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Contrasting features of wave number one during northern summer monsoon seasons of 1997 and 2002

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सार – इस शोध पत्र में मानसून 2002 (हाल ही के सूखे का वर्ष) और मानसून 1997 (सामान्य मानसून वर्ष) की तुलना निम्न क्षोभमंड़लीय क्षेत्रीय तरंग संख्या एक की और्जिकी की स्थानिक और कालिक भिन्नताओं के संदर्भ में की गई है। संवेग अभिगमन, गतिक ऊर्जा और तरंगों के बीच होने वाली परस्पर क्रिया के आकलन के लिए फोरियर तकनीक का उपयोग किया गया है। 850 हैक्टापास्कल पर लिए गए 153 दिनों (1 मई से 30 सितम्बर) के दैनिक भूमंडलीय ग्रिड प्वाइंट एन. सी. ई. पी. पवन (*u* और *v*) आँकड़ों के संबंध में इसमें अध्ययन किया गया है।

तरंग संख्या एक की और्जिकी की दैनिक और साप्ताहिक भिन्नताओं से यह पता चला कि जब तक 10 डिग्री उत्तर के आसपास तरंग संख्या एक का संवेग अभिगमन अथवा गतिक ऊर्जा प्रबल होती है तब तक वर्षा अच्छी होती है लेकिन तरंग की स्थिति अन्यथा होने पर वर्षा की स्थिति भी इसके विपरीत होती है। 1997 की तुलना में 2002 के दौरान तरंग संख्या एक का आयाम आधे के लगभग रहा जिसके फलस्वरूप पूरी मानसून ऋतु 2002 के दौरान संवेग का अभिगमन कम रहा और गतिक ऊर्जा की आपूर्ति अपर्याप्त रही। यह संभावना प्रकट की गई है कि 1997 के दौरान तरंग संख्या एक से निर्मुक्त हुई विशिष्ट गतिक ऊर्जा का पाँच गहन तंत्रों के प्रवर्तित होने में महत्वपूर्ण योगदान रहा होगा जिसकी वजह से मानसनू 2002 के दौरान गतिक ऊर्जा की क्षीण आपूर्ति हुई और एक भी तंत्र प्रवर्तित नहीं हो सका।

ABSTRACT. Temporal and spatial variations of the energetics of the lower tropospheric zonal wave number one are compared for monsoon 2002 (a recent drought year) and monsoon 1997 (a normal monsoon year). Fourier technique is used to calculate momentum transport, kinetic energy and wave to wave interaction. Daily global grid point NCEP wind (*u* & *v*) data at 850 hPa for 153 days (1 May to 30 September) are considered.

Daily and weekly variations of the energetics of wave number one indicate that as long as the momentum transport or kinetic energy of wave number one around 10° N is strong, the rainfall is better and *vice-versa*. The amplitude of wave number one was almost half during 2002 as compared to that of during 1997, which resulted into less transport of momentum and meager supply of kinetic energy throughout the monsoon season of 2002. The significant release of kinetic energy by wave number one may have played a vital role in triggering five intense systems during 1997 whereas the weak supply of kinetic energy may have failed to trigger a single system during monsoon 2002.

Key words – Temporal and spatial variations, Fourier technique, Momentum transport, Kinetic energy.

1. Introduction

Indian monsoon rainfall is very sensitive to the variations in the monsoon trough (Ramamurthy, 1969 and Desai, 1990). Monsoon trough, which is the semi-permanent feature of Indian monsoon, is a part of global Inter-Tropical Convergence Zone (ITCZ). The variations in the ITCZ cause variations in the monsoon trough and All India Monsoon Rainfall (AIMR). The studies of Pisharoty and Desai (1956), Krishnamurti and Bhalme (1976), Murakami (1976), Asnani and Awade (1978), Sikka and Grey (1981) also indicate that Indian monsoon is more than a local phenomena and interacts significantly with other components of the global circulations. The global circulations have wave like characters and the characteristics of a wave can be studied through its amplitude and phase. Fourier technique is an appropriate tool for computing amplitude and phase of a wave. Fourier representation of the global wind field has revealed the processes of generation, dissipation and transfer of kinetic energy in and among the waves of the atmosphere (Murakami, 1981). Saltzman (1970) summarised the results of several studies of Fourier domain (wave number domain). The global energetics in wave

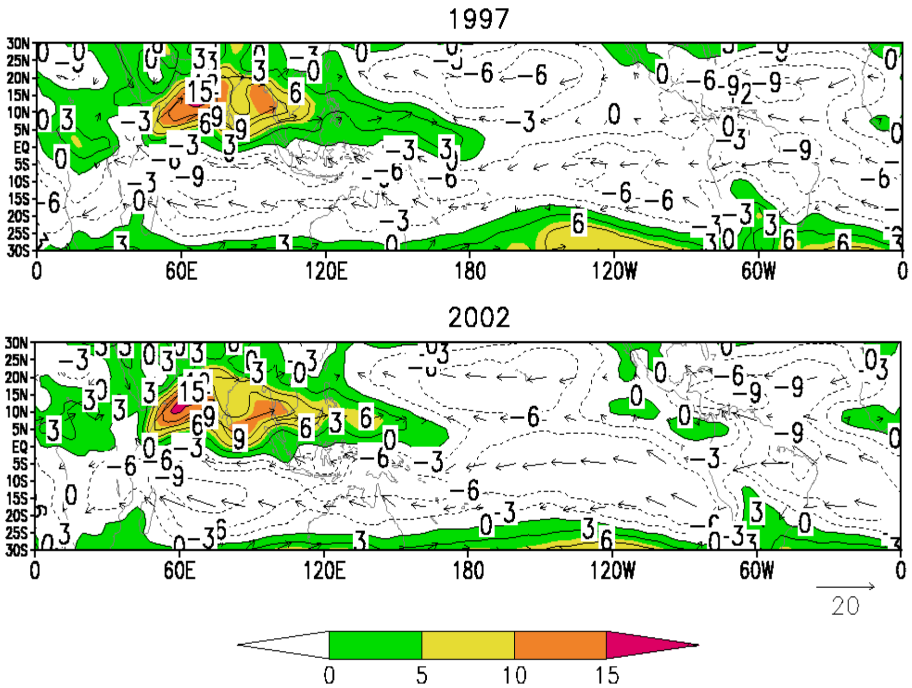


Fig. 1. Seasonal (June to August) wind field at 850 hPa

number domain during northern summer monsoon (June through August) season are studied by many workers. Studies of Krishnamurti and Kanamitsu (1981), Awade *et al.* (1982 and 1985), Bawiskar *et al*. (1989) and Bawiskar and Singh (1992) clearly indicate that the energetics of zonal waves influence AIMR on seasonal scale. The study of Bawiskar *et al*. (2002a) shows that energetics of planetary waves (waves 0,1 and 2) have significant correlation with AIMR on weekly scale, indicating intra-seasonal relationship. Bawiskar *et al*. (2002b) found that momentum transport of wave zero in the month of March gives a signal about the performance of forthcoming monsoon.

Monsoon 2002 is a recent drought year. The seasonal rainfall over the country as a whole was 81% of its long period average. During this monsoon, rainfall in July was only 49% of its long period average for July which is the lowest during past 100 years. The other negative aspect for monsoon 2002 was that, not a single depression was formed unlike in the past 130 years. In the present study, an effort is made to identify the factors responsible for the failure of monsoon 2002. For that, it is decided to study the temporal (1 May to 30 September) and spatial (30° S to 30° N) variations of the energetics of wave number one during monsoon 1997 (a normal monsoon year) and monsoon 2002. Bawiskar *et al*. (2002a) have found that energetics of wave number one not only dominate the latitudinal belt around 10° N but also have significant correlation with AIMR on weekly scale. Larger northward transport by wave number one over the belt enhance the rainfall activity over India. Secondly, the variance explained by wave number one alone is (Bawiskar *et al*. 1995) around 50% or more and therefore, any signal by wave number one would be worth considering.

2. Data and methodology

We have mainly concentrated on momentum transport J(n), kinetic energy K(n) and exchange of kinetic energy among the waves L(n) for two reasons *viz*., (*i*) the momentum transport represents the mass transport and kinetic energy represent the intensity of the wave and (*ii*) the computations of momentum transport and kinetic energy depend on the wind observations and therefore have a greater degree of accuracy.

Daily (1 May to 30 September) zonal (*u*) and meridional (*v*) wind data at 850 hPa between 30° N and 30° S are taken from National Centre for Environmental Prediction (NCEP) for the years 1997 and 2002. The details of the data are given by Kalnay *et al.* (1996). The grid size is 2.5° × 2.5°. The lower tropospheric data is considered because during northern summer monsoon season fluctuations in the lower troposphere are more than the fluctuations in upper troposphere (Unninayar and Murakami, 1978).

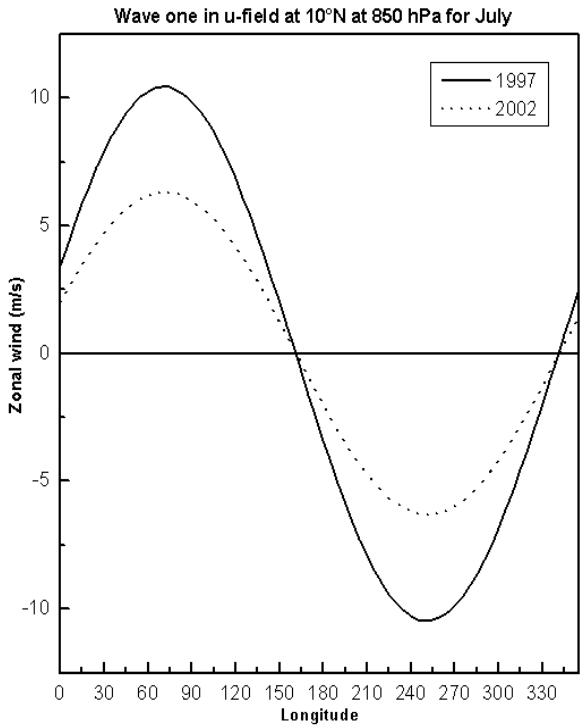


Fig. 2. Wave number one in *u*-field at 10° N at 850 hPa for July

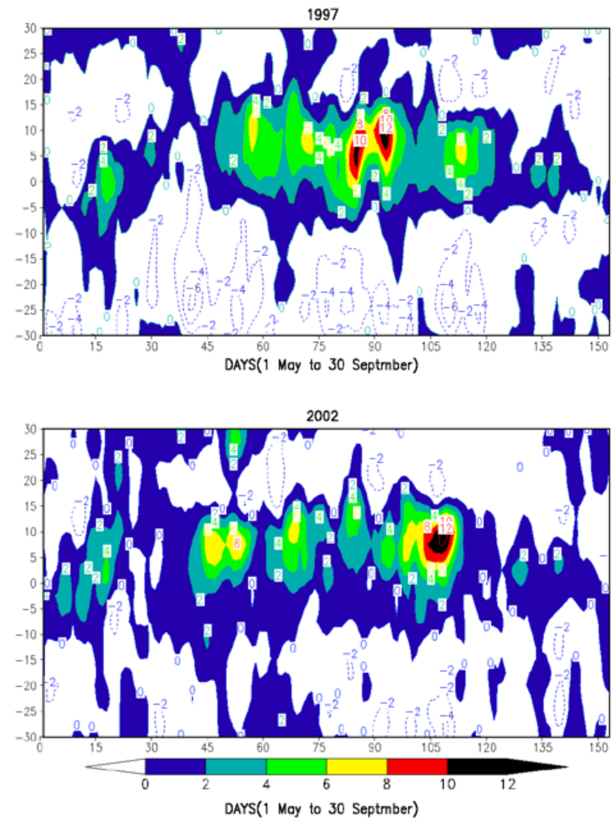


Fig. 3. Daily and latitudinal variation of momentum transport (m^2s^{-2}) of wave number 1 at 850 hPa

Weekly actual rainfall data during the monsoon seasons of 1997 and 2002 are taken from the weekly weather reports of India Meteorological Department (IMD) and all-India (India taken as one unit) weekly rainfall series are prepared.

The wind data are subjected to Fourier analysis. The Fourier coefficients are used to compute J(n), K(n) and L(n) where, n is the wave number. The derivations for J(n), K(n) and L(n) are given in detail by Bawiskar and Singh (1992).

3. Results and discussion

The dominance of a particular wave depends upon the wind structure around the globe. For example, if a particular latitudinal belt around the globe is completely covered either by easterlies or westerlies with no drastic changes in the direction and speed of the wind, wave 0 dominates over the other waves. When some portion of the global belt is covered by easterlies and the remaining portion by westerlies, wave number one dominates over the others and when the global belt contains patches of westerlies and easterlies, waves greater than one will have significant contribution. Fig. 1 gives the seasonal vector wind field superimposed by scalar analysis of *u*-component of wind at 850 hPa for the years 1997 and 2002. The latitudinal belt around 10° N is covered by westerlies (shaded) from 0° E to 180° E and the remaining belt beyond 180° E is covered by easterlies. These westerlies/easterlies are responsible for the formation and dominance of wave number one around 10° N. The westerlies over the Arabian sea and Indian land mass are the components of low level jet and influence AIMR (Paul *et al.* 1990). Thus, the westerlies influence the both, AIMR and energetics of wave number one over this region. Fig. 1 further shows that westerlies around 10° N extend beyond 180° E during 1997 while during 2002, it extends upto 175° E.

3.1. *Feature of wave number one*

The most significant contrast between monsoon 2002 and monsoon 1997 is the rainfall for the month of July. AIMR for July 2002 was 11.2 cm and for July 1997 was 22.4 cm. Wave number one during July provides a very interesting feature. Fig. 2 gives the nature of wave number one for the month of July. Even though the phase angle of wave number one is around 70° E during both the years, the amplitude (which is also the measure of energy) of wave number one during 2002 is nearly half as compared to that of 1997. This indicates that the weakening of wave number one might have resulted into record deficit rainfall during July 2002.

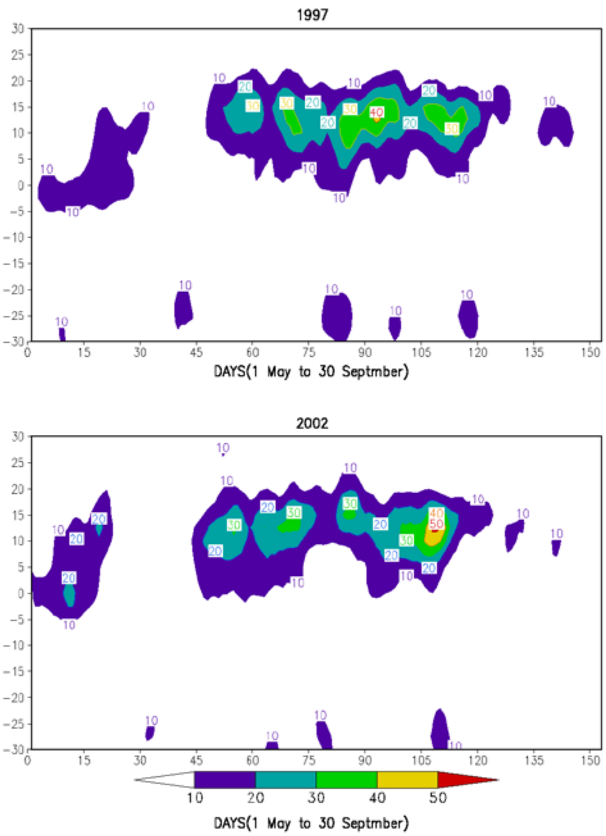
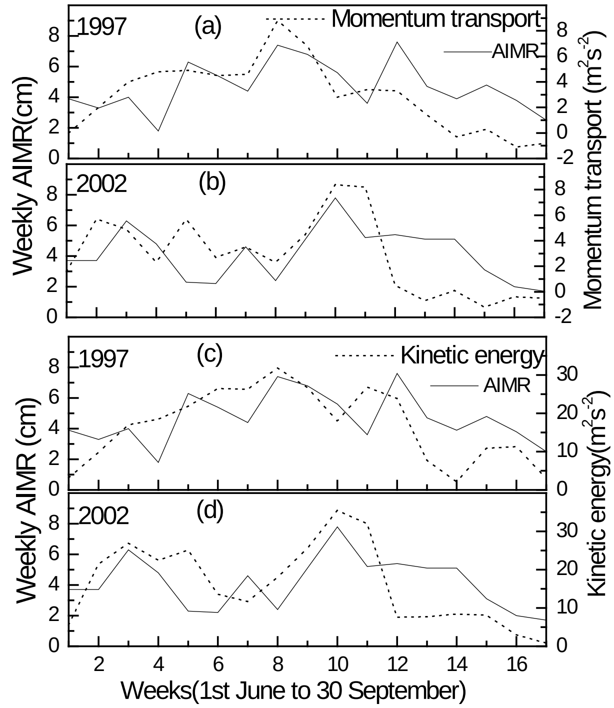


Fig. 4. Daily and latitudinal variation of kinetic energy (m^2s^{-2}) of wave number 1 at 850 hPa



Figs. 5(a-d). Comparison of weekly variation of momentum transport (m^2s^{-2}) and kinetic energy (m^2s^{-2}) of wave number one around 10° N at 850 hPa with weekly AIMR (cm)

3.2. *Momentum transport of wave number one*

During northern summer, the transport of momentum from southern latitudes is associated with warm and moist air mass. Larger the transport better is the rainfall. There are number of studies supporting the statement. Murakami (1974) showed that southward flux of easterly momentum into Southern Hemisphere increased during strong monsoon conditions and diminished during break monsoon situation. Awade *et al*. (1984) showed that there was a large northward transport of momentum during normal monsoon season as compared to drought monsoon season. Bawiskar *et al*. (1989) showed that the northward momentum transport by wave number one was four times larger during normal monsoon years as compared to drought monsoon years.

Fig. 3 gives daily variation of momentum transport of wave number one from 1st May to 30th September (153 days) between 30° N and 30° S. Positive (Negative) sign indicates northward (southward) transport of momentum. The figure indicates that northward momentum transport around 10° N starts building up from mid May and continues to be there till September during both the years. The latitude coverage of momentum transport during July 1997 is large and intense as compared to that of July 2002. The weak transport of momentum during July 2002 resulted into unprecedented deficit rainfall.

3.3. *Kinetic energy of wave number one*

Fig. 4 gives daily variation of kinetic energy of wave number one. Kinetic energy have two pulses of intensification. The first pulse of May moves northward with the time and subsides after May. The second pulse starts in mid June and remains stationary around 10° N throughout the monsoon season. The second pulse of 1997 shows many epochs of intense values while the second pulse of 2002 is marked by low values in general with presence of only one epoch of large energy during the second fortnight of August.

3.4. *Weekly relation*

Figs. 5 (a&b) gives comparison of weekly momentum transport and weekly AIMR. Both the years indicate a significant positive correlation between them. During 2002, the momentum transport and rainfall shoots up around week no. 11 (*i.e*., during mid-August). The variation indicates that larger momentum transport enhances the rainfall activity over India.

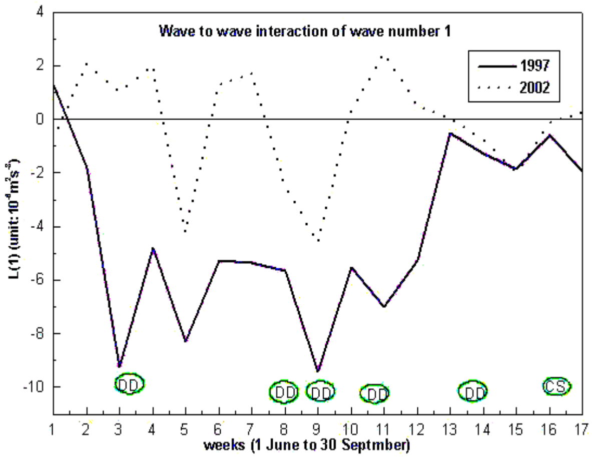


Fig. 6. Weekly variation of wave to wave interaction ($10^{-6}m^2s^{-3}$) of wave number one around 10° N at 850 hPa

Figs. 5 (c&d) gives a comparison of weekly kinetic energy of wave number one and weekly all-India rainfall. The variation is direct indicating intensification of wave number one is favourable to rainfall activity over India.

The July variation of momentum transport, kinetic energy and rainfall shows the increasing trend for 1997 and decreasing trend for 2002.

The other important aspect of both the variations is that the relationship between rainfall and the energetics of wave number one is more strong during July and August (active rainfall months) as compared to June and September.

3.5. *Wave to wave interaction*

Wave to wave interaction measures the rate of exchange of kinetic energy among the waves. Negative (positive) sign of L(n) indicates that wave number n is a source (sink) of kinetic energy to other waves. Bawiskar *et al.* (2000) showed that planetary waves were source of kinetic energy to short waves. Colton (1973) showed that synoptic disturbances removed energy from planetary waves during their growing stage and fed energy back to the planetary waves while decaying. Synoptic disturbances (lows, depressions and cyclonic storms) in the Bay of Bengal are the important features of Indian summer monsoon season and play a very important role in the distribution of rainfall during monsoon season over India through their intensification and westward movement across the monsoon trough. Jadhav (2002) has pointed out that maximum number of Low Pressure Systems (LPS) occurs in the Bay of Bengal.

The significant contrast between monsoon 2002 and monsoon 1997 is the number of intense systems formed in the Bay of Bengal. Four deep depressions (DD), one depression (D) and one cyclonic storm (CS) formed during 1997 whereas not a single system was observed during monsoon 2002. In this context, the fluctuations in L(1) are found to be worth considering. Fig. 6 gives weekly variation of L(1). The figure indicates that there is a significant release of kinetic energy by wave number one during monsoon 1997 whereas the supply of kinetic energy by wave number one was very weak during monsoon 2002.

4. Concluding remarks

Daily and weekly variations of the energetics of wave number one indicate that as long as the momentum transport or kinetic energy of wave number one around 10° N is intense, the rainfall is better and *vice-versa*. The amplitude of wave number one was almost half during July 2002 as compared to that of 1997. Weaker amplitude resulted into less transport of momentum and meager supply of kinetic energy throughout the monsoon season of 2002. The significant release of kinetic energy by wave number one might have led to the formation of six intense systems in the Bay of Bengal during 1997 whereas the weak supply of kinetic energy might have failed to trigger even a single system during monsoon 2002.

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