Marine

DEVELOPMENT OF FORECAST GUIDANCE FOR SANTA ANA CONDITIONS*

Lawrence D. Burroughs (1)
NOAA/NWS
Ocean Products Center
Washington, D.C.

ABSTRACT

A statistical system has been developed to provide forecast guidance on Santa Ana conditions along the southwestern coast of southern California and the associated winds at several locations. A description of the development of the system is given. Test results on independent data are shown. Examples of the guidance product are provided, and some operational considerations are presented.

1. INTRODUCTION

The Glossary of Meteorology (2) defines a Santa Ana as a "hot, dry, Foehn-like desert wind, generally from the northeast or east, especially in the pass and river valley of Santa Ana, Calif., where it is further modified as a mountain gap wind. . . ." Actually, all of southern California is affected. Wind speed and direction at the coast depend on synoptic scale events, interaction of the Santa Ana circulation with the sea breeze circulation, and topography. Intensity and duration are also dependent on synoptic forcing and mesoscale interaction.

The Santa Ana is generally thought of as a fire weather or aviation weather problem; however, it can also be a marine weather problem. This is particularly true in the San Pedro and Santa Barbara Channels and at the boat harbor at Avalon, Santa Catalina Island, California (AVC) (see Fig. 1). This paper describes the National Weather Service's efforts to develop automated forecast guidance for Santa Ana conditions along the southwestern coast of California. This system forecasts the presence or absence of Santa Ana conditions and the associated winds at the Naval Air Station, Point Mugu (NTD); the Marine Corps Air Station, Santa Ana (NTK); AVC; the Naval Facility, San Nicolas Island (NSI), and the Naval Air Facility, San Clemente Island (NUC) (see Fig. 1).

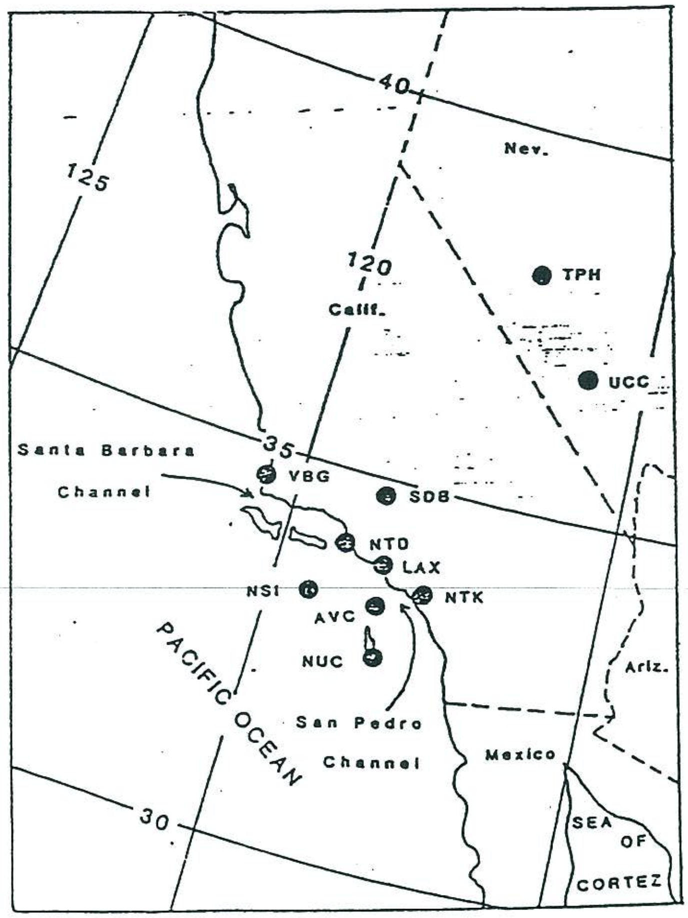

Fig. 1. Station locations for Santa Ana wind forecast system.

2. SYNOPTIC FORCING, MESOSCALE INTERACTION, AND TOPOGRAPHIC EFFECTS

Complete details about synoptic forcing, mesoscale interaction, and topographic effects are given by Rosenthal (3) and Richardson (4). Additional details, particularly about the vertical structure of Santa Anas are given by Fosberg et al. (5).

There are three major synoptic events which, when they occur simultaneously, normally give rise to Santa Ana conditions over southern California. These are the development of high pressure over the Great Basin (see Fig. 2), the passage of fronts through southern California, and the development of north to northeast flow aloft along the west coast of the United States. There is a fourth synoptic event which rarely occurs but which gives rise to some of the most intense Santa Ana winds at the coast. This event is the development of a surface low off the southern California coast in addition to the above conditions. The resulting Santa Ana is often associated with showery, unstable conditions and winds of gale (35 to 50 kt) or even storm (> 50 kt) strength.

According to Fosberg et al. (5), the Santa Ana is primarily a lee wave phenomenon, and air flow is nearly isentropic. The mountain ranges of southern California act as barriers to flow out of the Great Basin region. When flow is perpendicular to the mountain ranges, and the static stability and wind shear upstream of the ranges, mountain waves form. When the amplitude of the waves is large, they reach the surface; when the amplitude of the waves is small, they don't. There are periodic and aperiodic components in the surfacing. The periodic components are associated with the interaction of localized circulations, such as the sea breeze, with the mountain waves. The aperiodic effects are determined by the static stability and wind structure upwind of the mountain barrier and are the prime factors in the surfacing. In addition, the air is forced to flow around the San Gabriel mountains and through the major passes. Wind speeds tend to be enhanced through the passes because of venturi effects, and wind direction tends to be oriented along canyon and valley axes.

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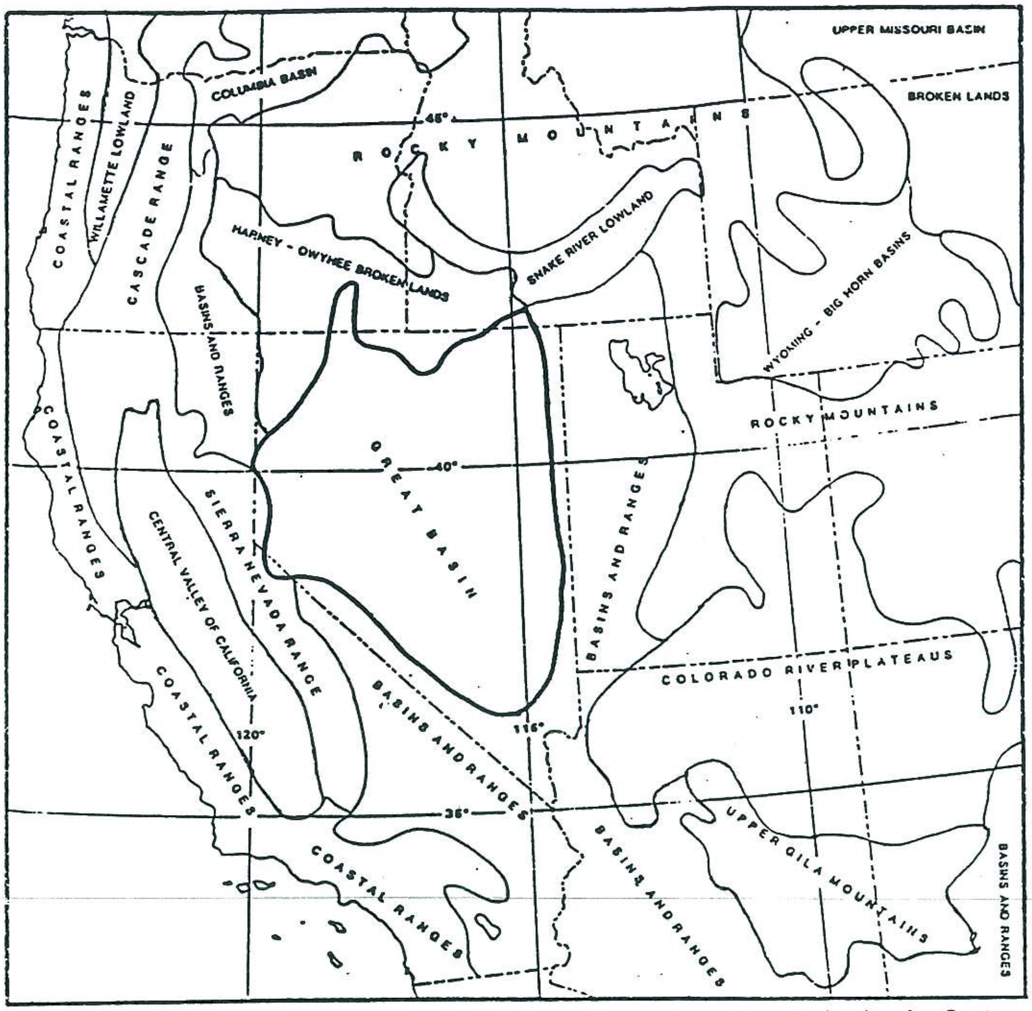

Fig. 2. Geographical divisions and subdivisions in the region where synoptic forcing for Santa Ana generation takes place.

The following definitions are made to distinguish between the conditions which bring about the formation of mountain waves associated with Santa Anas and the periods of northeast winds associated with the surfacing of the mountain waves (attributed to D. A Lea by Rosenthal (3)):

Santa Ana Burst—A single period of continuous Santa Ana surface winds.

Santa Ana Regime—An overall synoptic episode consisting of one or more bursts separated by not more than 24 hours.

According to Rosenthal (3), the average length of a regime is about 36 hours, while that of a burst is 6 to 8 hours. If a regime consists of more than one burst, the first burst is the longest and strongest, having the greatest average wind speeds and gustiest winds. Each succeeding burst becomes progressively weaker, shorter, and less gusty. The most frequent sustained maximum wind speeds are 15 to 19 kt with gusts of 25 to 29 kt.

3. METHODS

Because the Santa Ana is a rare event, statistical methods were used to develop forecast equations of the event and of the winds associated with the event. The statistical methods used employ linear relationships between a single variable (the predicand) and a set of independent variables (the predictors).

Two approaches are used to make the actual forecasts. The "perfect prog" approach (PP) (6) is used to make the Santa Ana regime forecasts. The model output statistics approach (MOS) (7) is used to make the Santa Ana wind forecasts at specific locations in the southern California coastal region. Both approaches dictate the data source for equation development; either can be used with any statistical procedure. In our development, discriminant analysis was used to derive the relationships for the Santa Ana regime forecasts, while multiple linear regression was used to derive the relationships for the Santa Ana wind forecasts. Specific details on the derivations will be given in section 5.

In the PP approach, all data used in the development of relationships is analyzed or observed data. Usually, the predictor and predictand are concurrent in time. When the equations are used to predict, forecast values of the predictors must be obtained and substituted into the equations to give a forecast of the predictand. The name perfect prog comes about because, in the forecast mode, the forecast data are entered into the equation as if they were equivalent to the analyzed data from which the equations were developed. The principle advantage of PP is that it is independent of the forecast model used. To develop the Santa Ana regime equations, analyzed data at 0000 GMT and 1200 GMT were related to observed data at the same hours.

The MOS approach uses model output predictor values in the formulation of the relationship; thus biases in the model forecasts are accounted for in the equations. To develop the Santa Ana wind forecast equations, model output at various forecast projections in time (6-, 12-, 18-, 24-, 30-, 36-, 42-, and 48 – h) and the initialization times were related to observed data at 3-h intervals from 0000 GMT through 2100 GMT.

Specific details about the data used in the development of the equations are given in Section 4.

4. DATA

4.1 Predictand Data

4.1.1 *Santa Ana Regime Equations.* Over the years, many criteria have been developed to establish the presence of Santa Ana conditions at the surface. Richardson (4) gives a comprehensive summary of these criteria. They take into account many of the phenomena observed during Santa Anas, such as temperature rise, humidity decrease, and wind direction, speed, and gustiness. Most of the criteria were developed for inland stations where fire danger is maximized by the conditions. Few authors have discussed Santa Ana conditions at the coast. Fosberg et al. (5) describe some aspects of these winds at the coast and over the Santa Barbara and San Pedro Channels (see Fig. 1).

Edinger et al. (8) show wind patterns over the Los Angeles basin as far as the coast, but not over water. Rosenthal (3) summarizes how Santa Ana conditions affect Point Mugu and San Nicolas Island.

The criteria used are based on a number of factors. They included the differentiation between Santa Ana regimes and bursts, the sustained wind speed at the coast, the gustiness of the wind, the wind direction, and the relative humidity at the coast. To determine if a Santa Ana affected the coast, wind speed and direction data and relative humidity data for NTD and NTK were evaluated at 3-h intervals.

To be classed as a Santa Ana of any strength, an event had to meet the following criteria:

1. During Santa Ana bursts, wind is from the northeast quadrant at either NTD or NTK or both;
2. To be included in a regime, bursts must be less than 24 hours apart;
3. For the entire Santa Ana regime, relative humidity is less than or equal to 50 percent;

To be classed as a strong Santa Ana, the event had to meet the following criteria:

4. During Santa Ana bursts, wind is from the northeast quadrant at both NTD and NTK, except at the beginning or end of a regime;
5. Criteria 2 and 3 above apply;
6. Wind speed at NTD or NTK is greater than or equal to 18 kt for at least one observation during the Santa Ana regime and greater than or equal to 15 kt for at least one observation at the other station.

The exception in criterion 4 accounts for the fact that a regime may affect one station before the other and/or longer than the other. If criteria 1 through 3 are met, then a value of 1 is given to the observations in the regime. If criteria 4 through 6 are met, then a value of 2 is given to the observations in the regime. If neither set of criteria are met, then a value of 0 is given to the observations. Although the observations were evaluated at 3-h intervals, only the 0000 GMT and 1200 GMT observations were used because predictor data were available only at those times. Data for the entire year were included. For the 10 years from 1973 through 1982, a total of 516 Santa Ana observations fitting the criteria were made. Of those, 212 fit criteria 4 through 6.

4.1.2 *Special MOS Wind Equations*. Wind speed and direction data at 3-h intervals were obtained for NTD, NTK, AVC, NSI, and NUC. Only data corresponding to the strong Santa Ana cases were used to derive wind forecast equations even though the period of record is from 1973 through 1982.

4.2 Predictor Data

4.2.1 *Santa Ana Regime Equations*. Gridpoint sea level pressure, 700-mb height, and 700-mb temperature data were obtained from a 63-point subset of the National Meteorological Center's Limited-Area Fine Mesh (9, 10) initializations at 0000 GMT and 1200 GMT for the same period of record as in Section 4.1.1. These data were offered as predictors in the development of the Santa Ana regime equations.

4.2.2 *Special MOS Wind Forecast Equations*. Table 1 lists the basic and derived variables used to derive special MOS wind forecast equations. Since these predictors were archived at grid points, they were interpolated to the forecast locations (NTD, NTK, AVC, NSI, and NUC). A biquadratic interpolation scheme was used. In deriving the equations for the 6- to 24-h forecast projections, model variables for 0 through 24 hours were considered; for 27- through 36-h, variables for 24 through 36 hours were considered; and for 39- through 48-h, variables for 36 through 48 hours were considered. The first and second harmonics of the day of the year were screened at each projection time.

Table 1. Potential LFM predictors for coastal MOS wind forecasts. An 'X' indicates no smoothing has been done, one asterisk (*) denotes smoothing with a five-point smoother, two asterisks (**) denote smoothing with a nine-point smoother, and blank indicates the field was unavailable at a projection time. (GEO = geostrophic, REL = relative, DOY = day of the year, CHNG = change)

Predictor Name	Model Output Forecast Projection in Hours								
	00	06	12	18	24	30	36	42	48
Cos (DOY × 2Pi/365)	X								
Sin (DOY × 2Pi/365)	X								
Cos (DOY × 4Pi/365)	X								
Sin (DOY × 4Pi/365)	X								
1000-mb GEO u-wind	*	*	*	*	*	**	**	**	**
1000-mb GEO v-wind	*	*	*	*	*	**	**	**	**
1000-mb GEO wind speed	*	*	*	*	*	**	**	**	**
1000-mb GEO REL vorticity	*	*	*	*	*	**	**	**	**
850-mb u-wind		X	X	*	*	*	**	**	**
850-mb v-wind		X	X	*	*	*	**	**	**
850-mb wind speed		X	X	*	*	*	**	**	**
850-mb REL vorticity		X	X	*	*	*	**	**	**
850-mb GEO u-wind	X	X	X	*	*	*	**	**	**
850-mb GEO v-wind	X	X	X	*	*	*	**	**	**
850-mb GEO wind speed	X	X	X	*	*	*	**	**	**
700-mb REL vorticity			X		*		**	**	**
500-mb REL vorticity			X		*		**	**	**
500-mb GEO u-wind	X	X	X	X	*	*	*	**	**
500-mb GEO v-wind	X	X	X	X	*	*	*	**	**
500-mb GEO wind speed	X	X	X	X	*	*	*	**	**
850-mb–1000-mb temperature			*		*		**	**	**
700-mb–1000-mb temperature			*		*		**	**	**
12-h CHNG in surface pressure					*				**
6-h CHNG in 500-mb height		X	X	X		*	*	**	
12-h CHNG in 500-mb height					*				**

5. EQUATION DEVELOPMENT

5.1 Development

5.1.1 *Development of Santa Ana Regime Forecast Equations*. The PP approach was used to develop regime forecast equations. Grid-point data from the LFM subset were used as potential predictors. Discriminant analysis was used to develop two discriminant functions. The first discriminates whether or not a Santa Ana regime exists. The second discriminates whether or not, given a Santa Ana is forecast, the Santa Ana regime will be strong enough to produce winds of 18 kt or greater at the coast at least once during the regime.

In meteorology, non-numerical events are often related to numerical predictors by the use of discriminant analysis. The non-numerical events are grouped, usually into an occurrence group or a nonoccurence group. The discriminant model derives group equations from the numerical predictors which best separate the groups. These equations have the same predictors, but different constants and coefficients. The group equations are used to derive a discriminant function which is then used to classify new predictor values into the groups (11, 12).

To determine which LFM model variables to use as predictors, a stepwise discriminant analysis procedure was employed. The predictand was a binary variable (the classification variable) which had a value of 0 (no) or 1 (yes) and defined the groups with which the predictors were to be associated. Potential predictors were chosen to enter or stay in the discriminant model according to specified criteria for the squared partial correlation of the predictor with the classification variable, controlling for the effects of the predictors already selected.

The procedure began by selecting the variable that contributed most to the discriminatory power (group separation) of the model and met the criterion to enter. At each succeeding step, if a variable already in the model failed to meet the criterion to stay, it was removed. Otherwise, the variable, not already in the model, that contributed most to the discriminatory power of the model and met the criterion to enter was added. When all variables in the model met the criterion to stay, and none of the other variables met the criterion to enter, the stepwise selection stopped (13). This procedure was used to determine which predictors were used in the final discriminant models. This procedure does not allow for weighting the groups in any way. We used a second procedure to do that.

Once the predictors for each discriminant model were chosen, a second discriminant analysis procedure was used. This procedure weighted the group equations according to the prior probabilities of the groups. The prior probabilities of the groups are generally determined by the frequency of occurrence of the groups within the sample of observations. However, they can be adjusted to any value. We adjusted them to maximize the threat score (number of correct forecasts/(number of forecasts + number of observations—number of correct forecasts)). This adjustment was made by an iterative procedure in which the prior probabilities were adjusted in a stepwise fashion until the threat score was maximized.

Discriminant functions were created from each discriminant model by subtracting the constants and coefficients of the no group equation from the yes group equation. If the value of the discriminant function, for a given set of LFM model output data, is greater than 0, a yes classification (1) is given. Otherwise, a no classification (0) is given.

The discriminant model consists of a couplet of equations. These are the group equations which have the form shown below:

$$G(0) = P(0)[A_O + A_1X_1 + A_2X_2 + \ldots + A_nX_n], \quad (1)$$

$$G(1) = P(1)[B_O + B_1X_1 + B_2X_2 + \ldots + B_nX_n], \quad (2)$$

where G(0) and G(1) are the discriminant functions for determining the probability of a no or a yes, respectively, p(0) and p(1) are the prior probabilities of a no or a yes, respectively, the A's and B's are constants or coefficients, and the X's are the predictors.

The discriminant functions are given by

$$D(a) = [G(1) - G(0)]_a, \quad (3)$$

$$D(b) = [G(1) - G(0)]_b, \quad (4)$$

where D(a) is the discriminant function to determine if a Santa Ana exists, and D(b) is the discriminant function to determine the strength of the Santa Ana.

Table 2 shows the resulting forecasts for various combinations of values for D(a) and D(b).

Table 2. Classification values from discriminant functions D(a) and D(b) with the associated Santa Ana regime forecast.

	Forecast		
Equation	None	Weak	Strong
D(a)	0	1	1
D(b)	0,1	0	1

Computations are made from the LFM initialization and at 6-h intervals for projections from 06 through 48 hours from LFM model output. To ensure there is consistency in the computations, an evaluation is made of all nine computations for a given cycle. If computations for Santa Ana conditions are separated by three or more 6-h intervals, no adjustments to the computations at the intervening times are made. Where the separation is less than three 6-h intervals, then the computations at the intervening times are adjusted to reflect Santa Ana conditions. This insures that forecasts of regimes as well as bursts will be made. For example, if an initial set of computations gives:

0100	0106	0112	0118	0200	0206	0212	0218	0300
strong	none	none	weak	none	none	none	weak	strong;

the final set of computations is adjusted to give:

0100	0106	0112	0118	0200	0206	0212	0218	0300
strong	strong	weak	weak	none	none	none	weak	strong

Similarly, if an initial set of computations gives:

0100	0106	0112	0118	0200	0206	0212	0218	0300
strong	weak	strong	none	weak	none	strong	weak	none

the final set of computations is adjusted to give:

0100	0106	0112	0118	0200	0206	0212	0218	0300
strong	strong	strong	strong	weak	weak	strong	weak	none

These adjustments are based on the definitions of bursts and regimes, so that if there is 24 or more hours between forecasts of Santa Ana conditions no adjustments are given. If there is less than 24 hours between, then adjustments are made. No adjustments are made to the first or last computation in any cycle.

5.1.2 *Development of Special MOS Wind Equations*. Although ten years of data were available, only those observations associated with strong Santa Ana regimes were used. This limited the sample to 45 cases and 158 observations.

Wind speed forecasts can be developed by deriving unbiased estimates of the u- and v-wind components and computing wind speed from them. Glahn (14) has shown this underestimates the wind speed. Therefore, we derived a separate equation for wind speed.

For a given observation time, measured wind speed and the associated u- and v-wind components were correlated with the interpolated forecast fields from the LFM. A forward-selection

Table 3. Results from three-way contingency table. Independent data for 1983 and 1984 were used in the computations. These results demonstrate the capabilities of each part of the Santa Ana forecast system. The values after the sample size are the number of weak Santa Ana observations and the number of strong Santa Ana observations respectively.

		Statistics					
					Bias		
Cycle (GMT)	Projection	Sample Size	Percent Correct	Skill Score	No	Weak	Strong
0000	Analysis	752/20/22	93	0.47	0.98	1.00	1.50
	12-h	752/30/23	92	0.29	1.02	0.30	1.39
	24-h	752/20/22	93	0.32	1.01	0.25	1.45
	36-h	752/30/23	91	0.22	1.01	0.23	1.57
	48-h	752/19/22	92	0.22	1.01	0.53	1.14
1200	Analysis	745/30/22	92	0.35	1.01	0.53	1.41
	12-h	745/20/21	92	0.30	1.00	0.30	1.76
	24-h	745/30/22	91	0.19	1.03	0.10	1.36
	36-h	745/19/21	93	0.19	1.01	0.32	1.14
	48-h	745/28/23	91	0.14	1.03	0.36	0.87

screening program was used to compute a sequence of multiple regression equations by considering each of the predictands (u, v, and wind speed) simultaneously. This was done so the individual forecast equations for u, v, and wind speed give consistent results. The potential predictor having the highest correlation with any one of the predictands was chosen initially. This same variable was then used as a predictor in all three equations. At each following step, the potential predictor with the highest partial correlation with any one of the predictands, after the effect of the previously selected predictors was removed, was added to the equation. This process was continued until 8 terms had been selected or none of the remaining potential predictors contributed 1.0% or more to the reduction of variance for any predictand. As a result, some of the equations were derived for each model cycle (0000 or 1200 GMT) and projection (6–48 hours at 3-h intervals). The resulting u, v, and wind speed equations are used to determine the wind direction and speed.

Although a separate regression equation is used for the estimated wind speed, Se, to avoid underforecasting the wind speed, in the mean, Carter (15) demonstrated that Se still tends to underestimate the occurrence of strong winds. To overcome this difficulty, inflation (6) is used to adjust Se to forecast extremes more often. This procedure adjusts the forecasts so that the variance of the forecasts and the observations in the developmental sample are approximately equal. The inflated forecast is given by

$$Si = (Se - Sm)/r + Sm \qquad (5)$$

where Se is the original objective estimate of the wind speed, Sm is the predictand mean derived from the developmental sample, r is the multiple correlation coefficient of the predictand with the predictors in the forecast equation, and Si is the inflated estimate of the wind speed. For Se < Sm, Si < Se; while for Se > Sm, Si > Se.

5.2 Tests and Evaluations

5.2.1 *Tests and Evaluations of the Santa Ana Regime Equations*. The Santa Ana regime equations were tested on an independent data set. Data from the years 1983 and 1984 were used. Since we had verification data only at 12-h intervals, we could not evaluate the performance of the equations at the intermediate 6-h intervals. Three scores were used to evaluate the equations: the Heidke Skill Score against chance, the bias (the number of forecasts/the number of observations), and the percent correct. A bias of one means there are as many forecasts of a given category as there are observations in that category. Two different contingency tables were used to compute the desired scores. A three-way contingency table was computed to evaluate all parts of the forecast system. A two-way contingency table was also computed to evaluate the system's ability to forecast Santa Anas at the coast regardless of strength. Details of the evaluations are given in Tables 3 and 4.

The results of Table 3 show that the system tends to underforecast weak Santa Anas and tends to overforecast strong Santa Anas. In general, skill decreases with projection. A pronounced decrease takes place at 12 hours and after 24 hours on the 0000 GMT cycle. A similar decrease occurs after 12 hours on the 1200

Table 4. Results of two-way contingency table. Independent data for years 1983 and 1984 were used in the computations. The results show the system's ability to forecast Santa Anas regardless of strength. The number after the sample size is the number of Santa Ana observations that occurred.

		Statistics				
					Bias	
Cycle (GMT)	Projection	Sample Size	Percent Correct	Skill Score	No	Yes
0000	Analysis	752/42	94	0.47	0.98	1.26
	12-h	752/53	92	0.34	1.02	0.77
	24-h	752/42	94	0.40	1.01	0.88
	36-h	752/53	91	0.27	1.01	0.81
	48-h	752/41	93	0.25	1.01	0.85
1200	Analysis	745/52	93	0.43	1.01	0.90
	12-h	745/41	93	0.34	1.00	1.05
	24-h	745/52	92	0.24	1.03	0.63
	36-h	745/40	93	0.19	1.01	0.75
	48-h	745/51	91	0.16	1.03	0.59

GMT cycle. However, there is some skill at all projections. Skill scores tend to be lower on the 1200 GMT cycle than on the 0000 GMT cycle. The 0000 GMT cycle has a diurnal pattern out to 36 hours. This may be due to the small number of Santa Ana observations and to the oscillation in the number of Santa Ana observations from cycle to cycle.

The results of Table 4 show that there is a tendency to underforecast the event except on the analysis on the 0000 GMT cycle and the 12-h projection on the 1200 GMT cycle. The biases on the 1200 GMT cycle tend to be worse than those on the 0000 GMT cycle. In general, skill scores are somewhat higher than in Table 3, but are still lower on the 1200 GMT cycle than on the 0000 GMT cycle. On both cycles there is a large drop in skill during the first 12 hours. There are apparent diurnal patterns in bias on both cycles and in skill on the 0000 GMT cycle. These oscillations are probably related to the oscillations in the number of Santa Ana observations from cycle to cycle.

5.2.2 *Tests and Evaluations of the Special MOS Wind Equations*. The special MOS Wind equations were tested on independent data from the months of January through March and October through December for the years 1983 and 1984. The results were compared with those from the operational coastal MOS wind equations at the same stations on the same data. Two sets of dates were used: one for the actual strong Santa Ana cases and one for the forecast strong Santa Ana cases. The first set of dates gives an indication of performance under operational conditions. Since the sample sizes are small, only a trend can be inferred. The statistics are only for those cases where the observed wind speed was 8 kt or greater. Only data from the 0000 GMT cycle 18-, 30-, and 42-h projections for NTD, NTK, NSI, and NUC are presented. The statistics used were the mean vector error; the mean absolute error of the wind direction, and the mean absolute error of the wind speed. The data are given in Table 5.

The results show that, in general, the special MOS wind forecast equations tend to do better than the normal operational MOS wind equations for observed Santa Ana conditions. The results for forecast Santa Ana conditions are mixed, but generally favor the special MOS wind forecast equations. From the results, it is evident that, where Santa Ana conditions are correctly forecast, the special MOS wind forecast equations give a better wind forecast. The poor performance at NSI is due primarily to the small sample size, but may also be due to a smaller developmental sample size for the forecast equations than at the other stations.

6. OPERATIONAL CONSIDERATIONS

6.1 Messages and Schedule

The forecasts are produced twice daily from LFM model output and are available to the field forecasters at about 0330 GMT and 1600 GMT. Table 6 lists the station call letters, station name, and station position for each station found in the Santa Ana bulletin (FZUS45). Examples of the bulletin are found in Figs. 3 and 4. Table 7 gives the abbreviations used in the bulletin. The bulletin is available to users over the Automation of Field Operations and Services (AFOS) communications system. Forecasts are made twice daily: once for each cycle (0000 and 1200 GMT) of the LFM-model. The Santa Ana regime forecasts are given at 6-h intervals from 0 to 48 hours, and are made from October through May. During the rest of the year, a statement is made saying, "NO SANTA REGIME FORECAST" (see Fig. 4).

The wind forecasts for each station are given at 3-h intervals from 6 to 48 hours. If a regime forecast for a given projection is none or weak, the normal coastal MOS wind forecasts are used. If the regime forecast for a given projection is strong, then the special Santa Ana MOS wind forecasts are used. Since the regime forecasts are made only at 6 hour intervals, a convention is needed to determine which wind forecast to use at the intermediate 3 hour projections. The regime forecast at the preceding 6 hour projection is used for the immediate projection. For example, if the forecast at the 6 hour projection is for strong Santa Ana conditions, then the forecast at the 9 hour projection is assumed to be for strong conditions also; therefore, the special Santa Ana MOS wind forecast equations would be used to make the wind forecast at the 9 hour projection. The wind direction and speed have the form ddff in the bulletin, where dd is the direction to the nearest 10 degrees and ff is the speed in knots. If the wind speed is 100 kt or greater 50 is added to the wind direction and the remainder of the wind speed is given as ff. If the wind direction and speed are missing for any reason, 9999 is

Table 5. Comparison of statistics between forecasts made with the special MOS wind equations and those made with the normal coastal MOS wind equations. Values are separated with a solidus (/). Independent data for January through March and October through December for years 1983 and 1984 were used to make the computations. All comparisons are for the 0000 GMT cycle. Results outside the parentheses are for forecast Santa Ana conditions. Statistics for wind speed and direction are for observed wind speeds of 8 kt or greater. (Stn = station, tau is the projection hour, and dashes mean no data were available.)

			Statistics		
				Mean Absolute Error	
Stn	Tau	Sample Size	Mean Vector Error	Wind Direction (deg)	Wind Speed (kt)
	18-h	15(8)	5.7/ 7.0(3.3/4.0)	12/14(10/10)	3.7/4.9(2.2/2.1)
NTD	30-h	11(5)	4.4/ 6.0(6.3/7.8)	18/23(18/24)	6.1/3.1(4.8/3.4)
	42-h	16(11)	7.2/ 8.4(5.4/6.4)	12/21(11/12)	5.1/6.6(3.7/4.9)
	18-h	11(6)	7.5/10.6(8.7/8.4)	15/38(30/33)	6.0/8.6(5.7/5.7)
NTK	30-h	5(3)	4.8/ 6.3(7.8/7.9)	12/16(13/13)	6.0/4.6(6.7/6.7)
	42-h	12(6)	13.7/10.6(13.7/8.7)	58/42(80/40)	10.8/9.8(9.8/6.5)
	18-h	4(1)	7.7/ 5.0(6.4/6.2)	38/20(40/30)	3.8/3.0(3.0/5.0)
NSI	30-h	—(—)	—/—(—/—)	—/—(—/—)	—/—(—/—)
	42-h	4(3)	8.4/ 8.3(10.8/7.5)	50/48(60/40)	2.8/4.5(2.3/6.3)
	18-h	9(3)	5.7/ 7.4(5.2/6.9)	23/34(17/37)	3.7/5.6(4.7/5.7)
NUC	30-h	5(2)	4.4/ 6.2(6.9/6.3)	18/24(25/20)	5.6/3.6(4.5/2.5)
	42-h	9(7)	5.7/ 8.6(6.8/7.5)	31/38(54/50)	2.2/4.4(2.6/4.7)

Table 6. List of stations found in the wind forecast portion of the FZUS45 KWBC bulletin.

Call Letters	Station Name	Latitude	Longitude
NTD	NAS Point Mugu, Calif.	34 07 N	119 07 W
NTK	MCAS Santa Ana, Calif.	33 42 N	117 50 W
AVC	Avalon, Santa Catalina Is., Calif.	33 20 N	118 20 W
NSI	NF, San Nicolas Is., Calif.	33 15 N	119 27 W
NUC	NAF, San Clemente Is., Calif.	33 01 N	118 35 W

```
FZUS45 KWBC 160000
FZUS45 SANTA ANA FCST 05/16/86 0000
SANTA ANA RGM FCST
DTG 1600 1606 1612 1618 1700 1706 1712 1718 1800
     NONE NONE NONE STNG STNG WEAK WEAK NONE NONE
CSTL WND FCSTS-SC
DTG 1606 1609 1612 1615 1618 1621 1700 1703 1706
     1709 1712 1715 1718 1721 1800
NTD 2904 2903 0000 3302 0623 0107 3017 0000 0601
     0603 0604 0405 1710 2407 2604
NTK 1603 1504 1505 1502 0000 2501 2704 0505 0000
     0000 0000 0901 2308 2408 2506
AVC 9999 9999 9999 2006 9999 1906 0612 2106 9999
     9999 9999 1904 0705 0605
NSI 9999 9999 9999 3208 3211 3311 3117 9999 9999
     9999 9999 3502 0000 3402 3202
NUC 2905 2602 2503 3002 2902 3208 3007 2501 1900
     0000 0000 0000 3402 2703 2802
```

Fig. 3. Sample FZUS45 Bulletin with Santa Ana regime forecast.

```
FZUS45 KWBC 180000
FZUS45 SANTA ANA FCST 06/18/85 0000
SANTA ANA RGM FCST
DTG 1800 1806 1812 1818 1900 1906 1912 1918 2000
     NO SANTA ANA REGIME FORECAST
CSTL WND FCSTS-SC
DTG 1806 1809 1812 1815 1818 1821 1900 1903 1906
    1909 1912 1915 1918 1921 2000
NTD 3002 2404 3402 3504 2608 2710 2810 2807 2904
    2803 3303 3304 2509 2710 2709
NTK 1803 1602 1402 1102 2306 2308 2406 2107 1704
    1602 1302 1504 2406 2311 2405
AVC 9999 9999 9999 2005 9999 0509 0707 0804 9999
    9999 9999 2206 9999 0809 0708
NSI 9999 9999 9999 3213 3214 3215 3118 9999 9999
    9999 9999 3215 3215 3218 3219
NUC 2706 2708 2805 2806 2709 2812 2813 2812 2710
    2709 2810 2710 2710 2712 2813
```

Fig. 4. Sample FZUS45 Bulletin with no Santa Ana regime forecast.

Table 7. Abbreviations used in the FZUS45 KWBC bulletin.

Abbreviation	Description
CSTL	Coastal
DTG	Date/Time Group
FCST/FCSTS	Forecast/Forecasts
RGM	Regime
SC	Southern California
STNG	Strong
WND	Wind

given. For those wishing detailed information on this bulletin, see Technical Procedures Bulletin No. 353 (16).

6.2 Forecasts

The forecast equations are dependent on the behavior of the numerical model and its output. When the forecaster has reason to believe that the model is not performing properly for a given situation, the regime or wind forecasts should be modified accordingly. For example, if a trough, front, or ridge has intensified or accelerated more than predicted by the model, corresponding changes to the guidance should be considered. Specific localized conditions and mesoscale features detected by real-time, ground-based or satellite observations should also be taken into account.

6.2.1 *Santa Ana Regime Forecasts*. This forecast system is designed to forecast Santa Anas as they affect the coast. This includes most, but not all Santa Ana occurrences. There are times when a Santa Ana regime affects the interior, but not the coast. This procedure will not predict those situations.

At Point Mugu, Santa Anas generally occur during the months of October through March. They have occurred as early as mid-September and as late as mid-June. With little variation, this is true throughout southern California.

Along the coast, Santa Anas exhibit diurnal variations which are also seasonally dependent. The onset of Santa Ana conditions can occur at any time of day; however, near the coast, variations in wind speed and direction are introduced by the interaction of the Santa Ana with the sea breeze. The Santa Ana is weakest at the coast in the afternoon, when opposed by the sea breeze. These variations are also seasonally dependent. Near the coast, Santa Ana conditions become less apparent or disappear entirely by mid-day. The time of disappearance is more variable in winter than in spring or fall. When Santa Ana conditions exist, the sea breeze is generally weaker, drier, and of shorter duration than under normal circumstances.

6.2.2 *Special MOS Wind Forecasts*. These equations are invoked only if a strong Santa Ana is forecast. The forecaster should check the wind forecasts for consistency with the forecasts at projections where strong Santa Ana conditions are not forecast.

Inflation moves each particular forecast away from the mean. Therefore, inflation causes fewer forecasts near the mean and more forecasts of extremes.

When wind speeds are below 8 kt, forecast wind directions may vary substantially from observed wind directions. This is generally due to the boundary layer circulation being weak and decoupled from the circulation above it. Under these conditions, the forecaster needs to adjust the automated guidance.

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NOTES AND REFERENCES

1. Larry Burroughs is a meteorologist with the Ocean Products center at the National Meteorological Center and has been with the National Weather Service since 1975. He received a B.S. in meteorology from the University of Wisconsin in 1963 and a M.S. in Meteorology from the University of Hawaii in 1974. Prior to his service with the National Weather service, Larry was an officer in the U.S. Navy.

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