# THE SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT

## MONTHLY DATA REPORT

## NO. 180

## JUNE 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

Bureau of Meteorology

**National Tidal Centre**
**Bureau of Meteorology**
**Australia**

GPO Box 421
Kent Town SA 5071
Australia

Tel: (+618) 8366 2730
Fax: (+618) 8366 2651
Website: http://www.bom.gov.au/oceanography/

**Quality Certification:**

I authorise the issue of this South Pacific Sea Level and Climate Monitoring Project Monthly Data Report for June 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

# June 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.

### *June 2010*

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

- Climate conditions across the tropical Pacific during June were consistent with a developing La Niña. Ocean heat content across the equatorial Pacific continued to cool, Trade Winds in the western equatorial Pacific were stronger than normal and cloudiness in the vicinity of the dateline was suppressed.

- Sea levels across the southwest Pacific region during June were for the most part at near normal levels for this time of the year. Cooling ocean temperatures and strengthening Trade Winds depressed sea levels along the equator, where the SEAFRAME stations at Kiribati and Nauru observed sea levels around 10cm lower than normal.

- The majority of international climate models predict further cooling of the tropical Pacific and the development of La Niña conditions 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 June, 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 | 0.0 |
| Tonga | 21°8'12.5"S / 175°10'50.5"W | Jan 1993 | +9.2 | -0.1 |
| Fiji | 17°36'17.7"S / 177°26'17.7"E | Oct 1992 | +5.4 | 0.0 |
| Vanuatu | 17°45'19.2"S / 168°18'27.7"E | Jan 1993 | +6.4 | -0.1 |
| 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 | +3.8 | -0.2 |
| Nauru | 0°31'45.9"S / 166°54'36.2"E | Jul 1993 | +4.5 | -0.2 |
| Solomon Is. | 9°25'44.1"S / 159°57'19.3"E | Jul 1994 | +5.7 | -0.1 |
| PNG | 2°2'31.5"S / 147°22'25.6"E | Sep 1994 | +6.3 | 0.0 |
| FSM | 6°58'49.9"N / 158°12'0.8"E | Dec 2001 | +14.3 | 0.0 |
| Marshall Is. | 7°6'21.7"N / 171°22'22.1"E | May 1993 | +3.8 | +0.1 |

## INTRODUCTION

Welcome to the June 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.

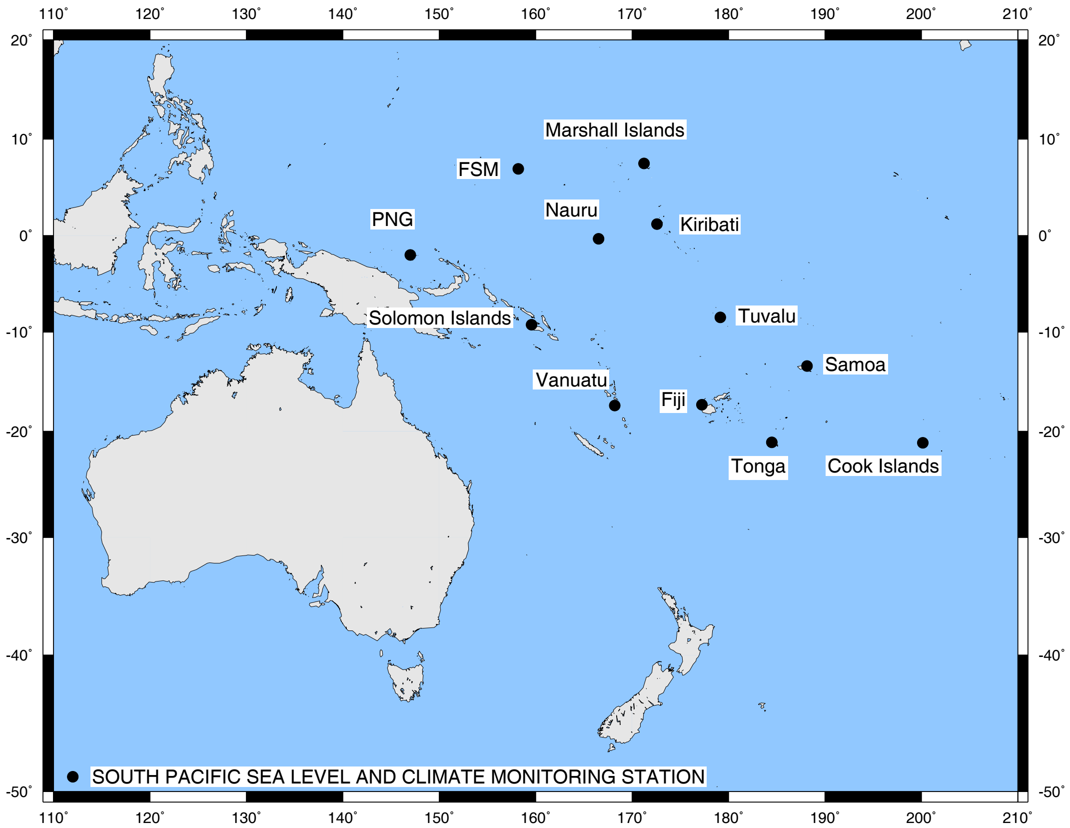


**Figure A:** *South Pacific Sea Level and Climate Monitoring Stations*

# JUNE CLIMATOLOGY

Climate conditions across the equatorial Pacific during June were consistent with a developing La Niña. Cooler than normal sea surface temperatures emerged in the eastern equatorial Pacific and a large volume of cooler than normal water temperatures continued to persist below the surface. Trade Winds were stronger than normal in the western equatorial Pacific and cloudiness in the vicinity of the dateline was suppressed. International climate models predict that Pacific Ocean temperatures will continue to cool and the likelihood of La Niña conditions developing this year is high.

The Southern Oscillation Index (SOI) has remained positive since April, although the June value of +2 is lower than the preceding months of +10 and +15 (**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 continued to cool across the central and eastern equatorial Pacific during June. Cooler than normal sea surface temperatures have emerged across the eastern equatorial Pacific, with anomalies below -1ºC in some patches. Warm sea surface temperature anomalies were observed in the far western equatorial Pacific and southwest Pacific region (**Figure C**).

Subsurface ocean temperatures continued to cool through June (**Figure D**), and have generally been in decline since December. Cool sub-surface anomalies extend across much of the equatorial Pacific, with anomalies below -3ºC being observed in the central equatorial Pacific.

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

The consensus among international computer models surveyed by the Bureau of Meteorology predict further cooling of the tropical Pacific over the coming months. La Niña conditions are expected to prevail 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/.*

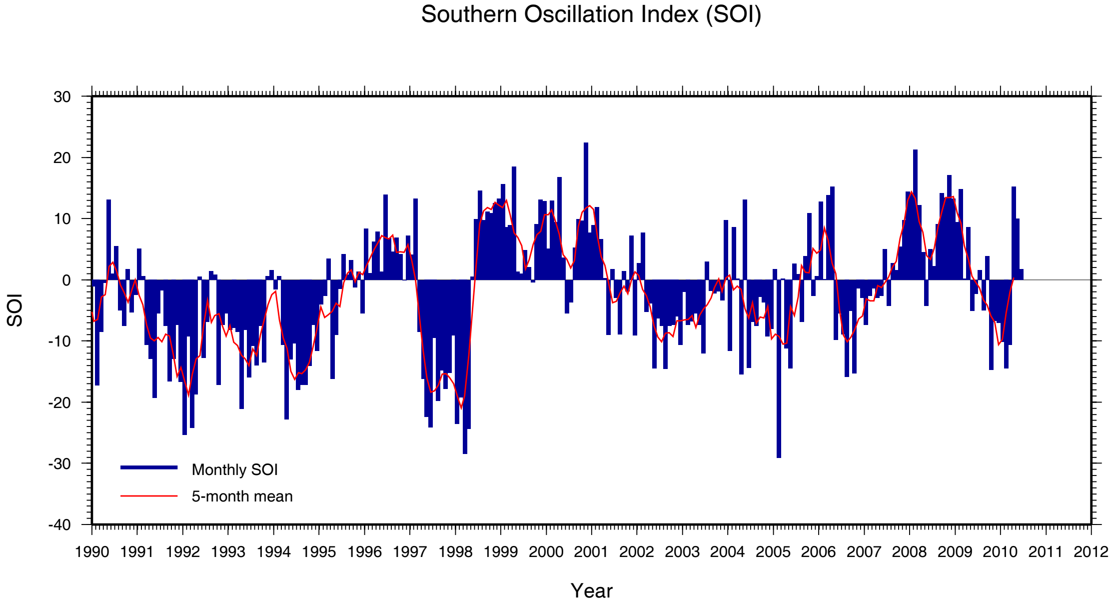


**Figure B:** *The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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

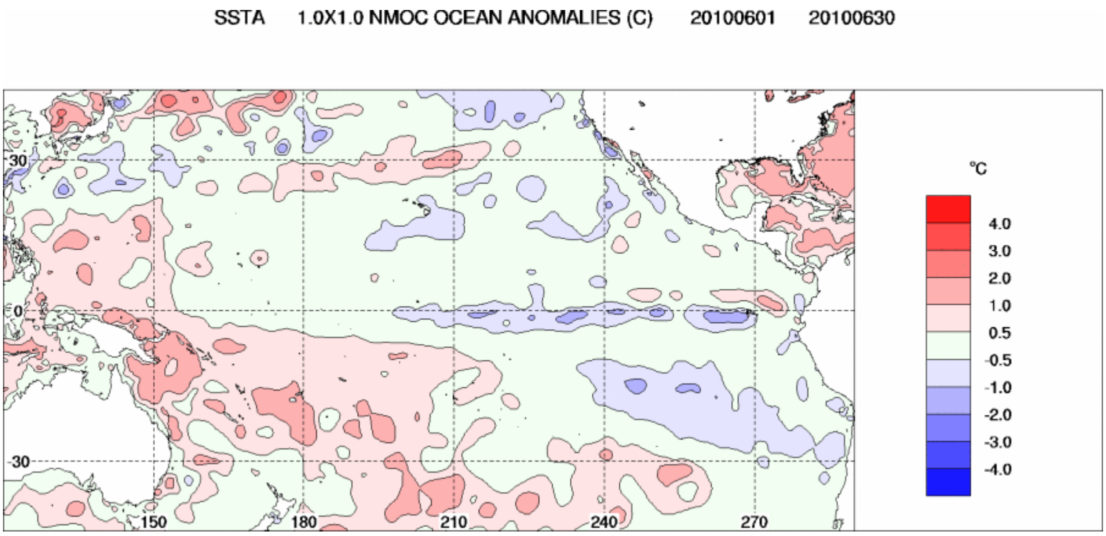


**Figure C**: *Sea surface temperature anomaly (°C) for June 2010.*

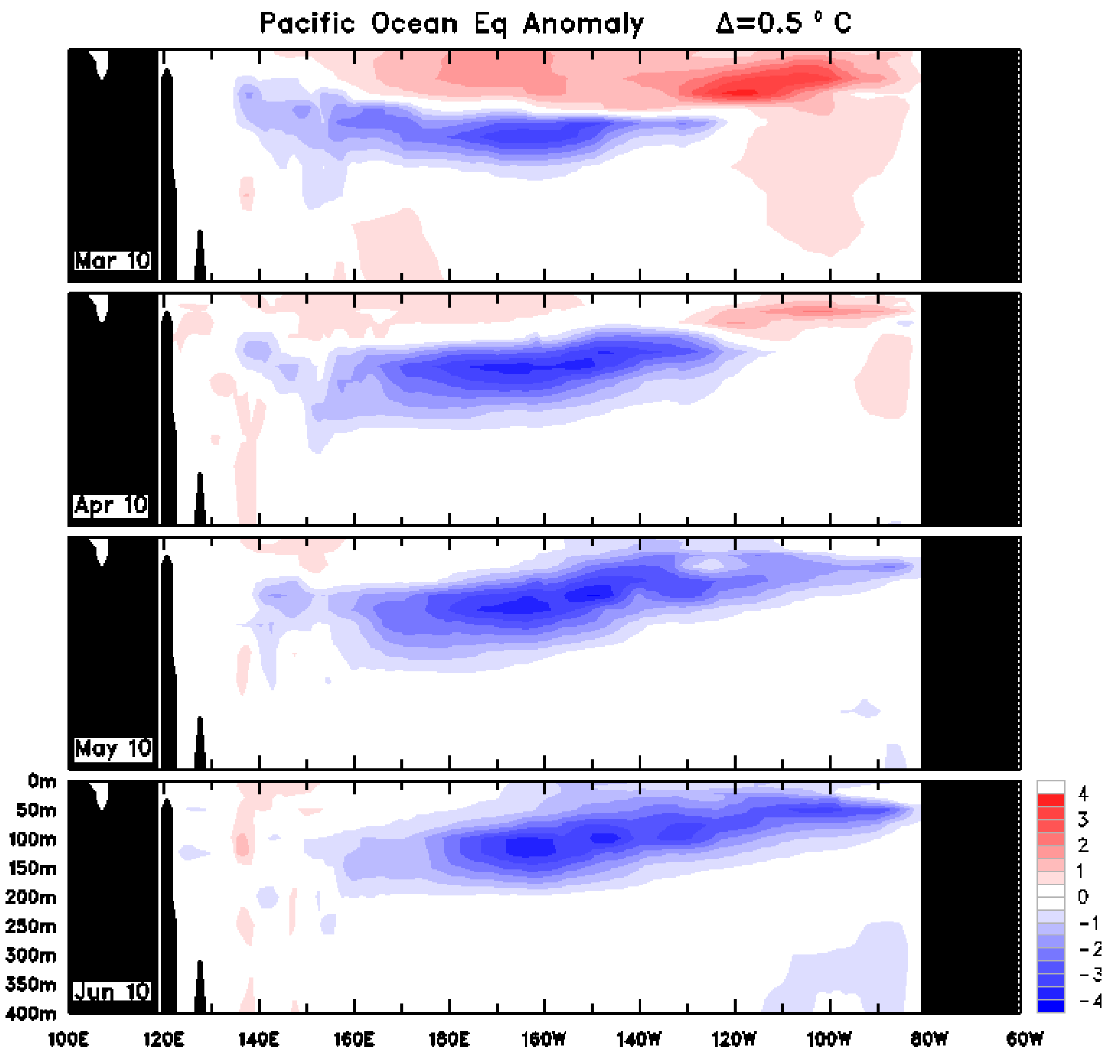


**Figure D**: *Equatorial depth-longitude section of ocean temperature anomalies for March 2010 through to June 2010. Contour interval is 0.5°C.*

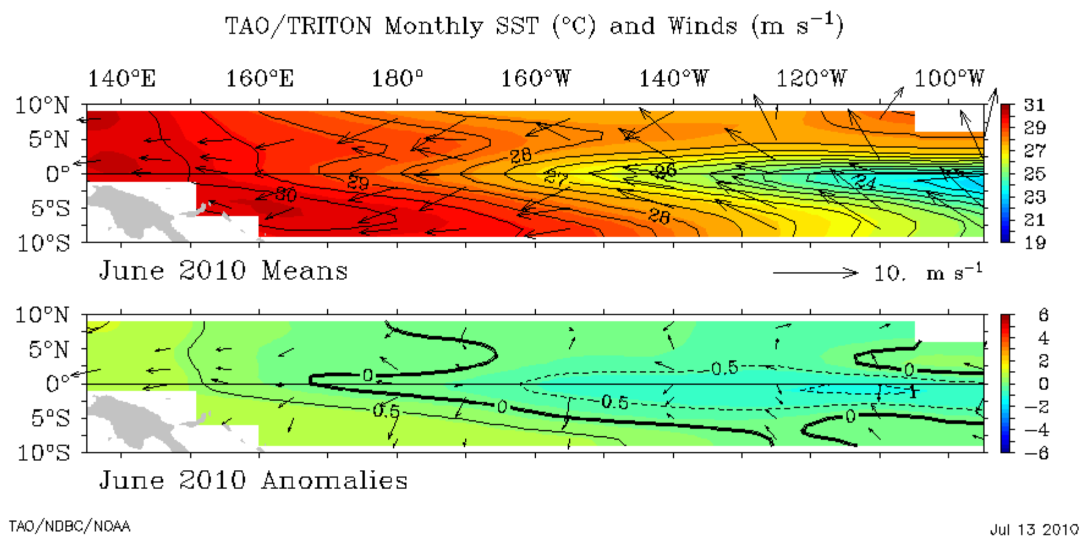


**Figure E:** *Monthly mean wind vectors (top) and anomalies (bottom) for June 2010. The colour-shaded contours represent the monthly mean sea surface temperatures (top) and anomalies (bottom).*

# JUNE 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 12th of June and a full moon on the 26th of June 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 occurs 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.

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.* The maximum water temperatures recorded at Vanuatu (28.6ºC) and Tonga (26.7ºC) during June 2010 are the highest June water temperatures on record for those stations.

**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.

Sea levels were close to what is normally observed at this time of the year at many stations during June 2010, in conjunction with near-neutral climate conditions. Sea level anomalies at Nauru and Kiribati were around 10cm below normal during June 2010, in connection with stronger than normal Trade Winds and cooling ocean temperatures depressing sea levels along the equator. Sea levels at Solomon Islands and Cook Islands were around 5cm lower than normal during June 2010.

Lower than normal sea levels are typically observed in the region 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 June 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*.

**Recent short-term sea level trends in the project area based upon SEAFRAME data through June, 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 | 0.0 |
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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 June 2010 barometric pressures were generally near average for this time of the year.

The **water temperature anomalies (Figure 15)** show warmer than normal conditions were observed at the majority of stations during June 2010, in agreement with warmer than normal sea surface temperatures across the southwest Pacific region (Figure C). The largest anomalies of around +1.0 °C were observed at Vanuatu, Fiji and Tonga.

The **air temperature anomalies (Figure 16)** show warmer than normal air temperatures were observed at nearly all stations during June 2010. The largest anomalies exceeded +1°C and were observed at PNG, Vanuatu, Fiji and Tonga. 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 June 2010, with the exception of Samoa and Cook Islands where ongoing data collection problems were encountered. Samoa continued to be affected by power supply problems, which were rectified by the installation of a new battery on the 28th of June. At Cook Islands the primary sea level sensor failed on the 2nd of June and data collected by the secondary sea level sensor were also of unacceptable quality. At Nauru there were continuing problems with the primary sea level sensor but replacement data from the secondary sea level sensor were used. Data communication problems were encountered at FSM, Nauru, PNG and Tuvalu, which resulted in a small amount of data loss.

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.

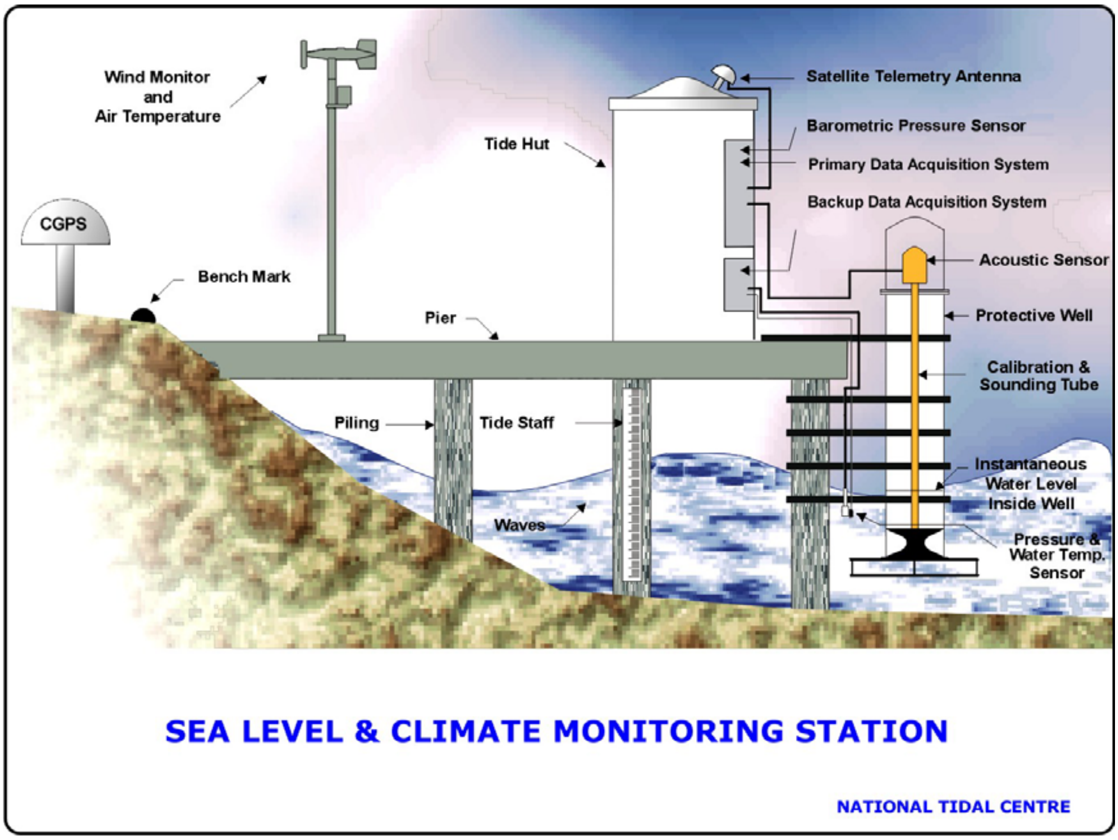
## SEAFRAME STATIONS

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

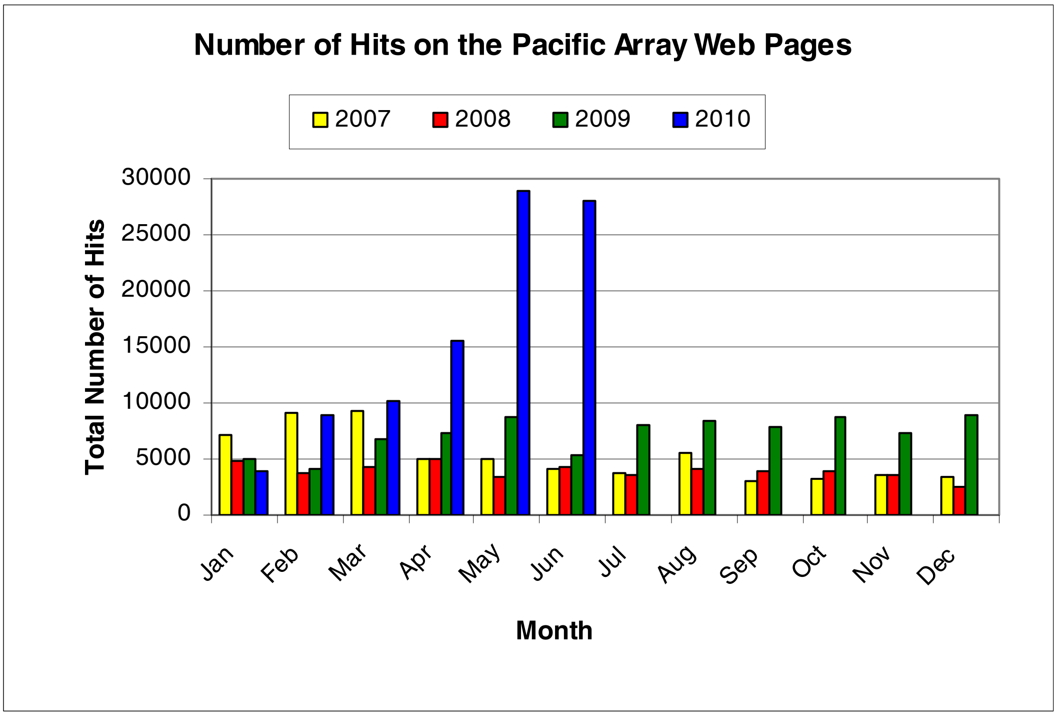
(2) Secondary water level (or backup) using a Druck pressure transducer mounted close to the seabed.

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:

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

## JUNE 2010
## SIX MINUTE WATER LEVEL OBSERVATIONS (m)

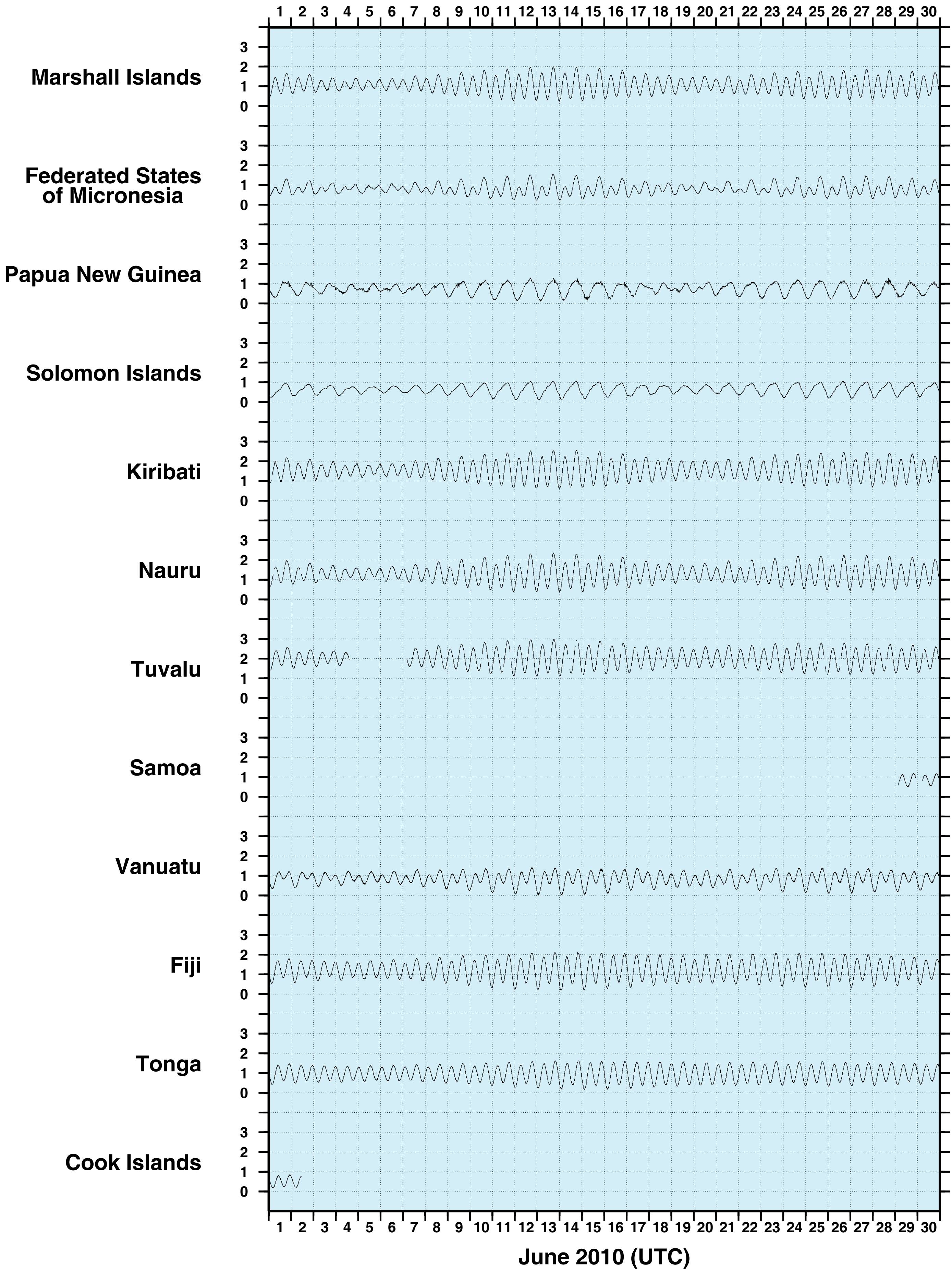


Figure 2

## JUNE 2010
## SIX MINUTE RESIDUAL WATER LEVELS (m)

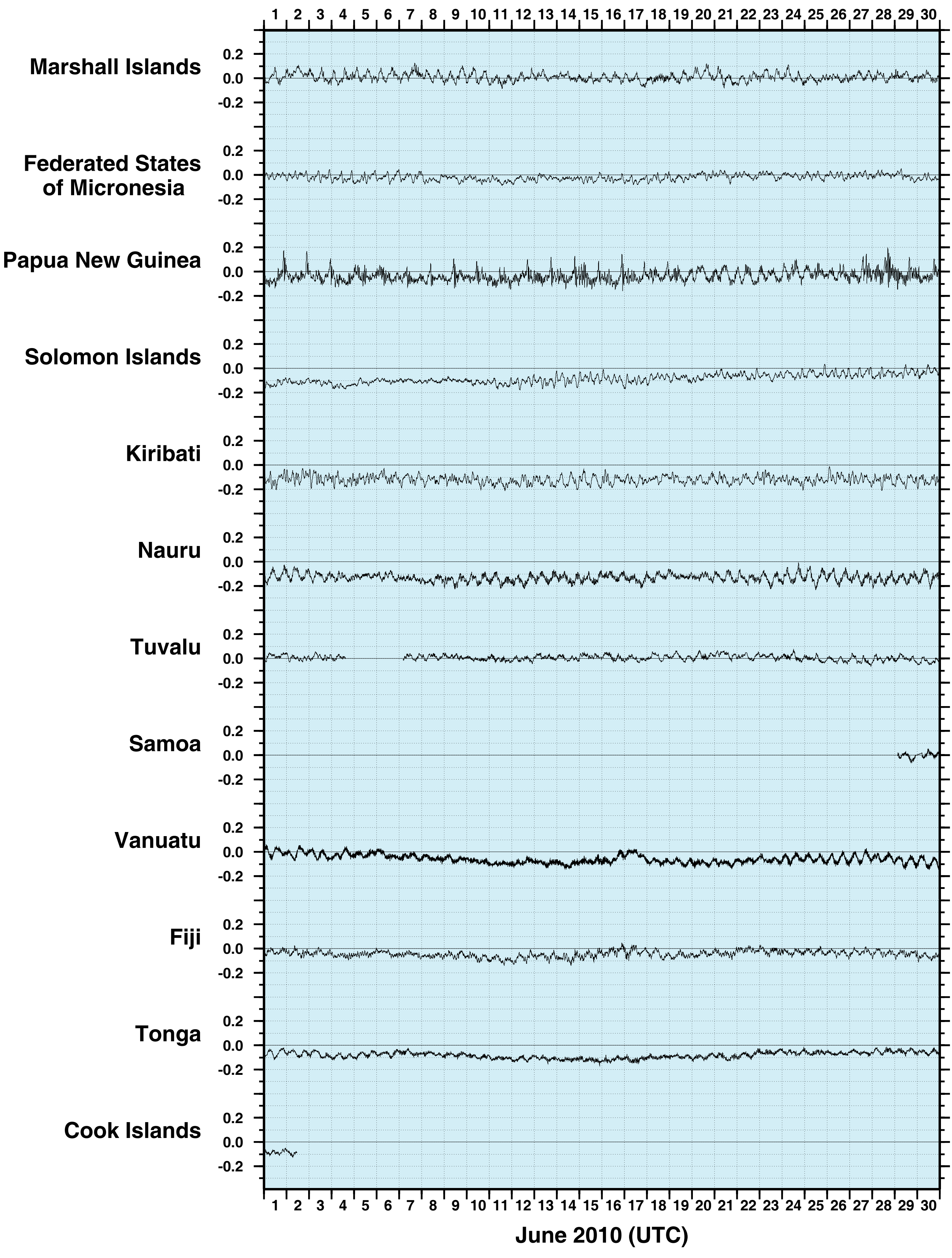


Figure 3

# JUNE 2010
# SIX MINUTE RESIDUALS
# ADJUSTED FOR ATMOSPHERIC PRESSURE (m)

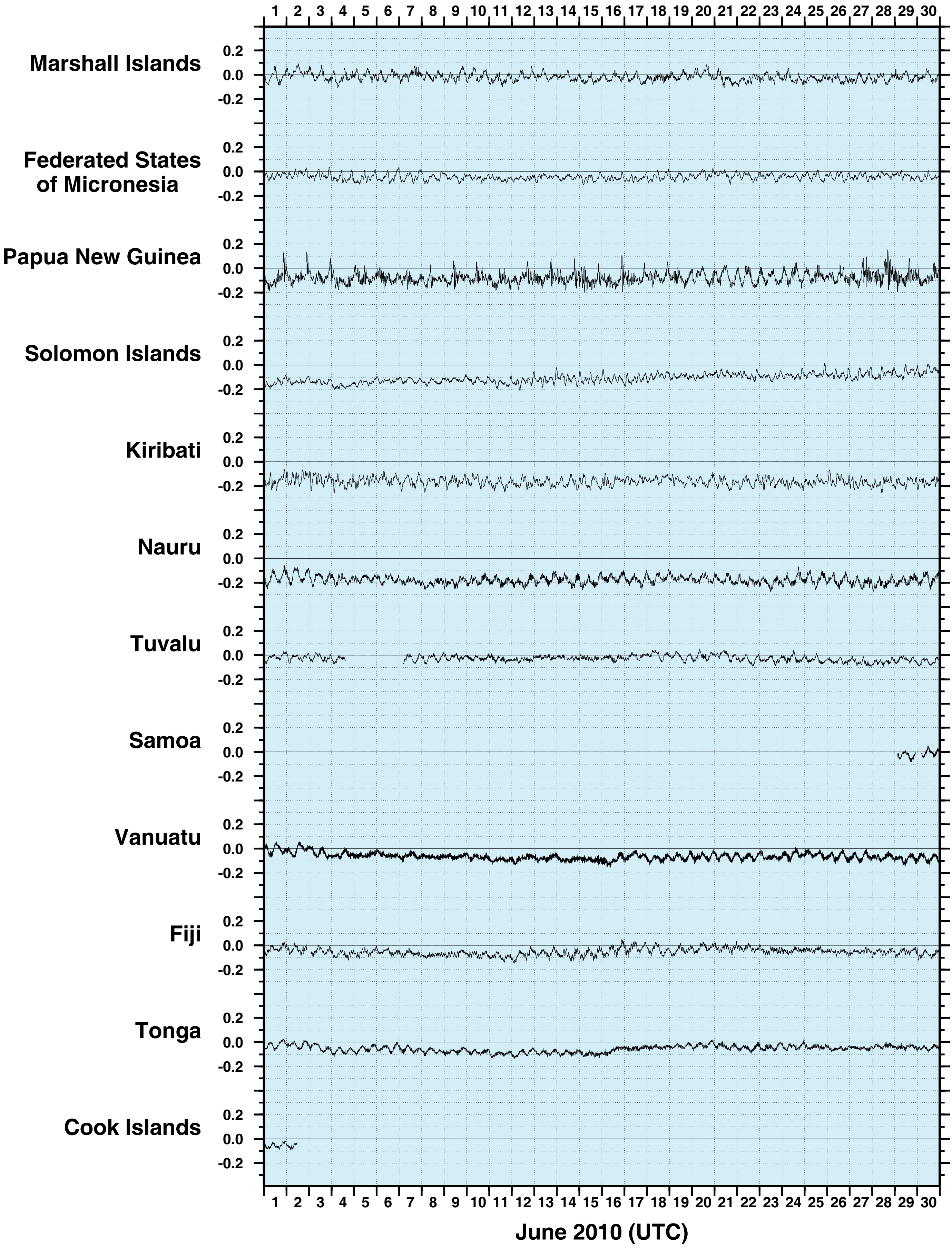


**Figure 4**

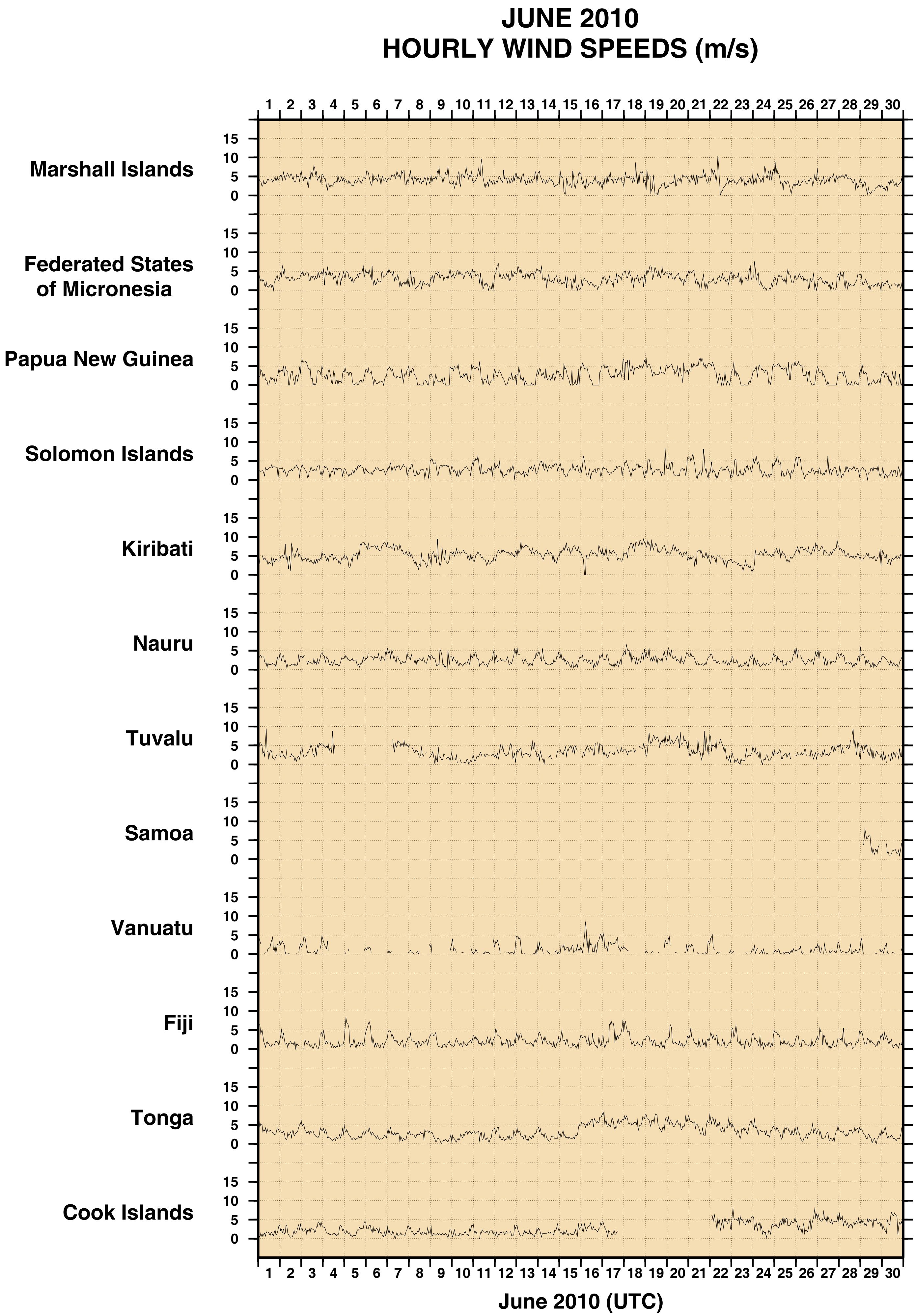
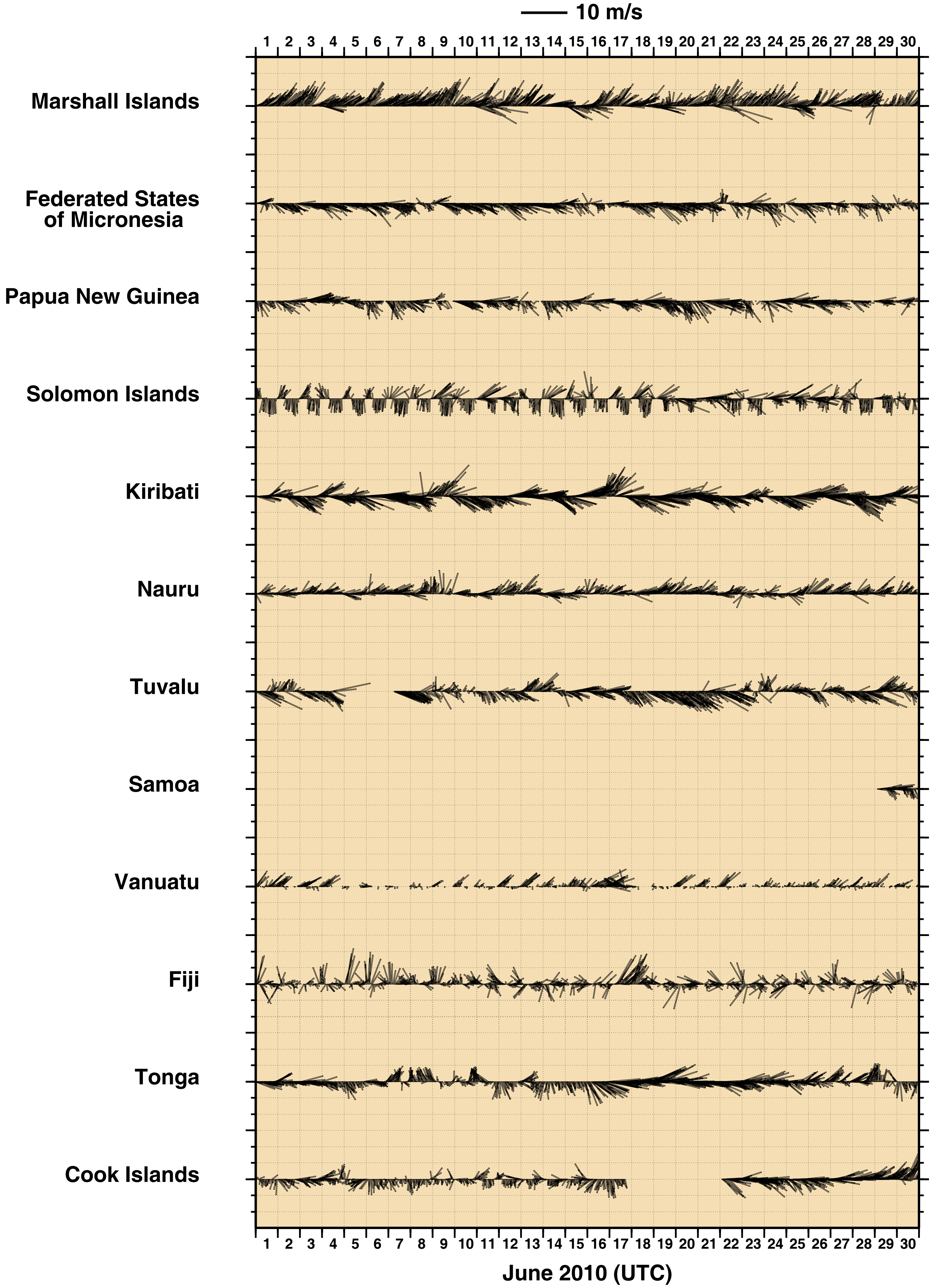

JUNE 2010
HOURLY WIND SPEEDS (m/s)
Marshall Islands
Federated States of Micronesia
Papua New Guinea
Solomon Islands
Kiribati
Nauru
Tuvalu
Samoa
Vanuatu
Fiji
Tonga
Cook Islands
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
June 2010 (UTC)

Figure 5

JUNE 2010

HOURLY INCIDENT WINDS (m/s, deg True)



## Figure 6

# JUNE 2010
# HOURLY MAXIMUM WIND GUSTS (m/s)

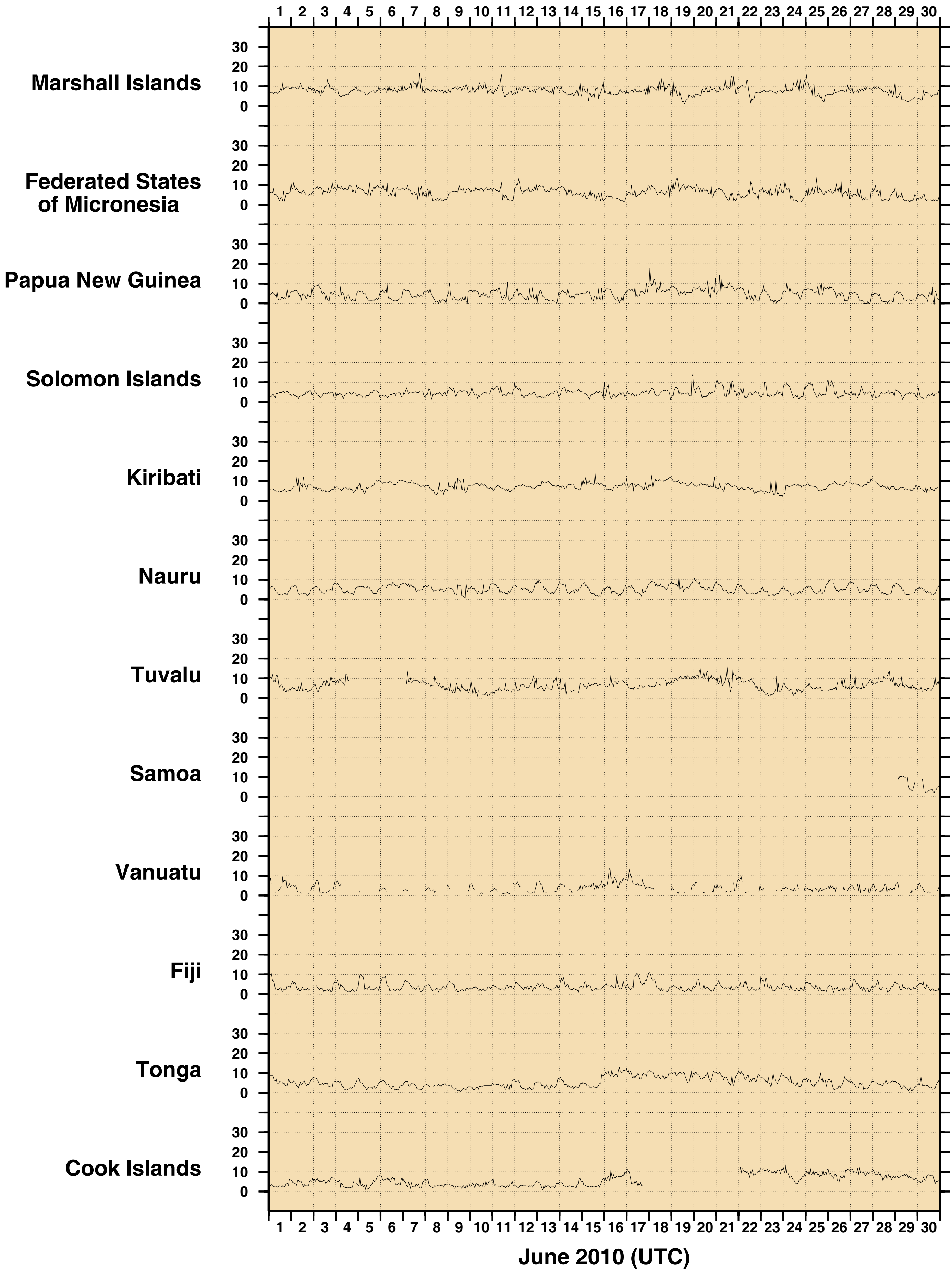


Figure 7

# JUNE 2010
# HOURLY AIR TEMPERATURES (˚C)

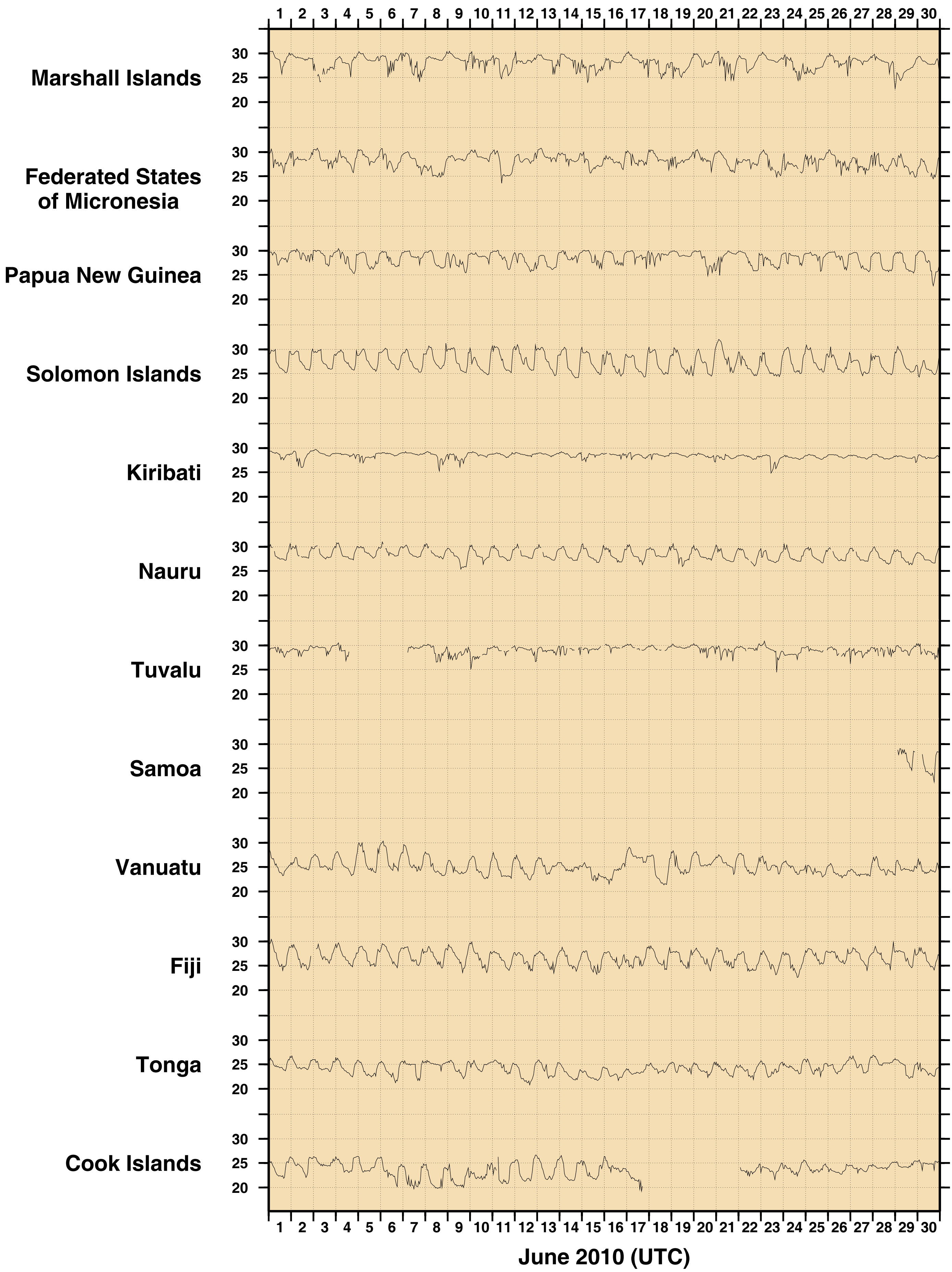
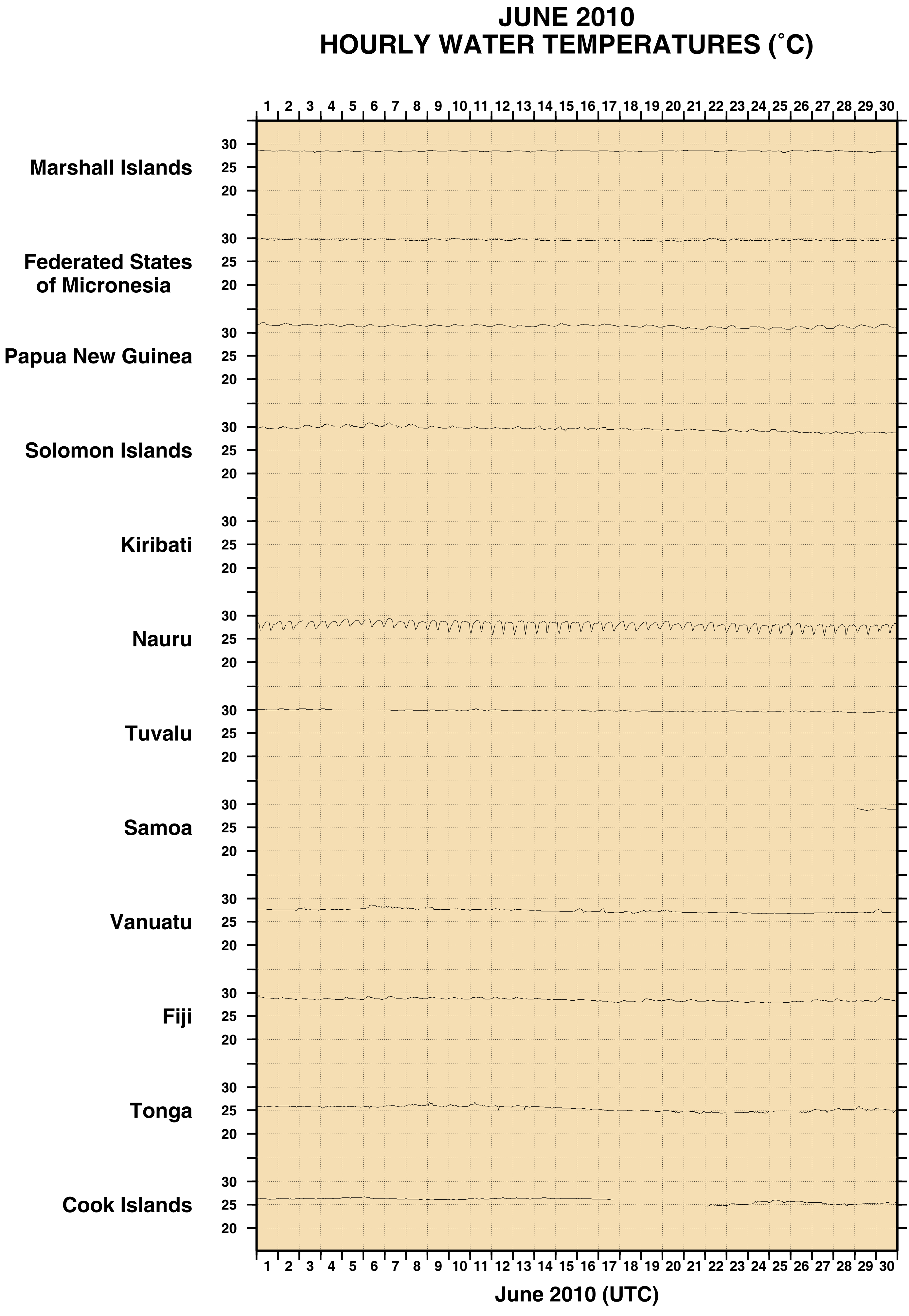


Figure 8


JUNE 2010
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
June 2010 (UTC)

## Figure 9
# JUNE 2010
# HOURLY ATMOSPHERIC PRESSURE (hPa)

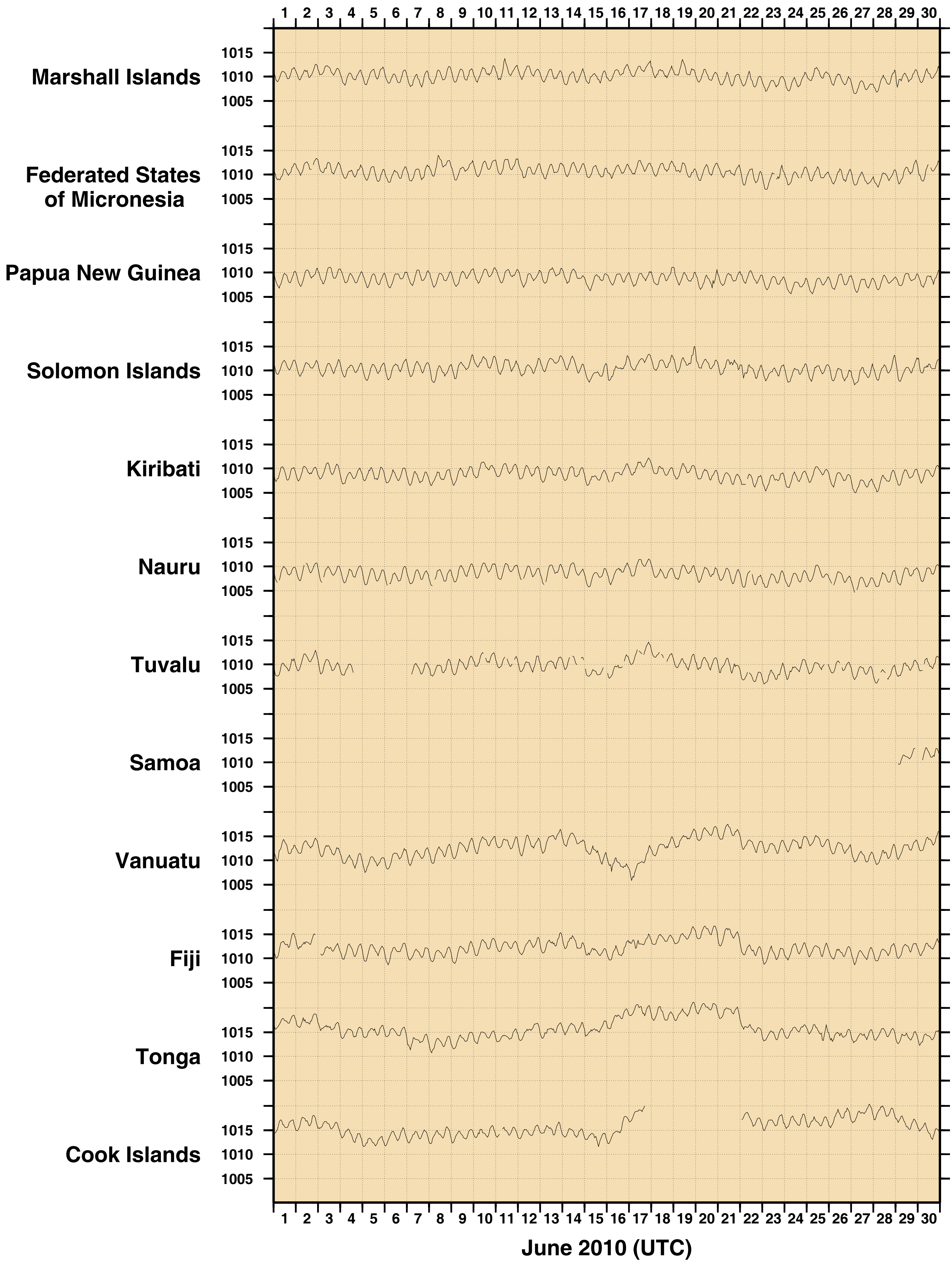
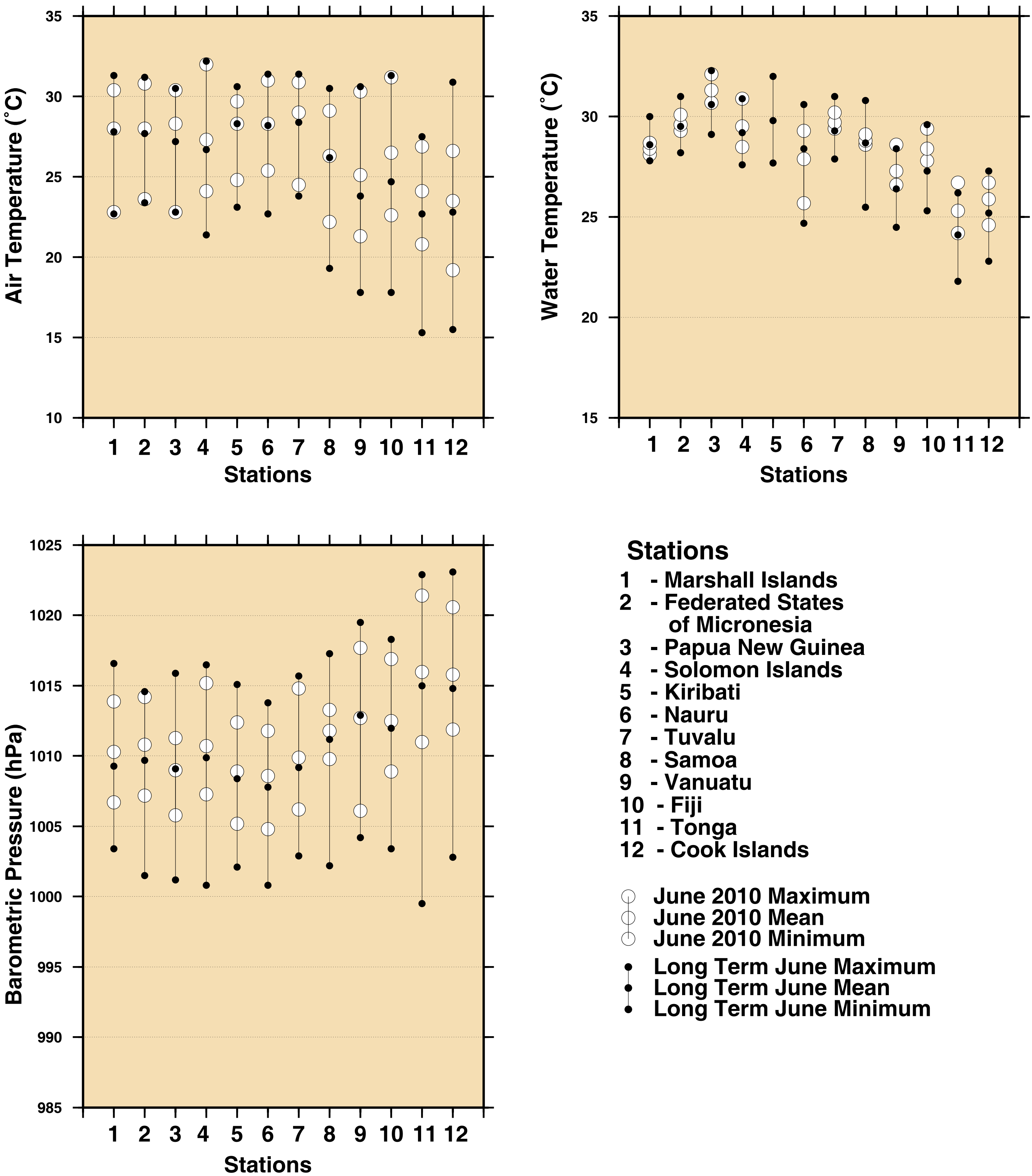


Figure 10

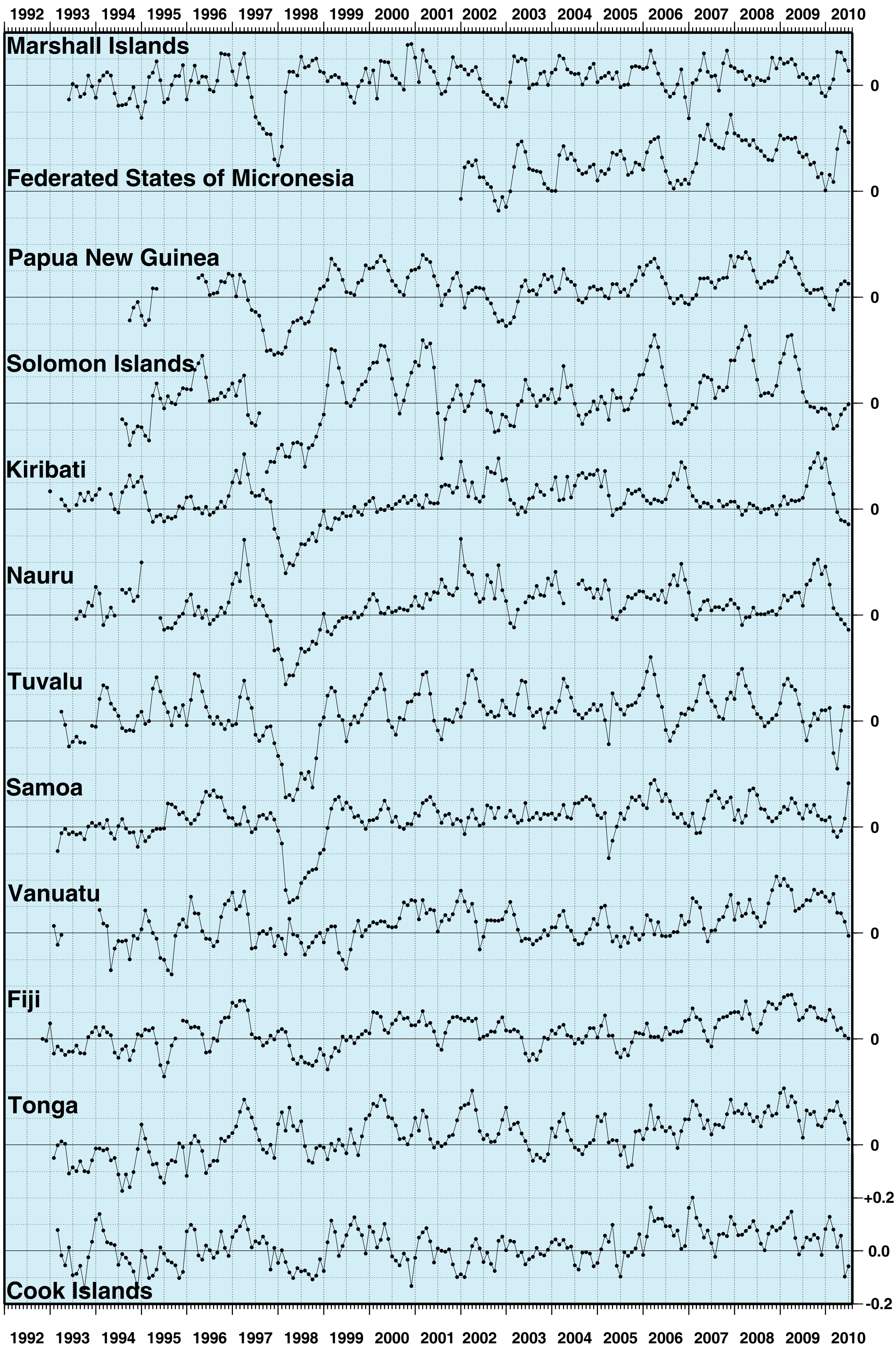
## Comparison of June 2010 Max, Min & Mean with Long Term June Values



## Figure 11

# MONTHLY MEAN SEA LEVELS TO JUNE 2010 (m)

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



## Figure 12

# SEA LEVEL ANOMALIES THROUGH JUNE 2010 (m)

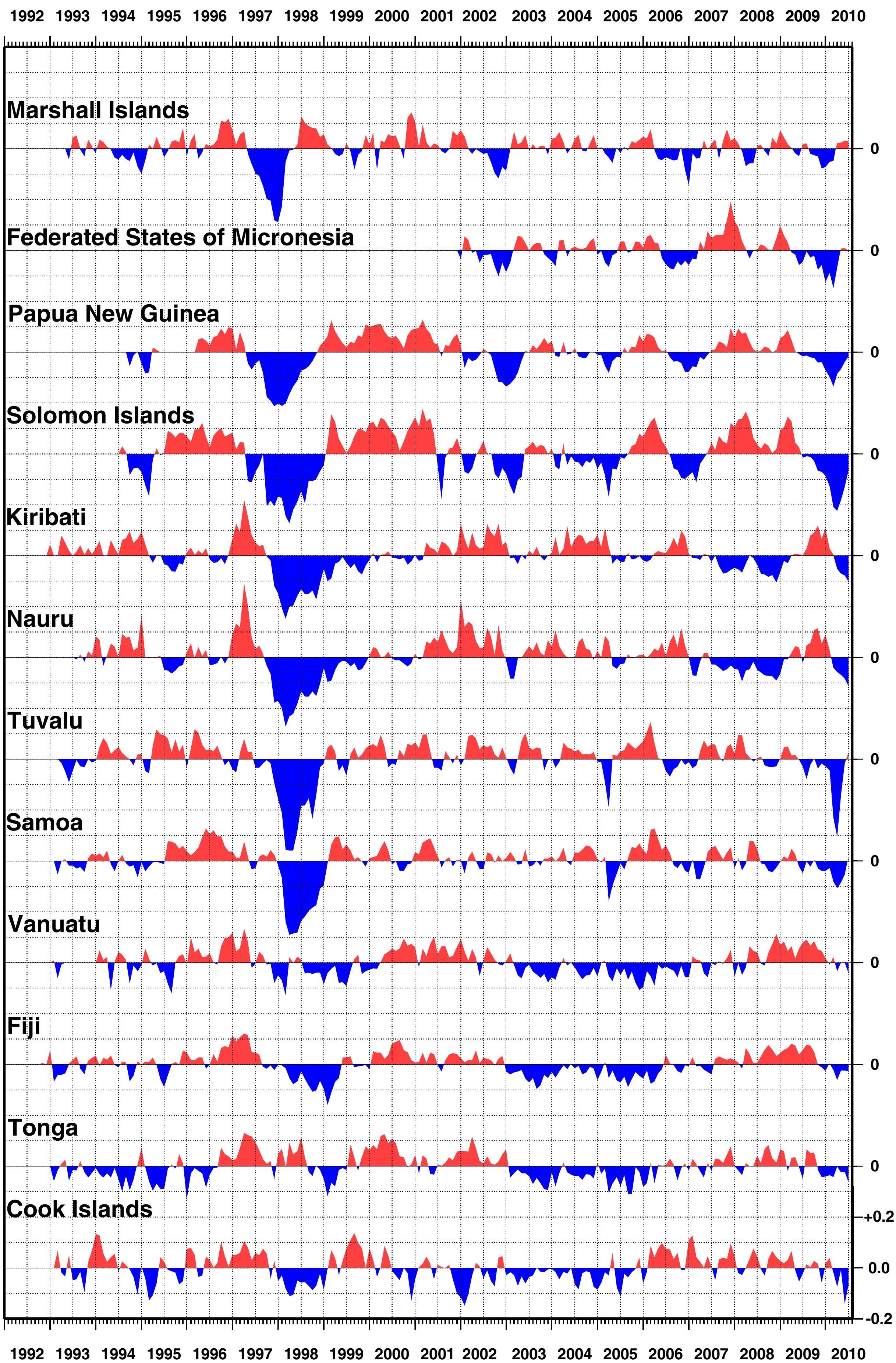
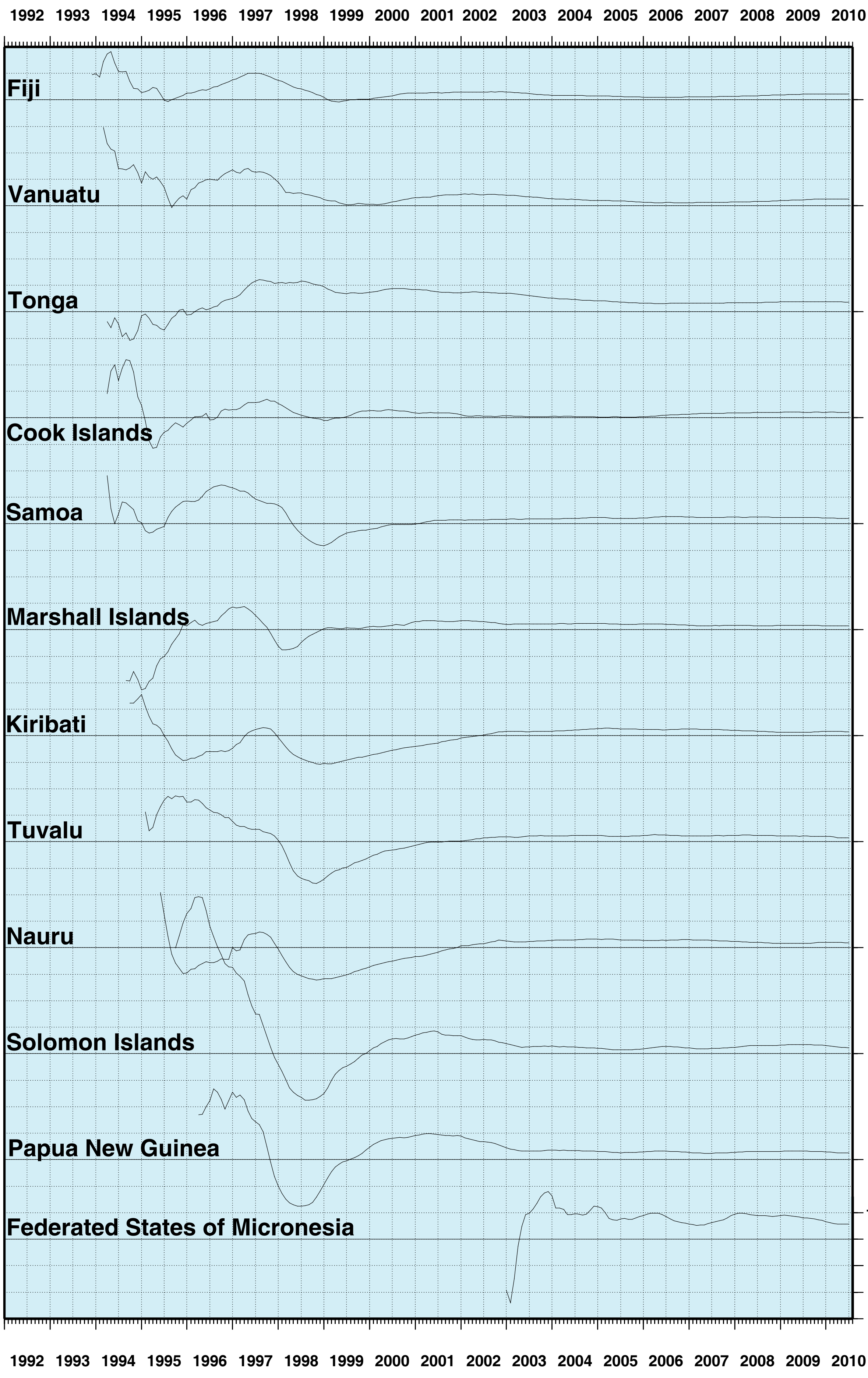


**Figure 13**

## SEA LEVEL TRENDS THROUGH JUNE 2010 (mm/year)



## Figure 14

# BAROMETRIC PRESSURE ANOMALIES THROUGH JUNE 2010 (hPa)

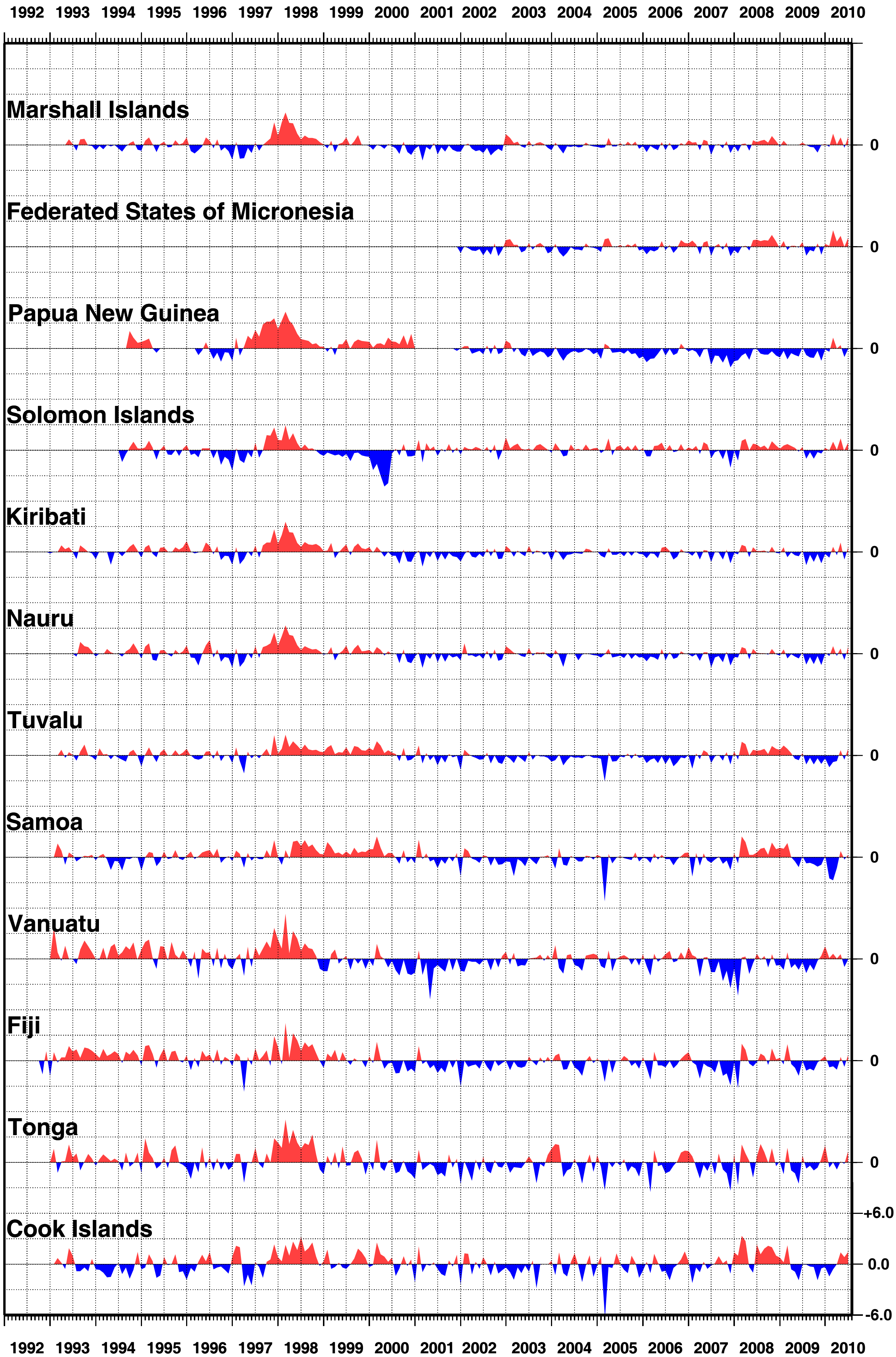


Figure 15

# WATER TEMPERATURE ANOMALIES THROUGH JUNE 2010 (˚C)

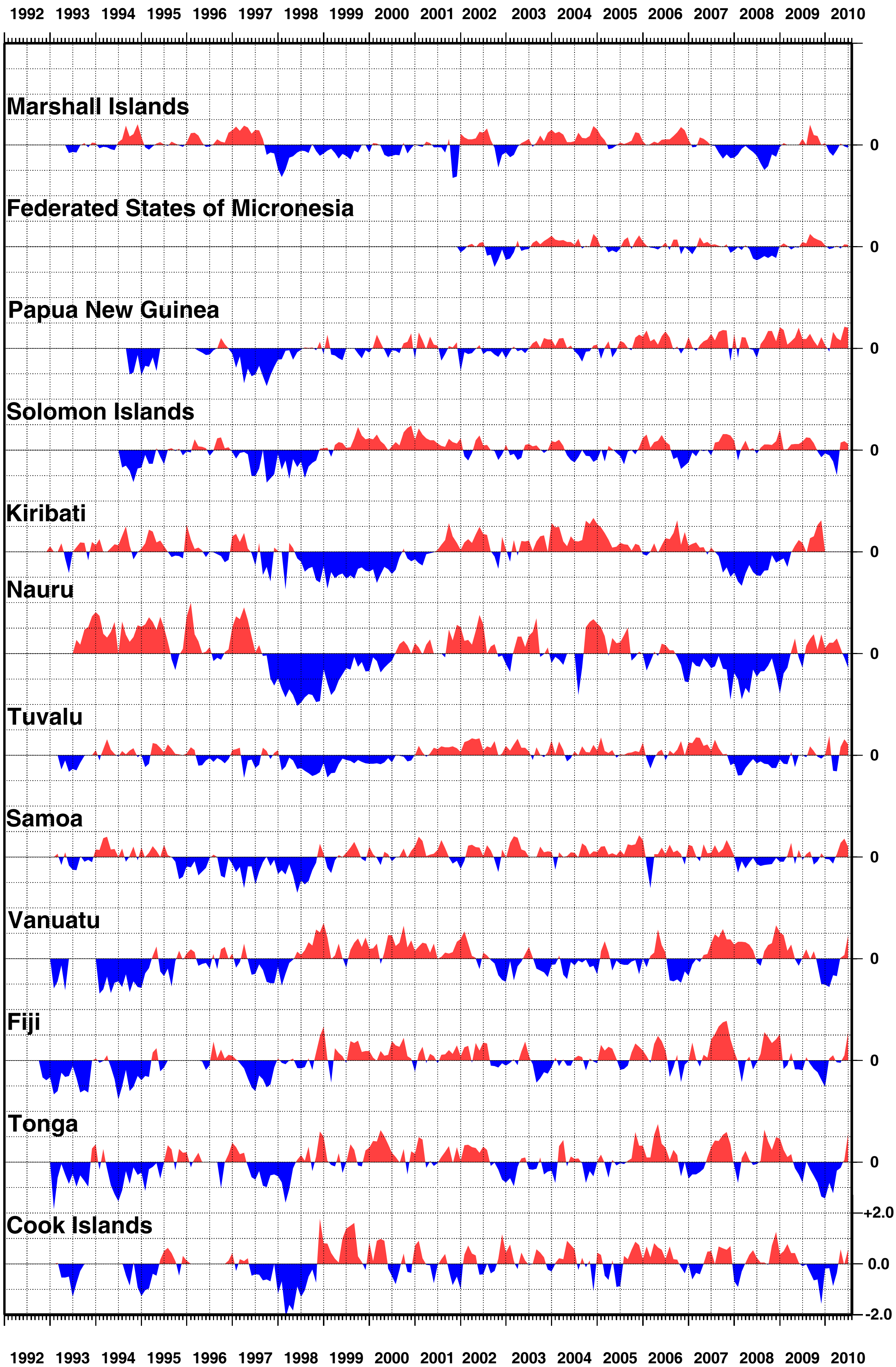


Figure 16

# AIR TEMPERATURE ANOMALIES THROUGH JUNE 2010 (°C)

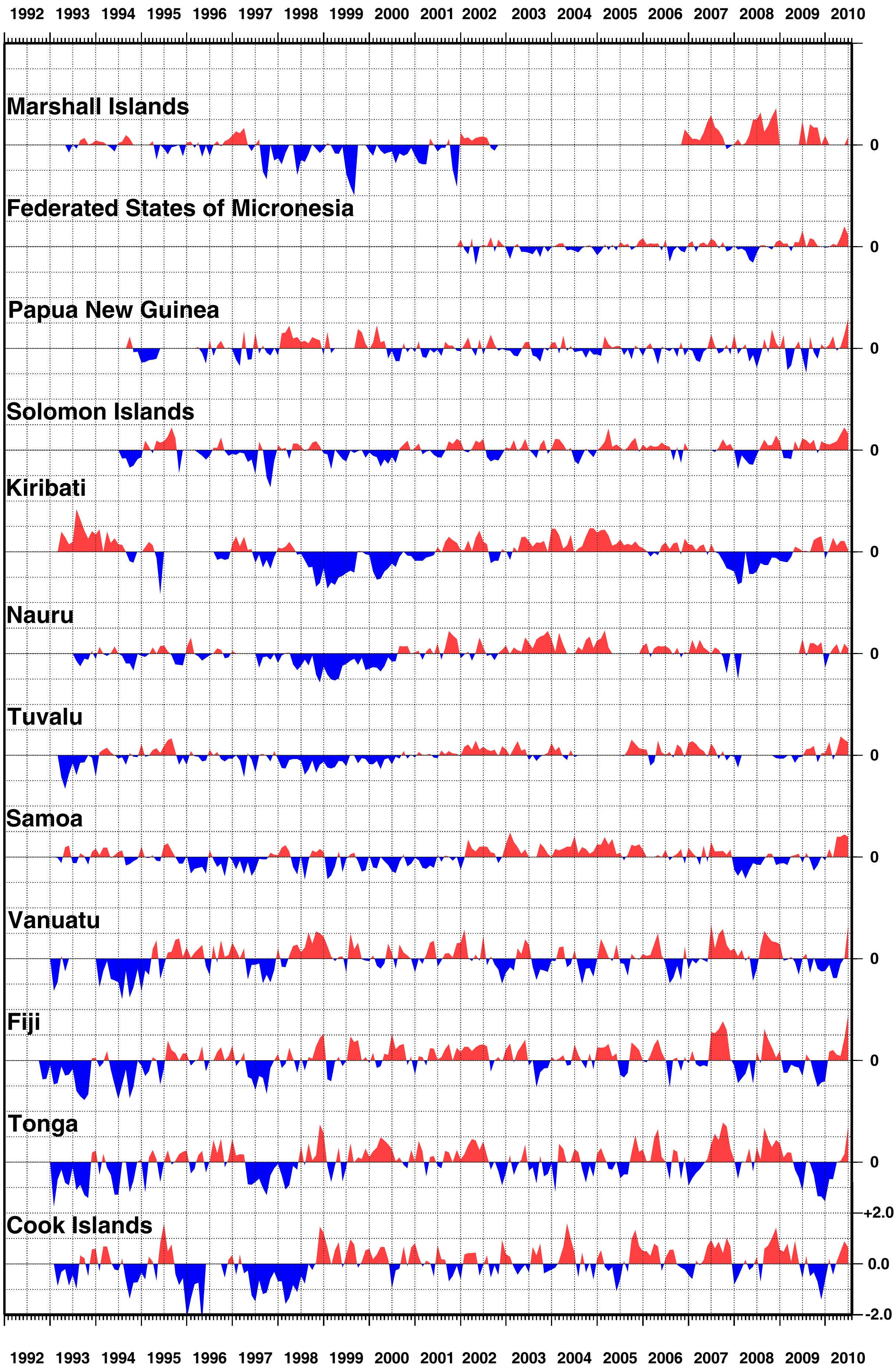


Figure 17

# SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED

GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE

* Patchy record