

**Model simulations**

## 5.3 Temperature and salinity comparisons

Calibration of temperature and salinity was undertaken for periods in the transition from summer to autumn and winter to spring.

A crucial aspect of the successful model performance in this study was the extension of the model offshore, so that oceanic processes could be sufficiently resolved. This study has made it clear that simulating these highly dynamic oceanic processes, and their control of exchange through the northern opening of Cockburn Sound, is critical to the accurate simulation of vertical stratification (and hence dissolved oxygen) processes within the Sound. Details of how the model represented these processes, in comparison to the field observations, are provided below.

### 5.3.1 Measurement specifications

#### 5.3.1.1 Deep basin

Temperature and salinity data at three locations in the deep basin of Cockburn Sound (Figure 2-4) were used for model comparisons. Station *South Buoy* was located within Mangles Bay approximately 2.2 km east of the Causeway. Station *North Buoy* was located near the northern entrance area approximately 2.6 km east of the northern tip of Garden Island. Station *Central Buoy* was located approximately 3.8 km south of North Buoy Station and approximately 2.2 km east of Garden Island. All locations were approximately 20.0 m deep. Two types of measurements were available at the sampling stations:

- (1) Continuous measurements available from Water Corporation's Real Time Management System (RTMS)
- (2) Profile data collected by the Marine and Freshwater Research Laboratory (MAFRL) conducted on behalf of Cockburn Sound Management Council (CSMC).

RTMS measurements were undertaken at different depths in each location at a one-hour interval. Details of the RTMS arrangements are summarised in Table 5-3. The profile data were collected over several days at an irregular frequency; in some instances, profiles were collected twice a day, in others every couple of days, and in others, every couple of weeks. In general, the vertical resolution of the profiles was 5 cm or less.

Data in 2008, 2011 and 2013 were chosen for model comparisons. Comparisons over the transition from summer to autumn period were undertaken between 01 January and 01 April 2008, between 23 February and 10 March 2011, and 05 April and 01 May 2013. Comparisons over the transition between winter and spring were undertaken for the period between 01 August and 01 November 2008. Measurements at North Buoy were only available routinely in 2008.

Although the RTMS also sampled salinity, these were deemed to be inaccurate with significant offset at all three locations when compared to the MAFRL profiles. The MAFRL data was considered more accurate. A comparison between RTMS and profile salinity data is shown in Figure 5-27 to Figure 5-32. Model calibration therefore focused on comparisons against the profile data, whilst the RTMS data was adopted to infer duration of salinity stratification events (rather than absolute salinities).

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Table 5-9 Details of RTMS arrangements

Station	Deployment depth	Number of temperature sensors	Sensor heights	Sampling interval
North Buoy	20.0 m	8	0.5, 2.0, 3.0, 5.0, 7.0, 9.0, 13.0 and 15.0 m	1 hour
Central Buoy	20.0 m	13	0.5, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 11.0, 12.0, 14.0 and 16.0 m	1 hour
South Buoy	20.0 m	11	0.5, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 11.0, 13.0 and 15.0 m	1 hour

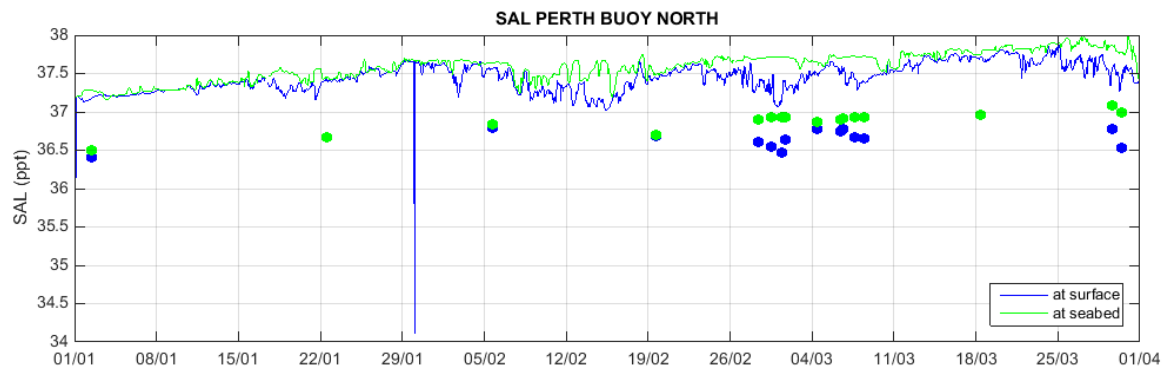


Figure 5-27 Salinity comparison between RTMS (lines) and profile data (points) at North Buoy from January to March 2008

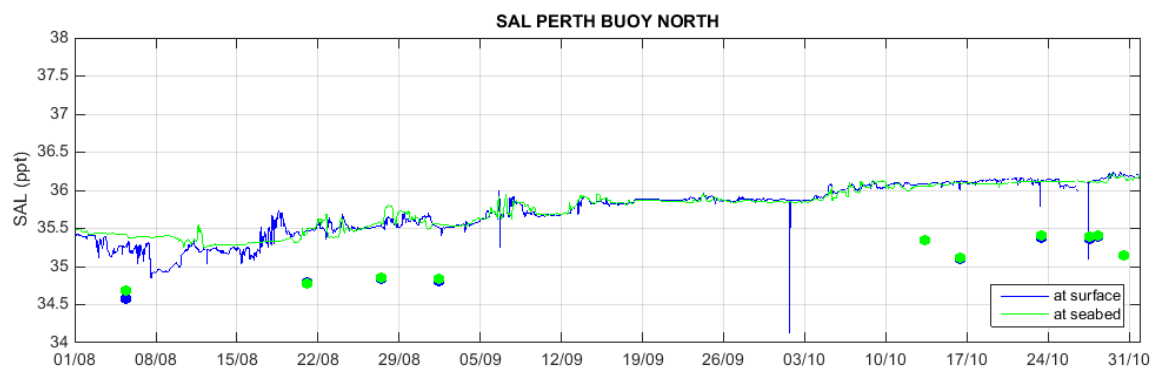


Figure 5-28 Salinity comparison between RTMS (lines) and profile data (points) at North Buoy from August to October 2008

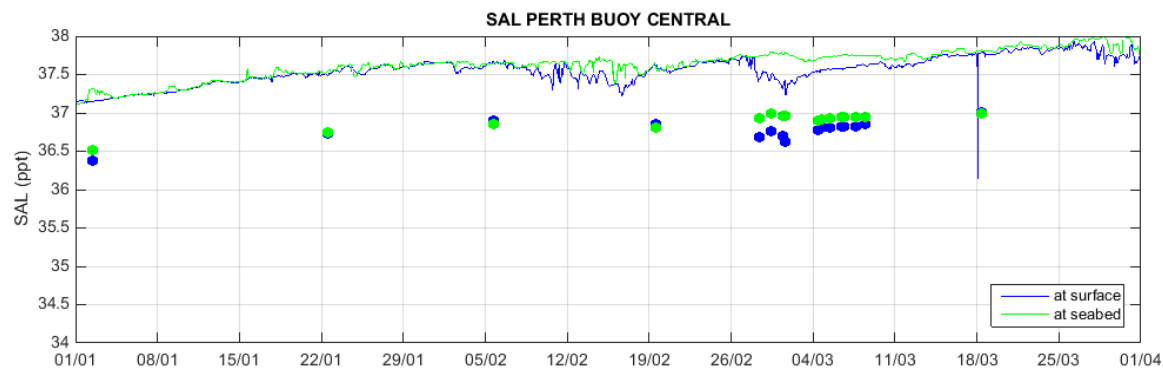


Figure 5-29 Salinity comparison between RTMS (lines) and profile data (points) at Central Buoy from January to March 2008

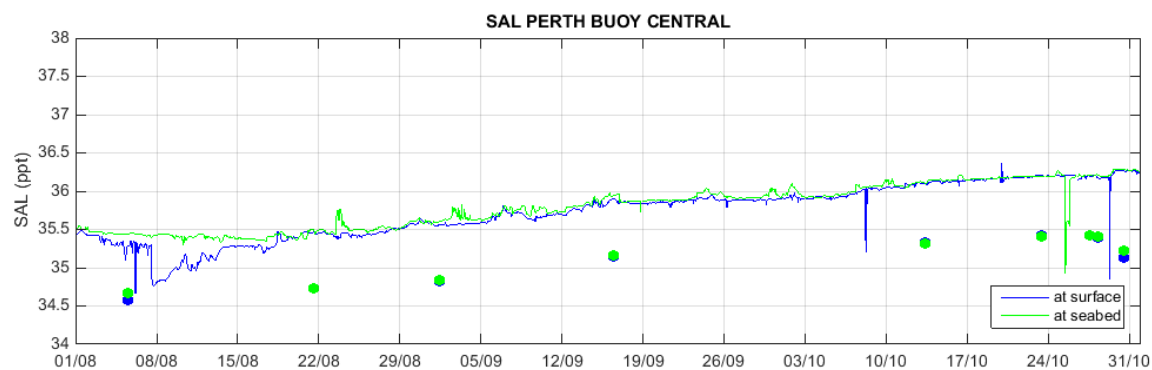


Figure 5-30 Salinity comparison between RTMS (lines) and profile data (points) at Central Buoy from August to October 2008

## Model simulations

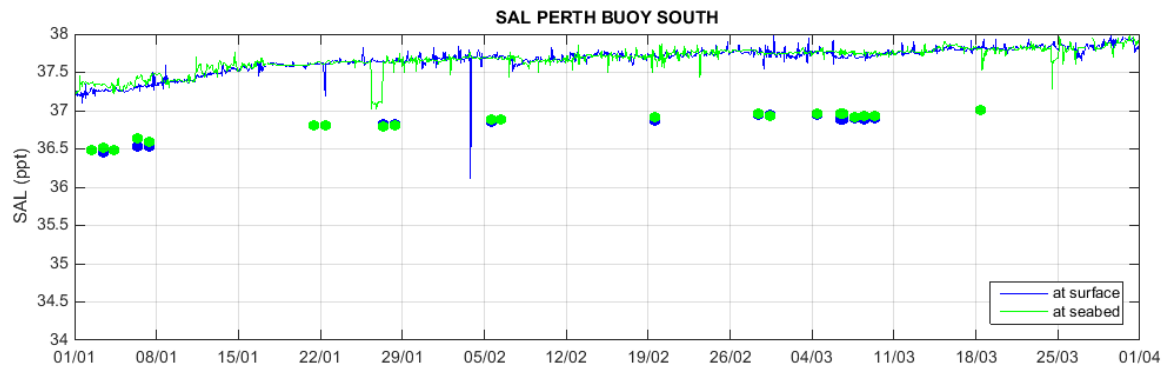


Figure 5-31 Salinity comparison between RTMS (lines) and profile data (points) at South Buoy from January to March 2008

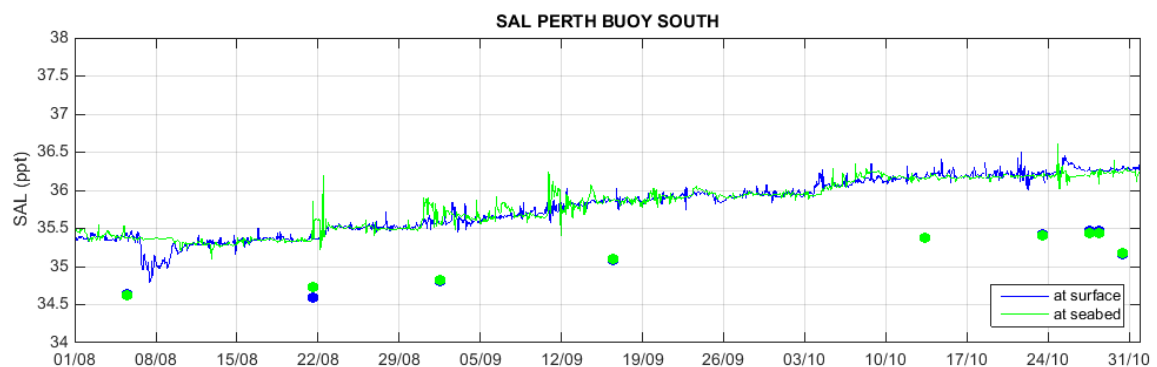


Figure 5-32 Salinity comparison between RTMS (lines) and profile data (points) at South Buoy from August to October 2008

### 5.3.1.2 MMMP array

For the simulations in 2011 and 2013, data was also collected at a series of locations within Stirling Channel (points R2, S2, and S3; Figure 2-16) and directly offshore at its connection with the deep basin. The offshore locations were sampled approximately 500 m (points A4 to A13), 1 km (points B1 to B16), 1.5 km (points C7 to C17), and 2km points (D1 to D20) from the channel confluence, in semi-circular concentric arrays (Figure 2-16). Point CT3 and CT7, which were much further afield, complemented the offshore locations (Figure 2-16). Measurements undertaken at these sampling stations included temperature, salinity and dissolved oxygen.

## 5.3.2 Model comparisons (2008)

### 5.3.2.1 Summer to early autumn 2008 - temperatures

Temperature comparisons in the transition from summer to spring in 2008 are shown for each of the sampling stations in Figure 5-33 to Figure 5-38. For the RTMS data the same comparisons are

## Model simulations

shown over higher resolution time intervals (Appendix F). The RTMS comparisons are shown in terms of temperature colour contours, where the colours indicate the water temperature, as given in the figures' colour bars. The x- and y-axes show time and height above the seabed, respectively.

The contours demonstrate that the model reproduced the increasing temperatures at the start of the period and ensuing cooling towards the end of the simulation at all three stations. Cooling between 19 and 26 February and 25 March and 01 April was also predicted by the model, and at similar rates to observations.

In this first cooling period, profiles were not collected. Contrastingly, over this same period air temperature measured at Garden Island revealed a gradual increase of air temperatures (Figure 5-39) consistent with atmospheric heating, and therefore counterintuitive to the observed water cooling, therefore suggesting that perhaps the reduction in the Sound temperature was produced from advection of colder offshore water into the Sound.

Subsequent to this period, an interesting feature was present in the model and measured data, which saw a combination of higher surface temperatures (and low salinities, see below), notably at North and Central Buoy stations. This period was important as it coincided with the lowest observed DO concentrations (Figure 2-12), and as such it deserves close attention as described below.

At the North and Central Buoy stations, despite the relatively low degree of temperature stratification, the profiles observed between 28 February and 01 March, presented distinct signatures, with marked changes in the depth of the thermocline (between 10 and 15 m), consistent with the signature of a less saline overflow. An overflow in this instance refers to the flow of less dense seawater over another mass of seawater of higher density. In this case, the overflow is characterised by lower salinities, and slightly higher temperatures. The indication this is an overflow was further supported by the temperature and salinity vertical gradients attenuation from North to South Buoys (c.f. Figure 5-34 and Figure 5-36 for panes relating to the described period) and the model simulation curtain animations listed in Appendix H. It is important to note that the recordings of the Swan River flows over this period were amongst the lowest in the year, and therefore the overflows waters originated elsewhere, and the model predicts these to be from offshore. This process is further explored in discussion of salinity dynamics in Section 5.3.2.2.

Similar characteristics in the water column were observed between 04 and 11 March, however the thermocline resided lower in the water column, at between 10 and 20 m depth. These two periods presented mild (for summer) and less variable air temperatures (between 20 and 25 °C) than normal, in combination with light winds with swift directional changes between westerlies and northerlies. Further, these two periods coincided with the rising limb of sub-tidal frequency waves (Figure 5-3). Both wind characteristics were in contrast to the intervening period (i.e. from 01 to 04 March), when stronger southerly sea breezes predominated, which in turn produced vertical mixing of the water column. The period between 01 and 04 March also coincided with the falling limb of a low-frequency (i.e. sub-tidal) wave.

The model generally replicated the depth of the thermocline at North and South Buoy well (Figure 5-34 and Figure 5-36). The changes in temperature across the thermocline were however mild in comparison to salinity, and that salinity variation was the main driver of the development of horizontal density gradients and the onset of vertical density stratification. As such, temperature played a

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secondary role in the described overflow dynamics at this time and was not as crucial for prediction of the vertical stratification patterns in Cockburn Sound. The salinity dynamics are further described in the next Section. At South Buoy, vertical temperature stratification was more gradual and mostly well replicated by the model (Figure 5-38).

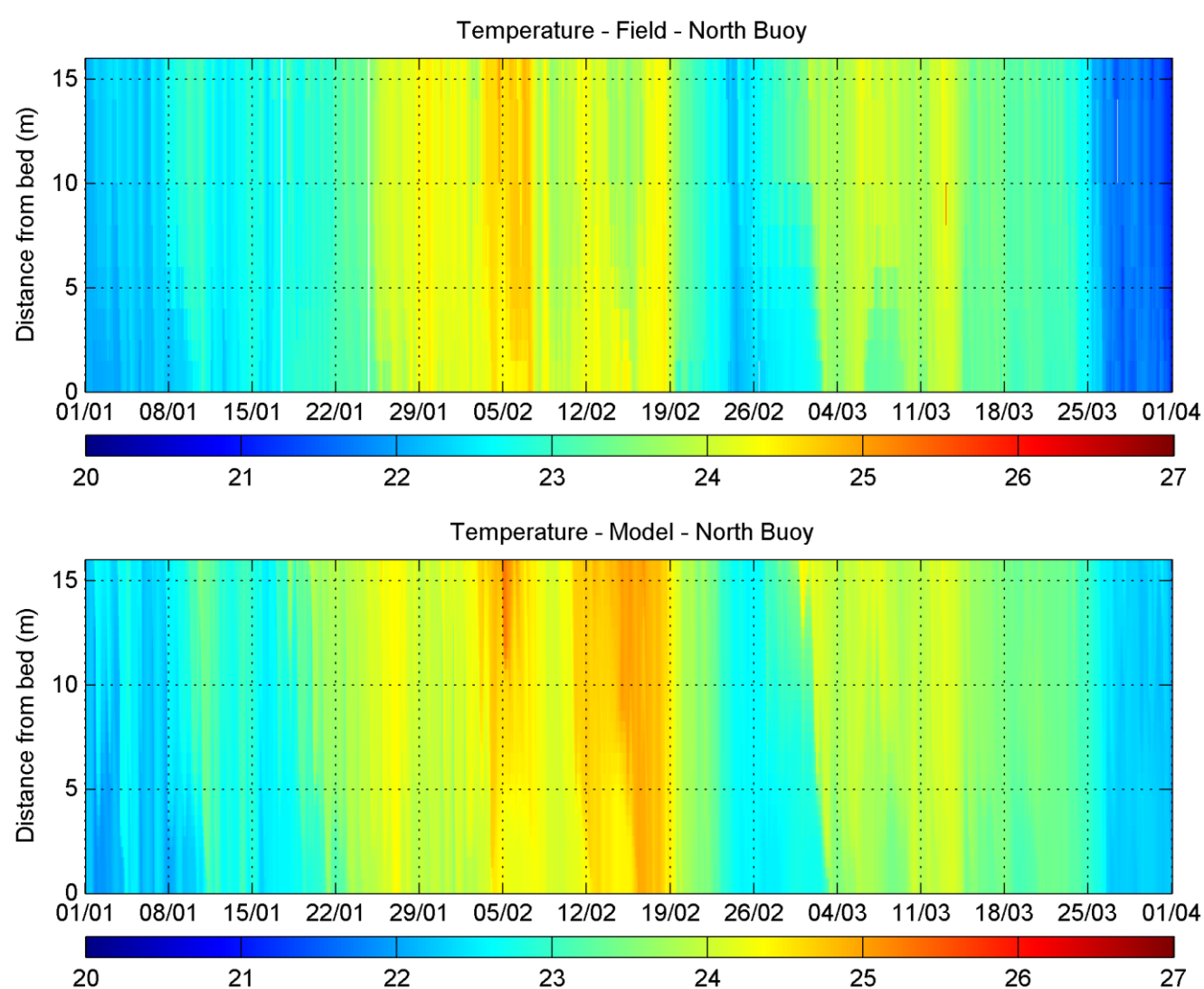


Figure 5-33 Comparisons between simulated temperatures and RTMS measurements at North Buoy in summer 2008

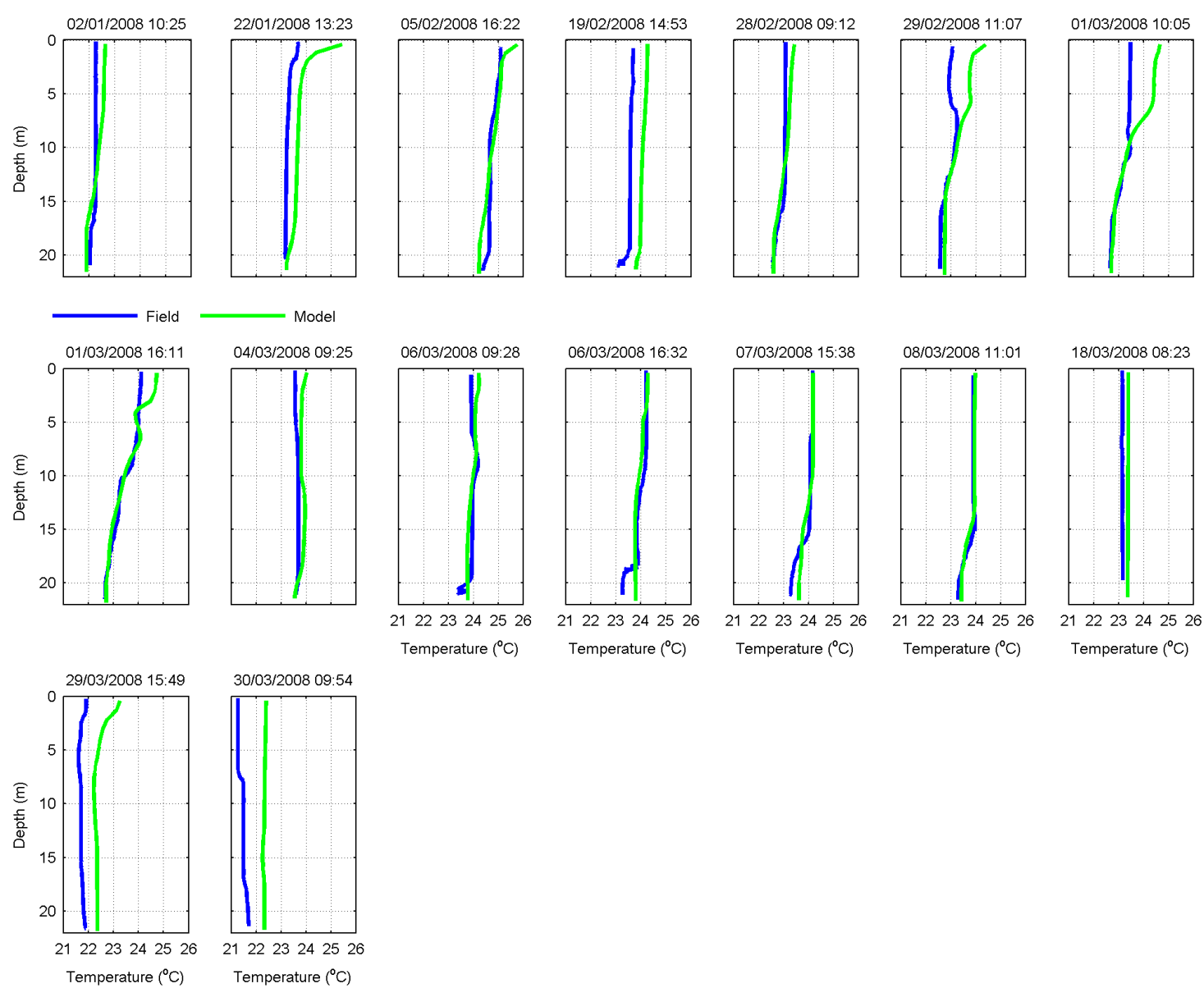


Figure 5-34 Comparisons between simulated temperatures and profile measurements at North Buoy in summer 2008

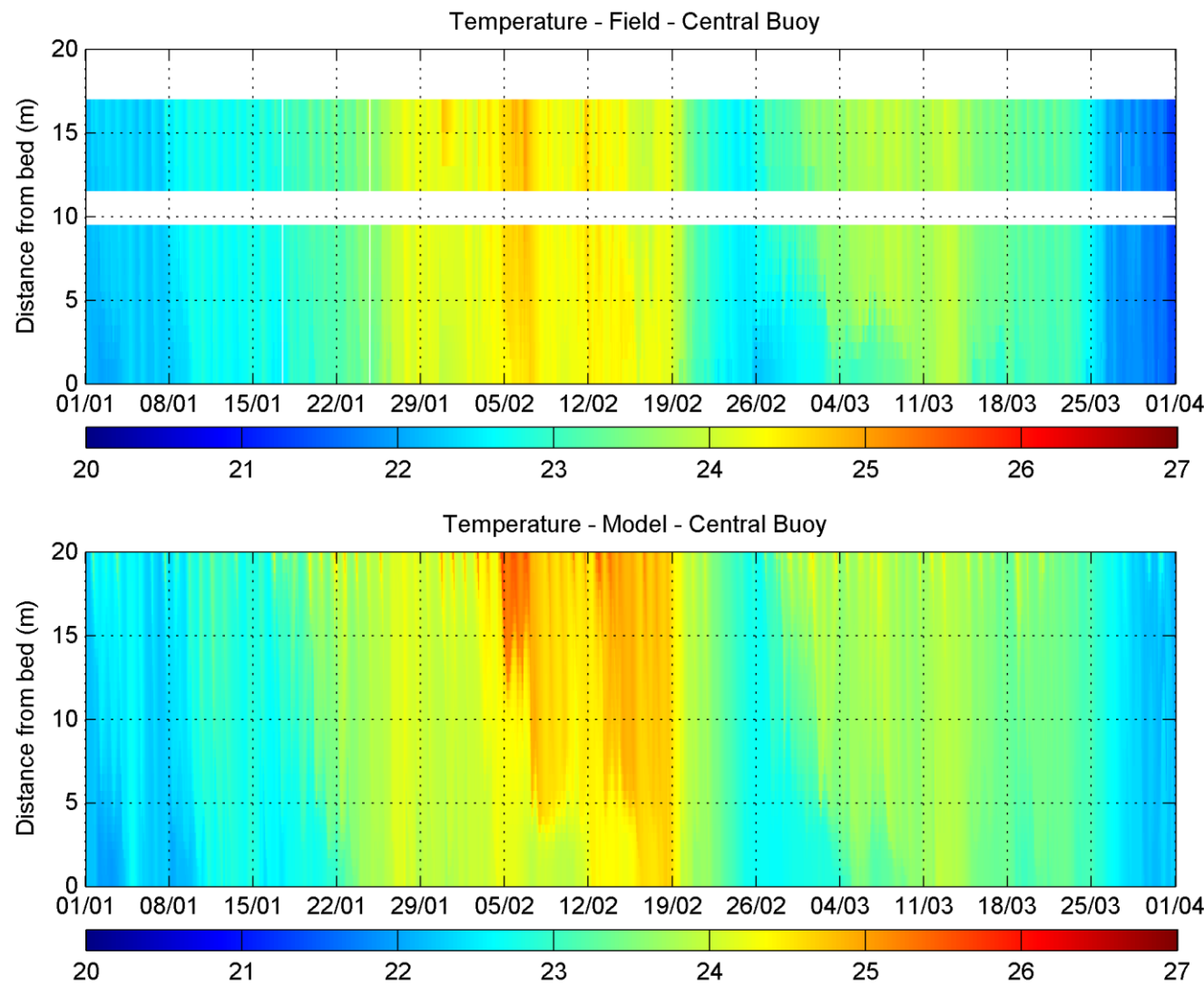


Figure 5-35 Comparisons between simulated temperatures and RTMS measurements at Central Buoy in summer 2008

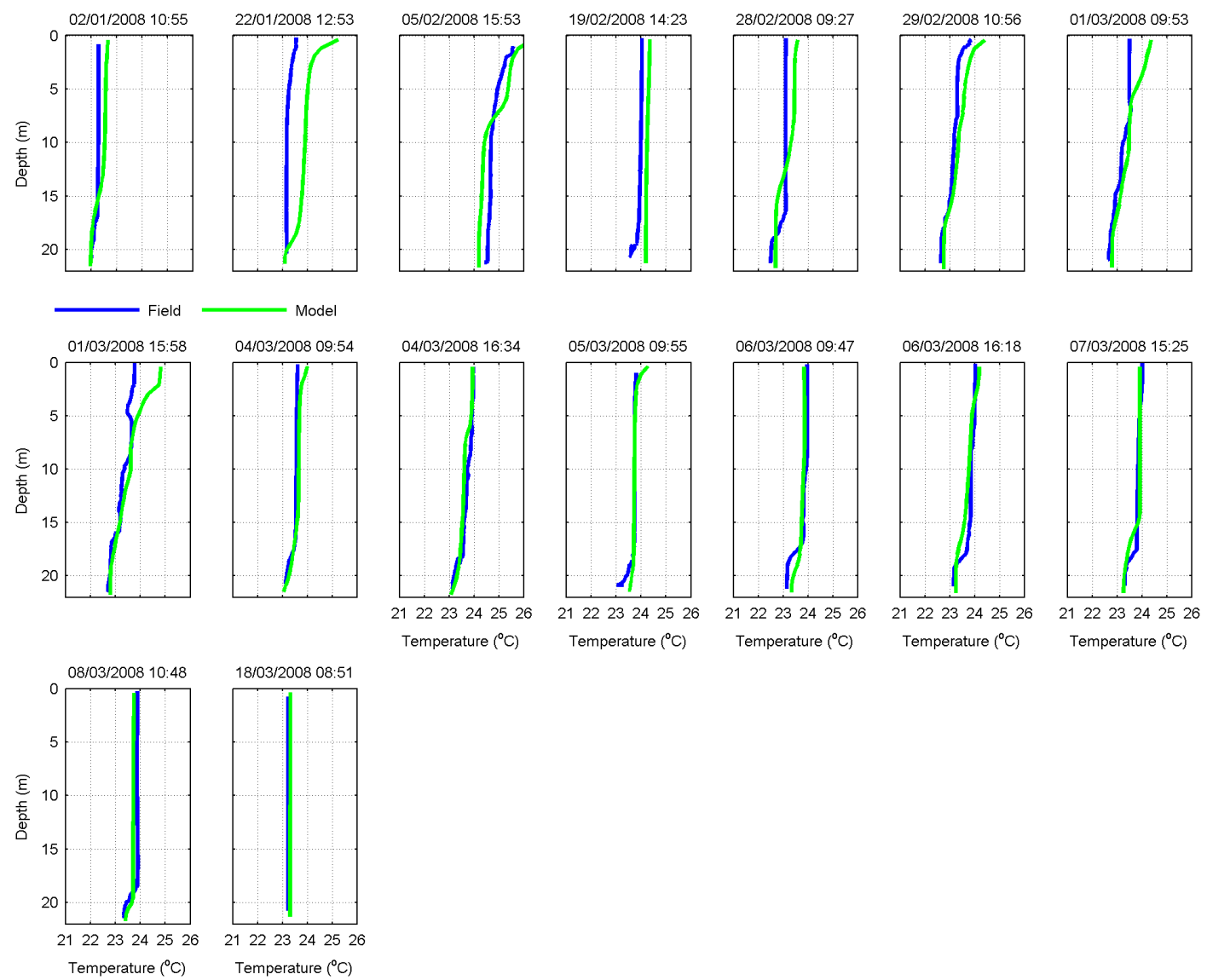


Figure 5-36 Comparisons between simulated temperatures and profile measurements at Central Buoy in summer 2008



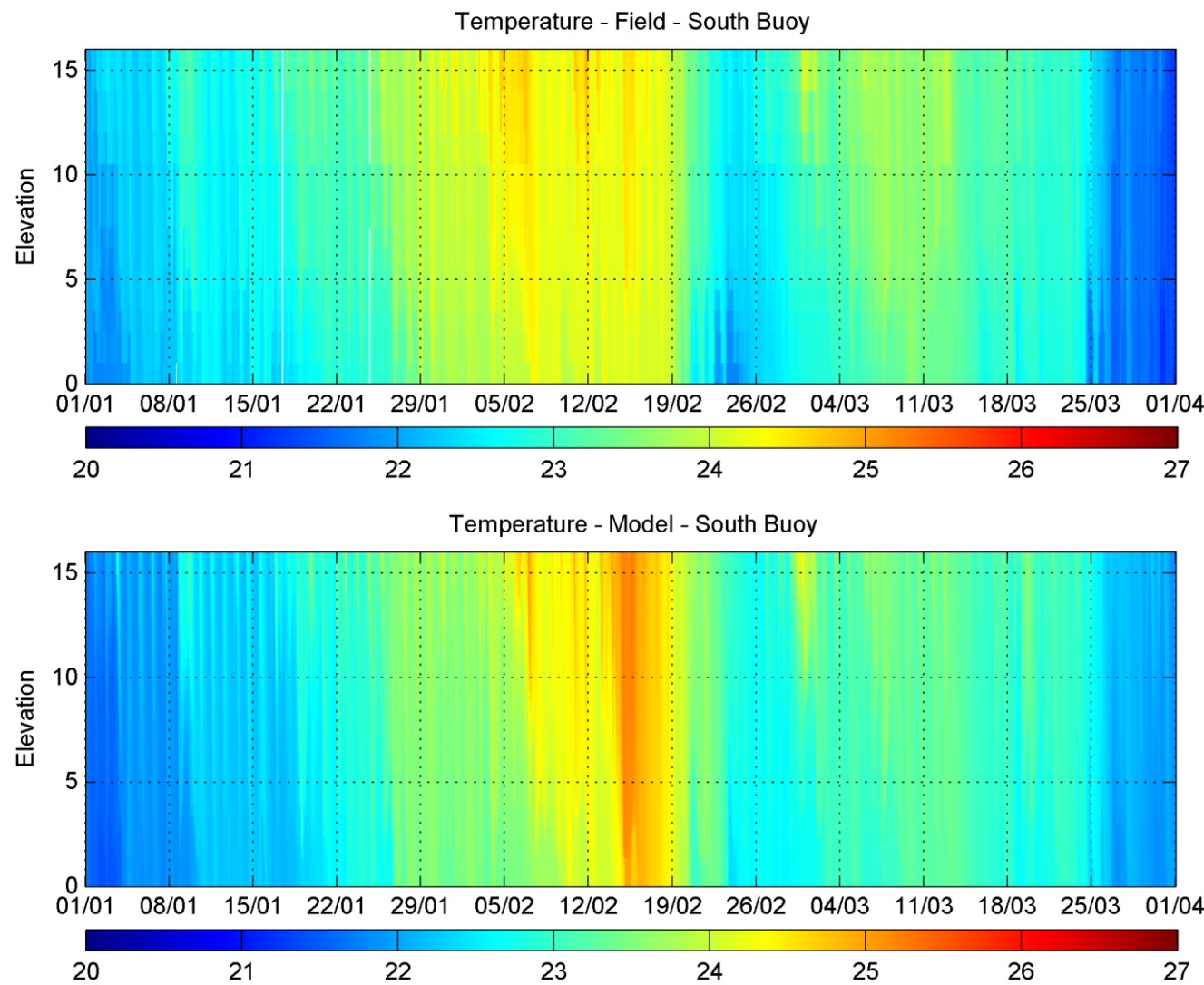


Figure 5-37 Comparisons between simulated temperatures and RTMS measurements at South Buoy in summer 2008

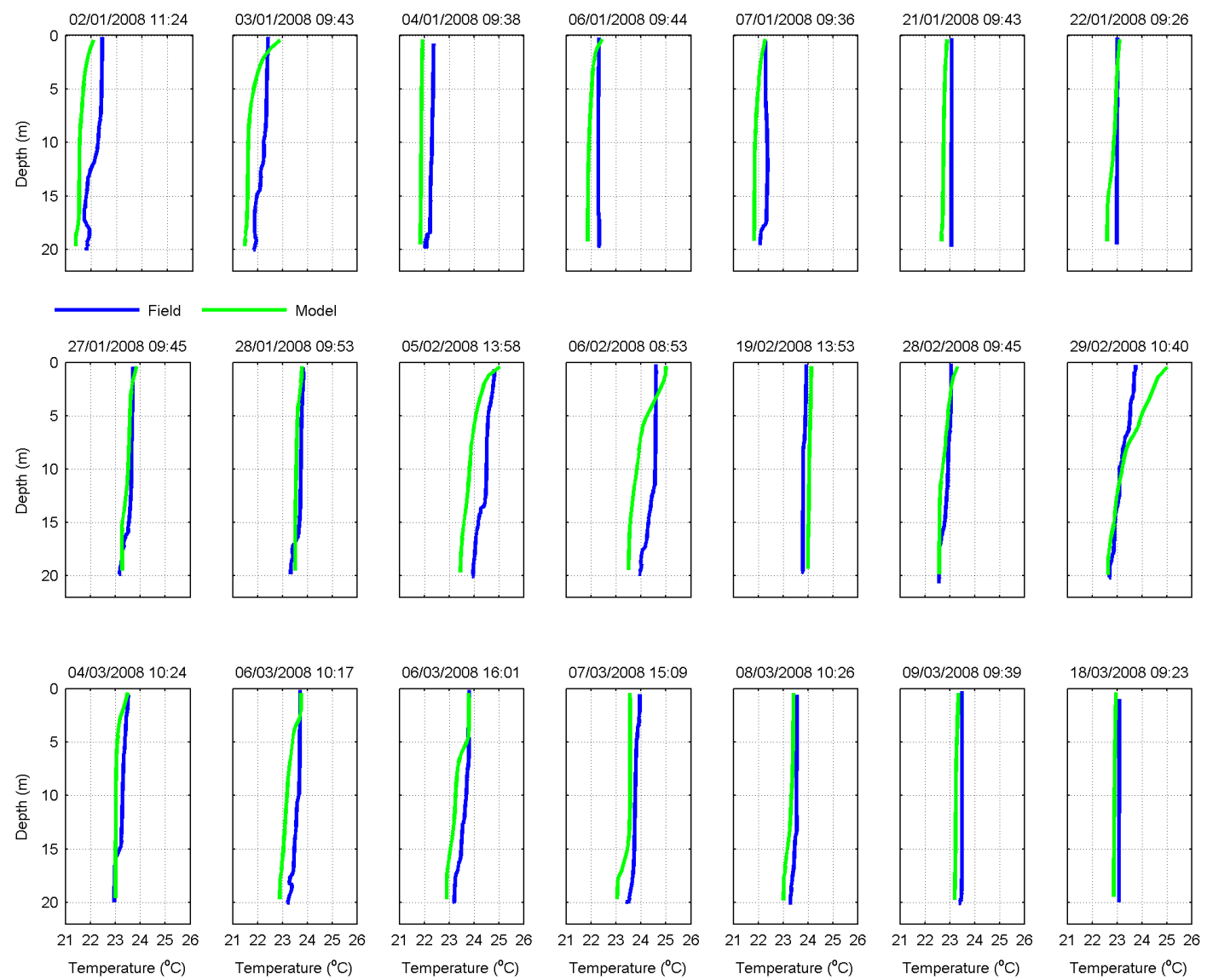


Figure 5-38 Comparisons between simulated temperatures and profile measurements at South Buoy in summer 2008

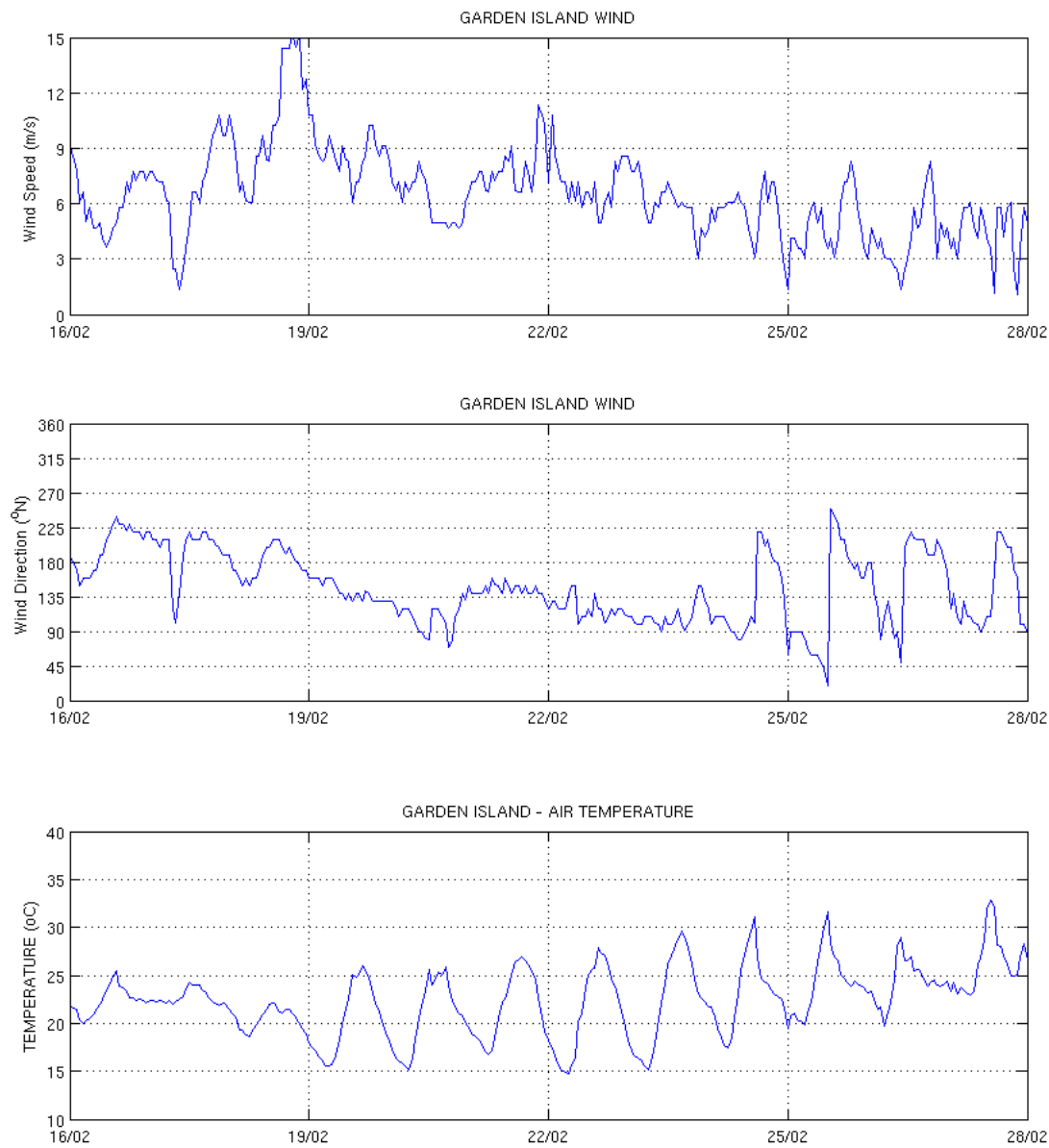
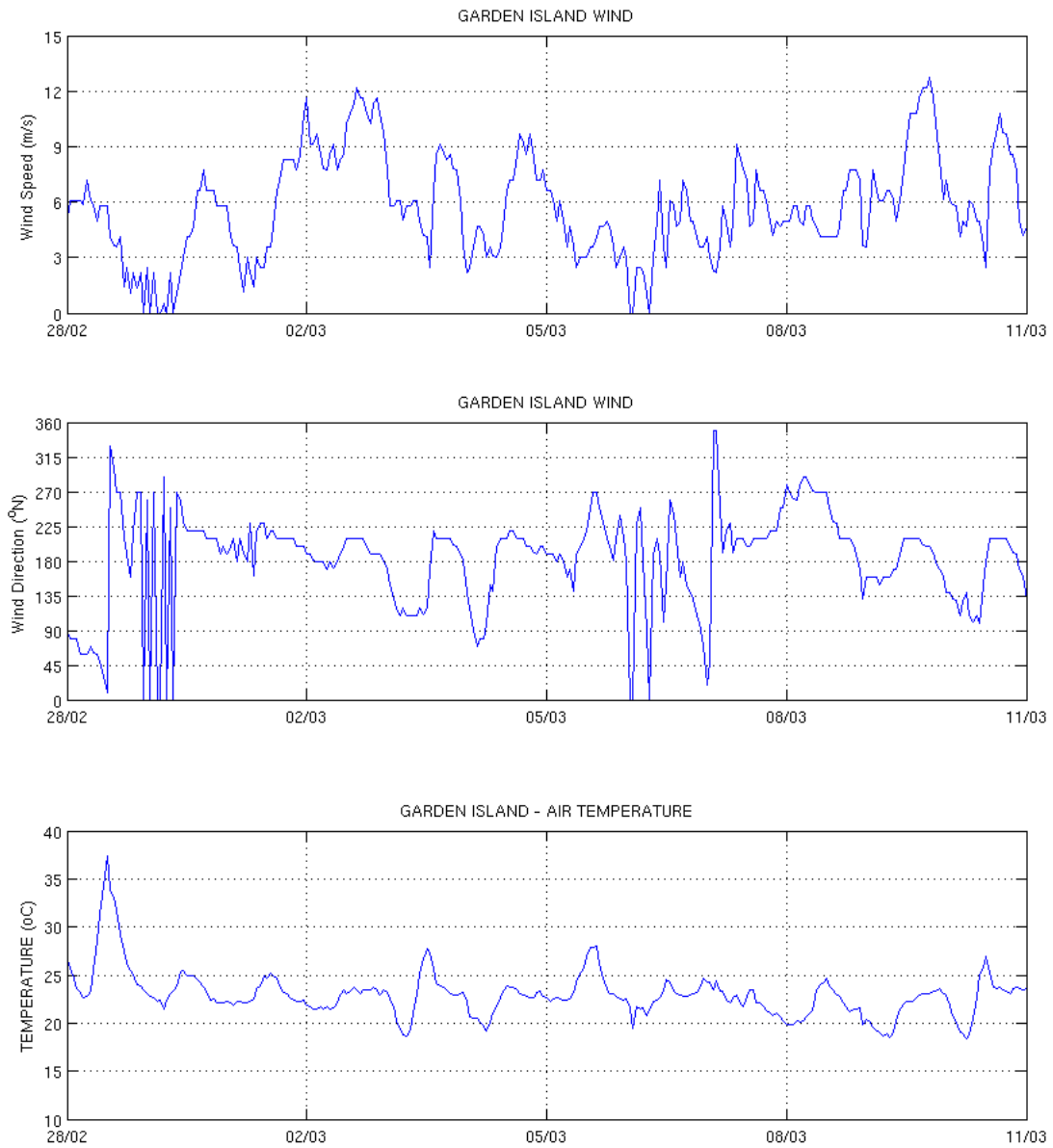


Figure 5-39 Wind and air temperature from BoM station at Garden Island (16 to 28 February 2008)



**Figure 5-40 Wind and air temperature from BoM station at Garden Island (28 February to 11 March 2008)**

## Model simulations

### 5.3.2.2 Summer to early autumn 2008 - salinities

Salinity comparisons in the transition period from summer to autumn 2008 are shown for each of the profiles at the North, Central and South Buoy stations in Figure 5-41 to Figure 5-43, respectively. The model results demonstrated that the overall salinity dynamics in summer was simulated accurately. In particular, the model reproduced the salinity reduction in the surface layer at North and Central Buoy stations (see panes between 28 February and 08 March in Figure 5-41 and Figure 5-42), whilst retaining a more uniform salinity profile at the South Buoy throughout most of the measured profiles (Figure 5-43). This characteristic of the Northern and Central Buoy (and not South Buoy) stations feeling the influence of coastal ocean processes as described in Section 5.3.2.1 is a recurring pattern throughout observations and predictions.

As an example, the profiles between 28 February and 08 March illustrates these conditions. The less dense overflow process described in Section 5.3.2.1 was further evidenced in Figure 5-41 and Figure 5-42. The profiles over the period show reduced salinities in the surface layer, consistent with the transport of offshore waters into the Sound. Again, it is noted that Swan River flows were negligible over the simulation period and could not contribute to the less saline overflows. The salinity stratification was interspersed by episodes of more uniform salinity profiles (see panels on 04 and 05 March in Figure 5-41 and Figure 5-42). The animation of a curtain along a north-south transect through Cockburn Sound presented in Appendix H assists to explain the formation of the observed changed between vertically mixed and stratified salinity conditions, similar to the observations and numerical experiments of D'Adamo (2002).

As discussed above, and shown in and Figure 5-39 and Figure 5-40, this period presented two episodes of very weak winds (25 to 01 March and 05 to 07 March) interspersed by episodes of stronger southerly breezes (02 to 05 March). Initially, waters in Cockburn Sound were more saline than offshore waters due to the well-known increased localised effects of evaporation in the Sound and the limited exchange in the southern end due to the presence of the Causeway. During the strong breeze episode however, the waters were vertically homogeneous due to wind mixing. As winds subsided, the horizontal salinity and density gradients became unstable with subsequent gravitational adjustment then leading to exchange between the Sound and northern (less saline) coastal ocean waters, and the observed vertical salinity profiles. The occurrence of rising limbs of low-frequency waves (Figure 5-3) further influenced the change in surface salinity from the North to Central Buoy (Figure 5-41 and Figure 5-42). This is an important process to be simulated, as it blankets the bottom waters from the atmosphere (at least at North and Central Buoys) and leads to DO depletion events observed in Cockburn Sound (see Section 2.3 and Section 5.5 below).

Following the above, the model predictions indicated the model's ability to replicate exchange of less saline water at the northern entrance. The model also replicated the limited influence of offshore waters at South Buoy. The vertical salinity gradients produced by the model were very similar to the observations and indicated the model was reproducing the salinity dynamics of the Sound over the period particularly well. In the absence of continuous (or at least frequent and regular) measurements at or near the northern entrance of Cockburn Sound, the model extension offshore was crucial in simulating the salinity dynamics by providing the necessary conditions that drive water exchange processes through the Sound's northern entrance.

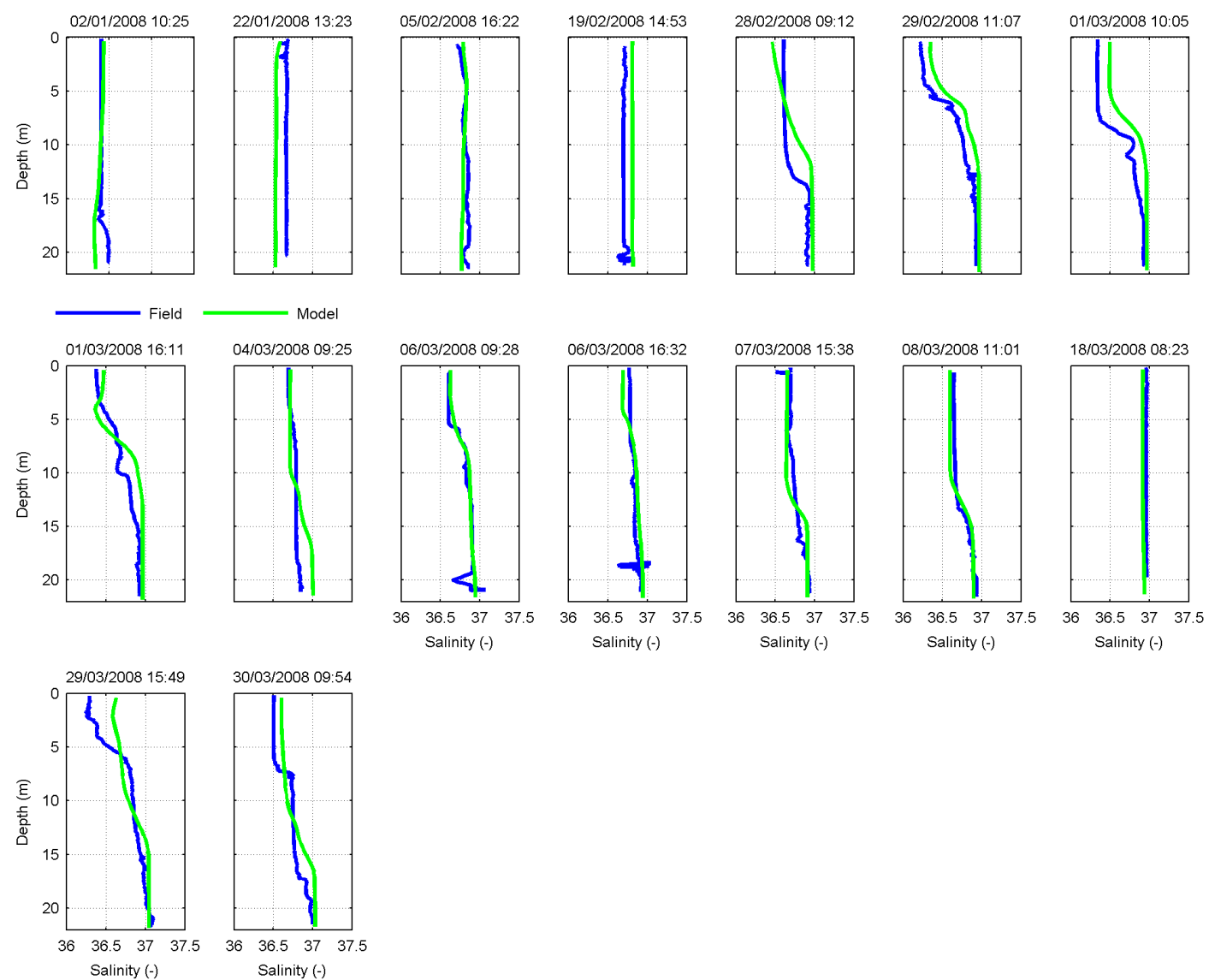


Figure 5-41 Comparisons between simulated salinities and profile measurements at North Buoy in the transition from summer to autumn 2008

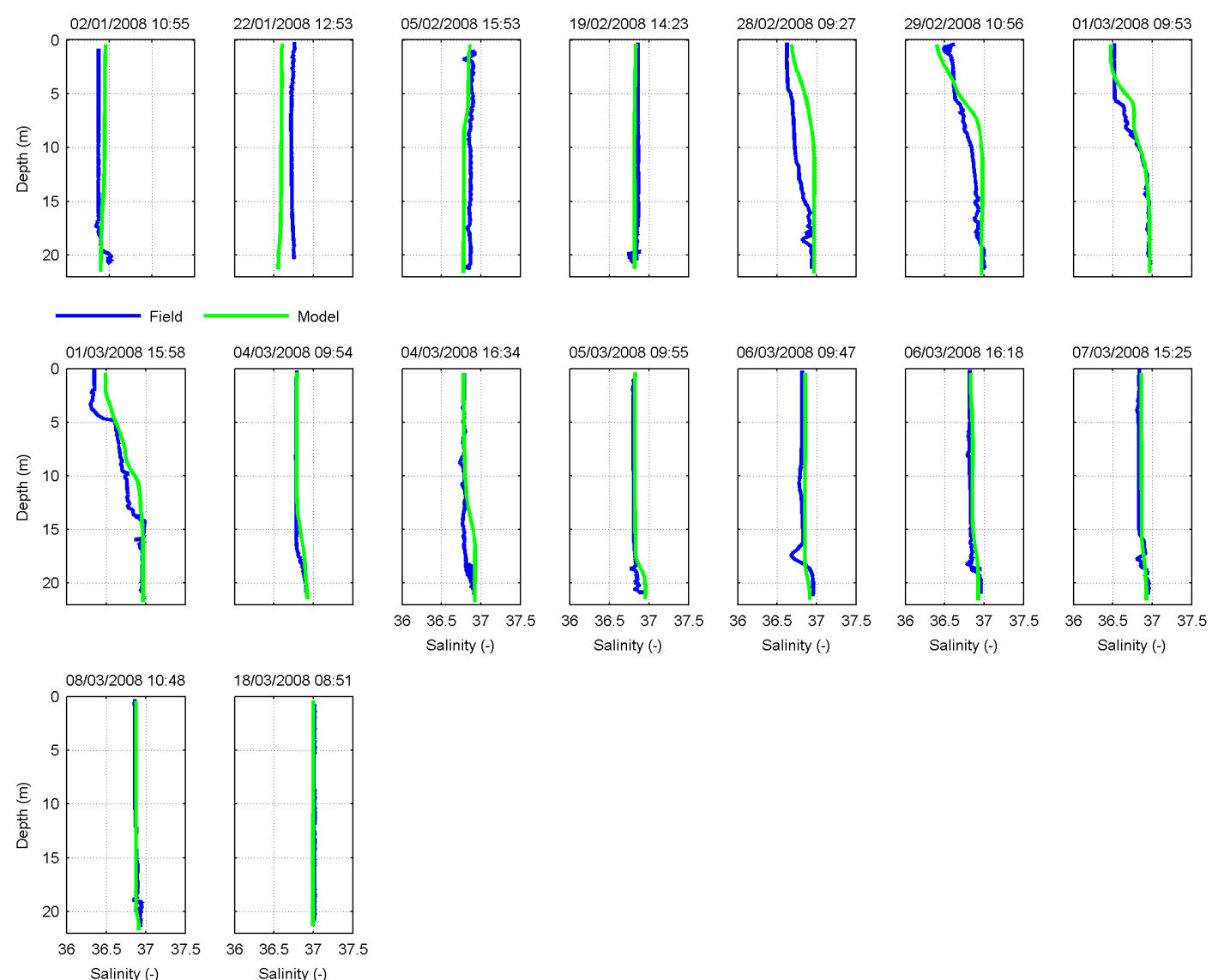


Figure 5-42 Comparisons between simulated salinities and profile measurements at Central Buoy in the transition from summer to autumn 2008

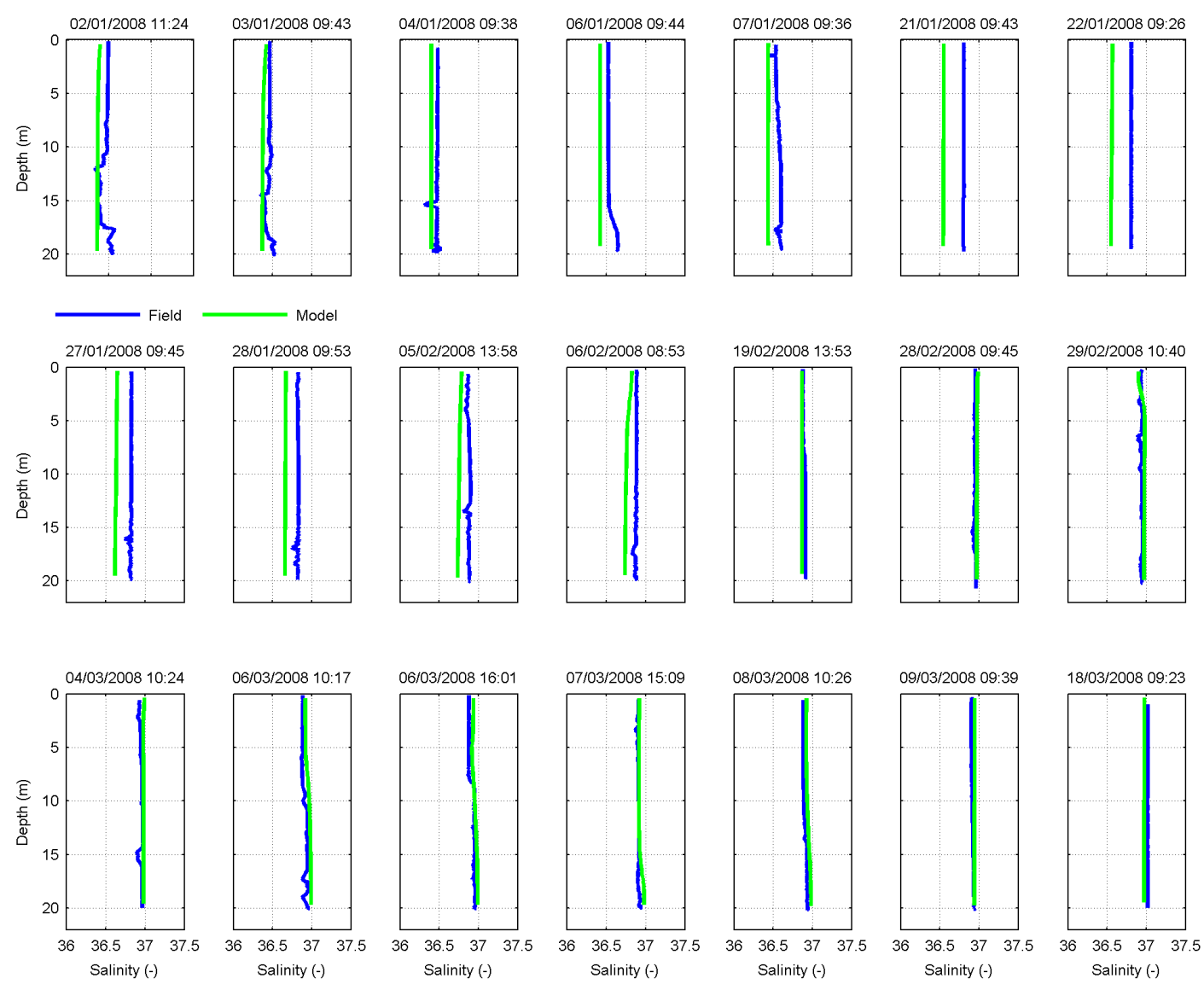


Figure 5-43 Comparisons between simulated salinities and profile measurements at South Buoy in the transition from summer to autumn 2008

**Model simulations****5.3.2.3 Winter to spring 2008 - temperatures**

Temperature comparisons in winter 2008 are shown for each of the sampling stations in Figure 5-44 to Figure 5-49. For the RTMS data the same comparisons are shown over higher resolution time intervals (Appendix F).

The contours demonstrate that the model reproduced the gradual temperature increase from August to October 2008 in all three stations (Figure 5-44 to Figure 5-49). In particular, the model captured the vertically uniform temperature conditions in August and September and the initial development of stratification accompanying the atmospheric heating in October. In contrast to the summer profiles, where heterogeneity was observed, the winter temperatures were very similar among the three sampling stations. This indicates that the model simulates the distinct summer and winter temperature conditions well.

Some of the winter profiles (e.g. 16 and 30 October at North Buoy, and 30 October at Central Buoy) presented unusually cold temperatures that were not reflected in either the RTMS measurements or the simulations. These profiles were therefore considered inaccurate and discarded for calculation of model error (Section 5.3.2.5 below).

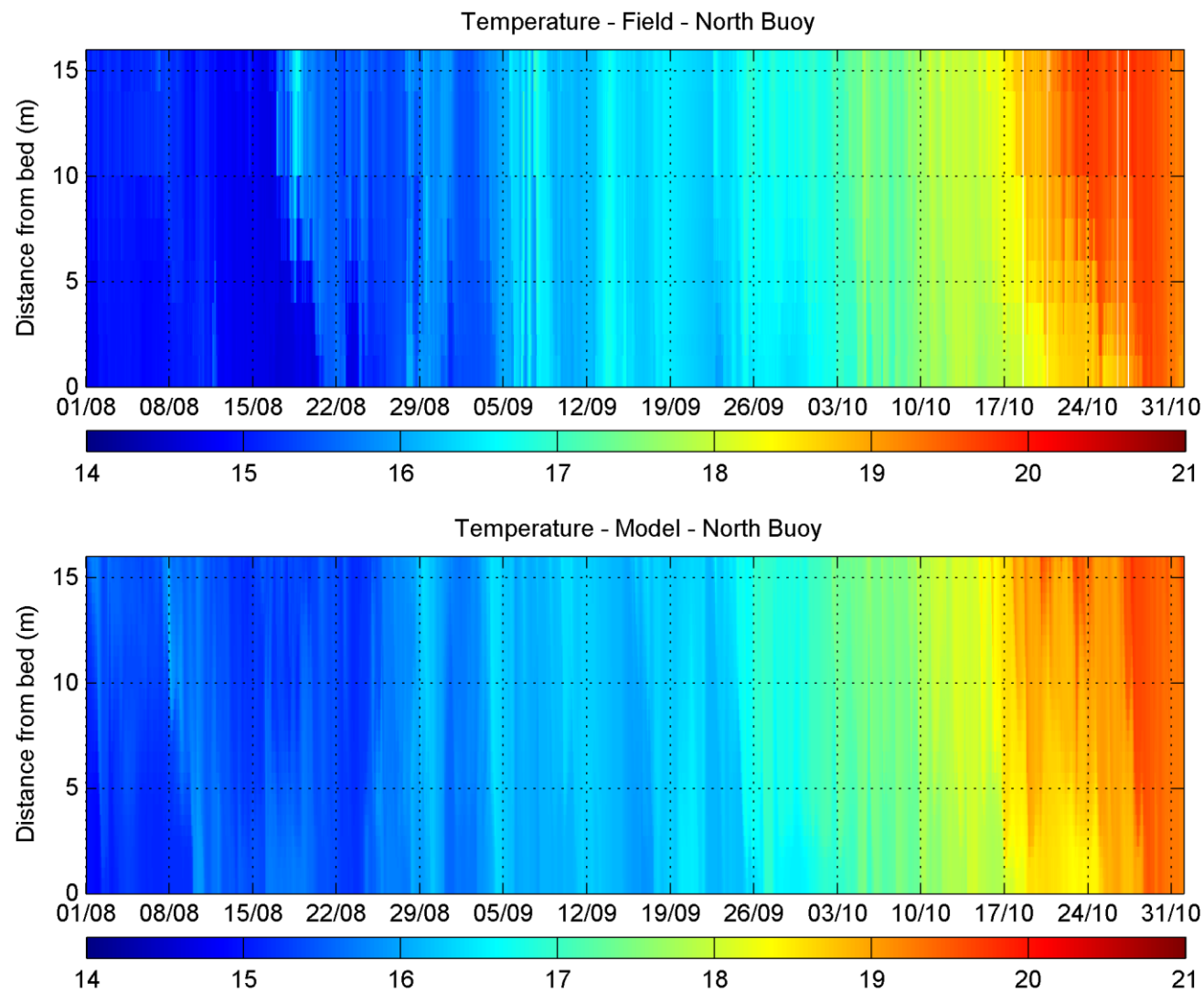


Figure 5-44 Comparisons between simulated temperatures and RTMS measurements at North Buoy in in the transition from winter to spring 2008

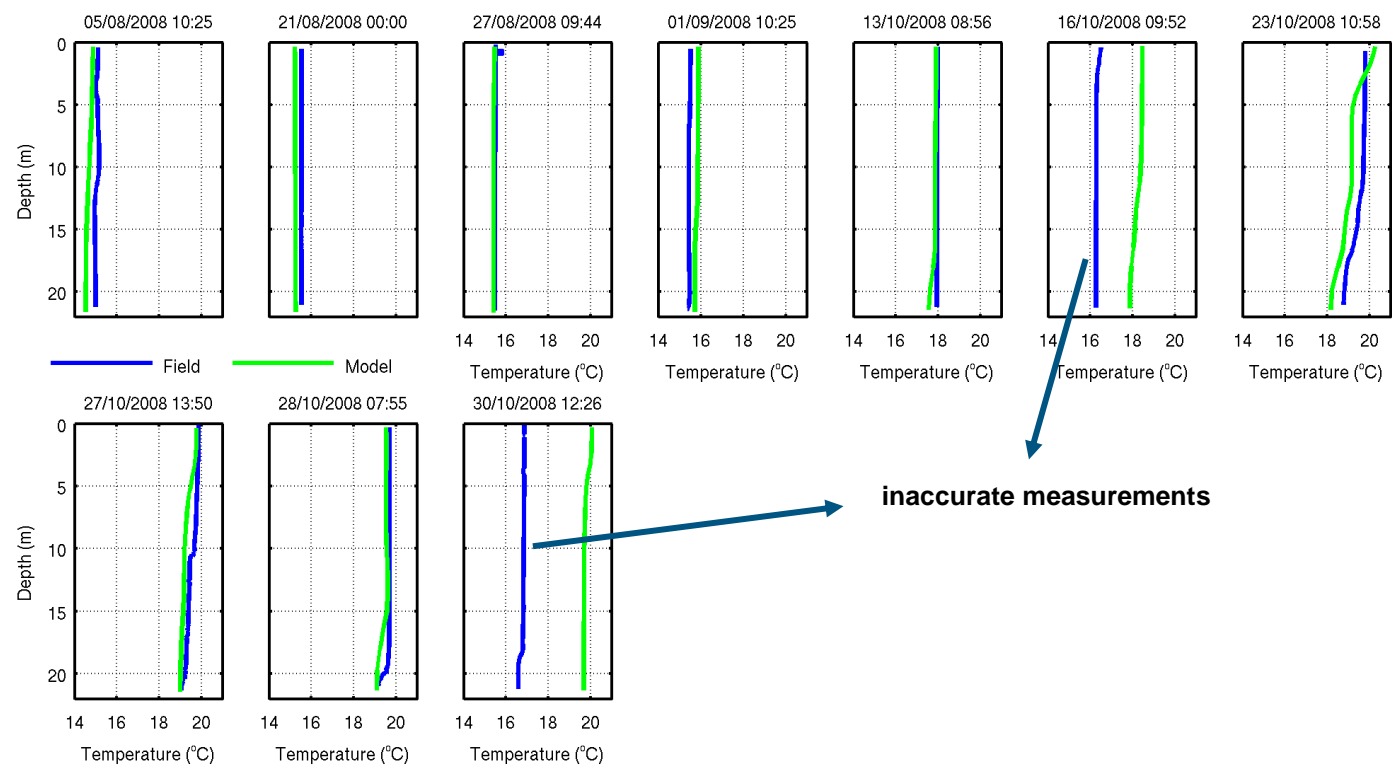


Figure 5-45 Comparisons between simulated temperatures and profile measurements at North Buoy in in the transition from winter to spring 2008. Note: profiles measured on 16 and 30 October were considered inaccurate (see text).



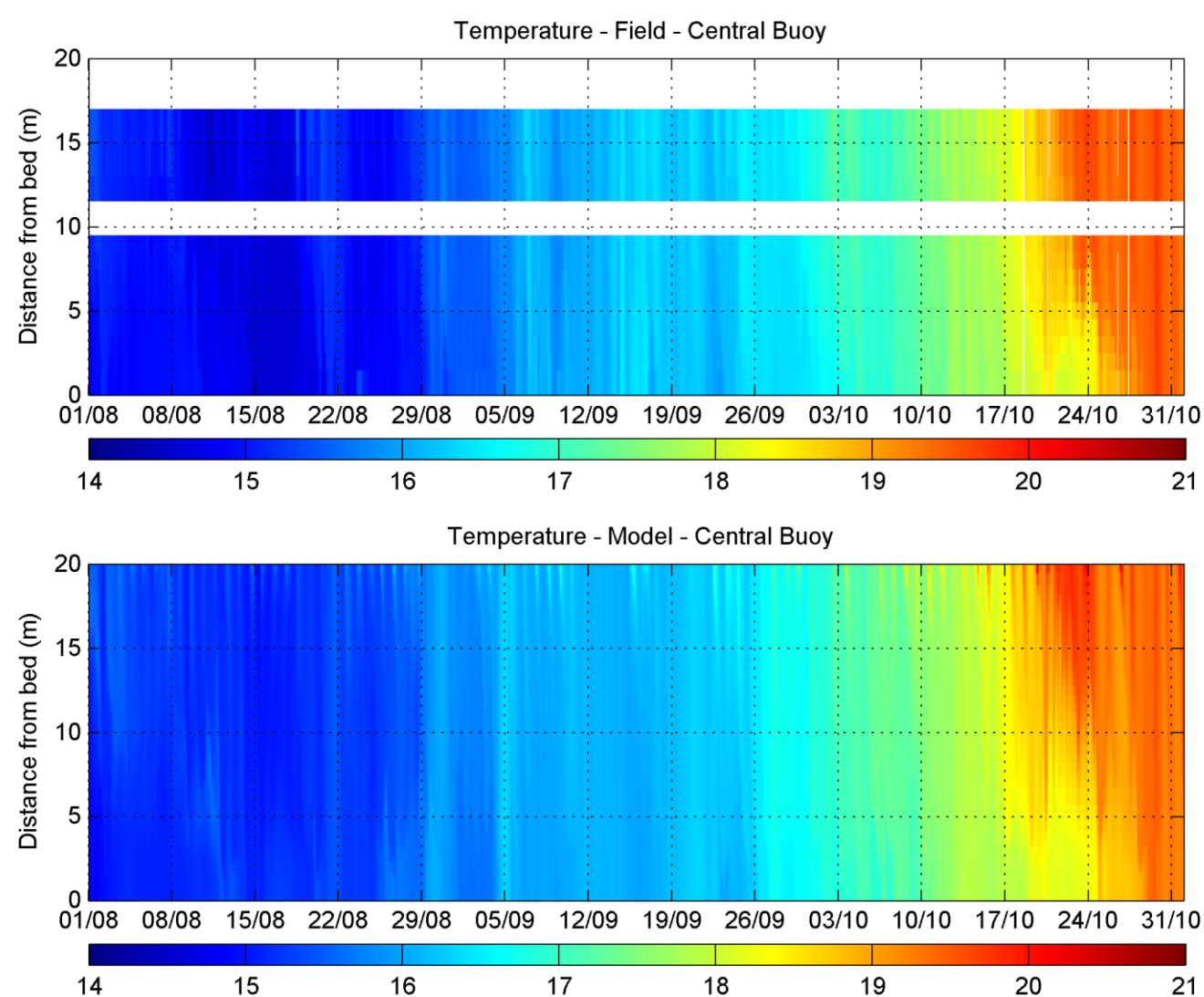


Figure 5-46 Comparisons between simulated temperatures and RTMS measurements at Central Buoy in in the transition from winter to spring 2008

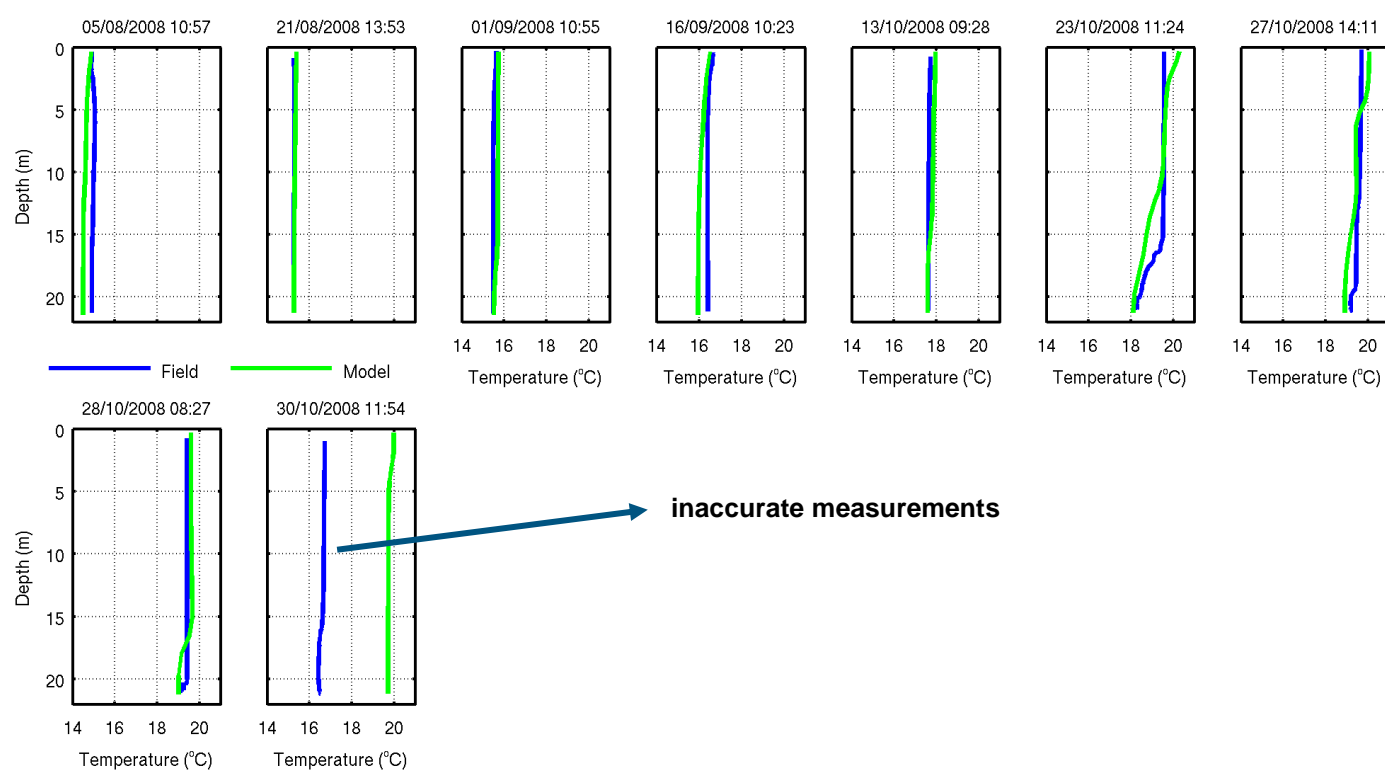


Figure 5-47 Comparisons between simulated temperatures and profile measurements at Central Buoy in in the transition from winter to spring 2008. Note: profiles measured on 16 and 30 October were considered inaccurate (see text).

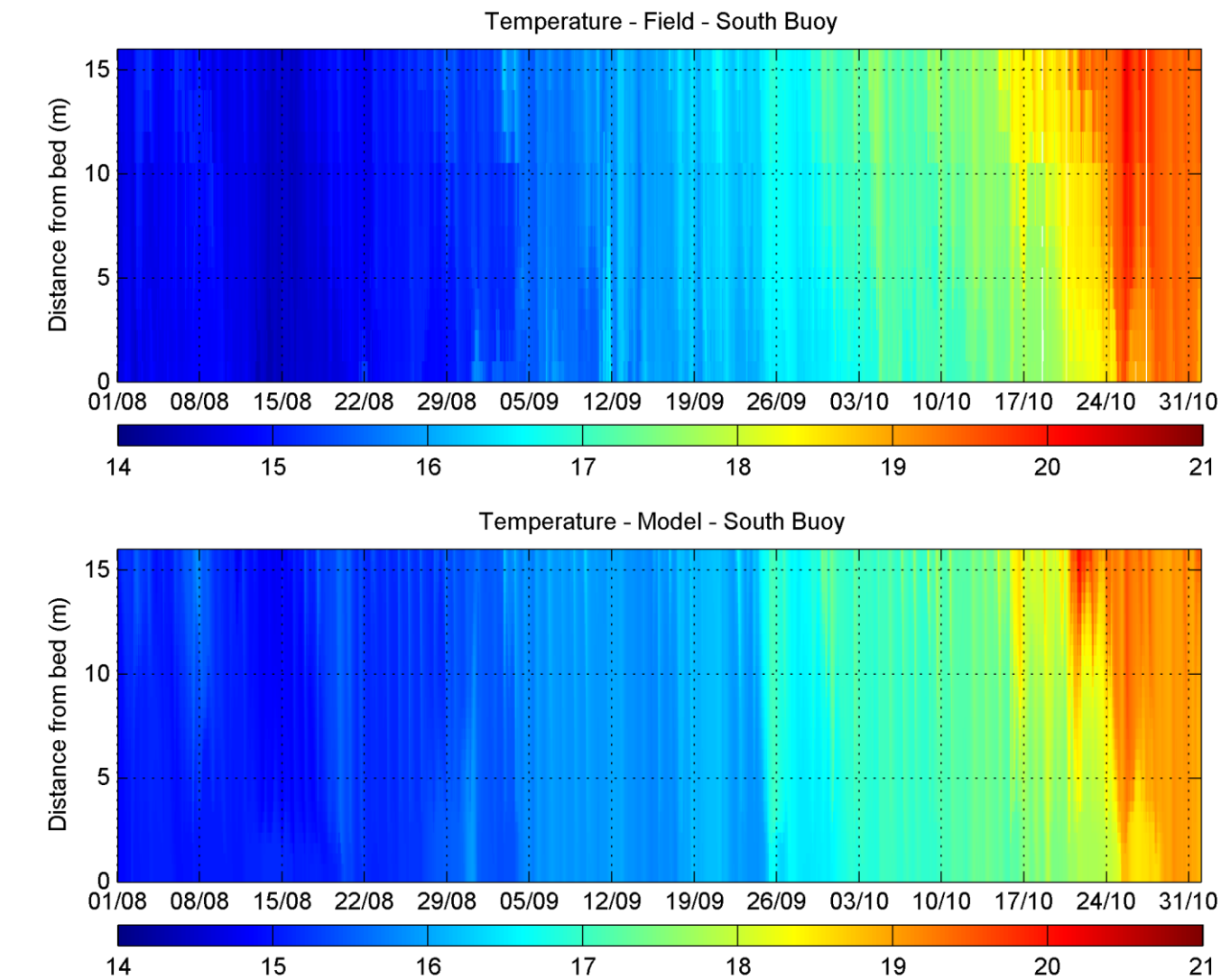


Figure 5-48 Comparisons between simulated temperatures and RTMS measurements at South Buoy in in the transition from winter to spring 2008

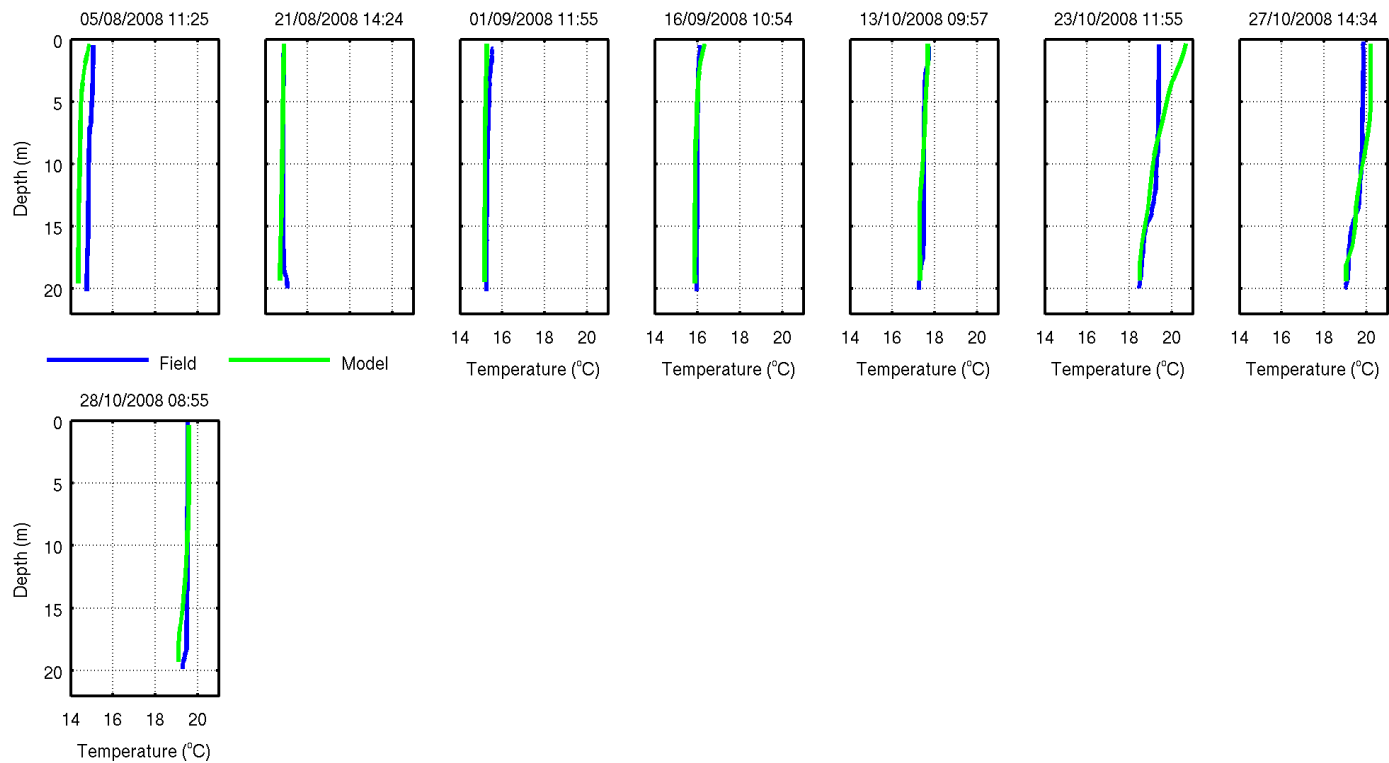


Figure 5-49 Comparisons between simulated temperatures and profile measurements at South Buoy in the transition from winter to spring 2008

**Model simulations****5.3.2.4 Winter to spring 2008 – salinities**

Salinity comparisons are shown for each of the winter profiles at the North, Central and South Buoy stations in Figure 5-50 to Figure 5-52, respectively. Except for the first profile on 05 August 2008 at the North and Central Buoy stations, the model results demonstrated that salinity in winter was well reproduced in the simulations.

With regards to the salinity reduction in the 05 August profiles, it is noted that the period coincided with relatively large Swan River flows (Figure 4-8). Whilst the model presented a similar reduction in salinity at the same time as the observed profile at North Buoy (Figure 5-50), the model did not replicate a corresponding reduction at Central Buoy (Figure 5-51). The shapes of the profiles were not as sharp as in the observations (Figure 5-50 and Figure 5-51). Although the magnitude of this second salinity reduction was not the same as the observation, the forcing mechanism and response were simulated by the model. Given the significant assumptions made in setting the Swan River inflow salinity and temperature boundary conditions (see Section 4.4.6) this mismatch in salinity reductions was not unexpected. With more accurate Swan River flow data, this model performance could be improved if required, but nonetheless the Swan River plume can be seen moving into Cockburn Sound (see animation link in Appendix H), and, most importantly, generating a vertical density stratification. A series of consecutive screen shots from the animation in Appendix H is presented in Figure 5-53 to Figure 5-57.

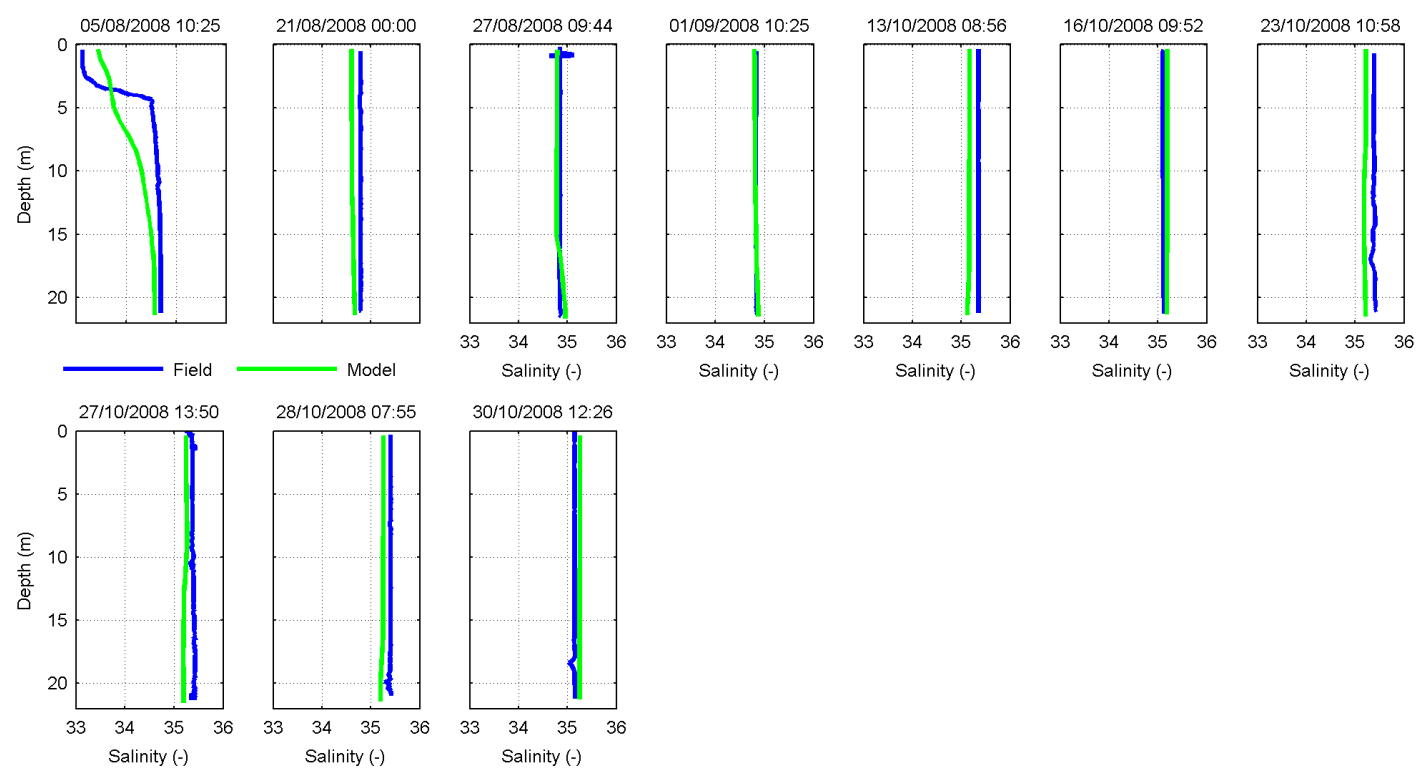


Figure 5-50 Comparisons between simulated salinities and profile measurements at North Buoy in the transition from winter to spring 2008

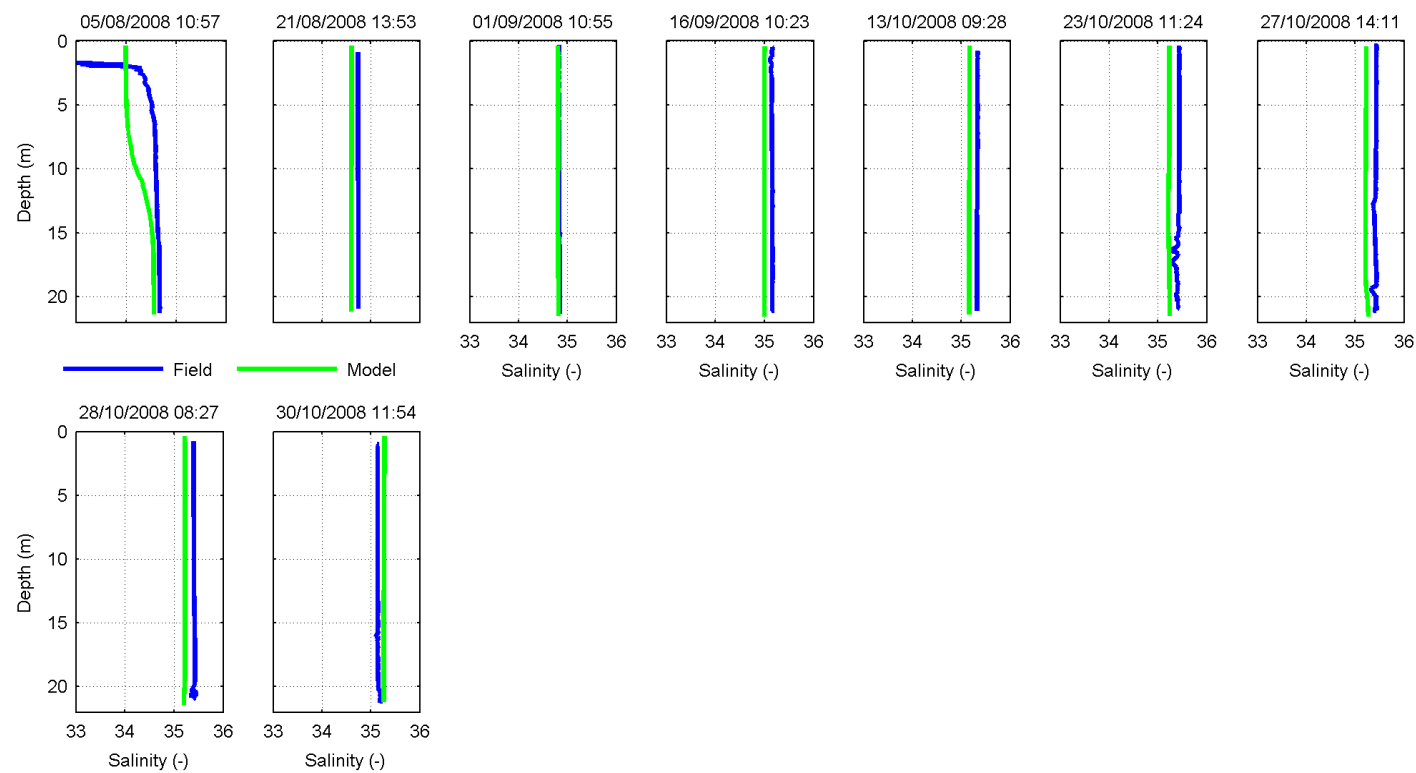


Figure 5-51 Comparisons between simulated salinities and profile measurements at Central Buoy in the transition from winter to spring 2008

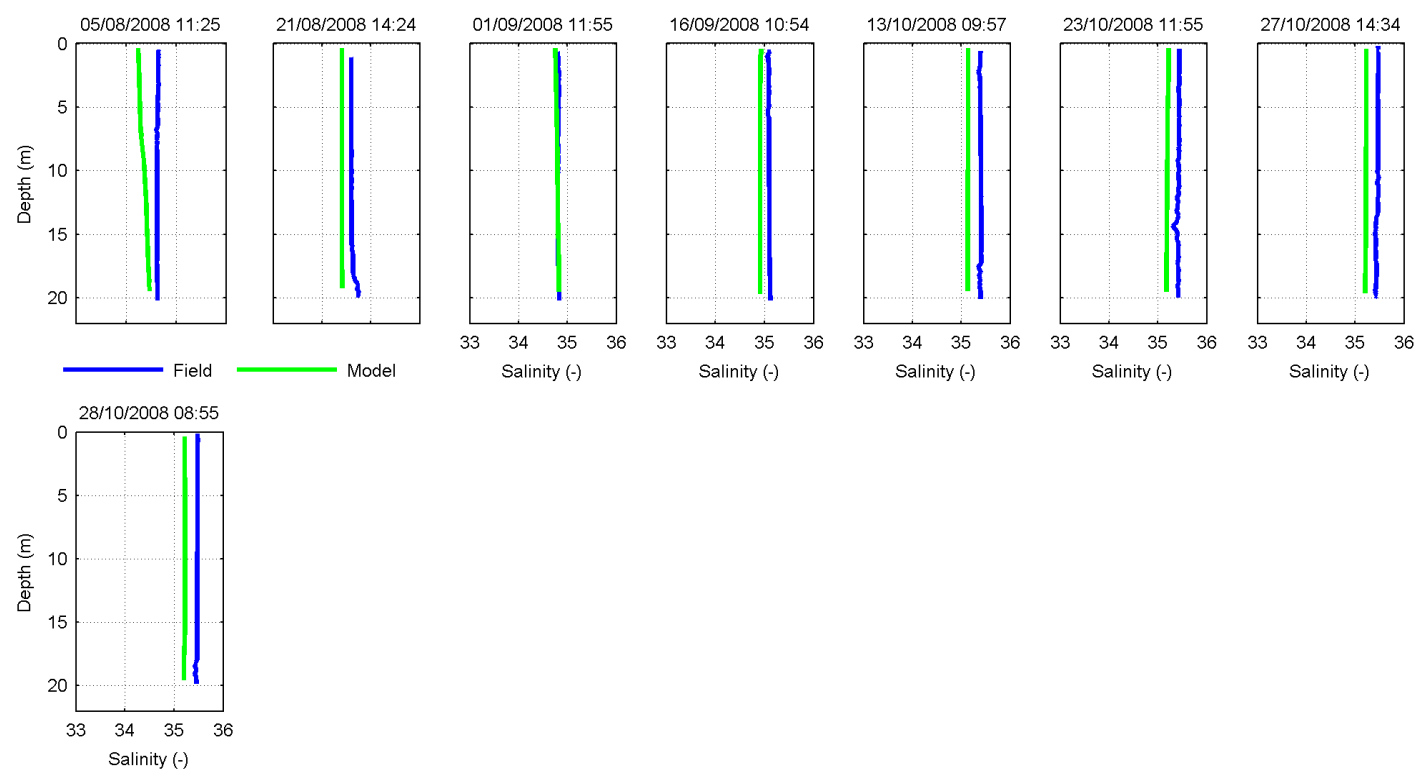


Figure 5-52 Comparisons between simulated salinities and profile measurements at South Buoy in the transition from winter to spring 2008



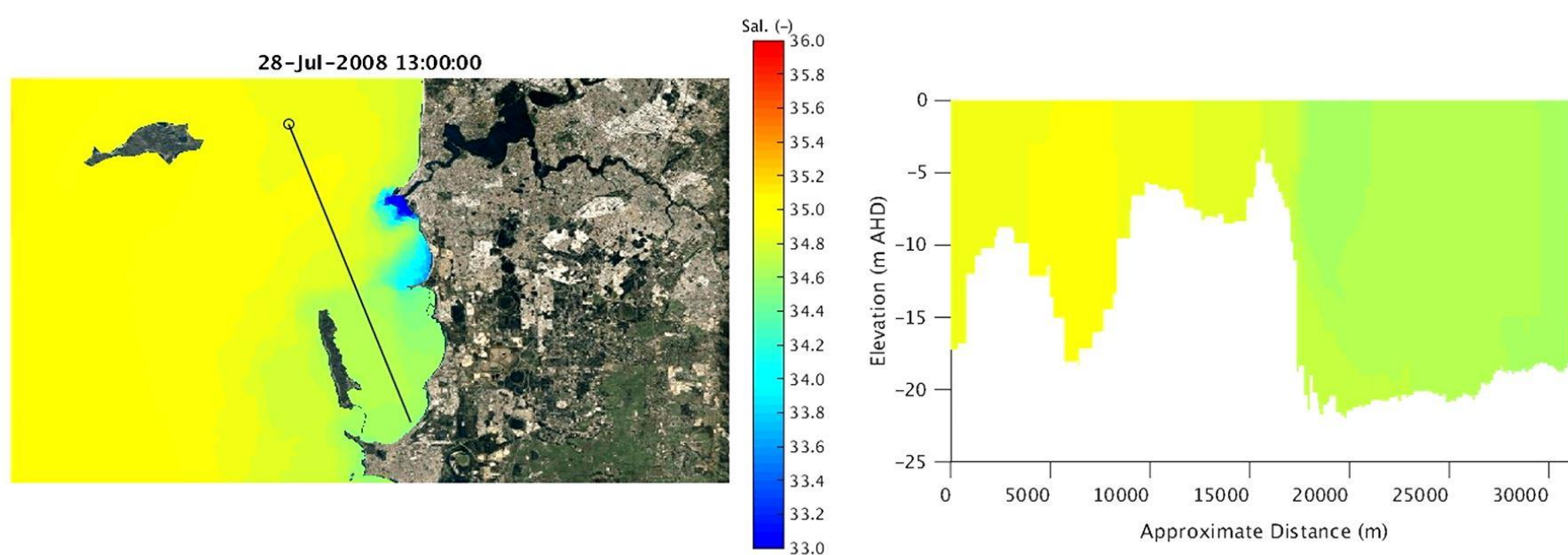


Figure 5-53 Swan River plume interacting with Cockburn Sound – 1 of 6

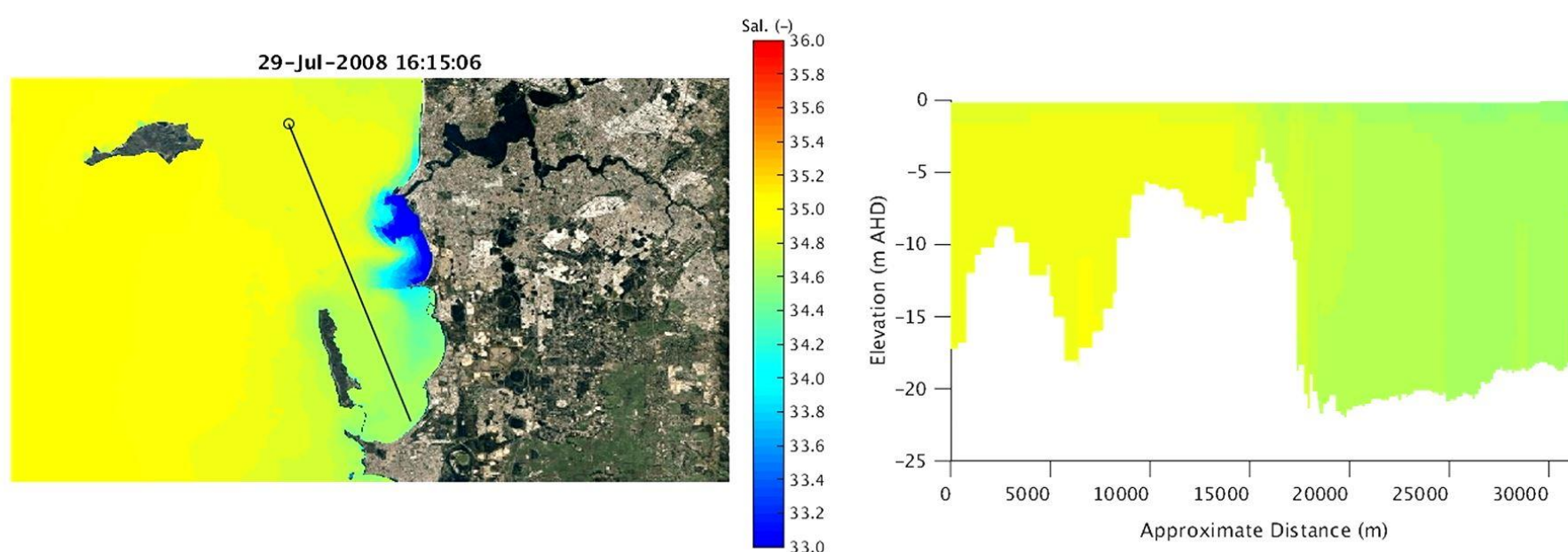


Figure 5-54 Swan River plume interacting with Cockburn Sound – 2 of 6

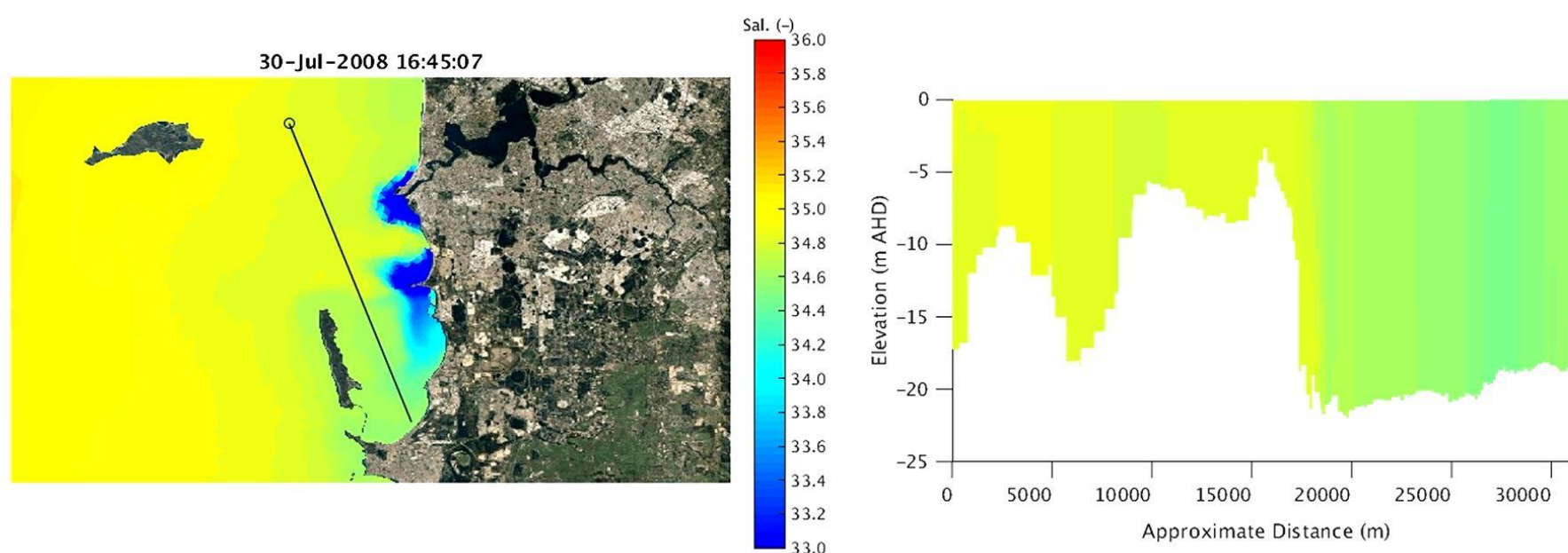


Figure 5-55 Swan River plume interacting with Cockburn Sound – 3 of 6



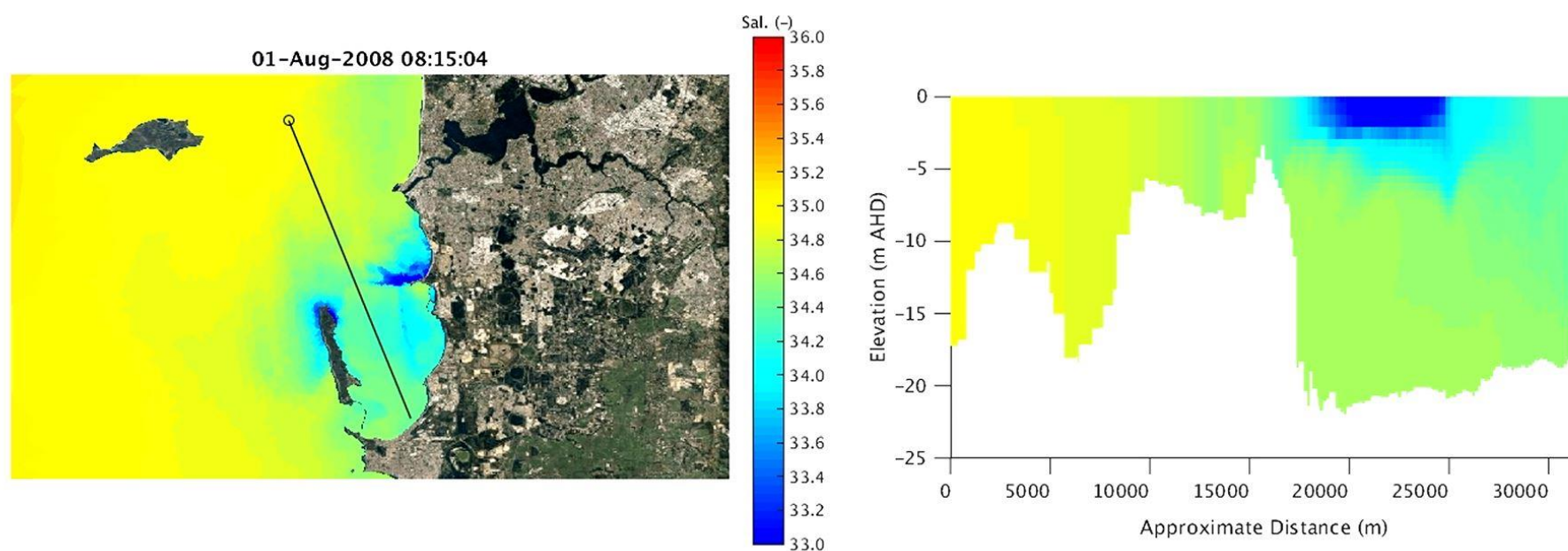


Figure 5-56 Swan River plume interacting with Cockburn Sound – 4 of 6

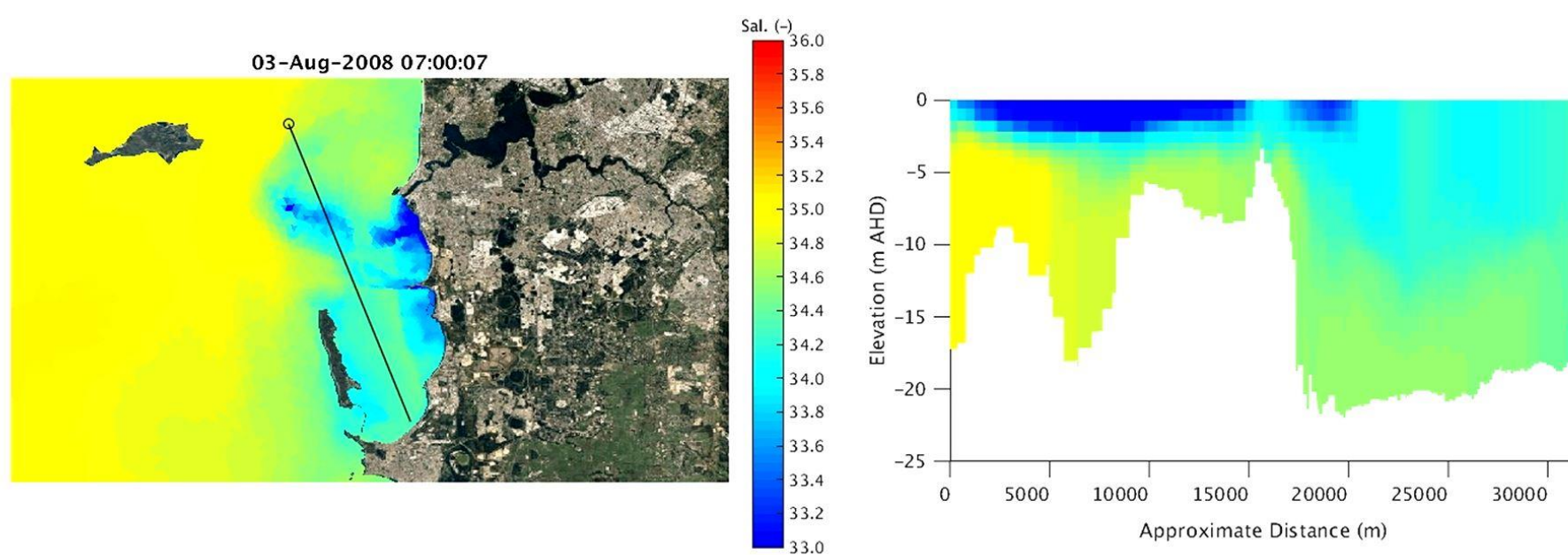


Figure 5-57 Swan River plume interacting with Cockburn Sound – 5 of 6

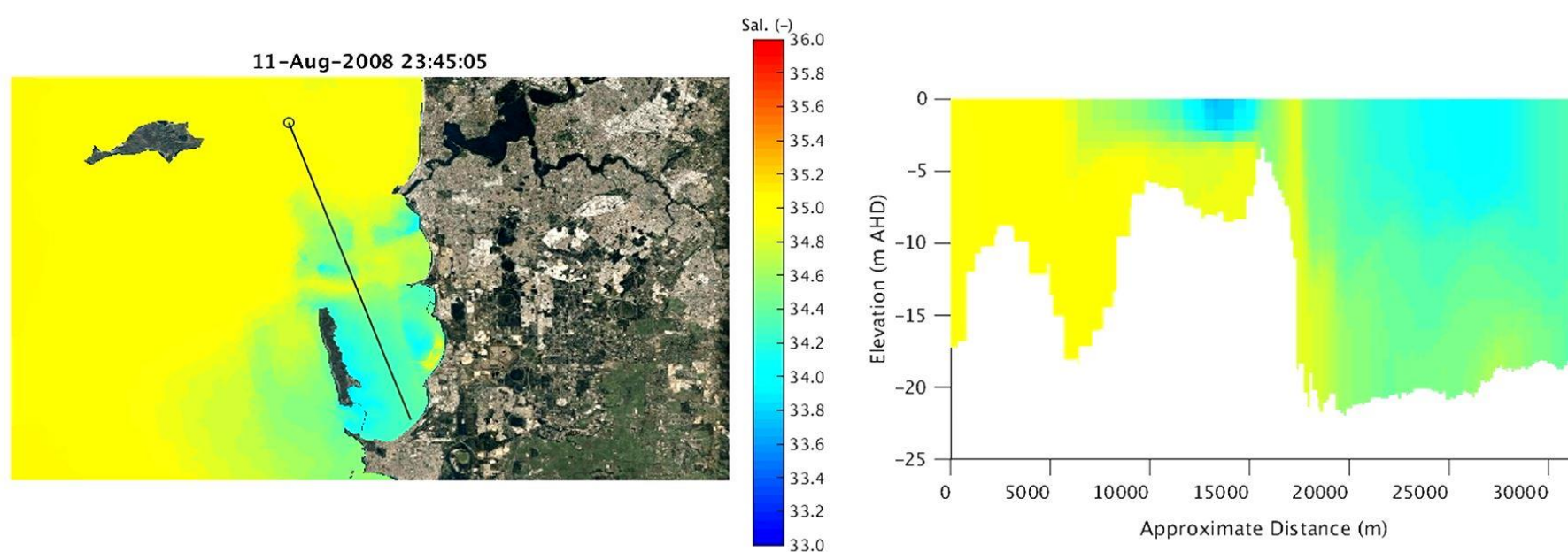


Figure 5-58 Swan River plume interacting with Cockburn Sound – 6 of 6

## Model simulations

### 5.3.2.5 Model Error

The model predictive skill for temperature and salinity were also tested statistically with calculations of the Index of Agreement, Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and coefficient of determination ( $R^2$ ) as defined in Appendix D. At project inception, the following calibration targets were agreed as indicators of satisfactory model validation (Table 5-10):

**Table 5-10 Calibration goals for temperature and salinity**

Variable	IOA	$R^2$	MAE	RMSE
Temperature (RTMS)	$\geq 0.7$	Not Used	$\leq 1.0$ °C	$\leq 1.5$ °C
Temperature (profiles)	Not Used	$\geq 0.9$	$\leq 1.0$ °C	$\leq 1.5$ °C
Salinity (profiles only)	Not Used	$\geq 0.8$	$\leq 0.4$	$\leq 0.7$

The model error statistics for all temperature, salinity and DO data presented in this report is also given in Appendix I.

### RTMS data

The statistical evaluation of the predicted summer temperatures at the RTMS locations are provided in Table 5-11 to Table 5-13 for North, Central, and South Buoy stations, respectively. These statistics confirmed the model predictive ability with temperature IOA's generally above 0.9 at North and Central Buoy and generally above 0.8 at the South Buoy. MAE was very similar across all stations, between 0.29 and 0.40 °C for North Buoy, 0.26 and 0.31 °C for Central Buoy, and between 0.31 and 0.34 °C for South Buoy. RMSE was between 0.36 and 0.78 °C for North Buoy, 0.33 and 0.57 °C for Central Buoy, and 0.58 and 0.86 °C for South Buoy.

Similarly, statistical evaluation of the predicted winter temperatures at the RTMS locations are provided in Table 5-11 to Table 5-13 for North, Central, and South Buoy stations, respectively. In this case the high level of agreement is shown by all IOA's above 0.91. MAE was very similar across all stations, between 0.33 and 0.36 °C for North Buoy, 0.28 and 0.30 °C for Central Buoy, and between 0.26 and 0.29 °C for South Buoy. RMSE was also very similar across all stations, between 0.42 and 0.59 °C for North Buoy, 0.36 and 0.63 °C for Central Buoy, and between 0.43 and 0.77 °C for South Buoy.

It is noted that other modelling investigations adopting similar data sets (e.g., CWR 2009) did not present model performance information in this regard. The values obtained for both summer and winter 2008 were well within those agreed at project inception.

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Table 5-11 Summary of model predictive skill statistics for temperature at North Buoy

Height (m)	Summer IOA (-)	Summer MAE (°C)	Summer RMSE (°C)	Winter IOA (-)	Winter MAE (°C)	Winter RMSE (°C)
0.5	0.94	0.29	0.56	0.97	0.33	0.42
2.0	0.98	0.29	0.36	0.97	0.33	0.42
3.0	0.97	0.30	0.38	0.97	0.33	0.42
4.0	0.97	0.32	0.40	0.98	0.33	0.42
5.0	0.97	0.34	0.43	0.98	0.33	0.42
7.0	0.89	0.37	0.78	0.97	0.33	0.43
9.0	0.92	0.39	0.64	0.96	0.35	0.58
13.0	0.95	0.40	0.50	0.95	0.36	0.59
15.0	0.94	0.29	0.56	0.97	0.33	0.42

Table 5-12 Summary of model predictive skill statistics for temperature at Central Buoy

Height (m)	Summer IOA (-)	Summer MAE (°C)	Summer RMSE (°C)	Winter IOA (-)	Winter MAE (°C)	Winter RMSE (°C)
0.5	0.98	0.26	0.33	0.96	0.29	0.52
2.0	0.98	0.26	0.33	0.96	0.29	0.52
3.0	0.98	0.26	0.33	0.96	0.30	0.52
4.0	0.98	0.26	0.33	0.96	0.30	0.52
5.0	0.98	0.26	0.34	0.96	0.30	0.52
6.0	0.98	0.27	0.34	0.96	0.30	0.52
7.0	0.98	0.27	0.35	0.96	0.30	0.52
8.0	0.98	0.27	0.35	0.96	0.30	0.52
9.0	0.98	0.28	0.36	0.98	0.29	0.37
12.0	0.94	0.29	0.57	0.98	0.28	0.36
14.0	0.94	0.30	0.57	0.95	0.29	0.63
16.0	0.97	0.31	0.39	0.95	0.29	0.63



## Model simulations

Table 5-13 Summary of model predictive skill statistics for temperature at South Buoy

Height (m)	Summer IOA (-)	Summer MAE (°C)	Summer RMSE (°C)	Winter IOA (-)	Winter MAE (°C)	Winter RMSE (°C)
0.5	0.80	0.31	0.86	0.91	0.29	0.77
2.0	0.84	0.31	0.74	0.93	0.29	0.70
3.0	0.84	0.31	0.74	0.94	0.29	0.68
4.0	0.84	0.31	0.74	0.96	0.27	0.56
5.0	0.84	0.31	0.74	0.97	0.27	0.47
6.0	0.84	0.32	0.74	0.97	0.27	0.48
7.0	0.89	0.31	0.59	0.96	0.27	0.56
8.0	0.90	0.32	0.58	0.97	0.26	0.48
11.0	0.84	0.33	0.76	0.97	0.26	0.47
13.0	0.83	0.34	0.76	0.98	0.26	0.43
15.0	0.88	0.33	0.61	0.96	0.27	0.62

**Profile Data**

The statistical evaluation of the temperature and salinity profiles is shown in Figure 5-59 to Figure 5-61. In this case, values from surface and bottom from both summer and winter simulations were aggregated, such that the performance of the model could be contrasted with other modelling investigations adopting similar data sets (e.g. CWR 2007c).

Temperature MAE and RMSE were below 0.4 °C for all stations. Salinity MAE was below 0.13 and RMSE was below 0.28.  $R^2$  was 0.99 for temperature and above 0.93 for salinity. Both the salinity and temperature performance were within those agreed at project inception (Table 5-10) and indicate the high degree of model performance.

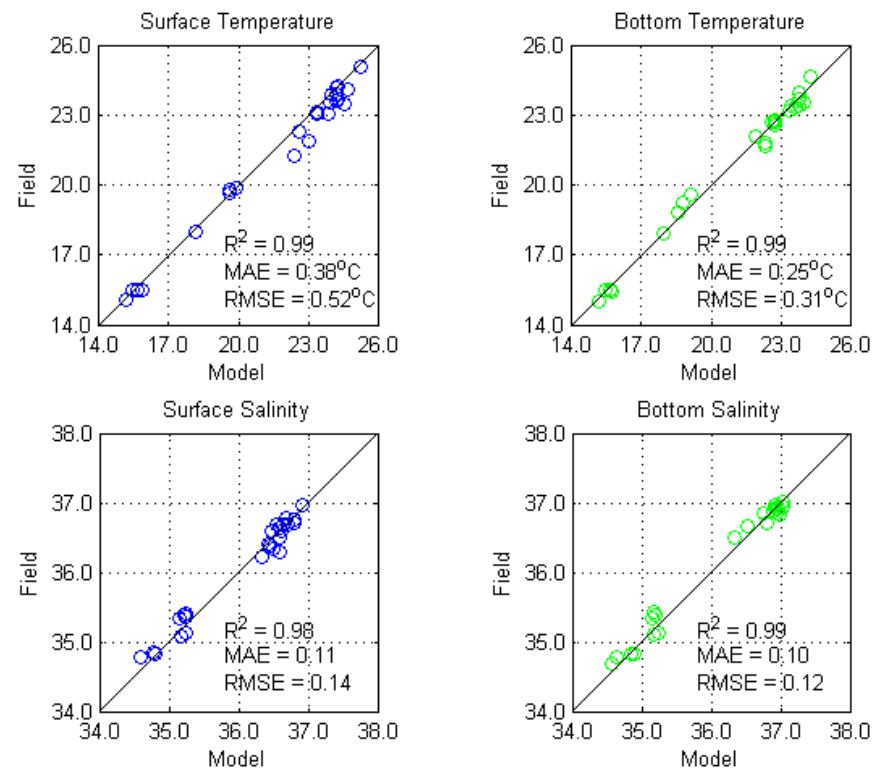


Figure 5-59 Model predictive skill statistics for temperature and salinity profiles at North Buoy (top and bottom values)

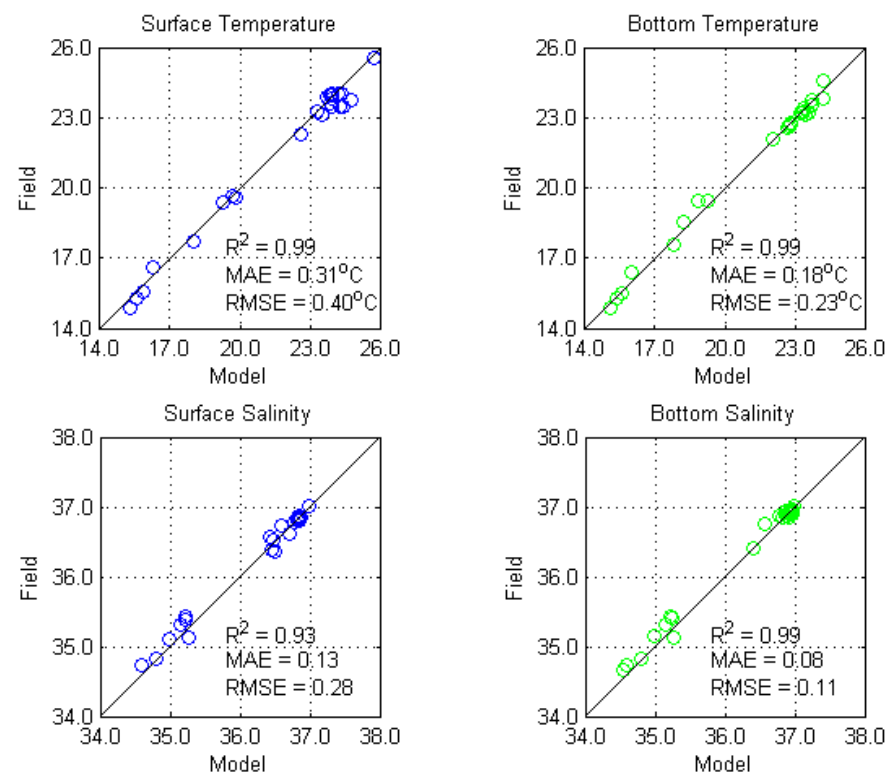


Figure 5-60 Model predictive skill statistics for temperature and salinity profiles at Central Buoy (top and bottom values)

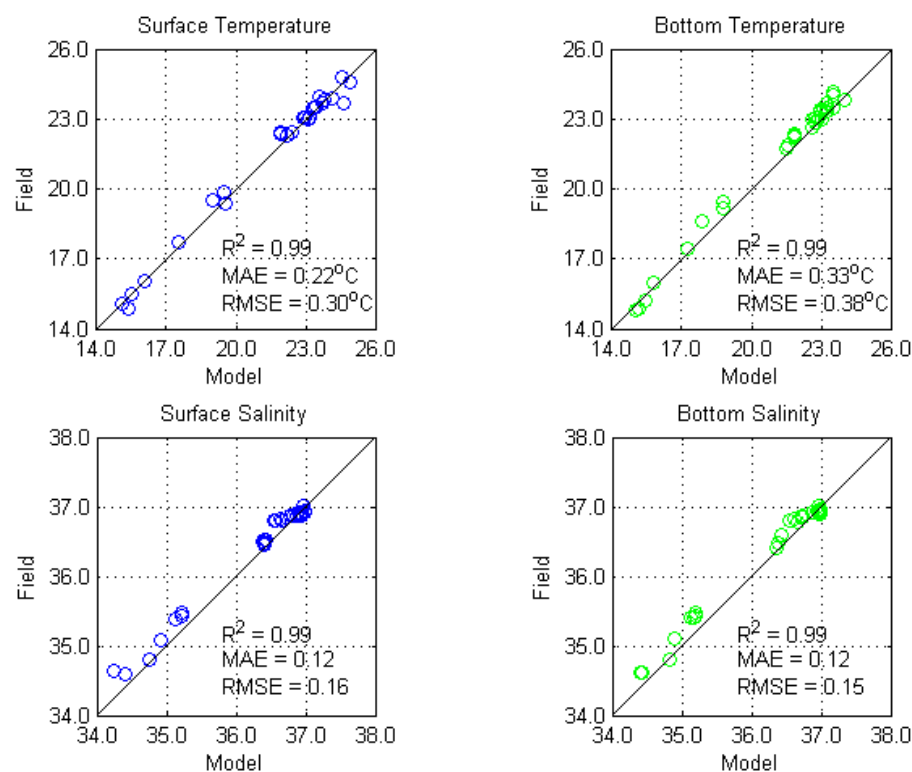


Figure 5-61 Model predictive skill statistics for temperature and salinity profiles at South Buoy (top and bottom values)

## Model simulations

### 5.3.3 Stratification duration

As discussed in Section 2.3 vertical density stratification plays a significant role in the development of lower benthic DO concentrations in Cockburn Sound, and the persistence of these events can have deleterious effects on local living organisms (ANZECC/ARMCANZ 2000). Therefore, simulations are required to accurately represent the duration of stratification for the purposes of estimating an organism's time of exposure to low DO conditions. This is particularly important for summer periods when the DO saturation levels are often observed to be reduced at depth.

The model's ability to simulate the duration of stratification periods was based on comparisons against the continuous RTMS temperature and salinity data. Density was also calculated from these data according to UNESCO (1981). Data at the level of the top- and bottom-most RTMS sensors in each of the stations were adopted to indicate stratification. To mitigate the impacts of the known RTMS salinity data inaccuracies (Figure 5-27 to Figure 5-32), the RTMS data was offset by the mean differences between the RTMS and profile salinities. The adopted difference was 0.77 salinity units across all stations. This reduced salinity was then applied to the density calculations, although this does introduce a level of uncertainty to the analysis, and comparisons between modelled and measured data should therefore be made within this limitation.

The comparisons of stratification duration in summer are shown for each of the stations in Figure 5-62 to Figure 5-64, whilst the comparisons for winter are shown in Figure 5-65 to Figure 5-67. Periods of observed stratification have been highlighted as hatched areas. In the transition from summer to autumn, the model captured the timing and duration of salinity stratification well at both North and Central Buoy stations. The model also reproduced temperature stratification onset and duration well. At South Buoy, the model reproduced the vertically homogeneous conditions of the measurements.

In winter, there were two instances when stratification was prominent across all stations (hatched areas in Figure 5-65 to Figure 5-67); early in August (driven by salinity) and throughout most of October, particularly toward the second half of the month (driven by temperature). In August, stratification was largely influenced by the low salinities associated with the Swan River flows whilst temperature from the seasonal heating caused stratification in October. The model reproduced both occurrences and was particularly accurate for the October predictions. As discussed earlier, the representation of timing and duration of the Swan River flows was influenced by the approximations adopted for its representation.

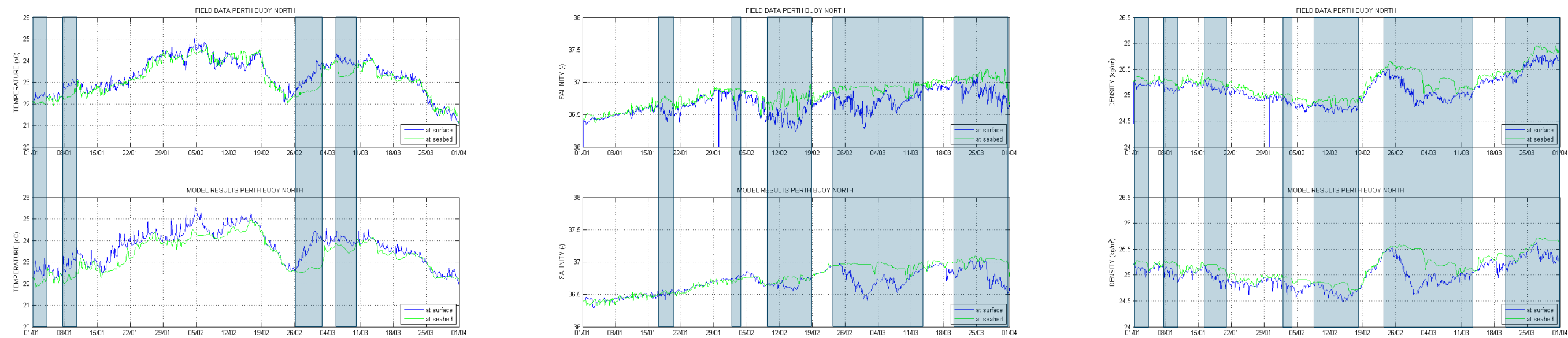


Figure 5-62 Temperature, salinity and density stratification in the transition from summer to autumn 2008 at North Buoy.

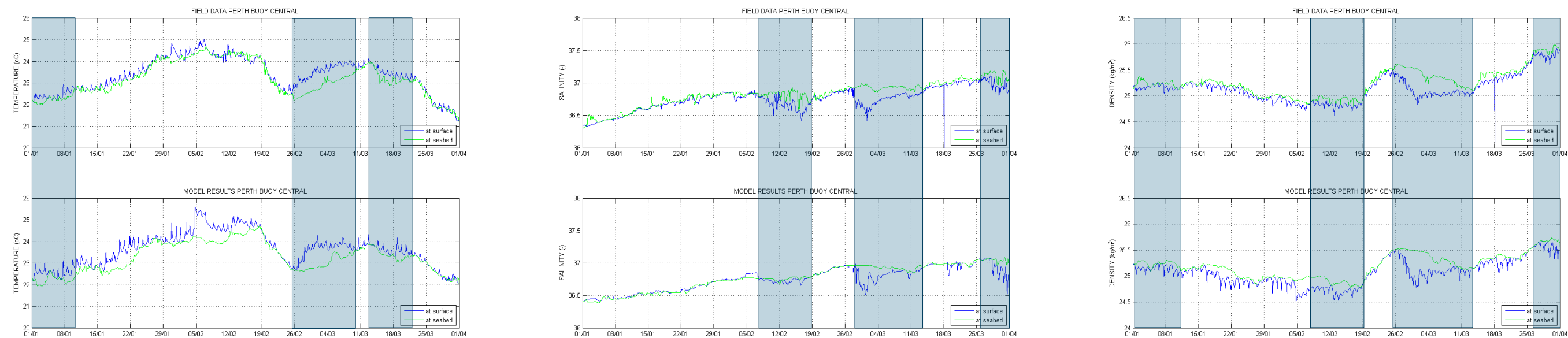


Figure 5-63 Temperature, salinity and density stratification in the transition from summer to autumn 2008 at Central Buoy.

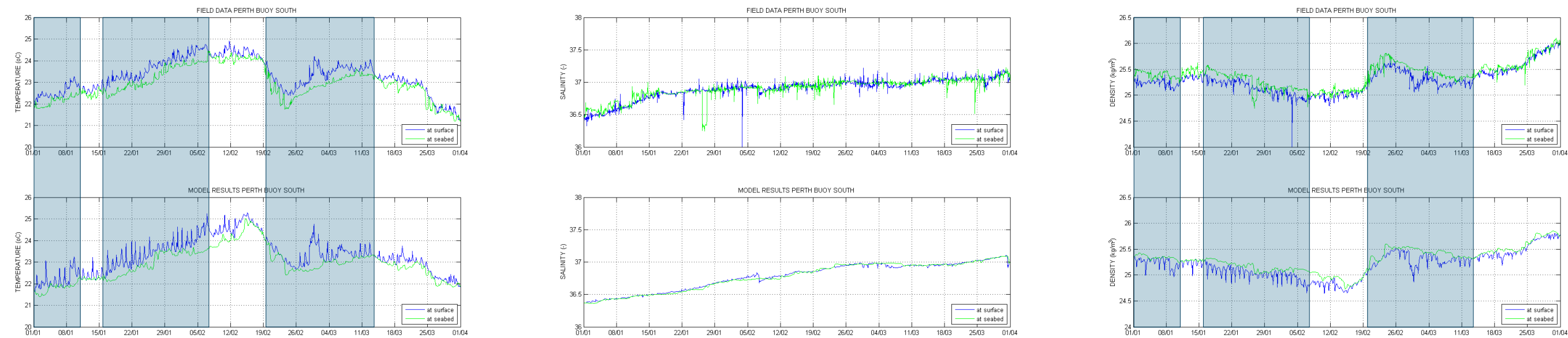


Figure 5-64 Temperature, salinity and density stratification in the transition from summer to autumn 2008 at South Buoy.

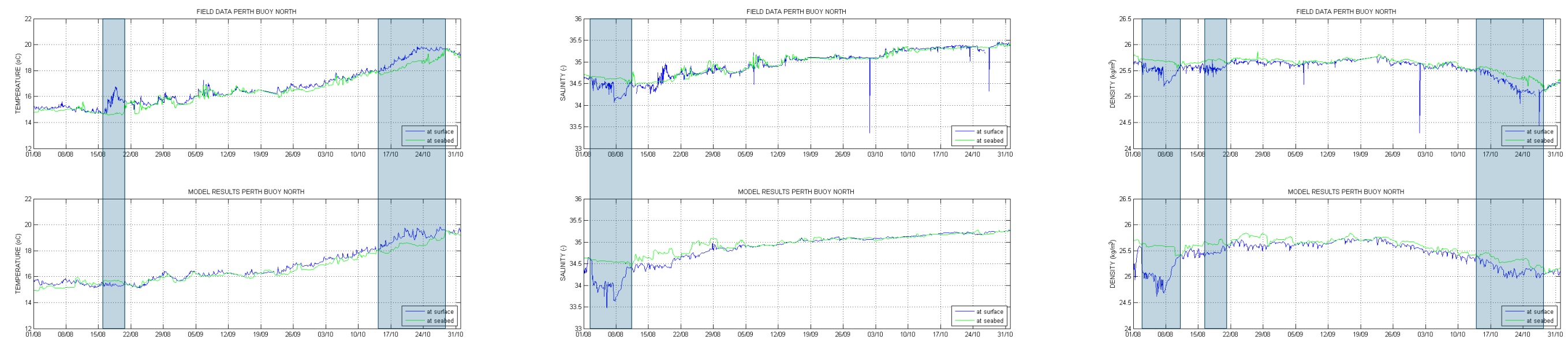


Figure 5-65 Temperature, salinity and density stratification in the transition from winter to spring 2008 at North Buoy.

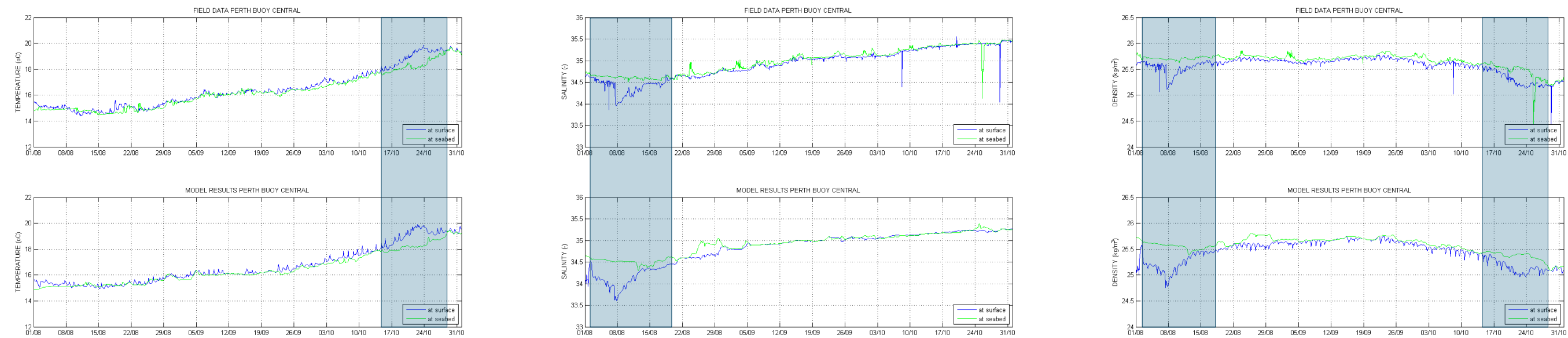


Figure 5-66 Temperature, salinity and density stratification in the transition from winter to spring 2008 at Central Buoy.

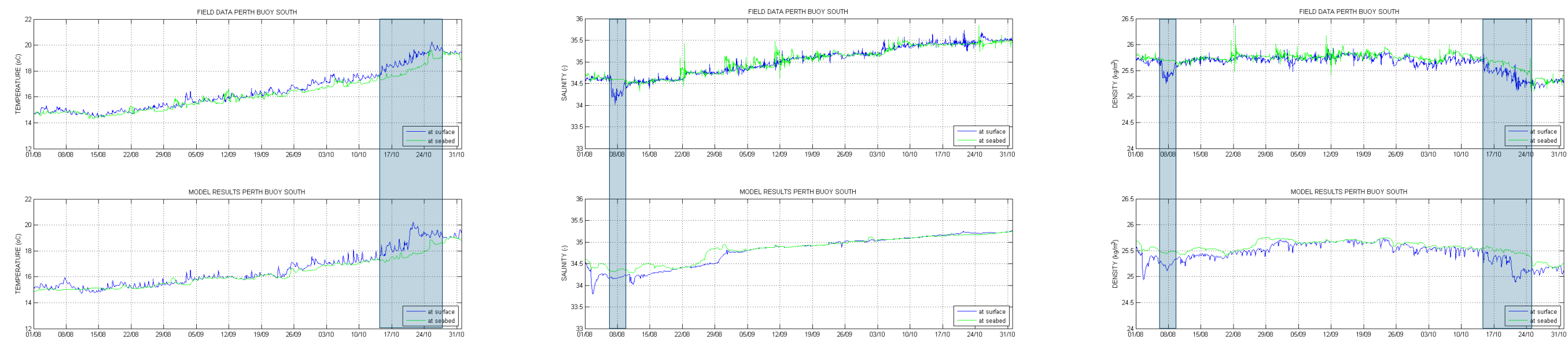


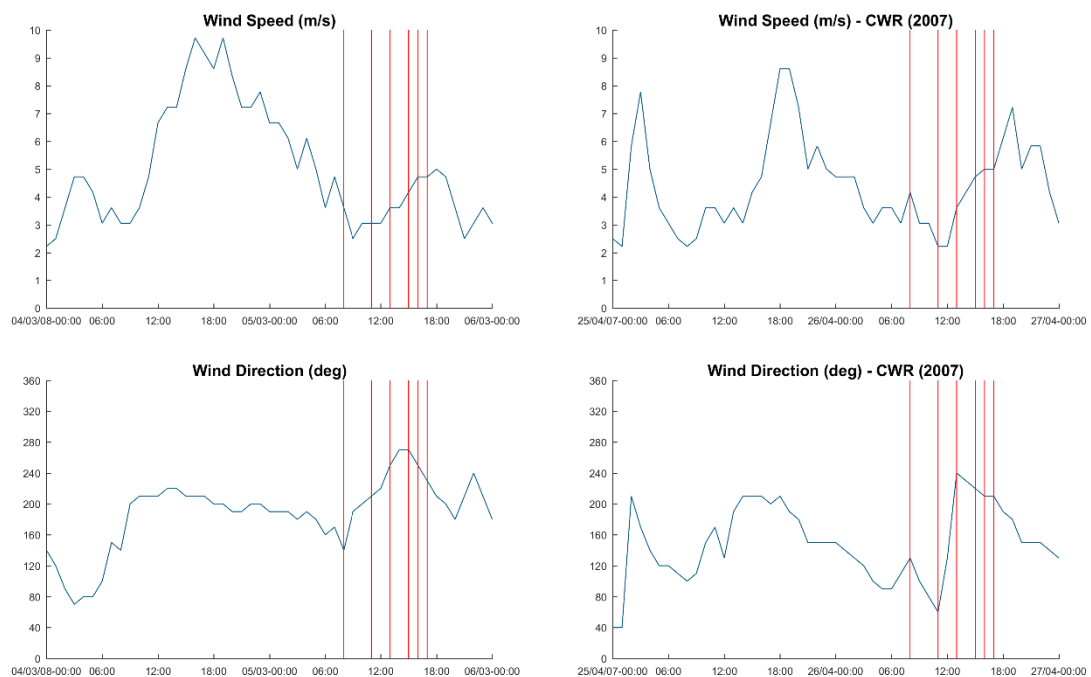
Figure 5-67 Temperature, salinity and density stratification in the transition from winter to spring 2008 at South Buoy.

## Model simulations

### 5.3.4 PSDP discharge plume

CWR (2007) undertook a field survey that measured the structure and evolution of the PSDP plume on the 26 April 2007. BMT did not simulate this period, so a period from a BMT simulation that had broadly similar wind and seasonal conditions (4 to 6 of March 2008) was chosen for comparison purposes. Figure 5-68 presents wind conditions over these periods.

Recognising that the BMT and CWR periods are not identical (and that the simulated PSDP flow rates were different to those operating on the day of the CRW, 2007 measurements), extractions at two times were taken from the BMT model to provide an indication of the variability of the plume's spatial and temporal evolution. It is noted that due to the BMT and CWR periods being approximately six weeks apart in the calendar year, background salinities are different between the two. This, and the inherent variability of the plume location, should be considered as part of model-measured comparisons.



**Figure 5-68 Comparison of the wind patterns between Mar 2008 and Apr 2007. Vertical red lines delineate approximate sample or model extraction times**

Figure 5-69 to Figure 5-74 present a comparison of the BMT Cockburn Sound model predictions with measured and modelled data taken from CWR (2007). Raw data from the CWR (2007) report was not available to BMT so the CWR (2007) data presented are simply screen shots from a digital report version. In all cases, four colour contour maps are presented in order from top to bottom as:

- CWR (2007) salinity measurements
- CWR (2007) ELCOM salinity predictions
- BMT model predicted salinity, 5 March 2008
- BMT model predicted salinity, 6 March 2008



## Model simulations

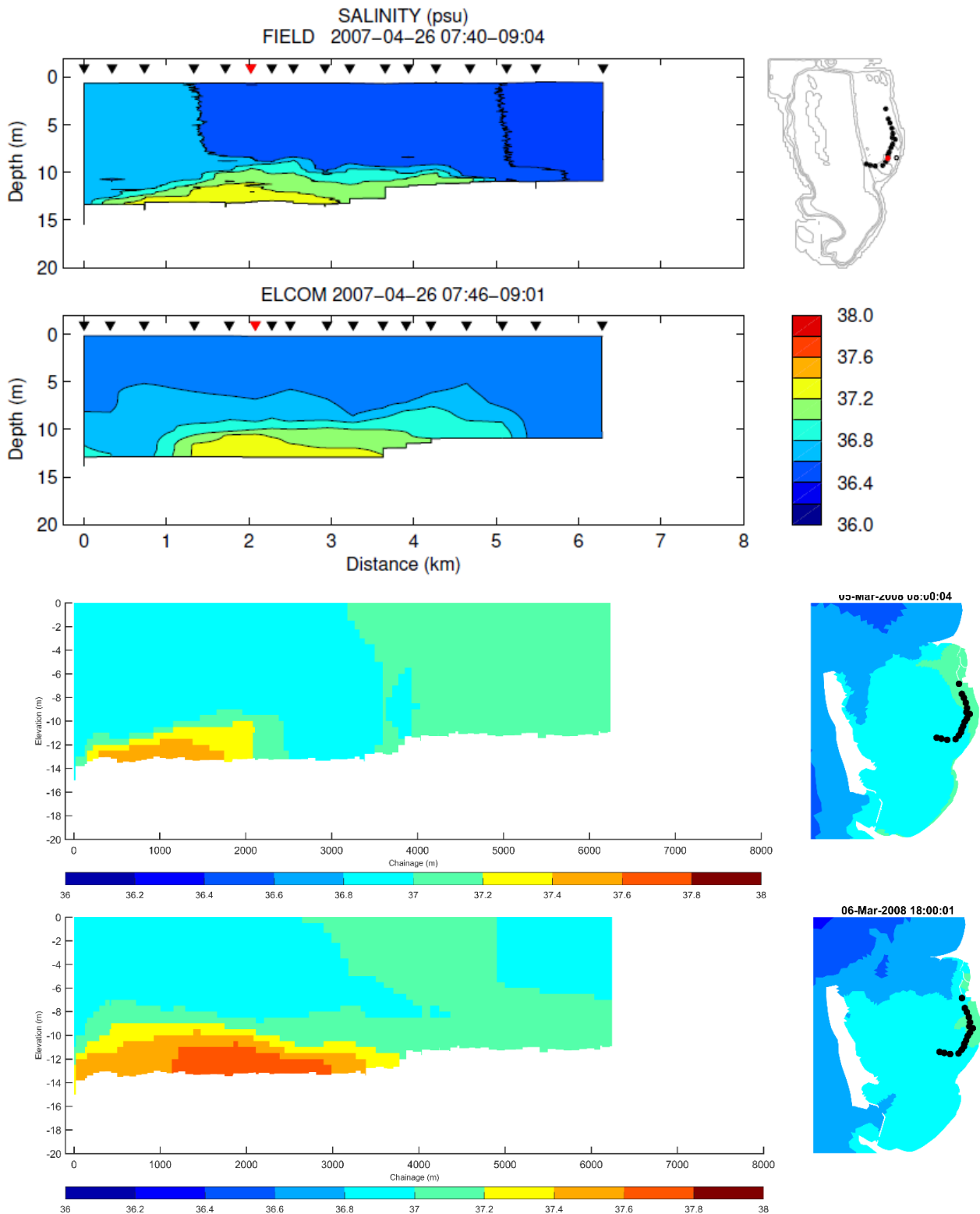
The plan location of each transect is presented at the right-hand side of each figure as a series of black dots. Similar colour scales have been used where possible, and all colour contours have been aligned horizontally as closely as possible for ease of ocular inspection. Sets of comparable transects are co-presented below.

### 5.3.4.1 *Transect 1: 0800 hrs*

Figure 5-69 presents measured and modelled data along a transect that follows Jervoise, Medina, Calista and Stirling Channels. The BMT modelled plume matches the observed field data closely, especially on the 6 March.

Of note, and further to the preceding discussion around the BMT and CWR (2007) comparisons being necessarily inexact, the BMT model predictions over the 5 and 6 March are noticeably different in places. This could be due to any number of factors, but the difference does underscore the potentially high spatial variability of the PSDP plume from day to day, and therefore the skill in the BMT model's predictions given the difference in the absolute time to the field measurements.

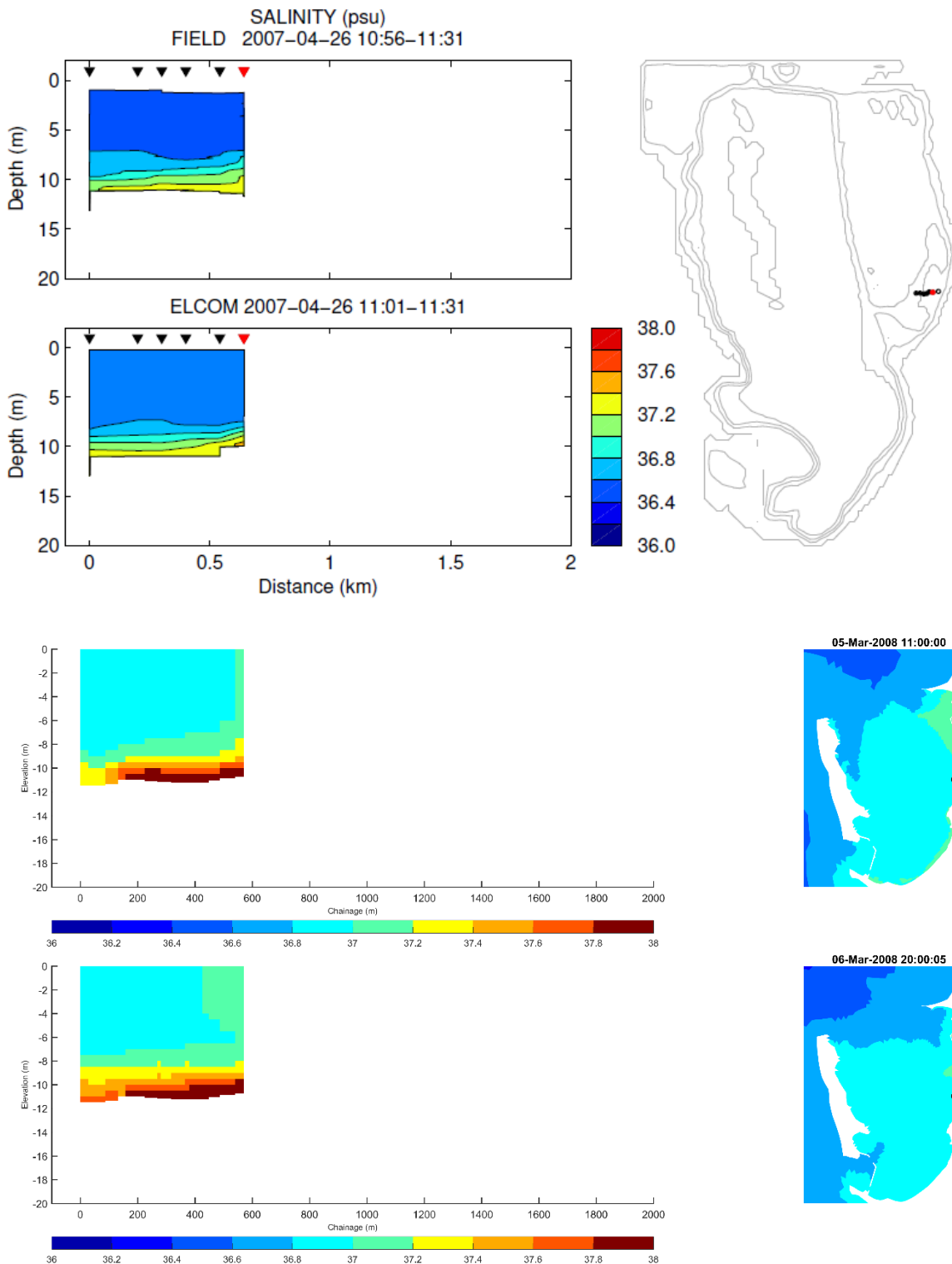




**Figure 5-69 Comparison of the salinity profiles along the main shipping channel. The difference in background salinity predicted by the BMT model is a result of the different month of the year it considers, compared to the CWR (2007) measurements**

**Model simulations****5.3.4.2 *Transect 2: 1100 hrs***

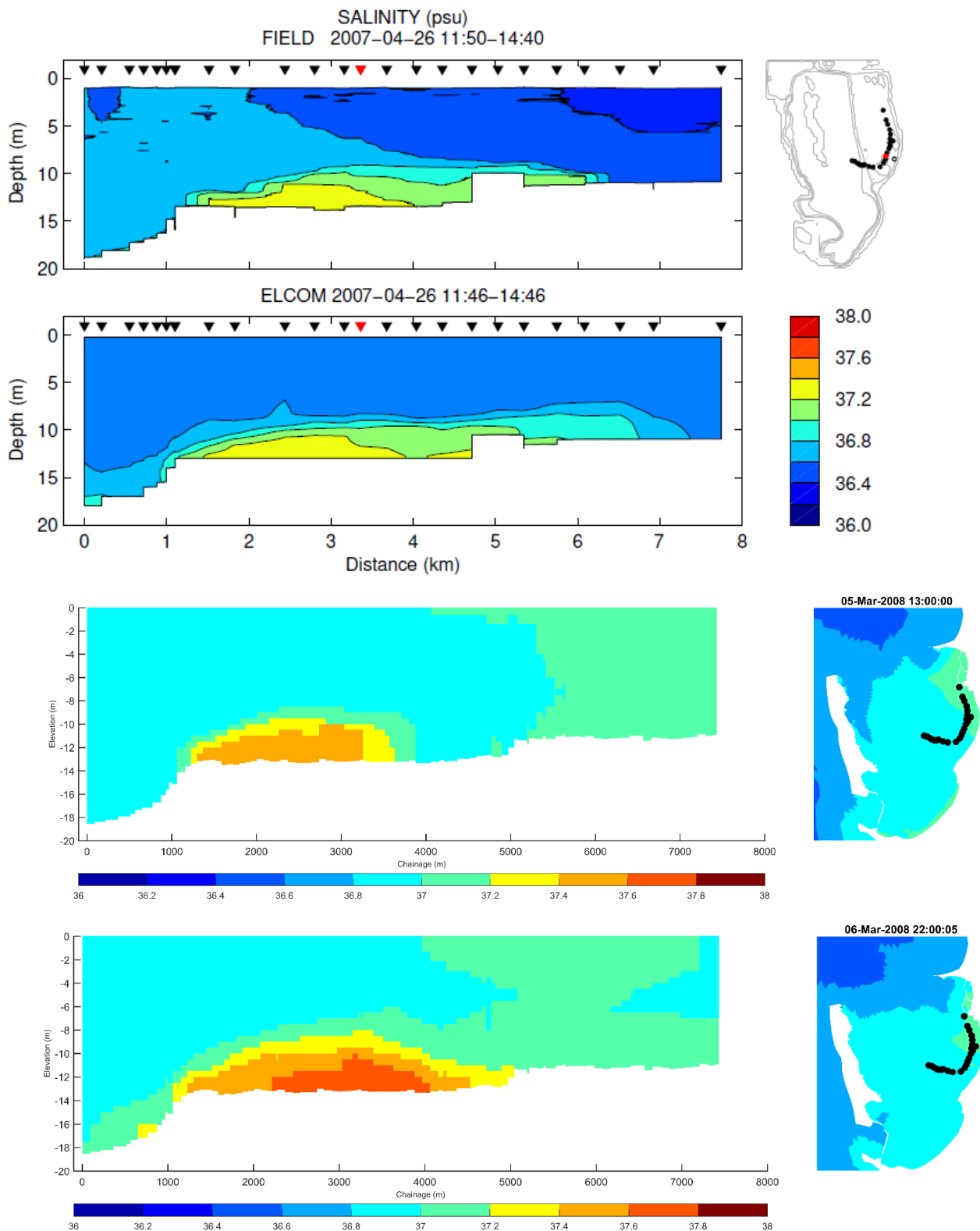
Figure 5-70 presents measured and modelled data along a transect from the diffuser to the main shipping channel. The shape and form of the BMT modelled plume matches the observed field data closely on both occasions (5th and 6th March), albeit with the BMT model predicting slightly elevated bottom salinities.



**Figure 5-70 Comparison of the salinity profiles along a transect from the diffuser to the main shipping channel. The difference in background salinity predicted by the BMT model is a result of the different month of the year it considers, compared to the CWR (2007) measurements**

**Model simulations****5.3.4.3 *Transect 3: 1300 hrs***

Figure 5-71 presents the structure of the plume with the transect commencing off the eastern shallows and traversing up the main shipping channel. Again, the form and morphology of the BMT predictions match the CWR (2007) data well. This includes prediction of the presence of a semi-permanent halocline structure in the shipping channels, that slowly leaks brine to offshore waters. Vertical mixing of brine in the shallows is also evident in the BMT predictions, which is consistent with CWR (2007) field measurements.

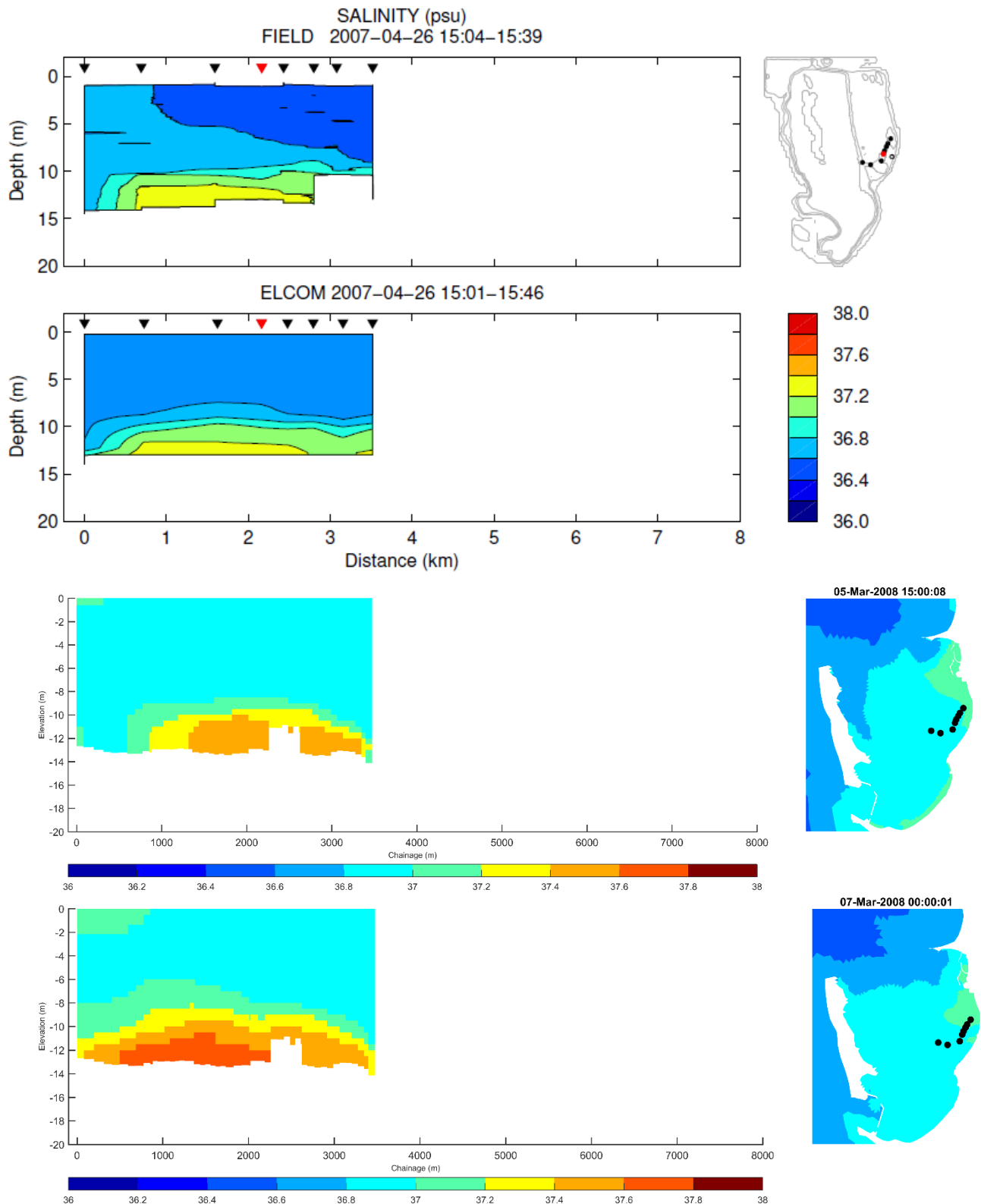


**Figure 5-71 Comparison of the salinity profiles along the main shipping channel and off the shelf. The difference in background salinity predicted by the BMT model is a result of the different month of the year it considers, compared to the CWR (2007) measurements**

**Model simulations****5.3.4.4 *Transect 3: 1500 hrs***

Figure 5-72 shows the structure of the plume with a transect starting alongside the diffuser and proceeding to along the main shipping channel to its exit. The shape and morphology of the field observations are reproduced well by the BMT model.

## Model simulations

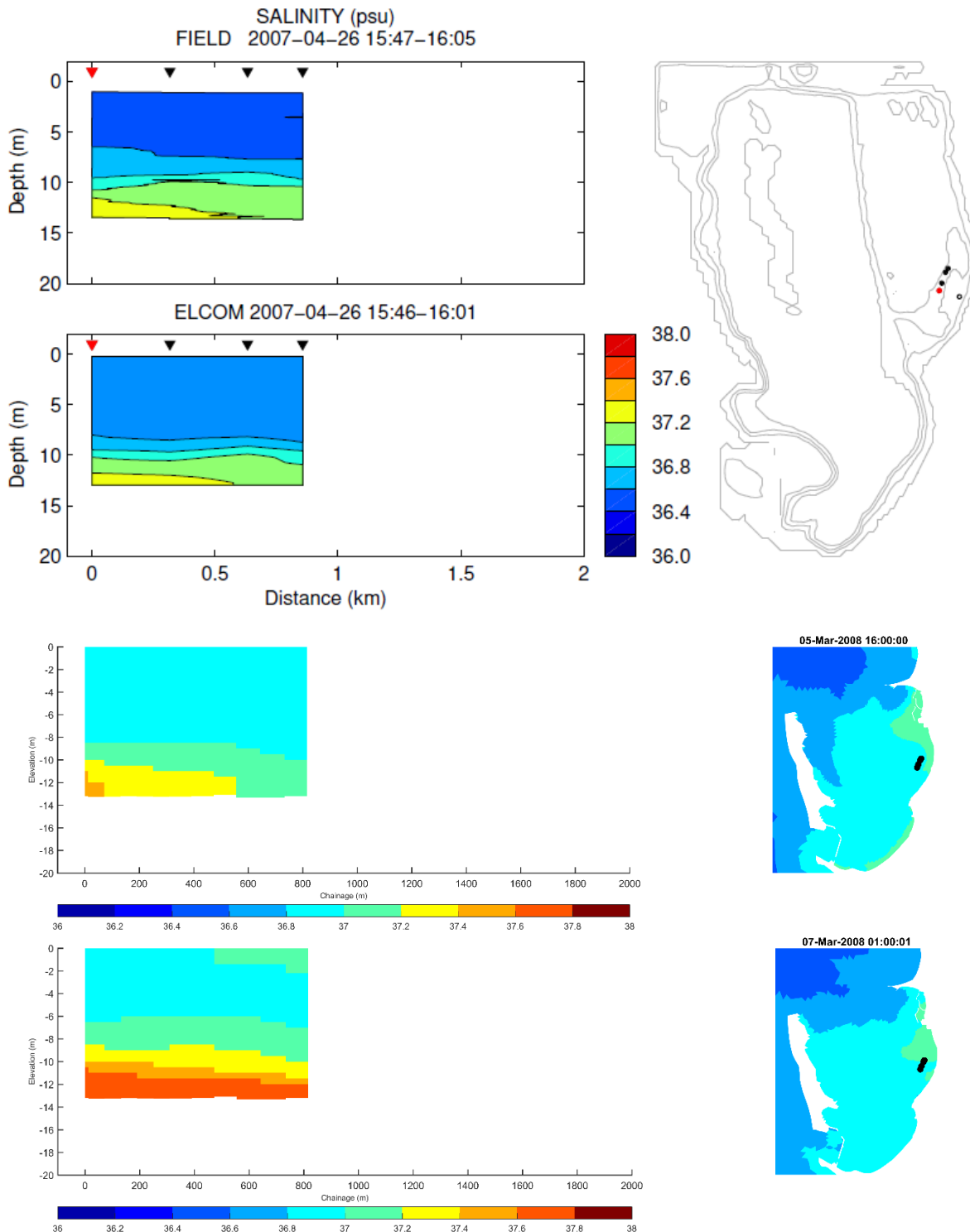


**Figure 5-72 Comparison of the salinity profiles along a section of the main shipping channel and near the diffuser. The difference in background salinity predicted by the BMT model is a result of the different month of the year it considers, compared to the CWR (2007) measurements**

**Model simulations****5.3.4.5 *Transect 3: 1600 hrs***

Figure 5-73 presents the transect commencing at the diffuser and traversing northwards along a bathymetric trough. Comparisons are favourable (although variable) with the height of the halocline reproduced well by the BMT model.



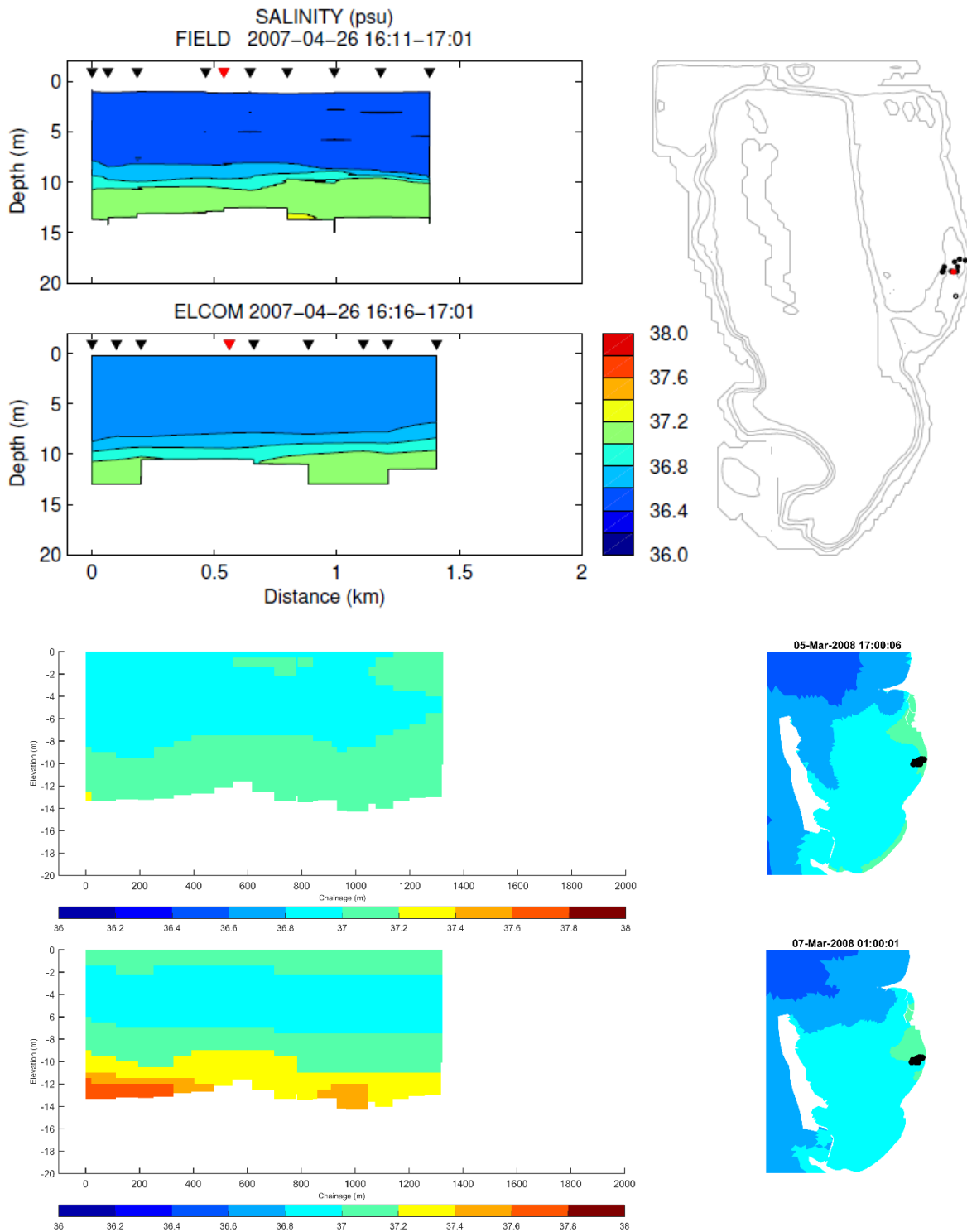


**Figure 5-73 Comparison of the salinity profiles along the main shipping channel north of the diffuser. The difference in background salinity predicted by the BMT model is a result of the different month of the year it considers, compared to the CWR (2007) measurements**

**Model simulations****5.3.4.6 *Transect 3: 1700 hrs***

Figure 5-74 presents a transect that commences along the main shipping channel and extends to the embayment north of the diffuser. The correspondence between measured and BMT's modelled data is clear.

## Model simulations



**Figure 5-74 Comparison of the salinity profiles along the main shipping channel and embayment north of the diffuser. The difference in background salinity predicted by the BMT model is a result of the different month of the year it considers, compared to the CWR (2007) measurements**

**Model simulations****5.3.5 Model comparisons (2013)**

Measurements undertaken as part of the MMMP in 2013 allowed for model comparisons not only in the deep basin, but also in the transition between the shallow eastern and the deep basins of Cockburn Sound. A total of 10 sets of profiles (a set consisted of all profiles collected on a single day) across the number of stations shown in Figure 2-16 were collected between 16 and 30 April 2013. The model comparisons against these measurements are shown below.

**5.3.5.1 Continuous temperature measurements**

Comparisons of simulated water temperature against RTMS data at Central and South Buoy stations in April 2013 are shown in Figure 5-75 and Figure 5-76, respectively (noting that salinity measurements at the RTMS were unreliable, see Section 5.3.1.1). Despite the malfunctioning of some of the sensors at both stations, the RTMS data provided a picture of the thermal evolution in the deep basin of Cockburn Sound (note RTMS measurements did extend to the top of the water column). Between 05 and 21 April, development of thermal stratification can be seen at both stations (noting that this stratified period coincided with the low wind conditions shown in Figure 2-15 and Figure 2-17) before a cooling trend was established. These general features were well replicated by the model.

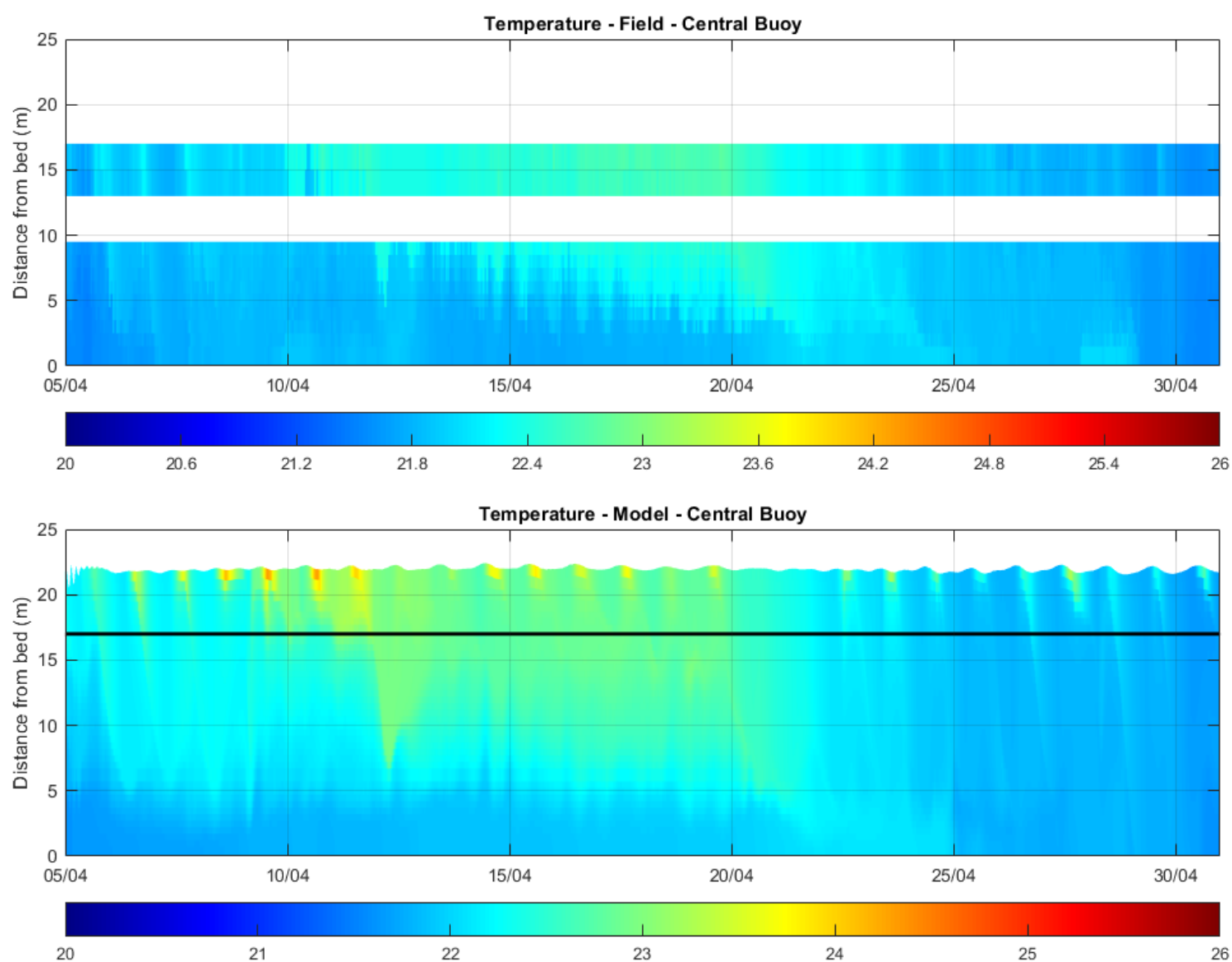


Figure 5-75 Measured (top) and simulated (bottom) water temperature data at the Central Buoy station. Horizontal black line indicates limit of top-most RTMS measurement

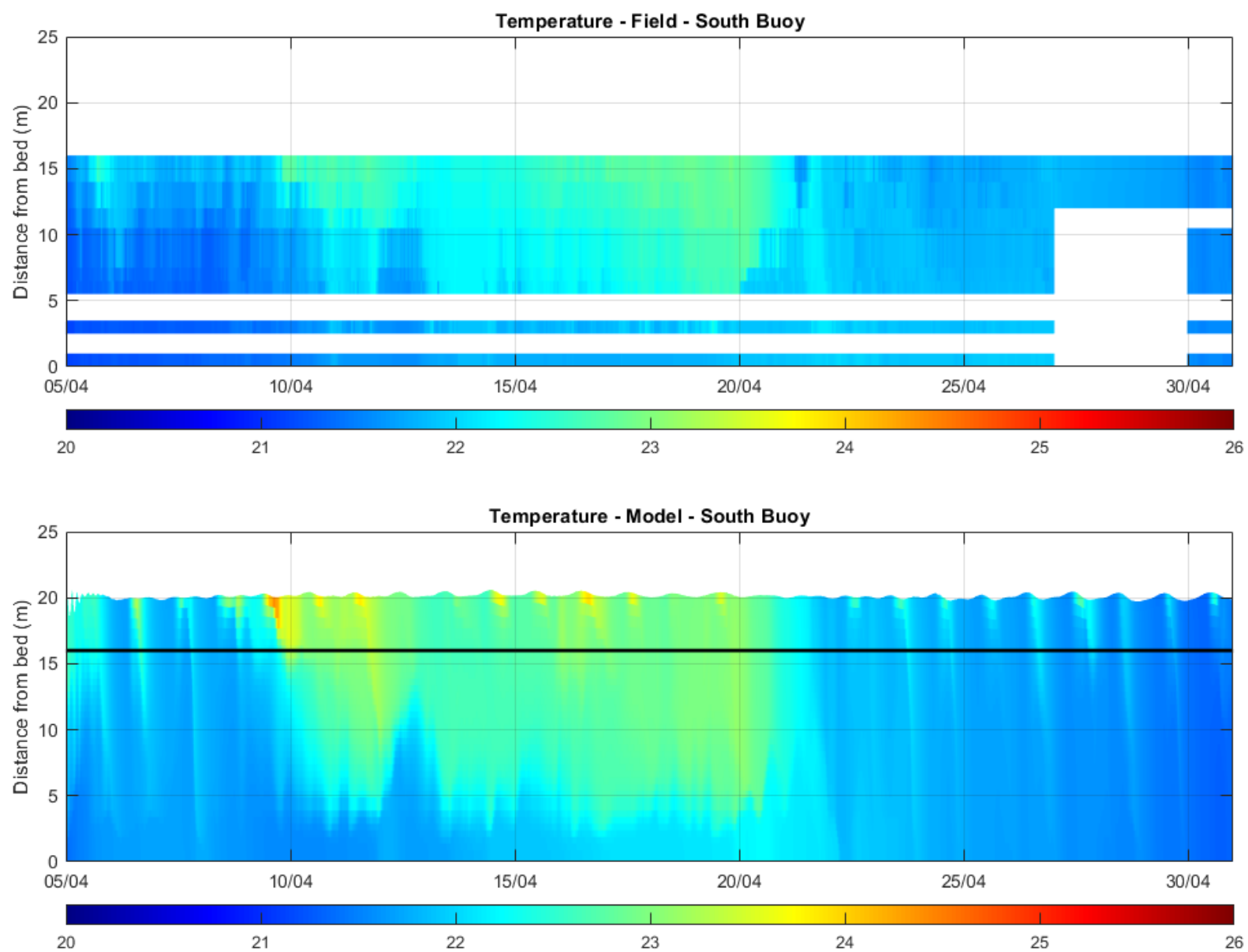


Figure 5-76 Measured (top) and simulated (bottom) water temperature data at the South Buoy station. Horizontal black line indicates limit of top-most RTMS measurement

## Model simulations

### 5.3.5.2 *Temperature and salinity profiles in the deep basin*

Comparisons of temperature and salinity profile data indicate the model simulated the change from stratified conditions to well mixed conditions in the deep basin stations (Figure 5-77 to Figure 5-80). It can also be seen that there was little variation in bottom salinities, consistent with an ingress to the Sound of less saline (surface) water over the period of interest.

At Central Buoy the model replicated this dynamic for profiles measured until 24 April, however the model did not replicate the less saline layers observed on 26 and 28 April (Figure 5-78). At South Buoy the model did not reproduce the less saline layer from 22 April onwards (Figure 5-80).

At this time of the year, the movement of less saline water into the Sound is expected to occur via exchange mechanisms through the northern entrance (see e.g. D'Adamo 2002, also Section 2.2.2.2, and therefore generally showing a more marked signature of less saline water at Central Buoy compared to South Buoy (see for example profiles between 09 and 20 April in Figure 2-17). For the period which the model is not reproducing the salinity stratification (i.e. after 22 April), profiles at South Buoy showed a more marked overflow signature (i.e. lower salinities) and an earlier response to lower surface salinities than Central Buoy (Figure 2-17) and any other locations north of it (Figure 2-17 and Figure 2-18). The temporal and spatial evolution of this fresher overflow is the reverse of what would be expected if such an overflow had its origins to the north of the Sound. Its presence is therefore not consistent with the expected hydrodynamic processes known to occur at this time of year and suggests that an unusual process is at play during this time. Despite considerable investigation into this matter, the origin of the less saline water remains unclear, but the following might corroborate to suggest that these waters originate from the southern areas of the Sound and its land surrounds:

- (1) The BoM Medina Research Centre station [received 14.5 mm of rain between 20 and 22 April](#), potentially generating a discharge of catchment-derived surface water to the Sound.
- (2) The wind field over the period was predominantly from the south, thus indicating transport from south to north (see Figure 5-81 and Figure 5-82) likely occurred, and that surface transport from north to south was unlikely.
- (3) As described above, South Buoy and CT3 presented lower surface salinity compared to all other sampling stations to their north.

Noting the model did not account for flows draining into Cockburn Sound may offer an explanation as to why the model did not reproduce the less saline layer from 22 April onwards. As a result, the model simulated a more well mixed water column compared to observations. The model did however replicate the well mixed conditions achieved after 28 April.

### 5.3.5.3 *Temperature and salinity profiles in the transition to the deep basin*

The semi-circular concentric suite of temperature, salinity and DO profiles collected in the transition between the shallow and deep basins of Cockburn Sound (Figure 2-16) are presented in Figure 5-83 to Figure 5-102. Each of the figures show one day of measurements, with each panel presenting a different location. The intent in these figures is to highlight features of the general hydrodynamics in the shallow and deep basins of Cockburn Sound within the locality of interest, as well as to illustrate

## Model simulations

the changes imposed on these features by the PSDP discharge. The order of station presentation (left to right in row 1, then left to right in row 2 and so on) is as follows:

- in-channel (R2, S2, and S3),
- inner (i.e. stations labelled A and B) to outer radii (stations labelled C and D), and
- deep-water stations (CT3 and CT7, bottom right hand corner of each figure)).

Stations labelled A to D were then ordered from north to south (e.g. A4, A7, A10 and A13). Not all profiles across stations A, B, C, and D were presented as they were typically very similar to their neighbouring profiles. The profiles shown were however spread so as to generally illustrate temperature and salinity transitioning from north to south.

Finally, the results of a simulation without the inclusion of the PSDP are presented in Figure 5-83 to Figure 5-102.

Of particular relevance in Figure 5-83 to Figure 5-102 are the profiles at R2, S2 and S3, as they present the most noticeable signature of the PSDP discharge. This was evident in the majority of the salinity profiles that reproduced the profile shapes and maximum near bed salinities (Figure 5-84, Figure 5-86, Figure 5-88, Figure 5-90, Figure 5-94, Figure 5-98, Figure 5-100 and Figure 5-102).

On some days, the simulated salinity profiles were less reflective of measurements (e.g. 22 and 24 April - Figure 5-92 and Figure 5-96, respectively). This likely stemmed from the following reasons:

- (1) The (unresolved) localised ingress of less saline water in the Sound from south (see Section 5.3.5.2);
- (2) Variations in the quality and quantity of the industrial discharges near the PSDP; and
- (3) Variations in the PSDP operation and discharge quality and quantity.

Regarding the localised ingress of less saline water from South, it can be seen there was a clear impact in the surface salinities across profiles between 22 and 26 April. The same reasoning for the lack of agreement in salinity in the deep basin therefore applies to the simulated profiles.

Regarding the industrial discharges, the following were considered in the April 2013 simulations:

- Kwinana Power Station Stage C (KPS-C);
- Kwinana Gas-Fired Power Station (KPS-GF);
- Newgen Kwinana Gas-Fired Power Station (Newgen);
- Cockburn Power Station (CKB);
- BP refinery; and
- TiWest.

Of these, KPS-C, KPS-GF, CKB and Newgen discharges are near the PSDP. Temperature data at S2 indicates (at least some of) the discharges were operating on 16 and 17 April, given the measured temperature profiles (Figure 5-83 and Figure 5-85). All subsequent days show well mixed layers and lower temperatures in comparison to those days (Figure 5-87, Figure 5-89, ...and Figure 5-101). Although wind mixing and penetrative convection could potentially determine the structure of these

## Model simulations

latter temperature profiles, the absence of a warmer surface layer (as shown in the model profiles) indicated that there was likely a reduced heat load coming from these industrial (cooling) water discharges (note that the simulated profiles in the surface layer of the deep basin away from the industrial discharges show remarkable resemblance to the measurements – see measurements at CT3 and CT7 ). As a result, the model overestimated the temperatures in the surface layer, particularly noticeably on the days following 17 April. For more accurate simulations of temperature, more precise information regarding flow rates and temperatures associated with these discharges is required.

Whilst the other industrial discharges may influence model performance, BMTs review of the data provided to it revealed that the PSDP discharge (over different time periods) was also unlikely to be constant (as specified in the model). There are several elements that support this view, including the reduction of the salinity data near the bed at S2 (an in-channel site) on 20 April (Figure 5-90) and the unstable temperature and salinity profiles<sup>2</sup> at several of the stations from 16 to 22 April (Figure 5-83 to Figure 5-92). The model was unable to replicate these unstable profiles.

Despite the above, the model replicated the fundamental dynamics of the discharge in the transition zone. In particular, the depth of the haloclines was generally well captured for the stations in the inner radii (series A and B stations). For stations in the outer radii (series C and D stations) and further into the deep basin (stations CT3 and CT7), the signature of the discharge plume was less pronounced as it assimilated with natural background conditions.

### 5.3.5.3.1 Effects of the discharge on salinity

The comparisons between simulations with and without the discharge (c.f. the green solid and dashed lines in Figure 5-83 to Figure 5-102) offer further insight in the capability of the model in predicting the effects of the PSDP discharge. For instance, there was a clear decrease of near bed salinity and saline bottom layer thickness from in-channel (S2, S3 and R2) to inner radii (A and B), to outer radii (C and D) and on to the deep basin proper (CT3 and CT7). In channel, near bed salinity increases (in relation to the absence of the discharge) suffered little alteration between S2 and S3 (0.4 to 1.1 units increase), however they reduced considerably right at the Stirling Channel exit (R2) to 0.05 to 0.60 units increase. The layer thickness was also considerably reduced (from ~7.0 m at S2 to ~3.0 m at R2) indicating there was an appreciable degree of mixing as the brine moved within the confinements of Stirling Channel.

The brine plume then mixed considerably as it entered the deeper areas of the Sound. Near bed salinity increases in the A stations were between 0.05 and 0.45 units, in the B stations were between 0.05 and 0.30 units, in the C stations between 0.0 and 0.30 units, in the D stations between 0.0 and 0.30 units, and in the CT stations between 0.0 and 0.25 units. Similar near bed increases were reported by CWR (2007b) and could also be inferred by looking at salinity changes across the measured haloclines near the bed. These increase values are close to the accuracy and precision of the most accurate salinity measurements undertaken with CTDs. For example, Seabird estimates

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<sup>2</sup> Unstable temperature (salinity) profiles are indicated by a clear evidence of colder (more saline) water overlaying warmer (less saline) water.



**Model simulations**

that dynamic accuracy of their CTD probes are at best 0.02 units, assuming a verified calibrated sensor in the lab (Seabird Scientific, 2016<sup>3</sup>).

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<sup>3</sup> Seabird Scientific (2016) Guide to Specifying a CTD – Understanding Impacts on Accuracy.

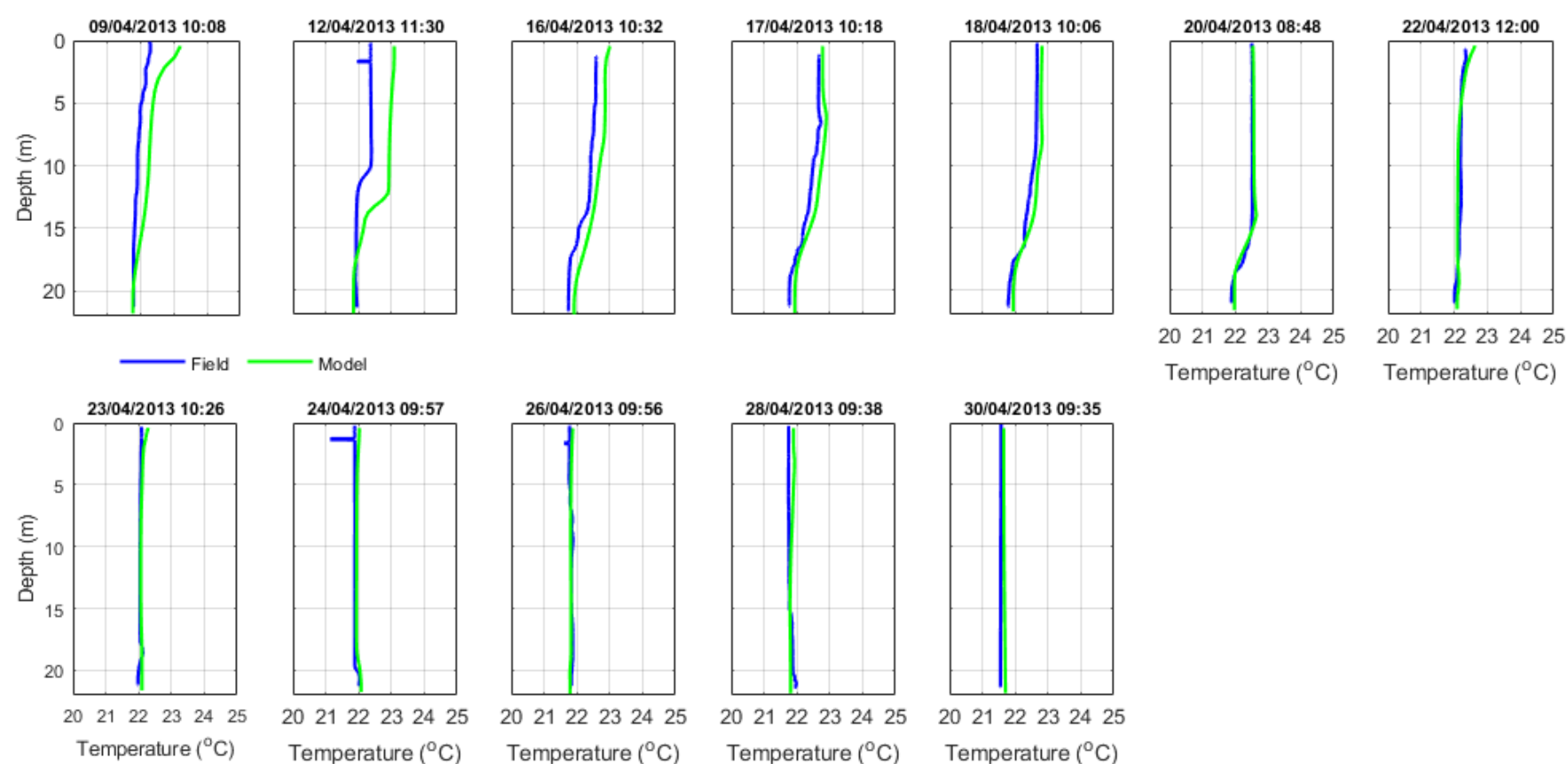


Figure 5-77 Comparison of measured and simulated water temperature profiles at Central Buoy station in April 2013

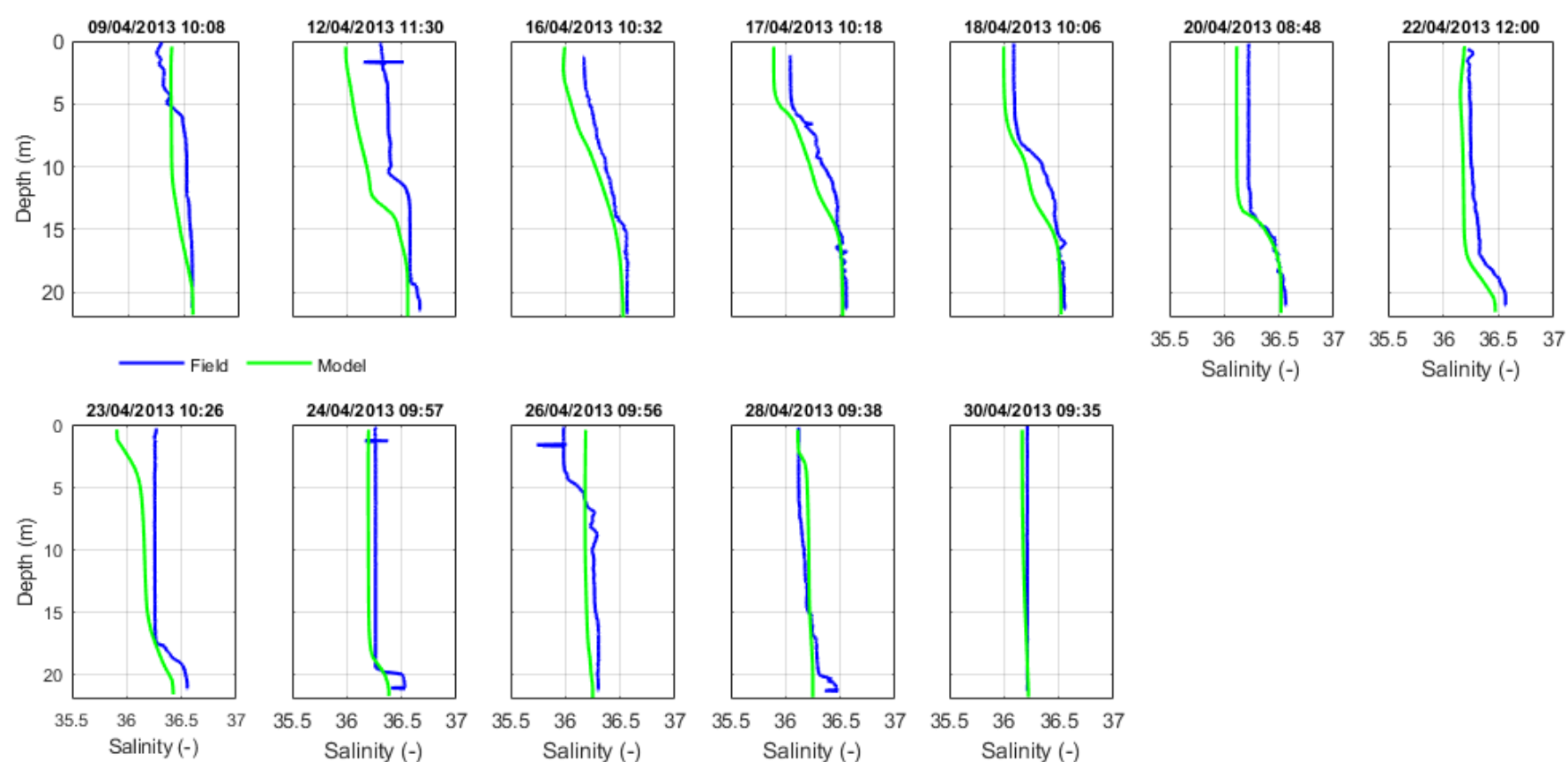


Figure 5-78 Comparison of measured and simulated water salinity profiles at Central Buoy station in April 2013

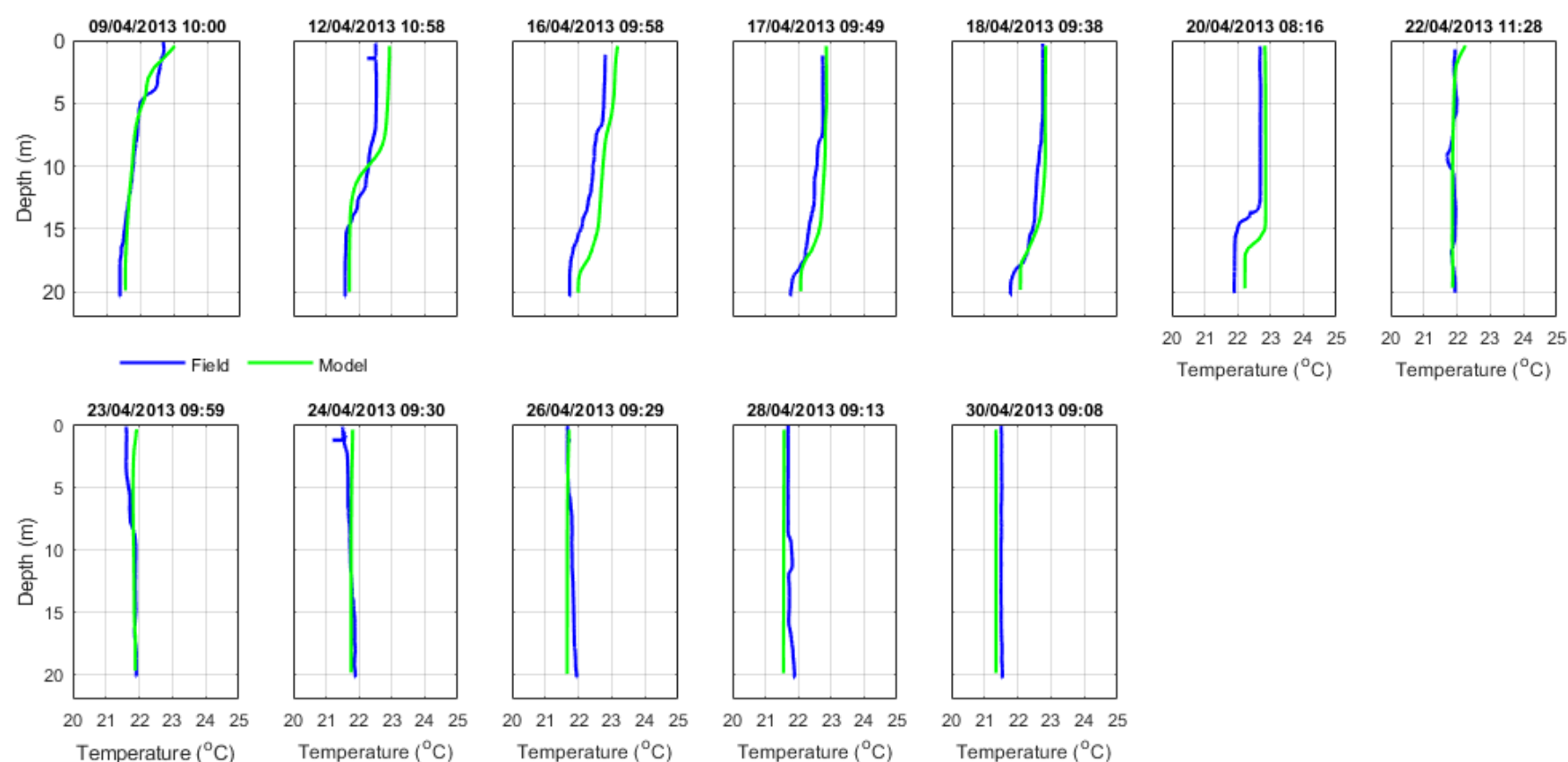


Figure 5-79 Comparison of measured and simulated water temperature profiles at South Buoy station in April 2013

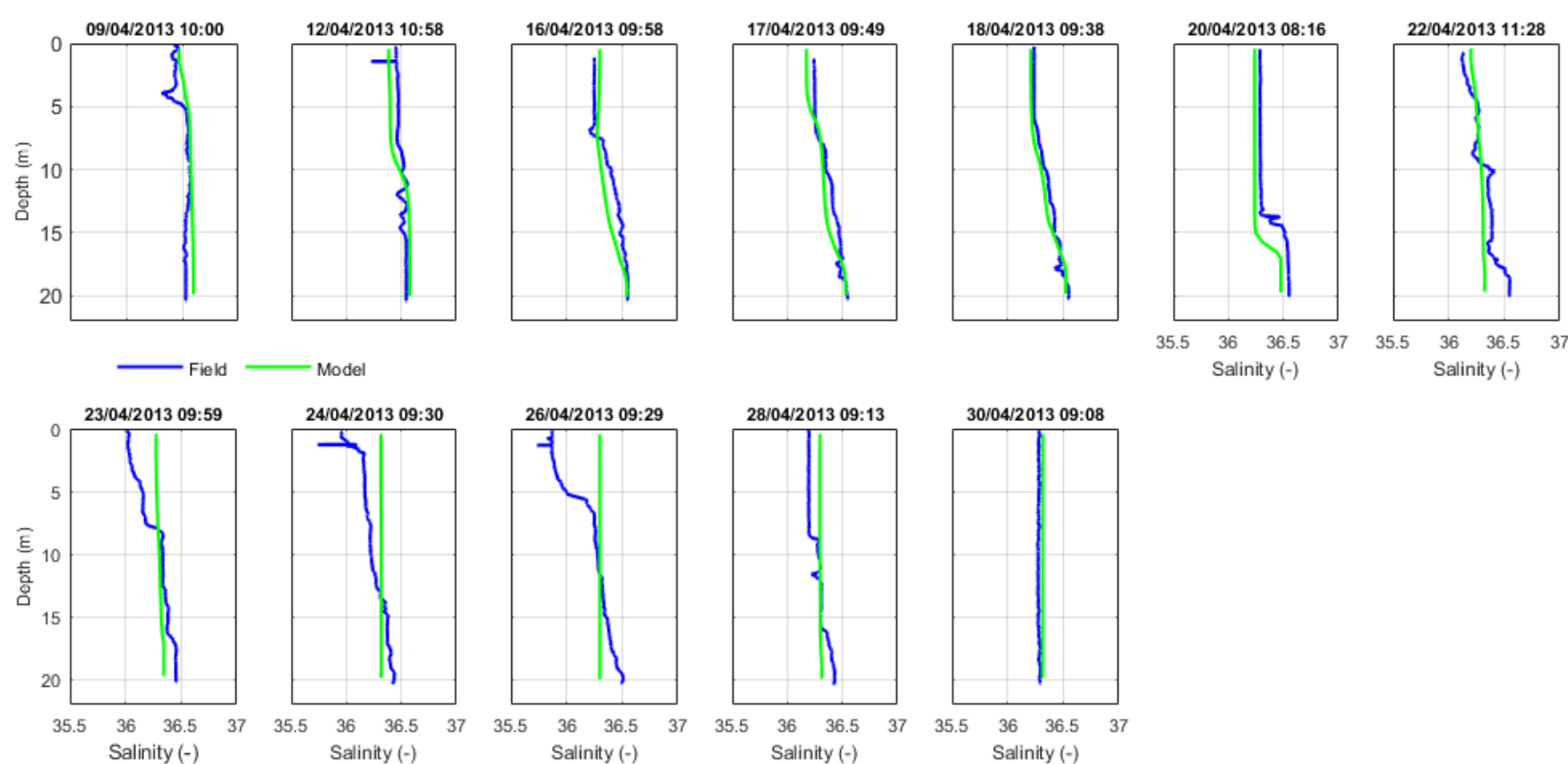


Figure 5-80 Comparison of measured and simulated water salinity profiles at South Buoy station in April 2013



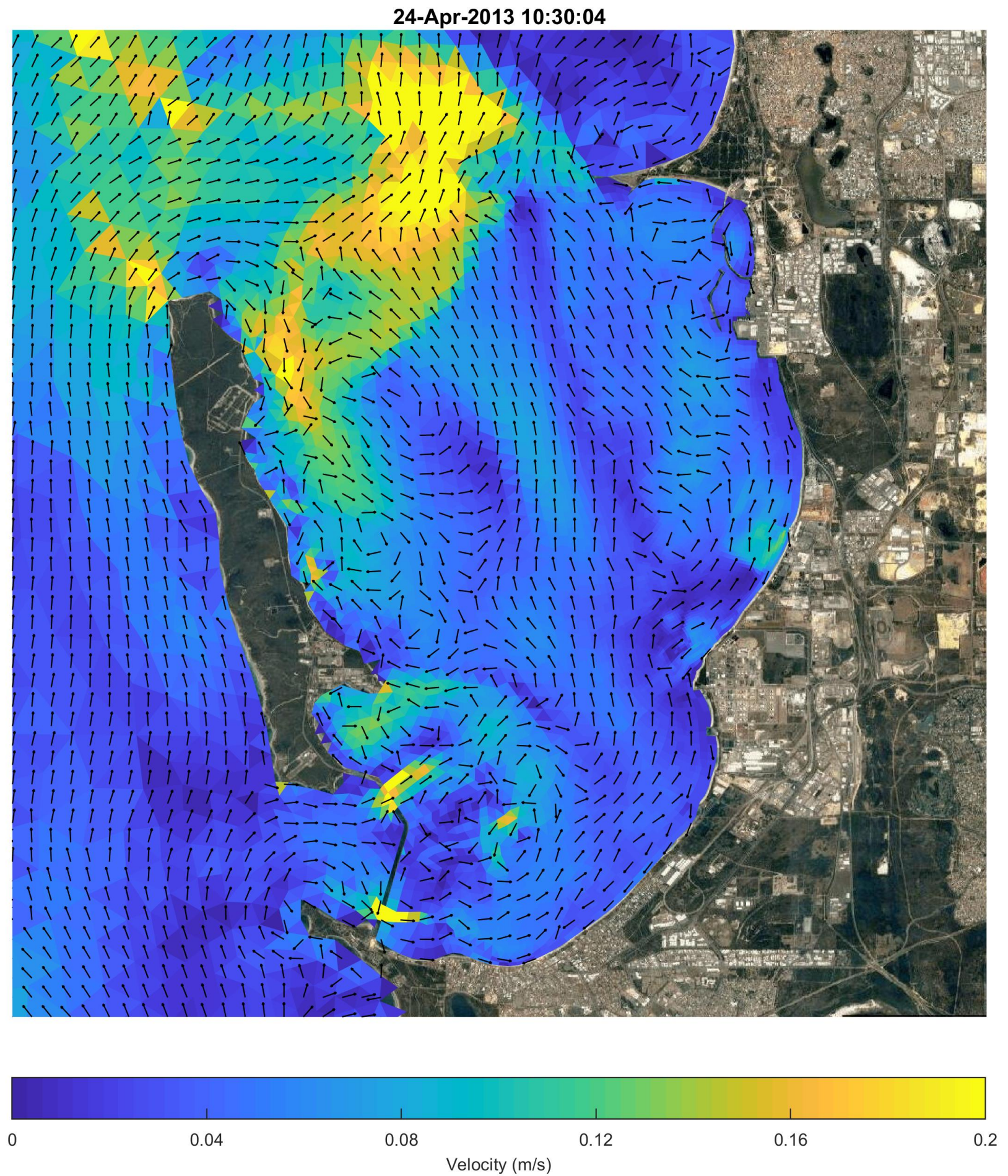


Figure 5-81 Snapshot of surface velocities on 24 April 2013

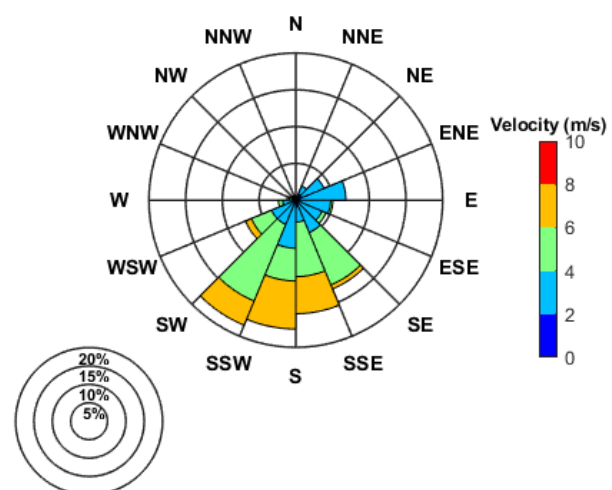


Figure 5-82 Wind rose of BoM measurements at Garden Island between 22 and 28 April 2013



16/04/2013

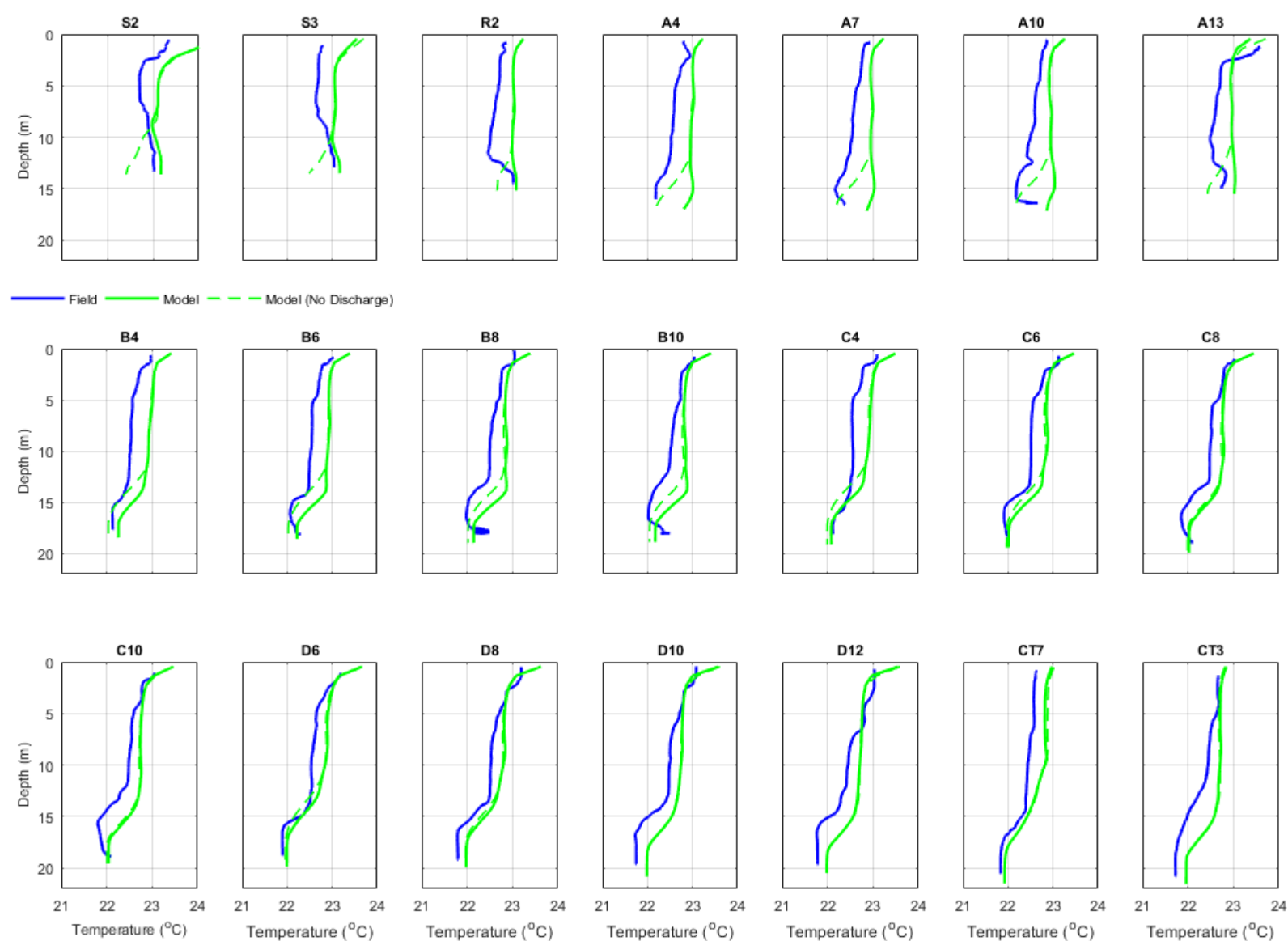


Figure 5-83 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 16 April 2013

16/04/2013

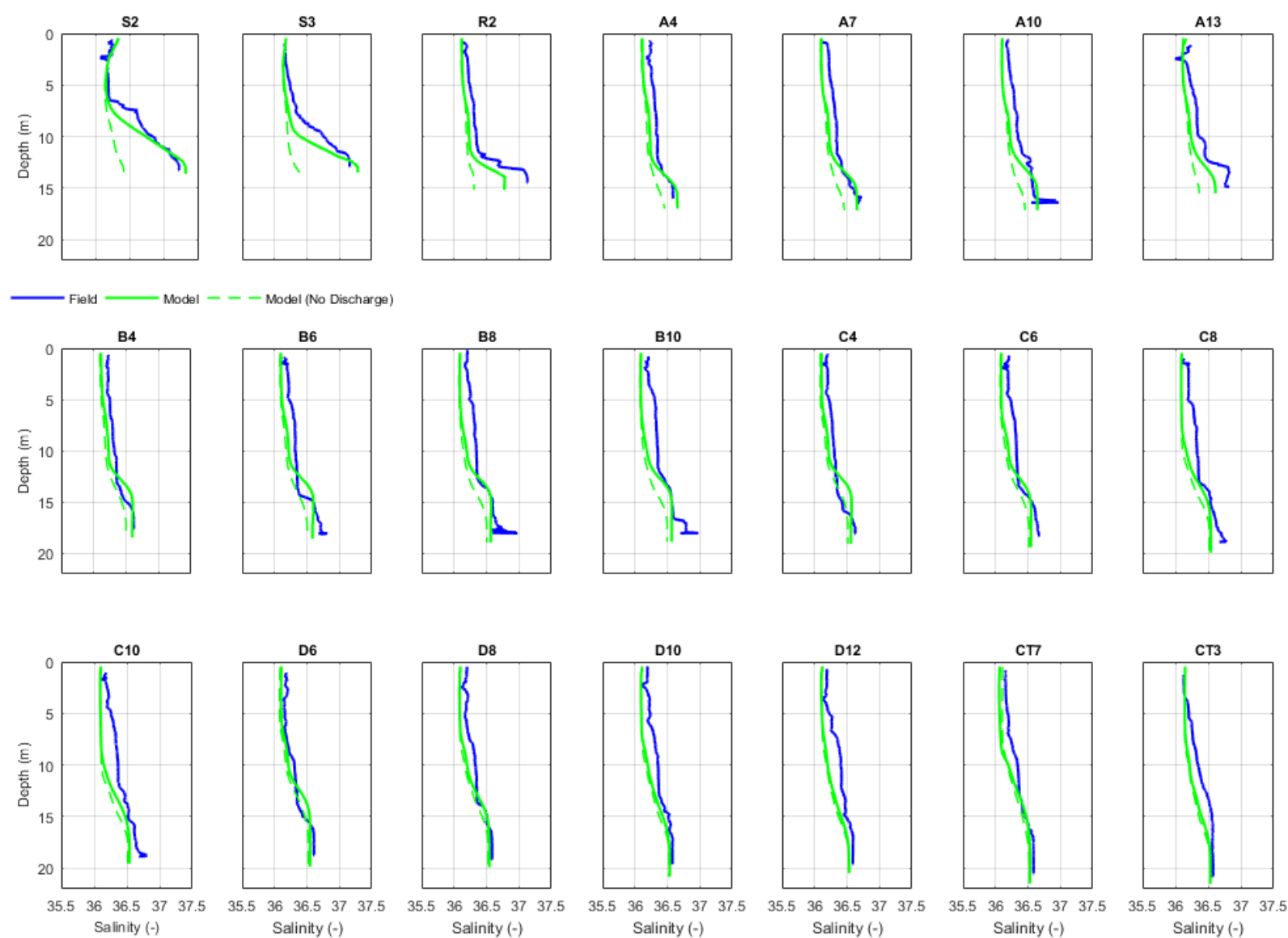


Figure 5-84 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 16 April 2013

17/04/2013

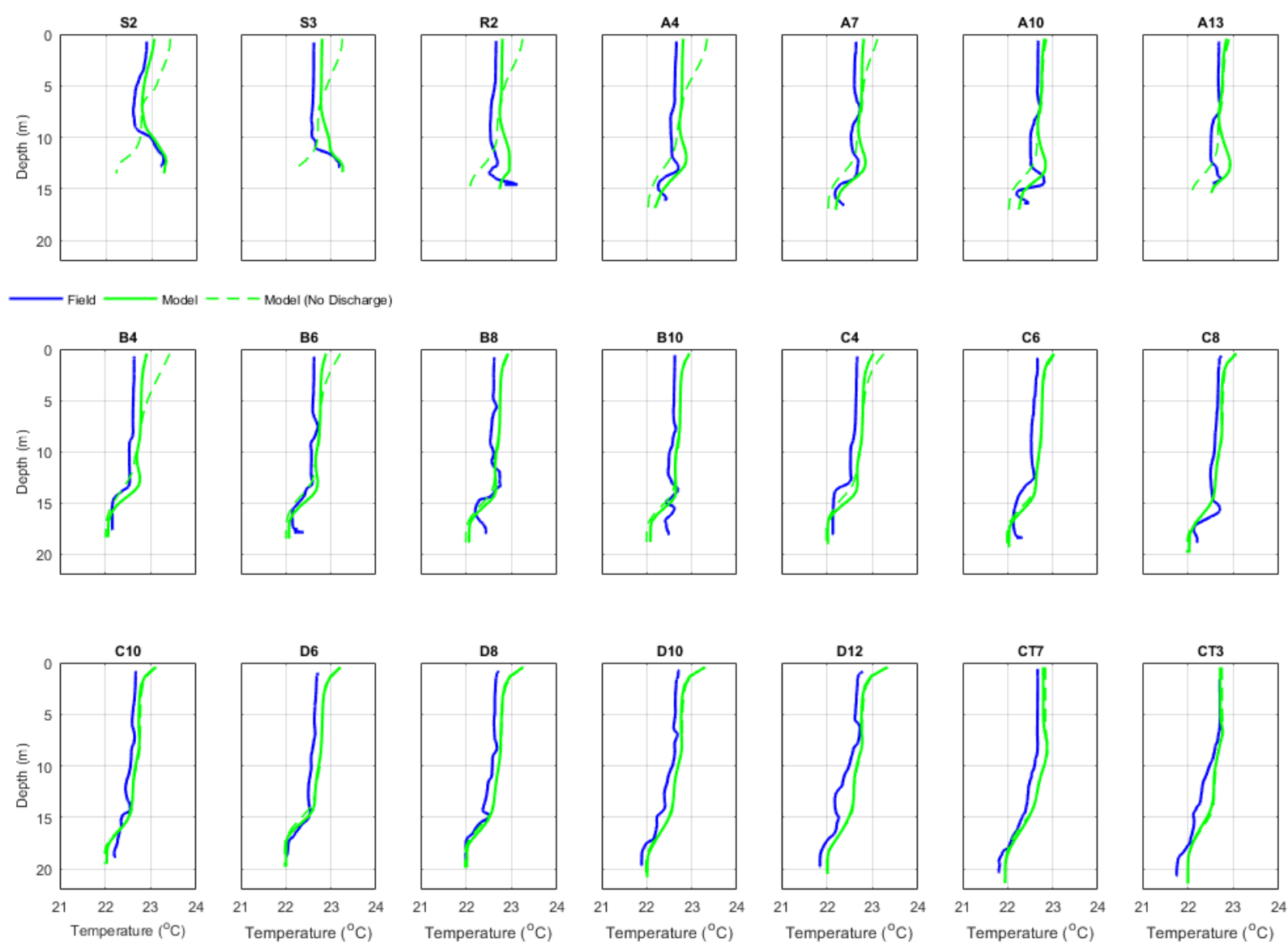


Figure 5-85 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 17 April 2013

17/04/2013

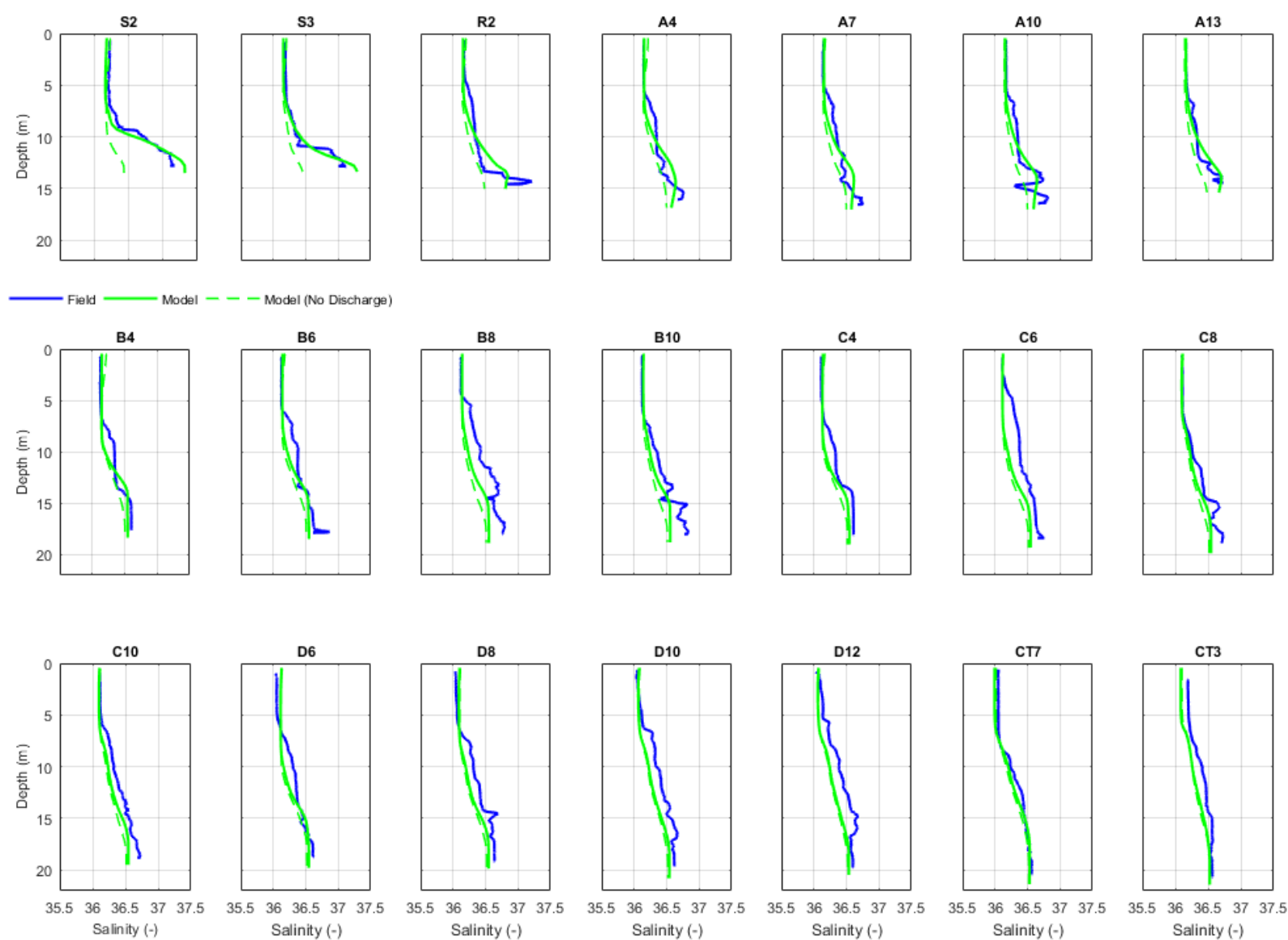


Figure 5-86 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 17 April 2013

18/04/2013

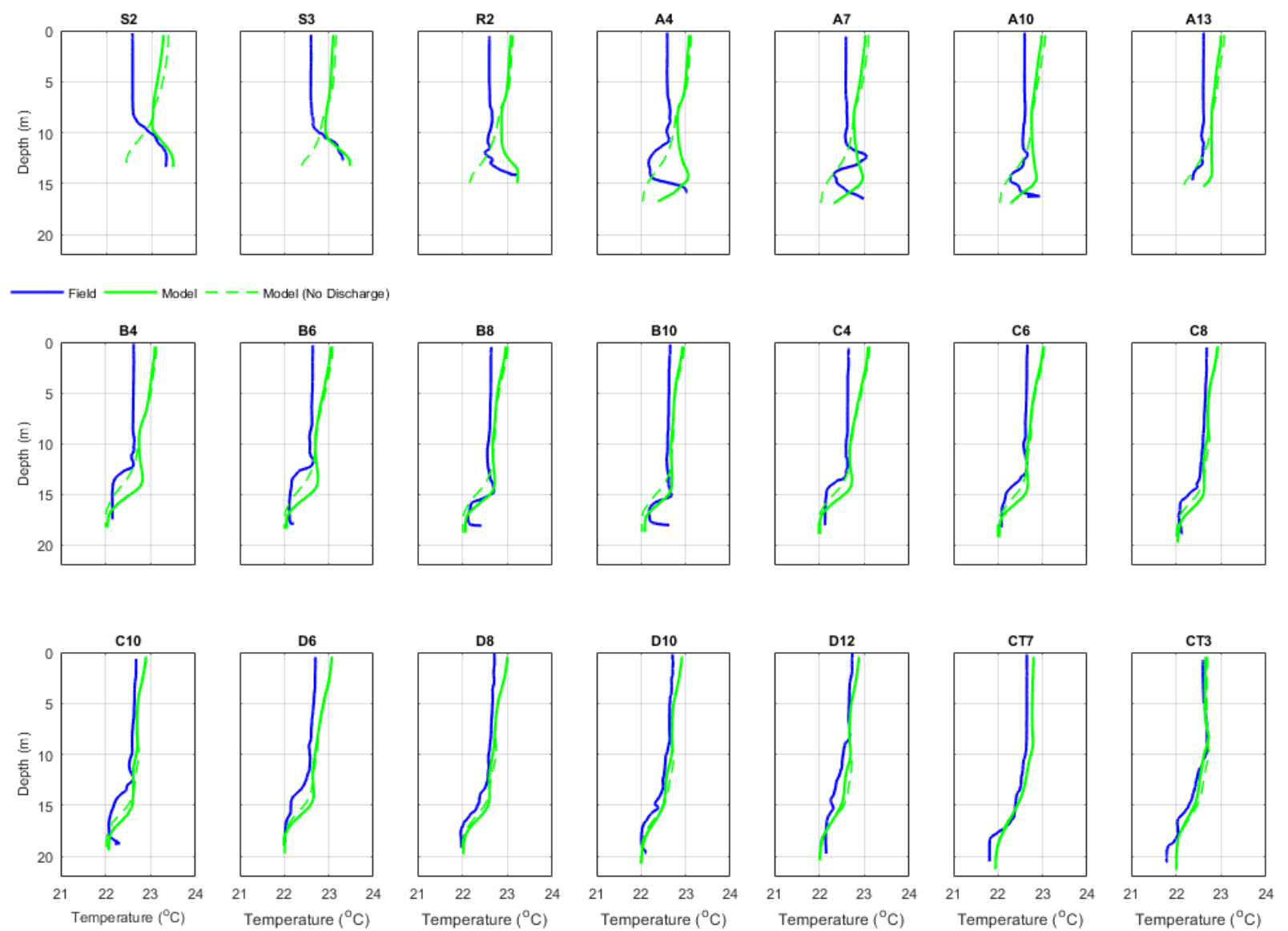


Figure 5-87 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 18 April 2013

18/04/2013

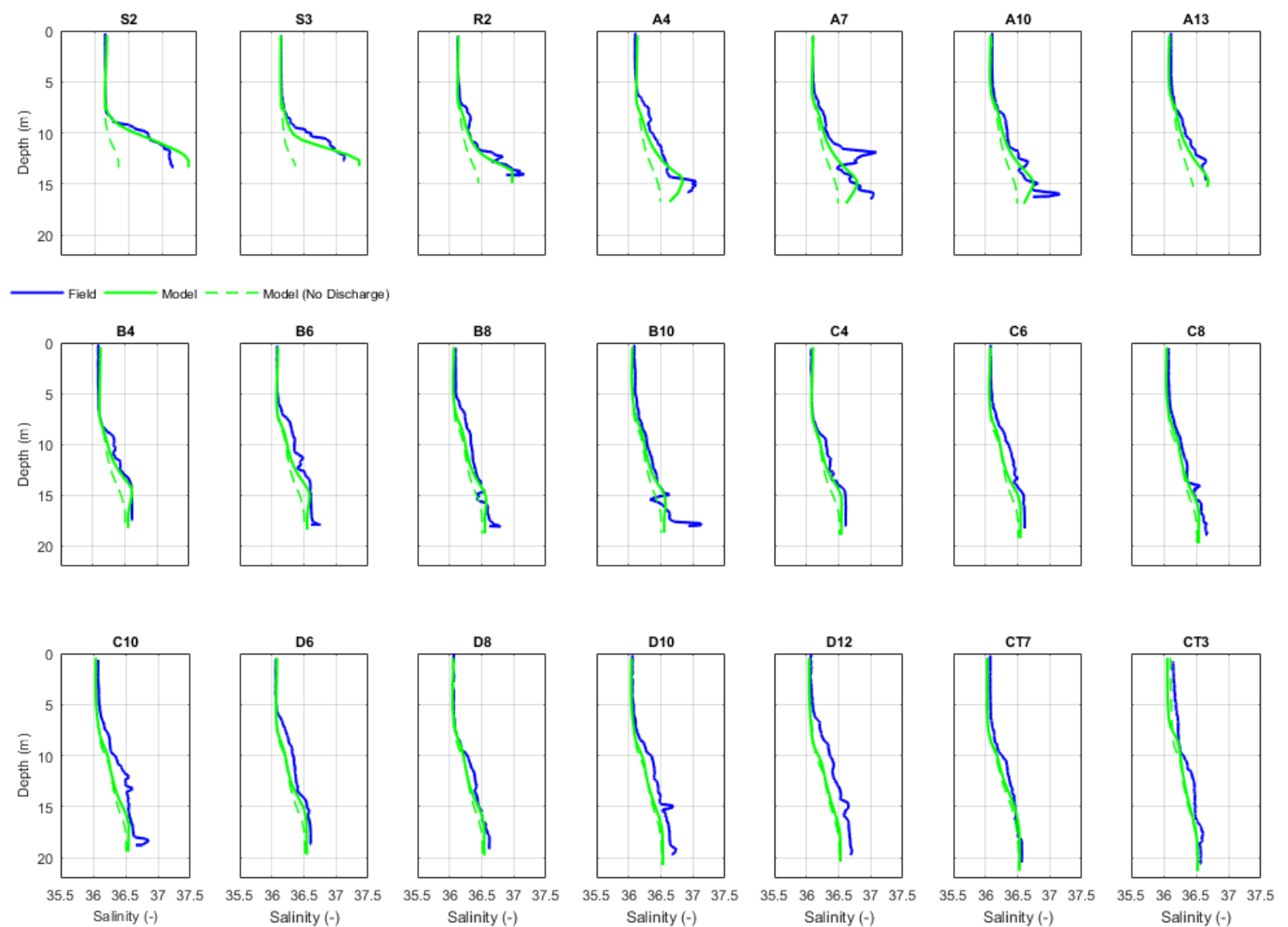


Figure 5-88 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 18 April 2013

20/04/2013

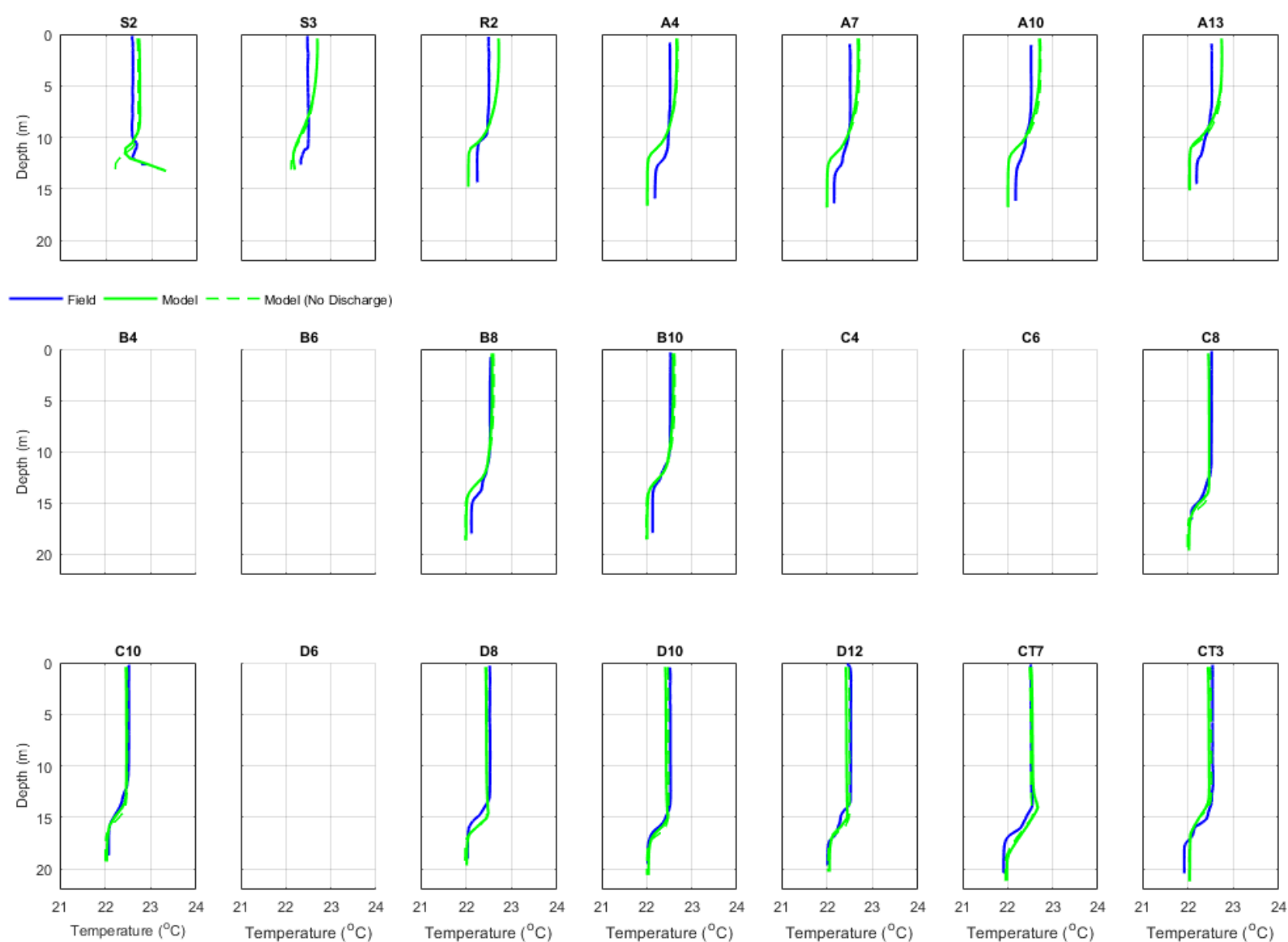


Figure 5-89 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 20 April 2013

20/04/2013

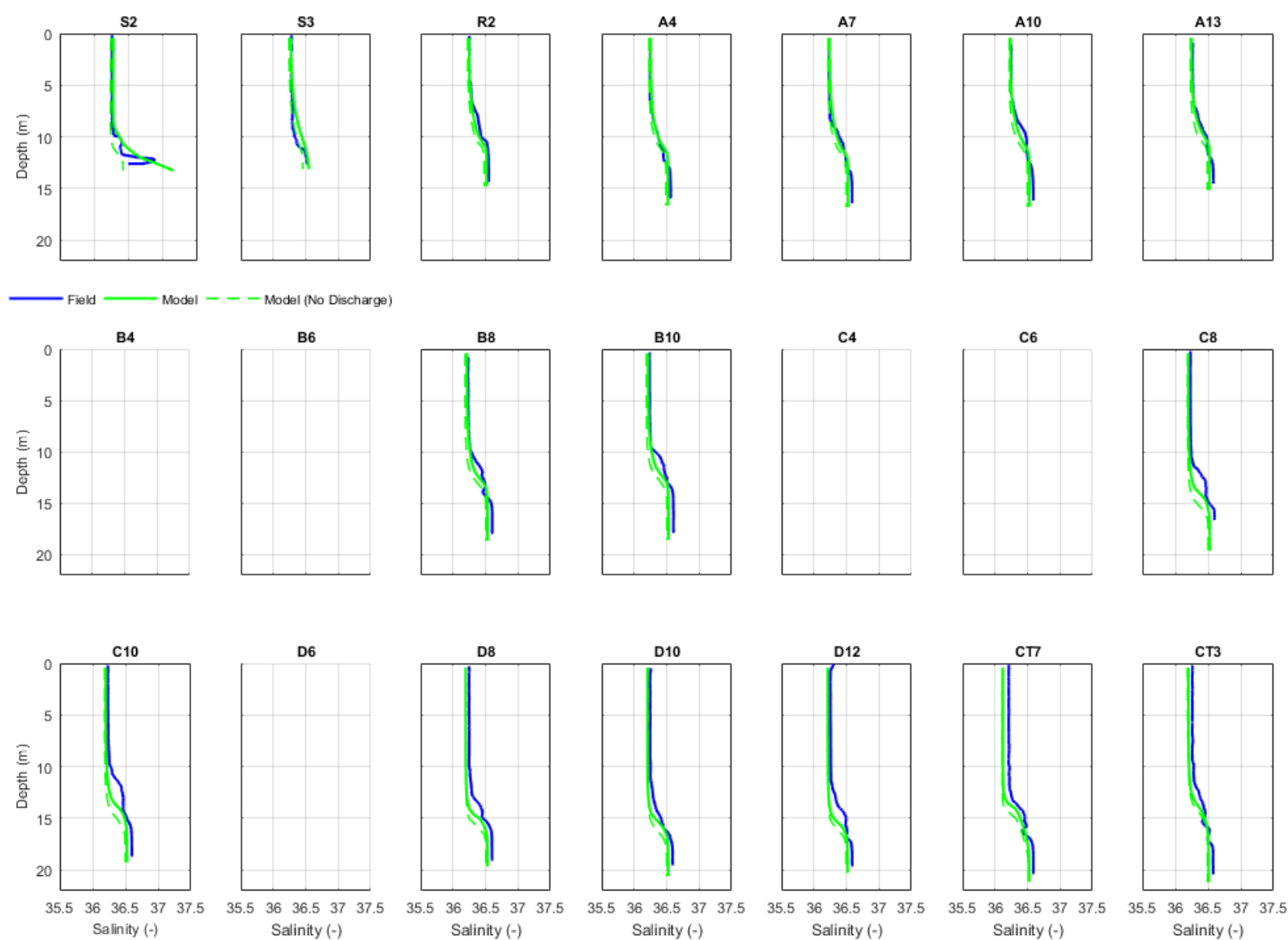


Figure 5-90 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 20 April 2013



22/04/2013

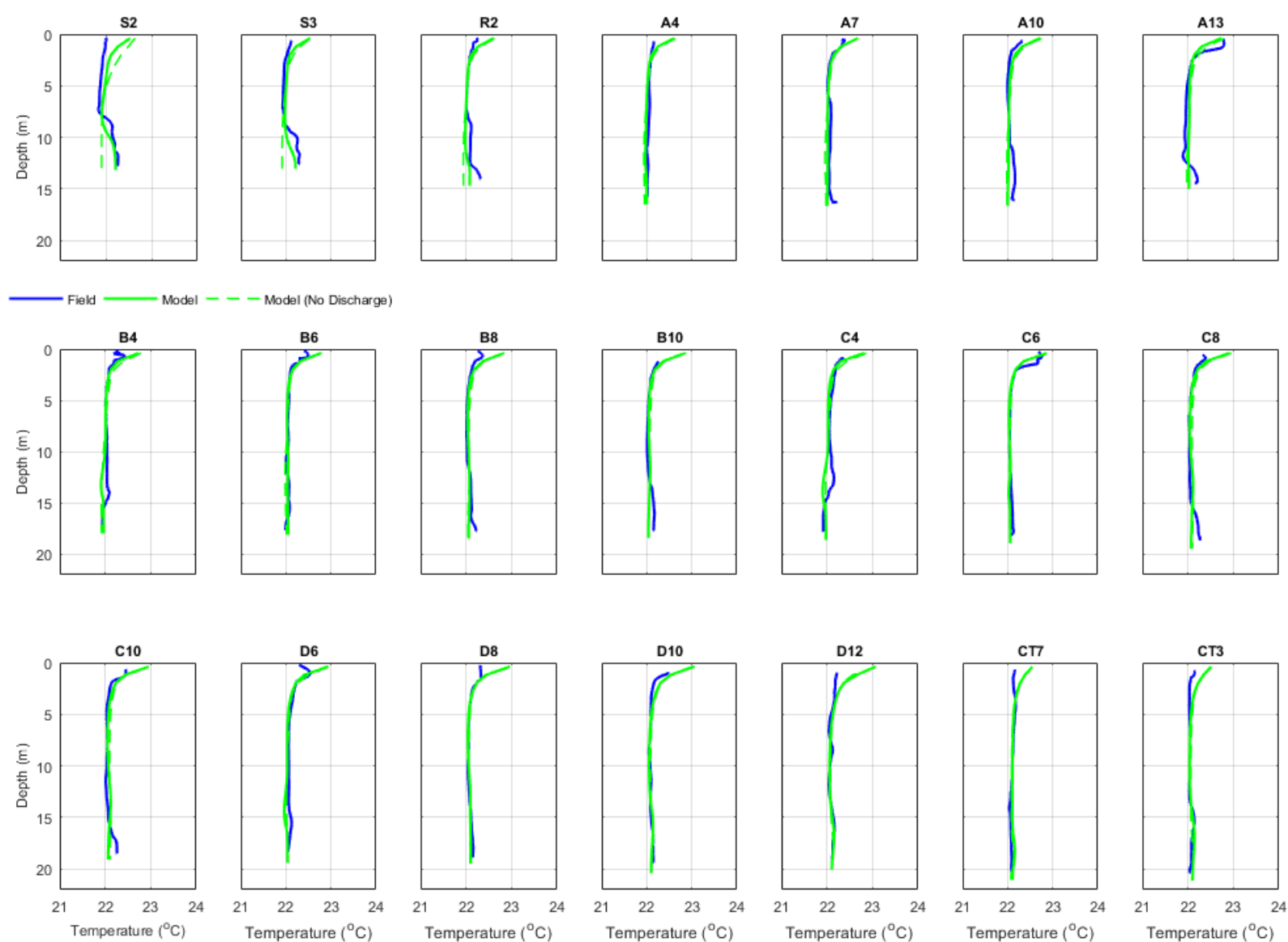


Figure 5-91 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 22 April 2013

22/04/2013

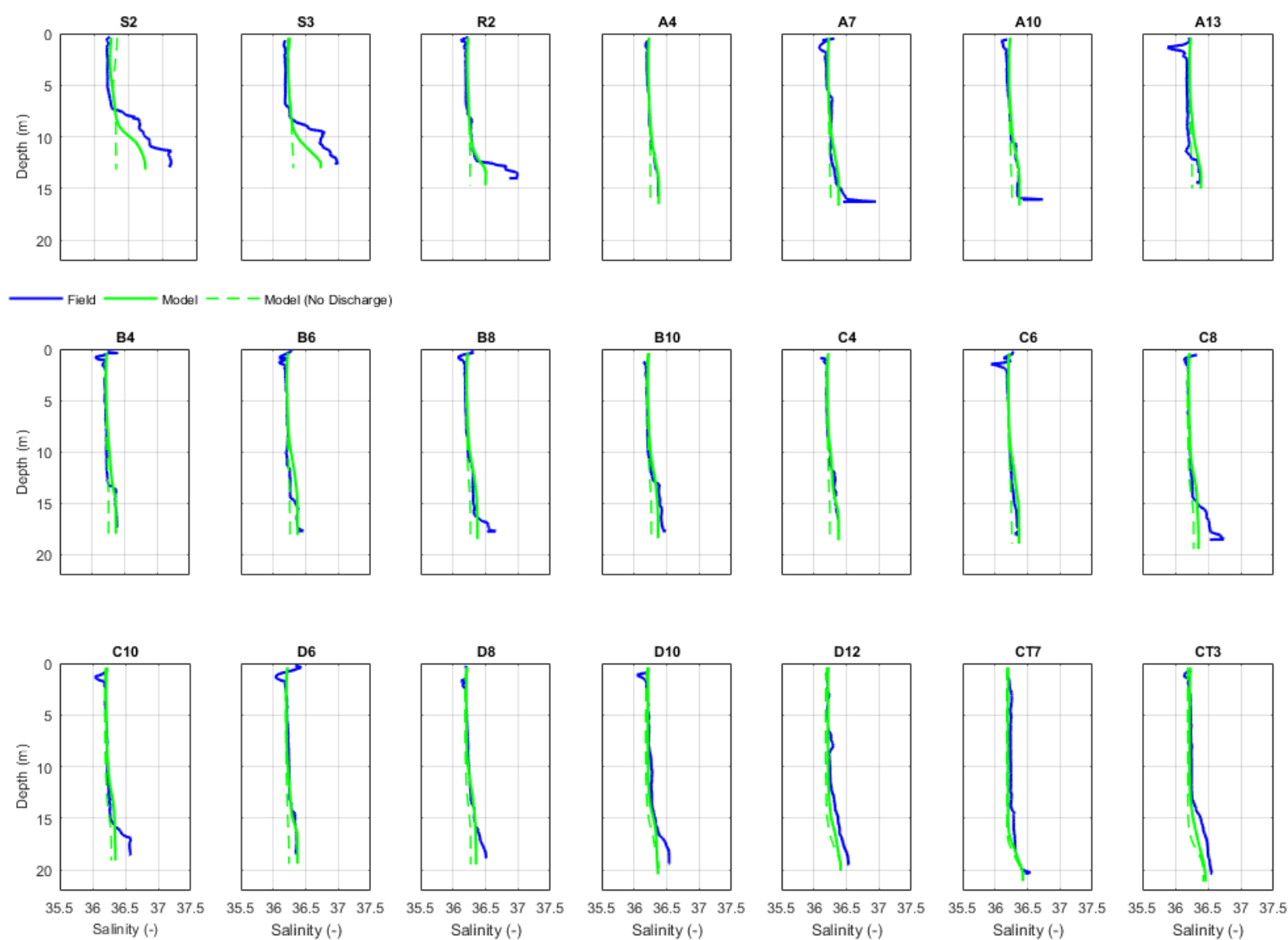


Figure 5-92 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 22 April 2013

23/04/2013

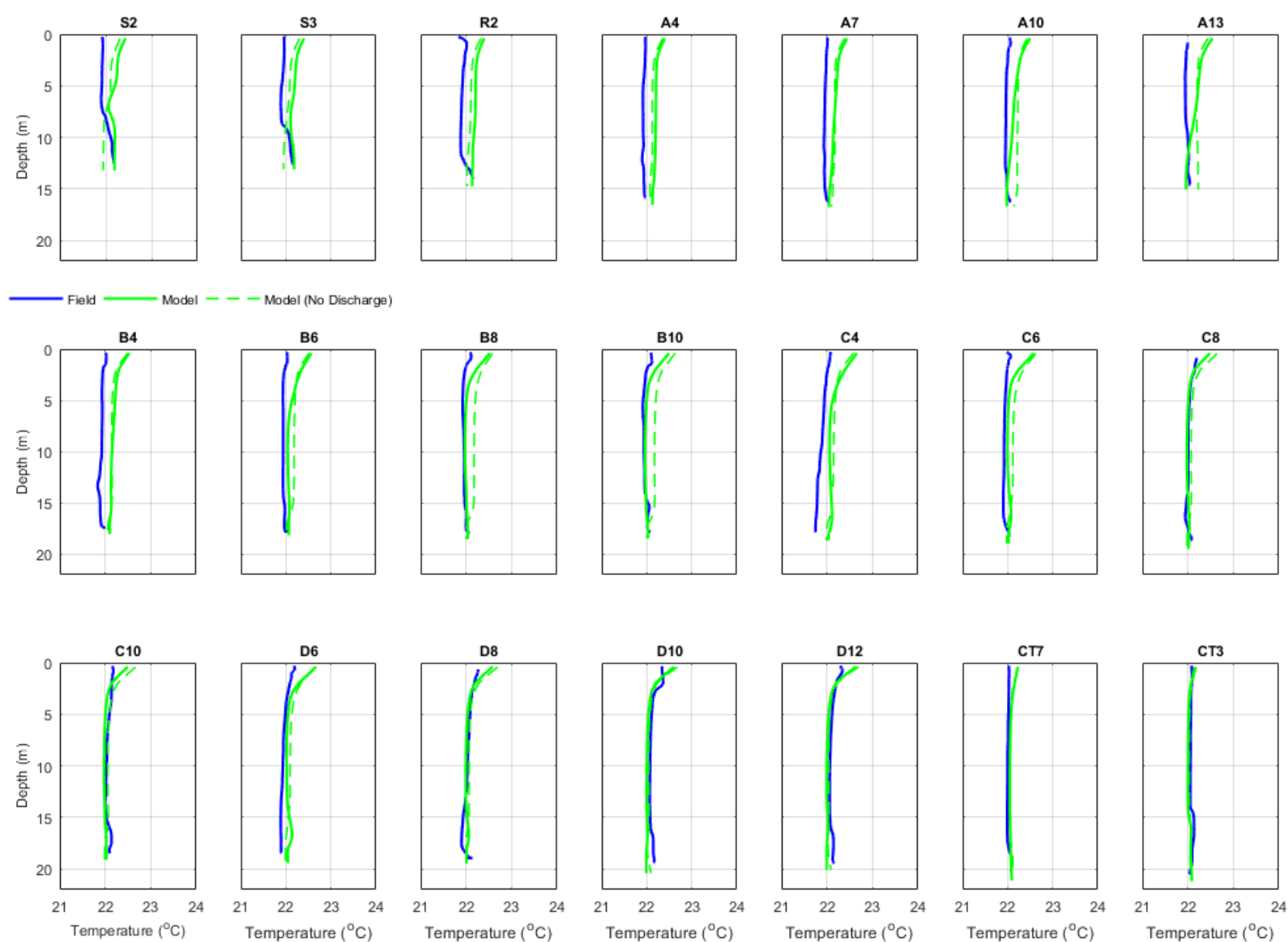


Figure 5-93 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 23 April 2013

23/04/2013

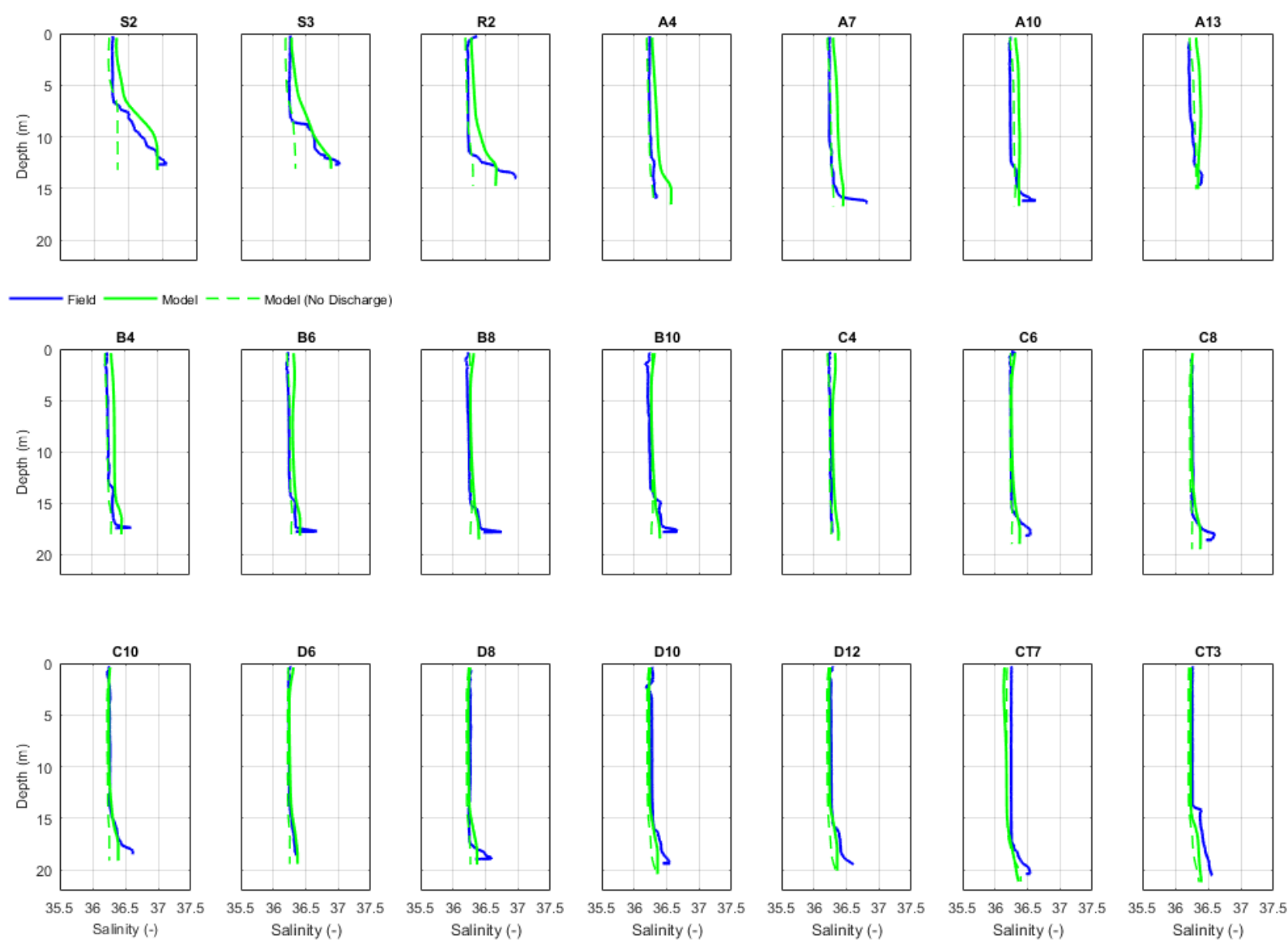


Figure 5-94 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 23 April 2013

24/04/2013

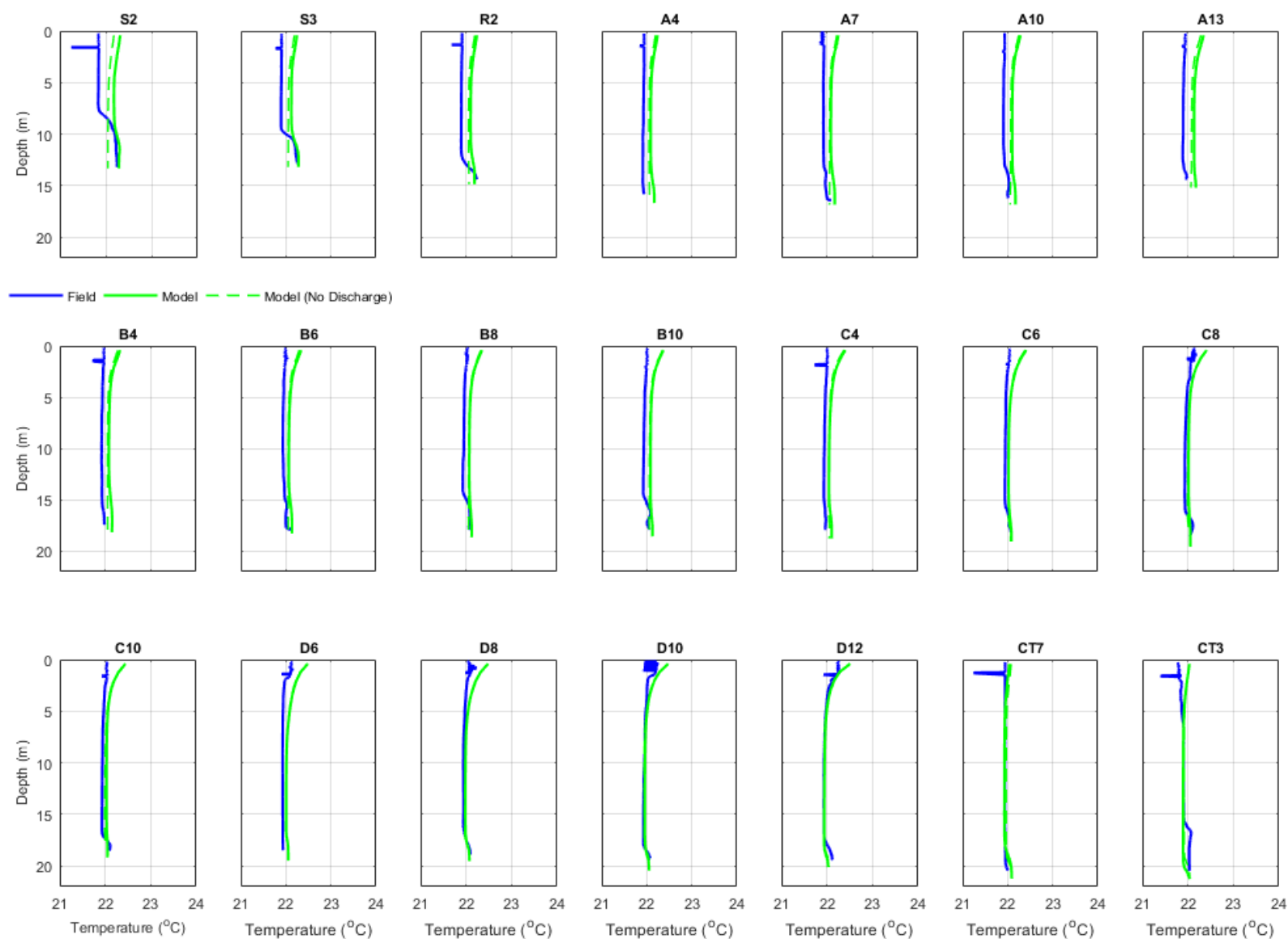


Figure 5-95 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 24 April 2013

24/04/2013

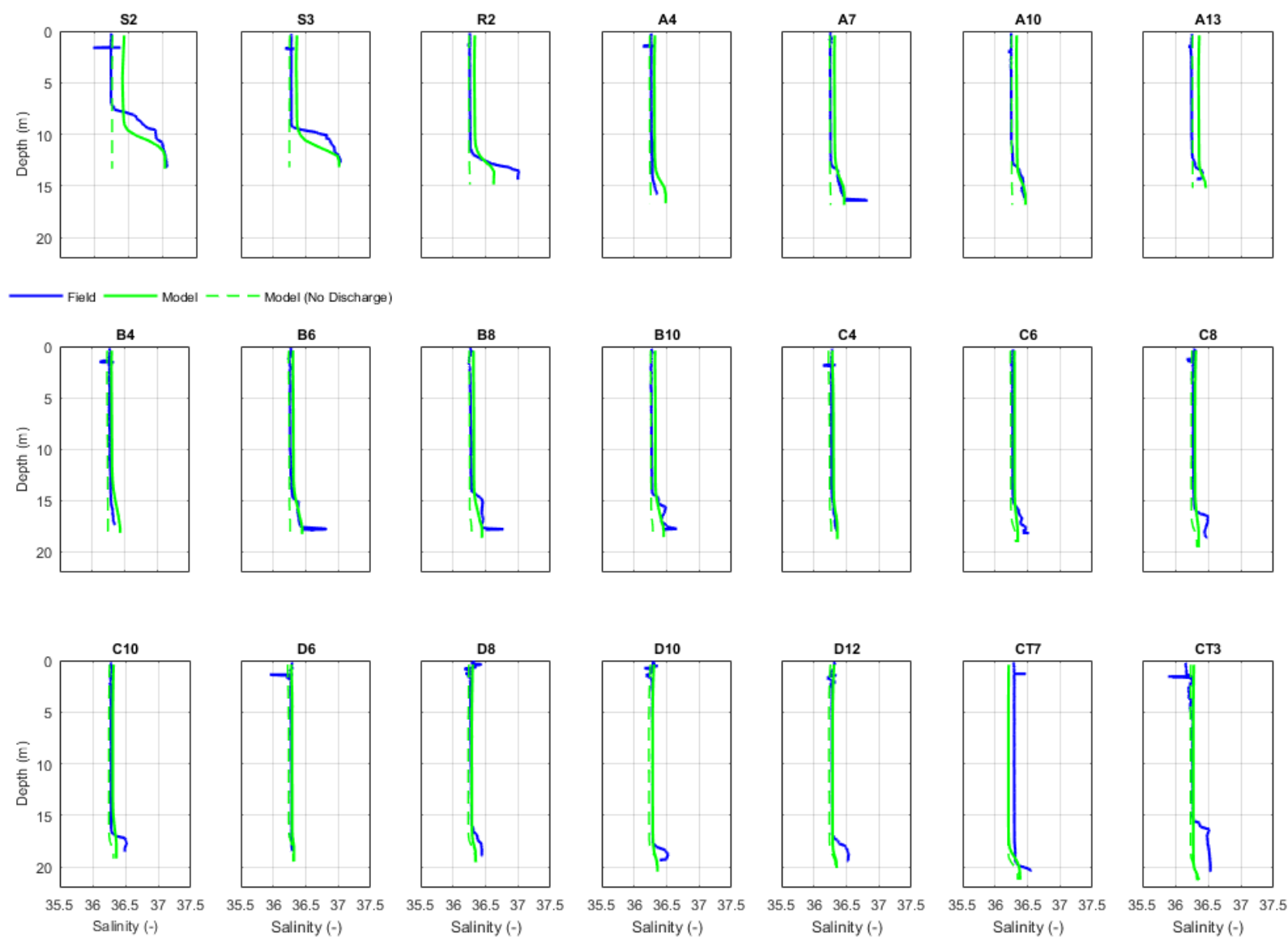


Figure 5-96 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 24 April 2013

26/04/2013

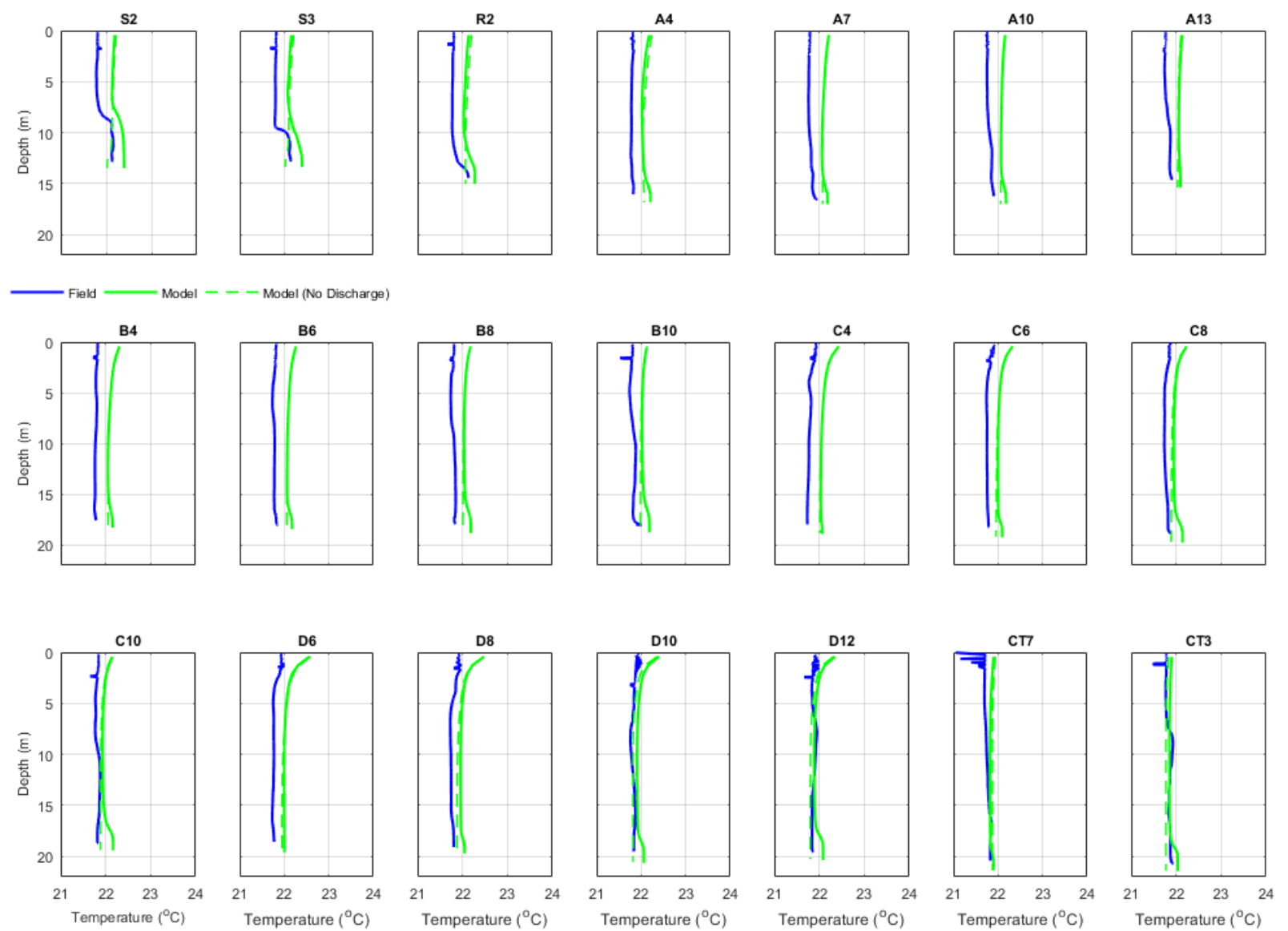


Figure 5-97 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 26 April 2013

26/04/2013

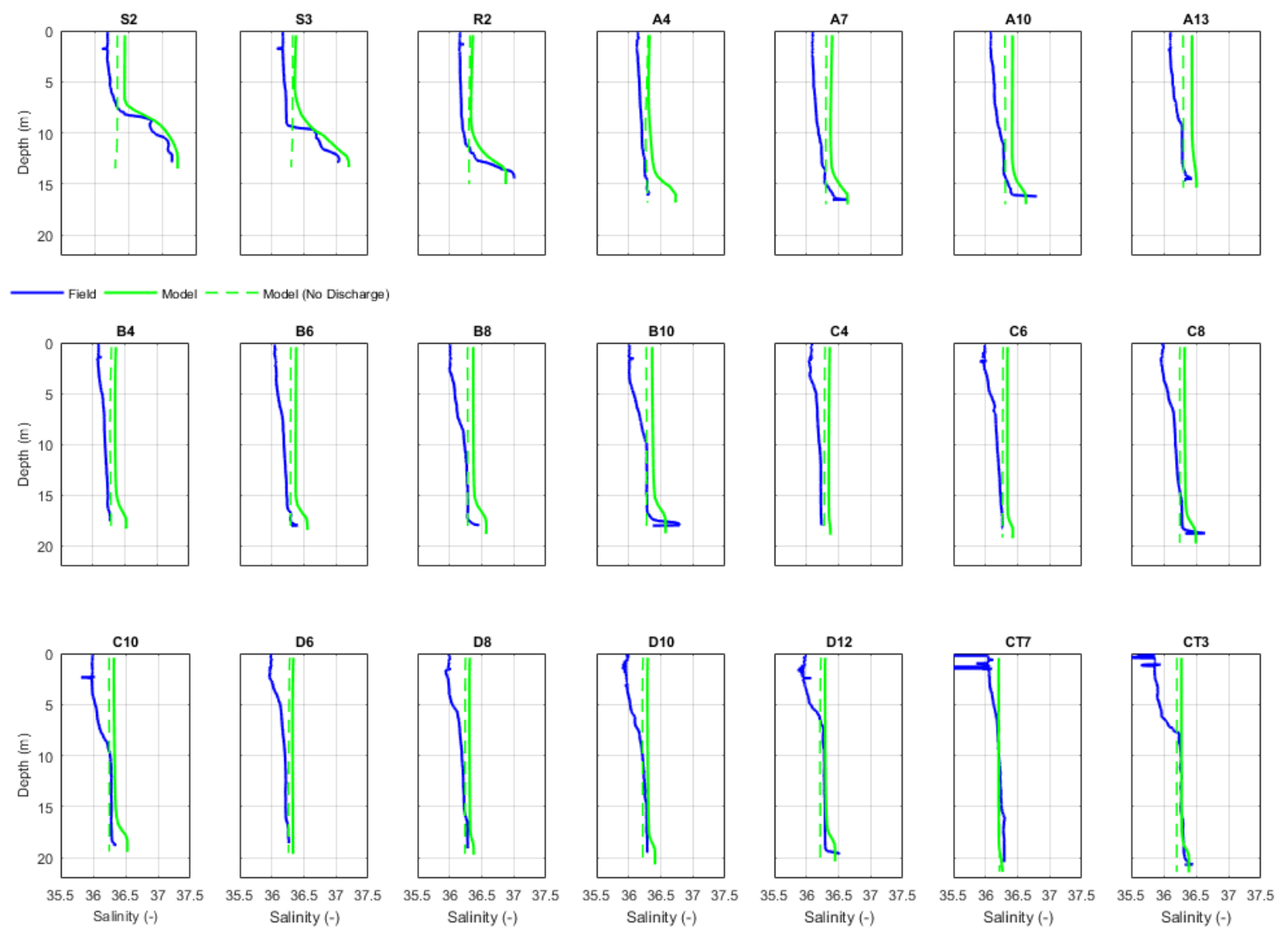


Figure 5-98 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 26 April 2013

28/04/2013

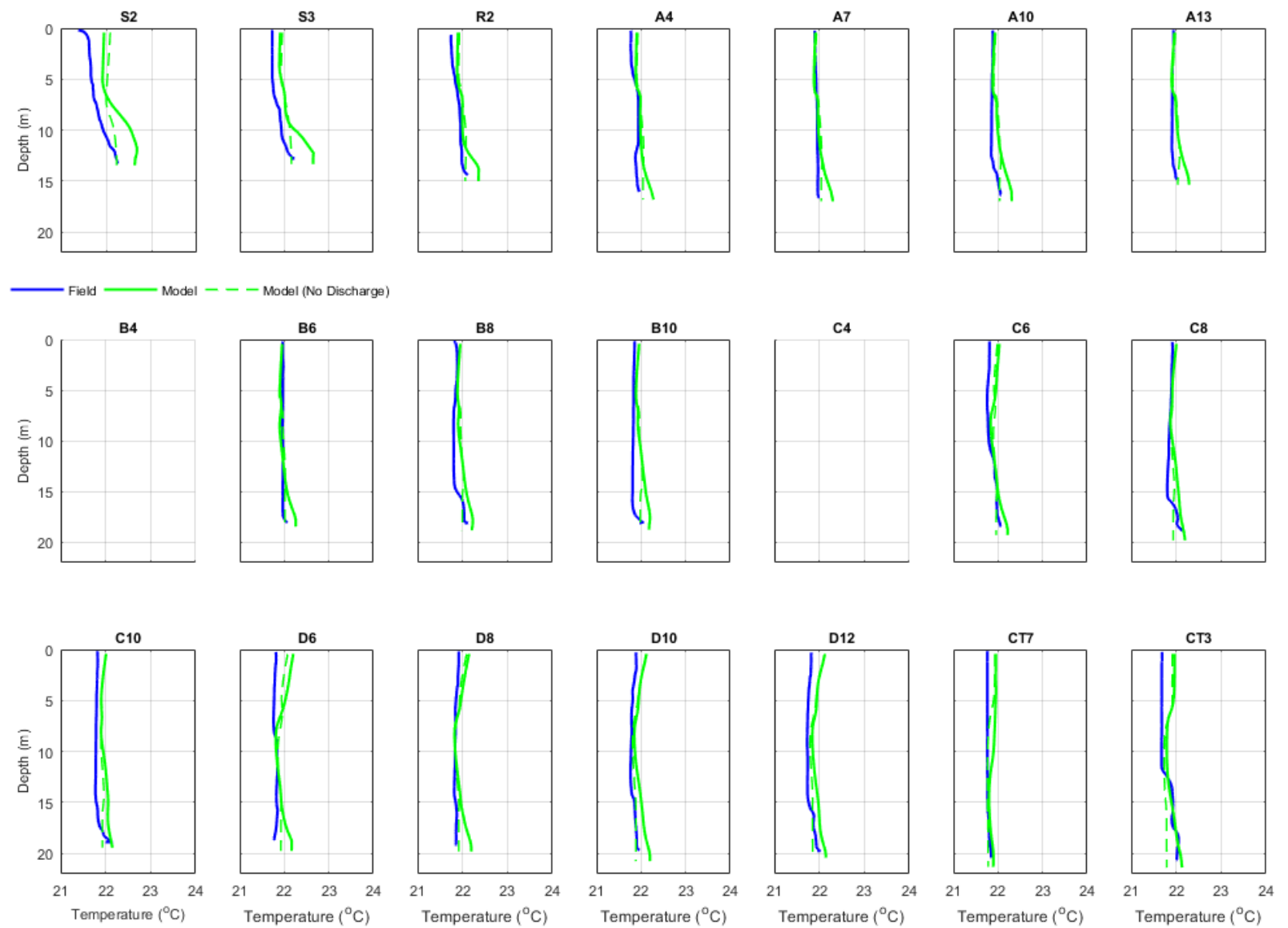


Figure 5-99 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 28 April 2013

28/04/2013

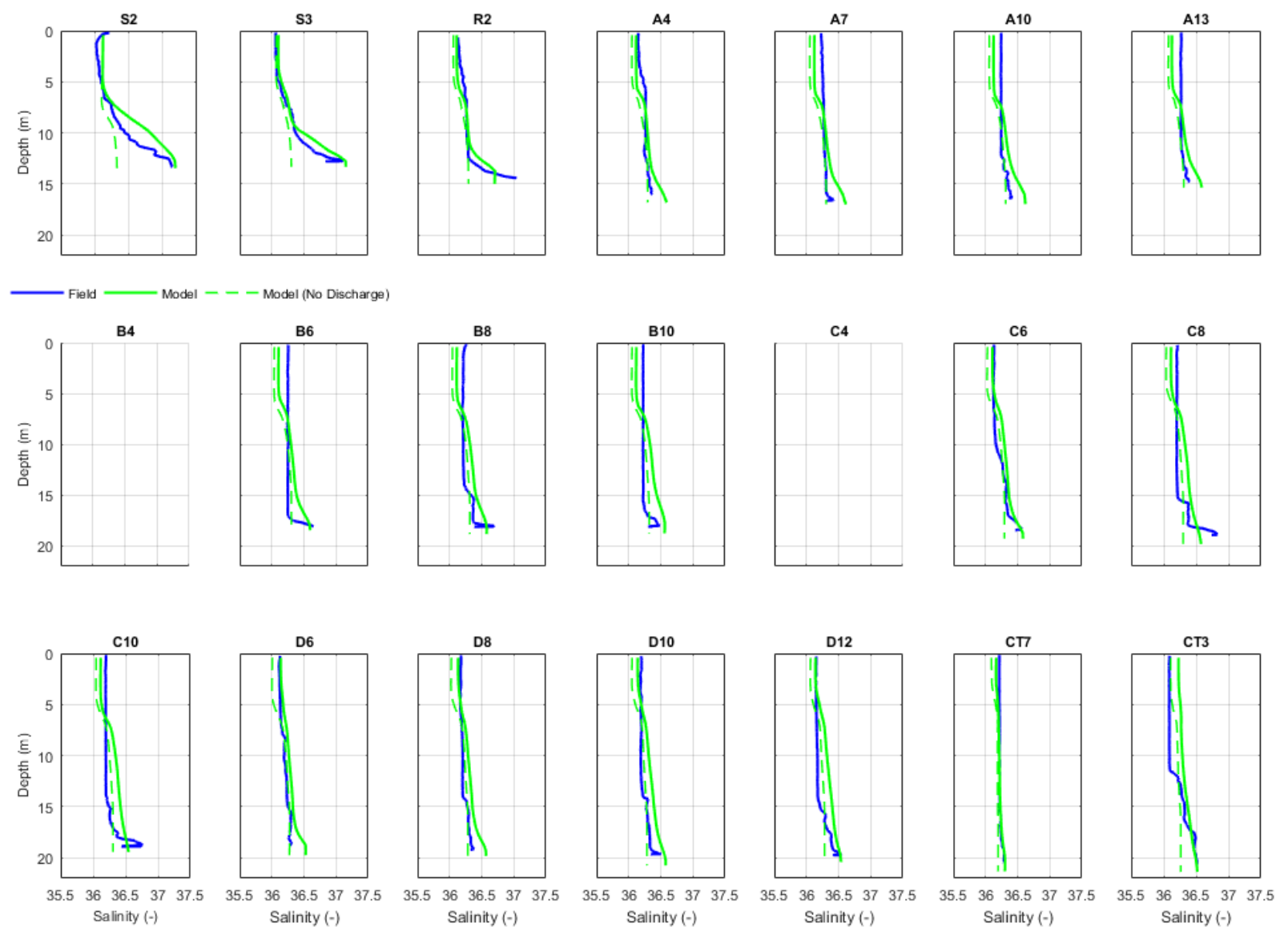


Figure 5-100 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 28 April 2013

30/04/2013

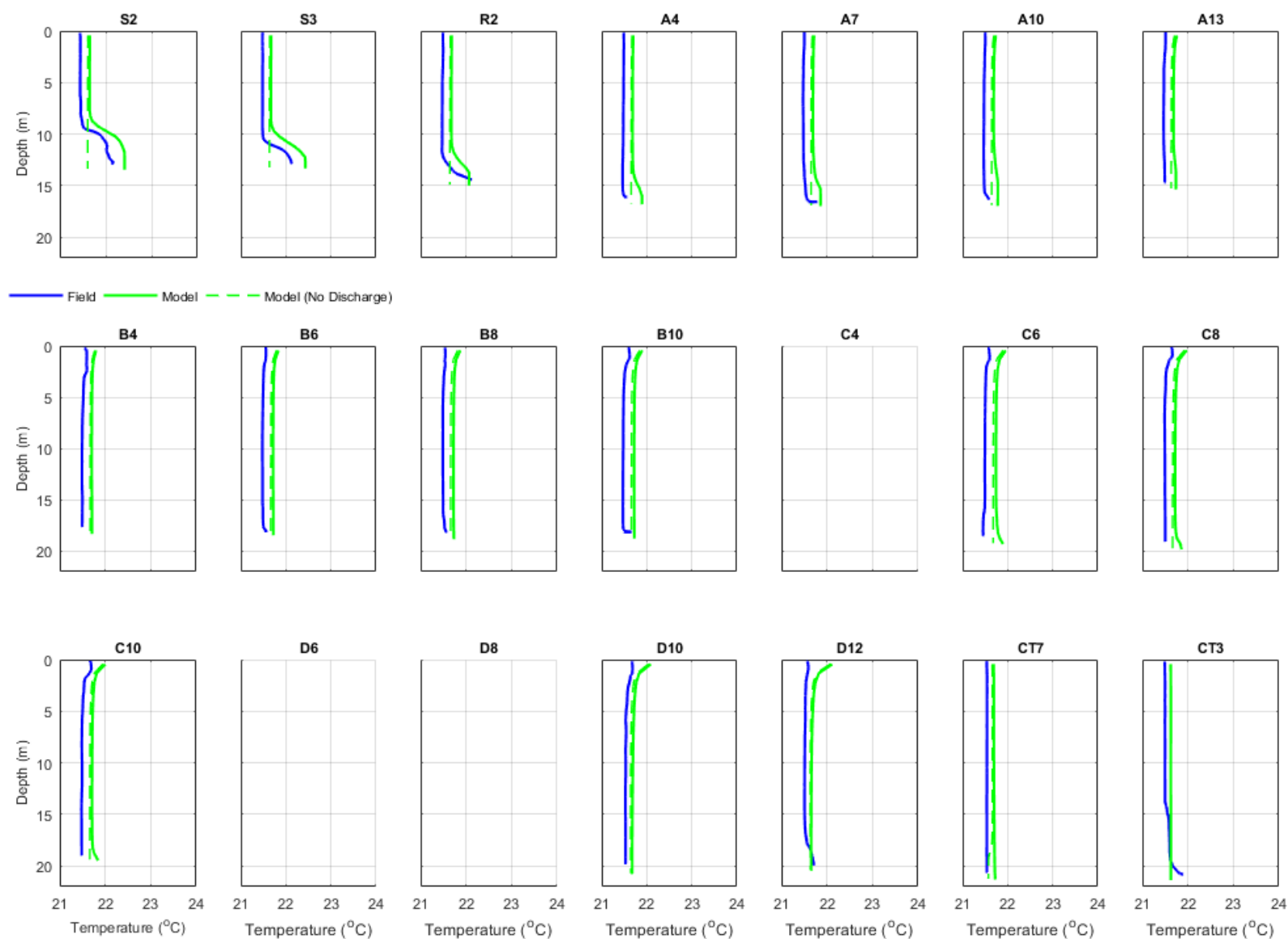


Figure 5-101 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 30 April 2013

30/04/2013

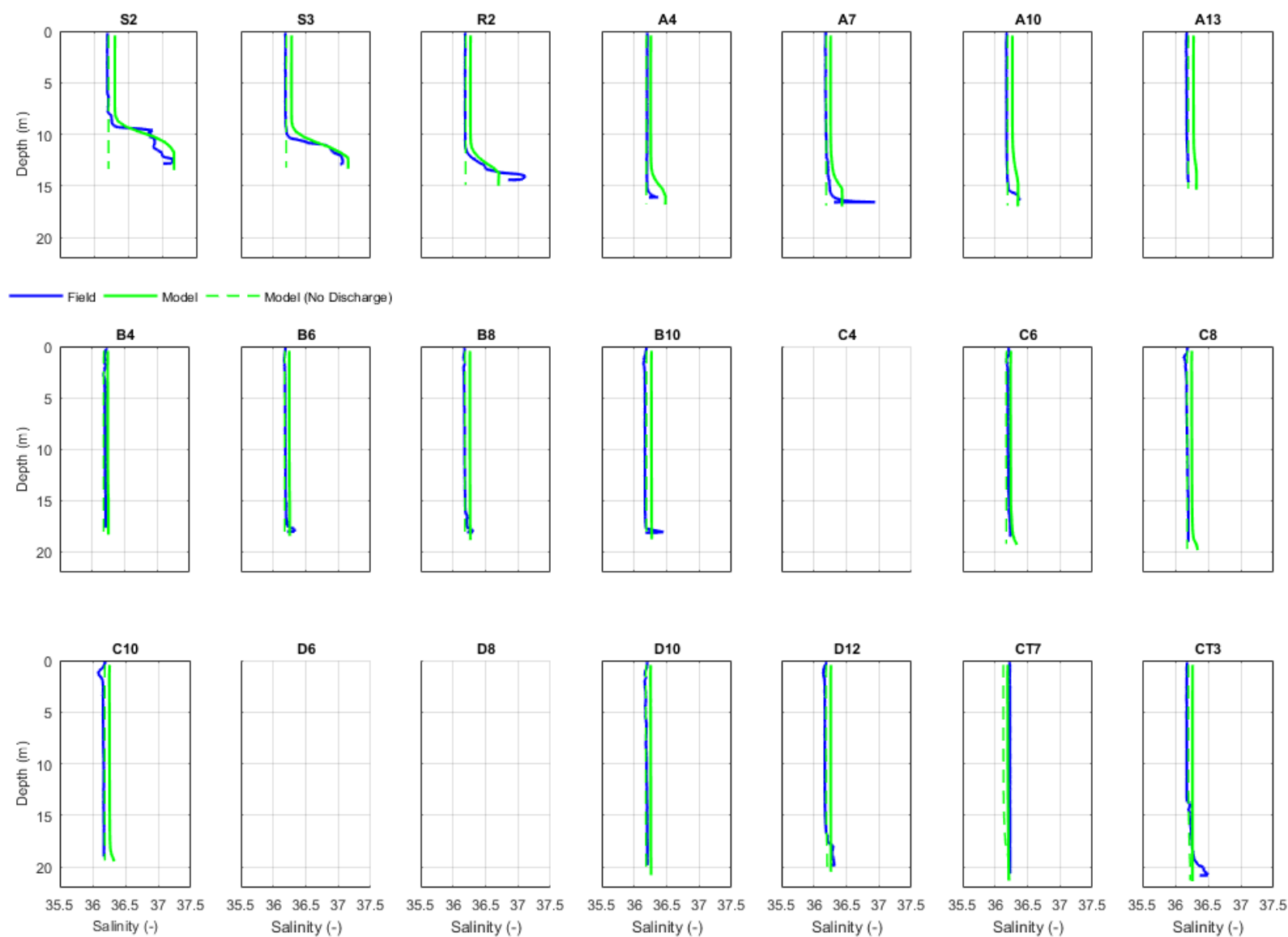


Figure 5-102 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 30 April 2013

## Model simulations

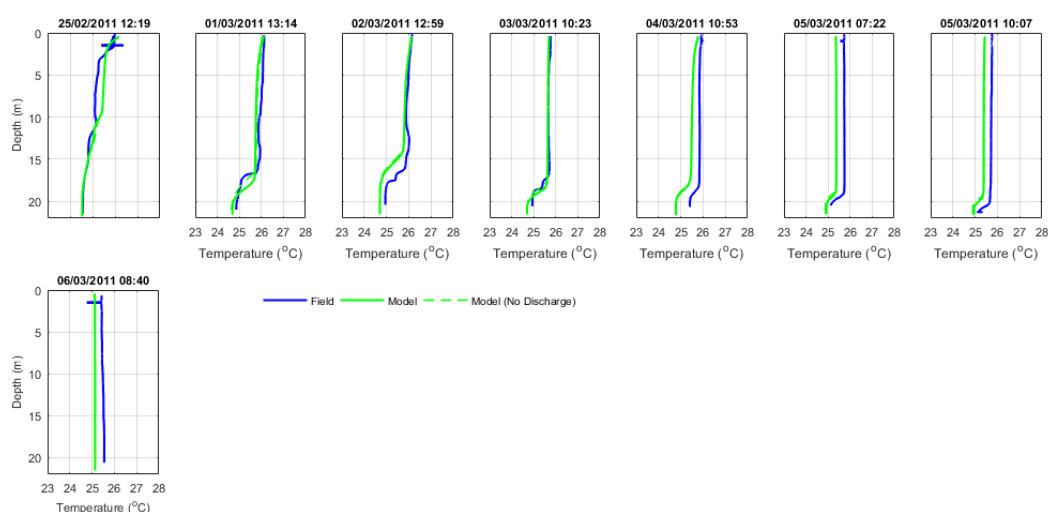
### 5.3.6 Model Comparisons (2011)

Between 01 and 05 March 2011 DO concentrations in Cockburn Sound reduced below 60% saturation (Figure 2-15), triggering the campaign of measurements specified in the MMMP. The temperature, salinity and DO data collected over the MMMP campaign offered another opportunity to assess the BMT model performance. In this campaign, the profiles in the semi-circular locations at the exit of Stirling Channel were collected only twice, on 04 and 05 November. The other days in the campaign (01, 03, 06, and 07 March) data were collected only in Stations R2, S2, S3, CT3 and CT7. Simulations with and without the inclusion of the PSDP discharge were undertaken between 23 February and 10 March for comparisons against these profiles. In this Section, comparisons are shown only for the days over which profiles were collected in the semi-circular locations. Data collected on the other days of the campaign are shown in Appendix G.

#### 5.3.6.1 Temperature and salinity profiles in the deep basin

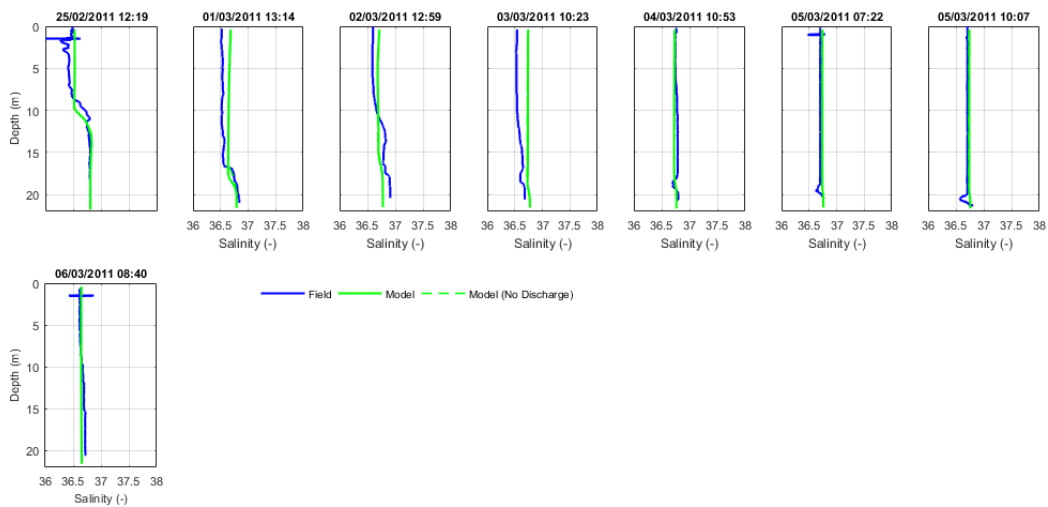
The temperature and salinity profile data (Figure 5-103 and Figure 5-104, respectively) collected in the Central Buoy and CT7 stations illustrate the conditions in Cockburn Sound's deep basin over the time of interest. The period starts with a temperature profile exhibiting both a shallow (diurnal) and deep thermocline on 25 February (Figure 5-103). The corresponding salinity profile displayed less saline water over the upper 10 m of water, with the underlying halocline co-locating with the thermocline (Figure 5-103 and Figure 5-104). The presence of this less saline layer is consistent with the ingress of less saline water to the Sound that is typically expected at this time of year.

For most of the simulated period, deepening of both thermocline and halocline ensued up until 06 March, when full water column mixing was observed. The model predicts the transition from shallow stratification, into deep stratification and its subsequent progression into full mixing with skill (Figure 5-103 and Figure 5-104). The model, however, slightly underpredicted temperature at times towards the simulation's end (Figure 5-103).



**Figure 5-103 Comparison of simulated and measured temperature profiles measurements at either Central Buoy (25 February and 06 March) or CT7 in March 2011 (remaining profiles)**





**Figure 5-104** Comparison of simulated and measured salinity profiles at either Central Buoy (25 February and 06 March) or CT7 in March 2011 (remaining profiles)

**Model simulations****5.3.6.2 Temperature and salinity profiles in the transition to the deep basin**

Similarly to the 2013 simulation results and measurements shown in Section 5.3.5.3, temperature and salinity profile data in the transition to the deep basin are shown in Figure 5-104 and Figure 5-105. Again, these figures present profiles collected over a same day at the different semi-circular and concentrically oriented sampling locations.

The model generally underpredicted temperature in the inner channel, inner and outer radii stations. As the predictions more closely resembled the measurements in the offshore stations (CT7 and CT3), it is very likely therefore that the lack of agreement might have stemmed from the constant specification of the flow and temperature in the nearby cooling water discharges. During model calibration it was identified that the shallow shelf temperature profile can be very sensitive to the specification of the quality and quantity of industrial discharges to the region, perhaps motivating collection of these data in future.

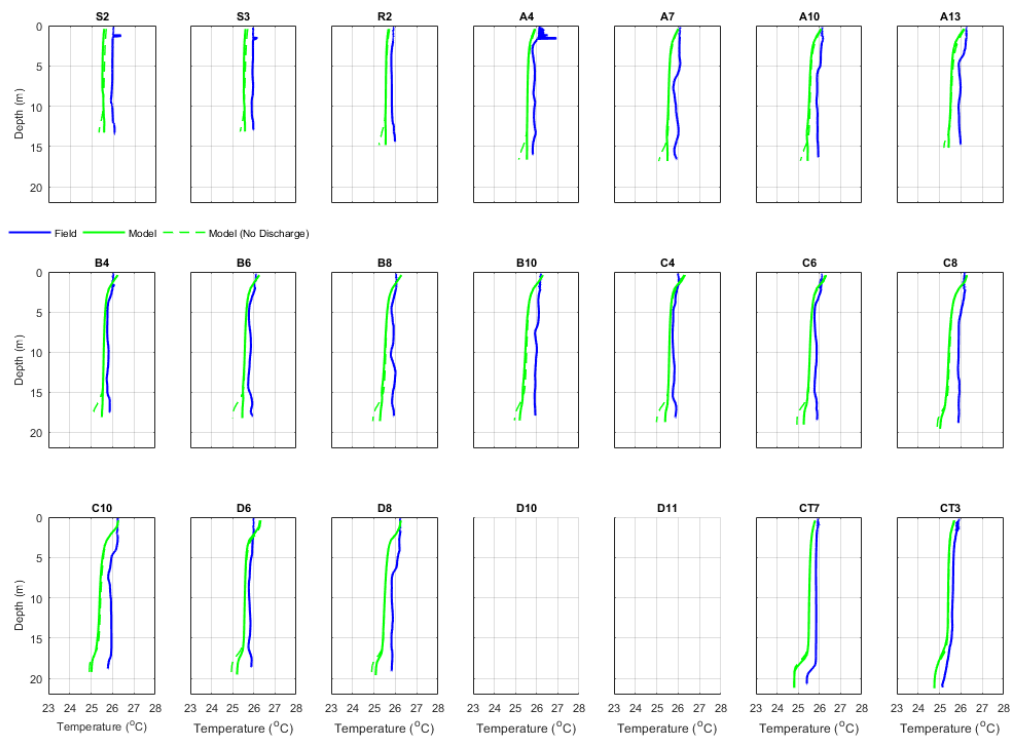
The model generally replicated the change in salinity and shape of profiles between the stations in Stirling Channel (R2, S2 and S3 stations) to the inner radii (A and B stations) (Figure 5-105). However, the upper portion of the water column (i.e. the portion less affected by the PSDP discharge) still presented a degree of stratification at some of A, B, C, and, to a lesser extent D stations. The model on these locations presented a more (albeit minor) mixed profile.

If compared to the simulation without the inclusion of the discharge, the calibrated (actual conditions) model presented a deep and more saline layer (at approximately 16 to 18 m depth), suggesting a small impact of the PSDP discharge. The similar size and salinity increase in this layer was also present in some of the measurements, indicating the model is well suited to the simulation of the brine discharge, accommodating very fine details of the associated plume dynamics.

On 05 March, both simulated and salinity profiles show increased mixing conditions. The model showed slightly more mixed conditions than the field data (e.g. some A locations, Figure 5-108). However, this does not detract the fact that the model is simulating the correct process dynamics (i.e. continual mixing over the simulated period).

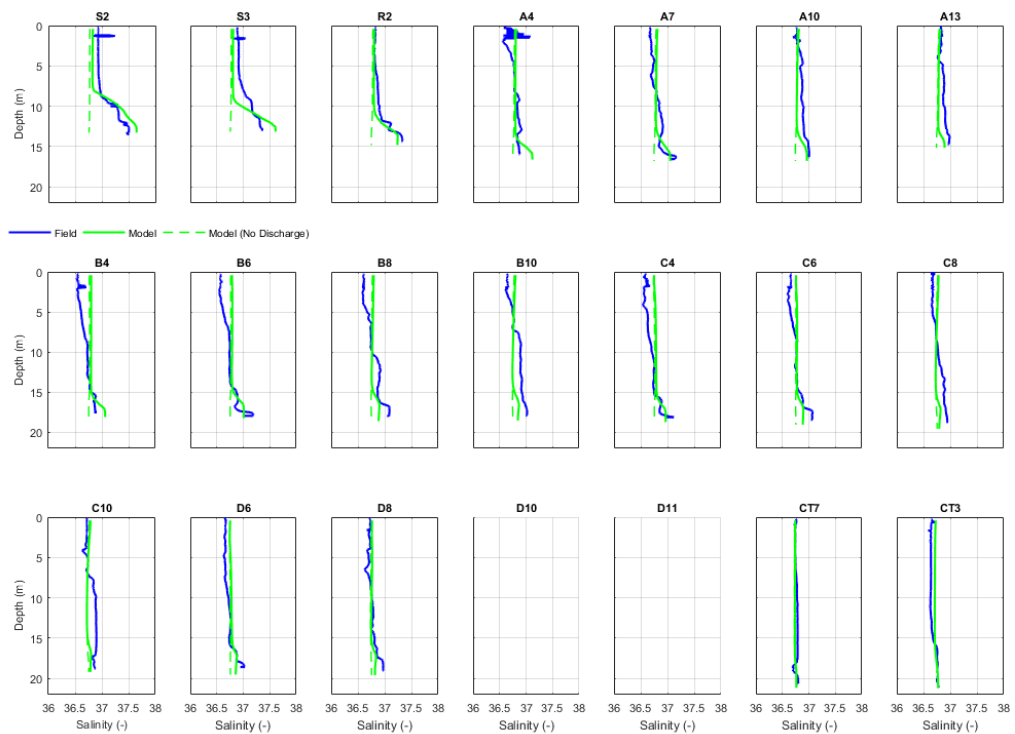
## Model simulations

04/03/2011



**Figure 5-105 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 04 March 2011**

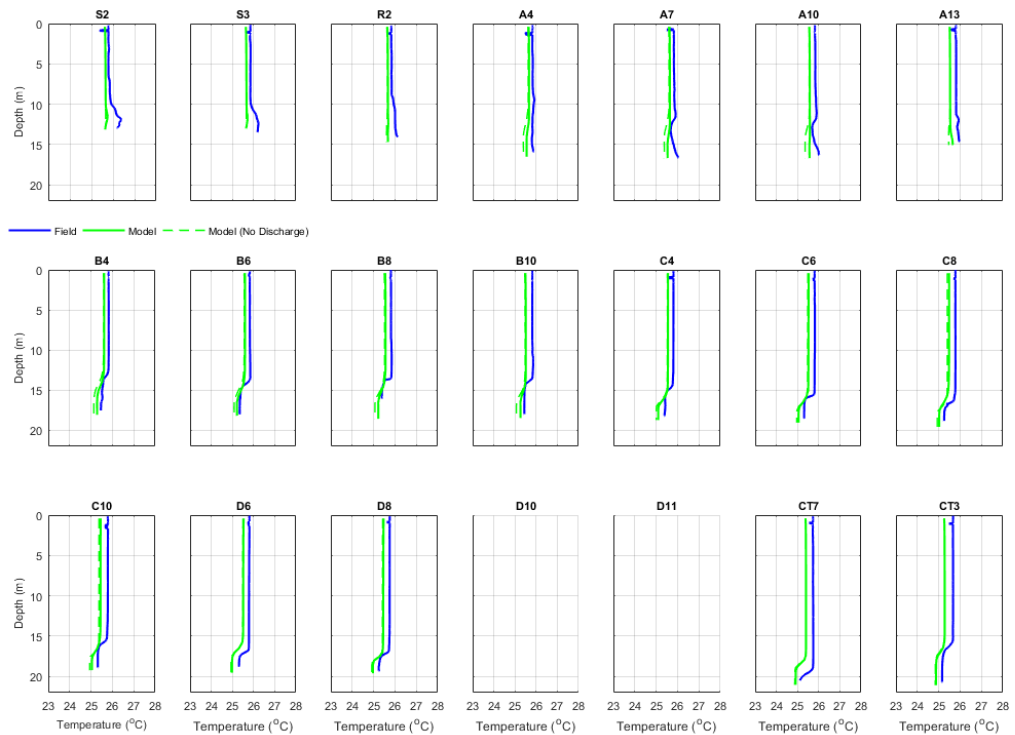
04/03/2011



**Figure 5-106 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 04 March 2011**

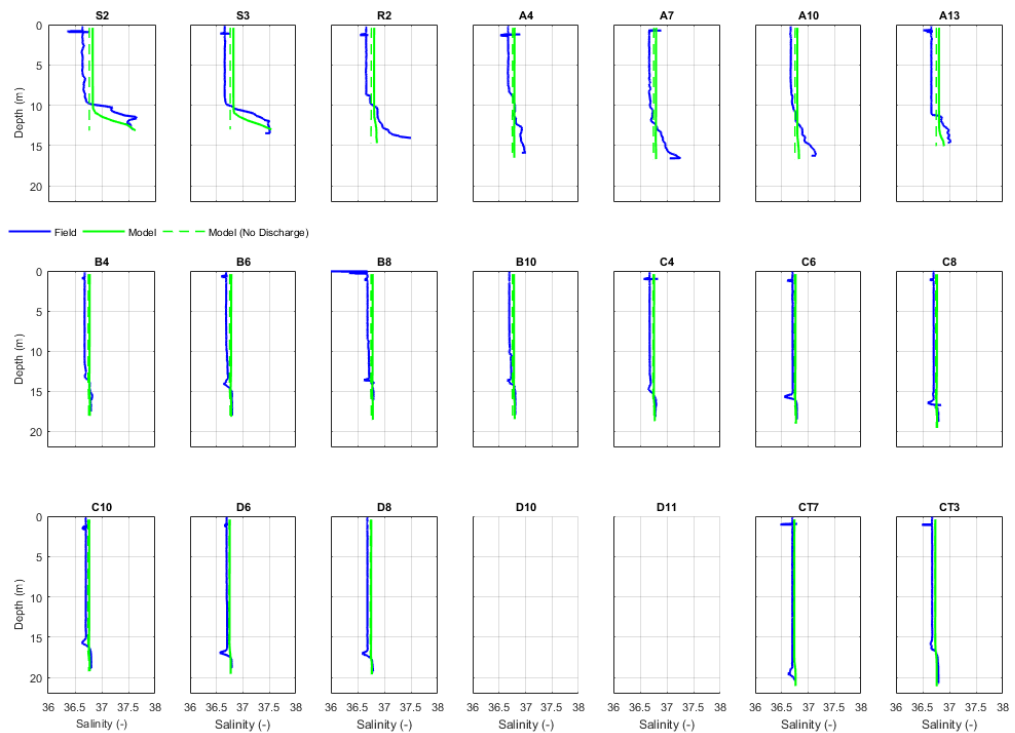
## Model simulations

05/03/2011



**Figure 5-107 Comparison of simulated and measured temperature profiles at a subset of the MMMP stations on 05 March 2011**

05/03/2011



**Figure 5-108 Comparison of simulated and measured salinity profiles at a subset of the MMMP stations on 05 March 2011**