

## Regional climate changes due to double CO<sub>2</sub> simulation by CCM3

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**सार** - CCM3 जलवायु निदर्श पर एक साम्य प्रयोग किया गया। प्रयोग के दौरान मॉडल वातावरण में CO<sub>2</sub> की मात्रा दोगुनी की गई और इसके परिणामस्वरूप जलवायु में आए परिवर्तनों की जाँच की गई। परिणामों से पता चला है कि निर्गमनी दीर्घ तरंग विकिरण में व्यापक कमी आई है जिसे मेघमयता में वृद्धि की संभावना का संकेत मिलता है। कुल वर्षा में महत्वपूर्ण परिवर्तन भले ही न हों किन्तु फिर भी जैसा कि पिछली दीर्घकालिक प्रवृत्तियों में देखा गया है भारत में वर्षा के कालिक और स्थानिक वितरण में परिवर्तन की संभावना है।

**ABSTRACT** . An equilibrium experiment has been conducted with CCM3 climate model in which the amount of CO<sub>2</sub> in the model atmosphere is doubled and the differences in resulting climate has been examined. The results show that there is an overall decrease in outgoing longwave radiation indicating the possible increase in cloudiness. The total rainfall may not change significantly but the temporal and spatial distributions over India are likely to change as observed in past long term trends.

**Key words** - CCM3, Climate, CO<sub>2</sub>, Monsoon, Change.

### 1. Introduction

Sensitivity experiments with global climate models indicate that Carbon Dioxide (CO<sub>2</sub>) plays an important role in global climate changes. There are two main kinds of experiments that have been performed with general circulation models (GCMs). The first are equilibrium experiments with double CO<sub>2</sub> and the other are transient experiment with gradual increase of CO<sub>2</sub>. In all these experiments, it is not just the direct changes in greenhouse radiative heating that are important, but also the complex feedback effects that must be dealt with and that makes this a difficult problem. An increase of CO<sub>2</sub> alone does not yield a sizable climate effect. It is the increased water vapour feedback that amplifies the direct radiative effect of CO<sub>2</sub>.

Manabe and Wetherald (1975) were pioneers in investigating climate change from increased CO<sub>2</sub> concentration with a GCM. Afterward several modelling studies have been conducted to find the possible changes in the simulated climate resulting from a doubling of CO<sub>2</sub>. MacCracken *et al.* (1990) described a model intercomparison of globally averaged warming as a function of globally averaged air-surface temperature. The characteristics of the models are quite different and the range of globally averaged mean air-surface temperature changes is 2.8° to 5.2° C. Sud and Smith (1985) have attempted a numerical study on the influence on local land surface processes on the Indian monsoon. In these

sensitivity experiments GLAS GCM is used to investigate the influence of changes in the land surface fluxes over the Indian subcontinent on the monsoon circulation and rainfall.

All sensitivity studies have concentrated on the global scale. Changes in climate are indeed, on average, occurring globally (Hansen, 1987), but changes at global scale are likely to have significant impact on regional areas. This paper discusses the response of Community Climate Model (CCM3) in the monsoon area due to the doubling of CO<sub>2</sub> in the atmosphere.

### 2. Model

The CCM3 is the fourth generation model in the series of NCAR's global climate model. The description of the model is given by Kiehl *et al.* (1996). The model has a standard horizontal spectral resolution of T-42 (approximately 2.8 × 2.8 degree transform grid) with 18 vertical levels with topmost level at about 2 hPa. The spectral transform method is used in the horizontal and finite differences are used in the vertical for solution of the dynamic equations for temperature, vorticity divergence and logarithm of surface pressure. The three dimensional semi Lagrangian method is used for transporting moisture. When compared to earlier version CCM2, changes to the model formulation fall in the following categories : modifications to the representation of radiative transfer through both clear and cloudy

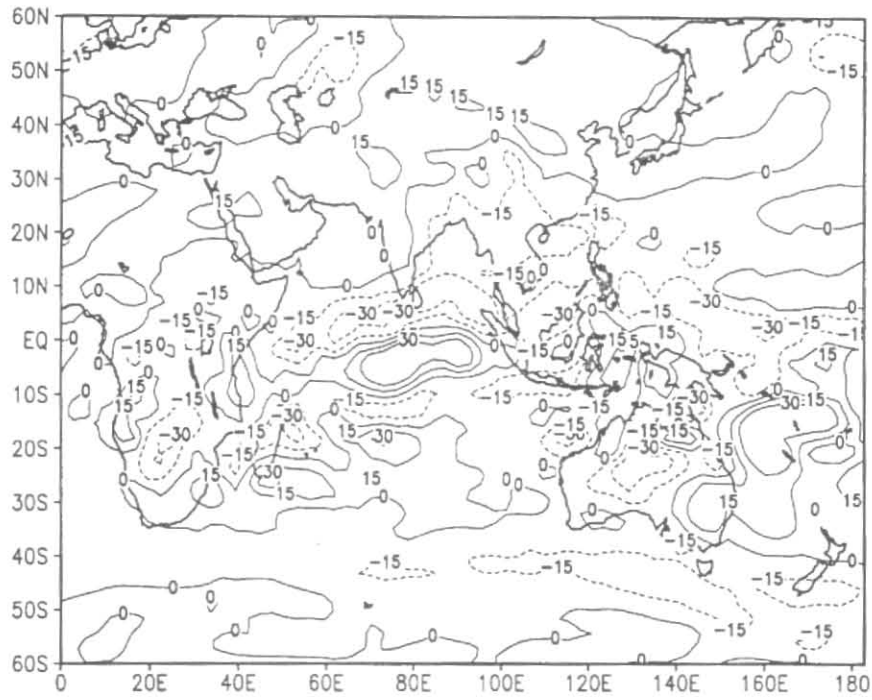


Fig.1. January OLR (2 x CO<sub>2</sub> - Control) (W/m<sup>2</sup>)

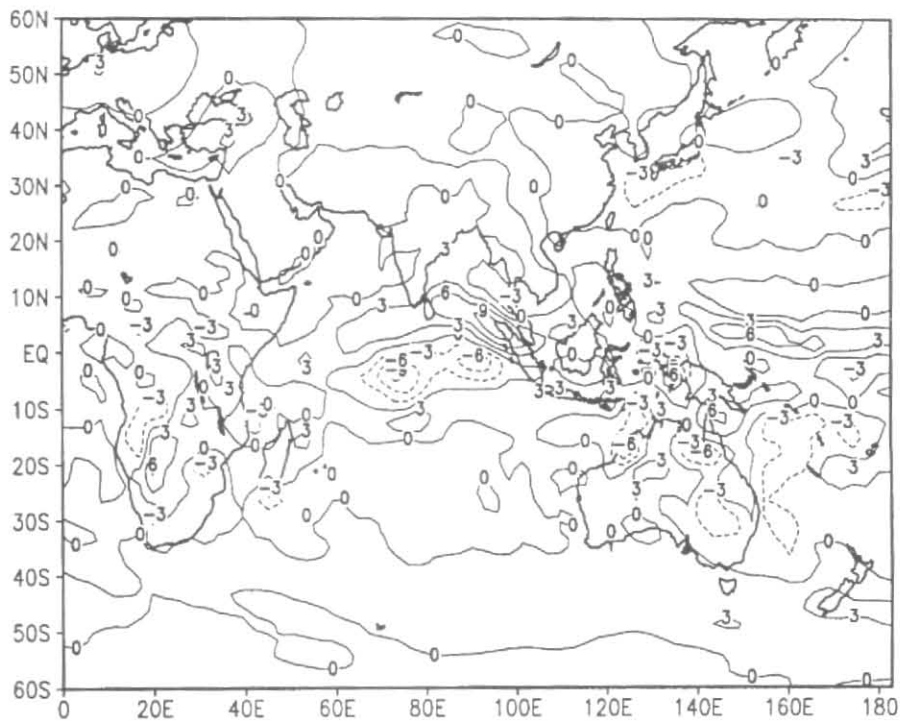


Fig.2. January Rainrate (2 x CO<sub>2</sub> - Control) (mm/day)

atmospheric columns, modification of hydrologic processes (*i.e.*, in the form of changes to the atmospheric boundary layer, moist convection and surface energy

exchange), the incorporation of a sophisticated land surface model, the incorporation of an optional slab ocean mixed layer ocean/thermodynamic sea-ice component

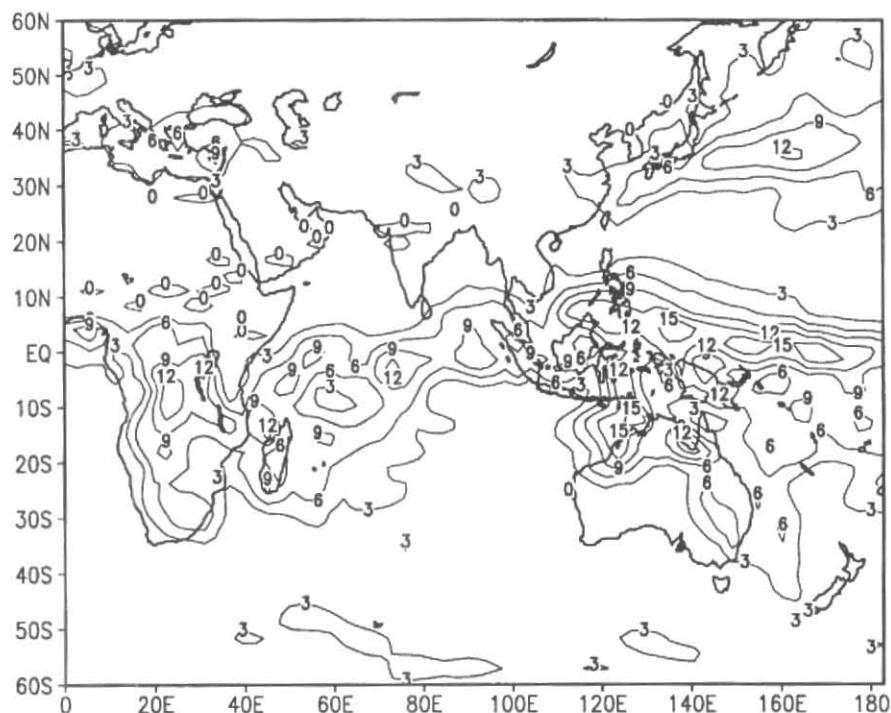


Fig.3. January Rainrate - Control run (mm/day)

Parameterised convection is represented using the deep moist convection formalism along with the mass flux scheme of CCM2. This change results in an additional reduction in the magnitude of the hydrologic cycle and a smoother distribution of tropical precipitation.

In most regards the simulated climate has significantly improved over earlier versions of the CCM, in particular, the intensity and distribution of simulated rainfall over south-east Asian summer monsoon are closer to observed climate.

The land surface model of CCM3 provides for the comprehensive treatment of land surface processes. This is a one dimensional model of energy, momentum, water and CO<sub>2</sub> exchange between the atmosphere and land, accounting for ecological differences among vegetation types, hydraulic and thermal differences among soil types and allowing for multiple surface types including lakes and wetlands within a grid cell. A detailed technical description of the land surface model is given by Bonan (1996).

### 3. Experiment

Here we have conducted an equilibrium experiment in which the amount of CO<sub>2</sub> in the model atmosphere is doubled and the differences in resulting climate examined. The integrations with CCM3 are started from 1 September 1984 initial data and climatological sea surface

temperature data. The double CO<sub>2</sub> (2 CO<sub>2</sub>) and control (1 CO<sub>2</sub>) experiments are integrated for two years. January, May and July averages are compared to see the changes in the south-east monsoon area due to doubling of CO<sub>2</sub> in the atmosphere.

### 4. Results and Discussions

Here particularly changes in outgoing longwave radiation (OLR) and rainfall in the eastern hemisphere during the months of January, May and July are discussed. The averages over different latitude belts are also discussed.

Fig.1 shows the changes in OLR during January month. It is observed that in the equatorial region there is a decrease in OLR upto 30 W/m<sup>2</sup> in some parts south of India and there is an increase in both northern and southern part. There is a large zonal belt of increase in 20 to 40° N upto 10-20 W/m<sup>2</sup>, particularly large over desert areas. These changes may be interpreted as more cloudiness over the equatorial region which is also reflected in the increase of 4-6 mm/day rainrate (Fig.2) over this region during January month. This may cause the intensification of north-east monsoon. Increase of OLR over desert areas may be due to increase in surface temperature in that area. The position of ITCZ, as seen in January rainrate of control run (Fig.3) may be slightly shifted northward.

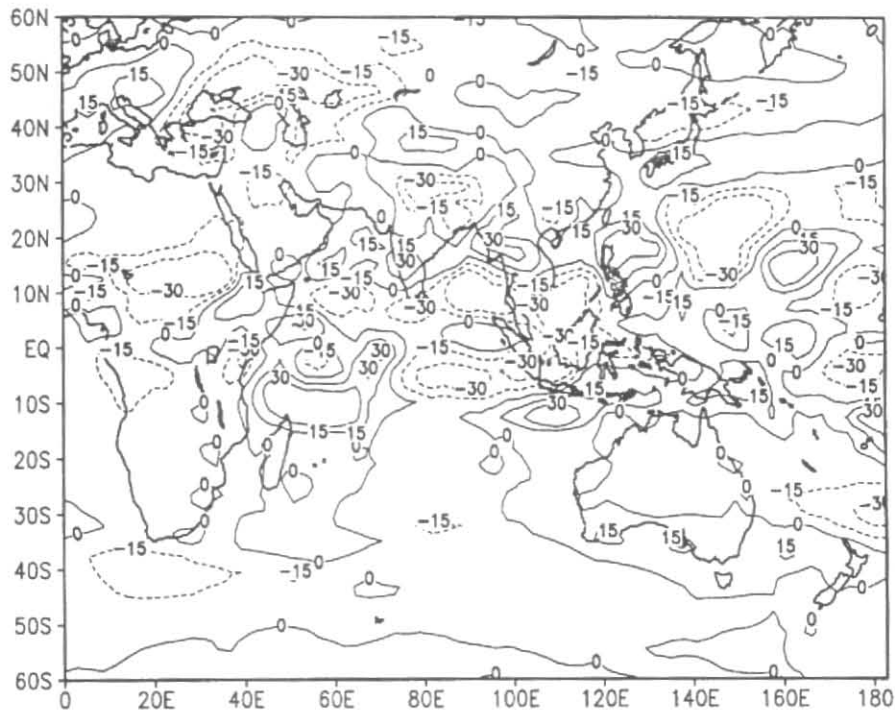


Fig.4. May OLR ( $2 \times \text{CO}_2$  - Control) ( $\text{W/m}^2$ )

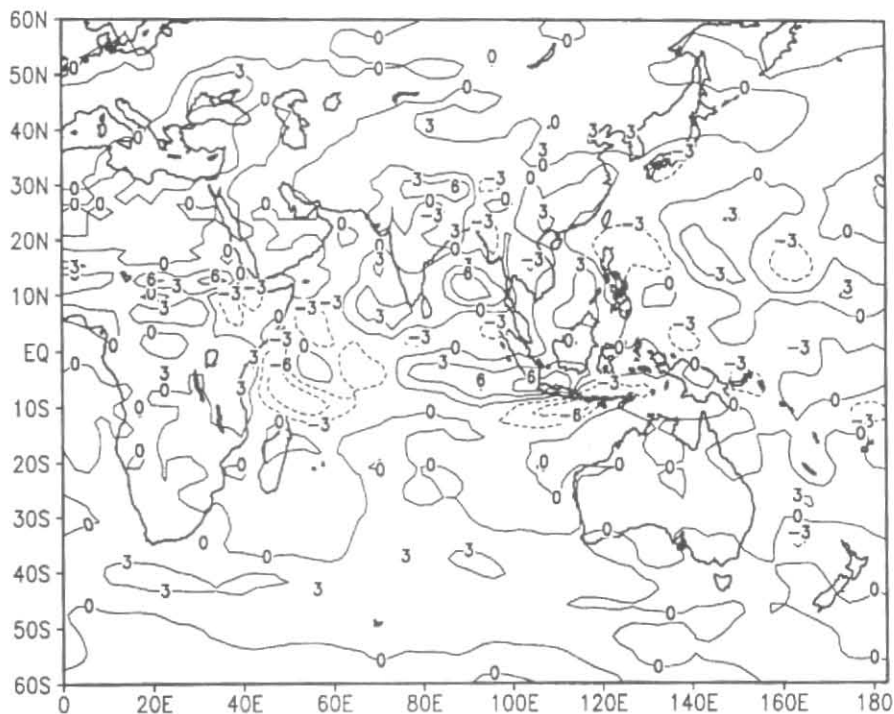


Fig.5. May Rainrate ( $2 \times \text{CO}_2$  - Control) (mm/day)

Fig.4 indicates the changes in OLR during May. There is an increase of 20-30  $\text{W/m}^2$  in the western Indian ocean south of equator and decrease of similar amount in

the eastern part. Similar dipole of opposite changes are seen in the rainrate differences (Fig.5). Changes in May rainrate over India are inversely correlated with the

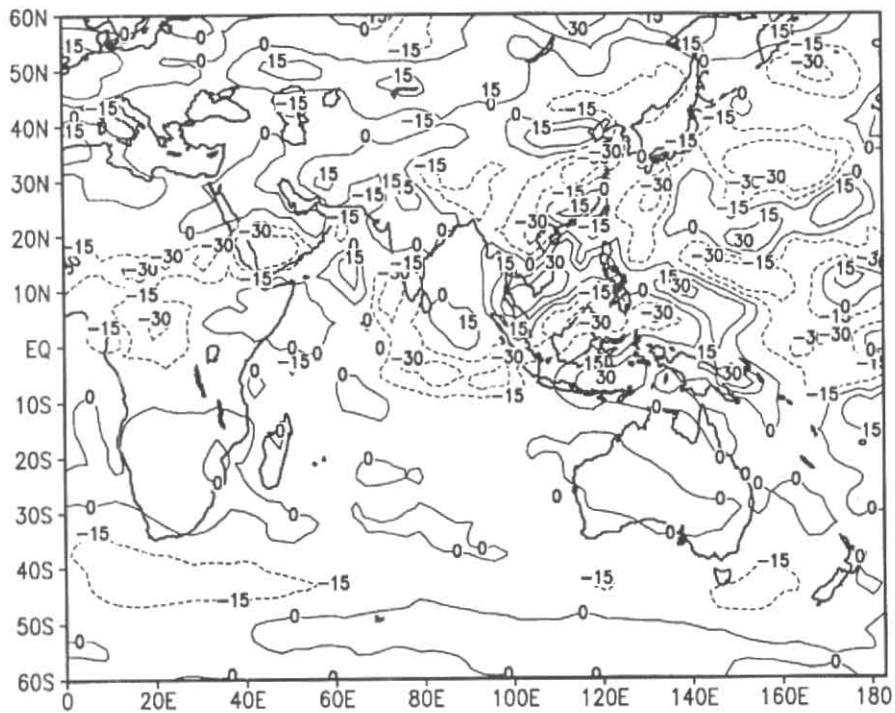


Fig.6. July OLR (2 x CO<sub>2</sub> - Control) (W/m<sup>2</sup>)

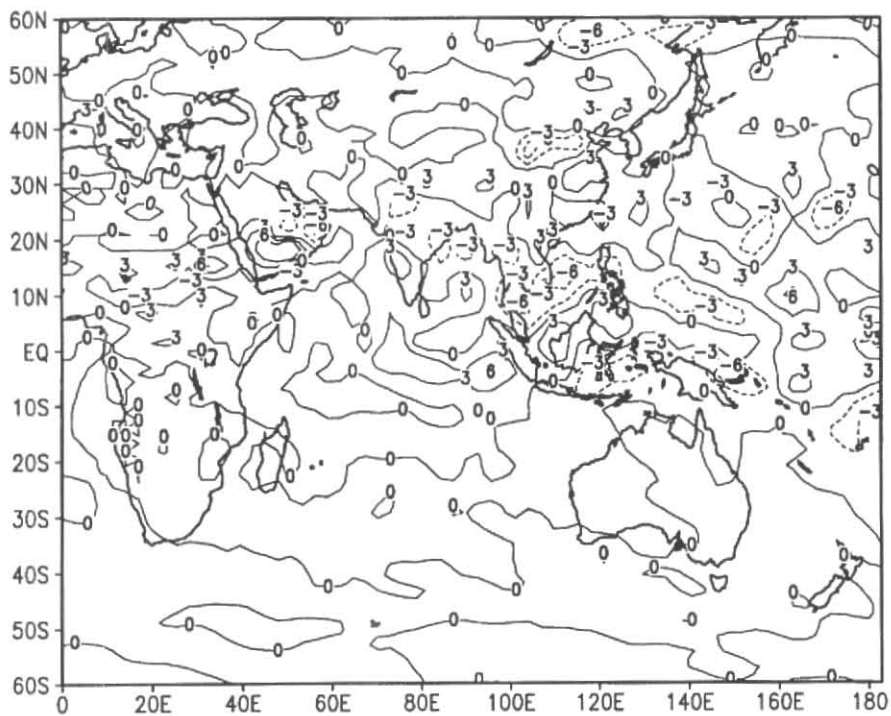


Fig.7. July Rainrate (2 x CO<sub>2</sub> - Control) (mm/day)

changes in OLR. Rainrate has increased over both south and northern part of India and it has decreased over peninsula. The rainrate increase in the south western part

upto 2-4 mm/day may indicate an early onset of monsoon in the Kerala coast. As there is a large variability in the date of southwest monsoon onset, this type of change is

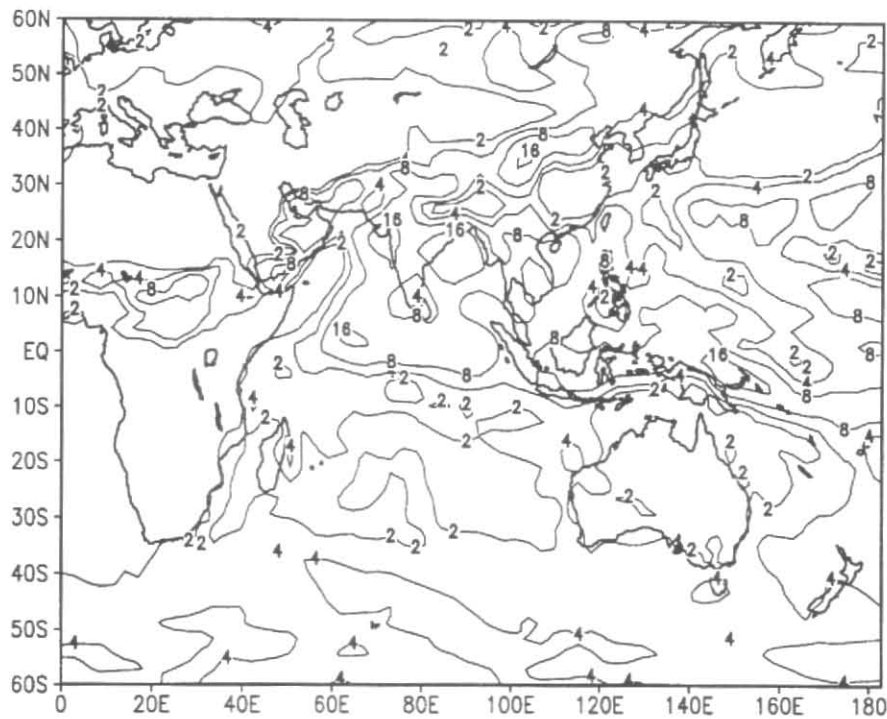


Fig.8. July Rainrate - Control run (mm/day)

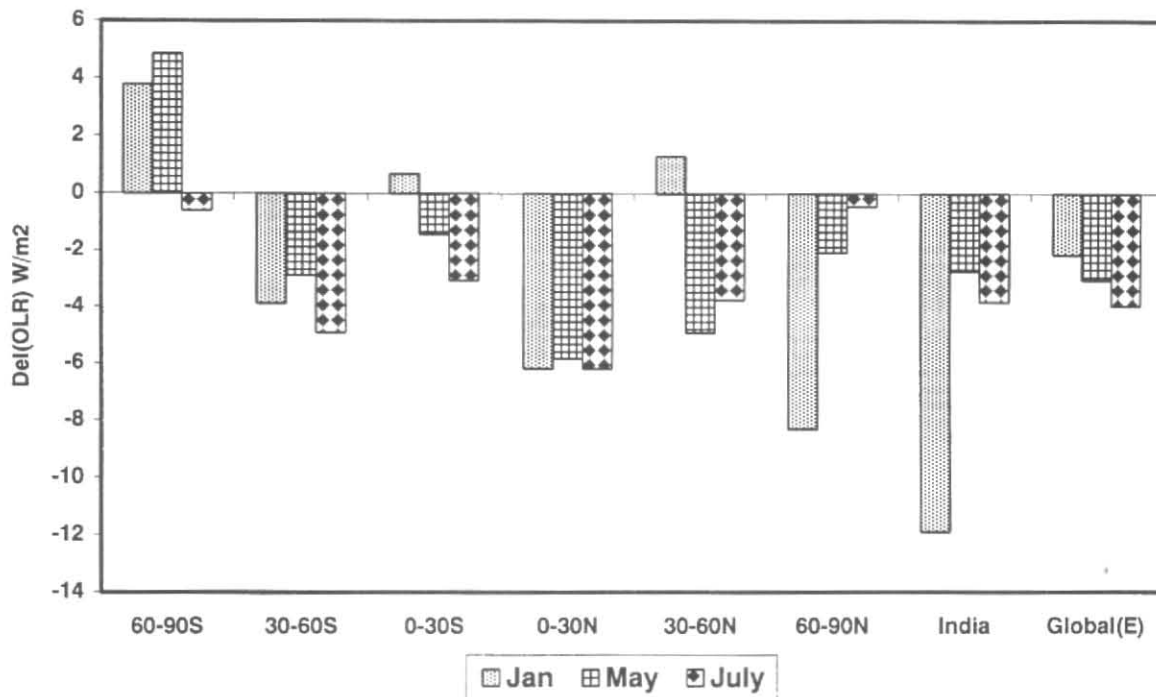
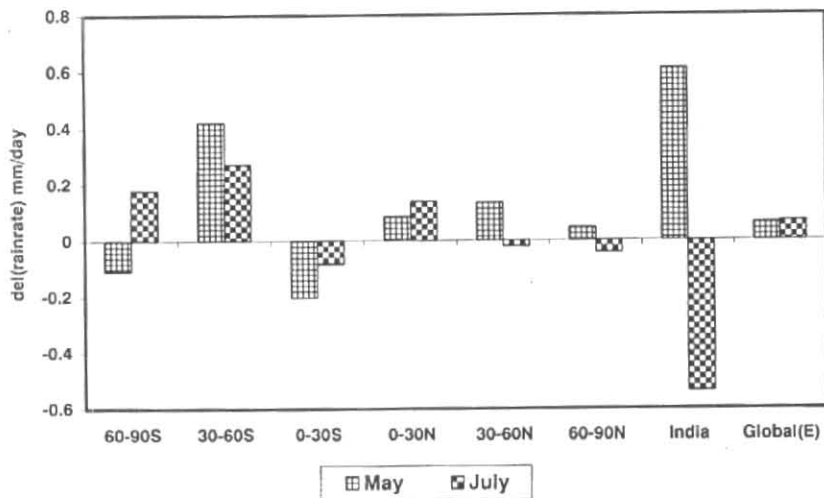
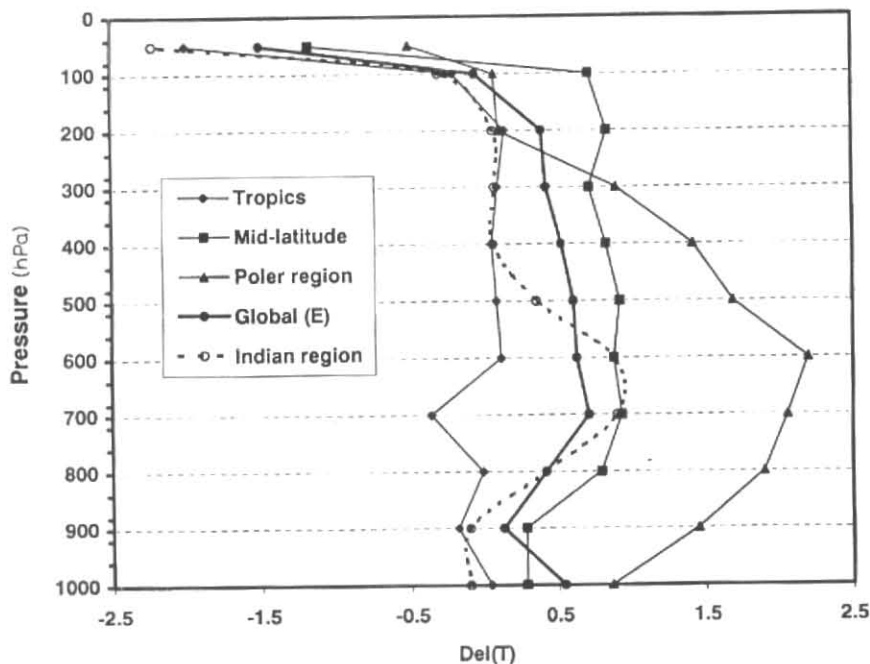


Fig.9. OLR difference (2 x CO<sub>2</sub> - Control) (W/m<sup>2</sup>)

not yet detectable, but in the long run there may be an advancement of the onset date due to continuous increase in CO<sub>2</sub> in the atmosphere.

Fig.6 represents the changes in OLR during July. There is a decrease in OLR in most part of the eastern hemisphere except a few pockets of increase. This means

Fig.10. Rainrate difference (2 x CO<sub>2</sub>- Control) (mm/day)Fig.11.  $\Delta T$  profile after CO<sub>2</sub> doubling over different parts

an overall increase in cloudiness which is also reflected in the rainrate increase during July (Fig.7). Over India there is an increase in rainrate in the south western part and decrease in the central and northern part and also in the Bay of Bengal. Similar long term trend is also seen in the observation (Rupa Kumar *et al.*, 1992). Similar observational trends confirms to certain extent the reliability of model simulation. The model control run simulates July rainfall (Fig.8) reasonably well over India. July being the peak rainfall month, the changes in July may be indicative of the changes in seasonal rainfall. Slight decrease in the north western part where

normal rainfall is very less may intensify the desertification.

Fig.9 shows the average OLR change in different latitude belts during January, May and July. Global averages of the eastern hemisphere shows a decrease in all three months. the maximum decrease of more than 4 W/m<sup>2</sup> is seen in July. This indicates that more energy is trapped in the atmosphere due to increase in CO<sub>2</sub>. There is decrease in all latitude belts except significant increase in 60-90° S during January and May. Over India there is a decrease of 2-4 W/m<sup>2</sup> in May and July and more than 10

W/m<sup>2</sup> during January. Corresponding to the OLR changes there is slight increase in the global average rainrate (Fig.10) over eastern hemisphere. In most latitude belts there is an increase or no significant change in rainrate except a decrease in 0-30° S during both May and July and in 60-90° S during May.

Over whole India there is an increase of 0.6 mm/day in rainrate during May whereas there is a decrease of similar amount in July. As already discussed that there is decrease in some parts and increase in other parts of India, there is no significant change in the average over whole India. Only the overall increase in May month may be indicative of early onset of monsoon. The total seasonal rainfall over whole India also may not have a significant change, but distribution is going to change.

Average atmospheric temperature changes over different regions of the northern part of eastern hemisphere are represented in Fig.11. Cooling is seen in all regions above 100 hPa and increase in most regions below 100 hPa. Maximum change is seen over polar region where the peak is more than 2° K at 600 hPa level. Mid-latitude change is peaking at 800 hPa and extends upto 100 hPa. Similar change is seen in global average over northern part of eastern hemisphere. In the tropical belt, change is not very significant except for a slight decrease in 700 hPa level.

Over India no significant change except for an increase of around 0.5 °K in 800-500 hPa level. One thing is noticeable here is that in all regions maximum changes may be seen in 700-600 hPa level which may be due to trapped radiation by clouds.

## 5. Conclusions

A climate model simulation is made here to see the regional changes in southwest monsoon region due to doubling of CO<sub>2</sub> in the atmosphere. Though the model simulation, because of its uncertainties, does not reflect the realistic situation, it gives an indication of possible changes which may occur in the long run. The results of this simulation shows that there is an overall decrease in OLR indicating the possible increase of cloudiness. Cloud radiation feedback may reduce the surface warming, but atmospheric temperature changes seem to peak at 700-600 hPa level. The total rainfall may not change significantly but the temporal and spatial distribution over India may change. The south western part may get more rainfall whereas central and northern part may get less rainfall.

Similar long term trend is also seen in the observation. This gives a confidence in the model simulation. Increase in May rainfall over southwest India may be indicative of early onset. This fact is not confirmed by the observation.

The results have to be taken with precaution that model is not a perfect representation of real earth-atmosphere system. Every aspect of a climate model is subject to uncertainties that limit the climate change predictive skill. With the improvement of these models one can rely more on quantitative simulation of possible climate change due to increase of CO<sub>2</sub> in the atmosphere. Ofcourse a transient experiment with gradual increase of CO<sub>2</sub> in the model coupled with a dynamic ocean will be better for this purpose.

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