THE SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT

MONTHLY DATA REPORT

NO. 179

MAY 2010

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 May 2010 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

May 2010

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.

May 2010

- The SEAFRAME network continued to collect high quality sea level and associated meteorological information for monitoring climate variability and climate change.
- Sea levels during the recent 2009/2010 El Niño were lower than normal across the region, but not at the extremely low levels observed during the strong 1997/98 El Niño. Lower than normal sea levels continued to be observed at some stations during May, but near-normal sea levels have generally been restored following the breakdown of El Niño conditions.
- Near-neutral climate conditions were observed across the tropical Pacific during May. Cooler than normal subsurface temperatures across much of the equatorial Pacific is expected to cause further cooling of the sea surface in the coming months.
- The majority of international climate models predict further cooling of the tropical Pacific and an increased likelihood of La Niña conditions developing in the latter part of the year.

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 May, 2010

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	+4.9	-0.3
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+9.3	0.0
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+5.5	0.0
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+6.5	0.0
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+5.1	0.0
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+3.7	0.0
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.9	-0.2
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+4.8	-0.2
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+5.9	-0.3
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+6.4	-0.1
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+14.3	+0.1
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+3.7	+0.1

INTRODUCTION

Welcome to the May 2010 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.

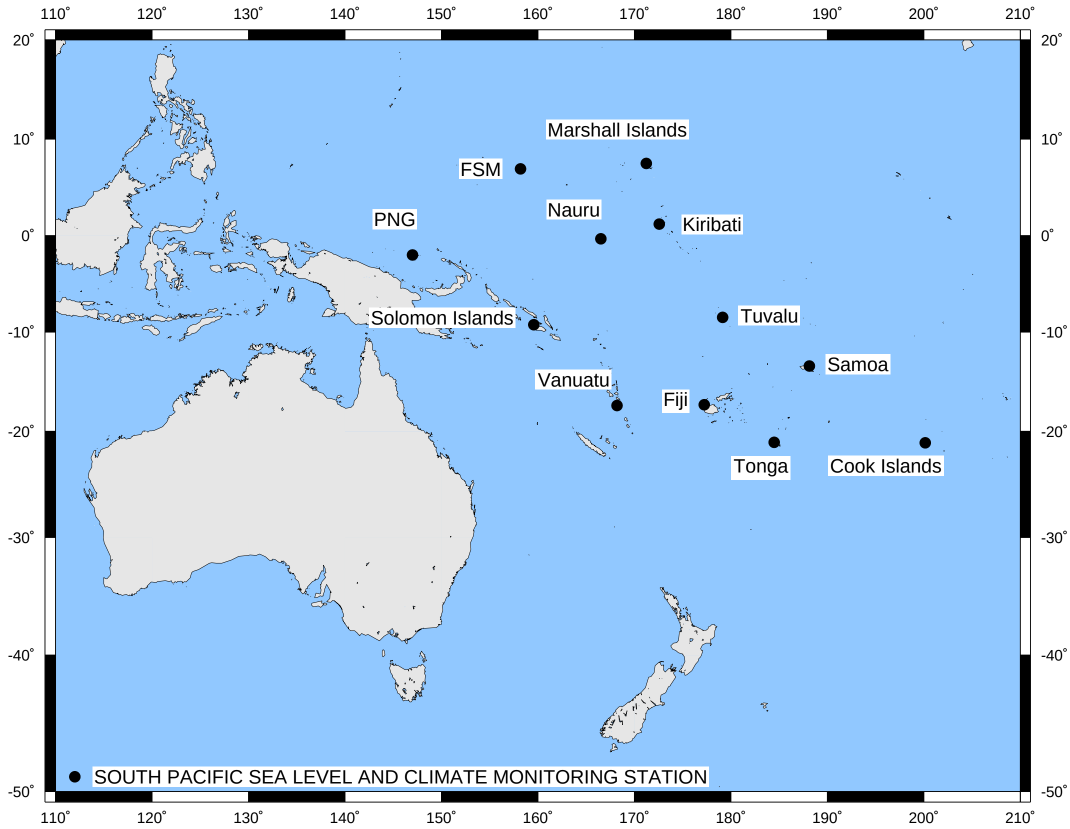

Figure A: *South Pacific Sea Level and Climate Monitoring Stations*

MAY CLIMATOLOGY

Climate conditions across the equatorial Pacific remained neutral during May, with sea surface temperatures, equatorial Trade Winds and cloudiness in the vicinity of the dateline all being near normal for this time of the year. However, cooler than normal subsurface ocean temperatures are persisting across the equatorial Pacific, which will likely affect sea surface temperatures and atmospheric conditions in the coming months. International climate models predict that Pacific Ocean temperatures will continue to cool and the likelihood of La Niña conditions developing this year has increased.

The Southern Oscillation Index (SOI) remained positive in May, with a value of +10 following the April value of +15 (**Figure B**). Sustained positive values of the SOI above +8 are typical of La Niña, so continued positive SOI values in the coming months will increase the chance of La Niña conditions developing later in the year.

Sea surface temperatures continued to cool across the central equatorial Pacific during May and are now near normal across most of the tropical Pacific, following the warmer conditions that prevailed during the recent El Niño. Small patches of warm anomalies still exist in the far western and far eastern equatorial Pacific (**Figure C**).

Subsurface ocean temperatures continued to cool through May, and have generally been in decline since December in connection with the decay of El Niño (**Figure D**). Cool anomalies at depth now extend across much of the equatorial Pacific, with anomalies in the central equatorial Pacific being more than -3ºC cooler than is normal for this time of the year.

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. During May 2010 Trade Winds were slightly stronger than normal in the western Pacific and of near-average strength in the central and eastern Pacific (**Figure E**). Cloudiness near the dateline fluctuated during May but was generally below average.

The consensus among international computer models surveyed by the Bureau of Meteorology predict further cooling of the tropical Pacific over the coming months, with an increased possibility of La Niña conditions developing in the latter part of the year.

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/.

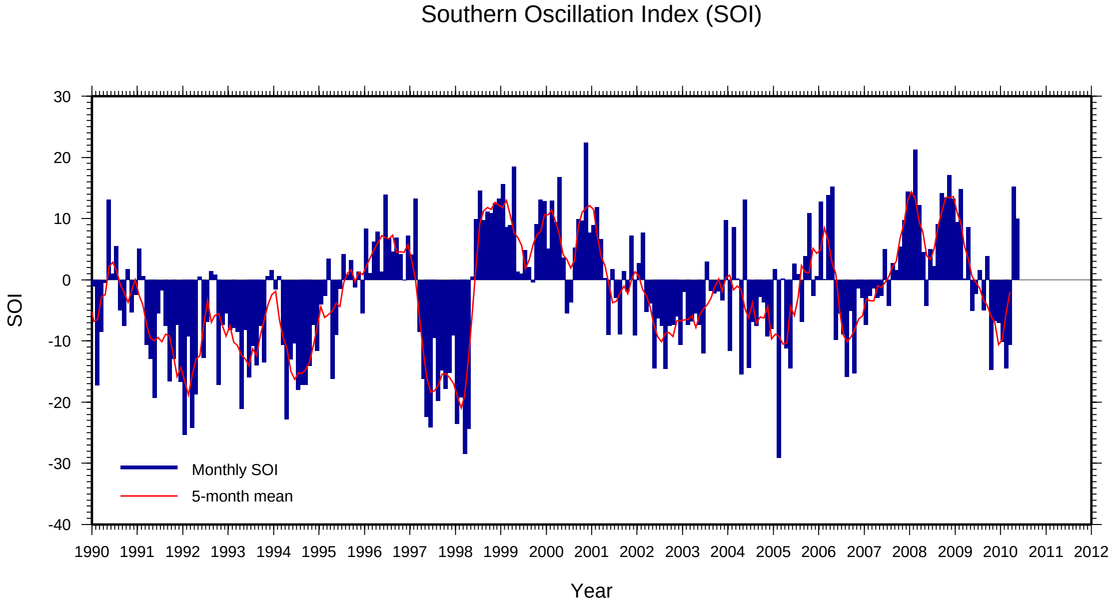

Figure B: *The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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

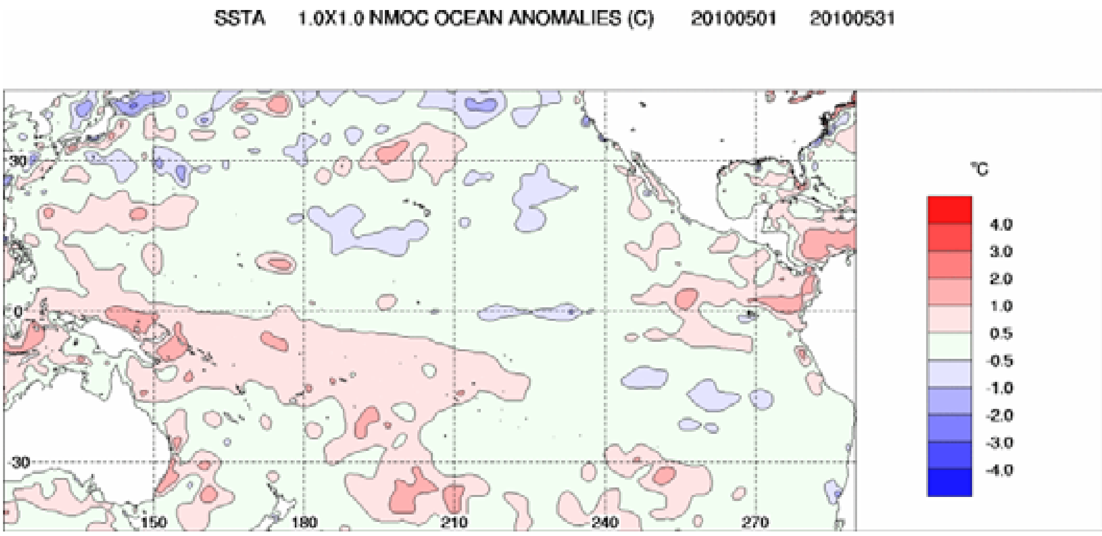

Figure C: *Sea surface temperature anomaly (°C) for May 2010.*

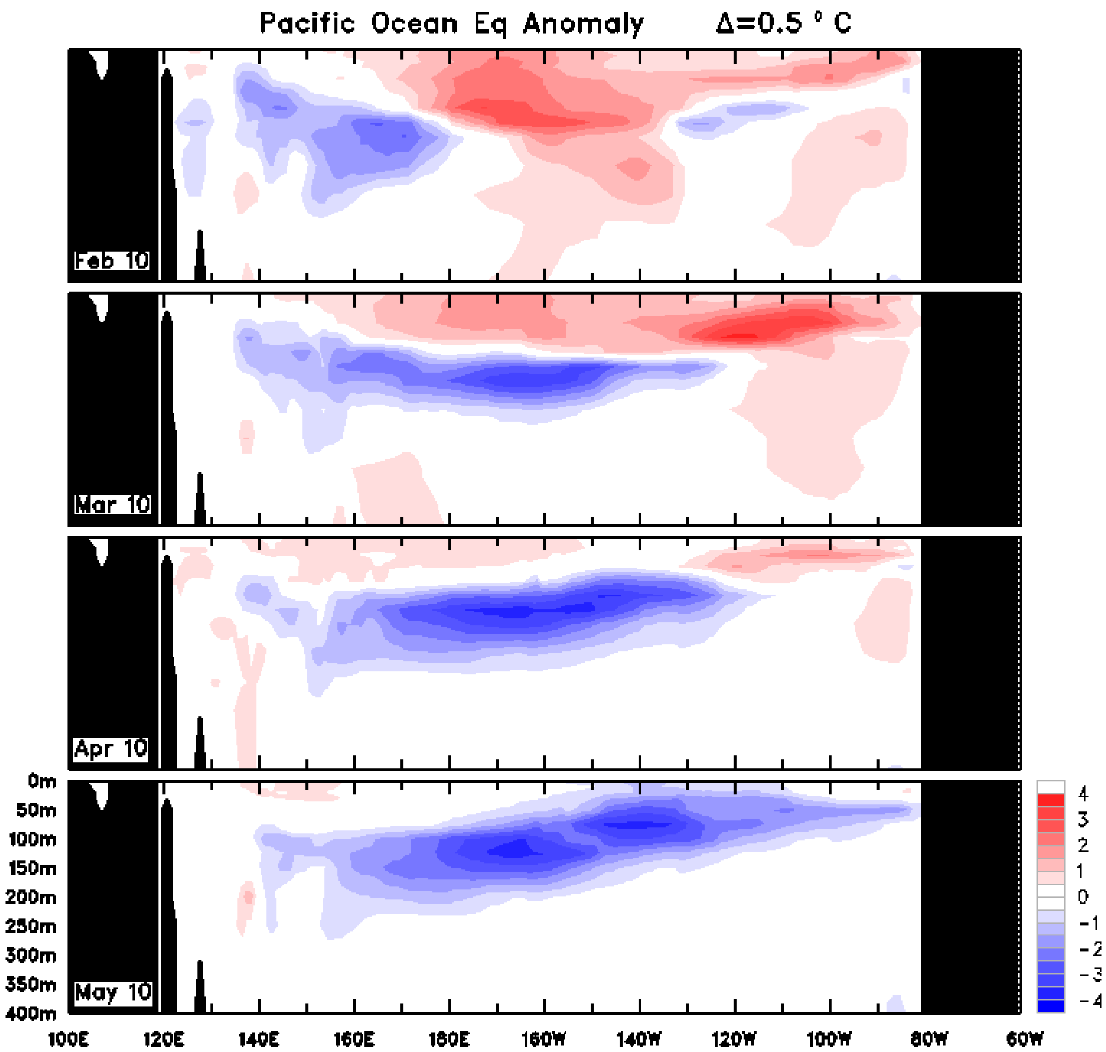

Figure D: *Equatorial depth-longitude section of ocean temperature anomalies for February 2010 through to May 2010. Contour interval is 0.5°C.*

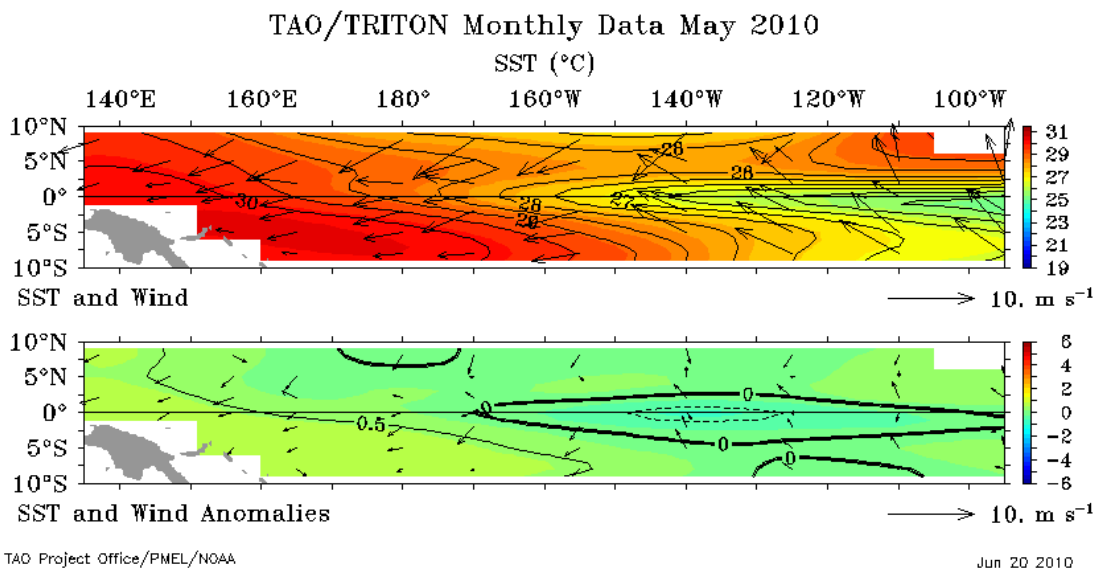

Figure E: *Monthly mean wind vectors (top) and anomalies (bottom) for May 2010. The colour-shaded contours represent the monthly mean sea surface temperatures (top) and anomalies (bottom).*

MAY 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). The greatest variations are called spring tides and tend to occur close to the full and new moon. There was a new moon on the 14th of May and a full moon on the 27th of May UTC.

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 often 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 phenomena referred to as a seiche), such as PNG when the wind suddenly changes strength or direction, at FSM during periods of reduced tidal range 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 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. FSM) 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 the tide, as it is 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 further 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*. A new minimum May barometric pressure was recorded at PNG (1002.3hPa).

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 to disrupt the annual sea level cycle at many of the SEAFRAME stations.

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.

Lower than normal sea levels were observed at many stations in late 2009 and early 2010 as a result of weakened Trade Winds during the 2009/10 El Niño. Sea levels began returning to more normal levels with the breakdown of El Niño in March and April and this trend has continued through May 2010, although negative sea level anomalies have continued to develop at Kiribati and Nauru in association with cooler than normal subsurface ocean temperatures along the equator. The largest anomalies during May 2010 were observed at Solomon Islands and Cook Islands, where sea levels were more than 10cm below normal.

Lower than normal sea levels are typical during El Niño, as can be seen during previous events in 1997/98, 2002/03 and 2006/07. The recent 2009/10 El Niño caused sea levels to fall significantly across the region, but not to the very low levels observed during the strong 1997/98 El Niño.

Sea Level Trends

The **short-term sea level trends** at individual stations as at May 2010 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*.

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Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+4.8	-0.2
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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 May 2010 barometric pressures were generally near average for this time of the year.

The **water temperature anomalies (Figure 15)** show near- to slightly warmer than normal conditions were observed during May 2010. The largest anomalies of between +0.5 and +1.0 °C were observed at PNG, Tuvalu and Samoa.

The **air temperature anomalies (Figure 16)** also show near- to slightly warmer than normal air temperatures were observed during May 2010. Anomalies nearing +1°C were observed at FSM, Solomon Islands, Samoa, Fiji and Cook Islands. 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 was good for most stations during May 2010. At Samoa 19 days of data was lost as a result of power supply problems. Data communication problems were encountered at FSM, Nauru, PNG and Tuvalu, which resulted in a small amount of data loss. At Nauru problems with the primary sea level sensor continued and data from the secondary sea level sensor were used.

Various problems were encountered with ancillary meteorological sensors, including the air temperature sensor at Marshall Islands, water temperature sensor at Kiribati, and the wind speed sensor at Vanuatu. The wind sensor at Tuvalu was repaired on 12th May 2010 following its failure on the 12th February 2010.

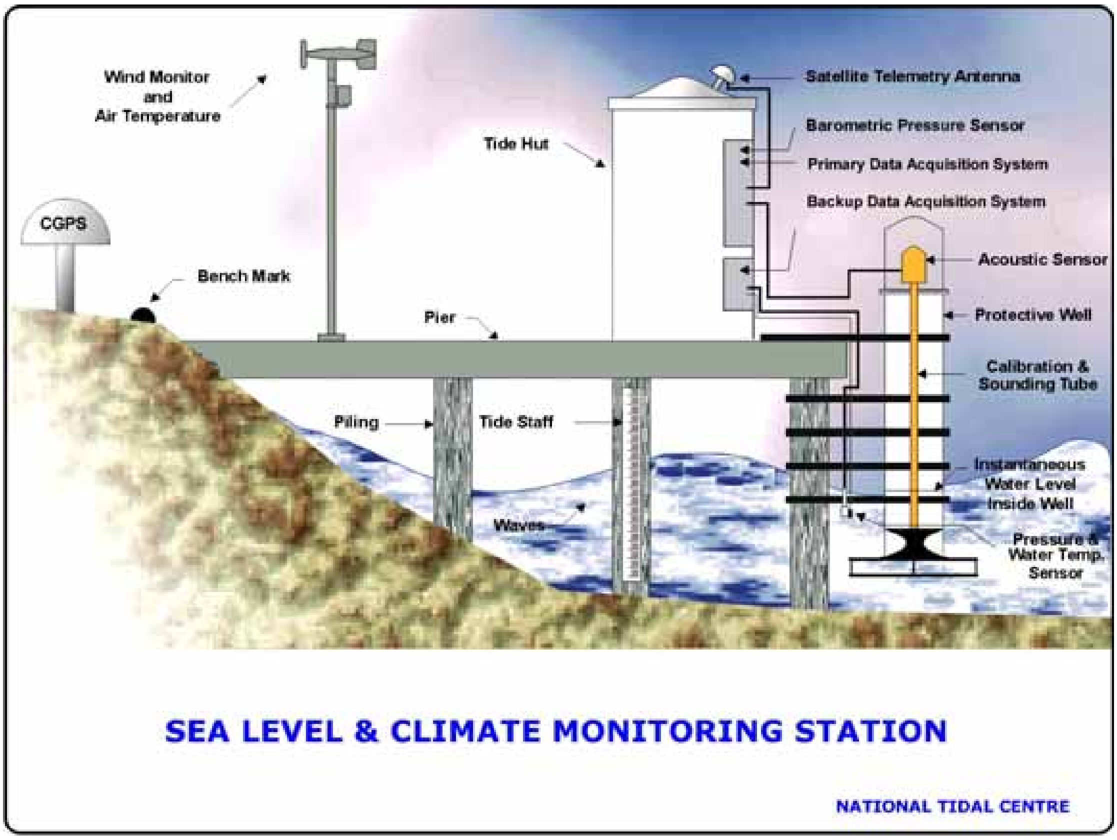
SEAFRAME STATIONS

SEAFRAME stations employ a 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 station is shown in the following figure. Water level sensors include:

(1) Primary water level using a Bartex 'AQUATRAK' acoustic-in-air sensor, and

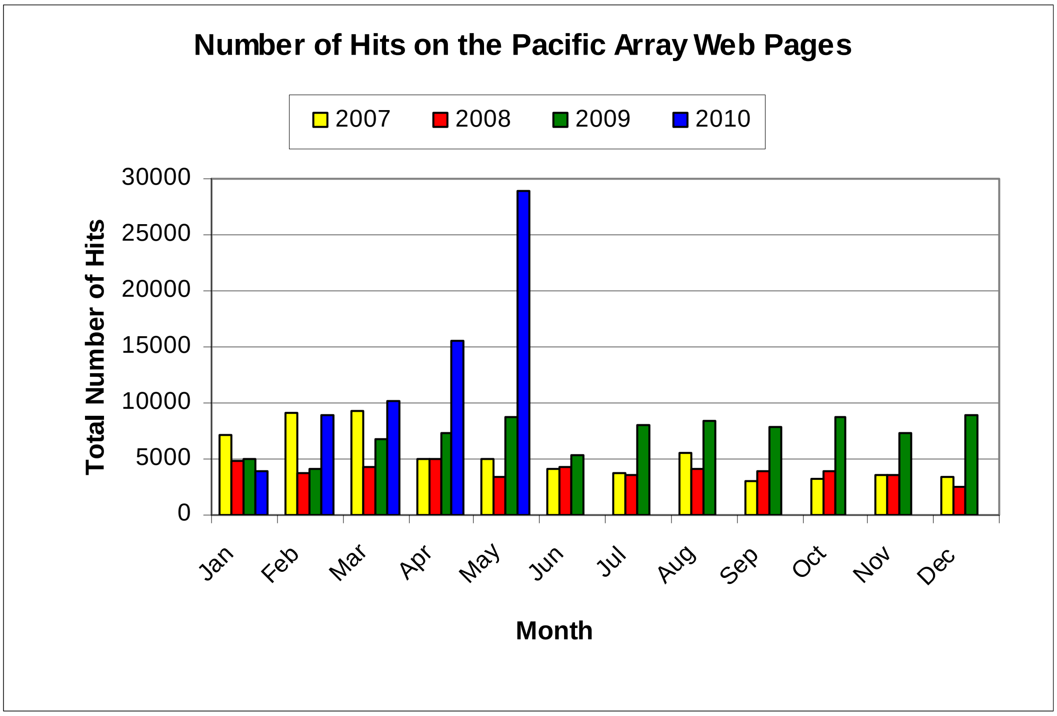
(2) Secondary water level (or backup) using a Druck pressure transducer mounted close to the seabed.

The primary and backup water level sensors provide water level values, which are averaged over three minutes and are logged every six minutes. The data logger has the memory capacity to store approximately one month of data. The meteorological sensors are logged to the SUTRON data logger on an hourly basis.



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 2007.



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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Fax: (+618) (08) 8366 2693
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.

Please also note the following:

Individuals and organisations are advised that quality controlled six-minute or hourly data from these stations are available on request from *NTC*. Some handling fees may be charged. For commercial agencies requesting data, some additional costs may be levied.

Figure 1

MAY 2010
SIX MINUTE WATER LEVEL OBSERVATIONS (m)

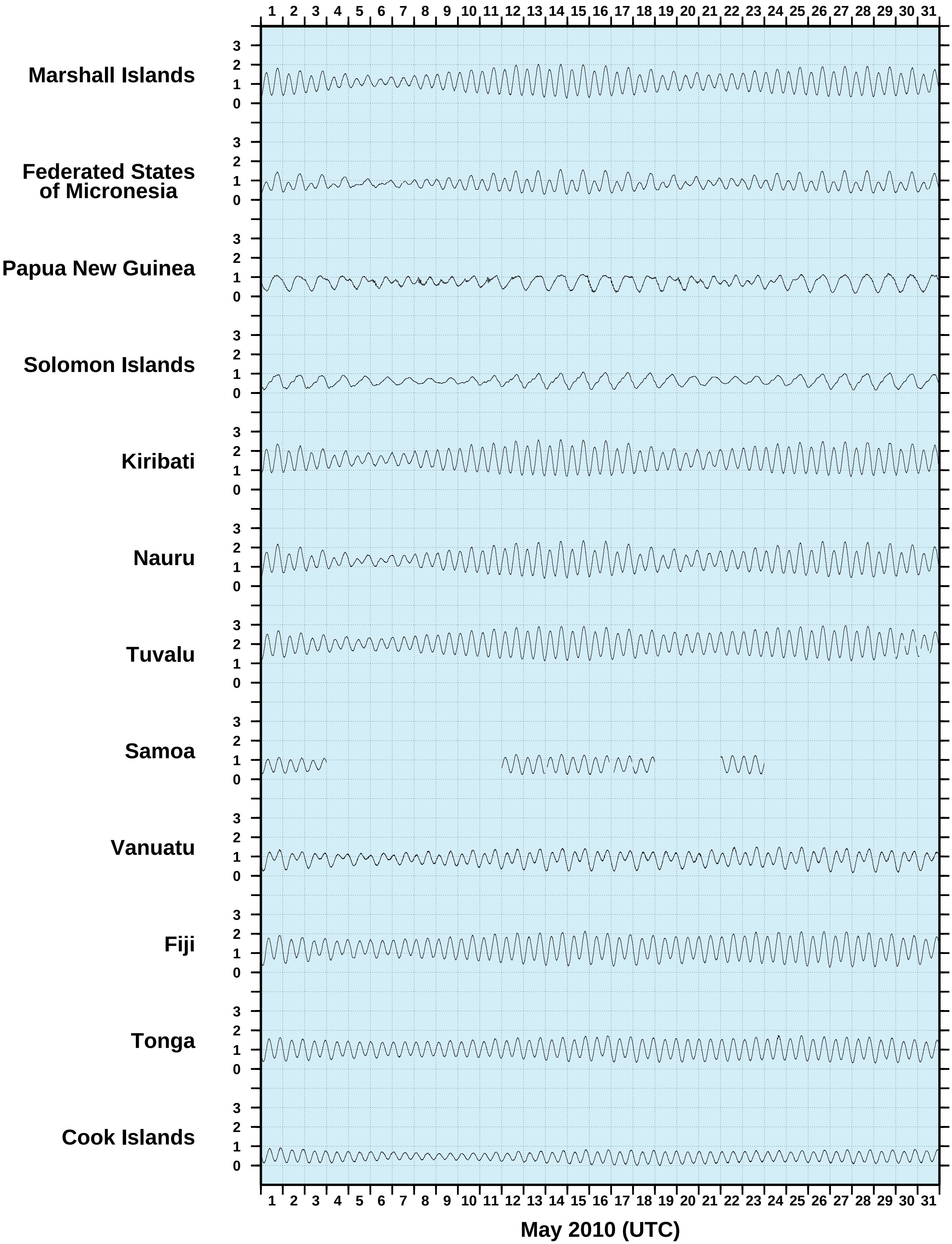


Figure 2

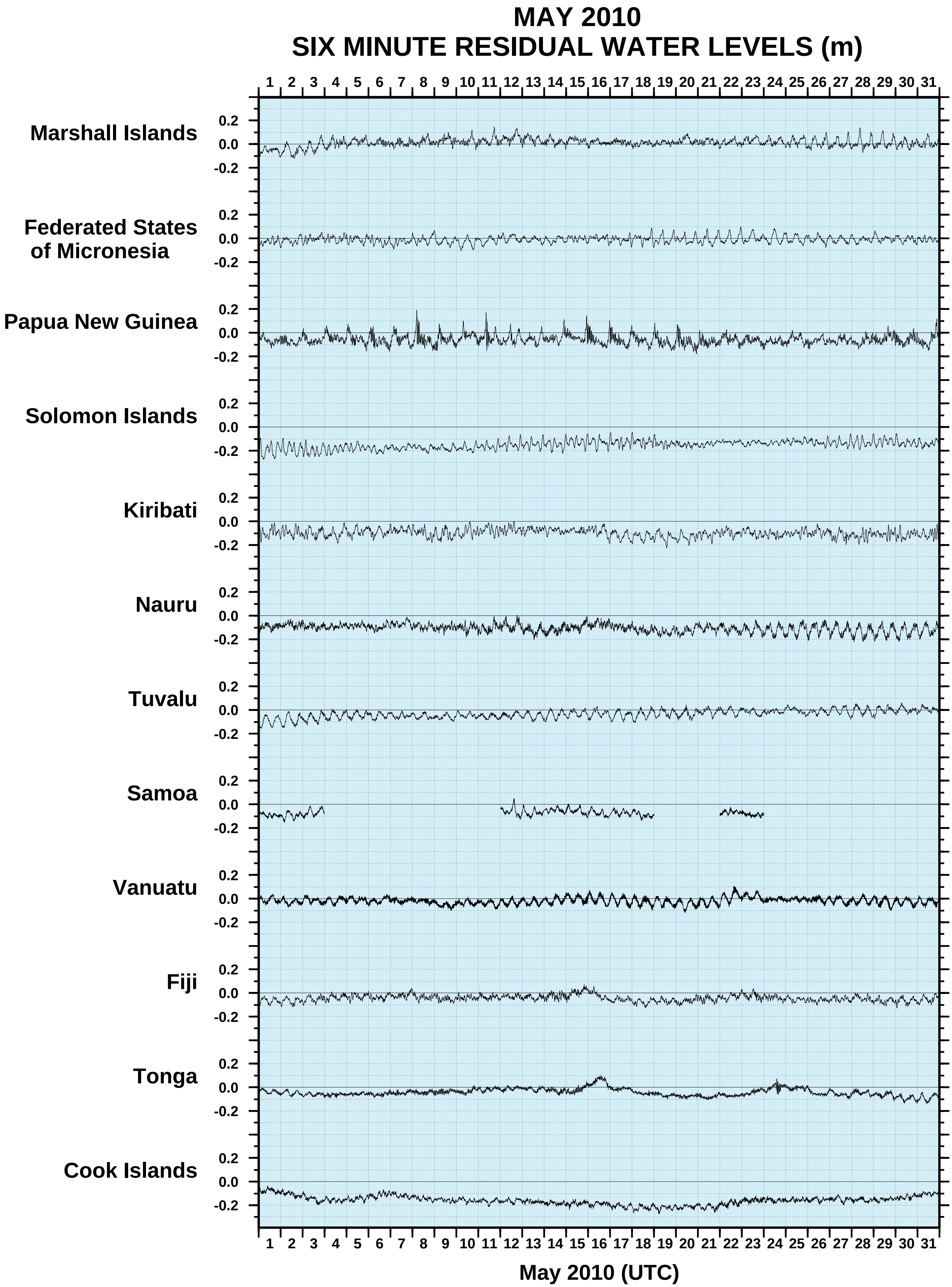

MAY 2010
SIX MINUTE RESIDUAL WATER LEVELS (m)
Marshall Islands
Federated States of Micronesia
Papua New Guinea
Solomon Islands
Kiribati
Nauru
Tuvalu
Samoa
Vanuatu
Fiji
Tonga
Cook Islands
0.2
0.0
-0.2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
May 2010 (UTC)

Figure 3

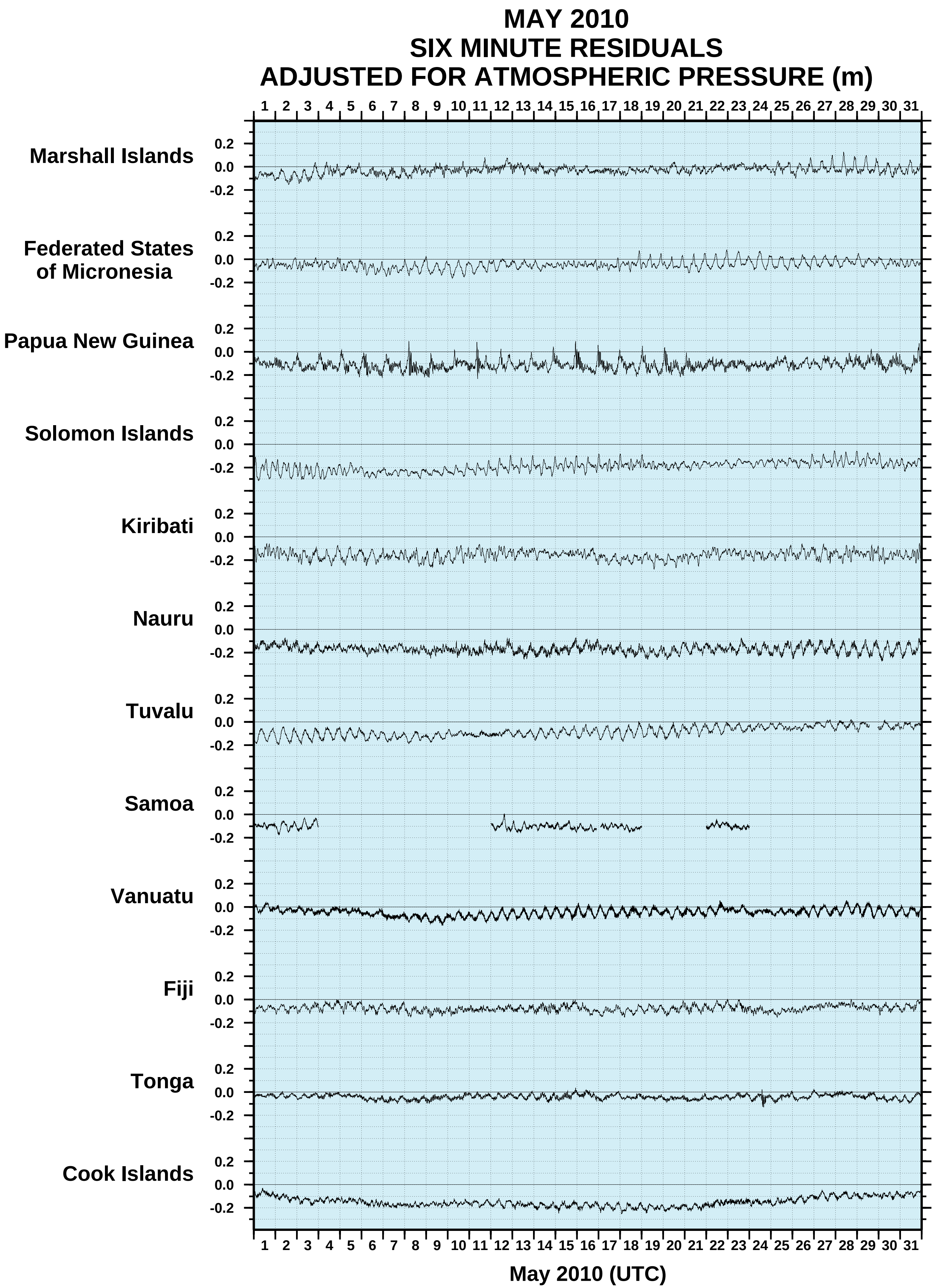
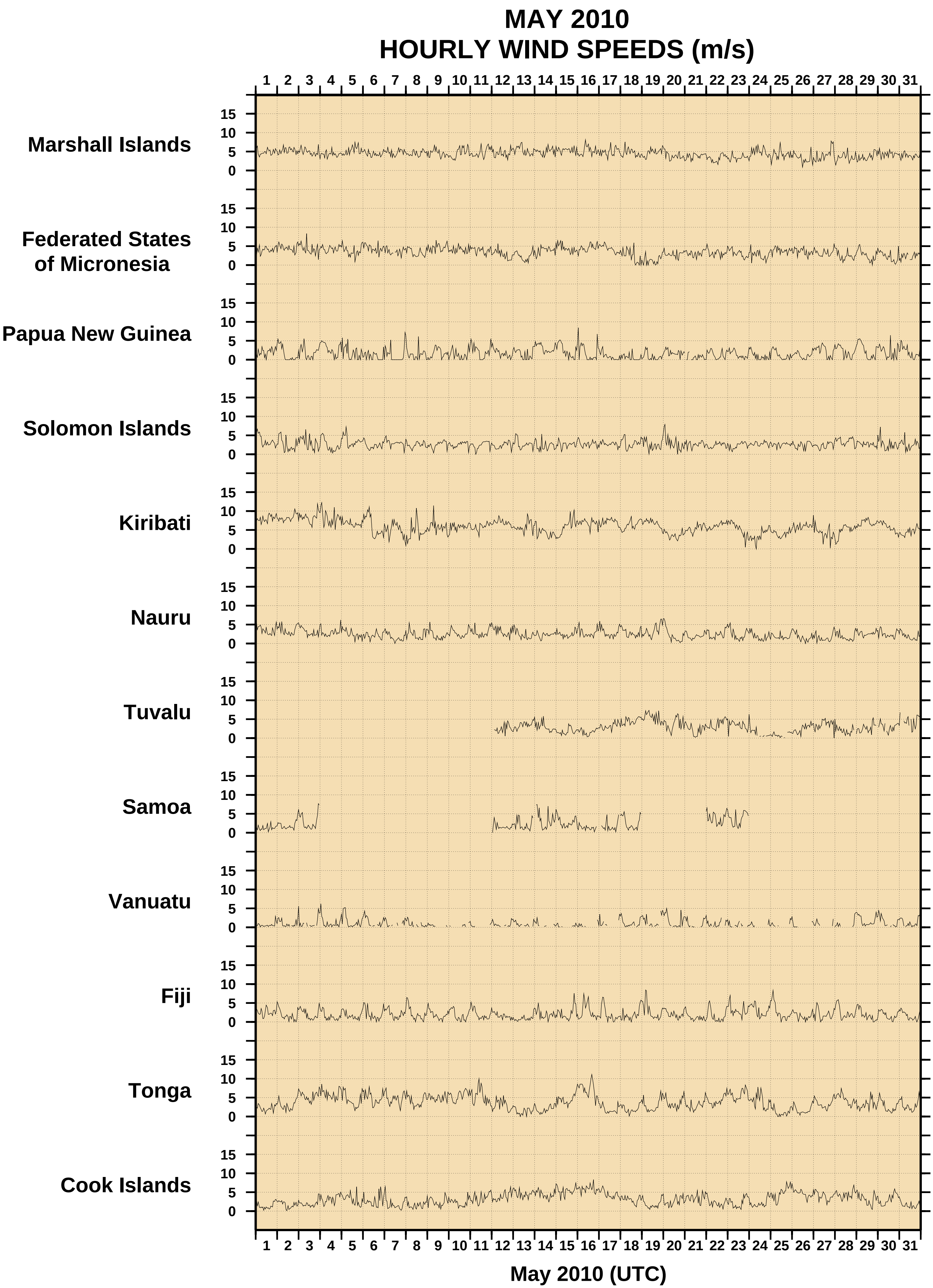

MAY 2010
SIX MINUTE RESIDUALS
ADJUSTED FOR ATMOSPHERIC PRESSURE (m)
Marshall Islands
Federated States of Micronesia
Papua New Guinea
Solomon Islands
Kiribati
Nauru
Tuvalu
Samoa
Vanuatu
Fiji
Tonga
Cook Islands
0.2
0.0
-0.2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
May 2010 (UTC)

Figure 1


MAY 2010
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
15
10
5
0
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 31
May 2010 (UTC)

MAY 2010
HOURLY INCIDENT WINDS (m/s, deg True)

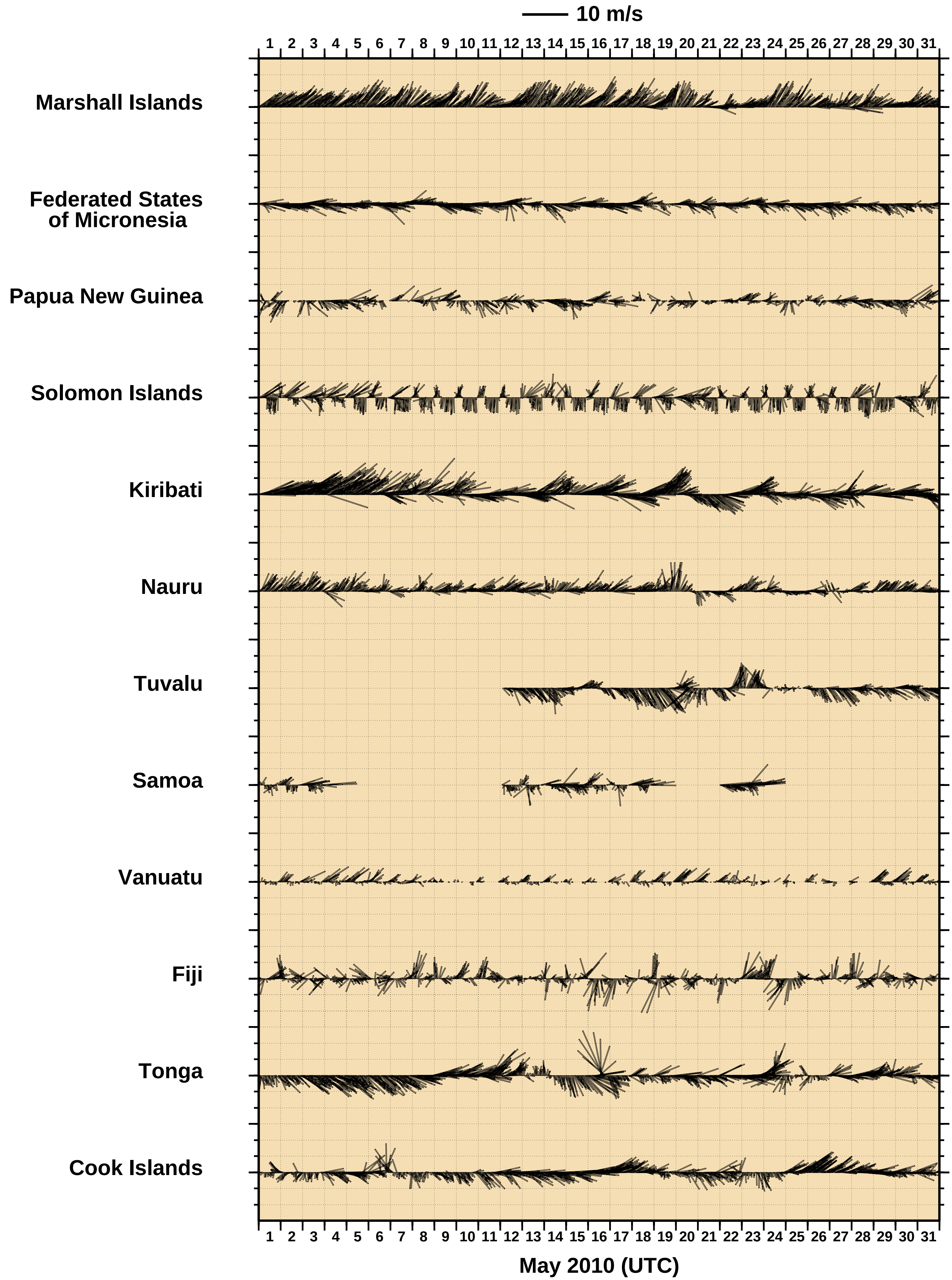


Figure 6

MAY 2010
HOURLY MAXIMUM WIND GUSTS (m/s)

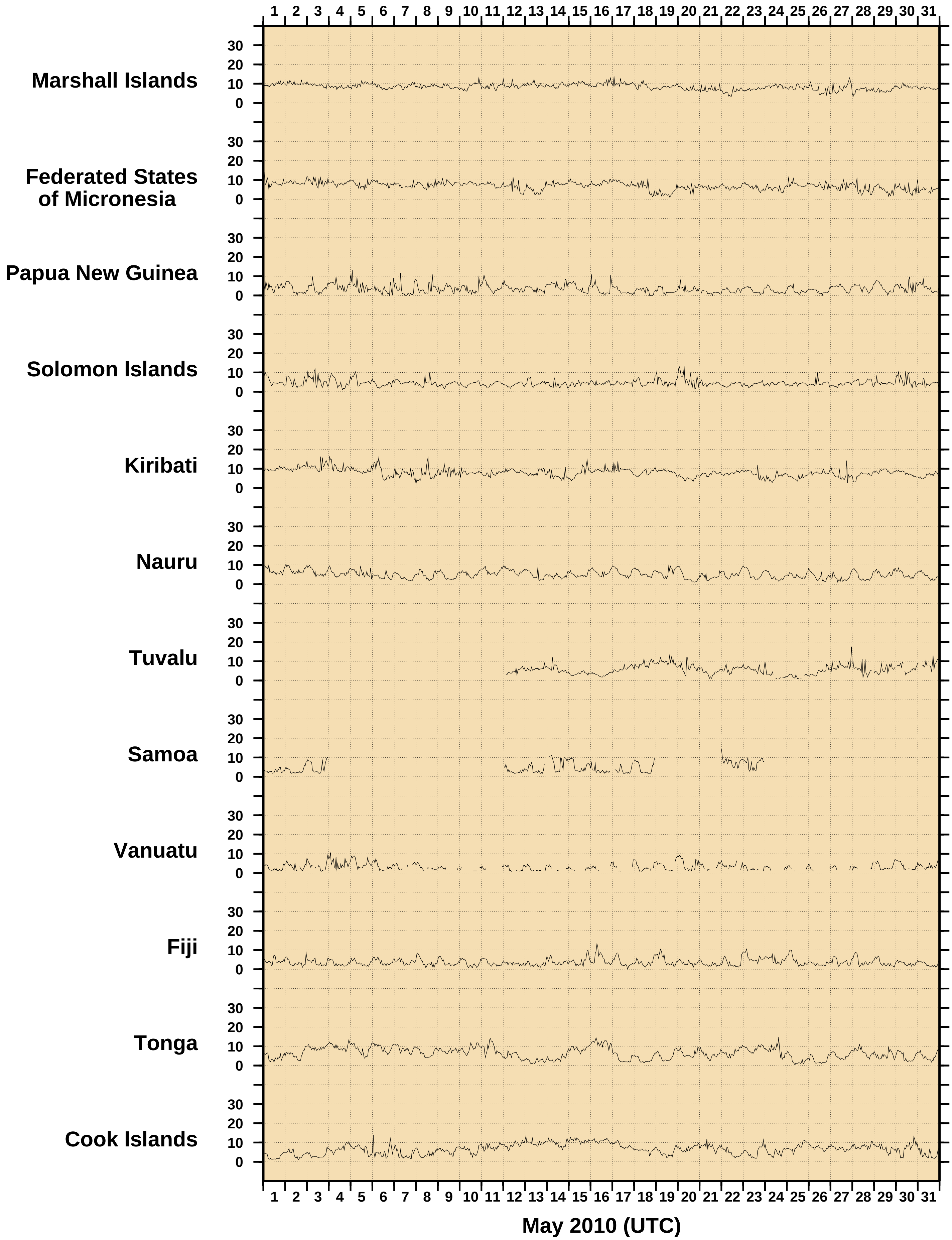


Figure 7

MAY 2010
HOURLY AIR TEMPERATURES (°C)

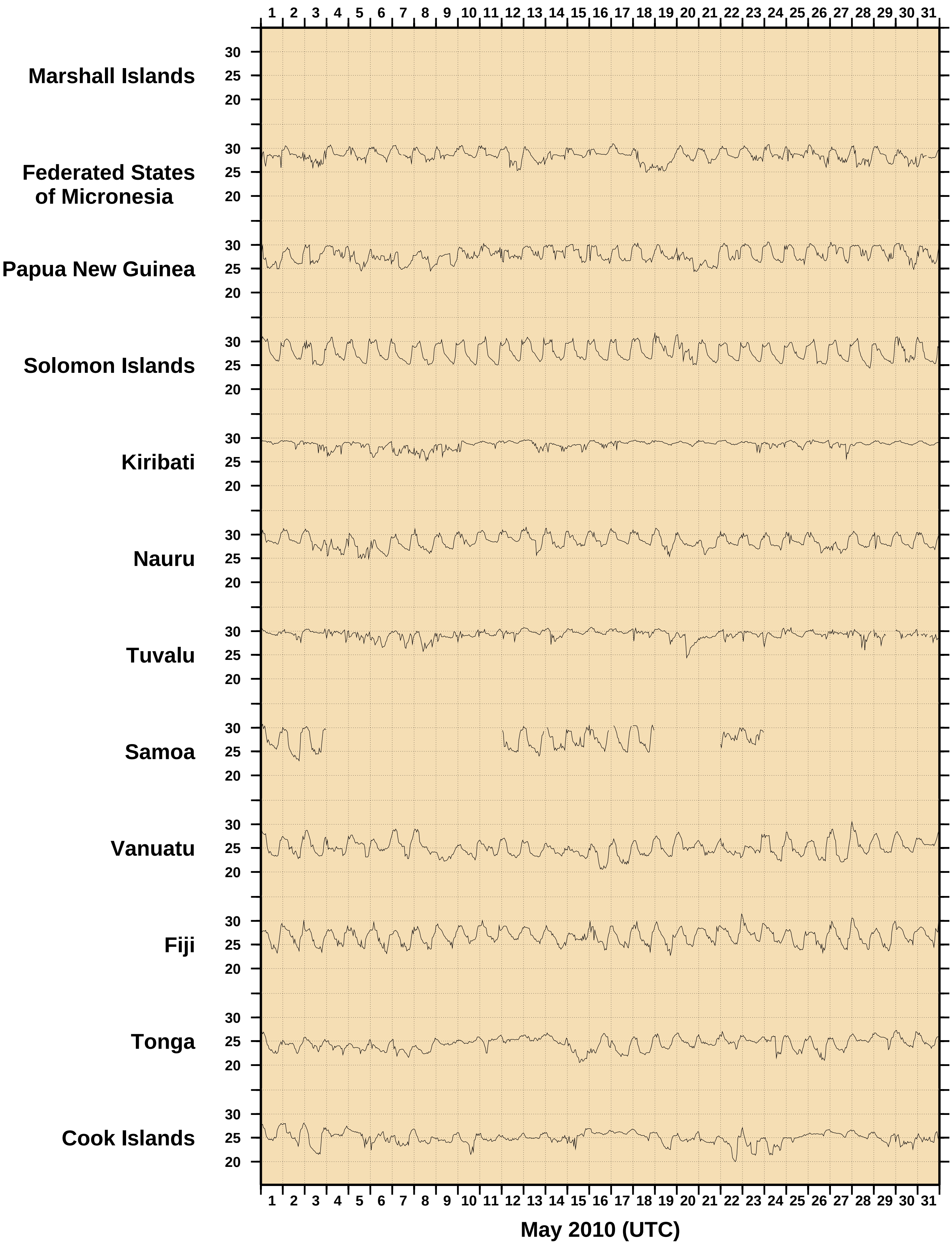


Figure 8

MAY 2010
HOURLY WATER TEMPERATURES (°C)

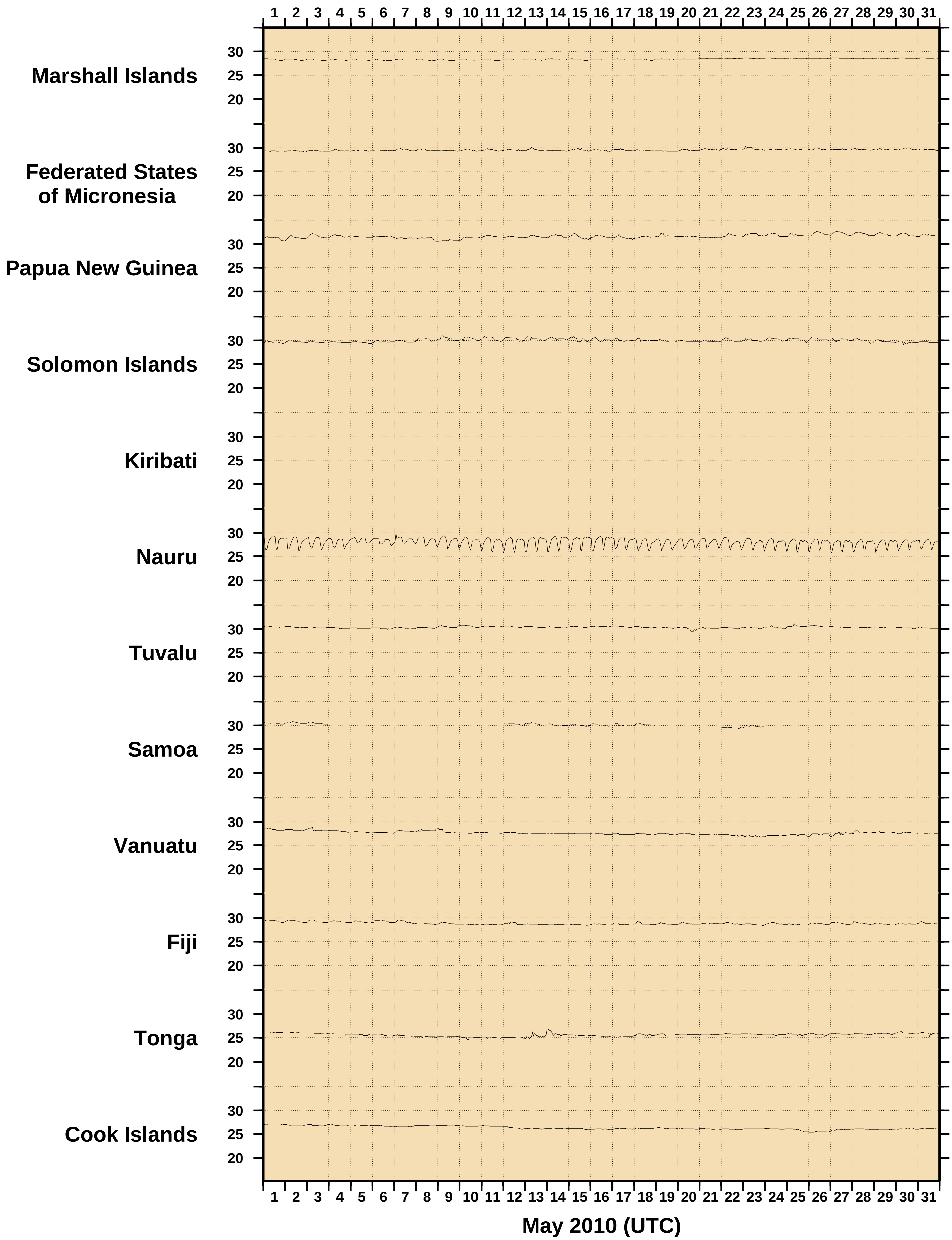


Figure 9

MAY 2010
HOURLY ATMOSPHERIC PRESSURE (hPa)

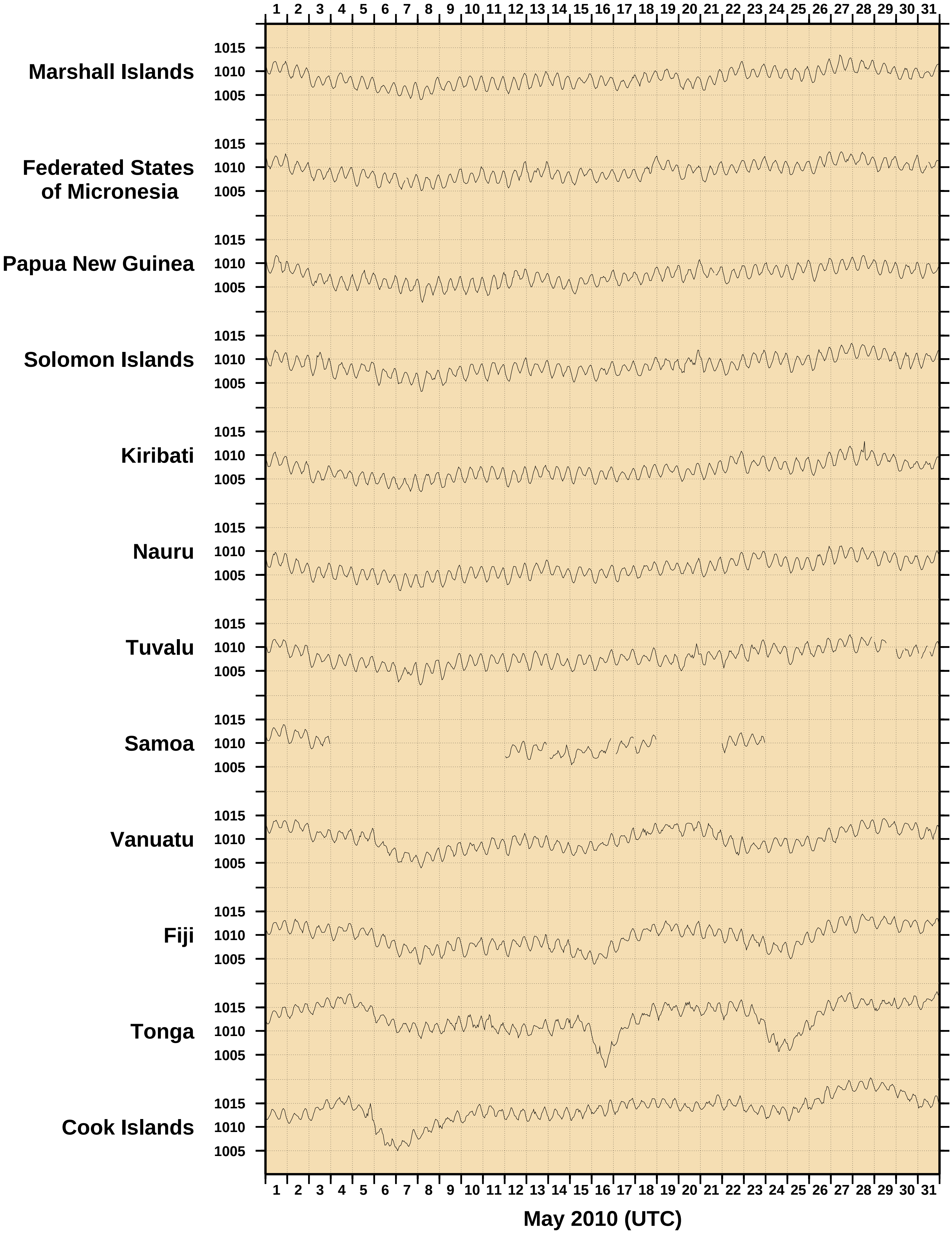


Figure 10

Comparison of May 2010 Max, Min & Mean with Long Term May Values

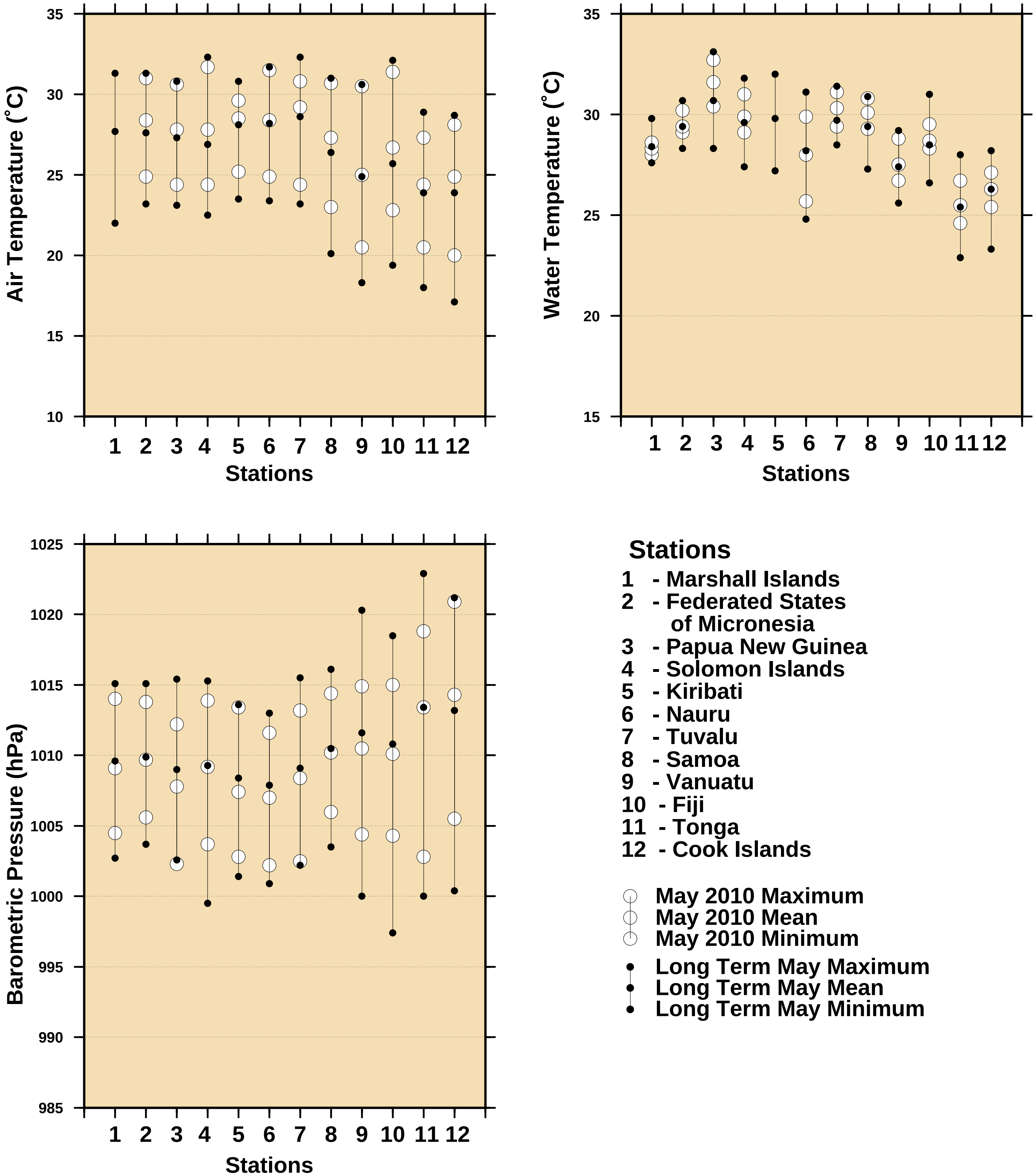


Figure 11

MONTHLY MEAN SEA LEVELS TO MAY 2010 (m)

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

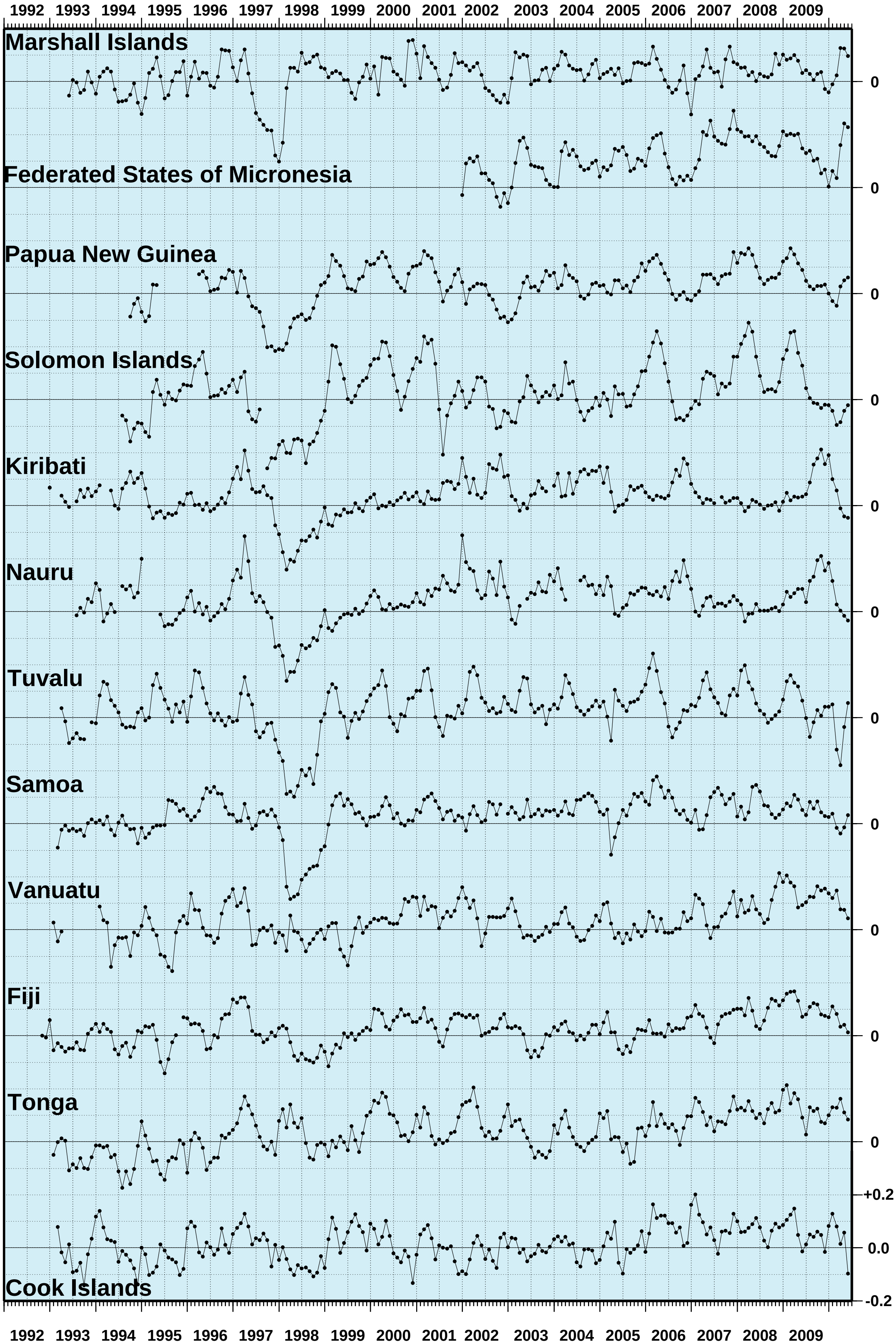


Figure 12

SEA LEVEL ANOMALIES THROUGH MAY 2010 (m)

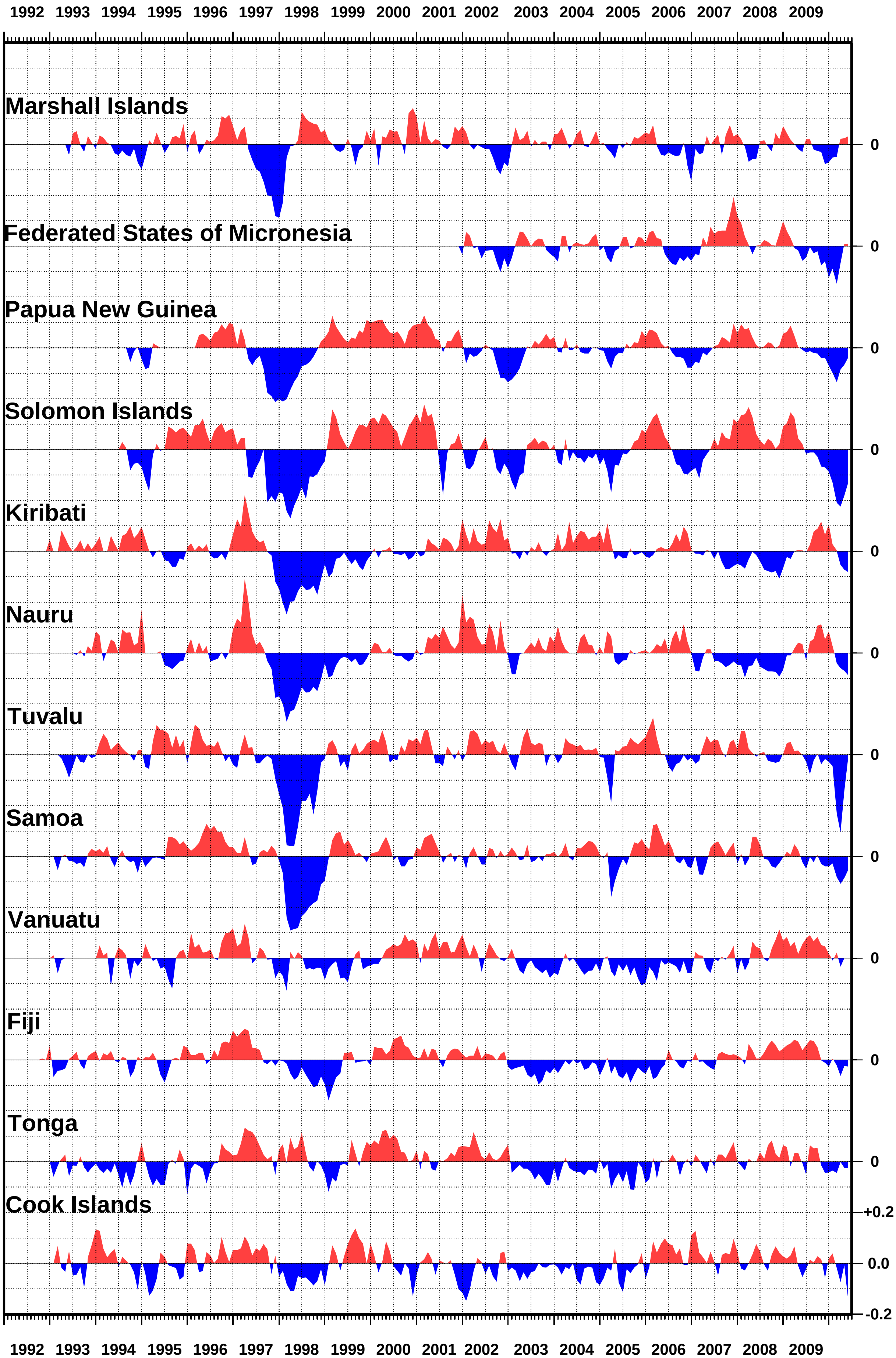


Figure 13

SEA LEVEL TRENDS THROUGH MAY 2010 (mm/year)

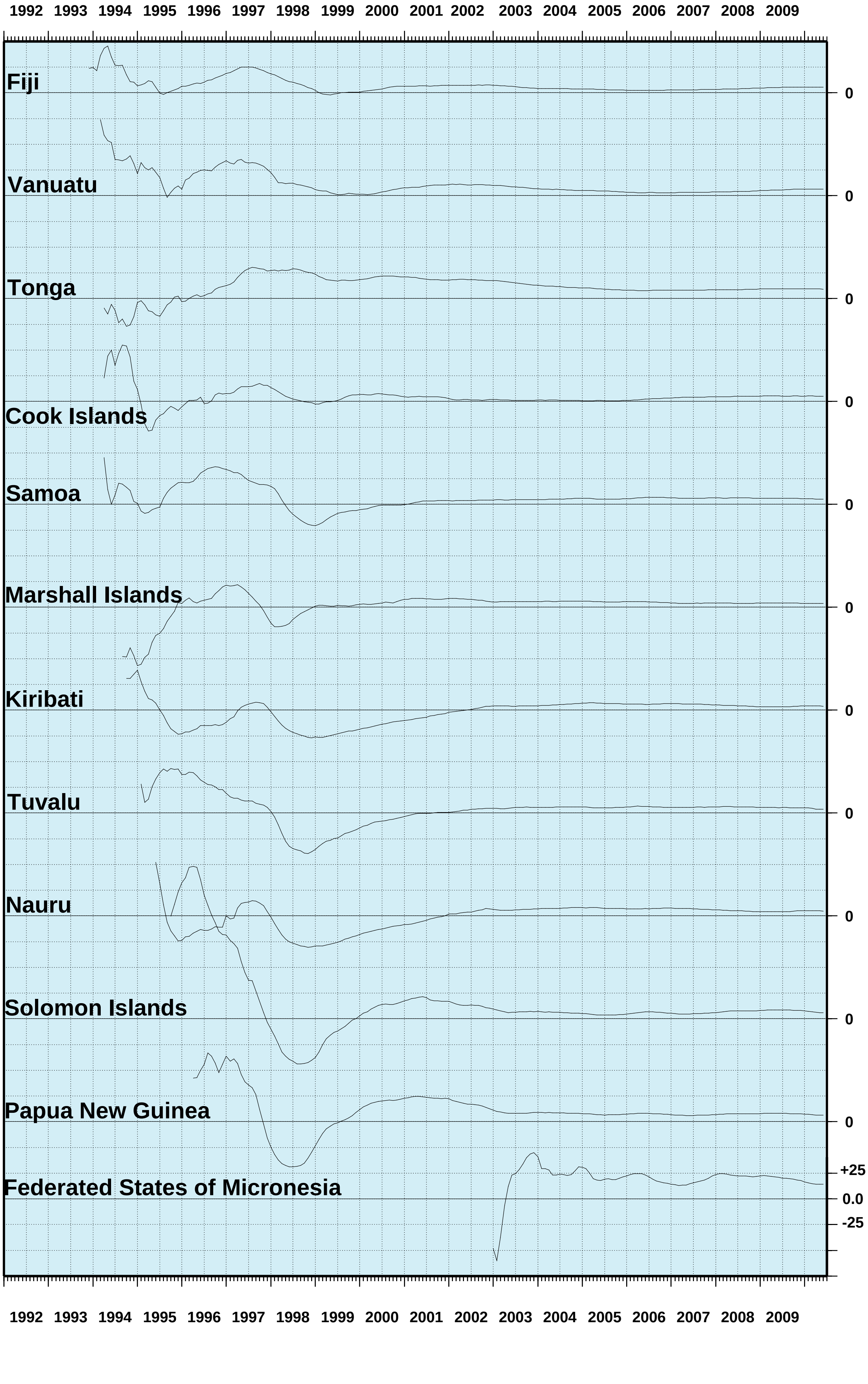


Figure 14

BAROMETRIC PRESSURE ANOMALIES THROUGH MAY 2010 (hPa)

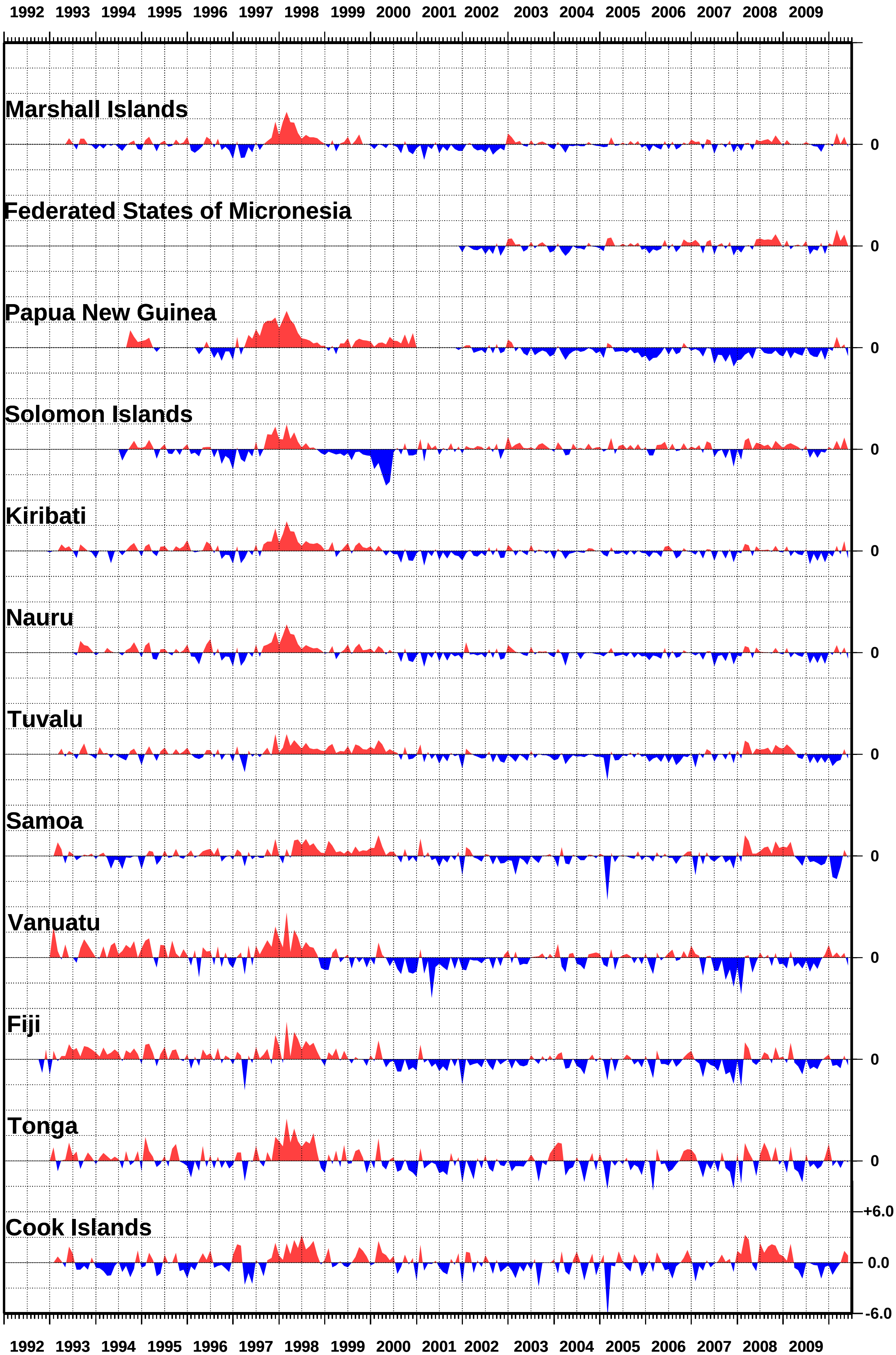


Figure 15

WATER TEMPERATURE ANOMALIES THROUGH MAY 2010 (°C)

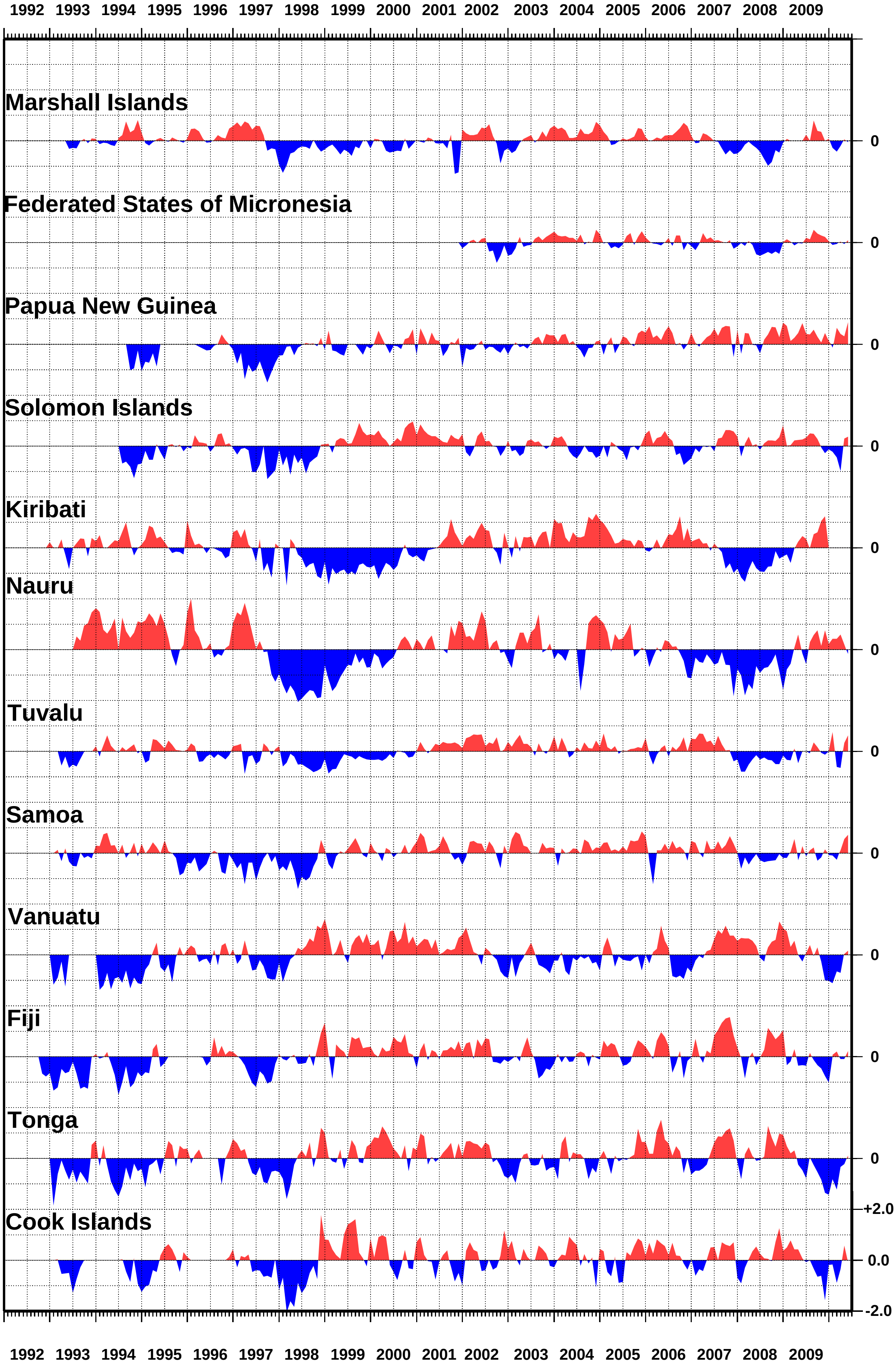
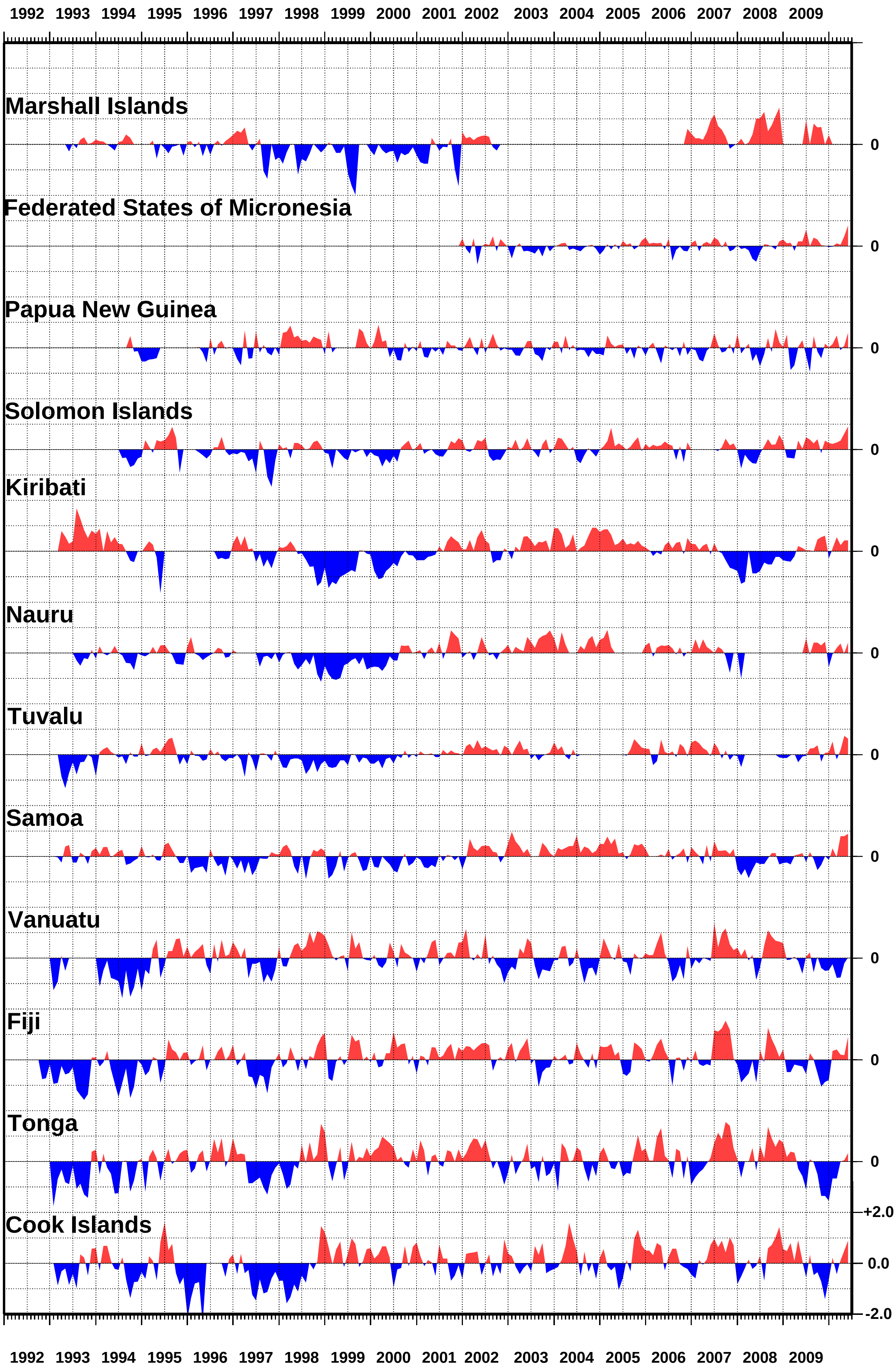


Figure 16

AIR TEMPERATURE ANOMALIES THROUGH MAY 2010 (°C)



SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED

GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE

* Patchy record