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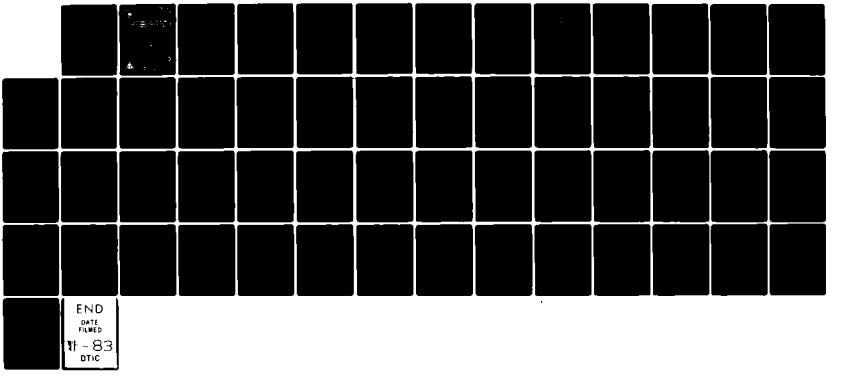

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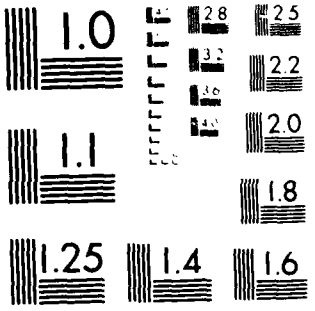

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SHORT-RANGE LOCAL FORECASTING OF COASTAL SUMMER STRATUS BY STATISTICAL TECHNIQUES - A PILOT STUDY

Wayne A. Sweet
Naval Environmental Prediction Research Facility

SEPTEMBER 1983

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Two different regression techniques applied to short range (24 hr or less) forecasting are examined at four naval air stations on the California coast. Regression estimates of event probabilities (REEP) was compared to logistic regression (LR) in forecasting summer stratus at Moffett NAS; REEP also was evaluated operationally at Moffett during the summer of 1982. The skill of the LR technique was examined at North Island, Miramar and San Nicolas NAS in Southern California for the stratus ceiling forecast. (Continued on reverse)

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Block 20, Abstract, continued.

The results of these evaluations indicated equal skills for REEP and LR. The REEP operational evaluation at Moffett NAS showed a level of skill equivalent to that possessed by the most experienced forecasters.

Either of these techniques would provide valuable forecasting capability for certain forecast parameters when applied to remote areas where archived data are available but little or no local forecasting experience exists.

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1. INTRODUCTION

1.1 FOCUS OF THE PILOT STUDY

Short range forecasts for periods of 24 hours or less usually are based on both the objective guidance provided by large scale models and the individual forecaster's experience gained over time at a particular location. The forecaster who lacks this personal experience, however, often must rely on "textbook" interpretation of a model's objective guidance, and thus possibly be handicapped in forecasting primarily mesoscale situations.

This study examines the skill, usefulness and applicability of two techniques that have been applied to short range forecasting as substitutes for local experience. They are known as regression estimates of event probability (REEP), and logistic regression (LR) probabilities.

These techniques are based on conditional climatologies (see Miller, 1979). They use surface observations coupled with forecast equations based on regression techniques, to produce probability forecasts.

The skills of the techniques in forecasting summer stratus ceilings at four naval air stations in California -- Moffett NAS, North Island NAS, Miramar NAS, and San Nicolas NAS -- were evaluated in this study. Both REEP and LR were used at Moffett; only LR was used at the other three stations. (REEP equations also were used operationally at Moffett NAS during the summer of 1982; see Appendix A for results of this evaluation.) Skill scores of each technique were compared to those of climatology, a readily quantifiable technique, to assess performance.

1.2 THE FORECAST PROBLEM

Summer stratus along the California coast presents a daily forecast problem. Depending on the location, stratus with ceilings as low as 500 ft can develop during the late afternoon or evening, dissipating sometime the following morning. A series of days with stratus occurring typically is followed by one to several clear days; California summer is typically either coastal stratus or clear.

Since the mid-latitude Pacific anticyclone is a persistent feature in the summer, and the large scale synoptic pattern does not change much, the forecast problem therefore is associated with subtle changes in the mesoscale features. Predictors such as surface winds, dew point depression, etc., are strong candidates.

Topographical features also play a major role since the stratus deck is confined to the marine layer. Cool sea surface temperatures along the California coast in summer cause a low level temperature inversion and an associated moist marine layer. The predominant on-shore pressure gradient forces this marine layer on shore, with diurnal modification from the sea breeze gradient. Coastal terrain features modify, or dam up this inland intrusion.

Moffett NAS, for example, is located on the southern edge of the San Francisco Bay, with the Santa Cruz range to the west (Figure 1). These hills cause the stratus to approach Moffett from the north, along the bay. The cool and moist marine layer must slide through the Golden Gate and push down the bay, so the stratus deck that occurs at Moffett is really a combination advection-formation event.

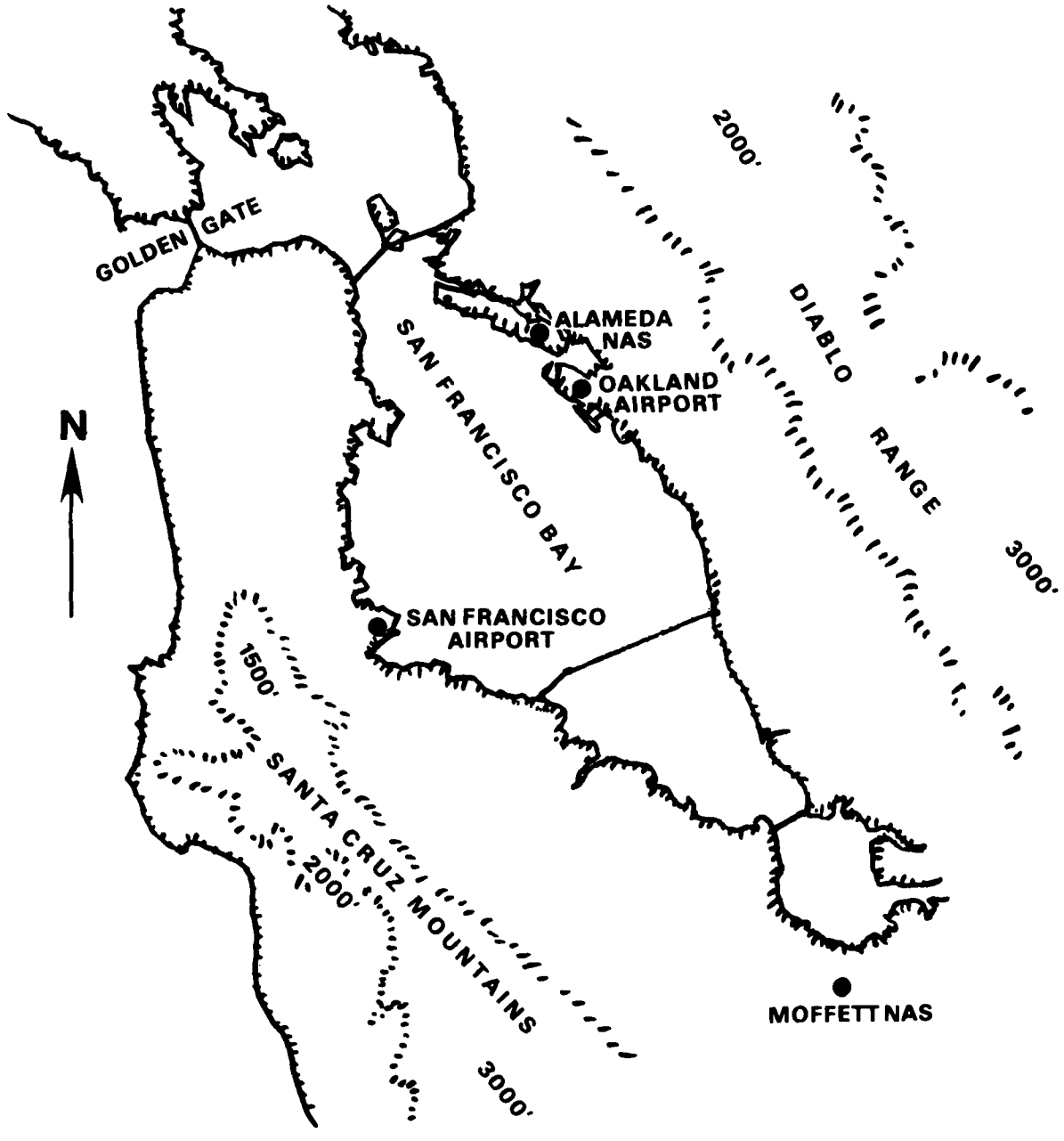

Figure 1. Locations of air stations and airports, with mountain elevations to the west and east, in the San Francisco Bay Region of Northern California.

At the three air stations in Southern California, the stratus deck has a clear path inland; field elevation and distance inland are the primary differences (see Figure 2). The lower latitude and much warmer sea surface temperatures along the southern coast also have an effect, causing thicker stratus decks with higher bases.

2. DESCRIPTIONS OF THE REEP AND LR TECHNIQUES

2.1 REGRESSION ESTIMATES OF EVENT PROBABILITIES (REEP)

The REEP technique (described in detail in Miller, 1964) uses surface observations from the forecast station and other surrounding stations. Each predictor variable is divided into subranges; these are then assigned values of 0 or 1, depending on the observed values.

(Lists of candidate predictors for both REEP and LR (logistic regression) techniques used in this pilot study are given for Moffett, North Island, Miramar and San Nicolas Naval Air Stations in Appendixes A-E respectively.)

As an example, the predictor variable "surface dew point depression" is divided into five subranges for Moffett NAS data:

Dummy Variable No.	Range (°F)
1	-8.0
2	8.1-10.0
3	10.1-12.0
4	12.1-14.0
5	>14.1

The dew point depression variable can now be represented by a vector,

$$D = (1,0,0,0,0),$$

which indicates the value is in the 0-8.0°F range. All the other predictor variables are categorized similarly, and the resulting single surface observation for any given day and time becomes simply a string of 0's and 1's.

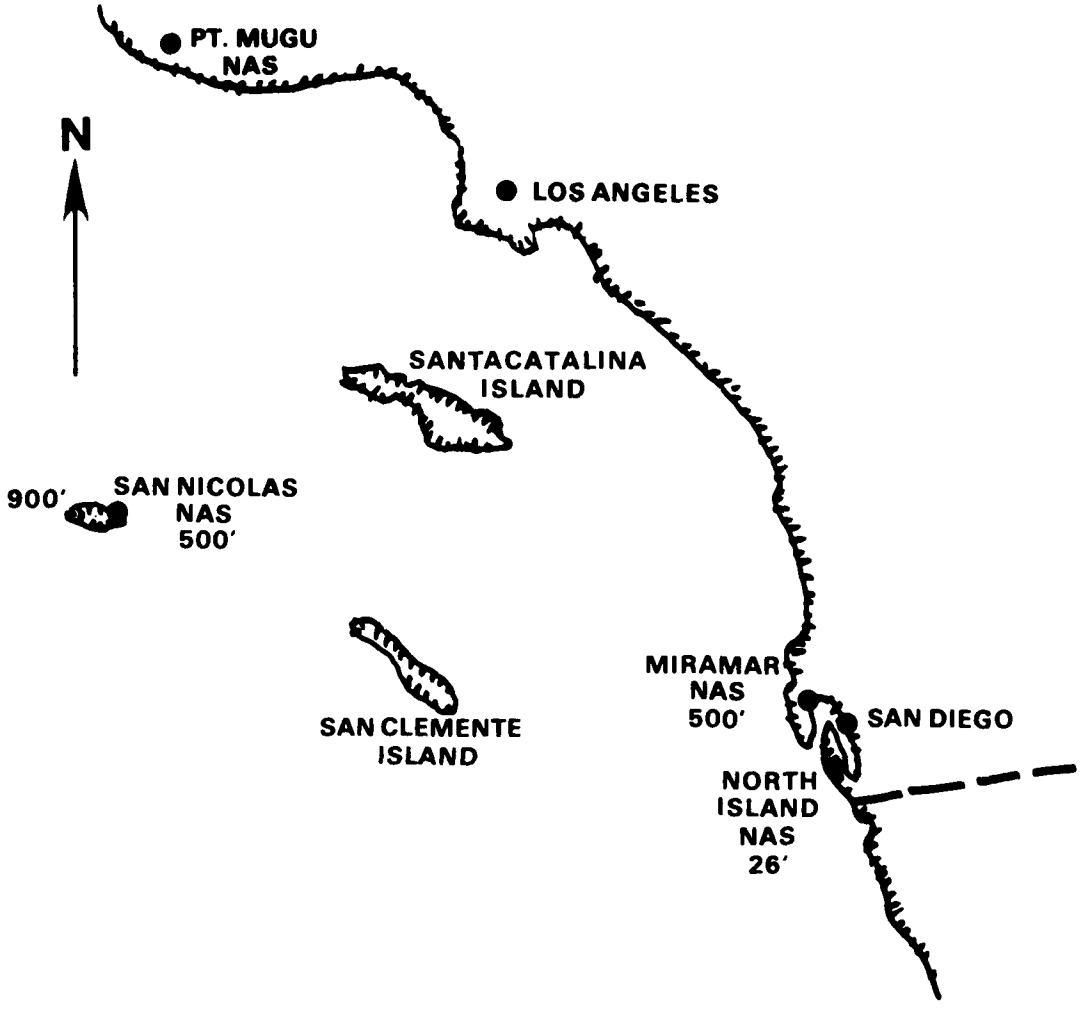

Figure 2. Locations of naval air stations in Southern California.

Using linear regression methods, forecast indices are found for each forecast category from the regression equations, one for each forecast category:

$$F_i = a_{0i} + a_{1i} x_1 + \ldots + a_{ni} x_n;\ i = 1, 2$$

The F_i's are the forecast indices for each ceiling category: F_1 for ceilings less than or equal to 1000 ft and F_2 for ceilings greater than 1000 ft, for example. The a_i represent the regression coefficients and the x_i represent the 0,1 dummy variables. Although more than two ceiling categories can be selected, greater skill results when only two are used.

F_i resembles a probability in two ways: $F_1+F_2 = 1$; and a larger F_i means that state i is more likely. However individu ` F_i are not bounded by 0 and 1. Therefore F_i is not rigorousl; probability and will be referred to as a forecast index.

An additional characteristic of REEP is that since the x equal 0 or 1, the magnitude of the a_{ij} directly show the pred. tors relative influence on the index value.

2.2 LOGISTIC REGRESSION (LR)

Consideration of a forecast parameter which has the properties of a probability leads to the following (logistic) transformation;

$$\theta_i = \frac{e^{\lambda_i}}{1 + e^{\lambda_i}} \qquad i = 1, 2$$

where

$$\lambda_i = \sum_{j=1}^{N} a_{ij} x_j;\ N = \text{No. of predictors}$$

and

$$\ln \left(\frac{\theta_i}{1-\theta_i}\right) = \lambda_i$$

is called the log-odds ratio.

Now $0 \leq \theta_1 \leq 1$ and $\theta_1 + \theta_2 = 1$, therefore θ satisfies the probability properties.

The coefficients a_{ij} are found from applying regression techniques to the dependent data sample (see Dixon, 1981). The advantage of LR is that continuous variables can be used without first categorizing; also, categorical variables can be used directly without transformation. However, only binomial predictands are allowed.

Predictor selection is based on a statistical stepwise procedure called asymptotic covariance estimate. An explanation of this procedure is beyond the scope of this report, and the reader is referred to Dixon, 1981, for information.

3. RESULTS

3.1 COMPARISONS OF REEP AND LR AT MOFFETT NAS

The REEP and LR equations are given in Appendices A and B, respectively, for ceilings 1000 ft and 2000 ft.

Five forecast valid times (VT) were selected for this pilot study; a common forecast generation time of 1800 LST allowed use of the 0000 GMT Oakland radiosonde data, and also was a time prior to stratus formation. The equations for REEP were generated from ten years of data; the equations for LR were generated from seven years of data.

Tables 1 and 2 show percent correct and threat scores for REEP, LR, and climatology for the dependent and independent data samples, respectively.

Threat score is defined as

$$TS = A/(A+B+C) \quad \text{where}$$

A is the number of correct stratus forecasts, B is the number of incorrect non-stratus forecasts, and C is the number of incorrect stratus forecasts.

Table 1. Dependent data comparisons.

a. Ceiling ≤2000 Ft

	Percent Correct			Threat Score		
VT	REEP	LR	CLIMO	REEP	LR	CLIMO
2200	88	83	88	.34	.37	.06
2400	77	83	72	.24	.55*	.16
0200	77	82	67	.57	.59	.20
0400	75	78	50	.61	.57	.28
0600	78	77	56	.64	.58	.28

b. Ceiling ≤1000 Ft

	Percent Correct			Threat Score		
VT	REEP	LR	CLIMO	REEP	LR	CLIMO
2200	92	82	92	.25	.23	.04
2400	85	85	85	.32	.46*	.08
0200	84	84	77	.51	.55	.13
0400	81	80	73	.48	.51	.16
0600	78	77	72	.47	.46	.16

Table 2. Independent data comparisons (200 observations).

a. Ceiling ≤2000 Ft

	Percent Correct			Threat Score		
VT	REEP	LR	CLIMO	REEP	LR	CLIMO
2200	88	82	87	.34	.37	.07
2400	78	82	75	.27	.57*	.14
0200	76	80	63	.54	.60	.22
0400	75	68	57	.62	.42	.27
0600	74	76	52	.57	.62	.32

b. Ceiling ≤1000 Ft

	Percent Correct			Threat Score		
VT	REEP	LR	CLIMO	REEP	LR	CLIMO
2200	91	90	92	.24	.09*	.04
2400	86	84	86	.24	.47*	.07
0200	72	78	76	.38	.50	.14
0400	75	62	70	.38	.43	.18
0600	70	70	69	.38	.47	.18

Given this relationship, $0 \leq TS \leq 1$ with TS = 1 represents a perfect score while TS = 0 indicates a no-skill score.

For ceilings $\leq$2000 the percent correct comparisons show both REEP and LR are better than climatology for the last four valid times (VT). LR also seems to be slightly better than REEP. For ceilings $\leq$1000 ft, however, no clear advantage can be seen for either method.

The threat score comparisons show both REEP and LR have definite skill over climatology*, with the exception of the 2200 VT LR in Table 2b. A contingency table for 2200 VT LR can be shown as

	Forecast	
	Ceiling	Ceiling
Observation	$\leq$1000 Ft	>1000 Ft	Total
Ceiling $\leq$1000 Ft	2	14	16
Ceiling $\geq$1000 Ft	6	178	184
Total	8	192	200

With the exception of the LR threat score for the 2200 VT in Table 2b, the only LR scores significantly better than REEP (5% chi square test) are for the 2400 VT forecast. This exception is easily explained: the above tabulation shows a small number of observed ceilings $\leq$1000 ft; therefore, a small fluctuation in the number of correct low ceiling forecasts can account for the low threat score for the 2200 VT LR forecast in Table 2b.

---

*Climatology threat score = P/(2-P) where P is the climatological probability.

The explanation for the universally better 2400 VT LR threat scores is not so clear. With the exception of Table 2b, the REEP 2400 VT scores seem inconsistent with the other REEP threat scores. As the valid time increases, the frequency of low ceilings increases. The threat scores characteristically become larger with increasing relative frequency. This trend in REEP threat score is not followed at the 2400 VT, even though the relative frequencies are nearly double those of 2200 VT.

It must be assumed that the data used for REEP equations had some anomalous characteristic at the 2400 observation; the 2400 VT equations therefore will not be considered in this comparison.

The following conclusions can be drawn for the REEP/LR comparison at Moffett NAS:

(1) Percent correct scores show that both REEP and LR are better than climatology, except for the 2200 VT forecasts.

(2) Threat scores are clearly better for both REEP and LR as compared to climatology.

(3) After the 2400 VT forecast is eliminated, REEP and LR show about the same skill scores.

3.2 REEP OPERATIONAL EVALUATION AT MOFFETT NAS

REEP operational evaluation results are given in Appendix A. REEP was used since Moffett did not have the LR program available at the time of the study. The subjective conclusions of the evaluation were (1) Reep was easy to use; (2) REEP has a skill about equal to that of an experienced forecaster; and (3) REEP does not improve a good forecaster's skill. (Close data examination reveals inconsistencies which cannot be completely resolved with the existing data; see Appendix 1.)

3.3 LR RESULTS FOR NORTH ISLAND, MIRAMAR AND SAN NICOLAS NAS

Appendices C, D, E give the LR equations for North Island, Miramar, and San Nicolas NAS.

Tables 3 through 5 give the dependent, independent and climatology skill scores for the three NAS.

Table 3a. North Island - ceiling $\leq$3500 Ft.

	Percent Correct			Threat Score			
LST	DEP	IND	CLIMO	DEP	IND	CLIMO	Relative Frequency
1900	67	72	62	.49	.52	.23	.38
0100	75	79	67	.73	.76	.50	.67
0700	84	74	76	.83	.74	.61	.76

Table 3a shows that (1) threat scores are better than climatology; (2) threat scores increase with lead time; (3) percent correct is not significantly better than climatology; and (4) relative frequency increases with lead time.

Table 3b reveals the same information as Table 3a, with the exception of point 3). In fact, percent correct overall is not as high as climatology, which clearly diminishes the forecast's worth despite of the better threat scores.

Table 3b. North Island - ceiling $\leq$1000 Ft.

	Percent Correct			Threat Score			
LST	DEP	IND	CLIMO	DEP	IND	CLIMO	Relative Frequency
1900	90	80	93	.29	.10	.04	.07
0100	73	57	76	.38	.34	.14	.24
0700	69	64	70	.43	.36	.18	.30

Tables 4a and 4b show that (1) threat scores are better than climatology; (2) percent correct about the same as climatology; (3) relative frequencies for the 0100 LT and 0700 LT forecasts are about the same; and (4) threat scores for 0100 LT and 0700 LT forecast are about the same.

Table 4a. Miramar - ceiling ≤3500 ft.

	Percent Correct			Threat Score			
LST	DEP	IND	CLIMO	DEP	IND	CLIMO	Relative Frequency
1900	76	82	72	.46	.58	.16	.28
0100	76	76	64	.71	.72	.47	.64
0700	79	75	69	.77	.72	.53	.69

Table 4b. Miramar - ceiling ≤1000 ft.

	Percent Correct			Threat Score			
LST	DEP	IND	CLIMO	DEP	IND	CLIMO	Relative Frequency
1900	86	90	92	.17	.26	.04	.08
0100	66	65	61	.51	.52	.24	.39
0700	61	56	62	.50	.47	.23	.38

In Tables 4a and 4b the scores for the LR again shows considerable skill over climatology. However, the similar percent correct for the two LR samples and climatology points out a weak overall forecast skill.

Tables 5a and 5b show that (1) threat scores are consistently higher than climatology; (2) percent correct is better than climatology, but lower than for the other three NAS; and (3) relative frequencies are higher for San Nicolas than for North Island or Miramar.

Table 5a. San Nicolas - ceiling ≤3500 ft.

	Percent Correct			Threat Score			
LST	DEP	IND	CLIMO	DEP	IND	CLIMO	Relative Frequency
1900	73	71	61	.69	.68	.43	.61
0100	76	73	68	.73	.70	.51	.68
0700	81	80	76	.80	.80	.61	.76

Table 5b. San Nicolas - ceiling ≤1000 ft.

	Percent Correct			Threat Score			
LST	DEP	IND	CLIMO	DEP	IND	CLIMO	Relative Frequency
1900	69	69	58	.52	.59	.27	.42
0100	68	68	53	.56	.60	.31	.47
0700	67	64	52	.55	.55	.32	.48

Because of point (3) relative to Tables 5a and 5b, very little variation occurs between the dependent and independent samples scores. This fact suggests that the equation's skill merely reflect the underlying climatology, and that differences between dependent and independent samples imply climatological differences in the samples themselves.

4. CONCLUSIONS AND RECOMMENDATIONS

Short-range stratus ceiling forecast equations were generated at four naval air stations on the California coast using logistic regression (LR) probabilities. A second statistical technique -- regression estimates of event probabilities (REEP) -- was used to develop Moffett NAS forecast equations. These equations were evaluated operationally at Moffett; when the logistic program became available later, they were compared to LR.

4.1 CONCLUSIONS

The REEP operational evaluation at Moffett indicated that although the technique has definite skill, the experienced forecaster could do as well not using it as an inexperienced forecaster could do using it. The concensus at Moffett was that REEP would be helpful to new duty forecasters, but that they would place less reliance on REEP after they gained more experience. The primary shortfall of both REEP and experienced forecasters lay in forecasting the transition from stratus to non-stratus sequence, and vice versa.

The REEP-LR comparison at Moffett showed essentially no difference in the two skill scores. Both were significantly better than climatology in the th eat score comparisons, but only marginally better in most percent-correct comparisons.

The LR equations for the three Southern California stations -- given in Appendices C, D and E -- yield unimpressive results. The threat scores were universally better than climatology, but the percent-correct scores were marginal, with some better and some worse than climatology.

Overall, the study's results indicate that the statistical forecast techniques are only marginally useful as forecasting tools in the particular applications investigated here. Certainly climatology can not be viewed as wholly valid competition, insofar as the actual competition for any forecast procedure would be the operational forecaster's skill scores (none available for this pilot study).

The stations do not have a universal forecast verification procedure; each office sets its own, and apparently can revise it at will. It becomes very difficult, therefore, to test a forecast procedure for operational usefulness when no long-term and rigorous skill scores exist for comparison.

At locations such as foreign coastal regions where there is archived data but no U.S. forecast experience, techniques like REEP or LR obviously would be useful. Two criteria must be met, however: (1) the location must have about 10 years of data available, and (2) the selected forecast parameters must have a significant dependency on local surface conditions. If the desired forecast parameter were rainfall intensity, then clearly these procedures would be useless. Parameters such as surface winds and visibility, however, would conceivably be candidates for such autonomous statistical procedures.

4.2 RECOMMENDATIONS

Based on the information and experience developed during the pilot study, the following are recommended:

(1) Establish universal forecast verification procedures at each NAS forecast office. These procedures should not be based only on simple percent correct (since such scores can be very misleading by themselves), but upon threat scores, Heidke skill scores, and meaningful forecast parameters such as ceiling height.

(2) Compile and archive verification statistics so that prospective forecast techniques can be compared prior to operational evaluation. The operational evaluation should be performed mainly to iron out any implementation problems and special situation difficulties.

(3) After a period of time, conduct a survey to determine areas of potential improvement in forecasts.

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APPENDIX A

EVALUATION OF REEP EQUATIONS AT MOFFETT NAS

A.1 RESULTS

Ceiling forecasts for 2200, 2400, 0200, 0400 and 0600 local time (LT) were developed for Moffett using regression estimates of event probabilities (REEP). The complete set of equations is given in Section A.2. Forecasts for ceilings above or below 1000 ft are generated using 1800 LT observations and Oakland 0000 GMT (1600 LT) radiosonde data. The ceiling forecasts are limited to the June-September period of summer coastal stratus occurrence at this location.

The evaluation began in June 1982 and used the forecast packet reproduced as Section A.3. Beginning in July with the arrival of a HP-41CV calculator and printer, the forecast procedure was automated and run on the calculator. An output example appears in Figure A-1.

Each day the duty forecaster recorded these forecasts and verifications for the previous day. Also noted was whether REEP was used alone or with additional guidance, or the forecast was based solely on other guidance. Tables A-1 and A-2 provide these records.

Table A-1. Moffett stratus forecast.

Forecast Made	REEP Alone	REEP and Other	Other
All	99%	83%	57%
Stratus	*	46%	44%

*None observed

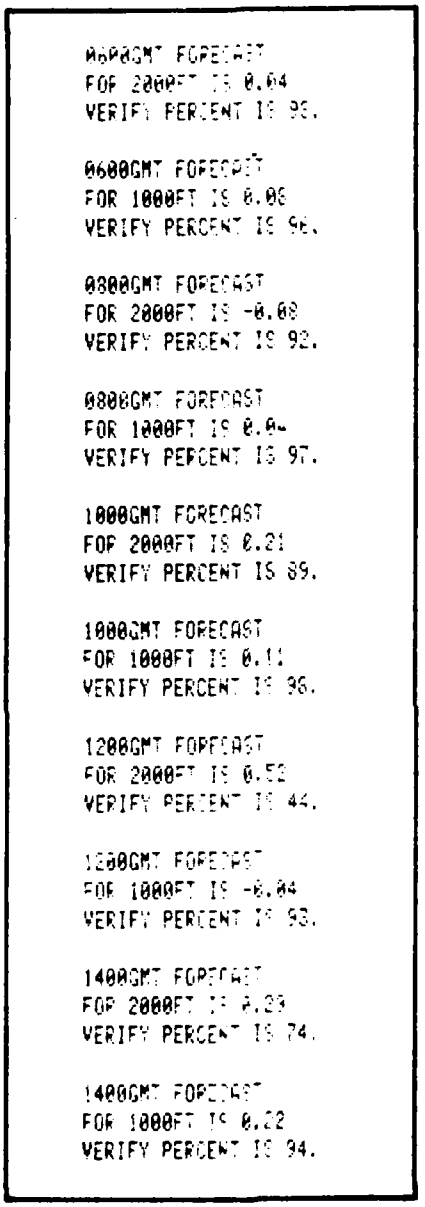

Figure A-1. HP-41CV output for 13 August 1982 giving $\leq$2000 ft and $\leq$1000 ft forecasts for all five forecast times.

Table A-2. Percent correct forecasts (forecaster "agreed" or "disagreed" with REEP).

Forecast Made	Agreed	Disagreed
Non-stratus	99.5%	*
Stratus	83%	24%

*None observed

Table A-1 gives the verification summary for the two types of forecasts. For "all" forecasts, REEP apparently was superior. For the non-stratus, no clear advantage resulted. The low score for the "stratus" forecasts compared to the "all" forecasts results from the difficulty of forecasting the stratus event. Long periods of clear weather were followed by short periods of stratus, and the initiation of such stratus periods is difficult to forecast.

Due to the long-running clear sequence, the persistence factor tends to influence the forecaster. During obvious clear spells, the forecaster is more likely to go with REEP alone. There also seemed to be some forecasters during the study who never trusted REEP and always indicated that they used additional guidance. This could easily contribute to the 83%-57% advantage over the "other" category.

The results in Table A-2 are a little harder to explain in the light of the unenthusiastic response related verbally by forecasters. The somewhat small sample size may have had some effect, but a complete explanation is unknown.

A.2 MOFFETT REEP EQUATIONS

The equations are functions of binary predictor variables X_i, whose values are "1" if the variable is in the given range and "0" otherwise. The X_i are listed at the end of this section.

Forecast Equations - Ceiling $\leq$1000'

Valid Time

2200 LT

$$F = .469+.183X_{-}-.254X_{15}-.141X_{4}$$

2400 LT

$$F = .245+.325X_{-}-.245X_{4}+.107X_{19}$$
$$+ .096X_{20}+.075X_{23}-.146X_{15}-.104X_{9}$$

0200 LT

$$F = .379+.352X_{-}-.272X_{6}+.173X_{20}-.141X_{24}-.099X_{22}$$

0400 LT

$$F = .325+.414X_{-}-.240X_{7}+.230X_{20}$$
$$-.257X_{24}-.095X_{22}-.153X_{18}-.121X_{26}$$
$$-.248X_{25}$$

0600 LT

$$F = .476-.257X_{8}+.273X_{-}-.071X_{22}$$
$$+.212X_{20}-.167X_{24}$$

Forecast Equations - Ceiling $\leq$2000'

2200 LT

$$F = .542+.301X_{.}-.348X_{16}-.155X_{10}$$

2400 LT

$$F = .165+.508X_{.}-.338X_{16}+.220X_{2}$$
$$-.129X_{11}+.110X_{17}+.131X_{19}$$

0200 LT

$$F = .224+.694X_{.}+.212X_{20}-.200X_{12}+.185X_{2}$$

0400 LT

$$F = .311+.544X_{.}+.286X_{20}+.248X_{2}$$
$$-.130X_{13}-.121X_{3}+.089X_{21}+.116X_{19}$$

0600 LT

$$F = .316+.685X_{.}+.186X_{20}-.162X_{14}$$
$$-.100X_{13}-.124X_{22}+.132X_{2}$$

List of Predictors (1800 LT observation unless specified)

At Moffett

X_1 = Dew point depression (0-8°F)

X_2 = Dew point depression (8-10°F)

X_3 = Dew point depression ($\geq$14°F)

X_4 = Previous Day's Ceiling ($\geq$1000') at 2200 LT

X_5 = Previous Day's Ceiling ($\geq$1000') at 2400 LT

X_6 = Previous Day's Ceiling ($\geq$1000') at 0200 LT

X_7 = Previous Day's Ceiling ($\geq$1000') at 0400 LT

X_8 = Previous Day's Ceiling ($\geq$1000') at 0600 LT

X_9 = Wind Speed (0-6 kt)

X_{10} = Previous Day's Ceiling ($\geq$2000°) at 2200 LT

X_{11} = Previous Day's Ceiling ($\geq$2000°) at 2400 LT

X_{12} = Previous Day's Ceiling ($\geq$2000°) at 0200 LT

X_{13} = Previous Day's Ceiling ($\geq$2000°) at 0400 LT

X_{14} = Previous Day's Ceiling ($\geq$2000°) at 0600 LT

At Alameda

X_{15} = Ceiling ($\geq$1000')

X_{16} = Ceiling ($\geq$2000')

X_{17} = Dew Point Depression (0-8°F)

X_{18} = Dew Point Depression ($\geq$14°F)

X_{19} = Wind Speed (12-15 kt)

At San Francisco

X_{20} = Dew Point Depression (0-8°F)

X_{21} = Wind Direction (282-326)

X_{22} = Wind Direction (237-281)

Oakland Radiosonde (0000 GMT)

X_{23} = Temperature, 950 mb (20-25°C)

X_{24} = Temperature, 950 mb (10.1-15.5°C)

X_{25} = Temperature, 950 mb (<10°C)

X_{26} = Temperature, 950 mb (15.6-20°C)

A.3 SAMPLE FORECAST PACKET USED AT MOFFETT NAS

MOFFETT STRATUS FORMATION FORECAST AID (SUMMER)

The following computation is meant as a forecast aid for a summer stratus formation forecast. It provides guidance for the stratus formation forecast which should then, at the forecaster's discretion, be supplemented by other information.

The computation uses the 0200GMT observations of Moffett, Alameda and San Francisco, and the 0000 GMT Oakland 950mb temperature data. Also used are "persistence" ceilings from the previous day at Moffett. Five forecast valid times (VT) are 0600GMT, 0800GMT, 1000GMT, 1200GMT, 1400GMT, which are referred to as computations A through E.

Each computation produces a number index, which falls ideally in an interval 0.0 to 1.0, however, negative numbers and numbers larger than 1.0 do occur. The forecast index, therefore, extends below 0.0 and above 1.0, which indicates lower and higher "probabilities" respectively. Two forecast indices are computed for each valid time, one for ceilings $\lessdot$2000' and one for ceilings $\lessdot$1000'.*

Following the computation for each forecast valid time is a suggested use of the indices and the interface with satellite and synoptic information. Forecasters may develop their own interface with such subjective factors.

The percentages appearing on the right of the "Forecast" column are the verification frequencies (i.e., the percentage of the time the forecast was incorrect in the developmental data).

* SYMBOLS

$\lessdot$ - Less than

$\leq$ - Less than or equal to

$>$ - Greater than

$\geq$ - Greater than or equal to

The following data will be needed.

Moffett (surface)

Dew point depression	(0200GMT)
Wind Speed	(0200GMT)
Previous day's ceiling	(0600, 0800, 1000, 1200, & 1400GMT)

San Francisco (SFO) (surface)

Wind direction	(0200GMT)
Dew point depression	(0200GMT)

Alameda (surface)

Dew point depression	(0200GMT)
Wind speed	(0200GMT)
Ceiling	(0200GMT)

Oakland (upper air)

Temperature 950mb	(0000GMT)

SHEET A

MOFFETT STRATUS FORMATION FORECAST VALID TIME: 0600 GMT

Computation for ceiling < 2000'

If the following parameters fall within the indicated ranges, add or subtract the number appearing on the right.

1.	Start with		.542
2.	Moffett dew. pt. dep. (0.0-8.0°F) (0200 GMT)	.301	
3.	Alameda ceiling (≥ 2000') (0200GMT)	-.348	
4.	Moffett previous days ceiling: 0600GMT (≥2000')	-.155	
	Index (TOTAL)		

If index is:	Forecast	
≤ .30	Do not forecast stratus (< 2000')	2%
.31 to .40	Do not forecast stratus unless other indications strongly differ	24%
.41 to .80	Need additional guidance from other indications	43%
> .80	Forecast stratus (<2000')	16%

Enter the forecast category (stratus/no stratus) on the final forecast sheet P.

Cont. A

MOFFETT STRATUS FORMATION VALID TIME: 0600GMT

Computation for: Ceilings <1000'

If the following parameters fall within the indicated ranges, add or subtract the numbers appearing on the right.

1.	Start with		.469
2.	Moffett dew. pt. dep. (0.0-8.0°F) (0200GMT)	.183	
3.	Alameda ceiling ≥1000' (0200GMT)	-.253	
4.	Moffett previous days ceiling: 0600GMT (≥1000')	-.141	
	Index (TOTAL)		

If index is:	Forecast	
≤.30	Do not forecast stratus (<1000')	4%
.31 to .40	Do not forecast stratus unless other indicators differ	28%
.41 to .70	Need additional guidance	54%
>.70	None occurred	

Enter forecast on sheet F.

Sheet B

MOFFETT STRATUS FORMATION FORECAST VALID TIME: 0800GMT

Computation for ceilings ∠2000'

If the following parameters fall within the indicated ranges, add or subtract the number appearing on the right.

1.	Start with		.165
2.	Moffett dew. pt. dep. (0.0-8.0°F) (0200GMT)	.508	
3.	Moffett dew. pt. dep. (8.1-10.0°F) (0200GMT)	.220	
4.	Alameda ceilings (≥2000') (0200GMT)	-.338	
5.	Moffett previous days ceilings at 0800GMT (≥2000')	-.129	
6.	Alameda dew. pt. dep. (0.0-8.0°F) (0200GMT)	.110	
7.	Alameda wind speed: (12-15kts) (0200GMT)	.131	
	Index (TOTAL)		

If index is:	Forecast	
≤.10	Do not forecast stratus (∠2000')	8%
.11 to .60	Need additional guidance	52%
.61 to .70	Forecast stratus (∠2000') unless other indications strongly differ	24%
≥.70	Forecast stratus (∠2000')	7%

Enter forecast on sheet F.

Cont. B

MOFFETT STRATUS FORMATION FORECAST VALID TIME: 0800GMT

Computation for ceiling <1000'

If the following parameters fall within the indicated ranges, add or subtract the numbers appearing on the right.

1.	Start with		.245
2.	Moffett dew. pt. dep. (0.0-8.0°F) (0200GMT)	.325	
3.	Moffett previous days ceiling at 0800GMT (≥1000')	-.244	
4.	SFO wind direction (282° - 8.0°F) (0200GMT)	.107	
5.	SFO dew. pt. dep. (0.0-8.0°F) (0200GMT)	.096	
6.	Oakland 950mb temp. (20-25°F) (0000GMT)	.075	
7.	Alameda ceiling (≥1000') (0200GMT)	-.146	
8.	Moffett wind speed (0-6kts) (0200GMT)	-.104	

If index is:	Forecast	
≤.20	Do not forecast stratus (<1000')	3%
.21 to .49	Do not forecast stratus (<1000') unless other indicators differs	34%
.50 to .60	Need addition guidance	49%
.61 to .80	Forecast stratus (<1000') unless other indicators differ	35%
>.80	Forecast stratus (<1000')	(0 for 4)

Enter forecast on sheet F.

Sheet C

MOFFETT STRATUS FORMATION FORECAST VALID TIME: 1000GMT

Computation for ceilings <2000'

If the following parameters fall within the indicated ranges, add or subtract the numbers on the right.

1.	Start with		.224
2.	SFO dew. pt. dep. (0.0-8.0°F) (0200GMT)	.212	
3.	Moffett previous days ceiling at 1000GMT (≥2000')	-.200	
4.	Moffett dew. pt. dep. (8.1-10.0°F) (0200GMT)	.185	
5.	Moffett dew. pt. dep. (0.0-8.0°F) (0200GMT)	.694	
	Index (TOTAL)		

If index is:	Forecast
≤.30	Do not forecast stratus (<2000') 11%
.31 to .40	None occurred
.41 to .50	Do not forecast unless other indicators differ 38%
.51 to .70	Forecast stratus unless other indicators differ 39%
≥.70	Forecast stratus (<2000') unless other indicators strongly differ 26%

Enter forecast on sheet F.

Cont. C

MOFFETT STRATUS FORMATION FORECAST VALID TIME: 1000GMT

Computation for ceilings <1000'

If the following parameters fall within the indicated ranges, add or subtract the numbers on the right.

1.	Start with		.379
2.	Moffett dew. pt. dep. (0.0-8.0°F) (0200GMT)	.352	
3.	Moffett 1000GMT ceiling previous day (≥1000')	-.272	
4.	SFO dew. pt. dep. (0.0-8.0°F) (0200GMT)	+.173	
5.	Oakland 950mb temp. (10.1-15.5°F) (0000GMT)	-.141	
6.	SFO wind direction (237°-281°) (0200GMT)	-.099	
	Index (TOTAL)		

If index is:	Forecast	
≤.20	Do <u>not</u> forecast stratus <1000'	2%
.21 to .40	Do <u>not</u> forecast stratus <1000' unless other indicators <u>strongly</u> differ	20%
.41 to .50	Do not forecast stratus <1000' unless other indicators differ	24%
.51 to .60	Forecast stratus <1000' unless other indicators differ	41%
.61 to .80	Need additional guidance	49%
>.80	Forecast stratus <1000' unless other indicators differ	23%

Enter forecast on sheet F.

SHEET D

MOFFETT STRATUS FORMATION FORECAST VALID TIME: 1200GMT

Computation for ceilings <2000'

If the following parameters fall within the indicated ranges, add or subtract the numbers on the right.

1.	Start with		.311
2.	Moffett dew. pt. dep. (0.0-8.0°F) (0200GMT)	.544	
3.	Moffett dew. pt. dep. (>14.0°F) (0200GMT)	-.121	
4.	Moffett dew.pt. dep. (8.1-10.0°F) (0200GMT)	.248	
5.	Moffett previous days ceiling at 1200GMT (≥2000')	-.130	
6.	SFO wind direction (282°-326°) (0200GMT)	+.089	
7.	SFO dew. pt. dep. (0.0-8.0°F) (0200GMT)	.286	
8.	Alameda wind speed (12-15kts) (0200GMT)	.116	
	Index (TOTAL)		

If index is:	Forecast	
≤.30	Do not forecast stratus <2000'	8%
.31 to .40	Do not forecast stratus unless other indicators strongly differ	16%
.41 to .49	Do not forecast stratus unless other indicators differ	26%
.50 to .90	Additional guidance needed	56%
>.90	Forecast stratus (<2000')	15%

Enter forecast on sheet F.

Cont. D

MOFFETT STRATUS FORMATION FORECAST VALID TIME: 1200GMT

Computation for ceiling <1000'

If the following parameters fall within the indicated ranges, add or subtract the number on the right.

1.	Start with		.325
2.	Moffett dew. pt. dep. (0.0-8.0°F) (0200GMT)	.414	
3.	Moffett previous days 1200GMT ceiling: (≥1000')	-.240	
4.	SFO dew. pt. dep. (0.0-8.0°F) (0200GMT)	.230	
5.	SFO wind direction (237°-281°) (0200GMT)	-.095	
6.	Alameda dew.pt. dep. (>14.0°F) (0200GMT)	-.153	
7.	Oakland 950mb temp. (15.6-20.0°F) (0000GMT)	-.121	
8.	Oakland 950mb temp. (<10.0°F) (0000GMT)	-.248	
9.	Oakland 950mb temp. (10.1-15.5) (0000GMT)	-.257	
	Index (TOTAL)		

If index is:	Forecast	
≤.30	Do not forecast stratus <1000'	7%
.31 to .40	Do not forecast stratus <1000' unless other indicators differ	36%
.41 to .70	Additional guidance needed	49%
.71 to .90	Forecast stratus <1000' unless other indicators differ	33%
>.90	Forecast stratus <1000'	15%

Enter forecast on sheet F.

Sheet E

MOFFETT STRATUS FORECAST VALID TIME: 1400GMT

Computation for ceilings <2000'

If the following parameters fall within the indicated ranges, add or subtract the number on the right.

1.	Start with		.316
2.	SFO dew. pt. dep. (0.0-8.0°F) (0200GMT)	.186	
3.	Moffett previous days ceilings: 1400GMT (≥2000')	-.162	
4.	SFO wind direction (237°-281°) (0200GMT)	-.124	
5.	Moffett dew. pt. dep. (8.0-10.0°F) (0200GMT)	.132	
6.	Moffett dew. pt. dep. (0.0-8.0°F) (0200GMT)	.685	
7.	Moffett dew. pt. dep. (>14.0°F) (0200GMT)	-.100	
	Index (TOTAL)		

If index is:	Forecast	
≤.20	Do <u>not</u> forecast stratus <2000'	12%
.21 to .30	Do not forecast stratus <2000' unless other indicators <u>strongly</u> differ	26%
.31 to .60	Additional guidance needed	48%
.61 to .80	Forecast stratus <2000' unless other indicators strongly differ	20%
.81 to .90	Additional guidance needed	52%
>.90	Forecast stratus <2000'	15%

Enter forecast on sheet F.

Cont. E

MOFFETT STRATUS FORMATION FORECAST VALID TIME: 1400GMT

Computation for ceilings <1000'

If the following parameters fall within the indicated ranges, add or subtract the number on the right.

1.	Start with		.476
2.	Moffett previous days ceiling, 1400GMT (≥1000')	-.257	
3.	Moffett dew. pt. dep. (0.0-8.0°F) (0200GMT)	.273	
4.	SFO wind direction (237°-281°) (0200GMT)	-.071	
5.	SFO dew. pt. dep. (0.0-8.0°F) (0200GMT)	.212	
6.	Oakland 950mb temp. (10.1-15.5°F) (0000GMT)	-.167	
	Index (TOTAL)		

If index is:	Forecast	
≤.40	Do not forecast stratus <1000'	6%
.41 to .49	Do not forecast stratus <1000' unless other indicators differ	33%
.50 to .89	Additional guidance needed	46%
> .90	Forecast stratus <1000'	20%

Enter forecast on sheet F.

Sheet F

VALID TIMES	FORECAST (< 2000')	FORECAST (<1000')
0600GMT	_____	_____
0800GMT	_____	_____
1000GMT	_____	_____
1200GMT	_____	_____
1400GMT	_____	_____

REMARKS:

1. Check continuity of ceiling forecast throughout the period.
2. Check for ridiculous results, example: Do not forecast ceiling <1000', without also forecasting ceiling <2000' for the same valid time.

APPENDIX B

LOGISTIC REGRESSION EQUATIONS FOR MOFFETT NAS

The logistic transformation is

$$\theta_i = \frac{e^{s_i}}{1+e^{s_i}} \quad i = 1, 2$$

where θ_1 is the probability of low ceilings and $\theta_2 = (1-\theta_1)$ is the probability of higher ceilings.

$$s_i = \sum_{j=1}^{N} A_{ij} X_j$$

X_j are the predictor variables and the A_{ij} are the constants found by using regression on the dependent data sample. The list of candidate predictors and forecast equations are given on succeeding pages.

List of Variables

X_1 = East-west component, Moffett wind (kt)

X_2 = North-south component, Moffett wind (kt)

X_3 = Moffett air temperature (°F)

X_4 = Moffett dew point depression (°F)

X_5 = Ceiling (F.T. minus 24 hrs) Moffett (Ft)

X_6 = Alameda Ceiling (Ft)

X_7 = East-west component, Alameda wind (kt)

X_8 = North-south component, Alameda wind (kt)

X_9 = Alameda air temperature (°F)

X_{10} = Alameda dew point depression (°F)

X_{11} = San Francisco (SFO) ceiling (Ft)

X_{12} = East-west component, SFO wind (kt)

X_{13} = North-south component, SFO wind (kt)

X_{14} = SFO air temperature (°F)

X_{15} = SFO dew point depression (°F)

X_{16} = Marine layer thickness (m)

X_{17} = Marine layer strength *

X_{18} = 700 mb temperature (°C)

X_{19} = 700 mb wind direction (0-90°)

X_{20} = 700 mb wind direction (90-180°)

X_{21} = 700 mb wind direction (180-270°)

X_{22} = 700 mb wind direction (270-360°)

Binary variables

X_{23} = 700 mb wind speed (kt)

X_{24} = 850 mb temperature (°C)

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*Defined as the average relative humidity from the surface to the marine layer top.

Forecast Equations

Ceiling $\leq$1000'

Valid Time

2200 LT

$$S = 15.319+.134X_1-.096X_2-.167X_3 -.100X_4-.634X10^{-3}X_5-.816X10^{-3}X_6 +.068X_7-.105X_8-.471X_9+.243X_{10} +.056X_{12}+.416X_{14}-.615X_{15}+.010X_{18} -.651X_{19}+.038X_{20}+.526X_{21}-.069X_{23}$$

2400 LT

$$S = 6.210+.113X_1-.058X_2-.296X_4 -.846X10^{-3}X_5-.592X10^{-3}X_6+.068X_7 -.170X_9+.109X_{11}-.194X_{15}+.006X_{17}$$

0200 LT

$$S = 7.461+.083X_1-.196X_4-.510X10^{-3}X_5 +.086X_7-.343X_9+.191X_{10}+.241X_{14} -.499X_{15}-.633X_{19}+.023X_{20}+.320X_{21} +.013X_{24}$$

0400 LT

$$S = 6.093+.061X_1-.196X_4-.510X10^{-3}X_5 +.086X_7-.343X_9+.191X_{10}+.241X_{14} -.499X_{15}-.633X_{19}+.023X_{20}+.320X_{21} +.013X_{24}$$

0600 LT

$$S = 6.137-.099X_4-.717X10^{-3}X_5 +.079X_7-.071X_9-.056X_{12}-.045X_{13} -.199X_{15}-.623X_{19}-.239X_{20}+.656X_{21} +.007X_{24}$$

Forecast Equations

Ceiling $\leq$2000'

2200 LT

$$S = .801 - .133X_2 - .331X_4 - .603X10^{-3}X_6 - .112X_8 - .356X_{15} + .008X_{24}$$

2400 LT

$$S = .510 + .150X_1 - .073X_2 - .500X_4 - .797X10^{-3}X_5 + .104X_7 - .176X_8 - .245X_{15} - .020X_{18} - .154X_{23} + .025X_{24}$$

0200 LT

$$S = 2.045 + .126X_1 - .339X_4 - .645X10^{-3}X_5 - .151X_8 - .236X_{15} - .563X_{19} - .124X_{20} + .522X_{21} - .077X_{23} + .012X_{24}$$

0400 LT

$$S = .993 + .091X_1 - .283X_4 - .487X10^{-3}X_5 - .076X_8 + .8898X10^{-3}X_{11} - .239X_{15} - .529X_{19} - .088X_{20} + .605X_{21} - .069X_{23} + .014X_{24}$$

0600 LT

$$S = -.100 - .185X_4 - .098X_{13} - .172X_{15} + .012X_{24}$$

APPENDIX C

LOGISTIC REGRESSION EQUATIONS FOR NORTH ISLAND NAS

The regression equations for S follow from the list of candidate predictors below. Observation time is 1200 LT unless otherwise stated. See Appendix B for definition and use of S.

List of Predictors

X_1 = East-west component, North Island wind (kt)

X_2 = North-south component, North Island wind (kt)

X_3 = North Island air temperature (°F)

X_4 = North Island dew point depression (°F)

X_5 = Ceiling (FT minus 24 hrs) North Island (Ft)

X_6 = East-west component, Miramar wind (kt)

X_7 = North-south component, Miramar wind (kt)

X_8 = Miramar air temperature (°F)

X_9 = Miramar dew point depression (°F)

X_{10} = East-west component, San Nicolas wind (kt)

X_{11} = North-south component, San Nicolas wind (kt)

X_{12} = San Nicolas air temperature (°F)

X_{13} = San Nicolas dew point depression (°F)

X_{14} = Marine layer height (m)

X_{15} = Marine layer strength *

X_{16} = 700 mb temperature (°C)

X_{17} = 700 mb wind direction (degrees)

---

*Defined as the average relative humidity from the surface to the marine layer top.

X_{18} = 700 mb wind speed (kt)

X_{19} = 850 mb temperature (°C)

X_{20}= 850 mb wind direction (degrees)

X_{21} = 850 mb wind speed (kt)

X_{22} = Marine layer height (Ft minus 24 hr) (m)

X_{23} = Surface pressure difference, San Nicolas - North Island (mb)

X_{24} = Surface pressure difference, Pt.Mugu - North Island (mb)

Forecast Equations

Ceiling $\leq$1000'

Valid Time

1900 LT

$$S = -4.713-.197X_4+.513X10^{-3}X_{14} +.022X_{19}$$

0100 LT

$$S = 1.624+.080X_1-.091X_3-.107X4 -.005X_{15}+.026X_{19}-.325X10^{-3}X_{22}$$

0700 LT

$$S = 2.783-.106X_4-.985X10^{-3}X_5 -.003X_{15}+.015X_{19}+.295X10^{-3}X_{22} +.046X_{24}$$

Forecast Equations

Ceiling $\leq$3500'

Valid Time

1900 LT

$$S = 10.58 - .074X_1 - .122X_3 - .164X_4 - .840X10^{-3}X_5 + .002X_{15} - .043X_{18}$$

0100 LT

$$S = 11.379 - .141X_3 - .081X_4 - .645X10^{-3}X_5 + .013X_{16} - .092X_{18}$$

0700 LT

$$S = 9.817 + .055X_1 - .140X_3 - .732X10^{-3}X_5 + .012X_{16} - .087X_{18} + .005X_{19}$$

APPENDIX D

LOGISTIC REGRESSION EQUATIONS FOR MIRAMAR NAS

The regression equations for S (see Appendix B for details) follow from the list of predictors below. Observation time is 1200 LT unless otherwise stated.

X_1 = East-west component, Miramar wind (kt)

X_2 = North-south component, Miramar wind (kt)

X_3 = Miramar air temperature (°F)

X_4 = Miramar dew point depression (°F)

X_5 = Ceiling (FT minus 24 hrs) Miramar (Ft)

X_6 = East-west component, North Island wind (kt)

X_7 = North-south component, North Island wind (kt)

X_8 = North Island air temperature (°F)

X_9 = North Island dew point depression (°F)

X_{10} = East-west component, San Nicolas wind (kt)

X_{11} = North-south component, San Nicolas wind (kt)

X_{12} = San Nicolas air temperature (°F)

X_{13} = San Nicolas dew point depression (°F)

X_{14} = Marine layer height (m)

X_{15} = Marine layer strength *

X_{16} = 700 mb temperature (°C)

X_{17} = 700 mb wind direction (degrees)

---

*Defined as the average relative humidity throughout the marine layer.

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X_{18} = 700 mb wind speed (kt)

X_{19} = 850 mb temperature (°C)

X_{20} = 850 mb wind direction (degrees)

X_{21} = 850 mb wind speed (kt)

X_{22} = Marine layer height (Ft minus 24 hr) (m)

X_{23} = Surface pressure difference, San Nicolas - North Island (mb)

X_{24} = Surface pressure difference, Pt.Mugu - North Island (mb)

Forecast Equations

Ceiling $\leq$1000'

Valid Time

1900 LT

$$S = -1.608-.201X_4-.018X_{16}+.020X_{19}$$

0100 LT

$$S = 1.978-.085X_4-.465X_{10}{}^{-3}X_5+.043X_{18}+.016X_{19}+.053X_{24}$$

0700 LT

$$S = -.553-.077X_4-.003X_{15}-.003X_{15}PV+.015X_{19}+.295X_{10}{}^{-3}X_{22}+.046X_{24}$$

Forecast Equations

Ceiling $\leq$3500'

1900 LT

$$S = 8.532 - .079X_1 - .073X^3 - .217X^4 - .850 \times 10^{-3}X5$$

0100 LT

$$S = 7.723 - .071X_1 - .0713^3 - .074X^4 - .667X10^{-3}X^5 + .010X_{16} - .101X_{18} - .296X_{22} + .043X_{24}$$

0700 LT

$$S = 10.273 - .136X_3 - .745X10^{-3}X_5 - .102X_{18} + .011X_{19}$$

APPENDIX E

LOGISTIC REGRESSION EQUATIONS FOR SAN NICOLAS NAS

The regression equations for S (see Appendix B for details) follow the list of predictor variables. Observation times are 1200 LT unless otherwise stated.

X_1 = East-west component, San Nicolas wind (kt)

X_2 = North-south component, San Nicolas wind (kt)

X_3 = San Nicolas air temperature (°F)

X_4 = San Nicolas dew point depression (°F)

X_5 = Ceiling (FT minus 24 hrs) Miramar (Ft)

X_6 = East-west component, Miramar wind (kt)

X_7 = North-south component, Miramar wind (kt)

X_8 = Miramar air temperature (°F)

X_9 = Miramar dew point depression (°F)

X_{10} = East-west component, North Island wind (kt)

X_{11} = North-south component, North Island wind (kt)

X_{12} = North Island air temperature (°F)

X_{13} = North Island dew point depression (°F)

X_{14} = Marine layer height (m)

X_{15} = Marine layer strength *

X_{16} = 700 mb temperature (°C)

X_{17} = 700 mb wind direction (degrees)

---

*Defined as the average relative humidity throughout the marine layer.

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X_{18} = 700 mb wind speed (kt)

X_{19} = 850 mb temperature (°C)

X_{20} = 850 mb wind direction (degrees)

X_{21} = 850 mb wind speed (kt)

X_{22} = Marine layer height (Ft minus 24 hr) (m)

X_{23} = Surface pressure difference, San Nicolas - North Island (mb)

X_{24} = Surface pressure difference, Pt.Mugu - North Island (mb)

Forecast Equations

Ceiling $\leq$1000'

Valid Time

1900 LT

$$S = 8.924 - .227X_3 + .028X_{19}$$

0100 LT

$$S = 6.282 - .137X_3 - .001X_5 - .001X_{14} + .018X_{19}$$

0700 LT

$$S = 8.434 - .163X_3 - .001X_{14} + .014X_{20} + .432X_{23}$$

Forecast Equations

Ceiling $\leq$3500'

1900 LT

$$S = 14.130 - .152X_{16} - .249X_8 - .001X_5 + .001X_{14} + .014X_{19} + .047X_{24}$$

0100 LT

$$S = 13.242 - .175X_3 - .001X_5 + .009X_{16} - .167X_{18} - .588X_{33}$$

0700 LT

$$S = 8.970 - .093X_3 - .001X_5 - .118X_{18} - .048X_{24} - .217X_4 - .850 \times 10^{-3}X_5$$

0100 LT

$$S = 7.723 - .071X_1 - .0713_3 - .074X_4 - .667X10\text{-}3X_5 + .010X16 - .101X18 - .296X^{22} + .043X^{24}$$

0700 LT

$$S = 10.273 - .136X^3 - .745X10\text{-}3X5 - .102X^{18} + .011X^{19}$$

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