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Tibetan anticyclone as simulated in a general circulation model

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सार —सामान्य परिसंचरण मॉडल में तिब्बत के प्रतिचक्रवात की धरातलीय परिसीमा अवस्थाओं के प्रति माध्य स्थिति की संवेदनशीलता तथा तीव्रता की जांच करना इस अध्ययन का ध्येय है । कुछ संख्यात्मक प्रयोगों से यह निष्कर्ष निकला है कि प्रतिचक्रवात की तीव्रता और स्थिति, भूमंडलीय समुद्र सतही तापमान से प्रभावित हैं । मॉडल में तिब्बत का उच्च दाब का क्षेत्र मानसून के महीनों में अपनी जलवायुविक अक्षांशीय स्थिति के निकट होता है और तब धरातलीय परिसीमा अवस्थाओं में मौसमी परिवर्तन आरंभ होते हैं तथा मॉडल को शीत ऋतु की आरम्भिक वायुमंडलीय अवस्थाओं से सुसम्बद्ध किया जाता है ।

ABSTRACT. The aim of this study is to investigate the sensitivity of the mean position and intensity of the Tibetan anticyclone simulated in a General Circulation Model (GCM) to prescribed surface boundary conditions. Results of some numerical experiments show that the intensity and position of the anticyclone are influenced by the global sea surface temperatures. The simulated Tibetan High is close to its climatological latitudinal position during monsoon months when the seasonal variations in the surface boundary conditions are introduced and the model is integrated from the initial atmospheric conditions corresponding to winter.

Key words — General circulation model, Simulation, Numerical experiments, Seasonal variation, Climatological values, Perpetual summer run.

1. Introduction

The upper level anticyclone in the northern hemisphere is one of the prominent quasi-permanent features of the atmosphere. Seasonal variations of streamfunction averaged over a number of years at 150 hPa pressure level (Hoskins *et al.* 1989) and at 200 hPa (Ramage and Raman 1972, Salder 1975) show that the axis of the anticyclone moves from its winter position at about 15°N latitude to about 28°N latitude over the Tibetan plateau during the northern hemisphere summer. It has been found (Murakami 1978) that the location and intensity of the centre of streamfunction at 200 hPa change slightly between good and bad monsoon years. Study (Keshavamurty *et al.* 1980) also suggests that shifts of quasi-stationary flow features over Tibet and the associated changes in meridional and vertical wind shears may have a bearing on the monsoon cyclogenesis. Some of the important studies on the maintenance of the anticyclone include those of Koteswaram (1958), Krishnamurti (1971), Murakami (1987) and Sardeshmukh and Held (1984). The process is essentially nonlinear. Numerical experiments show that the atmospheric circulation pattern depends on the surface boundary conditions. The purpose of the present study is to examine the effect of surface boundary conditions, *e.g.*, global Sea Surface Temperature (SST), Deep Soil Temperature (DST) and Deep Soil Moisture (DSM) on the location and intensity of the upper level anticyclone simulated in a GCM. It is primarily intended to examine, whether the global surface features in addition to the local orographic and thermodynamic effects (of Tibetan plateau) influence the simulation of the anticyclone.

2. Description of numerical experiments

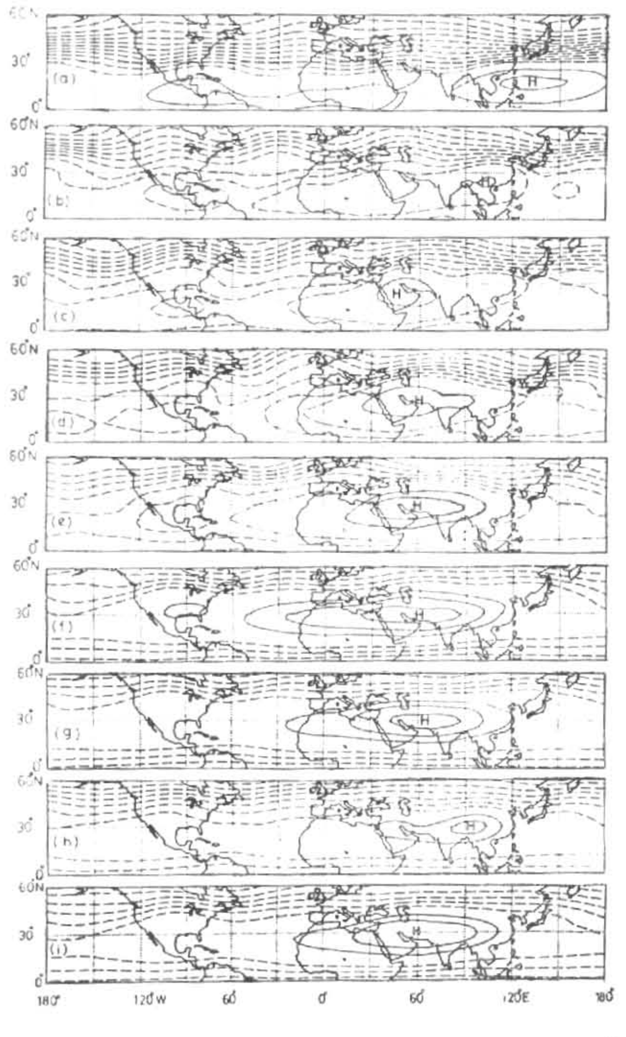
The numerical experiments have been conducted using the UGAMP (UK Universities' Global Atmospheric Modelling Project) climate model. The model has the horizontal resolution at T42 and there are 19 levels in the vertical. The physics in the model correspond to cycle 27 of the ECMWF model. It includes the large scale condensation, shallow convection, gravity wave drag, Kuo convection scheme and ECMWF radiation scheme. Results of four numerical experiments have been used in this discussion. In the first simulation (SIM1) the initial atmospheric conditions correspond to 15 January 1987, whereas the prescribed boundary conditions such as SST, DST, DSM are equal to their climatological values varying from month to month alongwith the change in the position of the sun. The model was integrated for 800 days. In the second simulation (SIM2), the initial atmospheric conditions again correspond to 15 January 1987, but the prescribed SST, DST and DSM are equal to their

July climatological values. Thus the winter atmosphere is subjected to an abrupt July forcing. This perpetual summer run was made for 200 days. It includes diurnal cycle. In the third experiment (SIM3) the model was integrated for 93 days from 1 June 1987 with the monthly varying boundary conditions same as in SIM1. Similarly in the fourth experiment (SIM4), the model was simulated for 93 days starting from 1 June 1988, with the same boundary conditions as in SIM1 and SIM3. The last two experiments were repeated with observed global SSTs of 1987 and 1988 respectively in place of the climatological SSTs. In all these experiments, the model does not include interactive soil moisture.

3. Results and discussion

In SIM1, 120 days of the model integration corresponds to the second half of May. Streamfunction maps show that there is not appreciable change in the position and intensity of the anticyclone at 200 hPa during this period. Hence we have shown the average streamfunction values of the first 120 days in Fig. 1(a). The axis of the anticyclone is positioned at about 15°N latitude corresponding to the normal winter position. It may be noted here that fractions in the day numbers occur on Fig. 1, because the model output are saved every 18 hours in the first experiment. Noticeable changes occur during the next 40 days of the model integration. Figs. 1(b-e) show the values of streamfunction during the next 40 days of model integration averaged over consecutive 10 days. The intensity as well as the location of the anticyclone change remarkably during this period. The monthly values of streamfunction at 200 hPa for July, August and September of the first summer season of the model are shown in Figs. 1(f-h). In July and August the position and intensity of the anticyclone do not undergo much change. The average surface temperature values indicate that the desert areas of central Africa and adjacent Eurasian and southwest Asian land mass get heated up increasingly with the approach of summer. First 120 days of model run indicate that the average surface temperatures of the desert area and Tibetan plateau increase by about 10°C before the end of Ma, and again by about 10°C during June. Hence with the increase in temperature of this land mass, the upper level anticyclone intensifies. The wind distribution at 200 hPa (figure not shown) also shows easterly jet (Koteswaram 1958) overlying tropical Asia and Africa. During the peak monsoon months of July and August [Figs. 1 (f&g)], the stıeamfunction has maximum intensity of 3×10^7 m²/s. The centre of the anticyclone also shifts to the northwest from its winter position. In September, when the Indian monsoon usually starts retreating from the subcontinent, the anticyclone becomes weak and shifts to the east [Fig. 1(h)]. The average streamfunction during the first model summer is shown in Fig. 1(i). There is not significant change in the monthly mean value of streamfunction and the location of the anticyclone during second model summer. Hence those maps are not shown here.

The appproximate positions of the centre of the anticyclone during different stages in SIM1 and SIM2 are shown in Fig. 2. The dot I indicates the approximate position of the centre of the anticyclone on the initial day (15 January 1987) of the model runs. The centres of the anticyclone corresponding to the



Figs. 1(a-i). Streamfunction at 200 hPa in SIM1 averaged over the days, (a) 0.75-119.25 (b) 120-129 (c) 129.75-138.75 (d) 139.5-149.25, (e) 150-159 and mean (f) July, (g) August, (h) September and, (i) JJA values. Contour interval is 1 $10^7 m^2/s$

Figs. 1(a-g) are shown by dots A to G respectively on Fig. 2. The dot H corresponds to the average position of the anticyclone during the first model summer months June, July and August. As compared to the ten year average streamfunction based on the ECMWF analyses (Hoskins *et al.* 1989), the seasonal position (H) of the centre of the anticyclone is to the west by about five degrees longitudes. The average positions of centre of anticyclone for consecutive 10 days starting from the initial day of the model integration (15 January 1987) in SIM2 are indicated by the crosses 1 to 9 in Fig. 2. Thus position 1 corresponds to the average position of anticyclone during day 1 to 10, position 2 corresponds to model days 11 to 20 and so on. The big cross at position 6 corresponds to the average position of the anticyclone during last 90 days of model integration. This shows that in response to the abrupt July forcings (SIM2), the anticyclone is anchored to a northward position (at position 6) compared to the seasonal varying forcings (SIM1) in which case it lies at H. As shown in Fig. 2 the equilibrium positions of

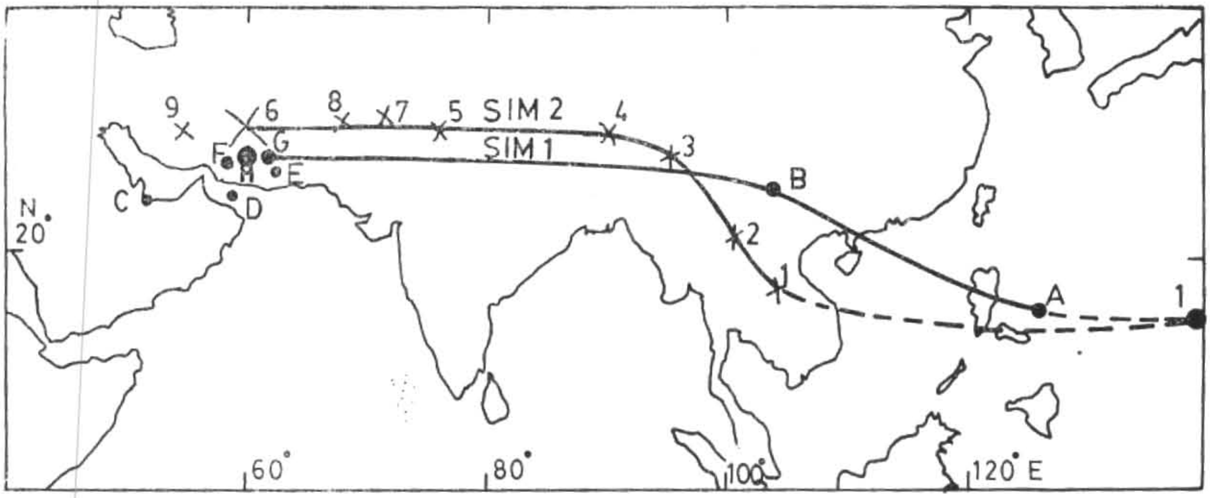


Fig. 2. Approximate location of the centre of the anticyclone during model integration. Dots refer to SIM1 and crosses to SIM2

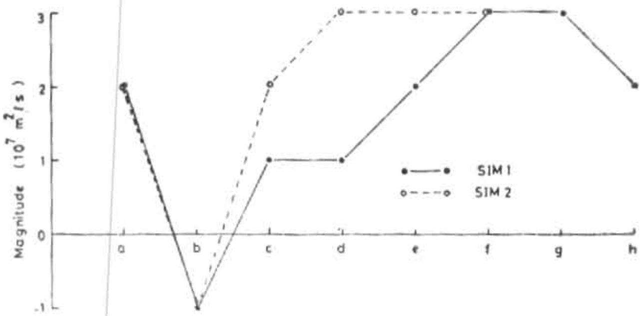


Fig. 3. Maximum value of streamfunction in : (a) : SIM1, and (b) SIM2 during model integration. The letters on the abscissa in (a) correspond to the respective anticyclones in Fig. 1. In (b) the letters a, b, c, d, e, f correspond to average values over days 1 to 10, 11 to 20, 21 to 30, 31 to 40, 41 to 110 and 111 to 200 respectively

the anticyclone in SIM1 an SIM2 are 28°N and 30°N latitudes respectively. The intensity of the anticyclone changes noticeably during 40-50 days of transition from winter to summer in SIM1 and SIM2 as shown in Fig. 3. During the peak monsoon months of July and August the magnitude of streamfunction is maximum and in September the magnitude again decreases.

JJA average streamfunction at 200 hPa as simulated by the model in SIM3 and SIM4 are shown in Figs. 4 and 5. In both the years 1987 and 1988, the model does not simulate the Tibetan anticyclone reasonably. However, in 1988, the anticyclone is better organized [Fig. 5(a)] when the observed SSTs are used than when their climatological values are used [Fig. 5(b)]. In 1987 there is not much difference between the two cases. It may be noted here that 1988 was a good monsoon year and 1987 was a bad monsoon year. JJA average streamfunction shown in Figs. 1(i), 4(b) and 5(b) are obtained in SIM1. SIM3 and SIM4 respectively when the same climatological surface boundary conditions are used in the model. The initial dates of model integration are different in these experiments. SIM1 run started from 15 January and it includes the transition phase from winter to summer circulation in surface boundary conditions. SIM3 and SIM4 integrations started from 1 June. Comparing Figs. 1(i), 4(b) and 5(b), it is evident that the model is able to simulate the Tibetan anticyclone reasonably well when the seasonal variations in the surface parameters are prescribed in the model. In SIM2 also the anticyclone is found to be reasonably well simulated in response to the abrupt July forcings. However, the anticyclone is anchored at a northern position (30°N) compared to its climatological position (28°N).

It is well known that large scale features of the tropical atmosphere are relatively insensitive to initial conditions of the atmosphere compared to the slowly varying surface boundary conditions (Charney and Shukla 1981), mainly SST. Results of co-ordinated numerical experiments (*e.g.*, Palmer *et al.* 1992, Dash 1992, Mo 1992) conducted for TOGA MONEG (Monsoon Numerical Experimentation Group) also indicate that the response of some large scale features of monsoon circulation to SST anomalies is much larger than the response to differences in the initial conditions in the month of June. The intensity and position of the Tibetan anticyclone simulated in the numerical experiments stated in the present paper also confirm the large influence of the surface boundary conditions. The better simulation of the anticyclone in SIM1 and SIM2 compared to that in SIM3 and SIM4 clearly indicates the dominant influence of the seasonally varying surface conditions : slowly varying in SIM1 and abruptly changing in SIM2. From the point of view of magnitude as well as position, the anticyclone simulated in SIM1

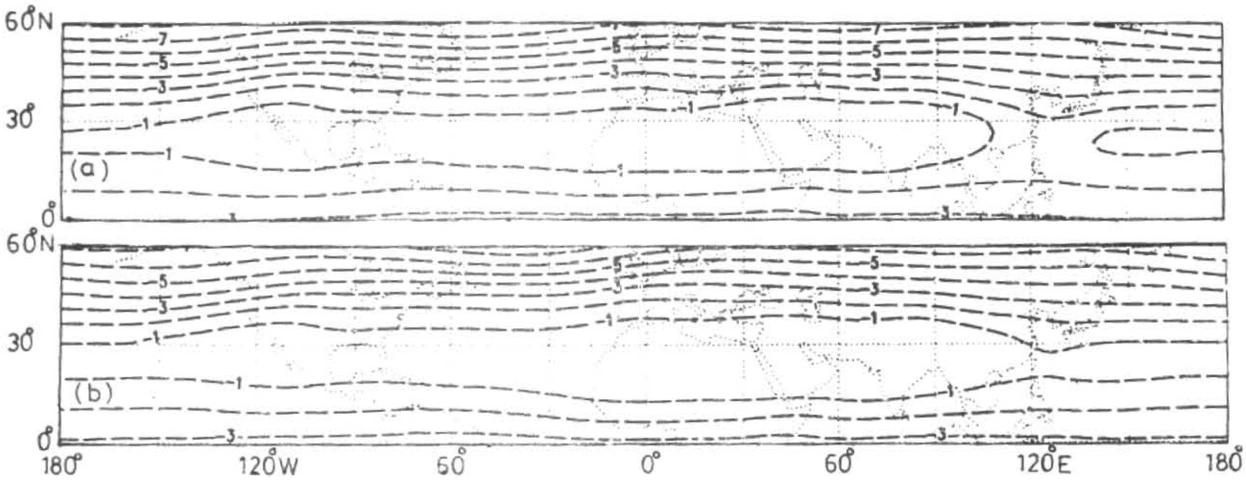


Fig. 4. JJA average streamfunction at 200 hPa in SIM3 with: (a) observed (1987), and (b) climatological SSTs. Contour interval is —1 × $10^7 m^2/s$

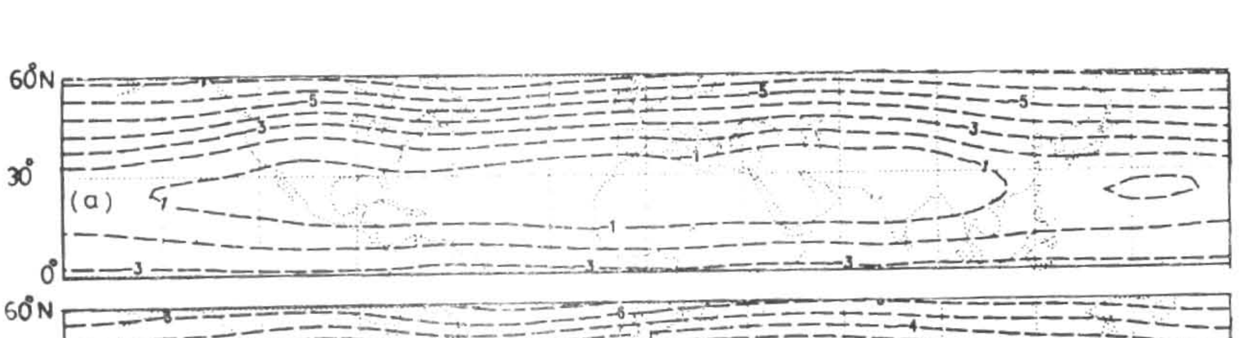


Fig. 5. JJA average streamfunction at 200 hPa in SIM4 with: (a) observed (1988), and (b) climatological SSTs. Contour interval is —1 × $10^7 m^2/s$

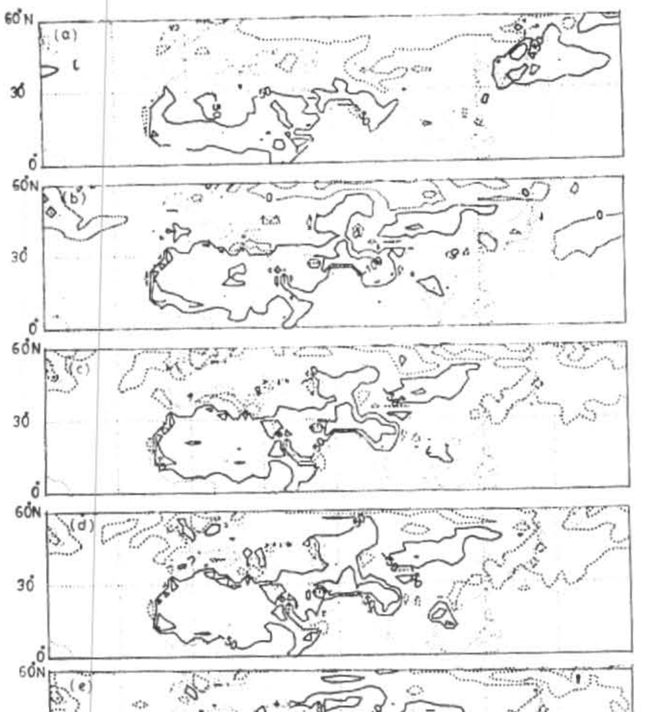


Fig. 6 JJA average sensible heat flux in SIM1. Contour interval is—50 W/m²

is the most reasonable one amongst all the four numerical experiments. Also because of the fact that the initial conditions in SIM1 and SIM2 are different from those in SIM3 and SIM4, one can not completely rule out the role of the initial atmospheric conditions in simulating the anticyclone averaged over the monsoon months. However, there is no denying the fact that the 'spin-up' problem in climate simulation may also contribute to the response shown due to the initial conditions. It is essential to conduct more numerical experiments with different initial conditions and to analyse the results carefully, before arriving at any conclusion concerning the influence of initial conditions on the simulation of the anticyclone.

The surface sensible heat flux as simulated by the model in SIM1 is shown in Fig. 6 during the transition from winter to summer circulation. As shown in Fig. 6(a), during winter season, there is no appreciable sensible heat flux over the plateau. With the advent of summer, more and more areas of the plateau gradually gets heated up and the sensible heat flux over the plateau increases (Fig. 6). The sensible heat flux over the arid western plateau is more than over the eastern plateau. This result agrees well with the inference of Yeh and Gao (1979) from 10 years of station data. The magnitude of the maximum sensible heat flux as simulated in the model also reasonably agrees with that in Flohn (1968). By analyzing the simulated surface latent heat flux (figures not shown) it is found that there is gradual increase of evaporation over the Arabian Sea, Bay of Bengal and the Indian Ocean during the transition phase from winter to summer. The maximum value of latent heat flux over the Indian Ocean is about 200 W/m² in July.

4. Conclusions

The results of this study show that the intensity and the location of the Tibetan anticyclone are affected by the seasonally varying surface forcings such as global SST, deep soil temperature and deep soil moisture prescribed in the GCM. The axis of the anticyclone settles to different equilibrium positions under the influence of different surface forcings. The Tibetan anticyclone during monsoon season is reasonably better simulated when the initial atmospheric conditions in the model correspond to January conditions compared to June conditions. The seasonal variations in the surface parameters introduced in the model simulate the mean position of the anticyclone at the right latitude. It may be inferred that in addition to the local thermodynamic and orographic effects of the plateau, the global distribution of surface forcings affect the position and intensity of heat and moisture sources/sinks which in turn affect the location and intensity of the Tibetan High. In order to examine the influence of the initial atmospheric conditions and seasonally varying surface forcings separately on simulation of the upper level anticyclone, it is essential to conduct some more experiments with different initial and boundary conditions and to look into the surface fluxes and upper level fields in detail. It is planned to carry out such experiments using parallel processors in the country.

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