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Indian Space Research Organisation- Current Meteorological Satellites and Recent Advances in Weather Forecasting

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SUMMARY

In the past ISRO designed satellite such as INSAT 1A, INSAT 2E etc. primarily for meteorological purposes. Despite of meteorological satellites various Climate & Environmental and Earth Observations satellites such as RESOURCESAT, CARTOSAT, Megha Tropiquese etc. were also incorporated for precise climatic studies. In this study there is an attempt to introduce those sensors component which are primarily responsible for collection of temperature, pressure and wind profile in the upper atmosphere. INSAT-3DR is the advanced met satellite was launched by ISRO in the year 2016 for measurement of highly precise atmospheric data. In the year 2021-22 ISRO has planned to launched for RISAT 1A which will be dedicated to climatic studies like albedo and reflectance, soil moisture, vegetation, snow & sea cover edge and depth.

INTRODUCTION

Agriculture production of Indian crop is mainly dependent on nature of South-west monsoon and management of crop during this time period. During the monsoon, rainfall variability at the local level makes farming more susceptible to natural disasters such as drought, floods, cyclones, heat and cold waves, hail, etc. Although all the physical dynamics, agronomic practices and inputs can be operated accordingly but vagaries of weather cannot be controlled. However antagonistic effects on crop can often be mitigated. Thus, risk on farms can be minimized by providing weather information correctly interpreted for their agricultural importance, containing advisories for the farm and broadcast well in advance of impending weather conditions. It is by far the most crucial of all the services that can be effectively rendered to the farming community. Agrometeorological Advisory Service (AAS) of the Indian Meteorological Department (IMD), Ministry of Earth Sciences (MoES) within the framework of the Gramin Krishi Mausam Sewa (GKMS) program help to collect and organize information on climate / weather, soil and crops and to merge them with weather forecasts to help farmers make management decisions. AAS provide a very special type of contribution to the farmer in the form of advice that can make a massive difference with agricultural invention taking benefit of benevolence weather and minimize the antagonistic effects of adverse weather conditions. (IMD 2020). For making the weather prediction accurate and reliable ISRO launched various highly advanced satellite. These satellites are incorporated with advanced generation sensors which helps in collection of variable weather parameters.

Satellite launched for meteorological purposes over the years

Kalpana-1 / MetSat-1 (Meteorological Satellite-1)

The first exclusive meteorological satellite developed by ISRO is the METSAT (Meteorological Satellite) launched by PSLV-C4 on 2nd September 2002. Until then, meteorological services were combined with telecommunications and television services in the INSAT system. METSAT is a counterpart to the imminent INSAT system, which would provide separate weather and telecommunications and satellite dissemination services. This will allow greater capacity to be built into INSAT satellites, both in terms of transponders and their radiated power, short of the limitations imposed by the design of meteorological instruments. For meteorological reflection, METSAT carries a steep resolution radiometer (VHRR) capable of imaging the Earth in water vapour, visible and thermal infrared bands. It also carries a data relay transponder (DRT) to gather data from meteorological stations (Kaila et. al., 2002).

Sensor Components

VHRR/2 is a tweaked variant of the INSAT-2A, -2B, and -2E VHRR Heritage Imagers. In the VIS, water vapour and TIR bands, the VHRR/2 observes a spatial resolution of 2 km in the VIS band and 8 km in the remainder. The Data Relay Transponder (DRT) is part of ISRO's DCS (Data Collection System). The aim is to collect data in the ground segment from unattended meteorological platforms. The DRT collects and retransmits signals from unattended weather data collection platforms to the central station. For detailed weather status and

forecasting, the data from these payloads is used. VHRR and DRT comprise the payloads on the dedicated meteorological satellite. The VHRR consists of three visible bands operating at 0.55-0.75 pm, 5.7-7.1 pm water vapour (WV) and 10.5-12.5 pm thermal infrared (TIR) to provide day and night coverage (WMO 2020).

INSAT 3A

INSAT-3A, a multipurpose satellite for the provision of telecommunications, television transmission, meteorological and search and rescue services, is the third satellite in the INSAT-3 constellation. It has twenty-four transponders, twelve operating at the standard frequency of the C-band, six in the expanded C-band and six in the Ku-band. INSAT-3A carries a Ku-band beacon as well. For meteorological observation, INSAT-3A carries a three-channel Very High Resolution Radiometer (VHRR). In addition, INSAT-3A has a Charge Coupled Device (CCD) camera that in the visible and short wave infrared bands operates with a spatial resolution of 1 km. A Data Relay Transponder (DRT) working in the UHF band is incorporated for real-time hydro meteorological data collection from unattended locations on land and river basins (ISRO).
Launched- April 9, 2003 on Ariane-5 from Kourou.

Sensor Components

A linear CCD detector array of three spectral bands is used by the analytical instrument. Applications of CCD detector data are used in climatology as well as in floral mapping. Of the three bands, the first two are identical to NOAA AVHRR bands 1 and 2, providing surveillance of the "vegetation index"; the third band is used for snow-covering, discrimination against snow & clouds and dimensions of aerosols (Vinay 2013).

Table1: Spectral bands of CCD Camera

Spectral bands	0.620 - 0.680 micro-meter, Vegetation indices band 0.770 - 0.860 micro-meter, Visible Near Infrared band 1.550 - 1.690 micro-meter, SWIR (Shortwave Infrared) band
Spatial resolution	1 km x 1 km

INSAT-3DR

INSAT-3DR is an advanced Indian meteorological satellite equipped with an atmospheric sounder and an imaging system. The major changes incorporated into INSAT-3D are—

- Middle Infrared Band imaging to have night time views of low clouds and fog.
- Two thermal infrared bands imaging for greater SST (Sea Surface Temperature) measurement exactitude.

Sensor Components

Imager- INSAT 3DR carries a multi-spectral imager for meteorological observations capable of producing Earth images in six wavelength bands important for meteorological observations, namely visible, short-wave infrared, mid-infrared, water vapour and two bands in thermal infrared regions. The imager engenders Earth discs every 26 minutes at a geostationary altitude of 36000 km and delivers information on numerous factors, such as outgoing long wave radiation, quantifiable precipitation estimates, sea surface temperature, snow cover extent, movement of clouds and winds, etc.

Sounder- INSAT-3DR now has 19 sounder channels that were previously flown in INSAT 3D. In the short-wave medium infrared, and long-wave infrareds the sounder has eighteen narrow spectral canals, and one channel in the visible area. It will provide information on temperature, humidity and integrated ozone vertical profiles. These profiles are available for the selected region by every one hour over the Indian landmass and for the entire Indian Ocean region for every six hours.

Data Relay Transponder- Data Relay Transponder on the INSAT-3DR can receive meteorological, hydrological and oceanographic information in the data collection network, including automated weather stations, automatic rain gauges as well as agromet stations, from remote uninhabited locations in the coverage area. The data is transmitted back to the extended C Band for downlinking.

Satellite Aided Search and Rescue (SAS&R) Transponder- The Satellite Assisted Search and Rescue Payload in INSAT-3DR collects and transmits the warning signal of the maritime, air and land user distress batteries to the Indian Mission Control Center (INNCC). India's main users of satellite assisted search and rescue services include the Indian Coast Guard, the Indian Airport Authority, and the General Board of Shipar, Defense Forces, and fishermen in India (ISRO 2016).

Table 2- Salient Feathers of INSAT-3DR

Feathers	Description
Launch Date	8 September 2016
Vehicle	GSLV-F05
Mission	Meteorological and Search & Rescue Services
Orbit	Geostationary
Payloads	Imager, Sounder, Data Relay Transponder and Search & Rescue Transponder

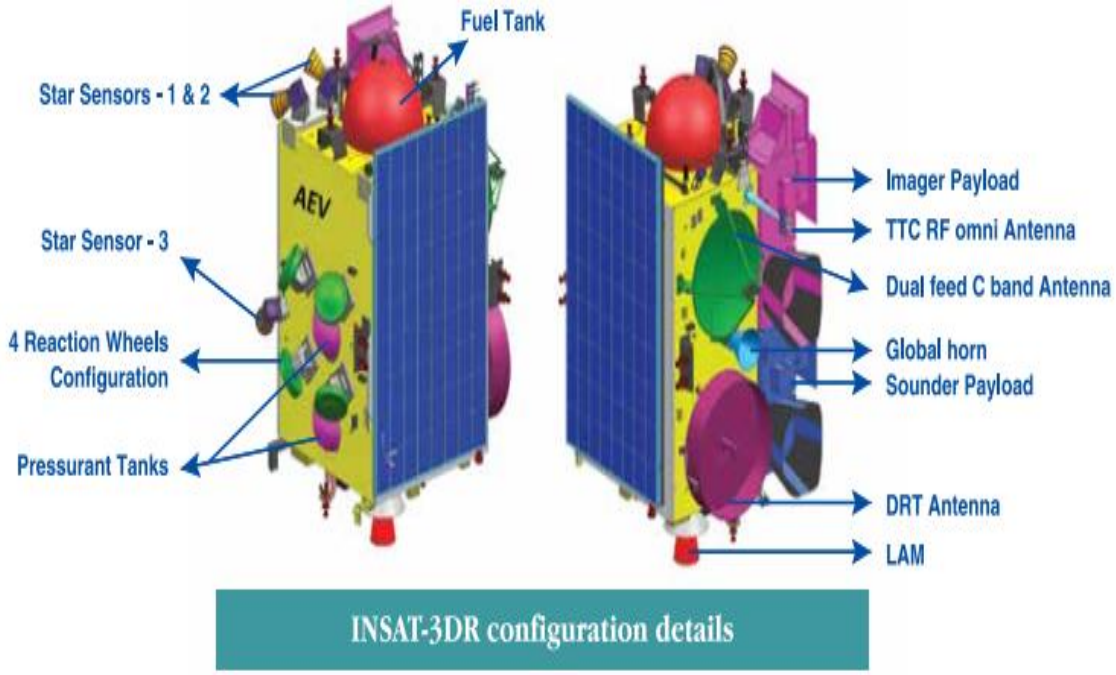
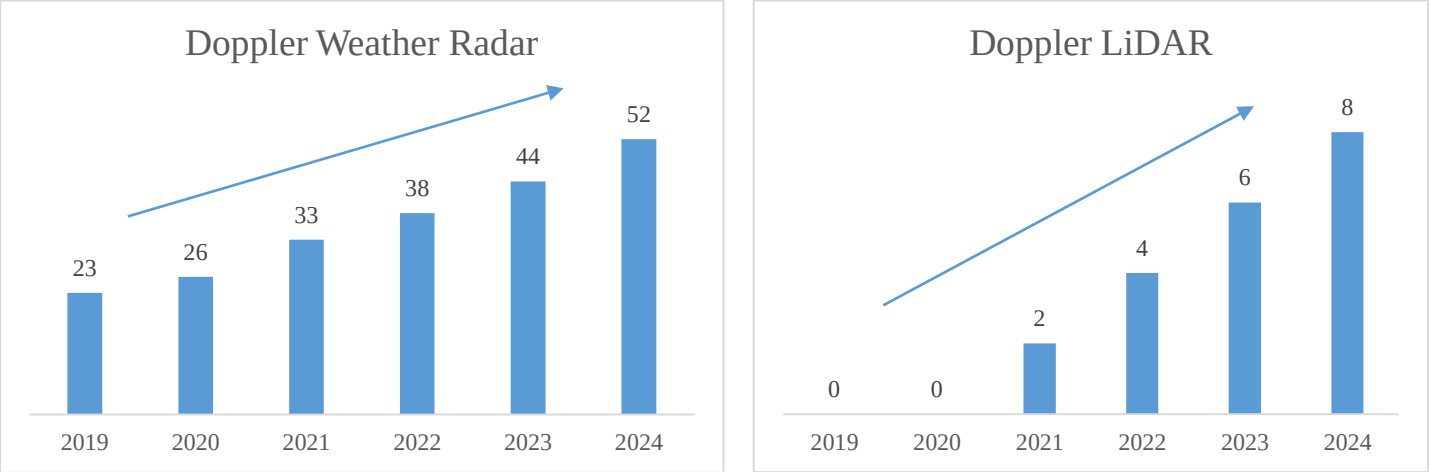


Figure 1- INSAT-3DR configuration details (source- ISRO)

Doppler Weather Radar & LiDAR Network

In several areas, including agricultural management, flight safety, and early warning of hazardous weather, wind and rainfall must be closely monitored. Wind and rain detection is also relevant for long-term analysis, such as climate change studies and future change prediction models. RADAR and LiDAR are the two most common methods of wind and rainfall detection. A high-frequency radio signal is emitted into the atmosphere by radar weather systems, where the radiation can interact with conductive particles. In order to cause Rayleigh scattering, the wavelength of the signal is considerably greater than the particles it will encounter. In order to provide reliable, precise information about the size and motion of the particles of interest, a significant amount of energy would also be reflected back into the radar receiver. Light Detection and Ranging (LiDAR) configurations are somewhat similar, but instead of radio waves, the signal is composed of laser light. Via a set of optics, light transmits from a source until a beam expander sends the collimated beam into the atmosphere. Reflected photons return to the receiver, a telescope, where the signal to be digitised is amplified and transformed by an optical analyser. Accurate information about thunderstorms, dust storms, hailstorms, rainfall and wind patterns is provided by Doppler radars. With a 250 km radius, 2-3 hours prior to extreme weather incidents, they aid in issuing nowcasts. There are currently 26 Doppler radars in the country.

Figure 2- Current and Proposed Radar and LiDAR stations in India (source IMD)



Upper area network

A meteorological observation made in the free atmosphere either directly or indirectly. Upper air observations includes- Pilot Balloon Observation, Radiosonde Observation, Radiowind Observation, Dropsonde and Aircraft Observation. In the year 2018, the India Meteorological Department (IMD) launched an indigenous GPS-enabled sonde, a pilot balloon, which will provide accurate information within an hour about wind speed and wind directions from higher atmospheric heights. Observations are taken twice daily by meteorologists at all observatories—at 11.30 a.m. and at 1.30 a.m. Thirty-nine radio probe and 62 pilot ballon monitoring units are working in India. The equipment comprises the network of upper air observatories. It is used to measure the atmosphere's vertical profile, like temperature, moisture, pressure, wind speed and the wind direction. Almost all atmospheric variables such as pressure, humidity and temperature are measured by radiosondes, while pilot wind observations have been restricted for observations of the upper air profile wind speed and direction only. The radiosonde uses the mechanical pressure sensor called a baroswitch in order to calculate the upper air ambient pressure profile. It is based on the vaccumization principle. A dropsonde is a weather system intended to fall out on the earth due to the force of gravity at specified altitudes. The GPS drop probe gathers data from the surrounding atmosphere which is transmitted via radio transmission to the aircraft remotely. It is intended to measure the atmospheric temperature, humidity, pressure and wind in weather systems.

CONCLUSION

Use of new technologies and artificial intelligence in the weather forecasting and agriculture will be very crucial. Mitigation strategies can be adopted by farmers against malevolent weather conditions. Although weather forecasting is very challenging but it provides protection for agriculture, human life, infrastructure, military etc.

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