Fisheries and Oceans Canada
Pêches et Océans Canada

Canadian Stock Assessment Secretariat
Research Document 98/115

Secrétariat canadien pour l'évaluation des stocks
Document de recherche 98/115

Not to be cited without
permission of the authors[1]

Ne pas citer sans
autorisation des auteurs[1]

Overview of Coastal Environmental Conditions in 1997

B. Petrie

Department of Fisheries and Oceans, Maritimes Region
Ocean Sciences Division, Bedford Institute of Oceanography
Box, 1006, Dartmouth, N. S. B2Y 4A2

[1] This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

[1] La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au secrétariat.

ISSN 1480-4883
Ottawa, 1998

Canada

ABSTRACT

A brief review of the general ocean state in 1997 indicates that sea surface temperature changes were quite coherent in the region with similar variations in the southern Gulf of St. Lawrence and the Scotian Shelf. However, in the Bay of Fundy conditions varied in a different manner. Freshwater runoff as indicated by Rivsum was exceptionally high during 1997. Satellite estimates of sea surface temperature for the nearshore areas indicates widespread coherent variability. Wintertime SST was generally above normal changing to below normal values in spring, particularly in the southern Gulf of St. Lawrence and the eastern Scotian Shelf. This variability was reflected somewhat in data from moored sub-surface instruments. In a number of locations, strong temperature fluctuations showed marked vertical and horizontal coherence.

RÉSUMÉ

Un bref examen de l'état général de l'océan en 1997 indique des changements assez cohérents de la température de surface de la mer dans la région, des variations similaires étant observées dans la partie sud du golfe du Saint-Laurent et le plateau Néo-Écossais. Toutefois, dans la baie de Fundy, les conditions ont varié de façon différente. Les apports d'eau douce, d'après l'indice Rivsum, ont été exceptionnellement élevés. Les estimations satellitaires de la température de surface indiquent pour les zones côtières des variations cohérentes de manière générale. La température de surface a généralement été supérieure à la normale au cours de l'hiver, puis est tombée sous la normale au printemps, en particulier dans le Sud du golfe du Saint-Laurent et l'Est du plateau Néo-Écossais. Ces variations se reflètent jusqu'à un certain point dans les données des instruments sous-marins ancrés. À un certain nombre d'endroits, les fluctuations prononcées de la température montrent une cohérence marquée sur les plans horizontal et vertical.

INTRODUCTION

The review of the nearshore oceanographic environment will consist of a number of sections that present both background material, that may be useful to put the 1997 data in context, and the assessment mainly of the water temperatures for the past year.

The background material consists of the long-term monthly mean temperature and salinity contoured with depth and by month. These plots will indicate the strength of the vertical stratification throughout the region. They allow us to estimate how much the temperature would change with a vertical movement of 5 or 10 m.

A number of indicators of overall ocean climate have been presented from year to year to give a general assessment of the state of the ocean. Rivsum, sea surface temperature at a number of sites throughout the region, the temperature and thickness of the cold intermediate layer in the Gulf of St. Lawrence, ice, and air temperatures are a few such examples. These will be discussed briefly to set the stage for the more specific data to follow.

In the last section, data from the very nearshore regions have been assembled as much as possible in order to make specific reference to each inshore fishing area. These data include sea surface temperatures as measured from satellites, temperature records from instruments moored in each region as part of an inshore monitoring program, and observations from ships when appropriate.

BACKGROUND MATERIAL

Temperature (T) and salinity (S) observations collected from ships have been used to create long-term, monthly averaged values (Petrie et al., 1996a, b). These plots show that the vertical gradients of T and S change dramatically throughout the year and region (Fig. 1-4). For example, the eastern Northumberland Strait, corresponding to LFA 26a, has the largest monthly vertical temperature change over the upper 50 m in the region. The temperature difference between 0 and 50 m in August amounts to about 17°C (Fig. 1). During May and June, when the lobster fishing season is open, the 0 to 50 m temperature differences are on average 5.6 and 9°C. During winter, the temperature is nearly constant with depth with significant vertical differences beginning to develop in April. Vertical temperature differences will vary from year to year, exceeding these values on some occasions, being less than them on others. In general, vertical temperature gradients in the southern Gulf of St. Lawrence are the largest in the Maritimes region.

As one moves onto the eastern Scotian Shelf from the Gulf, vertical temperature gradients decrease somewhat. On the Eastern Shore, the maximum average temperature change from 0 to 50 m is less than 14°C in August (Fig. 2). The vertical T gradients change dramatically as one moves past Cape Sable in southwest Nova Scotia into the Bay of Fundy-Gulf of Maine region. In this region, strong tidal flows provide the energy to constantly mix the water column. This mixing generally is large enough to keep the vertical T and S gradients weak for most of the year, even overcoming the seasonal input of heat from the atmosphere and freshwater runoff from large rivers such as the Saint John. For example, at Lurcher Shoal, corresponding to LFA 34, the largest T difference is slightly less than 2°C in August (Fig. 3). From this figure it is evident that T and S gradients are small throughout the year in comparison with the similar pictures from the southern Gulf of St. Lawrence. The same pattern is true in the Bay of Fundy and the shallower areas of the Gulf of Maine (Fig. 3, 4). Notice however that the runoff from the Saint John River does affect the vertical stratification in the area designated as Central Fundy (Fig. 3).

In the deeper parts of the Gulf of Maine, such as Georges Basin corresponding to LFA 41, tidal energy though still significant cannot mix the entire water column. In this region, the average T difference between 0 and 50 m is about 8°C.

The general oceanography of these regions affects the sampling strategy. In the southern Gulf of St. Lawrence, an area of strong vertical gradients and relatively rapid temperature changes, more moored instruments would be required to provide a reasonable representation of the vertical distribution of temperature. On the other hand, in some well-mixed regions of the Bay of Fundy and the Gulf of Maine, a single gauge may be adequate to provide a good representation of temperature over the upper 50 m of the ocean.

There are a number of processes that affect the long-term, seasonal and day-to-day temperature changes in the ocean. These processes include:

- atmospheric-ocean heat exchange - this process primarily controls the annual cycle of ocean temperature in the Maritimes region. Decadal, interannual and seasonal variability in the heat exchange can also modify the upper ocean temperatures.

- currents - changes in the direction and strength of currents can affect ocean temperature for short periods of time to periods lasting 10 years or more.

- freshwater runoff - changes in the freshwater runoff can affect upper ocean temperature by increasing the density contrast between the surface waters and the more saline deeper water. With greater density contrast, more energy is required to mix heat downward. Underlying waters may remain relatively cold during periods of high runoff.

- ice - in the late winter and early spring, atmospheric heat initially must melt the overlying ice in the Gulf of St. Lawrence and on the eastern Scotian Shelf. The heat required to do this is lost to the upper ocean. In addition, the ice can be melted from below causing water temperatures to fall. The ice is also a source of freshwater, increasing the vertical density contrast which can further affect ocean warming.

- wind - on the Atlantic coast of Nova Scotia and in the Gulf of St. Lawrence, wind-forced coastal upwelling is a significant process that can cause major changes of surface and sub-surface T for periods from several days to a months duration (e. g., Petrie et al., 1987).

GENERAL REVIEW OF THE STATE OF THE OCEAN

Ocean data

A detailed review of the environmental conditions in the northwest Atlantic for 1997 has been presented by Drinkwater et al. (1998). Their analysis will not be repeated here but some of the highlights will be mentioned along with some additional information. A summary is presented in Table 1.

Sea surface temperature (SST) data have been collected at some locations in the Maritimes region for about 75 years. Figure 5 shows a comparison of the 1997 monthly mean temperatures at 4 sites with their long-term means. The means ± one standard deviation are also shown. Temperature observations were collected in Grand Rivière from May to November in 1997. This site lies upstream of LFA 23 and therefore should provide some indication of the climate in the southern Gulf. During the first two months of sampling, May and June, the SST at Grand Rivière was about 1 standard deviation below normal. The SST was normal in July, above normal by nearly 1 standard deviation in August and September, near normal in October and above normal in November. At Port Borden, Prince Edward Island in the Northumberland Strait, SST was below normal, at times exceeding 1 standard deviation, from January to July. During August and September SST was near normal but decreased over the rest of the year.

On the Scotian Shelf, SST has been recorded continuously at Halifax since 1926. The pattern for 1997 is quite similar to that seen at Port Borden. That is, SST is generally below normal for the first 7 months of the year, above normal for August and September, and near normal thereafter. In the Bay of Fundy, the SST at St. Andrews followed a different pattern. For the most part (March-June, October-December) during the year, SST were near normal. For the other months, SST was above normal with the largest deviation in July.

Temperature and salinity have been collected over the entire depth at the Prince 5 station at the mouth of the Bay of Fundy. The temperature data only are presented in Figure 6 for 4 depths. The first thing to notice is that there is very little temperature difference among the records. In this region, strong tidal flows contribute to the rapid downward mixing of heat and freshwater, thus reducing the vertical gradients of these properties. At all depths, the 1997 temperature is within the ± 1 standard deviation lines. The greatest deviations from the normal temperatures occur at the surface.

Drinkwater et al. (1998) reported that the core temperature of the cold intermediate layer in the Gulf of St. Lawrence in mid July was about 0.4°C below normal. In addition, they indicated that during September, the area of the Magdalen Shallows with bottom temperatures <1°C was about 33,000 km^2, i.e., about 7,000 km^2 above normal. The total area of the Magdalen Shallows is about 90,000 km^2. The largest bottom temperature anomalies were found in the Shediac Valley and in the area lying between eastern Prince Edward Island and Georges Bay, Nova Scotia.

On the Scotian Shelf, Drinkwater et al. (1998) had very few data to make an unequivocal assessment of the ocean temperatures. In Sydney Bight, they found that in June ocean temperatures were above normal by as much as 2°C to about 20 m, then were below normal by about 1°C from 20 to 50 m. On the Eastern Shore, below normal temperatures by 1.5°C (0.5°C) at 0 m (50 m), gave way to above normal temperatures in June by 1.3°C, 0-20 m, to normal temperatures from 30-50 m. Over Lurcher Shoal, corresponding to LFA 34, January temperatures of about 0.5°C above normal at all depths evolved to April temperatures that were about 0.5 °C below normal.

Freshwater Inflow

Freshwater inflow specifically from the St. Lawrence River basin influences the hydrographic properties of the Gulf of St. Lawrence and the Scotian Shelf. In addition, at one time this runoff, known as Rivsum, was highly correlated with annual catches of lobster in the Gulf. However, the correlation has not held up with time (see Drinkwater 1987). Freshwater inflow from the St. Lawrence was high in 1997 with the first 5 months of the year having values at or above 1 standard deviation above normal (Fig. 7). Inflows remained at an elevated level for the remainder of the year.

Ice

Figures 8-10 show the variations of ice during 1997 and their behaviour relative to the long-term mean. Figure 8 presents the first and last days of ice appearance in the Gulf and on the eastern Scotian Shelf. January 1 corresponds to day 1. The original data were resolved in 0.5° latitude by 1° longitude polygons and any amount of ice in those areas constituted a presence. The anomalies of first and last appearance are shown in Fig. 9, where a minus (plus) sign means that ice appeared or disappeared earlier (later) than usual. The final plot shows the duration of ice in the region. Note that duration is not simply the difference between date of first and last appearance, but rather the number of days that ice was actually in the area. For example, ice could form early in an area, be moved out by wind for most of the winter, only to return at the end of winter before leaving the area permanently. The absence of ice for most of the winter is taken into account. In Fig. 10, a shaded positive anomaly indicates a duration longer than usual; this is generally associated with a cold year. For 1997, the area corresponding to LFA 26a, b and the eastern end of LFA 24 had longer ice durations than normal.

NEARSHORE OCEANOGRAPHIC DATA, 1997

In recent years the Jet Propulsion Laboratory (JPL) has been maintaining a sea surface temperature archive based on estimates of SST from the NOAA series of satellites. The archive contains data from October 1981 onward and is updated every few months. The spatial resolution of the data is approximately 18x18 km; the temporal resolution is one week. Buoy data are used to compute global calibration coefficients for the SST product. Conservative algorithms are used to remove cloud and ice-covered areas in the ocean; in addition, a rather severe mask is used to eliminate any areas that have land in them. Thus the nearshore zone is lost. However, in many areas of our region there are times when there are neither moored instruments nor ship surveys in progress. This dataset can provide estimates of ocean surface temperatures nearly all year round. A more complete description of the dataset, a regional comparison of *in situ* and satellite observations, and a climatology for 1981-1996 is provided by Mason et al. (1998).

The JPL SST database is maintained at Bedford Institute, is geo-referenced and can be accessed over the internet for data extractions. This dataset has been used to provide estimates of ocean SST for 1997 for comparison with the long-term weekly SST means from 1981-1996. The results are shown in Fig. 11a-f and are summarized by month in Table 2. The summary was done only for the months in each LFA when the lobster season was open.

Table 2 indicates the following:

- during the lobster season from the Gulf of St. Lawrence to Halifax, sea surface temperatures were below normal, sometimes by greater than 1 standard deviation. There is evidence as well that these below normal temperatures spilled into LFA 33 in May.
- the exception is LFA 25 which has a different fishing season. During August, September and October, this region experienced SST slightly above normal.
- the only sustained period of above normal SST was from Halifax westward to the Bay of Fundy for the early part of the year, specifically January and February.
- following this warm period, these areas had SST that were about normal.
- these patterns bear a weak resemblance to the air temperature anomalies reported by Drinkwater et al. (1998).

There are a couple of points to remember when examining the temperature trends from surface values. They can be misleading when it comes to subsurface temperatures. High SST for example may mean that heat is confined to the shallow upper layer and is not vigorously mixed downward into the subsurface waters. Thus subsurface temperatures could be cooler than usual. By similar reasoning, low SST may mean that heat has been extensively mixed downward, leading to higher than usual subsurface temperatures. On the other hand, freshwater runoff was much higher than usual in the Gulf in 1997 (Fig. 7). This would favour, all other things being equal, strong vertical stratification and above normal surface temperatures. However, spring SST in the Gulf tended to be below normal. This may be caused by the ice that remained in the Gulf later than usual thus slowing the warming of surface waters in the spring.

Nearshore temperature recorder data

Where possible, long-term monthly temperature means and their standard deviations were constructed using archived data recorded by moored instruments. (Note, in all figures the mean temperatures are plotted in mid-month.) Since the annual temperature variation can change significantly with depth, a number of depth intervals were grouped to create the climatology. The initial breakdown was 0-5m, 5^{+}-10m, 10^{+}-20 m, 20^{+}-40m, etc. to 100m. Adjustments were made in certain areas depending on the depths data were collected in 1997. These exceptions are noted in the appropriate figures. However, for a number of areas in the Maritimes region this was not possible because of the lack of data from moored instruments. In these cases, the temperature climatologies as compiled from ships' observations by Petrie et al. (1996 a, b) were used as reference datasets. These cases are noted on the figures and in the captions. For a number of areas, time series from moored instruments were collected at several different depths. Thus there is often more than one plot per LFA reflecting the distribution of observations. (Note that in all figures the moored data were converted to daily mean values.) In addition, there were a number of inshore lobster fishing areas for which data were not available when this review was prepared. Data may be available at a later time.

Data recorded in 1997 were available for LFA 23, 24, 25, 26a, 26b, 27, 29, 31b, 32, 33 and 41. In addition, daily temperatures were collected at St. Andrews and have been archived as monthly means (see Fig. 5); moreover, bi-weekly observations were taken at Prince 5 and are compiled similarly (see Fig. 6).

The following is a brief summary of the temperature observations during the months that fishing was open in each of the LFAs where data were available. An overview is presented in Table 3. It is important to note that the depths of the records from LFA 23-26 were recorded as shallow and deep, except for the instrument at Anse-Bleue whose depth was given as 27 m. The shallow data were taken as 0-5m, the deep as the bottom depth corresponding to the instruments' positions.

<u>LFA 23</u> - The long-term means in this region were determined from ships' observations. Temperatures from the shallow gauges are initially below the long-term mean in May with a marked transition occurring in the last half of May to above average temperatures in early June (Fig. 12). Temperatures remained above normal for the rest fishing season. All of the records show similar variations. The deeper gauges initially showed the same tendencies as the near-surface ones (Fig. 13). However, early in June they split into 2 groups with Escouminac, Neguac, and Anse-Bleue having above normal temperatures

and Pte. Verte, Stonehaven, Caraquet and Jacket River below normal. Considerable variability is seen throughout most of the rest of the time series.

LFA 24 - There are only 2 datasets from this area for 1997 and one, Shag Island 10m, is in fact just outside of LFA 24 to the north. The Malpeque data are considerably warmer than the climatological means at 0m for the southern Shallows. This perhaps reflects the enhanced temperatures often recorded in the nearshore relative to the more open adjacent ocean. The Shag Island time series is slightly above normal in May, slightly below normal in June.

LFA 25 - The time series shown for the range 0-5m are the long-term means and standard deviations based on Borden observations, and 1997 datasets from Borden and Shediac (Fig. 15). The Borden data are well below normal in late July and most of August; whereas, the Shediac observations are above normal from early August into September. From late September onward both datasets nearly coincide. The deeper time series show temperatures at Shediac considerably higher than those at Kouchibouguac. The W Northumberland 10m data are from the Gulf of St. Lawrence atlas.

LFA 26a - Throughout the May-June season all 3 near-surface gauges were recording temperatures well below normal (Fig. 17). The record from Cribbons Point was significantly cooler than the other two. Similar behaviour was evident at the deeper instruments (Fig. 18).

LFA 26b - The near-surface data from Port Hood and Pleasant Bay are remarkably similar throughout the record (Fig. 19). The deeper data, though less consistent, are very similar. The temperatures are below normal at the start but reach near-normal values in July (Fig. 20).

LFA 27 - The long-term mean for the near surface inshore temperatures is based on only a few moored instrument records. However, the variability evident in the 2m North Sydney (Fig. 21) record is also seen in the 11 m gauges (Fig. 22). The overall tendency is to move from a cooler than normal spring to an above normal late spring and early summer. There is marked coherence of the three records in Fig. 22. The variability and overall behaviour of the shallower records is also seen in the deeper records (Fig. 23).

LFA 29 - The 10m records from this region are quite different. The instrument at Petit-de-Grat features a cool event in mid-June with temperatures as much as 8°C below the corresponding ones at L'Ardoise (Fig. 24). The deeper records reflect the variability seen at Petit-de-Grat (Fig. 25).

LFA 31b - It is tempting to relate the events seen in LFA 29 centered round June 20 and towards the end to the record to the temperature drops seen somewhat later in Country Harbour (Fig. 26). Disturbances known as shelf waves can carry a temperature event from one region to another. They would propagate from east to west along the Atlantic coast of Nova Scotia, consistent with the events being detected in LFA 29 before they occurred in LFA 31b. In this area there is also the tendency for temperatures to move from the cool side of normal to the warm side in the spring. There is a cooling event in mid to late May. The variability in the shallower depths is also seen deeper (Fig. 27).

LFA 32 - However, the westward propagation is hard to see in this record. There are cooling events mid to late May, similar to the one in LFA 31b, followed by near normal conditions in June (Fig. 28). The deeper (14m) temperature record (Fig. 29) comes from a location in Ship Harbour that is separated from the ocean by a shallow sill. This location tends to be quite quiescent and not representative of a broad area.

LFA 33 - The January to May temperatures at shallow depths are essentially normal (Fig. 30).

LFA 36, 38 - The only data available at this time are from St. Andrews and Prince 5, which lie within or close to these areas. At both places, January and February temperatures tend to be above normal, March-June near normal. Prince 5 temperatures tend to be above normal in November, normal in December; whereas, temperatures at St. Andrews are normal both months.

LFA 41 - The fishing in this region is concentrated in Georges Basin, Northeast Channel, and slope region near Browns Bank. For the first half of the year there are temperature records from NE Channel at 24, 54 and 104 m. These series are shown in Fig. 31-33 along with ships' data from Georges Basin. The time series show warmer than normal temperatures early in the year giving way to cooler temperatures in March in the upper 50 m. This behaviour is similar to that seen in at St. Andrews, Prince 5 and in the JPL SST records. At 100m, temperatures are near normal values from January to June but with distinct periods that are well above average.

The shallow ships' data from Georges Basin are above normal in January and February, normal from March to mid-May, then are below normal until August. The 50m data fluctuate about normal values until July when they move above normal and remain there through September and October. The 100 m data feature a period of below normal temperatures in spring.

SUMMARY AND RECOMMENDATIONS

The JPL SST dataset was very consistent from region to region and throughout the year (Table 2). Temperatures were above normal at the start of the year in the western areas of the Maritimes Region where the fishing season was open. By May and June, the main time for the Gulf of St. Lawrence and eastern Scotian Shelf fishing seasons, SSTs were generally below normal. Some of this tendency was reflected in the surface and sub-surface *in situ* observations, particularly the above normal temperatures in areas 36, 38 and 41 in January and February. In the Gulf of St. Lawrence, there was some evidence of below to above normal temperatures in LFA 23 and 26. This was also the case in LFA

27. There was also evidence that events in one region were also seen in adjacent areas either at a later date, such as in areas 29 and 31b, or at the same time as in 31b and 32.

There were also a number of cases where records were quite coherent even though separated vertically or horizontally by significant distances. This behaviour was most readily seen in areas 26b and 27, less so in area 23.

A large group of DFO scientists and non-DFO researchers are collecting nearshore temperature data. At present the Ocean Science Division at BIO is maintaining an archive of any data of this type that are collected. The archive is available on-line through the internet or through requests made to OSD. The greater its holdings the more useful it could be.

With these things in mind, I would recommend:

1) The those gathering nearshore temperature (or other data) archive their results in the BIO database. The data should have positions (latitudes and longitudes), depths and times well-documented.

2) The creation of a geo-referenced database of nearshore temperature and salinity observations recorded by moored instruments. The existing database contains monthly statistics for each record plus a pointer to the raw data. These monthly statistics are averaged over too long a time to be useful for exercises such as the invertebrate fisheries RAP. Thus, one must go to the raw records and do additional processing. A more useful database would have geographically-referenced, daily mean values of temperature, and have processing tools for data extraction, statistical summary, anomaly generation and plotting. Our other databases now have these capabilities (e.g., the ship-based observations). Storing the data at daily intervals would results in a dataset of about 500,000 values. At the raw sampling rate, the number of points would be roughly 10 times greater. Having the data available as daily values would be a marked advantage for the preparation of environmental reviews, comparisons with long times series of nearshore catches, etc.

3) Some additional work should be carried out with nearshore temperature data throughout the region to determine how many instruments are required both vertically and horizontally to adequately sample temperature. Barring that, such a study should give insight on how well or poorly one does with 2 instruments in the highly stratified environments of the southern Gulf of St. Lawrence and Sydney Bight. The review of the 1997 data indicates that the situation may not be as bad as one may have suspected beforehand, given the high coherence implied by data series from these two regions.

ACKNOWLEDGEMENTS

I would like to thank the following persons: Ken Drinkwater and Roger Pettipas for providing some documents, data and plots that helped in the preparation of this review;

Marc Lanteigne, Pierre Pettigrew and John Tremblay provided data records from 1997 and earlier years from the southern Gulf of St. Lawrence and the Sydney Bight; and, Karen Atkinson for collating many data series in a common directory, putting together plots of some of the data from which I was able to judge their utility.

REFERENCES

Drinkwater, K., E. Colbourne and D. Gilbert. 1998. Overview of environmental conditions in the northwest Atlantic in 1997. Northwest Atlantic Fisheries Organization. NAFO SCR Doc. 98/38, 81 pp.

Drinkwater, K. 1987. "Sutcliffe revisited": previously published correlations between fish stocks and environmental indices and their recent performance. In "Environmental effects on recruitment to Canadian Atlantic fish stocks", I. Perry and K. Frank, editors. Can. Tech. Rep. Fish. Aquat. Sci. 1556, pp. 41-61.

Mason, C., B. Petrie and B. Topliss. 1998. Satellite measurement of sea-surface temperature and the study of ocean climate. Can. Tech. Rep. Hydrogr. Ocean Sci. 193, 101 pp.

Petrie, B. B. Topliss and D. Wright. 1987. Coastal upwelling and eddy development off Nova Scotia. J. Geophys. Res. 29, 12,979-12,991.

Petrie, B., K. Drinkwater, D. Gregory, R. Pettipas and A. Sandström. 1996. Temperature and salinity atlas for the Scotian Shelf and the Gulf of Maine. Can. Tech, Rep. Hydrogr. Ocean Sci. 171, 398 pp.

Petrie, B., K. Drinkwater, A. Sandström, R. Pettipas, D. Gregory, D. Gilbert and P. Sekhon. 1996. Temperature, salinity and sigma-t atlas for the Gulf of St. Lawrence. Can. Tech, Rep. Hydrogr. Ocean Sci. 178, 256 pp.

Table 1. Summary of Ocean Climate Review by Drinkwater et al. (1998)

Gulf of St. Lawrence

200-300m average T in Cabot Strait, 0.1°C above normal

Core of CIL 0.4°C below normal

Bottom T in Magdalen Shallows mostly below normal

Area of Shallows T<1°C in September 33,000 km^2, 7000 km^2 > normal

Freshwater inflow (Rivsum) 1,400 m^3/s above normal for year, up to $3{,}000^+$ m^3/s > normal on given month

Ice duration 10-20 d longer than normal in eastern Magdalen Shallows, 10 d less than normal in western Shallows

Scotian Shelf-Gulf of Maine

Surface T at St. Andrews and Prince 5 was normal to above normal

Deep T in Emerald Basin was 1.2°C above normal

Subsurface temperatures in Sydney Bight, Misaine Bank and Lurcher Shoal were slightly below normal but higher than in previous years

July 50m T from shelf wide groundfish cruise was mostly slightly below normal

Shelf edge temperatures some large variability about normal

TABLE 2. Temperature anomalies for 1997 compared to the long-term mean (1981-1996).

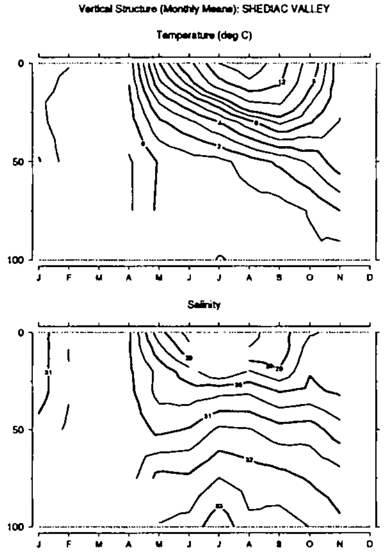
LFA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
23					b	b						
24					b	N						
25								a	a	N		
26A					bb	bb						
26B					bb	b						
27					bb	b	b					
28												
29						N	b					
30					b	N	b					
31A					b	b						
31B					b	b						
32				N	bb	b						
33	aa	aa	a	N	bb							N
34	aa	aa	N	N	b							aa
35				N	N							
36	a			N	N	N					N	N
38	a	a	N	a	N	N					N	a
41	aa	aa	b	N	b	N	a	b	a	b	N	N

Where:	N	,=normal	a	=< SD above normal	aa	,=SD or > above normal
	b	=<SD below normal	bb	,=SD or > below normal		,=no data

Table 3. Monthly temperature anomalies for 1997 compared to the long-term mean. The letters 'a', 'b', and 'N' correspond to above normal, below normal and normal temperatures.

LFA	Z(m)	J	F	M	A	M	J	J	A	S	O	N	D
23	0-5					b	a						
	10-20[1]					b	a/b						
24	5-10					N	b						
25	0-5[2]								a/b	a	N		
	5-10								a	a			
26a	0-5					b	b						
	10					b	b						
26b	0-5					b	b						
	20					b	b						
27	0-5					b	a						
	10					b	b						
	20					b	b						
29	10[3]					N	a/b						
	20					a	b						
31b	0-5					b	a						
	10					b	N						
32	0-5					b	N						
33	0-5		N	N	N	a							N
36	0	a	a	N	N	N	N					N	N
38	0	a	a		N	N	b					a	a
	25	a	a		a	N	N					a	N
	50	a	a		a	N	N					a	N
41	20[4]	a	a/b	b	b	b	b						
NEChn	50[5]	a	b	a	b	b	a/b						
	100[5]	a	b	a	a	N	a/b						
Georges	20	a	a	N	N	a	N	N		a	a		
Basin	50	b	N	a	N	a	N	a		a	a		
	100	N	N	a	N	N	b	a			N		

[1]June, some records above normal, some below;
[2]August, below normal at Borden, above at Shediac;
[3]June, above normal at L'Ardoise, below at Petit-de-Grat;
[4]February, above normal at Northeast Channel East, below at Northeast Channel West;
[5]June, above normal at Northeast Channel East, below at Northeast Channel West;



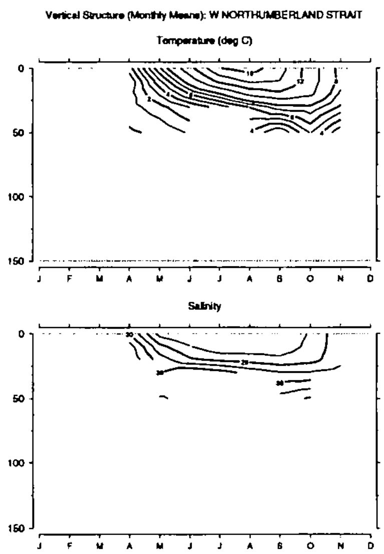
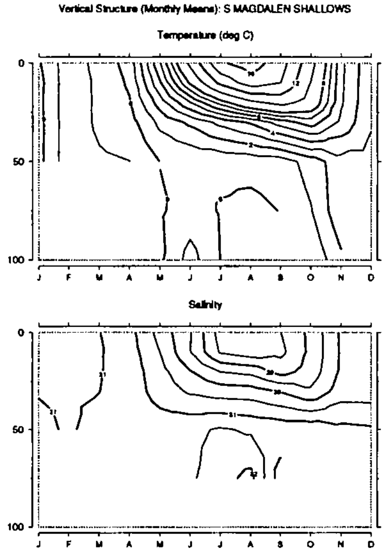


Figure 1. Vertical structure of the monthly average temperature and salinity for Shediac Valley (corresponding to LFA 23) and western Northumberland Strait (LFA 25).



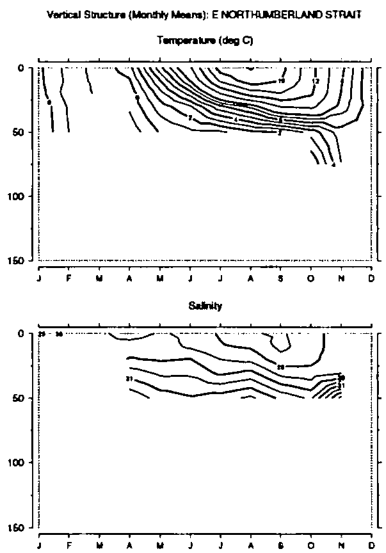
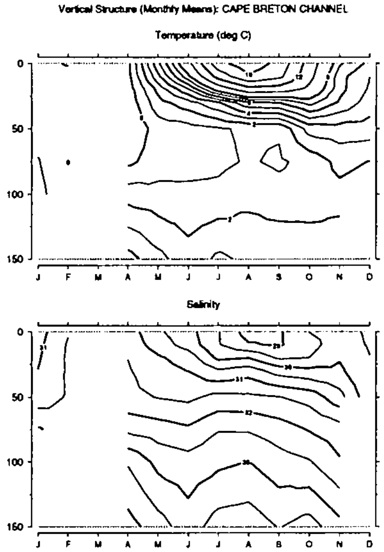


Figure 1 cont'd. Vertical structure of the monthly average temperature and salinity for South Magdalen Shallows (LFA 24) and eastern Northumberland Strait (LFA 26a).



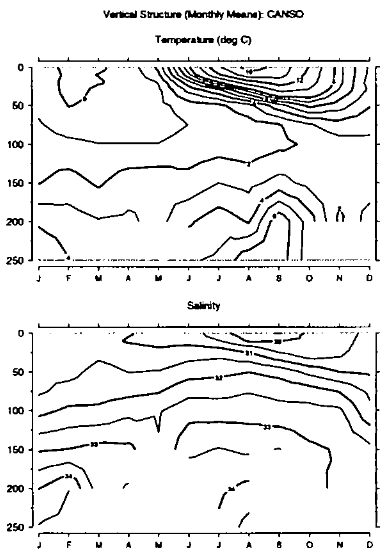
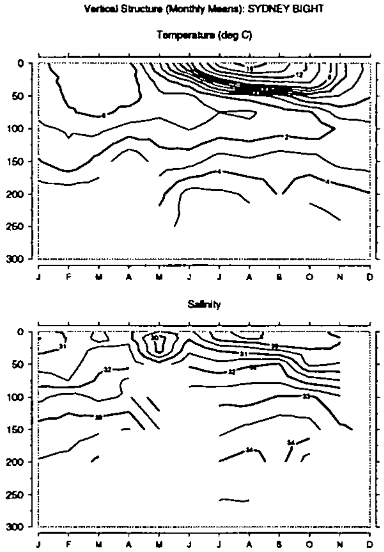


Figure 2. Vertical structure of the monthly average temperature and salinity for Cape Breton Channel (LFA 26b and Canso (LFA 29, 30 and 31a).



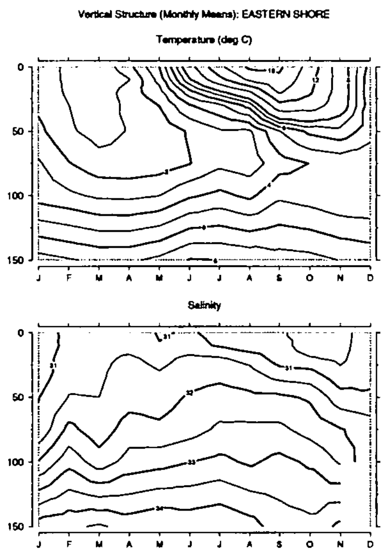


Figure 2 cont'd. Vertical structure of the monthly average temperature and salinity for Sydney Bight (LFA 27) and Eastern Shore (LFA 31b, 32).

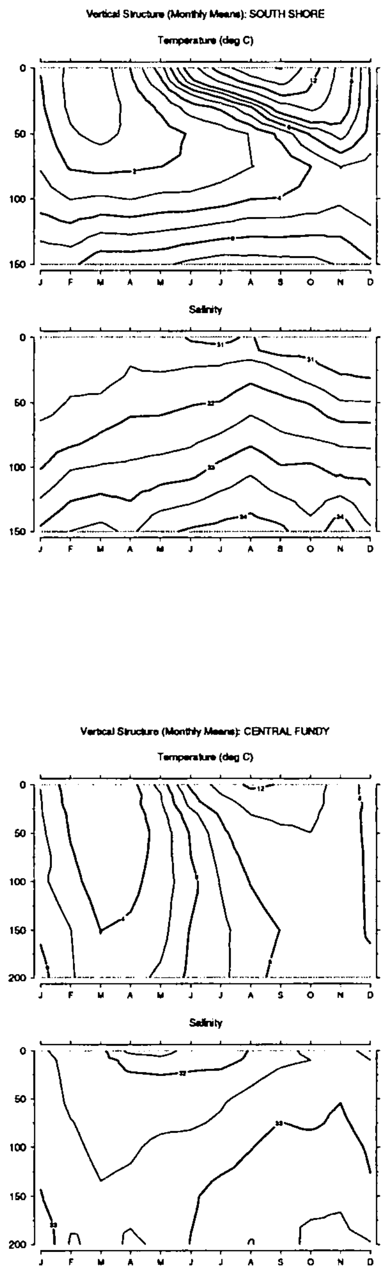


Figure 3. Vertical structure of the monthly average temperature and salinity for South Shore (LFA 33) and Central Fundy (LFA 35 and 36).

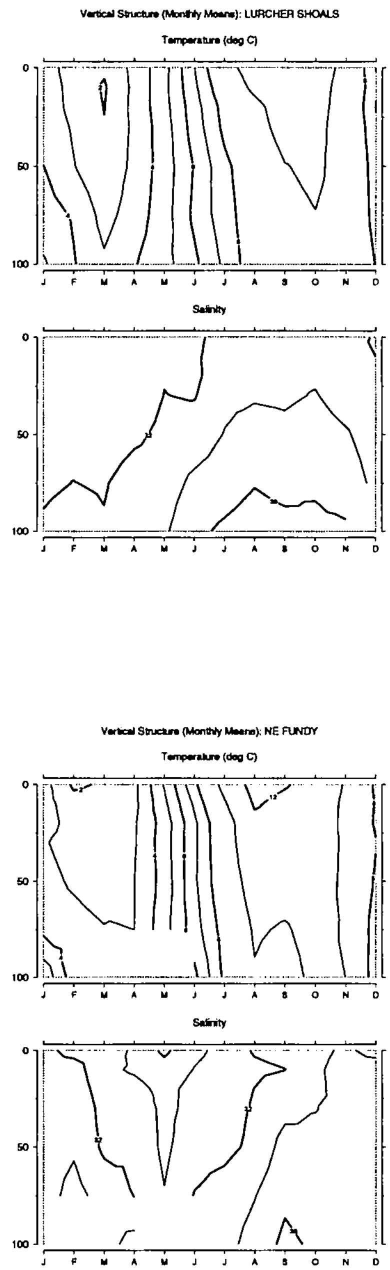


Figure 3 cont'd. Vertical structure of the monthly average temperature and salinity for Lurcher Shoals (LFA 34) and Northeast Fundy (LFA 35 and 36).

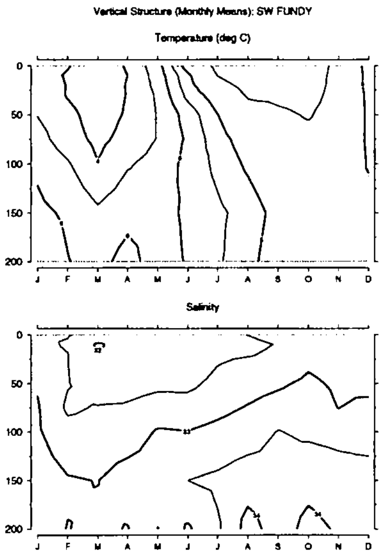


Figure 4. Vertical structure of the monthly average temperature and salinity for southwest Fundy (LFA 38).

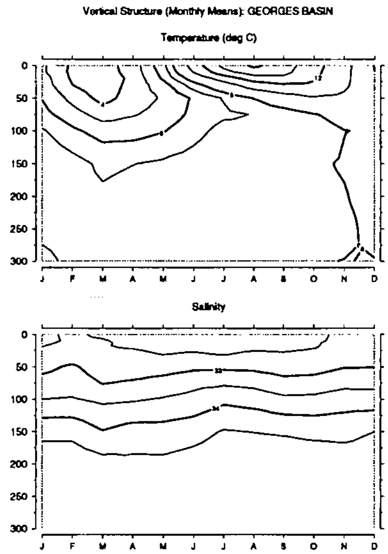


Figure 4 cont'd. Vertical structure of the monthly average temperature and salinity for Georges Basin (LFA 41).

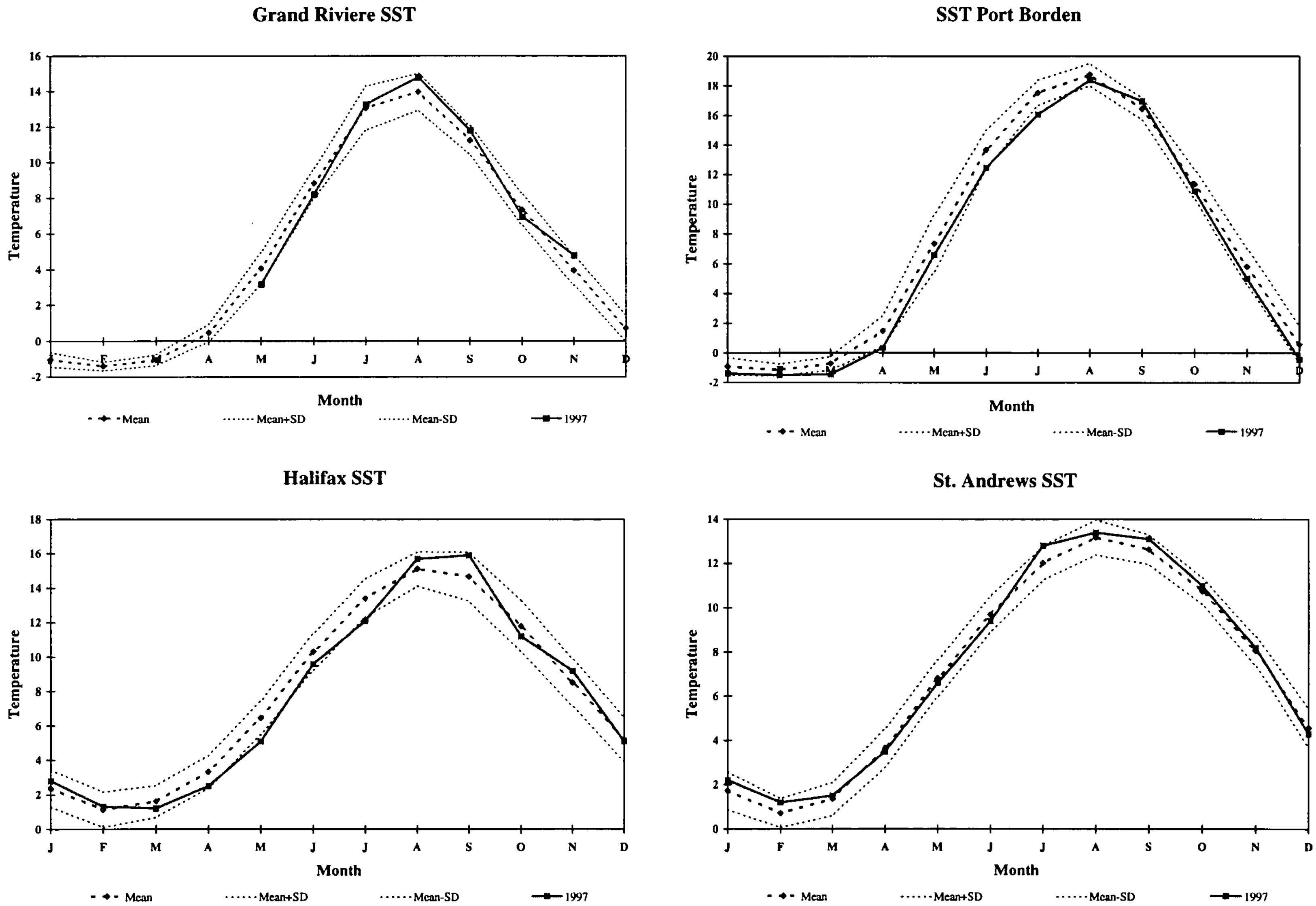


Figure 5. Long-term monthly mean sea surface temperatures (SST), means plus and minus 1 standard deviation, and 1997 monthly mean temperatures for Grand Riviere, Port Borden, Halifax and St. Andrews.

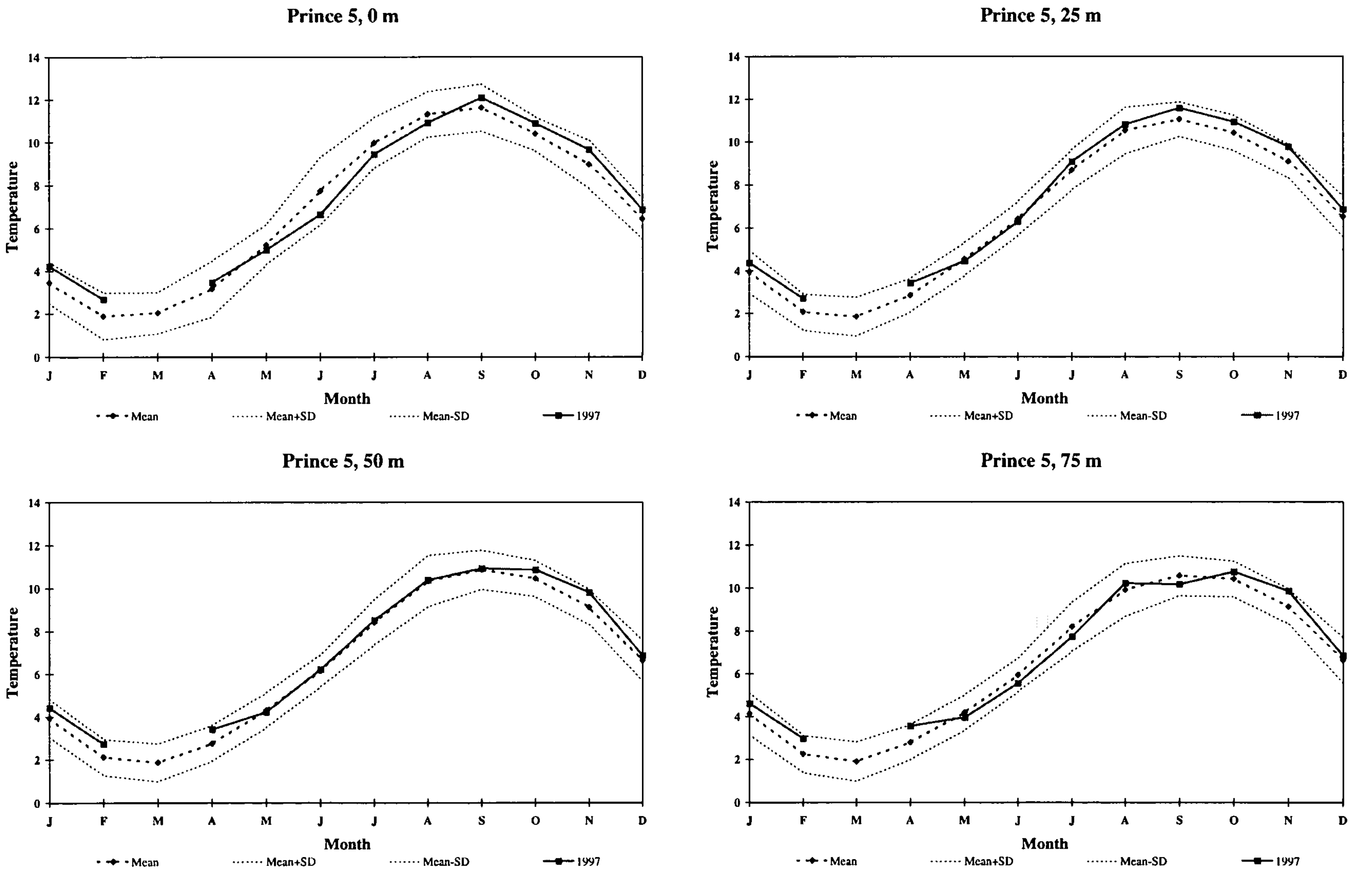


Figure 6. Long-term monthly mean temperatures, means plus and minus one standard deviation, and 1997 monthly mean temperatures at the Prince 5 station, 0, 25, 50 and 75 m, at the mouth of the Bay of Fundy.

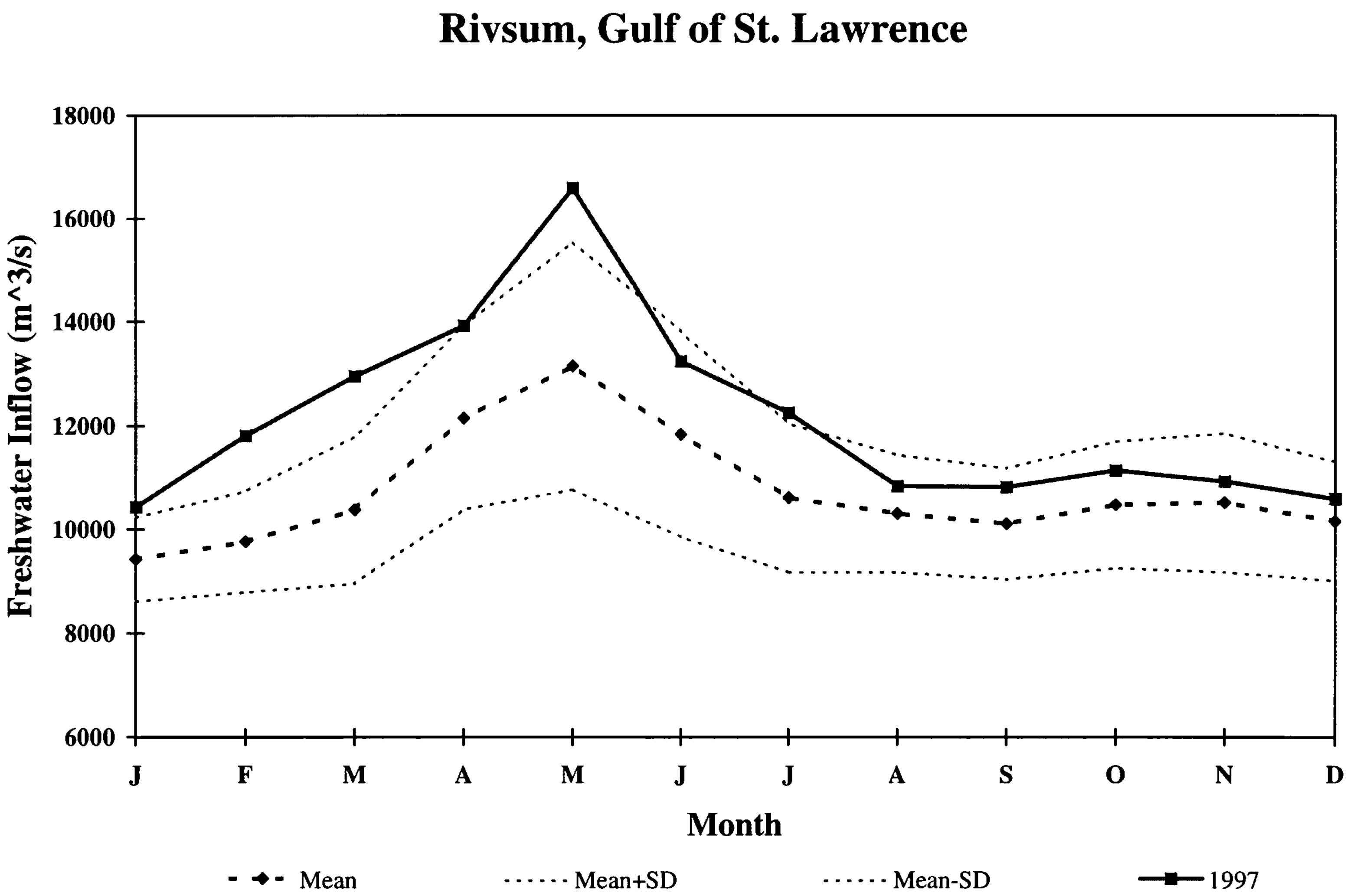


Figure 7. Monthly means of Rivsum from the St Lawrence drainage basin, means plus and minus 1 standard deviation and 1997 values.

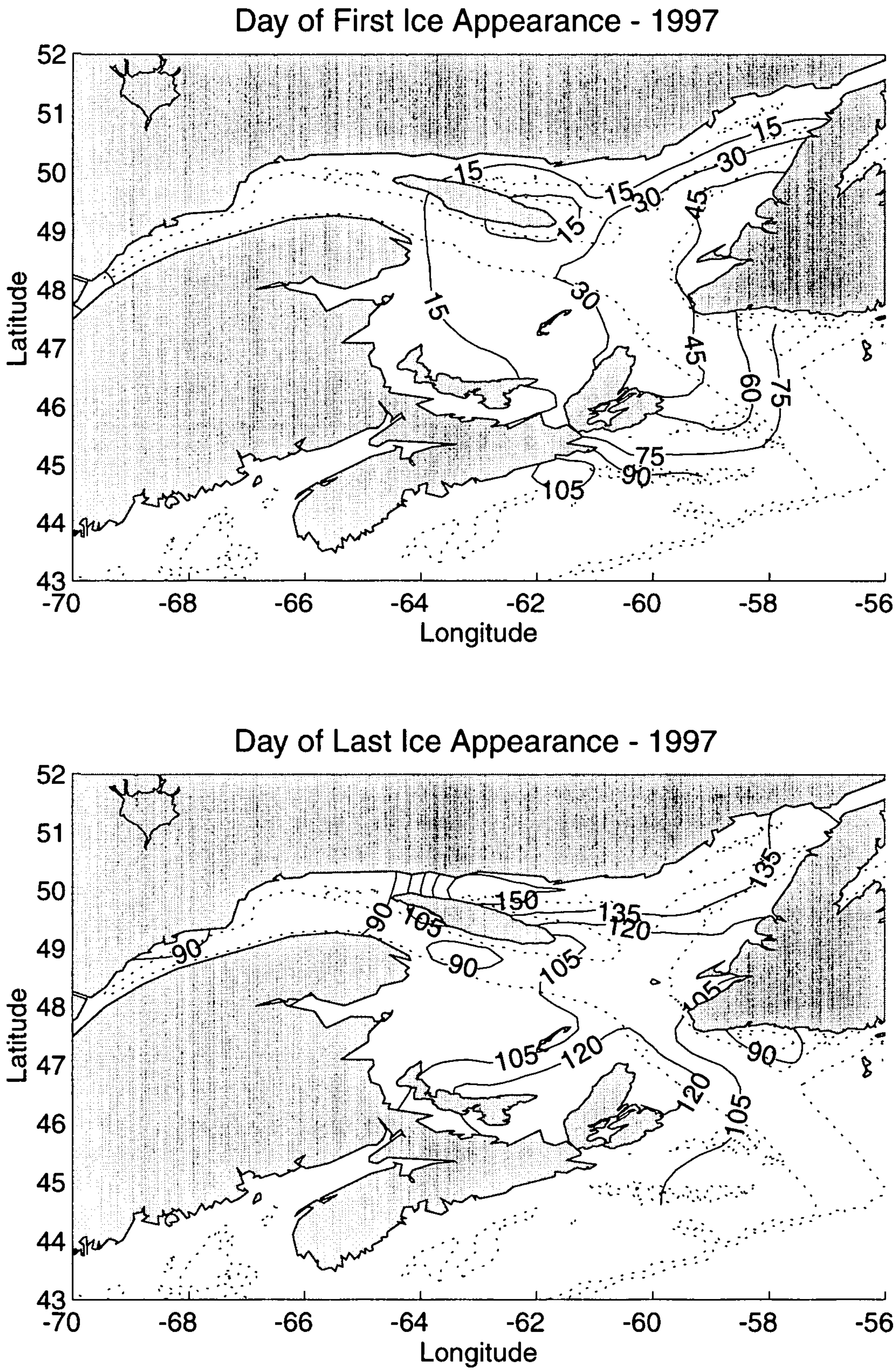


Figure 8. Day of first and last ice appearance (January 1 = 1).

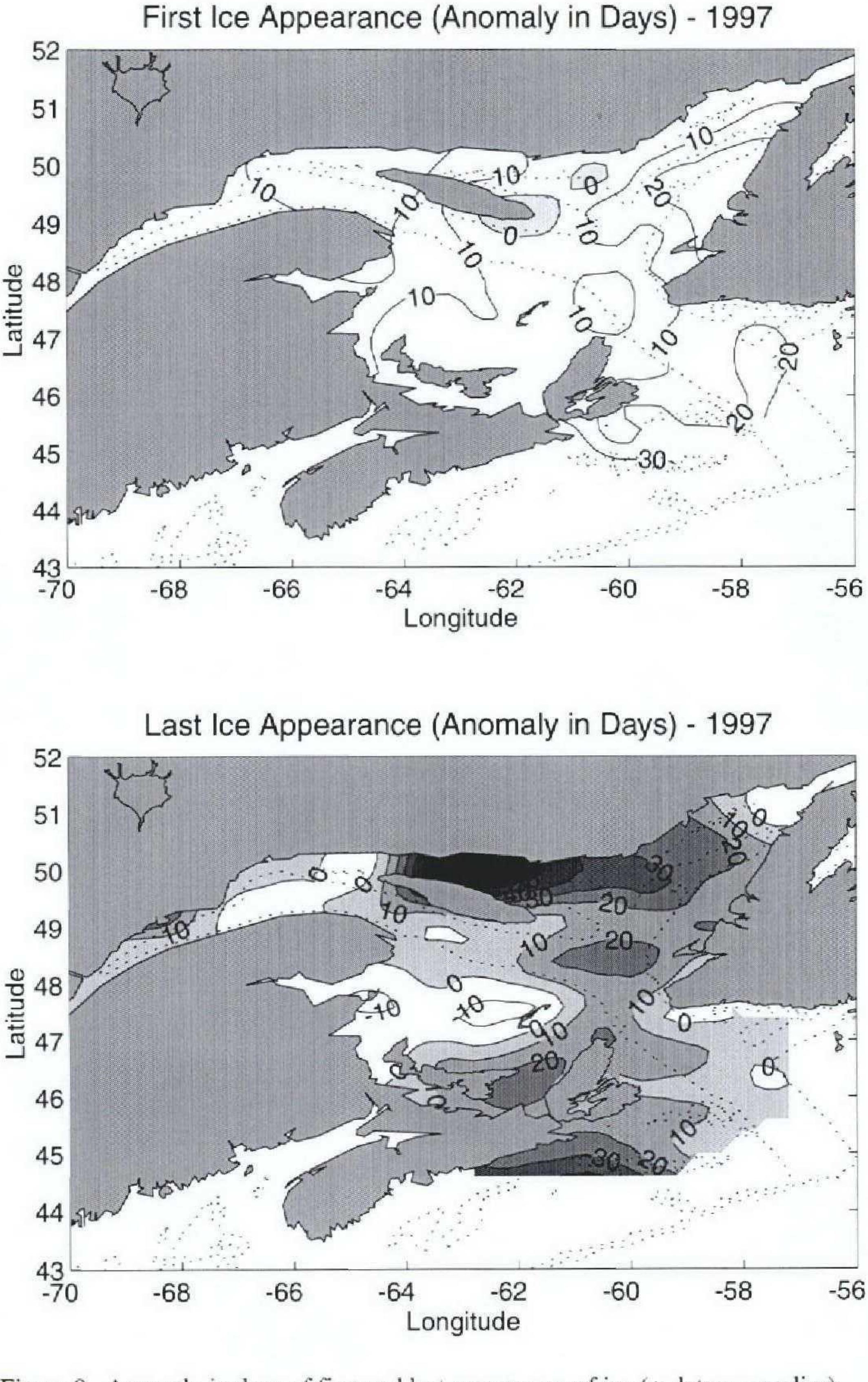


Figure 9. Anomaly in days of first and last appearance of ice (+=later; -=earlier).

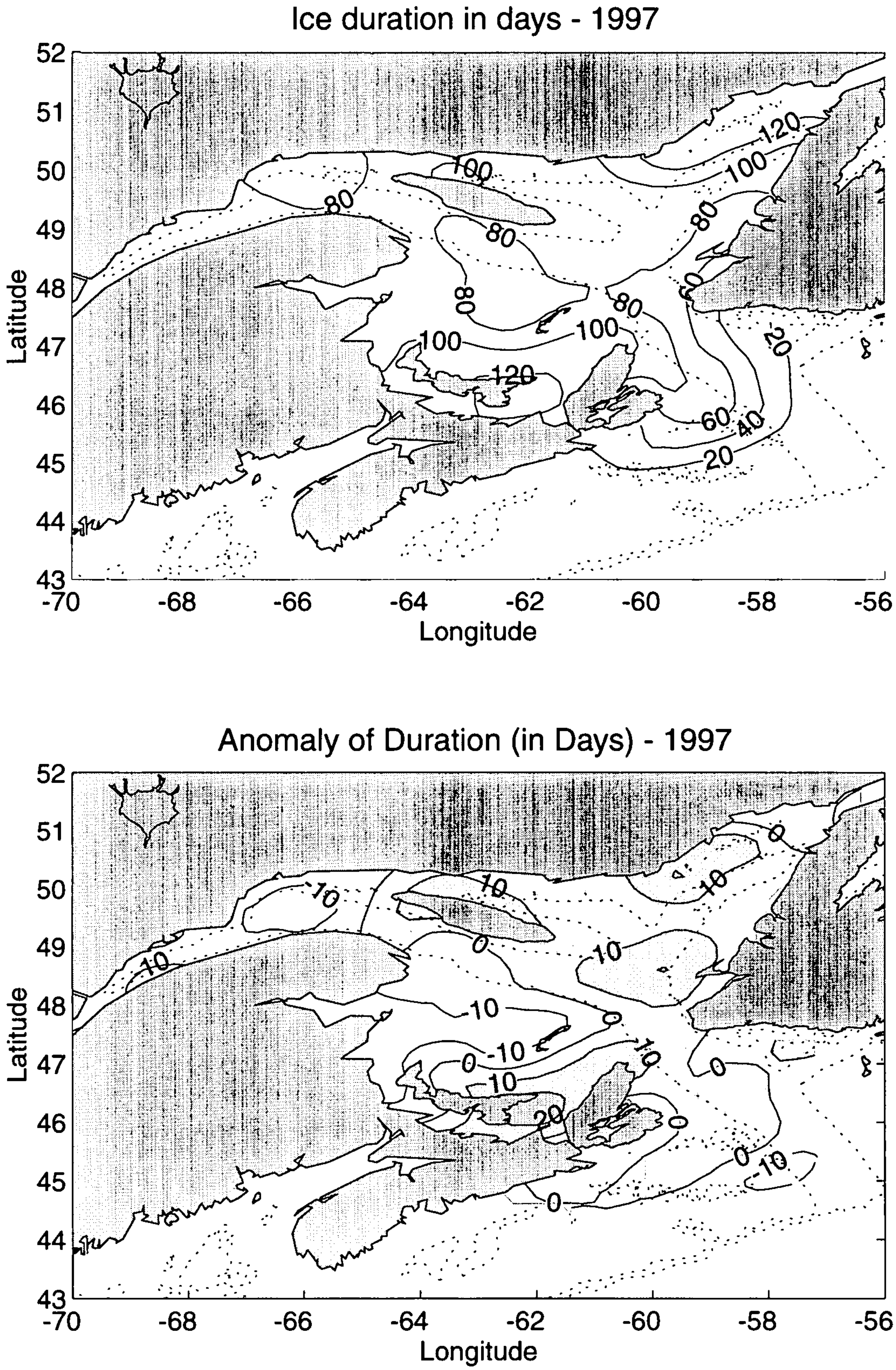


Figure 10. Ice duration and anomaly of duration in days.

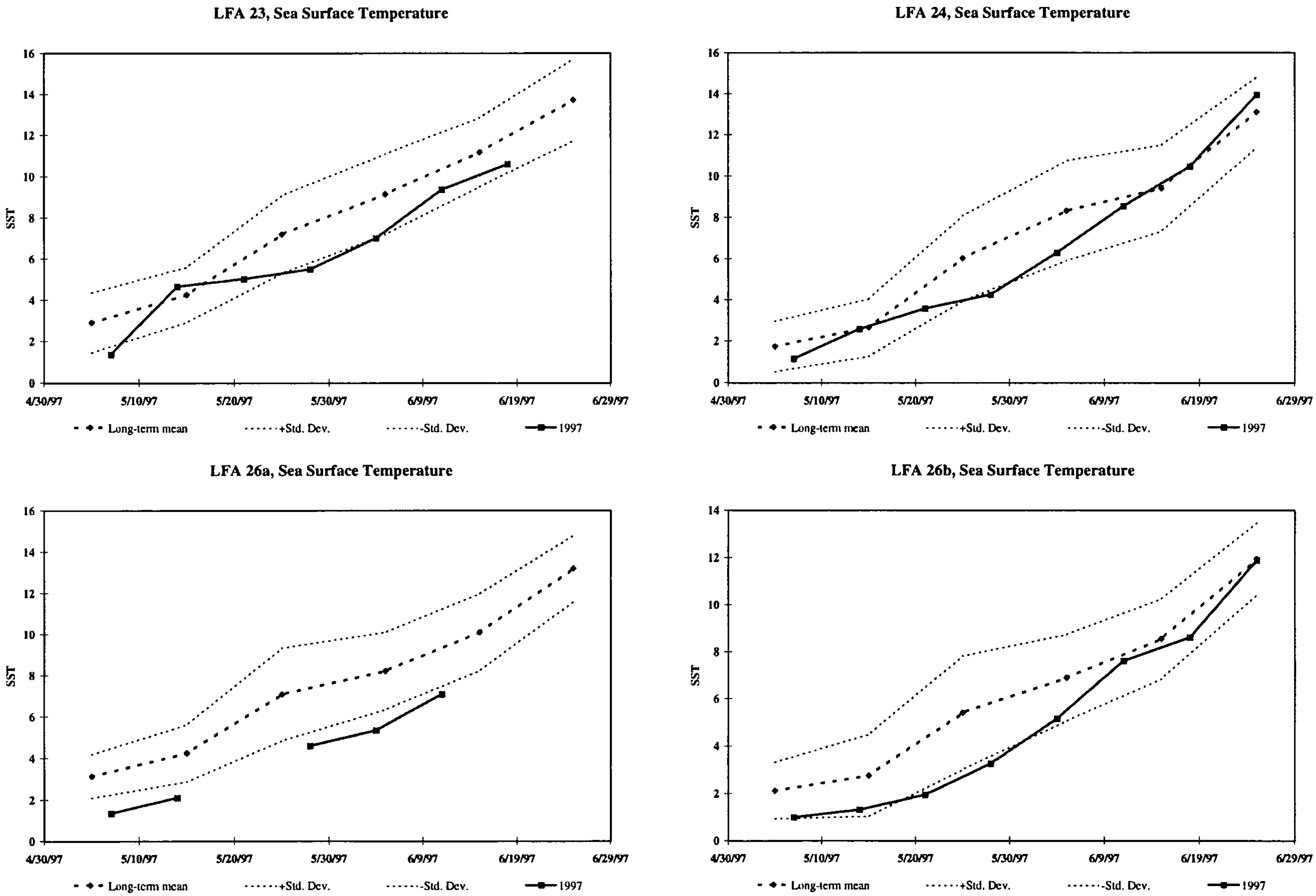


Figure 11. (a) Comparison of weekly SST for 1997 and the long-term (1981-1996) means for LFA 23, 24, 26a and 26b.

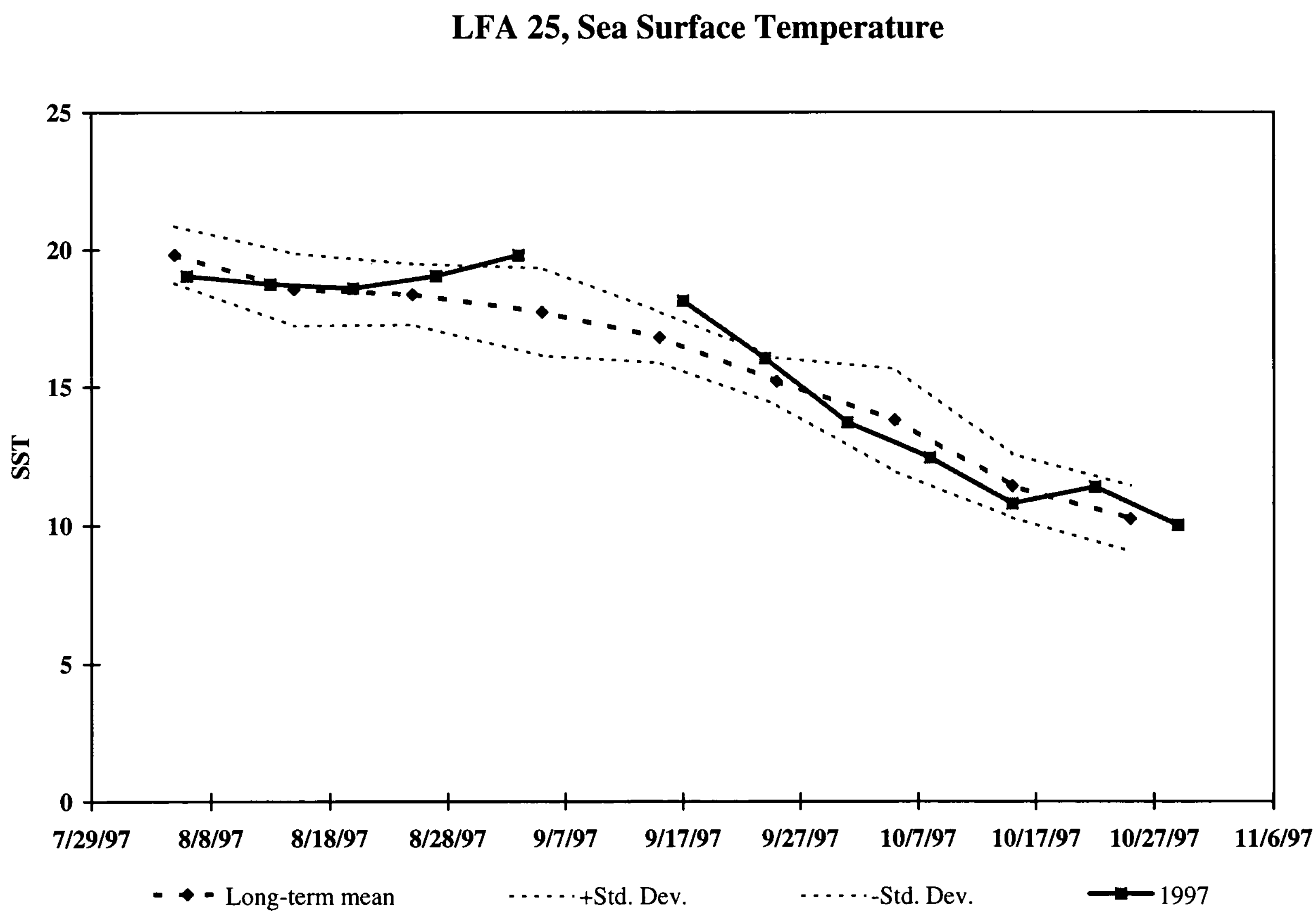
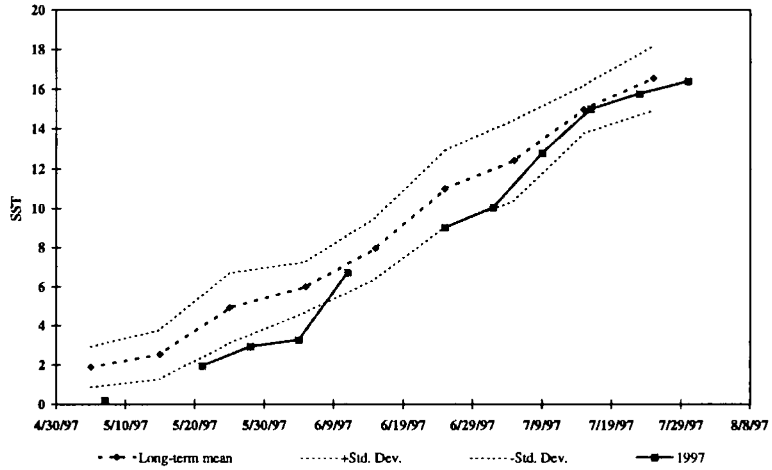
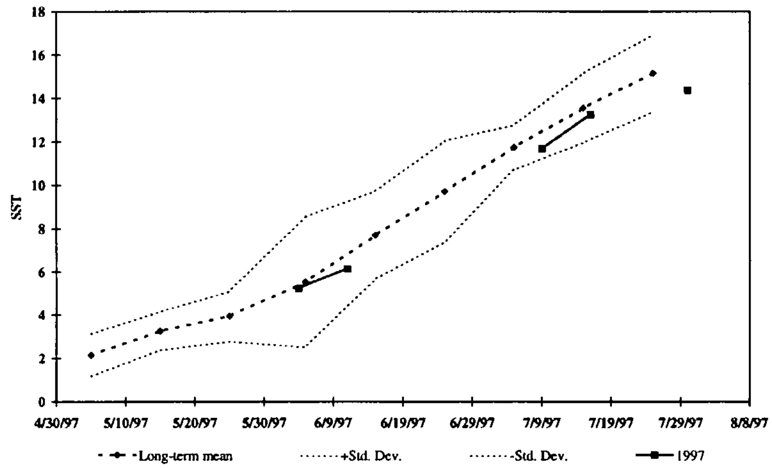


Figure 11(b) Comparison of weekly SST for 1997 and the long-term (1981-1996) means for LFA 25.

LFA 27, Sea Surface Temperature



LFA 29, Sea Surface Temperature



LFA 30, Sea Surface Temperature

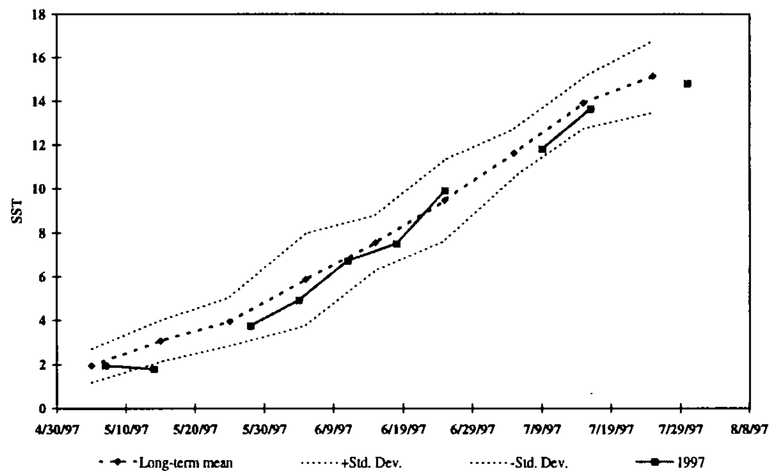


Figure 11(c). Comparison of weekly SST for 1997 and the long-term (1981-1996) means for LFA 27, 29 and 30.

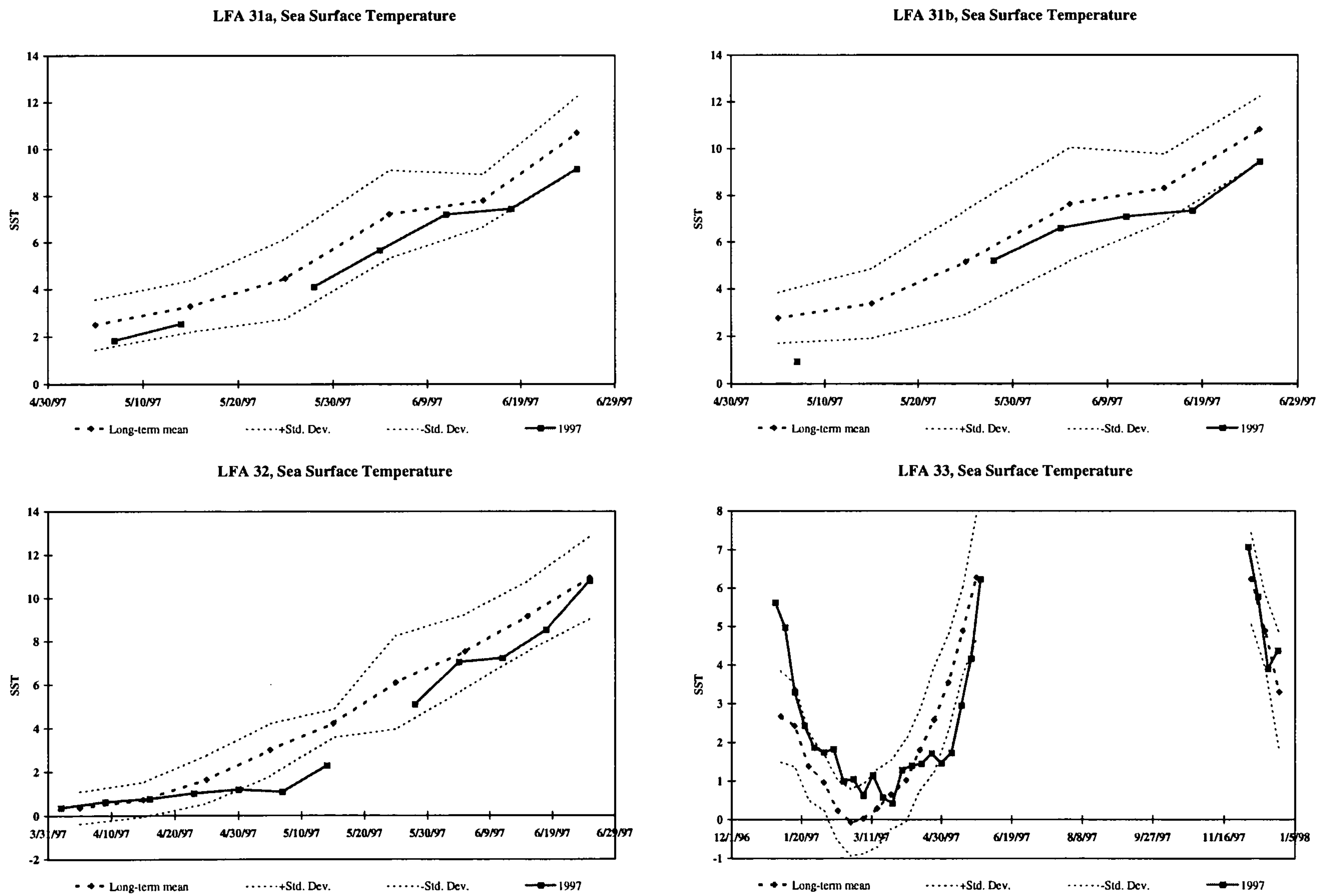


Figure 11(d). Comparison of weekly SST for 1997 and the long-term (1981-1996) means for LFA 31a, 31b, 32 and 33.

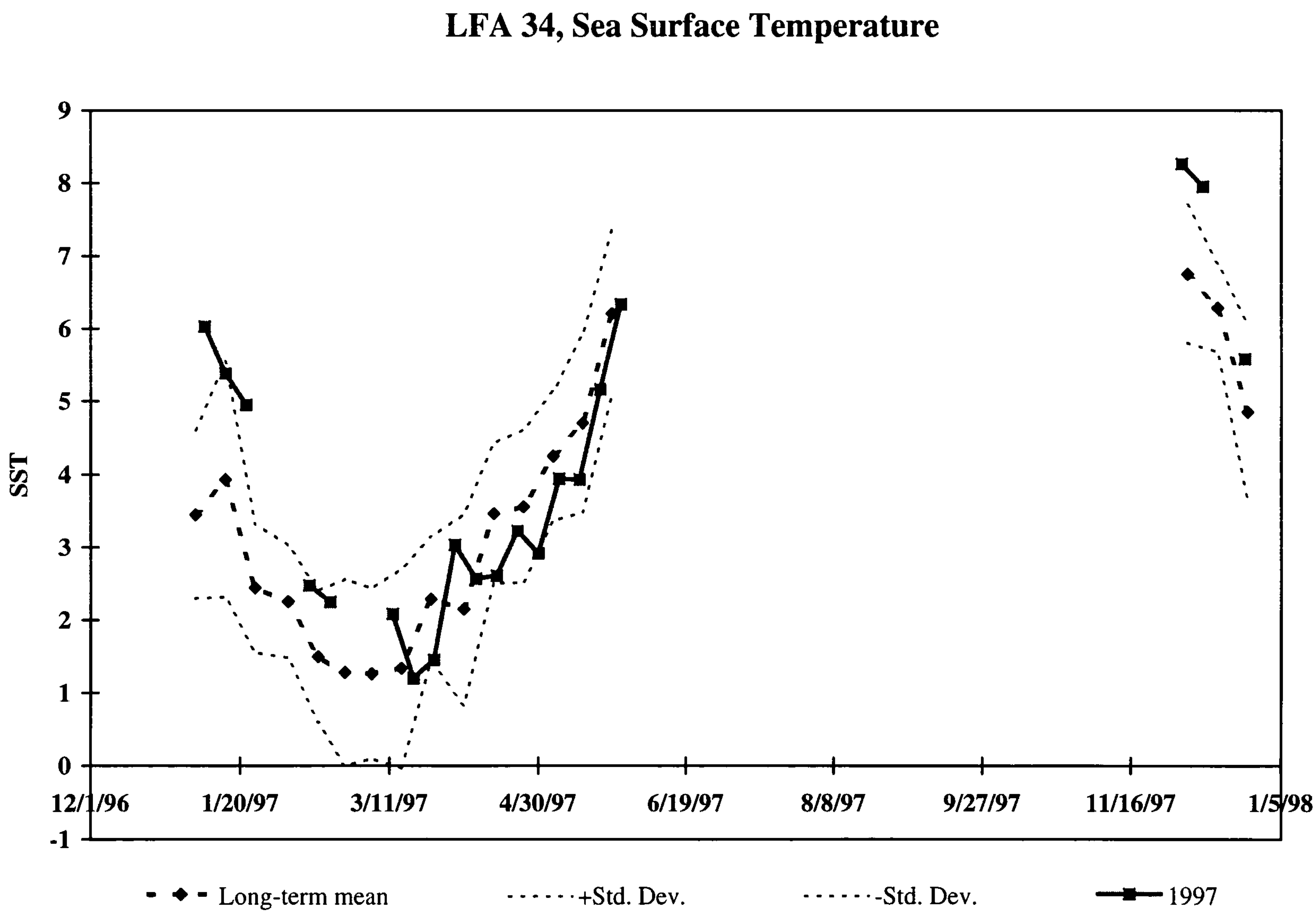
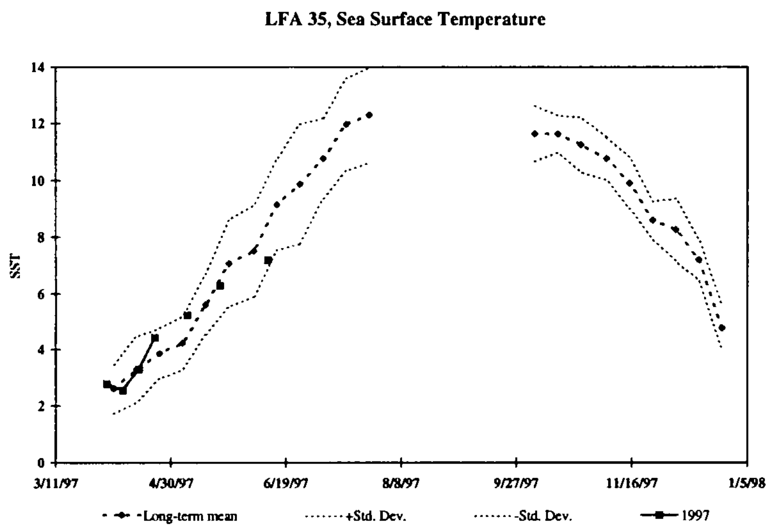
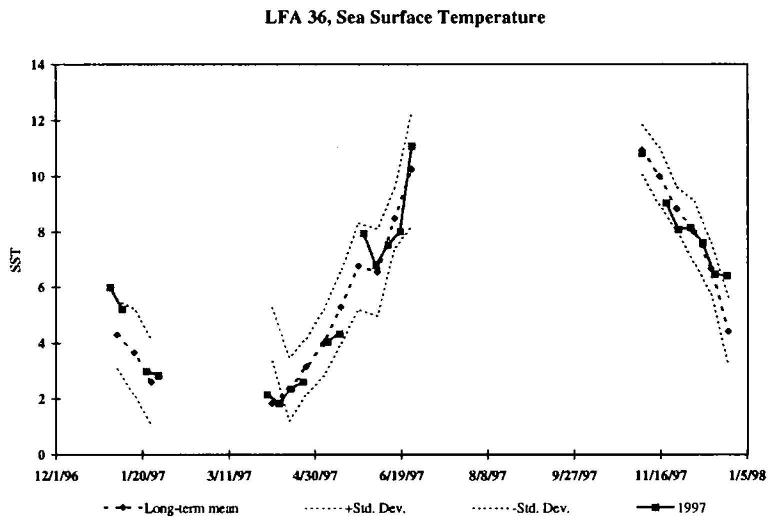


Figure 11(e). Comparison of weekly SST for 1997 and the long-term (1981-1996) means for LFA 34.





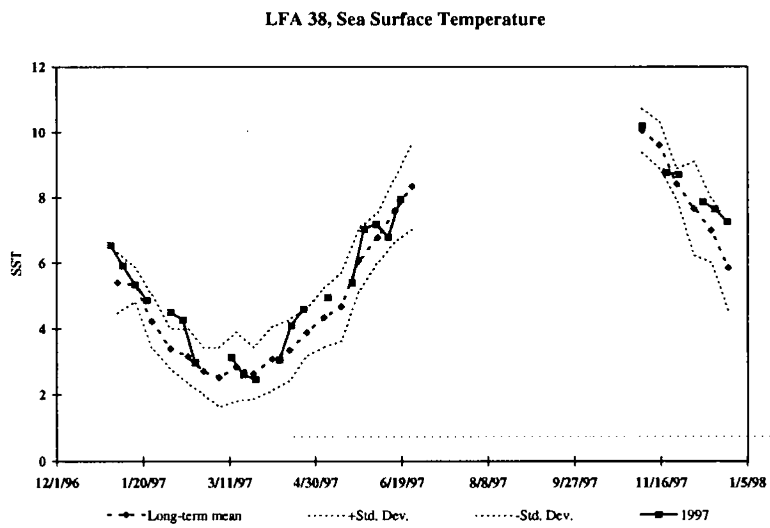


Figure 11(f). Comparison of weekly SST for 1997 and the long-term (1981-1996) means for LFA 35, 36 and 38.

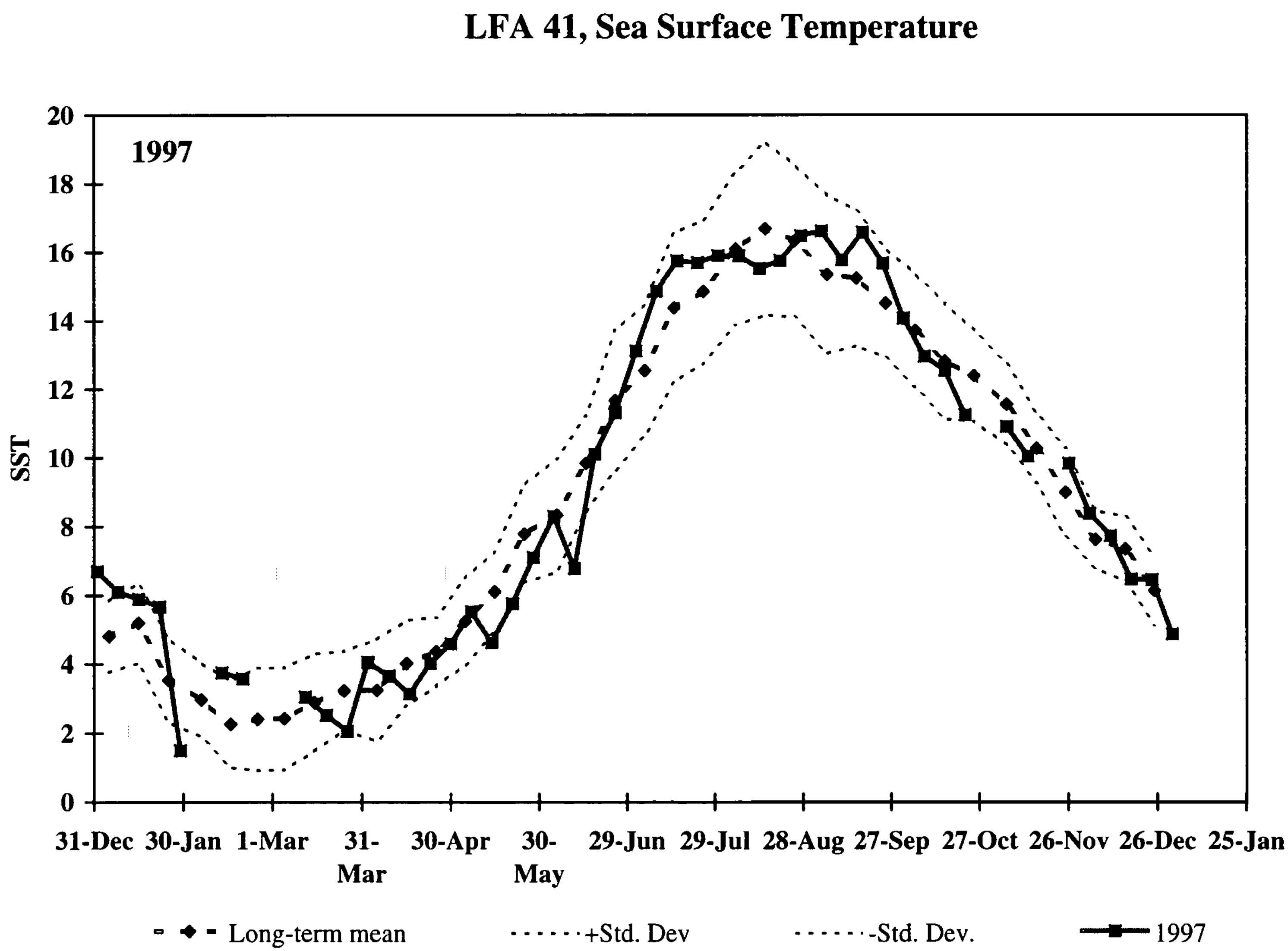


Figure 11(g). Comparison of weekly SST for 1997 and the long-term (1981-1996) means for LFA 41.

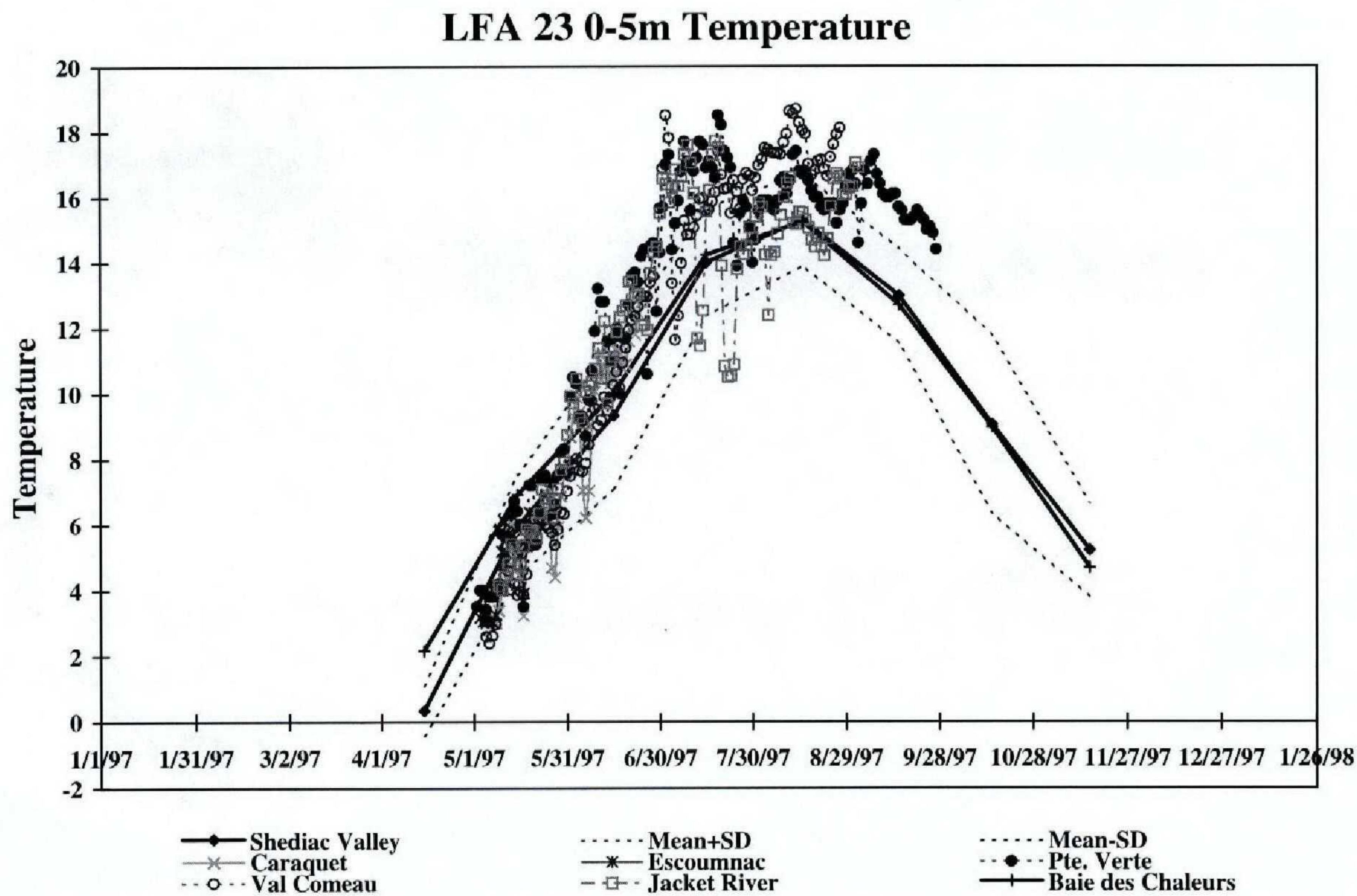


Figure 12. Long-term monthly means 0-5 m for LFA 23 (from GSL atlas, Shediac Valley), means plus and minus 1 standard deviation, 1997 surface temperature data from area, monthly means from Baie des Chaleurs.

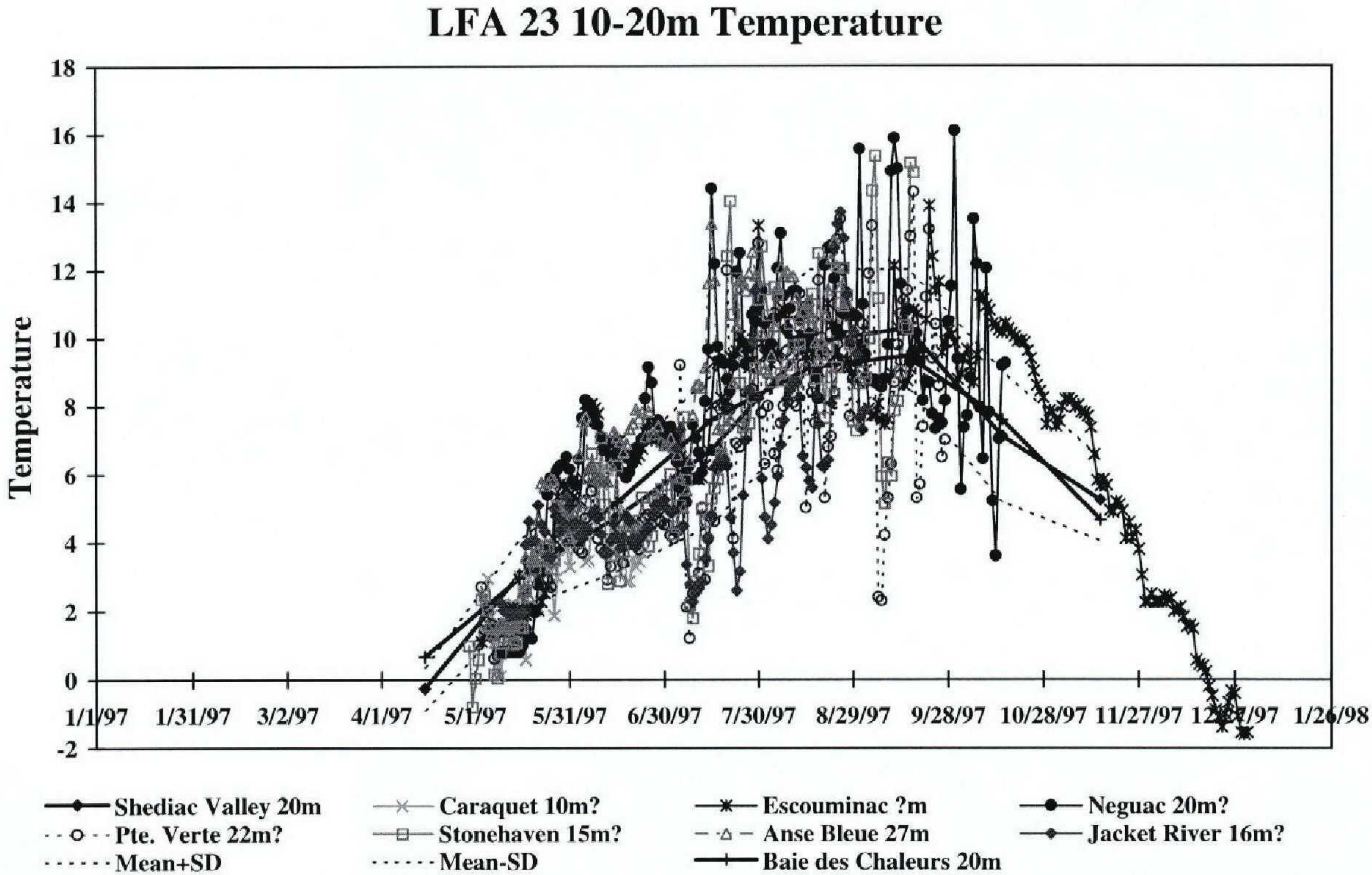


Figure 13. Long-term monthly means 20m for LFA 23 (from GSL atlas, Shediac Valley), 1997 data from the area, monthly means for Baie des Chaleurs.

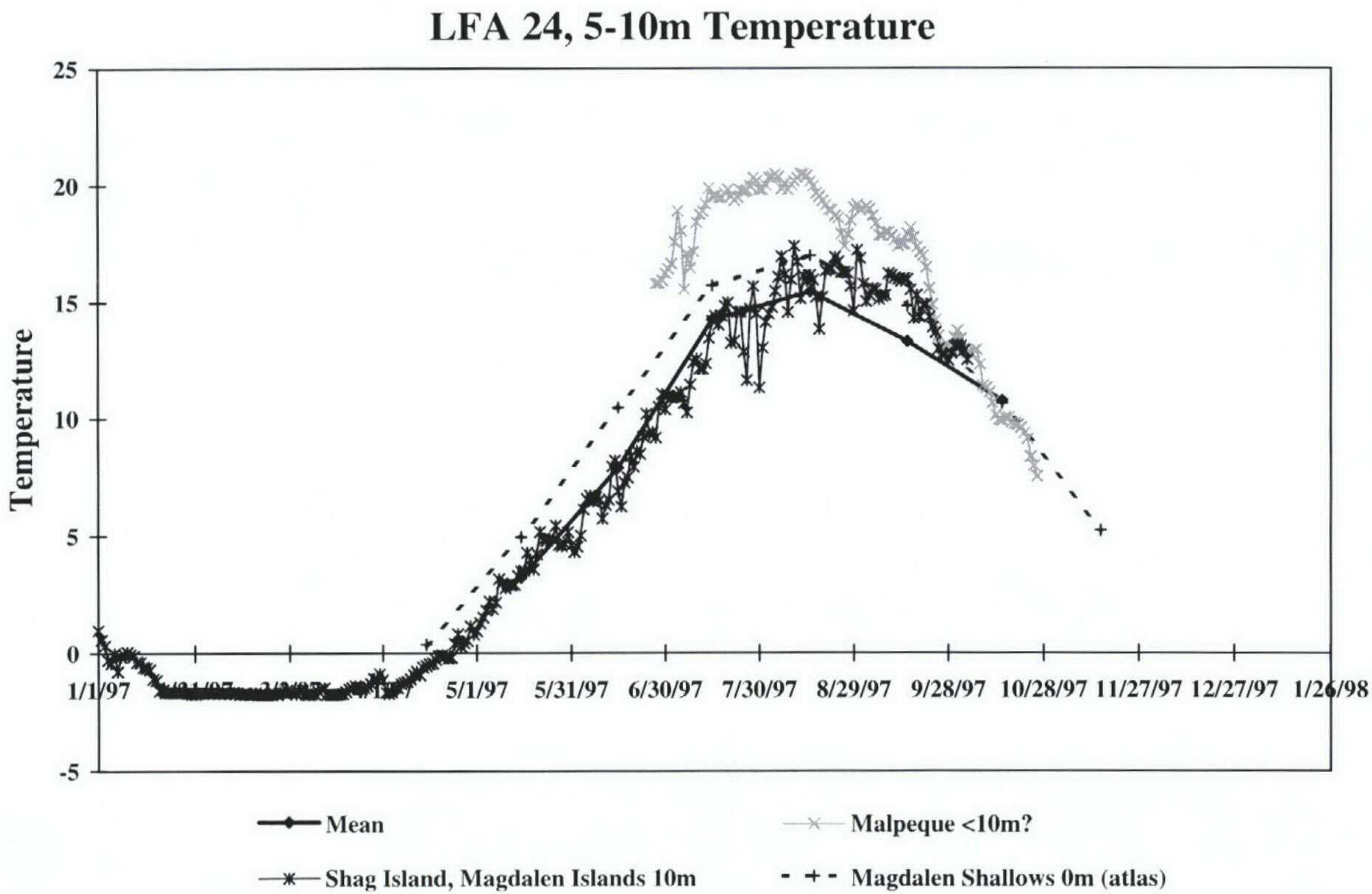


Figure 14. Long-term monthly means for LFA 24, 1997 data from the area, monthly means for Magdalen Shallows, 10m (from GSL atlas).

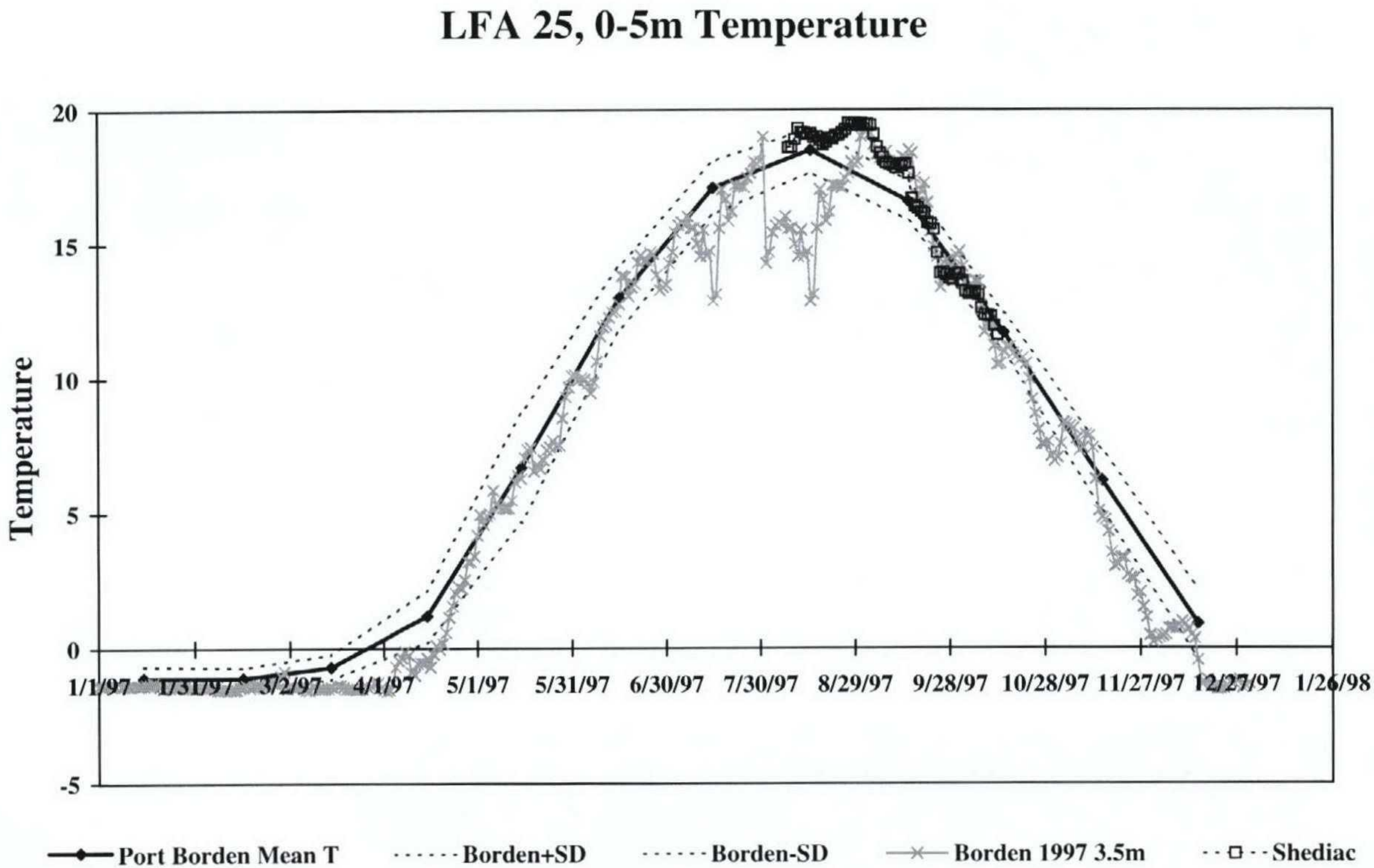


Figure 15. Long-term monthly means for LFA 25 (from the long-term record at Port Borden), + and - 1 standard deviation, and 1997 data from Port Borden and Shediac.

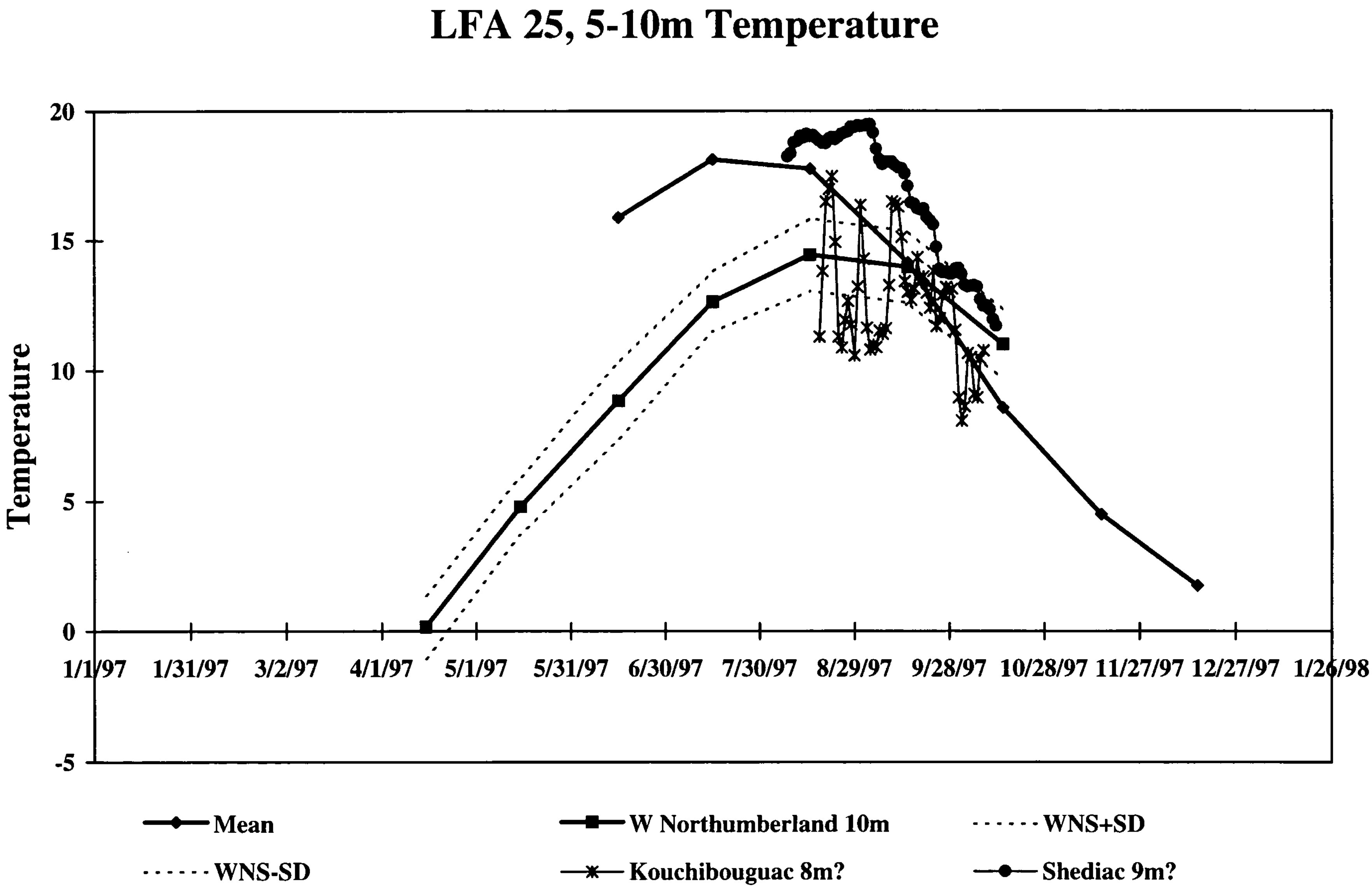


Figure 16. Long-term monthly means for LFA 25, means and means + and - 1 standard deviation for W Northumberland Strait from GSL atlas, 1997 data from area.

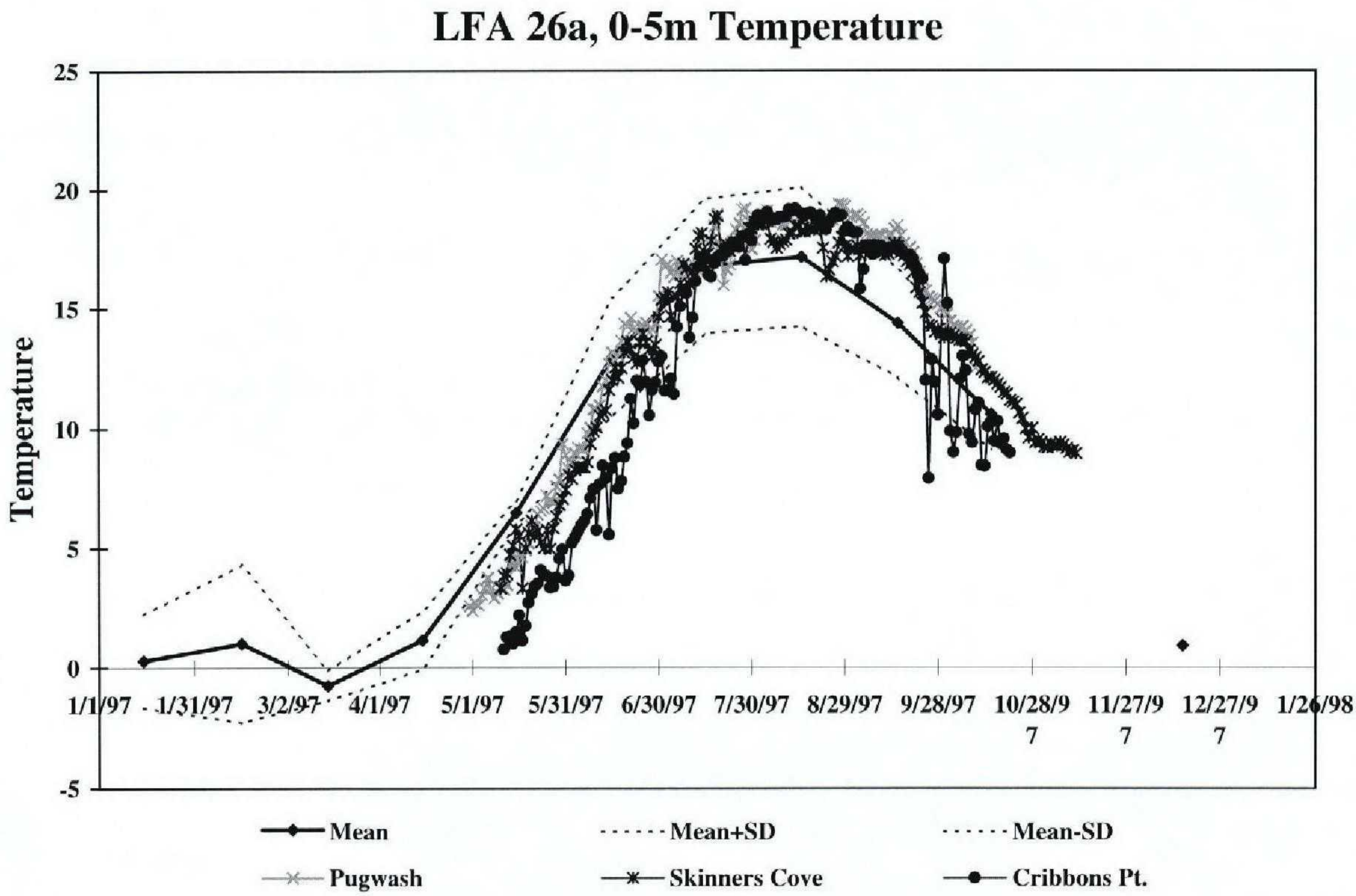


Figure 17. Long-term monthly means for LFA 26a, means + and - 1 standard deviation, 1997 data from the area.

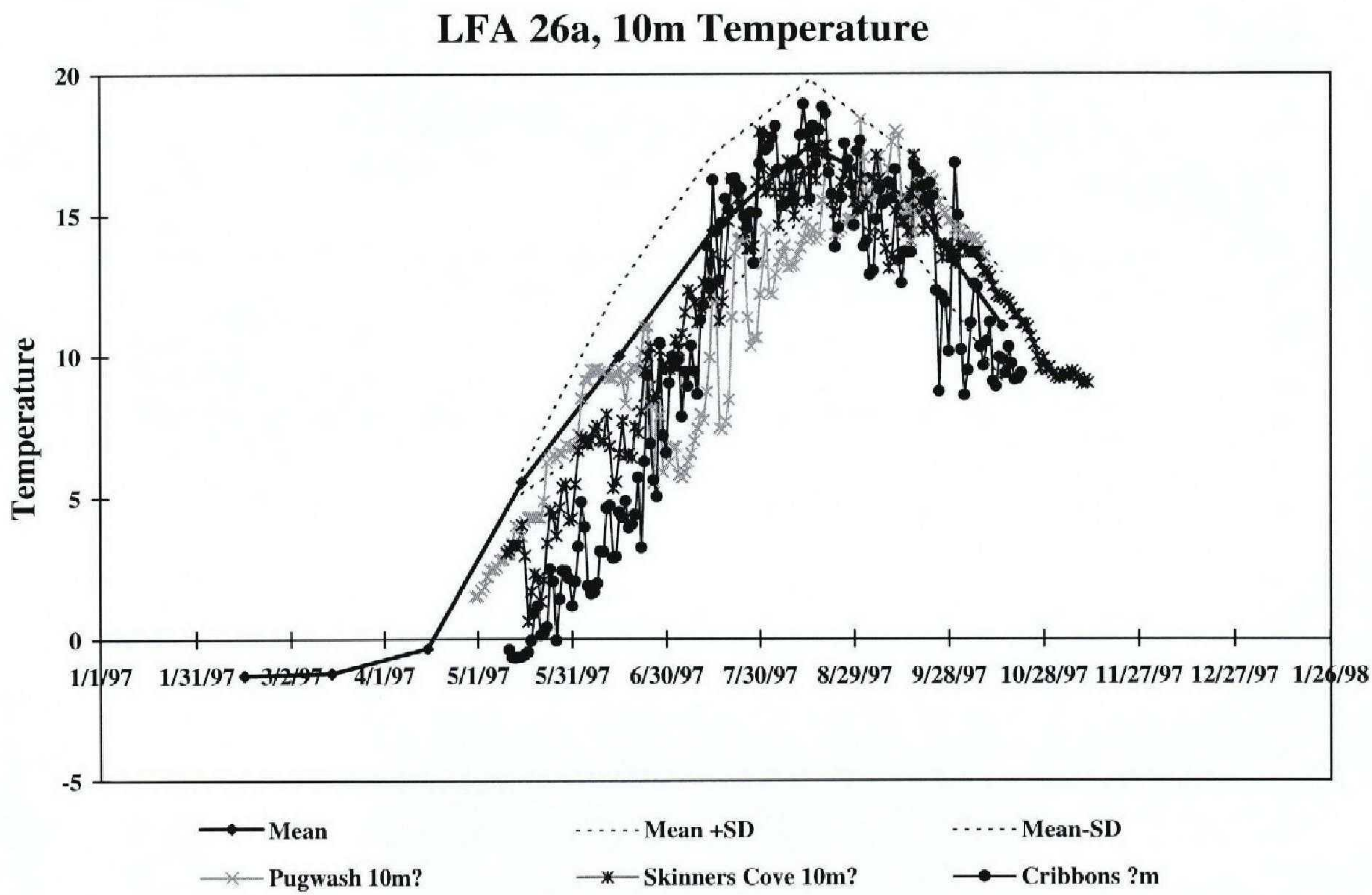


Figure 18. Long-term monthly means for LFA 26a, mean + and - 1 standard deviation, 1997 data for the area.

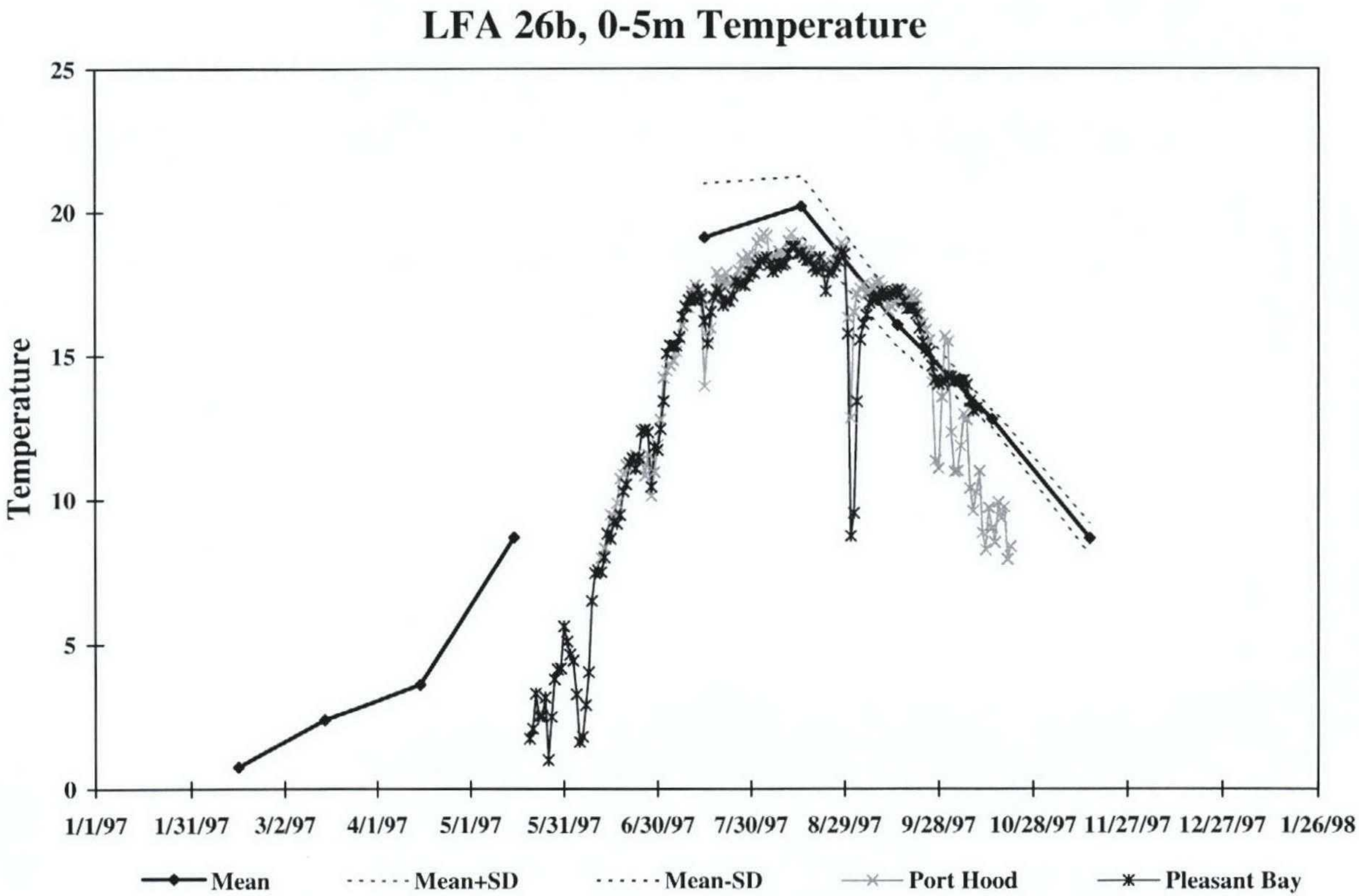


Figure 19. Long-term monthly means for LFA26b, mean + and - 1 standard deviation, 1997 data for the area.

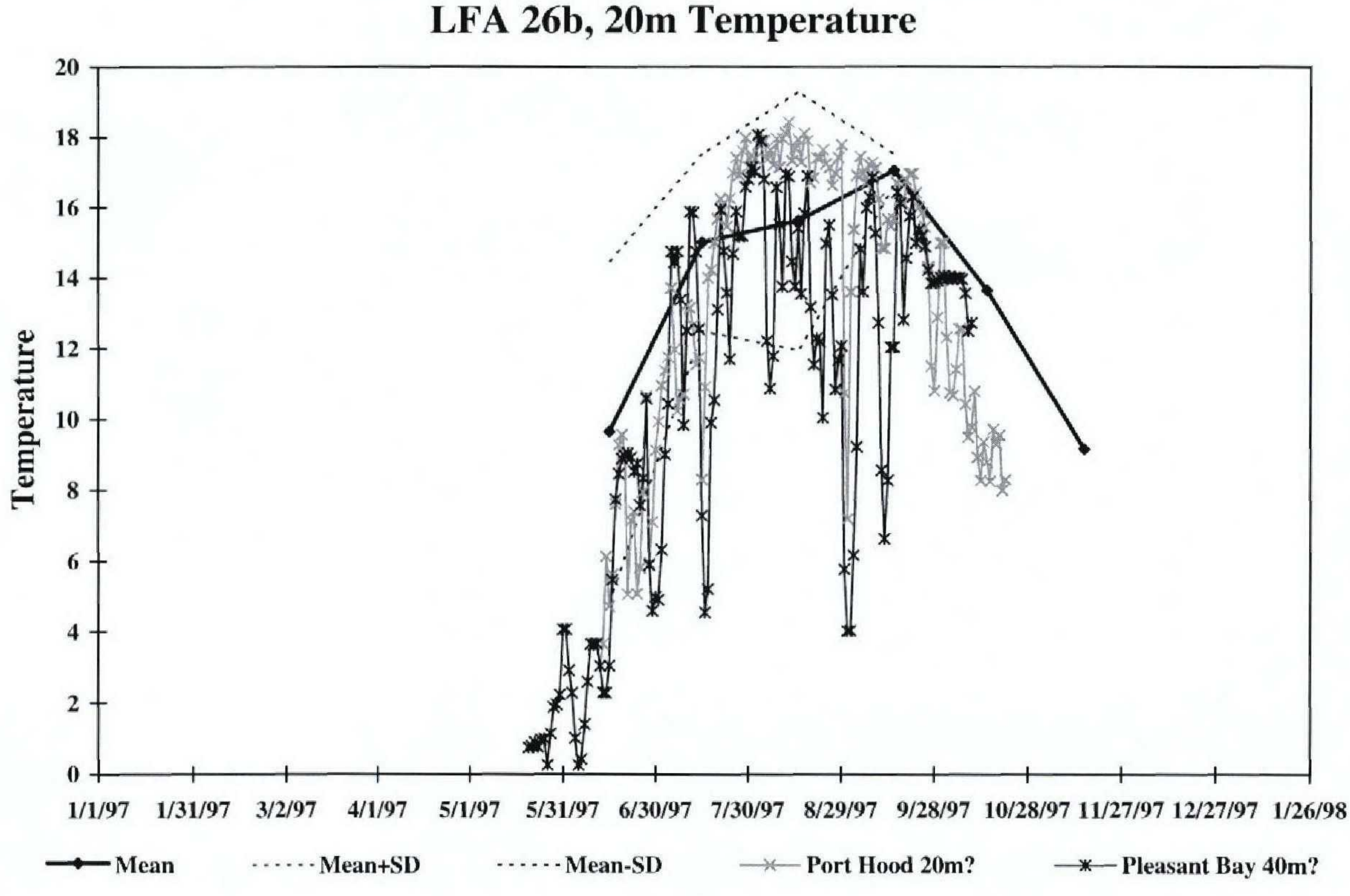


Figure 20. Long-term means for LFA 26b, means + and - 1 standard deviation, 1997 data for the area.

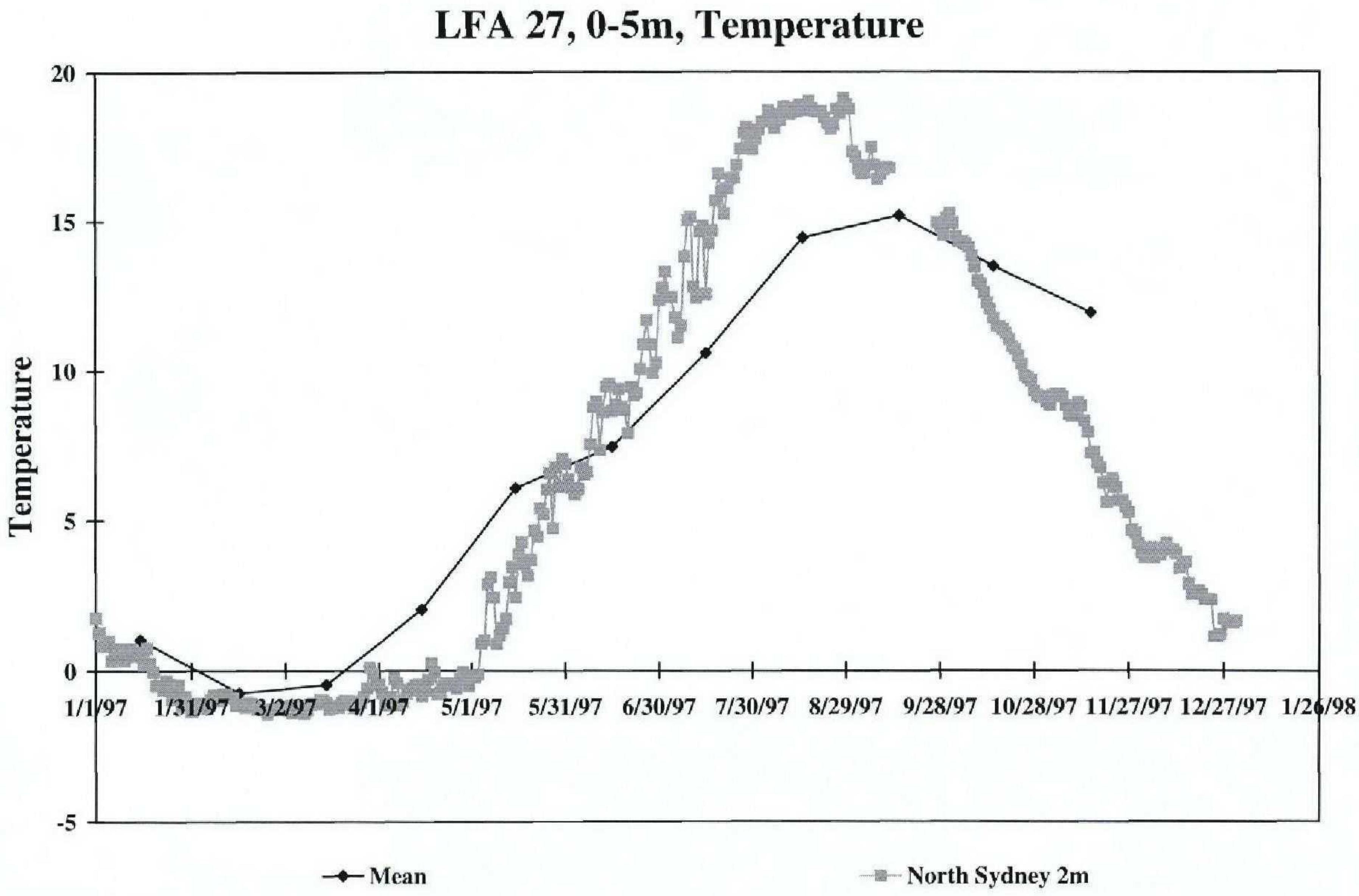


Figure 21. Long-term means for LFA 27, 1997 data for the region.

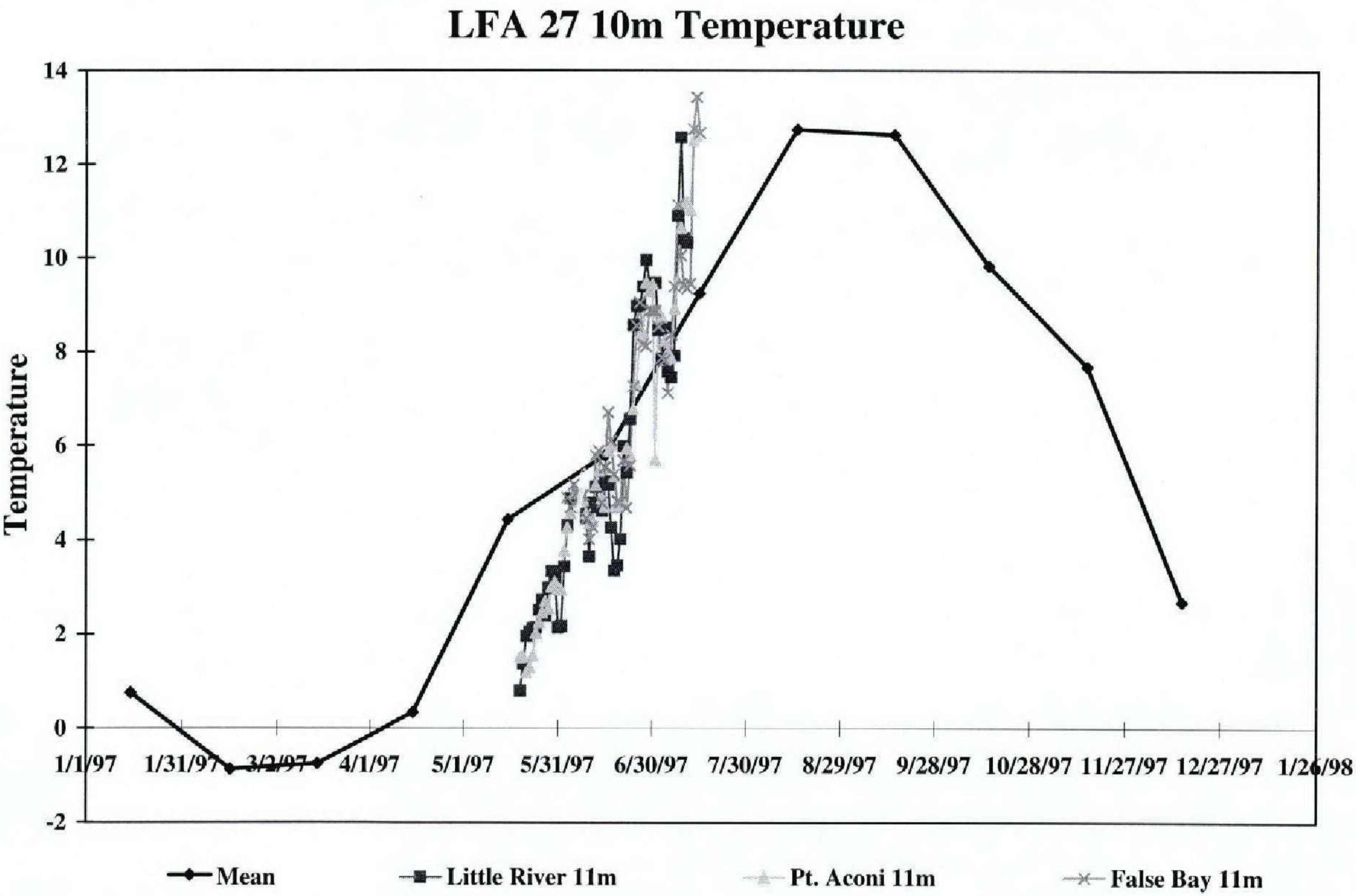


Figure 22. Long-term means for LFA 27, 1997 data for the area.

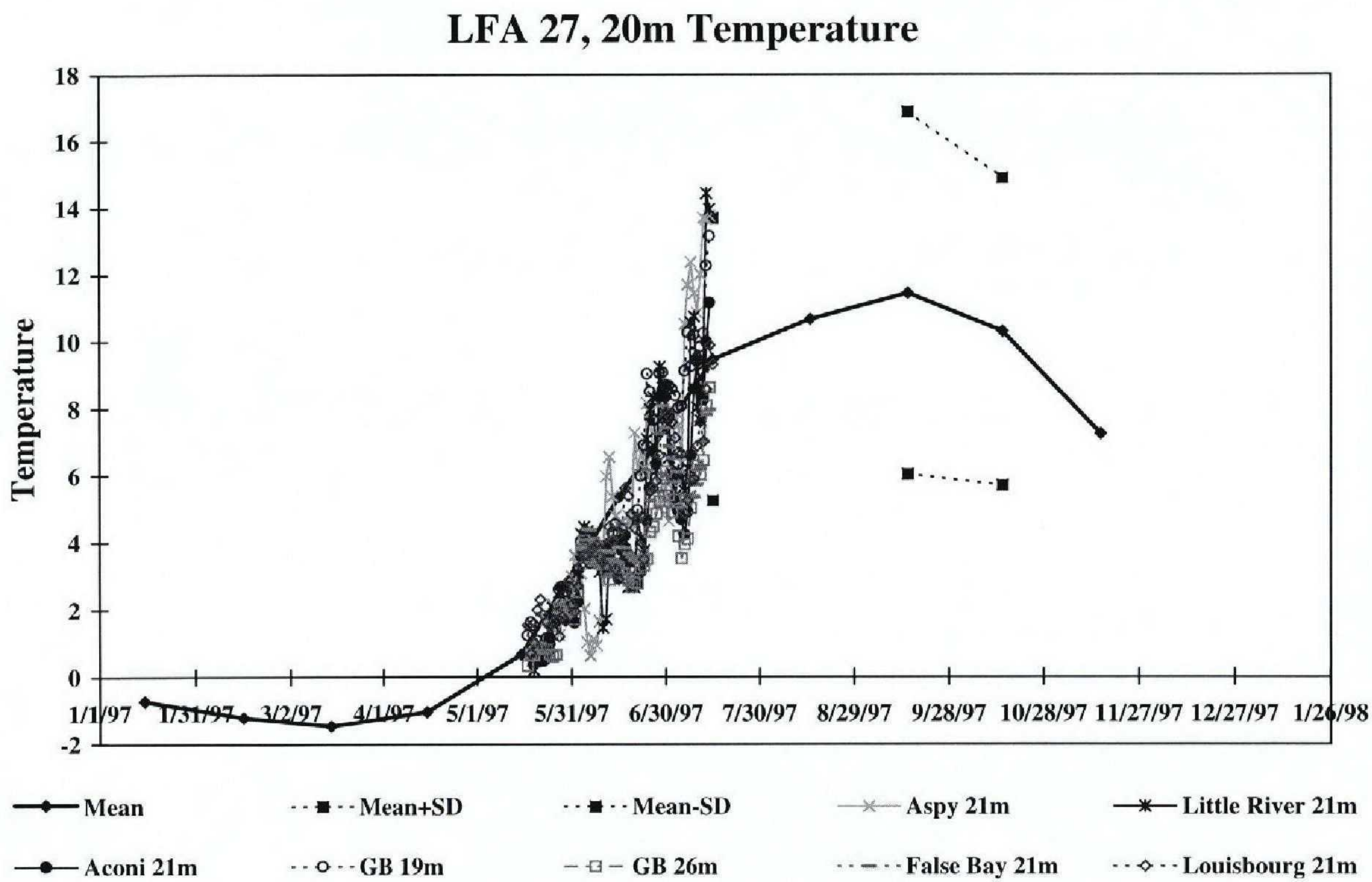


Figure 23. Long-term means for LFA 27, mean + and - 1 standard deviation, 1997 data for the region.

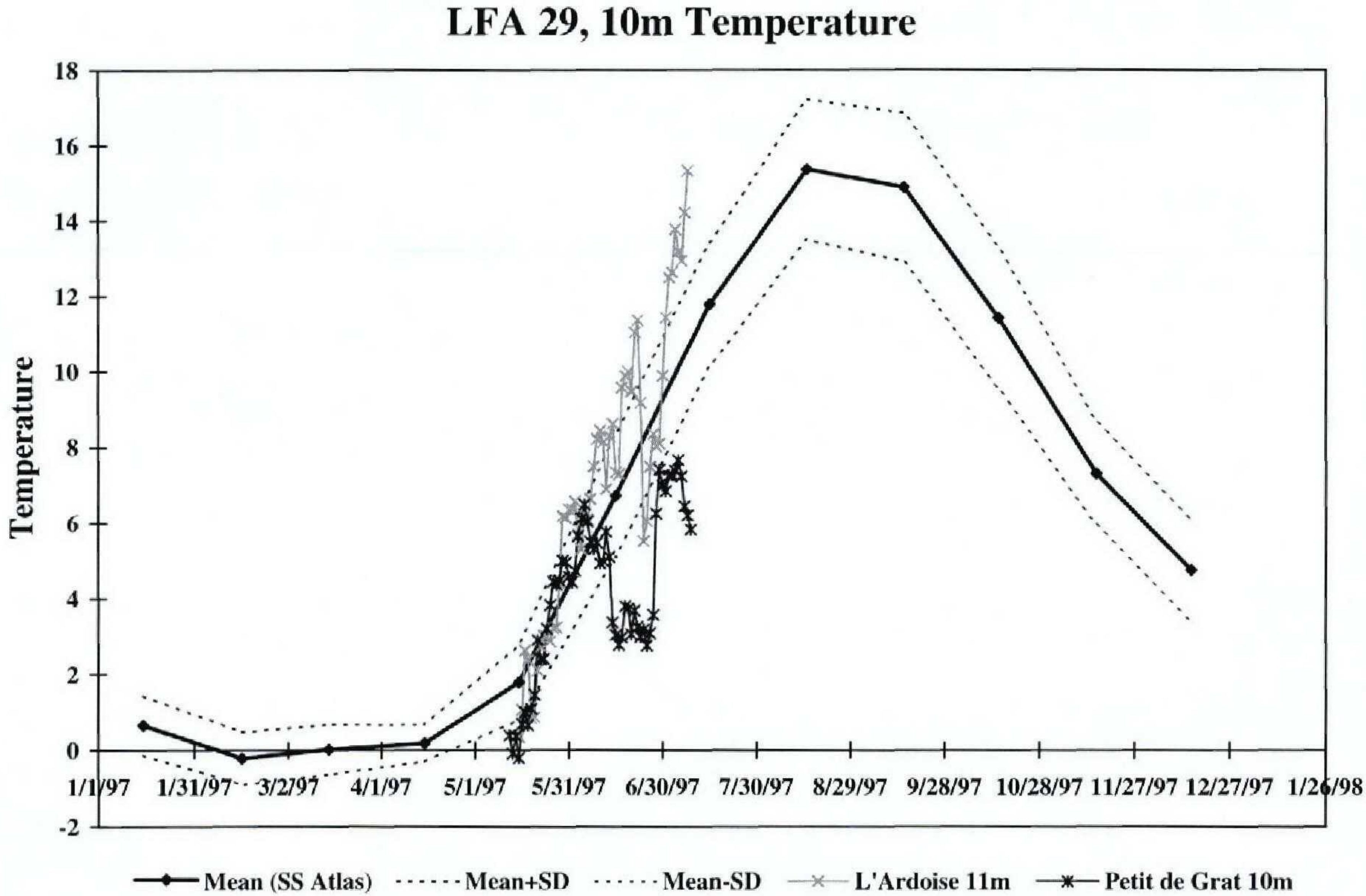


Figure 24. Long-term means for LFA 29 from Scotian Shelf atlas, mean + and - 1 standard deviation, 1997 data from the area.

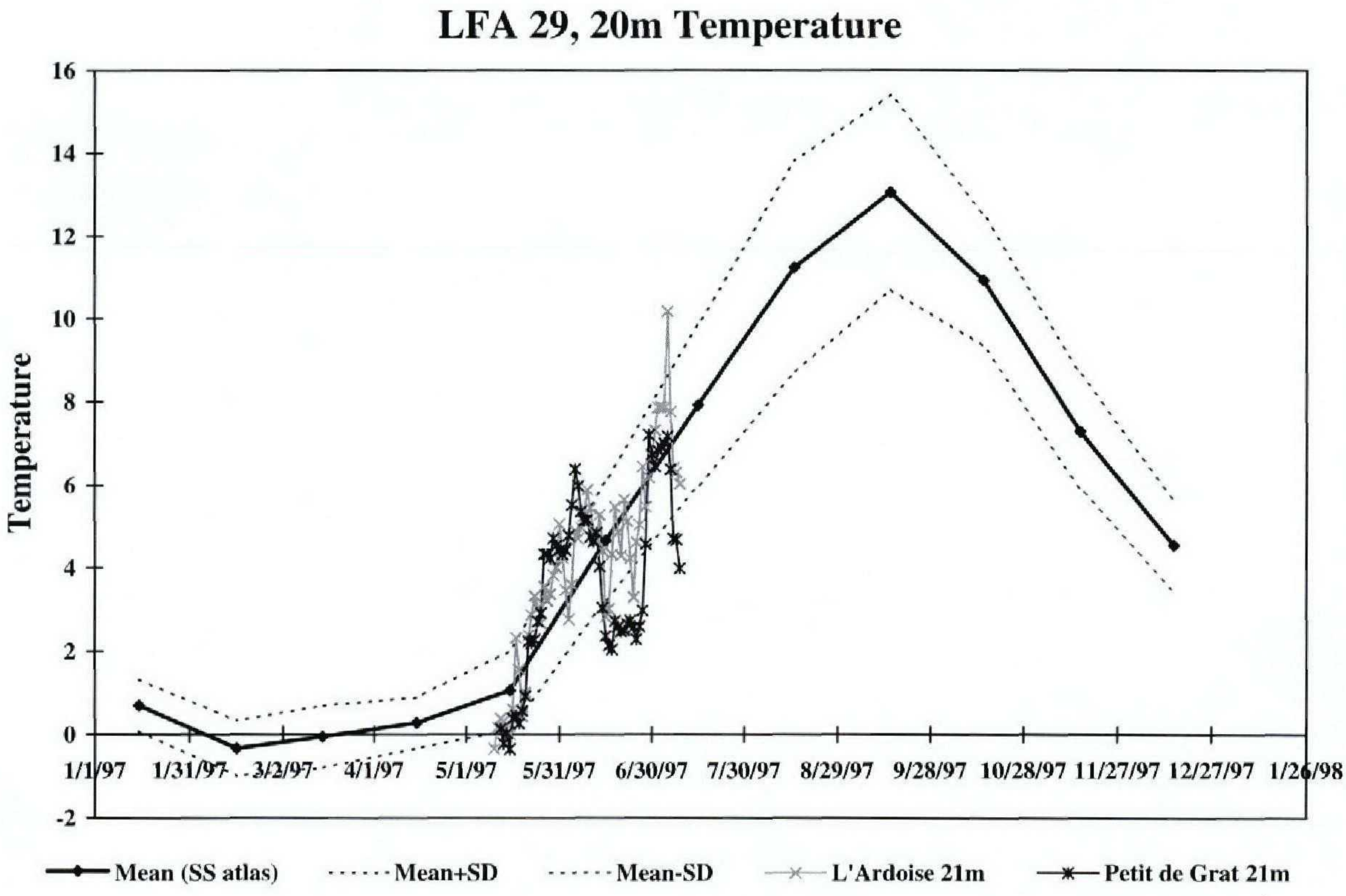


Figure 25. Long-term means for LFA 29 from Scotian Shelf atlas, mean + and - 1 standard deviation, 1997 data from the area.

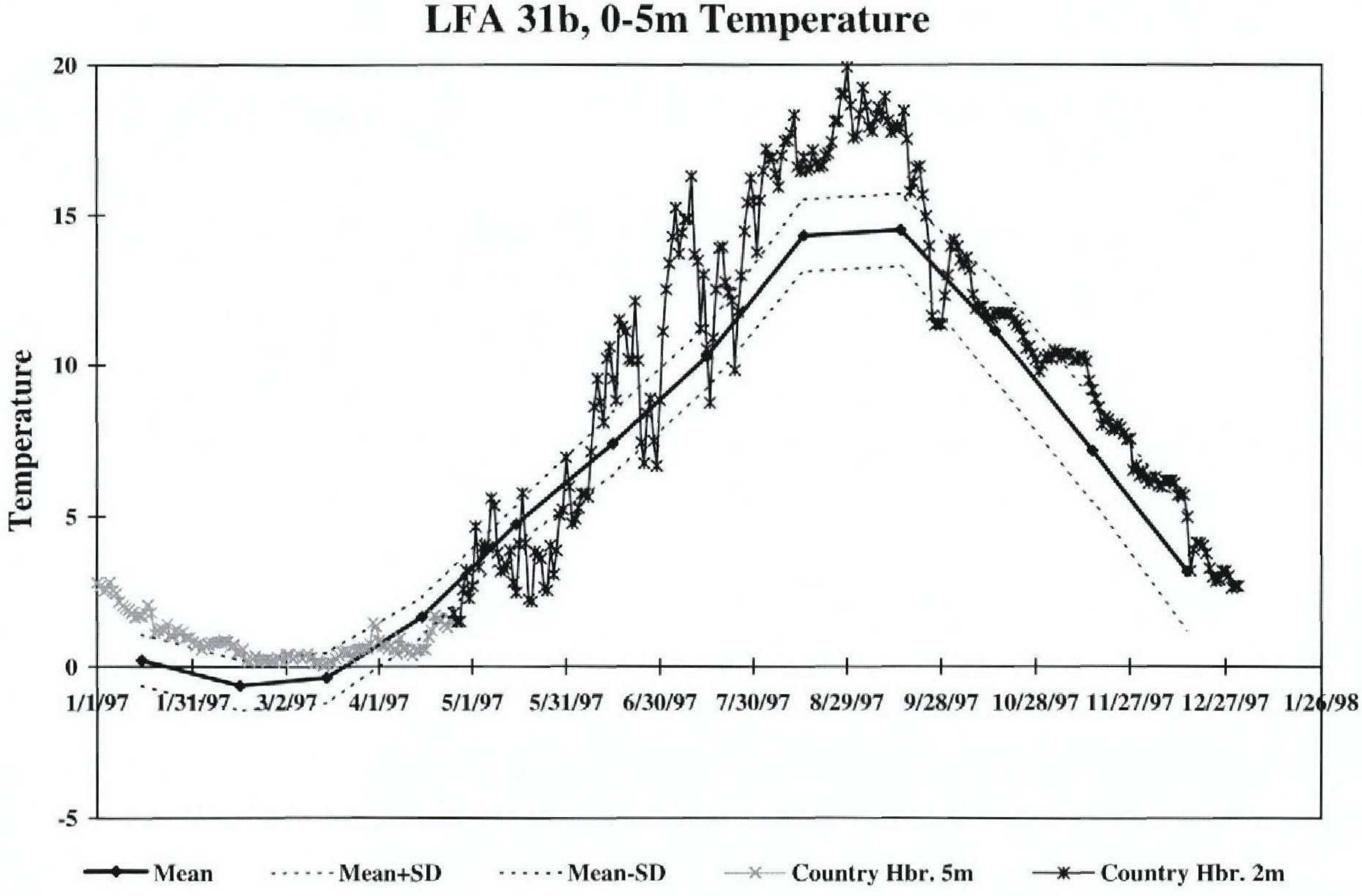


Figure 26. Long-term means for LFA 31b, mean + and - 1 standard deviation, 1997 data for the area.

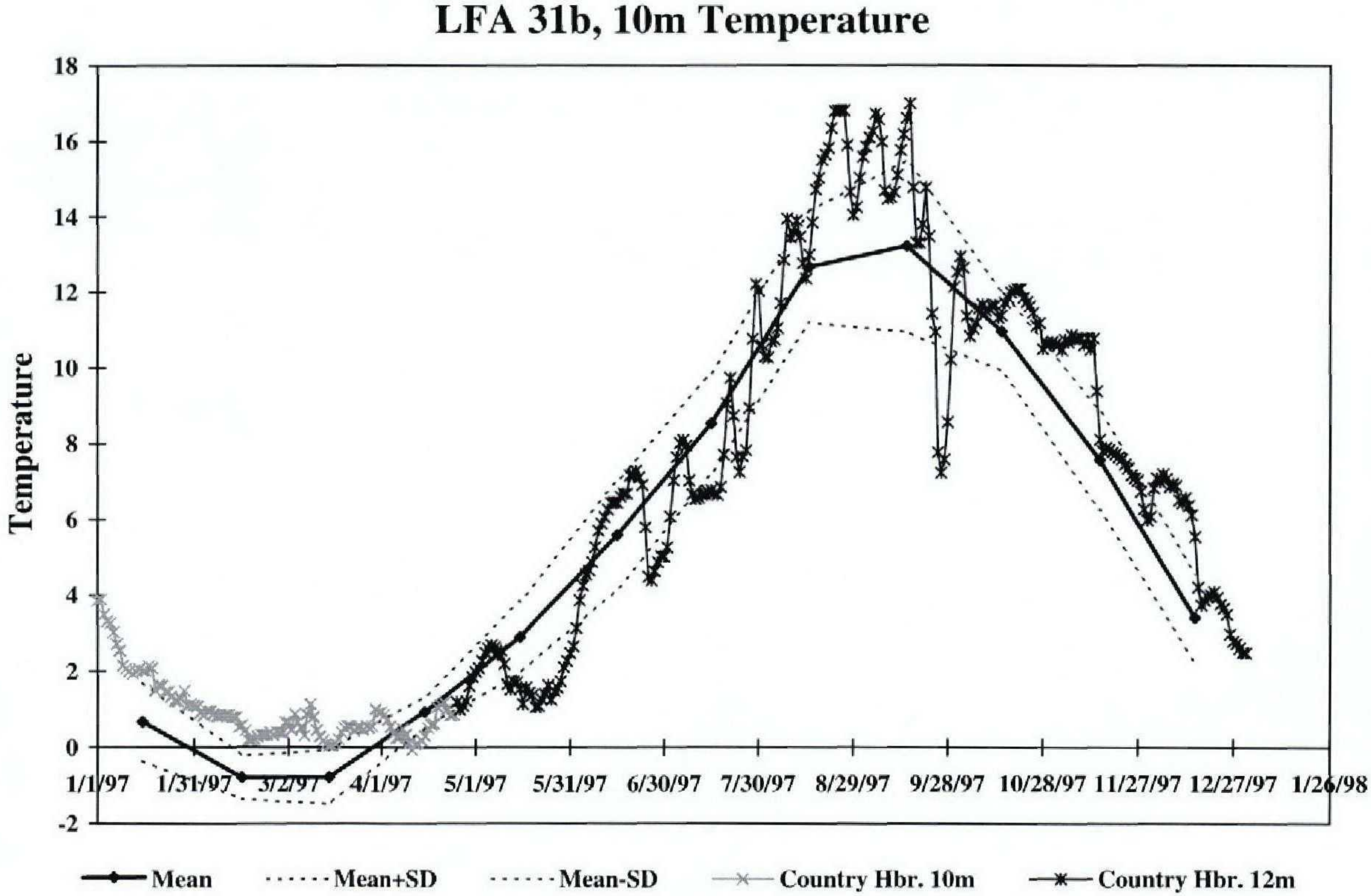


Figure 27. Long-term means for LFA 31b, mean + and - 1 standard deviation, 1997 data for the area.

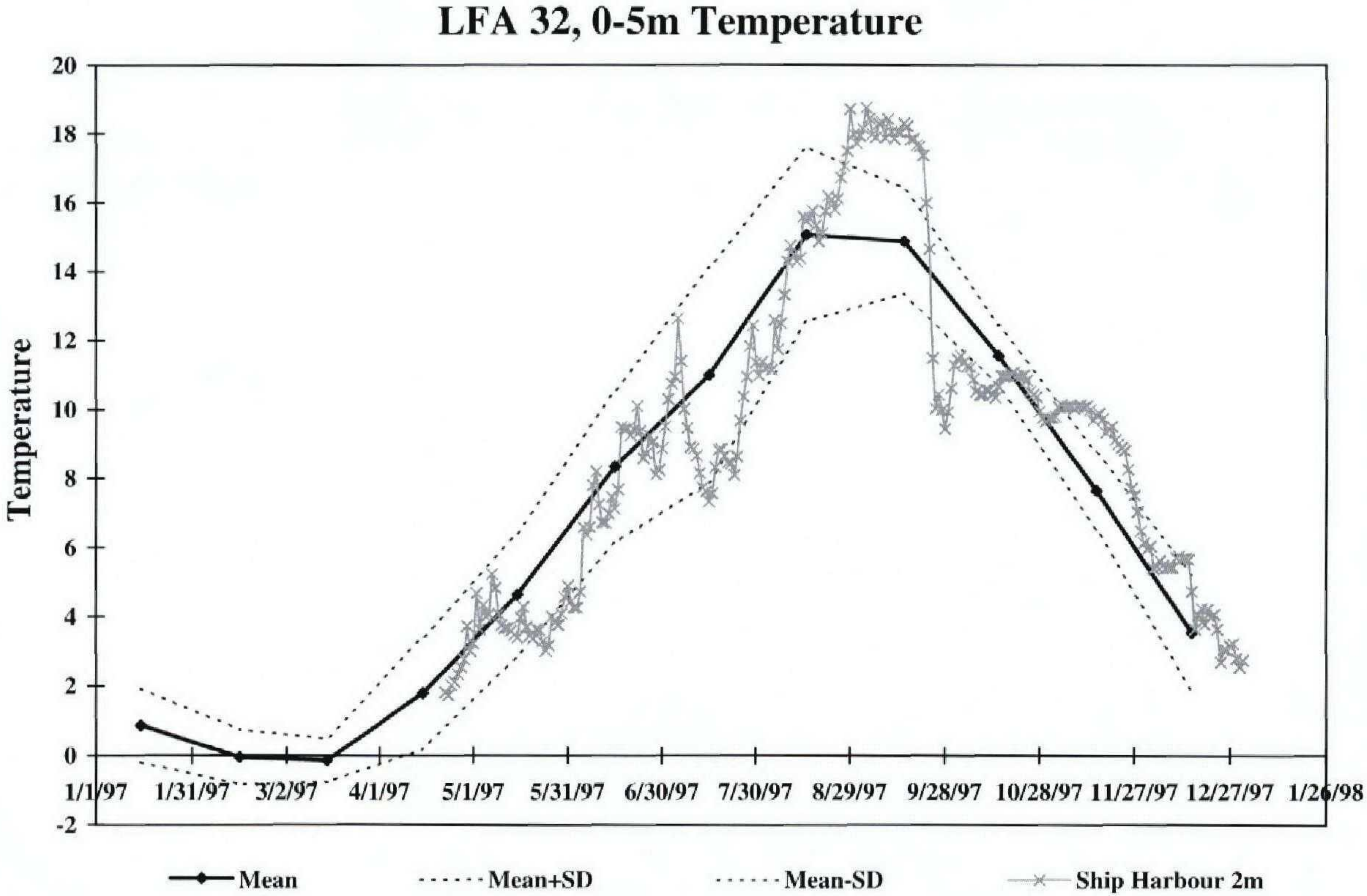


Figure 28. Long-term means for LFA 32, mean + and - 1 standard deviation, 1997 data for the area.

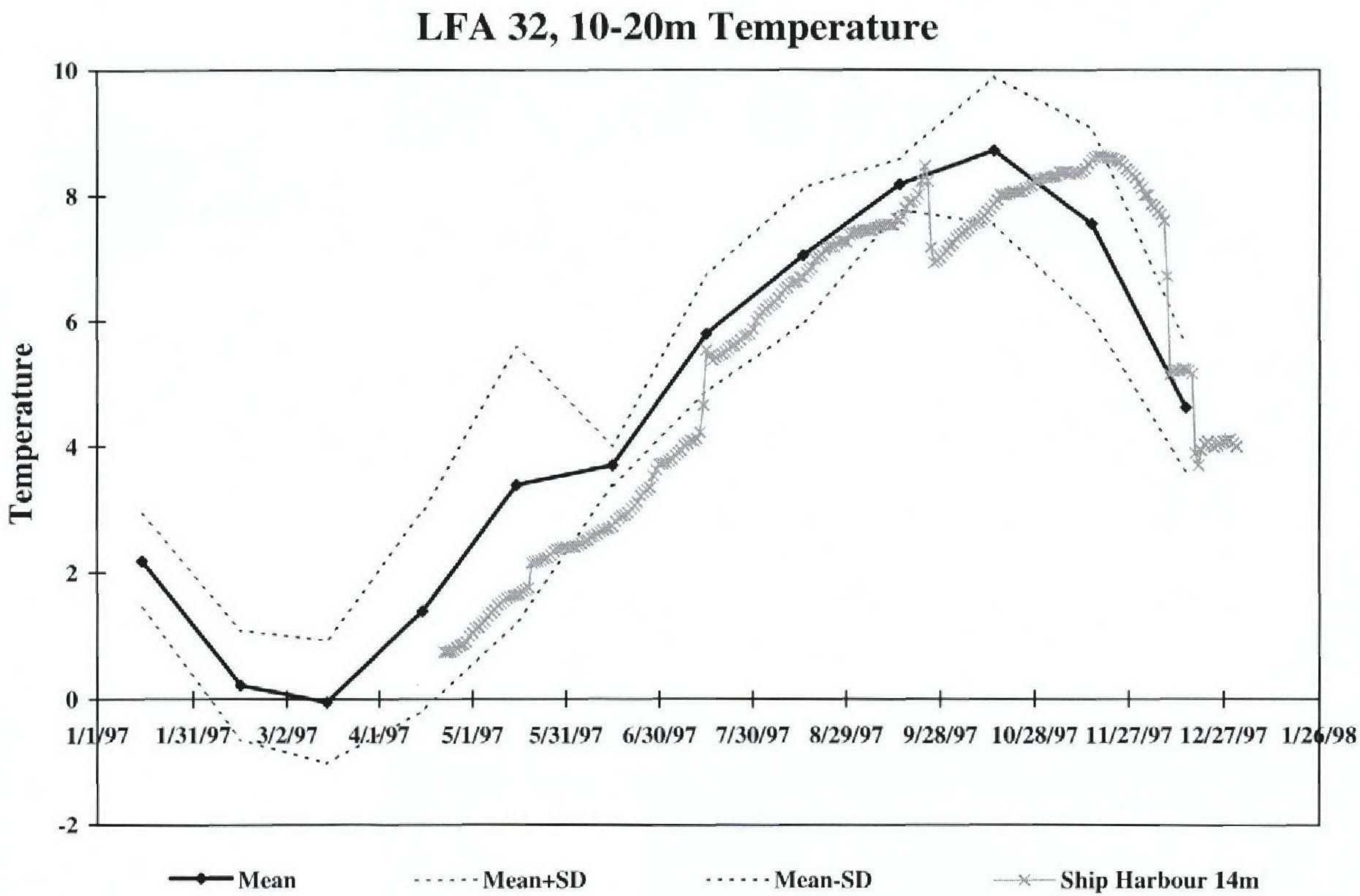


Figure 29. Long-term means for LFA 32, mean + and - 1 standard deviation, 1997 data from the area.

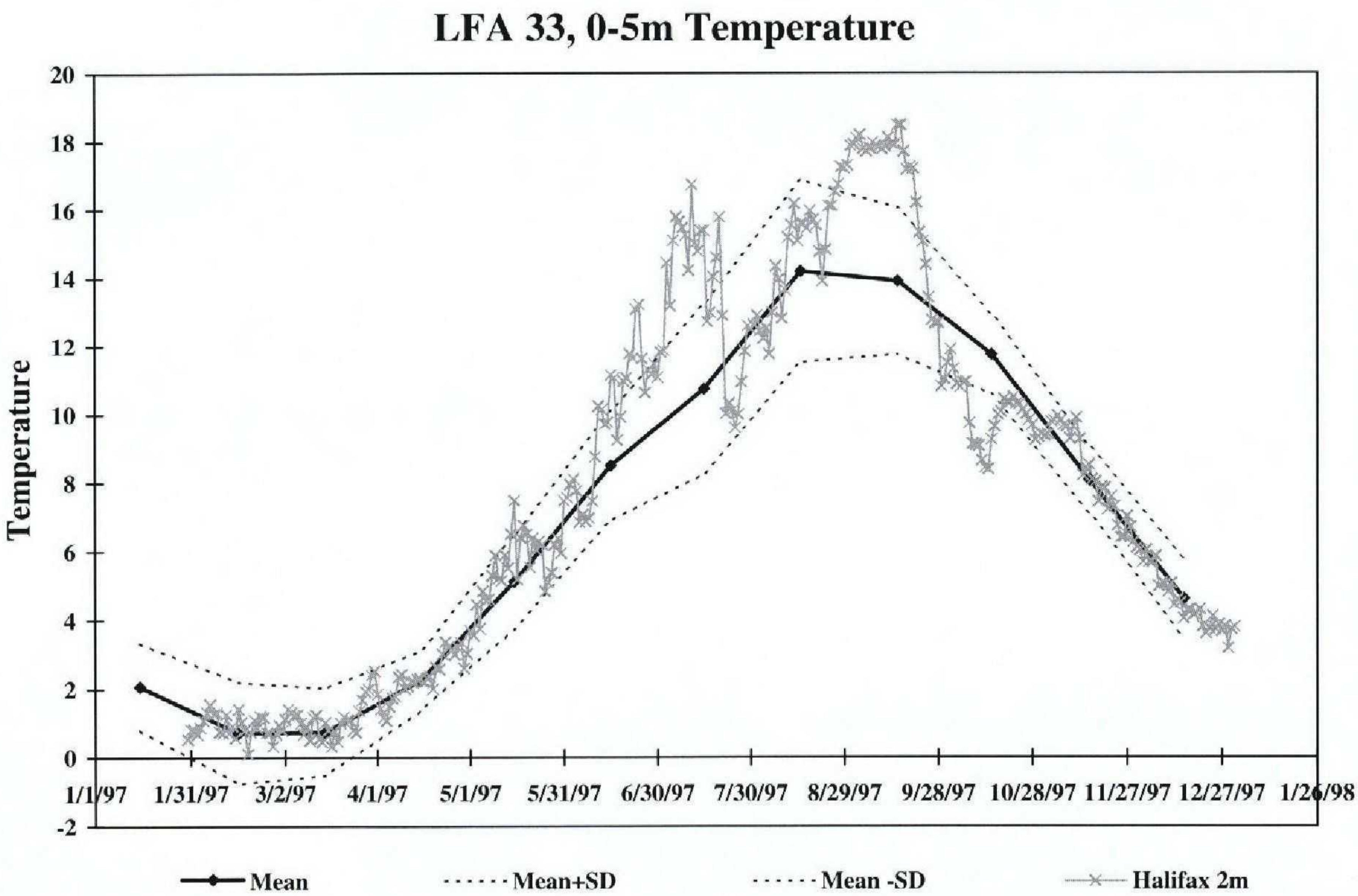


Figure 30. Long-term means for LFA 33, mean + and - 1 standard deviation, 1997 data for the area.

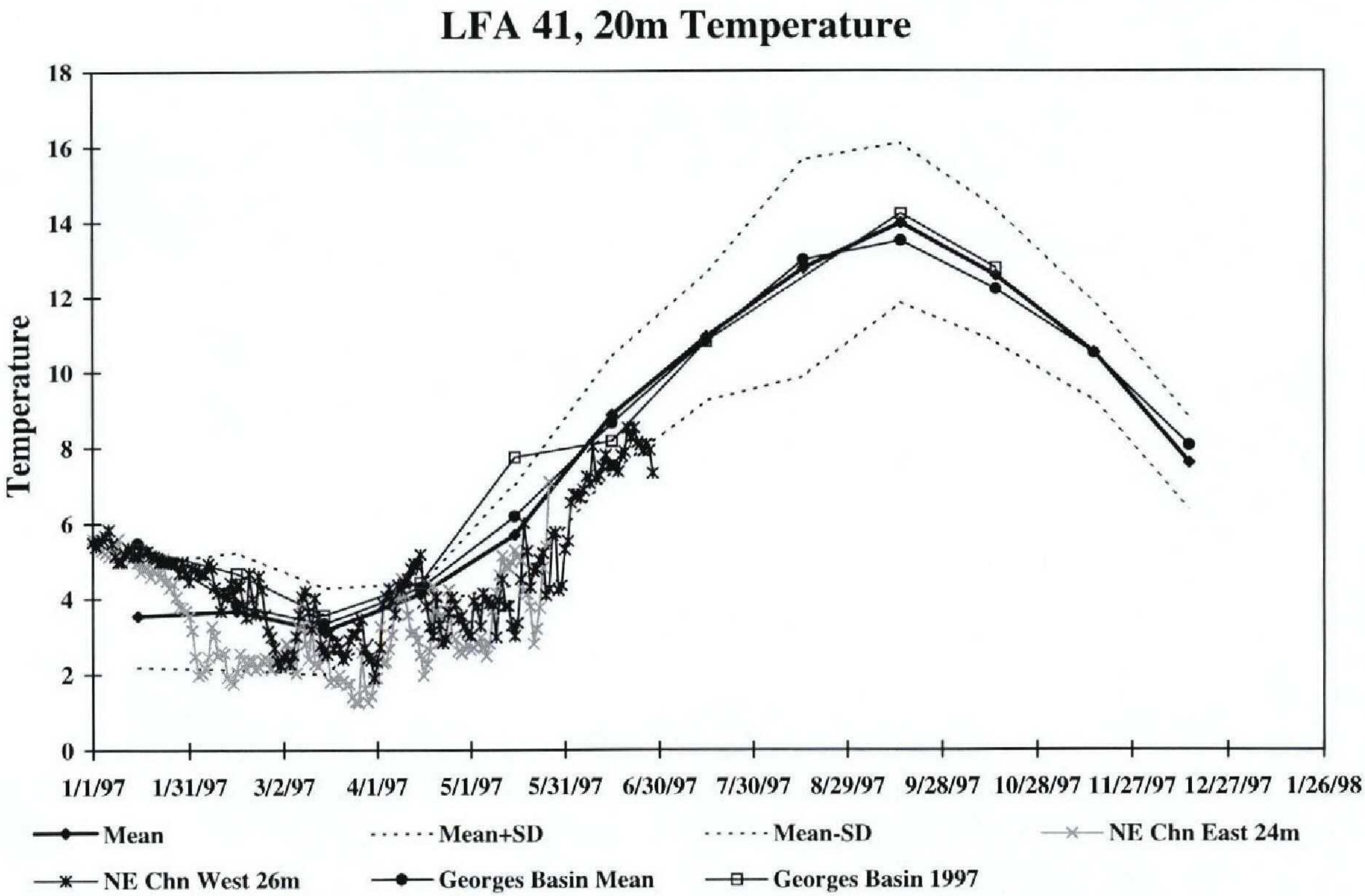


Figure 31. Long-term means for LFA 41 (NE Channel and Georges Basin), mean + and - 1 standard deviation, 1997 data for the area.

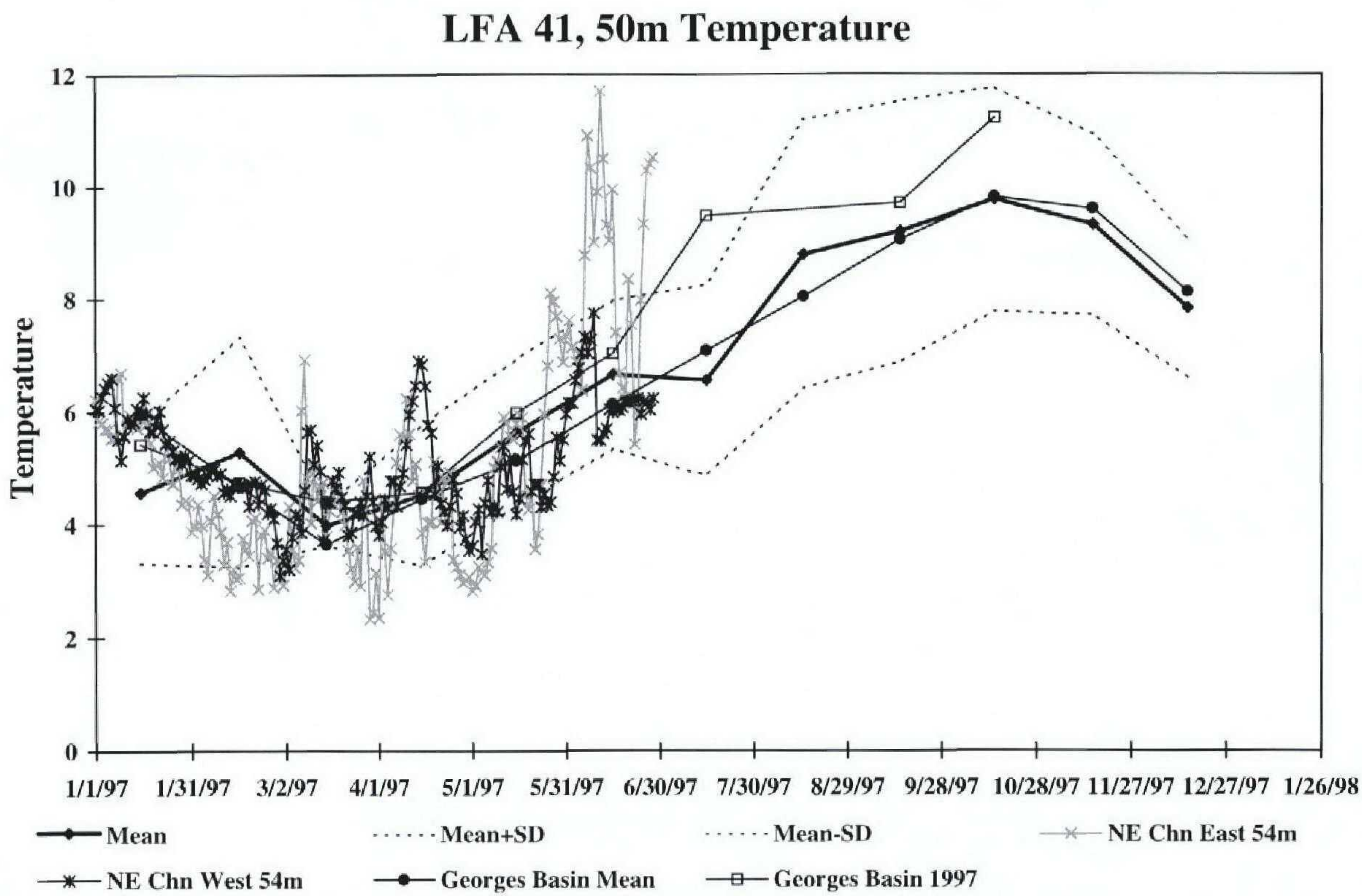


Figure 32. Long-term means for LFA 41 (NE Channel and Georges Basin), mean + and - 1 standard deviation, 1997 data for the area.

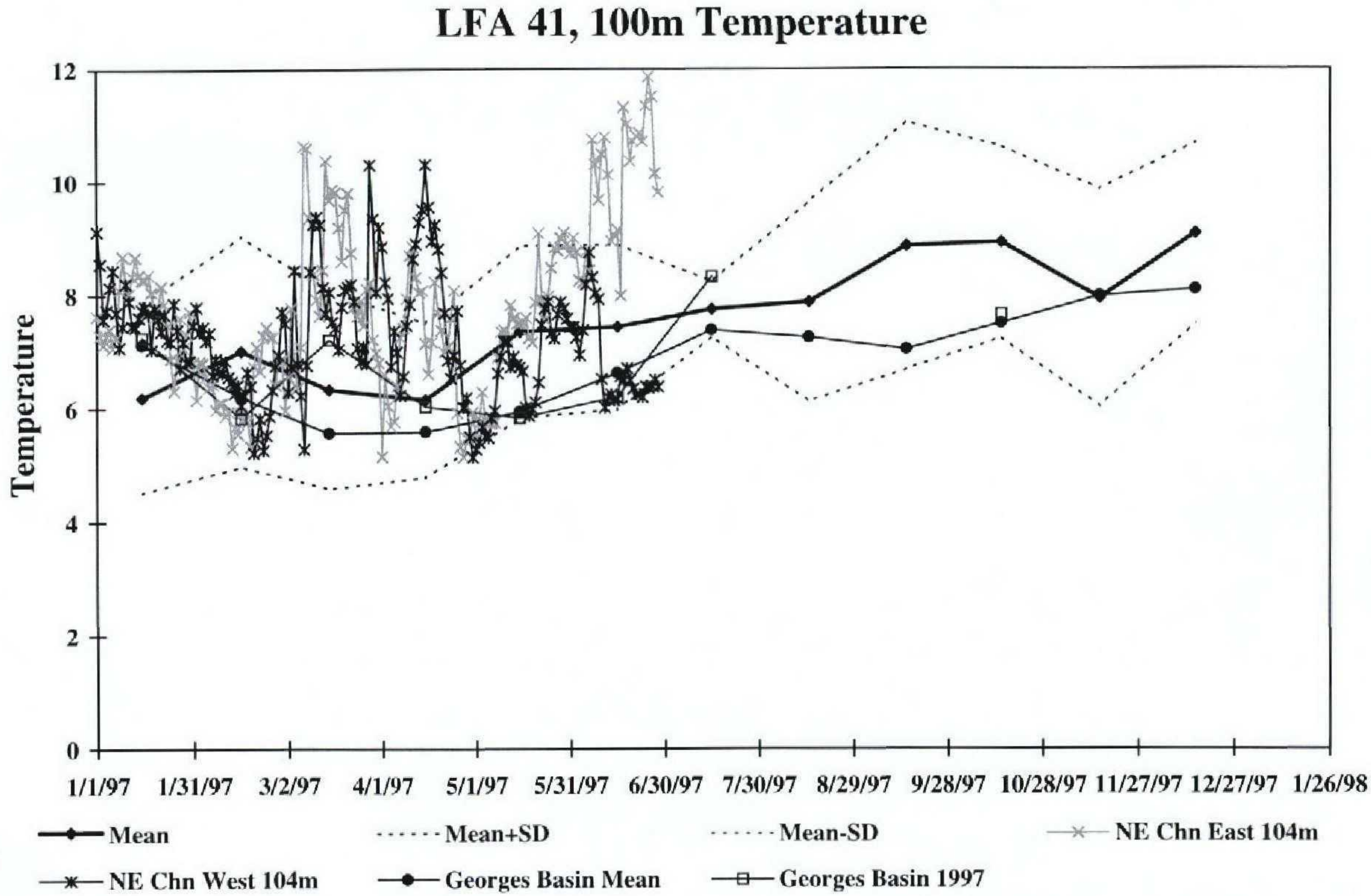


Figure 33. Long-term means for LFA 41 (NE Channel and Georges Basin), mean + and _ 1 standard deviation, 1997 data from the area.