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Technical Note

An Integrated Weather Station System

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T. A. Rajesh & S. Ramachandran

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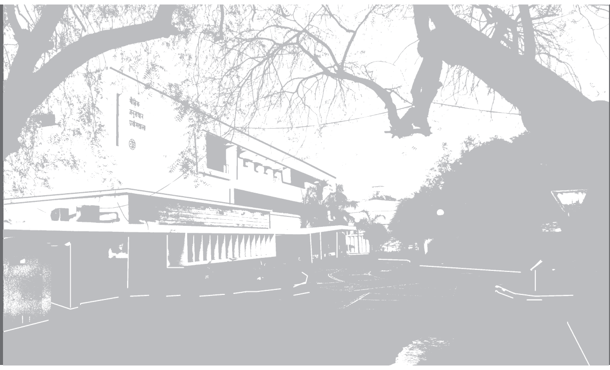

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An Integrated Weather Station System

T. A. Rajesh*[1], S. Ramachandran[1]

Abstract
In this technical note, we discuss about the design, development and implementation of the state–of the– art integrated weather station system (IWSS) for fixed and moving platform (Ship). The IWSS consists of weather transmitter for monitoring meteorological parameters, global positioning system (GPS) receiver, solar radiation sensor for the measurement of total (direct and diffuse) solar irradiance reaching the Earth's surface, and digital compass sensor for the measurement of heading and tilt of its mount on a moving platform (ship). The IWSS graphical user interface application software used to acquire data from each sensor has been developed in–house using Microsoft Visual Basic rapid application development language. As an application case study, we have discussed about the system implemented at two geographically distinct locations over land (Ahmedabad and Mt. Abu). The details of the various sensors and the data acquisition & control software are presented in this technical report.

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Contents

1. Introduction

Sensing the winds and weather has been important to man over the centuries. These are of equal concern and can have an even greater impact on our modern, high-tech life style. Weather affects a wide range of man's activities, including agriculture, and transportation. The affects involve the transport (short and long range) of gases and particulates matter through the atmosphere.

The conventional weather monitoring system consisted of individual sensors to measure one meteorological variable, each connected to a data collection device or logger. Modern technology has allowed the combination of several sensors into one integrated weather station. A weather station is a set of instruments for data collection on atmospheric phenomena, either on land or sea, in order to provide information for weather forecasts and to study the weather and climate. The measurements taken include temperature, relative humidity, barometric pressure, wind speed, wind direction, and precipitation. Temperature and humidity measurements are kept free from direct solar radiation and wind measurements are taken as free from any obstructions. The weather stations are used exclusively over the various land location throughout the globe, but when it is operated over a moving platform (like ship) the wind direction data needs to be corrected with reference to moving platform. Typically, a compass sensor (heading data) is used to obtain the ship heading information and used with the wind data from the weather station in order to obtain the corrected true wind direction. In the present work we have integrated a new generation weather station with total solar radiation sensor, global positioning system (GPS) receiver, and digital compass sensor. The GPS receiver is used exclusively on board a moving platform like Ship, in order to observe its varying geographical coordinates and to compute its heading information. A total solar radiation sensor (pyranometer) is used to measure the solar irradiance on the Earth's surface and quantify the presence of cloud. Table 1 illustrates the various sensors and the corresponding parameters been measured in the integrated weather station system. The state-of-the-art IWSS has been developed in-house with the objective to measure simultaneously the various surface meteorological parameters, solar irradiance reaching the Earth's surface over a fixed location and in addition to these; GPS and compass data are also observed on board a moving platform like Ship. In the meteorological calculations, typically scalar averaging are used for temperature, relative humidity, pressure, precipitation, and solar radiation. Winds being a vector quantity, the vector averaging for the horizontal wind speed and wind direction are computed as discussed below. From the sample of N observations of W_i (instantaneous horizontal wind direction) and U_i, (instantaneous horizontal wind speed) the mean east-west, V_e, and northsouth, V_n, components of the wind are,

$$V_e = \Sigma[U_i \sin(W_i)]/N \quad (1)$$

$$V_n = \Sigma[U_i \cos(W_i)]/N \quad (2)$$

The resultant mean wind speed and wind direction are,

$$WS = (V_e{}^2 + V_n{}^2)^{\frac{1}{2}} \quad (3)$$

$$WD = ArcTan(\frac{V_e}{V_n}) \quad (4)$$

Table 1. IWSS - sensors and measured parameters

Sr. No.	Sensors	Parameters
1	Weather station	Temperature, relative humidity, barometric pressure, wind speed, wind direction, and precipitation
2	Pyranometer	Total solar radiation
3	GPS receiver	Latitude, longitude, altitude, date, and time
4	Digital compass	Heading and tilt

Table 2. WXT520 weather station – sensors range and resolution

Sr. No.	Parameters	Sensors	Property
1	Wind speed	WINDCAP	Range: 0 to 60 m/s Resolution: 0.1 m/s
2	Wind direction	WINDCAP	Range: 0 to 360° Resolution: 1°
3	Precipitation	RAINCAP	Resolution: 0.01 mm
4	Pressure	Capacitive silicon BAROCAP	Range: 600 to 1100 hPa Resolution: 0.1 hPa
5	Temperature	Capacitive ceramic THERMOCAP	Range: -52 to +60 °C Resolution: 0.1 °C
6	Humidity	Capacitive thin film polymer HUMICAP	Range: 0 to 100 %RH Resolution: 0.1 %RH

2. Weather Station

A weather station consists of combination of several meteorological instruments for the measurement of temperature, relative humidity, pressure, wind speed, wind direction, and precipitation. In the present study we have used Vaisala weather station WXT520 [1], which has the capability to measure six weather parameters; wind speed, wind direction, temperature, relative humidity, barometric pressure, and precipitation. The advantages of WXT520 weather transmitter are compact, lightweight, low power consumption, accuracy and stability, and lack of moving parts. Figure 1 shows the Vaisala WXT520 weather transmitter.

The WXT520 weather station uses WINDCAP sensor for wind measurements. The wind sensor has an array of three equally spaced ultrasonic transducers on a horizontal plane. The wind speed and directions are calculated by measuring the time it takes the ultrasound to travel from each transducer to the other two. The Vaisala RAINCAP sensor is used for the precipitation measurement and it comprises of piezoelectrical sensor mounted on the bottom of a steel cover. It detects the impact of individual raindrops and the signal is proportional to the volume of the drops. The measurement principle of the pressure, temperature, and relative humidity sensors are based on the RC oscillators and two reference capacitors against which the capacitance of the sensors are continuously measured. The capacitive silicon BAROCAP, capacitive ceramic THERMOCAP, and capacitive thin film polymer HUMICAP sensors are used for pressure, temperature, and relative humidity measurements respectively.

Table2 shows the WXT520 weather station sensors with its corresponding range and resolution. Its digital output can be configured as RS-232, RS-485, RS-422, or SDI-12 serial communication protocol. In the present work we have configured WXT520 weather station for RS-232 communication protocol.

3. Global Positioning System receiver

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into lower earth orbit (20,200 km) [2]. GPS satellites encircle the earth twice a day and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate its exact location. It compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine its position. A GPS receiver must be locked on to GPS satellites signal of at least four satellites to calculate its 3D position (latitude, longitude and altitude) with precise time. GPS works in any weather conditions, anywhere in the world, 24 hours a day. In the present work, we have used GPS Receiver from M/s Sunrom, model no. 1141 (Figure 2) [3], which is an ultra-sensitive GPS receiver and can acquire GPS signals from 65 channels of satellites and output position data with high accuracy in extremely challenging environments and under poor signal conditions due to its active antenna and high sensitivity. The output is TTL serial data of 9600 baud rate which is standard NMEA 0183v3.0 protocol. Table 3 lists the GPS receiver specifications.

Table 3. GPS receiver – specifications

Sr. No.	Parameters		Unit
1	Sensitivity	-160	dBm
2	Channels	65	65 parallel channels all in view searching L1 C/A code
3	Position accuracy	5	Meters
4	Velocity accuracy	0.1	Meters/Second
5	Time accuracy	0.1	μS sync GPS time
6	Time to first fix for first power on	33	Second approx.
7	Update rate	1	Hz
8	Frequency	1, 1575.42	Mhz
9	C/A code	1.023	Mhz chip rate
10	Protocol format	NMEA0183 V3.01	GGA, GLL, GSA, GSV, RMC, VTG

Table 4. Pyranometer – specifications

Sr. No.	Parameters	Specification
1	Spectral range	285 to 2800 nm
2	Sensitivity	9μV/W/m^2
3	Response time	5 s
4	Field of view	180 °
5	Maximum solar irradiance	4000 W/m^2
6	Linearity	±0.5%
7	Temperature dependence	±1% over ambient temperature range
8	Operating temperature range	-40 °C to +80 °C

4. Total solar radiation sensor

The total solar radiation is defined as the sum of direct and diffuse solar irradiance and it is measured using a pyranometer on a plane surface (Watt/ m2). We have used pyranometer from Eppley, model no. PSP (Figure 2) [4], which is a World Meteorological Organization (WMO) first class radiometer designed for the measurement of global solar radiation in the wavelength bands 285 to 2800 nm.

Table 5. Compass sensor – specifications

Sr. No.	Parameters	Specification
1	Sensor	3-D Magnetic Sensor Array
2	Heading measurement range	0 to 360°
3	Heading measurement resolution	0.1°
4	Tilt measurement range (Pitch, Roll)	45°
5	Tilt measurement resolution (Pitch, Roll)	0.1°
6	Operating Temperature	-40 °C to +65°C

Figure 1. Vaisala weather transmitter WXT520

The pyranometer is based on a thermopile sensor. The thermopile sensitive surface is coated with a black matt paint, which allows the pyranometer not to be selective at different wave lengths. The pyranometer spectral range is determined by the transmittance of the two glass domes type K5. Radiant energy is absorbed by the thermopile black surface, creating a difference of temperature between the center of the thermopile (hot junction) and the pyranometer body (cold junction). The difference of temperature between hot and cold junction is converted into a difference of potential, due to Seebeck effect. In order to achieve a proper thermal insulation from the wind and to reduce the sensitivity due to thermal irradiance, it is equipped with two concentric glass domes. The pyranometer

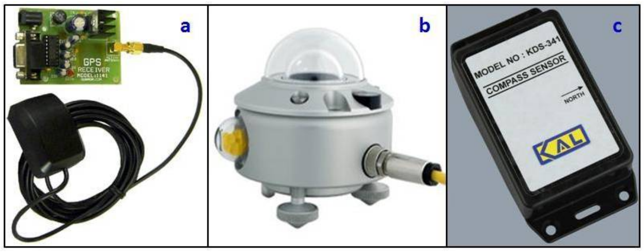

Figure 2. GPS receiver(a), Pyranometer(b), Compass sensor(c)

specification is shown in Table [4].

5. Compass sensor

A compass sensor measure heading and tilt of its mount. We have used compass sensor KDS-341 from M/s Komoline Electronics Pvt. Ltd (Figure 2) [5]. It is a solid-state device based on Honeywell HMC6343 3-axis compass sensor with a 16-bit RISC CPU MSP430 from Texas Instruments [6]. The module combines 3-axis magneto-resistive sensors and 3-axis micro-electro mechanical system (MEMS) accelerometers, analog and digital support circuits, microprocessor and algorithms required for heading computation.

6. Hardware Design and Implementation

The data from weather transmitter, digital compass, and GPS receiver are digital in nature and are configured to communicate with host computer through RS-232 serial interface. The total solar radiation sensor (pyranometer) provides an analog output in the range ± 150 mV, the analog signal is interfaced to host computer through combination of ADAM 4012 and ADAM 4520. ADAM 4012 is an industrial grade single channel analog input module with a resolution of 16 bit, sampling rate – 10 samples/sec, isolation voltage – 3 kVDC, input impedance - 2 MΩ, accuracy $\pm 0.05\%$, and RS-485 serial communication protocol [7]. It uses a microprocessor-controlled integrating A/D converter to convert sensor voltage, or current signals into digital data. When prompted by the host computer, the data is sent through its RS-485 interface. The RS-485 signals are transparently converted into isolated RS-232 signals using ADAM 4520, which is interfaced with host computer through its RS-232 serial port. The Isolated RS485 Converter ADAM 4520, provides 3 kVDC isolation to protect the host computer from ground loops and destructive voltage spikes on the RS-485 data lines and it offers internal surge- protection on their data lines [8]. The RS-232 interface was configured with a baud rate of 9600 bps with host computer which can have maximum shielded cable length of 75 meters [9]. Typically, a host computer has single RS-232 physical port and in order to have more physical serial port, we have used MOXA CP-168U 8-port Universal PCI serial board as shown in Figure 3. The CP-168U is a smart, 8-port universal PCI board designed using MU860(16C550C compatible) communication controller [10]. Figure 4 illustrates the schematic of various sensor interfaced with computer and which is used in the present work.

The weather transmitter, digital compass and GPS receiver digital signal can also be configured for RS-485 serial interface protocol. The RS-485 standard supports half-duplex communication, it requires two wires for both transmit and receive data. Handshaking signals (such as RTS, Request To Send) are normally used tocontrol the direction of the data flow [11]. RS-485 protocol is the most widely used communication interface in data acquisition and control applications where multiple nodes communicate with each other. It allows multiple devices (up to 32) to communicate at half-duplex or full-duplex on a single pair or double pair of wires respectively, at distances up to 1.2 km at (4000 ft) for maximum data rate 100kbps. Data is transmitted differentially on two wires and the properties of differential signals provide high noise immunity and long distance capabilities. Figure 5 shows the schematic of the integrated weather station system with RS-485 interface. The RS-485 signals from ADAM 4012, weather station, digital compass, and GPS receiver are converted to RS-232 signal using ADAM 4520. The RS-232 signal from ADAM 4520 is interfaced with the host computer serial port, as illustrated in Figure 5. The pricing information of each of the system and sub system are listed in Appendix C.

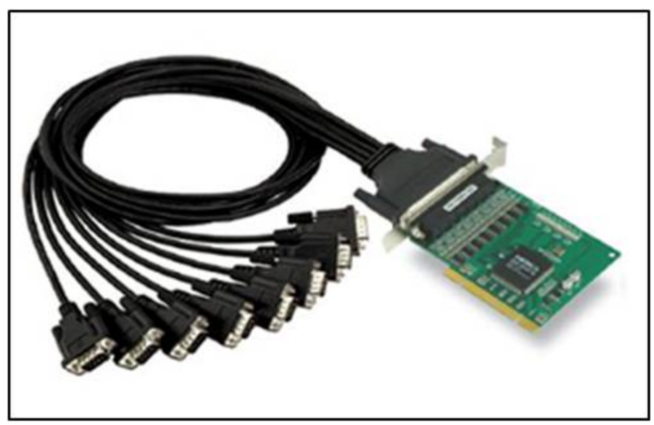

Figure 3. MOXA CP-168U 8-port Universal PCI serial board with cables

7. Software Design – functions & processes

The system control and data acquisition program "Integrated Weather Station System" (IWSS) is written in Visual Basic (VB) 6.0. It is an event-driven object- oriented programming language and integrated development environment from Microsoft. It enables the rapid application development of graphical user interface (GUI) application software [12].

The physical data acquisition from each sensor is implemented via 'timer' event through Microsoft Comm Control

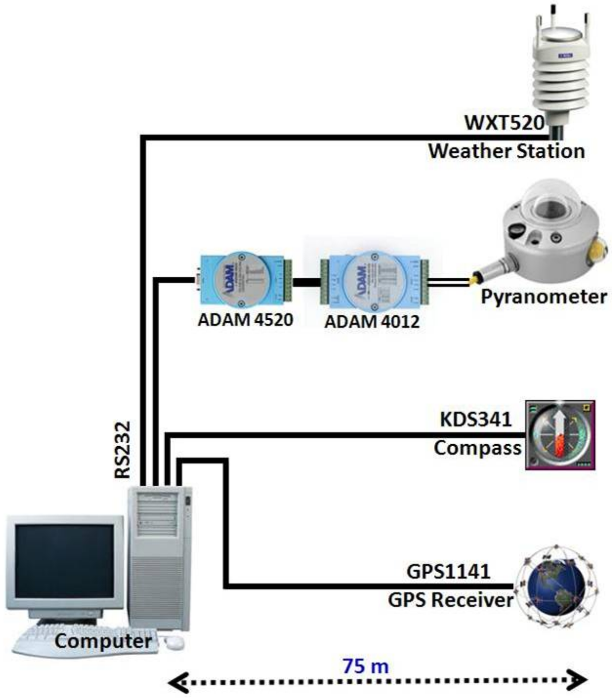

Figure 4. IWSS hardware schematic with RS-232 interface

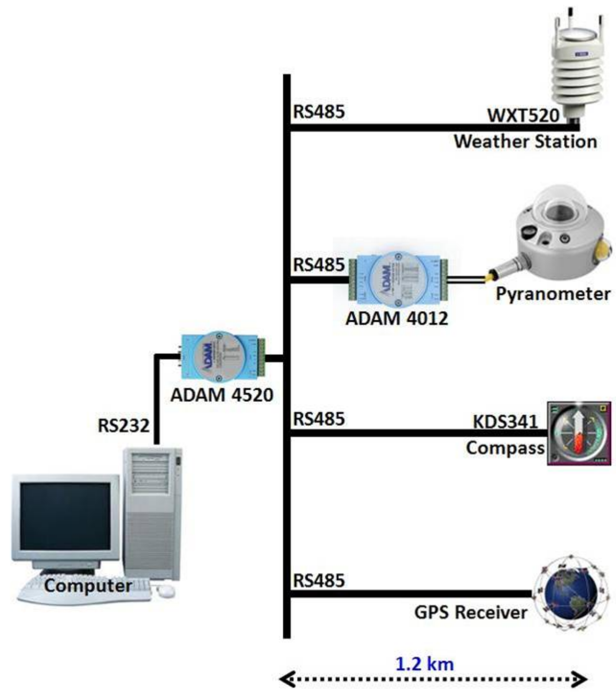

Figure 5. IWSS hardware schematic with RS-485 interface

6.0 (MSCOMM32.OCX) component. The IWSS GUI application consists of four functional commands; (1) Setup (2) Data (3) Refresh and (4) Exit as shown in Figure 9 (Appendix B). The IWSS software can be configured through "Setup" commands (Figure 10 - Appendix B) and the various user editable parameters are (a) Station (for location name), (b) Platform (Fixed or Moving), (c) ID (for the station identification), (d) Avg Time (in seconds for the data averaging), (e) Data Acquisition rate (in seconds for setting data acquisition interval), (f) WXT520 Interface (user has to define its physical interface with computer serial port and the port settings), (g) KDS341 Interface (user has to define its physical interface with host computer serial port and port settings), (h) GPS Interface (user has to define its physical interface with host computer serial port and port settings), (i) ADAM 4012 Setup (user has to define its physical interface with host computer serial port and port settings), (j) Solar Sensor sensitivity, (k) Corrections (to compute true wind direction from the measure compass & wind data when it is operated on board ship), (l) Auto Run (auto executes the program once the GUI application is loaded in the computer startup program), (m) Email Alert (transmits system generated alert to the configured email ID), (n) Log Raw data (enables to log the instantaneous data from each sensor), (o) data Path, (p) SMTP Address, (q) Email To, and (r) Email CC. The "Data" command takes the user to an online data acquisition screen as shown in Figure 11 (Appendix B). The left top frame shows the user configured parameters and left bottom metrological frame displays the measured temperature, relative humidity, pressure, wind speed, wind direction, and rainfall. The right frame shows the latitude, longitude, altitude, with GPS parameters, heading and tilt data, and solar radiation data. The IWSS data acquisition can be started and stopped through the corresponding commands as shown in Figure 11(Appendix B). The "Refresh" command reload the system parameters and "Exit" command quits the IWSS application software.

The flowchart of the application is shown in appendix A. When the IWSS software is executed for the first time in a host computer, it will prompt to configure the application setup. Once the software reads the system setup, it confirms the ports availability and the devices on the respective port. The program then starts acquiring the data from each device sequentially as per the user configured data acquisition rate. It displays the instantaneous data and averages the data before writing it in an ASCII file. The IWSS can also be configured to upload the daily data and system alert (if any) to the user defined email address.

8. Application – fixed platform case study

The IWSS can be configured and operated in both fixed and moving platform. Depending upon the physical distance between the host computer and various sensors we choose the serial communication protocol, RS-232 protocol is used for distance up to 75 m at 9600 baud rate and prefer to use RS-485 protocol for more than it up to 1.2 km. As an application case study of the IWSS, in this technical note we will discuss only the fixed platform based configured system with RS-232 interface. We have installed the Integrated Weather Station System at main campus, Aerosol Mass Spectrometer & Lidar

(AMSL) lab, PRL Ahmedabad (23.03 °N, 72.55 °E, 59.8 m AMSL) and Optical Aeronomy lab, PRL Mt. Abu (24.65 °N, 72.78 °E,

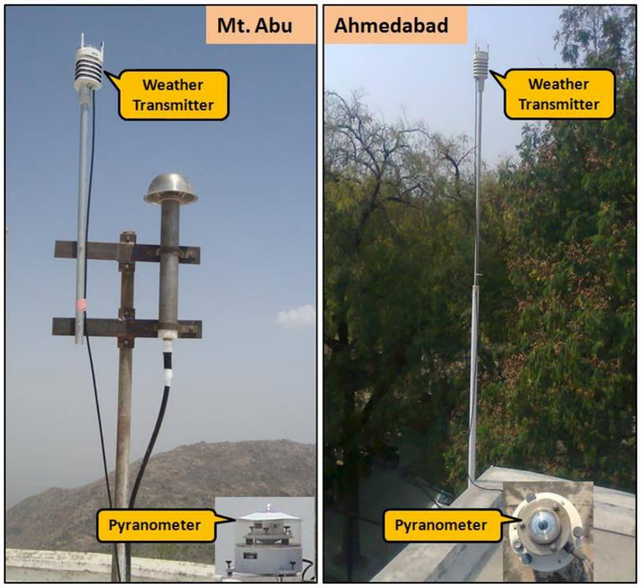

Figure 6. Weather station with pyranometer at Mt. Abu (left) & Ahmedabad (right) station

1.7 km AMSL), in order to observe the various surface meteorological parameters (temperature, relative humidity, pressure, wind speed, wind direction, and precipitation) along with total solar radiation reaching the Earth's surface. Figures 6 illustrate the weather station along with total solar radiation sensor installed at these locations. The system is running successfully at these two geographically distinct locations. Figures 7 and 8 show the hourly averaged diurnal plots for surface temperature, relative humidity, barometric pressure, and total solar radiation measured over Ahmedabad and Mt. Abu respectively. The average barometric pressure is found to be 1003 & 830 mbar and the maximum total solar irradiance is measured to be 770 & 1050 Watt m-2 at Ahmedabad & Mt. Abu respectively for the observed day.

9. Summary

An integrated weather station system has been designed, developed, and integrated indigenously at PRL. The IWSS front end sensors consist of weather station, GPS receiver, solar radiation sensor, and digital compass sensor and these sensors can be configured individually for either RS-232 or RS-485 serial communication protocol depending upon the distance between the sensor and the host computer. The IWSS software running in the host computer can be configured to operate it in fixed or moving platform mode. The heading data from compass sensor is used to compute the corrected wind direction from the measures wind data on a moving platform like ship. As an application case study we have discussed about the IWSS being operational at AMSL lab, PRL Ahmedabad

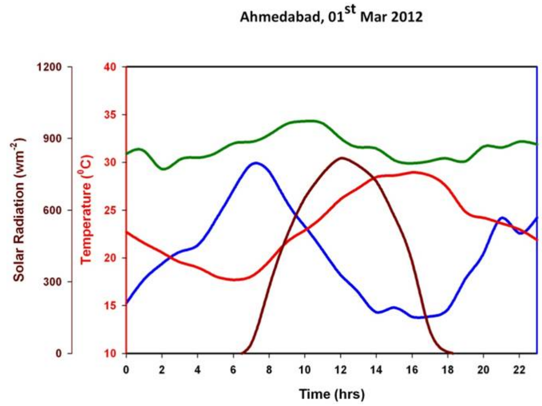

Figure 7. Hourly averaged diurnal plot for surface temperature, relative humidity, barometric pressure, and total solar radiation measured atPRL, Ahmedabad on Mar 01, 2012

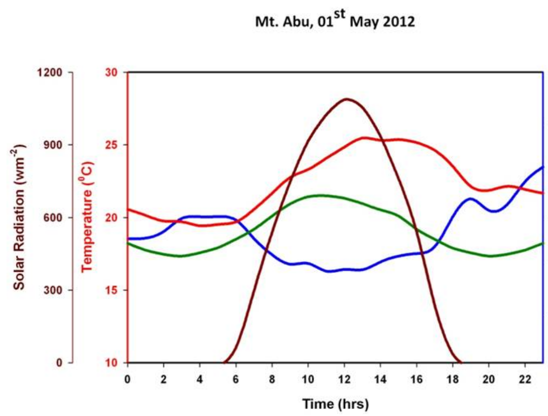

Figure 8. Hourly averaged diurnal plot for surface temperature, relative humidity, barometric pressure, and total solar radiation measured at PRL, Mt. Abu on May 01, 2012

and Optical Aeronomy Lab, PRL Mt. Abu in fixed mode in order to measure temperature, relative humidity, pressure, wind speed, wind direction, and precipitation along with total solar radiation reaching the Earth's surface. The user can configure the GUI application software as per requirement and it logs each and every user activity for any future references and troubleshooting. The IWSS application software in the distribution package can be made available to any user on request.

Acknowledgements

This work has been supported by Physical Research laboratory (PRL) and authors are thankful to the Director PRL. Authors would like to thank the PRL Workshop department and Civil & Maintenance Division (CMD) for their assistance and support in the system installation. We are also thankful to the members of the Space & Atmospheric Sciences Division of PRL who helped in this work.

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Appendix A

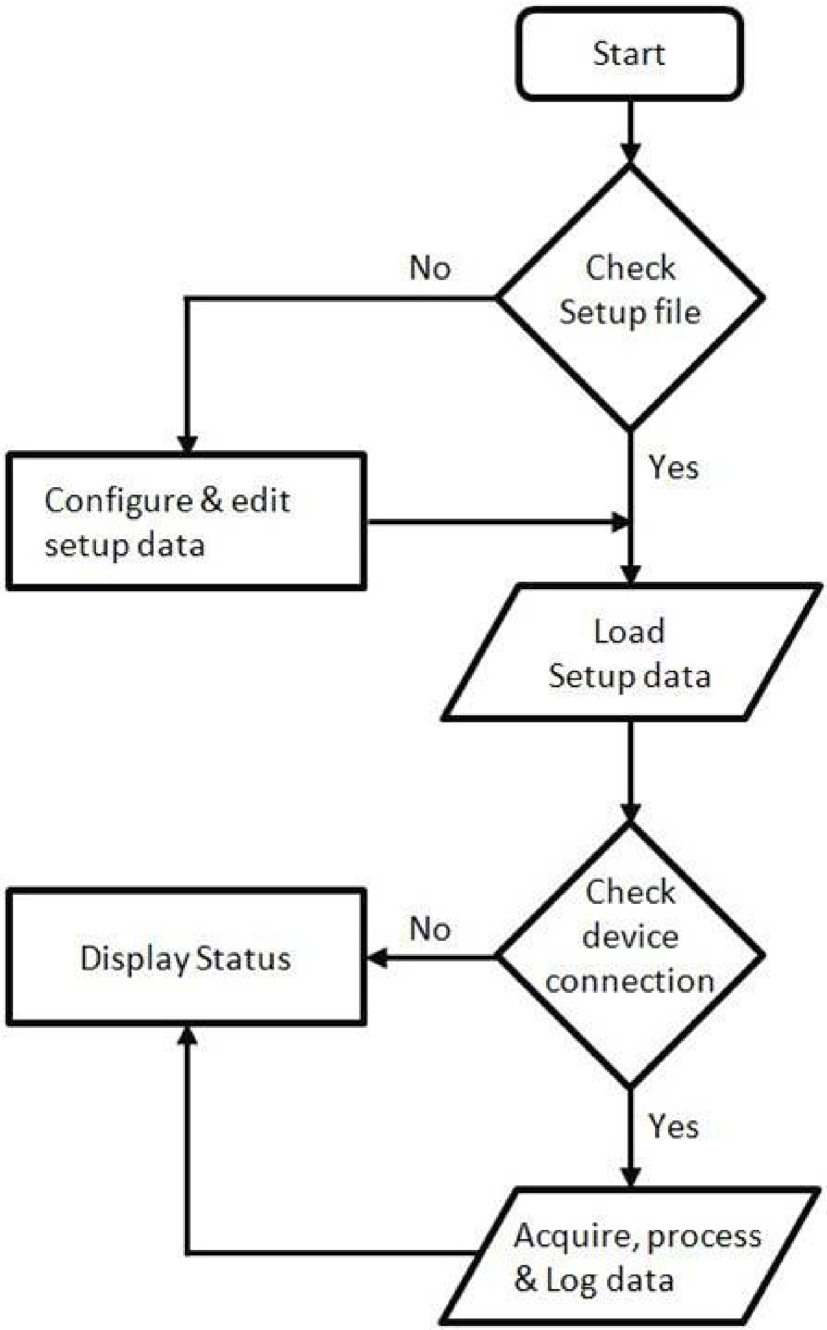

Figure 9. Flowchart

Appendix B: GUI Screen shots

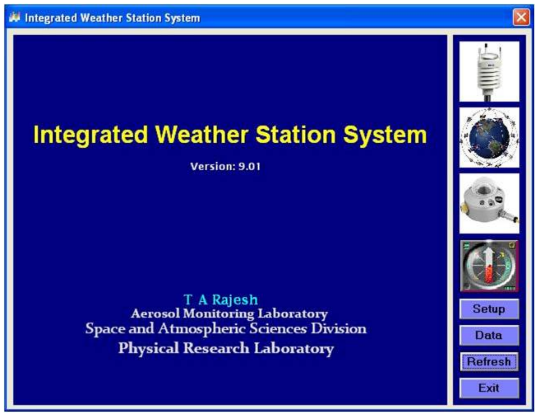

Figure 10. IWSS startup screen

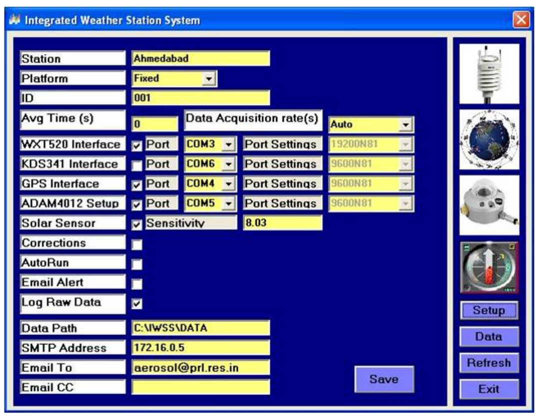

Figure 11. IWSS Setup screen

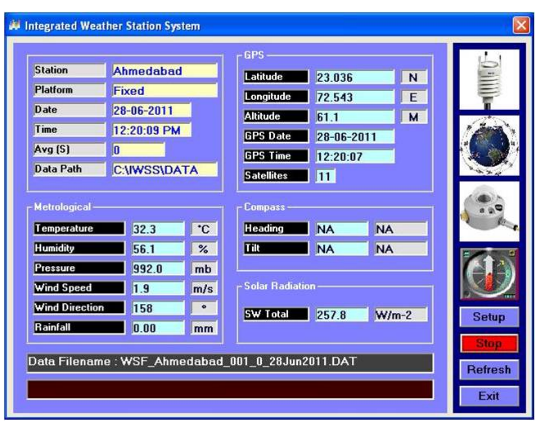

Figure 12. IWSS Setup screen

Table 6. Appendix C: Pricing Information

Sr. No.	**Product**	**Price**
1	Vaisala WXT520 weather station	1500 EURO
2	Sunrom GPS Receiver with antenna 1141	90 USD
3	PyranometerEppley	1000 USD
4	Heading & tilt compass sensor KDS 341	900USD
5	ADAM 4012	160USD
6	ADAM 4520	150USD
7	MOXA CP-168U Universal PCI serial board	180USD

PRL research
encompasses
the earth
the sun
immersed in the fields
and radiations
reaching from and to
infinity,
all that man's curiosity
and intellect can reveal

पीआरएल के
अनुसंधान क्षेत्र में
समविष्ट हैं
पृथ्वी एवं
सूर्य
जो निमीलित हैं
चुंबकीय क्षेत्र एवं विकिरण में
अनंत से अनंत तक
जिन्हे प्रकट कर सकती है
मानव की जिज्ञासा एवं विचारशक्ति