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Data Report

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Water Properties of Narragansett Bay Observed at GSO Dock from 1995 - 2011

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Narragansett Bay is a medium-sized (370 km^2) northeastern U.S. estuary. The Narragansett Bay watershed drains approximately 1,800 square miles through numerous freshwater inputs into the Bay. The major source of fresh water to the Bay is the Blackstone River. Narragansett Bay covers approximately 147 square miles with an undulating shoreline that creates a string of sheltered coves where water circulation may be restricted (Figure 1). The circulation in the Bay was described in detail by Rodgers (Rogers, 2008) and Kincaid, et. al. (Kincaid, et. al., 2003; Pilson, 1985). This report describes the time series data collected at the dock of Graduate School of Oceanography (GSO) at the Narragansett Bay Campus of the University of Rhode Island from 1995 through 2011. This site is located about 4.6 km from the mouth of the West Passage in Narragansett Bay.

A. Methods

In situ measurements of temperature, salinity, dissolved oxygen, pH, and pressure have been made at the GSO dock (41.49° N, 71.42° W) starting in June 1995 and continuing to the present. The average depth at the site is ~3 meters and the water is well mixed throughout the year. The data were collected using Yellow Springs Incorporated (*YSI*) sensors and sondes. Details of the calibration of these sensors and sondes have been described previously (Magnuson, 1994; Bergando et al, 2005, NBFSMN, 2007). The depth of the sampling platform was adjusted periodically during the 16 years of observations so the depth data, which reflected tidal activity, was normalized to zero. The average tidal range was ~0.5 m. The sampling interval varied slightly in this 16 year study: from June 1995 through July 1997, measurements were taken every 10 minutes; from August 1997 through February 1998, the sampling interval was extended to 20

minutes; starting in March 1998 and continuing to the present, measurements were taken every 15 minutes. Data taken at 20 minute intervals were linearly interpolated to 10 minutes. For the tidal analyses, hourly averages were used.

B. Observed Data

The observed temperature and salinity data for July 1995 through December 2011 are shown in Figure 2. The temperature profile illustrates that warming and cooling of the surface waters of the Bay were important features. Four periods of the annual cycle were defined:

i.) Temperature > 17^0 C (summer)

ii.) Temperature cooling from 17^0 C to 7^0 C (fall)

iii.) Temperature < 7^0 C (winter)

iv.) Temperature warming from 7^0 C to 17^0 C (spring).

The rational for the selection of these periods will be discussed later. The average temperature and salinity with the tidal component removed observed during each year were computed (Table 1). The number of days in each annual cycle and the maximum and minimum temperature and salinity for each year were also included. The mean temperature during the 16 years of observations was 11.8^0 C with a standard deviation of only 0.6^0 C. The average temperature of the Bay has been remarkably consistent during this 16 year study. There was more variability in the annual lower temperature than in the higher; the range for the minimum was 4.5^0 C whereas for the maximum it was only 2.5^0 C. The mean salinity for the 16 years was $30.15^0/_{00}$ with a standard deviation of $0.53^0/_{00}$. Again there was more variation in the lower salinity; the range for the minimum was $6.57^0/_{00}$ whereas for the maximum it was $1.23^0/_{00}$. This reflects the importance

of river flow on salinity (note the low salinity spikes in Figure 2).

C. Separation of Tidal Components

The tides are a significant factor influencing the water properties of the Bay. To separate the tidal and non-tidal components from the water properties, an harmonic analysis was made using the MATLAB program **t_tide** (Pawlowiez, et. al., 2002). The amplitude and phase of the tides are due to the gravitational forces exerted by the moon and sun as the earth rotates on its axis. In classical harmonic analysis, the tidal signal is modeled as the sum of set of sinusoids at specific frequencies. The tidal constituents important in Narragansett Bay are summarized in Table 2 (Rodgers, 2008). The program, ***t_tide***, requires a minimum of 30 days of continuous observations. There were gaps in the depth data during this 16 year study; however, from June 1996 to September 1997 the data were continuous and were used for ***t_tide***. Using this data observed over 400 consecutive days resolved most of the variations in planetary motions. The amplitude and phase determined from this year-long study can be used to predict the tides during other time periods. The observed and predicted tide data for a 31 day period during August 1996 are compared in Figure 3. The program ***t_tide*** was applied to the observed temperature and salinity data to separate the tidal and non-tidal components. For these properties the results were unacceptable. Although tidal activity does affect the temperature and salinity of the Bay, other factor such as air temperature and fresh water inputs were also important. These processes vary seasonally. Figure 4 illustrates the results obtained when the program ***t_tide*** was applied to the temperature data during 1996. There was a dramatic difference between the results obtained during the early summer than those obtained during the late summer and early fall. Since the

program, ***t_tide***, requires a minimum of 30 days of continuous observations and there were intermittent data gaps in temperature and salinity (Table 4 and 5), a different approach was used.

The ***Godin*** filter (Godin, 1972) was used to separate the tidal and non-tidal components of temperature and salinity. This technique required a minimum of three days of continuous data. The initial evaluation was made using the 1998 data which had several time gaps. The results were satisfactory. Although the magnitude of the tidal component varied throughout the year, the pattern was similar. The residual non-tidal component was consistent with the observed data.

To minimize the number of days not included in tidal analysis (for each data gap three days of observed data were lost), all data gaps were eliminated using the following technique:

i.) A 96 hour segment with a strong tidal signal was identified in the observed data close to the time of the data gap.

ii.) This segment was inserted into the observed data several time to fill the gap.

iii.) Adjustments were made to the slope and/or the height of the insert to make it consistent with the observed data.

The details of the inserts are summarized in Table 6 (temperature) and Table 7 (salinity). To verify that this technique did not alter the integrity of the data, the results obtained using the observed data and the "data with inserts" were compared. The results were identical for periods when the ***Godin*** filter was valid. Using the "data with inserts" provided 60 more days of continuous data. It should be emphasized that the "data inserts" were not included in the calculation of averages and rates.

The tidal and non-tidal components (corrected temperature) for 1996 - 2011 are shown in

Figure 5 through 20 for temperature and Figure 21 through 36 for salinity. The tidal and non-tidal components were color coded to reflect seasonal variations: blue for winter (temperature < 7^0 C); green for spring (temperature warming from 7^0 C to 17^0 C); red for summer (temperature > 17^0 C); and aqua for fall (temperature cooling from 17^0 C to 7^0 C). Data gaps indicate periods when inserts were used. Warming and cooling (spring and fall) lasted an average of 60 days, shorter than the average 118 days observed during the summer and winter. With few exceptions (winters between 2003 - 2005), the corrected temperature range was between 0^0 C to 25^0 C and the tidal temperature range was consistently between -3^0 C and $+3^0$ C. The greatest tidal variations occurred in spring and summer and the least in fall. For salinity, there was greater variation in the annual range. For example, in 1999 the corrected salinity range was from $17^0/_{00}$ to $31^0/_{00}$ and the tidal range was from $-1.0^0/_{00}$ to $1.0^0/_{00}$; whereas during 2010 the corrected salinity ranged from $22^0/_{00}$ to $32^0/_{00}$ and tidal variations were from $+6^0/_{00}$ to $-6^0/_{00}$. Seasonal variations were not consistent, but tidal variation was the greatest during periods of low salinity.

To examine this, an estimate of the lag time was calculated. The lag time used for this study was the difference in days between an increase in river flow and lower salinity observed at the GSO dock. Lag times were different for different rivers. Since the Blackstone River accounts for ~70% of the total fresh water input into the Bay, the gauged flow of this river was used for the lag time calculation. The results are summarized in Table 8. Flow data from the Blackstone River was obtained from USGS website (www.waterdata.usgs.gov/ri) and the weather data from the NOAA website (www.ndbc.noaa.gov). Salinity data were the average daily salinity measured at the GSO dock. Generally, the maximum in river flow occurred 1 day after the rain event. The day of the rain was the start time in Table 8. The background river flow

was the average flow one week before and one week after the event. The range of the lag time was from 1 day to 15 days indicating the complexity of the processes controlling river flow. The mean was 4.4 ± 3.7 days. There were times with multiple rain events and flows entering the system from other sources. On a seasonal scale, most of the freshwater flow to the Bay occurred between December and June with the maximum monthly flow typically in March. The flow was lowest during the summer months, July through September. The largest single day rain event (4 in) occurred on March 30, 2010; the total rainfall for the entire month was 12 inches. This event resulted in the greatest flood during the past 100 year with a peak flow of 382 m./sec. from the Blackstone River (note the scale change in Figure 35). The lowest daily average salinity observed at the GSO dock was $21.29^{0}/_{00}$ was also recorded during this event.

Using the Bay temperature as an indicator of seasonal changes provided a better understanding of the annual cycles. To determine the seasonal temperature ranges the corrected temperature (T_{Bay}) for the 16 year study was visually inspected.. The onset of warming (cooling) varied from year to year (Figure 2); but during warming (cooling) periods, each day was warmer (cooler) than the previous day. During summer (winter), there were temperature fluctuations and T_{Bay} varied between the maximum and minimum temperature of the season. For the entire 16 year study, when 7.0^{0} C < T_{Bay} > 17.0^{0} C, there was continuous warming or cooling of the Bay. Using this observation, four periods were defined:

i.) Temperature > 17^{0} C (summer)

ii.) Temperature cooling from 17^{0} C to 7^{0} C (fall)

iii.) Temperature < 7^{0} C (winter)

iv.) Temperature warming from 7^{0} C to 17^{0} C (spring).

The year, which were based on Bay temperature not the chronological year, started in early December and ended in February.

1. Tidal Corrected Temperature and Salinity

The average temperature and salinity, with the tidal component removed, observed during the summer ($T > 17^0$ C) and winter ($T < 7^0$ C) were computed (Table 9 and 10). The average mean temperature observed during the summer for this 16 year period was 19.99 ± 0.37^0 C and the average mean salinity was $30.58 \pm 0.62^0/_{00}$. The temperature range during the winter (5.2^0 C) was significantly greater than during the summer (1.2^0 C). The stratified condition observed in summer lead to more homogenous surface water. The Bay temperature was above 17^0 C for an average of 116 days. The shortest summer (100 days) was 1997; the longest (135 days) was 2007. There was more variability during the winter months ($T < 7^0$ C). The average temperature for these 16 years was 3.91 ± 0.82^0 C and the average salinity was $30.02 \pm 0.74^0/_{00}$. Although there was a marked difference in the temperature during the summer and winter, the salinity was consistent throughout the year ($2.1^0/_{00}$ in summer and $2.3^0/_{00}$ in winter). The Bay temperature was below 7^0 C for an average of 117 days. The shortest winter of 99 days was 2007; the longest (136 days) was 1996 and 2003.

The warming of the Bay began in mid-April and continued until mid-June, a period of approximately 60 days (Table 11). During this time the mean warming rate was 0.167 ± 0.023^0 C/day. The fastest rate was 0.208^0 C/day in 2007 and the slowest was 0.130^0 C/day in 1999. Cooling of the Bay started in October and continued through December. The average cooling rate was -0.164 ± 0.030^0 C/day and the cooling lasted an average of 60 days. The slowest rate of -0.112^0 C/day was observed in 2006 and the fastest rate of -0.208^0 C/day was

the next year (2007).

2. Tidal Temperature and Salinity

Tidal temperature and salinity are an indication of the horizontal stratification of the Bay (Wimbush, private communication). At a fixed location, such as the GSO dock, a lense of surface waters is moved with the tides. During a high tide, the offshore waters of RI Sound are drawn into the Bay; at low tide, the water from the Upper Bay are moved down the Bay. To determine when tidal fluctuations were the greatest during each year, the following procedure was used:

i.) The tidal temperature and salinity data with fractional Julian Day (JD) were sorted using the amplitude of the temperature/salinity as the criterium.

ii.) Only values of tidal temperature > 0.5^0 C and salinity > $0.4^0/_{00}$ were retained.

iii.) These data were again sorted according to ascending JD. The fractional portion of JD was truncated and the number of times/day the tidal temperature > 0.5^0 C and tidal salinity > $0.4^0/_{00}$ were determined.

The results for temperature are shown in Figure 37 and for salinity in Figure 38. The x-axis is the JD; the y-axis is the number of JD/year high tidal values were observed. For temperature, there was a minimum during February and October with a strong maximum during June/July and a weaker maximum in mid-January. For salinity, highest values were observed in the spring with lower values in summer and fall (Figure 38 top). Similar patterns were observed when the average river flow for the 16 year study were plotted (Figure 38 bottom).

Since the offshore surface waters in RI Sound are usually warmer than waters in Upper Narragansett Bay in winter and cooler in the summer, one might expect seasonal fluctuations in

the tidal temperature. Is this observed more often at high tide or low tide? To address these questions, the variations in tidal temperature at high and low tide were examined:

i.) For each year, a file was created with the fractional JD, the depth, temperature and salinity for all observations. These files were divided into seasonal components using the JD listed in Table 9-10.

ii.) These data were separated into tidal sections (time periods of ~ 12 hours representing a tidal cycle). The first point in each segment was the maximum depth (high tide); the minimum was low tide. The maximum temperature and its index (number of points after high tide) for each segment was determined. Since the data were hourly observations, the indices represented the number of hours after high tide and they ranged in values from 1 to 12 (13). Three groups were identified:

a.) high tide with an index of 1, 2, 12 (13) hours,

b.) low tide with an index of 5, 6, 7 hours,

c.) mid tide with an index of 3, 4, 8, 9, 10, 11 hours.

iii.) The data files were sorted using ascending tidal temperature as the criterium; only data with tidal temperature > 0.5^0 C at high tide or data with tidal temperature < - 0.5^0 C at low tide were retained. The purpose was to determine if the extreme tidal fluctuations occurred at high or low tide and if these varied seasonally.

iv.) The data for each season for each year were sorted by the index number and grouped into high tide and low tide bins. The percent of tidal temperature > 0.5 ^{0}C at high tide and the percent of tidal temperature < - 0.5^0 C at low tide for each

season was calculated. (Table 12).

The mean for the 16 year study showed more variation at high tide than at low tide for all seasons. In addition, there were greater variations in the winter and fall than during the spring and summer.

E. Comparison of Temperature with Off-Shore and Upper Bay Site

The water properties observed at the GSO dock were compared to those observed at two other locations. One was an off-shore site, the NOAA buoy in Buzzards Bay and the second was a station in the upper Bay, T-Wharf at the south end of Prudence Island.

1. Buzzards Bay

The NOAA buoy is located southeast of Newport RI (41.40°N, 71.03°W) and the surface water temperature collected at this location was used to evaluated the conditions in Buzzards Bay There were several significant gaps in the water temperature: from early February to December 1998; from January to December 2001; and from January to December 2004 (Figure 39). Tidal corrections were made using the ***Godin*** filter and the corrected data was partitioned into seasonal components using the criteria described previously. The amplitude of the tidal signal was similar to that observed in the Bay. The average temperature during summer and winter were calculated using the corrected data (Table 13). The summer mean temperature for the entire period was 19.28 ± 0.99^0 C similar to that observed at the GSO dock (19.97 ± 0.35^0 C); however different patterns were observed. In the summer at the GSO dock, the range of surface temperature was only 1.15^0 C during the 16 year study; at Buzzards Bay the range was 2.92^0 C. Closer inspection showed that during the past 3 years (2009 - 2011) the temperature observed in Buzzards Bay was

~ 1.0^0 C warmer than that observed at the GSO dock. During winter the mean temperature was essentially the same (3.68 ± 0.98^0 C at Buzzards Bay and 3.96 ± 0.83^0 C at GSO) but the range was much greater at the GSO dock (5.19^0 C) than in Buzzards Bay (2.41^0 C). Clearly the proximity of the land around the Bay influences the surface water temperature in the winter.

Warming in Buzzards Bay began in mid-April and continued to mid-June (Table 14). The shortest time was 50 days in 2010 and 2011 with a warming rate of 0.200^0 C/day. The longest period was 75 days in 2003 with a rate of 0.132^0 C/day. Buzzards Bay started cooling in mid-October and reached 7.0^0 C in mid-December. The shortest time was 52 days in 2010 with a cooling rate of -0.192^0 C/day. The longest period was 100 days in 2006 with a rate of 0.100^0 C/day.

2. Prudence Island

Data were also collected from the Upper Bay at a site on Prudence Island (T-Wharf at 41.80^0 N and 71.32^0 W) starting in 2003 (Figure 40). Tidal corrections were made using the ***Godin*** filter and the corrected data was partitioned into seasonal components (Table 15). There was little variation in the average summer temperature (20.61 ± 0.21^0 C) and the average surface water temperature was slightly warmer ($- 0.6^0$ C) than that at the GSO dock. The average winter temperature was 3.90 ± 0.76^0 C the same as that observed at the GSO dock (3.91 ± 0.82^0 C). Warming of the Bay observed at the T-Wharf station on Prudence Island began in mid-April and usually continued into June (Table 16). The exception was 2010, when the surface water reached 17.0^0 C on May 30. Cooling began in mid-October and usually extended into December. In 2006, the cooling period lasted into January (88 days); the shortest cooling period of 37 days was observed in 2007 (28 October - 26 December).

3. Comparison with GSO Dock

Since data were collected at different time periods at the three sites, a clearer understanding can be gained by examining annual seasonal differences. The average temperature differences are summarized in Table 17. Prior to 2009, the surface water temperature at Buzzards Bay in the summer was ~1.0^0 C cooler than that observed at the GSO dock. For the last three years the opposite was observed, Buzzards Bay was ~1.0^0 C warmer. During the winter, the temperature in Buzzards Bay was cooler or the same as that at the GSO dock. This warming trend in Buzzards Bay cannot be verified by the limitations of this time series. On Prudence Island in the summer, the mean surface water temperature at T-Wharf was ~ 0.8^0 C warmer than at the GSO dock. During the winter the temperature was the same.

The average warming and cooling rates for the entire 16 years of this study were essentially the same. The variation from year to year was almost as great as the range for the entire study. For example, the range in the warming rates at the GSO dock from 1996 to 2011 was 0.078^0 C/day. For the year 2006 the rate was 0.143^0 C/day and the next year (2007) it was 0.208^0 C/day, a difference of 0.065^0 C/day. The warming and cooling rates were dependent on weather conditions for that year. A better comparison can be made by examining the rates at the different sites during the same year. The difference between the warming rates calculated at Buzzards Bay and the GSO dock from 1996 - 2011 are summarized in Table 18. For the last two years (2010 - 2011) the warming rate was faster in Buzzards Bay than at the GSO dock; prior to 2010 it was slower or the same. The greatest deviation in cooling rates were in 2007 and 2010. The warming rate at Prudence Island was the same as that calculated at the GSO dock. The cooling rate was more variable but no trends were observed.

F. Conclusions

The temperature, salinity, dissolved oxygen, pH, and pressure of Narragansett Bay were measured at the GSO dock starting in June 1995 and continuing to the present The mean yearly temperature for the Bay was 11..8 ± 0.6^0 C and the mean salinity was 30.15 ± $0.53^0/_{00}$. Both temperature and salinity were very consistent during the summer when water column was stratified. In winter, when Bay waters were well mixed, there was more variability especially in temperature. There was usually a 20 degree temperature change during the year; thus, warming and cooling were promenade features in the seasonal cycle.

Seasonal changes were defined by Bay temperature rather than the chronological date. Four periods were defined:

i.) Temperature > 17^0 C (summer)

ii.) Temperature cooling from 17^0 C to 7^0 C (fall)

iii.) Temperature < 7^0 C (winter)

iv.) Temperature warming from 7^0 C to 17^0 C (spring).

The tides were important factors in Narragansett Bay and the tidal and non-tidal components were separated. For depth, the program ***t_tide*** was used to determine important constants. These constants were used to predict tides in the future. For temperature and salinity this program was unsatisfactory and ***Godin*** filter was used. to separate tidal and non-tidal components. Using the tidally corrected data and surface water temperature defined above, seasonal averages and warming and cooling rates were calculated. The mean summer temperature 19.99 ± 0.37^0 C and the mean salinity was 30.58 ± $0.62^0/_{00}$. For winter, the mean temperature was 3.91 ± 0.82^0 C and the salinity was 30.00 ± $0.74^0/_{00}$. The average warming rate

was 0.167 ± 0.023^0 C/day and the cooling rate was -0.164 ± 0.030^0 C/day.

Seasonal variations in the tidal component were examined by plotting the number of JD/year high tidal signals (temperature > 0.5^0 C)were observed against JD. For temperature, there was a strong maximum in June/July and weaker maximum in mid-January with a minimum during March and November. For salinity, highest values were observed in the spring with lower values in summer and fall, similar to the patterns observed for the average river flow. Since the offshore surface waters in RI Sound are usually warmer than waters in Upper Narragansett Bay in winter and cooler in the summer, the seasonal fluctuations in the tidal temperature were examined. There was more variation at high tide than at low tide for all seasons and there were greater variations in the winter and fall than during the spring and summer.

The relationship between river flow and salinity was examined by calculating the lag time. The lag time used for this study was the difference in days between an increase in river flow of the Blackstone River and lower salinity observed at the GSO dock. The average was 4.4 ± 3.7 days with a range from 1 to 15 days indicating the complexity of the processes controlling salinity variations.

The water properties observed at the GSO dock were compared to those observed at the NOAA buoy in Buzzards Bay and a station in the upper Bay, T-Wharf at the south end of Prudence Island. The annual seasonal differences were compared, since the data were collected at different time periods at the three sites. Prior to 2009, the surface water temperature at Buzzards Bay in the summer was ~1.0^0 C cooler than that observed at the GSO dock. For the last three years Buzzards Bay was ~1.0^0 C warmer. During the winter, the temperature in Buzzards Bay was cooler or the same as that at the GSO dock. On Prudence Island in the

summer, the mean surface water temperature at T-Wharf was ~ 0.8^0 C warmer than at the GSO dock. During the winter, temperature was the same. At Buzzards Bay, for the last two years (2010 - 2011), the warming rate was faster than that calculated at the GSO dock; prior to 2010 the rate was slower or the same. The greatest deviation in cooling rates were in 2007 and 2010. The warming rate at Prudence Island was the same as that calculated at the GSO dock. The cooling rate was more variable but no trends were observed.

G. Acknowledgments

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I. Table Legend

Table 1. Average Temperature and Salinity Observed at GSO Dock from 1995-2011 Tidal Component Removed.

Table 2. Tidal Amplitude and Phase Determined by *T_TIDE* for Depth.

Table 3. Summary of Consecutive Days for Depth Data at GSO Dock.

Table 4. Summary of Consecutive Days for Surface Temperature Data at GSO Dock

Table 5. Summary of Consecutive Days for Surface Salinity Data at GSO Dock.

Table 6. Summary of Insert Data for Surface Temperature Data at GSO Dock.

Table 7. Summary of Insert Data for Surface Salinity Data at GSO Dock.

Table 8. Lag Times Between Blackstone River and GSO Dock from 1996-2011.

Table 9. Average Temperature and Salinity Observed at GSO Dock during Summer from 1995-2011.

Table 10. Average Temperature and Salinity Observed at GSO Dock during Winter from 1995-2011.

Table 11. Warming and Cooling Rates Observed at GSO Dock for 1995-2011.

Table 12. Percent of Tidal Temperature > 0.5° C and < -0.5° C at High and Low Tide Observed at GSO Dock from 1996-2011.

Table 13. Average Temperature Observed at Buzzards Bay during Summer and Winter from 1995-2011.

Table 14. Warming and Cooling Rates Observed at Buzzards Bay for 1995-2011.

Table 15. Average Temperature and Salinity for T-Wharf Station on Prudence Island 2003-2010.

Table 16. Warming and Cooling Rates Observed at for T-Wharf Station on Prudence Island from 2003-2010.

Table 17. Comparison of Seasonal Temperature at GSO dock, Buzzards Bay and Prudence Island for 1996-2011.

Table 18. Warming and Cooling Rates Observed at GSO Dock, Buzzards Bay and Prudence Island for 1996 – 2011.

Table 1
Average Temperature and Salinity Observed at GSO Dock from 1995 - 2011
Tidal Component Removed

Year	*No Days*	*Avg Temp ± Std,* ^{0} *C*	*Avg Salinity ± Std* $^{0}/_{00}$	*Min Temp* ^{0} C	*Max Temp* ^{0} C	*Min Sal* $^{0}/_{00}$	*Max Sal* $^{0}/_{00}$
1996	359	10.74 ± 7.25	29.83 ± 0.92	-0.40	21.63	25.61	31.74
1997	345	11.50 ± 6.30	29.87 ± 1.29	1.56	22.17	25.97	32.01
1998	382	11.72 ± 6.25	29.53 ± 1.32	2.55	23.06	24.23	31.67
1999	364	12.68 ± 6.81	30.38 ± 1.01	0.87	22.96	27.04	31.79
2000	346	12.13 ± 6.75	30.56 ± 0.95	1.22	23.23	27.47	32.27
2001	387	11.65 ± 7.05	30.47 ± 1.28	0.99	23.17	24.36	32.41
2002	347	12.81 ± 6.45	31.00 ± 0.65	3.09	23.49	28.52	32.07
2003	364	11.08 ± 7.34	30.26 ± 1.09	-1.28	23.97	26.24	32.34
2004	379	11.14 ± 7.07	30.51 ± 0.91	-0.91	22.09	26.12	32.14
2005	353	11.68 ± 7.24	29.18 ± 1.22	-0.27	22.89	23.79	31.40
2006	404	11.72 ± 6.02	29.23 ± 1.53	3.26	23.71	24.13	32.17
2007	335	12.51 ± 6.75	30.96 ± 1.02	0.60	22.49	27.19	32.60
2008	374	9.71 ± 6.31	29.70 ± 1.04	2.07	22.61	25.52	31.35
2009	363	11.77 ± 6.70	30.14 ± 0.83	1.13	23.00	26.75	32.08
2010	355	11.56 ± 6.79	30.35 ± 1.76	0.21	22.47	21.95	32.47
2011	388	12.05 ± 7.18	30.10 ± 1.00	2.25	24.09	25.64	31.71
Mean	365 ± 12	11.80 ± 0.57	30.15 ± 0.53	1.06 ± 1.37	22.94 ±0.68	25.66 ± 1.65	32.00 ± 0.38

Table 2
Tidal Amplitude and Phase Determined by *T_TIDE* for Depth

Symbol	*Tidal Component*	*Frequency*	*Period*	*Amplitude*	*Phase*
M2	main lunar semi-diurnal	0.08051	12.42	0.486 ± 0.008	204.8 ± 1.0
N2	larger lunar elliptic semi-durnal	0.07900	12.66	0.117 ± 0.008	190.2 ± 4.1
S2	main solar semi-diurmal	0.08333	12.00	0.105 ± 0.008	223.2 ± 4.9
K1 *	lunar-solar declinational diurnal	0.04178	23.93	0.064 ± 0.010	85.6 ± 8.9
M4	second overtone of M2	0.16102	6.21	0.047 ± 0.005	76.2 ± 6.0
O1	lunar declinational diurnal	0.03873	25.82	0.048 ± 0.011	119.7 ± 12.2
M6	third overtone of M2	0.24153	4.14	0.004 ± 0.001	92.4 ± 11.2
S1 **	solar declinational diural	0.04167	24.00	-------	– -----

* Used for depth and salinity instead of S1.
** Used for temperature instead of K1

Table 3
Summary of Consecutive Days for Depth Data at GSO Dock

Property	*Year*	*Consecutive Day*	*Date*	*File name*	*MATLAB Name*
Depth	1995	171 - 218	20 Jun 95 - 06 Aug 95	dep95a_hr	contdep95_99
Depth	1995	335 - 364	01 Dec 95 - 30 Dec 95	dep95b_hr	contdep95_99
Depth	1996	366 - 429	01 Jan 96 - 04 Mar 96	dep96a_hr	contdep95_99
Depth	1996	443 - 512	18 Mar 96 - 26 May 96	dep96a_hr	contdep95_99
Depth	1996	526 - 731	09 Jun 96 - 31 Dec 96	dep96c_hr	contdep95_99
Depth	1997	732 - 975	01 Jan 97 - 01 Sep 97	dep97a_hr	contdep95_99
Depth	1997	986 - 1032	12 Sep 97 - 28 Sep 97	dep97b_hr	contdep95_99
Depth	1997	1036 - 1048	01 Nov 97 - 13 Nov 97	dep97c_hr	contdep95_99
Depth	1997	1055 - 1060	20 Nov 97 - 25 Nov 97	dep97d_hr	contdep95_99
Depth	1997	1071 - 1096	06 Dec 97 - 31 Dec 97	dep97e_hr	contdep95_99
Depth	1998	1097 - 1030	01 Jan 98 - 03 Feb 98	dep98a_hr	contdep95_99
Depth	1998	1137 - 1163	10 Feb 98 - 08 Mar 98	dep98b_hr	contdep95_99
Depth	1998	1173 - 1205	18 Mar 98 - 19 Apr 98	dep98c_hr	contdep95_99
Depth	1998	1216 - 1254	30 Apr 98 - 07 Jun 98	dep98d_hr	contdep95_99
Depth	1998	1263 - 1316	16 Jun 98 - 08 Aug 98	dep98e_hr	contdep95_99
Depth	1998	1340 - 1350	01 Sep 98 - 11 Sep 98	dep98f_hr	contdep95_99
Depth	1998	1362 - 1461	23 Sep 98 - 31 Dec 98	dep98g_hr	contdep95_99
Depth	1999	1462 - 1819	01 Jan 99 - 24 Dec 99	dep99a_hr	contdep95_99
Depth	2000	1830 - 1848	04 Jan 00 - 22 Jan 00	dep00a_hr	contdep00_11
Depth	2000	1897 - 1910	11 Mar 00 - 24 Mar 00	dep00b_hr	contdep00_11
Depth	2000	1932 - 1982	15 Apr 00 - 04 Jun 00	dep00c_hr	contdep00_11
Depth	2000	1987 - 2192	09 Jun 00 - 31 Dec 00	dep00d_hr	contdep00_11
Depth	2001	2193 - 2557	01 Jan 01 - 31 Dec 01	dep01a_hr	contdep00_11

Table 3 (cont.)

Property	*Year*	*Consecutive Day*	*Date*	*File name*	*MATLAB Name*
Depth	2002	2558 - 2560	01 Jun 02 - 03 Jan 02	dep02a_hr	contdep00_11
Depth	2002	2568 - 2922	11 Jan 02 - 31 Dec 02	dep02b_hr	contdep00_11
Depth	2003	2923 - 3280	01 Jan 03 - 24 Dec 02	dep03a_hr	contdep00_11
Depth	2003	3286 - 3287	30 Dec 03 - 31 Dec 02	dep03b_hr	contdep00_11
Depth	2004	3288 - 3471	01 Jan 04 - 02 Jul 04	dep04a_hr	contdep00_11
Depth	2004	3498 - 3653	29 Jul 04 - 31 Dec 04	dep04b_hr	contdep00_11
Depth	2005	3654 - 3889	01 Jan 05 - 24 Aug 05	dep05a_hr	contdep00_11
Depth	2005	3926 - 3957	30 Sep 05 - 31 Oct 05	dep05b_hr	contdep00_11
Depth	2005	3654 - 3889	01 Jan 05 - 24 Aug 05	dep05a_hr	contdep00_11
Depth	2005	3926 - 3957	30 Sep 05 - 31 Oct 05	dep05b_hr	contdep00_11
Depth	2006	4019 - 4192	01 Jan 06 - 23 Jun 06	dep06a_hr	contdep00_11
Depth	2006	4206 - 4307	04 Jul 06 - 16 Sep 06	dep06b_hr	contdep00_11
Depth	2006	4342 - 4383	20 Nov 06 - 31 Dec 06	dep06c_hr	contdep00_11
Depth	2007	4384 - 4619	01 Jan 07 - 24 Aug 07	dep07a_hr	contdep00_11
Depth	2007	4640 - 4716	14 Sep 07 - 29 Nov 07	dep07b_hr	contdep00_11
Depth	2008	4749 - 4886	01 Jan 08 - 17 May 08	dep08a_hr	contdep00_11
Depth	2008	4890 - 5031	21 May 08 - 09 Oct 08	dep08b_hr	contdep00_11
Depth	2008	5047 - 5079	25 Oct 08 - 26 Nov 08	dep08c_hr	contdep00_11
Depth	2008	5099 - 5114	16 Dec 08 - 31 Dec 08	dep08d_hr	contdep00_11
Depth	2009	5115 - 5479	01 Jan 09 - 31 Dec 09	dep09a_hr	contdep00_11
Depth	2010	5480 - 5845	01 Jan 10 - 31 Dec 10	dep10a_hr	contdep00_11
Depth	2011	5846 - 5858	01 Jan 11 - 12 Jan 11	dep11a_hr	contdep00_11
Depth	2011	5900 - 6211	23 Feb 11 - 31 Dec 11	dep11b_hr	contdep00_11

Table 4
Summary of Consecutive Days for Surface Temperature Data at GSO Dock

Property	*Year*	*Consecutive Day*	*Date*	*File name*	*MATLAB Name*
Temp	1995	182 - 299	01 Jul 95 - 26 Oct 95	tp95a_obs	gso95_obs
Temp	1995-96	335 - 429	01 Dec 95 - 04 Mar 96	tp95b_obs	gso96_obs
Temp	1996	457 - 731	01 Apr 96 - 31 Dec 96	tp96a_obs	gso96_obs
Temp	1997	732 - 975	01 Jan 97 - 01 Sep 97	tp97a_oba	gso97_obs
Temp	1997	986 - 1048	12 Sep 97 - 13 Nov 97	tp97b_obs	gso97_obs
Temp	1997-98	1071 - 1130	06 Dec 97 - 03 Feb 98	tp_98a_obs	gso98_obs
Temp	1998	1137 - 1164	10 Feb 98 - 09 Mar 98	tp_98b_obs	gso98_obs
Temp	1998	1173 - 1205	18 Mar 98 - 19 Apr 98	tp_98c_obs	gso98_obs
Temp	1998	1216 - 1255	30 Apr 98 - 08 Jun 98	tp_98d_obs	gso98_obs
Temp	1998	1263 - 1351	16 Jun 98 - 12 Sep 98	tp_98e_obs	gso98_obs
Temp	1998	1362 - 1461	16 Jun 98 - 31 Dec 98	tp_98f_obs	gso98_obs
Temp	1999	1462 - 1551	01 Jan 99 - 31 Mar 99	tp_99_obs10	gso99_obs
Temp	1999	1552 - 1817	01 Apr 99 - 22 Dec 99	tp_99_obs15	gso99_obs
Temp	2000	1829 - 1848	04 Jan 00 - 22 Jan 00	tp00a_obs	gso00_hrobs
Temp	2000	1862 - 2192	05 Feb 00 - 31 Dec 00	tp00b_obs	gso00_hrobs
Temp	2001	2193 - 2560	01 Jan 01 - 03 Jan 02	tp01a_obs	gso01_hrobs

Table 4 (cont.)

Property	*Year*	*Consecutive Day*	*Date*	*File name*	*MATLAB Name*
Temp	2002	2568 - 2922	11 Jan 02 - 31 Dec 02	tp02a_obs	gso02_hrobs
Temp	2003	2923 - 3287	01 Jan 03 - 31 Dec 03	tp03a_obs	gso03_hrobs
Temp	2004	3288 - 3471	01 Jan 04 - 02 Jul 04	tp04a_obs	gso04_hrobs
Temp	2004	3499 - 3653	29 Jul 04 - 31 Dec 04	tp04b_obs	gso04_hrobs
Temp	2005	3654 - 3889	01 Jan 05 - 24 Aug 05	tp05a_obs	gso05_hrobs
Temp	2005	3926 - 3995	30 Sep 05 - 08 Dec 05	tp05b_obs	gso05_hrobs
Temp	2006	4019 - 4350	01 Jan 06 - 28 Nov 06	tp06a_obs	gso06_hrobs
Temp	2006	4372 - 4383	20 Dec 06 - 31 Dec 06	tp06c_obs	gso06_hrobs
Temp	2007	4384 - 4620	01 Jan 07 - 25 Aug 07	tp07a_obs	gso07_hrobs
Temp	2007	4540 - 4717	14 Sep 07 - 30 Nov 07	tp07b_obs	gso07_hrobs
Temp	2008	4749 - 5031	01 Jan 08 - 08 Oct 08	tp08a_hr	gso08_hrobs
Temp	2008	5047 - 5079	24 Oct 08 - 25 Nov 08	tp08b_hr	gso08_hrobs
Temp	2008	5099 - 5114	15 Dec 08 - 30 Dec 08	tp08c_hr	gso08_hrobs
Temp	2009	5115 - 5479	01 Jan 09 - 31 Dec 09	tp09a_hr	gso09_hrobs
Temp	2010	5480 - 5781	01 Jan 10 - 28 Oct 10	tp10a_hr	gso10_hrobs
Temp	2010	5789 - 5844	05 Nov 09 -31 Dec 10	tp10b_hr	gso10_hrobs
Temp	2011	5845 - 5916	01 Jan 11- 13 Jan 11	tp11a_hr	gso11_hrobs
Temp	2011	5904 - 6209	01 Mar 11- 31 Dec 11	tp11b_hr	gso11_hrobs

Table 5
Summary of Consecutive Days for Surface Salinity Data at GSO Dock

Property	*Year*	*Consecutive Day*	*Date*	*File name*	*MATLAB Name*
Sal	1995	182 - 299	01 Jul 95 - 26 Oct 95	sal95a_obs	gso95_obs
Sal	1995-96	335 - 429	01 Dec 95 - 04 Mar 96	sal95b_obs	gso96_obs
Sal	1996	444 - 731	19 Mar 96 - 31 Dec 96	sal96a_obs	gso96_obs
Sal	1997	732 - 957	01 Jan 97 - 14 Aug 97	sal97a_oba	gso97_obs
Sal	1997	987 - 1048	13 Sep 97 - 13 Nov 97	sal97b_obs	gso97_obs
Sal	1997-98	1071 - 1130	06 Dec 97 - 03 Feb 98	sal_98a_obs	gso98_obs
Sal	1998	1137 - 1164	10 Feb 98 - 09 Mar 98	sal_98b_obs	gso98_obs
Sal	1998	1173 - 1205	18 Mar 98 - 19 Apr 98	sal_98c_obs	gso98_obs
Sal	1998	1216 - 1255	30 Apr 98 - 08 Jun 98	sal_98d_obs	gso98_obs
Sal	1998	1263 - 1351	16 Jun 98 - 12 Sep 98	sal_98e_obs	gso98_obs
Sal	1998	1362 - 1461	16 Jun 98 - 31 Dec 98	sal_98f_obs	gso98_obs
Sal	1999	1462 - 1551	01 Jan 99 - 31 Mar 99	sal_99_obs10	gso99_obs
Sal	1999	1552 - 1817	01 Apr 99 - 22 Dec 99	sal_99_obs15	gso99_obs
Sal	2000	1829 - 1848	04 Jan 00 - 22 Jan 00	sal00a_obs	gso00_hrobs
Sal	2000	1862 - 2192	05 Feb 00 - 31 Dec 00	sal00b_obs	gso00_hrobs
Sal	2001	2192 - 2556	01 Jan 01 - 30 Dec 01	sal01a_obs	gso01_hrobs

Table 5 (cont.)

Property	*Year*	*Consecutive Day*	*Date*	*File name*	*MATLAB Name*
Sal	2002	2568 - 2922	11 Jan 02 - 31 Dec 02	sal02a_obs	gso02_hrobs
Sal	2003	2923 - 3165	01 Jan 03 - 31 Aug 03	sal03a_obs	gso03_hrobs
Sal	2003	3189 - 3287	24 Sep 03 - 31 Dec 03	sal03b_obs	gso03_hrobs
Sal	2004	3288 - 3471	01 Jan 04 - 02 Jul 04	sal04a_obs	gso04_hrobs
Sal	2004	3499 - 3653	29 Jul 04 - 31 Dec 04	sal04b_obs	gso04_hrobs
Sal	2005	3654 - 3889	01 Jan 05 - 24 Aug 05	sal05a_obs	gso05_hrobs
Sal	2005	3926 - 3995	30 Sep 05 - 08 Dec 05	sal05b_obs	gso05_hrobs
Sal	2006	4019 - 4350	01 Jan 06 - 28 Nov 06	sal06a_obs	gso06_hrobs
Sal	2006	4372 - 4383	20 Dec 06 - 31 Dec 06	sal06c_obs	gso06_hrobs
Sal	2007	4384 - 4620	01 Jan 07 - 25 Aug 07	sal07a_obs	gso07_hrobs
Sal	2007	4665 - 4717	09 Oct 07 - 30 Nov 07	sal07b_obs	gso07_hrobs
Sal	2008	4749 - 5031	01 Jan 08 - 08 Oct 08	sal08a_hr	gso08_hrobs
Sal	2008	5047 - 5079	24 Oct 08 - 25 Nov 08	sal08b_hr	gso08_hrobs
Sal	2008	5099 - 5114	15 Dec 08 - 30 Dec 08	sal08c_hr	gso08_hrobs
Sal	2009	5115 - 5479	01 Jan 09 - 31 Dec 09	sal09a_obs	gso09_hrobs
Sal	2010	5480 - 5781	01 Jan 10 - 28 Oct 10	sal10a_hr	gso10_hrobs
Sal	2010	5789 - 5844	05 Nov 10 - 30 Dec 10	sal10b_hr	gso10_hrobs
Sal	2011	5845 - 5916	01 Jan 11 - 13 Jan 11	sal11a_hr	gso11_hrobs
Sal	2011	5904 - 6209	01 Mar 11 - 31 Dec 11	sal11b_hr	gso11_hrobs

Table 6
Summary of Insert Data for Surface Temperature Data at GSO Dock

Year	*Consecutive Day*	*Filename*	*Interpolation*			*MATLAB Name*
1995	182 - 299	tp95a_hr	observed			comttp_95_08
1995	300 - 334	tp95ab_hr	insert 335 - 338	repeat 8.75 times	slope 8.275	comttp_95_08
1995-96	335 - 429	tp95b_hr	observed			comttp_95_08
1996	430 - 456	tp95ba_hr	insert 457 - 460	repeat 7.75 times	slope 3.31	comttp_95_08
1996	457 - 731	tp96a_hr	observed			comttp_95_08
1997	732 - 975	tp97a_hr	observed			comttp_95_08
1997	976 - 985	tp97ab_hr	insert 972 - 975	repeat 2.5 times	slope 1.06	comttp_95_08
1997	986 - 1048	tp97b_hr	observed			comttp_95_08
1997	1049 - 1070	tp97ba_hr	insert 1071 - 1074	repeat 5.5 times	slope 2.69	comttp_95_08
1997-98	1071 - 1130	tp_98a_hr	observed			comttp_95_08
1998	1131 - 1136	tp98ab_hr	insert 1127 - 1130	repeat 1.5 times	add 0.1	comttp_95_08
1998	1137 - 1164	tp_98b_hr	observed			comttp_95_08
1998	1165 - 1172	tp98bc_hr	insert 1161 - 1164	repeat 12.0 times	slope -1.06	comttp_95_08
1998	1173 - 1205	tp_98c_hr	observed			comttp_95_08
1998	1206 - 1215	tp98cd_hr	insert 1216 - 1219	repeat 2.5 times	add 1.0	comttp_95_08
1998	1216 - 1255	tp_98d_hr	observed			comttp_95_08
1998	1256 - 1262	tp98de_hr	insert 1263 - 1266	repeat 1.75 times	add 1.0	comttp_95_08
1998	1263 - 1351	tp_98e_hr	observed			comttp_95_08
1998	1352 - 1361	tp98ef_hr	insert 1362 - 1365	repeat 2.5 times	slope 0.7	comttp_95_08
1998	1362 - 1461	tp_98f_hr	observed			comttp_95_08
1999	1462 - 1817	tp_99_hr	observed			comttp_95_08
1999-2000	1818 - 1828	tp99ba_hr	insert 1814 - 1817	repeat 2.78 times	add 1.0	comttp_95_08
2000	1829 - 1848	tp00a_hr	observed			comttp_95_08
2000	1849 - 1861	tp00ab_hr	insert 1862 - 1865	repeat 3.33 times		comttp_95_08
2000	1862 - 2192	tp00b_hr	observed			comttp_95_08
2001	2193 - 2560	tp01a_hr	observed			comttp_95_08
2002	2561 - 2567	tp01aa_hr	insert 2544 - 2560	repeat 2.0 times	add 1.19	comttp_95_08
2002	2568 - 2922	tp02a_hr	observed			comttp_95_08

Table 6 (cont.)

Year	*Consecutive Day*	*Filename*	*Interpolation*	*MATLAB Name*
				comttp_95_08
2003	2923 - 3287	tp03a_hr	observed	comttp_95_08
2004	3288 - 3471	tp04a_hr	observed	comttp_95_08
2004	3472 - 3498	tp04ab_hr	insert 3499 - 3503 repeat 7.75 times slope 2.93	comttp_95_08
2004	3499 - 3653	tp04b_hr	observed	comttp_95_08
2005	3654 - 3889	tp05a_hr	observed	comttp_95_08
2005	3890 - 3925	tp05ab_hr	insert 3926 - 3929 repeat 9.0 times	comttp_95_08
2005	3926 - 3995	tp05b_hr	observed	comttp_95_08
2005	3996 - 4018	tp05ba_hr	insert 4019 - 4022 repeat 5.75 times	comttp_95_08
2006	4019 - 4350	tp06a_hr	observed	comttp_95_08
2006	4351 - 4371	tp06ac_hr	insert 4372 - 4375 repeat 5.25 times slope 2.54	comttp_95_08
2006	4372 - 4383	tp06c_hr	observed	comttp_95_08
2007	4384 - 4619	tp07a_hr	observed	comttp_95_08
2007	4320 - 4640	tp07ab_hr	insert 4641 - 4644 repeat 5.25 times	comttp_95_08
2007	4541 - 4717	tp07b_hr	observed	comttp_95_08
2007	4718 - 4748	tp07ba_hr	insert 4713 - 4716 repeat 7.75 times slope 5.0	comttp_95_08
2008	4749 - 5032	tp08a_hr	observed	comttp_95_08
2008	5033 - 5046	tp08ab_hr	insert 4967 - 4970 repeat 4.5 times subtract 4.5 slope 2.96	comttp_95_08
2008	5047 - 5079	tp08b_hr	observed	comttp_95_08
2008	5080 - 5098	tp08bc_hr	insert 4967 - 4970 repeat 4.75 times	comttp_95_08
2008	5099 - 5113	tp08c_hr	observed	comttp_95_08
2009	5114 - 5479	tp09a_hr	observed	contdat09_11hr
2110	5480 - 5781	tp10a_hr	observed	contdat09_11hr
2110	5782 - 5788	tp10ab_hr	insert 5789 - 5790 repeat 7.75 times slope -2.56	contdat09_11hr
2010	5789 - 5845	tp10b_hr	observed	contdat09_11hr
2011	5845 - 5857	tp11a_hr	observed	contdat09_11hr
2011	5858 - 5903	tp11ab_hr	insert 5847 - 5904 repeat 46.0 times slope -0.5	contdat09_11hr
2011	5904 - 6210	tp11b_hr	observed	contdat09_11hr

Table 7
Summary of Insert Data for Surface Salinity Data at GSO Dock

Year	*Consecutive Day*	*Filename*	*Interpolation*			*MATLAB Name*
1995	182 - 299	sal95a_hr	observed			comtsal_95_08
1995	300 - 334	sal95ab_hr	insert 335 - 338	repeat 8.75 times	slope 0.13	comtsal_95_08
1995-96	335 - 429	sal95b_hr	observed			comtsal_95_08
1996	430 - 443	sal95ba_hr	insert 444 - 447	repeat 3.5 times		comtsal_95_08
1996	444 - 731	sal96a_hr	observed			comtsal_95_08
1997	732 - 957	sal97a_hr	observed			comtsal_95_08
1997	958 - 986	sal97ab_hr	insert 987 - 990	repeat 7.25 times		comtsal_95_08
1997	987 - 1048	sal97b_hr	observed			comtsal_95_08
1997	1049 - 1070	sal97ba_hr	insert 1071 - 1074	repeat 5.5 times		comtsal_95_08
1997-98	1071 - 1130	sal_98a_hr	observed			comtsal_95_08
1998	1131 - 1136	sal98ab_hr	insert 1131 - 1134	repeat 1.5 times	subtract 0.4	comtsal_95_08
1998	1137 - 1164	sal_98b_hr	observed			comtsal_95_08
1998	1165 - 1172	sal98bc_hr	insert 1152 - 1155	repeat 2 times	slope -2.75	comtsal_95_99
1998	1173 - 1205	sal_98c_hr	observed			comtsal_95_08
1998	1206 - 1215	sal98cd_hr	insert 1202 - 1205	repeat 2.5 times		comtsal_95_08
1998	1216 - 1255	sal_98d_hr	observed			comtsal_95_08
1998	1256 - 1262	sal98de_hr	insert 1252 - 1255	repeat 1.75 times		comtsal_95_08
1998	1263 - 1351	sal_98e_hr	observed			comtsal_95_08
1998	1352 - 1361	sal_98ef_hr	insert 1362 - 1365	repeat 2.5 times	slope -0.5	comtsal_95_08
1998	1362 - 1461	sal_98f_hr	observed			comtsal_95_08
1999	1462 - 1817	sal_99a_hr	observed			comtsal_95_08
1999-2000	1818 - 1828	sal99aa_hr	insert 1814 - 1817	repeat 2.75 times		comtsal_95_08
2000	1829 - 1848	sal00a_hr	observed			comtsal_95_08
2000	1849 - 1861	sal00ab_hr	insert 1862 - 1865	repeat 3.33 times		comtsal_95_08
2000	1862 - 2191	sal00b_hr	observed			comtsal_95_08
2001	2192 - 2556	sal01a_hr	observed			comtsal_95_08
2002	2557 - 2567	sal01aa_hr	insert 2570 - 2574	repeat 3.0 times		comtsal_95_08
2002	2568 - 2922	sal02a_hr	observed			comtsal_95_08

Table 7 (cont.)

Year	*Consecutive Day*	*Filename*	*Interpolation*	*MATLAB Name*
				comtsal_95_08
2003	2923 - 3161	sal03a_hr	observed	comtsal_95_08
2003	3162 - 3188	sal03ab_hr	insert 3189 - 3192 repeat 6.75 times slope 0.98	comtsal_95_08
2003	3189 - 3287	sal04b_hr	observed	comtsal_95_08
2004	3288 - 3471	sal04a_hr	observed	comtsal_95_08
2004	3472 - 3498	sal04ab_hr	insert 3467 - 3470 repeat 6.75 times slope 0.92	comtsal_95_08
2004	3499 - 3653	sal04b_hr	observed	comtsal_95_08
2005	3654 - 3889	sal05a_hr	observed	comtsal_95_08
2005	3890 - 3925	sal05ab_hr	insert 3886 - 3889 repeat 9 times slope 1.18	comtsal_95_08
2005	3926 - 3995	sal05b_hr	observed	comtsal_95_08
2005	3996 - 4018	sal05ba_hr	insert 3992 - 3995 repeat 6.75 times add 0.5	comtsal_95_08
2006	4019 - 4350	sal06a_hr	observed	comtsal_95_08
2006	4351 - 4371	sal06ac_hr	insert 4672 - 4375 repeat 5.25 times slope 3.0	comtsal_95_08
2006	4372 - 4383	sal06c_hr	observed	comtsal_95_08
2007	4384 - 4621	sal07a_hr	observed	comtsal_95_08
2007	4622 - 4639	sal07ab_hr	insert 4641 - 4644 repeat 4.5 times	comtsal_95_08
2007	4640 - 4748	sal07b_hr	observed	comtsal_95_08
2008	4749 - 5031	sal08a_hr	observed	comtsal_95_08
2008	5032 - 5046	sal08ab_hr	insert 4967 - 4970 repeat 4.5 times sub 4.5 slope 2.96	comtsal_95_08
2008	5047 - 5079	sal08b_hr	observed	comtsal_95_08
2008	5080 - 5098	sal08bc_hr	insert 4967 - 4970 repeat 4.75 times	comtsal_95_08
2008	5099 - 5114	sal08c_hr	observed	comtsal_95_08
2009	5114 - 5479	sal09a_hr	observed	contdat09_11hr
2110	5480 - 5781	sal10a_hr	observed	contdat09_11hr
2110	5782 - 5783	sal10ab_hr	insert 5789 - 5790 repeat 7.75 times slope -2.56	contdat09_11hr
2010	5784 - 5842	sal10b_hr	observed	contdat09_11hr
2011	5845 - 5857	sal11a_hr	observed	contdat09_11hr
2011	5858 - 5903	sal11ab_hr	insert 5847 - 5904 repeat 46 times -1.0	contdat09_11hr
2011	5904 - 6210	sal11b_hr	observed	contdat09_11hr

Table 8
Lag Times Between Blackstone River and GSO Dock

Event Date	JD	Rain No in	No JD	River Flow, m/sec No JD	Max Flow	Bkg Flow	Salinity, ‰ Daily Sal	Lag Time, days. Flow JD	Sal JD	Lag Days
1996										
4/16-4/30	472-486	---	--	7	168	52	27.50	473	486	13
10/20-11/03	659-673	---	--	7	175	23	28.80	660	673	13
1997										
2/14-2/20	775-782	1.07	2	6	52	25	29.10	778	782	4
11/1-11/5	1037-1041	2.00	2	5	23	6	29.80	1038	1041	3
11/7-11/13	1043-1049	1.65	5	5	20	11	30.76	1046	1049	3
1998										
1/5-1/19	1101-1115	3.43	9	12	62	21	28.70	1106	1115	9
1/23-1/30	1119-1126	2.46	5	9	97	26	29.10	1121	1126	5
3/10-3/20	1165-1175	4.20	5	9	198	424	24.20	1165	1175	10*
5/1-5/9	1217-1225	2.28	8	9	48	30	25.10	1123	1225	2
5/9-5/22	1225-1238	1.83	4	13	129	25	27.30	1127	1235	8*
6/11-6/27	1258-1274	6.05	14	15	173	20	25.80	1262	1268	6
6/30-7/7	1277-1284	2.27	3	7	132	23	25.60	1278	1282	4
1999										
2/2-2/9	1494-1501	2.28	7	6	116	39	27.00	1495	1501	6
2/25-3/13	1517-1533	2.86	9	12	81	34	28.00	1523	1533	11
5/23-5/29	1604-1610	1.29	3	6	34	8	29.80	1606	1610	4
2000										
7/25-8/15	2033-2054	4.89	12	12	28	7	29.30	2036	2054	18
9/19-9/27	2089-2097	1.67	3	4	11	6	30.80	2090	2097	7
11/26-12/05	2157-2166	1.36	2	8	16	8	30.60	2158	2166	8
12/16-12/24	2177-2185	2.97	5	9	58	14	30.20	2179	2185	6

Table 8 (cont.)

Event	JD	Rain	Rain JD	Flow JD	Max Flow	Bkg Flow	Daily Sal	Flow JD	Sal JD	Lag Days
2001										
3/21-3/27	2272-2278	2.52	4	7	253	63	27.50	2274	4478	4
3/29-4/3	2280-2285	4.22	2	5	212	77	26.00	2282	2284	2
6/2-6/8	2345-2361	1.26	2	4	42	14	30.30	2346	2361	5
2002										
3/30-4/7	2646-2654	1.77	4	6	43	18	29.76	2649	2654	5
5/12-5/26	2689-2703	4.34	6	14	83	18	29.40	2691	2699	8
6/5-6/16	2713-2724	2.02	3	7	56	14	28.80	2716	2724	8
11/16-11/28	2877-2889	3.11	5	13	40	330	30.41	2879	2889	10
2003										
3/29-4/6	3010-3018	2.71	6	8	104	53	26.40	3012	3018	6
8/9-8/15	3143-3149	2.09	5	5	38	12	26.60	3143	3149	6
10/15-10/20	3210-3215	2.02	4	6	22	10	30.90	3211	3215	4
10/26-11/07	3221-3233	2.09	7	8	84	17	28.20	3225	3233	8
2004										
3/31-4/8	3377-3385	3.61	5	8	136	27	28.20	3379	3380	1*
4/13-4/25	3390-3402	2.51	4	7	163	37	25.90	3391	2402	11
12/6-12/21	3627-3642	2.69	9	10	61	30	29.40	3633	3642	9
2005										
3/8-3/19	3720-3731	1.76	3	7	39	27	28.70	3721	3731	10
3/28-4/6	3740-3749	2.73	2	5	132	37	26.10	3741	3749	8
10/8-10/30	3934-3956	10.52	14	22	382	29	26.30	3942	3951	9
12/25-1/6/06	4012-4024	2.31	10	14	80	28	28.40	4014	4021	7
2006										
1/11-1/26	4029-4044	3.61	8	15	106	38	26.30	4037	4042	5
2/3-2/9	4052-4058	1.39	3	7	118	50	27.10	4055	4058	3
5/7-5/16	4145-4154	5.57	8	12	113	26	28.60	4153	4154	1
5/31-6/18	4169-4187	5.91	10	17	196	31	25.50	4177	4185	8*
6/26-7/7	4195-4206	4.20	8	10	95	26	24.58	4195	4206	11*

Table 8 (cont.)

Date	JD	No in	No JD	No JD	Max Flow	Bkg Flow	Daily Sal	Flow JD	Sal JD	Lag Days
2007										
2/25-3/18	4439-4460	4.95	13	12	93	24	29.80	4445	4459	14
3/23-3/31	4465-4473	4.18	4	9	79	42	28.80	4470	4471	1*
4/27-5/4	4500-4507	1.70	5	4	76	35	27.20	4501	4507	6
5/16-5/27	4519-4530	2.31	5	11	78	19	29.73	4522	4530	8
2008										
2/18-2/24	4797-4803	2.28	3	6	147	51	27.82	4798	4803	5
4/10-4/27	4849-4866	3.01	7	11	39	26	27.88	4852	4866	14
7/5-7/17	4935-4947	3.44	5	4	8	6	29.98	4935	4947	12
8/15-8/28	4976-4989	2.83	7	6	39	13	30.74	4977	4989	12
9/7-9/11	4999-5003	4.02	4	5	73	12	30.31	5000	5003	3
2009										
1/28-2/4	5142-5149	1.08	1	6	31	23	30.36	5144	5149	5
4/20-5/4	5224-5238	2.12	3	8	57	21	28.98	5226	5238	12
7/1-7/10	5296-5305	2.39	2	6	86	21	29.06	5298	5305	7
7/7-7/22	5302-5317	2.37	2	7	52	20	30.22	5303	5317	14
7/21-8/8	5316-5334	3.61	7	13	122	21	27.86	5320	5334	14
8/28-9/6	5354-5363	2.69	2	6	25	7	29.68	5356	5363	7
2010										
2/23-3/6	5533-5544	2.29	5	10	179	36	28.66	5536	5544	8*
3/13-3/21	5551-5559	2.31	3	6	231	48	27.54	5553	5559	6*
3/22-3/27	5560-5565	2.82	3	5	165	7	27.74	5562	5565	3*
3/29-4/5	5567-5573	5.30	2	8	382	54	21.29	5569	5570	1*
6/5-6/10	5604-5609	1.78	6	9	22	14	30.18	5606	5608	2
11/8-11/29	5760-5781	1.15	2	6	29	12	30.88	5770	5773	3
2011										
3/21-3/27	5893-5899	2.52	4	7	253	63	27.50	5895	5899	4
3/29-4/3	5901-5906	4.22	2	5	212	77	26.00	5903	5905	2

* multiple rain events

Table 9

Average Temperature and Salinity Observed at GSO Dock during Summer from 1995 - 2011

Year	*Consecutive Day*	*No Days*	*Date*	*Avg Temp ± Std, ^{0} C*	*Avg Salinity ± Std, $^0/_{00}$*
Temp < 17^0 C					
1995	182-289	107	01 Jul 95-16 Oct 95	20.34 ± 1.69	31.29 ± 0.35
1996	532-643	111	15 Jun 96-04 Oct 96	19.46 ± 1.11	30.30 ± 0.35
1997	905-1005	100	23 Jun 97-01 Oct 97	19.86 ± 1.03	------*
1998	1265-1372	107	18 Jun 98-03 Oct 98	19.86 ± 1.48	29.17 ± 1.32
1999	1616-1746	130	04 Jun 99-12 Oct 99	20.38 ± 1.72	30.97 ± 0.56
2000	1996-2108	112	18 Jun 00-08 Oct 00	20.61 ± 1.34	30.61 ± 0.43
2001	2355-2472	117	13 Jun 01-08 Oct 01	20.36 ± 1.35	30.52 ± 0.75
2002	2729-2843	114	21 Jun 02-13 Oct 02	20.61 ± 1.43	31.29 ± 0.51
2003	3093-3205	112	20 Jun 03-10 Oct 03	19.98 ± 1.56	-------**
2004	3455-3573	118	16 Jun 04-12 Oct 04	19.76 ± 1.43	30.56 ± 0.63
2005	3817-3939	122	12 Jun 05-13 Oct 05	-------***	-------***
2006	4193-4305	112	10 Jun 06-23 Oct 06	19.81 ± 1.54	29.78 ± 1.47
2007	4545-4680	135	12 Jun 07-25 Oct 07	19.48 ± 1.58	31.27 ± 0.61
2008	4910-5028	118	10 Jun 08-06 Oct 08	20.16 ± 1.45	30.48 ± 0.42
2009	5280-5396	116	15 Jun 09-09 Oct 09	19.82 ± 1.78	30.24 ± 0.75
2010	5639-5759	120	09 Jun 10-07 Oct 10	19.49 ± 1.64	31.29 ± 0.53
2011	6003-6136	133	08 Jun 11-19 Oct 11	20.47 ± 1.70	30.36 ± 0.87
Mean		117 ± 10		19.99 ± 0.37	30.58 ± 0.62

* no salinity data from 18 Aug 97 to 16 Sep 97 (961-990)

** no salinity data from 27 Aug 03 to 01 Sep 03 (3161-3196)

*** no temperature or salinity data from 27 Aug 05 to 02 Oct 05 (3893-3929)

Table 10

Average Temperature and Salinity Observed at GSO Dock during Winter from 1995 - 2011

Year	*Consecutive Day*	*No Days*	*Date*	*Avg Temp ± Std, ^{0} C*	*Avg Salinity ± Std, $^0/_{00}$*
Temp < 7^0 C					
1996	342-478	136	07 Dec 95-22 Apr 96	2.59 ± 1.72	29.999 ± 1.074
1997	704-834	130	03 Dec 96-13 Apr 97	4.84 ± 1.40	28.920 ± 0.981
1998	1071-1186	115	05 Dec 97-31 Mar 98	4.41 ± 0.97	29.443 ± 1.255
1999	1453-1556	103	22 Dec 98-05 Apr 99	4.26 ± 1.24	29.377 ± 1.095
2000	1818-1924	106	22 Dec 99-08 Apr 00	4.05 ± 1.90	30.898 ± 0.431
2001	2163-2304	141	03 Dec 00-23 Apr 01	3.15 ± 1.33	29.882 ± 1.361
2002	2551-2657	106	26 Dec 01-11 Apr 02	5.19 ± 0.98	31.159 ± 0.982
2003	2895-3031	136	05 Dec 02-20 Apr 03	2.76 ± 1.99	30.492 ± 1.154
2004	3259-3396	137	03 Dec 03-19 Apr 04	3.34 ± 1.92	30.852 ± 0.998
2005	3638-3752	114	16 Dec 04-09 Apr 05	3.09 ± 1.91	29.037 ± 0.789
2006	3991-4121	130	03 Dec 05-13 Apr 06	5.02 ± 0.86	29.504 ± 1.038
2007	4396-4495	99	12 Jan 07-22 Apr 07	4.09 ± 1.79	30.987 ± 1.193
2008	4730-4849	119	13 Dec 07-11 Apr 08	4.56 ± 1.18	29.794 ± 1.122
2009	5100-5216	116	18 Dec 08-12 Apr 09	3.75 ± 1.37	30.167 ± 1.052
2010	5463-5573	110	15 Dec 09-04 Apr 10	3.51 ± 1.80	30.304 ± 1.058
2011	5821-5947	126	08 Dec 10-13 Apr 11	-------*	-------*
Mean		118 ± 14		3.91 ± 0.82	30.000 ± 0.740

* no temperature or salinity data from 12 Jan 2011 to 05 Mar 2011 (5856-5908)

Table 11
Warming and Cooling Rates Observed at GSO Dock for 1995 – 2011

Year	*Consecutive Day*	*No Days*	*Date*	*Rate, ^{0} C / day*
Warming Rate				
1996	479 - 531	52	23 Apr 96 - 14 Jun 96	0.192
1997	835 - 904	69	14 Apr 97 - 22 Jun 97	0.145
1998	1187 - 1264	77	01 Apr 98 - 17 Jun 98	0.130
1999	1557 - 1615	58	06 Apr 99 - 03 Jun 99	0.172
2000	1925 - 1995	70	09 Apr 00 - 17 Jun 00	0.143
2001	2305 - 2354	49	24 Apr 01 - 12 Jun 01	0.204
2002	2658 - 2728	70	12 Apr 02 - 20 Jun 02	0.143
2003	3032 - 3092	60	21 Apr 03 - 19 Jun 03	0.167
2004	3397 - 3454	57	20 Apr 04 - 15 Jun 04	0.175
2005	3753 - 3816	63	10 Apr 05 - 11 Jun 05	0.159
2006	4122 - 4192	70	14 Apr 06 - 09 Jun 06	0.143
2007	4496 - 4544	48	23 Apr 07 - 11 Jun 07	0.208
2008	4850 - 4909	59	12 Apr 08 - 09 Jun 08	0.169
2009	5217 - 5279	62	13 Apr 09 - 14 Jun 09	0.161
2010	5574 - 5634	60	05 Apr 10 - 08 Jun 10	0.167
2011	5948 - 6002	54	14 Apr 11 - 07 Jun 11	0.185
Mean		61 ± 8		0.167 ± 0.023
Cooling Rate				
1995	290 - 341	51	17 Oct 95 - 06 Dec 95	-0.196
1996	644 - 703	59	05 Oct 96 - 02 Dec 96	-0.169
1997	1006 - 1070	64	02 Oct 97 - 04 Dec 97	-0.156
1998	1372 - 1452	80	04 Oct 98 - 21 Dec 98	-0.125
1999	1747 - 1817	70	13 Oct 99 - 21 Dec 99	-0.143
2000	2109 - 2162	53	09 Oct 00 - 02 Dec 00	-0.189
2001	2473 - 2550	77	09 Oct 01 - 25 Dec 01	-0.130
2002	2844 - 2894	50	14 Oct 02 - 04 Dec 02	-0.200
2003	3206 - 3258	52	11 Oct 03 - 02 Dec 03	-0.192
2004	3574 - 3637	63	13 Oct 04 - 15 Dec 04	-0.159
2005	3940 - 3990	50	14 Oct 05 - 02 Dec 05	-0.200
2006	4306 - 4395	89	24 Oct 06 - 11 Jan 07	-0.112
2007	4681 - 4729	48	26 Oct 07 - 12 Dec 07	-0.208
2008	5029 - 5099	70	07 Oct 08 - 17 Dec 08	-0.143
2009	5397 - 5462	65	10 Oct 09 - 14 Dec 09	-0.154
2010	5757 - 5820	63	08 Oct 10 - 07 Dec 10	-0.159
2011	6137 - 6207	70	20 Oct 10 - 30 Dec 11	-0.143
Mean		63 ± 12		-0.164 ± 0.030

Table 12
Percent of Tidal Temperature > 0.5° C and < -0.5° C at High and Low Tide
Observed at GSO Dock from 1996 - 2011

Year	Winter		Spring		Summer		Fall	
	High *%T>0.5^{0}C*	*Low* *%T<-0.5^{0}C*	*High* *%T>0.5^{0}C*	*Low* *%T<-0.5^{0}C*	*High* *%T>0.5^{0}C*	*Low* *%T<-0.5^{0}C*	*High* *%T>0.5^{0}C*	*Low* *%T<-0.5^{0}C*
1996	28	19	16	0	10	0	79	30
1997	53	42	14	0	6	3	44	21
1998	73	44	12	11	5	0	70	14
1999	40	37	4	0	5	0	91	67
2000	50	28	28	6	8	0	67	100*
2001	73	37	8	0	5	0	36	0
2002	65	44	6	0	2	0	90	73
2003	69	36	2	2	6	0	79	40
2004	74	51	18	0	26	9	81	50
2005	53	31	13	0	15	3	40	3
2006	47	53	11	0	14	0	65	56
2007	74	61	21	0	32	8	50	36
2008	62	37	17	0	5	0	52	25
2009	93	52	87	49	94	68	91	50
2010	79	43	23	7	7	0	69	25
2011	73	44	4	1	8	0	90	38
Mean	63	41	18	5	19	6	68	35

* less than 2 total

Table 13
Average Temperature Observed at Buzzards Bay
during Summer and Winter from 1995 - 2011

Year	*Consecutive Day*	*No Days*	*Date*	*Avg Temp ± Std* ^{0} *C*
Temp > 17°C				
1995	181- 289	108	30 Jun 95 - 16 Oct 95	18.88 ± 1.37
1996	555 - 638	83	08 Jul 96 - 29 Sep 96	18.36 ± 0.73
1997	915 - 1016	101	03 Jul 97 - 12 Oct 97	18.34 ± 0.76
1998	------	---	----------	-------
1999	1635 - 1755	120	23 Jun 99 - 21 Oct 99	19.90 ± 1.44
2000	-------	---	----------	-------
2001	-------	---	----------	-------
2002	2735 - 2844	109	27 Jun 02 - 14 Oct 02	18.92 ± 1.36
2003	3119 - 3198	79	16 Jun 03 - 03 Oct 03	18.32 ± 0.84
2004	-------	---	---------	-------
2005	3849 - 3943	94	15 Jul 05 - 17 Oct 05	19.04 ± 0.87
2006	4196 - 4298	102	27 Jun 06 - 07 Oct 06	18.62 ± 0.58
2007	4573 - 4668	95	09 Jul 07 - 12 Oct 07	18.81 ± 0.83
2008	4923 - 5033	110	23 Jun 08 - 11 Oct 08	18.94 ± 0.98
2009	5292 - 5398	106	27 Jun 09 - 11 Oct 09	20.54 ± 1.87
2010	5630 - 5766	136	31 May10- 14 Oct 08	20.74 ± 1.98
2011	6003 - 6141	138	08 Jun 11 - 24 Oct 08	21.24 ± 2.00
Mean		106 ± 18		19.28. ± 0.99

Table 13 (cont.)

Year	*Consecutive Day*	*No Days*	*Date*	*Avg Temp ± Std, ^{0} C*
Temp < 7°C				
1995	1 - 113	112	01 Jan 95 - 23 Apr 96	4.29 ± 1.16
1996	346 - 481	135	12 Dec 95 - 25 Apr 96	2.44 ± 1.83
1997	711 - 842	131	11 Dec 96 - 21 Apr 97	4.76 ± 1.38
1998	1081 - 1161	80	16 Dec 97 - 06 Mar 98	4.65 ± 1.15
1999	------	---	----------	-------
2000	------	---	----------	-------
2001	------	---	----------	-------
2002	*2545 - 2659	114*	19 Dec 01 - 12 Apr 02*	4.08 ± 1.01
2003	2899 - 3041	142	08 Dec 02 - 29 Apr 03	2.72 ± 2.13
2004	------	---	----------	-------
2005	------	---	----------	-------
2006	4001 - 4121	120	14 Dec 05 - 13 Apr 06	4.85 ± 0.98
2007	4400 - 4497	97	17 Jan 07 - 24 Apr 07	3.95 ± 1.30
2008	4729 - 4858	129	12 Dec 07 - 19 Apr 08	4.49 ± 1.11
2009	5106 - 5222	116	23 Dec 08 - 18 Apr 09	2.68 ± 2.04
2010	5461 - 5578	117	13 Dec 09 - 09 Apr 10	2.50 ± 2.18
2011	5820 - 5951	131	07 Dec 10 - 17 Apr 11	2.73 ± 1.91
Mean		119 ± 17		3.68 ± 0.98

* temperature extrapolated to 7°C . First point was 6.3° C on 03 Jan 2002 (2560).

Table 14
Warming and Cooling Rates Observed at Buzzards Bay for 1995 – 2011

Year	*Consecutive Day*	*No Days*	*Date*	*Rate ^{0} C / day*
Warming Rate				
1995	114 - 180	66	24 Apr 95 - 29 Jun 95	0.152
1996	482 - 554	72	26 Apr 96 - 07 Jul 96	0.139
1997	843 - 914	71	22 Apr 97 - 02 Jul 97	0.141
1998	------	---	----------	----
1999	1568 - 1634	66	17 Apr 99 - 22 Jun 99	0.152
2000	------	---	----------	----
2001	------	---	----------	----
2002	2660 - 2734	74	13 Apr 02 - 26 Jun 02	0.135
2003	3042 - 3118	76	30 Apr 03 - 15 Jun 03	0.132
2004	------	---	----------	----
2005	------	---	----------	----
2006	4122 - 4195	73	14 Apr 06 - 26 Jun 06	0.137
2007	4498 - 4572	74	25 Apr 07 - 08 Jul 07	0.135
2008	4859 - 4922	64	20 Apr 08 - 22 Jun 08	0.158
2009	5223 - 5291	68	19 Apr 09 - 26 Jun 09	0.147
2010	5579 - 5629	50	10 Apr 10 - 30 May 10	0.200
2011	5952 - 6002	50	18 Apr 11 - 07 Jun 11	0.200
Mean		67 ± 9		0.152 ± 0.024
Cooling Rate				
1995	290 - 345	55	17 Oct 95 - 11 Dec 95	-0.182
1996	639 - 710	71	30 Sep 96 - 10 Dec 96	-0.141
1997	1017- 1080	63	13 Oct 97 - 15 Dec 97	-0.159
1998	------	---	----------	----
1999	------	---	----------	----
2000	------	---	----------	----
2001	------	---	----------	----
2002	------	---	----------	----
2003	2845 - 2898	53	15 Oct 02 - 07 Dec 02	-0.189
2004	------	---	----------	----
2005	3944 - 4000	56	18 Oct 05 - 13 Dec 05	-0.179
2006	4299 - 4399	100	08 Oct 06 - 16 Jan 07	-0.100
2007	4669 - 4728	59	13 Oct 07 - 11 Dec 07	-0.169
2008	5034 - 5105	71	12 Oct 08 - 22 Dec 08	-0.140
2009	5399 - 5460	61	12 Oct 09 - 12 Dec 09	-0.164
2010	5767 - 5819	52	15 Oct 10 - 06 Dec 10	-0.192
2011	6142 - 6209	67	25 Oct 11 - 31 Dec 08	-0.149
Mean		64 ± 14		-0.160 ± 0.027

Table 15
Average Temperature and Salinity for T-Wharf Station on Prudence Island
2003 - 2010

Year	*Consecutive Day*	*No Days*	*Date*	*Avg Temp ± Std* ^{0}C	*Avg Salinity ± Std* $^{0}/_{00}$
Temp < 7°C					
2003	4 - 111	107	04 Jan 03 - 21 Apr 03	2.54 ± 1.97	29.90 ± 0.91
2004	338 - 415*	77*	04 Dec 03 - 19 Feb 04*	------*	------*
2005	717 - 825	108	17 Dec 04 - 05 Apr 05	3.19 ± 1.67	28.70 ± 0.90
2006	1073 - 1188	115	08 Dec 05 - 02 Apr 06	------ **	------**
2007	1472 - 1571	99	11 Jan 07 - 20 Apr 07	3.92 ± 1.87	28.87 ± 1.44
2008	1798 - 1925	127	03 Dec 07 - 08 Apr 08	4.44 ± 1.00	28.16 ± 1.68
2009	2160 - 2296	136	29 Nov 08 - 14 Apr 09	3.95 ± 1.45	28.52 ± 1.02
2010	2538 - 2647	109	12 Dec 09 - 31 Mar 10	3.77 ± 1.84	29.11 ± 1.97
Mean		115 ± 13		3.90 ± 0.76	28.88 ± 0.60
Temp > 17°C					
2003	174 - 284	110	23 Jun 03 - 11 Oct 03	20.84 ± 1.70	29.43 ± 1.26
2004	532 - 650	118	15 Jun 04 - 11 Oct 04	20.42 ± 1.42	30.86 ± 0.44
2005	891 - 1019	128	09 Jun 05 - 15 Oct 05	20.48 ± 2.00	29.86 ± 0.74
2006	1263 - 1382	119	16 Jun 06 - 13 Oct 06	20.71 ± 2.01	28.19 ± 2.30
2007	1629 - 1759	130	17 Jun 07 - 25 Oct 07	20.37 ± 1.72	30.36 ± 0.31
2008	1987 - 2117	130	09 Jun 08 - 17 Oct 08	20.53 ± 1.97	30.80 ± 0.95
2009	2369 - 2472	103	26 Jun 09 - 07 Oct 09	20.59 ± 1.82	29.43 ± 1.12
2010	2708 - 2840	132	31 May 10 -10 Oct 10	20.95 ± 2.00	30.21 ± 0.79
Mean		121 ± 11		20.61 ± 0.21	29.90 ± 0.88

* no data from 28 Jan 04 to 1 May 04 (362-487)
** no data from 19 Jan 06 to 9 Mar 06 (1115 to 1164)

Table 16
Warming and Cooling Rates Observed at for T-Wharf Station on Prudence Island from 2003 - 2010

Year	*Consecutive Day*	*No Days*	*Date*	*Rate ^{0} C / day*
Warming Rate				
2003	112 - 173	61	22 Apr 03 - 22 Jun 03	0.164
2004	416 - 531*	---	19 Apr 04 - 14 Jun 04*	----
2005	826 - 890	64	06 Apr 05 - 08 Jun 05	0.156
2006	1189 - 1262	73	03 Apr 06 - 15 Jun 06	0.137
2007	1572 - 1628	56	21 Apr 07 - 16 Jun 07	0.179
2008	1926 - 1986	60	09 Apr 08 - 08 Jun 08	0.167
2009	2297 - 2368	71	15 Apr 09 - 25 Jun 09	0.141
2010	2648 - 2707	59	01 Apr 10 - 30 May10	0.169
Mean		63 ± 6		0.016 ± 0.016
Cooling Rate				
2003	285 - 337	52	12 Oct 03 - 03 Dec 03	-0.192
2004	651 - 716	65	12 Oct 04 - 16 Dec 04	-0.154
2005	1020 - 1072**	52	16 Oct 05 - 07 Dec 05	-0.192
2006	1383 - 1471	88	14 Oct 06 - 10 Jan 07	-0.113
2007	1760 - 1797	37	26 Oct 07 - 02 Dec 07	-0.270
2008	2118 - 2159	41	18 Oct 08 - 28 Nov 08	-0.244
2009	2473 - 2537	64	08 Oct 09 - 11 Dec 09	-0.156
Mean		57 ± 17		-0.189 ± 0.054

* no data from 362-487 (28 Jan 04-01 May 04)
** no data from 1115 to 1164 (19 Jan 06 - 09 Mar 06)

Table 17

Comparison of Seasonal Temperature at GSO dock, Buzzards Bay and Prudence Island

Year	*No Days GSO*	*No. Days BB*	*No Days PI*	*GSO ^{0} C*	*Buzzards Bay ^{0} C*	*Prudence Island ^{0} C*
Temp > 17°C						
1996	111	83	---	19.46 ± 1.11	18.36 ± 0.73	------
1997	100	101	---	19.86 ± 1.03	18.34 ± 0.76	------
1998	107	---	---	19.86 ± 1.48	------	------
1999	130	120	---	20.38 ± 1.72	19.90 ± 1.44	------
2000	112	---	---	20.61 ± 1.34	------	------
2001	117	---	---	20.36 ± 1.35	------	------
2002	114	109	---	20.61 ± 1.43	18.92 ± 1.36	------
2003	112	79	110	19.98 ± 1.56	18.32 ± 0.84	20.84 ± 1.70
2004	117	---	118	19.76 ± 1.43	------	20.42 ± 1.42
2005	122	94	128	------	19.04 ± 0.87	20.48 ± 2.00
2006	111	102	119	19.81 ± 1.54	18.62 ± 0.58	20.71 ± 2.01
2007	136	95	130	19.48 ± 1.58	18.81 ± 0.83	20.37 ± 1.72
2008	118	110	130	20.16 ± 1.45	18.94 ± 0.98	20.53 ± 1.97
2009	116	106	103	19.82 ± 1.78	20.54 ± 1.87	20.59 ± 1.82
2010	121	136	132	19.49 ± 1.64	20.74 ± 1.98	20.95 ± 2.00
2011	133	138	---	20.47 ± 1.70	21.24 ± 2.00	------
Mean	117 ± 9	106 ± 18	122 ± 11	19.99 ± 037	19.28 ± 0.99	20.61 ± 0.21

Table 17 (cont.)

Year	*No Days GSO*	*No. Days BB*	*No Days PI*	*GSO* ^{0}C	*Buzzards Bay* ^{0}C	*Prudence Island* ^{0}C
Temp < 7 °C						
1996	136	135	---	2.59 ± 1.72	2.44 ± 1.83	------
1997	131	131	---	4.84 ± 1.40	4.76 ± 1.38	------
1998	114	80	---	4.41 ± 0.97	4.65 ± 1.15	------
1999	102	---	---	4.26 ± 1.24	------	------
2000	107	---	---	4.05 ± 1.90	------	------
2001	133	---	---	3.15 ± 1.33	------	------
2002	107	114	---	5.19 ± 0.98	4.08 ± 1.01	------
2003	136	142	107	2.76 ± 1.99	2.72 ± 2.31	2.54 ± 1.97
2004	137	---	---	3.34 ± 1.92	------	------
2005	114	---	108	3.09 ± 1.91	------	3.19 ± 1.67
2006	129	120	115	5.02 ± 0.86	4.85 ± 0.98	-----
2007	99	97	99	4.09 ± 1.79	3.95 ± 1.30	3.92 ± 1.87
2008	119	129	127	4.56 ± 1.18	4.49 ± 1.11	4.44 ± 1.00
2009	119	116	136	3.75 ± 1.37	2.68 ± 2.04	3.95 ± 1.45
2010	119	117	109	3.51 ± 1.80	2.50 ± 2.18	3.77 ± 1.84
2011	119	131	---	------	2.73 ± 1.91	------
Mean	120 ± 13	118 ± 18	114 ± 14	3.91 ± 0.82	3.68 ± 0.98	3.90 ± 0.76

Table 18

Warming and Cooling Rates Observed at GSO Dock, Buzzards Bay and Prudence Island for 1996 – 2011

Year	*No Day GSO*	*No Day BB*	*No Day PI*	*Rate, ^{0} C /day GSO*	*Rate, ^{0} C /day BB*	*Rate, ^{0} C /day PI*
Warming Rate						
1996	52	72	---	0.192	0.139	------
1997	69	71	---	0.145	0.141	------
1998	77	---	---	0.130	------	------
1999	58	66	---	0.172	0.152	------
2000	70	---	---	0.143	------	------
2001	49	---	---	0.204	------	------
2002	70	74	---	0.143	0.135	------
2003	60	76	61	0.167	0.133	0.164
2004	57	---	---	0.175	------	----
2005	63	---	64	0.159	------	0.156
2006	70	73	73	0.143	0.137	0.137
2007	48	74	56	0.208	0.135	0.179
2008	59	64	60	0.169	0.156	0.167
2009	62	68	71	0.161	0.147	0.141
2010	60	50	59	0.167	0.200	0.169
2011	54	50	---	0.185	0.200	----
Mean	61 ± 8	67 ± 9	63 ± 8	0.166 ± 0.022	0.152 ± 0.025	0.159 ± 0.015

Table 18 cont.

Year	*No Day GSO*	*No Day BB*	*No Day PI*	*Rate, ^{0} C /day GSO*	*Rate, ^{0} C /day BB*	*Rate, ^{0} C /day PI*
Cooling Rate						
1995	51	55	---	-0.196	-0.141	-------
1996	59	71	---	-0.169	-0.159	-------
1997	64	63	---	-0.156	------	-------
1998	79	---	---	-0.127	------	-------
1999	70	---	---	-0.143	------	-------
2000	53	---	---	-0.189	------	-------
2001	77	---	---	-0.130	------	-------
2002	50	---	---	-0.200	------	-------
2003	52	53	---	-0.192	0.189	-------
2004	63	---	52	-0.159	------	-0.192
2005	50	56	65	-0.200	-0.179	-0.154
2006	90	100	52	-0.111	-0.100	-0.192
2007	47	59	88	-0.213	-0.169	-0.113
2008	70	71	37	-0.143	-0.140	-0.270
2009	66	61	41	-0.151	-0.164	-0.244
2010	63	52	64	-0.159	-0.192	-0.156
2011	70	67	---	-0.143	-0.149	------
Mean	66 ± 12	71 ± 16	57 ± 17	-0.164 ± 0.030	-0.158 ± 0.027	-0.189 ± 0.054

J. Figure Legend

Figure 1. Map of Narragansett Bay. Sampling sites shown as white diamonds.

Figure 2. Observed temperature (top) and salinity (bottom) at the GSO dock from 1995 - 2011.

Figure 3. Observed (blue) and predicted (green) depth at GSO dock (normalized to zero) for August 1996 (top). Difference (obs.- pred.) between observed and predicted depths for August 1996.

Figure 4. Observed temperature at GSO dock from June 1996 - February 1997 (top). Tidal correction for same time period obtained using ***t_tide*** program (bottom).

Figure 5. Tidally corrected temperature at GSO dock for 1996 (top). Tidal temperature at GSO dock for 1996 (bottom).

Figure 6. Tidally corrected temperature at GSO dock for 1997 (top). Tidal temperature at GSO dock for 1997 (bottom).

Figure 7. Tidally corrected temperature at GSO dock for 1998 (top). Tidal temperature at GSO dock for 1998 (bottom).

Figure 8. Tidally corrected temperature at GSO dock for 1999 (top). Tidal temperature at GSO dock for 1999 (bottom).

Figure 9. Tidally corrected temperature at GSO dock for 2000 (top). Tidal temperature at GSO dock for 2000 (bottom).

Figure 10. Tidally corrected temperature at GSO dock for 2001 (top). Tidal temperature at GSO dock for 2001 (bottom).

Figure 11. Tidally corrected temperature at GSO dock for 2002 (top). Tidal temperature at GSO dock for 2002 (bottom).

Figure 12. Tidally corrected temperature at GSO dock for 2003 (top). Tidal temperature at GSO dock for 2003 (bottom).

Figure 13. Tidally corrected temperature at GSO dock for 2004 (top). Tidal temperature at GSO dock for 2004 (bottom).

Figure 14. Tidally corrected temperature at GSO dock for 2005 (top). Tidal temperature at GSO dock for 2005 (bottom).

Figure 15. Tidally corrected temperature at GSO dock for 2006 (top). Tidal temperature at GSO dock for 2006 (bottom).

Figure 16. Tidally corrected temperature at GSO dock for 2007 (top). Tidal temperature at GSO dock for 2007 (bottom).

Figure 17. Tidally corrected temperature at GSO dock for 2008 (top). Tidal temperature at GSO dock for 2008 (bottom).

Figure 18. Tidally corrected temperature at GSO dock for 2009 (top). Tidal temperature at GSO dock for 2009 (bottom).

Figure 19. Tidally corrected temperature at GSO dock for 2010 (top). Tidal temperature at GSO dock for 2010 (bottom).

Figure 20. Tidally corrected temperature at GSO dock for 2011 (top). Tidal temperature at GSO dock for 2011 (bottom).

Figure 21. Tidally corrected salinity at GSO dock for 1996 (top). Tidal salinity at GSO dock for 1996 (bottom).

Figure 22. Tidally corrected salinity at GSO dock for 1997 (top). Tidal salinity at GSO dock for 1997 (bottom).

Figure 23. Tidally corrected salinity at GSO dock for 1998 (top). Tidal salinity at GSO dock for 1998 (bottom). Note scale change from -4.0 to 4.0.

Figure 24. Tidally corrected salinity at GSO dock for 1999 (top). Tidal salinity at GSO dock for 1999 (bottom).

Figure 25. Tidally corrected salinity at GSO dock for 2000 (top). Tidal salinity at GSO dock for 2000 (bottom).

Figure 26. Tidally corrected salinity at GSO dock for 2001 (top). Tidal salinity at GSO dock for 2001 (bottom).

Figure 27. Tidally corrected salinity at GSO dock for 2002 (top). Tidal salinity at GSO dock for 2002 (bottom).

Figure 28. Tidally corrected salinity at GSO dock for 2003 (top). Tidal salinity at GSO dock for 2003 (bottom).

Figure 29. Tidally corrected salinity at GSO dock for 2004 (top). Tidal salinity at GSO dock for 2004 (bottom).

Figure 30. Tidally corrected salinity at GSO dock for 2005 (top). Tidal salinity at GSO dock for 2005 (bottom).

Figure 31. Tidally corrected salinity at GSO dock for 2006 (top). Tidal salinity at GSO dock for 2006 (bottom). Note scale change from -4.0 to 4.0.

Figure 32. Tidally corrected salinity at GSO dock for 2007 (top). Tidal salinity at GSO dock for 2007 (bottom).

Figure 33. Tidally corrected salinity at GSO dock for 2008 (top). Tidal salinity at GSO dock for 2008 (bottom).

Figure 34. Tidally corrected salinity at GSO dock for 2009 (top). Tidal salinity at GSO dock for 2009 (bottom).

Figure 35. Tidally corrected salinity at GSO dock for 2010 (top). Note scale change from 24.0 to 22.0. Tidal salinity at GSO dock for 2010 (bottom). Note scale change from -6.0 to 6.0.

Figure 36. Tidally corrected salinity at GSO dock for 2011 (top). Tidal salinity at GSO dock for 2011 (bottom).

Figure 37. The number of times/day the tidal temperature exceeded 0.5^0 C, normalized to 16 years of study.

Figure 38. The number of times/day the tidal salinity exceeded $0.4^0/_{00}$, normalized to 16 years of study (top). Average river flow of Blackstone River during the 16 year study (bottom).

Figure 39. Tidally corrected temperature at NOAA buoy in Buzzards Bay (41.40^0 N, 71.03^0 W) from 1995- 2011 (top). Tidal temperature at same location and for the same time period (bottom).

Figure 40. Tidally corrected temperature at T-Wharf on Prudence Island in Narragansett Bay (41.80^0 N and 71.32^0 W) from 2002 - 2010 (top). Tidal temperature at same location and for the same time period (bottom).

Figure 1. Map of Narragansett Bay, Rhode Island with station locations (GSO-GSO Dock, TW-TWharf on Prudence Island)

Figure 2. Observed Temperature and Salinity at GSO Dock 1995-2011

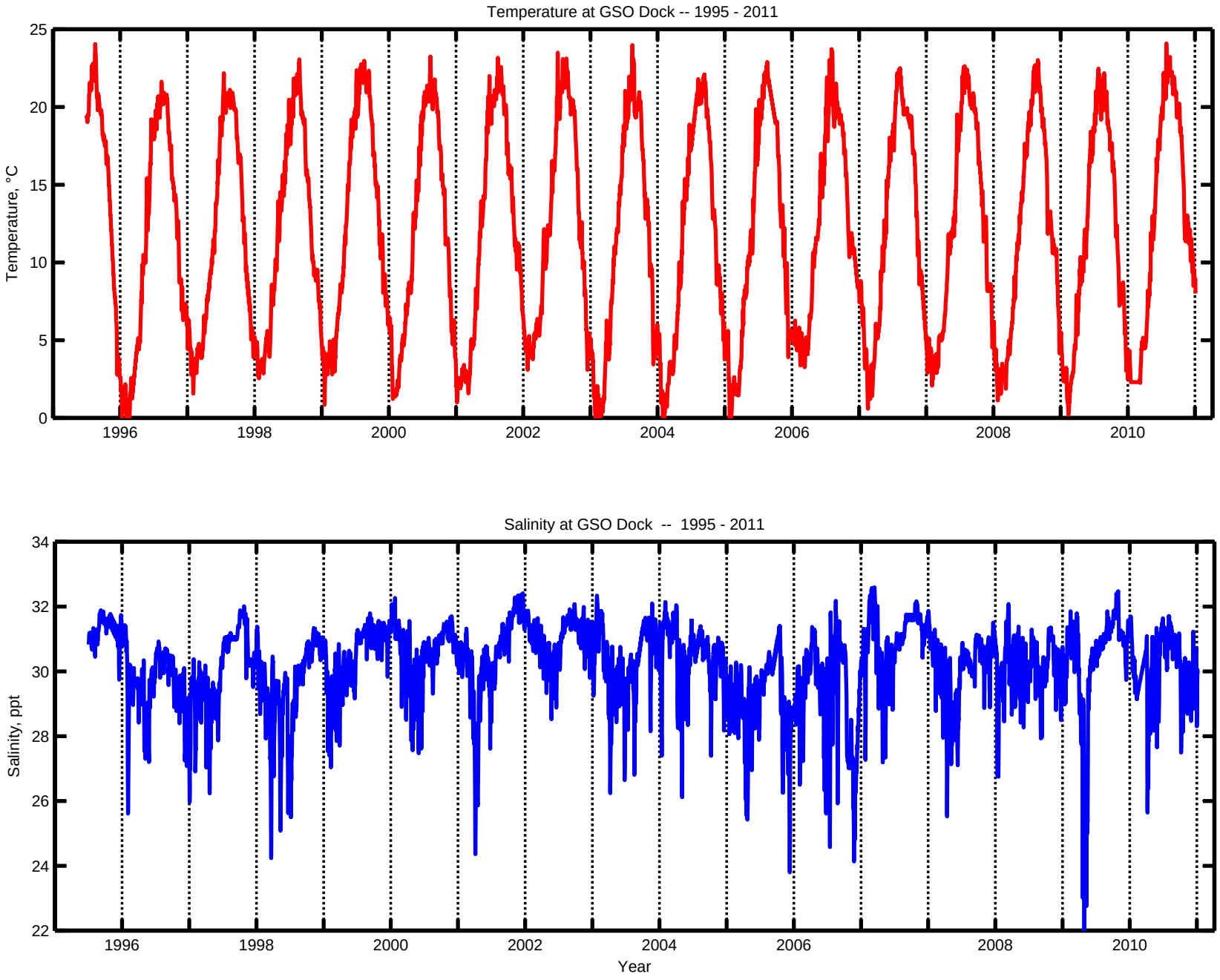

Figure 3. Observed and Predicted Tide -- August 1996

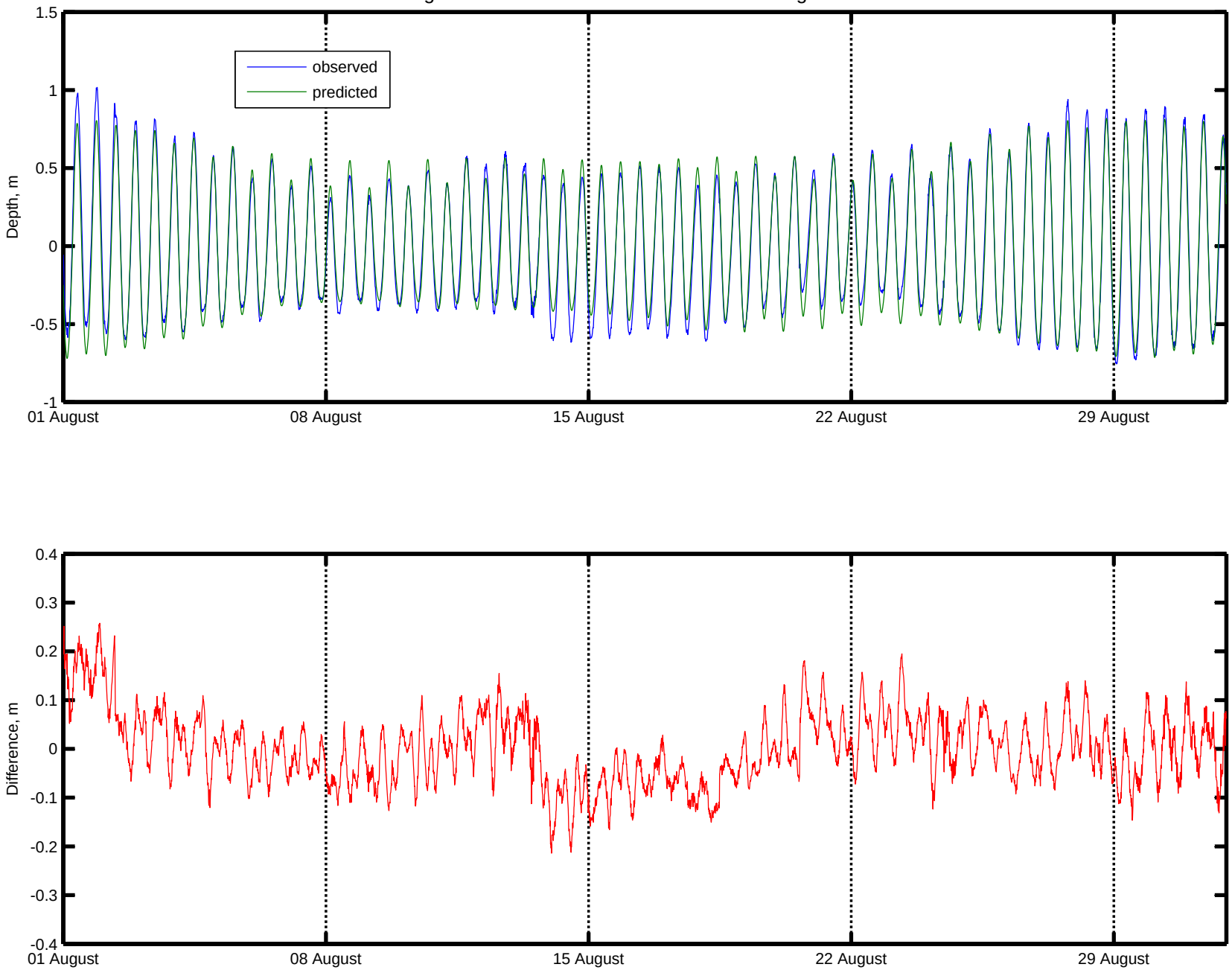

Figure 4. Harmonic Analysis Using T$_t$ide

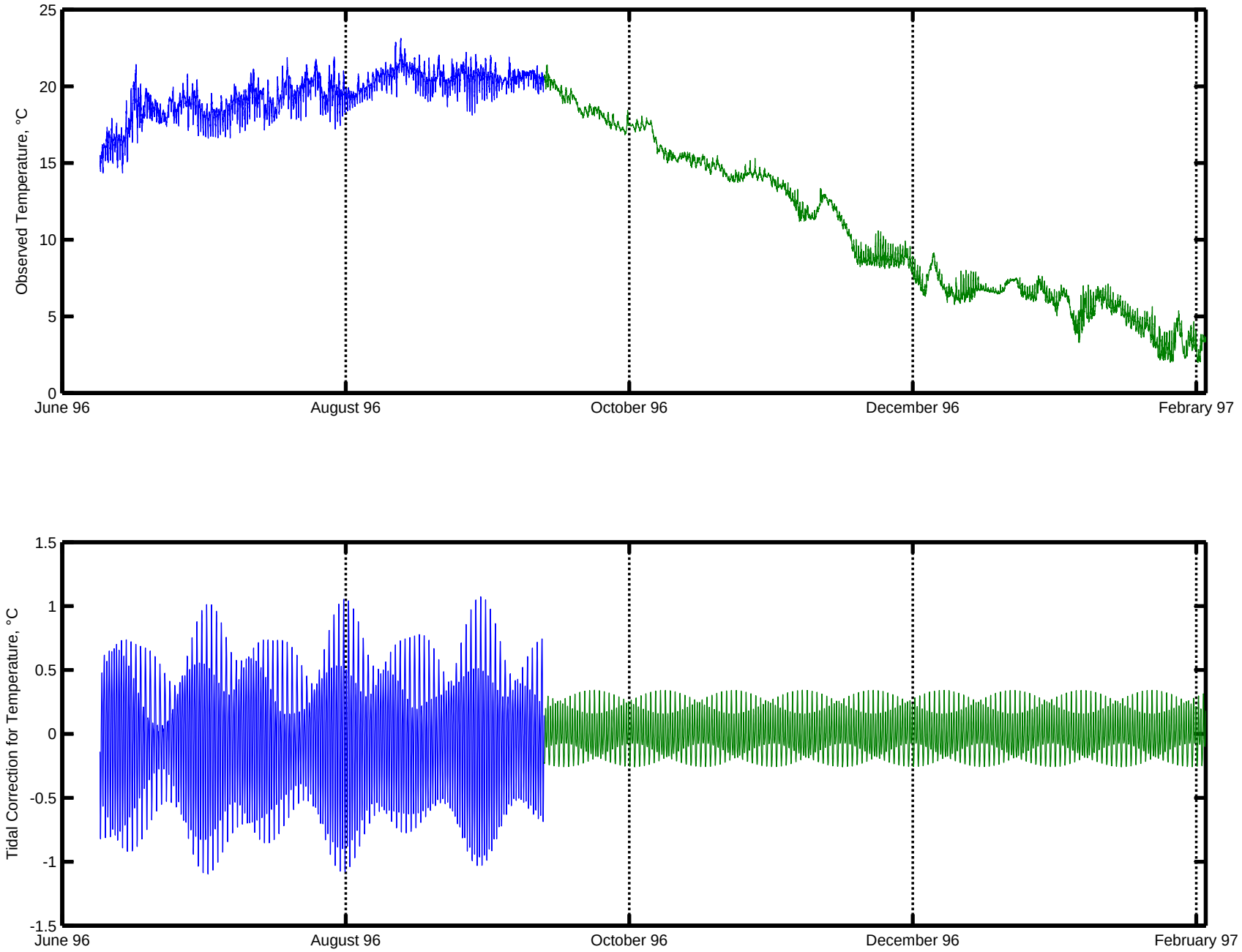

Figure 5. Corrected and Tidal Temperature -- 1996

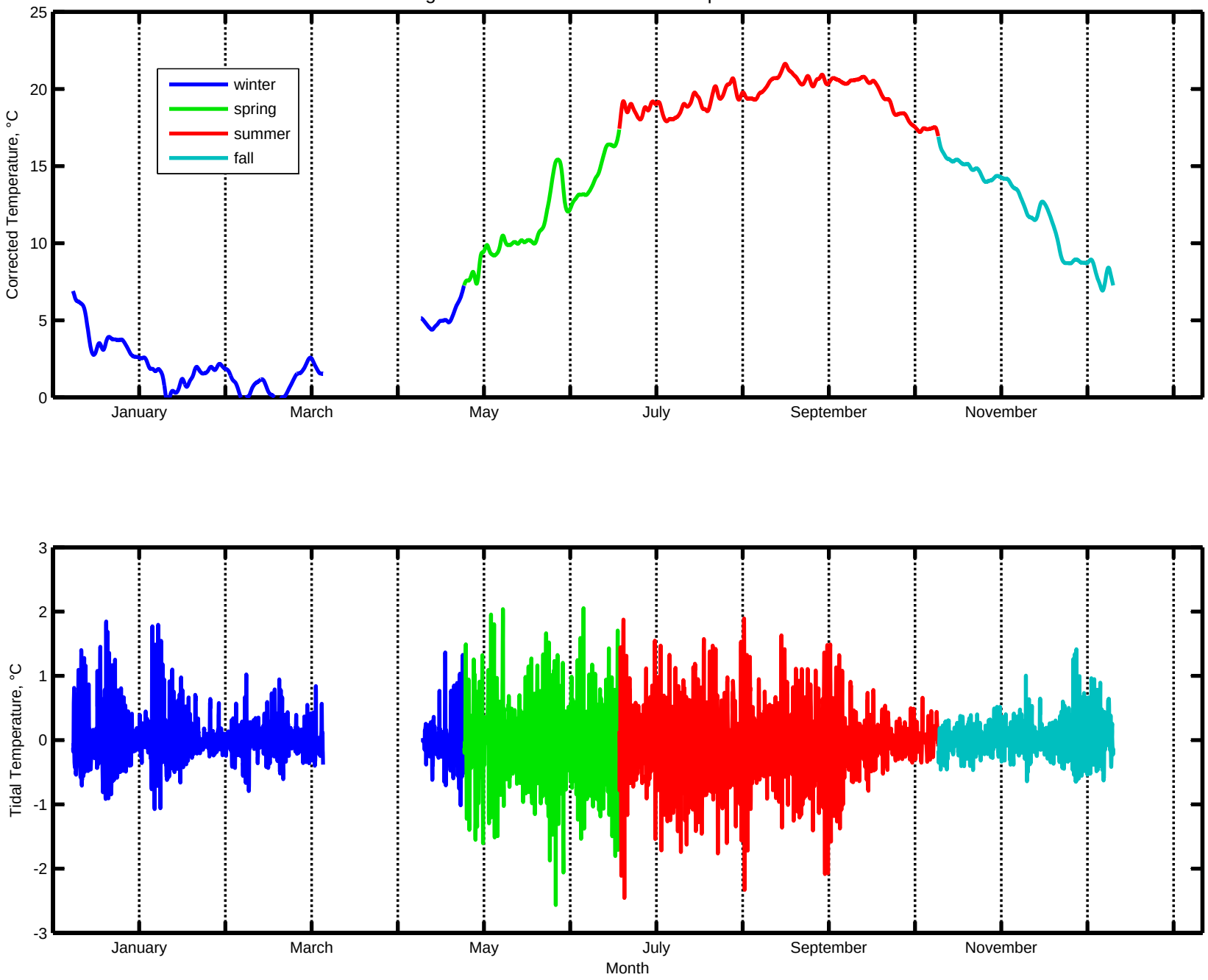

Figure 6. Corrected and Tidal Temperature -- 1997

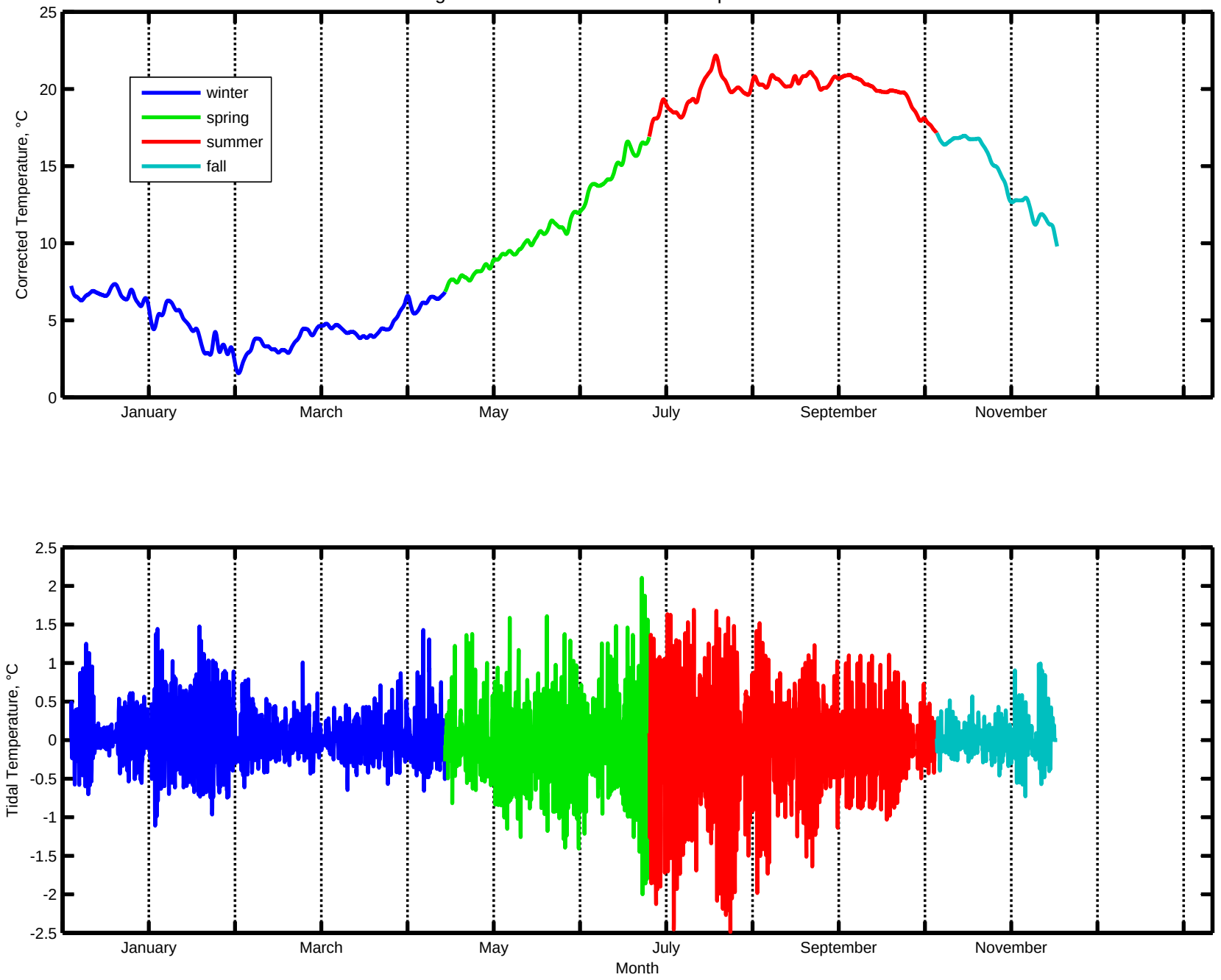

Figure 7. Corrected and Tidal Temperature -- 1998

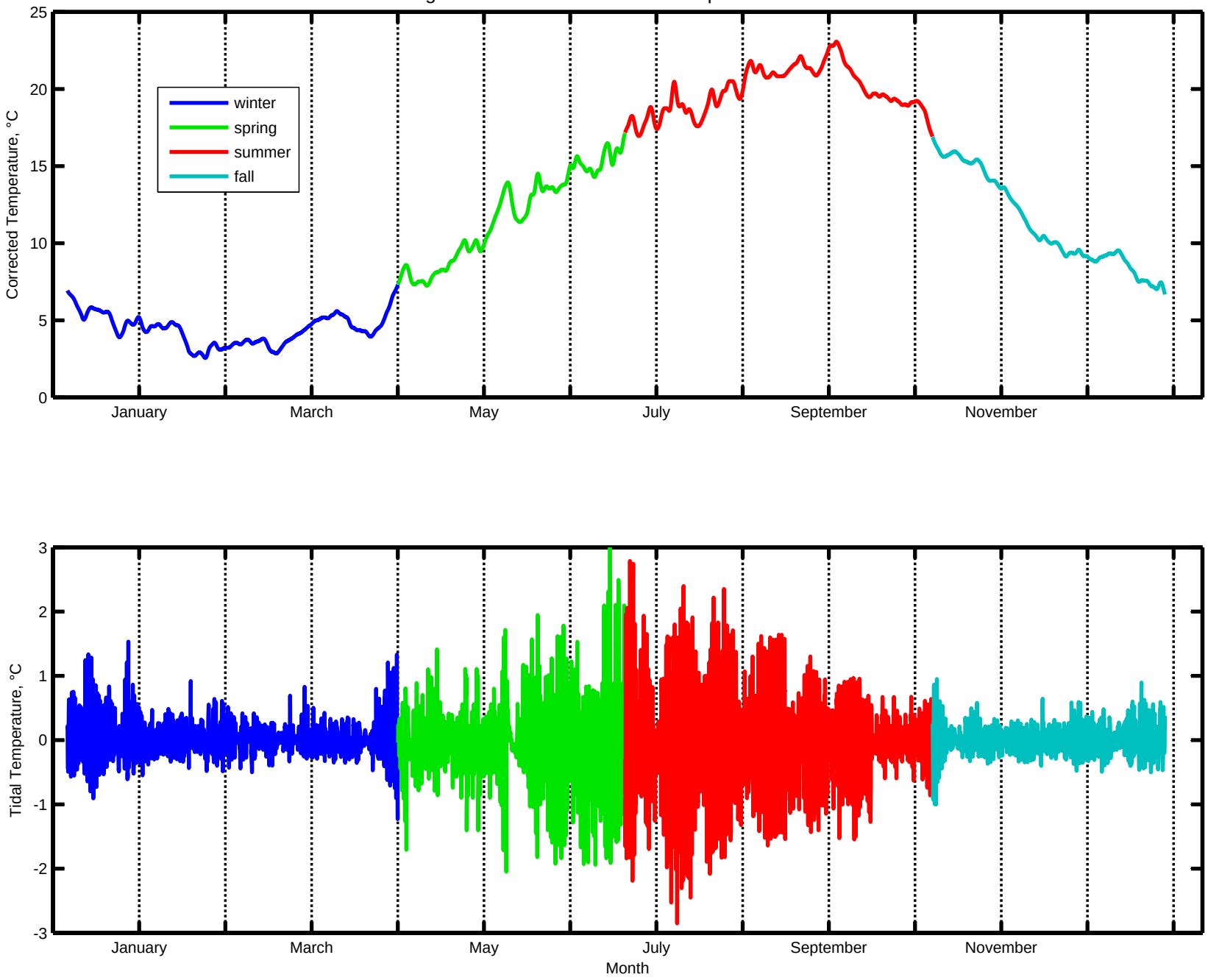

Figure 8. Corrected and Tidal Temperature -- 1999

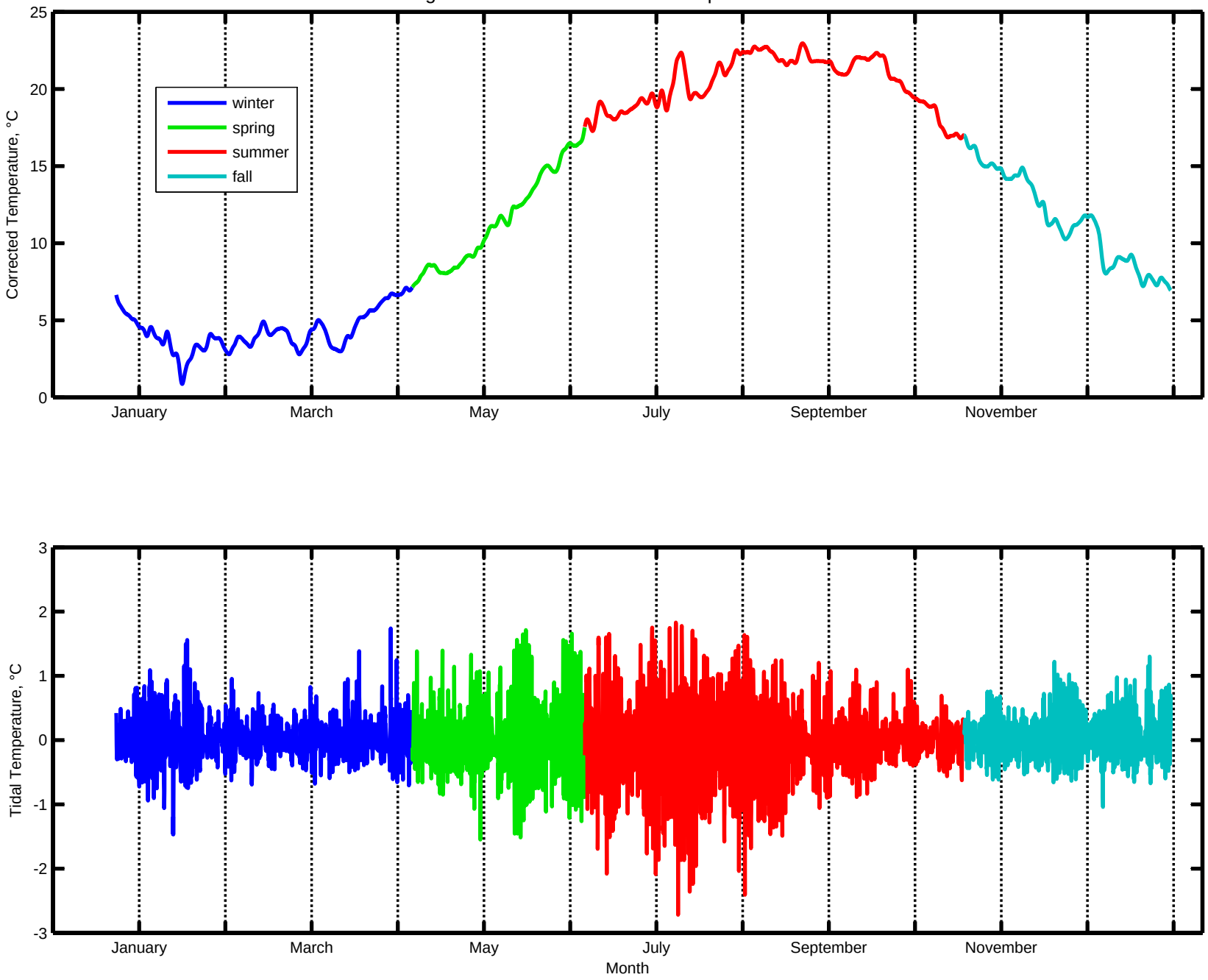

Figure 9. Corrected and Tidal Temperature -- 2000

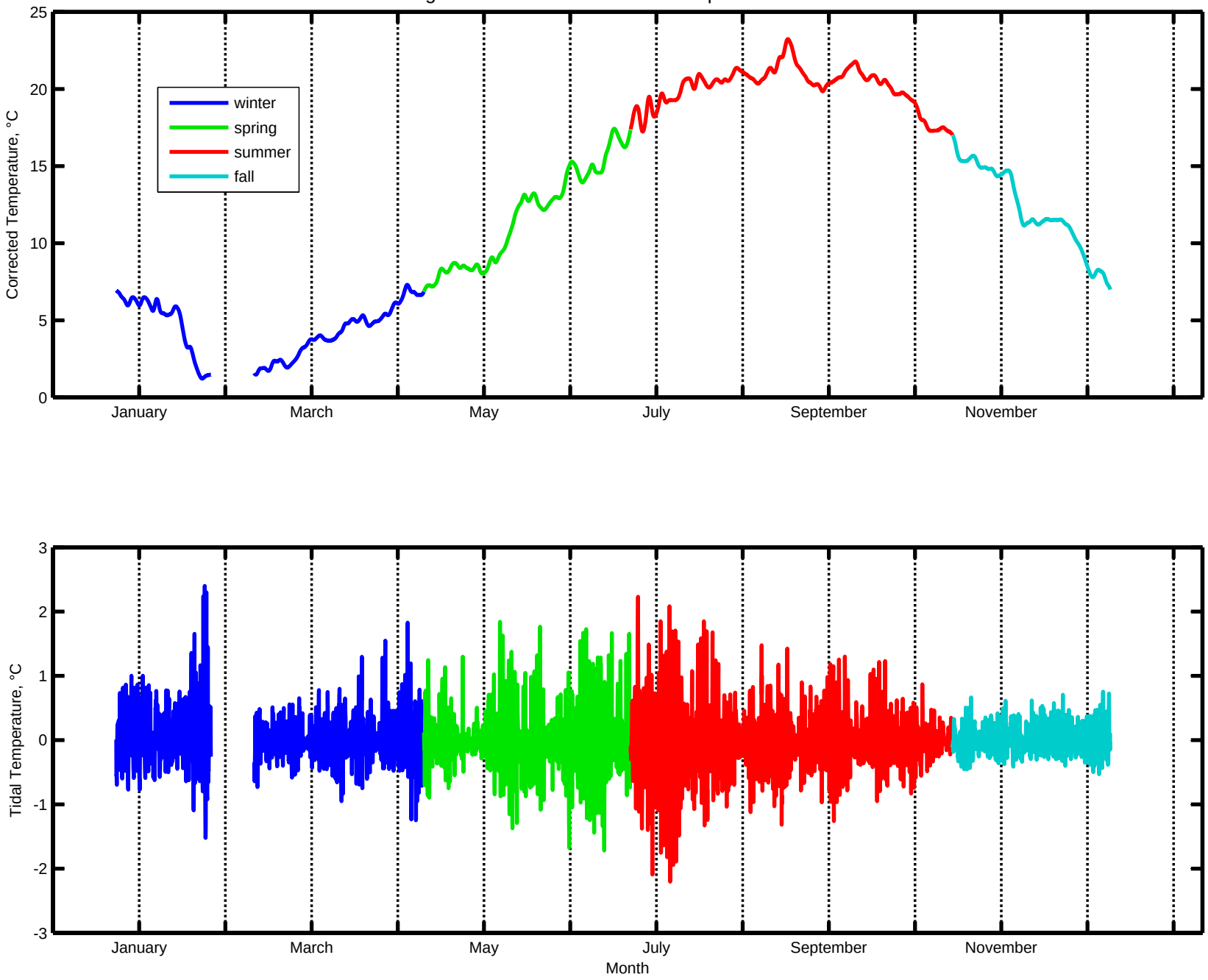

Figure 10. Corrected and Tidal Temperature -- 2001

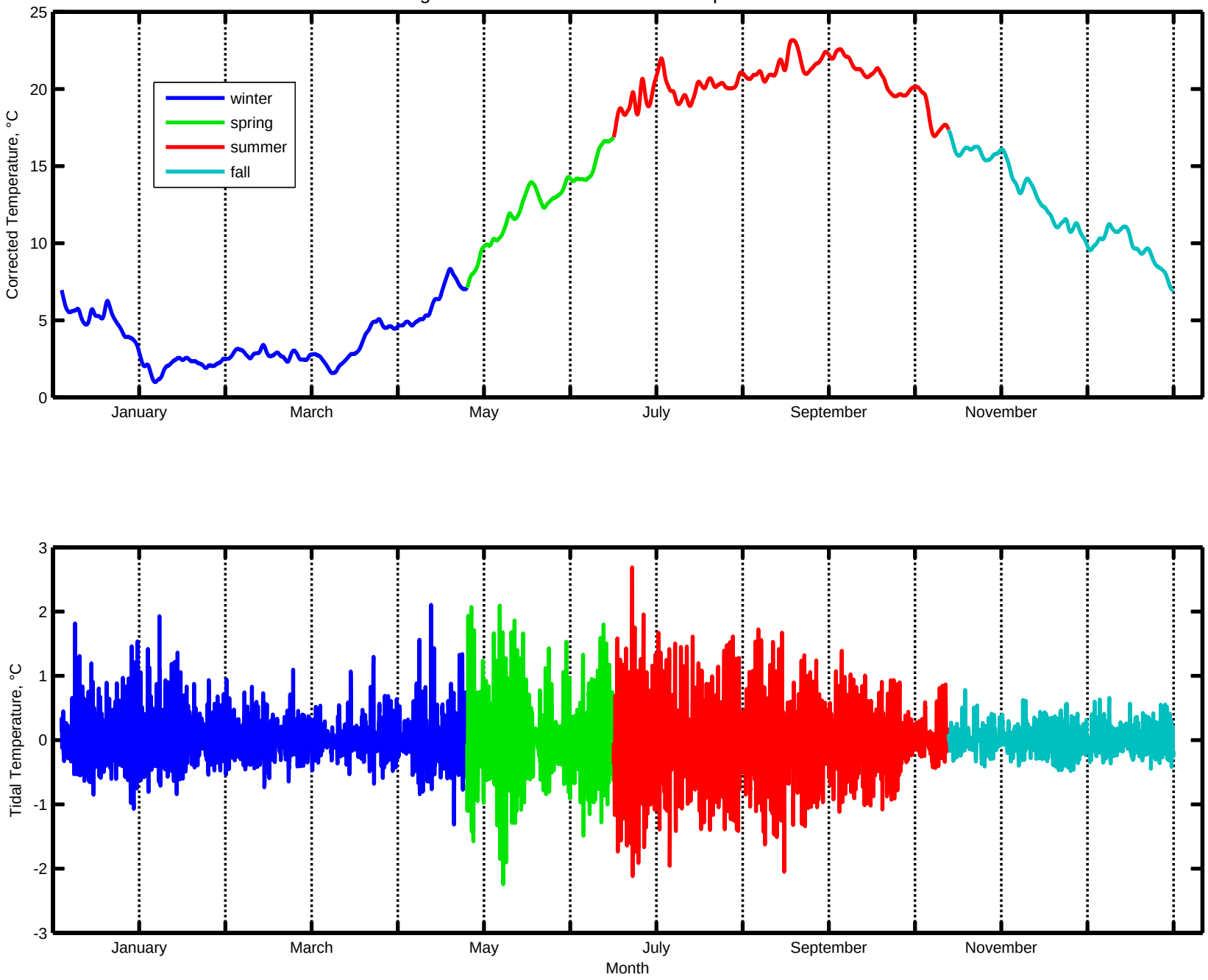

Figure 11. Corrected and Tidal Temperature -- 2002

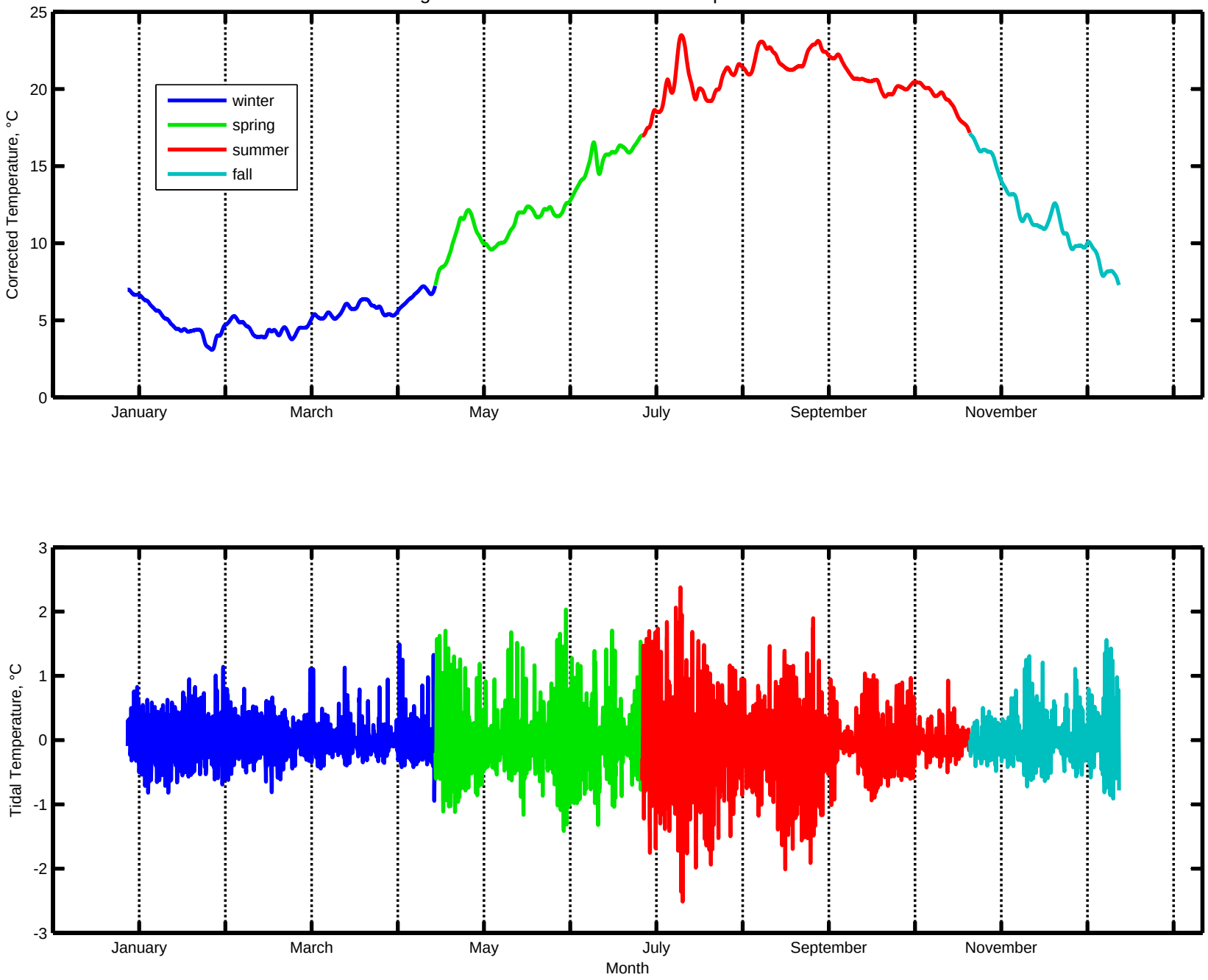

Figure 12. Corrected and Tidal Temperature -- 2003

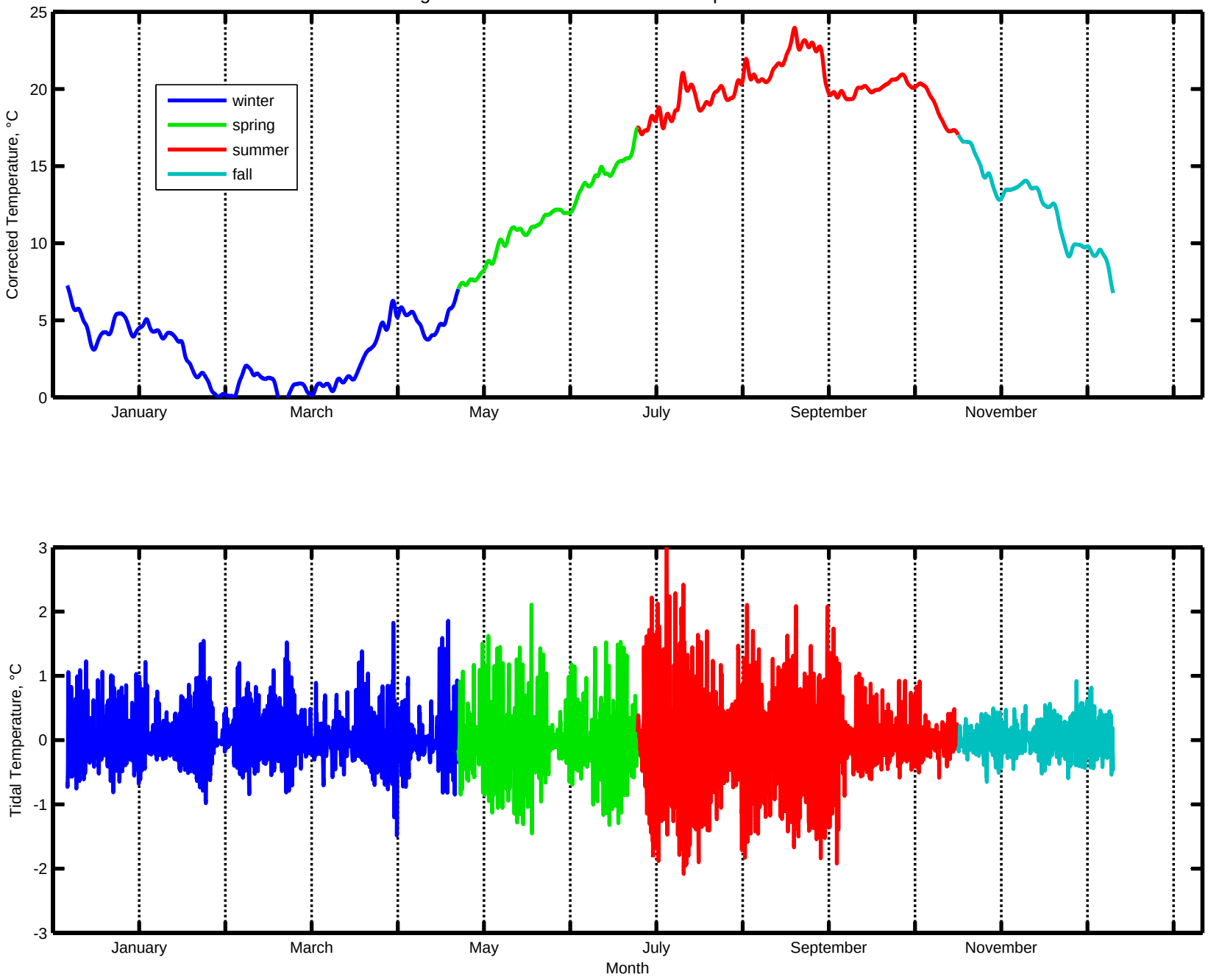

Figure 13. Corrected and Tidal Temperature -- 2004

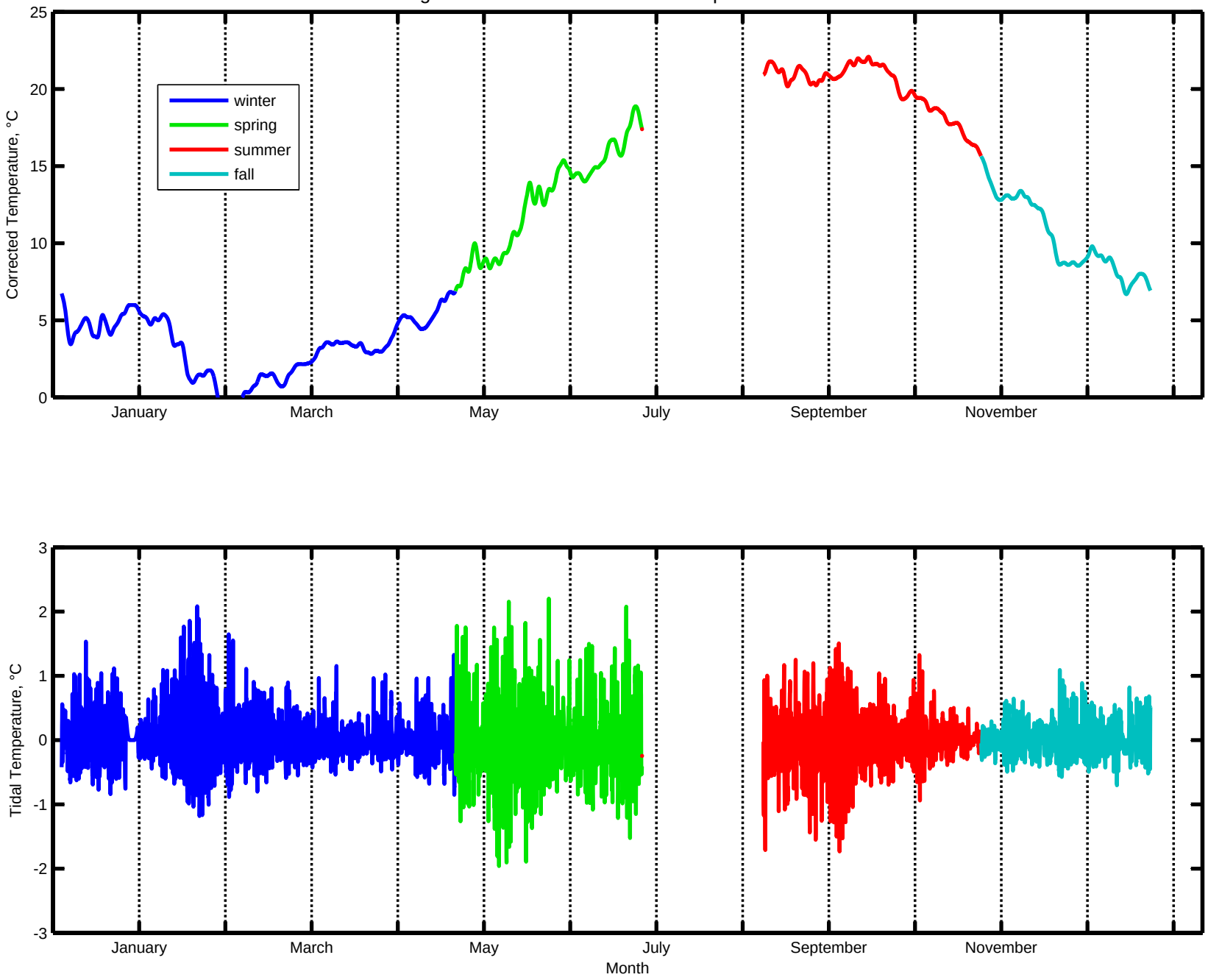

Figure 14. Corrected and Tidal Temperature -- 2005

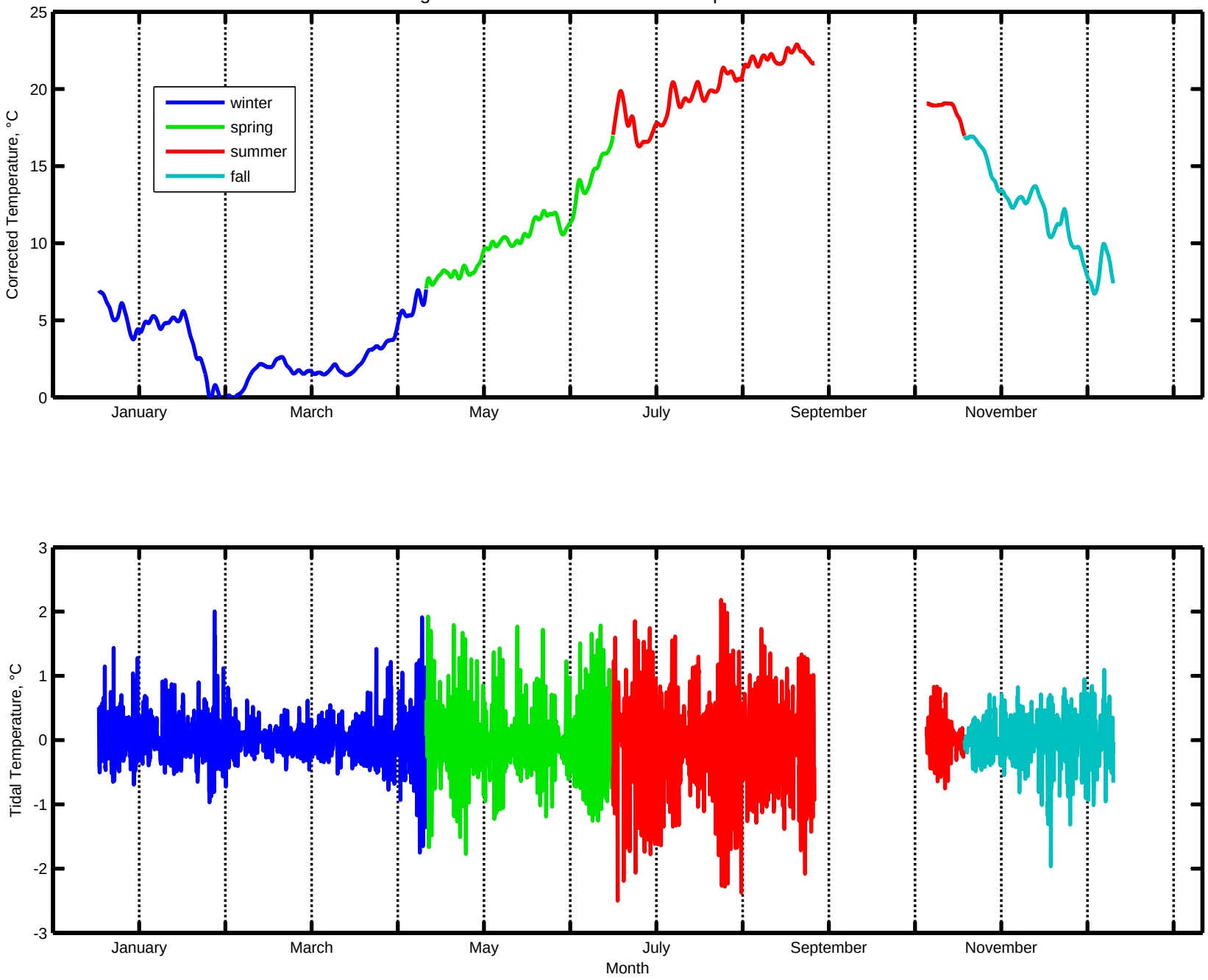

Figure 15. Corrected and Tidal Temperature -- 2006

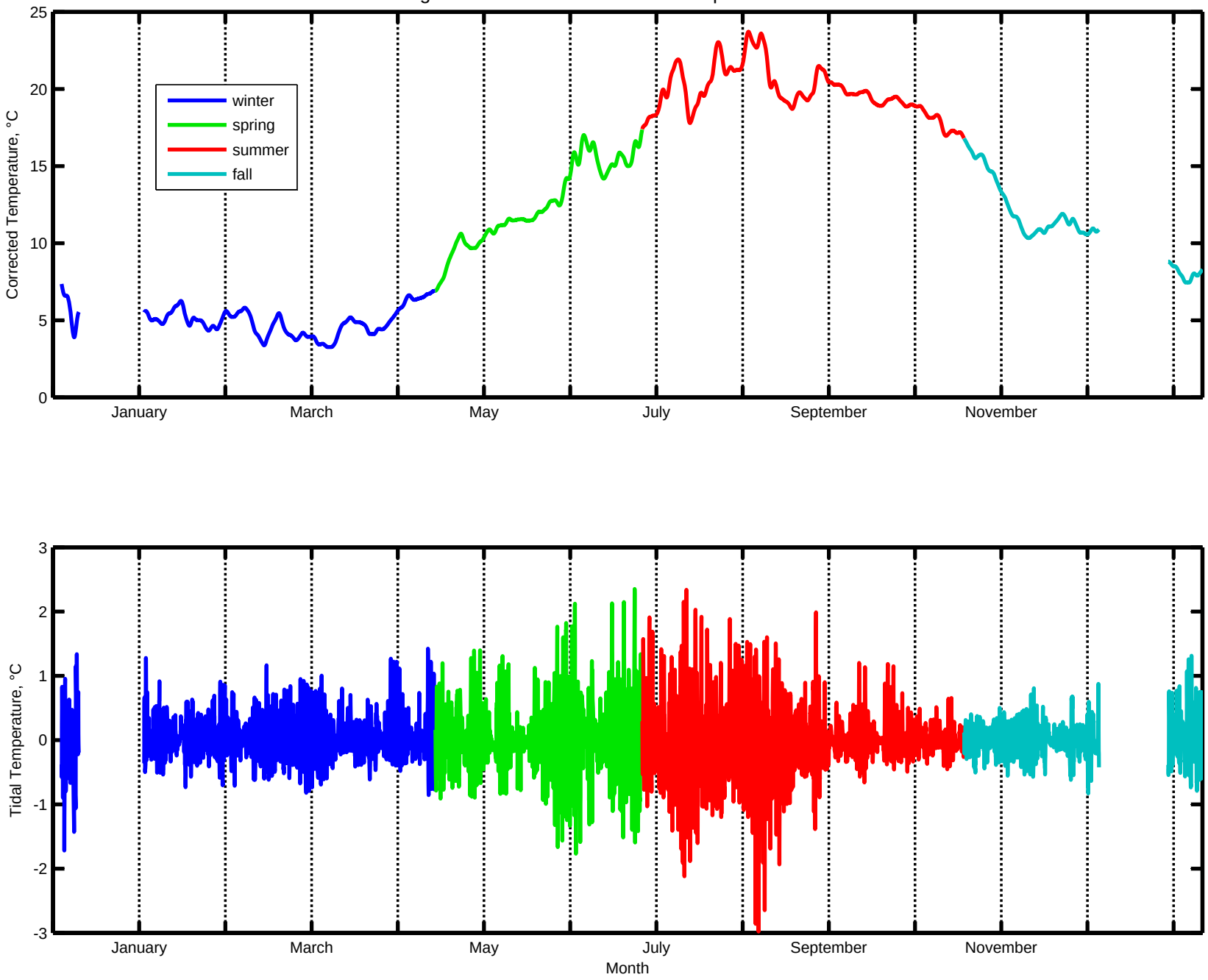

Figure 16. Corrected and Tidal Temperature -- 2007

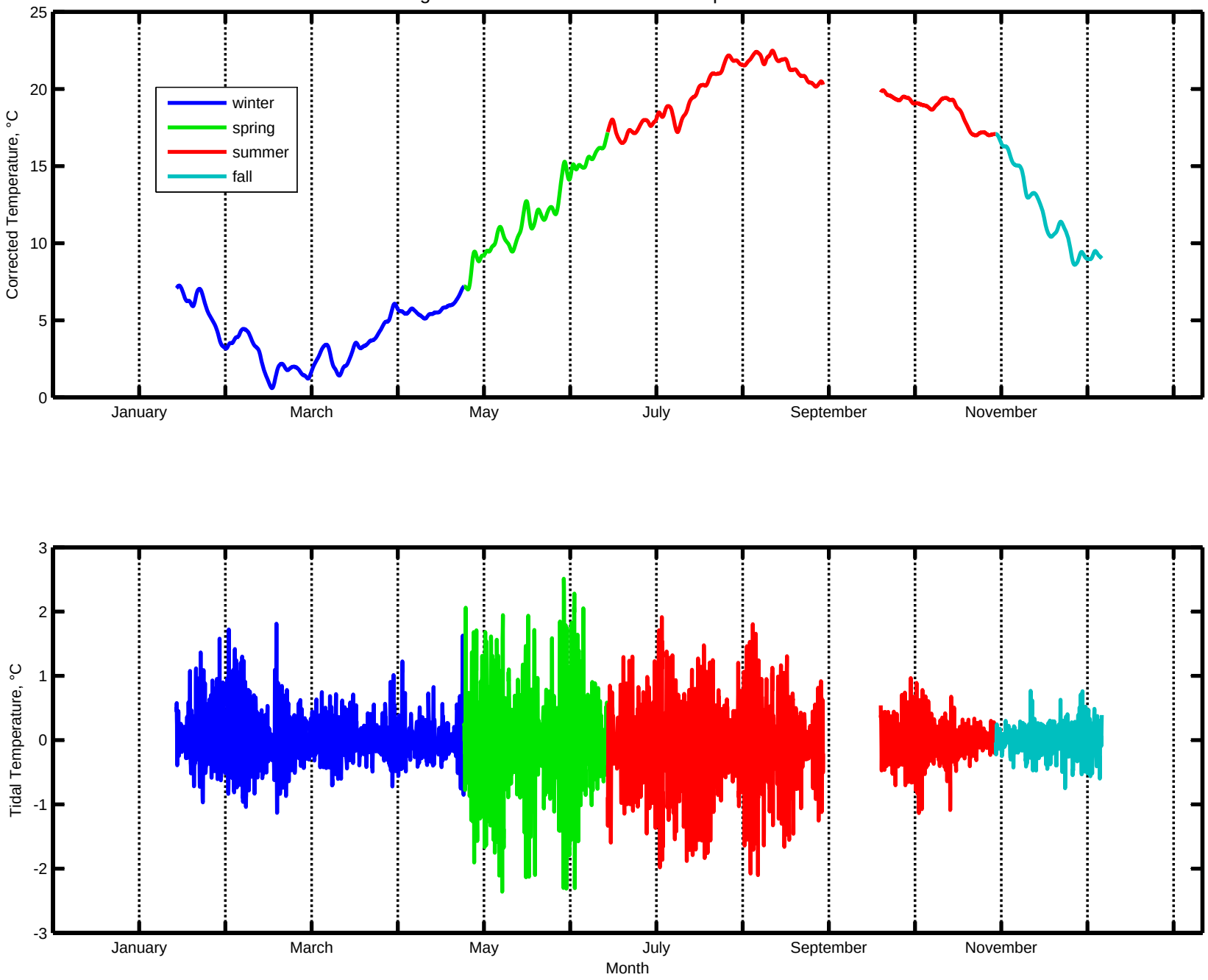

Figure 17. Corrected and Tidal Temperature -- 2008

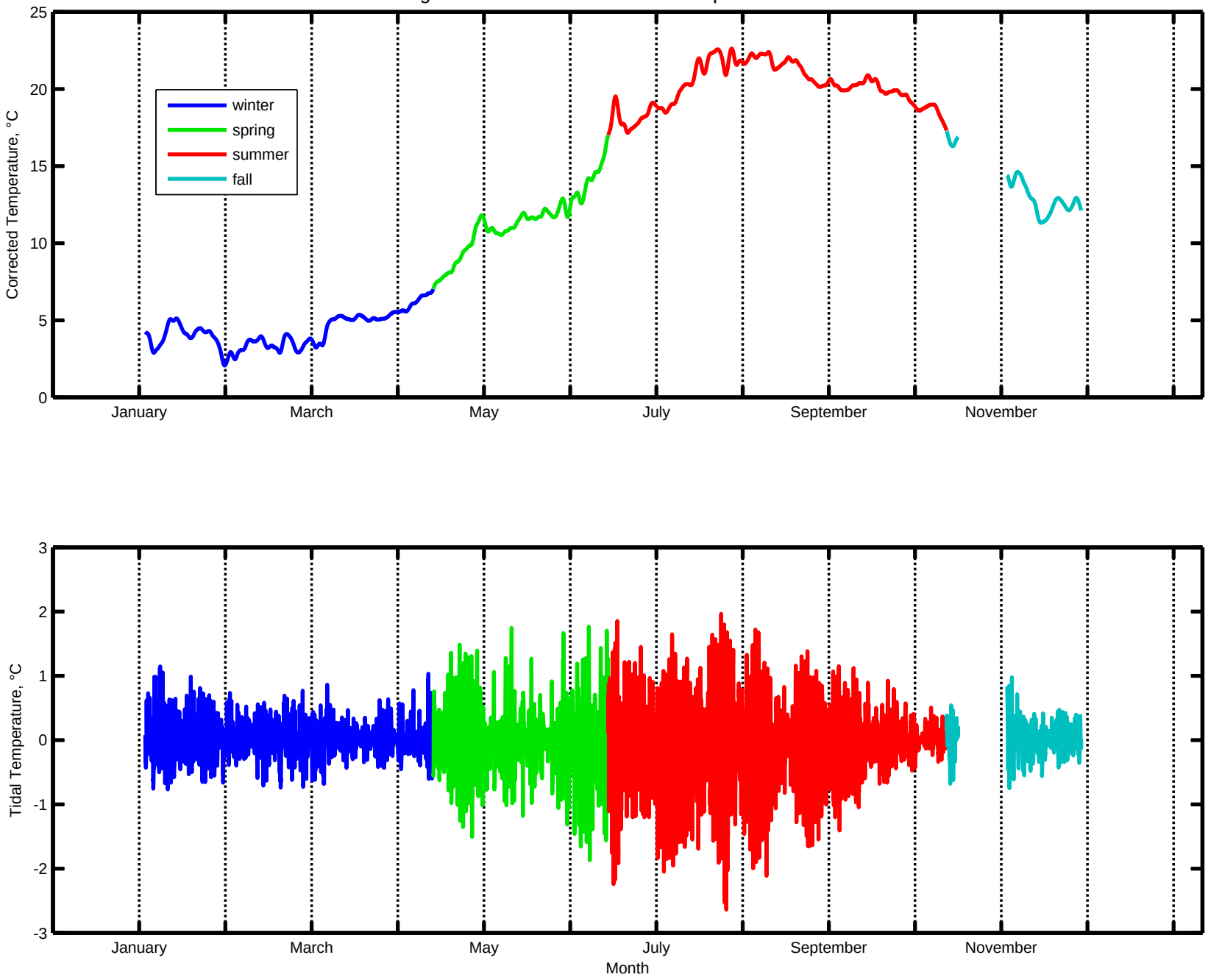

Figure 18. Corrected and Tidal Temperature -- 2009

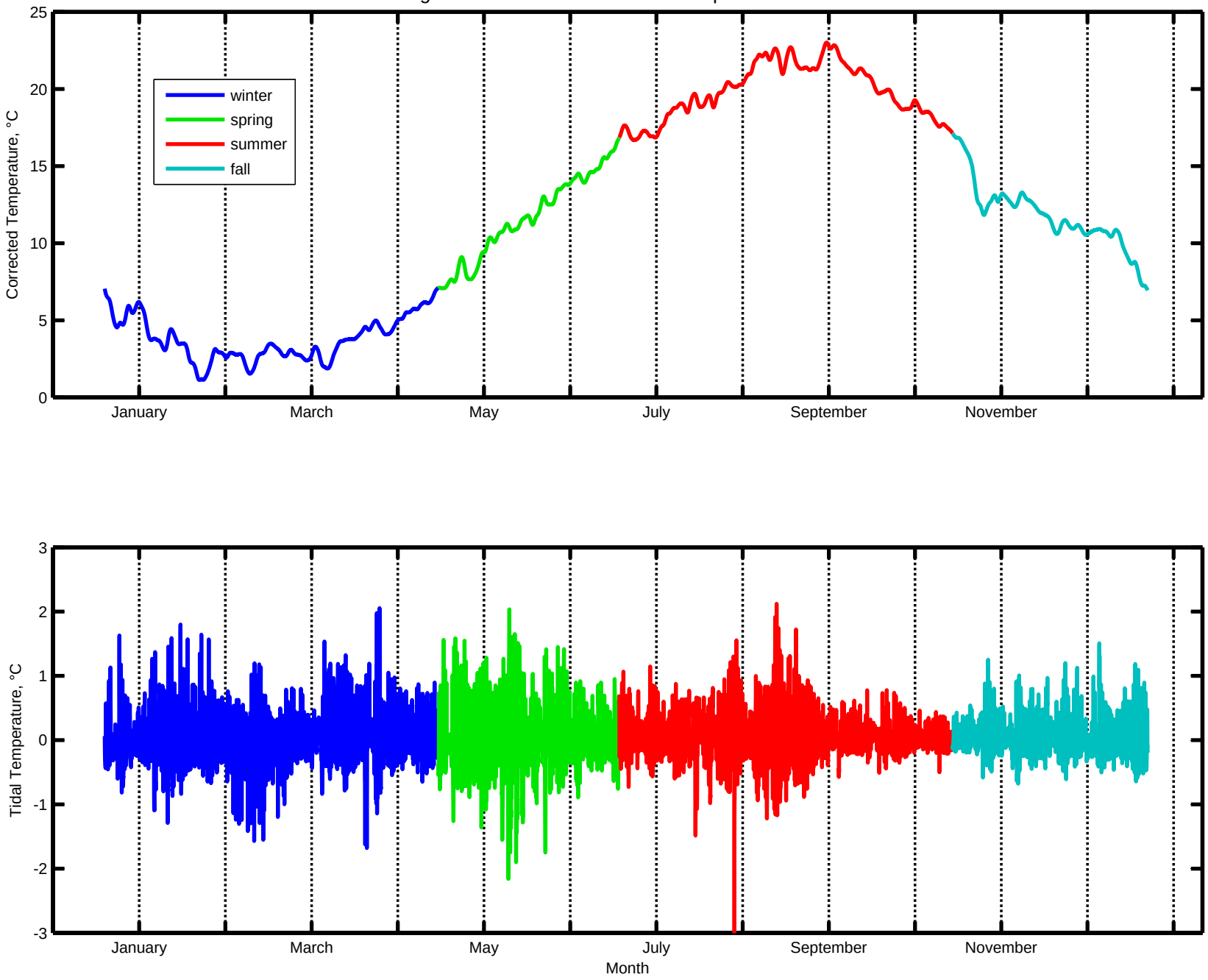

Figure 19. Corrected and Tidal Temperature -- 2010

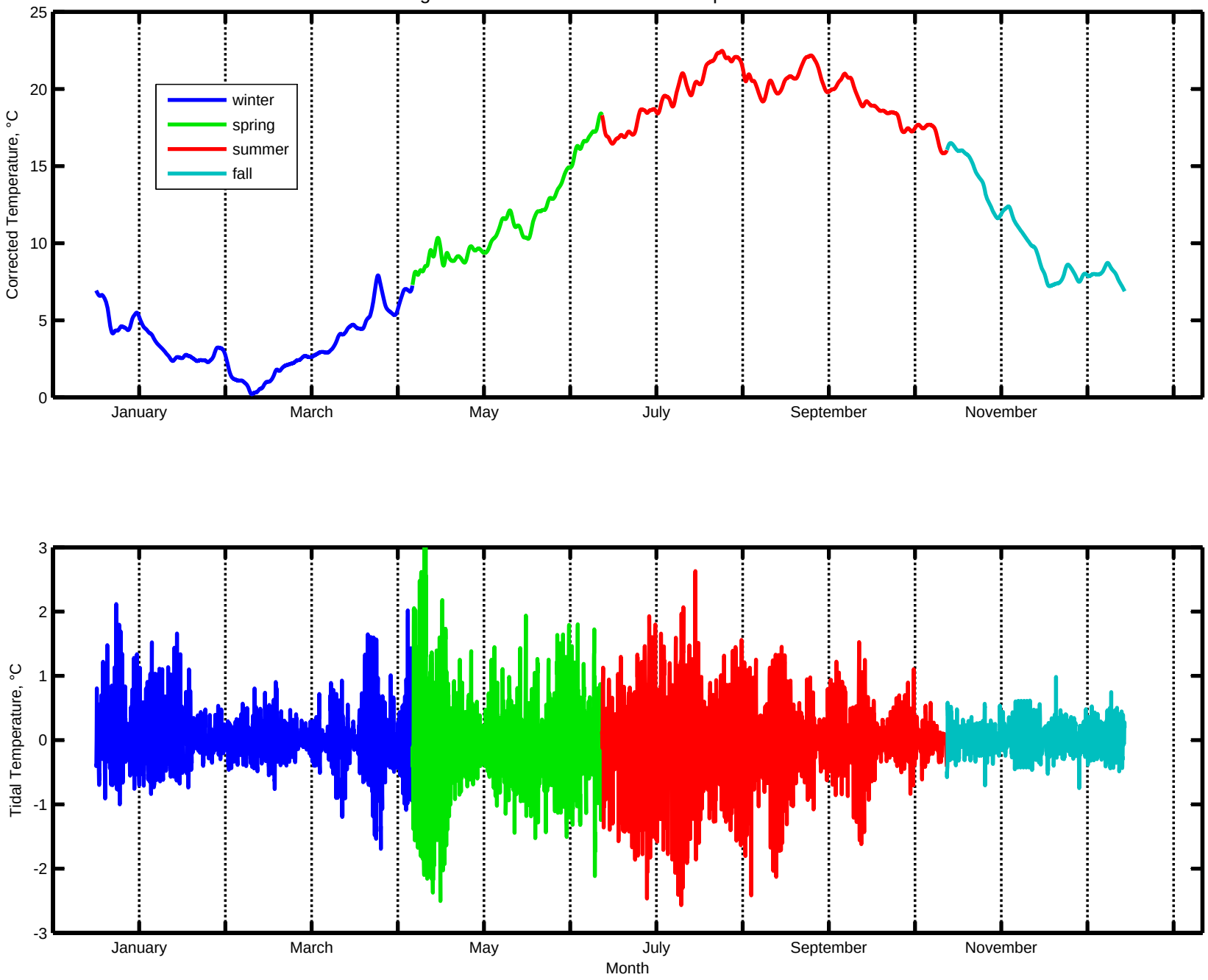

Figure 20. Corrected and Tidal Temperature -- 2011

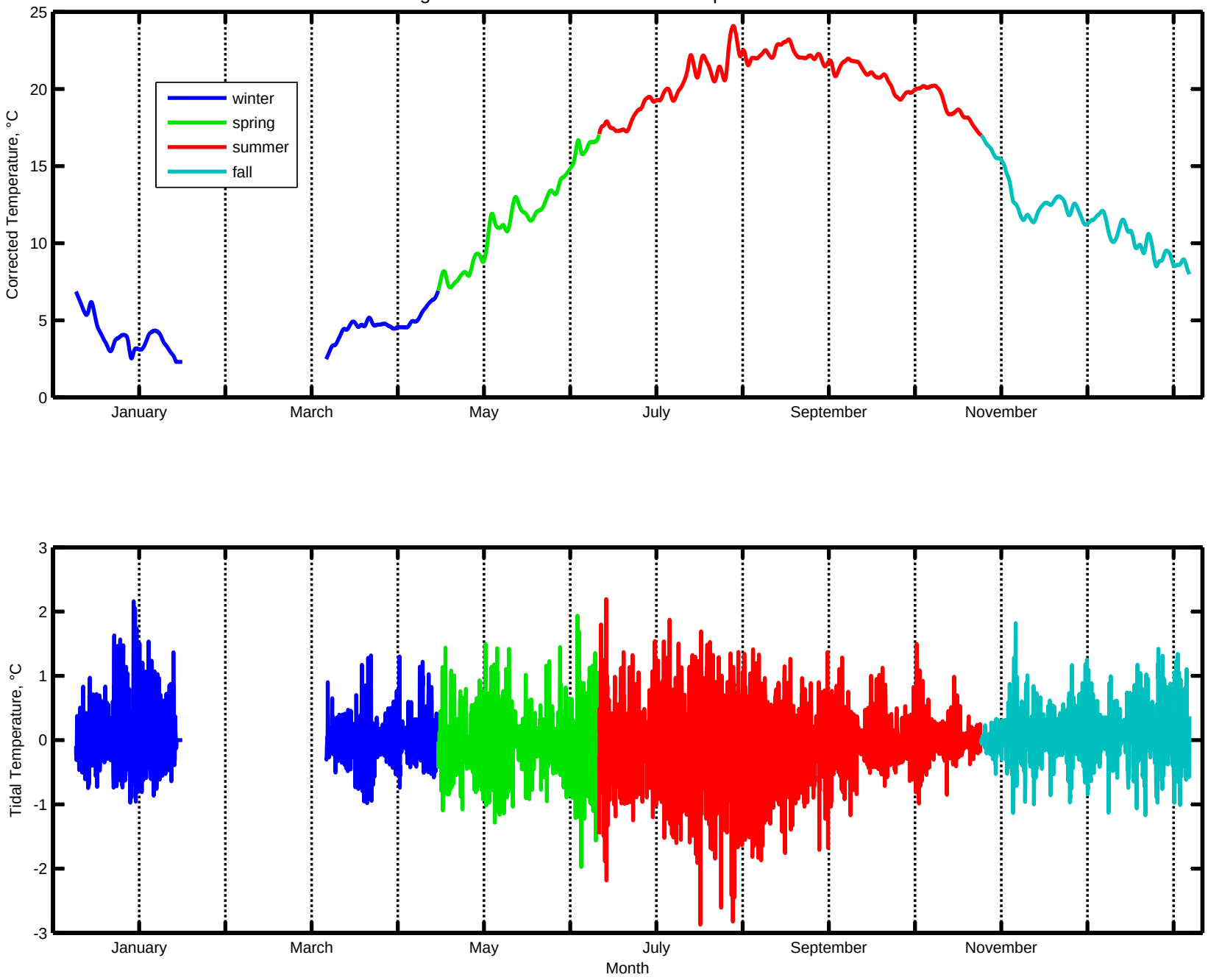

Figure 21. Corrected and Tidal Salinity -- 1996

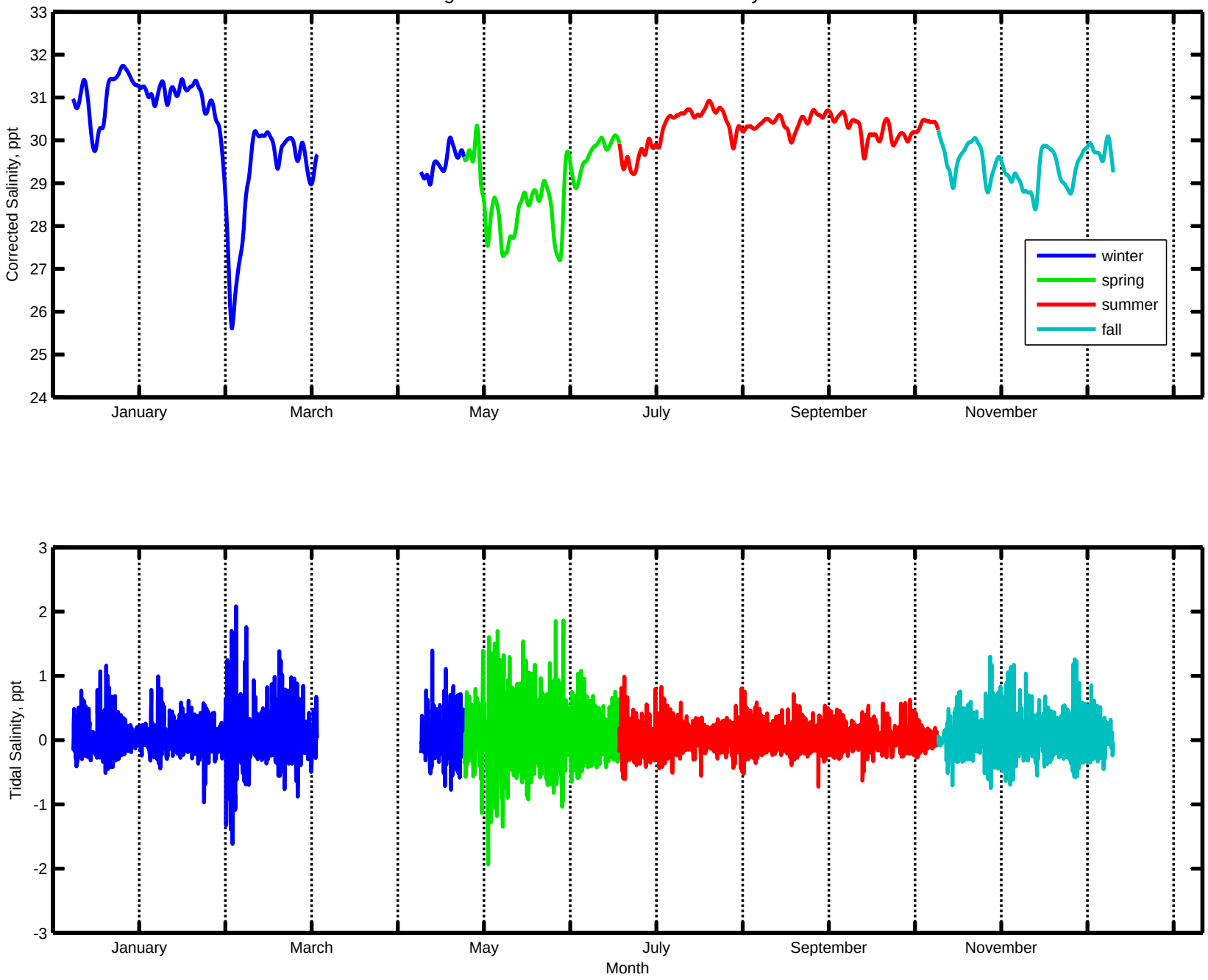

Figure 22. Corrected and Tidal Salinity -- 1997

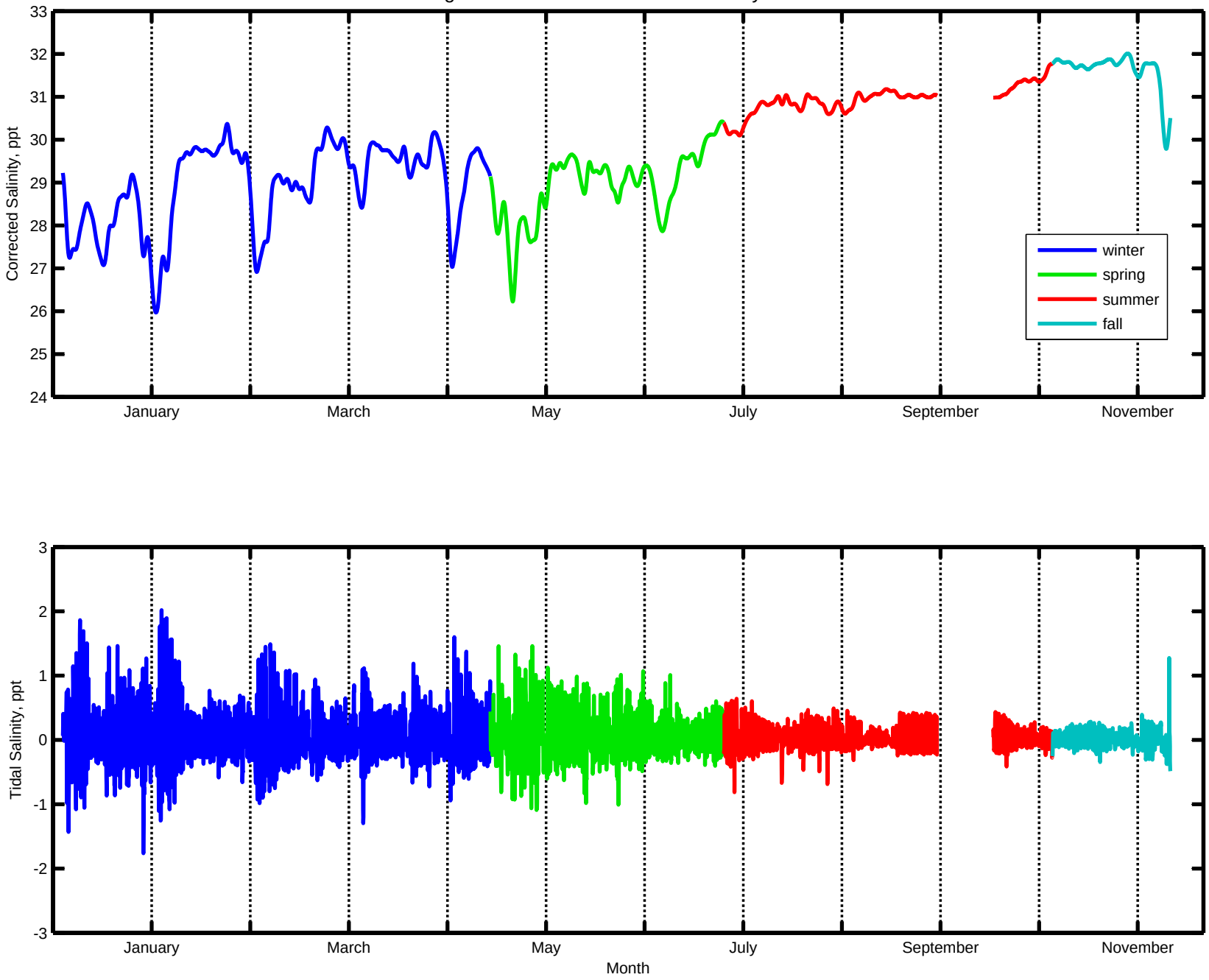

Figure 23. Corrected and Tidal Salinity --1998

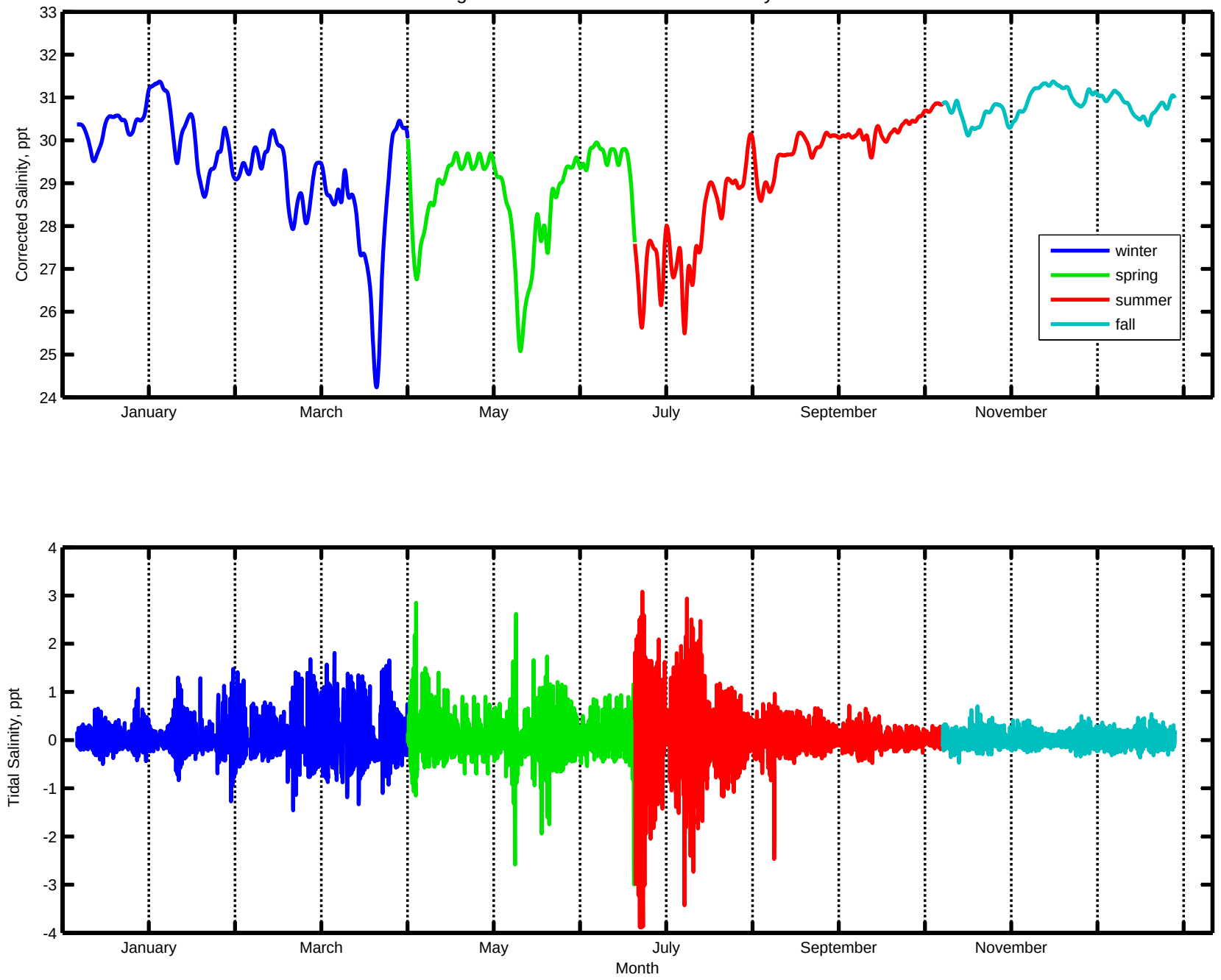

Figure 24. Corrected and Tidal Salinity -- 1999

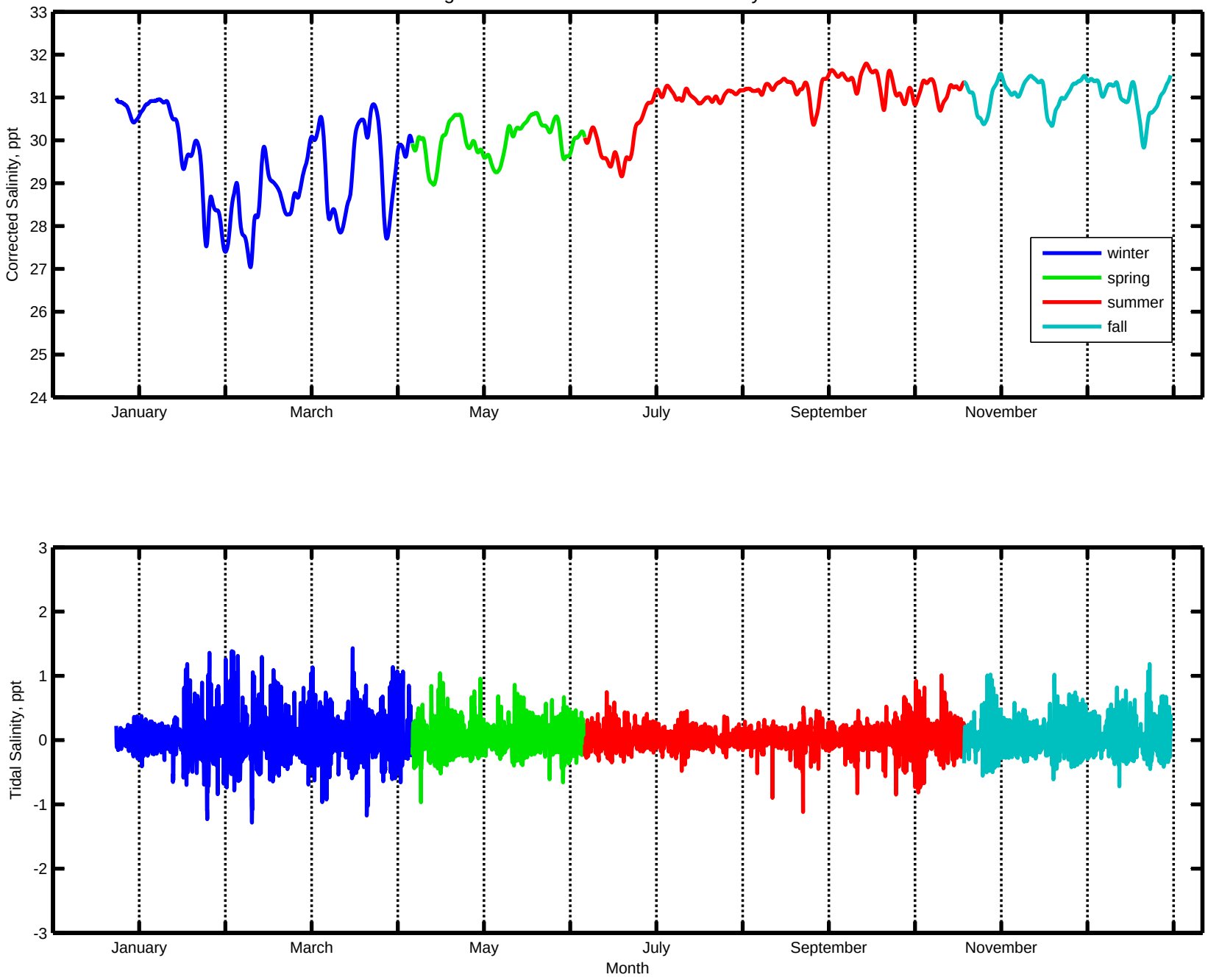

Figure 25. Corrected and Tidal Salinity -- 2000

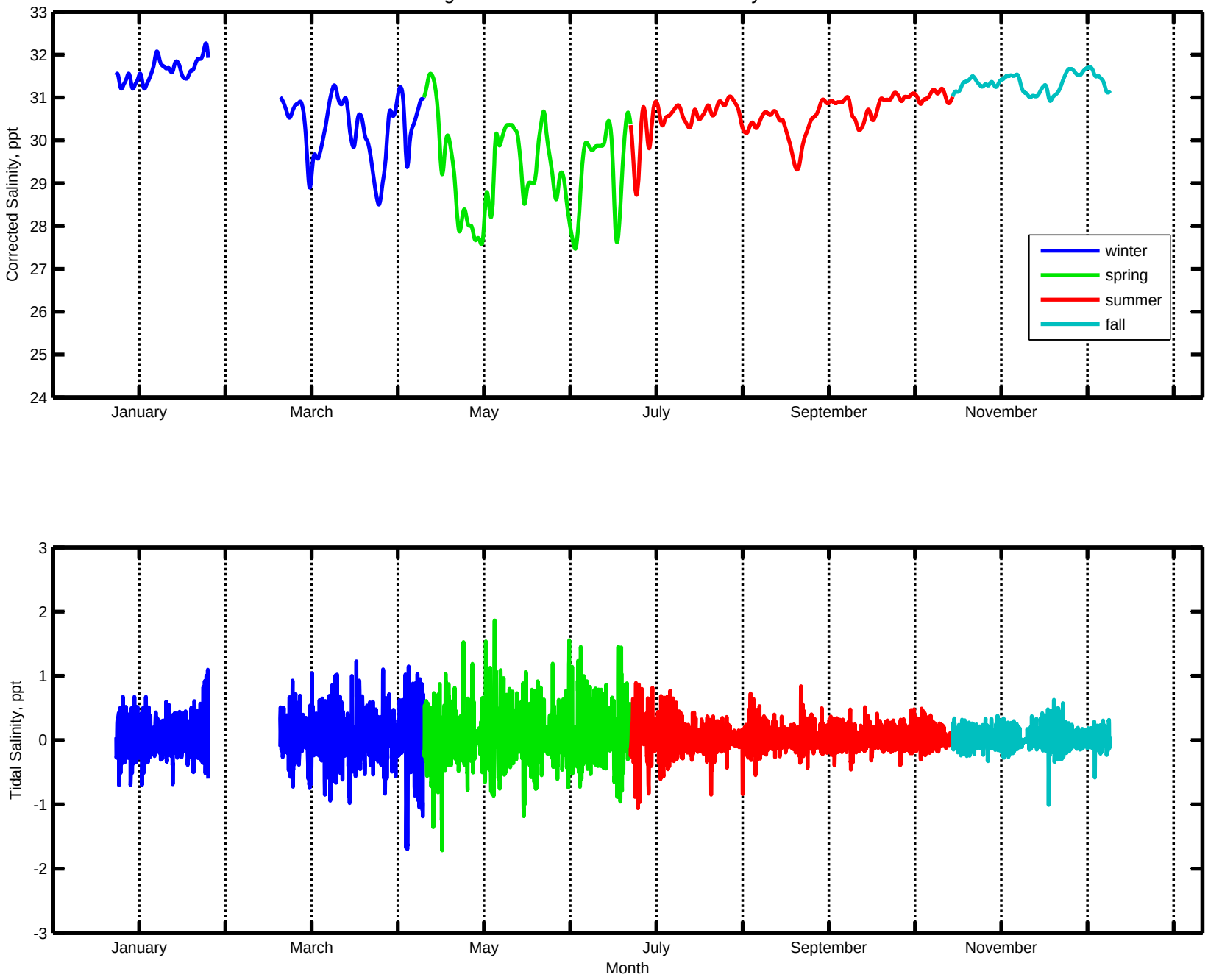

Figure 26. Corrected and Tidal Salinity -- 2001

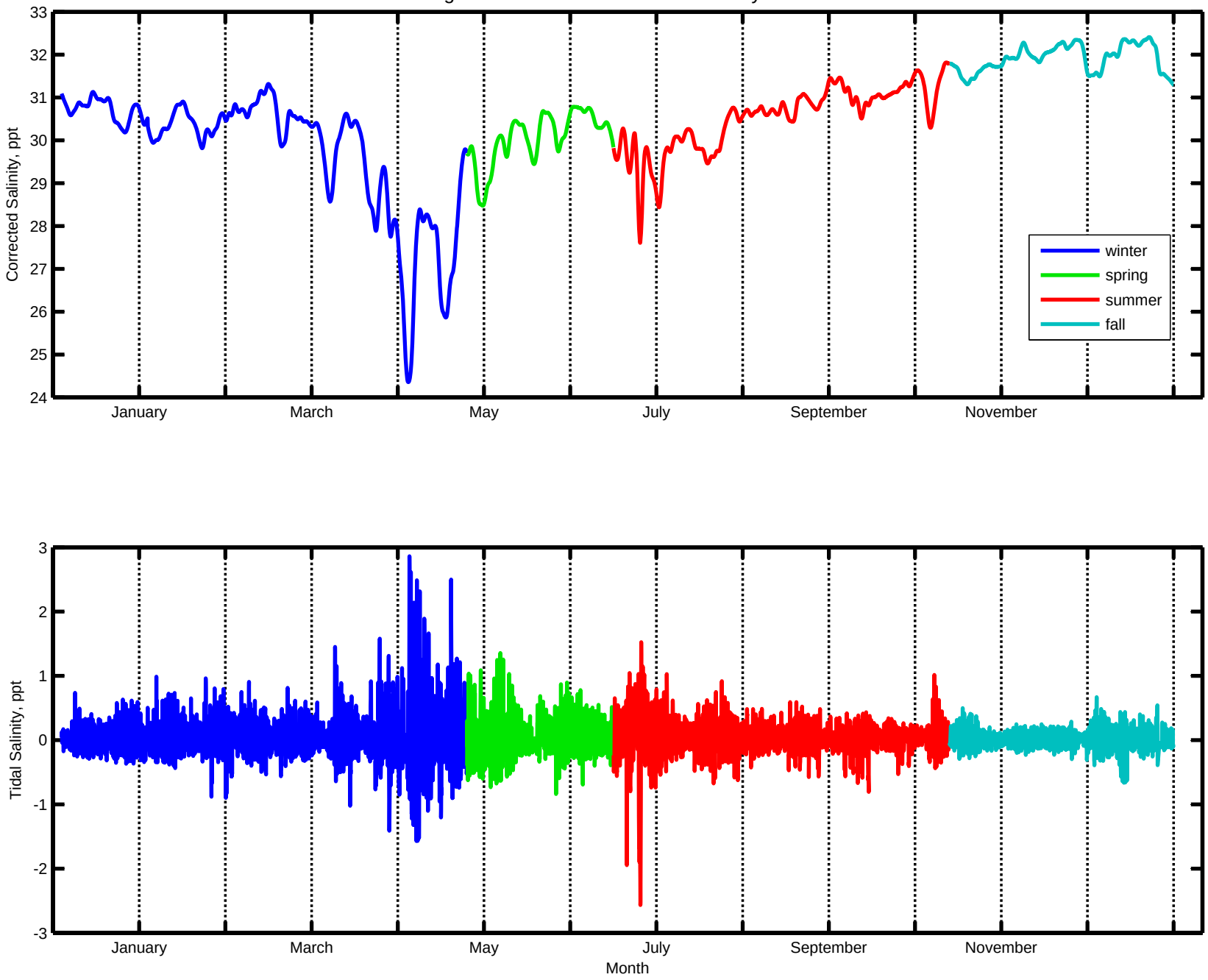

Figure 27. Corrected and Tidal Salinity -- 2002

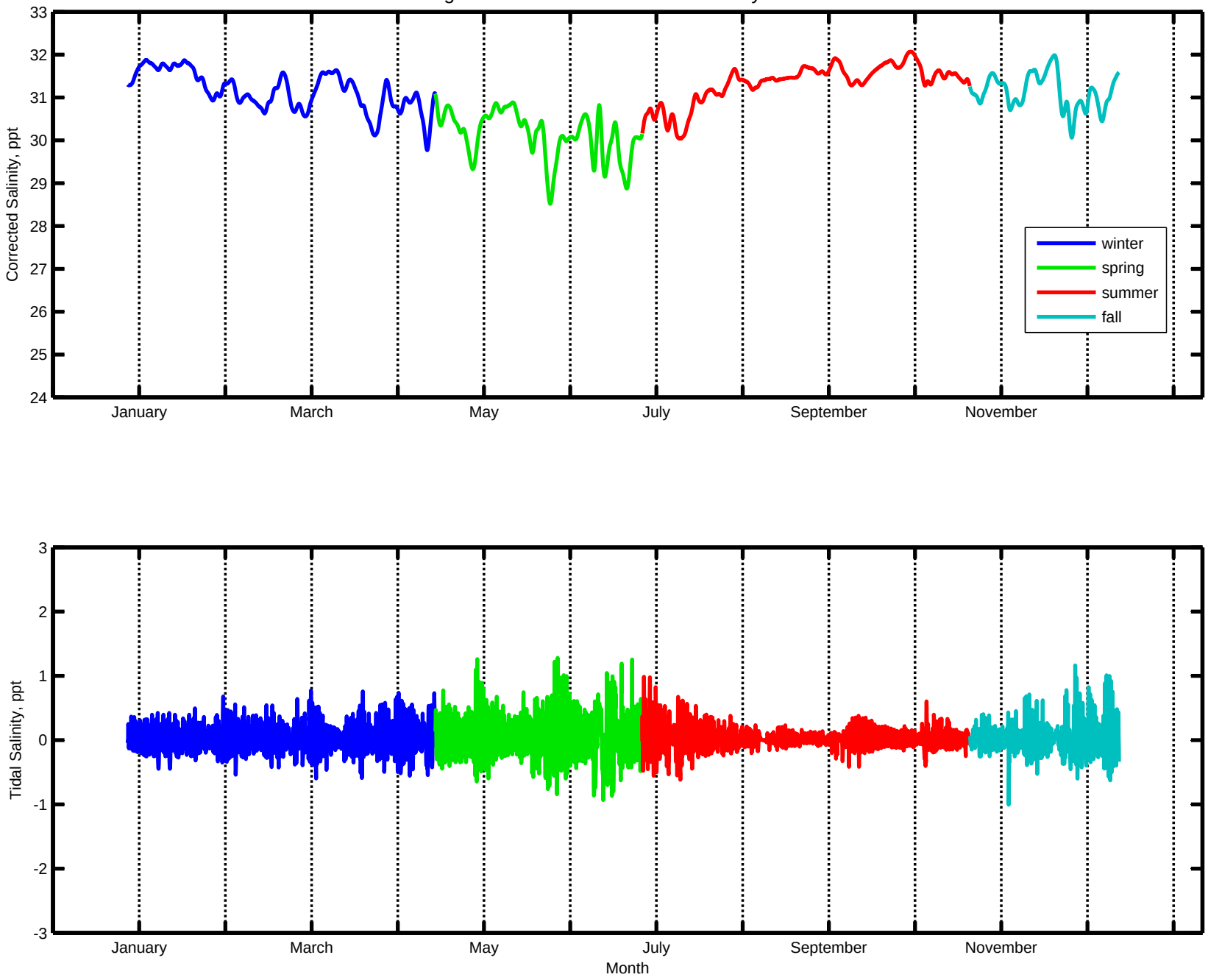

Figure 28. Corrected and Tidal Salinity -- 2003

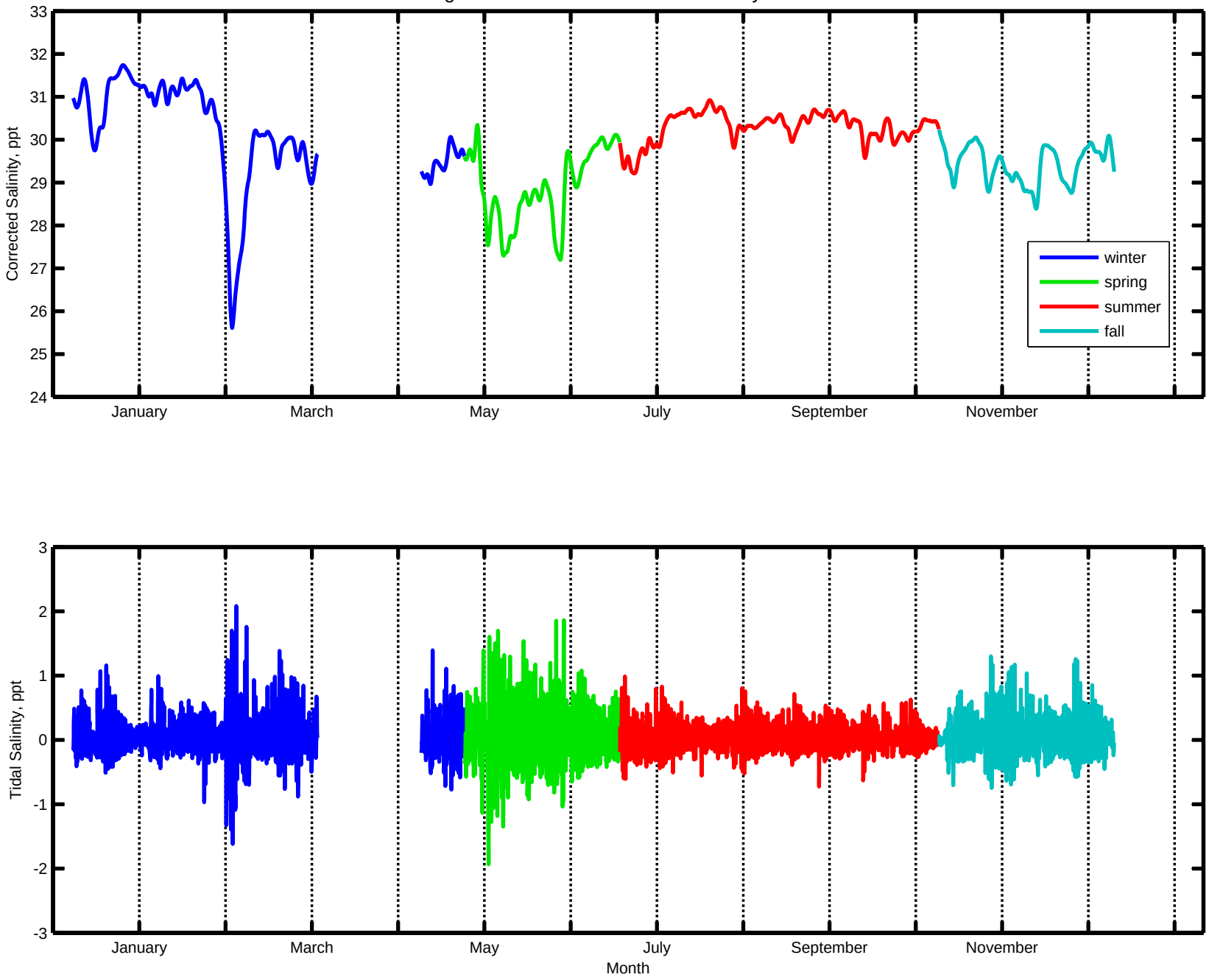

Figure 29. Corrected and Tidal Salinity -- 2004

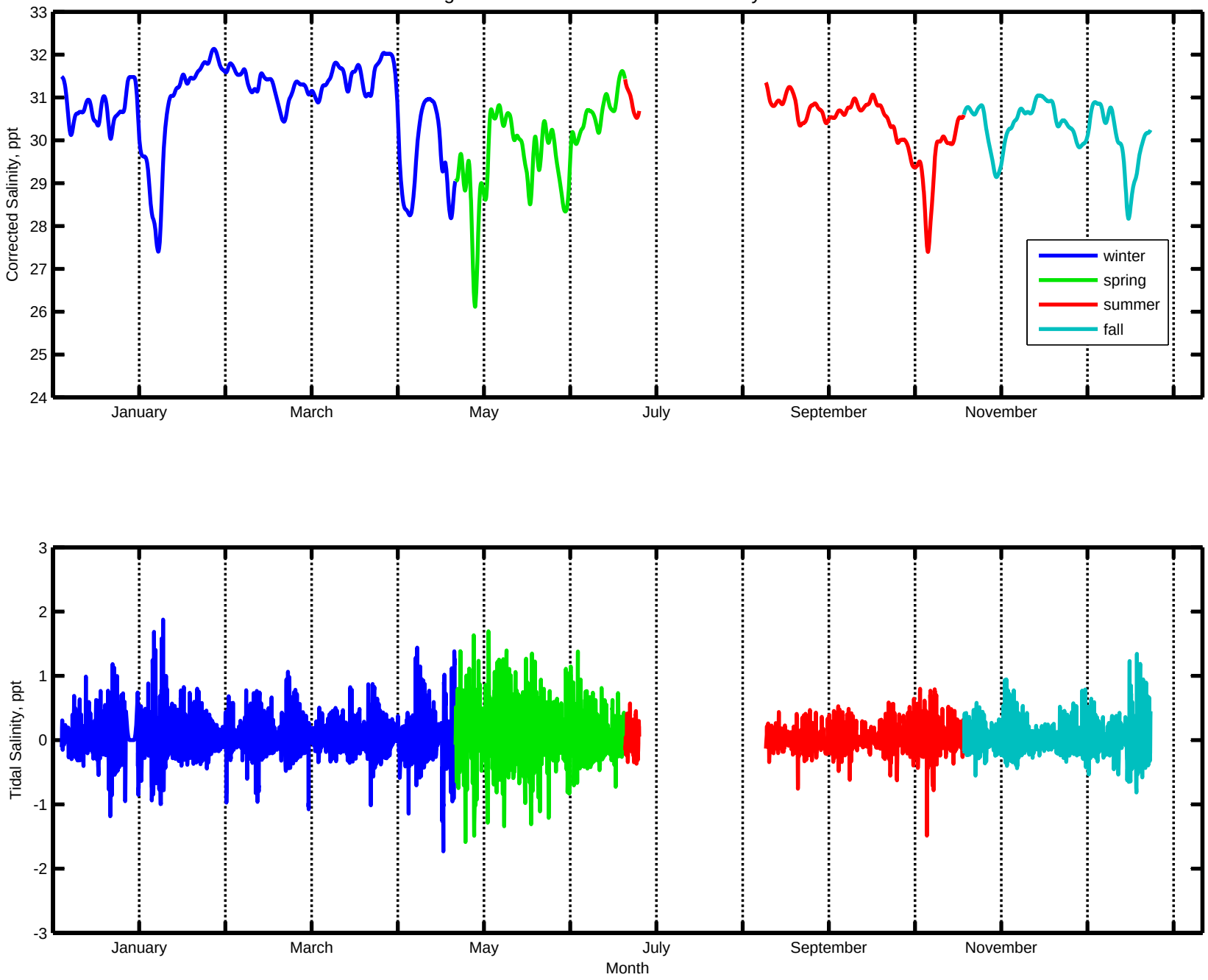

Figure 30. Corrected and Tidal Salinity -- 2005

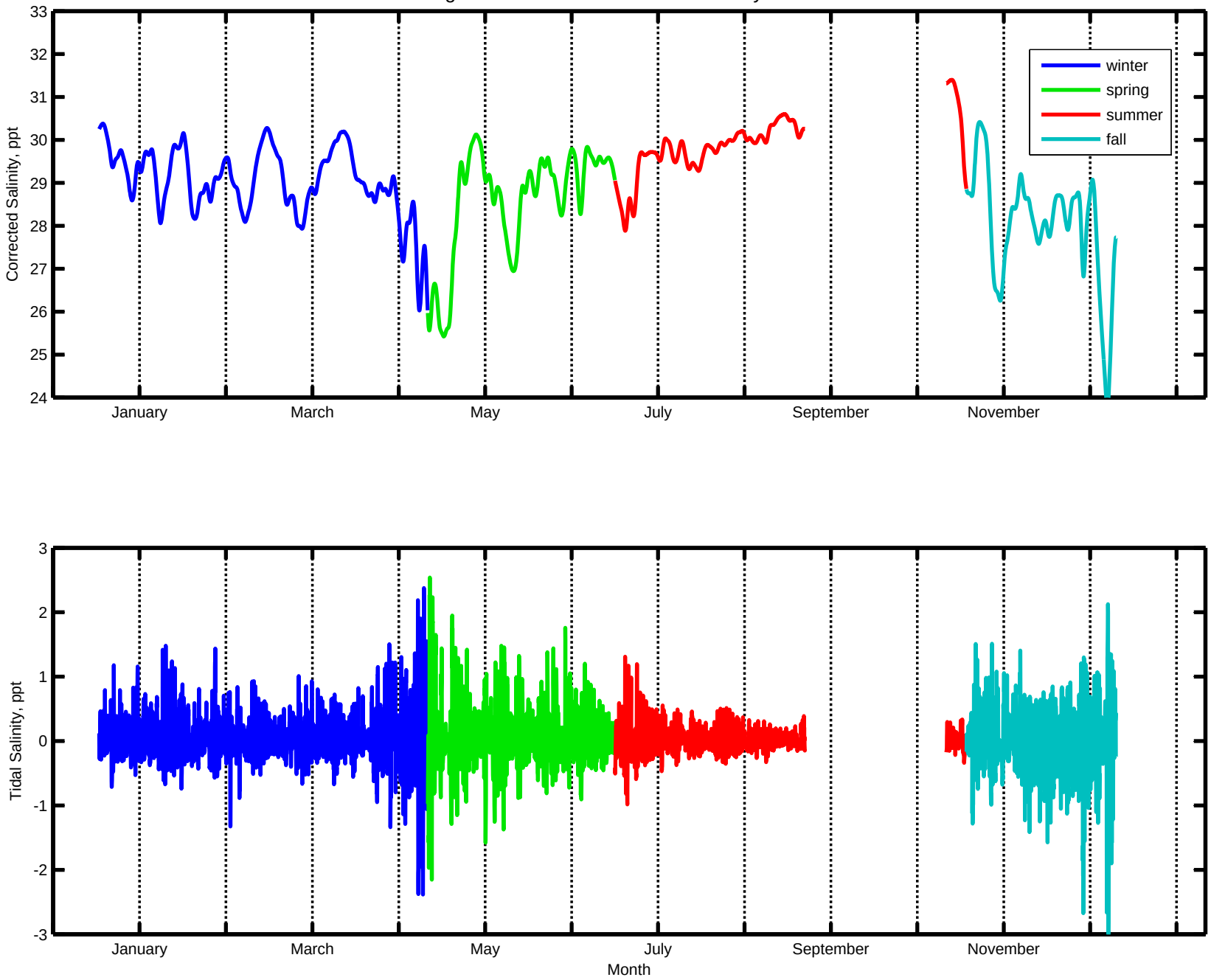

Figure 31. Corrected and Tidal Salinity -- 2006

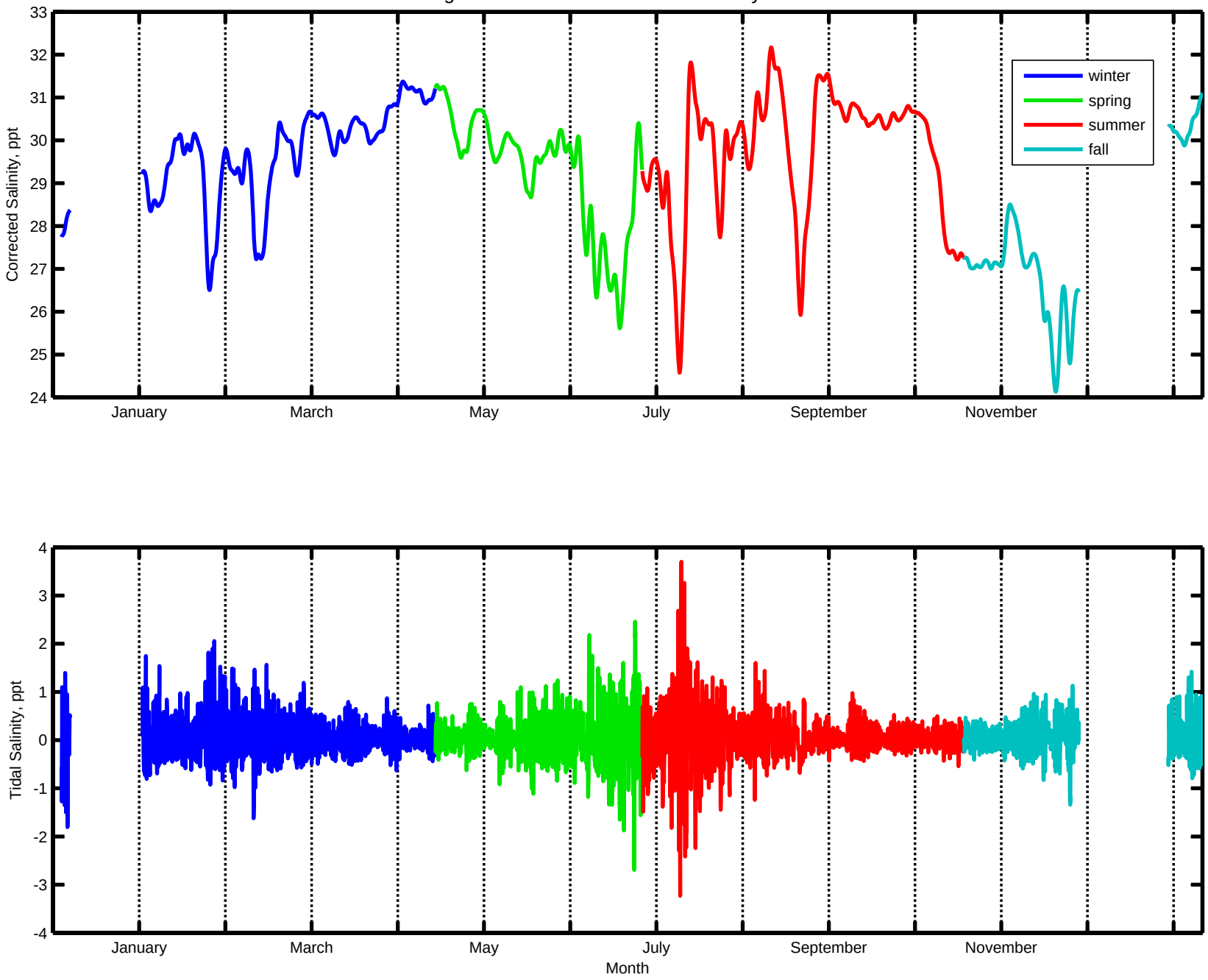

Figure 32. Corrected and Tidal Salinity -- 2007

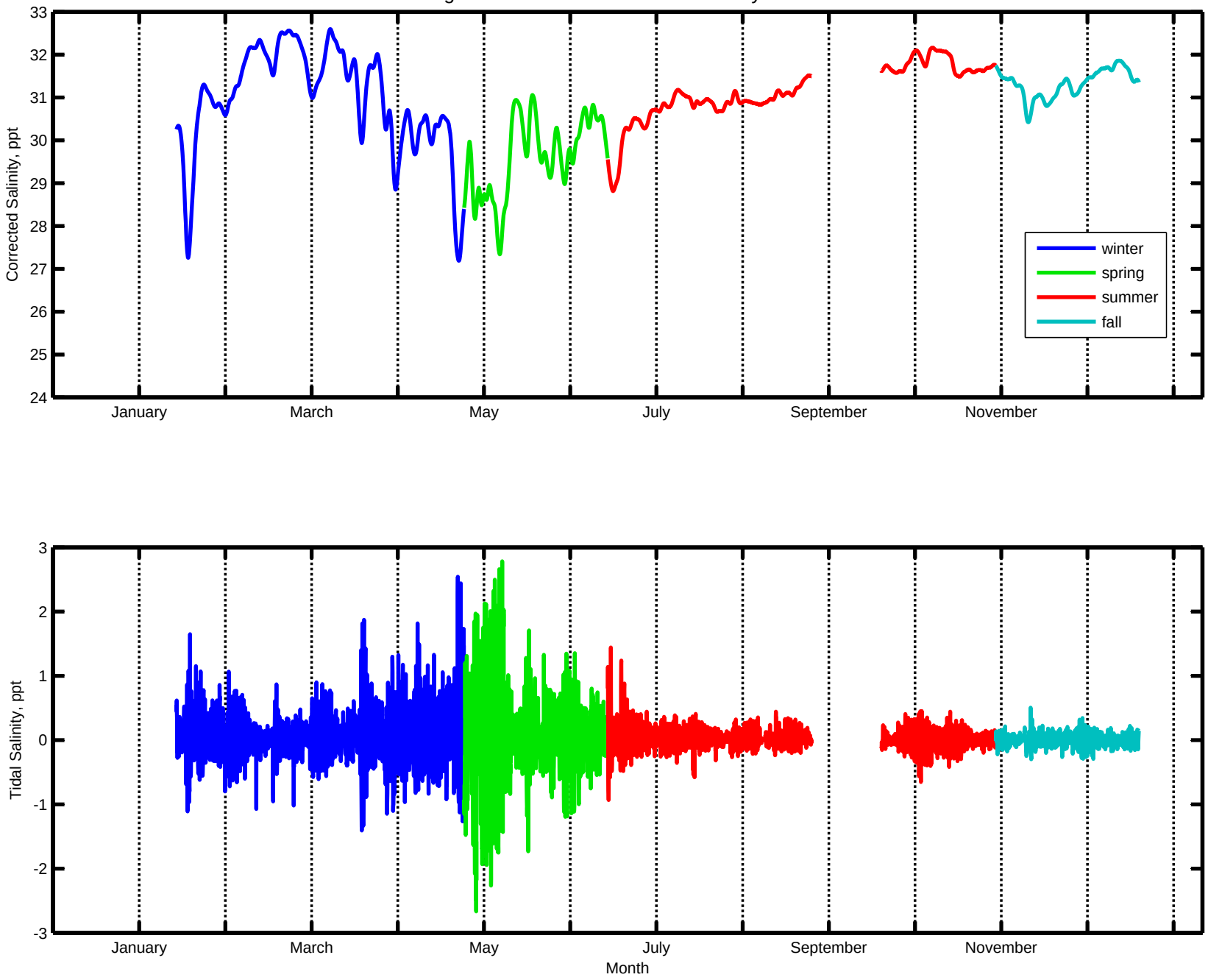

Figure 33. Corrected and Tidal Salinity -- 2008

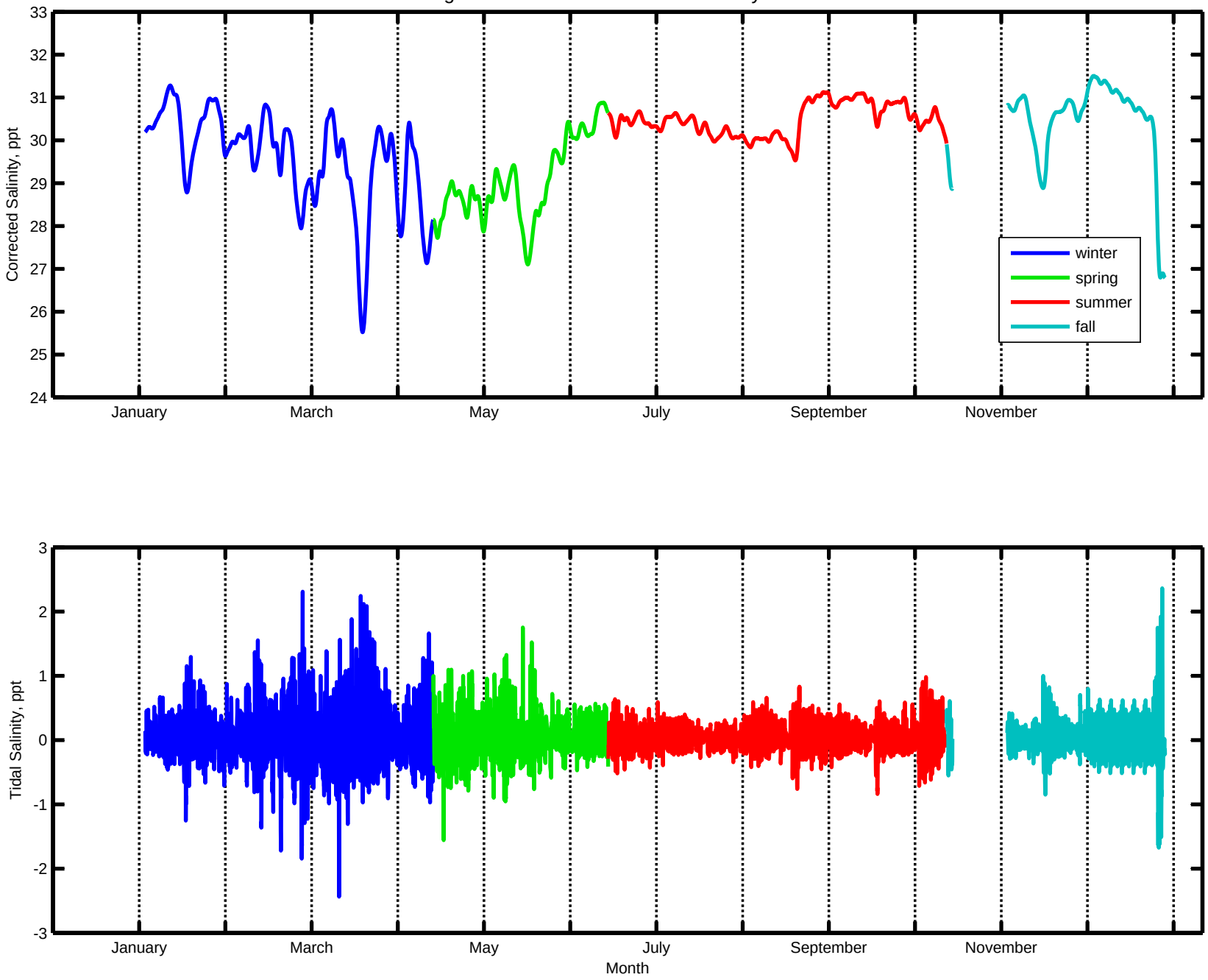

Figure 34. Corrected and Tidal Salinity -- 2009

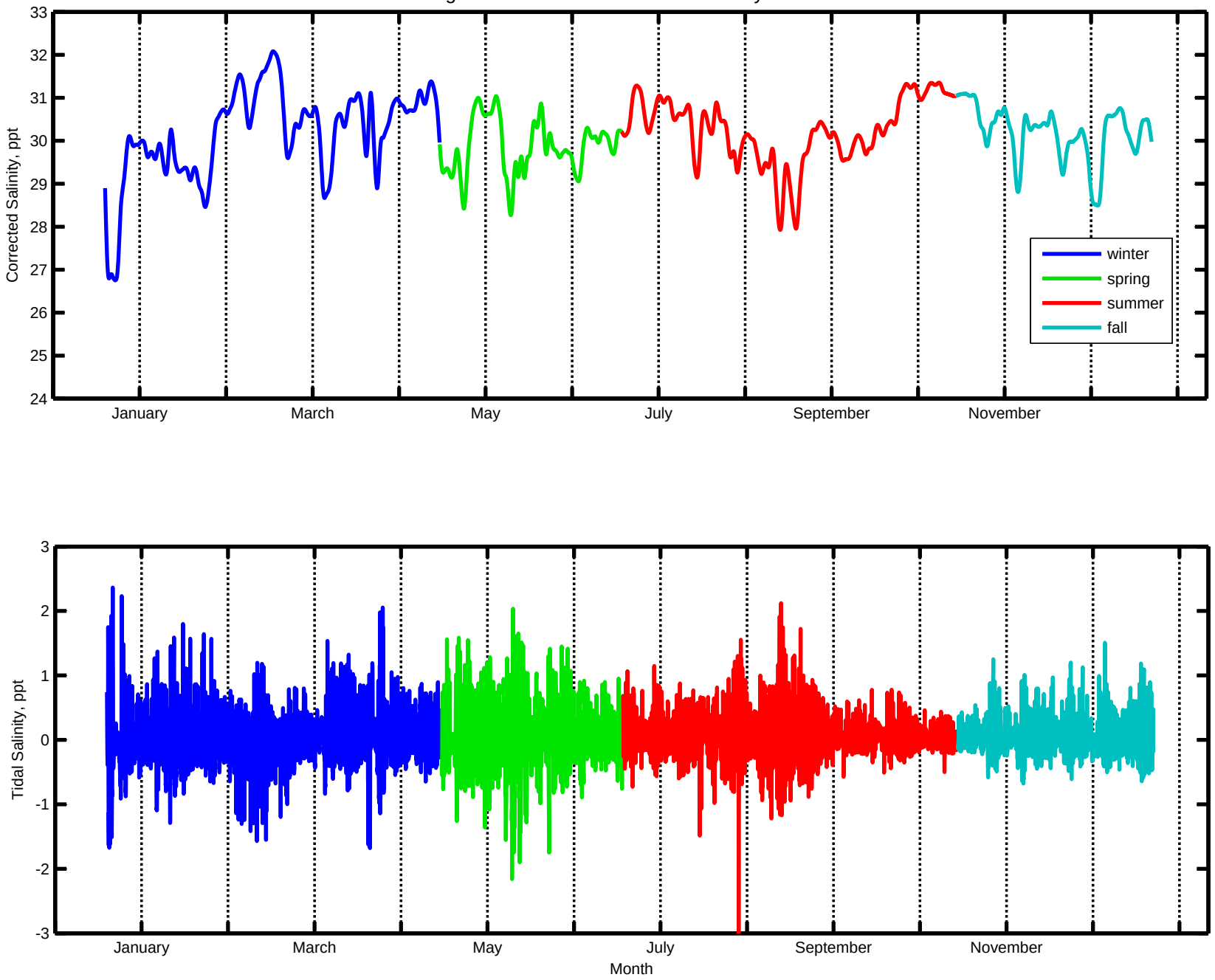

Figure 35. Corrected and Tidal Salinity -- 2010

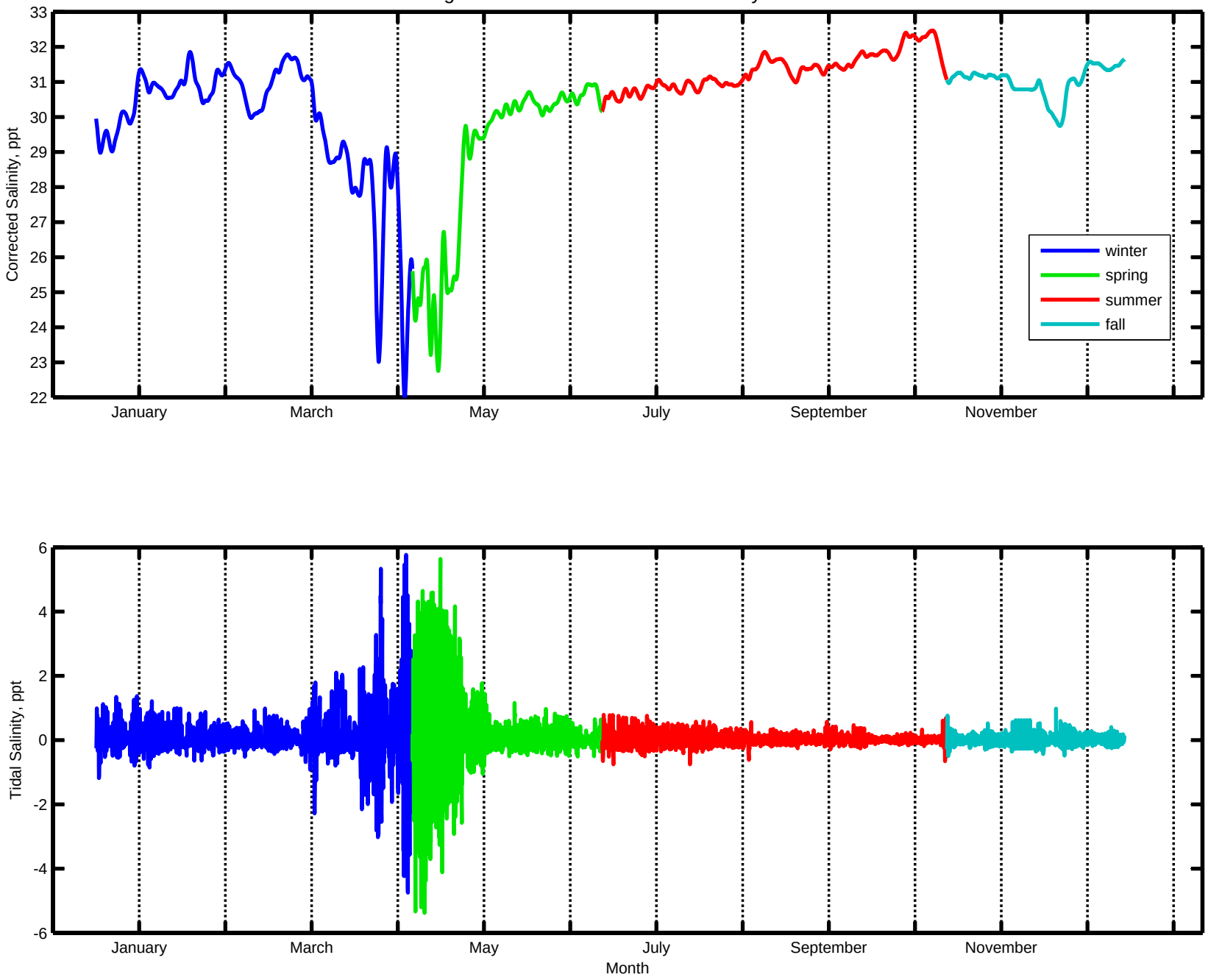

Figure 36. Corrected and Tidal Salinity -- 2011

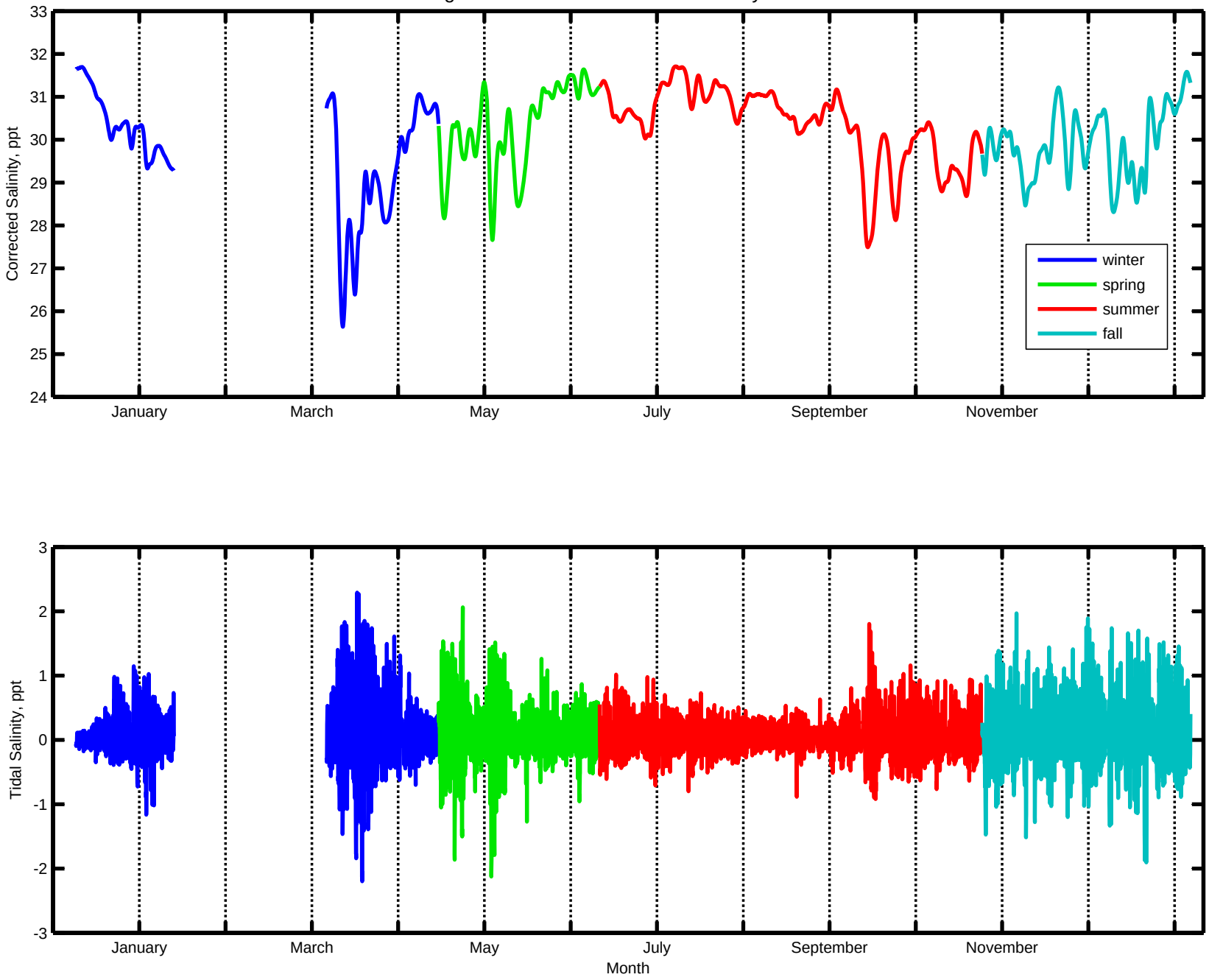

Figure 37. Tidal Temperature > 0.5°C

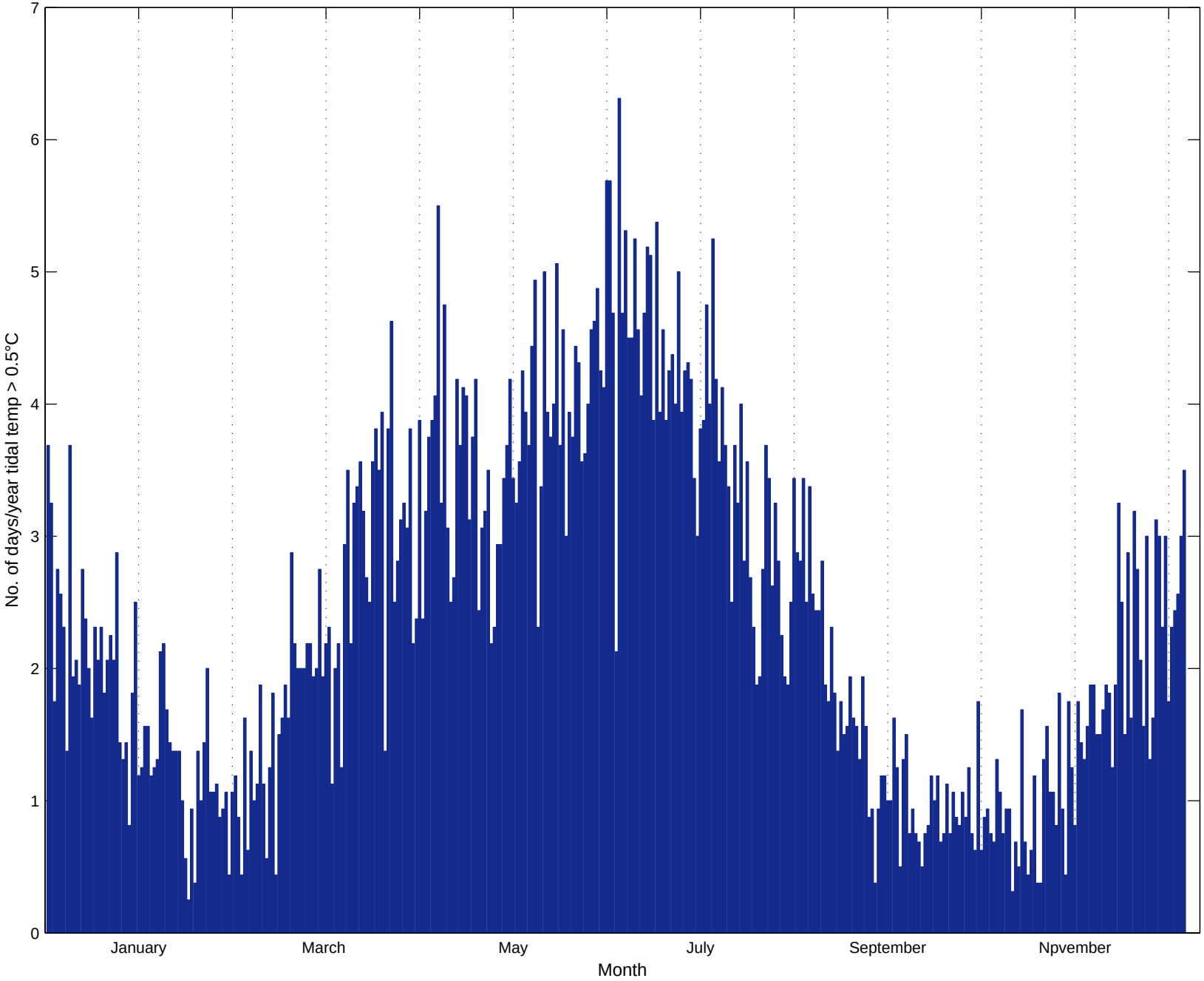

Figure 38. Tidal Salinity > 0.4 ppt and Blackstone River Flow

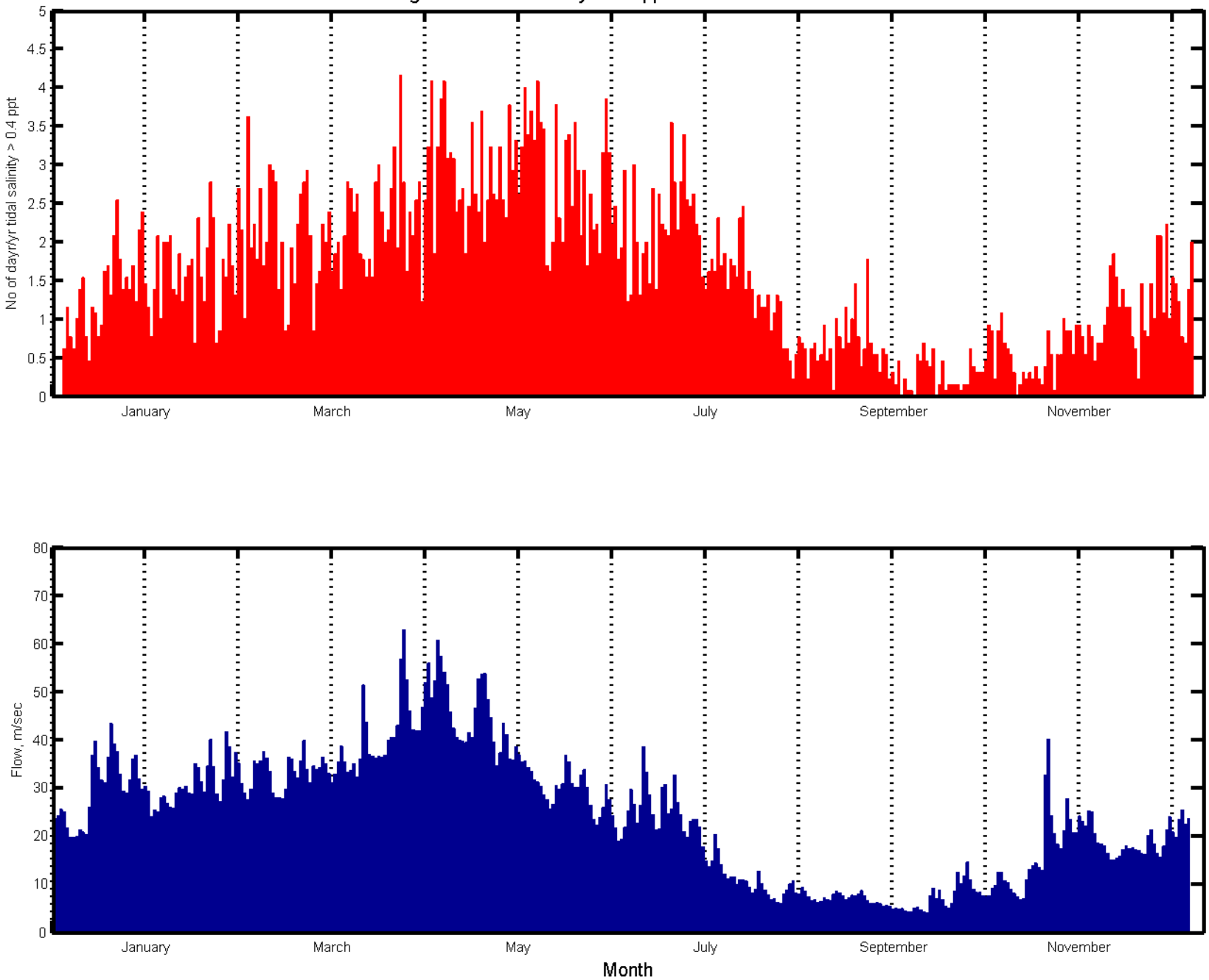

Figure 39. Buzzards Bay 1995-2011

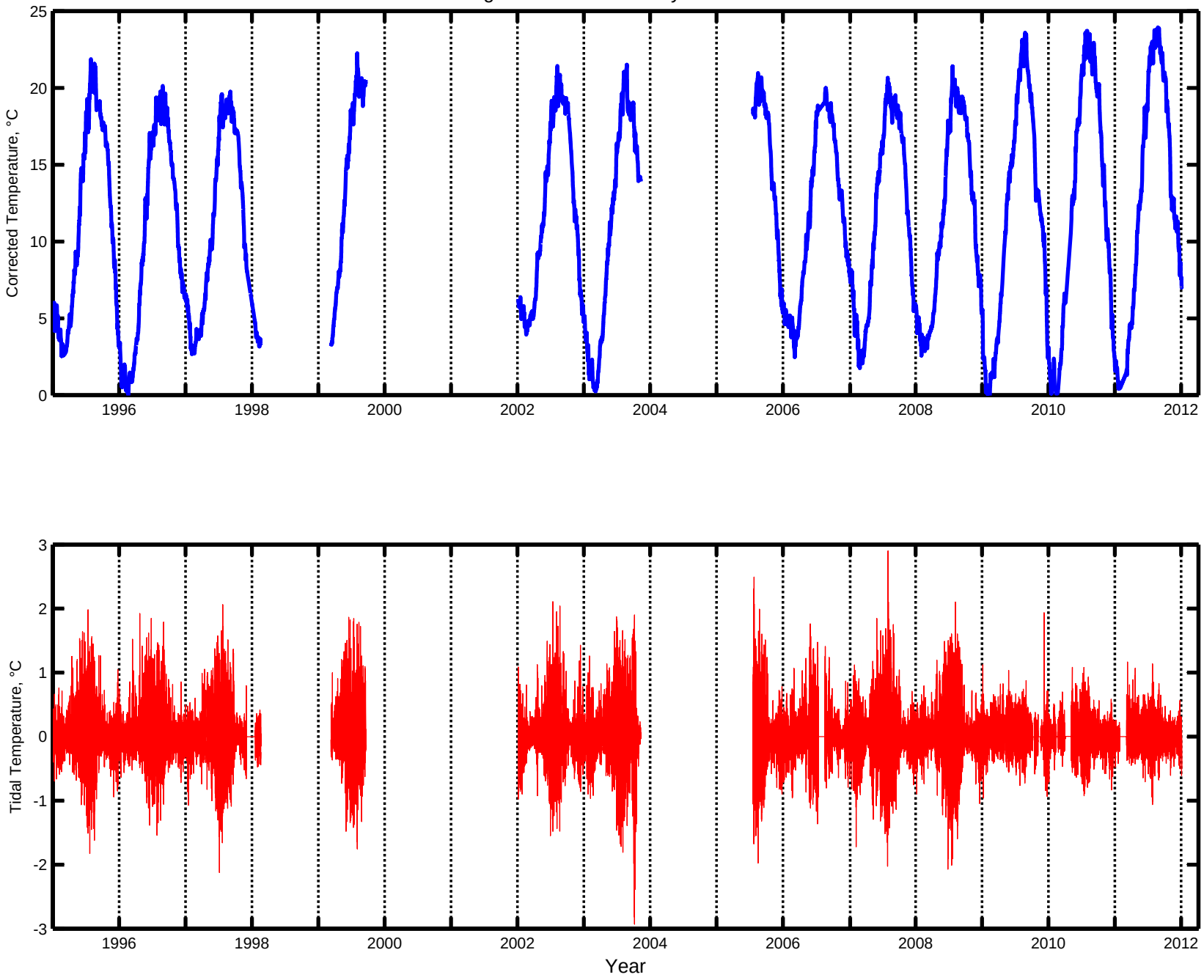

Figure 40. T-Wharf at Prudence Island 2002 - 2010