

Satellite data in monsoon research

PRANAV S. DESAI

Space Applications Centre, ISRO, Ahmedabad

सं. - भारतीय अंतरिक्ष अनुसंधान संगठन का अंतरिक्ष अनुप्रयोग केन्द्र विभिन्न क्षेत्रों में उपग्रह प्रेक्षण के अनुप्रयोग का अन्वेषण और प्रदर्शन करने में व्यस्त रहा है। इस समीक्षात्मक शोधपत्र में मानसून अनुसंधान में उपग्रह आंकड़ों के उपयोग, सेक (SAC) और इसरो (ISRO) मुख्यालय में हो रही प्रगति का वर्णन किया गया है। बृहत् में अध्ययन स्वस्थान आंकड़ों के संयोजन में उपग्रह आंकड़ों का प्रयोग करते हैं।

ABSTRACT. The Space Applications Centre of the Indian Space Research Organisation is engaged in exploring and demonstrating the application of satellite observation in various disciplines. In this review paper, the utilisation of satellite data in monsoon research, in progress at SAC and ISRO Headquarters, is described. Most of the studies use satellite data in combination with *insitu* data.

1. Introduction

Over the last decade, a variety of studies of aspects of monsoon have been conducted at SAC/ISRO, using satellite data, such as : monitoring the performance of monsoon, examining factors associated with intra-seasonal fluctuations of monsoon, searching for onset prediction indices, assessing the impact of satellite data in numerical medium-range monsoon prediction, attempting seasonal monsoon rainfall prediction and interannual scale monsoon prediction, studying oceanic heat budget, etc. The present paper is a brief review of the efforts and results in the above topics.

2. Monitoring of monsoon

In a study of the moisture supply of monsoon, the cross-equator-wind-index over the western equatorial Indian Ocean was found to provide a good "pulse" for the onset and activity of monsoon. The significant rise on onset, the gradual decay towards the break period, and a rapid revival thereafter of monsoon activity were all reflected in this index and in fact the latter preceded the former in the variations by a week or so.

A more quantitative and "practical" aspect of monsoon performance is of course the rainfall it brings to different sub-divisions of India. The INSAT digital data are capable of providing rainfall distribution by analysis of the brightness (visible channel) and the temperature (thermal infrared channel) of clouds and by tracking their growth, merger, etc in frequent INSAT imagery. An experiment for meso-scale rainfall estimation from GOES I/O VHRR images and its validation with coastal radar rainfall measurements was carried out with MONEX-1979 period data near Madras by scientists of SAC, IMD and University of Wisconsin (Bhandari *et al.* 1987) and the results were encouraging. Subsequently a critical analysis of GATE data was also made to improve the satellite-radar rain comparison.

A parameter, closely related to rainfall and monsoon activity, in general, is the planetary Outgoing Longwave Radiation (OLR). Attempt is initiated to derive OLR from INSAT VHRR (thermal IR) radiance data and to study variations of OLR in different phases of monsoon activity, as well as diurnal variations, which can be quite significant (Joshi and Simon 1988). The OLR patterns of June 1986 (pre-onset/post-onset phases) have been studied in detail, and the expected drop in OLR (due to clouds) after onset is evidenced.

3. Intraseasonal fluctuations of monsoon

The "moisture supply" of monsoon over the Arabian Sea, defined as the sum of cross-equatorial moisture flux and evaporation over the Arabian Sea, has been estimated from GOES I/O low-level winds and TIROS-N moisture profile during MONEX-1979, on a daily basis over June and July, and the fluctuations are broadly seen to presage the west coast rainfall fluctuations—onset, break, revival phases are well reflected in the moisture supply. Further, an approximate "moisture budgeting" of the atmosphere over the Arabian Sea was attempted.

The intraseasonal fluctuation of convective activity over land is known to be closely linked to the presence and spatial extent of the low-level monsoon inversion in the temperature profile over the Arabian Sea. The polar orbiting satellite sounder data were shown to be capable of depicting the extent of the inversion regime over the Arabian Sea using TIROS during MONEX-1979 as a test case (Narayanan and Rao 1981). Inversions were also observed subsequently over the desert (heat low) regions to the northwest of India from satellite sounding data; their presence appeared to herald the onset of monsoon (over Kerala) about a week in advance and their strength had a quasi-biweekly oscillation, a known period of monsoon fluctuation.

4. Onset prediction indices

Satellite-based onset prediction indices have been sought for, and a few promising ones have been brought out. The thermal nature of the monsoon suggests that at critical synoptic thermal features of monsoon, noticeable change should precede/accompany monsoon. Following this line of reasoning, satellite (NOAA) soundings were utilised to examine the temperature changes at different levels over the Pakistan heat low (Joshi and Desai 1985) and the Tibetan anticyclone, both of which are essentially thermal features. The temperatures at upper/mid-troposphere, particularly 300 mb, were seen to undergo significant warming—of the order of 12°C —in a relatively rapid fashion over about a 3 week period. The mid-point of this rise is found to occur about 10 days before the onset of monsoon (over Kerala) as observed in 2 years' data (1979, 1982). In fact the entire Tibetan plateau shows this feature. The further upper layers (100 mb for example) show a cooling trend almost as a mirror image of the warming at 300 or 200 mb. Diagnosis of this phenomenon is in progress and some role of subsidence is indicated. However, a planetary westward moving effect may also account for this. The cross-equatorial wind-index (Sec. 2) and the moisture supply, Arabian Sea inversions and the desert inversions referred in Sec. 3 above, also might act as onset indicators.

5. Satellite data impact in numerical prediction

With the advent of satellites in general and INSAT in particular, winds at 2 levels (850, 200 mb) and sea surface temperature, profiles of temperature, humidity etc are now available. With a view to assess the impact of such satellite data in medium-range monsoon prediction experiments have been initiated using a "Monsoon General Circulation Model" made available by scientists of Indian Institute of Technology, New Delhi. As "Standard" data sets the global objectively analysed fields ("FGGE analysis") were used in control runs, and this analysis represents the totality of all observations. The experimental runs used only satellite data as far as the winds are concerned. Thus the "replaceability" of total data with satellite data was evaluated (for winds).

The overall flow patterns at both 850 mb and 200 mb are nearly similar in the two kinds of runs although random differences are present with about a 3 m/s RMS difference at 850 mb, and 7 m/s at 200 mb. Also, if one were to attempt a computation of derived fields such as divergence, vorticity etc they would show considerable errors at places; even so the major circulation features such as troughs, anticyclones etc are almost well reproduced in the "satellite only" run.

6. Seasonal/interannual scale predictions

The empirical prediction of seasonal monsoon rainfall over India as a whole (and also over certain homogeneous zones) is a continuing topic of research. One of the predictors used fairly successfully the latitudinal position of the 500 mb ridge in April over the Indian Peninsula derived from upper air wind analysis based on radio wind stations' data. Since winds are only available from a few stations, it was decided to attempt delineations of the ridge using satellite geopotential

height fields, to see whether that provides any advantage without suffering in accuracy. The NOAA soundings provide temperature profiles at close intervals (horizontally) and over a wide area including oceanic regions. However, the surface pressure field is not given by satellites. Hence, conventional surface pressure analysis was combined with NOAA soundings to generate geopotential fields using hypso-metric equation and also applying water-vapour correction for density. Satellite temperature profile and moisture profile were thus utilised. The 500 mb ridge was located in the mean April field in 2 years, 1982 and 1987, this way. In both the years the latitudinal position of the ridge from satellite geopotential field was found to be south of the corresponding wind ridge (at 75°E which is the traditionally used longitude), by about 3 degrees latitude. The "Prediction", which could be made by about 15 May in principle (barring delays in data receipt/analysis etc), were matching with actual all India seasonal rainfall (June-September) fairly well, provided of course that this "bias" of 3 degrees was empirically corrected for. Obviously the work is still in initial stages since the "constancy", of the bias can hardly be checked, much less explained, with just 2 years' data. The above aspect of 500 mb ridge from NOAA soundings is described in several presentations/papers. Recently 200 mb ridge was found useful.

The interannual variability of monsoon rainfall over different sub-divisions of India was examined in relation to the strength of *El Nino*, in another study. Although this does not fit in the framework of direct satellite data utilisation, implicitly the satellite-observed Pacific Ocean surface temperatures (and later on, surface winds) as well as altimetric surface topography would be utilised as *El Nino* indicators or signatures. Hence this study is also included in the present discussions. The contribution here was, in making a statistical analysis of the relation if any, between previous year's monsoon rainfall and previous year's *El Nino* used together as 'Predictors' and the current year's monsoon rainfall as a predicand. In effect, the monsoon system is attributed a memory, i.e., a Markovian behaviour, and the *El Nino*'s impact on it also is considered to have a lag or delay of about a year. The finding, based on 118 years' historical data, was that in certain sub-divisions, certain combinations of monsoon and *El Nino* strengths of a year, lead to predictable monsoon strength the following year with a high probability. As an example the combination of "drought" and "moderate" or "strong" *El Nino* over northwest Indian divisions, portends an improved rainfall in the subsequent year. This is exemplified (and spot verified) by the case of 1988 wherein the rainfall over northwest India is normal (even excess in some divisions) after a severe drought of 1987 which was also a "moderate" *El Nino* year. Details are being communicated in two phases, first for the State of Gujarat as a pilot study (Vyas and Andharia 1988) and then for 30 sub-divisions of India (Vyas and Andharia 1989). A brief related study of the Pacific-Indian Ocean interaction was also attempted. In general, radiation parameters would be relevant to monsoon variability study and the efforts at outgoing longwave radiation, ocean surface absorbed short-wave radiation from satellite data in progress, would be useful in this context.

7. Heat budget of the Indian Ocean

The heat budget of the equatorial Indian Ocean, and the variations in it over the monsoon season were studied on a weekly basis; also studied were some associated dynamics responses such as the vertical motions of thermocline, the reversal of the zonal slope of the mixed layer, and the surface eastward current at the onset of monsoon (Simon and Desai 1986). As a preparation for the heat budget study, first the evaporation was estimated from satellite data and studied in relation to the progress of monsoon (Simon and Desai 1986). The specific case study of surface heat exchange variations associated with the onset vortex over the Arabian Sea was also made. A related study of oceanic gyre in the Arabian Sea was briefly made also, using thermal signature from INSAT data.

8. Concluding remarks

Some studies carried out or in progress have been described, pertaining to the use of satellite data in monsoon research, at Space Applications Centre and ISRO Headquarters. It is hoped that these various pieces would eventually fit together in a full framework, alongwith other scientists' efforts, for yielding useful monsoon prediction capability.

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