

# Use of charged coupled device payload on INSAT-2E for meteorological and agricultural applications

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*Successful commissioning of INSAT-2E satellite provides unique opportunity to the meteorologists for continuous monitoring of cloud cover pictures over India and adjoining land and sea areas at very high spatial resolution in three spectral bands. A new type of payload called charged couple device (CCD) has been flown for the first time on a geostationary satellite located over Indian region. The first few pictures obtained from the satellite are of very good quality and show fine structures of different weather systems. This new type of data has a number of meteorological and agriculture-related applications and the present paper brings out possible applications of this data.*

WITH the successful launch on 2 April 1999 of the last satellite of INSAT-2 series (INSAT-2E) fabricated indigenously and subsequent completion of in-orbit-tests of various payloads, from MCF Hassan on 26 April 1999, India Meteorological Department (IMD) has started getting a new data source for meteorological applications. A charged coupled device (CCD) payload on-board this satellite provides for the first time an opportunity for continuous surveillance of cloud cover and surface features during daytime at a very high spatial resolution. This capability combined with the unique combination of three channels in the visible, near IR and short wave IR bands makes CCD a very versatile instrument for a number of meteorological applications. A few CCD images have been received in IMD and preliminary findings show their potential use for many applications. The present paper brings out all possible applications of CCD payload.

## Description

A CCD camera is mounted on the earth viewing face of INSAT-2E satellite to provide imageries in visible band at 0.62–0.68  $\mu\text{m}$ , near IR band at 0.77–0.86  $\mu\text{m}$  and a short wave IR band at 1.55–1.69  $\mu\text{m}$ . The ground resolution at the sub-satellite point is nominally 1 km  $\times$  1 km and in the normal mode of operation the instrument is designed to scan a  $10^\circ \times 10^\circ$  field of view which corresponds to a ground area of about 6300  $\times$  6300 km.

Scanning is accomplished by an 8 inch mirror mounted at  $45^\circ$  to the optical axis of an 8 inch telescope which gathers radiation emanating from the earth's surface and clouds. The band separation is achieved through a

dichroic beam splitter and bandpass filters placed before detectors. Three linear arrays of CCDs of 300 elements for each channel are placed in the split focal plane of the optical system. The orientation of the long-axis of the devices is in the N–S direction and the imagery is generated by two-dimensional scanning of the field of view by the scan mirror. A field of  $10^\circ$  in N–S direction is covered by 25 scan lines in E–W direction. Every E–W scan of mirror will generate 900 video lines of imagery corresponding to 300 picture elements in each of the three spectral-bands. The video outputs from the CCDs are amplified individually, DC restored and digitized by 10 bit A/D converters.

The digitized data from all three bands along with other auxiliary data are formatted, randomized and transmitted in extended C-band by the CCD transmitter on-board the satellite at a data rate of 1.288 Mb/sec.

## Applications

A wide variety of applications are possible due to fine resolution and continuous temporal coverage provided by the CCD camera. Some of the important applications are discussed below.

### Tropical cyclone analysis

Initiation of cyclone development over the ocean is generally indicated by the presence of curved cumulus lines and their interaction with deep layer convection. Such lines can be better resolved in higher resolution imagery. During the life cycle of a storm, cloud features appear to change in surges and variability in the cyclone cloud pattern is partly due to convective scale activity

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within the cyclone which is better observed in high resolution images. The fine structure of the eye wall region of the cyclone is also better resolved in high resolution images. There are convective cores embedded in the eye wall whose spatial extent is of the order of 1 km or less. High resolution satellite imagery could also enable monitoring of tornadoes spawned by cyclones.

Hence with the availability of 1 km resolution visible imagery, commencement of cyclogenesis can be detected at an early stage, and the fixation of centre and the intensity estimation of the cyclone can be done more accurately. The improved capabilities will provide better cyclone warning services for the coastal populations.

#### *Local severe storms*

One of the most important factors responsible for generation and maintenance of deep convection leading to local severe storm formations, is the cumulus scale interactions which can be observed only through high resolution imagery. Such interactions are sometimes seen as arc clouds forming at thunderstorm outflow boundaries. These arc clouds have a width of 1–2 km and they sometimes interact with another arc boundary or other cloud fields to initiate severe convection, which gives rise

to adverse weather on very small spatial and temporal scales. Monitoring of such events is very important for issuance of intense precipitation advisories, aviation and flood forecasting applications. An example of one such imagery is shown in the CCD image taken at IMD, New Delhi on 23 May 1999. Thunderstorm clouds are seen off the west coast of India (Figure 1).

Observation of convergence lines is another important aspect for monitoring local severe storms. These lines can be resolved in high resolution imagery almost right from their inception stage.

#### *Heavy rainfall estimation*

For precise estimation of heavy rainfall from convective clouds high resolution visible channel imagery provides very important clues. In particular, the overshooting cloud tops which play a vital role in heavy rainfall leading to flash floods can be very well observed in high resolution imagery. Such observations are useful inputs to the heavy rainfall estimation models and are helpful in improving the accuracy of intense precipitation advisories being issued operationally by the department. This has useful applications in flash flood forecasting.

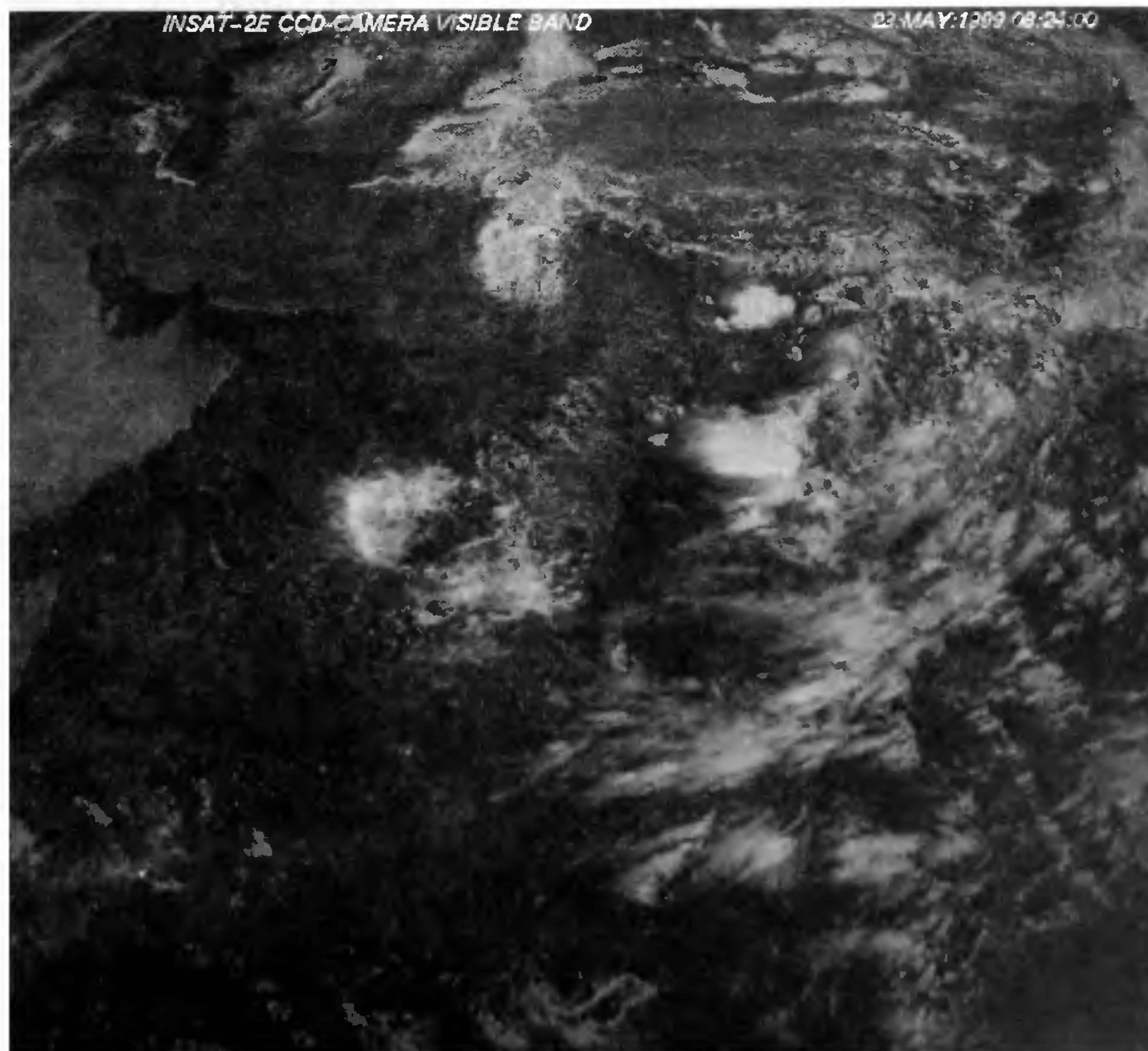


Figure 1.



*Mountain waves observations*

These waves occur on the leeward side of high mountains under certain meteorological situations. There are certain areas of very severe turbulence associated with large amplitude mountain waves. Observations of such waves are, therefore, very important for aviation forecasting. Due to the very small spatial scales of clouds associated with these waves, they can be better observed in the high resolution imagery.

*Sea breeze front*

Sea breeze front is an important mesoscale circulation which is sometimes found to be responsible for development of severe convection, particularly during afternoons along the Western Ghats on the west coast of India. Since sea breeze is a small-scale phenomenon, it can be observed much better with high resolution cloud imagery. The interaction of sea breeze with the already existing field of cumulus cells over an area sometimes triggers severe convection. High resolution cloud imagery is the only tool available for observations of such phenomenon.

*Snow detection*

Observations of aerial extent of snow cover are important for better management of water resources. These data are also one of the important inputs for long range monsoon forecast models. Snow estimation can be done with greater accuracy with higher resolution visible imagery. Inclusion of the 1.55–1.7  $\mu\text{m}$  band facilitates discrimination between snow and clouds because of the high sensitivity of this band to snow and water bodies on the earth's surface.

*Cloud motion vectors derivation*

Due to the increased resolution of 1 km in visible channel imagery, better identification of low level tracers can be done for cloud motion vectors (CMVs) derivation. This will improve the accuracy of the derived CMVs. Low wind speeds can be derived more accurately with 1 km resolution imagery. This has useful applications for improvement in the analysis of low level wind flow charts which are important for operational meteorology.

*Climate studies*

Surface albedo plays a critical role in the earth's climate system as it controls the solar energy observed by oceans

and continents. Of particular importance to climate sensitivity studies and projections of the climate under greenhouse warming conditions is the difference between cryospheric albedos (snow, sea ice) and the background ice/snow-free albedos. This difference determines the magnitude of the ice/snow albedo feedback. For mapping and monitoring of the distribution and variations of surface albedo, high resolution visible imagery, particularly in multi-channels, is very useful.

In addition to the various meteorological applications discussed above, the multi-channel 1 km resolution CCD camera system on-board a geo-stationary platform has some interesting applications in the field of remote sensing/earth resources studies. These are given below.

The earth resource satellites are normally designed for sun synchronous near-earth orbit. Such near-earth orbits, while ideal for providing high spatial resolution, have limited revisit capability. Sensors with wide swath like AVHRR on-board NOAA though provide a better revisit capability, do not have frequent nadir-passes over a given area of interest (approximately 9 days considering a single NOAA satellite). There are large geometric distortions and suitable corrections for varying view angle and atmospheric effects are required. Also, NOAA does not provide capability for constant monitoring of important phenomena/events and information, dynamic in nature. A geosynchronous platform provides such an opportunity. Use of such a platform for natural resource surveys has not been considered earlier since spatial resolution provided from such platforms has been too coarse for meaningful resource applications. However, with the advancement of technology it is now feasible to provide data with about 1 km spatial resolution, which opens up possibilities for carrying out some of the applications.

The geosynchronous orbit enables taking imagery at any desired time. Cloud cover is one of the major hindrances in getting imagery from an optical sensor. It is possible either by changing the time of observation or the date of observation to get cloud-free observation of any place with temporal resolutions of a few days even during monsoon. Observations when carried out at different times can be normalized for sun angle.

*Crop description*

Depending upon the crop calendars/growth cycles of co-existing confusion crops there is a specific period for which a crop under observation can be discriminated with minimum error. Many times imagery during that optimum period is not available either because the satellite pass does not take place or even if it takes place there may be cloud cover. Studies have shown that for large single-crop



dominated areas 1 km resolution data can provide regional/state level acreage estimates. The new CCD sensor is, therefore, likely to provide possibilities of regional level wheat acreage estimation for the states of Punjab, Haryana and western UP and for rabi, sorghum acreage estimation in central Maharashtra, etc.

It has been observed that for making estimate of rice in southern and eastern India, it is difficult to get cloud-free images from low earth orbiting satellites. Probability of getting cloud-free images with geosynchronous sensor during the peak vegetative period of crop is very high. Using 1 km spatial resolution data of NOAA, state level rice acreage estimation for Orissa has already been successfully carried out. It may be possible to develop some techniques for accurate estimation of acreage using combination of a coarse resolution data information over a large area and the fine resolution data information over same area and the fine resolution (Landsat/IRS) over limited areas where some success has been achieved in getting information without cloud cover. The crop yield estimation requires a growth profile to find out the maxima of the curve which seems to be more closely correlated with the yield. It is difficult to generate such profiles since optimum number of points on the curve are difficult to get due to poor temporal resolution and cloud cover. In this case a geosynchronous sensor will be helpful. Studies carried out using NOAA-AVHRR have shown that area under such a growth profile curve is a good indicator of yield. Data from geosynchronous sensor will allow users to generate such profiles and also keep updating these data as the crop grows. This may provide a means of improving yield prediction accuracy and also help constantly monitoring crop condition.

Geosynchronous sensor will allow daily monitoring of crop emergence, growth, its vigour and harvesting operations. This will be helpful for forecasting market arrivals, estimation of losses due to harvest-time rains, etc. It will also help monitoring of crops in largely single-cropped regions for mapping of regional extent and spread of diseases, losses by climatic episodes (e.g. hailstorms, etc.).

### *Drought monitoring*

Currently, for the purpose of drought monitoring, NOAA images for 2 weeks are integrated to produce a cloud-free image. This will also permit a closer monitoring of the drought situation.

### *Flood mapping and damage assessment*

Floods generally occur during the monsoon season in India when it is difficult to get cloud-free data from IRS series of satellites. Possibility of imaging the land mass more frequently with CCD sensor would provide much higher probability of getting cloud-free data. It should be possible to monitor the progress of floods and forecast likely areas to be inundated and also monitor the retreating process of water. Choice of NIR band along with red provides better contrast for water delineation and for assessing damage to cropped land.

### **Conclusion**

The CCD payload provided on the recently launched INSAT-2E satellite has opened up many new areas in operational meteorology and research related applications. The new type of data provided by this payload will also be useful for some agrometeorological and meteorological applications. The CCD payload is unique in the sense that it provides imagery with very high spatial and time resolutions in a few spectral bands not currently available on any other geostationary satellite. Further work has to be done at IMD and at other centres in order to make use of this new data source for specific applications.

1. Report of the TAG sub-group on Meteorological imaging Instruments for INSAT-2E, IMD document, January 1994.
2. Preliminary Design Review Document for CCD Payload of INSAT-2E, ISAC Document No. ISRO-ISAC-INSAT-2E-RR-0010, December 1996.