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Monthly Data Report – July 2022

Australian Baseline Sea Level Monitoring Array

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Table of Contents

List of Tables

List of Figures

Executive Summary

This summary, and the overview that follows, are intended to provide a synopsis of the recent month's observations in addition to longer term variations over the life of the project to date.

July 2022

- The Australian Baseline Sea Level Monitoring Array (ABSLMA) network continued to collect high quality sea level and associated meteorological information to support long-term sea level monitoring around Australia.
- The overall rate of sea level data returned from the operating network during July was 93.4%.
- Monthly mean sea levels were 5 – 10 cm lower than normal at Thevenard, Spring Bay, Portland, Lorne, Burnie and Cocos Island, but 5 cm higher than normal at Hillarys and Groote Eylandt.
- Monthly water temperatures were cooler than normal at Darwin, Rosslyn Bay and Broome but warmer than normal at Port Kembla.

Introduction

Welcome to the July 2022 Monthly Data Report for the Australian Baseline Sea Level Monitoring Array (ABSLMA). The report details the month-by-month operation of SEAFRAME sea level monitoring stations around Australia, including operational problems with the network and the occurrence of abnormal sea level events in the context of related astronomical tide, weather, and climate variations. A companion array of SEAFRAME sea level monitoring stations in Pacific Island Countries is supported under the Pacific Sea Level and Geodetic Monitoring Project.

The ABSLMA was originally developed and supported from grants under the Australian Climate Change Science Program through the Department of Climate Change and Energy Efficiency, with a primary goal to monitor long-period sea level changes around Australia focussing particularly on the enhanced greenhouse effect. Operation of the array continues to be supported by the Bureau of Meteorology, underpinning the advanced technologies gathering global observations for climate change research as well as providing real-time information for tidal monitoring and tsunami detection.

The Baseline sea level monitoring array consists of 15 standard SEAFRAME stations operated by the Bureau of Meteorology at representative sites around Australia, as well as two customised, privately-owned stations at Lorne and Stony Point (Figure 1). The SEAFRAME at Port Stanvac was removed in November 2010 to allow Mobil Refining Australia to decommission the oil refinery. Re-establishment of a tide gauge near Port Stanvac is being investigated.

The standard SEAFRAME stations not only measure sea level, but also observe several “ancillary” variables - air and water temperatures, wind speed, wind direction and barometric pressure. The privately-owned stations at Lorne and Stony Point do not measure the ancillary variables, although winds are measured at Stony Point.

The Bureau of Meteorology and Geosciences Australia, through their membership on the Intergovernmental Committee on Surveying and Mapping (ICSM) Tides and Sea Level Working Group (TSLWG), strive to sustain geodetic levelling programs implemented by various state surveying organisations in order to monitor shifts in the vertical of the sea level sensors due to local land movement.

Observations collected by the sea level monitoring network are routinely processed into a range of quality-controlled data products. The monthly data report is the primary source of up-to-date information relating to these data products.

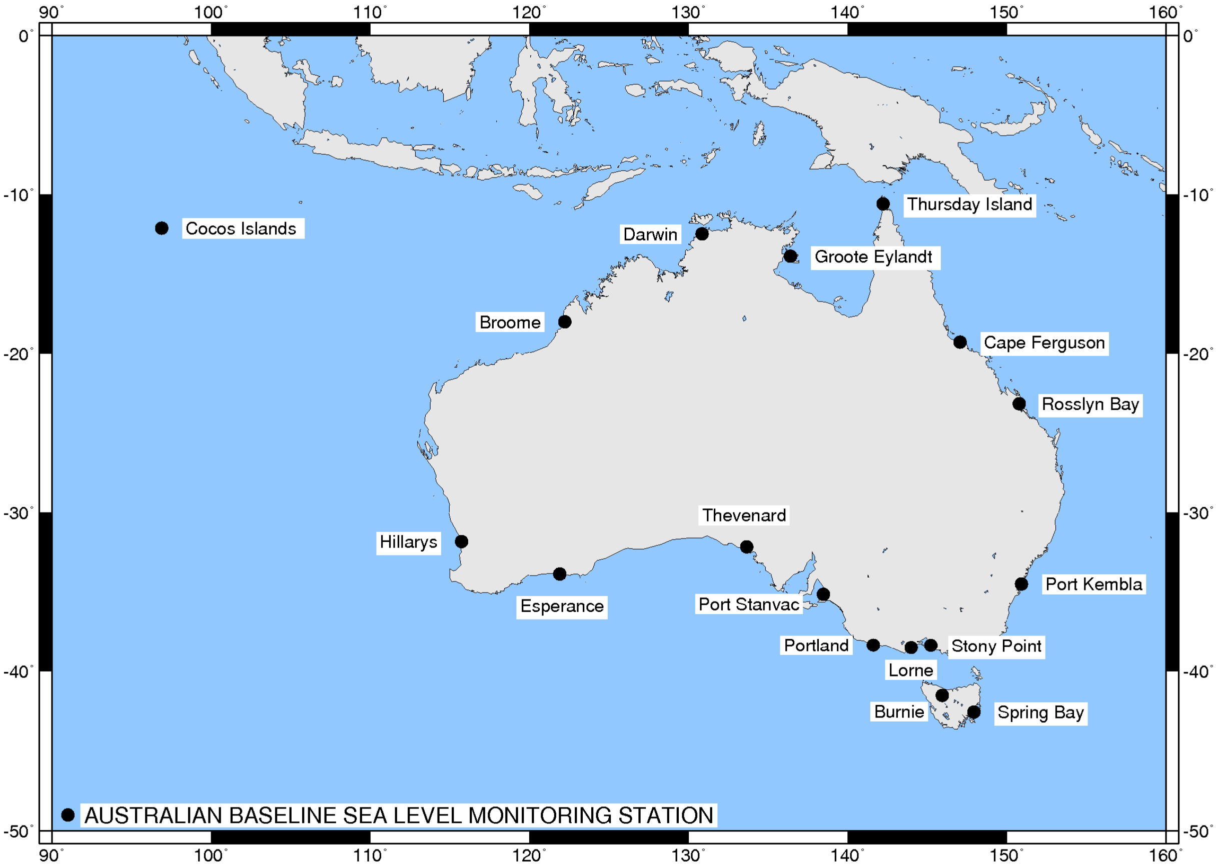

Figure 1. Australian Baseline Sea Level Monitoring Network of SEAFRAME stations.

Sea Level and Climate

Astronomical tides and weather conditions are largely responsible for daily perturbations in sea level, but over monthly, seasonal, and longer timescales sea levels around Australia are largely influenced by fluctuations in climate and ocean heat content.

Intra-annual or seasonal changes in sea level are closely linked to the annual solar radiation cycle and associated shifts in weather patterns and ocean current systems. Across southern Australia, sea levels tend to be at their highest during winter, while the opposite is true across northern Australia, where sea levels tend to be higher during the summer wet season. Further information relating to seasonal climate variations around Australia is provided by the Bureau of Meteorology at http://www.bom.gov.au/climate/

Inter-annual sea level variations are largely influenced by the El Niño – Southern Oscillation climate cycle, particularly across the northern and western Australian coastlines. Sea levels are generally lower than normal around Australia during El Niño, in response to cooler than normal ocean temperatures and higher than normal barometric pressures that are brought about by weaker than normal easterly Trade Winds across the Pacific. Conversely, during La Niña sea levels around Australia are generally higher than normal, in association with warmer than normal ocean temperatures and lower than normal barometric pressures, due to stronger than normal easterly Trade Winds across the Pacific.

A summary of recent and past El Niño – Southern Oscillation climate conditions is provided by the Bureau of Meteorology at http://www.bom.gov.au/climate/enso/

July SEAFRAME Data

Monthly Sea Level and Environmental Data

The observed sea levels (Figure 3) are dominated by the daily oscillations of the tide. In most cases, the tide rises and falls twice per day (semi-diurnal), but at Groote Eylandt and Hillarys the tide tends to have a single high and low per day (diurnal). Where the tides follow a semi-diurnal pattern, the greatest tidal variations are called spring tides, which tend to occur around the time of the new and full moons. A full moon fell on the 13th of July while a new moon fell on the 28th.

Gaps in the data are the result of instrumental errors or data retrieval problems and are discussed under Instrument Performance.

The residuals (Figure 4) are the differences between the observed sea levels and the astronomical tidal predictions. They highlight non-tidal sea level fluctuations, such as those due to the effects of weather or tsunamis.

Low pressure systems can produce storm surges where the combination of low barometric pressure and strong winds raise sea levels well above the predicted astronomical tides for a period of a day or more.

The non-tidal sea level fluctuations can be amplified or sustained by the shape of the bay or harbour in which the gauge is located. Some of the SEAFRAME stations are located in harbours that exhibit ‘sloshing’ under certain conditions (a phenomenon referred to as a seiche).

The sea level residuals at all stations from time to time and to some degree exhibit semi-diurnal or diurnal fluctuations which last a few days or weeks and then disappear. If these fluctuations were to persist, they would form part of the astronomical tide prediction and thus not appear as residuals. Consequently, semi-diurnal and diurnal residual fluctuations will always be transient in nature.

The barometrically corrected residuals (Figure 5) have had a major part of the effect of atmospheric pressure fluctuations removed from the sea level residuals of Figure 4. The rule of thumb for the ‘inverse barometer effect’ is that a 1-hPa fall in the barometer, if sustained over a day or more, produces a 1-cm rise in the local sea level (within the area beneath the low-pressure system).

The winds, temperatures and barometric pressures are plotted in Figure 6 to Figure 11. The incident winds in Figure 8 follow the meteorological convention, that is, they point in the direction the wind is coming from. For example, the winds at Cocos Island were from the south-east for much of July.

Air and water temperatures (Figure 9 and Figure 10) are plotted using the same vertical scale for the purpose of comparison. The air temperatures are seen to fluctuate over a much wider range than the water temperatures.

Barometric pressures (Figure 11) tend to fluctuate by around 3 hPa twice-daily at all stations as a

result of atmospheric tides, which are largest in the tropical regions and reduce to near zero toward the poles. The longer-term barometric pressure fluctuations that occur over periods of days to weeks are due to passing weather systems. These fluctuations tend to be larger at sites farther away from the equator, particularly those along the southern Australian coastline.

The monthly data extremes are put into perspective by Figure 12. In this figure, if an open circle falls above (below) a solid dot, a new maximum (minimum) for the particular month has been set. The data sets only include the ABSLMA data, which have been collected since May 1990 when the first station was installed at Darwin.

The SEAFRAME station at Thursday Island has only been collecting data since April 2015, and the monthly data extremes do not include data from an earlier tide gauge. The short data records for Thursday Island means that extreme levels are exceeded on a regular basis.

A record-low July sea level of 0.478 m was observed at Thursday Island this month.

Thursday Island also recorded a record-low July barometric pressure of 1005.0 hPa and a record-high water temperature of 27.4 °C.

Further sea level and meteorological statistical information is available at http://www.bom.gov.au/oceanography/projects/abslmp/data/monthly.shtml

Monthly Means and Anomalies

Figure 13 through Figure 16 show the monthly means, or simple arithmetic averages, for sea level, barometric pressure, water temperature and air temperature. The monthly means demonstrate the seasonal variations of the recorded parameters. Groote Eylandt, for example, normally experiences an annual sea level cycle of about 0.6 m that peaks around February of each year.

Figure 17 through Figure 20 show the monthly mean sea level, barometric pressure, air temperature and water temperature anomalies. The sea level anomalies are the residuals after tides, annual and semi-annual seasonal cycles and linear slope have been removed by way of harmonic tidal analysis of the complete record. The annual sea level cycle at Groote Eylandt (which has the largest consistent annual cycle) is quite notable in Figure 13 but less apparent in Figure 17. By removing the seasonal cycles, the anomalies help to bring out irregular features, such as lower than normal sea levels around much of Australia during the 1997/98 El Niño.

Monthly mean sea levels were lower than normal at Thevenard (by -10 cm), Spring Bay (-9 cm), Portland (-7 cm), Lorne (-7 cm), Burnie (-5 cm) and Cocos Island (-5 cm), but higher than normal at Hillarys (by +6 cm) and Groote Eylandt (+5 cm).

Monthly mean barometric pressures were generally higher than normal across the southern part of the network, most notably at Spring Bay (by +6.3 hPa), Burnie (+4.9 hPa) and Portland (+3.7 hPa), but slightly lower than normal across the northern part of the network, most notably at Cocos Island (by -2.0 hPa).

Monthly water temperatures were lower than normal at Darwin (by -1.6 °C), Rosslyn Bay (-1.1 °C) and Broome (-0.9 °C), but higher than normal at Port Kembla (by +1.2 °C).

Monthly air temperatures were cooler than normal at Rosslyn Bay (by -2.1 °C), Darwin (-1.8 °C), Cape Ferguson (-1.5 °C), Spring Bay (-1.3 °C) and Broome (-1.0 °C), but warmer than normal at Cocos Island (+0.7 °C).

Overall Rate of Movement in Sea Level

Table 1 shows the overall rate of movement in sea level at individual Australian Baseline stations based on the data so far collected at those sites. For most sites, the underlying data sets now exceed twenty years in length, Thursday Island being the exception.

The overall rates of movement are updated every month by calculating the linear slope during the tidal analysis of all the data available at individual stations. The rates are relative to the SEAFRAME sensor benchmark, whose movement relative to inland benchmarks is monitored by Geosciences Australia.

Please exercise caution in interpreting the overall rates of movement of sea level – the records are too short to be inferring long-term trends and have not been corrected for land movement or other parameters that may influence the reported rates.

Table 1. Updated overall rates of sea level movement based on SEAFRAME data from installation through July 2022.

Location	**Latitude**	**Longitude**	**Date of first data**	**Rate[1] (mm/yr)**	**Change in rate from previous month (mm/yr)**
Cocos Island	12°07'07.1"S	96°53'30.9"E	Sep 1992	7.1	0.0
Groote Eylandt	13°51'36.2"S	136°24'56.1"E	Sep 1993	4.9	0.0
Darwin	12°28'18.4"S	130°50'45.1"E	May 1990	5.9	0.0
Broome	18°00'03.0"S	122°13'07.1"E	Nov 1991	6.0	0.0
Hillarys	31°49'32.0"S	115°44'18.9"E	Nov 1991	6.5	0.0
Esperance	33°52'15.2"S	121°53'43.3"E	Mar 1992	4.4	0.0
Thevenard[3]	32°08'56.2"S	133°38'28.8"E	Mar 1992	4.1	-0.1
Port Stanvac[2]	35°06'31.0"S	138°28'1.3"E	Jun 1992	4.7	0.0
Portland	38°20'36.4"S	141°36'47.4"E	Jul 1991	2.9	0.0
Lorne	38°32'49.4"S	143°59'19.8"E	Jan 1993	2.4	0.0
Stony Point	38°22'19.7"S	145°13'28.9"E	Jan 1993	2.6	0.0
Burnie	41°03'0.3"S	145°54'54.0"E	Sep 1992	3.1	0.0
Spring Bay	42°32'45.1"S	147°55'57.8"E	May 1991	3.5	0.0
Port Kembla	34°28'25.5"S	150°54'42.7"E	Jul 1991	3.6	0.0
Rosslyn Bay	23°09'39.7"S	150°47'24.6"E	Jun 1992	5.0	0.0
Cape Ferguson	19°16'38.4"S	147°03'30.4"E	Sep 1991	5.1	0.0
Thursday Island	10°35'11.4"S	142°13'18.8"E	Apr 2015	17.4	+0.4

[1]Relative to SSBM (SEAFRAME Sensor Bench Mark)
[2]Port Stanvac decommissioned November 2010
[3]Thevenard recommissioned October 2020

Instrument Performance

In Figure 21, which shows sea level data return, the columns represent the percentage of quality-controlled data returned from the gauge each month.

Sea level data return from the operating network during July 2022 was 93.4% (83.9% when Port Stanvac, which was removed in November 2010, is included in the network) (Table 2).

At Rosslyn Bay the anemometer, air temperature sensor and backup radar water level sensor were subject to intermittent planned outages from the 21st of July due to work undertaken at the station.

The privately-owned station at Stony Point malfunctioned on the 10th of February 2022 and stopped transmitting data.

The performance of the meteorological sensors was generally satisfactory this month, although the water temperature sensors at Groote Eylandt, Esperance and Cape Ferguson remain faulty.

Erroneous Thursday Island air temperature data since the 18th of May has been removed from the record.

The anemometers at Esperance and Spring Bay were removed in 2012 and 2014 respectively, due to infrastructure changes at those sites.

Table 2. Rates of sea level data return.

Location	Installation Date	Data Return Since Installation (%)	Data Return in July 2022 (%)
Cocos Islands	Sep 1992	98.4	100.0
Groote Eylandt	Sep 1993	98.2	100.0
Darwin	May 1990	99.7	100.0
Broome	Nov 1991	97.4	100.0
Hillarys	Nov 1991	99.9	100.0
Esperance	Mar 1992	97.8	100.0
Thevenard[2]	Mar 1992	94.6	100.0
Port Stanvac[1]	Jun 1992	99.0	0.0
Portland	Jul 1991	99.4	100.0
Lorne	Jan 1993	95.8	94.4
Stony Point	Jan 1993	97.3	0.0
Burnie	Sep 1992	98.9	100.0
Spring Bay	May 1991	99.5	100.0
Port Kembla	Jul 1991	99.6	100.0
Rosslyn Bay	Jun 1992	99.4	99.8
Cape Ferguson	Sep 1991	98.1	100.0
Thursday Island	Apr 2015	98.2	100.0
Network Average		**98.3**	**87.9**

[1]Port Stanvac decommissioned November 2010
[2]Thevenard recommissioned October 2020

SEAFRAME Stations

Standard SEAFRAME stations now employ a TELMET (previously SUTRON) programmable data logger, water level gauges and other sensors. The data logger and associated electronics are normally housed in fibreglass huts. A sketch of a typical SEAFRAME station is shown in Figure 2.

Water level sensors include:

1. Primary water level using a Bartex 'AQUATRAK' acoustic-in-air sensor,
2. Secondary water level (or backup) using a Druck pressure transducer mounted close to the seabed, and
3. Tertiary water level using a Vega-puls62 radar sensor mounted above the water.

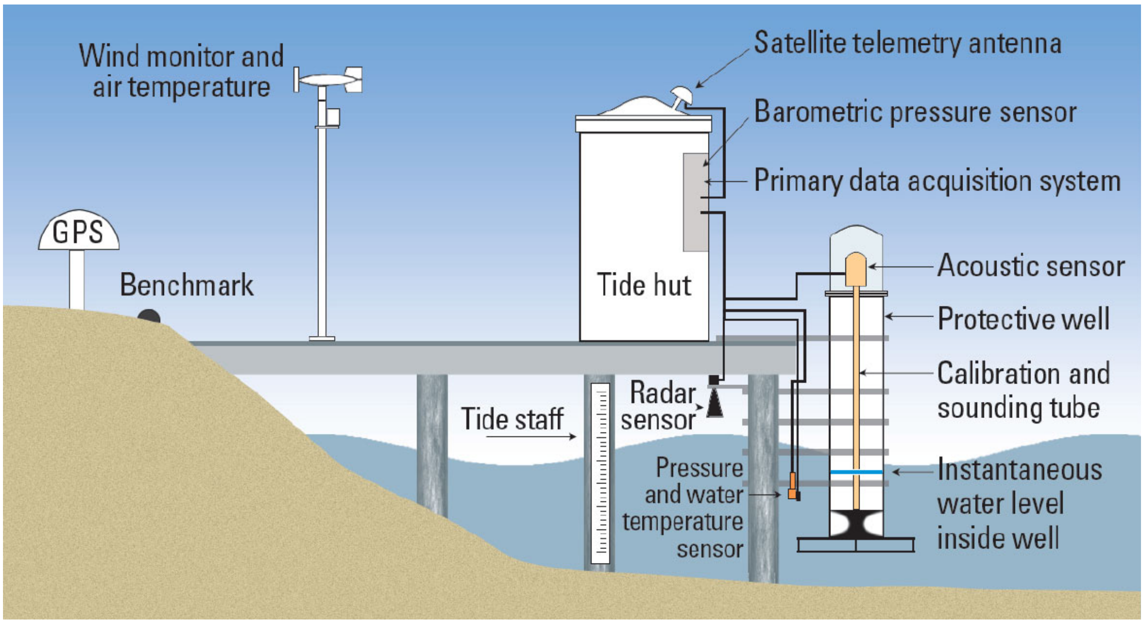

Figure 2. Schematic diagram of a SEAFRAME sea level monitoring station.

Further Information

Online Resources

ABSLMA Web site: http://www.bom.gov.au/oceanography/projects/abslmp/abslmp.shtml

ABSLMA Levelling Survey (Geosciences Australia): https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/gnss-networks/levelling-connections-between-gnss-sites-and-tide-gauges

Ocean Forecasts: http://www.bom.gov.au/oceanography/forecasts

ENSO Wrap-Up - El Niño / La Niña information: http://www.bom.gov.au/climate/enso/

Sea Level Rise (CSIRO): https://research.csiro.au/slrwavescoast/sea-level/

Acknowledgement

The Monthly Data Report is prepared by the Bureau of Meteorology.

Further enquiries about the Monthly Data Report may be made to:

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Website: http://www.bom.gov.au/oceanography/tides.shtml

Please also note the following:

While care has been taken in the collection, analysis, and compilation of the data, it is supplied on the condition that the Commonwealth of Australia shall not be liable for any loss or injury whatsoever arising from the use of the data.

Appendix 1: SEAFRAME Data Figures

Please note: The privately-owned stations at Stony Point and Lorne do not record air temperature, water temperature and barometric pressure data and are not present in Figures 5, 9, 10, 11 and 12. The tide gauge at Lorne does not record wind data and is not present in Figures 6, 7 and 8.

The anemometers at Esperance and Spring Bay have been removed.

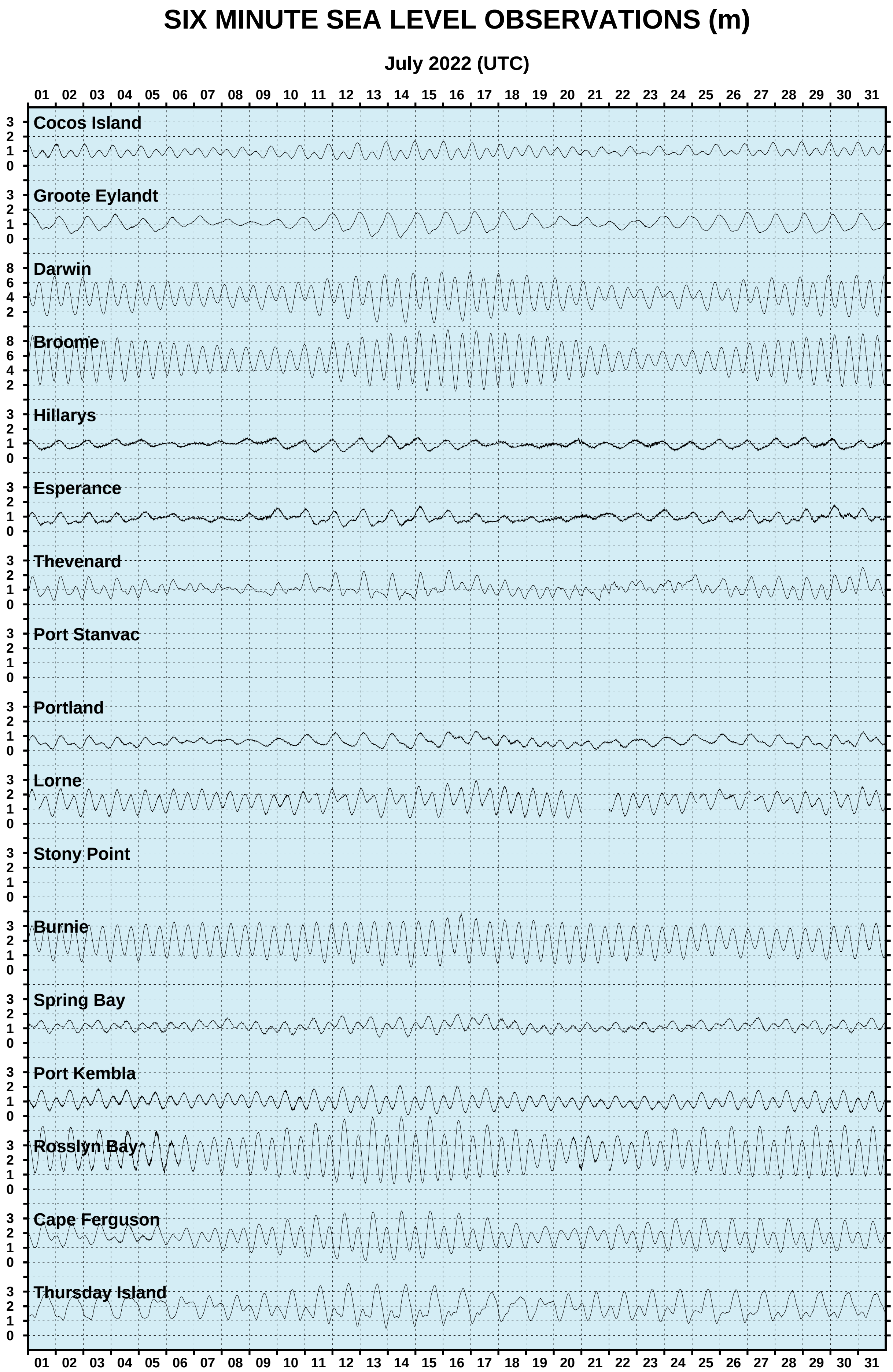


Figure 3. Sea level observations during July 2022.

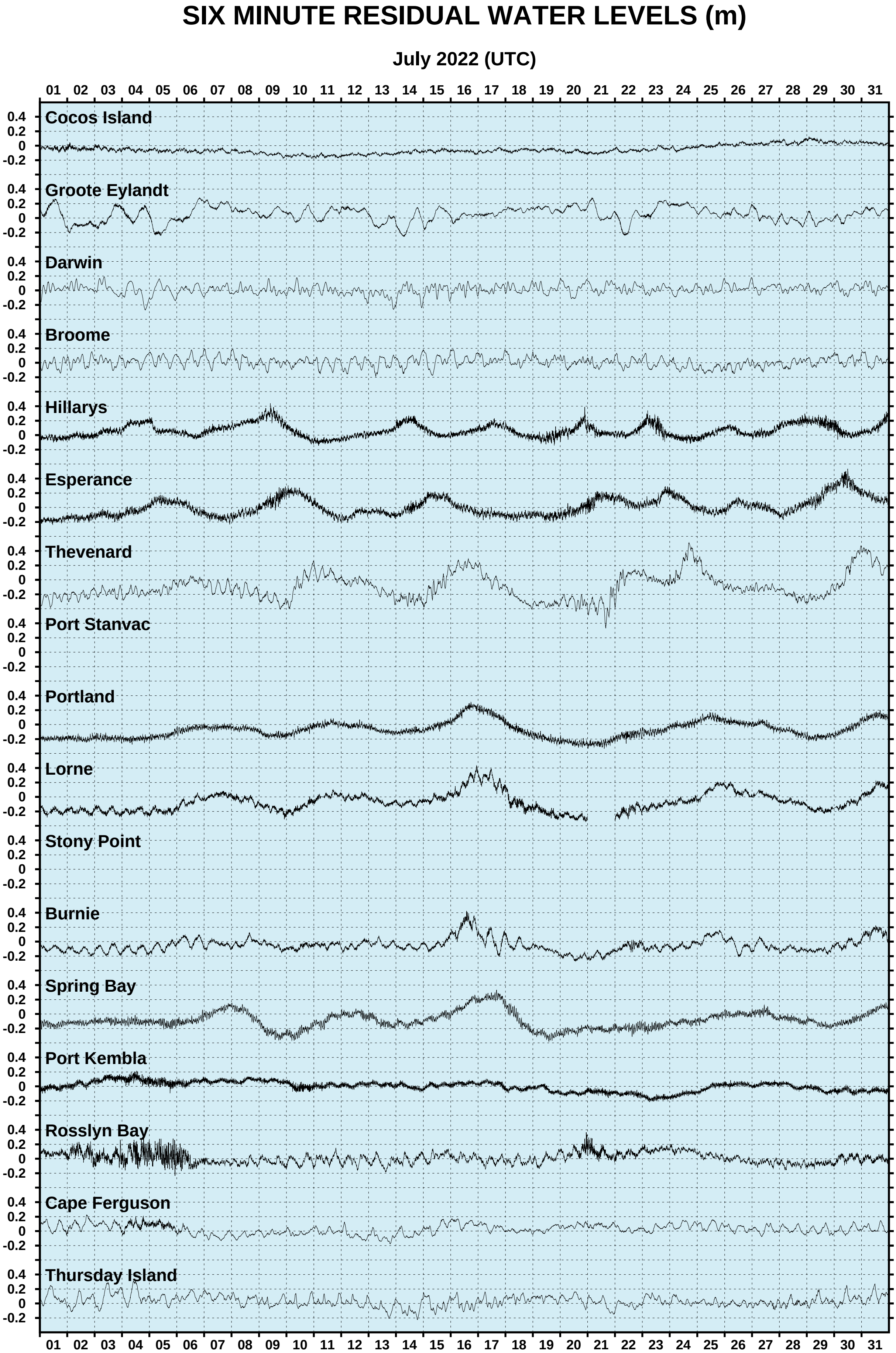


Figure 4. Residual sea levels during July 2022.

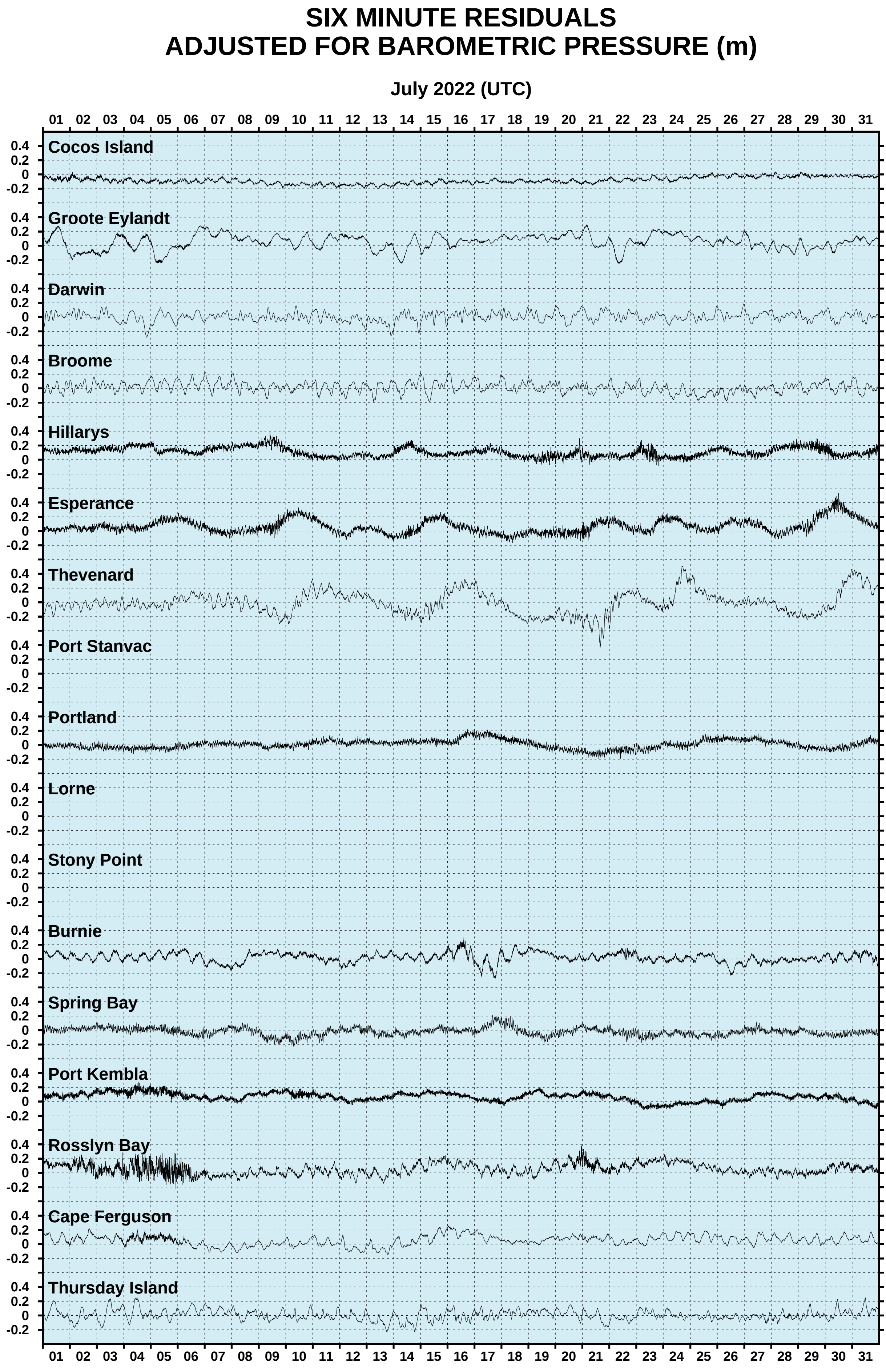


Figure 5. Residual sea levels adjusted for barometric pressure during July 2022.

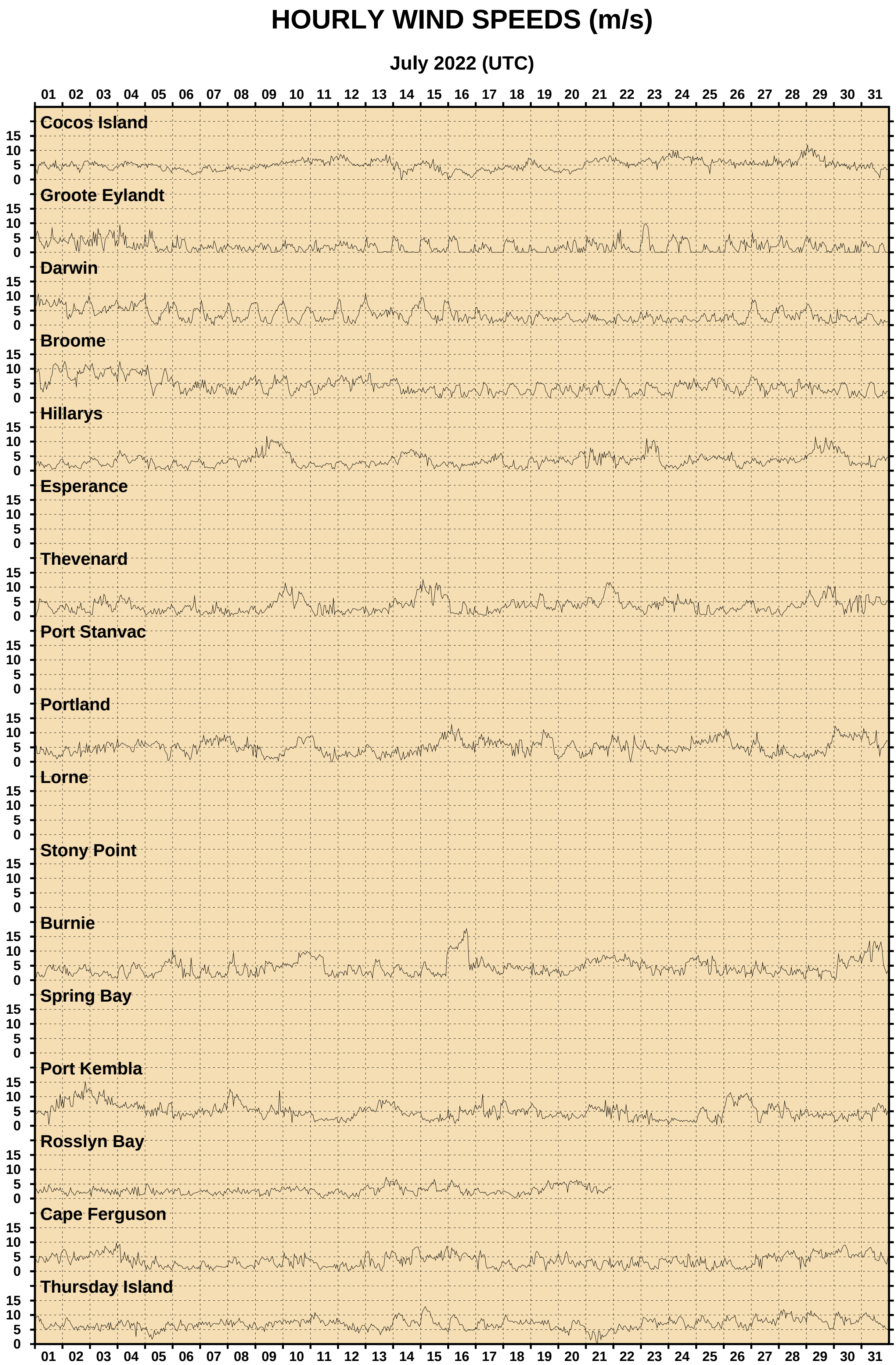


Figure 6. Wind speeds during July 2022.

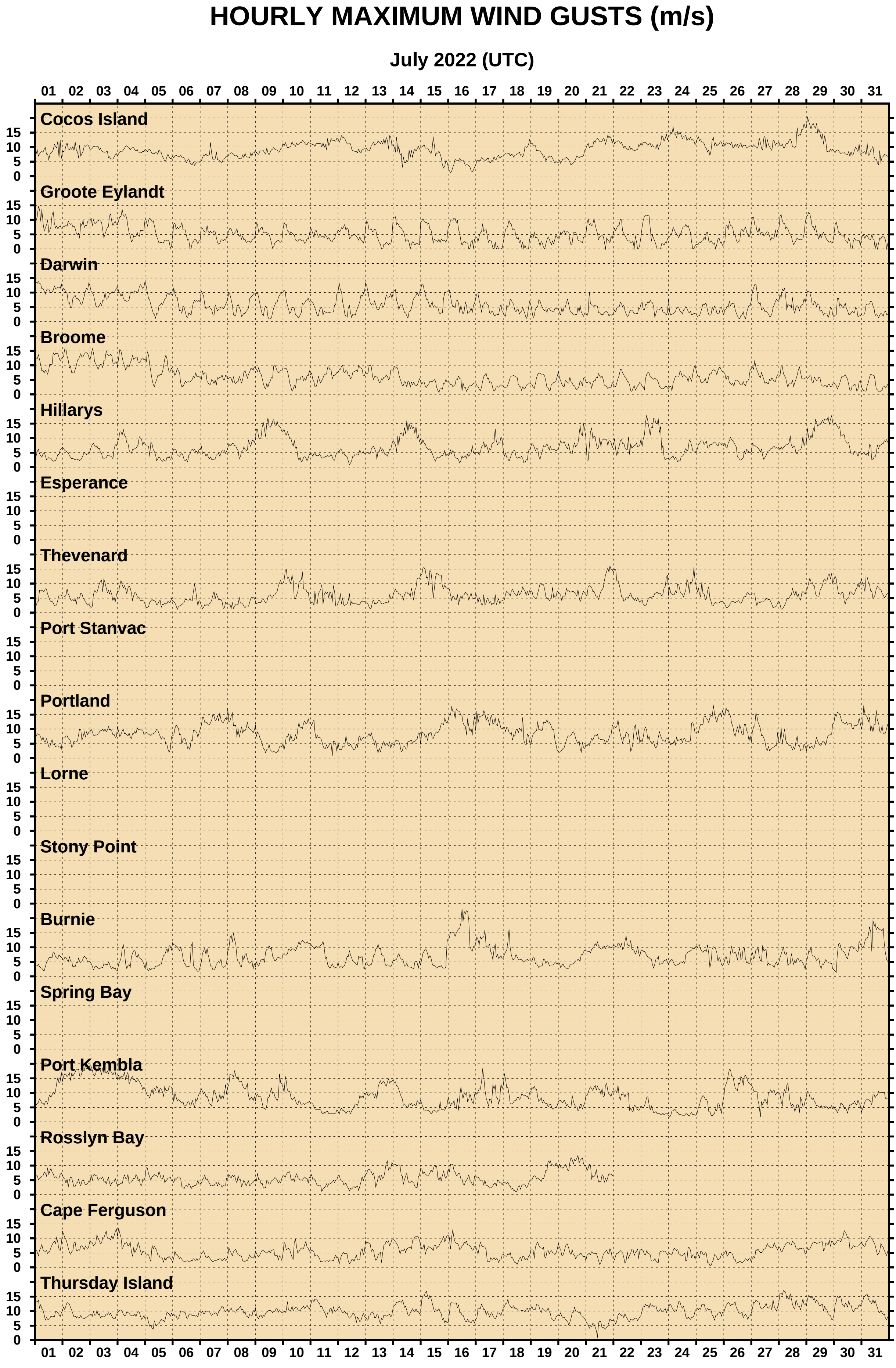


Figure 7. Wind gusts during July 2022.

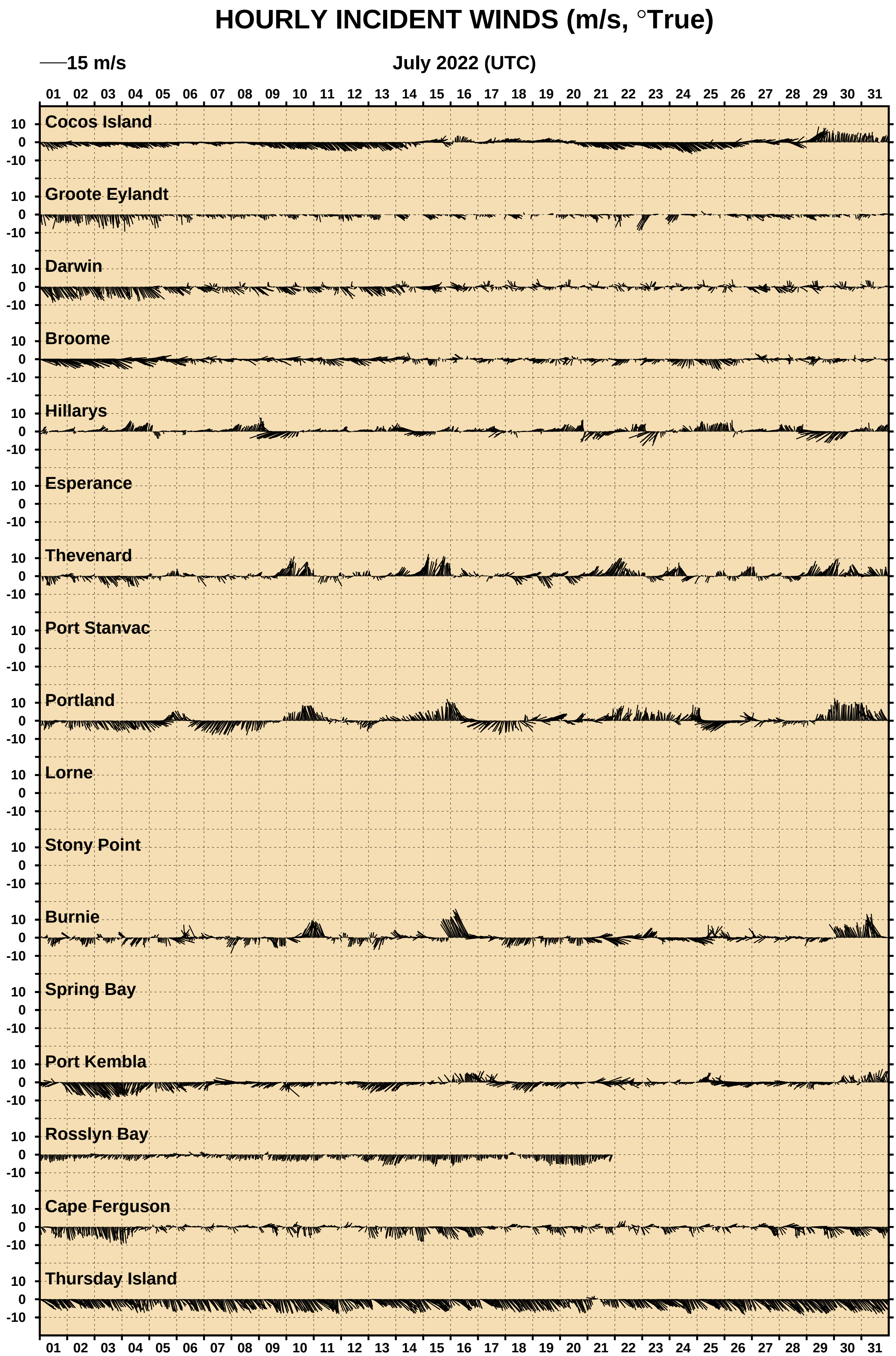


Figure 8. Incident winds during July 2022.

HOURLY AIR TEMPERATURES (°C)

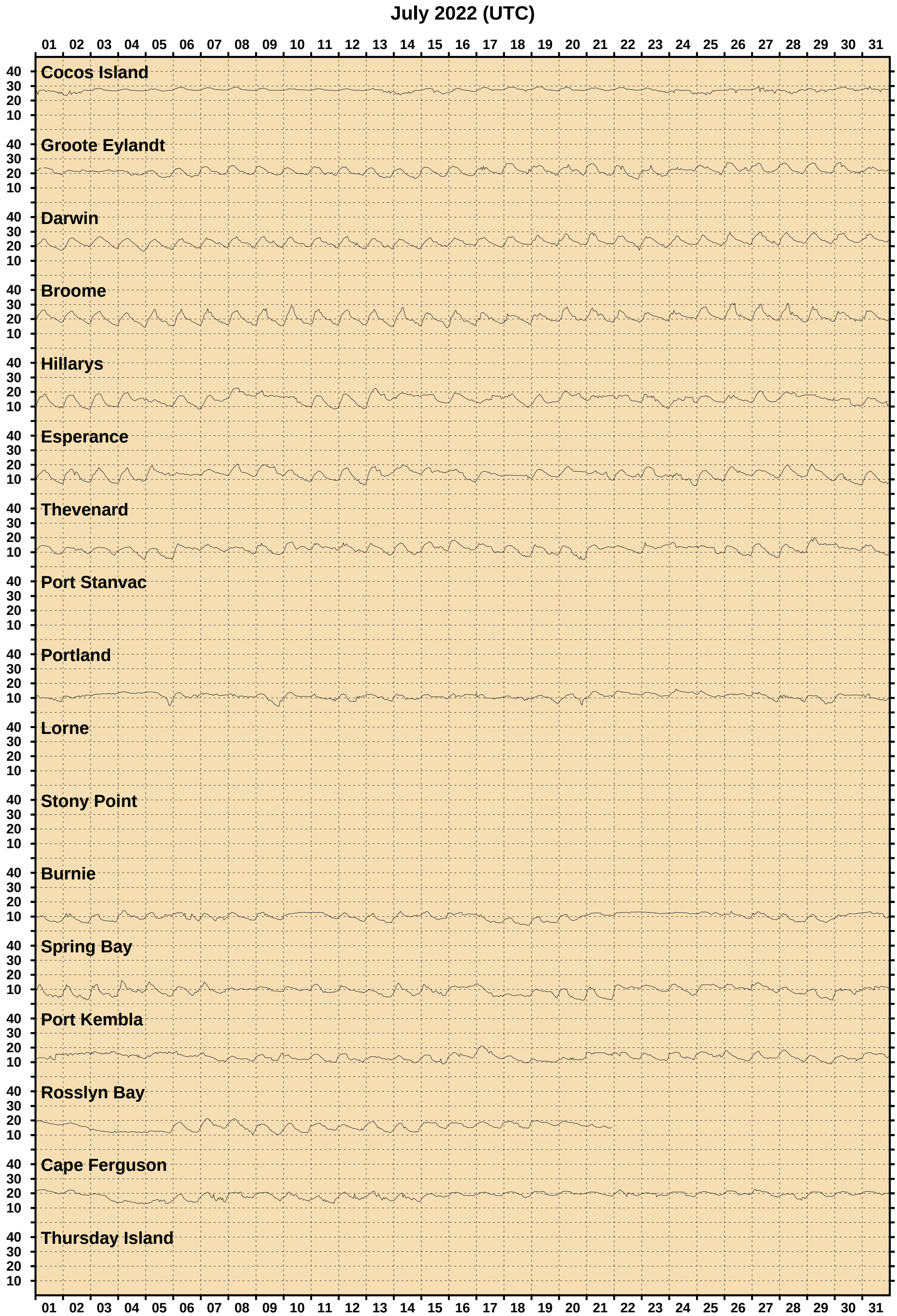


Figure 9. Air temperatures during July 2022.

HOURLY WATER TEMPERATURES (°C)

Figure 10. Water temperatures during July 2022.

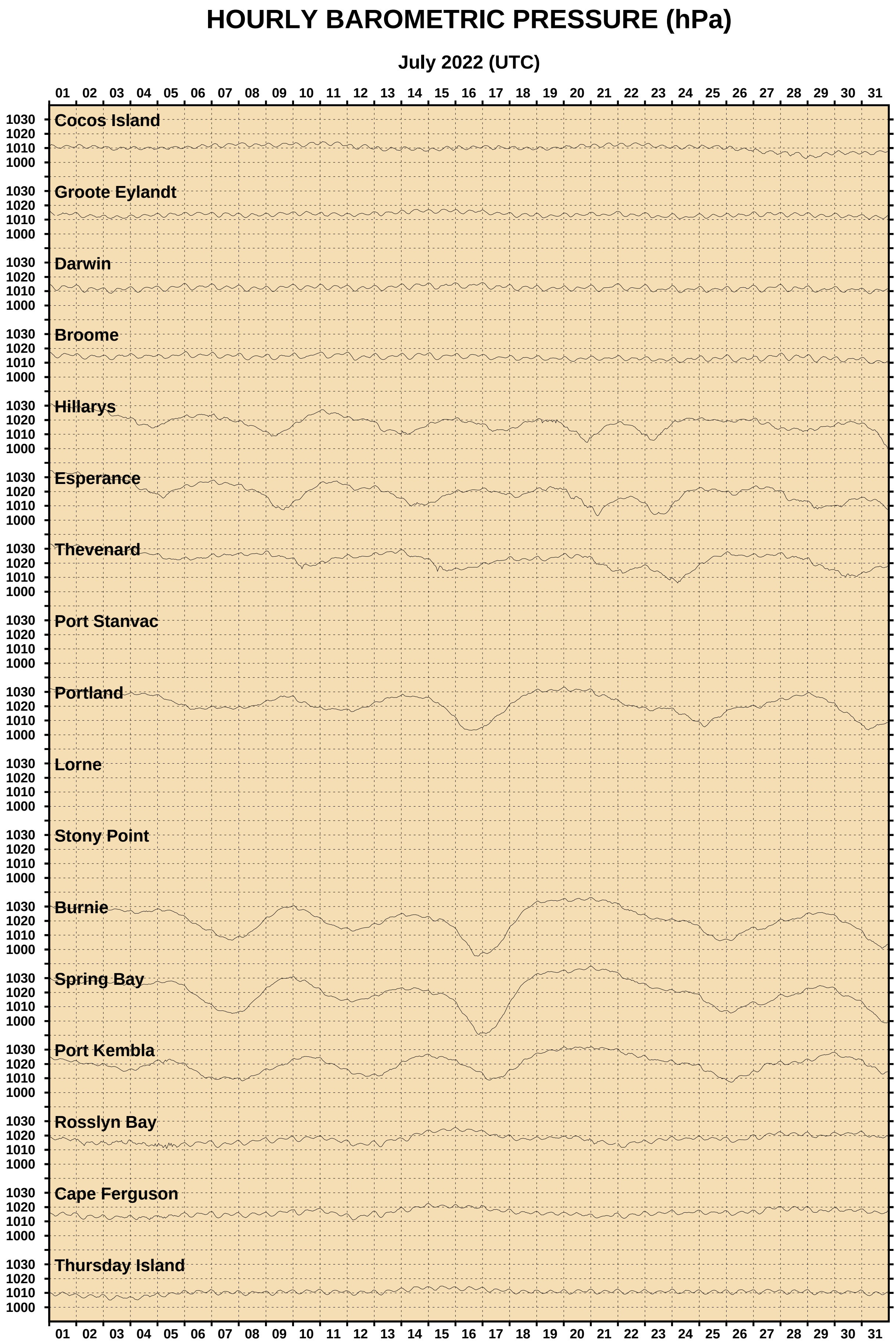
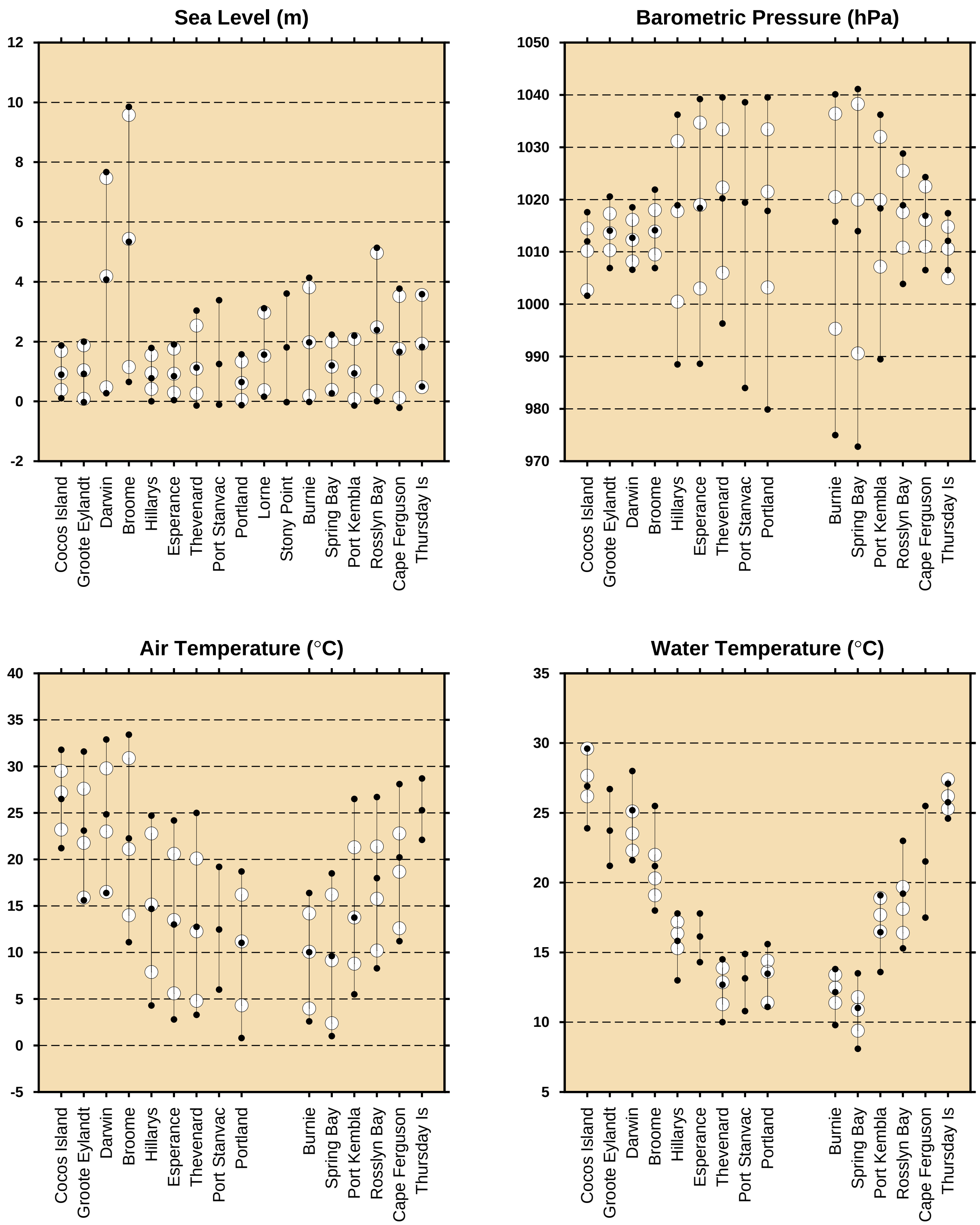


Figure 11. Barometric pressures during July 2022.

COMPARISON OF JULY 2022 MAX,MIN AND MEAN WITH LONG-TERM JULY VALUES



July 2022 Maximum
July 2022 Mean
July 2022 Minimum

Long-term July Maximum
Long-term July Mean
Long-term July Minimum

Figure 12. Comparison of July 2022 data with long-term July values.

MONTHLY MEAN SEA LEVELS THROUGH JULY 2022 (m)
(The zero line represents mean sea level)

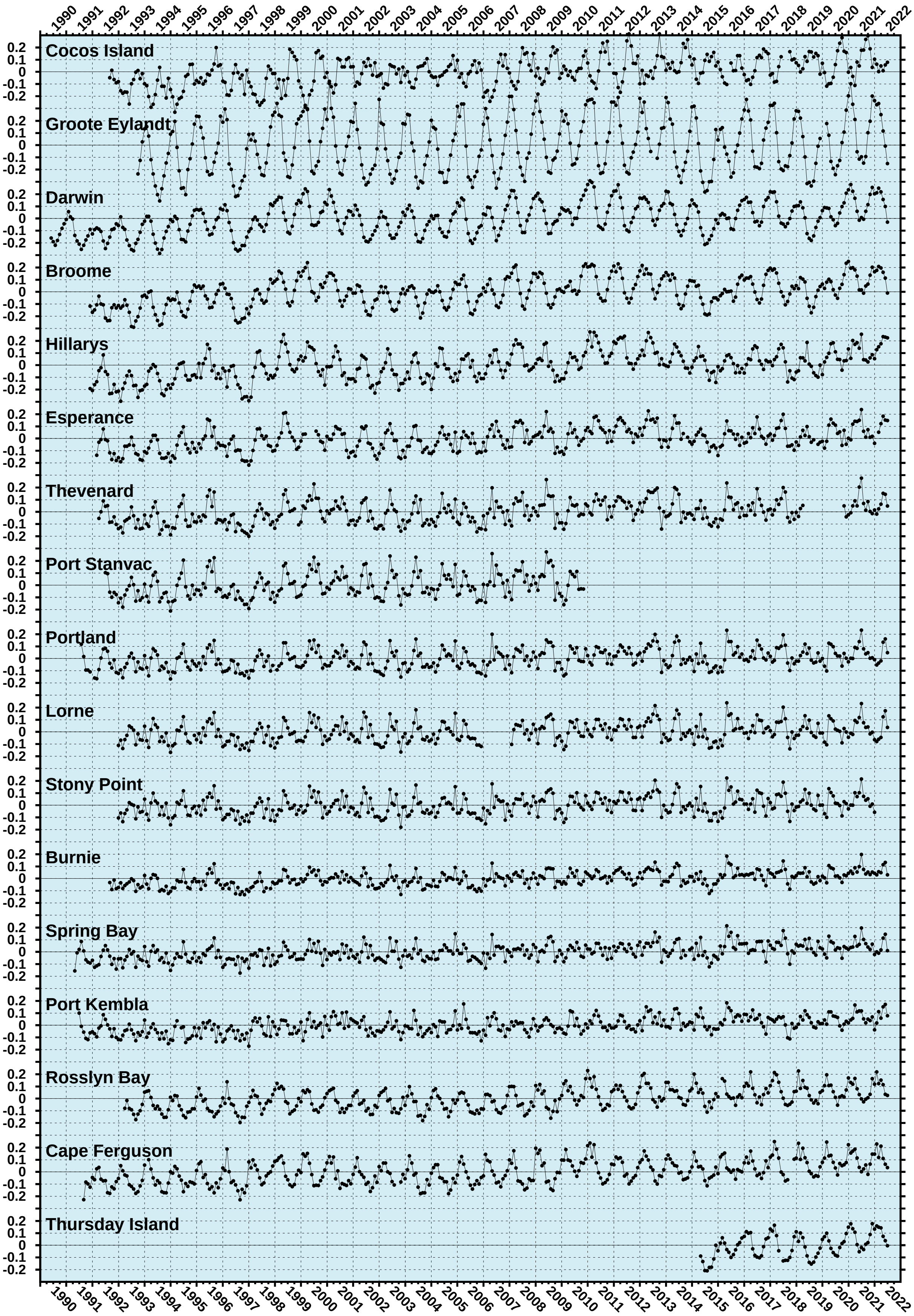


Figure 13. Monthly mean sea levels to July 2022.

MONTHLY MEAN BAROMETRIC PRESSURES THROUGH JULY 2022 (hPa)

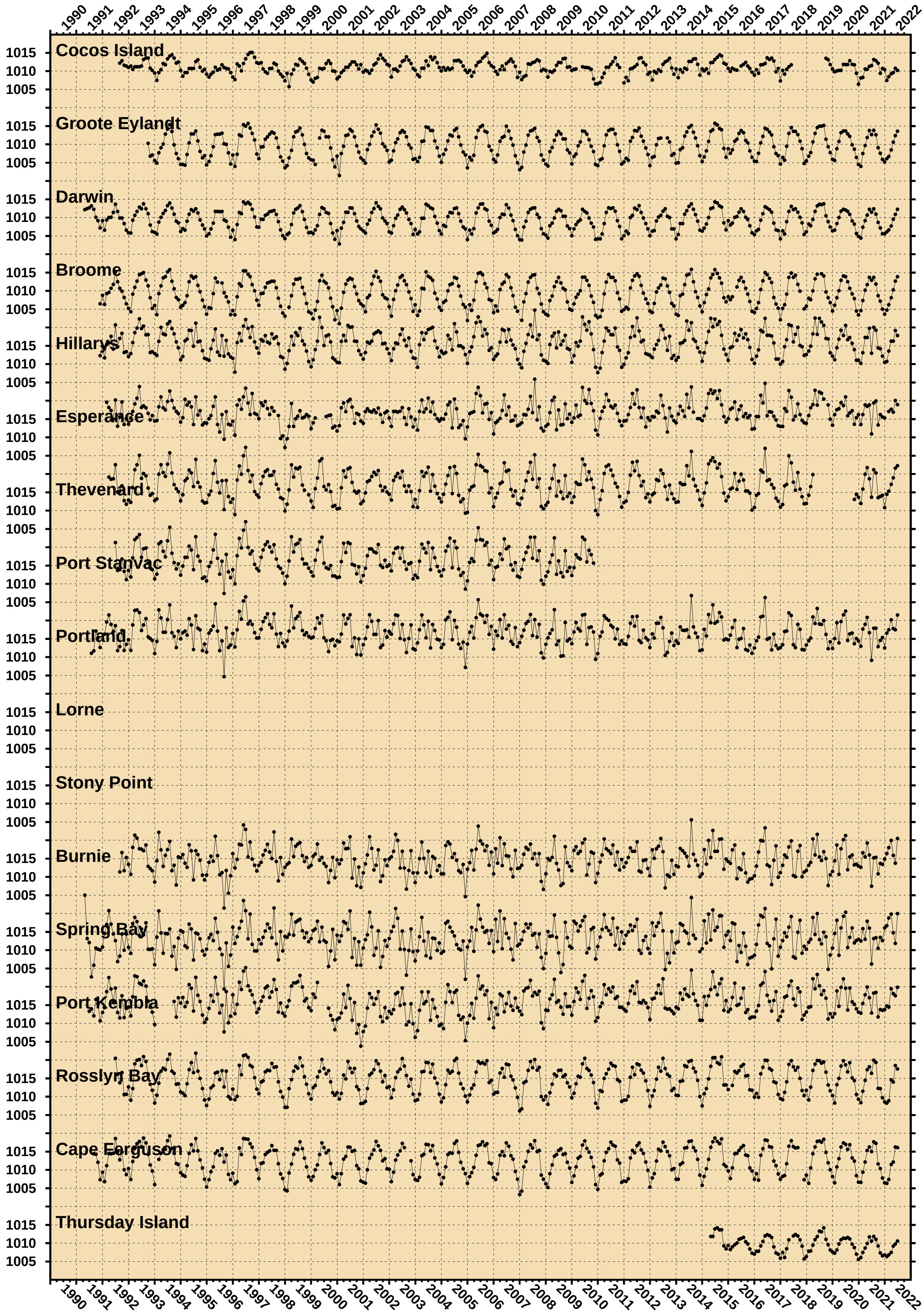


Figure 14. Monthly mean barometric pressures to July 2022.

MONTHLY MEAN WATER TEMPERATURES THROUGH JULY 2022 (°C)

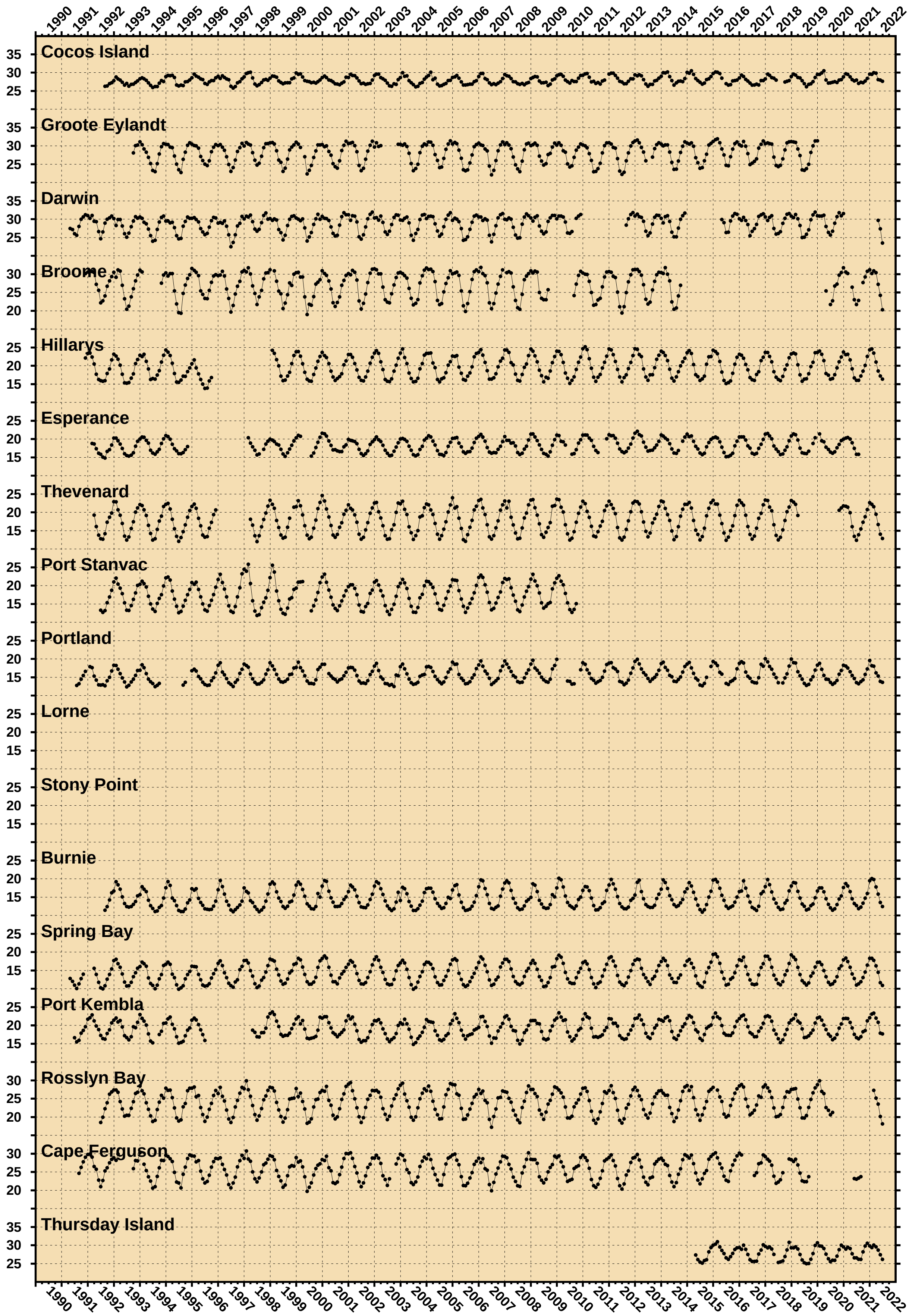


Figure 15. Monthly mean water temperatures to July 2022.

MONTHLY MEAN AIR TEMPERATURES THROUGH JULY 2022 (°C)

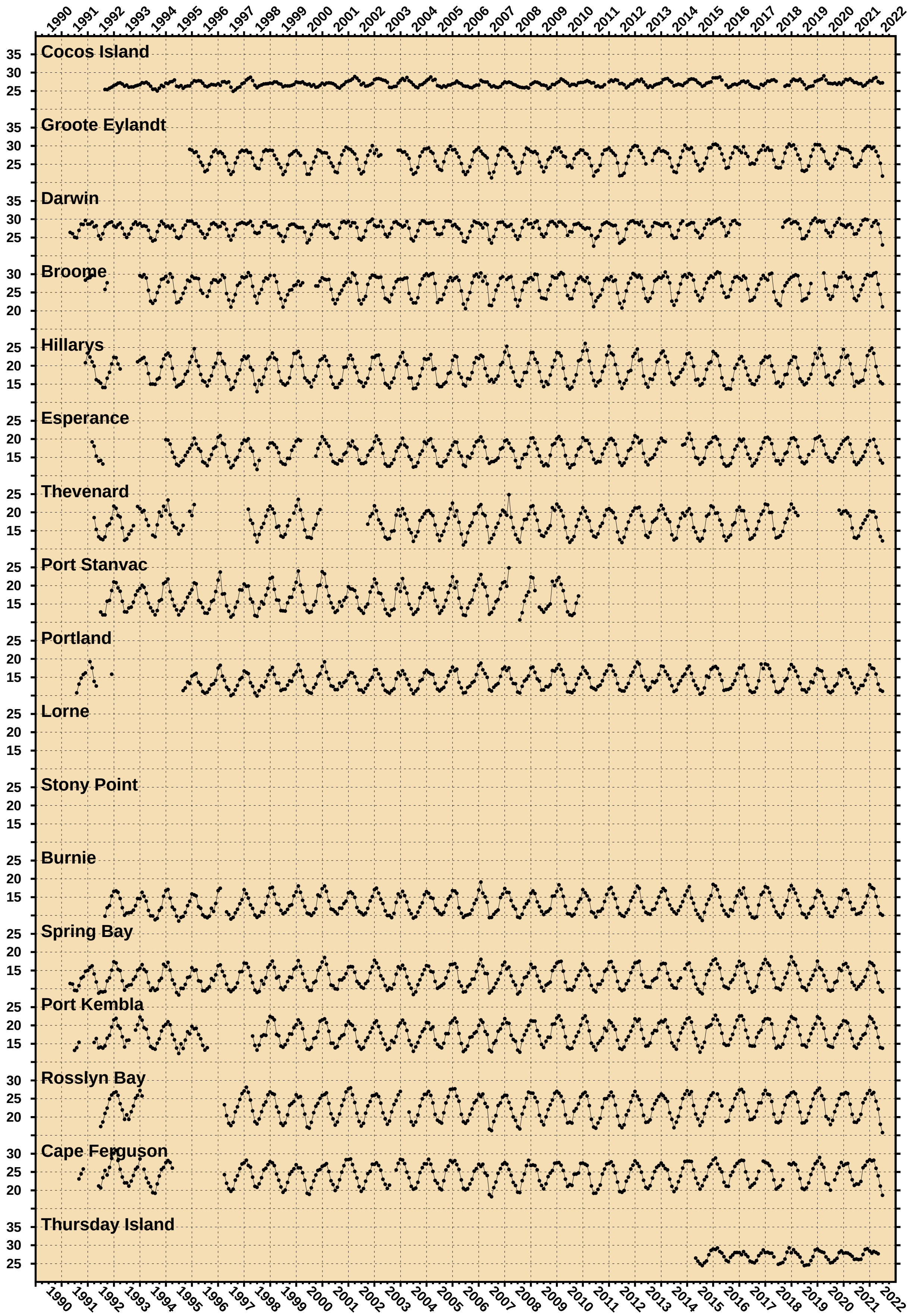


Figure 16. Monthly mean air temperatures to July 2022.

SEA LEVEL ANOMALIES THROUGH JULY 2022 (m)

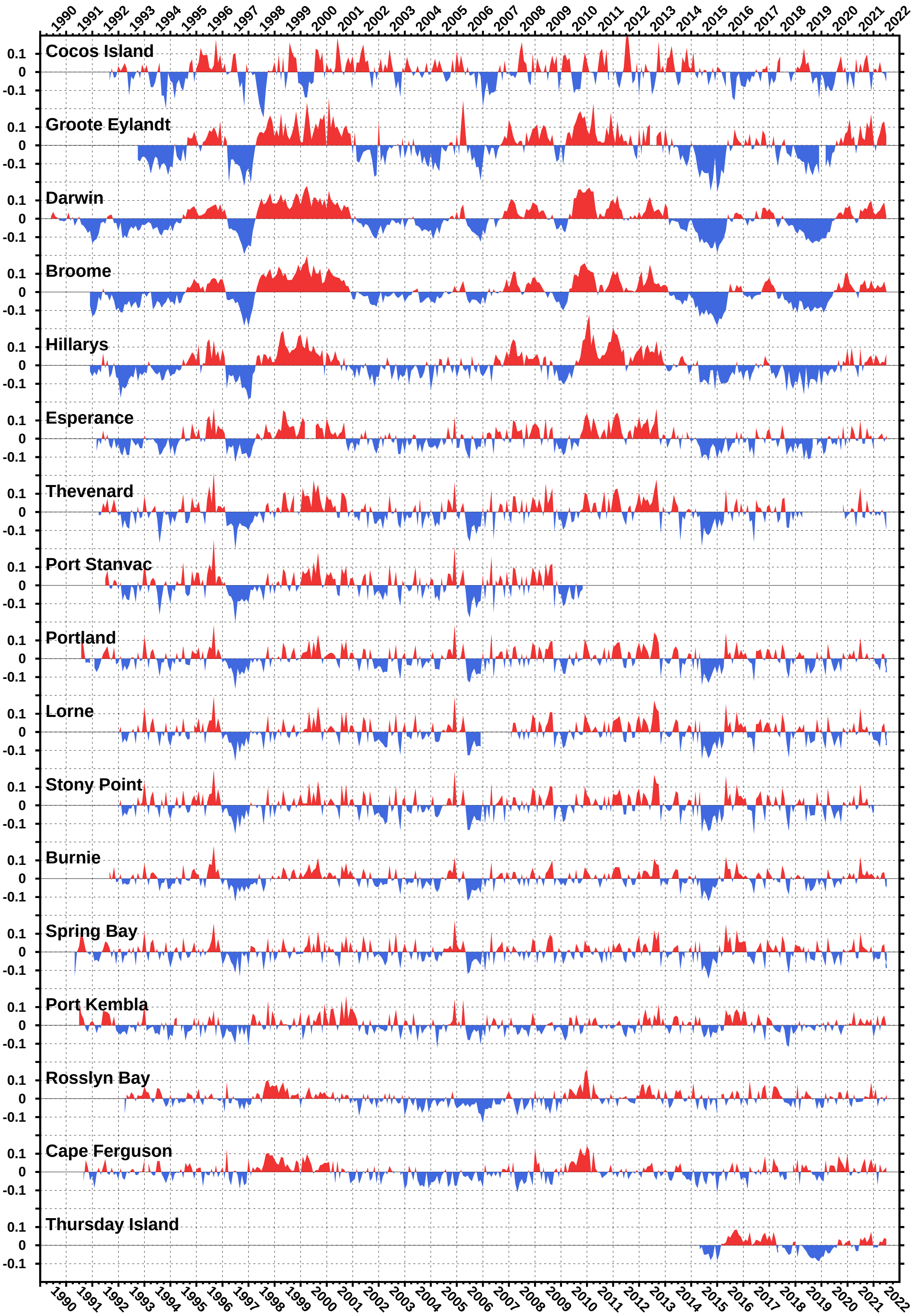


Figure 17. Monthly sea level anomalies to July 2022.

BAROMETRIC PRESSURE ANOMALIES THROUGH JULY 2022 (hPa)

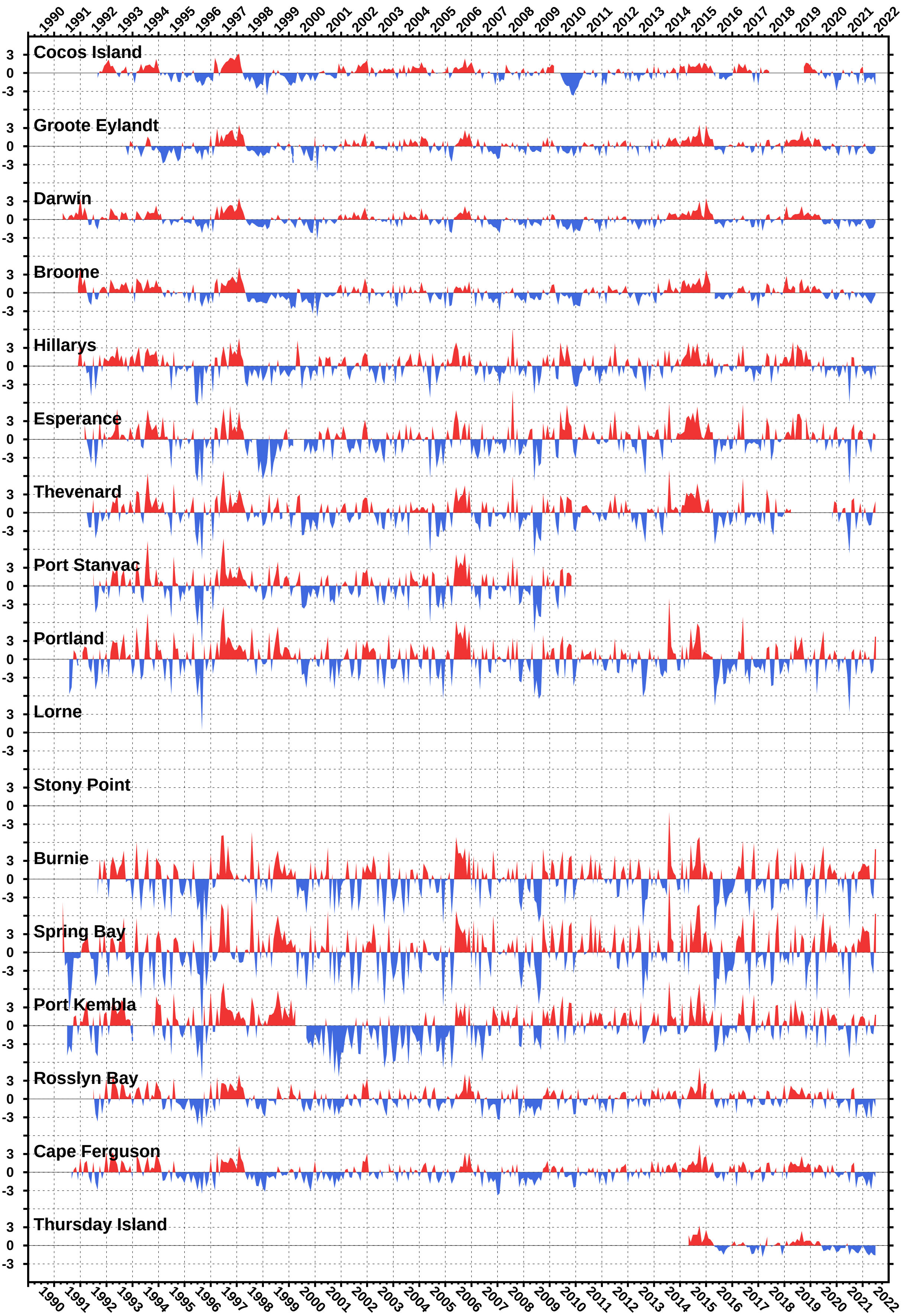


Figure 18. Monthly barometric pressure anomalies to July 2022.

WATER TEMPERATURE ANOMALIES THROUGH JULY 2022 (°C)

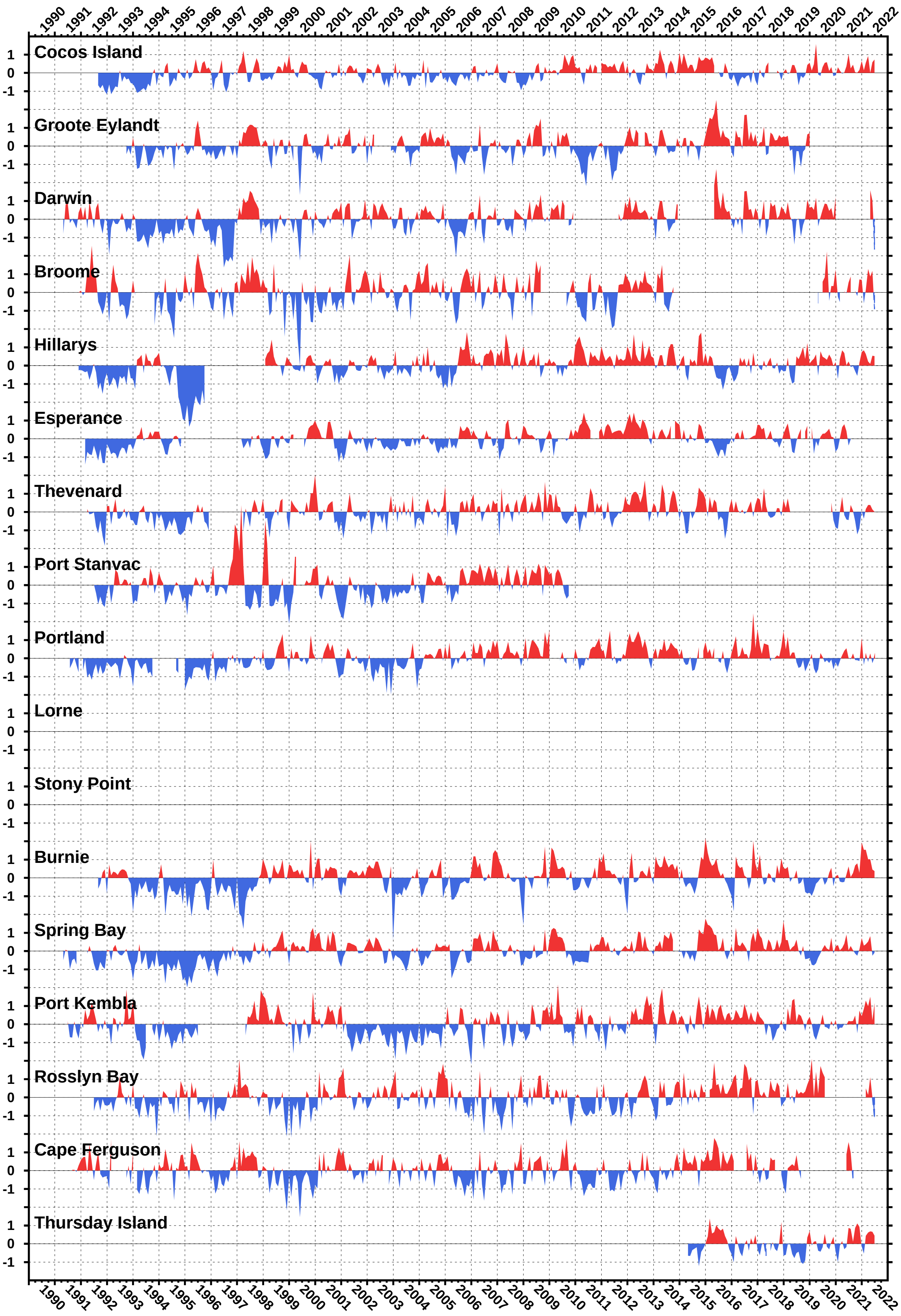


Figure 19. Monthly water temperature anomalies to July 2022.

AIR TEMPERATURE ANOMALIES THROUGH JULY 2022 (°C)

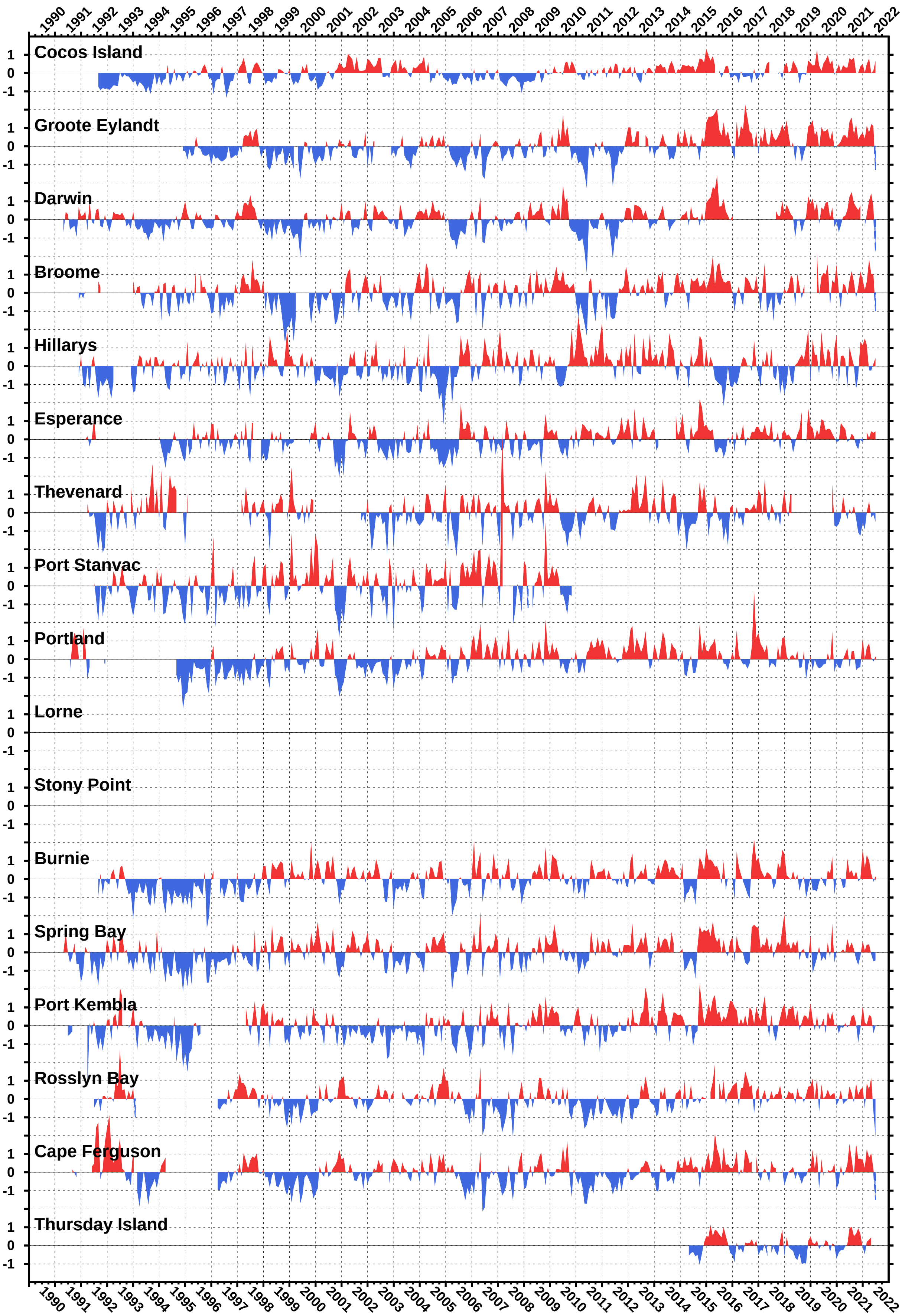


Figure 20. Monthly air temperature anomalies to July 2022.

MONTHLY SEA LEVEL DATA RETURN
THROUGH JULY 2022 (%)

Figure 21. Sea level data return.