HAVSTOVAN
FAROE MARINE RESEARCH INSTITUTE

Faroese standard sections 1988 - 2010

Tórshavn ·February 2012

Updated in June 2012

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HAVSTOVAN NR.: 12-02
TECHNICAL REPORT

Contents

Introduction

In 1988, the Faroe Marine Research Institute (FAMRI), then the Faroese Fisheries Laboratory, established three standard sections: Section N along 6°05'W northwards from the Faroe shelf, Section E towards Shetland, following the Faroe side of the old Scottish Nolsoy-Flugga section, and Section V westwards from the Faroe Shelf across the Faroe Bank. In 1994, a fourth section was added: Section S, following the Scottish Munken-Fair Isle section (Fig. 1).

On each of these sections, a number of standard stations were located at fixed positions and have remained in operation with a few exceptions: On the Scottish side of Section S, oil exploration activities have necessitated moving or cancelling some stations. On Section V, the stations originally continued on a straight line westwards, but in 1998, stations V11-V14 were cancelled and instead stations V15-V19 were established on a line northwestwards from Faroe Bank. In this report stations V15-19 and V11-V14 are termed Section W and Section X, respectively (Fig. 1). Table A1 – A6 in Appendix A lists positions of all standard stations.

In most years since 1988, there have been four CTD cruises each year covering all the standard sections. Bad weather or instrument failure has caused some cruises to be incomplete, but some of the standard stations have also been occupied on other cruises.

On each cruise, CTD profiling has been carried out at standard stations down to a maximum depth of 1300 m, except for the northernmost station on Section N, where larger depths have been measured. Several different CTD systems have been used; in later years with salinity samples at each station for salinity calibration. Long-term stability of the deep Norwegian Sea TS-characteristics furthermore allows reasonable accurate salinity calibration of older CTD data.

Atlantic Water (AW) is found in the upper layers of all these sections, and in this report, we define a number of AW indices and investigate their variation over season and through the period. The indices represent AW properties (T, S) and on section N also the areal extent of AW on the section. In addition, the effect of omitting one or two cruises in winter is investigated.

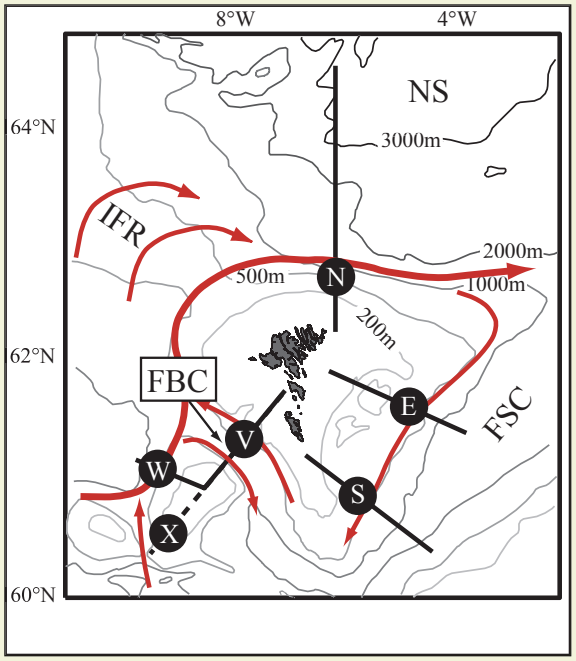

Figure 1. Topography of the Faroe Plateau and surroundings showing the Faroe Bank Channel (FBC), Faroe Shetland Channel (FSC), the Iceland-Faroe Ridge (IFR) and the Norwegian Sea (NS). Black lines indicate the Faroese standard sections, were each is labelled with a letter. Black dotted line indicates the old extension of section V (occupied until 1997). Red arrows indicate the general upper layer circulation of AW.

Definition of indices

The AW core on each section is defined as that 50m depth layer that has the highest salinity. The AW characteristics are calculated on all four sections and for Section V, three different AW cores are defined: East of the Faroe Bank, West of the Faroe Bank (stations V11-V14), and North of the Faroe Bank (stations V15-V19). This gives altogether 12 AW indices that are listed in Table 1.

The index that represents areal extent is found by adding all depth records that have salinities higher than a 50% mixing with Deep water or salinities higher than 35.0. The Deep water is here considered to have constant salinity, S=34.91. The areal indices are only considered appropriate for Section N and these two indeces are also listed in Table 1.

On section E and S crossing the Faroe Shetland Channel, the AW core definition along the whole section is not so appropriate, since the stations in the centre of the channel often are influenced by AW from the Continental Slope Current (CSC), which has higher salinities than the AW west and north of the Faroes. The AW on section E that we are interested in is the bifurcation from the Faroe Current crossing section N (Figure 1) and we expect this water to be similar or slightly fresher than the AW at section N. After testing the AW core definition on several parts of the section we ended up with only to use station E04 for the AW timeseries on section E. Station E04 is situated high on the shelf slope and is most suitable to represent the bifurcation of AW from the

Table 1

Describtion of AW indices

AW-N-T: Temperature of the AW core on Section N
AW-N-S: Salinity of the AW core on Section N
AW-E-T: Temperature of the AW core on Section E
AW-E-S: Salinity of the AW core on Section E
AW-S-T: Temperature of the AW core on Section S
AW-S-S: Salinity of the AW core on Section S
AW-V-T: Temperature of the AW core on Section V, east of Faroe Bank
AW-V-S: Salinity of the AW core on Section V, east of Faroe Bank
AW-W-T: Temperature of the AW core on Section V, northwest of Faroe Bank
AW-W-S: Salinity of the AW core on Section V, northwest of Faroe Bank
AW-X-T: Temperature of the AW core on Section V, southwest of Faroe Bank
AW-X-S: Salinity of the AW core on Section V, southwest of Faroe Bank
AW-N-Ar50%: Area of the AW on Section N saltier than 50% mixing with Deep water
AW-N-Ar35.0: Area of the AW on Section N saltier than 35.0

Faroe Current, since the current is likely to follow the bottom contours of the shelf slope.

At section S we use the same definition as on section E and choose station S03 to represent the AW on the Faroe side of the channel. Station S03 is on a similar depth contour as station E04.

The AW east of the Faroe Bank used to be defined as the 100 – 300 m average at stations V05 and V06 in the centre of the Faroe Bank Channel and later in this report this definition is compared to the new core definition described above.

Table 2 summarizes the AW timeseries definitions for each section.

Removing seasonal variation

Since the CTD data are sampled at irregular intervals methods like periodograms cannot be used to remove the seasonal variation. Fitting a cosine function to the data is often used, but after testing this method by comparing long term means from observations during summer only to observations for the whole year we found that a cosine function did not sufficiently remove the seasonal variation. Instead, monthly averages

Table 2

Description of CTD standard sections and the related AW definition. The first column lists the section name then come the station id's that are used to search for AW with conditional stations in parenthesis (i.e. stations that must be present in the data). Next is the bottom range for the stations and then the AW definition used for that section. The last three columns list the timeseries periods and average temperature and salinity, respectively, for the timeseries

Section	Stations	Bottom depth	AW def	Period	Avg temp	Avg sal
SSV (old)	V05-V06	790- 870	100-300m	1988-2010	8.52	35.27
SSV (new)	V02-V06	125- 870	50m core	1988-2010	8.81	35.30
	(V05-V06)	(790- 870)				
SSW	V16-V19	180-1024	50m core	1998-2010	9.17	35.33
SSX	V11-V14	120-340	50m core	1991-1997	8.49	35.25
SSN	N02-N14	110-3400	50m core	1987-2010	8.18	35.25
	(N02-N05)	(110-1700)				
SSE	E04	225	50m core	1988-2010	8.05	35.24
SSS	S03	280	50m core	1994-2010	8.14	35.25

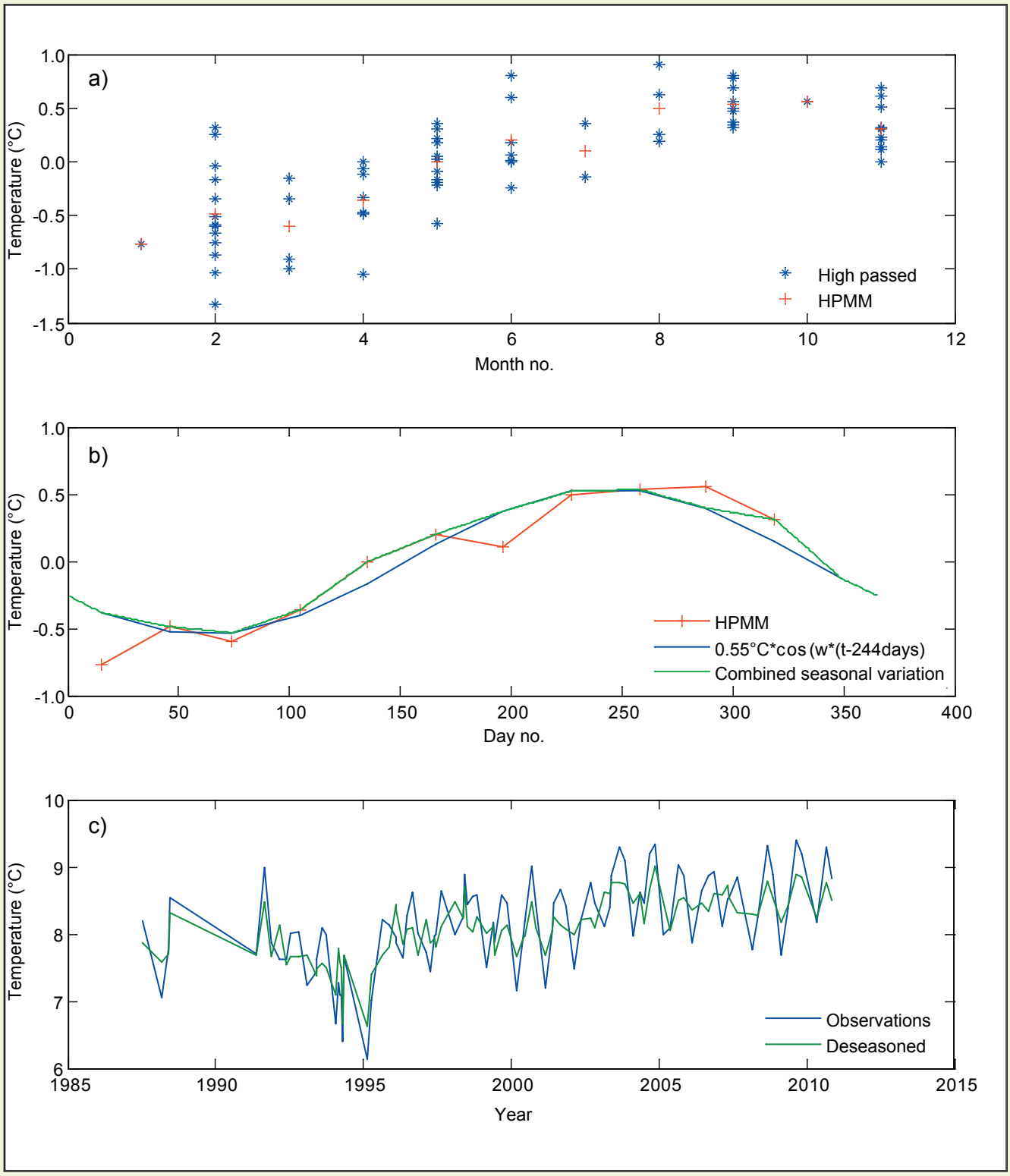

Figure 2. Deseasoning temperature at section N (an example). a) High passed observed temperature (blue) plotted by month of observation; red crosses are the high passed temperature monthly means (HPMM). b) HPMM, but now plotted against day no. in the year (redline with crosses), the least square cosine fit of HPMM (blue) and the combined seasonal variation (green). c) Observed (blue) and deseasoned (green) temperature timeseries for the period 1987 – 2010.

for the timeseries were calculated and used as the seasonal variation combined with the cosine function where data coverage was insufficient.

The more detailed process is as follows: For each of the temperature and salinity timeseries a 5-year running average is calculated and subtracted from the original data. The data points for 2.5 years in each end are omitted and the remaining series is detrended. For this high passed series, the monthly averages are first calculated. For those months in the year where the timeseries at least has 5 observations the monthly average value is used as the mid-month seasonal signal. To fill the gaps for the months with no or too few observations a cosine function is fitted to the high passed series:

$$x(t) = \cos(\omega t - \varphi)$$

With phase increments equal to one day, the phase, which gives the largest correlation, is found. The amplitude of the seasonal variation is found with linear regression, using the Matlab function Polyfit on the high passed series and the cosine function with the known phase. The mid-month values of the cosine seasonal signal is then calculated for each month and inserted into the gaps of the monthly averaged series. Thus, we now have a 12-point seasonal variation, which is piece-wise linearly interpolated into a 365-point seasonal variation. Figure 2 shows an example of the different steps in the deseasoning process. The timeseries used in Figure 2 has gaps larger than a year in the beginning of the series – such data points are not included in the deseasoning process. Plots of the T and S seasonal variation and of the observed and deseasoned timeseries for each of the sections is shown in Appendix B, as well as for the AW areas at SSN.

Timeseries

Deseasoned (observations – seasonal variation) timeseries of the AW core T and S for each of the sections are shown in Figure 3. In the early 1990s both temperature and salinities were at a minimum and have more or less been increasing until reaching record high values in the 2000s. The same variability is observed at all series, but the sections V, W and X have significantly higher temperatures and salinities than the sections N, E and S.

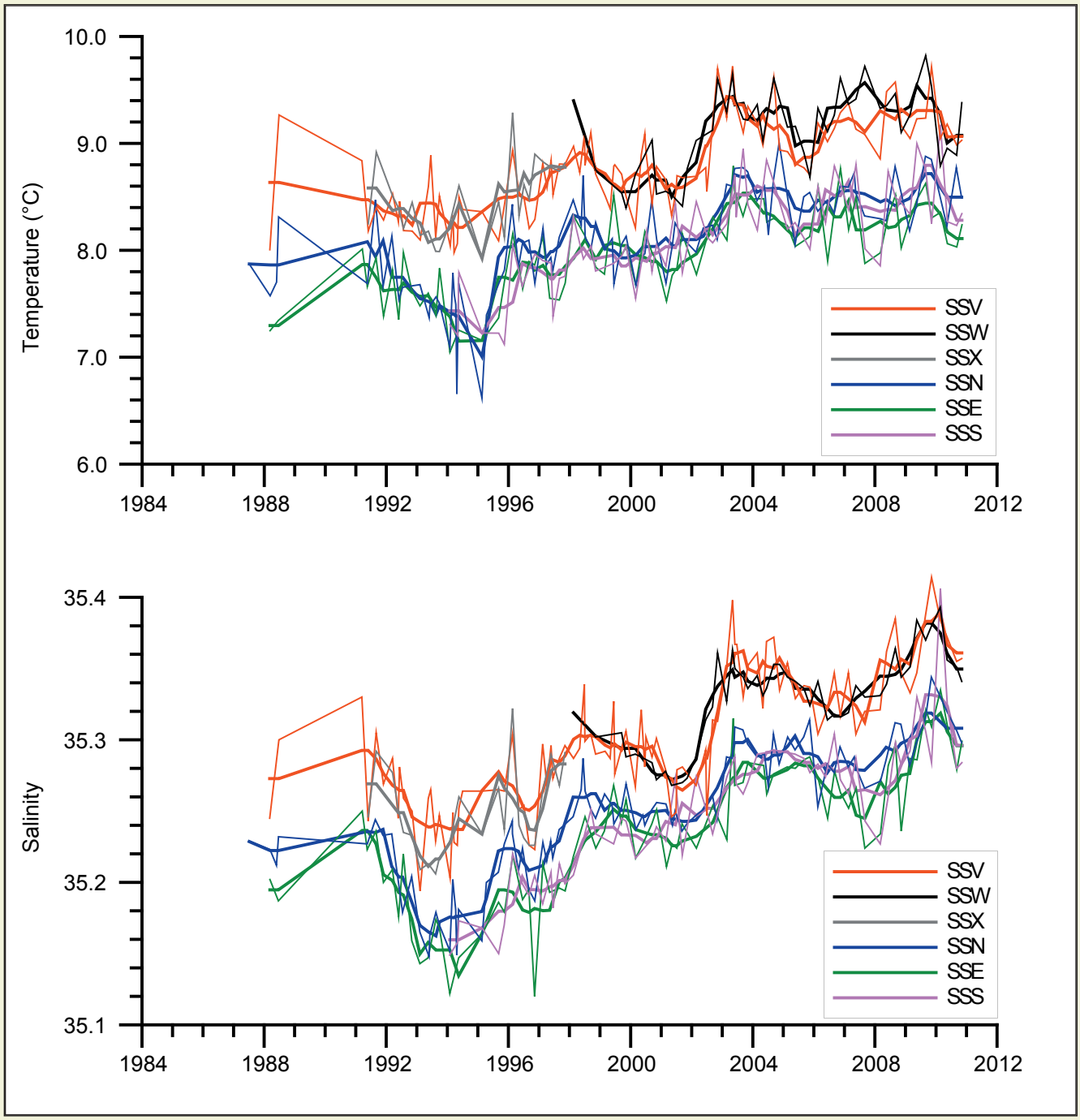

Figure 3. Timeseries of deseasoned core temperature (upper) and salinity (lower) at the six sections and subsections indicated by labels in Fig. 1. Thin lines are individual observations, while thick lines are one-year running mean.

Section V – old vs. new AW definition

In the Faroe Bank Channel we hitherto have used the two stations in the centre of the cannel (V05 and V06) where the average from these to stations at 100 – 300 meter depth has been used as the timeseries values. In Figure 4 this definition of the FBC timeseries is compared to an AW core definition along stations V02 through V06. As expected, the AW core definition generally has higher salinities and temperatures, which on average for the whole period is 0.03 in salinity and 0.3 °C in temperature.

With and without autumn and/or winter cruises

The standard sections usually have been occupied on cruises in February, May/June, September and November. The question now has arisen whether it is possible to reduce the number of occupations per year and if/how this would affect the timeseries. The most obvious cruises to abandon would be the February and/or the November cruises since these are more exposed to bad weather and the risk of incomplete sections and these periods are also the less interesting from a biological point of view. If only one of them is to be abandoned, November would be the obvious choice since February intuitively is expected to give a better representation of winter conditions. To test the effect of having no observations in winter 1-, 2-, 3- and 5-year running averages are calculated on the deseasoned series including all observations, excluding observations from October through December (autumn) and excluding observations from October through March (autumn and winter), respectively. These results are plotted in Appendix C for T and S for each of the sections. Generally, removing the autumn observations only has a small effect on the averaged series, while removing both autumn and winter has a rather large effect for some of the series in some periods. For both conditions a larger averaging period decreases the differences, but at the 5-year running average there still are rather large differences for some of the series (e.g. Section E, temperature, Figure C7).

The conclusion of this analysis thus is that the November cruises may be omitted in the future while the February cruises may not. The conclusion is based on a calculated seasonal variation from long timeseries sampled four times a year. Calculations of seasonal variations based on 3 samples per year has not been tested.

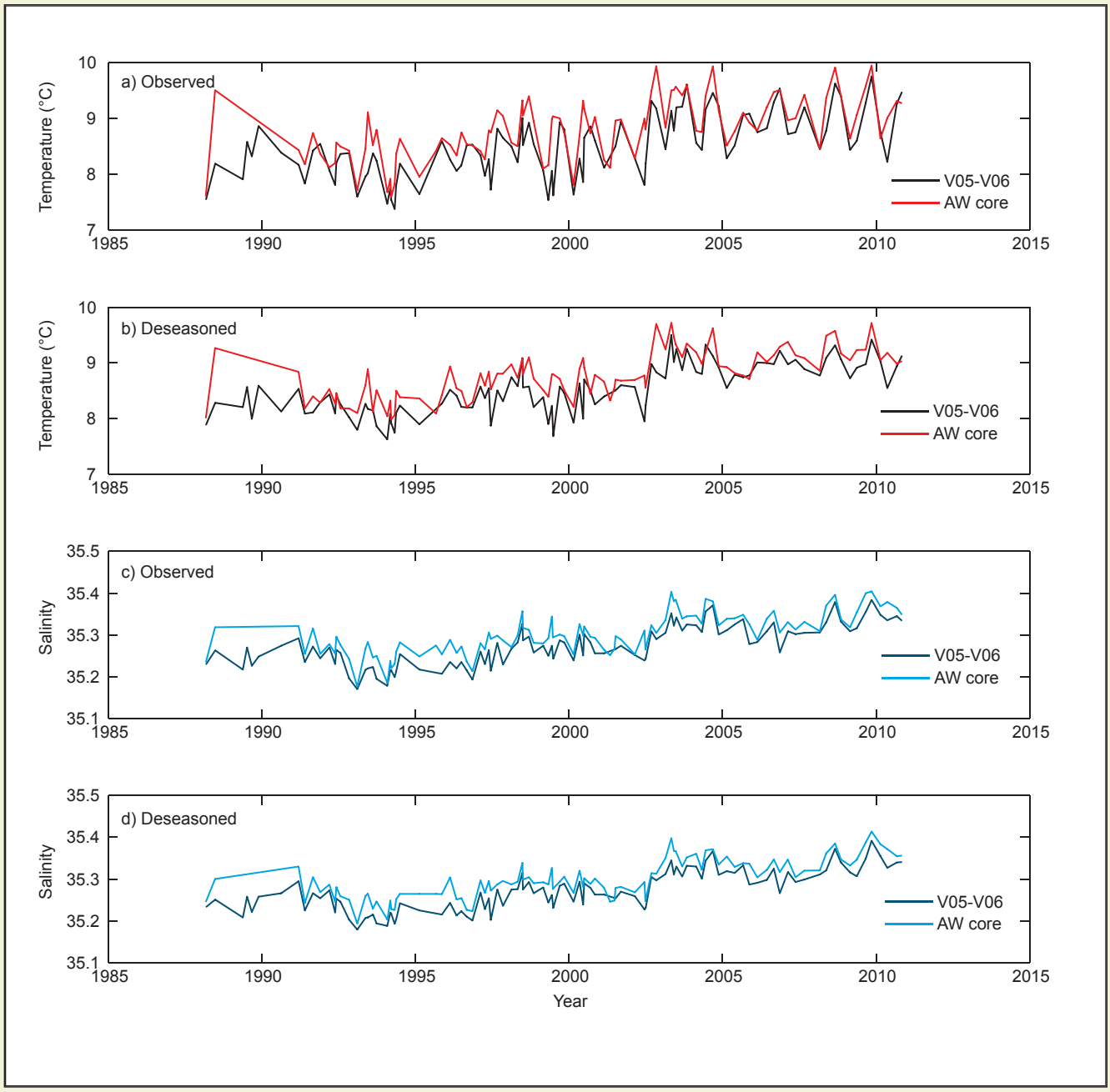

Figure 4. Comparison of timeseries based on an average from V05 and V06 and on an AW core definition for V02 – V06. Panels a) and b) are observed and deseasoned temperature timeseries, respectively, while panels c) and d) are observed and deseasoned salinity timeseries.

Appendix A – Details of standard sections

For each section is first a table listing metadata for the CTD stations. Then are shown examples of distribution of temperature and salinity along each section, except section X. On these plots detailed bottom topography along the sections is also shown.

Table A1. Section V (Faroe Bank Channel)

Station	Latitude	Longitude	Bottom depth
V01	61°50.00'N	7°00.00'W	75 m
V02	61°40.00'N	7°18.00'W	125 m
V03	61°30.00'N	7°35.00'W	235 m
V04	61°25.00'N	7°44.00'W	360 m
V05	61°20.00'N	7°53.00'W	790 m
V06	61°16.00'N	8°00.00'W	870 m
V07	61°13.00'N	8°06.00'W	440 m
V08	61°10.00'N	8°11.00'W	130 m
V09	61°05.00'N	8°20.00'W	95 m
V10	60°59.00'N	8°28.00'W	108 m

Table A2. Section W (Northwest of Faroe Bank). The section was initiated in 1998

Station	Latitude	Longitude	Bottom depth
V15	61°02.00'N	8°43.00'W	98 m
V16	61°05.00'N	8°58.00'W	180 m
V17	61°08.00'N	9°13.00'W	378 m
V18	61°11.00'N	9°28.00'W	720 m
V19	61°14.00'N	9°43.00'W	1024 m

Table A3. Section X (Southwest of Faroe Bank). The section was terminated in 1997

Station	Latitude	Longitude	Bottom depth
V11	60°52.00'N	8°40.00'W	135 m
V12	60°45.00'N	8°52.00'W	120 m
V13	60°35.00'N	9°08.00'W	175 m
V14	60°28.00'N	9°20.00'W	340 m

Table A4. Section N (Faroe Current)

Station	Latitude	Longitude	Bottom depth
N01	62°20.00'N	6°05.00'W	82 m
N02	62°30.00'N	6°05.00'W	110 m
N03	62°40.00'N	6°05.00'W	200 m
N04	62°50.00'N	6°05.00'W	550 m
N05	63°00.00'N	6°05.00'W	1700 m
N06	63°10.00'N	6°05.00'W	1900 m
N07	63°20.00'N	6°05.00'W	1700 m
N08	63°30.00'N	6°05.00'W	1800 m
N09	63°40.00'N	6°05.00'W	2150 m
N10	63°50.00'N	6°05.00'W	2900 m
N11	64°00.00'N	6°05.00'W	3400 m
N12	64°10.00'N	6°05.00'W	3200 m
N13	64°20.00'N	6°05.00'W	3400 m
N14	64°30.00'N	6°00.00'W	3300 m

Table A5. Section E (Nolsoy - Flugga). Only station E04 is used for the AW timeseries

Station	Latitude	Longitude	Bottom depth
E01	62°00.00'N	6°12.00'W	120 m
E02	61°54.00'N	5°45.00'W	280 m
E03	61°49.00'N	5°21.00'W	175 m
E04	61°42.00'N	4°51.00'W	225 m
E05	61°38.00'N	4°33.00'W	530 m
E06	61°35.00'N	4°15.00'W	960 m
E07	61°32.00'N	3°57.00'W	1200 m
E08	61°28.00'N	3°42.00'W	1220 m

Table A6. Section S (The Munk – Fair Isle). Only station S03 is used for the AW timeseries. Station S11 is not listed – due to oil exploration it has had three different positions and was finally cancelled in 2003.

Station	Latitude	Longitude	Bottom depth
S01	61°16.40'N	6°37.70'W	100 m
S02	61°12.00'N	6°22.00'W	240 m
S2A	61°07.20'N	6°09.40'W	250 m
S03	61°02.00'N	5°57.00'W	280 m
S3A	60°56.70'N	5°42.80'W	333 m
S04	60°51.00'N	5°29.00'W	610 m
S05	60°47.00'N	5°16.00'W	830 m
S06	60°43.00'N	5°06.00'W	910 m
S07	60°38.00'N	4°54.00'W	1020 m
S08	60°35.00'N	4°45.00'W	1085 m
	Borderline		
S09	60°29.00'N	4°26.00'W	975 m
S10	60°25.00'N	4°19.00'W	670 m
S12	60°16.00'N	3°59.00'W	200 m
S13	60°10.00'N	3°44.00'W	150 m

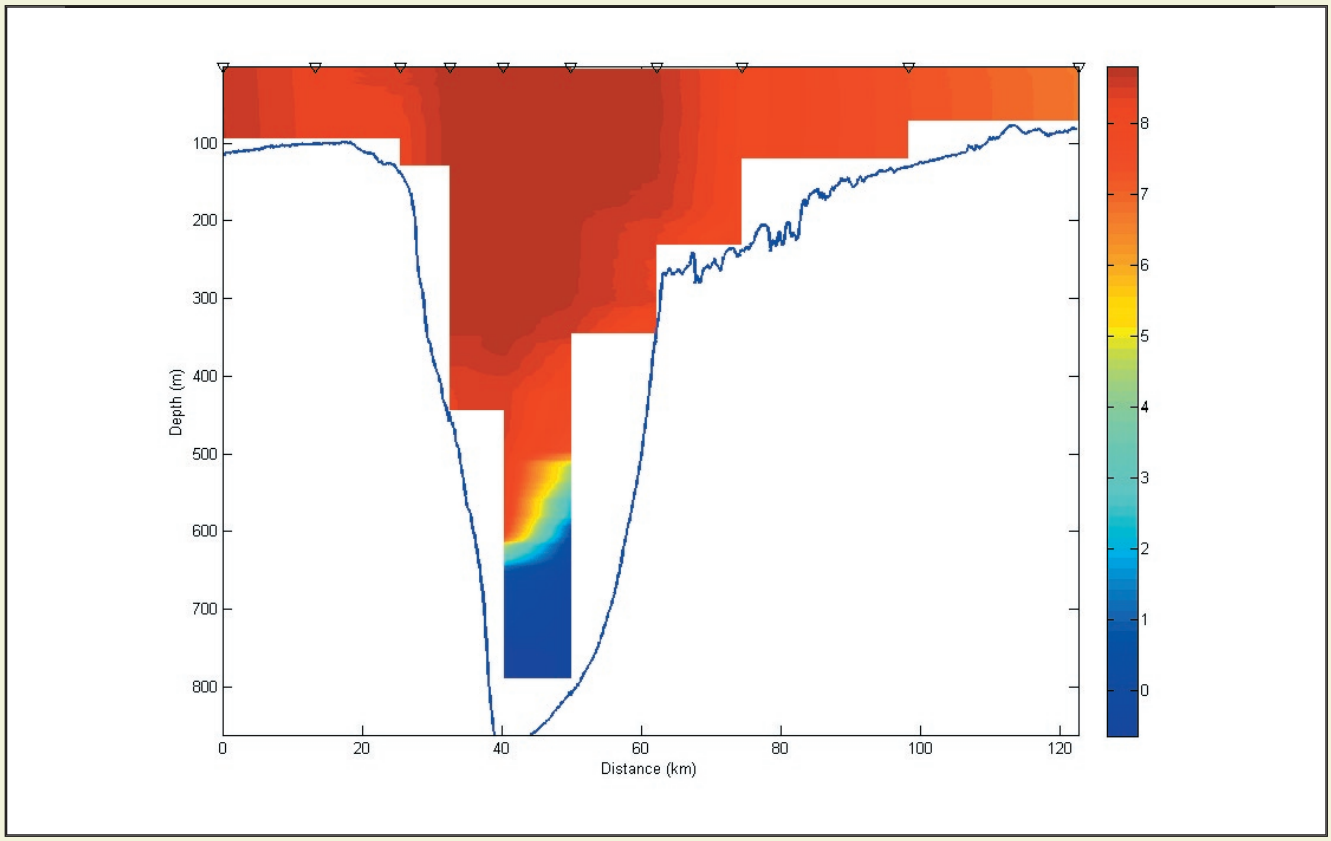

Figure A1. Example of temperature distribution along standard section V (Cruise 1002, February 2010). Blue line indicates bottom depth along the section. Black open triangles are locations of the standard stations where V10 is to the left and V01 to the right.

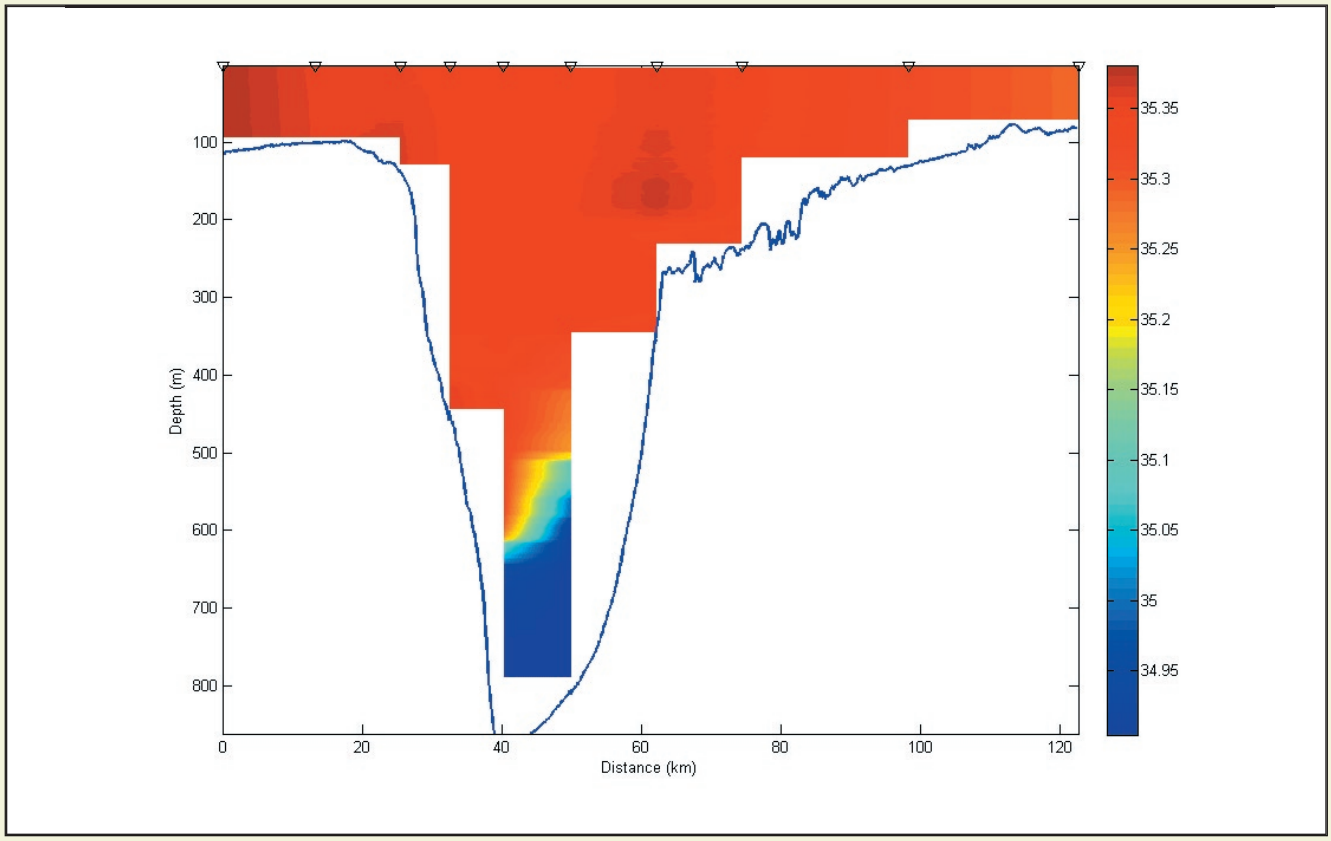

Figure A2. Example of salinity distribution along standard section V (Cruise 1002, February 2010). Blue line indicates bottom depth along the section. Black open triangles are locations of the standard stations where V10 is to the left and V01 to the right.

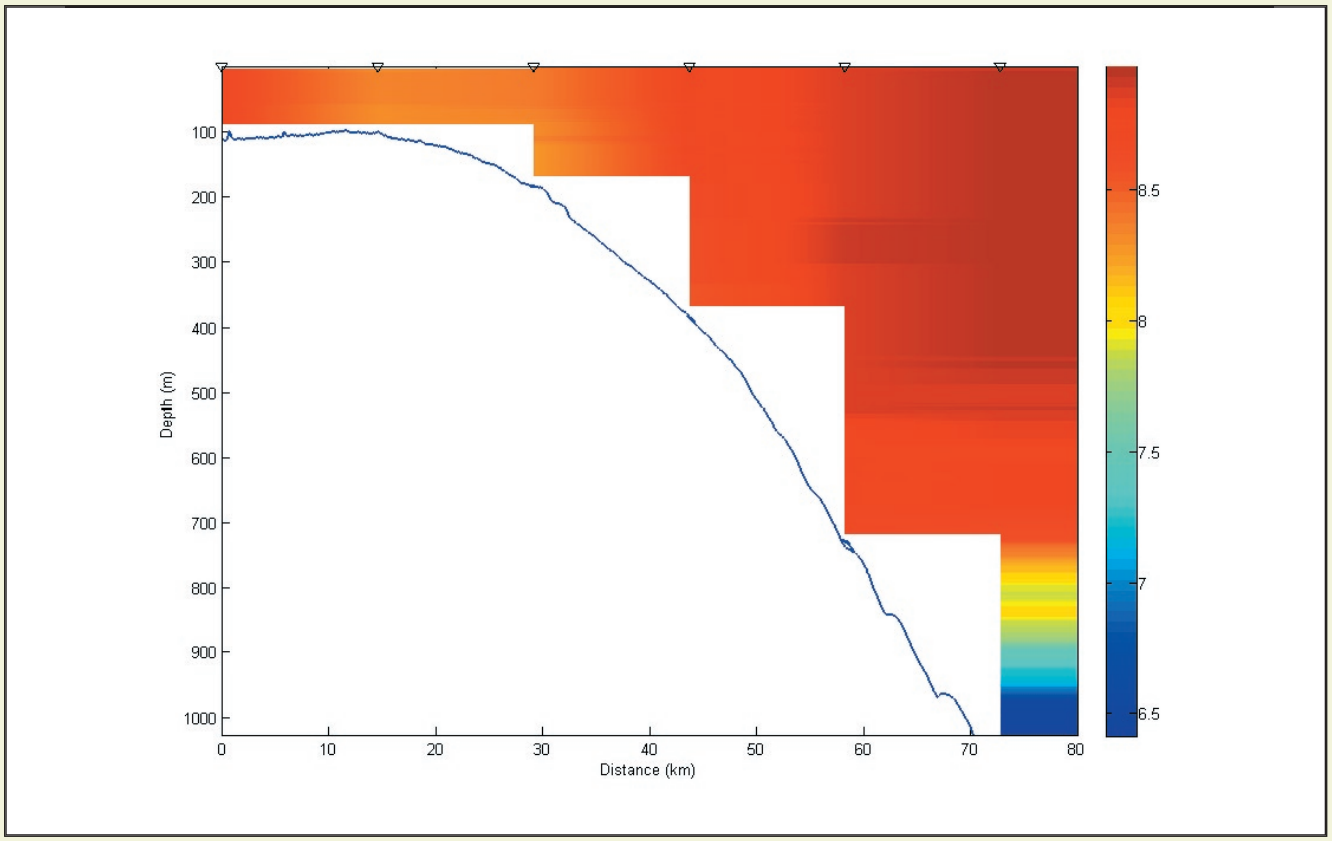

Figure A3. Example of temperature distribution along standard section W (Cruise 1002, February 2010). Blue line indicates bottom depth along the section. Black open triangles are locations of the standard stations where V10 is to the left and then comes V15 through V19.

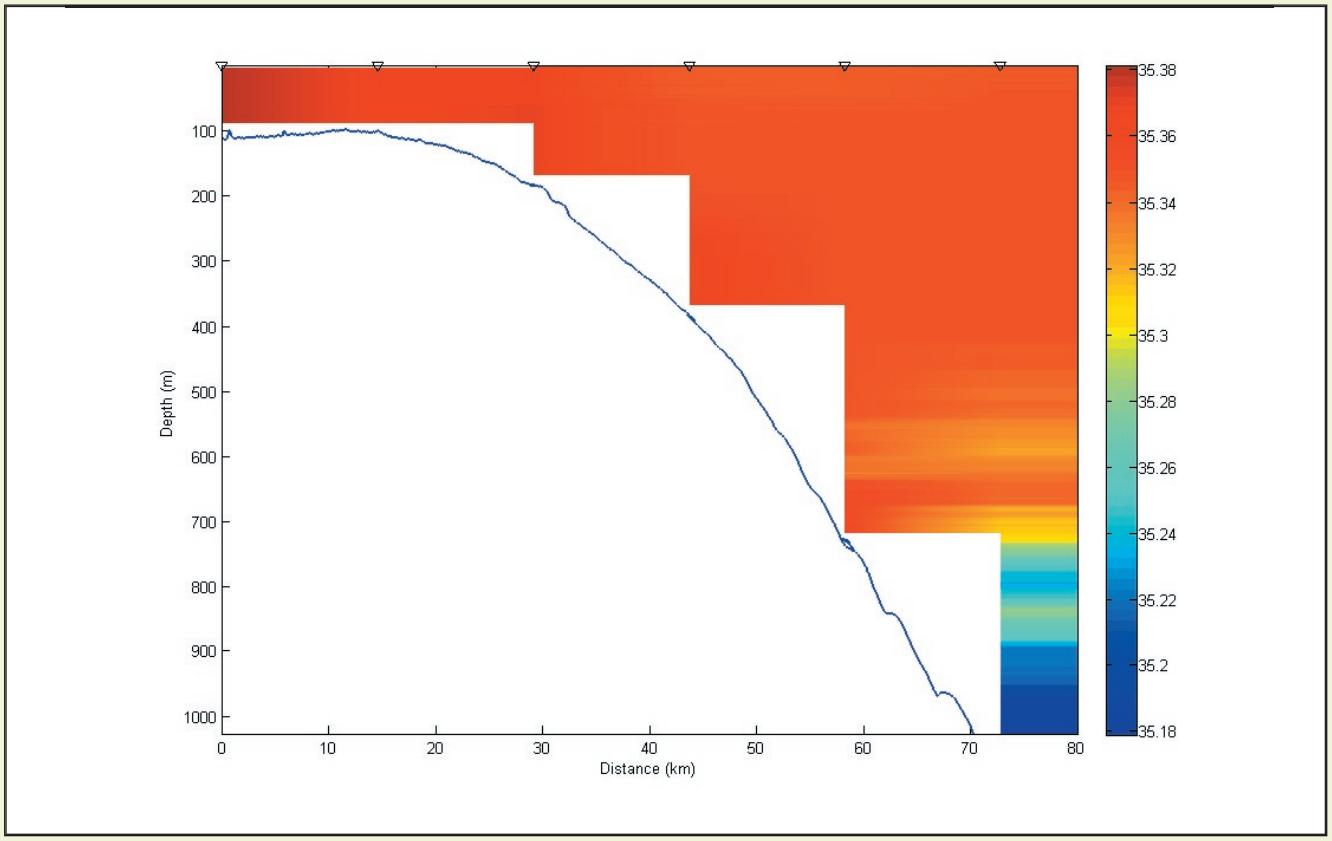

Figure A4. Example of salinity distribution along standard section W (Cruise 1002, February 2010). Blue line indicates bottom depth along the section. Black open triangles are locations of the standard stations where V10 is to the left and then comes V15 through V19.

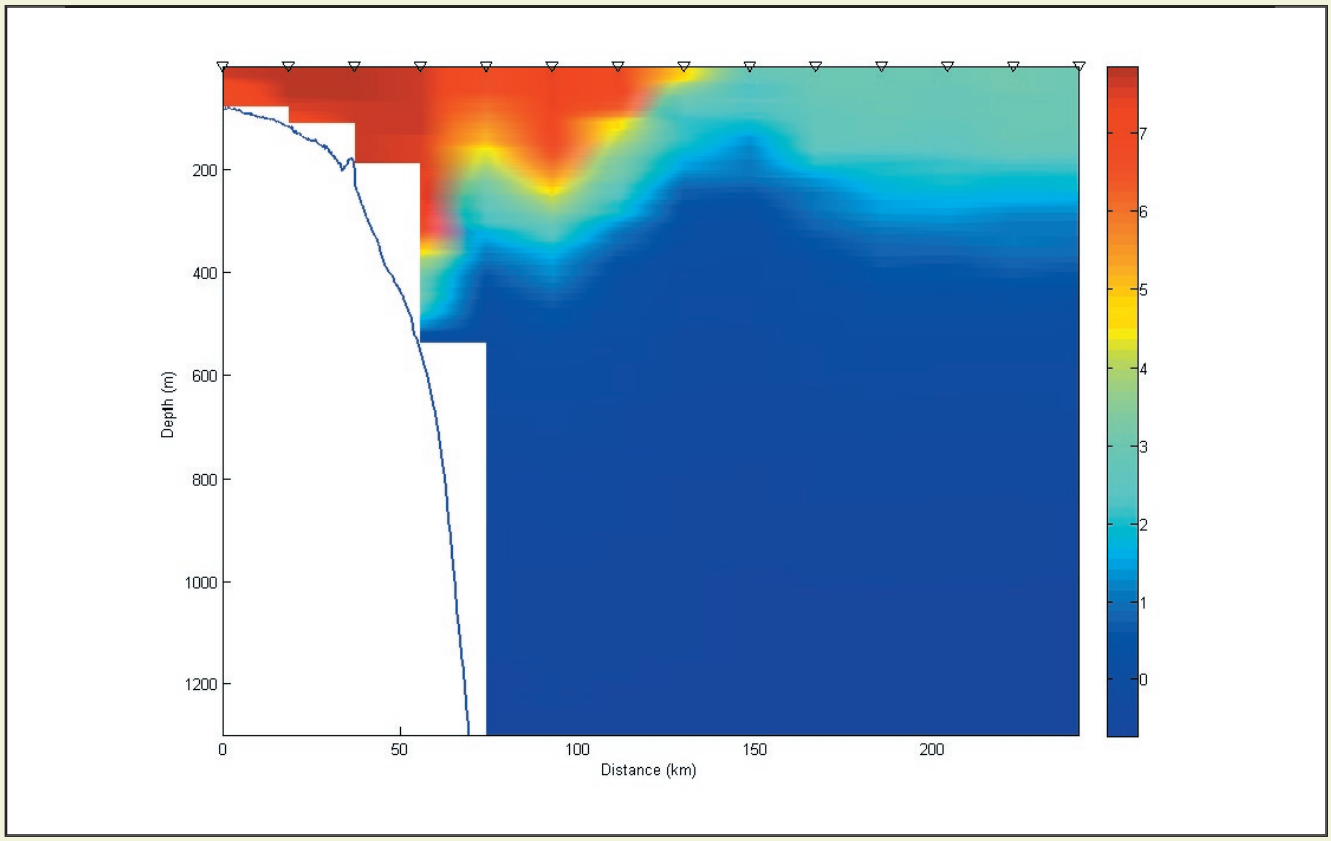

Figure A5. Example of temperature distribution along standard section N (Cruise 0904, February 2009). Blue line indicates bottom depth along the section. Black open triangles are locations of the standard stations where No1 is to the left.

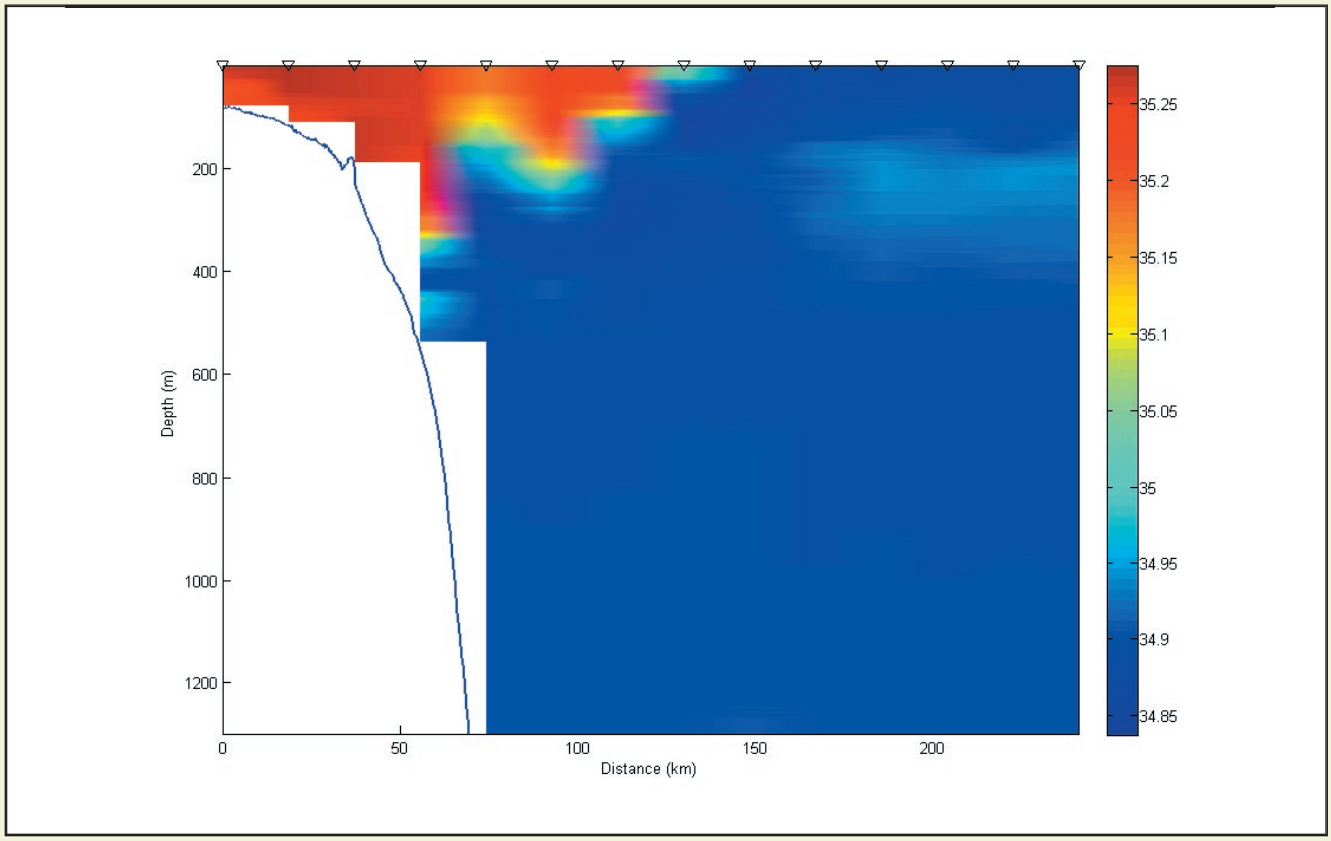

Figure A6. Example of salinity distribution along standard section N (Cruise 0904, February 2009). Blue line indicates bottom depth along the section. Black open triangles are locations of the standard stations where No1 is to the left.

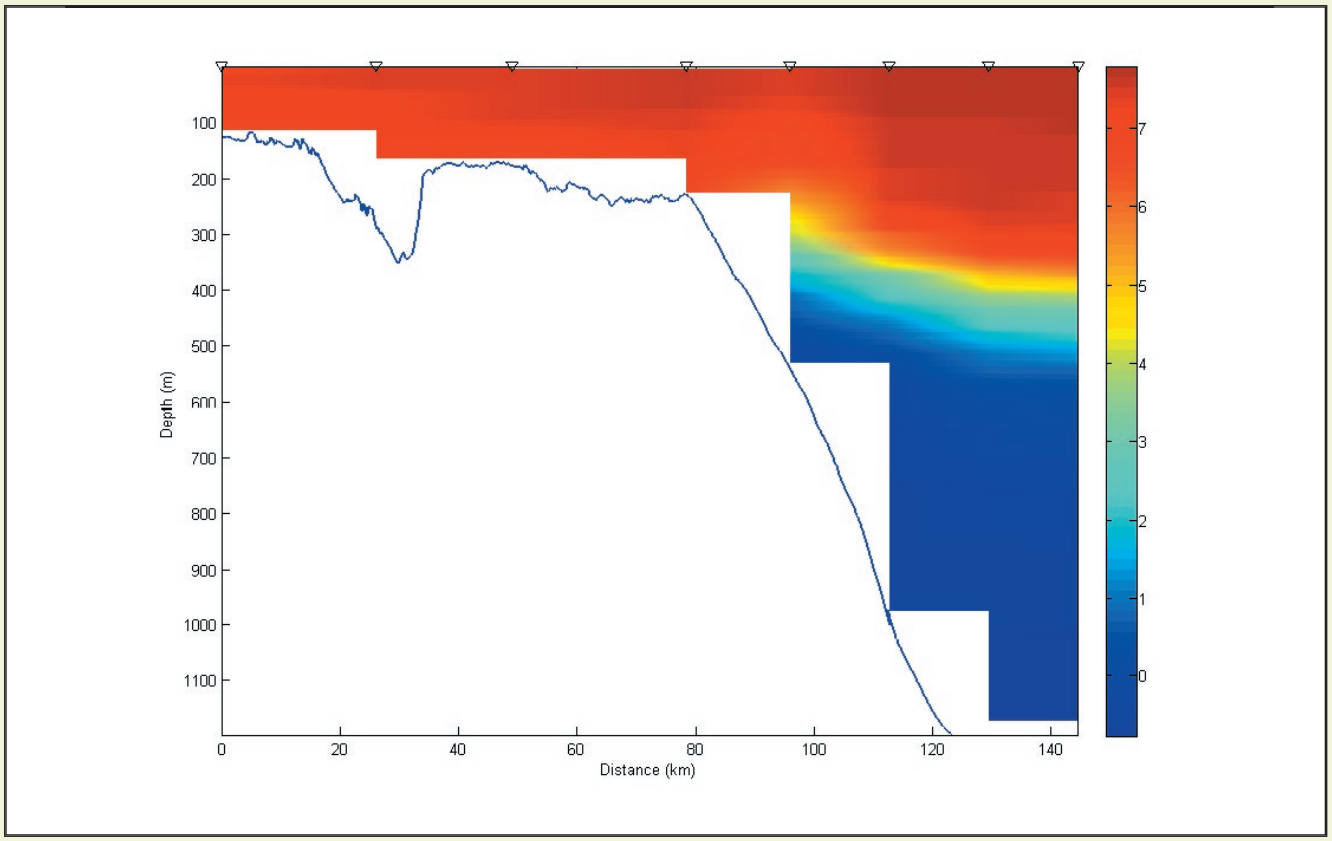

Figure A7. Example of temperature distribution along standard section E (Cruise 0904, February 2009). Blue line indicates bottom depth along the section. Black open triangles are locations of the standard stations where E01 is to the left.

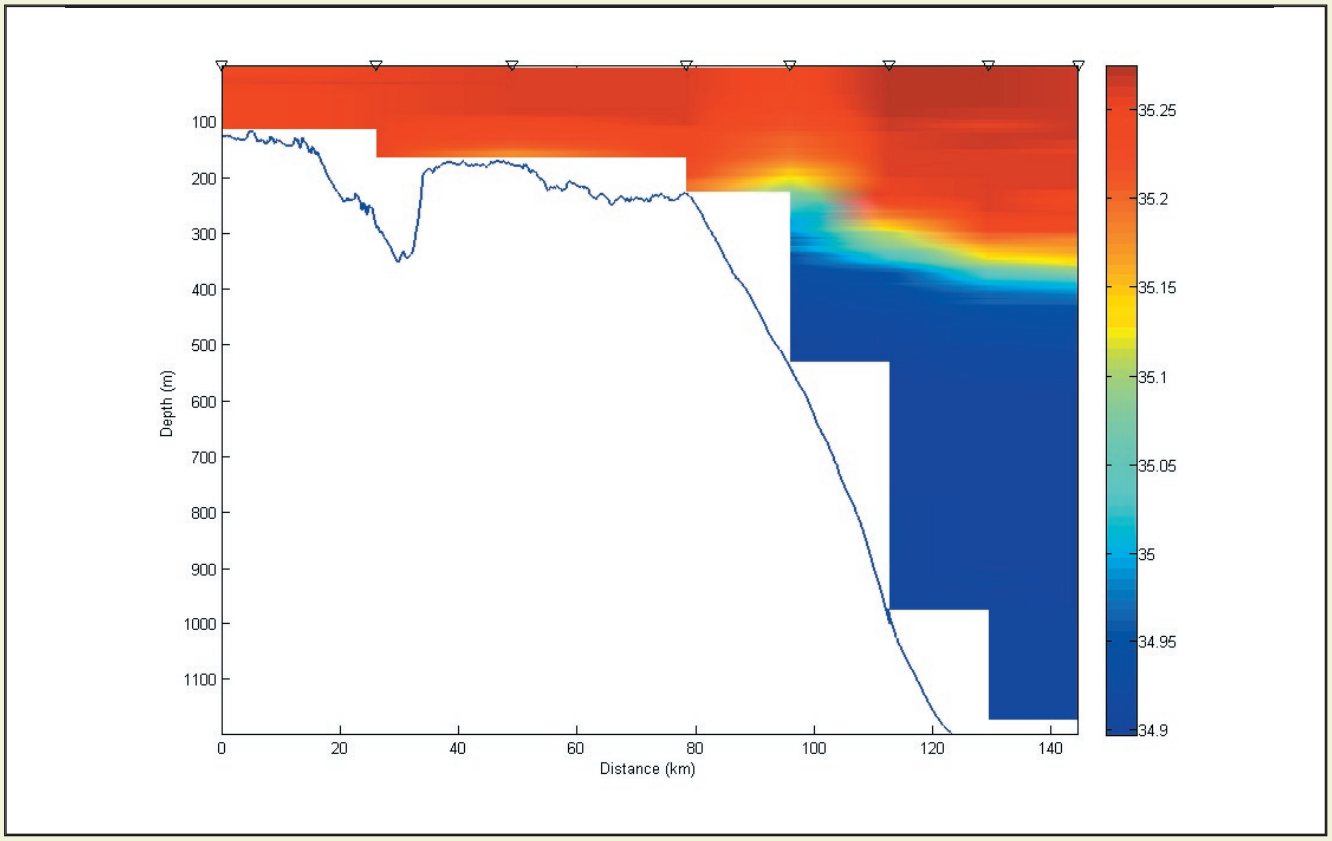

Figure A8. Example of salinity distribution along standard section E (Cruise 0904, February 2009). Blue line indicates bottom depth along the section. Black open triangles are locations of the standard stations where E01 is to the left.

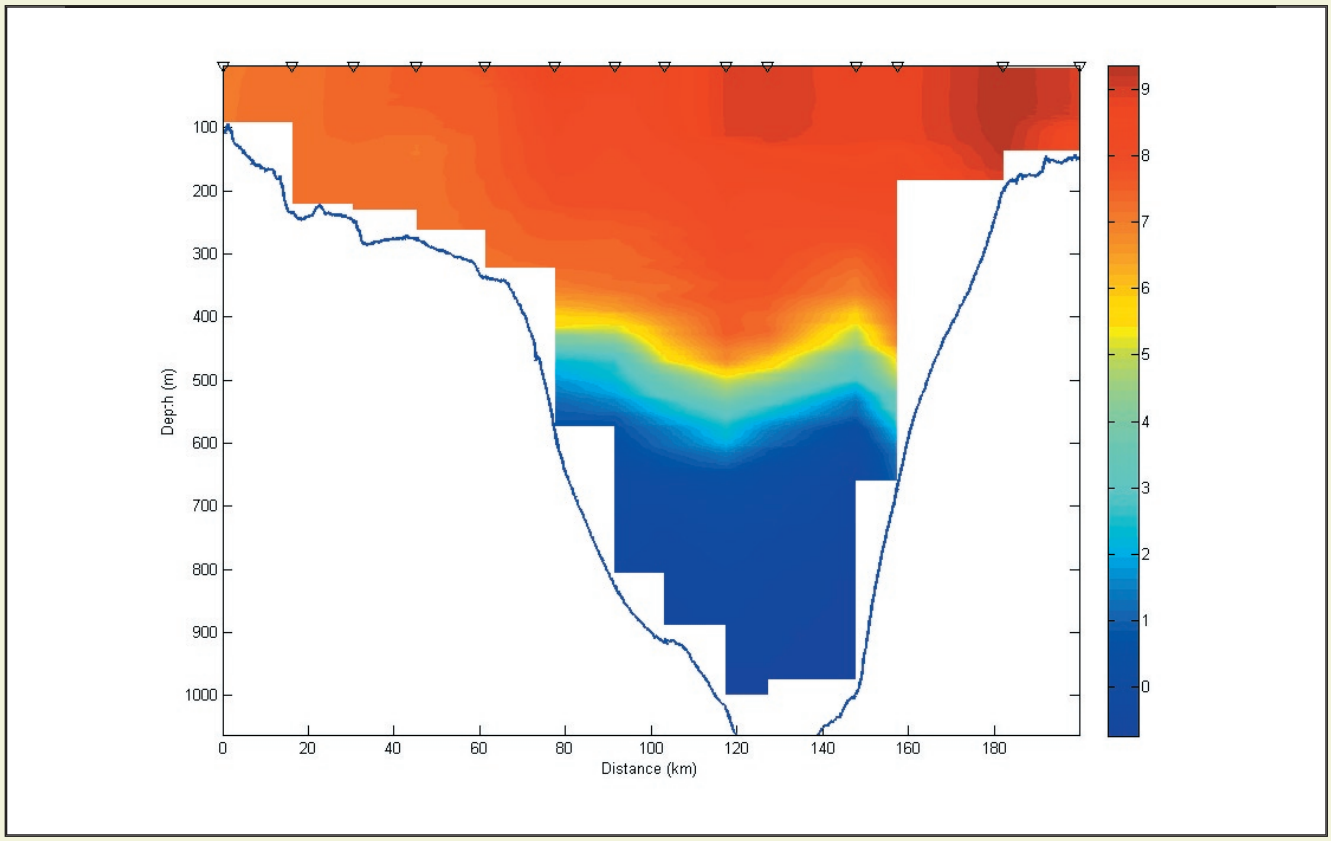

Figure A9. Example of temperature distribution along standard section S (Cruise 0904, February 2009). Blue line indicates bottom depth along the section. Black open triangles are locations of the standard stations where S01 is to the left.

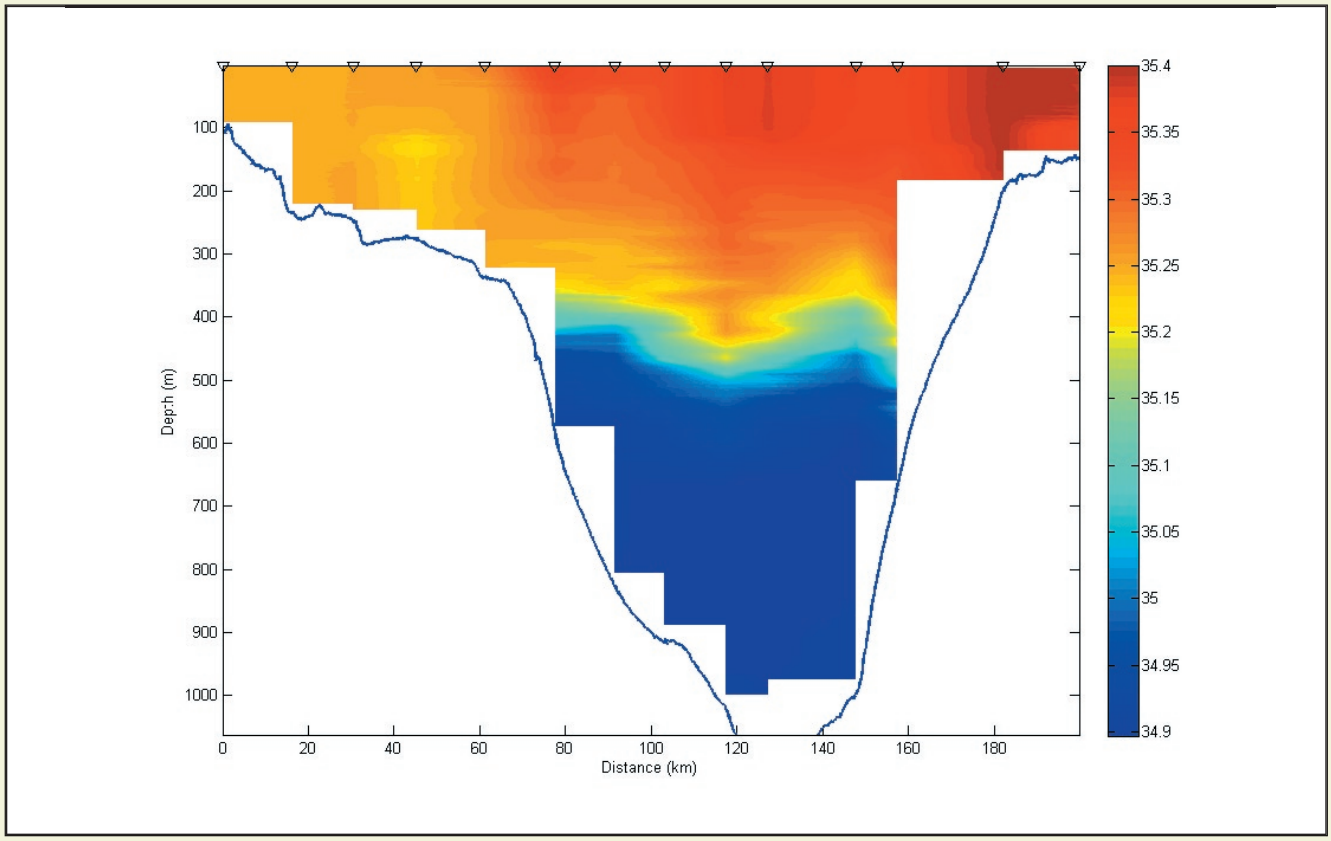

Figure A10. Example of salinity distribution along standard section S (Cruise 0904, February 2009). Blue line indicates bottom depth along the section. Black open triangles are locations of the standard stations where S01 is to the left.

Appendix B – Timeseries seasonal variation

The amplitude and phase of the seasonal variation for the T and S timeseries at each section is listed in Table B1 and in Table B2 is listed the seasonal variation for the two AW-N-Ar indices. Figures B1 – B6 are plots of the seasonal cosine and combined variation (as described in the section "Removing seasonal variation") and of the observed and deseasoned timeseries for both AW temperature and AW salinity at each section. Finally, Figure B7 is a similar plot but for the two AW-N-Ar timeseries. Deseasoned timeseries are calculated as original observations minus the combined seasonal variation on the day of observation.

Table B1

Amplitude and phase of the cosine seasonal variation for T and S at each of the sections.

Section name	T amplitude (°C)	T phase (days)	S amplitude	S phase (days)
SSV	0.4197	241	0.0199	192
SSW	0.4993	251	0.0219	214
SSX	0.4661	222	0.0308	167
SSN	0.5455	244	0.0231	227
SSE	0.7355	246	0.0336	212
SSS	0.7679	244	0.0390	225

Table B2

Amplitude and phase of the cosine seasonal variation for the AW area indices AW-N-Ar50% and AW-N-Ar35.0.

Area def.	Area amplitude (km^2)	Area phase (days)
50% mixing	3.6816	242
> 35.0	5.3458	255

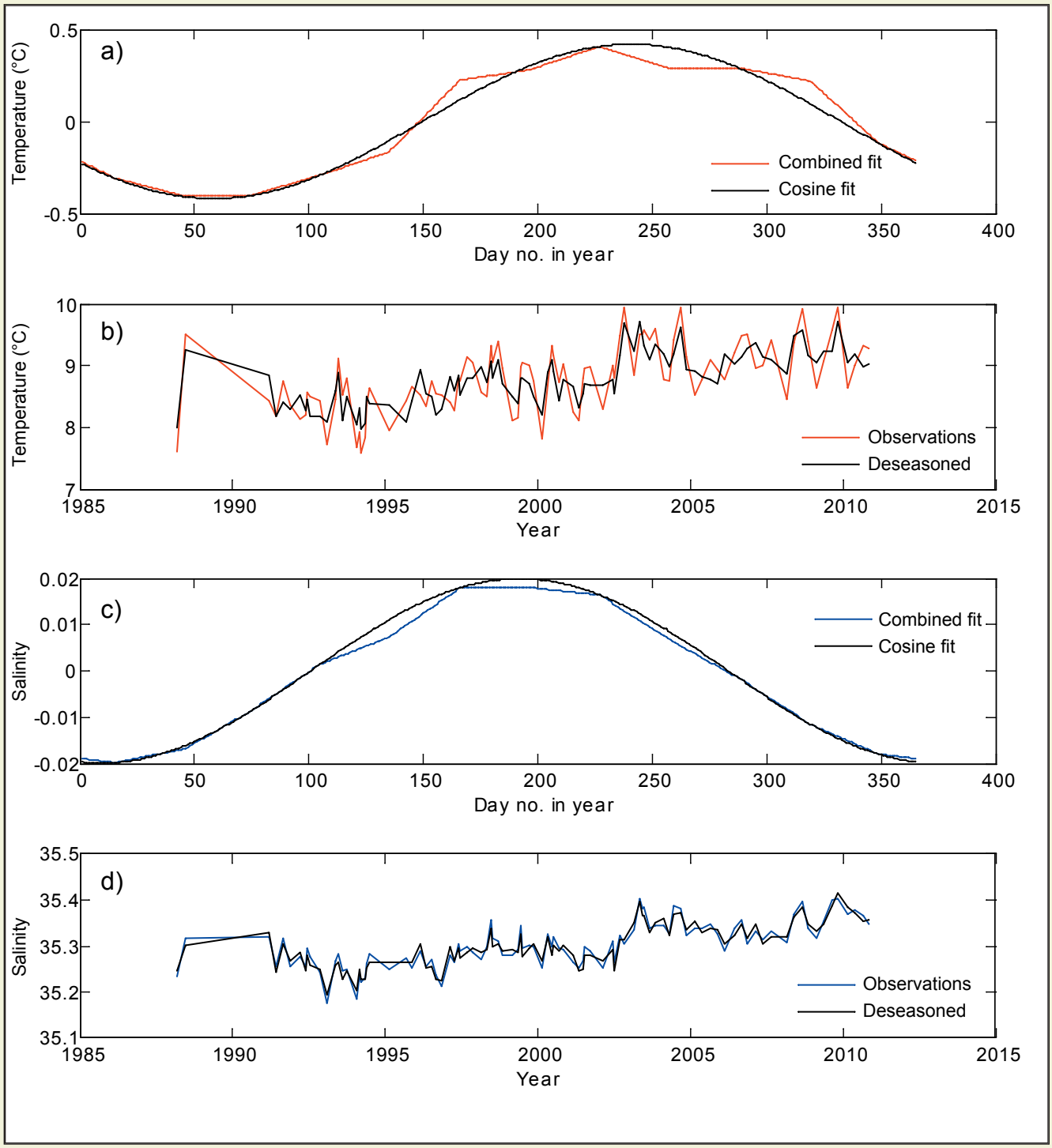

Figure B1. Standard section V seasonal signal in a) temperature and c) salinity and timeseries of observed and deseasoned b) temperature and d) salinity. The seasonal cosine fit for temperature (in °C) is T(t) = 0.4197*COS(w*(t-241days)) and for salinity is S(t) = 0.0199*COS(w*(t-192days)).

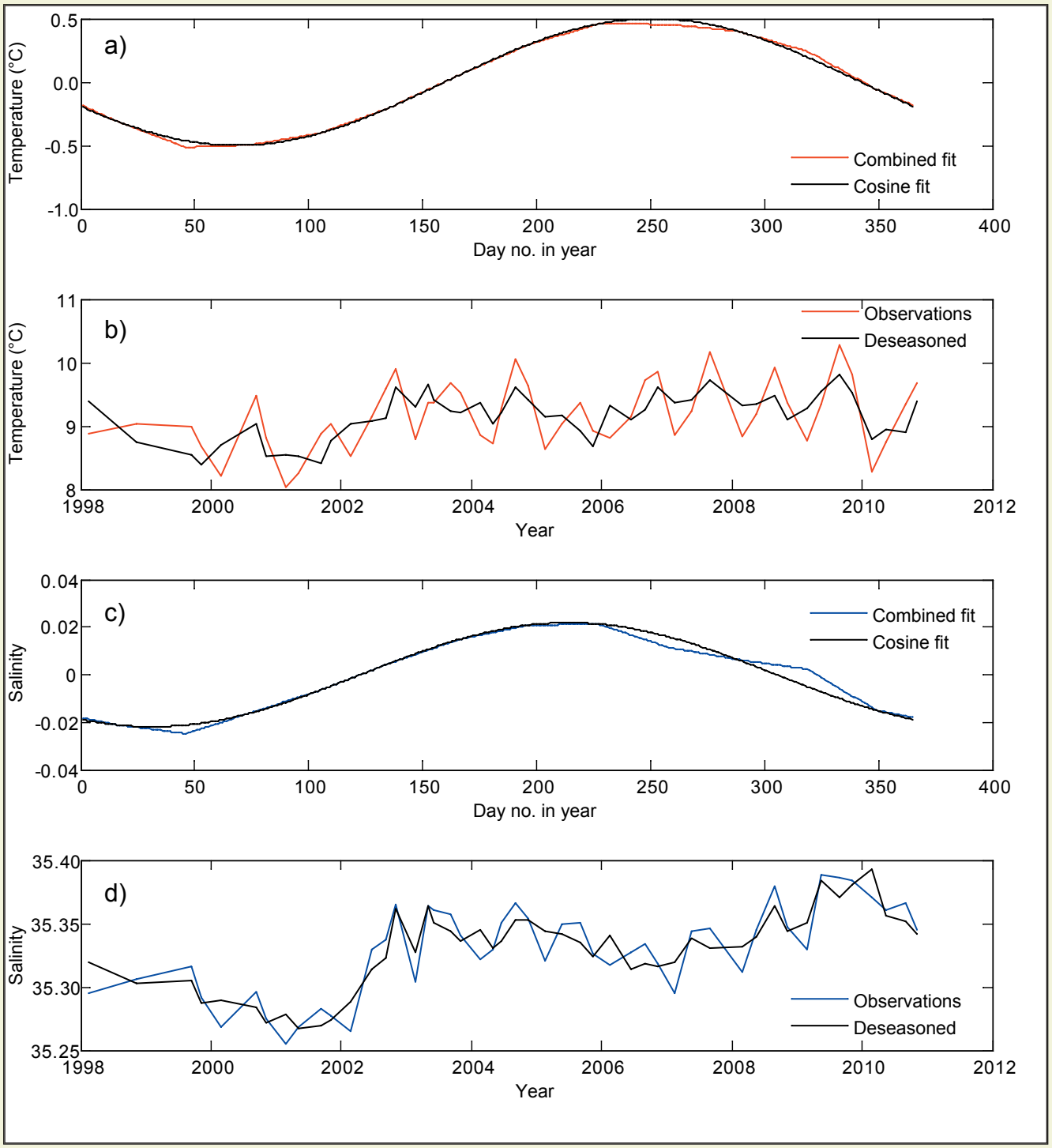

Figure B2. Standard section W seasonal signal in a) temperature and c) salinity and timeseries of observed and deseasoned b) temperature and d) salinity. The seasonal cosine fit for temperature (in °C) is T(t) = 0.4993*COS(w*(t-251days)) and for salinity is S(t) = 0.0219*COS(w*(t-214days)).

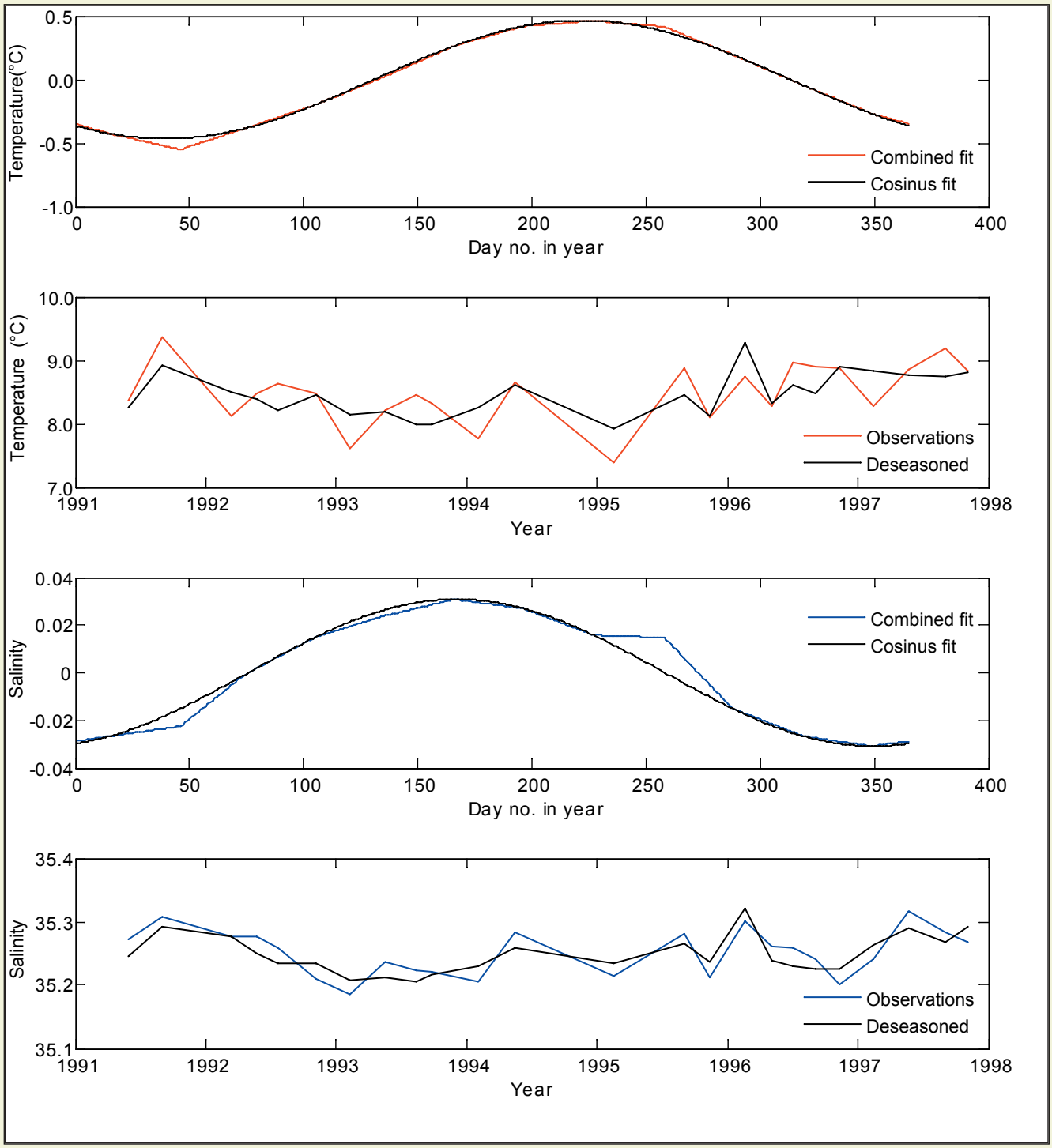

Figure B3. Standard section X seasonal signal in a) temperature and c) salinity and timeseries of observed and deseasoned b) temperature and d) salinity. Due to the short timeserie, the timeserie mean was subtracted from the serie before finding the seasonal variation rather than the 5-years running mean, where 2.5 years are cut at each end of the series. The seasonal cosine fit for temperature (in °C) is T(t) = 0.4661*COS(w*(t-222days)) and for salinity is S(t) = 0.0308*COS(w*(t-167days)).

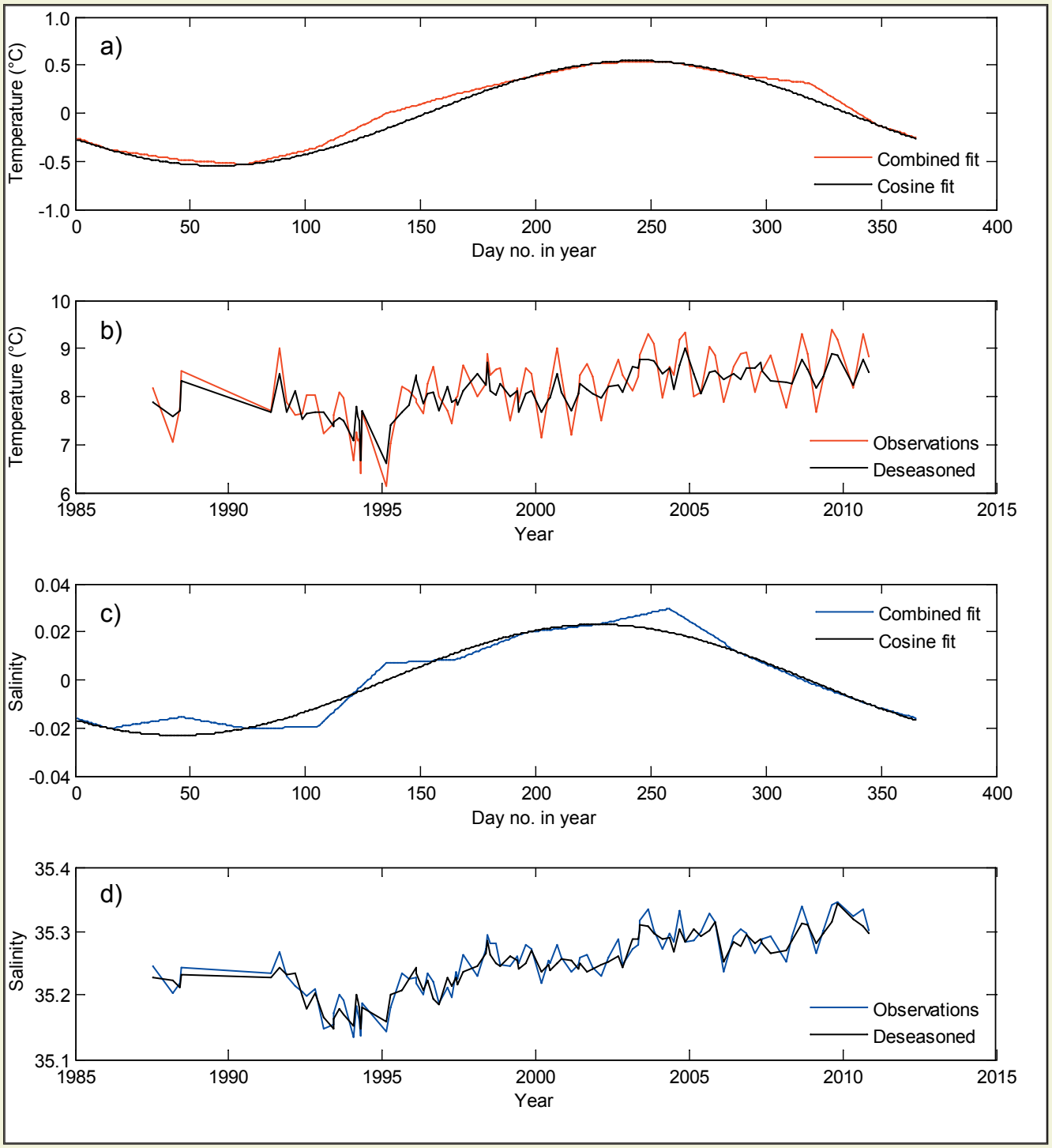

Figure B4. Standard section N seasonal signal in a) temperature and c) salinity and timeseries of observed and deseasoned b) temperature and d) salinity. The seasonal cosine fit for temperature (in °C) is T(t) = 0.5455*COS(w*(t-244days)) and for salinity is S(t) = 0.0231*COS(w*(t-227days)).

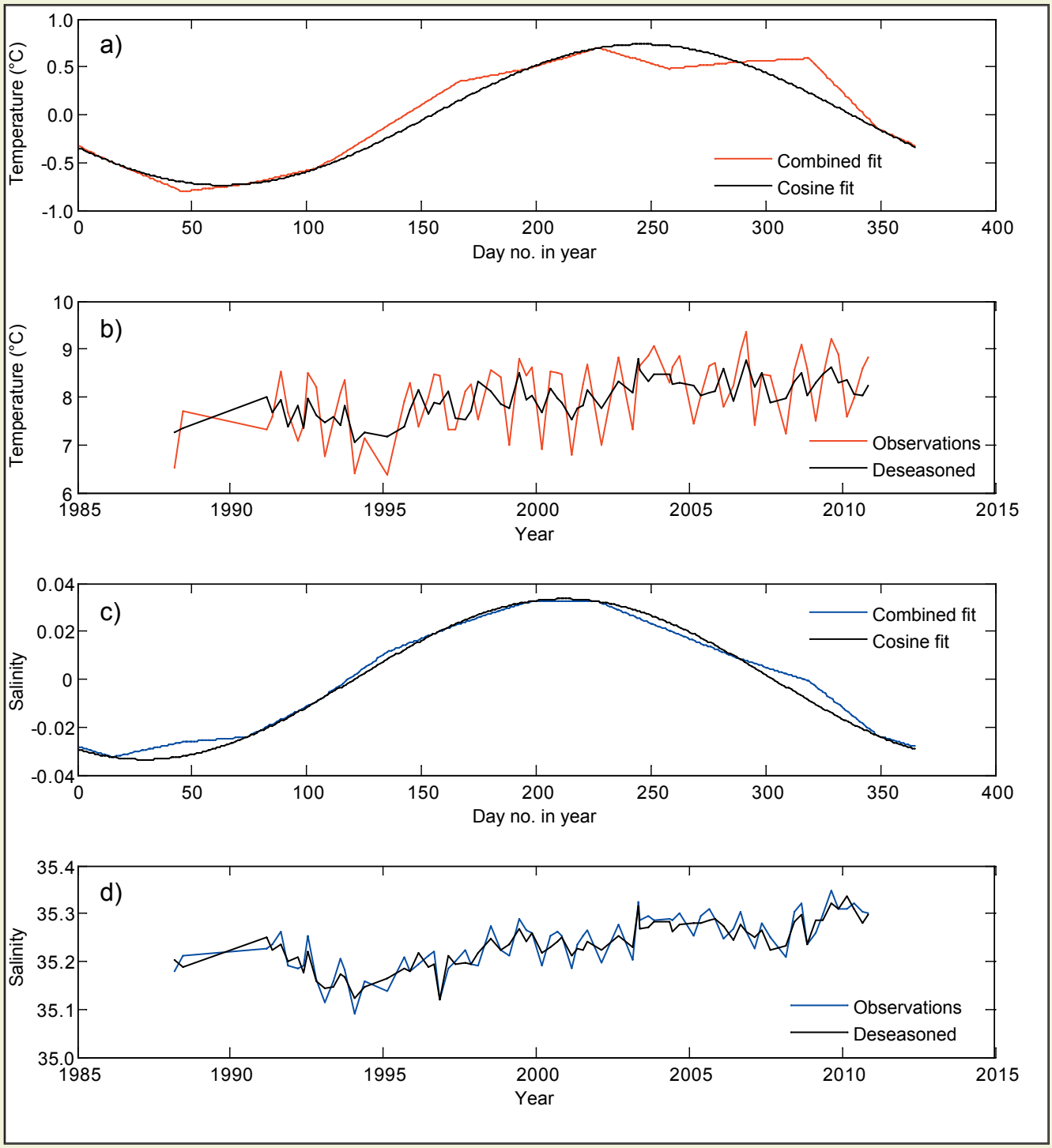

Figure B5. Standard section E, st E04, seasonal signal in a) temperature and c) salinity and timeseries of observed and deseasoned b) temperature and d) salinity. The seasonal cosine fit for temperature (in °C) is T(t) = 0.7355*COS(w*(t-246days)) and for salinity is S(t) = 0.0336*COS(w*(t-212days)).

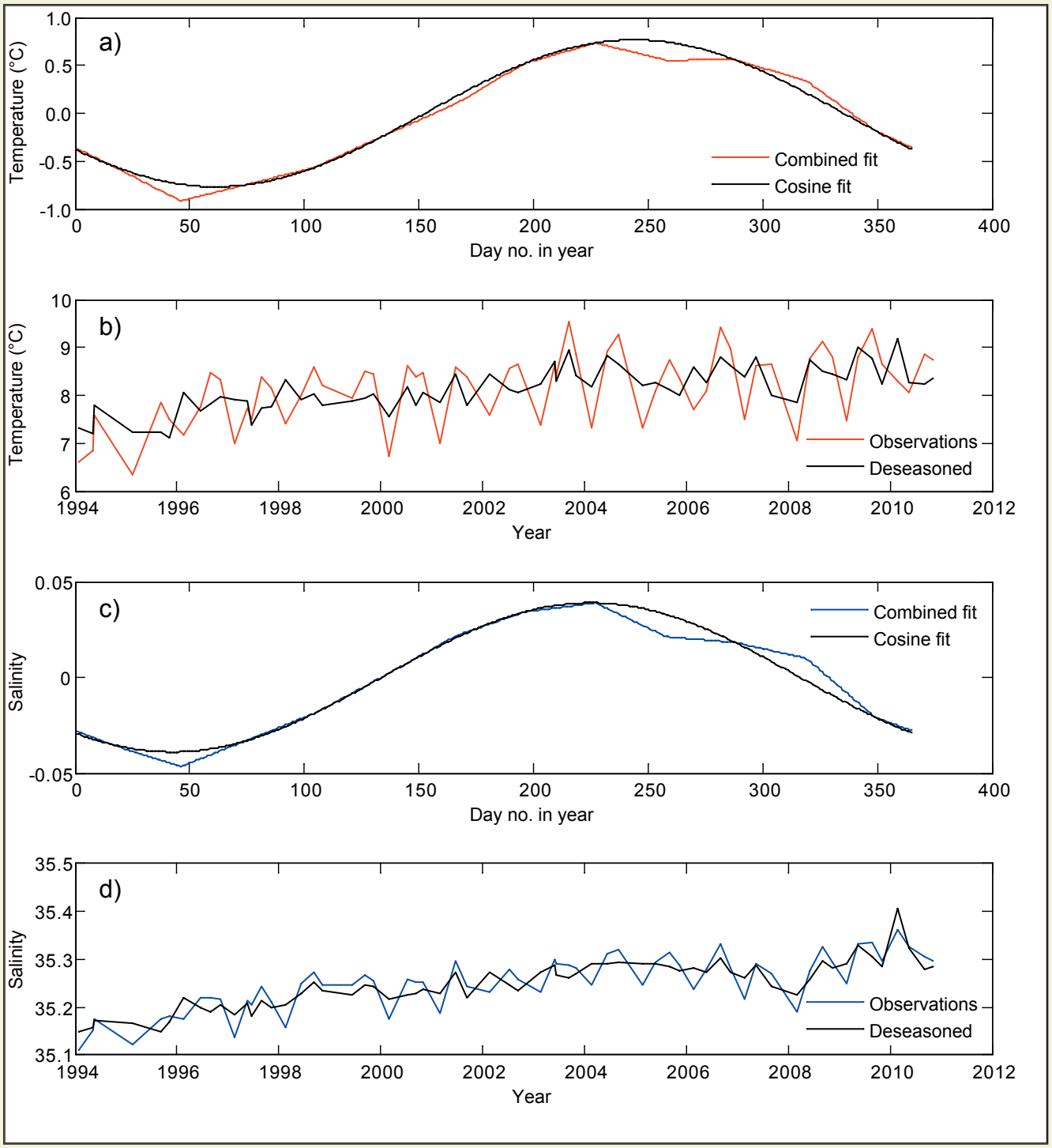

Figure B6. Standard section S, st S03, seasonal signal in a) temperature and c) salinity and timeseries of observed and deseasoned b) temperature and d) salinity. The seasonal cosine fit for temperature (in °C) is T(t) = 0.7679*COS(w*(t-244days)) and for salinity is S(t) = 0.0390*COS(w*(t-225days)).

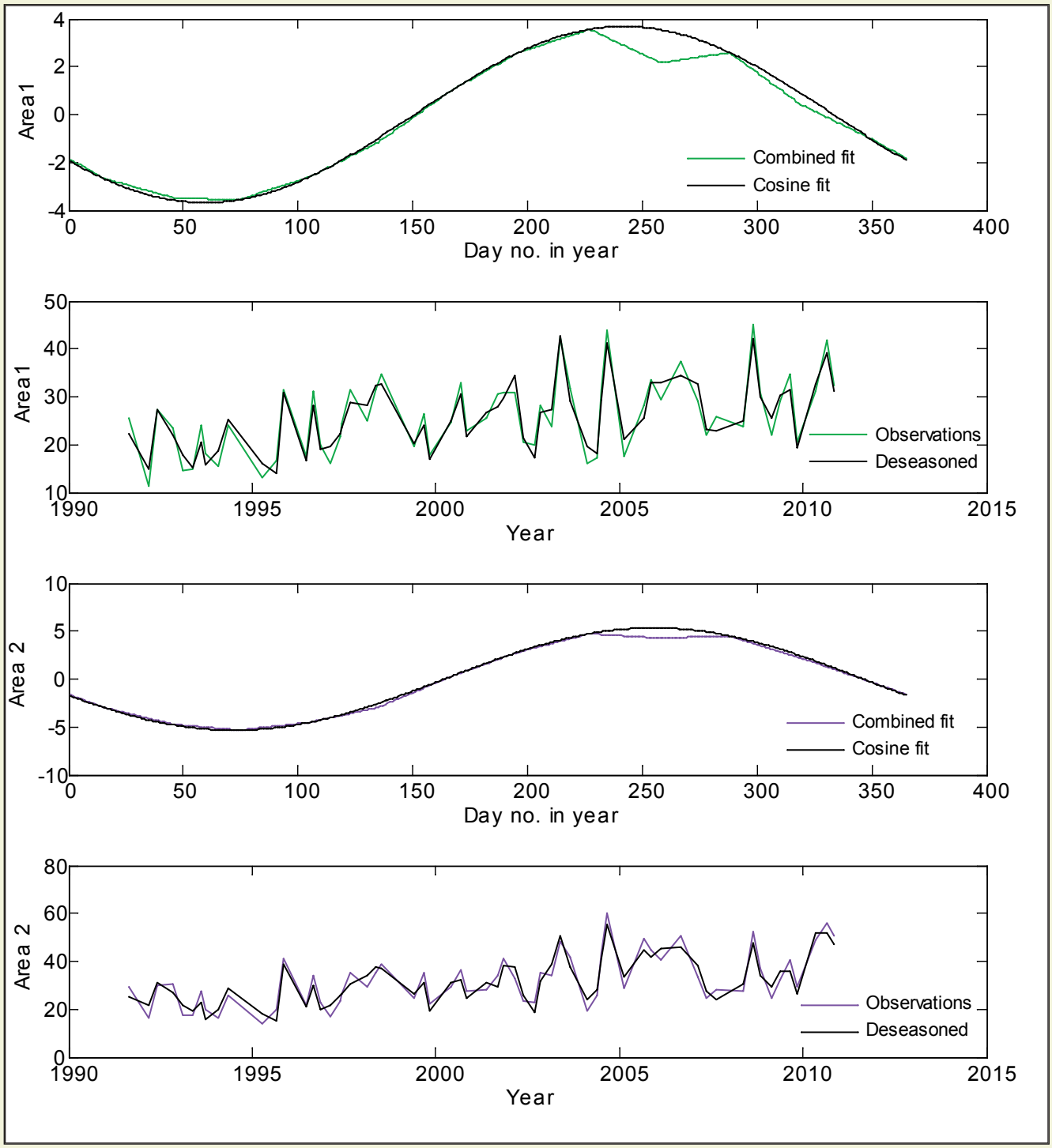

Figure B7. Standard section N seasonal signal in a) AW area 50% mixing and c) AW area > 35.0 and timeseries of observed and deseasoned b) AW area 50% mixing and d) AW area > 35.0. The seasonal cosine fit for AW area 50% mixing (in km^2) is A1(t) = 3.6816*COS(w*(t-242days)) and for AW area > 35.0 (in km^2) is A2(t) = 5.3458*COS(w*(t-255days)). Here, only sections with data on all 14 stations are used.

Appendix C – Timeseries with and without autumn and/or winter cruises

In this appendix, plots of 1-, 2-, 3-, 4- and 5-years running mean for the whole timeseries and for timeseries without autumn and autumn + winter cruises, respectively, are shown for the sections V, W, N, E and S. Section X is not included, since the occupation of it terminated in 1997.

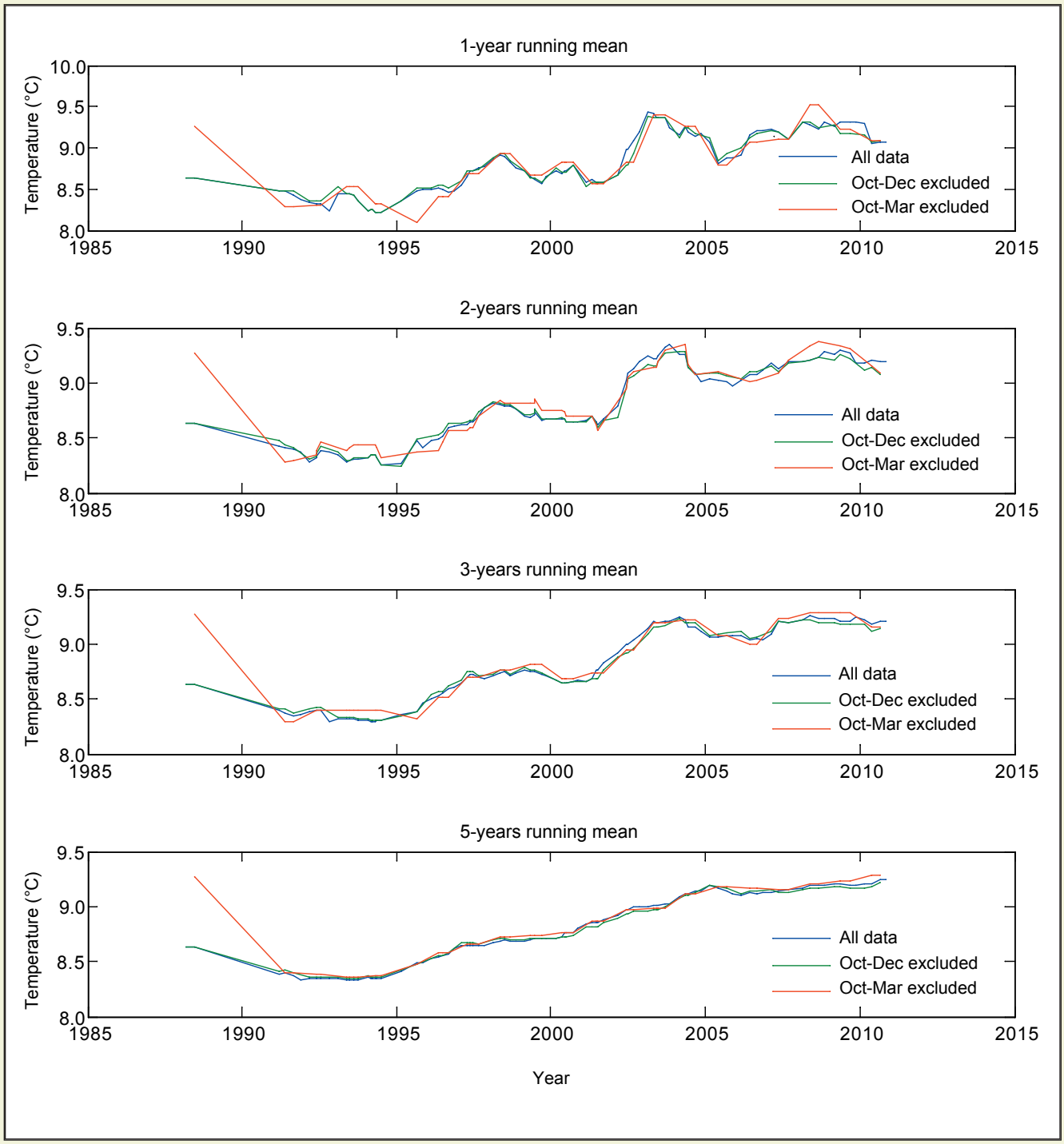

Figure C1. Temperature at Standard section V. 1-, 2-, 3- and 5-years running means for All observations (blue), Oct-Dec observations excluded (green) and Oct-Mar observations excluded (red).

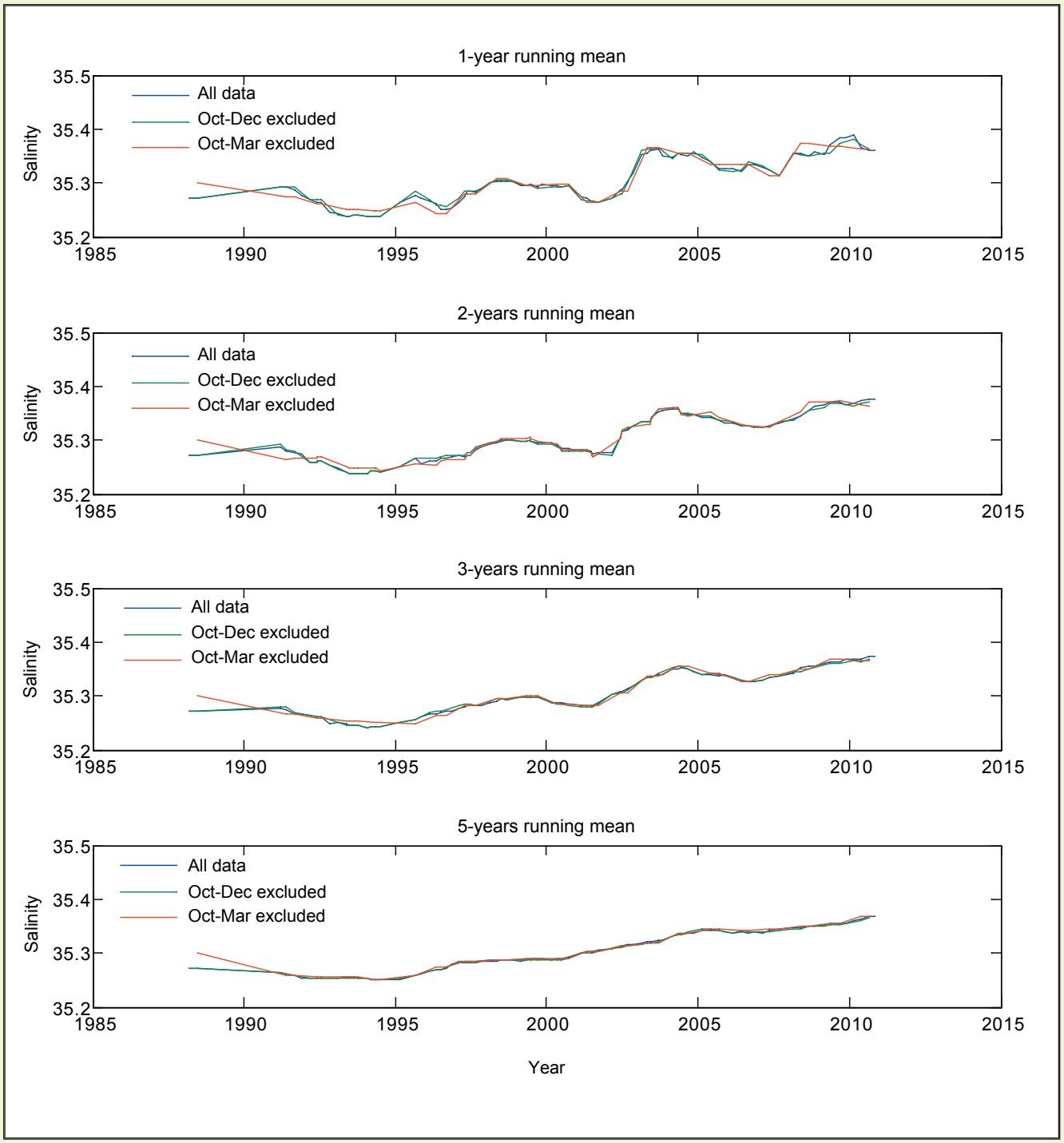

Figure C2. Salinity at Standard section V. 1-, 2-, 3- and 5-years running means for All observations (blue), Oct-Dec observations excluded (green) and Oct-Mar observations excluded (red).

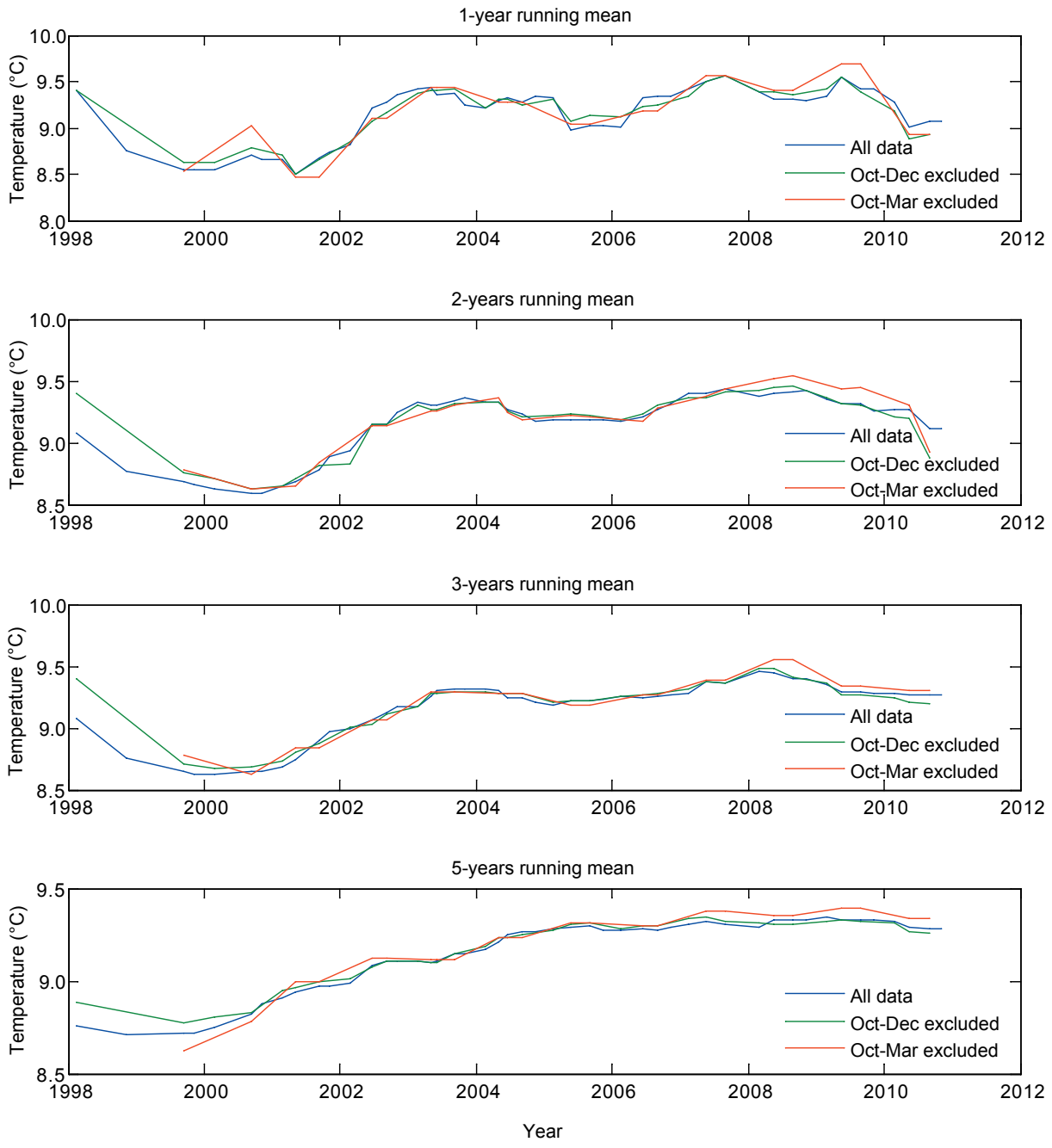

Figure C3. Temperature at Standard section W (Nortwest of Faroe Bank). 1-, 2-, 3- and 5-years running means for All observations (blue), Oct-Dec observations excluded (green) and Oct-Mar observations excluded (red).

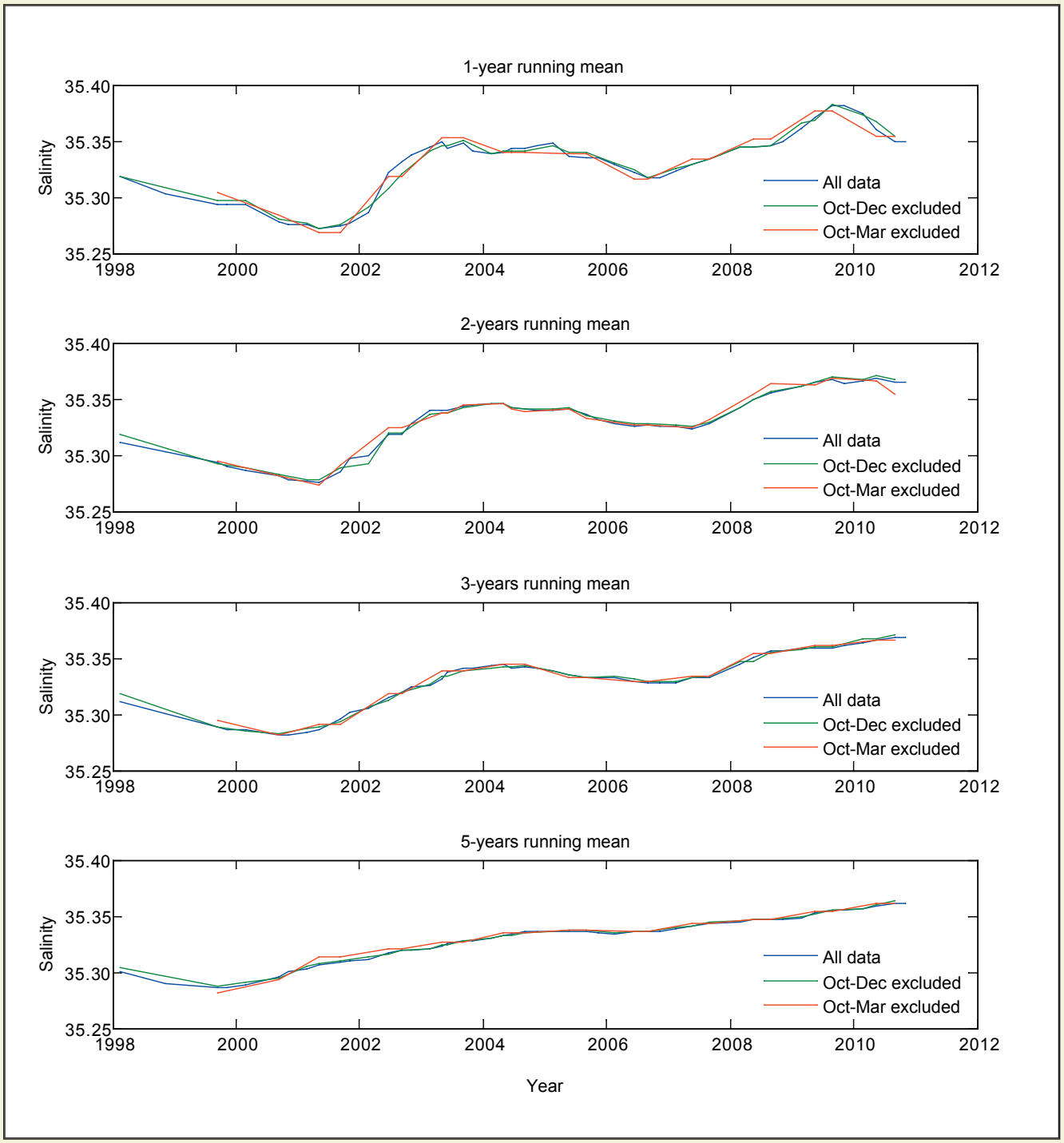

Figure C4. Salinity at Standard section W (Nortwest of Faroe Bank). 1-, 2-, 3- and 5-years running means for All observations (blue), Oct-Dec observations excluded (green) and Oct-Mar observations excluded (red).

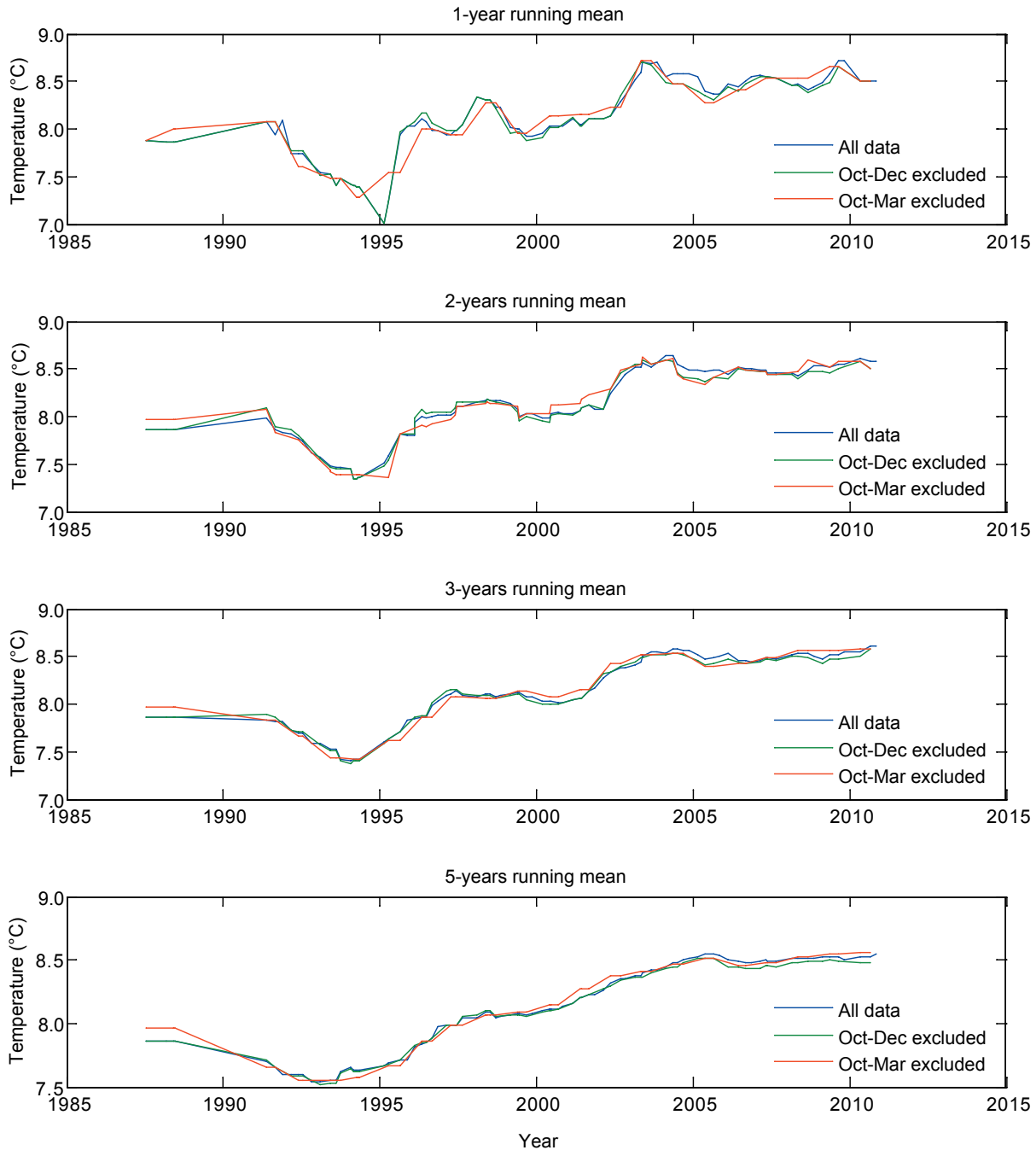

Figure C5. Temperature at Standard section N. 1-, 2-, 3- and 5-years running means for All observations (blue), Oct-Dec observations excluded (green) and Oct-Mar observations excluded (red).

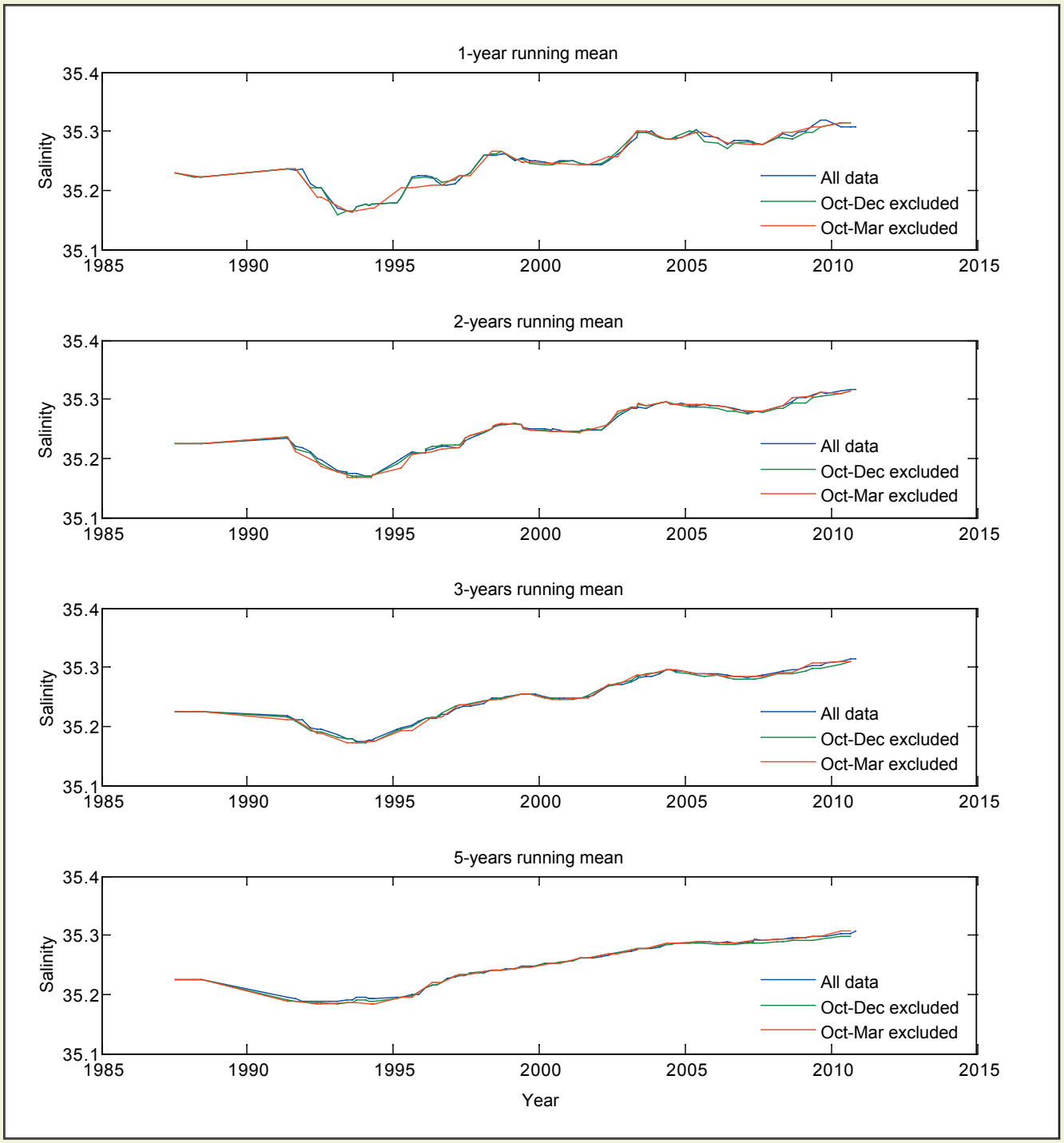

Figure C6. Salinity at Standard section N. 1-, 2-, 3- and 5-years running means for All observations (blue), Oct-Dec observations excluded (green) and Oct-Mar observations excluded (red).

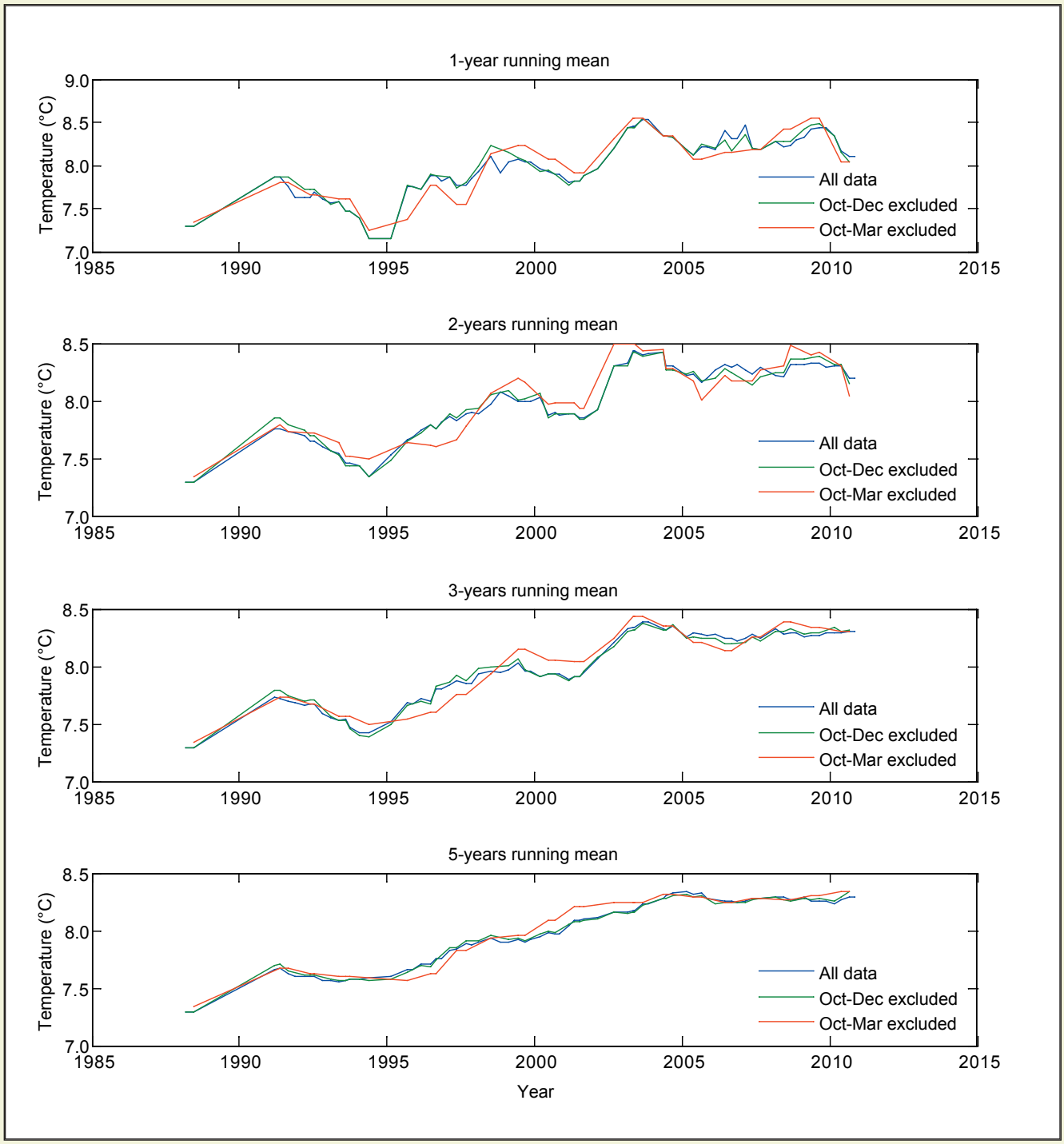

Figure C7. Temperature at Standard section E, st E04. 1-, 2-, 3- and 5-years running means for All observations (blue), Oct-Dec observations excluded (green) and Oct-Mar observations excluded (red).

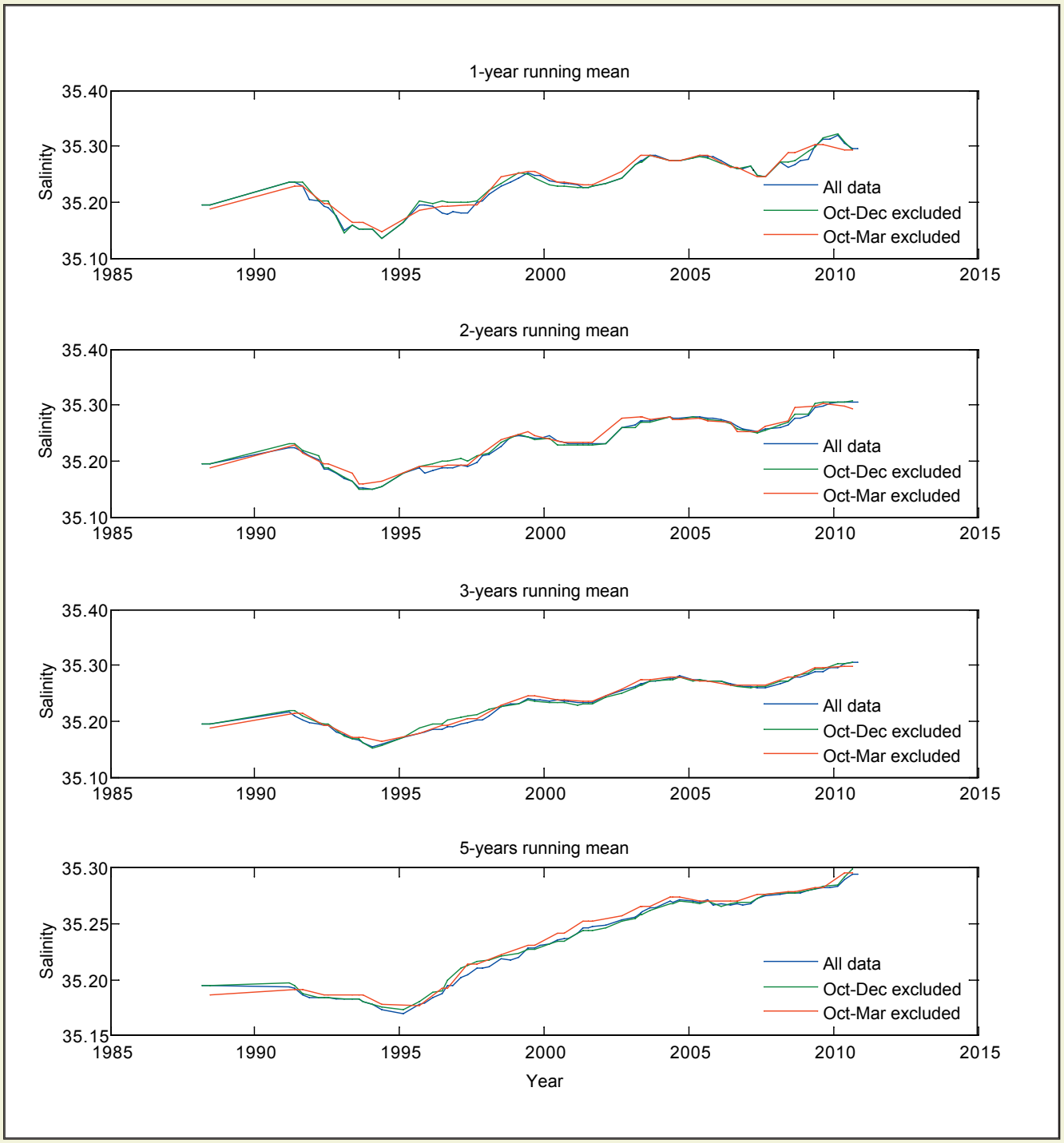

Figure C8. Salinity at Standard section E, st E04. 1-, 2-, 3- and 5-years running means for All observations (blue), Oct-Dec observations excluded (green) and Oct-Mar observations excluded (red).

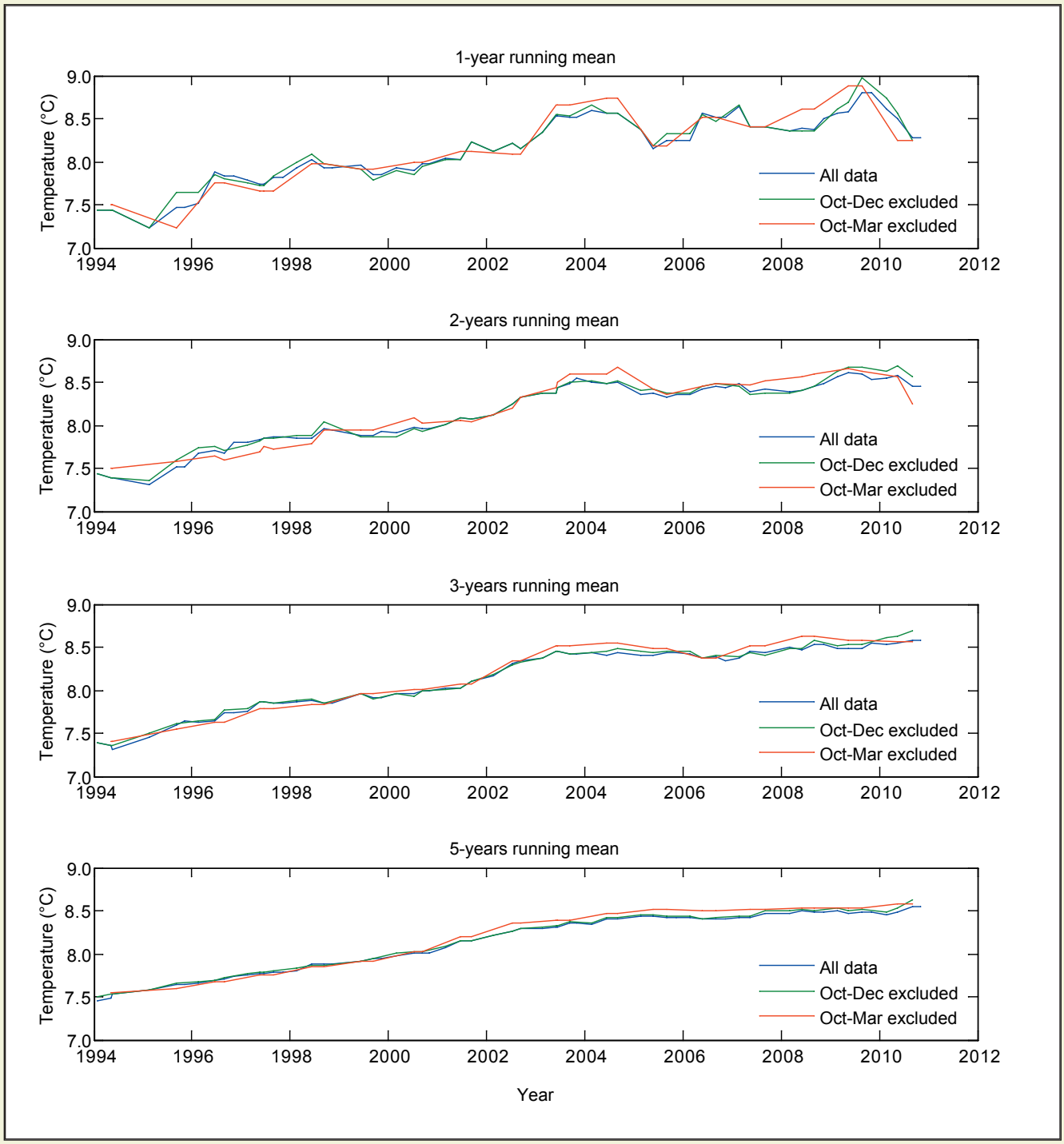

Figure C9. Temperature at Standard section S, st S03. 1-, 2-, 3- and 5-years running means for All observations (blue), Oct-Dec observations excluded (green) and Oct-Mar observations excluded (red).

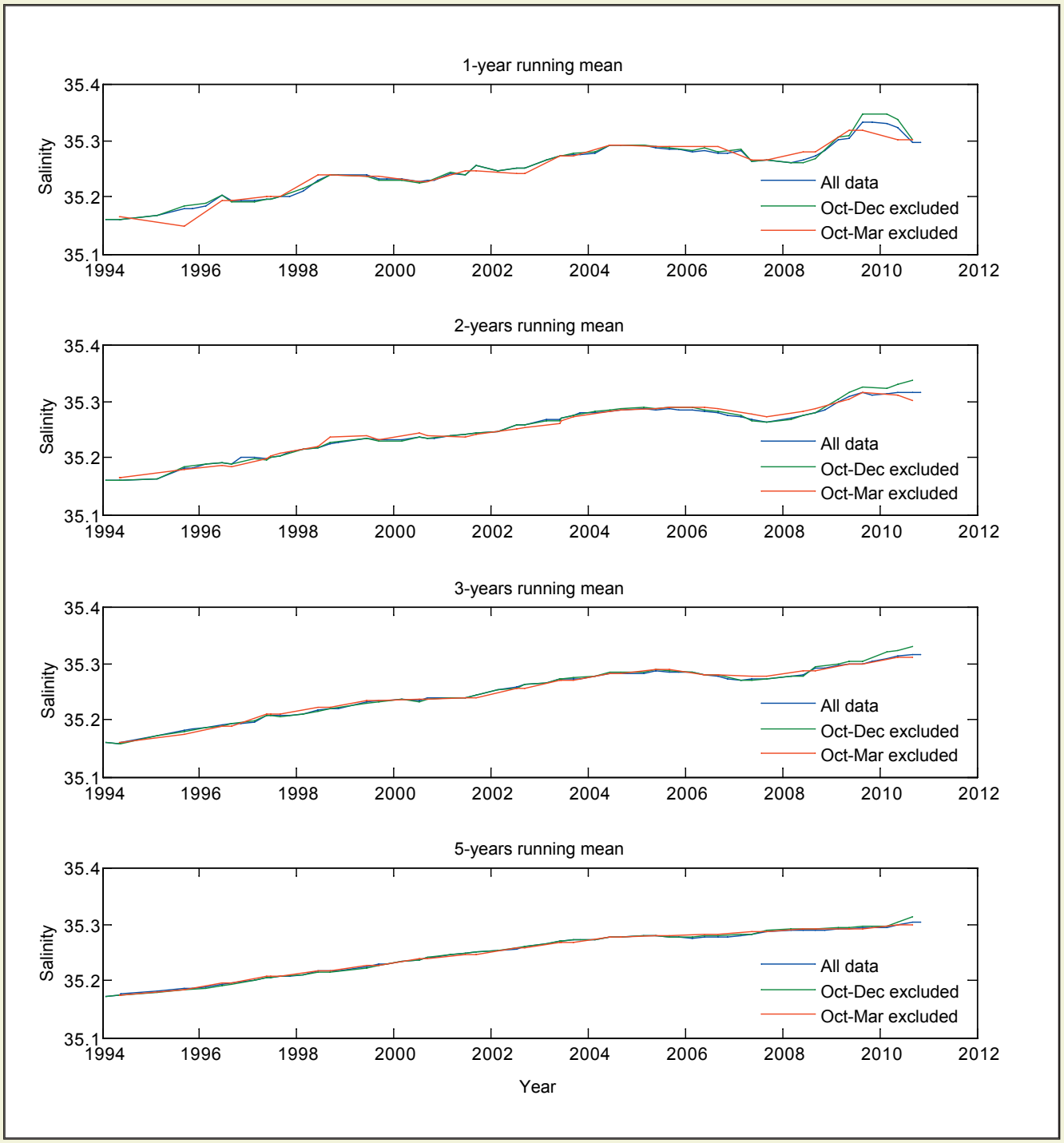

Figure C10. Salinity at Standard section S, st S03. 1-, 2-, 3- and 5-years running means for All observations (blue), Oct-Dec observations excluded (green) and Oct-Mar observations excluded (red).

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