[Reprinted from BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY, Vol. 29, No. 6, June, 1948, pp. 294–297.]
Printed in U. S. A.

California Stratus Forecasting Correlations, 1935 and Other Years*

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ONE OF THE MORE INTERESTING articles on California stratus † is that published in the February 1938 issue of the *Bulletin of the American Meteorological Society* by Petterssen, entitled "On the Causes and the Forecasting of the California Fog." In that discussion it was concluded that stratus at San Diego is of a convective nature and that therefore certain relationships may be expected. For example, the base of the stratus layer should coincide with the condensation level of the surface particles. Also, stratus could only be present when the condensation level of the surface air particles is lower than the base of the inversion. Thus, if the base of the inversion be assumed to be the cloud top, then the difference in height between the inversion base and the condensation level (BI–LCL) should correspond to the cloud thickness. Petterssen's data show: (*1*) that all cases of unbroken stratus occurred when the condensation level was below the base of the inversion, (*2*) that scattered stratus occurred when the condensation level was close to the base of the inversion, and (*3*) that all cases without stratus occurred when the condensation level was higher than the base of the inversion.

Petterssen suggested that, if stratus is of a convective nature, it should burn off early when the distance BI–LCL is small (thin stratus layer) and late when this distance is large (thick stratus layer). He mentioned that the time stratus breaks depends on other factors as well as upon cloud thickness. For example, when the inversion base is high the diurnal amplitude of temperature at any level below the base will be small and the effect of this small temperature variation upon dissolving of stratus will not be as great as the effect of the larger temperature variation which occurs with a lower inversion.

If the thickness of the stratus depends upon the height of the inversion base and upon the height of the condensation level, the normal variation of these two quantities is important. Petterssen computed their average diurnal variation and stated that the diurnal variation in the height of the inversion base was negligible. However, he presented data which indicated that the direction of the air current under the inversion brought about significant non-diurnal changes in the height.

Since Petterssen's study was made, the radiosonde has been placed in service and much additional data now are available. Some of these data have been collected at Scripps Institution for use in a fog-forecasting project under the Office of Naval Research. The data for San Diego have been compiled in a form similar to that used by Petterssen in order that a comparison may be made between his results using 1935 data and results using similar data from 1943, 1944, and 1945.

If the correlations noted in 1935 could be assumed to hold for all years, the forecasting of California stratus would be much simplified. However, it appears that Petterssen's study was based upon a relatively short period (57 days) when weather conditions were unusually stagnant and that the correlations worked out for this period cannot be assumed to hold as well in other periods. The same general tendencies appear, but they are not always as marked.

For first comparison, other periods of approximately the same length and weather conditions as the period in 1935 were selected. These periods were July 10 through September 12, 1944, and June 9 through

* (Prepared at Scripps Institution of Oceanography, University of California, August 8, 1947. The work represents results of research carried out for the Office of Naval Research, Navy Department, under contract with the University.) Contribution from the Scripps Institution of Oceanography, New Series, No. 370.

† In accordance with common usage the term 'California Fog' was used by Petterssen although he stated that the term 'California Stratus' would be more adequate. The latter is used here except in direct quotations from Petterssen.

August 3, 1945. To increase the number of observations for the statistical study, the three six-month periods from May through October in 1943, 1944, and 1945 were also used.

Cloud thickness was calculated in accordance with Petterssen's method by subtracting the height of the lifting condensation level (LCL) from the height of the inversion base (BI). Following are correlation coefficients relating calculated thickness of overcast at the time of the morning raob with hour of breaking of the overcast:

1935*	0.84	1943 (6 months)	0.36
1944 (65 days)	0.47	1944 (6 months)	0.17
1945 (56 days)	0.13	1945 (6 months)	0.05

* All 1935 data are reproduced from Petterssen's discussion. Computations for 1943, 1944, and 1945 were carried out by Miss Margaret Culbertson.

TABLE I shows the relation between calculated cloud thickness and observed sky cover below the inversion at time of the morning sounding.

TABLE II gives the average diurnal surface-temperature range at Lindbergh Field corresponding to given morning inversion heights.

A comparison between average lifting condensation levels at 0600 and 1500 PST, which are near the time of minimum and maximum respectively, is given in TABLE III.

A tabulation was made to show the average height of inversion base with different surface wind directions, see TABLE IV.

Finally, the average variation in height of inversion base between morning and evening observations was computed and found to be 104 meters duinrg the 65-day

TABLE I.—FREQUENCIES OF SKY COVERS BELOW THE INVERSION AT DIFFERENT VALUES OF CALCULATED CLOUD THICKNESS (BI-LCL)

(BI-LCL) (100s of meters)	Sky Cover at Raob Time: 1935			1944 (65 days)				1945 (56 days)				1943–45 (18 months)			
	O[1]	S[3]	C[4]	O	B[2]	S	C	O	B	S	C	O	B	S	C
>12 —												11		4	1
11 to 12												5	1	1	
10 to 11															2
9 to 10												5		1	
8 to 9												3		1	
7 to 8								1				9	3		
6 to 7								1				12	2	2	
5 to 6				3				1	1			19	2	1	
4 to 5				3				1				24	3	1	4
3 to 4	3			9				10				57	7	3	3
2 to 3	9	1		16		1		6		1		65	4	3	2
1 to 2	7			17	1	1	1	9			2	92	4	4	7
0 to 1	8	5		4	1		1	9		1	1	49	3	3	10
−1 to 0				1	1		3	3				16	5	1	10
−2 to −1				5				2		1	1	4	4	2	9
−3 to −2				4				1			2	2	1	2	7
−4 to −3				2			1						1		9
<−4				12									1		23

[1] O = overcast; [2] B = broken (.6–.9 sky covered); [3] S = scattered (.1–.5); [4] C = clear.

period in 1944, 106 meters during the 56-day period in 1945, and 90 meters for the eighteen-month period consisting of the six summer months from May through October in each of the three years 1943, 1944, and 1945. Thus the diurnal variation was at least twice that (40 meters) quoted by Petterssen.

TABLE II.—AVERAGE DIURNAL SURFACE TEMPERATURE RANGE WITH DIFFERENT HEIGHTS OF INVERSION BASE

Morning Height of Inversion Base (meters)	Diurnal Surface-Air-Temperature Range (°F)			
	1935	1944 (65 days)	1945 (56 days)	1943–45 (18 months)
0– 50	23	20 (1)†	— (0)	22 (31)
0– 100	17	20 (4)	— (0)	22 (38)
100– 200	14	20 (2)	13 (5)	18 (41)
200– 300	10	15 (5)	11 (4)	15 (41)
300– 400	9	16 (13)	13 (9)	15 (67)
400– 500	7	13 (7)	12 (8)	14 (62)
500– 600	7	12 (11)	11 (13)	12 (67)
600– 700	7	13 (8)	10 (4)	12 (48)
700– 800	8	12 (5)	8 (2)	12 (27)
800– 900	1	12 (5)	10 (4)	12 (35)
900–1000		12 (2)	10 (1)	11 (19)
1000–1100		11 (1)	— (0)	11 (23)
1100–1200			11 (1)	11 (15)
1200–1300			10 (2)	11 (11)
1300–1400			14 (1)	11 (3)
1400–1500				11 (5)
1500–2000				12 (22)
2000–3000				13 (6)

† Figures in parentheses indicate number of cases.

Sea-surface isotherms for particular times based on data collected by the *E. W. SCRIPPS* show patterns in the San Diego area which are quite different from the patterns of average isotherms of Thorade which Petterssen used. For an example, see the chart for August 16–26, 1938, FIGURE 1. Observations were made where dots appear. Many cruises have shown that the pattern of isotherms in FIGURE 1 is not unusual but that its main features are typical of the area covered. Upon the 1938 isotherms in FIGURE 1 are superimposed in dashed lines the isotherms of Thorade which were included in Petterssen's study.

TABLE III.—AVERAGE LIFTING CONDENSATION LEVEL AT 0600 AND 1500 PST

Time	Average Lifting Condensation Level (meters)			
	1935	1944 (65 days)	1945 (56 days)	1943–45 (18 months)
0600	500	316	353	378
1500	963	905	866	924

It is apparent that a pattern of sea-surface isotherms such as that which existed in August, 1938 would have considerable influence on formation and dissipation of stratus and upon the ceiling height. With westerly or northwesterly airflow, since cloudiness increases and ceiling lowers when there is surface cooling, it would be expected that the regions where the sea-surface temperature is below 63°F would have more extensive cloud cover and lower ceilings than the region just west of San Diego where the sea temperatures are as high as 70°. If a sufficiently thick layer of stratus were formed over the region of coldest water, the layer might be carried to San Diego before being entirely dissipated by the heating from below. The ceiling would gradually rise as the air moved toward San Diego and the cloud cover would extend inland for a distance which would depend on the temperature of the land surface, the tempera-

TABLE IV.—AVERAGE HEIGHT OF INVERSION BASE WITH DIFFERENT WIND DIRECTIONS

Wind Direction	Average Height of Inversion Base (meters)			
	1935	1944 (65 days)	1945 (56 days)	1943–45 (18 months)
N	210	437 (41)	503 (20)	518 (280)
E	200	600 (8)	538 (18)	692 (111)
S	640	657 (17)	559 (14)	708 (122)
W	450	490 (27)	478 (18)	641 (193)

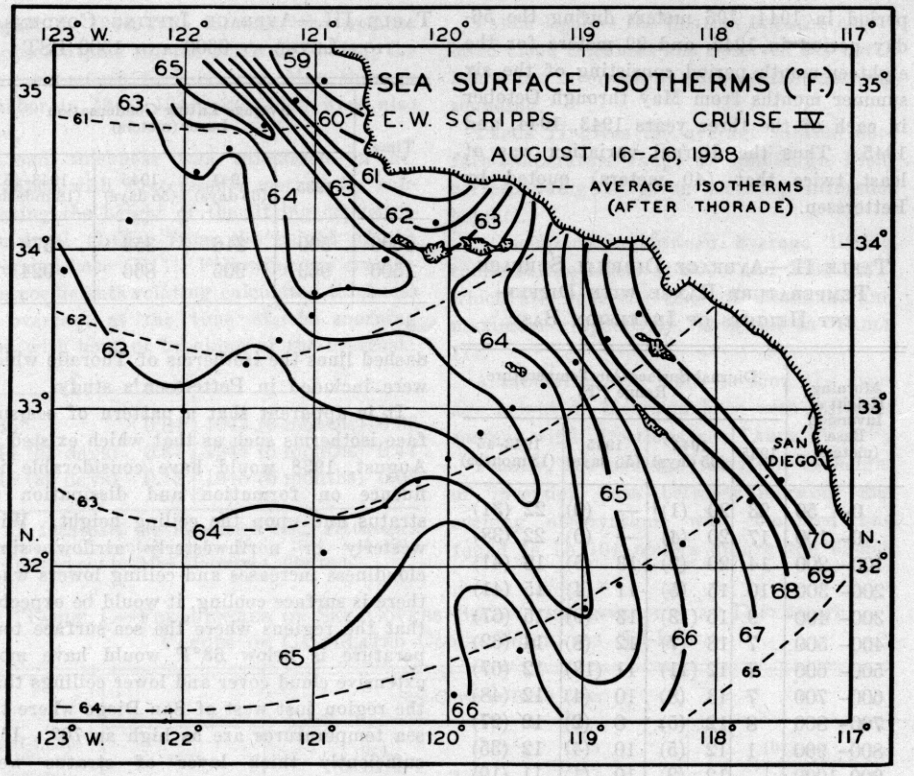

FIGURE 1

ture of air above it, and the strength of the onshore airflow.

The new sea-surface temperature data indicate that the role of this factor in stratus formation should be re-evaluated. It has been evaluated for surface fog at San Diego and the results summarized in a recent Scripps Institution Oceanographic Report titled "Sea Surface Temperature Variations Influencing Fog Formation in Southern California."

The compilations and comments above serve to strengthen some of the arguments presented by Petterssen and to weaken others. They indicate that the problem of stratus forecasting is not a simple one but is one which requires further intensive investigation. Indications are that some of the results of the fog-forecasting project at Scripps Institution will be applicable to stratus.