6 CONCLUSIONS

6.1 Brief Summary of the Results

The important results obtained from the study are summarised below :

1. A zonally averaged two dimentional model with differential heating in the north-south is capable of generating a 'monsoon cell' which is characterised, as observed, by a reversal of winds in the vertical, i.e. westerly in the lower levels and easterly aloft.

2. (a) In the wet model with the Himalayas, the simulated TEJ has a core speed of 36 m sec^{-1} at a height of 12 km at 20°N as against the observed TEJ with a core speed of 35 m sec^{-1} at 14 km at 15°N.

   (b) In the dry model with the Himalayas, the simulated circulation pattern remains unchanged as in 2(a). The TEJ has a core speed of 25 m sec^{-1}.

   (c) The presence of high amounts of moisture at the surface tend to decrease the intensity of the monsoon circulation. Higher amounts of moisture at the surface contribute only to higher amounts of precipitable water but not to precipitated water.

(d) Results in 2 (a) to 2 (c) lead to the inference that moisture is not the important factor in controlling the monsoon circulation,although it is essential for the occurence of rainfall.

3. (a) In the wet and dry models without the Himalayas, the circulations developed are markedly weaker than the circulation observed.

(b) In the wet model experiments, the precipitated water (rainfall) is about five times more with the Himalayas than without the Himalayas.

(c) Results in 3(a) and 3(b) above lead to the conclusion that <u>it is the presence of the Himalayas which has the dominant effect upon the development of the monsoon circulation</u>.

4. (a) The pattern of the simulated temperature field is similar to that of the observed temperature field. Also, the height of the tropopause, south of the Himalayas, increases with latitude in accordance with what is observed.

(b) The horizontal thermal gradient simulated, with moisture and with the Himalayas, at various heights is consistent with the observed upward-increasing easterly and has magnitude comparable with the observed thermal gradient at the corresponding heights.

(c) The horizontal thermal gradient at various heights in the dry model experiment without the Himalayas is considerably weak.

(d) The monsoon circulation would develop in the manner it is observed only if the horizontal thermal gradient is more than 0.5°C per degree latitude <u>in the upper troposphere</u>.

(e) A marked decrease in the Indian Ocean surface temperature by as much as 10°C does not significantly change the monsoon circulation both in its pattern and intensity.

5. The distribution of land and sea in the north-south as exists over the Indian Ocean longitudes is one of the essential factors for the development of the monsoon.

6. By incorporating the oceanic region south of the equator into the model, the circulation simulated became closer to the observed, suggesting that the monsoon activity does not remain limited to the region north of the equator.

6.2. Limitation of the Present Investigation

The model used in the present investigation is zonally averaged and hence it operates only in the two-dimentional vertical plane along any longitude which is 80°E in the present case. The model cannot answer, therefore, some of the important questions, such as, the interaction between the northern and the southern hemisphere, the role of westward or eastward moving depressions, and the importance of the Western Ghats.

Also, in the present model, the transport of heat across the latitude by ocean currents is neglected. But, in general, the contribution by ocean currents is estimated to be less than 10 per cent (Byers, 1959) of the total transfer of heat by air currents. Only warm ocean currents, like the Gulf Stream, are found to play an important role in transferring the heat across the latitude (Manabe et al, 1969).

The formation of depressions in the Bay of Bengal is a usual feature during the monsoon period. On occasions, depressions form in the Arabian Sea also. These depressions act as perturbations superimposed upon the main monsoonal flow. In the present model, no such disturbance is assumed to superimpose upon the zonal current.

During the process of computations by marching process, the zenith distance of the sun is kept constant at mean July position. Also, the rate of temperature change due to radiation is computed using the climatological distribution of water vapour, clouds, and ozone instead of the distribution obtained from the prognostic equations of water vapour and the photochemical equations os ozone.

These constraints are imposed for the simplicity of compu--tations in order to accelerate the approach of steady-state solution.

6.3 Further Scope of Work

Numerical simulation gives an opportunity to program controlled numerical experiments. This very facility affords ample scope to conduct experiments on the monsoon circulation with any variations in the physical parameters which will be impracticable to achieve otherwise in reality in order to know their effects. This aspect has been successfully demonstrated in the present investigation when the presence of the Himalayas and the moisture content of the atmosphere have not been taken into account in some of the experiments conducted with the model.

It is surprising that though the monsoon arrives every year to keep its date with India and the neighbouring countries its source of origin and the basic processes responsible for its development and maintenance are still shrouded in mystery. The main cause for this lies in the fact that the monsoon has not been throughly probed over the entire region of its activity, especially with respect to the regions south of the equator (the Indian Ocean) and north of 30°N (the Himalayas). The monsoon cannot be considered as an isolated system with its activity restricted only over the Indian subcontinent. Hence any studies to be made should necessarily be on a broad scale covering the Asiatic continent, as a whole, in the north and the Indian Ocean in the south. The need for such a type of study was clearly felt by the author while attempting to compile information presented in Chapter 1. As for example, very little is known about the relationship between the ITCZ and the monsoon trough and their individual roles in the determination of the rainfall pattern. Another important investigation lies in obtaining information on the distri--bution of diabatic heat sources and sinks over the Indian Ocean as well as over the Asiatic continent.

These and other important problems will have to be studied by considering only three-dimensional models instead of the simple two-dimensional one as used at present. Washington (1970) carried out an experiment using three-dimensional NCAR model to simulate the monsoon circulation. The main features of low-level circulation were well simulated. But, he obtained maximum precipitation over Arabia. Using a global model with complete hydrologic cycle, Manabe et al (1970) were able to simulate successfully the locations of ITCZ and tropical storms in the tropics for January. A complete ocean-atmosphere model taking into account the advection of heat by ocean currents and sea-upwelling and with topographic features including the Western Ghats, will certainly help understand the basic processes of diabatic heating and cooling and their importance in the genesis and development of the monsoon.

REFERENCES

Waghington, W.M.	1970	On the Simulation of the Indian Monsoon and Tropical Easterly JET Stream with NCAR General Circulation Model. Symp. on Tropical Meteorology, Hawaii
Manabe, S., J.L.Holloway, H.M.Stone	1970	Tropical Circulation in a Time-Integration of a Global Model of the Atmosphere. J.Atmos.Sci.27 pp.580-613