT 8 SCT C12 OVC 3410.

05Z 10 SCT C15 OVC 6 H.

11Z C15 OVC 3FH.

17Z C15 BKN 5H BKN V SCT 1010.

21Z MVFR CIG BCMG VFR.

NNNN

GENERALIZED EQUIVALENT MARKOV (GEM) MATRIX
TECHNIQUES DEVELOPEMENT LABORATORY

FOR STATION 'DCA'

VALID FROM 79061717 TO 79061816
BASED ON 79061716 SINGLE STATION SURFACE OBSERVATION

24 HOURLY FORECASTS AFTER OBSERVATION (LOCAL STANDARD TIME)

CATEGORY	OBS 16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MONTH (LOCAL) JAN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MONTH (LOCAL) FEB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MONTH (LOCAL) MAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MONTH (LOCAL) APR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MONTH (LOCAL) MAY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MONTH (LOCAL) JUN	95	95	94	94	94	94	94	94	93	93	93	93	93	93	93	93	92	92	92	92	92	92	92	92	92
MONTH (LOCAL) JUL	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	8
MONTH (LOCAL) AUG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MONTH (LOCAL) SEP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MONTH (LOCAL) OCT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MONTH (LOCAL) NOV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MONTH (LOCAL) DEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 1	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 2	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 3	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 4	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 5	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
HOUR (LOCAL) 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0
HOUR (LOCAL) 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
HOUR (LOCAL) 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
HOUR (LOCAL) 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
HOUR (LOCAL) 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0
HOUR (LOCAL) 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0
HOUR (LOCAL) 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0
HOUR (LOCAL) 16	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
HOUR (LOCAL) 17	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 18	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 19	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 20	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 21	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 22	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUR (LOCAL) 23	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WND DIR CALM	0	1	2	2	2	3	4	4	4	5	5	6	6	5	5	5	4	2	1	1	0	1	0	1	1
WND DIR NNE TO NE	0	14	18	19	18	17	17	18	16	16	16	16	16	18	16	18	18	18	16	14	11	12	10	9	9
WND DIR ENE TO E	0	2	6	11	12	13	13	11	13	12	11	11	11	11	12	11	12	12	12	12	12	11	11	10	11
WND DIR ESE TO SE	0	4	7	8	9	7	6	5	6	6	5	5	4	5	5	5	6	6	6	8	8	8	8	7	7
WND DIR SSE TO S	0	0	3	8	11	14	15	15	15	14	(13)	12	12	(12)	12	14	(17)	(22)	26	26	27	26	27	27	27
WND DIR SSW TO SW	0	5	4	4	6	8	10	(12)	(12)	(13)	14	(15)	(16)	15	(16)	(16)	16	13	10	10	11	11	11	12	12
WND DIR WSW TO W	0	0	0	2	2	4	(5)	5	7	8	10	9	9	11	10	8	6	5	(4)	6	6	9	8	9	9
WND DIR WNW TO NW	0	18	21	20	17	(16)	14	12	10	11	9	8	9	8	7	8	8	9	11	(11)	(14)	(14)	(15)	(14)	(14)
WND DIR NNW TO N	100	(56)	(38)	(28)	(23)	19	16	17	17	15	16	17	16	16	16	14	14	13	13	13	11	9	9	10	10
WND SPD (KTS) 0 TO 3	0	0	2	4	7	(9)	14	13	15	15	19	18	17	18	16	16	12	9	7	6	5	6	6	5	6
WND SPD (KTS) 4 TO 7	0	(10)	(24)	35	40	43	(42)	(45)	(47)	(49)	(47)	(50)	(50)	(50)	(50)	(47)	(45)	(42)	(38)	37	35	32	32	32	31
WND SPD (KTS) 8 TO 9	0	25	24	22	(20)	19	19	18	16	16	16	15	15	15	16	17	18	19	20	(20)	19	21	20	21	22
WND SPD (KTS) 10 TO 12	100	47	34	26	20	20	17	16	16	14	13	13	13	12	15	16	18	20	22	21	(21)	(24)	23	23	23
WND SPD (KTS) 13 TO 14	0	12	11	(8)	7	5	5	5	4	4	3	3	4	4	2	4	5	6	6	8	9	7	(9)	(9)	8
WND SPD (KTS) 15 TO 17	0	6	6	5	4	3	4	3	2	1	2	1	0	0	0	1	2	4	5	6	7	7	7	7	(7)
WND SPD (KTS) 18 TO 22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3	3	2	2	2
WND SPD (KTS) 23 TO 27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
WND SPD (KTS) 28 TO 32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WND SPD (KTS) 33 TO 45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SLP (MB) 980.1 TO 990.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SLP (MB) 990.1 TO 1000.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
SLP (MB) 1000.1 TO 1005.0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	2	2	3	2
SLP (MB) 1005.1 TO 1010.0	0	1	1	1	2	2	3	3	4	5	7	7	7	7	7	7	7	7	7	8	8	10	11	12	12
SLP (MB) 1010.1 TO 1020.0	100	(97)	(95)	(93)	(90)	(88)	(86)	(85)	(83)	(82)	(81)	(81)	(79)	(77)	(76)	(74)	(73)	(71)	(71)	(71)	(72)	(73)	(74)	(74)	(74)
SLP (MB) 1020.1 TO 1030.0	0	2	3	5	7	9	10	11	12	12	12	11	13	14	16	18	18	19	19	18	17	15	12	11	11
SLP (MB) 1030.1 TO 1090.0	0	0	0	0	1	1	1	1	1	0	1	1	1	0	1	1	2	2	2	2	0	0	0	0	0
DB TEMP (DEG F) -99 TO 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DB TEMP (DEG F) 15 TO 23	0	0	0	0	0	0	0	1	1	2	2	2	2	3	3	3	2	1	0	0	0	0	0	0	0
DB TEMP (DEG F) 24 TO 27	0	1	1	1	2	2	2	2	3	2	2	2	3	2	2	2	1	2	1	0	0	0	0	0	0
DB TEMP (DEG F) 28 TO 29	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
DB TEMP (DEG F) 30 TO 31	0	1	1	0	0	1	1	0	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0
DB TEMP (DEG F) 32	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
DB TEMP (DEG F) 33 TO 34	0	0	0	0	1	1	0	1	1	1	1	2	2	1	2	1	1	1	0	0	0	0	0	0	0
DB TEMP (DEG F) 35 TO 36	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	1	1	1	1	0	0	0	0	0	0
DB TEMP (DEG F) 37 TO 38	0	2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
DB TEMP (DEG F) 39 TO 40	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
DB TEMP (DEG F) 41 TO 42	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DB TEMP (DEG F) 43 TO 50	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
DB TEMP (DEG F) 51 TO 59	0	1	1	0	1	1	2	2	2	3	4	4	4	4	5	4	3	3	3	3	3	2	2	3	2
DB TEMP (DEG F) 60 TO 68	0	8	14	18	20	23	25	27	28	29	30	(31)	(31)	(30)	(29)	27	25	24	23	23	22	22	21	21	21
DB TEMP (DEG F) 69 TO 77	100	(78)	68	(61)	(59)	(57)	(56)	(54)	(51)	(49)	(47)	45	43	42	42	(45)	(46)	(44)	(42)	40	38	38	37	36	36
DB TEMP (DEG F) 78 TO 86	0	9	(13)	16	15	13	11	10	9	9	9	9	9	10	10	11	16	21	26	(28)	(29)	(28)	28	28	(29)
DB TEMP (DEG F) 87 TO 140	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	6	8	10	(12)	(12)	11
DPT DPR (DEG F) 0	0	11	11	8	6	5	4	4	4	4	4	3	3	4	4	3	3	3	2	1	1	1	1	1	1
DPT DPR (DEG F) 1	100	38	20	13	11	9	9	8	7	7	8	(8)	(8)	(8)	(7)	7	6	4	5	4	4	4	3	3	3
DPT DPR (DEG F) 2 TO 4	0	34	45	(46)	46	44	(42)	(41)	(41)	(40)	(40)	41	41	41	39	(36)	(31)	(25)	21	19	18	16	16	15	14
DPT DPR (DEG F) 5 TO 6	0	(8)	13	16	(17)	(16)	17	17	19	18	18	18	18	17	18	17	15	12	(9)	8	7	7	6	6	6
DPT DPR (DEG F) 7 TO 11	0	0	(3)	9	14	19	22	22	23	24	23	23	24	25	25	28	29	25	19	14	10	9	8	8	9
DPT DPR (DEG F) 12 TO 15	0	0	0	2	5	7	7	8	7	7	7	7	6	6	7	9	14	15	16	(14)	(10)	8	7	6	7
DPT DPR (DEG F) 16 TO 99	0	9	9	5	0	0	0	0	0	0	0	0	0	0	0	0	3	16	28	40	50	(55)	(59)	(60)	(59)
SKY CVR CLR	0	0	0	4	8	11	15	16	17	19	19	(20)	19	13	10	(7)	9	9	9	7	5	4	4	5	5
SKY CVR SCD	0	7	11	12	13	(13)	(11)	13	13	13	(15)	15	(15)	(19)	(20)	20	(21)	21	23	26	27	27	(30)	(30)	(29)
SKY CVR BKN	0	11	(13)	13	(13)	12	12	(13)	(13)	(12)	12	13	14	17	19	21	21	(20)	20	21	(24)	(25)	24	25	25
SKY CVR OVC	100	(82)	76	(71)	67	64	62	58	57	56	54	53	51	51	51	51	50	50	(48)	(47)	45	44	42	40	40
VSBY (ST MI) .00 TO .49	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
VSBY (ST MI) .50 TO .74	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	0	0
VSBY (ST MI) .75 TO .99	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	1
VSBY (ST MI) 1.0 TO 1.49	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1
VSBY (ST MI) 1.5 TO 1.99	0	0	1	1	1	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	1	1	2	1	2
VSBY (ST MI) 2.0 TO 2.49	0	1	2	2	2	3	3	3	3	3	3	3	3	3	4	5	4	4	3	3	3	2	2	2	2
VSBY (ST MI) 2.5 TO 2.99	0	2	2	3	3	3	3	3	4	3	4	4	4	4	4	5	5	4	4	3	2	2	2	2	2
VSBY (ST MI) 3.0 TO 3.99	0	3	5	6	6	7	7	8	8	8	8	8	7	9	9	11	11	10	7	6	5	5	4	4	3
VSBY (ST MI) 4.0 TO 4.99	0	2	4	6	7	7	7	7	7	7	7	8	8	8	9	9	9	6	6	4	4	3	3	3	3
VSBY (ST MI) 5.0 TO 5.99	0	3	5	6	8	8	8	7	8	8	8	9	(8)	(9)	(9)	8	8	7	6	5	(4)	4	3	3	4
VSBY (ST MI) 6.0 TO 6.99	0	6	8	9	9	9	9	9	8	9	9	(7)	8	9	10	(10)	(9)	(9)	9	(7)	6	(5)	(5)	5	5
VSBY (ST MI) 7.0 TO 99.00	100	(83)	(72)	(67)	(63)	(61)	(59)	(58)	(58)	(58)	(58)	58	57	53	49	47	48	54	(61)	68	72	75	76	(78)	(79)
NO WX	100	(77)	(65)	(59)	56	(54)	(52)	(53)	(53)	(53)	(53)	53	52	49	46	43	45	50	(58)	65	69	71	73	(74)	(74)
WX	0	23	35	41	(44)	46	48	47	47	47	47	(47)	(48)	(51)	(54)	(57)	(55)	(50)	42	(35)	(31)	(29)	(27)	26	26
NO F,IF	100	87	79	74	73	72	72	72	73	74	74	75	75	75	74	76	77	80	82	84	85	86	87	87	88
F,IF	0	13	21	26	27	28	28	28	27	26	26	(25)	(25)	(25)	(26)	(24)	(23)	(20)	18	16	15	14	13	13	12
NO GF	100	97	97	97	97	97	97	97	97	96	96	95	94	93	93	94	96	98	98	99	99	99	99	99	99
GF	0	3	3	3	3	3	3	3	3	4	4	5	6	7	7	6	4	2	2	1	1	1	1	1	1
NO K,H,D,KH,KD,HD,KHD	100	100	99	97	95	93	91	90	90	89	89	88	87	85	81	76	74	76	81	86	89	91	92	92	93
K,H,D,KH,KD,HD,KHD	0	0	1	3	5	7	9	10	10	11	11	12	13	15	19	24	26	24	19	(14)	(11)	(9)	(8)	8	7
NO BS,BD,BN,BY	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
BS,BD,BN,BY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO L	100	95	93	92	93	93	93	94	94	94	95	95	95	95	96	96	96	97	97	97	97	97	98	98	98
L-	0	5	7	8	7	7	7	6	6	6	5	5	5	5	4	4	4	3	3	3	3	3	2	2	2
NO R	100	93	91	89	88	89	88	89	89	90	90	90	90	90	90	90	91	92	92	93	93	94	94	94	94
R-	0	7	9	10	12	11	11	11	10	9	9	9	9	9	9	9	8	8	7	6	6	6	6	6	5
R	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
R+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO RW	100	95	94	94	95	95	94	95	95	96	96	96	96	97	97	97	96	97	96	97	96	96	96	96	95
RW-	0	4	6	6	5	5	5	4	4	4	4	3	3	3	3	3	3	3	3	3	3	4	4	4	4
RW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO S,IC	100	98	98	98	98	98	98	98	98	98	98	99	98	98	99	99	99	99	99	99	99	99	99	99	99
S-,IC-	0	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1	1	1	1	1	1	1	1
S,IC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S+,IC+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO SW,IP,SP	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
SW-,IP-,SP-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SW,IP,SP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO ZL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ZL-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO ZR	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ZR-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO T,A-	100	99	99	99	99	99	98	99	99	99	99	100	100	100	100	100	100	100	100	100	100	99	99	99	99
T,A-	0	1	1	1	(1)	1	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1
CLD CVR < 200 FT CLR	100	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(99)	(100)	(99)	(99)	(99)	(99)	(99)	(99)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
CLD CVR < 200 FT OVC	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0
CLD CVR < 500 FT CLR	100	(100)	(99)	(99)	(98)	(97)	(97)	(96)	(96)	(96)	(96)	(96)	(96)	(96)	(95)	(96)	(96)	(97)	(97)	(98)	(98)	(98)	(98)	(99)	(99)
CLD CVR < 500 FT SCD	0	0	0	0	0	1	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
CLD CVR < 500 FT BKN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CLD CVR < 500 FT OVC	0	0	1	1	2	2	3	3	3	3	3	4	4	4	4	4	4	3	2	2	1	2	1	1	1
CLD CVR < 1000 FT CLR	100	(81)	(75)	(74)	(74)	(74)	(74)	(75)	(75)	(77)	(77)	(77)	(77)	(77)	(78)	(79)	(81)	(83)	(85)	(86)	(87)	(88)	(89)	(90)	(90)
CLD CVR < 1000 FT SCD	0	4	5	5	6	6	5	5	5	4	5	4	4	4	4	4	3	3	2	2	2	2	2	2	2
CLD CVR < 1000 FT BKN	0	4	5	5	5	5	5	5	4	4	4	4	4	4	4	4	3	3	3	3	2	2	2	2	2
CLD CVR < 1000 FT OVC	0	11	14	15	15	15	15	15	15	15	15	15	14	14	14	13	12	11	10	9	8	8	7	6	6
CLD CVR < 3000 FT CLR	0	4	12	20	26	32	38	(41)	45	(48)	(51)	(52)	(54)	(55)	(57)	(59)	(60)	(61)	(62)	(64)	(67)	(69)	(73)	(74)	(76)
CLD CVR < 3000 FT SCD	0	9	(12)	13	12	(12)	(10)	10	(10)	9	9	9	9	8	7	8	8	8	9	8	6	7	5	6	6
CLD CVR < 3000 FT BKN	0	(10)	11	(10)	(10)	9	8	8	7	6	6	6	6	6	6	5	5	6	6	5	5	5	4	3	3
CLD CVR < 3000 FT OVC	100	77	64	57	51	47	44	40	38	37	34	33	32	31	30	29	27	25	23	23	21	19	17	17	15
PRES CHG (.1 MB) -900 TO -40	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	0	0	0	0	1	3	5	3	1
PRES CHG (.1 MB) -39 TO -30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	8	6	3
PRES CHG (.1 MB) -29 TO -20	0	0	0	0	0	0	0	0	0	1	2	2	1	0	0	0	0	0	0	2	9	16	22	21	13
PRES CHG (.1 MB) -19 TO -10	0	15	10	4	2	3	4	6	10	(14)	(19)	(19)	15	10	7	5	4	5	10	18	27	(35)	(33)	(34)	34
PRES CHG (.1 MB) -9 TO 0	100	(58)	(48)	37	28	22	25	28	(37)	43	42	43	(41)	38	29	21	20	26	32	43	(40)	28	22	24	(31)
PRES CHG (.1 MB) 1 TO 9	0	17	23	(31)	28	27	27	(33)	31	26	23	24	26	(29)	(29)	(29)	(29)	29	(33)	(25)	15	9	7	9	12
PRES CHG (.1 MB) 10 TO 19	0	9	14	20	(29)	(34)	(32)	27	20	14	12	11	14	19	26	32	33	(30)	20	11	5	2	2	3	6
PRES CHG (.1 MB) 20 TO 29	0	1	4	6	9	11	9	6	2	2	1	1	1	3	7	9	10	7	4	1	0	0	0	0	0
PRES CHG (.1 MB) 30 TO 39	0	0	1	2	3	2	2	1	0	0	0	0	0	0	1	3	3	2	2	0	0	0	0	0	0
PRES CHG (.1 MB) 40 TO 900	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CIG (100'S FT) 0 TO 1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
CIG (100'S FT) 2 TO 4	0	0	1	1	2	2	3	3	3	3	3	3	3	3	4	4	3	3	2	2	1	2	1	1	1
CIG (100'S FT) 5 TO 6	0	2	4	5	6	6	6	6	6	6	6	6	6	6	5	5	5	5	4	4	3	3	3	3	2
CIG (100'S FT) 7 TO 9	0	13	15	14	13	12	12	11	11	9	9	9	9	8	8	8	8	6	6	6	6	6	5	4	4
CIG (100'S FT) 10 TO 14	100	51	32	24	20	17	14	13	12	11	10	9	9	9	8	8	8	8	7	6	6	6	6	5	5
CIG (100'S FT) 15 TO 19	0	11	12	10	9	8	7	7	6	6	5	5	5	4	4	4	4	4	4	4	4	3	3	3	2
CIG (100'S FT) 20 TO 24	0	(5)	7	(8)	(7)	6	6	5	5	4	4	4	3	3	4	3	3	4	4	3	4	3	3	2	2
CIG (100'S FT) 25 TO 29	0	3	4	5	5	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	3	3	2	1	1
CIG (100'S FT) 30 TO 39	0	3	4	5	5	5	5	5	5	5	5	4	4	3	3	3	3	3	3	2	5	4	4	4	4
CIG (100'S FT) 40 TO 49	0	0	2	1	2	3	3	4	3	3	2	3	3	3	2	3	3	4	4	(3)	(4)	(4)	3	3	3
CIG (100'S FT) 50 TO 59	0	0	0	0	1	1	1	(1)	1	1	1	1	2	2	2	2	2	1	2	2	3	4	4	4	4
CIG (100'S FT) 60 TO 74	0	0	0	0	0	1	1	1	1	2	2	1	2	1	2	2	2	1	1	1	2	2	2	2	3
CIG (100'S FT) 75 TO 99	0	1	1	0	1	2	2	3	3	(3)	3	3	3	4	3	3	3	(3)	(3)	2	2	2	2	3	3
CIG (100'S FT) 100 TO 150	0	3	4	5	5	5	6	6	(6)	6	6	6	7	6	8	9	8	8	8	9	9	9	8	9	10
CIG (100'S FT) 151 TO UNL	0	8	(14)	21	24	(28)	(30)	32	34	37	(40)	(41)	(42)	(43)	(43)	(43)	(46)	47	49	50	50	51	(54)	(55)	(56)

Table 5. Generalized equivalent Markov matrix (GEMTRIX) which displays the estimated hourly conditional probabilities of all the weather elements at DCA based on the 1600 LST observation. Each of the 175 estimates is made from a regression equation having 175 independent variables. The actual observed interval or category is enclosed in parentheses when not obvious.

```
XXXX  XXX  XXXXX XXXX  XXXXX X   X
X    X   X   X   X   X   X    X X
X    XXXXX   X   XXXX    X     X
X    X   X   X   X  X    X    X X
XXXX X   X   X   X   X XXXXX X   X
```

CATEGORICAL GEMTRIX

TECHNIQUES DEVELOPEMENT LABORATORY

FOR STATION 'DCA'

VALID FROM 79061717 TO 79061816

BASED ON 79061716 SINGLE STATION SURFACE OBSERVATION

	OBS	24 HOURLY FORECASTS AFTER OBSERVATION (LOCAL STANDARD TIME)																								
CATEGORY	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MONTH (LOCAL)	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
HOUR (LOCAL)	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WND DIR	9	9	9	4	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	4	4	4	5	5
WND SPD (KTS)	4	4	4	3	3	2	2	2	2	2	1	1	1	1	1	1	2	2	3	3	4	4	4	4	4
SLP (MB)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
DB TEMP(DEG F)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	16	16	16	16	16
DPT DPR (DEG F)	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	5	6	7	7	7	7	7
SKY CVR	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
VSBY (ST MI)	12	12	12	12	12	12	11	11	11	11	10	10	10	9	8	8	8	8	9	11	12	12	12	12	12
WEATHER	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
FOG,IF	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1
GROUND FOG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1
K,H,D,KH,KD,HD,KHD	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	1	1	1	1	1	1
BS,BD,BN,BY	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
DRIZZLE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
RAIN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
RAIN SHOWERS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SNOW,IC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SNOW SHOWERS,IP	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FREEZING DRIZZLE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FREEZZING RAIN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
THUNDERSTORM,A-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CLD CVR < 200 FT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CLD CVR < 500 FT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CLD CVR < 1000 FT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CLD CVR < 3000 FT	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	2	2	1
PRES CHG (.1 MB)	5	5	5	6	7	7	7	6	6	5	5	5	5	6	6	7	7	7	6	5	4	3	2	3	4
CIG (100!S FT)	5	5	5	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	6	6	7	8	9	10	11

Table 6. Categorical matrix (CATRIX) generated from GEMTRIX in Table 5 from threshold probabilities designed to create distributions that agree with the observed distributions. The numbers in each cell are identified by referring to the intervals or categories in Table 2.

Table 7. Proposed weather element transformation intervals and categories to succeed those in Table 2.

1	MONTH (LOCAL)	JAN	51		10-19KTS
2		FEB	52	NNW-N	1 - 9KTS
3		MAR	53		10-19KTS
4		APR	54	NE	≥ 20KTS
5		MAY	55	SE	≥ 20KTS
6		JUN	56	SW	≥ 20KTS
7		JUL	57	NW	≥ 20KTS
8		AUG	58	SLP(MB) SLP	≤ 985.0
9		SEP	59		985.1 to 990.0
10		OCT	60		990.1 to 995.0
11		NOV	61		995.1 to 1000.0
12		DEC	62		1000.1 to 1005.0
13	HOUR (LOCAL)	00	63		1005.1 to 1010.0
14		01	64		1010.1 to 1015.0
15		02	65		1015.1 to 1020.0
16		03	66		1020.1 to 1025.0
17		04	67		1025.1 to 1030.0
18		05	68		1030.1 to 1035.0
19		06	69		1035.1 to 1040.0
20		07	70		1040.1 to 1090.0
21		08	71	DB TEMP	-130 to -31
22		09	72	(DEG F)	-30 to -26
23		10	73		-25 to -21
24		11	74		-20 to -16
25		12	75		-15 to -11
26		13	76		-10 to -6
27		14	77		-5 to -1
28		15	78		0 to 4
29		16	79		5 to 9
30		17	80		10 to 14
31		18	81		15 to 19
32		19	82		20 to 24
33		20	83		25 to 29
34		21	84		30 to 34
35		22	85		35 to 39
36		23	86		40 to 44
37	WIND ROSE	CALM	87		45 to 49
38	NNE-NE	1 - 9KTS	88		50 to 54
39		10-19KTS	89		55 to 59
40	ENE-E	1 - 9KTS	90		60 to 64
41		10-19KTS	91		65 to 69
42	ESE-SE	1 - 9KTS	92		70 to 74
43		10-19KTS	93		75 to 79
44	SSE-S	1 - 9KTS	94		80 to 84
45		10-19KTS	95		85 to 89
46	SSW-SW	1 - 9KTS	96		90 to 94
47		10-19KTS	97		95 to 99
48	WSW-W	1 - 9KTS	98		100 to 104
49		10-19KTS	99		105 to 109
50	WNW-NW	1 - 9 KTS	100		110 to 114

101	DB TEMP	115 to 150°F
102	DPT DEPRESSION	0
103	(DEG F)	1
104		2 to 4
105		5 to 7
106		8 to 11
107		12 to 15
108		16 to 19
109		20 to 25
110		26 to 35
111		36 to 50
112		51 to 115
113	SKY1	PARTIAL OBSCURATION
114		TOTAL OBSCURATION
115		CLR 0/10
116		SCD 1/10 to 5/10
117		BKN 6/10 to 9/10
118		OVC 10/10
119	HGT1 (100's FT)	0 to 1
120		2 to 4
121		5 to 6
122		7 to 9
123		10 to 14
124		15 to 19
125		20 to 24
126		25 to 29
127		30 to 39
128		40 to 49
129		50 to 59
130		60 to 75
131		76 to 99
132		100 to 150
133		≥ 151
134	SKY2	CLR 0/10
135		SCD 1/10 to 5/10
136		BKN 6/10 to 9/10
137		OVC 10/10
138	HGT2 (100's FT)	0 to 1
139		2 to 4
140		5 to 6
141		7 to 9
142		10 to 14
143		15 to 19
144		20 to 24
145		25 to 29
146		30 to 39
147		40 to 49
148		50 to 59
149		60 to 75
150		76 to 99
151		100 to 150
152		≥ 151
153	SKY3	CLR 0/10
154		SCD 1/10 to 5/10
155		BKN 6/10 to 9/10
156		OVC 10/10

157	HGT (100's FT)	0 to 1
158		2 to 4
159		5 to 6
160		7 to 9
161		10 to 14
162		15 to 19
163		20 to 24
164		25 to 29
165		30 to 39
166		40 to 49
167		50 to 59
168		60 to 75
169		76 to 99
170		100 to 150
171		≥ 151
172	VISIBILITY	0 to .49
173	(MI)	.50 to .74
174		.75 to .99
175		1.00 to 1.49
176		1.50 to 1.99
177		2.00 to 2.49
178		2.50 to 2.99
179		3.00 to 3.99
180		4.00 to 4.99
181		5.00 to 5.99
182		6.00 to 6.99
183		7.00 to 100.00
184	WEATHER	NO WX
185		F,IF
186		GF
187		K,H,D,KH,KD,HD,KHD
188		BS,BD,BN,BY
189		L-
190		L
191		L+
192		R-
193		R
194		R+
195		RW-
196		RW
197		RW+
198		S-,IC-
199		S,IC
200		S+,IC+
201		SW-,IP-,SP-
202		SW,IP,SP
203		SW+,IP+,SP+
204		ZL-
205		ZL
206		ZL+
207		ZR-
208		ZR
209		ZR+
210		T LIGHT
211		T HEAVY
212	PRES CHNG (MB)	-90.0 to -4.0

Table 7.
continued

213	PRES CHNG (CONT)	-3.9 to -3.0
214		-2.9 to -2.0
215		-1.9 to -1.0
216		-.9 to 0.0
217		.1 to .9
218		1.0 to 1.9
219		2.0 to 2.9
220		3.0 to 3.9
221		4.0 to 90.0

PERFORMING STEP 5:

The same forecasters were then provided the most recent synoptic charts. As a result they made one modification to the climatological FT they originally created. Namely, they added "Chance of Thundershowers" for 05Z. Thus the final FT became:

FORECASTER'S FINAL FT

DCA 8 SCT C12 OVC 3410.

05Z 10 SCT C16 OVC CHC TRW

11Z C15 OVC 3FH.

17Z C15 BKN 5H BKN V SCT 1010.

21Z MVFR CIG BCMG VFR.

NNNN

COMMENTS ON EXAMPLE

Favorable:

- Weather can actually be initiated and dissipated when employing the CATRIX. This, in fact, occurred in the example at numerous times, e.g., fog, haze, and their dissipation.
- Note that it was possible to enter "probabilities" for the month to split the effect of the observation not being at midmonth. The same thing could have been done if the time was a fractional part of the hour.
- In general there is a high degree of consistency among the weather elements in CATRIX throughout the 24-h period, e.g., between visibility, dewpoint depression, and the types of weather anticipated.

Unfavorable:

- Snow probabilities greater than 0.0 in June with temperatures in the 60's is disconcerting. This is due to there being no guarantee that adding terms in the regression equation, for certain input conditions, will yield acceptable probability estimates (technically referred to as the nonadditivity problem). The saving grace in this situation is that it did not, and would not likely, appear in CATRIX since CATRIX acts as a filter. This problem will be completely eliminated with the new statistical procedure called Discrete Likelihood Functions (DLF) because the probability under these initial conditions would come out to be 0.0 (see Miller 1979).
- Lack of consistency between the overall no weather variable and its component parts. However, this is correctable. In this example, the proper hierarchy would have been to ignore the NO WX variable and only allow for weather in the CATRIX when a particular type of weather, such as fog or haze, is catergorically estimated to occur.
- Ceiling conditions proved to be estimated on the pessimistic side relative to the actual outcome although a certain amount of fluctuation was observed.
- The intervals and categories chosen here do not appear to be optimal. Our future plans call for revamping them.

SUMMARY AND FUTURE WORK

It would seem that the procedure described and demonstrated here would be useful as an aid to the forecaster especially at short range, say, one to six hours. In particular, it has the following beneficial characteristics:

1. More skillful than climatology and persistence where independent verifications have shown GEM to be as good as or better than TAP (Terminal Alert Procedure; see Vercelli and Hefferman 1978) for ceiling and visibility. Thus, GEM would seem to be a logical successor to TAP for AFOS since it includes projections on all of the remaining weather elements.

2. Capable of giving interesting and useful "best" category estimates as demonstrated in the "creation" and "dissipation" of fog and haze.

3. Since only the current observation is required to use GEM, any significant changes encountered in the present weather can initiate an instantaneous update of future conditions. There is no need to wait for the record observation. It is anticipated that this will be extremely well suited to the AFOS era both as a monitoring device and as a highly refined climatological aid to the forecaster.

4. Needs only a minicomputer such as exists in AFOS to perform the necessary calculations.

5. Is fully objective with interpretable regression coefficients as can be seen by studying the cloud cover equations in Table 3.

6. Provides a "what if" capability for the forecaster by merely modifying the input.

Future plans call for the following refinements:

1. Defining better intervals and categories in the weather variable transformations. For example, see Table 7.

2. Developing a generalized operator system so that the same regression equations are applicable anywhere provided an observation and that location's climatology are available. This is made possible by extracting location climatology at the outset, before developing the generalized regression equations, and then having it reinstated to make the equation "location specific".

3. Mapping forecasts when these are available for the entire area. This would give a capability for analysis and "time-lapse" projection.

4. Accounting for interactions among the observed variables by means of a technique such as DLF will be tested.

5. Performing a spectral decomposition of the regression-equation matrix employing eigenvalue analysis. This should yield fundamental climatological concepts and interpretations.

6. Obtaining best single estimates in CATRIX for elements such as temperature in degrees F or C. These can and will be gotten by using expectation or some similar procedure.

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REFERENCES

Miller, R. G., 1964: Regression estimation of event probabilities. Tech. Report 7411-121, Contract Cwb 10704, Travelers Research Center, Inc., Hartford, Conn., 153 pp.

__________, 1968: A stochastic model for real-time on-demand weather predictions. Proceedings of the First Statistical Meteorological Conference, Hartford, Amer. Meteor. Soc., 48-51.

__________, 1979: Estimating event probabilities by discrete likelihood functions. Preprints Sixth Conference on Probability and Statistics in Atmospheric Sciences, Banff, Amer. Meteor. Soc., 93-97.

__________, and D. L. Best, 1979: A model for conveting probability forecasts to categorical forecasts. Preprints Sixth Conference on Probability and Statistics in Atmospheric Sciences, Banff, Amer. Meteor. Soc., 98-102.

__________, R. C. Whiton, and M. J. Kelly, Jr., 1977: Results of a single station forecasting experiment. Preprints Fifth Conference on Probability and Statistics in Atmospheric Sciences, Las Vegas, Amer. Meteor. Soc., 37-40.

Vercelli, D. J., and M. M. Hefferman, 1978: AFOS aviation local monitoring and updating program. Preprints Conference on Weather Forecasting and Analysis and Aviation Meteorology, Silver Spring, Amer. Meteor. Soc., 369-373.

Whiton, R. C., 1977: Markov processes in Selected Topics in Statistical Meteorology, edited by R. G. Miller, Air Weather Service Tech. Report AWS-TR-77-273, Chapter 7, 45 pp.