Applications of water-vapour imagery received from INSAT-2E satellite

R. C. Bhatia, Brij Bhushan and V. Rajeswara Rao

Successful commissioning of indigeneous satellite INSAT-2E in May 1999 has provided a new opportunity to the Indian meteorologists. It will now be possible to obtain continuous images in water-vapour channel with a spatial resolution of 8 km at sub-satellite point over India and adjoining oceanic areas. This new data source available from INSAT-2E satellite will be very useful for a number of meteorological applications as it will provide for the first time information about water-vapour distribution in the upper-air encompassing large oceanic areas generally not covered by conventional means of observations. The paper brings out physical basis of interpreting water-vapour images and possible areas of applications in day-to-day work of operational meteorology.

THE successful commissioning of the recently launched INSAT-2E satellite has ushered in a new era of meteorological applications. A water-vapour (WV) channel has been incorporated for the first time on the INSAT series of satellites. The WV channel located in the absorption band from 5.7 to 7.1 μm in the infrared region of the absorption spectrum is used for detecting presence of moisture in the middle levels of the atmosphere. This new type of data has got many useful applications in operational meteorology. This data is also very useful for NWP-related applications. The present paper brings out physical basis for interpreting WV channel data and its meteorological applications for operational day-to-day use and research in meteorology.

Technical characteristics

One of the meteorological payloads onboard INSAT-2E is a three channel very high resolution radiometer (VHRR) comprising visible channel in 0.55–0.75 μm band, a WV channel in 5.7–7.1 μm and a thermal infrared channel in 10.5–12.5 μm band. The heritage of INSAT-2E VHRR is from the similar payloads flown on the two earlier satellites of INSAT-2 series, viz. INSAT-2A and 2B, with certain modifications necessary for accommodating the WV channel. Main modifications have been done in IR channel optics, radiant cooler patch, routings of IR detector output leads through cooler and addition of processing and formating electronics for the WV channel. The field of view of WV is identical to that of IR channel, i.e. 224 micro radians corresponding to a ground resolution of 8 km at sub-satellite point. Noise equivalent temperature difference (NEDT) of the WV channel is specified as 0.5 K at 300 K. All other characteristics of INSAT-2E VHRR are similar to the VHRR already flown on INSAT-2A and 2B satellites.

Physical basis of interpretation

The WV channel imagery obtained in the band 5.7–7.1 μm is based on the strong absorption of emitted terrestrial radiation by atmospheric WV. The presence of WV in the atmosphere makes it very opaque in this particular region of the spectrum. However, if an atmospheric column is very dry, the atmosphere will be transparent. This inter-alia means that a weak signal received by the sensor in this band is indicative of the fact that much of the upwelling radiation has been absorbed by high concentration of WV. A strong signal at the satellites's radiometer indicates a very dry atmosphere. The images are processed in such a way that a moist atmosphere is shown as white and a very dry atmosphere is shown as black. The white shades are, therefore, generally high clouds, cirrus on top of deep tropical convection. Lighter shades of grey are indicative of the presence of moisture in the middle levels of the atmosphere. Dark areas generally indicate very dry atmosphere aloft. The transmittance characteristics of the atmosphere in the band 5.7–7.1 μm are such that the data received from the channel provides information about moisture which resides in the middle and upper atmosphere (between 600 and 300 hpa levels). Hence there is generally, a high correlation between the presence of cloud as indicated by visible and IR channels and high WV concentrations as seen from the WV channel imagery. The WV imageries also indicate the presence or otherwise of moisture in cloud-free areas.

The precise interpretation of imagery obtained in the 6.7 μm channel requires understanding of the factors

The authors are in the India Meteorological Department, Mausam Bhavan, Lodi Road, New Delhi 110 003, India.

Figure 1.

contributing to radiance measured at the satellite sensor which is converted to brightness temperature or to image gray shade. Radiation reaching the satellite may be from cloud tops, WV, earth's surface or a combination of the three with different weightages depending upon atmospheric conditions. Surface contribution is generally negligible in the 6.7 μm band which is more sensitive to the smaller amounts of moisture commonly at higher altitudes. Three basic factors affecting the amount of radiation measured in 6.7 μm band are:

(i) The amount of WV present in the path of radiation. Higher amounts of moisture in the radiation's path give rise to more absorption of the radiation emanating from lower levels. This results in colder brightness temperature under the generally observed condition of decreasing air temperature with height.

(ii) The vertical location of moisture in the atmosphere. Moisture located at higher altitudes gives rise to colder brightness temperatures. However, moisture in the higher less dense air, absorbs smaller amounts of radiation compared to that at lower levels.

(iii) The vertical change of air temperature in the atmosphere. In order to produce different brightness temperatures (BT) by varied amounts of moisture in the atmosphere, large vertical change of air temperature is necessary. Under certain atmospheric conditions, changes of moisture cannot produce large changes in BT. On the other hand, sometimes large BT changes (larger gray shade variations) can be produced by the same moisture distributions, particularly at low latitudes where there are large gradients in vertical distributions of temperature.

Because of the above mentioned complications, there is no single simplified relationship between atmospheric conditions and the variations of gray shades as observed in the images of WV channel. However, useful inferences can be drawn from a precise understanding of various contributing factors.

Applications

Imageries in the WV (5.7–7.1 μm) band greatly enhance insight into atmospheric circulation and humidity in the middle troposphere. Cloud patterns which appear separated from each other in the visible and thermal IR images can be recognized as parts of the same air mass in corresponding WV images.The nature of WV distribution results in extensive and continuous structures in WV band imagery. The motions of WV band structures are thus practical tracers to the winds in the region occupied by them. WV structures are thus able to delineate jet cores where there are no visible clouds. Their height assignment through the measured brightness temperatures is also more accurate unlike in thermal IR where elimination of sub-pixel clouds and discontinuities can be a serious problem. Due to the extensive nature of WV structures, middle tropospheric winds can be extracted at synoptic scale in cloud-free regions as well as regions of low clouds with almost uniform coverage. The delineation of moisture features in images which appear in the form of plumes, is also of great significance in predictions of heavy rainfall, the phenomena which initiate flash floods. A sample of WV imagery taken from INSAT-2E is shown in Figure 1. Some of the specific applications are as follows:

Forecasting tropical cyclone motion

The 6.7 μm channel WV imagery has been found to be of immense use for viewing the cloud processes associated with the movement of tropical cyclones. It is generally noticed that the recurvature of a north-westward moving tropical cyclone occurs under the influence of an approaching trough. Such interactions are very well brought out in the WV imagery. As the cyclone approaches the upper-air trough, moisture envelope of the cyclone builds northwards. However, if there is significant moisture dissipation on the north side, it indicates possibility of a westward turn. Such interactions, which are well brought out in the WV imagery, are useful tools available to the analysts to forecast motion of tropical cyclones.

Water-vapour plumes

Studies of many heavy precipitation cases have shown that there are several factors common to their occurrence. Two among them, i.e. WV plumes and cyclonic circulations are generally evident in the WV imagery. WV plume appears as a tongue or stream of moisture which can originate in the tropics, sub-tropics or mid-latitudes. The presence of a plume in combination with other mechanisms is often a major factor in enhancing rainfall amounts, especially if it originates in the tropics. Cyclonic circulations are also easily identified in the WV imagery and play a vital role in producing heavy rainfall and severe weather, they may or may not be associated with a WV plume.

Identification of moisture boundaries

One of the most important uses of WV imagery to the synoptic analyst is the identification of boundaries between different moisture regimes. Such boundaries help to identify deformation zones, locations of jet streams and other synoptic scale systems such as troughs and ridges. These are, therefore, useful aids available to the analysts for improving the analysis of weather charts in the data gap regions.

Understanding evolution of weather phenomena

Changes in observed brightness temperature with time provide very useful clues to the understanding of physical processes leading to evolution of various types of weather systems. This has interesting applications for research in atmospheric sciences.

Tropical applications

Water-vapour imagery is useful for analysis and forecasting at tropical latitudes. Considering the low density of upper-air data over large tropical areas, the WV imagery can be useful for improving the upper-air analysis which could be directly applied to improved wind information in support of aviation services. Since the upper-air circulation systems and their changes significantly influence surface weather conditions, WV images can be used to improve local weather forecast.

Conclusions

INSAT-2E satellite provides a new opportunity to explore the atmosphere over India and adjoining areas from an entirely new perspective, not attempted so far. The WV channel imagery received from this satellite provides useful clues to the operational meteorologists for day-to-day applications leading to improved understanding of different weather systems. Most of the published research work so far on the subject do not make use of WV imagery data over the longitude belt 60°E to 120°E. INSAT-2E will, therefore, provide for the first time the WV data over the vital regions of interest to Indian meteorologists and will open up lot of potential areas of research and operational meteorological applications.

1. Weldon, R. B. and Holmes, S. J., NOAA Technical Report, NESDIS 57, 17 April 1991, US Department of Commerce.