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TESTING OF OBJECTIVE GUIDANCE FOR HAWAII

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1. INTRODUCTION

In a memorandum dated November 9, 1981, the National Weather Service Pacific Region requested that the Techniques Development Laboratory (TDL) investigate the possibility of developing automated public weather guidance similar to the guidance already provided to the conterminous United States and Alaska. The guidance for Hawaii would be based on the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972) and would make use of forecast fields from the National Meteorological Center's Spectral model (Sela, 1980).

In February 1983, we began development of surface temperature and probability of precipitation (PoP) equations; about 2 1/2 years of Spectral model output data were available. Sets of equations also were derived based on persistence and climate in order to evaluate the performance of the MOS-based system.

The purpose of this report is to describe the details of the MOS and persistence/climate temperature and PoP equation derivations and to present the results of tests performed on independent data.

2. MOS EQUATION DEVELOPMENT

A. Temperature

Two sets of equations were derived to predict temperatures valid 18, 30, and 48 hours after 0000 GMT. The first set was developed by using the entire data sample of approximately 705 days from the period October 1980 to September 1982; this set will be referred to as the unstratified equations. The second set was developed by using approximately 356 days from the months of November to April during these same years; this set will be called the cool season equations. This was done in order to determine whether stratification of developmental data would produce better forecasts. For both equation types, equations were derived for individual stations.

The observed predictand data were available from the TDL hourly data collection, in addition to data obtained from the National Climatic Data Center (NCDC) in Asheville, North Carolina. Table 1 lists the Hawaiian hourly reporting stations which have sufficient predictand data available for the development of MOS equations. However, for testing purposes, the NCDC data were used, and thus, equations were developed only for the first-order stations (those stations listed in Table 1 with an asterisk).

The potential predictors that were screened appear in Table 2. These consisted of numerous forecasts fields from the Spectral model, various types of geoclimatic predictors, and weather elements observed at 0600 GMT.

Yesterday's calendar day maximum and minimum temperatures were also included. The screening procedure was allowed to select up to eight predictors, but only as long as each included one increased the reduction of variance by an additional one-half of one percent. Table 3 shows a sample cool season temperature forecast equation for Hilo.

B. Probability of Precipitation

We derived equations to forecast PoP for the first (6-18 h), second (18-30 h), and third (30-42 h) periods after 0000 GMT. Like those for temperature, unstratified and cool season equations were developed. However, unlike the temperature derivation, these equations were developed by grouping stations with similar characteristics into regions. Regionalization is desirable, particularly for the cool season sample, because it increases the developmental sample size.

Table 1 shows the six locations which had sufficient data for the PoP development. For each station, the observed relative frequency of precipitation during the first and second periods after 0000 GMT was determined for cases where the Spectral model 6-18 h and 18-30 h forecasts of precipitation amount were $\geq$ .01 inch. From this analysis, the six stations were grouped into two regions, one containing windward-facing stations (those denoted with a "ω" in Table 1) and the other containing leeward-facing stations (those denoted with a "ℓ" in Table 1).

The potential predictors we screened appear in Table 4. Note, once again, Spectral model forecasts, geoclimatic predictors, and observed weather elements appear in the list. Some of the fields were screened as binary predictors where the value of the predictor was set to 1 if the observed value was less than or equal to the binary cutoff, otherwise it was set to 0.

The screening procedure was allowed to select up to 16 predictors, but only as long as each one increased the reduction of variance by an additional one-tenth of one percent. A sample unstratified equation valid for the three windward-facing stations for the second-period PoP forecast appears in Table 5.

3. PERSISTENCE/CLIMATE EQUATION DEVELOPMENT

A. Temperature

Two sets of equations based on persistence/climate (unstratified and cool season) were derived for the four available first-order stations in the NCDC data archive. The unstratified set was developed on approximately 2900 days of data from the period of October 1974 to September 1982. The cool season set was developed on approximately 1450 days from eight seasons (November-April) covering the same time period. Both sets of equations were derived to forecast the temperature 18, 30, and 48 hours after 0000 GMT.

The potential predictors offered to the screening regression program included observed weather elements and geoclimatic predictors. We screened observations from the 0600 GMT report, i.e., the observed weather, opaque sky cover, temperature, dew point, and U and V wind components. We also screened day's maximum and minimum temperatures. For the 18-h forecast, yesterday's 1800 GMT temperature was screened; for the 48-h forecast, the 0000 GMT temperature was included as a predictor. An equation was allowed to contain up to eight predictors, but only as long as each one increased the reduction of variance by an additional one-half of one percent. A sample unstratified equation based on persistence/climate for the 48-h temperature after 0000 GMT at Lihue is shown in Table 6.

B. Probability of Precipitation

The PoP persistence/climate equations were developed in a similar manner to the temperature prediction equations. Equations were derived to forecast PoP for the first, second, and third periods after 0000 GMT for the four first-order stations. However, unlike the persistence/climate temperature derivation, these PoP equations were developed only for the cool season.

The potential predictors offered to the screening regression program were identical to those used for the persistence/climate temperature derivation, except we included the 6- and 12-h accumulated precipitation observation. Also, we screened yesterday's appropriate 6- and 12-h accumulated precipitation observation. For example, for the first period, the 6- and 12-h accumulated precipitation at 1800 GMT was screened. Each precipitation amount observation was screened as a binary predictor. A sample persistence/climate PoP prediction equation for the first period valid during the cool season at Honolulu appears in Table 7.

In order to assess the relative skill of both the MOS and persistence/climate equations, another set of prediction equations was derived on the cool season data sample by screening only geoclimatic predictors (sine and cosine of the day of the year).

4. VERIFICATION RESULTS

Approximately 178 days from the 1982-83 cool season were withheld from the developmental sample in order to be used as independent data. In all the verification tests, forecasts produced by the MOS equations were compared to forecasts made by the persistence/climate equations for the four first-order stations. All forecasts were produced from 0000 GMT cycle data.

A. Temperature

Results for the 18-, 30-, and 48-h forecasts are presented in Tables 8, 9, and 10, respectively. Each table shows the verification scores, as well as the total reduction of variance on the developmental sample, number of predictors per equation, and number of developmental cases for each type of equation. An examination of the mean absolute errors (MAE's) for all four stations over all forecast periods indicates that there is little difference between the various forecast schemes. The MAE's are all very small compared to typical MAE's in the conterminous United States. This is because the variance of the observed temperature is very small. For example, for the

1982-83 cool season, the standard deviation of the observed 1800 GMT temperature at Kahului (the station with generally the highest MAE and variance) was only 4.2°F.

The overall results suggest that the MOS unstratified equations are perhaps slightly better than the others. Furthermore, for the 30-h forecasts at Honolulu, a comparison was made for only those days where the observed temperature was ≥ 3°F different from the previous day. As a result, 56 days were identified, and MAE's were computed. With such a stratification of sample days, the MOS cool season equations were found to perform best. The MAE's for the MOS cool and unstratified, and the persistence/climate cool and unstratified equations were 2.3°F, 2.4°F, 3.1°F, and 3.5°F, respectively. These values correspond to 41%, 38%, 18%, and 9% improvements over persistence.

B. Probability of Precipitation

Forecasts from all four stations were combined to produce Brier scores (Brier, 1950) and reliability curves for all three periods. Comparative verification results for the MOS cool season and unstratified, and the persistence/climate and climate equation types are shown in Table 11. Figs. 1-3 are the reliability curves for the MOS unstratified, MOS cool, and persistence/climate equation types for the second period (18-30 h) forecasts. Figs. 4-6 show the composite reliability curves for all three forecast periods combined for each forecast system.

The results in Table 11 indicate that the MOS unstratified equations improved approximately 24%, 14%, and 8% over climate[1] Brier scores for the first, second, and third periods, respectively. The analogous improvements over climate for persistence/climate were 20%, 7%, and 5%. The reliability curves presented for the second period (Figs. 1-3) and for all three periods combined (Figs. 4-6) indicate that MOS was not substantially better than persistence/climate. These results suggest that PoP forecasting in Hawaii is quite difficult. This is also true in general for lower latitude regions of the conterminous United States, such as Florida and southern Texas.

5. CONCLUSIONS

Equations were developed to forecast temperature and PoP for first-order stations in Hawaii. Two types of MOS and persistence/climate equations were developed to predict the temperature 18, 30, and 48 hours after 0000 GMT. Two types of MOS and persistence/climate equations were also developed to predict the PoP for the first, second, and third periods after 0000 GMT.

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[1]Forecasts generated by the climate equations closely approximate daily relative frequencies. However, depending on the time of year, these forecasts can differ from the monthly relative frequency (traditionally used as climate) by as much as 5%. Hence, it is possible that use of monthly relative frequencies could have made climate more difficult to improve on.

Comparative verification of both the temperature and PoP forecasts on independent data from the 1982-83 cool season indicated that, in general, the MOS unstratified equations produced the best forecasts. However, during variable weather situations, the MOS cool season equations produced better forecasts.

The magnitude of improvement over persistence/climate for the temperature forecasts was minimal overall. The improvements of PoP forecasts over climate were also quite small. Because of the small improvements, we've decided to discontinue development of MOS guidance for Hawaii. In addition to the limited skill of the MOS forecasts compared to persistence/climate, we're also concerned about the National Meteorological Center's plans to introduce major changes in the Spectral model during 1984. These changes include addition of radiation computations and enhancement of the convective parameterization scheme. We think the proposed MOS guidance for Hawaii would deteriorate significantly after such modifications were introduced.

6. ACKNOWLEDGMENTS

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Table 1. Hawaiian stations for which temperature and probability of precipitation experimental forecast equations could be developed. The asterisk (*) indicates stations where persistence/climate equations could be developed. The "ω" and "ℓ" denote windward and leeward facing stations respectively.

Temperature	Probability of Precipitation
Barbers Point (PHNA)	Hilo (ITO) - ω
Hilo (ITO)*	Honolulu (HNL)* - ℓ
Honolulu (HNL)*	Lihue (LIH)* - ω
Lihue (LIH)*	Kahului (OGG)* - ℓ
Kahului (OGG)*	Kaneohe Bay (PHNG)* - ω
Kaneohe Bay (PHNG)	Wahiawa/Wheeler AFB (PHHI) - ℓ
Wahiawa/Wheeler AFB (PHHI)	

Table 2. Potential predictors available to the screening regression program for the derivation of MOS temperature prediction equations for Hawaii.

Predictors	Projection
a) Spectral Model Output	
Temperature (1000 mb, 700 mb, 500 mb)	12,24,36,48
Temperature (850 mb)	6,12,18,24,36,48
Dew point temperature (1000 mb, 850 mb)	6,12,18,24,30,36,42,48
Dew point temperature (700 mb, 500 mb)	6,12,18,24,30,36,42,48
Geostrophic U, V, S (1000 mb, 850 mb)	6,12,18,24,36,48
Mean relative humidity (surface to $\sim$ 490 mb)	6,12,18,24,30,36,42,48
Mean relative humidity (top B.L. to $\sim$ 720 mb)	6,12,18,24,36,48
Mean relative humidity ($\sim$ 720 mb to $\sim$ 490 mb)	6,12,18,24,36,48
Vertical velocity (850 mb, 700 mb)	12,24,36,48
b) Model Output Derived Predictors	
Dew point depression (1000 mb, 700 mb)	12,24,36,48
Dew point depression (850 mb, 500 mb)	6,12,18,24,36,48
Thickness (1000-500 mb)	6,12,18,24,36,48
Thickness (1000-850 mb)	6,12,18,24,36,48
Temperature advection (1000 mb)	12,24,36,48
Stability (850-1000 mb temperature diff.)	12,24,36,48
Stability (700-850 mb temperature diff.)	12,24,36,48
Relative vorticity (850 mb, 500 mb)	6,12,18,24,36,48
Relative vorticity advection (850 mb, 500 mb)	6,12,18,24,36,48
Moisture convergence (850 mb)	12,24,36,48
c) Observed and Geoclimatic Predictors	
Sine and cosine of the day of the year and twice the day of the year	--
Observed maximum/minimum temperature	0,-6
Observed weather elements (opaque sky cover, temperature, dewpoint, U, V, S)	6

Table 3. Sample MOS equation for predicting the 30-h temperature after 0000 GMT valid for the cool season at Hilo, Hawaii.

	Predictor (units)	Forecast Projection (h)	Cumulative Reduction of Variance	Coefficient
1.	1000-850 mb thickness (m)	24	0.327	0.084
2.	Yesterday's maximum temperature (°F)	0	0.370	0.077
3.	500-mb dew point depression (°C)	36	0.389	0.046
4.	850-mb geostrophic V (ms^{-1})	24	0.400	0.138
5.	1000-mb geostrophic U (ms^{-1})	36	0.418	-0.143
6.	Observed temperature (°F)	6	0.427	0.150
7.	Observed wind speed (kt)	6	0.437	-0.089
8.	500-mb geostrophic vorticity X 10^5 (s^{-1})	24	0.444	-0.102

Regression constant = 92.85 Total standard error estimate = 1.723 °F

Table 4. Potential predictors available to the screening regression program for the derivation of MOS PoP prediction equations for Hawaii.

Predictors	Projection
a) Spectral Model Output	
Mean relative humidity (surface to ∿ 490 mb)	6,12,18,24,30,36,42,48
Mean relative humidity (top B.L. to ∿ 720 mb)	6,12,18,24,36,48
Mean relative humidity (∿ 720 mb to ∿ 490 mb)	6,12,18,24,36,48
Precipitable water (surface to 490 mb)	0,12,24,36,48
Precipitation amount	12,18,24,36,42,48
Dew point temperature (1000 mb, 850 mb, 700 mb, 500 mb)	6,12,18,24,30,36,42,48
Geostrophic U, V, S (1000 mb)	6,12,18,24,36,48
Geostrophic U, V, S (850 mb)	12,24,36,48
Vertical velocity (850 mb, 700 mb)	12,24,36,48
b) Model Output Derived Predictors	
Dew point depression (1000 mb, 700 mb, 500 mb)	12,24,36,48
Dew point depression (850 mb)	6,12,18,24,36,48
Moisture convergence (850 mb)	12,24,36,48
Thickness (1000-850 mb)	6,12,18,24,36,48
Temperature advection (850 mb)	6,12,18,24,36,48
Relative vorticity (850 mb, 500 mb)	6,12,18,24,36,48
Relative vorticity advection (850 mb, 500 mb)	6,12,18,24,36,48
c) Observed and Geoclimatic Predictors	
Sine and cosine of the day of the year and twice the day of the year	--
Station latitude and longitude	--
Observed weather elements (opaque sky cover, temperature, dewpoint, precipitation amount, U, V, S)	6

Table 5. Sample MOS equation for predicting the second period PoP (18-30 hours) after 0000 GMT valid for the three windward facing stations during the entire year (unstratified).

	Predictor	Binary Cutoff	Units	Projection (h)	Cumulative Reduction of Variance	Coefficient
1.	Observed 12-h precip.	.01	in	6	0.046	-0.104
2.	Mean rel. humidity	--	%	30	0.079	0.012
3.	850-mb U wind	--	ms^{-1}	36	0.117	-0.022
4.	Observed U wind	--	kt	6	0.136	0.011
5.	850-mb rel. vorticity	--	$10^{-5}/s$	48	0.149	0.077
6.	850-mb vert. velocity	--	mbs^{-1}	36	0.157	120.5
7.	Observed 6-h precip.	.01	in	6	0.163	-0.086
8.	700-mb dew point dep.	9	°C	48	0.168	0.165
9.	700-mb dew point dep.	13	°C	48	0.172	-0.083
10.	500-mb dew point dep.	5	°C	36	0.175	-0.193
11.	Observed opaque clouds	2	tenths	6	0.177	-0.118
12.	Mean rel. humidity	80	%	48	0.180	-0.193

Regression constant = -0.031 Total standard error of estimate = 0.437

Table 6. Sample persistence/climate prediction equation for estimating the 48-h temperature after 0000 GMT valid for the entire year (unstratified) at Lihue, Hawaii.

Predictor (units)	Forecast Projection (h)	Cumulative Reduction of Variance	Coefficient
1. Yesterday's maximum temperature (°F)	0	0.444	0.406
2. Observed temperature (°F)	6	0.477	0.091
3. Cosine day of year	0	0.495	-1.324
4. Sine day of year	0	0.521	-1.151

Regression constant = 40.42   Standard error of estimate = 2.52 °F

Table 7. Sample persistence/climate prediction equation for estimating the first period PoP (6-18 hours) after 0000 GMT valid during the cool season at Honolulu, Hawaii.

Predictor	Binary Cutoff	Units	Projection (h)	Cumulative Reduction of Variance	Coefficient
1. Observed weather	5	--	6	0.118	-0.224
2. Observed 6-h precip.	.01	in	6	0.160	-0.169
3. Observed V wind	-	kt	6	0.186	0.015
4. Observed wind speed	-	kt	6	0.217	0.015
5. Observed opaque clouds	6	tenths	6	0.232	-0.085
6. Observed 12-h precip.	.01	in	-6	0.240	-0.084
7. Observed dew point	-	°F	6	0.246	0.009
8. Observed opaque clouds	9	tenths	6	0.251	-0.126

Regression constant = 0.137   Standard error of estimate = .348

Table 8. Comparative verification of temperature forecasts in Hawaii for 178 days during the 1982-83 cool season 18-h after 0000 GMT. The reduction of variance for overall is the average of the individual stations.

Station	Type of Forecast	Mean Observed Temp. (°F)	Mean Forecast Temp. (°F)	Mean Algebraic Error (°F)	Mean Absolute Error (°F)	Root Mean Square Error (°F)	Number of Absolute Errors ≤ 4°F	Regression Reduction of Variance (Terms/eqn)	Number of Developmental Cases
Hilo	MOS cool	69.1	69.1	0.0	1.8	2.3	123	0.47 (8)	353
	MOS unstratified		69.3	0.2	1.8	2.3	131	0.68 (5)	703
	Persistence/clim. cool		69.1	0.1	1.7	2.1	138	0.49 (5)	1443
	Persistence/clim. unst.		69.4	0.3	1.7	2.2	139	0.67 (8)	2917
Honolulu	MOS cool	69.5	70.5	1.0	2.2	2.9	117	0.68 (8)	354
	MOS unstratified		70.1	0.6	2.0	2.5	125	0.82 (8)	704
	Persistence/clim. cool		70.1	0.6	2.1	2.7	114	0.62 (7)	1448
	Persistence/clim. unst.		70.1	0.6	2.2	2.8	115	0.79 (6)	2921
Kahului	MOS cool	69.5	70.1	0.6	2.6	3.2	92	0.62 (8)	354
	MOS unstratified		70.4	0.9	2.5	3.2	103	0.80 (8)	704
	Persistence/clim. cool		69.7	0.2	2.7	3.3	92	0.51 (7)	1446
	Persistence/clim. unst.		69.9	0.3	2.6	3.3	98	0.76 (4)	2919
Lihue	MOS cool	70.6	71.0	0.4	2.0	2.6	122	0.64 (8)	354
	MOS unstratified		70.8	0.2	1.9	2.5	120	0.76 (6)	704
	Persistence/clim. cool		70.2	-0.5	2.1	2.7	113	0.59 (7)	1447
	Persistence/clim. unst.		70.4	-0.3	2.3	2.8	115	0.74 (5)	2919
Overall	MOS cool	69.7	70.2	0.5	2.2	2.8	454	0.60	--
	MOS unstratified		70.1	0.5	2.0	2.6	479	0.77	--
	Persistence/clim. cool		69.8	0.1	2.2	2.7	457	0.55	--
	Persistence/clim. unst.		69.9	0.3	2.2	2.8	467	0.74	--

Table 9. Same as Table 8 except for 30-h after 0000 GMT.

Station	Type of Forecast	Mean Observed Temp. (°F)	Mean Forecast Temp. (°F)	Mean Algebraic Error (°F)	Mean Absolute Error (°F)	Root Mean Square Error (°F)	Number of Absolute Errors ≤4°F	Regression Reduction of Variance (Terms/eqn)	Number of Developmental Cases
Hilo	MOS cool	71.3	71.6	0.3	1.7	2.1	134	0.44 (8)	354
	MOS unstratified		71.6	0.3	1.6	2.0	139	0.64 (6)	704
	Persistence/clim. cool		70.8	-0.5	1.7	2.0	135	0.35 (7)	1446
	Persistence/clim. unst.		70.8	-0.5	1.7	2.1	134	0.56 (6)	2920
Honolulu	MOS cool	71.7	72.5	0.9	1.7	2.2	136	0.57 (8)	354
	MOS unstratified		72.4	0.7	1.6	2.1	135	0.71 (7)	704
	Persistence/clim. cool		72.3	0.6	1.7	2.4	134	0.46 (5)	1448
	Persistence/clim. unst.		72.3	0.6	1.9	2.5	131	0.69 (4)	2921
Kahului	MOS cool	72.3	73.7	1.4	1.9	2.6	123	0.57 (8)	354
	MOS unstratified		73.1	0.8	1.7	2.3	128	0.74 (6)	704
	Persistence/clim. cool		72.9	0.7	1.8	2.3	131	0.49 (6)	1444
	Persistence/clim. unst.		72.8	0.5	1.8	2.3	134	0.72 (4)	2917
Lihue	MOS cool	72.1	71.7	-0.4	1.7	2.2	134	0.59 (8)	354
	MOS unstratified		71.8	-0.3	1.5	1.9	148	0.71 (6)	704
	Persistence/clim. cool		71.9	-0.2	1.6	2.1	141	0.44 (5)	1447
	Persistence/clim. unst.		71.9	-0.2	1.7	2.1	140	0.69 (5)	2919
Overall	MOS cool	71.8	72.4	0.5	1.8	2.3	527	0.55	--
	MOS unstratified		72.2	0.4	1.6	2.1	550	0.70	--
	Persistence/clim. cool		72.0	0.1	1.7	2.2	541	0.43	--
	Persistence/clim. unst.		72.0	0.1	1.7	2.3	539	0.67	--

Table 10. Same as Table 8 except for 48-h after 0000 GMT.

Station	Type of Forecast	Mean Observed Temp. (°F)	Mean Forecast Temp. (°F)	Mean Algebraic Error (°F)	Mean Absolute Error (°F)	Root Mean Square Error (°F)	Number of Absolute Errors $\leq 4°F$	Regression Reduction of Variance (Terms/eqn)	Number of Developmental Cases
Hilo	MOS cool	78.3	79.1	0.9	2.0	2.7	124	0.51 (8)	354
	MOS unstratified		79.0	0.7	2.1	2.7	121	0.45 (6)	704
	Persistence/clim. cool		78.0	-0.3	2.3	3.1	120	0.23 (5)	1446
	Persistence/clim. unst.		78.1	-0.1	2.3	3.1	118	0.32 (6)	2920
Honolulu	MOS cool	79.8	80.9	1.1	2.3	2.9	108	0.52 (8)	354
	MOS unstratified		80.9	1.1	2.2	2.9	116	0.68 (5)	704
	Persistence/clim. cool		79.2	-0.5	2.3	2.9	111	0.30 (3)	1448
	Persistence/clim. unst.		79.2	-0.6	2.3	2.9	110	0.60 (4)	2921
Kahului	MOS cool	81.2	81.7	0.5	2.2	2.8	112	0.53 (8)	354
	MOS unstratified		82.0	0.8	2.2	2.8	115	0.64 (7)	704
	Persistence/clim. cool		80.7	-0.5	2.6	3.1	98	0.25 (4)	1446
	Persistence/clim. unst.		80.5	-0.7	2.6	3.2	96	0.56 (4)	2919
Lihue	MOS cool	77.5	79.1	1.6	2.4	3.0	105	0.46 (8)	354
	MOS unstratified		78.1	0.6	2.2	2.8	114	0.58 (4)	704
	Persistence/clim. cool		78.0	0.5	2.2	2.9	114	0.18 (4)	1447
	Persistence/clim. unst.		78.0	0.6	2.2	2.9	113	0.52 (4)	2919
Overall	MOS cool	79.2	80.2	1.0	2.2	2.9	449	0.50	--
	MOS unstratified		80.0	0.8	2.2	2.8	466	0.59	--
	Persistence/clim. cool		79.0	-0.2	2.3	3.0	443	0.24	--
	Persistence/clim. unst.		79.0	-0.2	2.4	3.0	437	0.50	--

Table 11. Comparative verification of PoP forecasts in Hawaii for 178 days during the 1982-83 cool season. All forecast projections after 0000 GMT.

Projection	Type of Forecast	Avg. Prob.	Rel. Freq.	Brier Score	Impr. Over Climate
06-18	MOS cool	.261	.282	.292	22.1
	MOS unstratified	.259		.287	23.5
	Persistence/clim.	.277		.301	19.7
	Climate	.341		.375	--
18-30	MOS cool	.229	.221	.318	10.2
	MOS unstratified	.225		.303	14.4
	Persistence/clim.	.257		.331	6.5
	Climate	.280		.354	--
30-42	MOS cool	.340	.282	.342	8.3
	MOS unstratified	.298		.345	7.5
	Persistence/clim.	.312		.356	4.6
	Climate	.340		.373	--

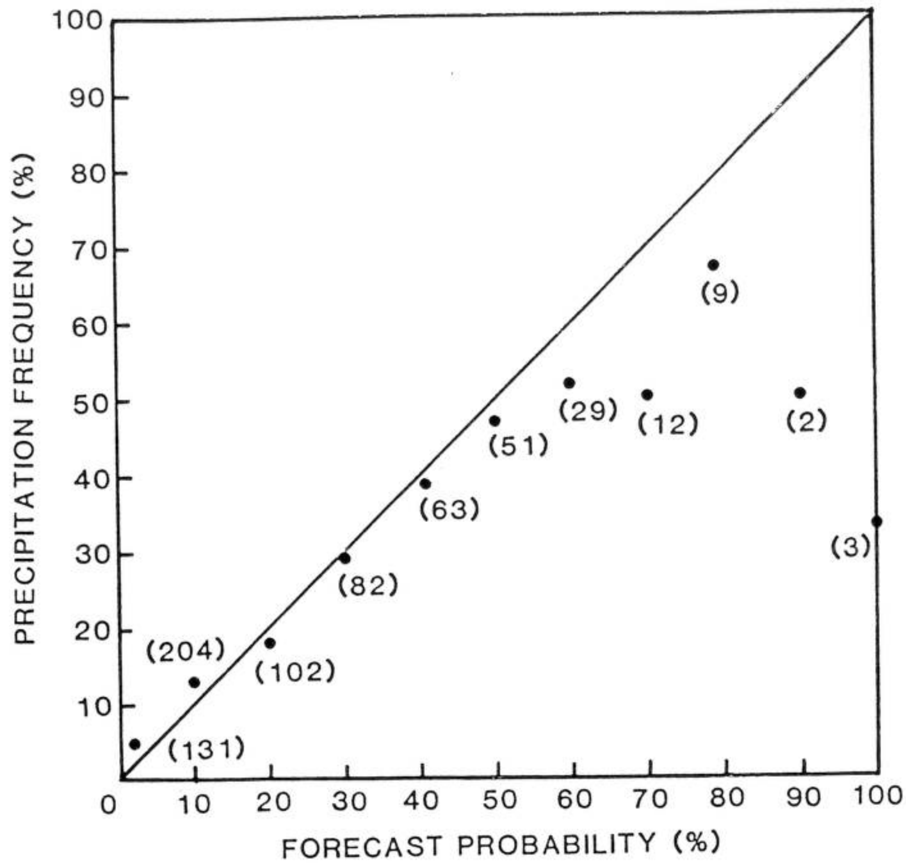

Figure 1. Reliability of forecasts produced by the MOS unstratified prediction equations for the second period (18-30 h) after 0000 GMT. Independent data were combined from four, first-order stations for the period November 1982-April 1983. The number of cases for each data point is shown in parentheses. The line denotes perfect reliability.

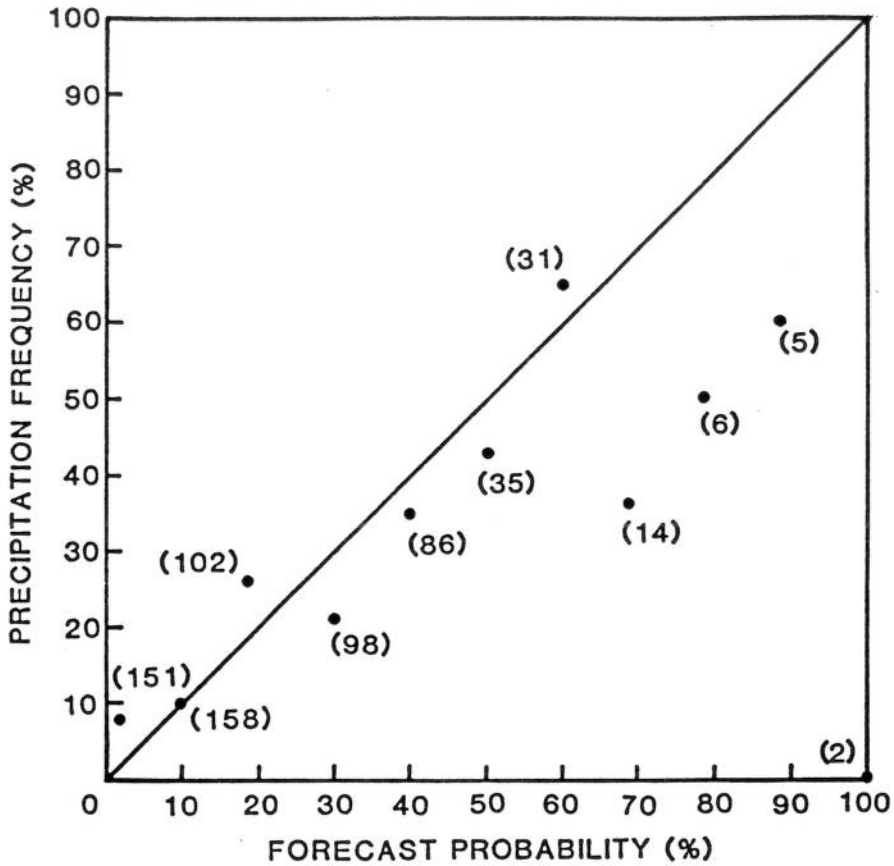

Figure 2. Same as Fig. 1 except for the MOS cool season prediction equations.

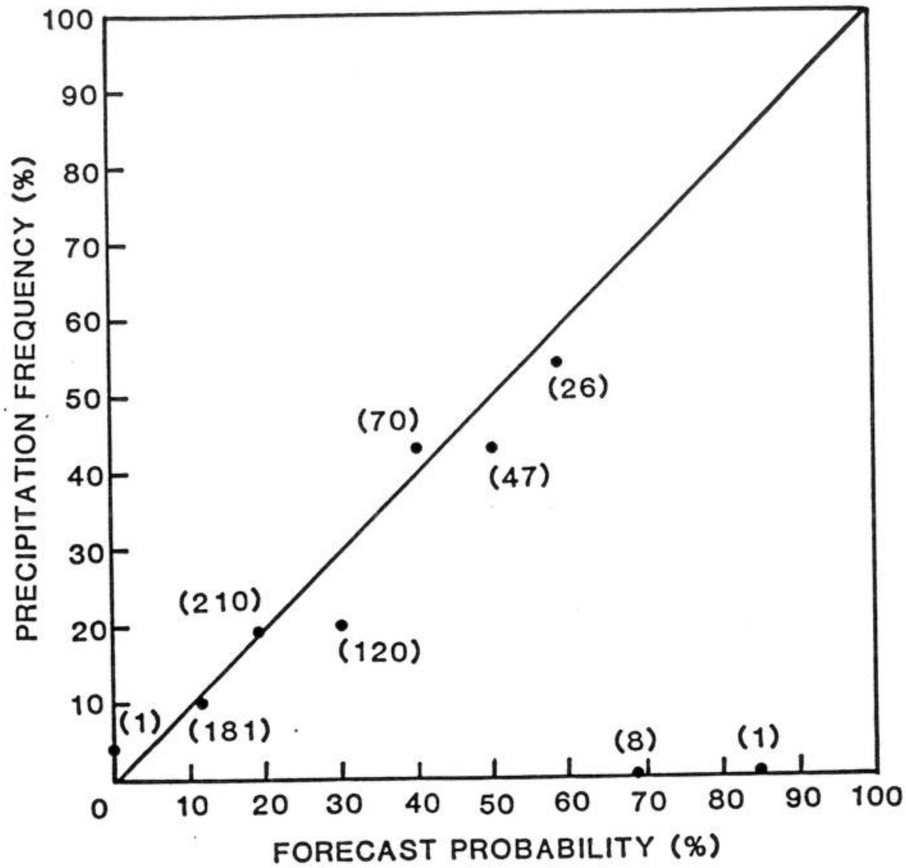

Figure 3. Same as Fig. 1 except for the persistence/ climate prediction equations.

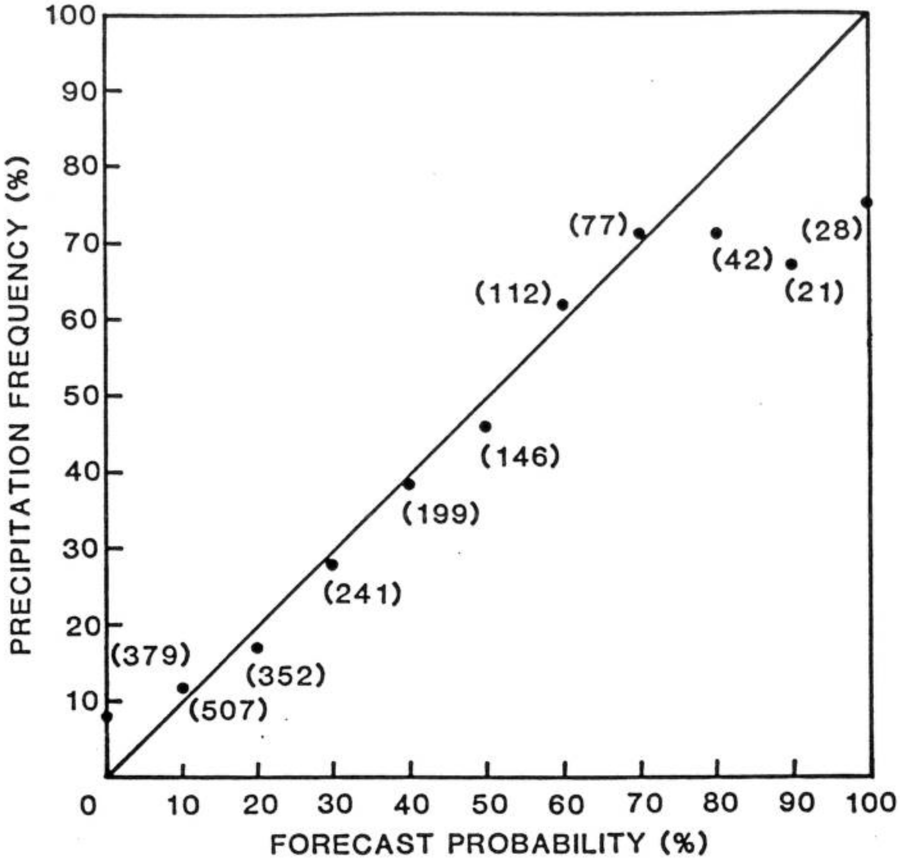

Figure 4. Same as Fig. 1 except for all three forecast periods combined.

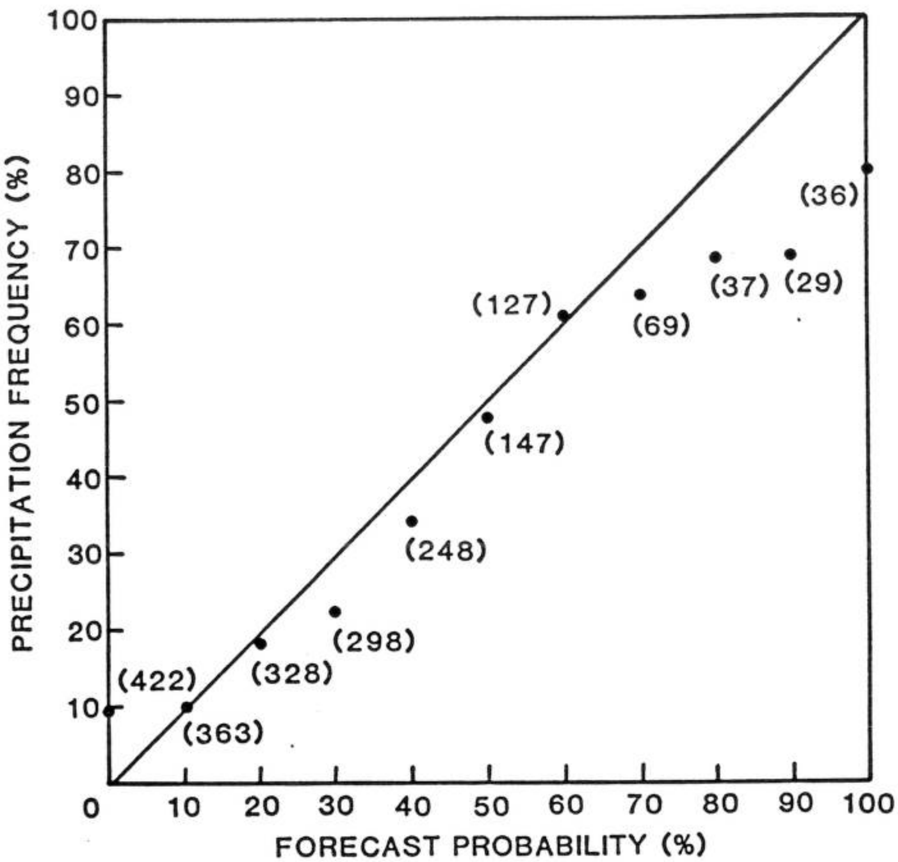

Figure 5. Same as Fig. 1 except for MOS cool season equations and for all three forecast periods combined.

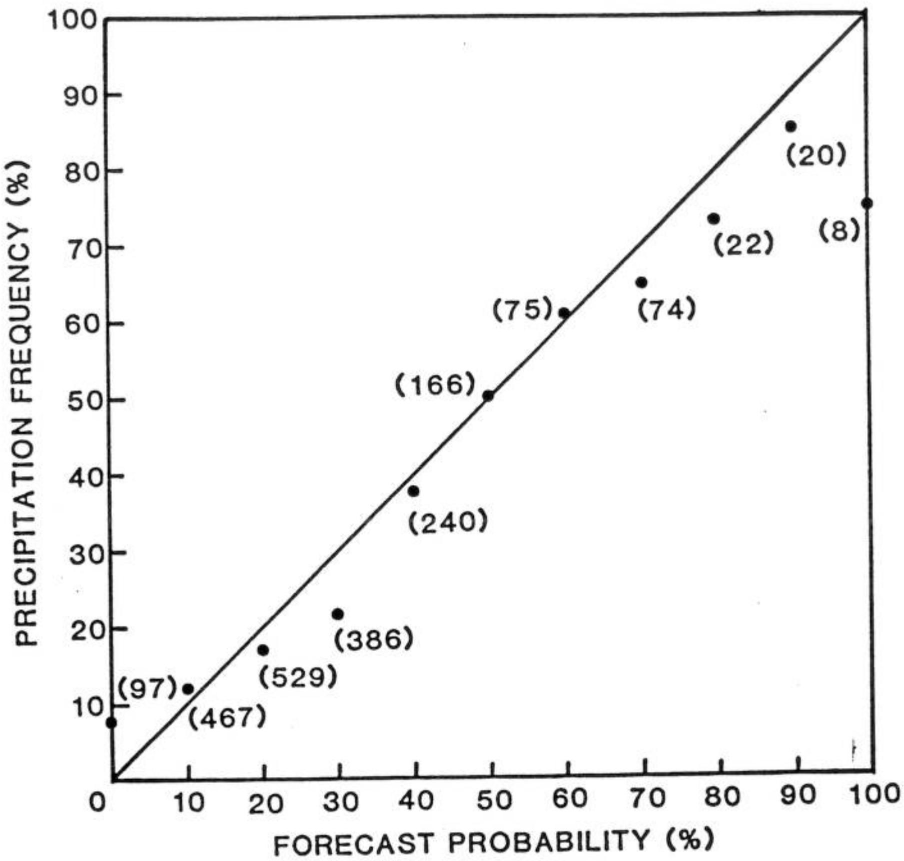

Figure 6. Same as Fig. 1 except for persistence/climate and for all three forecast periods combined.