Long-Range Forecasting and Climate Research

A note on the use of voluntary observing fleet data to estimate air-sea fluxes

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A NOTE ON THE USE OF VOLUNTARY OBSERVING FLEET DATA TO ESTIMATE AIR-SEA FLUXES

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D. E. Parker

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A note on the use of Voluntary Observing Fleet data to estimate air-sea fluxes

1. Observed daytime marine air temperatures on board ships are too high because of solar heating of the ship's fabric and sometimes of the screen itself (Figures 1, 2). The effect is, on average, of the order of 1°C. With observations made 4 times a day, at 00, 06, 12, 18 GMT, as has been the case since the Second World War, the effect has been greatest where "daytime" data are in local mid-morning and late afternoon, and "nighttime" data are in local late evening and shortly before dawn, as this captures the spurious diurnal cycle most effectively (Figures 1,2).

2. Biases of marine air temperature resulting from changes in the elevation of the measurement above sea-level are much smaller (Table 1). See also Folland et al (1984) and Bottomley et al (1988).

3. Pre-World War II sea surface temperature observations require instrumental corrections which vary with location and season.

Figure 3 shows the corrections applied by Bottomley et al (1988) to data up to 1900. The corrections applied to data from 1901 until World War II were made more positive by up to 0.04°C because instructions to mariners suggest that buckets were more often kept shaded from sunshine after about 1900. The corrections were chosen to represent the adjustment needed to be applied to the data, assumed to be mainly from uninsulated buckets, relative to the data typical of the period 1951-80, which were from a mixture of engine intake thermometers and mainly insulated buckets, along with a few hull sensors. Therefore they are not strictly absolute corrections for the biases of uninsulated buckets, even though they have been derived with the aid of physical models (Bottomley et al (1988); Folland and Parker (1988)).

4. The observed diurnal cycle of sea "surface" temperature is weaker and slightly more retarded in 1951-80 data, than it is in earlier data (Figure 4). This is mainly because the true diurnal cycle, which attenuates and lags with depth, was being sampled at a greater depth by the engine intake thermometers, which, according to World Meteorological Organization catalogues, were used on between 50% and 60% of ships in 1951-80. There is no known reason for a diurnally-varying bias in engine-intake data or in data from well-insulated buckets. The earlier data may have been affected by sunshine on the uninsulated buckets, but the resultant daytime heating (and consequent enhancement of the observed diurnal cycle) is not, according to the studies of Folland and Parker (1988), expected to have exceeded 0.1°C. Thus Figure 4 indicates, for the equatorial mid-Atlantic, real diurnal cycles of not less than 0.5°C peak-to-trough in the uppermost 0.5 m of ocean sampled by uninsulated buckets (the curves for 1856-80, 1881-1900, 1901-30), and a real diurnal cycle of about 0.35°C on average over the uppermost several metres (the curve for 1951-80). According to a recent questionnaire, engine intakes are mainly at 2 or 3 m but range from 0.5 to 10 m. Modern insulated buckets will have sampled the top 0.5 m.

Table 2 gives the numbers of data used to compute the diurnal cycles. All sea surface temperature data were first converted to anomalies from a version of the Bottomley et al (1988) climatology on 1° latitude x longitude and 5-day resolution, to prevent any bias from arising from geographical variations in sampling.

5. The mean true diurnal cycle of temperature in the uppermost several metres of the open ocean is (according to 1951-80 data) 0.4°C peak-to-trough in some tropical or summer areas, but 0.2° to 0.3°C more generally, and less than 0.1°C in midlatitude winter (Figure 5).

6. Although the observed diurnal cycle of marine air temperature (computed relative to the Bottomley et al (1988) night marine air temperature climatology for 1951-80) is enhanced by the solar heating effect on ships, (Figures 1, 2 and 6), the observed diurnal cycle of dewpoint is apparently almost unaffected by the ship and has approximately the same magnitude as that of sea "surface" temperature for the modern period (Figures 4 and 7).

7. The observed diurnal cycle of marine air temperature is enhanced by the heating effect even in winter (Figure 8), but is reduced when the wind is strong (Figures 9, 10) as expected from the increased ventilation on deck.

8. A study of many individual observations shows that observed marine air temperature (relative to climatology at a given location) depends on wind strength in a nonlinear manner (Figures 9, 10, 11, 12; Tables 3 and 4). This dependence is a function not only of the ventilation on deck but also of the local climatology. For example, in the Northwestern Atlantic in winter the strongest winds are in general from a northwesterly quarter and are associated with advection of very cold air from eastern Canada. Observed sea surface temperature is less sensitive to wind strength (Figures 13, 14, 15). Therefore air-sea fluxes computed from monthly averages, or especially monthly climatologies, of air temperature, dewpoint, sea surface temperature and wind strength are likely to be in error, though the effects are probably not large: of the order of 10% (Esbensen and Reynolds (1981)).

References

Bottomley, M., Folland, C. K., Hsiung, J., Newell, R. E. and Parker, D. E. 1988 Global Ocean Surface Temperature Atlas (GOSTA). A joint project of the Meteorological Office and the Dept. of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology. In Press.

Esbensen, S. K. and Reynolds, R. W. 1981 Estimating monthly averaged air-sea transfers of heat and momentum using the bulk aerodynamic method. J. Phys. Ocean., 11, 457-465.

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Table 1

Elevation corrections to global night marine air temperature (using Ri = -0.01, V = 6 m/sec).

Period	Assumed Deck Elevation	Correction (relative to 1951-80)
up to 1900	6 m	-0.15 C
1901-15	10 m	-0.09 C
1916-60	14 m	-0.02 C
1961-70	15 m	NIL
1971-75	16 m	+0.01 C
1976 onwards	17 m	+0.02 C

Table 2

Numbers of observations used in computing diurnal cycles

Figure		Number of observing hours	Number of observations for observing hour per curve
4	1856-80	6	3200- 5400
	1881-1900	6	2700- 2900
	1901-30	6	9400-10500
	1951-80	4	27300-29400
5a		4	2300- 4600
b		4	1800- 3500
c		4	41- 107
d		4	9000-11500
e		4	6700-10000
f		4	5800- 7600
g		4	336- 419
h		4	8900-10600
i		4	480- 660
j		4	5700- 6800
k		4	4600- 5300
l		4	900- 1220
6		4	30100-33500
7		4	26000-30700
8	1856-80	6	213- 232
	1881-1900	6	2100- 2200
	1901-30	6	7900- 9700
	1951-80	4	21900-23900

Table 3 Numbers of observations used in relating sea surface temperatures and marine air temperatures to wind strength

Figure		Beaufort Force										
		0	1	2	3	4	5	6	7	8	9	10
9	Day	5433	8579	19304	26220	23053	9282	3308	809	143		
	Night	6568	8484	20605	26282	19376	7280	2442	660	123		
10	Day	2515	4116	11927	20053	23416	15860	9702	5008	2327	459	
	Night	3463	4072	11938	20022	21654	13705	8203	4204	1858	391	
11	1856-80	74	174	465	752	1193	1483	1436	951	656	430	255
	1881-1900	325	744	1570	2956	4460	5096	4321	3409	1814	1085	587
	1901-30	856	1986	6360	12321	17796	19053	18127	14493	9486	5322	2970
	1951-80	1826	4003	14585	37420	61683	59471	54293	43236	32078	10711	5587
12	1856-80	189	498	1102	1814	2241	2154	1161	623	183	50	
	1881-1900	729	1814	3736	6034	6927	5354	2502	1103	341	117	
	1901-30	3281	7792	18131	26862	26325	16715	8726	3474	1341	354	
	1951-80	10722	20596	51854	95609	106262	60037	28958	10427	3295	511	
13	1856-80	63	141	405	673	1040	1254	1210	789	571	362	216
	1881-1900	323	724	1608	3032	4545	5112	4302	3393	1807	1071	571
	1901-30	850	1953	6310	12247	17700	18942	17957	14407	9385	5192	2910
	1951-80	1630	3482	12978	33495	54937	52859	48026	38046	27954	9258	4861
14	1856-80	161	447	954	1560	1964	1849	990	516	164	50	
	1881-1900	757	1788	3760	5973	6770	5211	2474	1111	334	123	
	1901-30	3405	8181	18854	27947	27085	17147	8874	3528	1346	360	
	1951-80	9807	18599	47022	87451	97476	55107	26608	9500	2990	457	
15	1856-80	581	1583	3131	5914	7884	4798	1004	119			
	1881-1900	652	2278	3502	4997	3447	1362	244	37			
	1901-30	3027	6498	13625	17984	12354	4193	740	92			
	1951-80	10825	18958	30851	35776	23145	4671	750	92			

Table 4

Beaufort Force	Mean speed (m/sec) (10 m above ground)
0	0.0
1	0.8
2	2.4
3	4.3
4	6.7
5	9.3
6	12.3
7	15.5
8	18.9
9	22.6
10	26.4
11	30.5

Figure 1. Day minus night marine air temperature observed on board ships, January 1951 to 1980 (contours every 0.5 °C)

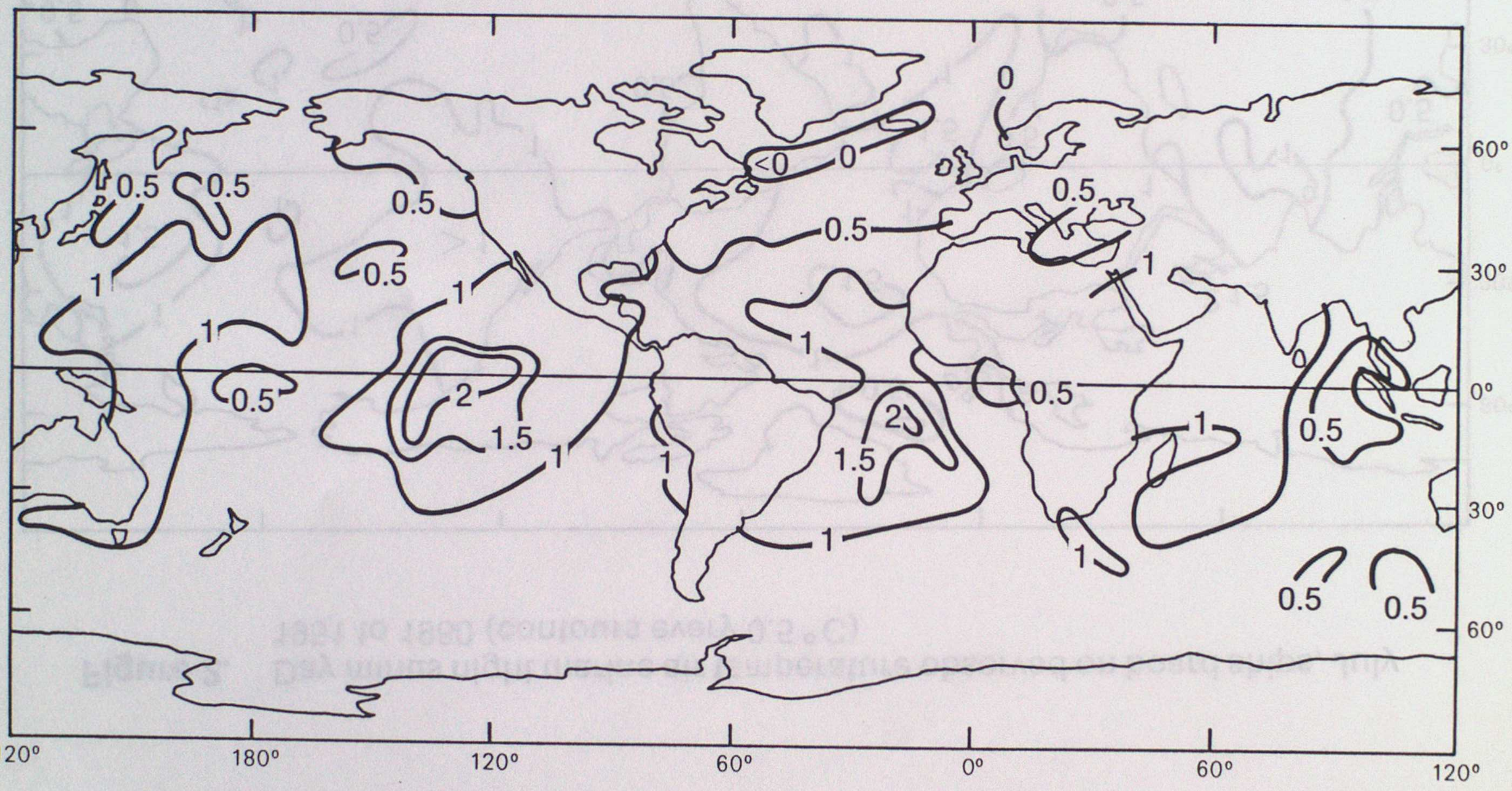
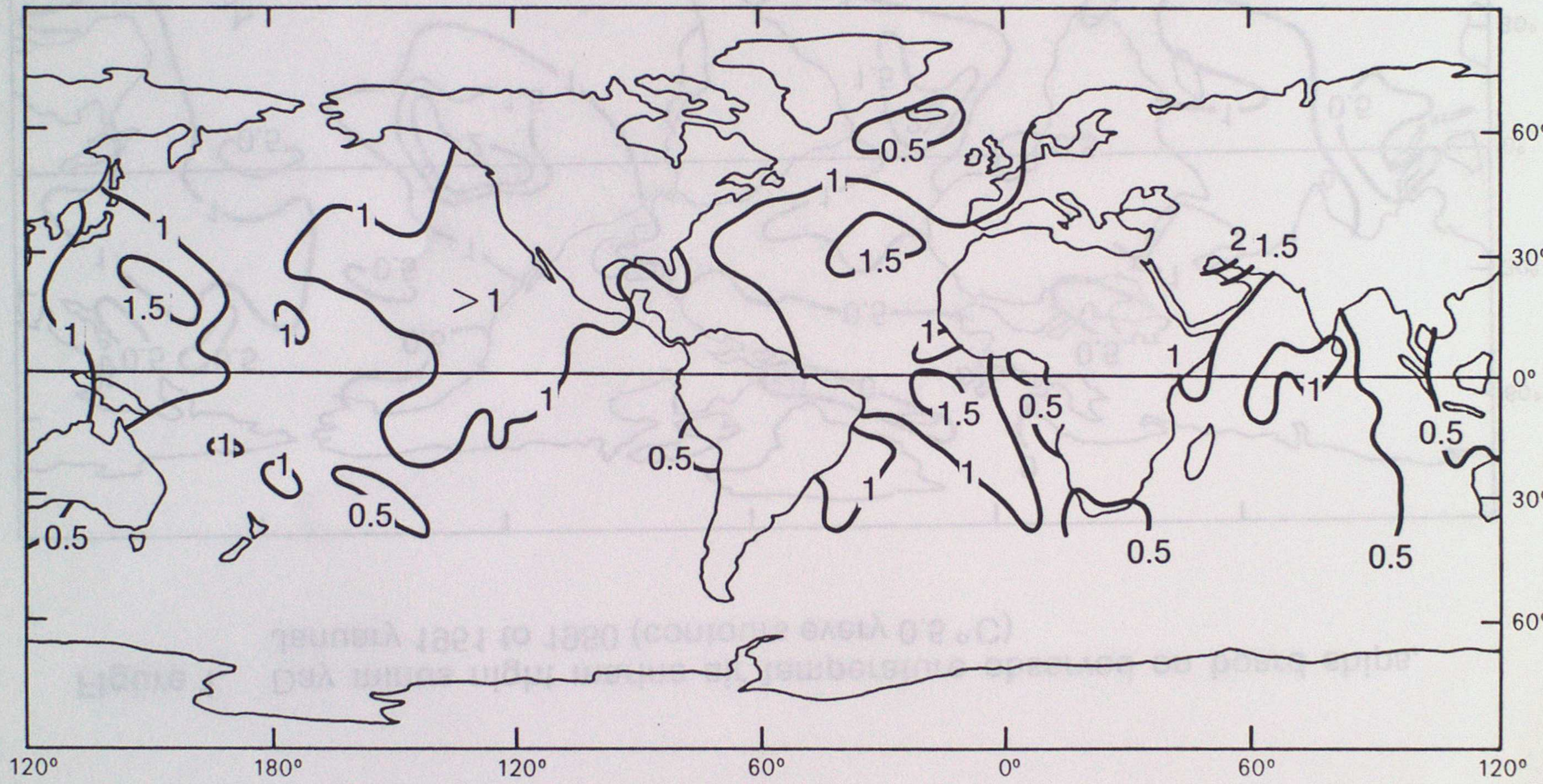


Figure 2. Day minus night marine air temperature observed on board ships, July 1951 to 1980 (contours every 0.5 °C)



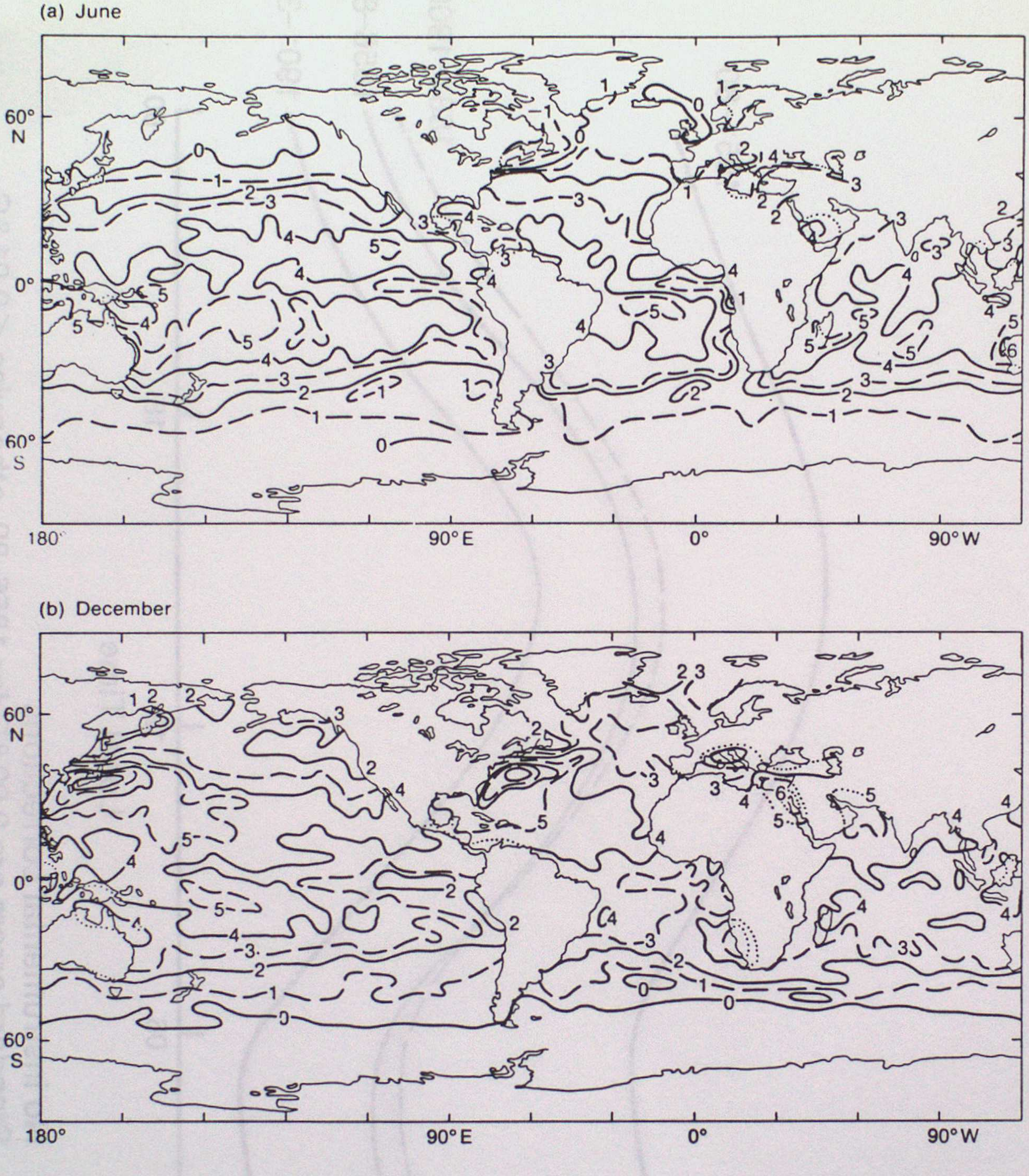
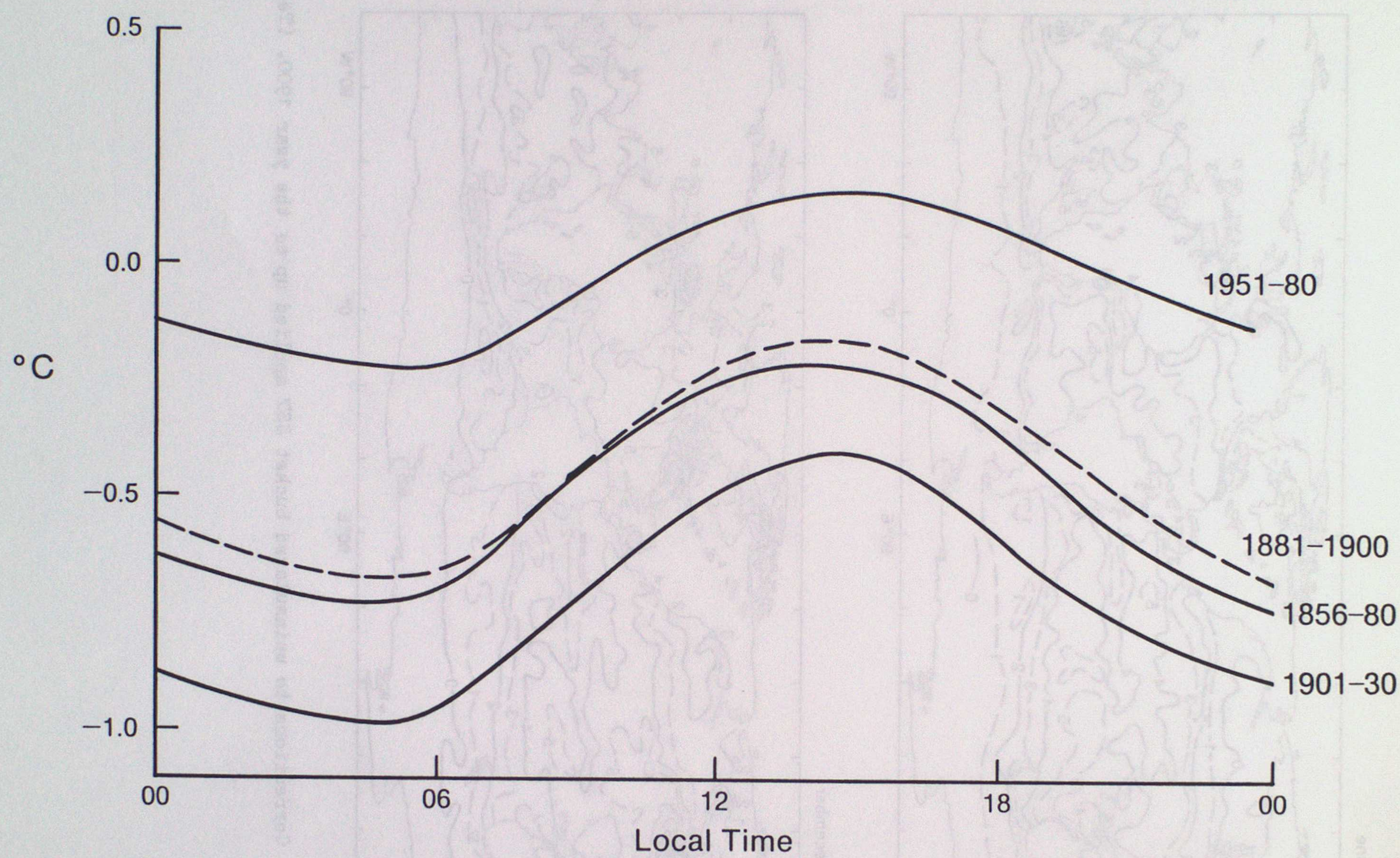


Figure 3. Corrections to uninsulated bucket SST applied up to the year 1900. (Tenths °C).

Figure 4. Diurnal cycles of observed sea surface temperature (anomaly w.r.t. 1951–80 all-hours climatology), 10° N–10° S, 10–30° W, Dec.–Feb.



No instrumental corrections

Standard errors are 0.02 °C for 1856–80, otherwise < 0.01 °C

Figure 5. Diurnal cycles of sea surface temperature anomaly, 1951–80, for January (×—×), April (+– –+), July (○·····○) and October (△–·–△)

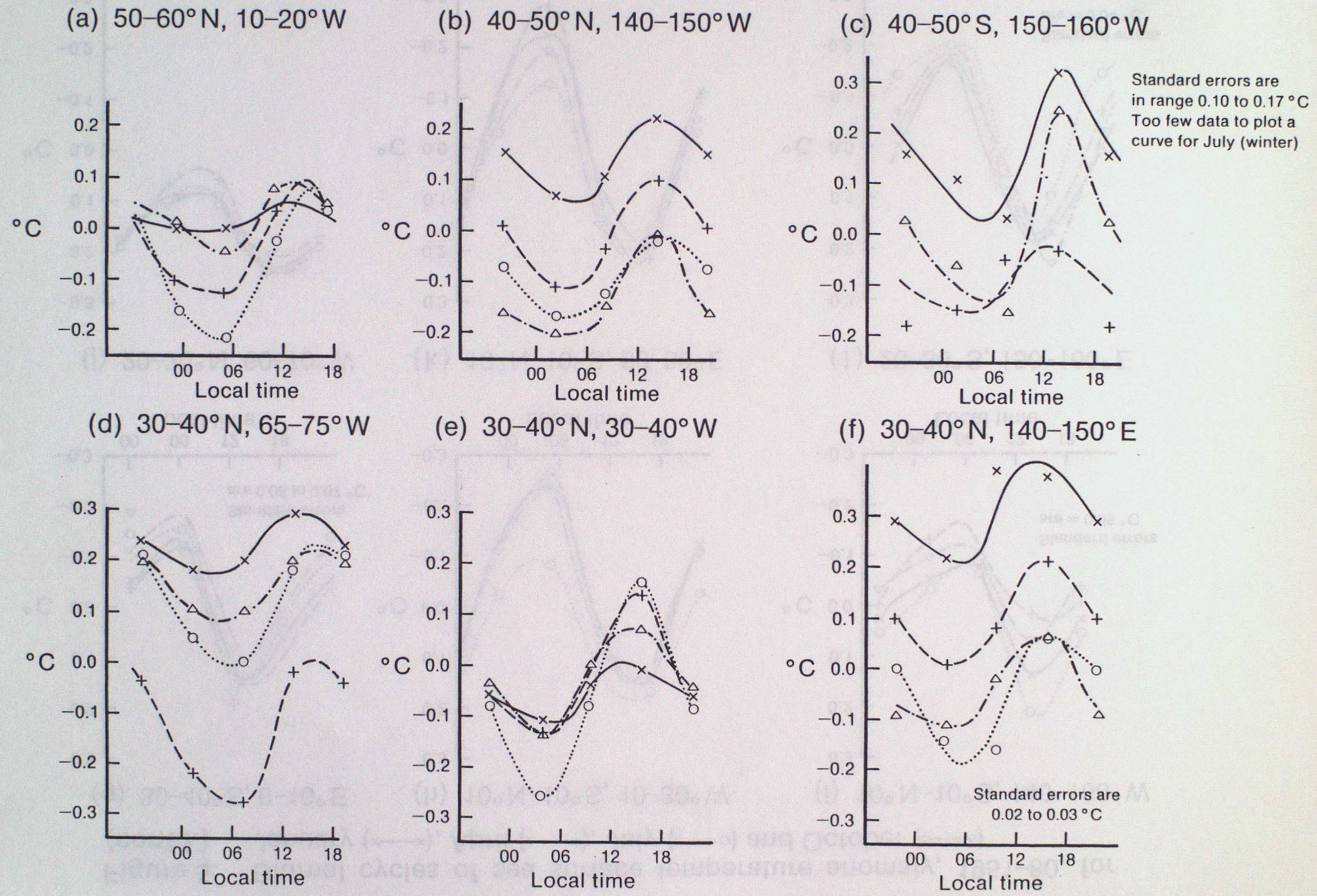


Figure 5. (contd.) Diurnal cycles of sea surface temperature anomaly, 1951–80, for January (×—×), April (+– –+), July (○·····○) and October (△–·–△)

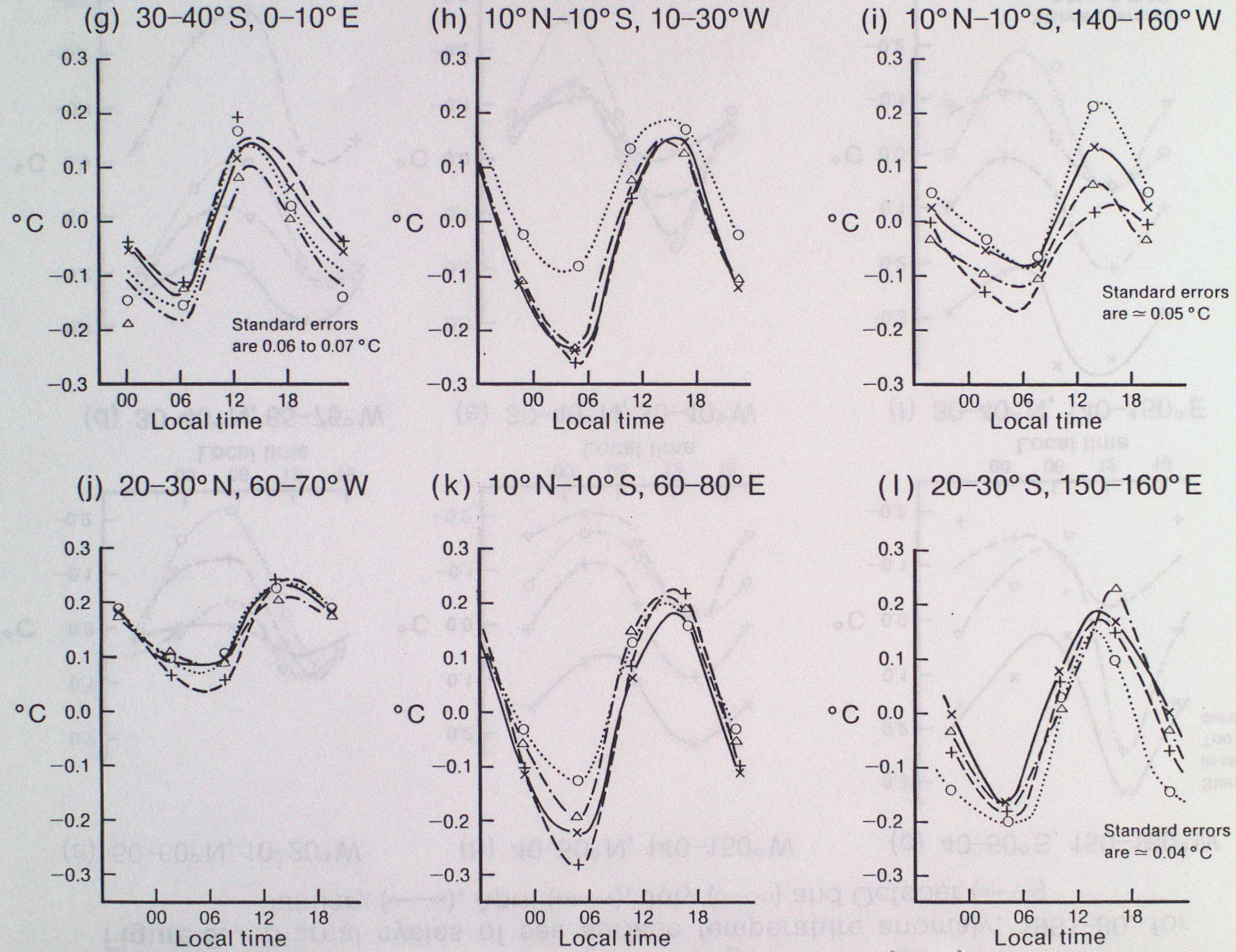


Figure 6. Diurnal cycle of observed marine air temperature (w.r.t. night-time climatology), 10° N–10° S, 10–30° W, 1951–80

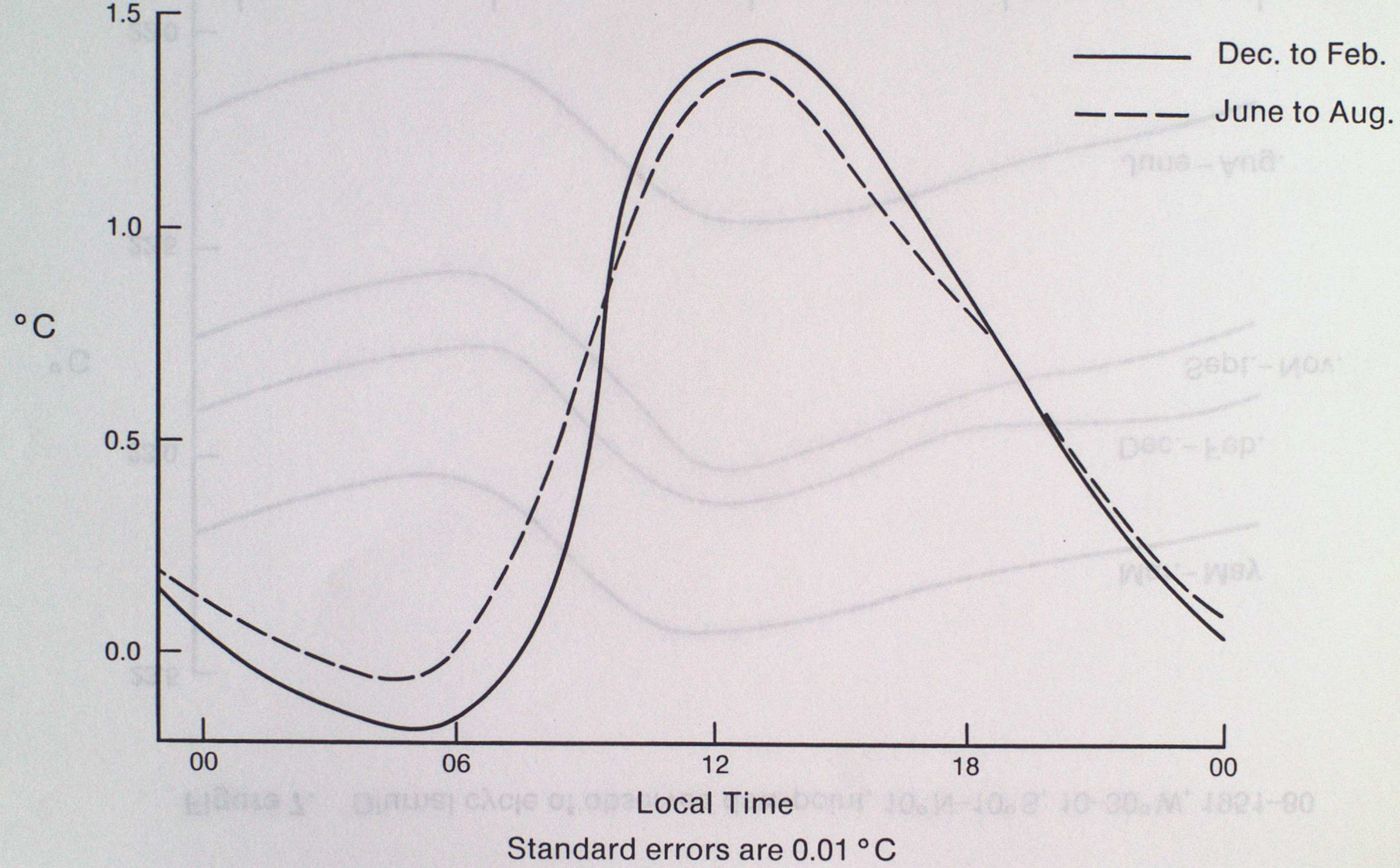
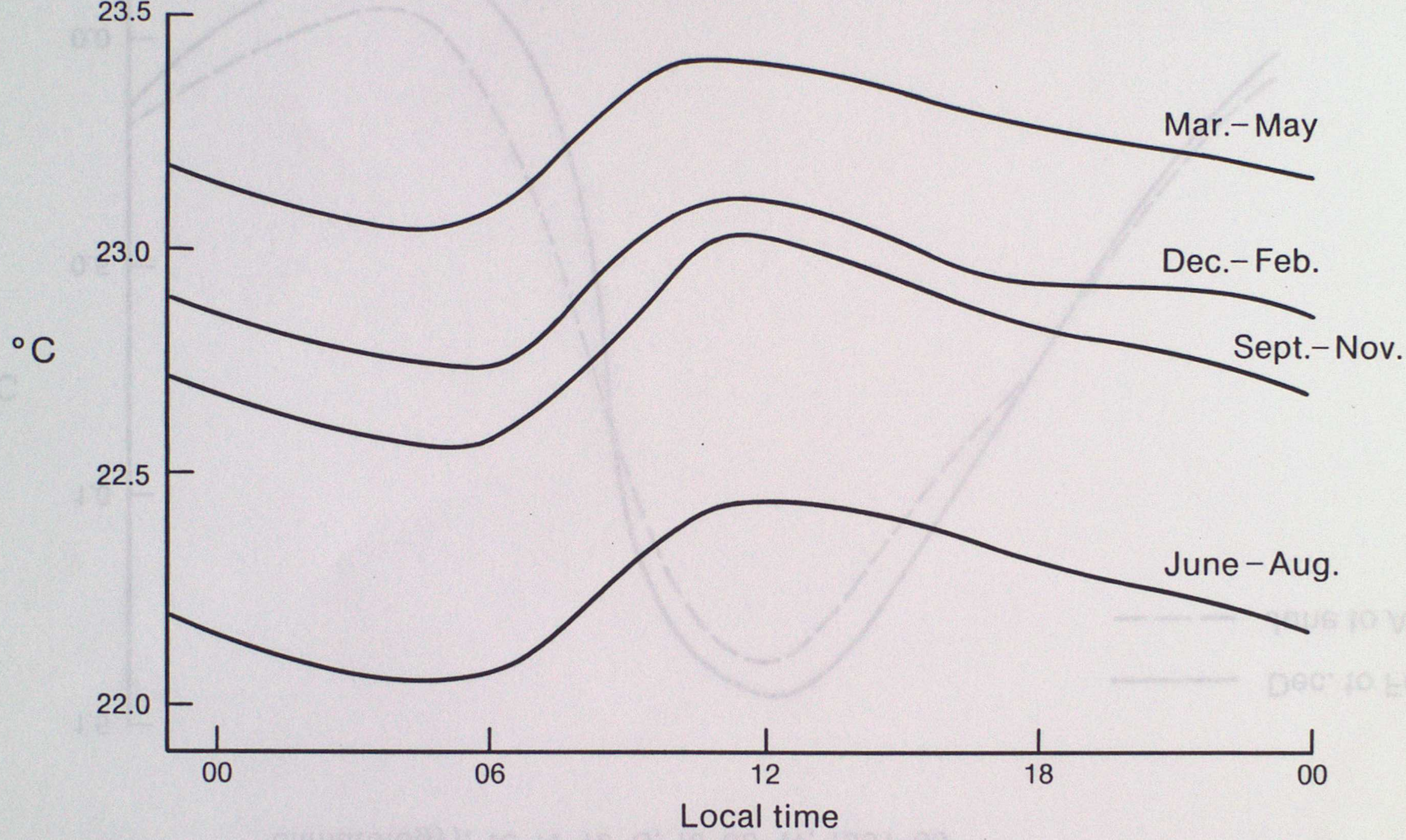


Figure 7. Diurnal cycle of observed dew-point, 10° N–10° S, 10–30° W, 1951–80



Standard errors are 0.01 °C

Figure 8. Diurnal cycles of observed marine air temperature (w.r.t. 1951–80 night-time climatology), 40–45° N, 50–70° W, Dec.–Feb.

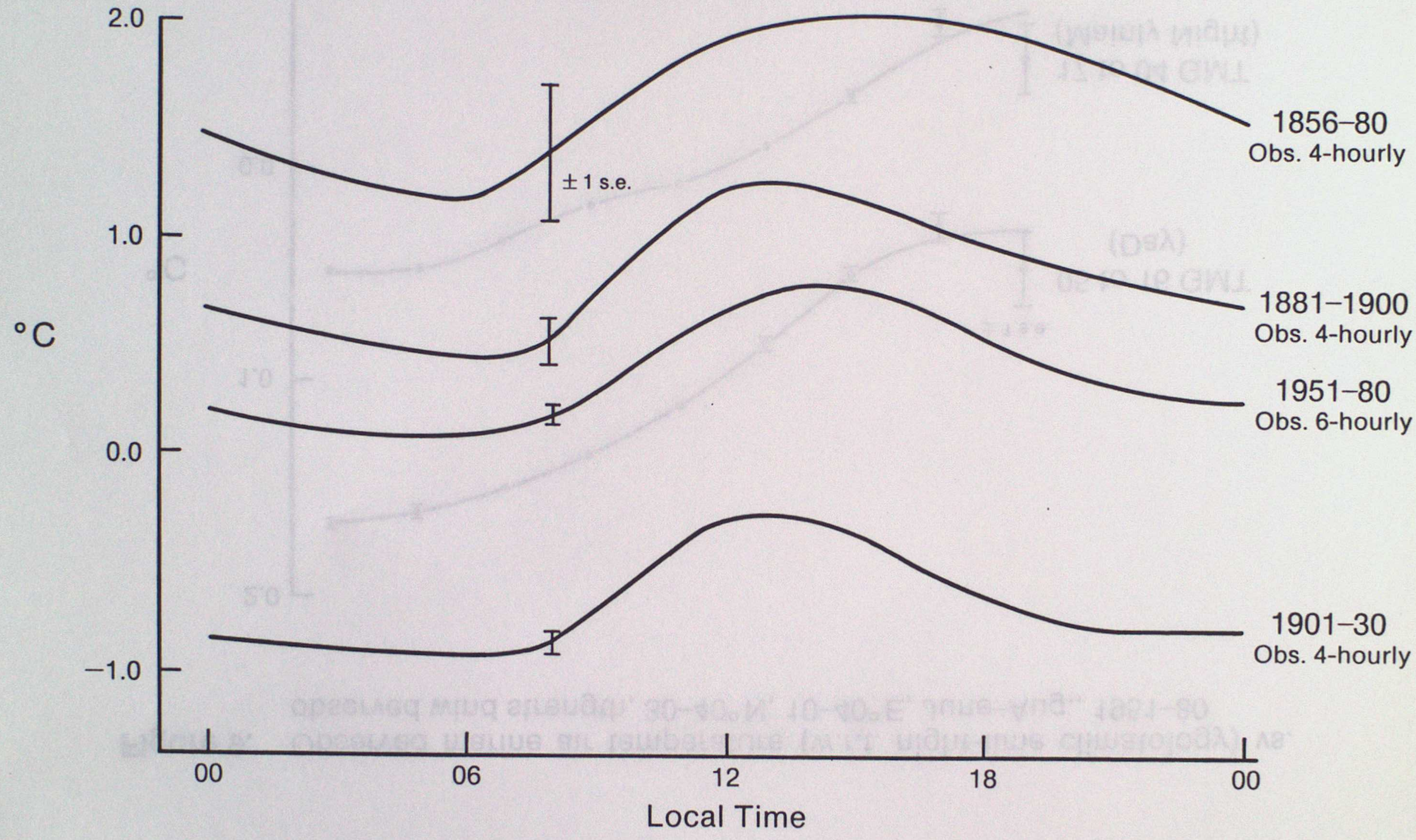


Figure 9. Observed marine air temperature (w.r.t. night-time climatology) vs. observed wind strength, 30–40° N, 10–40° E, June–Aug., 1951–80

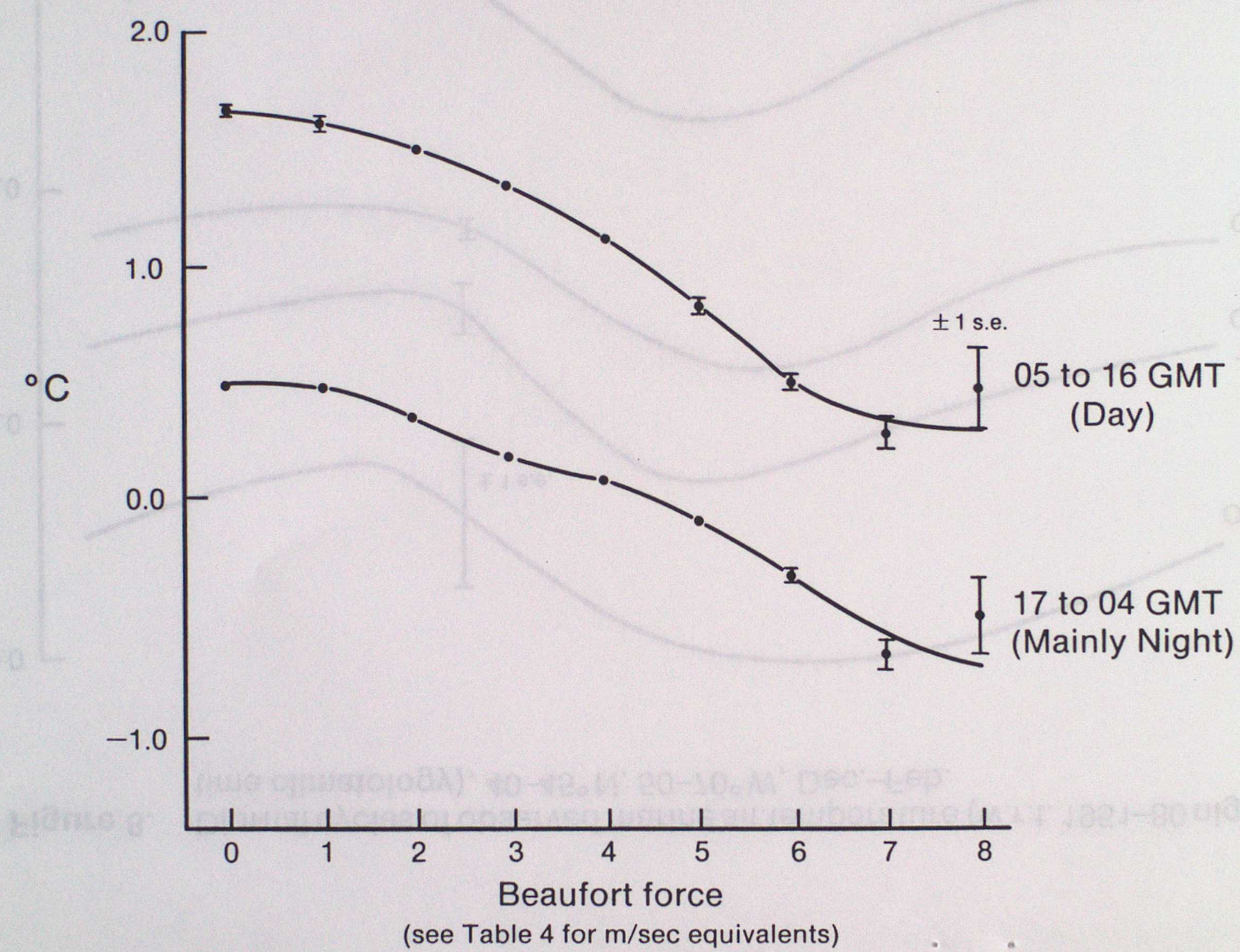


Figure 10. Observed marine air temperature (w.r.t. night-time climatology) vs. observed wind strength, 30–40° N, 10–40° E, Dec.–Feb., 1951–80

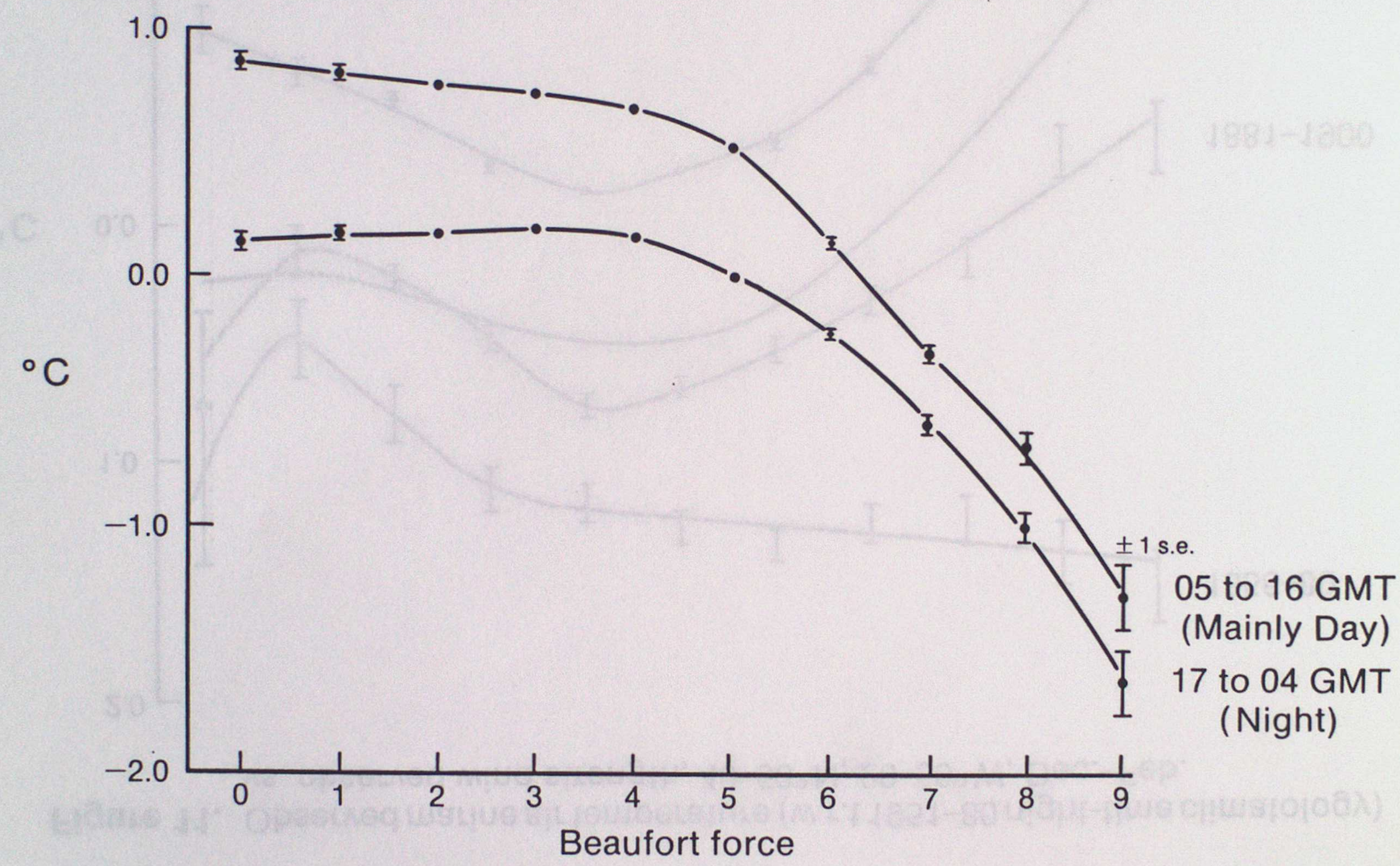


Figure 11. Observed marine air temperature (w.r.t 1951–80 night-time climatology) vs. observed wind strength, 40–50° N, 20–50° W, Dec.–Feb.

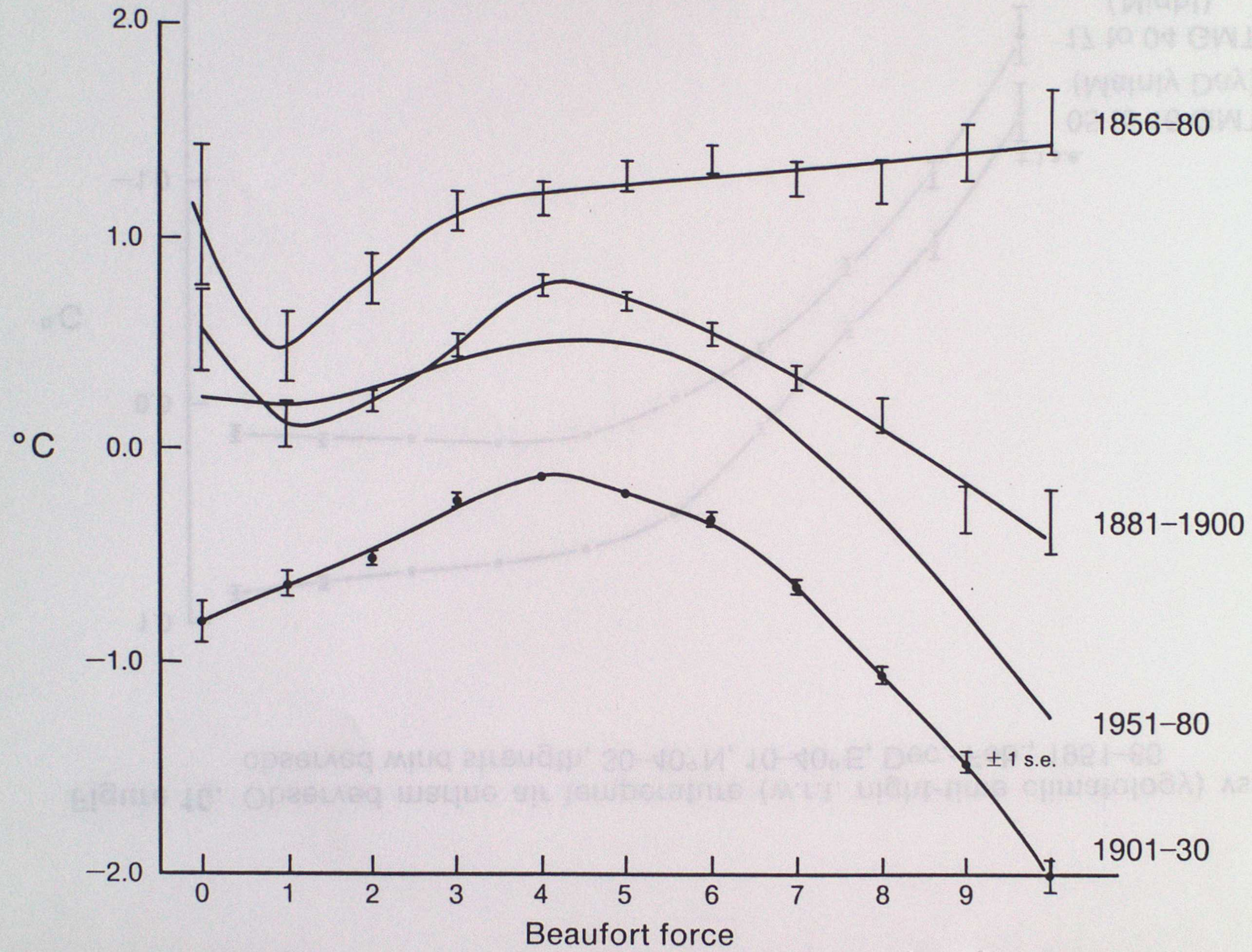


Figure 12. Observed marine air temperature (w.r.t. 1951–80 night-time climatology) vs. observed wind strength, 40–50° N, 20–50° W, June–Aug.

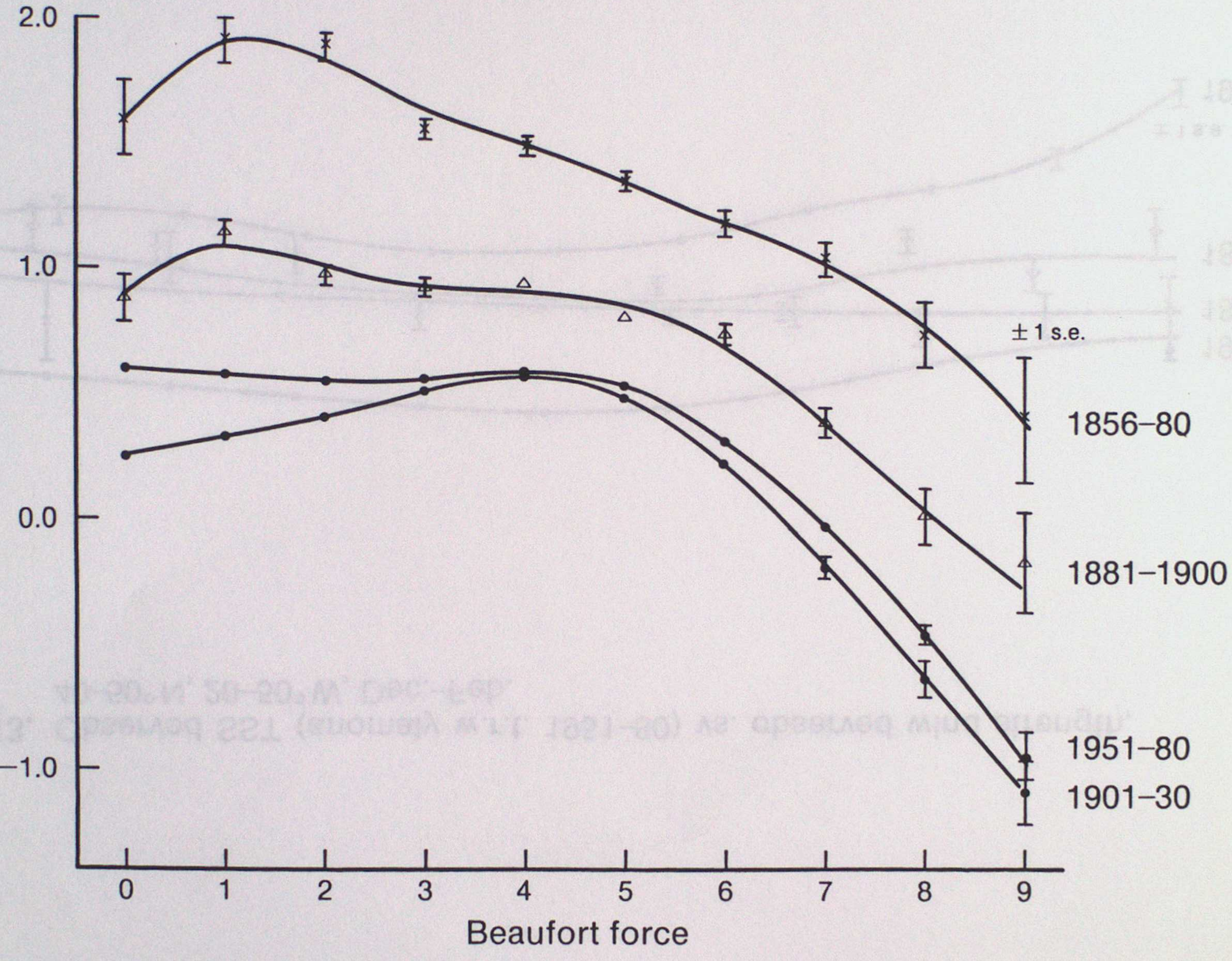


Figure 13. Observed SST (anomaly w.r.t. 1951–80) vs. observed wind strength, 40–50° N, 20–50° W, Dec.–Feb.

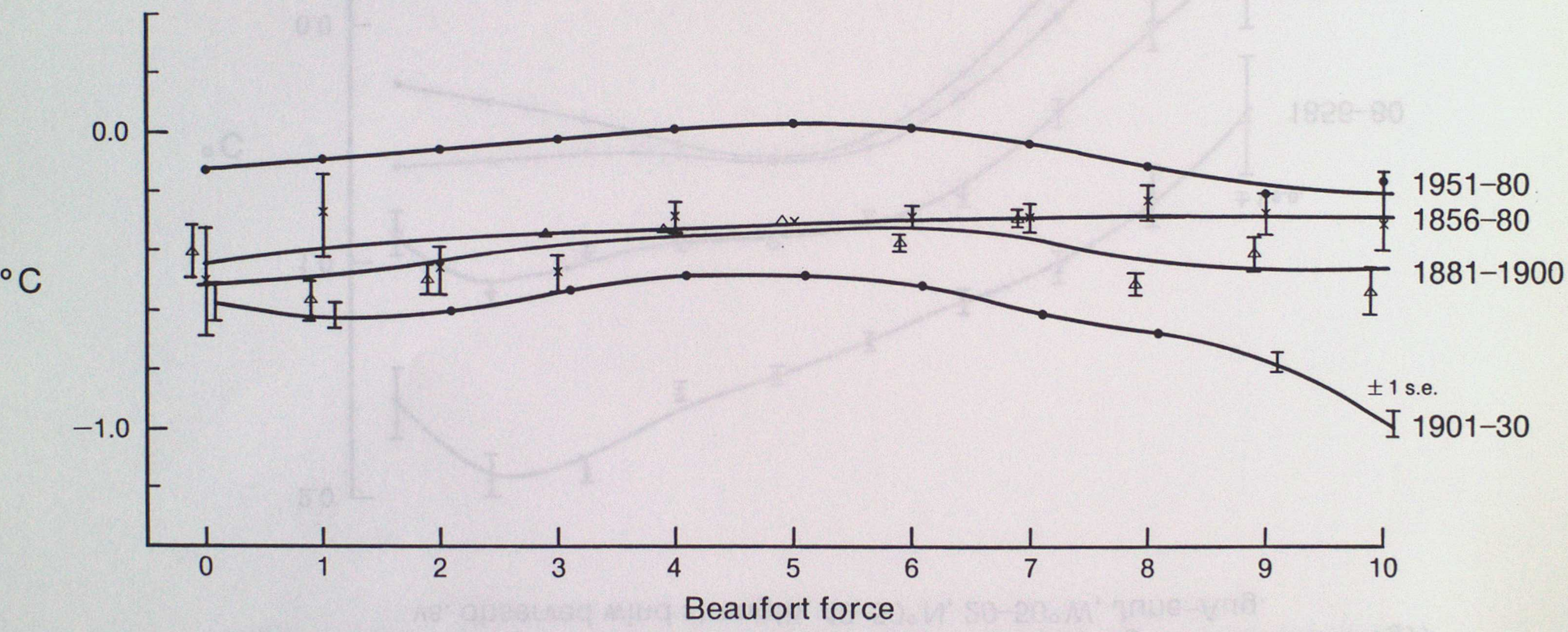


Figure 14. Observed SST (anomaly w.r.t. 1951–80) vs. observed wind strength, 40–50° N, 20–50° W, June–Aug.

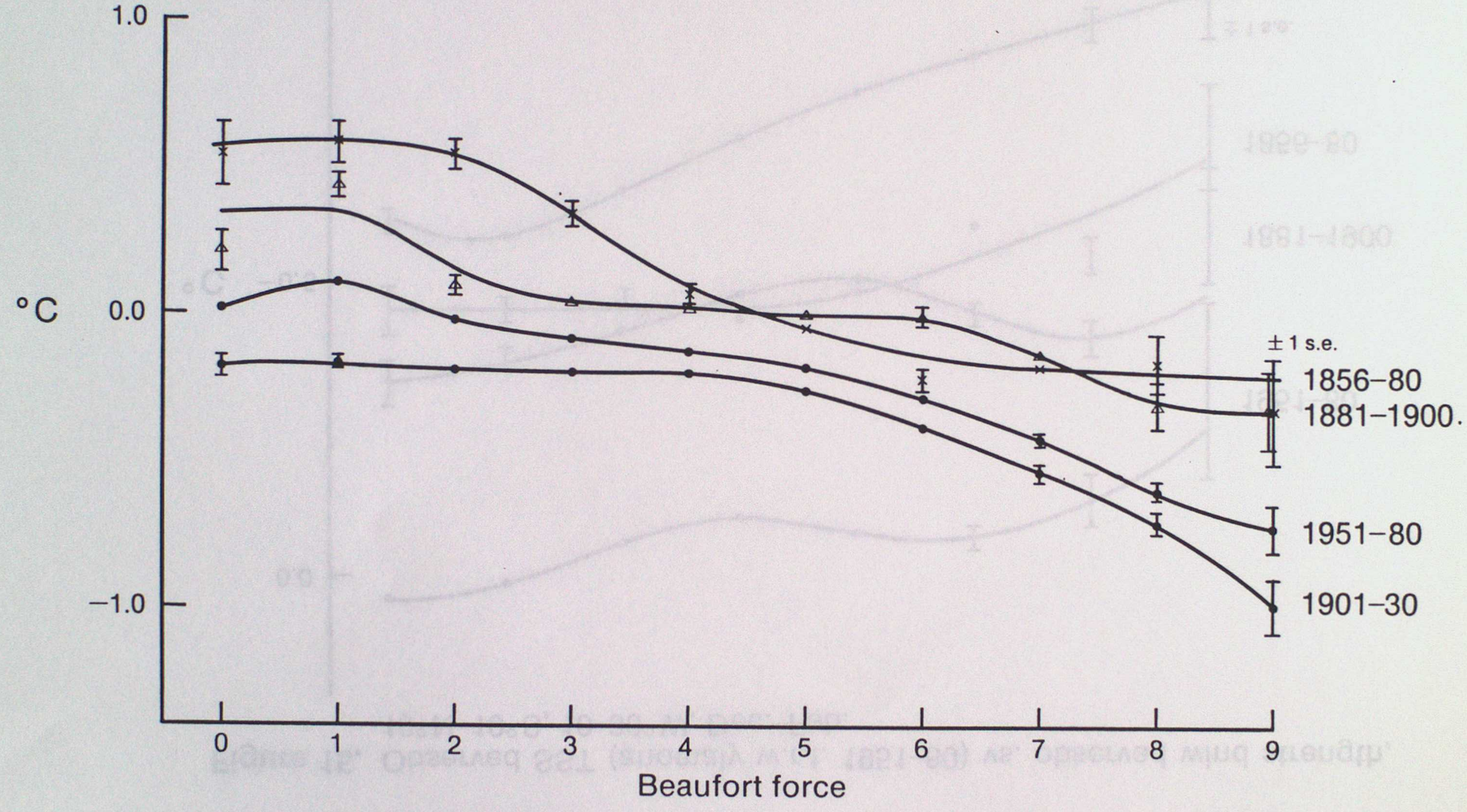
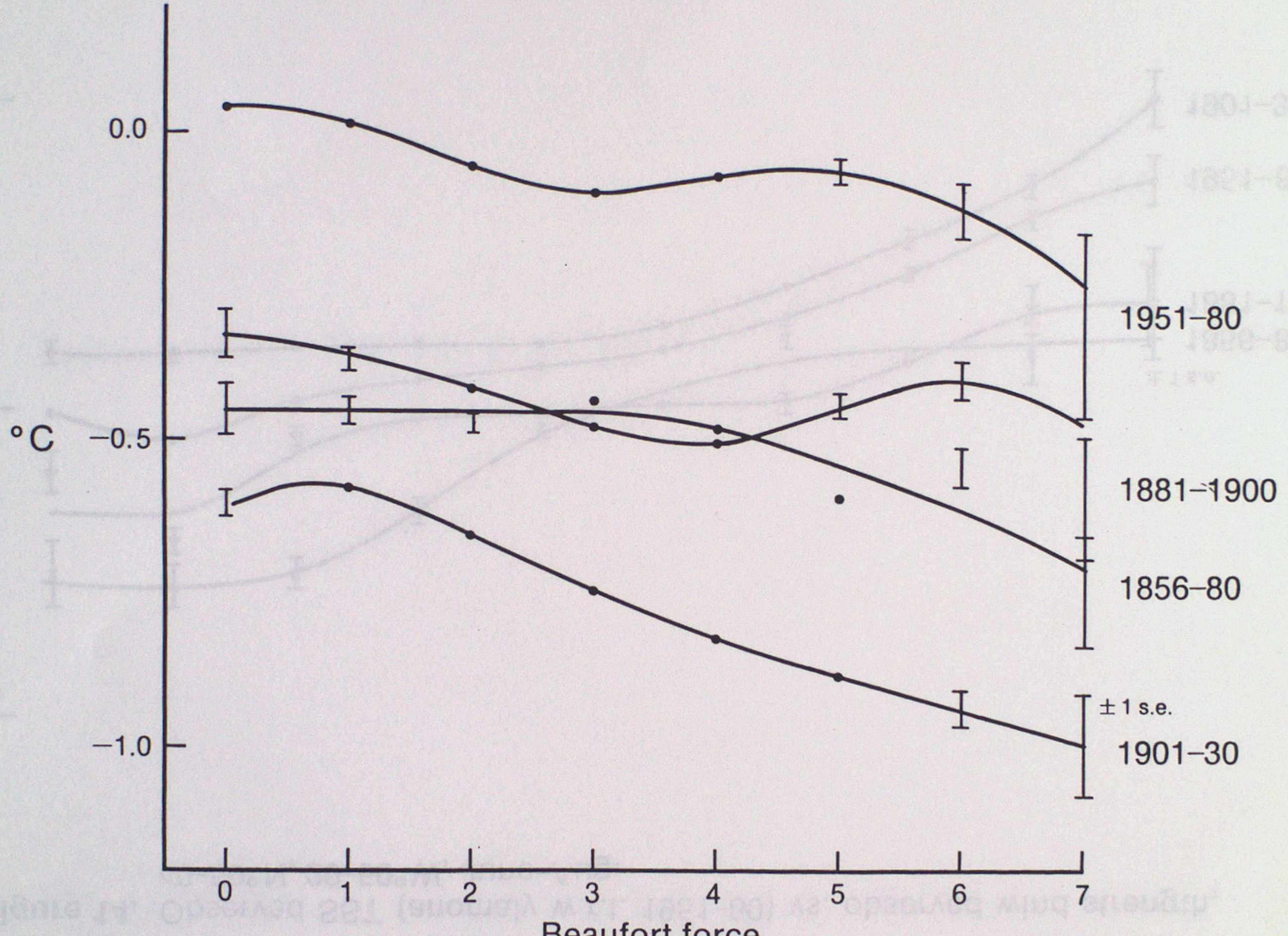


Figure 15. Observed SST (anomaly w.r.t. 1951–80) vs. observed wind strength, 10°N–10°S, 10–30°W, Dec.–Feb.



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