

**THE SOUTH PACIFIC SEA LEVEL & CLIMATE  
MONITORING PROJECT**

**MONTHLY DATA REPORT**

**NO. 168**

**JUNE 2009**



**Australian Government**

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**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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## **Bureau of Meteorology**

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#### **Quality Certification:**

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

June 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.

#### *June 2009*

- The SEAFRAME network continued to collect high quality sea level and associated meteorological information for monitoring climate variability and climate change.
- Sea levels during June were lower than what is normally observed at this time of the year at seven of the 12 monitoring stations. Further decreases are expected if climate conditions continue to evolve towards El Niño.
- Warmer than normal ocean temperatures and weaker than normal Trade Winds were observed across the equatorial Pacific. Observational data is showing strong indications that an El Niño event is developing across the Pacific basin.
- All international climate models predict further warming across the equatorial Pacific and the establishment of El Niño conditions in the second half 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 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	+5.3	-0.1
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+9.4	-0.1
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+5.4	+0.1
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+5.8	+0.2
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+6.0	-0.1
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+5.6	+0.3
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.3	0.0
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+4.2	-0.1
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+8.7	-0.1
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+8.1	-0.1
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+20.2	-0.6
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.2	0.0

## INTRODUCTION

Welcome to the June 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.

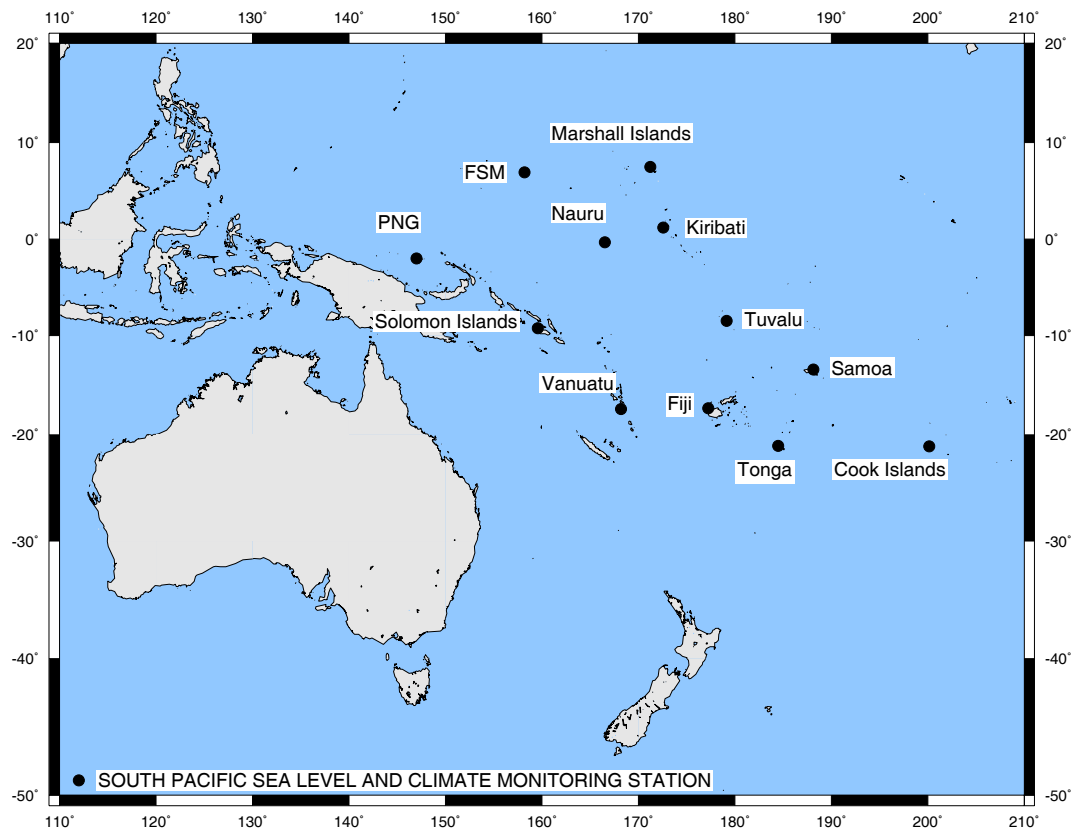
The SPSLCMP was developed as an Australian response to concerns raised by the member countries of the South Pacific Forum over the potential impacts of global warming on climate and sea levels in the Pacific. Support was provided for the installation of SEAFRAME monitoring stations across the South Pacific 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*

## JUNE CLIMATOLOGY

Climate conditions across the equatorial Pacific during June were characteristic of a developing El Niño. Ocean heat content continued to warm, equatorial Trade Winds were weaker than normal and equatorial cloudiness in the vicinity of the dateline increased. All international climate models are predicting that the equatorial Pacific will continue to warm above El Niño thresholds during the second half of 2009.

The Southern Oscillation Index (SOI) is yet to demonstrate a developing El Niño and actually rose during June to a monthly value of -2 following the May value of -5 (**Figure B**). Higher than normal atmospheric pressure in the vicinity of Tahiti during the last few weeks of June caused an increase in the SOI, but it is expected to fall again in line with the regional climate pattern.

Sea surface temperatures continued to warm steadily across the equatorial Pacific during June, as it has done since February 2009. Warm sea surface temperature anomalies are now well established across much of the equatorial Pacific, with anomalies of more than 1.0 °C being observed across the eastern equatorial Pacific in particular (**Figure C**).

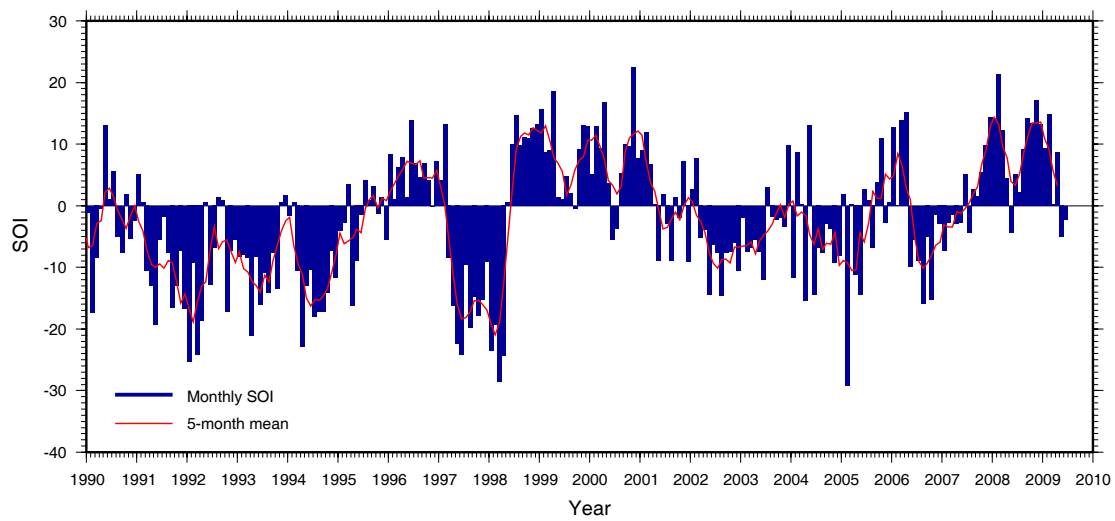
Subsurface temperatures also continued to warm steadily during June. Warmer than normal subsurface temperatures continue to extend across the entire equatorial Pacific and have intensified in the eastern equatorial Pacific (**Figure D**).

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. During June 2009 the easterly Trade Winds were weaker than normal across much of the equatorial Pacific (**Figure E**). Cloudiness over the equatorial Pacific near the dateline continued to increase during June, which is consistent with a developing El Niño.

All six international computer models surveyed by the Bureau of Meteorology are unanimous in their predictions of further sea surface warming and the establishment of El Niño conditions in the coming months. As such the likelihood of an El Niño developing in 2009 is higher than it was a month ago.

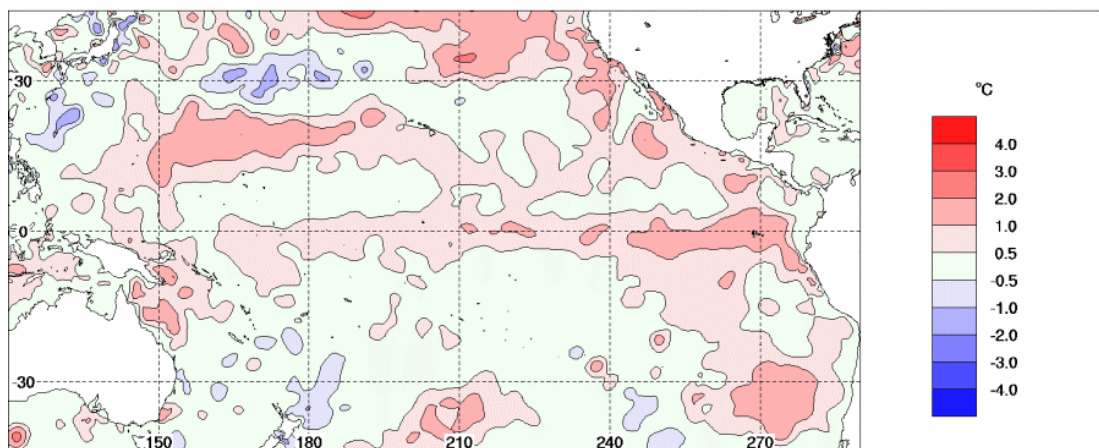
*The preceding description of the climatology of the Pacific region, and Figures B, C and D are based on information sourced from the National Climate Centre of the Australian Bureau of Meteorology at <http://www.bom.gov.au/climate/>. Figure E was generated from the Tropical Atmosphere Ocean project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

## Southern Oscillation Index (SOI)

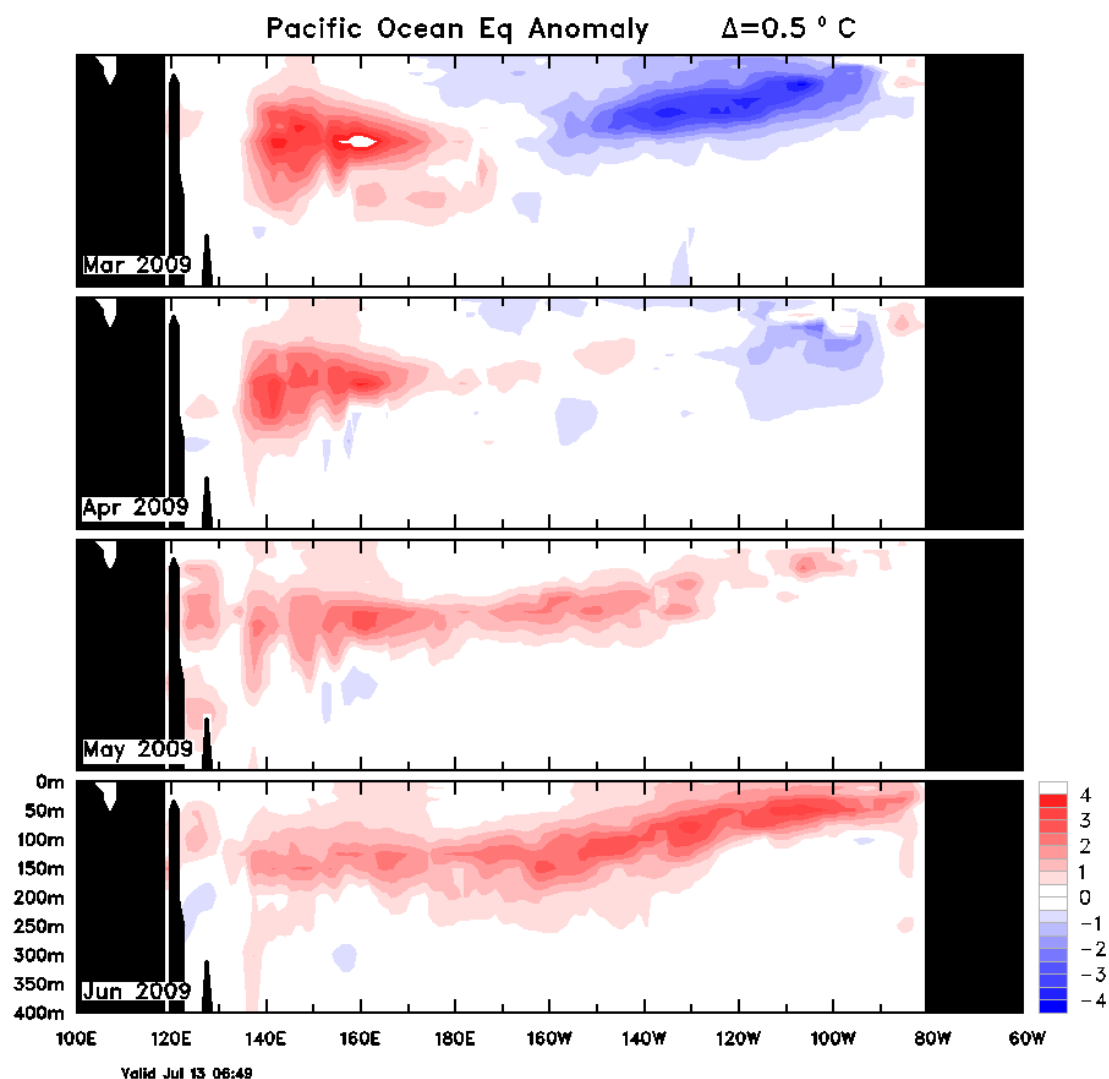


**Figure B:** The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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

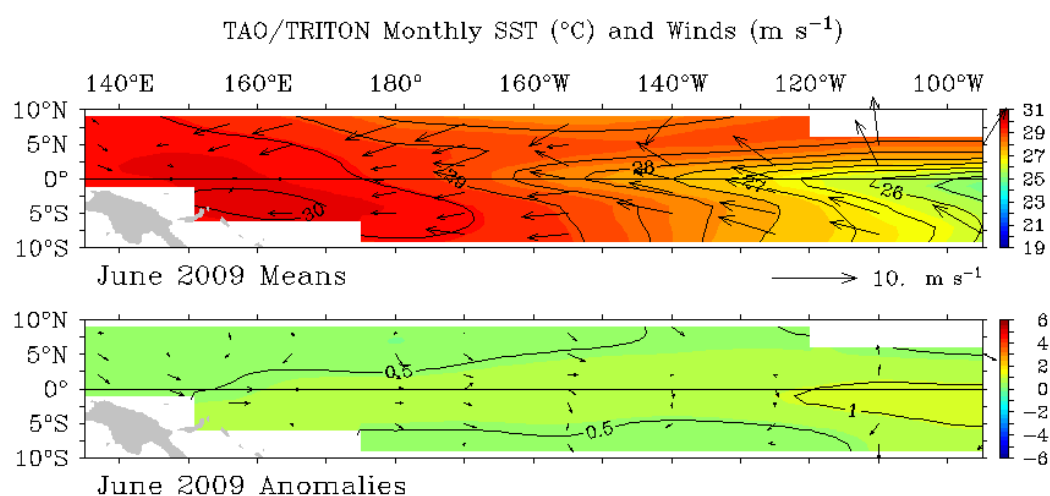
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**Figure C:** Sea surface temperature anomaly ( $^{\circ}\text{C}$ ) for June 2009.



**Figure D:** Equatorial depth-longitude section of ocean temperature anomalies for March 2009 through to June 2009. Contour interval is  $0.5^{\circ}\text{C}$ .



TAO/NDBC/NOAA

Jul 13 2009

**Figure E:** Monthly mean wind vectors (top) and anomalies (bottom) for June 2009. 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 full moon on the 7<sup>th</sup> of June and a new moon on the 22<sup>nd</sup> 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 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.

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. Wind gusts at Cook Islands reached 20 m/s (72 km/hr or 39 knots) on 6<sup>th</sup> June 2009 due to the influence of a low barometric pressure system.

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 maximum June air temperature of 31.2°C was recorded at FSM and new minimum June air temperatures were recorded at PNG (22.8°C) and Tonga (15.3°C). New minimum June water temperatures were recorded at Nauru (24.7°C) and Tonga (21.8°C). New maximum June barometric pressures were recorded at Tonga (1022.9hPa) and Cook Islands (1023.1hPa).

### 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 June 2009 lower than normal sea levels were observed at FSM, PNG, Solomon Islands, Tuvalu, Samoa, Tonga and Cook Islands. Higher than normal sea levels continued to be observed at Vanuatu and Fiji, while at Marshall Islands, Kiribati and Nauru sea levels were near to what is normally observed at this time of the year. If El Niño conditions continue to develop across the equatorial Pacific then further falls in sea level may be observed.

### Sea Level Trends

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

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Location	Lat / Long	Installation Date	Trend (mm/yr)	Change from previous month
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Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.3	0.0
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+4.2	-0.1
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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 2009 barometric pressures were near normal across the region. In association with the warming trend, barometric pressure anomalies appear to be increasing across the region.

The **water temperature anomalies** (**Figure 15**) show slightly higher than normal water temperatures were observed at PNG, Solomon Islands and Kiribati during June 2009. Slightly lower than normal water temperatures were observed at Nauru, Tuvalu and Tonga, while elsewhere water temperatures were near to what is normally observed at this time of the year.

The **air temperature anomalies** (**Figure 16**) during June 2009 reveal air temperatures were slightly warmer than normal around Marshall Islands, FSM, Solomon Islands and Nauru, and slightly cooler than normal at Fiji, Tonga 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 very high during June 2009, with only small losses of data from PNG, Nauru, Samoa and Fiji due to communication problems. At Tuvalu and Vanuatu problems with the primary sea level sensors were encountered and data from the secondary sea level sensors were used. Calibration and maintenance of the Nauru SEAFRAME was performed from 17-22 June 2009, including repair of the air temperature sensor.

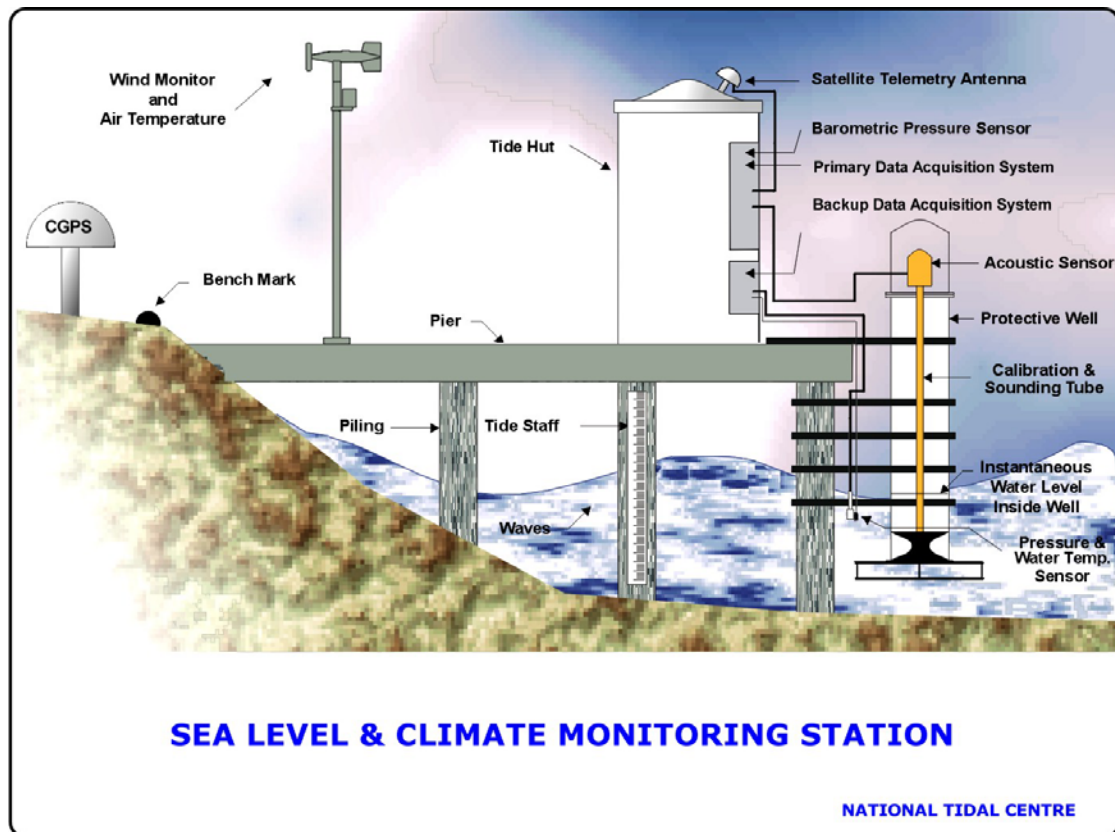
At Tuvalu the water temperature sensor failed and data from the backup water temperature sensor were used. Similarly at Tonga data from the backup water temperature sensor were used to replace intermittent spikes in the primary water level sensor. At Marshall Islands intermittent problems with the air temperature, water temperature and barometric pressure data were encountered and erroneous data were 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:

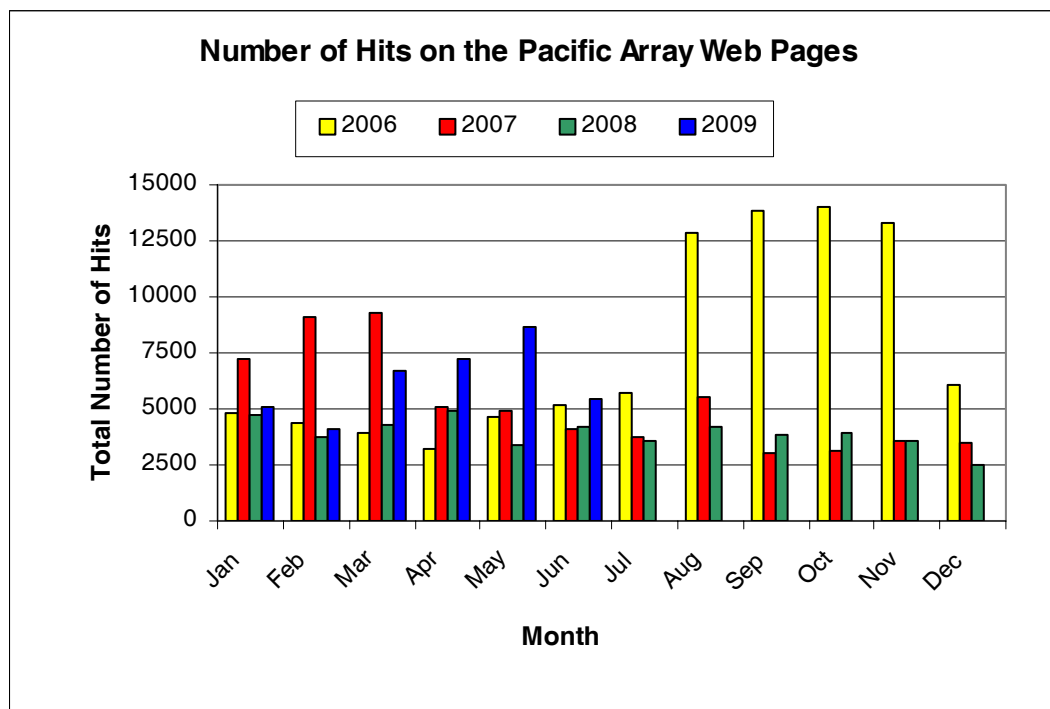
- (1) Primary water level using a Bartex 'AQUATRAK' acoustic-in-air sensor, and
- (2) Secondary water level (or backup) using a Druck pressure transducer mounted close to the seabed.

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 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>

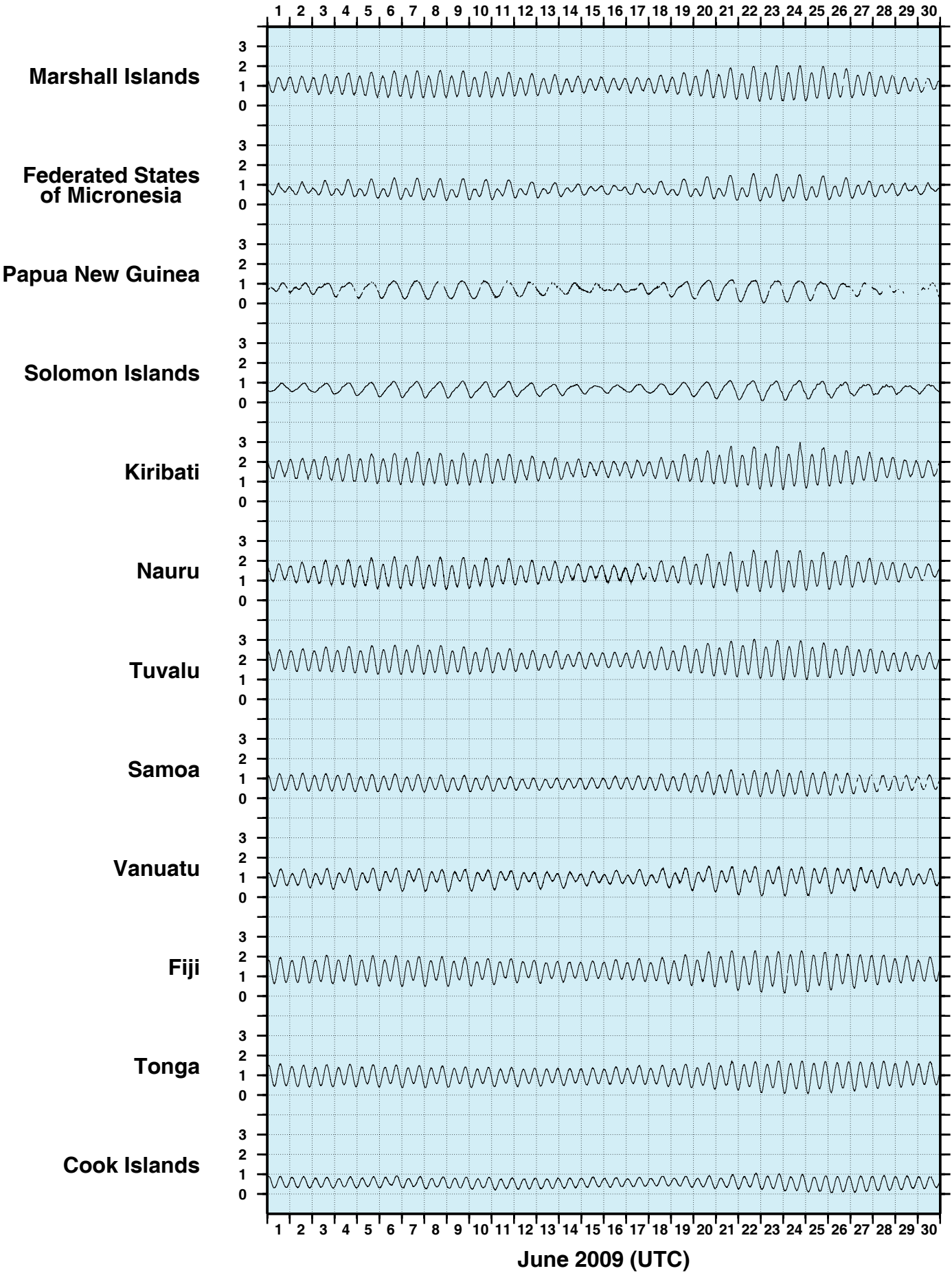
Please refer to: <http://www.bom.gov.au/oceanography/projects/spslcmp/spslcmp.shtml> for details.

Please also note the following:

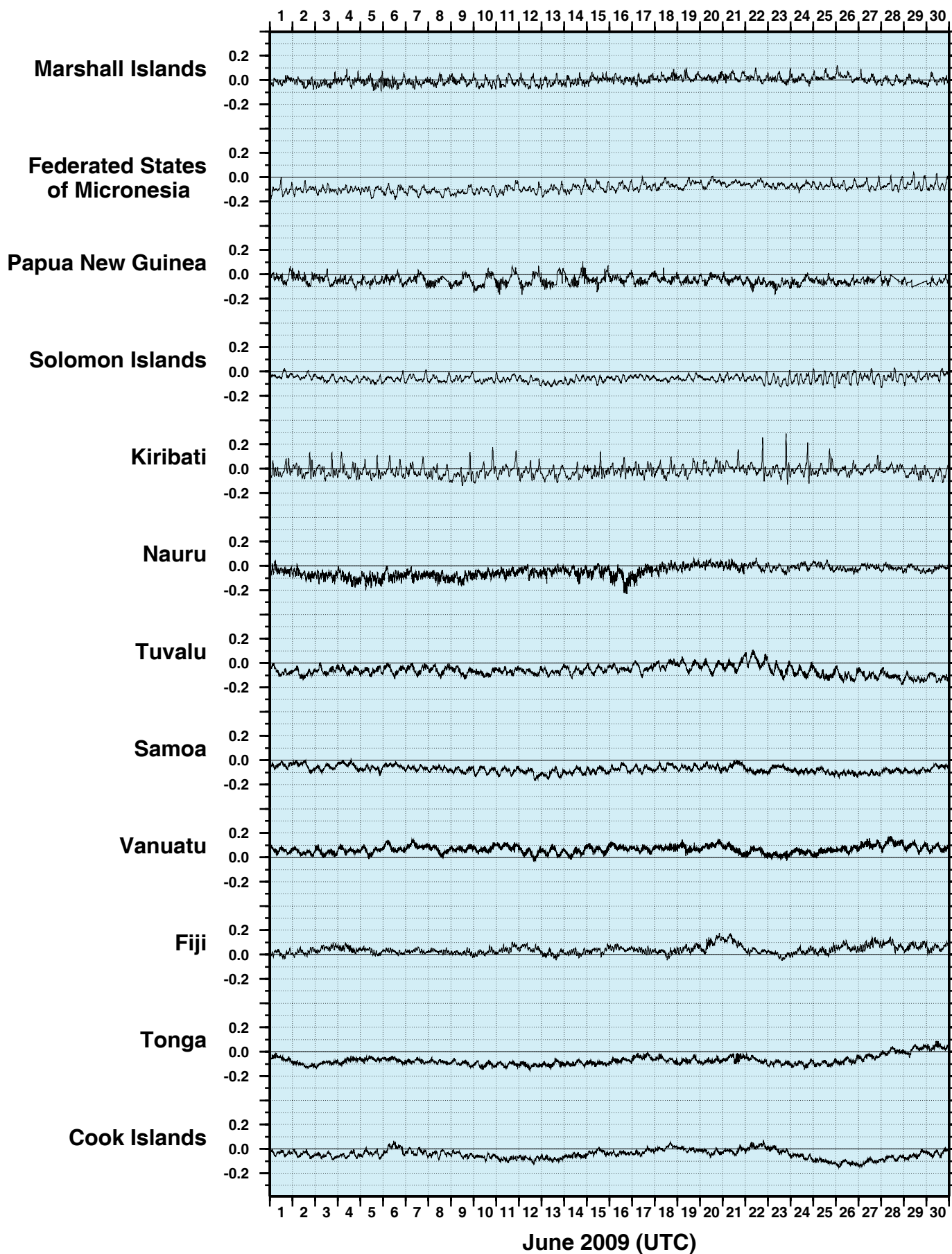
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Individuals and organisations are advised that quality controlled six-minute or hourly data from these stations are available on request from *NTC*. Some handling fees may be charged. For commercial agencies requesting data, some additional costs may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

**Figure 1**  
**JUNE 2009**  
**SIX MINUTE WATER LEVEL OBSERVATIONS (m)**



**Figure 2**  
**JUNE 2009**  
**SIX MINUTE RESIDUAL WATER LEVELS (m)**





**Figure 3**  
**JUNE 2009**  
**SIX MINUTE RESIDUALS**  
**ADJUSTED FOR ATMOSPHERIC PRESSURE (m)**

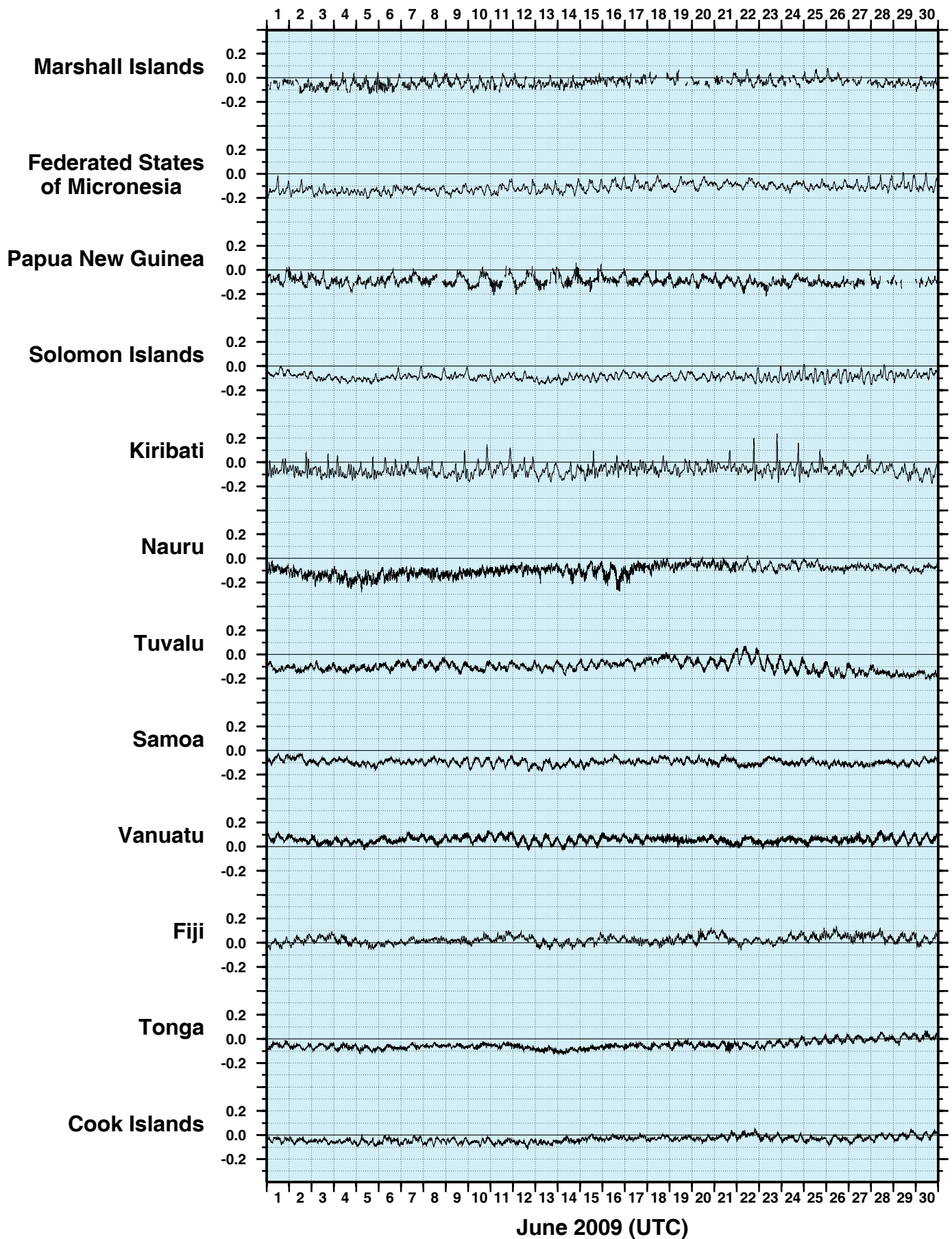


Figure 4

**JUNE 2009**  
**HOURLY WIND SPEEDS (m/s)**

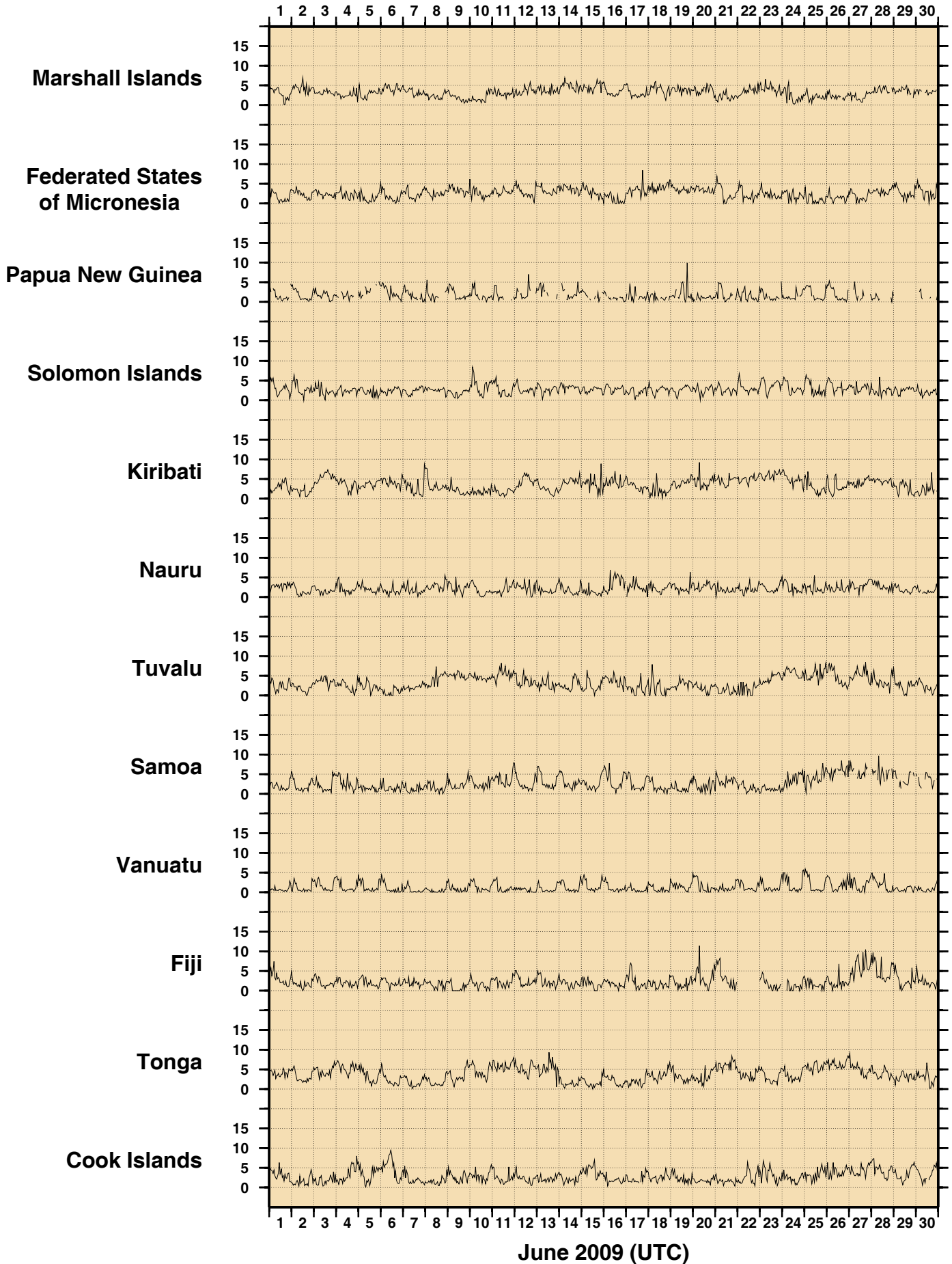
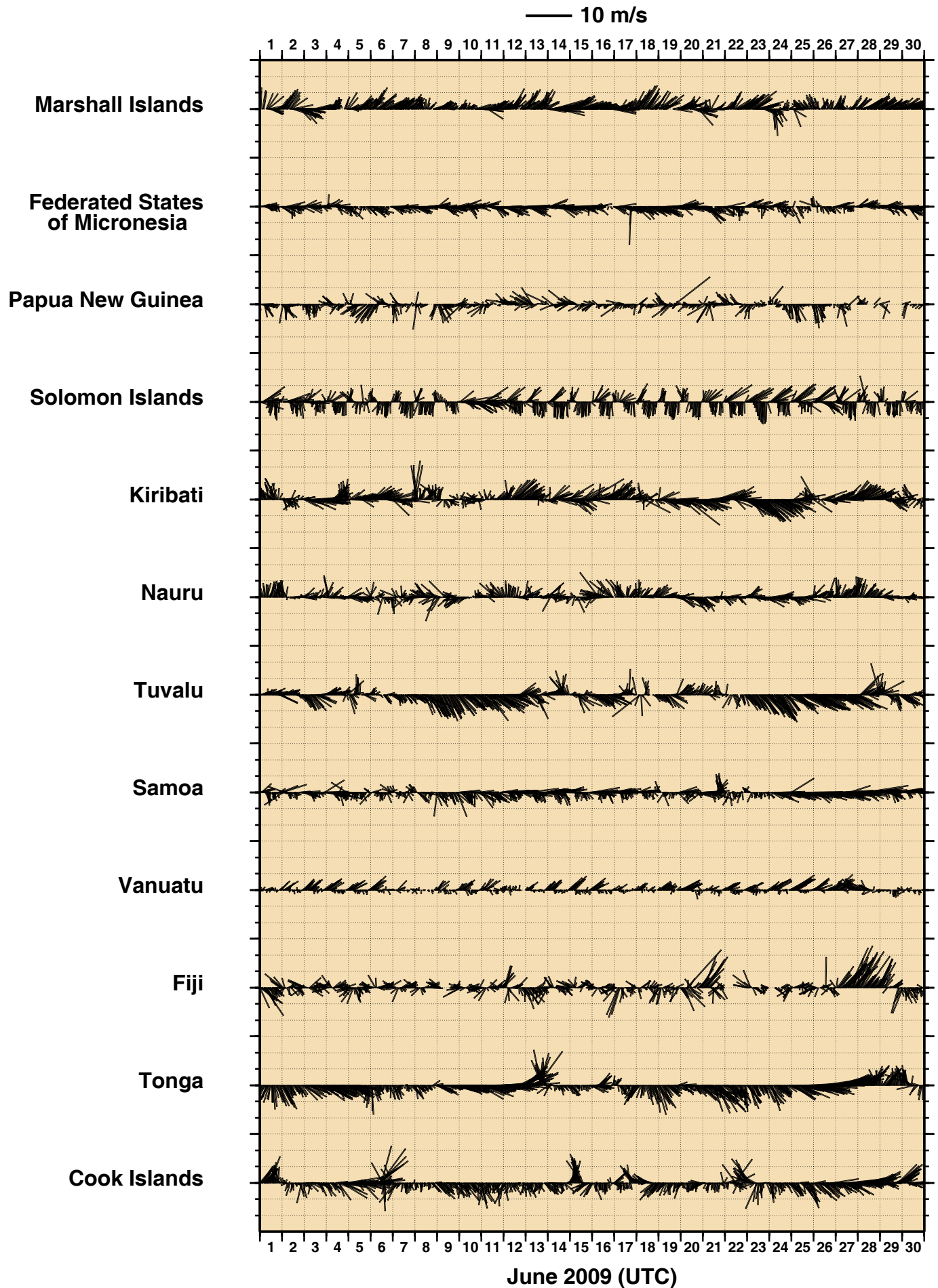
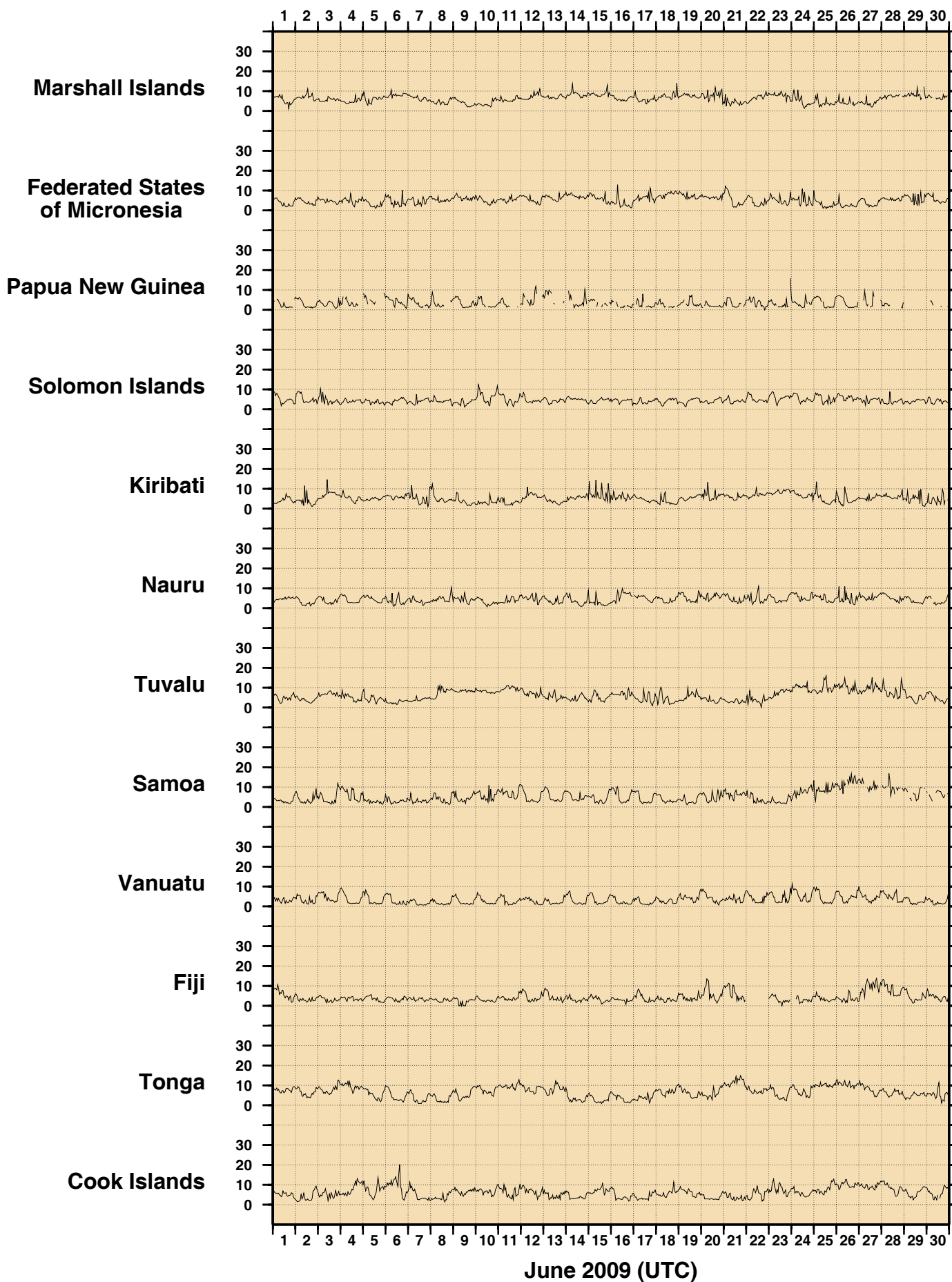


Figure 5  
JUNE 2009  
HOURLY INCIDENT WINDS (m/s, deg True)



**Figure 6**  
**JUNE 2009**  
**HOURLY MAXIMUM WIND GUSTS (m/s)**



**Figure 7**  
**JUNE 2009**  
**HOURLY AIR TEMPERATURES (°C)**

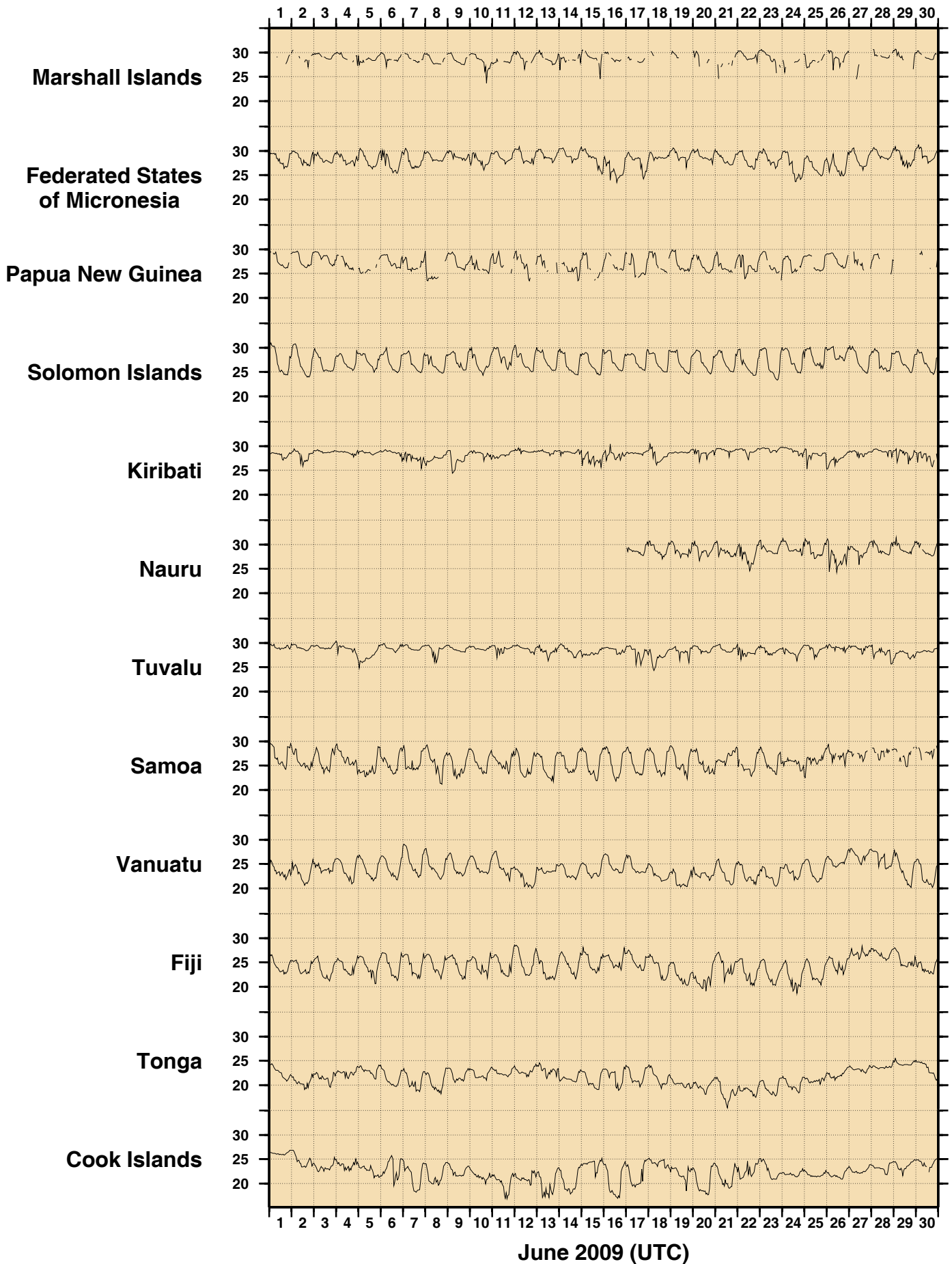
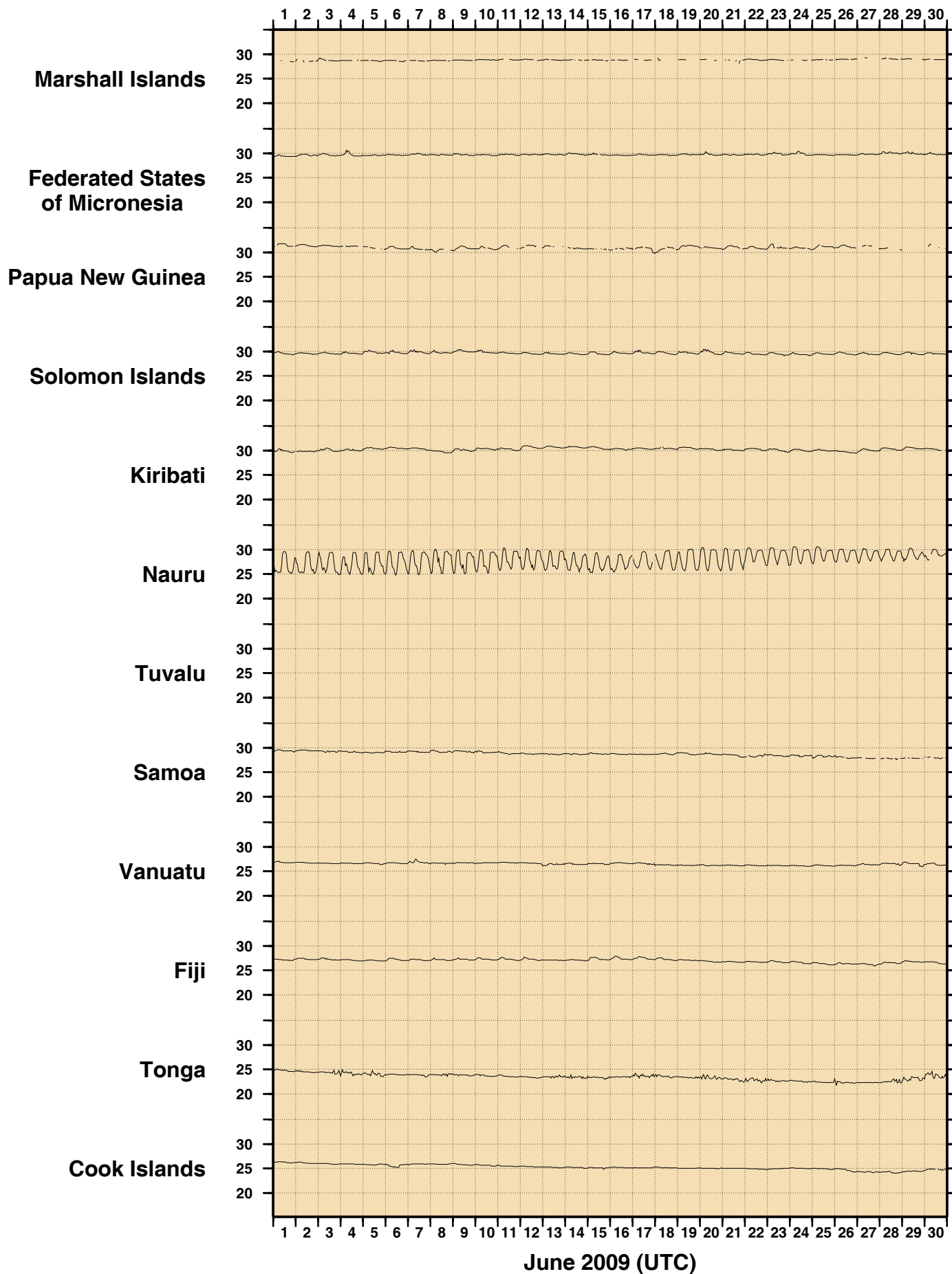




Figure 8  
JUNE 2009  
HOURLY WATER TEMPERATURES (°C)



**Figure 9**  
**JUNE 2009**  
**HOURLY ATMOSPHERIC PRESSURE (hPa)**

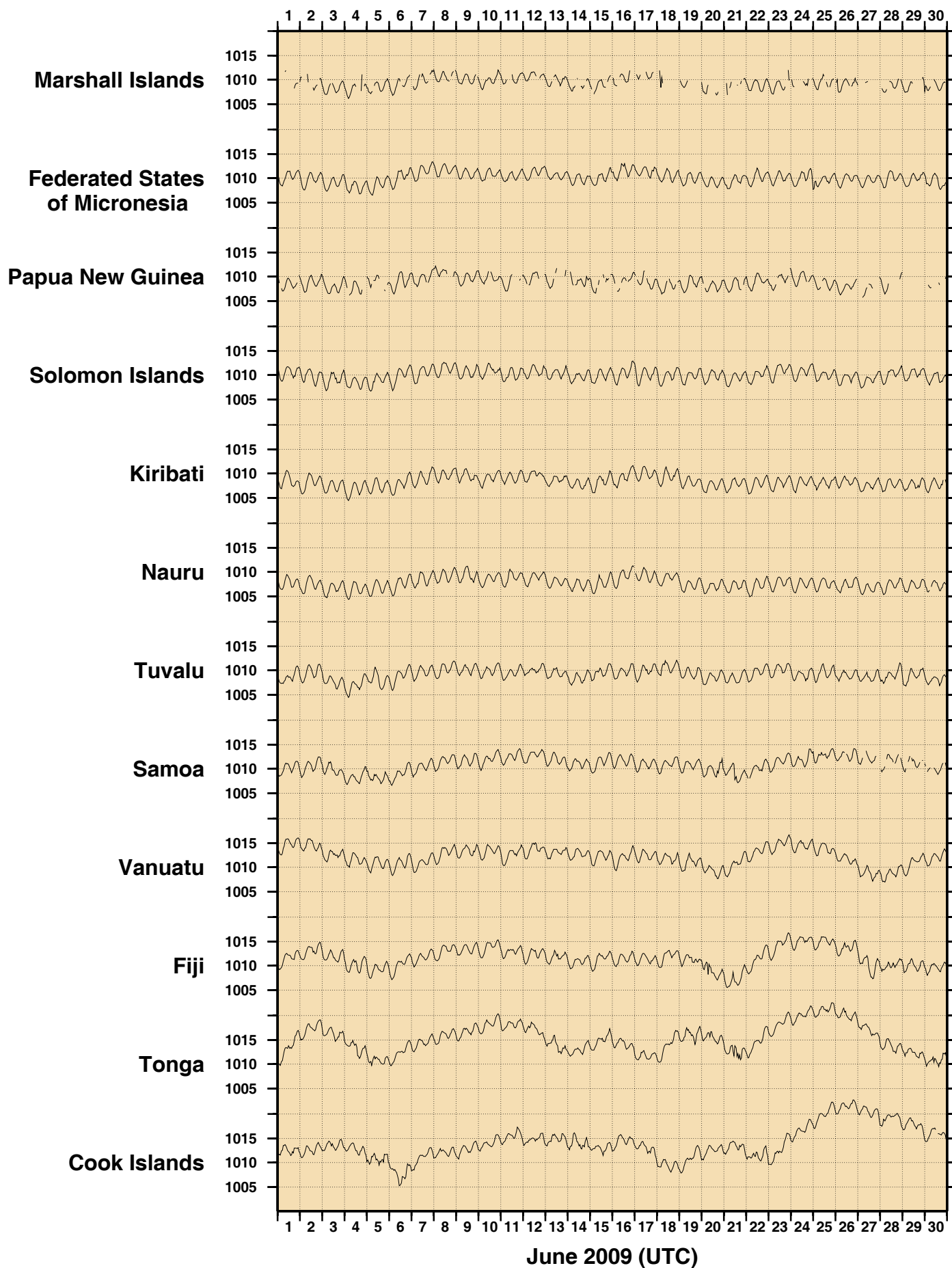
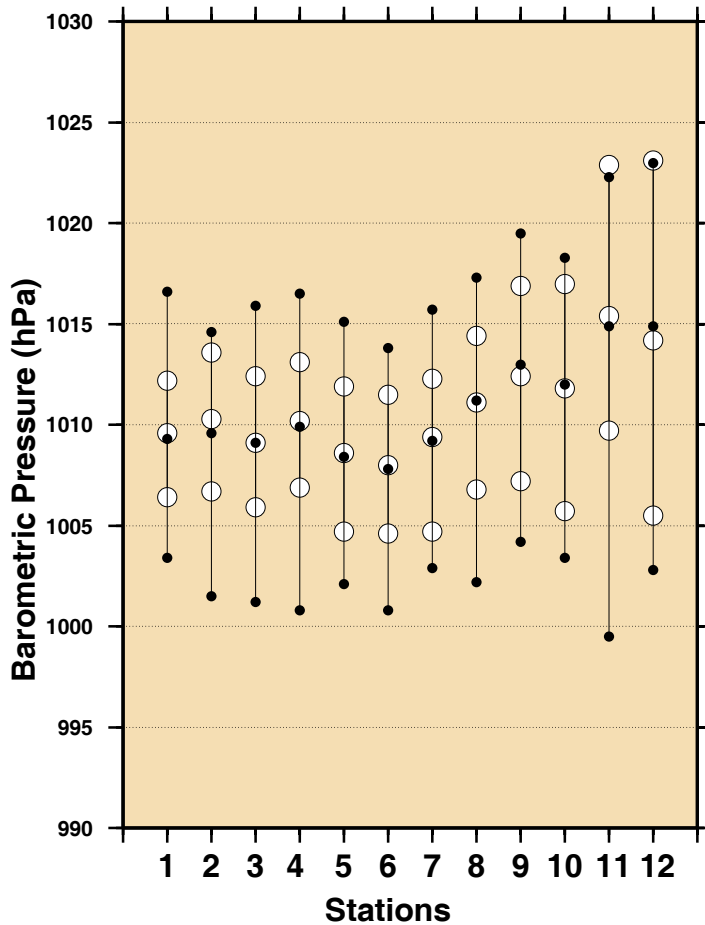
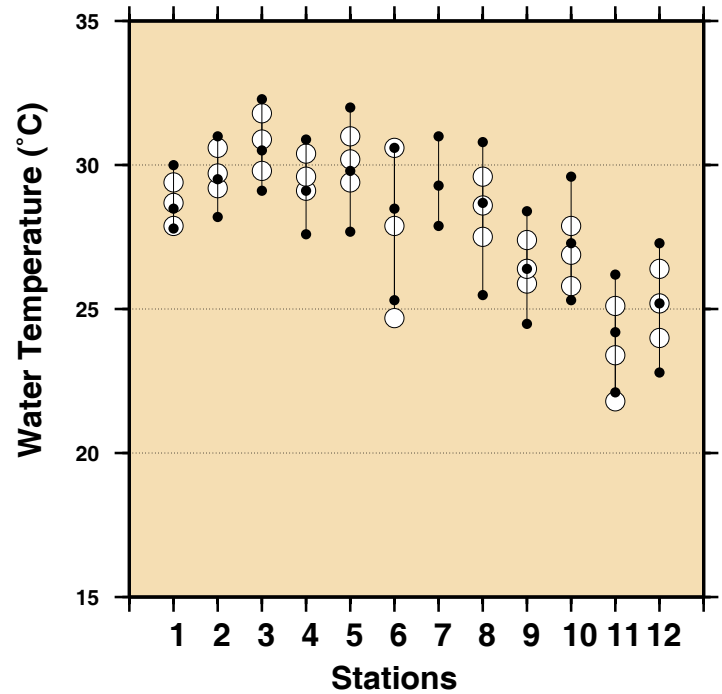
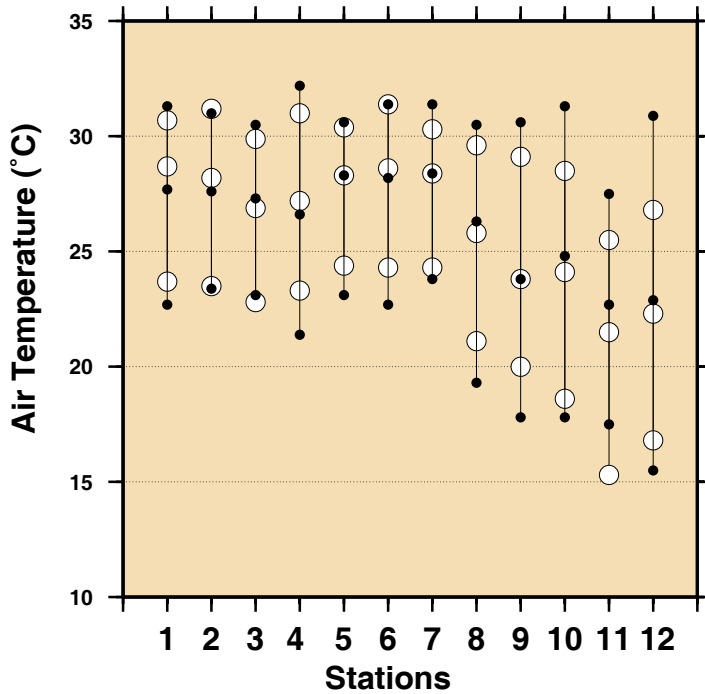


Figure 10

## Comparison of June 2009 Max, Min & Mean with Long Term June 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

- June 2009 Maximum
- June 2009 Mean
- June 2009 Minimum
- Long Term June Maximum
- Long Term June Mean
- Long Term June Minimum



Figure 11

## MONTHLY MEAN SEA LEVELS TO JUNE 2009 (m)

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

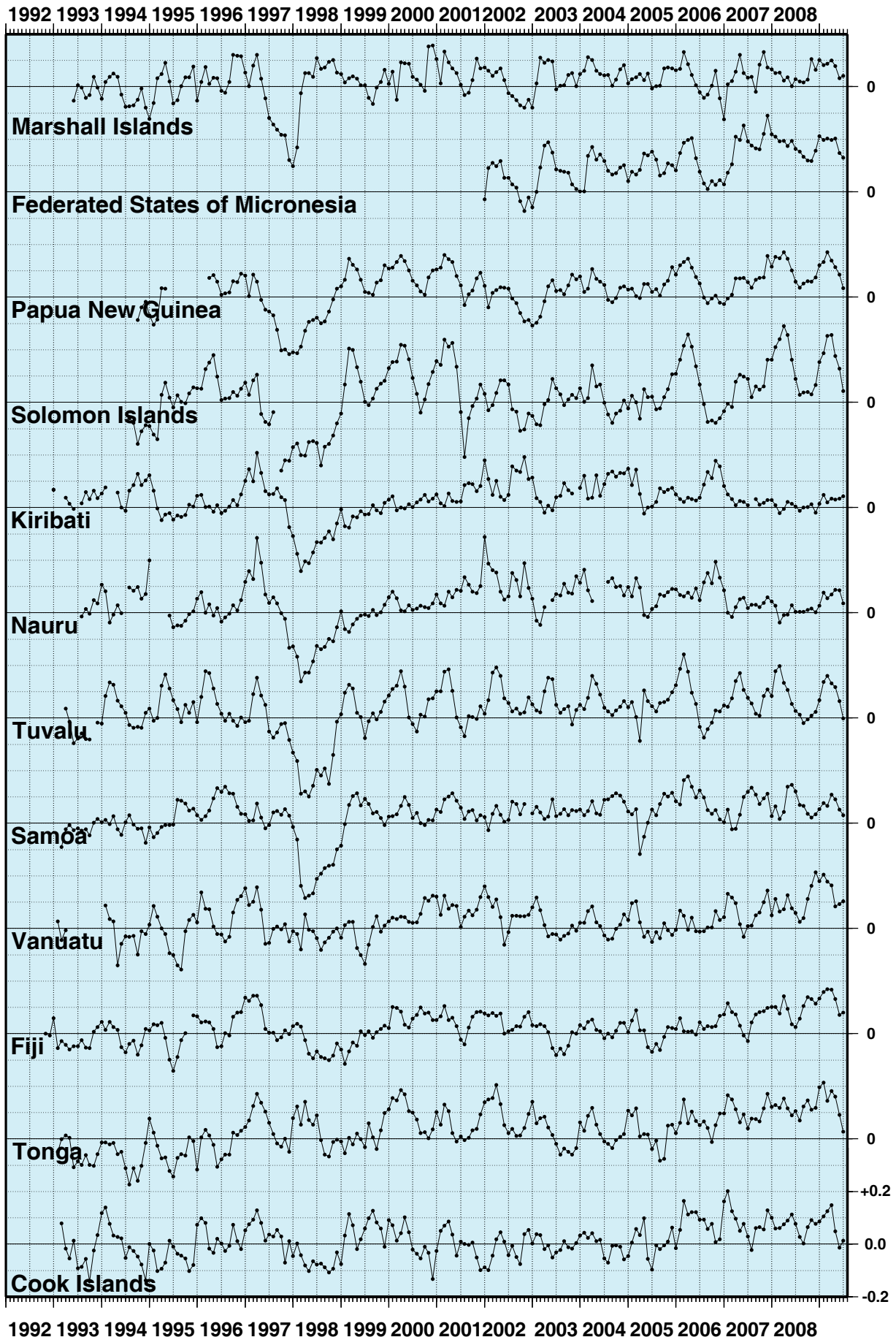
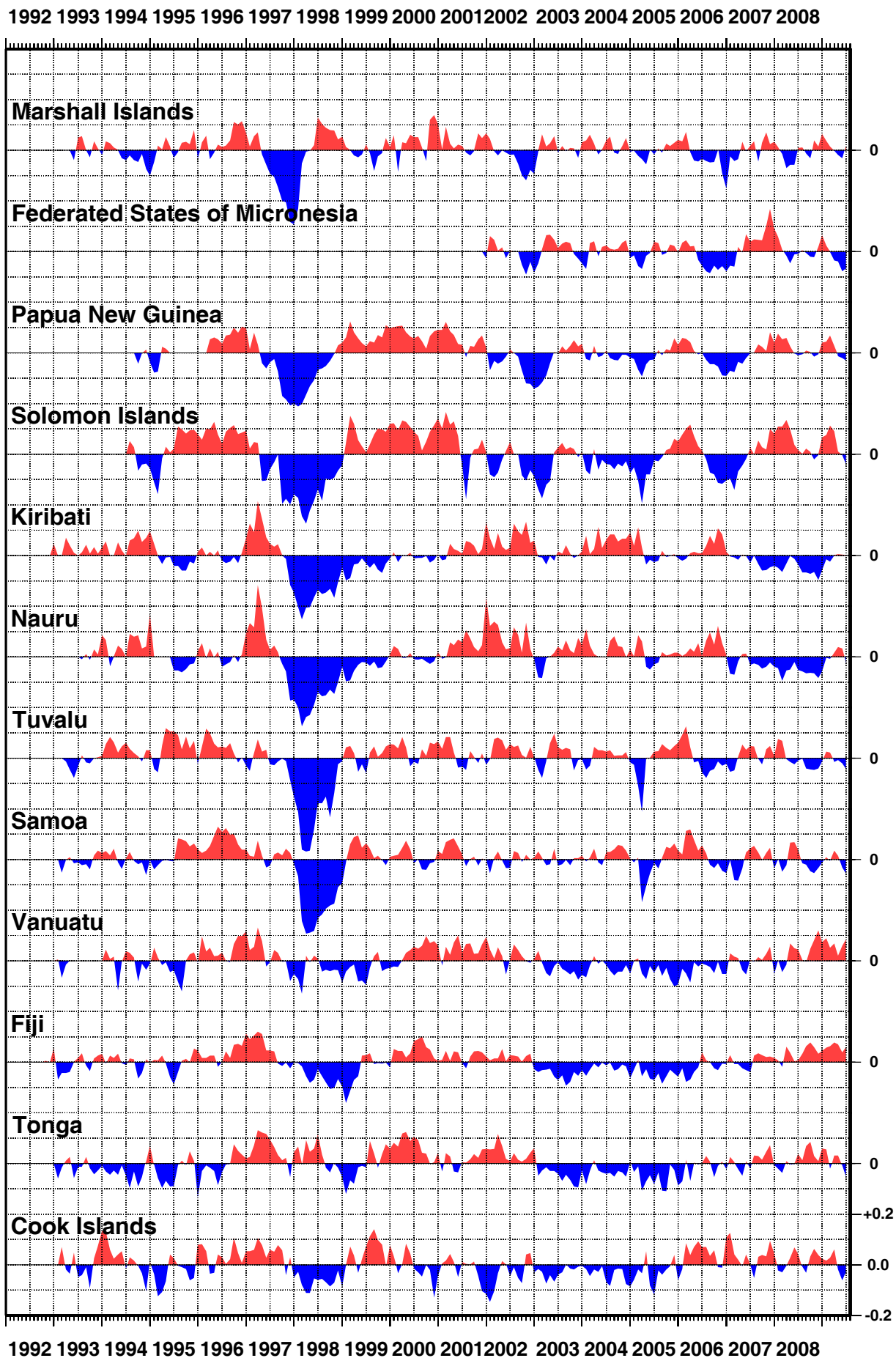


Figure 12  
**SEA LEVEL ANOMALIES THROUGH JUNE 2009 (m)**



**Figure 13**  
**SEA LEVEL TRENDS THROUGH JUNE 2009 (mm/year)**

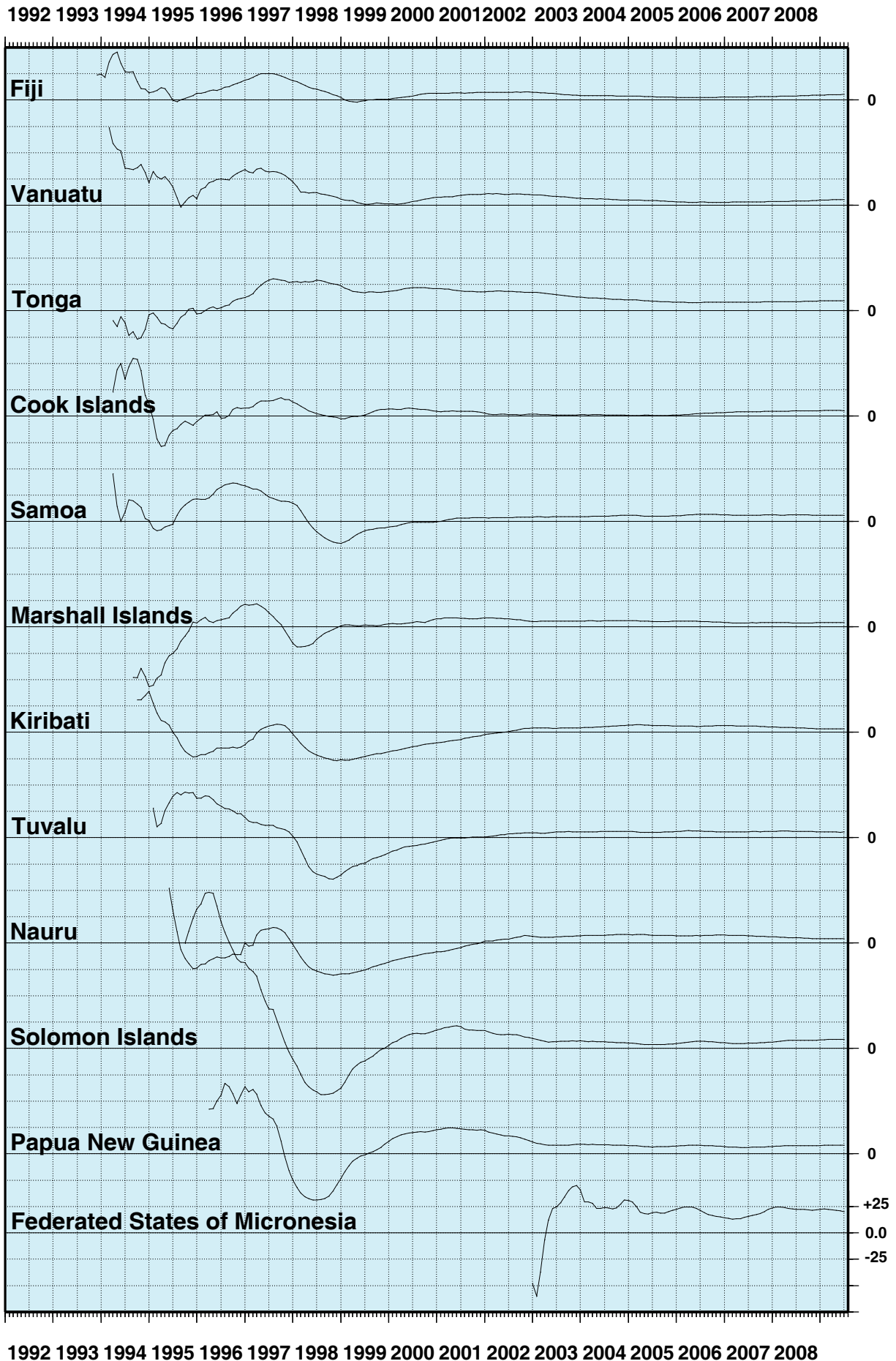
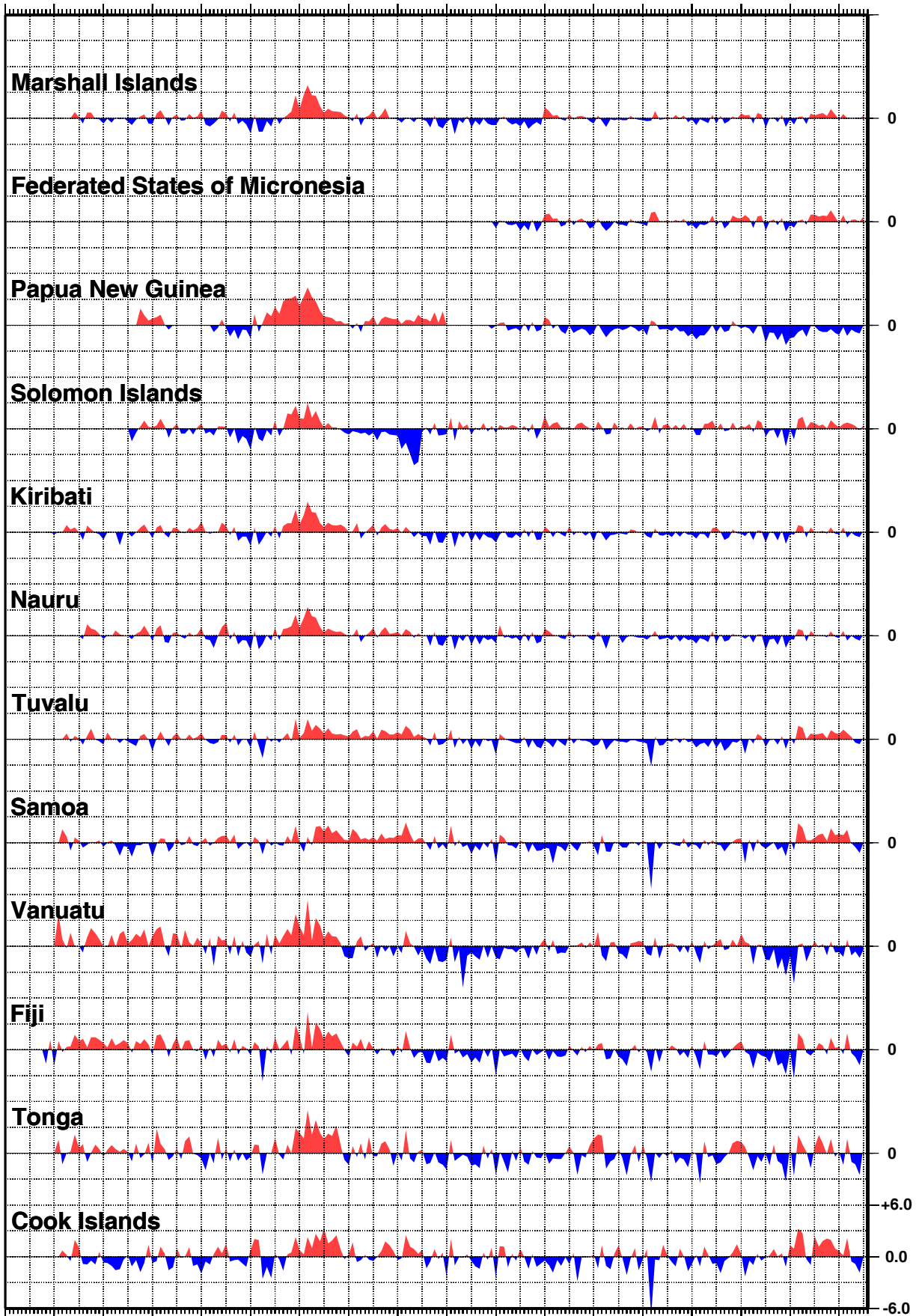


Figure 14

# BAROMETRIC PRESSURE ANOMALIES THROUGH JUNE 2009 (hPa)

1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008



1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008

Figure 15  
**WATER TEMPERATURE ANOMALIES  
 THROUGH JUNE 2009 (°C)**

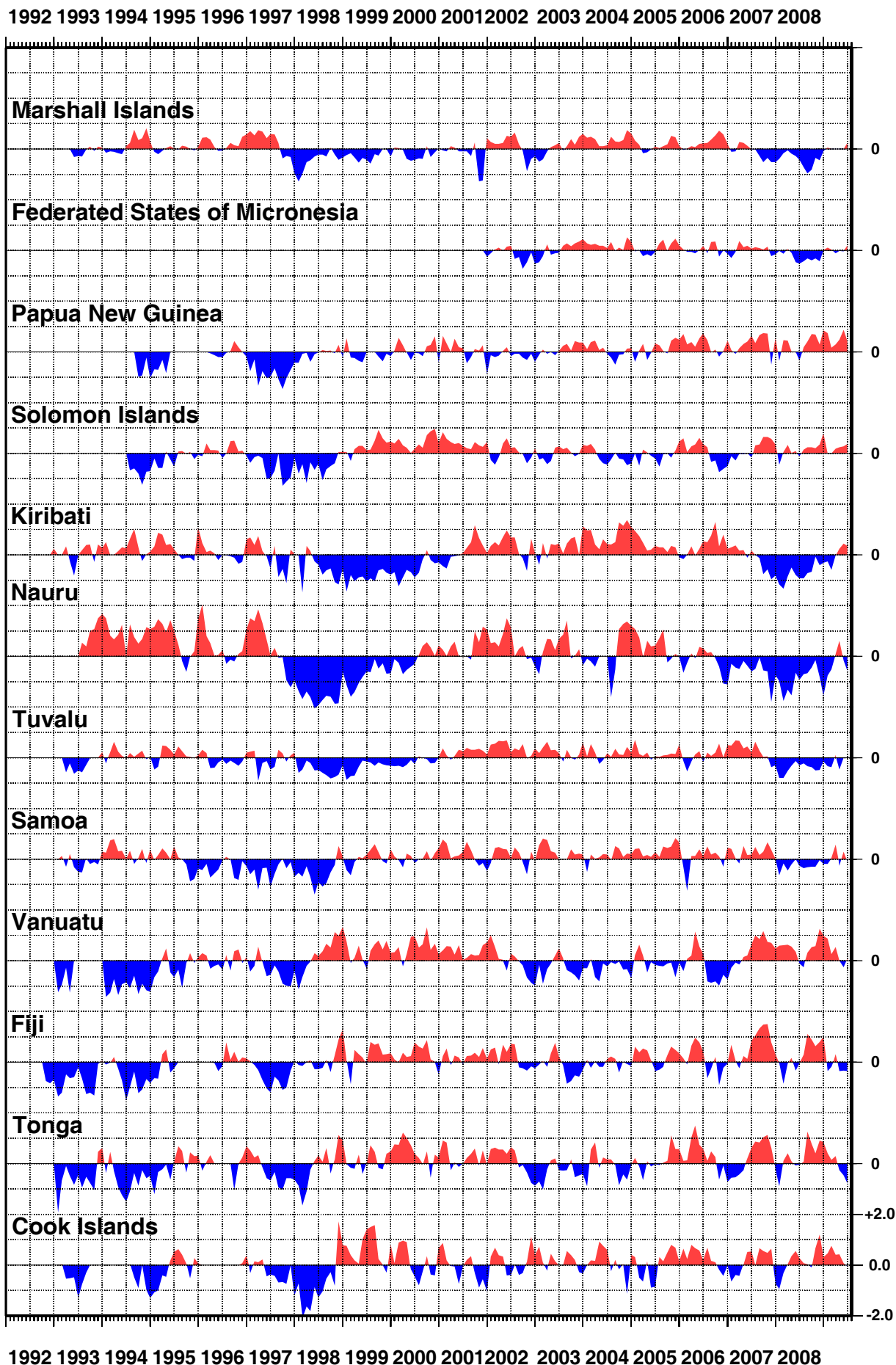
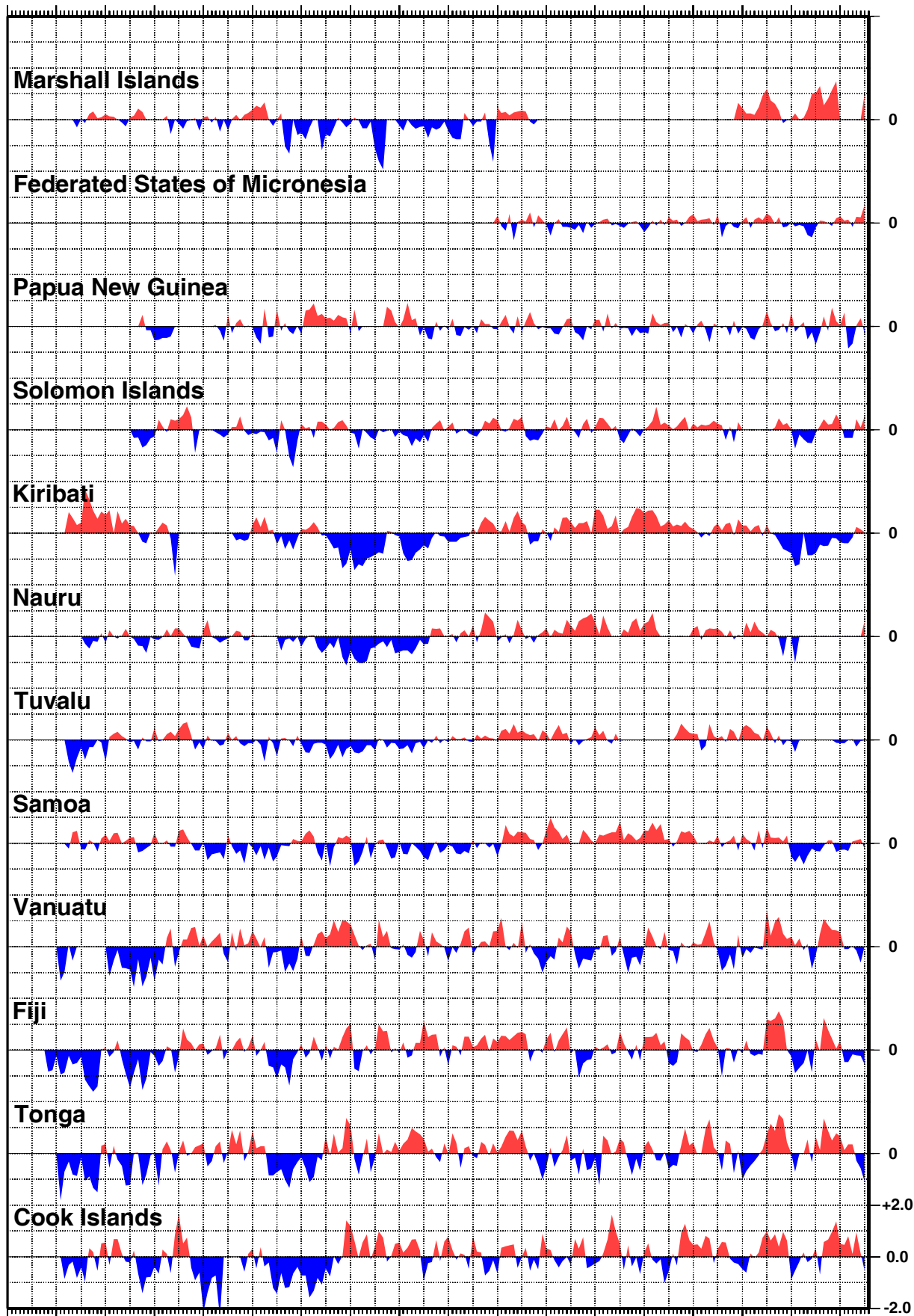


Figure 16  
**AIR TEMPERATURE ANOMALIES  
THROUGH JUNE 2009 (°C)**

1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008



1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008

Figure 17

# SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED

GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE

\* Patchy record

