

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

**MONTHLY DATA REPORT**

**NO. 166**

**APRIL 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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#### **Quality Certification:**

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

**April 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.

#### *April 2009*

- The SEAFRAME network continued to collect high quality sea level and associated meteorological information for monitoring climate variability and climate change.
- Tropical Cyclone Lin brought strong winds, low barometric pressure and elevated sea levels to Tonga on the 4<sup>th</sup> April 2009. Sea levels during the storm reached 0.5m higher than the predicted tide, although higher sea levels were observed around the time of the new moon later in the month.
- Monthly averaged sea levels were near to what is normally observed at this time of the year in keeping with neutral climate conditions. The largest sea level anomalies observed for April were -7cm at Tuvalu and +7cm at Fiji.
- Ocean temperatures continued to warm across the equatorial Pacific during April and are now closer to what is normally observed at this time of the year. Climate conditions are clearly neutral with respect to the El Niño – Southern Oscillation.
- The majority of international climate models predict climate conditions will remain neutral until at least the middle of the year. Three of the six models surveyed predict that El Niño conditions will develop toward the latter 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.

<b>Recent short-term sea level trends in the project area based upon SEAFRAME data through April, 2009</b>				
<b>Location</b>	<b>Lat / Long</b>	<b>Installation Date</b>	<b>Trend (mm/yr)</b>	<b>Change from previous month</b>
<b>Cook Is</b>	21°12'17.1"S / 159°47'5.2"W	Feb 1993	+5.5	0.0
<b>Tonga</b>	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+9.6	+0.1
<b>Fiji</b>	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+5.2	+0.1
<b>Vanuatu</b>	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+5.5	+0.1
<b>Samoa</b>	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+6.2	0.0
<b>Tuvalu</b>	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+5.5	-0.2
<b>Kiribati</b>	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.3	0.0
<b>Nauru</b>	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+4.2	+0.1
<b>Solomon Is.</b>	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+8.8	0.0
<b>PNG</b>	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+8.2	0.0
<b>FSM</b>	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+21.6	-0.5
<b>Marshall Is.</b>	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.2	0.0

## INTRODUCTION

Welcome to the April 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.

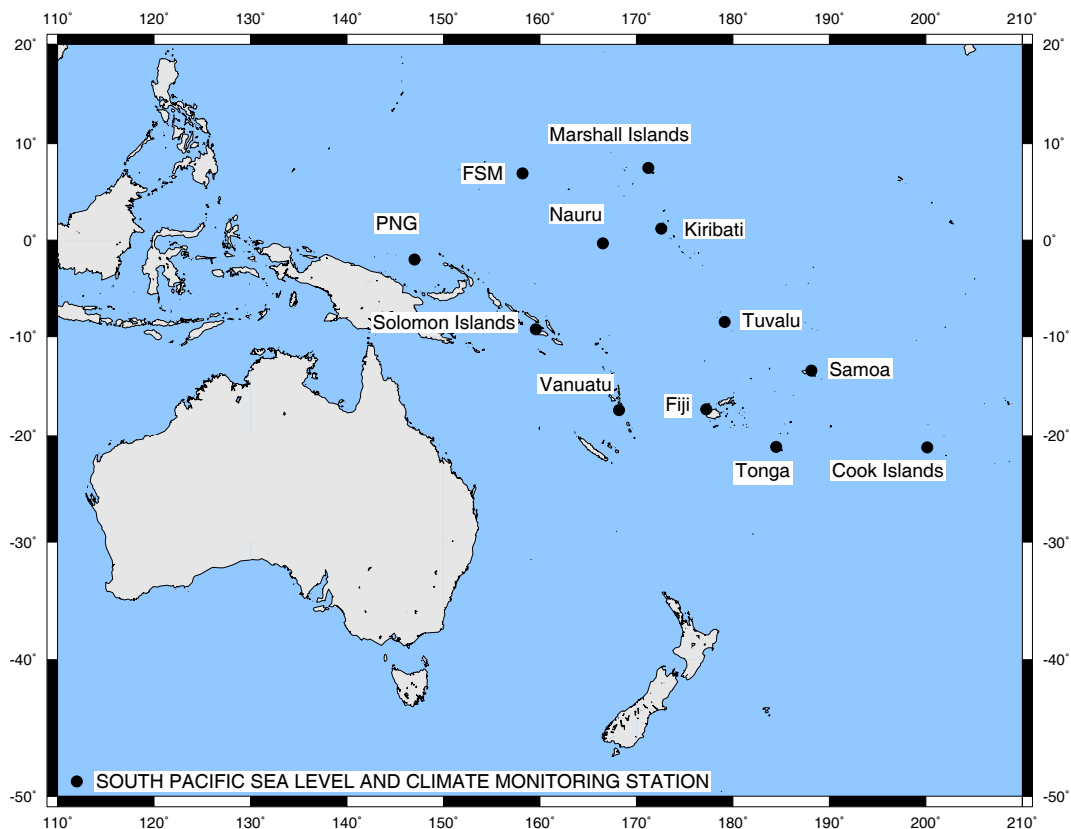
The SPSLCMP was developed as an Australian response to concerns raised by the member countries of the South Pacific Forum over the potential impacts of global warming on climate and sea levels in the Pacific. Support was provided for the installation of SEAFRAME monitoring stations across the South Pacific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

## APRIL CLIMATOLOGY

Climate conditions across the equatorial Pacific were neutral with regards to El Niño - Southern Oscillation (ENSO) during April. Ocean heat content continued to warm, resulting in near-average ocean temperatures across most of the equatorial Pacific, and there was a further weakening of equatorial Trade Winds. The majority of climate models predict neutral conditions will persist until at least mid-year.

The Southern Oscillation Index (SOI) rose during April in response to an increase in mean sea level pressure at Tahiti and a decrease at Darwin, but began to fall again late in the month. The monthly average value was +9 following the March value of zero (**Figure B**).

Sea surface temperatures continued to warm across the equatorial Pacific during April, which resulted in the disappearance of the cool anomalies previously observed across the central and equatorial Pacific. Sea surface temperatures are close to normal across most of the equatorial Pacific, with the exception of the far eastern region where they are warmer than normal (**Figure C**, **Figure E**).

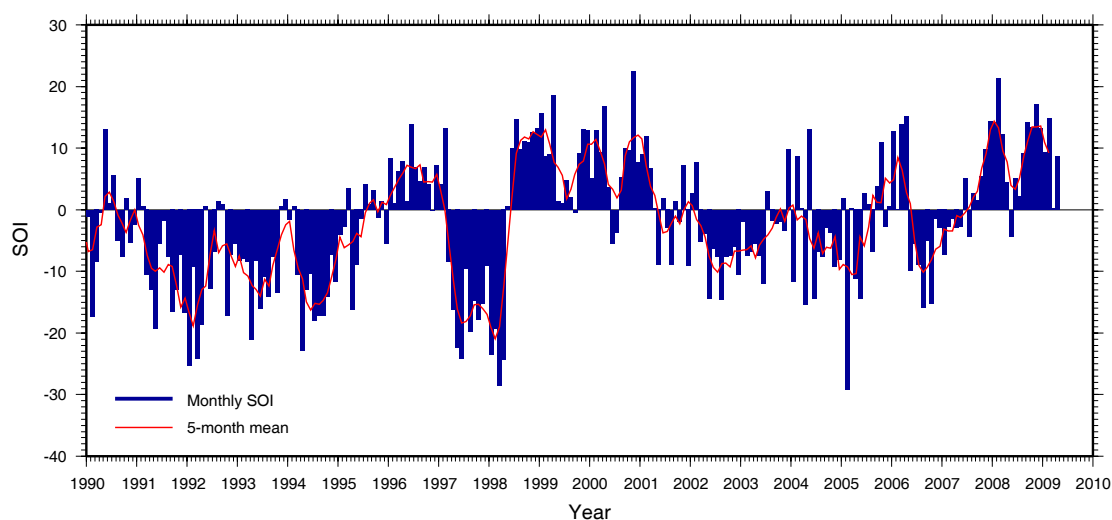
Subsurface temperatures also continued to warm during April, resulting in the disappearance of the cool subsurface anomalies that have recently persisted across the central and eastern equatorial Pacific (**Figure D**). Warmer than normal subsurface temperatures continue to be observed in the western 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 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 continued to weaken, particularly during late April when anomalous westerly winds began to be observed. Averaged over the course of the month the Trade Winds were of near average strength (**Figure E**). Cloudiness over the equatorial Pacific near the dateline continued to increase during April in association with warming sea surface temperatures in that region and is now at near-normal levels.

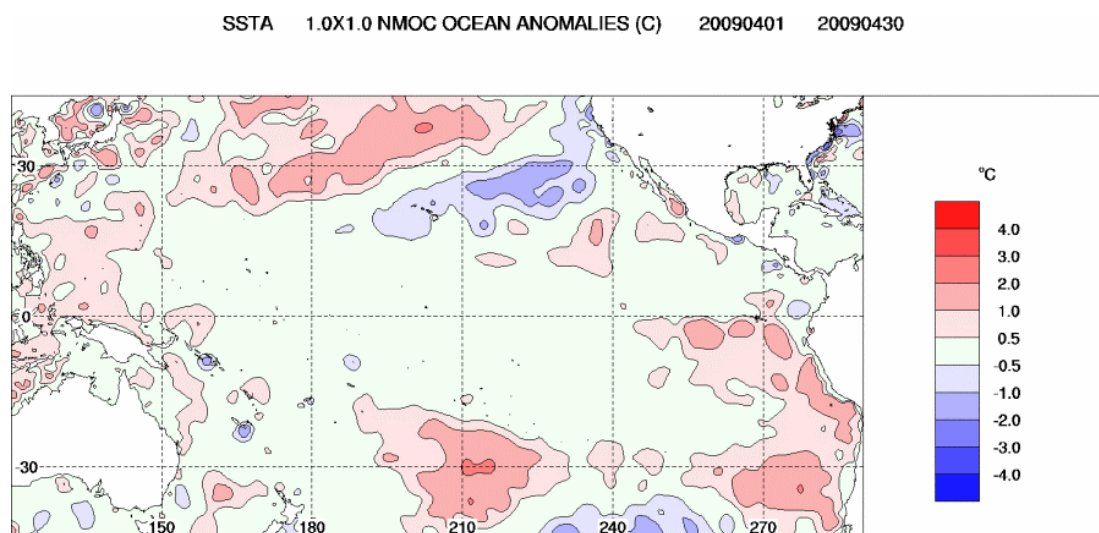
The consensus among six international computer models is that climate conditions will remain neutral across the equatorial Pacific until mid-year. Three of the six models are predicting that El Niño conditions will develop later in the year, with the remaining three suggesting conditions will remain neutral.

*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/>.*

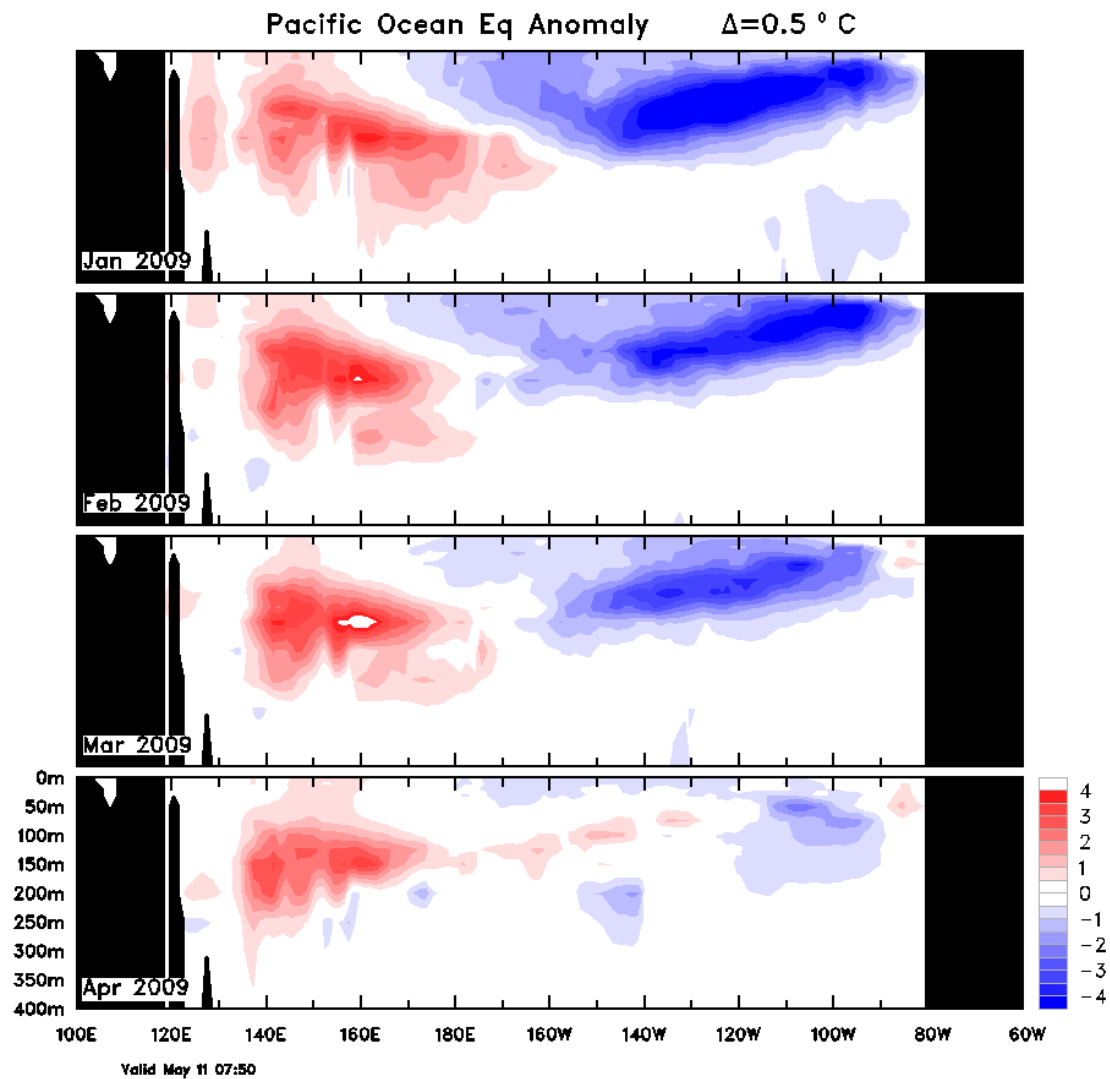
## Southern Oscillation Index (SOI)



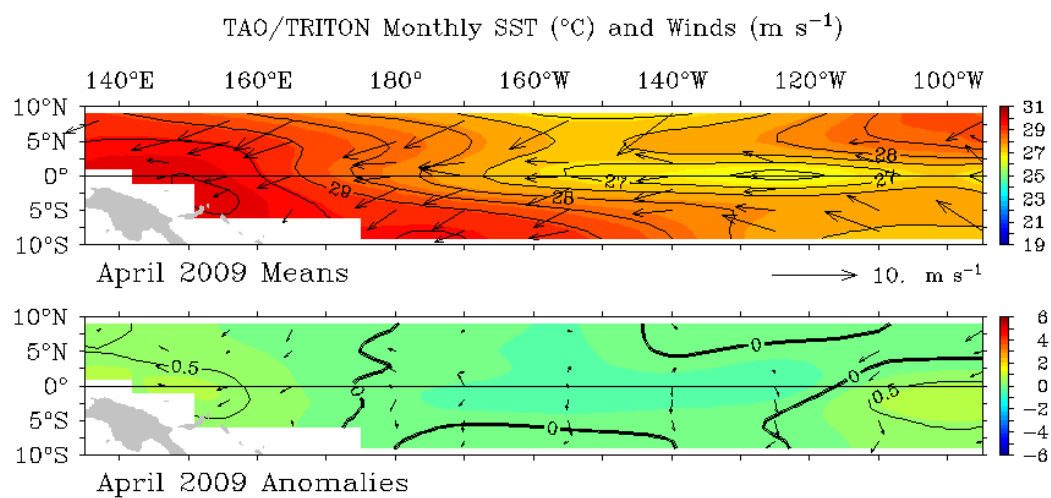
**Figure B:** The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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



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



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



TAO/NDBC/NOAA

May 11 2009

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



## APRIL 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 9<sup>th</sup> of April and a new moon on the 25<sup>th</sup> of April 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 reveal a storm surge was observed at Tonga on the 4<sup>th</sup> and 5<sup>th</sup> April 2009 as a result of Tropical Cyclone Lin. Sea levels during this time reached 0.5m higher than the predicted astronomical tide, although higher sea levels were recorded on the 26<sup>th</sup> April the day after the new moon.

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). In comparing Figures 2 and 3, the barometric pressure correction accounts for slightly more than half of the storm surge observed at Tonga on the 4<sup>th</sup> April 2009. Barometric-pressure corrected residuals are not available for Marshall Islands due to problems with the barometric pressure sensor.

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 Tonga reached 30 m/s (108 km/hr or 58 knots) as Tropical Cyclone Lin passed Tonga on 4<sup>th</sup> April 2009.

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. At Tonga barometric pressure fell to as low as 985.8hPa during the passage of Tropical Cyclone Lin.

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 April air temperature of 32.2°C was recorded at Tuvalu, a new maximum April water temperature of 32.8°C was recorded at PNG and new minimum April water temperatures were recorded at Tuvalu (28.3°C) and Samoa (27.5°C). New maximum April barometric pressures were recorded at FSM (1015.4hPa) and Samoa (1015.4). The 985.8hPa barometric pressure recorded at Tonga during the passing of Tropical Cyclone Lin was the lowest April reading on record.

### 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 April 2009 sea levels were close to what is normally observed at this time of the year at most sites, in keeping with neutral climate conditions being observed over the equatorial Pacific. The largest monthly mean sea level anomalies observed for April were -7cm at Tuvalu and +7cm at Fiji.

### Sea Level Trends

The **short-term sea level trends** at individual stations as at April 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 April , 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	0.0
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+9.6	+0.1
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Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+6.2	0.0
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+5.5	-0.2
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	+8.8	0.0
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	+21.6	-0.5
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.2	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 April 2009 barometric pressures were near normal at all stations.

The **water temperature anomalies** (**Figure 15**) show water temperatures were within 0.5°C of what is normally observed at this time of the year at all stations.

The **air temperature anomalies (Figure 16)** reveal air temperatures during April 2009 were close to average at most sites, with the exception of Cook Islands where the SEAFRAME instrumentation is showing air temperatures nearly 1°C above 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.

Sea level data return was very high during April, with only one day unable to be retrieved at PNG due to communication problems. At Nauru and Tuvalu problems with the primary sea level sensors were encountered and data from the secondary sea level sensors were used. Intermittent problems with the primary sea level sensor were also encountered at Vanuatu.

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.

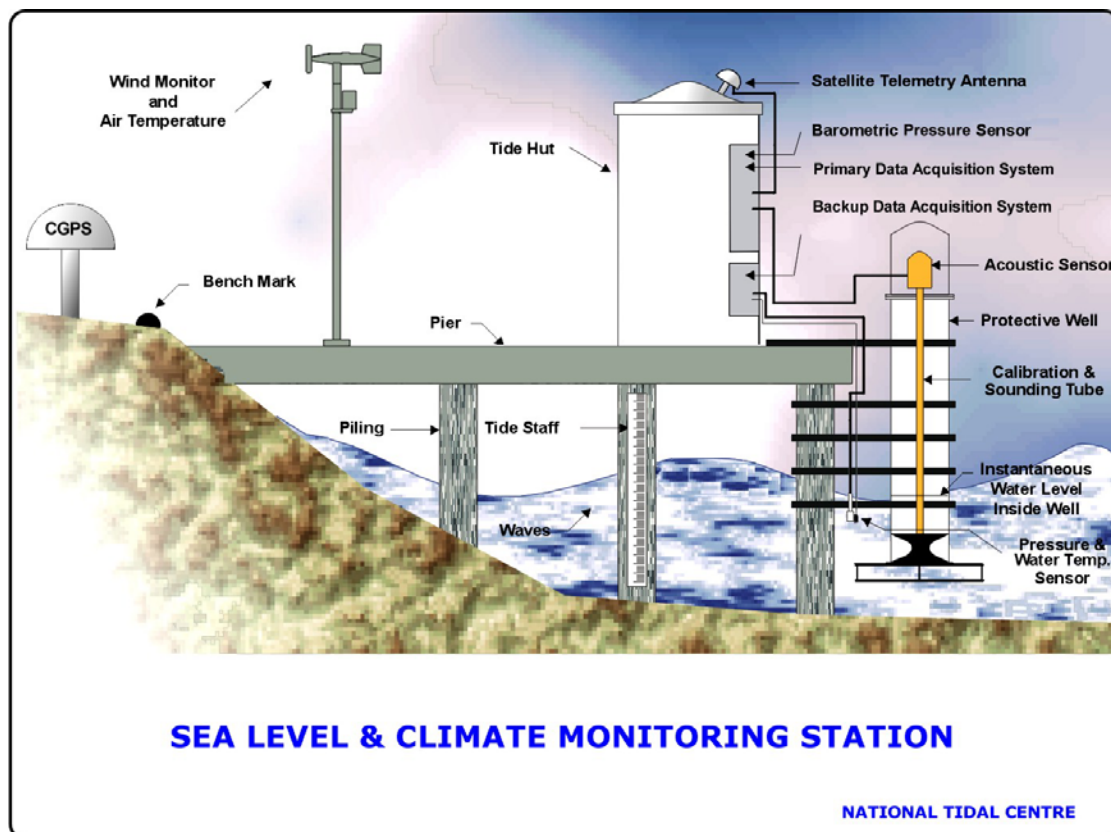
Communication problems were experienced at PNG, Kiribati, and Marshall Islands but aside from PNG most of the data were recovered.

### **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:

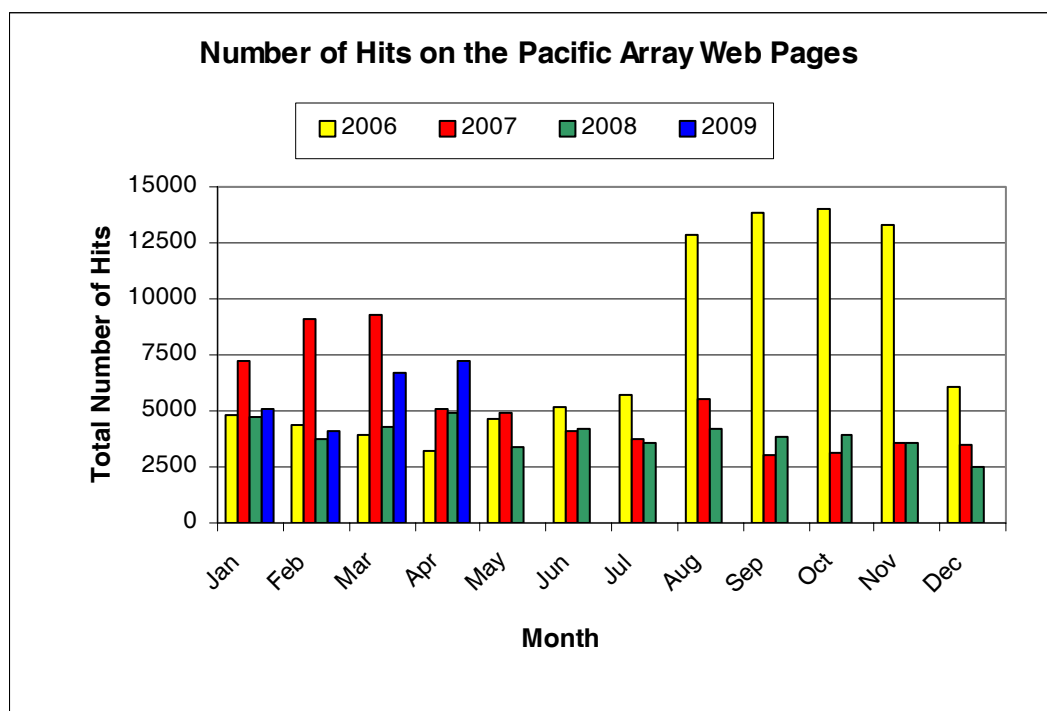
- (1) Primary water level using a Bartex 'AQUATRAK' acoustic-in-air sensor, and
- (2) Secondary water level (or backup) using a Druck pressure transducer mounted close to the seabed.

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:

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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**  
**APRIL 2009**  
**SIX MINUTE WATER LEVEL OBSERVATIONS (m)**

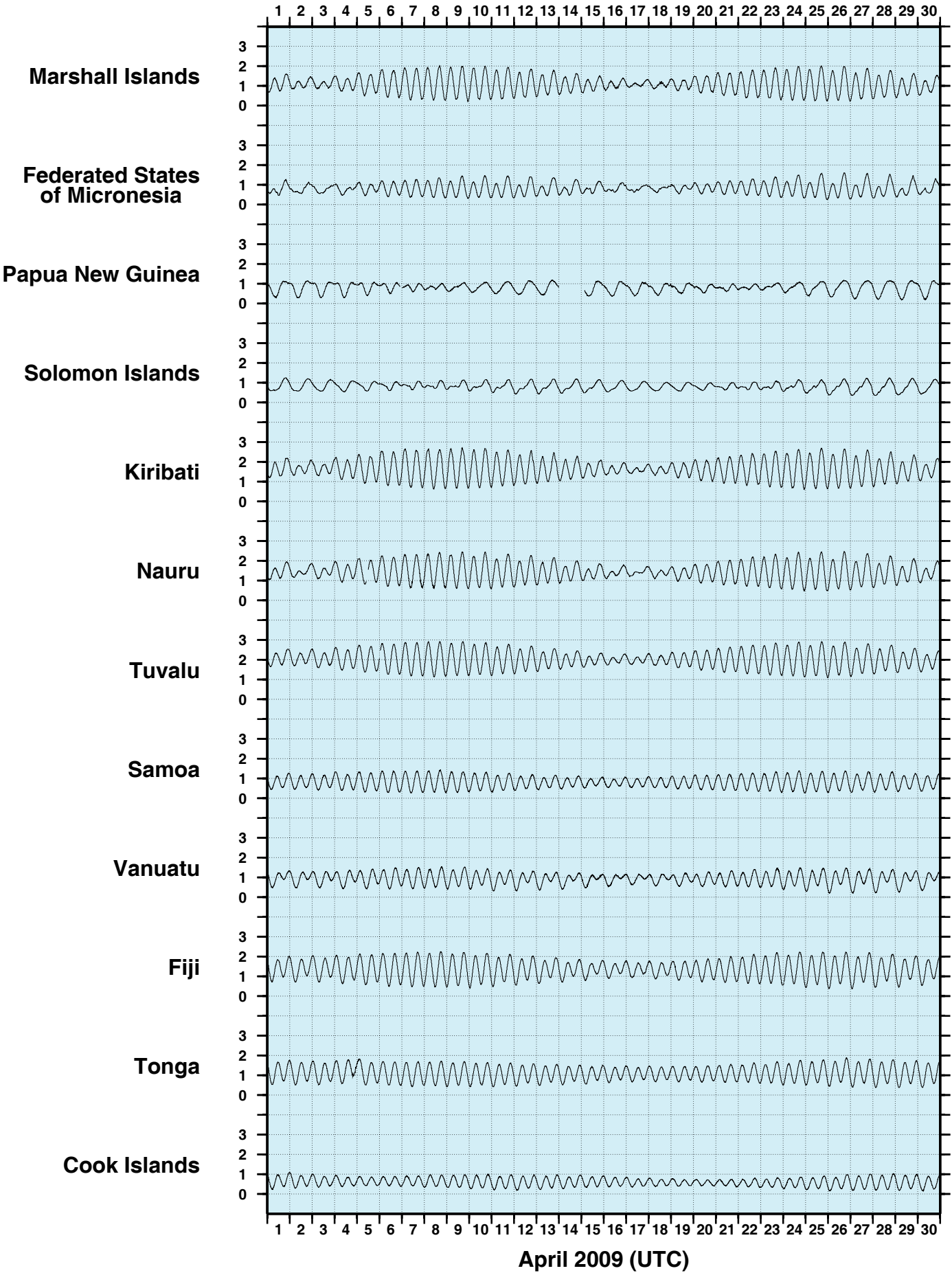
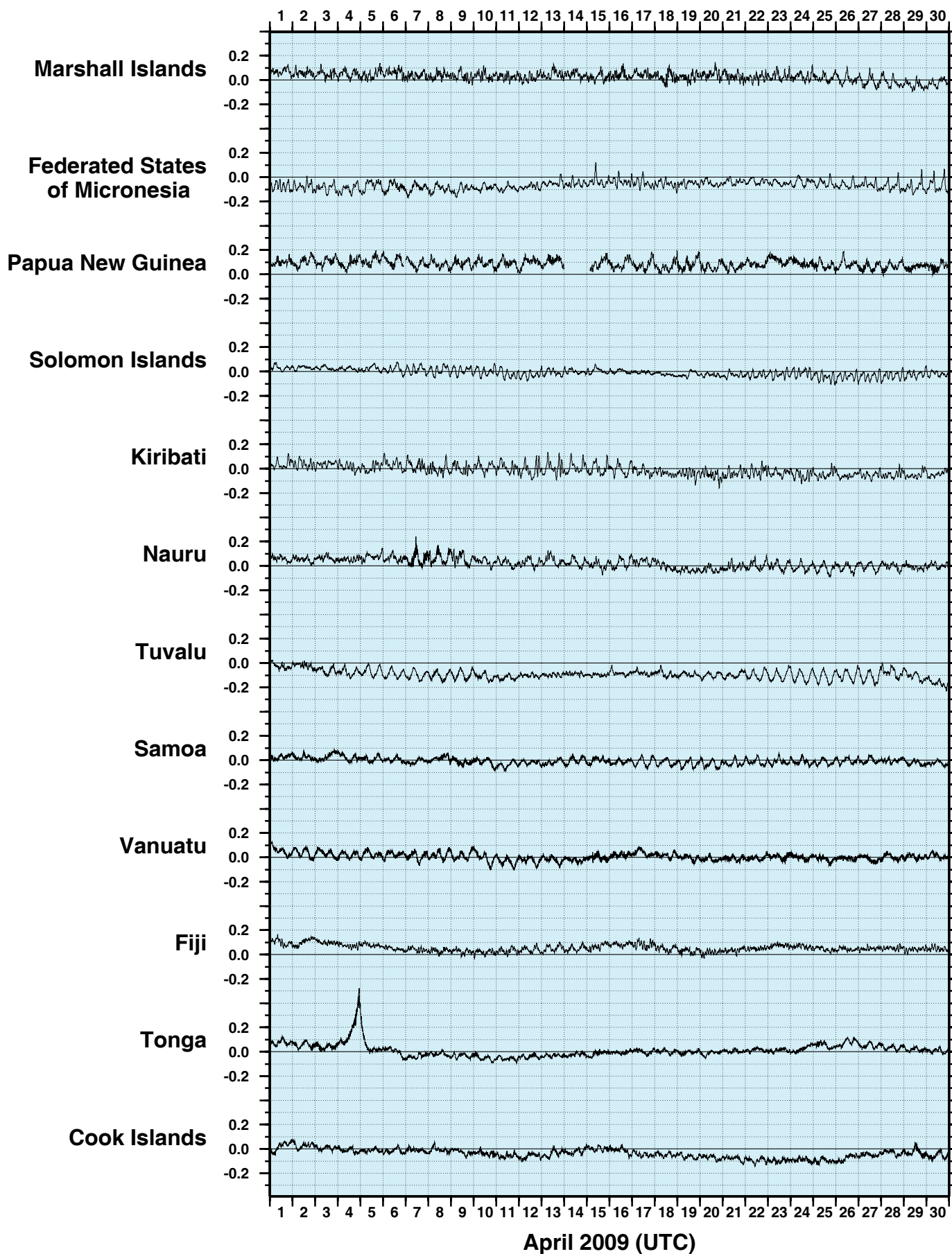


Figure 2  
APRIL 2009  
SIX MINUTE RESIDUAL WATER LEVELS (m)





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

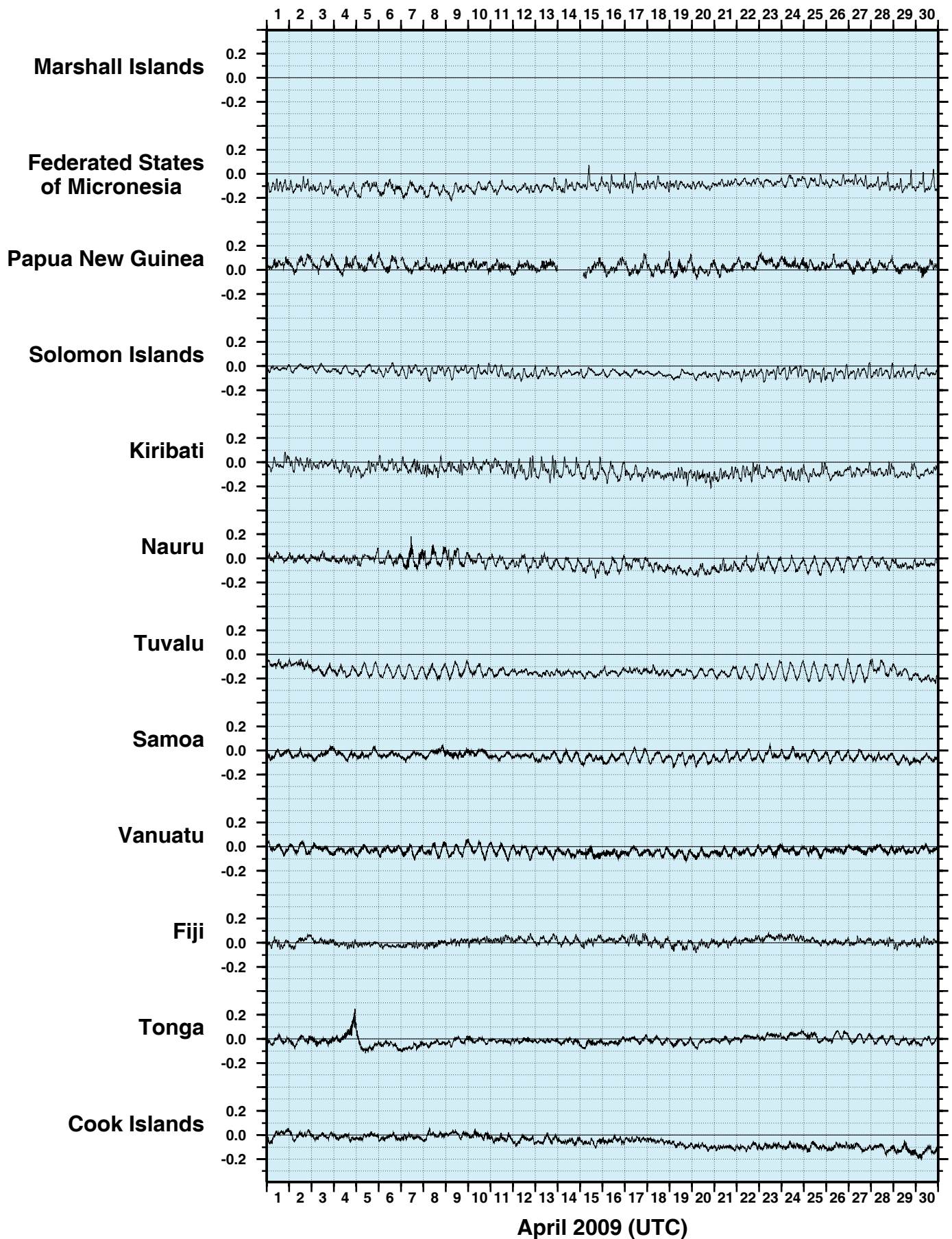


Figure 4

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

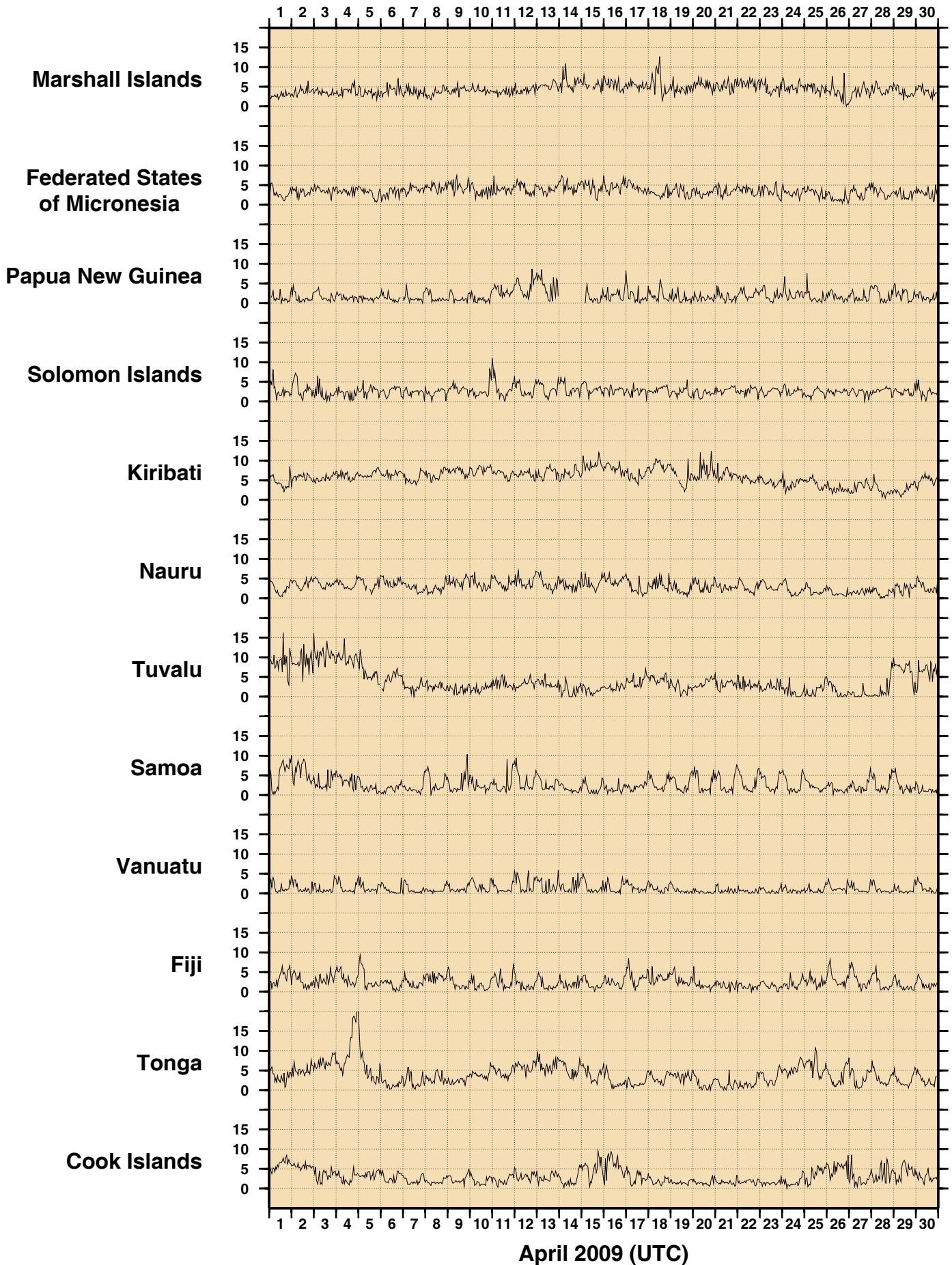
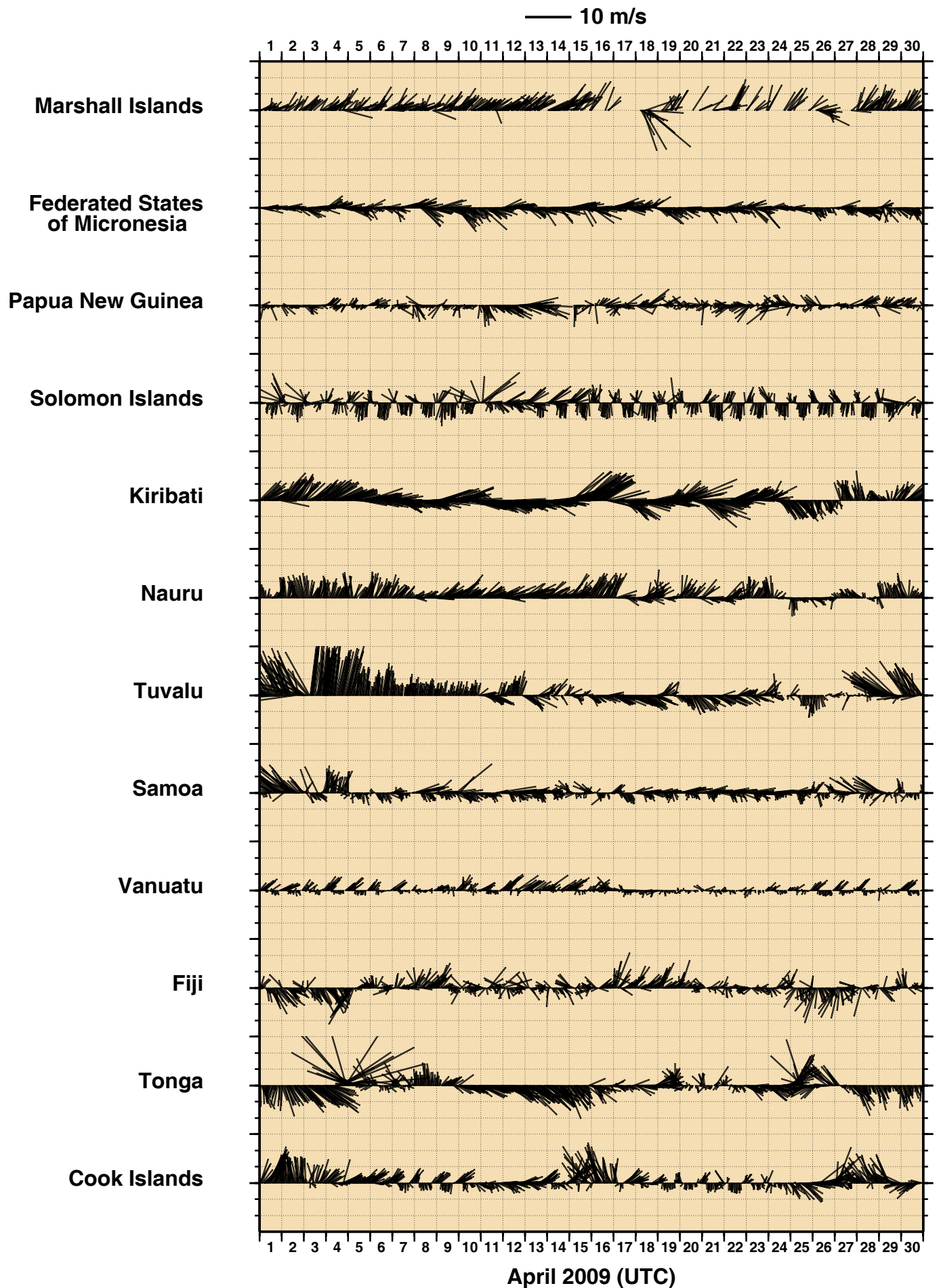
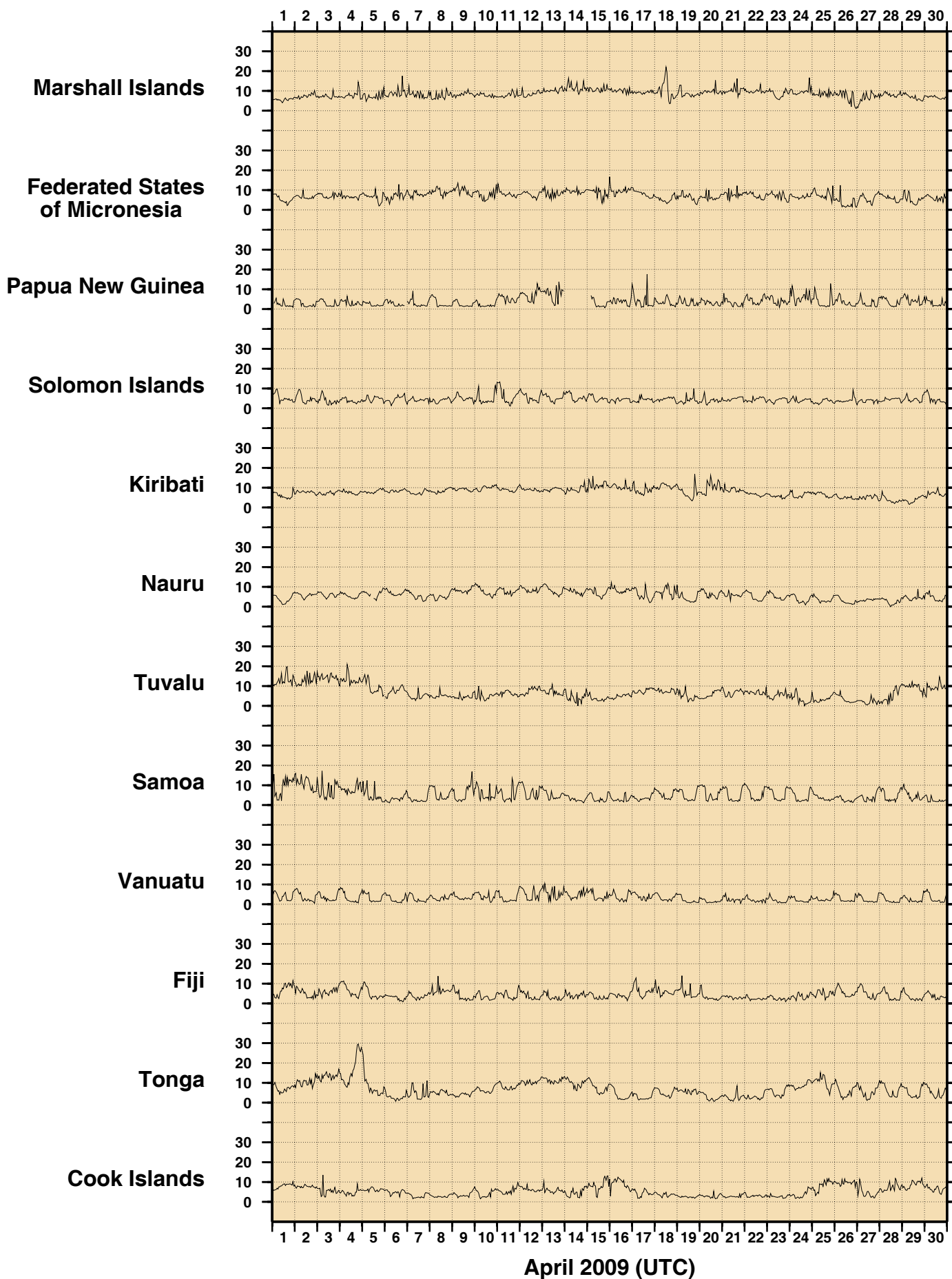


Figure 5  
APRIL 2009  
HOURLY INCIDENT WINDS (m/s, deg True)



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



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

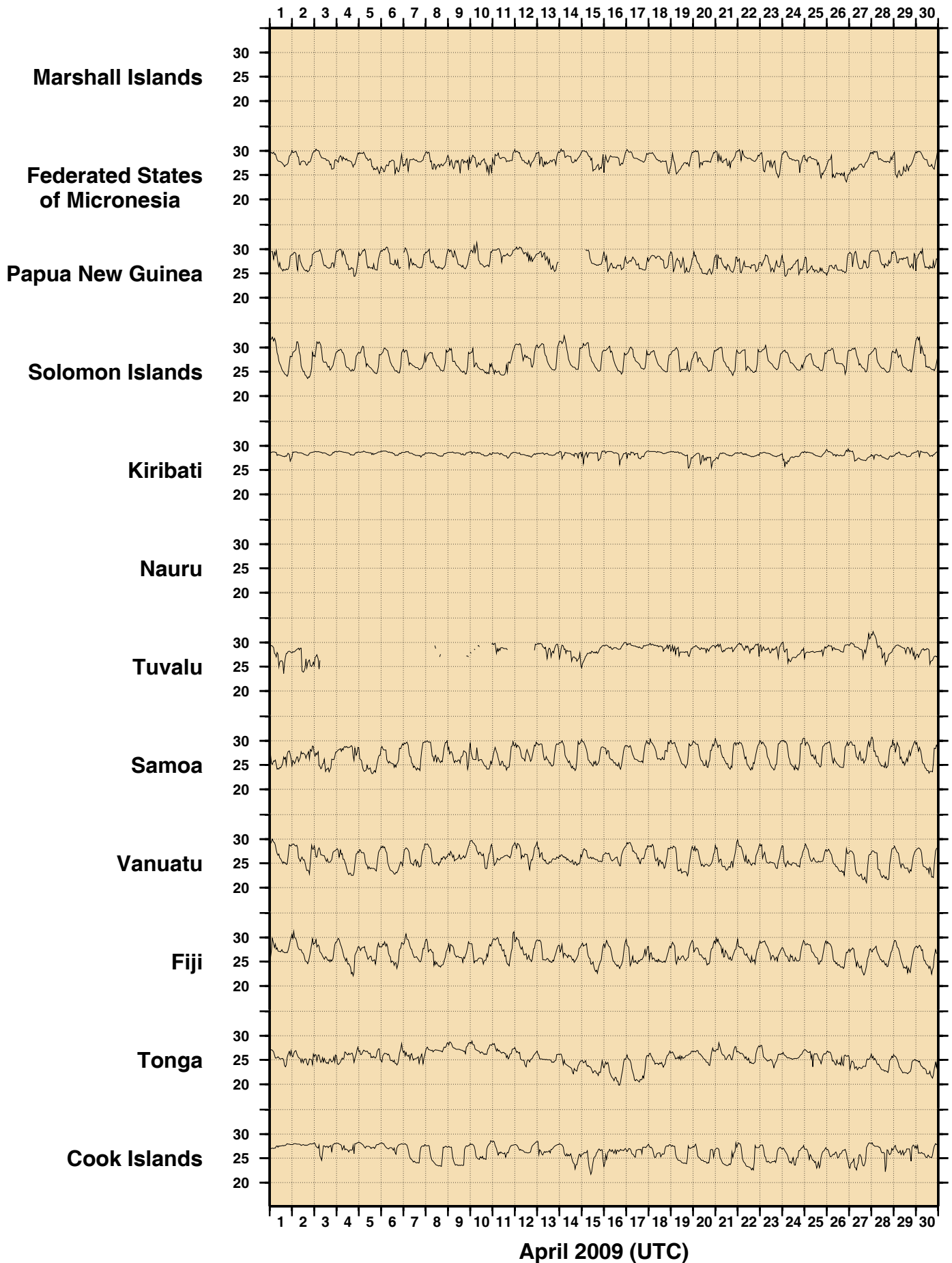
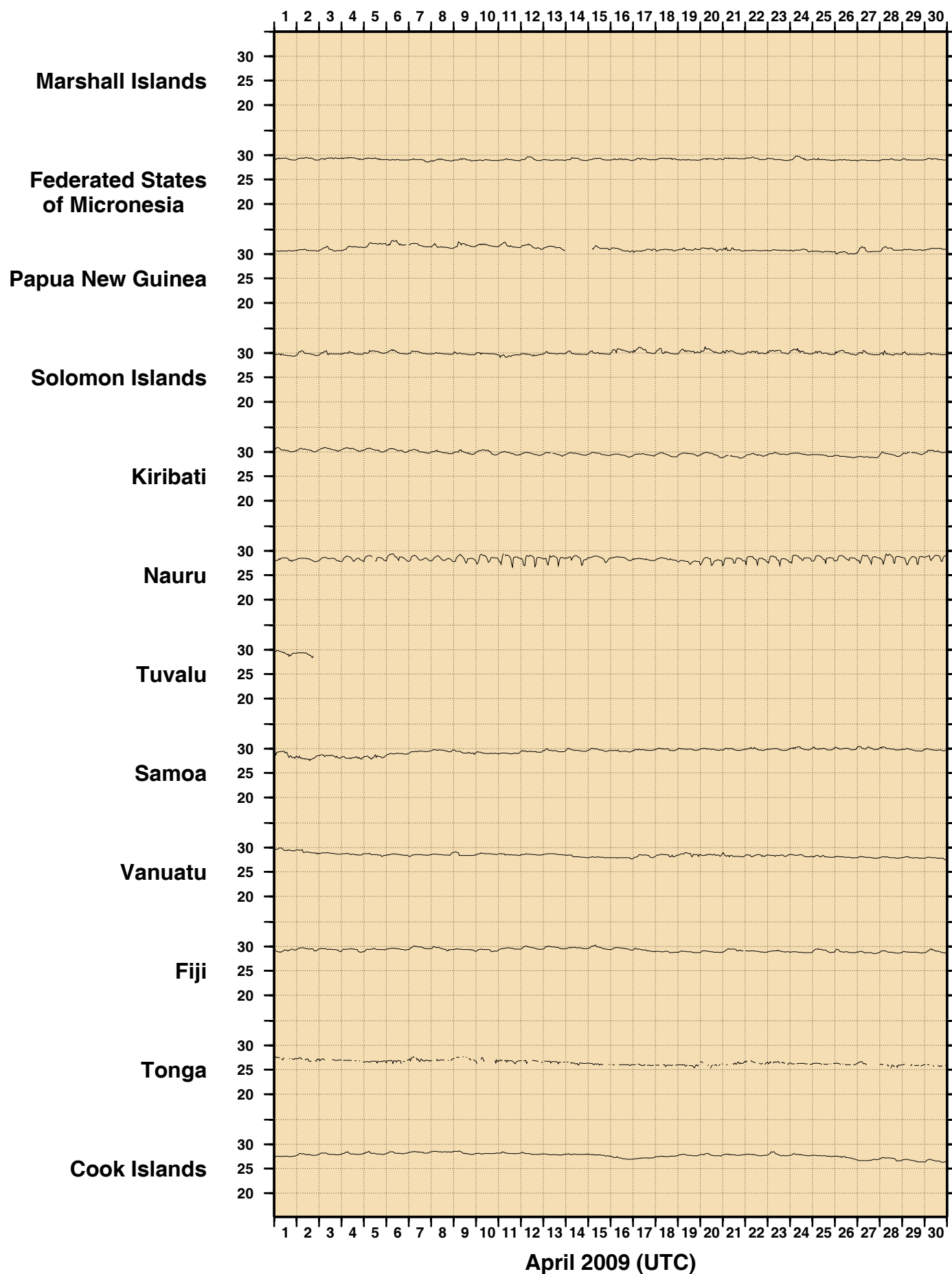




Figure 8  
APRIL 2009  
HOURLY WATER TEMPERATURES (°C)



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

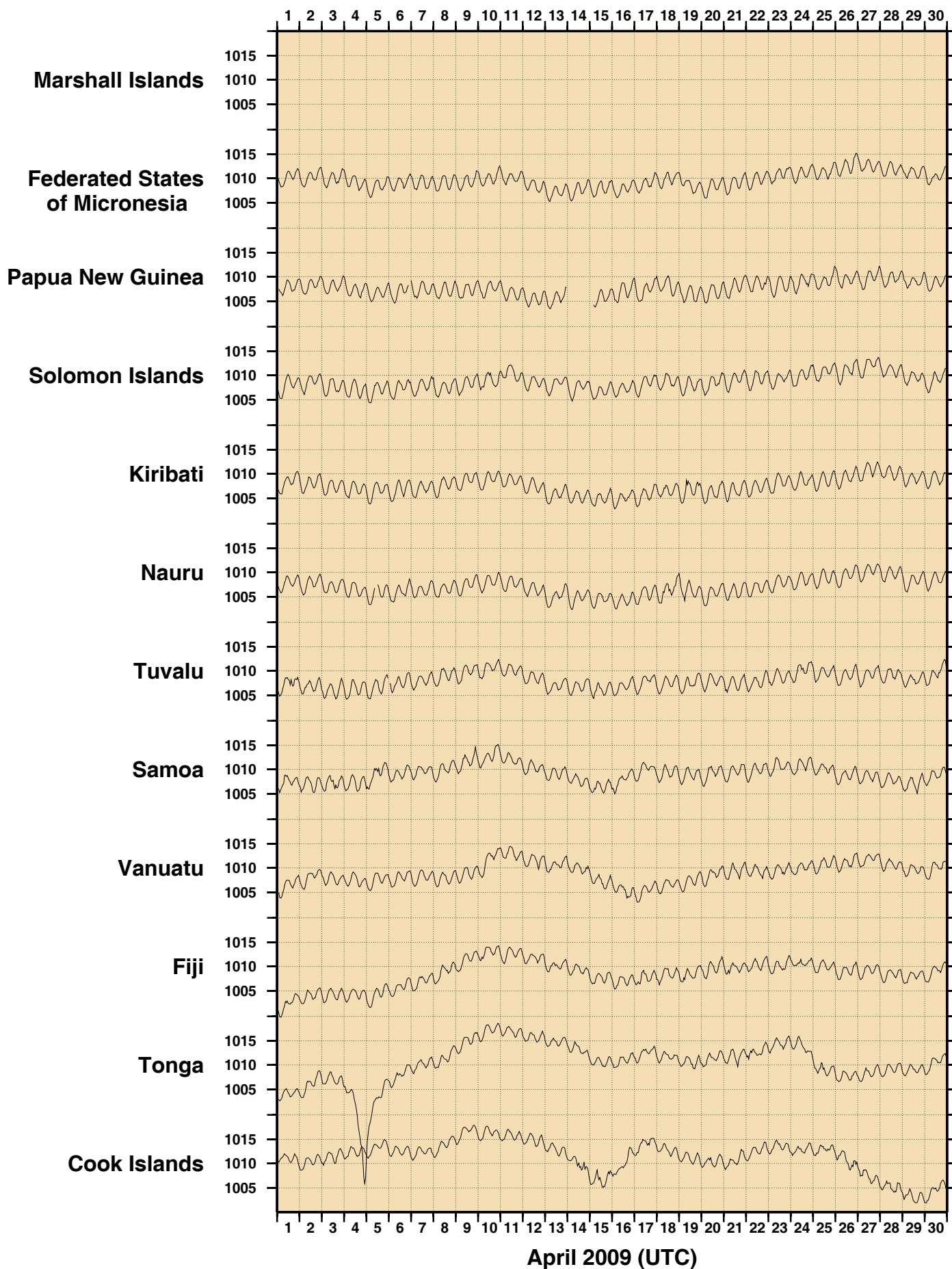
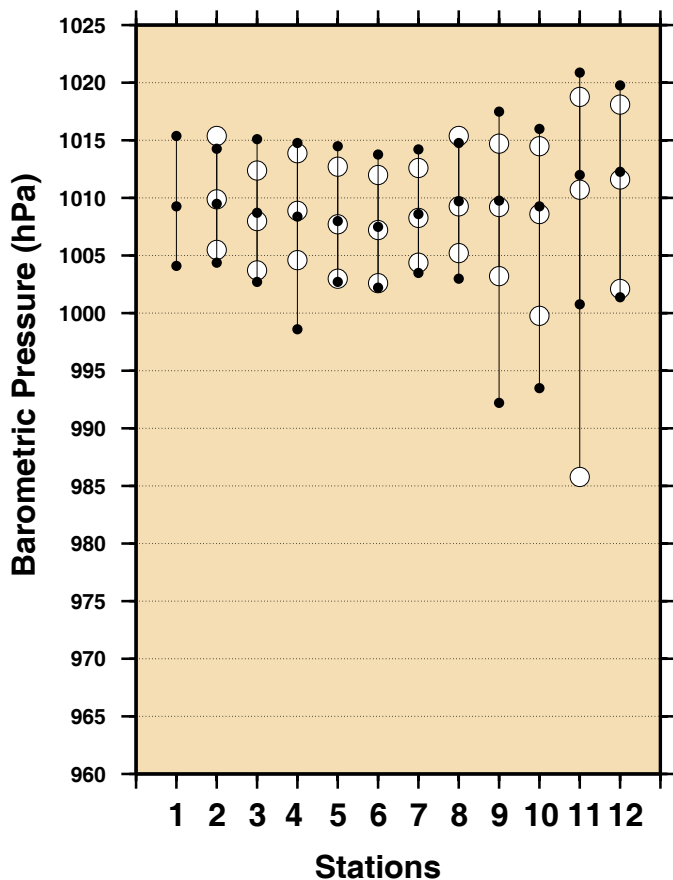
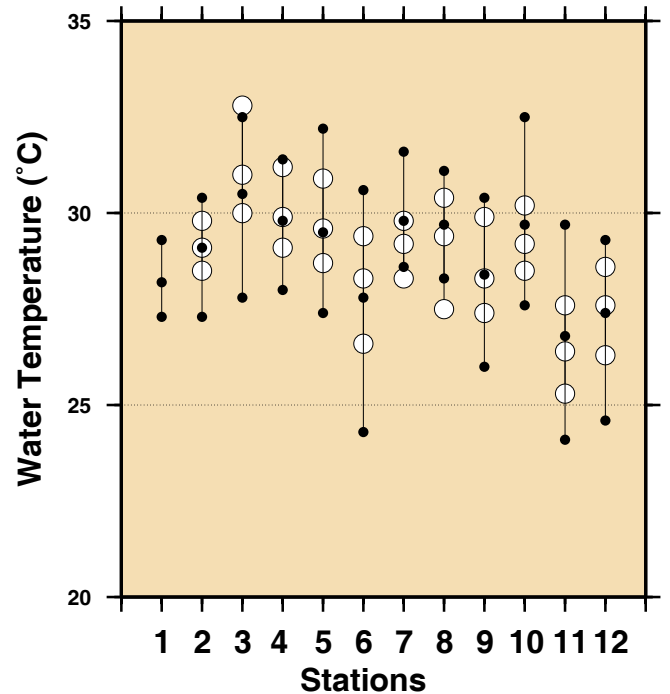
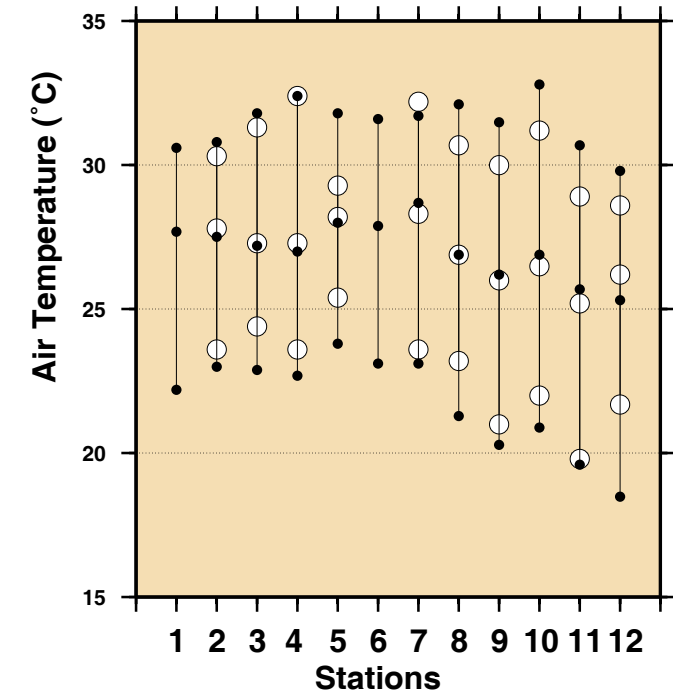


Figure 10

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

- April 2009 Maximum
- April 2009 Mean
- April 2009 Minimum

- Long Term April Maximum
- Long Term April Mean
- Long Term April Minimum



Figure 11

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

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

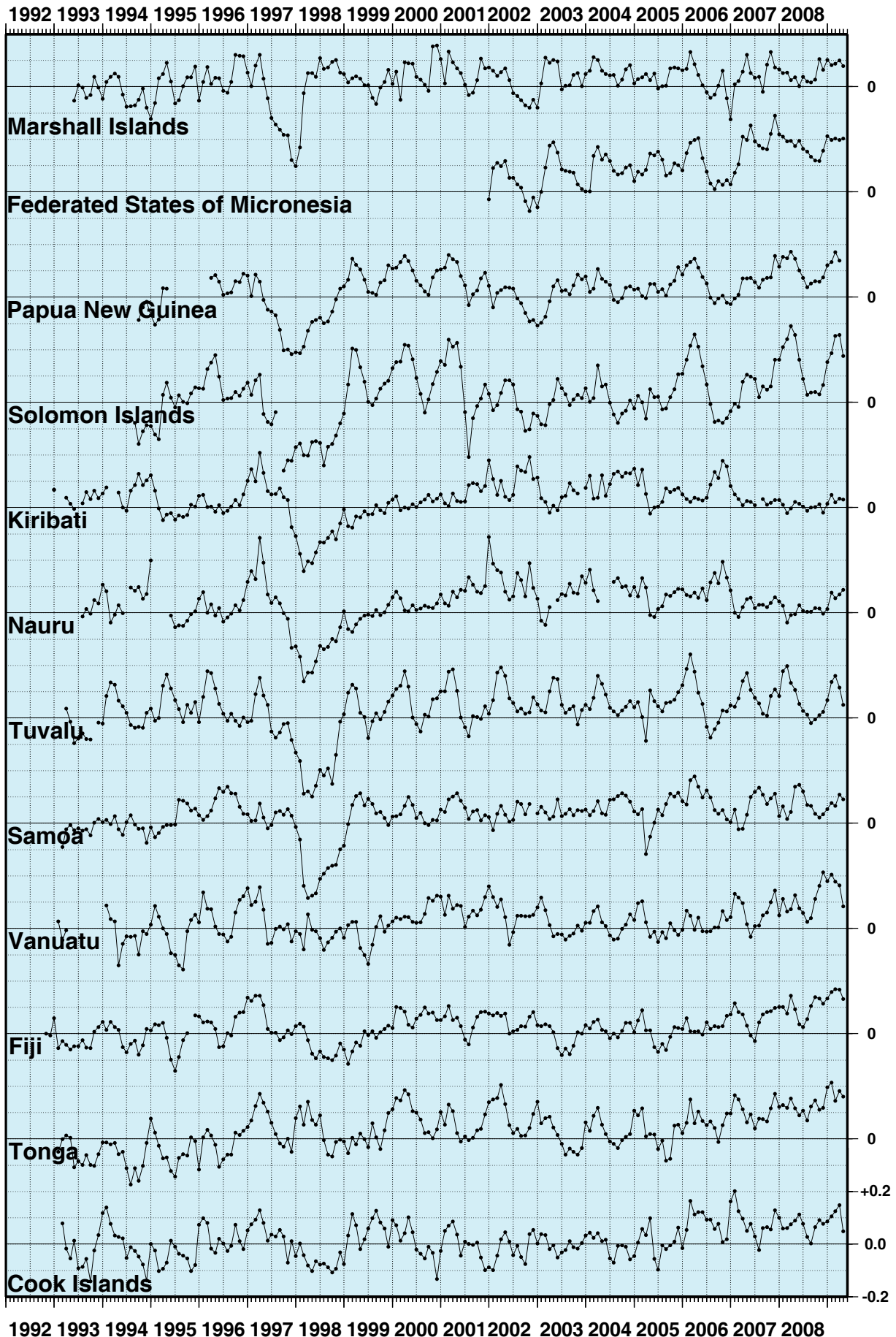


Figure 12  
SEA LEVEL ANOMALIES THROUGH APRIL 2009 (m)

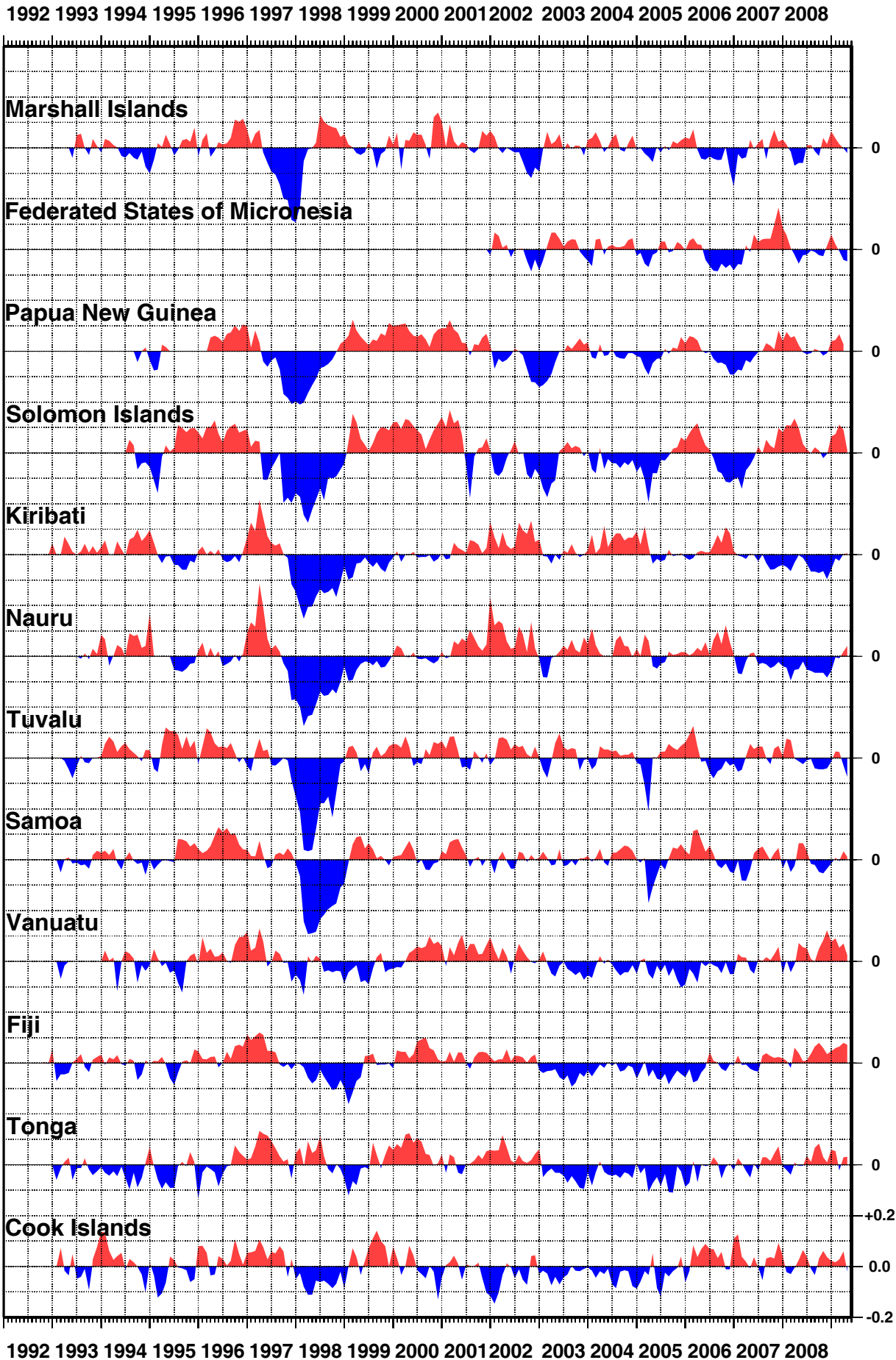


Figure 13

## SEA LEVEL TRENDS THROUGH APRIL 2009 (mm/year)

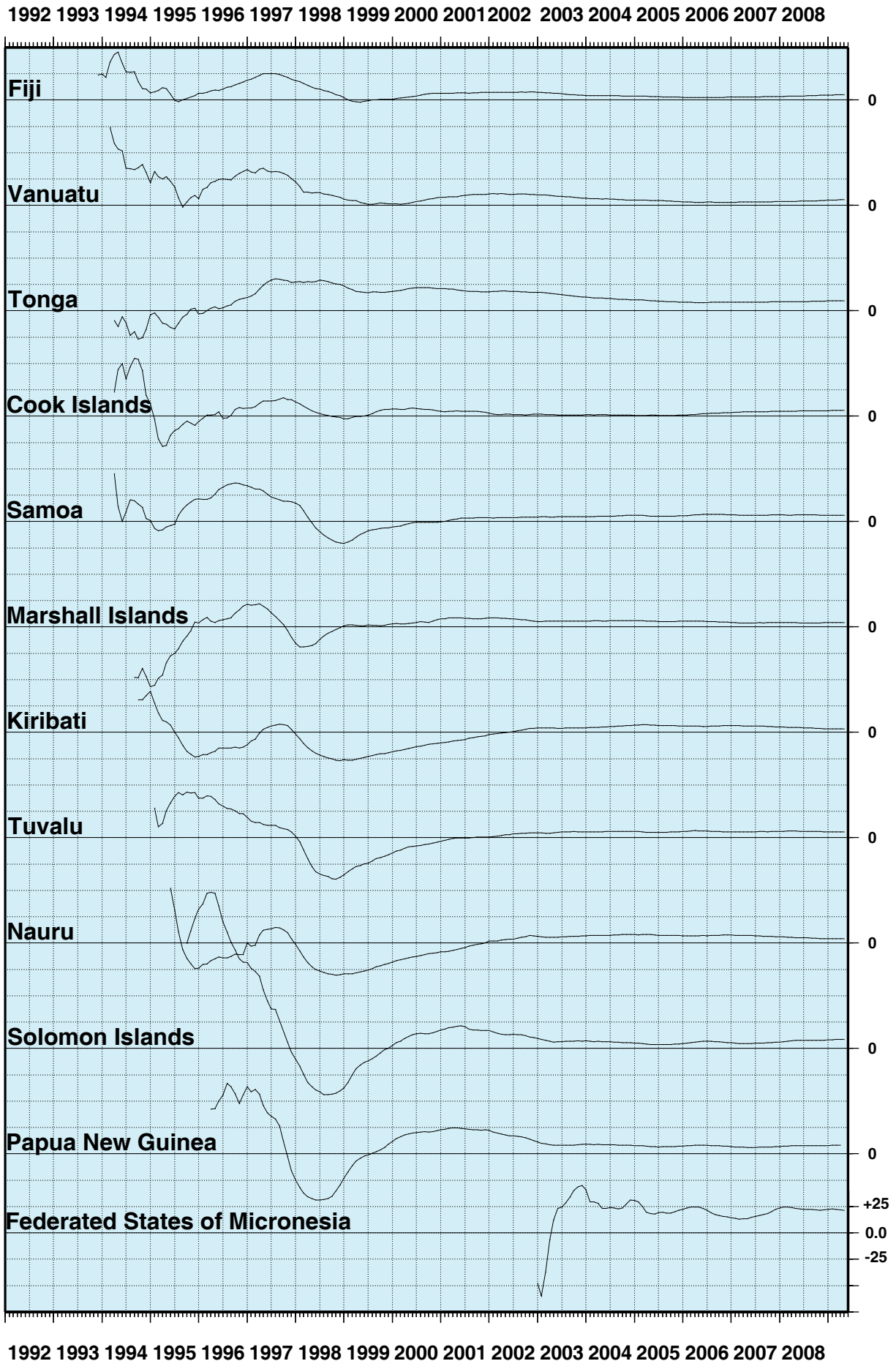


Figure 14

# BAROMETRIC PRESSURE ANOMALIES THROUGH APRIL 2009 (hPa)

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

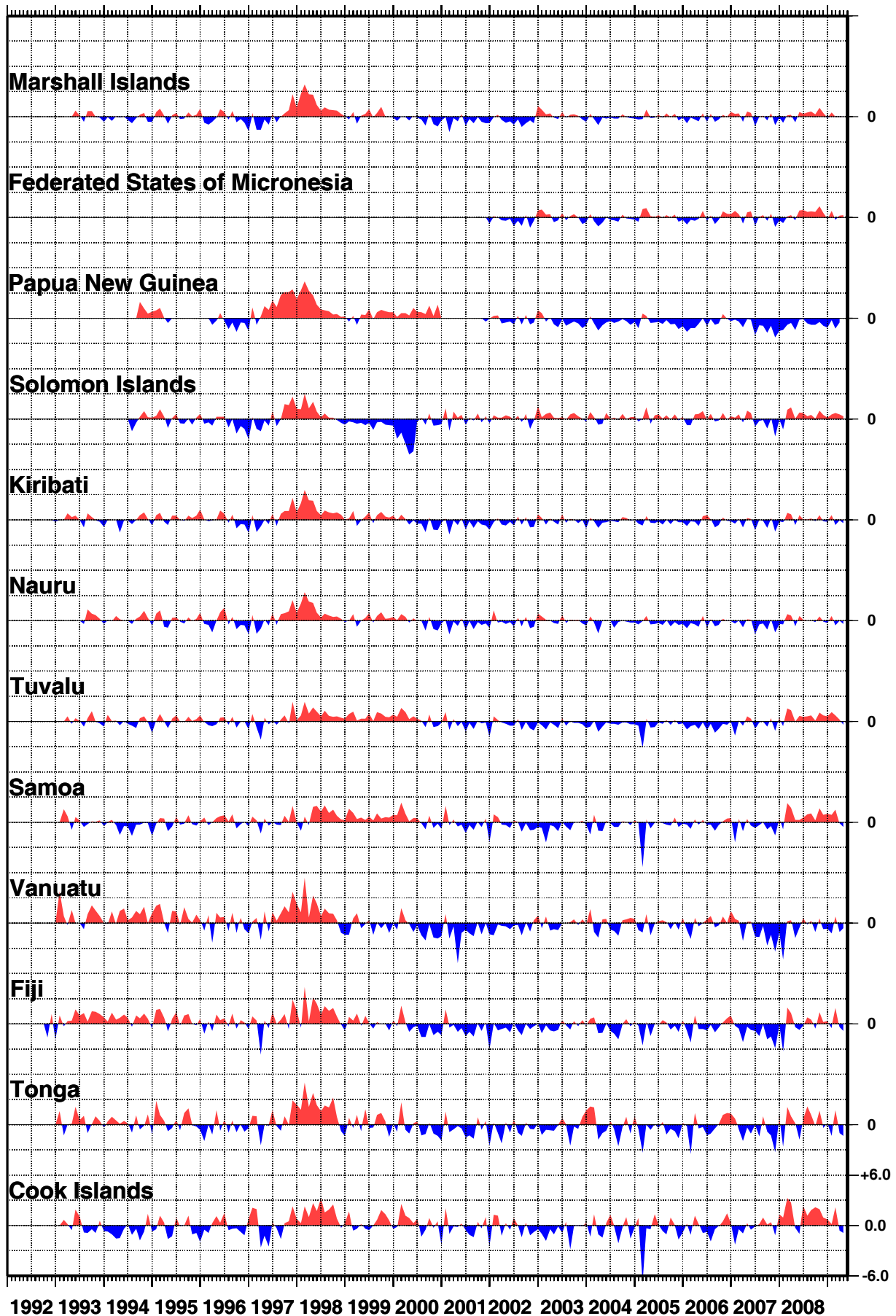


Figure 15  
**WATER TEMPERATURE ANOMALIES  
THROUGH APRIL 2009 (°C)**

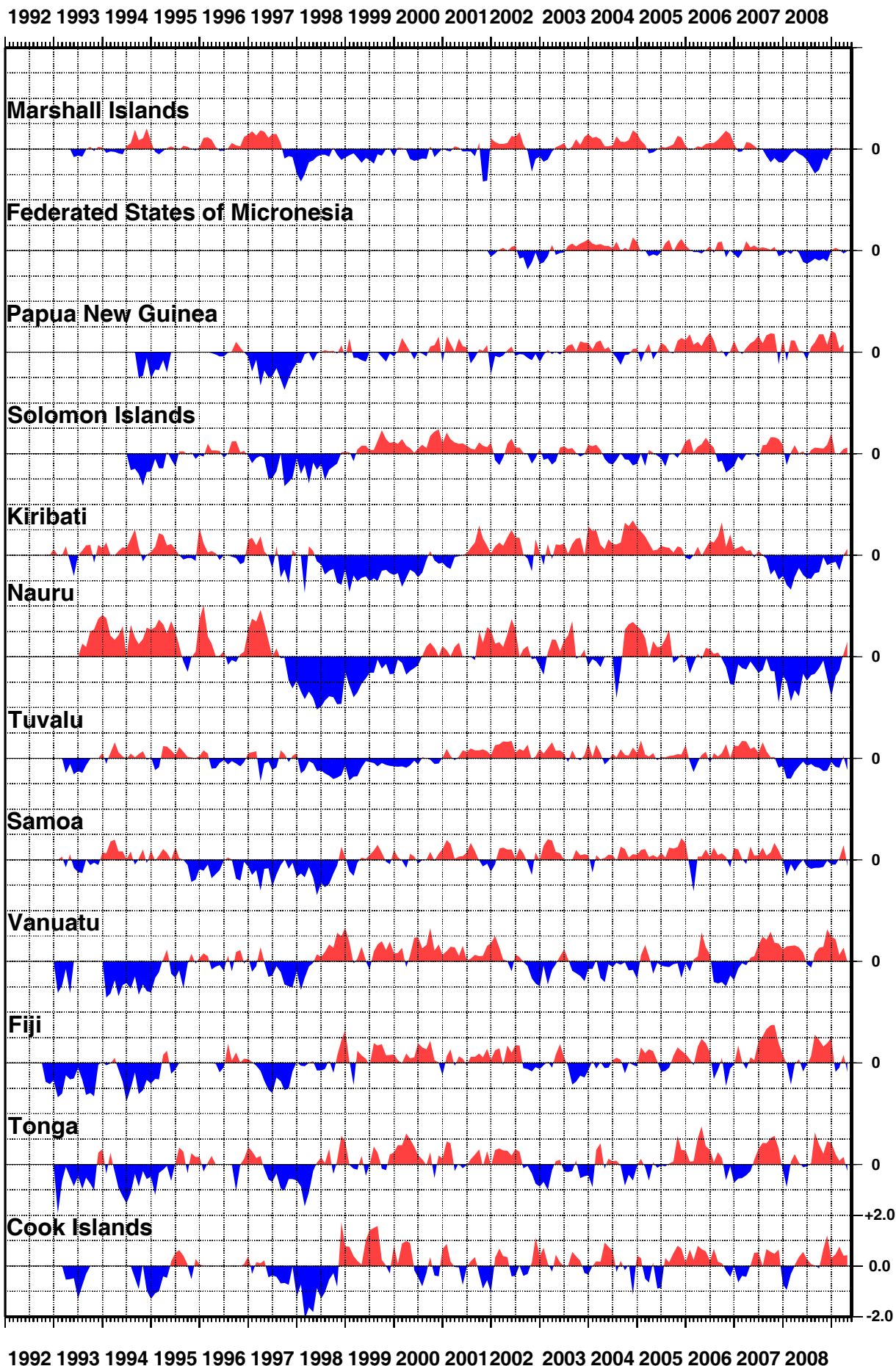


Figure 16  
**AIR TEMPERATURE ANOMALIES  
THROUGH APRIL 2009 (°C)**

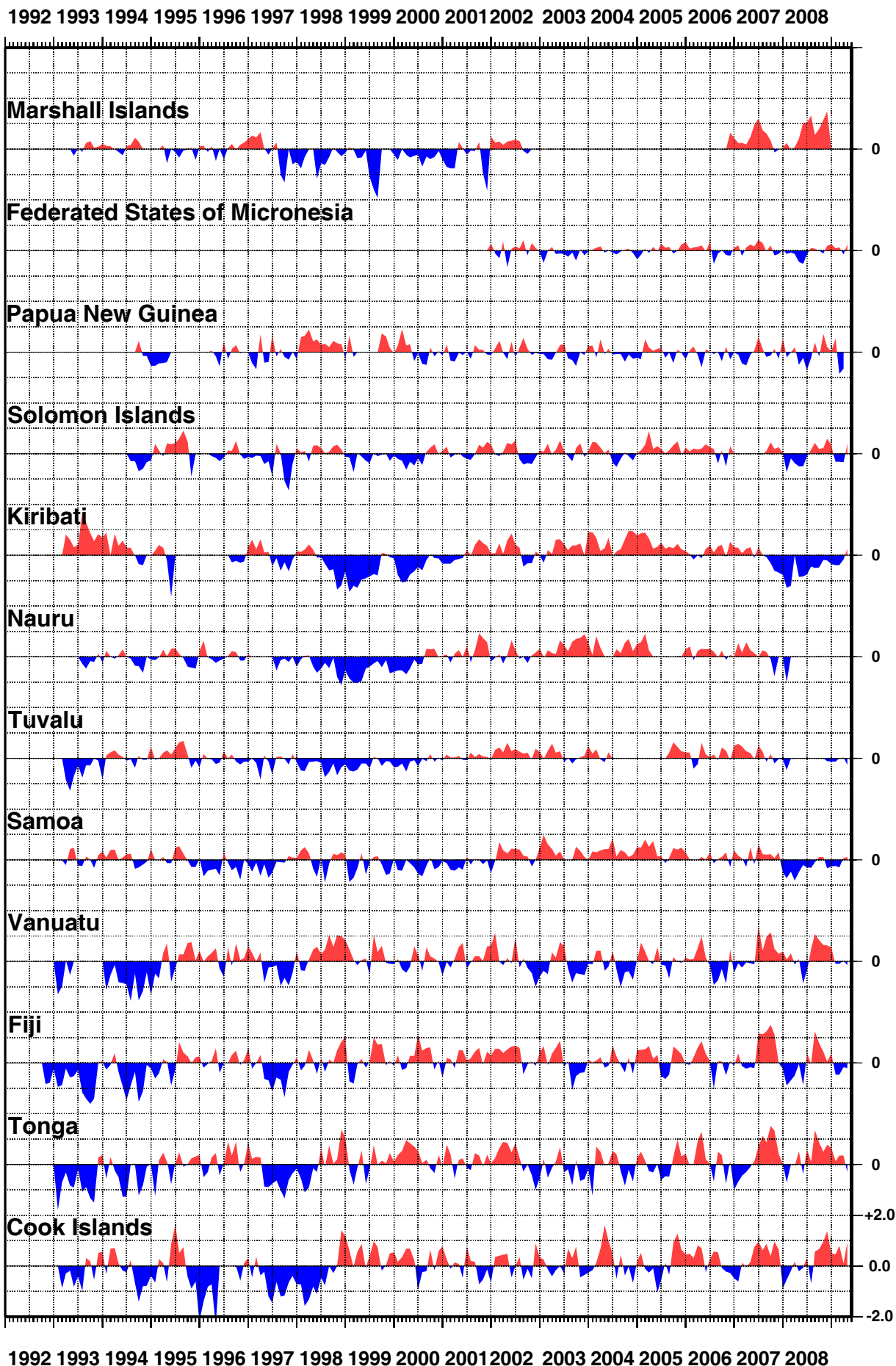


Figure 17

# SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED

GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE

\* Patchy record

