

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

MONTHLY DATA REPORT

NO. 185

NOVEMBER 2010



Australian Government

Bureau of Meteorology

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



Australian Government

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Quality Certification:

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

November 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.

November 2010

- The SEAFRAME network continued to collect high quality sea level and associated meteorological information for monitoring climate variability and climate change.
- No extreme weather or tsunami events were observed by the SEAFRAME network in November 2010.
- Mean sea levels at Marshall Islands, FSM, PNG, Solomon Islands and Samoa were slightly higher than normal during November. The monthly mean sea level at Marshall Islands for November 2010 is the highest on record.
- Mean sea levels remained lower than normal at the equatorial stations of Kiribati and Nauru, in association with cooler than normal equatorial ocean temperatures, while lower than normal sea levels also developed at Vanuatu, Fiji, and Tonga.
- La Niña climate conditions remained dominant through November 2010 and include cooler than normal ocean temperatures across the equatorial Pacific, stronger than normal Trade Winds in the western and central equatorial Pacific and below average cloudiness in the vicinity of the dateline.
- The majority of international climate models predict that the La Niña event will persist through the southern hemisphere summer and gradually weaken in the first quarter of 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 November, 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	+4.8	0.0
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+8.7	-0.2
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+5.0	-0.1
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+5.9	-0.1
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+5.3	+0.1
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+3.9	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	+6.2	+0.1
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+6.8	+0.1
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+16.1	+0.4
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.2	+0.2

INTRODUCTION

Welcome to the November 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.

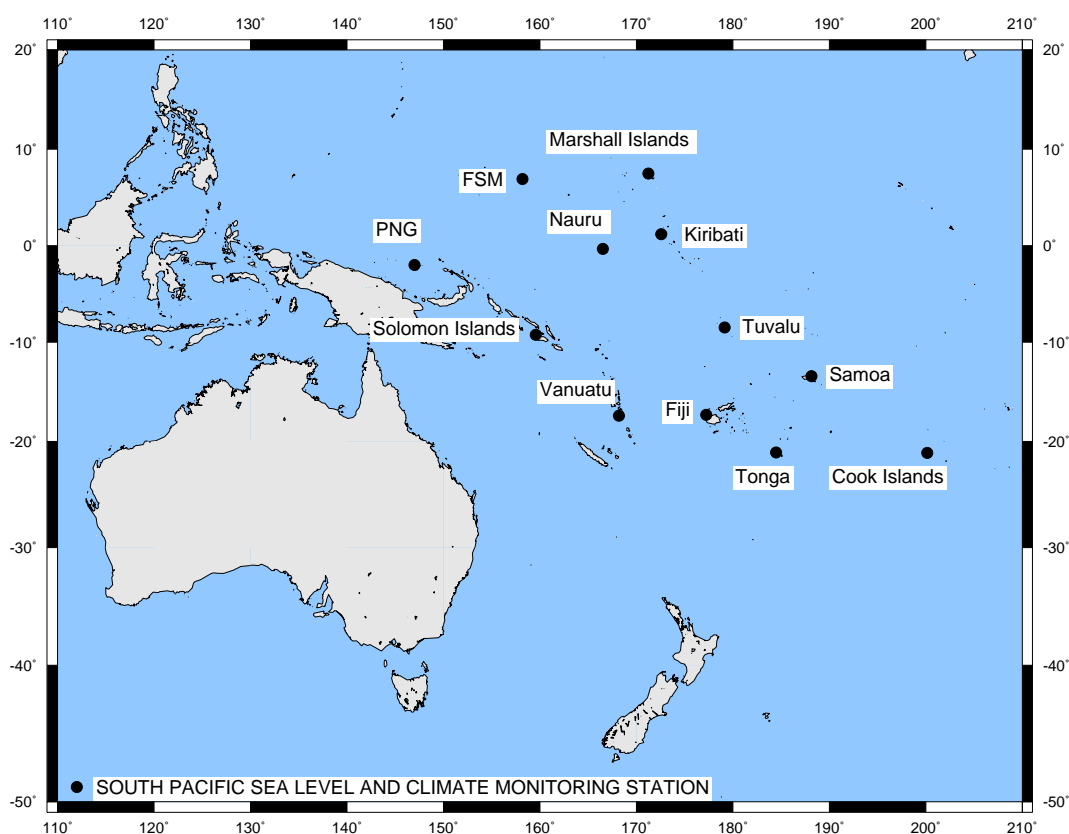


Figure A: *South Pacific Sea Level and Climate Monitoring Stations*

NOVEMBER CLIMATOLOGY

La Niña climate conditions continued to be observed across the equatorial Pacific during November, including cooler-than-normal ocean temperatures and stronger-than-normal Trade Winds across the equatorial Pacific. The Southern Oscillation Index (SOI) remained strongly positive and cloudiness was suppressed over the central equatorial Pacific. International climate models predict that the La Niña event will persist through the southern hemisphere summer.

The Southern Oscillation Index (SOI) has been positive since April (**Figure B**). The November value was +16 following on from the highest October value on record of +18. 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 remained cooler than normal during November. Anomalies of more than 1°C cooler than normal extended along much of the equator (**Figure C**). Sea surface temperatures across the southwest Pacific were slightly warmer than normal, but the warm anomalies in this area generally cooled during through November.

Subsurface ocean temperatures across the central and eastern equatorial Pacific remain cooler than normal, particularly east of the dateline where anomalies of -4°C continue to be observed. The central and eastern equatorial Pacific has been cooler than normal since April 2010, while in the western equatorial Pacific warm subsurface temperature anomalies have developed over the last four months. (**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 remained stronger than normal across the western and central Pacific during November 2010 (**Figure E**). Cloudiness near the dateline remained below average during November 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 through the southern hemisphere summer but gradually weaken in the first quarter of 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)

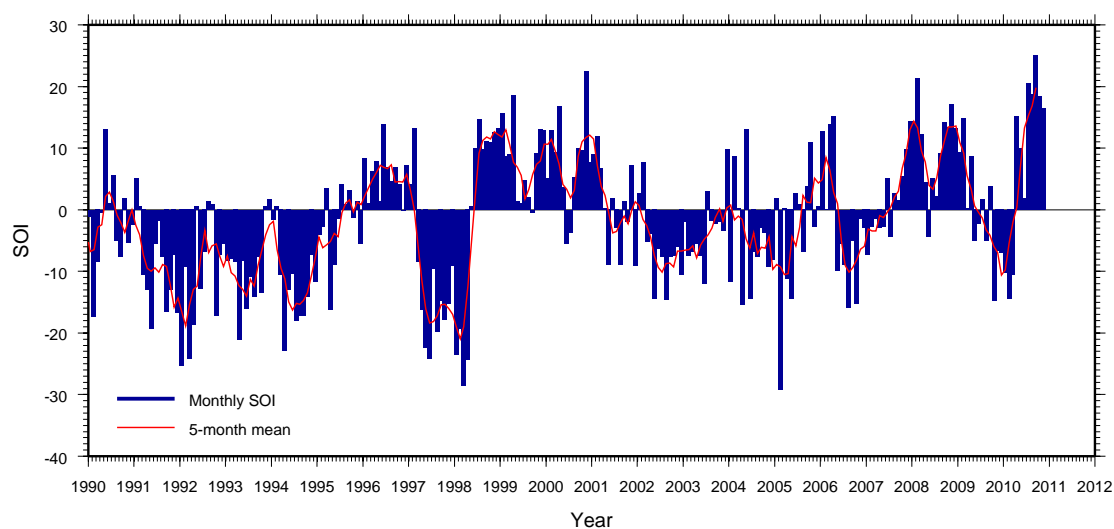


Figure B: The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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

SSTA 1.0X1.0 NMOC OCEAN ANOMALIES (C) 20101101 20101130

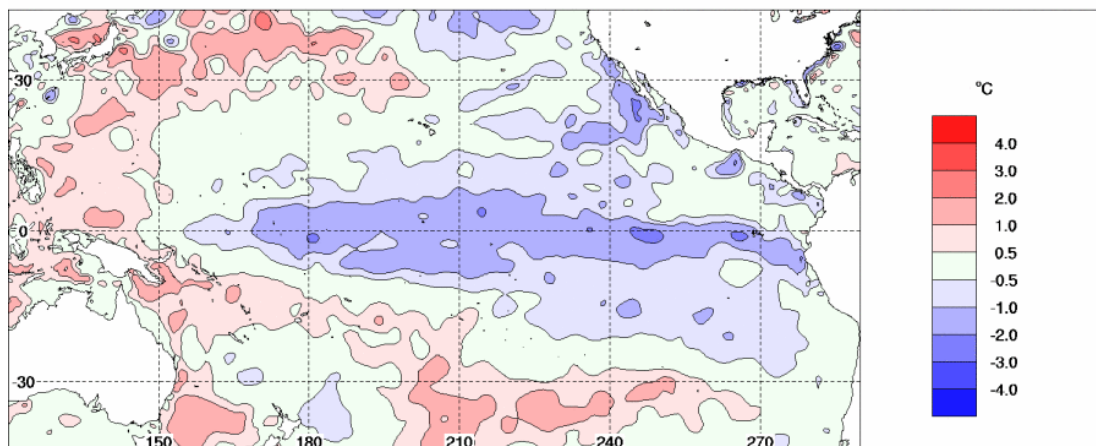


Figure C: Sea surface temperature anomaly ($^{\circ}\text{C}$) for November 2010.

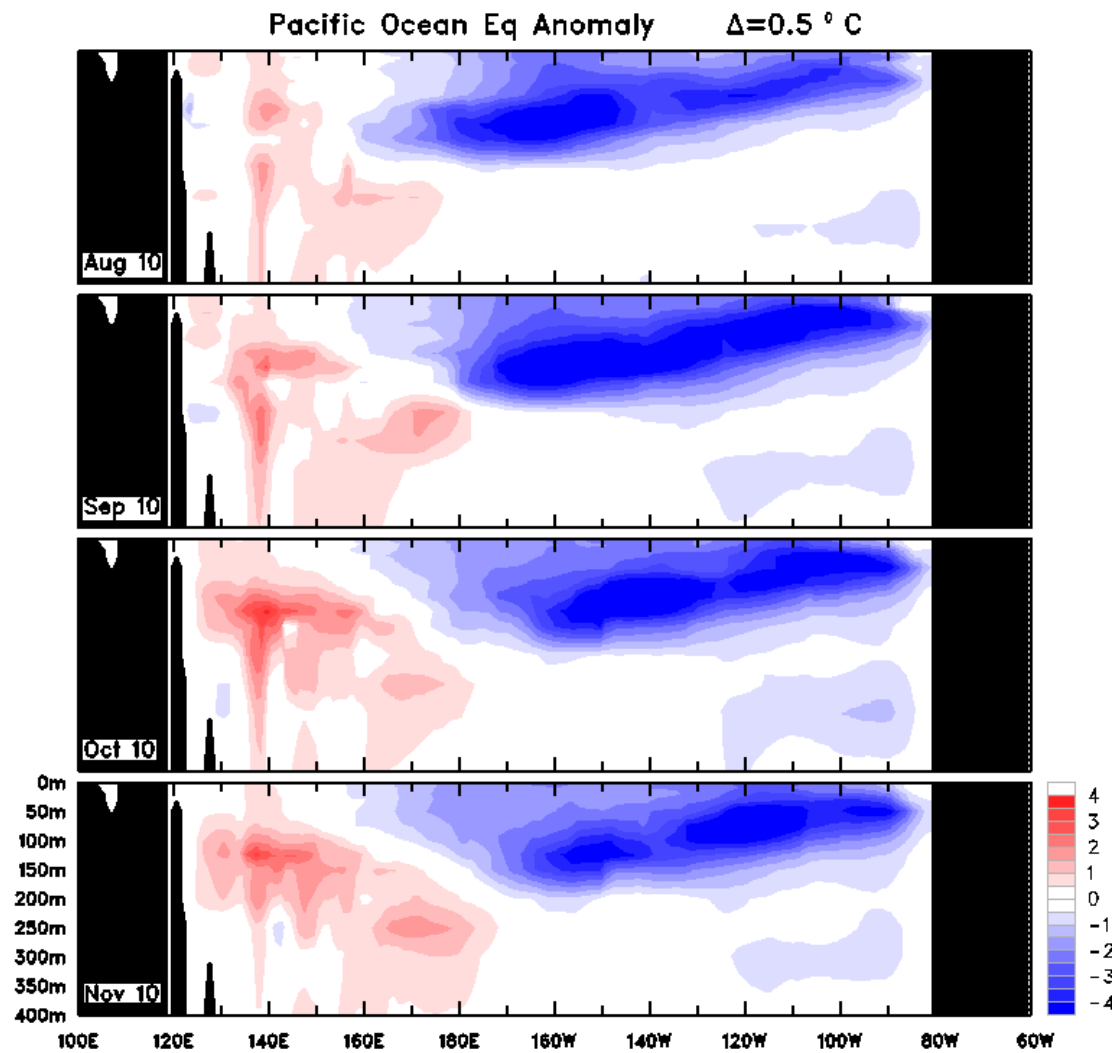


Figure D: Equatorial depth-longitude section of ocean temperature anomalies for August 2010 through to November 2010. Contour interval is 0.5°C .

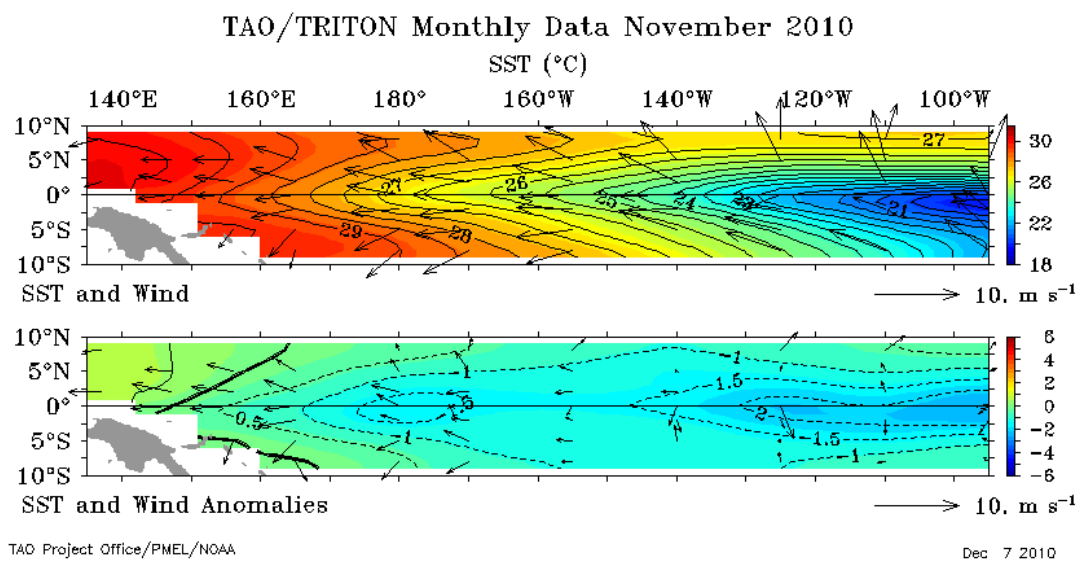


Figure E: Monthly mean wind vectors (top) and anomalies (bottom) for November 2010. The colour-shaded contours represent the monthly mean sea surface temperatures (top) and anomalies (bottom).

NOVEMBER 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 6th of November and a full moon on the 21st of November UTC.

Gaps in the data are the result of instrumental errors or data retrieval problems and are discussed under **Instrument Performance**.

The **residuals (Figure 2)** are the differences between the observed sea levels and the tidal predictions. They highlight non-tidal sea level fluctuations, such as those due to the effects of weather or tsunamis. Tropical cyclones often produce storm surges where the combination of low barometric pressure and strong winds raise sea levels well above the predicted tides for a period of a day or more. The non-tidal sea level fluctuations can be amplified or sustained by the shape of the harbour in which the gauge is located. Some of the SEAFRAME stations are located in harbours that are favourable to persistent 'sloshing' under certain conditions (a phenomena referred to as a seiche), such as occurs at PNG when the wind suddenly changes strength or direction, at FSM during periods of reduced tidal range and at Nauru during strong westerly winds.

The sea level residuals at all stations, to some degree, exhibit semi-diurnal or diurnal fluctuations, which last a few days or weeks and then disappear. If these peaks were to persist, rather than appear as occasional 'transients', then the tidal analysis would be able to account for them, and the end result would be virtual eradication from the residuals.

The **barometrically corrected residuals (Figure 3)** have had the effect of atmospheric pressure fluctuations removed from the sea level residuals of Figure 2. The rule of thumb for the 'inverse barometer effect' is that a 1-hPa fall in the barometer, if sustained over a day or more, produces a 1-cm rise in the local sea level (within the area beneath the low pressure system).

The **winds, temperatures and barometric pressures** are plotted in **Figures 4 to 9**. The short lines in **Figure 5** follow the meteorological convention, that is, they point in the direction the wind is coming *from*. For example, the winds at 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.* A record maximum November air temperature of 33.3 °C was recorded at Samoa. Record minimum November air temperatures were recorded at the equatorial stations Kiribati (23.1 °C) and Nauru (23.6°C) as well as at Samoa (20.7 °C).

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 of 1.176 m at Marshall Islands for November 2010 is the highest on record, surpassing the previous record of 1.175 m observed in September 2010 and also 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.

Positive sea level anomalies were observed in Marshall Islands, FSM, PNG, Solomon Islands and Samoa during November, although mean sea levels at these sites were generally within 10cm of what is normally observed at this time of the year. Sea levels remained around 5cm lower than normal at the equatorial stations of Kiribati and Nauru, in association with cooler than normal equatorial ocean temperatures. Sea levels at Vanuatu, Fiji, and Tonga were also 5 to 10cm below normal during November. Sea levels at the remaining sites of Tuvalu and Cook Islands were generally near average for this time of the year.

Sea Level Trends

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

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Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+6.2	+0.1
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+6.8	+0.1
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+16.1	+0.4
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.2	+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 November 2010 barometric pressures were generally near average for this time of the year.

The **water temperature anomalies** (**Figure 15**) show cool anomalies of around -1°C were observed at Kiribati and Nauru during November 2010 in agreement with the presence of cooler-than-normal sea surface temperatures across the equator (**Figure C**). Slightly cooler-than-normal water temperatures were also observed at Marshall Islands and Tuvalu. Warmer than normal conditions continued to be observed at PNG, Vanuatu and Cook Islands, but the recent warm anomalies at Fiji and Tonga have cooled, in line with general sea surface temperature cooling in this region, and water temperatures at these sites are normal for this time of the year.

The **air temperature anomalies (Figure 16)** show cooler conditions were observed at the equatorial stations Kiribati and Nauru during November in similarity with the water temperature anomalies. Warm anomalies at Samoa, Vanuatu, Fiji and Tonga in recent months cooled through November and air temperatures there are now near normal for this time of the year. Warm air temperature anomalies around $+0.5^{\circ}\text{C}$ persist at PNG 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.

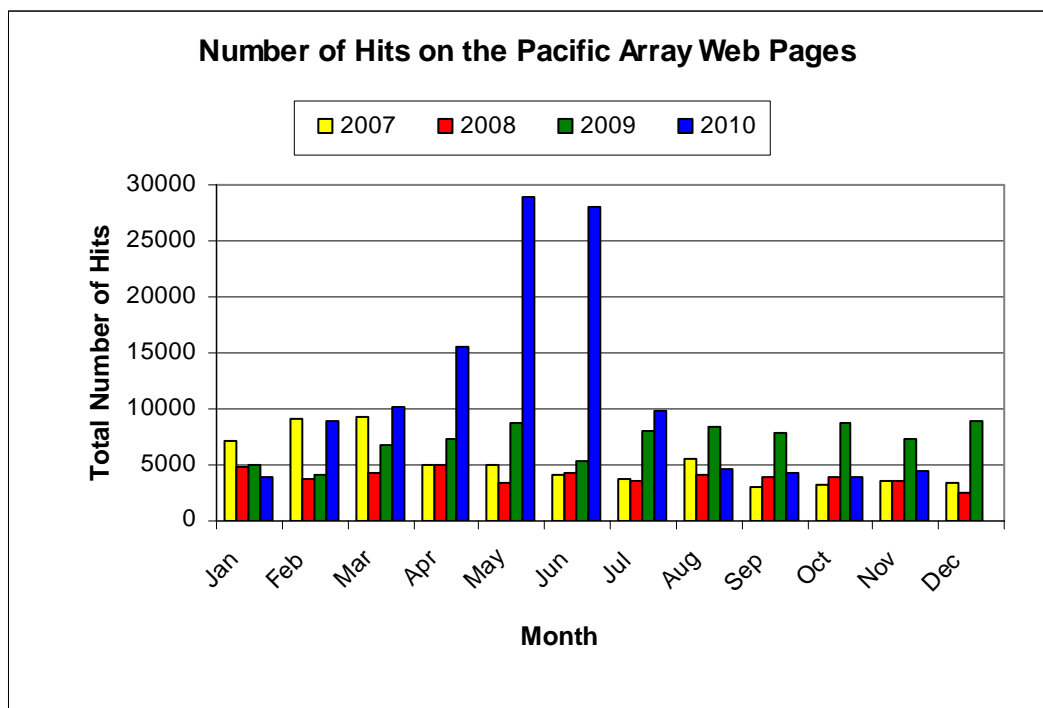
Instrument Performance

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 good for most stations during November 2010 with the exception of Tuvalu, which continues to be hampered by intermittent data communications problems, and Fiji where systems problems caused an outage from 6 – 14 November. Calibration and maintenance visits were performed at Nauru and Kiribati during November and while in transit technical staff also attended to and resolved the problem with the Fiji SEAFRAME station. The primary acoustic sea level sensor at Nauru was restored on 11 November, having been inoperative since March 2010. Similarly the water temperature sensor at Kiribati was repaired on 5 November, having been inoperative since November 2009. Isolated communications problems were experienced at FSM, Nauru, PNG, Tuvalu, Samoa and Tonga through November.

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.

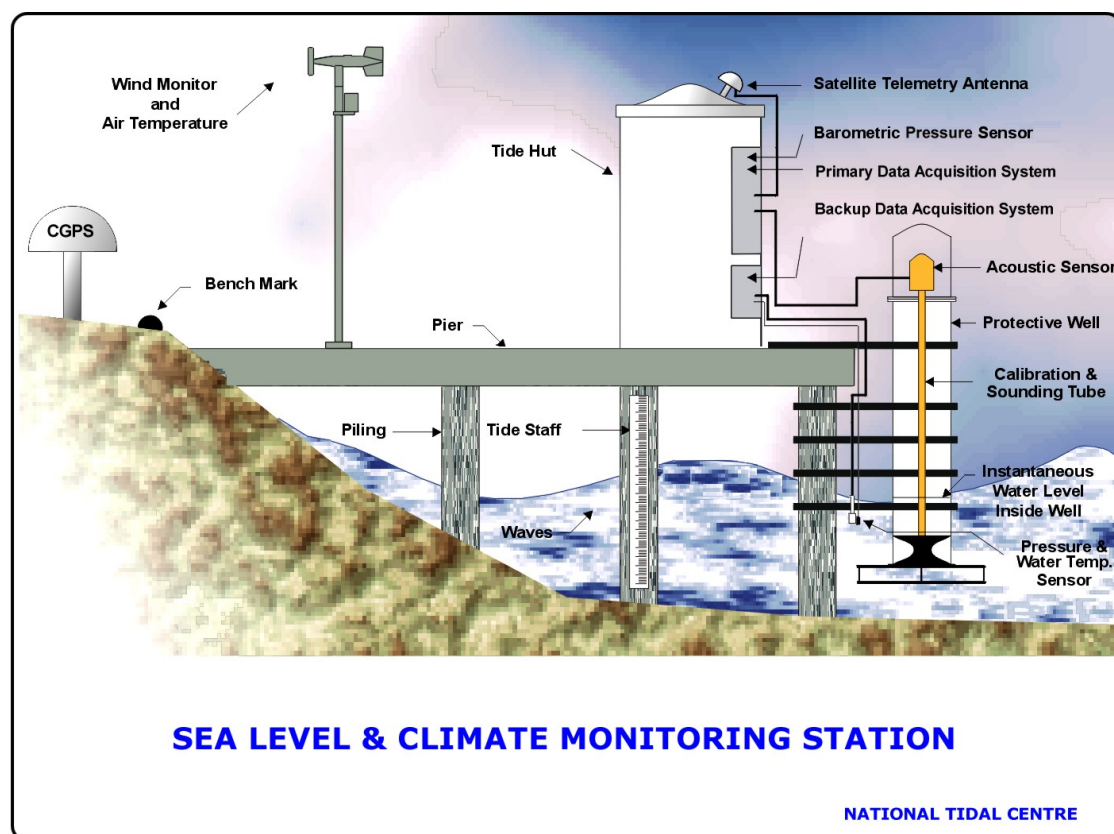


SEAFRAME STATIONS

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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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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Figure 1

NOVEMBER 2010

SIX MINUTE WATER LEVEL OBSERVATIONS (m)

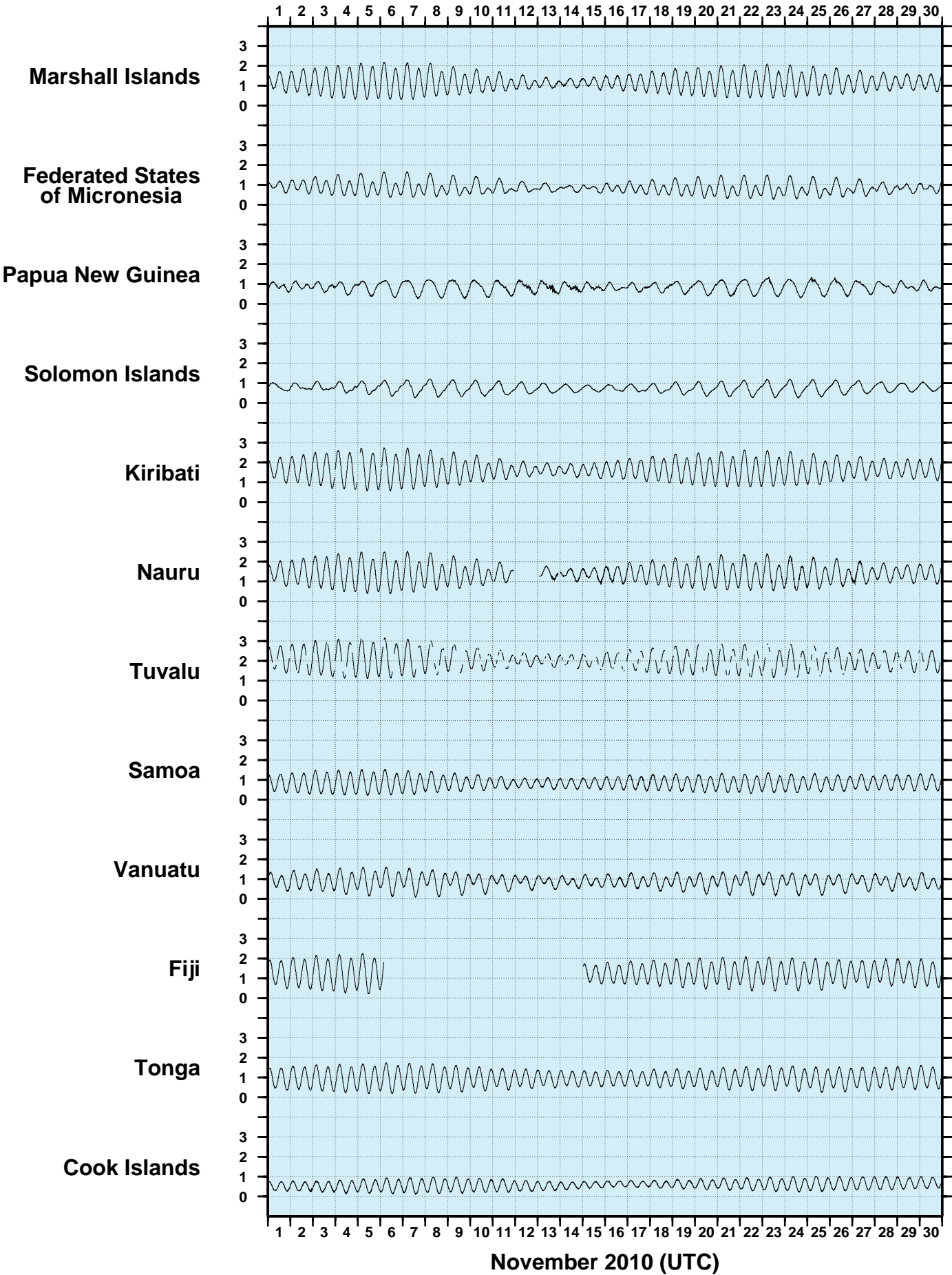


Figure 2
NOVEMBER 2010
SIX MINUTE RESIDUAL WATER LEVELS (m)

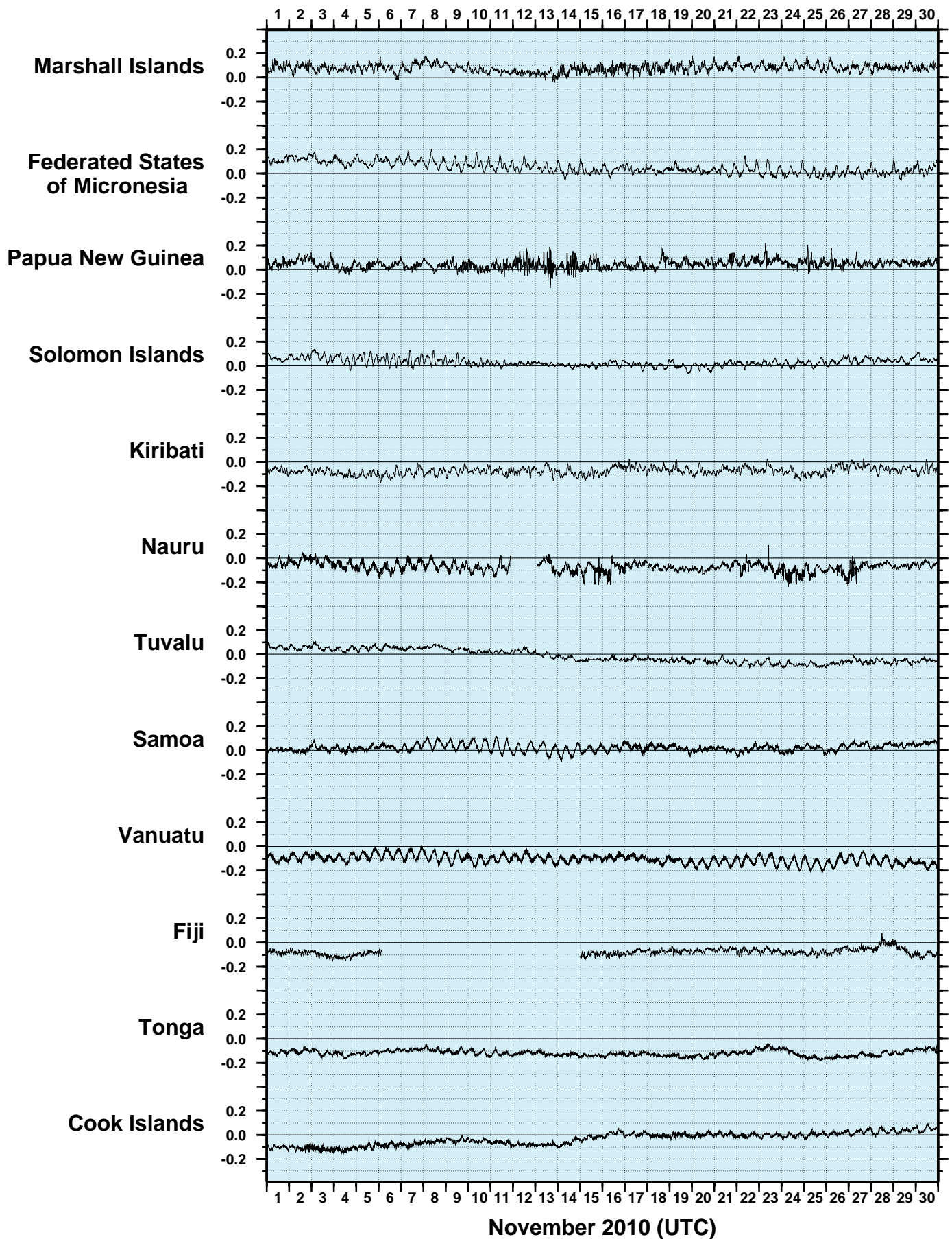


Figure 3

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

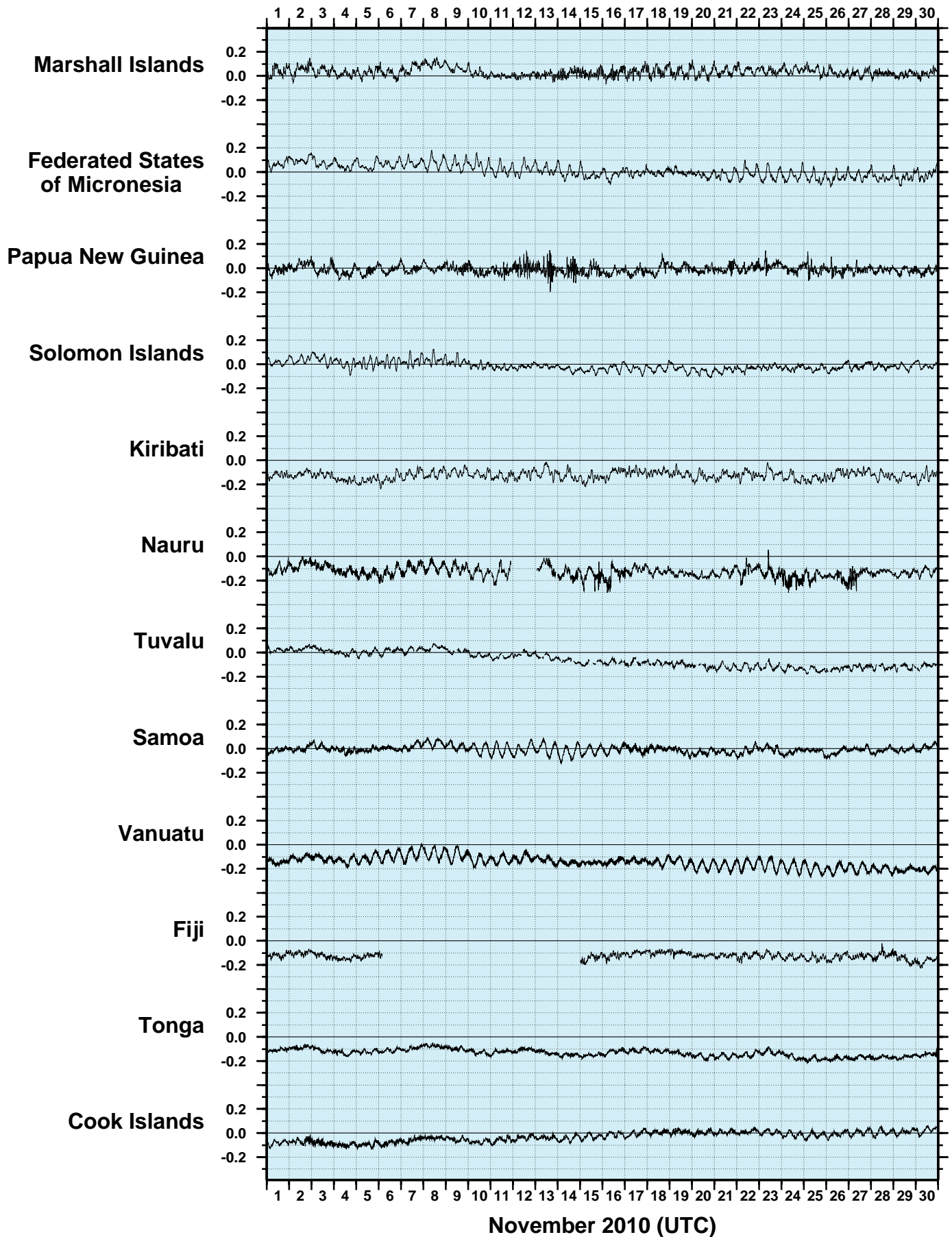


Figure 4

NOVEMBER 2010 HOURLY WIND SPEEDS (m/s)

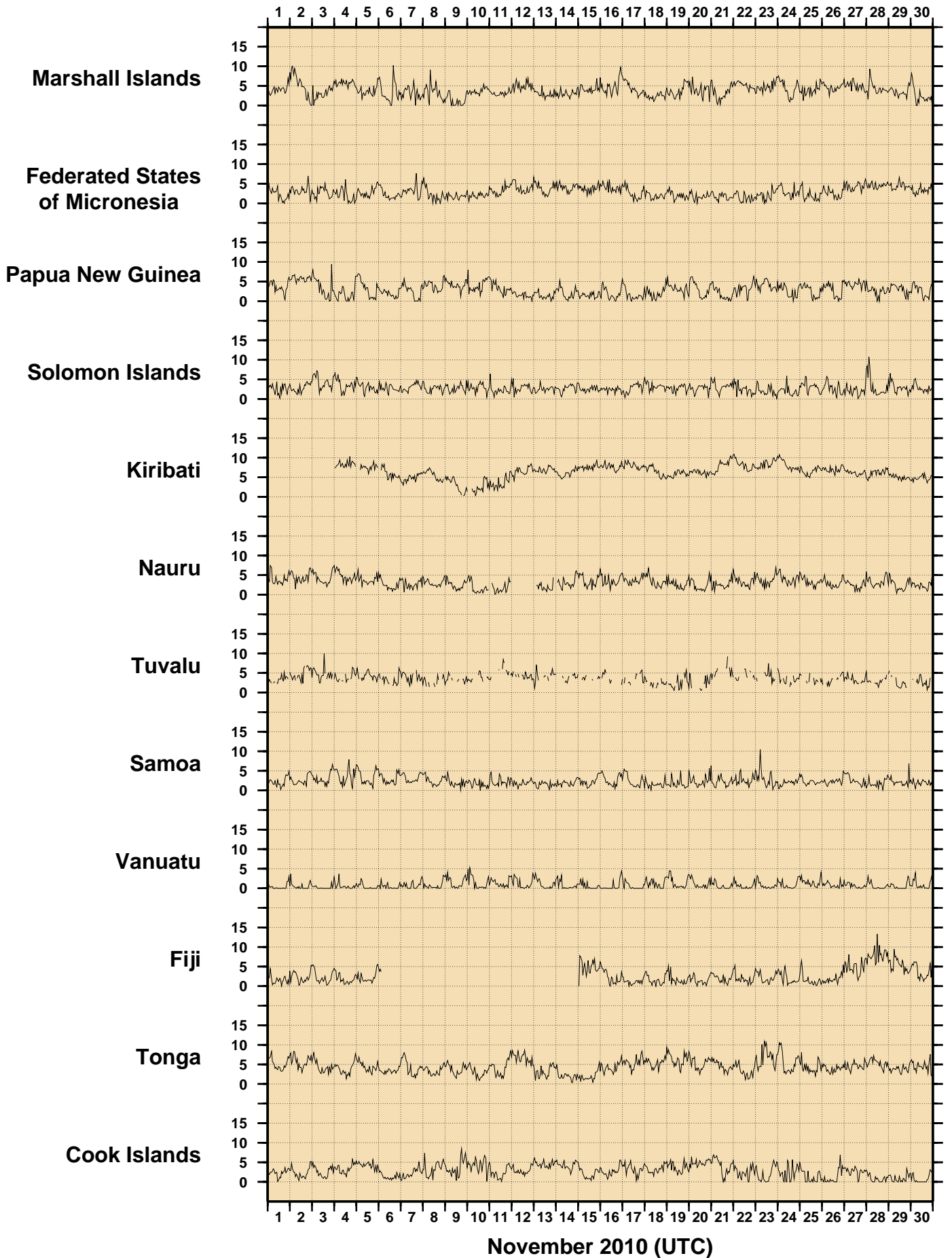


Figure 5
NOVEMBER 2010
HOURLY INCIDENT WINDS (m/s, deg True)

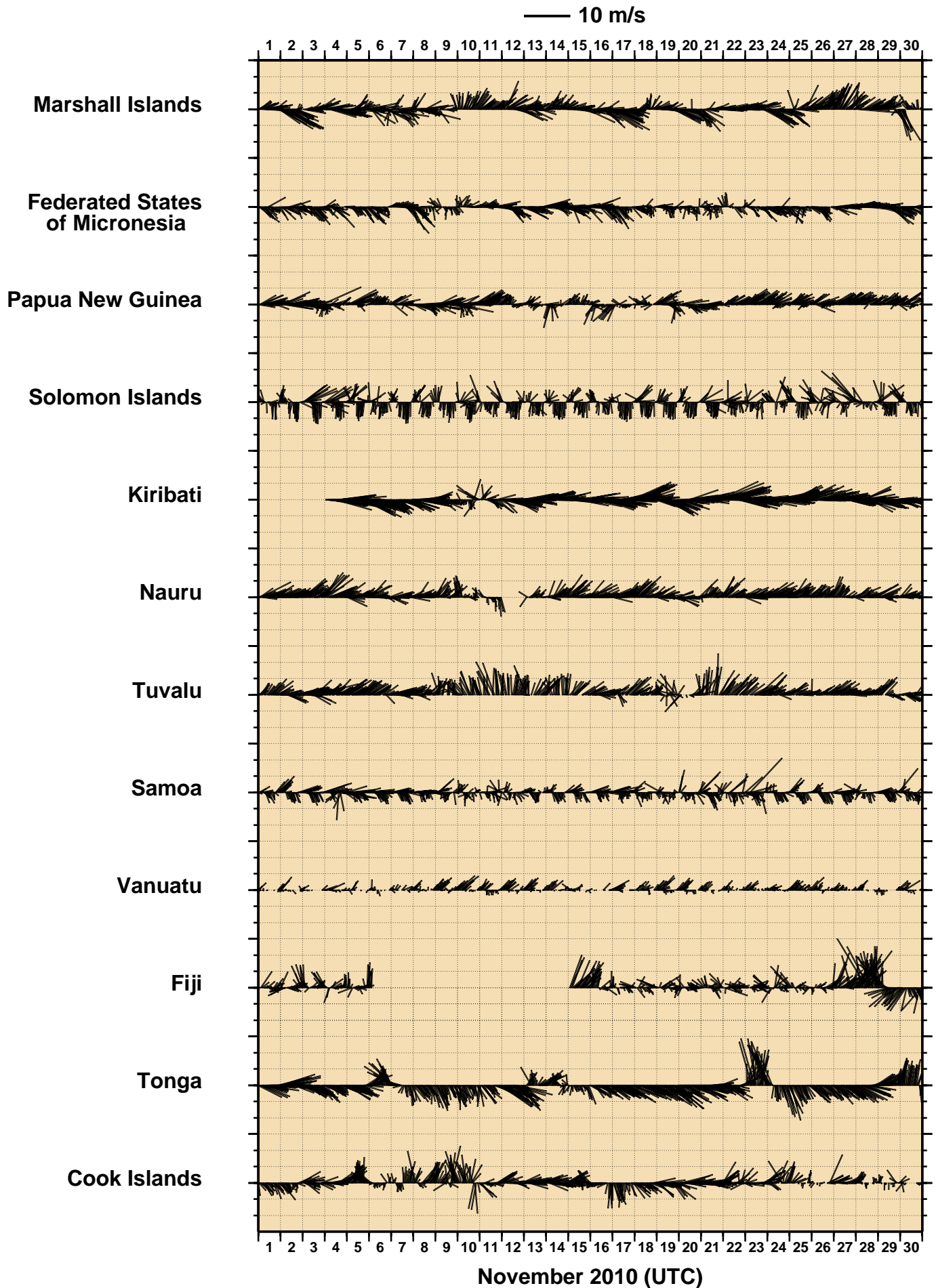


Figure 6
NOVEMBER 2010
HOURLY MAXIMUM WIND GUSTS (m/s)

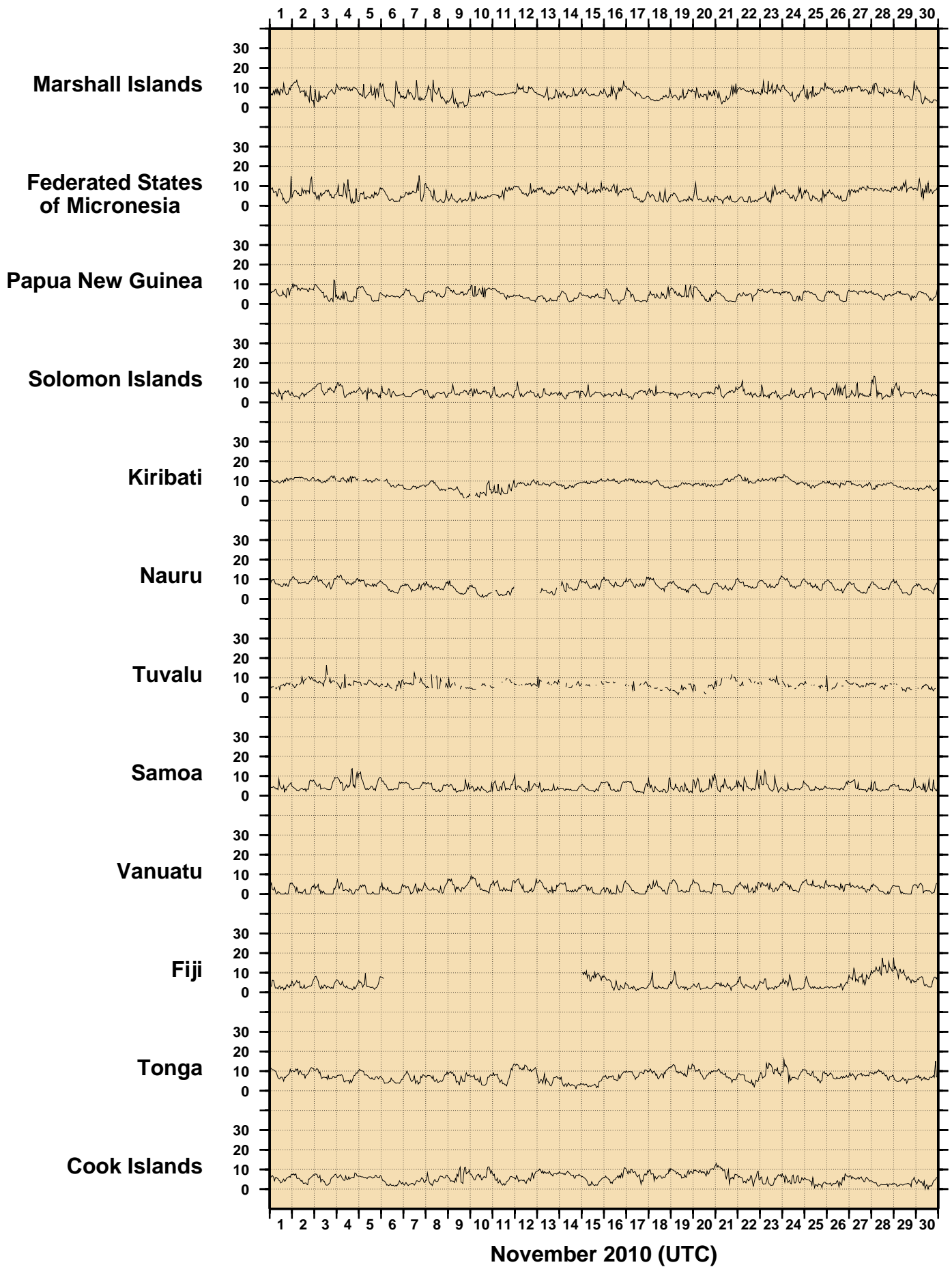


Figure 7



Figure 8
NOVEMBER 2010
HOURLY WATER TEMPERATURES (°C)

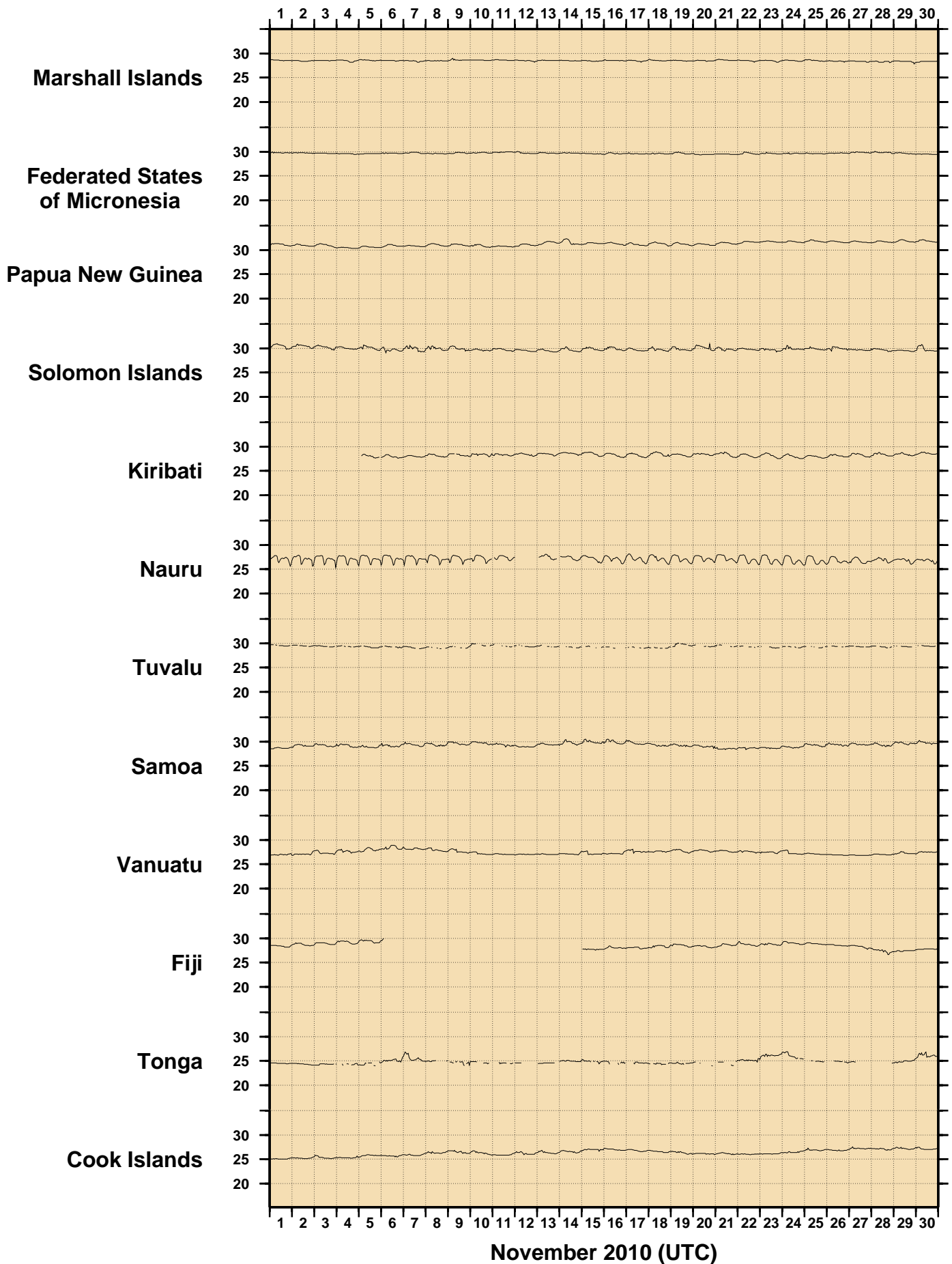


Figure 9
NOVEMBER 2010
HOURLY ATMOSPHERIC PRESSURE (hPa)

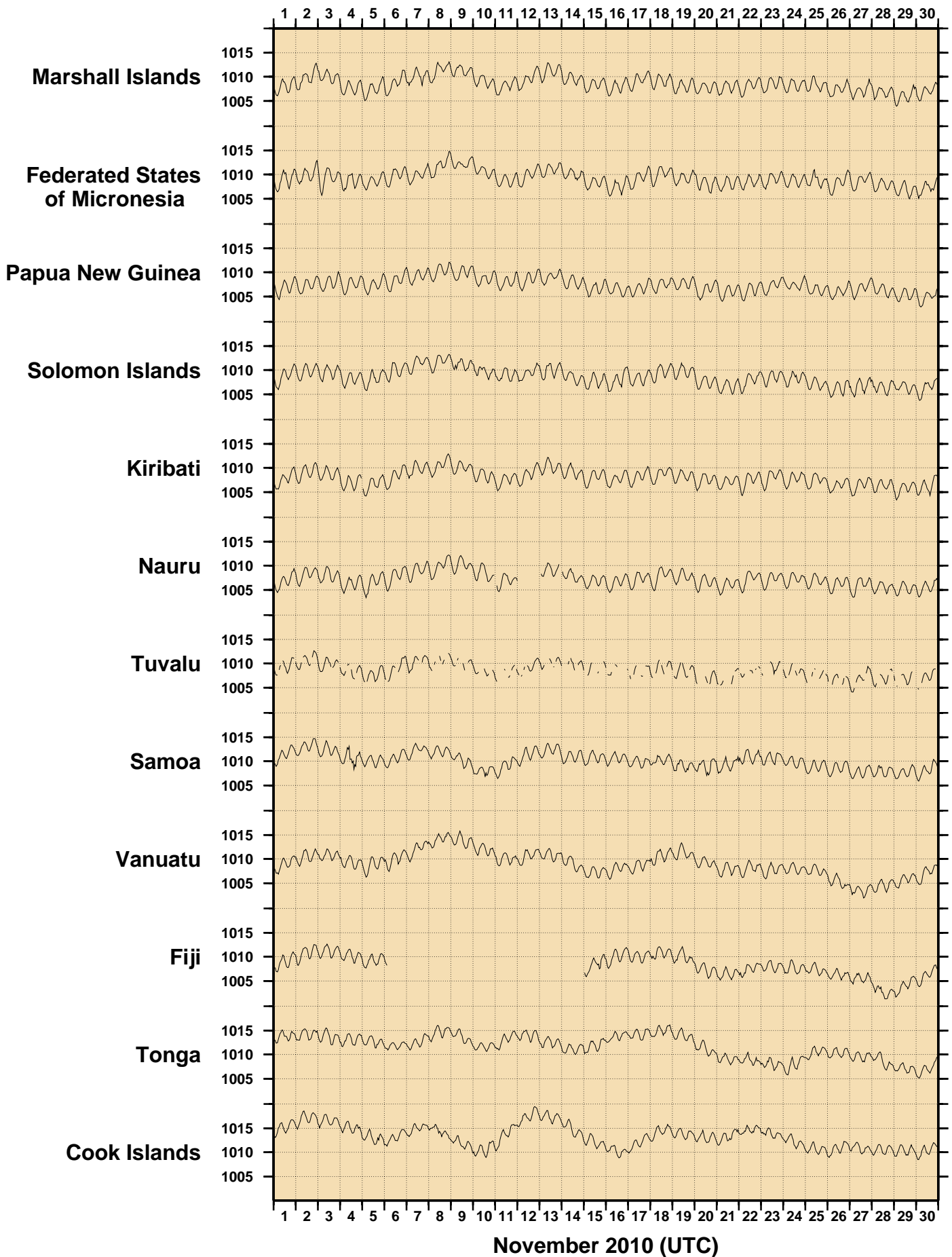
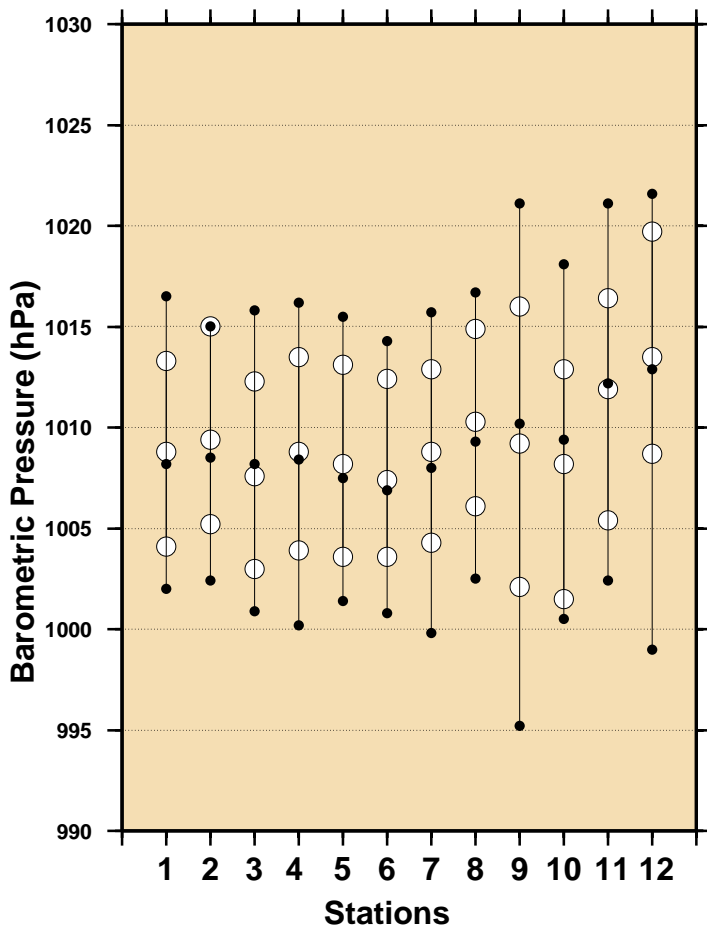
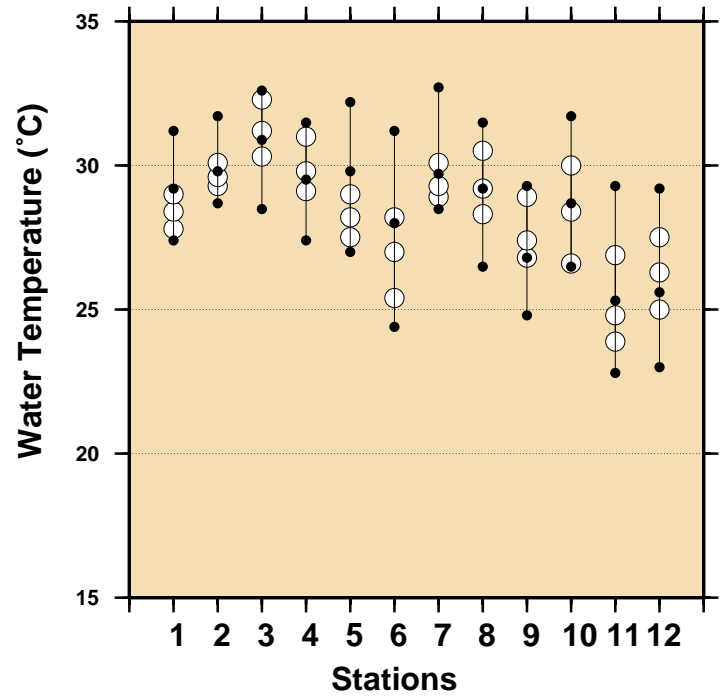
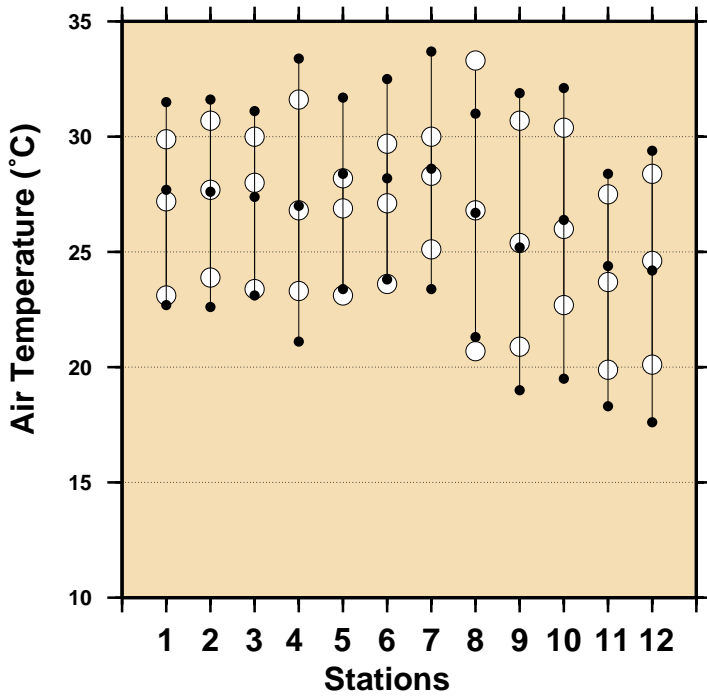


Figure 10

Comparison of November 2010 Max, Min & Mean with Long Term November 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

- November 2010 Maximum
- November 2010 Mean
- November 2010 Minimum
- Long Term November Maximum
- Long Term November Mean
- Long Term November Minimum

Figure 11

MONTHLY MEAN SEA LEVELS TO NOVEMBER 2010 (m)

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

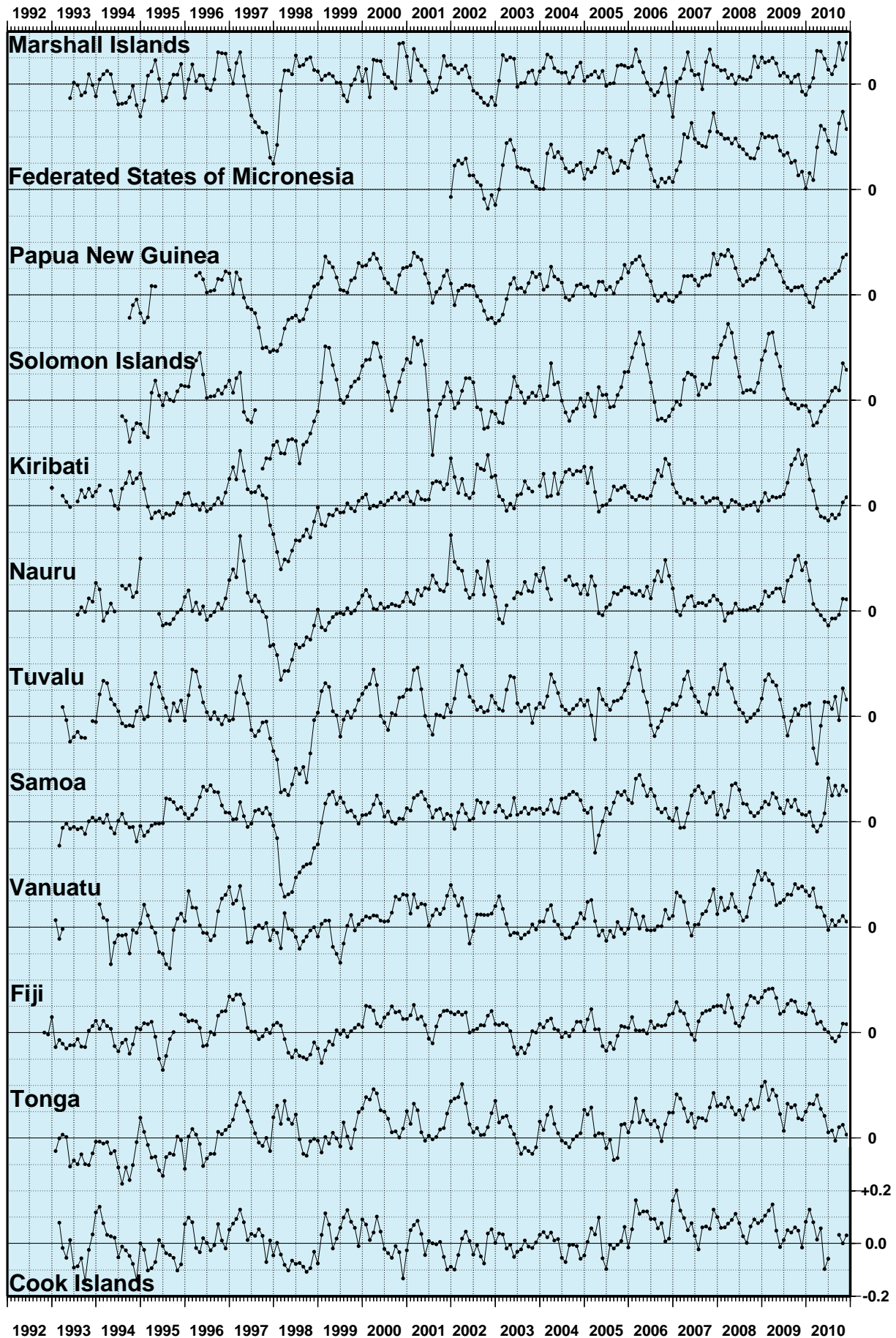


Figure 12
SEA LEVEL ANOMALIES THROUGH NOVEMBER 2010 (m)

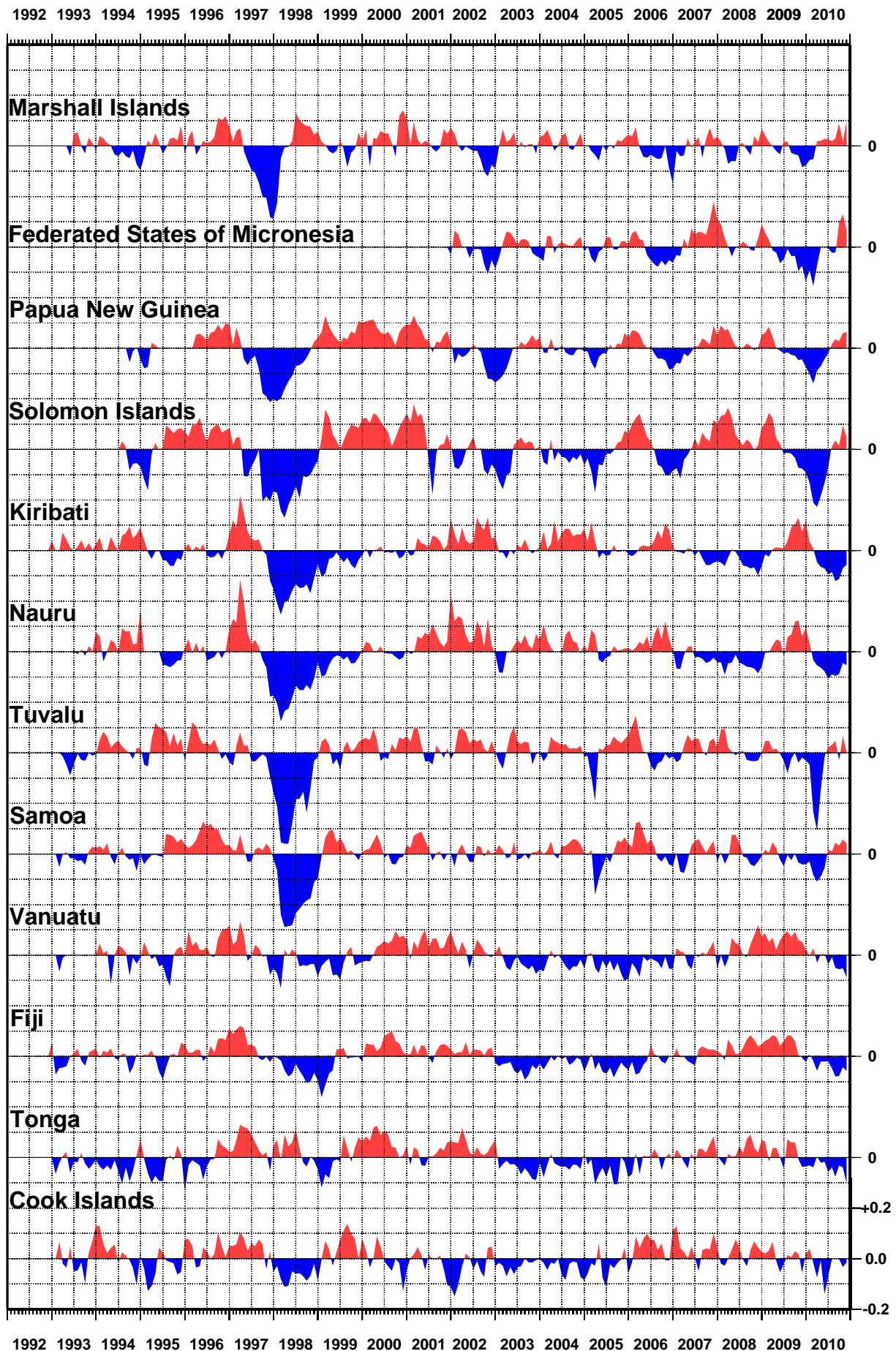


Figure 13

SEA LEVEL TRENDS THROUGH NOVEMBER 2010 (mm/year)

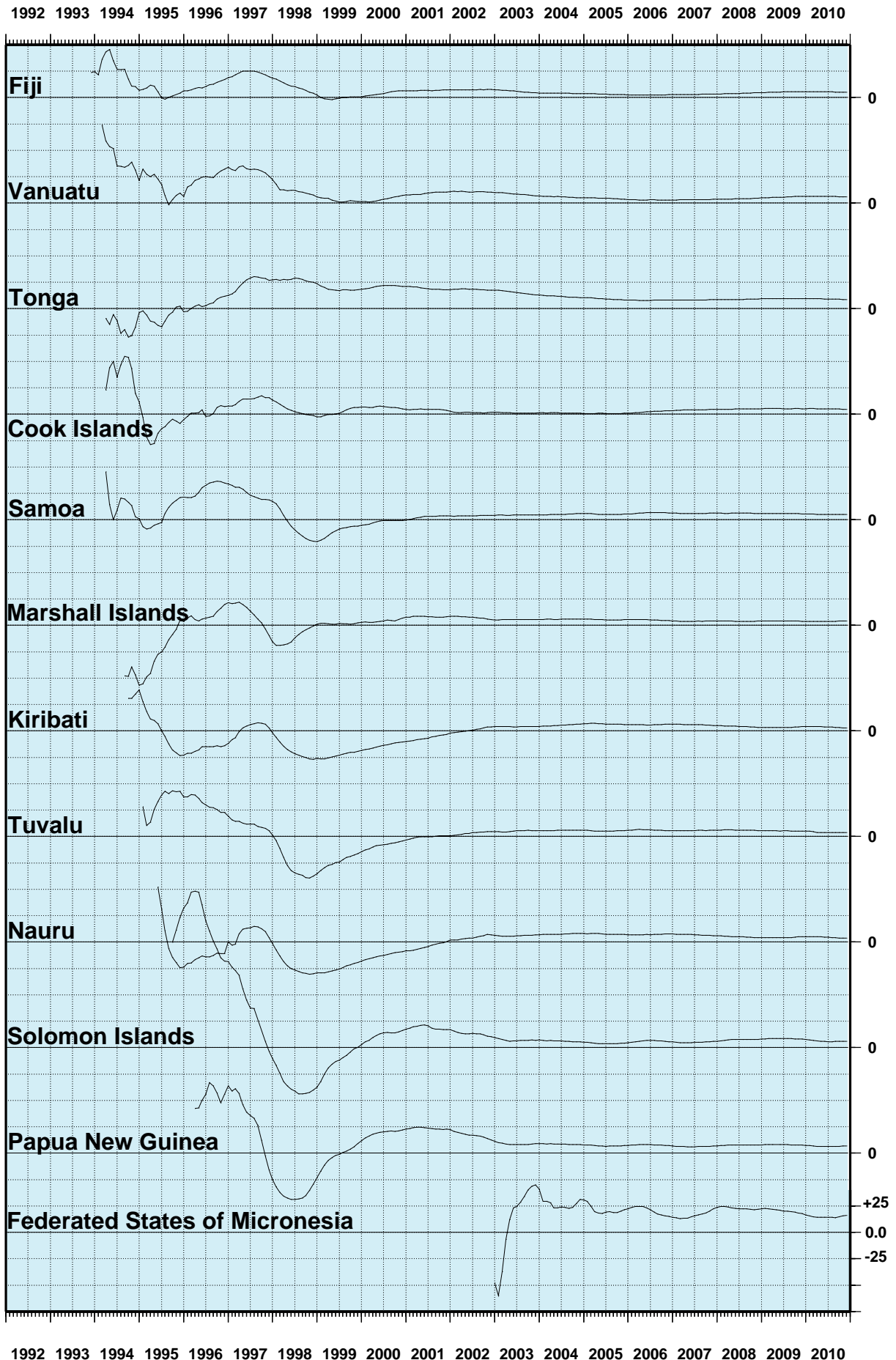


Figure 14

BAROMETRIC PRESSURE ANOMALIES THROUGH NOVEMBER 2010 (hPa)

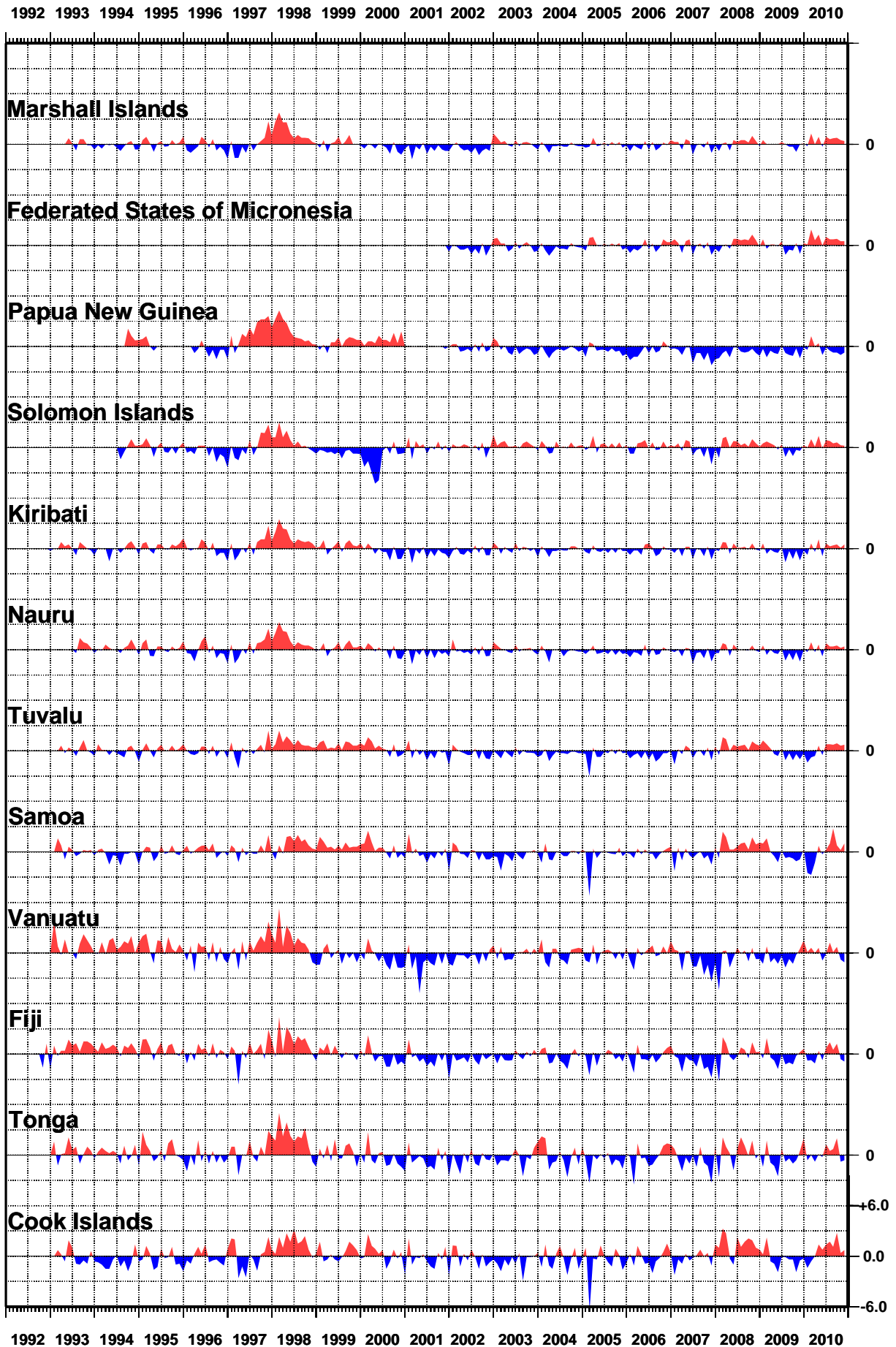


Figure 15
WATER TEMPERATURE ANOMALIES
THROUGH NOVEMBER 2010 (°C)

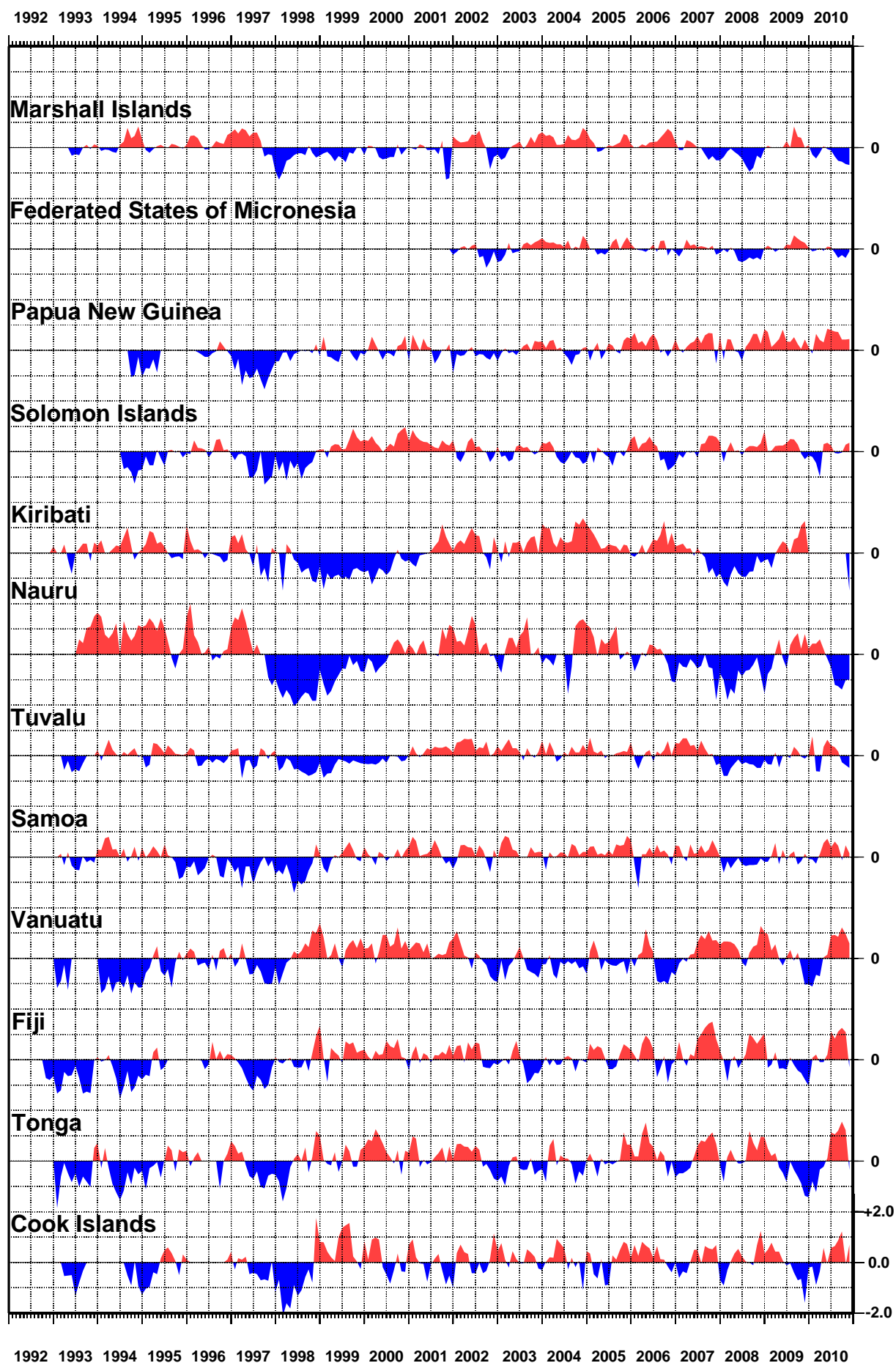
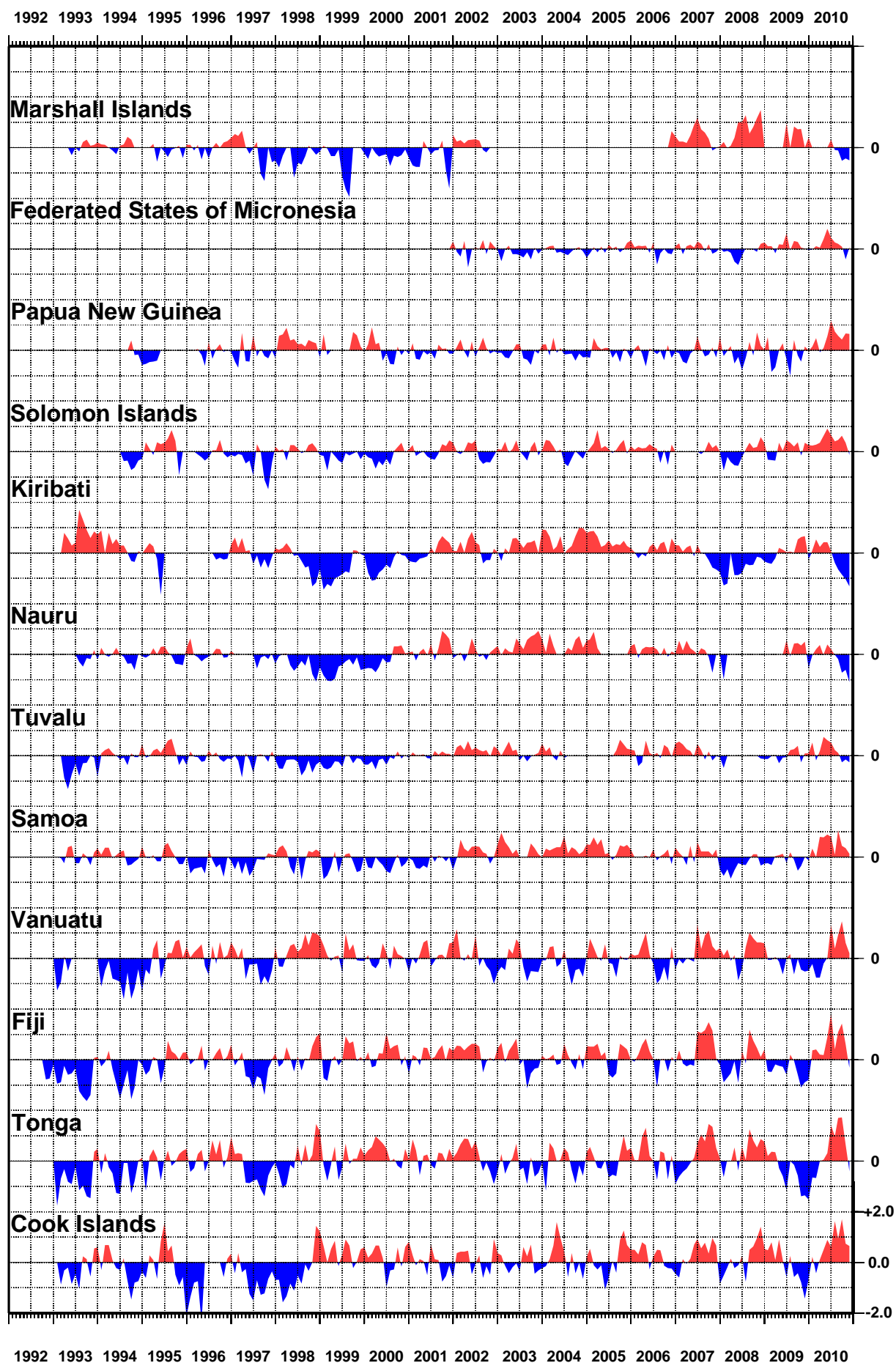


Figure 16
**AIR TEMPERATURE ANOMALIES
 THROUGH NOVEMBER 2010 (°C)**



SEA LEVEL DATA RETURN

*** Patchy record**

