THE MONSOON EXPERIMENT (MONEX)

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ABSTRACT

The article reviews the history and development of the Monsoon Experiment (Monex), as a sub-progamme of the Global Atmospheric Research Programme (GARP). It describes the structure of Monex, and the observational plans for the experiment, especially from (*a*) land/ocean based platforms and (*b*) space platforms. The scientific objectives and the possible benefits likely from this experiment are discussed in the context of future developments.

1. INTRODUCTION

THE Global Atmospheric Research Programme (GARP) organised by the World Meteorological Organisation (WMO) and the International Council of Scientific Unions (ICSU) in 1967 had two main objectives: (i) to study the large-scale fluctuations in the atmosphere which control changes in weather, and (ii) to examine the physical basis of climate. The first objective was aimed at increasing the accuracy of weather forecasts for periods ranging from one day to several weeks, while the second was to provide scientists with a rationale for understanding and, if possible, predicting climatic changes. Both objectives are important to India, which has an agriculture oriented economy.

The major international experiment which, in some sense, will see the culmination of the first GARP objective, is now in progress. This is the First Global Experiment FGGE of 1979. The Monsoon Experiment or Monex is part of this and was first proposed by India as a GARP sub-programme.

2. THE STRUCTURE OF MONEX

Monex is not the first international study of the monsoons. There were three earlier studies, the International Indian Ocean Expedition (IIOE) of 1963-65, and the Indo-Soviet experiments (ISMEX) of 1973 and 1977. The Monsoon experiment of 1979 will be on a much larger scale, with three components designed to study (i) the summer monsoon, (ii) the winter monsoon, and (iii) the west African monsoon (WAMEX).

Two phases of intensive observations or Special Observation Periods (SOP) are planned, each of roughly two months' duration. The first which began on January 5, 1979 will end on March 7, 1979. The second begins on May 1 and ends on June 30, 1979. India's main interest will be in the second special observation period, because it coincides with the onset and early phase of the summer monsoon. The second period does not, however, cover the second half of the monsoon, when monsoon depressions in the north Bay of Bengal are most frequent. To overcome this lacuna, India, the USA and the USSR have agreed to continue their observational programme till August 31, 1979 over the Bay of Bengal. The Monsoon Experiment (Monex) thus extends a little beyond the second observation period.

To coordinate Monex activities, two International Monex Management Centres (IMMC) have been set up; in Kuala Lampur for the winter Monex and in New Delhi for the summer Monex. The JOC have also set up a Board for the monsoon sub-programme to oversee the plans and activities of these international centres. These centres might continue on a quasi-permanent basis if there is a need.

3. THE OBSERVATIONAL PLAN FOR SUMMER MONEX

During the field phase of the experiment, the conventional programme for data collection in India will be considerably intensified. By using additional platforms which are either (i) land/ocean based or (ii) space based.

3.1. *Land/ocean based platforms*

(i) *Research ships* : Five research vessels from the USSR, four from India and one from France are expected to take part. The USSR ships will carry out their observations in a combination of fixed and moving polygons over the monsoon region. Numerical modelling experiments suggest an optimum spacing of 500 km for data platforms over active regions of interest. The relative merits of moving and stationary polygons have been a subject of much debate. While for investigations such as the computation of budgets for vertical transfer of momentum, sensible heat or water vapour, a stationary polygon over a fixed region is preferable, for studies of atmospheric characteristics over as wide a region as possible in a Lagrangian sense, a moving polygon is better.

The Indian ships will carry out observations from May 1 to July 31, in the Arabian Sea and in the Bay of Bengal, while the French vessel "Marion Dufrense" will take observations from the Seychelles to the east coast of Africa from May 10 to June 30, 1979. Its main objective is to study oceanic upwelling and the low level wind maxima off the coast of east Africa. An innovation which might be used on three of the

Indian ships to measure upper winds, for the first time, will be the use of the 'omega' navigation system for tracking balloons.

(ii) *Aircraft* : A fully instrumented research aircraft of the Indian National Remote Sensing Agency will take observations during the summer monsoon period over the Arabian Sea and the Bay of Bengal. In addition three research aircraft from the USA will operate with Bombay as their base from May 20 to June 5 and later to Calcutta, to study the Bay of Bengal depressions from July 1 to July 30.

(iii) *Extension of conventional measurements by Indian stations* : Arrangements are in progress to extend the routine meteorological programme of Indian stations for the duration of Monex at seven stations.

Nine radiometersonde stations, including one on a ship, will measure the net radiative flux at different levels of the atmosphere once every week. Provision also exists for more frequent observations, if necessary. The radiation programme will also include measurements of turbidity over land stations, and on ships. This will help to compile data on aerosol characteristics over the monsoon region.

(iv) *Radar observations* : The Indian network of S and X band radar stations will be used to study cloud structures, especially those associated with monsoon depressions. Integrated with the three radar stations of Bangla Desh and the Burmese station at Kyaupyu, it will provide a fairly good network over the north Bay of Bengal. A portable radar set, along with a digital processor, is likely to be provided by the US to augment this network.

(v) *Boundary layer studies* : Measurements of the vertical flux of momentum, sensible heat and water vapour in the constant-stress layer of the atmospheric boundary layer are planned. These studies are being arranged at a station off the east coast of India by the Indian Institute of Science, Bangalore and the US Monex Project team.

3.2. *Space-based platforms*

Of the space-based platforms, the reception of cloud images from a US geostationary satellite in real time, and wind vectors in non-real time, will be the most important development during Monex. Originally a geostationary satellite from the USSR had been expected to provide data for the monsoon regime but as this has not been possible for technical reasons, the US geostationary satellite, GOES-IO, will now be moved to a location along 60° E. Cloud images from this satellite will be relayed to India through Meteosat, a geostationary satellite launched by the European Space Agency. It is expected that real time images from GOES-IO will be received at Bombay and will be relayed to other Indian centres by radio facsimile service to assist aircraft operations during the Monex period. Cloud vectors will be computed and provided to the summer International Monex Management Centre on non-real time by the University of Wisconsin.

In addition to these reception facilities, data on clouds and winds may be provided by the geostationary satellite (GMS) launched by Japan, but will cover only the eastern fringe of the region of interest for summer Monex. Cloud images from polar orbitting satellites will also be received in real time at seven stations in India. Useful data on clouds are expected from TIROS-N from the USA and METEOR from the USSR.

Pictures from GOES-IO received four times a day, will have an approximate resolution of 3-5 km in the visible and 7 km in the infrared. The wind vectors will have 200 km resolution for mesoscale activity studies and a resolution of 500 km for the study of large-scale motion. Pictures will also be available of the total water vapour content of the atmosphere observed by METEOSAT-I. It is clear that much of the new information that we expect out of Monex will lean on new developments in satellite technology.

4. Data Management

As the data are received on fast telecommunication lines, quality control checks require considerable programming efforts for ensuring satisfactory data. These checks are designed to satisfy homogeneity and consistency of data. At the Summer IMMC in Delhi computer programmes will ensure that the data coming out of telecommunication lines are immediately checked, and put on standard formats.

5. Scientific Objectives of Monex

General information on this subject is available in a WMO publication on the monsoon experiment[4] (1976). There are three main monsoon features on which advance information is needed :

(i) Approximate dates of onset over different climatological regimes of the country, (ii) An estimate of the total quantum of rainfall likely over the ninety-day monsoon period and (iii) An indication of likely periods, of about 5–7 days' duration of heavy rain, or deficient rain over different parts of India.

(i) *Modelling experiments* : A monsoon model needs consideration of three aspects : (i) the physics put into the model, (ii) a computational technique for a nonlinear turbulent medium, and (iii) a verification programme for the model output.

The monsoon may be viewed as the atmosphere's response to several external forces. The principal forces are : (i) solar and terrestrial radiation, (ii) the impact of mountains, (iii) clouds and precipitation, (iv) the influence of oceans, and (v) frictional effects over land and sea. But along with the data, research on the computational aspects of numerical models will also be necessary. Primitive equation models are being constructed by scientists in India.

A major difficulty with monsoon modelling lies in the presence of the Himalayas. When the Himalayas are included in a numerical model, difficulties with boundary conditions at the earth's surface arise. The mountain also generates highly dispersive and fast moving gravity waves that propagate both eastwards and westwards. Monex data could help in the design of suitable boundary conditions and filtering devices for monsoon models.

(ii) *The earth-atmosphere radiation balance* : Model simulation of the monsoon, summarised by Gilchrist[5], suggest that the monsoon is sensitive to alterations in the earth-atmospheric radiation balance. Global satellite observations now provide daily data on the net radiation balance over the monsoon area. The radiometersonde network will provide data on the net radiative heating in each layer of the atmosphere. This will be augmented by radiation observations by US aircraft. Indeed Monex could provide a much needed follow-up of the radiation programme initiated in India by Mani *et al.*[7]

(iii) *Monsoon depressions* : The factors that lead to the formation of depressions and their subsequent movement are not yet well understood. Shukla[8] and Keshavamurti *et al.*[6] suggest that the formation of the depression is associated with an instability mechanism. To test this an accurate determination of the wind profile over the Bay of Bengal is needed. A numerical experiment by Das and Bedi[1] suggests that the track of a depression studied during ISMEX–77 would have been far to the north, if the Himalayas were removed. A study of larger number of depressions might confirm this result.

(iv) *The monsoon trough* : Short period fluctuations in monsoon rain areas are often caused by north-south movements of an elongated zone of low pressure, which runs roughly parallel to the southern periphery of the Himalayas. Das and Bedi[2] suggest that the trough is not the mechanical effect of mountains; indeed, relative heating is needed to generate the trough. On the other hand, an analytical treatment by Gadgil[3] suggests that the trough is a Rossby mode oscillation generated by air flowing across the Western Ghats. The problem has not yet been settled, but flights by US aircraft during Monex should provide data on the radiation aspect.

(v) *Clouds and rainfall* : Clouds alter the distribution of solar and terrestrial radiation through absorption, reflection and scattering. The change in phase from vapour to liquid drops in clouds is accompanied by release of latent heat. This is an important source of non-adiabatic heat for the atmosphere. As clouds occur on a scale that is too small for the model to capture; their cumulative effect has to be parameterized in numerical models. Attempts to do this with cloud data are in progress.

6. Conclusions

If this experiment is successful, it should enable Indian meteorologists to improve their understanding of the monsoon. It may also be possible to estimate, how far the different features of the monsoon are predictable. The experiment could at the same time throw some light on the specification of the optimum observing system needed for further monsoon studies.

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