THE SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT

MONTHLY DATA REPORT

NO. 161

NOVEMBER 2008

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

Bureau of Meteorology

National Tidal Centre
Bureau of Meteorology
Australia

GPO Box 421
Kent Town SA 5071
Australia

Tel: (+618) 8366 2730
Fax: (+618) 8366 2651
Website: http://www.bom.gov.au/oceanography/

Quality Certification:

I authorise the issue of this South Pacific Sea Level and Climate Monitoring Project Monthly Data Report for November 2008 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 2008

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 2008

- The SEAFRAME network continued to collect high quality sea level and associated meteorological information for monitoring climate variability and climate change.

- Record high sea levels were observed at Vanuatu during November 2008. The monthly mean sea level exceeded the previous record set in October 2008 by 5cm.

- Lower than normal sea levels continue to be observed in the near-equatorial region surrounding Kiribati, Nauru, Tuvalu and Samoa in association with near to lower than normal water temperatures. South of the equator higher than normal sea levels were observed at Vanuatu, Fiji, Tonga and Cook Islands in conjunction with higher than normal water temperatures.

- La Niña – like characteristics have developed across the equatorial Pacific, including stronger than normal Trade Winds and cooler than normal subsurface waters, but overall climate conditions remain neutral.

- The majority of international climate models predict that neutral climate conditions will persist into early 2009. Two of six models predict a return to La Niña conditions during the southern hemisphere summer.

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, 2008

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	+9.2	0.0
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+4.6	+0.1
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+4.8	+0.3
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+6.1	-0.1
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+5.7	-0.1
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.5	-0.2
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+4.2	-0.2
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+7.9	0.0
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+7.8	0.0
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+21.8	+0.2
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.0	0.0

INTRODUCTION

Welcome to the November 2008 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.

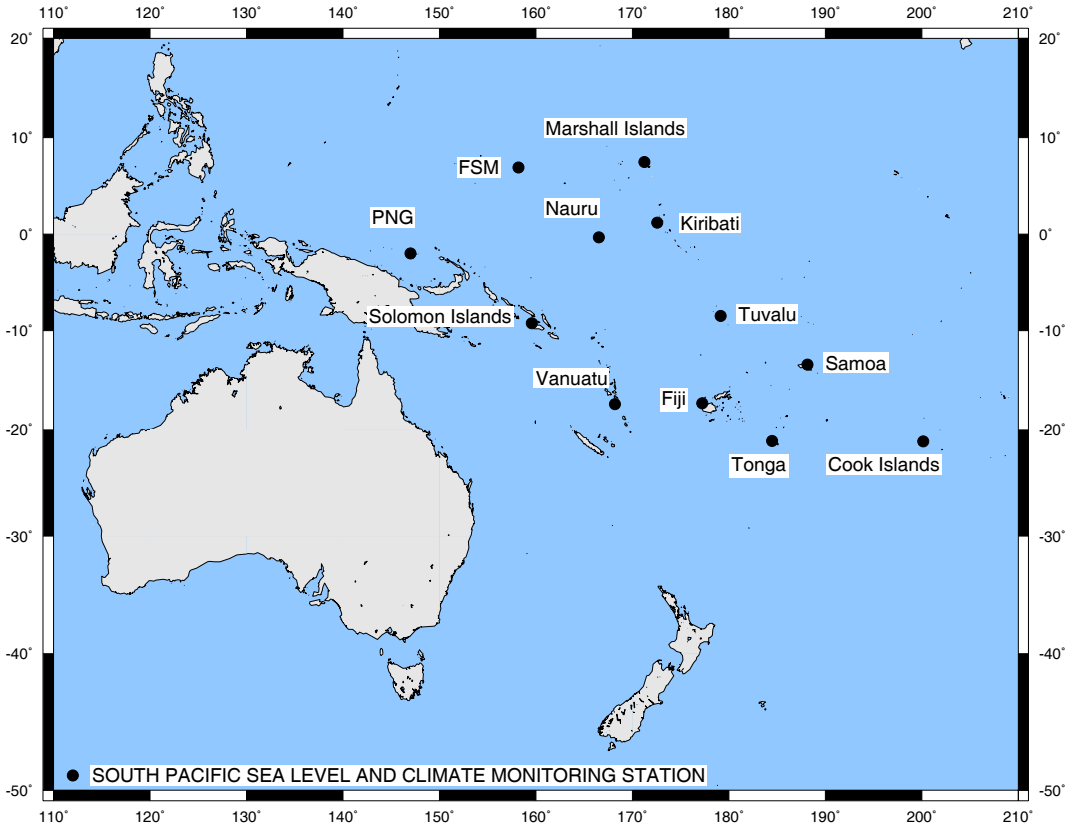


Figure A: *South Pacific Sea Level and Climate Monitoring Stations*

NOVEMBER CLIMATOLOGY

La Niña-like characteristics began to develop across the equatorial Pacific during November, but overall climate conditions remain neutral with regards to the El Niño / Southern Oscillation. Subsurface temperatures have continued to cool and Trade Winds are stronger than normal in the western Pacific. Sea surface temperatures across the equatorial Pacific remain close to normal. The majority of climate models predict neutral conditions will persist into next year, although some are forecasting a return to La Niña conditions.

The Southern Oscillation Index (SOI) increased in November to +17 following the October monthly value of +13 (**Figure B**). Strongly positive SOI values have been observed since August 2008 in response to sustained higher than normal barometric pressure near Tahiti.

Maps of the sea surface temperature anomalies (**Figure C, Figure E**) show near-normal conditions continued to prevail across most of the equatorial Pacific during November, although isolated patches of cooler than normal temperatures were observed in the west-central equatorial Pacific. Extensive areas of warmer than normal sea surface temperatures were observed in the southwest and northwest Pacific. Renewed cooling of subsurface waters at thermocline depths across the central and eastern equatorial Pacific was observed during November (**Figure D**).

During El Niño (warm-episode) conditions there is a sustained weakening of the Trade Winds across much of the equatorial Pacific and an increase in cloudiness in the central Pacific particularly near the dateline. During La Niña (cold-episode) conditions there is a reversal of this situation, with stronger Trade Winds and a decrease in cloudiness in the central Pacific. Trade Winds during November were stronger than normal, particularly over the western half of the equatorial Pacific (**Figure E**). Cloudiness over the equatorial Pacific near the dateline continued to be slightly below normal during November in keeping with slightly cooler than normal sea surface temperatures in that region.

Four among six international computer models predict neutral climate conditions will persist across the equatorial Pacific into early 2009, but the remaining two models predict La Niña conditions will return during the southern hemisphere summer.

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/.

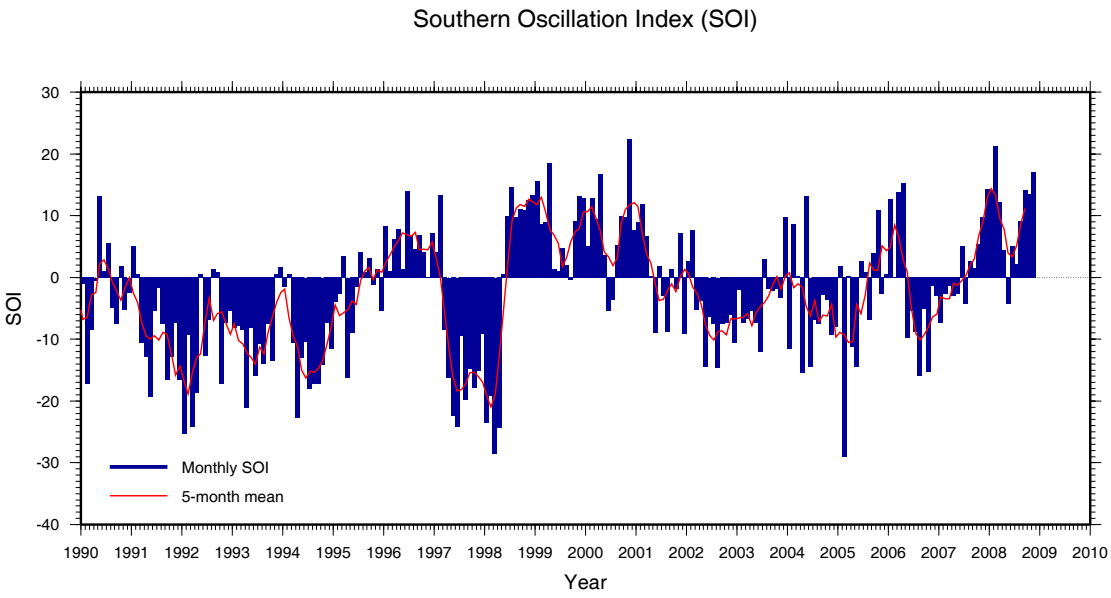


Figure B: *The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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

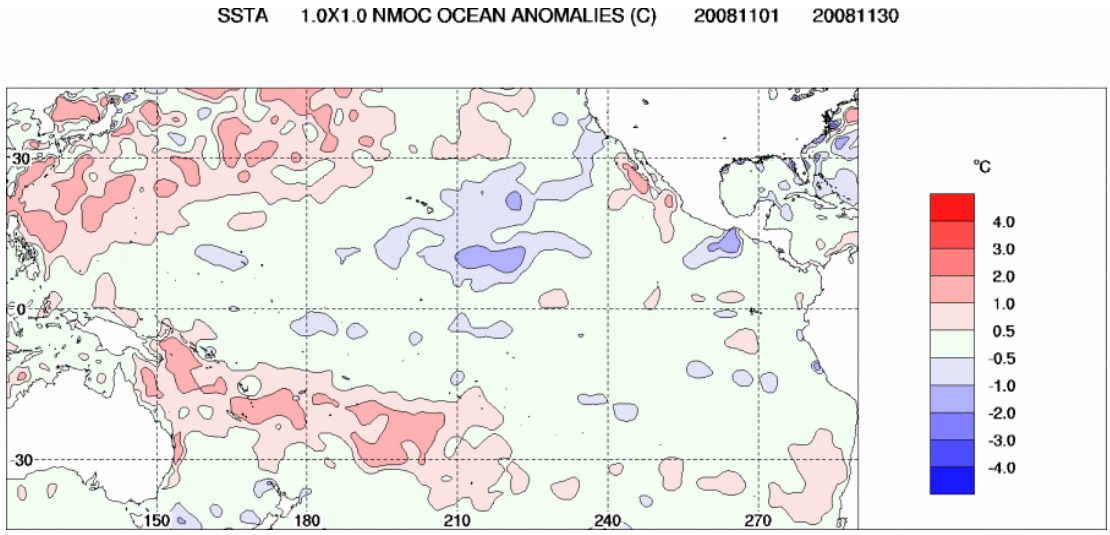


Figure C: *Sea surface temperature anomaly (°C) for November 2008.*

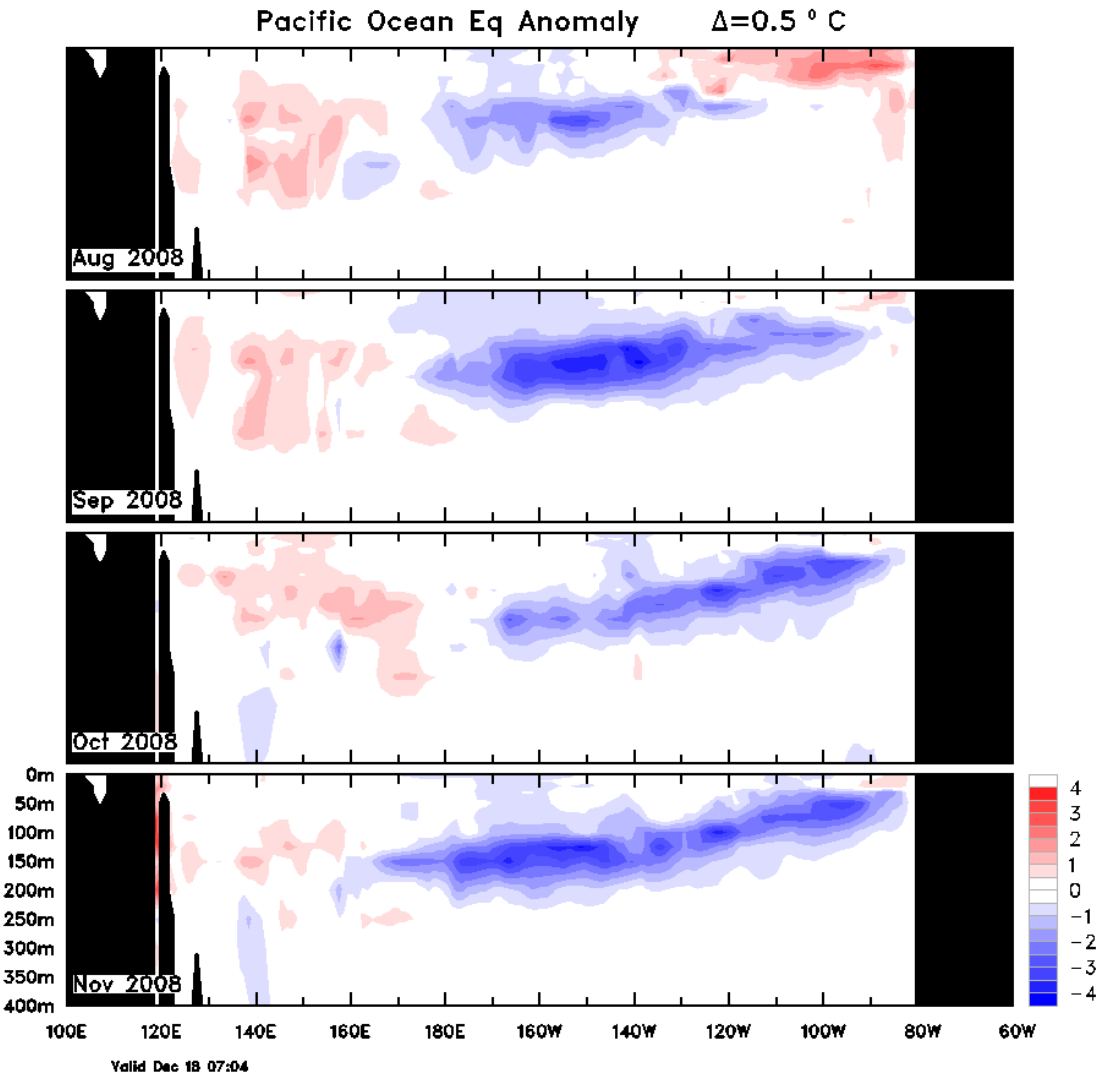


Figure D: *Equatorial depth-longitude section of ocean temperature anomalies for August 2008 through to November 2008. Contour interval is 0.5°C.*

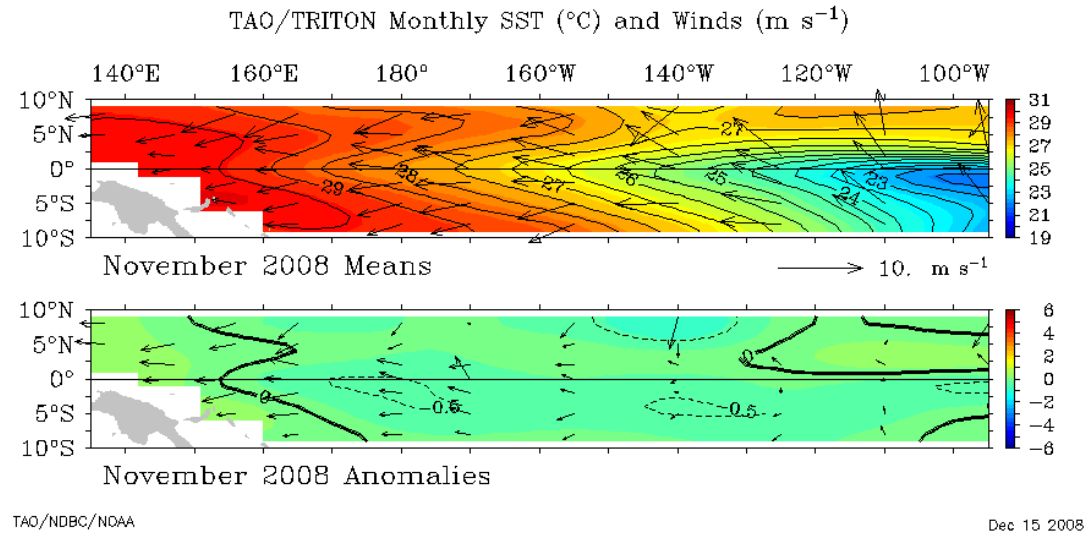


Figure E: *Monthly mean wind vectors (top) and anomalies (bottom) for November 2008. The colour-shaded contours represent the monthly mean sea surface temperatures (top) and anomalies (bottom).*

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 full moon on the 13th of November and a new moon on the 27th of November UTC. A record maximum sea level of 1.771m was recorded at Vanuatu on 13th November 2008 when the full moon high tide coincided with a positive sea level anomaly of 0.2m.

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. Significant residual sea level fluctuations are occasionally observed at FSM during periods of neap tides.

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

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

The **winds**, **temperatures** and **barometric pressures** are plotted in **Figures 4** to **9**. The short lines in **Figure 5** follow the meteorological convention, that is, they point in the direction the wind is coming *from*. For example, the winds at Marshall Islands prevailed from the northeast for most of the month. Daily fluctuations in wind strength and direction observed at Solomon Islands, Nauru, Samoa, Vanuatu and Fiji are indicative of daily sea breezes caused by diurnal temperature variations.

Air and water temperatures **(Figures 7** and **8)** are plotted using the same vertical scale for the purpose of comparison. The air temperatures are seen to fluctuate over a much wider range than the water temperatures. At some sites (e.g. FSM) the water temperature shows almost no variation, although the air temperature varies by several degrees between night and day. At Nauru a twice-daily fluctuation in water temperature is related to the tide, as it is usually more pronounced during the larger spring tides.

Barometric pressures **(Figure 9)** tend to fluctuate by around 3 hPa twice-daily at all stations as a result of atmospheric tides, which are largest in the tropical regions and reduce to near zero toward the poles. The longer-term barometric pressure fluctuations that occur over periods of days to weeks are due to passing weather systems. These fluctuations tend to be larger at sites further away from the equator such as Cook Islands and Tonga.

The **meteorological data** are put into perspective by **Figure 10**. In this figure, if an open circle falls above (below) a solid dot, a new maximum (minimum) for the particular month has been set. *The data sets only include South Pacific Sea Level and Climate Monitoring Project data, which have been collected since October 1992 when the first station was installed (Fiji). The data from FSM has only been collected since December 2001.* New maximum November air temperatures were recorded at Marshall Islands (31.5°C) and Vanuatu (31.9°C) and new minimum November air temperatures were recorded at FSM (22.6°C) and Tuvalu (23.4°C). A new November maximum barometric pressure of 1015.0 hPa was observed at FSM.

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 Vanuatu for November 2008 of 1.068m is the highest on record and exceeds the previous record of 1.017m observed in October 2008.

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 November 2008 higher than normal sea levels were observed at the southern stations of Vanuatu, Fiji, and Cook Islands and lower than normal sea levels were experienced at the equatorial stations of Nauru and Kiribati as well as at Tuvalu and Samoa. Elsewhere sea levels were near to what is expected at this time of the year. The largest sea level anomaly was 0.12m at Vanuatu, which contributed to the record high sea level observations at that station.

Sea Level Trends

The **short-term sea level trends** at individual stations as at November 2008 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 November, 2008

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	+9.2	0.0
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+4.6	+0.1
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+4.8	+0.3
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+6.1	-0.1
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+5.7	-0.1
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+3.5	-0.2
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+4.2	-0.2
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+7.9	0.0
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+7.8	0.0
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+21.8	+0.2
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.0	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 November 2008 barometric pressures were near normal at most stations and generally within 1hPa of what is expected for this time of the year.

The **water temperature anomalies (Figure 15)** show conditions at Vanuatu, Fiji, Tonga and Cook Islands during November 2008 were around +1°C warmer than normal. Slightly warmer than normal water temperatures were also observed at PNG and Solomon Islands. These SEAFRAME observations are in accordance with the warmer than normal sea surface temperatures in the southwest Pacific as shown in Figure C. Slightly cooler than normal water temperatures were observed nearer to the equator at Marshall Islands, FSM, Kiribati, Nauru and Tuvalu during November 2008.

The **air temperature anomalies (Figure 16)** during November 2008 also reveal +1°C warmer than normal conditions in the southwest Pacific surrounding Vanuatu, Tonga and Cook Islands. A significant anomaly of +1.5°C was observed at Marshall Islands. Elsewhere air temperature observations were near normal for this time of the year. At Nauru no air temperature data were received. 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. Very good sea level data return was achieved in November 2008.

The air temperature sensor at Nauru continued to experience problems and the erroneous data were removed from the record. The air temperature, water temperature and barometric pressure observations at Marshall Islands contained numerous isolated errors or 'spikes' that were removed from the record. To a lesser extent similar problems were encountered with the water temperature observations at Kiribati and Tonga.

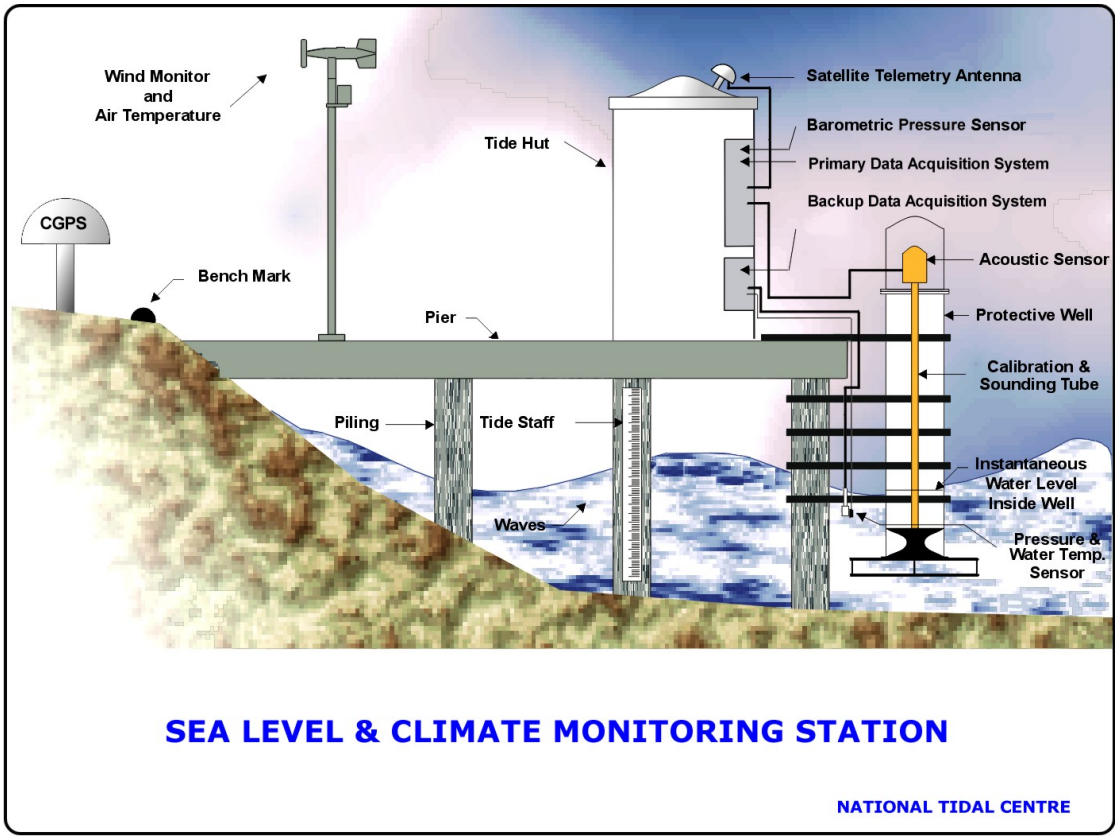
SEAFRAME STATIONS

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

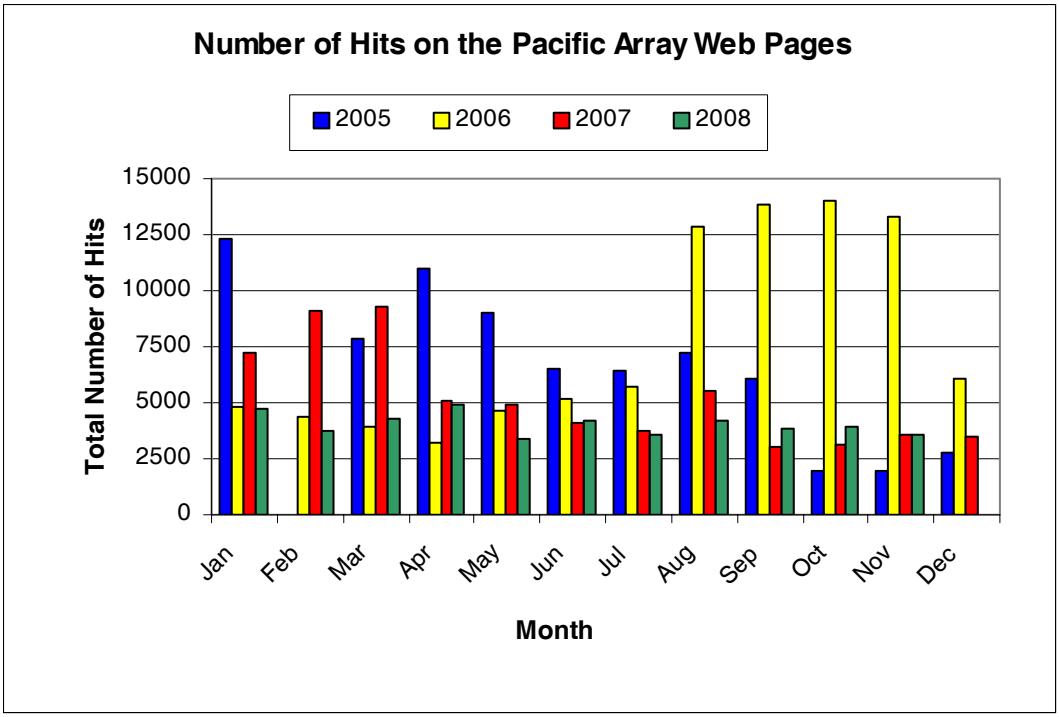
(2) Secondary water level (or backup) using a Druck pressure transducer mounted close to the seabed.

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 2005. Note that the web statistics for February 2005 are not available due to technical difficulties.



The *Monthly Data Report* is prepared by *NTC* for *AusAID*.

NTC would appreciate feedback from readers on the content and presentation of the *Monthly Data Report*.

Please spare a few moments to let us know your constructive opinion.

Further communication on the *Monthly Data Report* may be made to *NTC*. Anyone interested in a more detailed account of the project should contact:

National Tidal Centre
Bureau of Meteorology
PO Box 421
Kent Town SA 5067
Tel: (+618) (08) 8366 2600
Fax: (+618) (08) 8366 2693
Website: http://www.bom.gov.au/oceanography/tides.shtml

Or visit the project website at http://www.bom.gov.au/pacificsealevel

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

Please also note the following:

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

NOVEMBER 2008
SIX MINUTE WATER LEVEL OBSERVATIONS (m)

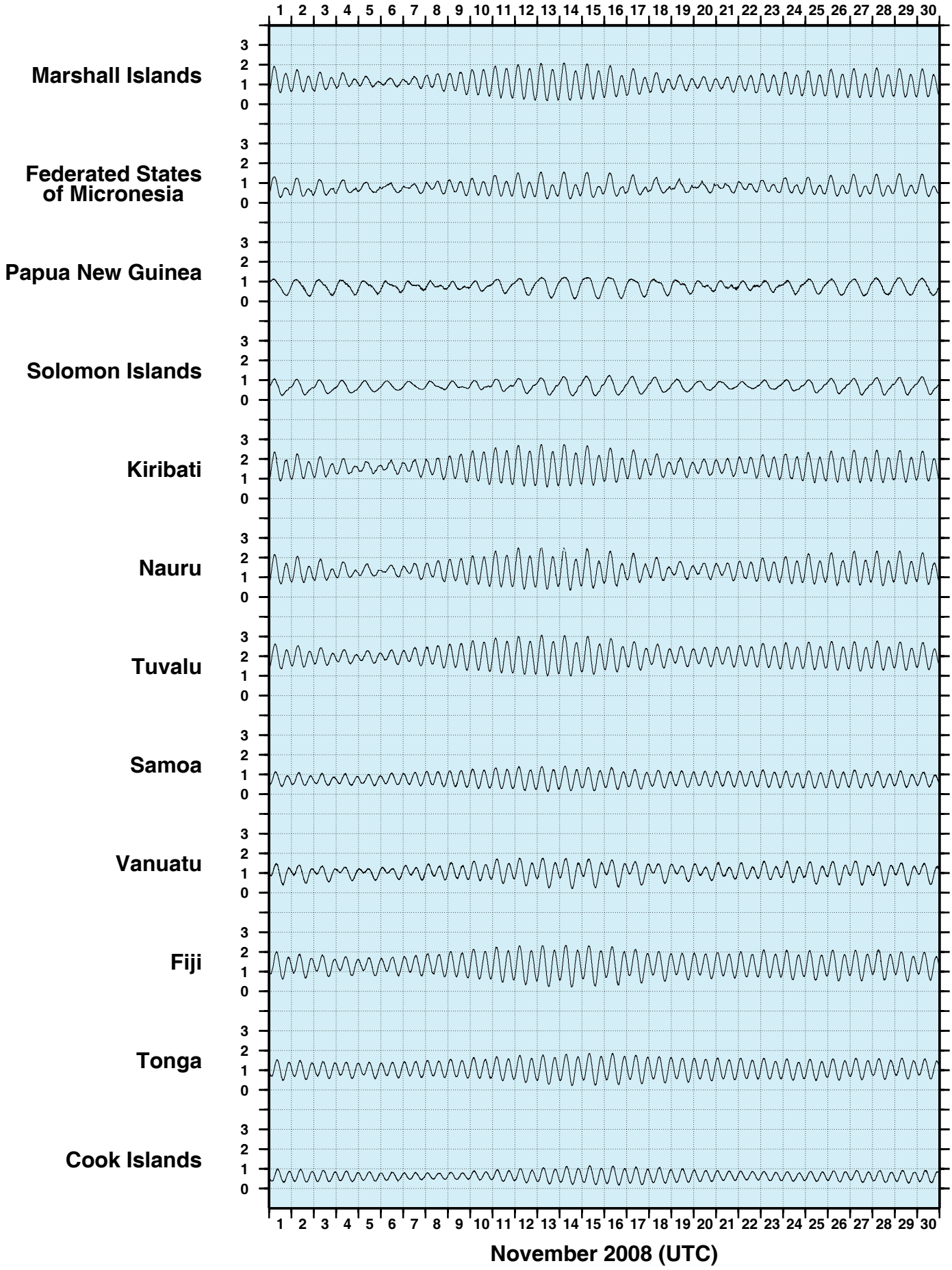


Figure 2

NOVEMBER 2008
SIX MINUTE RESIDUAL WATER LEVELS (m)

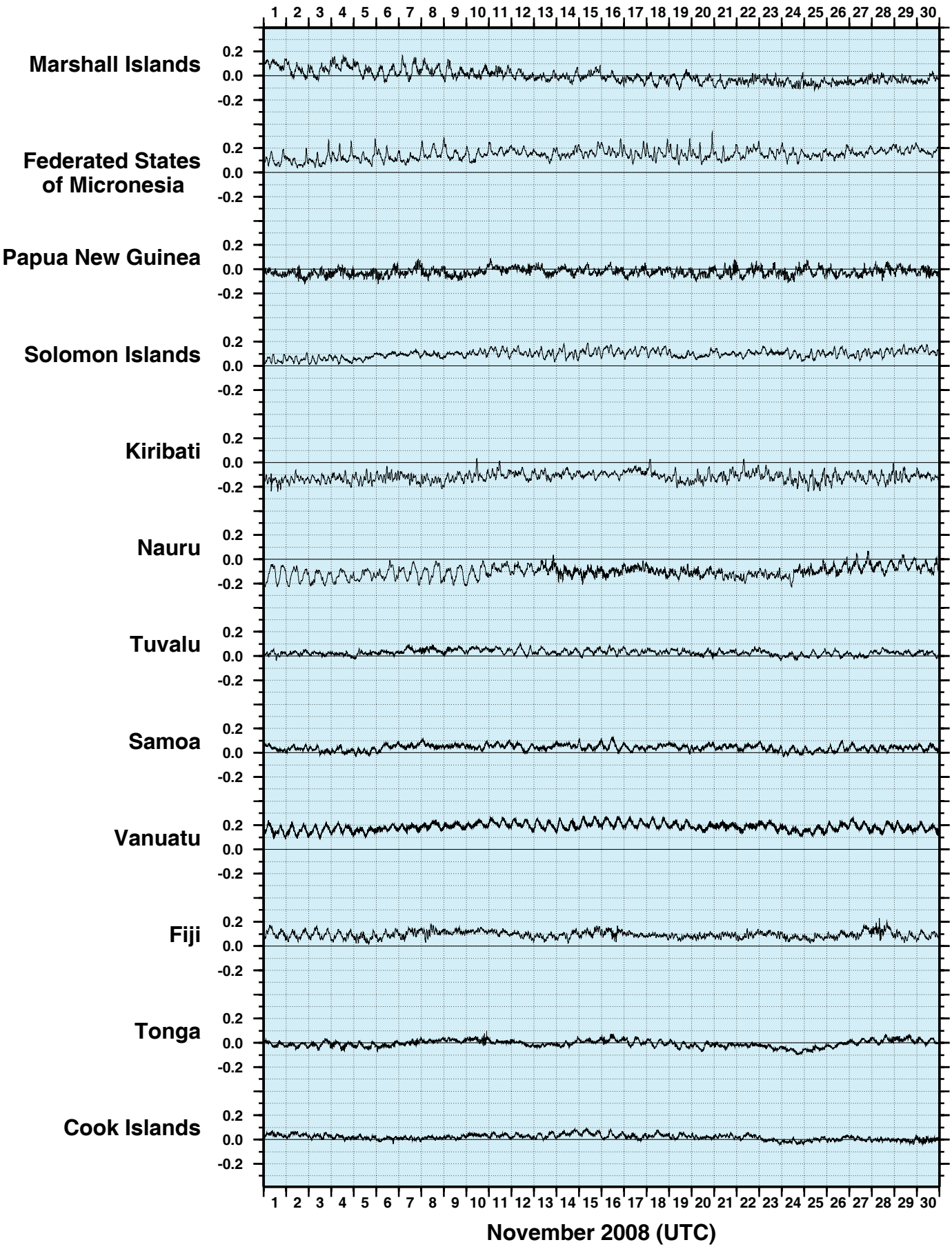


Figure 3

NOVEMBER 2008
SIX MINUTE RESIDUALS
ADJUSTED FOR ATMOSPHERIC PRESSURE (m)

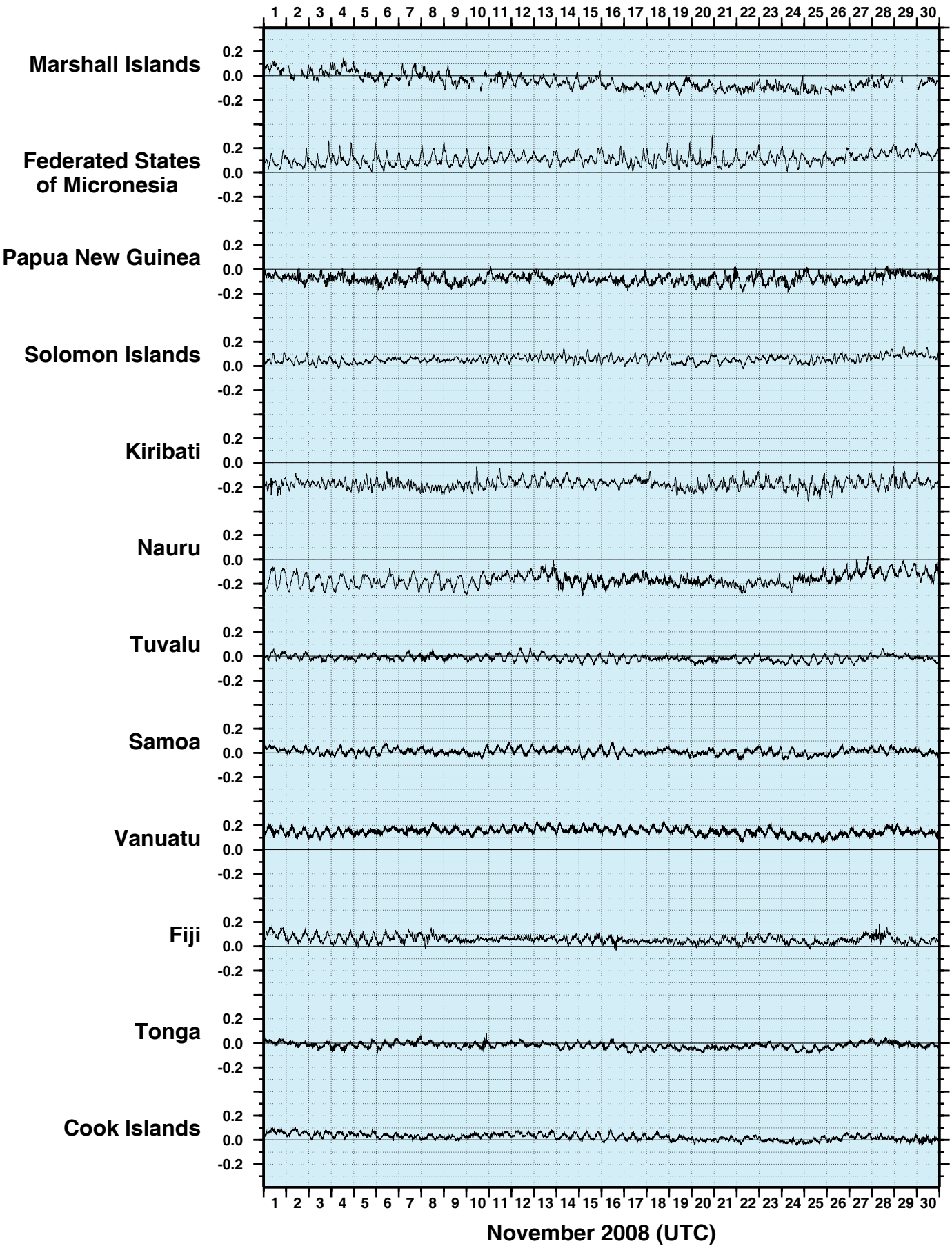


Figure 4

NOVEMBER 2008
HOURLY WIND SPEEDS (m/s)

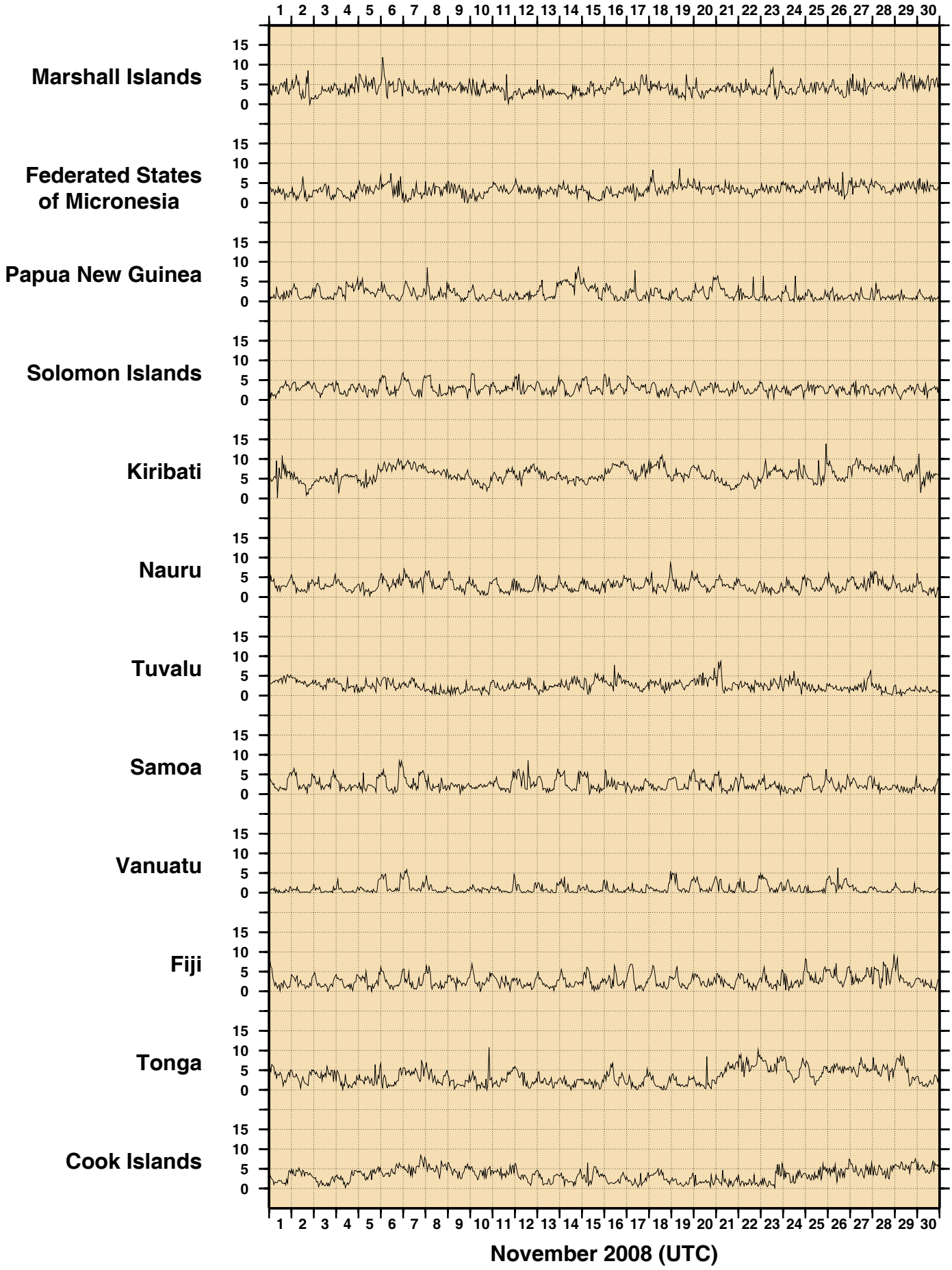


Figure 5

NOVEMBER 2008
HOURLY INCIDENT WINDS (m/s, deg True)

—— 10 m/s

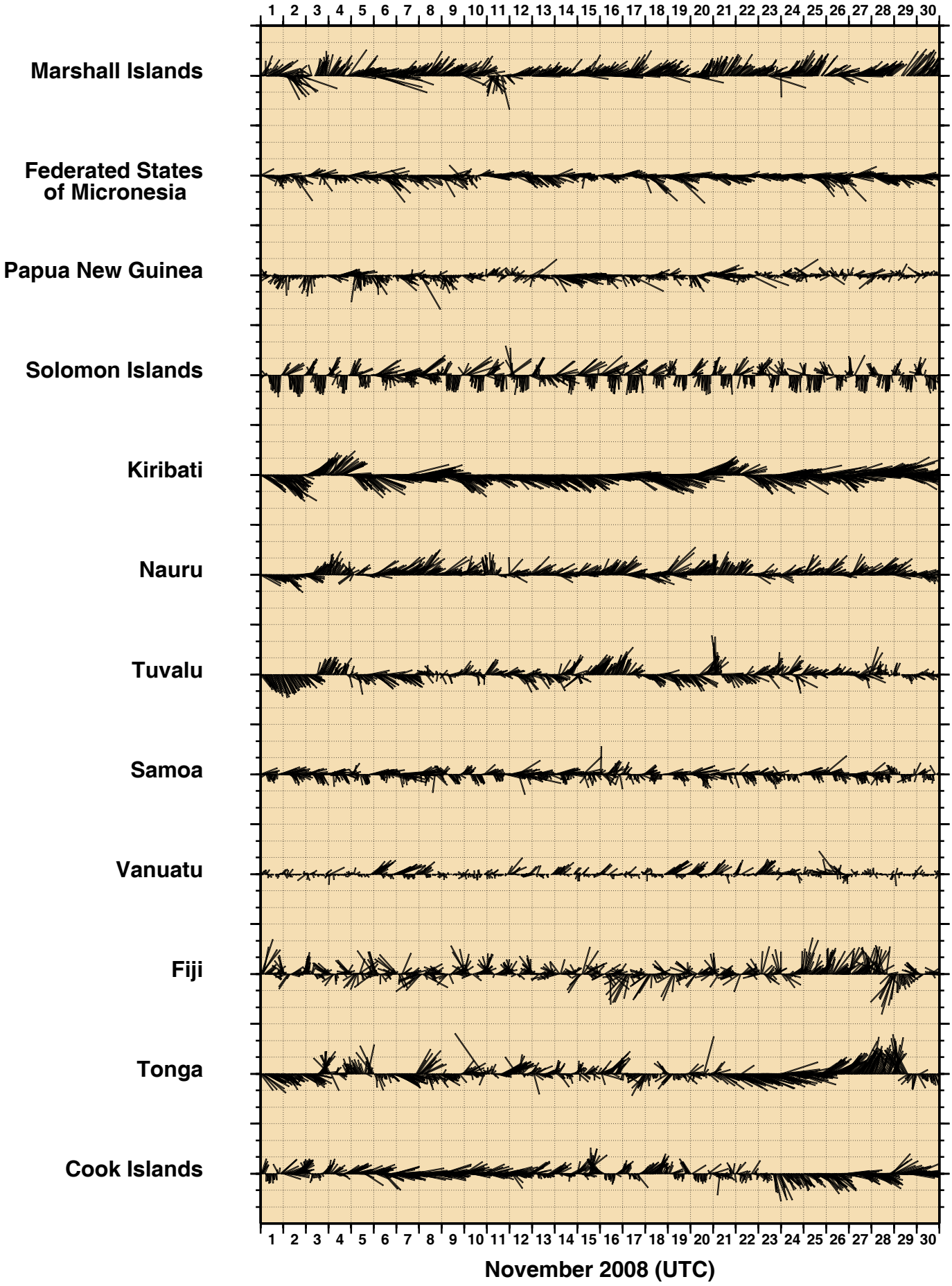


Figure 6

NOVEMBER 2008
HOURLY MAXIMUM WIND GUSTS (m/s)

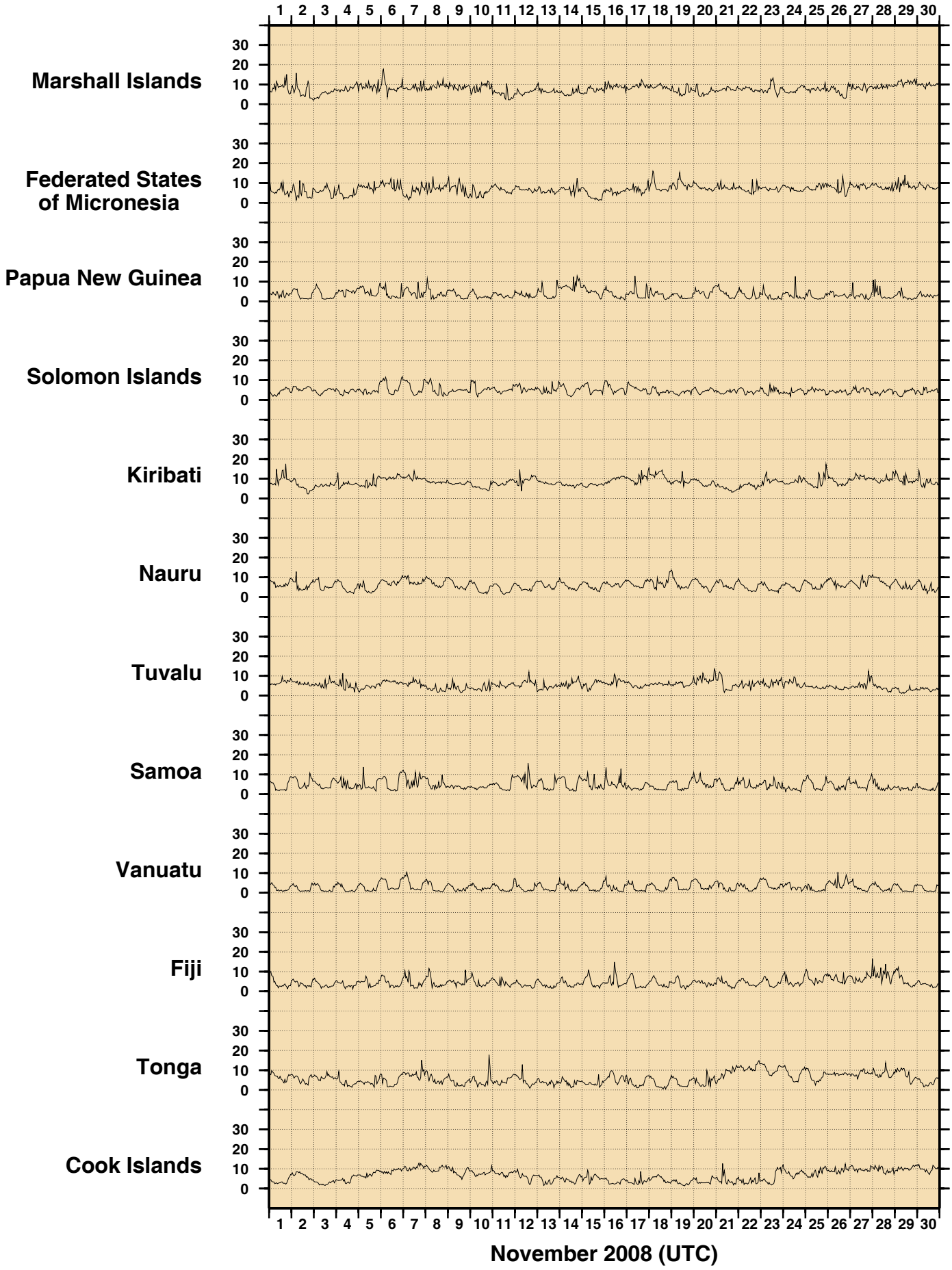


Figure 7

NOVEMBER 2008
HOURLY AIR TEMPERATURES (˚C)

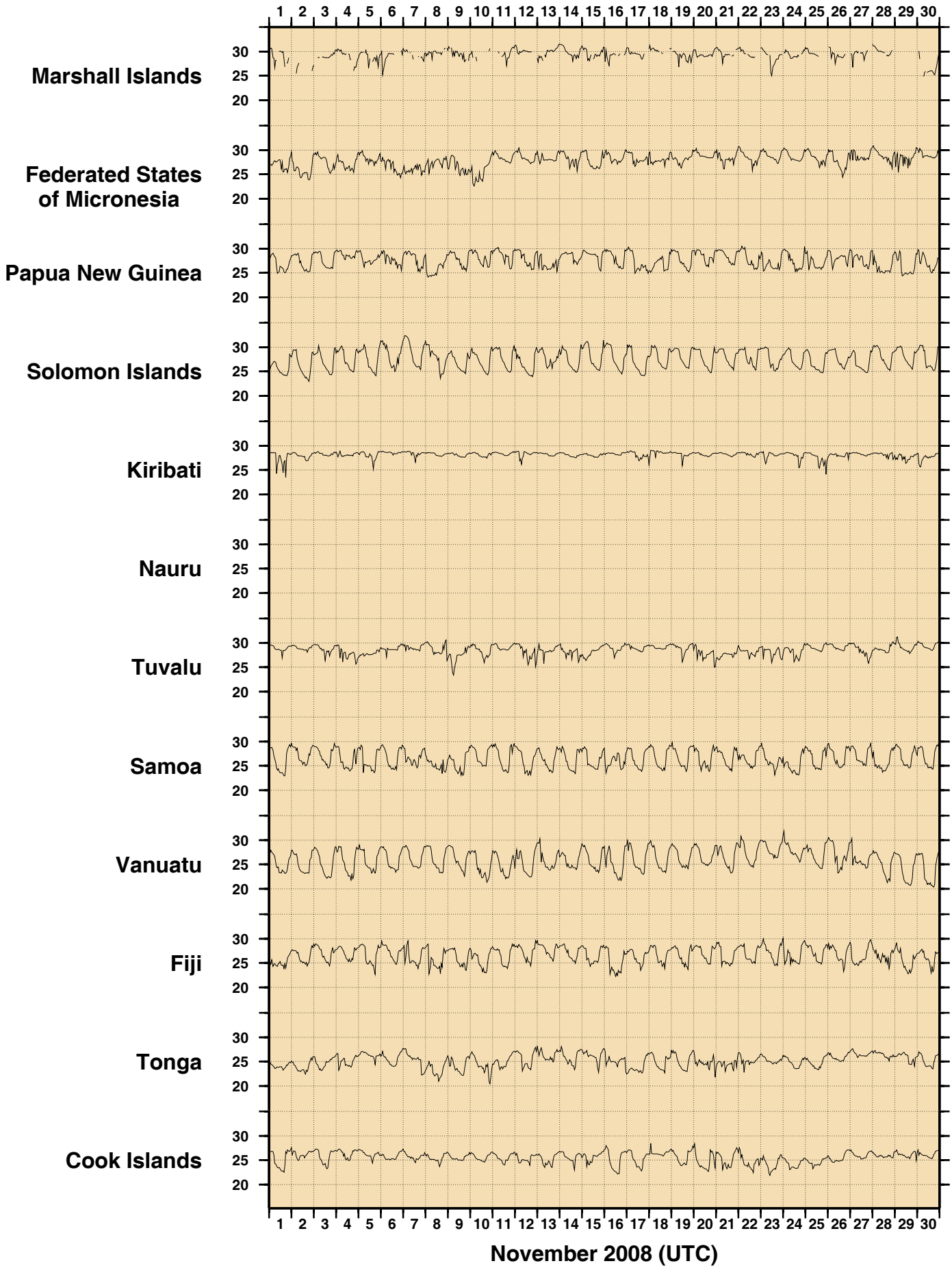


Figure 8

NOVEMBER 2008
HOURLY WATER TEMPERATURES (˚C)

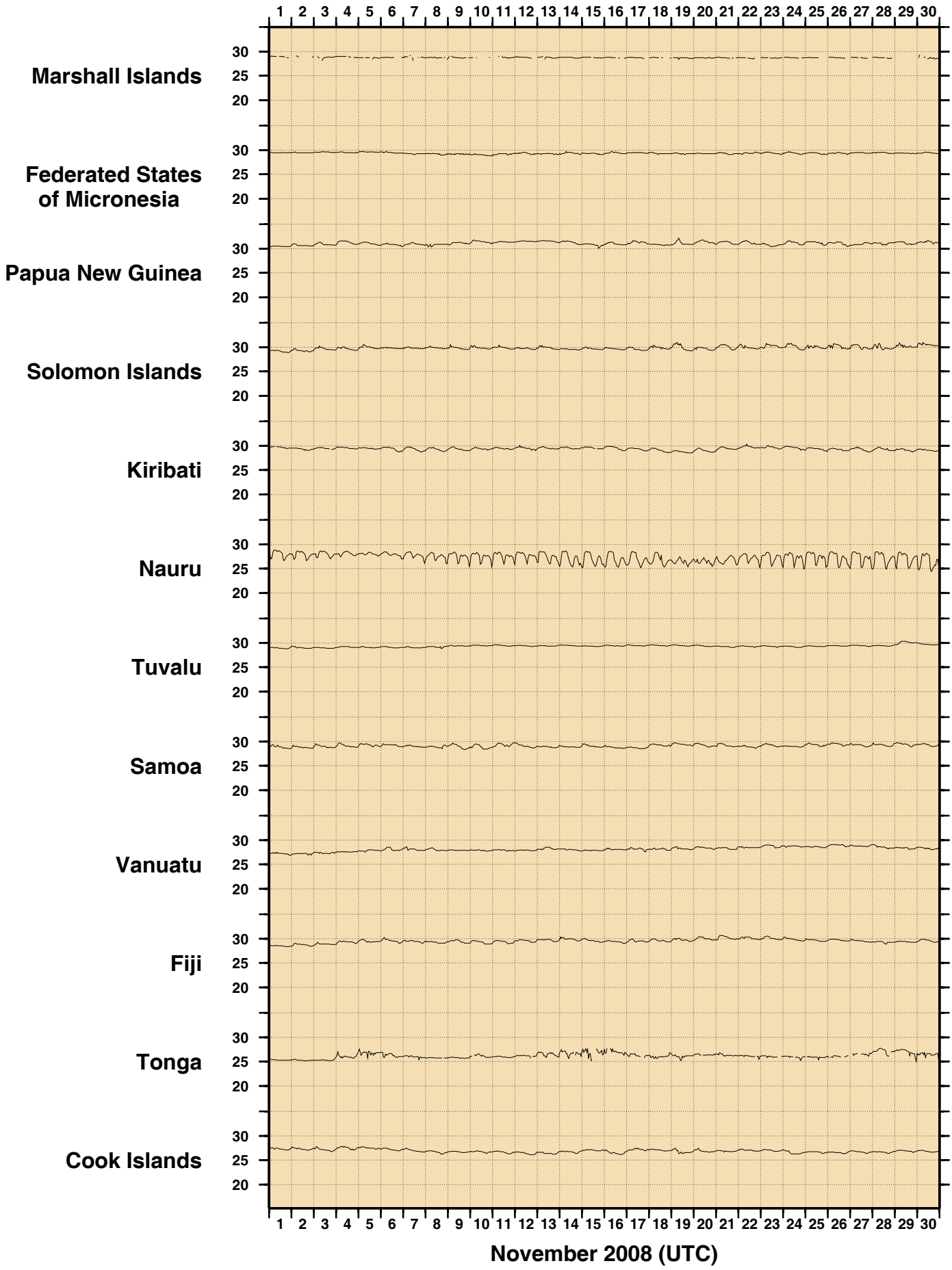


Figure 9

NOVEMBER 2008
HOURLY ATMOSPHERIC PRESSURE (hPa)

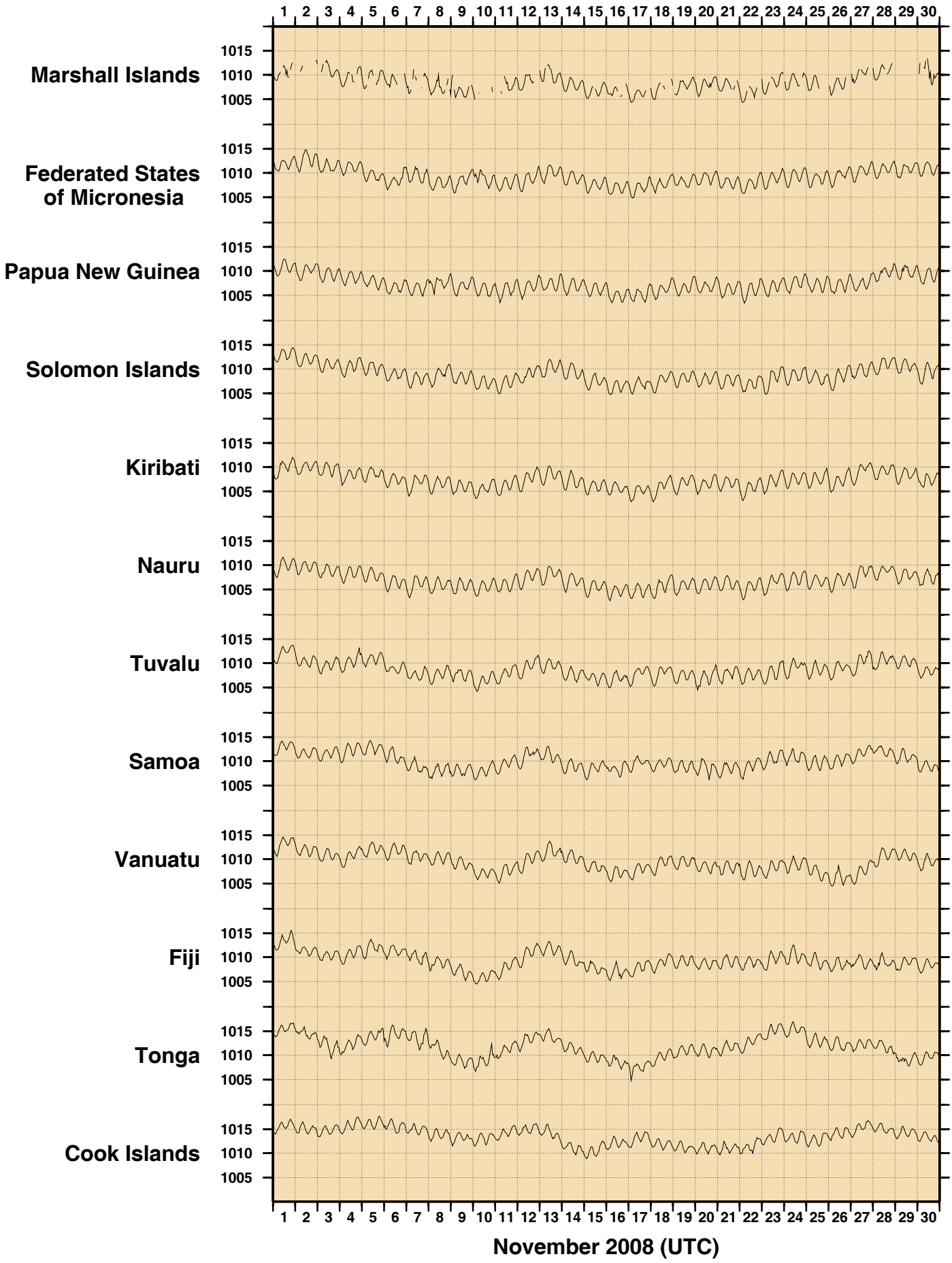
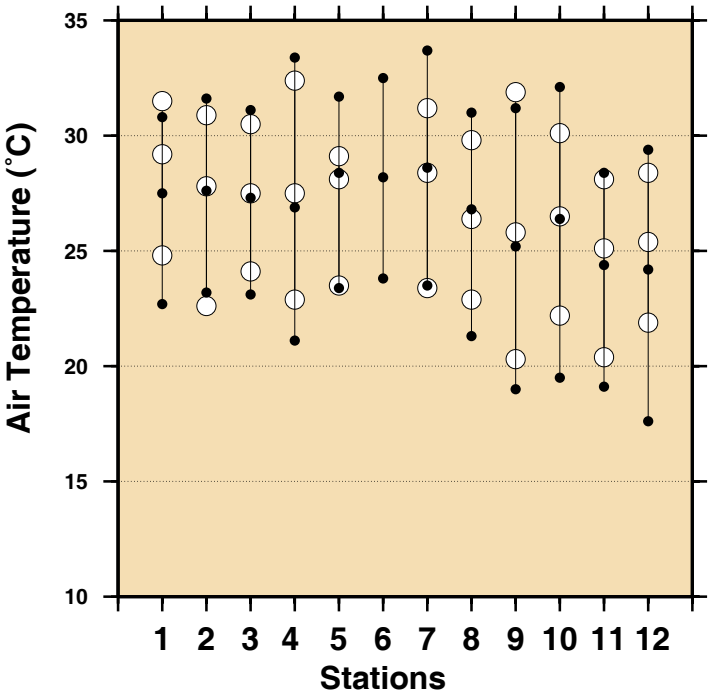
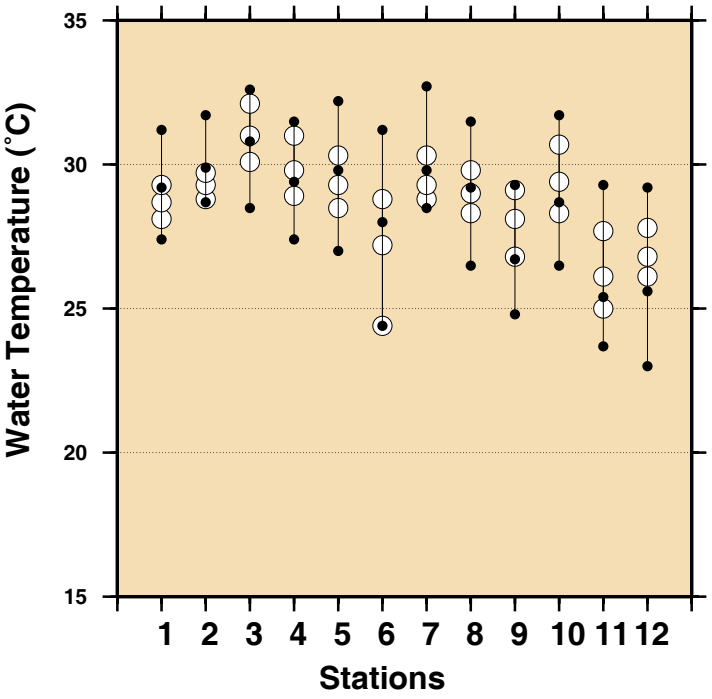
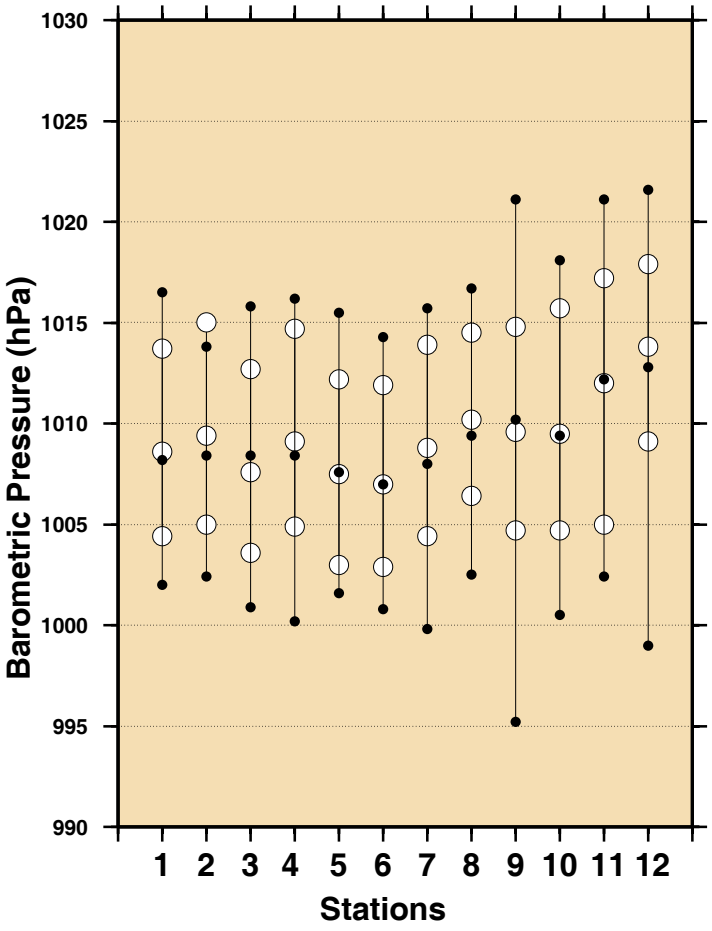


Figure 10

Comparison of November 2008 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 2008 Maximum
November 2008 Mean
November 2008 Minimum
Long Term November Maximum
Long Term November Mean
Long Term November Minimum

Figure 11

MONTHLY MEAN SEA LEVELS TO NOVEMBER 2008 (m)

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

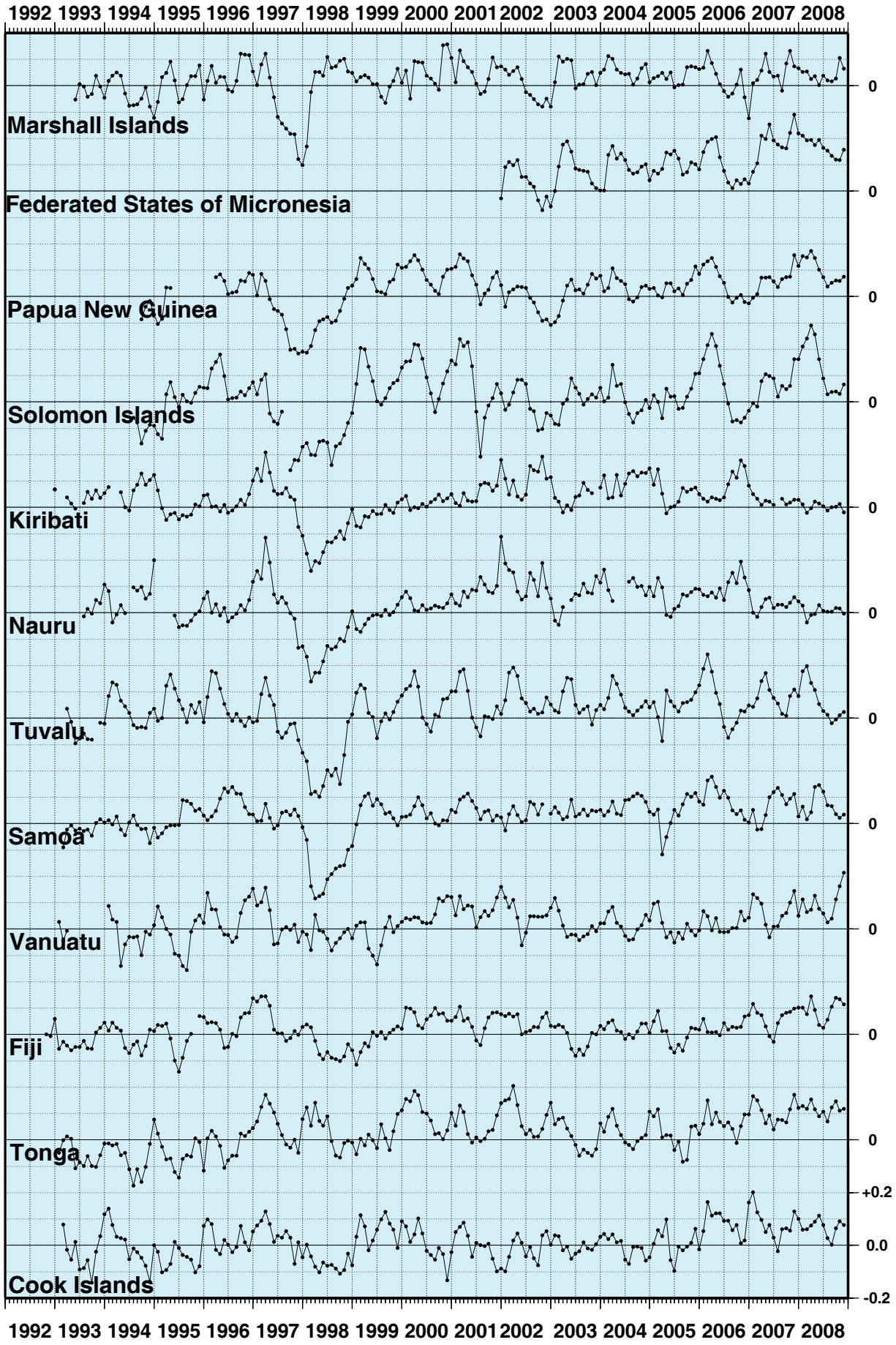


Figure 12

SEA LEVEL ANOMALIES THROUGH NOVEMBER 2008 (m)

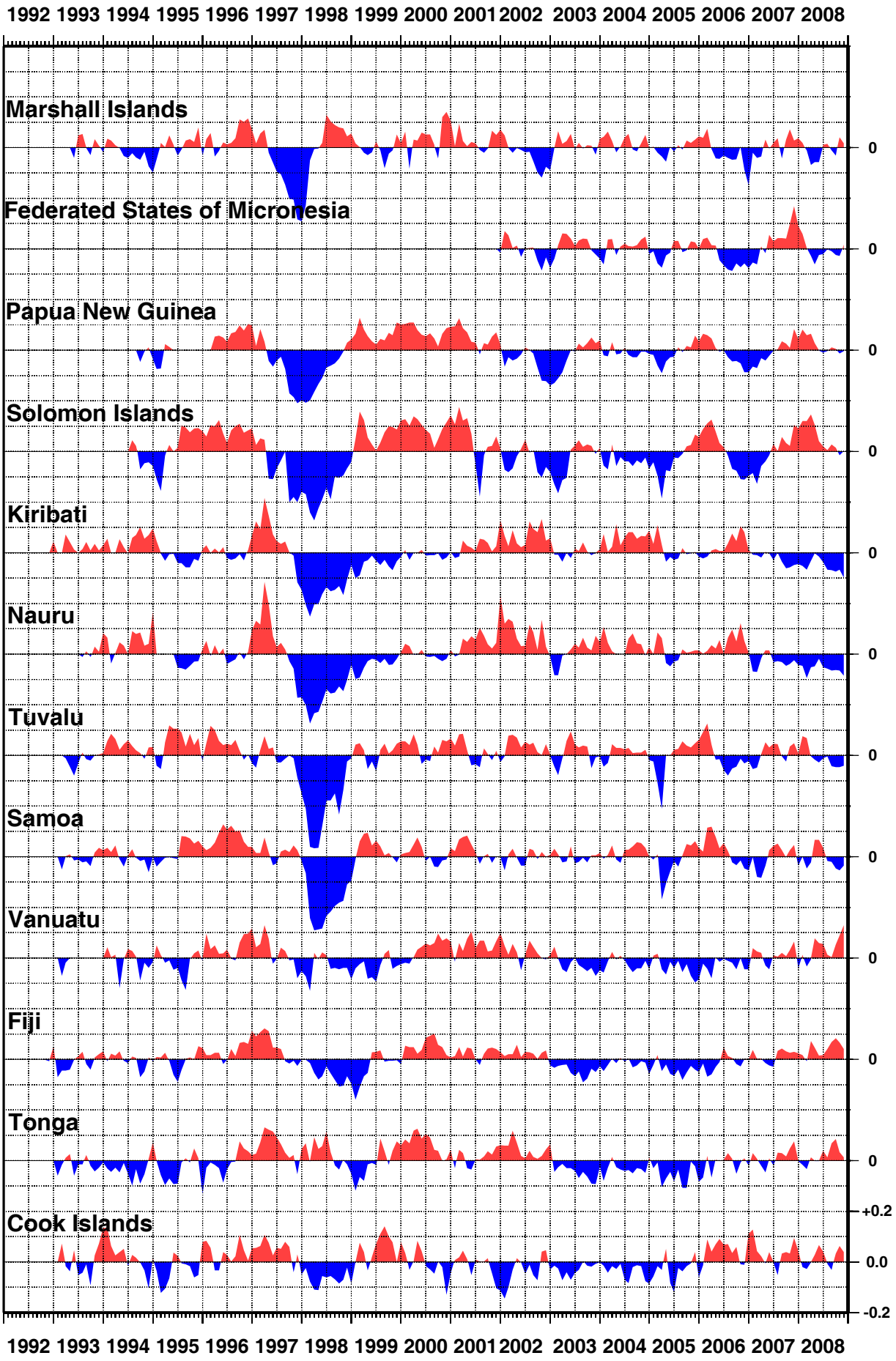


Figure 13

SEA LEVEL TRENDS THROUGH NOVEMBER 2008 (mm/year)

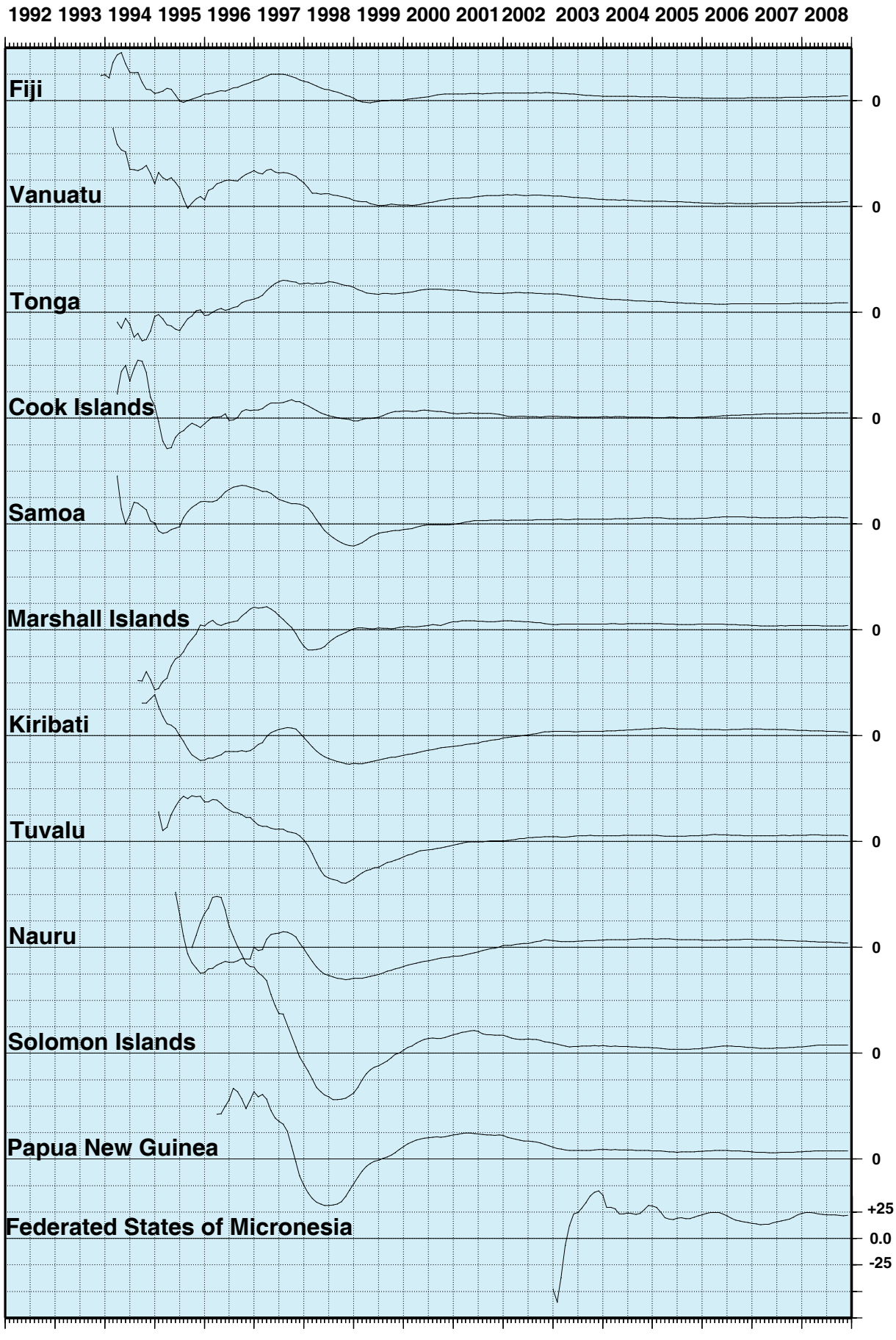


Figure 14

BAROMETRIC PRESSURE ANOMALIES THROUGH NOVEMBER 2008 (hPa)

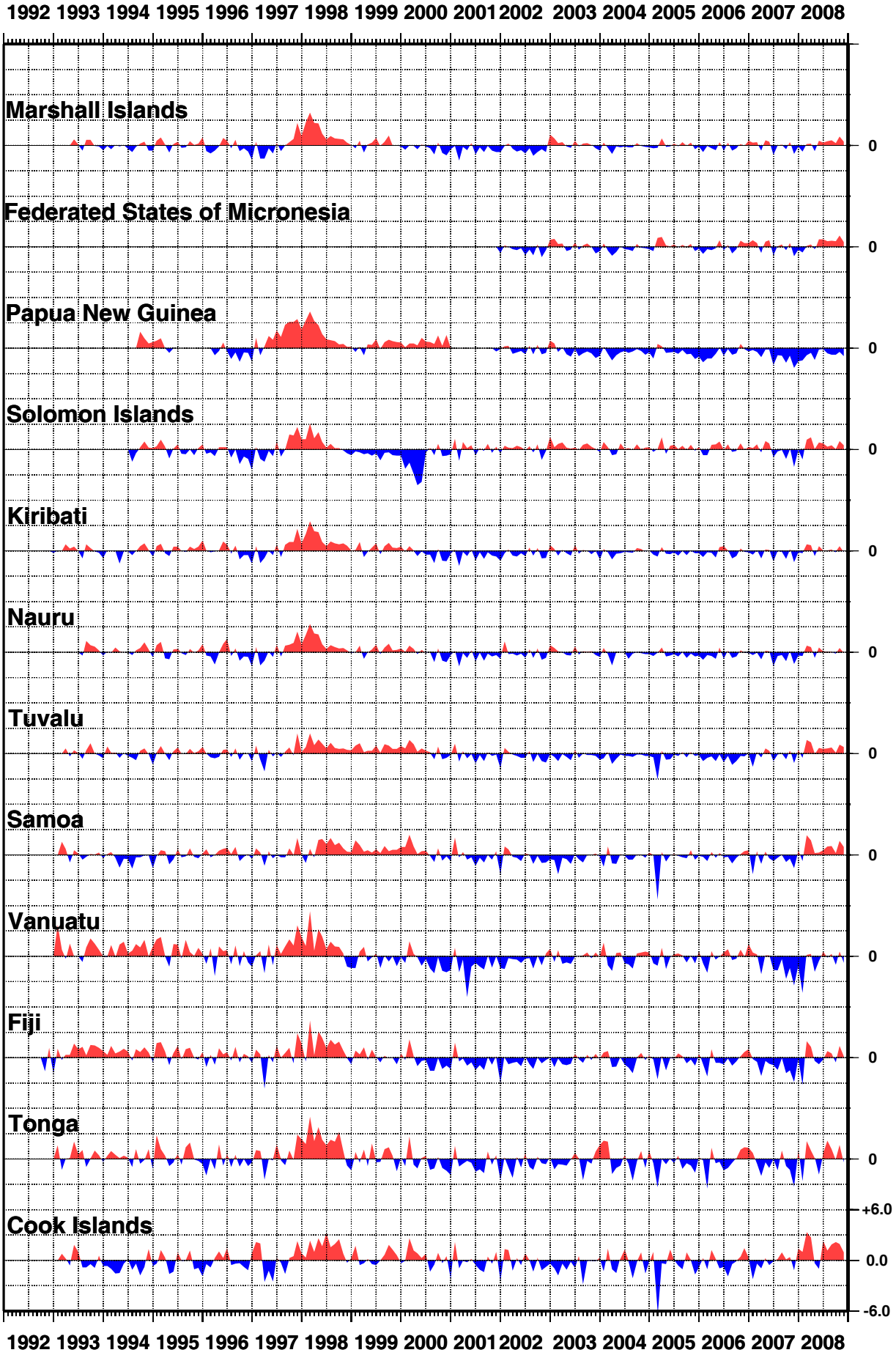


Figure 15

WATER TEMPERATURE ANOMALIES THROUGH NOVEMBER 2008 (˚C)

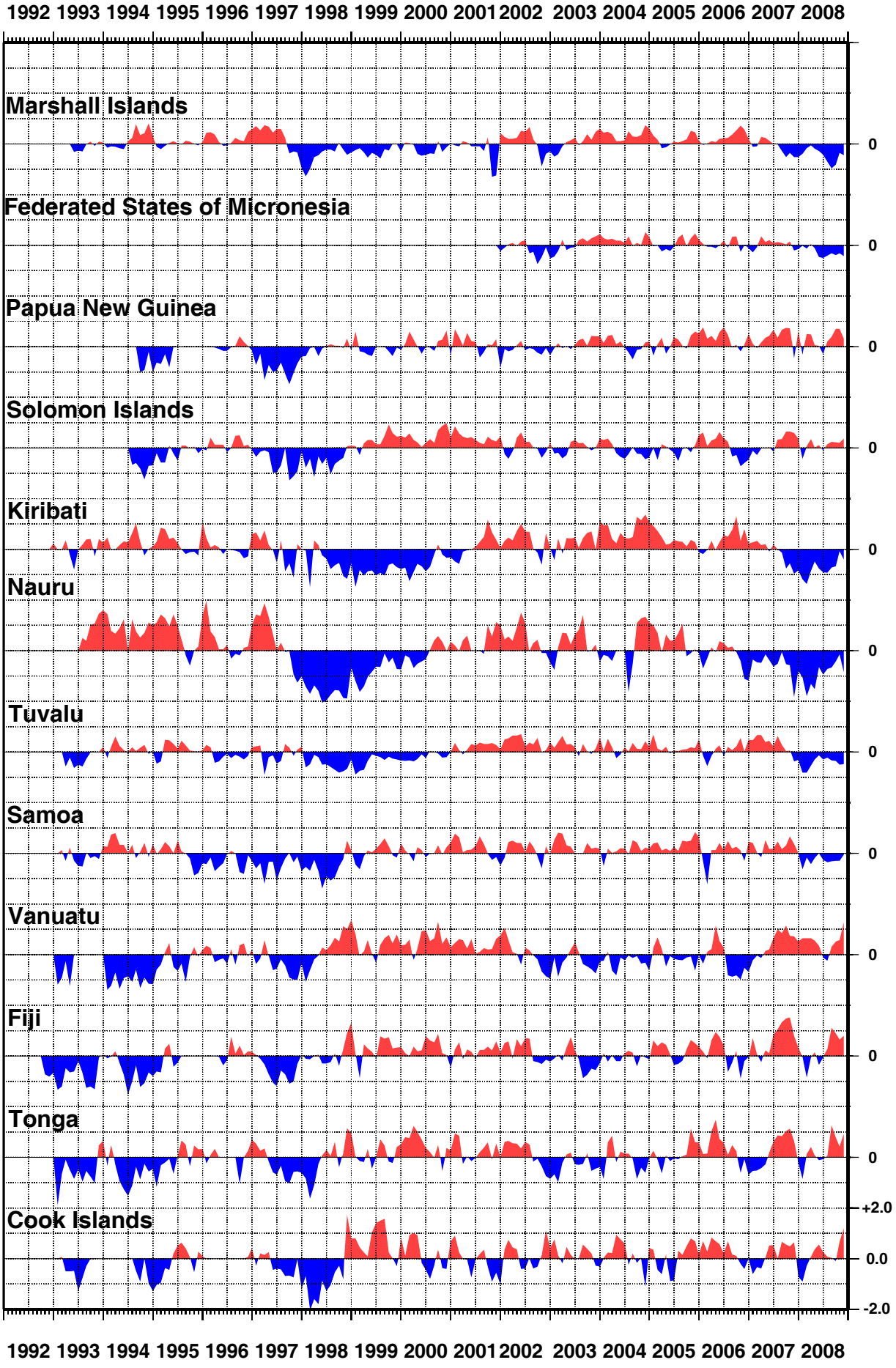


Figure 16

AIR TEMPERATURE ANOMALIES THROUGH NOVEMBER 2008 (˚C)

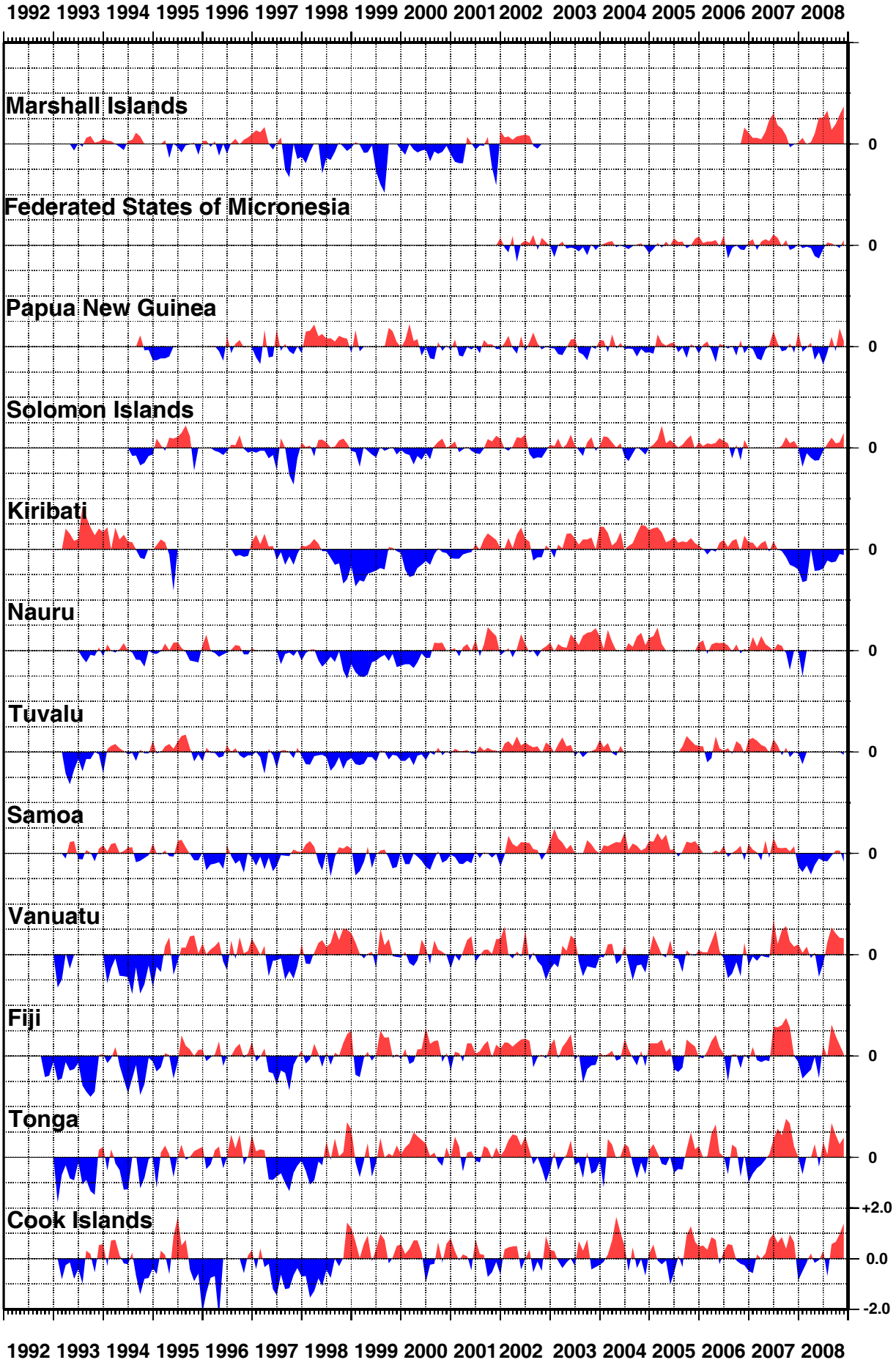


Figure 17

SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED
GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE
* Patchy record