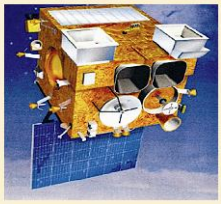
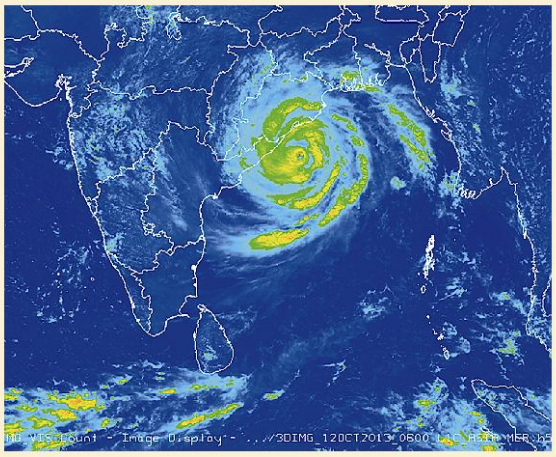
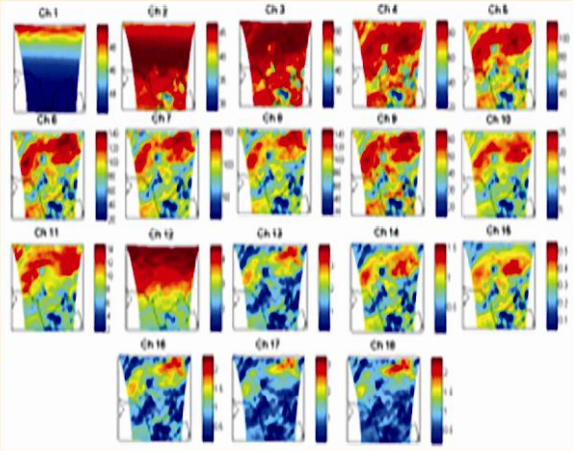


INSAT-3D

Observing Weather from Space.....

Products Catalog





2014

National Satellite Meteorological Centre,
India Meteorological Department,
Lodi Road, New Delhi-110003,
INDIA

INSAT-3D DATA PRODUCTS CATALOG

This catalog describes the INSAT-3D payloads, processing system and data products which are available from the INSAT-3D Meteorological Data Processing System (IMDPS) at National Satellite Meteorological Centre (NSMC), India Meteorological Department, New Delhi. A data product implied here is the valuable information retrieved from INSAT-3D Imager and Sounder Payload data. Sample of each product along with a short description of the algorithms, processing steps, frequency, accuracy, applications and availability are described.

1. Introduction

INSAT-3D: India launched an exclusive meteorological satellite on 26th July, 2013 from French ,Guyana using ARIANE rocket. The INSAT-3D is an exclusive meteorological satellite with the following mission objectives:

- To monitor earth's surface, carryout oceanic observations and its environment in various spectral channels of meteorological importance.
- To provide the vertical profile of temperature and humidity parameters of the atmosphere.
- To provide the data collection and data dissemination capabilities from the Data Collection platforms (DCPs).
- To provide the satellite aided search and rescue services.

To accomplish the mission objectives, INSAT-3D has following payloads on board the spacecraft:

- Six channel imager
- Nineteen channel sounder
- Data Relay Transponder(DRT)
- Satellite aided Search and Rescue(S&SR) System

Meteorological payloads are state-of-art and have significant technological improvement in sensor capabilities and higher resolution compared to earlier INSAT missions. The Imaging System of INSAT-3D has the following significant improvements over that of KALPANA and INSAT-3A:

- Imaging in Middle Infrared band to provide night time pictures of low clouds and fog.
- Imaging in two Thermal Infrared bands for estimation of Sea Surface Temperature (SST) with better accuracy.
- Higher Spatial Resolution in the Visible and Thermal Infrared band.

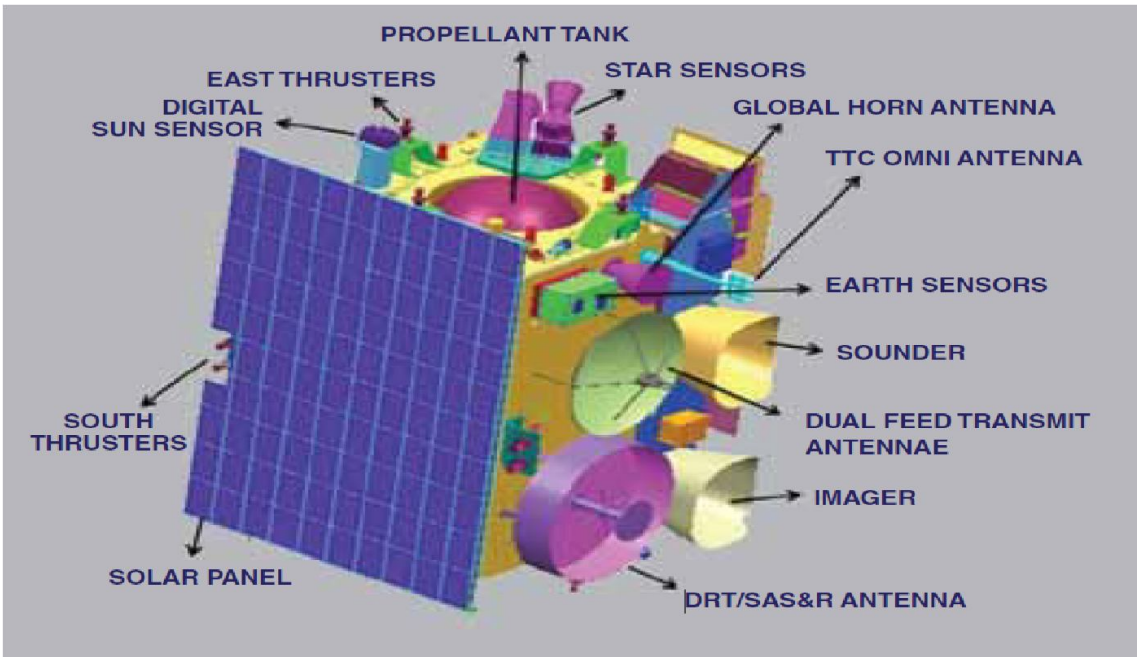
INSAT-3D adds a new dimension to weather monitoring through its atmospheric Sounding System, which provides vertical profiles of temperature (40 levels from surface to ~ 70 km), humidity (21 levels from surface to ~ 15 km) and integrated ozone from surface to top of the atmosphere. INSAT-3D provides continuity to earlier missions and further augment the capability to provide various meteorological as well as search and rescue services.

It is also proposed to establish a land based CAL/VAL site for INSAT-3D satellite for Visible and SWIR channel over Jaisalmer, Rajasthan, which would be suitable for calibrating and validating the radiometric gain of an in-flight satellite imaging

optical sensor.A joint-campaign to this effect has already been carried out atJaisalmer site with NRSC,RRSC,SAC,(ISRO), IITM and NPL scientists during 14-23 December 2013. The outcome of the observation results will finalize the CAL/VAL site.

2. Spacecraft:

The INSAT-3D islocated at 82Degrees East. It is a momentum-biased 3-axis body stabilized geostationary spacecraft, using star trackers for precise pointing control. It has well proven I-2K buswhich is built around the imaging payload requirement to maintain mass and volume to a minimum, to meet the payload thermal control requirements, locating the electronics from the signal to noise ratio consideration etc. The spacecraft has dry mass of 958.5 kg. The nominal design life is 7.7 years. One sided solar array of 1.9mx2.8m panel size has been considered on south surface to meet the power requirements. Also it avoids the thermal loads on payloads providing a better thermal regime for payloads. The payload Electro Optics Modules (EOMs) are on the payload deck (on the North-East corner). All the payload electronic packages are mounted on the underside of North equipment panel.



INSAT-3D configuration details

Salient Features	
MISSION	**Meteorological and Search & Rescue Services**
ORBIT	**Geostationary**
LOCATION	**82 deg E Longitude**
MASS AT LIFT-OFF	**2060 Kg**
DIMENSIONS	**2.4m x 1.6m x 1.5m**
MISSION LIFE	**7.7 years**
PAYLOADS	**Imager, Sounder, Data Relay Transponder and Satellite Aided Search & Rescue (SAS&R) transponder**

3. INSAT-3D Payloads

3.1 Imager

The INSAT-3D Imager is an improved design of VHRR/2 (Very High Resolution Radiometer) heritage instrument flown on the Kalpana-1 and INSAT-3A missions. INSAT-3D carries a multi-spectral Imager (optical radiometer) capable of generating the images of the earth in six wavelength bands significant for meteorological observations, namely, visible, shortwave infrared, middle infrared, water vapor and two bands in thermal infrared regions, offering an improved 1 km resolution in the visible band for the monitoring of mesoscale phenomena and severe local storms. Imager specification is as follows.

Imager Specifications

Spectral Band	**Wave length μm**	**Ground Resolution**	**Quantization bits**	**IGFOV μ□rad**
VIS	0.55 – 0.75	1 Km	10	28
SWIR	1.55-1.70	1 Km	10	28
MIR	3.80-4.00	4 Km	10	112
WVP	6.50-7.10	8 Km	10	224
TIR 1	10.3-11.3	4 Km	10	112
TIR 2	11.5 – 12.5	4 KM	10	112

The two new SWIR and MWIR bands with a resolution of 1 km and 4 km, respectively, enables better land-cloud discrimination and detection of surface features like snow. One more significant improvement is the split-band TIR channel with two separate windows in 10.2-11.2 and 11.5-12.5 μm regions with a 4 km resolution.
This new element helps in the extraction of sea surface temperature over the Indian region with far greater accuracy since the dual-window algorithm can be applied to eliminate the atmospheric attenuation effects. The 1 km resolution of the visible channel and 4 km resolution of the thermal IR channels improves the accuracy of the derived products like outgoing long wave radiation and cloud motion vectors.The Imager generates images of the earth disk from geostationary altitude of 36,000 km every 26 minutes and provide information on various parameters, namely, outgoing long-wave radiation, quantitative precipitation estimation, sea surface temperature, snow cover, cloud motion winds, etc.

The salient features of INAST-3D Imager are as follows:

1. Blackbody calibration sequence is modified as compared to VHRR of earlier satellites.

2. Two flexible mode of operation:

    - Full frame mode scans 18 degree EW x18 degree NS covering the entire Earth disc.

- Program mode covering 18 degree in EW direction NS coverage can be defined in terms of number of lines to be scanned.

3. High Resolution mode: in the Fast Scan direction IFOVs are over sampled by 1.75 times.

3.2 Atmospheric Sounder

INSAT-3D carries a newly developed 19 channel sounder, which is the first such payload to be flown on an ISRO satellite mission. The Sounder has eighteen narrow spectral channels in shortwave infrared, middle infrared and long wave infrared regions and one channel in the visible region. The ground resolution at nadir is nominally 10x10km for all nineteen channels. The specification of Sounder is as follws.

Sounder Specifications

Channel	**Spectral Range microns**	**Resolution**
VISIBLE	0.67– 0.72	10X 10 kms.
SWIR	3.67– 4.59	10X 10 kms
MIR	6.38– 11.33	10X 10 kms
LWIR	11.66 – 14.85	10X 10 kms

It provides information on the vertical profiles of temperature, humidity and integrated ozone. These profiles are available for a selected region over Indian landmass every one hour and for the entire Indian Ocean Region every six hours.

The salient features of INSAT-3D sounder design are as follows:

1. Blackbody calibration sequence is modified as compared to VHRR of earlier satellites.
2. In order to improve noise performance, facility to collect two or four samples (0.2 sec or 0.4 sec step & dwell time) of the same area also which can then be processed on ground. This will increase the sounding time proportionally.
3. A biannual rotation of yaw by 180 degree has been introduced to reduce the cooler patch temperature. This is to be taken care during processing.

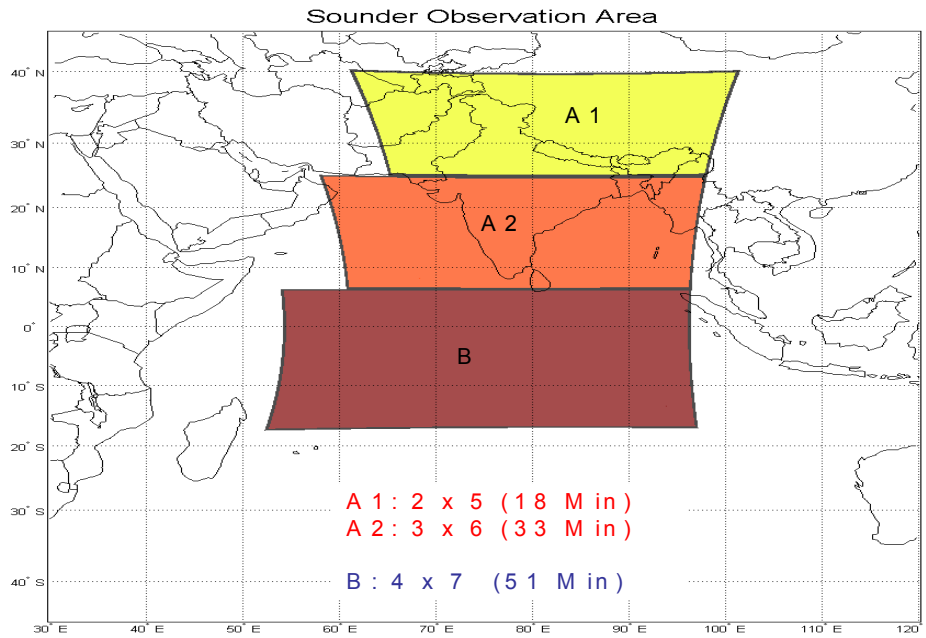
3.3 Mode of operation of INSAT-3D, Imager and Sounder:

There are three modes of operation of INSAT-3D satellite for Imager & Sounder payloads:

Mode of Operation	Time of coverage	Coverage Area
Full frame mode	26 minutes	18x18 degrees
ProgrammedNormal scan mode	23 minutes	14x18degrees
Programmed Sector scan mode	6 minutes	4 degrees in NS & 18 degrees in EW

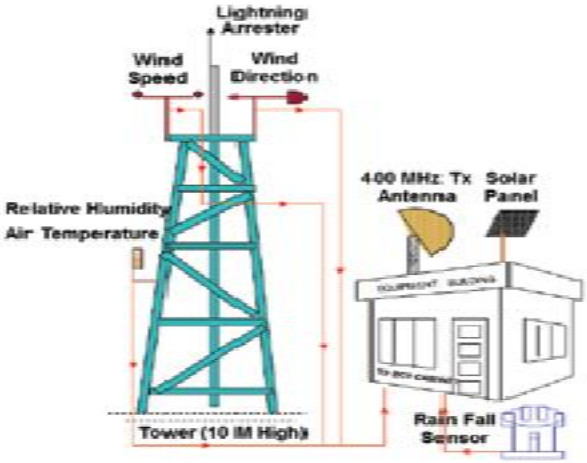
<u>Sounder Scan Schedule (6 Hour cycle):</u>

00:00-00.18Z : Region A1 00:20-00.52Z : Region A2
01:00-01.18Z : Region A1 01:20-01.52Z : Region A2
02:00-02.18Z : Region A1 02:20-02.52Z : Region A2
03:00-03.18Z : Region A1 03:20-03.52Z : Region A2
04:00-04.18Z : Region A1 04:20-04.52Z : Region A2
05:00-05.52Z: <u>Region B</u>



3.4 Data Relay Transponder (DRT):

Data Relay Transponder (DRT) on-board INSAT-3D is very useful for receiving meteorological, hydrological and oceanographic data from remote, uninhabited locations over the coverage area from Data Collection Platforms (DCPs) like Automatic Weather Station (AWS), Automatic Rain Gauge (ARG) and Agro Met Stations (AMS). The data is relayed back for down linking in extended C-Band

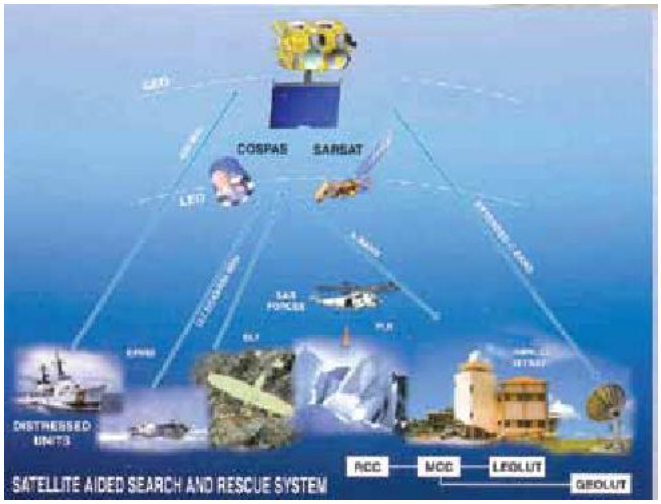


INSAT Data Collection Platform **Elements of Data Collection Platform**

For extreme weather related disasters such as cyclone, floods and drought, real time observations of the associated parameters with appropriate network density is very important. Satellite enabled Data Collection Platforms provide a unique solution for gathering meteorological data from all over the country including remote and inaccessible places. India Meteorological Department (IMD) and ISRO have established more than 1800 Data Collection Platforms.INSAT-3D provides continuity of service of DRT which is currently carried by KALPANA-1 and INSAT-3A.

3.5 Satellite Aided Search and Rescue (SAS & R) Transponder:

INSAT-3D is equipped with a Search and Rescue payload (operating in 406 MHz) that picks up and relays the alert signals originating from the distress beacons of maritime, aviation and land based users to the Indian Mission Control Centre (INMCC) located at ISRO Telemetry, Tracking and Command Network (ISTRAC), Bangalore. The major users of Satellite Aided Search and Rescue service in India are the Indian Coast Guard, Airports Authority of India (AAI), Directorate General of Shipping, Defence Services and fishermen. The Indian service region includes a large part of the Indian Ocean region covering India, Bangladesh, Bhutan, Maldives, Nepal, Seychelles, Sri Lanka and Tanzania for rendering distress alert services. INSAT-3D joins INSAT-3A to provide operational Search and Rescue service



4.INSAT-3D Meteorological Data Receiving Earth Station (IMDRES)

Master Control Facility (MCF) Hasan, ISRO on behalf of ANTRIX has established, the 'INSAT-3D Meteorological Data Receiving Earth Station (IMDRES)' comprising of the ground reception infrastructure, Quick Look Processing & Archival system and Monitoring and Controlling system at IMD premises in New Delhi.

4.1 Earth Station & Baseband System:

The station incorporates 7.2m shaped Cassegrain antenna with Ext. C-band, Dual linearly polarized, receive feed system & operation in the Ext. C-band frequency range 4.5 to 4.8 GHz in receive band. The antenna pedestal is an elevation-over-azimuth type, providing adequate steer ability to look at geostationary satellites. Azimuth and Elevation axis are motorized. The antenna is integrated with Antenna control system with various built-in modes for tracking operation. The system comprises of Downlink chains to receive Imager, Sounder and AWS Data from INSAT-3D. Sufficient redundancy is incorporated to handle any failures and to enable IMD to receive the uninterrupted data from INSAT-3D.

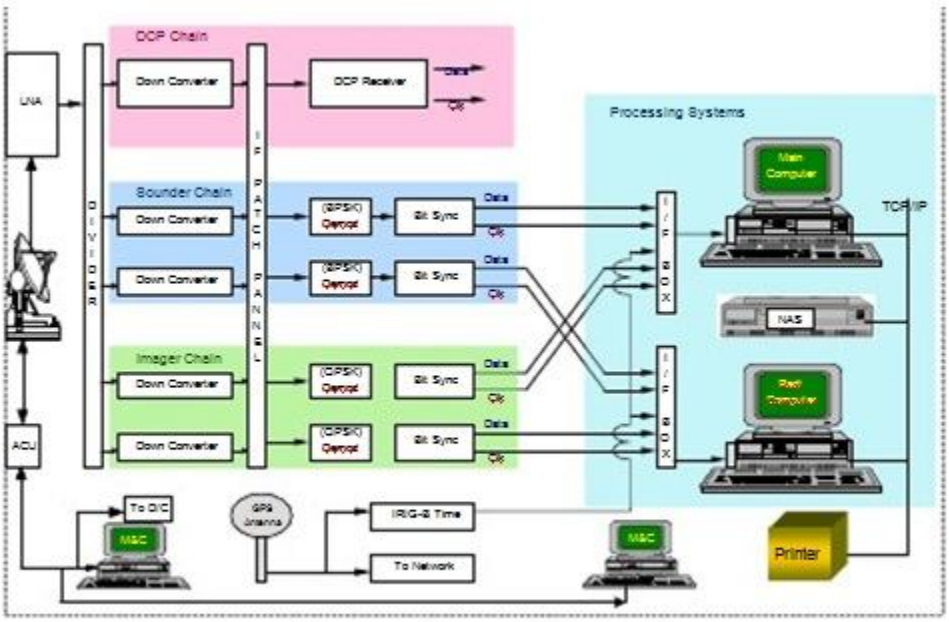
7.2 m Extended C Band Terminal

IMDRES comprises of six RF chains. They are designated as two mutually redundant RF Chains for each Sounder & Imager, an AWS chain and a spare chain. It also comprises of adequate RF and IF instruments for necessary measurements/ monitoring and two mutually redundant Quick Look Processing & Archival systems configured to the RF chains through Interface Boxes.

4.2 Quick Look Processing & Archival System

The Quick Look Processing & Archival System is a vital element at IMD for day-to-day operations of satellite meteorology. It is expected to cater to the following specific requirements of IMD.

- A quick information about the downlink signal LOCK Status.
- A quick Look Image Display in real-time to ensure proper reception of image data.
- Automated Image Data Archival into Network Attached Storage(NAS),which serves as a backup data repository for further processing at IMD as well as an emergency data source for MCF.
- A Quick reference to few informatory parameter status/values from the onboard imaging payloads in real-time.



Configuration of IMDRES

4.3 IMDRES Software Components

The software enables the operation of system in two modes:

- User Mode: For routine operations by the end user (operator). Since the software is expected to provide mainly the quick look display, most of the operations are automated with minimum user interaction.

- System Administrator Mode: For the system configuration management, routine
housekeeping, automation control, etc by the system administrator.

Acquisition Module of the software is responsible for the data acquisition. Signal lock is shown by GREEN indicator and the unlock status is shown by RED. The Application Module of the software provides the following.

- Data Archival: Automatic full data archival into NAS as well as the average data archival for each imaging operation.
- Image Display: For quick look image displays of all channels.
- Page Display: For referring the informatory parameter display.
- Real Time Graph: For a quick glance of the trends of few parameters.

M&C System provides access to the equipments residing in the earth station.The system is designed based on client-server concept. The Software uses TCP/IP protocol. The M&C server software executing at earth station computer communicates with all equipments through RS-232 cables. The client software executing in client computer (located in IMD building) communicates with the server through network and collects all the information about the equipments of the earth station.

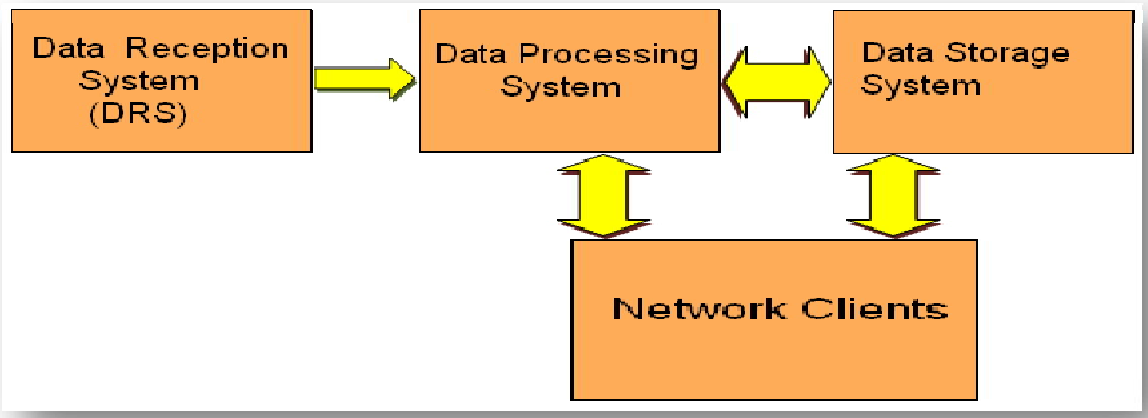
5.INSAT-3D METEOROLOGICAL DATA PROCESSING SYSTEM (IMDPS)

Indian Space Research Organization (ISRO) provides end-to-end solution for reception and processing of INSAT-3D data and derivation of meteorological parameters. An indigenously designed and developed INSAT-3D Meteorological Data Processing System (IMDPS) has been installed and commissioned at IMD, New Delhi with a Mirror Site at Space Applications Centre, Bopal, Ahmedabad. IMDPS caters to the processing of all data transmitted by the Imager, Sounder and DRT payloads.IMDPS also simultaneously processes data of INSAT-3A and Kalpana-1 satellites. The data archival and dissemination is through IMD, New Delhi.The IMDPS system acquires raw data from serial data streams, processes the data and generates various quantitative products from the processed data for

operational utilization by various users. Additionally, the system is capable of processing, ingesting and analyzing Automatic Weather Station (AWS) and Global Telecommunication System (GTS) data.

5.1 System Overview

The Requirements of INSAT-3D Meteorological Data Processing system (IMDPS) are realized using specialized software and hardware. Following are the major sub-systems for processing of INSAT Meteorological Data. The main architecture of IMDPS system consists of Data Reception system, (DRS) Data Processing System (DPS), Data Storage System (DSS), Network Clients System (NCS) and Satellite Images Display System (SIDS)



5.2 Data Acquisition and Quick Look Display System (DAQLS)/ Data Reception(DR) System

The DAQLS and DR system is the front-end system for Data Acquisition and processing chain to capture, archive, display and transferring the RAW data and Meta data to the DP System for subsequent Processing. Each DR system receives the base band serial data stream of the satellite sensor from the corresponding RF-IF segment. Every sensor (Imager, Sounder, VHRR and CCD) base band data streams are handled independently. DR systems for each sensor stream are implemented in redundant configuration. The major functions are

- Frame synchronization,
- Frame and Format verification,
- Data Acquisition,
- Raw data archival
- Processed Quick Look Display (P-QLD), HK display and logger,
- Data transfer to DP, Raw data Replay suits,
- Online BER measurement

The main functions like Data Acquisition and Raw data archival are implemented in these systems. The DR systems are connected to Data Processing System through TCP/IP network. Each DR system transfers a processed raw sensor image to the connected Data Processing computer immediately after the compilation of Image.

The Hardware elements of the DR systems are,

a. Bit synchronizer Units
b. Computer Interface Units (CIUs)
c. Data Reception Servers (DR Servers)
d. Raw Archival Disks
e. Display work station
f. LTO drive and media

Bit Sync. Unit receives the base band serial stream from the Demodulator, and provides the Serial Randomized NRZ-L data along with synchronized clocks. It generates TTL serial data along with synchronized 0 deg. and 90 deg. clocks. It also performs the functions of

- Code conversion from NRZ-S to NRZ-L (for VHRR, SOUNDER)
- Clock hold in case of short period breaks in the data stream.
- Track and hold the output data to the specified frequency in case of disturbances in demodulator output

The CIU unit(s) receives the Serial Base band data with clock from the Bit Synchronizer(s). They perform the functions of Frame Synchronization, DE randomization, and formatting the data.

Real time Data Acquisition, Disk Archival and DP image data transfer, P-QLD, RAW Displays are implemented on the DR Server. It also includes a Telemetry logger and a real time display of some telemetry items. The software is implemented such that Data Ingest along with all applications can be operated at the same time on the single Server. The DR systems are configured on a dual CPU server with OVMS operating system. Each Server is capable to process two independent base band chains, with all the required DR functions.

Raw Archival Disks and LTO-3 drives are directly connected with DR servers through SCSI interface for raw data backup. Printers are connected with LAN switch. Additional Display workstations to support Online QLD and HK Displays are connected to the Servers through network.

DR software suites run on the DR Servers. Two independent such suites (one each for the base band chain configured on the server) are normally operational on each server (VHRR/CCD/Sounder/Imager).
The DR software consists of suites for

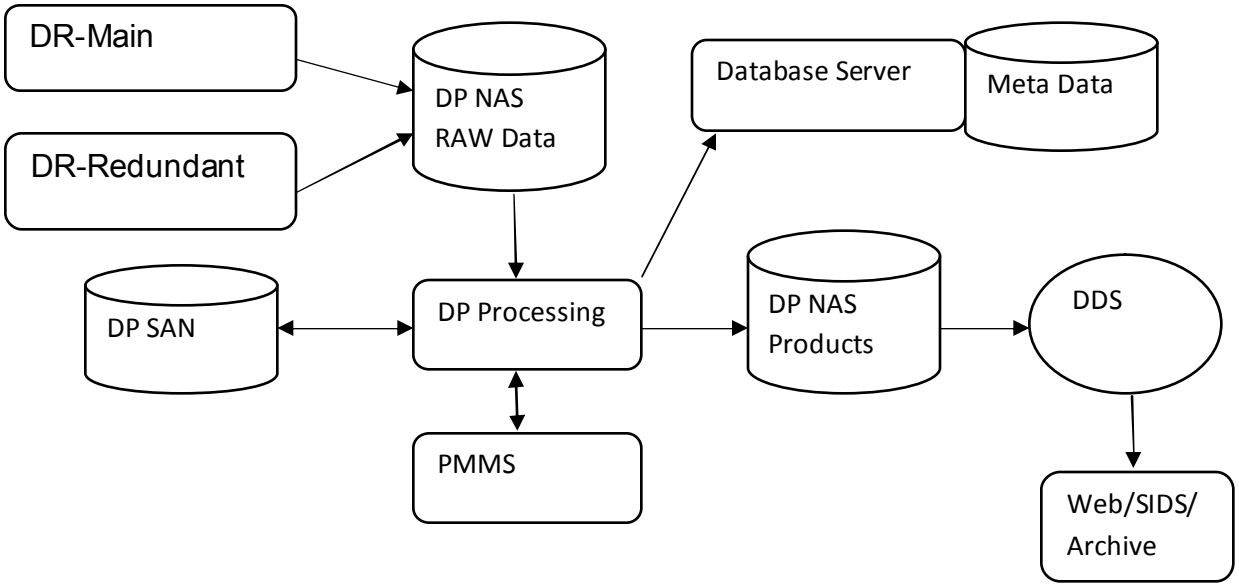
- Data Acquisition and CIU control and Ingest, with automatic transfer to "DP" computers.
- Real time data acquisition and ingest with online status updates.
- Band wise Quick Look Display (partially processed) on Console and networked display workstations.
- Raw Data Archival, with secondary archival on LTO.
- Telemetry logger.
- Online processing of raw data stream for band separation, telemetry stripping.
- Offline data transfer of raw Image data to "DP" computers DR software suite implementation aresuch that they can be operated individually and independently in a very flexible manner (eg. P-QLD , TM processing, Ingest are all independent)

The numbers of application tasks like P-QLDs, HK plots, HK displays are automatically limited for a given Sensor data stream to avoid server resource crunch. The main Data acquisition and Ingest suits module distributes the raw data to all other application modules.

DR software for a given DR-Main and DR-Redundant chain operate independently and exclusively with respect to one another. Two independent such suites (of different Sensor data streams) can be operated on each server.
DR software is implemented using C++, Fortran, System services of O/S, X-window GUI, on the OVMS server platform.

5.3 Data Processing System (DPS)

The Data Processing System (DPS) is main component of the IMDPS system. The raw data from DRS is transferred to the Data Processing System via TCP/IP network. The main function of DPS is to process the data received from DRS and give the desired products. The DPS consists of 7 main severs having 5 DELL PE 6850 servers (INSAT-3D Imager, INSAT-3D Sounder, INSAT-3A CCD, INSAT-3A VHRR and KALPANA-1 VHRR servers), a DELL PE 2950 server (Image Analysis Server) and 2 HP xw6400 servers (Ancillary Data Processing System & CCD application server). All the raw data from DRS is processed in these servers & the desired products are obtained. After processing the data is transferred to an external storage system for storing the data.

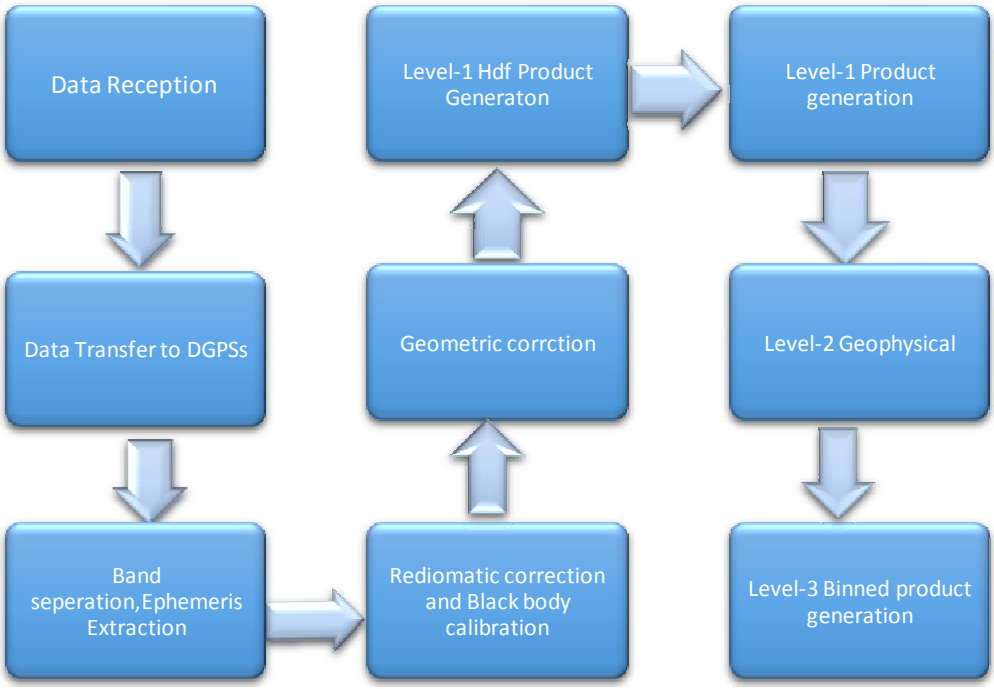


5.4 IMDPS Data Products Generation Software (DPGS)

The main function of INSAT-3D data Products Generation software is to process the raw data received from Data Acquisition and Quick Look System (DAQLS) and generate predefined data products. The Processing level and supported formats for each type of data products are given in subsequent paras.
DPGS performs the following functions:

- Generates the ephemeris information for the given date, time of acquisition.
- Extracts different band images, space look data, black body data, AOCS, Fast/Slow scan servo error information and the ancillary information ATM (Analog and Digital Telemetry), DTM (Digital telemetry) from the raw data
- Corrects for the servo error
- Radiometric corrections
- Geometric corrections
- Generates supported digital data product in HDF5
- Generates various pre-defined Geo-physical parameter Products.
- Dissemination of Products

Data Products Generation Chain



5.4.1INSAT-3D Data Products Corrections

5.4.1.1 Raw data Extraction: Image data along with telemetry (both analog and digital), servo profile, attitude, space look and black body information are extracted for each acquisition.

Servo Correction: The mirror position is commanded from ground. Suppose, during one fast scan sweep the commanded angle is θ. However, due to various reasons, the mirror might image at position θ+δθ. In the next frame, at the same position as above, the commanded position is again θ, but the mirror might image at θ+δθ'. This difference in the actual position of the mirror in two successive frames when commanded to look at the same portion of the earth gives rise to a break in features. A linear feature will look broken. The error δθ is called servo error. If the image has to be corrected, this break in the features has to be removed. This process is called servo correction. Unless this is done, even the earth disk will not look a full circle, but rather like a circular gear wheel. Servo error profile obtained from raw data is used to correct servo error. Following corrections are done as part of servo correction:

- Servo Correction
- Stagger Correction
- Oversampling Removal

•Linearity Correction

5.4.1.2 Radiometric Corrections

The response of the different detectors in the array has to be normalized for correct interpretation by different applications. This is done by generating a Calibration Lookup table. Before launch, the calibration lookup table is generated in the Laboratory. However, after launch, these values tend to change. The change is detected using the Cold Space and Black body data available with every acquisition. Using this cold space data and the on board temperature at the time of acquisition, new calibration look up table is generated. The calibration lookup table is provided with every product to the user.
Following corrections are done as part of radiometric corrections:

•Detector normalization
•Line loss correction
•Black Body Calibration and BT (Brightness Temperature) Table Generation
•Radiometric Normalization
•Line Loss Correction
•Stripe Removal (if any)

5.4.1.3 Geometric Corrections

The aim of Geometric correction is to assign proper geo-location (latitude/longitude) coordinates to the different pixels of the image data and compute viewing angle for satellite and Sun. Following corrections are done.

•Navigation (Computation of Geo-location using ephemeris, attitude and imaging model)
•Computation of Satellite/Sun Azimuth/Elevation
•Yaw Flip Correction
- System level Geo referencing for small area of interest (AOI) defined by the user– Sector Product. Following additional corrections are done for sector products of Map projection resampling

•Boundary file generation
•Residual Attitude Computation

Image and Mirror Motion Compensation (IMC/MMC) have been incorporated in INSAT-3D. However the effect of this will be reflected only in the mirror position. This is available as part of Auxiliary data to Data Products System. The DTM contains twenty samples of the fast scan mirror positions for every frame. Polynomial fit through these twenty points and this curve is used to interpolate

the fast scan mirror positions at other locations. Similar interpolation is done to calculate the slow scan mirror positions.

Another new element in INSAT-3D is the half yearly yaw flip– the satellite will be rotated by 180 degrees once in six months. The DP software takes care of the yaw flip effect. The information is available in the form of yaw angle and using this product are generated in the 'upside' mode.

Imaging Mechanism

The payload consists of a scan mirror that rotates in the west to east (east to west) direction over an angle of 9°. This sweep covers a field of view of 18°□on the earth in the west to east (east to west) i.e Fast Scan direction. Each of these sweeps is called a frame. This sweep is repeated times, by changing the angle of the mirror in the north south direction. The starting angle for the slow scan can be set at users' request, thus enabling coverage of different areas.

Navigation: Geolocation

The first step is to find the coordinates of the points imaged by the various detector elements during the full slow/fast scan. The slow scan and fast scan angles are obtained from the telemetry data coming along with the video data. The satellite state vector is obtained by using an orbit determination algorithm. The inputs for this are obtained from Mission Control. Since the satellite is stationary and the field of view is large in both north-south and west-east directions, sometimes, the satellite might look into cold space. This is taken care in the model.
In one frame, the slow scan varies from sayΦst to Φend, while the fast scan angle varies fromθst toθend.
For
$\Phi st \leq \Phi \leq \Phi end$, $\theta st \leq \theta \leq \theta end$

Using the geometric model and modeling the earth as a spheroid, the point on the ground imaged by the particular detector element is found out as (xg, yg, zg) in the inertial frame of reference
Thus, the mapping
$(detector\_no, \theta, \Phi) \rightarrow (\varphi, \lambda)$
is established.
This map gives the geolocation information of the data acquired.

System level Geocoding

Geocoding is the process of projecting the satellite image data into a proper map projection with a constant spatial resolution, and aligning the same to true

North, so that the data can be overlaid on a map. For this, the corner coordinates are given apriori. These are converted into map projection coordinates in the desired projection.

5.4.2Product Formatting and Dissemination

All products are generated in HDF5 (Hierarchical Data Format) format and corresponding image chips are generated in JPEG format. Atmospheric Motion vectors (AMVs) are generated in BUFR (Binary Universal Format for Representation of Meteorological data) format also. All products are disseminated through IMD web and GTS network.

5.5 Data Dissemination Server

Various Products are disseminated by Rule based Data Dissemination Software. Based on requirement dissemination rule can be modified to include new products for dissemination.

Few of the functionalities include

- **Transfer of Imager to the web site.**
- **Conversion of products to GTS format and transmission to Meteorological communications computer.**
- **Encoding of products and AWS data in WMO format and transmission to Meteorological Communications Computers (MCC).**

5.6 Ancillary Data Processing System (ADPS)

The Ancillary Data Processing system caters to the requirements of ingesting data from other sources and conversion of the data to the required format for archival of the same at the central data storage. This archived data is used by Data Products/Parameter Retrieval system for processing.

5.7 Database Management System

The Database Management System is using ORACLE 10g as a backend Database server and it contains Metadata of all processed products available on the central store. This database also contains information about the permanent databases such as GCP and boundary database, Ingested Auxiliary Data i.e. data from GTS and AWS and other information, which are used during the Data Products Generation and by Image Analysis software.

5.8 Product Monitoring and Management System (PMMS) and PSS

The Product Monitoring and Management Software (PMMS) have an interface with the Database management system and Process Scheduling Server (PSS), which runs on all configured Data processing systems.

The PMMS is capable of displaying the current processing status as well as the status of products already processed on configured data processing system. The GUI automatically updates the status of the process and displays the status by using proper coloring scheme. This software also has capability to display all sub-sampled data associated with the product for all acquisition for the operator-selected date. Operator is also provided capability to display images associated with the final product in full resolution as part of product visualization.

The Software requirements can broadly be classified under following categories

- Management
- Report Generation
- Monitoring
- Visualization

Process scheduling server is for Management of Products, Processes and Product Scheduling.

5.9 Data Dissemination Software (DDS)

It disseminates the generated Internet Products, SIDS products and LRIT/HRIT products to designated systems.
Following Data Dissemination modes are planned as part of data dissemination activity

- Transfer of Imager to the web site.
- Conversion of products to GTS format and transmission to Meteorological communications computer.
- Encoding of products and AWS data in WMO format and transmission to Meteorological Communications Computers (MCC).

6. Geo-physical Product Generation

Parameter Retrieval (PR) and Meteorological maps from INSAT Data Geo-Physical parameters are retrieved with INSAT-3D/INSAT-3A/Kalpana-1 Meteorological data on an operational basis in Near Real time and Meteorological Image data Products generated and Geo-Physical Maps disseminated automatically.

Geo-physical products getsgenerated as soon as Level-1 processing is over. All geophysical parameters take Level-1 data as input along with dynamic forecast data, climatological data, DEM and few static inputs.

7. Geophysical (GP) parameter retrieval

Different types of Geophysical parameters Products are retrieved using Imager and Sounder.

7.1 Imager GP Products : Atmospheric Motion Vector Winds, Outgoing Long wave Radiation (OLR), Upper Troposphere Humidity (UTH), Sea Surface Temperature (SST), Quantitative Precipitation Estimates (QPE), Fire, Smoke, Fog, snow cover and Aerosols}.
The lists of Imager derived geo-physical parameters are given in Table below:

Geophysical parameters from Imager

No.	Parameter	Input Channels/Data
1	Cloud Mask (CM)	MIR, TIR-1, TIR-2
2	Outgoing Longwave Radiation (OLR)	WV, TIR-1, TIR -2
3	Quantitative Precipitation Estimation (QPE) GPI, IMRSA and HE	TIR-1, TIR- 2
4	Sea Surface Temperature (SST)	SWIR, MIR, TIR – 1, TIR – 2
5	Snow Cover	VIS, SWIR, TIR – 1, TIR – 2
6	Fire	MIR , TIR -1
7	Smoke	VIS, MIR, TIR –1, TIR –2
8	Aerosol	VIS, TIR –1, TIR -2
9	Cloud Motion Wind Vector (CMV)	VIS, TIR-1, TIR –2
10	Water Vapor Wind Vector (WVWV)	WV, TIR-1,TIR –2
11	Upper Tropospheric Humidity (UTH)	WV, TIR-1, TIR –2
12	Fog	SWIR, MIR, TIR-1, TIR-2

7.2 Sounder GP Products : Algorithms and products (e.g. temperature, humidity profiles, and total ozone) are tested INSAT-3D sounder radiances and operational products are generated.

Geophysical parameters from Sounder

No.	Parameter	Input Data
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 atstandard pressure levels
6	Dry Microburst Index	Sounder retrieved temperature and humidity profiles atstandard pressure levels
7	Maximum Vertical Theta-E Differential	Sounder retrieved temperature and humidity profiles atstandard pressure levels
8	Wind Index	Geo- potential Height and retrieved temperature and humidity profiles at standard pressure levels

8. INSAT-3D Data Products Type and Format

8.1 Product File Naming Convention

All the INSAT-3D products are provided in HDF5 format.

The hdf5 product file name is coined as:

SSNNN_DDMMMYYYY_HHmm_LOP_XXX.h5

Where

SS=Satellite ID (e.g. 3D for INSAT-3D)
NNN=Sensor ID (IMG for Imager, SND for Sounder)
DDMMMYYYY=Date of Acquisition (DD=Day of Month, MMM=Month of the year, YYYY= year of Pass e.g. 01JAN2014)
HHmm=Time of Acquisition (HH=Hour of day mm=minute of the hour)
LOP=Level of Processing (L1B, L1C, L2B, L2G, L2P, L3B, L3G)
XXX=Parameter Name) or STD or Sector Name
e.g. 3DIMG_01JAN2014_0730_L1B_STD.h5

8.2 INSAT-3D Data Products Types

The various types of data generated by the Data Products System in different formats are:

- LEVEL - 0 (Raw) – for internal use and archival
- LEVEL - 1 (Full Globe, Sector)
- LEVEL - 2 (Geo-physical)
- LEVEL - 3 (Binned Geo-Physical)

The information on HDF, its design philosophy, and its logical and physical formats, the reader is referred to NCSA web http://hdf.ncsa.uiuc.edu/. The HDF5 library and utilities (provided by NCSA) can be used to read the contents of the HDF products. Google KML C++ libraries available at http://code.google.com are used for writing KML products.

Following section gives INSAT-3D Data Products Types.

INSAT-3D Imager Products

S.No.	Data Product	Processing Level	Code	Format	Remarks
Standard Products					
1	Standard Product Full Disk	L1B	STD	HDF	Per Pixel Lat& Lon as viewed by Satellite
2	Standard Product Full Disk Fixed Grid	L1C	STD	HDF	Projected on Fixed Grid
3	Standard Sector Product	L1C	Sector mnemonic	HDF	Map Projected
Geo-Physical Parameters					
1	Outgoing long wave radiations	L2B	OLR	HDF	Per Pixel
2	Rainfall using Hydro Estimator	L2B	HEM	HDF	Per Pixel
3	FOG	L2C	FOG	HDF	Per Pixel
4	SNOW	L2C	SNW	HDF	Per Pixel
5	Cloud Mask	L2B	CMK	HDF	Per Pixel
6	Upper Troposphere Humidity	L2B	UTH	HDF	PerPixel
7	Sea Surface Temperature	L2B	SST	HDF	PerPixel
Geo-Physical Parameters (Point)					
1	FIRE	L2P	FIR	KML	Point
2	SMOKE	L2P	SMK	KML	Point
3	Atmospheric Motion	L2P	AMV	HDF	VIS, TIR, WV, MIR

	Vectors				(Point)
Geo-Physical Parameters (Gridded)					
1	INSAT Multi-Spectral Rainfall Algorithm (IMSRA)	L2G	IMR	HDF	0.1 deg x 0.1deg
2	Quantitative Precipitation Estimation	L2G	QPE	HDF	1 deg x 1 deg
3	Aerosol Optical Depth	L2G	AOD	HDF	0.1 deg x 0.1 deg
Binned Geo-Physical Parameters (Temporally Binned)					
1	Outgoing long wave radiations	L3B	OLR	HDF	Daily, Weekly, Monthly and Yearly Per Pixel
2	Rainfall using Hydro Estimator	L3B	HEM	HDF	Daily, Weekly, Monthly and Yearly (Per Pixel)
3	Sea Surface Temperature	L3G	SST	HDF	Daily, Weekly, Monthly and Yearly 0.5 deg X 0.5 deg
4	Upper Troposphere Humidity	L3G	UTH	HDF	Daily, Weekly, Monthly and Yearly 0.1 deg x 0.1 deg
5	INSAT Multi-Spectral Rainfall Algorithm (IMSRA)	L3G	IMR	HDF	Daily, Weekly, Monthly and Yearly 0.1 deg x 0.1deg
6	Quantitative Precipitation Index	L3G	QPI	HDF	Daily, Weekly, Monthly and Yearly (1 deg x 1 deg)

INSAT-3D Sounder Products

S.No.	Data Product	Processing Level	Code	Format	Remarks
Standard Products					
1	Standard Product	L1B	STD	HDF	Per Pixel Lat& Lon as viewed by Satellite
Geo-Physical Parameters					
1	Vertical Profiles and Derived products	L2B	PFL	HDF	Profile on 3x3 Pixels (Average)

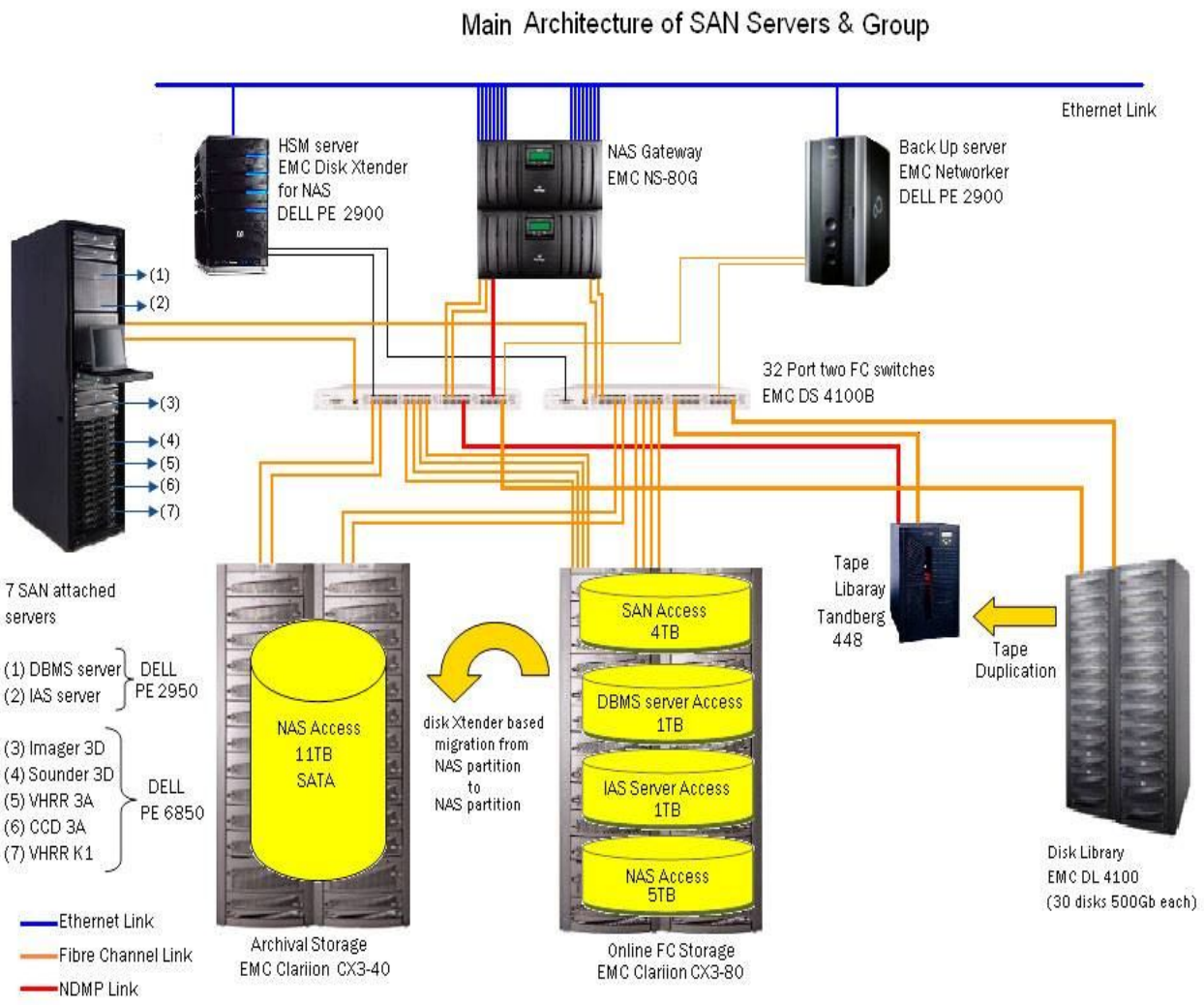
9.IMDPS Storage Infrastructure

The processed data volume of all scans of all channel of INSAT-3A (VHRR, CCD), KALPANA-1 (VHRR) and INSAT-3D (Imager & sounder) is works out to be approx. 4 GB per hr. during imaging duration. Assuming 20 hrs.imaging duration per day the data volume for one month would be around 2.4 Tb. To cater to this data storage requirement an 11 TB SAN online and 11 TB Archival SAN along with NAS gateway, 11TB disk library and 48 slot LTO based tape library (DLT 400/800 GB media) are used in IMDPS storage system. The storage infrastructure consists of various parts as shown below :

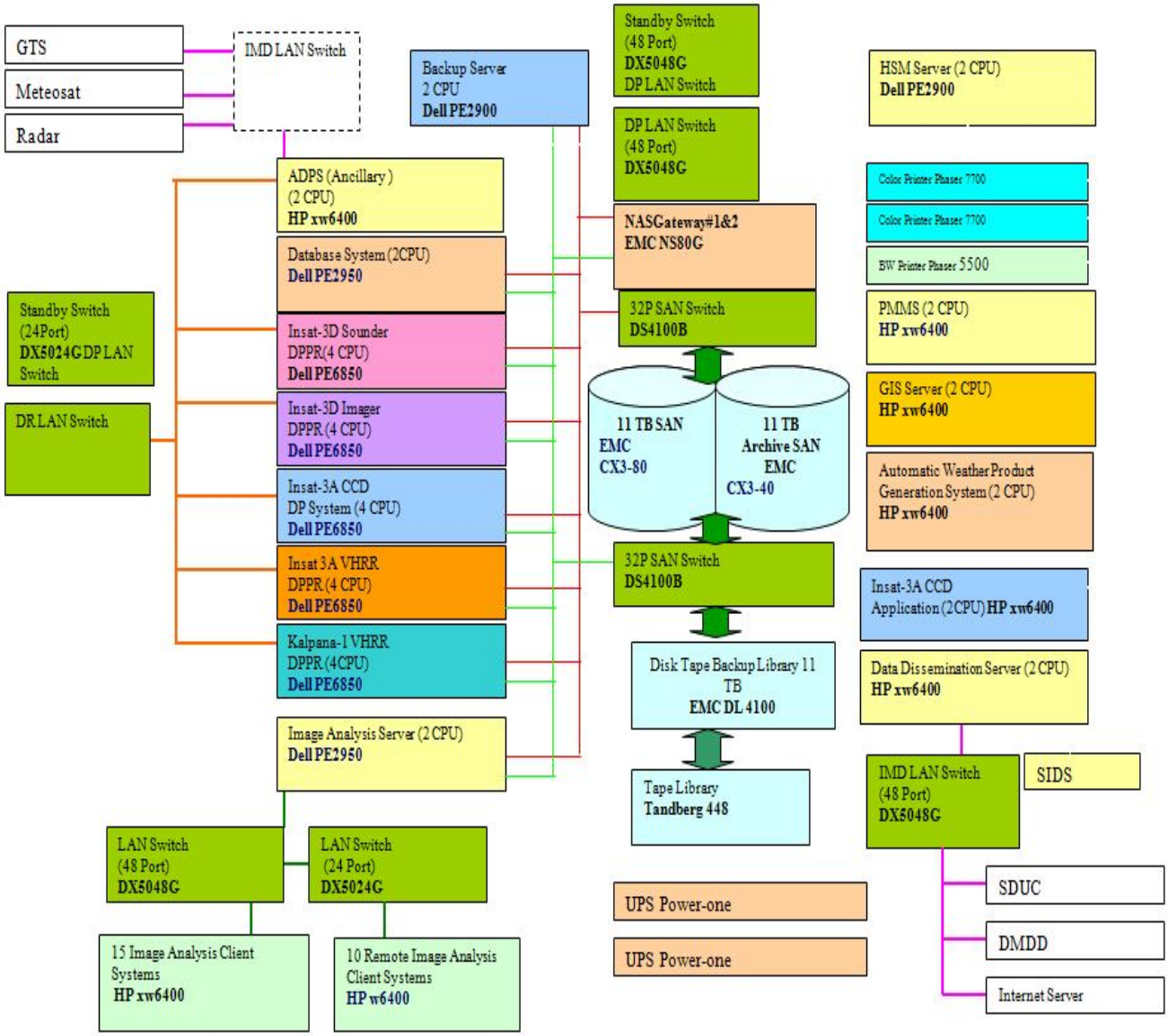
All the components of the storage infrastructure are now explained below:

9.1 Storage Area Network/Online SAN Storage(used in IMDPS system)

In IMD, an EMC CX3-80 model is being used as a SAN server which is used to connect all the storage devices with the main data processing servers. This



SAN server is made the Online FC storage which stores all the live data from the 3 satellite (i.e. KALPANA-1, INSAT-3A, INSAT-3D).
An EMC CX3-80 model is being used here which is one of the most powerful midrange storage arrays, it provides high expandability and a higher application performance. The EMC CX3-80 shares the same hardware and software architecture as the CX3 model 40 & model 20 but with faster processors, high capacity, greater connectivity and greater throughput.



Data Processing System and Storage System Architecture

10. Network Clients System

To cater the requirement of user 25 image analysis client workstations, one data dissemination server, one product monitoring and management system and one AWPGS server are used as a network client and continuously interact with data processing system and data storage system.

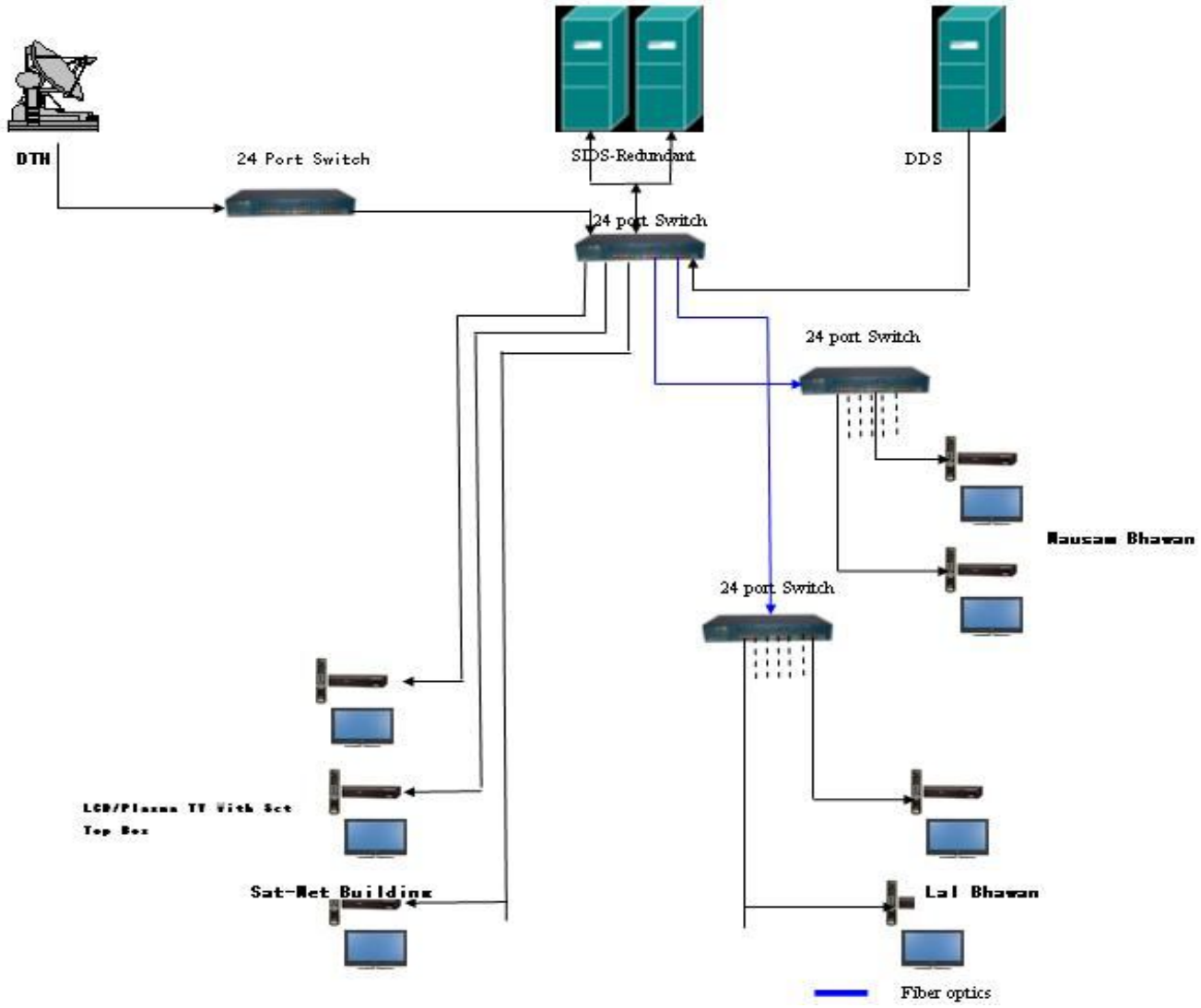
11. Satellite Image Display System (SIDS)

The Satellite Image Display System (SIDS) is one of the sub systems of INSAT-3D METEOROLOGICAL Data Processing System (IMDPS). It consists of two HP XW6600 workstation, TV Display 26”/42”,24 port gigabyte Ethernet LAN switch, Ku BAND DTH (Including Antenna LNBF & Receiver with remote control) ,Client Set-top box.The prime objective is to receive the images from Data Dissemination Service system (DDS) and transmit to TV receivers available at 25 different locations within the IMD campus. Transmission of signal from SIDS (head-end) system to LCD TV receiver (user end) using LAN cable network. SIDS system interacts with DDS to receive the images for transmission.

The Satellite Imagery Display System (SIDS) as the name suggests, is an image display system capable of:-

- Receiving images from 19 different folders of DDS and transmitting these to TV receivers (LCD).
- Transmitting images (of different satellite and sensors) to 19 channels and 1DD news channel.
- Display of animated images as a video for showing the movement of clouds.
- Functioning automatically and work (fetching data from DDS and sending to TV receiver sets at user end) without any user intervention.

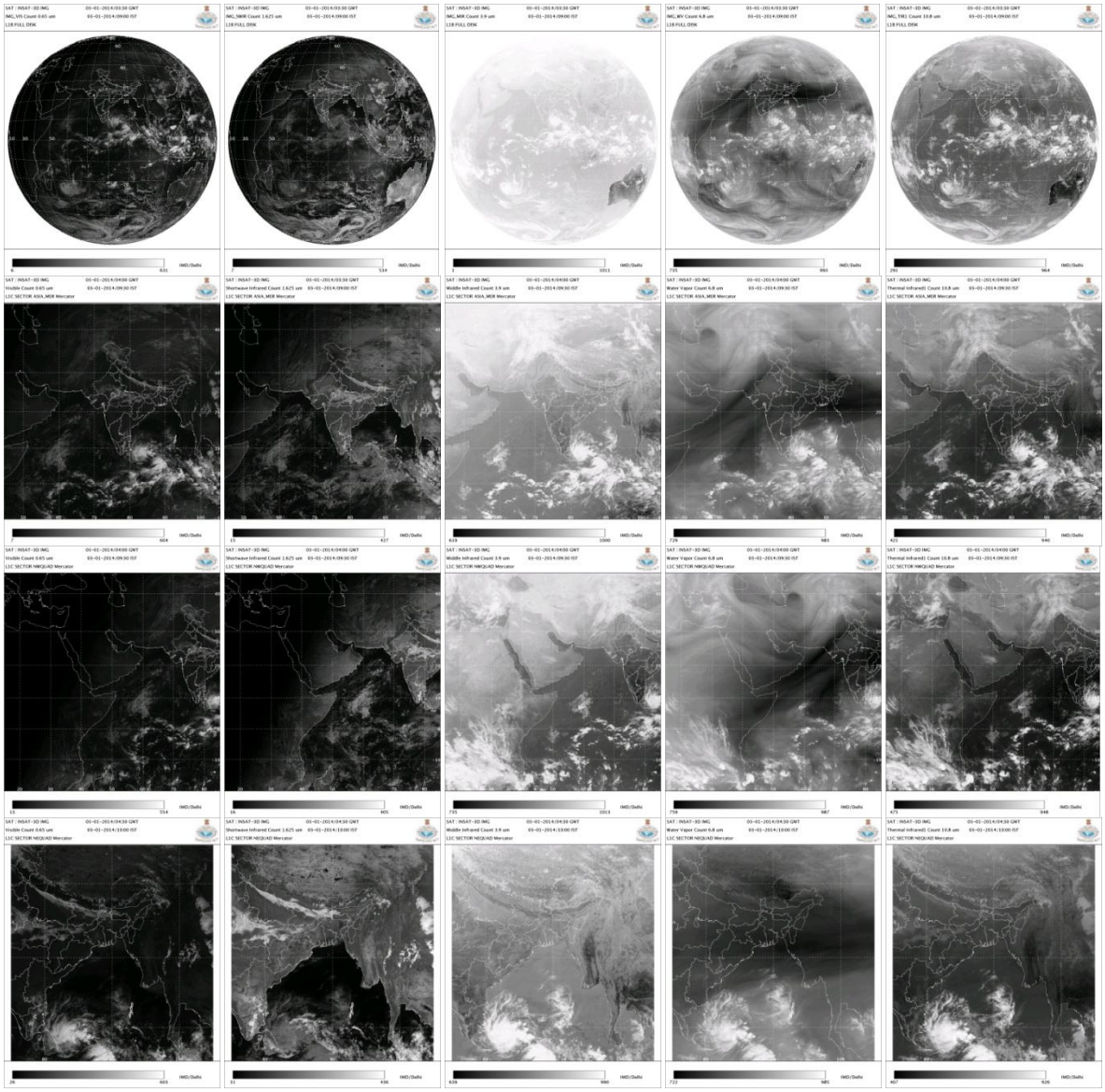
SIDS have adding features of scheduling the image delivery system in terms of setting time interval for searching and sending/ replacing by latest image at server end on start and stop, crop, adding annotation and scrolling text.

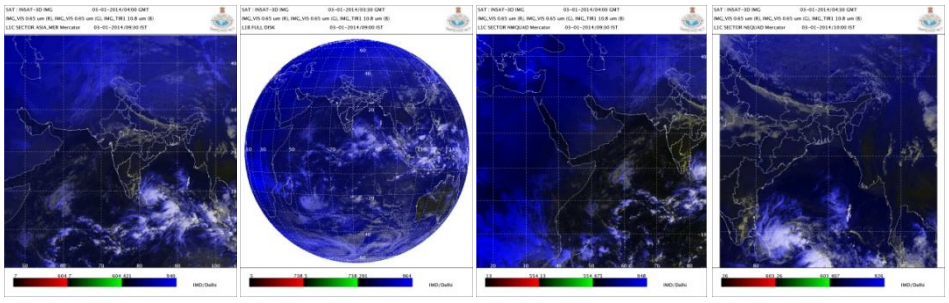


Satellite Imagery Display System (SIDS)

12. INSAT-3D IMAGER SAMPLE DATA PRODUCTS

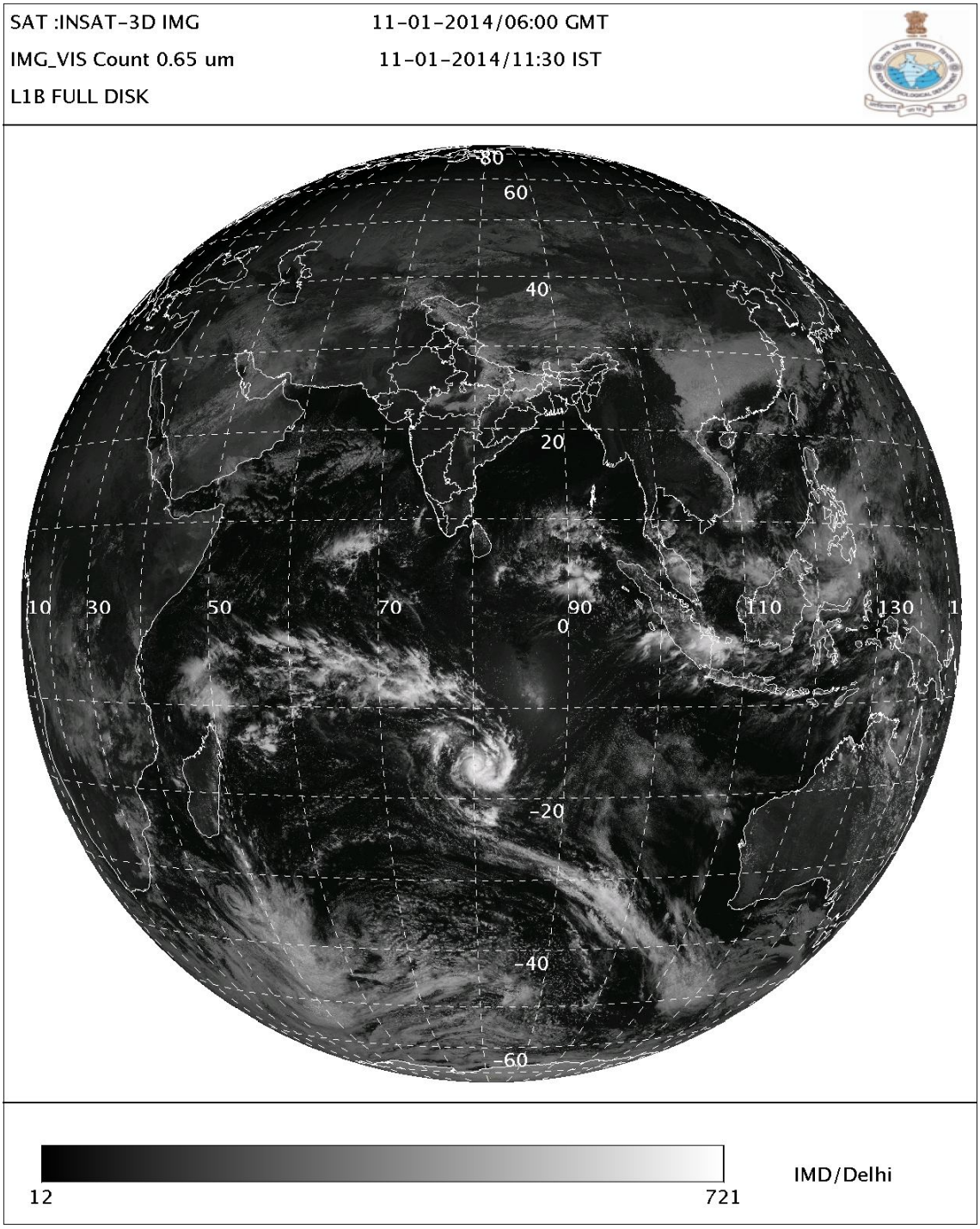
INSAT-3D Images and products are generated in real-time and disseminated through IMD Web to user community.





12.1 Imager FULL GLOBE Images

VISIBLE Band



SWIR Band

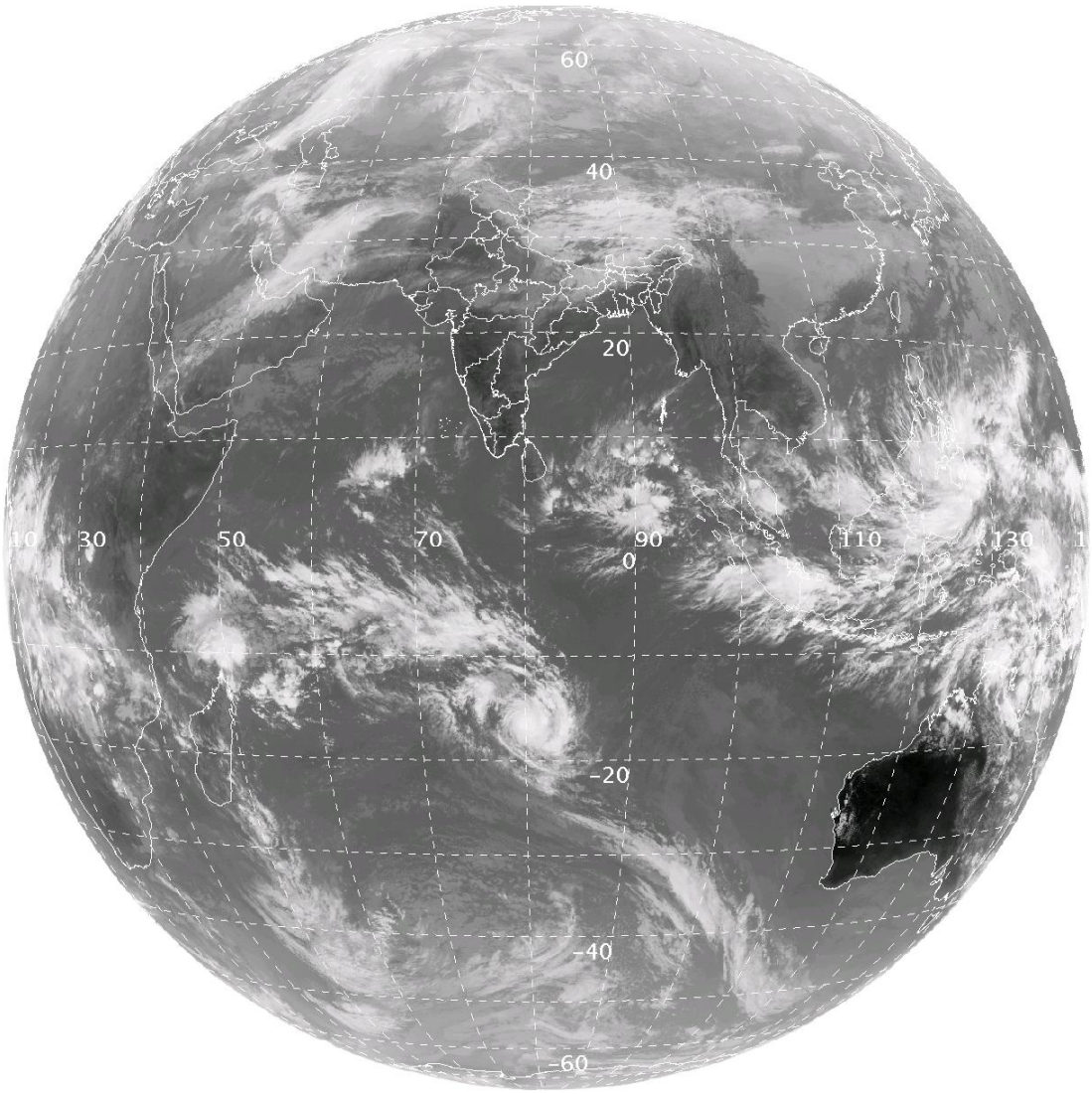

SAT :INSAT-3D IMG
11-01-2014/06:00 GMT
IMG_SWIR Count 1.625 um
11-01-2014/11:30 IST
L1B FULL DISK
80
60
40
20
10
30
50
70
90
0
110
130
-20
-40
-60
16
631
IMD/Delhi

TIR1 Band

SAT :INSAT-3D IMG 11-01-2014/06:30 GMT

IMG_TIR1 Count 10.8 um 11-01-2014/12:00 IST

L1B FULL DISK



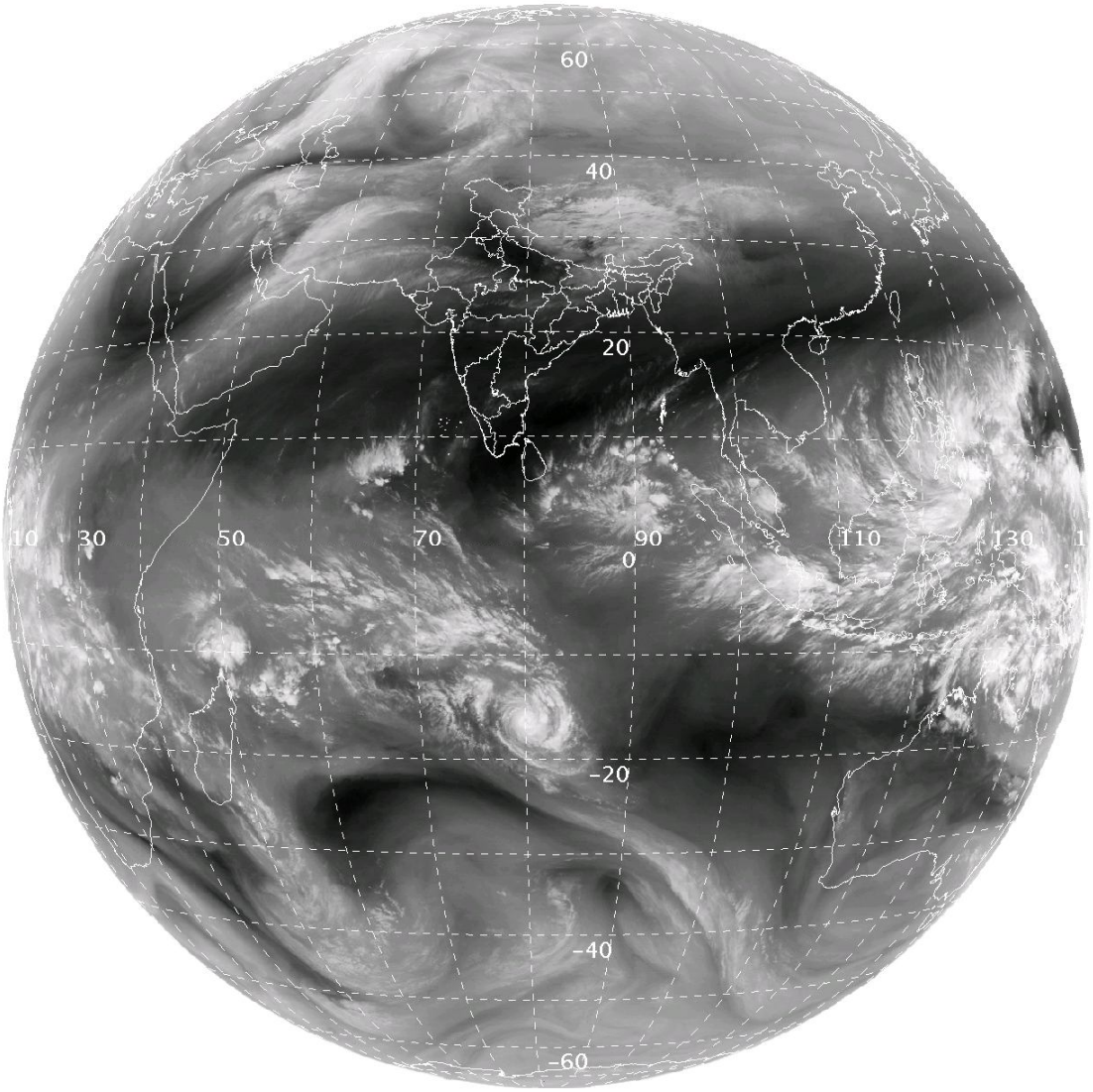
IMD/Delhi

WV Band

SAT :INSAT-3D IMG 11-01-2014/06:30 GMT

IMG_WV Count 6.8 um 11-01-2014/12:00 IST

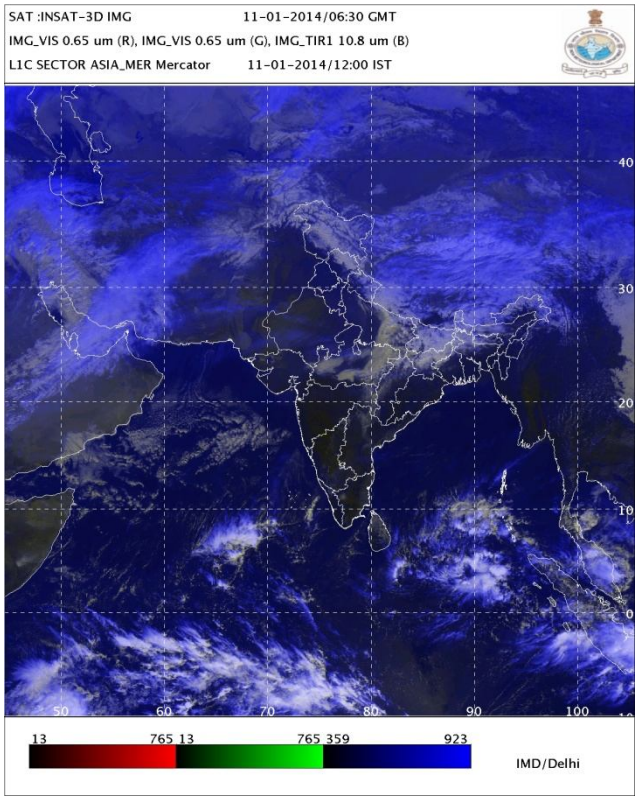
L1B FULL DISK



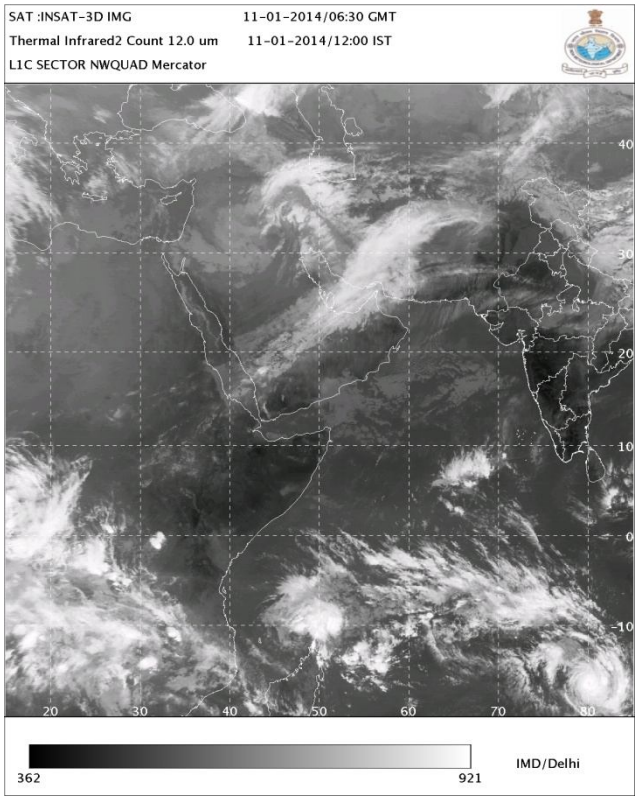
IMD/Delhi

12.2 Imager Sector Images

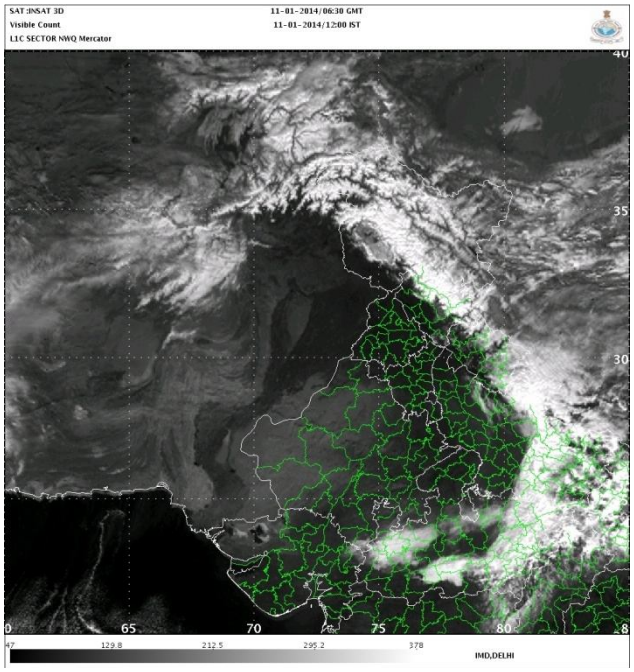
ASIA SECTOR RGB



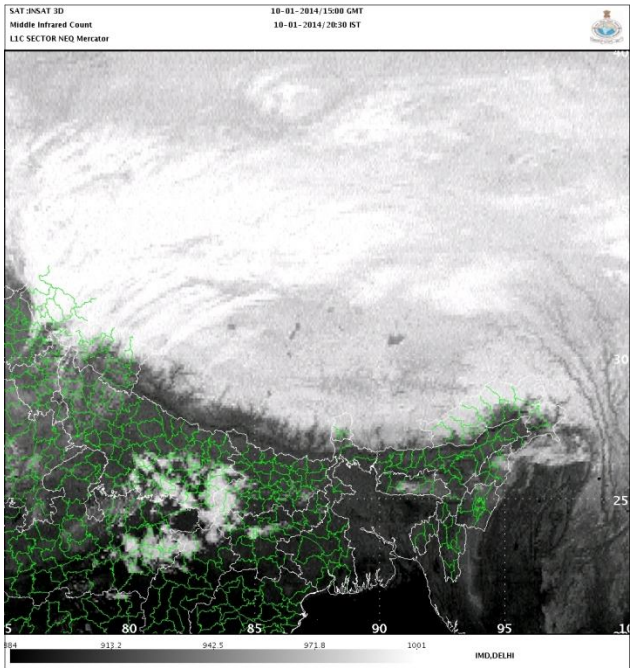
NORTH-WEST SECTOR(TIR2)



NORTH-WEST SECTOR (VIS) with District boundary



NORTH-EAST SECTOR (MIR) with District Boundary

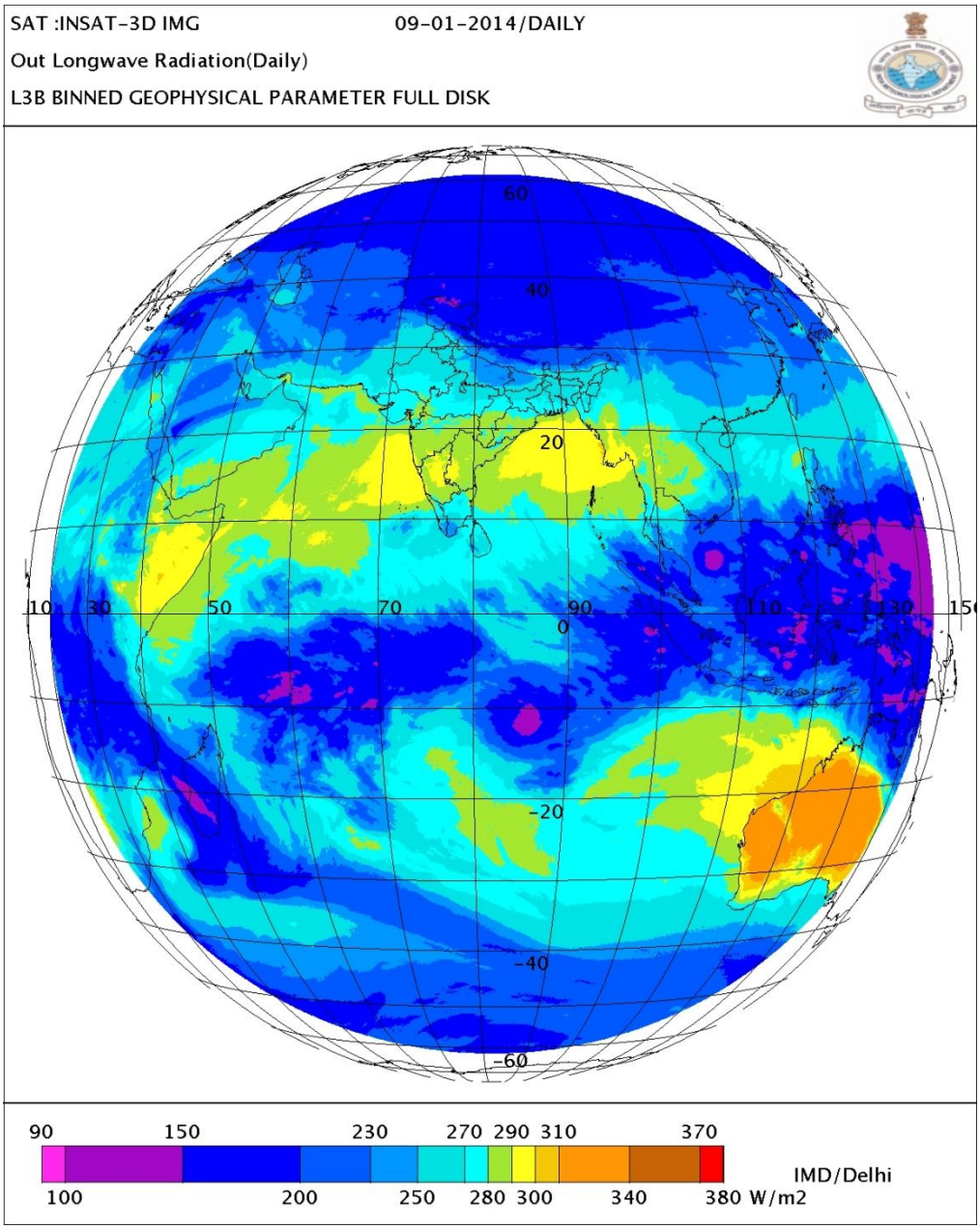


13. INSAT-3D IMAGER GEO-PHYSICAL PARAMETERS

Following Imager geophysical parameters are available in HDF5 format.

- Outgoing Longwave Radiation (OLR)
- Quantitative Precipitation Estimation (QPE)
- Sea Surface Temperature (SST)
- Cloud Motion Vector (CMV)
- Water Vapour wind (WVW)
- Upper Tropospheric Humidity (UTH)
- Snow cover
- Snow depth *
- Fire
- Smoke
- Aerosol
- Fog
- Cloud Mask

13.1 Outgoing Long wave Radiation (OLR)



13.1.1 Introduction

The outgoing long wave radiation is a crucial parameter for studying many areas in the field of atmospheric sciences. The OLR has been used traditionally for radiation budget studies of the Earth atmospheric system. The OLR also has been used for the atmospheric circulation studies over tropical region. This is

mainly due to the fact that in the tropics, the OLR is largely modulated by cloudiness. In particular it varies with the cloud top temperature, and consequently, low values of OLR indicate major convective system.

13.1.2Brief Methodology

Total outgoing long wave radiation (OLR) flux, thermally emitted from earth atmosphere system, is estimated by applying regression equation relating OLR flux with Geostationary Indian National Satellite (INSAT) VHRR observed WV (5.7 to 7.1µm) and infrared window radiances (10.5 to 12.5 µm). The coefficients of the regression equations is determined from results of the radiative transfer model simulation with various atmospheric conditions. To develop the empirical relationship between narrow band radiances and OLR a large database of spectral radiance fields L (θ, λ) was built using the Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART) model. The radiative transfer computations were performed at 19400 wavelengths covering the thermal region 3–100 µm and for 4704 realistic conditions of the Earth–atmosphere system. Genetic Algorithm is used to find the optimum regression equation relating the broadband flux (OLR) with that of WV (5.7 to 7.1µm) and infrared window radiances (10.5 to 12.5 µm).

13.1.3 Output Specificatiion

Parameter	Unit	Min	Max	Accuracy	Resolution	Frequency
OLR	Wm-2	90	350	2 %	1 x 1 deg	Half Hourly,Hourly, Daily,Monthly and Seasonal.

13.1.4 Format of the output and the domain

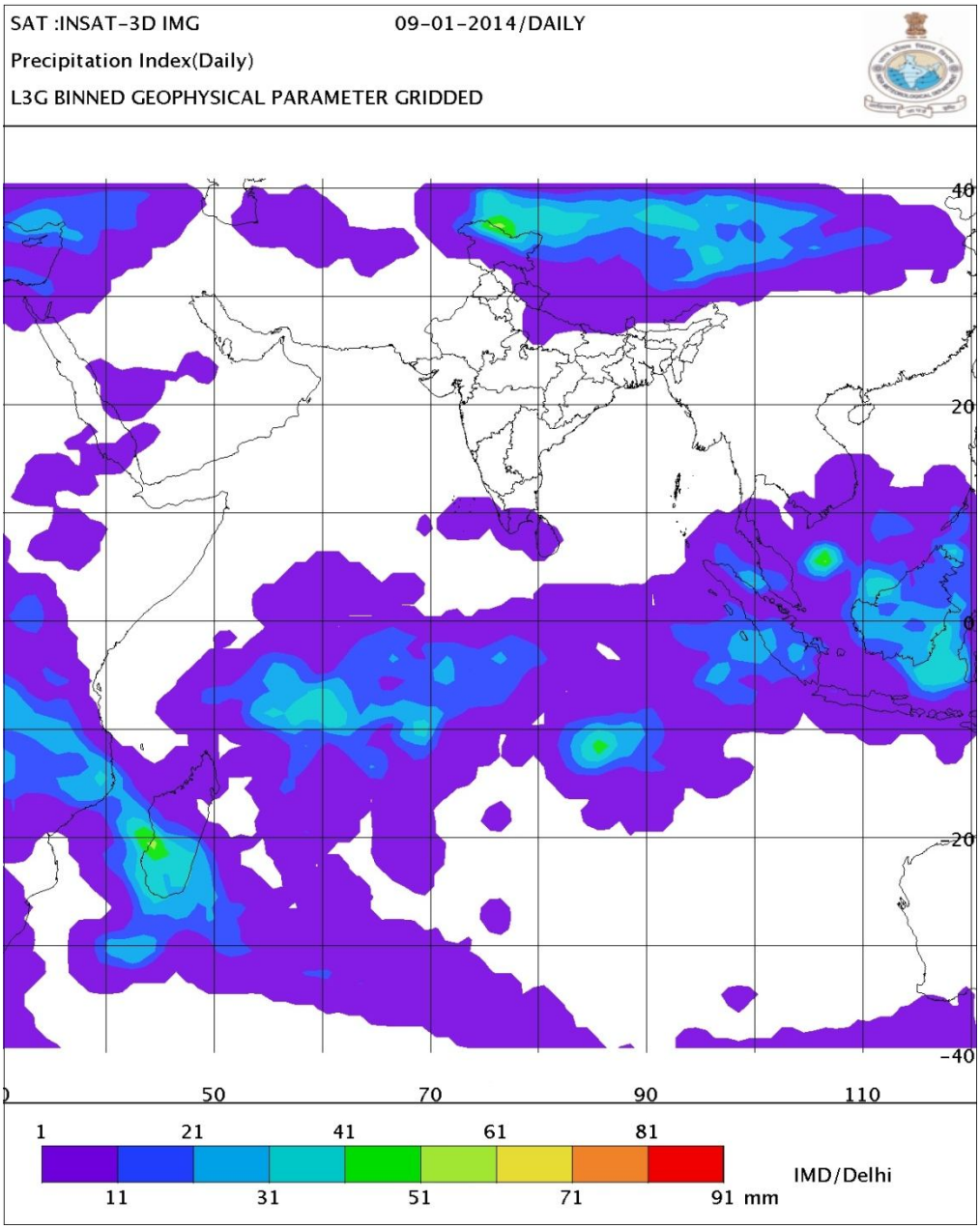
Lat, Lon, OLR,

Domain: 40 S to 40 N, 30 E to 120 E

13.1.5 Applications

OLR is an important value for the earth radiation budget. Absorption of solar radiation and emission of terrestrial radiation drive the general circulation of the atmosphere and are largely responsible for the earth's weather and climate. It is also used as one of the parameters for declaring on-set of monsoon over Kerala.

13.2. Satellite Rainfall Estimation



There are two main objectives under the rainfall retrieval algorithms from INAST-3D. These techniques are popularly known as GOES Precipiattion Index (GPI) and Insat Multispectral Rainfall Algorithm (IMSRA) methods.

13.2.1 Operational Implementation Rainfall Estimation using GPI

Step 1 : Conversion from gray count to BT
Step 2: Histogram Generation:

Step 3: Grid-wise Statistics
Step 4: Grid-wise Rain Clod Detection:
Step: 5 Sub-Grid Scale Rainfall

13.2.2Operational Implementation of Rainfall Estimation using IMSRA

Step 1 **:**Conversion from gray count to BT

Step 2: Cloud Classification using an IR and WV channels.
Step 3: Grid Average of IR TBs (0.250x0.250) to match with microwave rainfall from TRMM (i.e. INSAT-3D-IR-TBs and TRMM Precipitation Radar rainfall).
Step 4: Calibration of IR brightness temperatures with the contemporary microwave radiometric measurements of rainfall (e.g. TRMM PR Rainfall).
Step 5. The model based forecast of precipitable water and relative humidity for correction of rainfall equation based on above calibration procedure.
Step 6: Validation using DWR and AWS
Step 7. Processing of the data for the different temporal scales

13.2.3 Format of the output and the domain

For both GPI and MSRA the domain for rainfall estimation mainly would be the same but the QPE from GPI and IMSRA are available in 1x1 and 0.25x0.25 degree grids respectively.

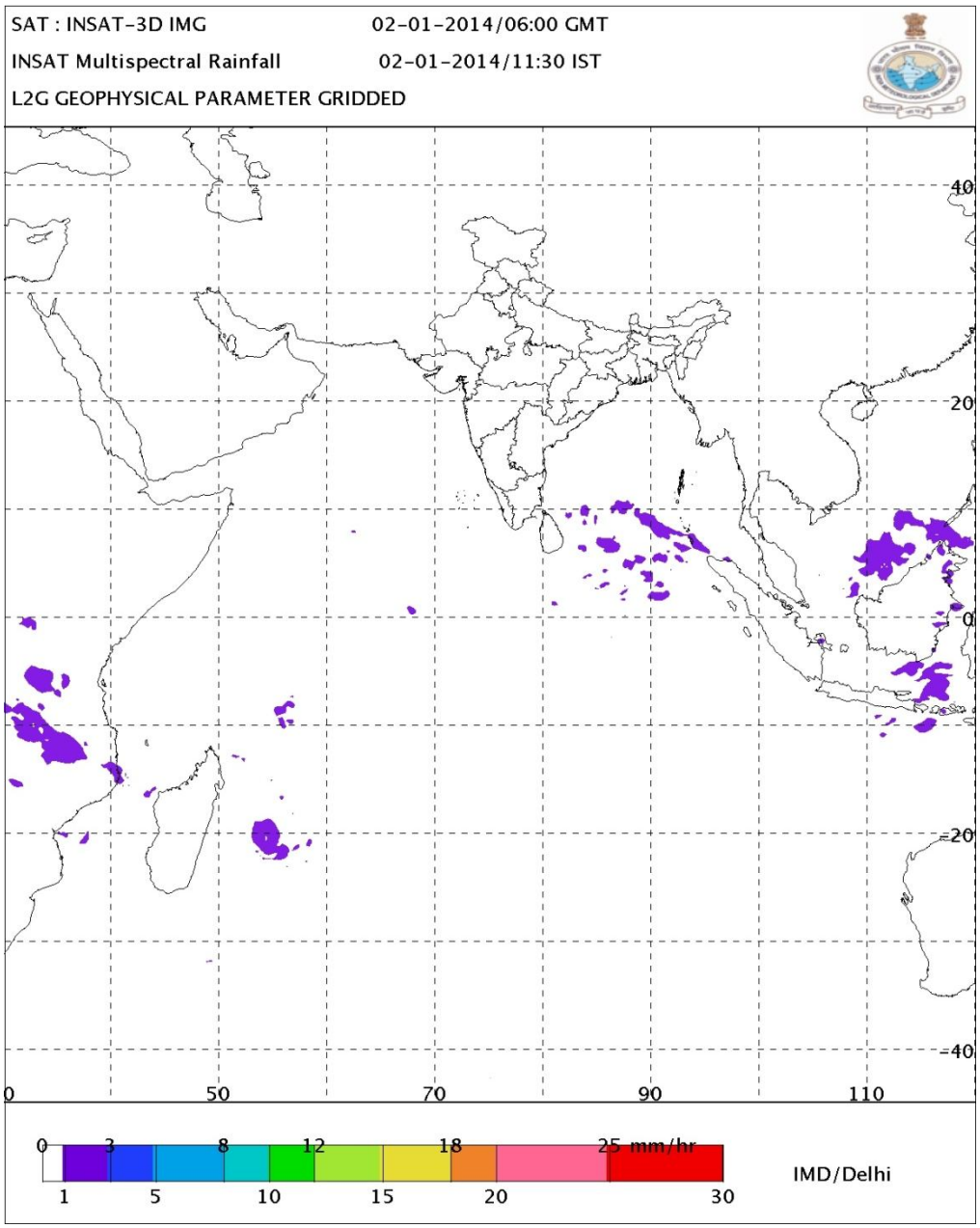
ASCII table: latitude , longitude , Rainfall

Domain : 40 S to 40 N, 30 E to 120 E,

Frequancy: Half Hourly,Hourly, Daily,Monthly and Seasonal.

13.2.4 Method of validation

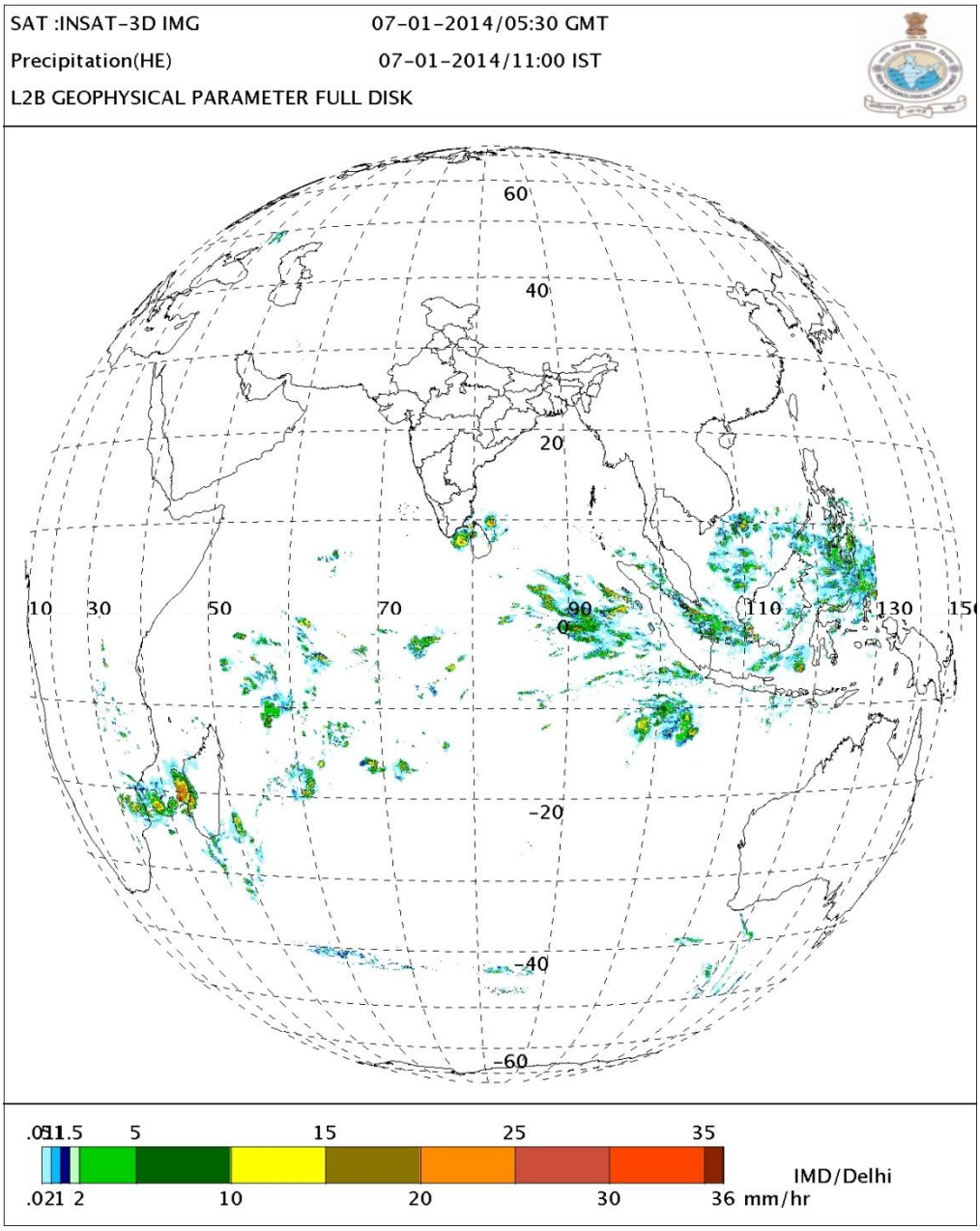
The state of art method for validation of QPE with the ground truth on different temporal and spatial scale will be carried out mainly with the data of DWR, AWS and Rain Gauges.



13.2.5 Applications

The IMSRA approach is used to optimize the identification of raining clouds located at a given altitude estimated from the cloud-top temperature. This product can be used to identify the location of rain/heavy rain quantitatively. It can also distinguish thick cirrus clouds from deep convective cores.

13.3 Operational Implementation of High-Resolution Rainfall Measurements (Hydro-Estimator)



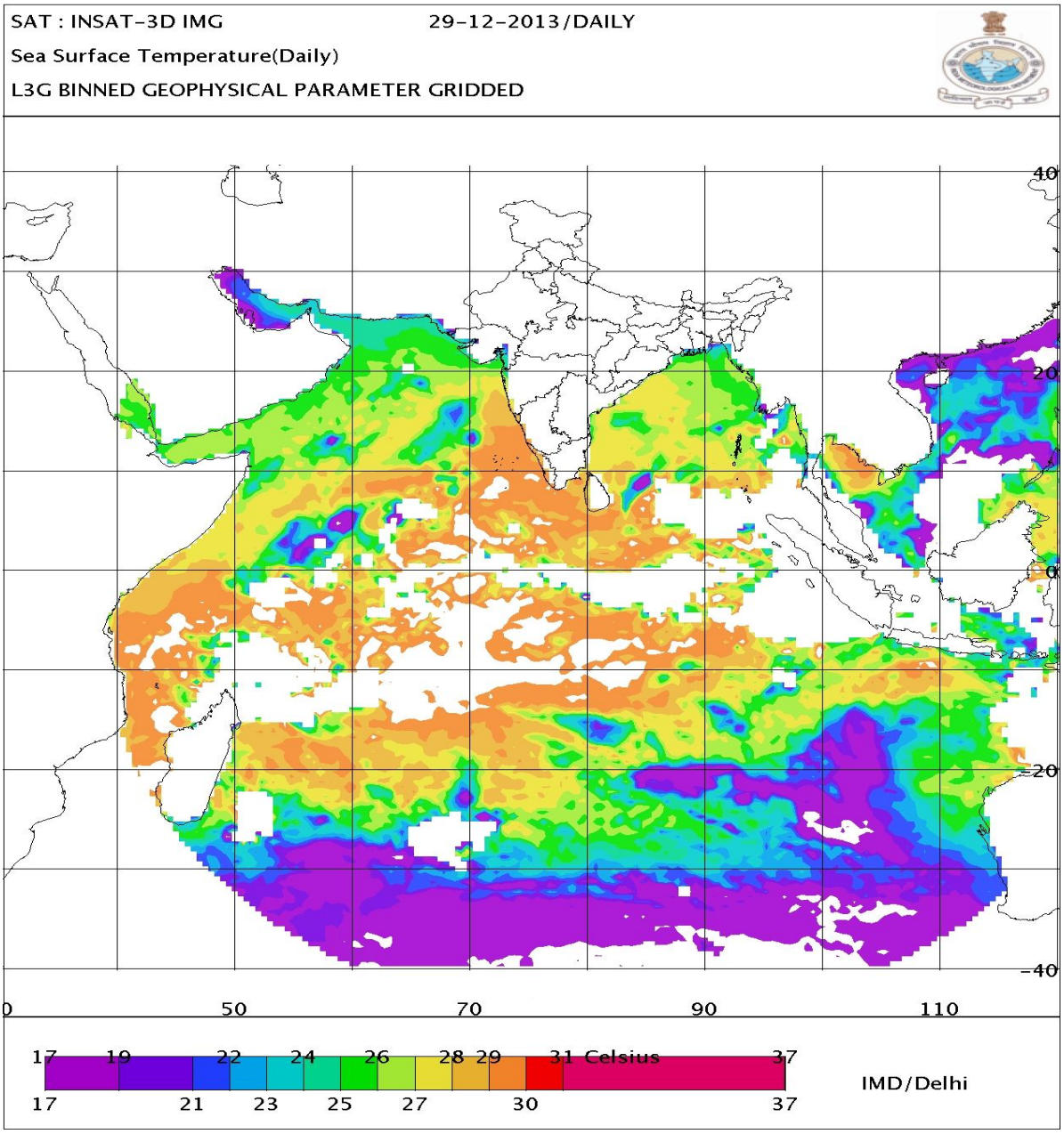
1. Provides pixel-scale, half-hourly precipitation measurements over land and oceans.
2. The rain at a pixel is considered to be effected by the brightness temperature of the surrounding pixels. This helps in determining the location of the pixel (for example, over active core area or over anvil).

3. At a pixel under consideration, the IR measurements are blended with NWP model fields for more precise rain detection and measurement
4. Dynamically varying brightness temperature – rain rate relationships are established for convective and stratiform rain at each pixel. These relationships are determined by pixel location in the storm and available TPW from NWP model. Rain at a pixel is a combination of both convective and stratiform.
5. NWP model derived TPW and RH used for rain detection and wet tropospheric correction (e.g., dryer atmosphere below cloud base results evaporation of rain drops)
6. NWP model derived 850 mb wind fields laced with surface tropography is used for enhancement/reduction in rain amount due to orography.
7. Equilibrium level computed using NWP model derived T and RH (or T and Td) profiles is used to make corrections for rain from warm clouds.

13.3.1Application

The HE uses infrared (IR) window channel (10.7-µm) brightness temperatures as the main basis for discriminating raining from non-raining areas and for estimating rainfall rates, and also uses data from numerical weather prediction models to provide additional information about moisture availability, subcloud evaporation of precipitation, impact of the thermodynamic profile on cloud heights, and orographic enhancement or reduction of rainfall.

13.4 Sea Surface Temperature (SST)



13.4.1 INSAT – 3D derived SSTs

Sea surface temperature would be derived from split thermal window channels (10.2-11.3µm, 11.5 –12.5µm) during daytime and using additional mid IR

window channel (3.7 – 4.1µm) during nighttime over cloud free oceanic regions. The most important part of the SST retrieval from IR observations is the atmospheric correction. Specially over tropics, this atmospheric correction is dominated by the high variability in vertical distribution of the intervening atmospheric water vapor. This correction has beendone through suitable characterization of tropical atmospheres in radiative transfer model to determine the brightness temperatures of INSAT-3D channels and then generating the regression coefficients for SST retrieval.

13.4.2 Operational Implementation

Step-1. Determine radiances using the processed Imager data and convert radiances to temperature using lookup table.
Step-2. Processing for discrimination between radiances from cloud free sea surface and those from the cloud tops
Step-3. Correction for atmospheric attenuation is taken care in SST computation for multichannel SST retrieval, but in case of availability of only one thermal channel, total water vapour field will be required externally from model output.
Step-4. Computation of SST
During daytime, for cloud free pixels, SST is computed as

$$SST= A_0 + A_1* T_{11}+ A_2*dT + A_3*dT^2$$

Where A_0, A_1, A_2, and A_3 are satellite zenith angle dependent coefficients determined by radiative transfer model.

$$dT = T_{11} – T_{12}$$

T_{11} and T_{12} are brightness temperatures for the split-window channels.
During Nighttime, for cloud free pixels, SST is computed as

$$SST= B_0 + B_1*T3 + B_2 *dT + B_3 *dT^2$$

Where B_0, B_1, B_2, and B_3 are satellite zenith angle dependent coefficients determined by radiative transfer model.
$dT = T_{11} – T_{12}$
T_{11} and T_{12} are brightness temperatures for the split-window channels and T_3 is the brightness temperature for channel 3 of IMAGER.
Single channel SST is computed as
$SST = a + b*Tb +c*WV$

Where

Tb is brightness temperature of the IR imager channel, WV is total water vapour content, a, b and c are regression coefficients generated through radiative transfer model

Step-5.Quality control/Editing of derived SSTs.

Satellite data are included into the final file if the absolute difference between the satellite SST and the climatology is strictly below 3 C. The channel 5 standard deviation must also be lower or equal to 1 C.

13.4.3 Output Specificatiion

Parameter	Unit	Min	Max	Theoretical Accuracy	Resolution
SST(day)	Kelvin	285	310	1 – 2 K	0.5 x 0.5 deg
SST(night)	Kelvin	285	310	<1K	0.5 x 0.5 deg

13.4.4 Format of the output and the domain

ASCII table: latitude , longitude , sst

Domain :

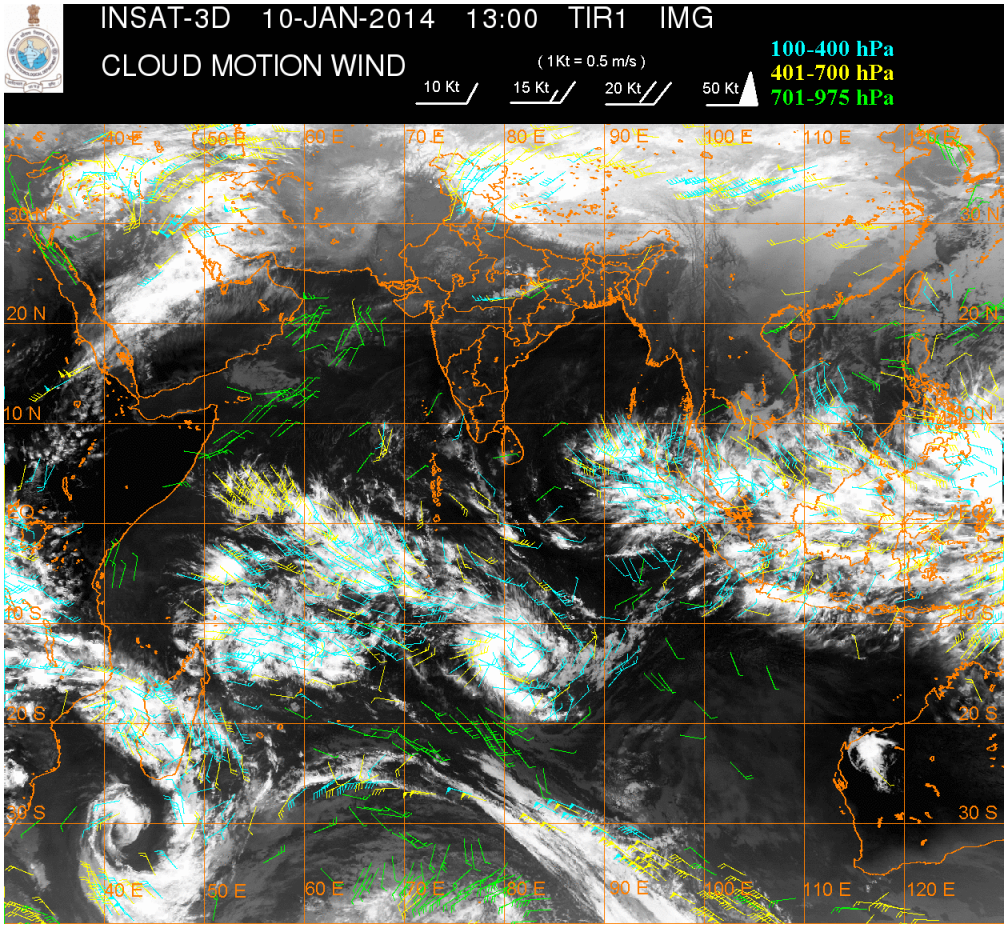
40 S to 40 N, 30 E to 120 E ,

Frequancy: Half Hourly, Hourly, Daily, Monthly and Seasonal.

13.4.5 Applications

Sea surface temperature affects the behavior of the Earth's atmosphere above, so their initialization into atmospheric models is important. While sea surface temperature is important for tropical cyclogenesis, it is also important in determining the formation of sea fog and sea breezes.

13.5Cloud Motion Vectors (CMV)



13.5.1 Introduction

Wind is a key parameter for weather forecasting, meteorological studies and climate related applications. As a result of persistent efforts by the scientists and operational community world over, sufficiently reliable techniques have been developed for using the imagery data from geostationary meteorological satellites in order to derive Atmospheric Motion Vectors (AMV) by tracking movement of clouds and moisture features in successive half hourly images. The globally derived Atmospheric motion vector (AMV) fields are now well established and constitute an essential product especially for numerical weather prediction (NWP) related applications. These data are now being routinely assimilated in operational models by many NWP centers in the world.

Early attempts to quantify the accuracy level of these winds based on manual methods to track moisture features in animated image sequences met with modest success. The water vapor images from geostationary satellites have

allowed the estimation of both upper-level moisture flow and the flow that corresponds to water vapor layers. The resulting product or water vapor wind (WVWs) has generally an improved coverage with respect to the CMV product, the major advantage being the availability of many more targets in the image.

There are five types of wind products are being generated at IMDPS from INAST-3D imager such as Visible(Day)/MIR wind (Night), WVW from WV channel and CMV from IR1 channel and two blended products of low level wind (using VIS/MIR channel and WV) and high level winds (WV and IR1 channel).

13.5.2 Operational Implementation CMV at IMDPS

Step 1: Conversion from gray count to BT

In this step a radiation model will be used to convert the instrument measured radiances into brightness temperature. This requires an accurate definition of the spectral response of the satellite.

Step 2: Tracer selection from image

Cloud tracer selection will be done by evaluating the maximum local gradients surrounding each pixel in the target array and selecting the maximum brightness temperature of the window.

Step 3: Model wind input for tracking

In this step numerical model forecast upper-level winds is required to economize the search area.

Step 4: Tracking

The tracking employs a simple search for the mean absolute difference of the radiance difference between the target and search arrays in subsequent half hourly images. This search will be done in the direction of ± 30° of model wind. The cross-correlation algorithm will also be employed for search operation.

Step 5: Wind generation

Calculate the wind speed and wind direction. Repeat the Step 1 to Step 4 for 2nd and 3rd half-hourly images. Again calculates wind speed and direction. If the two vectors survived the consistency checks, an average will be calculated and this will become the representative of CMV.

Step 6: Initial height assignment

The brightness temperature in the target window will be averaged and matched with collocated numerical model temperature profile. The level of optimum fit will be assigned as initial height.

Step 7: 3D objective analysis

3D-objective analysis of the CMVs will be done using background information from model forecast. Recursive filter (RF) analysis will be employed for object

Step 8: Speed bias adjustment and variational method

At this point an adjustment to CMV speed will be applied based on well known slow bias in upper-tropospheric winds. This slow bias will be mitigated by an empirically determined correction term.The CMV heights will be then adjusted by conducting a vertical search aimed at minimizing a simple variational penalty function using the initial wind analyses and the model forecast.

Step 9: Final 3D objective analysis

The RF analysis will be repeated by using reassigned CMV in step 8 and output of the first analysis (step 7) as a background field. The output after this analysis will provide quality estimates for each vector based the local quality of the analysis. Vectors which will fail threshold quality will be rejected.

13.5.3 Format of the output and the domain

The following parameters will be provided as output of CMV

a) Zonal and meridional components of the wind vectors.

b) Latitudinal and longitudinal position.

c) Height of CMV

The HDF product will be available in the following format:

Parameter	Latitude	Longitude	Level	U	V	Quality	Wind	Wind
Comp	CompFlag		Speed				Dir	
CMV	Deg N	Deg E	hPa	m/s	m/s	%	m/s	Deg

Frequency: Hourly, 3-Hourly.

13.5.4 Method of validation

The evaluation of CMV should be taken into both qualitative and quantitative measures. Quantitative assessment of the CMV product is possible from statistical analyses and impact on NWP. The traditional method of validation is matching observations with collocated radiosondes. The statistical validation will be done according to the CGMS winds evaluation reporting guidelines. These statistics can provide a fixed measure of product quality over time and can be employed in determining observation weight in objective data assimilation. At the CGMS XXIII the Working Group on Satellite Tracked Winds recommended that evaluation of operational wind production quality should be accomplished with a new standardized reporting method. The recommended three parts to the report are;

i) Monthly means of speed bias and rms vector difference between radiosondes and satellite winds for low (>700 hPa), medium (700-400 hPa), and high (< 400 hPa) levels together with the radiosonde mean wind speed. This should be done for three latitude bands : north of 20 N, the tropical belt (20 N to 20 S), and south of 20 S.

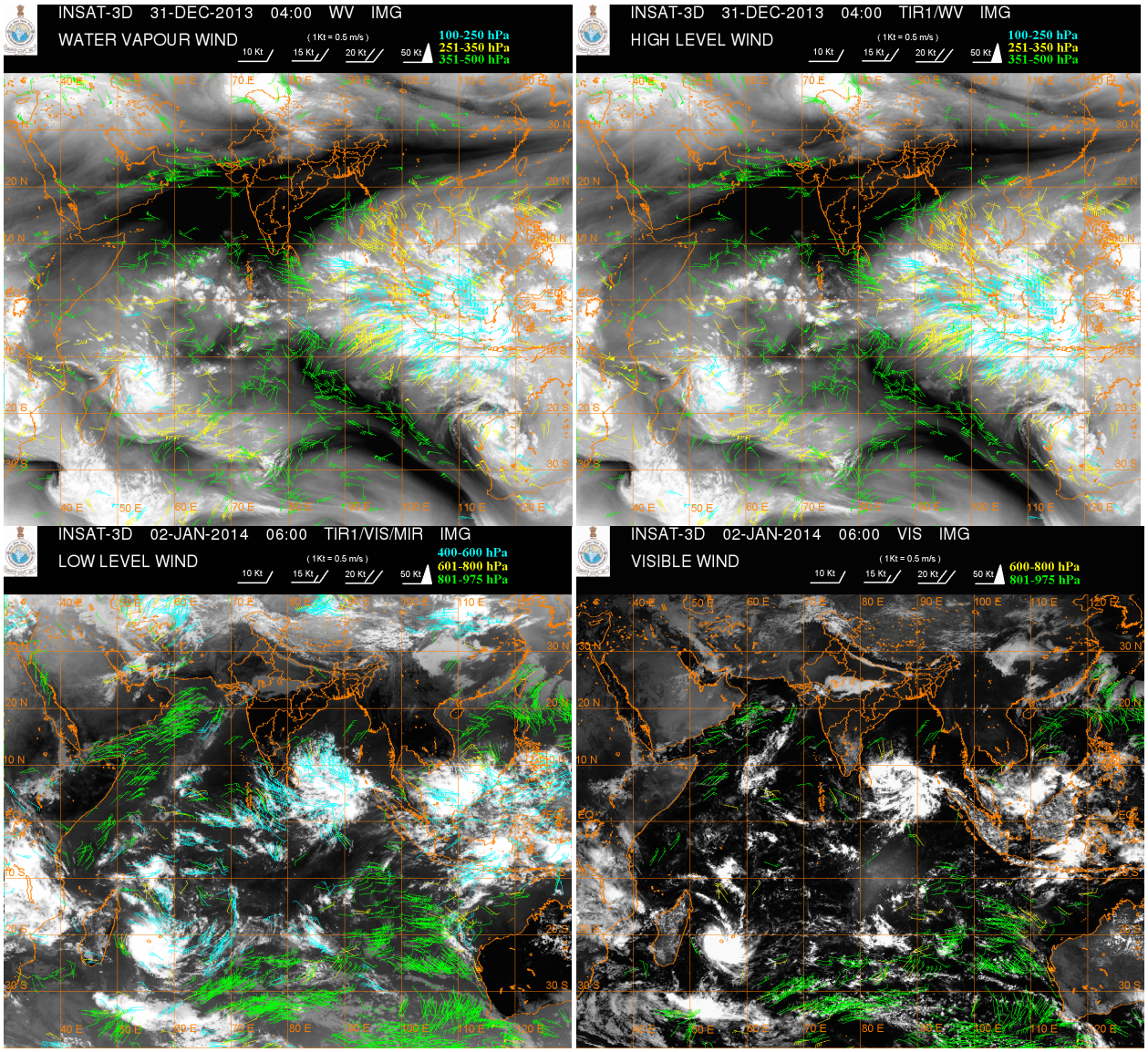
ii) Trends of the evaluation statistics for the monthly cloud motion vectors and water vapor motion vectors through the last 12 months.

iii) Information on recent significant changes in the wind retrieval algorithm.

13.5.5 Applications

The main application of the satellite-derived cloud-motion vectors is their use as winds in the data analysis for numerical weather prediction. At data sparse region they constitute an indispensable data source for numerical weather prediction. The CMV`salso gives the indication of trough, ridges, circulation, steering current jetstream etc.

13.6Water Vapor Wind Vector (WVWV)



13.6.1 Introduction

In early nineties, forecasters have used extensively the water vapor radiances from geostationary satellites qualitatively. In quantitative studies, the first attempt was made by manually tracking moisture features in automated image sequences. Later studies on this area have shown much maturity with ability of automated wind extraction methods for producing spatially coherent Water Vapor

Wind Vector (WVWV) fields comparable in quality to operational cloud tracked winds. The U.S Geo-stationary Operational Environmental Satellites (GOES-8 etc series) are equipped with one imager and two sounder water vapor channels. As of GOES-13 the spatial resolution of the WV imager has been improved from 8Km to 4 Km at the sub-satellite point, and the radiometer is spectrally wider with a central wavelength of 6.5 micro m instead 6.7 micro m. The sounders look progressively deeper into the troposphere as the spectral band wavelength moves away from the 6.3micro m absorption band center. This facts opens the opportunity for a 3-dimensional reconstruction of atmospheric motions. Water vapor winds from image data taken by the WV channel aboard the Japanese satellite Geo stationary Meteorological Satellite (GMS)-5 have been produced since 1995, and clear-sky WV segments have been separated since 1998.

13.6.2 Operational Implementation

Step 1 : Conversion from gray count to BT

In this step a radiation model will be used to convert the instrument measured radiances into brightness temperature. This requires an accurate definition of the spectral response of the satellite.It is important that the different instruments are sensing radiation from slightly different parts of H2O absorption band. Sampling the centre of the absorption band yields radiation from the upper levels of the troposphere, similarly sampling away from the centre of the absorption band yields radiation from lower levels of the atmosphere.

Step 2: Tracer selection from image

Water-vapor images tracer selection will be done by evaluating the bidirectional gradients surrounding each pixel in the target array and selecting the maximum brightness temperature of the window exceeding some thresholds value.

Step 3: Model wind input for tracking

In this step numerical model forecast upper-level winds is required to economize the search area.

Step 4: Tracking

The tracking employs a simple search for the minimum in the sum of squares of the radiance difference between the target and search arrays in subsequent half hourly images. This search will be done in the direction of ± 30° of model wind. The cross-correlation algorithm will also be employed for search operation.

Step 5: Wind generation

Calculate the wind speed and wind direction.Repeat the Step 1 to Step 4 for 2nd and 3rd half-hourly images.Again calculate wind speed and direction. If the two vectors survived the consistency checks, an average will be calculated and this will become the representative of WVWV.

Step 6: Initial height assignment

The brightness temperature in the target window will be averaged and matched with collocated numerical model temperature profile. The level of optimum fit will be assigned as initial height.

Step 7: 3D objective analysis

3D-objective analysis of the WVWV will be done using background information from model forecast. Recursive filter (RF) analysis will be employed for objective analysis.

Step 8: Speed bias adjustment and variational method

At this point an adjustment to WVWV speed will be applied based on wellknown

slow bias in upper-tropospheric winds. This slow bias will be mitigated by an empirically determined correction term. The WVWV heights will be then adjusted by conducting a vertical search aimed at minimizing a simple variational penalty function using the initial wind analyses and the model forecast.

Step 9: Final 3D objective analysis

The RF analysis will be repeated by using reassigned WVWV in step 8 and output of the first analysis (step 7) as a background field. The output after this analysis will provide quality estimates for each vector based on the local quality of the analysis. Vectors which will fail the empirically determined threshold quality will be rejected.

Format of the output and the domain
As output of WVWV the following parameters will be provided to IMD:
a) Zonal and meridional components of the wind vectors.
b) Latitudinal and longitudinal position.
c) Height of WVWV
The format of the final product will be like this:

Parameter	Latitude	Longitude	Level	U Comp	V Comp	Quality Flag	Wind Speed	Wind Dir
WVWV	Deg N	Deg E	hPa	m/s	m/s	Flag	m/s	Deg

Frequency: Hourly, 3-Hourly.

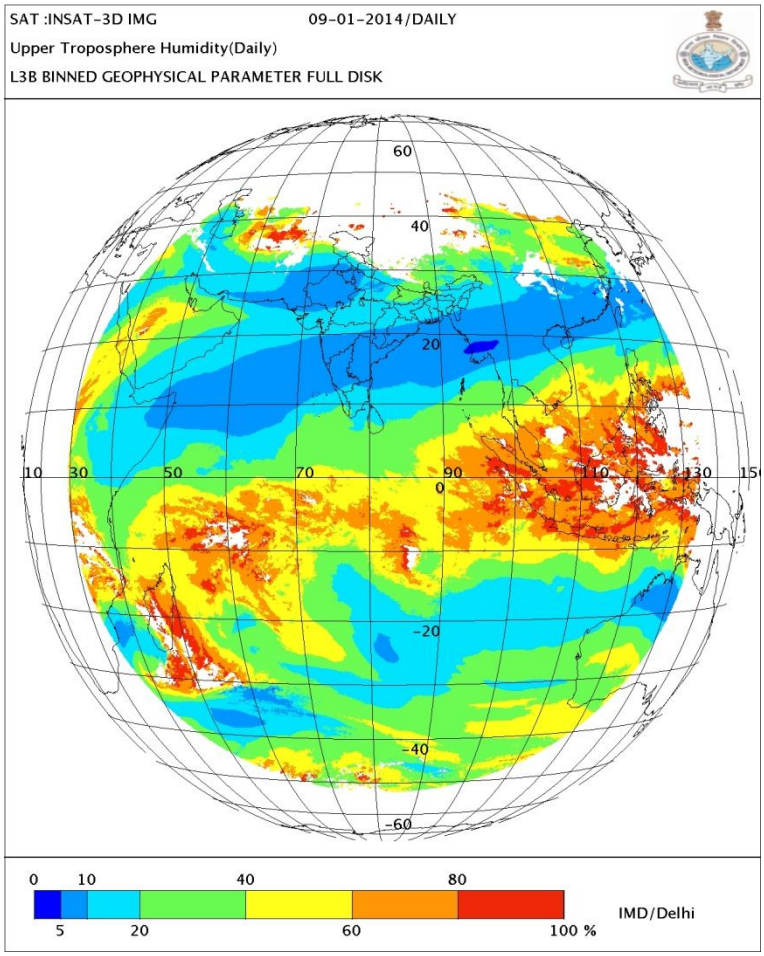
13.6.3 Methods of validation

Similar to CMV and other winds.

13.6.4 Applications

It has been demonstrated by studies that, the upper level winds derived from satellites have proved to be very useful for predicting the future track position of depressions and well marked low pressure areas with deep vertical extent. On the basis of their potential use for better future track predictions it is possible to give more accurate heavy rainfall warnings to the areas likely to be affected by these weather systems. It is possible to give more precise warnings to the affected areas at least 24 to 48 hours in advance since these types of weather systems are steered by the upper level winds.

13. 7Upper Tropospheric Humidity (UTH)



13.7.1 Introduction

Upper Tropospheric Humidity (UTH) is an estimate of the mean relative humidity of the atmosphere between approximately 600 hPa and 300 hPa. UTH is basically a measure of weighted mean of relative humidity according to the weighting function of the water vapour channel. Therefore, UTH is more likely a representative of the relative humidity around the atmospheric layer where weighting function of water vapour channel peaks.

13.7.2 Brief Methodology

UTH formulation is based on the analytical expression developed by *Soden and Bretherton* [1996],

$$ln[UTH \,.\, p_o / \cos(\theta)] = a + b \,.\, Tb_{wv}$$

where, p_o is the normalized or scaled reference pressure and is equal to the pressure of the level at temperature 240K divided by 300 hPa, i.e., $p_o = p(T=240K)/300$. Standard tropical atmospheric profile of temperature is used, as INSAT-3D a geostationary satellite making observations over most of the tropical region extending up to the mid-latitudes. A training dataset of atmospheric profiles is generated using standard tropical temperature profile and different values of relative humidity above 800 hPa ranging from 1% to 100% with the interval of 1% at the lower values and 5% at higher values. Satellite zenith angle was varied from $\theta = 0°$ to $\theta = 65°$, such that the interval $\Delta\sec(\theta) = 0.1$ to keep equal interval in the path lengths. Empirical coefficients are computed from this simulated dataset.

Cloudy pixels are identified and excluded from further calculations using standard cloud detection algorithm. In the 5 x 5 pixel box, if the number of cloudy pixels is more than 25 % than the brightness temperature of clear pixels are averaged. Using the zenith angle, p_0 (computed empirically using a polynomial function of latitude and month) and the UTH coefficients for corresponding satellite and month of the observation, UTH is calculated using the clear WV channel brightness temperature.

13.7.3 Output

Parameter	Unit	Min	Max	Accuracy	Resolution
UTH	%	0	100	30 %	0.5° X 0.5°

Frequency: Half Hourly, Hourly, Daily and Monthly

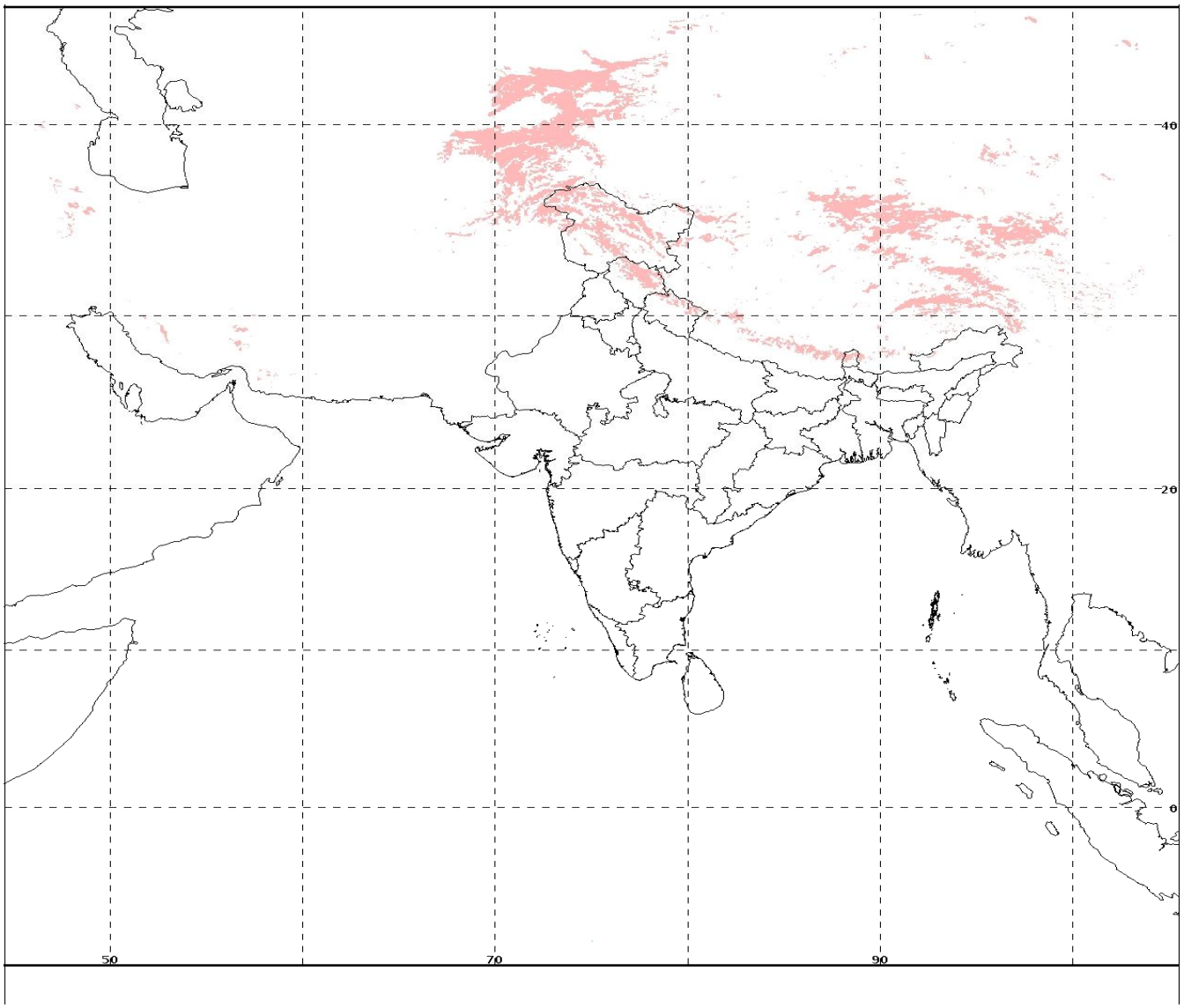
13.7.4 Format of the output and the domain

Binary file giving details of the time and location of the retrieval, zenith angle, % of clear pixels used in averaging within 5 x 5 pixel box, and UTH (%). Domain: 40 S to 40 N, 30 E to 120 E

13.7.5 Applications

Upper tropospheric humidity (UTH) is a crucial parameter for meteorology and climate research. The UTH are used together with global cloud imagery to study the relationship between deep convection and moisture in the upper troposphere.

13.8Snow-Cover Mapping



13.8.1 Introduction

The snow-mapping algorithm will use a grouped-criteria technique using the Normalized Difference Snow Index (NDSI) and other spectral threshold tests to identify snow on a pixel-by-pixel basis, and to map snow cover in dense forests. The NDSI is usefulness for snow mapping, as it reflects more in the visible than in the short-wave IR part of the spectrum. In addition, the reflectance of most clouds remains high in the short-wave IR, while the reflectance of snow is low. Validation of the INSAT snow maps will be carried out using snow maps generated using AWiFS data of Resourcesat and a limited amount of field measurements. In addition, validation will also be carried out using visual

interpretation and the MODIS snow maps. The accuracy of the snow maps will vary with land-cover type. Hence, the Snowmap algorithm has been and will continue to be tested for a variety of land covers. Error estimates have been determined from field measurements for different land covers, and these errors are used to estimate the expected maximum monthly and annual errors in Himalayan snow mapping using the algorithm.

13.8.2 Operational Implementation

Step 1 : Conversion from gray count to Reflectance and BT

In this step, the DN values will be converted into Radiance, Reflectance and Brightness temperature using calibration coefficient available with INSAT 3D data. The radiometrically processed data will also be geolocated and this will provide a radiometrically and geometrically corrected product to be used further in algorithm.

Step 2 : Cloud elimination

This step includes the cloud screening from the INSAT 3D image. Cloud screening is based on the temperature data and will help to clear cloudy pixels which possibly are not feasible to screen out using visible and SWIR channel based NDSI image.

Step 3 : Generation of NDSI image

Normalized Difference Snow Index will be computed using the normalized ratio of visible and SWIR channel as given below;

NDSI = Rfl (visible) – Rfl (SWIR) / (Rfl (visible) + Rfl (SWIR)

Step 4: Ortho rectification

It will provide area on slope and provide correct area of snow cover. This will generate a daily snow cover map. Composite images of 10 days will be used to generate a 10 Daily snow cover map and this map will provide maximum snow areal extent. Snow pixel will be identified in 10 daily products, if occurs on any single day.

13.8.3 Output Specificatiion

Parameter	Unit	Min	Max	Accuracy	Resolution
SCM	**Km2**	**-**	**-**	**-**	**1 x 1 deg**

13.8.4 Format of the output and the domain

Geolocated Snow map & Areal extent of snow cover in Himalayan region.

40 Sto 40 N; 30 E to 120 E

Frequency: Half Hourly

13.8.5 Applications

The highly reflective nature of snow combined with its large surface coverage makes snow an important determinant of the Earth's radiation balance. Many areas of the world rely on snowmelt for irrigation and drinking water and must monitor snow packs closely throughout the winter and spring for assessment of water supply.

13.9Snow Depth Estimation

13.9.1 Introduction

Important step in estimation of snow depth is generation of snow fraction map. Since Himalayan region is highly mountainous, the data processing would initially need calibration, georeferencing, atmospheric correction, snow pixel detection, cloud masking, local illumination angle correction, diffuse radiation correction, BDRF correction and orthorectification. This will be followed by Linear or non-linear mixing modeling to estimate snow fraction in each pixel. The mixing modeling would need large spectral reflectance library of snow and other land features of Himalayan region, to identify end members of snow and snow free terrain. Next important step in the investigation is to develop a relationship between snow fraction and depth. This would need field snow depth data. In North America this relationship was developed using 1400 field observatories. Relationship was found useful; if snow depth is less than 27 cm. Field data needs to be collected from India Meteorological Department.

13.9.2 Operational Implementation

Step 1: Conversion from gray count to BT

In this step, the DN values will be converted into Radiance, Reflectance and Brightness temperature using calibration coefficient available with INSAT 3D data. The radiometrically-processed data will also be geolocated and this will provide a radiometrically and geometrically corrected product for further analysis.

Step 2: Cloud elimination

This step includes the cloud screening from the INSAT 3D image. Cloud screening is based on the temperature data and will help to clear cloudy pixels, which possibly are not feasible to screen out using visible and SWIR channel based NDSI image.

Step 3: Topographic and Atmospheric correction

In this step, DEM data will be used to compute the terrain parameters like slope and aspect of the terrain, which will further be used to compute the local illumination angle. Atmospheric correction algorithm will be applied to compute the atmospherically corrected radiance and reflectance values with standard procedures. This step will provide us the atmospherically and topographically corrected radiances and reflectance.

Step 4: Snow pixel identification

Snow pixel identification will be done by using NDSI based approach which uses thenormalized ratio of visible and SWIR wavelength reflectance. This prepares a binary mapof either snow or non-snow pixels.

Step 5: Snow fraction retrieval

Fractional snow map will be prepared by using linear mixing approach. This considers land and pure snow as end members and computes the snow fraction of any particular pixel using reflectance value.

Step 6: Snow Depth Estimation

A statistical relationship was developed between snow fraction and depth (Romanov and Tarpley, 2004). Snow depth will be estimated by using this relationship for each pixel.

13.9.3 Output Specificatiion

Parameter	Unit	Min	Max	Resolution
SD	**cm**	**-**	**-**	**1 x 1 deg**

13.9.4 Format of the output and the domain

Geolocated Snow depth map.

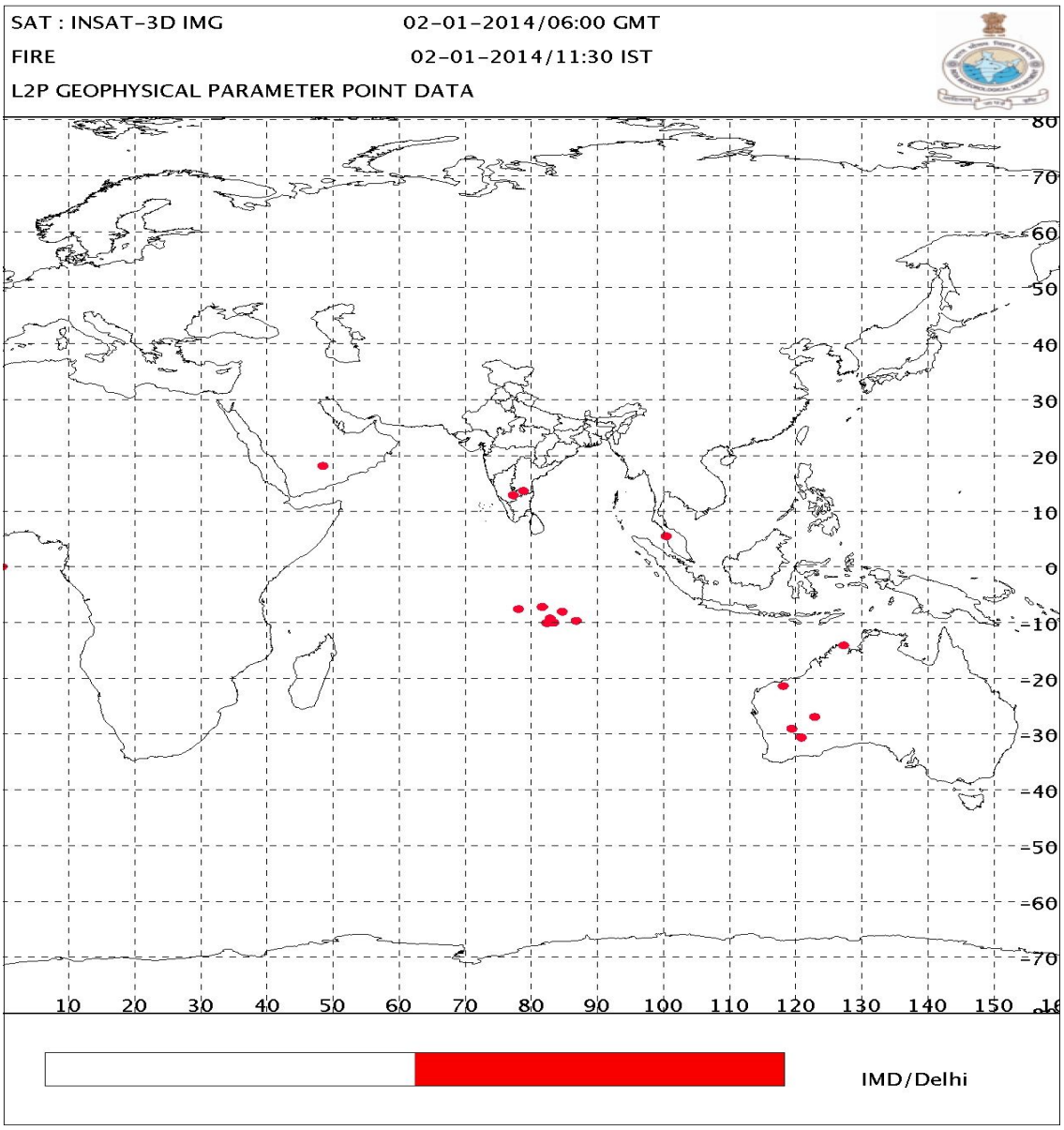
40 S to 40 N; 30 E to 120 E.

Frequency: Half Hourly

13.9.5 Applications

Three of the most important properties of a snow cover are depth, density, and water equivalent. If the snow depth and density are known, then the snow-water-equivalent (SWE) may be calculated. SWE is a hydrologically important parameter as it determines the amount of water that will be available as snowmelt.

13.10 FIRE IDENTIFICATION



13.10.1 Introduction

Forest fire management in tropical countries is one of the major issues. Satellite data with suitable spectral bands, good temporal resolution and bare minimum spatial resolution, which can locate fire, can play an important role in development of country's forest fire management system. One of the most important critical elements of the forest fire management system in the country is the real time detection of fire and its progression monitoring; study the rate, direction and quantitative estimation of fire spread. Geostationary satellite like

INSAT-3D with imager data of 4x4 km. in MIR and in TIR-I and TIR-II will help in detecting and monitoring of large scale forest fires in Indian subcontinent.

13.10.2 Brief Methodology

The fire detection algorithm employs multi channelthresholding contextual technique. The algorithms will first masks out ocean, desert, water and cloud pixels and then proceed further. The contextual algorithms identify a fire pixel based on the level of contrast between the potential fire pixel and its "background" pixels (the definition of background varies according to kernel size). An initial threshold test will reduce the number of candidate pixels to be applied to the contextual algorithm surrounding the subject pixel values. The initial thresholds are more liberal to avoid missing real fires. The second test computes the mean and standard deviation of the threshold variables from non-potential fire pixels surrounding a potential fire pixel. After obtaining these statistics, they are used to re-define the thresholds to confirm a fire. Background temperature will be updated with a separate algorithm which will use TIR-1 and TIR-2 Channels of INSAT-3D. The fine tuning of threshold values and kernel size will be done after validation experiments for known fire pixels.

13.10.3 Output Specificatiion

Output: lat ,lon, Fire flag (Image)

Fire flag: 1 - Fire pixels, 0 - Non-fire pixels

Resolution: 4 x 4 Km

13.10.4 Format of the output and the domain

Lat, Lon, Fire,

Domain:

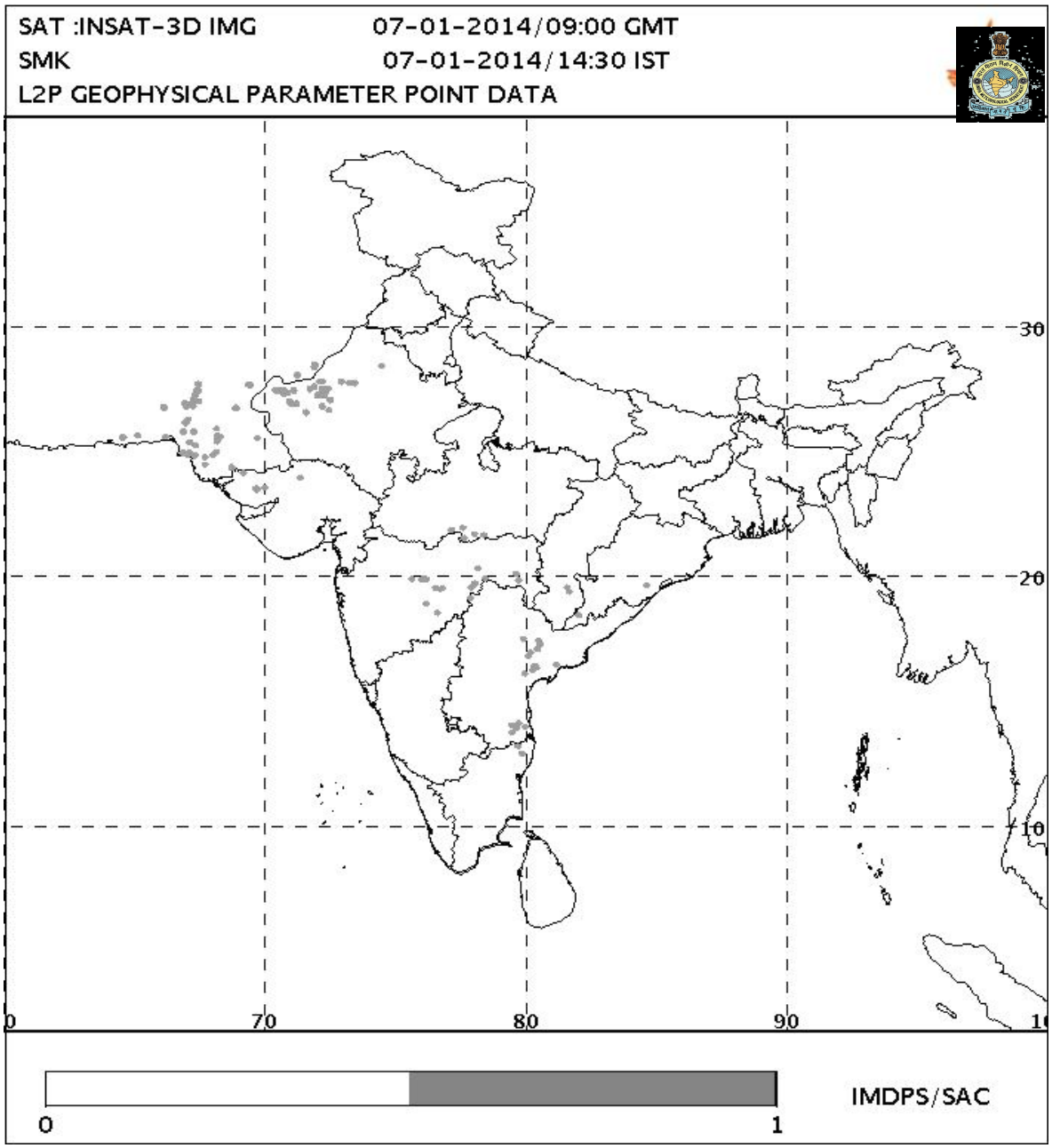
40 S to 40 N, 30 E to 120 E

Frequency: Half Hourly

13.10.5 Applications

To reduce impacts of forest fire in boreal forest area, the early fire detection is one of essential components in firefighting activity because of difficulties of fire suppressing in remote area without water.

13.11Smoke Identification (SI)



13.11.1 Introduction

Smoke is a form of particulate matter, which contains liquid or solid particles of the size ranging from 1−200µm. It is formed by combustion or other chemical processes. Each year more than 100 million tons of smoke aerosols are released into the atmosphere as a result of biomass burning. More than 80percent of this burning is in the tropical regions. Smoke plumes can travel over hundreds or

even thousands of kilometers horizontally and also reach up to stratosphere under certain atmospheric circulation conditions. Thus smoke can have an impact far beyond the region of fire activity. Smoke plays a major role on the radiation balance of the earth-atmosphere system. Smoke particles scatter and absorb incoming solar radiation, thereby having a two-fold impact, i.e. a cooling effect at the surface, but warming effect on the atmosphere. Since the magnitude of the scattering effect outweighs that of absorption, smoke has a net cooling effect at the top of the atmosphere-surface system. This is often called the direct effect of smoke aerosols. Smoke can also modify the short wave reflective properties of clouds by acting as cloud condensation nuclei. Under a limited supply of water vapor, an increased number of nuclei result in smaller cloud droplets that have higher reflectivity than larger cloud droplets .This effect called the indirect radiative forcing, is difficult to quantify and has large uncertainties associated with the sign and magnitudes. Understanding such numerous and complex effects of smoke on weather and climate requires a good knowledge of the spatial and temporal variation of smoke and its optical properties, which is only feasible by means of satellite observation.

13.11.2 Operational retrieval implementation

The operational implementation of the retrieval process can be enumerated as follows:

1. Conversion of gray counts to radiance and brightness temperatures
2. Conversion of gray counts to Albedo for the VIS channel

This is done with the help of conversion tables.

3. Calculation of solar reflectance angle

To exclude sun glint processing path is taken for solar reflectance angle θr greater than threshold value (approximately 20deg)],

$$cos(\theta_r) = sin(\theta)sin(\theta_0)cos(\phi) + cos(\theta)cos(\theta_0) \qquad (3)$$

where θ is the viewing zenith angle, Φ is the azimuth angle and, θ_0 is the Solar Zenith Angle.

4. Defining of thresholds

Using training dataset of forest fires over the Indian region for VIS, MIR , TIR-1 and TIR-2 channels, thresholds have to be defined for tests listed above. The methodology to be followed is to first assume initial value of thresholds based on literature and then fine tune them, using visual inspection.

5. Implementation of five pass tests

6. Cloud edge detection algorithm

A difference image is produced from 10.7 and 3.9μm channels and an adjacent pixel test is performed to detect cloud edges.

13.11.3 Output

Generation of smoke map

13.11.4 Format of the output and the domain

Output: lat ,lon, Smoke flag

Smoke flag: 1 - Smoke pixels, 0 - Non-smoke pixels

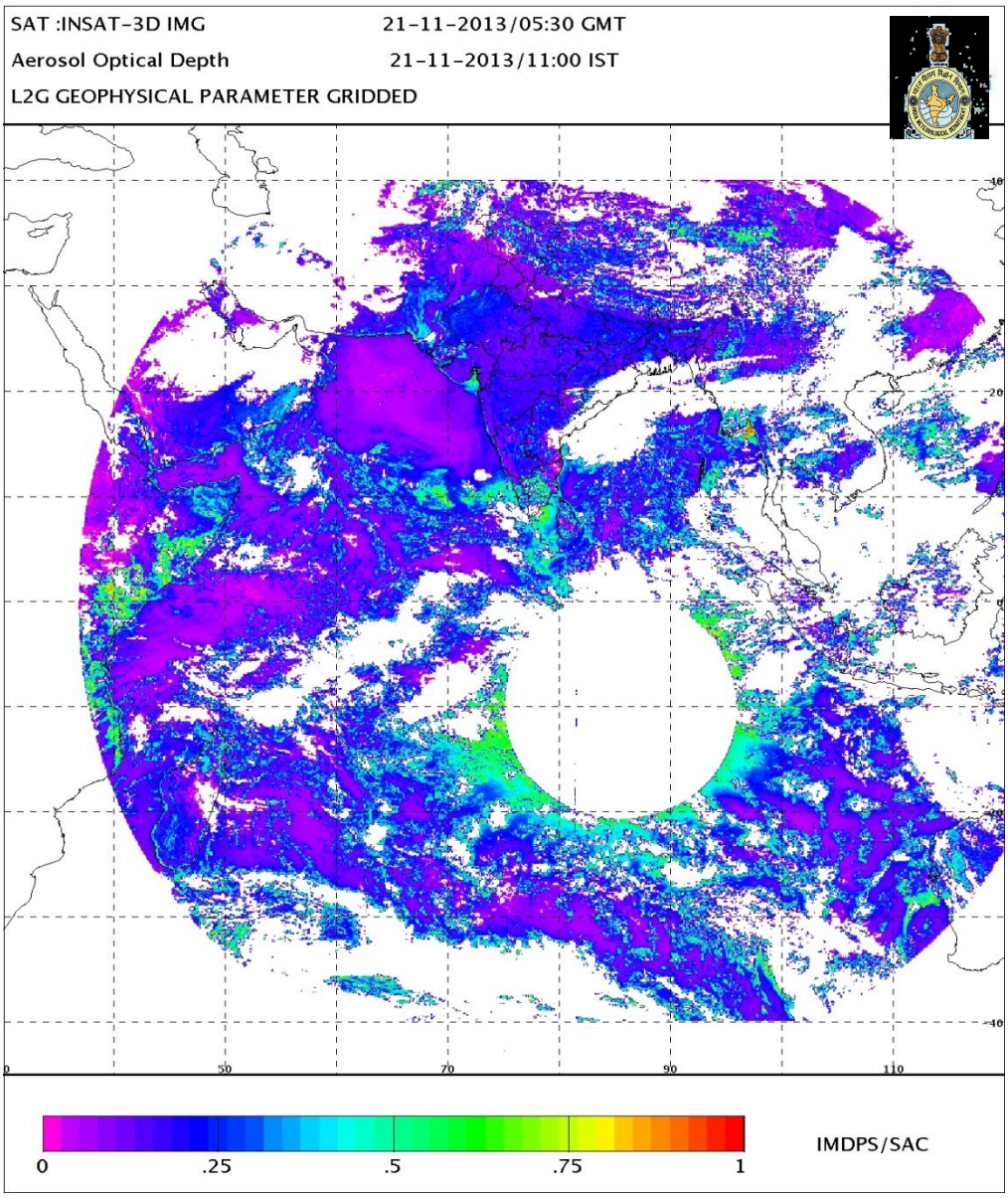
Domain : 40 S to 40 N, 30 E to 120 E

Frequency: Half Hourly, Daily and Monthly

13.11.5 Applications

Identification of smoke on satellite imagery is a prerequisite to study and retrieve physical, chemical, and optical properties of smoke.

13.12 AEROSOL OPTICAL DEPTH (AOD)



13.12.1 Introduction

Aerosols play an important role in numerous aspects of human life. Aerosols have large-scale effects, such as their impact on climate by redistributing solar radiation and interacting with clouds. Aerosol information is also critical for atmospheric correction algorithms for multi-spectral satellite sensors and military operations. The climate effects of atmospheric aerosols may be comparable to CO2 greenhouse effects, but with opposite sign and larger uncertainty. Aerosols have a significant impact on human life beyond the climate

element. When in the lower troposphere, aerosols cause poor air quality, reduction of visibility, and public health hazards. Satellite remote sensing provides a means to derive aerosol distribution at global and regional scales.

13.12.2 Operational Implementation

Step 1 : Conversion from gray count to Visible radiance and BT
Step 2 : Cloud and sun glint elimination
Step 3 : Generation of surface reflectance image using darkest observations using last 20 days data
Step 4: Atmospheric correction of INSAT-3D visible image for molecular scattering and gaseous absorption
Step 5 : Correction for surface reflectance
Step 6: Use LUTs for the inversion of aerosol optical depth (AOD)

13.12.3 Output

Parameter	Unit	Min	Max	Accuracy	Resolution
Aerosol	Dimensionless	0	2	15-20%	4Km

Optical depth at 650 nm

Frequency: Half Hourly, Daily and Monthly

13.12.4 Format of the output and the domain

Lat , Lon, AOD ,

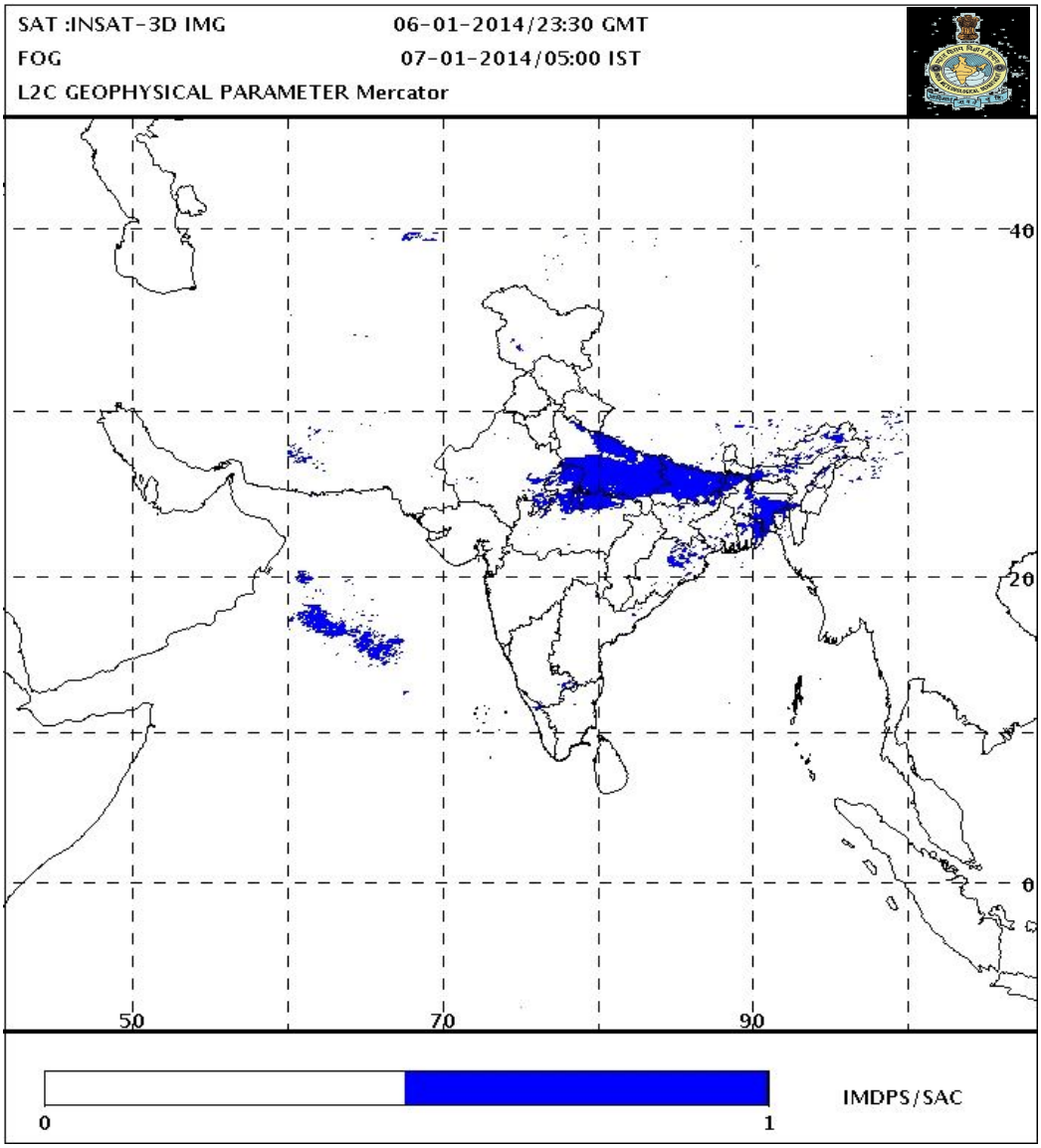
Domain :

40 S to 40 N, 30 E to 120 E

13.12.5 Applications

Atmospheric correction of remotely sensed surface features, Monitoring of sources and sinks of aerosols, Monitoring of volcanic eruptions and forest fire, Health and Environment, Air quality and Climate Change

13.13FOG



13.3.1 Introduction

Fog affects visibility near the surface and hence is an important parameter for aviation, transport on land and sea. Its detection and monitoring by means of satellites is an upcoming area of research. General methodology involves identifying some threshold radiances or brightness temperatures at different wavelengths which can distinguish fog from other cloud and surface features. Night time fog detection is done by looking at the 10.8 and 3.9μm channel brightness temperatures, in analogy to the method applied to GOES data. This technique relies on fog pixels displaying higher brightness temperature differences as compared to clear pixels and those covered by other clouds. This

technique is very efficient in detecting fog during night time. Identifying fog during day time is a bit complex. A variety of methods are being tried. But with the radiance measurements very limited in the visible region, many of these methods are not applicable for INSAT. In view of these one can try the use of same infrared channels that are used for night time for day time too. However difference between the two channel brightness temperatures alone is not sufficient. The threshold identification is dynamic and depends on the solar zenith angle, local surface albedo and a host of radiative transfer model simulations with various fog and cloud properties. In short the crux of the method is elimination of possibility of different cloud types before coming to the conclusion that the pixel contains fog. Neither day time nor night time algorithm works during dusk and dawn.

13.13.2 Operational Implementation

Night Time Fog Detection

- Conversion of grey count to Brightness temperature
- Difference between 10.8 and 3.9µm channel brightness temperatures.
- Cloud elimination (In the above step if difference is greater than 2.5 they are assumed to represent opaque clouds).
- Fog detection (Intermediate temperature differences between 0.5 and 2.5 K).

Day Time Fog Detection

- Gross cloud check (dynamical threshold between 10.8 and 3.9µm).
- Ice cloud check (estimated using 3.9µm channel brightness temperature).
- Spatial clustering of resulting water clouds.
- Brightness temperature of these clusters compared with adjacent cloud free pixels to identify if a cloud cluster is within 2000 meters above ground to identify low clouds.
- For all low cloud clusters the homogeneity of the cloud top height is tested.10.8 µm brightness temperature is taken as a proxy for altitude. Where its variation within a cloud cluster remains below a pre-defined maximum standarddeviation, the cloud cluster is identified as fog/low stratus.

13.13.3 Output Specificatiion

Parameter	Unit	Min	Max	Accuracy	Resolution
FOG	Flag	0 (not a fog)	1 (fog)	-	0.5 x 0.5 deg

Frequency: Hourly

13.13.4 Format of the output and the domain

Lat, lon, fog

Domain: 40 S to 40 N, 30 E to 120 E.

13.13.5 Application: It can useful for aviation and transport advisory especially at airports.

13.14 Cloud Mask (CMK)

13.14.1 Introduction

The discrimination of cloud from the clear sky is necessary for many geophysical parameter retrieval from INSAT data. Clouds are generally characterized by higher reflectance and lower temperature than the underlying earth surface. As such, simple visible and infrared window threshold approaches offer considerable skill in cloud detection. However, there are many surface conditions when this characterization of clouds is inappropriate, most notably over snow and ice. Additionally, some cloud types such as thin cirrus, low stratus at night, and small cumulus are difficult to detect because of insufficient contrast with the surface radiance. Cloud edges cause further difficulty since the instrument field of view will not always be completely cloudy or clear.

INSAT-3D VHRR will measure radiances in one visible and one SWIR band at 1 km spatial resolution, one MIR and two TIR bands at 4 km resolution, and one WV band at 8 km resolution. Radiances from 3 IR spectral bands TIR –1 , TIR –2 and MIR which are of same resolution of 4km will be used in the INSAT cloud mask algorithm to estimate whether a given view of the earth surface is unobstructed by clouds.

13.14.2 Brief Methodology

The basis of the methodology is, first to generate a clear composite of the maximum brightness temperature in thermal channels to get rough idea about the surface temperature in the clear sky condition at a particular time. This will be the reference background temperature on which the threshold for a particular location will be determined to discriminate cloud. Several test like BT threshold test, Difference Test ($BT_{11} - BT_{3.7}$), Difference Test ($BT_{3.7} - BT_{12}$), Spatial variability test , Spatial Uniformity test, Adjacent pixel test, Temporal Uniformity test, Final threshold test will be applied on each pixel to find our whether the pixel is cloudy, clear, partially cloudy or partially clear.

13.14.3 Output Specificatiion

Parameter	Resolution
CMK	pixel

13.14.4 Format of the output and the domain

Scan , pixel, cloud flag

If cloudflag = 0 , pixel is clear

If cloudflag = 1 , pixel is cloudy

If cloudflag = 2, probably clear

If cloudflag = 3, probably cloudy

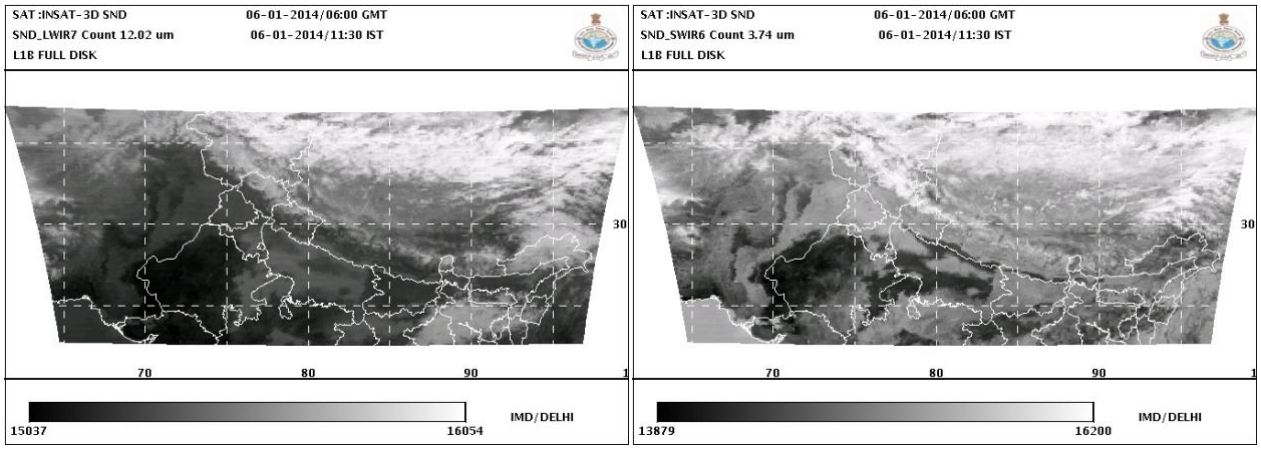
If cloudflag = 9, Cold space

Domain :

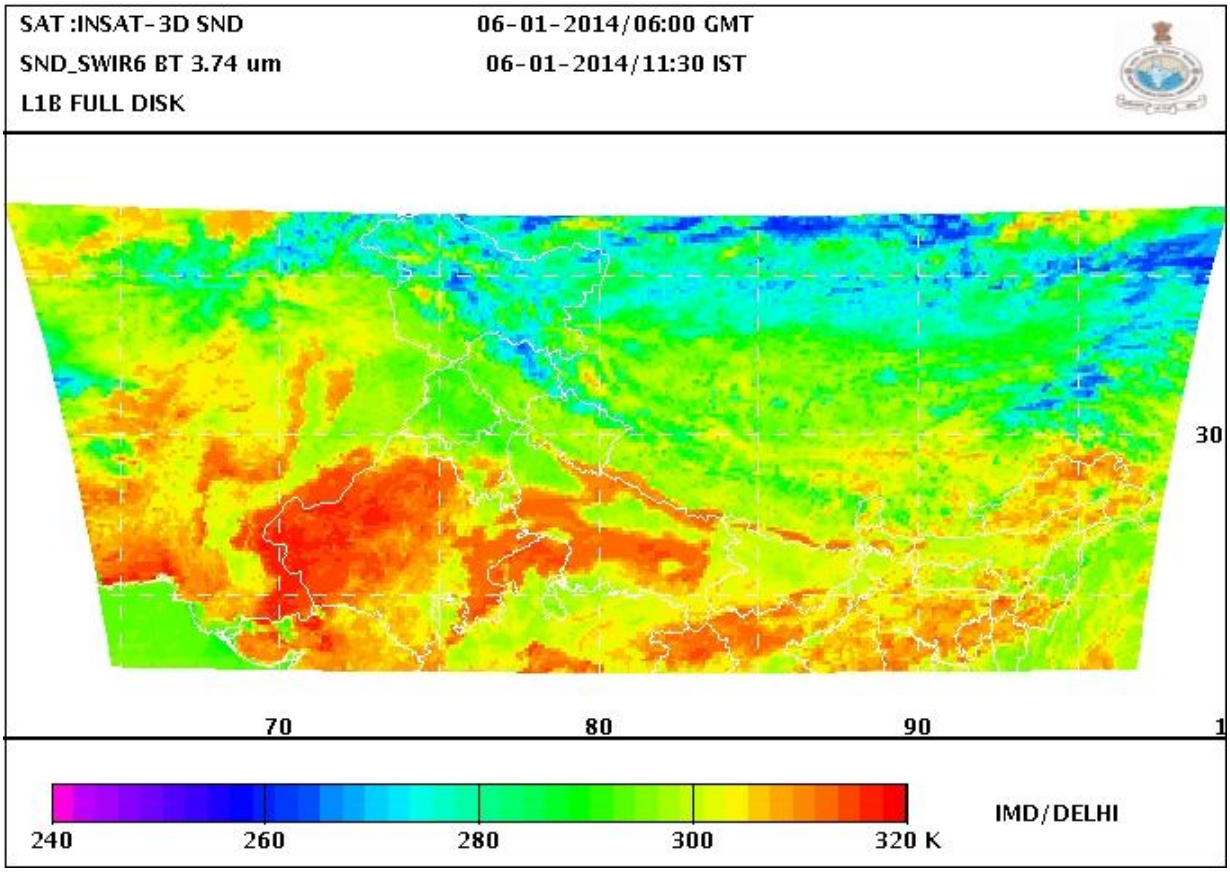
Image Domain

13.15.5Application: It can be used for detection and removal of clouds from Imager and Sounder payloads.

14. SOUNDER ATMOSPHERIC PARAMETERS

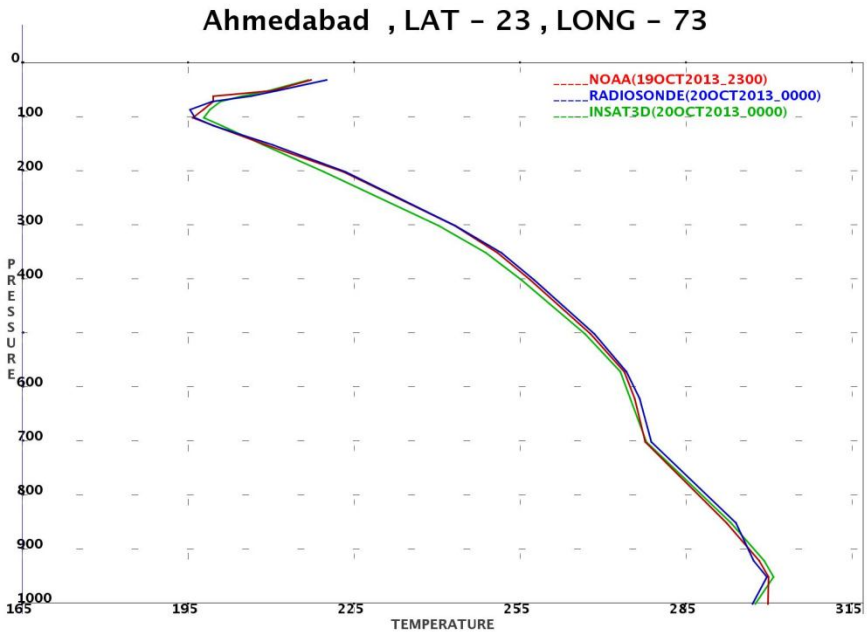


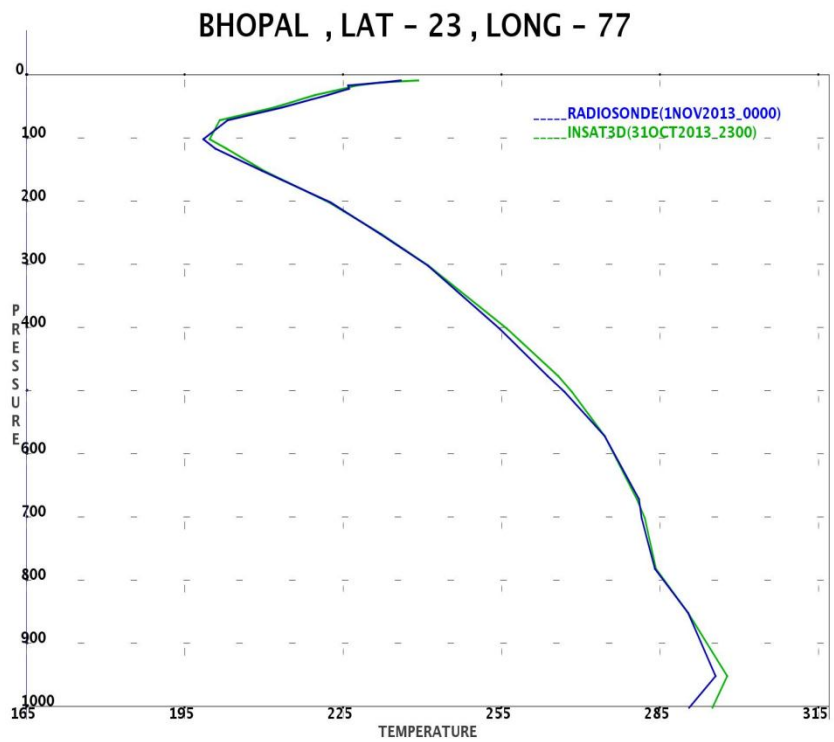
BT Image (SWIR6)



Temperature, Moisture profile from INSAT-3D Sounder

INSAT3-D Sounder Profile over the Indian region





14.1 Introduction

INSAT-3D will carry an 18-channel infrared Sounder (plus a visible channel) along with a 6 channel Imager. This algorithm is designed for retrieving vertical profiles of atmospheric temperature and moisture along with total column ozone content in the atmosphere from clear sky infrared radiances in different absorption bands observed through INSAT-3D. INSAT-3D Sounder channels are similar to those in GOES-12 Sounder and many of the spectral bands are similar to High resolution Infrared Radiation Sounder (HIRS) onboard NOAA ATOVS. Hence, present algorithm for INSAT-3D Sounder is adapted from the operational HIRS and GOES algorithms developed by Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin.

14.2 Algorithm

The algorithm includes generation of the hybrid first guess atmospheric profiles using a linear combination of regression retrieval and NWP model forecast. This is followed by a non-linear physical retrieval procedure (Li et al. 2000; Ma et al. 1999) to make the first guess consistent with the Sounder observations. The PFAAST atmospheric radiative transfer model (Hanon et al., 1996) has been used for the forward computation of sounder channel radiances alongwith the Jacobians, which is used in the physical retrieval. The regression coefficients are computed for 150 zenith angle classes (0 to 65° with increment of $\Delta\sec(\theta) = 0.01$) for 3 latitude zones (20S-20N, 20N/S-40N/S, 40N/S-60N/S) from radiosonde database (SeeBor dataset, University of Wisconsin) separately for land and ocean. The set of predictors include sounder channel brightness temperature (T_b) and its quadratic term (T_b^2) along with the surface pressure (P_s) from NWP forecast. The atmospheric profiles obtained from regression retrieval is combined with the NWP forecast profiles to generate a hybrid regression profile that is used as first guess for the physical retrieval. The physical retrieval procedure involves minimization of the following cost function:

$$J(X)=[Y^m - Y(X)]^T.E^{-1}.[Y^m - Y(X)] + (X - X_0)^T.H^{-1}.(X - X_0)$$

Where, X is the atmospheric profile vector, X_0 is the first guess, Y is the observation vector, $Y(X)$ is the forward model, E is observation error covariance matrix, and H is the a priori matrix that constrains the solution, usually the first guess error covariance matrix.

14.3 Output Specification

Following parameters will be retrieved from INSAT-3D Sounder:

Parameter	Resolution	Expected Accuracy
Temperature profile	30 km x 30 km (3 x 3 Pixels) 30-vertical pressure levels*	1 - 2 °C
Water vapour profile upto 100 hPa	30 km x 30 km (3 x 3 Pixels) 21-vertical pressure levels ~30%	
Ozone profile	30 km x 30 km (3 x 3 pixels) 40 vertical pressure levels	
Total Column Ozone	30 km x 30 km (3 x 3 pixels)	~ 5-10 % Dob unit
Surface skin temperature	30 km x 30 km (3x 3 pixels)	~ 0.5 –1 °C

- **Algorithm has option for retrieved at 30 km (3 x 3 pixels) and 10 km resolution (each pixel).**

Vertical Pressure Levels (40) in hPa :

1000, 950, 920, 850, 750, 700, 670, 620, 570, 500, 475, 430, 400, 350, 300, 250, 200, 150, 135, 115, 100, 85,70,60, 50, 30, 25, 20, 15, 10, 7, 5, 4, 3, 2, 1.5, 1, 0.5, 0.2, 0.1

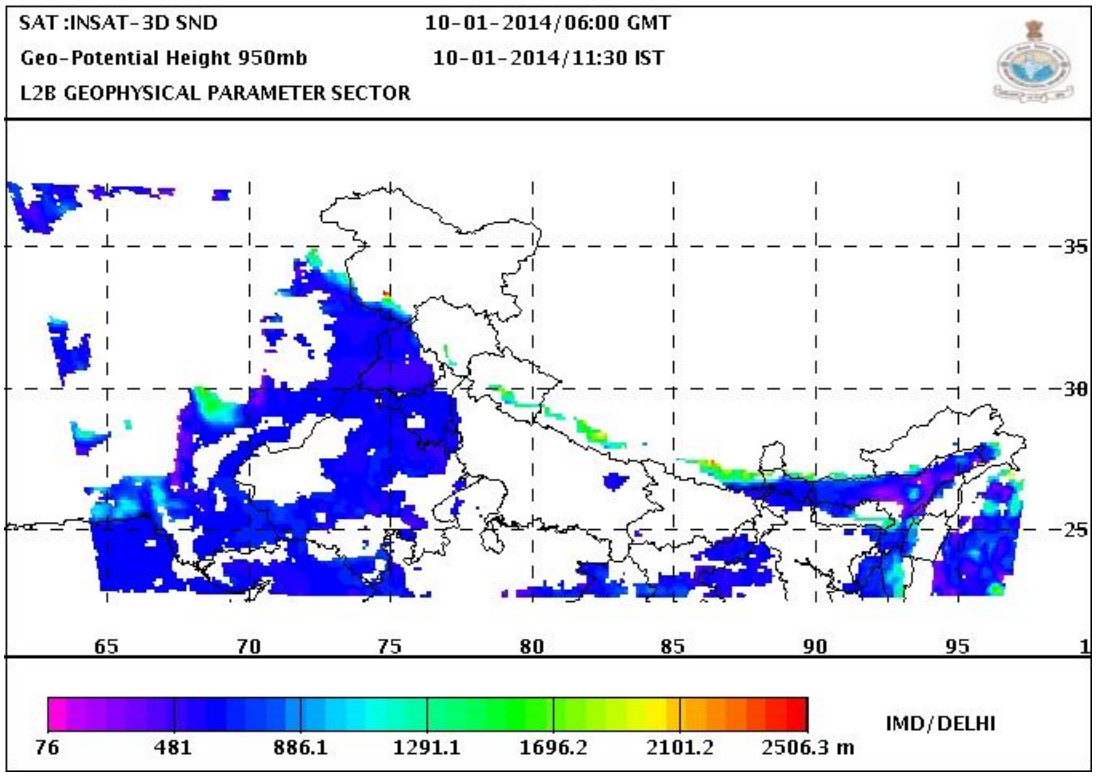
14.4 Format of the output and the domain

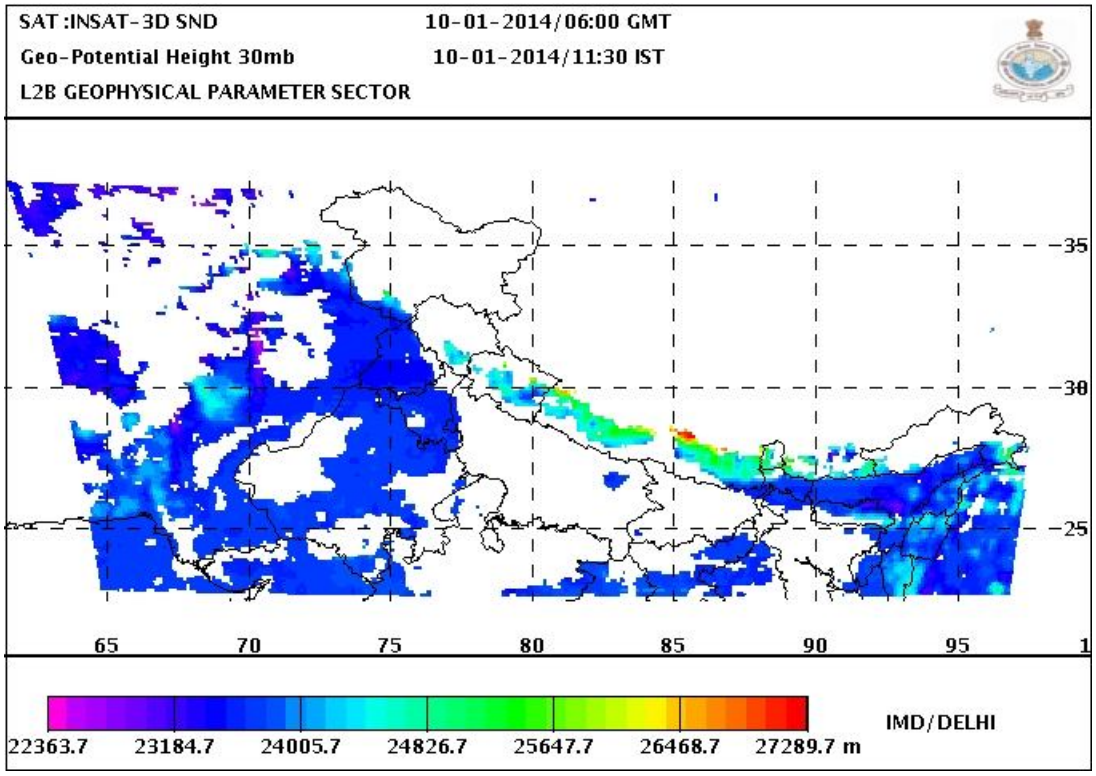
Direct access binary format with each record giving details of time of observations, location, forecast profiles, regression first guess profiles, final physical retrieval output profiles, surface skin temperature, total column ozone, and other auxiliary information. These retrievals will be made within 60 degrees from the sub-satellite point.

15. Application parameters from Sounder derived products

- Geopotential height,
- Layer and total precipitable water,
- Lifted index from sounder,
- Dry microburst index,
- Maximum vertical theta-e differential,
- Wind index

15.1 GEOPOTENTIAL HEIGHT





15.1 Introduction

Geopotential height fields (GPH) at a pressure level indicate the source and sinks of air masses. Generally high pressure areas have relatively higher geopotential heights than low pressure areas. It is also a fundamental quantity that is used in atmospheric general circulation models. At mid-latitudes they also indicate the underlying large-scale waves such as Rossby waves. By looking at the geopotential heights one can infer the first guess atmospheric wind pattern (also known as geostrophic approximation) especially for mid-latitudes.

15.2 Methodology :

Given surface pressure, and temperature profile, height at any pressure level or thickness of atmospheric layer from surface to a particular pressure level is computed using the formula:

$$Z = \frac{R_d \overline{T_v}}{g} \ln(\frac{P_s}{P}) \quad \text{Unit: meters}$$

P_s – Surface Pressure, P – Given pressure where geopotential height is to be calculated, $\overline{T_v}$ - Layer mean virtual temperature.

15.3 Output Specificatiion

Parameter	Unit	Min	Max	Accuracy	Resolution
GPH	Meters	-	-	+/- 10 m	0.5 x 0.5 deg

Frequency: Hourly

15.4 Format of the output and the domain

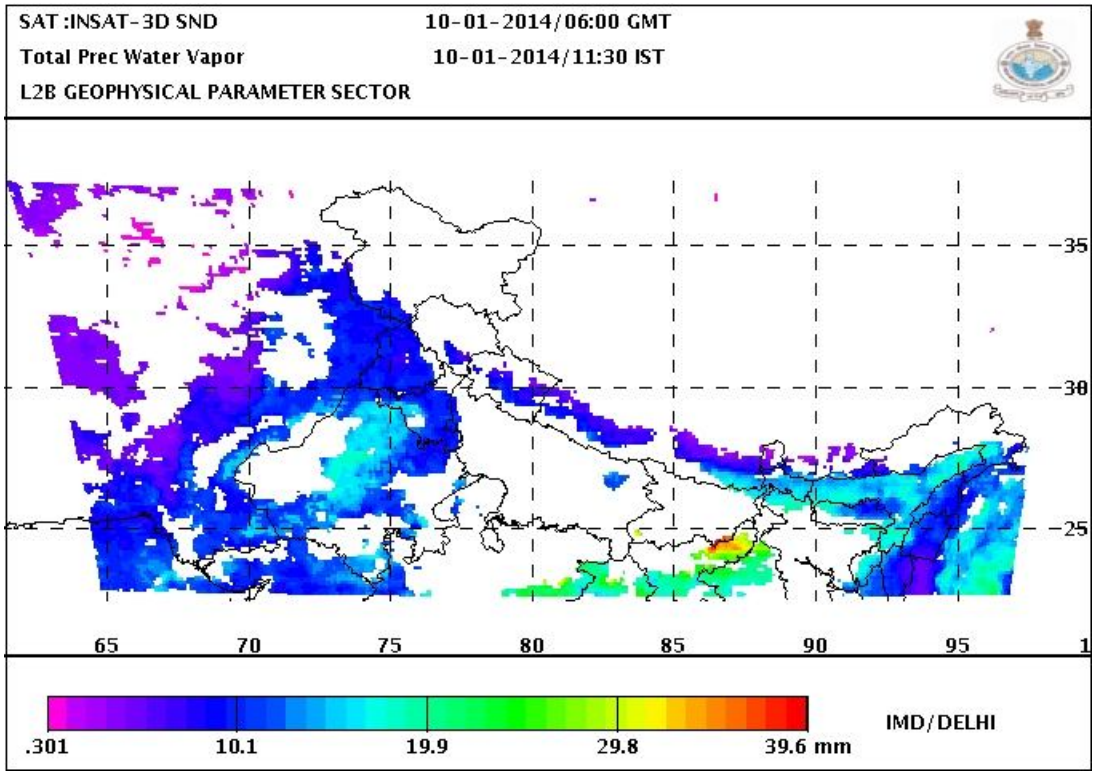
Latitude, Longitude, Pressure (1000 to 0.1 hPa), GPH. Domain: 40 S to 40 N, 30 E to 120 E.

Vertical Pressure Levels (40) in hPa :

1000, 950, 920, 850, 750, 700, 670, 620, 570, 500, 475, 430, 400, 350, 300, 250, 200, 150, 135, 115, 100, 85,70,60, 50, 30, 25, 20, 15, 10, 7, 5, 4, 3, 2, 1.5, 1, 0.5, 0.2, 0.1

15.5 Application: It can be used to analyze the structure of the tropical cyclones.

15.2 Total and Layer Precipitable Water



15.2.1 Introduction

Water vapor content in the atmosphere modifies the air mass characteristics. Presence of air mass lightens the air mass thereby increasing the potential for convective activity. As an air parcel rises, it cools dry adiabatically until saturation vapor pressure is reached. Once saturation vapor pressure is reached some of the water vapor condenses forming liquid droplets, and releasing latent heat. This latent heating reduces the amount of cooling and makes the air parcel morebuoyant. This information is very essential for accurate prediction of weather and goes as an input parameter in numerical weather prediction models.

15.2.2Methodology

Layer precipitable water may be computed using the formula

$$PW = \int_{p1}^{p2} \frac{q}{g} dp$$

where p1 and p2 are bounding pressures of each layer in Pa, q – specific humidity in Kg/Kg. Total precipitable water is also computed from the same formula with p1 as surface pressure and p2 as top of the atmosphere pressure (i.e. about 100 hPa beyond which water vapor amount is assumed to be in negligible). Unit of precipitable water is mm depth of equal amount of liquid water above a surface of one square meter (if pressure is in Pa and specific humidity is in Kg/Kg).

15.2.3 Output Specificatiion

Parameter	Unit	Min	Max	Accuracy	Resolution
PW	mm	0	-	25%	0.5 x 0.5 deg

Frequency: Hourly

15.2.4 Format of the output and the domain

lat, lon, PW (at three layers) and TPW (total precipitable water vapor).

Domain: 40 S to 40 N, 30 E to 120 E.

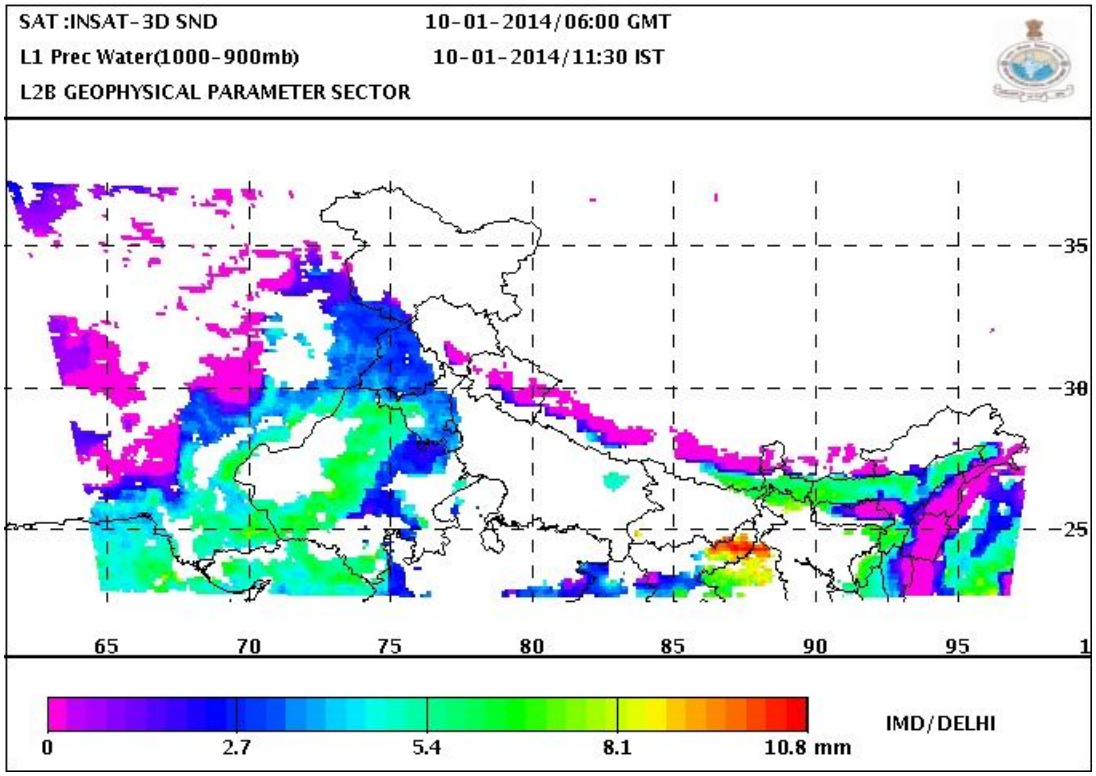
Perceptible water can also been observed at three different layers. The distinct layers are

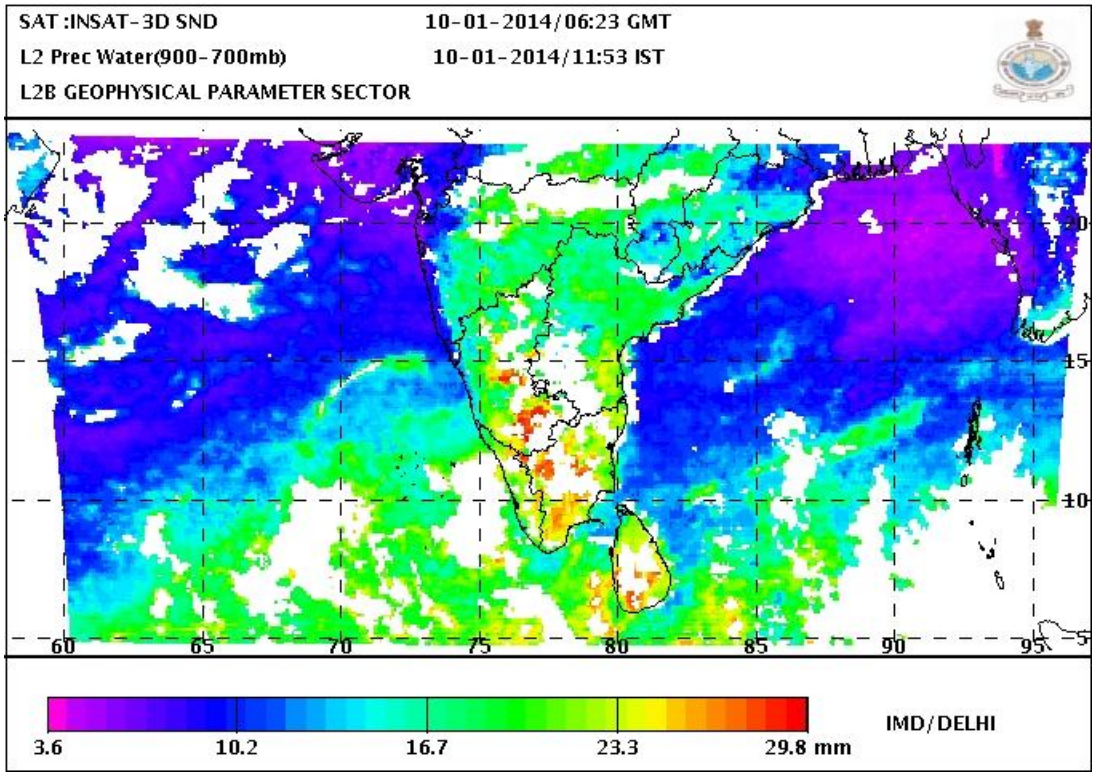
Low level preciptable water vapor (LPW) - 1000 hPa to 900 hPa

Mid levelpreciptable water vapor - 900 hPa to 700 hPa

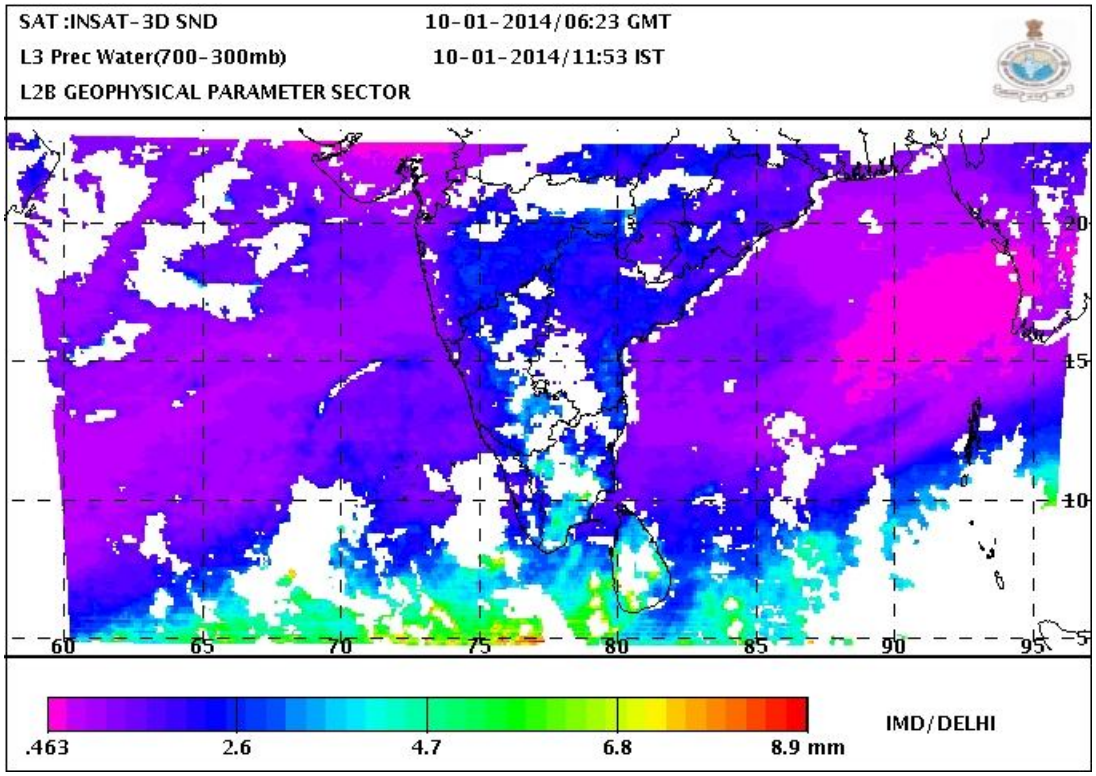
High level preciptable water vapor - 700 hPa to 300 hPa

Low and Mid LevelPreciptable Water Vapor



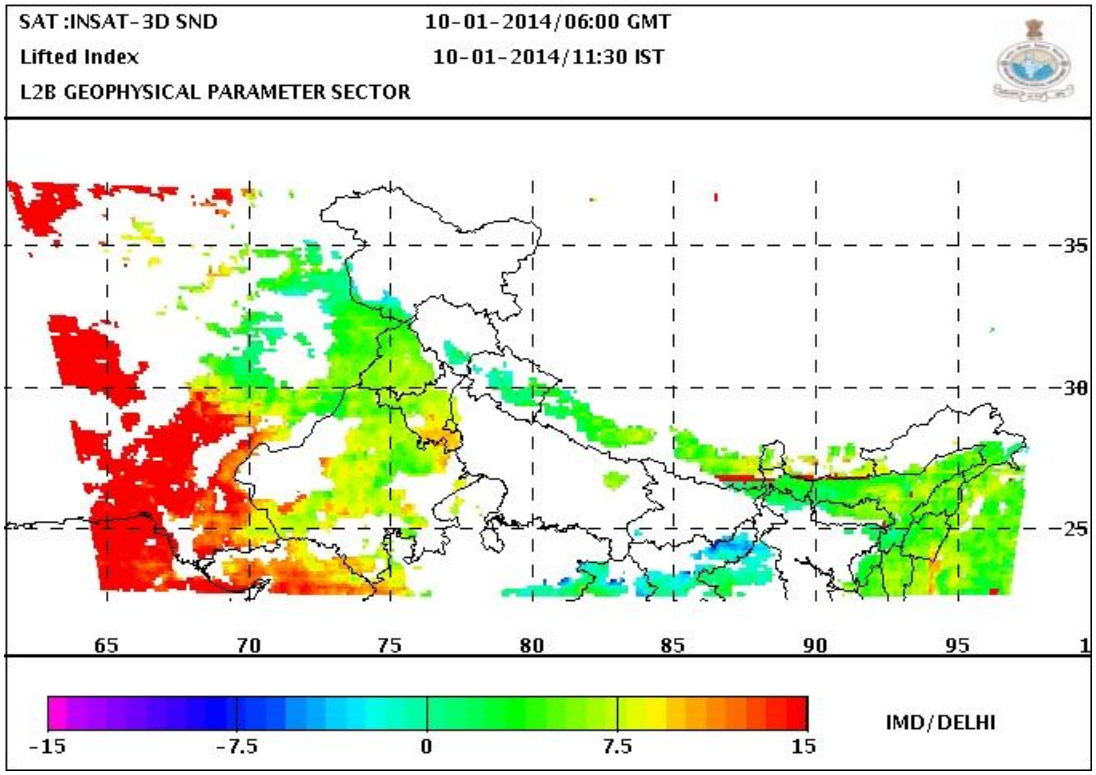


High LevelPreciptable Water Vapor



15.2.5 Applications: Layer & Total precipitable water products can provide additional details about tropical cyclone structure such as asymmetries and moisture gradients that aid in interpreting tropical cyclones interaction with dry/moist air.

15.3 LIFTED INDEX



15.3.1 Introduction

Lifted index is an indicator of convective activity. It is calculated in the following steps.:

1. Mean boundary layer (usually lowest 100 hPa layer) temperature and humidity are calculated.

2. A parcel of air with the above calculated temperature and humidity is lifted from the middle of the boundary layer dry adiabatically up to lifting condensation level and then moist adiabatically up to 500 hPa.

3. The environmental temperature minus the parcel temperature at 500 hPa calculated in the above step is the lifted index (LI).

If the parcel temperature is warmer than the environmental temperature it indicates that the parcel can rise further on its own and LI will be negative. Based on a large number of LI calculations from radiosonde observations, it is observed that LI less than -5 implies a very strong likelihood of thunderstorm activity.

15.3.2 Output Specificatiion

Parameter	Unit	Min	Max	Accuracy	Resolution
LI	Deg C	-	-	2-3 degC	0.5 x 0.5 deg

Frequency: Hourly

15.3.3 Format of the output and the domain

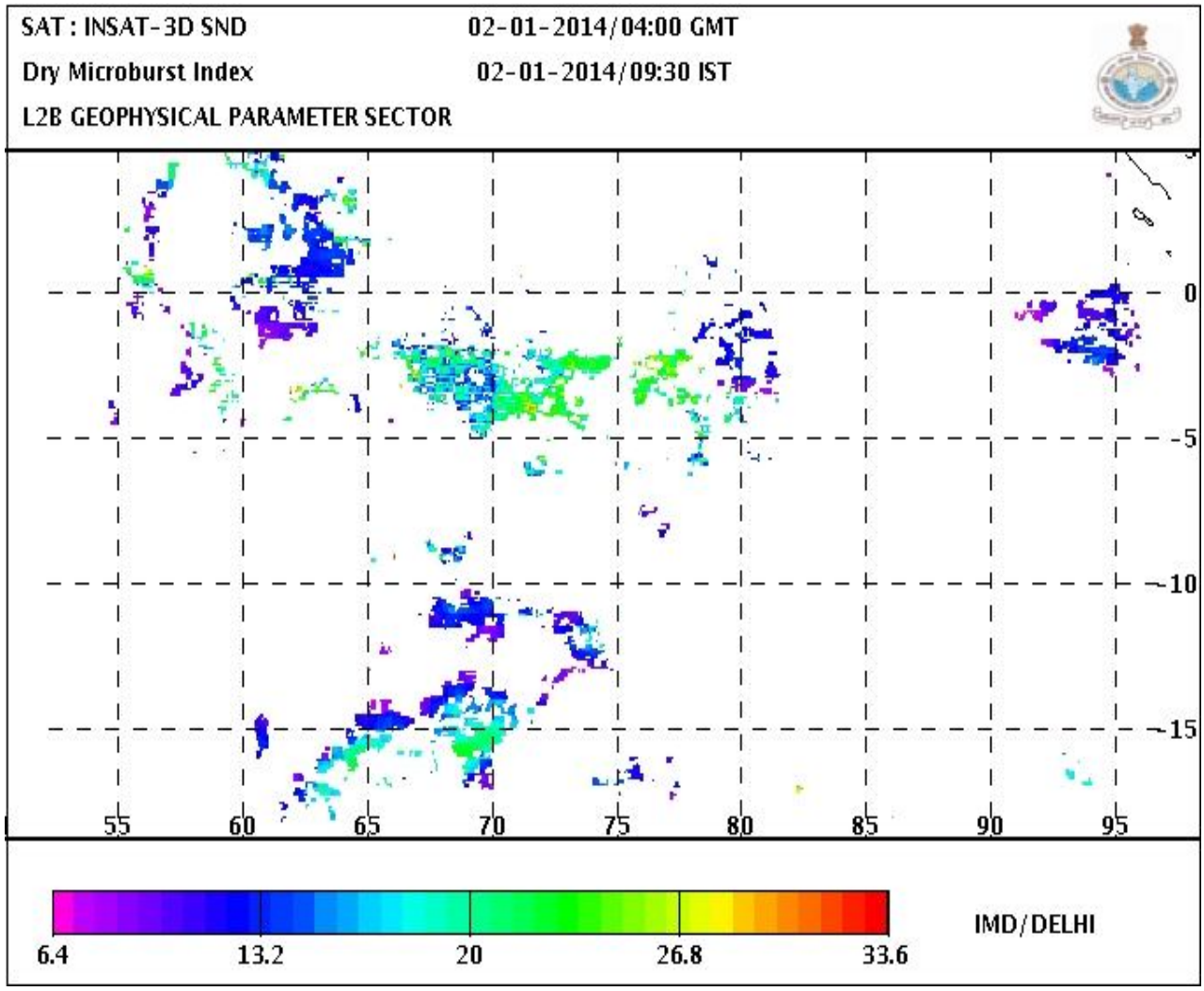
lat, lon, LI

Domain: 40 S to 40 N, 30 E to 120 E.

15.3.4 Applications

Time sequence of geographical pattern of LI may be monitored to study large scale convective activity and its relation to synoptic circulation systems.

15.4. DRY MICROBURST INDEX



15.4.1 Introduction

Evaporative cooling of falling rain is often a much larger effect than the liquid water loading. In regions such as the western Great Plains of the United States (e.g. near Denver), the environmental air is often so dry that evaporative cooling causes dangerous downdraft called downbursts. Hazardous downbursts can occur even under cloud bases where precipitation evaporates before reaching the ground. The smaller-diameter but intense downbursts are called microbursts. Downbursts of 0.5 to 5 km in diameter have been observed. For extreme cases, downdraft speeds of nearly 10 m/s have been observed 100 m above ground. This is particularly hazardous to landing and departing aircraft, because this

vertical velocity can sometimes exceed aircraft climb rate. Doppler radars can detect some of the downbursts and give early warning to pilots (Roland Stull, 2000). In India dry desert regions, elevated plains, mountain regions where air is very dry may be susceptible to microburst.

15.4.2 Methodology

Dry microburst index is generally calculated using the formula,

$$DMI = \Gamma + (T - T_d)_{700} - (T - T_d)_{500}$$

Γ - lapse rate (^{0}C km-1) of the layer from 700 hPa to melting level (i.e. layer at 0o C), T – Temperature (^{0}C), Td – Dew point (^{0}C). Usually DMI is not calculated for any retrieval unless the following three conditions are satisfied:

(1) Γ > 6 K km-1 (somewhat stable for convective activity)

(2) (T - Td)700>= 8 K (implies a very dry atmosphere close to surface)

(3) (T-Td)500<= 8 K (implies some level of saturation at this level)

Suitability of these conditions needs to be studied for the Indian region.

15.4.3 Output Specificatiion

Parameter	Unit	Min	Max	Accuracy	Resolution
DMI		-	-	2-3 degC	0.5 x 0.5 deg

Frequency: Hourly

15.4.4 Format of the output and the domain

Lat, Lon, DMI

Domain: 40 S to 40 N, 30 E to 120 E.

15.4.5 Applications

Generally dry microburst occurs in situations characterized by high convective cloud bases and strong evaporational cooling in the sub-cloud layer, resulting in little or no precipitation at the surface

15.5 MAXIMUM VERTICAL THETA-E DIFFERENTIAL

15.5.1 Introduction

Equivalent potential temperature (θe) is the potential temperature that a saturated air Parcel would have if raised moist adiabatically to the top of the atmosphere. It is given by the formula

$$\theta_e = \theta \exp(\frac{Lq}{C_p T})$$

Where θ - Potential temperature, L – Latent heat of condensation, q – Specific humidity, T – Temperature, Cp – Specific heat of dry air at constant pressure. As the moisture decreases with height, θe also decreases with height and reaches a minimum in the middle troposphere, then increases again into the upper troposphere. A quantity called dry microburst potential index (MDPI) is calculated by dividing thetaed by 30. As this formula for MDPI is empirical, its suitability over the Indian region needs to be studied.

15.5.2 Methodology

From the retrieved temperature and humidity data calculate theta-e at standard pressure levels using the equation given in the previous section. Calculate the difference between the lowest level theta-e and subsequent levels up to 500 hPa. The maximum of these differences is maximum vertical thetae difference (thetaed).

15.5.3 Output Specificatiion

Parameter	Unit	Min	Max	Accuracy	Resolution
THETAED	°C	-	-	2-3degC	0.5 x 0.5 deg

Frequency: Hourly

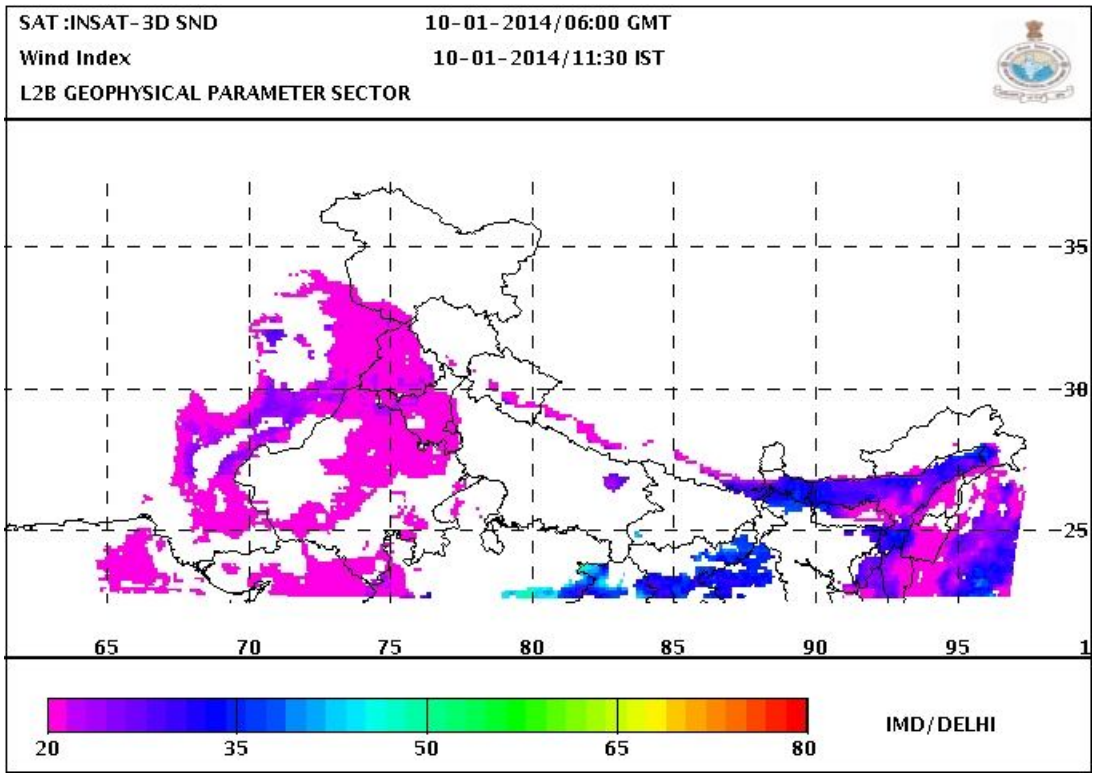
15.5.4 Format of the output and the domain

Lat, lon, thetaed

Domain: 40 S to 40 N, 30 E to 120 E.

15.5.5 Applications: The maximum vertical θe differential between the boundary layer and middle troposphere is a measure of atmospheric instability in the vertical direction. Larger the theta-e differential, more unstable is the atmosphere in the vertical direction.

15.6 WIND INDEX



15.6.1 Introduction

Wind Index (WI) is a parameter based on vertical equations of momentum and continuity with certain simplifying assumptions. It is given by the formula

$$WI = 5[H_M R_Q (T^2 - 30 + Q_L - 2Q_M]^{1/2}$$

Where WI – Maximum wind gust (knots, at the surface)

HM – Height above ground of melting level (in km)

RQ – QL/12 but not >1, QL – Mean mixing ratio (g/Kg) in lowest 1 km

T – Lapse rate ($^oC\ km^{-1}$) from surface to melting level, QM – Mixing ratio at melting level.

15.6.2 Methodology

1) From the retrieved temperature profile at standard pressure level, the pressure

level at which temperature reaches 0° C is estimated by means of interpolation. Height of the melting layer is then estimated by using the standard formula based on hydrostatic approximation.

2) Mixing ratio at melting level is also obtained by means of interpolation of retrieved humidity.

3) Mean mixing ratio in the lowest one km is also estimated by using retrieved specific humidity profile at standard pressure levels.

4) Lapse rate between surface and melting layer is easily estimated by dividing surface temperature by height of the mixing layer (in km).

These parameters are substituted in the formula for WI given above.

15.6.3 Output Specificatiion

Parameter	Unit	Min	Max	Accuracy	Resolution
WI	knots	0	-	-	0.5x 0.5 deg

Frequency: Hourly.

15.6.4 Format of the output and the domain

Lat, lon, WI

Domain: 40 S to 40 N, 30 E to 120 E.

15.6.5 Applications: Wind index provides guidance on the maximum possible wind gusts that can occur with given atmospheric conditions, if convection were to occur. This is useful for generating short-range warnings and forecasts.

16. DATA AVAILABILITY

All derived products from the INSAT-3D/INSAT-3A/Kalpana-1 satellites are made available to users through IMD website www.imd.gov.in. For more information, please contact:

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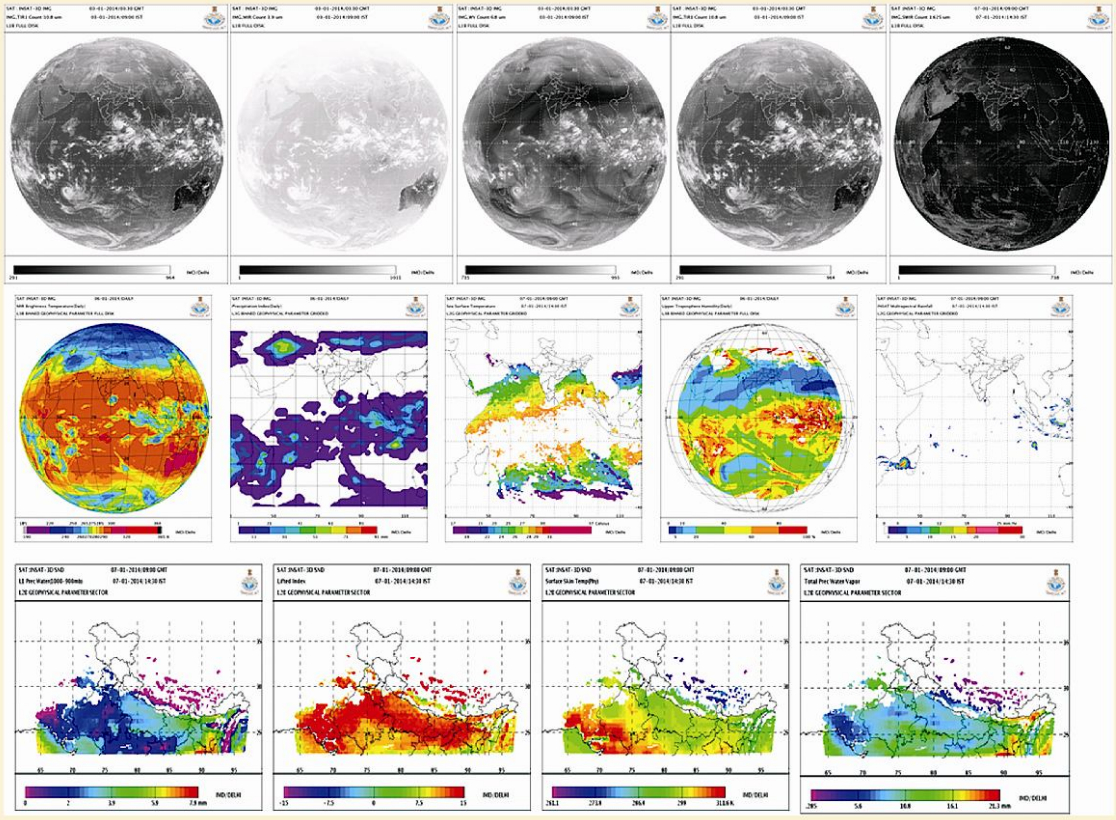
Glimpses of INSAT-3D Meteorological Images



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