

ESTABLISHING A NETWORK OF 550 AUTOMATIC WEATHER STATIONS AND 1350 AUTOMATIC RAIN GAUGE STATIONS ACROSS INDIA: SCHEME, SCOPE AND STRENGTHS.

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ABSTRACT

India Meteorological Department is in the process of strengthening of its surface observational network in a phased manner. A network of 125 Automatic Weather Stations (AWS) has been established in the year 2006-07 under the project "Replacement of old and obsolete network of Data Collection Platforms". Under the IMD Modernization Programme Phase-I, the network is being expanded with additional 550 AWS and 1350 Automatic Rain Gauge (ARG) stations. The sensors for parameters Air Temperature, Relative Humidity, Atmospheric Pressure, Rainfall, Wind and Global Solar Radiation are interfaced with each AWS. Out of 550 AWS planned for installation, 127 will be Agro-AWS with additional sensors for parameters soil temperature, soil moisture, leaf temperature and leaf wetness. Out of 1350 ARGs planned for installation, 500 will have additional sensor for recording Air Temperature and Relative Humidity. Meteorologically unrepresented districts of India are being considered on priority for installation of AWS and ARG. Typically one AWS and two ARGs are planned for installation in each district. A meso-network of 12 AWS has been established in and around National Capital Region. Meso-networks of ARGs are being established in flood prone river basins viz. Brahmaputra, Ganga, Mahanadi, Tapi, Narmada, Godavari and Krishna. Thus, by the year 2010, a fairly uniform and dense surface observational network of 675 AWS and 1350 ARGs is expected to be available to meet operational requirements of the nation.

The ALOHA or Pseudo Random Burst Sequence (PRBS) technique had been in use for data transmission through Data Relay Transponder (DRT) onboard INSAT series of satellites since early 1980s. This technique is particularly suitable when number of AWS simultaneously sharing a common communication channel in a random manner is not too large. In view of planned massive expansion of the network an open loop Time Division Multiple Access (TDMA) technique in which each station is assigned a time stamp of one second is being used for data transmission through DRT onboard INSAT 3A (93.5 Deg. E). As of now, data of about 600 AWS and ARG stations are available for operational utilization. The network scheme, scope of data in operational meteorology, agro-meteorological services etc along with telemetry system are presented. Preliminary performance of the network during severe weather condition of Phyan Cyclone that crossed the west coast of India in November 2009 is also presented.

The objective of modernization program to establish a network of about 1100 AWS and 3600 ARGs across India will be achieved by the year 2012.

Key words: AWS, Agro-AWS, ARG, ALOHA/PRBS, TDMA

Introduction

India Meteorological Department operates a network of Automatic Weather Stations across India since early 1980ies. In order to strengthen the surface observational network IMD decided to replace old and obsolete Data Collection Platforms with state of art satellite linked Automatic Weather Stations (AWS).

A network of 125 Automatic Weather Stations has been established across India in the year 2006-07. The network consists of 100 AWS procured from M/s. Sutron Corp., USA and 25 AWS procured from M/s. Astra Microwave Products Ltd., Hyderabad. The data transmission in ALOHA or Pseudo Random Burst Sequence (PRBS) mode through Data Relay Transponder (DRT) onboard the geostationary satellite KALPANA-1 (74 E) serves as telemetry system. The data is received at the central receiving Earth Station located at Pune. Details of telemetry system are given in and network details are same as given by Vashistha et al (2005) and Ranalkar et al. (2007).

In the year 2006, a steering committee constituted by the Ministry of Earth Sciences, Govt. of India recommended expansion of Automatic Weather Stations in a phased manner. For initial two years the AWS network will serve as augmentation of the conventional observatory network and thereafter depending upon performance of the network the observations will be taken with AWS and visual observations will be taken by observers.

The AWS network has applications in operational meteorology, agro-meteorology (McNew et. al, 1991; Hubbard et. al, 1983) hydrological applications like flash flood forecasting (Mc Culloch and Strangeways, 1966), NWP models etc. In view of these potential applications of AWS data, a massive expansion of network of automatic weather observing systems is recommended by the steering committee constituted by the Ministry of Earth Sciences. A network of about 1100 AWS and 3600 Automatic Rain Gauge Stations (ARG) will be established in India in phased manner through implementation of modernization programme. Under the first phase of the programme a network of 550 AWS and 1350 ARGs is being established.

Network Plan

Under the modernization program of IMD the AWS network is being expanded through implementation of modernization programme in phased manner. In phase-I of the project a network of 550 Automatic Weather Stations and one Time Division Multiple Access (TDMA) type receiving Earth Station is being established. 253 districts in Indo-Gangetic plains, Himachal Pradesh, Central India and south peninsular India are meteorologically unrepresented. An AWS is being installed in these districts on priority. The sensors for parameters air temperature, relative humidity, atmospheric pressure, wind speed, wind direction, rainfall, global solar radiation will be interfaced with each AWS. The density map depicting planned network of AWS is shown in Figure 1.

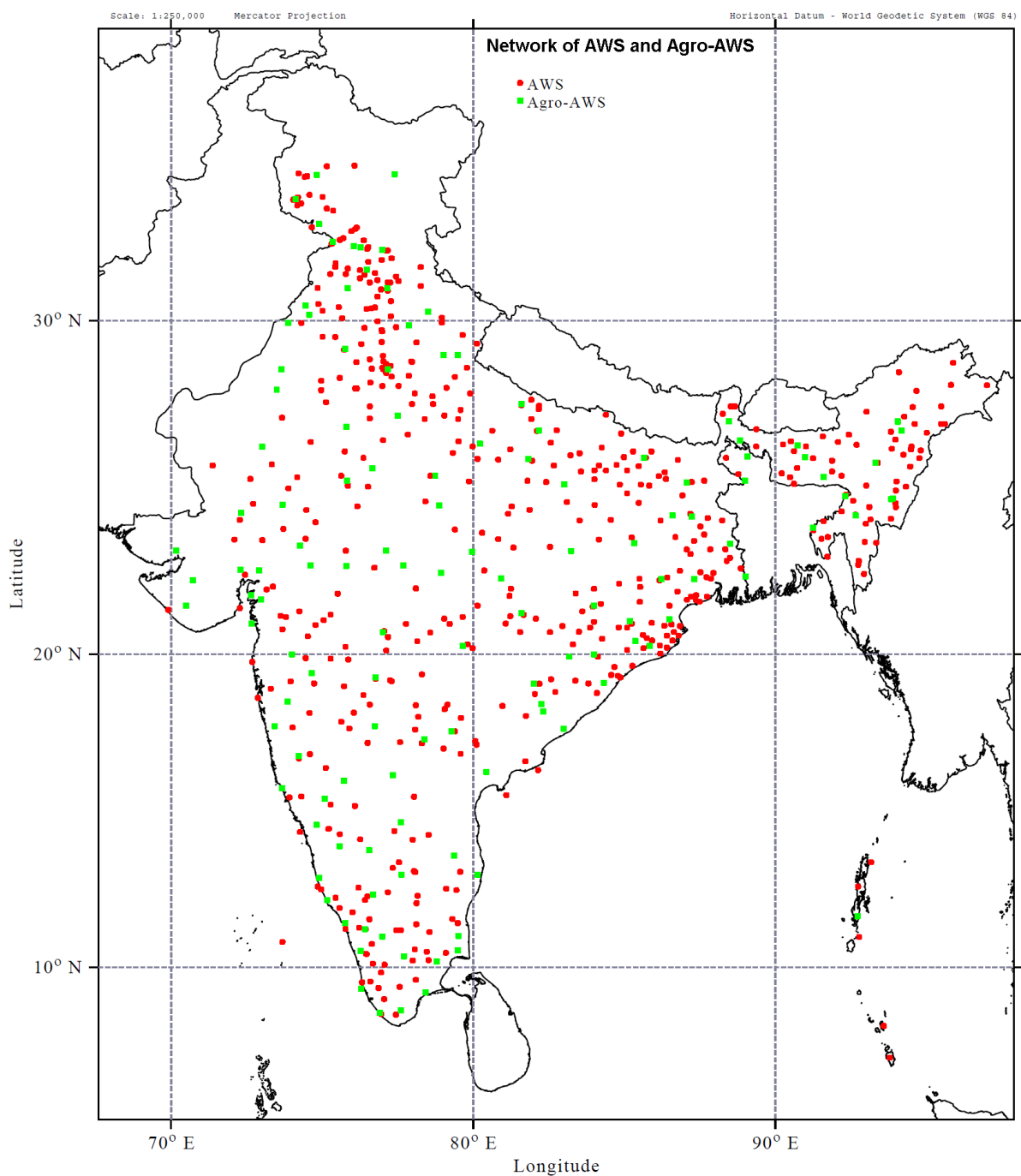


Figure 1: Planned network of Automatic Weather Stations (423 AWS + 127 Agro-AWS).

For better understanding of the processes by which climate affects crop growth and yield as well as incidences of pests and diseases it is decided that out of 550 AWS planned for installation in phase-I, 127 stations will be Agro-AWS with additional sensors for parameters soil temperature, soil moisture, leaf temperature and leaf wetness. These AWS will be installed in different Agro-Climatic zones of India. The planned network of Agro-AWS is shown in Figure 2.

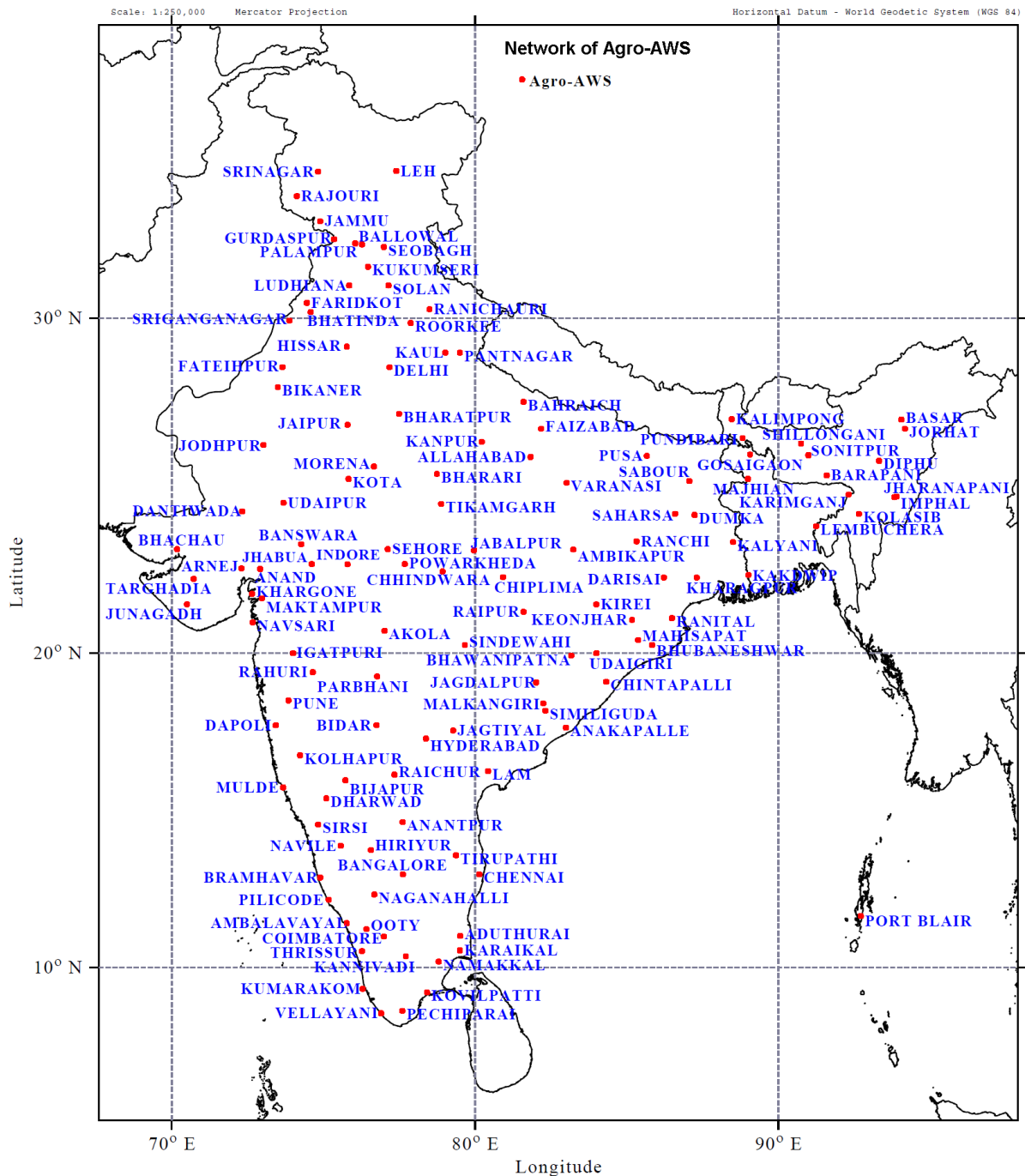


Figure 2: Network of 127 Agro-Automatic Weather Stations.

The present surface observational network is sufficient to meet the large scale and synoptic scale weather development however there is a deficiency for monitoring of meso-scale systems. For the development and delivery of fairly skillful, reliable and useful forecasts on the high impact disastrous weather events over different parts of the country, it is essential that meso-scale observational network is established over selected areas in the country. A meso-network established in and around national capital region is depicted in Figure 3.

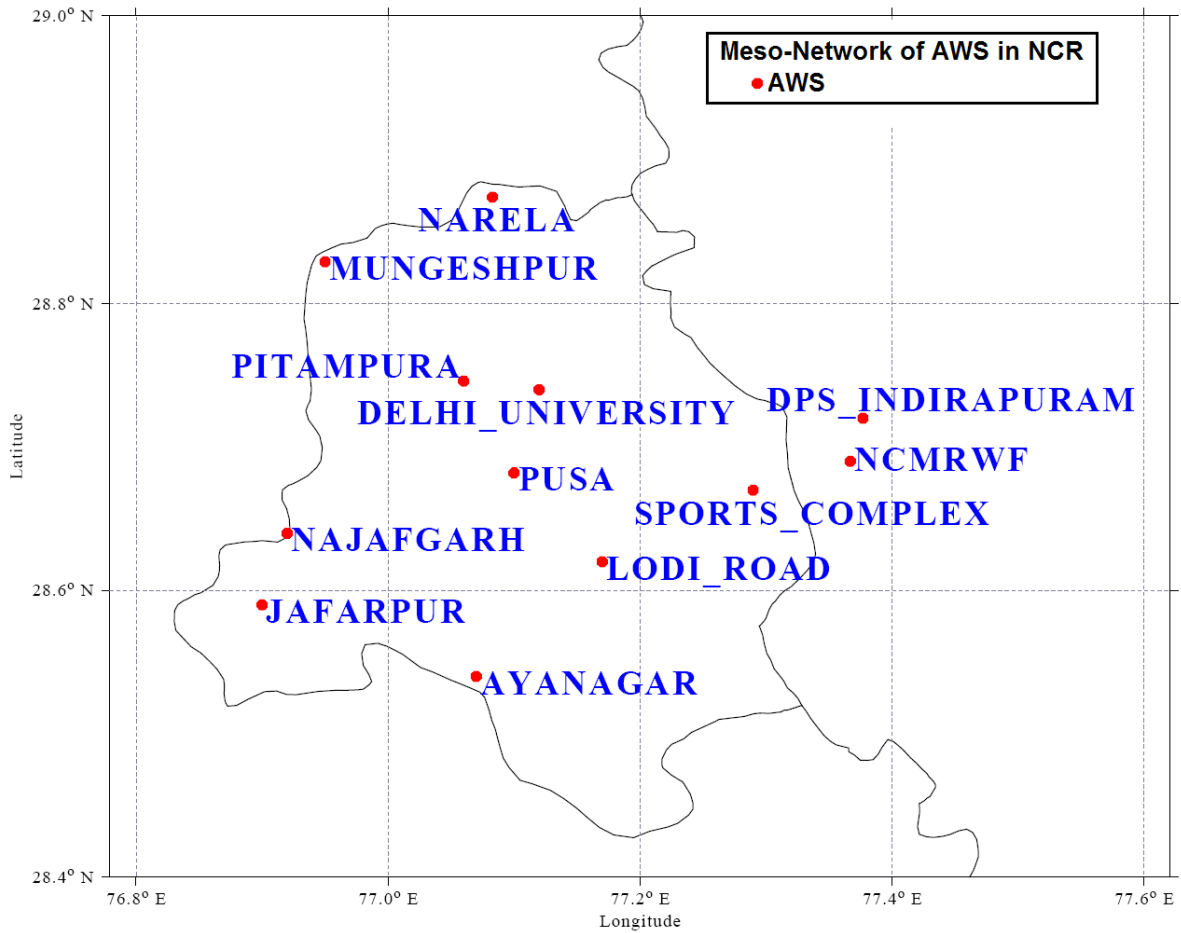


Figure 3: Meso-network of AWS in and around National Capital Region.

In order to improve monitoring of districtwise rainfall monitoring a network of 1350 Automatic Rain Gauge Stations is being established during Phase-I of the modernization project. It is planned to install at least two Automatic Rain Gauge Stations in each district of India during Phase-I of the project. Out of 1350 ARG stations, 500 stations are being equipped with additional sensors for temperature and humidity observations. The ARG stations are also being installed on priority in flood prone river basins such as Brahmaputra, Ganga, Mahanadi, Tapi, Narmada, Godavari and Krishna.

System Details

Data logger and Transmitter

The data logger consists of 16 analog single ended channels with 16 bit A/D conversion. The analog voltage input range is 0-2.5 V. The logger also consists of digital channels such as 1 RS232 port for interfacing of sensors, 1 true industry standard RS485 port, 2 SDI-12 ports and 4 number of 16 bit counter/frequency inputs. The measurement interval is programmable. The logger also has 1 MB solid state flash memory for data storage and is also equipped with a USB 2.0 port for retrieval of data through pen drive. The data logger supports varied transmission

modes such as telephone, satellite (both Pseudo Random Burst Sequence and Time Division Multiple Access), GSM/GPRS, radio modem etc.

A UHF satellite transmitter is used for transmission to INSAT series of satellites. The features of UHF transmitter are given in Table 1 below.

Table 1: Specifications of UHF transmitter

Parameter	Specifications
Carrier frequency band	402.0 MHz to 403.0 MHz Carrier Frequency: 402.74 MHz for AWS network and 402.76 MHz for ARG network
Carrier settability	In steps of 100 Hz
Modulator	BPSK
Data bit rate	4.8 KBPS (user selectable)
Data coding	NRZ (L)
Frequency stability	
a) Long term:	Better than ± 1 ppm/year
b) Over temperature range:	Better than ± 1 ppm
Signal Bandwidth	6.0 KHz
Output power	3-10 Watt (user selectable)
Power stability	± 1 dB
Spurious	-60 dB or better
Harmonics	-55 dB or better
Environmental operating temperature	-40 C to +55 C

A crossed Yagi antenna is used to transmit data from satellite transmitter installed at remote stations. The antenna polarization field configurable and can be set either to LHCP or RHCP depending upon the satellite. The mounting arrangements are such that 360 azimuth and 180 elevation angle adjustment are possible. High gain allows operation with AWSs transmitting less than 10 Watt output. The specifications of antenna systems are given in Table 2 below.

Table 2: Typical features of crossed Yagi antenna.

Parameters	Specifications
Transmit frequency	402.0 MHz to 403.0 MHz
Gain	Minimum 11 dBi or better
Polarization	LHCP and RHCP (switchable at field)
3 dB beamwidth	40
VSWR	1.2:1
Impedance	50 ohms
Axial Ratio	4 dB
Operating wind speed	250 kmph
Wind survival	300 kmph
Material	Solid construction/ rust proof and oxidation

Connector type	proof for use in coastal and saline areas.
Mounting	N type
Operating temperature	Elevation angle engraved on the mounting -40 C

Sensor characteristics

Sensors for the parameters atmospheric pressure, air temperature, relative humidity, rainfall, wind speed, wind direction and global solar radiation are interfaced with all AWS station in the network. In addition 127 stations are equipped with soil temperature, soil moisture, leaf temperature and leaf wetness. The sensor characteristics are listed in Table 3.

Table 3: AWS sensor details and characteristics.

Parameter	Type and Make	Height	Accuracy	Range & Resolution
Air temperature	Thermistor (RM Young make)	2 m	± 0.2 C	-40 C to +60 C, Resolution: 0.1 C
Relative humidity	Capacitive type (RM Young make)	2 m	± 3%,	0% to 100%, Resolution: 1%
Atmospheric pressure	Accubar solid state (RM Young make)	1.5 m	0.2 hPa	600-1100 hPa (100 hPa above datum value), Resolution: 0.1 hPa.
Rainfall	Tipping Bucket (Komoline make)	0.6 to 1 m		Resolution: 0.5 mm
Wind speed	Ultrasonic (Gill Instruments, UK)	10 m	1.2 m/s	0-60 m/s Resolution: 0.1 m/s
Wind direction	Ultrasonic (Gill Instruments, UK)	10 m	1 °	0°-360° Resolution: 1 °
Global solar radiation	Silicon photo-diode Licor-200SZ	2 m	5% against Eppley lab	0.3- 4 μm
Soil temperature	Komoline make	--5 cm and -20 cm		-40 C to +75 C Resolution: 0.1 C
Soil moisture	Delta T	-20 cm		
Leaf Temperature	Komoline make	-	0.2 C	-40 C to +75 C Resolution: 0.1 C
Leaf Wetness	Komoline make	-	± 0.2	1%

TDMA Scheme for data transmission

A dedicated meteorological satellite INSAT-3A located at 93.5 E is used for data communication to the central receiving Earth Station. Though geostationary satellite communication has a limitation of being a one way communication and near real time data transmission (Brock et.al 1995), it is most cost-effective and reliable for a nation-wide network. The use of INSAT-3A Data Relay Transponder (DRT) is regulated by IMD and Indian Space Research Organization (ISRO). The regulations include transmission of data on assigned frequency channel (within a band of 402.65 to 402.85 MHz) and at specified time stamp at a baud rate of 4800 with 0 and 180 Degree Phase-Shift Keyed Non Return to Zero-Level (PSK NRZ-L) encoded modulation.

The ALOHA/PRBS technique had been in use for AWS data transmission since early 1980s. This communication technique is primarily suitable when number of AWS simultaneously sharing a common communication channel in a random manner is not too large. As the number of AWS increases the loss of data burst due to collision also increases. It can be shown that maximum theoretical channel utilization for slotted ALOHA technique is 36.8% and that for classical case of perfectly random transmission is 18.4% (Abramson N., 1977). Thus ALOHA/PRBS technique is not efficient in utilizing channel capacity when large number of AWS are required to be transmitted per channel. In view of massive expansion of surface observational network a more efficient transmission technique called TDMA was envisaged and finalized by ISRO. This transmission technique is being used for network of AWS and ARGs being established under modernization project for data transmission through DRT onboard INSAT-3A (93.5 °E). This technique can accommodate large number of AWS and ARGs per channel. It is now mandatory for all DRT users to operate all future networks with TDMA transmission technique.

The sampled data from each sensor of a particular AWS Station is formatted into a Data frame and transmitted in a burst mode. Each TDMA type of transmitting system has a unique GPS synchronized time of transmission. Details of the burst data format are shown in Figure 4. The CRC is calculated for 262 data bits. It is then scrambled with 1 byte consisting of all '0's and is added with the scrambled bits, after which the entire bits are convolution coded. Preamble (CR, BTR and UW) is appended with the convolution coded bits. The resulting bits are then differentially coded and transmitted. The system has flexibility to accommodate more number of channels by suitable changes in the TDMA Transmission scheme.

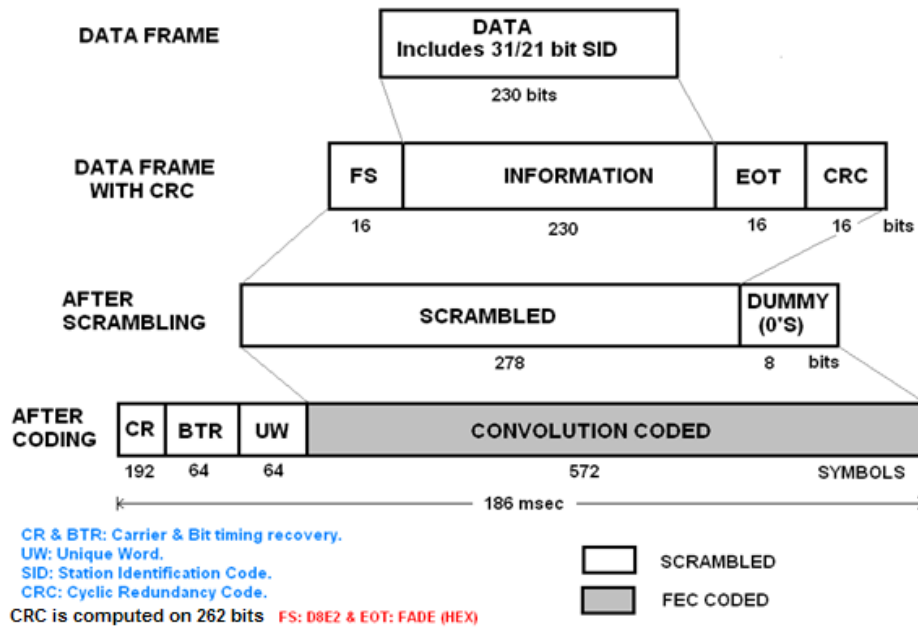


Figure 4: Details of TDMA burst format.

The burst duration is 186 msec (892 bits @ 4800 bits/sec). TDMA is an open loop system with timings derived from GPS receiver which is a part of AWS. Each AWS is assigned a unique one second time stamp. Thus, ideally 3600 stations can be accommodated for transmission per satellite channel. Although, not essential in TDMA technique, each AWS is configured to send repeat transmission after 30 minutes (twice in an hour) to ensure that data is successfully received at the earth stations. This reduces the channel capacity to 1800 stations. Practically we need to provide some time slots to allow for collisions of GPS unlocked stations and therefore the throughput may be slightly less than expected. The polynomials for generation of CRC, scrambling, convolution code are given in Table 4.

Table 4: Details of TDMA frame generation

1	CRC CODE GENERATION	Polynomial; CRC-CCITT-16 $X^{16}+X^{12}+X^5+1$
2	DATA SCRAMBLING	Polynomial: $1+X^{-1}+X^{-15}$ Initial State: 6959 (Hex)
3	CONVOLUTION ENCODING	Convolution Coding ½ Rate, Constraint Length K=7 Polynomial: G1=133(Octal), G2=171(Octal)
4	HEADER DETAILS	CR: 192 Symbols (all '0's) BTR: 64 Symbols (all '1's) UW: 64 Symbols (07EA CDDA 4E2F 28C2 (Hex)) Note: UW transmitted with LSB first of every byte, starting from 07EA.

		(See Fig.4)
5	RF DATA ENCODING	Differential coding (NRZ-L) is done for the entire burst (Preamble and the convolution coded bits) before RF modulation.

The one second frame is worked out taking into account the following details:-

- a) 20 millisecond differential propagation delay over coverage area.
- b) RTC clock accuracy around 1 millisecond per day.
- c) GPS receiver updates RTC once every twenty four hours to conserve battery power of AWS.
- d) GPS receiver accuracy of less than 1 microsecond.
- e) Guard time required in the present burst receiver at Hub station.

The main features of the TDMA scheme, which also defines the capacity of the network, are as given under:-

- a) Total number of AWS that could be accommodated in a single carrier is 1800.
- b) By including CRC in the data frame, data validity could be ensured.
- c) With preserving BCH coding of SID, data quality could be checked and valid data retrieved even for the bad CRC.
- d) By preserving present SID (Station Identification Code) structure of IMD, SID for all users of DRT could be standardized. The SID consists of 21bits (9 bits for user type, 2 bits for priority, and 10 bits for Platform ID)
- e) With Forward error correction convolution coding, better data quality is ensured.
- f) With one repeat transmission, reliability of data reception is improved.

The probability of loss of data due to burst collision is high in PRBS transmission technique and moreover it is poor in utilizing channel capacity. Hence, a more efficient transmission technique called TDMA is being used for data transmission through DRT onboard INSAT-3A.

Data Receiving Earth Station

A TDMA type data receiving Earth Station has been established at IMD Pune for reception of AWS and ARG station data. The received raw data is decoded in real time and engineering values of meteorological parameters are retrieved and archived. The Earth station is capable of receiving downlink transmissions in entire 300 MHz band (4500-4800 MHz) from DRTs onboard INSAT series of satellites. The block diagram of Earth Station is shown in Figure 5.

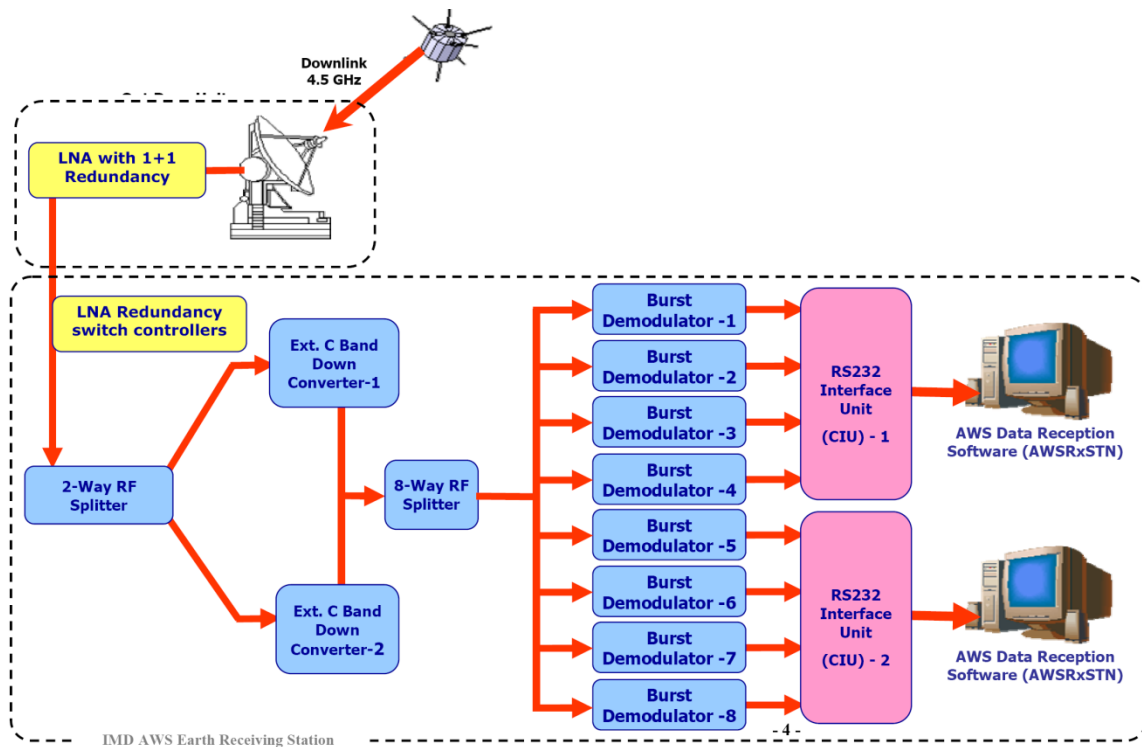


Figure 5: Block diagram of TDMA type receiving Earth Station

The Earth Stations consists of following syb-systems.

1. 3.8 m diameter parabolic antenna.
2. Low Noise Amplifier in redundant mode.
3. C-band frequency downconverter in redundant mode.
4. Burst demodulator in redundant mode.
5. Data processing workstation.
6. Data processing and archival software.

An antenna (3.8 m diamter) has been installed at Pune Earth Station site. The antenna is chosen so as to meet the telemetry link budget calculations. The antenna is a prime focus type with manual step track controller and is used in Rx only mode. The C-band redundant LNA includes primary and back LNAs and an automatic switching controller. In case of primary LNA failure, fast automatic switchover to backup LNA takes place minimising the down time. A redundant LNA is mounted in parallel with primary LNA. The system controller automatically switchover the LNA to redundant by sensing changes in amplifier current. Provision of manual switching is also available. Comtech make model DT-4503/X frequency convertor has been used in the system. The downconverter has +20dBm minimum output level at 1 dB compression point and 45 dB of gain. This permits longer cable runs. The Earth Station demodulator/DSP receiver and AWS data processing equipments can simultaneously receive, process and disseminate the data from eight carrier

frequencies. Thus data from about 7200 stations can be received at the earth station. The AWS data transmitted through any INSAT satellite in extended-C band is received at the Earth Station. The received signal is downconverted and fed to burst demodulator. The demodulated data stream is then fed to data processing system. The processing software received raw data in real time through satellite link. The data is stored in raw files for further processing. The received raw data is then decoded into engineering values and is archived in a database. The processed data can be viewed in tabular and graphical format. The data can also be exported in text, MS Excel formats. The data is then converted into WMO synop code and is then made available through GTS for weather forecasting. The data is also made available at www.imd.gov.in. The screenshots are shown in Figure 6 and Figure 7.

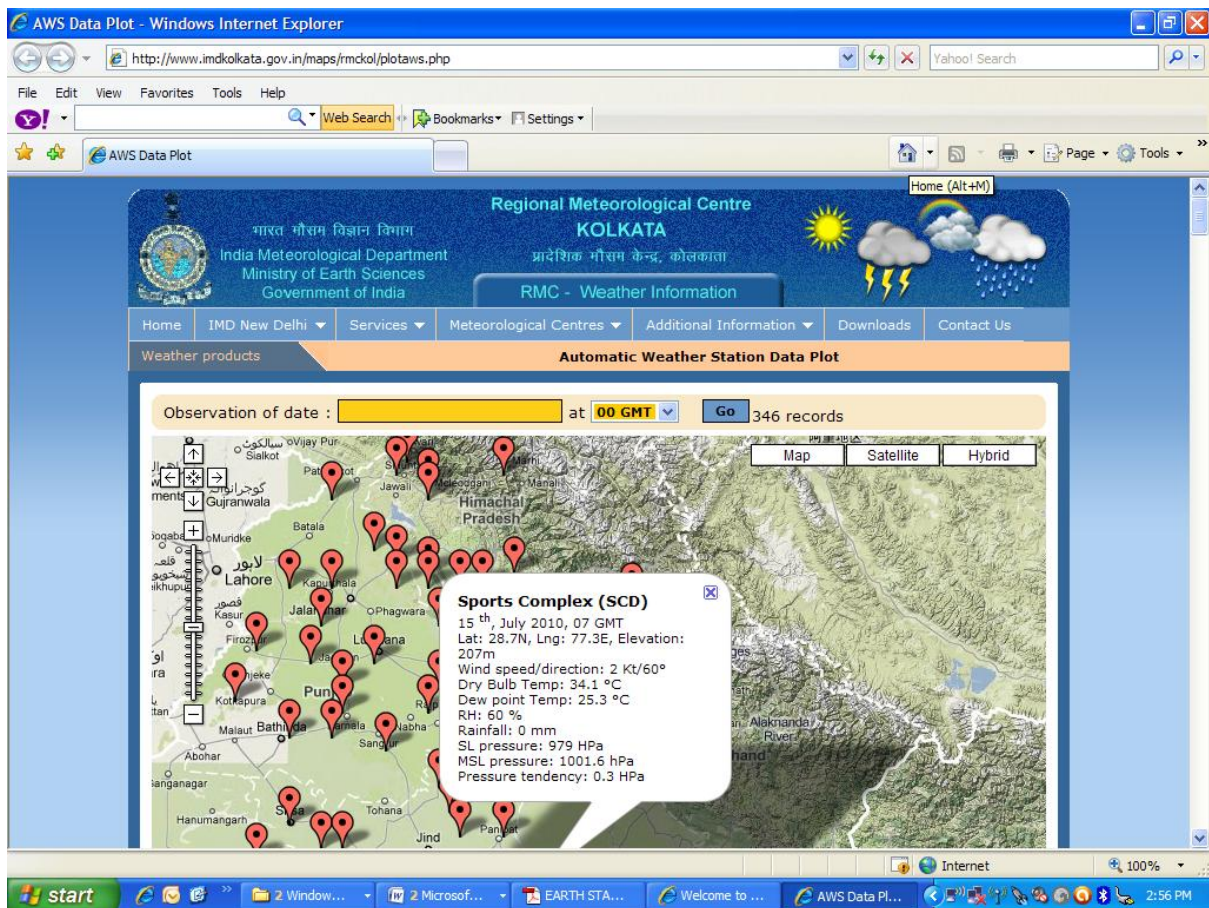


Figure 6: Graphical display of AWS data at www.imd.gov.in

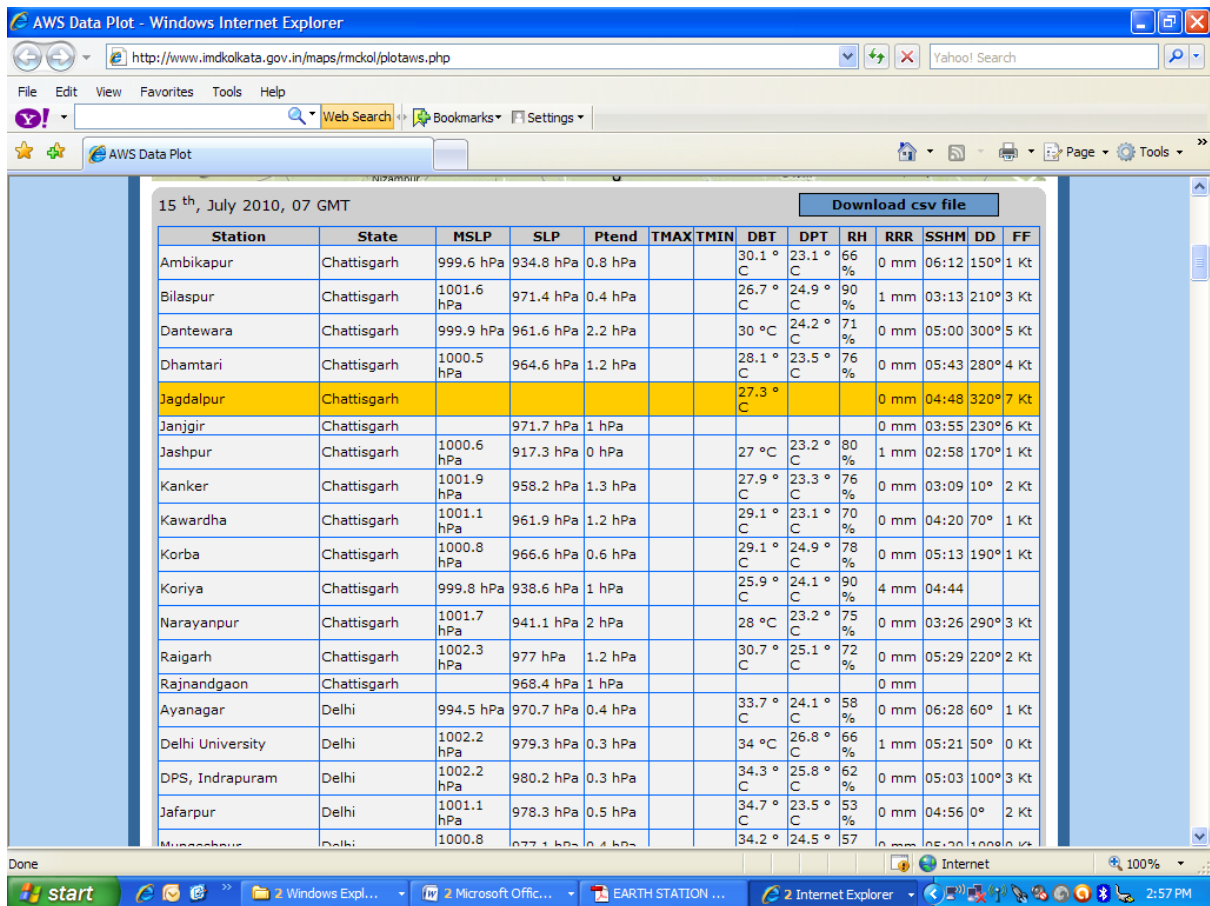


Figure 7: AWS data display in tabular format at www.imd.gov.in

Network Performance

Under modernization project phase-I, 37 AWS and 65 ARGs have been installed in the state of Maharashtra and 27 AWS have been installed in the state of Gujarat by Oct. 2009. Thus a sufficiently dense network of AWS and ARGs is now available in Maharashtra and Gujarat.

In association with active northeast monsoon surge, a low pressure area formed over Comorin area on 7th November, 2009. It became well marked over Lakshadweep area on 8th Nov. 2009. It concentrated in to a depression and lay centered at 1430 hrs IST of 9th November, 2009 over southeast and adjoining east central Arabian Sea near 11.00 °N/72.00 °E, about 70 km west of Amini Divi. It moved initially in a north-northwesterly direction till 10th morning and then re-curved to north-northeast. It intensified into a deep depression at 0830 hrs IST and into a cyclonic storm 'Phyan' at 2330 hrs IST of 10th November, 2009. Continuing its north-northeastward movement, the cyclonic storm 'Phyan' crossed north Maharashtra coast between Alibaug and Mumbai between 1530 and 1630 hrs IST of 11th November. The daily rainfall recorded by AWS and ARGs in coastal Maharashtra is depicted in Figure 8.

Daily rainfall of 11/11/2009 as recorded by AWS Network

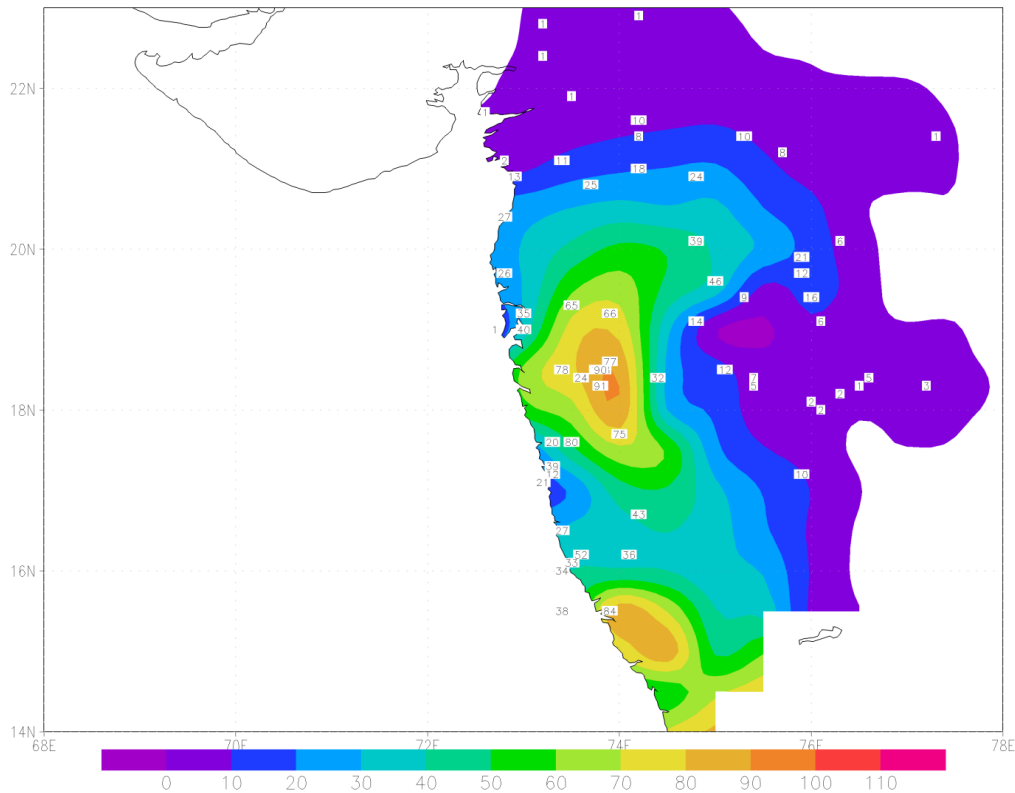


Figure 8: Performance of AWS and ARG network during Phyan Cyclone.

Concluding Remarks

The surface data obtained with the strengthening of surface observational network especially the network of Automatic Weather Stations and Automatic Rain Gauge Stations by induction of state of art technology is expected to be useful in both synoptic scale and meso-scale forecasting of weather events. The network is expected to serve following needs of IMD

1. Weather forecast
2. Issue of agriculture advisory
3. Water resources, flood forecasting
4. Research

As of Mid-July 2010 about 300 AWS and 323 ARG stations have been installed at field sites of which about 10 AWS and 30 ARG stations have some problems. Thus about 97% of AWS network and about 90% of ARG network is functional.

Acknowledgement

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