National Weather Service
Office of Meteorology

Technical Procedures Bulletin

Series No. **391**

Subject:

Forecast Guidance for Santa Ana Conditions

Program Requirements and Development Division, Silver Spring, MD 20910

SIGNIFICANT CHANGE FROM LAST BULLETIN ON THIS SUBJECT NO. 353

April 16, 1991
W/NMC21:LDB

This bulletin, prepared by Mr. Lawrence D. Burroughs of the National Meteorological Center (NMC), describes the automated Santa Ana forecast guidance system, which was first implemented in 1985. The system forecasts the presence or absence of Santa Ana conditions and the associated winds at the following stations: Naval Air Station Point Mugu, Calif. (NTD); Marine Corps Air Station Santa Ana, Calif. (NTK); Catalina Ridge Buoy (46025); Naval Facility San Nicolas Island, Calif. (NSI); and Naval Air Facility San Clemente Island, Calif. (NUC). The wind forecasts for the Santa Ana Forecast System and the Coastal Wind Forecast System are made with modified perfect prognosis (MPP) equations, while the Santa Ana regime forecast equations are perfect prognosis (PP) equations.

The changes described in this bulletin were implemented on December 12, 1990. Users were notified of the change in National Technical Information Message (NTIM) 90-8, which was issued on December 10, 1990. The AFOS product identifier for the NTIM is WSHPNSNMC and the WMO header is NOFS10 KWBC.

Technical Procedures Bulletin No. 353 is now operationally obsolete.

Mary M. Heffernan
Chief, Services Development Branch

FORECAST GUIDANCE FOR SANTA ANA CONDITIONS

by Lawrence D. Burroughs[1]

1. INTRODUCTION

The Glossary of Meteorology (Huschke, 1959) 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 on the California coast depend on synoptic scale events, interaction of the Santa Ana circulation with the sea breeze circulation, and topography. Intensity and duration of Santa Ana conditions are also dependent on synoptic forcing, mesoscale interaction, and topographic effects (Rosenthal (1972) and Richardson (1973)). Additional details, particularly about the vertical structure of Santa Anas, are given by Fosberg et al. (1966). The season for Santa Anas is generally from October through May. They have been known to occur as early as mid-September or as late as mid-June. The centrally produced forecast guidance is available from October through May.

The Santa Ana is generally thought of as a fire weather problem; however, it can also be a marine weather problem. This is particularly true for the San Pedro and Santa Barbara Channels and for the boat harbor at Avalon, Santa Catalina Island. The Santa Ana forecast system forecasts the presence or absence of Santa Ana conditions and the associated winds at NTD, 46025, NTK, NSI, and NUC (see Fig. 1).

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, the passage of fronts through southern California, and the development of a 500-mb wave centered near the west coast of the United States, such that air flows from the Northeast over the coast range of mountains in southern California. There is a fourth synoptic event that 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, or even storm, strength.

According to Fosberg et al. (1966), the Santa Ana is primarily a lee wave phenomenon, and air flow is nearly isentropic. When the amplitude of the waves is large, they reach the earth's surface (this is often referred to as surfacing.); when the amplitude is small, they don't. There are periodic and aperiodic components in the surfacing. The periodic effects 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.

The following definitions are made to distinguish between the conditions that bring about the formation of mountain waves associated with Santa Ana weather and the conditions that result from the surfacing of the mountain waves:

Santa Ana Burst - A single period of continuous Santa Ana surface winds (averages 6 to 8 hours in length).

Santa Ana Regime - An overall synoptic scale event usually lasting 36 hours and consisting of more than one burst separated by less than 24 hours between bursts.

1 Ocean Products Center Contribution No. 36

Since 1985, several events have occurred or are planned to occur which made it necessary to redesign the Santa Ana Forecast System. These events include the closing of one station; the addition of two new buoy stations; and the withdrawal of the Limited-area Fine-mesh Model (LFM) from the NMC operational job stream sometime in 1992. As a result of these events, a new Santa Ana Forecast System has been designed. The overall size of the new system has increased from 5 to 6 stations. The bulletin format for the wind forecasts has changed from forecasts at 3-h intervals out to 48 hours to forecasts at 6-h intervals out to 48 hours because it was not possible to derive equations at 3-h intervals. Additionally, the Santa Ana Forecast System has been converted from an LFM-based package to an Regional Analysis and Forecast System (RAFS)-based package.

The system forecasts the presence or absence of Santa Ana conditions and the associated winds at the following stations: NTD, NTK, 46025, NSI, and NUC. When a strong Santa Ana is forecast, special equations are used to make the wind forecasts at these stations. When no Santa Ana or a weak Santa Ana is forecast, the coastal wind forecast equations (NWS, 1991) are used at these stations. Wind forecasts at Point Conception Buoy (46023) are also included because it is located in the area covered by the Santa Ana wind bulletin. The winds at 46023 are rarely affected by Santa Ana conditions, so only forecast equations from the Coastal Wind Forecast System are used to make forecasts for it.

The new forecast equations were implemented in conjunction with the redesigned Coastal Wind Forecast System on December 12, 1990. Users were notified of the change in National Technical Information Message (NTIM) 90-8, issued on December 10, 1990. The AFOS product identifier for the NTIM is WSHPNSNMC and the WMO header is NOFS10 KWBC.

2. METHOD

A single station approach based on the MPP technique was used to derive new wind forecast equations which are used when strong Santa Anas are forecast. A set of equations was developed for each site. The MPP approach uses LFM initialization (00) and 6-h model (06) projection as though they were perfect analyses and relates them to the appropriate observed data. Two sets of equations were derived - one for each cycle. These special equations are only valid during the Santa Ana season from October through May. To derive the 0000 UTC cycle 00-h equation (eq 1), predictors from the LFM 0000 UTC initialization were related to the observed u-wind and v-wind components and to the observed wind speed at 0000 UTC. Likewise, predictors from the LFM model 06-h projection on the 0000 UTC cycle were related to the observed winds at 0600 UTC (eq 2). Predictors from the LFM 1200 UTC cycle initialization were related to observed winds at 1200 UTC (eq 3). Predictors from the LFM model 06-h projection on the 1200 UTC cycle were related to the observed winds at 1800 UTC (eq 4). RAFS model output are then used with these equations to produce forecasts at each projection from 6 - 48 hours as shown in Table 1.

RAFS PROJ	RAFS 0000 UTC CYCLE	RAFS 1200 UTC CYCLE
06	Eq 2	Eq 4
12	Eq 3	Eq 1
18	Eq 4	Eq 2
24	Eq 1	Eq 3
30	Eq 2	Eq 4
36	Eq 3	Eq 1
42	Eq 4	Eq 2
48	Eq 1	Eq 3

Table 1. The application of the modified perfect prognosis forecast equations to each cycle and projection of RAFS output. Equation identification is given by equation number (eq) as explained in the text.

The PP technique was used to develop forecast equations for Santa Ana conditions at the coast. The potential predictors were taken from a subset of grid-point data from LFM initializations on both the 0000 and 1200 UTC cycles for the years 1978 through 1988. Categorical predictand data were developed for the same period. Categories are no Santa Ana, weak Santa Ana, or strong Santa Ana. Development of the predictand data is explained in detail in Section 3. A discriminant analysis package from the Statistical Analysis System (SAS) Institute (1985) was used to derive equations relating the predictor data to the predictand data. RAFS initializations and model output are used with these equations to produce forecasts at each projection from 0 - 48 hours.

3. DEVELOPMENT AND DEFINITIONS

The development of two sets of forecast equations is described in this section. One set - the Santa Ana Regime equations - determine whether or not conditions exist for a Santa Ana to occur and be felt along the coast of southern California and over the coastal waters and whether or not, if Santa Ana conditions are forecast, there will be winds of sufficient strength to require at least Small Craft Advisories some of the time. The other set - special wind forecast equations - are used to predict the winds during periods when strong Santa Anas are predicted by the former set of equations.

a. Predictand Data

1) Santa Ana Regime Equations

Over the years, many criteria have been developed to forecast or nowcast the presence of Santa Ana conditions at the surface. Richardson (1973) 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 studies have addressed Santa Ana conditions at the coast and over the Santa Barbara and San Pedro Channels (see Fig. 1). Edinger et al. (1964) show Santa Ana wind patterns over the Los Angeles basin as far as the coast, but not over water. Rosenthal (1972) summarizes how Santa Ana conditions affect Point Mugu and San Nicolas Island.

Our criteria for determining when a Santa Ana exists and how strong it is were 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 6-h intervals. To be classed as a Santa Ana *of any strength*, the following criteria had to be met:

(1) During Santa Ana bursts, winds had to be from the northeast quadrant at either NTD or NTK, or both;

(2) To be included in a regime, bursts had to be less than 24 hours apart;

(3) For the entire Santa Ana regime, relative humidity had to be less than or equal to 50 percent;

To be classed as a *strong* Santa Ana, the following criteria had to be met:

(4) During Santa Ana bursts, winds had to be from the northeast quadrant at both NTD and NTK, except at the beginning or end of a regime;

(5) Criteria (2) and (3) applied;

(6) During the Santa Ana regime, sustained wind speed at either NTD or NTK had to be greater than or equal to 18 knots (kt) for at least one observation and greater than or equal to 15 kt for at least one observation at the other station.

The exception in criteria (4) accounts for the fact that a regime may affect one station before another and/or longer than another. If criteria (1) through (3) were met, then a value of 1 was given to the observations in the regime. If criteria (4) through (6) were met, then a value of 2 was given to the observations in the regime. If neither set of criteria were met, then a value of 0 was given. For the 11 years from 1978 through 1988, a total of 392 Santa Ana observations fitting the criteria were taken. Of those, 180 fit criteria (4) through (6), and were, therefore, classified as strong Santa Anas.

2) Special Wind Equations

Wind speed and direction from 0000 through 1800 UTC at 6-h intervals were obtained from records spanning the period from January 1978 through December 1988. Data were used for the following stations: NTD, 46023, NTK, NSI, and NUC. Refer to Table 4 for station names and locations and to Fig. 1 for a map showing the stations.

b. Predictor Data

1) Santa Ana Regime Equations

LFM grid-point initialized sea level pressure and 700 millibar (mb) height data were obtained from a 63-point subset of the LFM grid at 12-h intervals for the same period of record as above (see Fig. 2). The individual grid-point data were used as predictors for deriving the equations.

2) Special Wind Equations

Table 2 lists the basic and derived variables offered to the screening regression program along with their projection times. Since these predictors were archived at grid points, they were interpolated to the forecast locations shown in Table 4.

Predictor Name	Predictor Projection Hour	
	00	06
COS (DOY x 2 pi/365)	X	X
SIN (DOY x 2 pi/365)	X	X
COS (DOY x 4 pi/365)	X	X
SIN (DOY x 4 pi/365)	X	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		*
850 mb V-WIND		*
850 mb WIND SPEED		*
850 mb REL VORTICITY		*
850 mb GEO U-WIND	*	*
850 mb GEO V-WIND	*	*
850 mb GEO WIND SPEED	*	*
850 mb GEO REL VORTICITY	*	*
500 mb U-WIND		*
500 mb V-WIND		*
500 mb WIND SPEED		*
500 mb REL VORTICITY		*
500 mb GEO U-WIND	*	*
500 mb GEO V-WIND	*	*
500 mb GEO WIND SPEED	*	*
500 mb GEO REL VORTICITY	*	*
500 mb HEIGHT CHNG (6-h)		*

Table 2. Potential predictors for the modified perfect prognosis wind equations. The X means no smoothing has been done. The asterisk indicates smoothing has been done with a five point smoother. A blank denotes the field was unavailable. GEO = Geostrophic; REL = relative; CHNG = change, and DOY = day of the year. **Please note - all winds are earth oriented.**

c. Equation Development

1) Santa Ana Regime Equations

One equation set was developed to forecast no Santa Ana, weak Santa Anas, or strong Santa Anas at the coast. A strong Santa Ana is one in which the sustained winds are 18 kt or greater some of the time along the coast.

To determine which variables to use, a stepwise discriminant analysis procedure was used. The selection procedure began with no variable in the model. At each step, if a variable already in the model failed to meet the criteria to stay, the worst such variable was removed. Otherwise, the variable that contributed most to the discriminatory power of the model was entered. When all variables in the model met the criteria to stay, and none of the other variables met the criteria to enter, the stepwise selection process stopped (SAS Institute, 1985).

Once the variables were chosen, a second discriminant analysis procedure was used to develop classification equations. The equations take into account the within group co-variance matrices and the prior probabilities of each group. The prior probabilities are generally determined by the frequency of occurrence of the groups within the sample of observations or by the climatological frequency of occurrence of each group, if known. By using the prior probabilities, allowance is made for climatology. There is a classification equation for each group. Each equation gives the probability that a given observation belongs to a certain group. The group with the highest probability is chosen if no threshold probabilities are used; however, threshold probabilities are used to optimize the bias (measures over or under forecasting) so that it is as close to one as possible. When the bias is one, there is neither over, nor under forecasting. The threshold probabilities were created empirically with RAFS output. There are threshold probabilities for each forecast projection. This means that although the equations are PP equations and are independent of the model, the thresholds are model dependent and are changed when output from a different model is used with the equations. This helps to account for model biases and makes the forecasts more like the Model Output Statistics guidance.

Forecasts are made at 6-h intervals from 00 through 48 hours from RAFS output. To ensure consistency in the forecasts, an evaluation is made of all nine forecasts for a given cycle. If two forecasts for Santa Ana conditions are separated by more than two projections with forecasts of no Santa Ana conditions, no adjustments to the forecasts at the intervening projections are made. Where the separation is less than three projections, the forecasts at the intervening projections are adjusted to reflect Santa Ana conditions. Four projections represents 24 hours. If the beginning and ending projections are strong, then the intermediate projections are adjusted to be strong also because the whole period is assumed to represent a single strong regime. Likewise, if the beginning and ending projections are strong and weak, respectively or vice versa, the intermediate projections are adjusted such that the one closest to the strong is changed to strong and the one closest to weak is changed to weak. If there is only one intermediate projection to adjust, it is given the value of the projection before it. For example, if an initial set of nine projections gives forecasts of:

strong, none, none, weak, none, none, none, weak, strong;

the final set of projections is adjusted to be:

strong, strong, weak, weak, none, none, none, weak, strong.

Likewise, if an initial set of nine projections gives forecasts of:

weak, none, none, strong, none, weak, none, none, none;

the final set of projections is adjusted to be:

weak, weak, strong, strong, strong, weak, none, none, none.

An evaluation of forecasts made with the new equations and threshold probabilities versus those made with the old showed the new equations and thresholds to be as good as or better than the old equations and thresholds. The evaluation was done on independent data.

2) Special Wind Forecast Equations

Although 11 years of data were available, only those observations associated with strong Santa Ana regimes were used. This limited the sample to a possible 180 observations, but because some predictor data were missing, there were only about 160 observations available from which to derive the equations.

Wind speed forecasts (hereafter referred to as "s") can be developed by deriving unbiased estimates of the u- and v-wind components and computing s from them. Glahn (1970) has shown this underestimates the observed wind speed. Therefore, a separate equation for s was derived.

For a given observation time, measured wind speed and the associated u- and v-wind components were correlated with interpolated predictor fields from the LFM. A forward-selection screening program was used to compute a sequence of multiple regression equations by considering each of the predictands (u, v, and s) simultaneously. This was done so the individual forecast equations for u, v, and s produce more meteorologically consistent results. The potential predictor having the highest correlation with any one of the predictands was chosen initially. Each subsequent term in the regression equation is chosen so that, in combination with all previously chosen predictors, the additional term yields the highest possible extra reduction in variance. This process was continued until 10 terms had been selected or none of the remaining potential predictors contributed 1.0 percent or more to the reduction of the variance for any predictand. As a result, some of the equations may have less than 10 terms. Separate sets of equations were derived for each model cycle (0000 or 1200 UTC). In day-to-day operations, the equations are used with RAFS output in accordance with the method shown in Table 1. The resulting computations of u, v, and s are used to determine the wind speed and direction for each projection from 6- to 48-h.

A comparison of forecasts from the new equations versus the old was done on a small sample of independent data. The results showed the new equations to be as good as the old equations. But because strong Santa Anas are so rare, and the sample was so small, more definitive results are not possible.

Under the old operational system, wind speeds were adjusted by inflation (Klein et al., 1959) to forecast extremes more often. The evaluation of the new equations also showed that inflation is no longer necessary. Therefore, no inflation of the wind speeds is done in the new system.

4. FORECAST CONTENT AND DISSEMINATION

Table 3 provides the abbreviations used in the Santa Ana bulletin. Table 4 lists the call letters, name, and latitude/longitude for each station found in the Santa Ana bulletin. Buoy 46023 has been added because it is a southern California station, not because it is a part of the Santa Ana forecast system. Examples of the bulletin are shown in Figs. 3 and 4.

Abbreviation	Description
CSTL	Coastal
D	Date
FCST/FCSTS	Forecast/Forecasts
MSGN	Missing
RGM	Regime
SC	Southern California
STNG	Strong
UTC	Coordinated Universal Time
WND	Wind

Table 3. Abbreviations used in the Santa Ana bulletin.

The Santa Ana bulletin is transmitted to NWS users on the Western Region Distribution Circuit of the AFOS network. It is also available to Domestic Data Service subscribers via the Family of Services. The AFOS product identifier is CCCMRPCA2 (where CCC is the local node identifier) and the WMO header is FZUS45 KWBC. The product is transmitted at approximately 0500 and 1700 UTC daily.

In each bulletin, the Santa Ana regime forecasts are given at 6-h intervals from 00 through 48 hours, and are made from October through May. During the rest of the year, a statement is made saying, "NO SANTA ANA REGIME FORECAST" (see Fig. 4). One line is used to give the forecasts for all projections. The forecasts are qualitative worded forecasts. If no Santa Ana conditions are forecast to affect the coast, NONE is shown below the appropriate date/time group (D/UTC). If Santa Ana conditions are forecast to affect the coast, either WEAK or STNG (strong) is shown. If the forecast cannot be made for any reason, MSNG (missing) is shown.

The wind forecasts at each station are given at 6-h intervals from 6 - 48 hours on one line. The date/time group headings (2206, 2212, ..., 2400) of the bulletin correspond to the valid date and time (D/UTC) of the forecasts. The wind forecast is presented in ddff format, where dd is wind direction in tens of degrees and ff is the wind speed in knots. For wind speeds of 100 knots or greater, 50 is added to dd, and the excess of wind speed over 100 knots is coded in ff. For example, a wind from the west (270 degrees) at 100 knots would be coded as 7700. Where there is a missing value, 9999 is coded.

If a regime forecast for a given projection is NONE or WEAK, the normal coastal wind forecasts are used. For 46023 this is always true. If the regime forecast for a given projection is STNG, then the special Santa Ana wind forecasts described in section 3 are used at NTD, 46025, NTK, NSI, and NUC.

5. OPERATIONAL CONSIDERATIONS

The forecast equations are dependent upon the behavior of the RAFS output. When the forecaster has reason to believe that the model is not performing properly for a given situation, he or she should modify the forecast guidance accordingly. For example, if a trough or front 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 also should be taken into account.

a. Santa Ana Regime Forecasts

These forecasts are designed to give guidance about 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 is not designed to predict those situations.

While minor variations occur throughout southern California, 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.

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 surfacing mountain waves, developed in response to a Santa Ana regime, and the sea breeze along the coast. Santa Ana winds are 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.

According to Rosenthal (1972), 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.

b. Santa Ana Wind Forecasts

These forecasts are only made if a strong Santa Ana is forecast. The forecaster should check the wind forecasts for consistency with the

Call letters	Station Name	Latitude/Longitude (degrees/minutes)	
46023	POINT CONCEPTION BUOY	34 18N	120 42W
NTD	NAS POINT MUGU, CA	34 07N	119 07W
46025	CATALINA RIDGE BUOY	33 42N	119 06W
NTK	MCAS SANTA ANA, CA	33 42N	118 50W
NSI	NF SAN NICOLAS ISLAND, CA	33 15N	119 27W
NUC	NAF SAN CLEMENTE IS., CA	33 01N	118 35W

Table 4. List of stations found in the wind forecast portion of the Santa Ana bulletin The AFOS PIL for this product is CCCMRPCA2 and the WMO header is FZUS45 KWBC.

forecasts at projections where strong Santa Ana conditions are not forecast.

c. Coastal Wind Forecasts

During the months of June through September and when the Santa Ana regime forecasts are NONE or WEAK, the coastal wind forecast equations are used to make the forecasts at each of the stations listed in Table 4. When wind speeds are below 8 knots, 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 forecast equations do not perform well, and the forecaster will need to adjust the guidance.

For complete information on the Coastal Wind Forecast System, of which the wind forecasts in the Santa Ana bulletin are a subset, see Technical Procedures Bulletin No. 390 (NWS, 1991).

6. REFERENCES

Edinger, J. G., R. A. Helvey, and D. Baumhefner, 1964: Surface wind patterns in the Los Angeles basin during "Santa Ana" conditions, Final Report, Part 1, Department of Meteorology, University of California at Los Angeles in cooperation with Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture for Office of Civil Defense, Office of the Secretary of the Army, 72 pp.

Fosberg, M. A., C. A. O'Dell, and M. J. Schroeder, 1966: Some characteristics of the three-dimensional structure of Santa Ana winds, U.S. Forest Service Research Paper PSW-30, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, 35 pp.

Glahn, H. R., 1970: A method for predicting surface winds. ESSA Technical Memorandum WBTM TDL-29, Environmental Science Services Administration, U.S. Department of Commerce, 18 pp.

Huschke, R. E., ed., 1959: Glossary of Meteorology, American Meteorological Society, Boston, 638 pp.

Klein, W. H., and H. R. Glahn, 1974: Forecasting local weather by means of model output statistics, *Bull. Amer. Meteor. Soc.*, **55**, 1217-1227.

____, B. M. Lewis, and I. Enger, 1959: Objective prediction of five-day mean temperatures during winter, *J. Meteor.*, **16**, 672-682.

National Weather Service, 1985: The Regional Analysis and Forecast System (RAFS), NWS Technical Procedures Bulletin No. 345, National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, 7 pp.

____, 1991: Coastal and offshore wind guidance, NWS Technical Procedures Bulletin No. 390, NOAA, U.S. Department of Commerce, 14 pp.

Newell, J. E., and D. G. Deaven, 1981: The LFM-II Model--1980, NOAA Technical Memorandum NWS NMC-66, NOAA, U.S. Department of Commerce, 20 pp.

Richardson, R. T., 1973: The Continental Contribution to the Climate of Southern California, Ph.D. Dissertation, University of Oregon, 202 pp.

Rosenthal, J., 1972: Point Mugu forecasters handbook, Pacific Missile Range Technical Publication PRM-TP-72-1, Geophysics Division, Pacific Missile Range, Department of the Navy, 426 pp.

Statistical Analysis System (SAS) Institute, 1985: SAS User's Guide: Statistics. SAS Institute Inc., 956 pp.

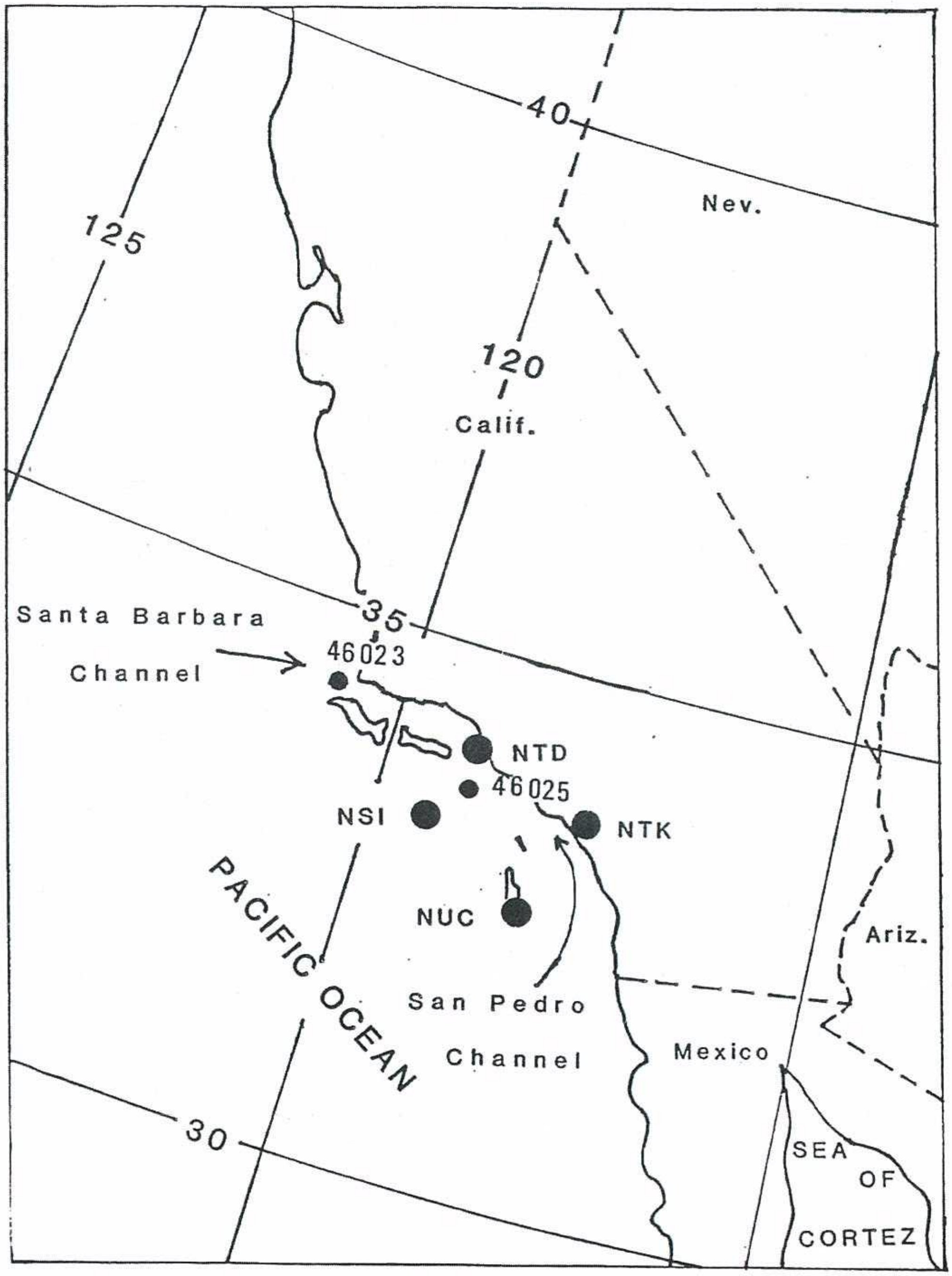

Figure 1. Santa Ana wind forecast system station locations.

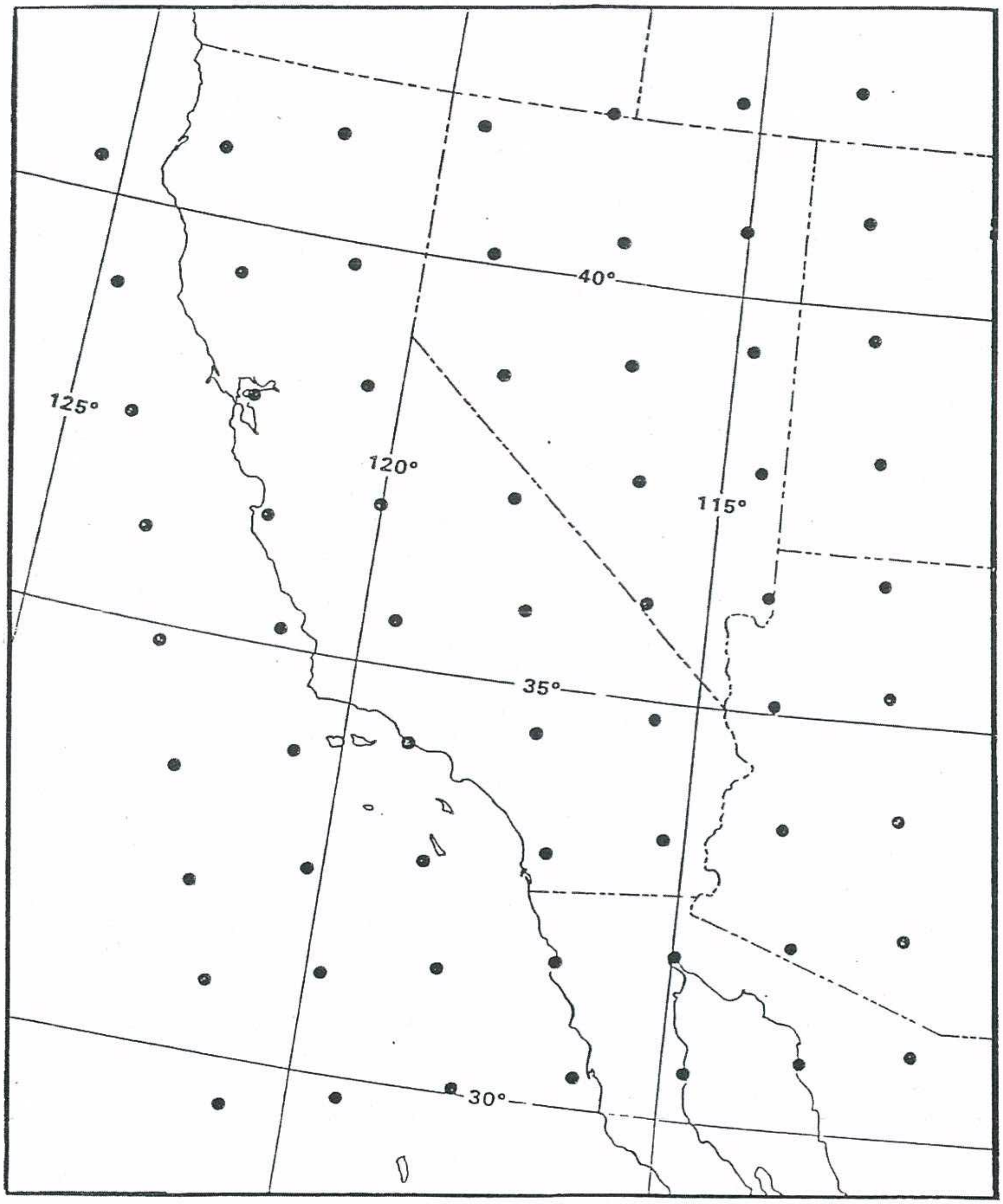

Figure 2. LFM subgrid used for deriving the Santa Ana regime forecast equations.

```
FZUS45 KWBC 02/21/88 0000
SANTA ANA RGM FCST
D/UTC 2100 2106 2112 2118 2200 2206 2212 2218 2300
      WEAK WEAK WEAK WEAK WEAK WEAK STNG STNG NONE
CSTL WND FCSTS-SC
D/UTC 2106 2112 2118 2200 2206 2212 2218 2300
46023 2504 1204 0808 0709 0510 0622 0617 2506
NTD   2903 0902 0705 0602 0412 0524 0618 2106
46025 2702 1403 0606 0507 0609 0617 0810 2305
NTK   2004 1202 1304 0906 0608 0415 0610 2403
NSI   9999 9999 0503 0405 9999 9999 0708 2804
NUC   2705 1602 1203 0905 0708 0612 1004 2104
```

Figure 3. Sample bulletin with Santa Ana regime forecast.

```
FZUS45 KWBC 06/26/88 1200
SANTA ANA RGM FCST
D/UTC 2612 2618 2700 2706 2712 2718 2800 2806 2812
      NO SANTA ANA REGIME FORECAST
CSTL WND FCSTS-SC
D/UTC 2618 2700 2706 2712 2718 2800 2806 2812
46023 2504 1204 2703 2403 1803 0000 2705 2606
NTD   1805 2604 0603 1205 1809 2604 3501 0802
46025 2404 2203 2604 2004 1604 0000 2802 2505
NTK   1001 2606 2506 1803 0402 2608 2406 1802
NSI   9999 0502 3004 9999 9999 0000 2804 9999
NUC   2303 2102 2405 2103 1702 0000 2104 2707
```

Figure 4. Sample bulletin with no Santa Ana regime forecast.