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# Monthly Data Report – April 2014

Australian Baseline Sea Level Monitoring Array

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# 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.

**April 2014**

- 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 station at Port Stanvac remains dismantled, while routine workplace-safety power shutdowns continue to be enforced at Broome when fuel tankers are in dock resulting in the loss of approximately 31 hours of data.
- Asbestos removal work conducted at the Broome Port caused the additional loss of about one week's worth of Broome tide gauge data.
- The Cape Ferguson tide gauge was directly passed over by Cyclone Ita on the 13$^{th}$ of April 2014. The site remained operational throughout the storm recording wind gusts of up to 106 km/h with storm surges up to 68.5 cm.
- The Cape Ferguson tide gauge experienced a power systems failure resulting in the loss of data between the 2$^{nd}$ and the 7$^{th}$ days of the month. This outage was unrelated to the passage of Cyclone Ita.
- Significant Sea Level anomalies were observed at Cocos Islands, Darwin, Broome and Hillarys.
- A new record April maximum air temperature of 32.6 °C was observed at Portland, while Port Kembla registered a new April maximum water temperature of 18.6 °C. Related to the passage of Cyclone Ita, Cape Ferguson observed a new record April minimum barometric pressure of 996.5 hPa.

# Introduction

Welcome to the April 2014 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 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 14 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 the SEAFRAME station at Port Stanvac is dependent on longer-term decisions relating to the future of the wharf.

The standard SEAFRAME stations not only measure sea level, but also observe a number of "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) Permanent Committee on Tides & Mean Sea Level (PCTMSL), 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.

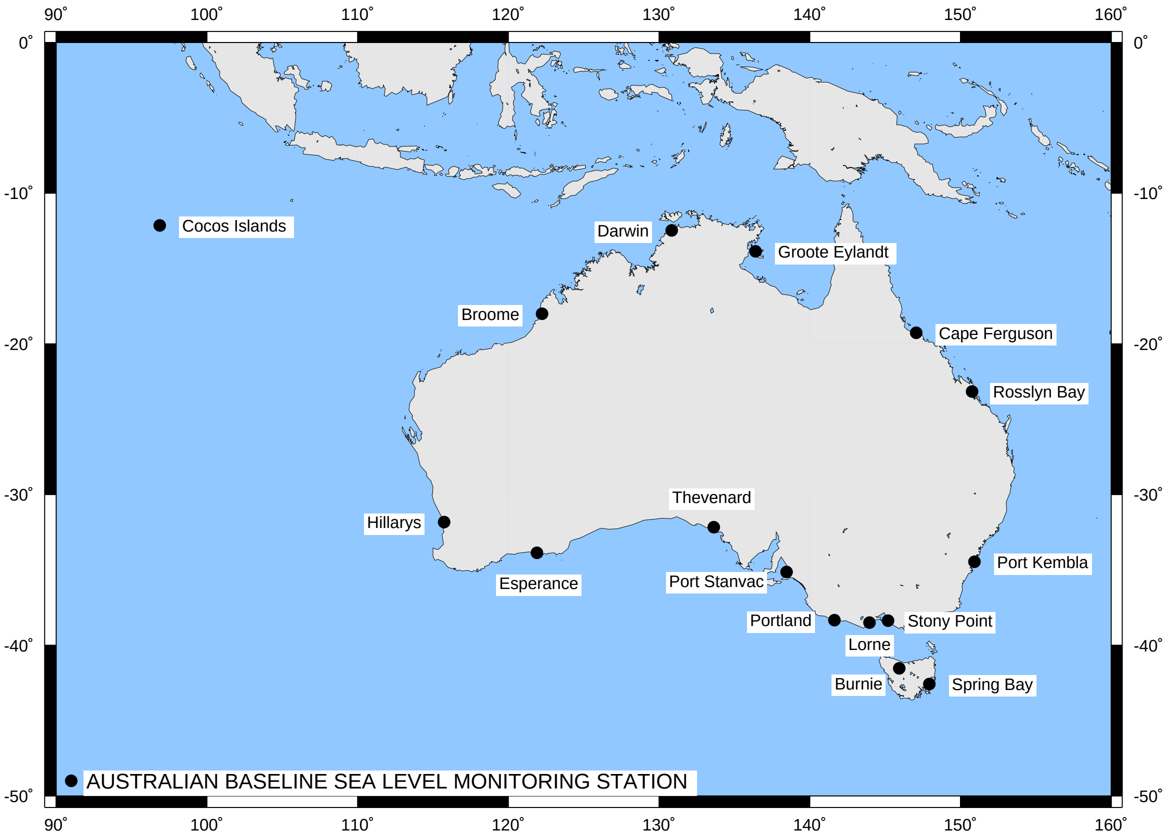


**Figure 1. Australian Baseline Sea Level Monitoring Network of SEAFRAME stations.**

# 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/

# April 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. During April 2014 a full moon fell on the 15th whilst the new moon fell on the 29th.

Additionally this month a total lunar eclipse occurred on the 15th while an annular solar eclipse that was visible in Australia occurred on the 29th. Theoretically these astronomical events do have an impact on the size of the tides observed in that the two gravitational effects that give rise to tides are relatively more in unison than in opposition, however it is stressed that this impact is minimal and usually less than the day to day natural variability.

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. A prime example of this occurred this month at Cape Ferguson. At 00:00 UTC on the 13th of April 2014 Cyclone Ita passed directly over the tide gauge. With the exception of the backup Druck sea level pressure sensor, the site operated correctly throughout the storm providing the Bureau of Meteorology with a rare set of measurements of the meteorology inside the eye of a cyclone, and rarer still, these measurements included that of the coastal sea level. Wind gusts peaked at 29.3 m/s (106 km/h) before dying off to absolute calm at 00:07 UTC inside the eye of the storm. After the eye passed the winds returned to a maximum gust of 17.5 m/s (63 km/h) and were impinging from the opposite direction to those before the eye. The storm surge swept up by Cyclone Ita peaked with a residual of +68.5 cm at around 23:00 UTC on the 12th, just at the leading edge of the eye as it passed over the tide gauge.

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, 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). However, as Cape Ferguson demonstrated this month, winds and fast fluctuations can also have a profound effect on sea level residuals. This evidenced by how the maximum storm surge attained during the cyclone was a residual of +68.5 cm, yet the inverse barometer effect only accounted for 16.7 cm of this.

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 Thevenard prevailed from the southeast between the 9th and 15th days inclusive of this month.

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.

During this month there was, not surprisingly, a substantial revision to the April minimum barometric pressure at Cape Ferguson, which recorded a low of 996.5 hPa, down from the previous long-term April record of 1002.3 hPa. A new April maximum water temperature was recorded at Portland of 32.6 °C while Spring Bay recorded a new April maximum air temperature of 18.6 °C. Curiously enough, there was no new record April maximum or minimum sea level this month at any ABSLMA tide gauge. The maximum sea level at Cape Ferguson still fell short of its current April maximum of 3.77 m by 30 cm. Cyclone Ita passed over Cape Ferguson approximately two hours after the predicted high tide.

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

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.

The sea level anomalies for April 2014 persist to be negative for all locations except Cocos Island (+12.6 cm). Notable negative sea level anomalies were along the north-west coast of Australia with -0.5 cm at Darwin, -7.4 cm at Broome and -7.5 cm at Hillarys.

The anomalies of barometric pressure, water and air temperature are determined in the same manner as the sea level anomalies, except the linear slope is not calculated.

The barometric pressure anomalies (Figure 18) show higher than normal barometric pressures were observed at SEAFRAME stations during the 1997/98 El Niño. For April 2014 negative barometric pressure anomalies between 0 and -2.5 hPa were observed at all sites.

Every ABSLMA station recorded a positive water temperature anomaly, with most exceeding 0.5 °C. Four sites recorded water temperature anomalies exceeding 1.0 °C, being Cocos Islands (1.4 °C), Darwin (1.1 °C), Port Kembla (1.5 °C) and Rosslyn Bay (1.1 °C). Air temperature anomalies were positive at all sites, except at Esperance which recorded -1.7 °C. However these were surprisingly lower in magnitude relative to the water temperature anomalies. Only one significant positive air temperature anomaly was observed this month, being at Port Kembla with +1.0 °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 many of the sites, the underlying data sets now exceed twenty years in length.

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.

Please exercise caution in interpreting the overall rates of movement of sea level – the records are too short to be inferring long-term trends.

**Table 1. Updated overall rates of sea level movement based on SEAFRAME data from installation through April, 2014.**

| 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 | 8.5 | 0.1 |
| Groote Eylandt | 13°51'36.2"S | 136°24'56.1"E | Sep 1993 | 8.6 | 0.0 |
| Darwin | 12°28'18.4"S | 130°50'45.1"E | May 1990 | 8.7 | 0.0 |
| Broome | 18°00'03.0"S | 122°13'07.1"E | Nov 1991 | 9.3 | -0.1 |
| Hillarys | 31°49'32.0"S | 115°44'18.9"E | Nov 1991 | 10.1 | -0.1 |
| Esperance | 33°52'15.2"S | 121°53'43.3"E | Mar 1992 | 6.9 | 0.0 |
| Thevenard | 32°08'56.2"S | 133°38'28.8"E | Mar 1992 | 5.5 | 0.0 |
| 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 | 3.8 | 0.0 |
| Lorne | 38°32'49.4"S | 143°59'19.8"E | Jan 1993 | 3.5 | 0.0 |
| Stony Point | 38°22'19.7"S | 145°13'28.9"E | Jan 1993 | 3.4 | 0.0 |
| Burnie | 41°03'0.3"S | 145°54'54.0"E | Sep 1992 | 3.5 | 0.0 |
| Spring Bay | 42°32'45.1"S | 147°55'57.8"E | May 1991 | 3.8 | 0.0 |
| Port Kembla | 34°28'25.5"S | 150°54'42.7"E | Jul 1991 | 3.4 | 0.0 |
| Rosslyn Bay | 23°09'39.7"S | 150°47'24.6"E | Jun 1992 | 4.5 | 0.0 |
| Cape Ferguson | 19°16'38.4"S | 147°03'30.4"E | Sep 1991 | 4.7 | 0.0 |

[1]Relative to SSBM (SEAFRAME Sensor Bench Mark)
[2]Port Stanvac decommissioned November 2010

## 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 network was 97.0% (91.0% including Pt Stanvac) during April 2014 (Table 2). As mentioned previously, no data has been collected from Port Stanvac since November 2010 following the removal of the station to allow Mobil Refining Australia to rehabilitate and vacate the Port Stanvac oil refinery precinct. The Broome Port Authority's policy of switching off the power when fuel ships are in dock resulted in the loss of approximately 31 hours of data at Broome this month. Additionally there was some asbestos removal being undertaken at the Broome port which required the Broome tide gauge to be offline for a further 7 days and 4 hours. No site experienced an outage for routine maintenance this month; however Cape Ferguson did experience a power systems failure resulting in it being offline between roughly 08:00 UTC on the 2nd through to 05:00 UTC on the 7th whereupon it was fixed by a local technician. This outage was unrelated to the passage of Cyclone Ita.

The anemometers at Groote Eylandt and Esperance continued to be switched off during the month of April as they have not yet been repaired.

### Table 2. Rates of sea level data return.

| Location | Installation Date | Data Return Since Installation (%) | Data Return in April 2014 (%) |
|---|---|---|---|
| Cocos Islands | Sep 1992 | 99.5 | 100 |
| Groote Eylandt | Sep 1993 | 98.7 | 100 |
| Darwin | May 1990 | 99.8 | 100 |
| Broome | Nov 1991 | 97.9 | 72.0 |
| Hillarys | Nov 1991 | 99.9 | 100 |
| Esperance | Mar 1992 | 98.0 | 100 |
| Thevenard | Mar 1992 | 99.5 | 100 |
| Port Stanvac[1] | Jun 1992 | 85.2 | 0.0 |
| Portland | Jul 1991 | 99.3 | 100 |
| Lorne | Jan 1993 | 94.4 | 99.9 |
| Stony Point | Jan 1993 | 98.9 | 100 |
| Burnie | Sep 1992 | 98.5 | 100 |
| Spring Bay | May 1991 | 99.7 | 100 |
| Port Kembla | Jul 1991 | 99.5 | 100 |
| Rosslyn Bay | Jun 1992 | 96.3 | 100 |
| Cape Ferguson | Sep 1991 | 98.2 | 83.7 |
| **Network Average** | | **97.7** | **91.0** |

[1]Port Stanvac decommissioned November 2010

# 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.

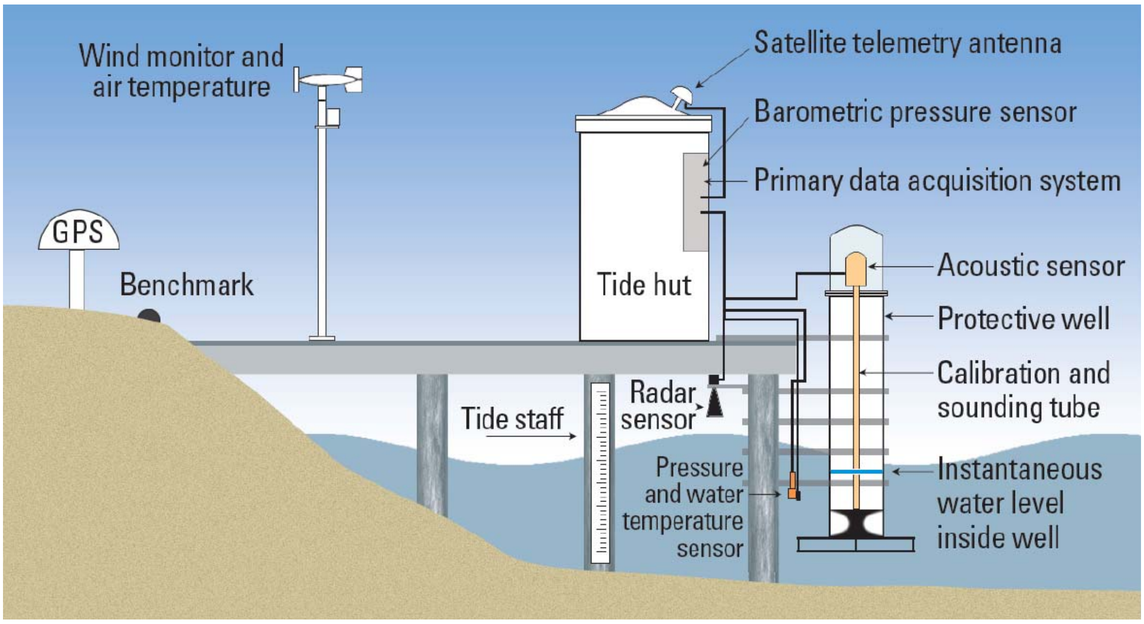


**Figure 2. Schematic diagram of a SEAFRAME sea level monitoring station.**

# Further Information

## Online Resources

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

ABSLMA Levelling Survey (Geosciences Australia): ftp://ftp.ga.gov.au/geodesy-outgoing/local_tie/TideGaugeLeveling/ABSLMA/

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): http://www.cmar.csiro.au/sealevel/index.html

## 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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Kent Town SA 5067
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Email: ntc@bom.gov.au
Website: http://www.bom.gov.au/oceanography/tides.shtml

Please also note the following:

# 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.

## SIX MINUTE SEA LEVEL OBSERVATIONS (m)

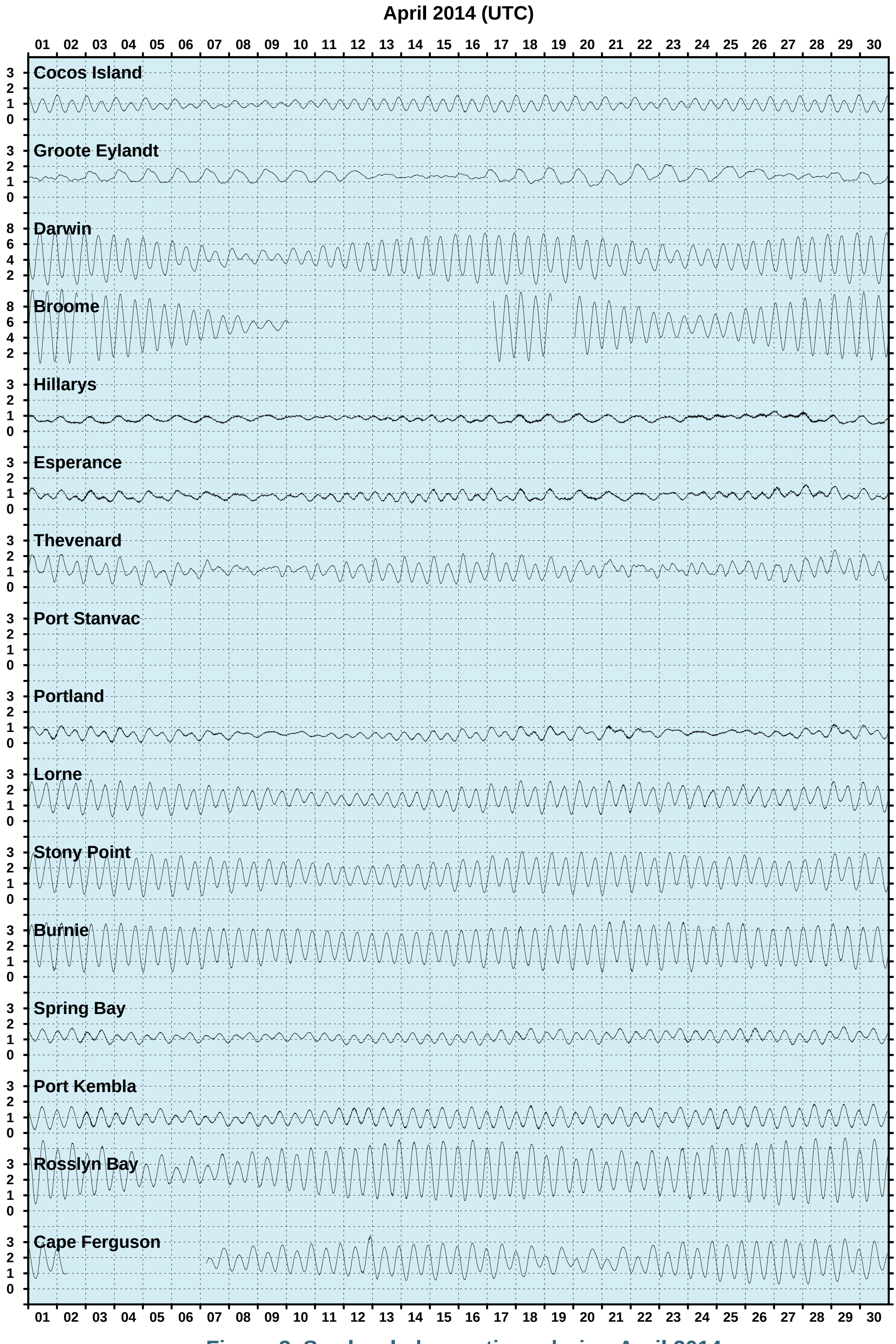


**Figure 3. Sea level observations during April 2014.**

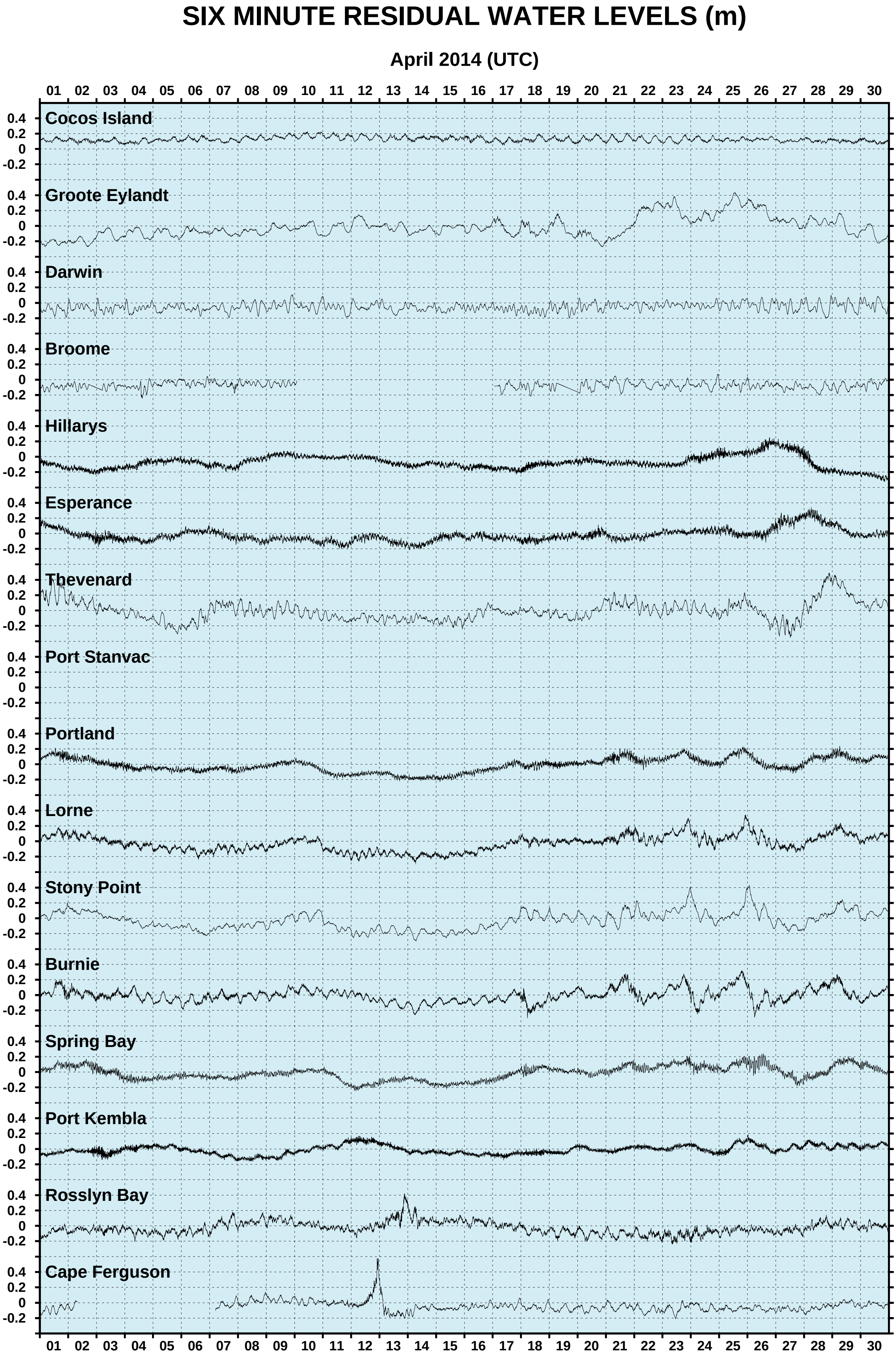


**Figure 4. Residual sea levels during April 2014.**

# SIX MINUTE RESIDUALS
# ADJUSTED FOR BAROMETRIC PRESSURE (m)

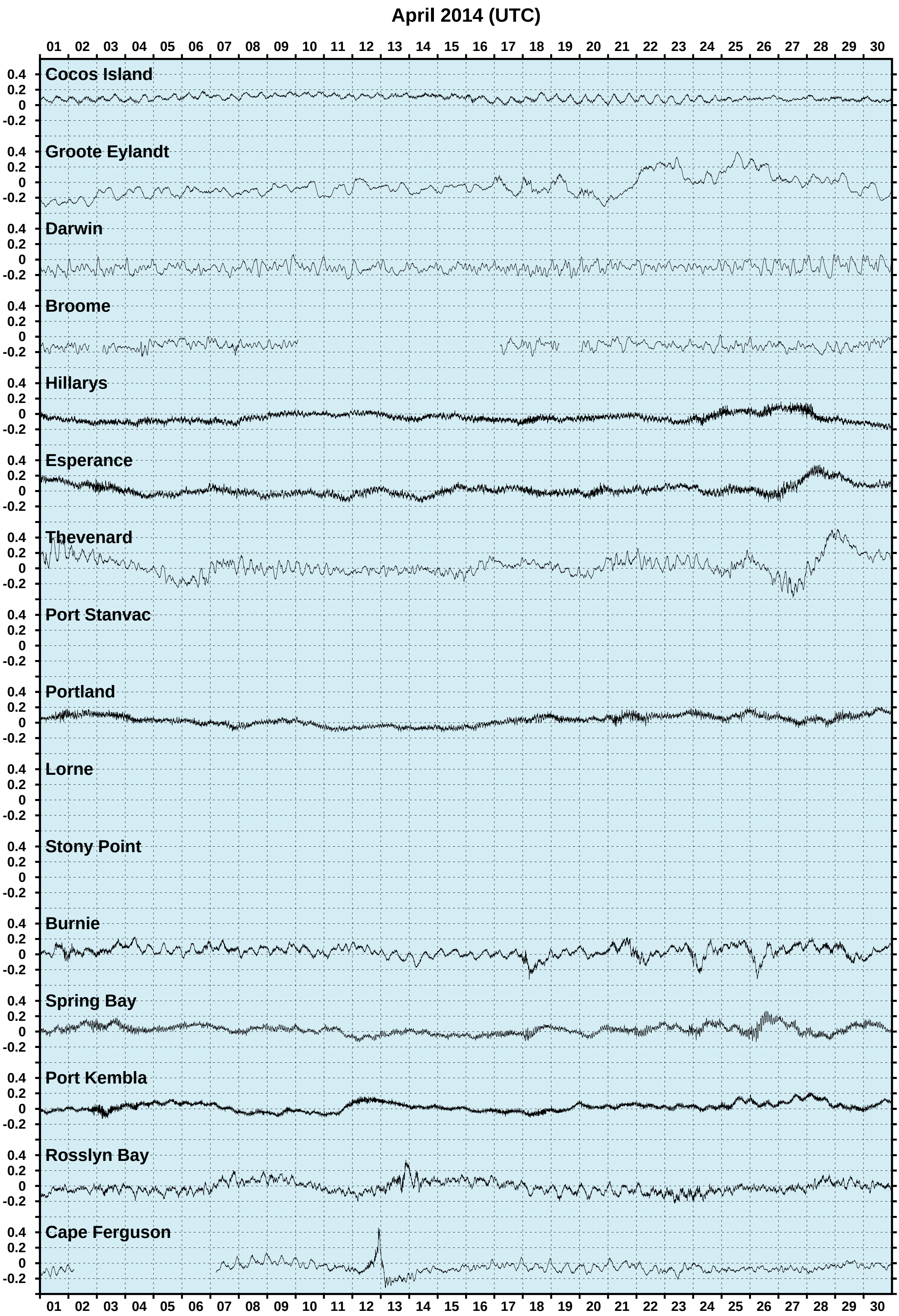


**Figure 5. Residual sea levels adjusted for barometric pressure during April 2014.**

# HOURLY WIND SPEEDS (m/s)

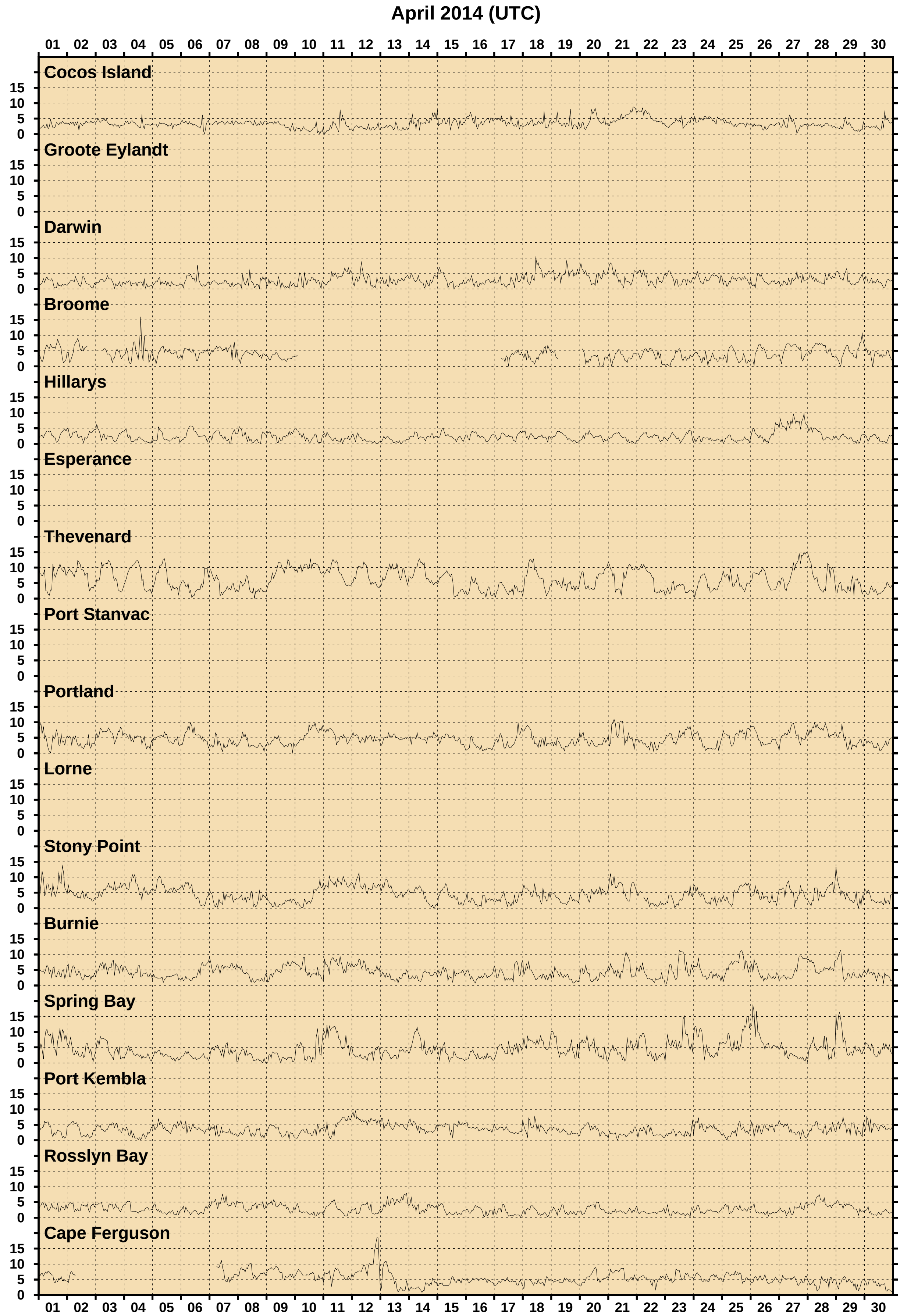


**Figure 6. Wind speeds during April 2014.**

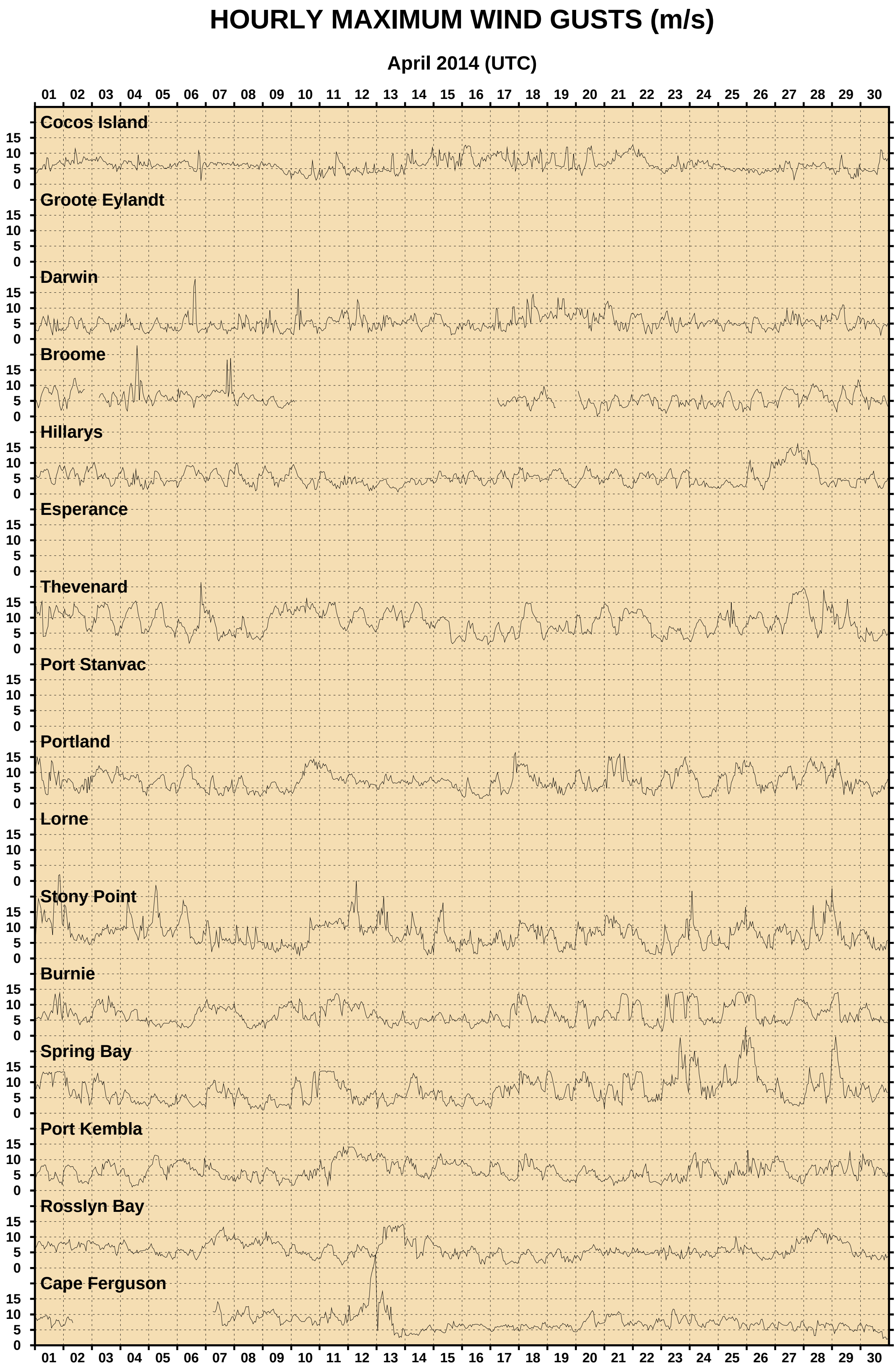


**Figure 7. Wind gusts during April 2014.**

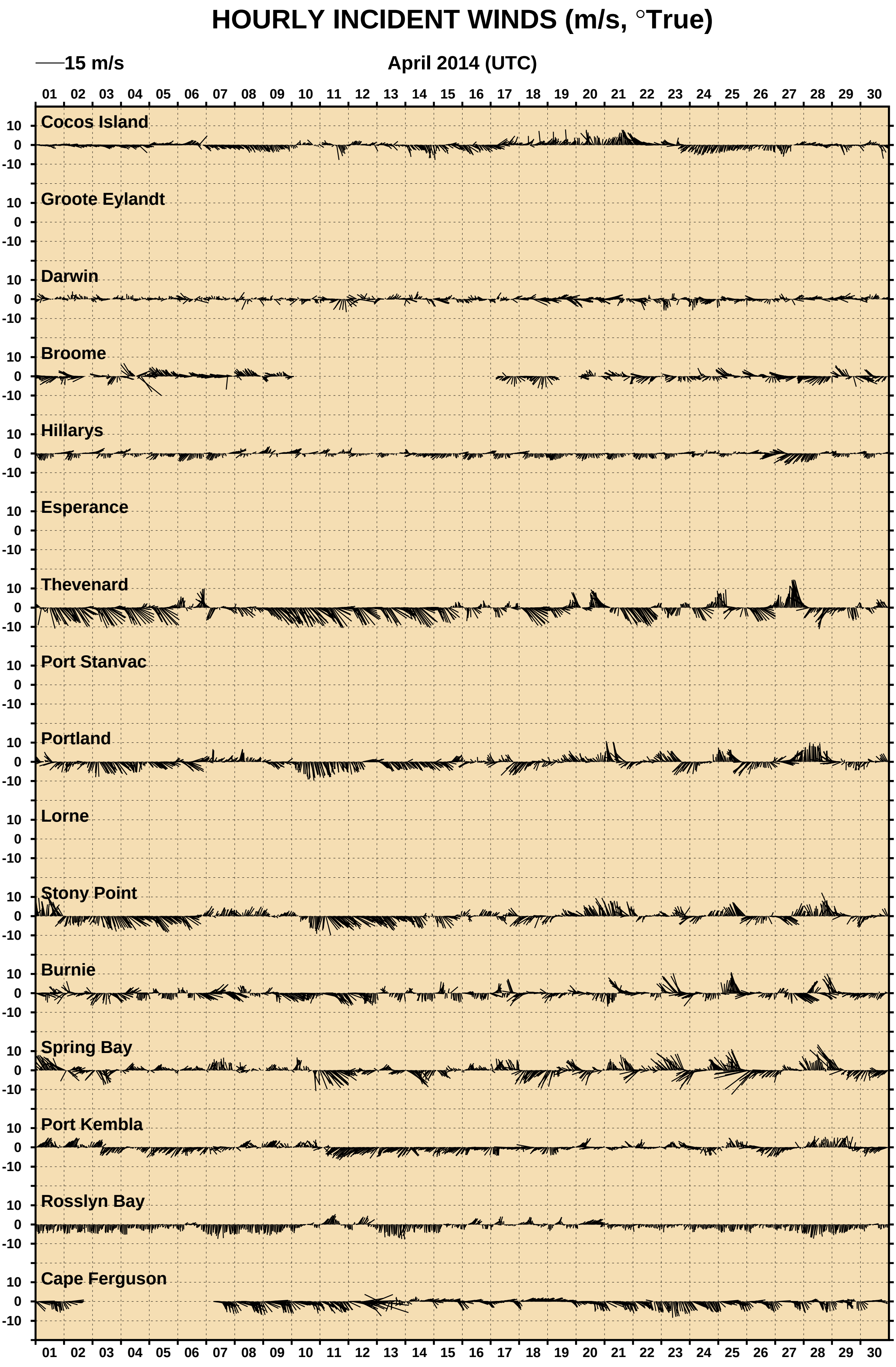


**Figure 8. Incident winds during April 2014.**

# HOURLY AIR TEMPERATURES (°C)

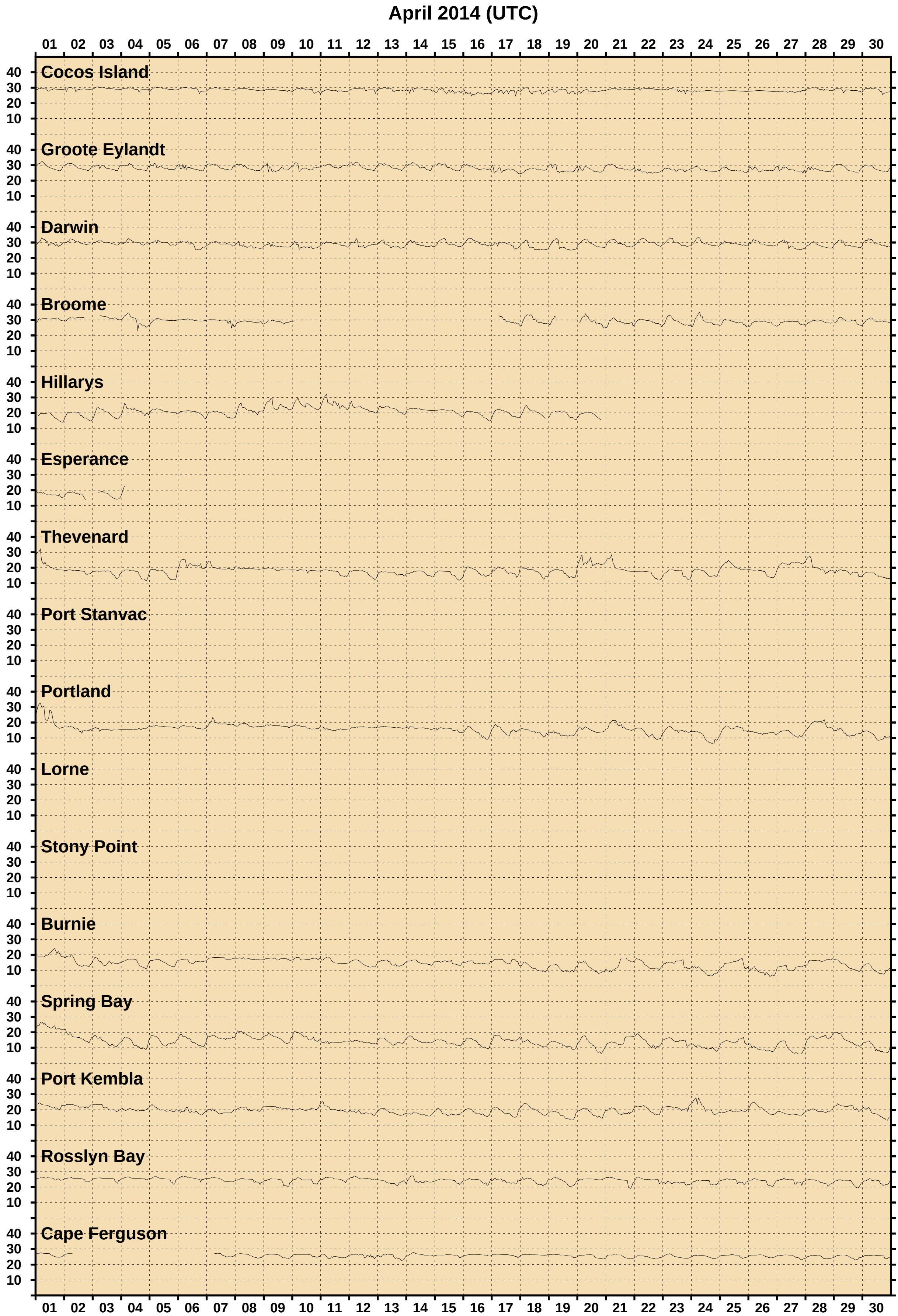


**Figure 9. Air temperatures during April 2014.**


Figure 10. Water temperatures during April 2014.

## HOURLY BAROMETRIC PRESSURE (hPa)

April 2014 (UTC)

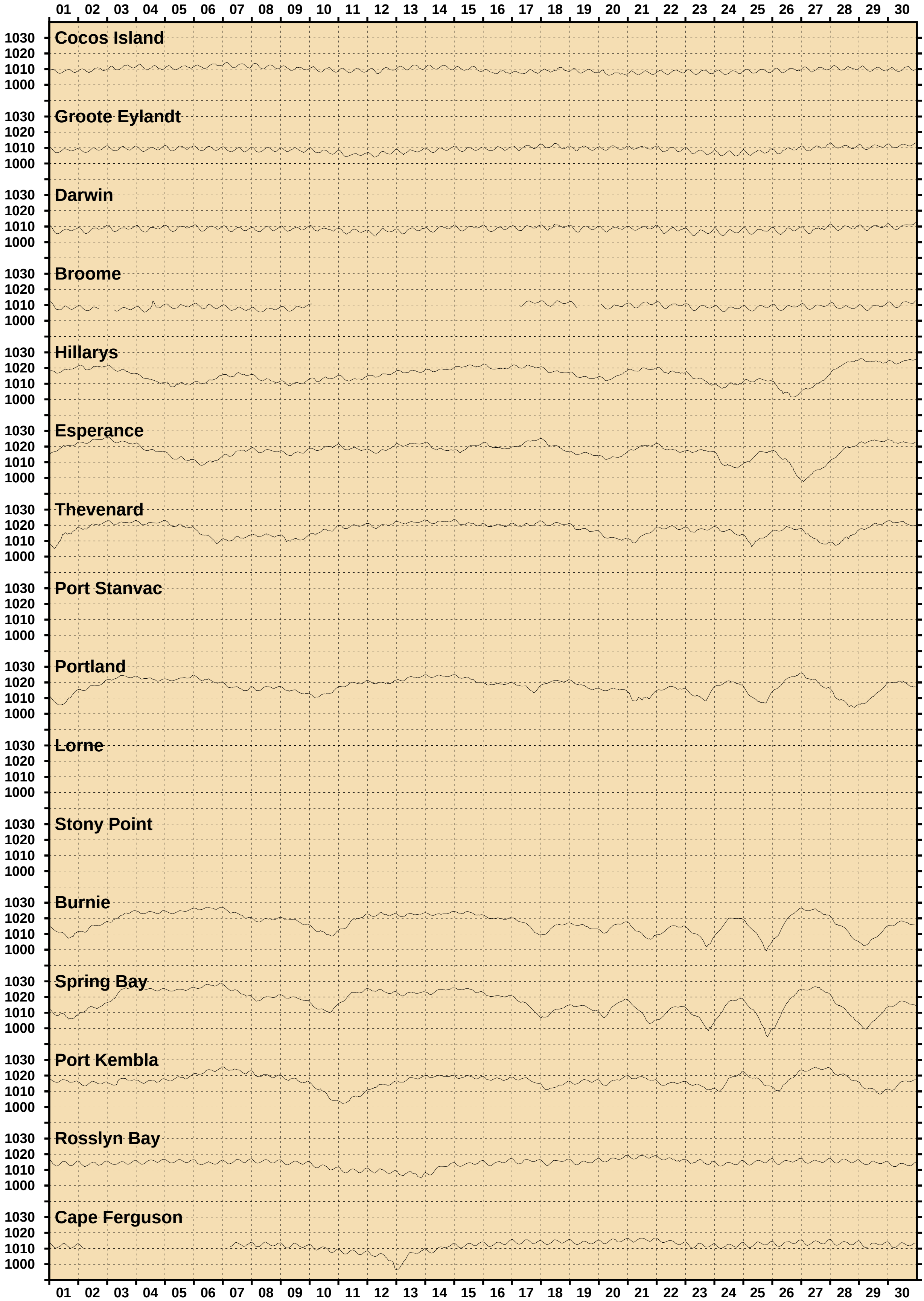


**Figure 11. Barometric pressures during April 2014.**

# COMPARISON OF APRIL 2014 MAX,MIN AND MEAN WITH LONG-TERM APRIL VALUES

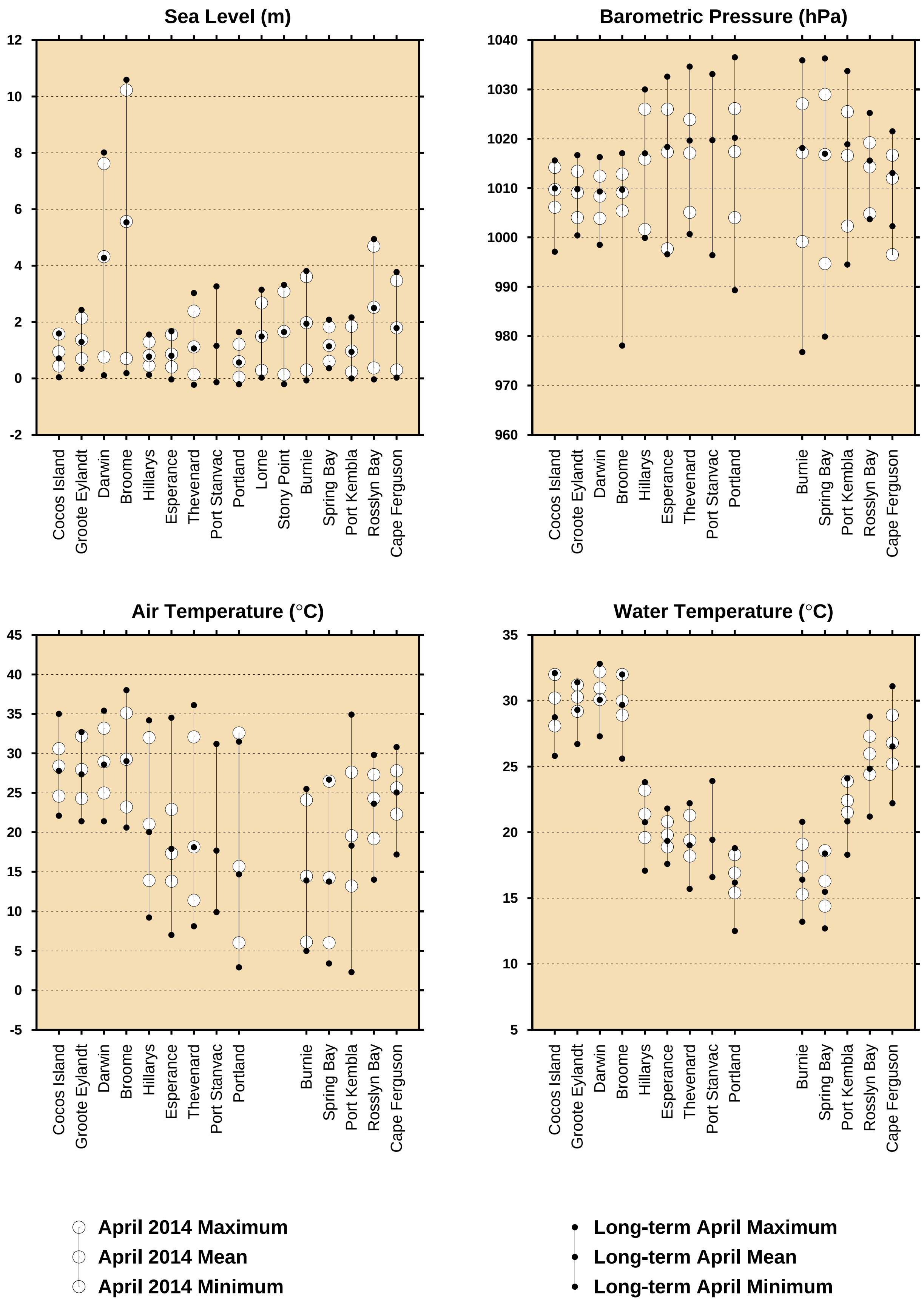


**Figure 12. Comparison of April 2014 data with long-term April values.**

## MONTHLY MEAN SEA LEVELS THROUGH APRIL 2014 (m)
## (The zero line represents mean sea level)

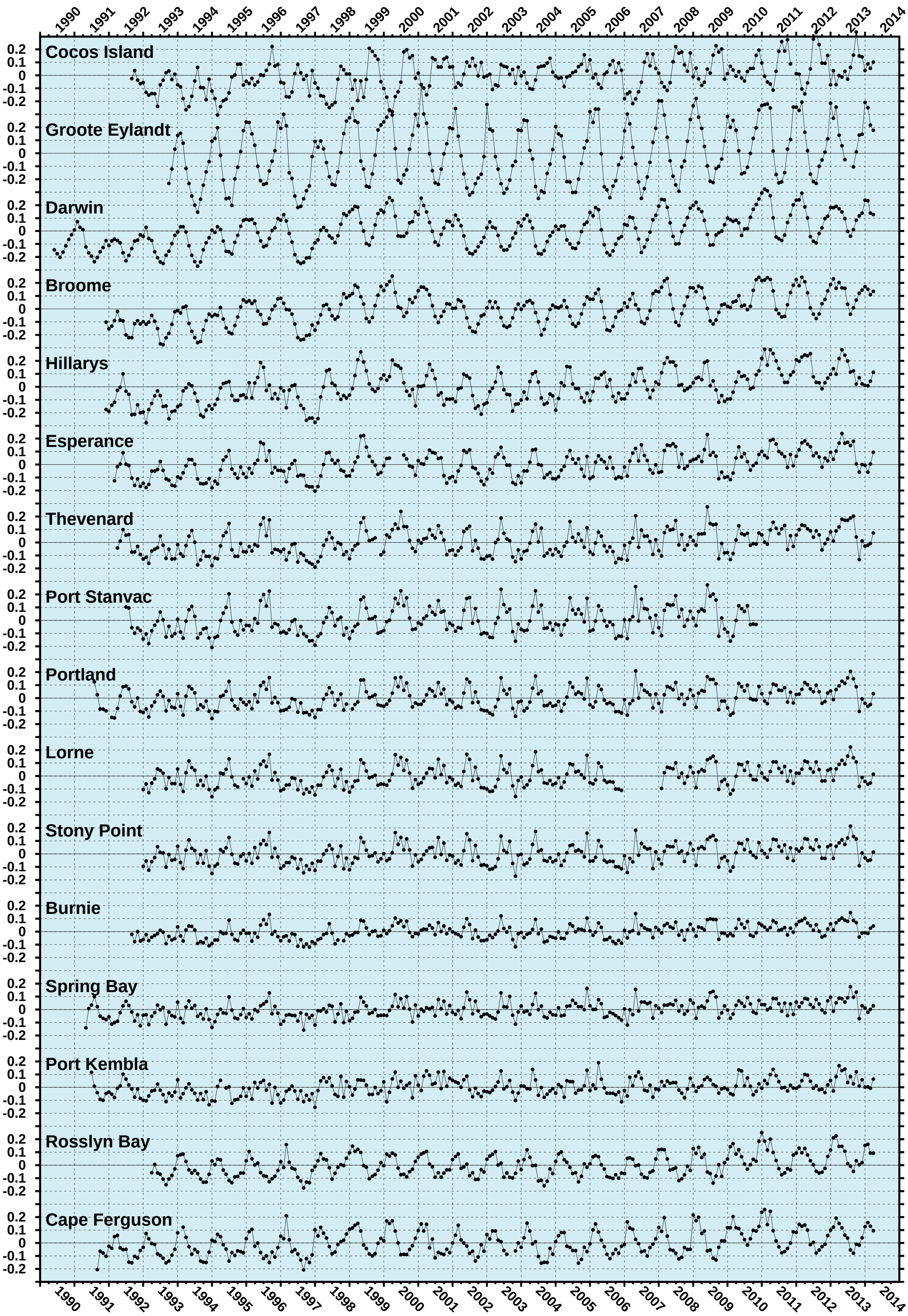


**Figure 13. Monthly mean sea levels to April 2014.**

# MONTHLY MEAN BAROMETRIC PRESSURES THROUGH APRIL 2014 (hPa)

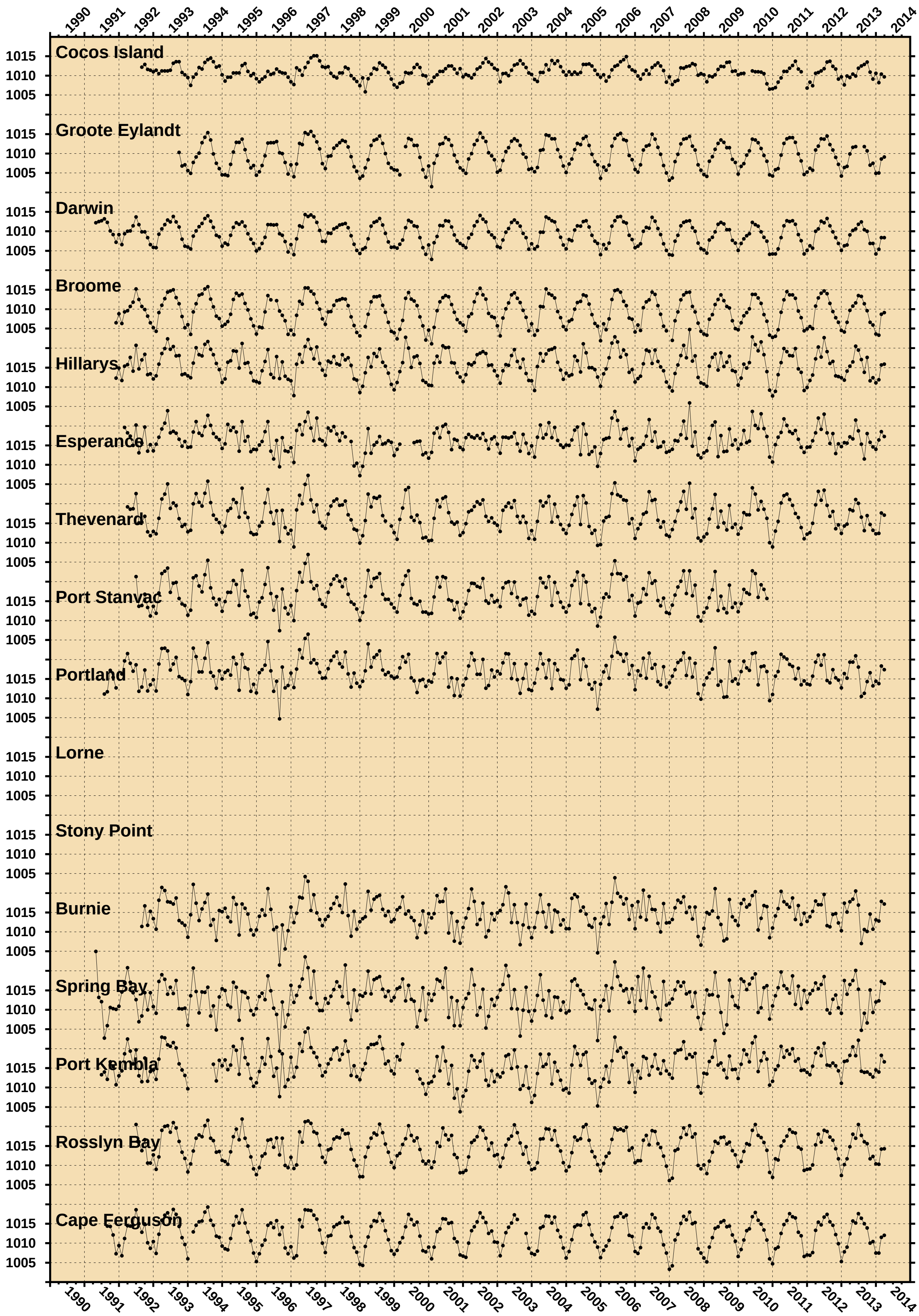


Figure 14. Monthly mean barometric pressures to April 2014.

# MONTHLY MEAN WATER TEMPERATURES THROUGH APRIL 2014 (°C)

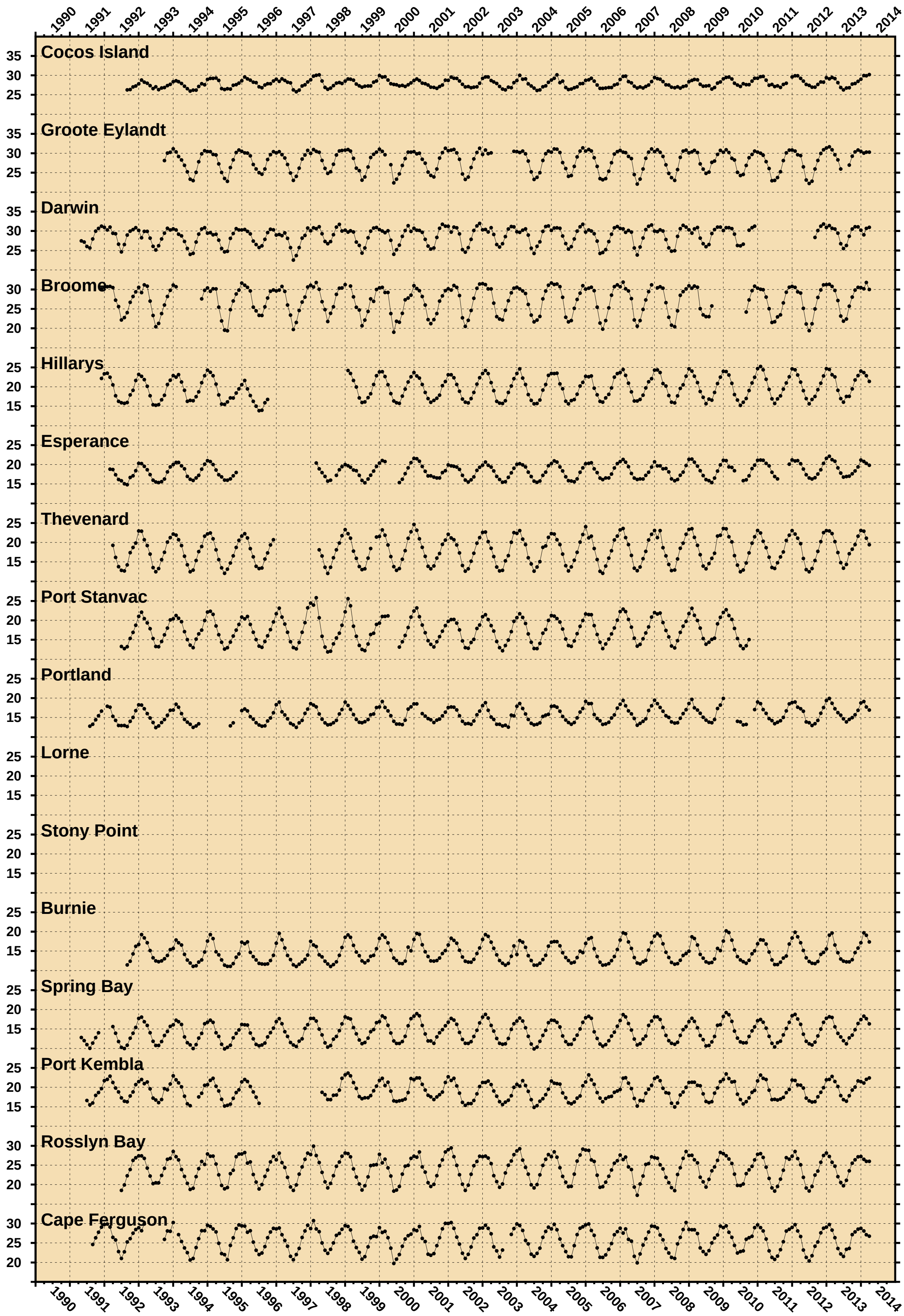


**Figure 15. Monthly mean water temperatures to April 2014.**

# MONTHLY MEAN AIR TEMPERATURES THROUGH APRIL 2014 (°C)

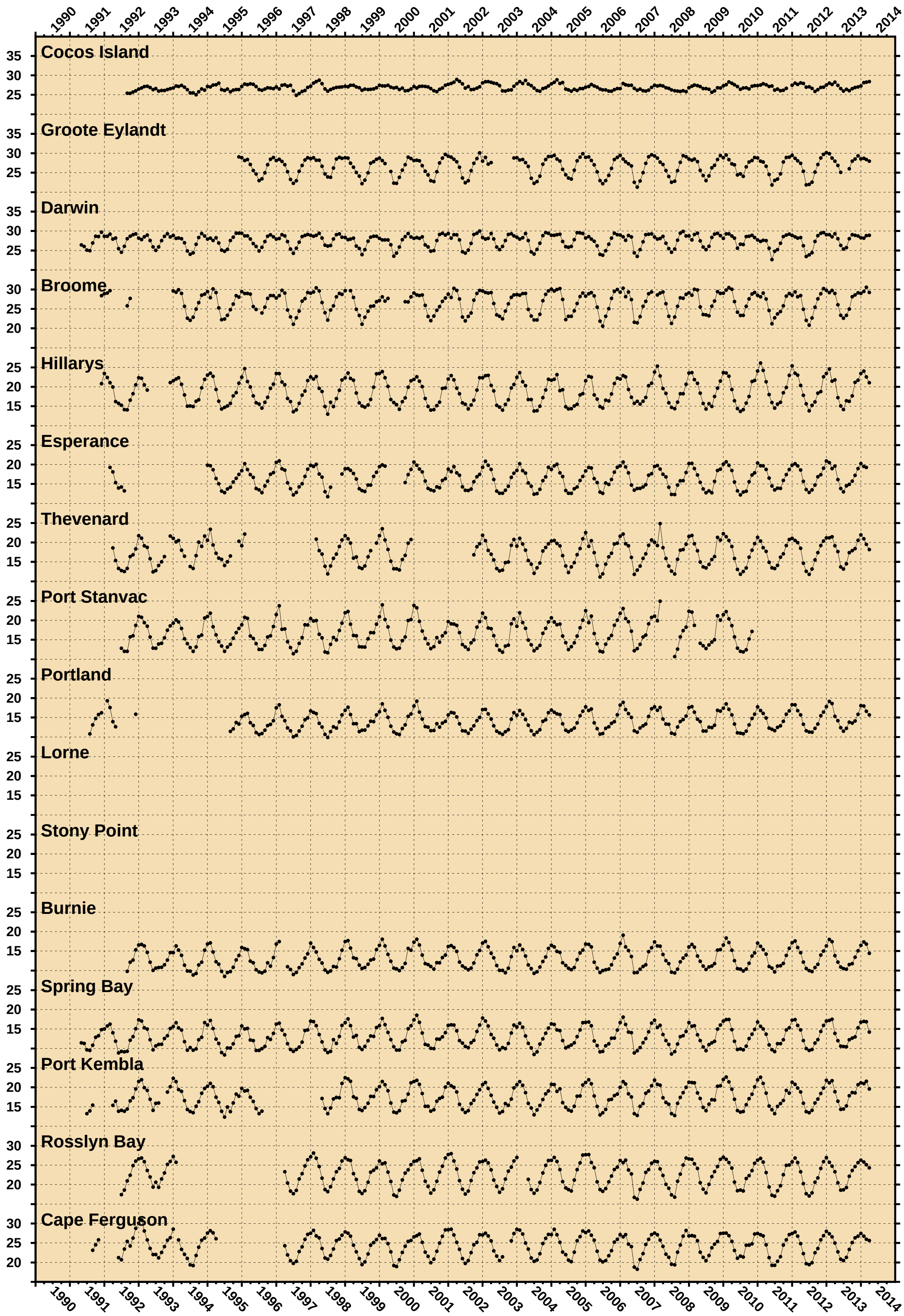


**Figure 16. Monthly mean air temperatures to April 2014.**

# SEA LEVEL ANOMALIES THROUGH APRIL 2014 (m)

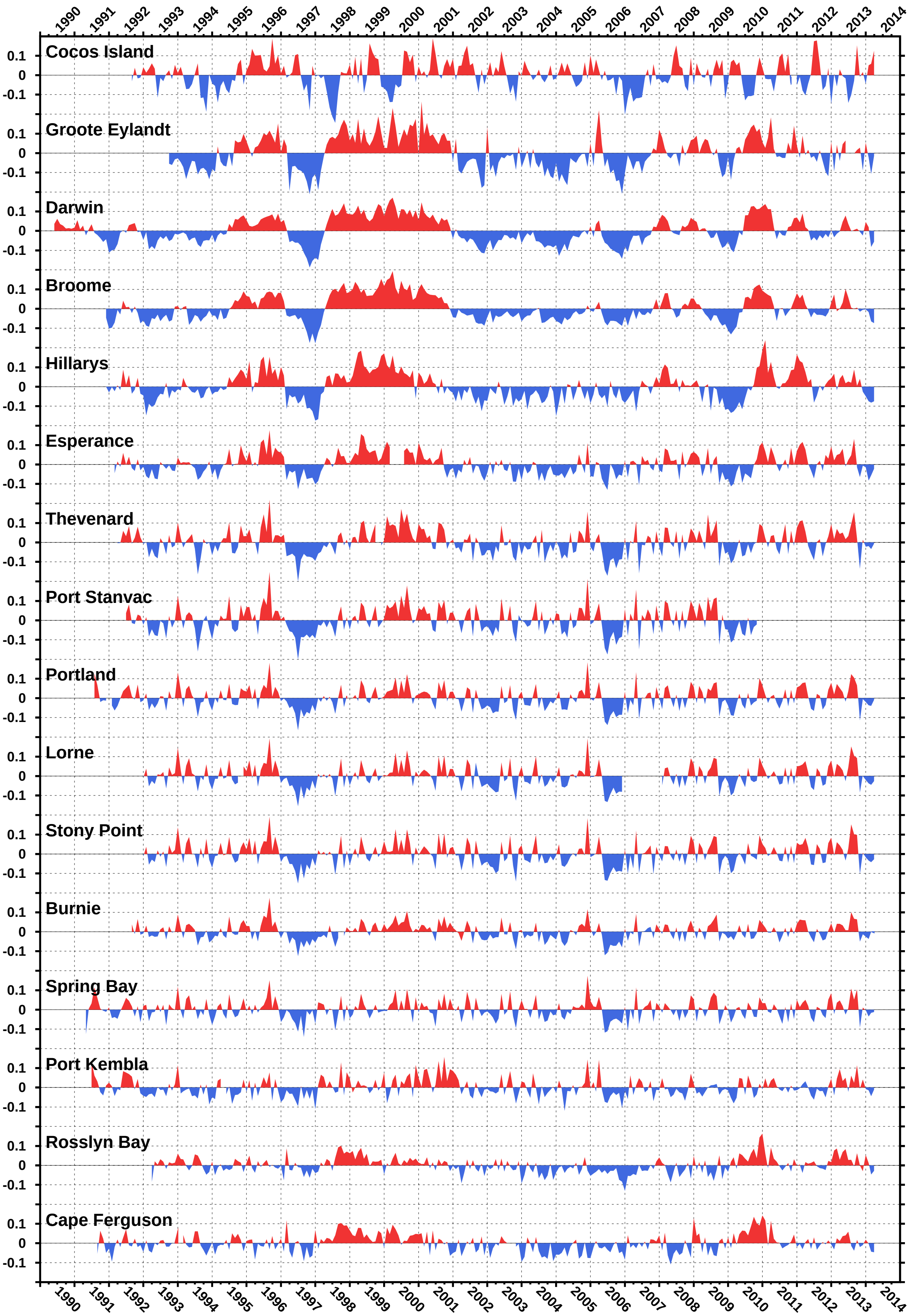


**Figure 17. Monthly sea level anomalies to April 2014.**

# BAROMETRIC PRESSURE ANOMALIES THROUGH APRIL 2014 (hPa)

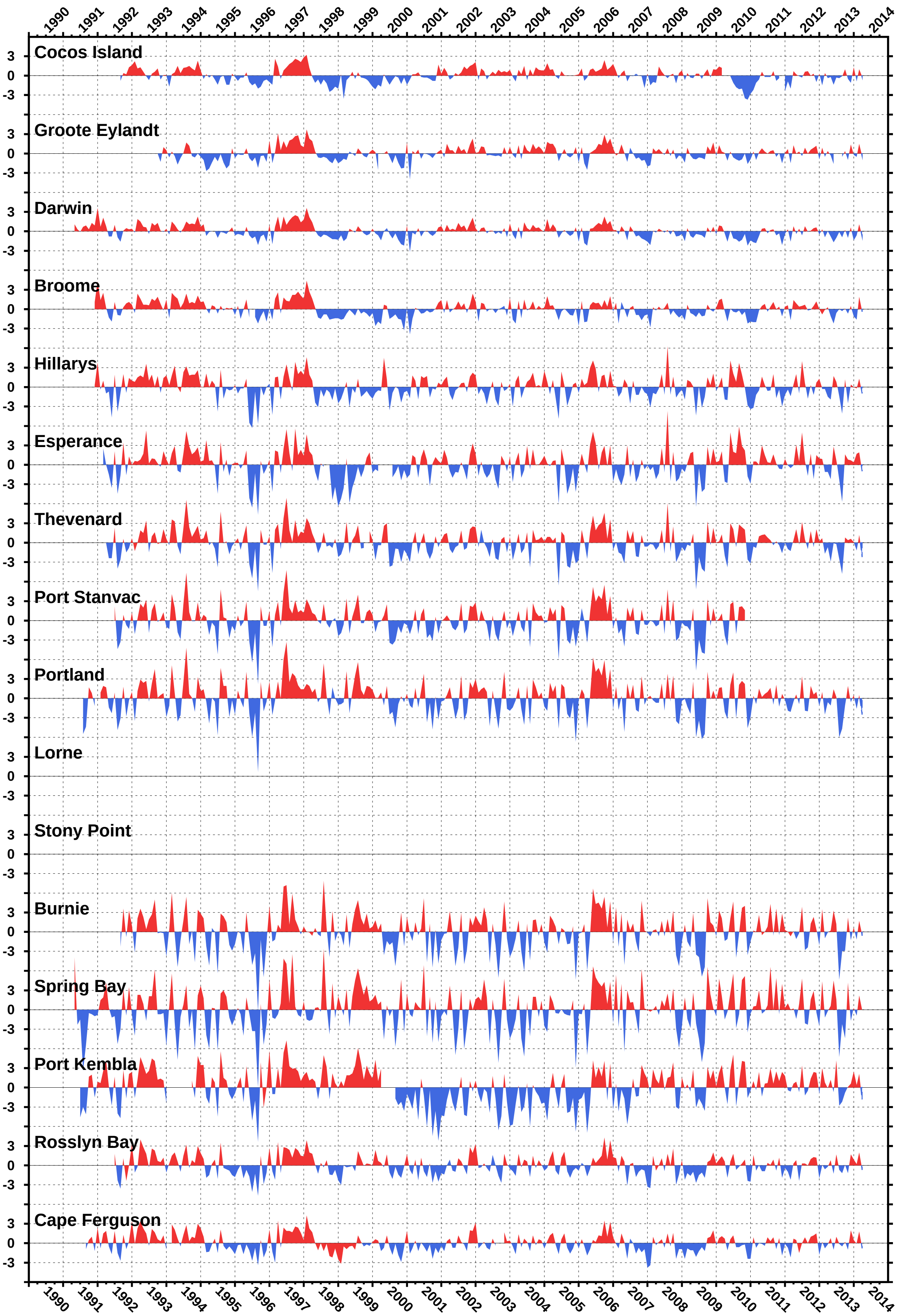


**Figure 18. Monthly barometric pressure anomalies to April 2014.**

# WATER TEMPERATURE ANOMALIES THROUGH APRIL 2014 (°C)

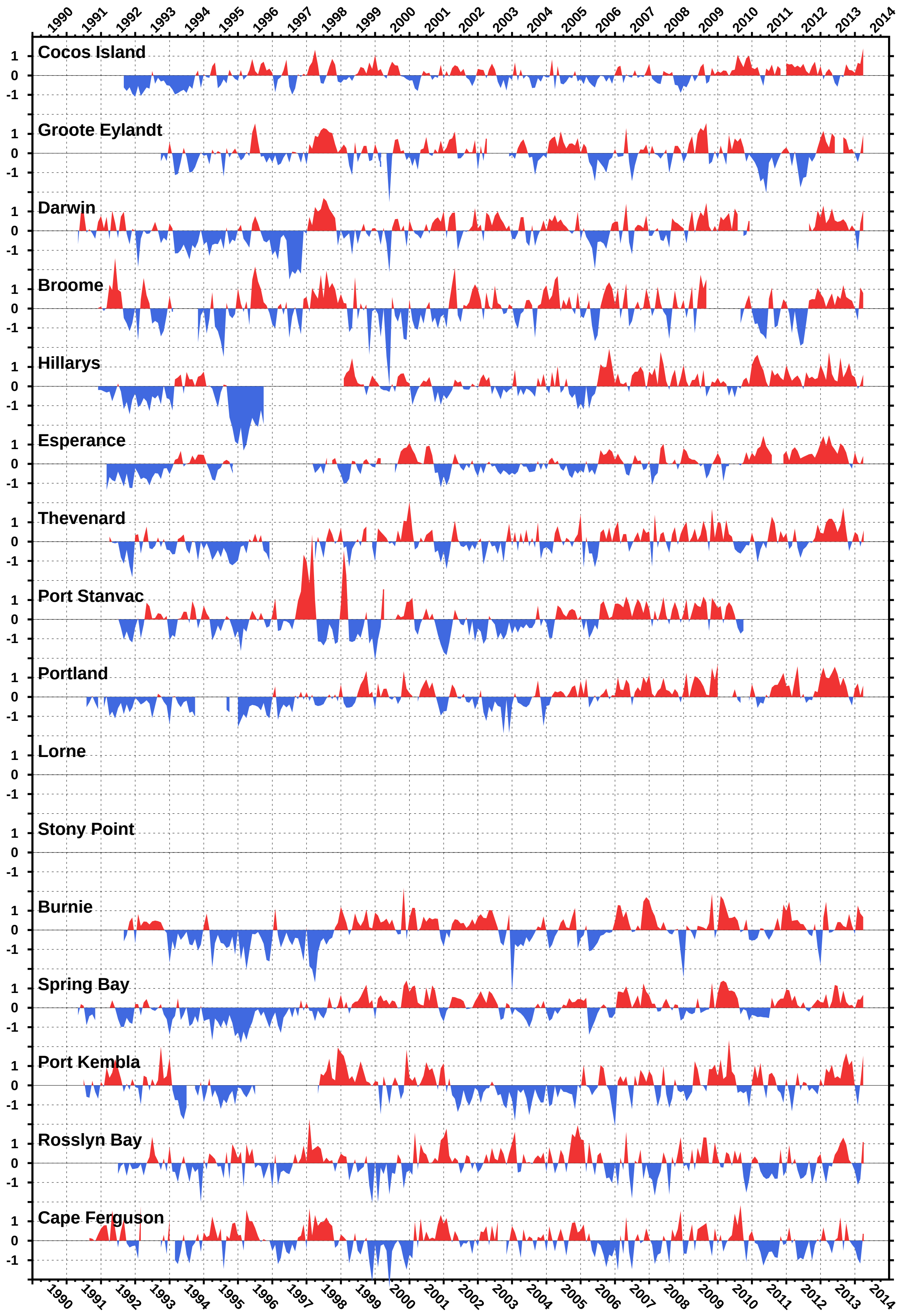


**Figure 19. Monthly water temperature anomalies to April 2014.**

## AIR TEMPERATURE ANOMALIES THROUGH APRIL 2014 (°C)

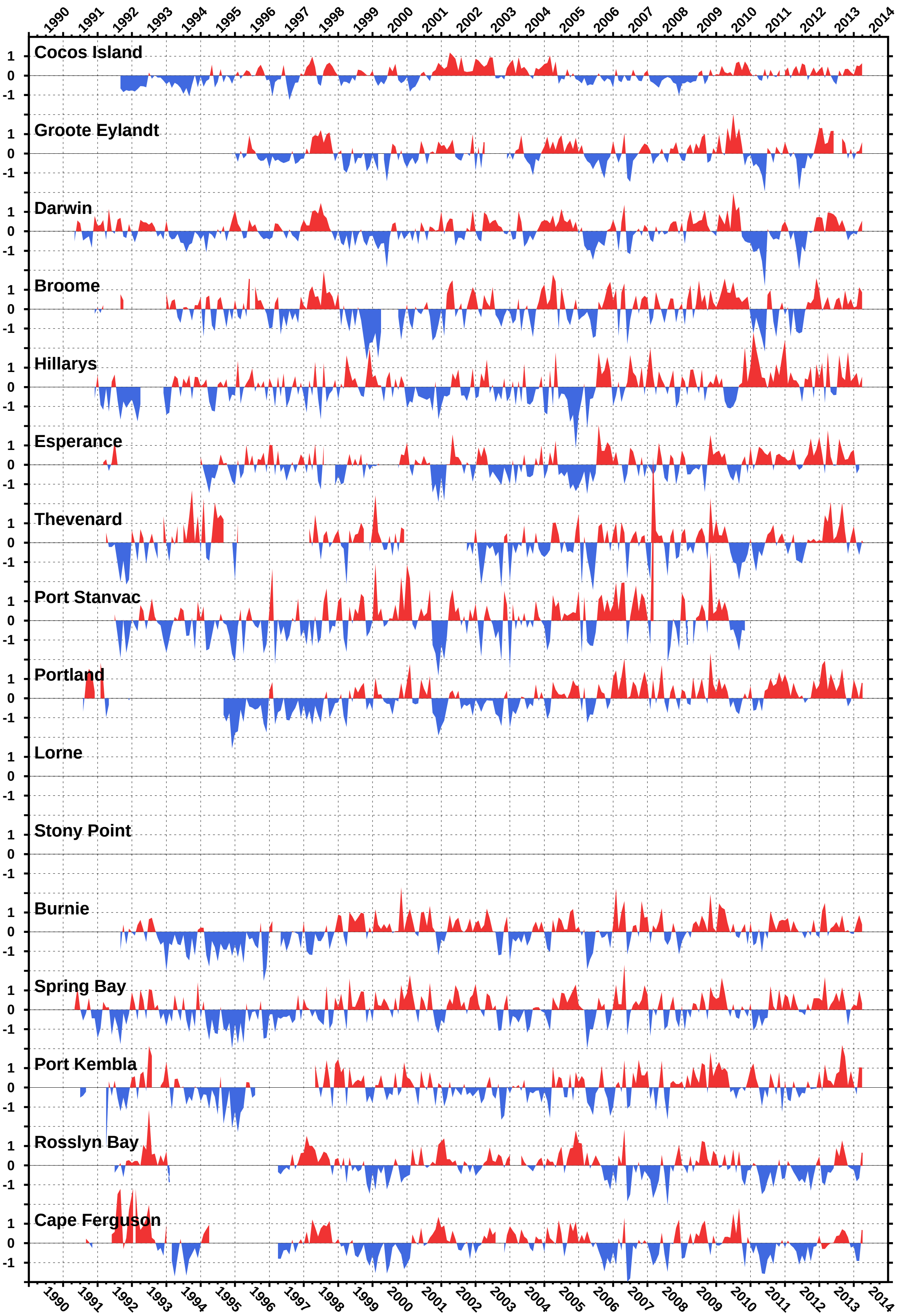


**Figure 20. Monthly air temperature anomalies to April 2014.**

# MONTHLY SEA LEVEL DATA RETURN
# THROUGH APRIL 2014 (%)

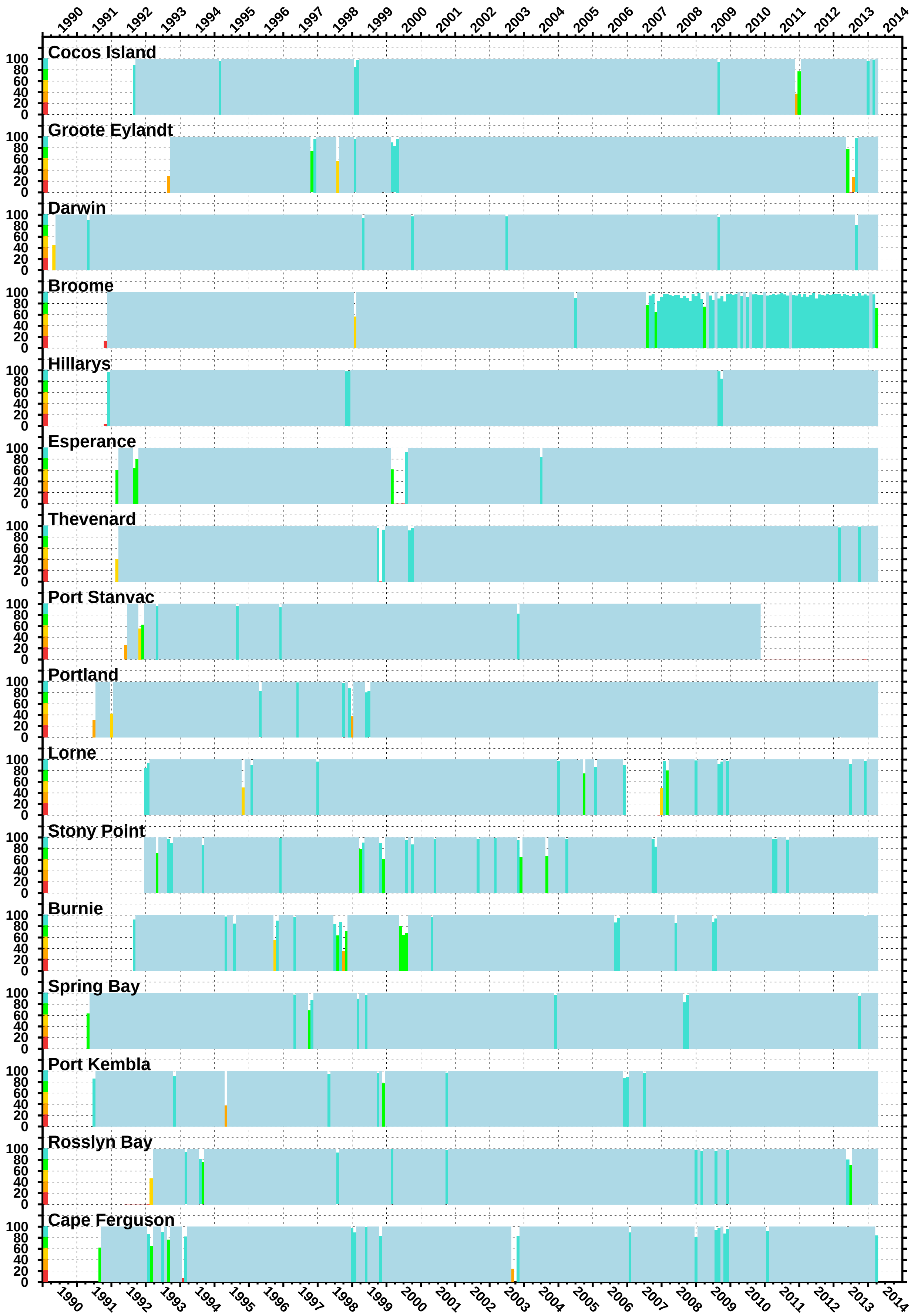


Figure 21. Sea level data return.