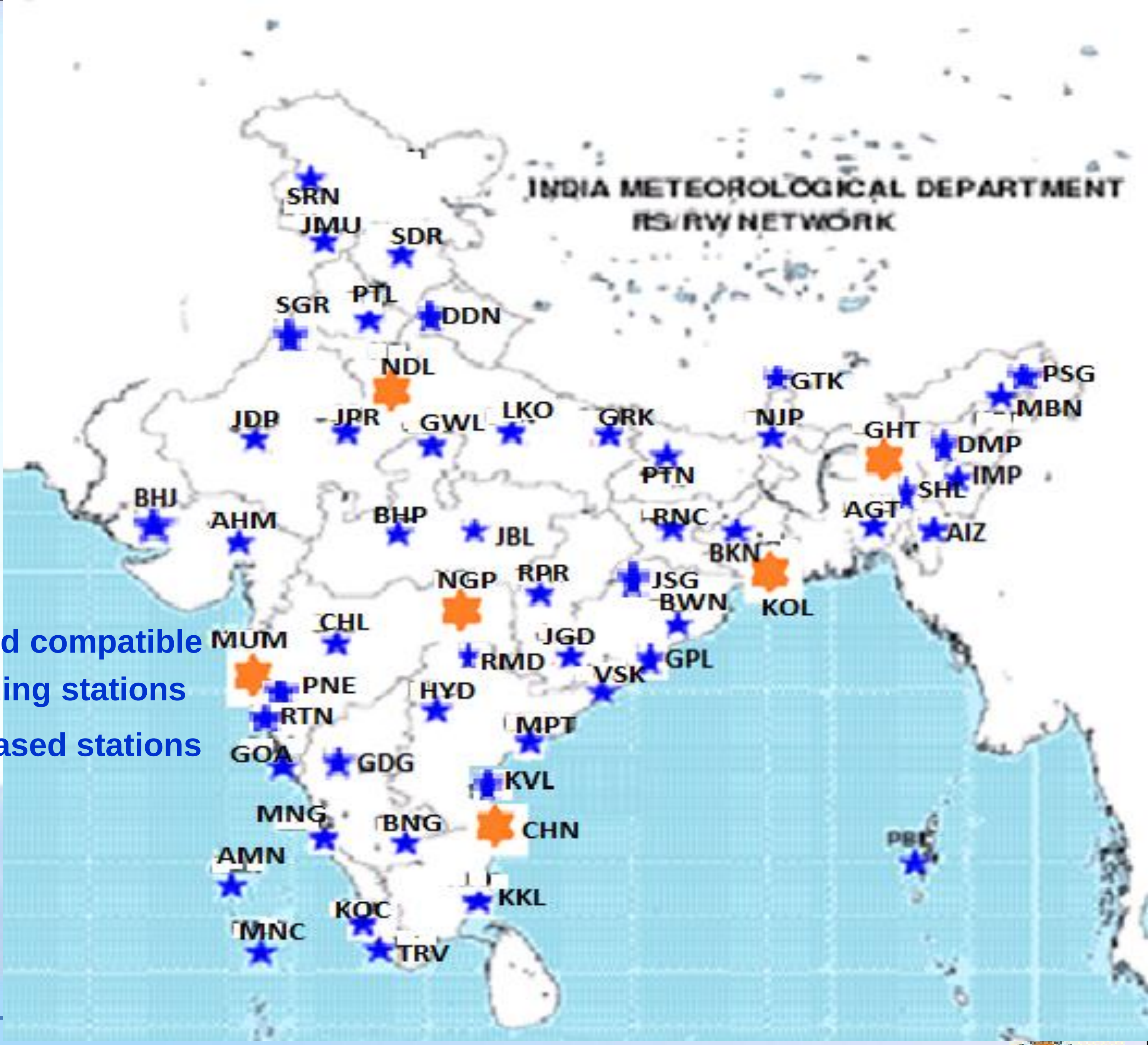
Upper Air Observations

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

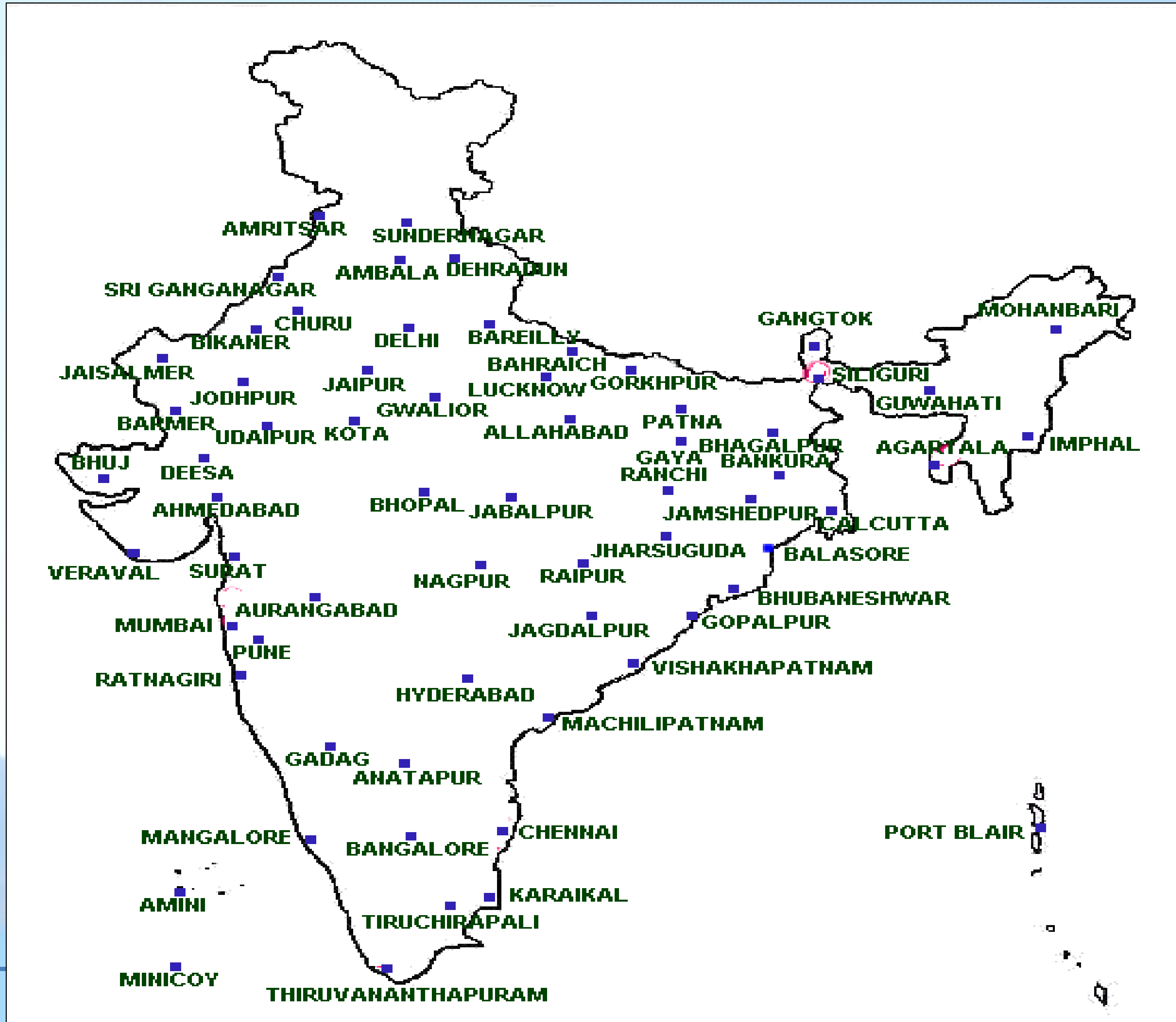
56 Radiosonde Radiowind (RS/RW) stations.



GUAN standard compatible Radiosounding stations

Other GPS based stations

- 62 stations having pilot balloon observations.



Elements of observations

- **In Radiosounding:-**

1.Temperature
2.Humidity / Dew point temperature
3.Pressure / Height
4.Wind Direction
5.Wind Speed

- **In Pilot Balloon Observations:-**

1.Wind Direction
2.Wind Speed

Measurement

- **In Radiosounding:-**

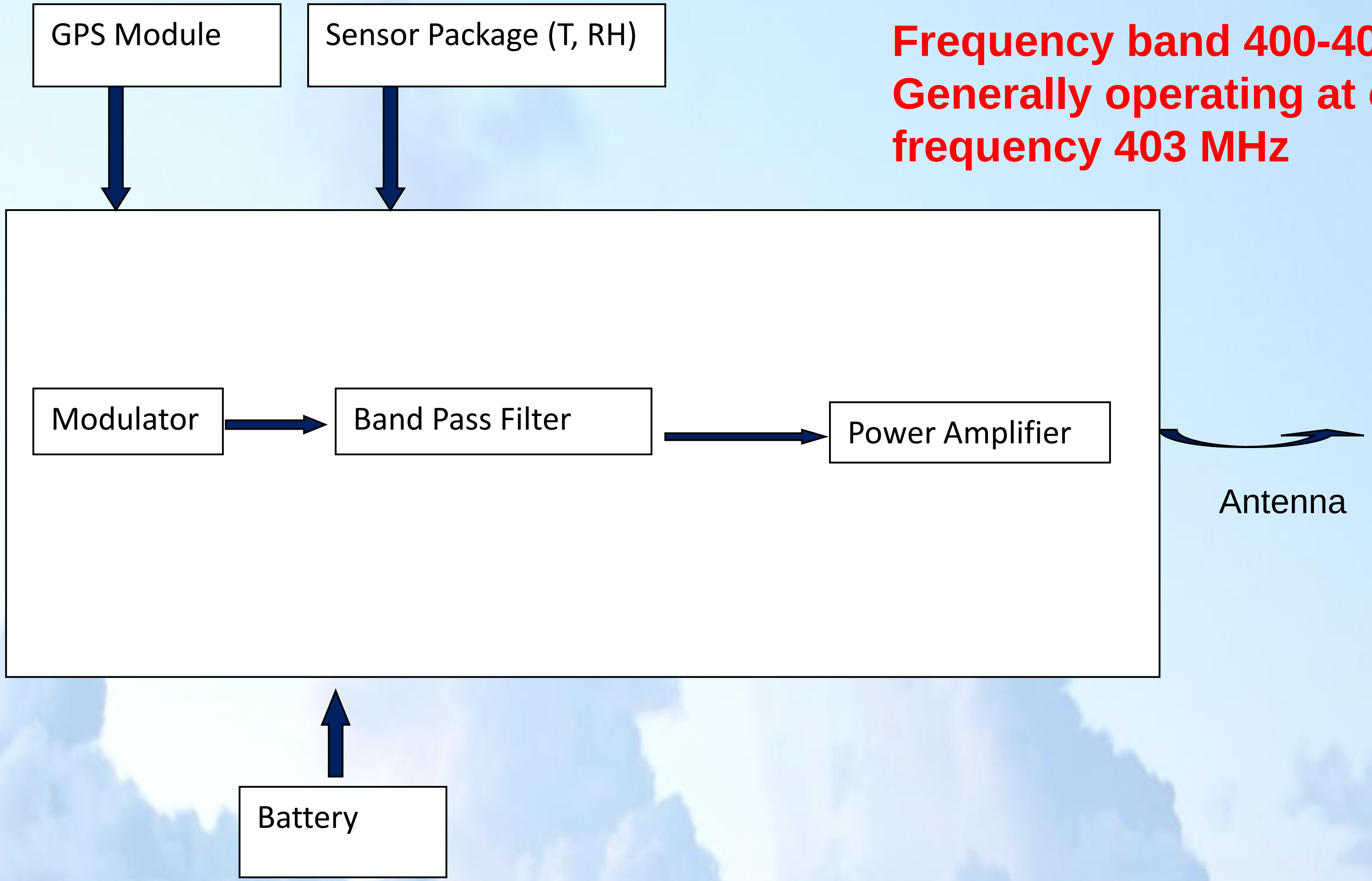
1.Temperature--	Thermistors (Rod/Bead)
2.Humidity / Dew point temp	Hygristor (LiCl, C, Cap)
3.Pressure / Height	Press sensor, GPS height
4.Wind Direction	Tracking with GPS
5.Wind Speed	Tracking with GPS

- **In Pilot Balloon Observations:-**

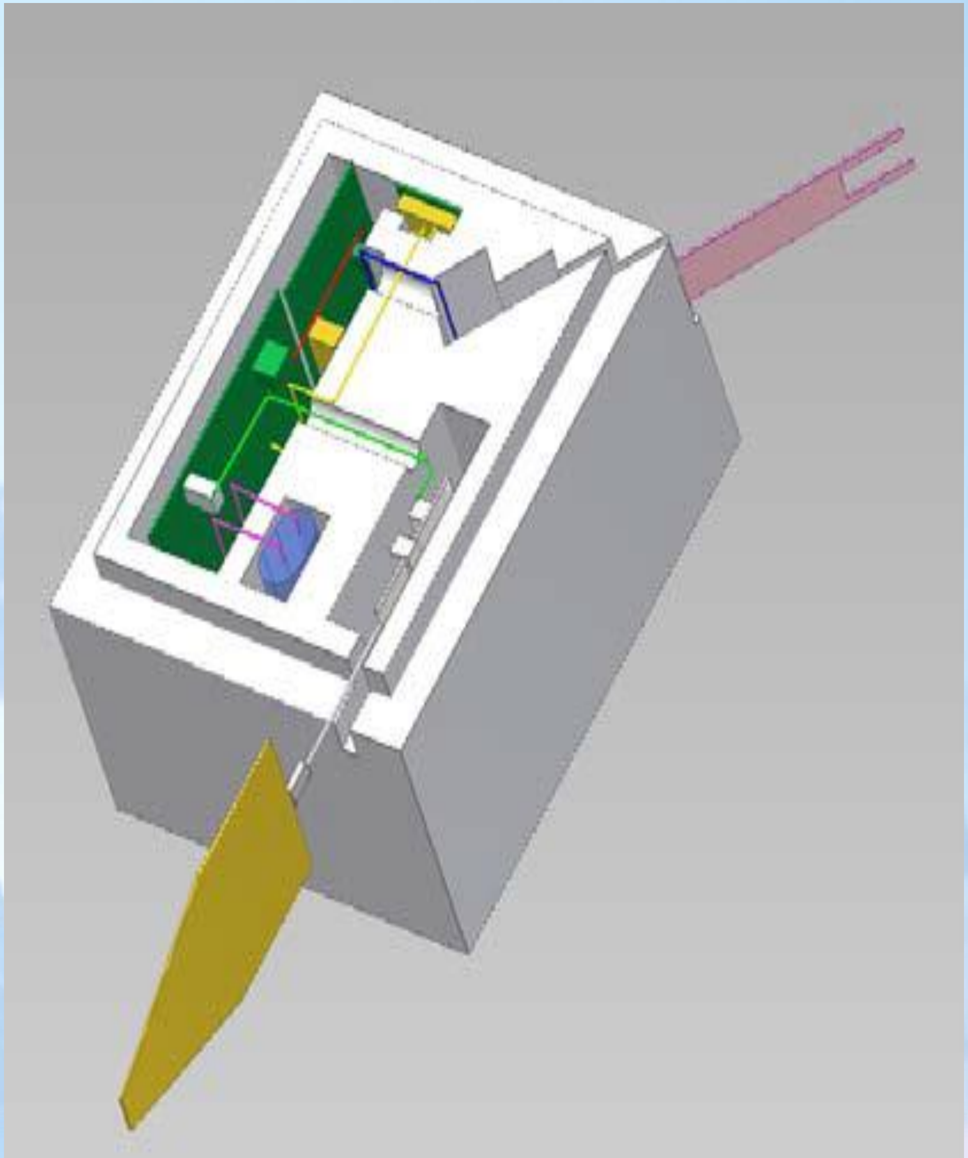
1.Wind Direction	Tracking of balloon
2.Wind Speed	Tracking of balloon

RADIOSONDE BLOCK DIAGRAM

Frequency band 400-406 MHz
Generally operating at centre frequency 403 MHz



Radiosonde launch



Radiosonde

GPSonde includes the following subsets:

- Temperature and humidity sensor boom
- 3D GPS Module
- Transmitter
- Microprocessor board
- Battery pack

GPS antenna for satellite reception and 400Mhz antenna for ground transmission.

Sounding Systems

- **Radiosounding:-**

1.GPS based radiosounding systems

2.Radiotheodolite based sounding systems

3.Radiosonde Ground equipment using optical theodolite for wind observations.

4.Satellite derived profiles

- **Wind only (Pilot Balloon) Observations:-**

1.Optical Theodolites

2.Wind Profilers

3.SODAR

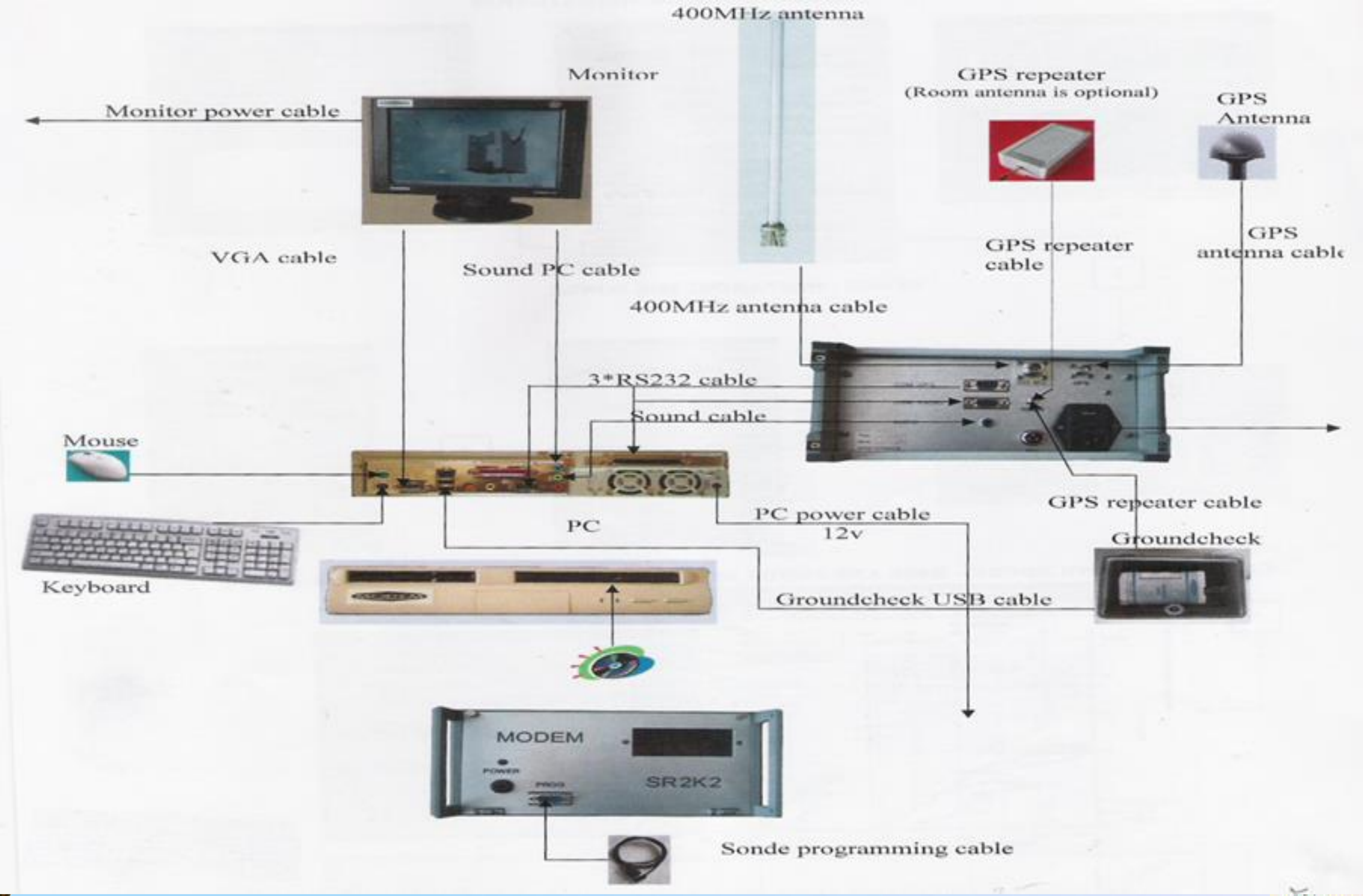
4.LIDAR

5.Pilot Sonde

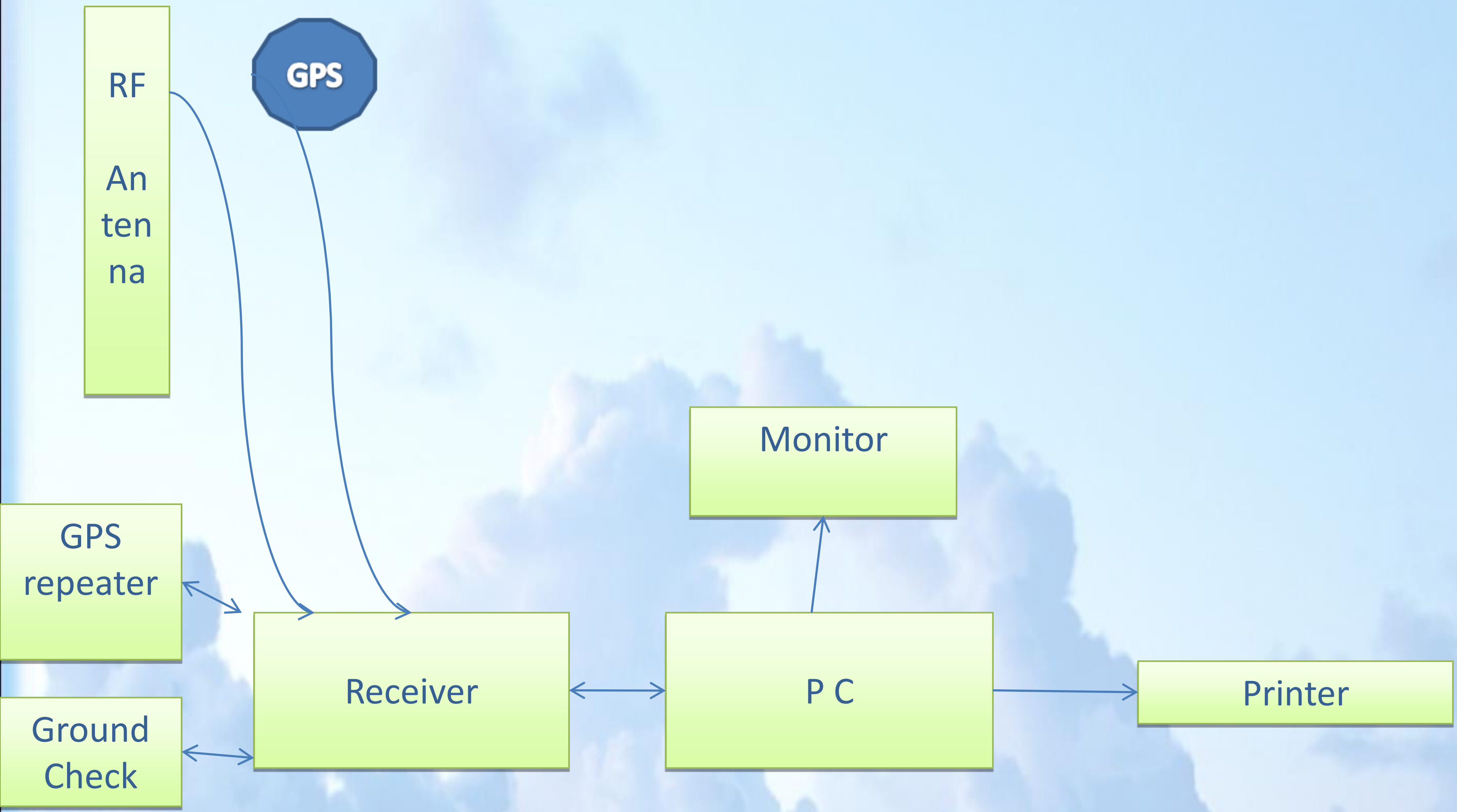
GPS based Sounding Systems

- GPS based radiosounding systems are latest in sounding.
- Fully Automatic.
- User Friendly.
- Auto tracking of balloon (transmitter)
- Auto detection.
- Minimum human interference.
- Very Light and portable type systems.
- Easy to maintain.

Radiosounding system (Ground equipment)



Block diagram GPS based Radiosounding system

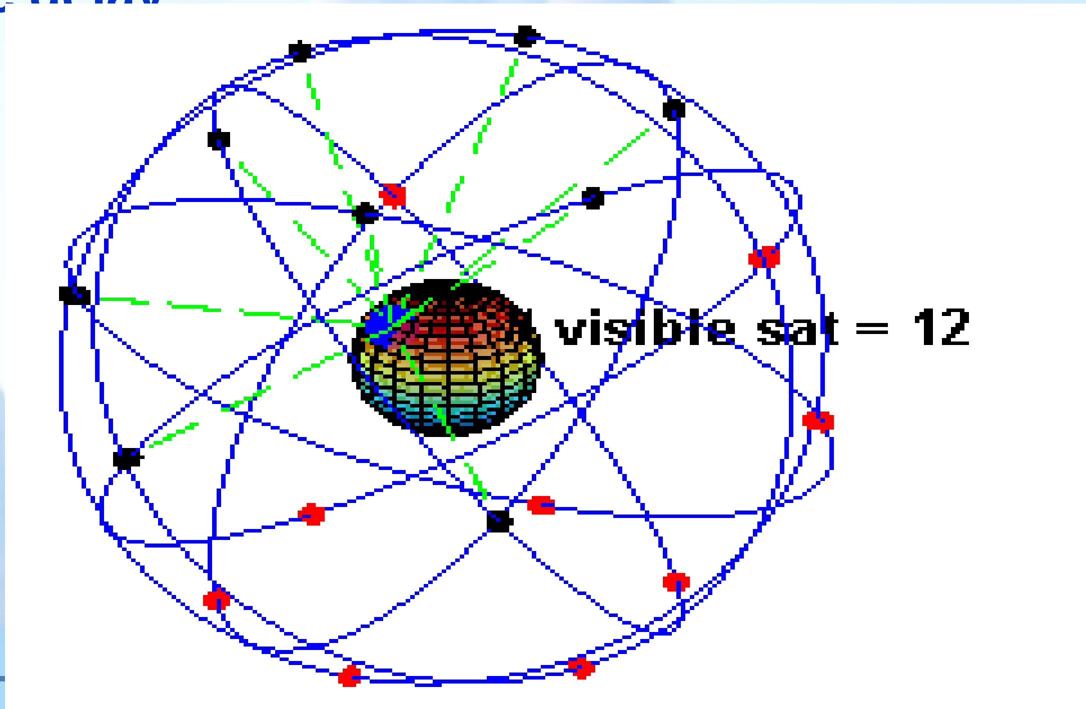


The GPS

- The Global Positioning System (GPS) is a space-based global navigation satellite system (GNSS) that provides location and time information in all weather, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites.
- It is maintained by the United States government and is freely accessible by anyone with a GPS receiver with some technical limitations.
- Originally intended for military applications but in the 1980s the government made the system available for civilian use. It consists of 31 satellites placed into orbit.
- Using messages received from a minimum of four visible satellites, a GPS receiver is able to determine the times sent and then the satellite positions corresponding to these times sent.
- While in upper air wind observations the latitude and longitude values obtained at each second is used for computing the drift of balloon by converting geographic co-ordinates to units electronic map (UTM) co-ordinates viz. North and East components (Northings and Eastings).
- Thus the wind components in zonal and meridional directions are then computed from these Northings and Eastings. The data is filtered to remove the noise before final winds are calculated.

The GPS

The GPS receiver compare the time a signal was transmitted by the GPS satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurement from a few more satellites, the receiver can determine the user's position by triangulation. Precise location of interest to geophysists required correction of position errors due to atmospheric delay.



Antennae

There are three antennas for signal reception. They are:

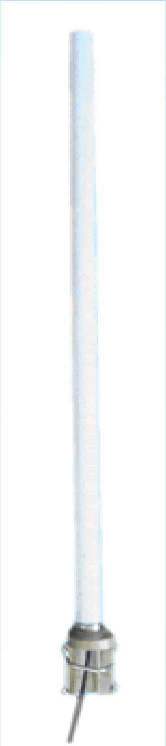
GPS ANTENNA:

TRIMBLE BULLET GPS antenna is providing GPS signals from GPS Satellite to the SR2K2 which will be used as a reference GPS ground station for differential processing (DGPS).

Antennae

<u>400 MHz ANTENNA(VERTICAL)</u>:

Omnidirectionnal active antenna with built-in low noise preamplifier. Its small size makes installation easy either on horizontal or vertical support. This antenna is used to receive the signal from 0° - 45° and 135° - 180°.



<u>TURNSTILE ANTENNA</u>:

It is a hemispherical antenna used to avoid silent zone, when the sonde attains elevation between 45° -135°. The tracking of sonde which is being a major difficulty in the existing systems has thus been overcome.   The antenna is capable to receive signals from within the range of 500 kms. All the antennas may be disconnected when not in use to prevent damage from lightening.

Data Acquisition

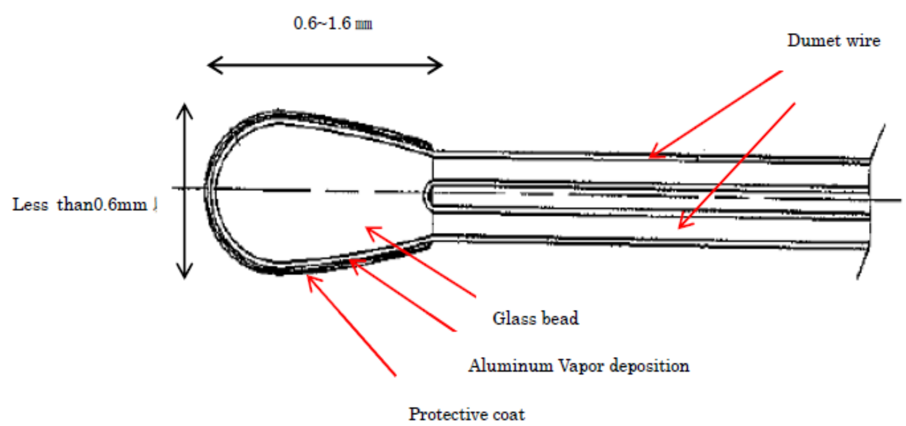
TEMPERATURE:

Temperature sensor consists in a thermistor chip wrapped into a glass ball. Its tiny size (0.9 x 2 mm) allows response time around 1 to 1.3 second. Temperature sensor is led on a layer processed against humidity and solar radiations. Boom end is painted with a special white coating to reduce solar radiation effects

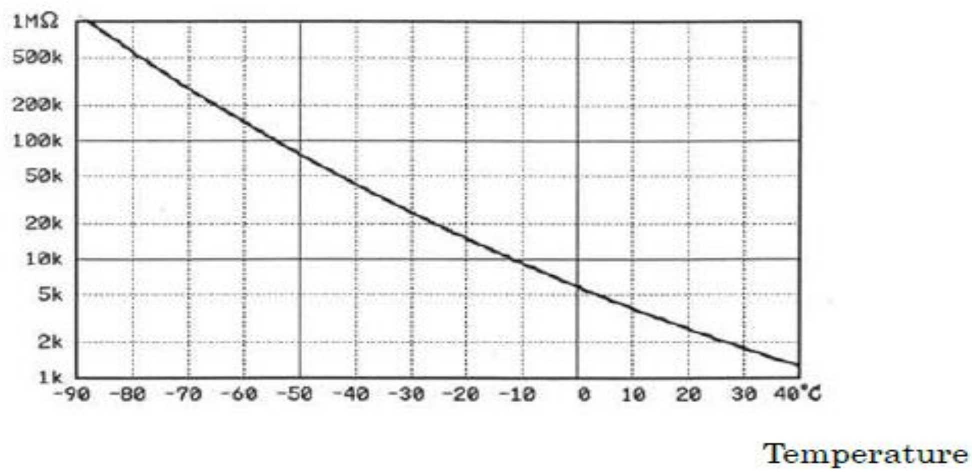
- **Thermistor of which resistance widely varies with temperature fluctuation.**
- **The thermistor is sintered from metallic oxide; Manganese, nickel, cobalt etc, and the feature is small and light, and quick response against temperature fluctuation.**
- **Thermistor used is NTC thermistor which increases resistance to temperature reducing.**
- **The tip of thermistor has vapor deposition of aluminum to reduce the influence by infrared radiation.**
- **The range of the temperature sensor is between -90ºC-60ºC with the accuracy of 0.1ºC.**

Thermistor

The cross section view of thermistor tip



Thermistor resistance



hygristor

HUMIDITY:

Humidity sensor consists in a capacitor of which value is directly proportional to relative humidity. It is composed of three components:

a) Basic layer as an electrode

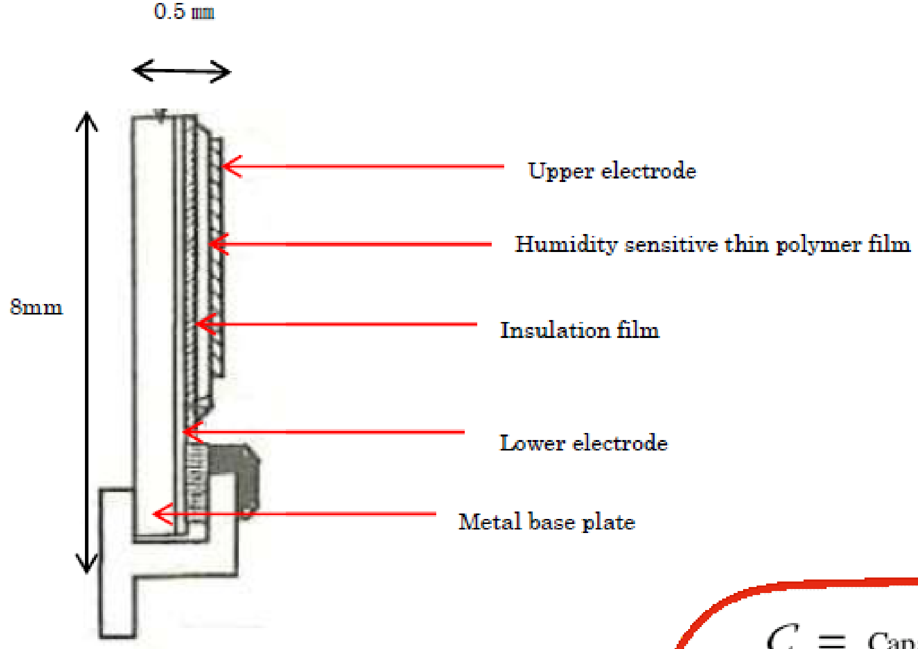
b) A dielectric of which characteristics vary along with Relative Humidity.

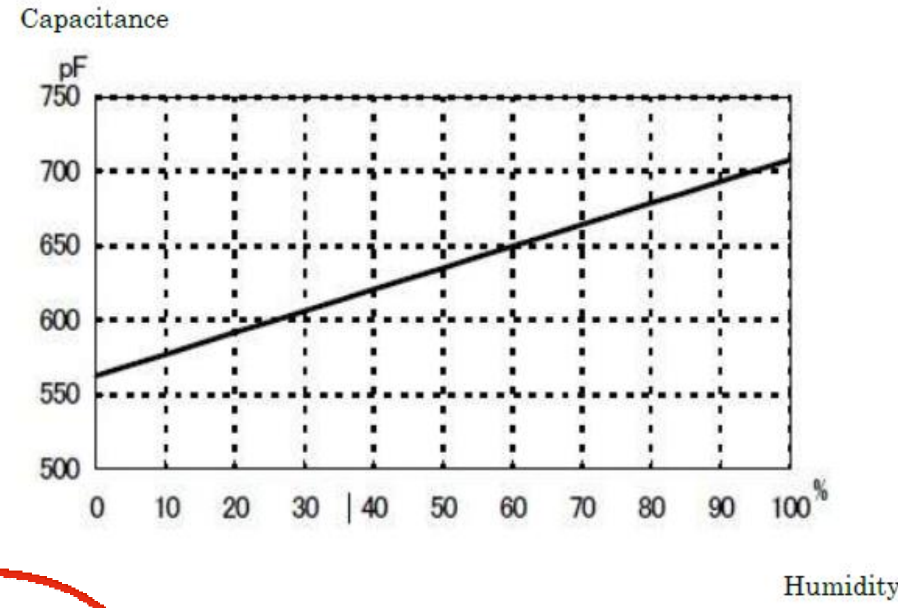
c) A short response porous electrode as the second electrode of the capacitor.

A cap is provided for protecting the sensor from rain and mechanical damage.

- Most relative humidity sensor require protection from contamination by precipitation early in the ascent.
- None of the operational radiosonde relative humidity sensors are reliable enough for good quality humidity measurements at low temperature and low pressure in the stratosphere

hygristor





C = Capacitance

$$C = \frac{\varepsilon A}{d}$$

A = Area of plates

d = Plate spacing (thickness of dielectric)

ε = Dielectric constant

PRESSURE

PRESSURE:

Pressure is calculated from GPS altitude, temperature and humidity according to the barometric equation (Laplace Law).

- **The main pressure sensor is aneroid capsule.**
- **Change in pressure is always measured by a small electrical or mechanical change.**
- **The typical maximum deflection of an aneroid capsule is about 5 mm, so that the transducer used with the sensor has to resolve a displacement of 5 micrometer.**
- **Pressure can be calculated using hydrostatic equation**

$$\frac{\partial p}{\partial z} = -g\rho$$

The negative sign ensure the pressure decreases with increasing height

Wind Observations

GPS WIND FINDING:

3D GPS module provides the position of the sonde (latitude, longitude and altitude) as well as speed components (North-South, East-West and Z). These data are correlated to time. Position is calculated every second by triangulation method between 4 or more satellites. Velocity is not calculated from the difference between two positions but directly issued from Doppler.   Differential GPS is used to compare the data in order to clear satellite disturbances and eventual interferences and thus most accurate data are obtained.

Wind Observations from Doppler Shift

The measurement method of wind direction and velocity is available by Doppler shift of GPS receiver on GPS radiosonde to GPS satellite.

A Doppler shift means that the radio wave frequency received by the GPS sonde receiver varies to transmitter's frequency (GPS satellite) when the receiver (GPS radiosonde) relatively shifts to the transmitter.

It is necessary to receive radio wave from 3 GPS satellites at least in order to get the 3D components of relative velocity. And the GPS radiosonde receives the radio wave from 4 satellites in order to correct the error of the frequency of GPS satellite and GPS receiver on radiosonde,

Wind Observations from Doppler Shift

The GPS receiver in the radiosonde measures the Doppler shift of the carrier frequency. It has two components one due to satellite motion and the other due to sonde motion.

The radiosonde transmitter sends the Doppler shift information to the ground station and the GPS receiver on the ground station will measure the Doppler shift of the carrier frequency of the satellite independently. Satellite Doppler shift is subtracted from the radiosonde Doppler shift.

$$\delta r = \frac{C}{f_{car}} \cdot f_{dop}$$

δr : Relative velocity (m/s)of GPS satellite and GPS radiosonde

C : Velocity of light(m/s)

f_{car} : GPS carrier frequency1.57542(GHz)

f_{dop} : Doppler sift frequency (Hz)

IMS100-GUAN Standard Radiosonde

Temperature	Measurement range	-95°C to +60°C
	Resolution	0.1°C
	Uncertainty[*2,3]	0 to 16km : <0.4°C Above 16km : <0.8°C
	Response time	< 0.4 s (1,000 hPa, 5 m/s)
Humidity	Measurement range	0%RH to 100%RH
	Resolution	0.1%RH
	Uncertainty[*2,3]	0 to 12km : <5%RH[*4] 12 to 17km : <5%RH
	Response time	< 0.2 s (Absorbing, 1,000 hPa, 6 m/s , 0°C) < 14 s (Absorbing, 1,000 hPa, 6 m/s, -60°C)

Pressure	Measurement range	1050.0 hPa to 3.0 hPa
	Resolution	0.1 hPa
	Uncertainty[*2,3,5]	1km : <1.2hPa 10km : <1.0hPa 16km : <0.5hPa 24km : <0.2hPa 32km : <0.1hPa
Geopotential Height	Measurement range	-500 m to 40,000 m
	Resolution	0.1 m
	Uncertainty[*2,3,5]	1km : <11gpm 5km : <11gpm 10km : <11gpm 16km : <11gpm 20km : <11gpm 32km : <11gpm

Wind Direction	Measurement range	0° to 360°
	Resolution	0.01°
	Uncertainty[*3,5,6]	0 to 16km: <1°with speed <10m/s <1° with speed >10m/s Above 16km: <1°with speed <10m/s <1° with speed >10m/s
Wind Speed	Measurement range	0 m/s to 200 m/s
	Resolution	0.01 m/s
	Uncertainty[*3,5,6]	0 to 16km : <0.15m/s Above 16km : <0.15m/s

Radio-theodolite based Systems

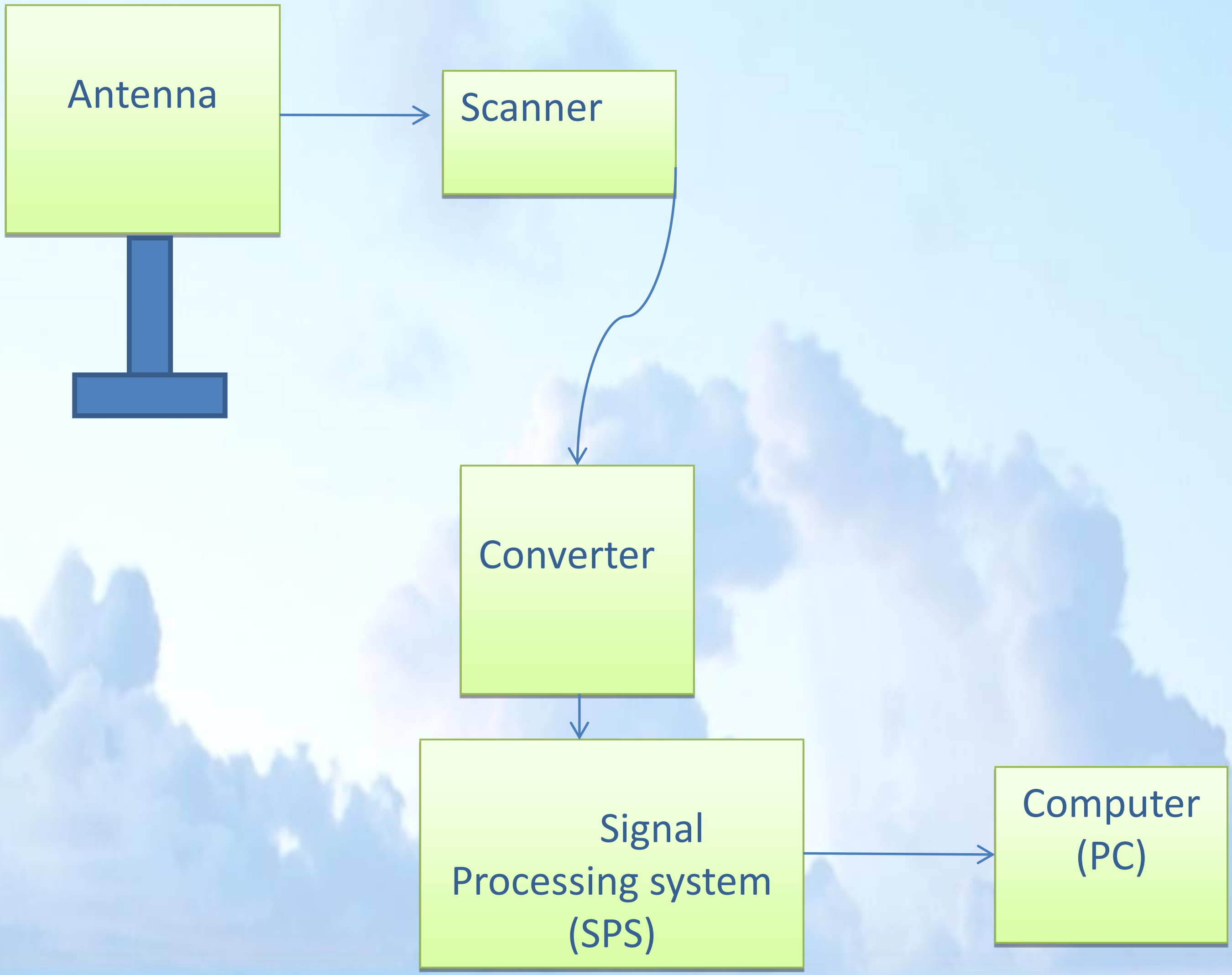
- Based on tracking of transmitter for sounding.
- New systems-- Auto tracking, but manual locking.
- Old systems-- manual tracking of balloon.
- Heavy systems because of large size of tracking antennae.
- More wear and tear--difficult maintenance.

Radio-theodolite based Systems

IMD used following type of radiotheodolite based systems-

1. **IMS-1500 radiotheodolite**
2. **SAMEER make raddiotheodolites**
3. **Radiosonde Ground Equipment (RSGE)**

Block Diagram-IMS



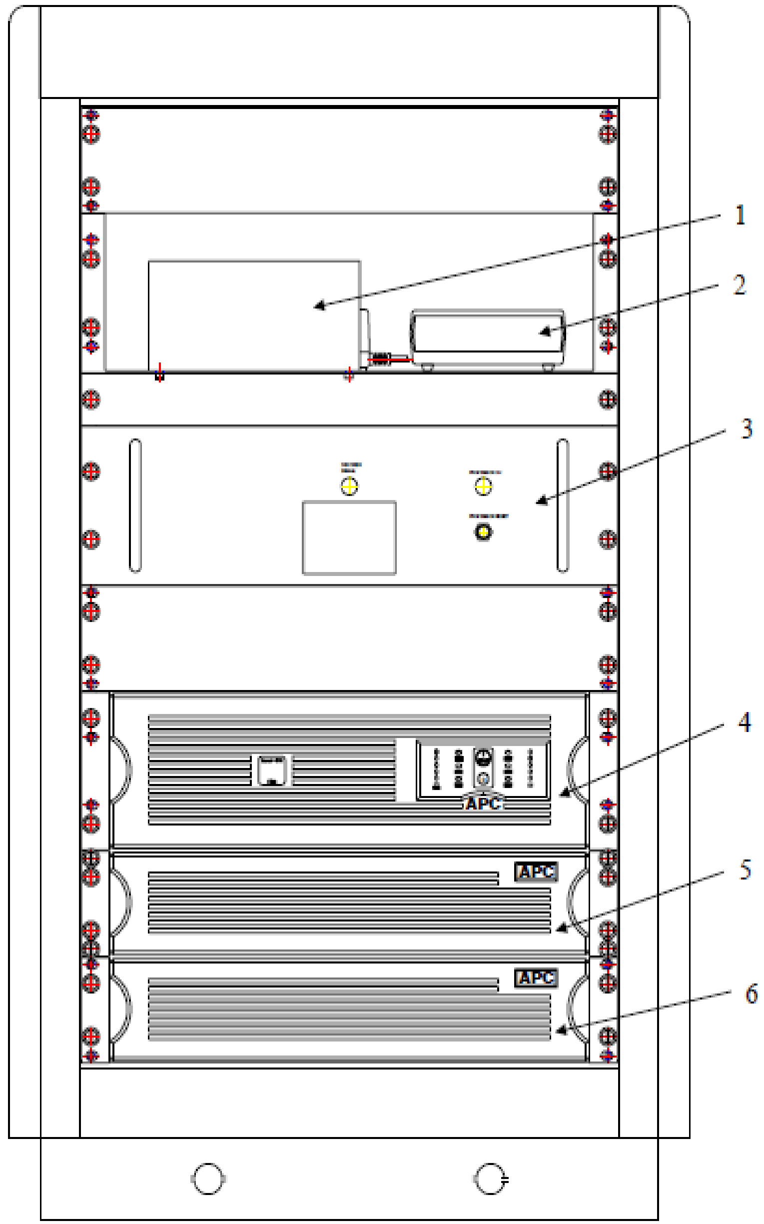
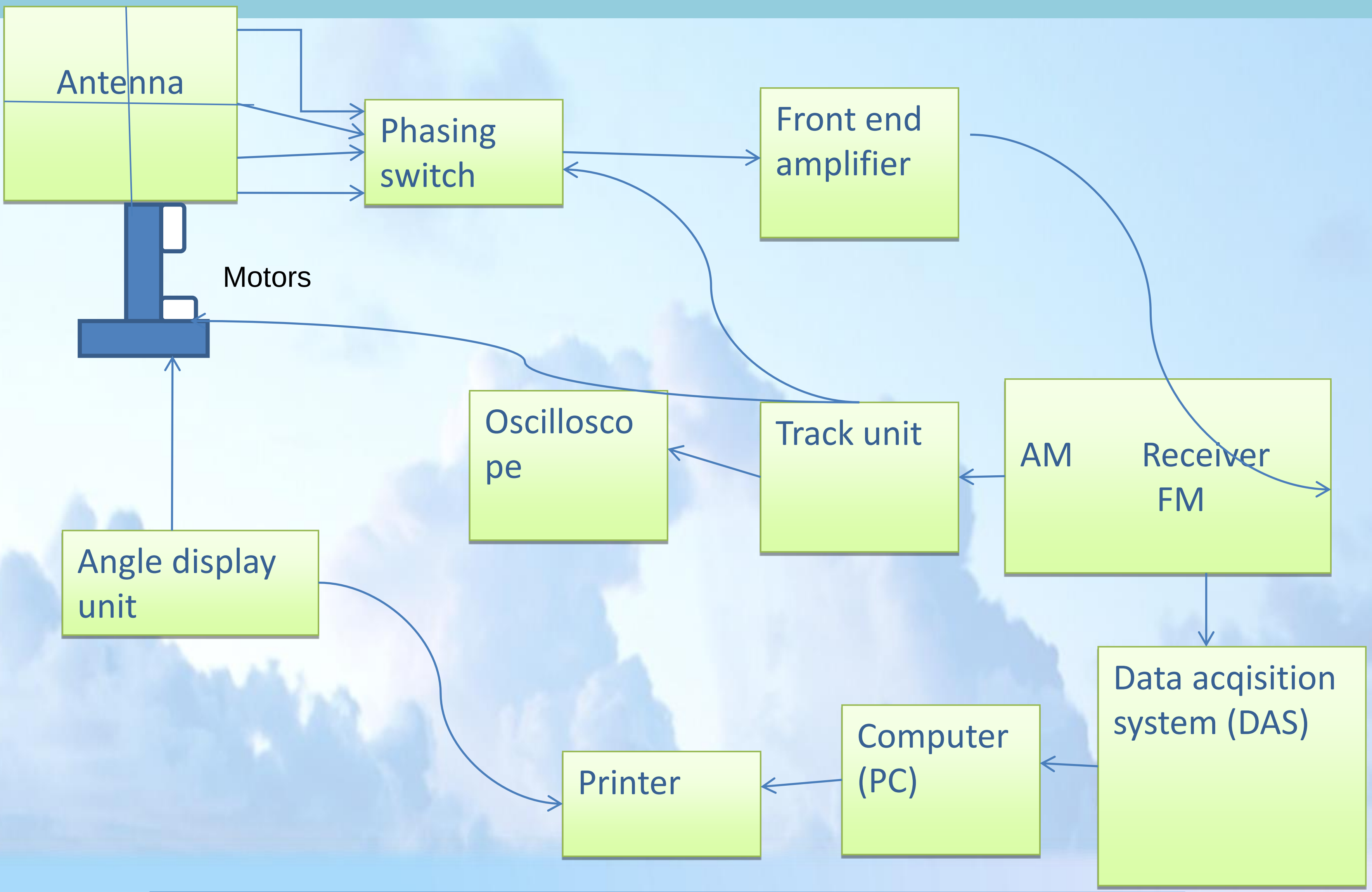


Figure 1-3: IMS-1500 Equipment Rack Assembly

The Equipment Rack consists of:

– Power Supply (1)
– Data converter with its 17 VAC power supply (2)
– Signal Processing System (SPS) (3)
– Uninterruptible Power Supply (UPS) (4)
– Battery Pack (5)
– Battery Pack 6)

Block Diagram-SAMEER



Block Diagram-Details

SAMEER make radiotheodolite is a semi-automatic system. The tracking (of transmitter) part is done by operator manually and data computation (analysis) is automatic.

Antenna: The antenna system consist of 32 centre fed dipole antennae distributed in 4 bays.

Phasing Switch:- It is signal combiner which electronically combines the 4 signals from each bay of antenna. It is situated at antenna itself.

Front End Amplifier:- Pre-amplifier situated at the antenna to amplify the received signal.

Receiver:- System is equipped with superhetrodyne type of receiver. The signal from front end amplifier comes to the receiver through along cable. AM part of the signal is used for tracking information of the radiotheodolite and FM signal, carrying Met information is demodulated and processed by receiver and fed to DAS.

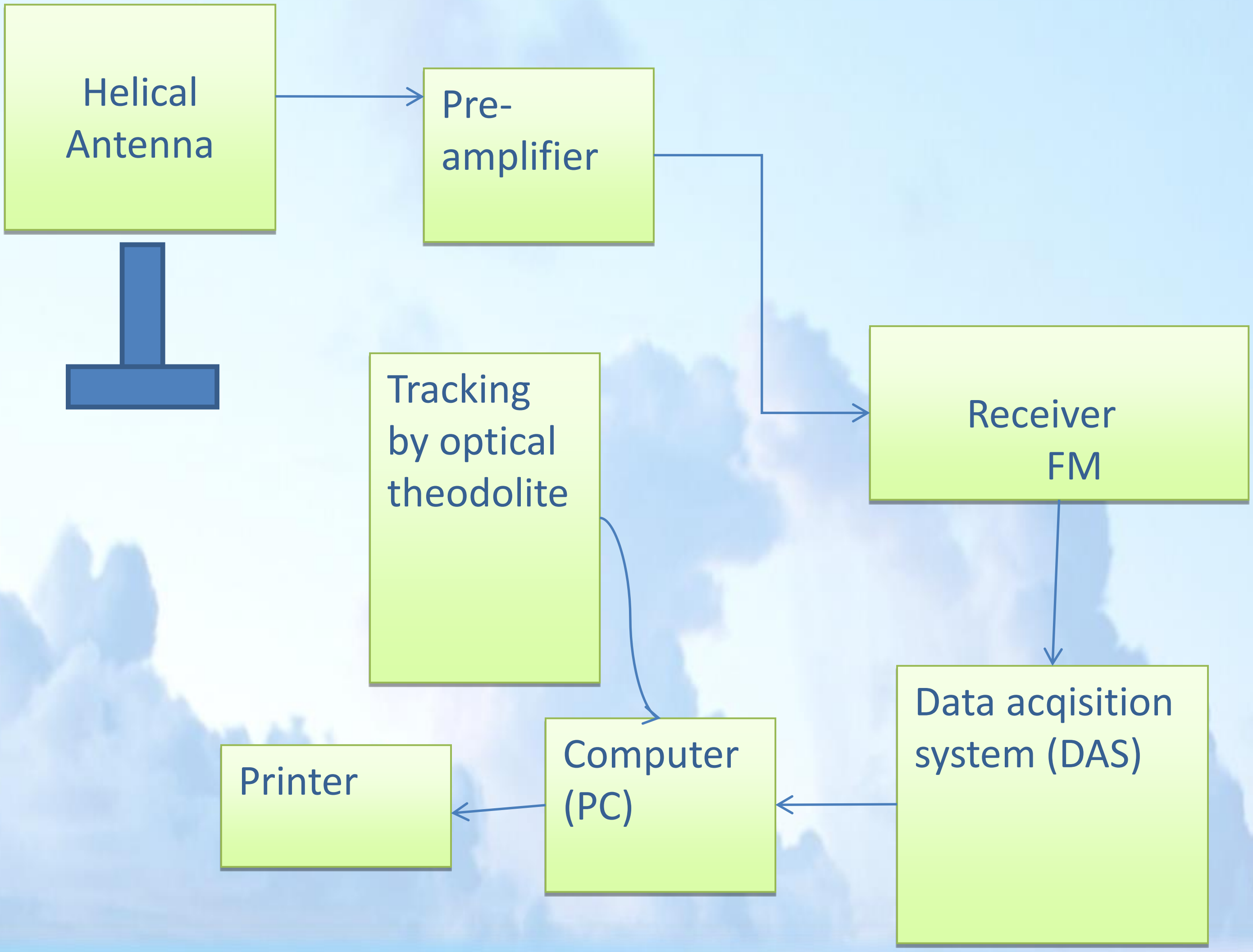
Data Acquisition System (DAS):- DAS is an interface between receiver and computer. It converts frequency form signal into PC readable form.

Personal Computer:- Simple personal computer, analyses and process the raw data, and final out produced in WMO defined formats like TEMPCODE, T-phi gram etc.

Track Unit:- Using AM signal from receiver, track unit produces pictorial information of antenna position with respect to the transmitter carrying balloon, in turn gives the position of radiosonde in the air every minute which lead to the calculation of the wind direction and speed. Track unit also controls the movement of antenna, which is through two motors situated at the antenna itself, one for azimuthal rotation and other for elevation rotation. It also provide switching pulses to phasing switch to combine the 4 signal from 4 sections of the antenna.

Oscilloscope:- The pictorial output of track unit of antenna position in terms of 4 rectangular bars (pips) is displayed on the oscilloscope.

Block Diagram-RSGE



Comparison between systems

S. N	Parameter	SAMEER	IMS	RSGE	GPS
1.	Carrier freq	401 (390-410)	1680 (1669.57-1700)	401 (395-406)	403 (400-406)
2.	IF	33	110	10.7	--
3	Tracking technique	Lobe switching	Conical scanning	helical	GPS
4	Balloon tracking	Manual	Automatic	Manual	Automatic
5	Data Computation	Automatic	Automatic	Automatic	Automatic

After sounding

- After sounding the system computes various parameters at different levels in the upper atmosphere up to 40 Km height.
- Final out put is a coded message as per WMO format used world wide.
- Data out put also available in pictorial form like trajectory of the balloon, t-phi gram, Stuve diagram, t-logP diagram, multi-curve display etc.
- The coded message is transmitted to the analysis and forecasting centres immediately after the observations.

Pilot Balloon(Only Wind) Obsns.

- These stations are taking wind observations (Direction and speed).
- Some stations take two ascents a day 0000 & 1200 UTC.
- Some stations take four ascents at synoptic hours.

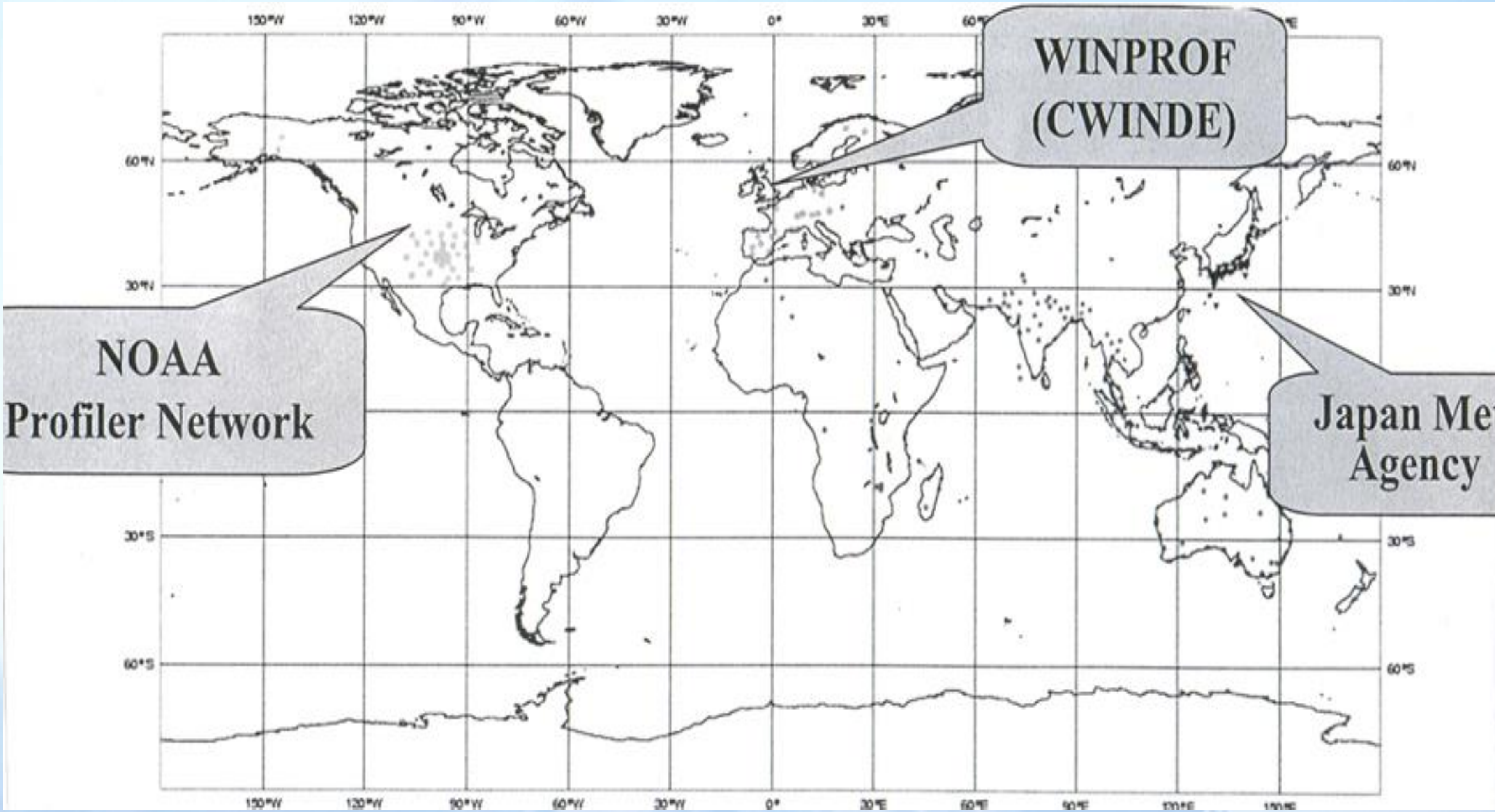
Various techniques for wind observations:-

1. Optical theodolite
2. Wind Profiler
3. SODAR
4. LIDAR
5. Pilot sonde

Wind Profiler

- In case of upper wind observations, Wind Profilers are capable to provide hourly or more frequent wind speed and direction values as a function of altitude.
- A wind profiler is a type of weather observing equipment that uses radar to detect the wind speed and direction at various elevations above the ground.
- Readings are made at different heights above sea level, up to the extent of the mid-troposphere.
- Above this level there is inadequate water vapour present to produce a radar "bounce."

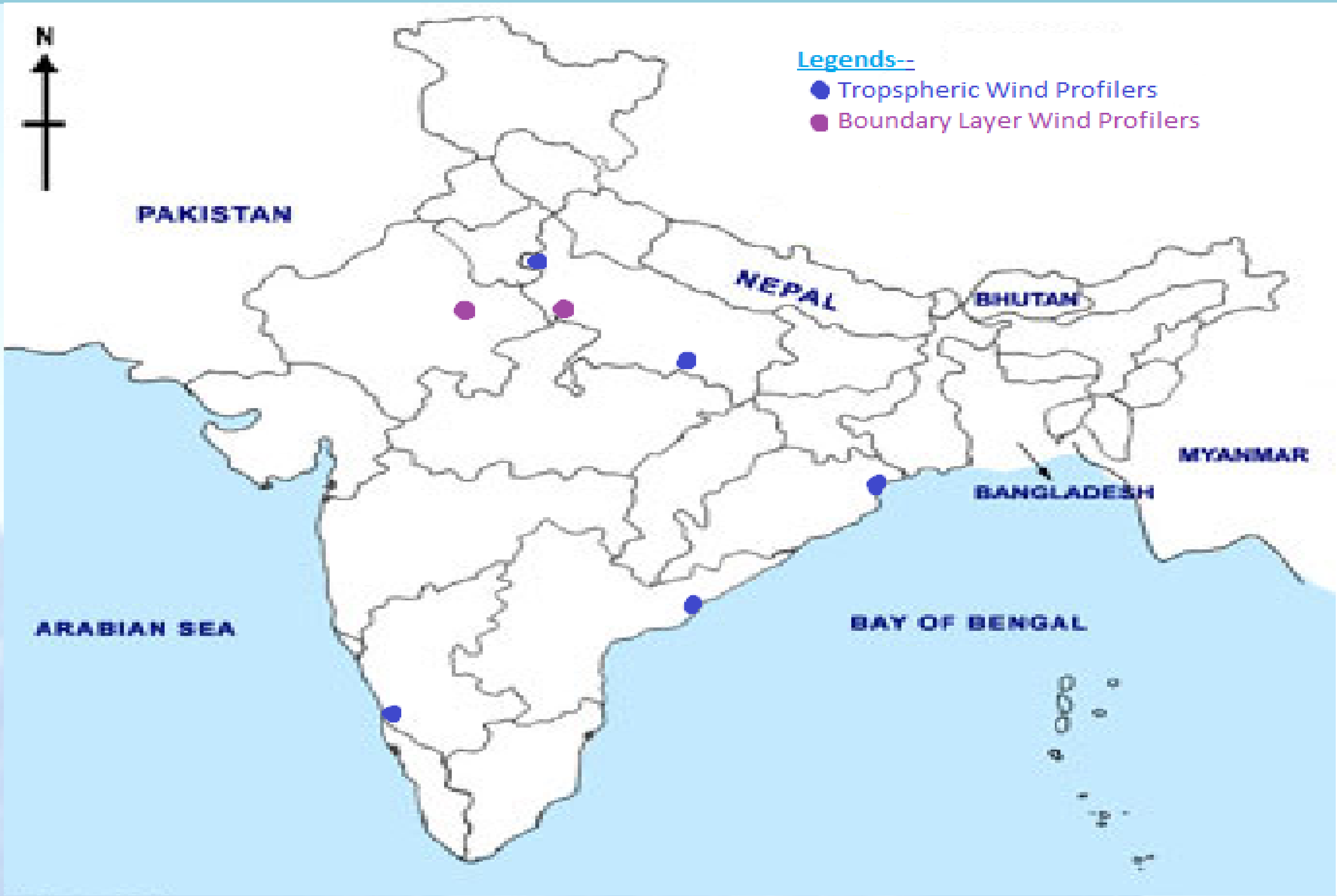
Major Wind Profiler Networks in the World



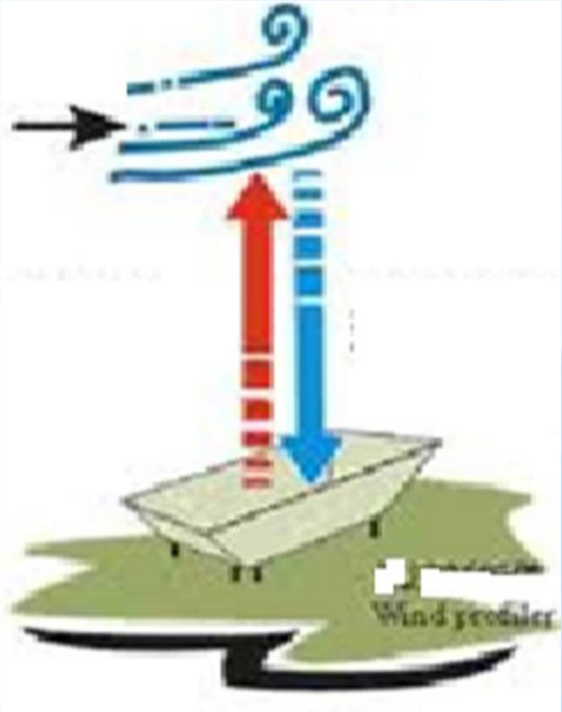
Major Wind Profiler Networks in the World

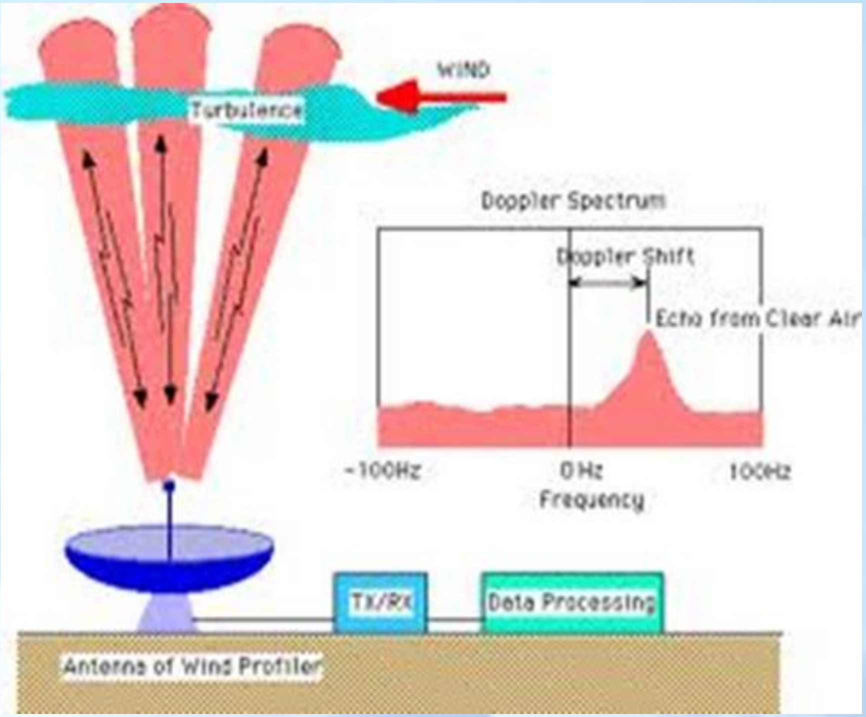
S.No	Network	Profiler
1	NOAA Profiler network, USA	35 UHF profiler (32 @ 404 MHz, 3 @449 MHz
2	JMA Wind Profiler network, Japan	31 profilers @ 1357 MHz
3	WINPROF, ECMWF network	21 WPR, 2 SODAR (19 LT WPs-14 Vaisala 3 Degreane make)

Proposed IMD network



4. Concept


Wind profiler


WIND
Turbulence
Doppler Spectrum
Doppler Shift
Echo from Clear Air
-100Hz
0 Hz
100Hz
Frequency
TX/RX
Data Processing
Antenna of Wind Profiler

….Contd..

- High time resolution data: typical 30 minutes.
- Data almost instantaneous available (Nowcasting)
- Eulerian type of measurement (true vertical profile, all Heights measured at same time).
- Unambiguous profiles, independent of the assimilation system.
- Almost all weather.
- Existing and proven.

…..Contd…

- The biggest advantage of the wind profiler is that it continuously monitors the direction and speed of the wind without any break point or gap which makes it one of the accurate and efficient equipment in the field of environmental sciences and whether forecasting.
- It can prevent many fatal disastrous affect that can occur in the situation of storm and ocean imbalance.
- As it can measure the wind direction and speed above the sea level so it can easily detect from the speed of the wind about tidal waves and far storms that can hit the area in few hours.
- Very useful in reporting and alarming the flight situations which can prevent the major crashes. The flight reporting center can inform the pilot on cockpit in time about the upcoming air pockets that can pressurize the aircraft.
- This is done when the wind radar profilers measure the intensity turbulence and wind speed and inform the atmospheric stability to choose the appropriate action.
- Hence an important tool for NOWCASTING.

SODAR system

- SODAR (Sonic Detection And Ranging), is a meteorological instrument which measures the scattering of sound waves by atmospheric turbulence. SODAR systems are used to measure wind speed at various heights above the ground of the lower layer of the atmosphere.
- Sodar systems are like RADAR (radio detection and ranging) systems except that sound waves rather than radio waves are used for detection. Other names used for sodar systems include sounder, echosounder and acoustic radar.

Contd.

- ❖Obtaining atmospheric wind profiles at remote unmanned sites is a major technological challenge.
- ❖ Wind profilers that are based on Doppler radar techniques do not have the resolution that is required for boundary layer studies.
- ❖Doppler sodar techniques offer the possibility of continuous wind profiling.
- ❖Doppler sodar systems work by transmitting acoustic pulses upward into the atmosphere and detecting the Doppler shift in the backscatter signal. By using off-vertical acoustic paths, it is possible to calculate the velocity profile of the reflector, which is then assumed to be identical to the wind profile (Neff and Coulter 1986).
- ❖Their disadvantage is that they are relatively power hungry compared to more passive systems, such as automatic weather stations.

Importance: Winds in boundary layer

- PB (No. of ascents / Min ht measurable)
- Wind profilers (Min ht measurable)
- RS/RW (No. of ascents)
- Lidar (High cost)

Applications

- Meteorology
- Aviation Meteorology
- Environmental Impact studies
- Planetary boundary layer research
- Inversion detection
- Sea / land breeze studies
- Research in atmospheric dynamics
- Environmental monitoring
- Wind energy site evaluation

Pilot Sonde

- Even after modernization of the PB network. The data availability has not increased much because the observations by optical theodolites have constraints of getting less data in disturbed weather like fog, rain, cloudiness etc when it is eagerly needed.
- To overcome these weather constraints a weather proof system of PB observations is required.
- In radiosonde / radiowind (RS/RW) observations, most of the Meteorological agencies in the world have adopted the GPS based system of observations.
- On the same lines using the GPS technique the Pilot Balloon sonde may be developed and using that PB network may be further modernized.

Hardware Requirements

- The system requirement can be divided into two parts;

  A). The ground receiver system

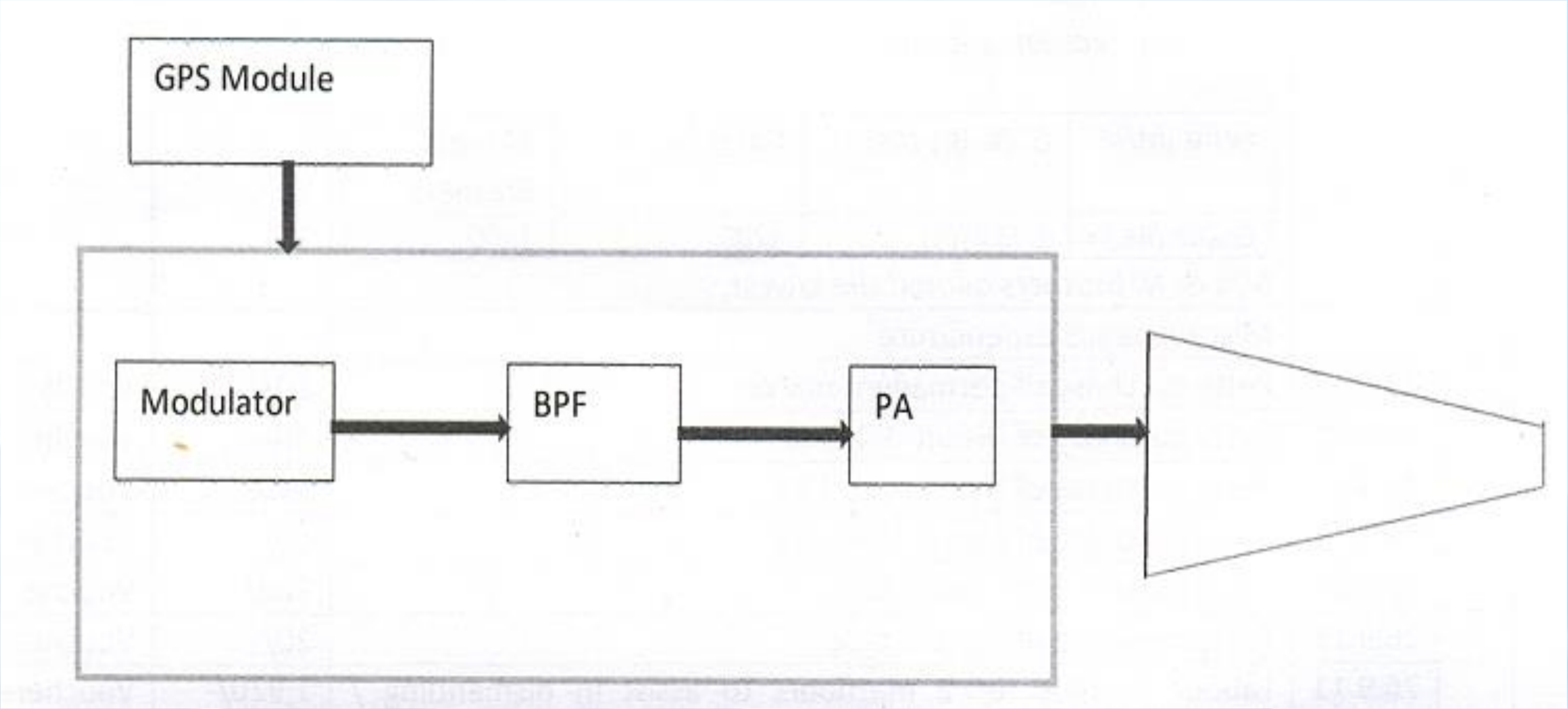
  B). The Pilotsonde

A).The GPS based ground receiver systems being used with RS/RW system can be used for PB observations, hence no separate ground equipment are required.

- There are so many different type of brands are available in the world market which can be directly used.
- Even indigenous GPS based receiver system are also available.

B). Pilot-sonde

The proposed pilot balloon sonde block diagram is given below;



Software requirements

- The wind computation part of the RS/RW software may be used in the pilotsonde observations, as it is capable of;

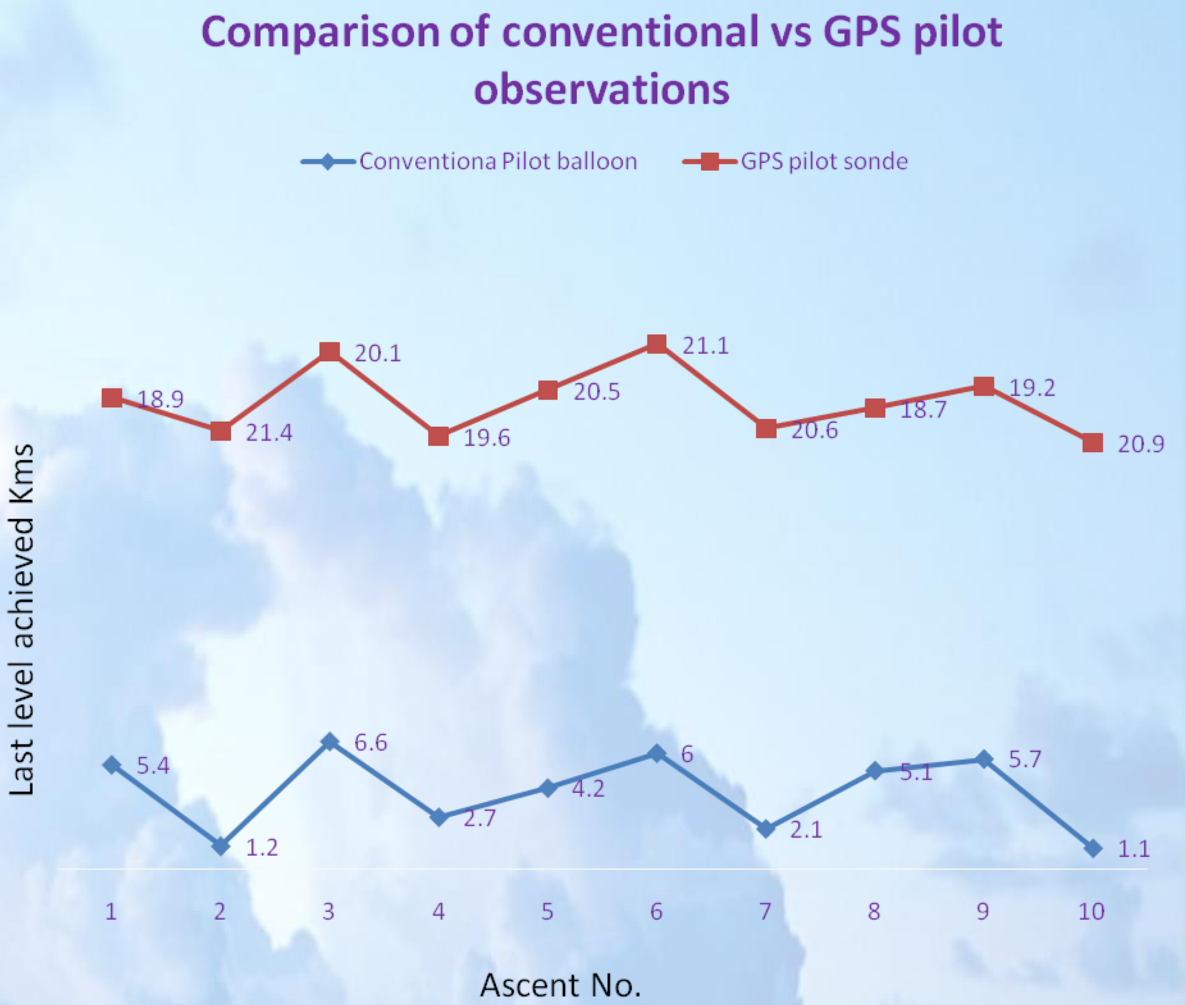
1. Displaying real time wind data with graphical user interface,
2. Display of complete processed results along with plots,
3. Generation of flight report
4. Generation of coded PB messages.

Advantage

- It is evident from GPS based RS/RW ascent that the flight termination in most of the cases is balloon burst.
- The GPS receiver does not lose the signal while ascending.
- The data availability depends mainly on the quality of balloon in all weather conditions.
- Whereas, the presently used PB observations using optical theodolites are heavily dependent on weather conditions.
- With optical theodolites, we get more data in clear weather and the data availability decreases with adverse weather.
- We get less data or no data when it is urgently required by the forecaster.
- The average height of PB balloon observations even after modernization of PB network, by providing each station a good quality optical theodolite system has an increase of just 0.5 to 1 km only and some stations have no change in their status of maximum height coverage.
- It is mainly because of weather constraints.
- The use of GPS based system in PB observations is expected to remove all these constraints.

Justifications

- For the data availability to a large extent, in most of the cases up to 20 Kms of height, especially in adverse weather conditions, when the data is eagerly awaited, the investment is justified.
- Hence it is feasible to implement the use of pilotsonde on operational basis in upper air network of IMD at PB stations.



Applications

- Meteorology
- Aviation Meteorology
- Environmental Impact studies
- Planetary boundary layer research
- Inversion detection
- Sea / land breeze studies
- Research in atmospheric dynamics
- Environmental monitoring
- Wind energy site evaluation

Upper air observations: Ozonesonde

- Scientists have been studying the concentration of ozone in the atmosphere since the 1920s.
- Early 1930s, several estimates of the average vertical distribution of ozone in the atmosphere were made.
- The spectrum of direct sunlight was measured during sunrise or sunset by comparing two wavelengths: one strongly absorbed by the atmosphere (short) and the other weakly absorbed (long).
- In 1929, during observations at Spitzbergen, Götz noticed that the skylight was relatively richer in shorter wavelengths when the sun was setting compared to when it was a few degrees above the horizon. This phenomenon became known as the "Umkehr Effect."

Upper air observations: Ozonesonde

- The first ozone measurements in India were made in Kodaikanal during 1928-29 as part of Dobson's worldwide total ozone measurement.

- In 1940, the India Meteorology Department (IMD) acquired the first Dobson Spectrometer, and primary observations were made in Pune. Later, a network of six stations was established in India for ozone observation, including Srinagar, New Delhi, Varanasi, Kolkata, Ahmedabad, and Kodaikanal.

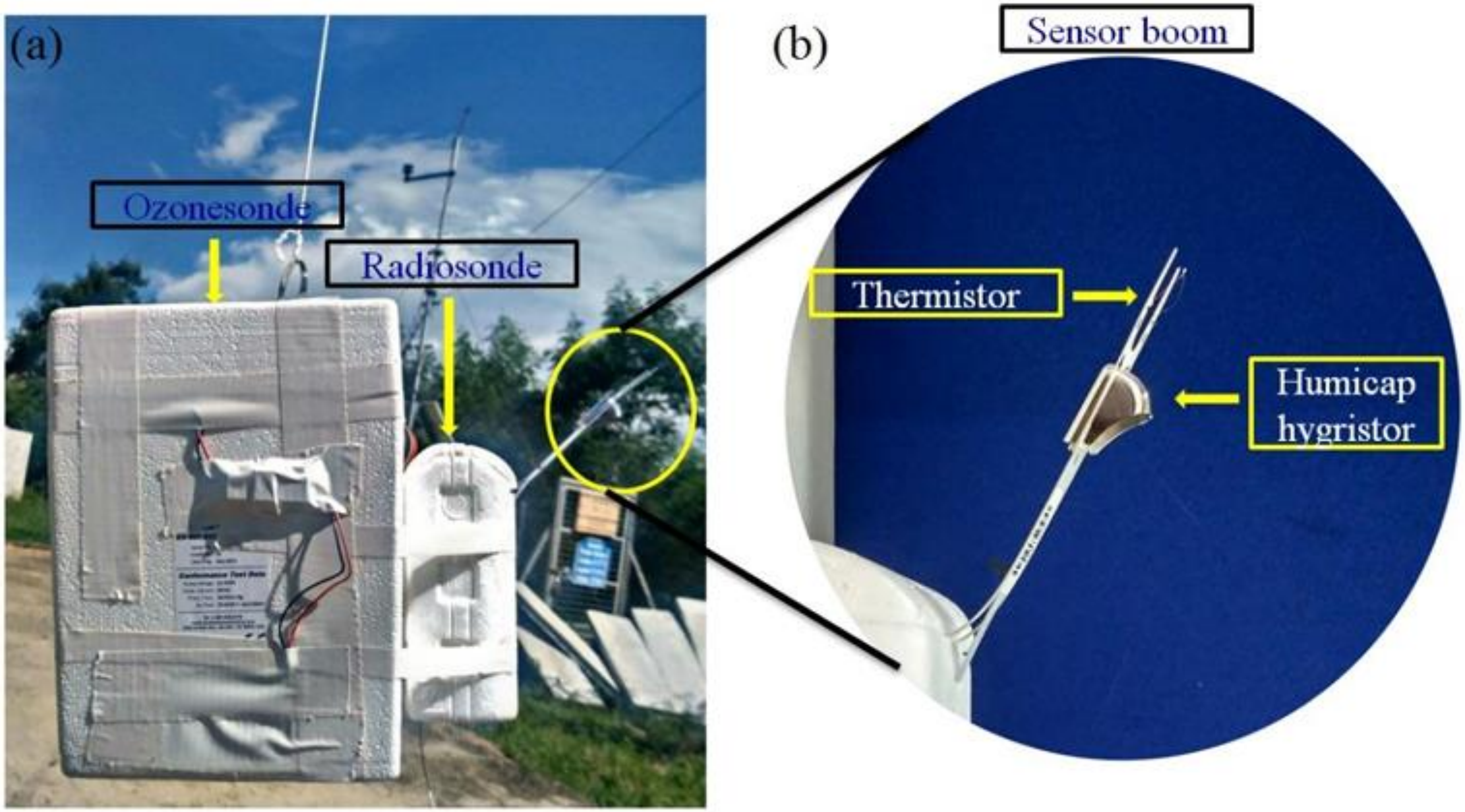
- The measurement of the vertical distribution of ozone using electrochemical sondes began in India in 1964 in Pune.

Ozonesonde

- Regular ozonesonde launches every fortnight started in 1971 at three stations: Trivandrum, Pune, and New Delhi.

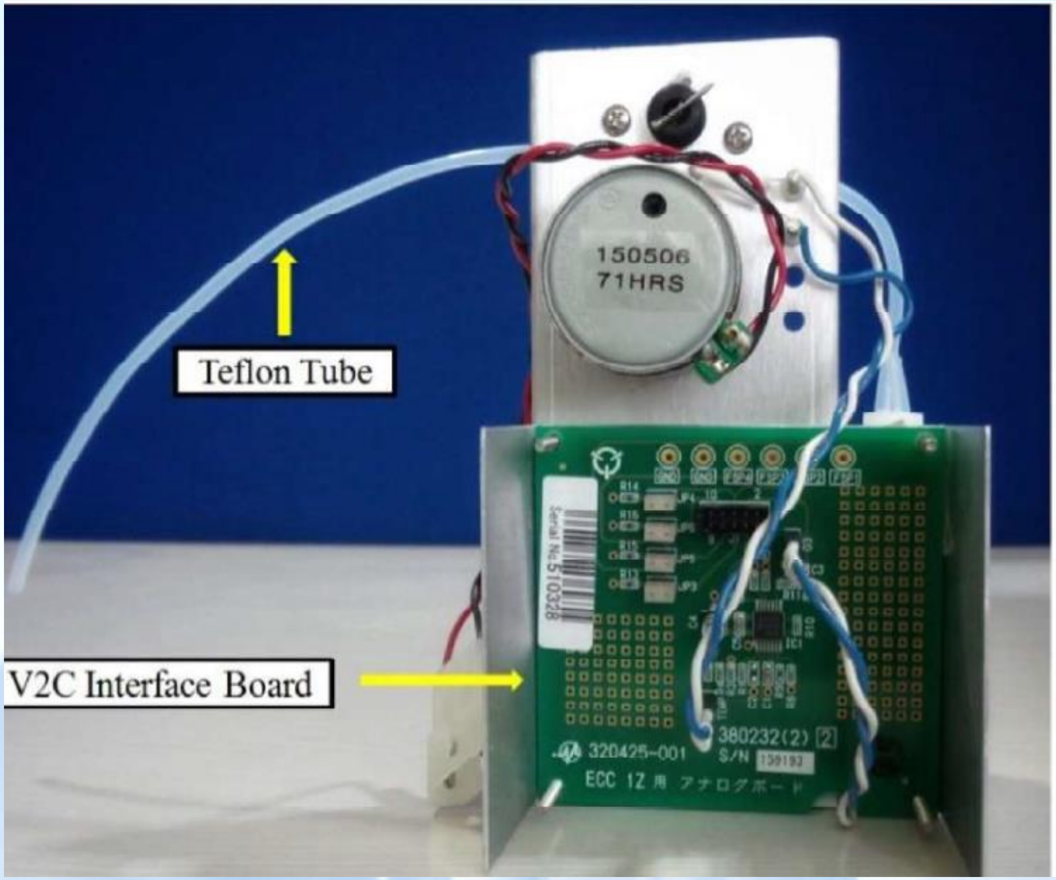
- The sounding was performed with the Brewer bubbler electrochemical sonde, developed by the Ozone Research Laboratories of IMD in Pune and constructed in the Departmental Workshop at Pune.

Ozonesonde

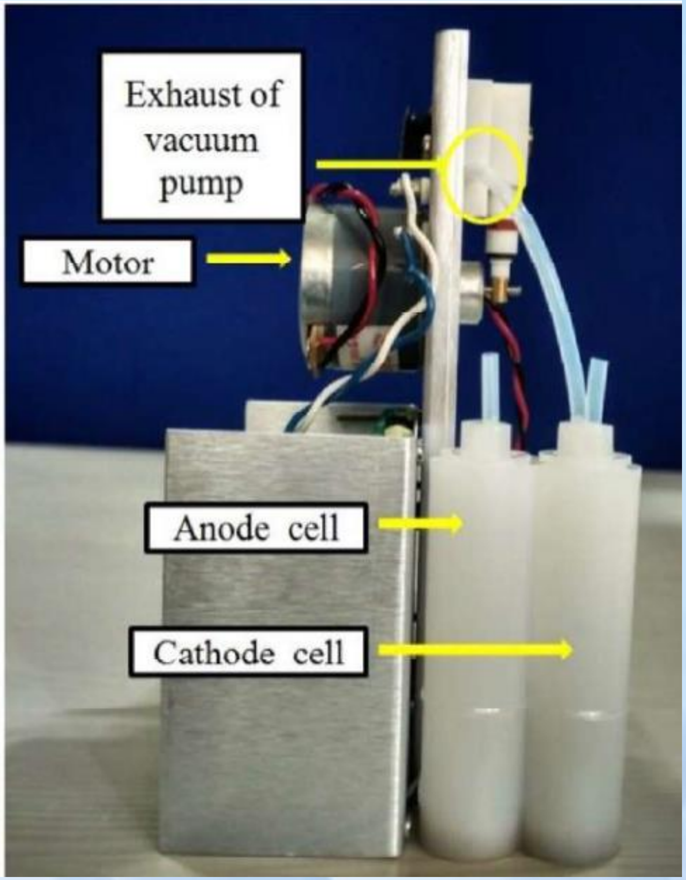


(a)
Ozonesonde
Radiosonde
(b)
Sensor boom
Thermistor
Humicap hygristor

Ozonesonde



Teflon Tube
V2C Interface Board
150506
71HRS
320425-001
380232(2)
ECC 1Z 用 アナログボード



Exhaust of vacuum pump
Motor
Anode cell
Cathode cell

Ozonesonde

- Ozone is measured with a electrochemical concentration cell(ECC) ozonesonde coupled with V2C interface electronic to a meteorological radiosonde.
- The ECC ozonesonde is lightweight, compact, inexpensive and of simple design.
- Contains motor-driven Teflon/glass air sampling pump, a thermistor for measuring pump temperature, an ozone sensing electrochemical concentration cell, and an electronic box containing V2C interface circuitry which couples the ozone sensor to the meteorological radiosonde.
- Measured parameters are telemetered to a ground receiving station are ozone, sonde pump temperature, sonde pump motor voltage and current, air pressure, air temperature and humidity.

Ozone sensor

- The ozone sensor of the ECC ozonesonde is made of two bright platinum electrodes immersed in potassium iodide (KI) solutions of different concentrations contained in separate cathode and anode chambers.
- The chambers are linked with an ion bridge that, in addition to providing an ion pathway, without mixing anode and cathode solutions.
- The electrolyte also contain Potassium bromide (KBr) and a buffer whose concentration in both half cell are same.
- 0.13 V is provided by the difference in potassium iodide concentrations in the two half cells.

ECC sensor solution

1. Cathode solution
   To 500 ml distilled water add:

   5.00 g KI
   12.50 g KBr
   0.63 g $NaH_2PO_4.H_2O$
   2.50 g $Na_2HPO_4.12H_2O$
   or
   1.87 g $Na_2HPO4.7H_2O$

1. Anode solution
   fill a 100 ml plastic bottle one-half full with 50 ml cathode solution (prepares described above) . Add 70 g KI crystals to the solution, and shake vigorously to dissolve the crystals. Some crystals will remain undisclosed, indicating that the solution is saturated

Chemical Reactions and results

Iodine is formed according to the relation

$$2KI + O_3 + H_2O \rightarrow 2KOH + I_2 + O_2$$

The cell converts the iodine to iodide according to

$$I_2 + 2e \rightarrow 2I^-$$

Ozone concentration in the sampled air to be derived from

$$P3 = 4.307 \times 10^{-3} (i_m - i_b) T_b t$$

p_3 : ozone partial pressure in nanobars

i_m : measured sensor outputs current in micro amperes

I_b : is the sensor background current in microamperes

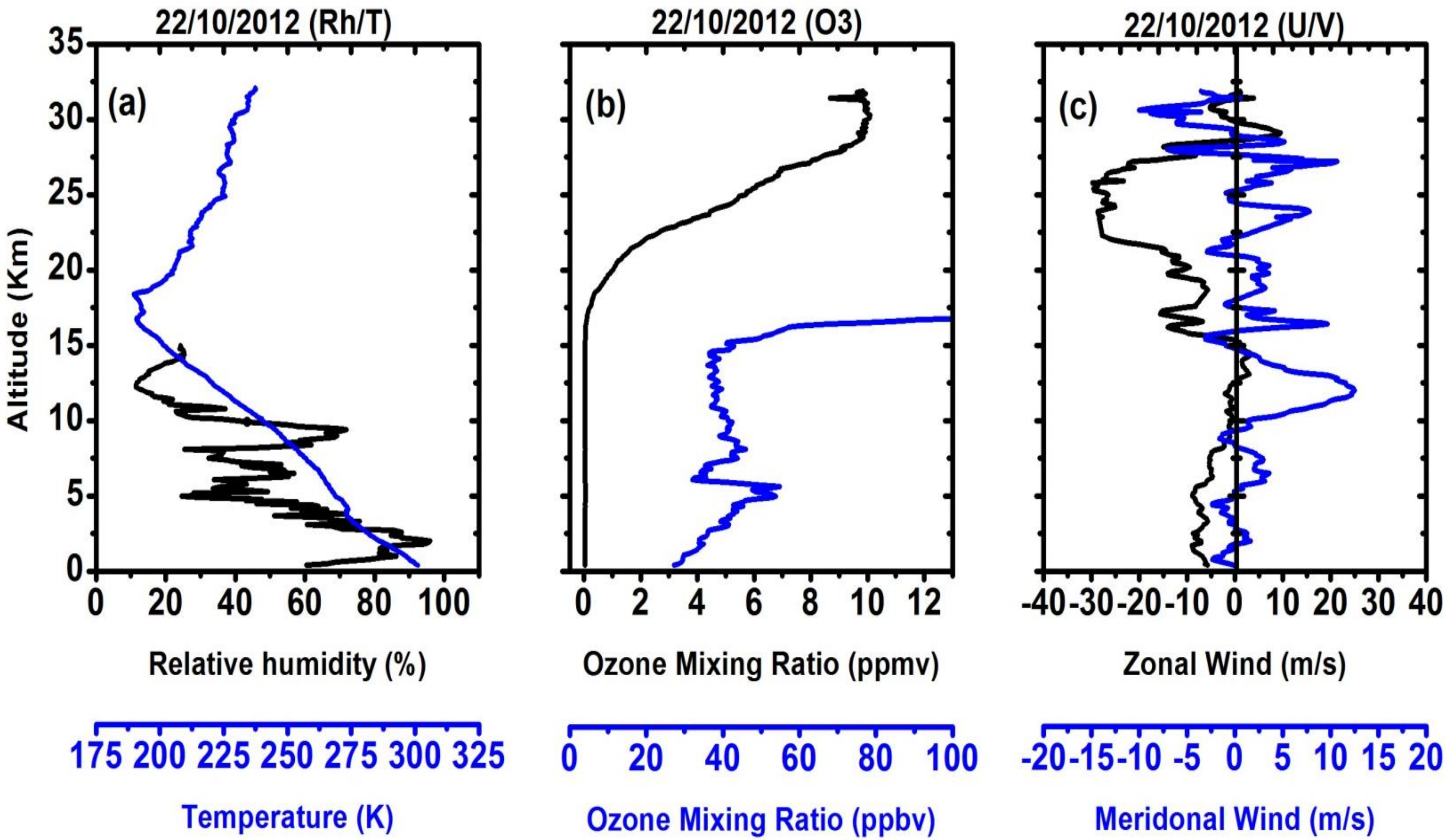
T_p : pump temperature in Kelvin

t : time in seconds taken by the sonde gas sampling pump to force 100 ml of air through the sensor.

Measured ozone is derived from

$$O_3(ppbv) = 1000P_3/P = 4.307 (i_m - i_b) T_b t/P$$

Typical profiles of Ozonesonde observations from Tropics



Upper Air Instrument Intercomparison

Upper Air Intercomparison

Intercomparison name	Venue	Time
Upper Air Instrument Intercomparison (UAII)	Lindenberg, Germany	2022
High Quality Radiosonde Systems	Yangjiang, China	2010
High Quality Radiosonde Systems	Vacoas, Mauritius	2005
GPS Radiosondes	Alcantara, Brazil	2001

Process involved in the Intercomparison

- **Laboratory Phase:** The participating radiosonde systems are tested in a controlled laboratory environment.

- **Field Intercomparison:** This phase involves performing 40 soundings per system in the field. The field intercomparison creates a working standard reference using two independent GRUAN Data Products from certified radiosondes.

- **Evaluation:** The evaluation of the various participating systems is performed against the uncertainty requirements defined in WMO's OSCAR database for various application areas.

- **Report Generation:** A detailed report is generated at the end of the intercomparison, presenting the outcomes of the campaign.

OSCAR: Observing Systems Capability Analysis and Review Tool

What is GRUAN?

GRUAN, which stands for the **Global Climate Observing System (GCOS) Reference Upper-Air Network**, provides data products that are based on measurements and processing that adhere to the GRUAN principles. These data products are open, documented in peer-reviewed literature, traceable to SI standards, and contain the best possible estimates of the measurement uncertainties.

Immler et al., 2010, ACP

The GRUAN data products (GDP) are created through a transparent and well-documented data processing applied to raw measurement data. This process uses correction methods that are based on extensive characterization of the instrument and its sensors, yielding a GDP that is devoid of manufacturer-dependent artifacts.

Examples of GRUAN data products:

RS92-GDP.2: Certified RS92 GRUAN data product version 2
RS-11G-GDP.1: Certified RS-11G GRUAN data product version 1
RS41-GDP.1: Certified RS41 GRUAN data product version 1
IMS-100-GDP.2: Certified iMS-100 GRUAN data product version 2

Manufactures selected in UAII-2022

Table 3.1: List of manufacturers selected to participate in the 2022 UAII. The first column lists the full names of the participating manufacturers, the 'model' column lists the full names of the radiosonde models, with the short names that are used in the report in parenthesis (if applicable).

Manufacturer	Country	Model	Participated
Azista Industries Pvt. Ltd.	India	ATMS-3710	yes
Aerospace Newsky Technology Co., Ltd.	China	CF-06-AH	yes
Graw Radiosondes GmbH & Co. KG	Germany	DFM-17	yes
Tianjin Huayuntianyi Special Meteorological Sounding Tech. Co., Ltd.	China	HT-GTS(U)2-1 (GTH3)	yes
Diel Met Systems (Pty) Ltd. trading as InterMet	South Africa	iMet-54	yes
Meisei Electric Co., Ltd.	Japan	iMS-100	yes
Meteomodem	France	M20	yes
Vikram Sarabhai Space Center, Indian Space Research Organisation	India	PS-B3	yes
Vaisala Oyj	Finland	RS41-SG (RS41)	yes
Weathex	Rep. of Korea	WxR-301D	yes
JSC "Radiy"	Russian Fed.	MRZ-N1	**no**
Shanghai Changwang Meteotech Corp.	China	GTS3	**no**

Application Areas

- Aeronautical Meteorology: Relative humidity in the FT is not considered.
- Nowcasting/ Very short range forecasting: UTLS Temperature and Relative humidity didn't considered.
- Global numerical weather prediction and real time monitoring
  Or : UTLS Relative humidity didn't considered.
  High resolution numerical prediction
- Atmospheric climate forecasting and monitoring: All the atmospheric layers considered.

Each Application have different uncertainty limit.

OSCAR Criteria

- The "Threshold" level corresponds to "*the minimum requirement to be met to ensure that data are useful*".

- The "Breakthrough" level corresponds to "*an intermediate level between "threshold" and "goal" which, if achieved, would result in a significant improvement for the targeted application. The breakthrough level may be considered as an optimum, from a cost-benefit point of view, when planning or designing observing systems*".

- The "Goal" level corresponds to "*an ideal requirement above which further improvements are not necessary*".

Aeronautical Meteorology

Table 9.2: ORUC Threshold (T), Breakthrough (B) and Goal (G) values $\Theta_{x,\mathcal{L}}$ used to assess the performances of the upper-air instruments participating in the UAII 2022, grouped by application area, as a function of the associated geophysical variable x and atmospheric layer $\mathcal{L}$. The "High-Resolution Numerical Weather Prediction" and "Global Numerical Weather Prediction and Real-time Monitoring" application areas are shown together, on the basis that their ORUC values are almost always identical (with differences tagged accordingly). Extracted from the WMO OSCAR webpages on 2023-05-31.

Geophysical variable x	Atmospheric layer $\mathcal{L}$	Unit	$\Theta^T_{x,\mathcal{L}}$	$\Theta^B_{x,\mathcal{L}}$	$\Theta^G_{x,\mathcal{L}}$	OSCAR Id
2.8 - Aeronautical Meteorology						
Atmospheric temperature	PBL FT UTLS	K	5.0	3.0	2.0	15
Relative humidity	PBL	%RH[1]	10.0	7.0	5.0	21
Wind (horizontal) vector	PBL UTLS	$m\,s^{-1}$	5.0	3.0	2.0	23
Wind (horizontal) vector	FT	$m\,s^{-1}$	5.0	2.7	2.0	22

Nowcasting/ Very short range forecasting

Geophysical variable x	Atmospheric layer $\mathcal{L}$	Unit	$\Theta^T_{x,\mathcal{L}}$	$\Theta^B_{x,\mathcal{L}}$	$\Theta^G_{x,\mathcal{L}}$	OSCAR Id
2.3 - Nowcasting / Very Short-Range Forecasting						
Atmospheric temperature	PBL	K	3.0	1.0	0.5	427
Atmospheric temperature	FT	K	2.0	1.0	0.5	428
Relative humidity	PBL	%RH[1]	10.0	5.0	2.0	704
Relative humidity	FT	%RH[1]	20.0	8.0	5.0	448
Wind (horizontal) vector	PBL UTLS	$m\,s^{-1}$	5.0	2.0	1.0	452, 453
Wind (horizontal) vector	FT	$m\,s^{-1}$	8.0	2.0	1.0	451

Global numerical weather prediction and real time monitoring

Geophysical variable x	Atmospheric layer $\mathcal{L}$	Unit	$\Theta^{T}_{x,\mathcal{L}}$	$\Theta^{B}_{x,\mathcal{L}}$	$\Theta^{G}_{x,\mathcal{L}}$	OSCAR Id
2.1 - Global Numerical Weather Prediction and Real-time Monitoring						
2.2 - High-Resolution Numerical Weather Prediction						
Atmospheric temperature	PBL FT UTLS	K	3.0	1.0	0.5	255-257, 339-341
Atmospheric temperature	MUS	K	5.0[2]	3.0[2]	0.5[2]	254
Relative humidity	PBL FT	%RH[1]	10.0	5.0	2.0	302, 303, 378, 379
Wind (horizontal) vector	PBL UTLS	$m\,s^{-1}$	5.0	3.0[3]	1.0	312, 313, 384, 385
Wind (horizontal) vector	FT	$m\,s^{-1}$	8.0	3.0	1.0	311, 383
Wind (horizontal) vector	MUS	$m\,s^{-1}$	10.0[2]	5.0[2]	1.0[2]	310

Atmospheric climate forecasting and monitoring

Geophysical variable x	Atmospheric layer $\mathcal{L}$	Unit	$\Theta^T_{x,\mathcal{L}}$	$\Theta^B_{x,\mathcal{L}}$	$\Theta^G_{x,\mathcal{L}}$	OSCAR Id
2.5 - Atmospheric Climate Forecasting and Monitoring						
Atmospheric temperature	PBL FT UTLS MUS	K	0.5[4]	0.25[4]	0.05[4]	778, 779, 780, 1016
Relative humidity	PBL FT	%RH	0.5[4]	0.25[4]	0.05[4]	789, 997
Relative humidity	UTLS	%RH	1.0[4]	0.5[4]	0.25[4]	790
Wind (horizontal) vector	PBL FT UTLS	$m\,s^{-1}$	2.5[4]	1.5[4]	0.5[4,5]	781, 988, 989
Wind (horizontal) vector	MUS	$m\,s^{-1}$	5.0[4]	2.5[4]	0.5[4]	1017

[1] Converted from $\%\,g\,kg^{-1}$ to %RH (see Appendix K)
[2] High-Resolution Numerical Weather Prediction: not applicable
[3] High-Resolution Numerical Weather Prediction, for the PBL: 2.0
[4] Converted from 2σ to 1σ level (see Sec. 9.3.1.2).
[5] For the PBL: 0.25

TTAA

Part: A

SECTION1	$M_iM_iM_jM_j$	$YYGGI_d$	IIiii
SECTION2	$99P_oP_oP_o$ $P_1P_1h_1h_1h_1$ ------------- $P_nP_nh_nh_nh_n$	$T_oT_oT_{ao}D_oD_o$ $T_1T_1T_{a1}D_1D_1$ $T_nT_nT_{an}D_nD_n$	$d_od_of_of_of_o$ $d_1d_1f_1f_1f_1$ $d_nd_nf_nf_nf_n$
SECTION 3	$88P_tP_tP_t$	$T_tT_tT_{at}D_tD_t$	$d_td_tf_tf_tf_t$
SECTION 4	77 $P_mP_mP_m$ 66 $P_mP_mP_m$ 77999	$d_md_mf_mf_mf_m$	$4V_bV_bV_aV_a$

TTAA

Section1:	MiMiMiMi	YYGGid IIiii	
	TTAA	67001 42809	
Section2:	$99P_0P_0P_0$	$T_0T_0T_{a0}D_0D_0$	$d_0d_0d_0f_0f_0$
	99001	30622	18002
	$P_1P1h_1h_1h_1$	T_1T1T1D_1D1	$d_1d_1d_1f_1f_1$
	00016	32456	36004

92717	27032	21026
85467	26263	22024
70150	13456	32013
50589	01571	32013
40764	09563	08507
30980	24762	06512
25110	34558	09026
20260	46562	06031
15445	61362	09044
10685	78965	08538

TTAA

Section3:	$88P_tP_tP_t$	$T_t\ T_t\ T_{at}$	$d_td_td_tf_tf_t$
	88102	78565	08538
Section4:	77999	$d_md_md_mf_mf_m$	$4V_bV_bV_bV_b$
	31313	53808	82316=

4 indicates that the vertical wind shear data follow; the next 4 digits represent the shear (in kt) 3,000 feet below and 3,000 feet above the level of maximum wind.

TTBB

Part: B

SECTION 1	$M_iM_iM_jM_j$	YYGG/	IIiii
SECTION 5	$n_on_oP_oP_oP_o$	$T_oT_oT_{ao}D_oD_o$	
	$n_1n_1P_1P_1P_1$	$T_1T_1T_{a1}D_1D_1$	

	$n_nn_nP_nP_nP_n$	$T_nT_nT_{an}D_nD_n$	
SECTION 6	2 1 2 1 2	$n_on_oP_oP_oP_o$	$d_od_of_of_of_o$
		$n_1n_1P_1P_1P_1$	$d_1d_1f_1f_1f_1$

		$n_nn_nP_nP_nP_n$	$d_nd_nf_nf_nf_n$
SECTION 8	4 1 4 1 4	$N_hC_LhC_MC_H$	
SECTION 9	5 1 5 1 5 5 2 5 2 5 ------------- 5 9 5 9 5	Code groups to be developed regionally	
SECTION 10	6 1 6 1 6 6 2 6 2 6 ------------- 6 9 6 9 6	Code groups to be developed regionally	

TTBB

Section1:	MiMiMiMi	YYGGid IIiii
	TTAA	67001 42809
Section:5	$n_0n_0P_0P_0P_0$	$T_0T_0T_{a0}D_0D_0$
	00001	30622
	$n_1n_1P_0P_0P_0$	T_1T1T1D_1D1
	11985	32045
	22914	27859
	33909	28661
	44901	29064
	55868	27059
	66842	26063
	77813	24864
	88804	25065
	99730	17660
	11708	14256

TTBB

Section:6	21212	$n_0n_0P_0P_0P_0$	$d_0d_0d_0f_0f_0$
		00001	18002
		$n_1n_1P_0P_0P_0$	$d_1d_1d_1f_1f_1$
		11987	19517
		22927	21030
		33807	21007
		44668	32524
		55631	30512
		66596	27525
		77428	07504
		88154	09045
		99112	07548
		11105	09043
Section:8	41414		

Future Plans

- **Sustenance of 6 Nos of high quality GPS based system- WMO-GUAN standard network.**
- **Expansion of GUAN standard network from 6 to 12 stations by up-gradation of 6 operational RS/RW stations to GUAN standard.**
- **Continuation of all 56 RS/RW stations with twice a day ascents.**
- ***Further expansion of operational RS/RW stations from 56 to 63 -procurement of GPS radiosondes from Indian sources to promote 'make in India' initiative.***
- **Up-gradation of PB network to GPS based.**
- **Continuous RS/RW observations from Maitri and Bharati (Antarctica)**

Thank You