Frequently Asked Questions - Satellite Related

1. **What is a Satellite?**
   A satellite is an object either natural or artificial moving around any other celestial object. Moon is a natural satellite of earth. Similarly, all the planets or objects move around sun is also called satellite. INSAT is a series of artificial satellite launched by India which move around the earth for various scientific and commercial applications.

2. **What is Satellite Meteorology?**
   Satellite Meteorology is a branch of meteorology, to observe and measure various meteorological parameter and meteorological and non-meteorological events of earth's land, ocean and atmosphere from space through remote sensing technique.

3. **Why meteorological satellites are needed?**
   The conventional method of Meteorological observations is mostly covering land region from limited number of stations. However, the earth satellites are an important observational tool which provides vast information to be used for issuing accurate weather forecasts and helps in global climate monitoring.

4. **What is Satellite Orbit?**
   An orbit is a regular path followed by the satellite.

5. **What is Geostationary orbit?**
   A geostationary orbit or geostationary Earth orbit or geosynchronous equatorial orbit (GEO) is a circular orbit at a height of 35,786 kilometres from the earth surface above the Earth's equator and follow the direction of the Earth's rotation.

6. **What is the difference between Geosynchronous satellite and Geostationary satellite?**
   Both geostationary and geosynchronous follows the earth rotation, but geosynchronous orbit has some inclination with equatorial plane of the earth whereas geostationary orbit under ideal condition has zero inclination.
   All geostationary orbits are geosynchronous but the reverse is not true.

7. **What is Polar orbiting satellites?**
   A satellite whose orbital plane is inclined close to 90 degrees with respect to earth equatorial plane is called polar orbiting satellite. Such a satellite moves from pole to pole in a circular orbit above the earth surface.

8. **What is a Geostationary Satellite?**
   Any satellite placed in Geostationary orbit is a geostationary satellite. Geostationary stationary satellites see the fixed area of the earth surface all the time. A geostationary orbit or geostationary Earth orbit or geosynchronous equatorial orbit (GEO) is a circular orbit at a height of 35,786 kilometres from the earth surface above the Earth's equator and follow the direction of the Earth's rotation. The angle of inclination of geostationary orbit with respect to equatorial plane of the earth is zero under ideal condition.

9. **What is GMT or UTC?**

GMT stands for Greenwich Mean Time, now called UTC (Universal Coordinated Time), and is the local time at Greenwich-England, which is at 0° longitude. Weather observations, including satellite images, are recorded in GMT as a way of solving the problem of trying to use weather data from different time zones.

Greenwich Mean Time (GMT) is a time zone based upon the Prime Meridian (0-degree longitude), which goes through the Royal Observatory in Greenwich, England. Coordinated Universal Time, or Universal Time Coordinated (UTC), is a time standard, or a system of time-keeping, and is often used interchangeably, as the actual times are the same. All weather-related observations are reported in UTC or GMT time format.

10. What is the difference between geostationary and polar orbiting satellites?

Geostationary satellite looks the fixed area of earth surface al all the time. Whereas, polar orbiting satellite cover the entire earth surface at regular time intervals.

11. What are the advantages / disadvantages of Geostationary meteorological satellite over polar orbiting meteorological satellite?

The electromagnetic energy reaching the satellite from fixed area of earth surface decreases as the height of the satellites increases, thereby decrease the spatial resolution. The geostationary satellite which is far away from the earth surface as compared to polar satellites has less spatial resolution than polar orbiting satellite.

On the other hand, Geostationary satellite make continuous observation of a fixed area of the earth surface at high temporal resolution than the polar orbiting satellite which is having advantage of global coverage at regular intervals.

12. What type of satellites are being used to monitor the weather of Indian region by Indian Government?

India uses most of the time, INSAT series of Geostationary satellite. India also uses polar satellite data of other countries origin for weather observation and forecasting.

13. Which Indian Geostationary satellites are currently used by IMD operationally and their locations?

IMD uses INSAT-3DR (74°E), INSAT-3D (84°E) & Kalpana-1 (72.4°E) operationally.

14. What are Channels/Spectral bands?

The satellites typically sense the earth and its atmosphere in some specific wavelength bands known as channels/spectral bands.

15. What payloads are present on Kalpana-1?

Kalpana -1 is located at 72.4°E carried three payloads viz VHRR, DRT and S&R. For meteorological observation, Kalpana-1 carried a three channel Very High-Resolution Radiometer (VHRR) with 2 km resolution in the visible band and 8 km resolution in thermal infrared and water vapour bands. A Data Relay Transponder (DRT) operating in UHF band was incorporated for real-time hydro meteorological data collection from unattended platforms located on land and river basins. The data was then relayed in extended C-band to a central location.

16. What are the channels/spectral bands present on VHRR payload of Kalpana-1?

VHRR payload of Kalpana-1 has following channels: i) VISIBLE wavelengths (0.55 - 0.75 um) (reflected solar radiation). ii) IR (thermal infra-red) (10.5 - 12.5 um). (emission channel. Each point on the earth emits radiation in proportion to its hotness/coldness. So, this channel gives a thermal image of the earth) iii) WV (water-vapour) (5.7 - 7.1 um). (This is also an emission band. The image shows differences in water vapour absorption in the atmosphere).

17. What meteorological payloads are present on INSAT-3D/3DR?

INSAT-3DR is located at 74°E & INSAT-3D is located at 84° E. They have four payloads viz IMAGER, SOUNDER, DRT and S&R. The payloads 6-channel Imager and a 19 –channel Sounder are similar to GOES payloads of USA.

First time SOUNDER payload has been put up on an Indian satellite which derives vertical profile of Temperature and Humidity. These satellites permit programmable scanning of a special sector, with defined N-S and E-W coordinates. The data is available at a higher resolution as compared to the previous operational satellites. So, the geophysical products from these satellites are more accurate and of higher resolution.

18. What is Imager and Sounder payloads?

Imager is a payload, make images of earth surface in Window channel such as visible, Shortwave IR, Mid Infrared, water vapour & Thermal infra-red region of electromagnetic spectrum. These channels are less affected by atmospheric components and used for cloud identification.

Sounder is a payload, which measure radiances from different height of earth atmosphere in various IR channels and give temperature, humidity profiles of the atmosphere. The sounder channels are highly modulated by atmospheric components.

19. What are the specifications of Imager payload channels on INSAT 3D & 3DR satellite?

Channels Number	Channel ID	Channel name	Spectral range (µm)	Resolution (Km)	Purpose
1.	VIS	visible	0.55 – 0.75	1.0	Clouds, Surface features
2.	SWIR	Short wave infrared	1.55 – 1.70	1.0	Snow, Ice and water phase in clouds
3.	MIR	Mid Infrared	3.7 – 3.9	4.0	Clouds, Fog, Fire
4.	WV	water vapour	6.5 – 7.1	8.0	Upper-Troposphere Moisture
5.	TIR1	long wave infrared	10.3 – 11.3	4.0	Cloud top and surface temperature
6.	TIR2	split	11.5 - 12.5	4.0	Lower-Troposphere Moisture

20. What are the specifications of sounder payload channels on INSAT 3D & 3DR satellite?

Detector	Ch. No.	**l $_c$ (mm)**	**n_c (cm^{-1})**	**NE∆T @300K**	**Principal absorbing gas**	**Purpose**
Long wave	1	**14.67**	682	0.17	CO_2	Stratosphere temperature
	2	**14.32**	699	0.16	CO_2	Tropopause temperature
	3	**14.04**	712	0.15	CO_2	Upper-level temperature
	4	**13.64**	733	0.12	CO_2	Mid-level temperature
	5	**13.32**	751	0.12	CO_2	Low-level temperature
	6	**12.62**	793	0.07	water vapor	Total precipitable water
	7	**11.99**	834	0.05	water vapor	Surface temp., moisture
Mid wave	8	**11.04**	906	0.05	window	Surface temperature
	9	**9.72**	1029	0.10	ozone	Total ozone
	10	**7.44**	1344	0.05	water vapor	Low-level moisture
	11	**7.03**	1422	0.05	water vapor	Mid-level moisture
	12	**6.53**	1531	0.10	water vapor	Upper-level moisture
Short wave	13	**4.58**	2184	0.05	N_2O	Low-level temperature
	14	**4.53**	2209	0.05	N_2O	Mid-level temperature
	15	**4.46**	2241	0.05	CO_2	Upper-level temperature
	16	**4.13**	2420	0.05	CO_2	Boundary-level temp.
	17	**3.98**	2510	0.05	window	Surface temperature
	18	**3.76**	2658	0.05	window	Surface temp., moisture
Visible	19	0.695	14367	-	visible	Cloud

All bands have spatial resolution of 10 km. All bands have radiometric resolution of 12 bits/sample

21. What is a satellite image?

It is a pictorial representation of radiance reaching onboard satellite sensor from the earth/cloud of different spectral bands.

22. What do you mean IR and VIS image? How it can be useful?

IR stands for infrared and VIS stands visible portion of the electromagnetic spectrum. IR images are temperature sensitive. Higher the temperature of the object higher radiance reaching the satellite and the target appears bright. Thus, in an IR image, objects of different temperature appear different brightness level. For example, in true IR image, cloud appears dark and desert appears bright. However, to visualize the image in a conventional way it is inverted so that cloud/desert appears bright/dark in inverted IR image. Since IR image is temperature dependent, the temperature information is obtained by approximating the object to black body and applying planks function. IR mages can be obtained during day and night time and therefore it is used to monitor the earth and atmospheric events all the time.

It is also to be noted that objects of same temperature appear different brightness level (radiance) depending the IR wavelength and depends emissivity of the objects.

On the other hand, visible images obtained during day time and depend on albedo of the target surface. Thus cloud, which is having high value of albedo than land surface appears brighter and land appears darker in the visible image. During day time, Visible images are useful to observe and monitor fog, smoke, dust storms, volcano, cyclone movement, thunder storms, cloud identification, snow coverage etc.

23. What is a sector image?

To study the weather condition of a region, we can select that area which is known as sector. We are interested in the weather of India, so we select that area.

24. Why satellites images some time not available on IMD website?

There are times when there are glitches in our system, but a more likely explanation is that there may be a problem in reception or dissemination of the image. The problems in reception include, an artifact effect in the images, patch temperature variation & satellite maintenance maneuver, during these events the satellite operation is stopped temporarily and images are not taken.

The artifact caused by sun incursion directly into sensors, it happens during both equinox seasons, normally from early February to mid-May and early August to mid-November every year, because of which images between 1700UTC to 2130UTC are not available on website.

25. How to interpret SWIR channel image?

The short-wave IR is close to red end portion of visible spectrum and highly reflective in nature during day time. It is strongly absorbed by water vapour so not much useful for temperature determination. But it is useful to discriminate snow and ice, cloud-top phase, monitor snow cover, day time Fog, cirrus cloud Convective R/F estimation, Cloud radiative properties, NDSI during day time. Not much usefulness during night time.

26. How to interpret Mid Infra-Red Window channel image?

The Mid IR window channel (3.9um) has more temperature sensitivity than thermal infrared and has many applications in conjunction with thermal infrared channels. It is almost impossible to detect fog or low clod in conventional IR (10-12 µm) images in night if the fog top has a similar temperature to that of the adjacent ground. In this 3.9 µm channel, however the water droplets in fog can be differentiated from a land or sea surface at the same temperature because of emissivity difference. It is also used to identify night time fire/hotspot, volcanic eruption and ash detection in conjunction with thermal infrared window channel. During day time, this channel is modulated by reflected sunlight, the day time image is warmer than night time image. The sun glint by the sea surface produces glow in this channel and shows sea brighter than small cirrus cloud.

27. How to interpret WV absorption channel (6.9um) image?

The band 6.5 -7.1um is called water vapour band. This is not an atmospheric window but is a part of the IR spectrum where water vapour is dominant absorbing gas. So naturally baseline information will not be available for this channel. In a normal moist atmosphere, most of the radiation received by the satellite originates between mid and upper part of the troposphere. Moist air or cloud in the lower half of the troposphere is not depicted well in WV imagery. But thick high clouds, such as cumulonimbus, anvils stand out prominently.

Broad scale flow patterns of moisture, upper tropospheric cyclone, raising and subsidence of moisture appears bright and dark respectively. The jet streams are delineated by sharp gradients in moisture, with dry air on the pole ward side. The atmospheric motion vector derived from WV imagery is directly used in NWP models.

28. How to interpret TIR-1 channel image?

The band between 10.3 – 11.3 µm are called thermal infrared band. Because the radiances emitted by the surface is less affected by the atmospheric components it is mainly used to detect temperature of the emitting surface such as sea surface temperature, land surface temperature, cloud temperature air mass boundaries, convergence zone, surface lows and thunderstorms both day and night. Because cloud top temperature decreases with height, thermal IR images show good contrast between clouds at different levels unlike visible image.

29. How to interpret TIR-2 channel image?

TIR-2 window region 11.5 - 12.5 µm, is contaminated by low level water vapor, and thus is called the "dirty window" and used to achieve higher accuracy SST, noise correction in RT model & to monitor Lower-Troposphere Moisture. TIR2 Images from Indian Geostationary satellites are available in Full Disk, Asia_Mer sector, NW sector, NE sector, High Resolution images with District Boundaries (NW, NE, SW, SE sectors) of Indian region.

30. What is validation of satellite data?

To verify satellite measurements, it should be compared against independent measurements like surface data, upper air data & other satellite data periodically. This process is called validation.

31. What Geophysical parameters are being generated using INDAT-3D/3DR IMAGER operationally?

Sl. No	Parameter	Level	Abb.	Format	Resolution (Spatial & Temporal)	Channels used to derive
1	Outgoing long wave radiations	L2B/L3B	OLR	HDF	Per Pixel (Half hourly, Daily, Weekly, Monthly and Yearly)	WV, TIR-1, TIR -2
2	Rainfall using Hydro Estimator	L2B/L3B	HEM	HDF	Per Pixel (Half hourly, Daily, Weekly, Monthly and Yearly)	TIR-1, TIR- 2
3	Fog	L2C/L3C	FOG	HDF	Per Pixel (Half hourly, Daily, Weekly, Monthly and Yearly)	SWIR, MIR, TIR-1, TIR-2
4	Snow	L2C/L3C	SNW	HDF	Per Pixel (Half hourly, Daily, Weekly, Monthly and Yearly)	VIS, SWIR, TIR – 1, TIR –2
5	Cloud Mask	L2B/L3B	CMK	HDF	Per Pixel (Half hourly, Daily, Weekly, Monthly and Yearly)	MIR, TIR-1, TIR-2

6	Upper Troposphere Humidity	L2B/L3B	UTH	HDF	Per Pixel (Half hourly, Daily, Weekly, Monthly and Yearly)	WV, TIR-1, TIR –2
7	Sea Surface Temperature	L2B/L3B	SST	HDF	Per Pixel (Half hourly, Daily, Weekly, Monthly and Yearly)	MIR, TIR -1, TIR -2
8	Land Surface Temperature	L2B/L3B	LST	HDF	Per Pixel (Half hourly, Daily, Weekly & Monthly)	TIR -1, TIR -2
9	Insolation	L2B/L3B	INS	HDF	Per Pixel (Half hourly, Daily, Weekly, Monthly and Yearly)	TIR -1, TIR -2
10	FIRE	L2P	FIR	KML	Point (Half hourly)	MIR, TIR -1
11	SMOKE	L2P	SMK	KML	Point (Half hourly)	VIS, MIR, TIR 1, TIR –2
12	Atmospheric Motion Vectors (VIS/MIR, TIR, WV)	L2P	AMV	HDF	Point (Half hourly)	VIS, TIR-1, TIR –2 & WV
13	INSAT Multi-Spectral Rainfall Algorithm (IMSRA)	L2G	IMR	HDF	0.1 deg x 0.1 deg (Half hourly, Daily, Weekly & Monthly)	TIR-1, TIR- 2
14	Quantitative Precipitation Estimation	L2G	QPE	HDF	1 deg x 1 deg (Half hourly, Daily, Weekly & Monthly)	TIR-1, TIR- 2
15	Aerosol Optical Depth	L2G	AOD	HDF	0.1 deg x 0.1 deg	VIS, TIR –1, TIR -2

32. What is the total count of Satellite Images generated operationally per scan per half hourly?

Sector Name	Channels	No. of Images
Full-Disk	IR1, IR1_Temp, IR2, IR2_Temp, MIR, MIR_Temp, VIS, SWIR, WV, WV_temp, MP	11
Asia-Sector	IR1, IR1_Temp, IR2, IR2_Temp, MIR, MIR_Temp, VIS, SWIR, WV, WV_temp, MP, CTBT	12
NEQUAD-Sector	IR1, IR1_Temp, IR2, IR2_Temp, MIR, MIR_Temp, VIS, SWIR, WV, WV_temp, MP	11

NWQUAD-Sector	IR1, IR1_Temp, IR2, IR2_Temp, MIR, MIR_Temp, VIS, SWIR, WV, WV_temp, MP	11
SGP-Sector	IR1, IR1_Temp, IR2, IR2_Temp, MIR, MIR_Temp, VIS, SWIR, WV, WV_temp, MP	11
NEQ (HR-Sector)	IR1_HR, IR1_HRBlue, IR1_Temp_BD, IR1_Temp_NHC, IR2_HR, IR2_HRBlue, VIS_HR, VIS_HRBlue, WV_HR, WV_HRBlue, MIR_HR, MIR_HRBlue, SWIR_HR, SWIR_HRBlue	14
NWQ (HR-Sector)	IR1_HR, IR1_HRBlue, IR1_Temp_BD, IR1_Temp_NHC, IR2_HR, IR2_HRBlue, VIS_HR, VIS_HRBlue, WV_HR, WV_HRBlue, MIR_HR, MIR_HRBlue, SWIR_HR, SWIR_HRBlue	14
Bay of Bengal (HR-Sector)	IR1_HR, IR1_HRBlue, IR1_Temp_BD, IR1_Temp_NHC, IR2_HR, IR2_HRBlue, VIS_HR, VIS_HRBlue, WV_HR, WV_HRBlue, MIR_HR, MIR_HRBlue, SWIR_HR, SWIR_HRBlue	14
Arabian Sea (HR-Sector)	IR1_HR, IR1_HRBlue, IR1_Temp_BD, IR1_Temp_NHC, IR2_HR, IR2_HRBlue, VIS_HR, VIS_HRBlue, WV_HR, WV_HRBlue, MIR_HR, MIR_HRBlue, SWIR_HR, SWIR_HRBlue	14
Amarnath Yatra (HR-Sector)	IR1_HR, IR1_HRBlue, IR1_Temp_HR, IR2_HR, VIS_HR, VIS_HRBlue, WV_HR, SWIR_HR, SWIR_HRBlue, MIR_HR, MIR_Temp_HR,	11
Vaishno Devi (HR-Sector)	IR1_HR, IR1_HRBlue, IR1_Temp_BD, IR1_Temp_NHC, IR2_HR, IR2_HRBlue, VIS_HR, VIS_HRBlue, WV_HR, WV_HRBlue, MIR_HR, MIR_HRBlue, SWIR_HR, SWIR_HRBlue	14
Nepal (HR-Sector)	IR1_HR, IR1_HRBlue, IR1_Temp_HR, IR2_HR, VIS_HR, VIS_HRBlue, WV_HR, SWIR_HR, SWIR_HRBlue, MIR_HR, MIR_Temp_HR, DMP	12
Fog (HR-Sector)	IR1_HR, IR1_HRBlue, IR1_Temp_HR, IR2_HR, VIS_HR, VIS_HRBlue, WV_HR, SWIR_HR, SWIR_HRBlue, MIR_HR, MIR_Temp_HR, DMP, NMP	13
	Total No of Images generated half hourly	**162**

33. What are the Geophysical parameters are being generated from INDAT-3D/3DR SOUNDER data operationally?

Sl. No.	Parameter	Data Input
1.	Temperature, Humidity profile and Ozone	Brightness temperatures for 18 Sounder Channel and grey count for channel 19
2.	Geo-potential Height	Sounder retrieved temperature and humidity profiles at 40 pressure levels
3.	Layer Perceptible Water	Retrieved humidity at standard pressure levels
4.	Total Perceptible Water	Retrieved humidity at standard pressure levels
5.	Lifted Index	Sounder retrieved temperature and humidity profiles at standard pressure levels
6.	Dry Microburst Index	Sounder retrieved temperature and humidity profiles at standard pressure levels
7.	Maximum Vertical Theta-E Differential	Sounder retrieved temperature and humidity profiles at standard pressure levels
8.	Wind Index	Geo- potential Height and retrieved temperature and humidity profiles at standard pressure levels

Frequently asked questions – GNSS Meteorology

1. **What is GNSS?**
   The term GNSS refers to 'Global Navigation Satellite System' is a constellation of satellites moving around earth transmitting coded signals from space and provides navigation and timing information on receiving the signal. The **Global Positioning System** (**GPS**) constellation originally **Navstar owned by US,** Russia's GLONASS, Europeans' Galileo (yet functional), China's BeiDuo constellations are examples of GNSS. India's IRNSS (Indian regional Navigation satellite system) is a regional constellation covers Indian region only.

2. **What is GNSS signal?**
   The GNSS satellites continuously transmit navigation signals in two or more frequencies in L band. These signals contain ranging codes and navigation data to allow the users to compute the travelling time of the signal from satellite to receiver and the satellite coordinates at any epoch.

3. **How does GPS receivers determine its 3D position from GNSS signal?**
   A GNSS receiver's job is to locate four or more GNSS satellites, figure out time of flight of the signal from each satellite and estimate the distance from each satellite. To determine the range, it is necessary the clock on receiver and satellites must be synchronised. Based on a simple mathematical principle called triangulation or trilateration deduce its own location.
   The GPS receiver compares the time a signal was transmitted by a GPS 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 the user's position by triangulation. Precise location of interest to geophysists required correction of position errors due to atmospheric delays.

4. **What are the errors involved in the GNSS signal measurements?**
   i. Satellite clock error
   ii. Orbital error,
   iii. Receiver clock error
   iv. Antenna phase error,
   v. Multipath error
   vi. Atmospheric/ionospheric error and
   vii. Selective Availability etc.,

5. **What is GNSS Meteorology?**
   GNSS Meteorology is an active method of measuring earth atmosphere refractivity using ground based GNSS receivers or receivers on LEO satellites. Microwave radio signals transmitted by GNSS satellites are delayed (refracted)by the atmosphere as they propagate in the atmosphere. The delay in GNSS signals reaching earth based receivers or receivers on Leo satellites due to presence of water vapour is nearly proportional to the quantity of water vapour integrated along the signal path.

6. **What is Integrated Precipitable Water Vapour (IPWV)?**
   The amount of atmospheric water vapour (in kilogram) overlying per unit area of the earth surface. Its unit is kg/m^2.

7. **What is Precipitable Water Vapour (PWV) and how it is related with IPWV?**
   PWV is defined as the height (mm) of liquid water that would result from condensing all the water vapour in a column from the surface to the top of the atmosphere. In other words, PWV = IWV/ρ, where ρ is the density of water in kg/m^3.

8. **What are the two types of atmospheric Delay? And how it can be removed?**
   The GNSS signal delay in the earth atmosphere is composed of Ionospheric and neutral delay (or Tropospheric delay). The ionospheric delay can be measured and removed by measuring the time of flight between two radio signals (L1 and L2) that travel along similar paths using dual frequency receiver and exploiting the known dispersion relations for the ionosphere. The troposphere, which contains most of the water vapour delays both the L1 and L2 signal equally. Signal delays in the nutral atmosphere are due to changes in pressure, temperature and water vapour. Therefore, tropospheric delay cannot be minimized by using the dual frequency receiver since the electrically neutral atmosphere is nondispersive below 30 GHz. However, this can be removed by using special geodetic algorithms.

9. **What are the components of Tropospheric delay? And how it can be calculated?**
   Tropospheric delay has two components: Hydrostatic and Wet delay. The Hydrostatic delay is due to the total mass of the atmosphere above the receiver (Antenna) which can be determined by accurate measurement of surface pressure. Wet delay is due to total amount of water vapor along the GNSS signal path and can be calculated by subtracting hydrostatic delay from the tropospheric delay.

10. **What is Mapping function? And how IPWV derived from the wet delay?**
    Mapping function relates the Zenith path delay to delays along paths with arbitrary elevation angle. Depending on the mapping function used, the hydrostatic and wet components can be incorporated together or treated separately. The IPWV derived from wet delay by multiplying with some constants, which is function of mean temperature of the atmosphere and the specific gas constant for water vapour.

11. **How Accurate is the GNSS derived IPWV?**
    1-2 mm accuracy with temporal resolution of few minutes.

12. **What are the application GNSS derived IPWV?**
    i) Nowcasting (for example Fog forecast, Flash flood monitoring, Thunderstorm etc)
    ii) Monsoon monitoring
    iii) NWP model for short term forecast between 6-12 hours
    iv) Ideal data for climate research
    v) Calibration of satellite sensors

13. **What are the other major application of ground based GNSS receiver?**
    i) Reference station
    ii) Time transfer
    iii) Plate tectonic studies
    iv) Ionosphere measurement
    v) Geodesy etc.