Current status and Future Prospects of Indian Satellite

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Indian Space Programme for Earth Observations

• Payload and Satellite: Design & Fabrication

• Launch (Design, Fabrication & Launch):
  » Polar: Operational
  » Geostationary: Operational

• Retrievals

• Applications with Users
Indian Missions for Weather & Climate Studies: Current & Future

Kalpana-1
2002
- CMV, OLR, Rainfall
- VHRR

- CMV, OLR, Rainfall
- Aerosol
- VHRR, CCD

INSAT-3D (2008)
- SST, CMV, OLR, Rainfall, T, h Profile
- 6-Ch VHRR IR Sounder

OCEANSAT–1/2 (1999/2008)
- MSMR, OCM, Scatterometer
- Vector Winds Aerosol

MEGHA-TROPIQUES (2008)
- MW Imager, WV Sounder, ScaRaB
- SS Wind, TWV, Rainfall
- T, h Profile, Radiation Budget
## INDIAN NATIONAL SATELLITE (INSAT) FOR METEOROLOGICAL APPLICATIONS

**INSAT -1 : Geostationary Satellite Series**

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Launch Date</th>
<th>Met. Payload with Wavelength Bands</th>
<th>Major Applications</th>
</tr>
</thead>
</table>
| INSAT-1A  | 10 April 1982 | Very High Resolution Radiometer (VHRR)  
Visible 0.55-0.75\(\mu\)m  
IR 10.5 - 12.5\(\mu\)m | ▪ Monitoring cyclones & monsoon  
▪ CMV Winds  
▪ OLR  
▪ Rainfall Estimation |
| INSAT-1B  | 8 August 1983 | -do- | -do- |
| INSAT-1C  | 22 July 1988 | -do- | -do- |
| INSAT-1D  | 12 June 1990 | -do- | -do- |
### INSAT -2: Geostationary Satellite Series

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Launch Date</th>
<th>Met. Payload with Wavelength Bands</th>
<th>Major Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>INSAT-2A</td>
<td>10 July 1992</td>
<td>Very High Resolution Radiometer (VHRR) Bands 0.55-0.75 $\mu$m &amp; 10.5 - 12.5 $\mu$m</td>
<td>▪ Monitoring cyclones &amp; monsoon&lt;br▪ CMV Winds&lt;br▪ OLR&lt;br▪ Rainfall Estimation&lt;br▪ Mesoscale features&lt;br▪ Flood/intense precipitation advisory&lt;br▪ Snow detection</td>
</tr>
<tr>
<td>INSAT-2B</td>
<td>23 July 1993</td>
<td>Very High Resolution Radiometer (VHRR) Bands : 0.55-0.75 $\mu$m &amp; 10.5 - 12.5 $\mu$m</td>
<td></td>
</tr>
<tr>
<td>INSAT-2E</td>
<td>April 1999</td>
<td>VHRR : As above + WV Bands : 5-7.1 $\mu$m&lt;brCCD : Bands : 0.63 - 0.79 $\mu$m 0.77 - 0.86 $\mu$m 1.55-1.70 $\mu$m</td>
<td></td>
</tr>
</tbody>
</table>

### Location of INSAT-2E: 83ºE

### INSAT 2E - CCD

<table>
<thead>
<tr>
<th>Detectors</th>
<th>Spectral Bands ($\mu$m)</th>
<th>Spatial Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible (Vis)</td>
<td>0.63-0.68</td>
<td>1 Km</td>
</tr>
<tr>
<td>Near Infrared (NIR)</td>
<td>0.77-0.86</td>
<td>1 Km</td>
</tr>
<tr>
<td>S W Infrared (SWIR)</td>
<td>1.55-1.7</td>
<td>1 Km</td>
</tr>
</tbody>
</table>
INSAT-3A & Kalpana-1

Location: INSAT 3A: 93.5ºE
Kalpana-1: 74ºE

Payload:
(i) VHRR & CCD camera in INSAT 3A
(ii) VHRR in Kalpana-1

• VHRR Bands (µm)
  – Visible: 0.55 – 0.75
  – Water vapour: 5.70 – 7.10
  – Thermal Infra Red: 10.5 – 12.5

• Resolution (km):
  2 X 2 for Visible
  8 X 8 for WV & TIR

• CCD Camera Bands (µm)
  – Visible: 0.62 – 0.68
  – Near Infra Red: 0.77 – 0.86
  – Short Wave Infra Red: 1.55 – 1.69

• Resolution (km): 1 X 1 for all bands
Current Geostationary Meteorological Satellites the South and South West Asian Region
High Convective clouds and Fog Detection using INSAT-2E – CCD data

Deep Convective Clouds

FOG
QPE in mm 06-Oct-05 06:00Z
Kalpana-1 (IMD, N Delhi)

OLR in W/m² 06-Oct-05 06:00Z
Kalpana-1 (IMD, N Delhi)
CMV 07-Oct-05 00:00Z Kalpana-1 (IMD, N Delhi)

Low Level CMV

Medium Level CMV

High Level CMV
TeraScan HRPT Acquisition and Processing System

1.2m HRPT Tracking Antenna

Optional Items
- Color DeskJet Printer
- UPS

Sun Ultra-10 Acquisition and Processing
- HRPT Receiver
- DAT Drive
- Antenna Pedestal

Color DeskJet Printer
- UPS
Indian Remote Sensing Satellites (IRS)
IRS data is being used for a diverse range of applications such as:

- Crop acreage and production estimation of major crops,
- Drought monitoring and assessment based on vegetation condition,
- Flood risk zone mapping and flood damage assessment,
- Hydro-geomorphological maps for locating underground water resources,
- Irrigation command area status monitoring,
- Snowmelt run-off estimation,
- Land use and land cover mapping,
- Urban planning,
- Biodiversity characterisation,
- Forest survey,
- Wetland mapping,
- Environmental impact analysis,
- Mineral prospecting,
- Coastal studies,
- Integrated surveys for developing sustainable action plans

### IRS Sensors

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Launch Date</th>
<th>Sensors</th>
<th>Channels</th>
<th>Resolution</th>
<th>Swath / Repetivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRS-1A</td>
<td>17.03.1988</td>
<td>LISS-1</td>
<td>0.45-0.52μm, 0.52-0.59μm, 0.62-0.68μm, 0.77-0.86μm</td>
<td>72.5 m</td>
<td>148 km / 22 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LISS-2</td>
<td>0.45-0.52μm, 0.52-0.59μm, 0.62-0.68μm, 0.77-0.86μm</td>
<td>36.25 m</td>
<td>147 km / 22 days</td>
</tr>
<tr>
<td>IRS-1B</td>
<td>29.08.1991</td>
<td>Same as IRS-1A</td>
<td>0.52-0.59μm, 0.62-0.68μm, 0.77-0.86μm, 1.55-1.70μm</td>
<td>23.5 m</td>
<td>141 km / 24 days</td>
</tr>
<tr>
<td>IRS-1C</td>
<td>28.12.1995</td>
<td>LISS-3</td>
<td>0.45-0.52μm, 0.62-0.68μm, 0.77-0.86μm, 1.55-1.70μm</td>
<td>188 m</td>
<td>770 km / 24 days</td>
</tr>
<tr>
<td>IRS-1D</td>
<td>29.09.1997</td>
<td>Same as IRS-1C</td>
<td>0.50-0.75μm</td>
<td>5.8 m</td>
<td>70 km / 5 days</td>
</tr>
<tr>
<td>IRS-P3</td>
<td>21.03.1996</td>
<td>WiFS</td>
<td>Same as IRS-1C but additional band in MIR</td>
<td>1569 x 1395 m</td>
<td>195 km / 24 days</td>
</tr>
<tr>
<td>IRS-P4</td>
<td>26.05.1999</td>
<td>OCM</td>
<td>402-422nm, 433-453nm, 480-500nm, 500-520nm, 545-565nm, 660-680nm, 745-785nm, 845-885nm</td>
<td>360 x 236 m</td>
<td>1420 km / 2 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MSMR</td>
<td>6.6, 10.6, 18, 21 for SST, SSWS, TWV, LWC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
INDIAN IMAGING CAPABILITY

In the image, there are several satellite images showcasing different resolutions. The resolutions and corresponding images are as follows:

- 360m
- 188m
- 72m
- 36m
- 1KM
- 1m
- 5.8m
- 23m
RESOURCESAT - 1

In-orbit replacement for IRS 1C/1D with enhanced capabilities

Launch: 17th October, 2003
Orbit: Sun synchronous, 817 km
Payloads: LISS-4, LISS-3, AWiFS & PAN
Camera Tilt: ± 26°

RISAT - 1

Multimode C-band SAR to provide all weather imaging capability

Launch: 2005
Orbit: Sun synchronous, 586 km
Payload: SAR
Spectral Range: C-band
Resolution: 3-50 m in different modes
Swath: 10-240 km in different modes

<table>
<thead>
<tr>
<th>SENSOR</th>
<th>BANDS</th>
<th>RESOLUTION (m)</th>
<th>REPETIVITY (Days)</th>
<th>SWATH (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LISS-3</td>
<td>G, R, NIR, SWIR</td>
<td>23.5</td>
<td>24</td>
<td>140</td>
</tr>
<tr>
<td>LISS-4</td>
<td>G, R, NIR</td>
<td>5.8</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td>PAN (R)</td>
<td></td>
<td>5.8</td>
<td>5</td>
<td>70</td>
</tr>
<tr>
<td>AwIFS</td>
<td>G, R, NIR, SWIR</td>
<td>55</td>
<td>5</td>
<td>700</td>
</tr>
</tbody>
</table>
Indian Remote Sensing – R&D Satellites for Climate / Weather
IRS-P4

Specifications

Altitude 720 Km
Swath 1360 Km
Repetivity 2 days
Orbit inclination 98
Launch May 26, 1999
Sensors MSMR & OCM
<table>
<thead>
<tr>
<th>Sensor</th>
<th>OCM - 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution (km)</td>
<td>0.360</td>
</tr>
<tr>
<td>Swath(km)</td>
<td>1420</td>
</tr>
<tr>
<td>Repeativity(days)</td>
<td>2</td>
</tr>
<tr>
<td>Equatorial crossing (hrs)</td>
<td>12:00</td>
</tr>
<tr>
<td>Spectral bands (nm)</td>
<td>412±10, 443±10, 490±10, 510±10, 555±10, 670±10, 765±20, 865±20</td>
</tr>
<tr>
<td>Radiometric quantisation</td>
<td>12</td>
</tr>
<tr>
<td>SNR</td>
<td>~350</td>
</tr>
</tbody>
</table>

- **Weight**: 65 Kg
- **Frequency**: 6.6, 10.6, 18 and 21 GHz
- **Polarization**: V & H
- **Spatial Resolution**: 40 to 120 Km
- **Temperature Resolution**: 1 K
# Parameters from MSMR

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Channels</th>
<th>Accuracy</th>
<th>Resolution</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>WV</td>
<td>21 with 18 &amp; 10</td>
<td>0.4 g/cm²</td>
<td>50 x 36 Km</td>
<td>0.2-7.5 Kg/cm²</td>
</tr>
<tr>
<td>CLW</td>
<td>21 with 18 &amp; 10</td>
<td></td>
<td>50 x 36 Km</td>
<td>0 - 80 mg/cm²</td>
</tr>
<tr>
<td>SSW</td>
<td>10 with 6,18 &amp; 21</td>
<td>2.0 ms⁻¹</td>
<td>75 x 75 Km</td>
<td>2 - 24 ms⁻¹</td>
</tr>
<tr>
<td>SST</td>
<td>6 with 10,18 &amp; 21</td>
<td>1.5 K</td>
<td>150 x 146 Km</td>
<td>273 - 303 K</td>
</tr>
</tbody>
</table>

R & D Parameters: Rainfall, Sea Ice, Soil Moisture
At present MSMR on Oceansat-1 happens to be only spaceborne microwave sensor with 6 GHz channel, and hence with better SST sensing capability compared to microwave sensors.

MSMR provides SST estimations over global oceans even under cloud cover.

A reasonable comparison of MSMR SST is found with AVHRR SST.
MSMR Wind Speed

OCEANSAT-1 MSMR having 6, 10, 18 and 21 GHz frequencies (V & H Pol.),
provides global ocean surface wind speed with 2 days repetivity. These products
are feeding into ocean state and atmospheric models.

For Temporal Diff. < 1 hour

I. Slope = 0.71, Interc. = 0.87 m/s, R=0.66, (75 km)
II. Slope =0.84, Interc. = -0.31 m/s, R=0.73 (150 km)
MSMR like other microwave sensors is capable of total integrated precipitable water (water vapour) measurements in the marine atmosphere. A reasonably good comparison is found with TMI / SSM/I derived WV.
<table>
<thead>
<tr>
<th>Sensor</th>
<th>OCM - 1</th>
<th>OCM - 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution (km)</td>
<td>0.360</td>
<td>0.360</td>
</tr>
<tr>
<td>Swath(km)</td>
<td>1420</td>
<td>1420</td>
</tr>
<tr>
<td>Repeativity(days)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Equatorial crossing (hrs)</td>
<td>12:00</td>
<td>12:00</td>
</tr>
<tr>
<td>Spectral bands (nm)</td>
<td>412±10</td>
<td>412±10</td>
</tr>
<tr>
<td></td>
<td>443±10</td>
<td>443±10</td>
</tr>
<tr>
<td></td>
<td>490±10</td>
<td>490±10</td>
</tr>
<tr>
<td></td>
<td>510±10</td>
<td>510±10</td>
</tr>
<tr>
<td></td>
<td>555±10</td>
<td>555±10</td>
</tr>
<tr>
<td></td>
<td>670±10</td>
<td>620±10</td>
</tr>
<tr>
<td></td>
<td>765±20</td>
<td>745±20</td>
</tr>
<tr>
<td></td>
<td>865±20</td>
<td>865±20</td>
</tr>
<tr>
<td>Radiometric quantisation</td>
<td>12</td>
<td>---</td>
</tr>
<tr>
<td>SNR</td>
<td>~350</td>
<td>---</td>
</tr>
</tbody>
</table>
Image shows distribution of algal bloom in open ocean waters of Arabian sea. High pigment patches are present in bottom-left corner of image.
Chlorophyll-a distribution in Arabian Sea and Bay of Bengal using IRS-P4 OCM data 29 & 30 January 2000
FUTURE INDIAN METEOROLOGICAL SATELLITES

- OCEANSAT-2 (2008)
- INSAT-3D (2008)
- MeghaTropiques (2008)
OCEANSAT–2

OCM, Scatterometer (Ku Band)

Vector Winds
Aerosol
INSAT - 3D

Improved Understanding of Mesoscale Systems

6 Channel IMAGER
- Spectral Bands (µm)
  - Visible: 0.55 - 0.75
  - Short Wave Infra Red: 1.55 - 1.70
  - Mid Wave Infra Red: 3.80 - 4.00
  - Water Vapour: 6.50 - 7.00
  - Thermal Infra Red – 1: 10.2 - 11.3
  - Thermal Infra Red – 2: 11.5 - 12.5
- Resolution: 1 km for Vis, SWIR
  4 km for MIR, TIR
  8 km for WV

19 Channel SOUNDER
- Spectral Bands (µm)
  - Short Wave Infra Red: Six bands
  - Mid Wave Infra Red: Five Bands
  - Long Wave Infra Red: Seven Bands
  - Visible: One Band
  - Thermal Infra Red – 1: 10.2 - 11.3
  - Thermal Infra Red – 2: 11.5 - 12.5
- Resolution (km): 10 X 10 for all bands
- No of simultaneous sounding per band: Four
**NINETEEN CHANNEL ATMOSPHERIC SOUNDER**

A-19 channels atmospheric sounder for derivation of vertical temperature and moisture profiles with a resolution of 10 km at Sub-Satellite and capability of full disk coverage every half-hour is proposed on board INSAT 3D.

**SIX CHANNELS IMAGER ON INSAT 3D**

<table>
<thead>
<tr>
<th>Channel No.</th>
<th>Wavelength Band (um)</th>
<th>Resolution (Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.55 - 0.75</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1.55 - 1.70</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>3.7 - 3.95</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>6.5 - 7.1</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>10.3 - 11.3</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>11.3 - 12.5</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Channel No.</th>
<th>Central Wavelength in um</th>
<th>Principal absorbing constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.71</td>
<td>CO-2 band</td>
</tr>
<tr>
<td>2</td>
<td>14.37</td>
<td>CO-2 band</td>
</tr>
<tr>
<td>3</td>
<td>14.06</td>
<td>CO-2 band</td>
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<tr>
<td>4</td>
<td>13.96</td>
<td>CO-2 band</td>
</tr>
<tr>
<td>5</td>
<td>13.37</td>
<td>CO-2 band</td>
</tr>
<tr>
<td>6</td>
<td>12.66</td>
<td>water vapor</td>
</tr>
<tr>
<td>7</td>
<td>12.02</td>
<td>water vapor</td>
</tr>
<tr>
<td>8</td>
<td>11.03</td>
<td>window</td>
</tr>
<tr>
<td>9</td>
<td>9.71</td>
<td>ozone</td>
</tr>
<tr>
<td>10</td>
<td>7.43</td>
<td>water vapor</td>
</tr>
<tr>
<td>11</td>
<td>7.02</td>
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<tr>
<td>12</td>
<td>6.51</td>
<td>water vapor</td>
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<tr>
<td>13</td>
<td>4.57</td>
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<td>14</td>
<td>4.52</td>
<td>N-2 0</td>
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<tr>
<td>15</td>
<td>4.45</td>
<td>CO-2</td>
</tr>
<tr>
<td>16</td>
<td>4.13</td>
<td>CO-2</td>
</tr>
<tr>
<td>17</td>
<td>3.98</td>
<td>window</td>
</tr>
<tr>
<td>18</td>
<td>3.74</td>
<td>window</td>
</tr>
<tr>
<td>19</td>
<td>0.69</td>
<td>vis</td>
</tr>
</tbody>
</table>
Megha Tropiques

For studying water cycle and energy exchanges in the tropical belt

Low inclination (20º) for frequent simultaneous observations of tropics
- Water vapour
- Clouds
- Cloud condensed water
- Precipitation
- Evaporation

SAPHIR
- Water vapour profile
- Six atmospheric layers up to 12 km height
- 10 km Horizontal Resolution

SCARAB
- Outgoing fluxes at TOA
- 40 km Horizontal Resolution

MADRAS
- Precipitation and cloud properties
- 89 & 157 GHz: ice particles in cloud tops
- 18 & 37 GHz: cloud liquid water and precipitation
- 23 GHz: Integrated water vapour

AND ...???

Contributing to Global Precipitation Mission (GPM)
**Mission Objective**

- Understanding the water cycle and energy exchanges that characterize the Tropical Convective System (TCS)

- Improving models for weather prediction particularly of cyclones, floods etc.

**Our Objective**

- Retrieval and Validation of rainfall over ocean and land and their Assimilation in Atmospheric & Oceanic Models.

- Understanding the Interannual variation of rainfall in relation to the Intraseasonal oscillation (ISO)