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Temperature Conditions in Lobster Fishing Areas 27-33 on the Scotian Shelf: 1999-2003

Caractéristiques de la Température dans les Aires de Pêche du homard 27-33 sur le Plateau Néo-Écossais pour la Période 1999-2003

B. Petrie and R.G. Pettipas

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

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ABSTRACT

A review of physical oceanographic conditions for Lobster Fishing Areas 27-33 on the Scotian Shelf from 1999 to 2002 is presented. The analysis is based almost entirely on nearshore temperature times series collected by local fishermen through the Fishermen and Scientists Research Society supplemented by some data collected by Fisheries and Oceans and satellite-derived sea surface temperatures. From the records we compute the average temperature, the temperature trend and the variability of temperature in a period roughly corresponding to the fishing season in each area. Average temperatures during the fishing season were generally high in 1999 and 2001, cold in 2002 and 2003 and mixed in 2000. The variability was typically high in 1999 and 2003, low in 2000 and 2002 and mixed in 2001.

RÉSUMÉ

Ce document présente une synthèse des conditions océanographiques physiques dans les zones de pêche du homard 27 à 33, sur le plateau néo-écossais, de 1999 à 2002. L'analyse est fondée presque exclusivement sur les séries chronologiques de températures relevées par des pêcheurs côtiers affiliés à la Fishermen and Scientists Research Society, complétées par des données recueillies par Pêches et Océans et des mesures par satellite de la température de la surface de la mer. À partir de toutes ces données, nous avons calculé la température moyenne ainsi que la tendance et la variabilité des températures sur une période correspondant à peu près à la saison de pêche dans chaque zone. Les températures moyennes durant la saison pêche étaient généralement élevées en 1999 et en 2001, froides en 2002 et en 2003 et mixtes en 2000. La variabilité des températures était habituellement forte en 1999 et en 2003, faible en 2000 et en 2002 et mixte en 2001.

INTRODUCTION

We present an analysis of temperature recorded by instruments deployed through the auspices of the Fishermen and Scientists Research Society (FSRS) in nearshore zone of the Scotian Shelf from northern Cape Breton to Cape Sable in southwest Nova Scotia. This region encompasses Lobster Fishing Areas 27-33 (see Fig. 1 for the boundaries of LFA 27-33; Fig. 2 for the FSRS deployments in 2001). Instruments are deployed generally twice per year, in the spring and fall. Spring moorings cover LFA 27-34; fall deployments are for LFA 33 and 34. The goal is to cover the fishing seasons in each LFA, though not all gauges span the complete time period. Vemco temperature recorders with 0.1^{o}C resolution and $\pm$0.2^{o}C accuracy are moored in lobster traps and consequently are subject to recovery from day to day and sometimes are moved during the fishing season. Depth changes are generally ~10 m though some exceed 100 m.

Our goal is to present some of the data, primarily from 1999-2003, for the lobster fishing areas, derive some parameters describing the time series, and finally produce a general summary of conditions. This is an overview report, an initial look at the observations. The dataset is very large, approaching 700 time series; changes of instrument position during the mooring period introduce complications in data interpretation. We expect more specific, localized, cross-discipline studies will follow.

Before dealing with the moored temperature data, we present time series of monthly sea surface temperature (SST) anomalies derived from satellite observations from 1997 to 2003 (Fig. 3). This database consists of satellite measurements of (nominally) weekly averaged surface temperature for the Northwest Atlantic (35-67°N, 35-77°W). The data are obtained from the Physical Oceanography Archive Centre of the Jet Propulsion Laboratory (JPL, http://podaac.jpl.nasa.gov/sst/sst_data.html). Updates to the Ocean Sciences database are approximately quarterly as data become available from JPL. The anomalies are constructed using the average temperatures for the period 1985-2003. The SST anomalies are remarkably coherent in all of the areas with above normal temperatures in 1999 and 2000, slightly below normal values in early 2001, a period of about 1 year of above normal SST anomalies in 2001-2002, and finally below normal temperatures in the latter half of 2002 and 2003.

DATA AND ANALYSIS

Depth changes of the instruments during the fishing season complicate the interpretation of the temperature records. This problem is exacerbated by the time of year the moorings are in place: in spring when the thermocline is developing, and in fall when it is breaking down. During these two periods, the temperature variations with depth (the vertical gradients) are usually large; vertical movements of a few meters can give temperature changes that could be interpreted as temporal variations if a record of the instrument depth were not available. At each site, a log sheet of the instrument position was maintained. From these log sheets, we constructed time series of the latitude, longitude and depth changes. We note that changes in the depth were recorded frequently without an accompanying change of position. An example of the time series of instrument depth is shown in Fig. 4. The depth changed 34 times over a range of 11 m during the mooring period. A large number of the records (order 50%) had significant depth changes during their mooring period. In this initial analysis of the total dataset, we did not use these records. We confined ourselves to records that remained at a constant or nearly constant depth (<2 m changes).

Temperature changes that occurred when traps and instruments were recovered from day to day during the season were edited from the records.

An additional constraint was the length of the mooring period. Ideally we would have preferred to have the records span the entire fishing season. However, within each fishing area, some records began later than the opening day of the season, some ended before the last day. To obtain a sufficient number of records to cover a broad range of depth, say the upper 20 m, we set start and end dates for our analysis that generally were less than the full fishing season. Table 1 summarizes the dates of the fishing seasons and the analysis periods for each LFA. The last column of the table also shows the number of days of the analysis period.

We sub-divided LFA 27 into 3 parts based on coastline orientations: LFA27N, from Cape North to St. Ann's Bay; LFA27SB, from St. Ann's Bay to Scaterie Island; and LFA27S, from Scaterie Island to the western boundary of the zone along the south-facing coast of Cape Breton. We hypothesised that the nearshore response to wind forcing would differ in these subareas because of their differing orientation of the wind to the dominant coastal orientation. LFA31 has two sections with different fishing seasons: 31A consisting of western Chedabucto Bay and the south-facing area of Cape Canso and 31B, the remainder of LFA31. LFA33 is usually considered as consisting of two parts: 33E from Halifax to west of Lunenburg and 33W from Lunenburg to Cape Sable.

Figure 5 shows the long-term, daily average water temperatures for the upper 10 m in the coastal zone for LFA 27-33. These averages have been taken from the current version of the coastal temperature database and do not include the FSRS time series. The figure also indicates the times of the fishing seasons. For LFA33, we show the period as November 29 to January 15 for reasons that will become clear later. There are several things to notice. First, LFA30 does not have any temperature time series in the database. Second, LFA28-31A have very short datasets, the equivalent of 2.4 to 3.5 years of observations. Third, the lobster fishing seasons correspond to times of the years when temperature is increasing or decreasing approximately linearly. Similar results but generally less data are available in the 10-20 and 20-30 m ranges.

The time series in Fig. 5 suggest an analysis approach that could provide a concise summary of the 1999-2003 datasets from the lobster fishing areas. We illustrate the approach in Fig. 6. The observed times series is decomposed into a mean, linear trend and residual record (observations with the mean and trend removed). The series is characterized by three numbers: the mean temperature, the linear trend and the variability. We express the trend as the temperature change (ΔT) over the analysis period as given in

Table 2, i.e., the slope of the line times the number of days in the analysis period. The variability is given as twice the standard deviation of the residual record. Another potential parameter to present is the temperature at the beginning of the record from the linear fit. This is related to the mean temperature and the temperature change over the analysis period as T(at start of record, i.e., the intercept)=T(mean)-0.5*ΔT. For the record shown in Fig. 6, the mean is 4.62^{o}C, the slope times the analysis period (for brevity we shall refer to this as the slope) is 9.41^{o}C, and twice the standard deviation is 3.61^{o}C.

In order to derive the mean parameters necessary to calculate anomalies for each year, all of the averages, slopes and standard deviations are grouped for each LFA and a second degree polynomial is fitted to the data. In Fig. 7, we show an example for the average temperatures for LFA27SB. An anomaly is calculated for each average as the difference between the polynomial fit and the observation. The anomaly for a particular year is the average of the anomalies in that year. This is not an entirely satisfactory approach. We would prefer to have datasets of sufficient length in each region that could be used to derive the reference means, trends and variances. Typically data series of about 30 years duration are used for reference periods in meteorology and oceanography. This criterion is approached only for LFA33 at present (Fig. 5). However, we shall consider shorter reference periods when the FSRS data are combined with the BIO archived series.

We shall now present the time series and summary statistics from records at constant or nearly constant depths from LFA27-33 in the following format: time series of temperature for 1999-2003 if available (for LFA33E there are some data from 1997 and 1998); the profiles of the average temperatures, the slopes and two standard deviations. We shall briefly highlight some of the notable features. These last three variables will be summarized to quantify the interannual variability in the region.

LFA27N

The notable feature of the time series is the higher temperatures observed in 1999 (Fig. 8). This is very apparent in the average temperature summary plot which shows 1999 warmer than the other years by about 2^{o}C. The rate of warming, i.e. the slope, for 1999 is also very high, whereas the variability (2 SD) is similar to the other years. Also note the coherency of the temperature variations in some of the records, those in 2000 and 2002 in particular. We also note that the fishing season started in cooler conditions in 2001, but the water warmed quickly particularly at 22.3 m where the warming rate was as high as in 1999.

LFA27SB

The highest temperatures for this region also occurred in 1999 with values 1-3^{o}C warmer than in the other years (Fig. 9). This area also had warm conditions in 2001 when the warming rate was the highest of all the years.

LFA27S

The very limited datasets from this region indicate again that 1999 had above average temperatures (Fig. 10). Year 2001 had the highest warming rate after 1999. A temperature oscillation with a period of about one week is clearly seen in 2000, likely the result of atmospheric forcing or the propagation of a coastal-trapped wave from the Gulf of St. Lawrence.

LFA28

Few time series are available for the Bras d'Or Lakes, LFA28 (Fig. 11). The spatial resolution of our current satellite sea surface temperature database does not allow recovery of data from LFA28. We recovered of data from Bras d'Or Lake, which is large enough so that land effects on the estimated SSTs can be avoided. These data represent a considerably larger area than the single point, subsurface temperature series. They cover the period May 1 – July 15 and indicate that 1999 was the warmest period with SST about 2^{o}C above normal for the period shown. The coldest year, 2002, featured temperatures that were about 1.3^{o}C below normal. These SST anomalies are based on the 1998 to 2003 period.

LFA29

The few available time series for this region indicate that 1999 is the warmest year with a rapid increase of temperature at the start of the season; it also features the highest low frequency variability (Fig. 12).

LFA30

Again because of the few available time series we have recovered satellite SST data for LFA30 (Fig. 13). For the period May 1 – July 31, these data indicate that 1999 SST was about 1^{o}C above the 1998-2003 average; the cold years were 2002 and 2003 with values nearly 1^{o}C below normal. Note that there were no July data available for 2003, only May and June observations were used to form the anomalies for that year. The warming rate was greatest in 2001, mainly due to a sudden temperature increase at the end of June.

LFA31A

Most years only have one time series at differing depths in most years; these are not sufficient data to determine the temperatures in one year relative to another (Fig. 14). Again we examined SST for this region (not shown) and found that 1999, in contrast to the other areas discuss so far, was cool (0.43^{o}C below the 1998-2003 average) for the May – July period. The years 2002 and 2003 were about 0.7 to 1.1^{o}C below normal. The years 1998, 2000 and 2001 were 0.4 to 0.9^{o}C above normal. Noteworthy again is the high warming rate in 2001.

LFA31B

The time series are all centered around 10 m, a depth where the vertical gradient can be strong in the spring (Fig. 15). Despite the small depth separations of the recorders, the average temperatures show considerable variation with depth with little difference apparent among years. As in LFA31A, the warming rate was high in 2001.

LFA32

There are a minimum of 5 time series in any one year (Fig. 16). The warmest temperatures are found in 2000 mainly due to warmer conditions at the beginning of the season. Year 2003 had the highest warming rates of all years. The range from the highest to lowest average temperatures is about 3°C. The variability given by 2 standard deviations has a range of about 2°C.

LFA33E

The fall time period shows that the warm years were 1999 and 2001 (Fig. 17). The coldest years are 1997, when there was a limited data collection, and 2002. The 2003 data from the fall are not available yet. There was a broad range of cooling rates among the years with the smallest rate in 1999. The magnitude of the variability (2 SD) in this area at this time of year is small with 2 standard deviations of 0.5-1°C.

Most of the lobster fishery in LFA33E occurs in the fall but there is some fishing towards the end of the season in the following spring. The range of average temperatures for May is about 2°C with 2000 the warmest year (Fig. 18).

LFA33W

Vertically well-mixed conditions and the coldest temperatures were seen in fall of 2002 (Fig. 19). Average temperatures from 1999 to 2001 were similar and were about 1.5-2°C warmer than in 2002. The variability is nearly the same from year to year and has a small magnitude. About two thirds of the fishery occurs in the fall.

Strong vertical stratification is apparent in 2002 and 2003 during spring (Fig. 20). Overall, 2003 appears to be the coldest year.

There were few time series that were maintained over the entire fishing season approximately the same depth. One series, off Western Head, was quite consistent, providing a long record for most years with a mooring depth (~5 m) that had a range of about 2 m among all years (Fig. 21). The time series in Fig. 21 are labelled by there start time. These series indicate that the fall of 2001 was about 2°C warmer at this site than for the 3 other years that had data. The record beginning in the fall of 1999 has a sharp transition in late February to warmer temperatures such that the spring of 2000 proved to be the warmest. The averages for 2 periods (Jan. 15 – Feb. 28; Mar. 1 – Apr. 20) are summarized as a bar chart for this site. There were other gauges of more limited duration that were generally kept at the same depth. These are displayed along with the Western Head data and temperatures from satellite observations as Jan. 15 –Mar. 1 averages plotted at their mooring depths. They are consistent with the Jan.-Mar. period cold in 2001 and 2003 and warmer by as much as 2°C in 2002. The final bar chart shows the consistent variation shown by the Western Head (~5 m) and the satellite averages for the same period.

SUMMARY

The anomalies of average temperature, slope and variability over the analysis period and for 1999 to 2003 are shown in Fig. 22 (separate plots for each LFA of the average temperature and variability anomalies are shown in Fig. 23 and 24 for clarity) compiled in Tables 2-4. We focus on the results for the average temperature and variability. We note that the results displayed for LFA28 and LFA30 are for SST derived from satellite data. Average temperatures were generally warm in 1999 and 2001; 2002 and 2003 featured typically cooler temperatures; the results were mixed for 2000 with cooler temperatures prevailing from LFA27-30, the eastern sector, and warmer temperatures in LFA31-33. The higher warming rate for several LFAs is visible in year 2001. The variability (2 standard deviations) also shows distinct patterns with generally high variability in 1999 and 2003, low in 2000 and 2002, and mixed, high in LFA27, low elsewhere in 2001.

In our examination of these data, we were impressed with the overall consistency of the records within an area. For some of the datasets, the coherence of the variability among time series at different depths and positions even for events only lasting a few days was at times impressive. Some analyses directed at examining the spatial and temporal scales of variability are warranted.

We have examined air temperatures (reference period for climate normals 1971-2000), ice cover (Fig. 25) and wind (not shown) to see if they are related to the 1999-2003 ocean temperatures. Air temperatures were above normal in 1999-2000, corresponding to predominantly warm and mixed conditions in those years. The coldest period was the winter and spring of 2003 which coincides with the cold ocean temperatures in the spring of that year. Ice cover south of Cabot Strait was below normal in all years but 2003 when the quantity of ice was substantially above normal by up to a factor of 3 at some times (Fig. 25). Again this corresponds to the cold conditions in the spring of 2003. The ice affects temperature first as the response to cold winters, the water has to cool enough to form ice; second, ice reflects incoming solar radiation thus reducing heat input; and, third in order for the ice to melt, the incoming radiation first has to supply the latent heat of fusion to convert ice to water before the temperature of the underlying water can increase. The wind fields are incomplete, the 2003 data are not yet available. However, the data in hand do not show obvious connections to the ocean temperature conditions either through overall magnitude or upwelling potential. Future work could examine the coupling of the wind field with air-sea temperature difference and investigate the higher frequency response of temperature to wind variations.

A major source of ocean water for the nearshore zone of Nova Scotia is the flow out of the Gulf of St. Lawrence. We expect that this would be reflected in the correlation of temperature anomalies along the coast, strong through LFA27 and decrease down the coast but still show reasonable values. We show the correlations of temperature anomaly relative to LFA27N and they <u>suggest</u> that the Gulf outflow does play a significant role in the temperature variations along the coast (Fig. 26). We note that there are only about 5 data points in each time series. Another process that plays a significant role along the Nova Scotia coast is wind driven upwelling and downwelling. Other studies have suggested that

the upwelling response is stronger along certain areas of the coastline (e.g.., Petrie et al., 1987; Donohue, 2000).

These FSRS data add considerably to the existing coastal temperature database available through the DFO Maritimes Ocean Sciences Division Website. The website address is http://www.mar.dfo-mpo.gc.ca/science/ocean/home.html. It would be useful to derive a long-term climatology for each of the LFAs based on the combination of these datasets. These long-term averages, slope and variability could then serve as the reference for the examination of year-to-year changes. This would be an improvement over the procedure we used of fitting FSRS data with a polynomial and averaging the within-year differences to get an overall anomaly for each year in the 1999-2003 period. However, the FSRS data will require modification of the existing coastal temperature database which cannot accommodate time series whose positions change during the mooring period. This leads to the recommendation that at least one set of temperature recorders is deployed at constant depths ranging over the fished depth range within each LFA. Using the current deployments are a guide, that would mean instruments at ~5 m intervals from 5-25 m deployed at the start, recovered at the end, and not moved during the season. The vertical spacing of gauges, the number within a region (for example, LFA27 may require an array of instruments at 3 sites), and the length of the deployment period would require more thought and consideration of the biological issues that need to be addressed.

ACKNOWLEDGEMENTS

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Petrie, B., B. Topliss and D. Wright 1987. Coastal upwelling and eddy development off Nova Scotia. J. Geophys. Res., 29, 12979-12991.

Table 1. Lobster fishing seasons and analysis periods for LFA 27-33.

LFA	Fishing Season	Analysis Period
27N, SB	May15 – July 15	May 15 – July 10, 56 d
27S	May 15 – July 15	May 20 – July 10, 51 d
28	May 9 – July 9	May 15 – June 24, 40 d
29	May 9 – July 9	May 15 – July 1, 47 d
30	May 20 – July 20	May 20 – July 15, 56 d
31A	May 1 – June 30	May 11 – June 30, 50 d
31B	April 20 – June 20	April 22 – June 18, 57 d
32	April 20 – June 20	April 20 – June 18, 59 d
33E, W	Last Monday Nov – May 31	Nov 29 – Dec 31, (32 d); Jan 15 – Mar 1 (33W, 45 d); May 1-31 (33E, 30 d); April 21- May 31 (33W, 40 d)

Table 2. Anomalies of Average temperatures over the periods listed in Table 1.

Year	27N	27SB	27S	28	29	30	31B	32	33E Fall	33E Spr	33W Fall	33W Spr
1997									-0.74			
1998				0.28		0.57			-0.68			
1999	2.01	2.41	1.45	1.83	2.91	0.98	0.17	-0.26	0.92	0.24	0.30	0.28
2000	0.46	-0.12	0.17	-0.74	-0.73	-0.39	0.70	1.37	0.00	0.76	-0.06	0.21
2001	-1.40	0.27	0.49	0.39	1.08	0.16	0.20	-0.61	1.03	-0.65	0.41	-0.20
2002	-0.27	-0.66	0.06	-1.31	0.00	-0.91	-0.38	-0.57	-1.46	-0.31	-1.74	0.40
2003	-1.37	-1.08	-0.91	-0.46	-1.21	-0.82	0.02	0.13		-0.09		-0.82

Table 3. Anomalies of Slope (Trend times length of Analysis Period) over the periods listed in Table 1.

Year	27N	27SB	27S	29	31B	32	33E Fall	33W Fall
1997							-0.43	
1998							0.02	
1999	1.88	2.23	0.67	0.01	-0.02	-0.24	0.99	1.13
2000	-0.13	-1.10	-3.01	-0.80	-1.42	-0.46	-1.20	-0.95
2001	0.71	2.84	3.90	-0.90	0.87	-0.53	-0.15	-0.41
2002	-1.09	-2.95	-1.23	0.85	-0.78	-0.94	0.74	1.38
2003	-1.32	-0.70	-1.00	0.56	0.46	1.33		

Table 4. Anomalies of 2*Standard Deviation over the periods listed in Table 1.

Year	27N	27SB	27S	29	31B	32	33E Fall	33W Fall
1997							0.03	
1998							-0.25	
1999	-0.19	-0.40	0.74	0.76	0.87	0.69	0.04	0.01
2000	-0.02	-0.25	-0.77	0.02	-1.04	-0.79	0.13	-0.10
2001	0.68	0.46	0.58	-0.38	-0.27	-0.30	-0.12	0.04
2002	-0.73	-0.23	-0.70	-0.33	-0.48	-0.40	-0.05	0.05
2003	0.43	0.24	0.09	0.21	0.27	0.41		

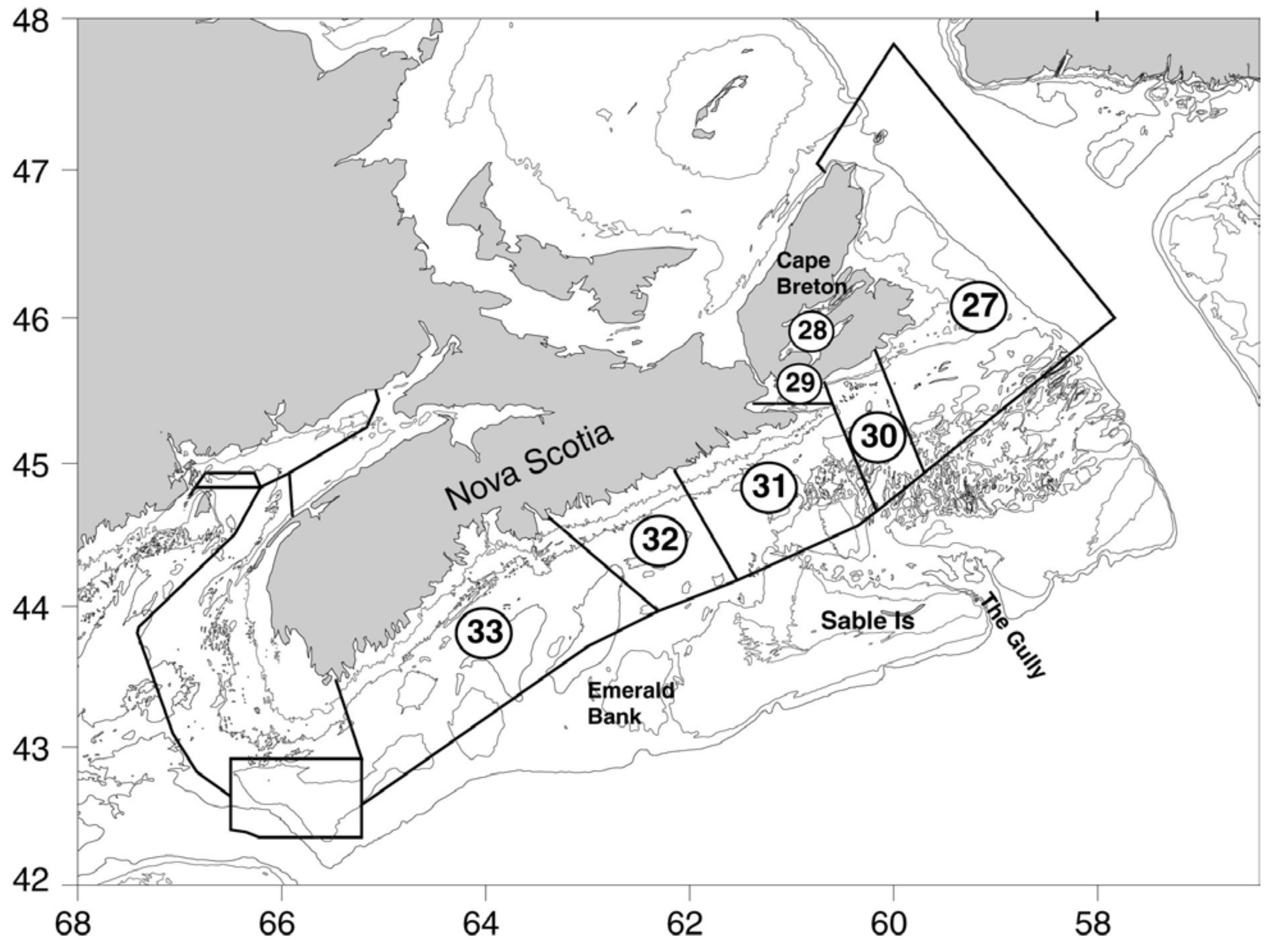


Figure 1. The Scotian Shelf and the Gulf of Maine showing the boundaries of Lobster Fishing Areas 27-33.

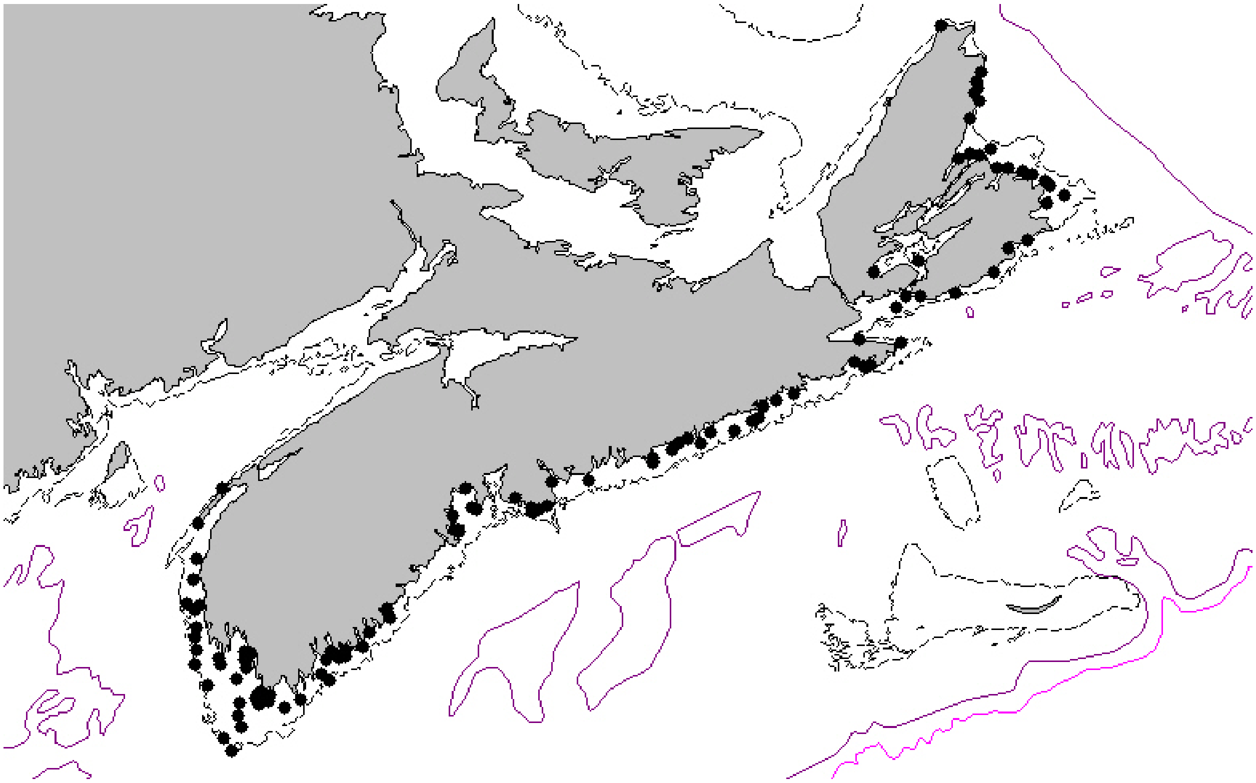


Figure 2. The locations (solid dots) of 105 temperature gauges deployed under the auspices of the Fishermens and Scientists Research Society in the spring of 2001.

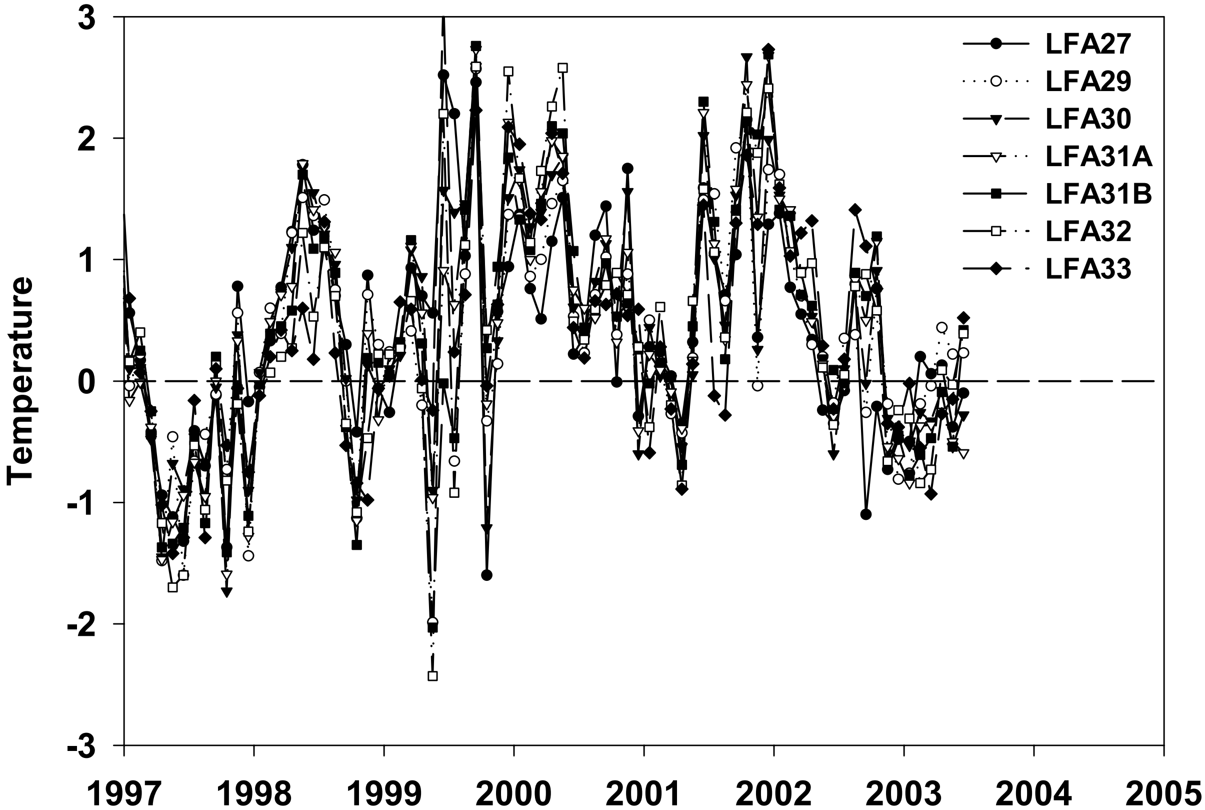


Figure 3. Time series of sea surface temperature anomalies 1997-2003 derived from satellite observations. The anomalies are obtained by subtracting the long-term mean (1985-2003) from the actual measurements.

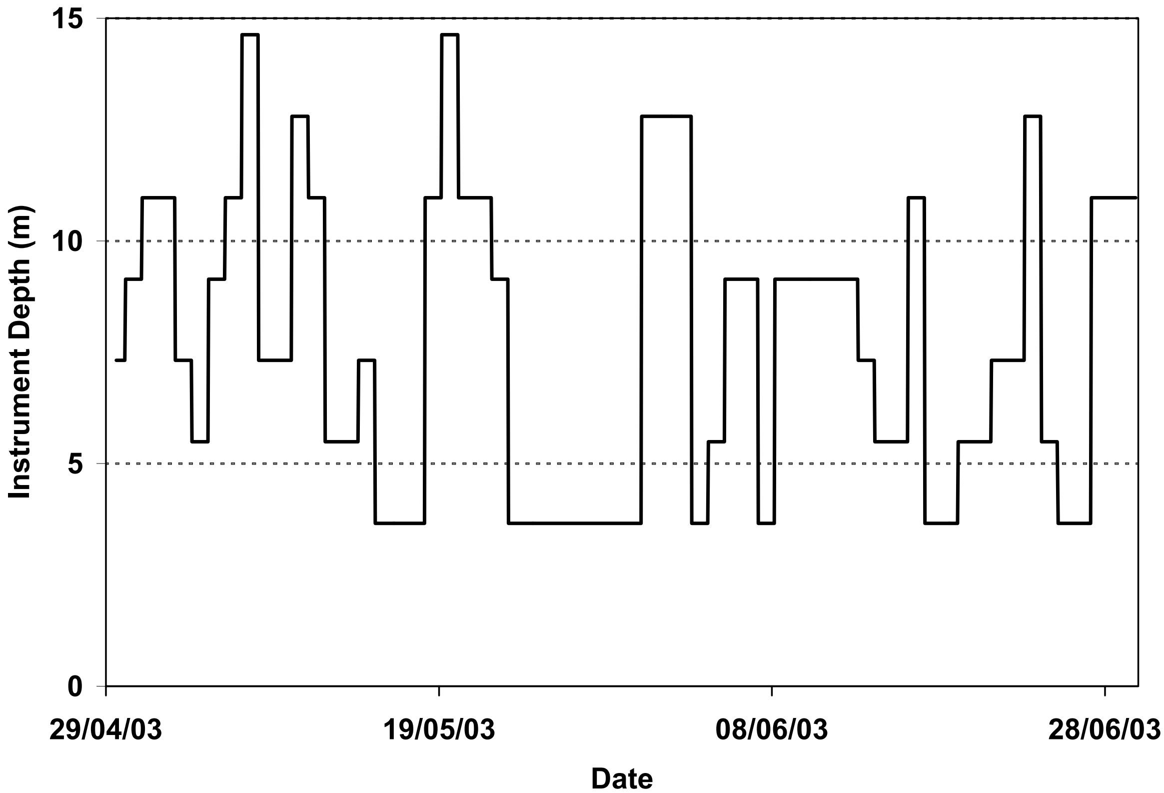


Figure 4. Example of a time series of instrument depth constructed from the station log sheets for the spring of 2003.

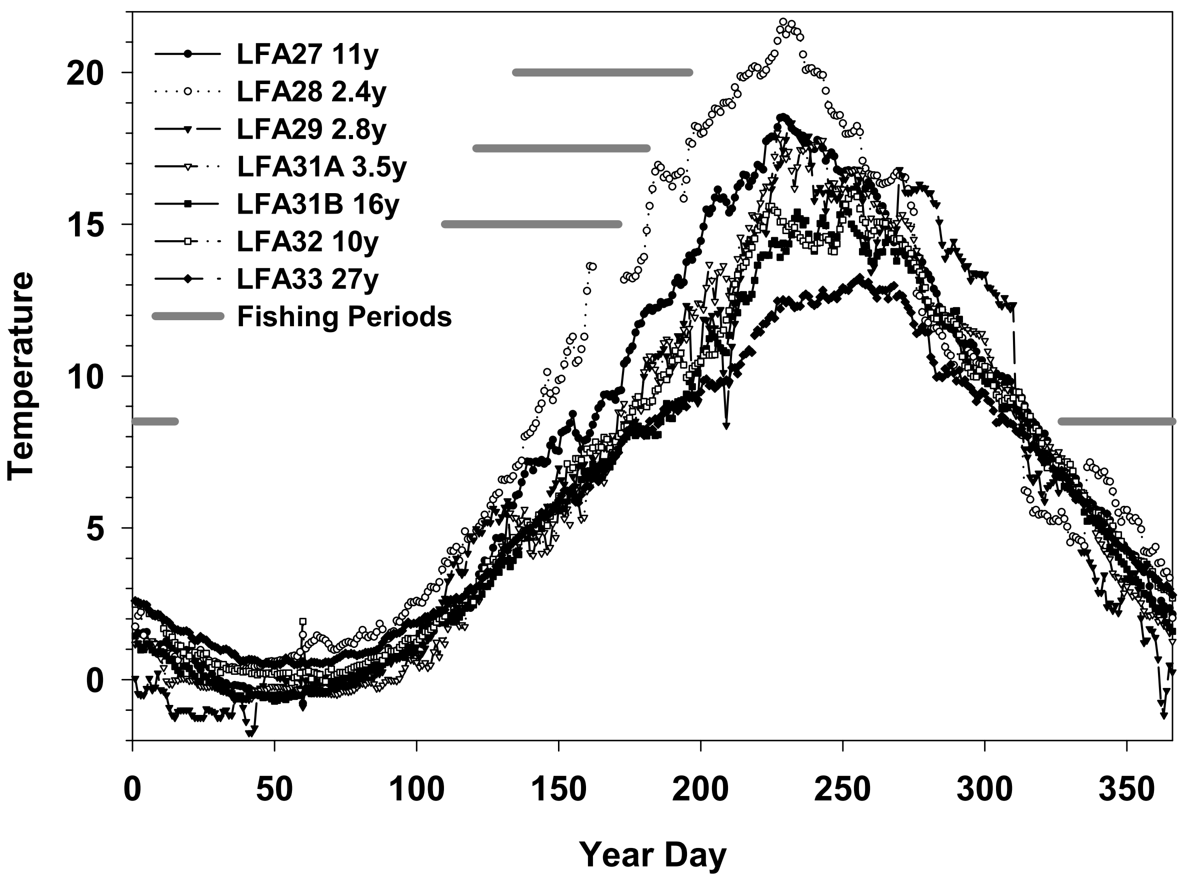


Figure 5. The average daily water temperatures in the upper 10 m from the specified Lobster Fishing Areas. The horizontal solid grey lines show the length of the fishing seasons in he areas. The legend indicates the number of years of data that went into the daily averages.

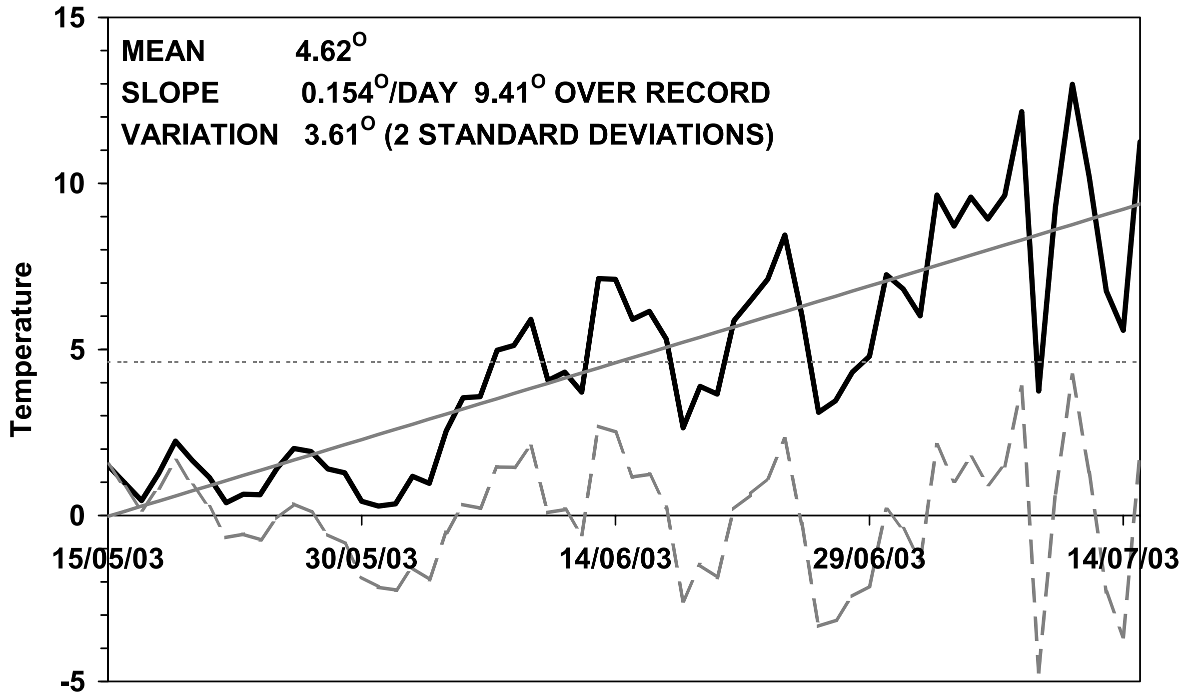


Figure 6. The temperature record from LFA27, 22.3 m in 2003 (solid black line), the mean (grey, dotted line), the linear trend (solid grey line) and residual (temperature with mean and trend removed; grey, long dashed line) over the record.

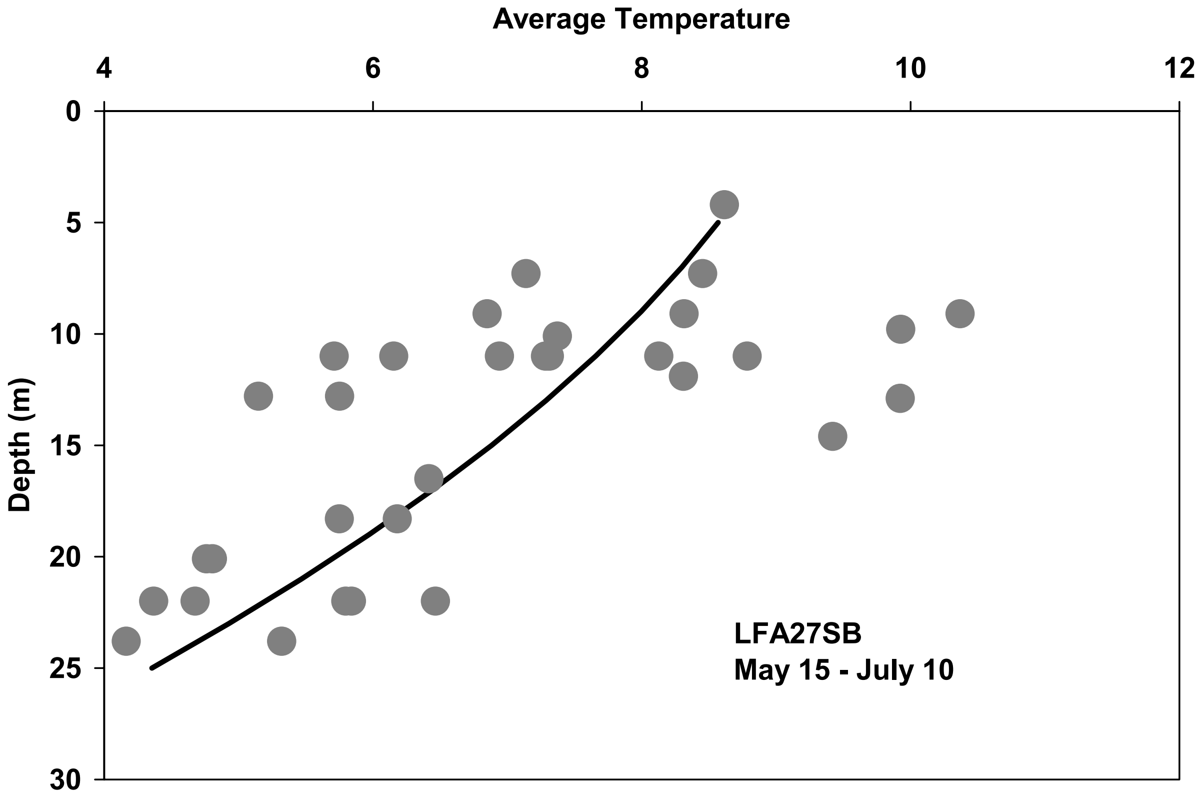


Figure 7. Average temperature at for all records from 1999-2003 for LFA27SB from May 15 to July 10 (grey dots). The least square fit of a second degree polynomial to the data is also shown.

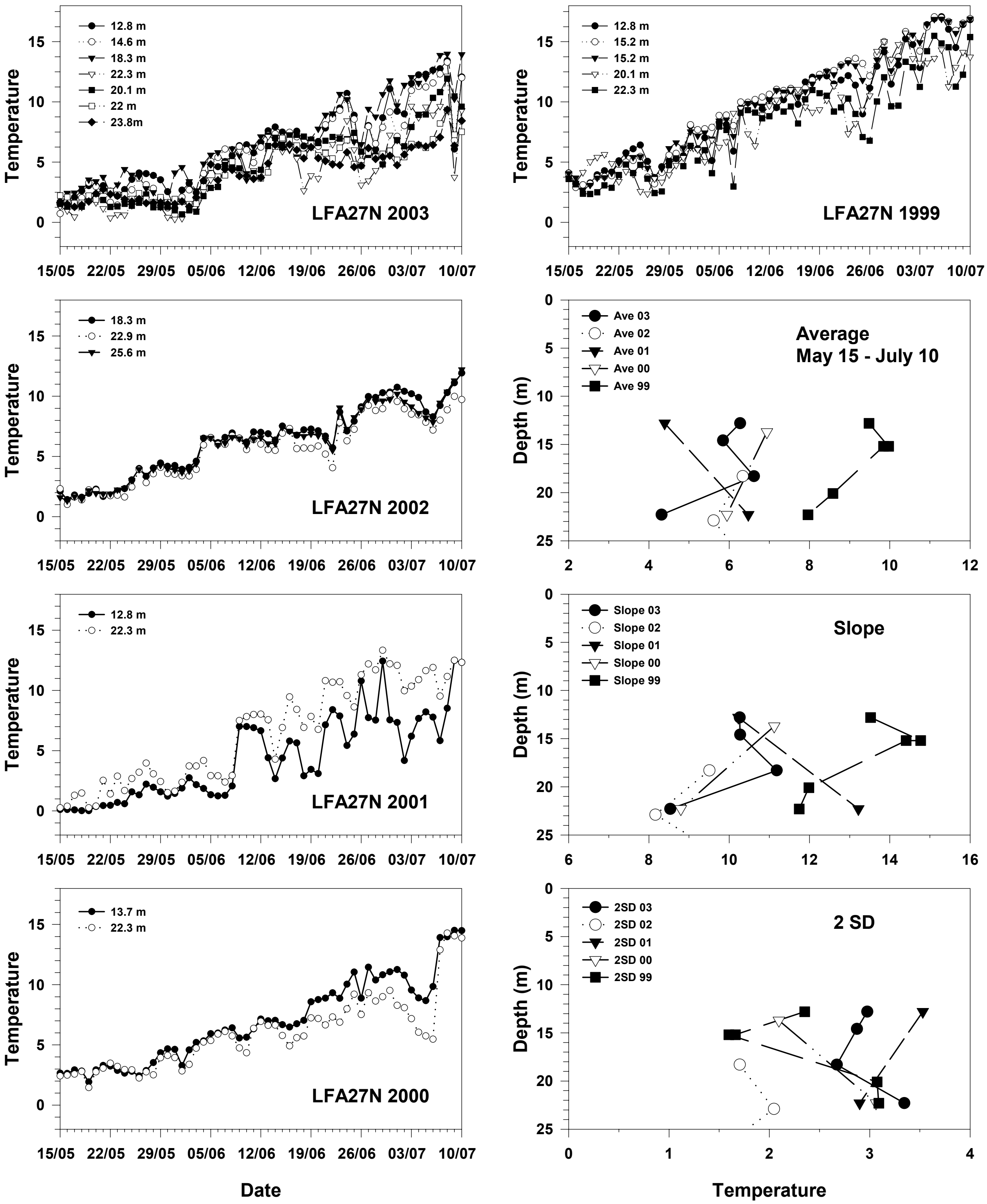


Figure 8. Time series of daily temperatures for LFA27N for 1999-2003 at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown.

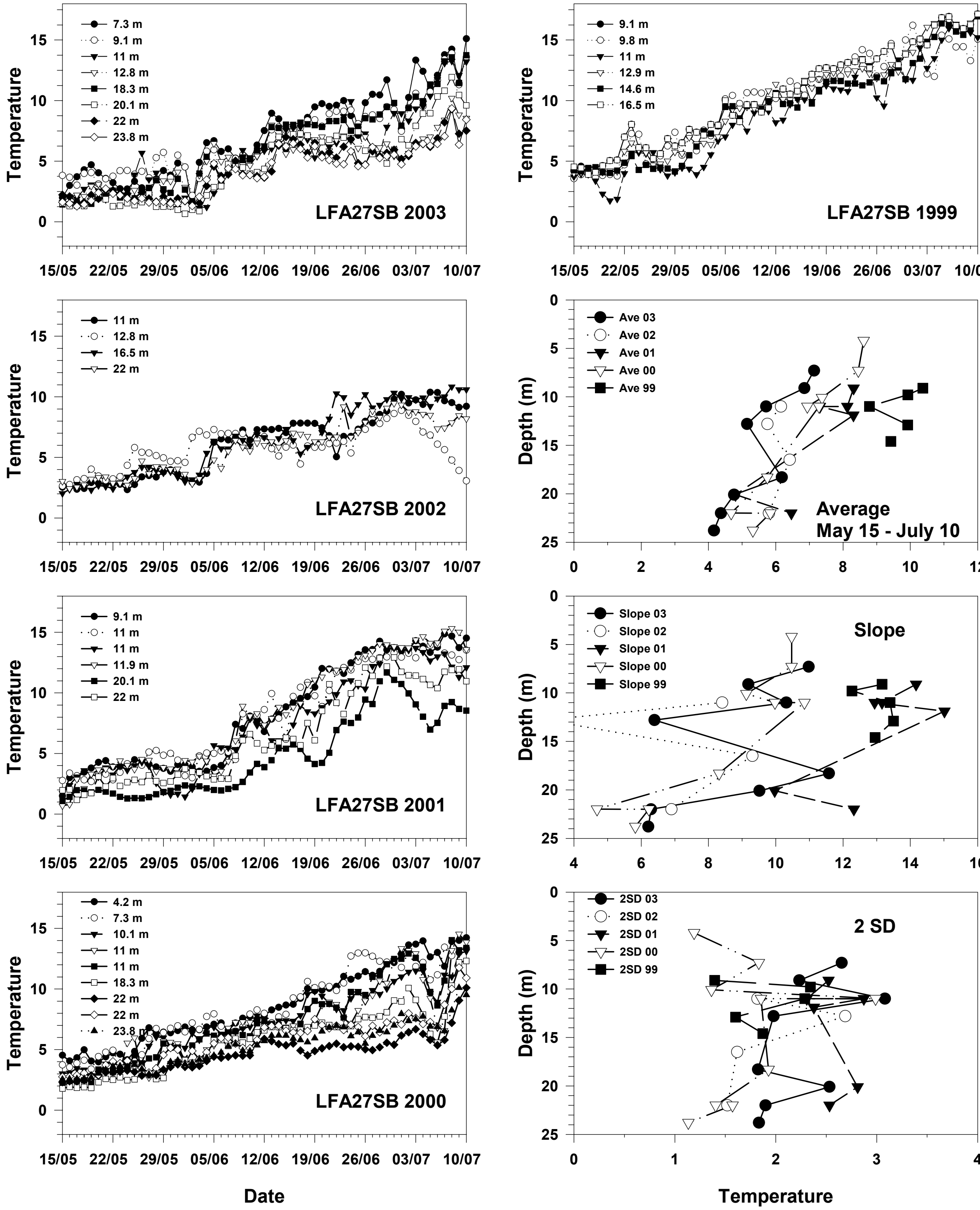


Figure 9. Time series of daily temperatures for LFA27SB for 1999-2003 at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown.

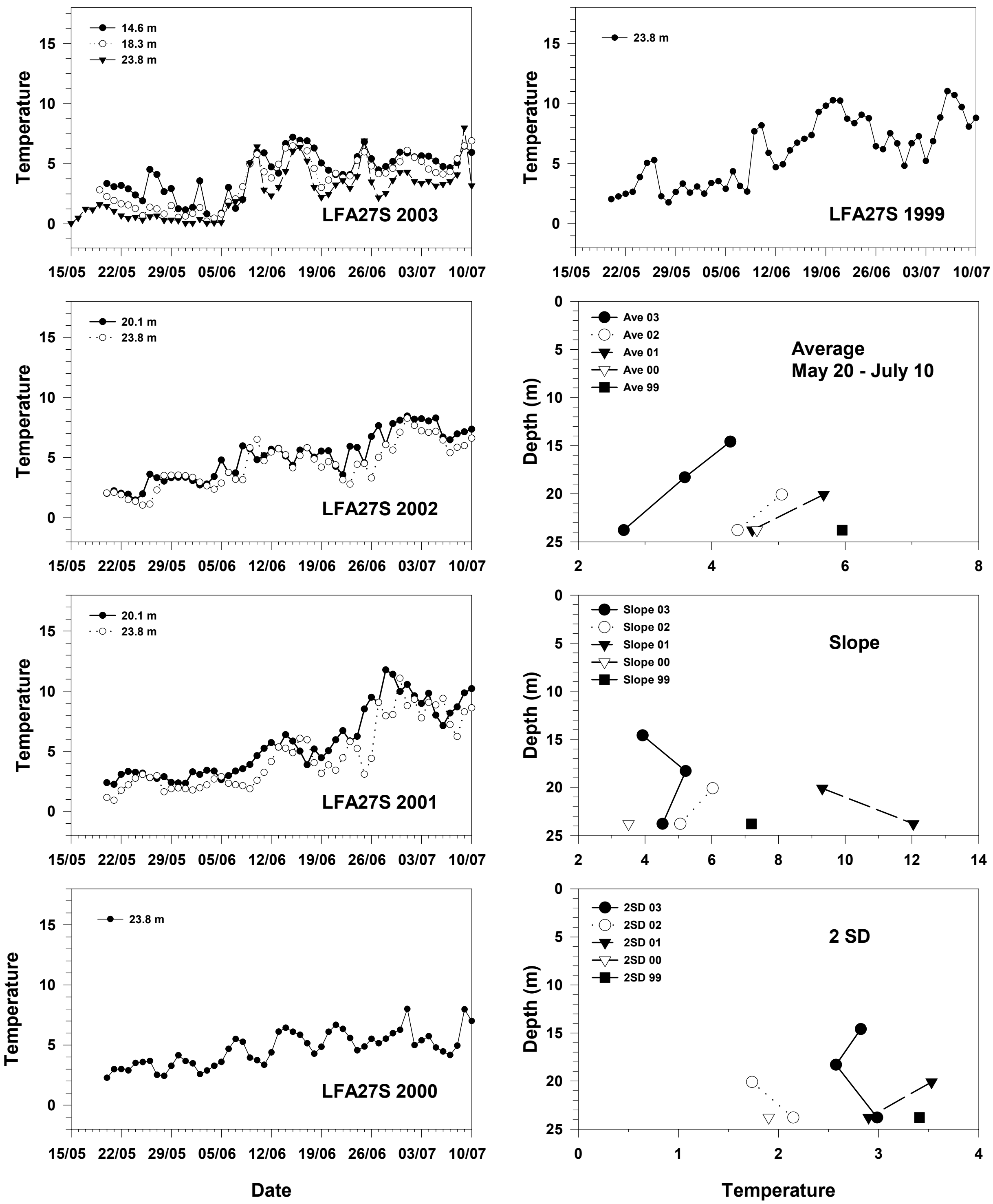


Figure 10. Time series of daily temperatures for LFA27S for 1999-2003 at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown.

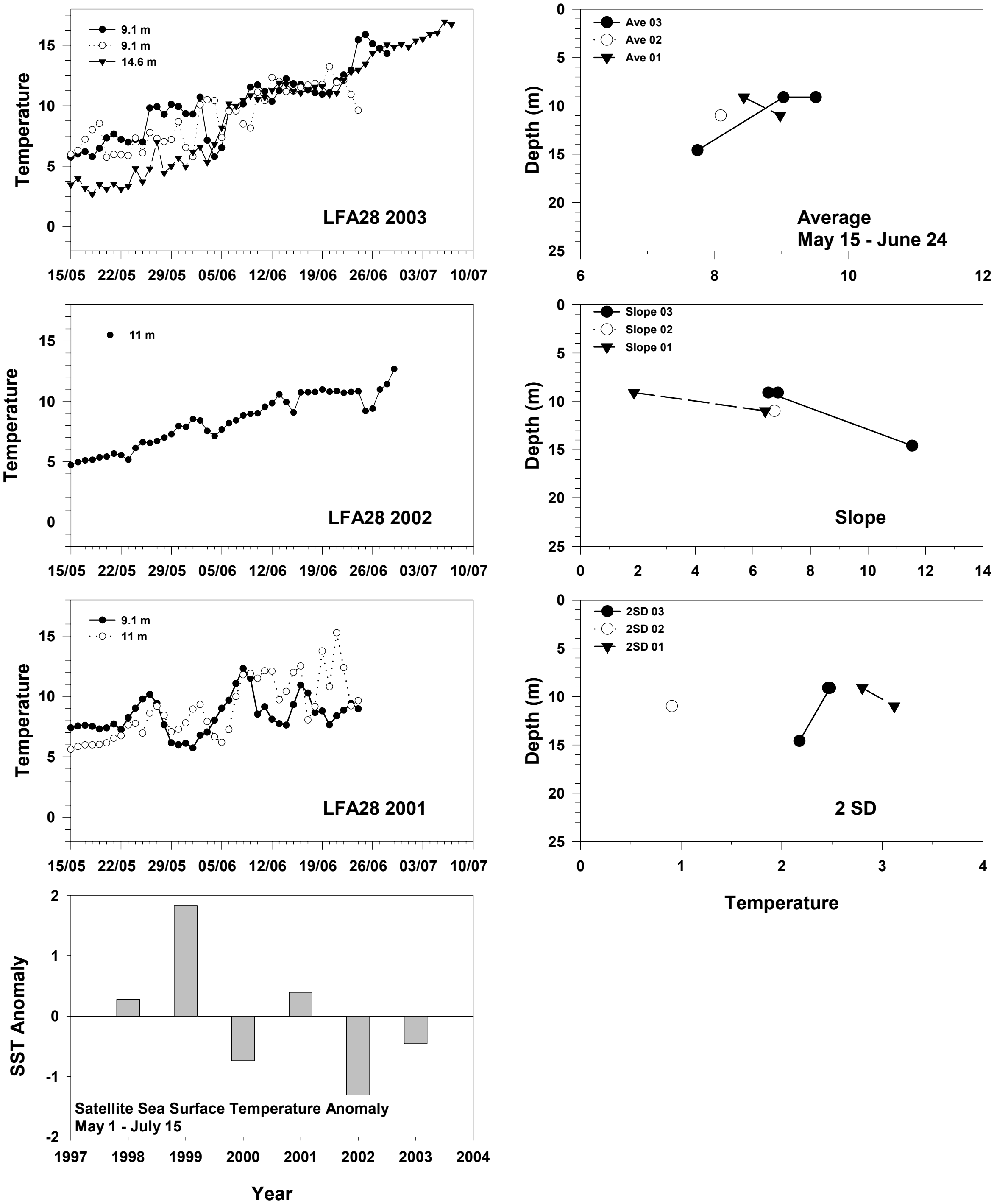


Figure 11. Time series of daily temperatures for LFA28 for 2001-2003 at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown. Satellite-derived sea surface temperature anomalies for 1998-2003 are shown.

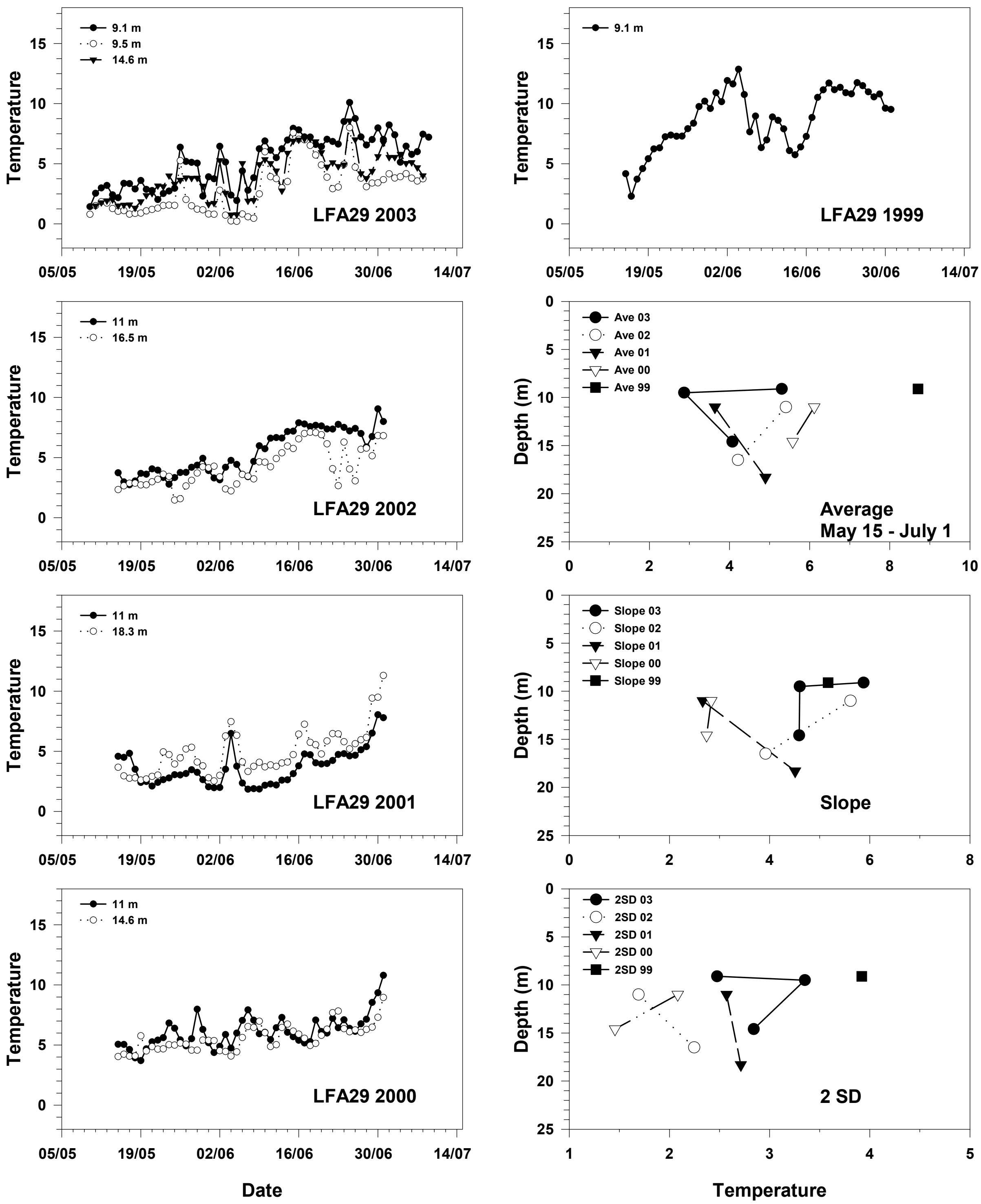


Figure 12. Time series of daily temperatures for LFA29 for 1999-2003 at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown.

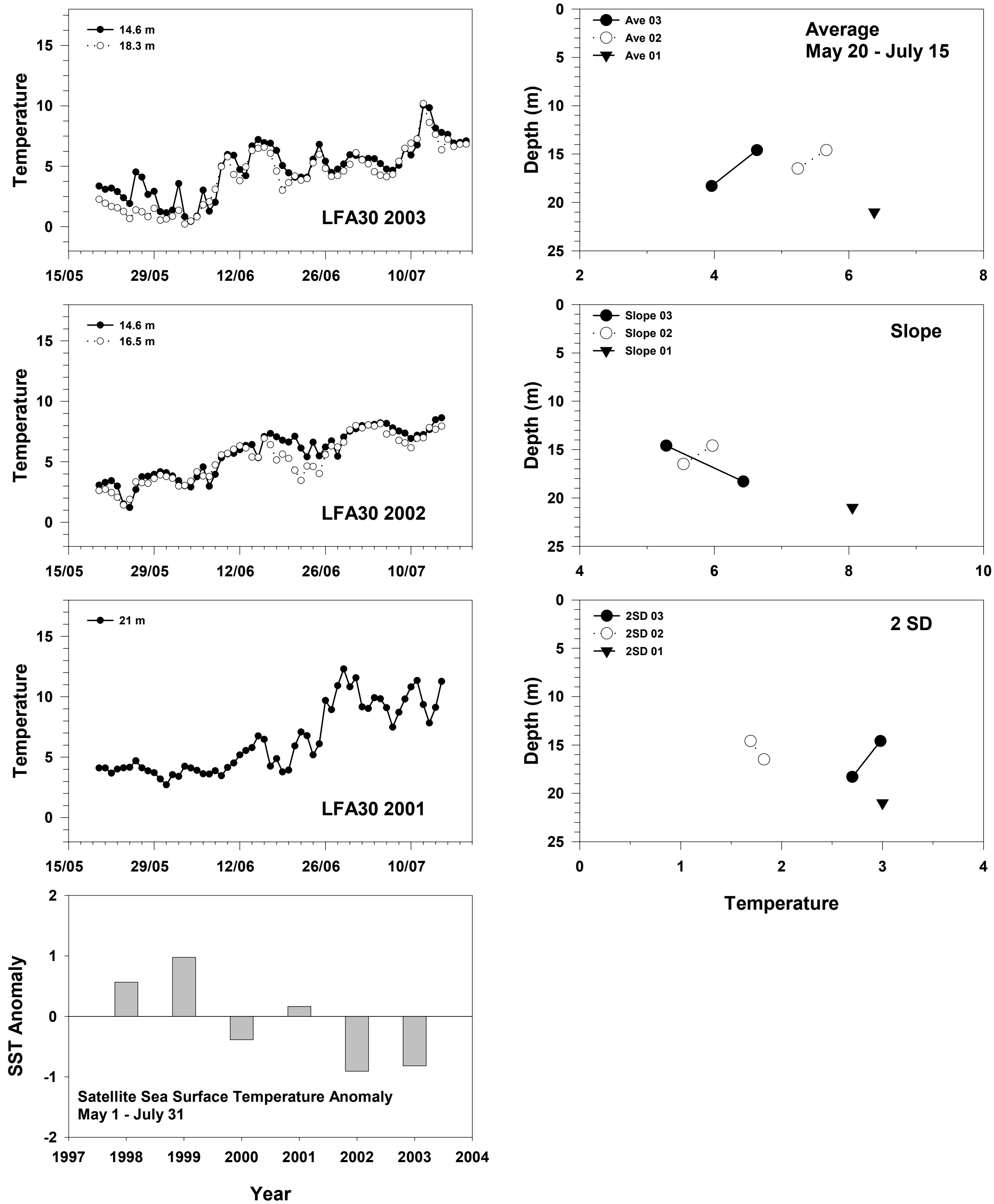


Figure 13. Time series of daily temperatures for LFA30 for 2001-2003 at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown. Satellite-derived sea surface temperature anomalies for 1998-2003 are shown.

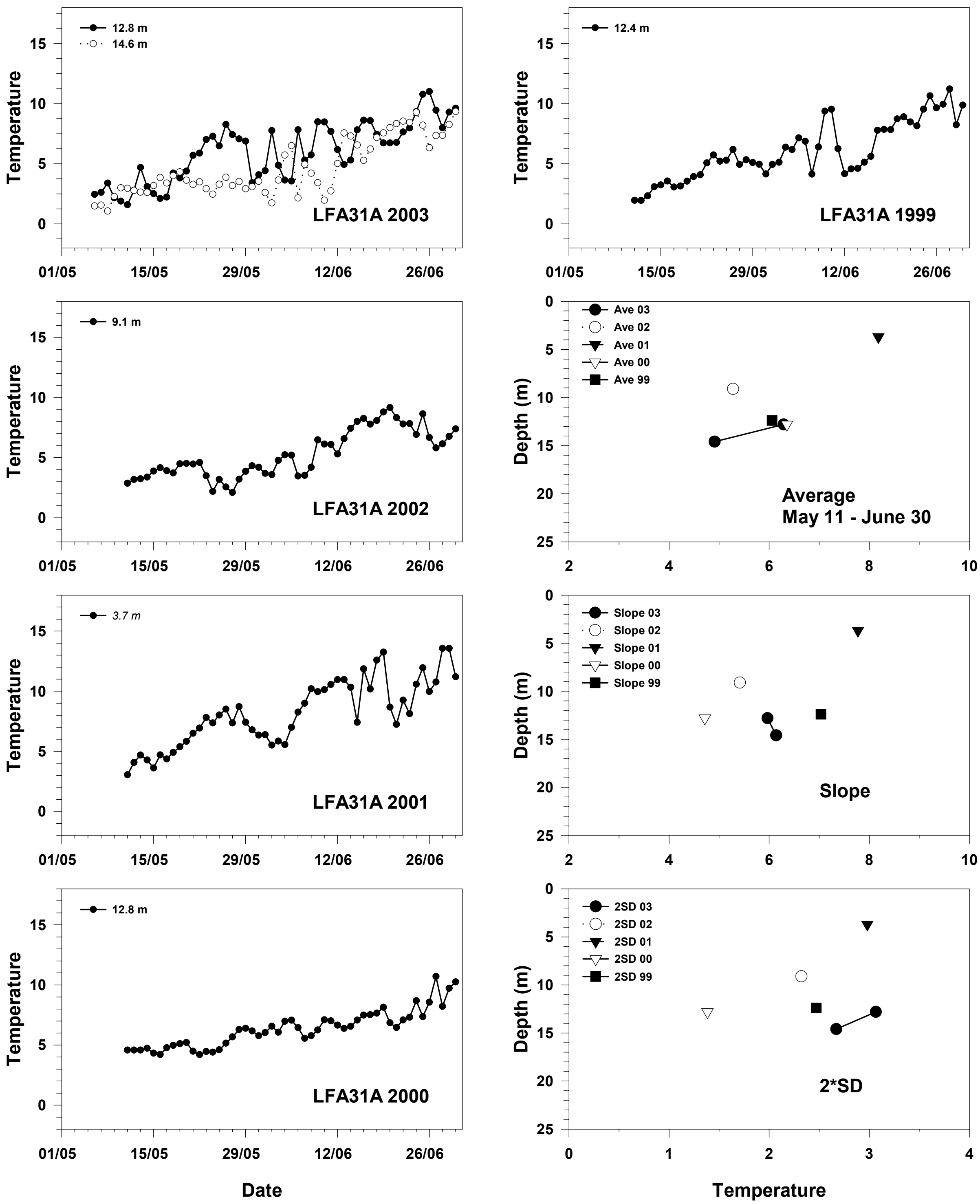


Figure 14. Time series of daily temperatures for LFA31A for 1999-2003 at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown.

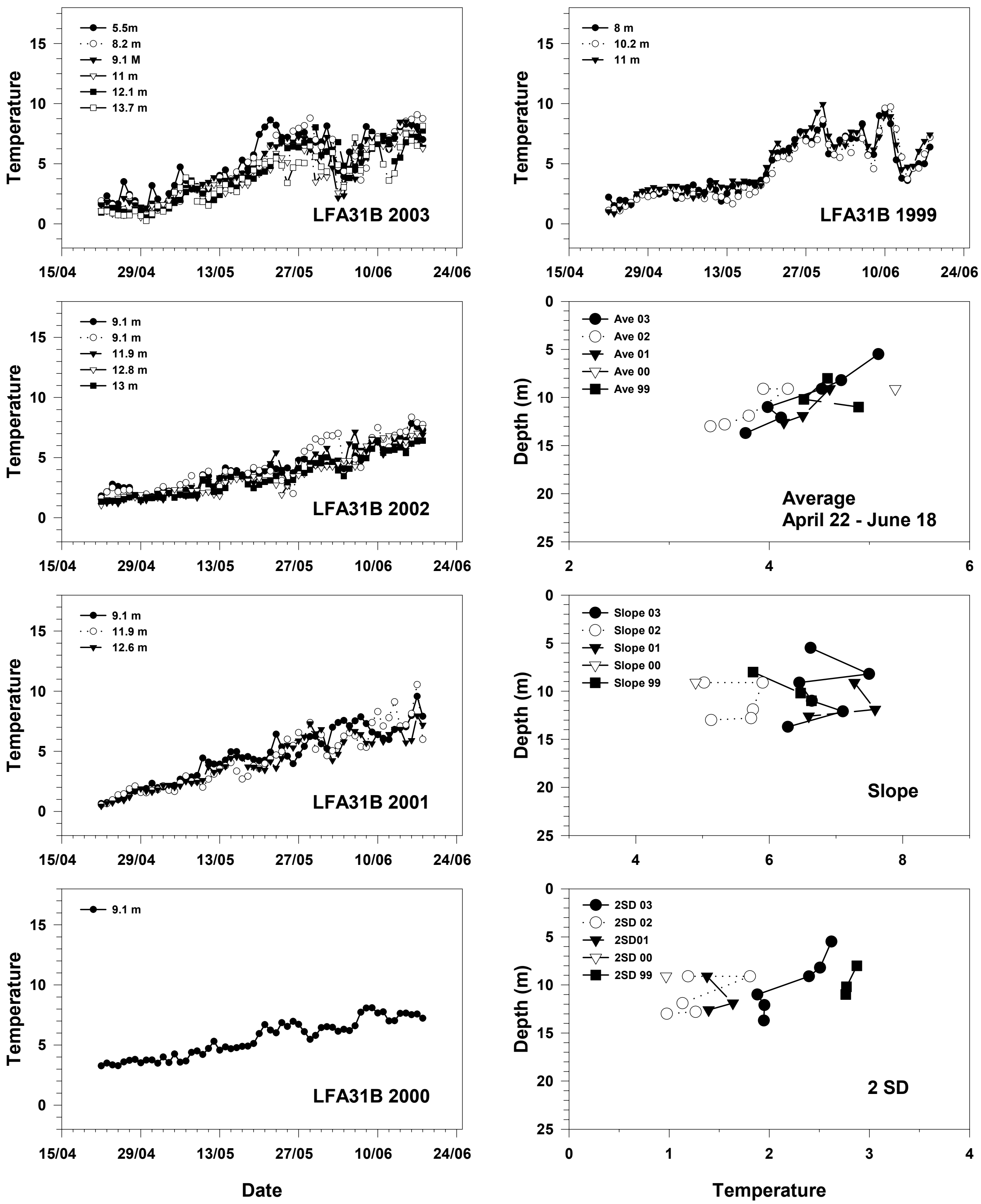


Figure 15. Time series of daily temperatures for LFA31B for 1999-2003 at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown.

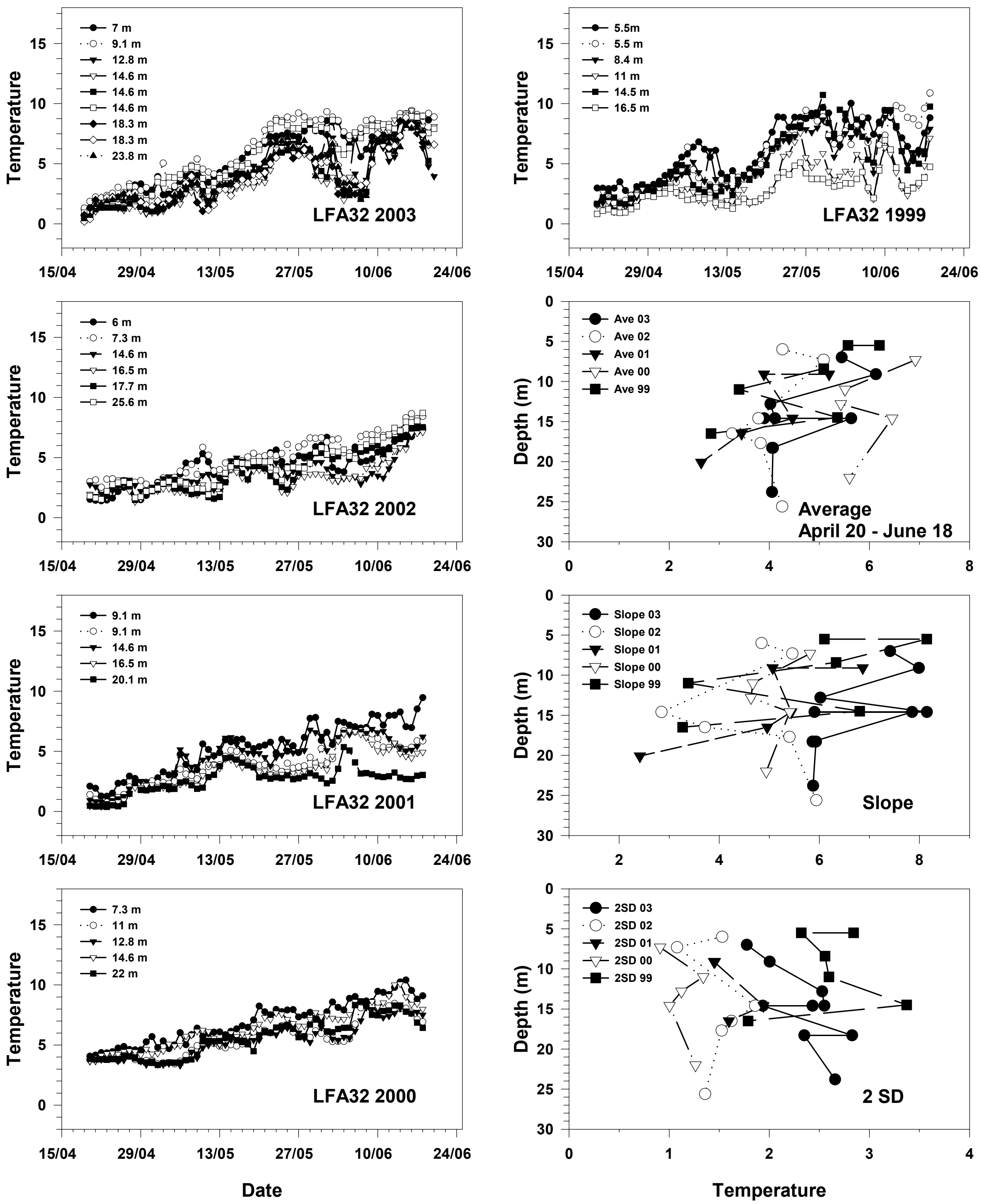


Figure 16. Time series of daily temperatures for LFA32 for 1999-2003 at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown.

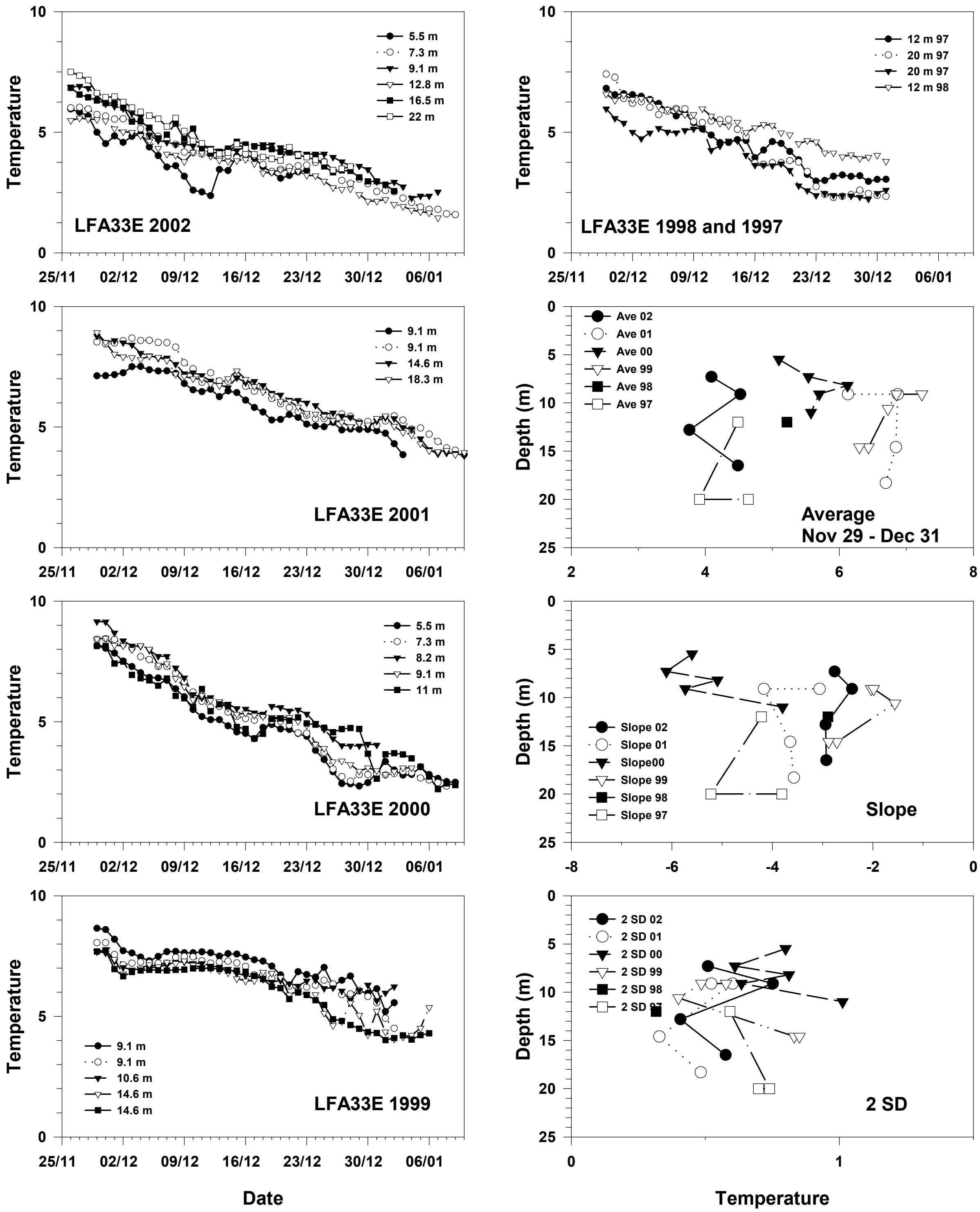


Figure 17. Time series of daily temperatures for LFA33E for 1999-2003 fall period at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown.

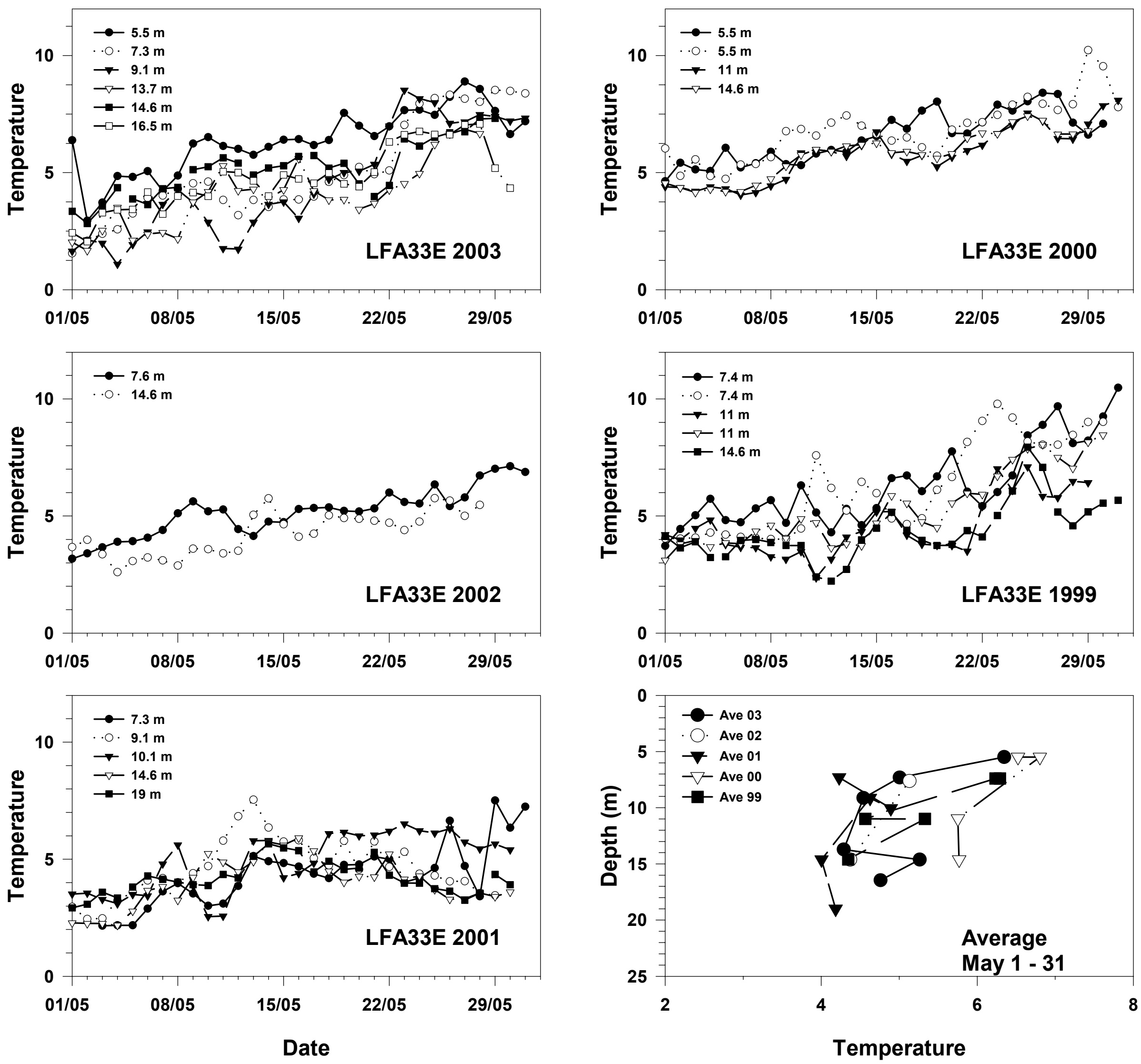


Figure 18. Time series of daily temperatures for LFA33E for 1999-2003 spring period at depths indicated in the legends. The depth profile of average temperatures is also shown.

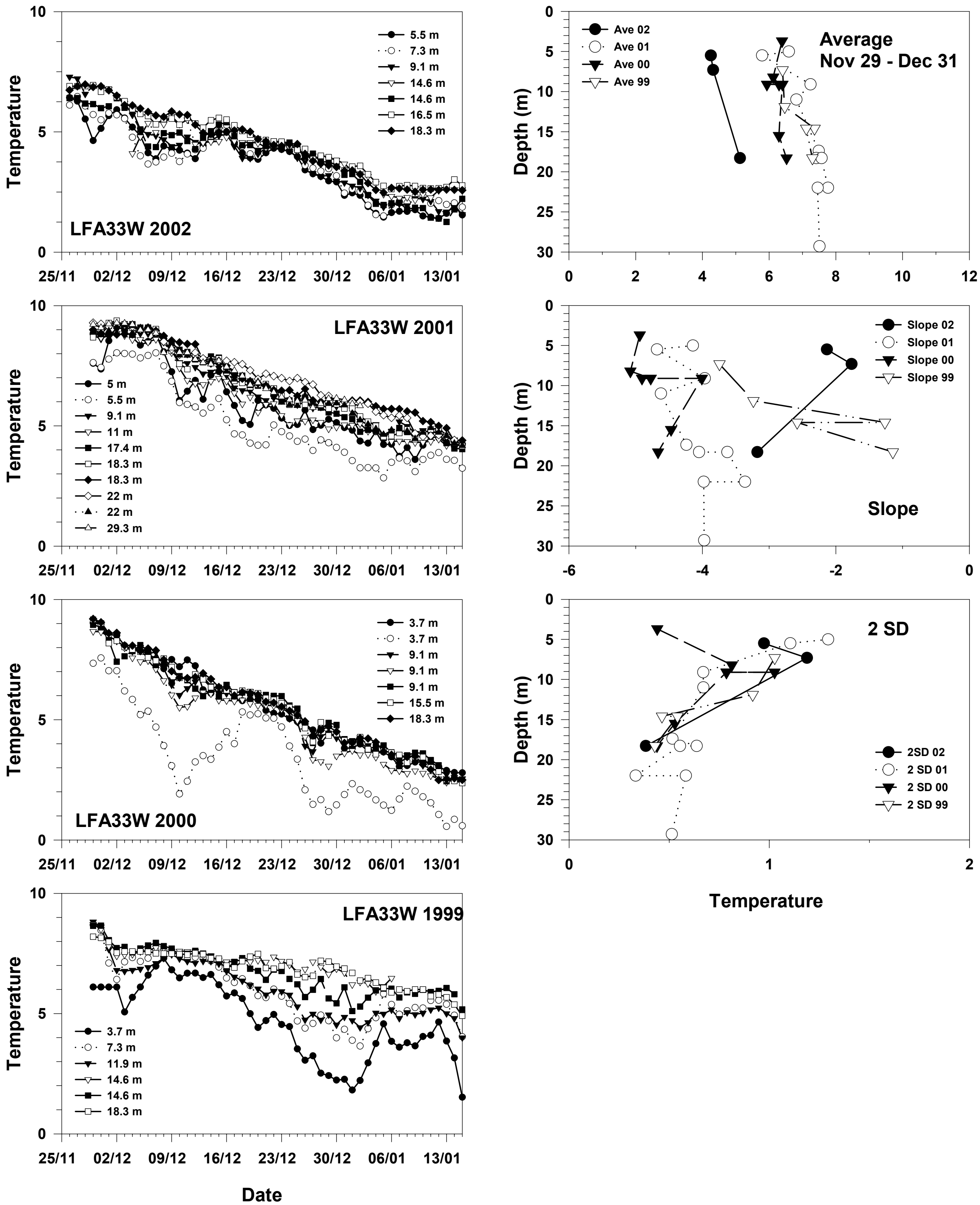


Figure 19. Time series of daily temperatures for LFA33W for 1999-2003 fall period at depths indicated in the legends. The depth profile of average temperatures, slope and 2 times the standard deviation are also shown.

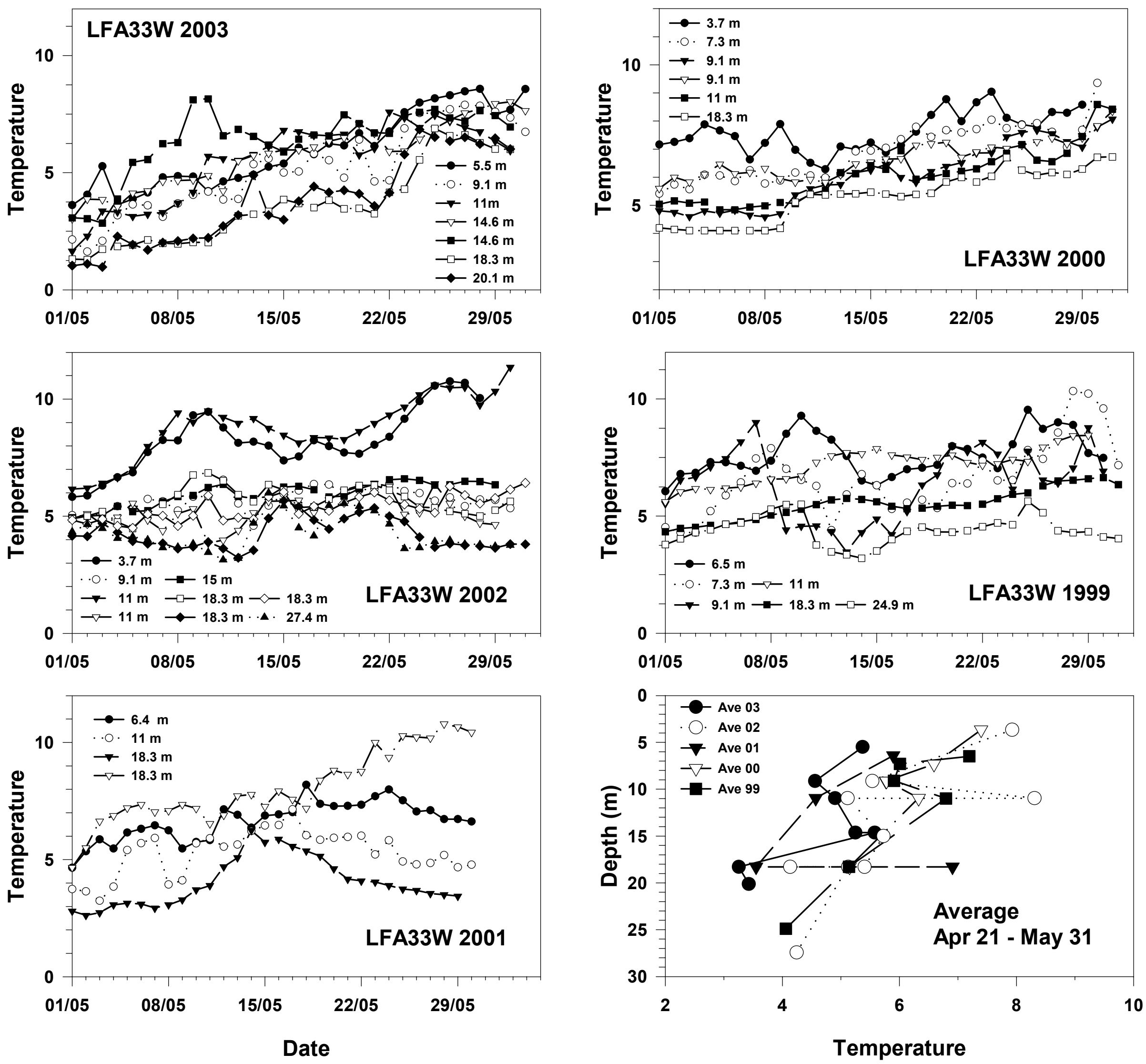


Figure 20. Time series of daily temperatures for LFA33W for 1999-2003 spring period at depths indicated in the legends. The depth profile of average temperatures is shown.

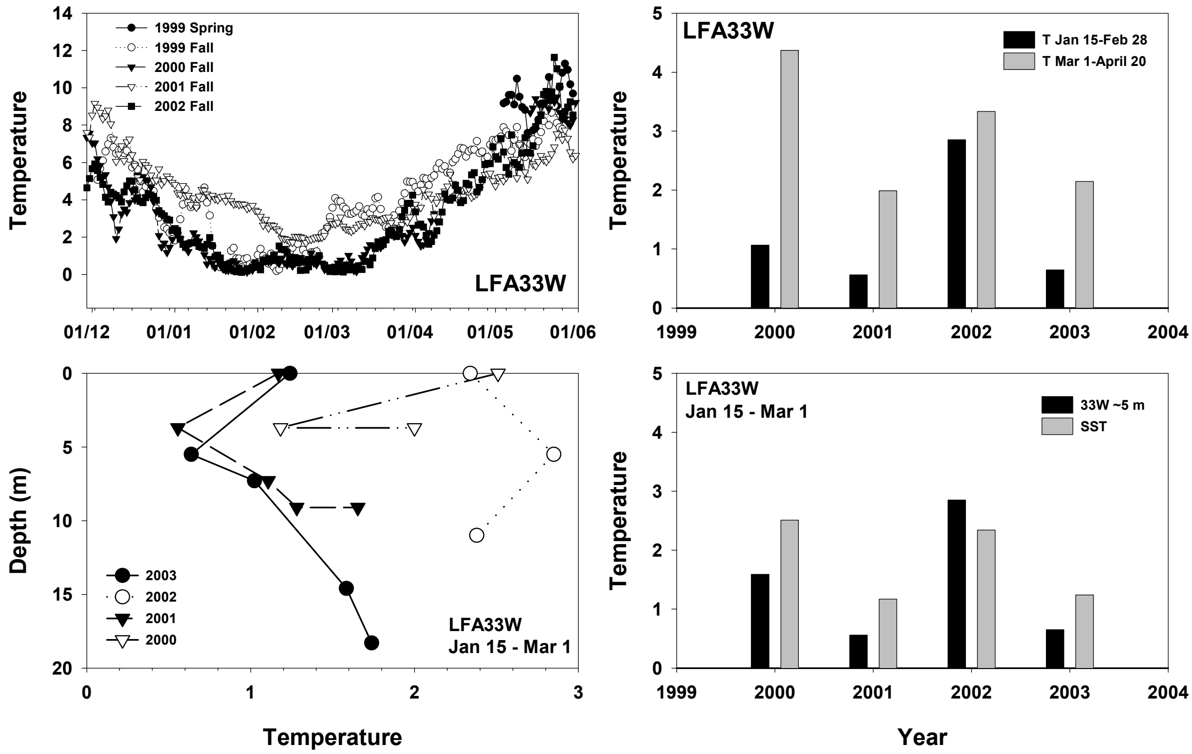


Figure 21. Time series of daily temperatures that extend through the winter for LFA33W for 1999-2003 period. The depth profile of average temperatures, and average for specified periods of the ~5 m and satellite-derived sea surface temperature data are also shown.

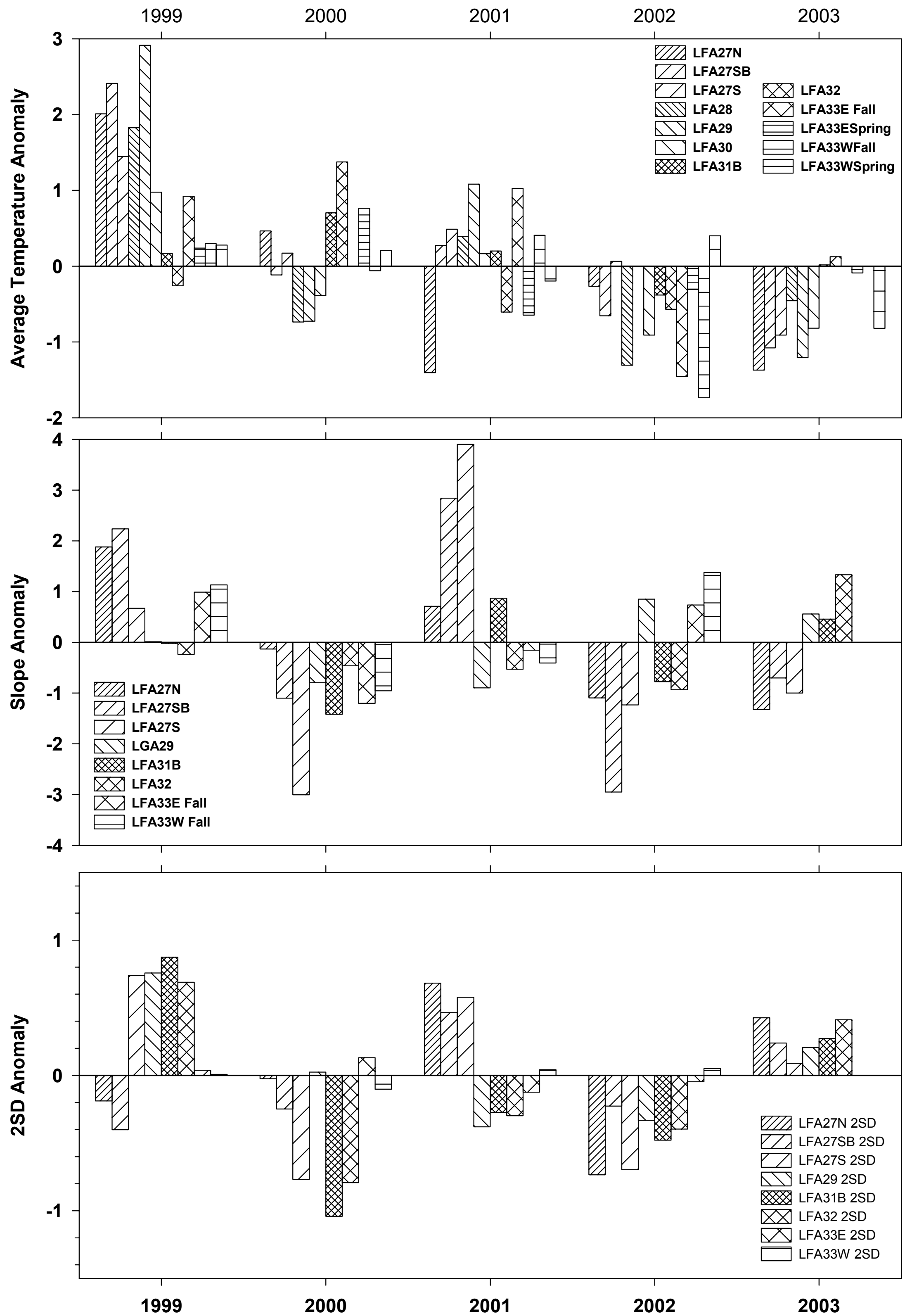


Figure 22. Anomalies of the average temperature, slope and 2 standard deviations for 1999-2003 over the time periods listed in Table 1.

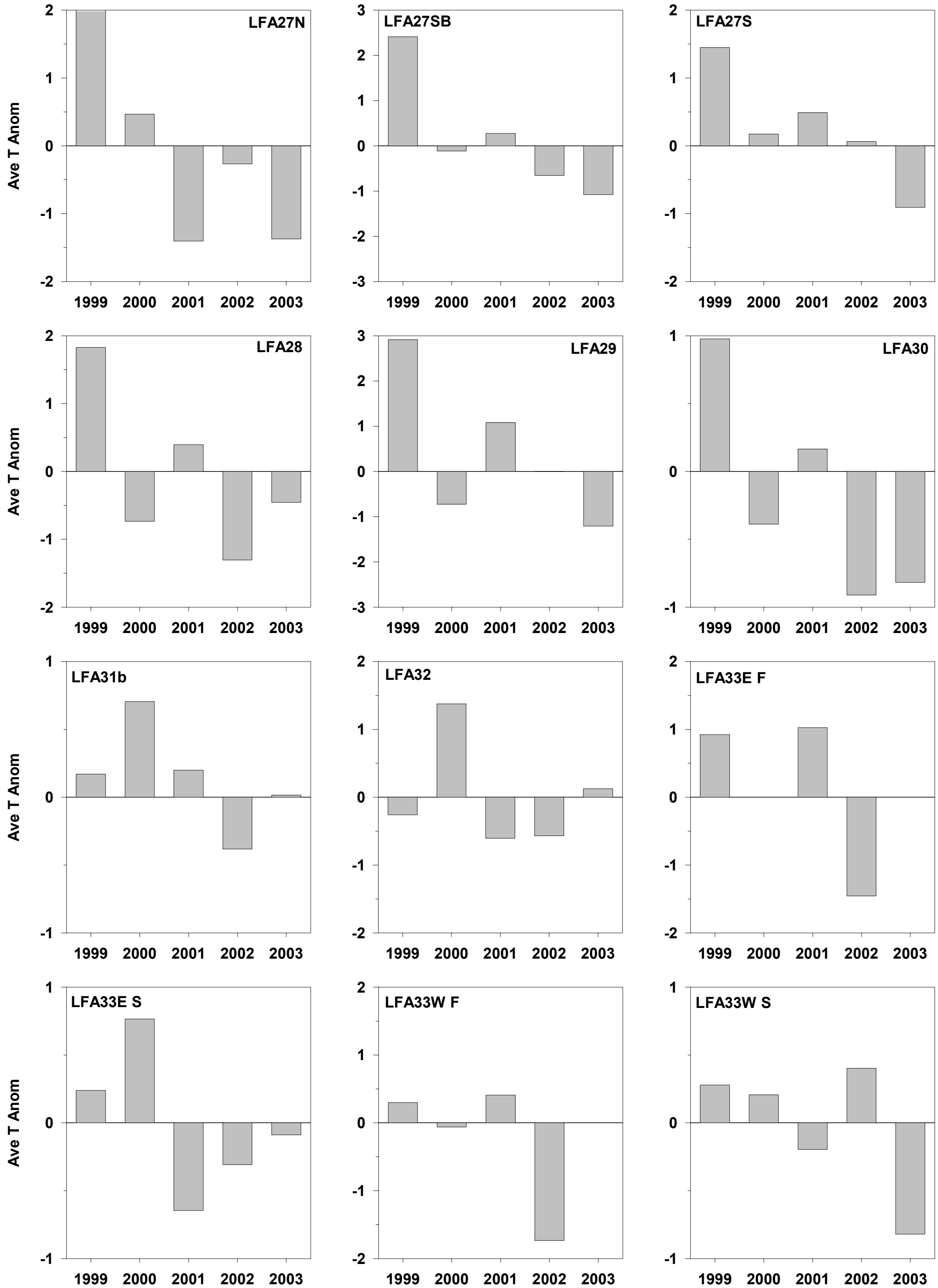


Figure 23. Anomalies of the average temperature for 1999-2003 over the time periods listed in Table 1 for each LFA separately.

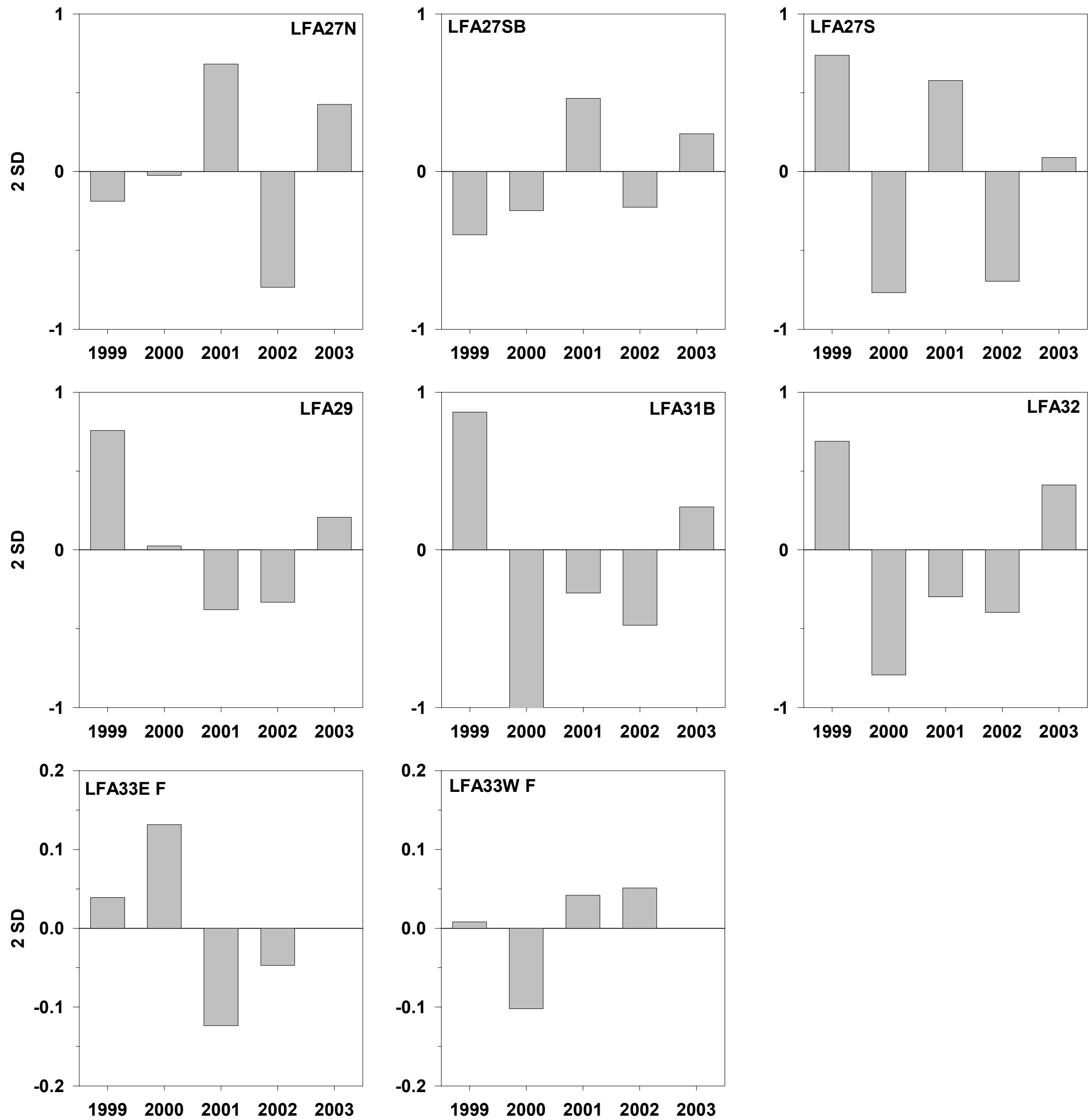
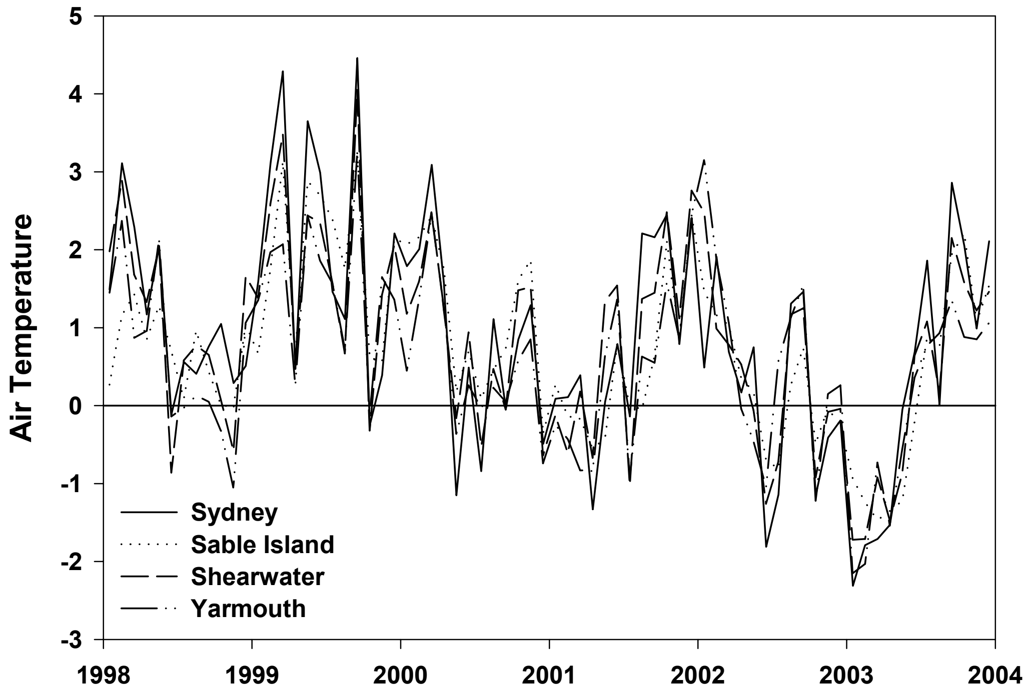


Figure 24. Anomalies of 2 standard deviations for 1999-2003 over the time periods listed in Table 1 for each LFA separately.



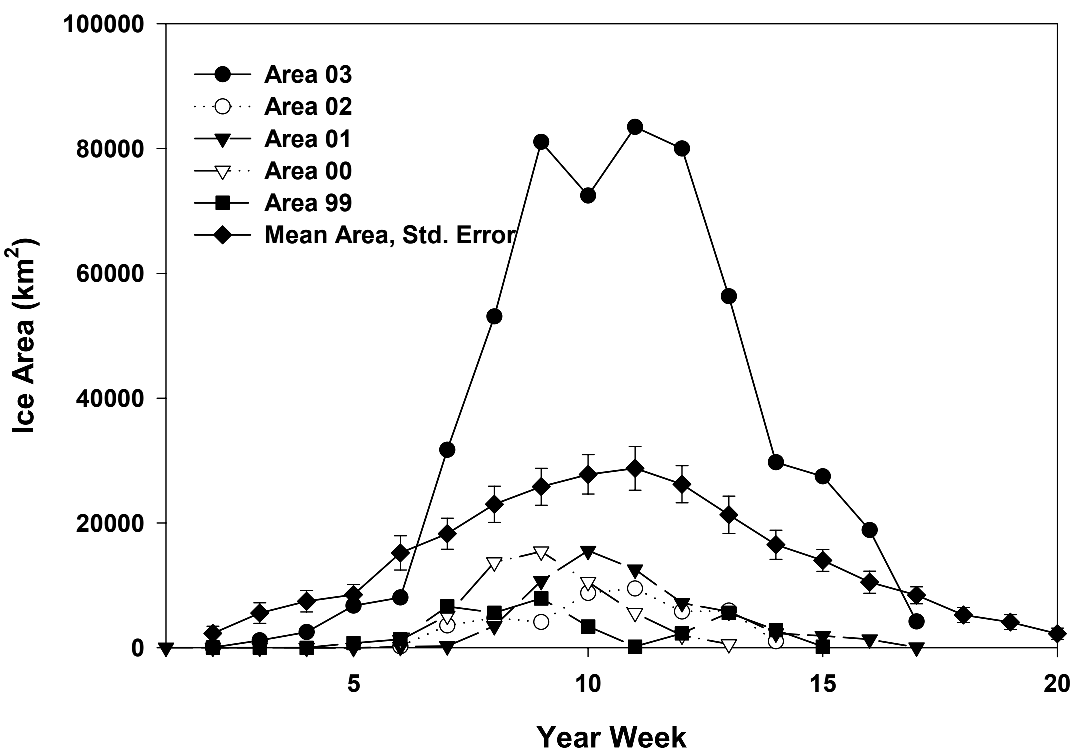


Figure 25. Air temperature anomalies and ice cover south of Cabot Strait for 1999-2003.

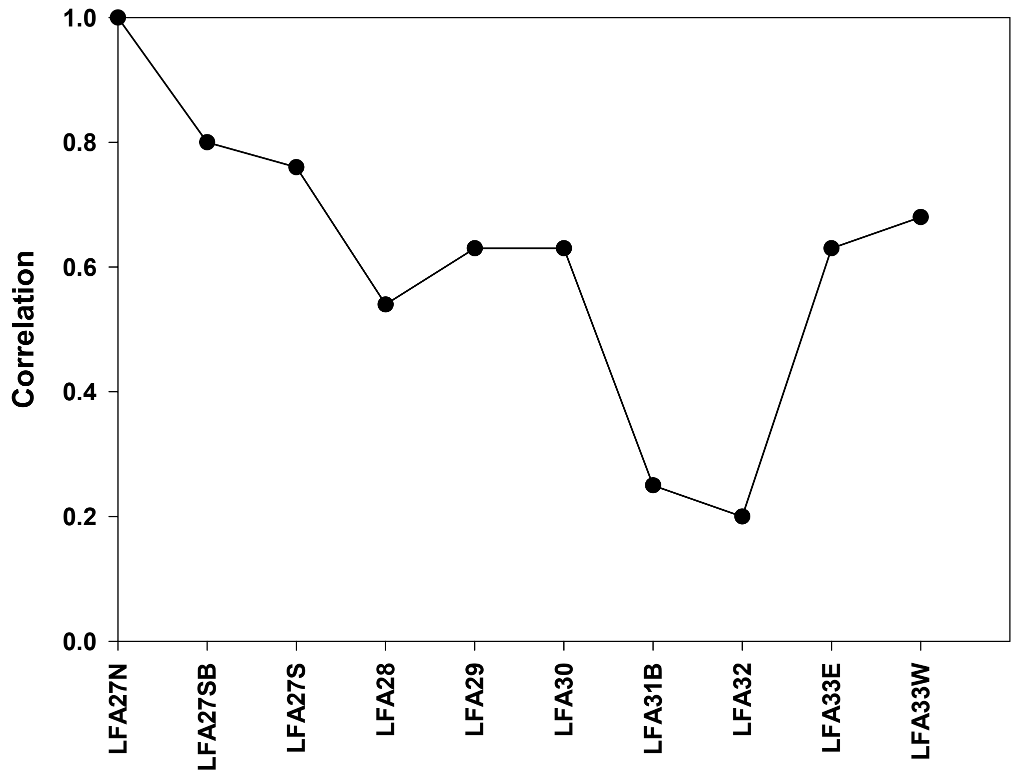


Figure 26. Correlation of spring temperature anomalies relative to LFA27N.