Climate and Oceans Support Program in the Pacific

Australian Government
Bureau of Meteorology

Monthly Data Report - February 2013

Pacific Sea Level Monitoring Project

Australian Government

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.

February 2013

- The SEAFRAME network continued to collect high quality sea level and associated meteorological information for monitoring climate variability and climate change.
- The overall rate of sea level data return for February was very good at 98.8%. Specific problems were encountered with the satellite data transmissions from Tuvalu which restricted its rate of sea level data return to 86.8%.
- Monthly sea levels during February were mostly near normal for this time of the year, although notable anomalies of -10cm were observed at Solomon Islands and Cook Islands.
- Tsunami signals were detected at several stations following a magnitude Mw8.0 earthquake that struck in the vicinity of the Solomon Islands on 6th February 2013. The SEAFRAME at Vanuatu registered a tsunami of around 55cm, while a tsunami gauge closer to the source at Lata, Solomon Islands recorded a 1.8m tsunami. The SEAFRAME at Honiara was less exposed to the tsunami and only recorded a signal of 15cm.

Introduction

Welcome to the February 2013 Monthly Data Report for the Pacific Sea Level Monitoring Project (PSLMP). The report details the month by month operation of the SEAFRAME monitoring stations in the Pacific, including operational problems with the network or with satellite communications, the occurrence of abnormal sea level events and the interpretation of sea level fluctuations in the context of related astronomical tide, weather and climate variations.

The PSLMP continues the work of the South Pacific Sea Level and Climate Monitoring Project (SPSLCMP) under a wider Climate and Oceans Support Program in the Pacific (COSPPac) initiative. The SPSLCMP was originally developed as an Australian response to concerns raised by the member countries of the South Pacific Forum over the potential impacts of global warming on climate and sea levels in the Pacific with the principal objective of 'the provision of an accurate long term record of sea level in the South Pacific for partner countries and the international scientific community which enables them to respond to and manage related impacts'.

The project's sea level monitoring network consists of 12 SEAFRAME stations providing wide coverage across the Pacific Islands Forum region (Figure 1). The 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.

An associated geodetic measurement program, implemented by Geosciences Australia, supports levelling surveys to first order, to determine shifts in the vertical of the sea level sensors due to local land movement, as well as continuous Global Positioning System (CGPS) stations to determine the vertical movement of the land with respect to the International Terrestrial Reference Frame.

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.

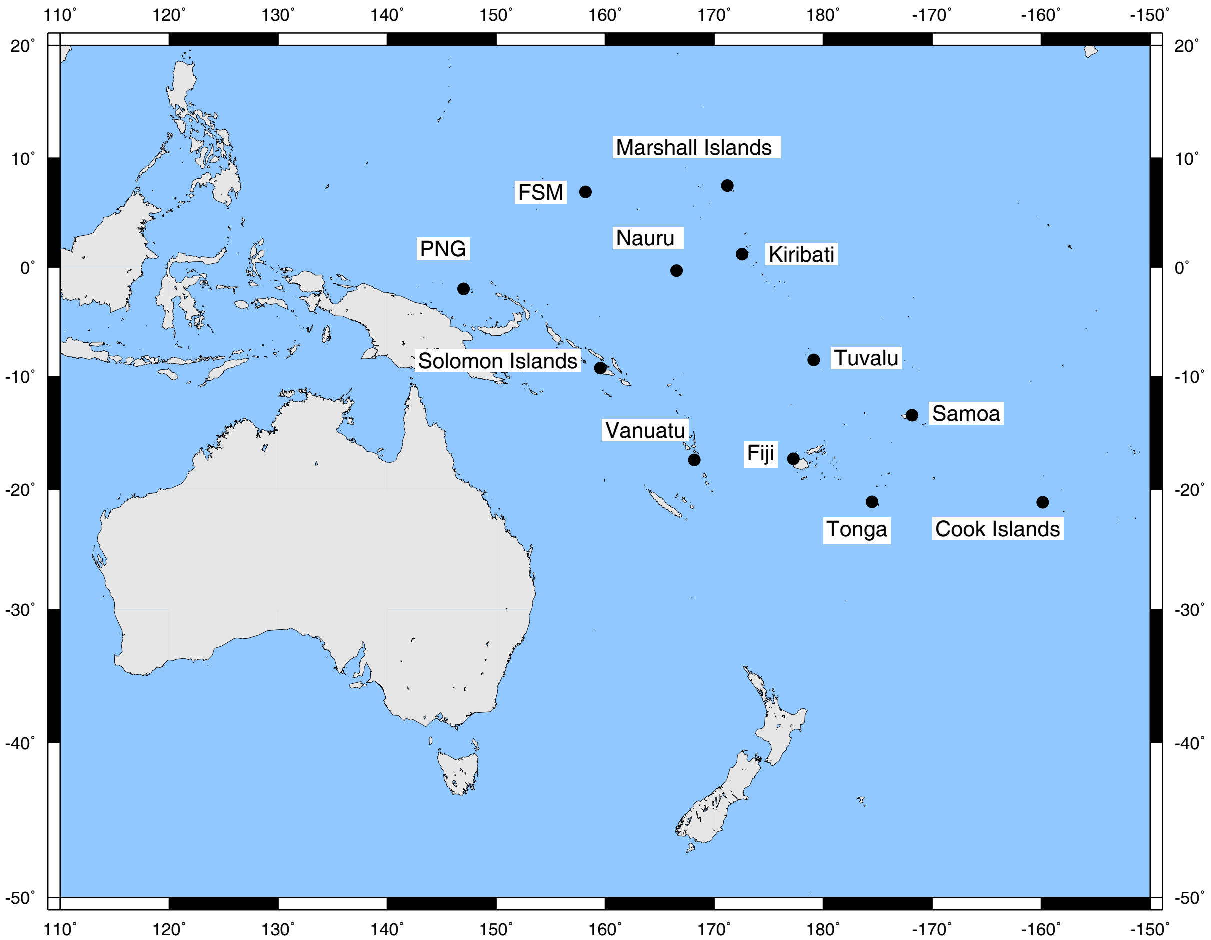

Figure 1. Pacific Sea Level Monitoring Network of SEAFRAME stations

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 in the tropical Pacific are largely influenced by fluctuations in climate and ocean heat content across the Pacific.

The El Niño – Southern Oscillation climate cycle plays a key role in sea level variability. During El Niño sea levels are generally lower than normal across the western equatorial Pacific, as measured by the project's sea level network, in response to weaker than normal easterly Trade Winds, cooler than normal ocean temperatures and higher than normal barometric pressures in this region. On the other hand during La Niña the easterly Trade Winds are typically stronger than normal, ocean temperatures are warmer than normal and barometric pressures are lower than normal across the western Pacific, which often results in higher than normal sea levels at many of the project stations.

The sea level stations at PNG, Solomon Islands, Tuvalu and Samoa lie along a zone of convergent winds, known as the South Pacific Convergence Zone. Sea levels at these stations may become higher or lower than normal depending on the strength of these convergent winds or the shifting position of the convergence zone relative to its climatological mean. The sea level stations at Nauru and Kiribati lie very close to the equator and can both be influenced by sea level signals propagating along the equatorial waveguide.

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

Further climate information for Pacific Island countries is provided by the Climate and Ocean Monitoring and Prediction (COMP) Project under the Climate and Oceans Support Program in the Pacific (COSPPac).

February 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 PNG and the Solomon Islands 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 10th of February and a full moon on the 25th of February.

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. Tropical cyclones 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 SEAFRAME network helped detect a tsunami that was generated by an undersea earthquake of magnitude Mw8.0 that struck at 1:12 UTC on 6th February 2013 around 76km west of Lata, Solomon Islands. The residual sea levels (Figure 5) following the earthquake show trough-to-peak tsunami signals of 15cm at Solomon Islands (Honiara), 55cm at Vanuatu and around 10cm at Samoa, Fiji and Tonga. A tsunami warning gauge located at Lata, Solomon Islands registered a trough-to-peak tsunami signal of around 1.8m.

The non-tidal sea level fluctuations can be amplified or sustained by the shape of the 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), such as at PNG when the wind suddenly changes strength or direction, at FSM during smaller neap tides and at Nauru during strong westerly winds.

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 Marshall Islands prevailed from the northeast 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. At some sites (e.g. Marshall Islands) the water temperature shows almost no variation, although the air temperature varies by several degrees between night and day. At Nauru a twice-daily fluctuation in water temperature is related to interactions between tides and terrestrial (land-based) water discharging into the wharf area. The water temperature fluctuations there are usually more pronounced during the larger spring tides.

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 such as Cook Islands and Tonga.

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 Pacific Sea Level Monitoring Project data, which have been collected since October 1992 when the first station was installed at Fiji. The data from FSM has only been collected since December 2001. Notable extremes this month include record high February air temperatures at Marshall Islands (30.6 ºC), FSM (31.8 ºC) and Kiribati (30.6 ºC). Further sea level and meteorological statistical information is available at http://www.bom.gov.au/oceanography/projects/spslcmp/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 figure shows that Tuvalu, for example, normally experiences an annual cycle of about 0.2 metres, reaching a peak around February or March. One effect of the El Niño of 1997-1998 was very low sea levels which disrupted the annual sea level cycle at many of the SEAFRAME stations.

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 Tuvalu (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 across the region during the 1997/98 El Niño.

Monthly sea levels during February 2013 were around 10cm lower than normal at Solomon Islands and Cook Islands. Elsewhere across the network the monthly sea levels were generally near normal for this time of the year, albeit slightly lower than normal at Marshall Islands, FSM, Samoa, Vanuatu and Fiji and slightly higher at PNG and Tuvalu.

Overall Rate of Movement in Sea Level

Table 1 shows the overall rate of movement in sea level at individual Pacific stations based on the data so far collected at those sites. For many of the sites, the underlying data sets are around 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 February, 2013.

Location	Latitude	Longitude	Date of first data	Rate (mm/yr)	Change in rate from previous month (mm/yr)
Cook Is	21°12'17.1"S	159°47'5.2"W	Feb 1993	+5.6	-0.1
Tonga	21°8'12.5"S	175°10'50.5"W	Jan 1993	+9.1	0.0
Fiji	17°36'17.7"S	177°26'17.7"E	Oct 1992	+6.0	-0.1
Vanuatu	17°45'19.2"S	168°18'27.7"E	Jan 1993	+4.8	-0.1
Samoa	13°49'36.4"S	171°45'40.7"W	Feb 1993	+7.6	-0.1
Tuvalu	8°30'8.9"S	179°11'42.6"E	Mar 1993	+3.9	0.0
Kiribati	1°21'54.2"N	172°55'58.8"E	Dec 1992	+3.4	0.0
Nauru	0°31'45.9"S	166°54'36.2"E	Jul 1993	+4.4	0.0
Solomon Is.	9°25'44.1"S	159°57'19.3"E	Jul 1994	+7.6	-0.1
PNG	2°2'31.5"S	147°22'25.6"E	Sep 1994	+8.6	0.0
FSM	6°58'49.9"N	158°12'0.8"E	Dec 2001	+17.2	-0.1
Marshall Is.	7°6'21.7"N	171°22'22.1"E	May 1993	+5.8	-0.1

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 substantially higher than normal barometric pressures were observed at SEAFRAME stations during the 1997-1998 El Niño. In comparison monthly average barometric pressures during February 2013 were much closer to normal.

Water temperature anomalies (Figure 16) during February 2013 were around +0.5 ºC at Nauru, indicating warmer than normal conditions, and around -1.0 ºC at Cook Islands. Water temperatures at Marshall Islands, FSM, PNG, Solomon Islands, Kiribati, Samoa, Vanuatu, Fiji and Tonga through February were close to what is expected at this time of the year. Water temperature data were unable to be collected at Tuvalu during February due to technical problems.

Air temperature anomalies (Figure 17) during February 2013 were around +1.5 ºC at FSM, +1.2 ºC at Kiribati and +0.5 ºC at Marshall Islands and Samoa. Air temperatures were closer to normal at other sites, albeit slightly cooler than average at Vanuatu and Cook Islands and slightly warmer at Solomon Islands. No air temperature data were able to be collected from Nauru and Tuvalu during February due to technical problems. Over the duration of the record the air temperature anomalies generally (although not always) follow the water temperature anomalies, which is an indication of the large influence the ocean has upon the climate of the Pacific Islands.

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 98.8% during February 2013 (Table 2). The satellite data packets received from Tuvalu during February were quite corrupted and while 86.8% of sea level data were able to be deciphered none of the ancillary data were able to be decoded.

Aside from Tuvalu additional problems encountered with the ancillary sensors during February included the air temperature sensor at Nauru, the water temperature sensor at Tonga and the wind monitors at FSM and Fiji. The erroneous data received from these problematic sensors were removed from the quality-controlled archived records.

Table 2. Rates of sea level data return

Location	Installation Date	Data Return Since Installation (%)	Data Return in February 2013 (%)
Cook Is	Feb 1993	96.8	99.3
Tonga	Jan 1993	98.4	100
Fiji	Oct 1992	98.8	100
Vanuatu	Jan 1993	95.0	100
Samoa	Feb 1993	96.4	100
Tuvalu	Mar 1993	96.2	86.8
Kiribati	Dec 1992	93.9	100
Nauru	Jul 1993	92.7	99.3
Solomon Is.	Jul 1994	98.5	100
PNG	Sep 1994	93.3	100
FSM	Dec 2001	96.8	99.7
Marshall Is.	May 1993	98.1	100
Network Average		**96.2**	**98.8**

SEAFRAME Stations

SEAFRAME stations employ either a SUTRON or TELMET (for upgraded stations) 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-puls radar sensor mounted above the water (at upgraded sites).

For SUTRON stations, the water level samples are averaged over three minutes and logged every six minutes, while meteorological sensors are logged on an hourly basis. With the upgraded TELMET stations, 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 SUTRON algorithm. Both SUTRON and TELMET data loggers have the memory capacity to store approximately one month of data

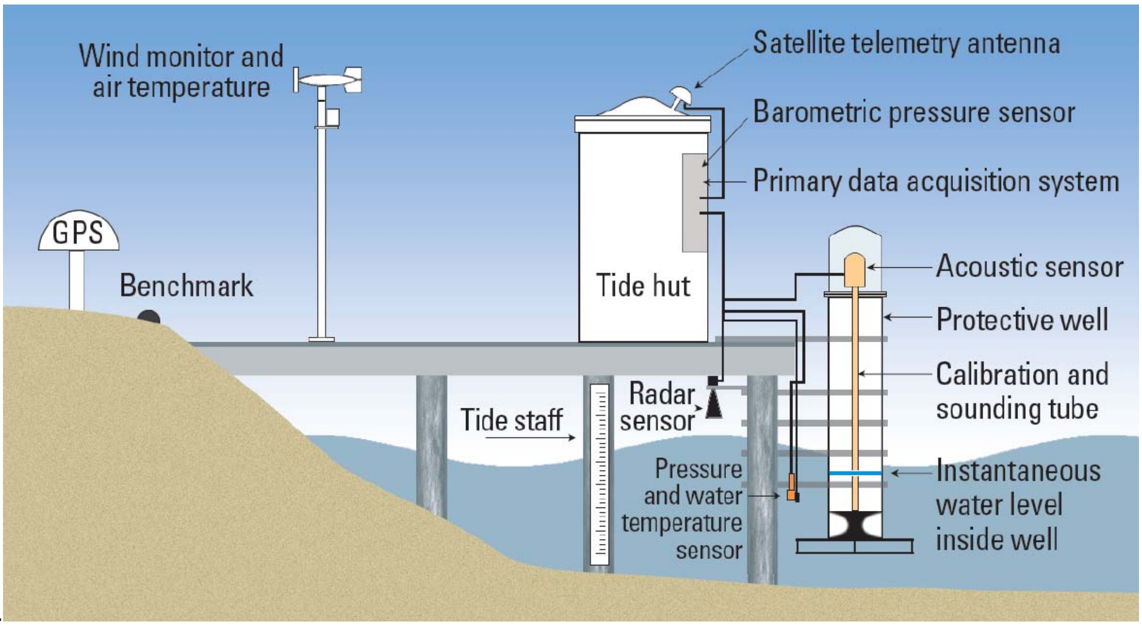

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Figure 2. Schematic diagram of a SEAFRAME sea level monitoring station.

Observation Network Upgrade Project

The Observation Network Upgrade Project (ONUP) is scheduled to upgrade all Pacific SEAFRAME stations by Dec-2013 with modernised TELMET data loggers, real-time satellite communications and additional radar-type water level sensors. The status of the station upgrades is given in Table 3.

Table 3. Schedule of SEAFRAME station equipment upgrades.

Location	Latitude	Longitude	SUTRON Installation Date	TELMET Upgrade Date
Cook Is	21°12'17.1"S	159°47'5.2"W	Feb 1993	Oct 2012
Tonga	21°8'12.5"S	175°10'50.5"W	Jan 1993	Mar 2011
Fiji	17°36'17.7"S	177°26'17.7"E	Oct 1992	Jun 2011
Vanuatu	17°45'19.2"S	168°18'27.7"E	Jan 1993	May 2012
Samoa	13°49'36.4"S	171°45'40.7"W	Feb 1993	Aug 2011
Tuvalu	8°30'8.9"S	179°11'42.6"E	Mar 1993	To be upgraded
Kiribati	1°21'54.2"N	172°55'58.8"E	Dec 1992	Oct 2011
Nauru	0°31'45.9"S	166°54'36.2"E	Jul 1993	To be upgraded
Solomon Is.	9°25'44.1"S	159°57'19.3"E	Jul 1994	Nov 2011
PNG	2°2'31.5"S	147°22'25.6"E	Sep 1994	Aug 2012
FSM	6°58'49.9"N	158°12'0.8"E	Dec 2001	Sched. Apr 2013
Marshall Is.	7°6'21.7"N	171°22'22.1"E	May 1993	Dec 2012

Further Information

Online Resources

COSPPac Web site: http://www.bom.gov.au/cosppac/

PSLMP Web site: http://www.bom.gov.au/oceanography/projects/spslcmp/spslcmp.shtml

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

Geoscience Australia South Pacific Regional GNSS Network (Levelling Survey and Continuous GPS Monitoring): http://www.ga.gov.au/earth-monitoring/geodesy/gnss-networks.html

Acknowledgement

The Monthly Data Report is prepared for AusAID by the National Tidal Centre (NTC), Bureau of Meteorology under the Pacific Sea Level Monitoring (PSLM) Project, Climate and Oceans Support Program in the Pacific (COSPPac).

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

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Kent Town SA 5067
Tel: (+618) (08) 8366 2730
Email: ntc@bom.gov.au
Website: http://www.bom.gov.au/oceanography/tides.shtml

Please also note the following:

Appendix 1: SEAFRAME Data Figures

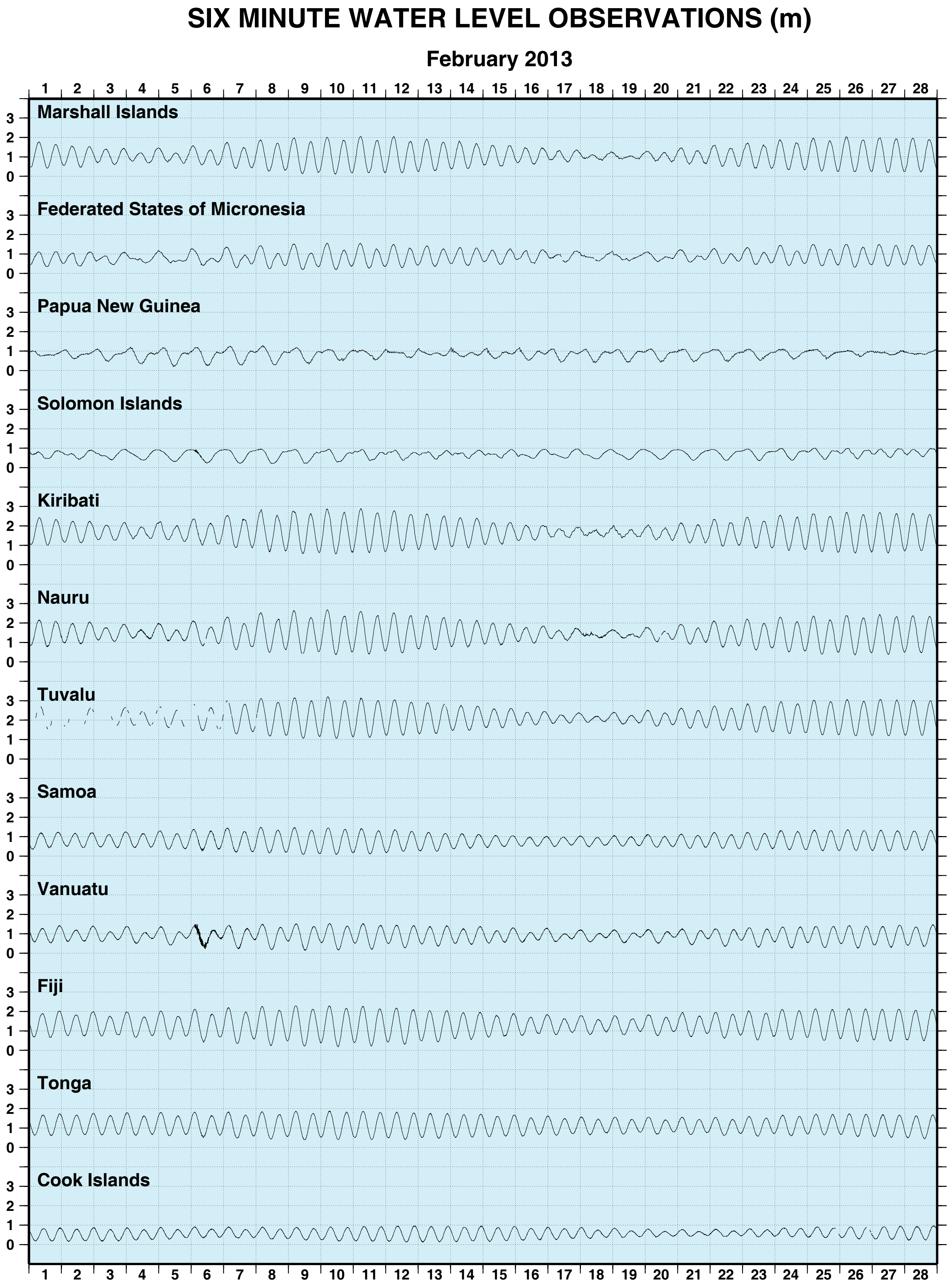

Figure 3. Sea level observations during February 2013.

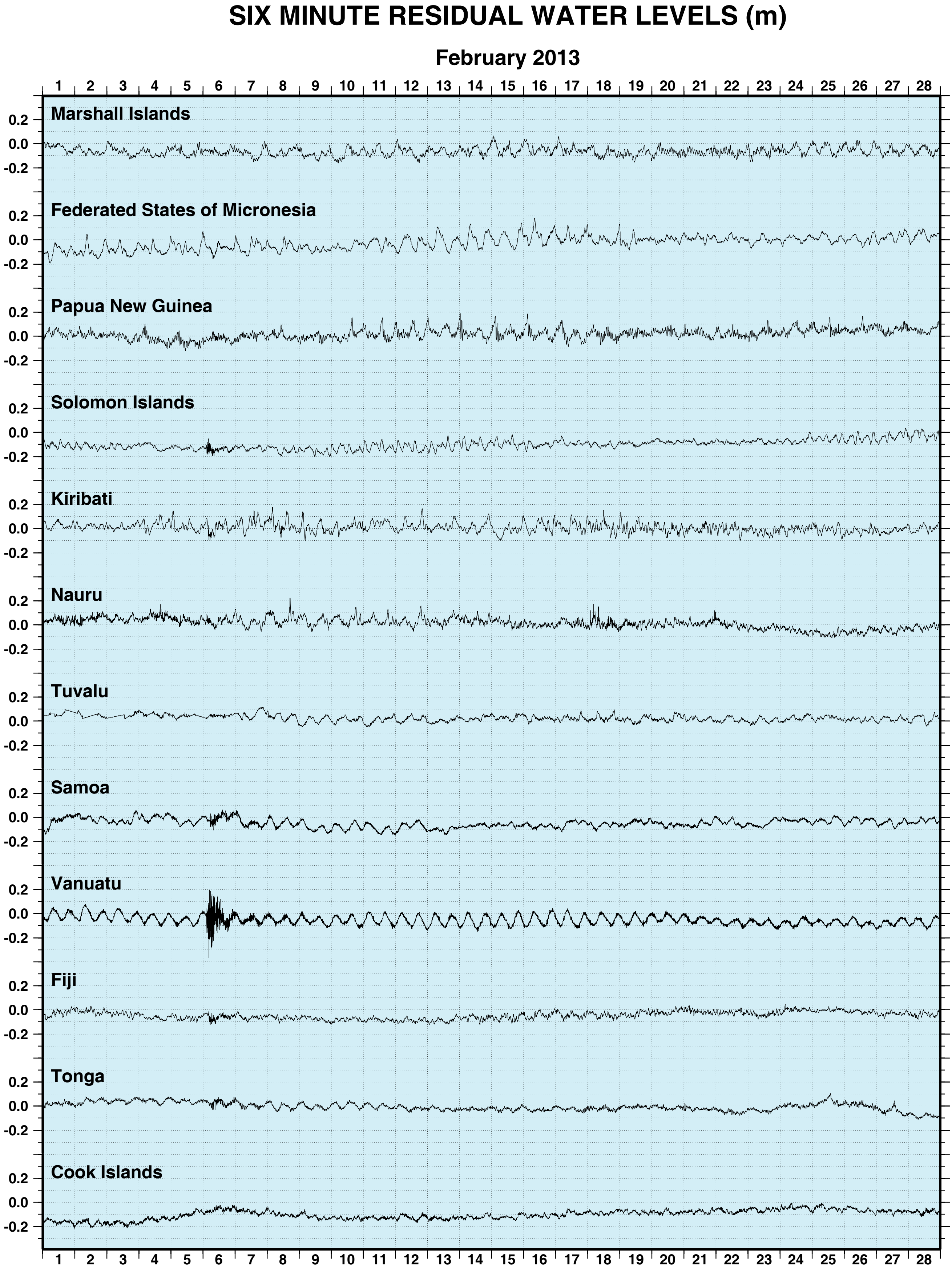

Figure 4. Residual sea levels during February 2013.

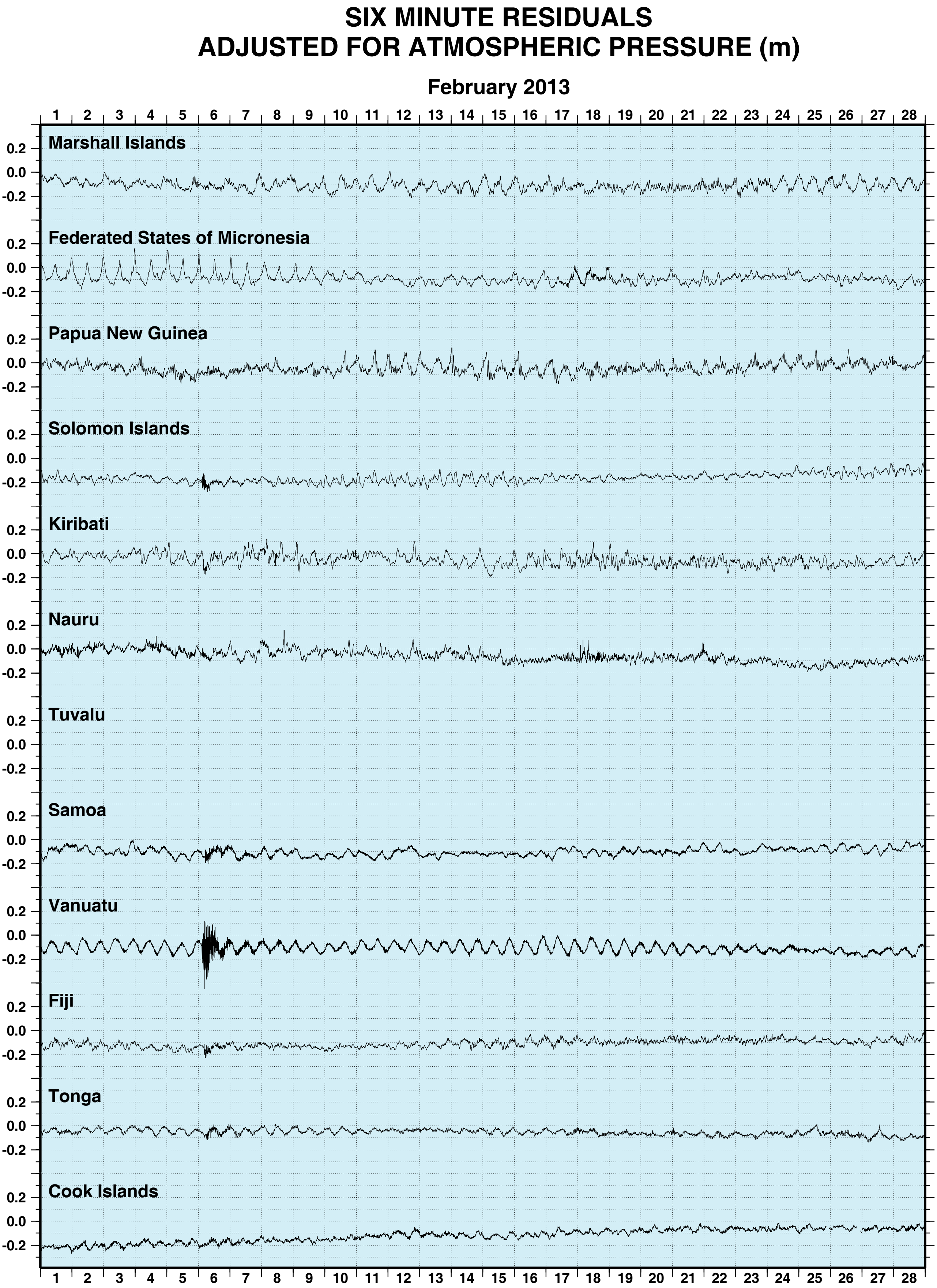

Figure 5. Residual sea levels adjusted for atmospheric pressure during February 2013.

Figure 6. Wind speeds during February 2013.

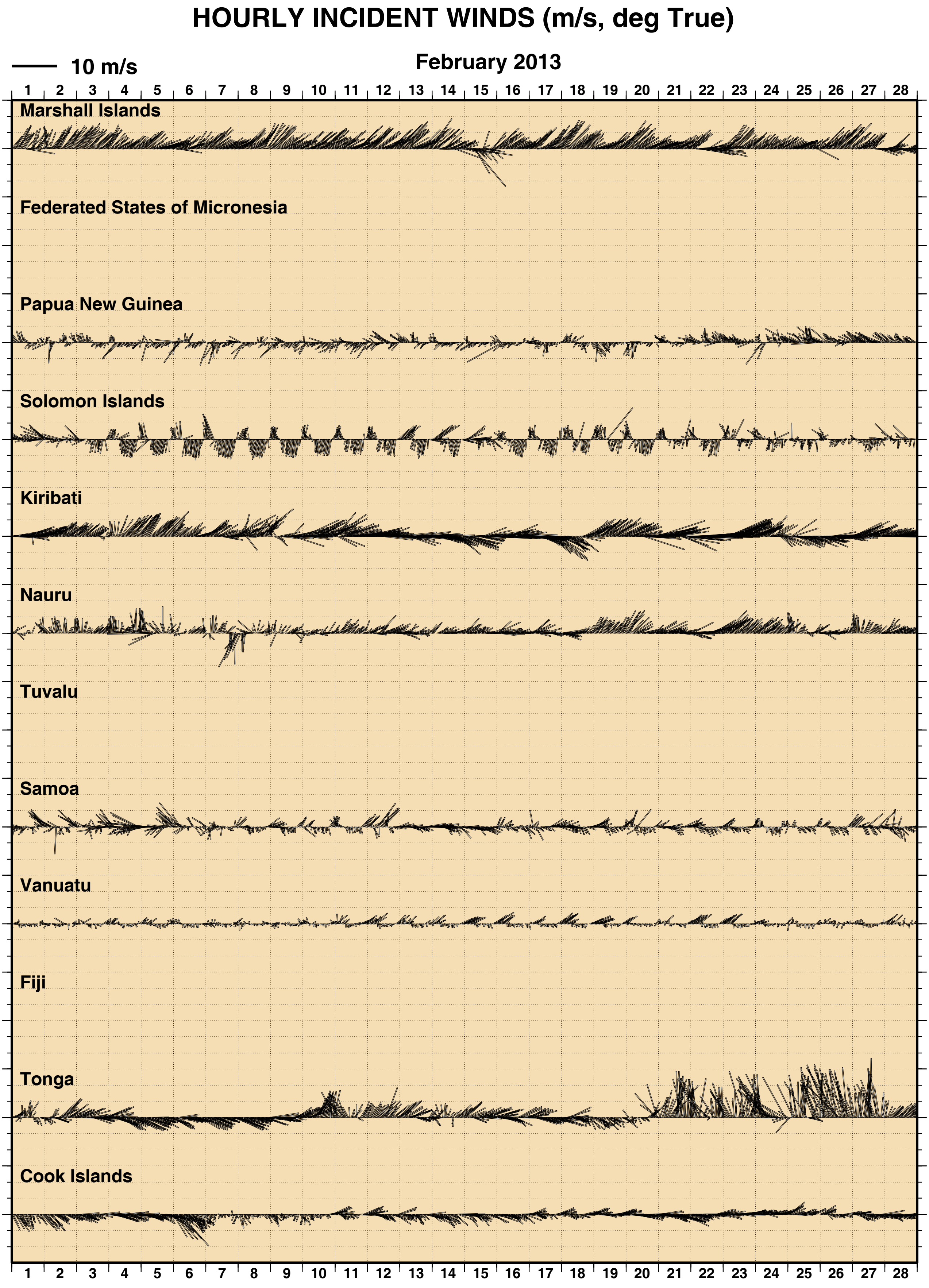

Figure 7. Incident winds during February 2013.

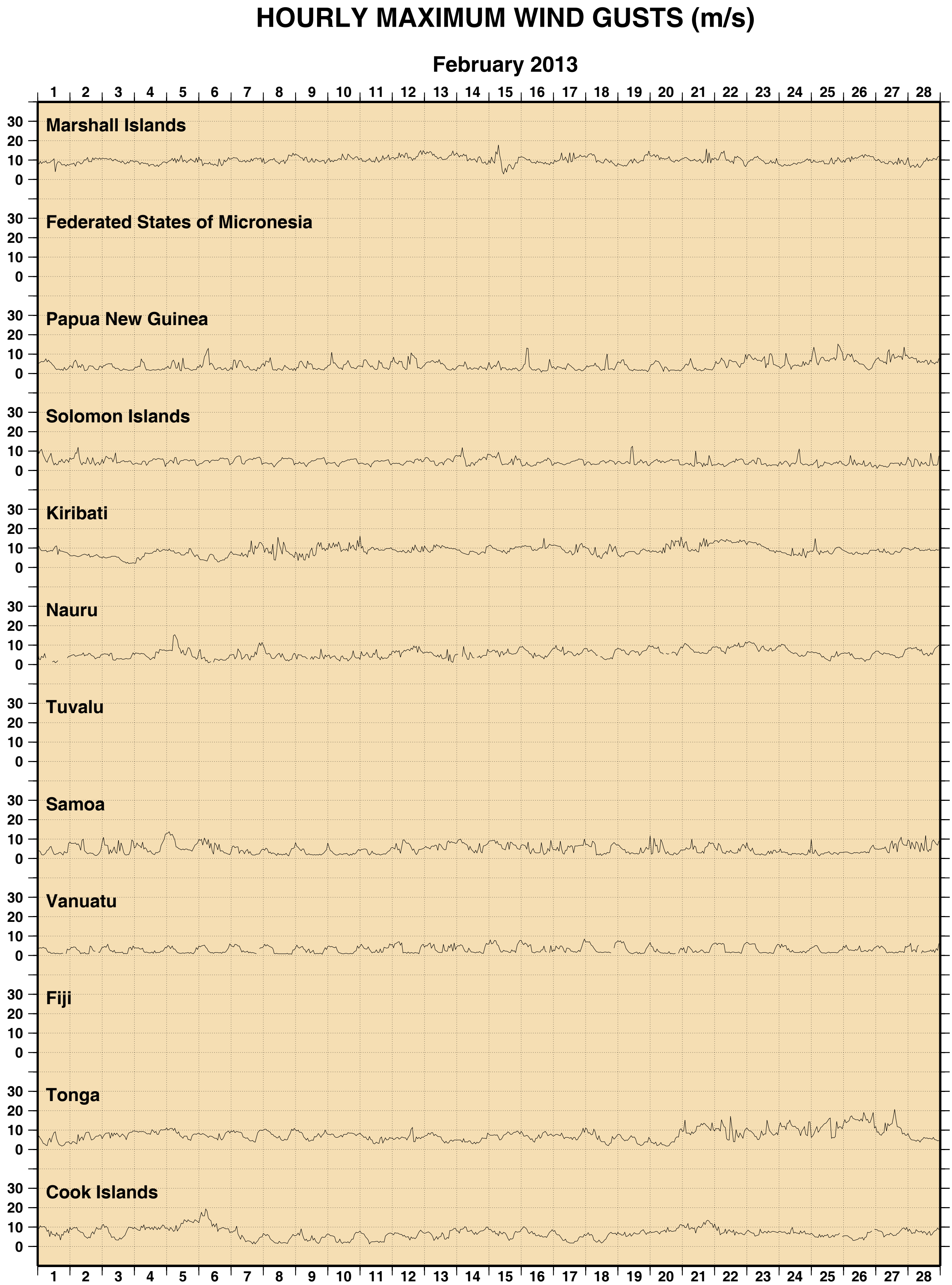

Figure 8. Wind gusts during February 2013.

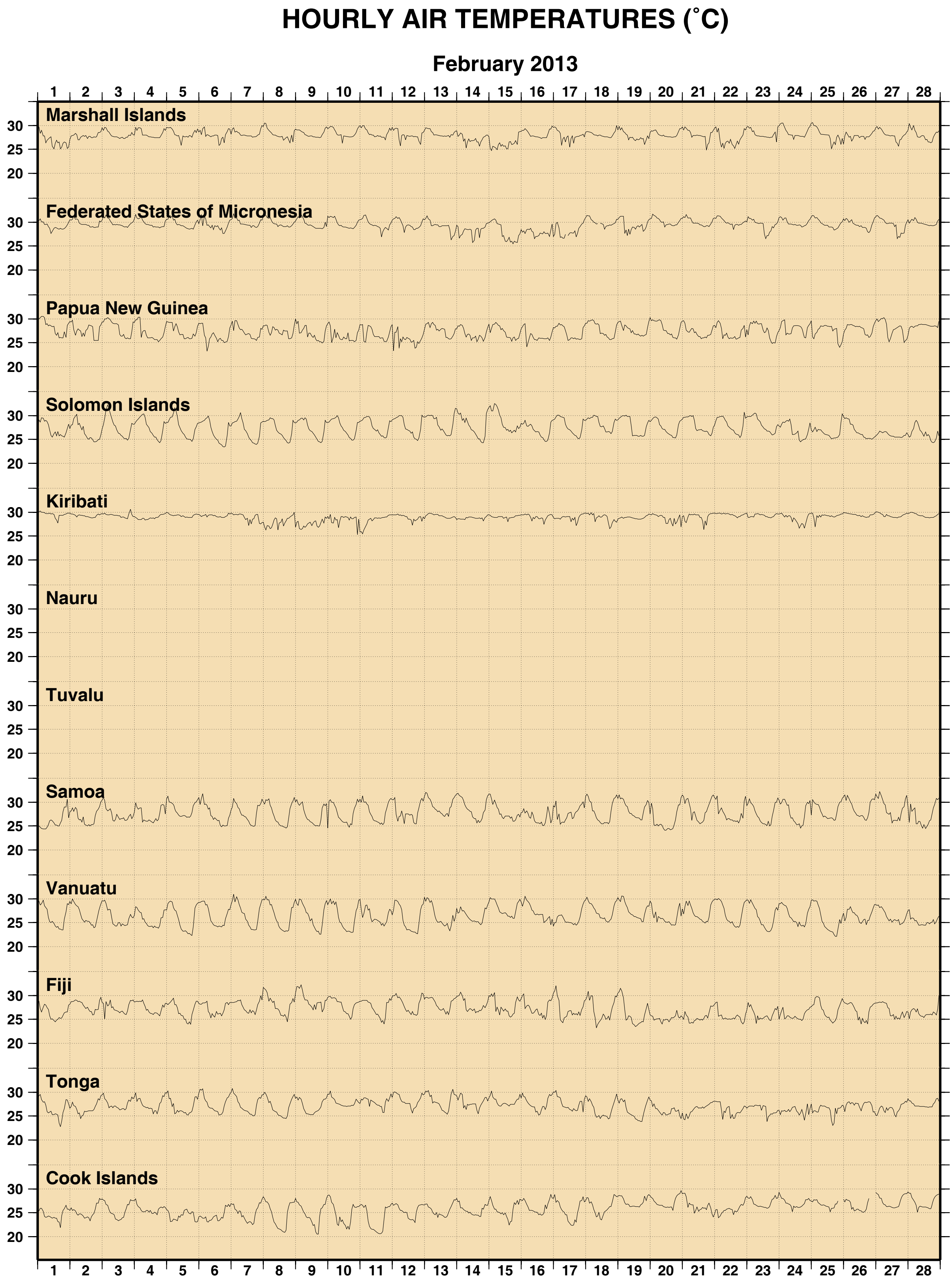

Figure 9. Air temperatures during February 2013.

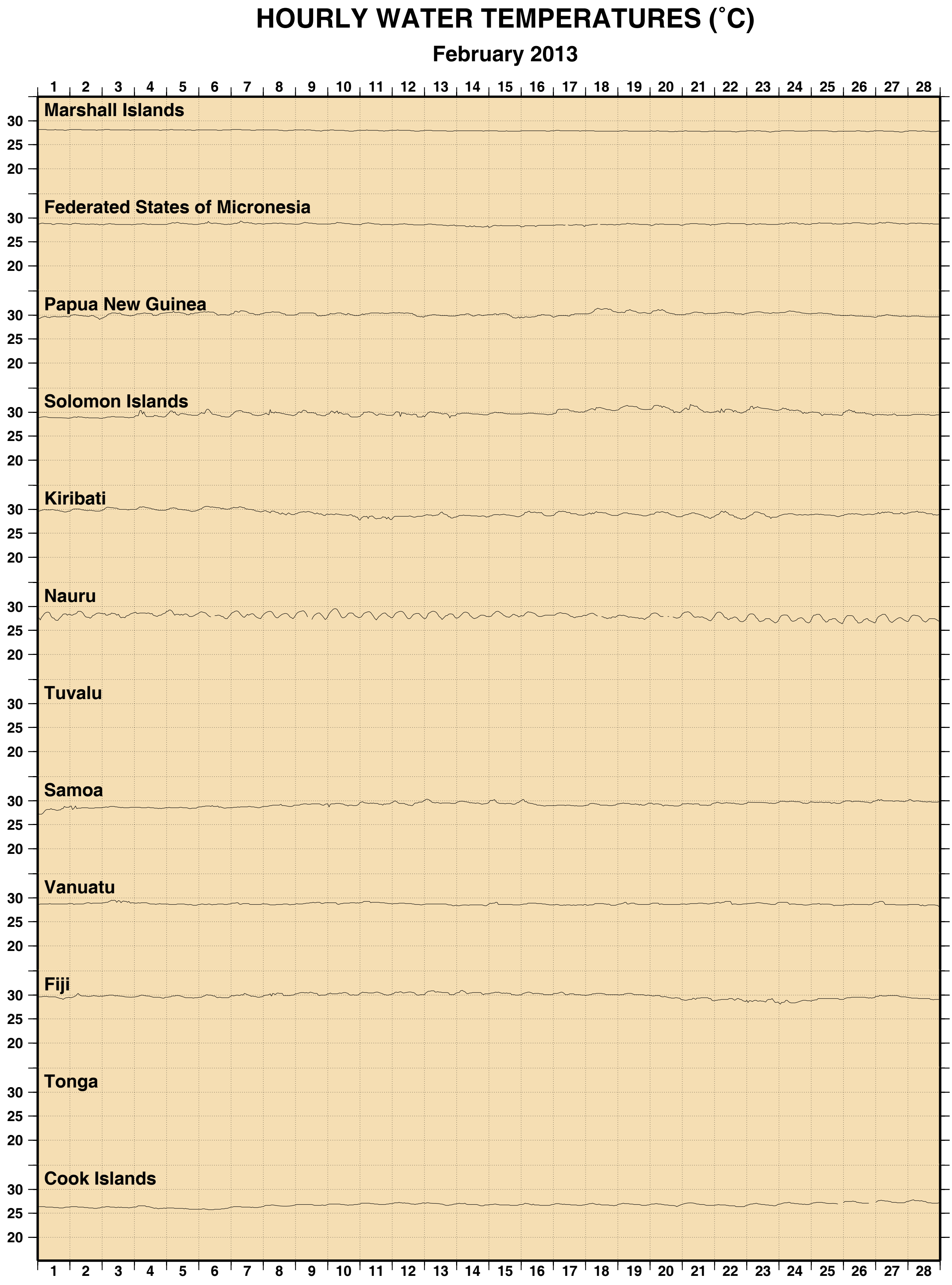

Figure 10. Water temperatures during February 2013.

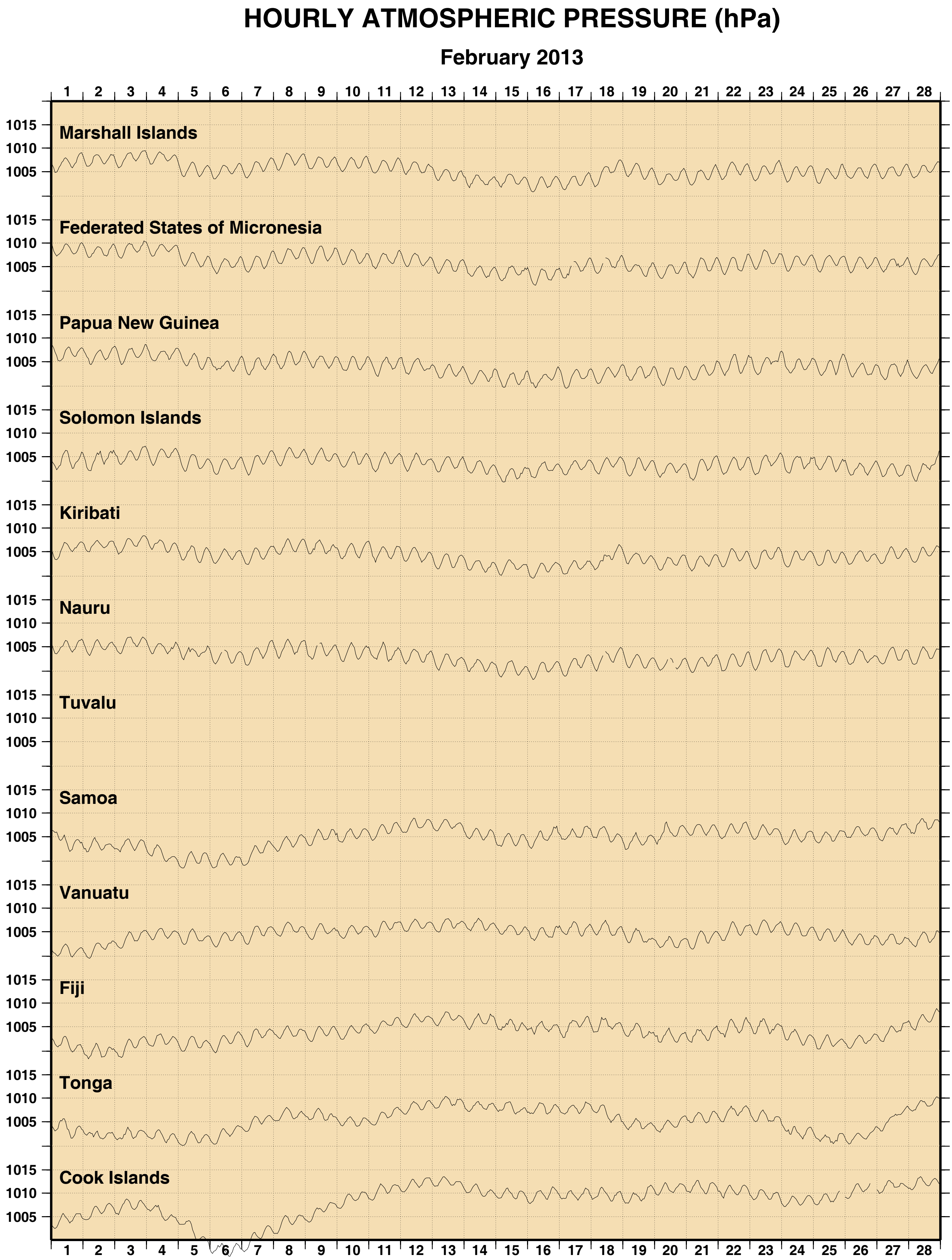

Figure 11. Atmospheric pressures during February 2013.

Comparison of February 2013 Max, Min & Mean with Long Term February Values.

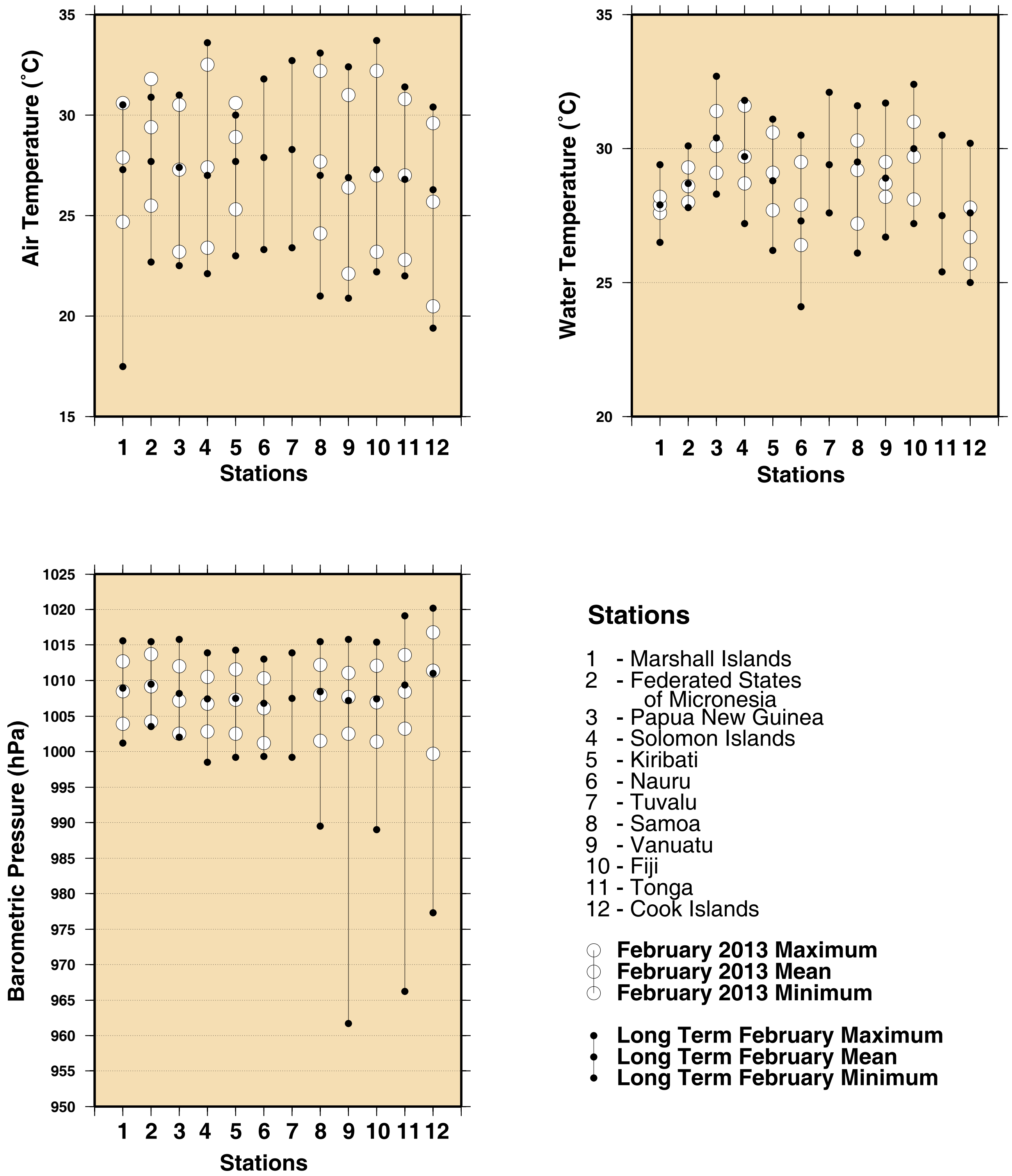

Figure 12. Comparison of February 2013 ancillary data with long term February values

MONTHLY MEAN SEA LEVELS TO FEBRUARY 2013 (m)

The zero line represents an arbitrary fixed offset from the zero of the tide gauge.

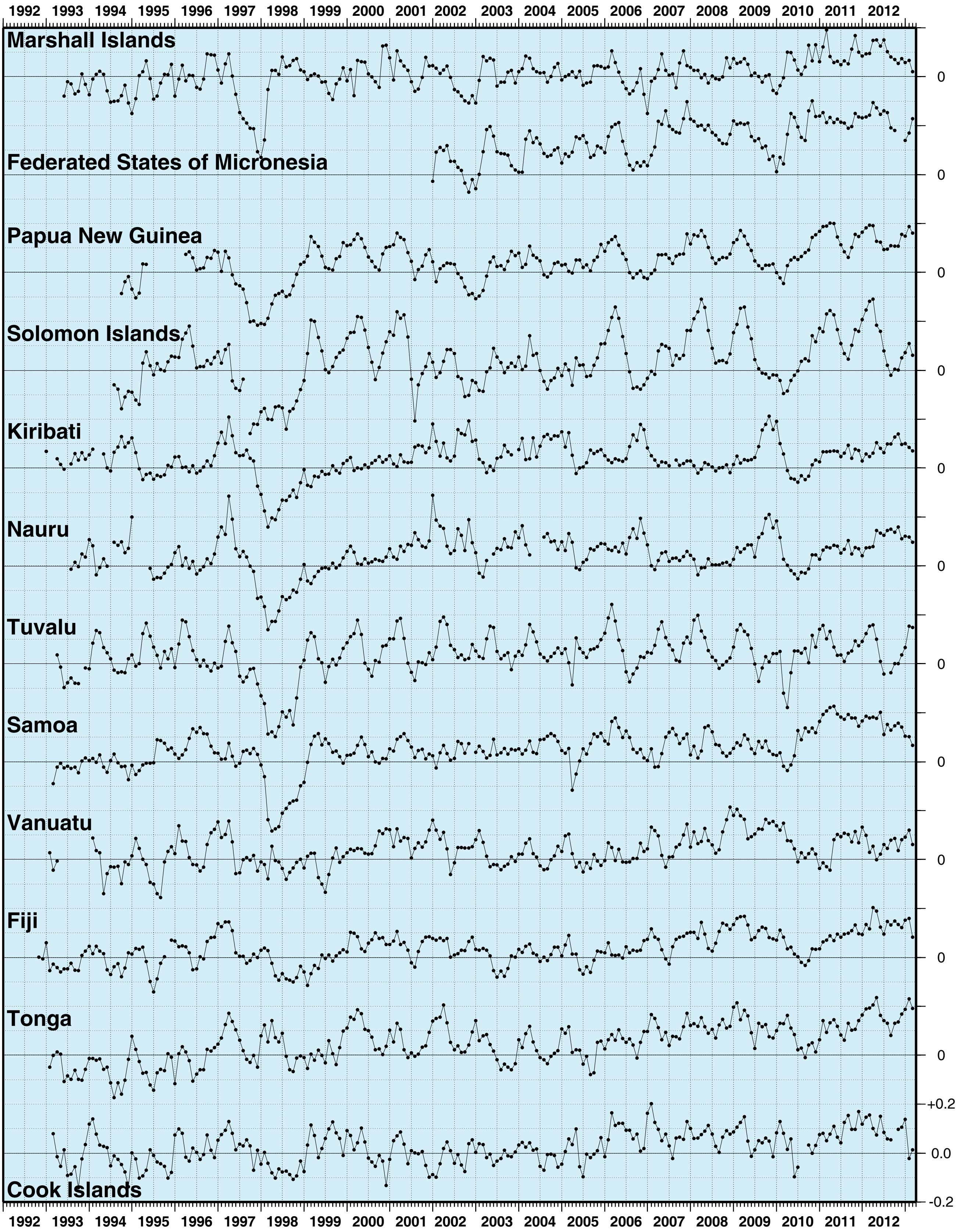

Figure 13. Monthly mean sea levels to February 2013

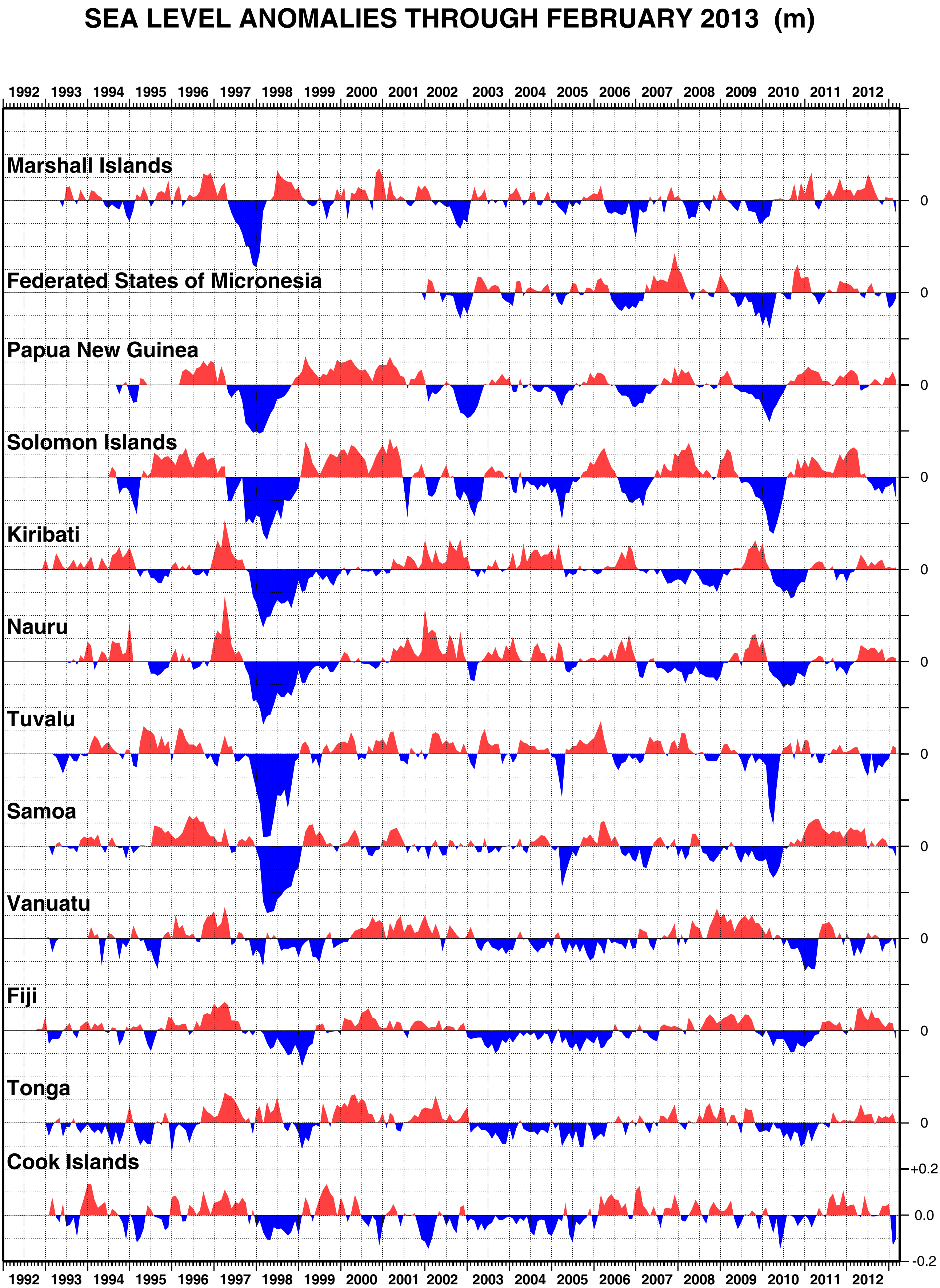

Figure 14. Monthly sea level anomalies to February 2013.

BAROMETRIC PRESSURE ANOMALIES THROUGH FEBRUARY 2013 (hPa)

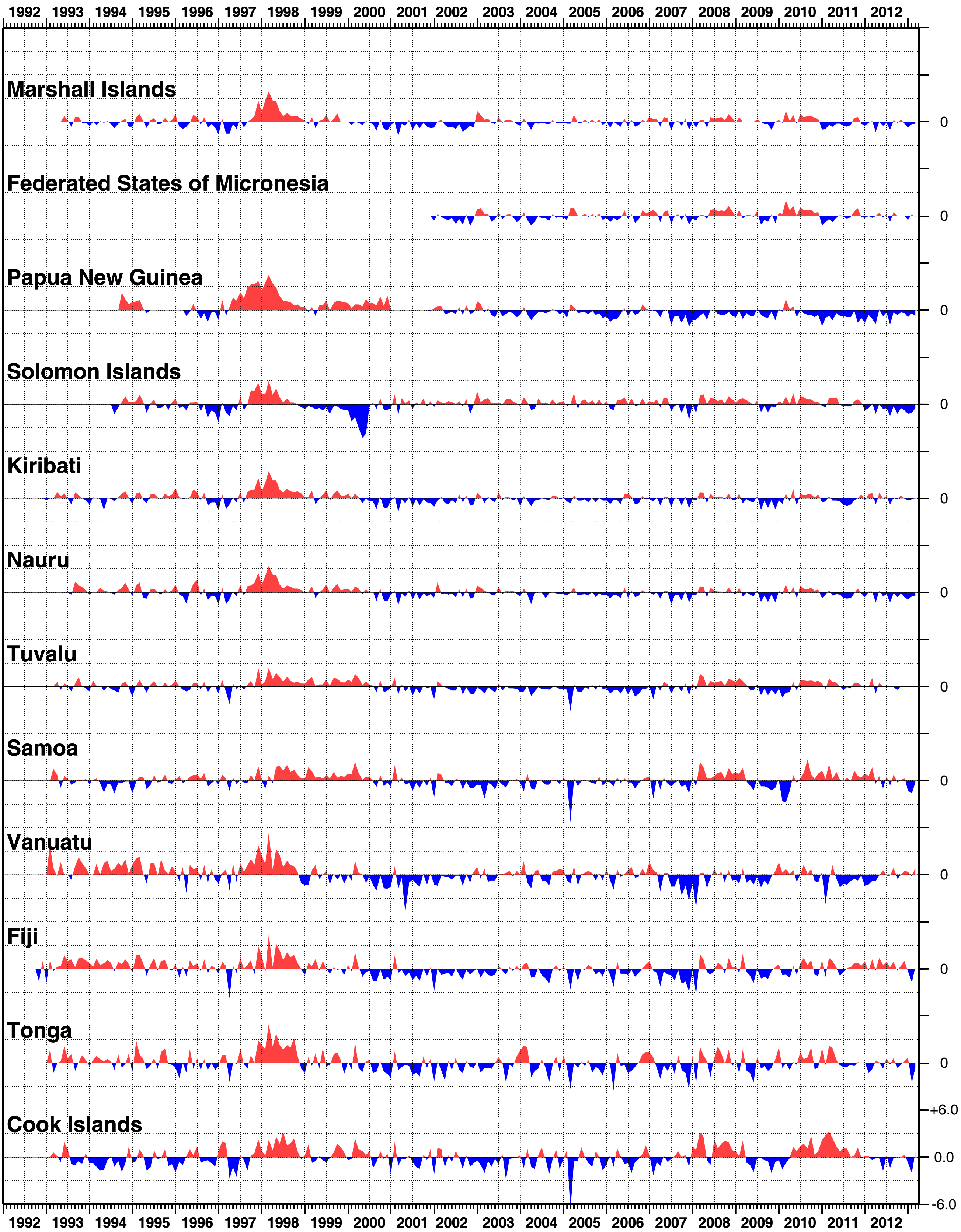

Figure 15. Monthly barometric pressure anomalies to February 2013.

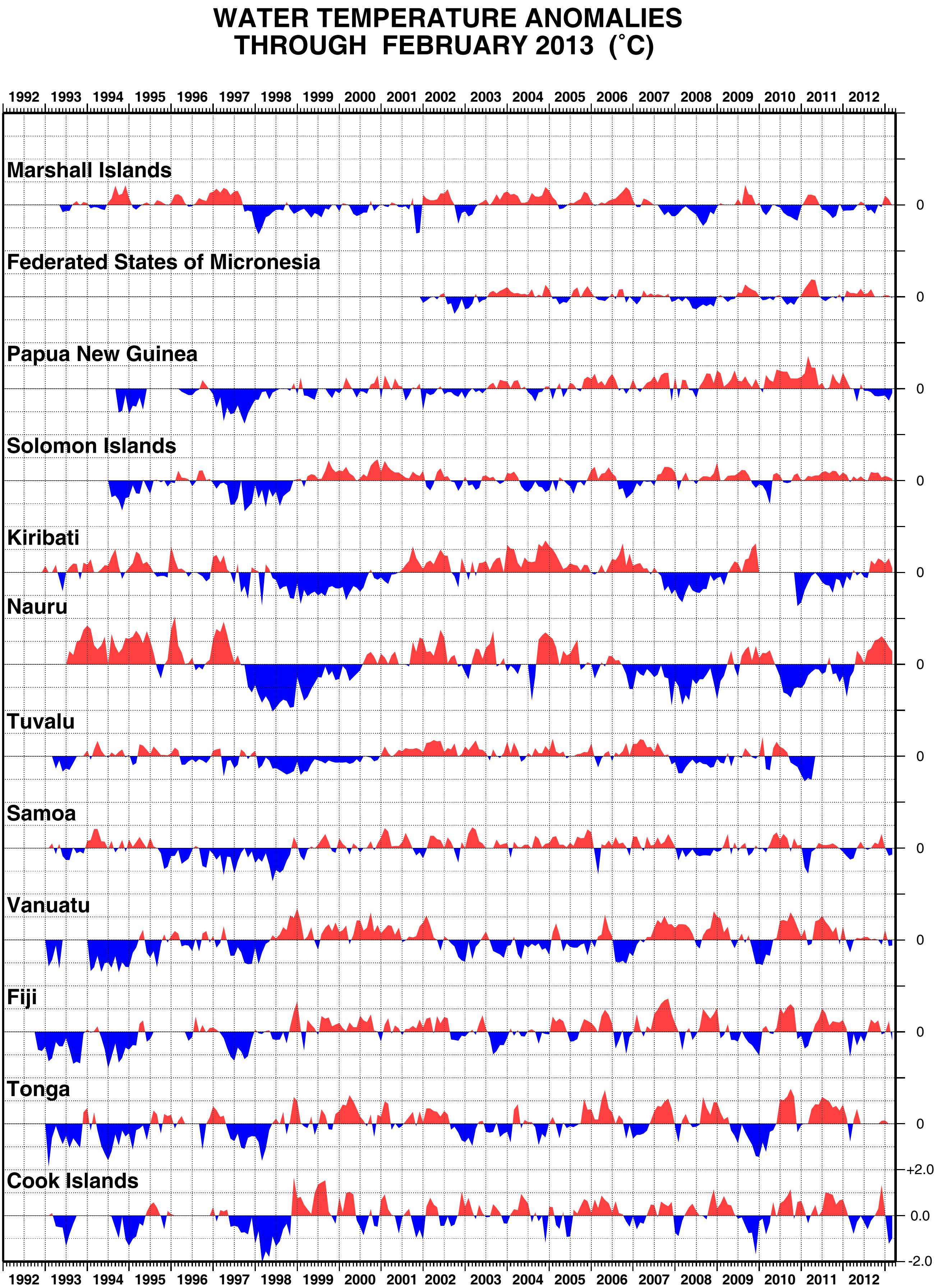

Figure 16. Monthly water temperature anomalies to February 2013.

AIR TEMPERATURE ANOMALIES THROUGH FEBRUARY 2013 (˚C)

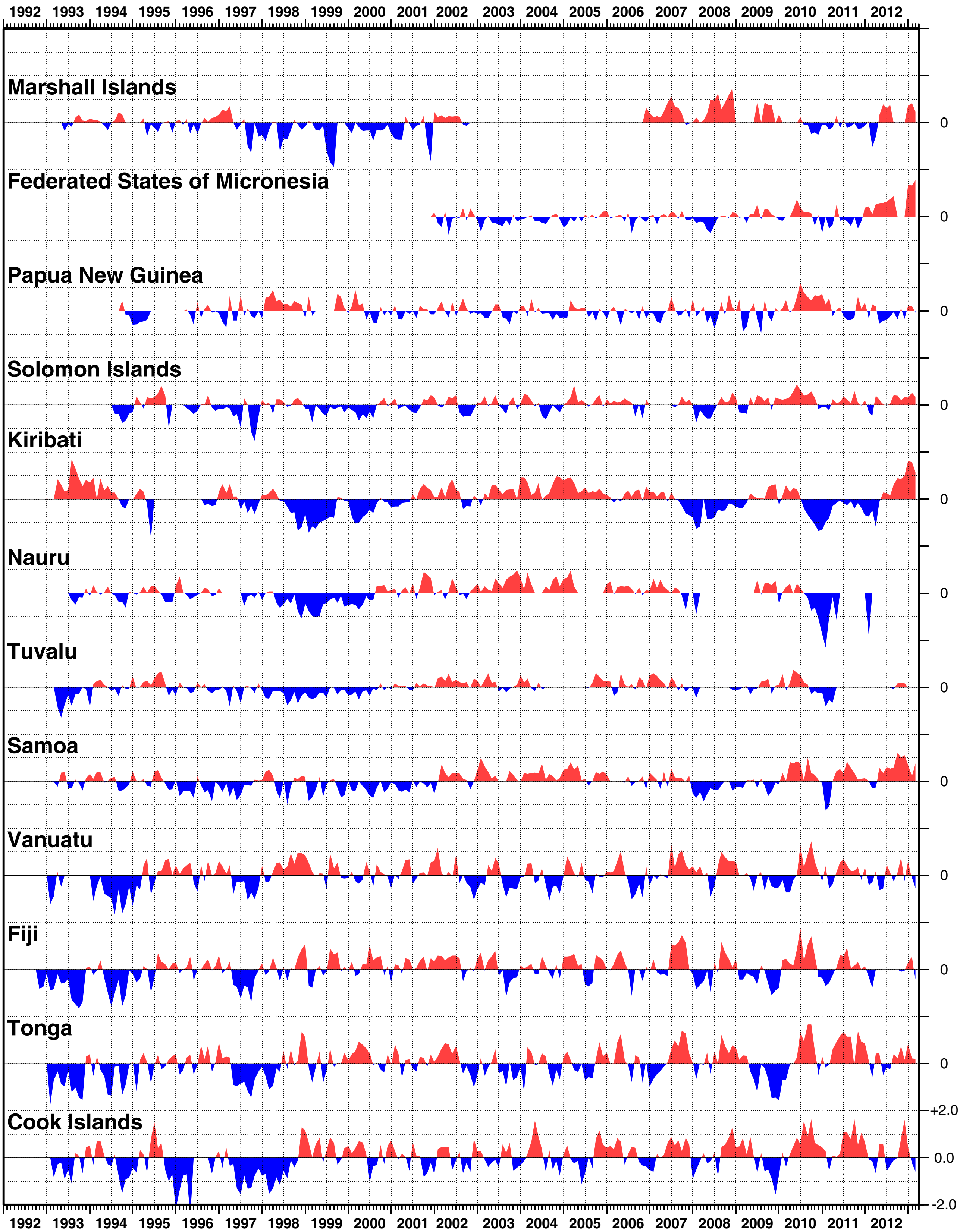

Figure 17. Monthly air temperature anomalies to February 2013.

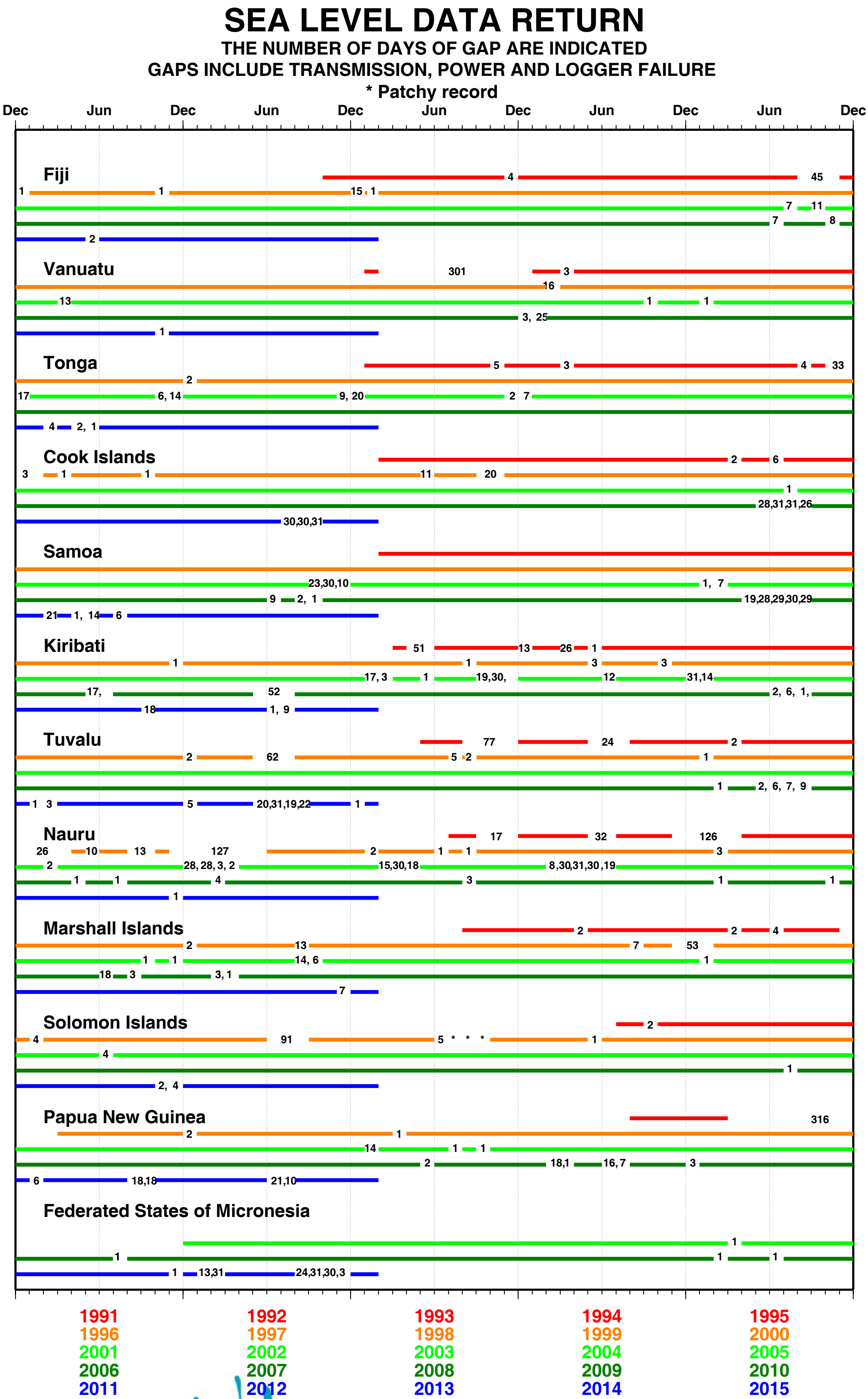

Figure 18. Sea level data return.