THE SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT

MONTHLY DATA REPORT

NO. 165

MARCH 2009

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 March 2009 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

March 2009

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.

March 2009

- The SEAFRAME network continued to collect high quality sea level and associated meteorological information for monitoring climate variability and climate change.

- A tsunami was detected by the SEAFRAME stations at Tonga, Vanuatu, Cook Islands and Fiji following an undersea earthquake of magnitude Mw7.6 that struck near Tonga on 19th March 2009. The trough-to-peak tsunami height recorded by the SEAFRAME at Tonga was 15cm.

- Higher than normal sea levels were observed at Solomon Islands, Vanuatu and Fiji. At Solomon Islands sea levels during March were on average 10cm higher than normal.

- Ocean heat content warmed across the equatorial Pacific during March but remains warmer than normal in the western Pacific and cooler than normal in the eastern Pacific. Climate indicators are now well within their neutral range in terms of the El Niño – Southern Oscillation.

- The majority of international climate models predict ocean warming will continue in the coming months but climate conditions will remain neutral until at least the middle 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 March, 2009

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	+5.5	+0.1
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+9.5	+0.1
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+5.1	+0.2
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+5.4	+0.2
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+6.1	+0.1
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+5.7	-0.1
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.2	0.0
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+4.1	0.0
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+8.7	+0.2
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+8.2	0.0
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+22.0	-0.5
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.3	0.0

INTRODUCTION

Welcome to the March 2009 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, that 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.

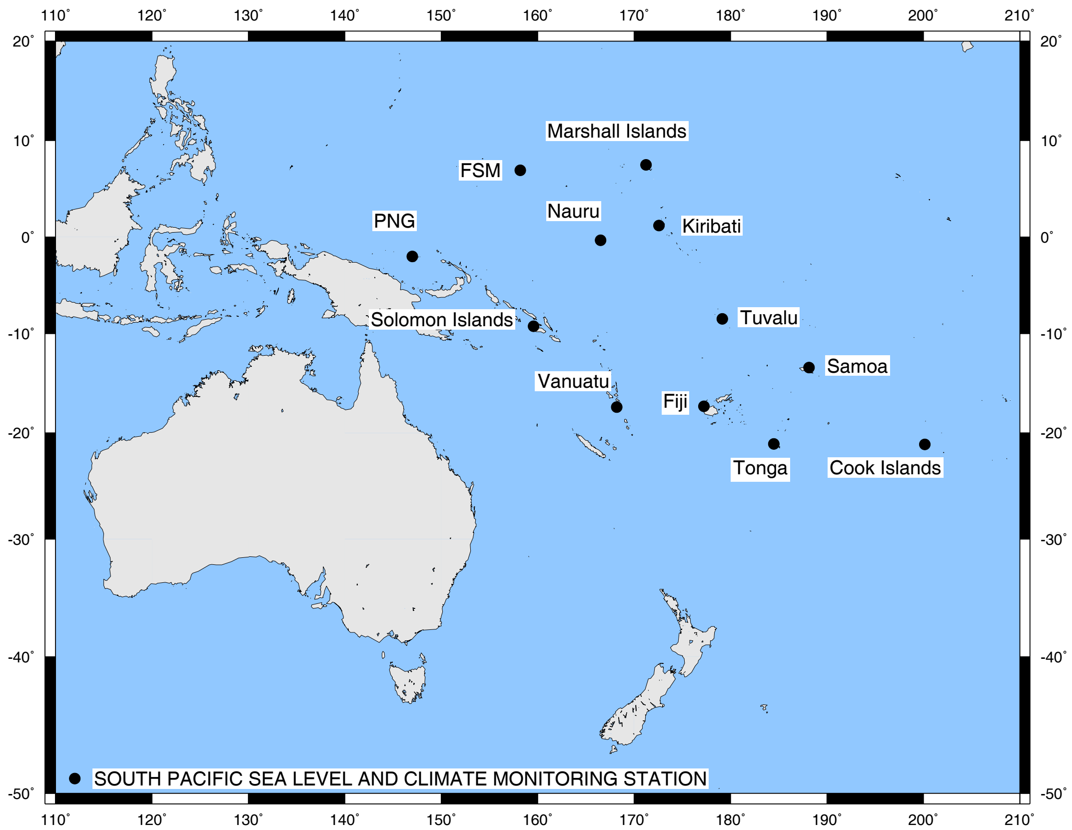

Figure A: *South Pacific Sea Level and Climate Monitoring Stations*

MARCH CLIMATOLOGY

Neutral climate conditions were observed across the equatorial Pacific during March. Lingering La Niña (cold episode) indicators continued to fade as ocean temperatures across the equatorial Pacific warmed, Trade Winds weakened and the Southern Oscillation Index fell sharply. The majority of climate models predict neutral conditions will persist until at least mid-year.

The Southern Oscillation Index (SOI) fell notably from its strongly positive February value of +15 to a March value of 0, in response to a fall in mean sea level pressure at Tahiti and an increase at Darwin (**Figure B**). The mean sea level pressures at both Tahiti and Darwin are now near normal.

Sea surface temperatures warmed across the equatorial Pacific during March, although cooler than normal temperatures continue to be observed across the central and equatorial Pacific (**Figure C, Figure E**). By the end of March these cool anomalies had weakened considerably.

Subsurface temperatures also warmed during March and remain cooler than normal across the central and eastern equatorial Pacific (**Figure D**). Subsurface temperatures in the western equatorial Pacific are warmer than normal.

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 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 weakened during March to near average strength (**Figure E**), but at the end of the month weak anomalous westerly flow was observed across most of the equatorial Pacific. Cloudiness over the equatorial Pacific near the dateline has increased in recent months in association with slight surface warming in the region, but remains below normal.

The consensus among six international computer models is that sea surface temperatures will continue to warm across the equatorial Pacific in the coming months but climate conditions will most likely remain in the neutral range.

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/.

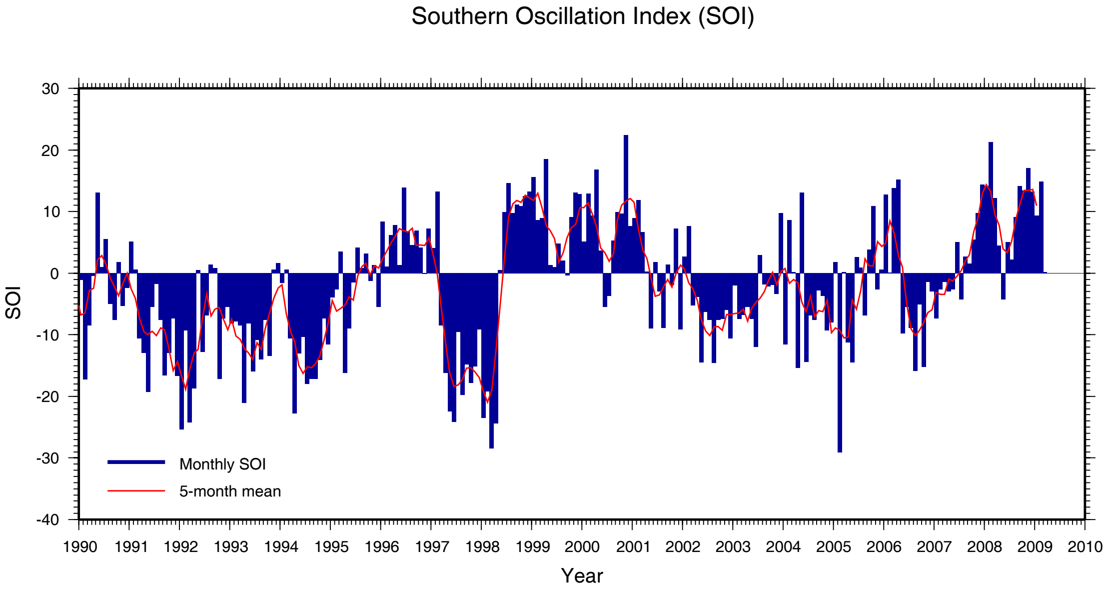

Figure B: *The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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

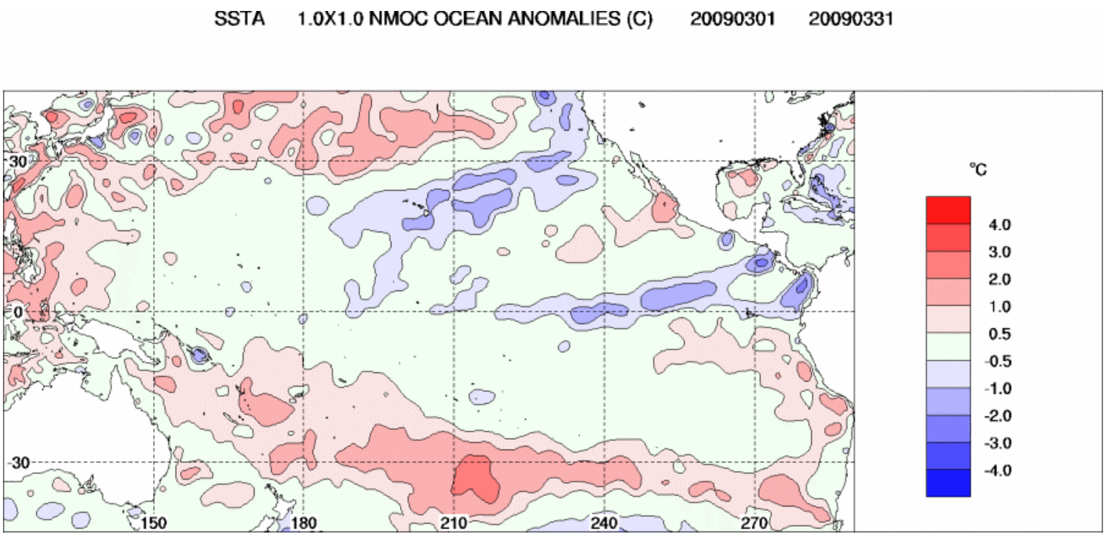

Figure C: *Sea surface temperature anomaly (°C) for March 2009.*

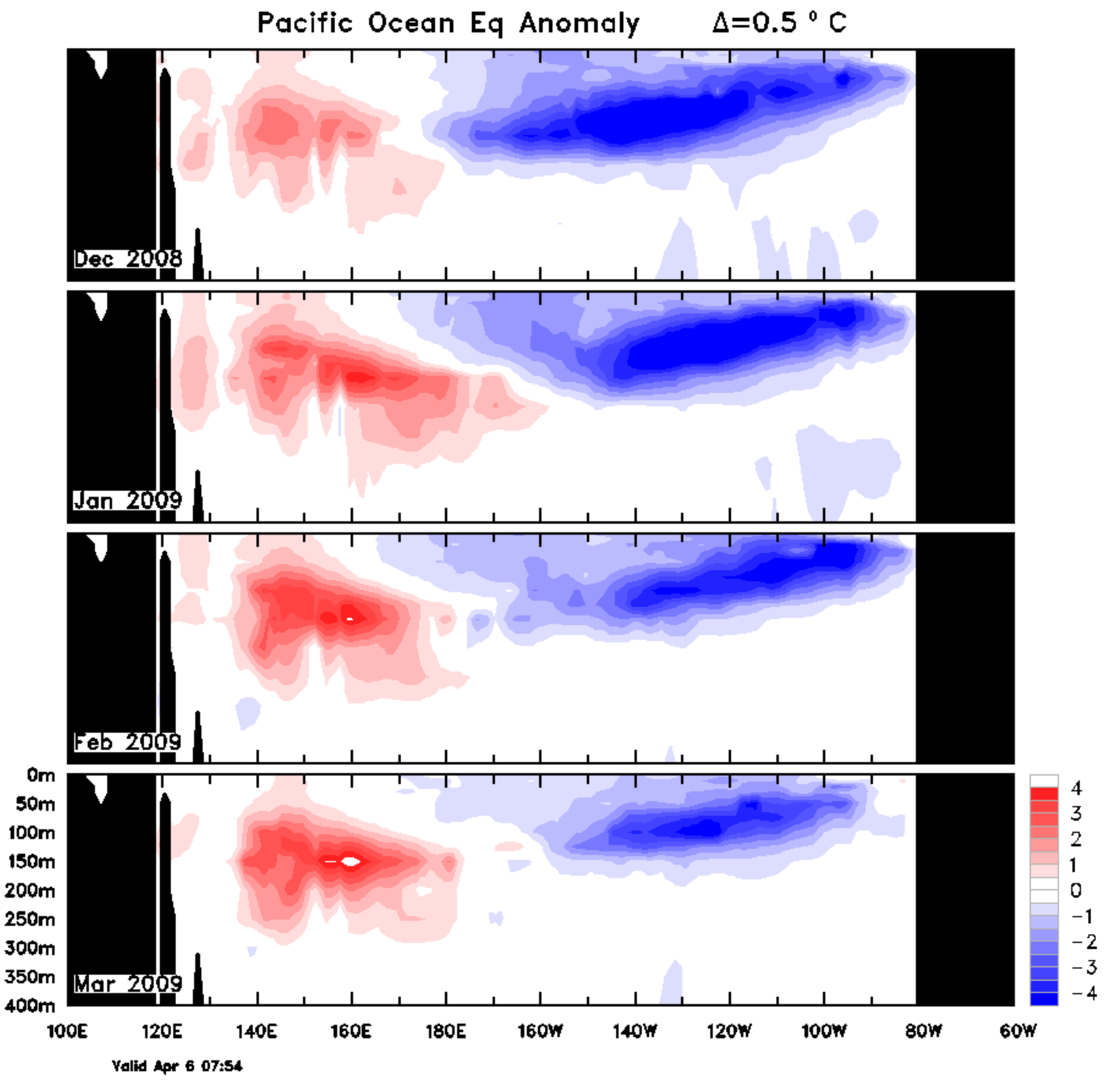

Figure D: *Equatorial depth-longitude section of ocean temperature anomalies for December 2008 through to March 2009. Contour interval is 0.5°C.*

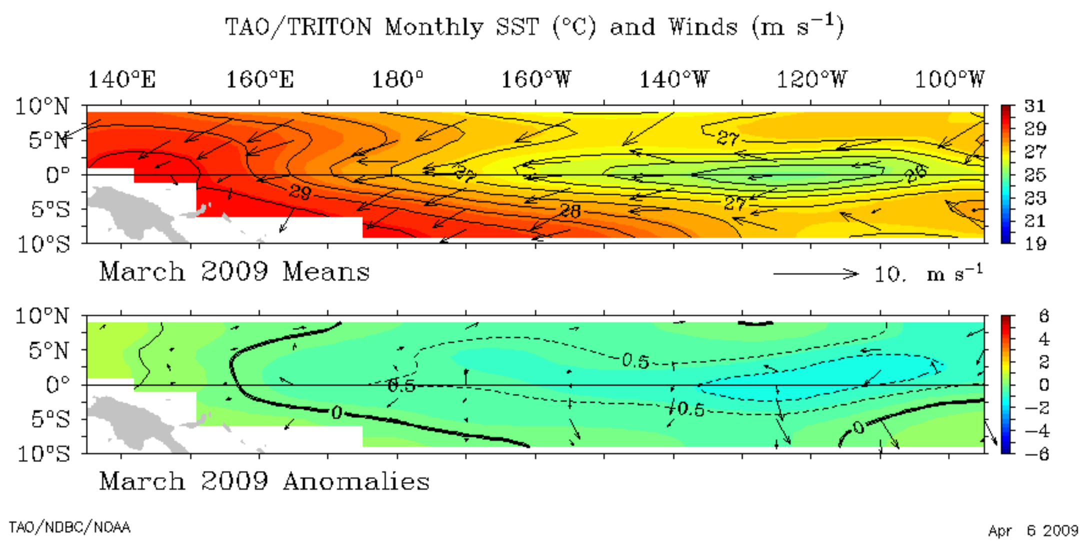

Figure E: *Monthly mean wind vectors (top) and anomalies (bottom) for March 2009. The colour-shaded contours represent the monthly mean sea surface temperatures (top) and anomalies (bottom).*

MARCH 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 full moon on the 11th of March and a new moon on the 26th of March 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 the non-tidal sea level fluctuations such as those due to the short-term effects of weather or tsunamis. Residual sea level fluctuations may also be amplified or sustained by the shape of the harbour in which the gauge is located. Persistent sloshing of water within a bay or harbour, for example, is known as a seiche. Seiches are often recorded at PNG when the wind suddenly changes strength or direction.

On the 19th March 2009 a tsunami was generated following an undersea earthquake of magnitude Mw7.6 and epicentre located near Tonga. The tsunami was detected by the SEAFRAME station at Tonga, where its trough-to-peak height was 15cm. It was also recorded at Vanuatu (11cm), Cook Islands (6cm) and Fiji (2cm).

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.* New maximum March air temperatures were recorded at Samoa (32.1°C) and Vanuatu (32.9°C) and new minimum March air temperatures were recorded at FSM (23.1°C) and PNG (23.2°C).

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.

In March 2009 higher than normal sea levels were observed at Solomon Islands, Vanuatu and Fiji, with the largest anomaly of 10 cm at Solomon Islands. Elsewhere sea levels were within 5 cm of what is normally observed at this time of year.

Sea Level Trends

The **short-term sea level trends** at individual stations as at March 2009 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 March, 2009				
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	+5.5	+0.1
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Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+6.1	+0.1
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+5.7	-0.1
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.2	0.0
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+4.1	0.0
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+8.7	+0.2
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+8.2	0.0
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+22.0	-0.5
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.3	0.0

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 March 2009 barometric pressures were near normal at most stations.

The **water temperature anomalies (Figure 15)** show slightly warmer than normal conditions at Samoa, Vanuatu, and Cook Islands during March 2009. Elsewhere water temperatures were close to average for this time of the year.

The **air temperature anomalies (Figure 16)** reveal air temperatures during March 2009 were close to average at most sites, with the largest anomaly being –0.7°C at PNG. 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.

Calibration and maintenance was undertaken at Solomon Islands and PNG during March 2009. At PNG a power supply problem caused data loss from 15th-30th March.

At Nauru problems with the primary sea level sensor were encountered and data from the secondary sea level sensor were used. Replacement of primary sea level measurements with data from the secondary sensor was also required at Tuvalu from the 8th of March and Vanuatu from the 29th of March.

The air temperature sensor at Nauru continued to experience problems and data were removed from the record.

At Marshall Islands problems with the air temperature, water temperature and barometric pressure data were encountered and have subsequently been removed from the record. Intermittent problems were also experienced with the water temperature sensor at Tonga.

Communication problems were experienced at PNG and Vanuatu and small gaps exist where data were unable to be recovered.

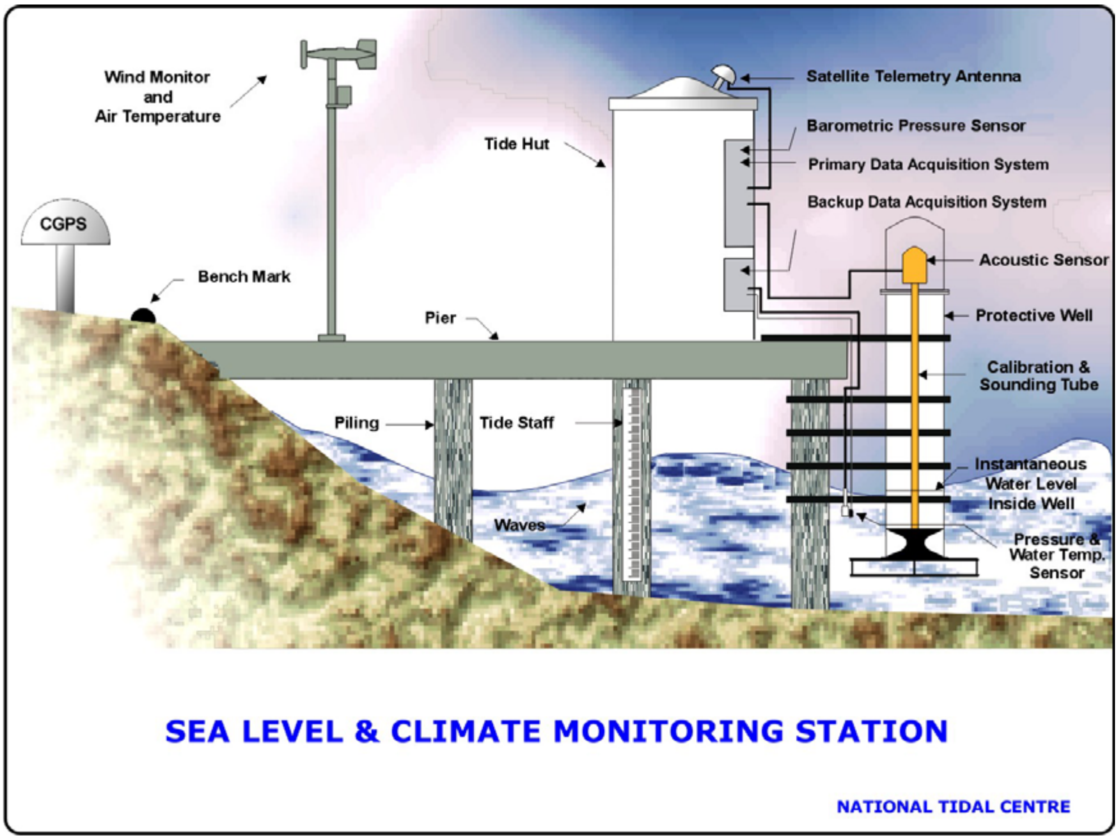
SEAFRAME STATIONS

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

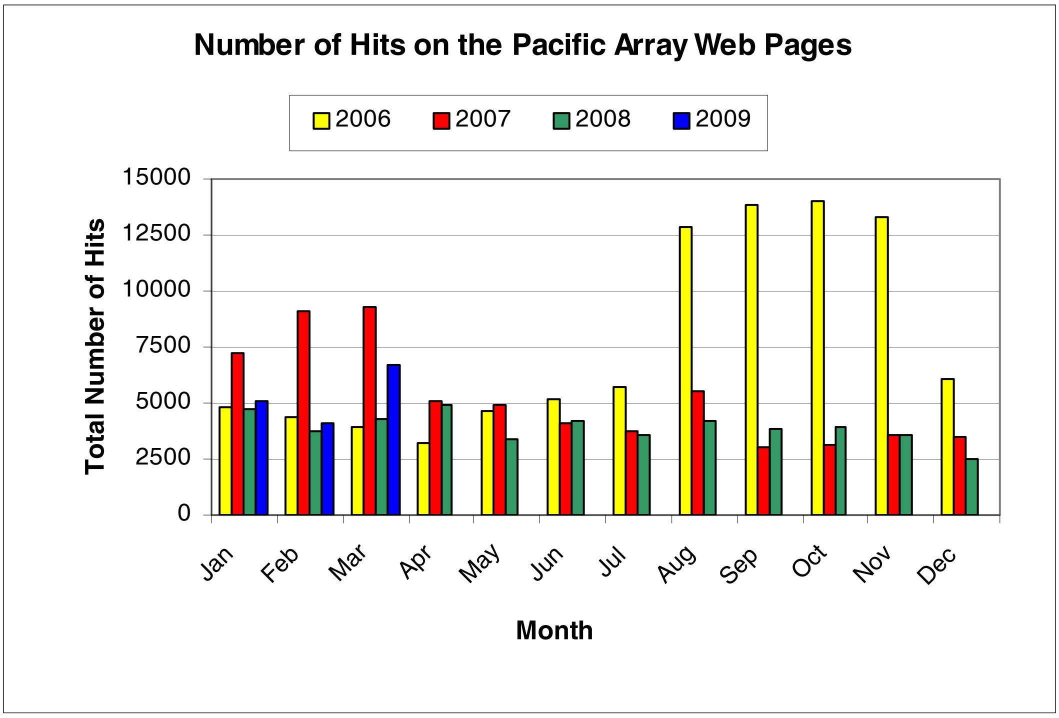
(2) Secondary water level (or backup) using a Druck pressure transducer mounted close to the seabed.

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 2006.



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:

National Tidal Centre
Bureau of Meteorology
PO Box 421
Kent Town SA 5067
Tel: (+618) (08) 8366 2600
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

MARCH 2009
SIX MINUTE WATER LEVEL OBSERVATIONS (m)

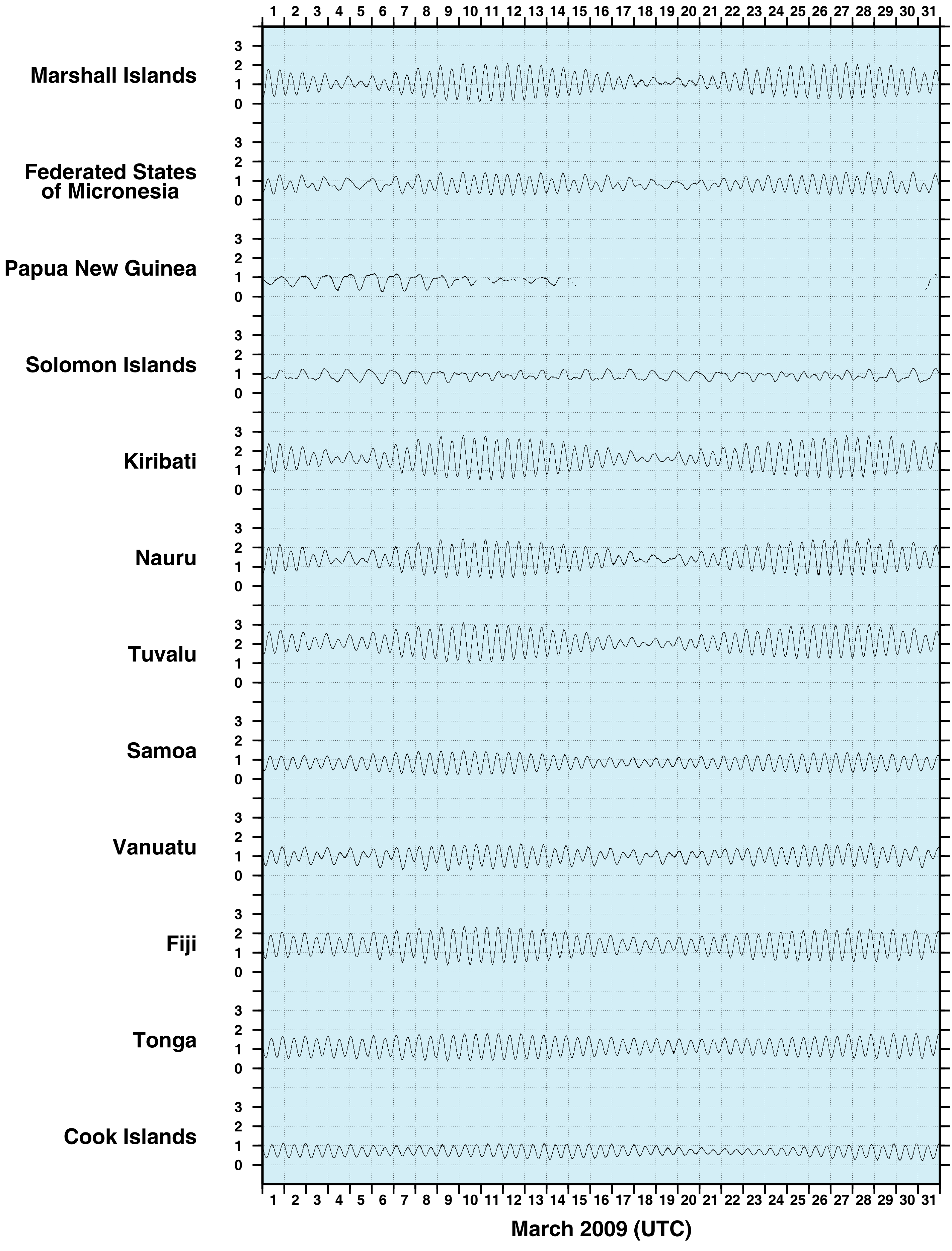


Figure 2

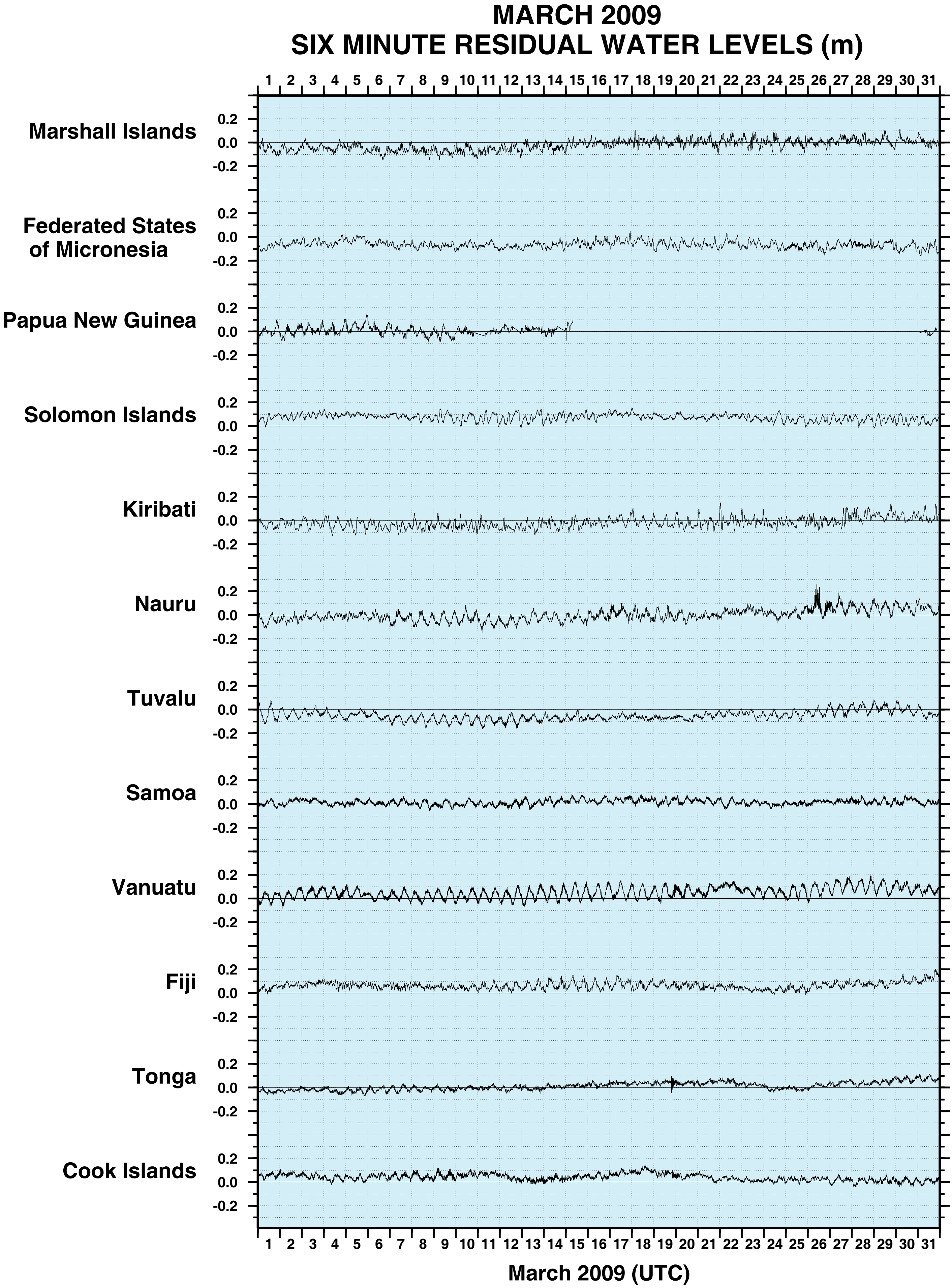

MARCH 2009
SIX MINUTE RESIDUAL WATER LEVELS (m)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Marshall Islands
Federated States of Micronesia
Papua New Guinea
Solomon Islands
Kiribati
Nauru
Tuvalu
Samoa
Vanuatu
Fiji
Tonga
Cook Islands
0.2
0.0
-0.2
March 2009 (UTC)

Figure 3

MARCH 2009
SIX MINUTE RESIDUALS
ADJUSTED FOR ATMOSPHERIC PRESSURE (m)

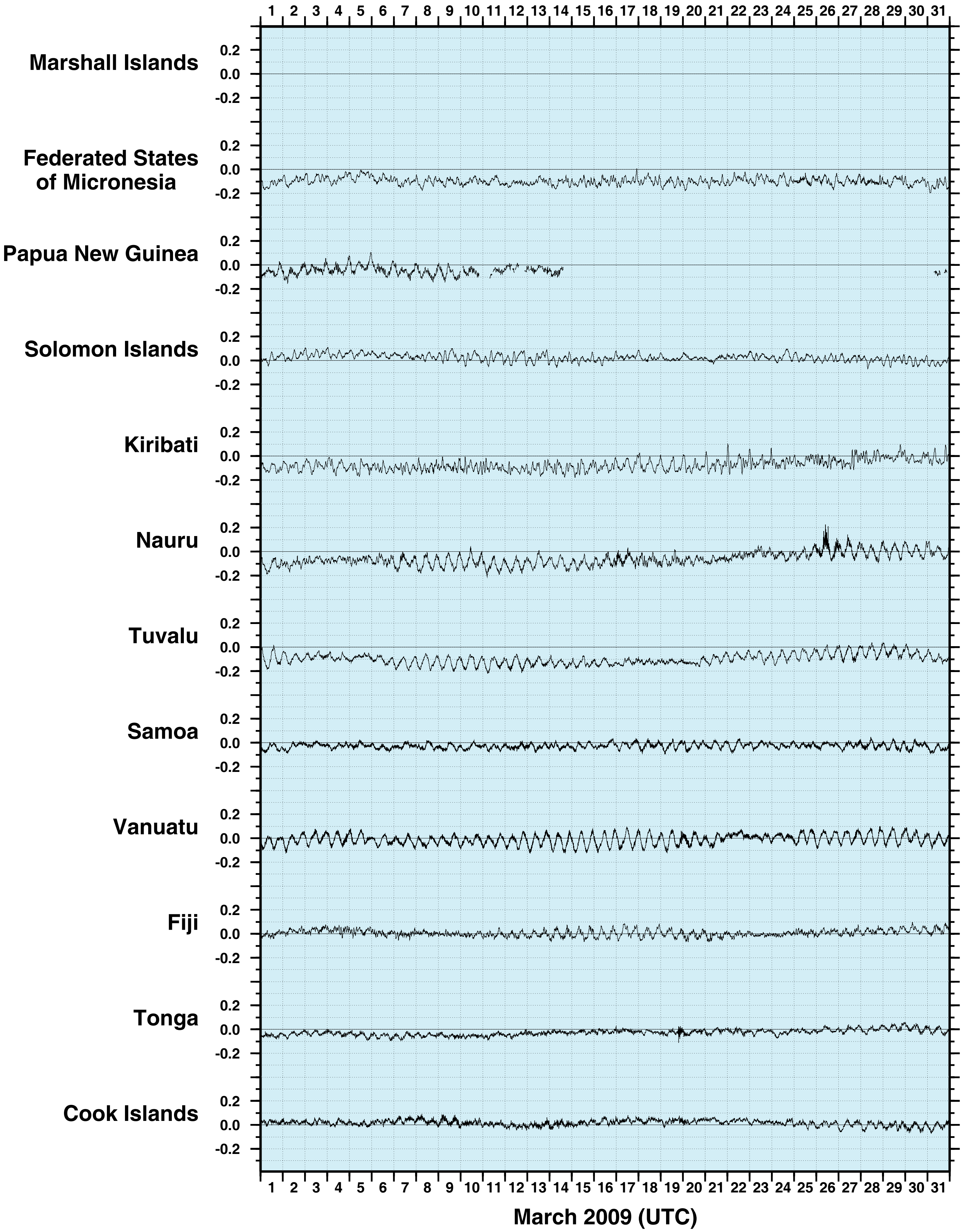


Figure 4

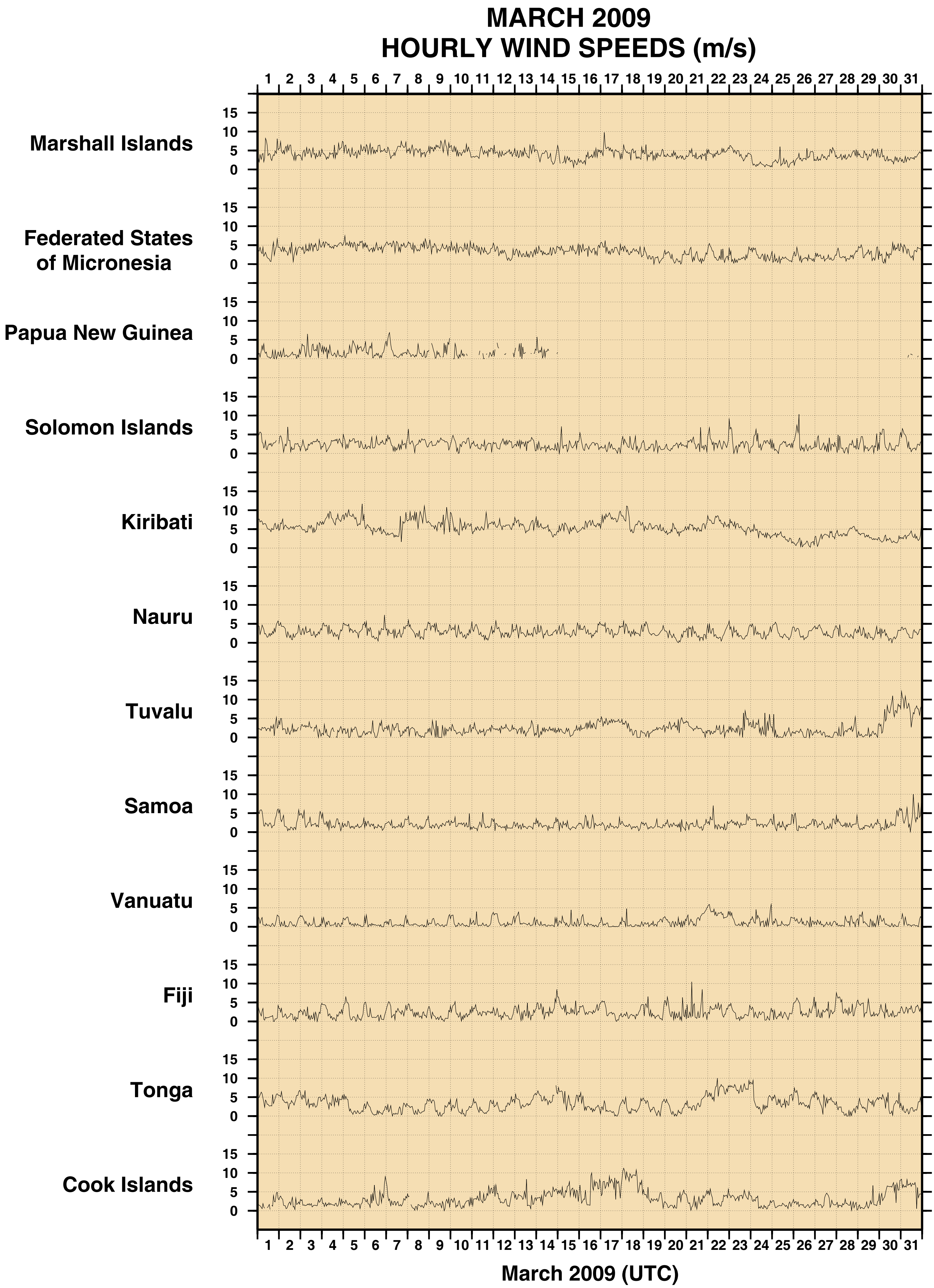

MARCH 2009
HOURLY WIND SPEEDS (m/s)
Marshall Islands
Federated States of Micronesia
Papua New Guinea
Solomon Islands
Kiribati
Nauru
Tuvalu
Samoa
Vanuatu
Fiji
Tonga
Cook Islands
0
5
10
15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
March 2009 (UTC)

Figure 5
MARCH 2009
HOURLY INCIDENT WINDS (m/s, deg True)

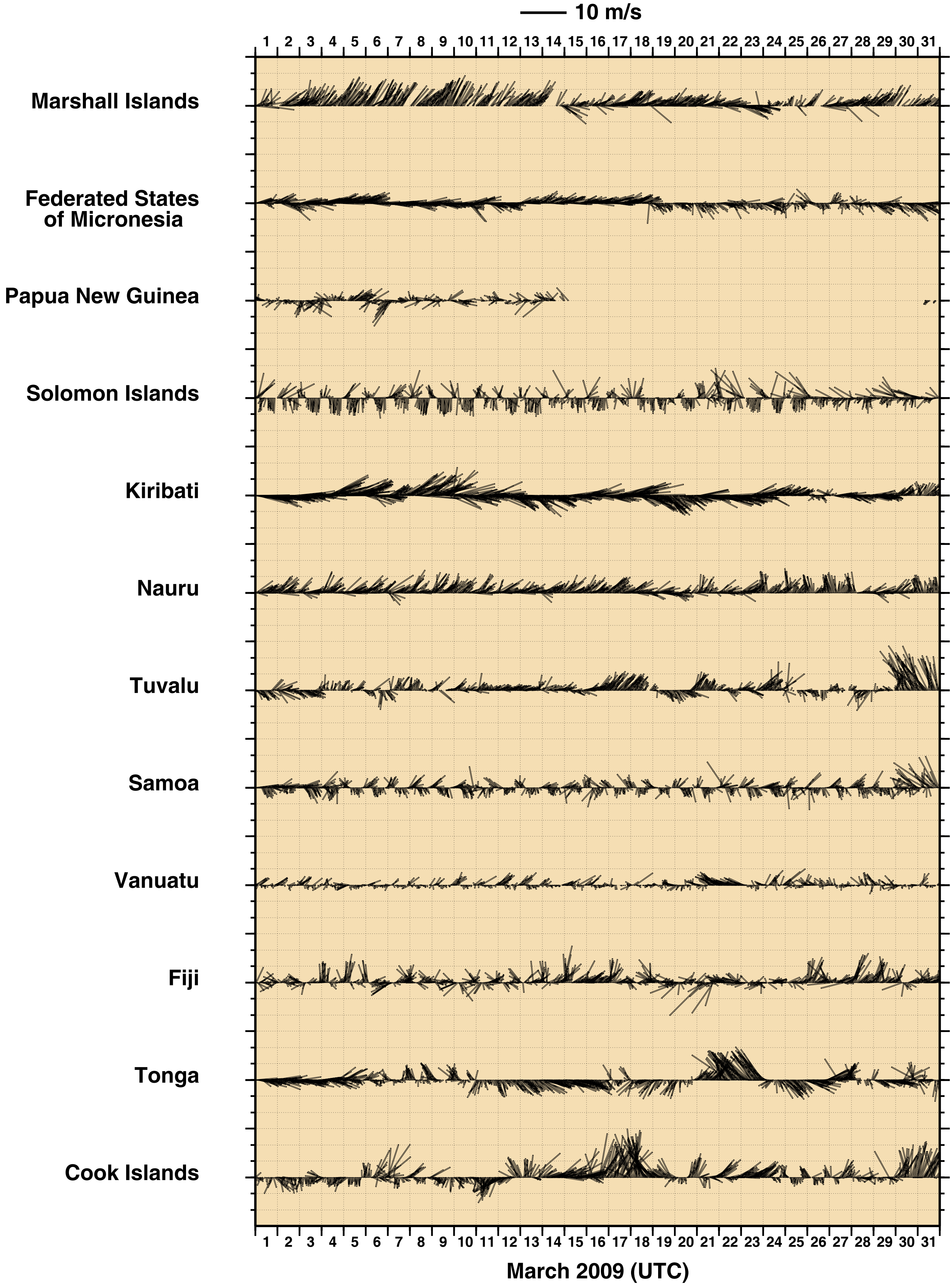


Figure 6

MARCH 2009
HOURLY MAXIMUM WIND GUSTS (m/s)

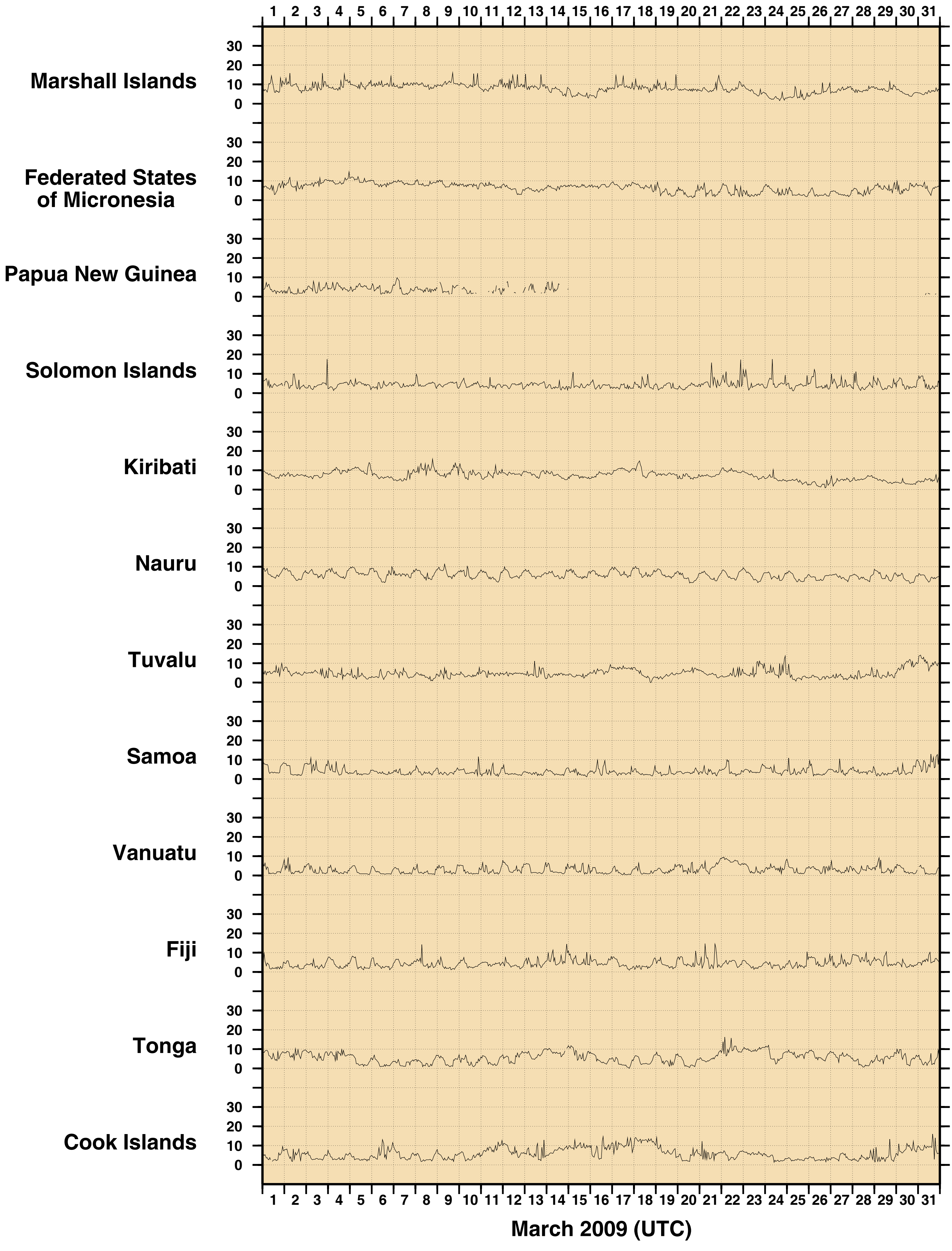


Figure 7

MARCH 2009
HOURLY AIR TEMPERATURES (˚C)

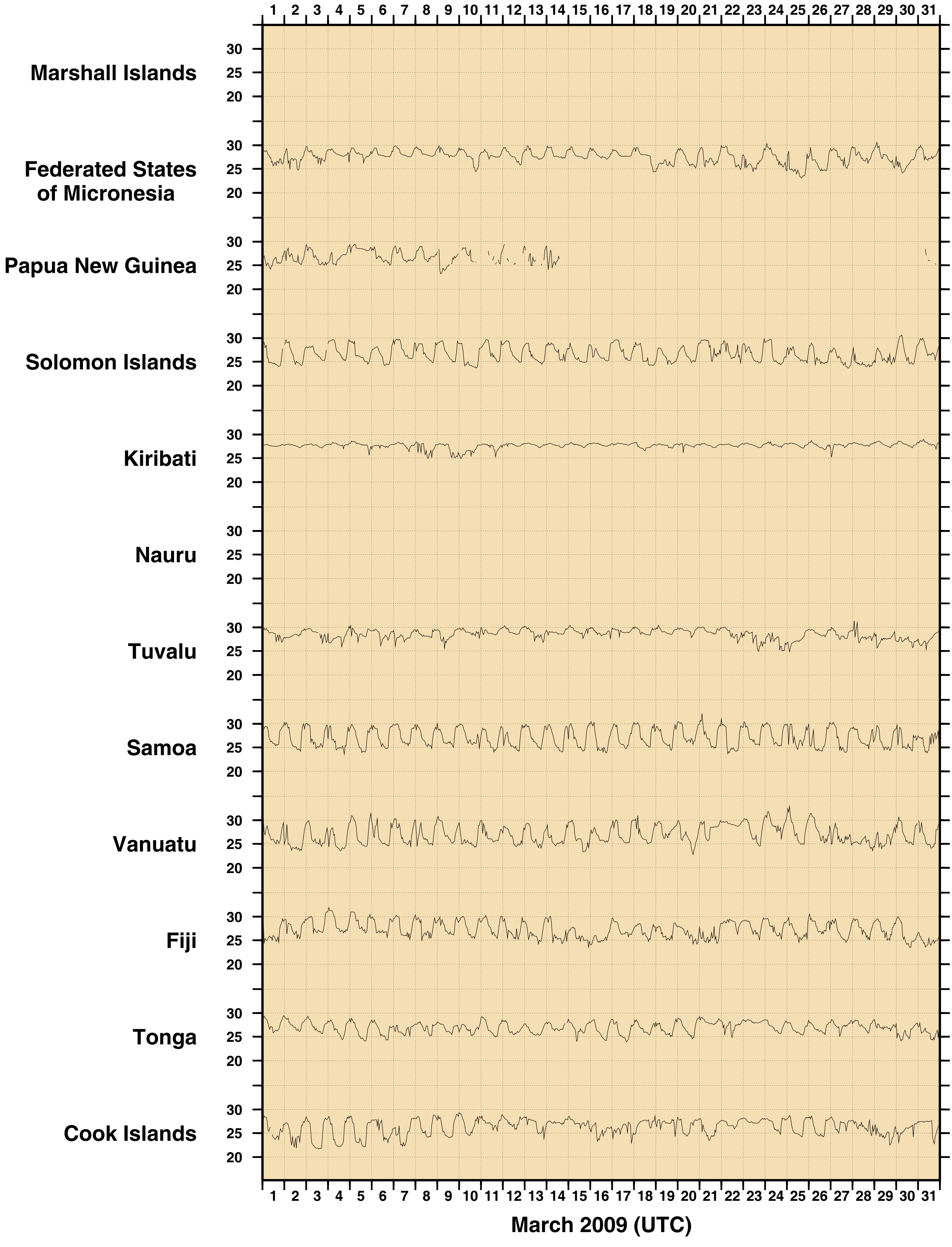


Figure 8

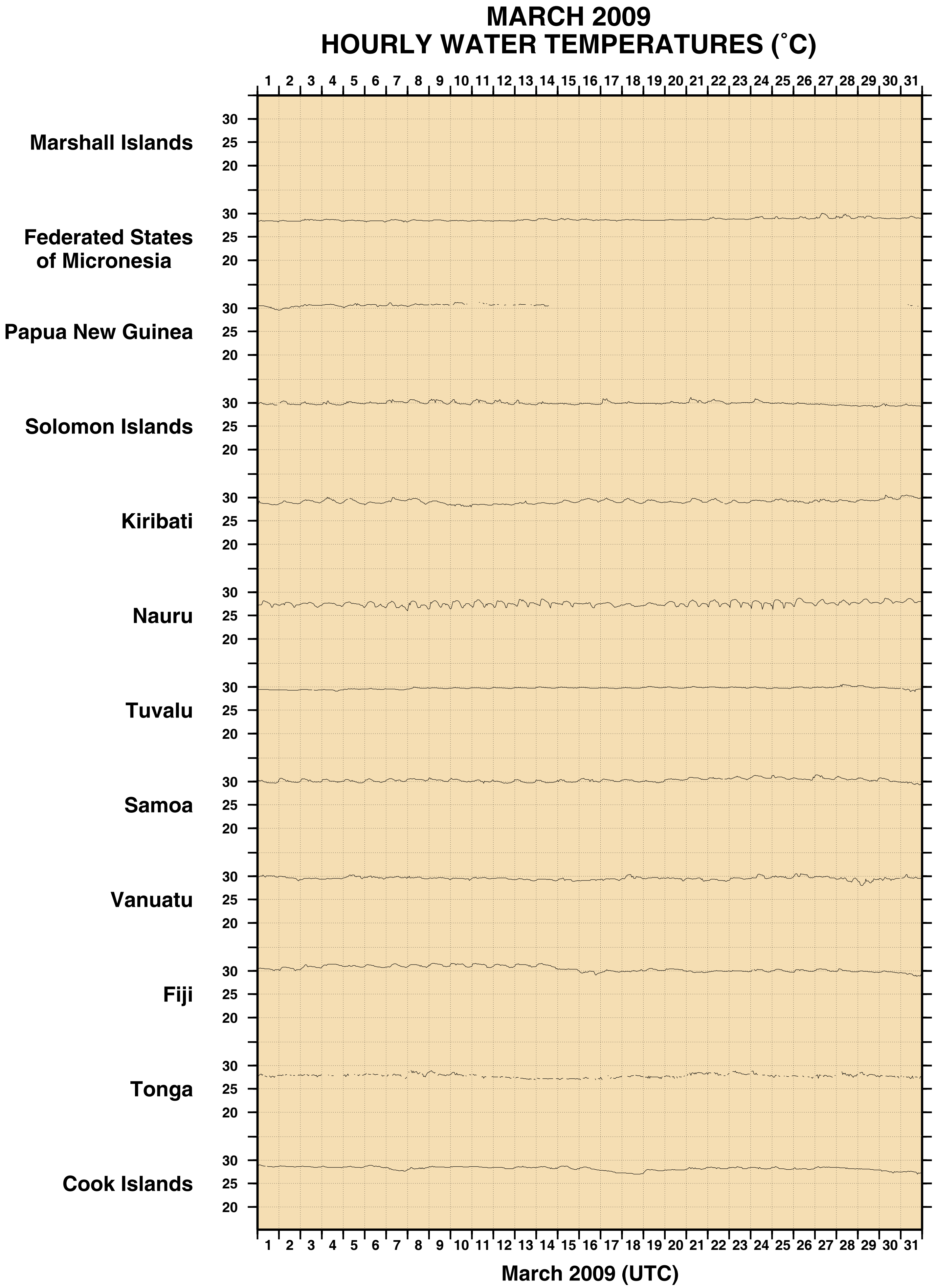

MARCH 2009
HOURLY WATER TEMPERATURES (˚C)
Marshall Islands
Federated States of Micronesia
Papua New Guinea
Solomon Islands
Kiribati
Nauru
Tuvalu
Samoa
Vanuatu
Fiji
Tonga
Cook Islands
30
25
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
March 2009 (UTC)

Figure 9

MARCH 2009
HOURLY ATMOSPHERIC PRESSURE (hPa)

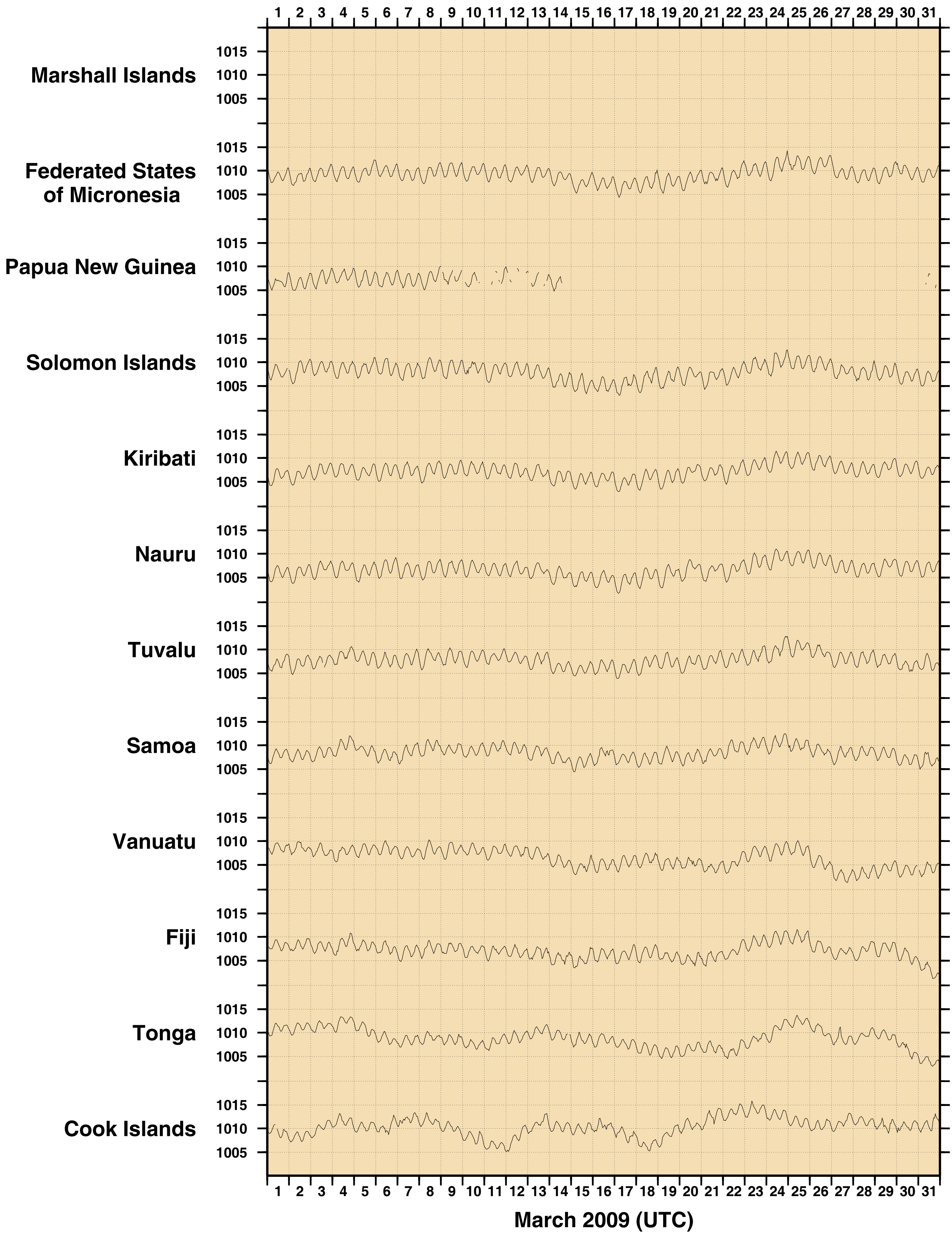
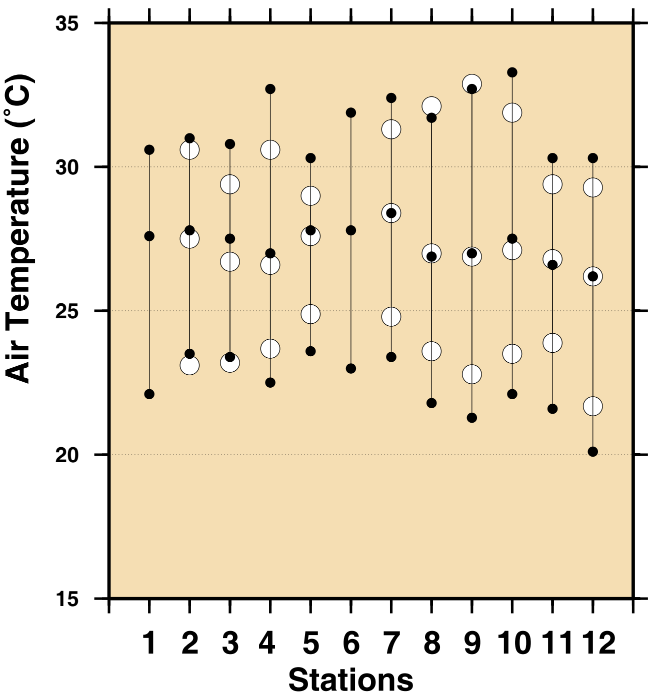
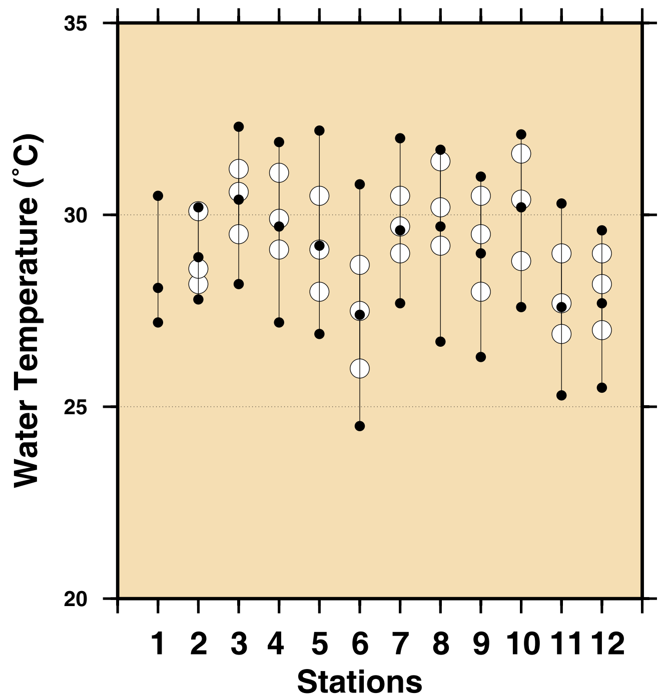
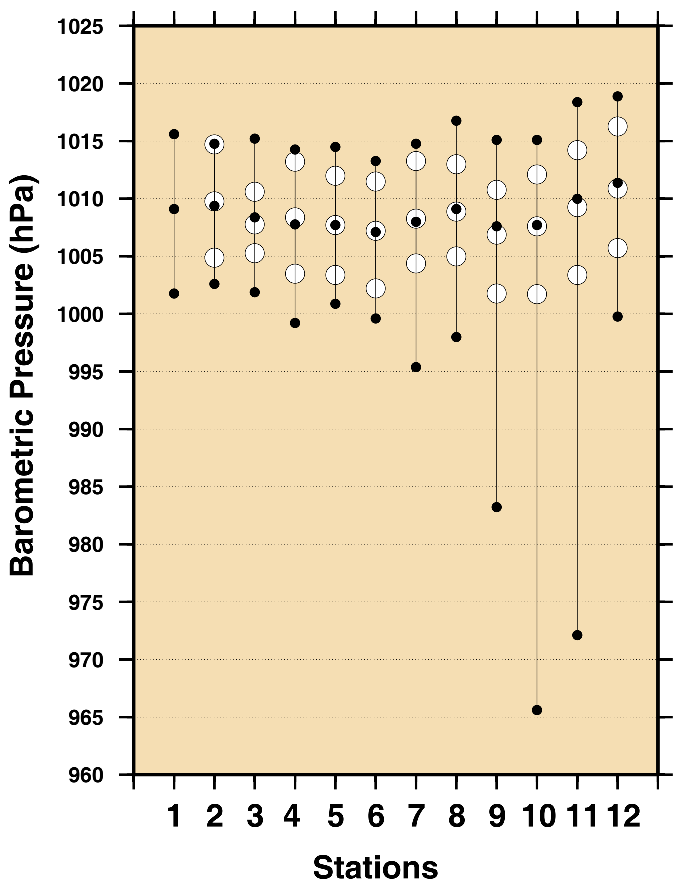


Figure 10

Comparison of March 2009 Max, Min & Mean with Long Term March 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

○ March 2009 Maximum
○ March 2009 Mean
○ March 2009 Minimum

• Long Term March Maximum
• Long Term March Mean
• Long Term March Minimum

Figure 11

MONTHLY MEAN SEA LEVELS TO MARCH 2009 (m)

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

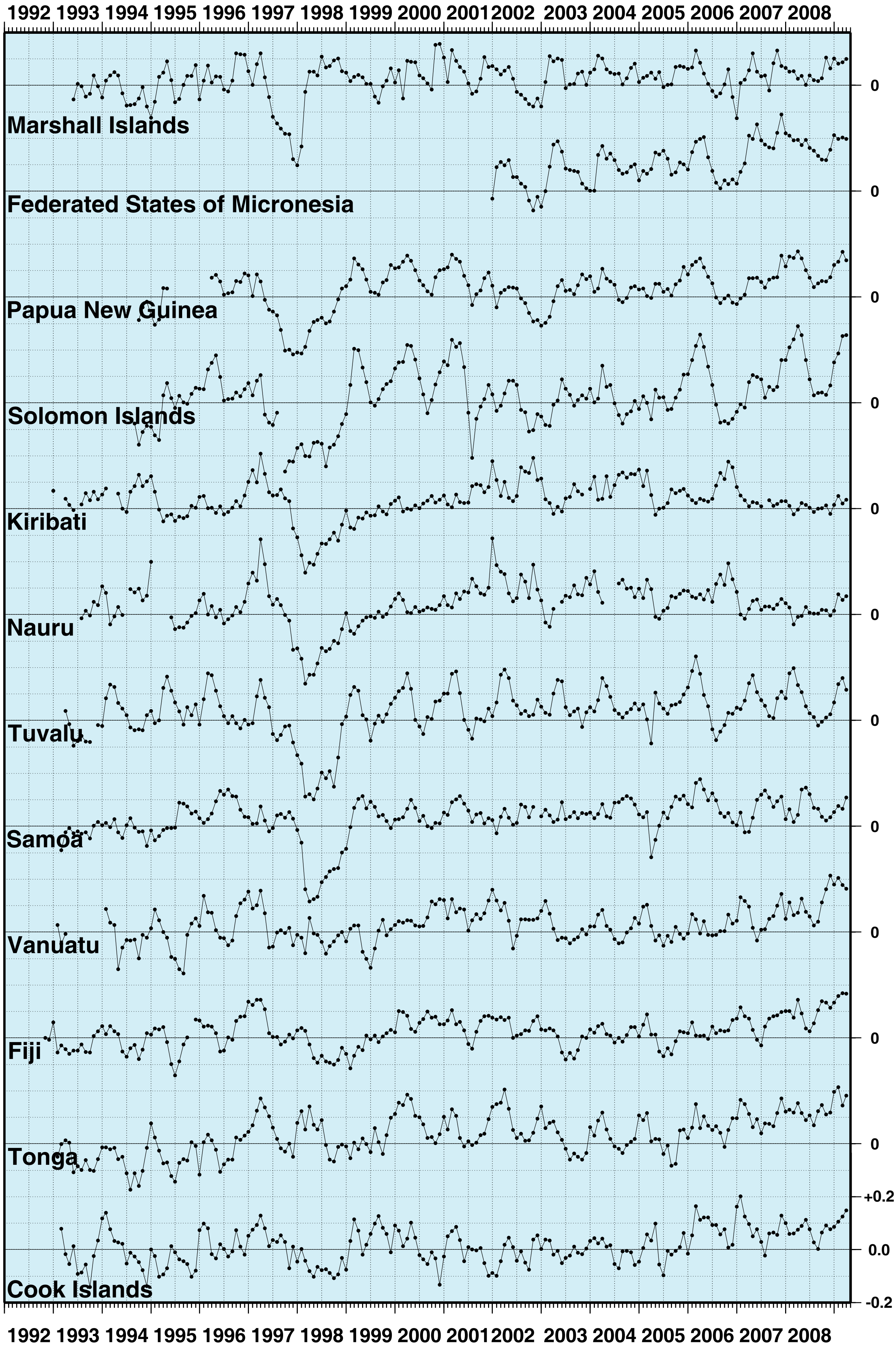


Figure 12

SEA LEVEL ANOMALIES THROUGH MARCH 2009 (m)

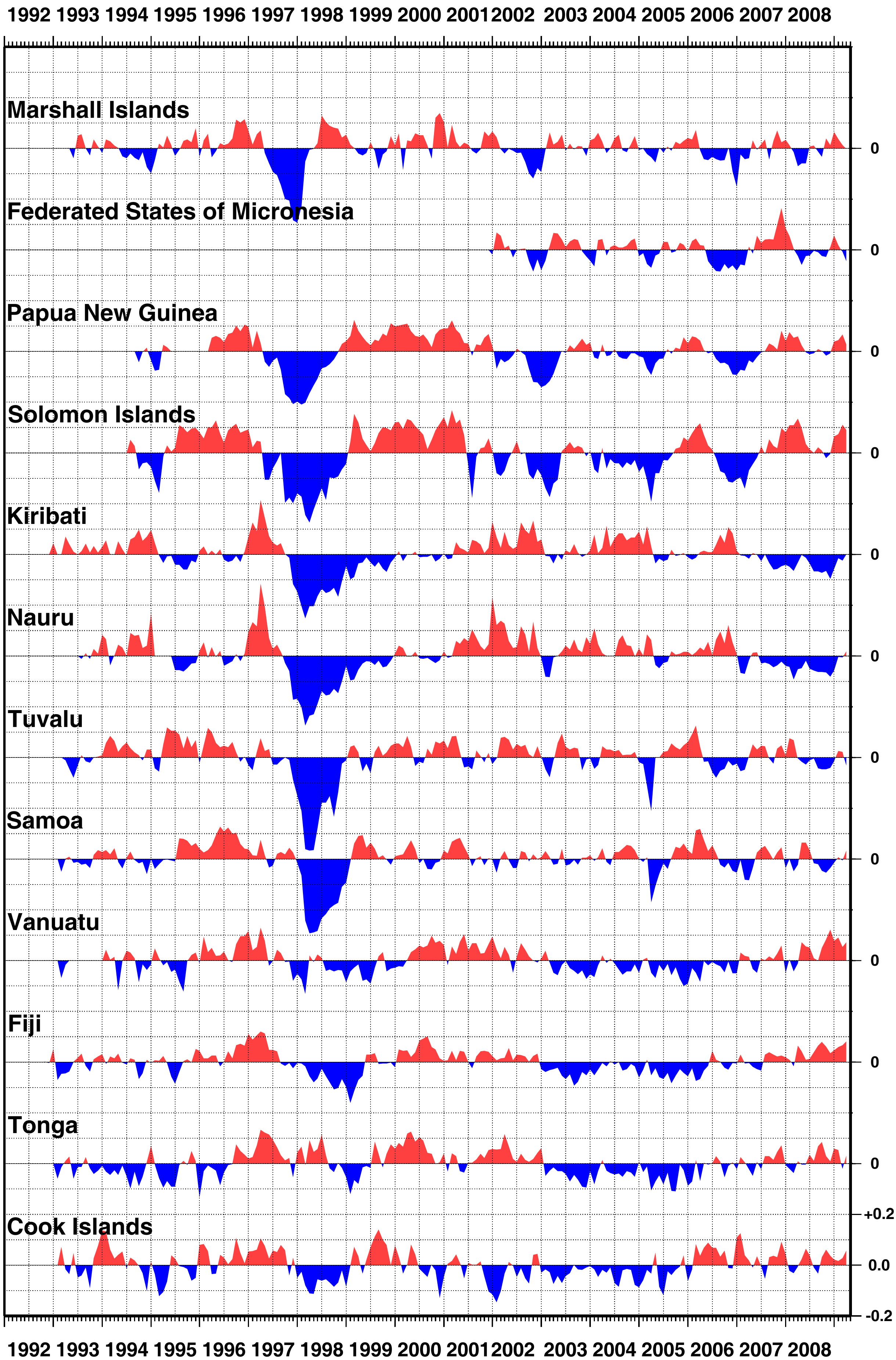


Figure 13

SEA LEVEL TRENDS THROUGH MARCH 2009 (mm/year)

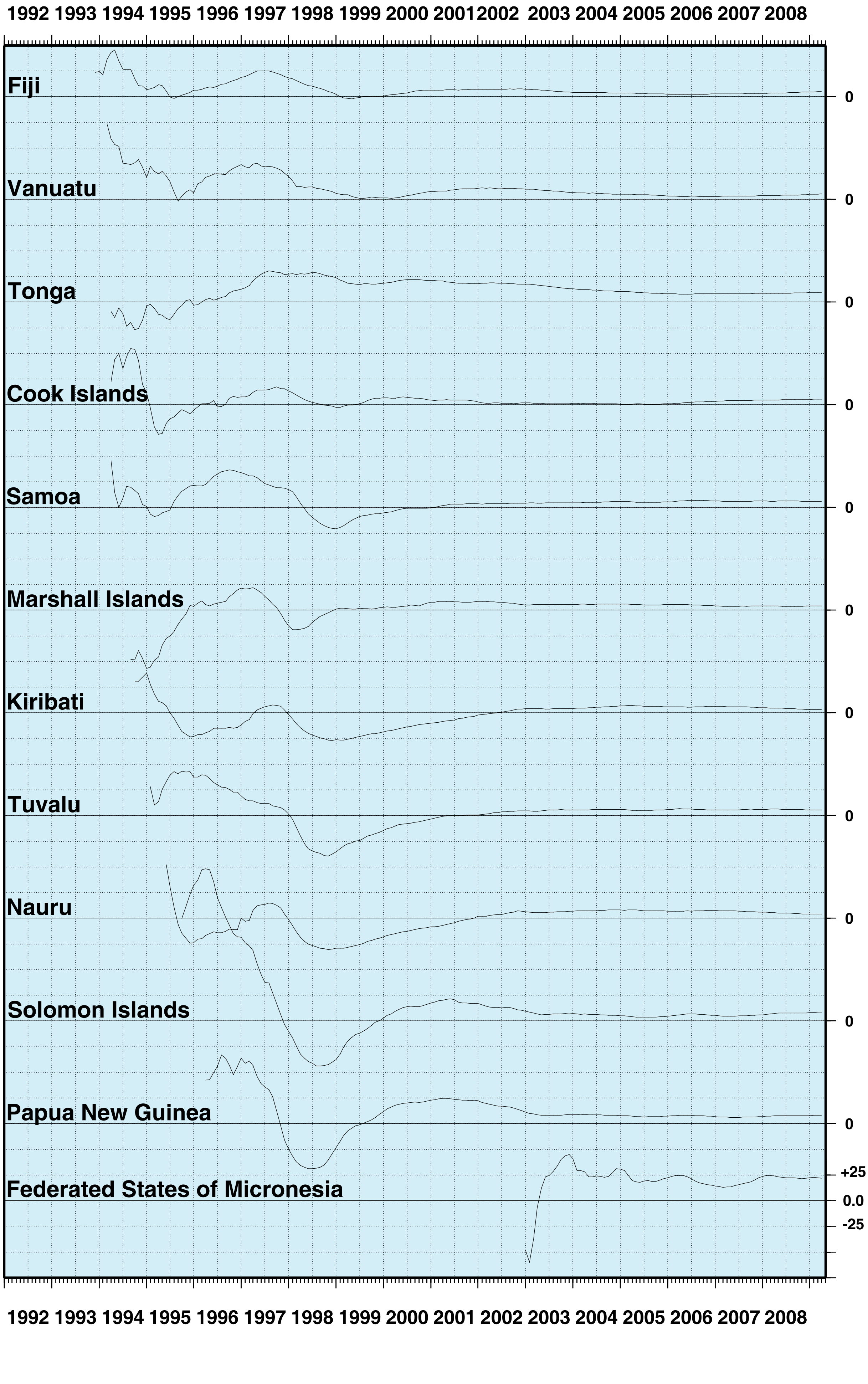


Figure 14

BAROMETRIC PRESSURE ANOMALIES THROUGH MARCH 2009 (hPa)

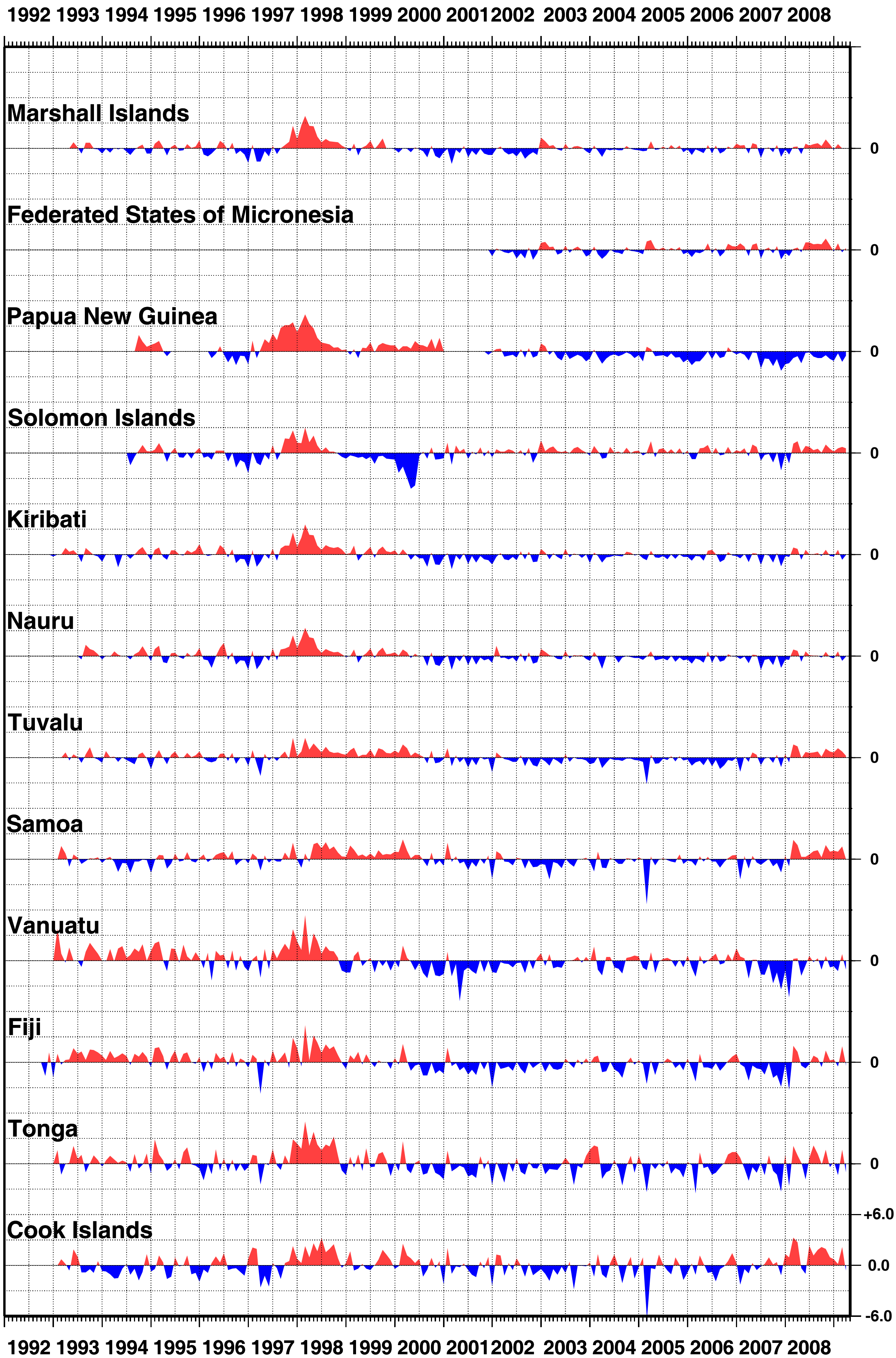


Figure 15

WATER TEMPERATURE ANOMALIES THROUGH MARCH 2009 (˚C)

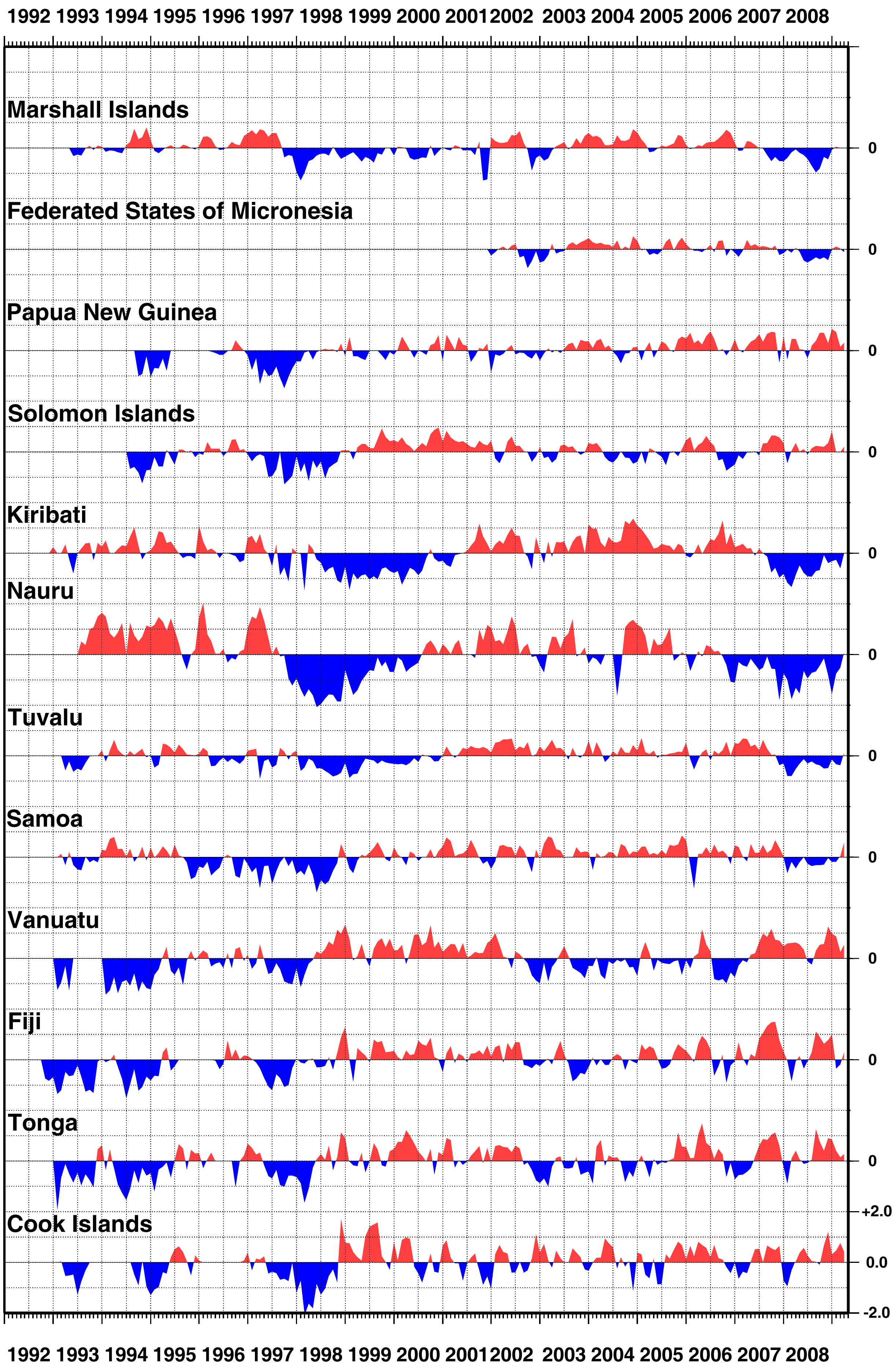


Figure 16

AIR TEMPERATURE ANOMALIES THROUGH MARCH 2009 (˚C)

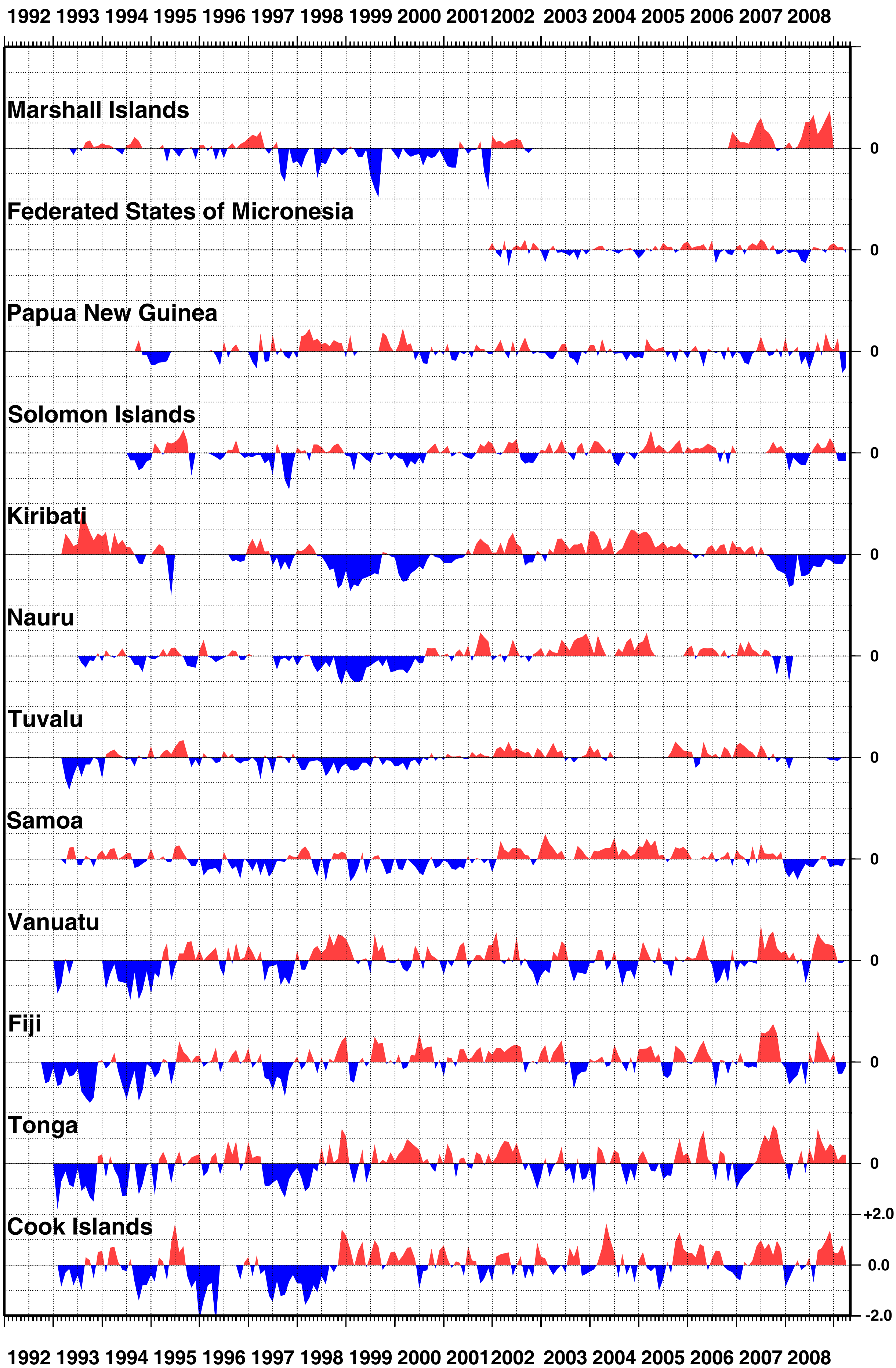


Figure 17

SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED
GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE
* Patchy record