THE SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT

MONTHLY DATA REPORT

NO. 187

JANUARY 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 January 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

January 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.

January 2011

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

- Tropical Cyclone Wilma produced a small storm surge of 20cm at Nuku'alofa, Tonga.

- Strong La Niña conditions continued to affect the Pacific basin, including cooler than normal ocean temperatures across the equatorial Pacific, stronger than normal Trade Winds in the western equatorial Pacific and below average cloudiness on the equator near the dateline.

- Sea levels were around 10cm higher than normal at Marshall Islands, PNG and Samoa and 5cm higher than normal at FSM, Solomon Islands and Tuvalu as a result of the La Niña. The mean sea levels at PNG and Samoa during January were their highest on record.

- La Niña conditions appeared to have peaked and began to ease in late January. International climate models predict that conditions will continue to ease and neutral conditions will gradually return sometime toward the middle of the year.

Short-Term Trends

It is important to stress that as the sea level record becomes longer, the short-term trend estimate becomes more stable and reliable. Observed trends in sea level include natural variability, for example, events such as El Niño and effects due to many other atmospheric, oceanographic and geological processes. Longer-term data sets for all stations are required in order to separate the effects of the different signals. ***Please exercise caution in interpreting the short-term trends in the table below*** – they will almost certainly change over the coming years as the data set increases in length. Figure 13 later in this report provides the "time history" of the short-term trend at all project locations.

Recent short-term sea level trends in the project area based upon SEAFRAME data through January, 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	+4.8	0.0
Tonga	21°8'12.5"S / 175°10'50.5"W	Jan 1993	+8.6	0.0
Fiji	17°36'17.7"S / 177°26'17.7"E	Oct 1992	+4.8	-0.1
Vanuatu	17°45'19.2"S / 168°18'27.7"E	Jan 1993	+5.4	-0.2
Samoa	13°49'36.4"S / 171°45'40.7"W	Feb 1993	+5.6	+0.2
Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+4.1	+0.1
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+2.9	0.0
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+3.7	0.0
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+6.5	+0.1
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+7.2	+0.2
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+17.0	+0.5
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.5	+0.2

INTRODUCTION

Welcome to the January 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.

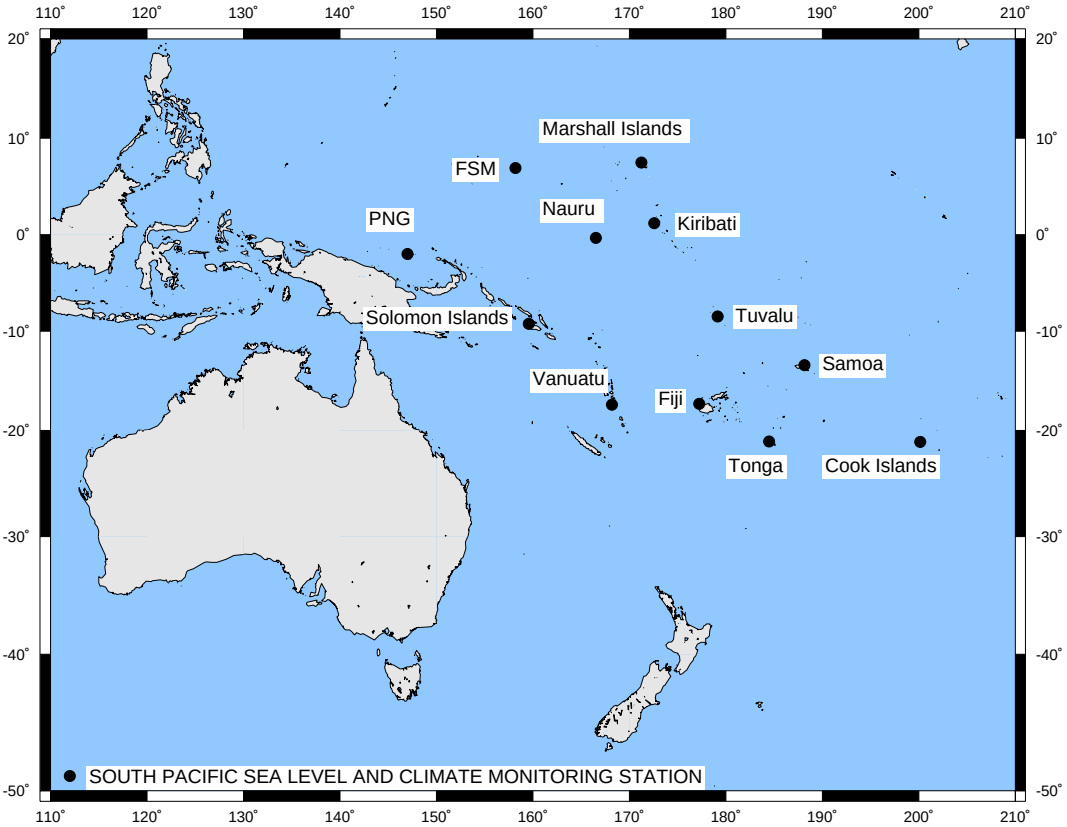

Figure A: *South Pacific Sea Level and Climate Monitoring Stations*

JANUARY CLIMATOLOGY

The equatorial Pacific continued to experience one of the strongest La Niña events on record. Ocean temperatures were considerably cooler than normal across the central and eastern Pacific although they continued to warm at depth in the far western equatorial Pacific. Atmospheric conditions include stronger than normal Trade Winds, suppressed cloudiness over the central equatorial Pacific and strongly positive values of the Southern Oscillation Index (SOI). La Nina conditions have eased from their peak a month ago and international climate models suggest a return to neutral conditions during the southern hemisphere autumn is the most likely outcome.

The Southern Oscillation Index (SOI) has been positive since April 2010 and remained strongly positive during January (**Figure B**). The January 2011 value of +20 is the highest January SOI value since the La Niña of 1974. 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 remained at least 1ºC cooler than normal across much of the equatorial Pacific during January (**Figure C**). Warmer than normal sea surface temperatures were observed in the far western equatorial Pacific and in a band extending across the south Pacific.

Cooler than normal subsurface ocean temperatures continued to be observed across the central and eastern equatorial Pacific, particularly east of the dateline where anomalies remain around -4ºC. The central and eastern equatorial Pacific has been cooler than normal since April 2010. Warm subsurface temperature anomalies continued to develop in the western equatorial Pacific and began to propagate eastward (**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 Pacific during January 2011 (**Figure E**). Cloudiness near the dateline remained well below average during January and has generally been suppressed since late April.

The consensus among international computer models surveyed by the Bureau of Meteorology suggest that La Niña conditions will gradually weaken and approach neutral conditions by the southern hemisphere winter.

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/.

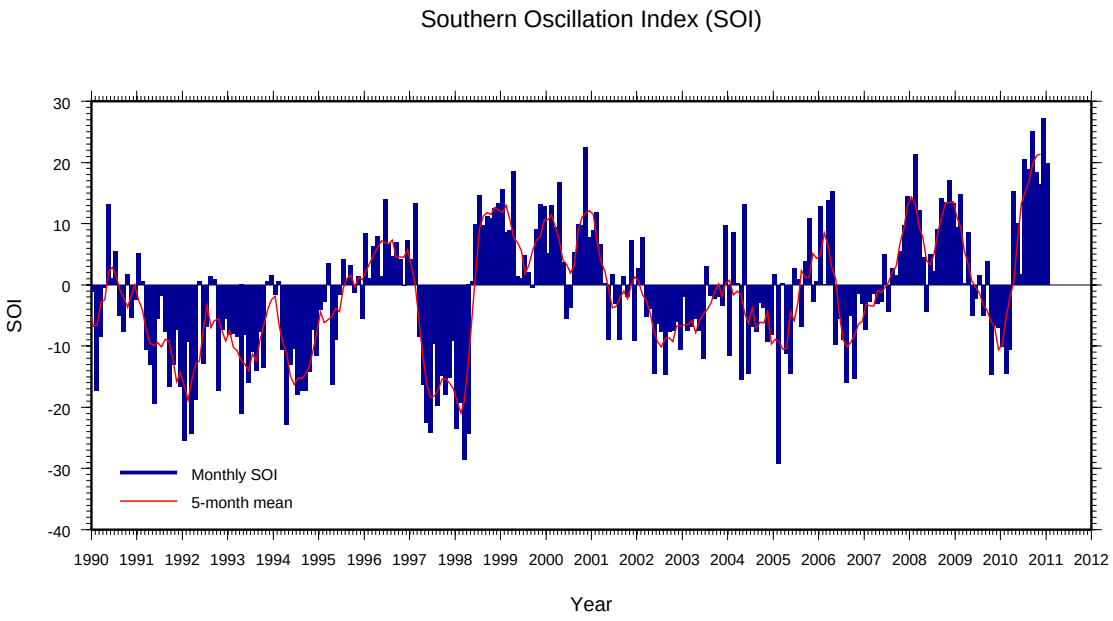

Figure B: *The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the long-term standard deviation of that difference for the relevant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

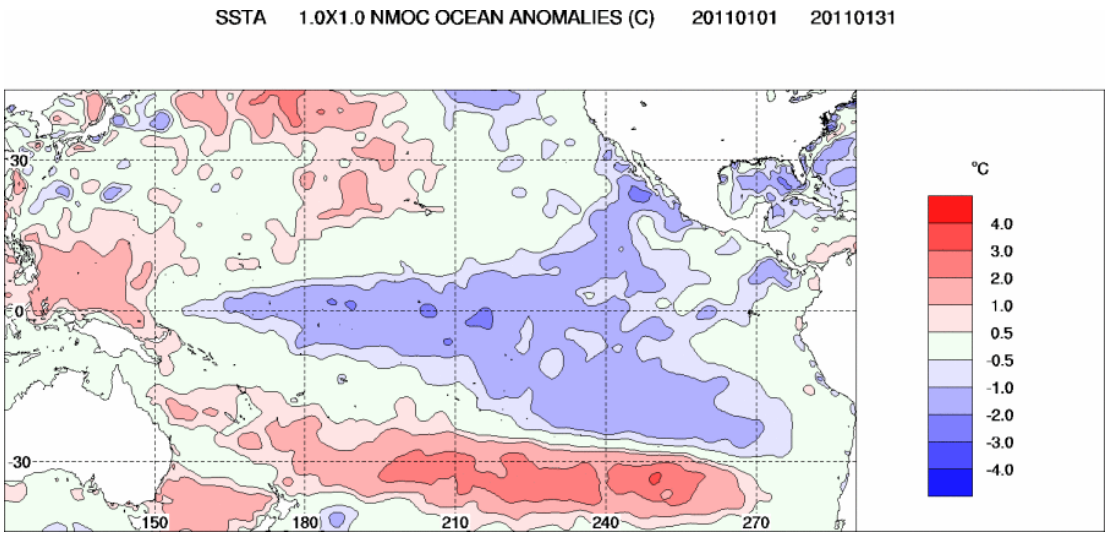

Figure C: *Sea surface temperature anomaly (°C) for January 2011.*

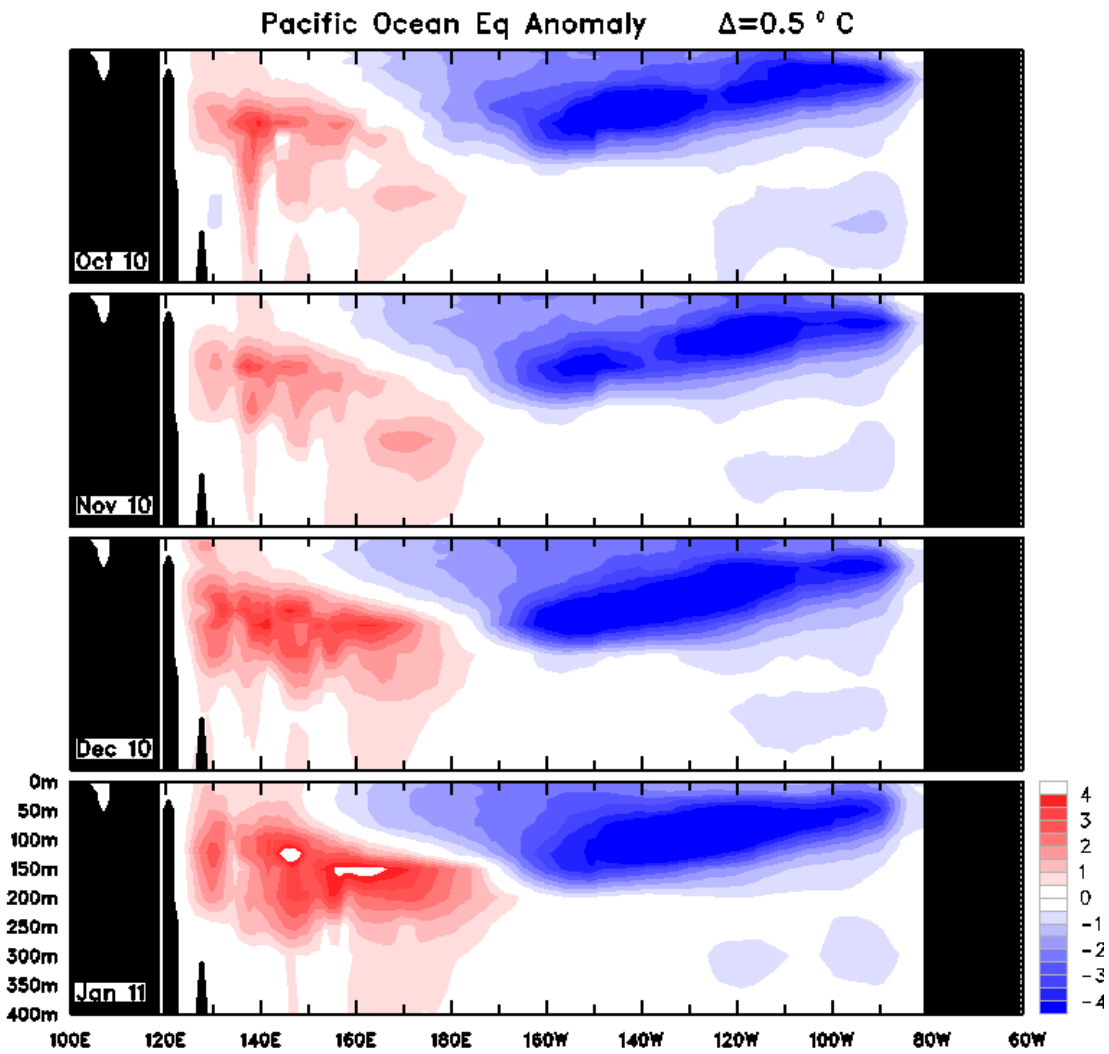

Figure D: *Equatorial depth-longitude section of ocean temperature anomalies for October 2010 through to January 2011. Contour interval is 0.5°C.*

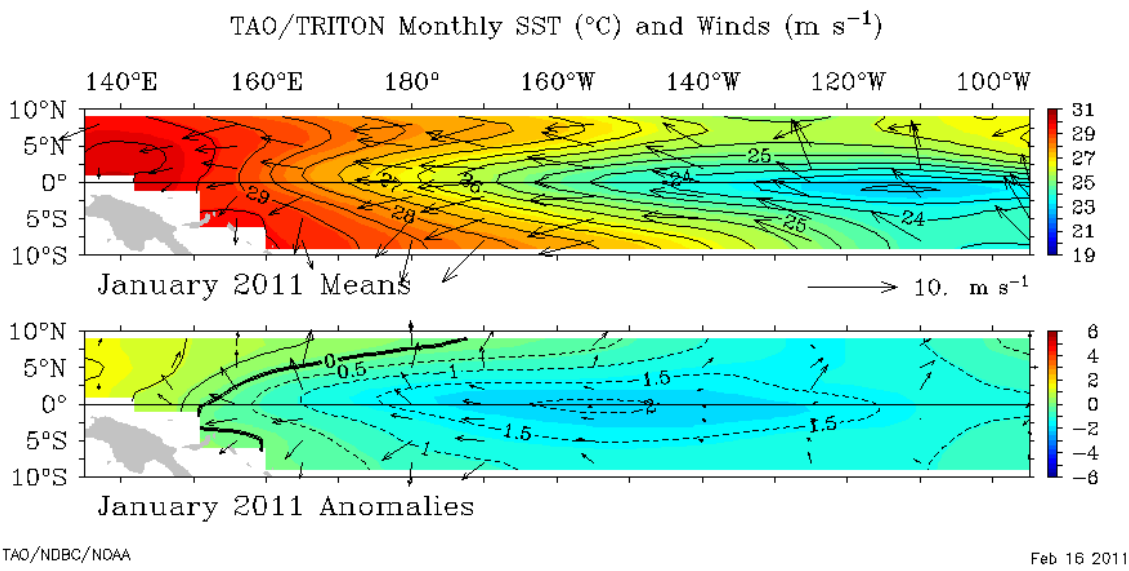

Figure E: *Monthly mean wind vectors (top) and anomalies (bottom) for January 2011. The colour-shaded contours represent the monthly mean sea surface temperatures (top) and anomalies (bottom).*

JANUARY 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 4th of January and a full moon on the 19th of January 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. This occurred at Tonga on the 24th – 25th January as a result of Tropical Cyclone Wilma. A small storm surge of 0.2m was observed by the SEAFRAME at Nuku'alofa.

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 low barometric pressure associated with Tropical Cyclone Wilma accounted for at least half of the storm surge observed at Nuku'alofa, Tonga on the 24th – 25th January.

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.

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 groundwater discharge 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. Tropical Cyclone Vania began to form in the vicinity of Vanuatu, culminating in low barometric pressure on the 12th of January. Tropical Cyclone Wilma produced low barometric pressure at Tonga on the 24th – 25th January.

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 January air temperature of 32.4 ºC was recorded at Samoa and record minimum January air temperatures were recorded at Marshall Islands (20.0 ºC), Nauru (22.5 ºC) and Samoa (20.7 ºC). A record minimum January water temperature was observed at Tuvalu (26.9 ºC). A record maximum January barometric pressure was recorded at Cook Islands (1019.5 hPa) and record minimum January barometric pressures were recorded at Marshall Islands (1002.0 hPa), FSM (1002.3 hPa) and Nauru (1000.7 hPa).

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 levels observed at PNG and Samoa during January were their highest on record.

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.

Sea levels during January 2011 were around 10cm higher than normal at Marshall Islands, PNG and Samoa and around 5cm higher than normal at FSM, Solomon Islands and Tuvalu. Higher than normal sea levels at these stations are linked to La Niña climate conditions, particularly the warmer than normal ocean temperatures in the far western Pacific and stronger than normal Trade Wind convergence along the South Pacific Convergence Zone. Sea levels were around 12cm below normal at Vanuatu, 5cm below normal at Fiji and close to normal at Tonga and Cook Islands. At the equatorial sites of Kiribati and Nauru sea levels were close to normal for the first time in around 12 months, having been consistently lower than normal since February 2010.

Sea Level Trends

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

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Tuvalu	8°30'8.9"S / 179°11'42.6"E	Mar 1993	+4.1	+0.1
Kiribati	1°21'54.2"N / 172°55'58.8"E	Dec 1992	+2.9	0.0
Nauru	0°31'45.9"S / 166°54'36.2"E	Jul 1993	+3.7	0.0
Solomon Is.	9°25'44.1"S / 159°57'19.3"E	Jul 1994	+6.5	+0.1
PNG	2°2'31.5"S / 147°22'25.6"E	Sep 1994	+7.2	+0.2
FSM	6°58'49.9"N / 158°12'0.8"E	Dec 2001	+17.0	+0.5
Marshall Is.	7°6'21.7"N / 171°22'22.1"E	May 1993	+4.5	+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. Barometric pressures during January 2011 were generally near

normal, although notable anomalies were observed at Cook Islands (+3 hPa) and Vanuatu (-3 hPa).

The **water temperature anomalies (Figure 15)** show water temperatures were as much as 1 ºC cooler than normal at Kiribati and Nauru during January 2011 in agreement with the presence of cooler-than-normal sea surface temperatures across the equator (Figure C). Water temperatures were also 0.5-1 ºC cooler than normal at Tuvalu, Samoa and Fiji. Water temperatures at PNG were 0.5 ºC warmer than normal, while the remaining stations in the network observed near normal water temperastures for this time of the year.

The **air temperature anomalies (Figure 16)** show Nauru experienced conditions that were 2 ºC cooler than normal during January and Kiribati 1 ºC cooler than normal. Air temperatures were also 0.5-1 ºC cooler than normal at Tuvalu, Samoa and Fiji. At the remaining sites air temperatures were within 0.5 ºC of what is typical for this time of the year. 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.

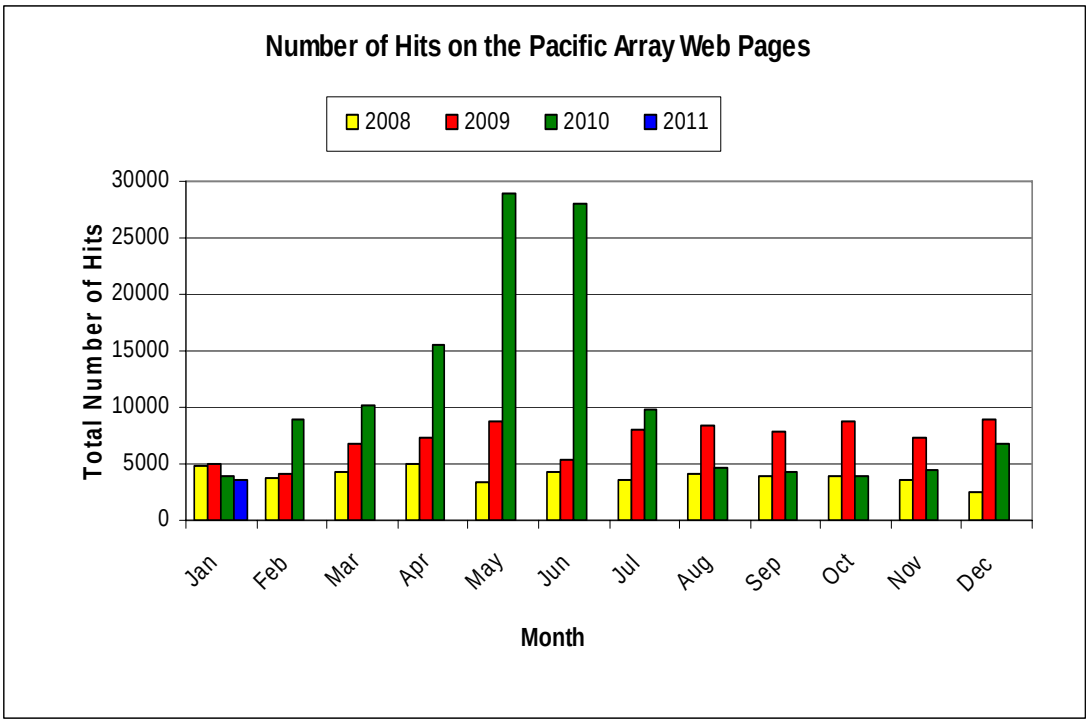
Instrument Performance

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 January 2011 was very good overall. Small amounts of data were unable to be recovered from Tuvalu due to satellite and telephone data communications problems. Intermittent problems (spikes) continued to be encountered with the air temperature sensor at Nauru and the water temperature sensor at Tonga, and erroneous data were removed from the archived record. Likewise some erroneous wind monitor readings from Vanuatu and PNG were removed from the record. Barometric pressure, air and water temperature data weren't being logged at PNG at the beginning of the month due to a problem that developed with the firmware on the 17th of December. Diagnostic tests were undertaken remotely and subsequent actions allowed normal operation to resume on 24th January.

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.


Number of Hits on the Pacific Array Web Pages
2008
2009
2010
2011
Total Number of Hits
30000
25000
20000
15000
10000
5000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

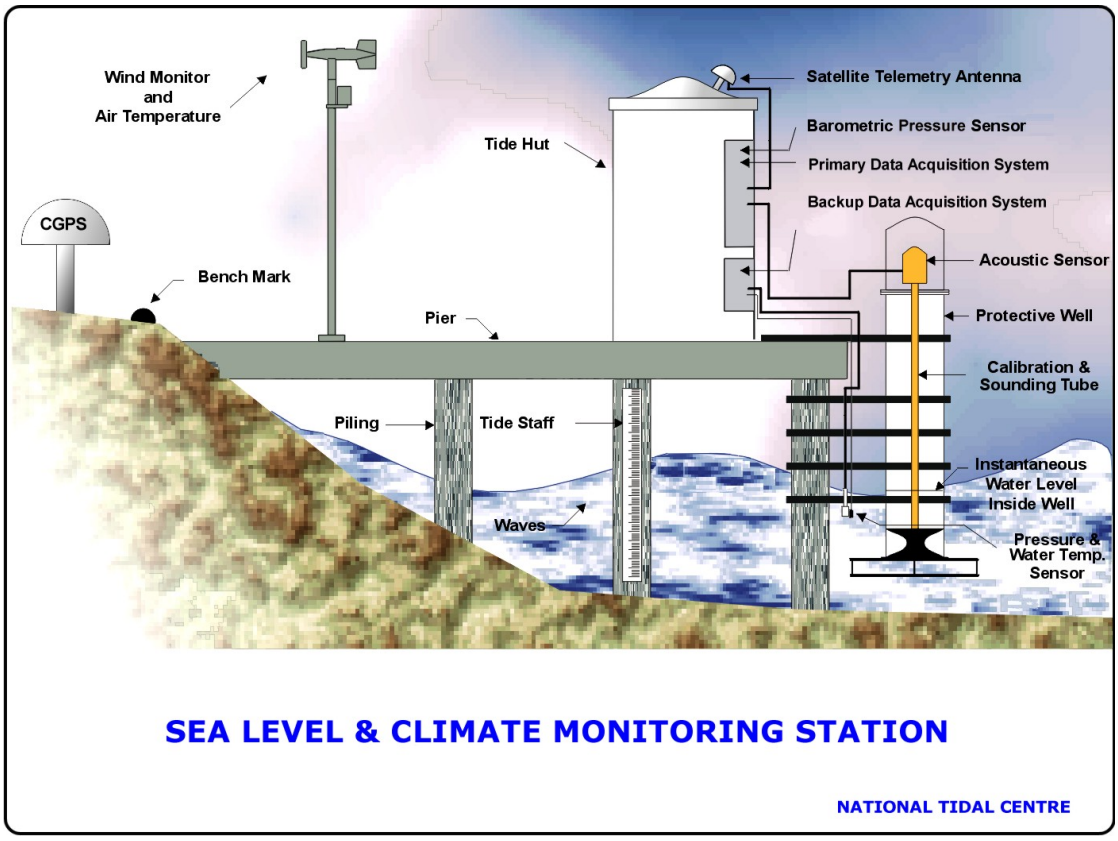
SEAFRAME STATIONS

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.

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Figure 1

JANUARY 2011
SIX MINUTE WATER LEVEL OBSERVATIONS (m)

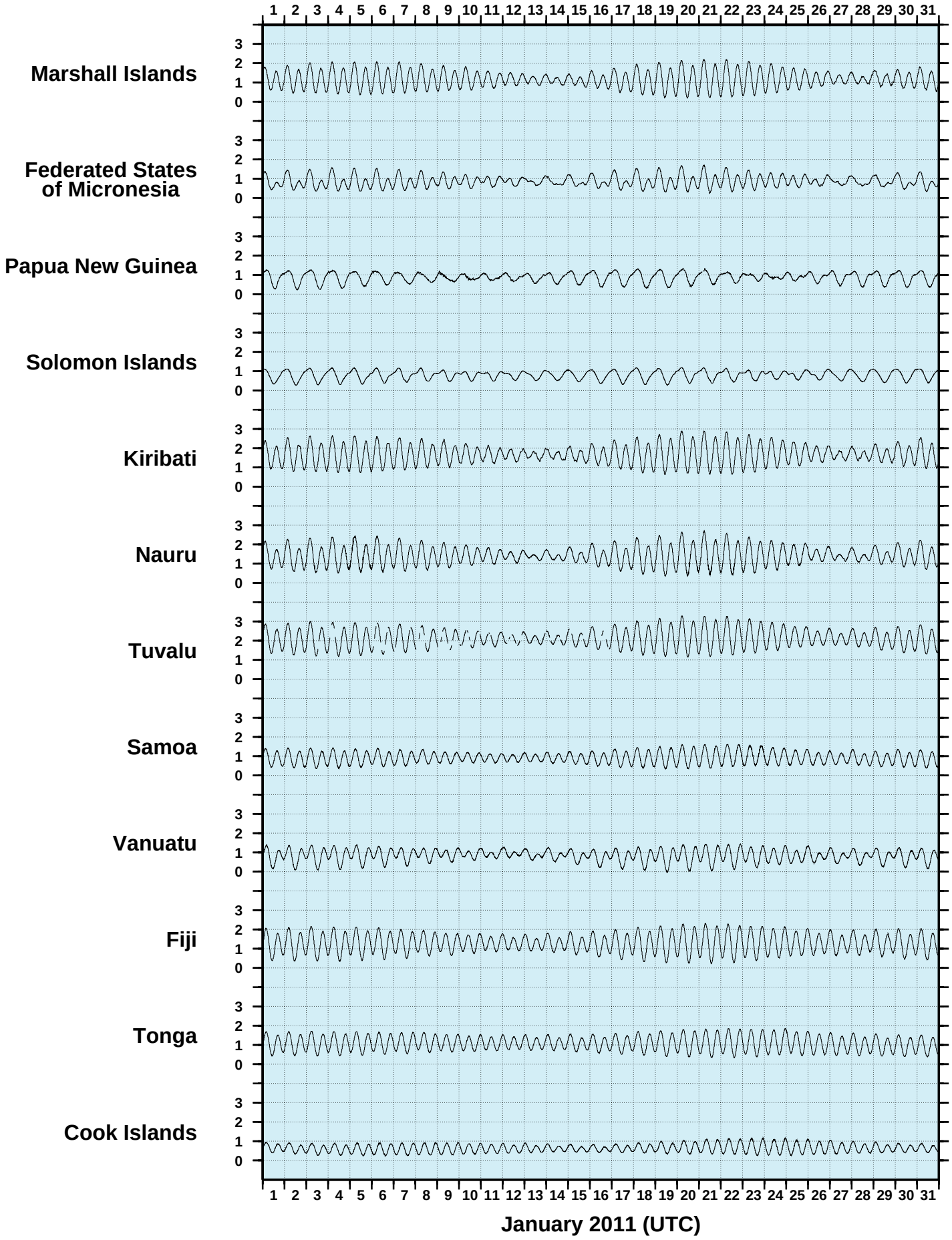


Figure 2

JANUARY 2011
SIX MINUTE RESIDUAL WATER LEVELS (m)

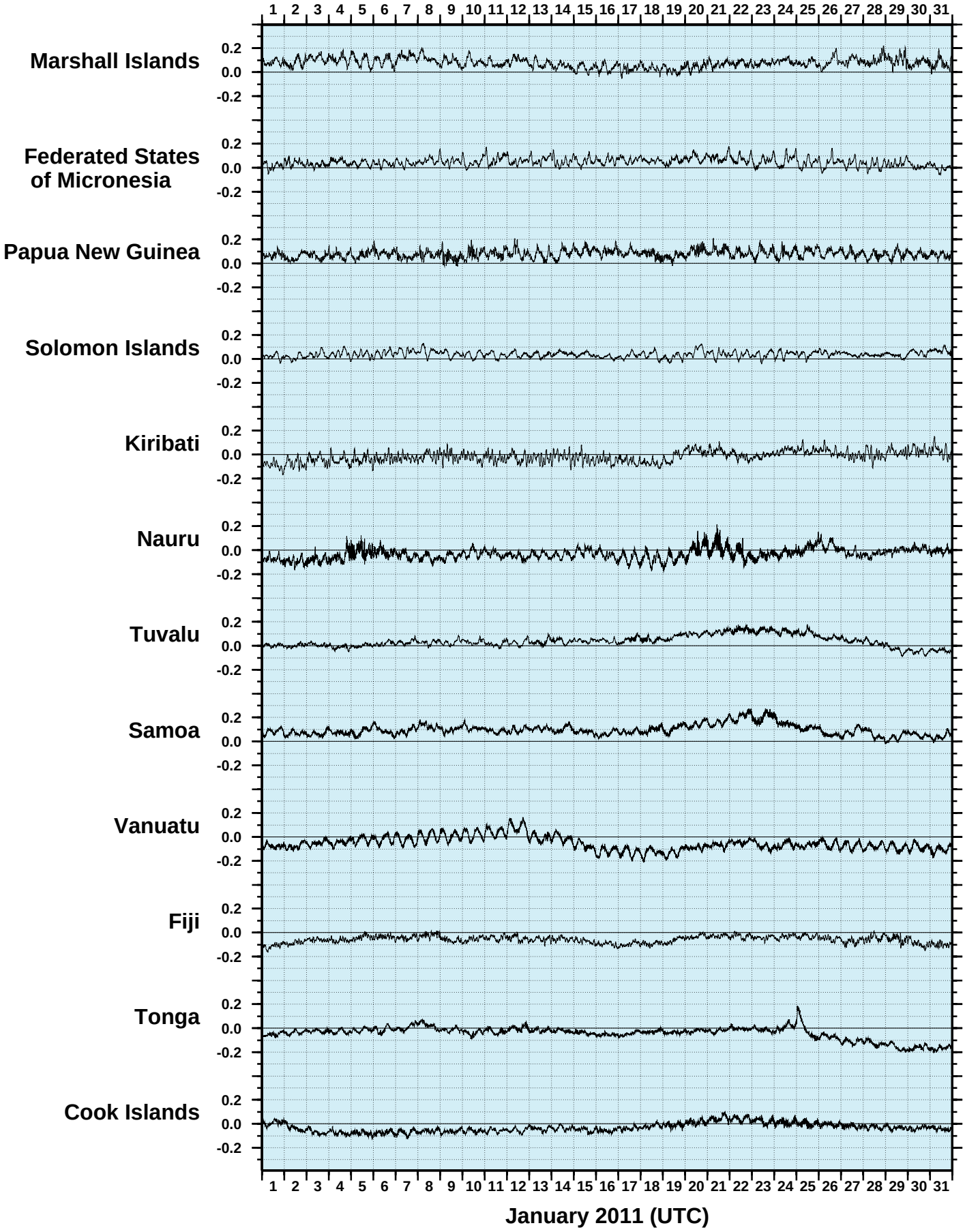


Figure 3

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

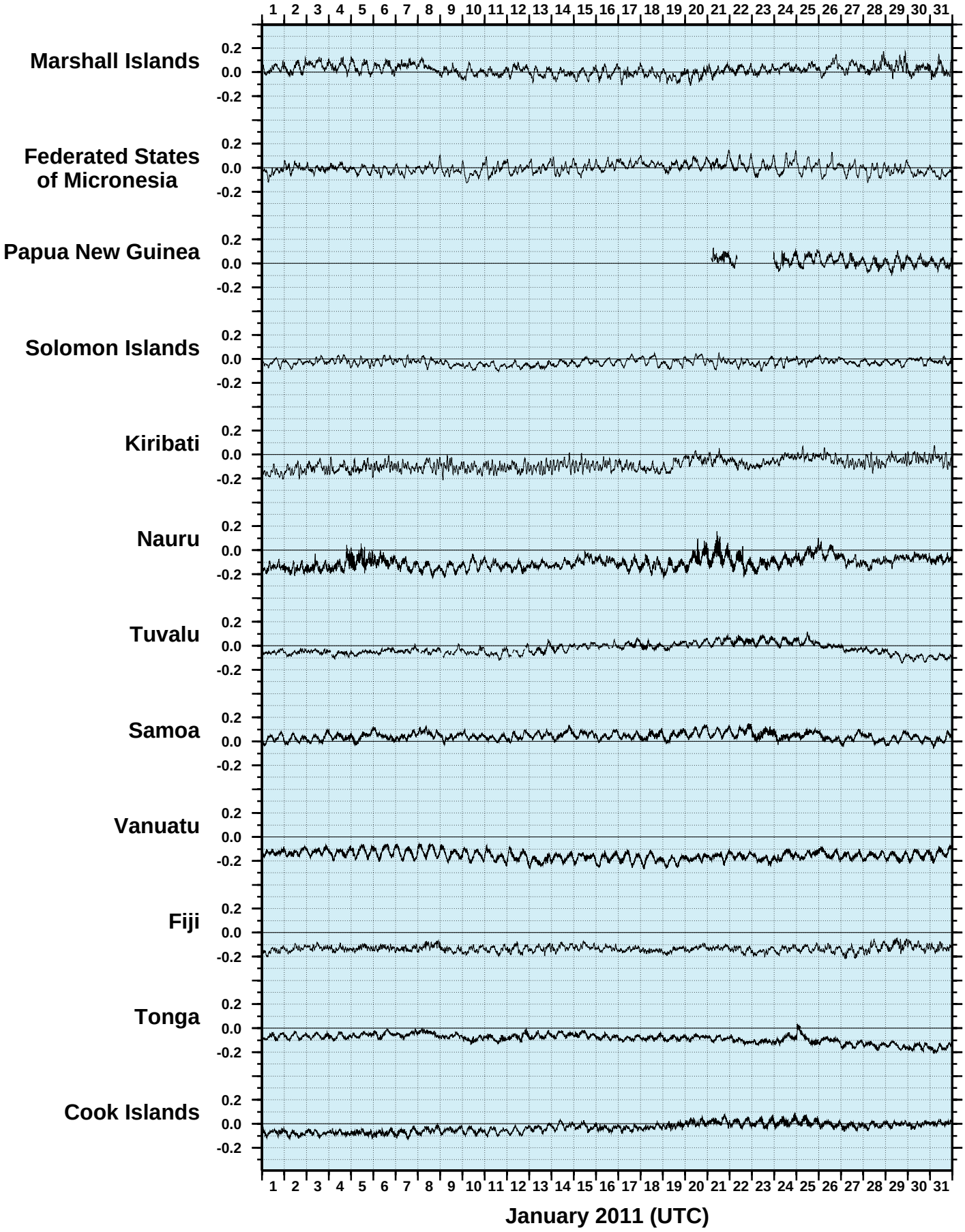


Figure 4

JANUARY 2011
HOURLY WIND SPEEDS (m/s)

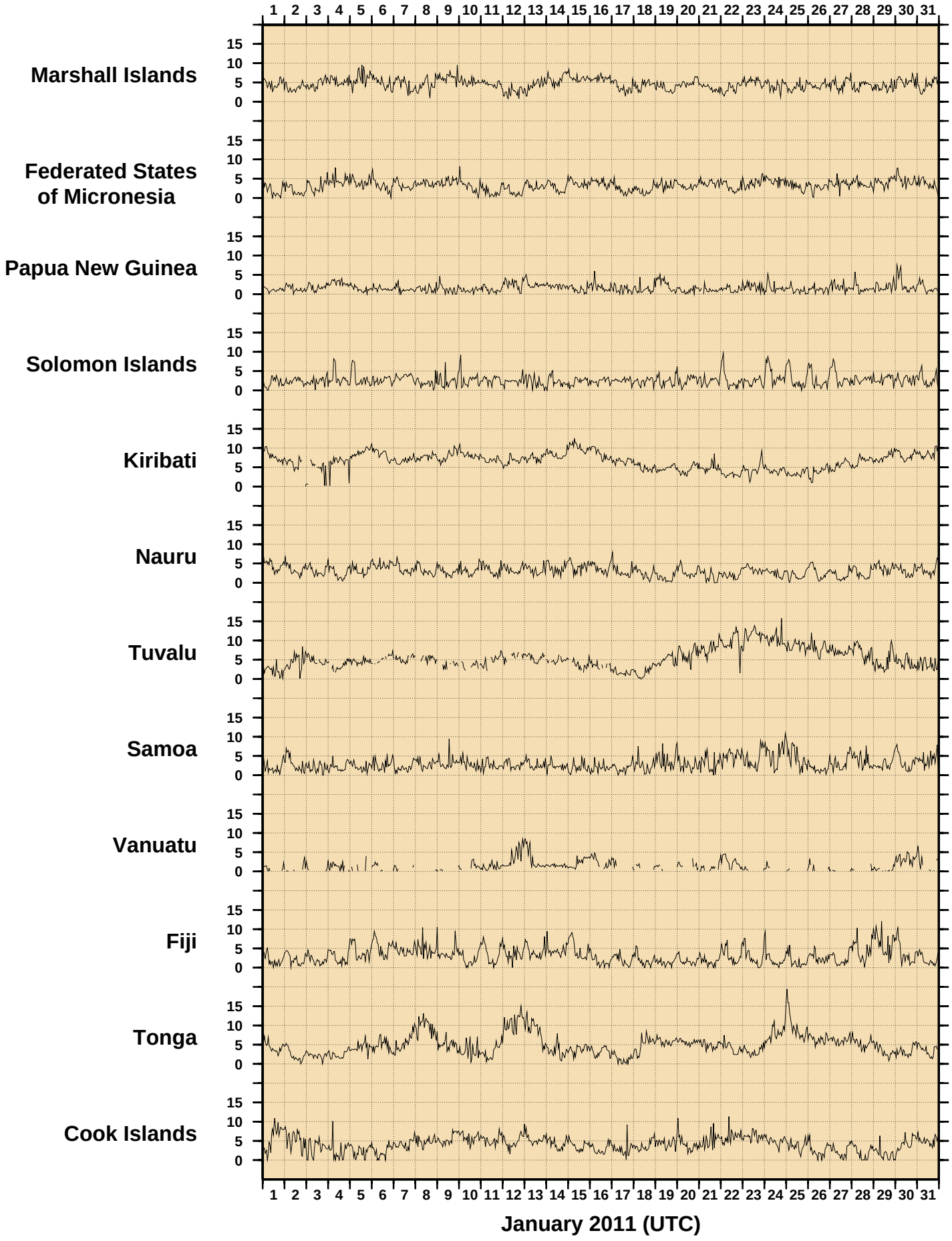


Figure 5

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

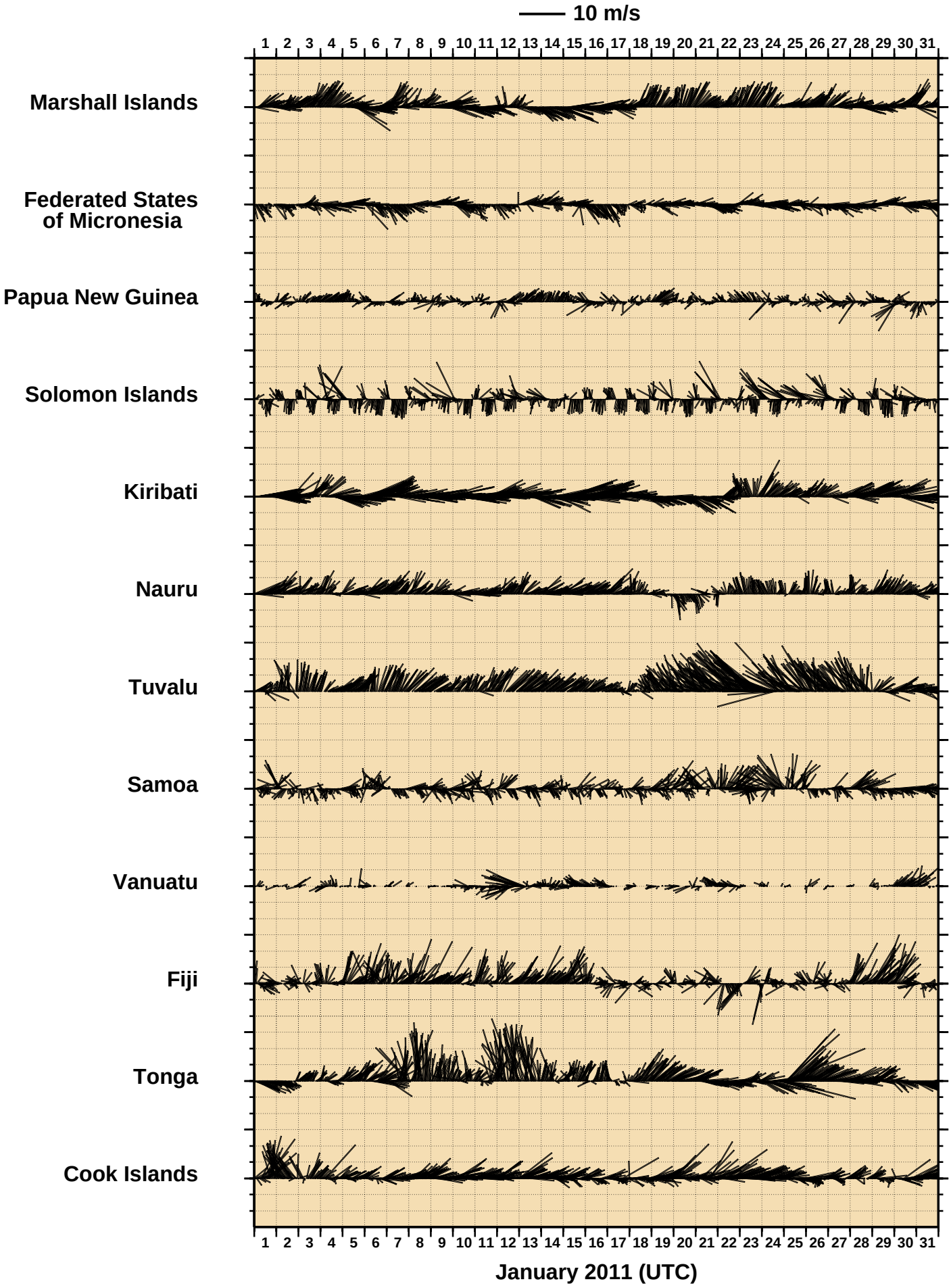


Figure 6

JANUARY 2011
HOURLY MAXIMUM WIND GUSTS (m/s)

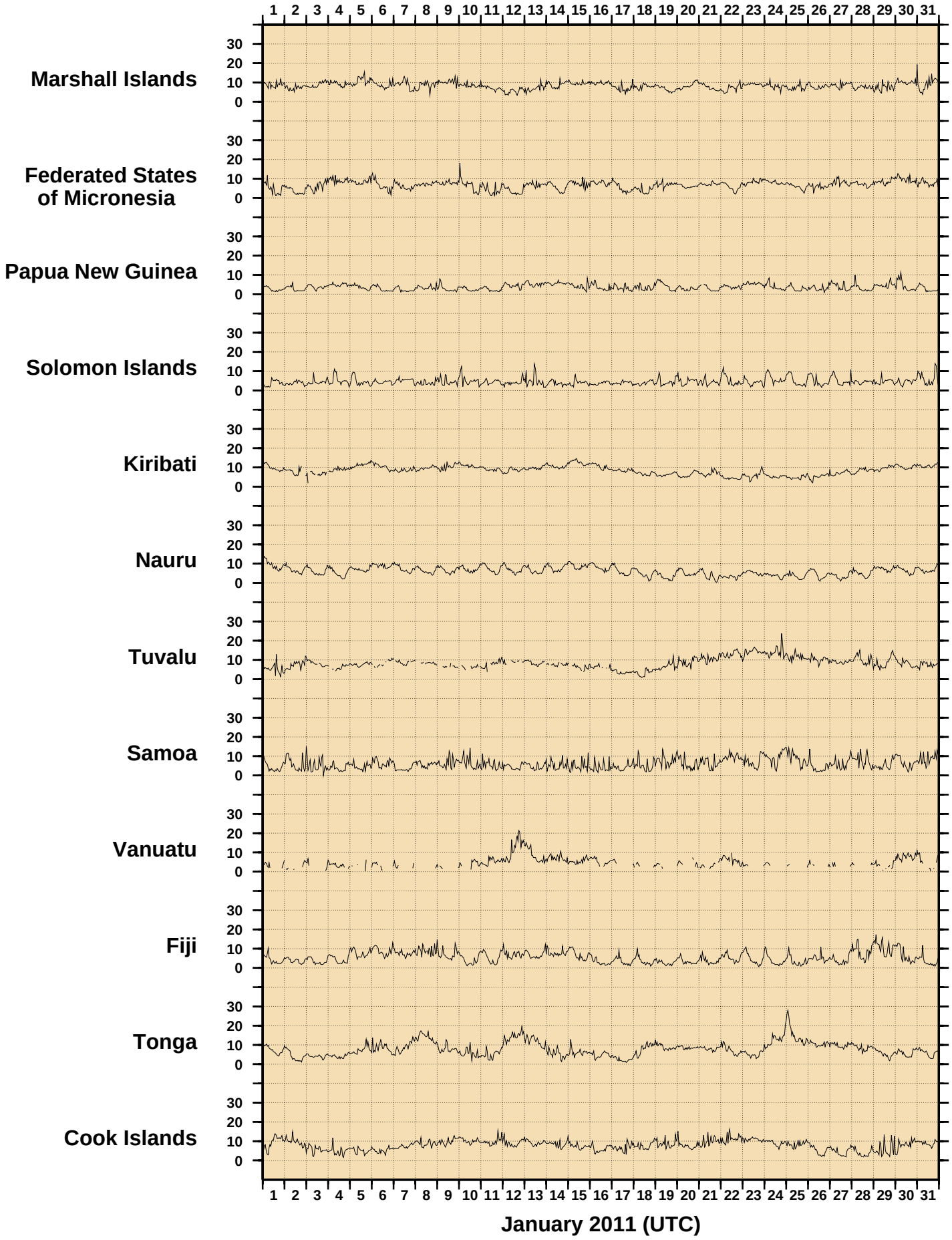


Figure 7

JANUARY 2011
HOURLY AIR TEMPERATURES (˚C)

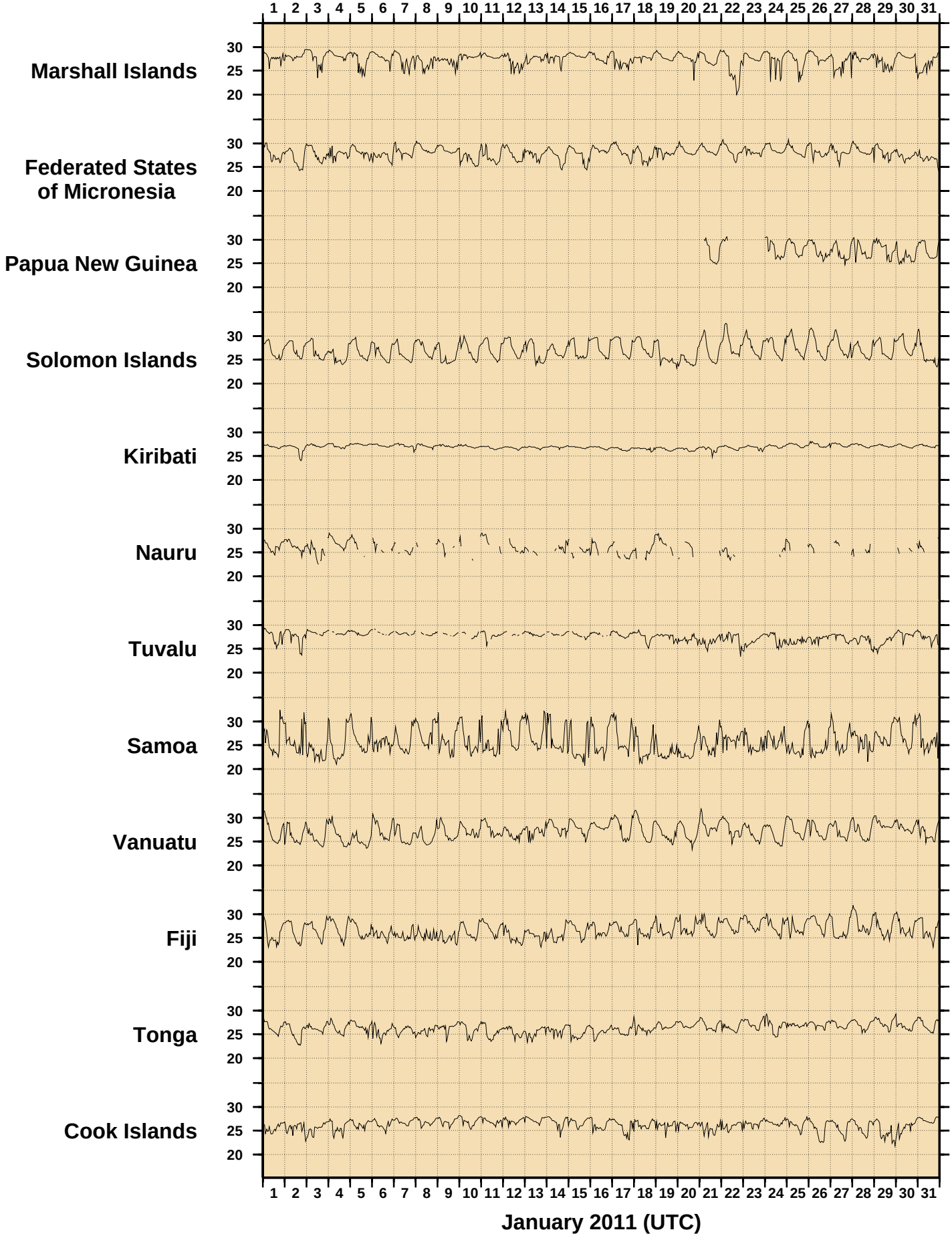


Figure 8

JANUARY 2011
HOURLY WATER TEMPERATURES (°C)

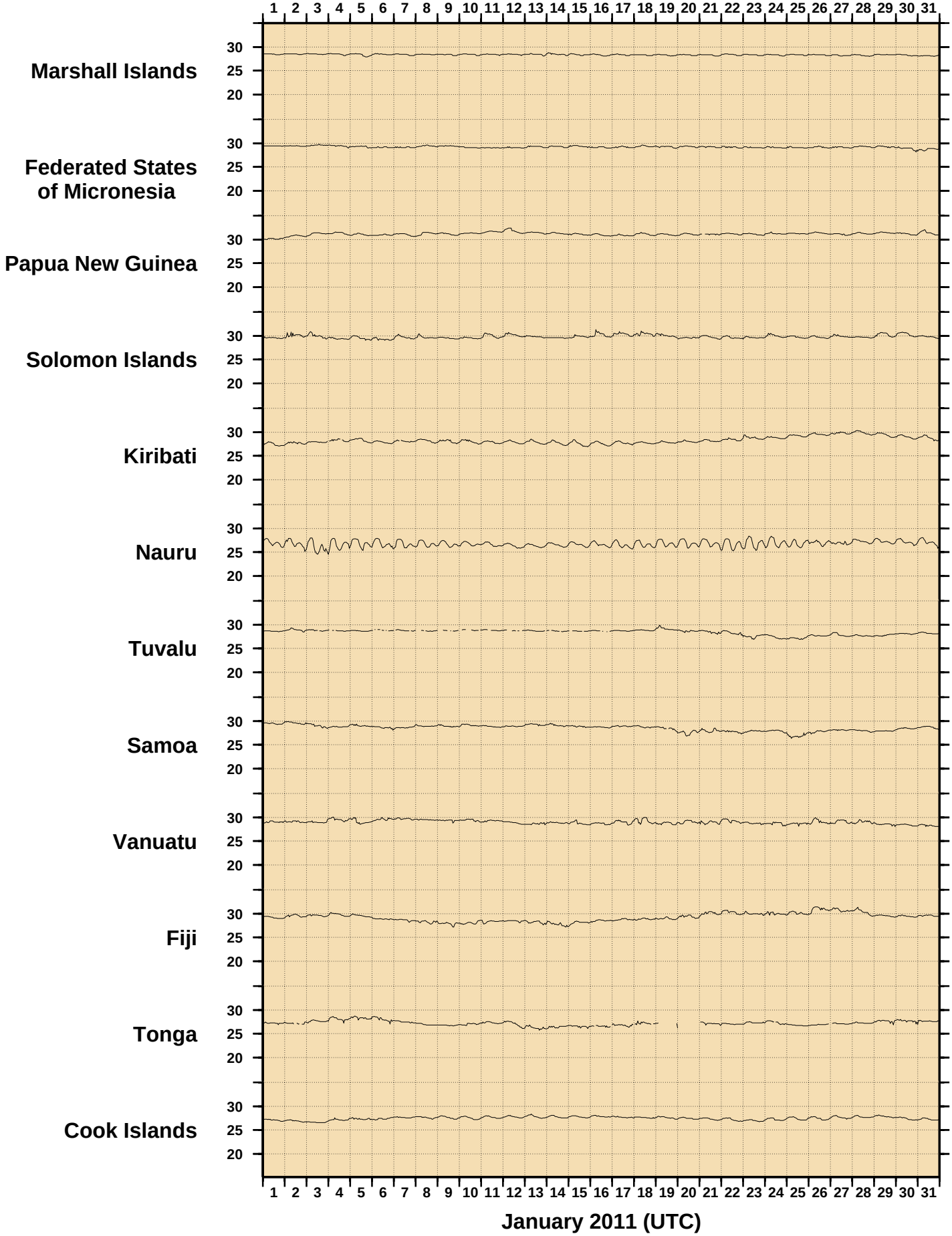


Figure 9

JANUARY 2011
HOURLY ATMOSPHERIC PRESSURE (hPa)

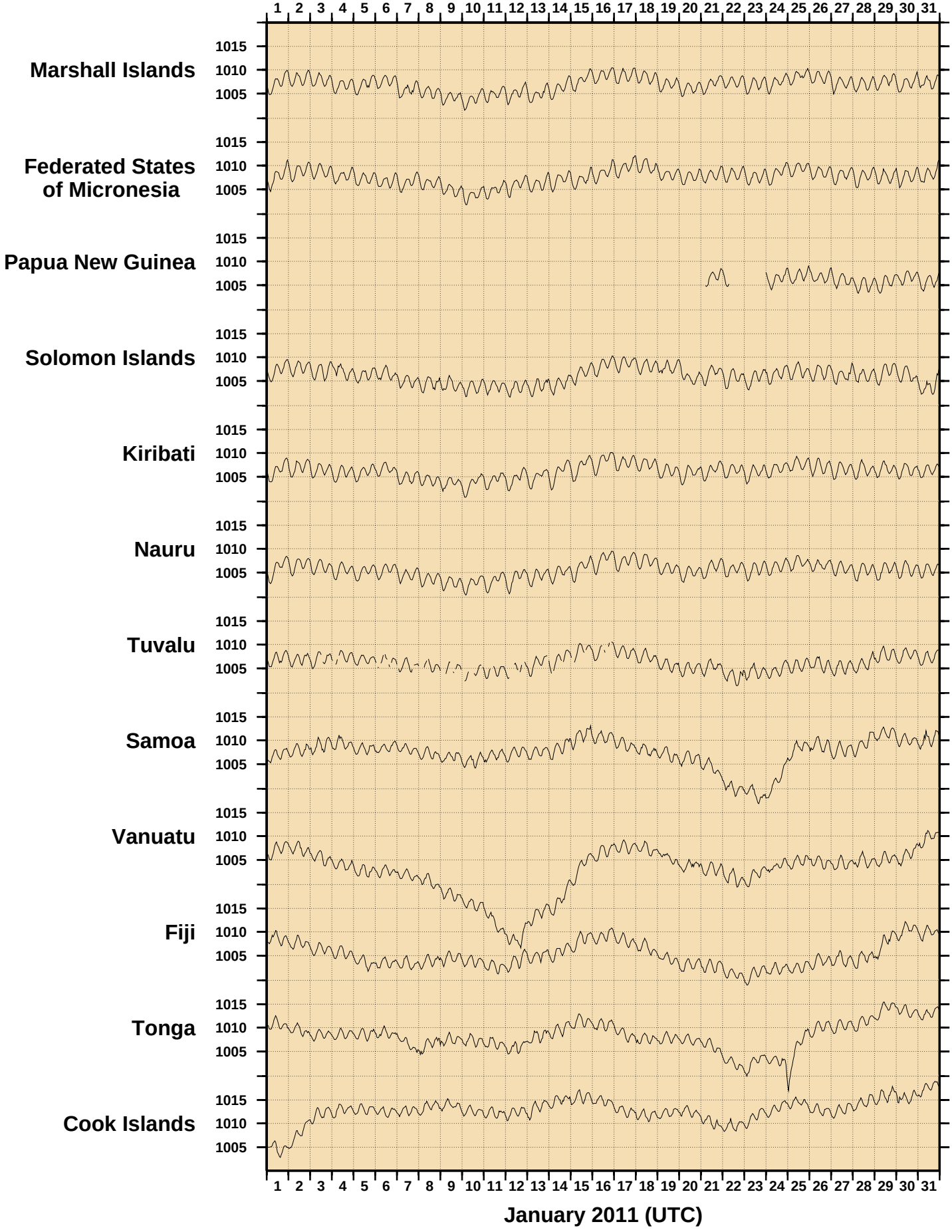
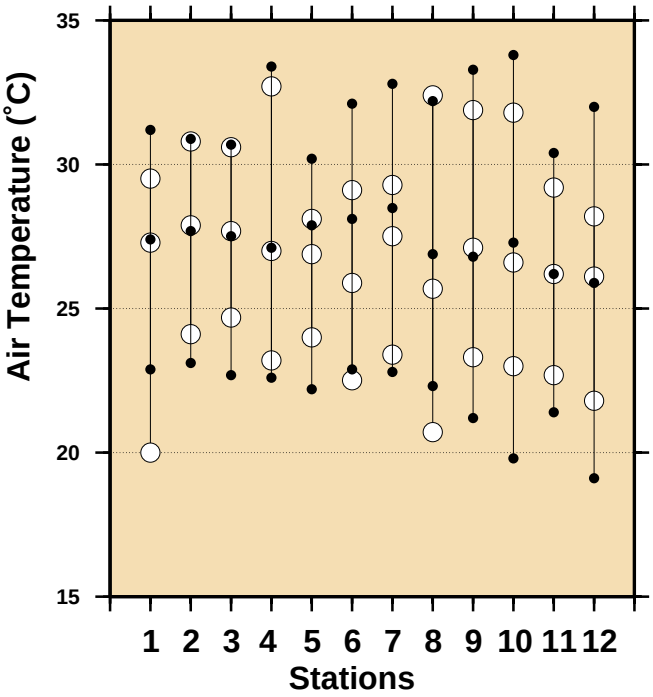
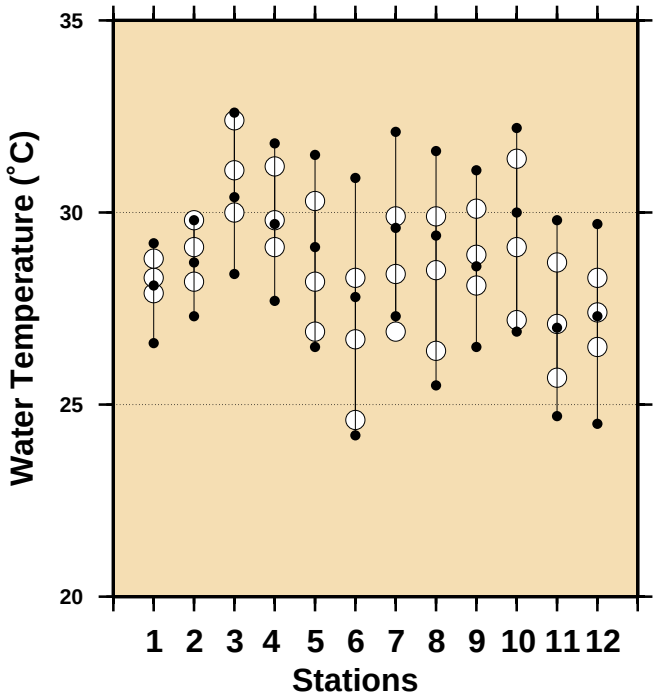
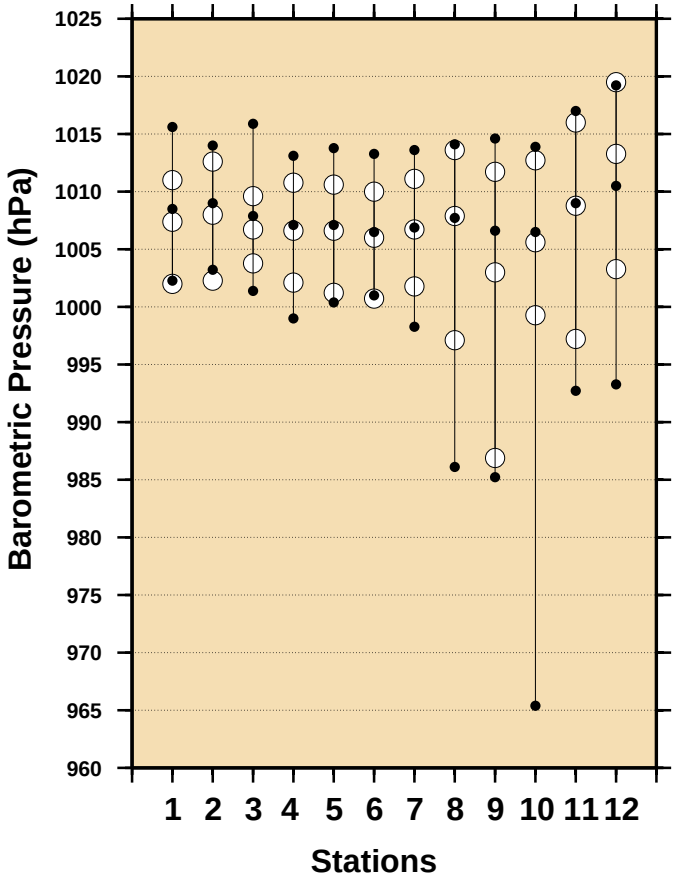


Figure 10

Comparison of January 2011 Max, Min & Mean with Long Term January 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

January 2011 Maximum
January 2011 Mean
January 2011 Minimum

Long Term January Maximum
Long Term January Mean
Long Term January Minimum

Figure 11

MONTHLY MEAN SEA LEVELS TO JANUARY 2011 (m)

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

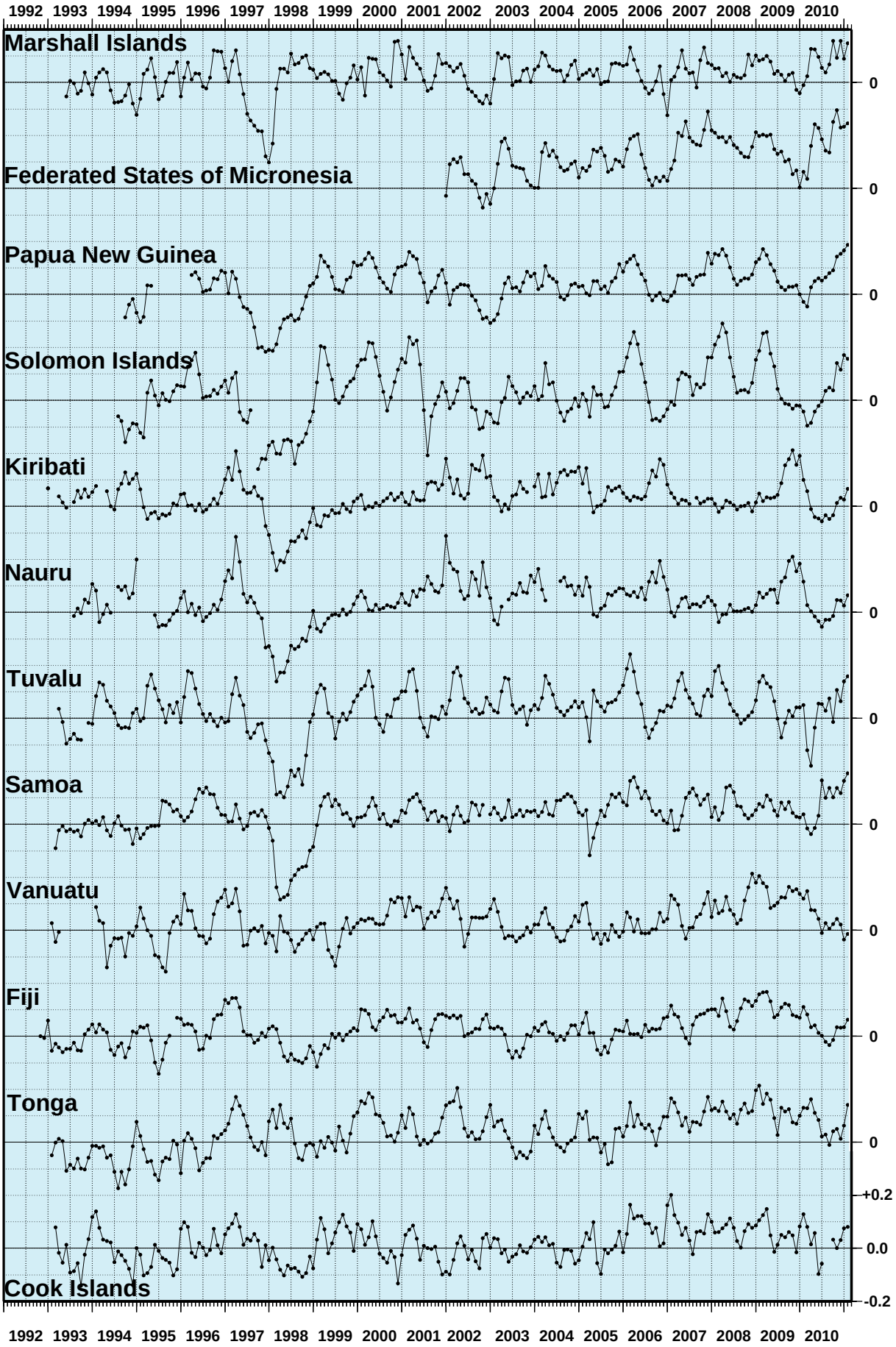


Figure 12

SEA LEVEL ANOMALIES THROUGH JANUARY 2011 (m)

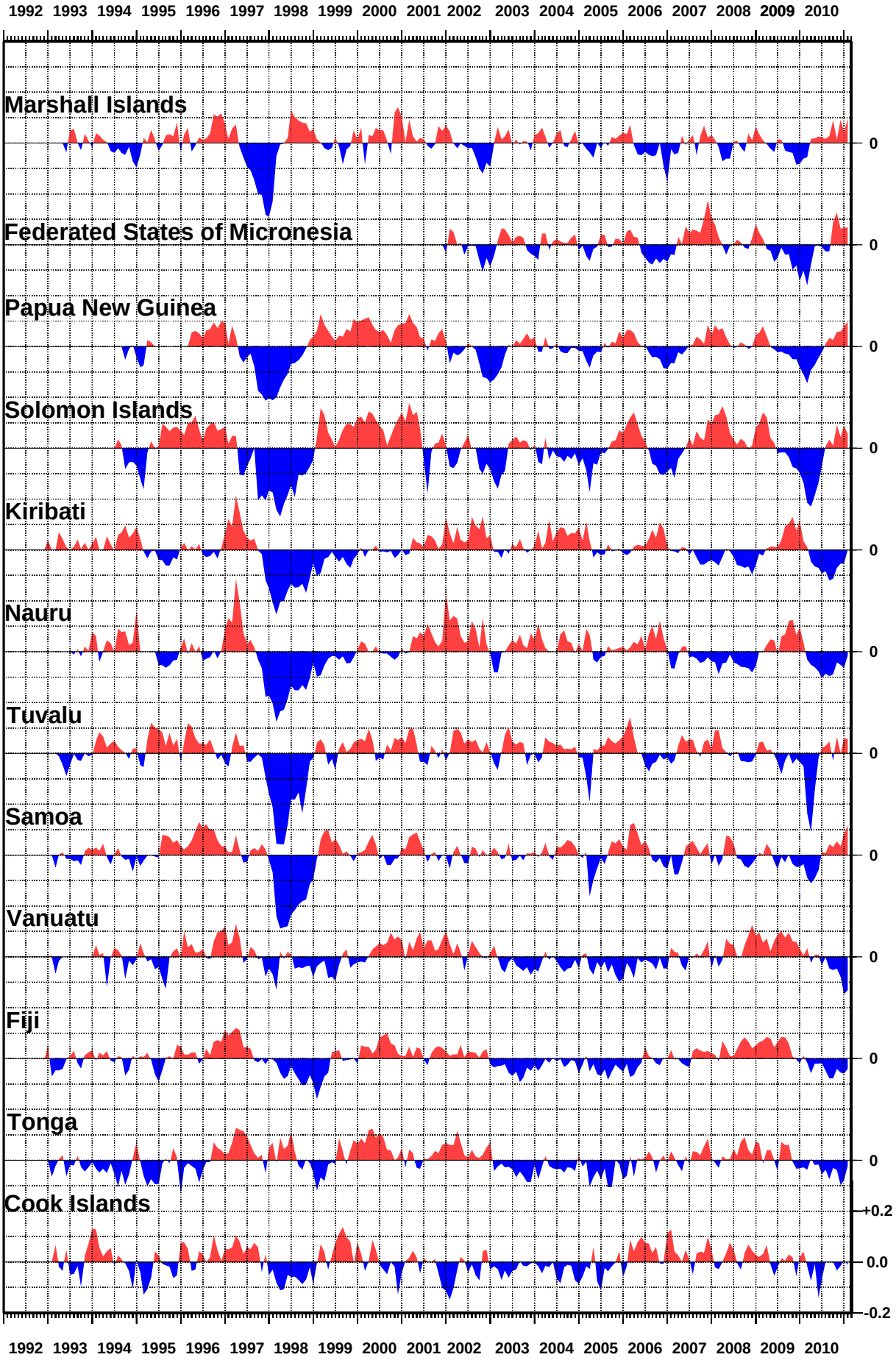


Figure 13

SEA LEVEL TRENDS THROUGH JANUARY 2011 (mm/year)

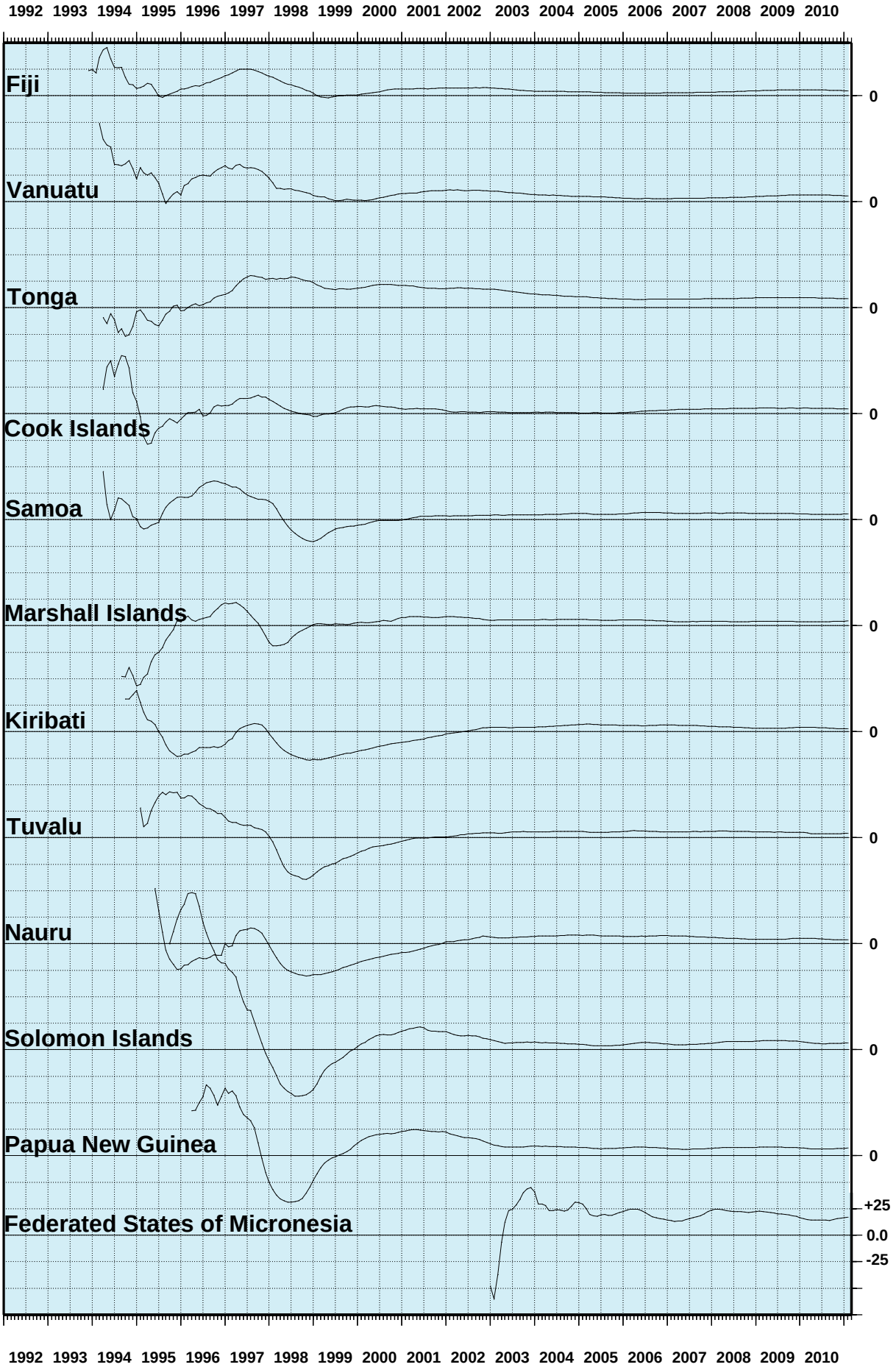


Figure 14

BAROMETRIC PRESSURE ANOMALIES THROUGH JANUARY 2011 (hPa)

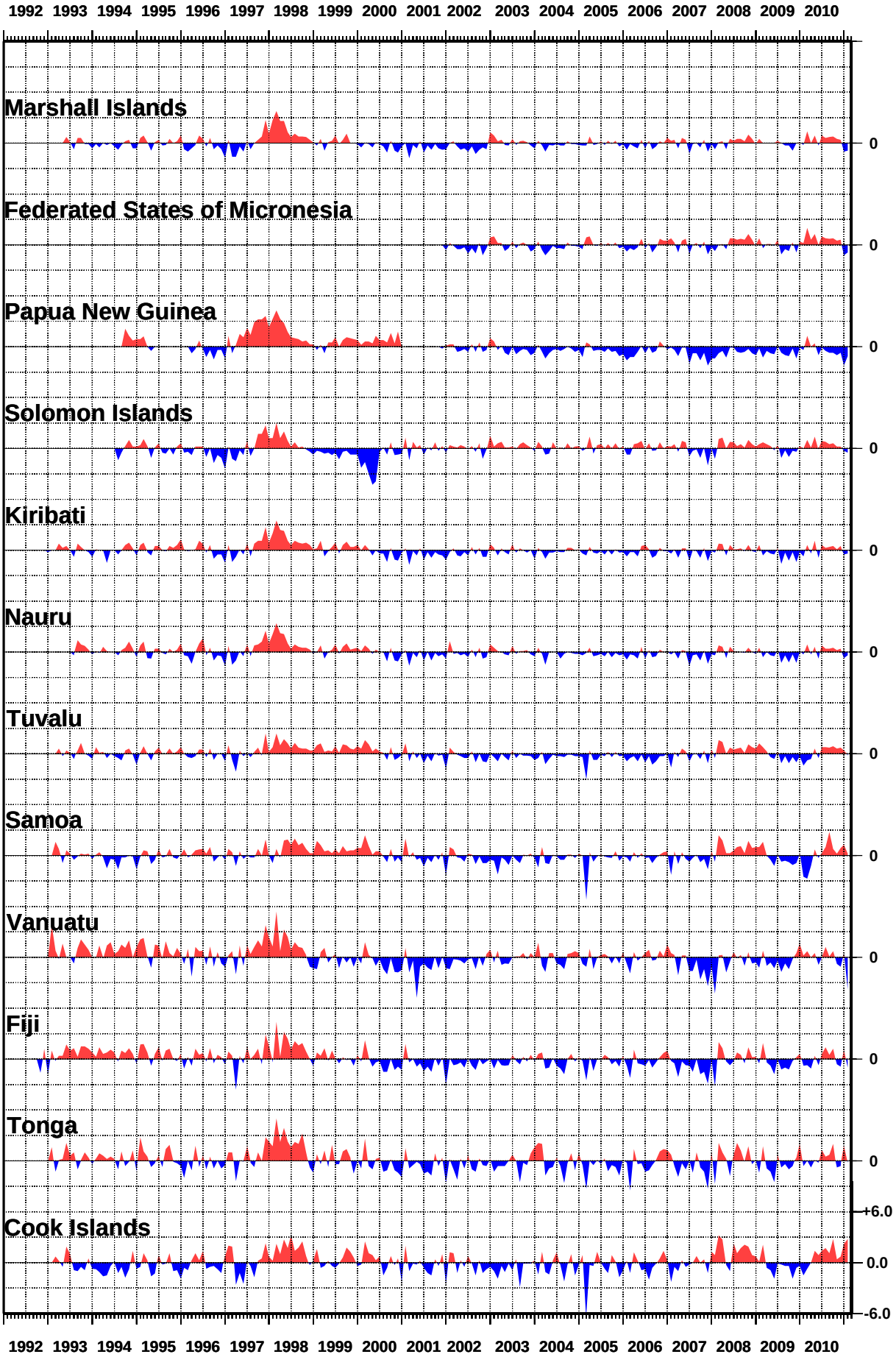


Figure 15

WATER TEMPERATURE ANOMALIES THROUGH JANUARY 2011 (°C)

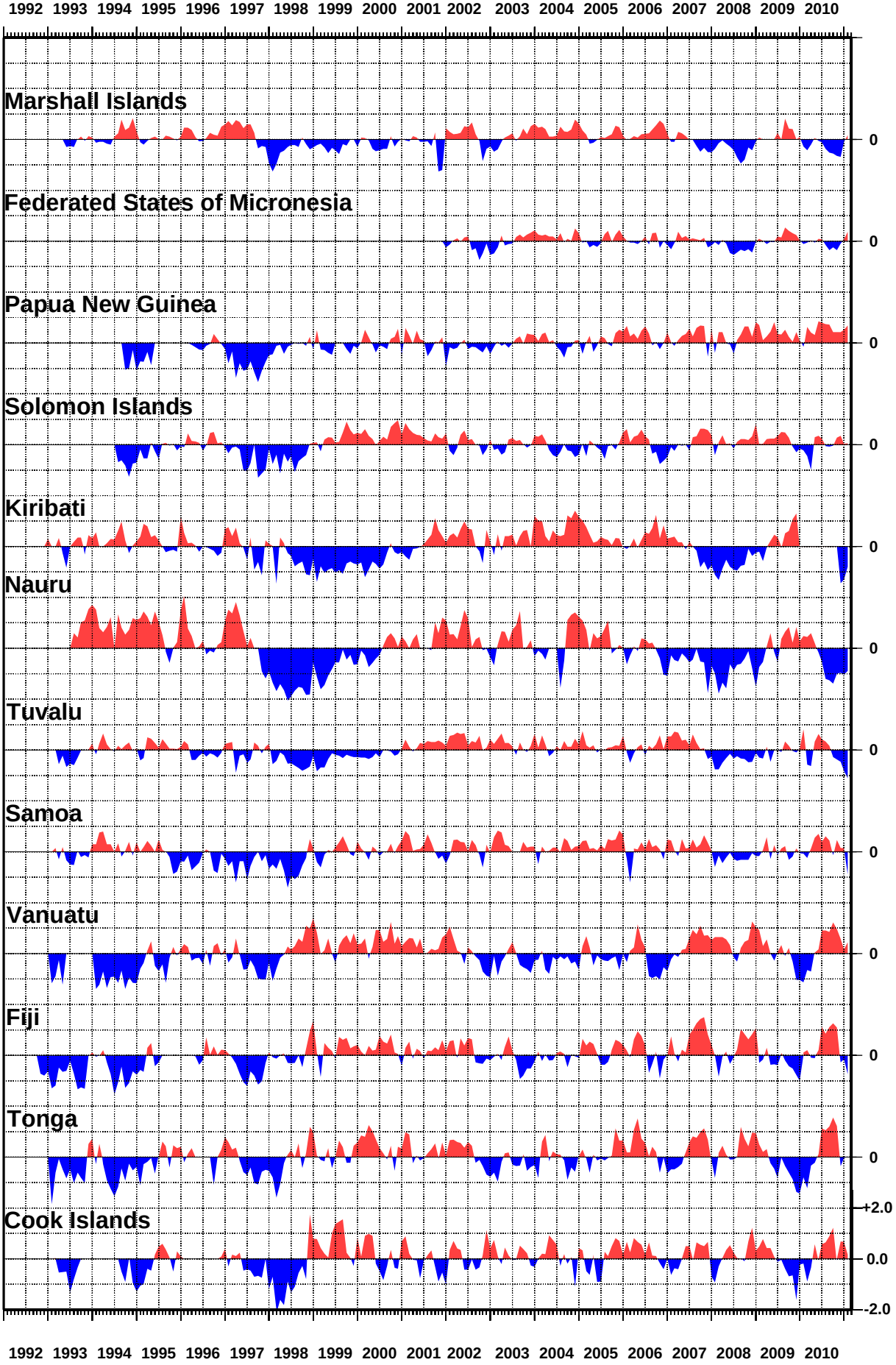


Figure 16

AIR TEMPERATURE ANOMALIES THROUGH JANUARY 2011 (°C)

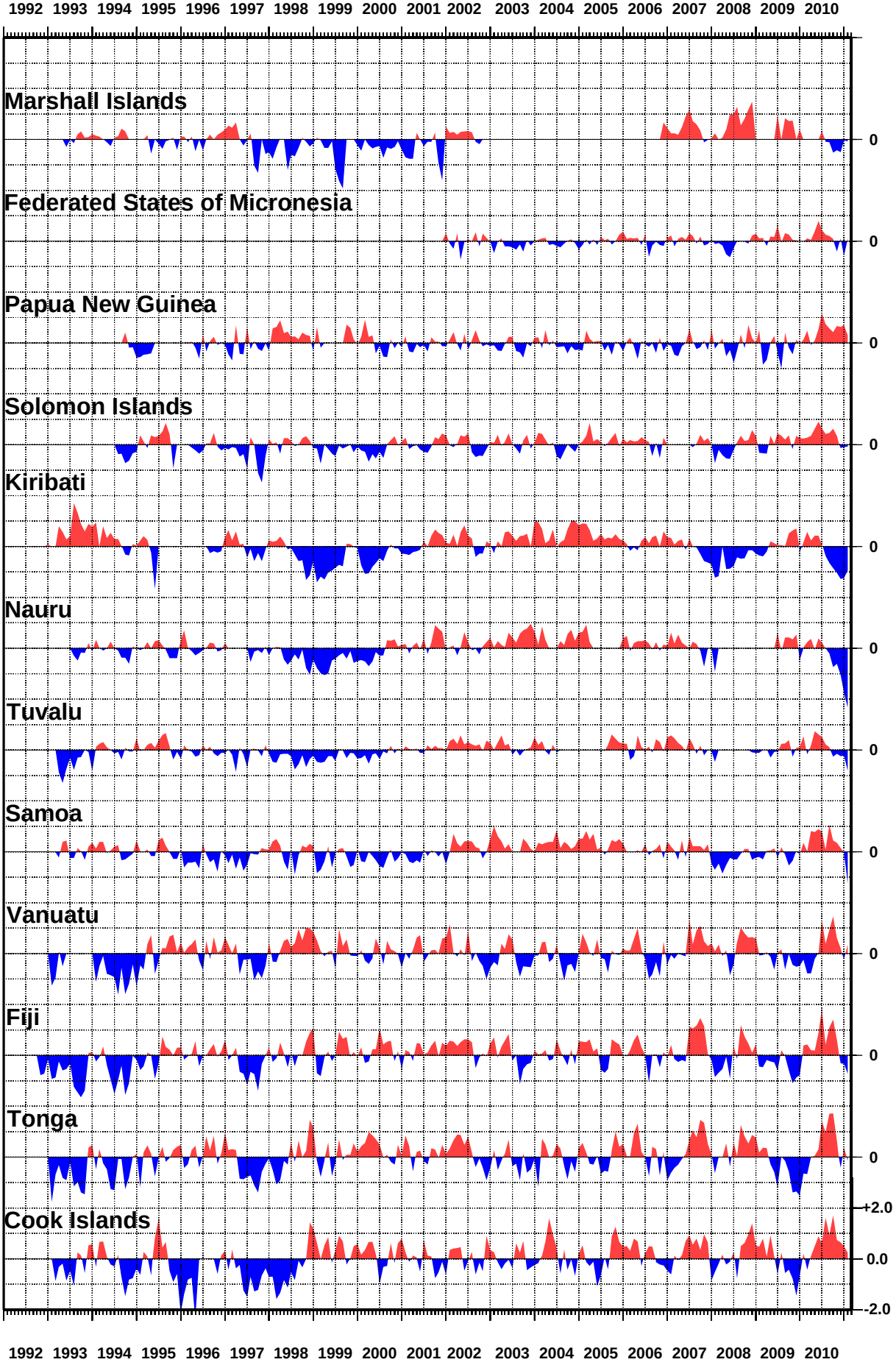
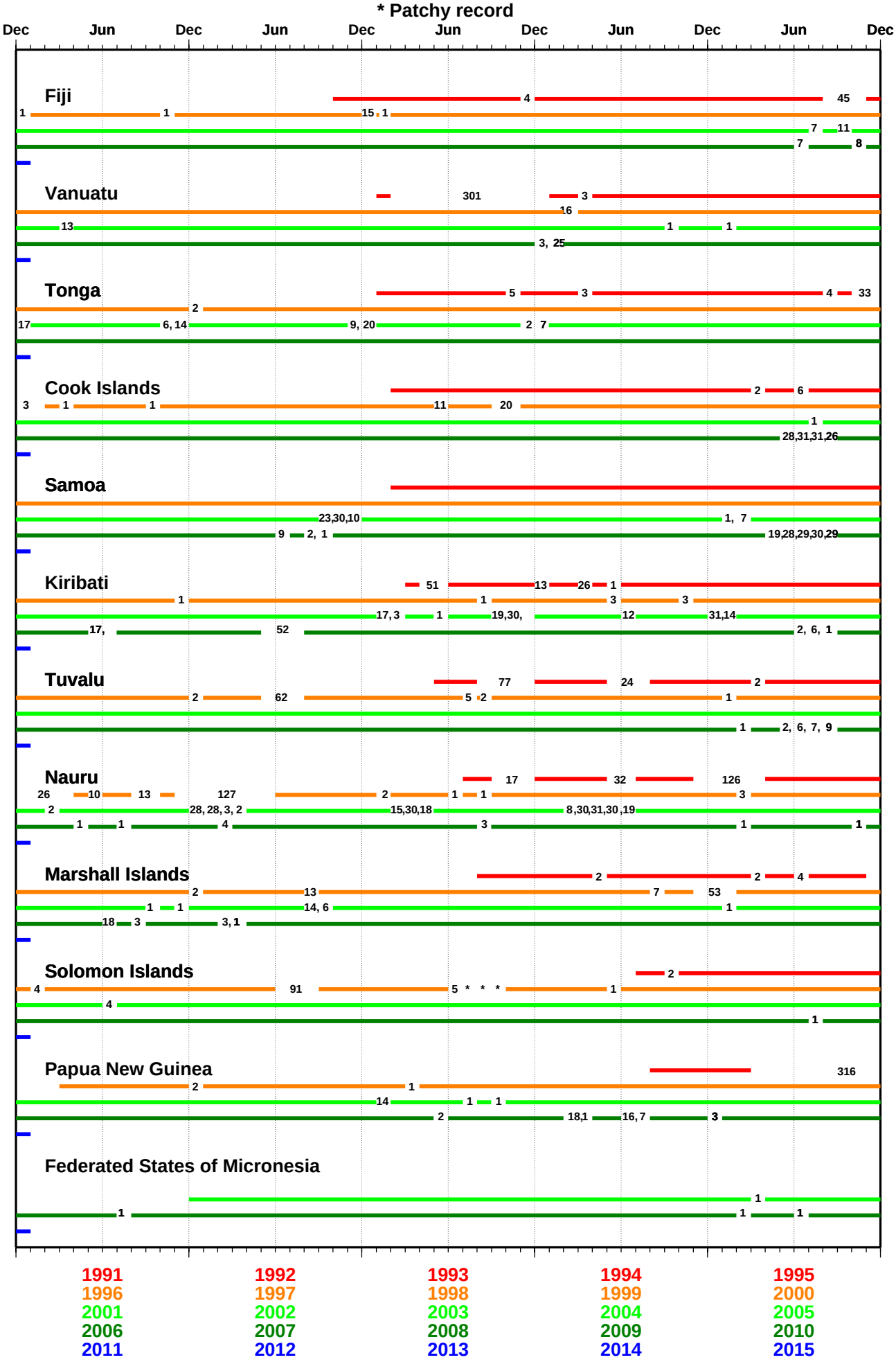


Figure 17

SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED

GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE

* Patchy record