

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

**MONTHLY DATA REPORT**

**NO. 183**

**SEPTEMBER 2010**



**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 September 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**

**September 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.

#### ***September 2010***

- The SEAFRAME network continued to collect high quality sea level and associated meteorological information for monitoring climate variability and climate change.
- Technical problems with the equipment at Samoa and Cook Islands were resolved by way of special service visits during September and those stations have returned to good health.
- The La Niña event strengthened during September and the Southern Oscillation Index reached its highest monthly value since 1973. Climate conditions associated with the event include cooler than normal ocean temperatures across the equatorial Pacific, stronger than normal Trade Winds and below average cloudiness in the vicinity of the dateline. In contrast, warmer than normal sea surface temperatures were observed south of the equator across the southwest Pacific.
- Sea levels were depressed across the equator, where the SEAFRAME stations of Kiribati and Nauru registered anomalies around 10cm below normal. Slightly lower than normal sea levels were observed at Vanuatu and Fiji, while higher than normal sea levels developed at Marshall Islands and FSM.
- The majority of international climate models predict that the La Niña event will persist into 2011.



## 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 September, 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	+8.9	-0.1
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+5.1	-0.1
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+6.2	-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	+3.8	0.0
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.2	-0.2
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+4.0	-0.2
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+5.9	0.0
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+6.5	+0.1
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+14.8	+0.7
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.0	+0.2

## INTRODUCTION

Welcome to the September 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,

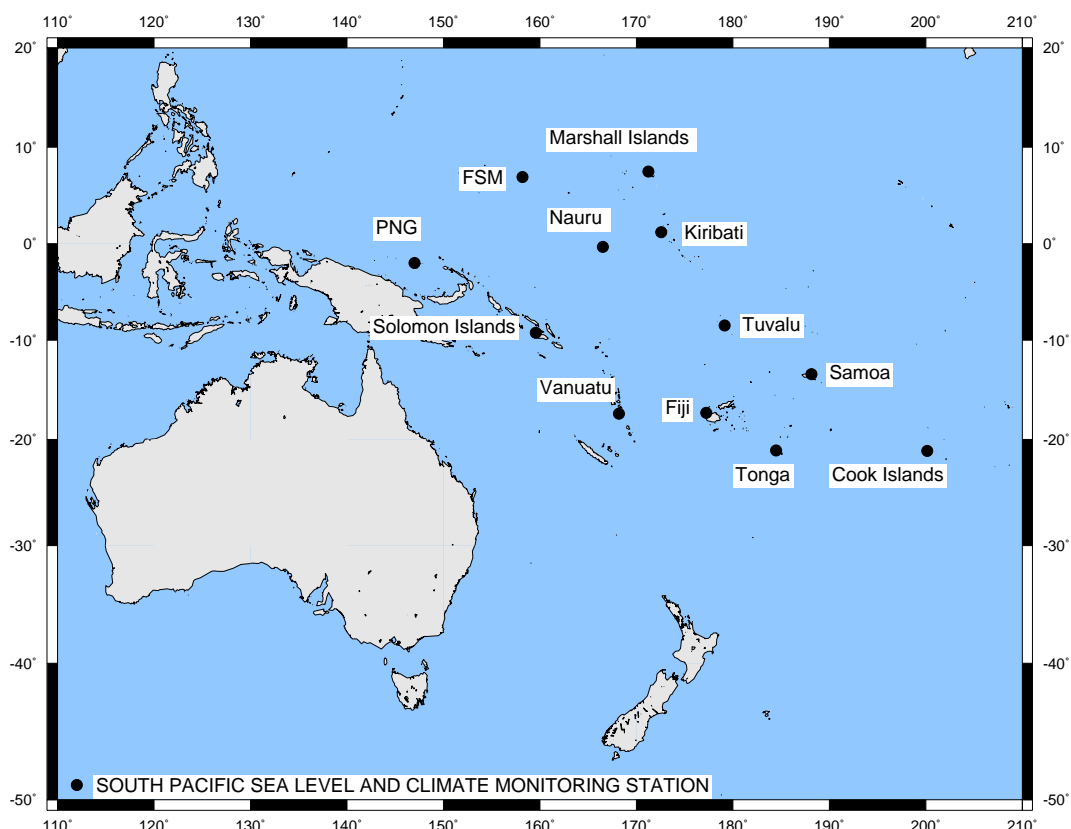


wind direction and atmospheric pressure. There is an associated programme of levelling to first order, to determine shifts in the vertical of the sea level sensors due to local land movement. Continuous Global Positioning System (CGPS) measurements are now also being made to determine the vertical movement 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*



## SEPTEMBER CLIMATOLOGY

La Niña climate conditions strengthened across the equatorial Pacific during September. The Southern Oscillation Index (SOI) reached its highest monthly value since 1973, while cooler-than-normal ocean temperatures across the central equatorial Pacific were at levels typical of a moderate La Niña. Trade Winds were stronger than normal across the western and central Pacific and cloudiness was suppressed over the central equatorial Pacific. International climate models predict that the La Niña event will persist into early 2011.

The Southern Oscillation Index (SOI) has been positive since April and remained well above La Niña thresholds during September, with a value of +25 following the August value of +19 (**Figure B**). The September SOI of +25 is the highest it has been since November 1973. 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 September. Sea surface temperatures along much of the equator are at least 1°C cooler than normal. Sea surface temperatures in the far western equatorial Pacific and southwest Pacific on the other hand remain more than 1°C warmer than normal (**Figure C**).

Subsurface ocean temperatures across the central and eastern equatorial Pacific continued to cool through September. Subsurface temperatures east of the dateline were 4°C cooler than normal. Subsurface temperatures across the equator have been in decline since December 2009 and cooler than normal since April 2010 (**Figure D**).

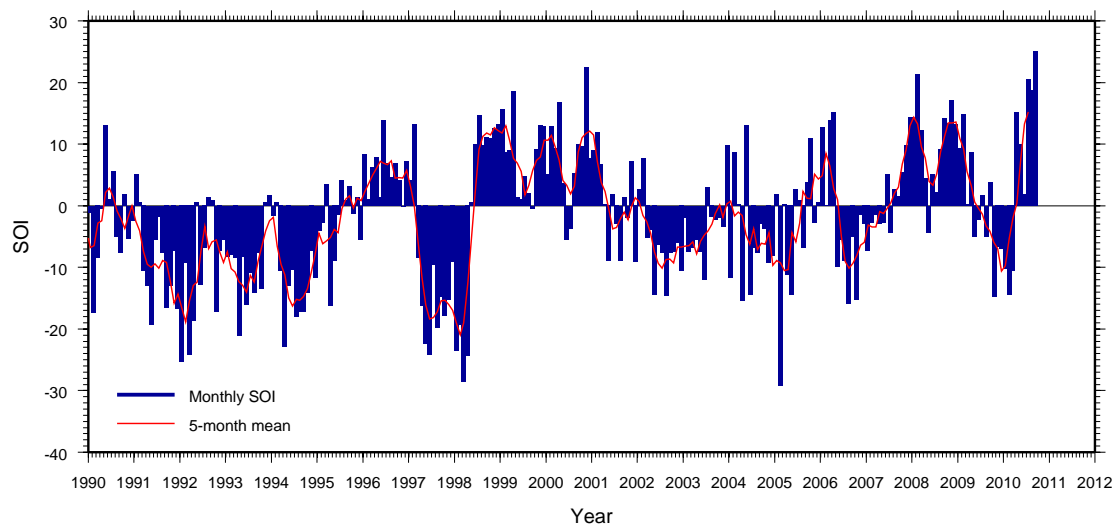
During El Niño (warm-episode) conditions there is a sustained weakening of the Trade Winds across much of the equatorial Pacific and an increase in cloudiness in the central equatorial Pacific particularly near the dateline. During La Niña (cold-episode) conditions there is a reversal of this situation, with stronger Trade Winds and a decrease in cloudiness in the central Pacific. During September 2010 Trade Winds were stronger than normal across the western and central Pacific (**Figure E**). Cloudiness near the dateline remained below average during September and has generally been suppressed since late April.

The consensus among international computer models surveyed by the Bureau of Meteorology predicts that La Niña conditions are expected to persist but gradually weaken into early 2011.

*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/>.*

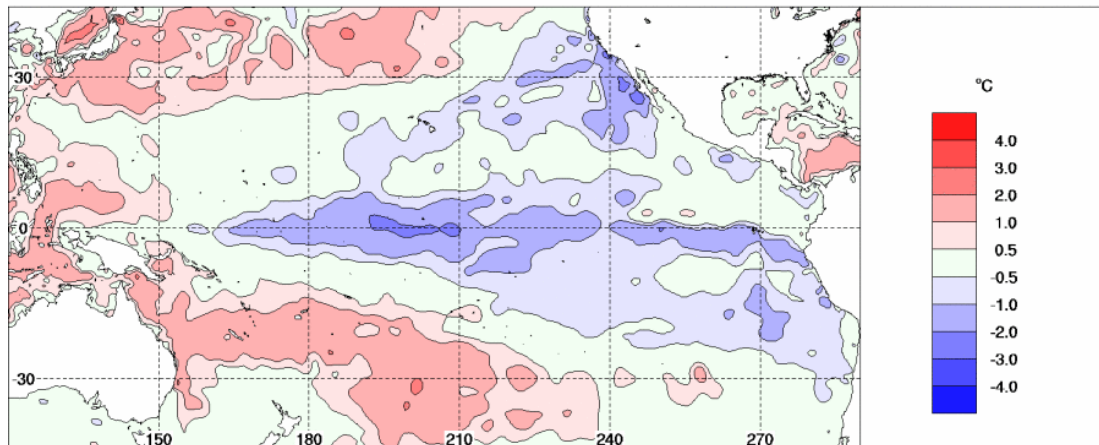


## Southern Oscillation Index (SOI)



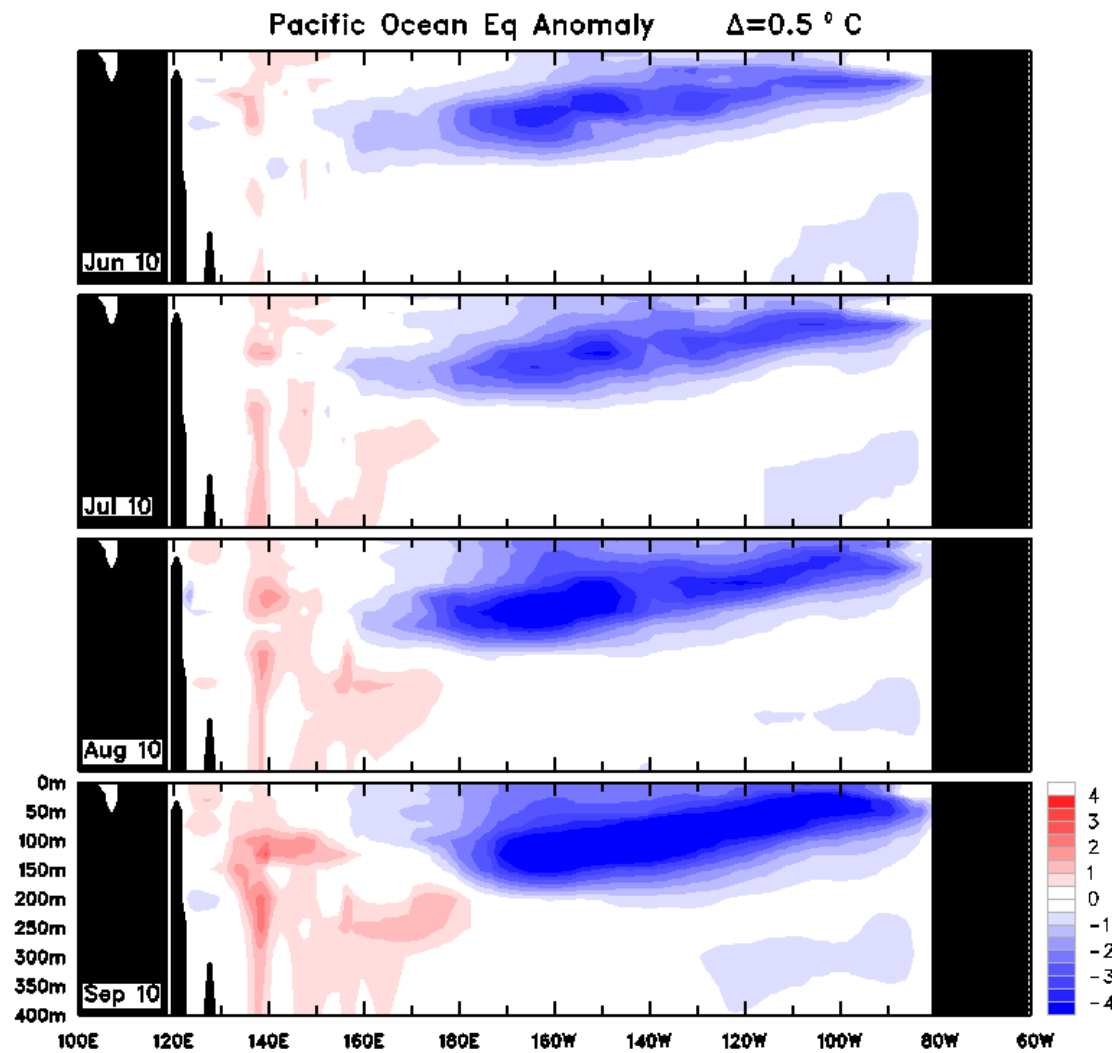
**Figure B:** The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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

SSTA 1.0X1.0 NMOC OCEAN ANOMALIES (C) 20100901 20100930

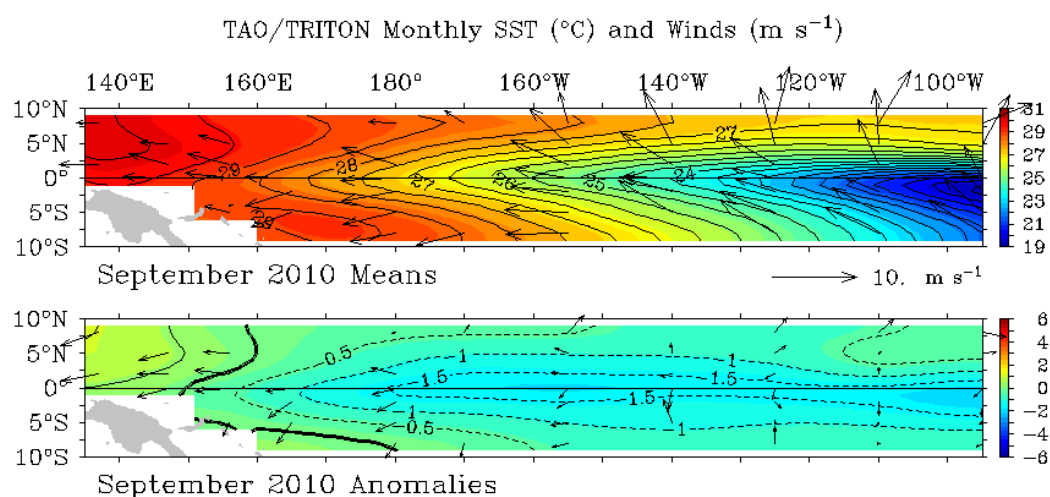


**Figure C:** Sea surface temperature anomaly ( $^{\circ}\text{C}$ ) for September 2010.





**Figure D:** Equatorial depth-longitude section of ocean temperature anomalies for June 2010 through to September 2010. Contour interval is  $0.5^\circ\text{C}$ .



TAO/NOBC/NOAA

Oct 19 2010

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



## SEPTEMBER 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 8<sup>th</sup> of September and a full moon on the 23<sup>rd</sup> of September UTC. The new moon coincided with lunar perigee, when the moon is nearest to earth during its monthly orbit, and the combined effect was particularly large spring tides at this time.

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 Vanuatu 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 farther 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 air temperatures recorded at Samoa (31.8°C) and Tonga (27.0°C) during September 2010 are their highest September air temperatures on record. Record minimum September air temperatures were recorded at Marshall Islands (22.2 °C) and PNG (21.8°C). A record maximum September water temperature of 26.5 °C was recorded at Cook Islands. Record maximum September barometric pressures were recorded at Tuvalu (1015.4hPa), Fiji (1019.4hPa) and Tonga (1024.6hPa).

### 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. The monthly mean sea level at Marshall Islands in September 2010 is the equal highest on record, equalling the monthly mean sea level observed in November 2000.

**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.

Significantly lower than normal sea levels continued to be observed at the equatorial stations of Kiribati and Nauru through September, where anomalies persist at around -10cm. Marginally lower than normal sea levels were also observed at Vanuatu and Fiji. Higher than normal sea levels developed at Marshall Islands and FSM during September while elsewhere sea levels were generally within 5cm of what is normal for this time of the year.

### Sea Level Trends

The **short-term sea level trends** at individual stations as at September 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 September, 2010				
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Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+5.9	0.0
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+6.5	+0.1
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+14.8	+0.7
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.0	+0.2

### 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 September 2010 barometric pressures were generally near to slightly above 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 September 2010, in agreement with warmer than normal sea surface temperatures across the southwest Pacific region (**Figure C**). Anomalies in excess of +1°C were observed at Vanuatu, Fiji, Tonga and Cook Islands. Cooler-than-normal water temperatures were observed at Nauru in agreement with the presence of cooler-than-normal sea surface temperatures across the equator (**Figure C**).



The **air temperature anomalies (Figure 16)** also show warmer than normal air temperatures were also observed at the majority of stations during September 2010. Air temperature anomalies in excess of  $+1^{\circ}\text{C}$  were observed at Vanuatu, Fiji, Tonga and Cook Islands and cooler than normal air temperatures were observed at the equatorial stations Kiribati and Nauru in connection with the regional sea surface temperature pattern. 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.

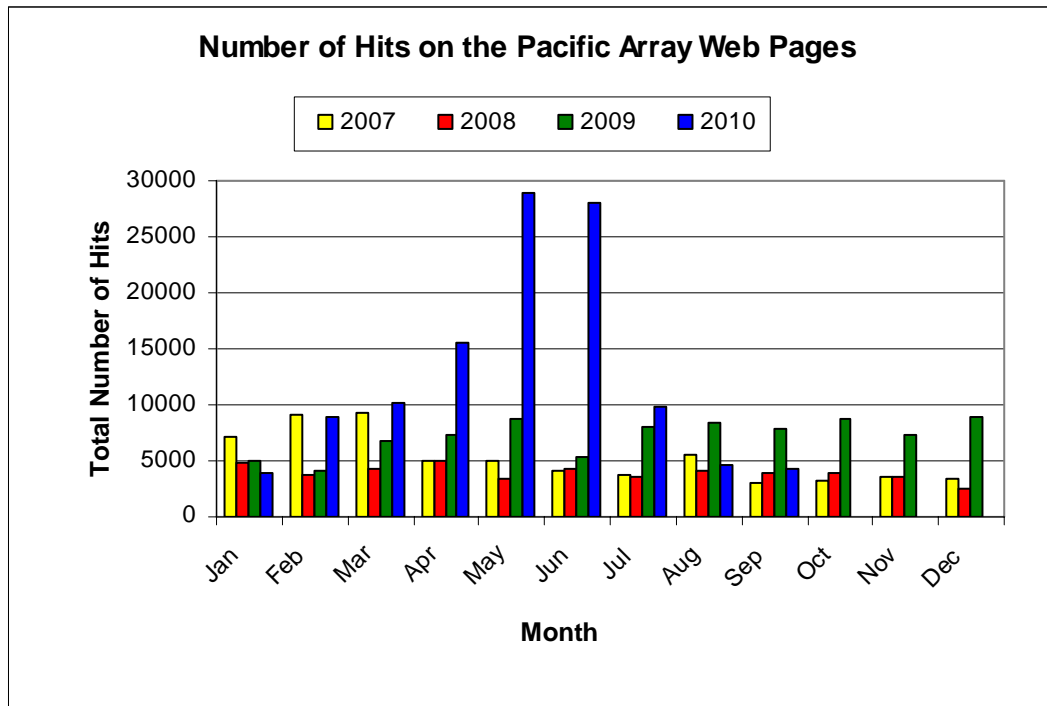
Sea level data return was good for most stations during September 2010, although returns from Samoa and Cook Islands continued to be hampered by technical difficulties. Power supply problems disrupted operations at Samoa but these were resolved at a special service visit on the 30<sup>th</sup> of September. The primary and secondary sea level sensors at Cook Islands were inoperative but were repaired during a special service visit on the 27<sup>th</sup> of September. The primary sea level sensor at Nauru continued to be inoperative but replacement data from the secondary sea level sensor were used.

Intermittent data communications problems were experienced at Tuvalu throughout September, while isolated communications problems were experienced at FSM, Nauru, and Tonga. At Kiribati one day of data was lost following a 'rebooting' of the data logger and the water temperature sensor remained inoperative throughout September.



## 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.



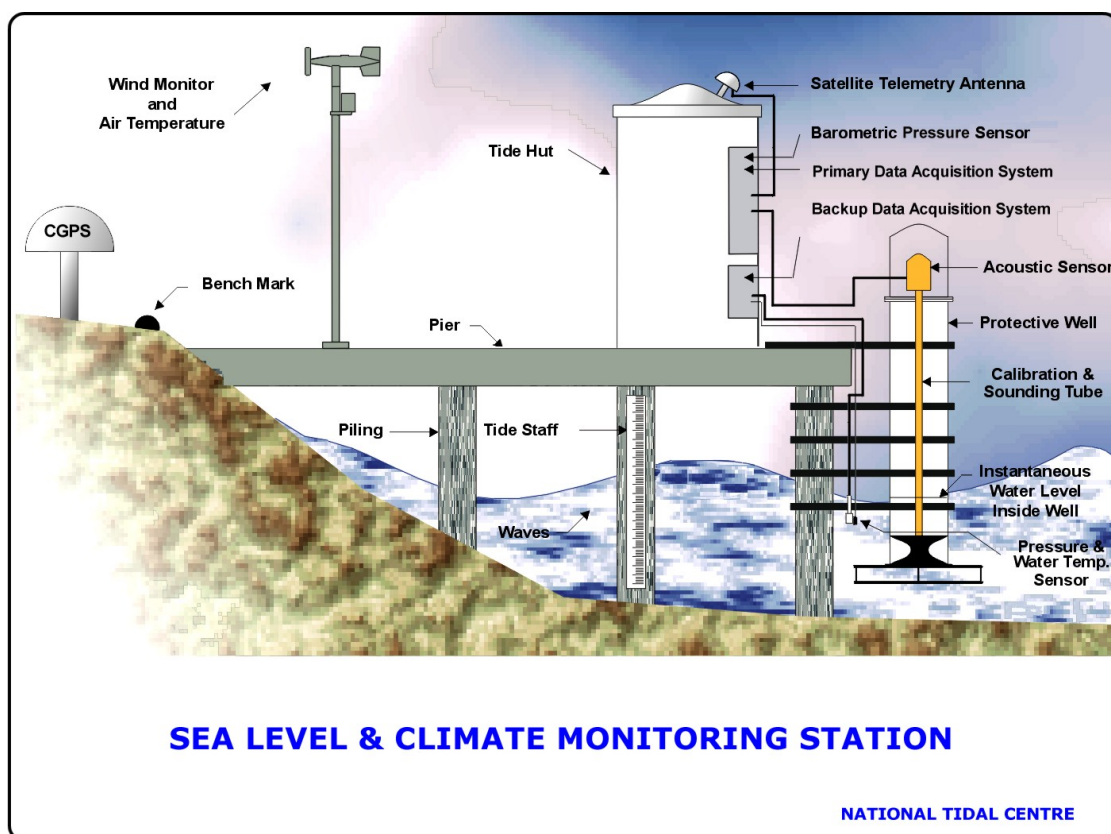


## SEAFRAME STATIONS

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.





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/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.

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Figure 1

**SEPTEMBER 2010**  
**SIX MINUTE WATER LEVEL OBSERVATIONS (m)**

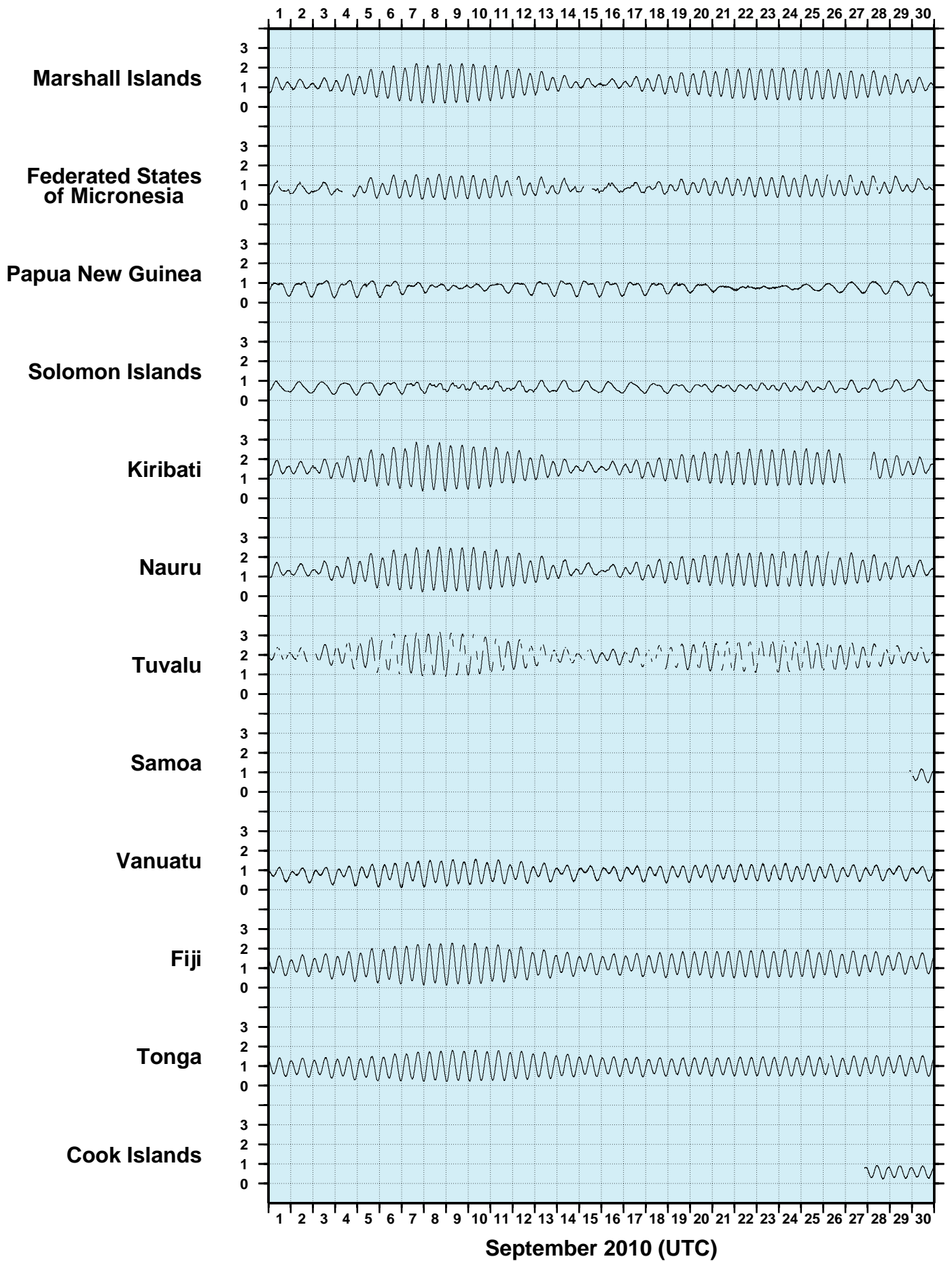




Figure 2  
SEPTEMBER 2010  
SIX MINUTE RESIDUAL WATER LEVELS (m)

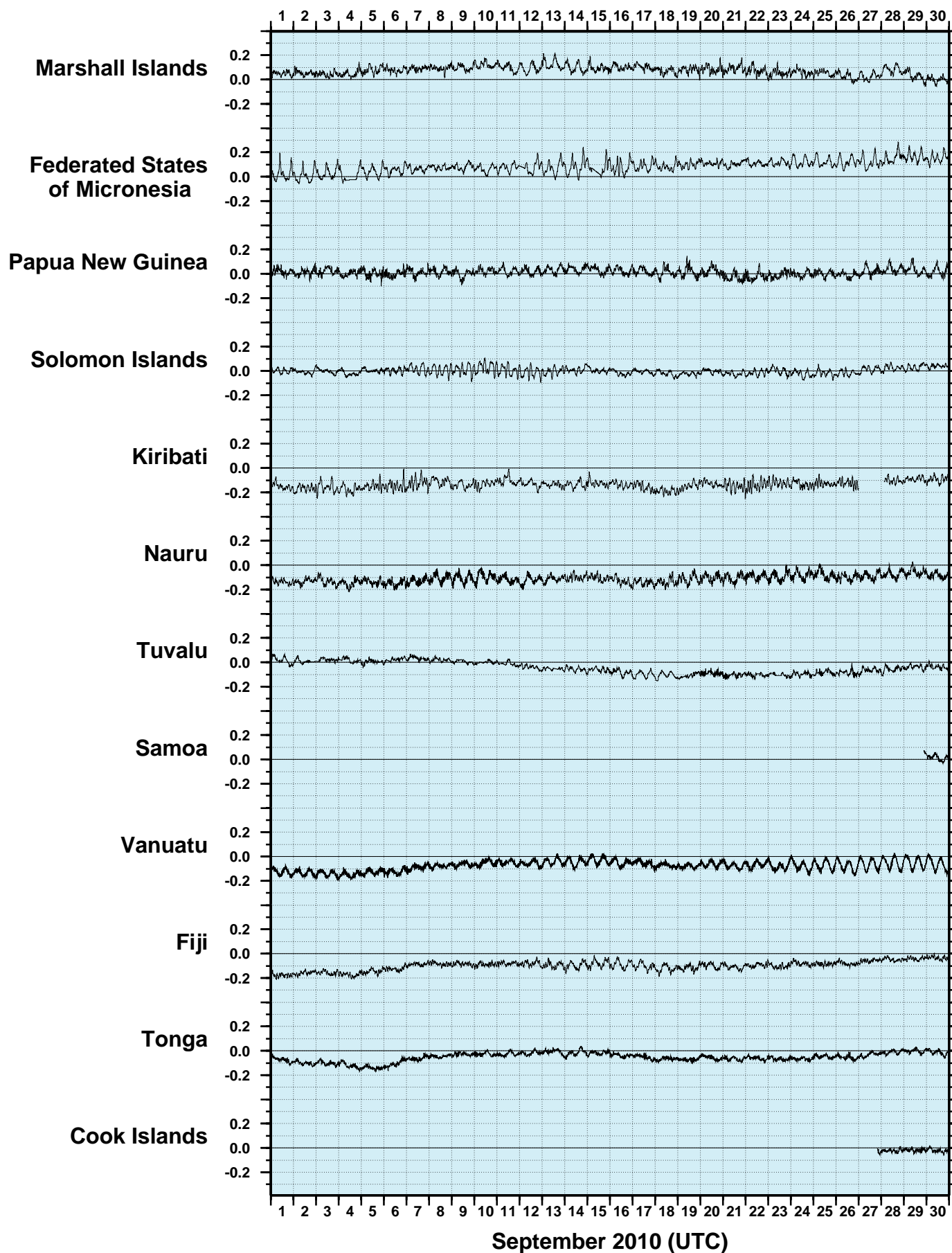




Figure 3

**SEPTEMBER 2010  
SIX MINUTE RESIDUALS  
ADJUSTED FOR ATMOSPHERIC PRESSURE (m)**

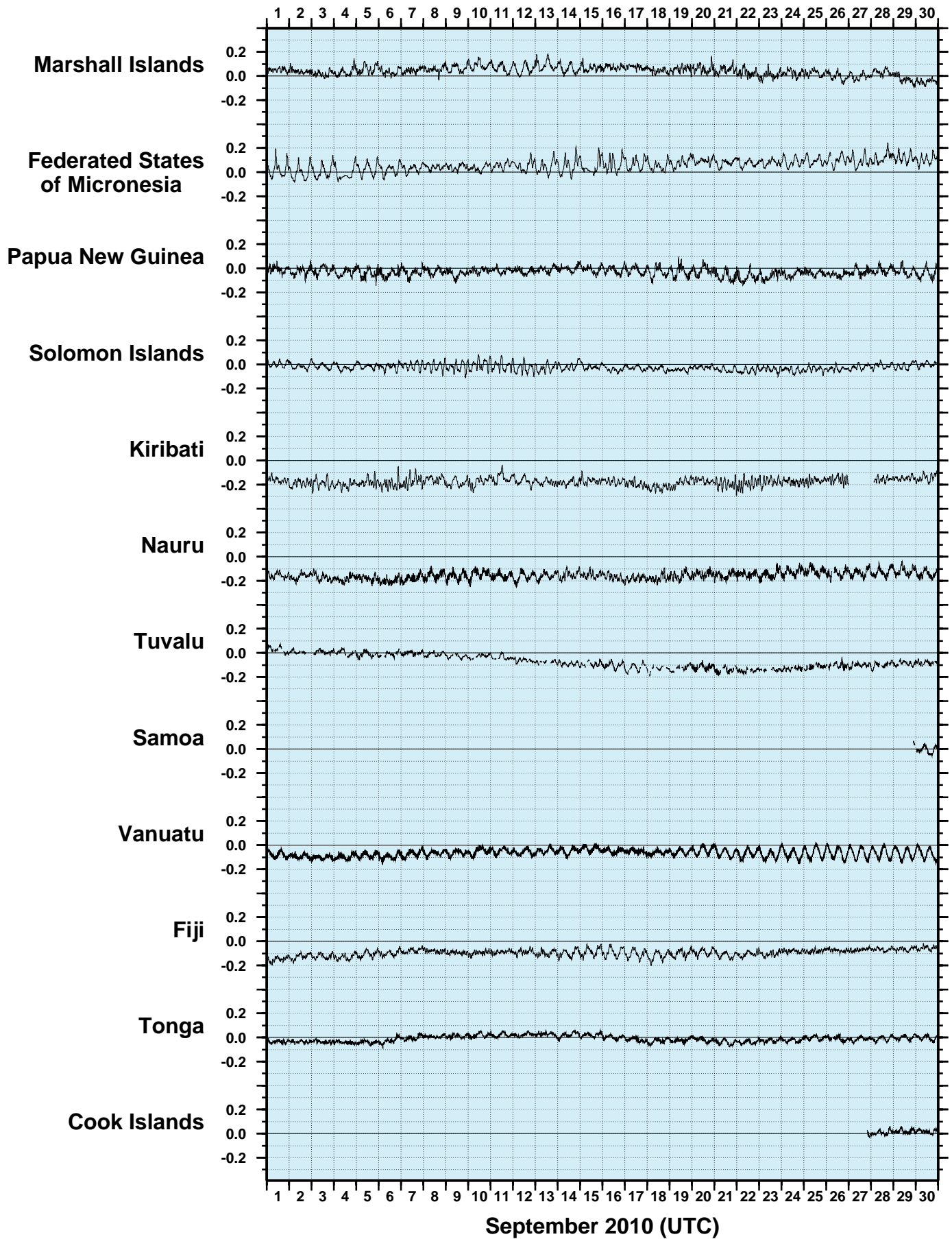




Figure 4

# SEPTEMBER 2010 HOURLY WIND SPEEDS (m/s)

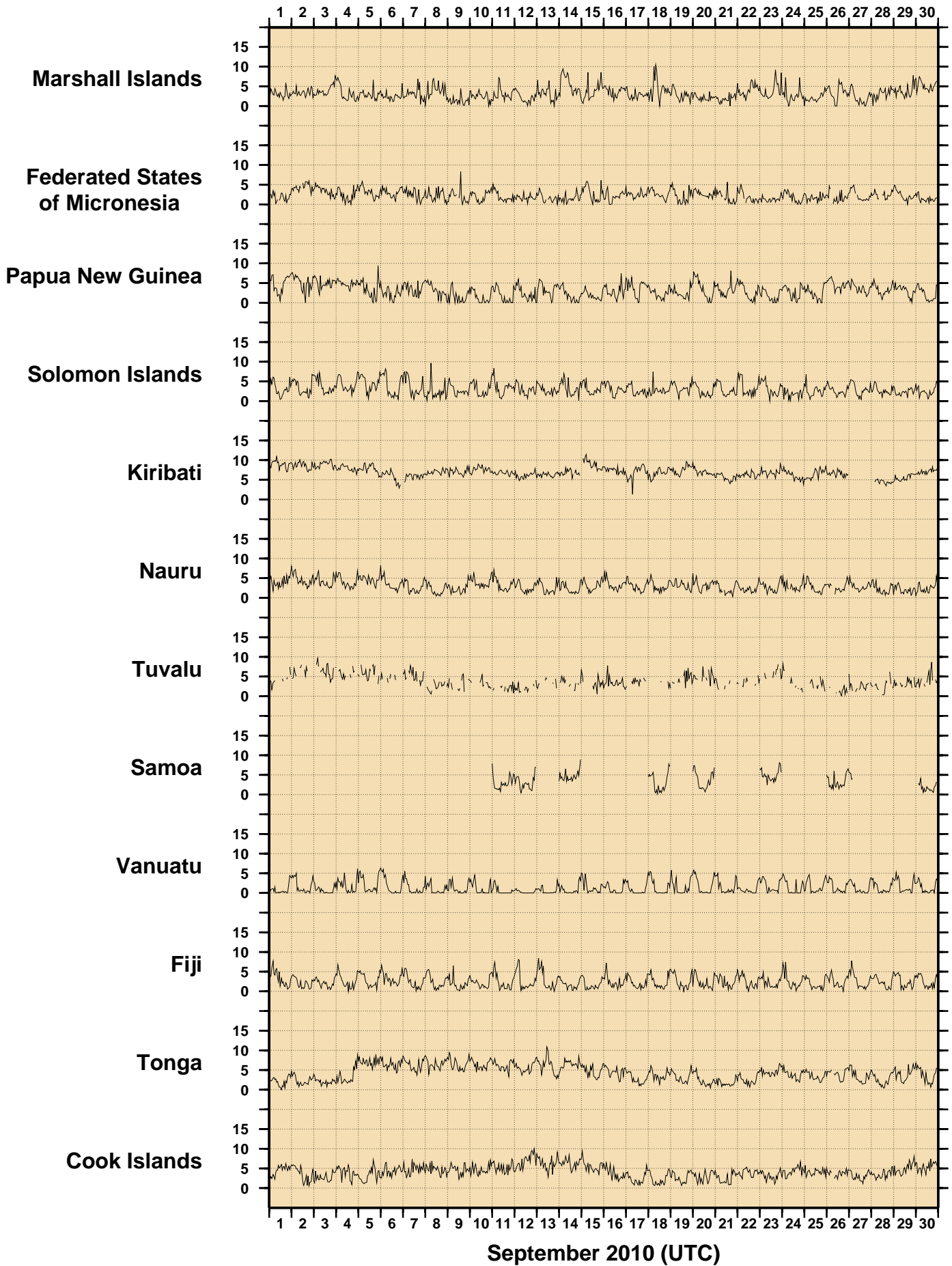




Figure 5  
SEPTEMBER 2010  
HOURLY INCIDENT WINDS (m/s, deg True)

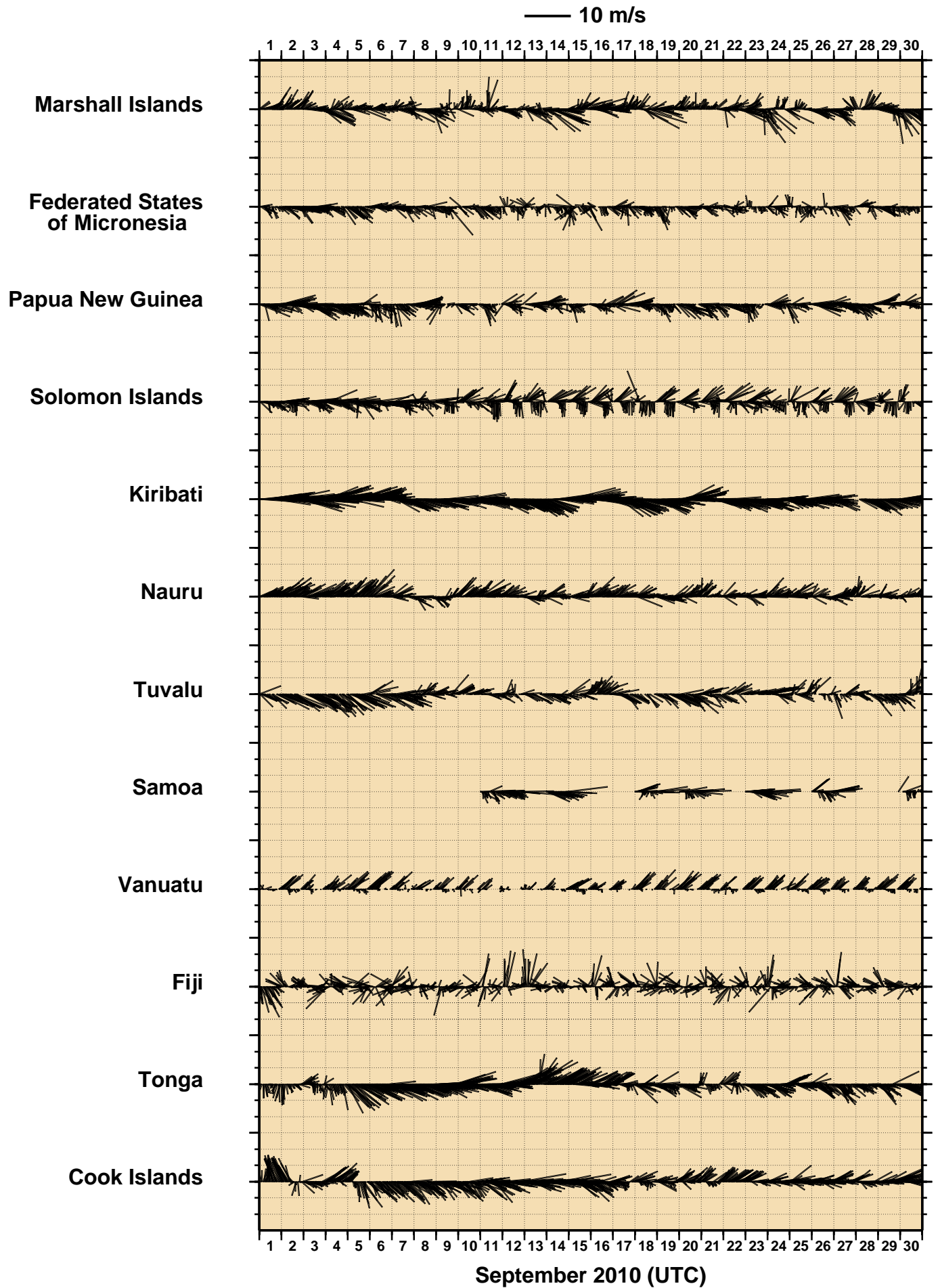




Figure 6  
**SEPTEMBER 2010**  
**HOURLY MAXIMUM WIND GUSTS (m/s)**

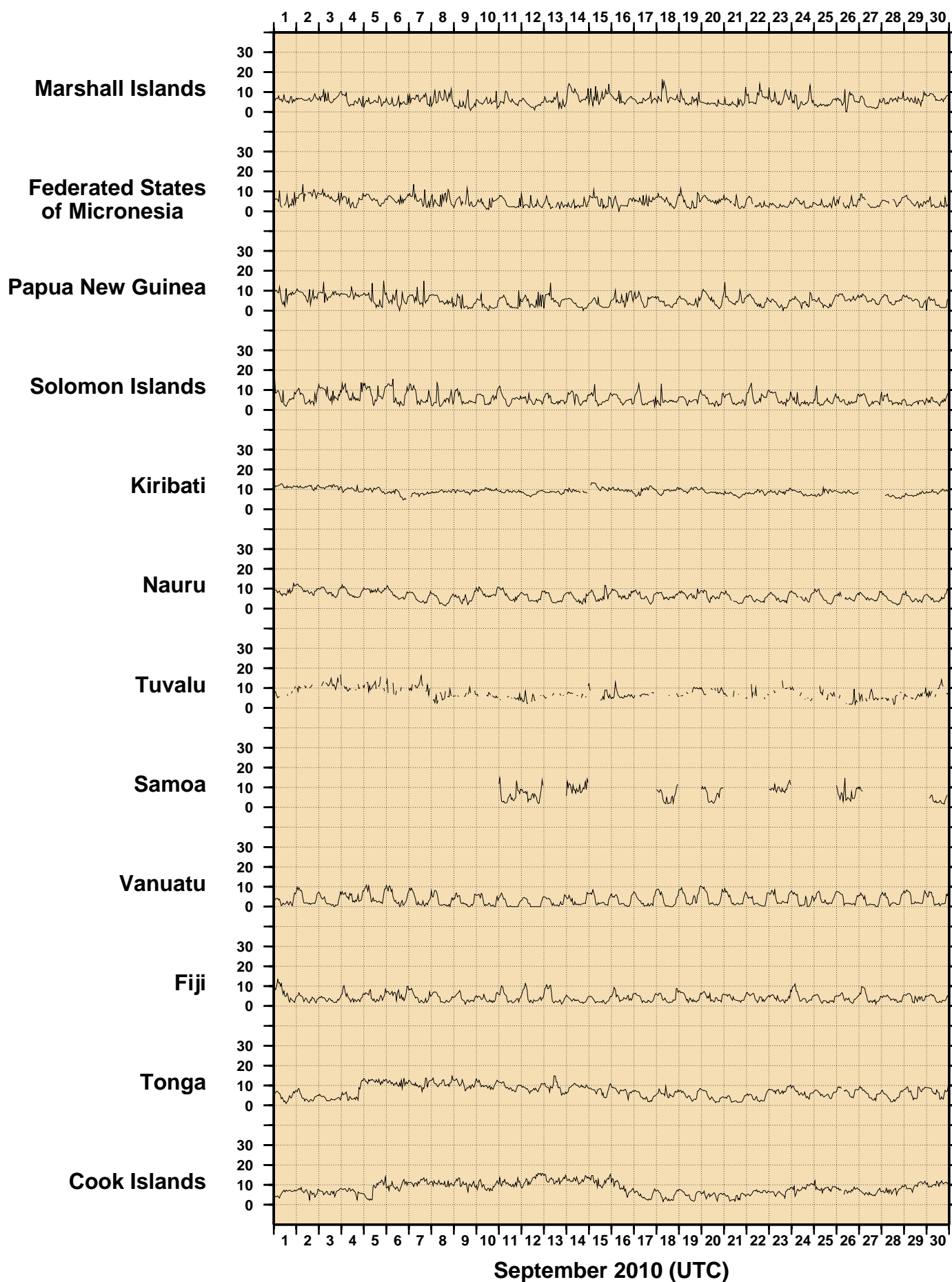




Figure 7  
**SEPTEMBER 2010**  
**HOURLY AIR TEMPERATURES (°C)**





Figure 8  
SEPTEMBER 2010  
HOURLY WATER TEMPERATURES (°C)

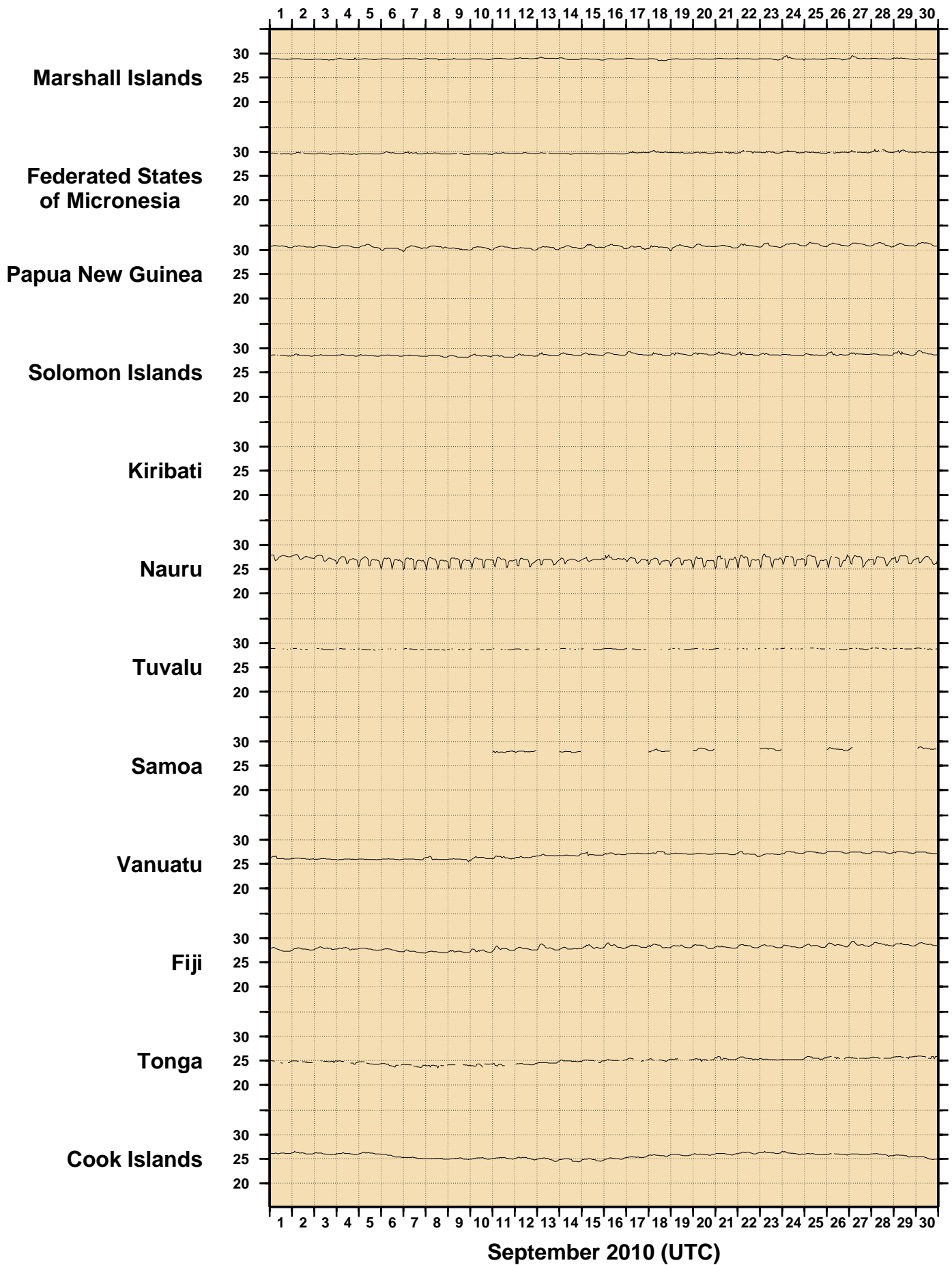




Figure 9  
**SEPTEMBER 2010**  
**HOURLY ATMOSPHERIC PRESSURE (hPa)**

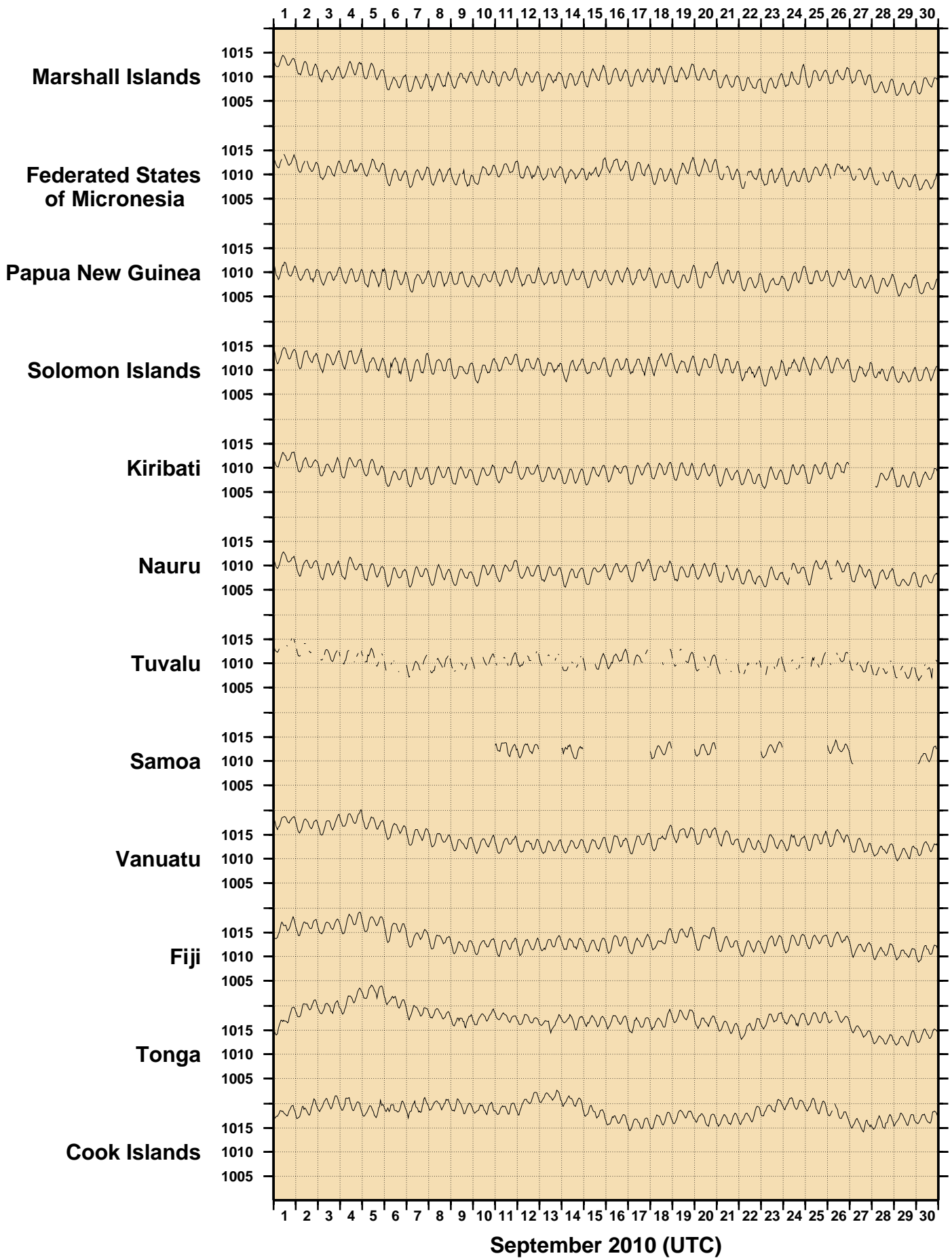
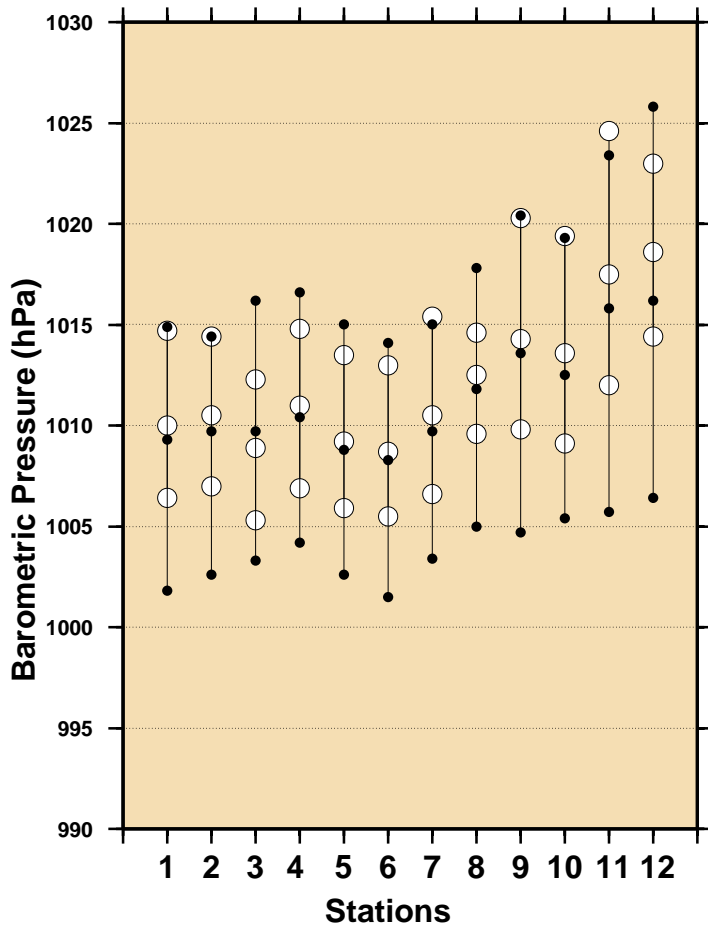
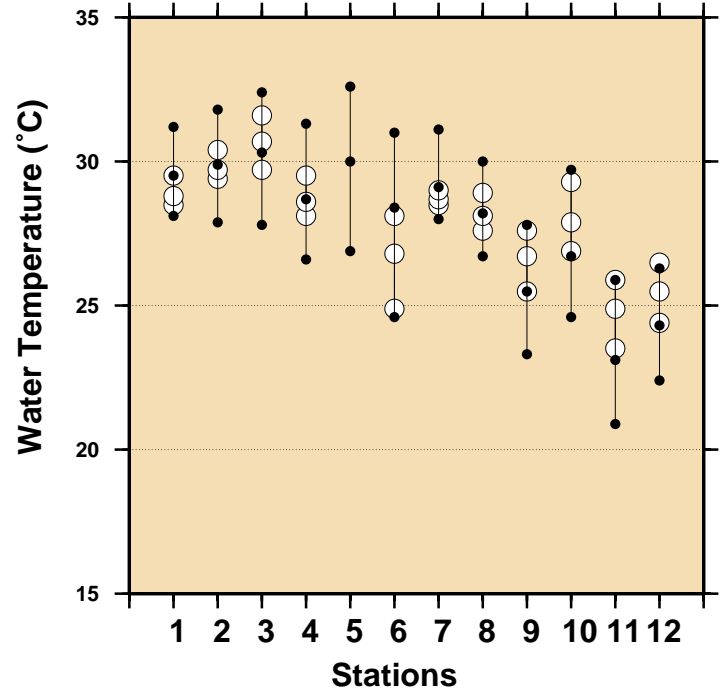
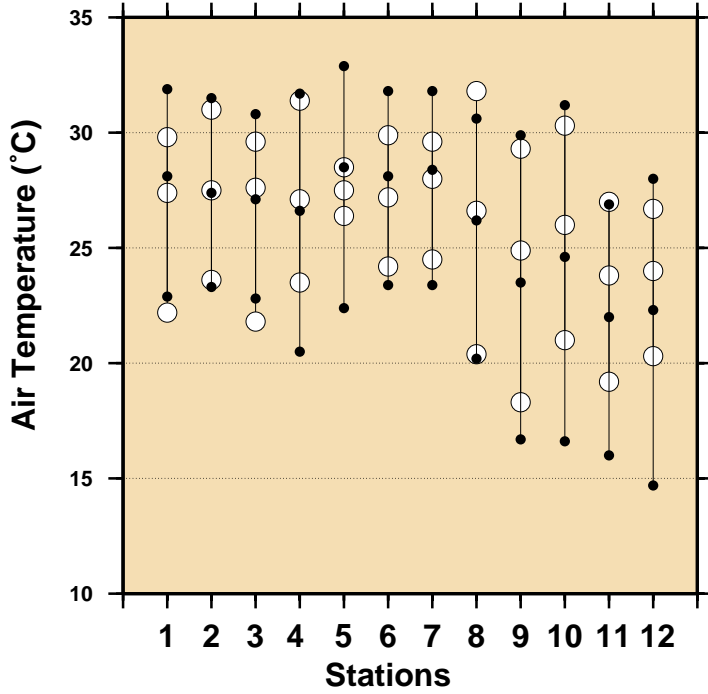




Figure 10

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

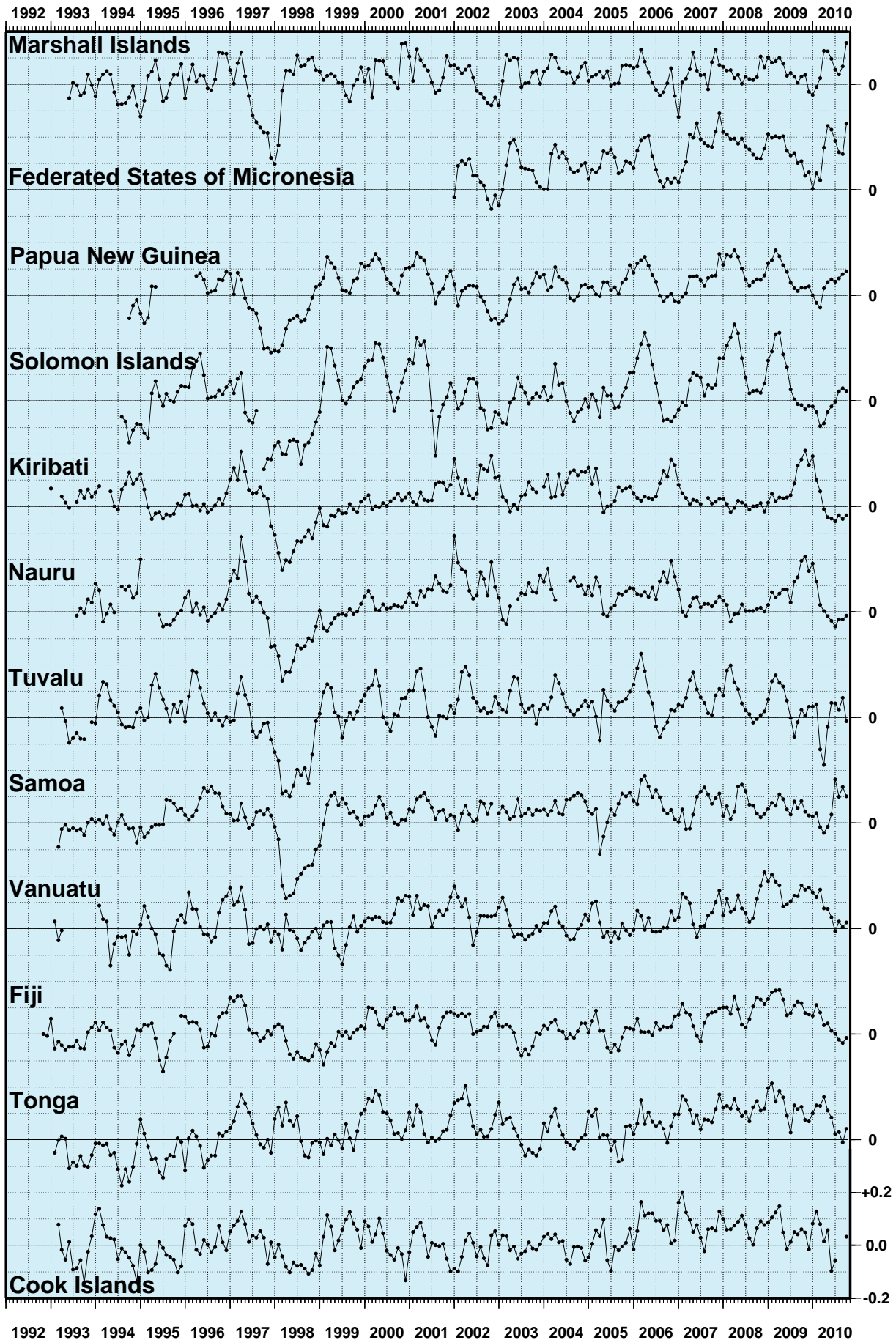
- September 2010 Maximum
- September 2010 Mean
- September 2010 Minimum
- Long Term September Maximum
- Long Term September Mean
- Long Term September Minimum



Figure 11

## MONTHLY MEAN SEA LEVELS TO SEPTEMBER 2010 (m)

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





[illegible]



Figure 13

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

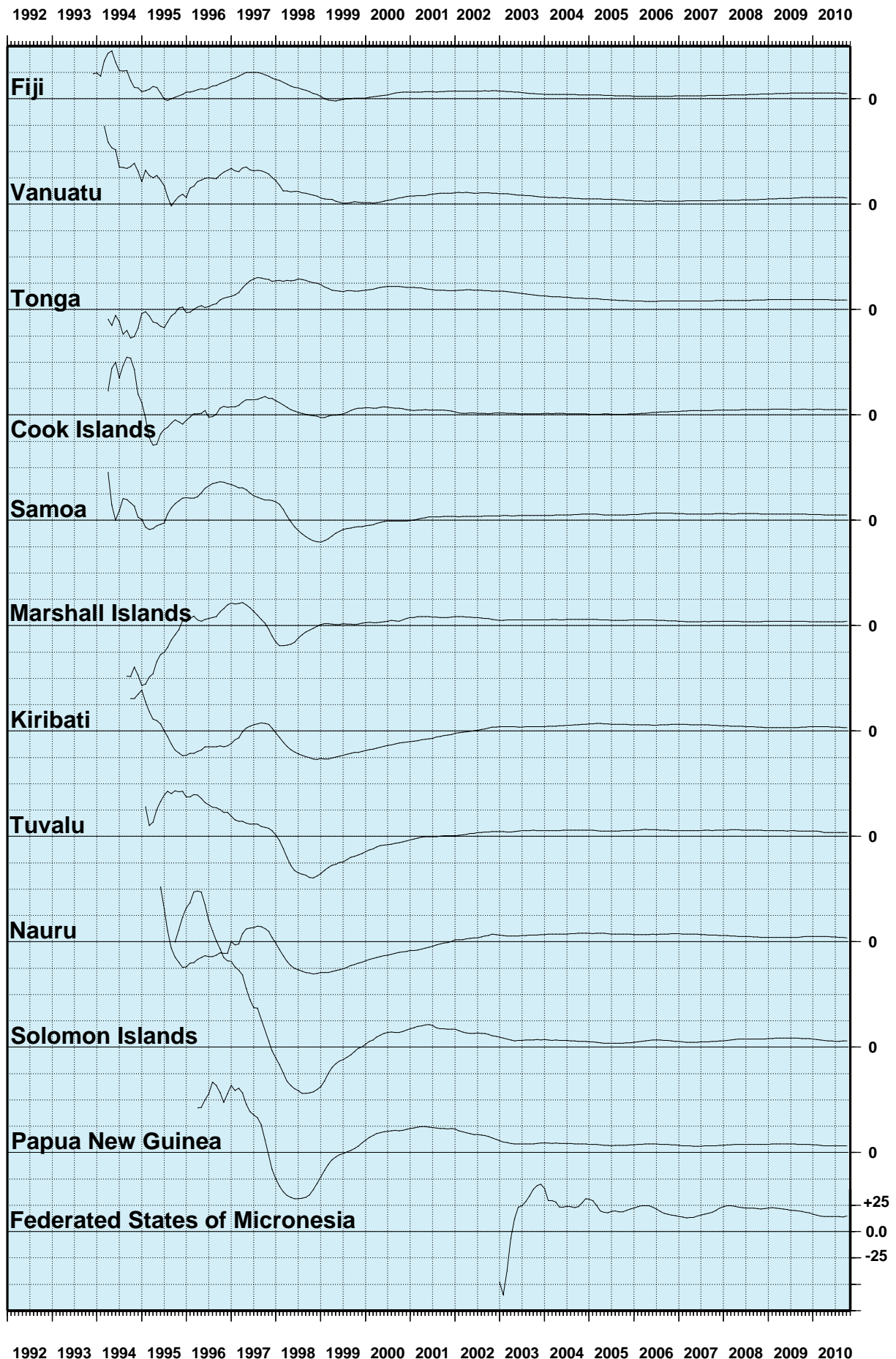




Figure 14

# BAROMETRIC PRESSURE ANOMALIES THROUGH SEPTEMBER 2010 (hPa)

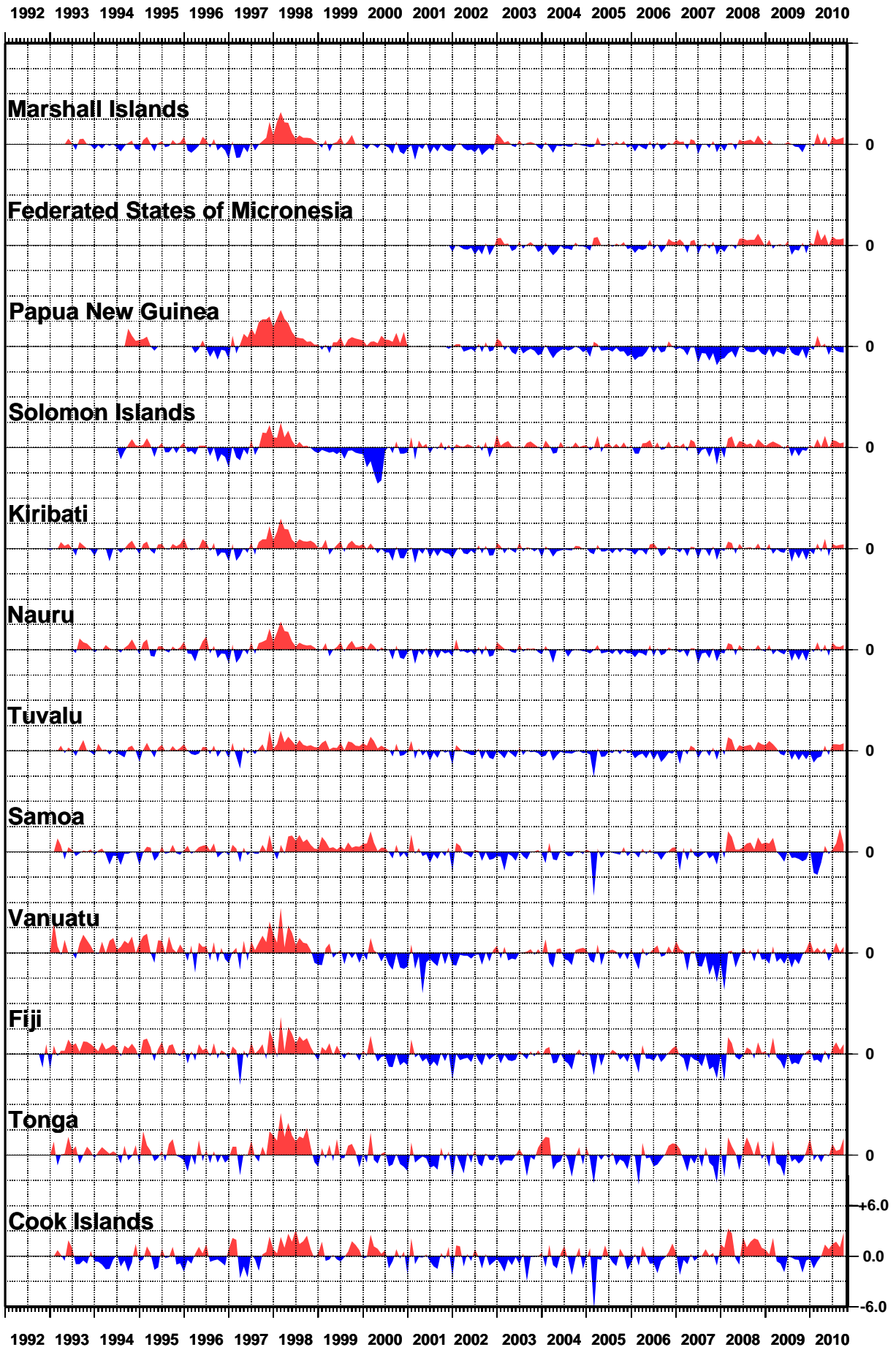




Figure 15  
**WATER TEMPERATURE ANOMALIES  
 THROUGH SEPTEMBER 2010 (°C)**

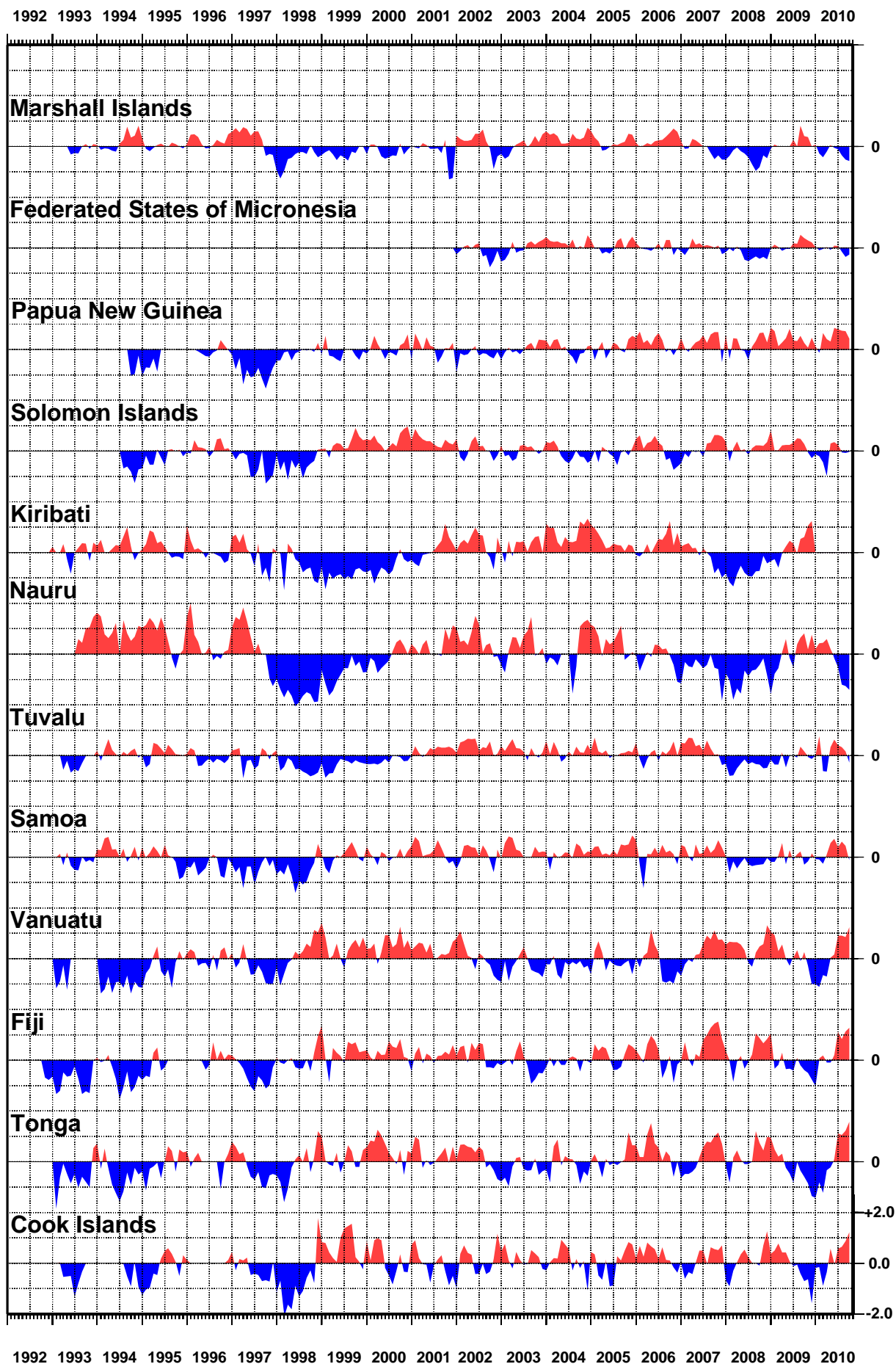
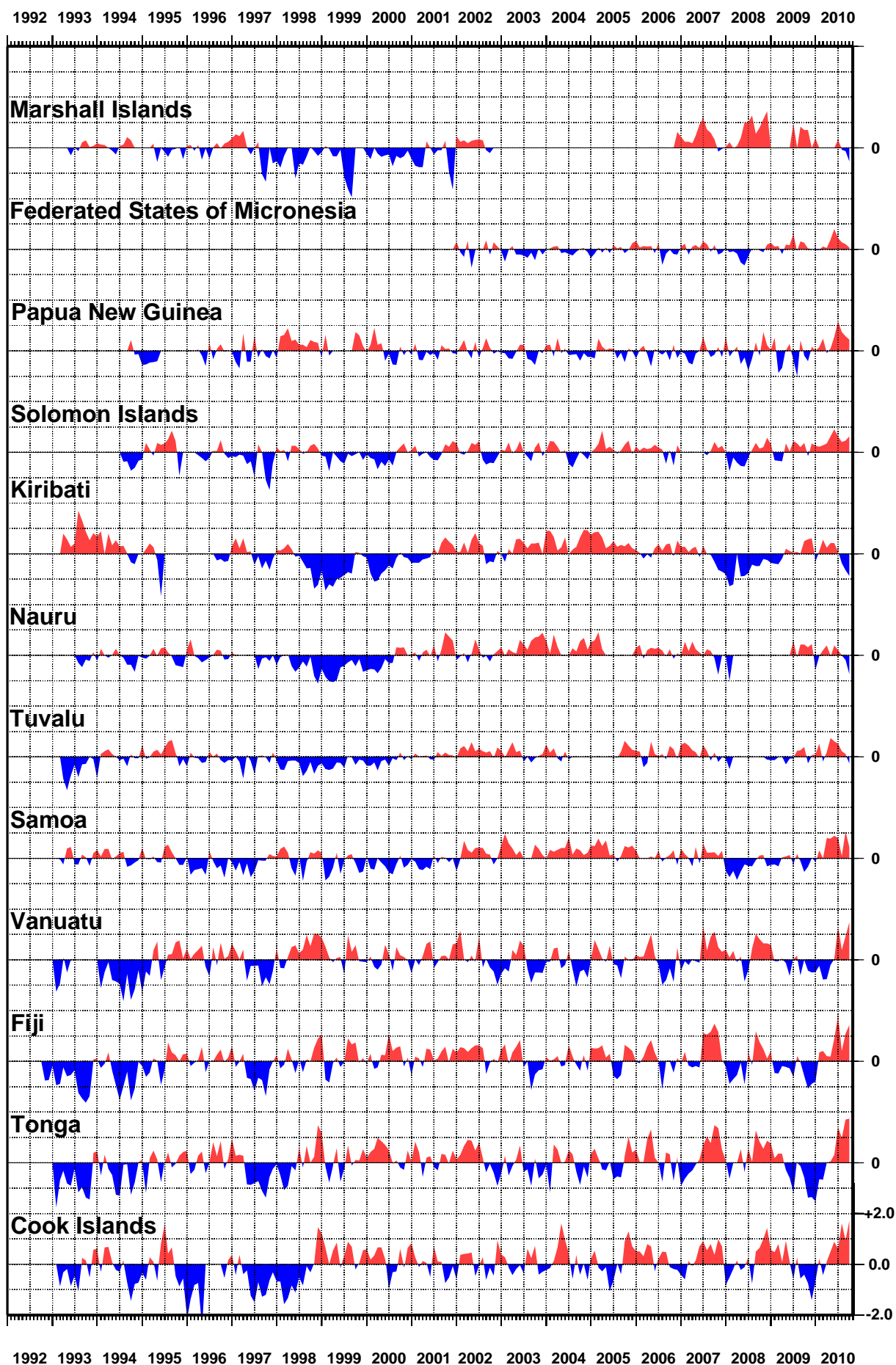




Figure 16  
**AIR TEMPERATURE ANOMALIES  
THROUGH SEPTEMBER 2010 (°C)**





## SEA LEVEL DATA RETURN

\* Patchy record

