Smithsonian Tropical Research Institute
Physical Monitoring Program
Bocas Tower Weather Station - Parameters

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1 Introduction

The Bocas del Toro Field Station is located on Colon Island in Bocas del Toro province near the border with Costa Rica. To the east is the Caribbean Sea and to the west is a large enclosed bay containing extensive coral reefs and grassbeds surrounded by banana plantations, farms, and forests including extensive mangroves. The area is rapidly being developed for tourism.

Between 2002 and 2005, NOAA operated a weather station at the Bocas Field Station, which recorded hourly values of oceanographic and meteorological data, including Air Temperature, Relative Humidity, Solar Radiation, Ocean Temperature, Wind Speed and Wind Direction. By mid 2005 STRI installed its own automated weather station over the bay located to the west of the Field Station ($9^o21'02.96''N, 82^o15'28.27''W$), and since then it has been collecting oceanographic and meteorological data at 15 minute intervals. The STRI weather station consists of a 10m tall tower sitting on wooden-floored platform installed over the ocean.

2 Variables Measured

The Bocas weather station is fully automated. The station measures physical variables using a 10s sampling rate and records 15min maximum, minimum and average values for Solar Radiation, Air Temperature, Relative Humidity and Wind Speed. In addition, the station records the 15min Wind Direction Vector Mean and its standard deviation, the 15min rainfall total, plus samples 15min values for Ocean Temperature and Tide level.

2.1 Tide Level

Currently, the Tide level is given as the distance between the Ocean Surface at the sensor head in meters. In order to compute the **Tide level in centimeters (cm)** in terms of Average Sea Level, use the **wdist** value given (file BOCAS_TOWER_WDIST_M.DBF.CSV) and plug it into the formula: $(2.3252 - wdist) \times 100$.

The table below lists the variables measured, along with the corresponding units.

Variable	Units
Solar Radiation	W/m^2
Air Temperature	Celsius
Relative Humidity	%
Wind Speed	km/h
Wind Direction	Degrees from magnetic north
Rainfall	mm
Ocean Temperature	Celsius
Tide (wdist)	m

3 Data Files

3.1 Data File Descriptions

Description of the contents for each on the comma separated value (.csv) formatted files.

Filename	Contents
BOCAS_TOWER_SRN_M.DBF.csv	Average solar radiation - North pyranomter
BOCAS_TOWER_SRNMN_M.DBF.csv	Minimum solar radiation - North pyranometer
BOCAS_TOWER_SRNMX_M.DBF.csv	Maximum solar radiation - North pyranometer
BOCAS_TOWER_SRS_M.DBF.csv	Average solar radiation - South pyranomter
BOCAS_TOWER_SRSMN_M.DBF.csv	Minimum solar radiation - South pyranometer
BOCAS_TOWER_SRSMX_M.DBF.csv	Maximum solar radiation - South pyranometer
BOCAS_TOWER_WS_M.DBF.csv	Average wind speed
BOCAS_TOWER_WSMN_M.DBF.csv	Minimum wind speed
BOCAS_TOWER_WSMX_M.DBF.csv	Maximum wind speed
BOCAS_TOWER_WDVM_M.DBF.csv	Wind direction vector mean
BOCAS_TOWER_WDSD_M.DBF.csv	Wind direction standard deviation
BOCAS_TOWER_AT_M.DBF.csv	Average air temperature
BOCAS_TOWER_ATMN_M.DBF.csv	Minimum air temperature
BOCAS_TOWER_ATMX_M.DBF.csv	Maximum air temperature
BOCAS_TOWER_RH_M.DBF.csv	Average relative humidity
BOCAS_TOWER_RHMN_M.DBF.csv	Minimum relative humidity
BOCAS_TOWER_RHMX_M.DBF.csv	Maximum relative humidity
BOCAS_TOWER_RA_M.DBF.csv	Total rainfall
BOCAS_TOWER_WT_M.DBF.csv	Sample ocean temperature
BOCAS_TOWER_WDIST_M.DBF.csv	Sample distance between the ocean surface and the sensor head

3.2 Data Labels

The data files listed above, contain a header with labels describing the content of the corresponding data columns. The meaning of these labels is detailed in the table below. Missing data records are marked with either -1.00 or -9.00.

Label	Description
date_t	Datetime
at	Air Temperature
atmn	Air Temperature Minimum
atmx	Air Temperature Maximum
ra	Rain
rh	Relative Humidity
rhmn	Relative Humidity Minimum
rhmx	Relative Humidity Maximum
sr	Solar Radiation
srmn	Solar Radiation Minimum
srmx	Solar Radiation Maximum
wdsd	Wind Direction Standard Deviation
wdvm	Wind Direction Vector Mean
ws	Wind Speed
wsmn	Wind Speed Minimum
wsmx	Wind Speed Maximum
wdist	Distance between the Ocean Surface and the Sensor Head
wt	Water Temperature (Ocean Temperature)
tag	Marks an unusual aspect of a data point
ss	Sensor Substitution Code (1)
ds	Datum Status Level (2)
pt	Point Measurement (3)

1. Sensor Substitution Code: Marks data that was substituted from another sensor.

2. Datum Status Level: As data is checked for errors it will move up a series of data quality levels - currently this mechanism in being designed. If this field is empty or if it contains an L (Legacy Data) it means that the data has not been checked for errors, i.e. raw data.

3. Point Measure: It indicates whether the measurement is a point measure, i.e. a sample, or not.

4 Current Instruments

List of the current instruments operating at the Bocas weather station.

- Datalogger - CR1000, Campbell Scientific Inc.
- Solar Radiation - LI200S, LI-COR Biosciences.
- Temperature and Relative Humidity - CS215, Campbell Scientific Inc.
- Wind Speed and Direction - RMY05103, R.M. Young.
- Rainfall - CS700, Campbell Scientific Inc.
- Ocean Temperature - CS107, Campbell Scientfic Inc.
- Tide Level - Aquatrak 5000, Aquatrak Corp.

4.1 Datalogger

CR1000 datalogger. View the full specifications for this Datalogger at http://www.campbellsci.c
datalogger.

Figure 1: CR1000 Datalogger

4.2 Solar Radiation Sensor

Solar radiation is measured with LI-COR LI200S pyranometers. The LI-200S measures incoming solar radiation with a silicon photovoltaic detector mounted in a cosine-corrected head. The current output from the LI-200S, which is directly proportional to solar radiation, is calibrated against an Eppley Precision Spectral Pyranometer under natural daylight conditions (400 to 1100nm) in units of watts per square meter ($\frac{W}{m^2}$).

Figure 2: LI200S pyranometer

LI200S Specifications

Stability:	$< \pm 2\%$ change over a 1 year period
Response Time:	$10\mu s$
Cosine Correction:	Cosine corrected up to 80^o angle of incidence
Operating Temperature:	-40 to $+65$ ^oC
Relative Humidity:	0 to 100%
Accuracy:	Absolute error in natural daylight is $\pm 5\%$ maximum; $\pm 3\%$ typical
Sensitivity:	$0.2kWm^{-2}mV^{-1}$
Linearity:	Maximum deviation of 1% up to $3000\frac{W}{m^2}$
Light Spectrum Waveband:	400 to $1100nm$

Spectral Response

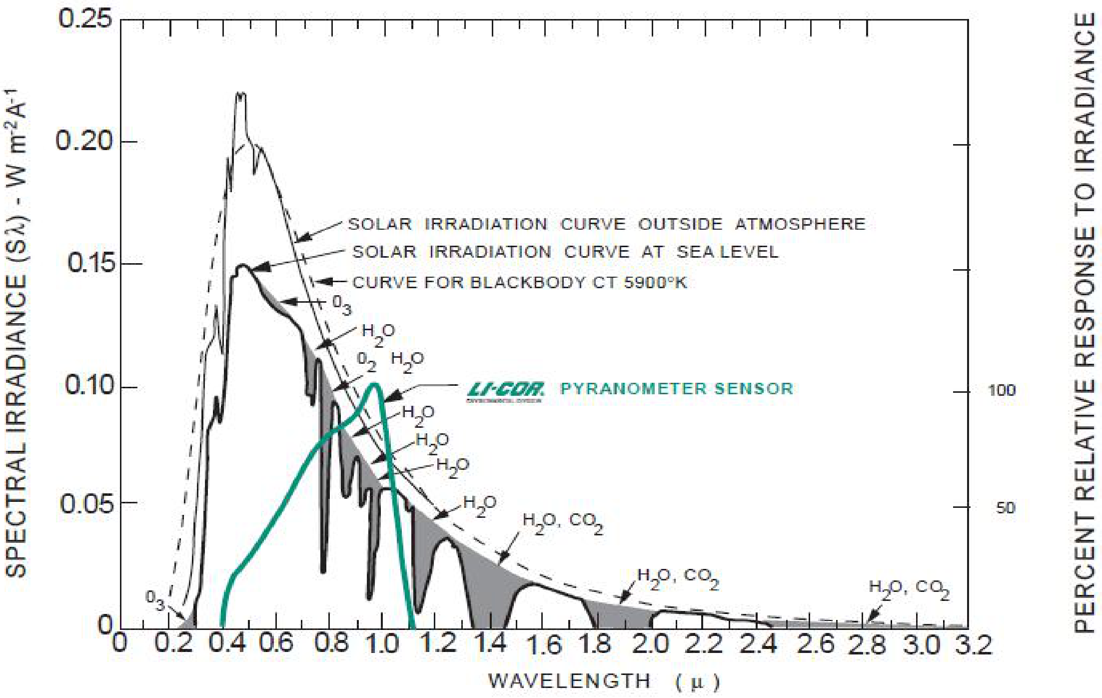

Figure 3: LI200S % of Relative Response

4.3 Temperature and Relative Humidity Sensor

Temperature and Relative Humidity are measured using a CS215 T&RH probe from Campbell Scientific. The CS215 probe uses a single chip element (SHT75 from Sensirium AG) that incorporates both a Silicon Bandgap Temperature sensor and a Capacitive RH sensor. In the field, this sensor is deployed inside a non-aspirated radiation shield.

Figure 4: CS215 Sensor

CS215 Specifications

Temperature Measurement	
Operating Range:	-40 to $+70^oC$
Accuracy:	$\pm0.3^oC$ at 25^oC, $\pm0.4^oC$ over $+5$ to $+40^oC$ $\pm0.9^oC$ over -40 to $+70^oC$
Response Time:	$120s$ (63% response time in air moving at $1ms^{-1}$)
Relative Humidity	
Operating Range:	0 to 100% RH (-20 to $+60$ ^oC)
Accuracy:	$\pm2\%$ over 10 to 90%, $\pm4\%$ over 0 to 100%
Short Term Hysterisis:	$< 1\%$ RH
Temperature Dependence:	Compensated to better than $\pm2\%$ over -20 to 60^oC
Stability:	Better that $\pm1\%$ per year
Response Time:	$< 10s$ (63% response time in air moving at $1ms^{-1}$ and $< 85\%$ RH)

4.4 Wind Speed and Wind Direction Sensor

Wind Speed and Wind Direction are measured using a 05103 propeller type Wind Monitor from R.M.Young. The Wind Speed is measured with a helicoid-shaped, four-blade propeller and the Wind Direction, i.e. Vane position, is measured by the rotation of a 10 kOhm potentiometer.

Figure 5: 05103 Wind Monitor

05103 Specifications

<u>Wind Speed</u>

Range:	0 to $360 Km/hr$
Accuracy:	$\pm 1.08 Km/hr$ or 1% of the reading
Starting Threshold:	$3.6 Km/hr$
Distance Constant: **(63% Recovery)**	$2.7m$

<u>Wind Direction</u>

Range:	0 to 360^o mechanical 355^o electrical (5^o open)
Accuracy:	$\pm 3^o$
Starting Threshold at 10^o **displacement**:	$3.96 Km/hr$
Delay Distance (50% **recovery**):	$1.3m$
Damping Ratio:	0.3
Damped Natural Wavelength:	$7.4m$
Undamped Natural Wavelength:	$7.2m$

4.5 Rainfall Sensor

The rainfall is measured with a CS700 rain gauge from Campbell Scientific. The rain funnels into a tipping bucket mechanism that tips for every 0.254mm of rain collected. Each tip is marked by a dual reed switch closure that is recorded by the datalogger.

Figure 6: CS700 Rain Gauge

CS700 Specifications

Measurement Range:	0 to 700mm/hr
Accuracy:	Better than +2% at 50mm/hr
Resolution:	0.254mm

<u>**Environmental Conditions**</u>

Temperature:	0 to +50^oC
Humidity:	0 to 100%

4.6 Ocean Temperature Sensor

The Ocean temperature is measured with a model 107 temperature probe from Campbell Scientific. The sensor uses a thermistor to measure temperature and it is designed to measure air/soil/water temperatures.

Figure 7: 107 Temperature Probe

107 Specifications

Measurement Range: -35^o to $+50^oC$
Temperature Survival Range: -50^o to $+100^oC$
Steinhart-Hart Equation Error: $\leq \pm 0.01^o$ over -35^o to $+50^oC$

4.7 Tide Gauge

Tide (sea level) is measured with a 5000 series sensor from Aquatrak Corporation. The sensor emits acoustic pulses that are sent to the liquid surface using a sounding tube. The pulses generate an echo upon striking the water surface and the time lag between the pulse generation and the echo return is used to calculate the distance between the sensor head and the liquid surface.

Figure 8: Aquatrak Sensor

AQUATRAK SPECIFICATIONS

Resolution:	$1mm$
Accuracy:	$\pm 0.025\%$
Precision-Repeatability:	$\pm 0.01\%$
Stability - Drift over 1 year:	0
Temperature Drift:	$< 1ppm/^{o}C$

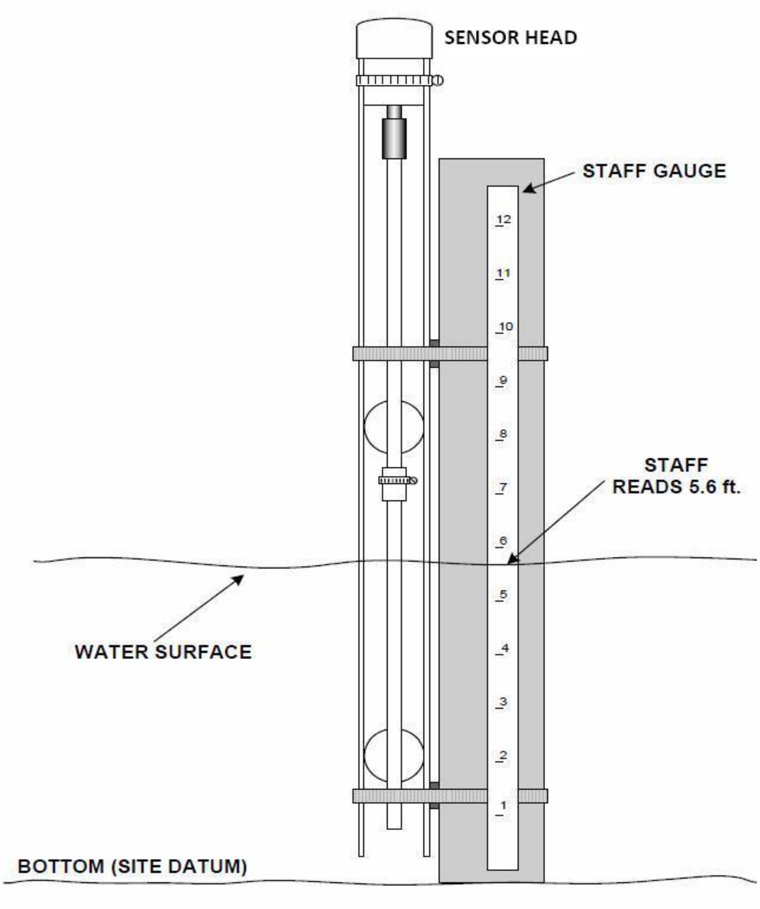

Figure 9: Aquatrak Tide Gauge Installation

5 Sensor Deployment Notes

This section provides detailed background information on the sitting of the sensors deployed at the Bocas weather station, and it aims at pointing out any shortcomings of the data collected at the station.

The World Meteorological Organization (WMO) has a set of guidelines for sensor sitting and exposure. However, in the field, it is not always possible to strictly follow these guidelines and as a result sometimes sensors are deployed in non-ideal conditions. Also, it should be noted that the Physical Monitoring Program provides local environmental data at sites of interest to STRI Scientists, therefore it deploys sensors at such sites instead of deploying sensors at sites that strictly meet standard guidelines for sensor deployment. Wherever the WMO guidelines are not met, the data may still be used to look at inter-annual variation/comparison of a parameter. Here we point out any shortcomings on the sitting of the sensors deployed at Bocas, and the corresponding implications for the data collected at the site.

5.1 Solar Radiation

There are two solar radiation sensors (pyranometer type) installed at the Bocas Weather Station. The pyranometers are installed on two arms (about 1m long) located arround 2m from the station's base platform. One arm extends from the tower to the south and the other to the north. From September to mid April, in Panama, the sun follows a southern path and consequently during this period, and around 12:00 noon, the tower casts a shadow on the north facing pyranometer. Similarly, between mid April to the end of August the sun follows a Northern path and the tower casts a shadow on the south facing pyranometer.

5.2 Wind

According to WMO guidelines the standard exposure of wind instruments over level, open terrain is 10m above ground. Where "open terrain is defined as an area where the distance between the anemometer and any obstruction is at least 10 times the height of the obstruction." For an instrument installed over the Ocean the WMO guidelines indicate that the anemometer should be mounted 10m above the water line. [WMO, 2008]

At the Bocas Weather Station the anemometer is installed at the top of a 10m tall tower, and consequently it is roughly 10m above the water line. However, the forest at the Bocas Field station, located to the North and East of the weather station, has an average canopy height around 20m and the forest edge is roughly 100m away from the anemometer. As it stands, the forest blocks the Northeast winds (trade winds) blowing from the Caribbean and these are not properly registered by the Bocas anemometer.

5.3 Rainfall

Rainfall measurements provided by tipping bucket type raingauges, such as the one deployed at the Bocas station, are influenced by the wind field of the immediate surroundings. More specifically, the raingauge acts as an obstruction to the wind, causing the wind to speed up over the top of the collector and around its sides, while eddies form within the collector. Speeding up over the top causes some drops to miss the gauge, i.e. forces drops to pass over it, while the eddies can lift drops out of the funnel. These two disturbances caused by the wind field result in the raingauge underestimating the amount of rainfall. Also, these disturbances increase with wind speed, and this in turn increases with height, and so too do the losses. Furthermore, it is known that a rainguage located at a height of about 10m above ground on open terrain will underestimate the amount of rain by as much as 20%, while a rainguage located at 45m above ground will have an error of about 50%. [Strangeways, 2003]

Given the above, ideally a raigauge should be installed on the ground and with homogeneous dense vegetation that is kept the same height as the gauge via regular clipping. At the Bocas Weather Station the raiguage is attached to the side of the tower (on a 1m long arm) at about 4m above the water line. As such the Bocas rainguage underestimates the amount rainfall.

6 Historical Notes - recent history

- May 13, 2010 - Replaced the battery by a new 12V, 24AH battery. The previous battery's voltage was dropping 10.6V during the night. Installed a new datalogger CR1000 S/N : 31713. Removed the datalogger CR10X $S/N : X35151$. The station was converted to Pakbus.

- February 5, 2010 - The battery was replaced by a 12V, 17AH battery. The previous battery's voltage was dropping 10.6V during the night.

- January 19, 2010 - Installed a new Temp&RH sensor CS215 $S/N : E3989$. Removed the Temp&RH sensor HMP45C $S/N : Y3250082$.

- August 4, 2009 - Installed Temp&RH sensor HMP45C $S/N : Y3250082$. Removed the Temp&RH sensor CS500 S/N : 300868. On July 15, 2009 the CS500 sensor started to give bad air temperature readings and subsequently it went into failure.

- April 3, 2009 - The tide gauge was fixed on this date. The gauge was not operational since the Feb. 4th replacement of the datalogger - wiring problem.

- April 1, 2009 - Both pyranometers were replaced. Installed pyranometers: North LI-COR PY61708, South LI-COR PY61697. Removed pyranomters: North LI-COR PY48833, South LI-COR PY48820.

- April 1, 2009 - Replaced the anemometer by a calibrated/repaired anemometer, S/N : 40007. Removed anemometer S/N : 59509.

- February 4, 2009 - A calibrated CR10X logger with serial number $S/N : X35152$ was installed. It replaced the CR10X logger with $S/N : X39060$.

References

[WMO, 2008] World Meteorological Organization (2008) *Guide to Meteorological Instruments and Methods of Observation*. WMO Geneva, Switzerland.

[Strangeways, 2003] Strangeways, Ian (2003) *Measuring the Natural Environment*. Cambridge University Press, Cambridge, U.K.