THE SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT

MONTHLY DATA REPORT

NO. 195

SEPTEMBER 2011

Australian Government

Bureau of Meteorology

This project is sponsored by the Australian Agency for International Development (AusAID), and is managed by the Bureau of Meteorology with its National Tidal Centre (NTC) providing key technical support.

Australian Government

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Quality Certification:

I authorise the issue of this South Pacific Sea Level and Climate Monitoring Project Monthly Data Report for September 2011 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 2011

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 2011

- 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 equatorial Pacific during September resembled the early stages of a developing La Niña. Ocean temperatures across the equatorial Pacific were cooler than normal and Trade Winds were stronger than normal.

- Climate conditions at SEAFRAME stations during September were close to normal for this time of the year, although a general cooling trend over the last few months has been observed which is related to the developments across the equatorial Pacific.

- Monthly sea levels for September 2011 were 5cm higher than normal at Marshall Islands, Solomon Islands, Samoa, Fiji and Cook Islands. Sea levels at the other SEAFRAME stations were close to normal for this time of the year.

- International climate models predict that a La Niña event will develop by the end of the year and persist into the first quarter of 2012, but is not expected to be as strong as the 2010/11 La Niña.

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, 2011

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	+5.2	+0.1
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+8.5	0.0
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+5.1	0.0
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+5.3	0.0
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+6.6	+0.1
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+4.0	0.0
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.0	-0.1
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+3.8	-0.1
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+7.2	+0.1
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+7.7	0.0
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+17.0	0.0
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.9	+0.1

INTRODUCTION

Welcome to the September 2011 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.

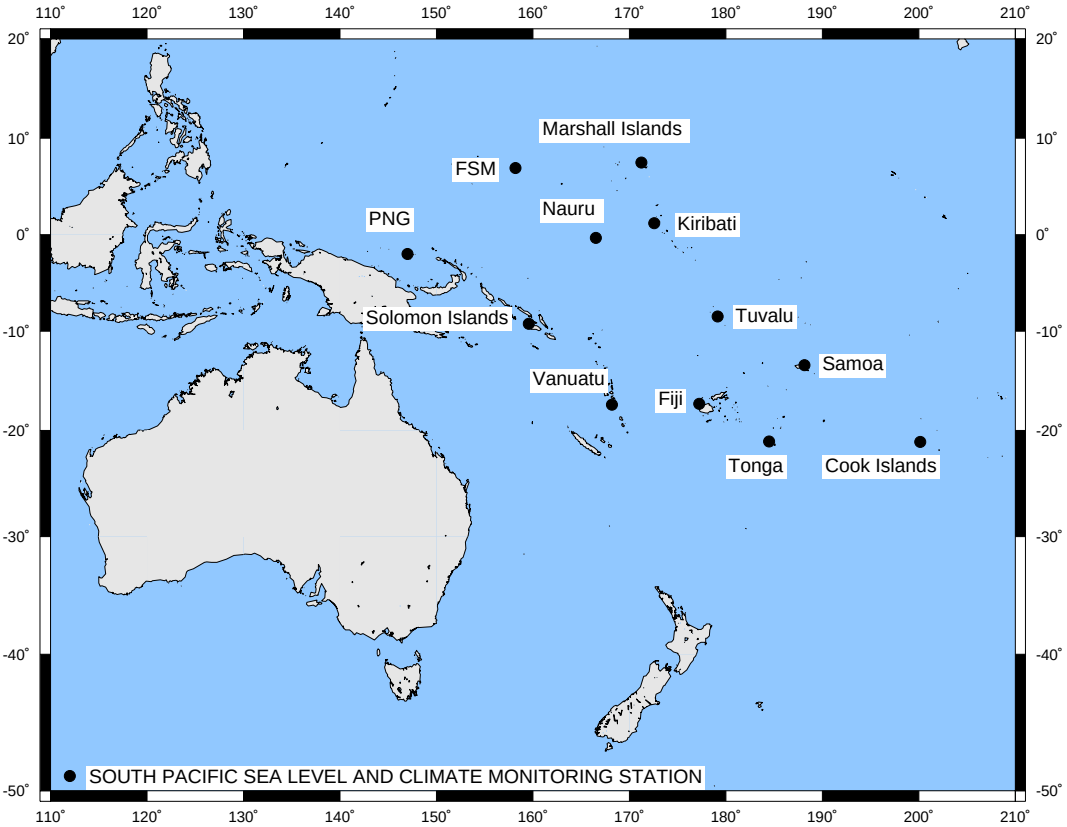


Figure A: *South Pacific Sea Level and Climate Monitoring Stations*

SEPTEMBER CLIMATOLOGY

Climate conditions across the equatorial Pacific during September resembled the early stages of a developing La Niña event, where atmospheric and ocean indicators reached La Niña thresholds. Equatorial Pacific Ocean temperatures continued to cool and Trade Winds were stronger than normal. International climate models predict further cooling and full development of a La Niña by the end of the year, but the event is not expected to be as strong as the 2010/11 La Niña.

The Southern Oscillation Index (SOI) returned to positive values characteristic of La Niña during September, increasing to +11.7 following the August value of +2.1 (**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 across the equatorial Pacific continued to cool during September. Sea surface temperatures across the central equatorial Pacific were clearly cooler than normal, with anomalies ranging from -0.5ºC to -1.0ºC (**Figure C**). Sea surface temperatures remain slightly warmer than normal in some areas of the southwest Pacific.

Subsurface ocean temperatures cooled significantly across the equatorial Pacific during September. The extent of cool anomalies across the central and eastern equatorial Pacific continued to increase while there was a reduction in the extent of warm anomalies across the western 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 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. Trade Winds were stronger than normal across the western and central equatorial Pacific during September (**Figure E**). Cloudiness near the dateline was slightly suppressed during September.

The consensus among international computer models surveyed by the Bureau of Meteorology is that La Niña thresholds will be exceeded by the end of 2011 and persist into the first quarter of 2012.

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/.

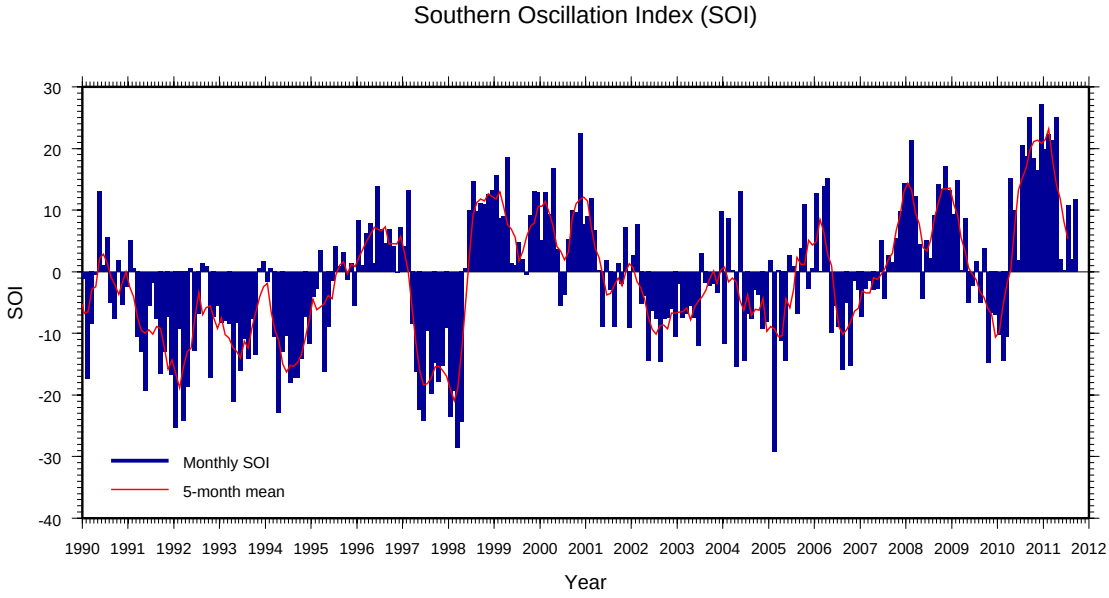


Figure B: *The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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

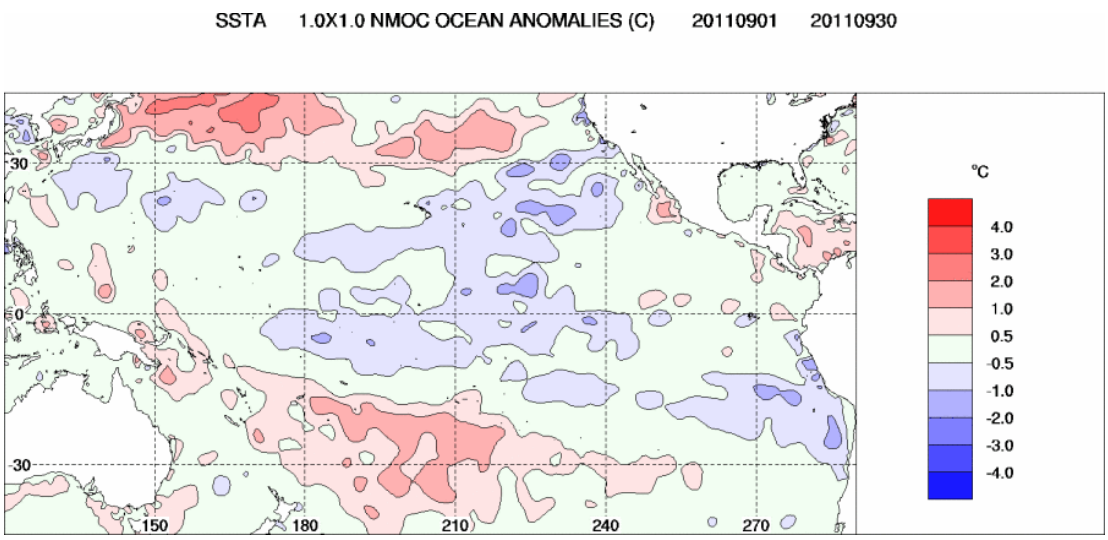


Figure C: *Sea surface temperature anomaly (°C) for September 2011.*

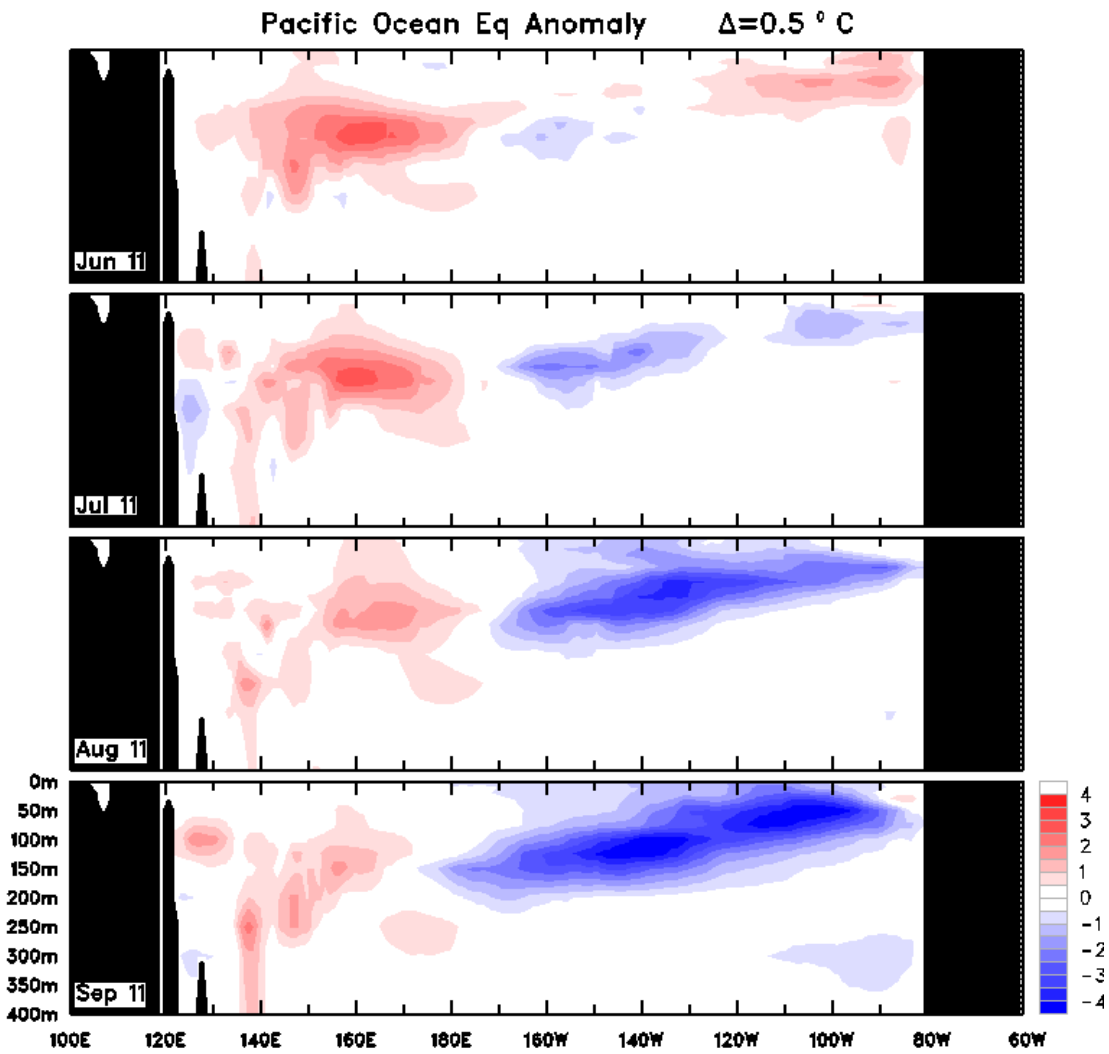


Figure D: *Equatorial depth-longitude section of ocean temperature anomalies for June through to September 2011. Contour interval is 0.5°C.*

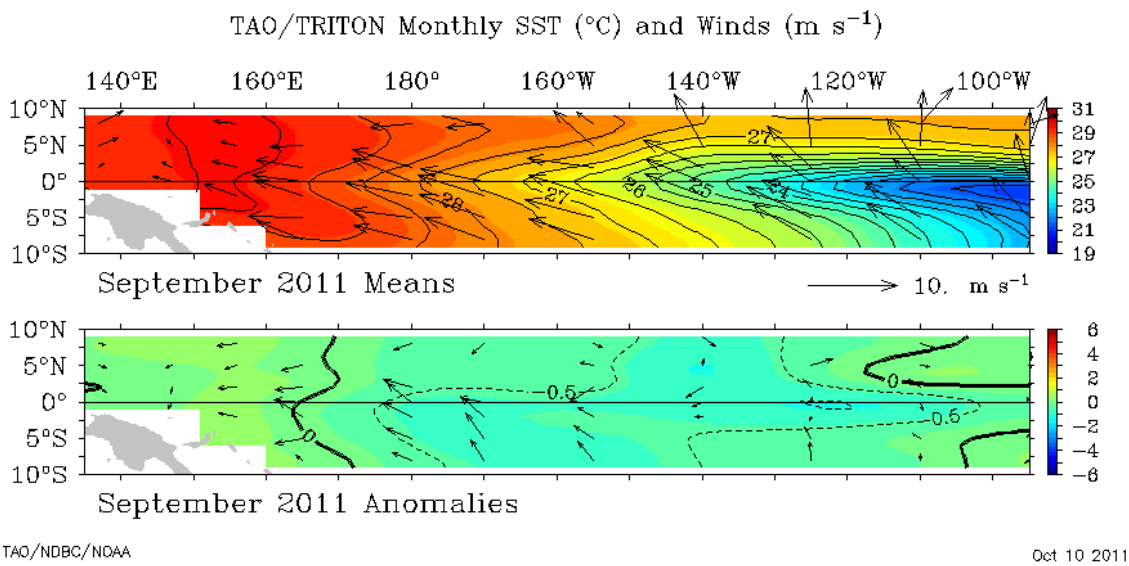


Figure E: *Monthly mean wind vectors (top) and anomalies (bottom) for September 2011. The colour-shaded contours represent the monthly mean sea surface temperatures (top) and anomalies (bottom).*

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). Where the tides are semi-diurnal the greatest tidal variations are called spring tides, which tend to occur close to the full and new moon. There was a full moon on the 12th of September and a new moon on the 27th of September 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 phenomenon referred to as a seiche), such as 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 interactions between tides and terrestrial (land-based) water discharging into the wharf area. The water temperature fluctuations there are 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*. No new record September maximum (or minimum) air temperature, water temperature or barometric pressure was observed across the network, although a water temperature of 26.5 ºC was observed at Cook Islands which is equal to the current record September maximum water temperature.

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 very low sea levels which disrupted 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.

Monthly mean sea levels during September 2011 were around 5cm higher than normal at Marshall Islands, Solomon Islands, Samoa, Fiji and Cook Islands. At the remaining 7 stations they were near normal for this time of the year.

Sea Level Trends

The **short-term sea level trends** at individual stations as at September 2011 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, 2011

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	+5.2	+0.1
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+8.5	0.0
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+5.1	0.0
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+5.3	0.0
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+6.6	+0.1
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+4.0	0.0
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.0	-0.1
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+3.8	-0.1
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+7.2	+0.1
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+7.7	0.0
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+17.0	0.0
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.9	+0.1

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. September 2011 barometric pressures were close to normal for this time of the year.

The **water temperature anomalies (Figure 15)** show warmer than normal conditions continued to be observed at Vanuatu, Fiji, Tonga and Cook Islands through September, although the anomalies across this southern area of the network have moderated in the last few months. Slightly warmer than normal water temperatures were also observed at PNG and Solomon Islands while cooler than normal water temperatures continued to evolve at Marshall Islands and Kiribati. Water temperatures at FSM, Nauru and Samoa during September were near normal for this time of the year.

Air temperature anomalies (Figure 16) at Samoa, Vanuatu, Fiji, Tonga and Cook Islands peaked at close to +1ºC in mid-2011 but have generally cooled since then. During September 2011 air temperatures at Vanuatu, Fiji and Tonga were back to near normal levels, while they were around +0.5ºC at Samoa. The exception to the cooling trend occurred at Cook Islands, where the monthly air temperature anomaly for September was +1.5ºC. At the other stations air temperatures remained close to

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.

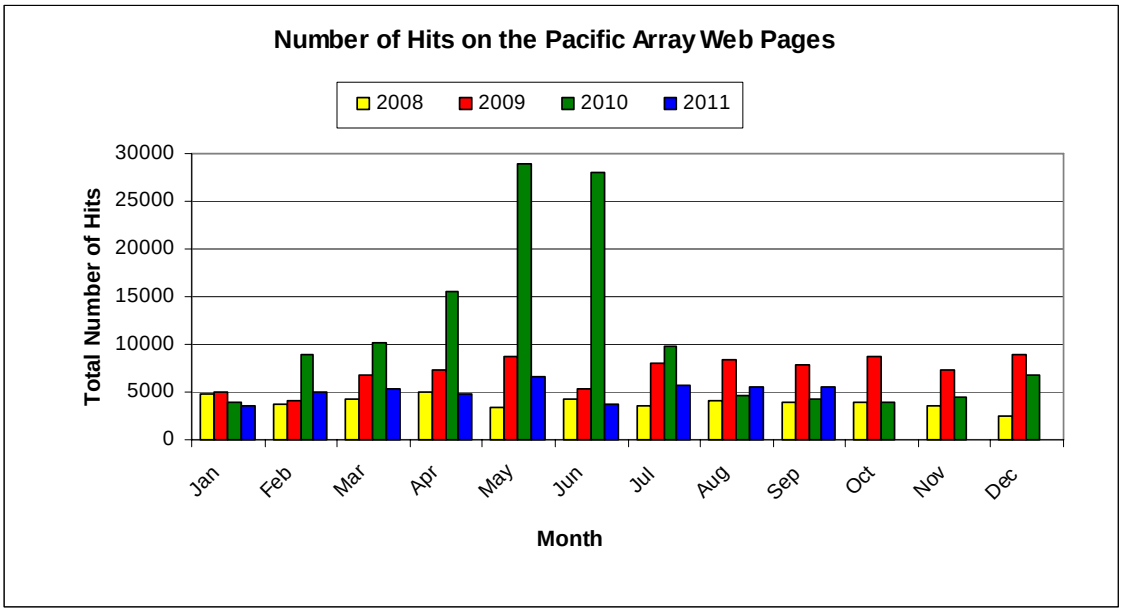
Instrument Performance

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 during September 2011 was very high for all stations except PNG, where power supply problems developed from the 12th of September. The primary sea level sensor at Kiribati reported some erroneous readings on 5th of September which have been removed from the archived record. Minor satellite and dial-up communications problems resulted in small data loss from Samoa, PNG and Nauru. Problems encountered with the ancillary sensors during September included the air temperature sensors at Nauru and Tuvalu, the water temperature sensors at Tuvalu and Tonga and the wind monitors at Kiribati, Vanuatu, Tuvalu and Tonga. The erroneous data received from these problematic sensors were removed from the archived records.

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 2008.



SEAFRAME STATIONS

SEAFRAME stations employ either a SUTRON or TELMET (for upgraded stations) 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 SUTRON station is shown in the following figure.

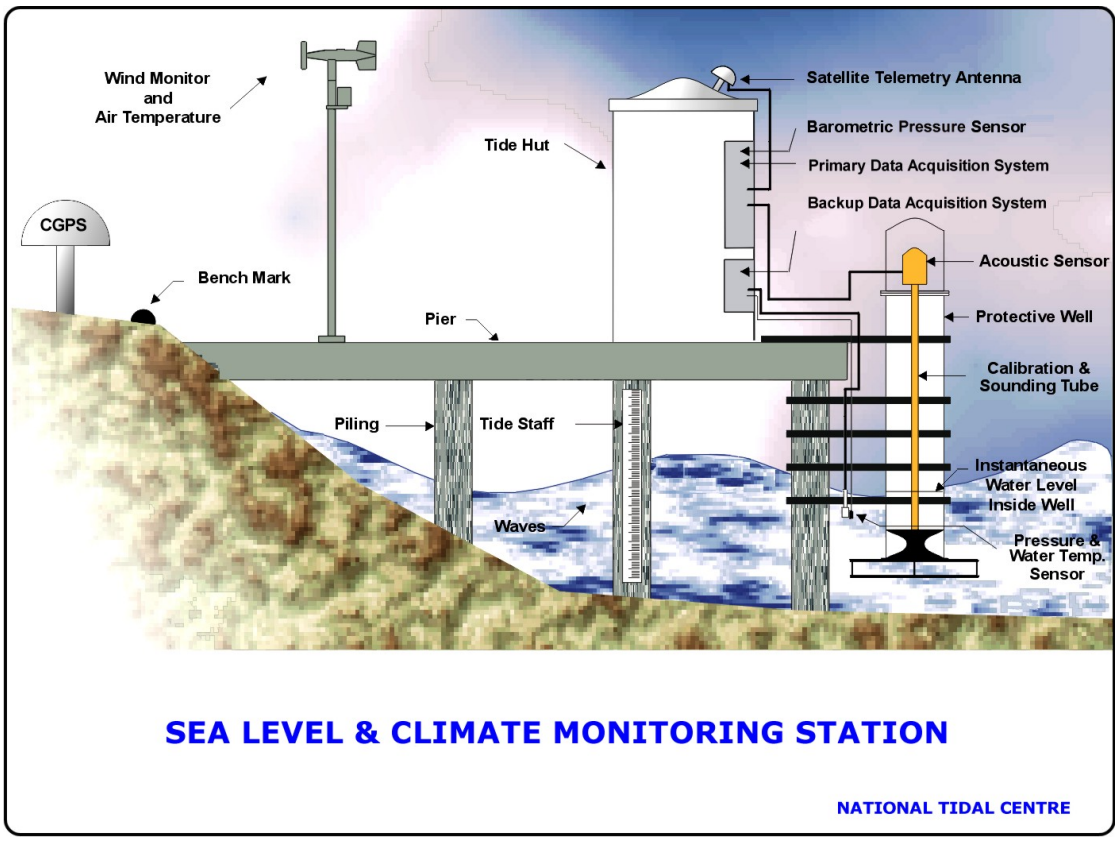
Water level sensors include:

(1) Primary water level using a Bartex 'AQUATRAK' acoustic-in-air sensor,

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

(3) Tertiary water level using a Vega-puls radar sensor mounted above the water (at upgraded sites).

For SUTRON stations, the water level samples are averaged over three minutes and logged every six minutes, while meteorological sensors are logged on an hourly basis. With the upgraded TELMET stations, the water level samples are averaged over one minute and, together with meteorological data, logged every minute. Appropriate weighted-average and time-centred data is computed remotely which conforms to the SUTRON algorithm. Both SUTRON and TELMET data loggers have the memory capacity to store approximately one month of data.



The Observation Network Upgrade Project (ONUP) is scheduled to upgrade all Pacific SEAFRAME stations by mid-2013 with modernised TELMET data loggers, real-time satellite communications and additional radar-type water level sensors. The status of the station upgrades is given in the following table.

Status of Station Equipment Upgrades to September, 2011

Location	Lat / Long	SUTRON Installation Date	TELMET Upgrade Date
Cook Is	21°12'17.1"S / 159°47'5.2"W	Feb 1993	To be upgraded
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	Mar 2011
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	Jun 2011
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	To be upgraded
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	Aug 2011
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	To be upgraded
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	To be upgraded
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	To be upgraded
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	To be upgraded
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	To be upgraded
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	To be upgraded
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	To be upgraded

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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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 2011
SIX MINUTE WATER LEVEL OBSERVATIONS (m)

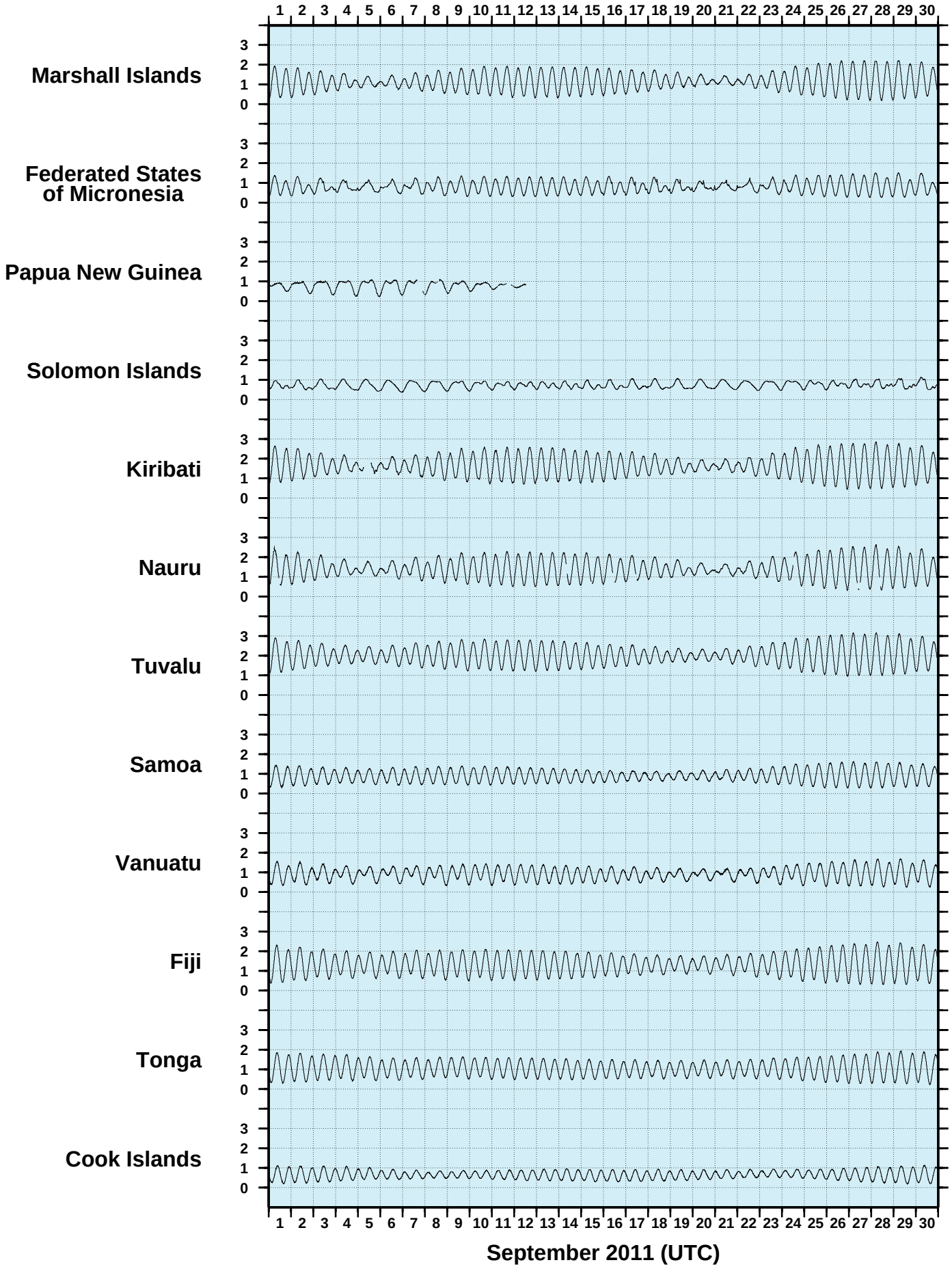


Figure 2

SEPTEMBER 2011
SIX MINUTE RESIDUAL WATER LEVELS (m)

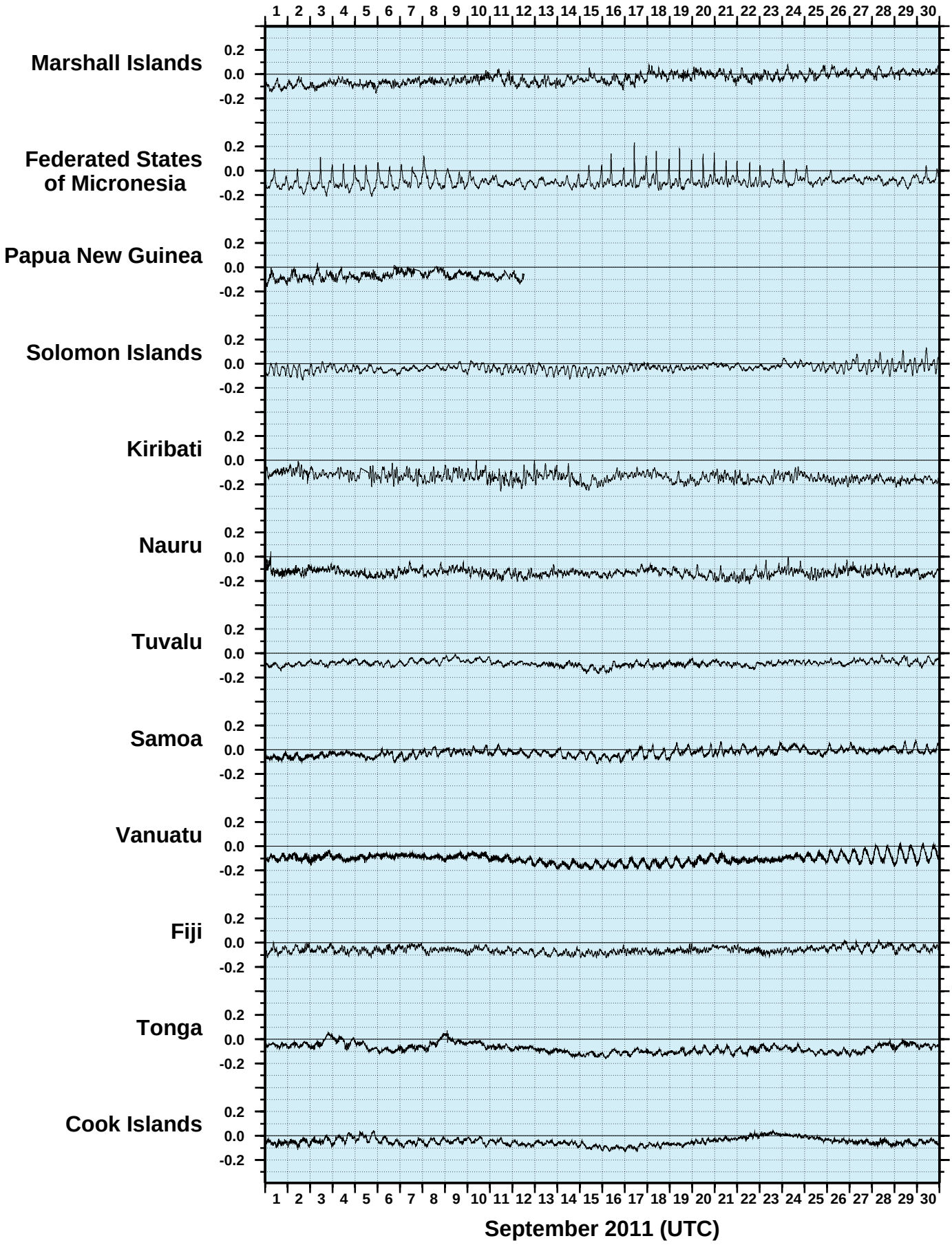


Figure 3

SEPTEMBER 2011
SIX MINUTE RESIDUALS
ADJUSTED FOR ATMOSPHERIC PRESSURE (m)

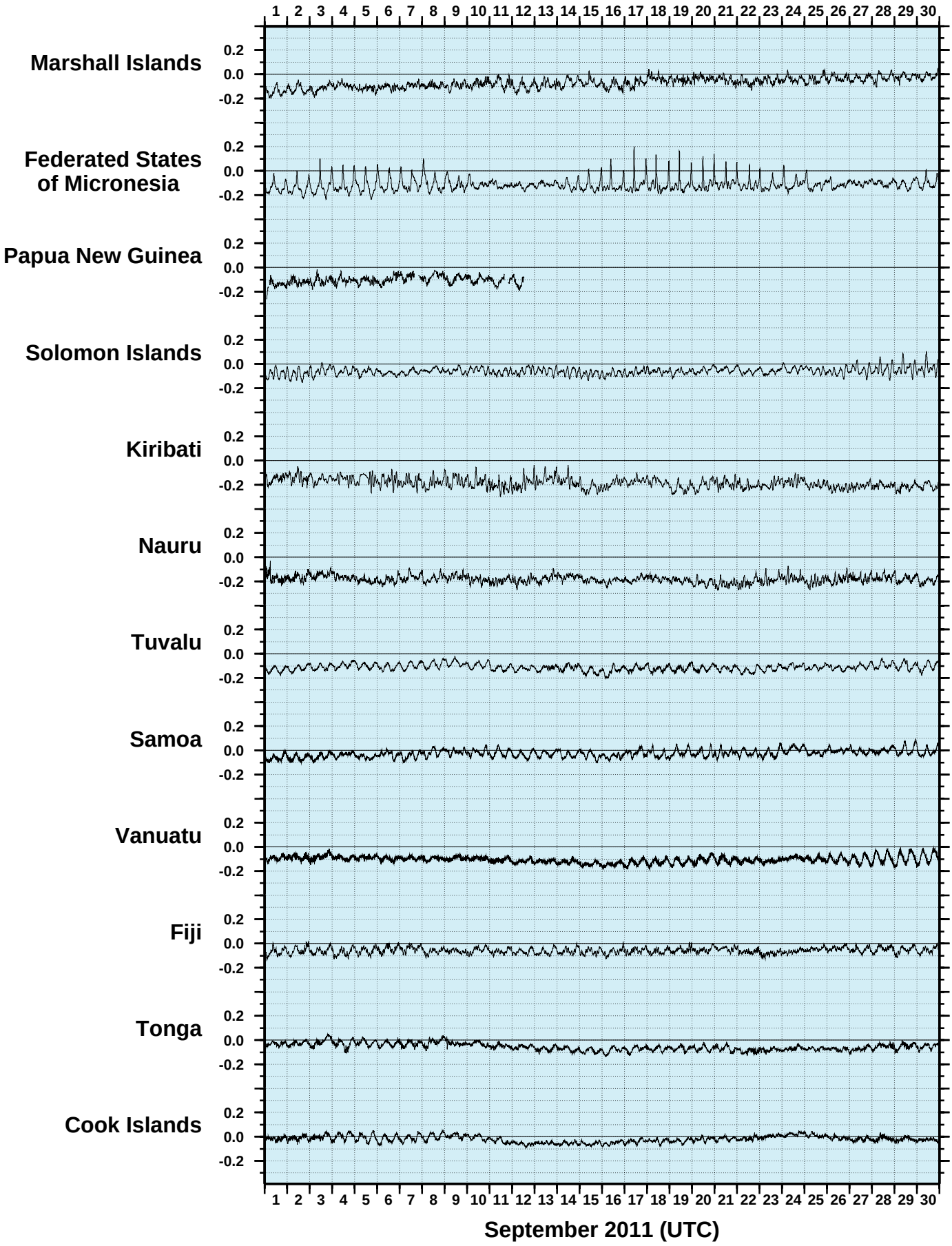


Figure 4

SEPTEMBER 2011
HOURLY WIND SPEEDS (m/s)

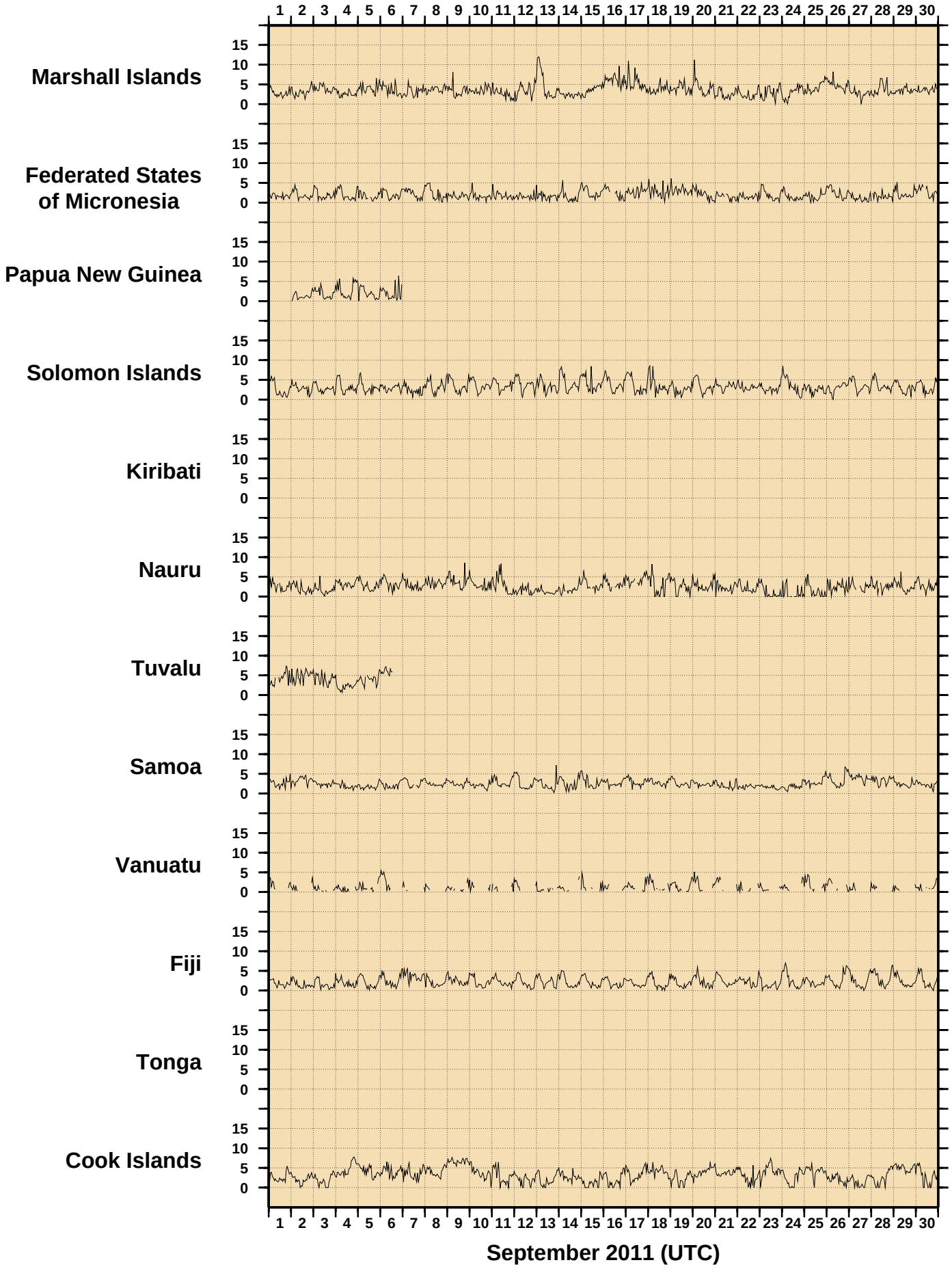


Figure 5

SEPTEMBER 2011
HOURLY INCIDENT WINDS (m/s, deg True)

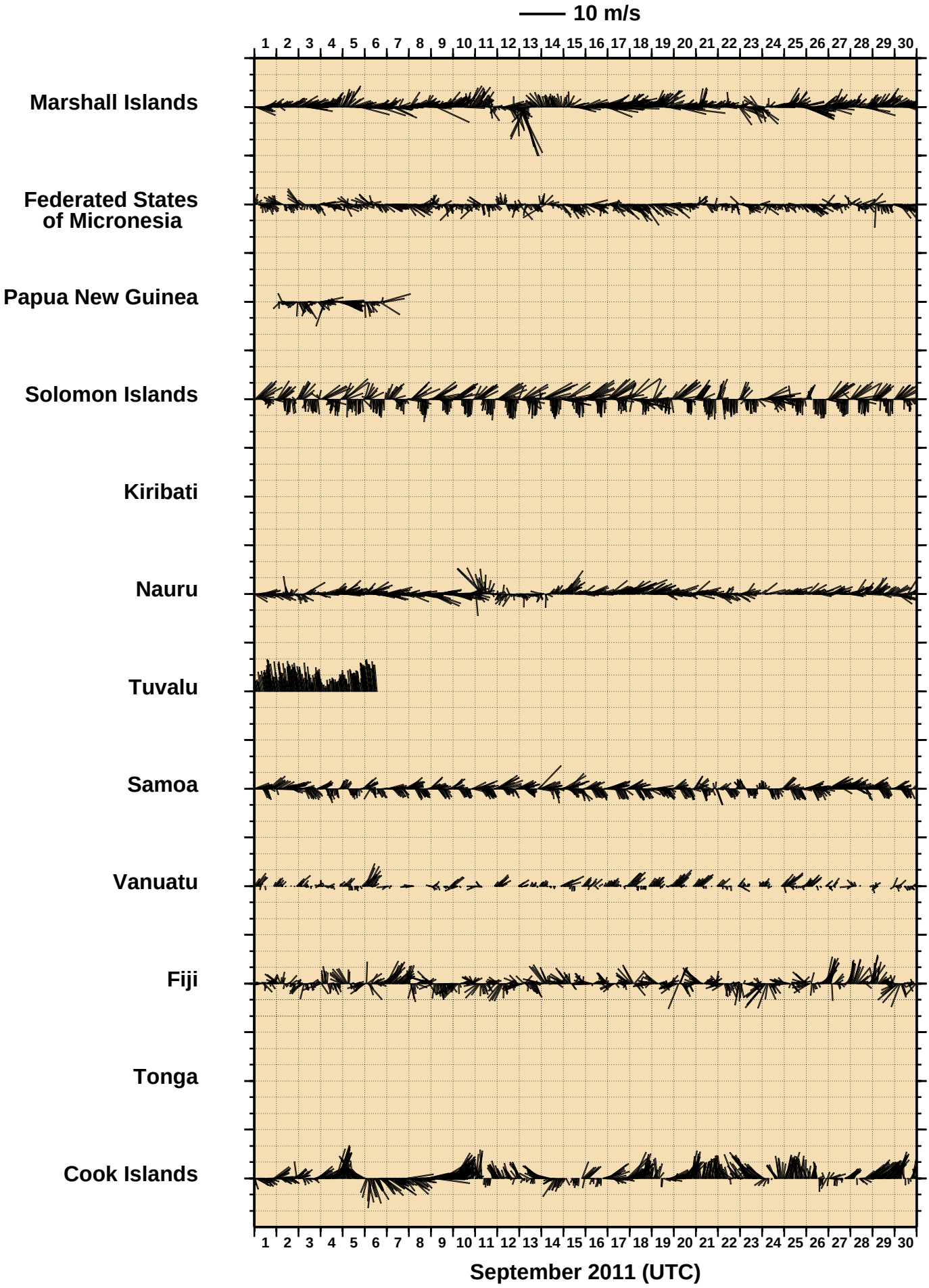


Figure 6

SEPTEMBER 2011
HOURLY MAXIMUM WIND GUSTS (m/s)

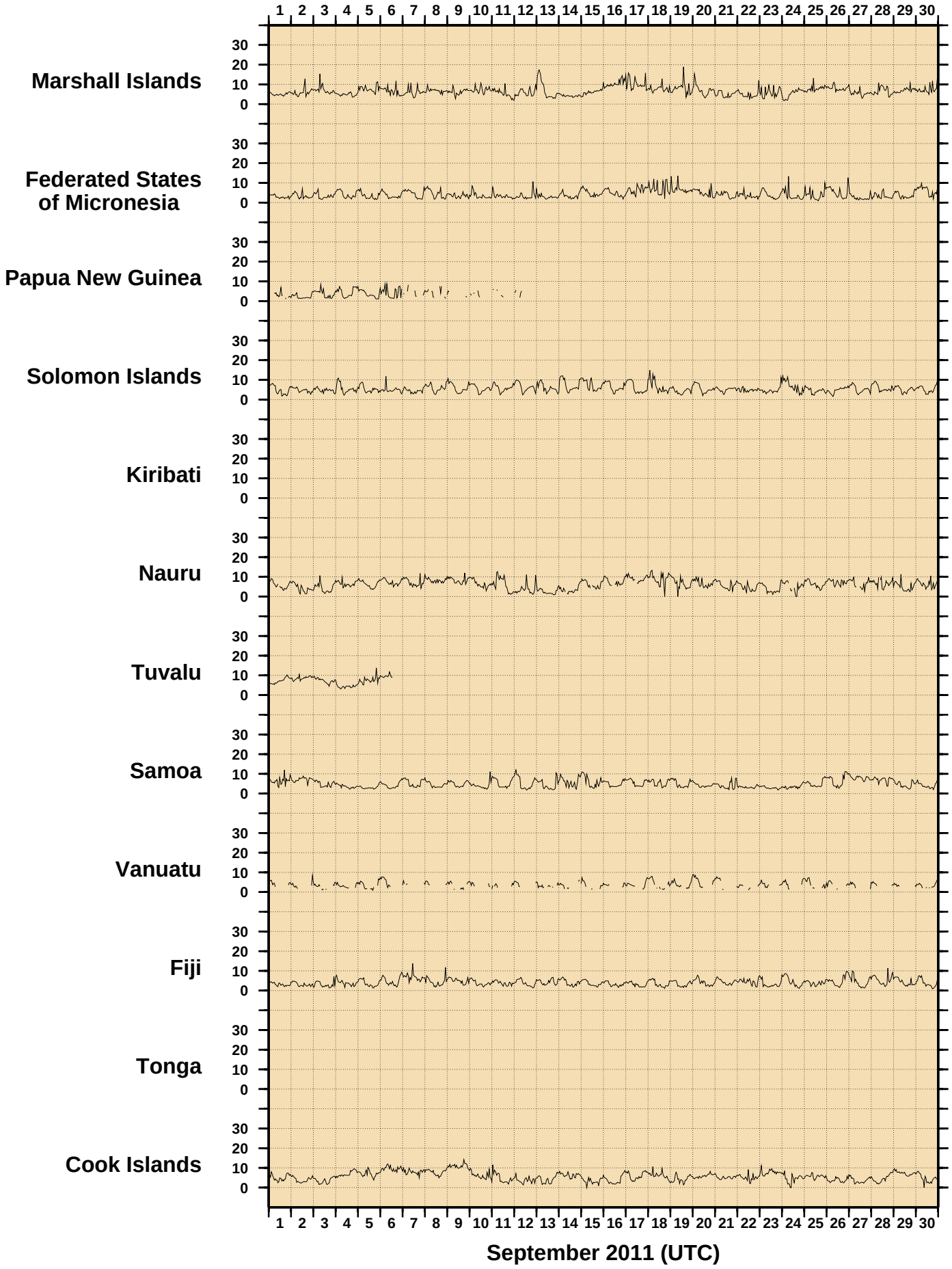


Figure 7

SEPTEMBER 2011
HOURLY AIR TEMPERATURES (°C)

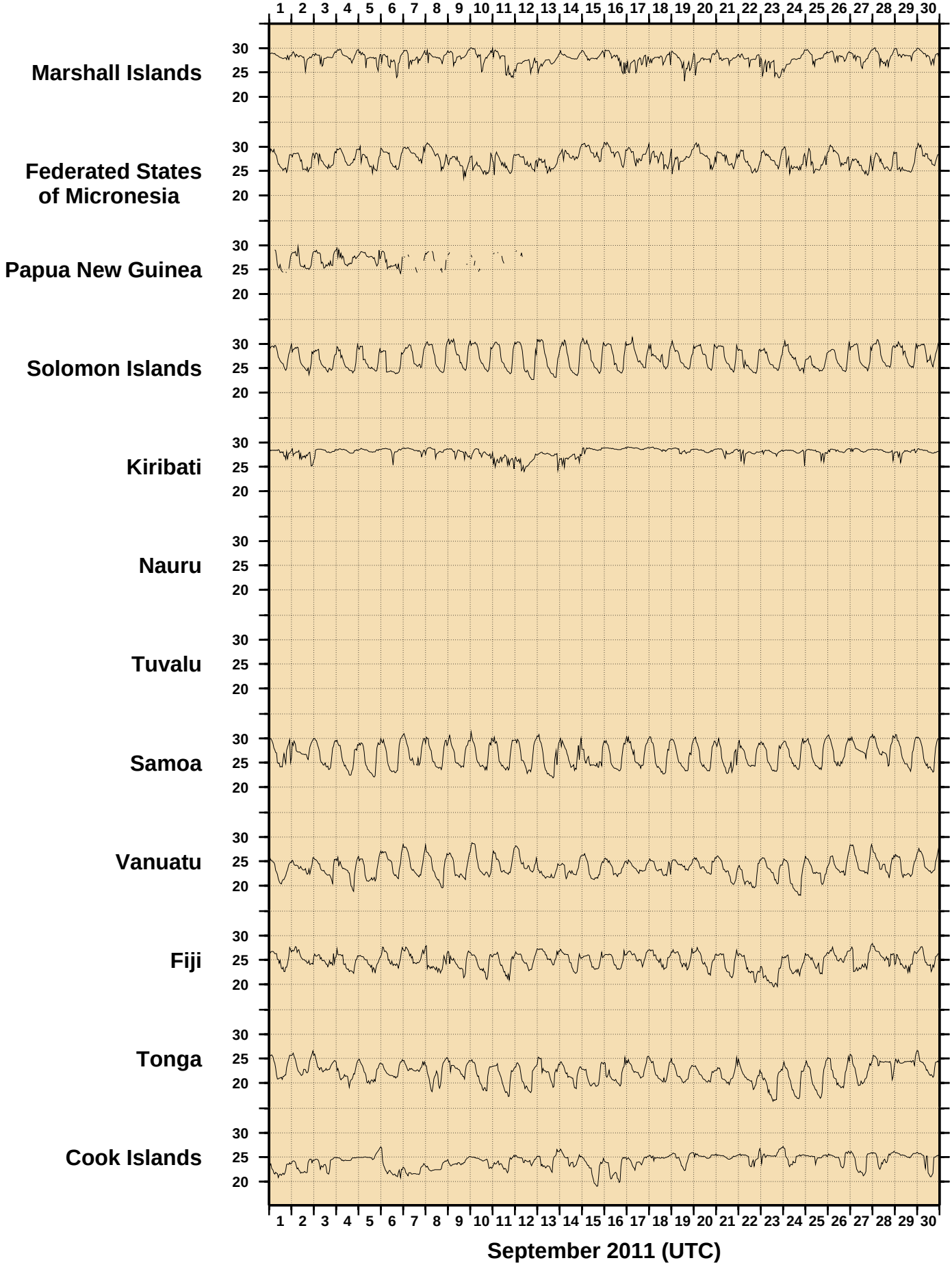


Figure 8

SEPTEMBER 2011
HOURLY WATER TEMPERATURES (˚C)

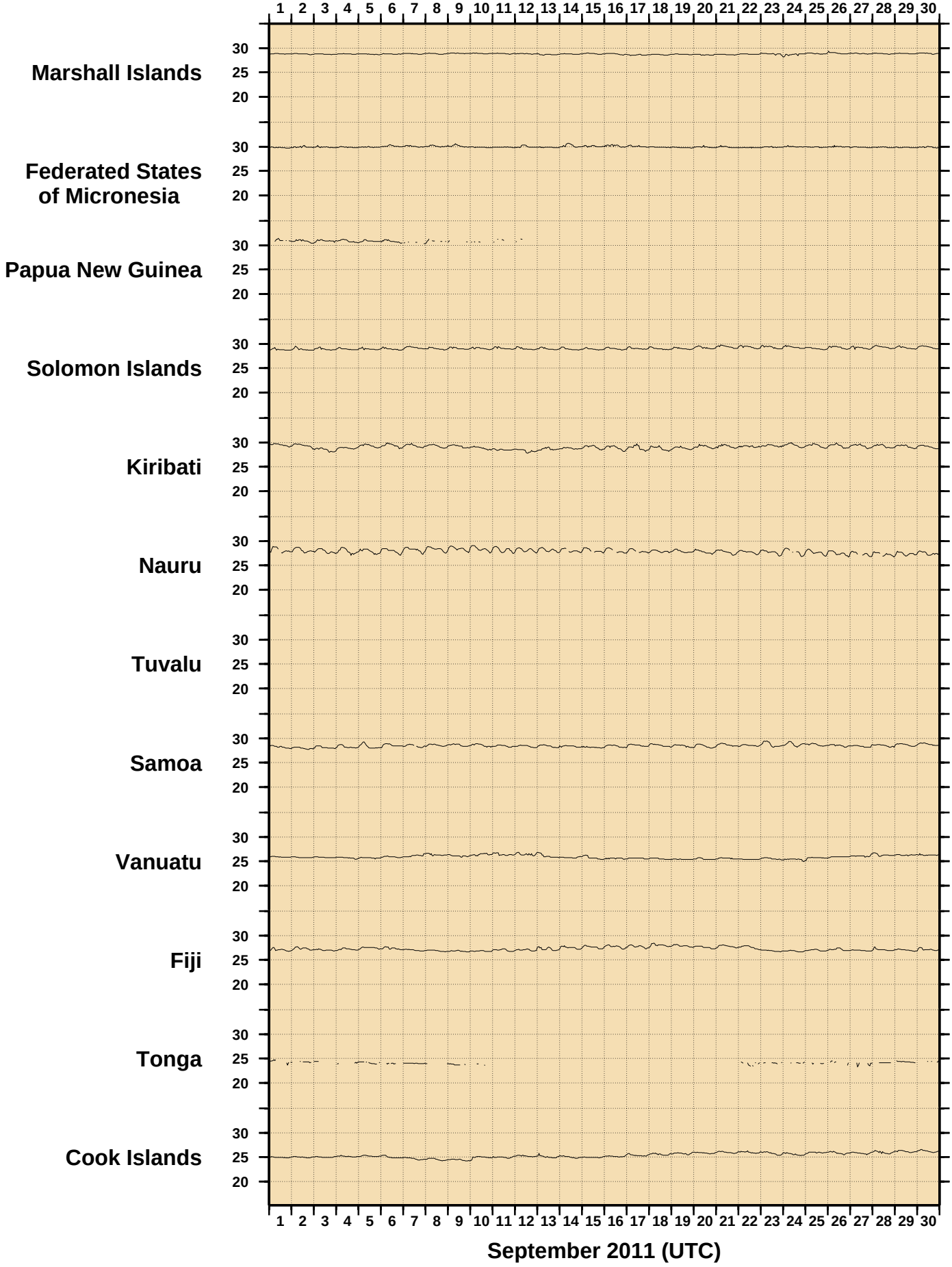


Figure 9

SEPTEMBER 2011
HOURLY ATMOSPHERIC PRESSURE (hPa)

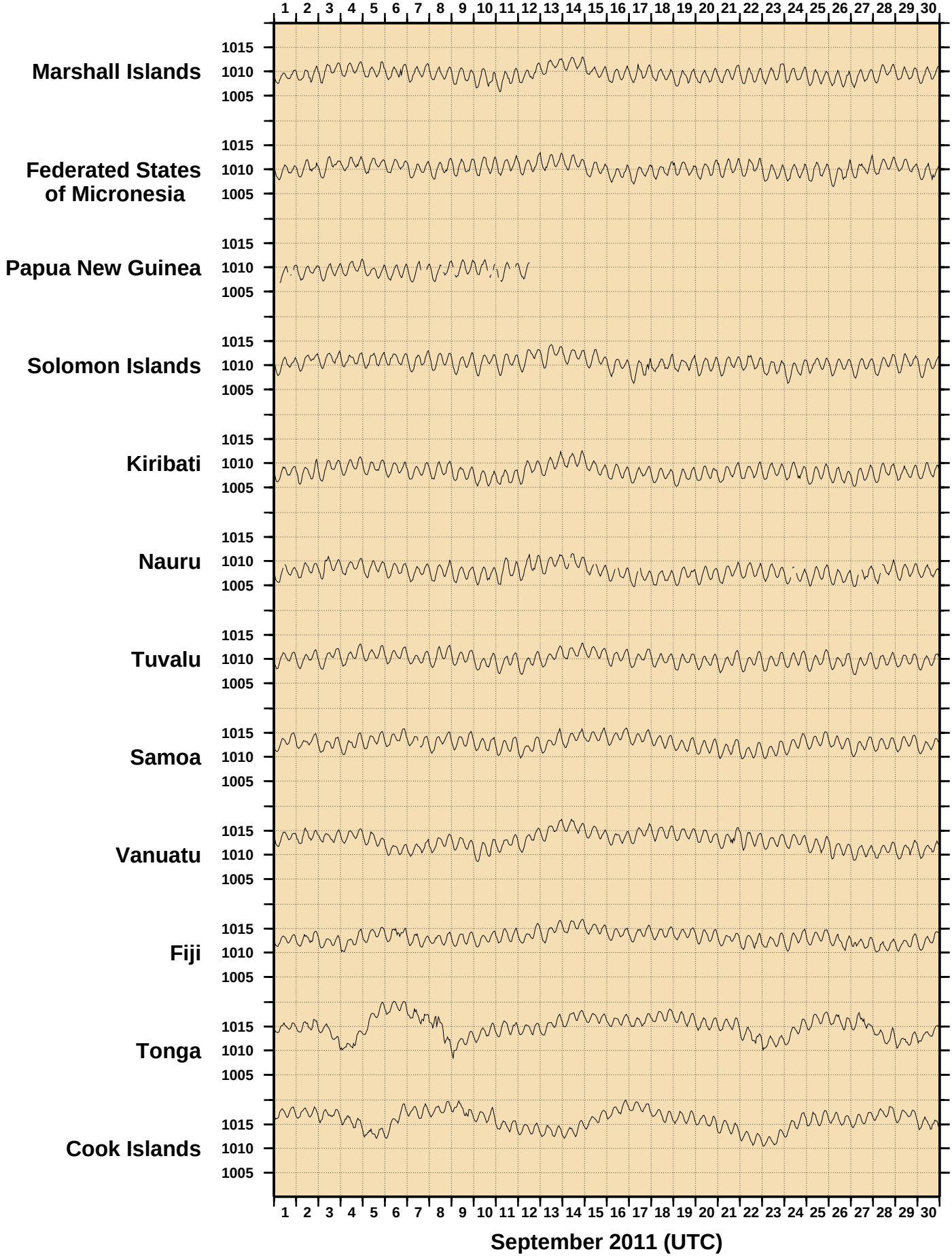


Figure 10

Comparison of September 2011 Max, Min & Mean with Long Term September Values

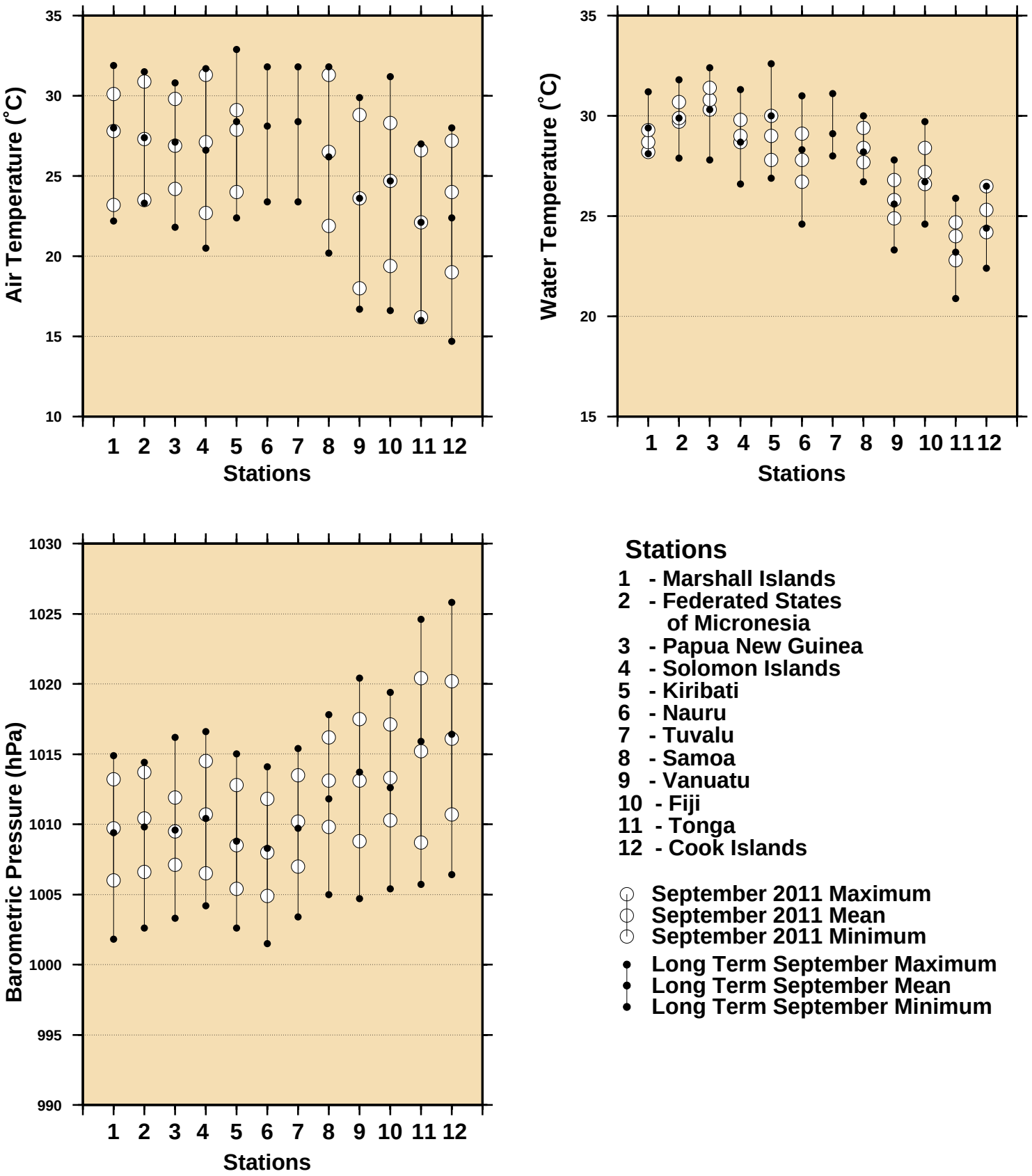


Figure 11

MONTHLY MEAN SEA LEVELS TO SEPTEMBER 2011 (m)

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

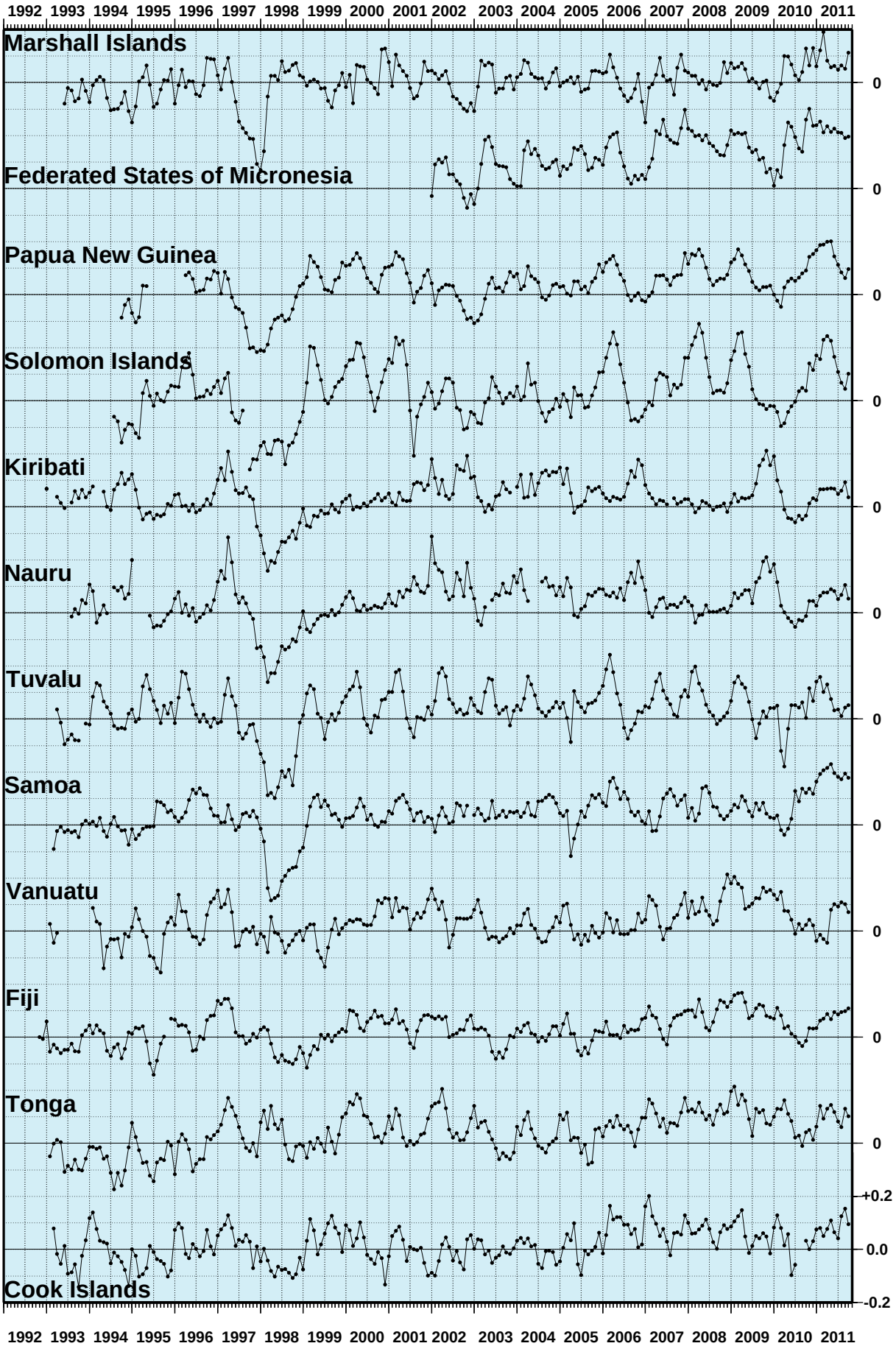


Figure 12

SEA LEVEL ANOMALIES THROUGH SEPTEMBER 2011 (m)

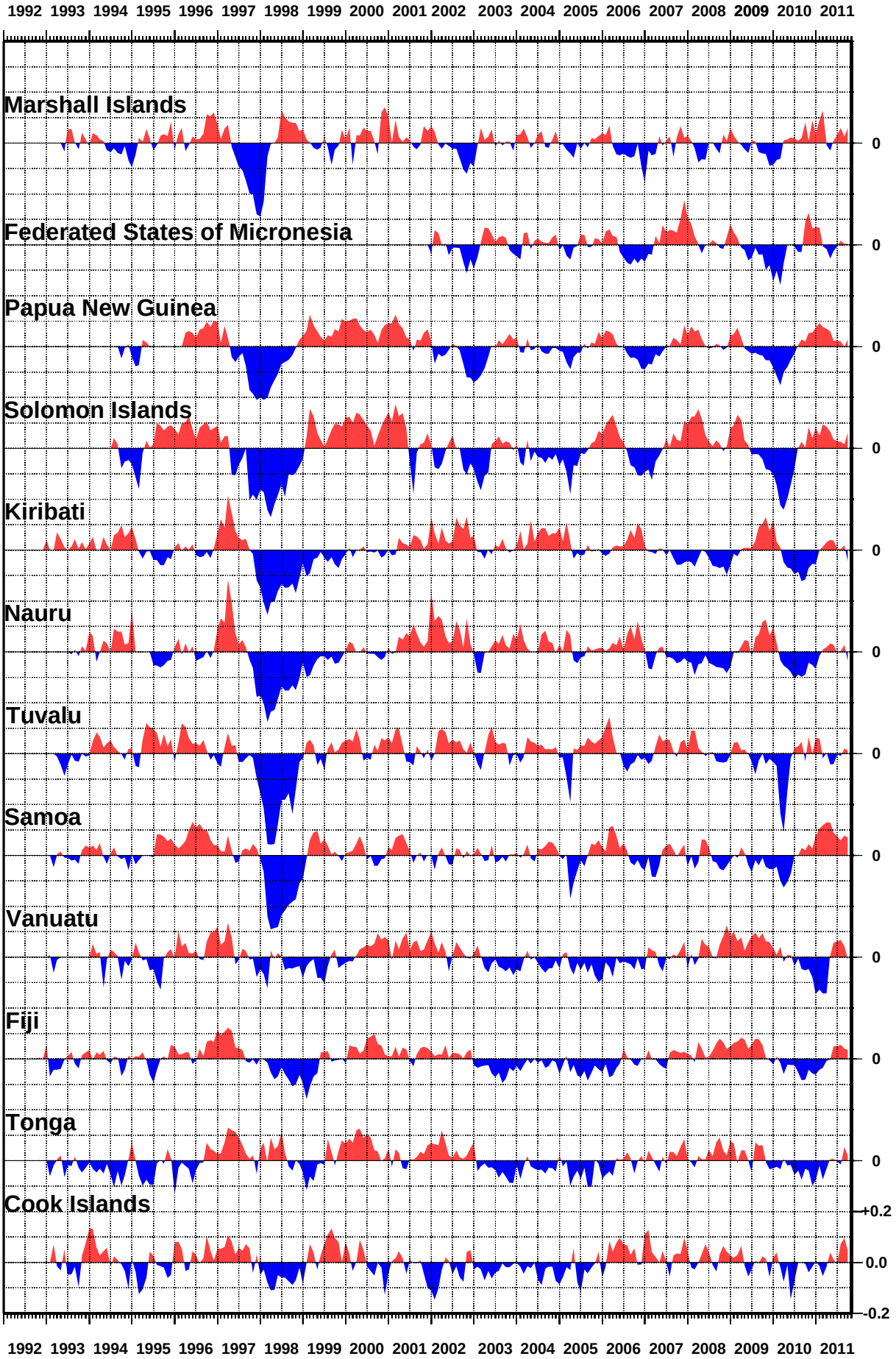


Figure 13

SEA LEVEL TRENDS THROUGH SEPTEMBER 2011 (mm/year)

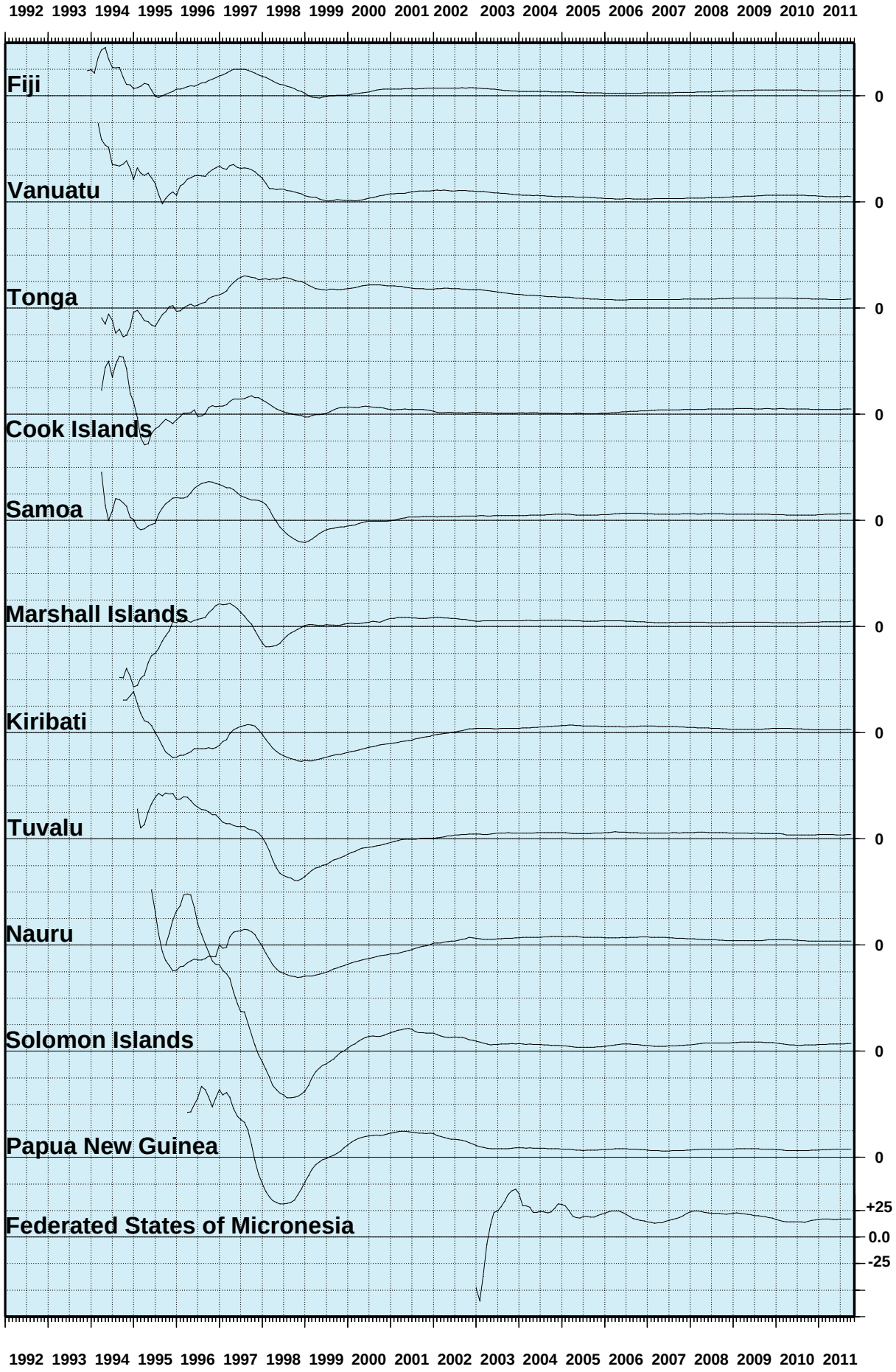


Figure 14

BAROMETRIC PRESSURE ANOMALIES THROUGH SEPTEMBER 2011 (hPa)

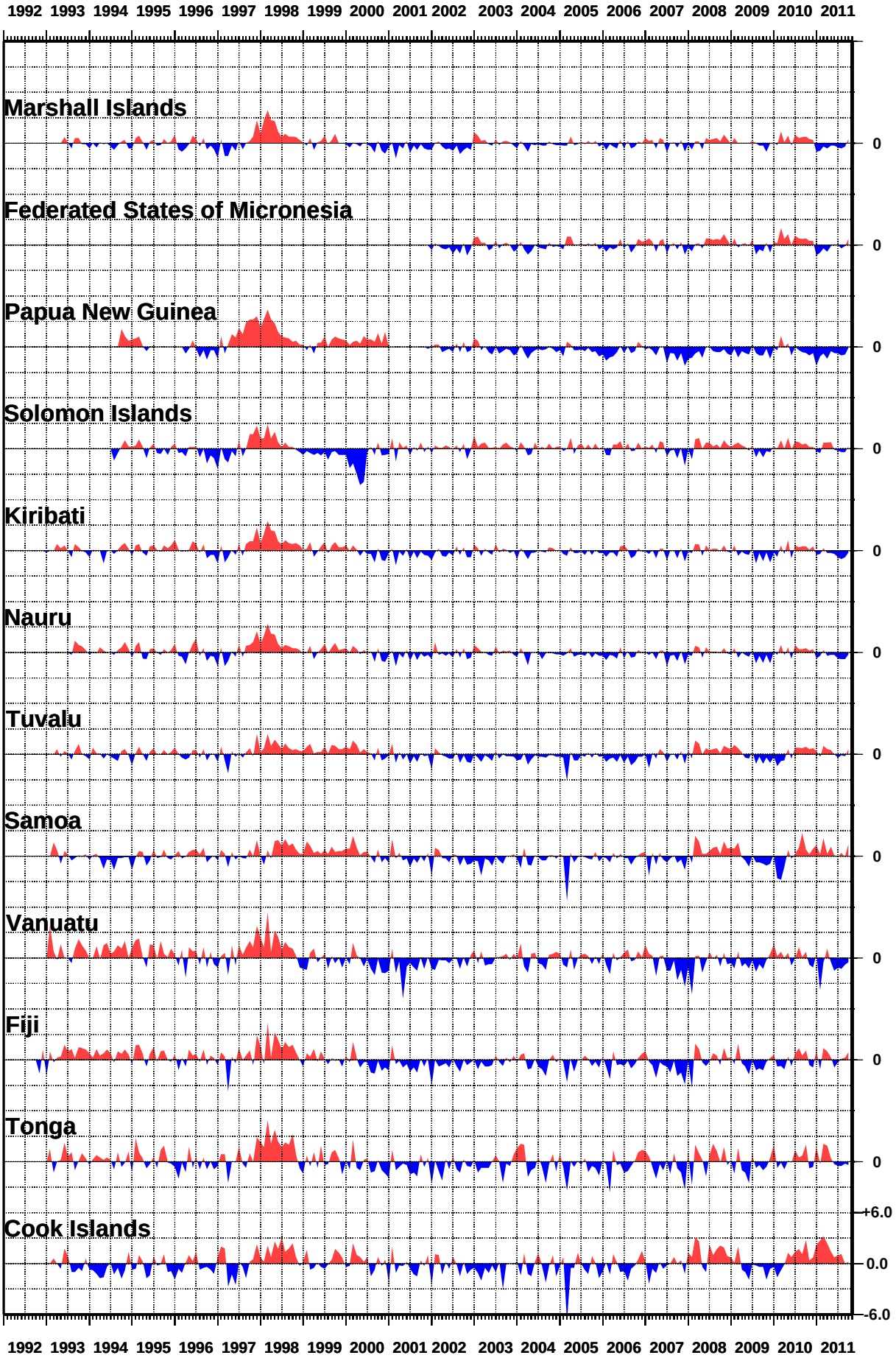


Figure 15

WATER TEMPERATURE ANOMALIES THROUGH SEPTEMBER 2011 (°C)

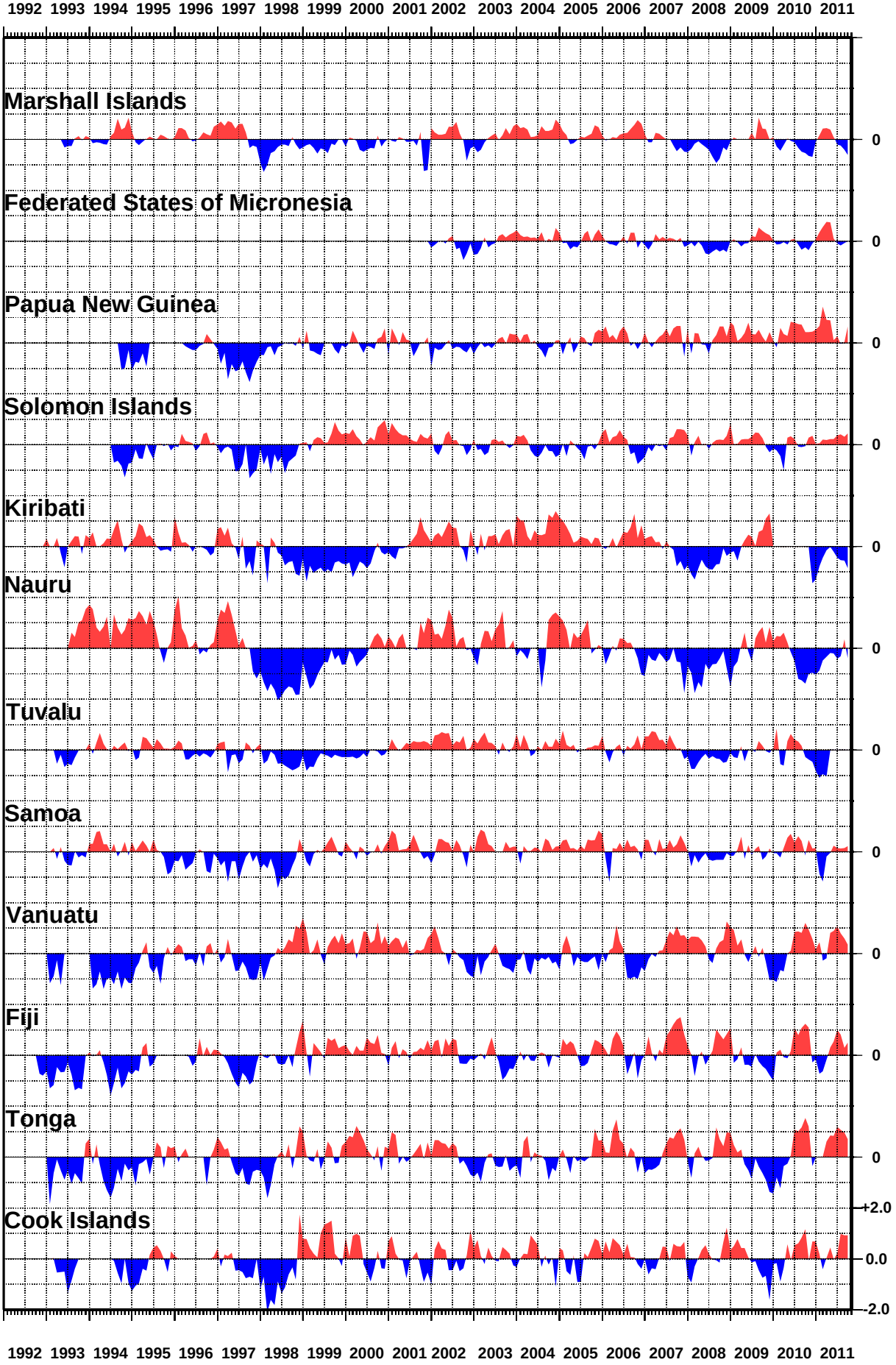


Figure 16

AIR TEMPERATURE ANOMALIES THROUGH SEPTEMBER 2011 (°C)

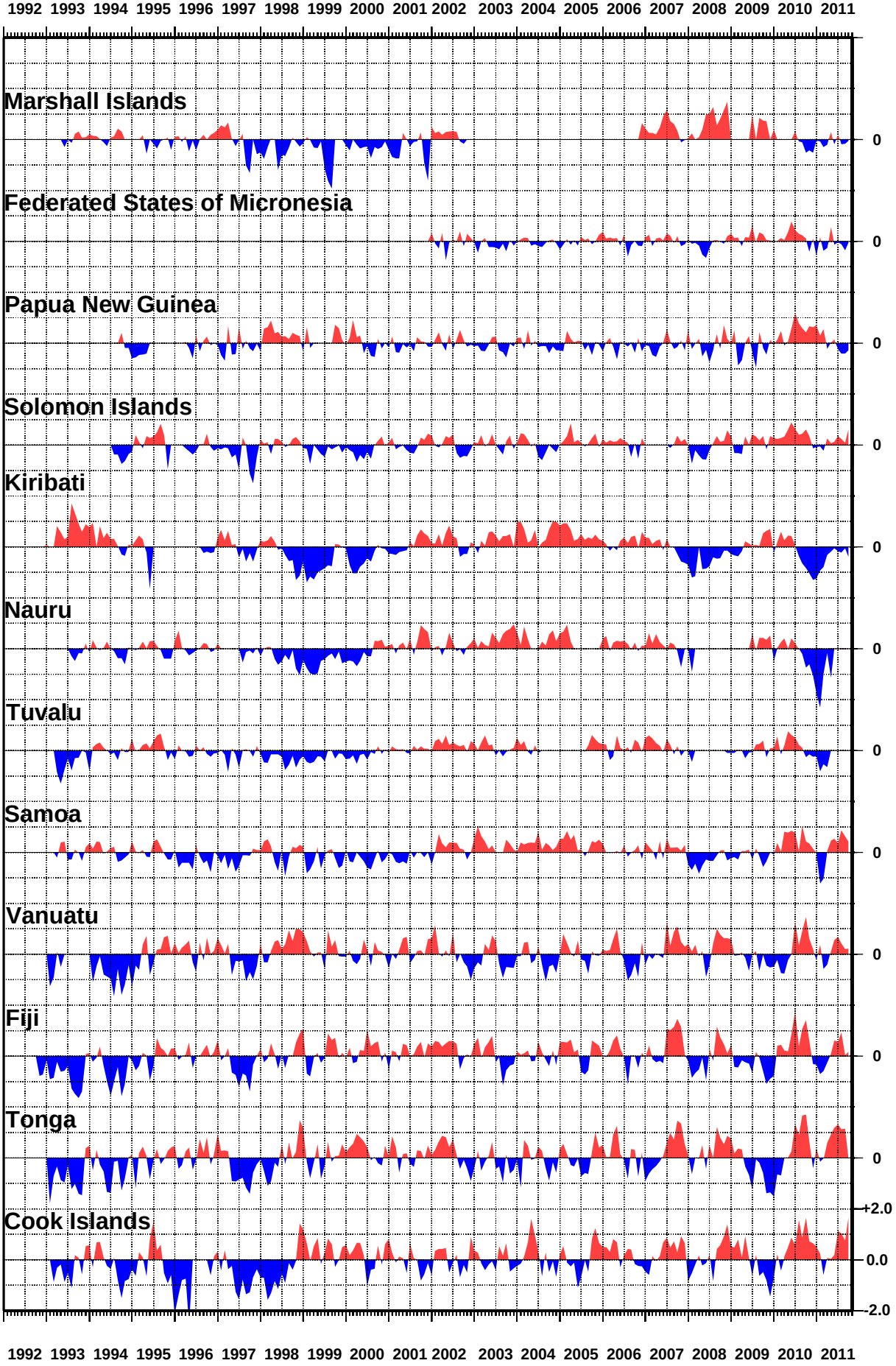
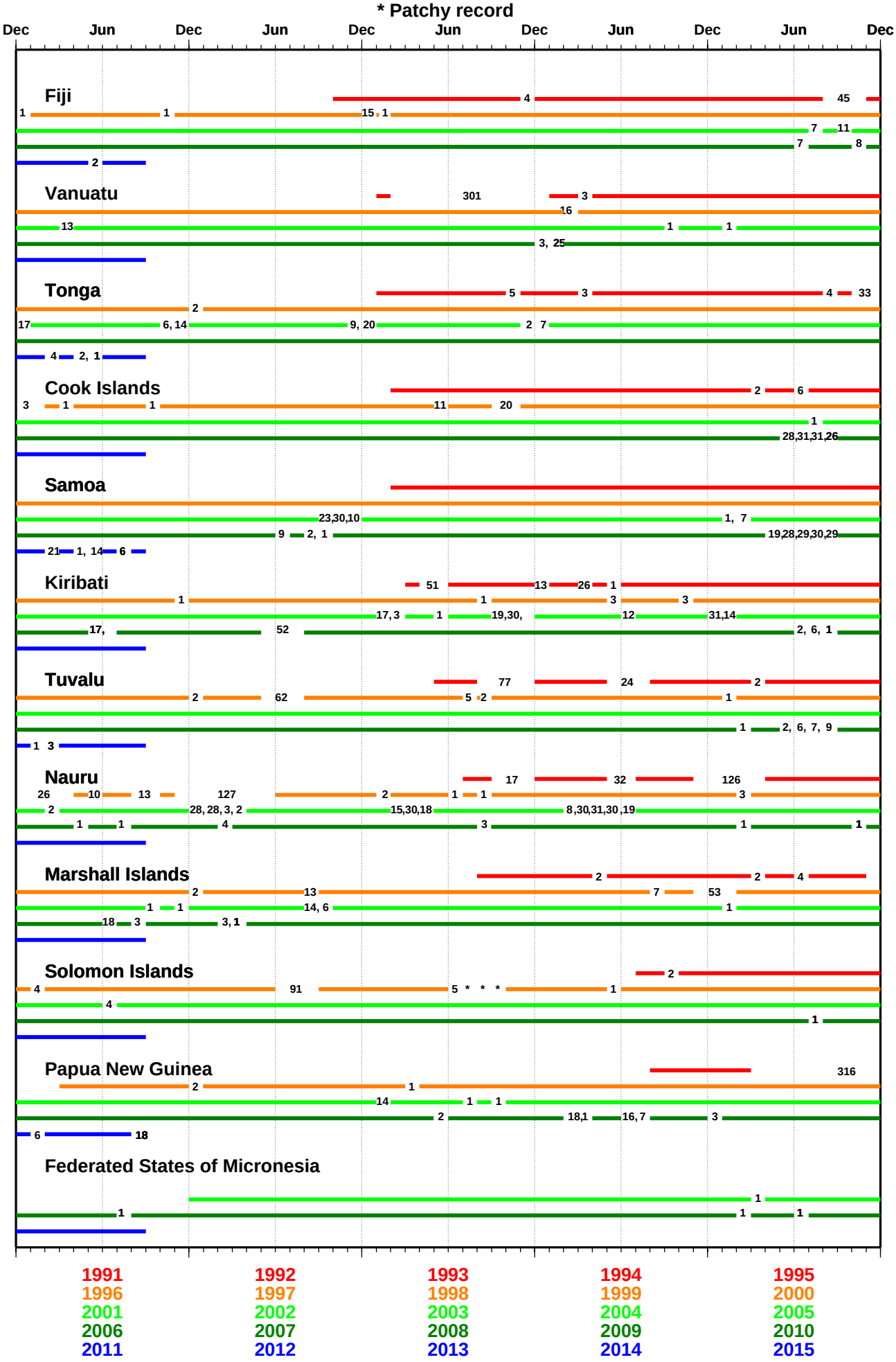


Figure 17

SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED

GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE

* Patchy record