

# ALTITUDE ERRORS DUE TO REFRACTION (\*)

by

LIEUT.-COMMANDER P. V. H. WEEMS, U. S. NAVY.

For average conditions of the atmosphere errors in the observed sextant altitude due to refraction are extremely small. In fact, under *average* conditions excellent results may be obtained with altitudes under five degrees. The Japanese Hydrographic Department has perhaps done more than any other agency to determine accurately the error due to refraction, and to publish tables for making suitable corrections.

A unique opportunity was afforded the writer to investigate a case of excessive refraction when the observed altitude was greater than  $35^{\circ}$ , and when the temperature and air pressure were apparently normal. The excessive refraction caused a distinct mirage with inverted images. The refraction errors were doubtless caused by smoke and dust from a forest fire and from a desert sand storm. The conditions encountered might parallel those along the shores of Arabia and further explain and substantiate the reports of excessive refraction errors in that locality.

Doubtless many navigators arrive at an erroneous "fix" due to the erratic effects of refraction. Seldom, however, is he in a position to get a careful check on the error caused by refraction. A unique opportunity offered itself to nail the lie of the false horizon on 6 March 1933 as the destroyer force stood out of San Diego harbor. Someone noted that the Coronados Islands resembled an aircraft carrier in company with several smaller ships. This unusual condition resulted from a peculiar mirage along the sea horizon. The sea was calm with light airs from the North, temperature  $64^{\circ}$  F., barometer 29.97, wet bulb  $56^{\circ}$  F., sky clear, with a fringe of smoke and haze 1 degree high along the horizon. A forest fire raged about 50 miles North of Coronado and the smoke from it spread along the horizon from North to West and Southwest. Also, a sand storm, or "Santa Ana", had been blowing off the desert about 50 to 75 miles North of the observer's position.

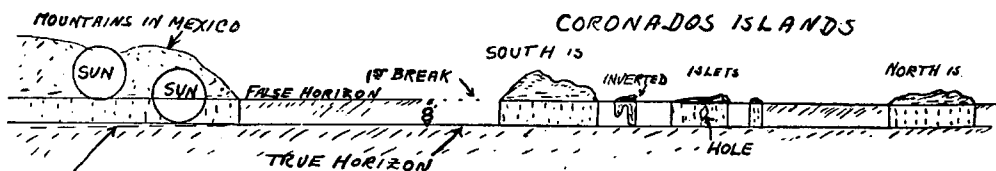


FIG. 1 MIRAGE FROM SAN DIEGO HARBOR 0920, 6 MARCH 1933

(\*) NOTE: The opinions and assertions in this article are the private ones of the writer, and are not official. — P. V. H. W.

As is the case with the usual mirage, it changed every few minutes. The condition at 0920, as viewed from the whistling buoy which is 13 miles from the islands, is shown in Fig. 1. North Coronado Island resembled an aircraft carrier shortly before this time. The horizon was raised 8' as measured by sextant. This was made especially noticeable by the fact that the islands stood out of the water as indicated. Without the islands to give a reference mark, it would have been difficult to detect the fact that there was a distinct false horizon 8' above the true one. Only by careful observation was the true horizon noticeable, yet with a careful observation with binoculars it was seen to be sharp and distinct.

DATE	← 6	MARCH	1933	→
Body	←	SUN		→
GCT	17-32-35	17-34-02	18-02-13	18-03-15
GHA	72-08.8	72-08.8	87-09	87-09
CORR	8-08.8	8-40.5	33	48.8
GHA	80-17.6	80-49.3	87-42	87-57.8
LONG	117-15.5	117-15.5	117-21	117-21.0
LHA	36-57.9	36-26.2	29-39	29-23.2
DEC	5-38.85	5-38.2	5-37.8	5-37.8
LHA - A	22-08.7	22-6.30	30-5.66	39-9.23
DEC - B	210	210	210	210
R - A	22-29.7	22-8.40	30-7.76	31-1.33
DEC - A	100-806	100-806	100-806	100-806
R - B	9628	9321	6027	5913
K - A	91178	91475	94779	94823
K	7-02.05	6-59.5	6-28.6	6-27.5
LAT	32-38.0	32-38.0	32-39.0	32-39.0
K ~ L	39-40	39-37.5	39-07.6	39-06.5
K - B	11364	11338	11027	11016
R - B	9638	9329	6027	5913
Hc - A	20992	20667	17054	16929
Hc	38-04.5	38-2.5	42-28.4	42-37.5
Hc	38-02.7	38-18.2	42-26.8	42-33.4
a	1.88	6.88	1.68	4.18
HORIZON	TRUE	FALSE	TRUE	FALSE
R - A	22-29.7	22-8.40	30-7.76	31-1.33
Hc - B	10-39.1	10-9.91	13-2.20	13-32.4
Z - A	11906	11849	17556	17809
Z <sub>n</sub>	130-31	130-26	138-08	138-26
NOTE:	A USED FOR LOG	COSECANT		
	B " " "	SECANT		

Fig. 2. Comparison of observations taken on true and on false horizons.

errors to be expected under similar conditions but with no way of detecting the error. Unfortunately the sun was over land, making it uncertain whether or not a land horizon was used. By checking the distance, it was found that the land was beyond the visible horizon. The true horizon was not clear under the sun; in fact it appeared to dip as shown by the dotted line in Fig. 1. In taking the sun's altitude, the lower limb was not brought quite as low as it might have been. However, the results of the observations taken on

Some peculiar features were noted about the islands. The top of the second islet from the right, a tiny one which ordinarily could hardly be seen, stood up like a large pillar. There was a hole, or channel, in the middle island which appeared diamond-shaped. Finally, an inverted image appeared on the second islet or rock from the left as shown in Fig. 1. The islet appeared larger at the top than at the bottom. This is the same effect as when a ship on the horizon appears to be upside down due to a mirage. In the latter case the masts and stacks would appear to be resting on the horizon and supporting the hull above it.

At one time the false horizon extended from the West around to Imperial Beach. About 0920, however, a portion of the false horizon cleared away as shown, making it evident that an error would result by using the false or upper horizon. Since the ship's position was accurately known, a series of observations were made in order to determine the nature and extent of the

the two horizons give a difference of 5' as compared with the measured distance of 8' taken about twenty minutes before. A half hour later, with the phenomenon disappearing, another set of observations were taken which gave a difference of 2.4'; Fig. 2 shows the computations as made by H. O. N<sup>o</sup> 211, the Air Almanac and a second setting watch.

The actual observations were as follows:—

G. C. T.	ALTITUDE		
17-31-58	37-47.5	} ON TRUE HORIZON.	} Lat. 32-38 N. Long. 117-15.5 W.
17-32-40	37-53.0		
17-33-07	37-58.0		
<hr/>			
17-32-35	37-52.8	AVERAGE	
17-33-44	37-59	} ON FALSE HORIZON	
17-34-43	38-09		
17-35-39	38-17		
<hr/>			
17-34-42	38-08.3	AVERAGE	
18-01-55	42-14	} ON TRUE HORIZON	} Lat. 32-39 N. Long. 117-21 W.
18-02-14	42-17		
18-02-30	42-19		
<hr/>			
18-02-13	42-16.7	AVERAGE	
18-02-56	42-21	} ON FALSE HORIZON	
18-03-15	42-23		
18-03-35	42-26		
<hr/>			
18-03-15	42-23.3	AVERAGE	

HEIGHT OF EYE, 27 FEET.

I. C. = 0.

SPEED, 12 KNOTS.

COURSE, 345 DEGREES.

TEMPERATURE (DRY BULB) 64 DEGREES F.

(WET BULB) 56 DEGREES F. AT 0900.

BAROMETER 29.97.

The mirage had completely disappeared by about 1000.

