THE SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT

MONTHLY DATA REPORT

NO. 202

APRIL 2012

Australian Government

Bureau of Meteorology

This project is sponsored by the Australian Agency for International Development (AusAID), and is managed by the Bureau of Meteorology with its National Tidal Centre (NTC) providing key technical support.

Australian Government

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Quality Certification:

I authorise the issue of this South Pacific Sea Level and Climate Monitoring Project Monthly Data Report for April 2012 in accordance with National Tidal Centre Quality Assurance procedures.

William Mitchell
Manager - National Tidal Centre

South Pacific Sea Level and Climate Monitoring Project

Monthly Data Report

April 2012

EXECUTIVE SUMMARY

This summary, and the overview that follows, are intended to provide a synopsis of the Monthly Data Report and of the trends observed over the life of the project to date.

April 2012

- The SEAFRAME network continued to collect high quality sea level and associated meteorological information for monitoring climate variability and climate change. The station at FSM was returned to service following failure of data communications equipment in late February.

- Climate conditions across the equatorial Pacific remained neutral (neither El Niño nor La Niña). Ocean temperatures across the equatorial Pacific continued to warm, both above and below the sea surface, following the cooler conditions that prevailed during the 2011-12 La Niña. Sea surface temperatures during April were near normal across most of the equatorial Pacific, aside from warm anomalies that continued to develop in the far eastern equatorial Pacific.

- Monthly sea levels during April were around 10cm higher than normal at Fiji and Tonga and 5cm higher than normal at Marshall Islands, Kiribati, Nauru and Samoa. Sea levels at Vanuatu remained around 5cm lower than is normal for this time of the year.

- The monthly mean sea level at Tonga during April was the highest on record, while the monthly mean sea level at Fiji remained only 1cm below the record-high level set in March.

- International climate models predict that neutral climate conditions will persist across the Pacific at least until the middle of the year. Some models predict that El Nino conditions will develop in the second half of 2012.

Short-Term Trends

It is important to stress that as the sea level record becomes longer, the short-term trend estimate becomes more stable and reliable. Observed trends in sea level include natural variability, for example, events such as El Niño and effects due to many other atmospheric, oceanographic and geological processes. Longer-term data sets for all stations are required in order to separate the effects of the different signals. ***Please exercise caution in interpreting the short-term trends in the table below –*** they will almost certainly change over the coming years as the data set increases in length. Figure 13 later in this report provides the "time history" of the short-term trend at all project locations.

Recent short-term sea level trends in the project area based upon SEAFRAME data through April, 2012

Location	Lat / Long	Installation Date	Trend (mm/yr)	Change from previous month
Cook Is	21°12'17.1"S / 159°47'5.2"W	Feb 1993	+5.6	0.0
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+8.8	+0.1
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+5.5	+0.1
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+5.0	-0.1
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+7.4	+0.1
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+4.2	0.0
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.0	+0.1
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+3.8	+0.1
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+8.3	0.0
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+8.3	0.0
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+17.8	0.0
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+5.5	+0.1

INTRODUCTION

Welcome to the April 2012 Monthly Data Report for the South Pacific Sea Level and Climate Monitoring Project (SPSLCMP). 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 or climate events, interpretation of sea level fluctuations in the context of El Niño and the emergence of trends in the data.

The SPSLCMP was 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. Support was provided for the installation of SEAFRAME monitoring stations across the South Pacific Forum region.

SEAFRAME gauges not only measure sea level by two independent means, but also observe a number of "ancillary" variables - air and water temperatures, wind speed, wind direction and atmospheric pressure. There is an associated programme of

levelling to first order, to determine shifts in the vertical of the sea level sensors due to local land movement. Continuous Global Positioning System (CGPS) measurements are now also being made to determine the vertical movement of the land with respect to the International Terrestrial Reference Frame.

The AusAID funded project has, as its principal objective ***'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 monitoring network consists of 12 SEAFRAME stations, providing a wide coverage across the Southwest Pacific basin. All of these stations (see Figure A), with the exception of the Pohnpei (FSM) gauge, which was established in December 2001, have been operational since October 1994.

The monthly data report, one of a range of information products produced by the project, is the primary form of SPSLCMP data dissemination. Its content is designed to provide up-to-date access to the project's data products.

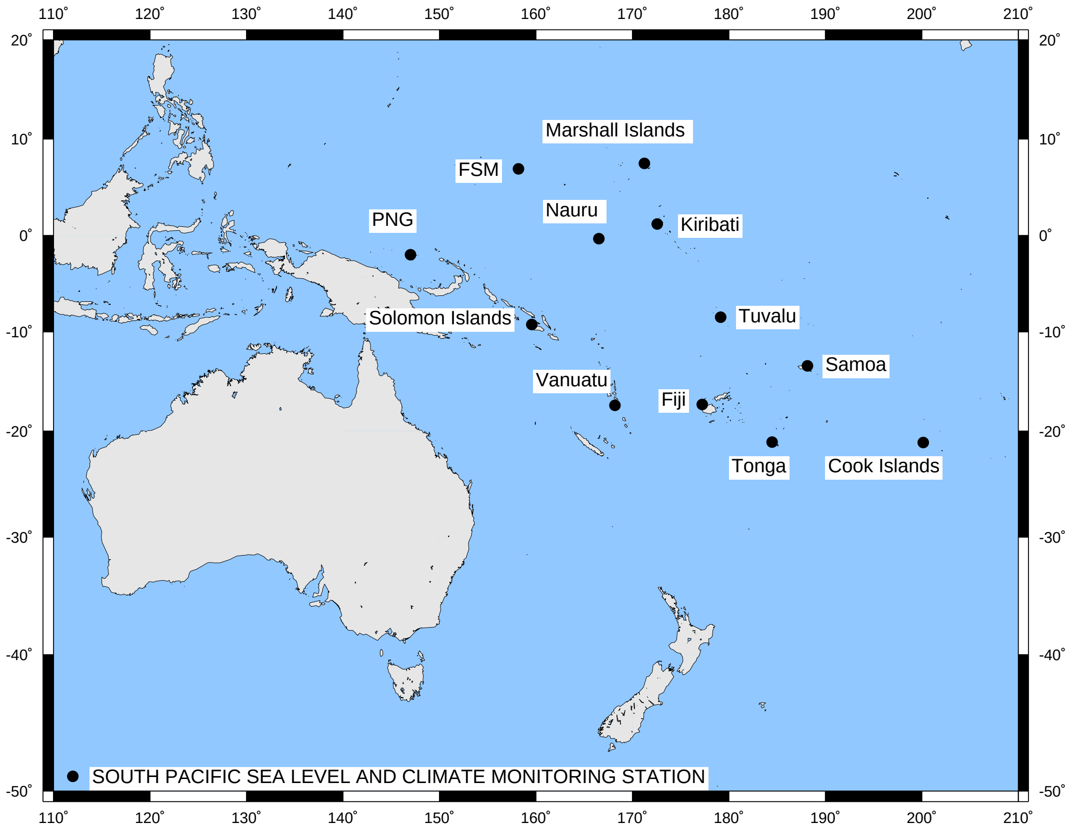


Figure A: *South Pacific Sea Level and Climate Monitoring Stations*

APRIL CLIMATOLOGY

Climate conditions across the equatorial Pacific remained neutral (neither El Niño nor La Niña) during April. Climate model guidance suggests that the tropical Pacific will continue to warm in the coming months, with some models predicting El Niño conditions developing in the second half of 2012.

The Southern Oscillation Index (SOI) fell during April to a value of -7.1 following the March value of +2.9, but remains in the neutral range (**Figure B**). Sustained positive values of the SOI above +8 are typical of La Niña, while sustained negative values below –8 are typical of El Niño.

Sea surface temperatures (SSTs) warmed across the central and eastern equatorial Pacific during April. Near-normal sea surface temperatures were observed across most of the tropical Pacific with the exception of the far eastern equatorial Pacific where warmer-than-normal sea surface temperature anomalies strengthened during April (**Figure C**).

Subsurface ocean temperatures warmed dramatically across the eastern equatorial Pacific during April, but remain slightly cooler than normal. The cool subsurface temperature anomalies in this region have been in decline since January (**Figure D**). Warm subsurface temperature anomalies continued to be observed across the western equatorial Pacific during April.

During El Niño (warm-episode) conditions there is a sustained weakening of the Trade Winds across much of the equatorial Pacific and an increase in cloudiness in the central equatorial Pacific, particularly near the dateline. During La Niña (cold-episode) conditions there is a reversal of this situation, with stronger Trade Winds and a decrease in cloudiness in the central Pacific. Trade Winds during April were generally near normal across the equatorial Pacific (**Figure E**). Cloudiness near the dateline fluctuated during April but on average was typical for this time of the year.

The consensus among international computer models surveyed by the Bureau of Meteorology is that neutral climate conditions will persist across the Pacific until the middle of the year, with a heightened risk of El Nino conditions developing in the second half of 2012.

The preceding description of the climatology of the Pacific region, and Figures B, C and D are based on information sourced from the National Climate Centre of the Australian Bureau of Meteorology at http://www.bom.gov.au/climate/. Figure E was generated from the Tropical Atmosphere Ocean project website courtesy of PMEL, NOAA at http://www.pmel.noaa.gov/tao/.

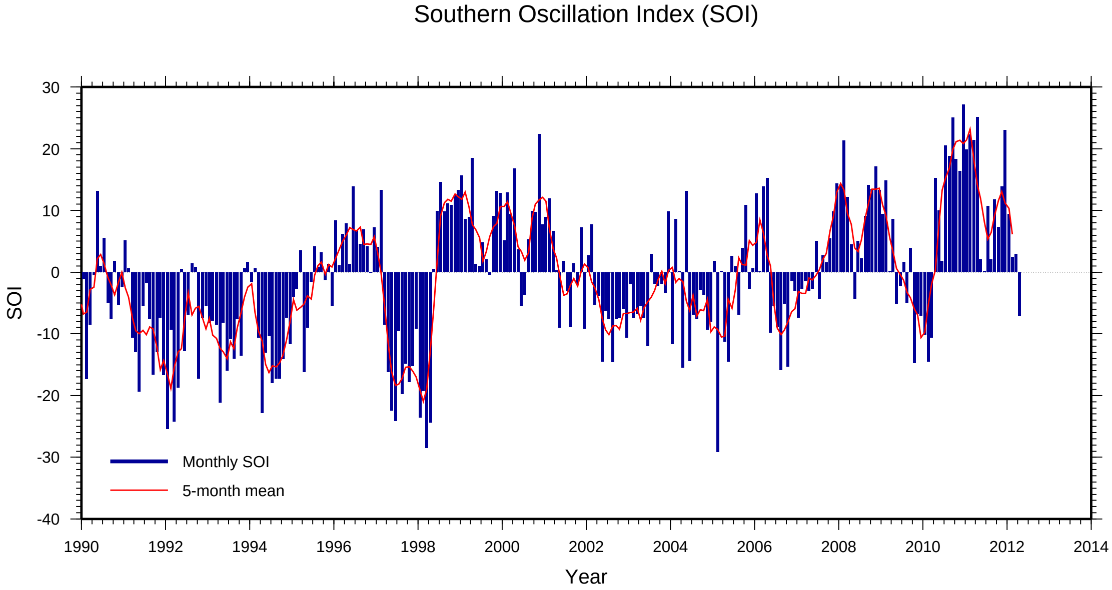


Figure B: *The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant month.*

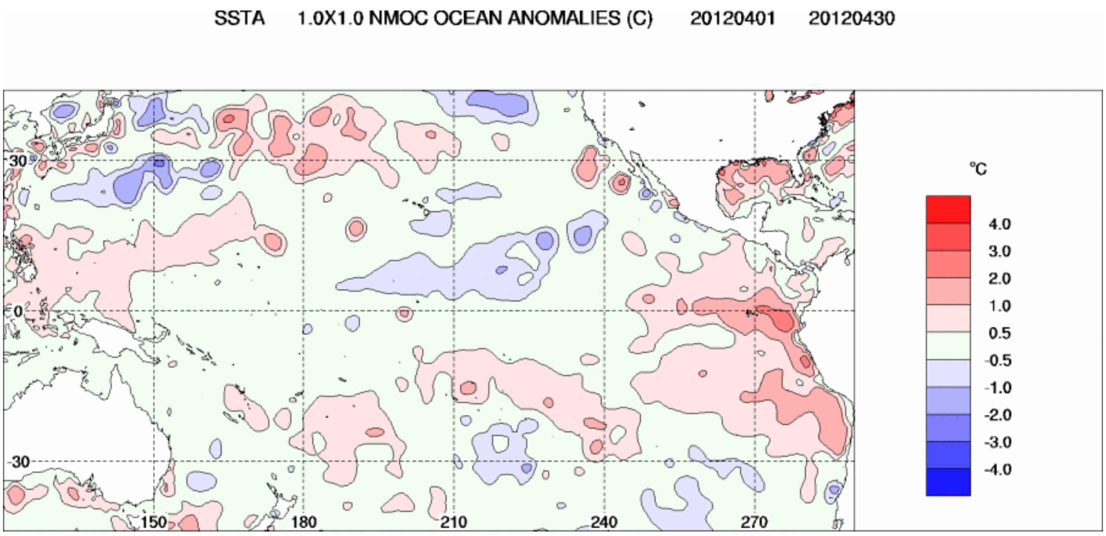


Figure C: *Sea surface temperature anomaly (°C) for April 2012.*

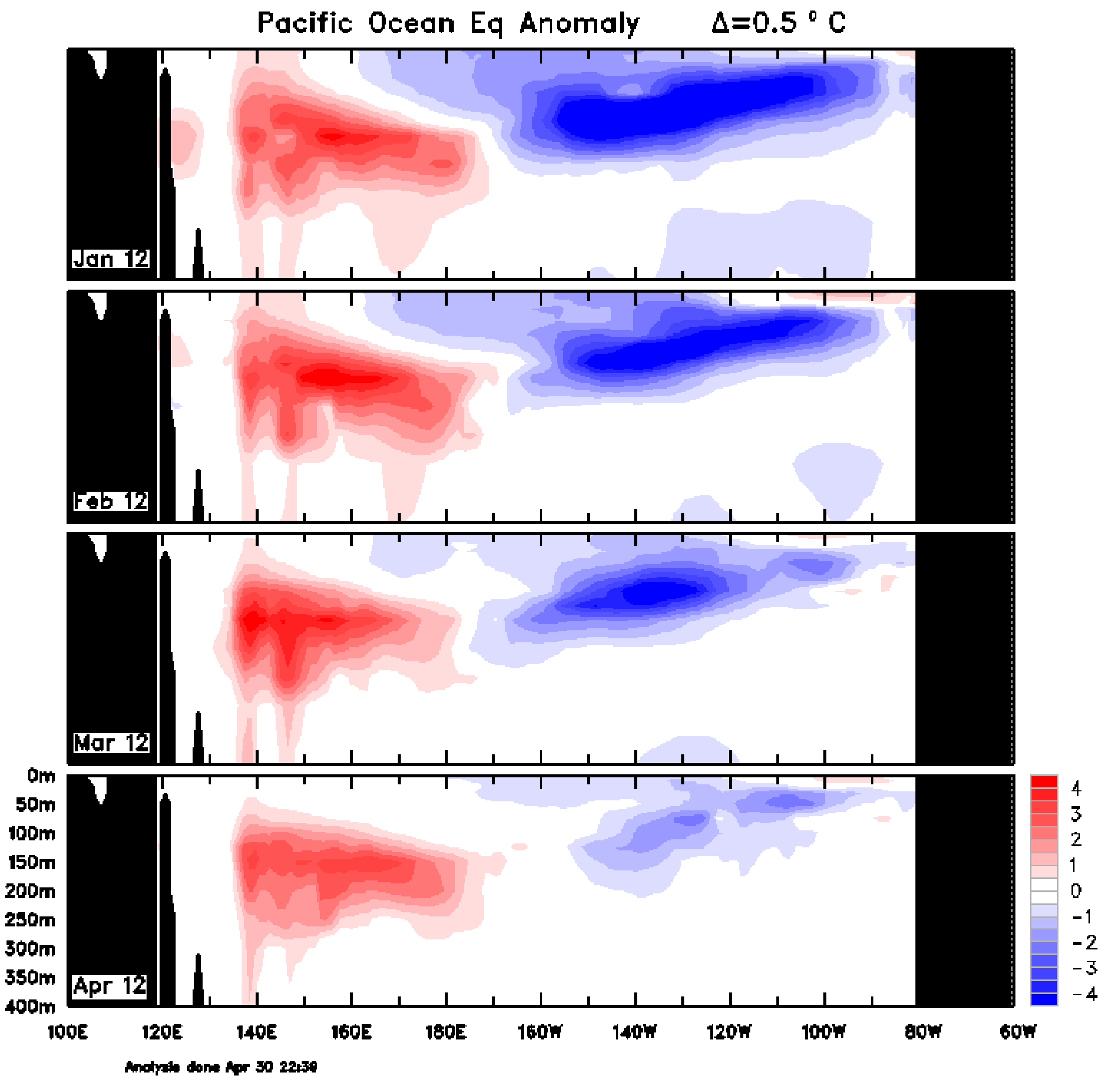


Figure D: *Equatorial depth-longitude section of ocean temperature anomalies for January through to April 2012. Contour interval is 0.5°C.*

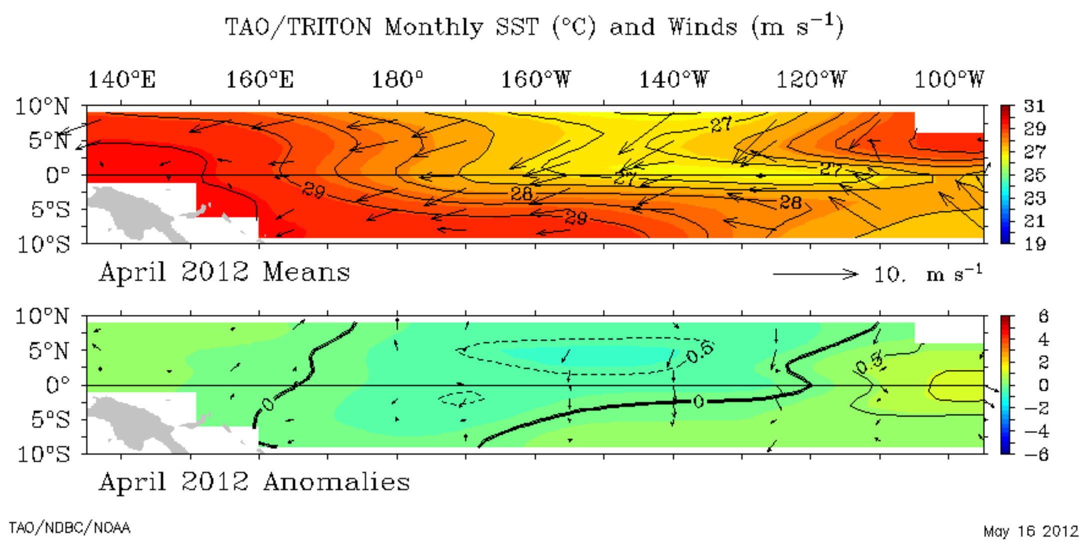


Figure E: *Monthly mean wind vectors (top) and anomalies (bottom) for April 2012. The colour-shaded contours represent the monthly mean sea surface temperatures (top) and anomalies (bottom).*

APRIL SEAFRAME DATA

Monthly Sea Level and Environmental Data (Figures 1-10)

The **observed sea levels (Figure 1)** 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 full moon on the 6th and a new moon on the 21st of April.

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

The **residuals (Figure 2)** are the differences between the observed sea levels and the 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 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 harbour in which the gauge is located. Some of the SEAFRAME stations are located in harbours that are favourable to persistent '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 periods of reduced tidal range and at Nauru during strong westerly winds.

No significant storm surge was observed across the network during April, although sea levels at Fiji and Tonga remained higher than the predicted astronomical tides throughout the month, as shown by the positive residuals at these stations. An undersea earthquake of magnitude Mw6.5 struck near Vanuatu on 14th April 2012, but a tsunami was barely detectable at the SEAFRAME station at Port Vila due to the modest size of the earthquake.

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 peaks were to persist, rather than appear as occasional 'transients', then the tidal analysis would be able to account for them, and the end result would be virtual eradication from the residuals.

The **barometrically corrected residuals (Figure 3)** have had the effect of atmospheric pressure fluctuations removed from the sea level residuals of Figure 2. 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 **Figures 4** to **9**. The short lines in **Figure 5** 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 **(Figures 7** and **8)** 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 9)** 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 10**. 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 South Pacific Sea Level and Climate Monitoring Project data, which have been collected since October 1992 when the first station was installed (Fiji). The data from FSM has only been collected since December 2001.* New record-high April maximum air temperatures were observed at Solomon Islands (32.7 ºC) and Vanuatu (31.6 ºC), while at Cook Islands the equal-highest April air temperature on record of 29.8 ºC was observed. A record low April minimum air temperature of 23.5 ºC was observed at Kiribati. Water temperatures reached 29.3 ºC at Marshall Islands, the equal-highest April water temperature on record, and fell to 26.9 ºC at Fiji, which is the lowest April water temperature on record.

Mean Sea Level and Anomalies (Figures 11-13)

Figure 11 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.

The monthly mean sea level at Tonga for April 2012 is the highest on record at that location, surpassing that set in January 2009. The monthly mean sea level at Fiji remained high during April, falling just 1cm from the record-high level set in March.

Figure 12 shows the monthly mean **sea level anomalies,** or departures from normal conditions after tides, annual and semi-annual seasonal cycles and the sea level trend have been removed. The annual cycle at Tuvalu (which has the largest consistent annual cycle) is quite notable in **Figure 11** but less apparent in **Figure 12**. 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.

The recent anomalies show sea levels during April were around 10cm higher than normal at Fiji and Tonga and 5cm higher than normal at Marshall Islands, Kiribati, Nauru and Samoa. Sea levels at Vanuatu remained around 5cm lower than is normal for this time of the year. Meanwhile, sea levels at FSM, PNG, Solomon Islands, Tuvalu and Cook Islands were near normal for this time of the year.

Sea Level Trends

The **short-term sea level trends** at individual stations as at April 2012 are shown in the following table. Sea level trends are updated every month by allowing for a linear trend term in the tidal analysis of all the data available at individual stations. *Please exercise caution in interpreting the trends* – they will continue to change over the coming years as the data sets increase in length. The evolution of the monthly trend values (in mm per year) at each station from one year after installation to present is depicted in **Figure 13**. This figure illustrates that as the sea level record becomes longer, the relative sea level trend estimates become more stable and reliable. The reason for this is that the trends from short sea level records are affected by the natural sea level variability occurring on inter-annual, El Niño and decadal timescales due to atmospheric, oceanographic and geological processes. Longer-term data sets for all stations are required in order for the underlying trend to emerge from these short-term variations. Further details are available from the *National Tidal Centre (NTC), Australian Bureau of Meteorology*.

Recent short-term sea level trends in the project area based upon SEAFRAME data through April, 2012

Location	Lat / Long	Installation Date	Trend (mm/yr)	Change from previous month
Cook Is	21°12'17.1"S / 159°47'5.2"W	Feb 1993	+5.6	0.0
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+8.8	+0.1
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+5.5	+0.1
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+5.0	-0.1
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+7.4	+0.1
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+4.2	0.0
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.0	+0.1
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+3.8	+0.1
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+8.3	0.0
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+8.3	0.0
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+17.8	0.0
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+5.5	+0.1

Barometric Pressure, Water Temperature and Air Temperature Anomalies

The anomalies of barometric pressure, water and air temperature (**Figures 14** to **16**) are determined in the same manner as the sea level anomalies (**Figure 12**), except the trend is not calculated.

The **barometric pressure anomalies (Figure 14)** show substantially higher than normal barometric pressures were observed at SEAFRAME stations during the 1997-1998 El Niño. In April 2012 barometric pressures were reasonably close to what is expected at this time of the year, in line with neutral climate conditions.

The **water temperature anomalies (Figure 15)** were close to zero, indicating normal conditions, at most stations during April. Slightly cooler than normal conditions were observed at PNG, Fiji and Cook Islands, while slightly warmer than usual conditions were observed at Nauru and Tonga, but the size of the anomalies at these stations did not exceed +/- 0.5 ºC.

Similarly, the **air temperature anomalies (Figure 16)** during April indicated near normal conditions across the network. Although slightly warmer than normal air temperatures were observed at FSM, Samoa, Tonga and Cook Islands and slightly cooler than normal air temperatures were observed at PNG and Vanuatu, air temperatures were generally within 0.5 ºC of what is typical for this time of the year. 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

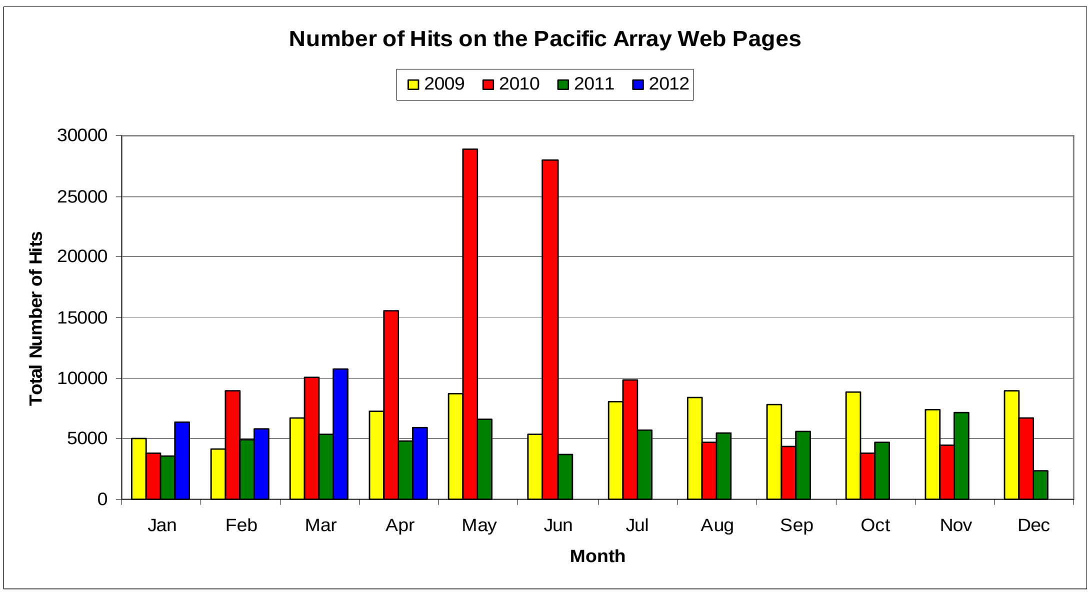
In **Figure 17,** which shows **sea level data return,** colour is used to distinguish five-year project phases. The number of missing days is noted in gaps in the bars.

Sea level data return during April 2012 was very good across the network. Calibration and maintenance was undertaken at FSM during April, including repair of satellite and telephone communications and recovery of 30 days of data from the logger which had not been able to be acquired remotely.

Problems encountered with the ancillary sensors during April included the air temperature sensors at Nauru, Tuvalu and Fiji, the water temperature sensors at Tuvalu and Tonga and the wind monitors at Nauru, Tuvalu and Vanuatu. The erroneous data received from these problematic sensors were removed from the archived records.

Web Hits

The following chart shows the number of times the Pacific pages on the *NTC* web site have been visited, by month since January 2009.



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 SUTRON station is shown in the following figure.

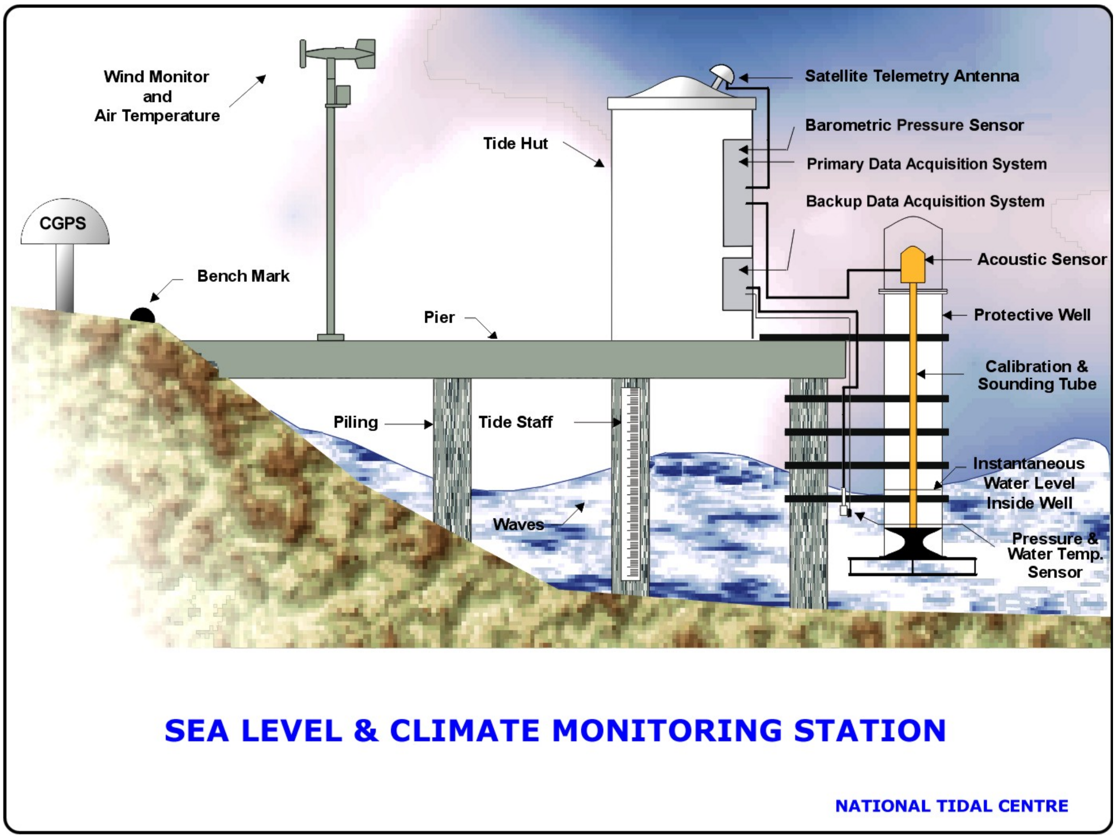
Water level sensors include:

(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.



The Observation Network Upgrade Project (ONUP) is scheduled to upgrade all Pacific SEAFRAME stations by mid-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 the following table.

Status of Station Equipment Upgrades to April, 2012

Location	Lat / Long	SUTRON Installation Date	TELMET Upgrade Date
Cook Is	21°12'17.1"S / 159°47'5.2"W	Feb 1993	To be upgraded
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	To be upgraded
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	To be upgraded
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	To be upgraded
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	To be upgraded

The *Monthly Data Report* is prepared by *NTC* for *AusAID*.

NTC would appreciate feedback from readers on the content and presentation of the *Monthly Data Report*.

Please spare a few moments to let us know your constructive opinion.

Further communication on the *Monthly Data Report* may be made to *NTC*. Anyone interested in a more detailed account of the project should contact:

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

Or visit the project website at http://www.bom.gov.au/pacificsealevel

Please refer to: http://www.bom.gov.au/oceanography/projects/spslcmp/spslcmp.shtml for details.

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Figure 1

APRIL 2012
SIX MINUTE WATER LEVEL OBSERVATIONS (m)

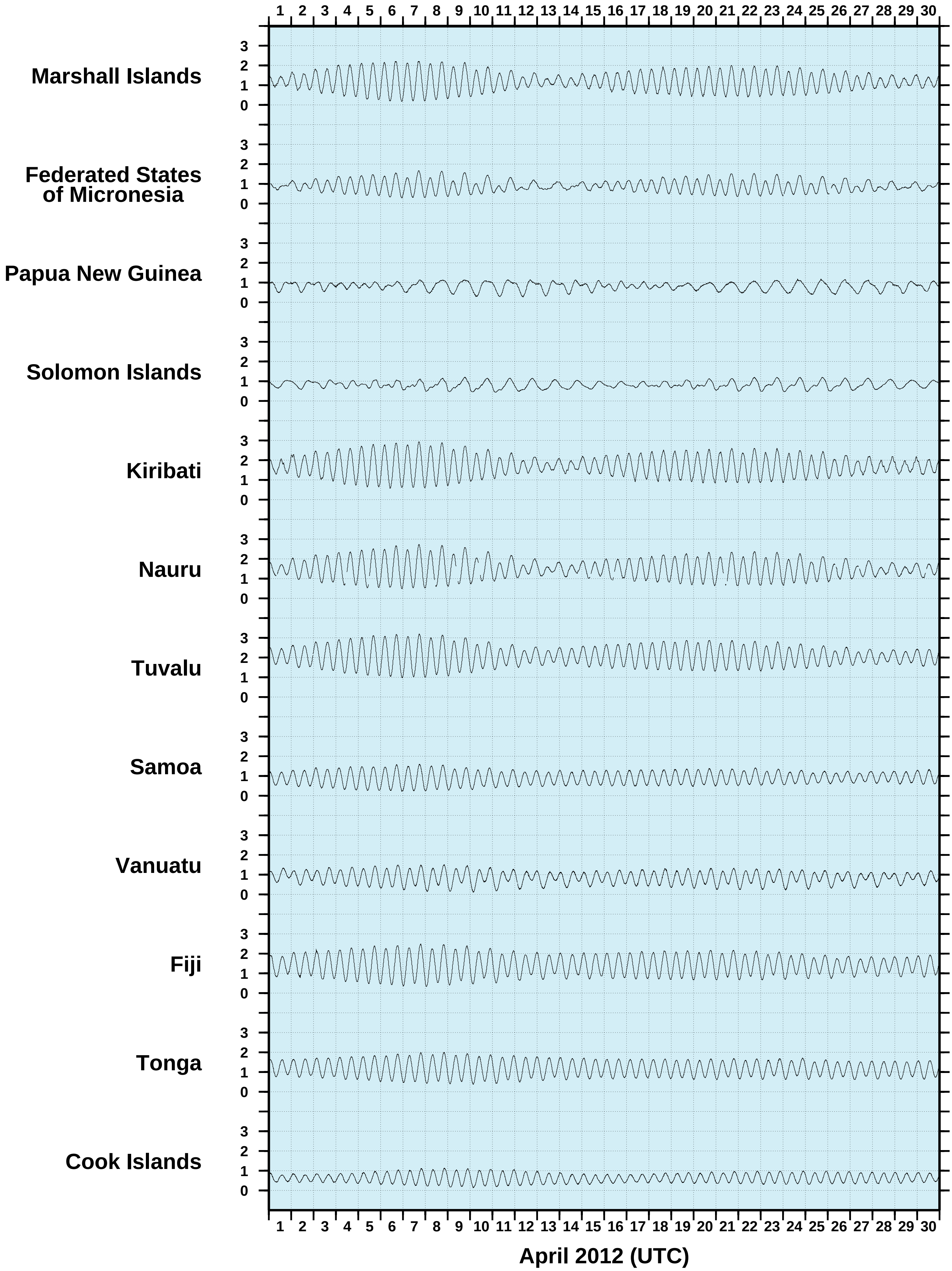


Figure 2

APRIL 2012
SIX MINUTE RESIDUAL WATER LEVELS (m)

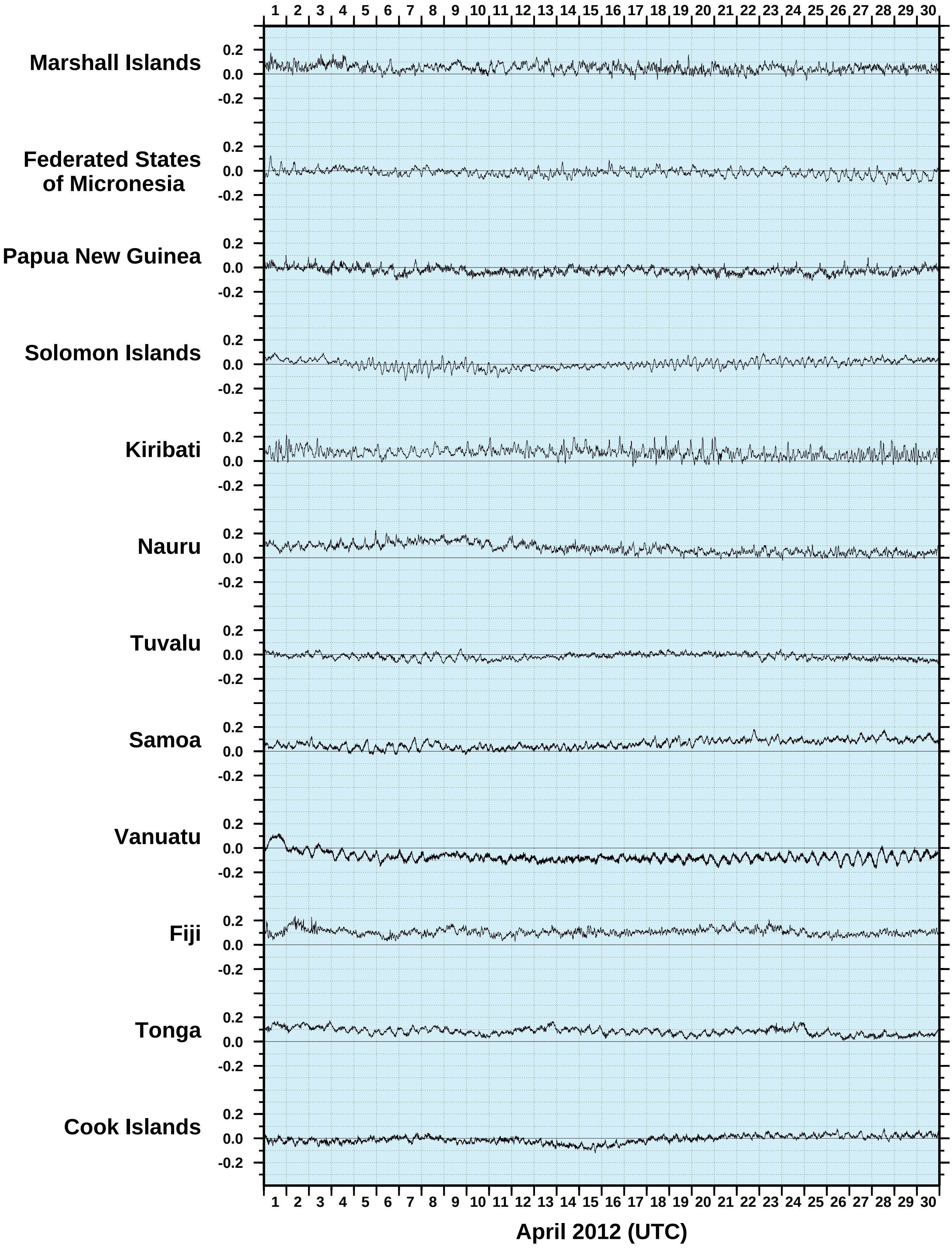


Figure 3

APRIL 2012
SIX MINUTE RESIDUALS
ADJUSTED FOR ATMOSPHERIC PRESSURE (m)

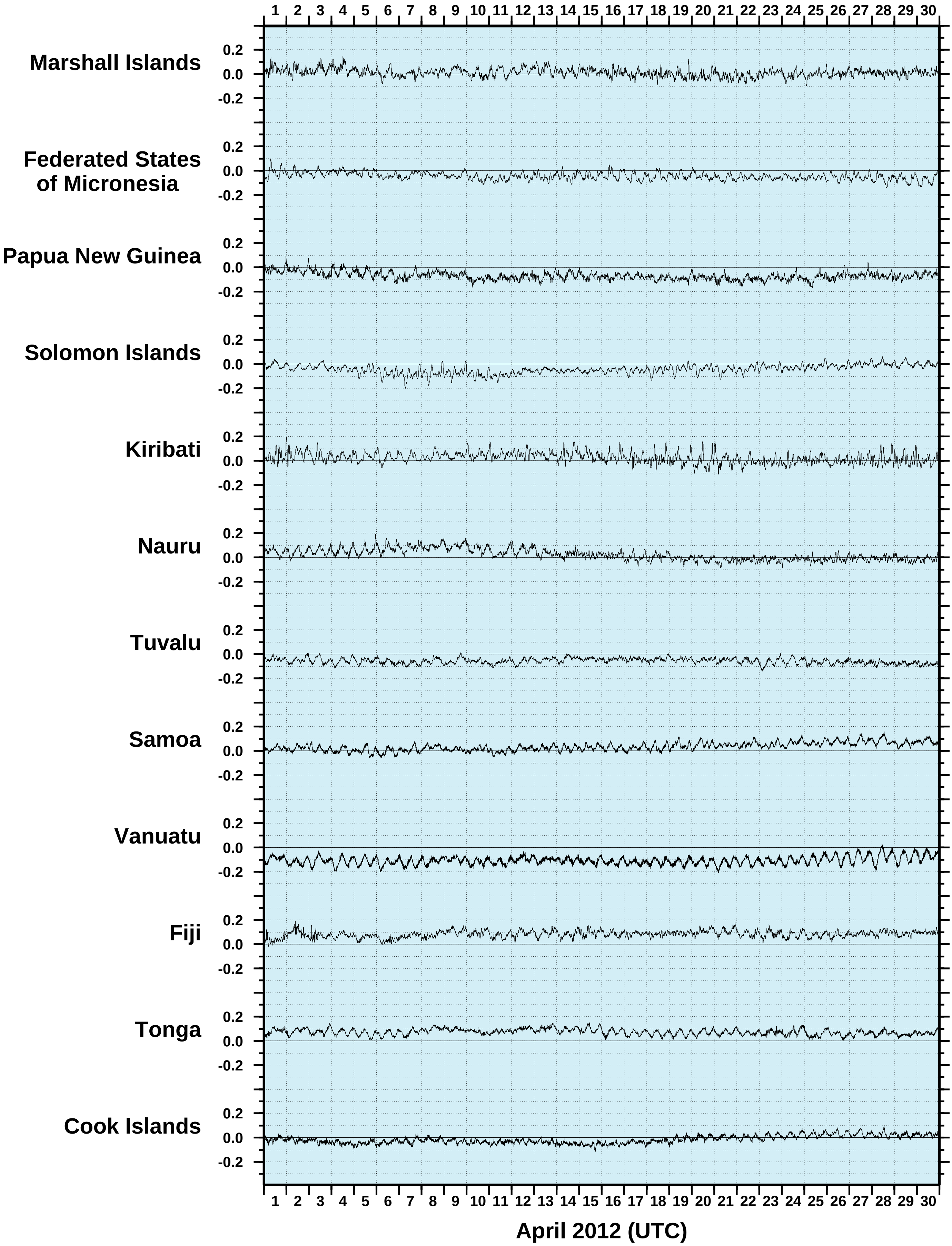


Figure 4

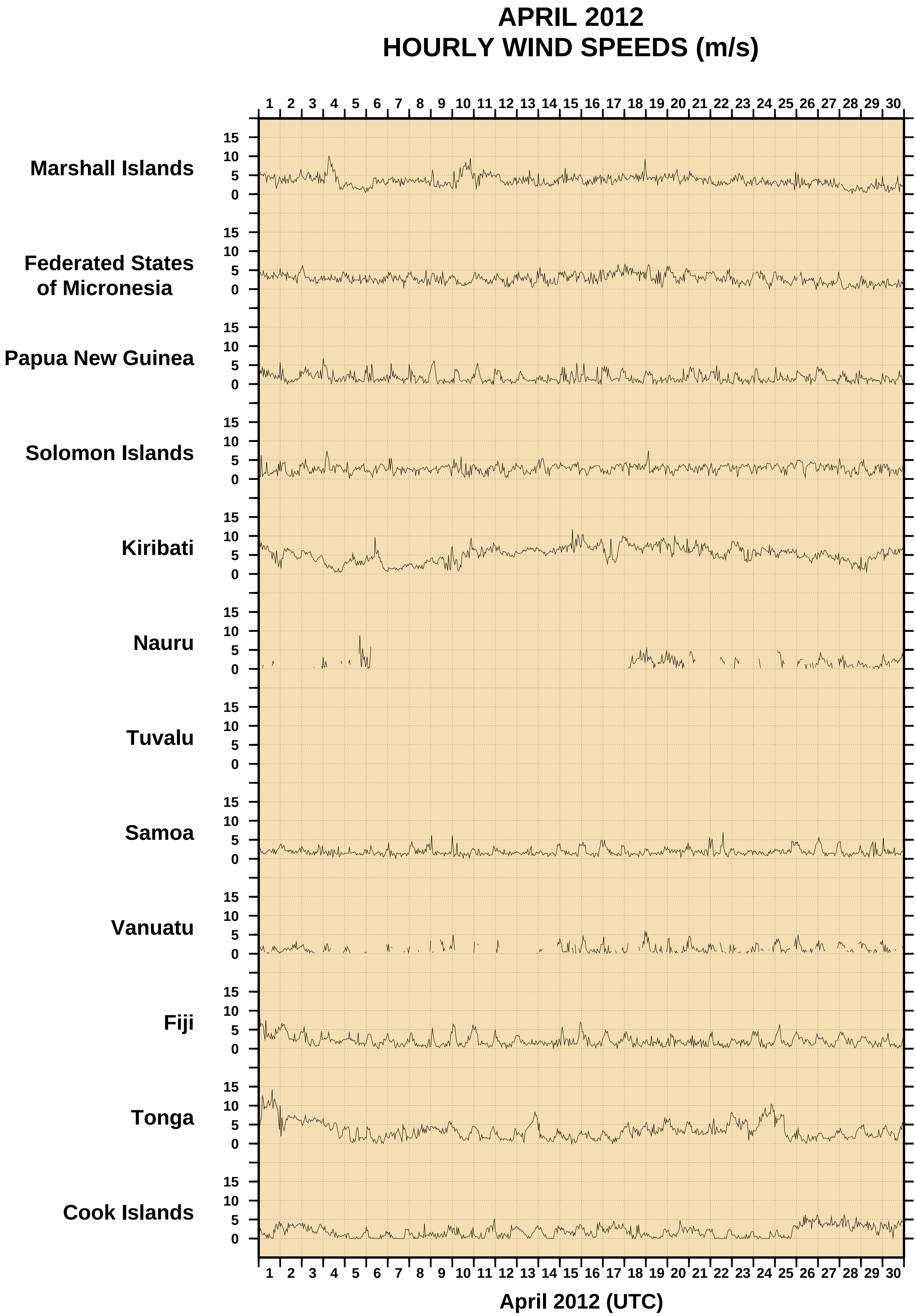

APRIL 2012
HOURLY WIND SPEEDS (m/s)
Marshall Islands
Federated States of Micronesia
Papua New Guinea
Solomon Islands
Kiribati
Nauru
Tuvalu
Samoa
Vanuatu
Fiji
Tonga
Cook Islands
0
5
10
15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
April 2012 (UTC)

Figure 5

APRIL 2012
HOURLY INCIDENT WINDS (m/s, deg True)

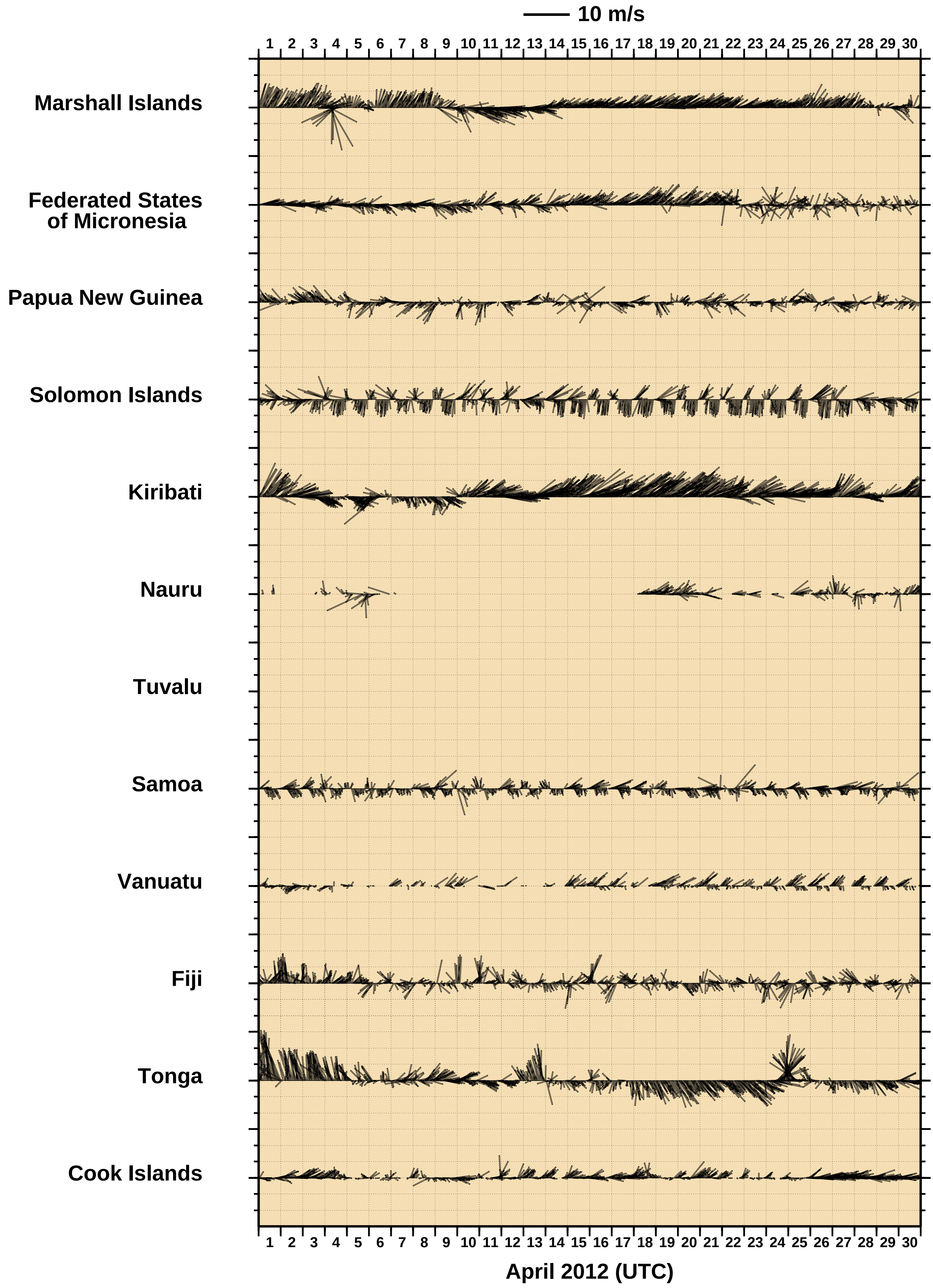


Figure 6

APRIL 2012
HOURLY MAXIMUM WIND GUSTS (m/s)

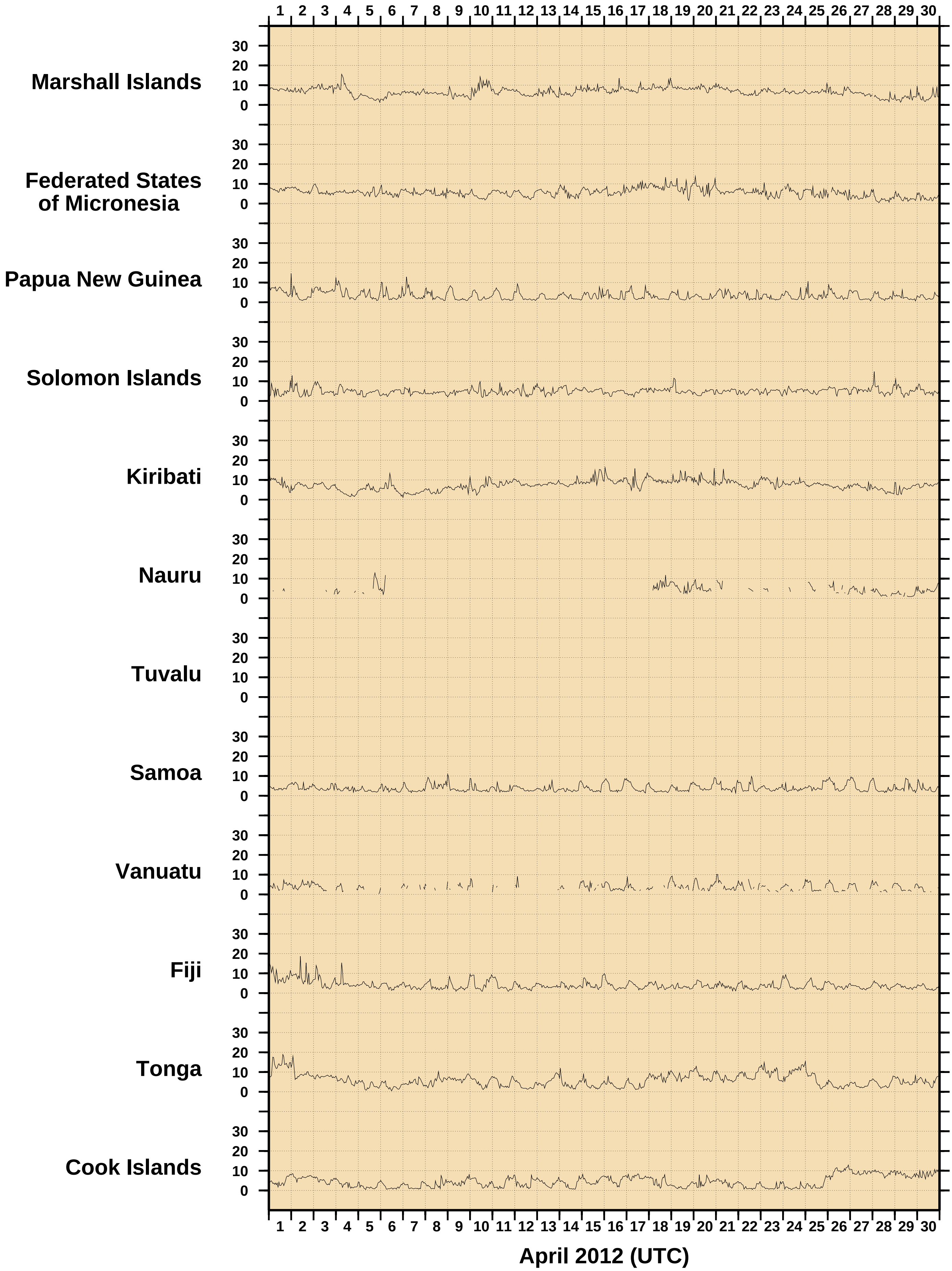


Figure 7

APRIL 2012
HOURLY AIR TEMPERATURES (˚C)

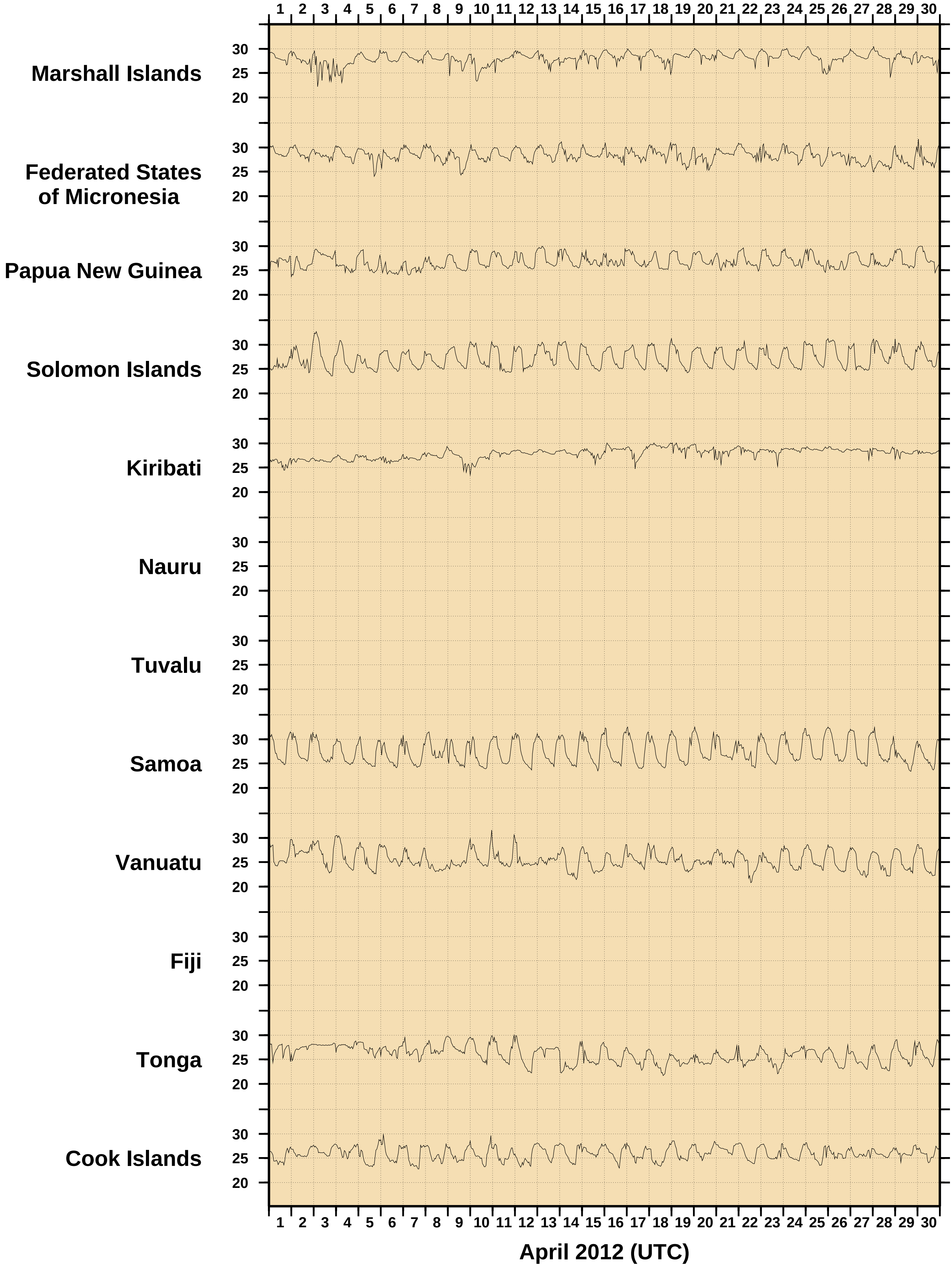


Figure 8

APRIL 2012
HOURLY WATER TEMPERATURES (˚C)

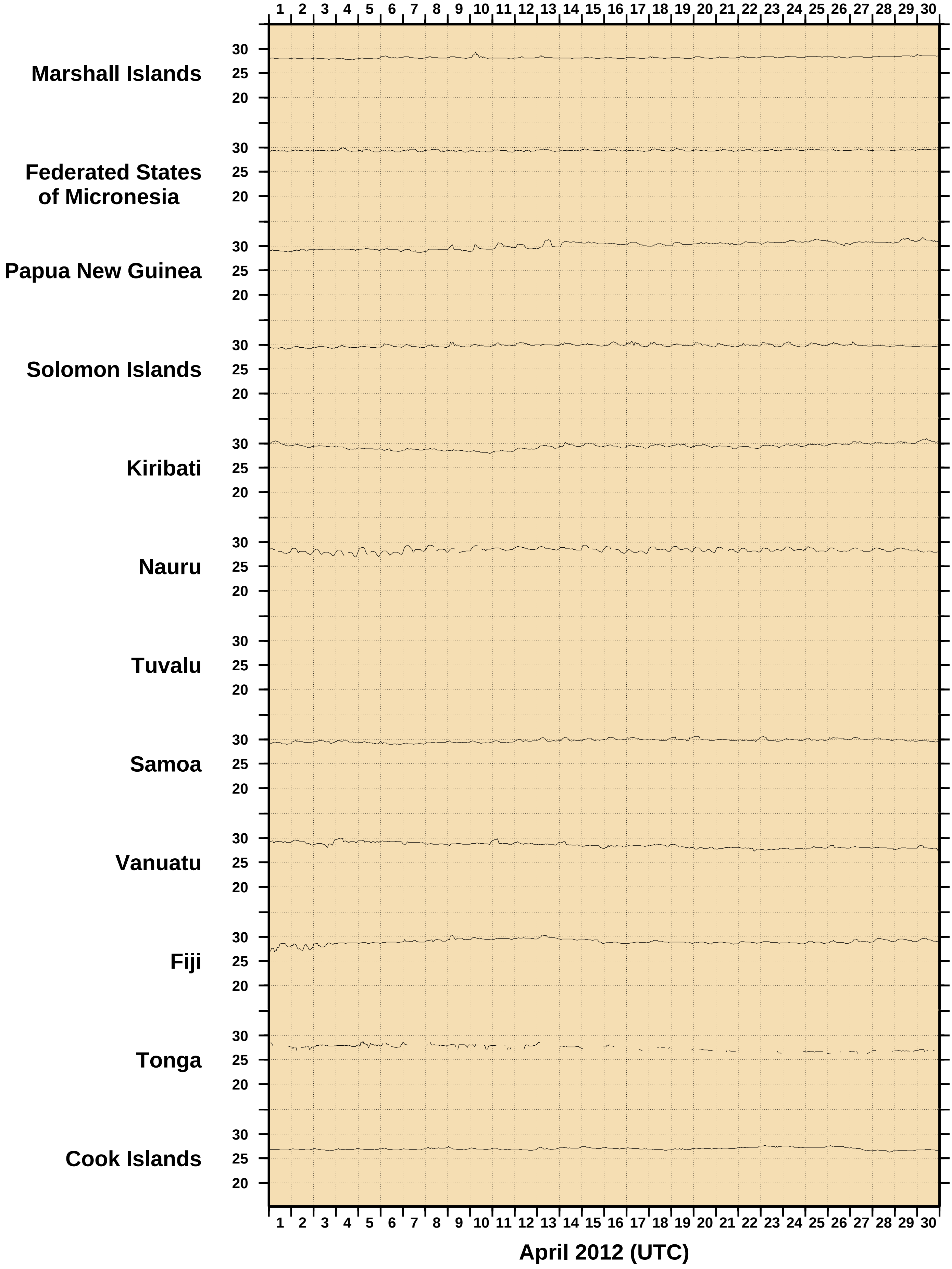


Figure 9
APRIL 2012
HOURLY ATMOSPHERIC PRESSURE (hPa)

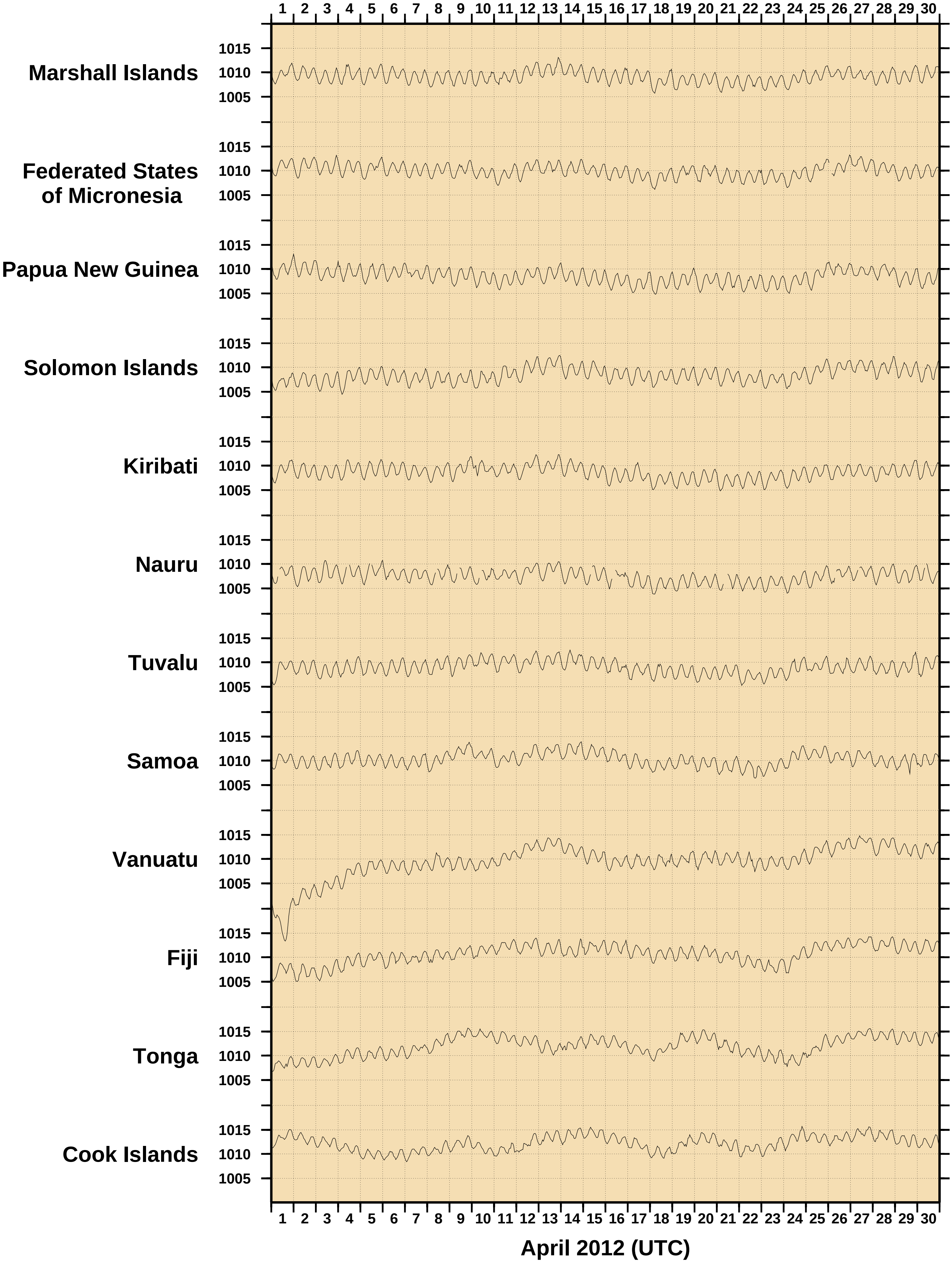
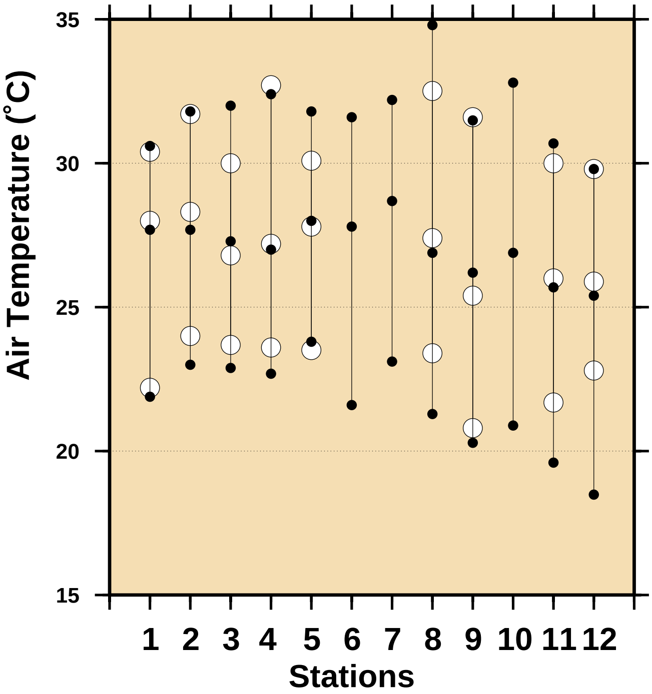
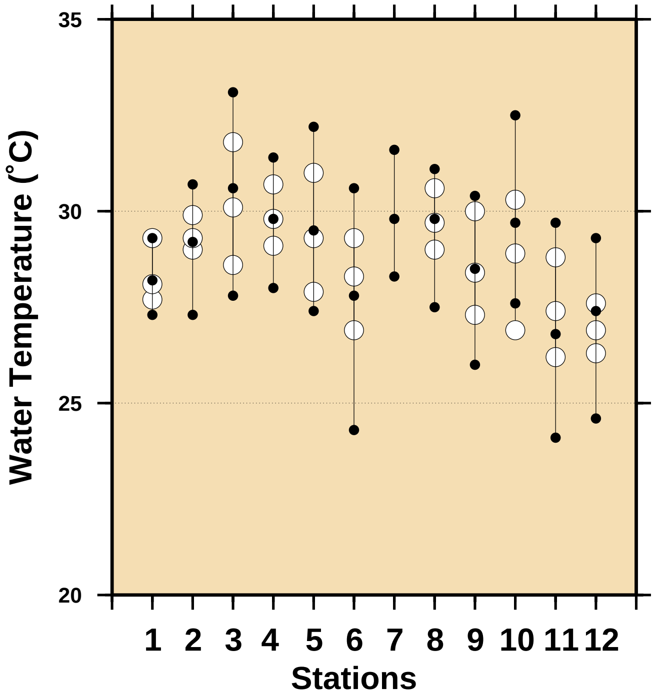
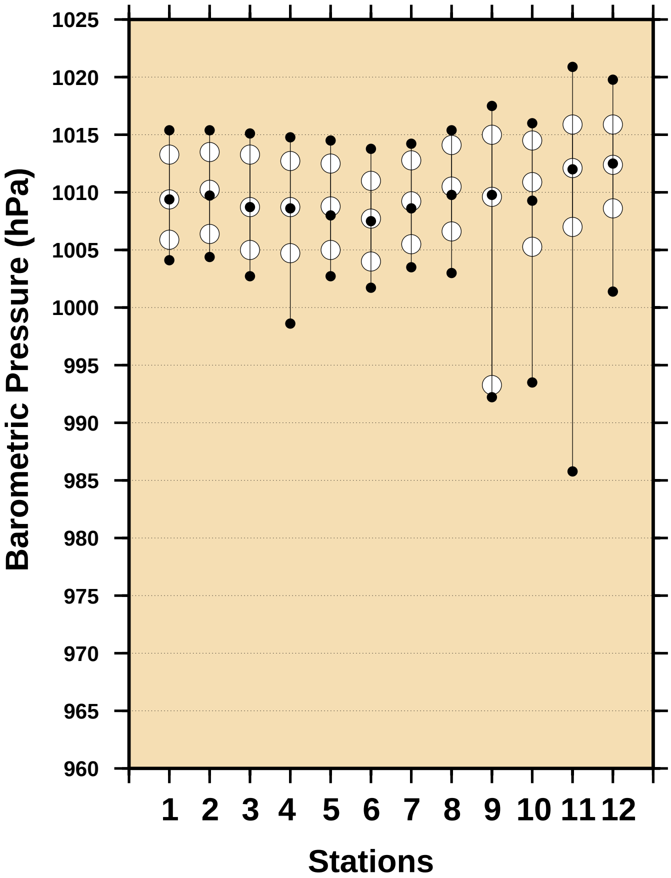


Figure 10

Comparison of April 2012 Max, Min & Mean with Long Term April Values.







Stations

1 - Marshall Islands
2 - Federated States of Micronesia
3 - Papua New Guinea
4 - Solomon Islands
5 - Kiribati
6 - Nauru
7 - Tuvalu
8 - Samoa
9 - Vanuatu
10 - Fiji
11 - Tonga
12 - Cook Islands

○ April 2012 Maximum
○ April 2012 Mean
○ April 2012 Minimum

● Long Term April Maximum
● Long Term April Mean
● Long Term April Minimum

Figure 11

MONTHLY MEAN SEA LEVELS TO APRIL 2012 (m)

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

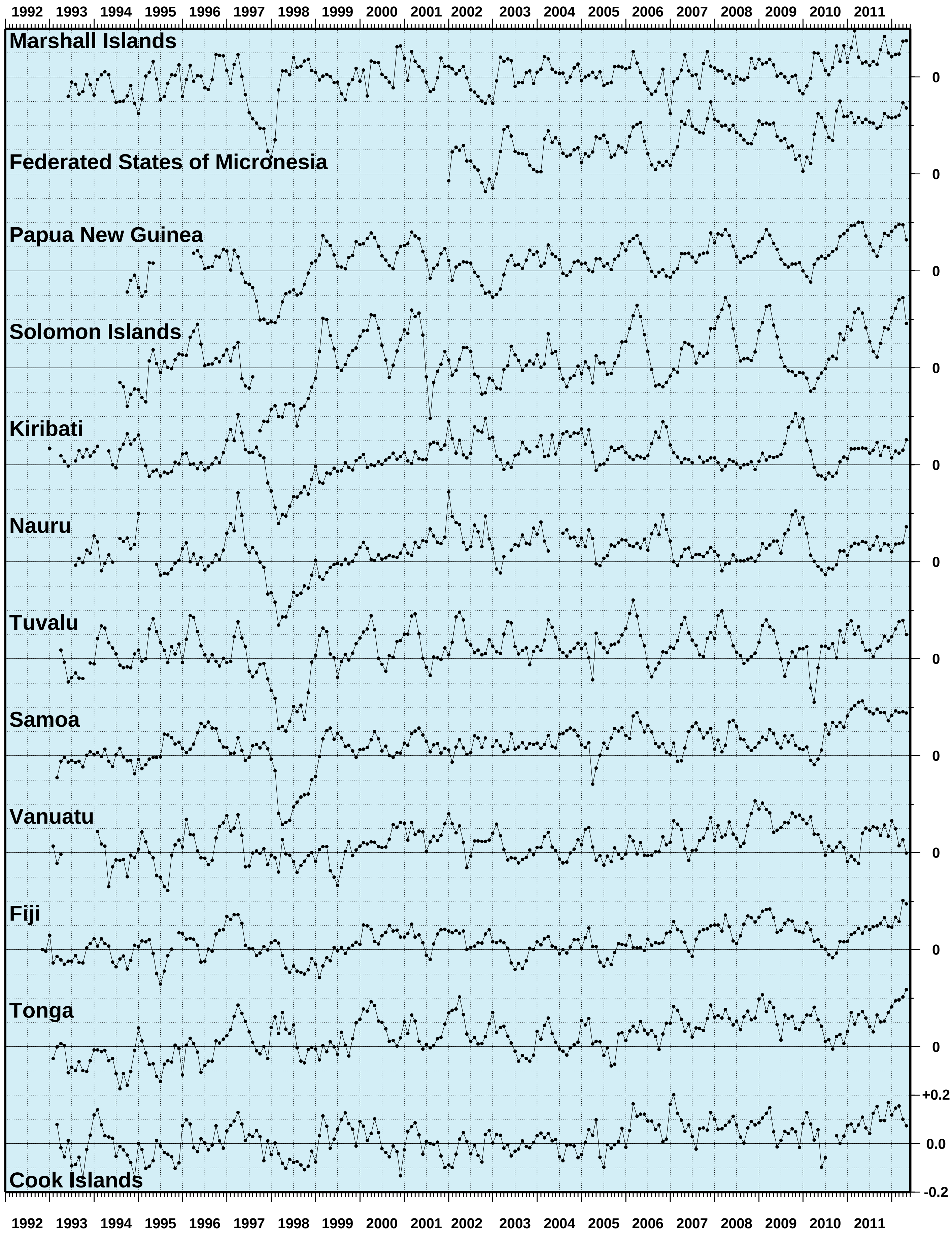


Figure 12

SEA LEVEL ANOMALIES THROUGH APRIL 2012 (m)

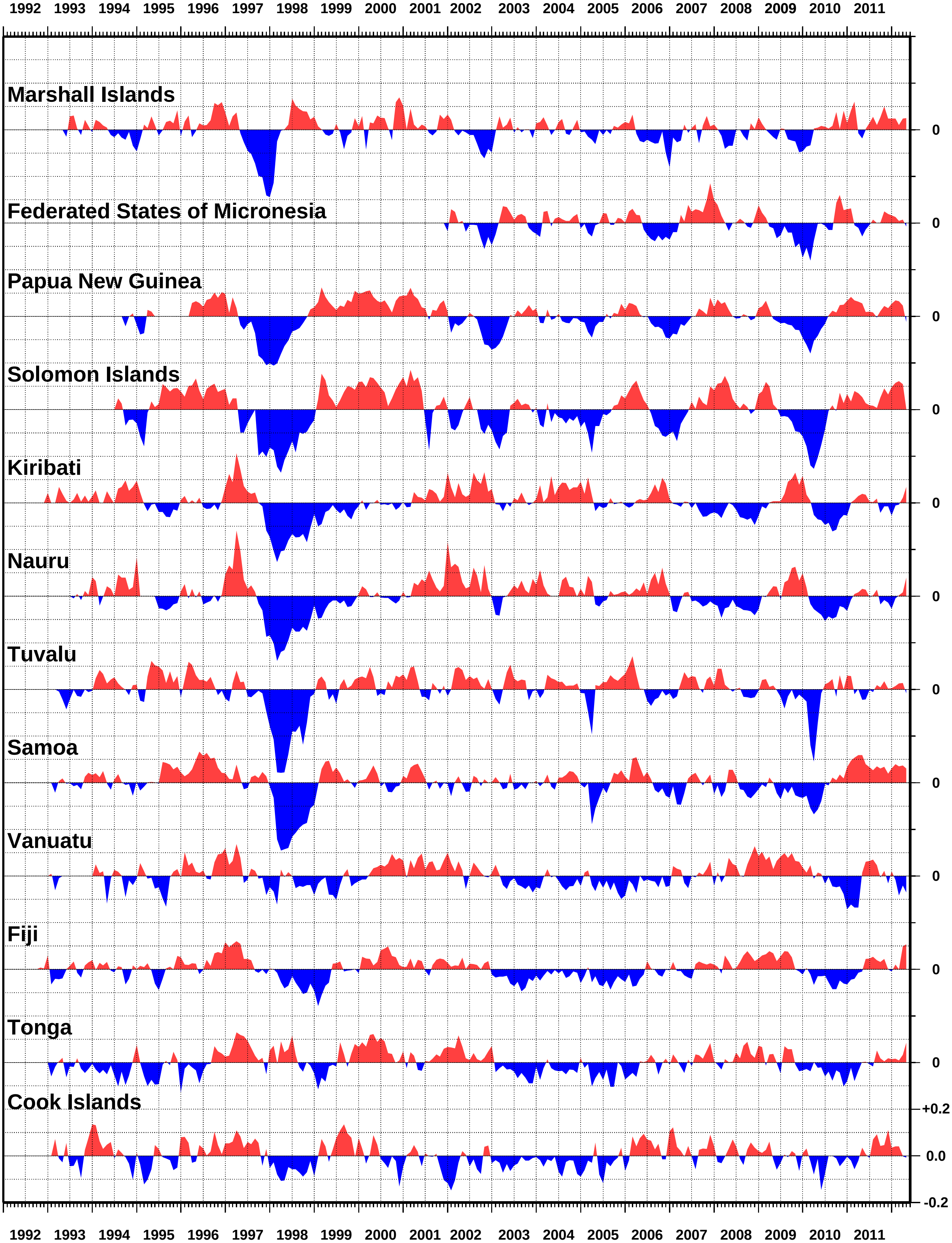


Figure 13

SEA LEVEL TRENDS THROUGH APRIL 2012 (mm/year)

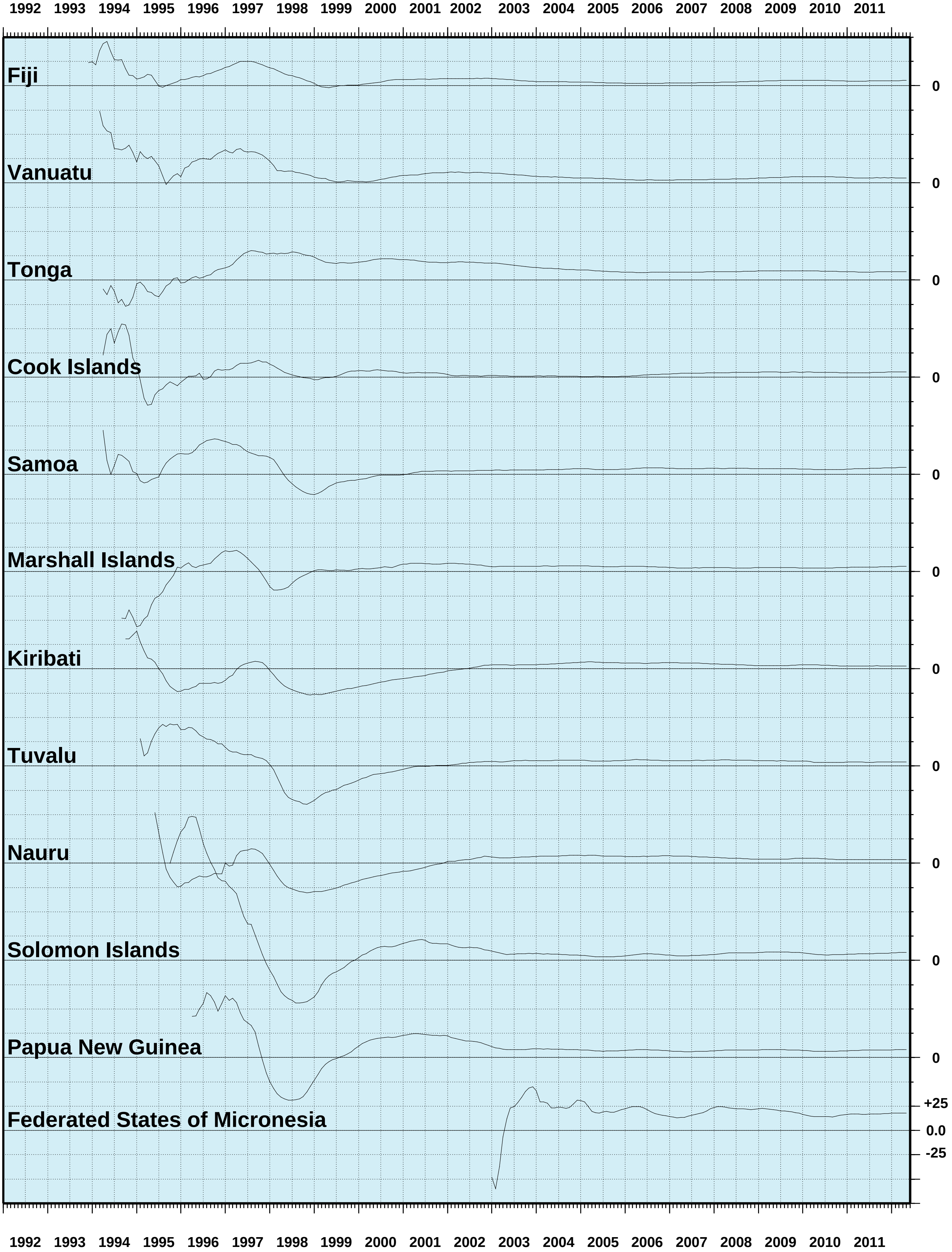


Figure 14

BAROMETRIC PRESSURE ANOMALIES THROUGH APRIL 2012 (hPa)

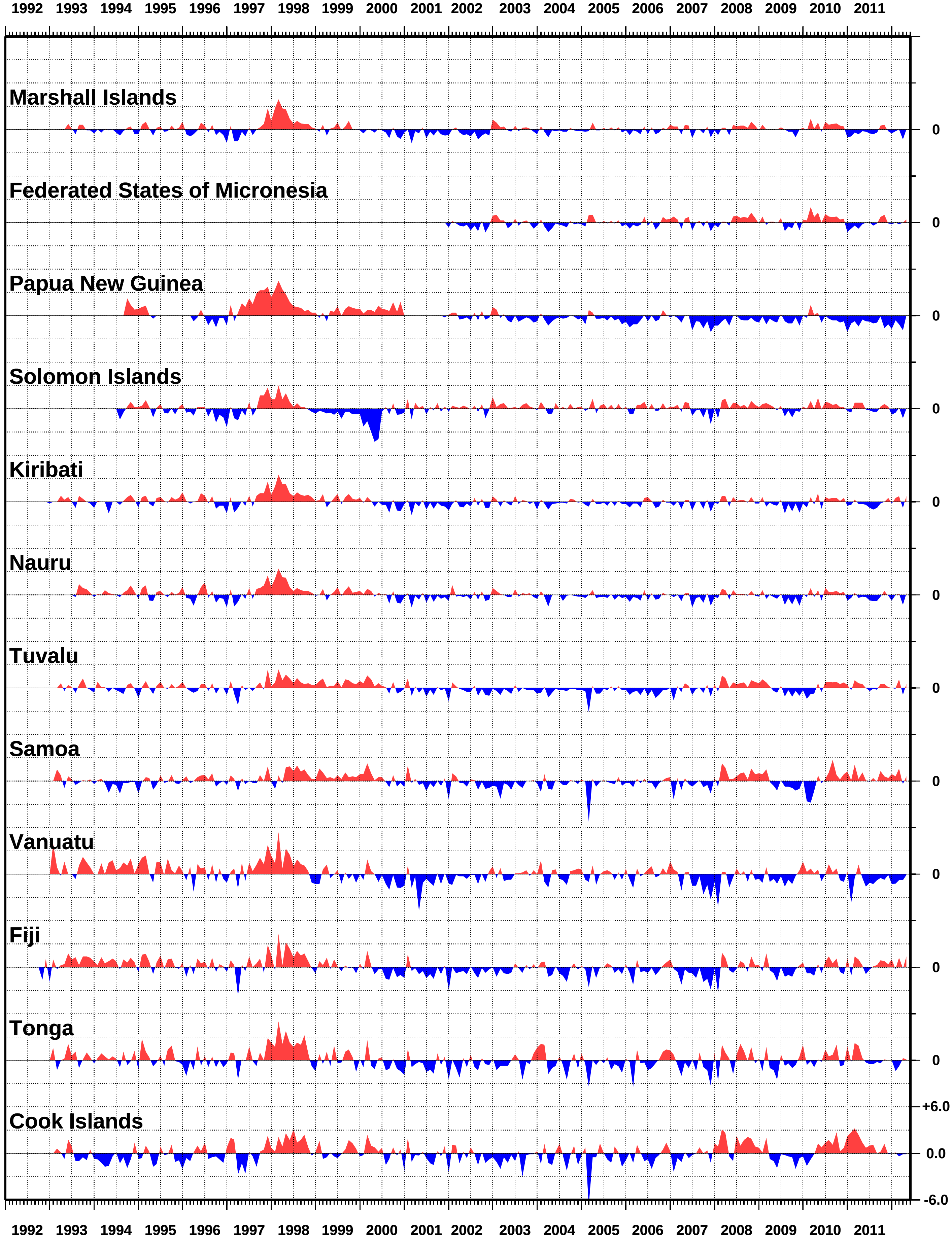


Figure 15

WATER TEMPERATURE ANOMALIES THROUGH APRIL 2012 (°C)

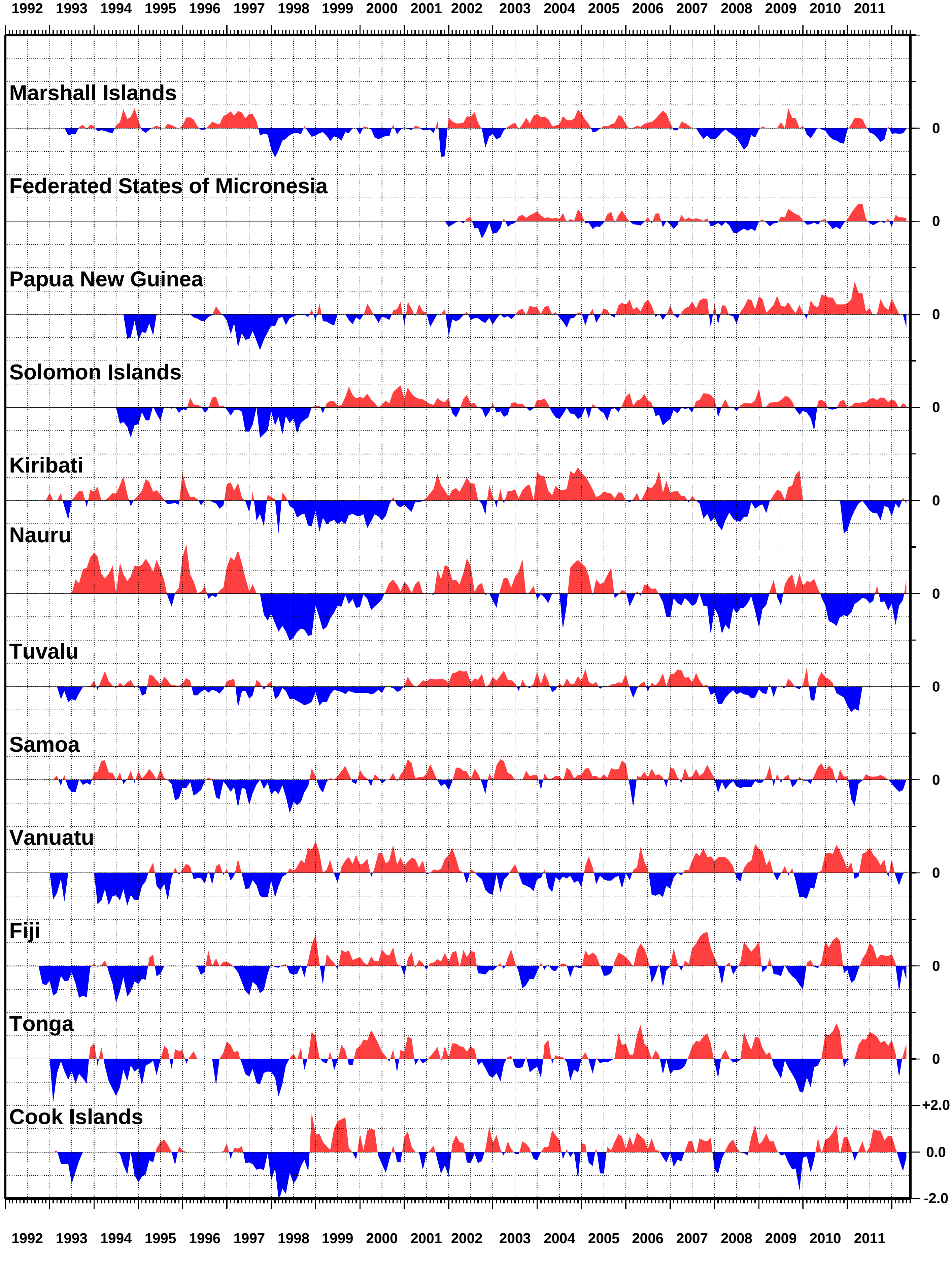


Figure 16

AIR TEMPERATURE ANOMALIES THROUGH APRIL 2012 (°C)

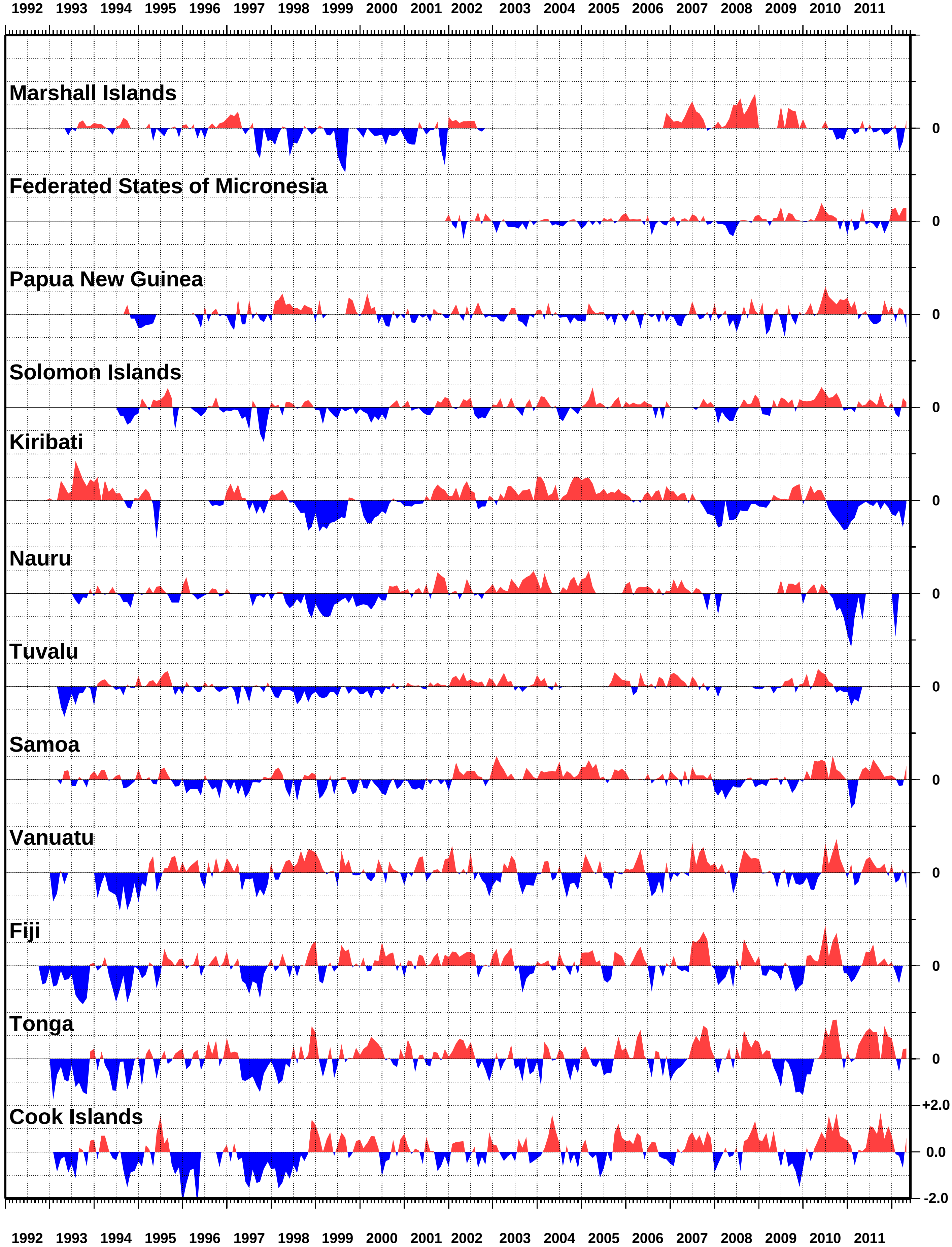


Figure 17

SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED

GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE

* Patchy record