*Indian J. Met. Geophys.* (1971), 22, 365-368

551.507.362.2 : 556 : 551.579

# Meteorological satellites—a major hydrological tool

S. BANERJI

*National Committee for International Hydrological Decade,*
*C. S. I. R., New Delhi*

ABSTRACT. Hydrological forecasting includes the aspects of assessment of flows under the different regimes of the river which are very well related with the seasonal precipitation and has a great impact on all the aspects of national activity where water is needed for their development. Hydrology is intimately connected with the atmospheric processes, the movement of cyclones and depressions and the onset and withdrawal of monsoon. If advance informations on these weather aspects are available to the Hydrologists, it would save the country from many a catastrophy. As an example, the case of Damodar flood of September-October, 1959 may be cited. Similarly many multipurpose dams could be utilised more economically for controlling floods.

Another hydrological aspect, *i. e.*, low flow is important for the agriculturist. If, through a proper interpretation of satellite pictures, he is assured of some extra water associated with the passage of disturbances he can draw little more liberally from the rationed supply of water at the crucial period of the crop development.

Through proper interpretation of the satellite pictures of snow cover over inaccessible areas of Himalayas we will be filling a big gap in the understanding of our water balance. In addition the cooperation which we can render through analysis and rapid transmission of satellite information to neighbouring countries will be a great contribution.

## 1. Introduction

Since the launching of the meteorological satellite TIROS I in April 1960 more than a million photographs of the earth and its associated cloud, ice, snow cover would have been received from the weather satellites. Although the earlier photographs from TIROS were not very useful because of their limited picture storage capacity and poor resolution, those developed later with higher resolution camera system of much higher dynamic ranges have proved of immense benefit for meteorological as well as hydrological purposes; in the latter the emphasis was on snow hydrology. The United States operational programmes were conducted to develop satellite snow surveillance capability. The importance of these weather satellite as remote sensors for meteorological system and parameters of importance to the various hydrological aspects particularly in hydrological forecasting has also been developed in the USA. In this article, an attempt is made to highlight the important role that correct interpretation of weather satellite pictures can play in ameliorating human sufferings directly resulting from the various hydrological problems.

## 2. Practical utility of satellite pictures in the construction and operation of multipurpose dams

The construction of multipurpose dams like the Nagarjunasagar Dam on river *Krishna* or the Bhakra Dam on *Sutlej* takes several years. During this construction by parts, a certain onrush of flood waters not only disrupts the progress, but sometimes works to the detriment of the construction already carried out. Such dangers are still more in multipurpose dams where power houses are constructed downstream for production of energy. If information through satellite pictures of meteorological systems likely to cover the watersheds of such dams can be made available to the construction engineers well in time, much of the expenditure due to the damage can be saved. NIMBUS satellite and ESSA operational satellites have been found to be helpful in USA and Canada for these projects.

The use of weather satellites in the operation of water resources projects, however, present immense possibilities of very efficient operation leading to optimum water utilisation and flood production. For example, during the low flow

season, satellite pictures may indicate the possibility of the command area of a dam coming under the influence of meteorological system which may cause sufficient precipitation so as to increase the inflow into the dam. The extent to which such an extra supply can be of help is, however, indicated through satellite pictures and satellite nephanalysis. The operational engineer can take liberty in releasing more water for agricultural purposes at the critical period before the monsoons so that the overall efficiency of the multipurpose dams in the production of power and providing irrigation facilities for agriculture can be optimised. In the absence of such information, the operation engineer will not take any chance to release water below the minimum storage level, no matter, howsoever detrimental this non-release of irrigational waters may be to the crops standing in the fields down-stream. This was so, as far the operation during the low flow conditions were considered. The flood control operations have no less benefit to derive from satellite nephanalysis and pictures of moving weather systems. A case study may be cited in this connection. Weather was mainly dry in the Gangetic Plain during the concluding phase of the monsoon in 1959. After 12 September till the end of the month, practically dry weather prevailed over the whole of Bihar, West Bengal and the adjoining areas. All the three dams in the Damodar complex were, therefore, kept filled to the brim by the middle of September. The dry spell was broken on 30 September 1959, when rains started over Gangetic West Bengal and Chota Nagpur plateau under the influence of a severe cyclonic storm from the Bay of Bengal whose centre was located on the 30 morning, 250 km southeast of Calcutta. Crossing the coast near Balasore, the storm rapidly weakened and moved northwest between 1 and 2 October and caused very heavy precipitation in the catchments of river *Mor*, *Ajoy*, *Bhagirathi* and *Damodar* basin between 30 September and 2 October. As already stated, the dams in the Damodar area particularly those in the lower reaches were kept full and when the effect of this storm was still being felt in the lower reaches which were already in the grip of moderate to severe floods, some releases from the dam which were unavoidable for the safety of the dams, had to be made worsening the flood situation in the lower reaches. If the satellite crossing over the Indian sub-continent had been commanded to give pictures of the storms when they were still in the formative stage between Andamans and the Indian coast and weather radars could have helped in indicating the final position and movement of the storm, flood control operation of the dam could have been made very judiciously without aggravating the flood situation in the lower reaches and still maintaining the economic level of water in the reservoir.

### 3. Satellite pictures in water resource and water balance studies

The possibility of use of satellite pictures in the management of our water resources projects was discussed above. The other field in which these have proved of immense usefulness and high economic import was in the assessment of snow and glacial reserves of a country. The advanced countries like USA and Canada have utilised weather satellites for this purpose to a great extent (Popham 1966). On a rough estimate the total volume of frozen water in the global land area is $30 \times 10^6$ km$^3$ locked up as ice and snow, though most of it is in and around the poles (Nace 1969). We have no assessment of our snow and glacial resources. It is understood that the glacial and snow reserves in areas with variant topography can be assessed with ease. This technique has been used to determine snow line in Himalayas in Gemini V photographs (IHD/WMO Report). It has been recognised that so far as India is concerned its glacial masses are in areas where sharp topographic features make any human attempt on their physical assessment well nigh impossible because of their inaccessibility. It should be immediately apparent to us that here is a field in which we need enormous resources if we want complete glaciological surveys made through expeditions, but survey is possible through satellites where we can utilise them at low cost by making the passing satellite to focus their cameras to assess our snow and glacial reserves. It is understood that application of weather satellite in the determination of snow-melt in mountainous terrains had been operational in western U.S.A. in the determination of areal extent, depth and density of snow pack and its water equivalent. Some snow surveys carried out in this country with the help of Dr. Church by joint collaboration with Central Water & Power Commission and India Meteorological Department in 1946-47 indicated a 5-10 per cent increase in the flow in our perennial northern rivers due to snow-melt (in the pre-monsoon period). When we are considering millions of cusecs of runoff during the monsoon season, the amount of runoff obtained from snow-melt may be insignificant, but in terms of economic benefits to the standing crops that may be on the point of wilting, this supply can be of immense benefit. Also the extent and degree of snow-melt which is a direct result of the variation in snowfall in areas below the permanent snow lines could give a very early indication in the management of our irrigation if it is possible to interpret the pictures of our snow reserves properly. The large scale fluctuation in the glaciological and snow

reserves, affect the heat budget of the area and this is presumed to have a large influence on the onset of monsoon.

Besides the assessment of ice and glacial resources through satellite images these pictures are also useful to hydrologists in inaccessible areas, in depicting the watershed morphology which determines the course of the river and its flood flow during the flood season. Although this particular aspect (Colwell 1968) has not yet been widely utilised, the possibility of such a development is very bright and which in turn will spare untold sufferings of the people occupying flood plains in the lower reaches. India has built 12000 km of embankments to save the population occupying the flood plains but complete safety cannot be ensured to them unless the information of flood formation in the water-shed area is known fairly ahead of their actual onslaught and warning could be given. This is particularly applicable to rivers over the region from Bihar to Assam. Meteorologists know all too well that associated with a break-monsoon synoptic situation, heavy precipitation results in the water-shed of our rivers like *Gandak*, *Bagmati*, *Kosi* and *Brahmaputra* culminating in enormous flood flow about which we could do little. We would not feel so helpless in anticipating the onslaught of floods if satellite pictures are available to us.

Very high resolution cameras taking pictures from levels lower than 150 nautical miles have also been utilised to assist the hydrologist in another aspect, namely the geophysical exploration of groundwater. This field has, however, not been prominently emphasised in the developed countries because of their affluence in commanding aerial flights to obtain aerial mozaics for groundwater exploration.

#### 4. Hydrological Forecasting

Last but not the least is the immense possibility for this country in utilising satellite pictures for hydrological forecasting. This is a field which has been highly emphasised by the W.M.O. in its World Weather Watch programme whose plans have been elaborated in 2 streams. The first stream proposal will improve the information available to all countries of the world for water resources studies and second presents the possibility of inclusion of water resources management aspects. In the hydrological forecasting it will not only suffice to indicate whether the area is going to have low or high flow but the volume or level of flows have also to be indicated for the protection of life, property and agricultural commodity. Through the application of satellite infrared imagery determination of large scale evapotranspiration losses which is of direct importance to the water budget of large areas has also been envisaged by the World Weather Watch. The possibility of monitoring soil moisture conditions (Parther 1965) qualitatively, in the outcrop of the watershed through improved infrared cameras (Rose & Thomas 1968) before the flood formation processes commence opens a field of great promise for our hydrologists in issuing flood warning for the north Indian rivers. Since the country is now embarking upon the project of establishing a flood forecasting system, our hydrologists will highly benefit from the development of satellite meteorology for hydrological forecasting.

#### 5. Conclusion

Hydrological events are random in nature and many even remain unrecorded. In view of the short period or inadequate hydrological data, even results obtained through application of stochastic or deterministic approaches to this data are fraught with danger let alone the evaluation of statistical probability of recurrences. There can be no substitute for actual observations.

In the above discussions, an attempt has been made to highlight the hydrological aspects when exploitation of weather satellite pictures and infrared photometry have immense potentialities of practical use. Assessment of our ungauged glacial and snow resources, aerial extent of snow pack, its depth, density and water equivalent in assessing snow-melt, use of flood formation pictures of the satellite and assessment of mass evaporation and heat budget through infrared imagery by

no means exhaust the list that hydrology would seek to exploit of weather satellites. In bringing these facts an attempt has been made to highlight the hydrological aspects on which the weather satellites would be called upon to assist the scientists. The challenge of operational and interpretational difficulties of weather satellites have to be overcome to our best advantage.

*REFERENCES*


| | | |
|---|---|---|
| Colwell, R. N. | 1968 | Remote Sensing of Natural Resources, *scient. Am.*, **128**. 1, p. 55. |
| Nace, R. L. | 1969 | *Water, Earth & Man* by R. J. Chorley, (Methuen). p. 40. |
| Parker, D. C. and Walff, F. M. | 1965 | *Remote sensing*, International Sci. & Tech., 43/20. |
| Popham, R. W. and Flanders, A. F. | 1966 | Second Progress Rep. on Satellite applications to Snow Hydrology—Proc. 23rd Eastern Snow Conf., Hertford (Con.). USA. |
| Rose, C. W. and Thomas, D. A. | 1968 | Remote sensing of land surface temperature and some application of land evaluation, *Land Evaluation* by G. A. Stewart (Macmillian-Melbourne). |
| W.M.O | 1968 | *Satellite application to snow Hydrology*, Rep. on WMO/IHD Projects. |