A STUDY ON CERTAIN ASPECTS OF THE DYNAMICS AND ENERGETICS OF THE ASIAN SUMMER MONSOON

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TO

MY

PARENTS

CERTIFICATE

This is to certify that the thesis entitled "A Study on Certain Aspects of the Dynamics and Energetics of Asian Summer Monsoon" being submitted by K.J. RAMESH for the award of degree of DOCTOR OF PHILOSOPHY, is a record of the original bonafide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis. The results presented in this thesis have not been submitted in part or full to any other University or Institute for award of any degree/diploma.

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A C K N O W L E D G E M E N T S

All experience is an arch
where through gleams that untravelled world
whose margin fades for ever
and for ever when I move .. ..

The one and the only thing that has no end is knowledge. The 'Anugeetha' tells that all creations including the factor of time have their end. But knowledge, the more it is pried into, the more there is to be pried. The span of life is measured, and man's days are counted. Hence there is the imperative need to know, to seek, to find before it is too late. Man has perhaps one thing to know or gain. That is the ability to know his ability. In this direction I have in my own humble way delved into the knowledge of the winds and the clouds popularly termed atmosphere. The time has come when I am to pronounce what I have learnt to the technically proficient powers that be for the confirmation of the truths that have been expounded which are of greater value than the distinction going with it.

In the preparation of this humble treatise many have helped me to whom I conscientiously confess my deep debt of gratitude.

At the outset I have my philosopher and guide DR. MOHANTY. He has stood by me through thick and thin in my what I may call, the adventure through the skies. Suffice it to say that my prayers ever shall not be without thoughts of him.

There are some selected few who in their life, not only attain greater things but also by their example teach us to have aspiring minds. PROF. M.P. SINGH, the Head, Centre for Atmospheric Sciences has encouraged and heartened me to pursue my cause in a style unique to himself. I always remember him with reverence.

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No less important in this effort are my parents who have appreciated and encouraged me in all my thoughts and my existence in the world of Meteorology is almost entirely due to them. May the Almighty preserve them.

There is my wife Sudha who has assisted greatly at the finishing stages and stimulated the completion of the work. The best I can do in this circumstance is to express my feeling of pride towards her.

I should sin if I did not remember the gracious Lord for the opportunities He has afforded for the exploration of certain aspects of the ethereal unseen world. If this could be of any help in any measure to any, I deem that I will have been amply rewarded.

K.J. RAMESH

SUMMARY

Diagnostic studies with the help of kinetic energy,vorticity,angular momentum budgets and the study on the circulation characteristics during various phases of the summer monsoon have been carried out. Inter-seasonal characteristics of the summer monsoon seasons (1979 Vs 1983) are studied since the deficient rainfall over India as a whole during the 1979 season was equal to (-1.73σ) from its normal rainfall and the excess rainfall during 1983 season was equal to (1.24σ). In order to compare the similarities and differences seen in the large scale dynamics and energetics of the Asian summer monsoon during the constrasting years of summer monsoon activity, the FGGE level-IIIb data for the year 1979 (year of large deficient rainfall) and the operational analyses of the ECMWF for the year 1983(year of excess rainfall) are used in this study.

During the excess rainfall season, the low level vortex over the Head Bay of Bengal is intense at the south eastern tip of the monsoon trough due to the enhanced southerly component in the low level(850mb) westerlies and in the upper level(200mb) easterlies extend right up to the Eastern Atlantic with a much stronger TEJ over the Indian peninsula. But in a deficient rainfall year, the upper level easterlies are found only up to the east coast of Africa with a weaker TEJ over India. Further, the cyclonic vortex over the NW-India(850mb) and an anti-cyclonic vortex over the Tibet(200mb) are found to be relatively stronger in a good summer monsoon season as compared with a season of having a weak monsoon circulation.

The low level convergent center(at 850mb) over the SE-Asia which is crucial for the summer monsoon activity along with another convergent center over the West Pacific are found in an excess rainfall season. But during a deficient rainfall season due to the westward shift of the West Pacific convergent center, the convergent center(otherwise found over the SE-Asia) is not observed. The east-west circulations(with large velocity potential gradients) are found to be stronger in a good summer monsoon season with a very strong upper level(200mb) divergent center.

Zonal averaged(30°E-150°E) vertical cross-sections reveal that the upper level kinetic energy maximum is found in between 7.5°N and 15°N latitudes during the active phases of the summer monsoon. A northward shift in its position is found during the dry spells and once the activity is revived, the kinetic energy maximum comes back to its earlier

position. The cross-sections of the divergence field show that the magnitudes of the low level convergence($10^{o}N-25^{o}N$) and the upper level divergence have an increasing trend during the onset and active periods of the summer monsoon and a decrease during the break monsoon situations. Further, the cross-sections of the vorticity field show that a zone of cyclonic vorticity is found all through the summer monsoon season around $15^{o}N$ latitude. In the upper levels, a zone of anti-cyclonic vorticity which is centered at $30^{o}N$ extends up to $10^{o}N$ during the active periods while its extension towarads the equator reduces during the suppressed phases of the summer monsoon. Also, at the lower levels the intensity of the low level cyclonic vorticity decreases during the break monsoon situations and cyclonic vorticity alone is found all through the troposphere around $15^{o}N$ latitude thus making the convective activity to suppress.

Vertically integrated structure of the kinetic energy budget terms during the summer monsoon season shows a zone of flux divergence over the Bay of Bengal,adjoining peninsular India and a zone of flux convergence over the Arabian Sea. The magnitude of the flux divergence found over the Bay of Bengal is more in a good monsoon season. The adiabatic generation of kinetic energy is found over the regions of strong kinetic energy flux divergence and adiabatic destruction is found over the areas of kinetic energy flux convergence. Notably, the kinetic energy generation is significantly large over the Indian peninsula in an excess rainfall season. Over the areas where the adiabatic production of kinetic energy dominates the flux transport, a zone of kinetic energy dissipation is found. In a good monsoon season(1983), kinetic energy dissipation is found all over the India and neighbourhood indicating the existence of a strong circulation. However, in a deficient rainfall season(1979), a weak source of kinetic energy observed over the peninsular India indicating the inadequacy in the production of kinetic energy from the available potential energy source. In addition, many systematic changes are found in the kinetic energy budget terms during the various phases of the summer monsoon.

The intensity of the planetary vorticity flux divergence and the relative vorticity flux divergence are found to be more in an excess rainfall year(1983). Further, the generation of vorticity by the divergence and the tipping terms is also significantly large in a good summer monsoon season over the peninsular India and the Bay of Bengal. During a weak summer monsoon season with the deficient rainfall(1979), a vorticity source is found. Through this analysis, it became evident that an excess rainfall year is characterized by the increased vorticity generation with in the domain itself by the divergence and tipping terms through the intense upward motion and divergence fields which inturn lead to the enhanced convective activity.

It is found that a good summer monsoon season is characterized by a net flux divergence of vorticity where as during a weak summer monsoon season, a net flux convergence of vorticity is found. Thus, in an excess rainfall year(1983),the depletion of the vorticity through the flux divergence is to be compensated by the generation processes. However, until the summer monsoon fully establishes itself all over the country, the generation processes may not be able to meet the depletion of vorticity by the advective terms.

It is found that the Ω-term and the zonal pressure gradient term are the most dominant terms over the India and neighbourhood. All through the summer monsoon season, the net effect of these two terms is to generate the zonal momentum over the monsoon region. Also, the transient eddy motions tend to produce flux convergence all through the summer. Mountain torque term is negative(dissipating the zonal momentum) before the onset of the summer monsoon and becomes positive(zonal momentum generation) after its establishment. The maximum influx of zonal momentum is found through the western boundary while the outflow is found through the eastern boundary. It is found that the zonal pressure gradient term generates zonal momentum substantially in the upper troposphere while it dissipates in the lower troposphere.

Ω-term shows strong flux convergence of momentum in the lower troposphere and flux divergence in the upper troposphere. Until, the establishment of the summer monsoon, the zonal pressure gradient term dominates the Ω-term and after its establishment, a considerable amount of increase in the Ω-flux convergence in the lower levels is found and there after the Ω-term dominates the zonal pressure gradient term. In a good summer monsoon season(1983), the low level Ω-flux convergence could penetrate up to 500mb or so with the increased southerly component in the lower tropospheric wind fields. The increase in the intensity of the low level Ω-flux convergence ater the establishment of the summer monsoon is essential to maintain the low level monsoon westerlies against the surface friction.

C O N T E N T S