# THE SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT

## MONTHLY DATA REPORT

## NO. 141

## MARCH 2007


**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

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**Quality Certification:**

I authorise the issue of this South Pacific Sea Level and Climate Monitoring Project Monthly Data Report for March 2007 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

# March 2007

## 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.

### *March 2007*

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

- The monthly mean sea level at FSM in March was the highest on record, although SEAFRAME observations have only been collected there for just over 5 years.

- No significant sea level anomaly was detected at the SEAFRAME stations in March. Near-normal sea levels are consistent with near-neutral climate conditions that are currently prevailing in the Pacific.

- A 10cm tsunami was detected by the SEAFRAME at Vanuatu on the 25$^{th}$ of March following a magnitude Mw7.3 earthquake 335 km to the SSE of Port Vila.

- Meteorological effects such as low barometric pressure and strong winds due to Tropical Cyclone Betty were recorded by the Vanuatu SEAFRAME on the 27$^{th}$ and 28$^{th}$ March.

- A significant pool of cooler than normal subsurface water remains in the eastern equatorial Pacific and continues to affect surface temperatures in that region.

- The majority of international climate models predict that cool neutral conditions will prevail in the Pacific over the coming months.

### *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 March, 2007**

| 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 | +4.1 | +0.1 |
| **Tonga** | 21°8'12.5"S / 175°10'50.5"W | Jan 1993 | +8.2 | 0.0 |
| **Fiji** | 17°36'17.7"S / 177°26'17.7"E | Oct 1992 | +2.9 | 0.0 |
| **Vanuatu** | 17°45'19.2"S / 168°18'27.7"E | Jan 1993 | +3.3 | +0.1 |
| **Samoa** | 13°49'36.4"S / 171°45'40.7"W | Feb 1993 | +5.9 | -0.2 |
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| **Kiribati** | 1°21'54.2"N / 172°55'58.8"E | Dec 1992 | +6.2 | -0.1 |
| **Nauru** | 0°31'45.9"S / 166°54'36.2"E | Jul 1993 | +7.2 | -0.1 |
| **Solomon Is.** | 9°25'44.1"S / 159°57'19.3"E | Jul 1994 | +4.8 | -0.1 |
| **PNG** | 2°2'31.5"S / 147°22'25.6"E | Sep 1994 | +6.3 | -0.1 |
| **FSM** | 6°58'49.9"N / 158°12'0.8"E | Dec 2001 | +13.5 | +0.5 |
| **Marshall Is.** | 7°6'21.7"N / 171°22'22.1"E | May 1993 | +3.8 | -0.1 |

## INTRODUCTION

Welcome to the March 2007 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 gauges 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. SEAFRAME gauges were installed in the participating Forum Countries.

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.

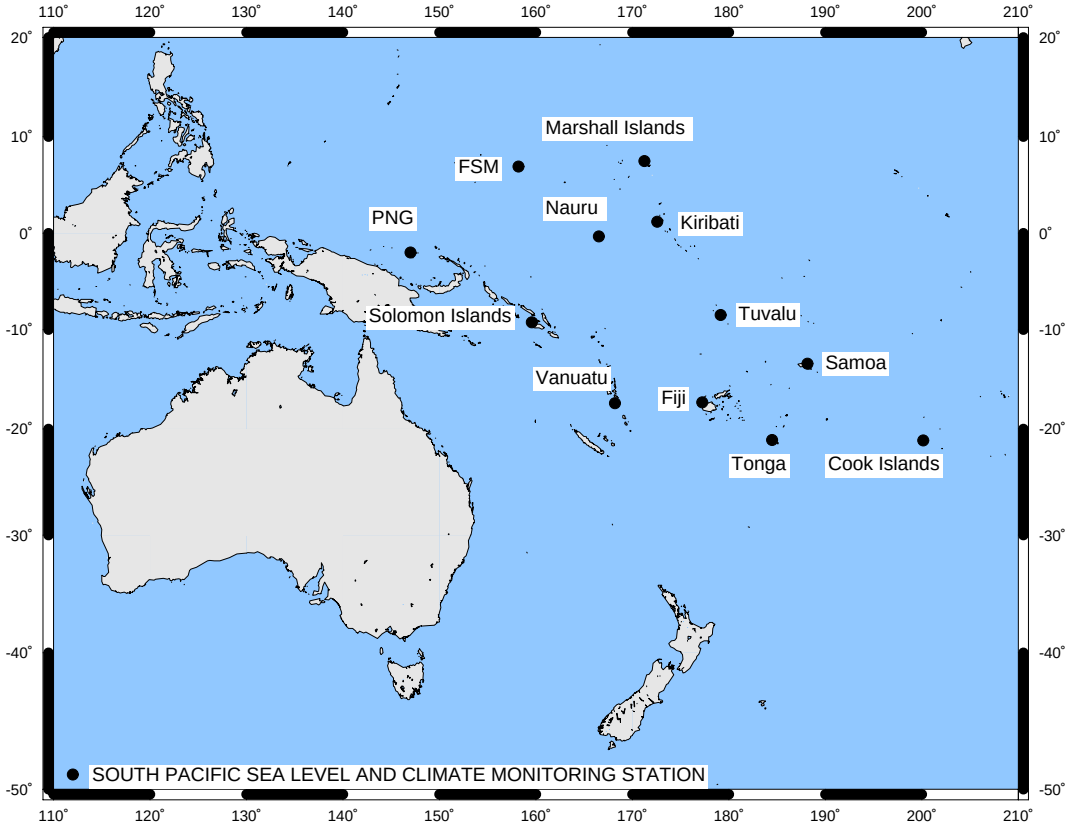


**Figure A:** *South Pacific Sea Level and Climate Monitoring Stations*

## MARCH CLIMATOLOGY

Neutral climate indicators were observed across the Pacific during March, including the Southern Oscillation Index (SOI), sea surface temperatures, equatorial Trade Winds and cloudiness. The rapid cooling of sea surface temperatures that occurred across the equatorial Pacific in January and February has slowed. A return to warm El Niño conditions during 2007 is considered unlikely.

The Southern Oscillation Index (SOI) (**Figure B**) had a March value of –1, which is indicative of near-neutral atmospheric circulation across the equatorial Pacific. Sea surface temperatures were near normal across much of the equatorial Pacific during March, although cooler than normal sea surface temperatures continued to develop in the far eastern equatorial Pacific (**Figure C, Figure E**).

Subsurface waters continued to cool across the eastern equatorial Pacific during March (**Figure D**) and continue to affect surface temperatures in that region. Further cooling in the eastern Pacific could potentially lead to the development of basin-wide La Niña conditions.

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 near the dateline. During La Niña (cold-episode) conditions there is a reversal of this situation, with stronger Trade Winds and decreased cloudiness in the central Pacific. The TAO/TRITON array of moored buoys revealed Trade Winds across the equatorial Pacific were of near to slightly above average strength in the central equatorial Pacific during March (**Figure E**). Near average cloudiness was observed in the central equatorial Pacific during March.

The general consensus from twelve international computer models is that climate conditions on the cool side of neutral are likely to prevail across the Pacific during 2007.

*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/.*

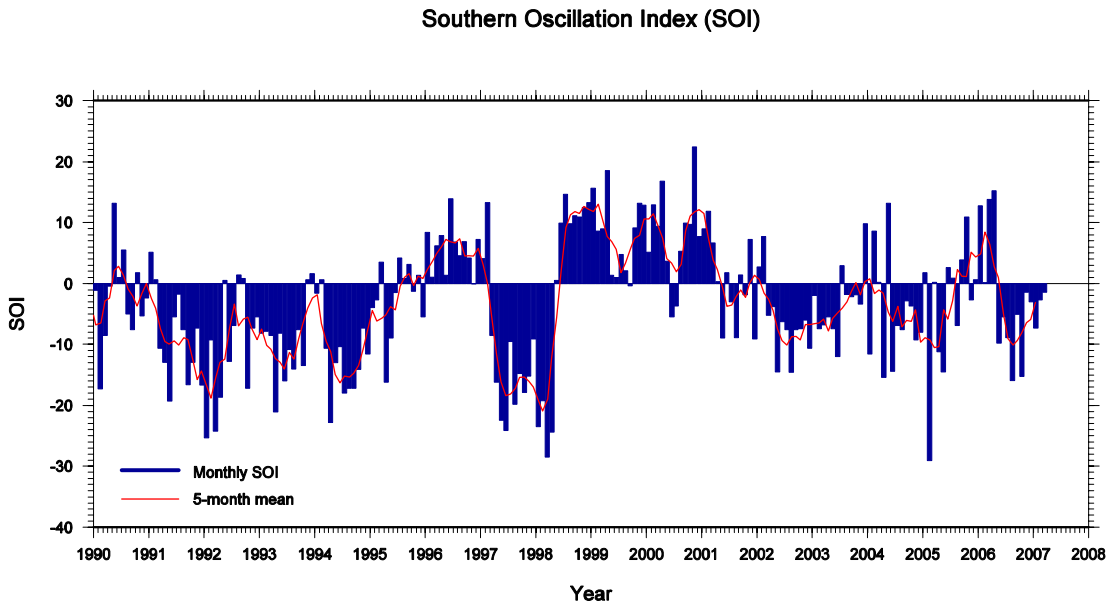


**Figure B:** *The five-month weighted mean and individual monthly means of the Southern Oscillation Index (SOI). The SOI is ten times the monthly anomaly of the difference in mean sea level pressure between Tahiti and Darwin, divided by the standard deviation of that difference for the relevant month, based on the period 1933-92.*

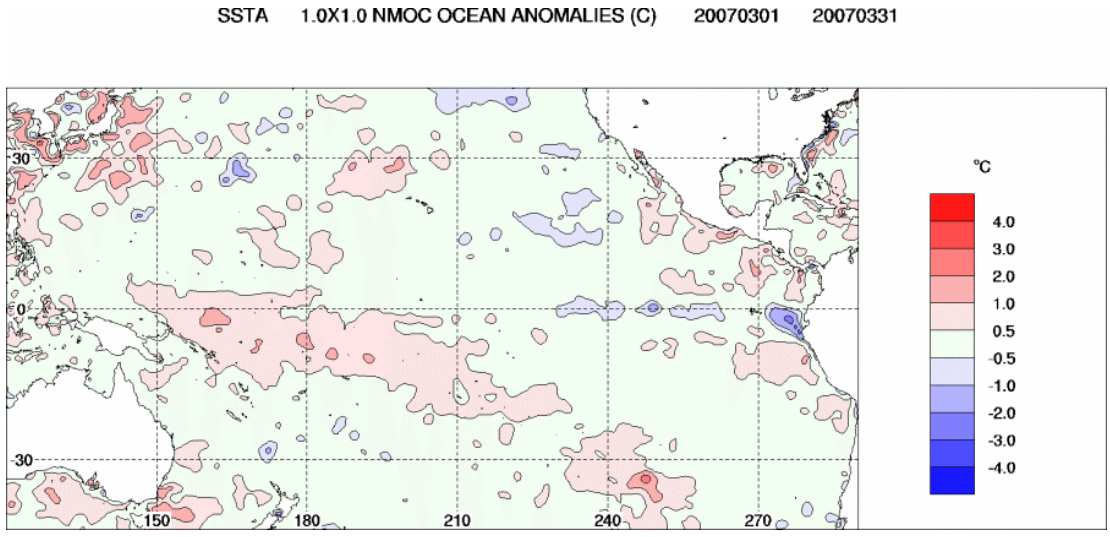


**Figure C**: *Sea surface temperature anomaly (°C) for March 2007.*

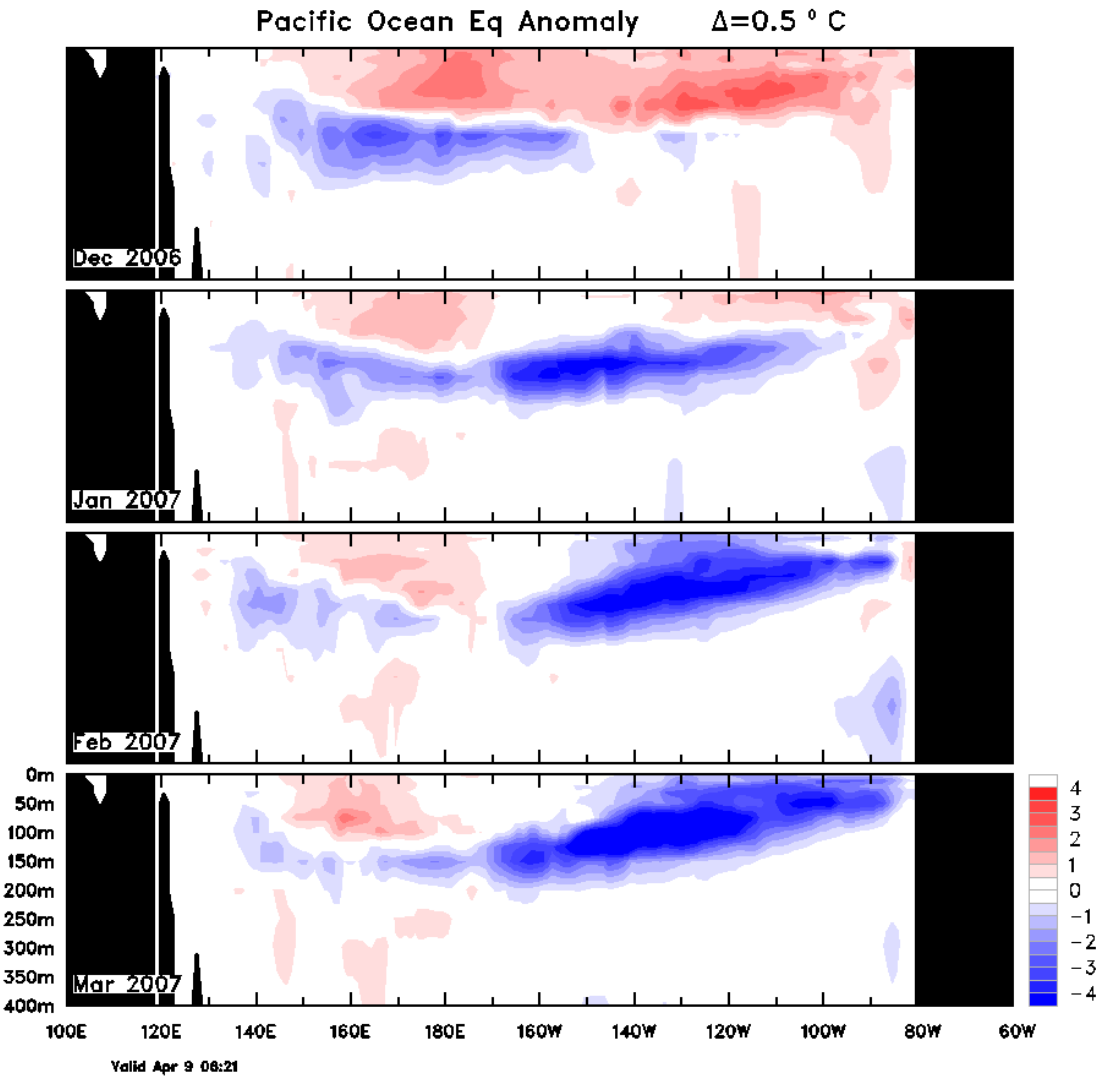


**Figure D**: *Equatorial depth-longitude section of ocean temperature anomalies for December 2006 through to March 2007. Contour interval is 0.5°C.*

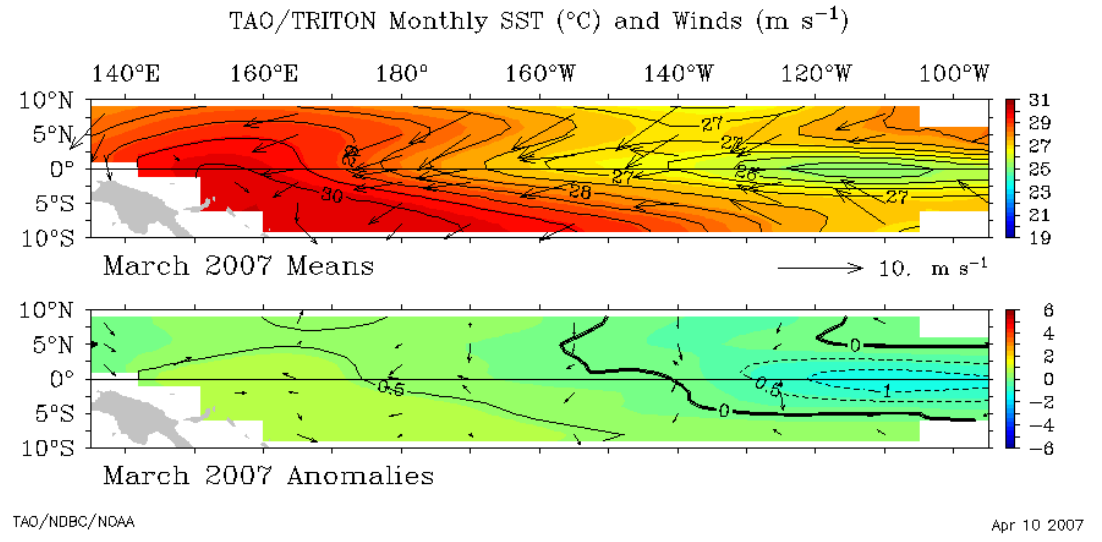


**Figure E:** *Monthly mean wind vectors (top) and anomalies (bottom) for March 2007. The colour-shaded contours represent the monthly mean sea surface temperatures (top) and anomalies (bottom).*

## MARCH 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 tend to occur close to full and new moons. There was a full moon on the 3rd of March and a new moon on the 19th of March. For sites just east of the dateline, the official dates of full and new moon are normally one day ahead.

Gaps in the data are the result of instrumental 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 are an indication of the non-tidal fluctuations in the sea level record such as those due to the short-term effects of the weather. The residuals are also influenced by the shape of the harbour in which the gauge is located. The sloshing of the sea backward and forward within a harbour is called a seiche. Papua New Guinea (Manus Island), for example, often experiences a seiche within Seeadler Harbour when the wind suddenly changes strength or direction. Residual sea level fluctuations are also often observed at the site of the FSM gauge.

Following an Mw7.3 earthquake at 00:40 UTC on the 25th of March a small tsunami of height 10cm measured from trough to peak was detected at the Vanuatu gauge. The epicentre was 335 km SSE of Port Vila and the first tsunami waves arrived at Port Vila about 40 minutes later. Tsunami waves were not detected at any of the other SEAFRAMES in the region.

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). In comparing Figures 2 and 3, the effect of low barometric pressure (Figure 9) on sea level is noticeable at Cook Islands on the 9th and 10th of March and also at Vanuatu on the 27th and 28th of March.

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. The maximum wind gusts observed each hour **(Figure 6)** show the strongest winds of 18 m/s (35 knots) were observed at Fiji on 9th of March**.** Less than 24 hours later the same weather system produced strong winds at Cook Islands. No wind data was collected at Solomon

Islands because the wind mast and wind sensor remain temporarily removed to allow for refurbishment of the wharf.

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. The SEAFRAME at Nauru records twice-daily fluctuations in water temperature that are related to the tide, since they are usually more pronounced during the larger spring tides.

Barometric pressures **(Figure 9)** tend to fluctuate by around 3 hPa twice per day 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, which tend to be larger at sites further away from the equator (eg. at Cook Islands and Tonga).

Tropical Cyclone Becky developed to the northwest of Vanuatu on the 26$^{th}$ of March and passed near Vanuatu before dissipating near New Caledonia on the 30$^{th}$ of March. Low barometric pressure and strong winds were observed at the Port Vila gauge on the 27$^{th}$ and 28$^{th}$ of March, but no damage was reported.

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 FSM data frequently goes outside the range but is of less significance because of the short record (since December 2001). Figure 10 shows that a new March maximum air temperature was recorded at Vanuatu and a new March minimum air temperature was recorded at Samoa. At FSM in March a new maximum water temperature and a new minimum barometric pressure were recorded. The mean barometric pressures for March 2007 were lower than the long-term March means at all stations.

**Mean Sea Level and Anomalies (Figures 11-13)**

**Figure 11** shows the **monthly mean sea levels**, which is a simple arithmetic average of the sea levels relative to an arbitrary zero. The figure shows that Tuvalu 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 March 2007 monthly mean sea level at FSM is the highest on record, although the record there is relatively short.

**Figure 12** shows the **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.

The anomalies for March 2007 indicate sea levels were near normal at most stations, which is consistent with the near-neutral climate conditions being observed across the

Pacific at this time. The largest anomaly was observed at Samoa where sea levels were on average around 8cm lower than what is expected at this time of the year.

**Sea Level Trends**

**Short-term sea level trends** (in mm per year), at individual stations, from one year after installation to the present, are depicted in **Figure 13**. The values are calculated by continuously updating the tidal analysis with a short-term trend, based upon all data available at individual stations. Further details are available from the *National Tidal Centre (NTC), Australian Bureau of Meteorology*. It is important to stress that as the sea level record becomes longer, the short-term trend estimate becomes more stable and reliable. It is also to be noted that the observed trends in sea level include natural variability, for example, events such as El Niño and effects due to 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 these data* – they will almost certainly change over the coming years as the data set increases in length. The trend value is highly variable for the above-mentioned reasons.

**Recent short-term sea level trends in the project area based upon SEAFRAME data through March, 2007**

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**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 March 2007 lower than normal barometric pressures were observed at all stations.

The **water temperature anomalies (Figure 15)** during March 2007 indicate near normal conditions at most stations, although temperatures remain on average 0.5 ˚C cooler than normal at Nauru, Tonga and Cook Islands and 0.5 ˚C warmer than normal at Tuvalu.

The **air temperature anomalies (Figure 16)** show no significant anomaly was observed during March 2007 in agreement with the near-neutral climate conditions that currently prevail across the Pacific. The largest anomaly is around –0.5 ˚C at PNG. 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.

At Solomon Islands the air temperature sensor and anemometer (wind sensor) remain temporarily dismantled as the wharf continues to be refurbished. Satellite data transmissions were not received from Marshall Islands after the 29$^{th}$ of March and data is yet to be recovered from the log. Erroneous sea level data from Nauru were omitted from the record leaving gaps on the 1$^{st}$ March and 5$^{th}$ – 7$^{th}$ March. Dial-up communications problems were experienced at Nauru, Tuvalu, Marshall Islands, Samoa and Solomon Islands and some small data gaps may exist where data were unable to be recovered.

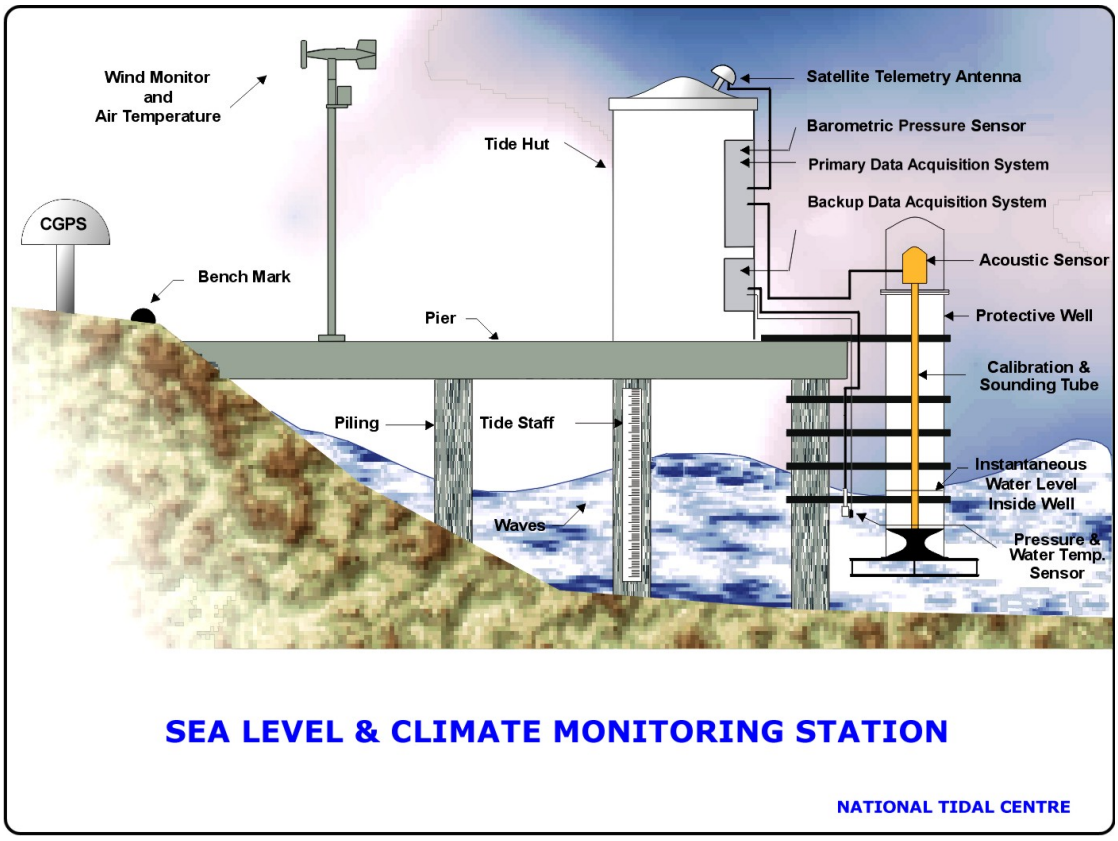
## SEAFRAME STATIONS

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

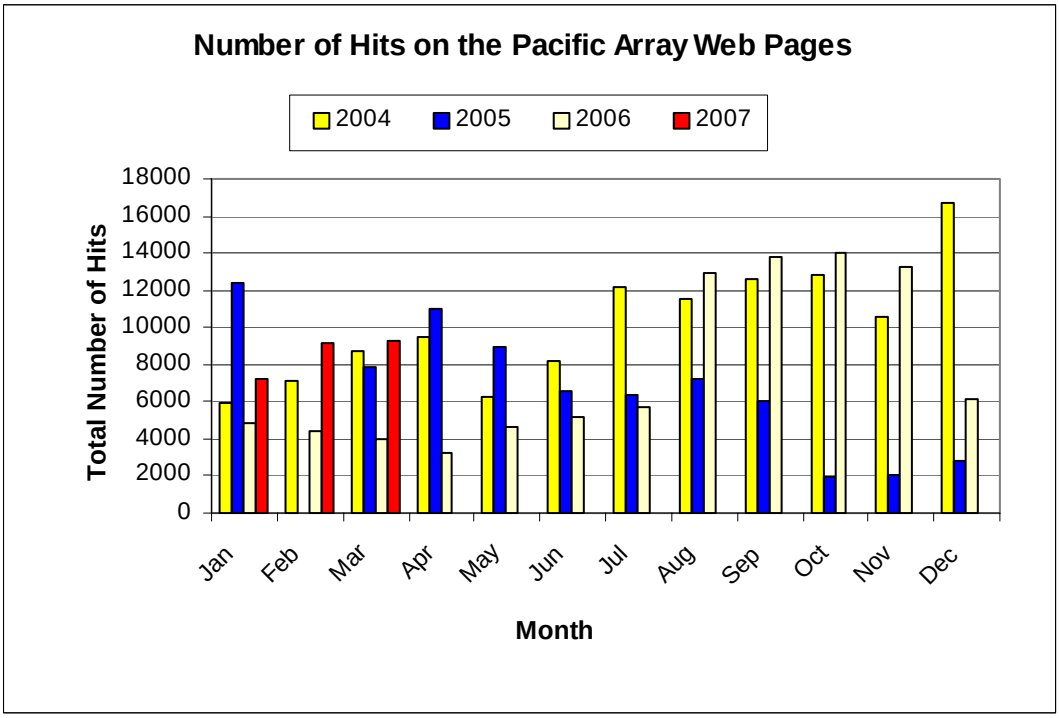
(2) Secondary water level (or backup) using a Druck pressure transducer mounted close to the seabed.

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 2004. 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:

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Fax: (+618) (08) 8366 2693
Website: http://www.bom.gov.au/oceanography

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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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

# MARCH 2007
# SIX MINUTE WATER LEVEL OBSERVATIONS (m)

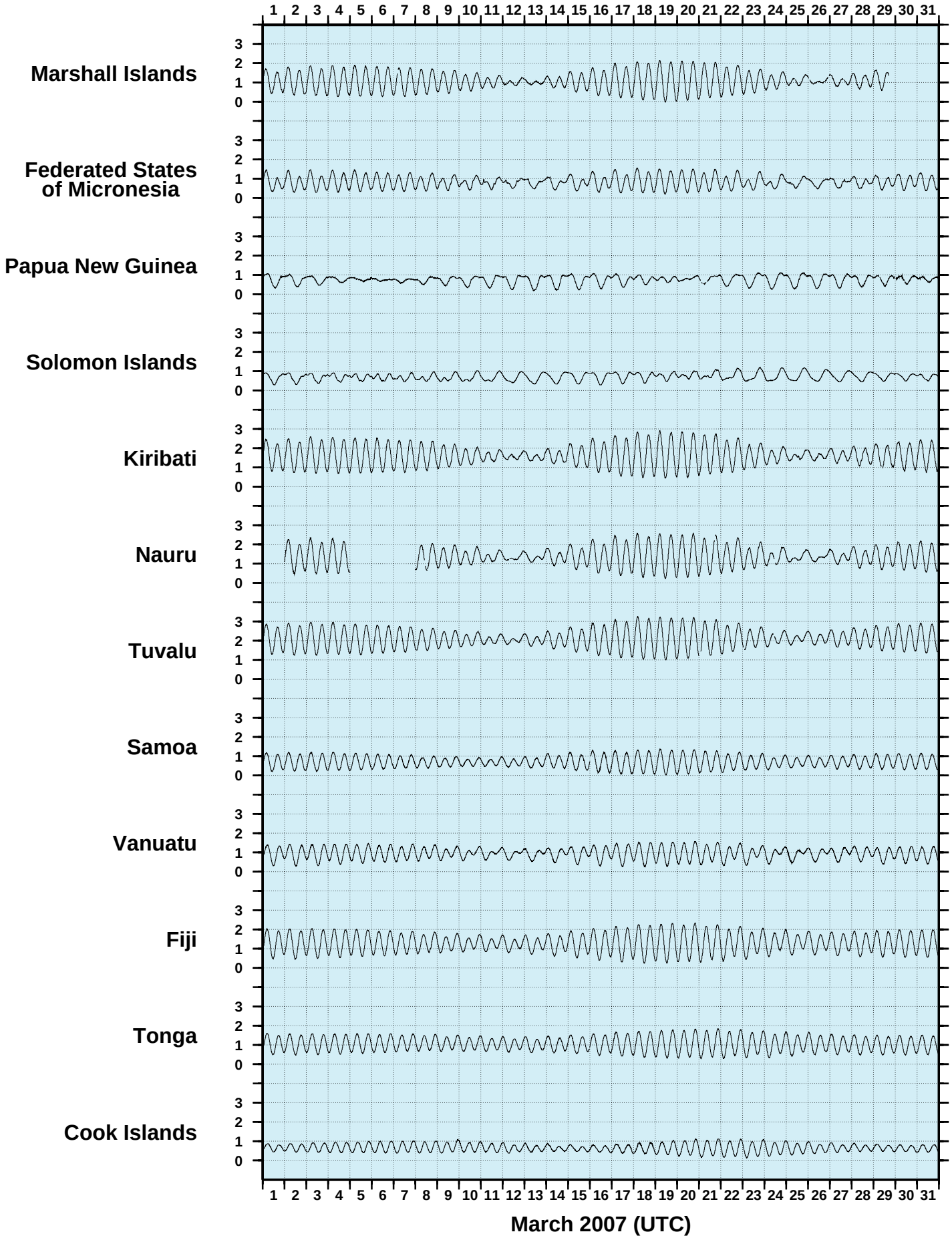


Figure 2

# MARCH 2007
# SIX MINUTE RESIDUAL WATER LEVELS (m)

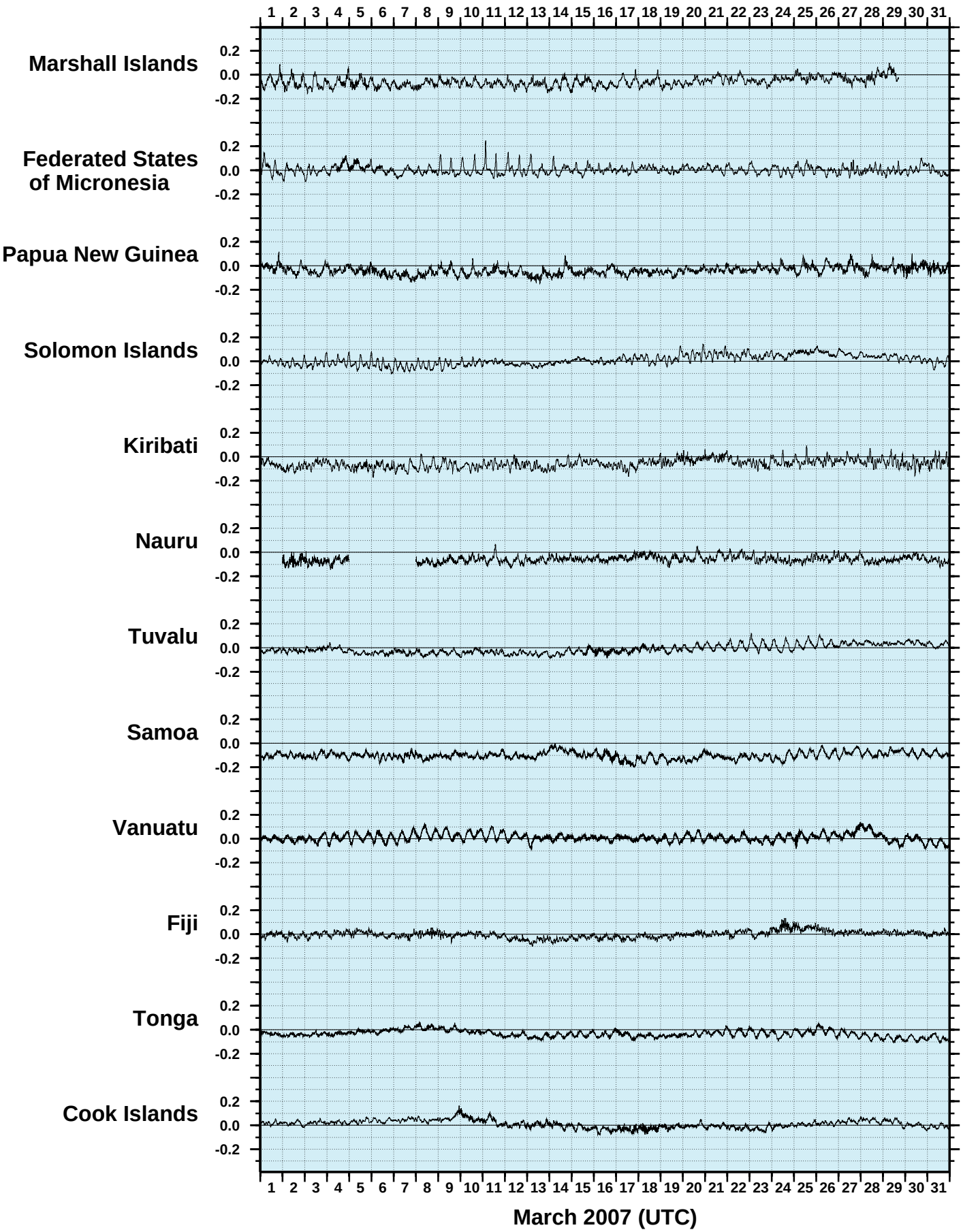


Figure 3

# MARCH 2007
# SIX MINUTE RESIDUALS
# ADJUSTED FOR ATMOSPHERIC PRESSURE (m)

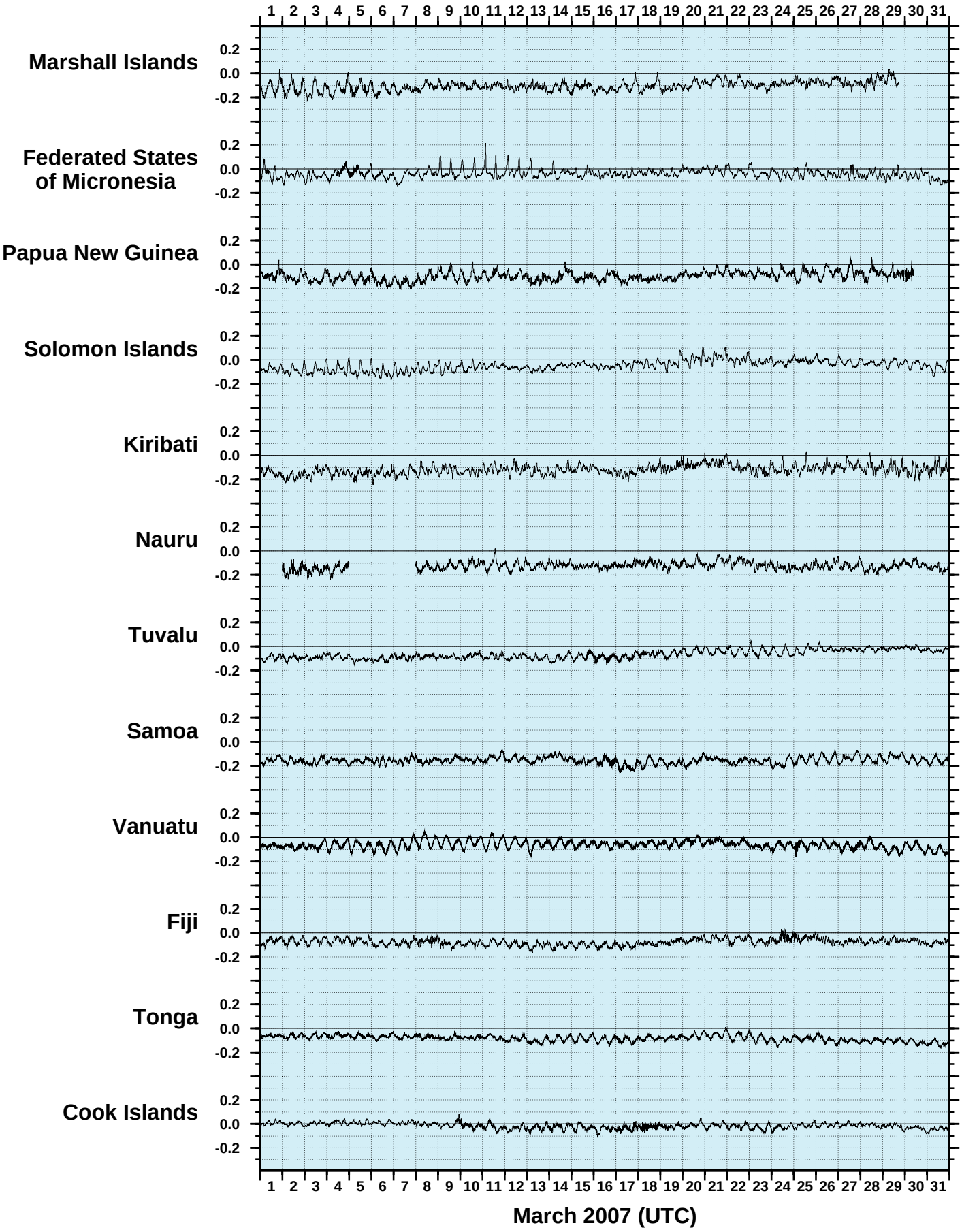


Figure 4

# MARCH 2007
# HOURLY WIND SPEEDS (m/s)

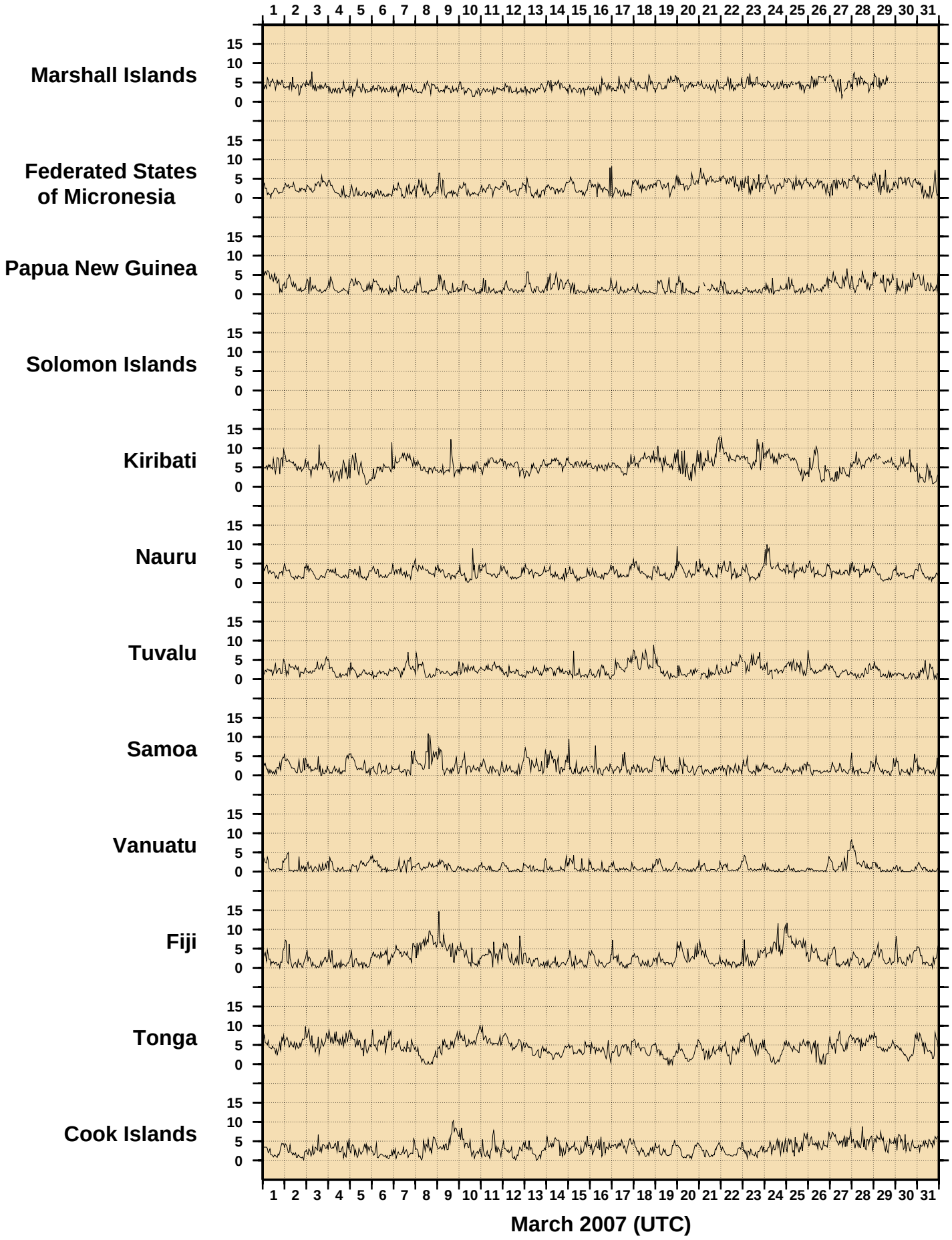


Figure 5

# MARCH 2007
# HOURLY INCIDENT WINDS (m/s, deg True)

—— 10 m/s

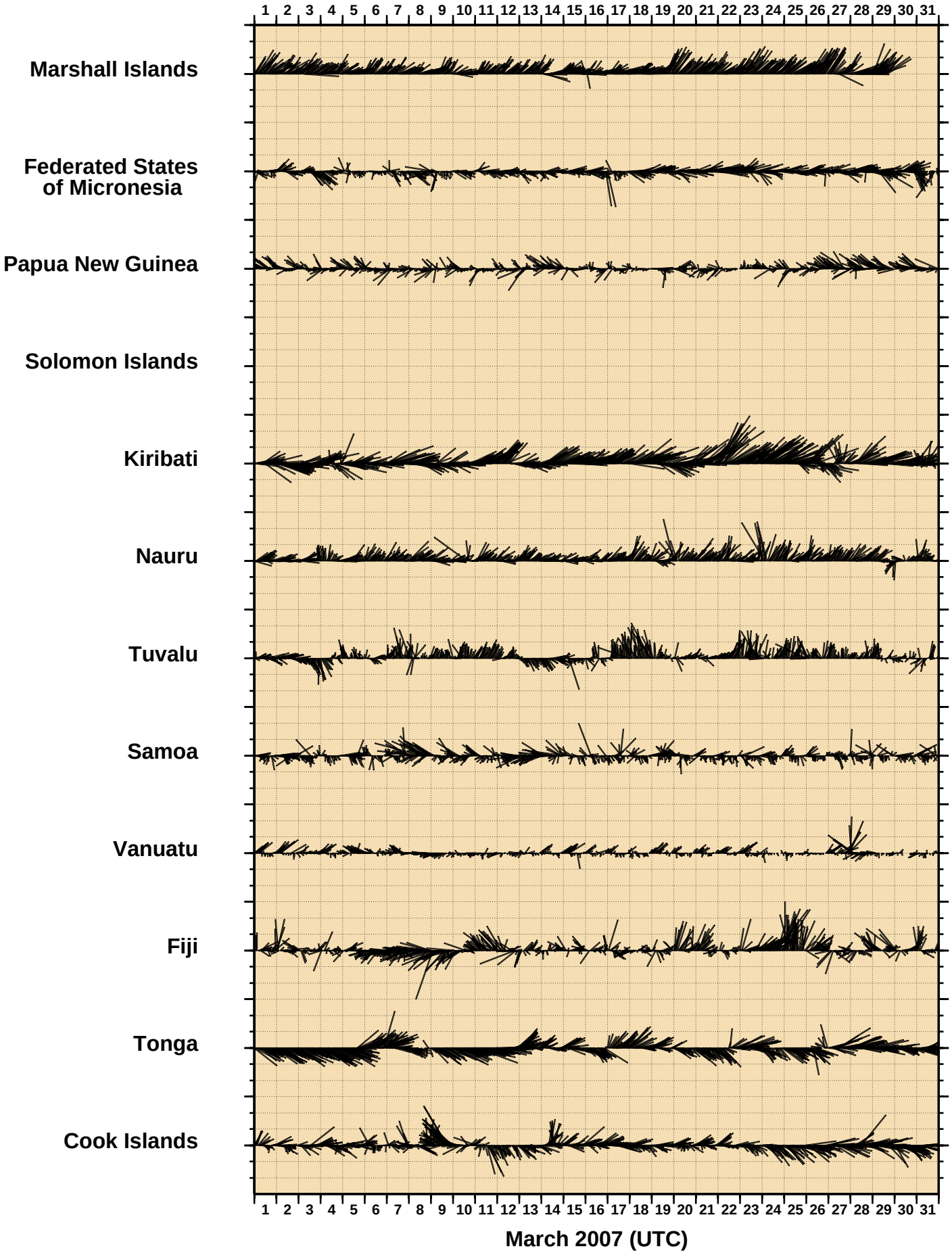


Figure 6

# MARCH 2007
# HOURLY MAXIMUM WIND GUSTS (m/s)

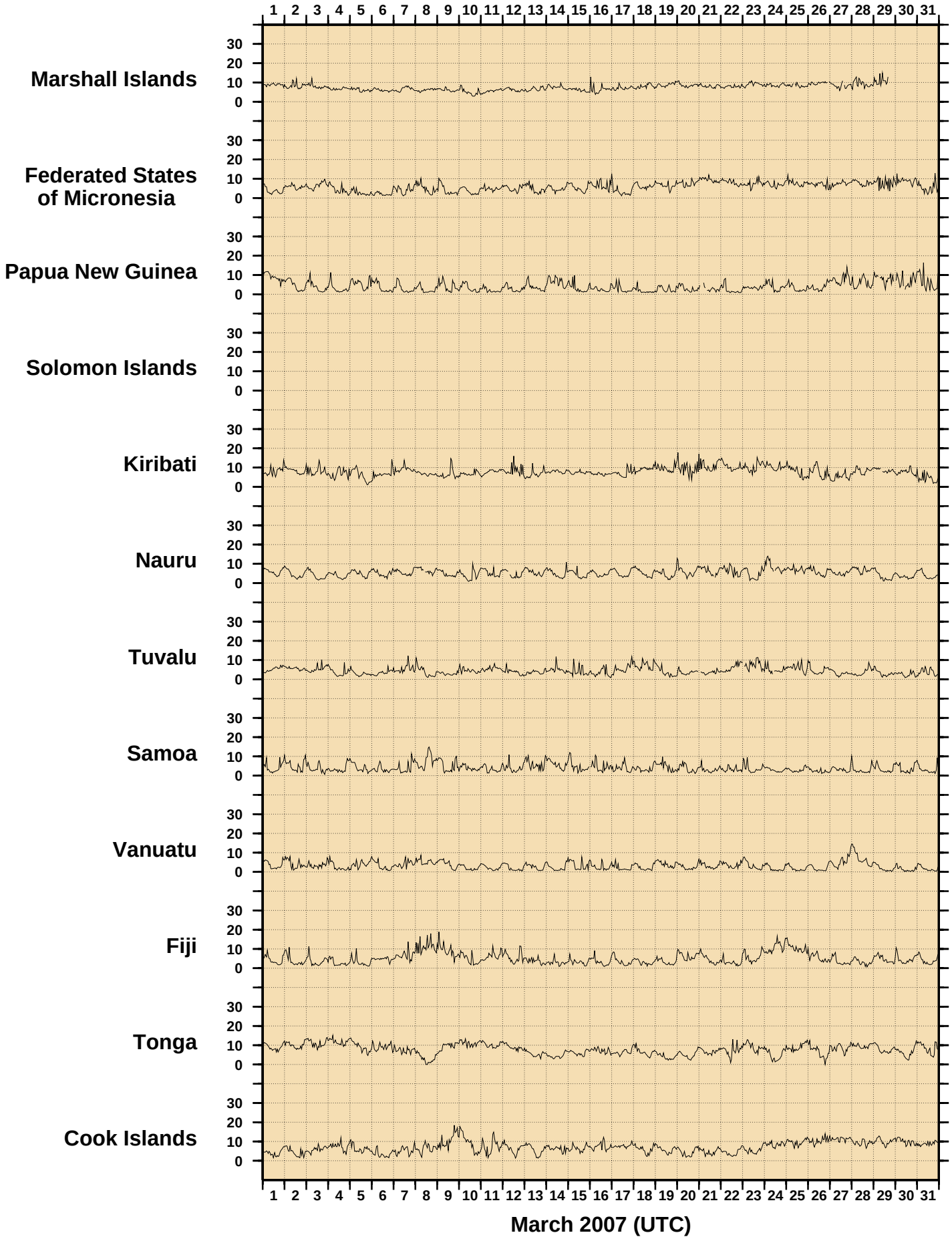


Figure 7

# MARCH 2007
# HOURLY AIR TEMPERATURES (°C)

Figure 8

# MARCH 2007
# HOURLY WATER TEMPERATURES (°C)

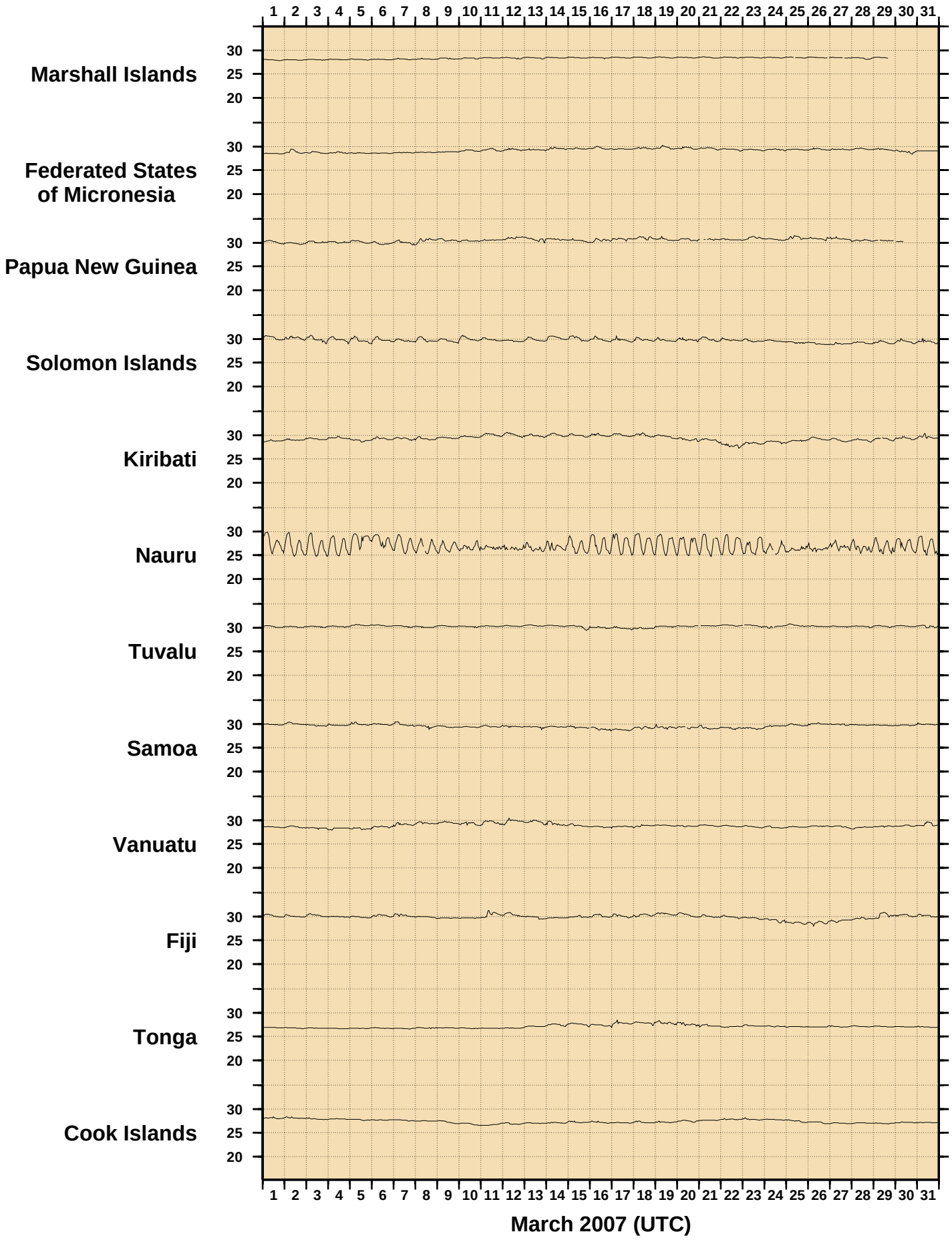


Figure 9

# MARCH 2007
# HOURLY ATMOSPHERIC PRESSURE (hPa)

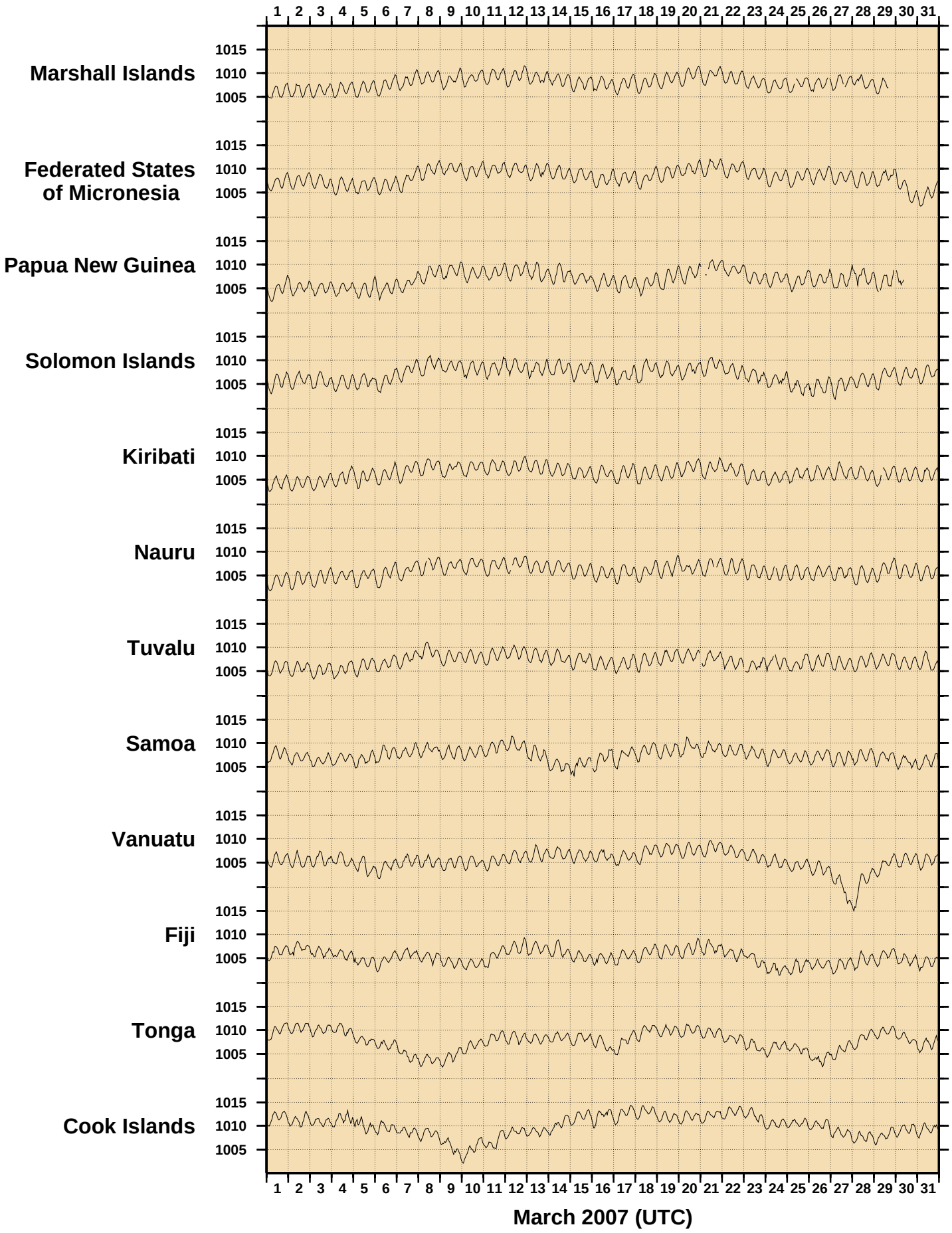
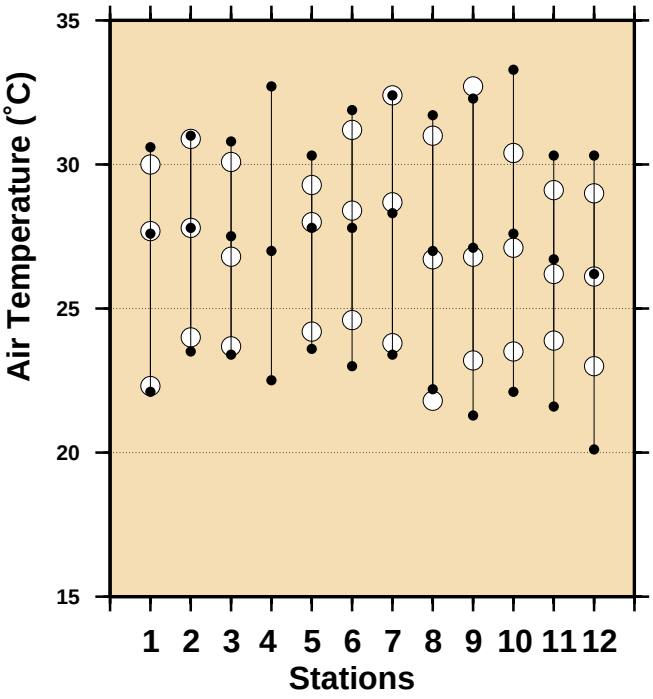
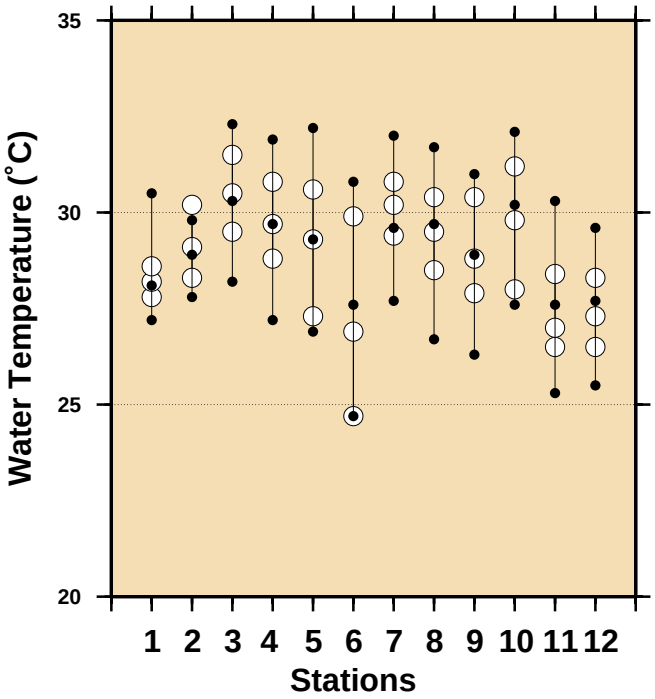
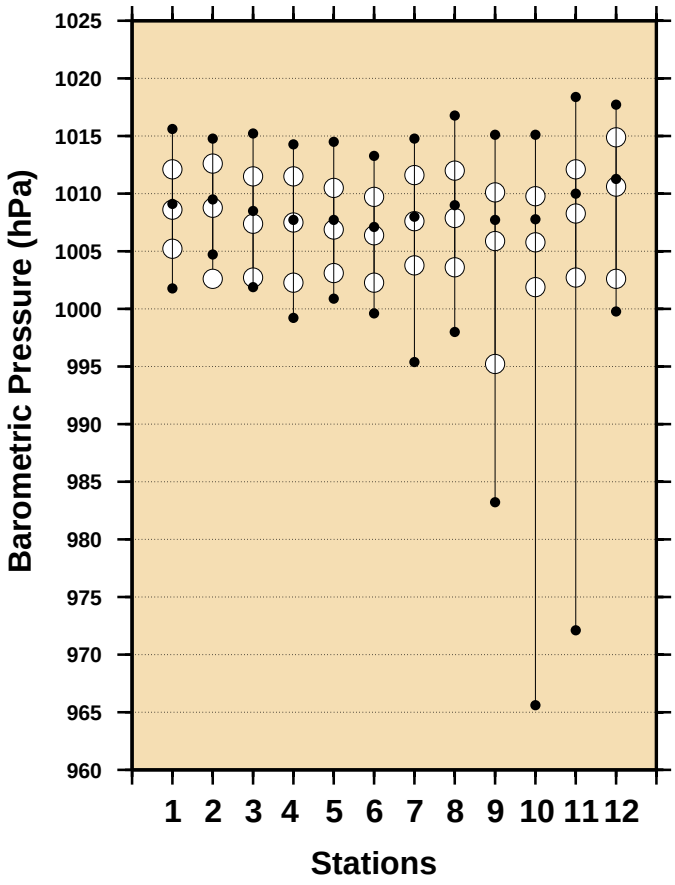


**Figure 10**

## Comparison of March 2007 Max, Min & Mean with Long Term March 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

March 2007 Maximum
March 2007 Mean
March 2007 Minimum

Long Term March Maximum
Long Term March Mean
Long Term March Minimum

**Figure 11**

# MONTHLY MEAN SEA LEVELS TO MARCH 2007 (m)

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

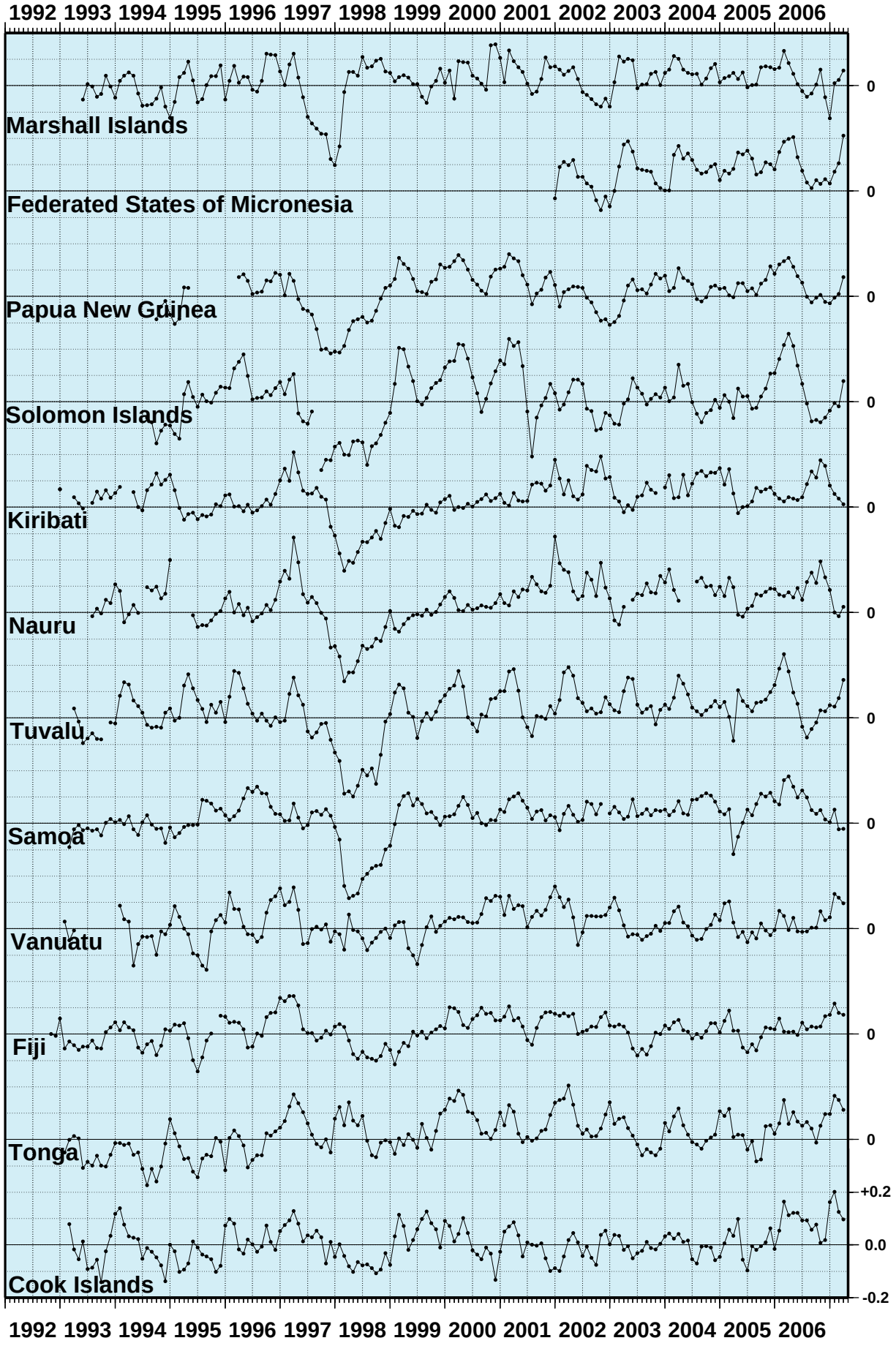


Figure 12

# SEA LEVEL ANOMALIES THROUGH MARCH 2007 (m)

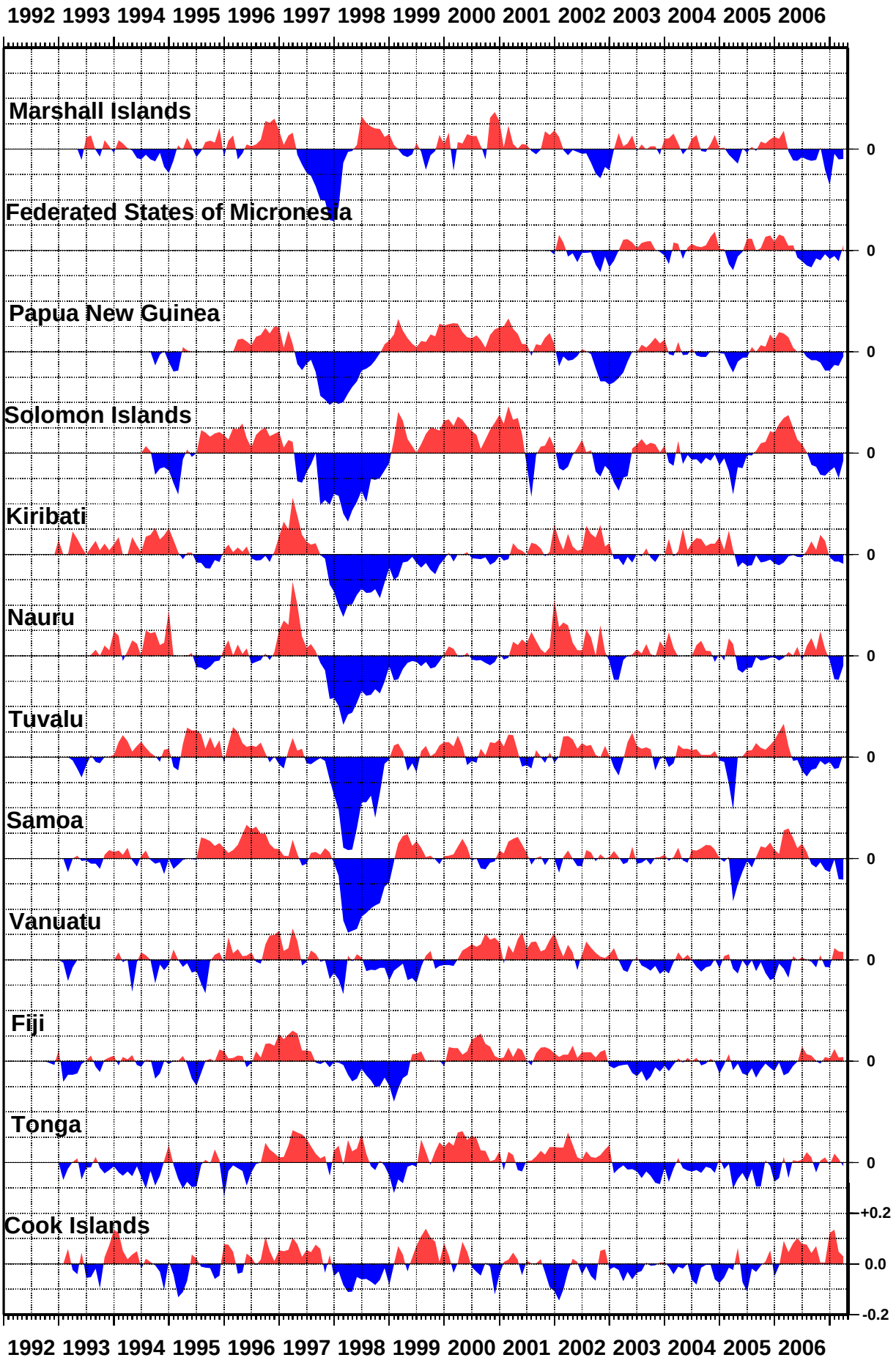


**Figure 13**

# SEA LEVEL TRENDS THROUGH MARCH 2007 (mm/year)

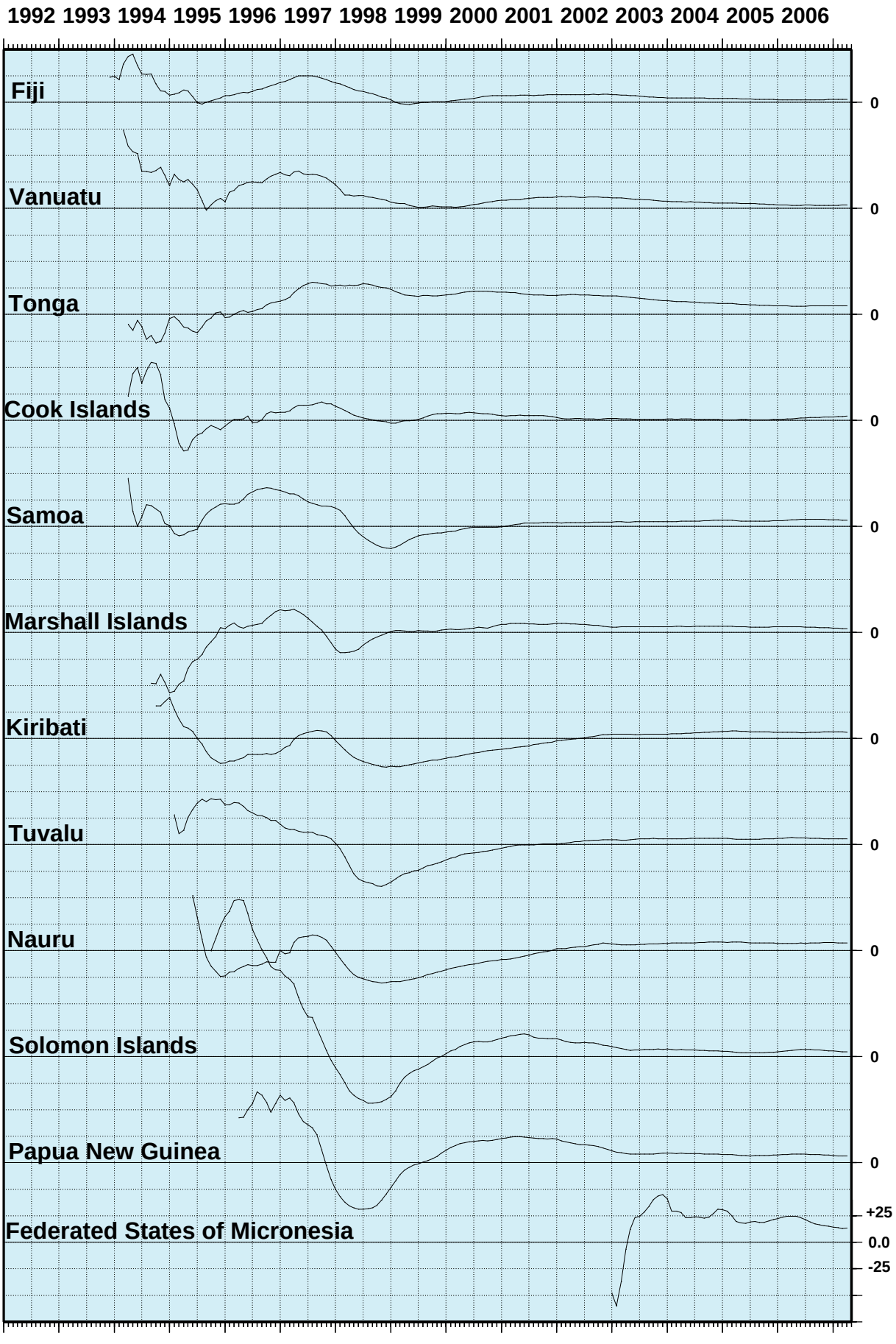


Figure 14

# BAROMETRIC PRESSURE ANOMALIES THROUGH MARCH 2007 (hPa)

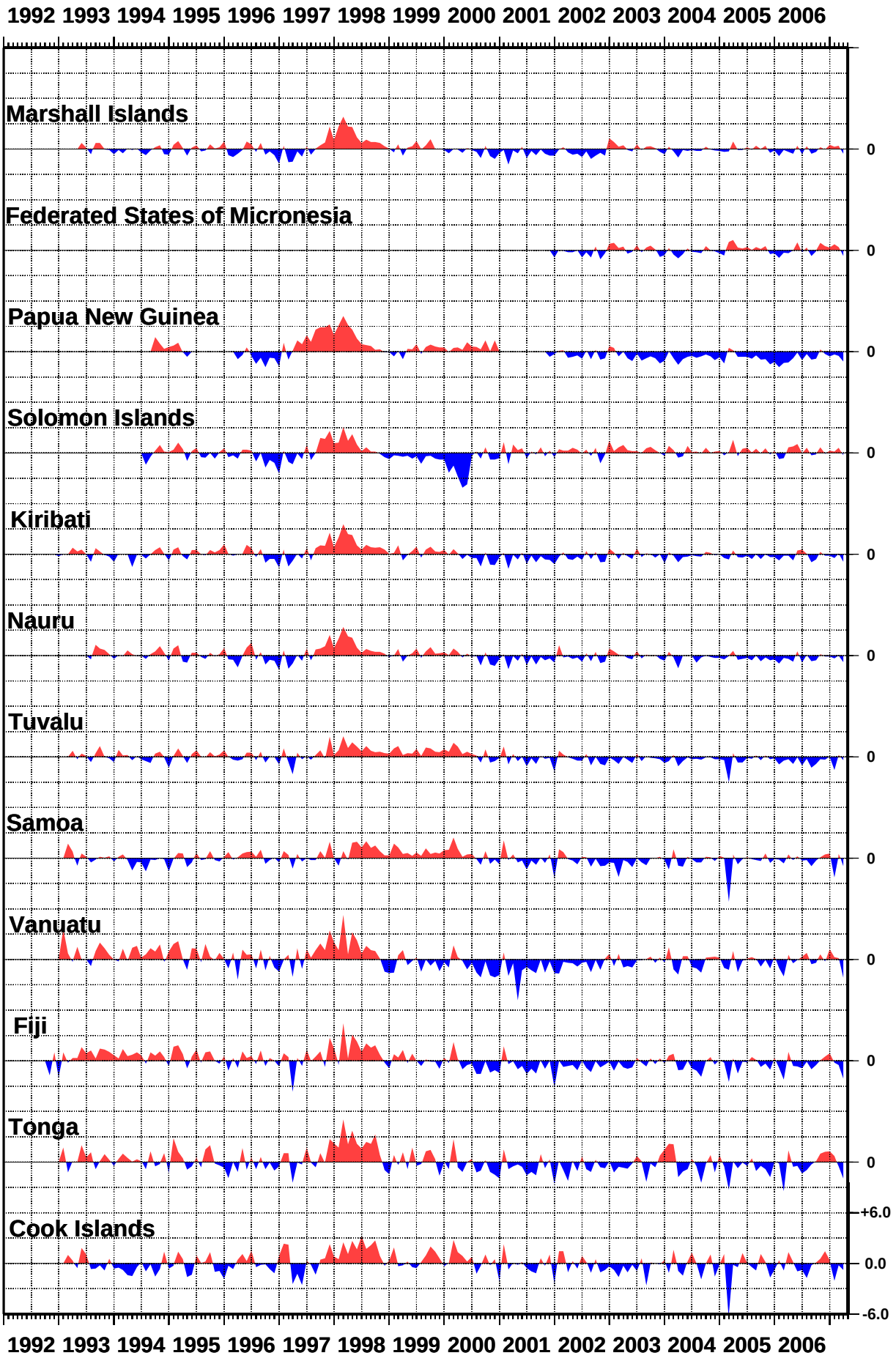


Figure 15

# WATER TEMPERATURE ANOMALIES THROUGH MARCH 2007 (˚C)

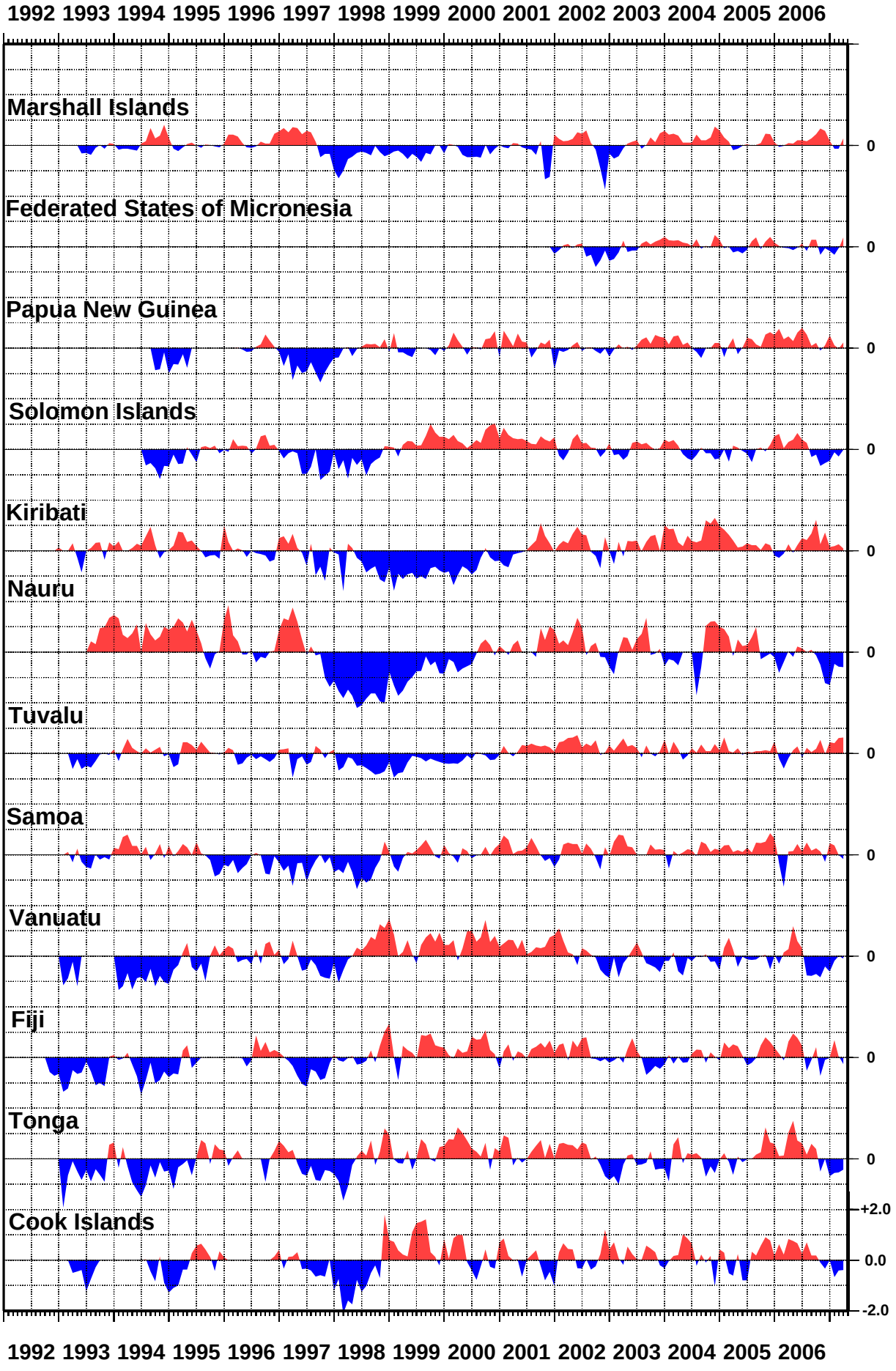


Figure 16

# AIR TEMPERATURE ANOMALIES THROUGH MARCH 2007 (˚C)

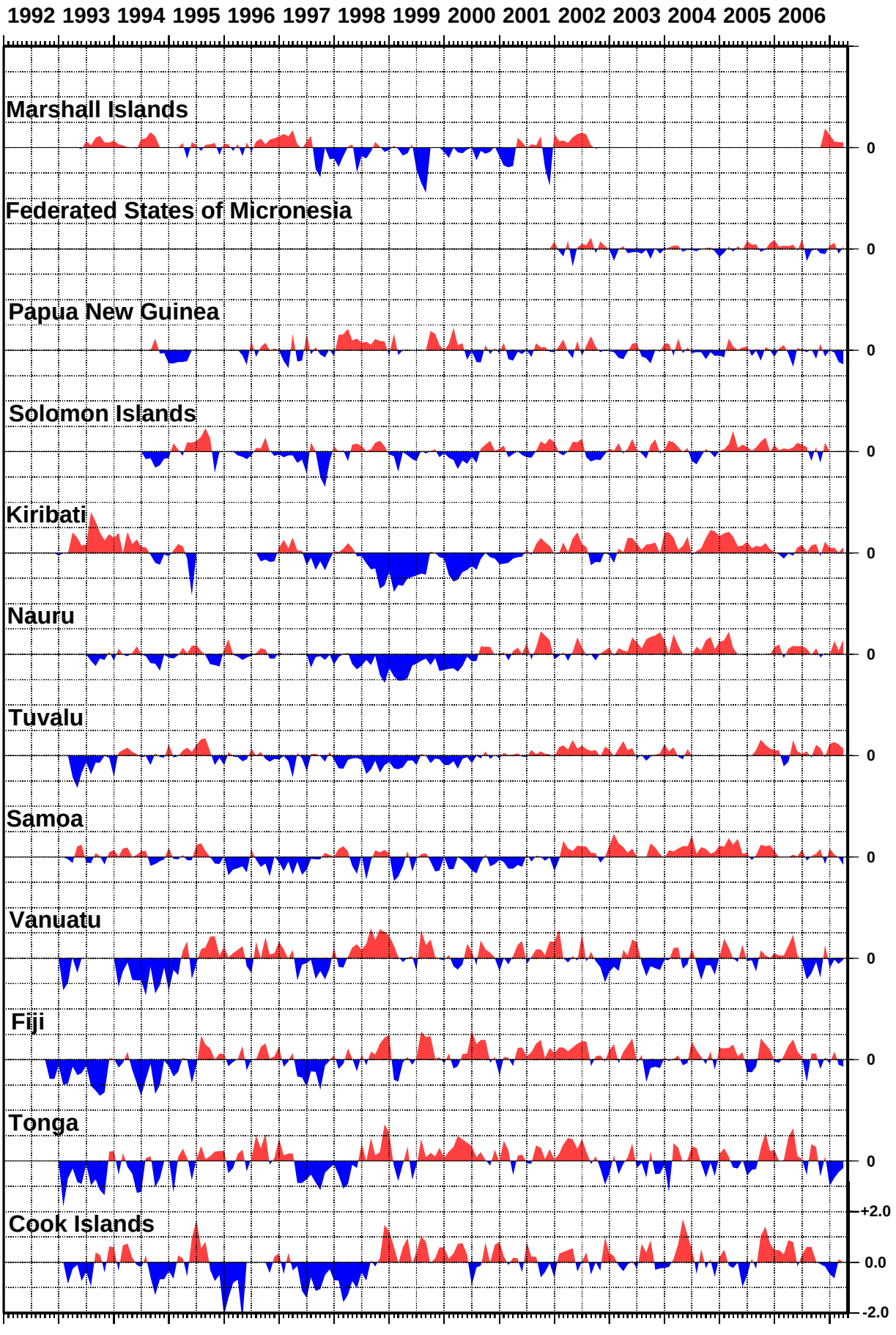


Figure 17

# SEA LEVEL DATA RETURN

THE NUMBER OF DAYS OF GAP ARE INDICATED

GAPS INCLUDE TRANSMISSION, POWER AND LOGGER FAILURE

* Patchy record