

## An indigenous state-of-the-art Digital Automatic Recording System (DARS) for surface meteorological observatories

P. S. BIJU, ANJIT ANJAN\*, R. D. VASHISTHA\* and K. SANTHOSH

*India Meteorological Department, Thiruvananthapuram, India*

*\*India Meteorological Department, Pune*

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e mail : [psbijumet@yahoo.com](mailto:psbijumet@yahoo.com)

**सार** – डॉप्लर मौसम रेडार (डी. डब्ल्यू. आर.) वास्तविक समय मौसम निदर्शों आदि जैसे आधुनिक तात्कालिक पूर्वानुमान में सहायक उपकरणों के साथ वास्तविक समय परस्पर क्रिया की मांग को देखते हुए भारत मौसम विज्ञान विभाग में अभी मौजूद स्वतः अभिलेखित उपकरणों को आधुनिक बनाने की तत्काल आवश्यकता है। हालाँकि भारत मौसम विज्ञान विभाग ने वायुमंडलीय दाब, पवन गति, पवन दिशा, वायु तापमान, सापेक्षिक आर्द्रता और वर्षा जैसे मौसम वैज्ञानिक प्राचलों के स्वचालित मापन, संग्रहण, प्रदर्शन और सम्प्रेषण के लिए आधुनिक अंकीय स्वचालित अभिलेखन प्रणाली (डी. ए. आर. एस.) की अभिकल्पना कर उसे विकसित किया है। इस प्रणाली का मूल स्रोत भारत मौसम विज्ञान विभाग द्वारा निर्मित मौजूद उच्च पवन गति अभिलेखन प्रणाली (एच. डब्ल्यू. एस. आर.) है जिसे विश्वस्तरीय बाजार में उपलब्ध इलेक्ट्रॉनिक मौसम वैज्ञानिक संवेदकों की विभिन्न किस्मों के साथ अनुकूल रूप से समाकलित करते हुए भारत के पूर्वी तट पर 15 से भी अधिक तटीय वेधशालाओं में लगाया गया है। इस प्रणाली की अभिकल्पना, विकास, संस्थापना और आँकड़ा वैधता की विभिन्न अवस्थाओं के दौरान लेखक उपस्थित रहे। आयातित ए. डब्ल्यू. एस. और ग्राउंड ट्रुथ प्रेक्षणों के संबंध में अपने ही देश में तैयार की गई प्रणाली और इसकी आँकड़ा गुणवत्ता की अभिकल्पना के पहलुओं और मानसून अवधि के दौरान पवन और वर्षा के स्थानिक भिन्नताओं का अध्ययन करने के लिए एक जिले के चुनिंदा गाँवों में इन्हें लगाने के प्रस्ताव का इस शोध पत्र में उल्लेख किया गया है।

**ABSTRACT.** The existing self recording instruments of India Meteorological Department (IMD) urgently require modernization by considering the demand for its real time interface with the modern now-casting tools like Doppler Weather Radar (DWR), real time weather models etc. Hence IMD has designed and developed a state-of-the-art Digital Automatic Recording System (DARS) for the automatic measurement, storage, display and communication of meteorological parameters like Atmospheric pressure, Wind speed, Wind direction, Air temperature, Relative humidity and Rainfall. The system has its origin from the existing IMD make High Wind Speed Recording (HWSR) System installed at more than 15 coastal observatories in the eastern coast of India, by suitable integration with different types of electronic meteorological sensors available in the global market. Authors have participated at various stages of design, development, installation, and data validation of the system. This paper highlights the design aspects of indigenous system and its data quality with respect to imported AWS and ground truth observations and the proposal for its installation at selected villages in a district to study the spatial variation of Wind and Rainfall during Monsoon period.

**Key words** – DARS, AWS, Sensors, WMO.

### 1. Introduction

India Meteorological Department has a large number of surface observatories especially meant for synoptic observations equipped with self recording instruments for the automatic recording of Air temperature, Relative Humidity, Atmospheric pressure, Wind and Rainfall. Even in the midst of its extreme accuracy in readings, they could not have the capability to interface with the modern now casting tools like Doppler weather radar, real time

weather models etc. Even though some of these stations are equipped with Automatic Weather Stations (AWS), it is not a solution for the continuous record of weather parameter since it can give only the hourly values at the time of transmission. Hence IMD has designed and developed a Digital Automatic Recording System (DARS) for the automatic measurement, storage and communication of weather parameters like Atmospheric pressure, Wind direction, Wind speed, Air temperature, Relative Humidity and Rainfall with open system

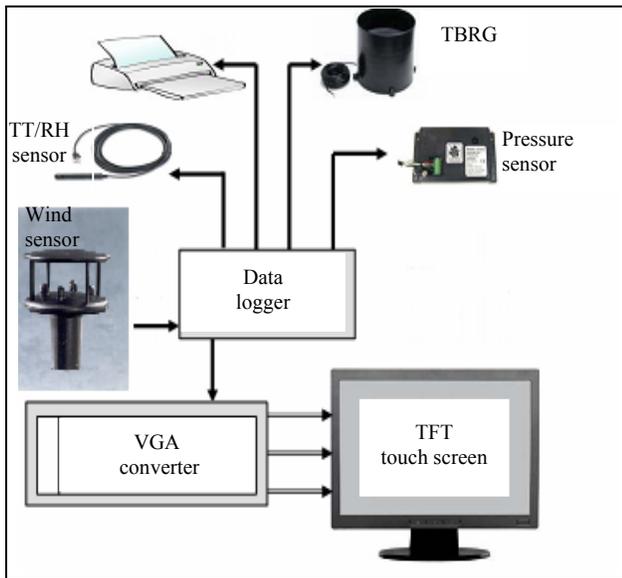


Fig. 1(a). Complete system of DARS

Legend : VGA - Video Graphics Adaptor, TBRG - Tipping Bucket Rain Guage, TFT - Thin Film Technology

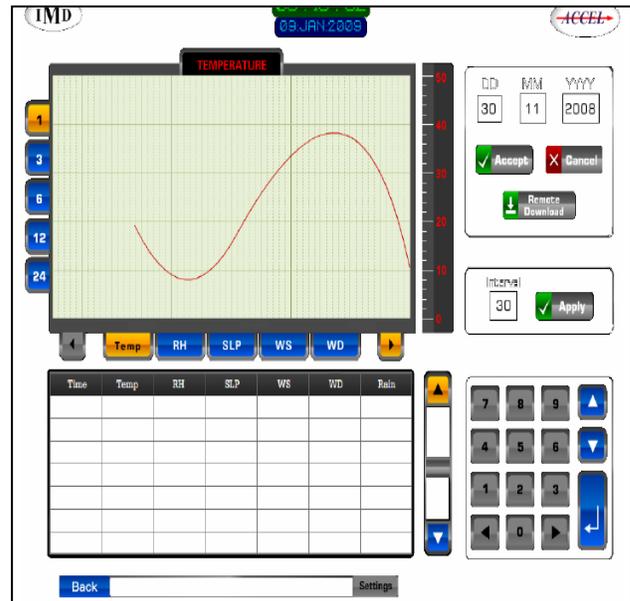


Fig. 1(c). Touch screen display (download window)

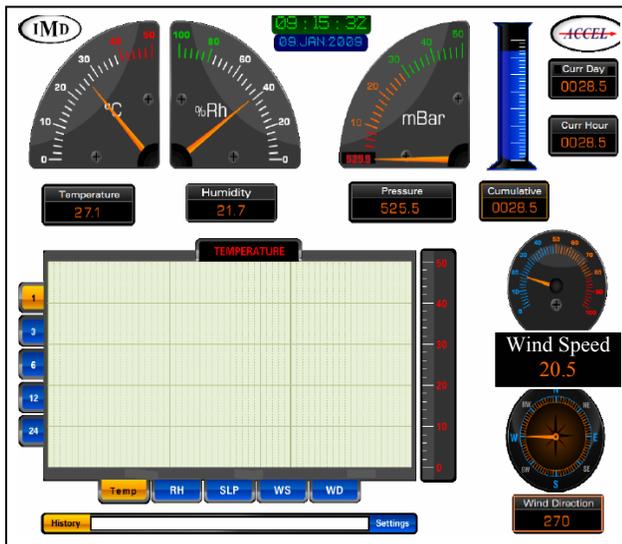


Fig. 1(b). Touch screen display (main window)

architecture. Originally it is a High Wind Speed Recording (HWSR) System (Vashista *et al.*, 2010) integrated with electronic sensors for Air temperature, Relative humidity, Atmospheric pressure and Rainfall. One such full compliment of the system is installed at the observatory of Meteorological centre, Thiruvananthapuram collocated with the imported Automatic Weather Station (AWS) and manual surface observatory (ground truth observations). The main component of the system is a data logger with electronic

meteorological sensors powered by a 42 AH sealed maintenance free battery continuously charged with a solar panel. The logging system can continuously work for 10 years without any human intervention and no mains power is required for its operation. The system has a data storage capacity of 10 years for one minute averaged data of all the parameters and the data retrieval can be done through USB thumb drives. The hard copy also can be made available through dot matrix printers. As easiness to the forecasters, the system is interfaced with TFT (Thin Film Transistor technology) touch screen displays for instantaneous values of met parameters and also have the graphical output with data retrieval facility. The system is added with the facility to communicate with the centralised server through GSM connectivity.

Authors have participated at various stages of design, development, installation and data validation of the system and also involved in the post warranty maintenance of the imported AWS. Hence an attempt has been done in this paper to compare the data of DARS with the imported AWS and ground truth observations to establish the data quality of the newly designed system.

## 2. System description

The complete system of DARS is depicted in Fig. 1(a). The main components comprises (i) sensors and data logger at the field site and (ii) VGA converter and TFT (Thin Film Transistor) touch screen display in the weather room. The main window and download window of the TFT display are shown Figs. 1(b&c). All the units

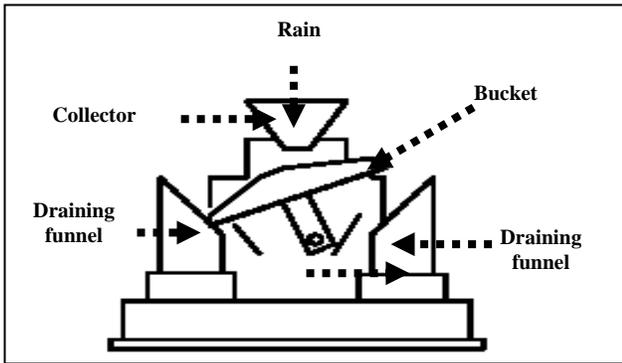


Fig. 2. Tipping bucket mechanism

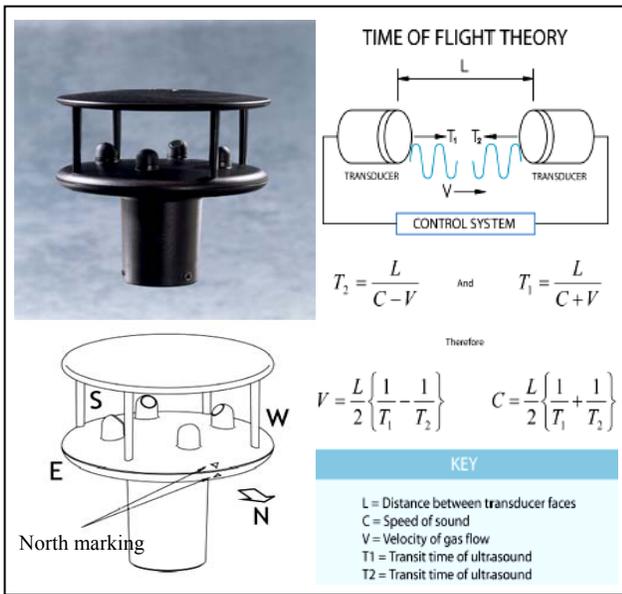


Fig. 3. Ultrasonic wind sensor and its principle

in field are powered by a 42 AH sealed maintenance free battery with a solar charger and the power consumption of the system is made very low in such a way that the battery alone can power the system for at least three months in the absence of solar energy. The data logger is having a memory capacity to store the one-minute averaged data of all the parameters for 10 years.

2.1. Sensors

The indigenous DARS utilises IMD make Tipping Bucket Rain Gauge (TBRG) for the measurement of rainfall, Young make Solid state pressure sensor, Gill make Wind sensor and Rotronics make Air temperature and Relative humidity sensors. All these sensors are calibrated at IMD Pune, before putting it in to the field components of the system.

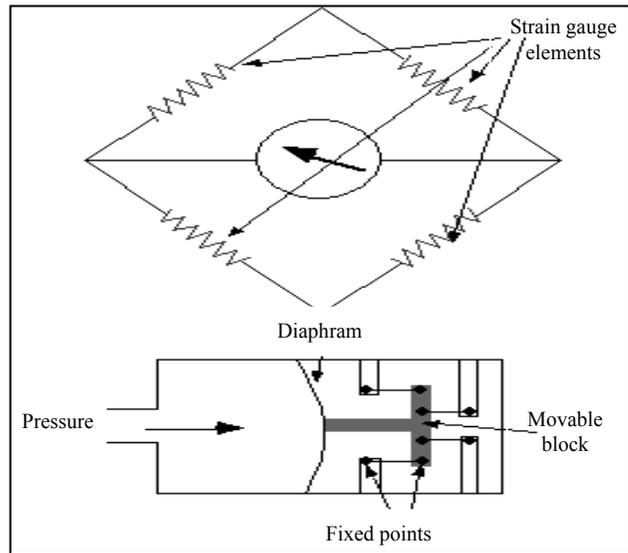


Fig. 4. Working principle of solid state pressure transducer

2.1.1. Tipping Bucket Rain Gauge (TBRG)

The IMD make TBRG measures the rainfall with a resolution of 0.5 mm and it gives out one electrical pulse for every 0.5 mm of rainfall. It consists of a twin bucket mounted on a horizontal shaft and has two stable positions as shown in Fig. 2. The collector diameter is 20 cm and hence its area may be 314 cm<sup>2</sup>. Thus a volume of 15.7 cm<sup>3</sup> (314 × 0.05) of rain water corresponds to 0.5 mm of rainfall. The rainfall collected by the receiver reaches to one of the twin buckets through a funnel. The weight of 15.7 cm<sup>3</sup> of rainwater causes the tilting of the bucket from one stable position to another stable position and brings the other bucket under the funnel for collecting water. Every time the bucket tilts, a small magnet attached to the horizontal shaft of the bucket actuates a reed switch generating one electrical pulse.

2.1.2. Ultrasonic wind sonic sensor

Ultrasonic wind sensor is a combined sensor for wind direction and speed. It is based on Doppler principle as depicted in Fig.3. It measures the times taken for an ultrasonic pulse of sound to travel from the North (N) transducer to the South (S) transducer, and compares it with the time for a pulse to travel from S to N transducer. Likewise times are compared between West (W) and East (E), and E and W transducer. If, for example, a North wind is blowing, then the time taken for the pulse to travel from N to S will be faster than from S to N, whereas the W to E and E to W times will be the same. The wind speed and direction can then be calculated from the differences in the times of flight on each axis. This

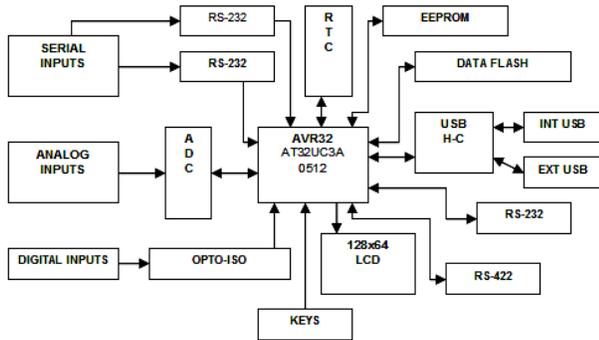


Fig. 5. Schematic of data logger

Legend : AVR32→32 processor (RISC Architecture), USB H-C → USB Host controller, INT → Internal EXT→ External EEPROM → Electrically erasable Programmable Memory, LCD → Liquid crystal display, OPTO – ISO → Optical isolator, RTC → Real Time Clock, RS 232 → Serial to TTL converter, RS 422 → IC for converting the signal in to RS 422

calculation is independent of factors such as temperature. The sensor has a range of 0-60 m/s for wind speed with a resolution of 0.01 metres/sec and is having no mechanical parts.

### 2.1.3. Temperature and Humidity sensor

A hygroclip (Biju *et al.*, 2008) is used for the measurement of air temperature and relative humidity whose accuracy has been proven in its use for the IMD make Integrated Automated Current Weather Instrument System (IACWIS) operational at 18 aeronautical meteorological observatories and stations of IMD (Biju *et al.*, 2008).

### 2.1.4. Solid state pressure sensor

A solid-state pressure transducer is used for the measurement of station level pressure and the measurement is independent of temperature and gravity. It senses the pressure as the force per unit area acting on the diaphragm as shown in Fig. 4. Relationship between the pressure and the movement of the diaphragm is governed by the stiffness of the diaphragm. As pressure is applied to the strain gauge, the increase in length and decrease in diameter of the wire, increases the resistance to the flow of current through the wires of the Wheatstone bridge. This change in the wires electrical resistance causes a voltage change that can be quantified to reflect the amount of pressure that changed the wires length & diameter. The electrical signal can be amplified & measured; when calibrated, it is proportional to the pressure change.

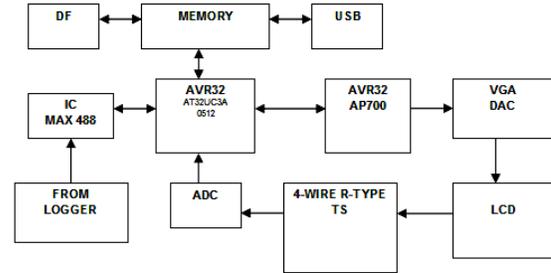


Fig. 6. Schematic of VGA converter

Legend : DF→Data flash, ADC→ Analog to Digital converter, IC→ Integrated Chip, AVR 32→32 bit processor (RISC Architecture), LCD→ Liquid Crystal Display, 4 - WIRE R - TYPE TS→ 4 wire Resistive type Touch screen

## 2.2. Data logger

The data logger used in DARS has the same architecture as that of HWSR (Vashistha *et al.*, 2010), but here RISC (Reduced Instruction Set Computing) is used in its full strength and its design tools available in the website (Vashistha *et al.*, 2010). The internal structure of data logger is shown in Fig. 5. The one and only difference in this logger from that of HWSR is the availability of three selectable input channels for serial, analogue and digital outputs of the sensors available in the global market.

## 2.3. VGA converter

This is an additional facility given to the system for the display of weather parameters in a touch screen TFT display. The output of data logger is made as RS 422 signal in view of its communication up to a distance 1 km from the field site to the weather room. The VGA (Video Graphics Adaptor) unit converts the RS 422 signal into VGA signal compatible with the TFT touch screen for the display of all the weather parameters. It can also display the extreme values like maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, maximum pressure, minimum pressure, maximum wind speed and minimum wind speed during the previous 24 hours of the day starting from 00:00 hrs of GMT. However the minimum temperature will be updated at 03:00 hrs of GMT and maximum temperature will be updated at 12:00 hrs of GMT using the same technology as that of Automatic Weather Stations (AWS). Fig. 6 shows the design of VGA converter used in the DARS. The same AVR 32 micro-controller as that of data logger is used in VGA converter and the conversion of RS422 signal in to TTL signal (Biju *et al.*, 2008) is done by IC MAX 488. One more powerful processor also engaged in the VGA converter, which handles all functions related to

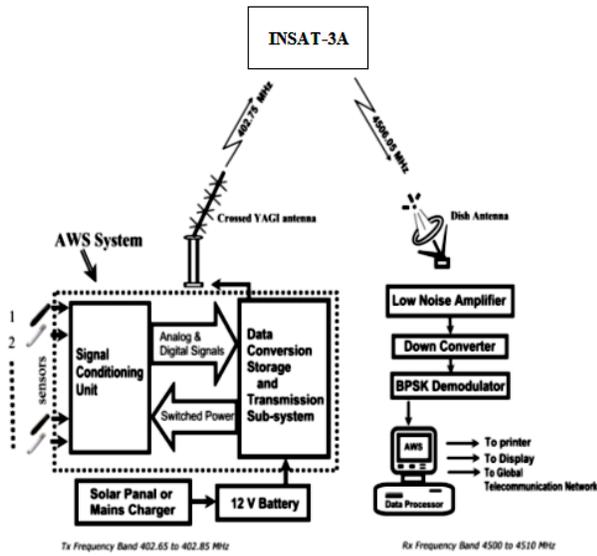


Fig. 7. Schematic of imported AWS

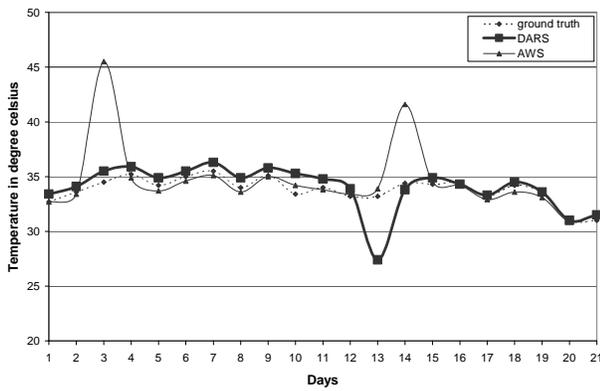


Fig. 8. Comparison of maximum temperature at Thiruvananthapuram in May 2010 (Pre-monsoon)

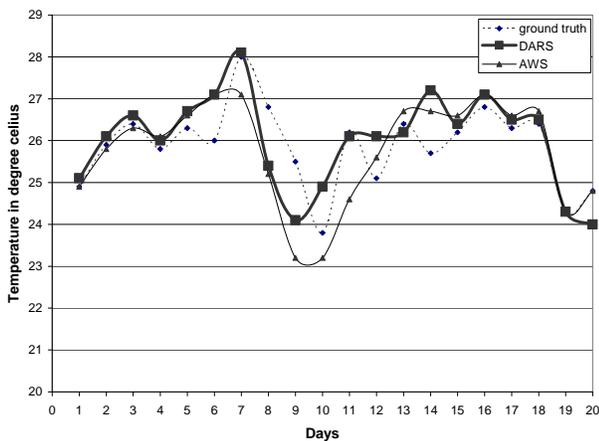


Fig. 9. Comparison of minimum temperature at Thiruvananthapuram in May 2010 (Pre-monsoon)

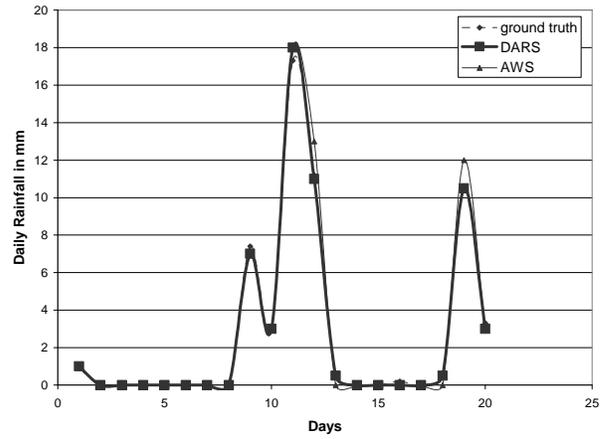


Fig. 10. Comparison of daily rainfall at Thiruvananthapuram in May 2010 (Pre-monsoon)

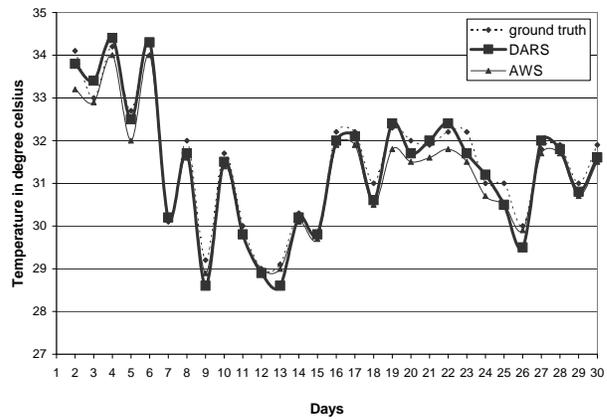


Fig. 11. Comparison of maximum temperature at Thiruvananthapuram in June 2010 (SW Monsoon)

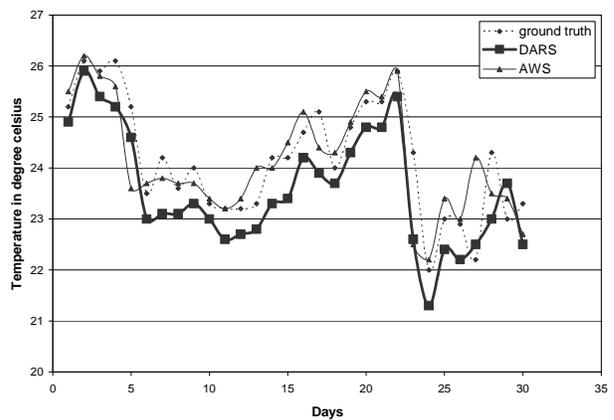


Fig. 12. Comparison of minimum temperature at Thiruvananthapuram in June 2010 (SW Monsoon)

**TABLE 1**  
**Distinction between DARS and AWS**

Properties	DARS	Imported AWS
Communication	Instantaneous	Hourly
Use of IMD make sensors	Possible	Not possible without the help of the vendor
Integration	Possible	Not possible without the help of the vendor
Wind averaging	Vector averaging	Only the value at the time of transmission
Distant cable communication	Possible up to 1 km and up to 16 km with the use of cable modems	Not possible
Mode of communication	Cable or Wi-Fi	Satellite
Data Storage	10 years of 1-minute averaged data	Maximum 1 year
Slave displays	10 Nos. in a system	Only one in a system
GSM connectivity	Possible	Not possible
Data retrieval using USB	Possible	Not possible
Continuous recording on every minute	Available	Not available
Observation of gust, squall etc	Possible	Not possible

the drivers of touch screen display. At the same time the main processor handles the permanent storage of data in the VGA converter for about 15 days and it can be retrieved at the weather room using USB Thumb drives.

### 3. Measurement in AWS

The AWS co located with DARS is of Sutron-USA make and is based on PRBS (Pseudo Random Burst Sequence) technology with 9210 data logger (<http://www.sutron.com>). The schematic of AWS is shown in Fig. 7. A distinction between the observational methods of DARS and AWS have been tabulated in Table 1. Even though the performances of both the systems are extremely good, the continuous numerical and graphical display of weather parameters for every second can be considered as an additional advantage of DARS over AWS.

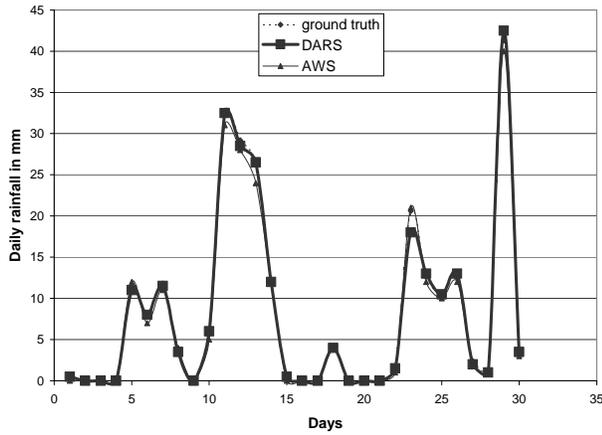
### 4. Data quality

The data of AWS is analysed for the three years from 2007-10 and the data of DARS is analysed from March to December of 2010 and is compared with the ground truth observations. Most of the months all the parameters are in close correlation with the manual observatory within the tolerable accuracy limits specified by WMO [WMO, 1992 (a&b)] as well as ICAO (ICAO, 2004). In the present analysis three months are selected for the year 2010, in which the sensors of DARS and AWS have shown little out correlation on some days and are illustrated in

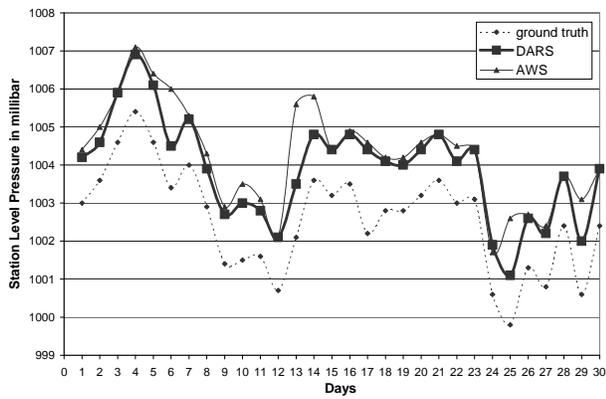
Figs. 8-17. However both the systems have shown very high accuracy in all the other months of 2010.

In the month of May 2010 (Pre-monsoon), the temperature sensor of DARS has failed only for one day to record the correct maximum temperature but for all other days the variation is exactly in the same dips and humps with that of ground truth observations as shown in Fig. 8. The failure was reasonable and is the disadvantage of most of electronic temperature sensors used in automatic observatories that after a sudden fall of temperature in rainy days, the sensor may be adversely affected by the influence of high relative humidity for some period. However some of the costly sensors available in the market have remedial actions in these situations. The cost of such sensors is about 5-6 times higher than the sensor used in DARS. In Fig. 8 it is seen that imported AWS shows extremely high values at two occasions in the month presumably due to internal transmission errors in the system. Figs. (9 & 10) depict the excellent data quality of both the systems in the measurement of minimum temperature and daily rainfall. The over lapping of daily rainfall data of DARS on the ground truth observations in Fig. 10 can be considered as an example for considering IMD make Tipping bucket rain gauge as the proper substitute for all the existing rain gauge in India.

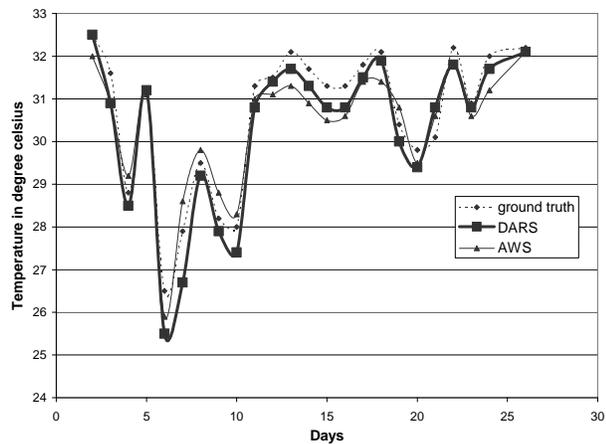
Similar results can be seen in Figs. (11- 13) for the Monsoon season of 2010. However in the case of minimum temperature imported AWS is little bit ahead in



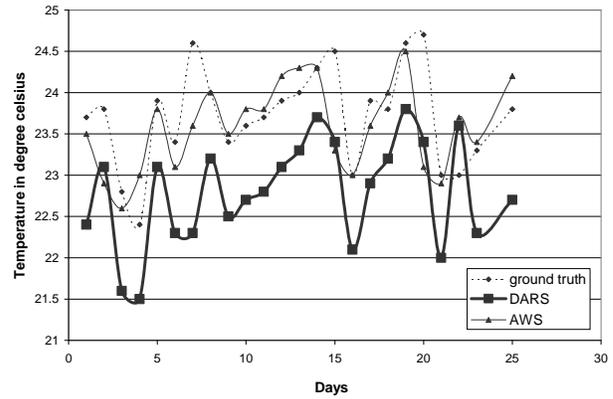
**Fig. 13.** Comparison of daily rainfall at Thiruvananthapuram in June 2010 (SW Monsoon)



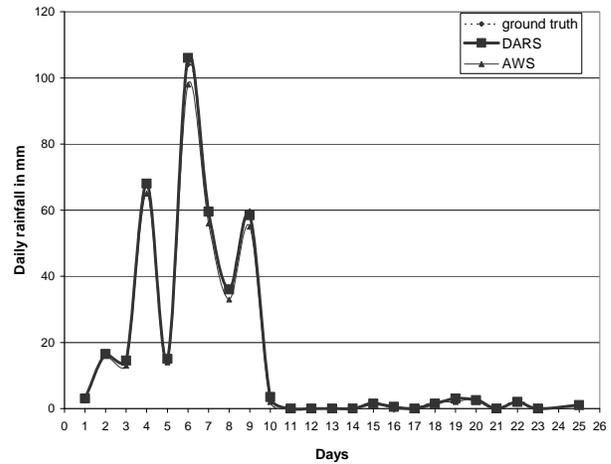
**Fig. 14.** Comparison of station level pressure at Thiruvananthapuram in June 2010 (SW Monsoon)



**Fig. 15.** Comparison of Maximum Temperature at Thiruvananthapuram in October 2010 (NE Monsoon)



**Fig. 16.** Comparison of Minimum Temperature at Thiruvananthapuram in October 2010 (NE Monsoon)



**Fig. 17.** Comparison of daily rainfall at Thiruvananthapuram in October 2010 (NE Monsoon)

its accuracy, but the data of DARS also falls within the accuracy limits. The performance of pressure sensors can be seen in Fig. 14 and the variations are similar in all the seasons. It is seen that a difference of 1hPa can be seen continuously in all the seasons and months and is due to the difference in height of cistern level of the ground truth observations and the height of sensor of DARS and AWS. But the variation pattern shows that DARS is more accurate than AWS in the measurement of pressure.

In the post Monsoon season (October), occurrence of heavy rainfall increases the hysteresis loss of the sensors of DARS and hence its accuracy was not better than that of AWS, but still it lies within the required accuracy limits as shown in Figs. 15 -17.

### 5. Conclusion

The system presented here as DARS is capable of integration with any sensors available in the global market

and hence it can be integrated with transmissometers, forward scatter meters and ceilometers so as to make a complete automatic synoptic observatory. Its accurate data quality and additional facilities compared to other automated systems enables it for the use at meteorological centres, meteorological observatories, aeronautical meteorological observatories and stations as a replacement of self recording instruments. The appearance of this system [Figs. 1(b&c)] may be more suitable for the current weather desk at airports. Since the cost of production of DARS is only one-third of the automatic systems available in the global market, its installation can be done at more places in a district for supporting now casting, verification of district level forecasts, and study of spatial variation of wind and rainfall during the monsoon period. Since the rainfall accuracy of this system is excellent, it can be utilized for district wise monitoring of daily rainfall on operational basis and can be integrated with Doppler Weather Radars to verify the Marshall-palmer relations for an accurate now casting especially in Monsoon seasons.

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