

## **XBT data collected along the Southern Ocean “chokepoint” between New Zealand and Antarctica, 1994-2023**

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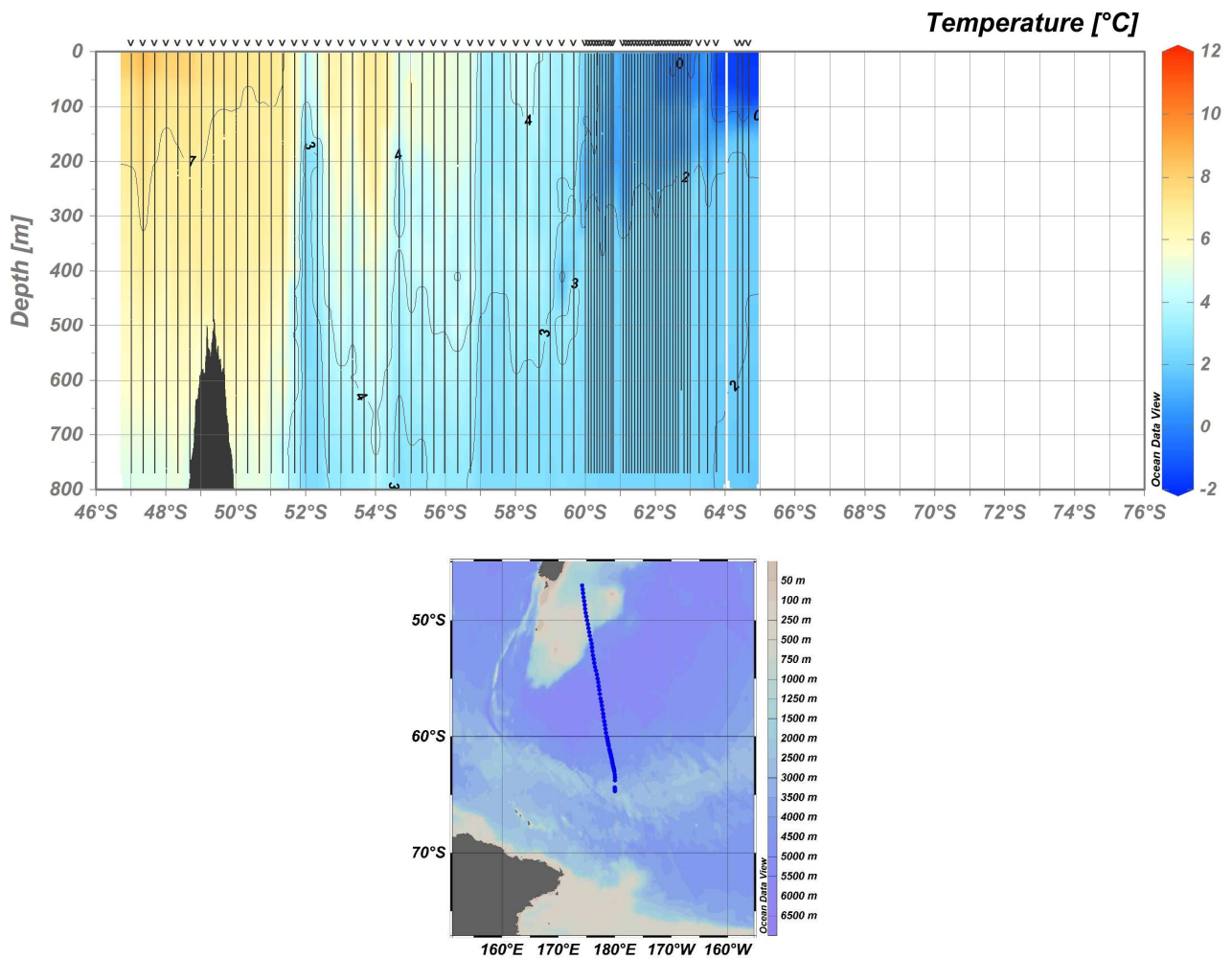
### **Contents of this file**

**S1-S36.** XBT temperature vertical sections for all the available PNRA expeditions

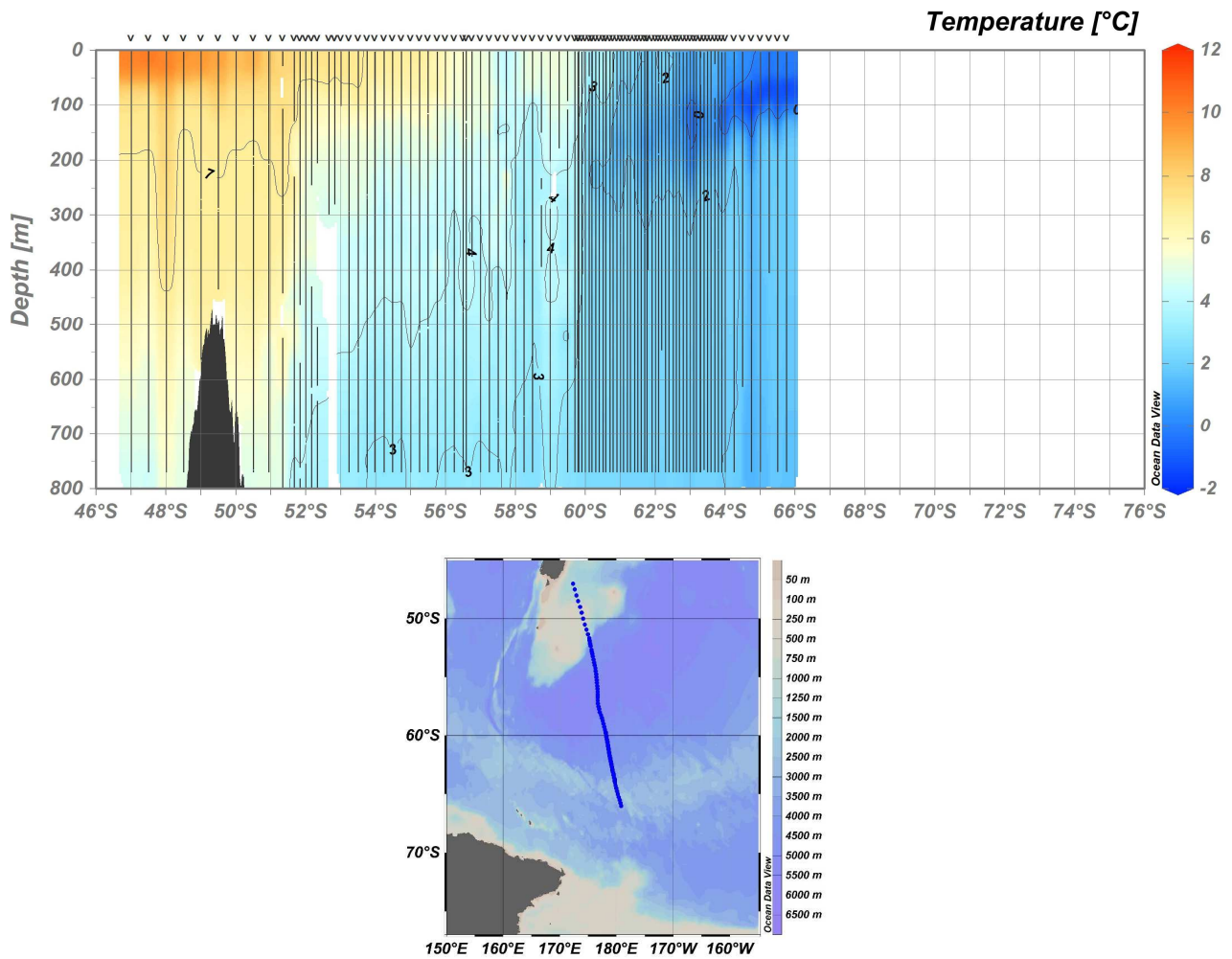
**S37.** Python XBT data visualisation code example

**S38.** Temperature vertical profiles of the XBT good data (QF=1) collected during the PNRA\_XXXVIII expedition realized through the Python code in S37

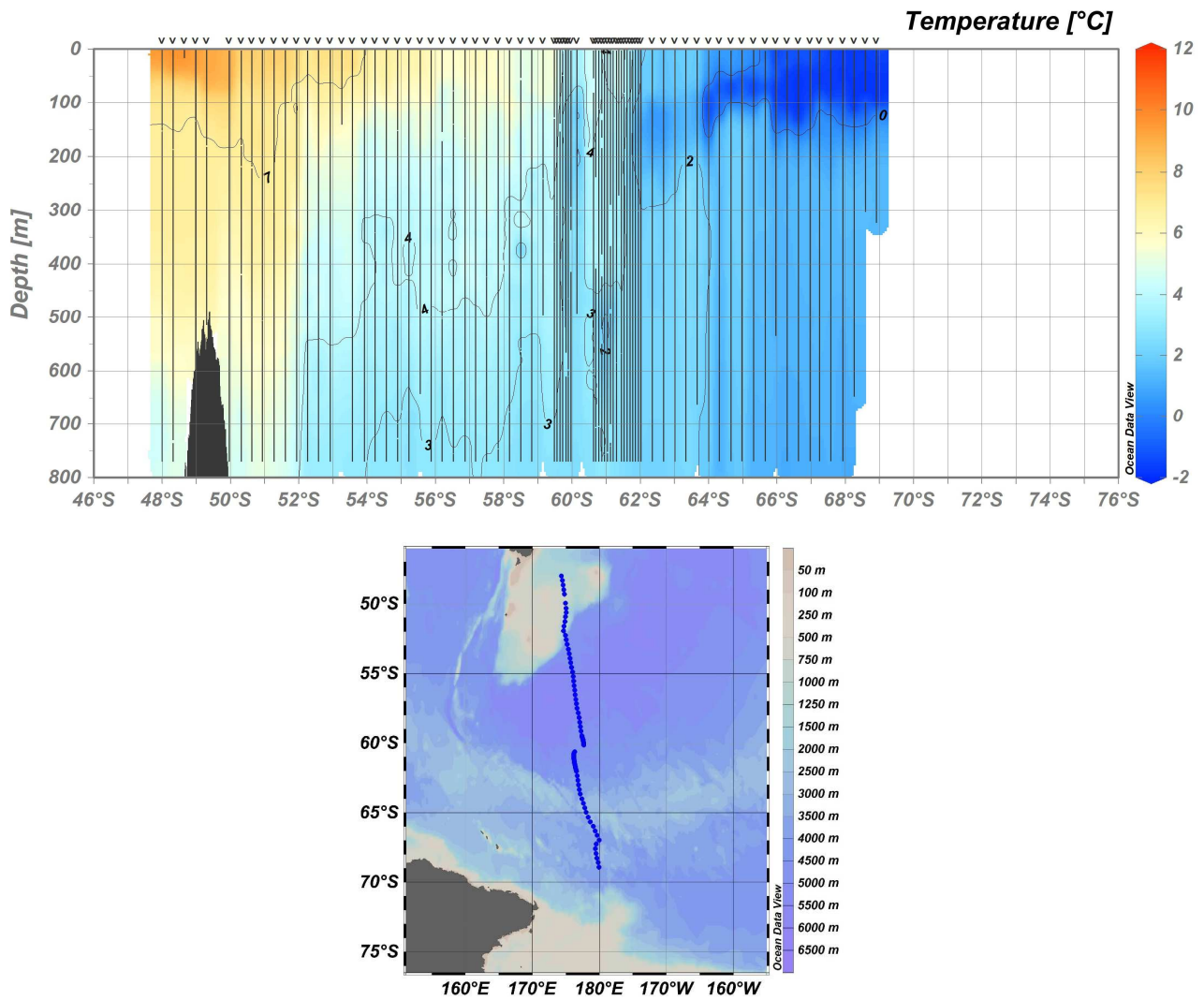
**S39.** Temperature latitudinal section of the XBT good data (QF=1) collected during the PNRA\_XXXVIII expedition realized through the Python code in S37



**S1.** Temperature vertical section from XBT data collected during the first leg of the PNRA\_X cruise conducted from 03 November 1994 to 06 November 1994 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

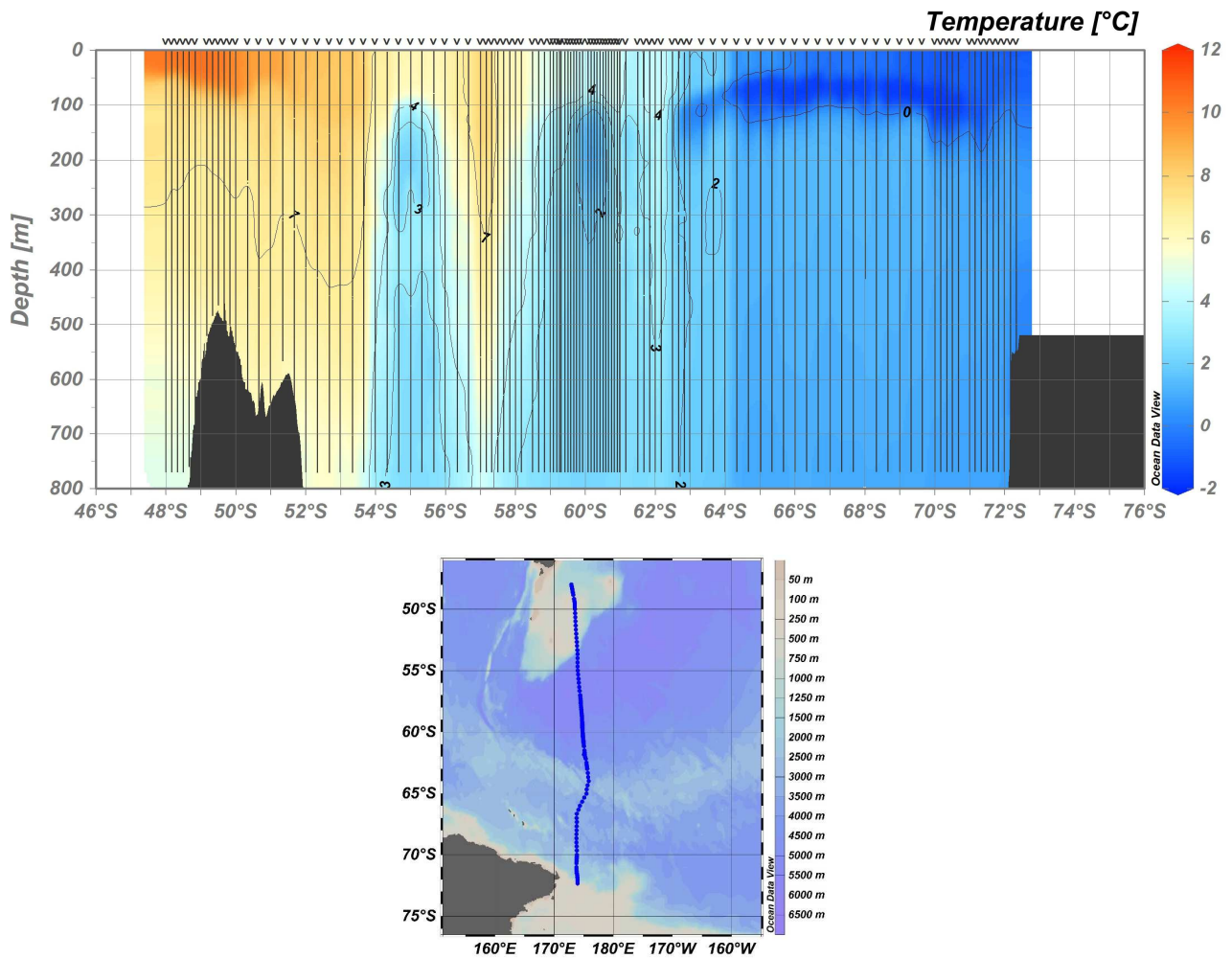


**S2.** Temperature vertical section from XBT data collected during the second leg of the PNRA\_X cruise conducted from 28 December 1994 to 01 January 1995 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

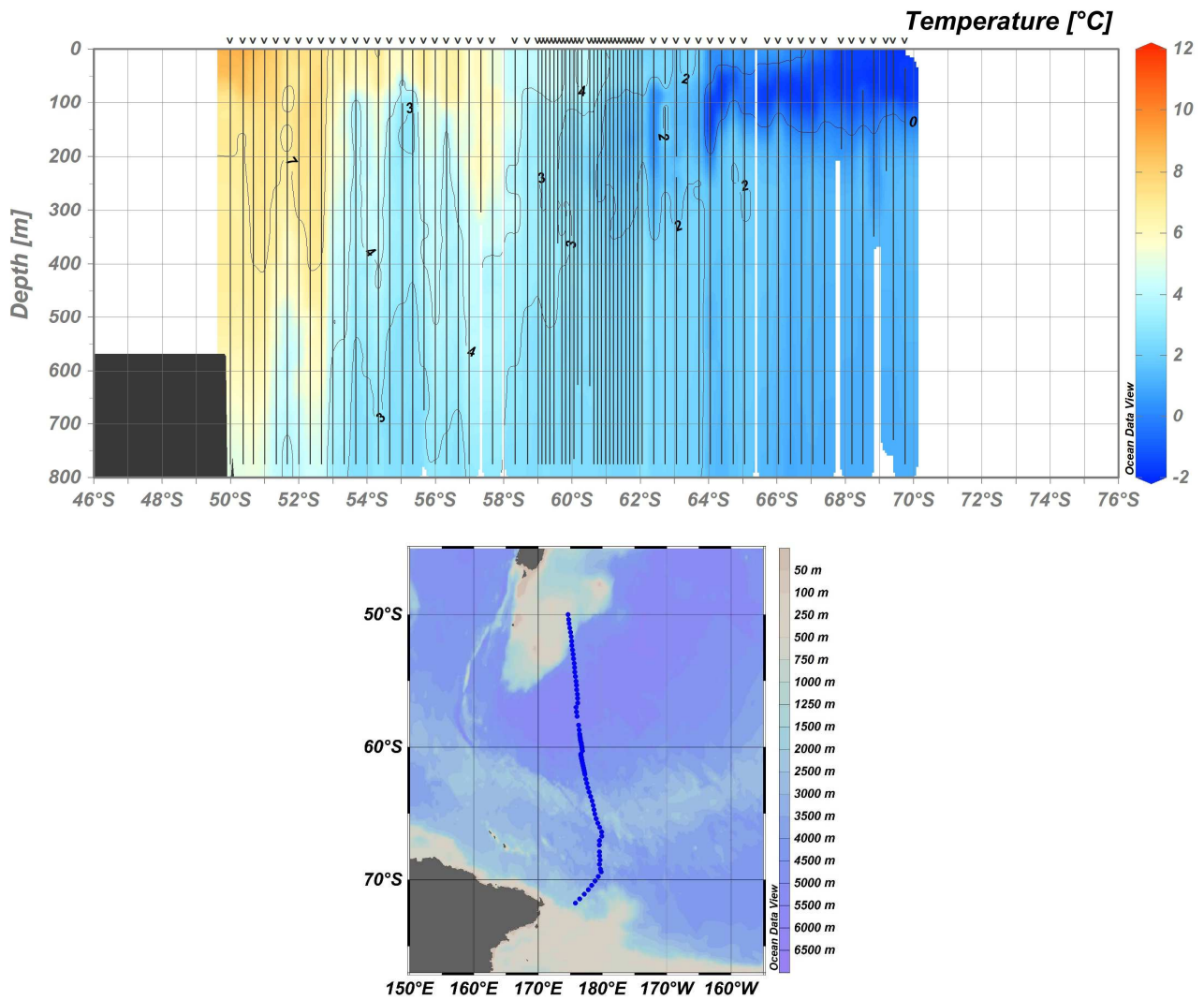


**S3.** Temperature vertical section from XBT data collected during the third leg of the PNRA\_X cruise conducted from 06 January 1995 to 11 January 1995 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

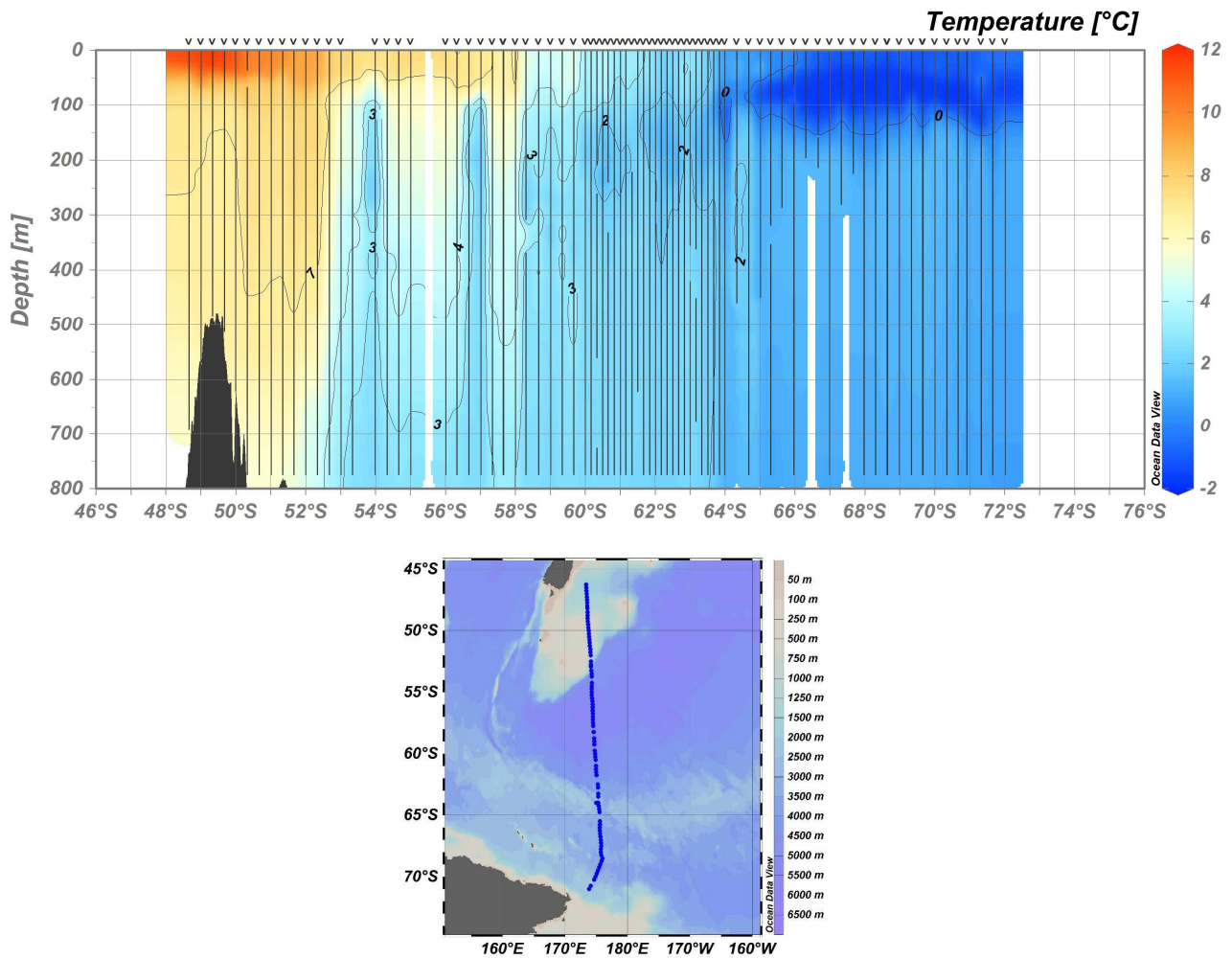




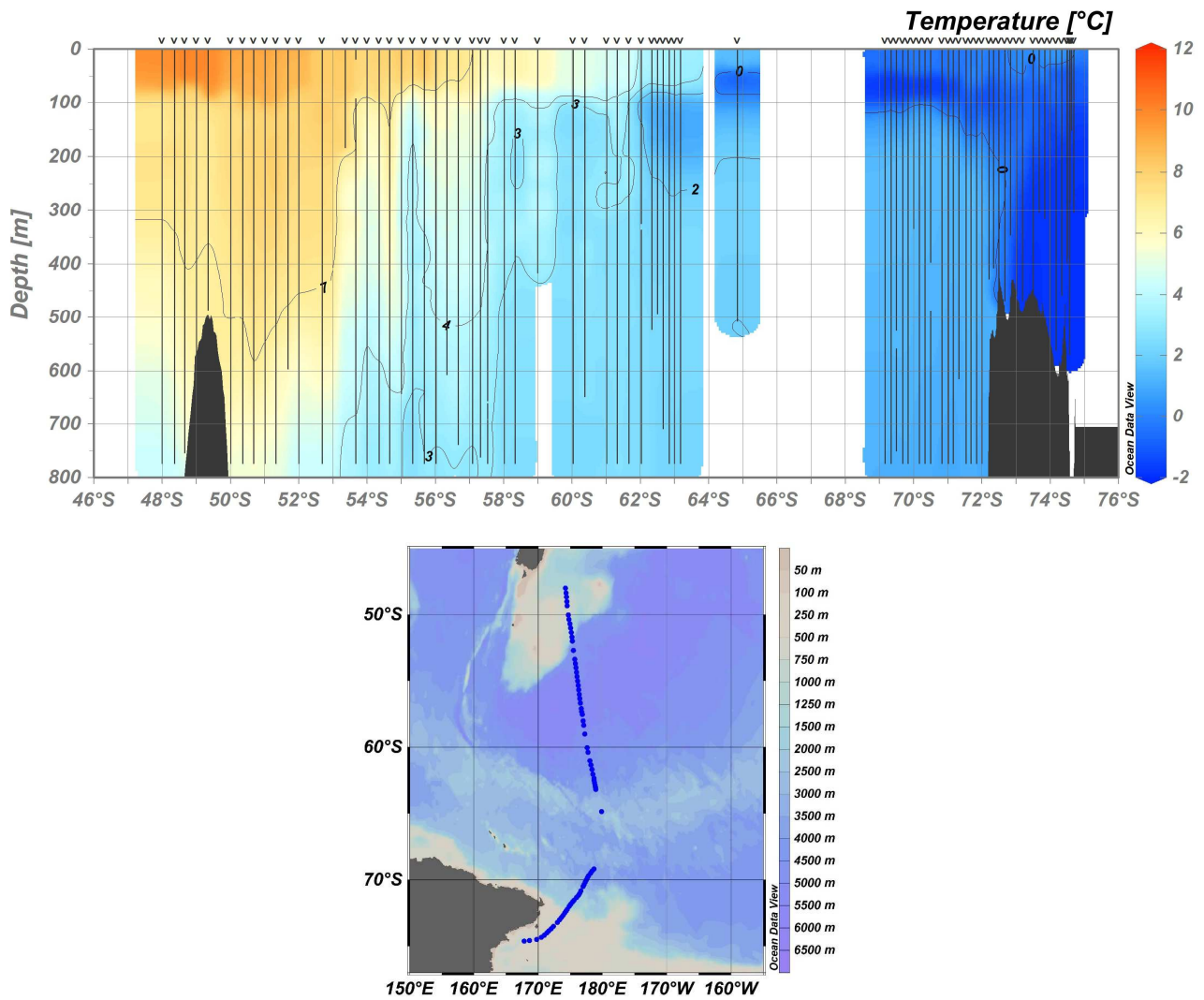
**S4.** Temperature vertical section from XBT data collected during the forth leg of the PNRA\_X cruise conducted from 26 February 1995 to 02 March 1995 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



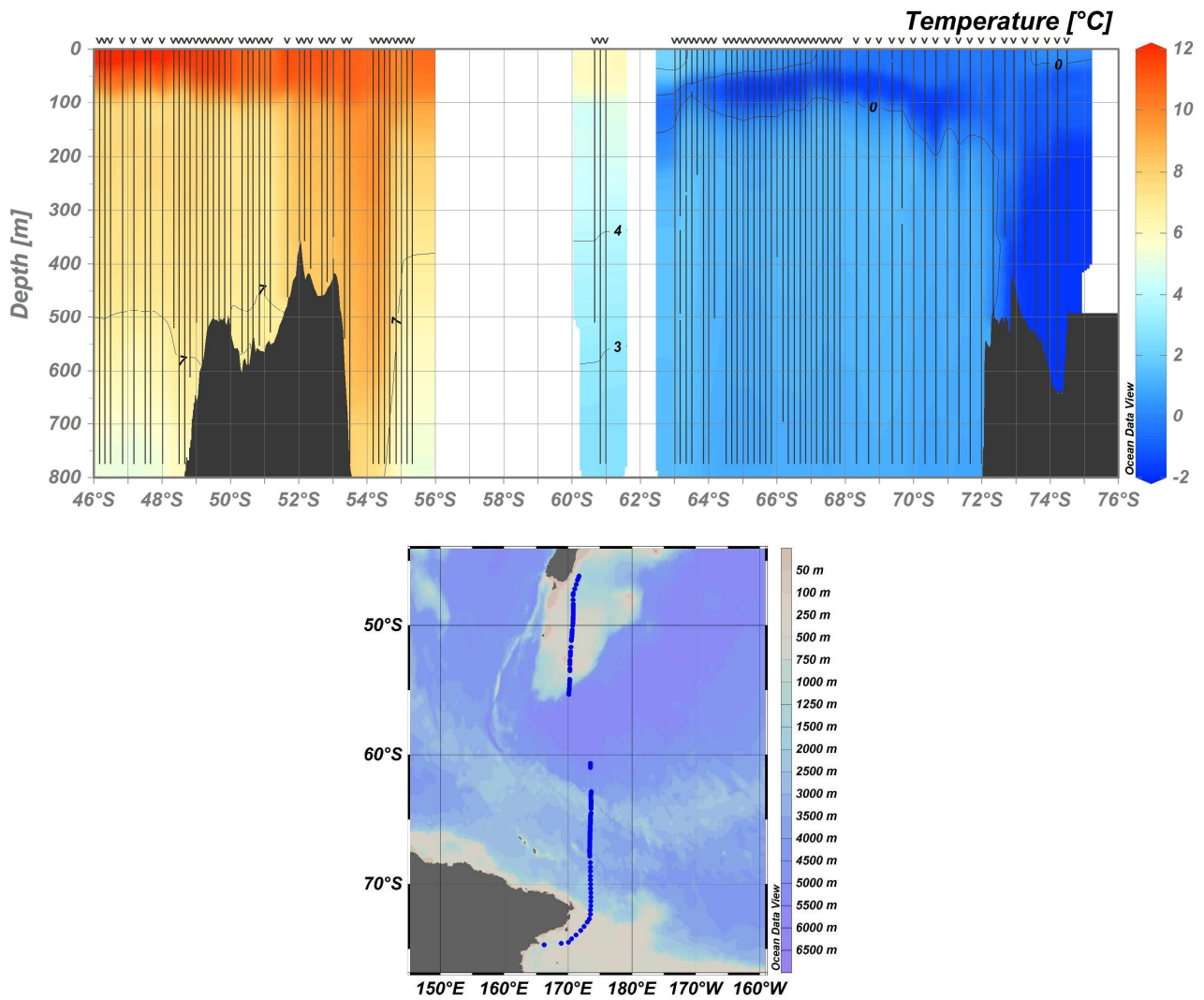
**S5.** Temperature vertical section from XBT data collected during the first leg of the PNRA\_XI cruise conducted from 07 January 1996 to 11 January 1996 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



**S6.** Temperature vertical section from XBT data collected during the second leg of the PNRA\_XI cruise conducted from 13 February 1996 to 18 February 1996 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

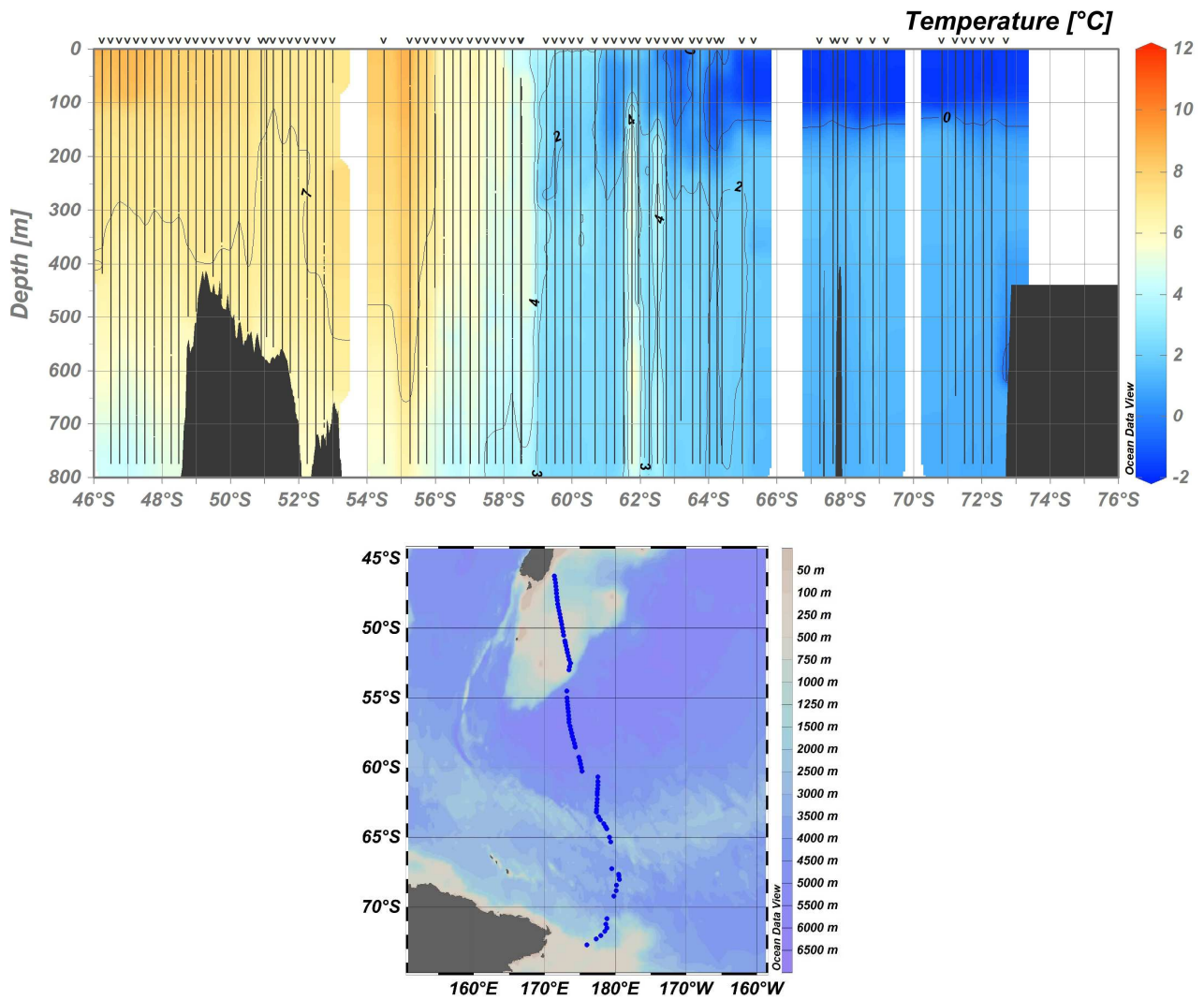


**S7.** Temperature vertical section from XBT data collected during the first leg of the PNRA\_XII cruise conducted from 26 January 1997 to 30 January 1997 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

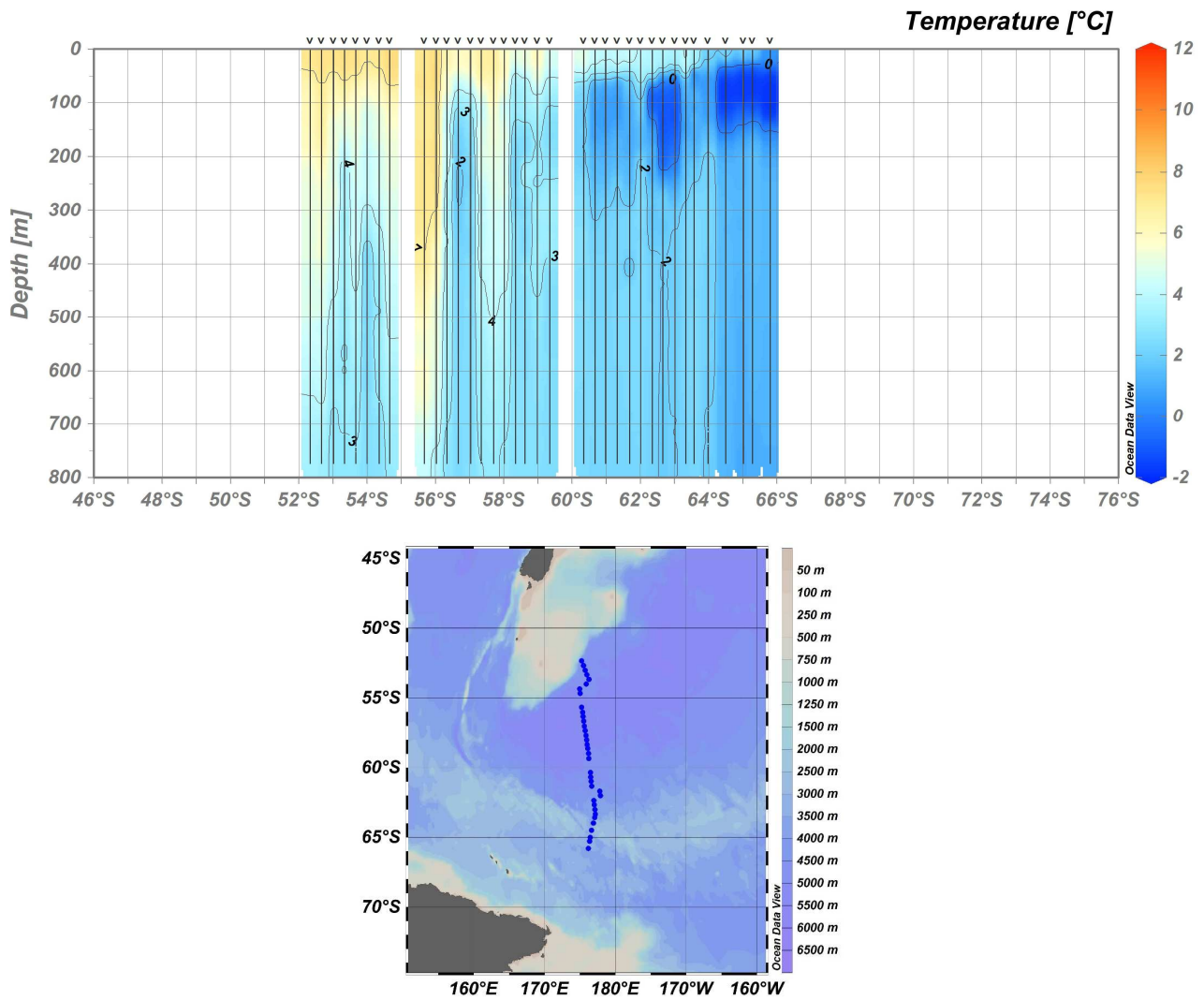


**S8.** Temperature vertical section from XBT data collected during the second leg of the PNRA\_XII cruise conducted from 14 February 1997 to 19 February 1997 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



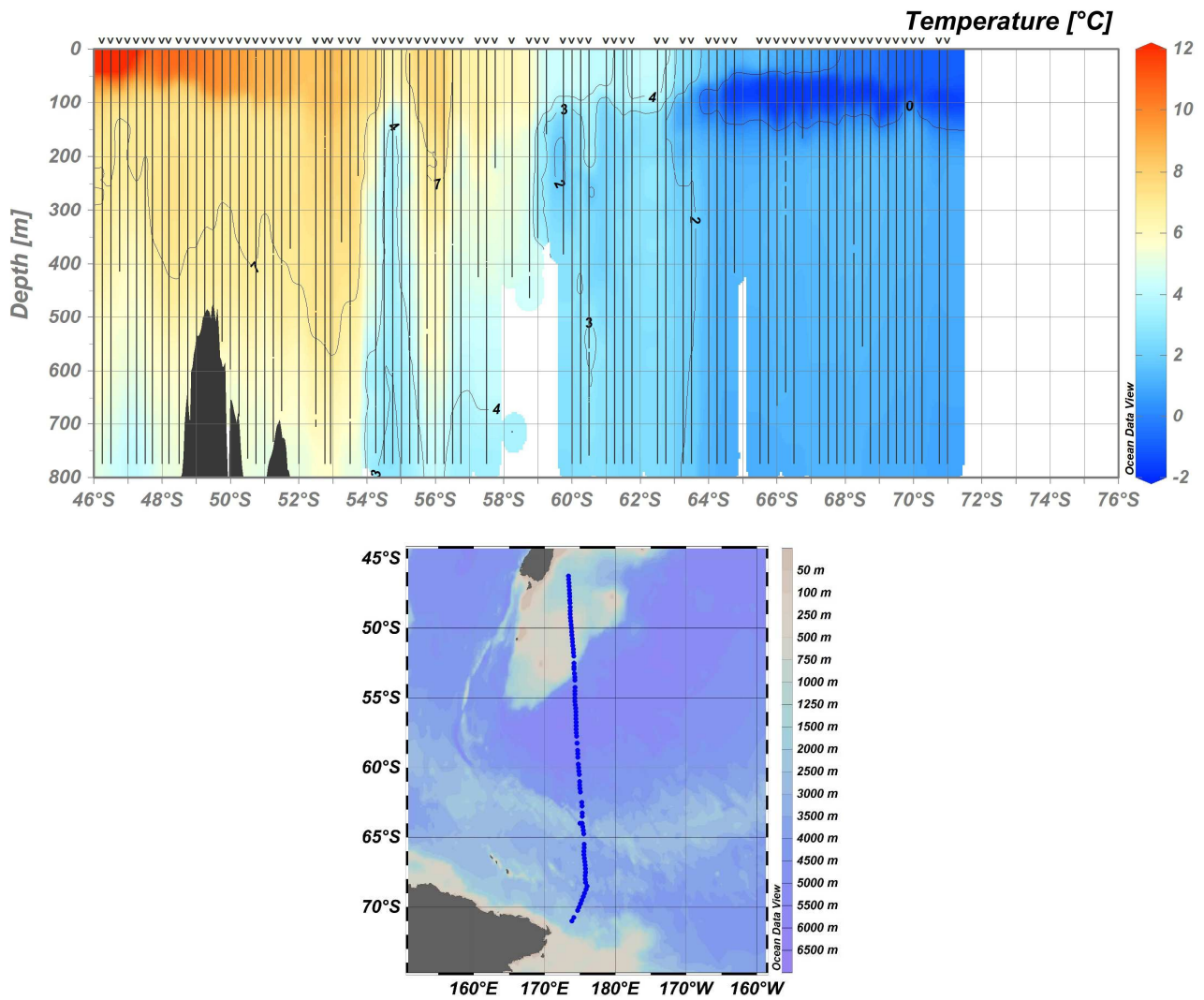


**S9.** Temperature vertical section from XBT data collected during the first leg of the PNRA\_XIII cruise conducted from 23 November 1997 to 28 November 1997 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

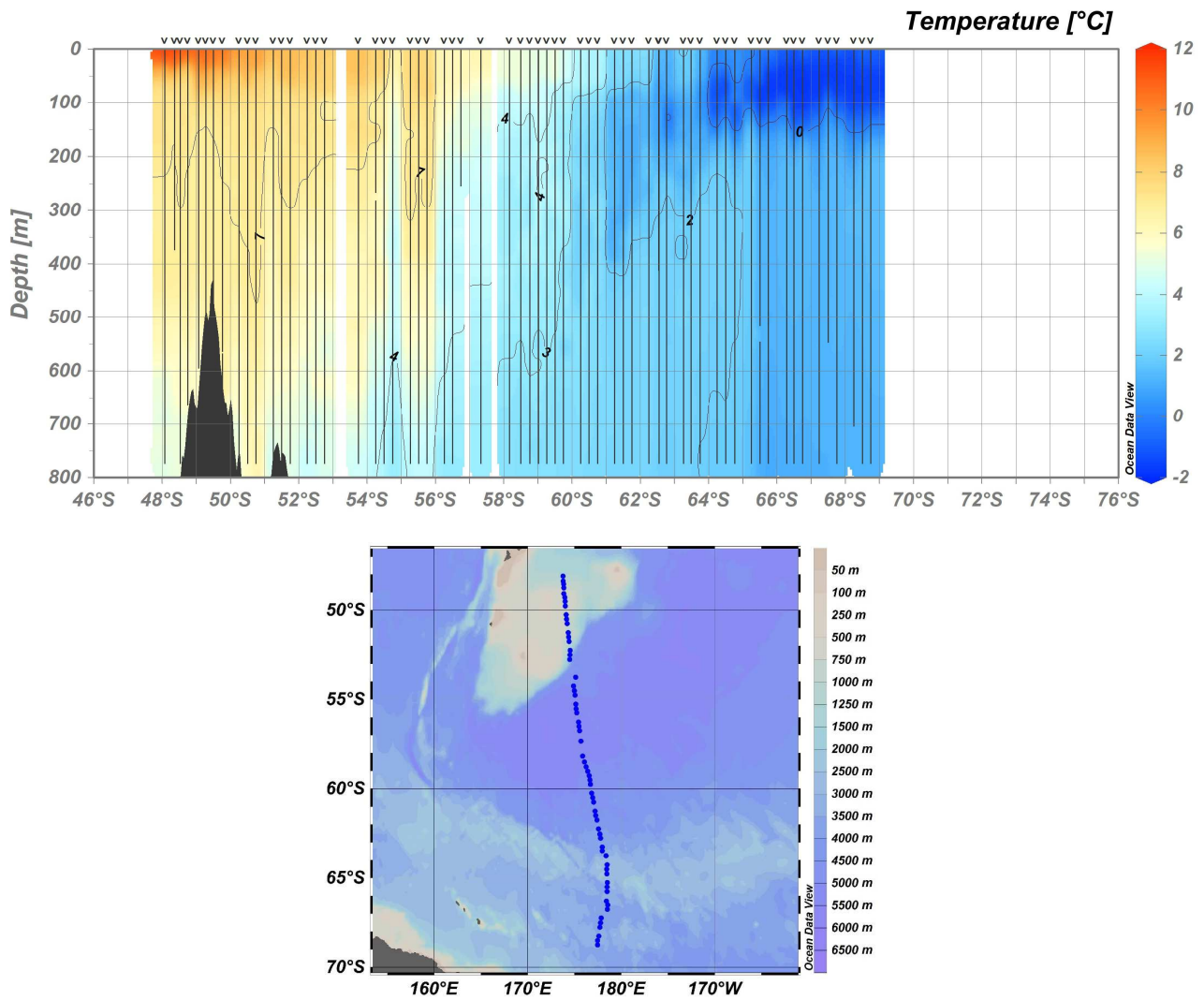


**S10.** Temperature vertical section from XBT data collected during the second leg of the PNRA\_XIII cruise conducted from 09 January 1998 to 12 January 1998 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

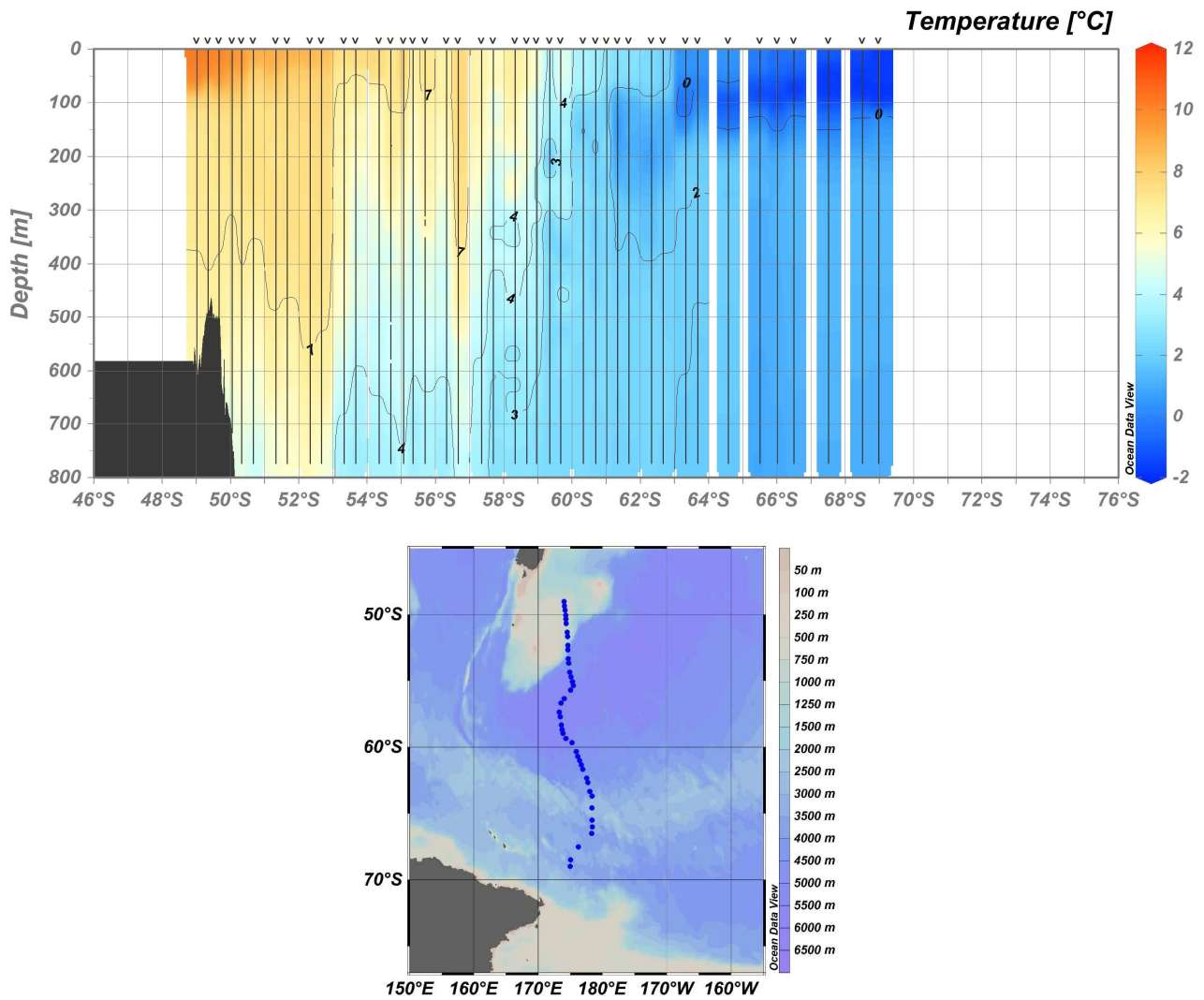




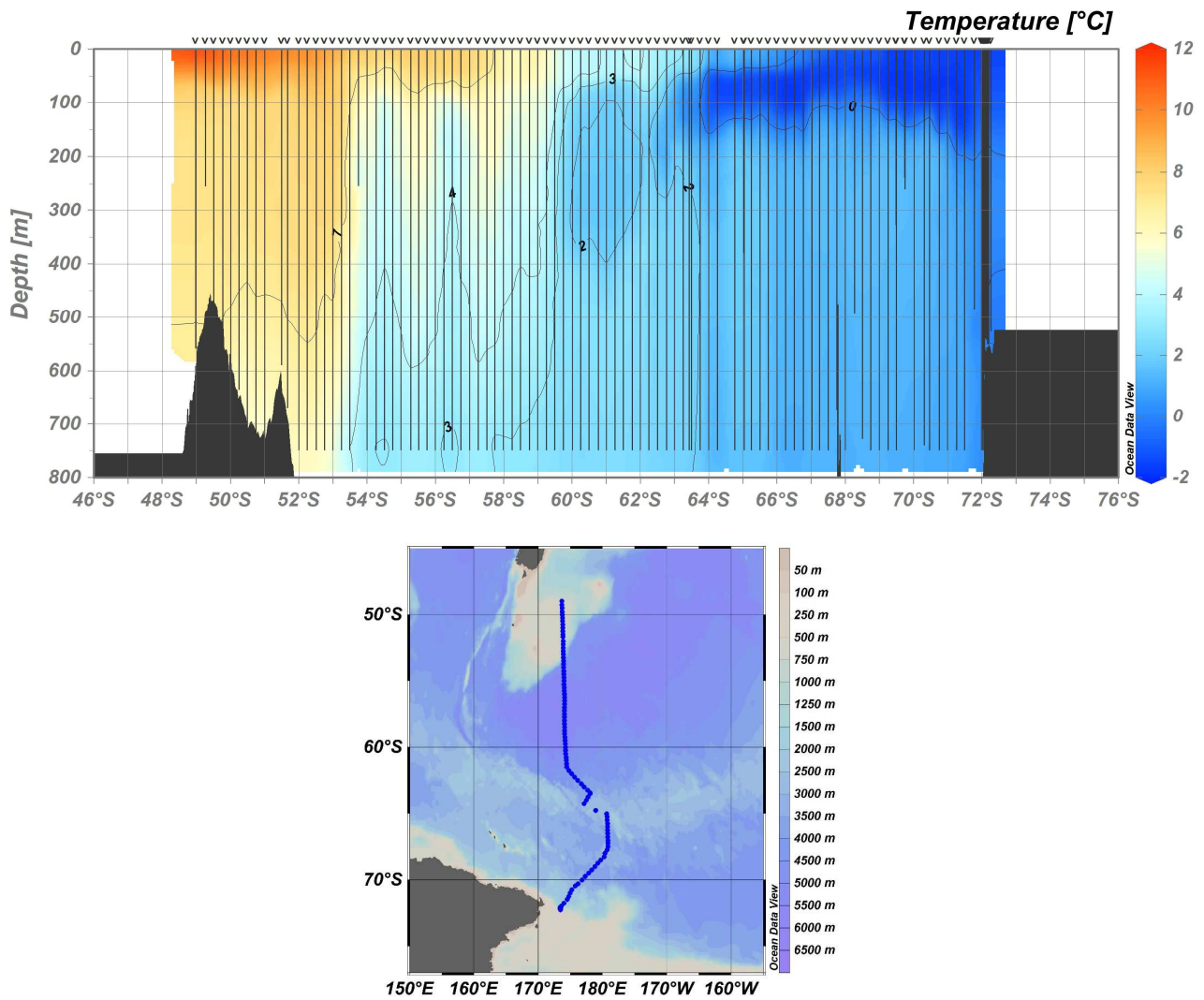
**S11.** Temperature vertical section from XBT data collected during the third leg of the PNRA\_XIII cruise conducted from 28 February 1998 to 06 March 1998 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



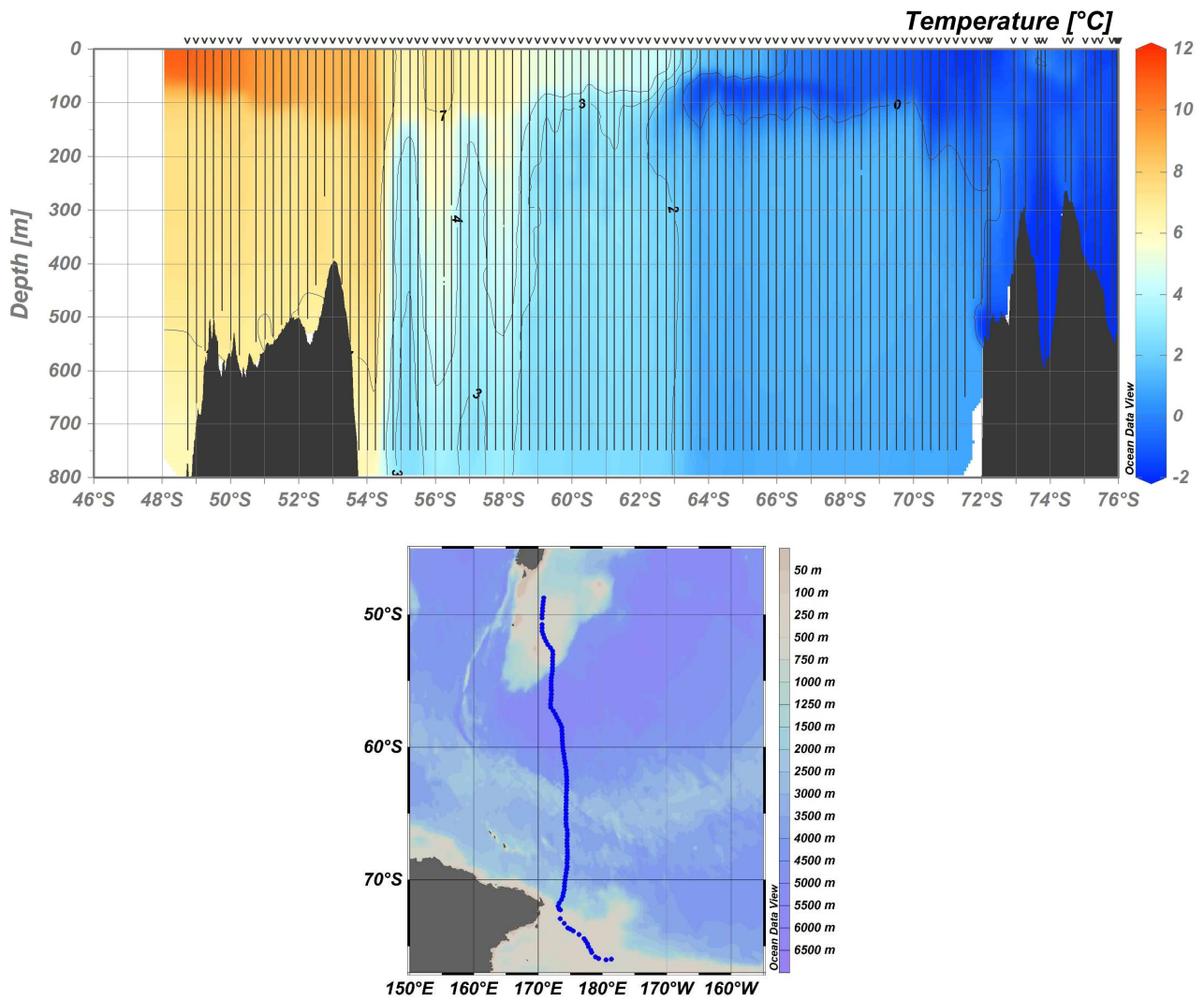
**S12.** Temperature vertical section from XBT data collected during the PNRA\_XIV cruise conducted from 05 January 1999 to 11 January 1999 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



**S13.** Temperature vertical section from XBT data collected during the PNRA\_XV cruise conducted from 07 January 2000 to 12 January 2000 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

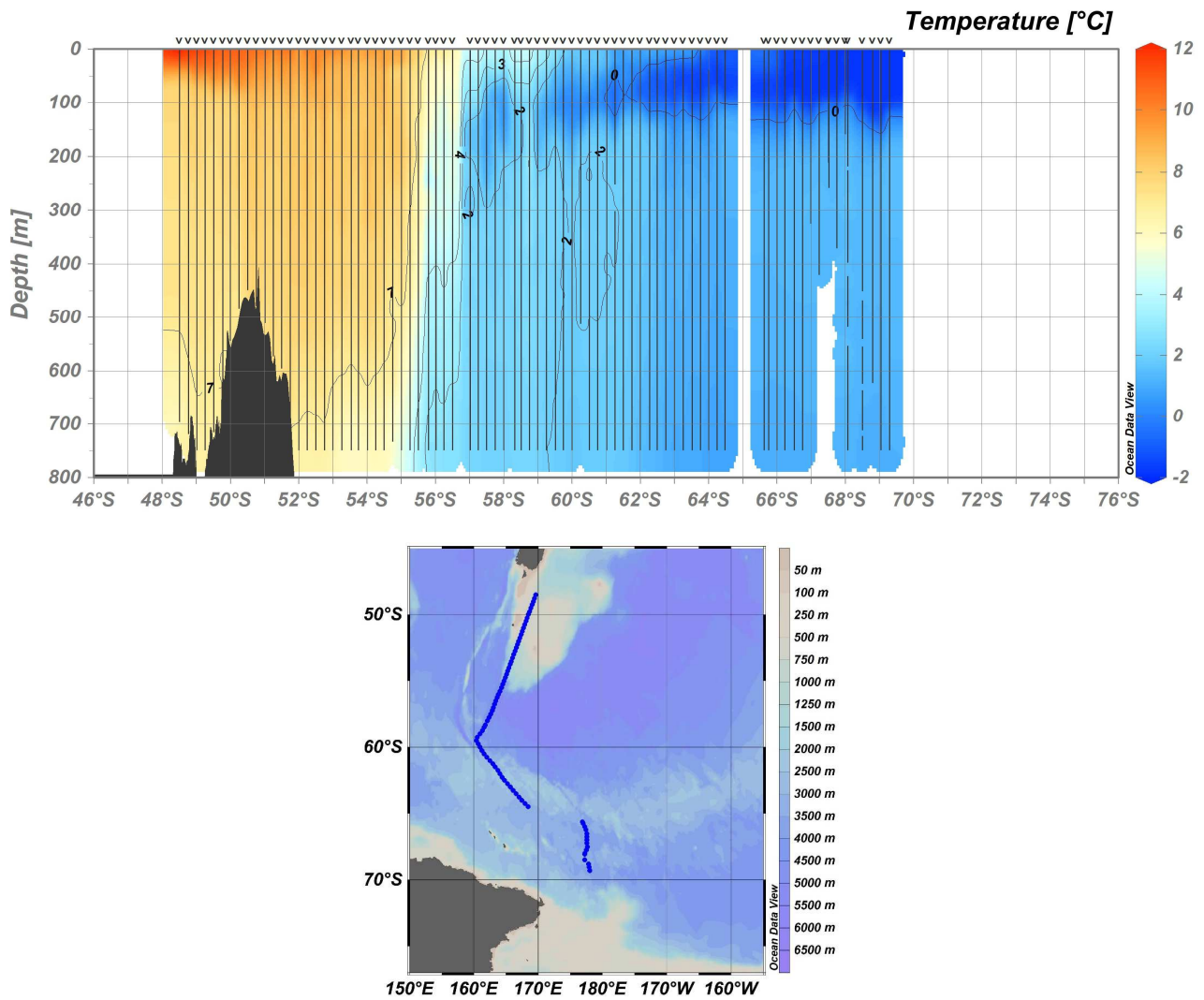


**S14.** Temperature vertical section from XBT data collected during the first leg of the PNRA\_XVI cruise conducted from 06 January 2001 to 10 January 2001 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

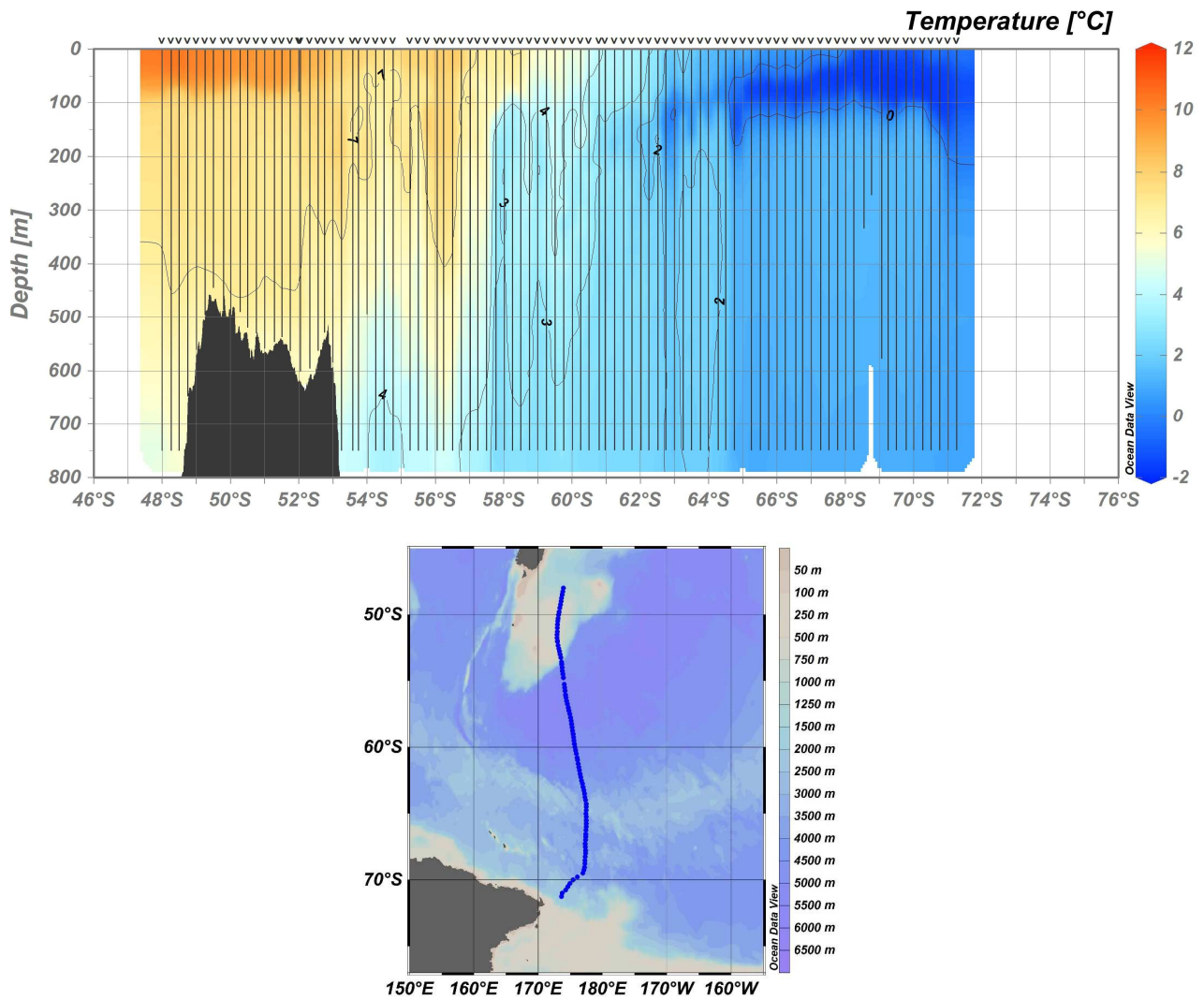


**S15.** Temperature vertical section from XBT data collected during the second leg of the PNRA\_XVI cruise conducted from 21 February 2001 to 26 February 2001 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



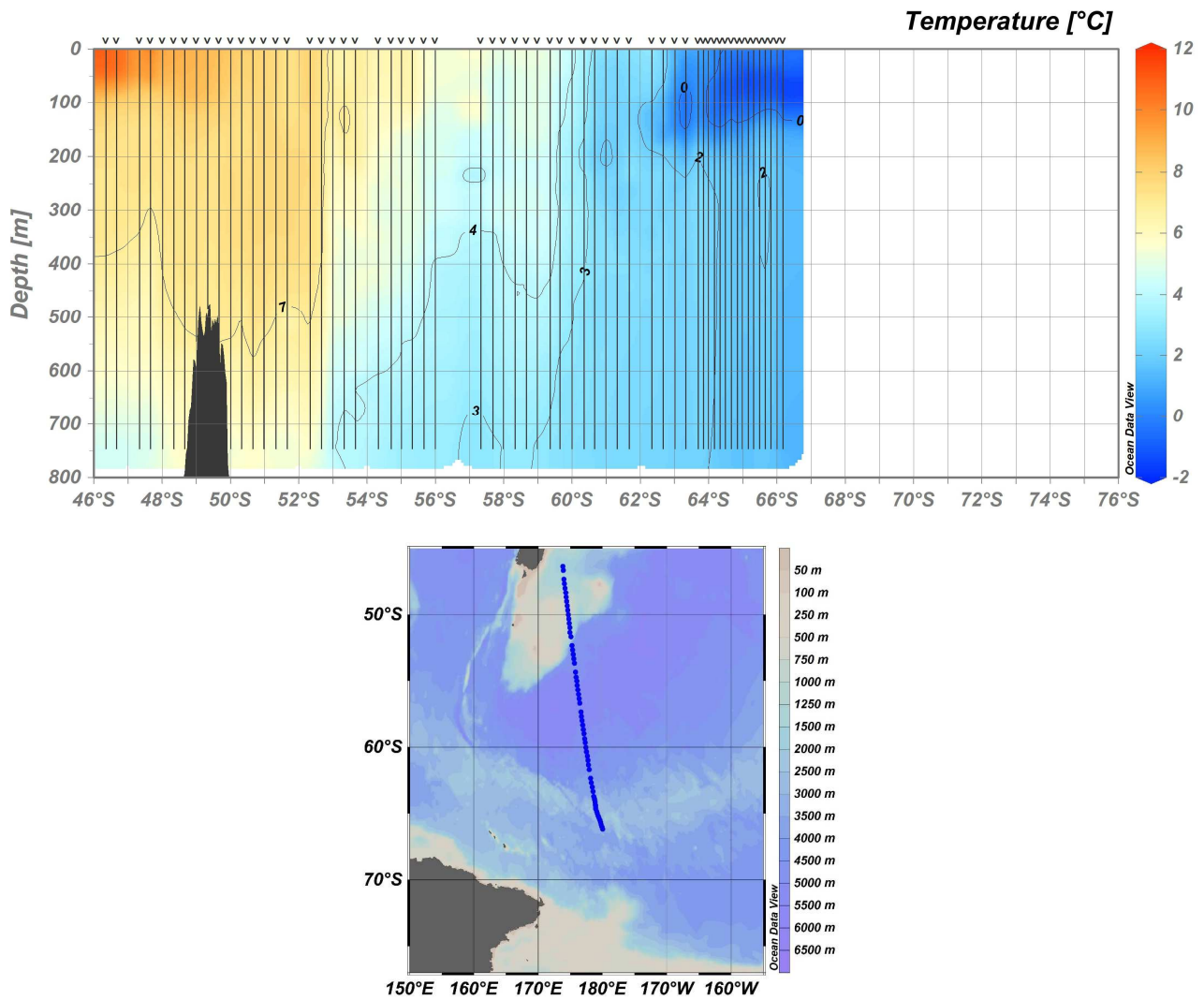


**S16.** Temperature vertical section from XBT data collected during the PNRA\_XVII cruise conducted from 24 December 2001 to 28 December 2001 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

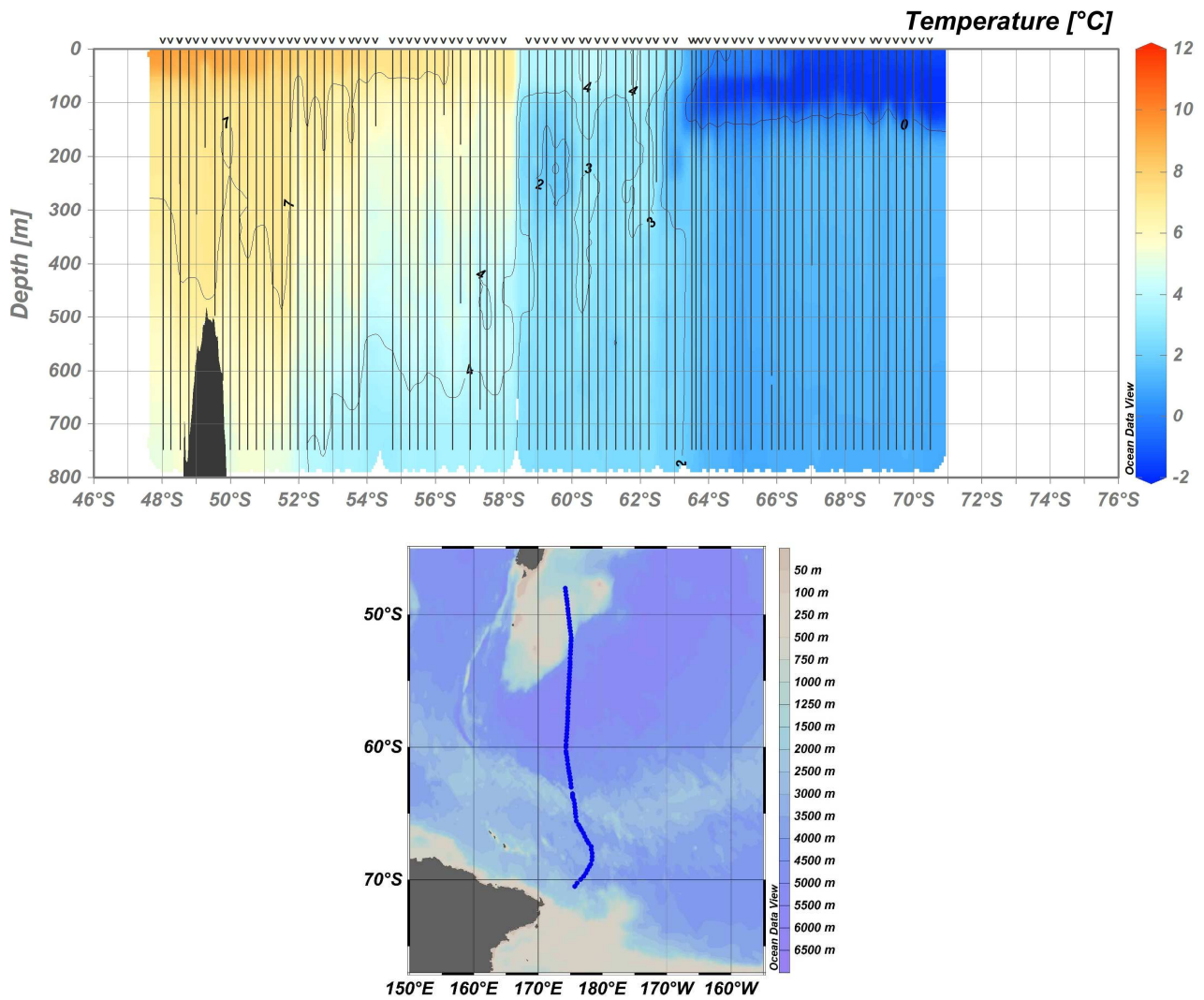


**S17.** Temperature vertical section from XBT data collected during the PNRA\_XVIII cruise conducted from 06 January 2003 to 11 January 2003 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

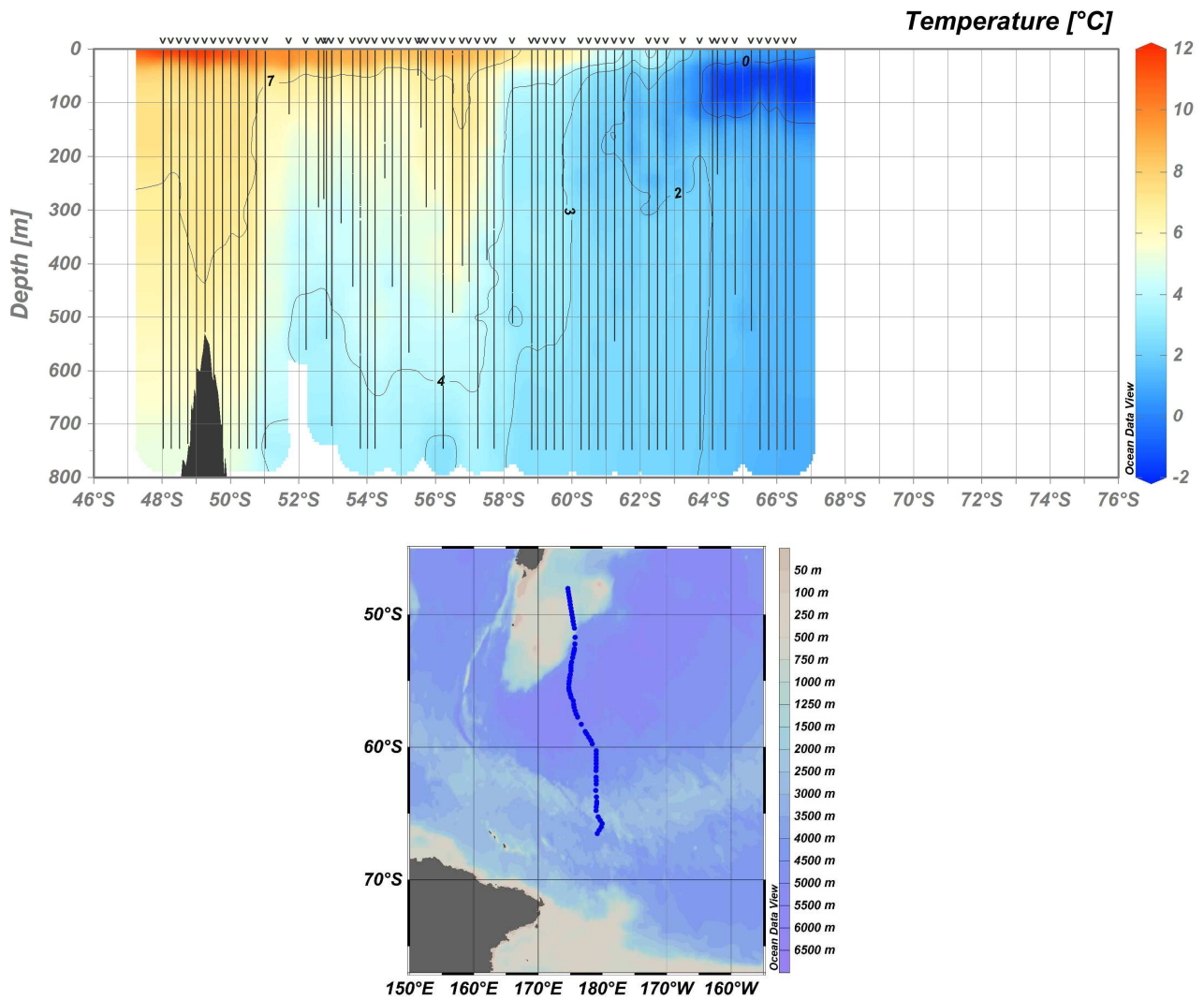




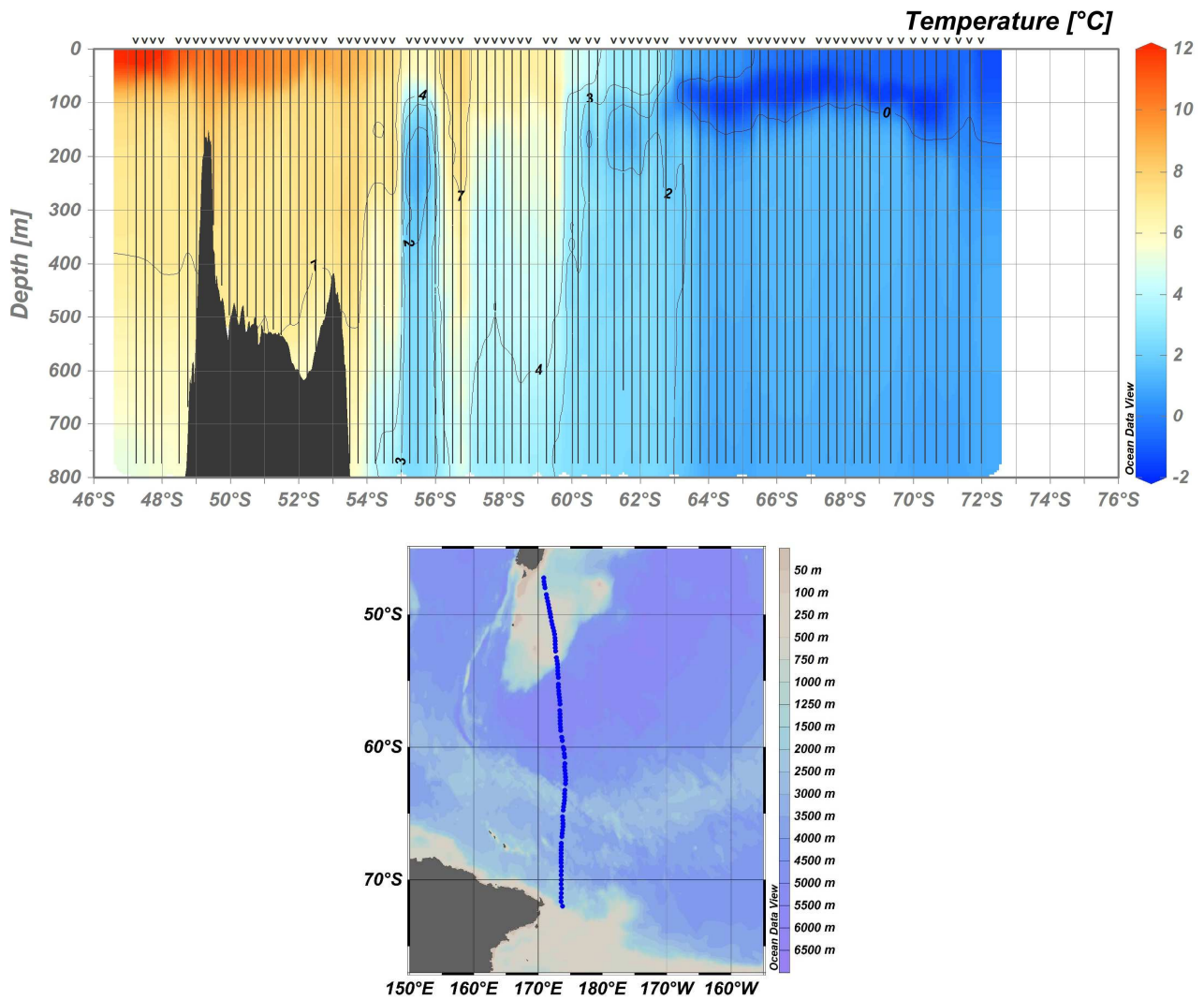
**S18.** Temperature vertical section from XBT data collected during the PNRA\_XIX cruise conducted from 24 December 2003 to 28 December 2003 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



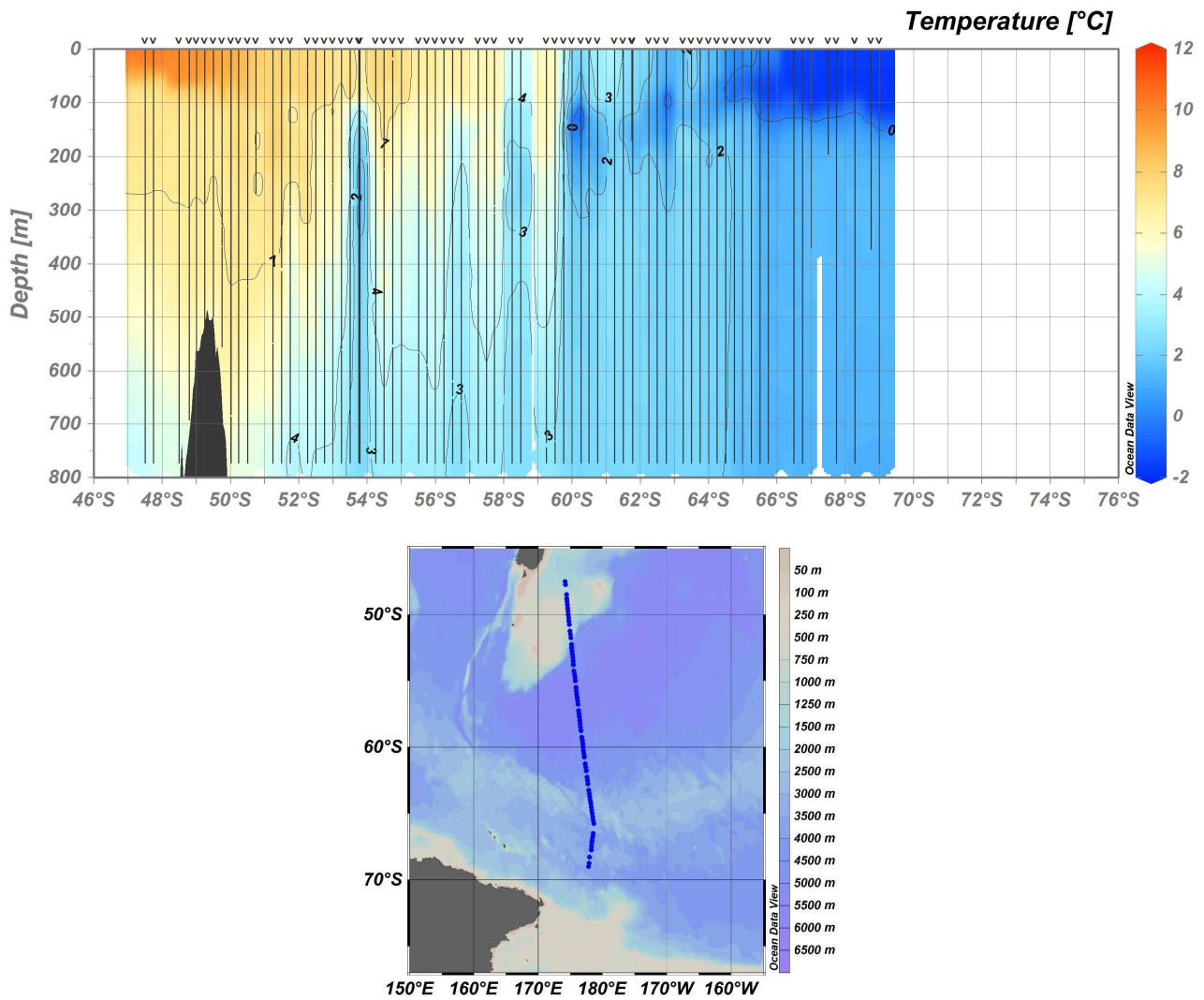
**S19.** Temperature vertical section from XBT data collected during the PNRA\_XX cruise conducted from 01 January 2005 to 06 January 2005 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



**S20.** Temperature vertical section from XBT data collected during the PNRA\_XXI cruise conducted from 01 January 2006 to 04 January 2006 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

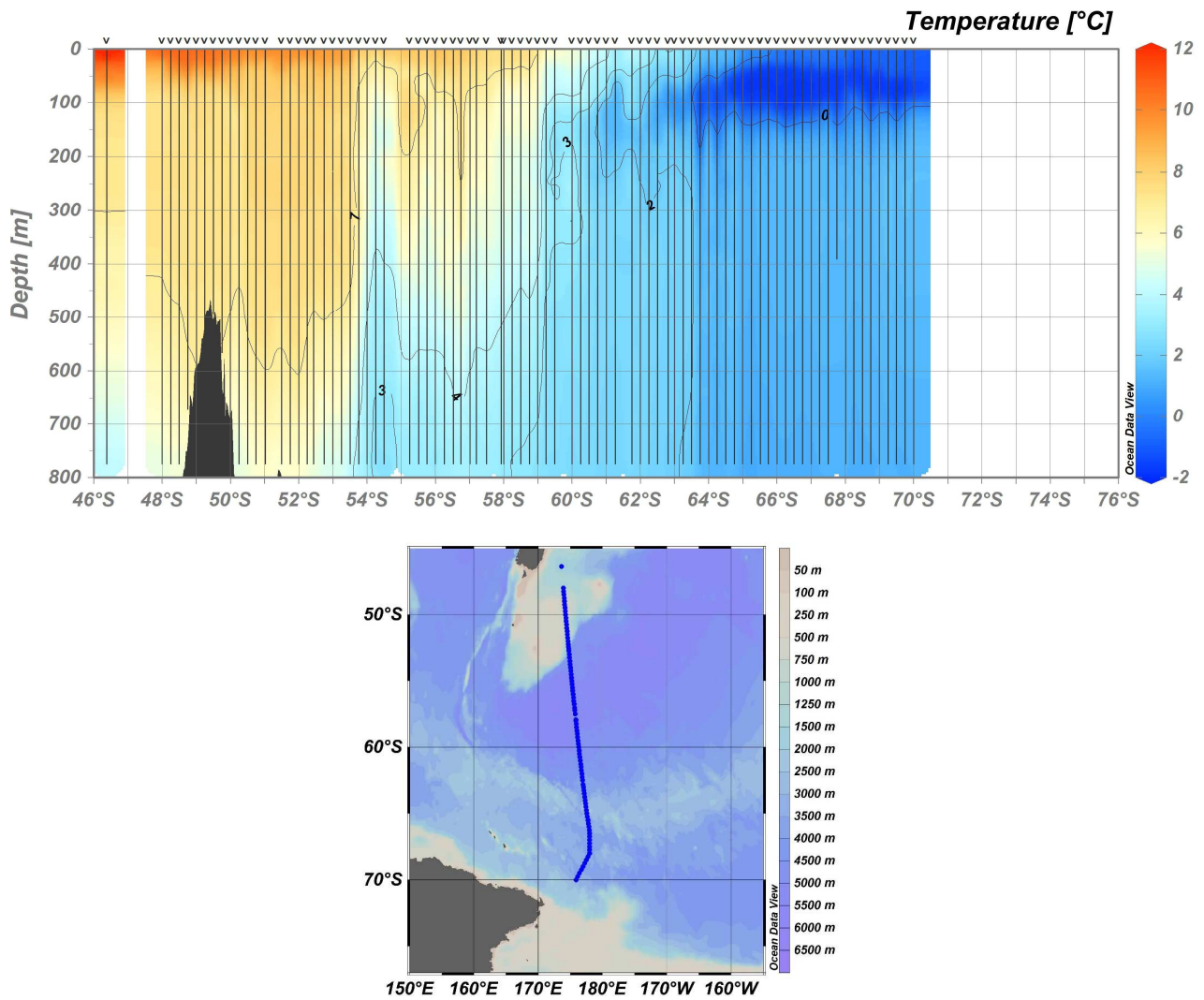


**S21.** Temperature vertical section from XBT data collected during the PNRA\_XXII cruise conducted from 05 February 2007 to 10 February 2007 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

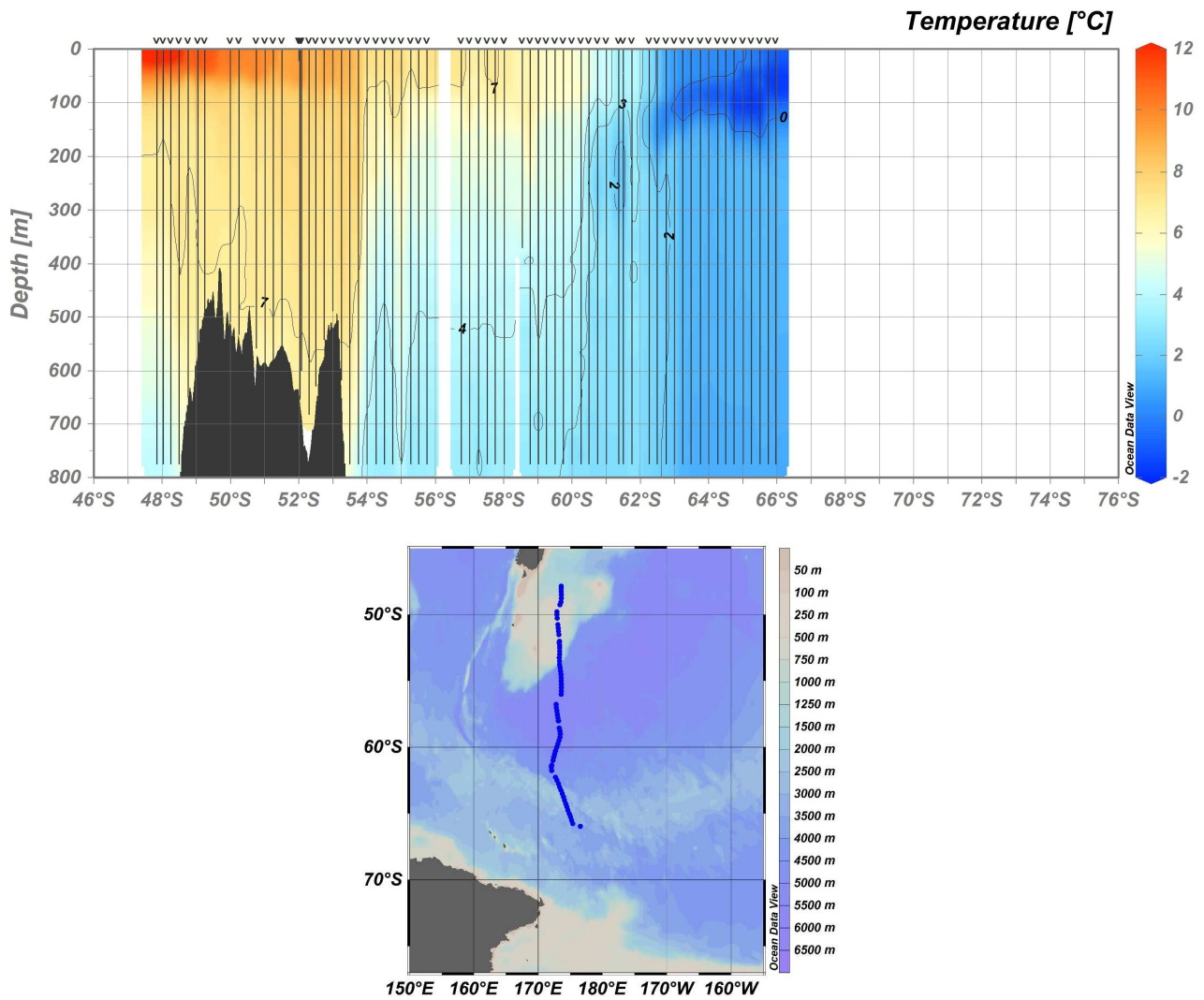


**S22.** Temperature vertical section from XBT data collected during the PNRA\_XXIII cruise conducted from 16 January 2008 to 21 January 2008 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



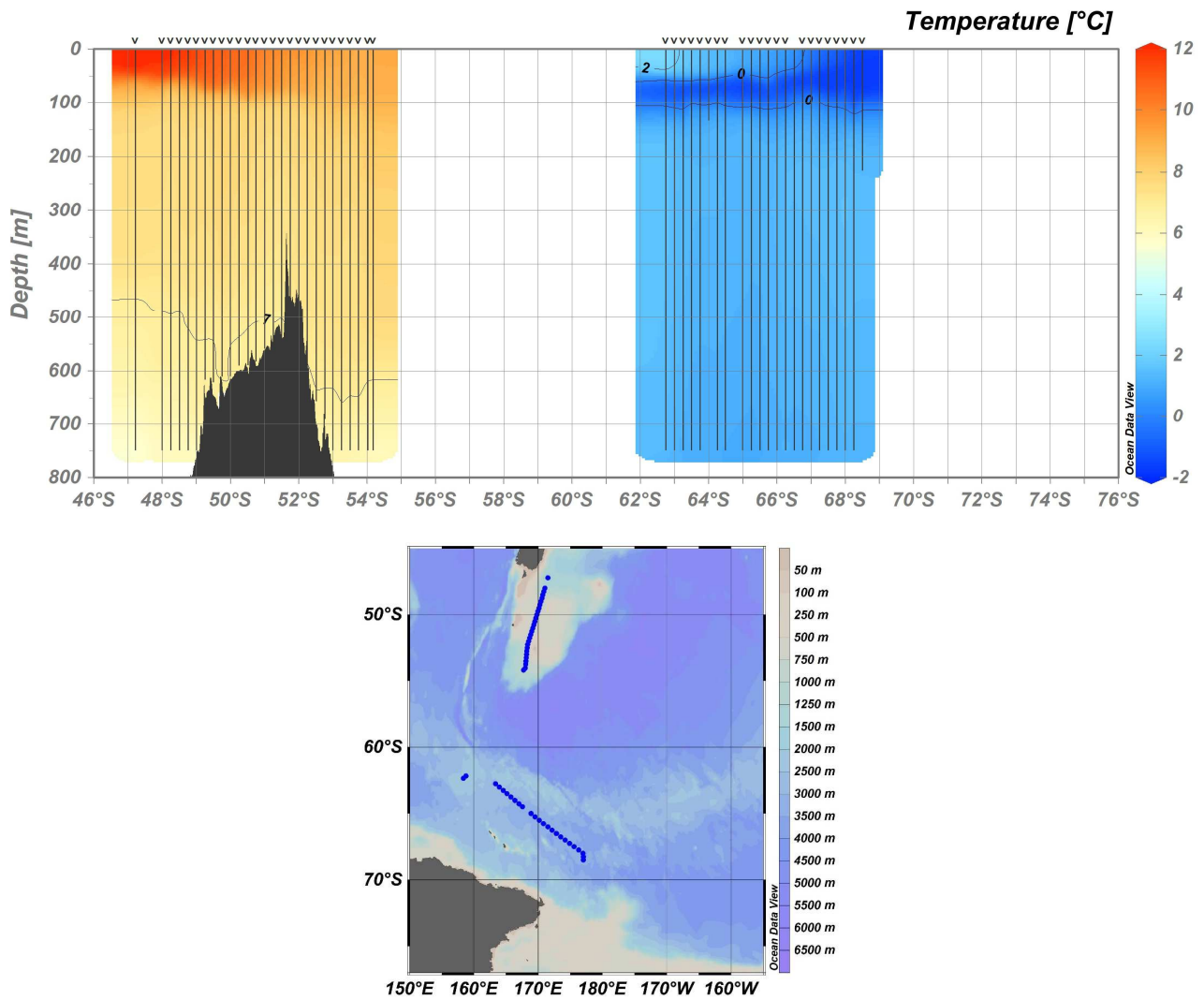


**S23.** Temperature vertical section from XBT data collected during the PNRA\_XXV cruise conducted from 25 January 2010 to 29 January 2010 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

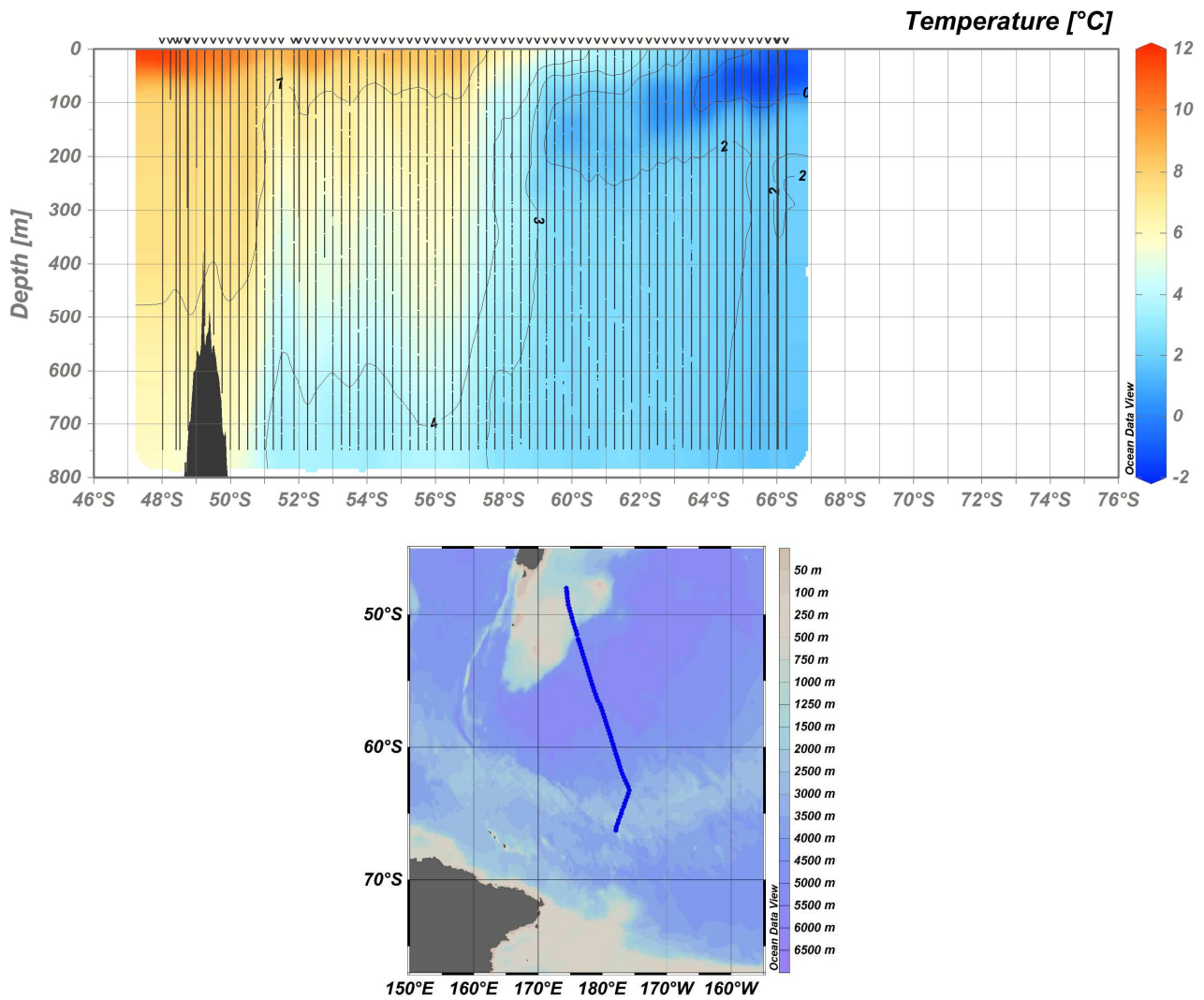


**S24.** Temperature vertical section from XBT data collected during the PNRA\_XXVII cruise conducted from 13 January 2012 to 19 January 2012 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

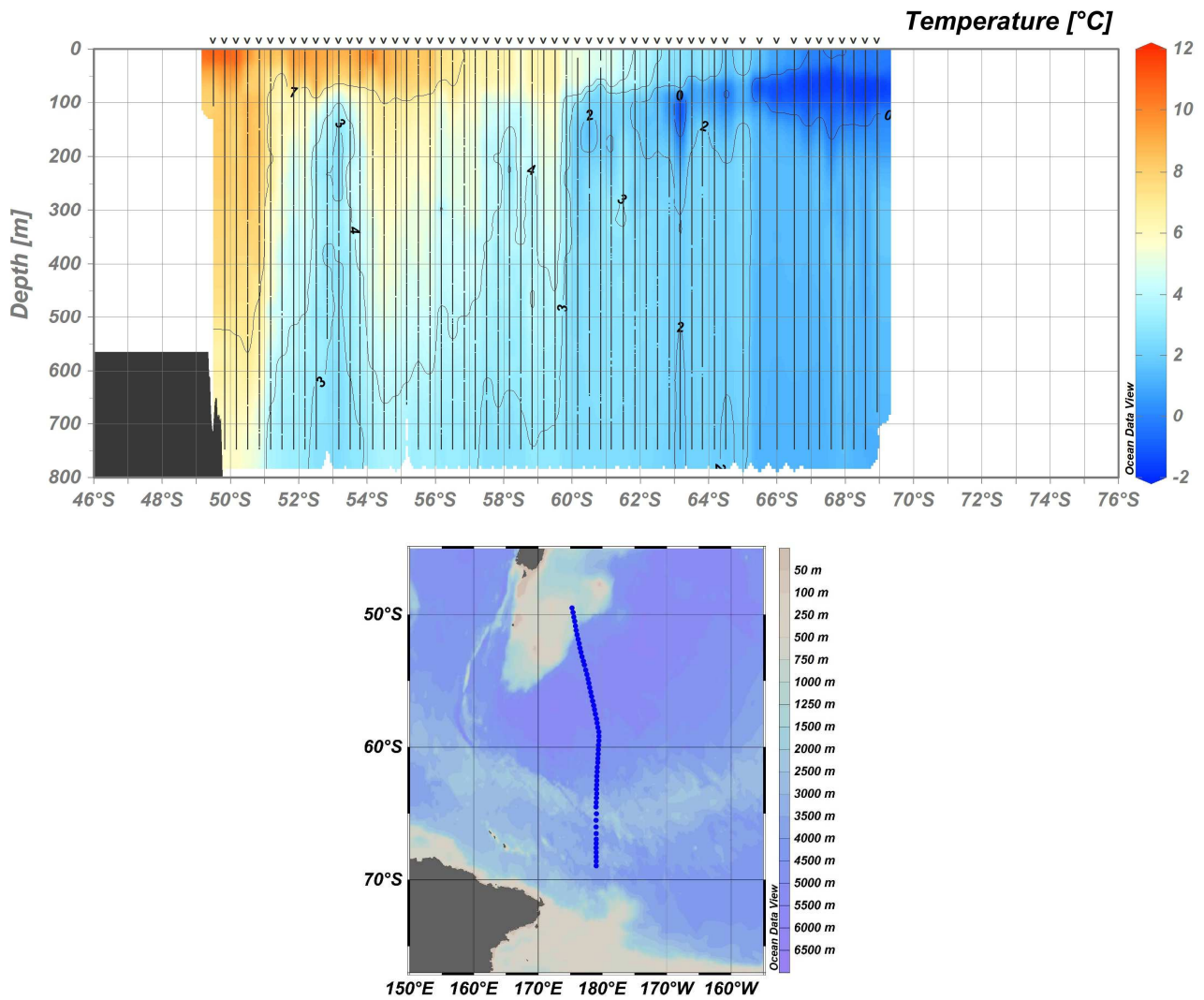




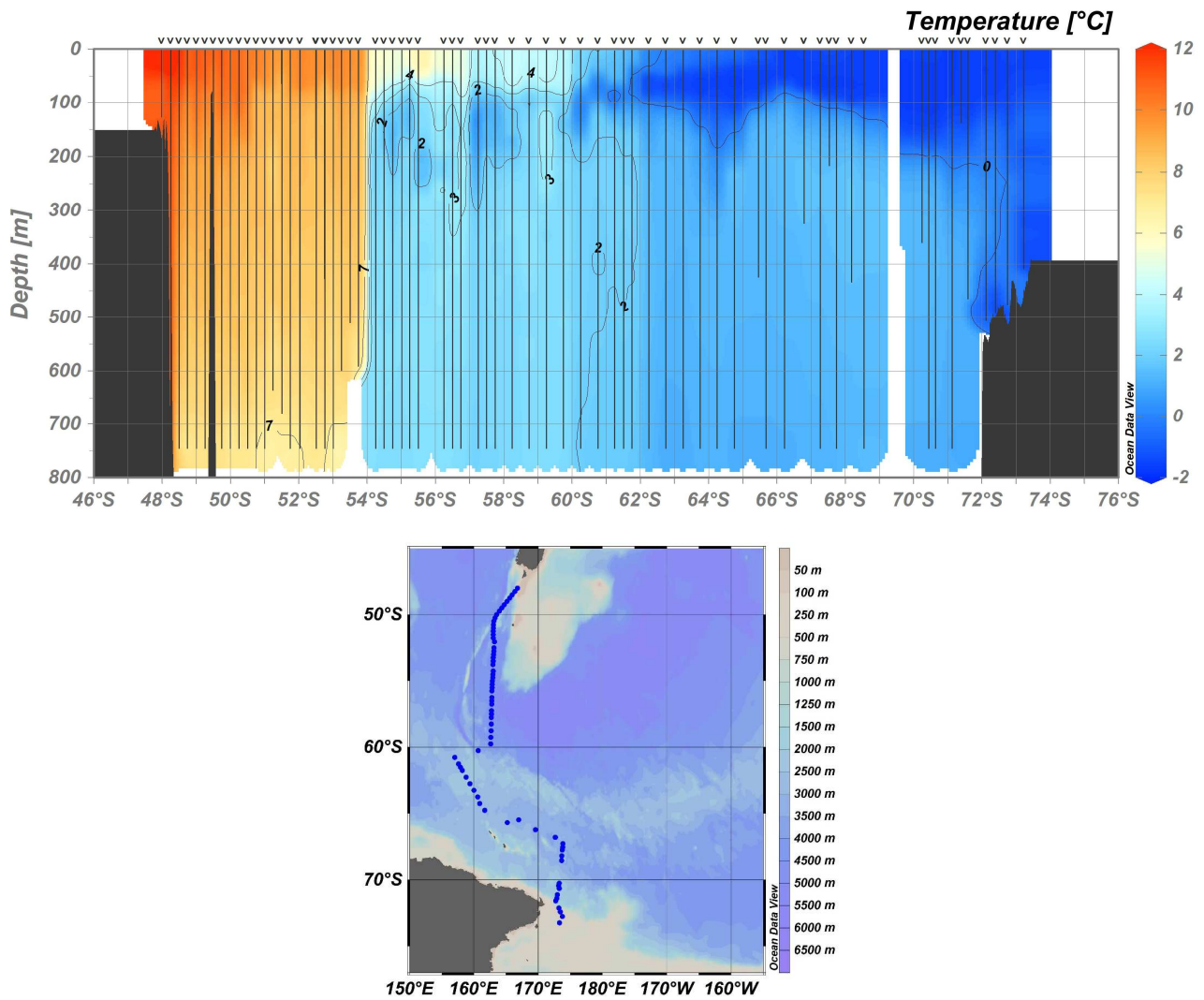
**S25.** Temperature vertical section from XBT data collected during the PNRA\_XXVIII cruise conducted from 24 January 2013 to 06 February 2013 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



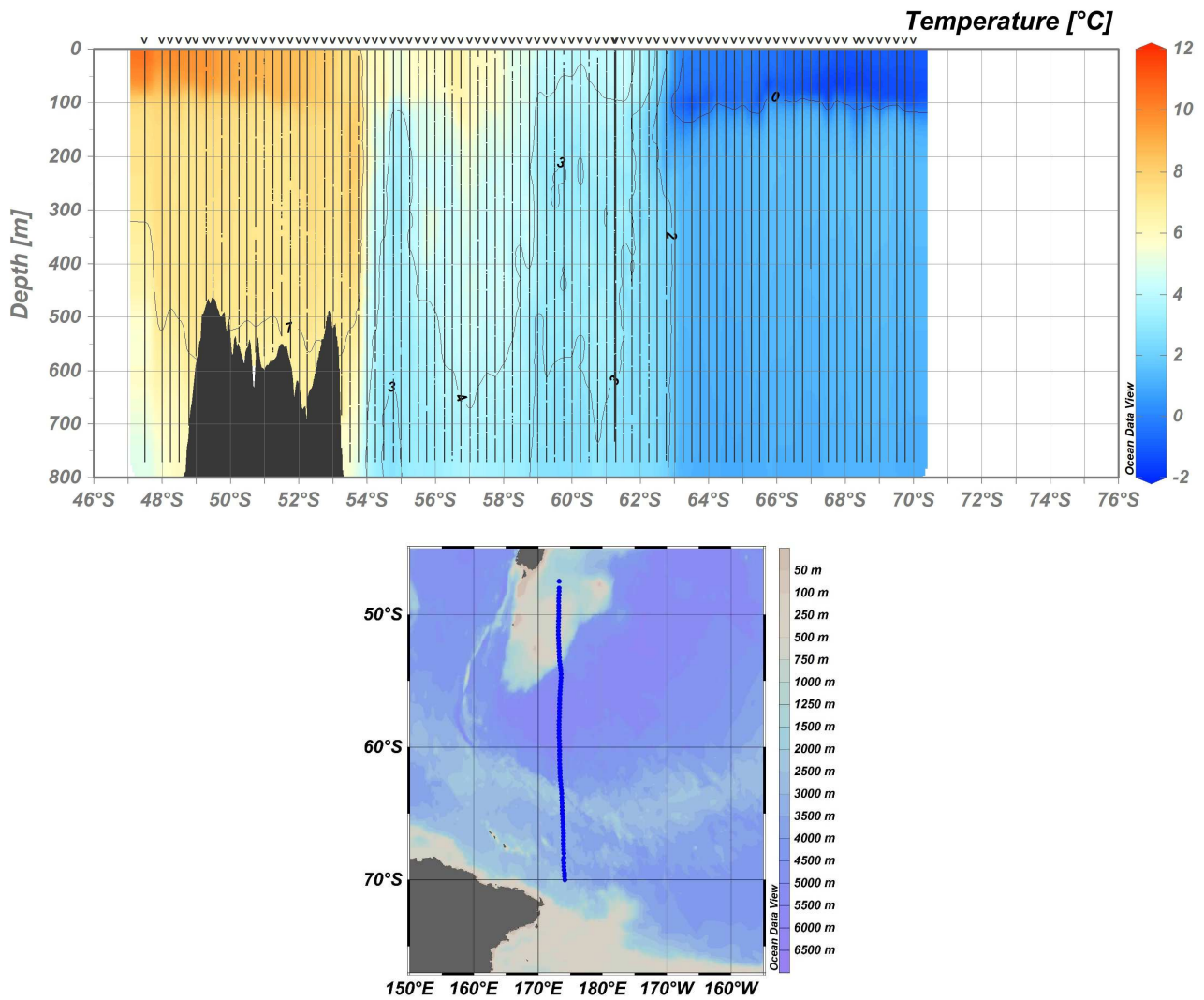
**S26.** Temperature vertical section from XBT data collected during the PNRA\_XXIX cruise conducted from 30 December 2013 to 03 January 2014 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



**S27.** Temperature vertical section from XBT data collected during the PNRA\_XXIX cruise conducted from 14 February 2014 to 18 February 2014 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

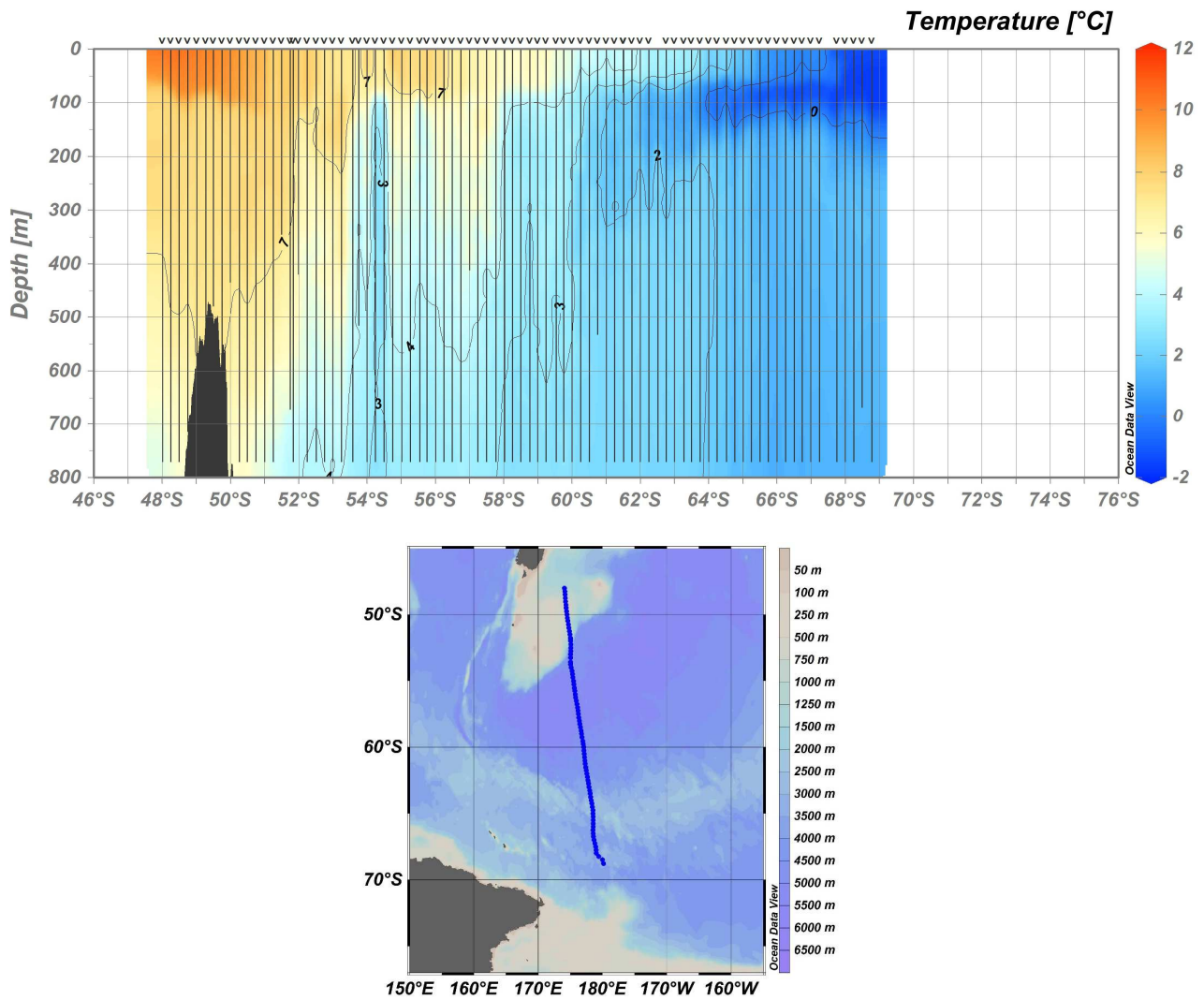


**S28.** Temperature vertical section from XBT data collected during the PNRA\_XXX cruise conducted from 02 January 2015 to 07 January 2015 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

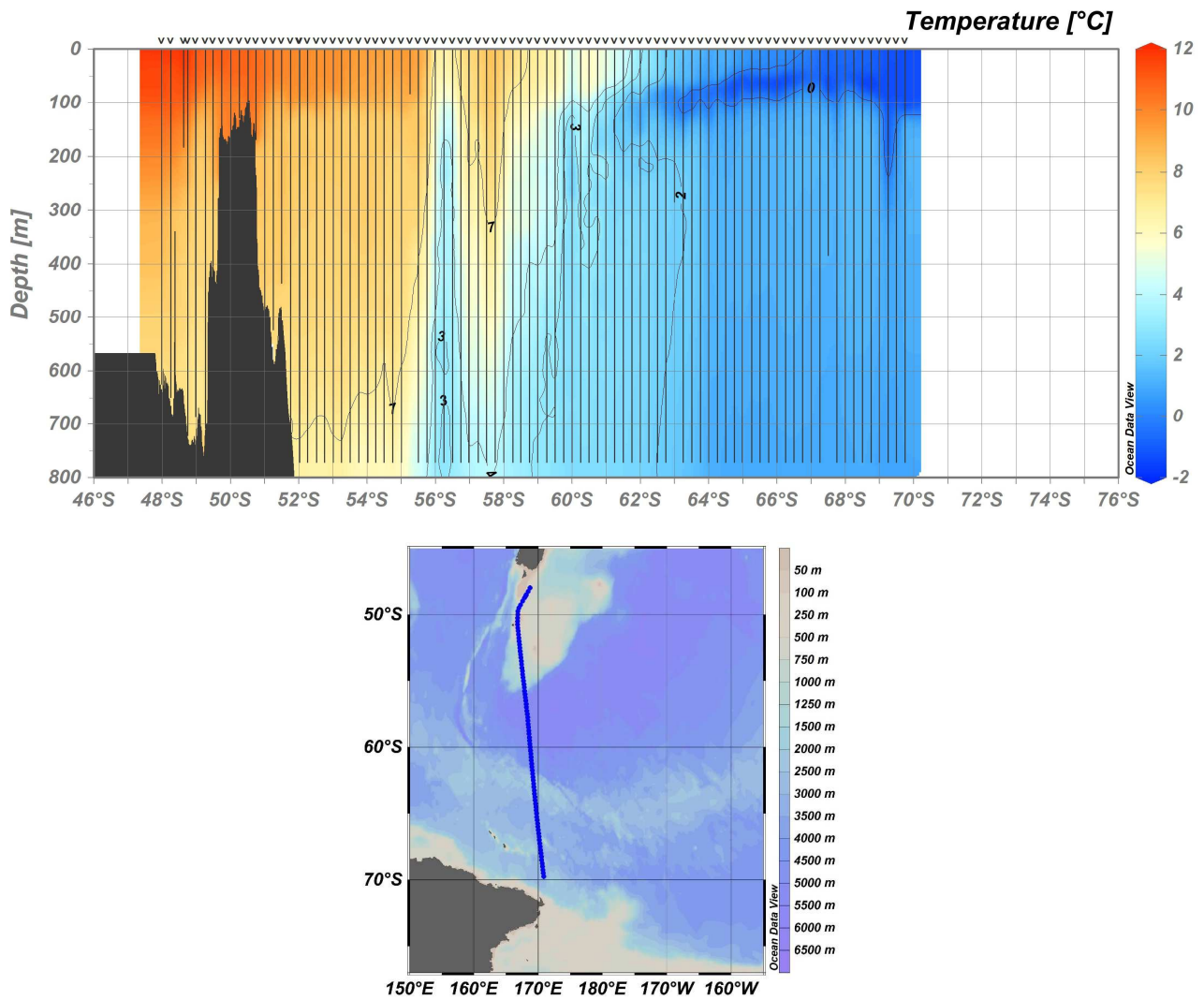


**S29.** Temperature vertical section from XBT data collected during the PNRA\_XXXI cruise conducted from 16 January 2016 to 21 January 2016 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



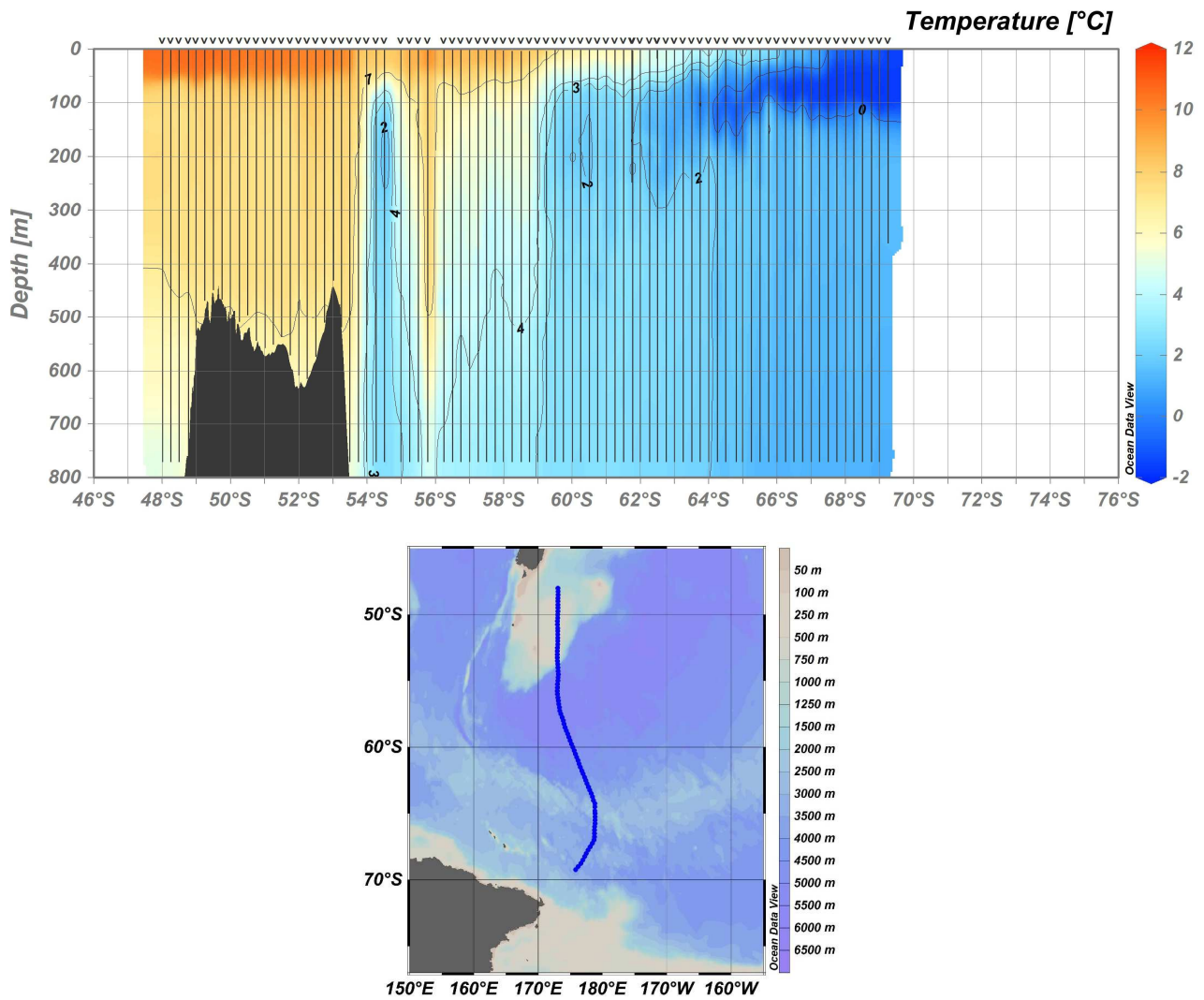


**S30.** Temperature vertical section from XBT data collected during the PNRA\_XXXII cruise conducted from 31 December 2016 to 05 January 2017 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

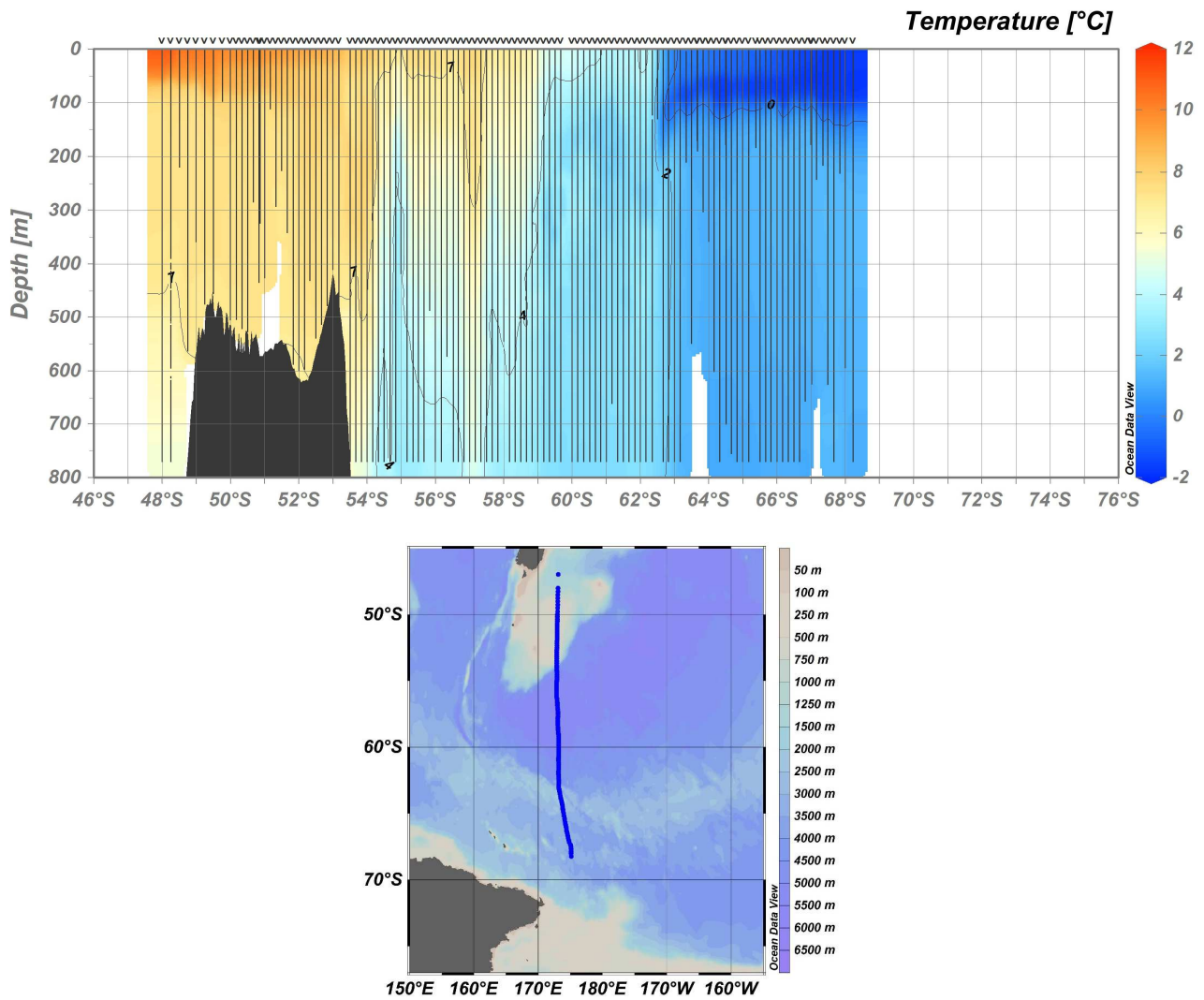


**S31.** Temperature vertical section from XBT data collected during the PNRA\_XXXIV cruise conducted from 08 February 2019 to 12 February 2019 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

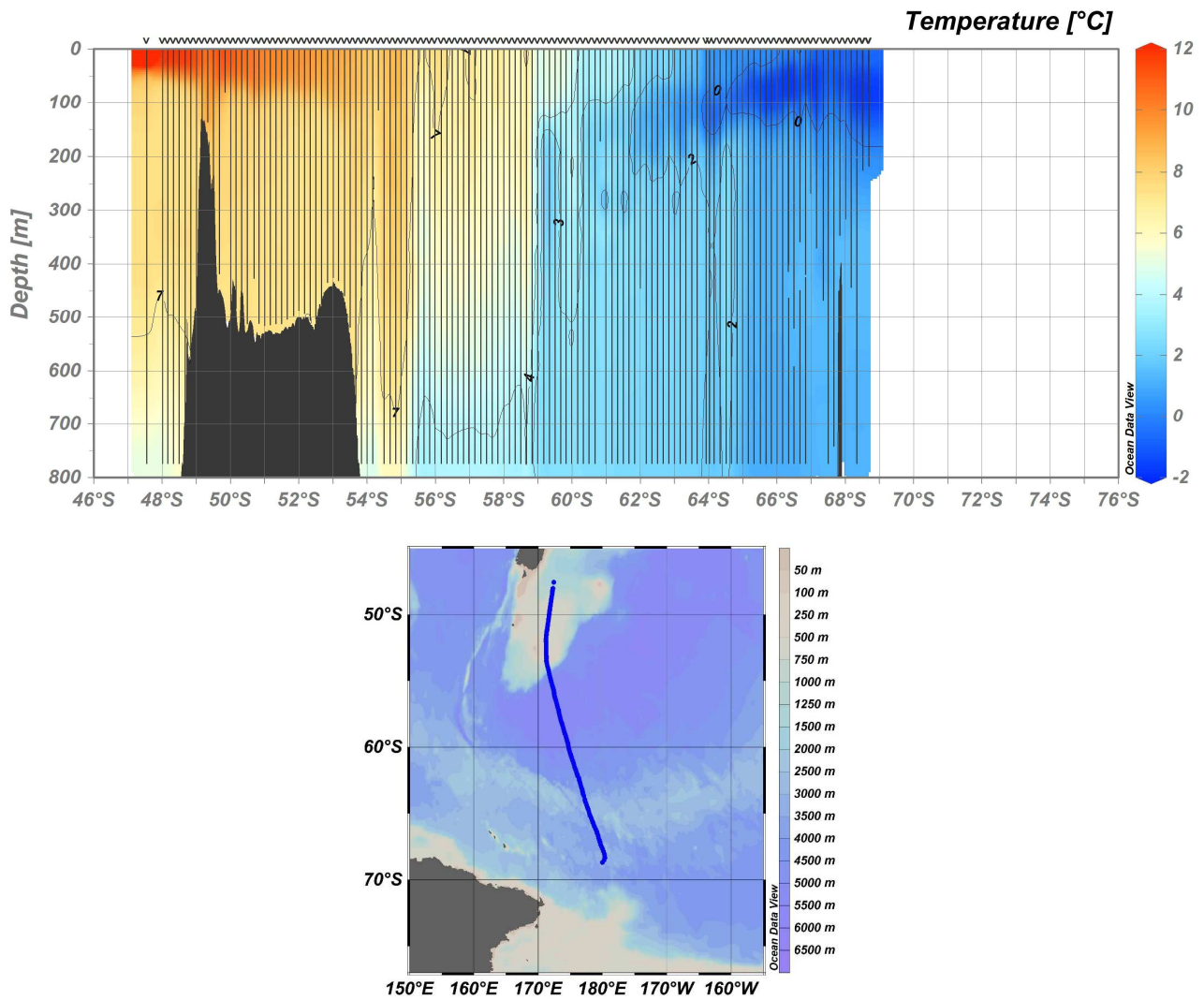




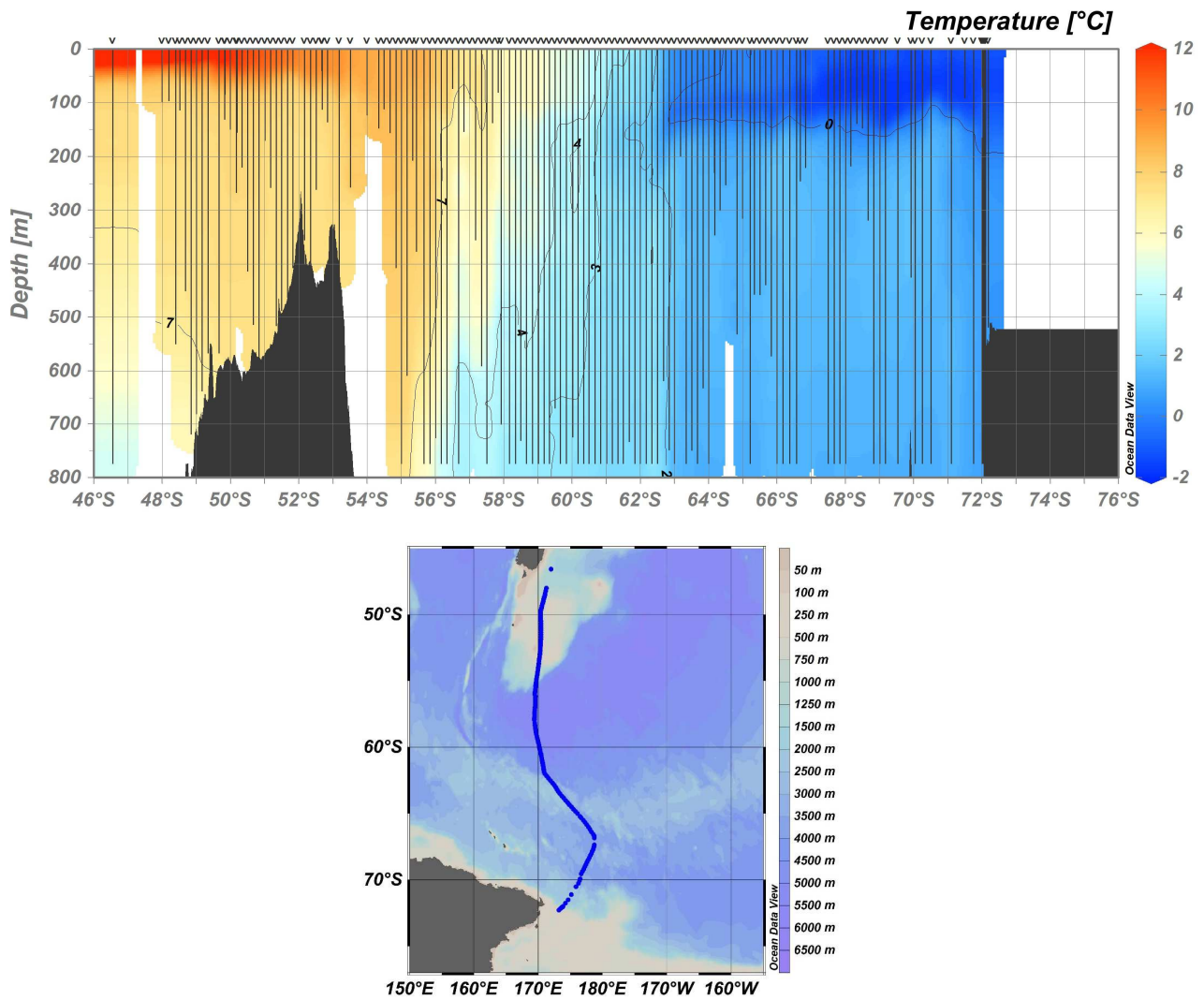
**S32.** Temperature vertical section from XBT data collected during the PNRA\_XXXV cruise conducted from 07 January 2020 to 12 January 2020 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



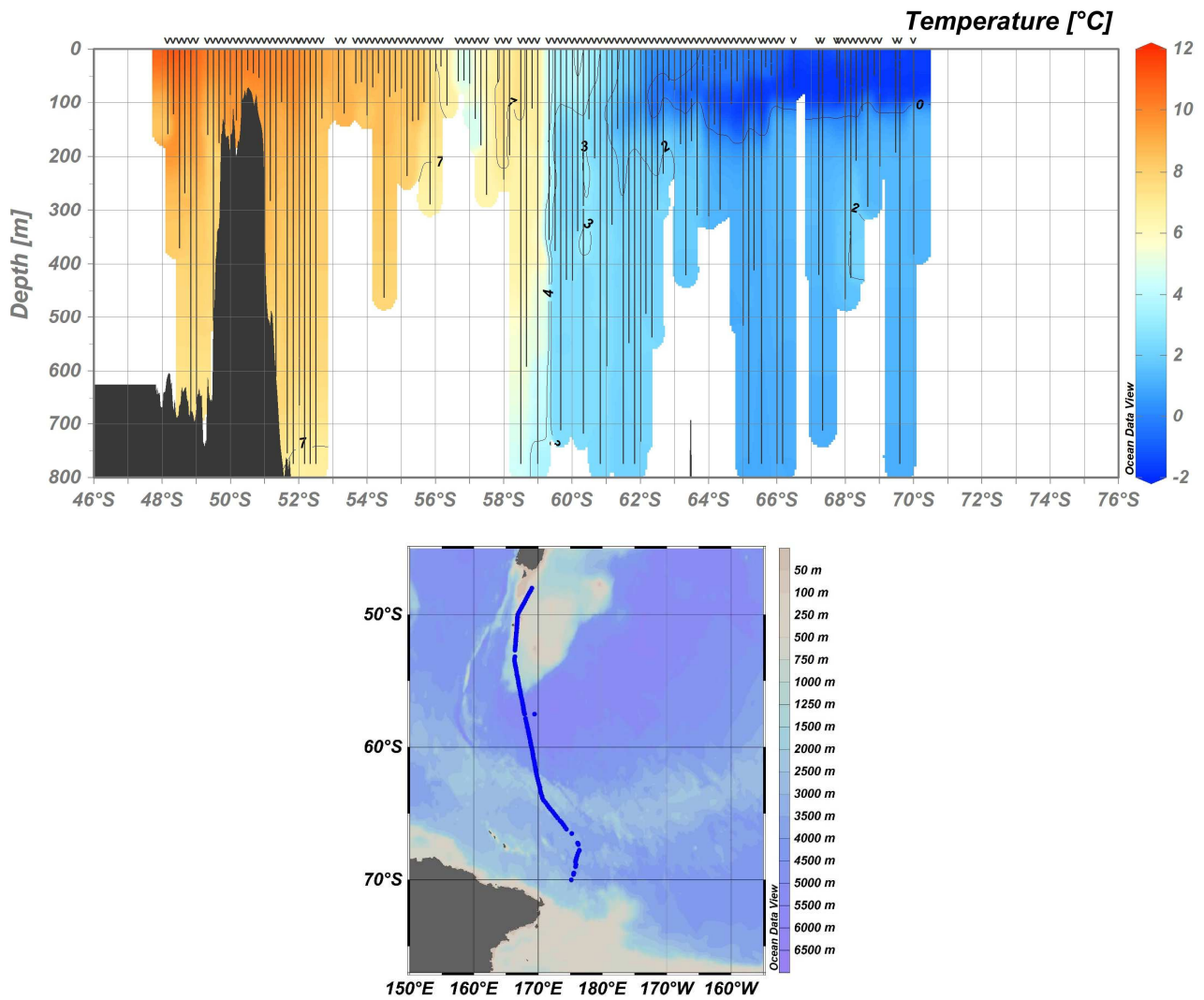
**S33.** Temperature vertical section from XBT data collected during the PNRA\_XXXVI cruise conducted from 25 December 2020 to 02 January 2021 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



**S34.** Temperature vertical section from XBT data collected during the PNRA\_XXXVII cruise conducted from 08 January 2022 to 13 January 2022 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



**S35.** Temperature vertical section from XBT data collected during the PNRA\_XXXVIII cruise conducted from 06 January 2023 to 12 January 2023 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.



**S36.** Temperature vertical section from XBT data collected during the PNRA\_XXXIX cruise conducted from 07 January 2024 to 12 January 2024 along the New Zealand–Antarctica “chokepoint” - PX36 transect. Zonal interpolation is based on a spatial weighting model that incorporates three adjacent temperature profiles, considering a maximum influence range of 60 km along the zonal direction and 20 m along depth. The dark grey mask represents the bathymetry. The map of XBT casts positions is displayed below the section. Plots were realized using Ocean Data View software.

**S37.** Python code for visualizing XBT data through a scatter plot of vertical temperature profiles and a latitudinal temperature section, as illustrated in S38 and S39

```
import pandas as pd
import numpy as np
from scipy.interpolate import griddata
import matplotlib.pyplot as plt
import os

# Define the file path
file_path = r'The relative file path to the .txt file, indicating its location in the file system. For
example, it could be an absolute path like: C:\Users\User\Documents\example.txt'

# Remove lines starting with '/' from the file
with open(file_path, 'r', encoding='latin-1') as file:
    lines = file.readlines()

filtered_lines = [line for line in lines if not line.startswith('/')]

# Save filtered lines to a temporary file
temp_file_path = r'The relative path to the directory where the temporary file should be saved.'
with open(temp_file_path, 'w') as temp_file:
    temp_file.writelines(filtered_lines)

# Read the cleaned file into a DataFrame
df = pd.read_csv(temp_file_path, sep='\t', skiprows=0)
os.remove(temp_file_path) # Remove the temporary file

# Add column names to the DataFrame
df.columns = [
    'Cruise', 'Station', 'Type', 'mon/day/yr', 'hh:mm',
    'Longitude [degrees_east]', 'Latitude [degrees_north]',
    'Bot. Depth [m]', 'Elapsed Time [s]',
    'Depth 1 [m]', 'Depth 2 [m]', 'Depth 3 [m]',
    'Temperature 1 [°C]', 'Temperature 2 [°C]', 'QF'
]

# Filter the good Data, where QF < 2 (Quality Filter)
df_filtered = df[df['QF'] = 1]
```



### # --- SCATTER PLOT: Depth vs Temperature ---

```
plt.scatter(  
    df_filtered['Temperature 2 [°C]', df_filtered['Depth 3 [m]'],  
    color='black', s=10  
) # Scatter plot with black dots  
  
plt.gca().invert_yaxis() # Invert y-axis for depth  
plt.xlim(-2, 12) # Temperature limits  
plt.xticks(range(-2, 13, 2)) # Tick every 2 degrees  
plt.ylim(800, 0) # Depth limits  
plt.yticks(range(0, 801, 100)) # Tick every 100 meters  
  
# Add axis labels and title  
  
plt.xlabel('Temperature [°C]', fontweight='bold')  
plt.ylabel('Depth [m]', fontweight='bold')  
plt.title('Depth vs Temperature, fontweight='bold')  
  
# Add grid  
  
plt.grid(which='both', linestyle='--', linewidth=0.5, alpha=0.7)  
plt.show()  
plt.close()
```

### # --- INTERPOLATION AND CONTOUR PLOT ---

```
# Extract necessary columns: latitude, depth, and temperature  
  
lat = df_filtered['Latitude [degrees_north]']  
depth = df_filtered['Depth 3 [m]']  
temp = df_filtered['Temperature 2 [°C]']  
  
# Generate a grid for interpolation  
  
# Create a latitude grid with 400 points between the minimum and maximum latitude  
lat_grid = np.linspace(np.nanmin(lat), np.nanmax(lat), 400)  
  
# Create a depth grid with 400 points between the minimum and maximum depth  
depth_grid = np.linspace(np.nanmin(depth), np.nanmax(depth), 400)  
  
# Create a meshgrid for latitude and depth (grid points for interpolation)  
lat_grid, depth_grid = np.meshgrid(lat_grid, depth_grid)
```

```

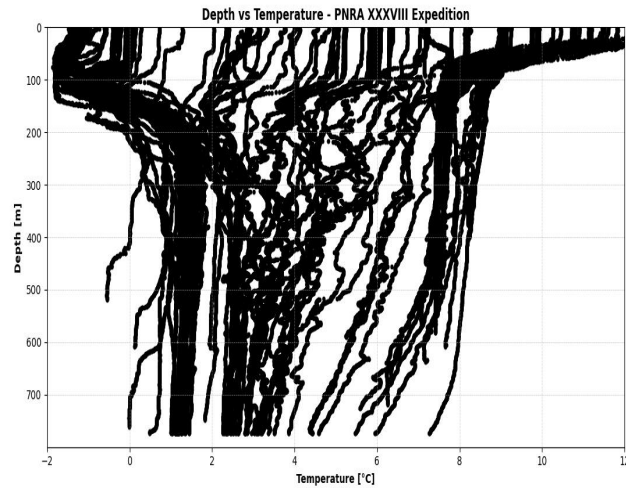
# Combine data into a single array for processing and filter out rows containing NaNs
data = np.array([lat, depth, temp]).T # Combine latitude, depth, and temperature into a single array
valid_data = data[~np.isnan(data).any(axis=1)] # Remove rows with any NaN values
lat, depth, temp = valid_data[:, 0], valid_data[:, 1], valid_data[:, 2] # Separate the cleaned data
# Perform linear interpolation of the temperature data on the generated grid
temp_grid = griddata(
    (lat, depth), # Original data points (latitude and depth)
    temp,         # Corresponding temperature values
    (lat_grid, depth_grid), # Interpolation grid
    method='linear' # Use linear interpolation
)
# Plot the interpolated data as a contour plot
plt.figure(figsize=(10, 6))
contour = plt.contourf(
    lat_grid, depth_grid, temp_grid,
    levels=100, cmap="turbo", vmin=-2, vmax=12 # Set color range from -2 to 12°C
)
# Add a colorbar to the plot
cbar = plt.colorbar(contour, label="Temperature [°C]", ticks=np.arange(-2, 13, 2))
cbar.set_label("Temperature [°C]", fontweight='bold') # Add a bold label for the colorbar
# Add specific contour lines on top of the filled contours
contour_levels = [0, 2, 3, 4, 7] # Contour levels of interest
contour_lines = plt.contour(
    lat_grid, depth_grid, temp_grid,
    levels=contour_levels, colors='black', linewidths=1 # Black contour lines
)
plt.clabel(contour_lines, fmt='%1.0f', colors='black', fontsize=7) # Add labels to contour lines
# Set axis labels and title
plt.xlabel("Latitude [Degrees South]", fontweight='bold') # Label for latitude
plt.ylabel("Depth [m]", fontweight='bold') # Label for depth
plt.title(

```

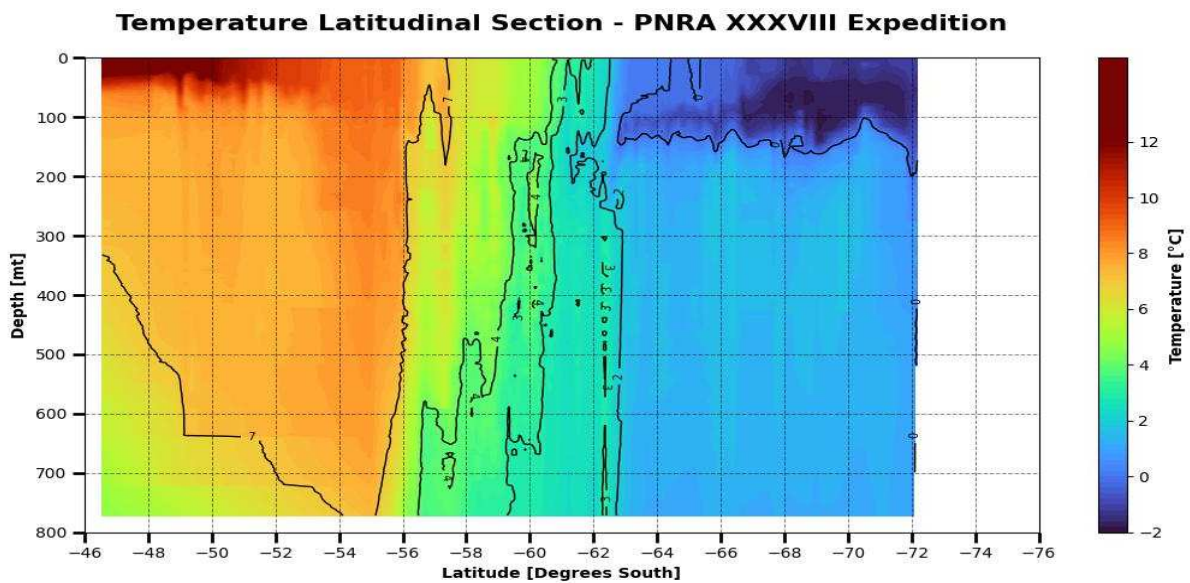
```

    "Temperature Latitudinal Section",
    fontweight='bold', fontsize=16, pad=20 # Bold title with padding
)
# Customize the depth axis (y-axis)
plt.gca().invert_yaxis() # Invert depth axis to show 0 at the top
plt.ylim(800, 0) # Set depth limits from 800 to 0
plt.yticks(np.arange(0, 801, 100)) # Tick labels every 100 meters
# Customize the latitude axis (x-axis)
plt.gca().invert_xaxis() # Invert latitude axis for correct orientation
plt.xlim(-46, -76) # Set latitude limits from -46 to -76 degrees south
plt.xticks(np.arange(-76, -45, 2)) # Tick labels every 2 degrees
# Customize plot margins and ticks
plt.tick_params(axis='both', which='major', length=7, width=2) # Major tick appearance
plt.tick_params(axis='both', which='minor', length=4, width=1.5) # Minor tick appearance
# Add a grid to the plot
plt.grid(True, linestyle='--', linewidth=0.7, color='black', alpha=0.5) # Dashed black grid with
transparency
# Show the plot
plt.show()

```



**S38.** Temperature vertical profiles of the XBT good data (QF=1) collected during the PNRA\_XXXVIII expedition realized through the Python code in S37



**S39.** Temperature latitudinal section of the XBT good data (QF=1) collected during the PNRA\_XXXVIII expedition realized through the Python code in S37