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Monthly Data Report - October 2013

Australian Baseline Sea Level Monitoring Array

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Published by Bureau of Meteorology

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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.

October 2013

- The SEAFRAME 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.
- Spring Bay was offline for routine maintenance for most of the 29th and 30th of October 2013, whereas Thevenard experienced a brief power systems failure during the 23rd.
- No new maximum or minimum long term October air temperature, water temperature or barometric pressure was observed this month at any ABSLMA site.
- Water temperature and air temperature anomalies persist to be universally positive in nature and sea level anomalies in excess of +10cm have once again been observed in the south eastern sites as well as Cocos Islands. The sites at Spring Bay and Port Kembla registered positive sea level anomalies in excess of +10cm together with many other sites in the nation's south east registering sea level anomalies between +5cm and +10cm.

Introduction

Welcome to the October 2013 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 atmospheric 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.

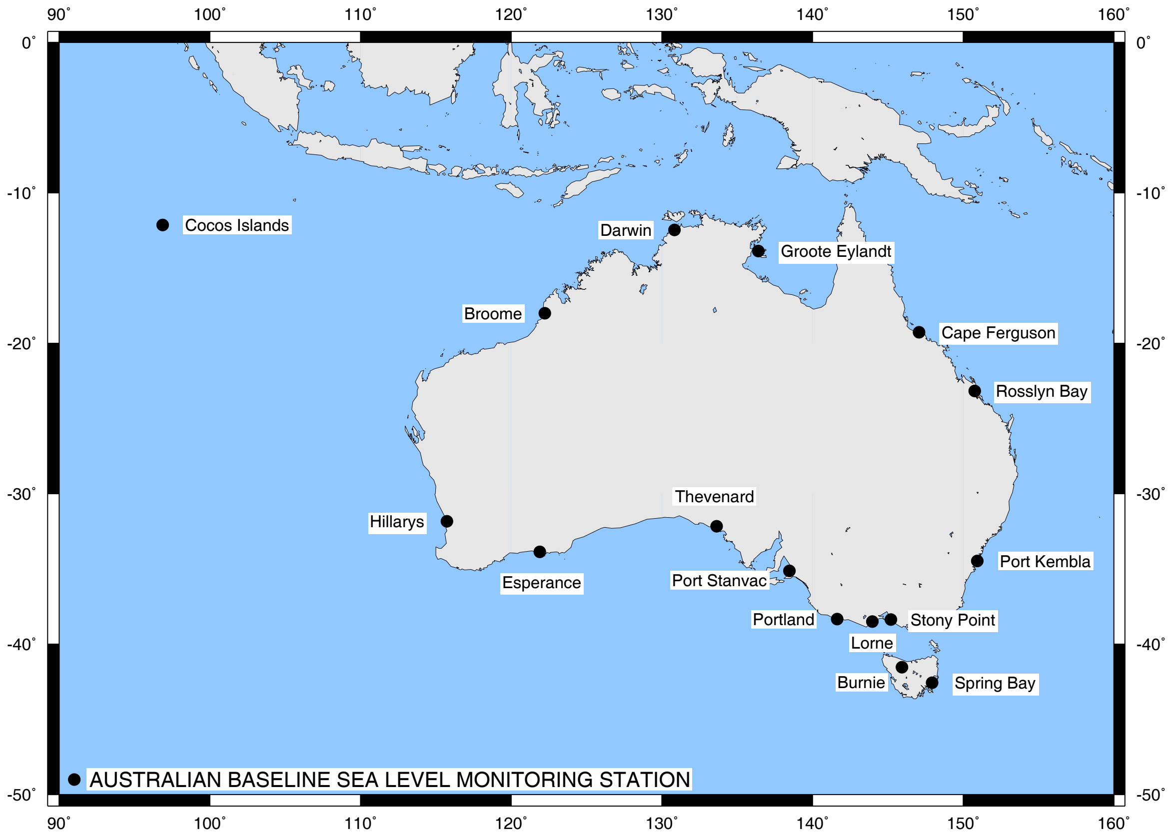

Figure 1. Australian Baseline Sea Level Monitoring Network of SEAFRAME stations

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/

October 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 full and new moons. There was a new moon on the 5th of October and a full moon on the 19th of October.

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. Such effects can often be tracked along the southern Australian coastline, moving eastward as a coastally trapped wave.

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 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 7 follow the meteorological convention, that is, they point in the direction the wind is coming from. For example, the winds at Cocos Islands prevailed from the southeast for most of the 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 meteorological data 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 Australian Baseline Sea Level Monitoring Array data, which have been collected since May 1990 when the first station was installed at Darwin.

During this month no new record for maximum or minimum air temperature, water temperature or barometric pressure was observed at any ABSLMA site for the month of October.
http://www.bom.gov.au/oceanography/projects/abslmp/data/monthly.shtml

Mean Sea Level and Anomalies

Figure 13 shows the monthly mean sea levels, which are simple arithmetic averages of the sea levels, relative to an arbitrary zero. The monthly mean sea levels contain seasonal variations. Groote Eylandt, for example, normally experiences an annual sea level cycle of about 0.6m that normally peaks around February.

Figure 14 shows the monthly mean sea level anomalies, which are the residuals after tides, annual and semi-annual seasonal cycles and linear slope have been removed by way of a harmonic tidal analysis of the complete record. The annual cycle at Groote Eylandt (which has the largest consistent annual cycle) is quite notable in Figure 13 but less apparent in Figure 14. 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 monthly mean sea level anomalies for October 2013 exceeded 10cm at Cocos Islands, Spring Bay and Port Kembla, while sea level anomalies greater than 5 cm were observed at Portland, Lorne, Stony Point, Burnie and Rosslyn Bay. Monthly mean sea levels at the other stations were typical for this time of year.

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 October, 2013.

Location	Latitude	Longitude	Date of first data	Rate[1] (mm/yr)	Change in rate from previous month (mm/yr)
Cocos Islands	12°07'07.1"S	96°53'30.9"E	Sep 1992	+8.3	+0.2
Groote Eylandt	13°51'36.2"S	136°24'56.1"E	Sep 1993	+8.8	0.0
Darwin	12°28'18.4"S	130°50'45.1"E	May 1990	+8.8	0.0
Broome	18°00'03.0"S	122°13'07.1"E	Nov 1991	+9.4	0.0
Hillarys	31°49'32.0"S	115°44'18.9"E	Nov 1991	+10.4	0.0
Esperance	33°52'15.2"S	121°53'43.3"E	Mar 1992	+7.1	0.0
Thevenard	32°08'56.2"S	133°38'28.8"E	Mar 1992	+5.7	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	+4.1	+0.1
Lorne	38°32'49.4"S	143°59'19.8"E	Jan 1993	+3.8	+0.1
Stony Point	38°22'19.7"S	145°13'28.9"E	Jan 1993	+3.7	+0.1
Burnie	41°03'0.3"S	145°54'54.0"E	Sep 1992	+3.7	+0.1
Spring Bay	42°32'45.1"S	147°55'57.8"E	May 1991	+3.9	+0.1
Port Kembla	34°28'25.5"S	150°54'42.7"E	Jul 1991	+3.5	+0.1
Rosslyn Bay	23°09'39.7"S	150°47'24.6"E	Jun 1992	+4.5	+0.1
Cape Ferguson	19°16'38.4"S	147°03'30.4"E	Sep 1991	+4.8	0.0

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

Barometric Pressure, Water Temperature and Air Temperature Anomalies

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 15) show higher than normal barometric pressures were observed at SEAFRAME stations during the 1997-1998 El Niño. Barometric Pressures for October 2013 were quite typical with the anomalies varying between all sites. A significant lower than normal barometric pressure anomaly was observed at Spring Bay reaching -4.3 hPa with the next closest site, located at Burnie observing a barometric pressure anomaly of -2.9 hPa

Water temperature anomalies (Figure 16) during October 2013 continued to indicate warmer than normal conditions at the majority of stations. Water temperature anomalies near or exceeding +1.0 °C were observed at the east coast sites, being Port Kembla, Rosslyn Bay and Cape Ferguson.

Similarly, the air temperature anomalies (Figure 17) during October 2013 indicated warmer than normal conditions at all sites. (However, these anomalies were small with only Broome and Port Kembla observing air temperature anomalies near or exceeding +1.0 °C.)

Instrument Performance

In Figure 18, which shows sea level data return, colour is used to distinguish five-year project phases. The number of missing days is noted in gaps in the bars.

Sea level data return from the network was 99.4% during October 2013 (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 13 hours of Broome sea level and ancillary data during October. The site at Thevenard experienced a power systems failure which was fixed by the local port authority staff resulting in only the loss of 12 hours of data. Spring Bay was offline for roughly 39 hours for a scheduled maintenance visit.

The anemometers at Groote Eylandt and Esperance continued to be switched off during the month of October as they have not yet been repaired. Spring Bay experienced a serious weather event on the 2nd of October resulting in its anemometer being damaged, which was subsequently repaired during the maintenance visit on the 29th.

Table 2. Rates of sea level data return

Location	Installation Date	Data Return Since Installation (%)	Data Return in October 2013 (%)
Cocos Islands	Sep 1992	99.6	100
Groote Eylandt	Sep 1993	98.7	99.7
Darwin	May 1990	99.8	99.9
Broome	Nov 1991	98.1	98.2
Hillarys	Nov 1991	99.9	100
Esperance	Mar 1992	98.0	100
Thevenard	Mar 1992	99.5	98.3
Port Stanvac	Jun 1992	96.0	0.0
Portland	Jul 1991	99.3	100
Lorne	Jan 1993	94.3	99.9
Stony Point	Jan 1993	98.9	100
Burnie	Sep 1992	98.5	100
Spring Bay	May 1991	99.7	94.8
Port Kembla	Jul 1991	99.5	100
Rosslyn Bay	Jun 1992	96.2	100
Cape Ferguson	Sep 1991	98.2	100
Network Average		**98.4**	**99.4**

[2]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.

For the original SUTRON data loggers, the water level samples were averaged over three minutes and logged every six minutes, while meteorological sensors were logged on an hourly basis. With the current TELMET data loggers, the water level samples are averaged over one minute and, together with meteorological data, logged every minute. Appropriate weighted-average and time-centred data is computed remotely which conforms to the historical SUTRON algorithm. The current TELMET data loggers have the memory capacity to store approximately one month of data.

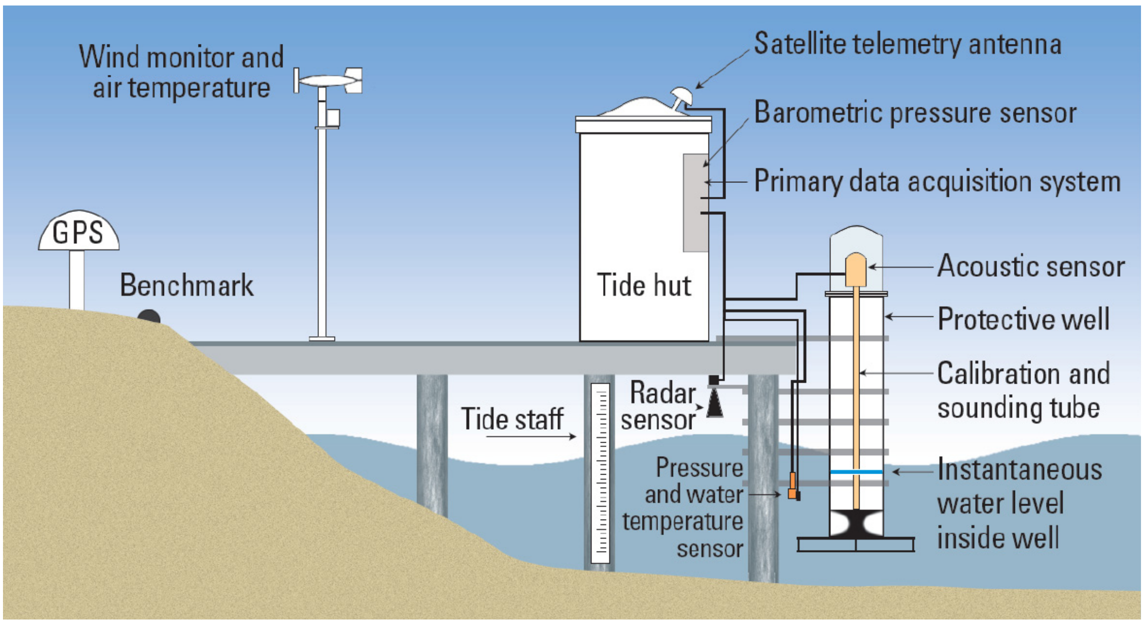

Figure 2. Schematic diagram of a SEAFRAME sea level monitoring station.

Baseline Refurbishment

Refurbishment of the Australian Baseline Sea Level Monitoring Array was undertaken in 2009 with grant funding from the Department of Climate Change and Energy Efficiency. The refurbishment involved installation of TELMET data loggers, improved real-time communications equipment and additional radar-type water level sensors. The dates of the station refurbishments are given in Table 3.

Table 3. Schedule of SEAFRAME station equipment refurbishment.

Location	Latitude	Longitude	SUTRON Installation Date	TELMET Refurbishment Date
Cocos Islands	12°07'07.1"S	96°53'30.9"E	Sep 1992	Sep 2009
Groote Eylandt	13°51'36.2"S	136°24'56.1"E	Sep 1993	Oct 2009
Darwin	12°28'18.4"S	130°50'45.1"E	May 1990	Sep 2009
Broome	18°00'03.0"S	122°13'07.1"E	Nov 1991	Sep 2009
Hillarys	31°49'32.0"S	115°44'18.9"E	Nov 1991	Sep 2009
Esperance	33°52'15.2"S	121°53'43.3"E	Mar 1992	Sep 2009
Thevenard	32°08'56.2"S	133°38'28.8"E	Mar 1992	Nov 2009
Port Stanvac	35°06'31.0"S	138°28'1.3"E	Jun 1992	Sep 2009
Portland	38°20'36.4"S	141°36'47.4"E	Jul 1991	Aug 2009
Lorne	38°32'49.4"S	143°59'19.8"E	Jan 1993	Privately owned
Stony Point	38°22'19.7"S	145°13'28.9"E	Jan 1993	Privately owned
Burnie	41°03'0.3"S	145°54'54.0"E	Sep 1992	Jul 2009
Spring Bay	42°32'45.1"S	147°55'57.8"E	May 1991	Oct 2009
Port Kembla	34°28'25.5"S	150°54'42.7"E	Jul 1991	Oct 2009
Rosslyn Bay	23°09'39.7"S	150°47'24.6"E	Jun 1992	Dec 2009
Cape Ferguson	19°16'38.4"S	147°03'30.4"E	Sep 1991	Aug 2009

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 National Tidal Centre (NTC), Bureau of Meteorology.

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

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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.

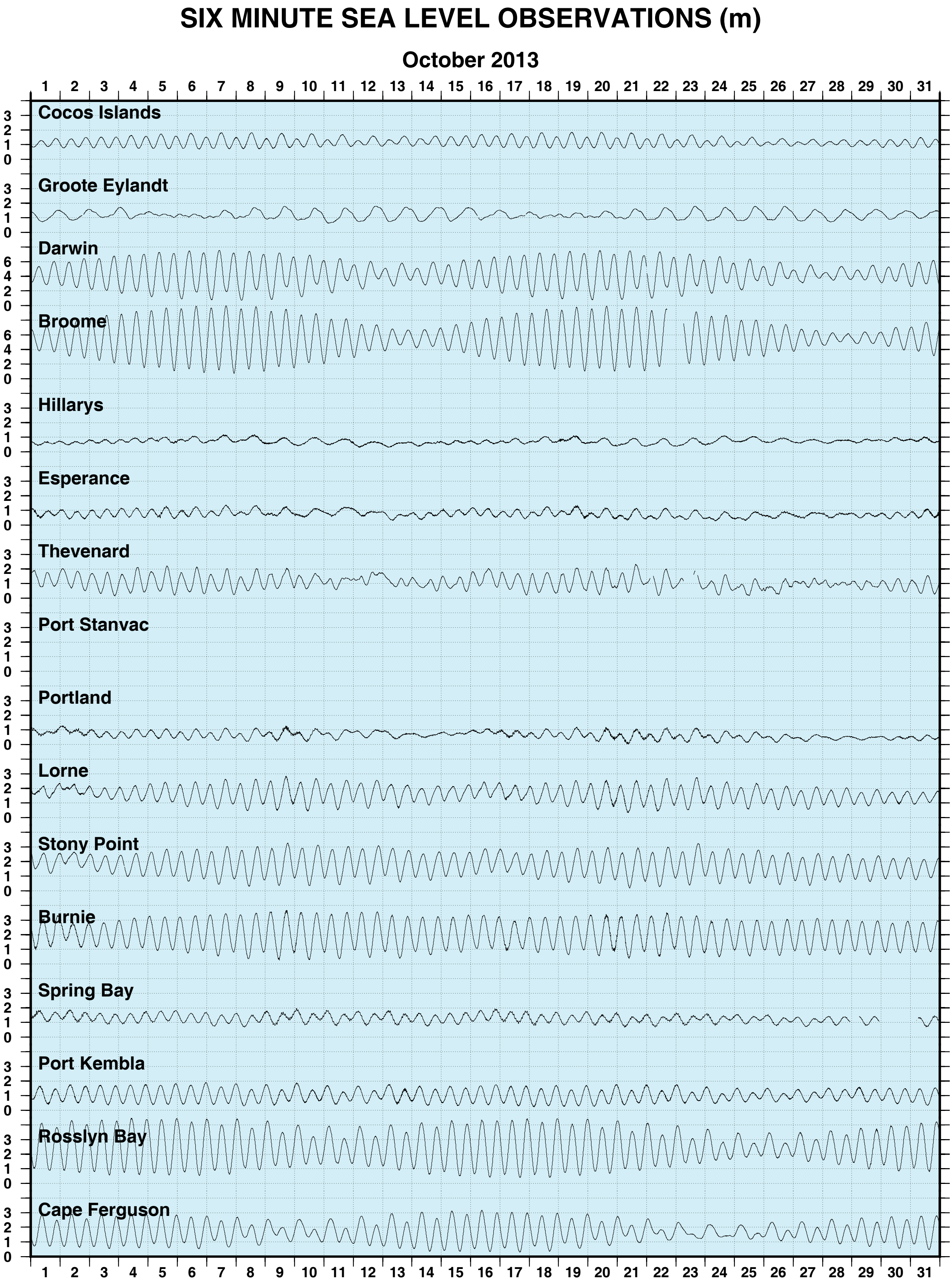

Figure 3. Sea level observations during October 2013.

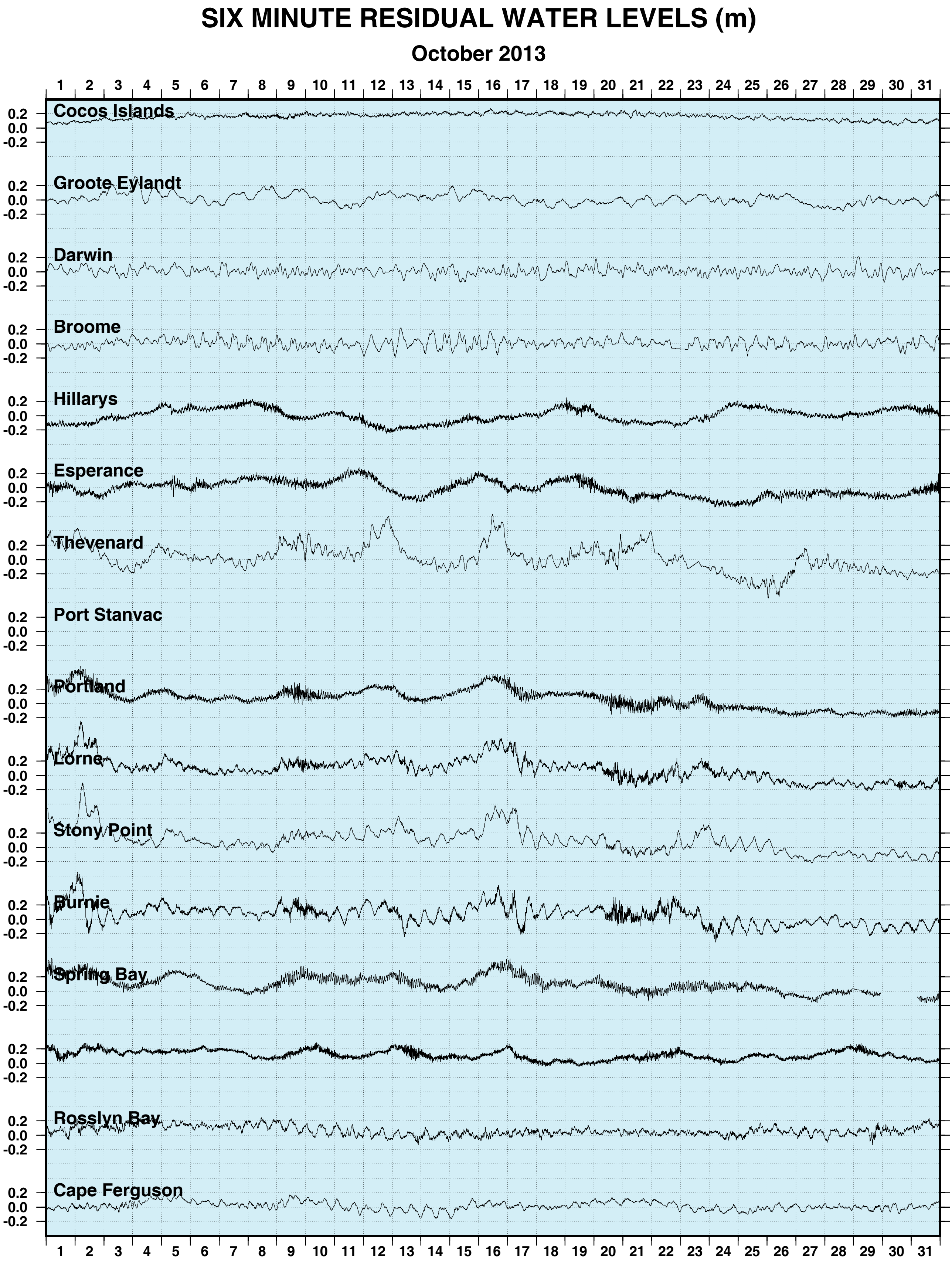

Figure 4. Residual sea levels during October 2013.

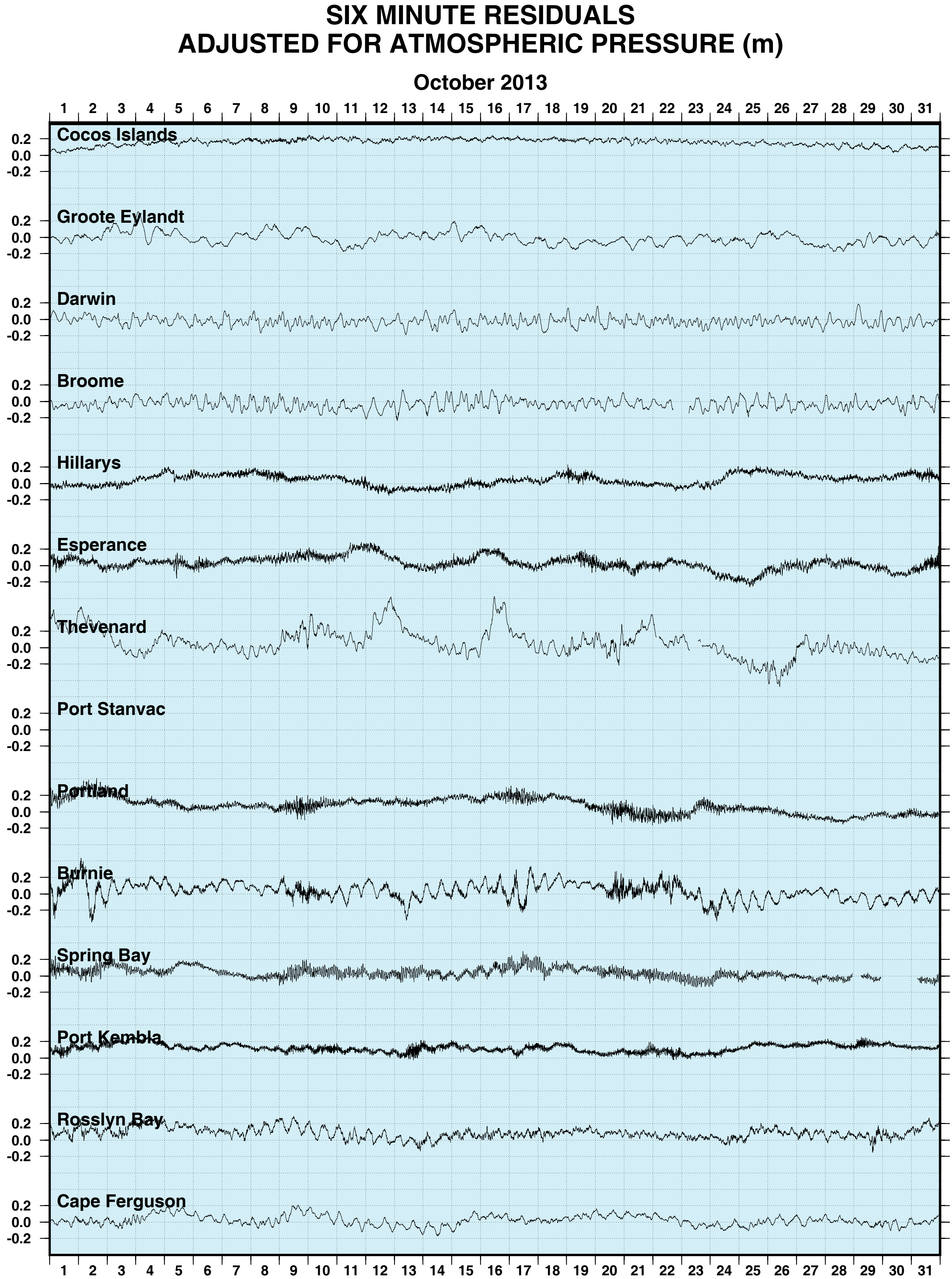

Figure 5. Residual sea levels adjusted for atmospheric pressure during October 2013.

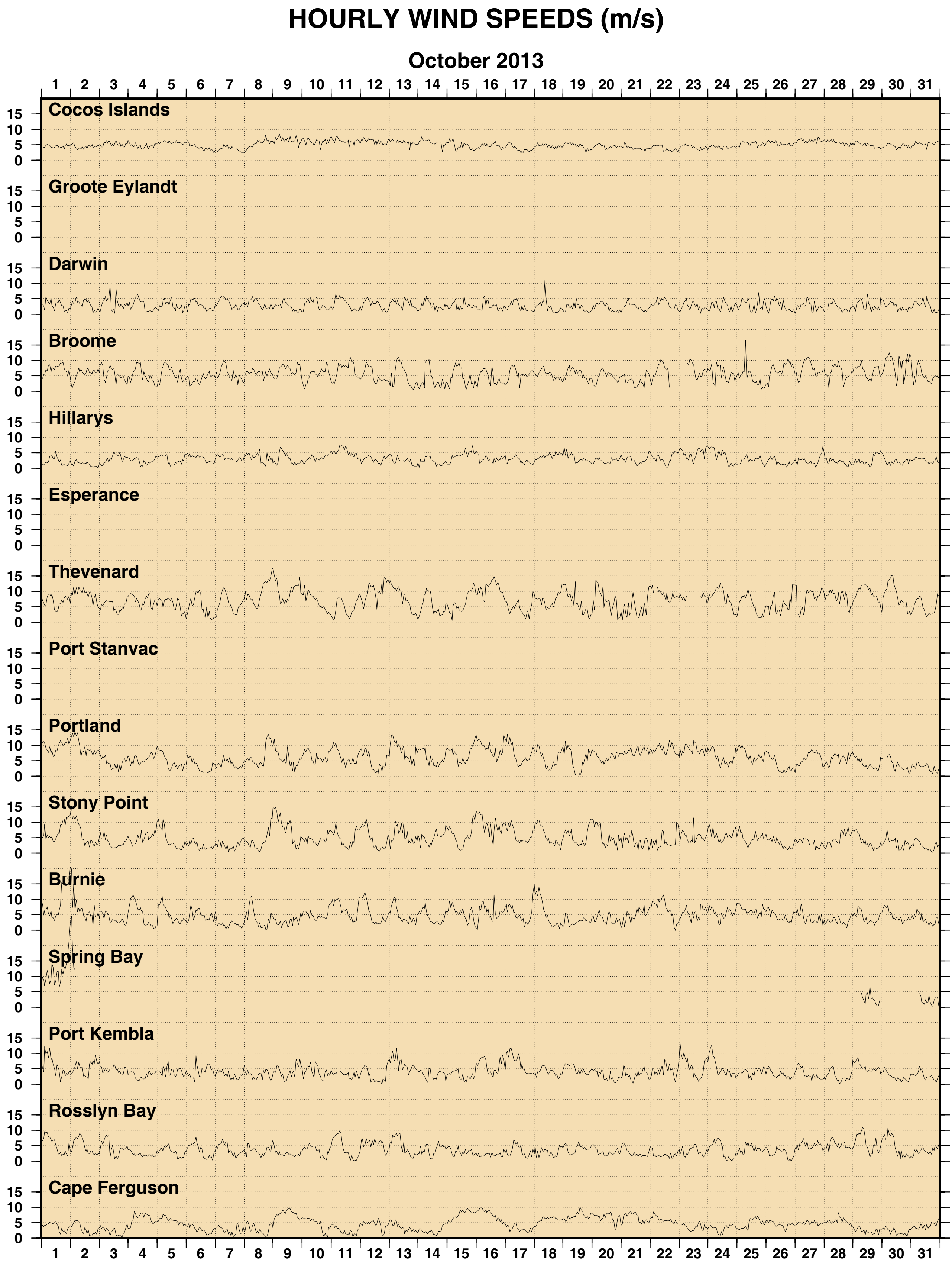

Figure 6. Wind speeds during October 2013.

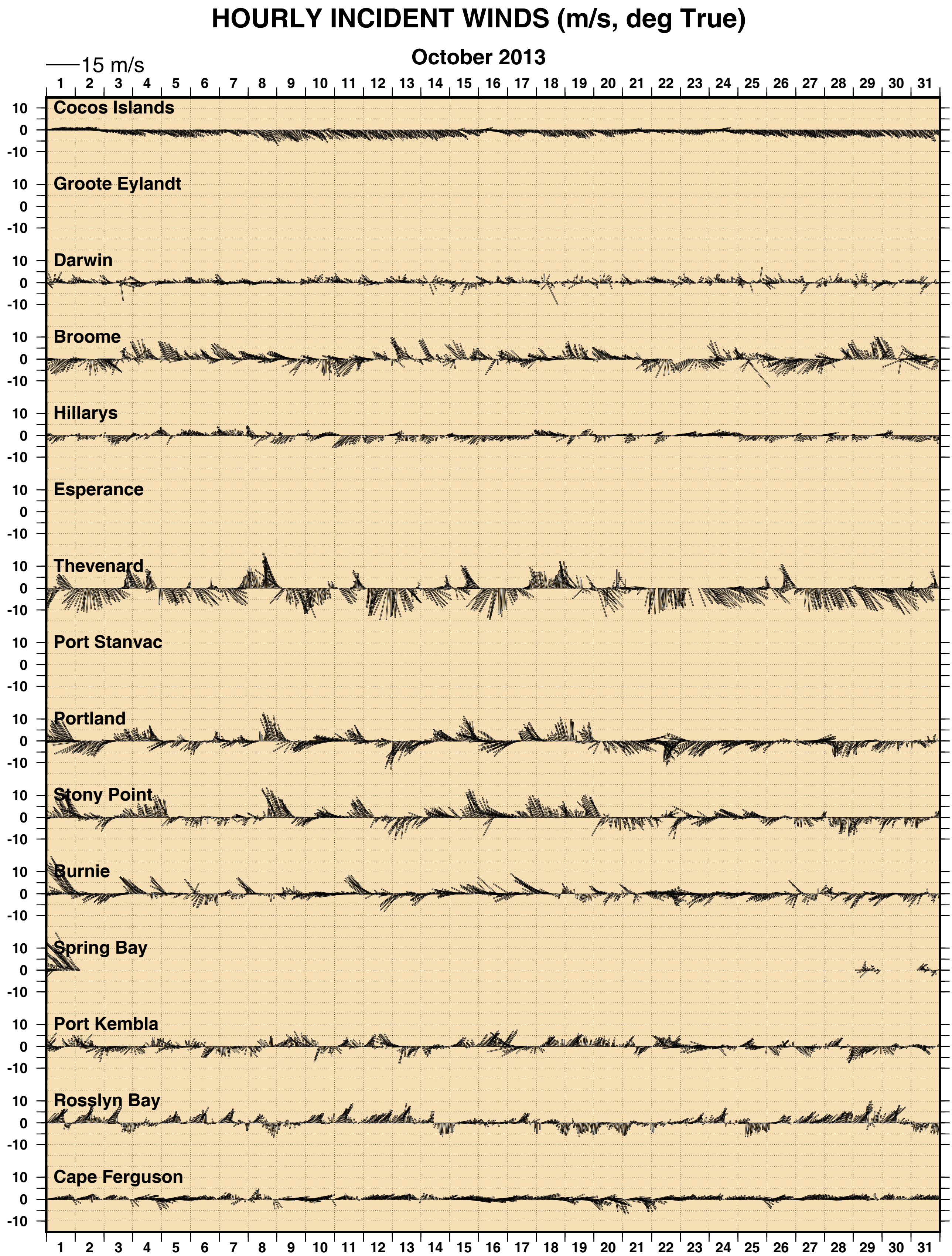

Figure 7. Incident winds during October 2013.

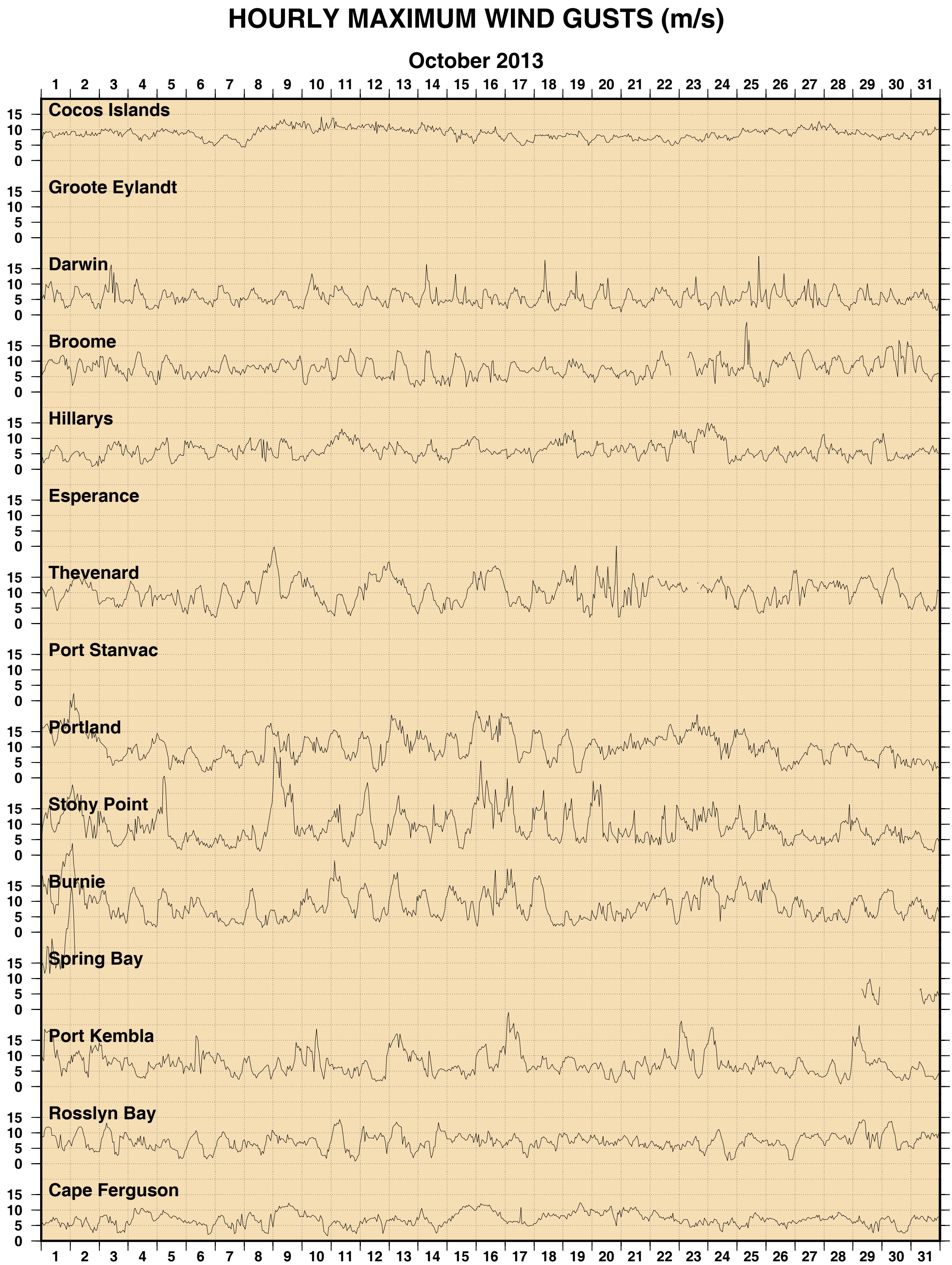

Figure 8. Wind gusts during October 2013.

HOURLY AIR TEMPERATURES (˚C)

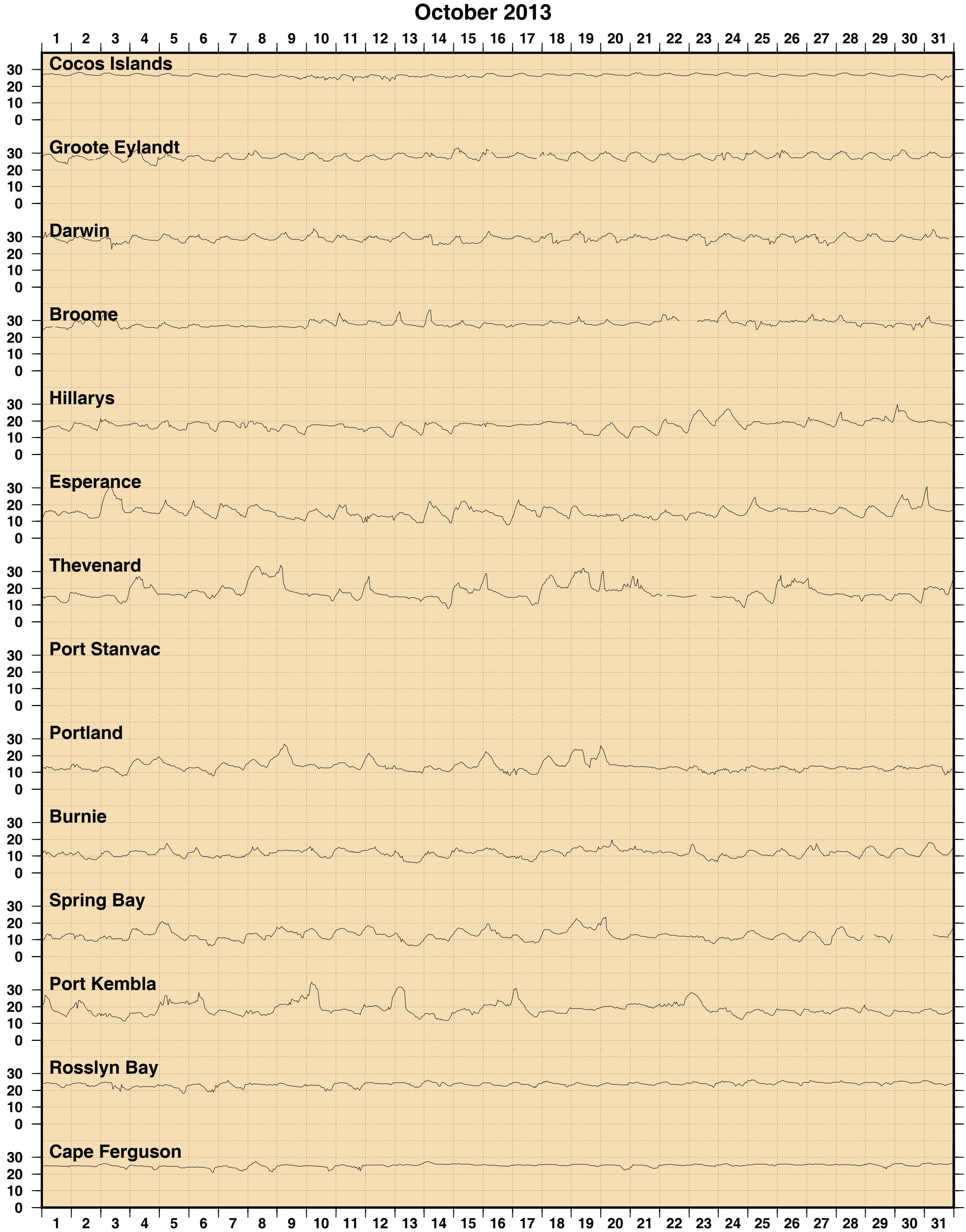

Figure 9. Air temperatures during October 2013.

Figure 10. Water temperatures during October 2013.

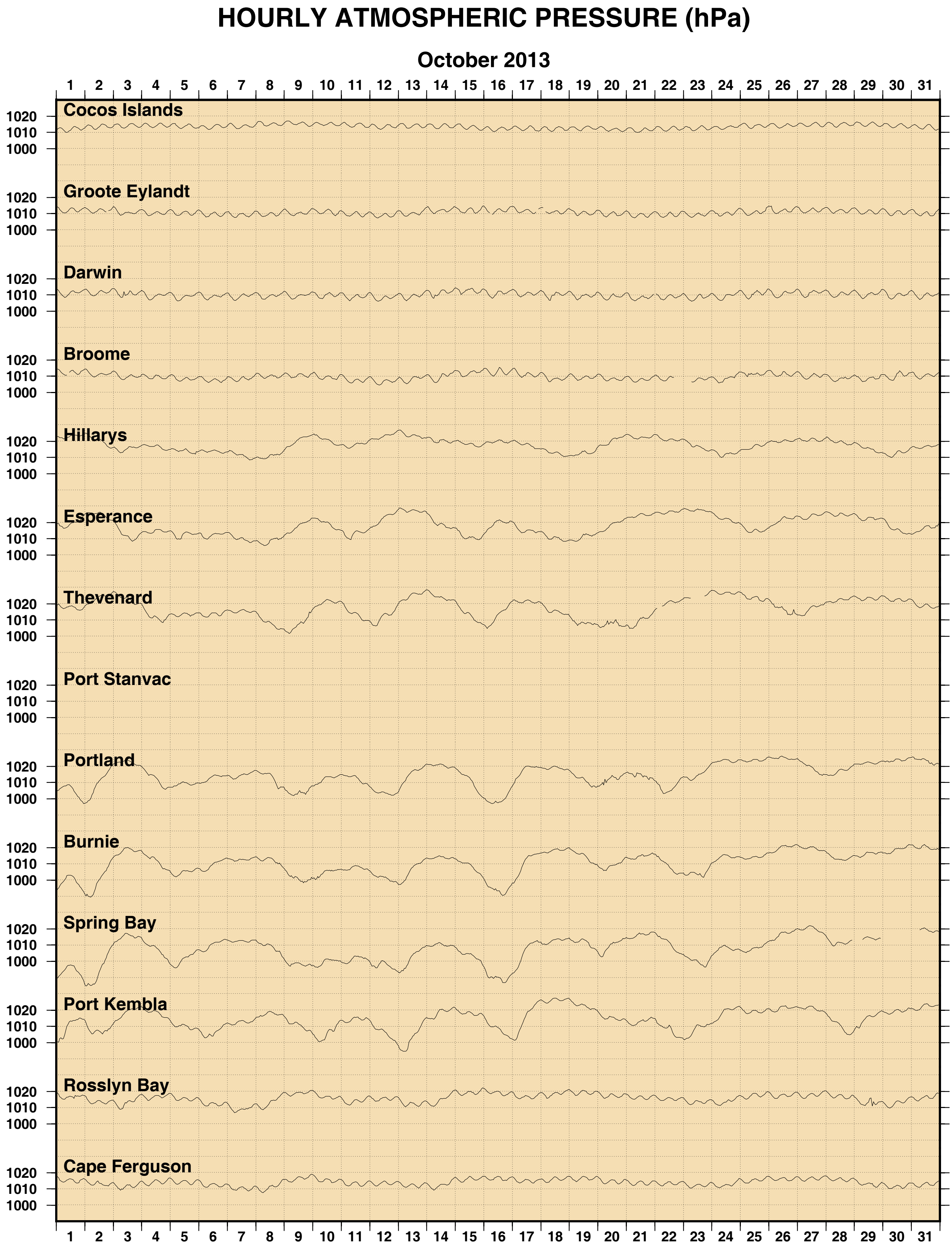

Figure 11. Atmospheric pressures during October 2013.

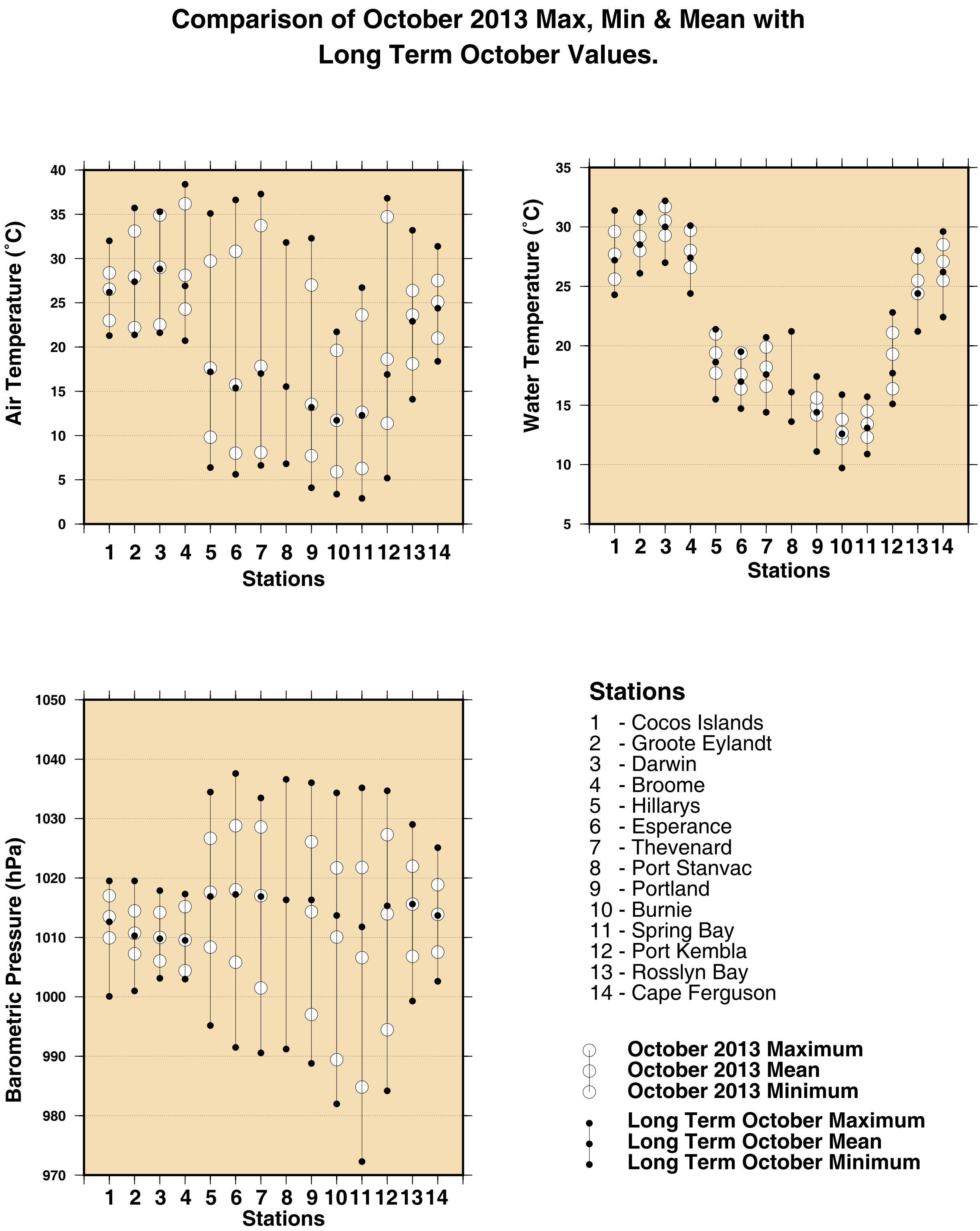

Figure 12. Comparison of October 2013 ancillary data with long term October values.

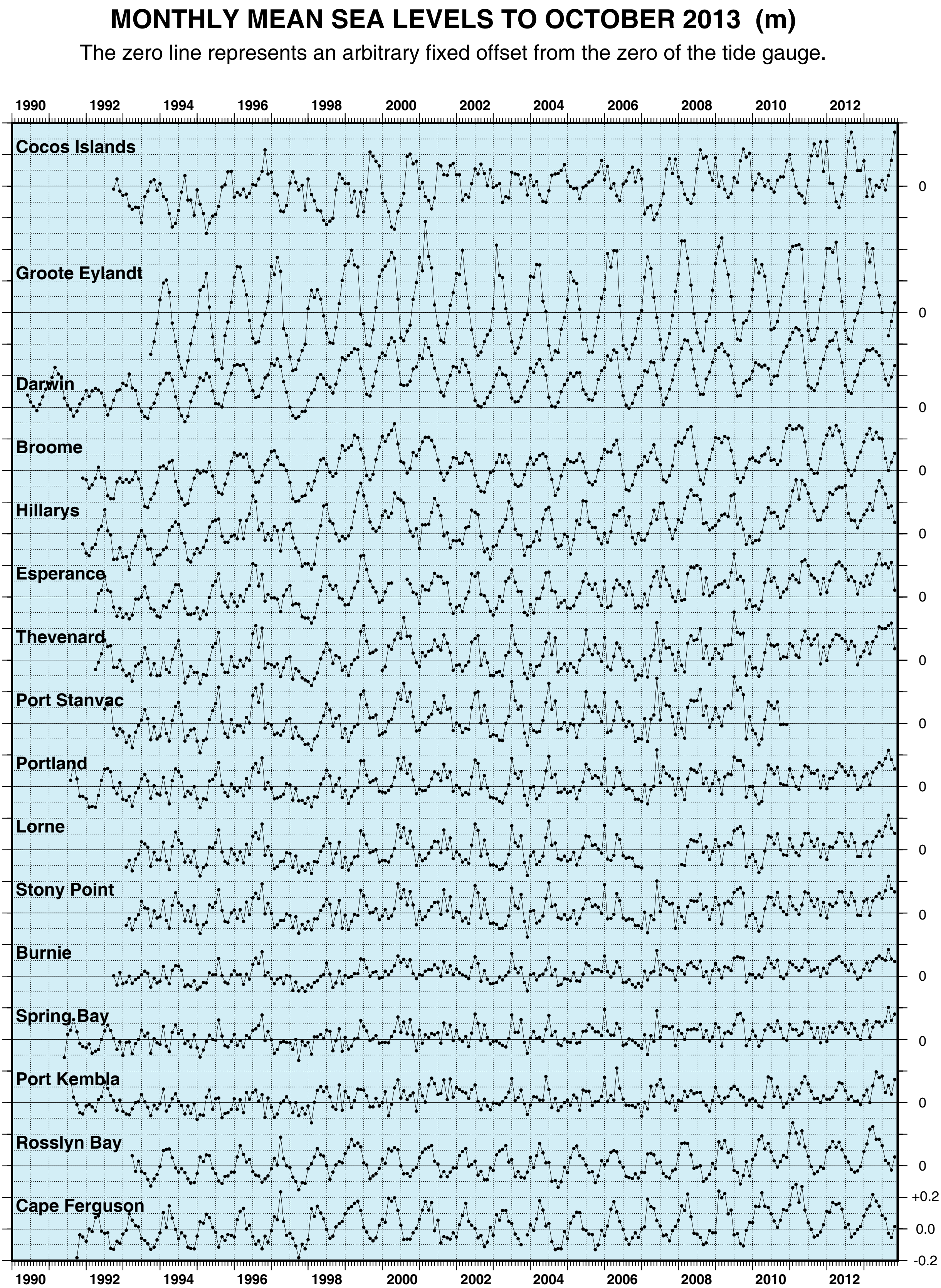

Figure 13. Monthly mean sea levels to October 2013.

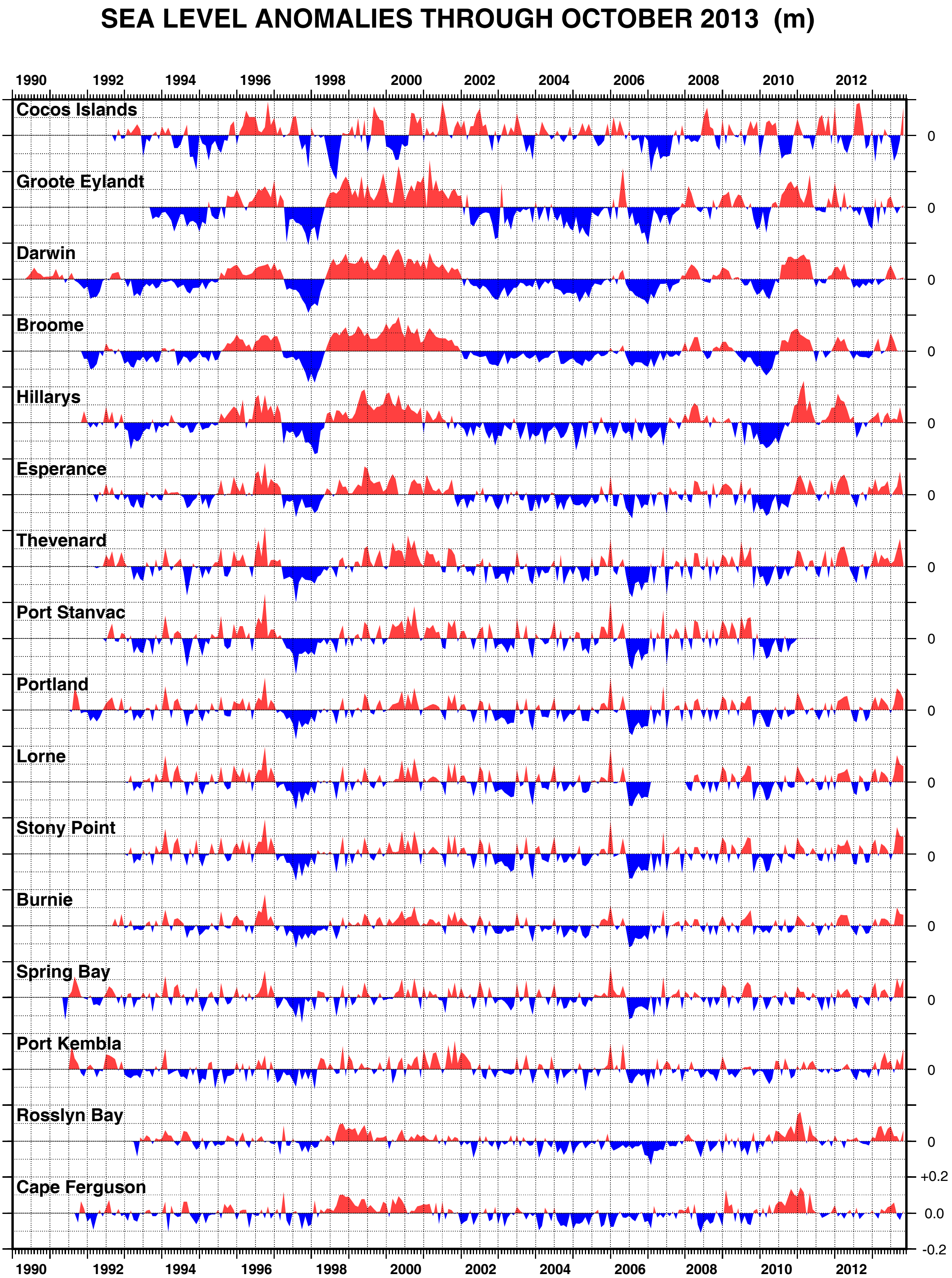

Figure 14. Monthly sea level anomalies to October 2013.

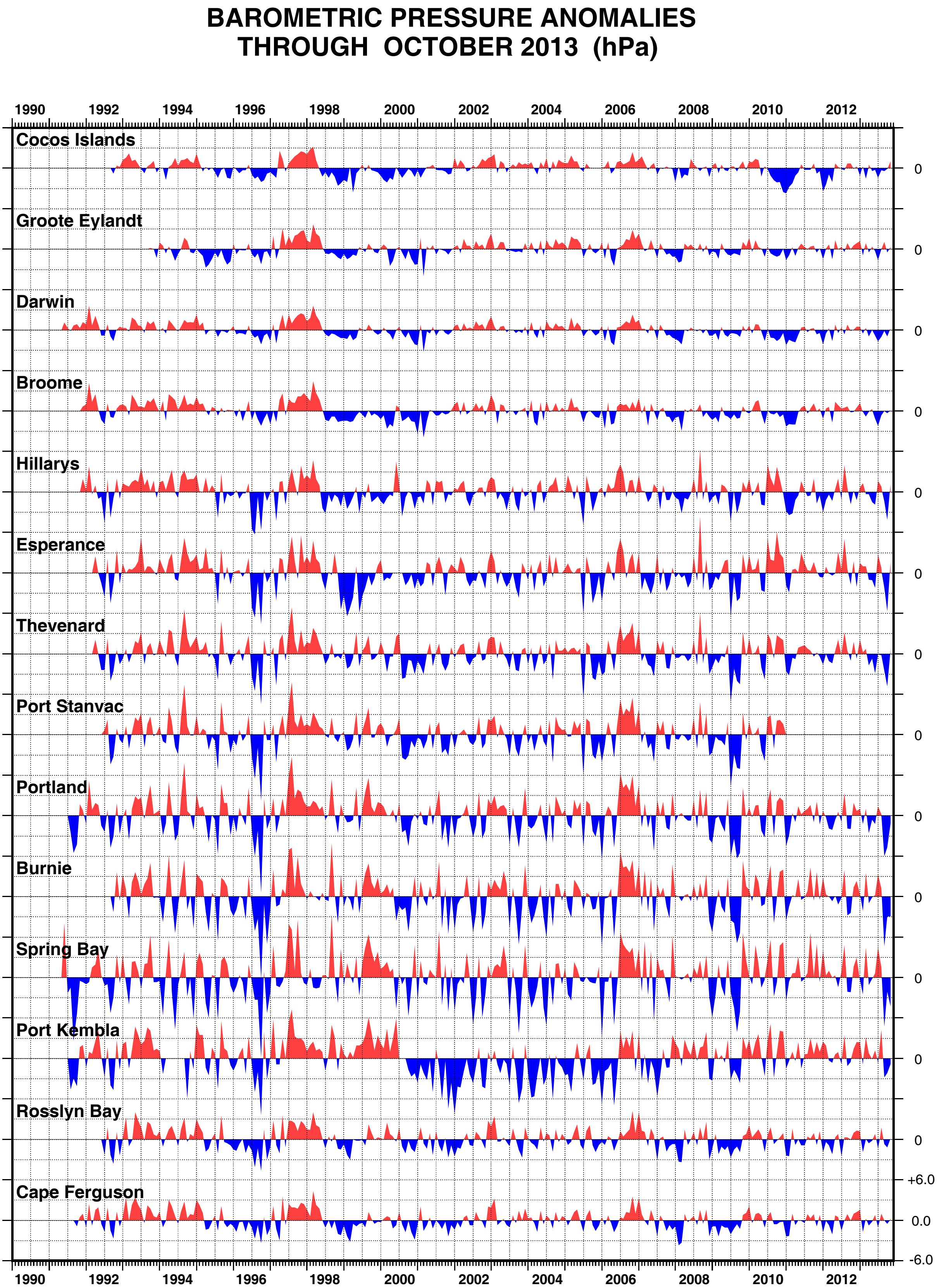

Figure 15. Monthly barometric pressure anomalies to October 2013.

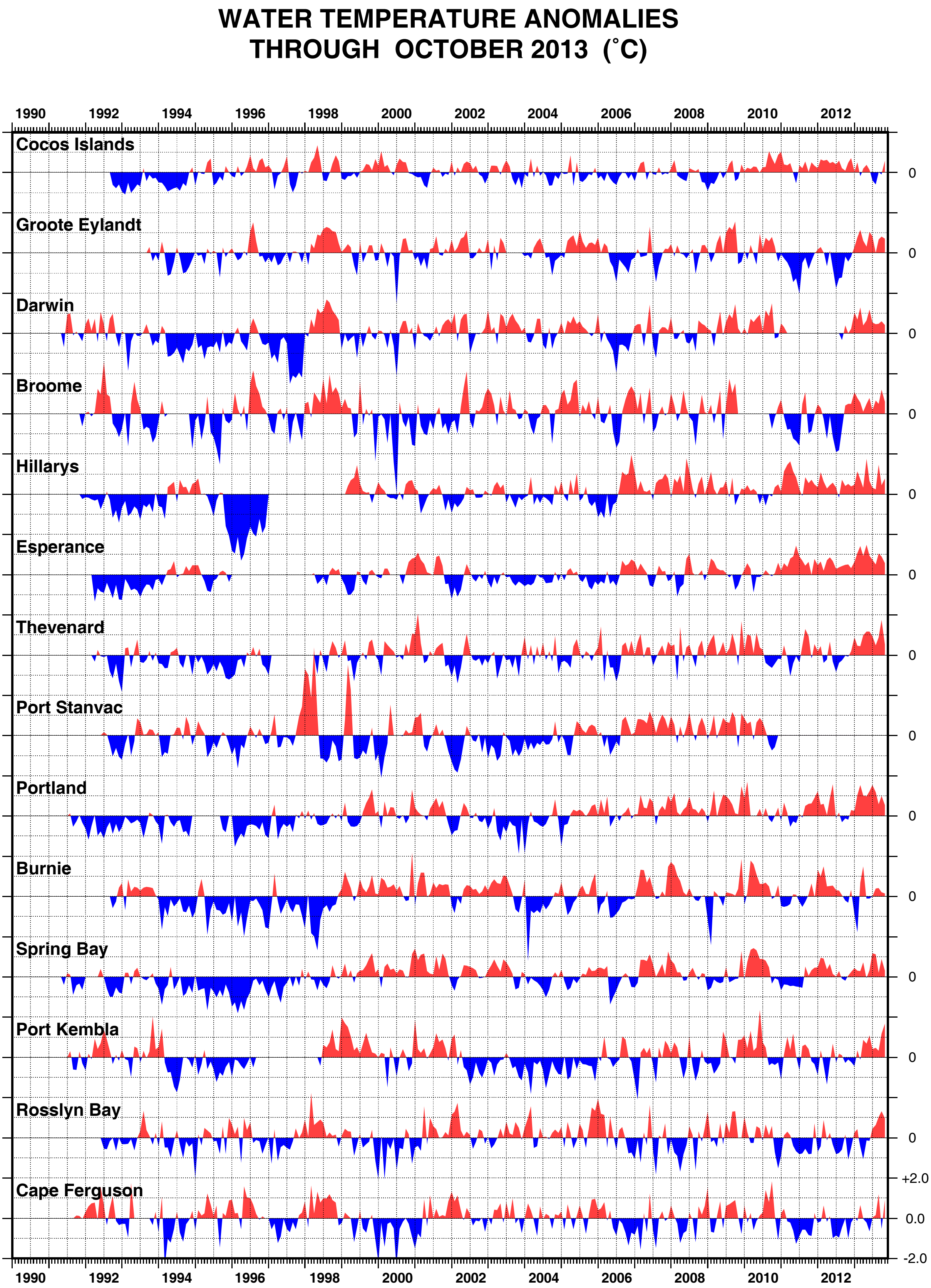

Figure 16. Monthly water temperature anomalies to October 2013.

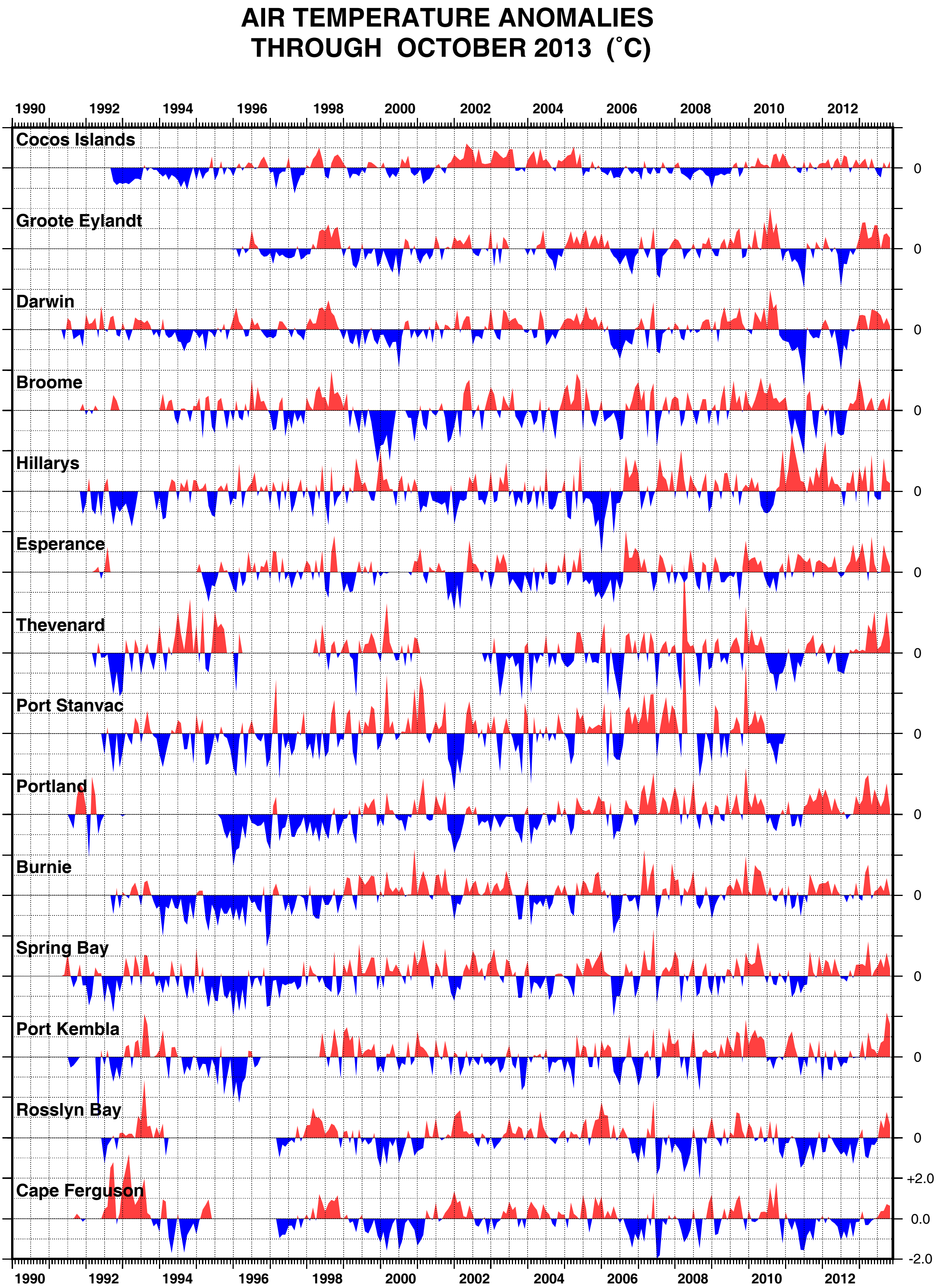

Figure 17. Monthly air temperature anomalies to October 2013.

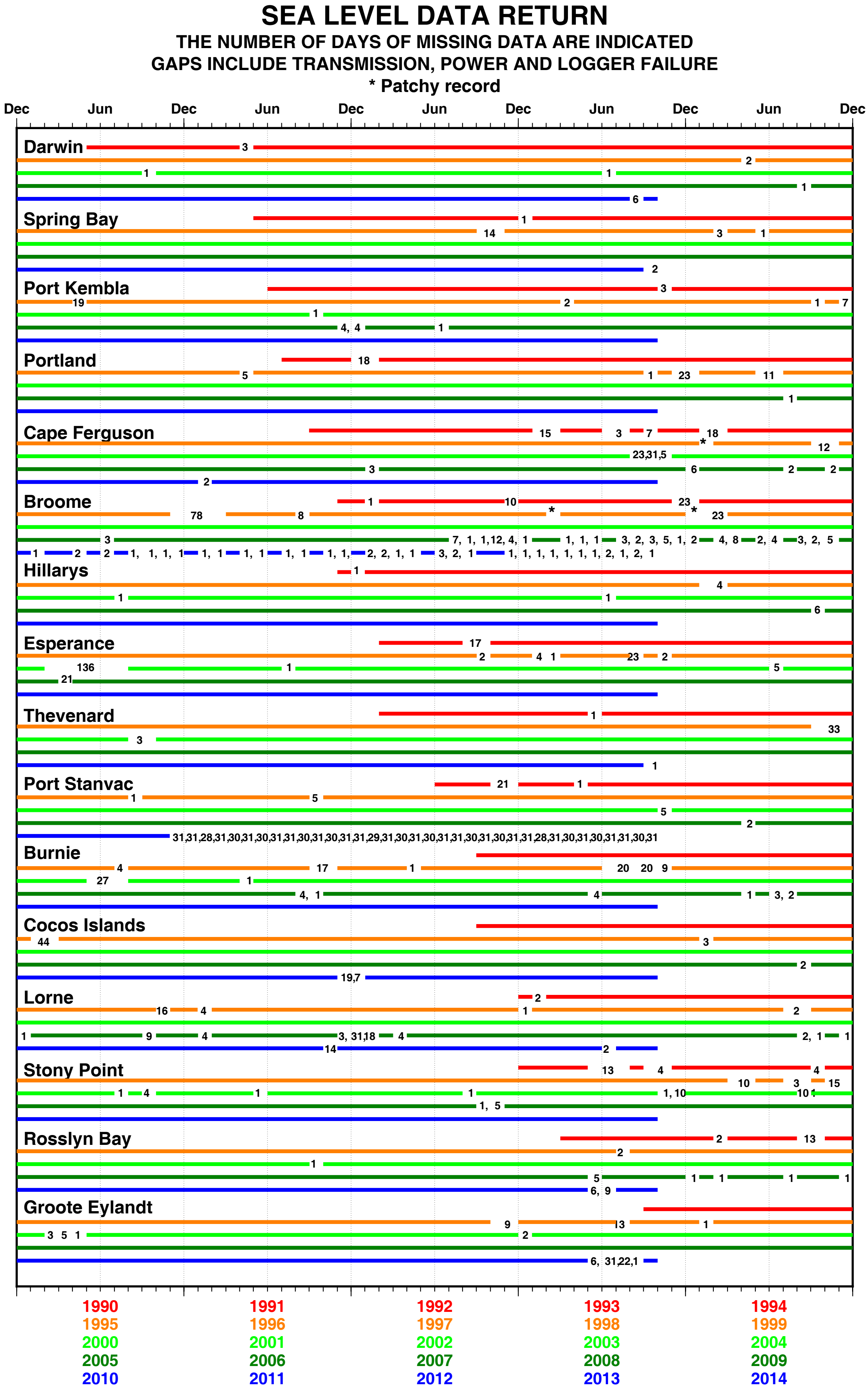

Figure 18. Sea level data return.