THE SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT

MONTHLY DATA REPORT

NO. 153

MARCH 2008

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 2008 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 2008

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 2008

- The SEAFRAME network continued to collect high quality sea level and associated meteorological information for monitoring climate variability and climate change.
- The monthly mean sea levels recorded by the SEAFRAME stations at PNG and Solomon Islands in March 2008 were the highest on record.
- In general sea levels during March 2008 were higher than normal at PNG, Solomon Islands and Fiji and lower than normal at Kiribati, Nauru and Marshall Islands.
- No extreme event such as a tropical cyclone or tsunami was observed by the SEAFRAME network.
- La Niña climate conditions weakened across the eastern equatorial Pacific during March. Cooler than average ocean temperatures in the central equatorial Pacific, stronger than normal Trade Winds in the western equatorial Pacific and below average cloudiness near the dateline continued to persist.
- The majority of international climate models predict that neutral climate conditions will return in the next few months.

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, 2008

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**	**+4.7**	**0.0**
Tonga	**21°8'12.5"S / 175°10'50.5"W**	**Jan 1993**	**+8.7**	**0.0**
Fiji	**17°36'17.7"S / 177°26'17.7"E**	**Oct 1992**	**+3.7**	**+0.2**
Vanuatu	**17°45'19.2"S / 168°18'27.7"E**	**Jan 1993**	**+3.6**	**0.0**
Samoa	**13°49'36.4"S / 171°45'40.7"W**	**Feb 1993**	**+6.1**	**0.0**
Tuvalu	**8°30'8.9"S / 179°11'42.6"E**	**Mar 1993**	**+6.3**	**0.0**
Kiribati	**1°21'54.2"N / 172°55'58.8"E**	**Dec 1992**	**+4.6**	**-0.1**
Nauru	**0°31'45.9"S / 166°54'36.2"E**	**Jul 1993**	**+5.4**	**-0.2**
Solomon Is.	**9°25'44.1"S / 159°57'19.3"E**	**Jul 1994**	**+7.3**	**+0.4**
PNG	**2°2'31.5"S / 147°22'25.6"E**	**Sep 1994**	**+7.7**	**+0.2**
FSM	**6°58'49.9"N / 158°12'0.8"E**	**Dec 2001**	**+24.0**	**-0.5**
Marshall Is.	**7°6'21.7"N / 171°22'22.1"E**	**May 1993**	**+4.2**	**-0.2**

INTRODUCTION

Welcome to the March 2008 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.

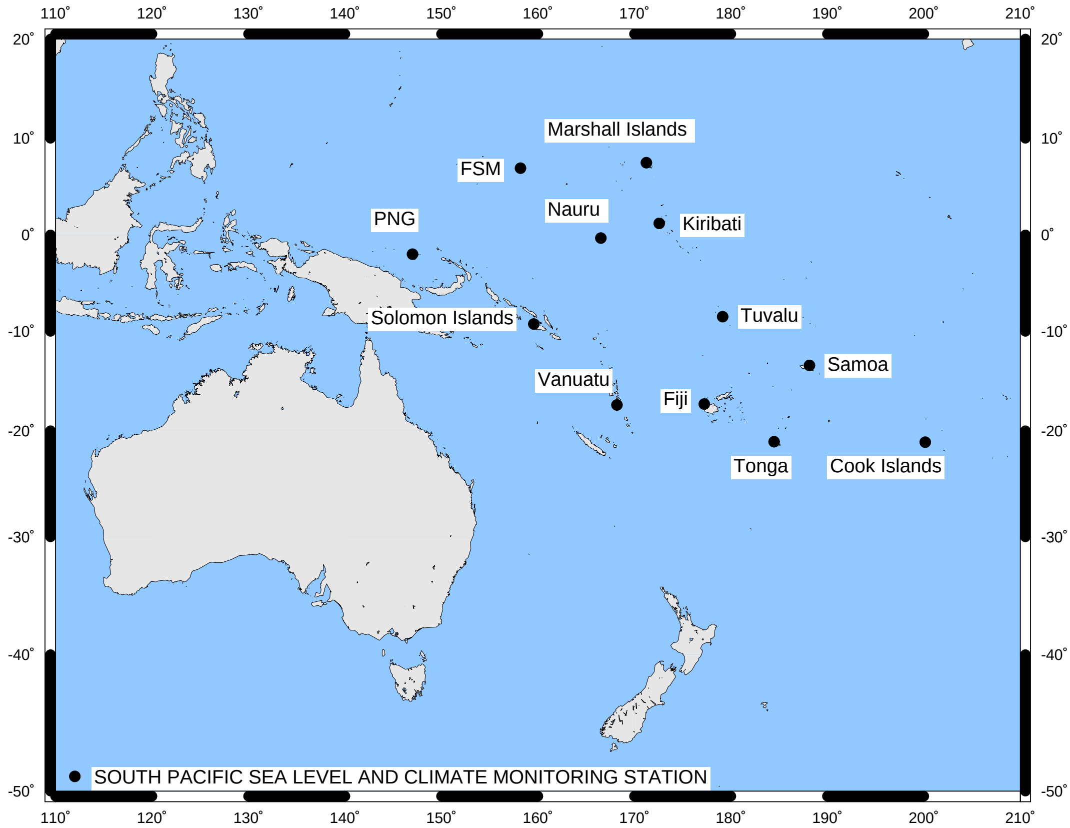

Figure A: *South Pacific Sea Level and Climate Monitoring Stations*

MARCH CLIMATOLOGY

Climate conditions observed across the equatorial Pacific during March showed that the La Niña event has begun to weaken. Cooler than normal sea-surface and sub-surface temperatures in the eastern equatorial Pacific have warmed and decreased in volume. Other climate indicators such as the Southern Oscillation Index, the strength of the Trade Winds and the amount of cloudiness across the central equatorial Pacific remain typical of La Niña. Neutral climate conditions are expected to return in April or May.

The Southern Oscillation Index (SOI) during March was positive at +12 and remains in the La Niña range (**Figure B**). This positive SOI value was due to higher than normal barometric pressures at Tahiti rather than low barometric pressures at Darwin. The SOI has fallen since the February SOI value of +21.3.

Sea-surface temperature (SST) anomalies below -1˚C continued to be observed across the central equatorial Pacific but have decreased in area. There are now no anomalies below -2˚C. Surface temperatures in the eastern equatorial Pacific continued to warm and areas of warmer than normal SST have developed there, although this is not considered to be a sign of a developing El Niño. In the far western Pacific sea surface temperatures remain slightly warmer than normal (**Figure C, Figure E**).

The cooler-than-normal sub-surface temperature pattern typical of La Niña weakened during March (**Figure D**). Cool sub-surface anomalies in the eastern equatorial Pacific weakened, while positive anomalies in the western equatorial Pacific intensified.

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 decreased cloudiness in the central Pacific. The TAO/TRITON array of moored buoys revealed Trade Winds continued to be stronger than normal across the western to central equatorial Pacific during March in relation to the La Niña event. Periods of weaker than average Trade Winds have been observed across the eastern equatorial Pacific during February and March, and this has led to the surface warming in that region (**Figure E**). Cloudiness in the equatorial Pacific near the dateline continued to be well below average during March in keeping with the La Niña.

The results from six international computer models predict that cool La Niña conditions will decay in the next few months and that neutral conditions will persist in the Pacific through to October 2008.

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/.

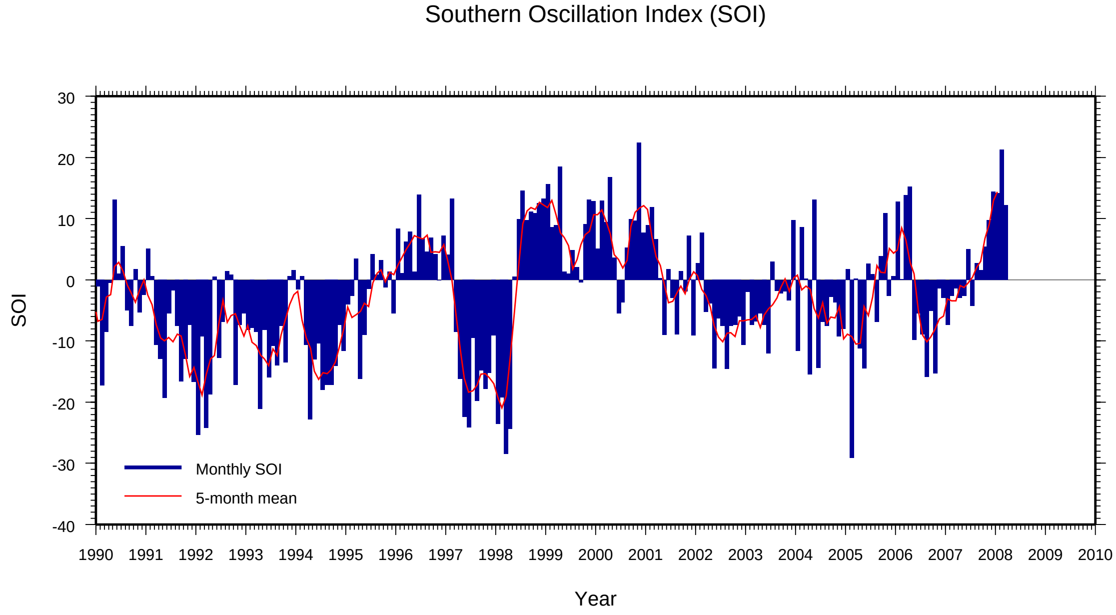

Figure B: *The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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

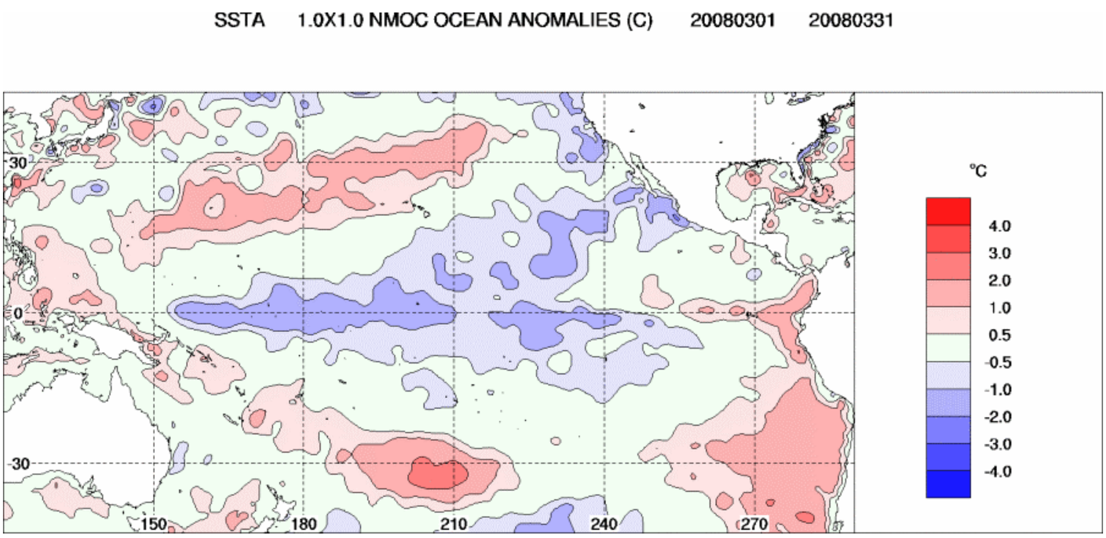

Figure C: *Sea surface temperature anomaly (°C) for March 2008.*

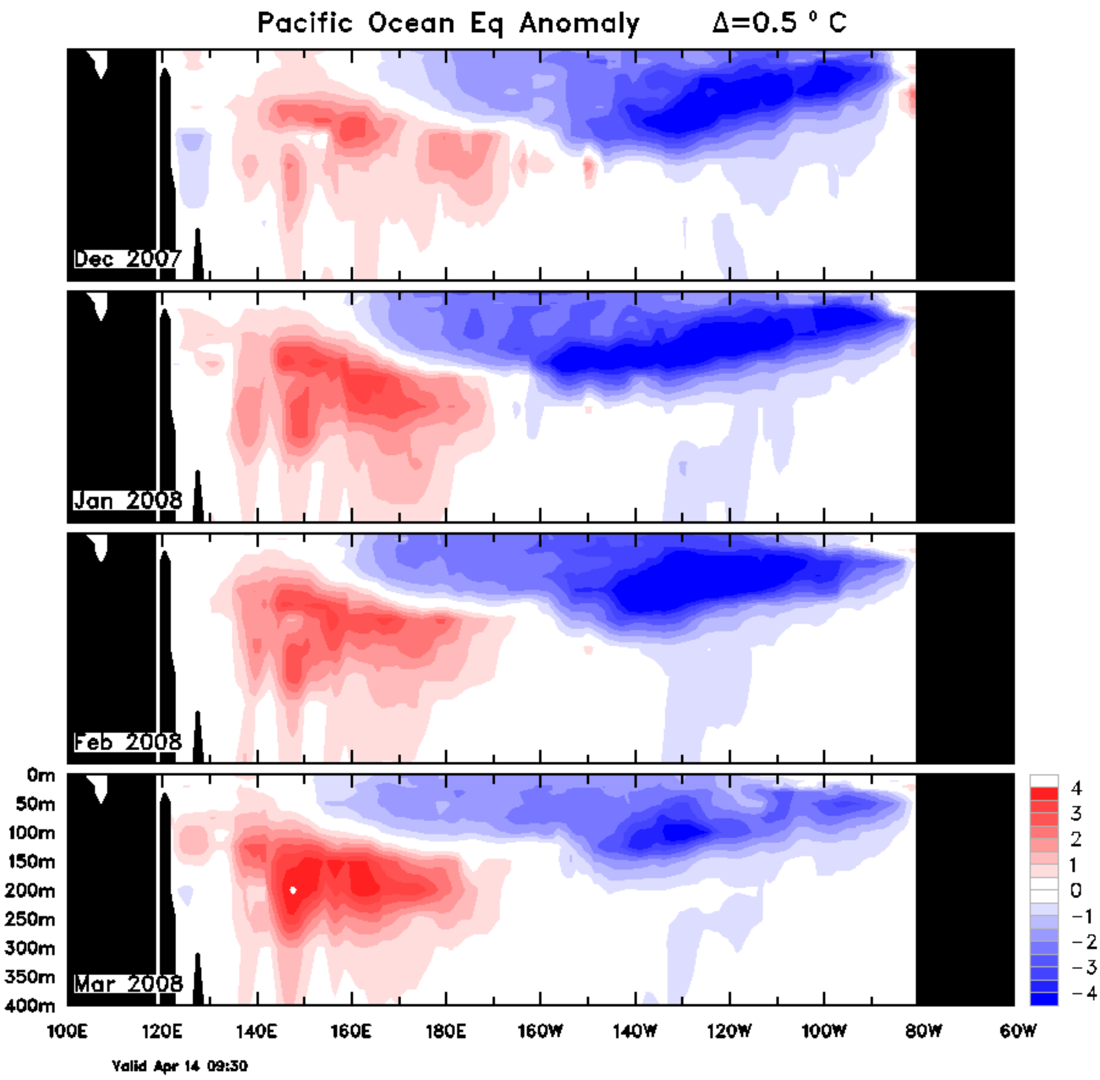

Figure D: *Equatorial depth-longitude section of ocean temperature anomalies for December 2007 through to March 2008. Contour interval is 0.5°C.*

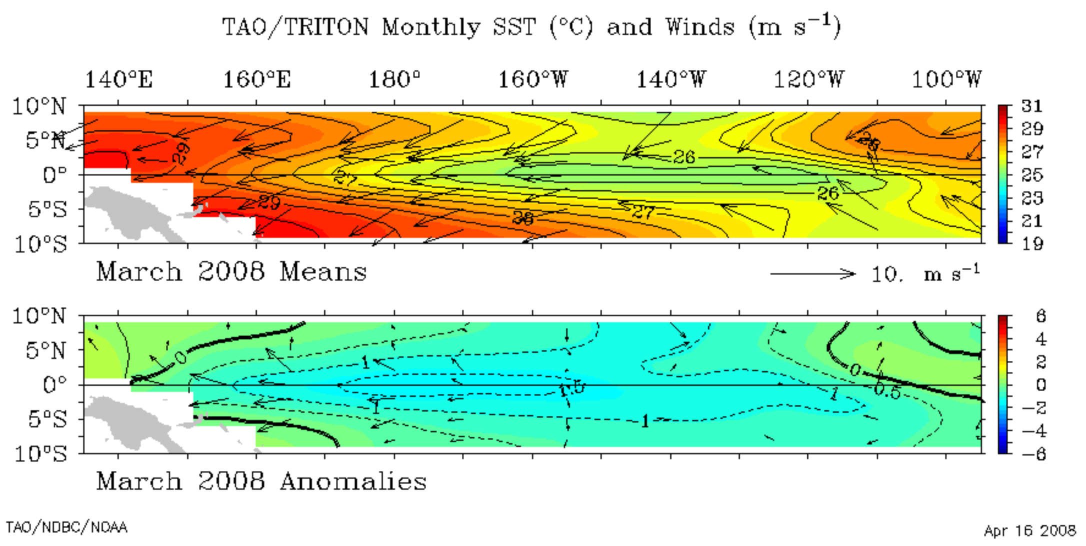

Figure E: *Monthly mean wind vectors (top) and anomalies (bottom) for March 2008. The colour-shaded contours represent the monthly mean sea surface temperatures (top) and anomalies (bottom).*

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 tend to occur close to the new and full moon. There was a new moon on the 7th of March and a full moon on the 21st 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 effects can also be amplified or sustained by the shape of the harbour in which the gauge is located. Resonant behaviour such as persistent sloshing of water within a bay or harbour is also known as a seiche. Seiches are often recorded at PNG when the wind suddenly changes strength or direction and at Vanuatu following the arrival of a tsunami.

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. The maximum wind gust observed by the network during March was 25 m/s (49 knots or 90 km/hr) at Marshall Islands on the 12th of March (**Figure 6**).

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 evident and 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 March water temperature was recorded at Nauru, and a new maximum March barometric pressure was recorded at Cook Islands.

Mean Sea Level and Anomalies (Figures 11-13)

Figure 11 shows the **monthly mean sea levels**, which is a simple arithmetic average 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.

The monthly mean sea levels recorded at PNG and Solomon Islands in March 2008 were the highest on record.

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 2008 positive anomalies (higher than normal sea levels) were observed at PNG, Solomon Islands and Fiji. The positive anomalies at PNG (+7 cm) and Solomon Islands (+15 cm) are associated with the highest monthly mean sea levels on record at those stations. Negative sea level anomalies to around –5 cm were observed at Kiribati, Nauru and Marshall Islands. Sea levels were near normal at the remaining stations.

Sea Level Trends

The **short-term sea level trends** at individual stations as at March 2008 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, 2008

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Nauru	**0°31'45.9"S / 166°54'36.2"E**	**Jul 1993**	**+5.4**	**-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 March 2008 higher than normal barometric pressures were observed at Tuvalu, Samoa, Fiji, Tonga and Cook Islands. Barometric pressures were near normal at the remaining stations.

The **water temperature anomalies (Figure 15)** show cooler than normal conditions continued to be observed at the equatorial stations Kiribati and Nauru as well as at Tuvalu during March 2008. Water temperatures were warmer than normal at Vanuatu and near normal at the remaining sites.

The **air temperature anomalies (Figure 16)** show air temperatures at Samoa and Fiji during March 2008 were at least 0.5˚C cooler than normal on average. Where quality data was collected from the other sites air temperatures were generally near normal. 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.

At Tuvalu the air temperature data were removed from the record due to a faulty sensor. At Nauru both the primary sea level sensor and the air temperature sensor produced erroneous readings. Data from the backup sea level sensor were used while the air temperature readings were removed from the record. At Kiribati the air temperature sensor radiation screen fell off on the 6^{th} of February, and subsequent data have been removed from the record. The wind sensor at Kiribati also developed a fault on the 10^{th} of March. At Solomon Islands erroneous wind directions have been recorded since 30^{th} July 2007 and the wind data have been removed from the record.

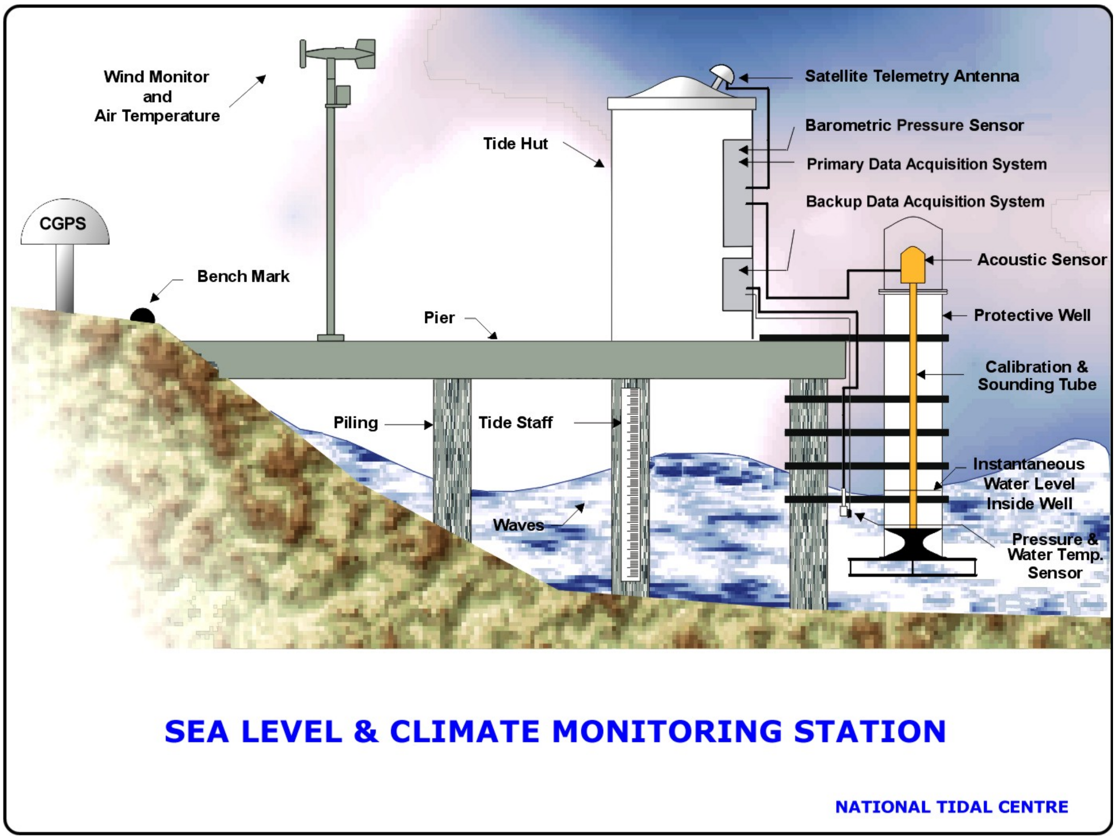
SEAFRAME STATIONS

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

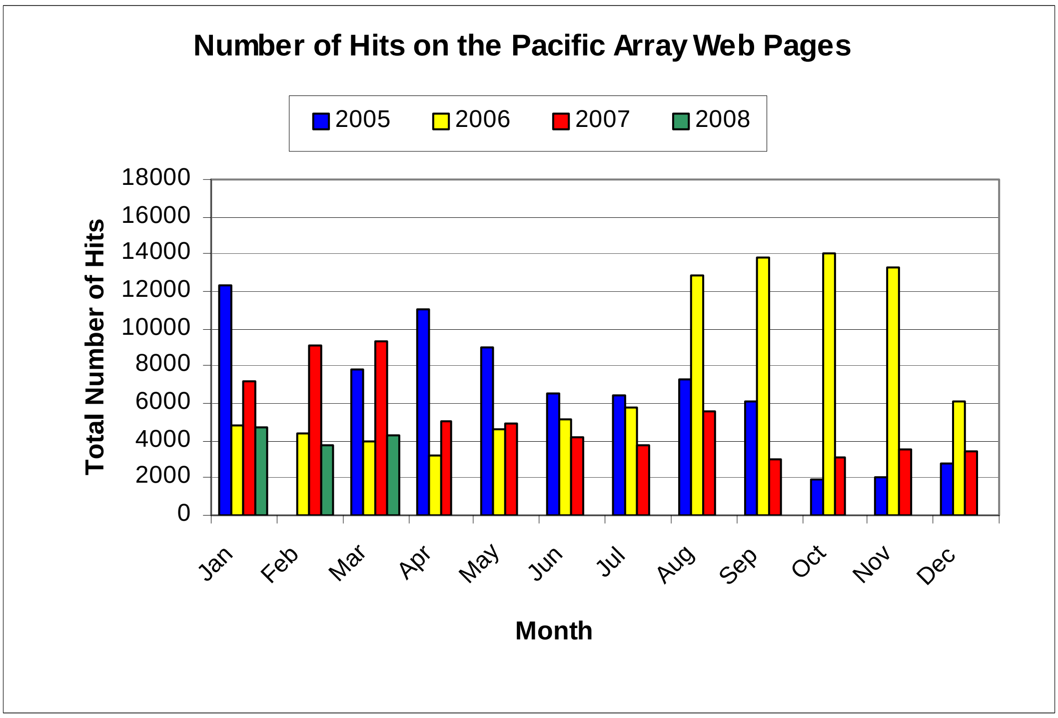
(2) Secondary water level (or backup) using a Druck pressure transducer mounted close to the seabed.

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 2004. Note that the web statistics for February 2005 are not available due to technical difficulties.



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

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 2008
SIX MINUTE WATER LEVEL OBSERVATIONS (m)

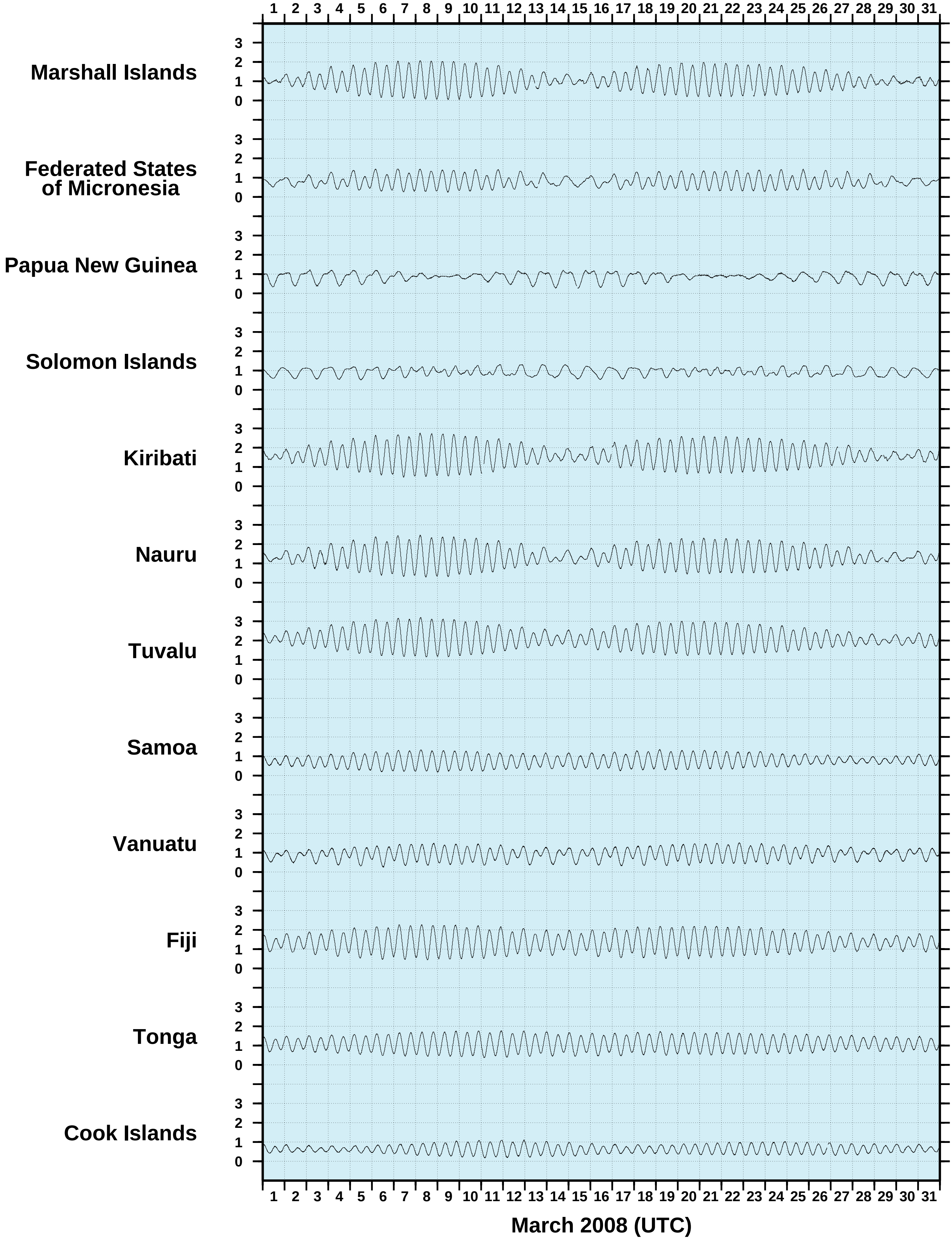


Figure 2

MARCH 2008
SIX MINUTE RESIDUAL WATER LEVELS (m)

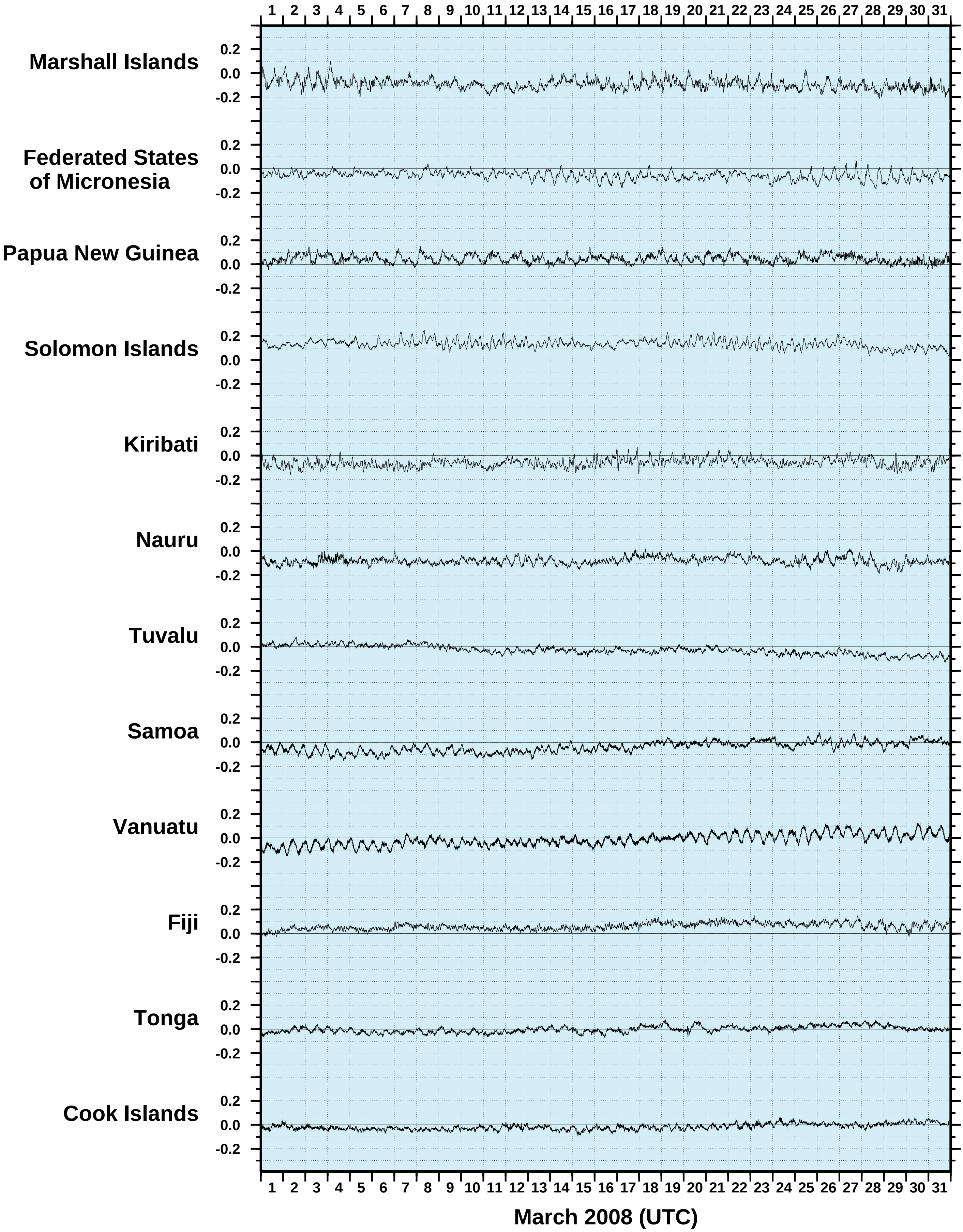


Figure 3

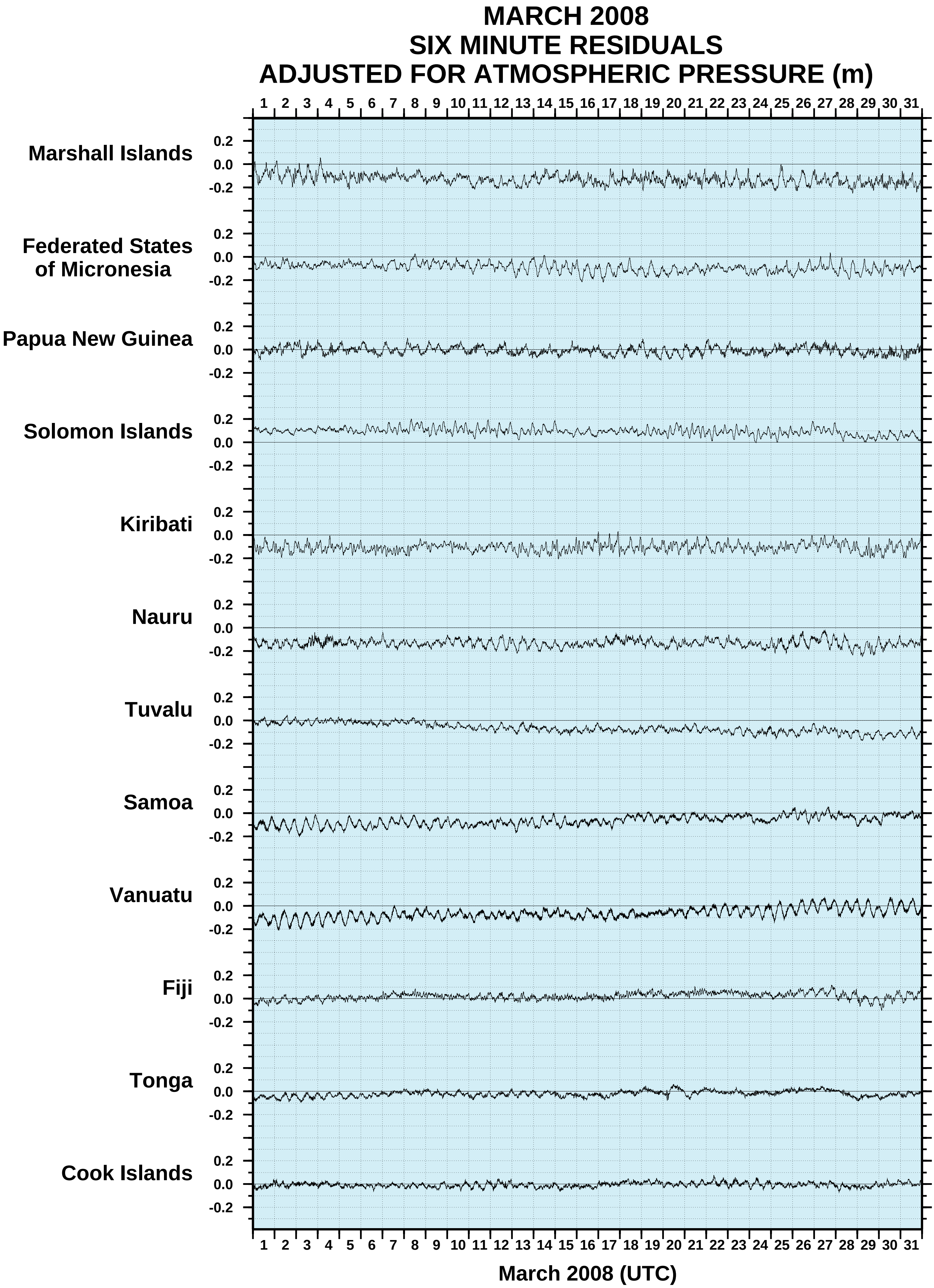

MARCH 2008
SIX MINUTE RESIDUALS
ADJUSTED FOR ATMOSPHERIC PRESSURE (m)
Marshall Islands
Federated States of Micronesia
Papua New Guinea
Solomon Islands
Kiribati
Nauru
Tuvalu
Samoa
Vanuatu
Fiji
Tonga
Cook Islands
0.2
0.0
-0.2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
March 2008 (UTC)

Figure 4

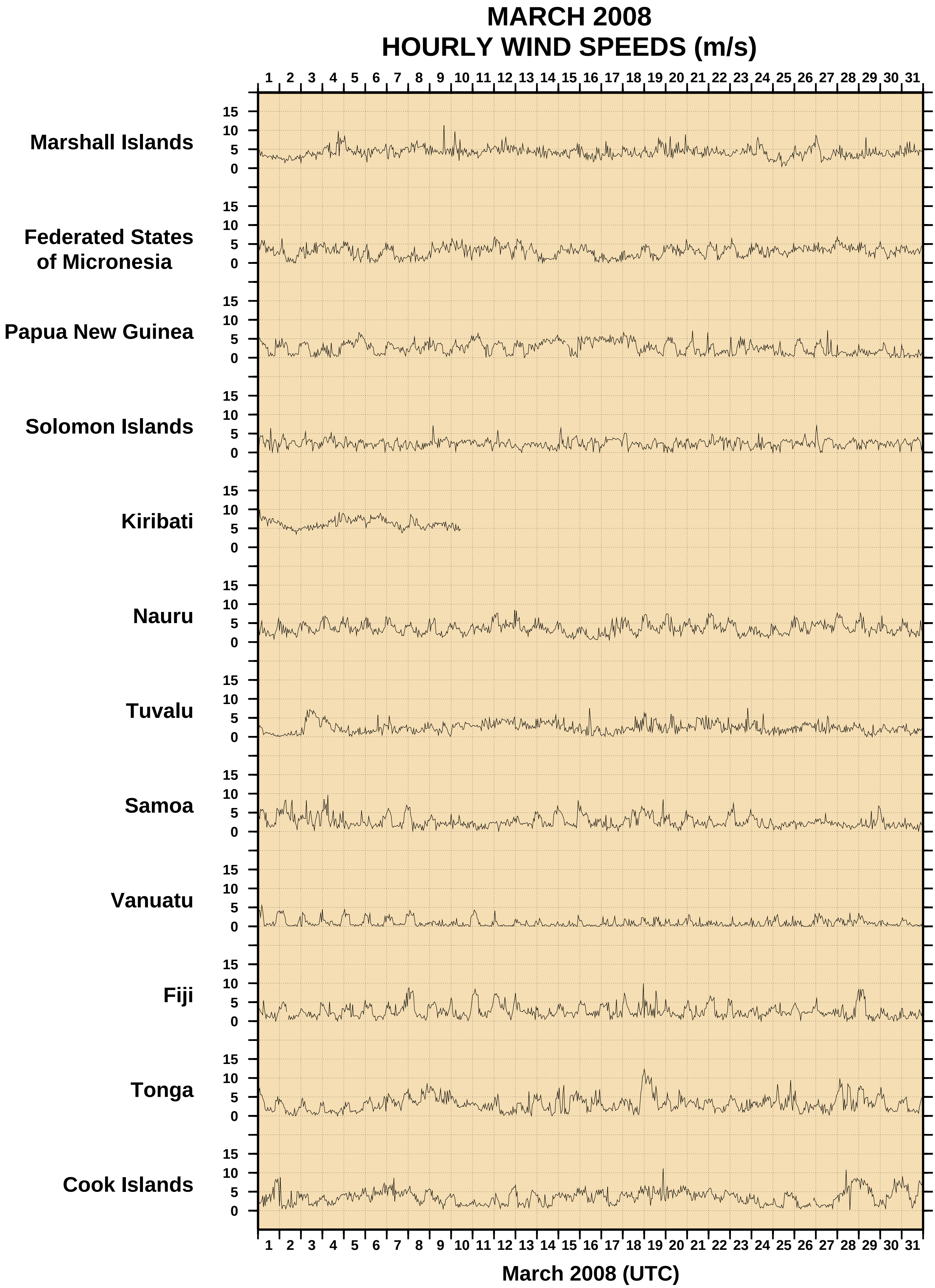

MARCH 2008
HOURLY WIND SPEEDS (m/s)
Marshall Islands
Federated States of Micronesia
Papua New Guinea
Solomon Islands
Kiribati
Nauru
Tuvalu
Samoa
Vanuatu
Fiji
Tonga
Cook Islands
0
5
10
15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
March 2008 (UTC)

Figure 5

MARCH 2008

HOURLY INCIDENT WINDS (m/s, deg True)

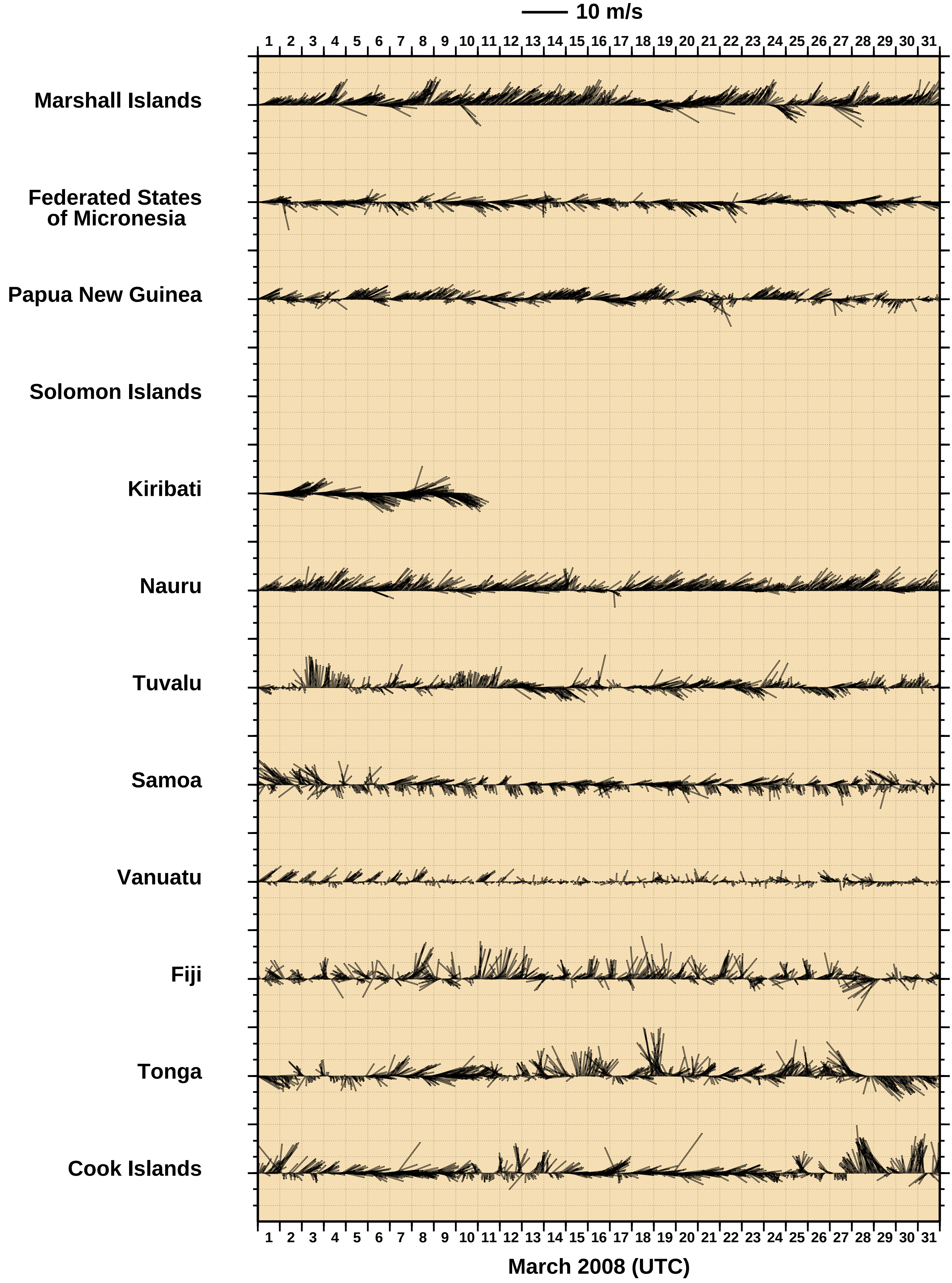


Figure 6

MARCH 2008
HOURLY MAXIMUM WIND GUSTS (m/s)

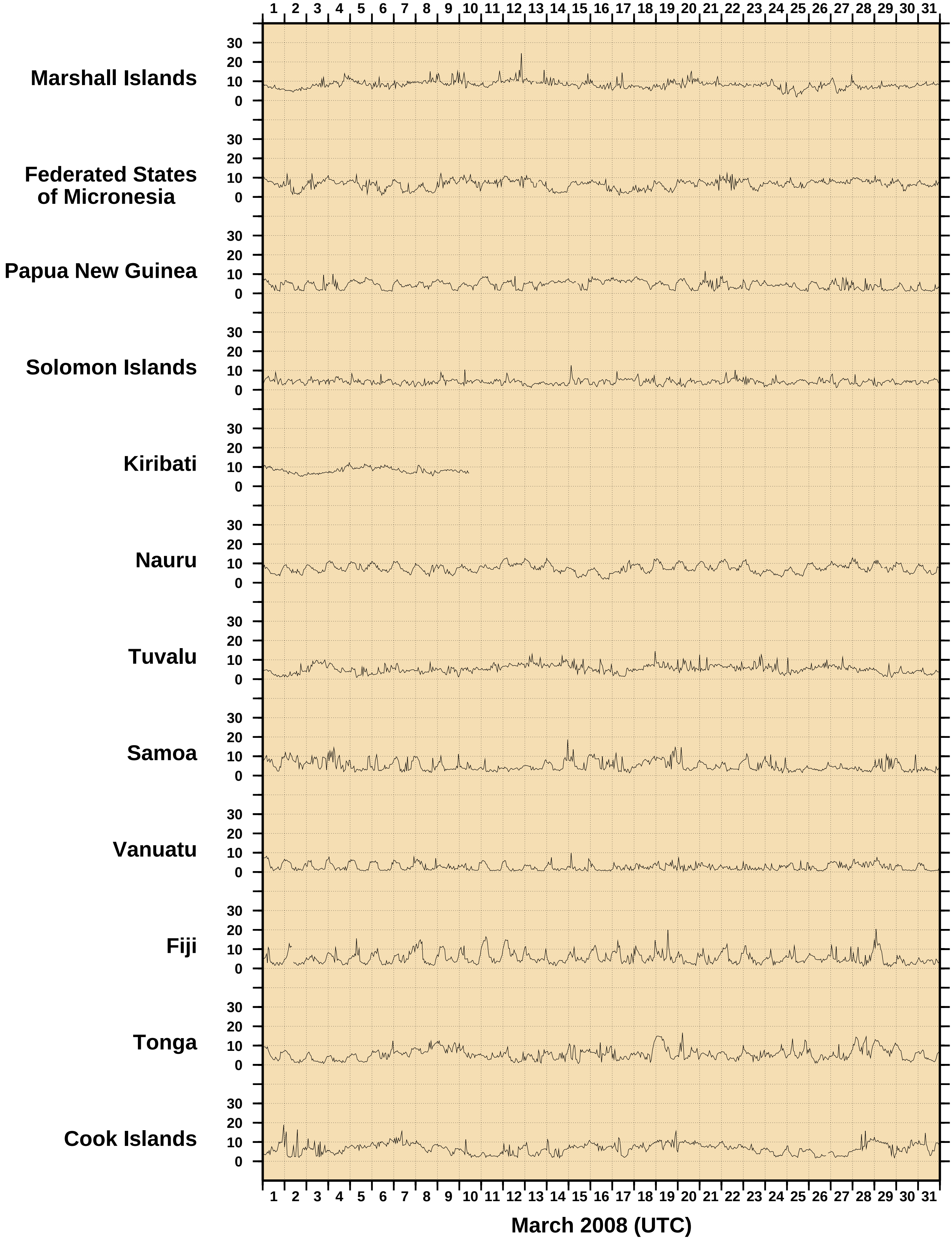


Figure 7

MARCH 2008
HOURLY AIR TEMPERATURES (˚C)

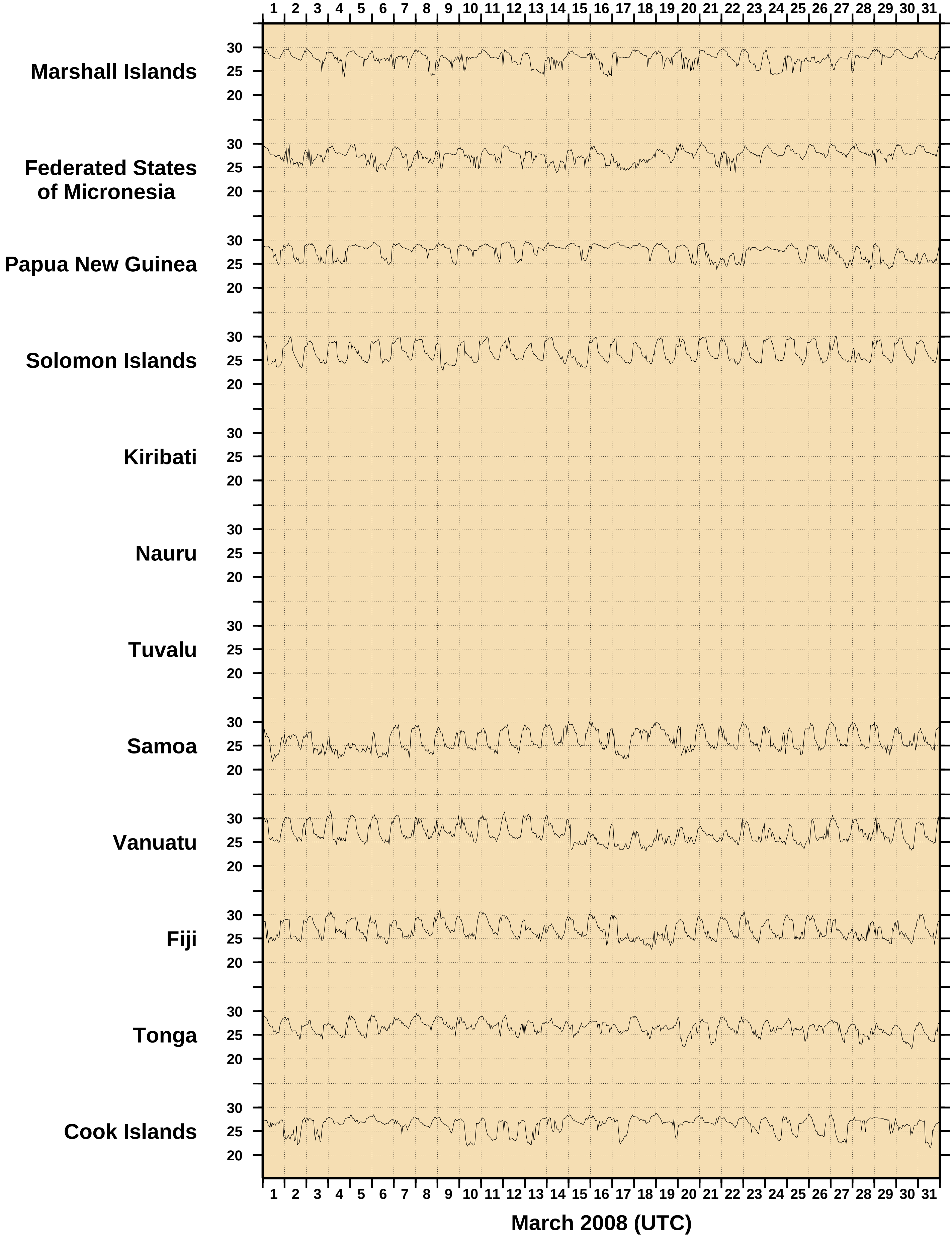


Figure 8

MARCH 2008
HOURLY WATER TEMPERATURES (˚C)

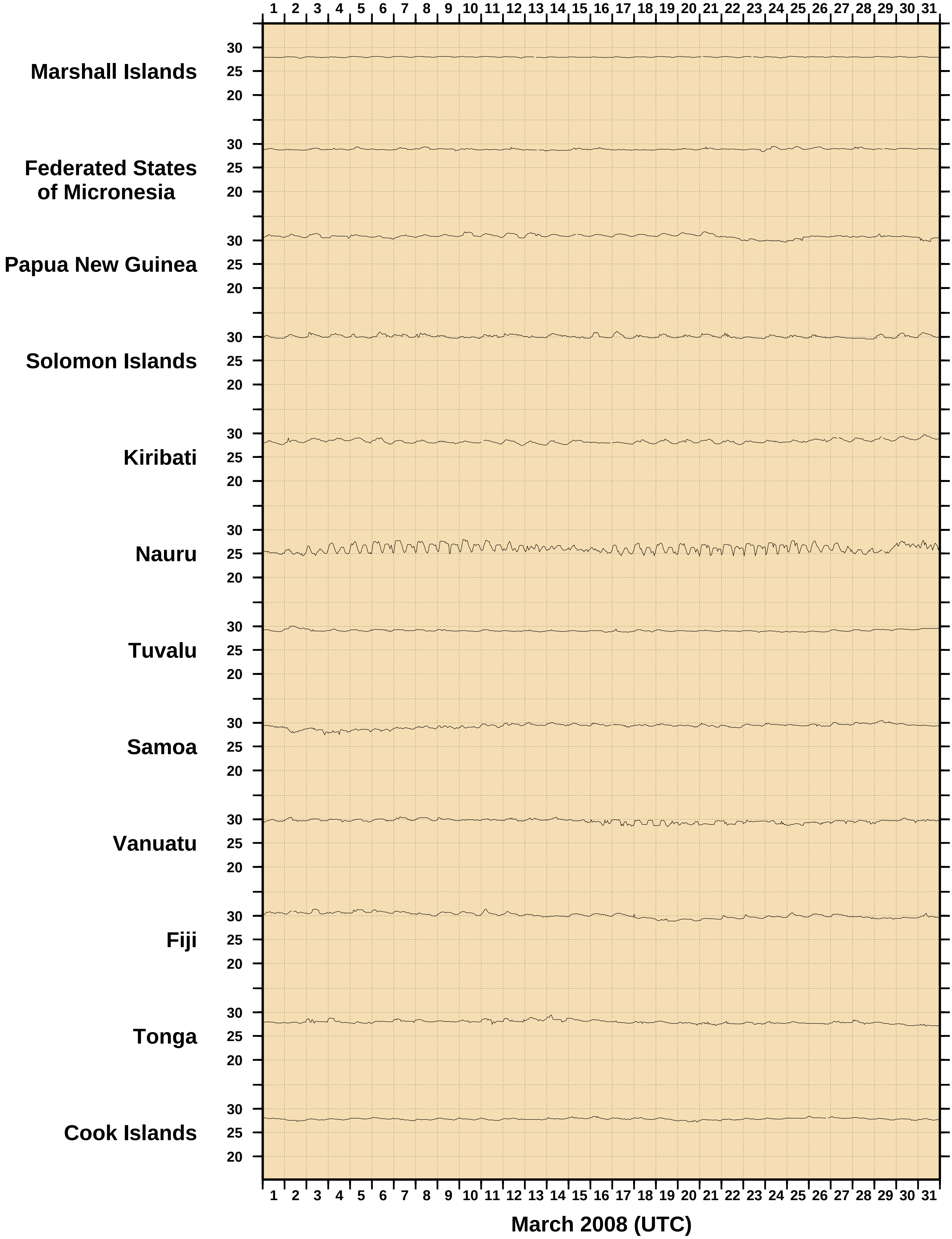


Figure 9

MARCH 2008
HOURLY ATMOSPHERIC PRESSURE (hPa)

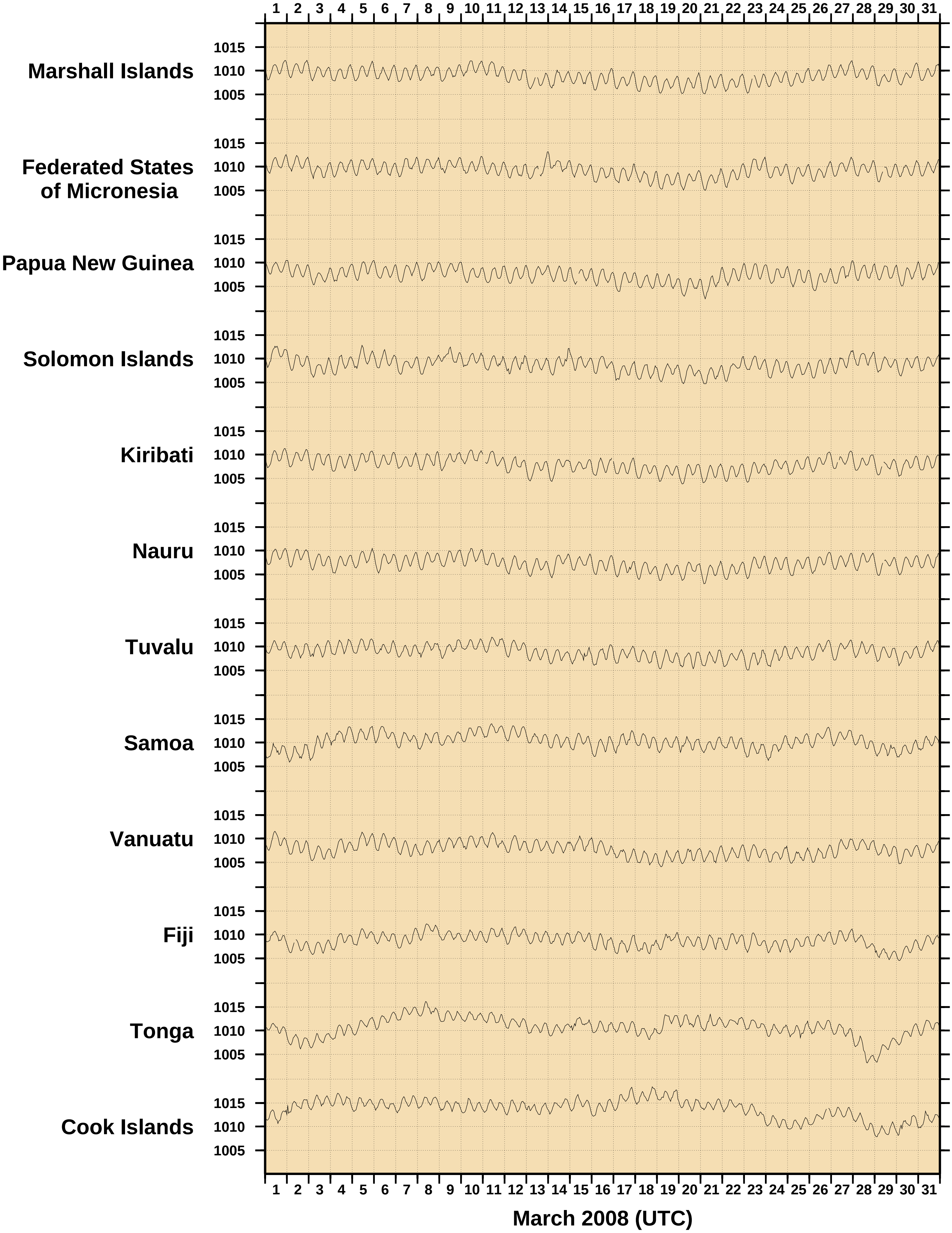
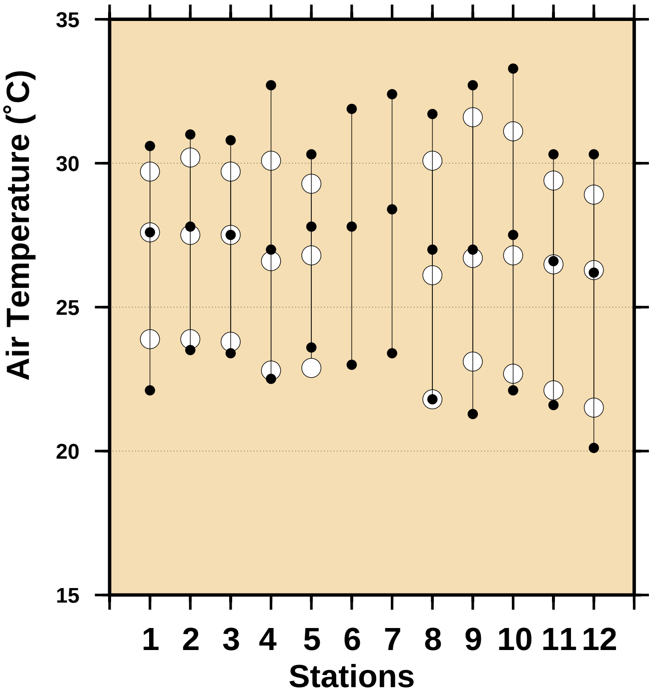
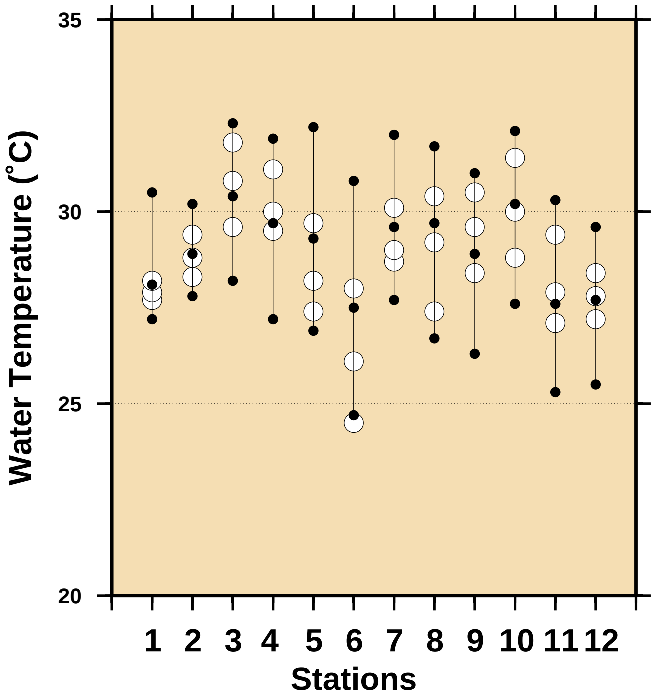
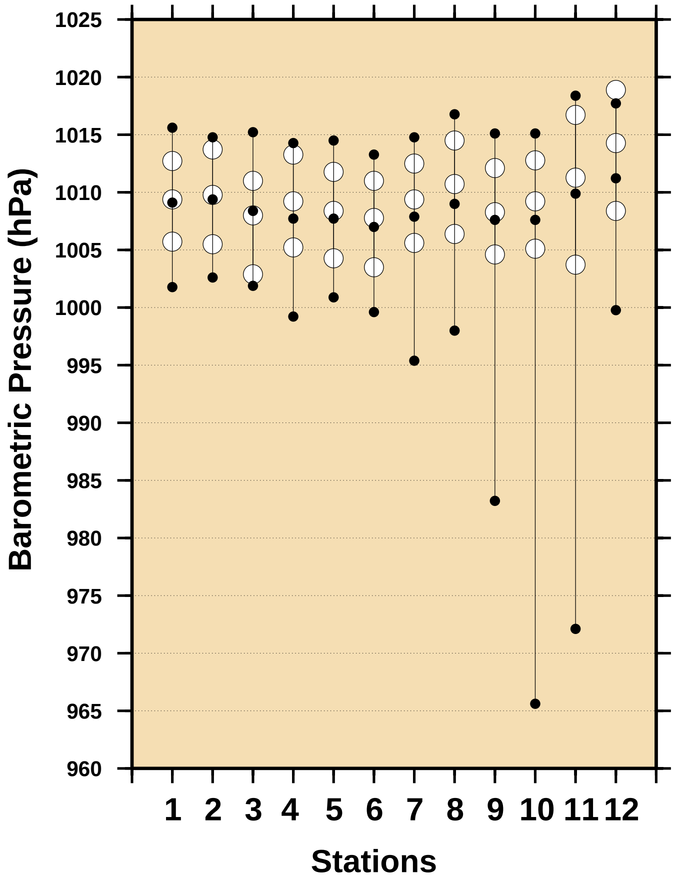


Figure 10

Comparison of March 2008 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 2008 Maximum
March 2008 Mean
March 2008 Minimum

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

Figure 11

MONTHLY MEAN SEA LEVELS TO MARCH 2008 (m)

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

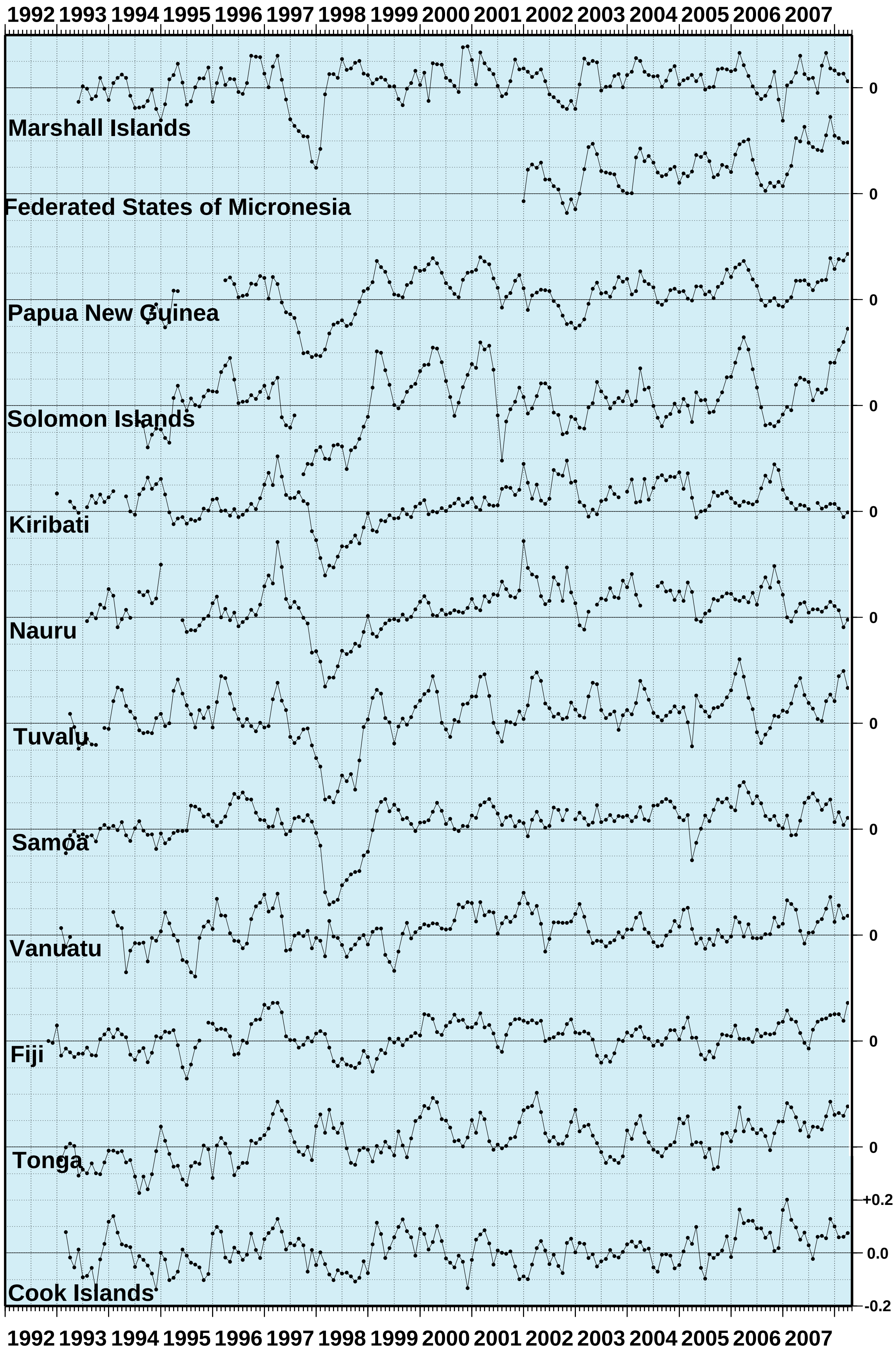


Figure 12
SEA LEVEL ANOMALIES THROUGH MARCH 2008 (m)

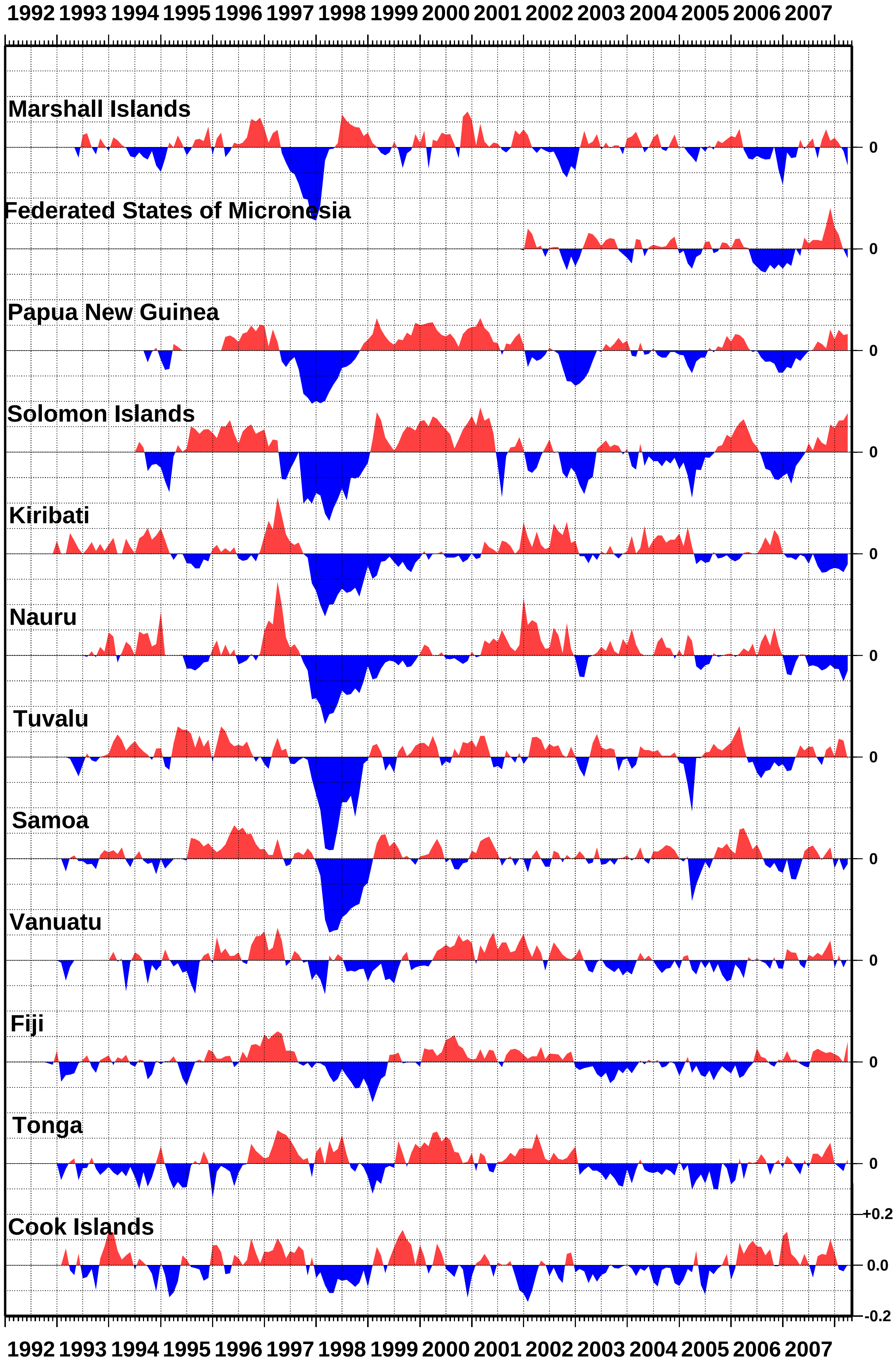


Figure 13

SEA LEVEL TRENDS THROUGH MARCH 2008 (mm/year)

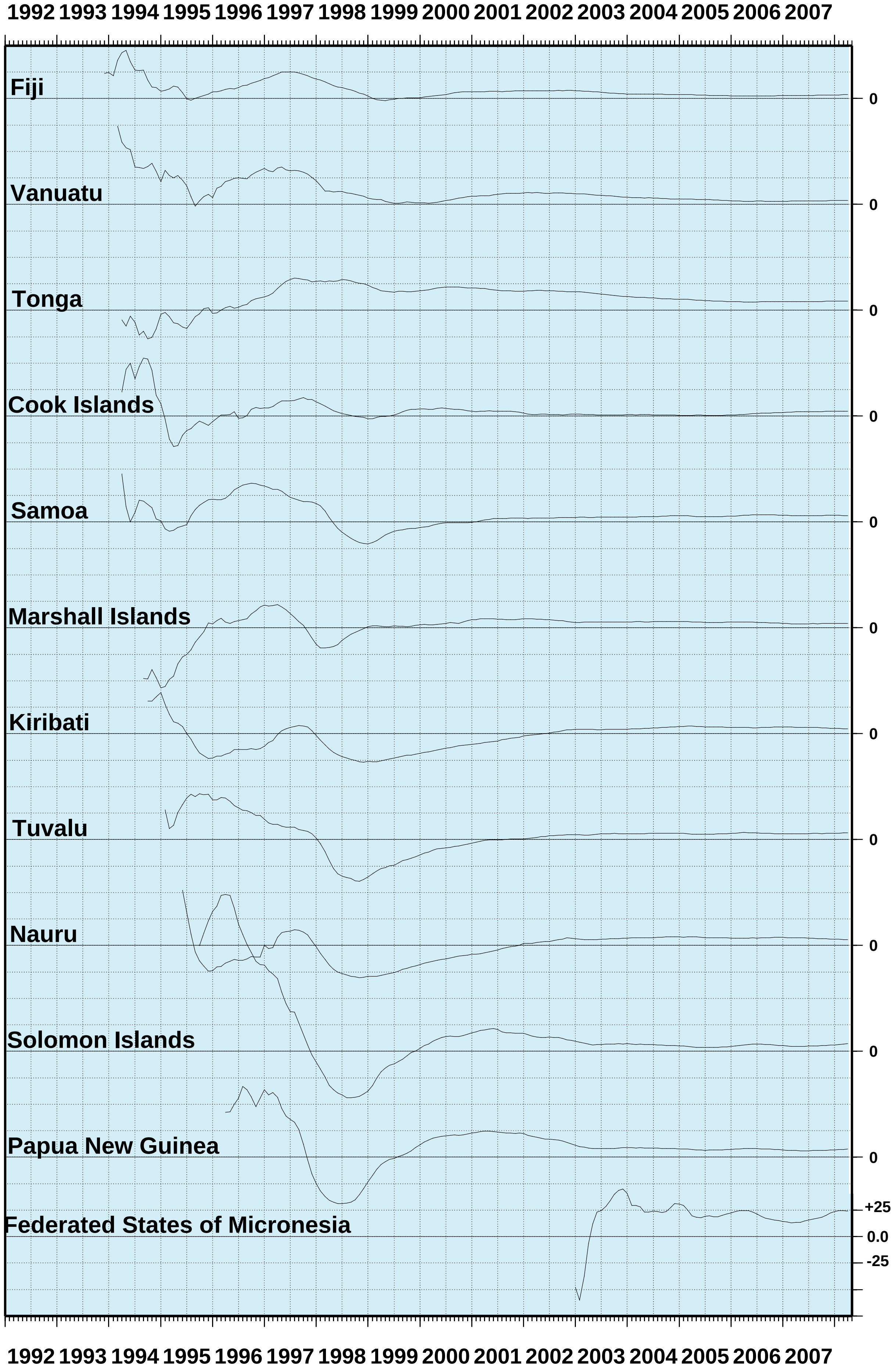


Figure 14

BAROMETRIC PRESSURE ANOMALIES THROUGH MARCH 2008 (hPa)

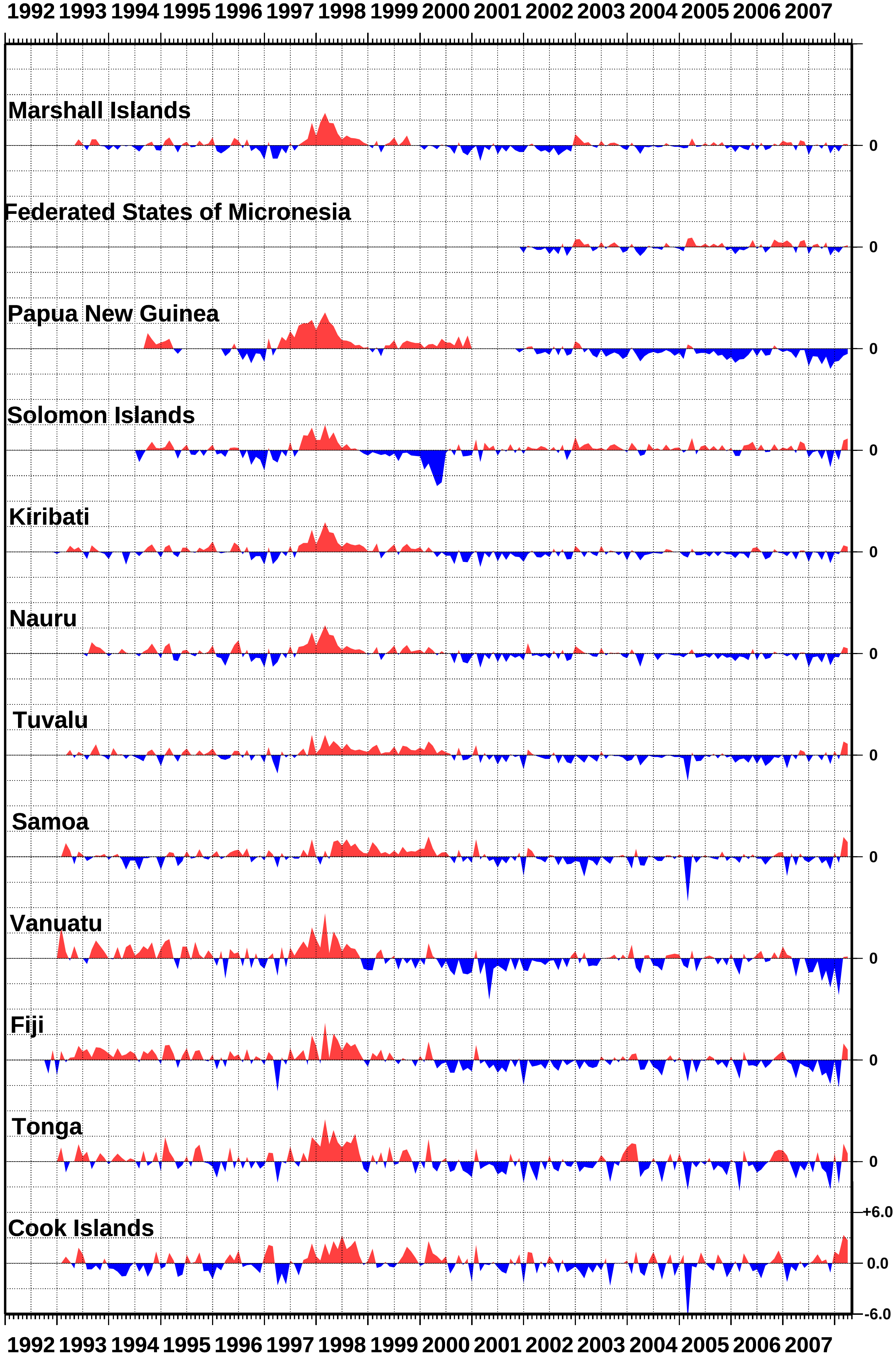


Figure 15

WATER TEMPERATURE ANOMALIES
THROUGH MARCH 2008 (°C)

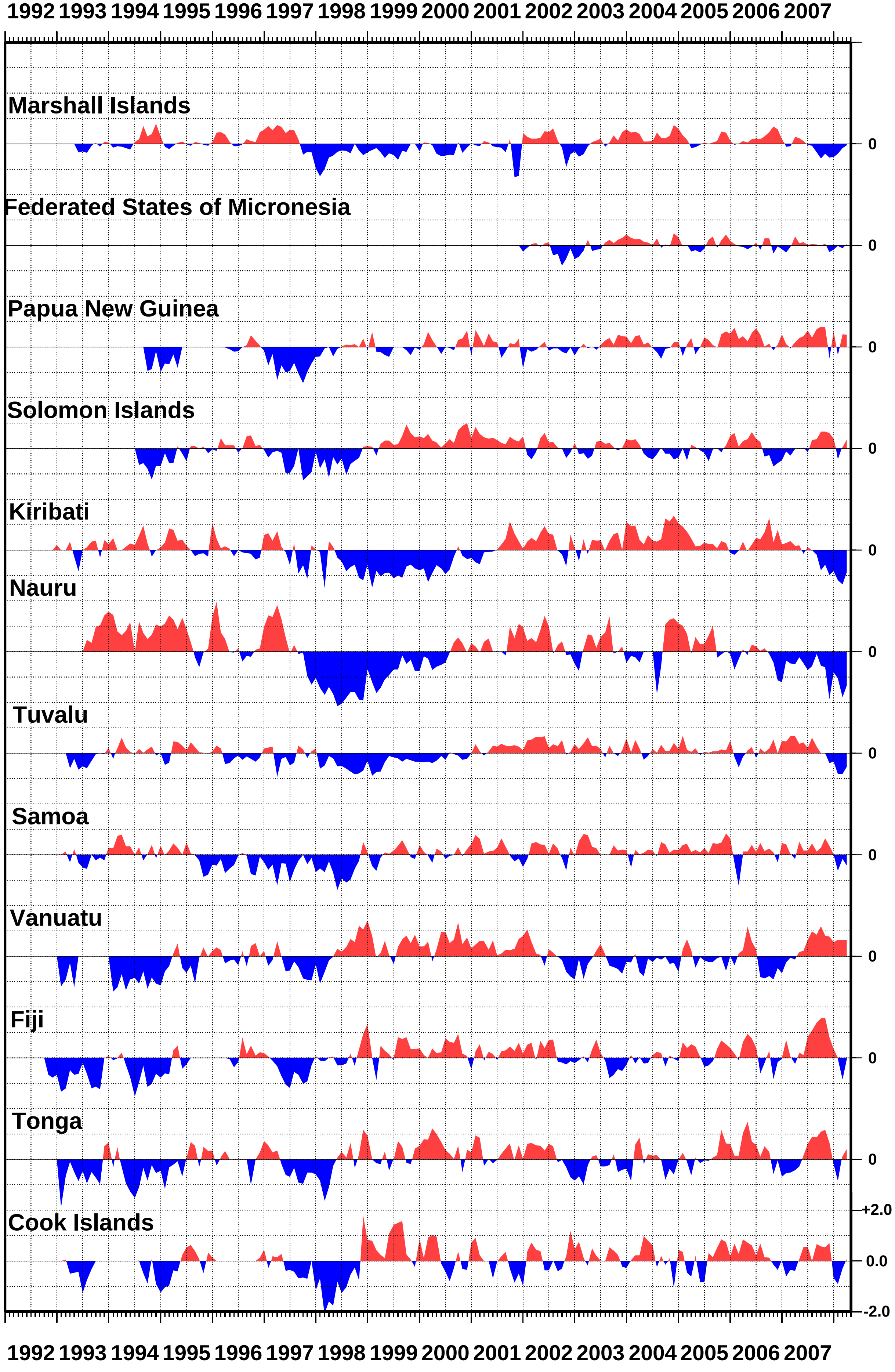


Figure 16

AIR TEMPERATURE ANOMALIES THROUGH MARCH 2008 (°C)

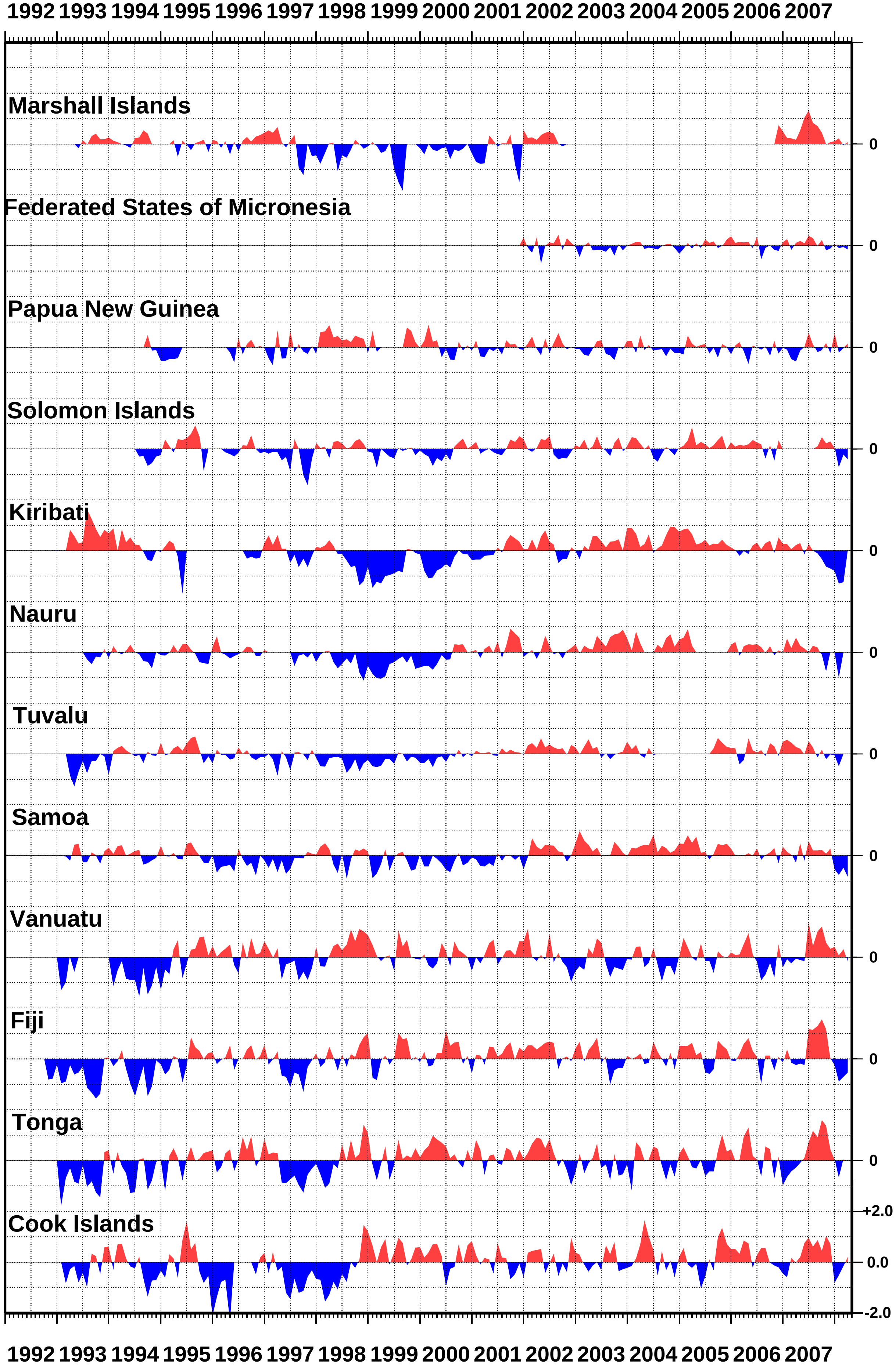


Figure 17

SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED

GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE

* Patchy record