THE EFFECT OF EURASIAN SPRING SNOW COVER ON INDIAN SUMMER MONSOON

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1. INTRODUCTION

There is strong empirical evidence that the areal extent of Eurasian spring snow cover is negatively correlated with the following summer rainfall over India (Hahn and Shukla, 1976; Dickson, 1984). As a possible mechanism for snow-monsoon relationship, it has been conjectured that "large and persistent winter snow cover over Eurasia can delay and weaken the spring and summer heating of the land masses that is necessary for the establishment of the large scale monsoon flow. During the spring and summer seasons following winters with excessive snow, most of the solar energy is used for melting the snow or evaporating from wet soil" (Shukla, 1987). The purpose of this study, which is similar to the one by Barnett et al. (1989), is to examine the physical and dynamical feedbacks responsible for the empirical relation. Toward this end, we have made general circulation model (GCM) experiments with varying Eurasian snow cover. The rationale for the experiments is that the Indian monsoon is a dynamically stable circulation system and its interannual variability is largely determined by slowly varying surface boundary conditions (Charney and Shukla, 1981).

2. EXPERIMENTAL DESIGN

We have made two anomaly experiments with the COLA (Center for Ocean-Land-Atmosphere Interactions) - GCM (R40, L18) to simulate global circulations in an annual cycle mode from February 2 through September 30. The experiments were identical except for the specified initial snow cover (extent and depth) over Eurasia on February 2.

The snow cover data were obtained from NASA which were derived from SMMR (Scanning Multi-channel Microwave Radiometer) on the Nimbus-7 satellite (Chang et al, 1987). These data were available for the nine year period, November 1978 - August 1987. From these data, we determined maximum ("heavy") and minimum ("light") snow depth at each gridpoint for February 2 over Eurasia. The first experiment specified the heavy snow cover and the second experiment the light snow cover. Fig. 1a and 1b, respectively, show light and heavy snow cover (water equivalent) distribution over Eurasia. In the model, the water equivalent 1 mm is equal to 5 mm deep snow. The large differences between heavy and light snow cover are south of 50°N, especially over Tibet and Europe.

3. RESULTS

Fig. 2 shows a 500 mb May temperature difference between heavy and light snow cover experiments. The temperature for heavy snow is more than 3K cooler over Tibet. This reduces the north-south temperature gradient between 30°N and the equator over the Indian subcontinent. The impact of the temperature gradient is to reduce the intensity of circulation. Fig. 3a shows the mean JJA 850 mb wind for the light snow cover experiment. This is a typical lower tropospheric circulation during the monsoon season with an easterly current ~10m/s in the Indian Ocean, the Somali jet ~20m/s and the westerly current ~15m/s over the Indian peninsula. The circulation pattern for the heavy snow cover experiment is similar but weaker in strength. The difference in the circulation between heavy and light snow cover experiments is shown in Fig. 3b. In the heavy snow cover experiment the Somali jet is weaker by about 2m/s and the westerly current over the peninsula is weaker by about 3m/s.

The influence of initial snow cover on the circulation also reflects in the precipitation pattern. The mean JJA precipitation rate for the light snow cover experiment is shown in Fig. 4a. There is one center of maximum precipitation rate on the west coast of the Indian peninsula and another large center of maximum precipitation rate near the foothills of the eastern section of Himalayas. Fig. 4b shows the difference in the mean JJA precipitation rate between heavy and light snow cover experiments. The deficit in the rain rate is over the centers of maximum precipitation rate in Fig. 4a.

The results show that the Eurasian snow cover not only influences Indian monsoon but also the Chinese monsoon and the global circulations. For example, the influence of heavy snow cover is to reduce the strength of trades in the eastern equatorial Pacific Ocean. Fig. 5a shows the mean JJA vertically integrated moisture convergence and superimposed mean 850 mb wind over the Pacific Ocean for the light snow cover experiment. The dark shaded areas are the divergence of moisture associated with the semipermanent high pressure systems in the eastern Pacific Ocean and over Australia. The positive contours show the convergence of moisture associated with the ITCZ and SPCZ. The 850 mb wind vectors show the typical prevailing trades. The difference between a similar figure for the heavy snow cover experiment and Fig. 5a is shown in Fig. 5b. Anomalous 850 mb westerly flow in the eastern Pacific Ocean indicates weaker trades in the heavy snow cover experiment. Also, it shows reduced convergence of moisture in the SPCZ. This is probably because weaker monsoon circulations in the heavy snow cover experiment are associated with weaker Walker circulations over the Pacific Ocean. Similar results were reported by Barnett *et al.* (1989).

4. CONCLUSIONS

Cooling the continent, especially over the Tibetan Plateau by melting excessive snow cover and by the heat flux of evaporation, reduces the north-south temperature gradient. This leads to an overall weaker monsoon circulation. Weaker monsoon circulation is associated with a weaker Walker circulation and hence weaker trades over the Pacific Ocean. These results are based on one run for each experiment. Even though the tropical circulations are dynamically stable additional runs are necessary with slightly perturbed initial conditions to obtain an ensemble and a measure of variability to test the significance of these results in a statistical sense.

5. REFERENCES

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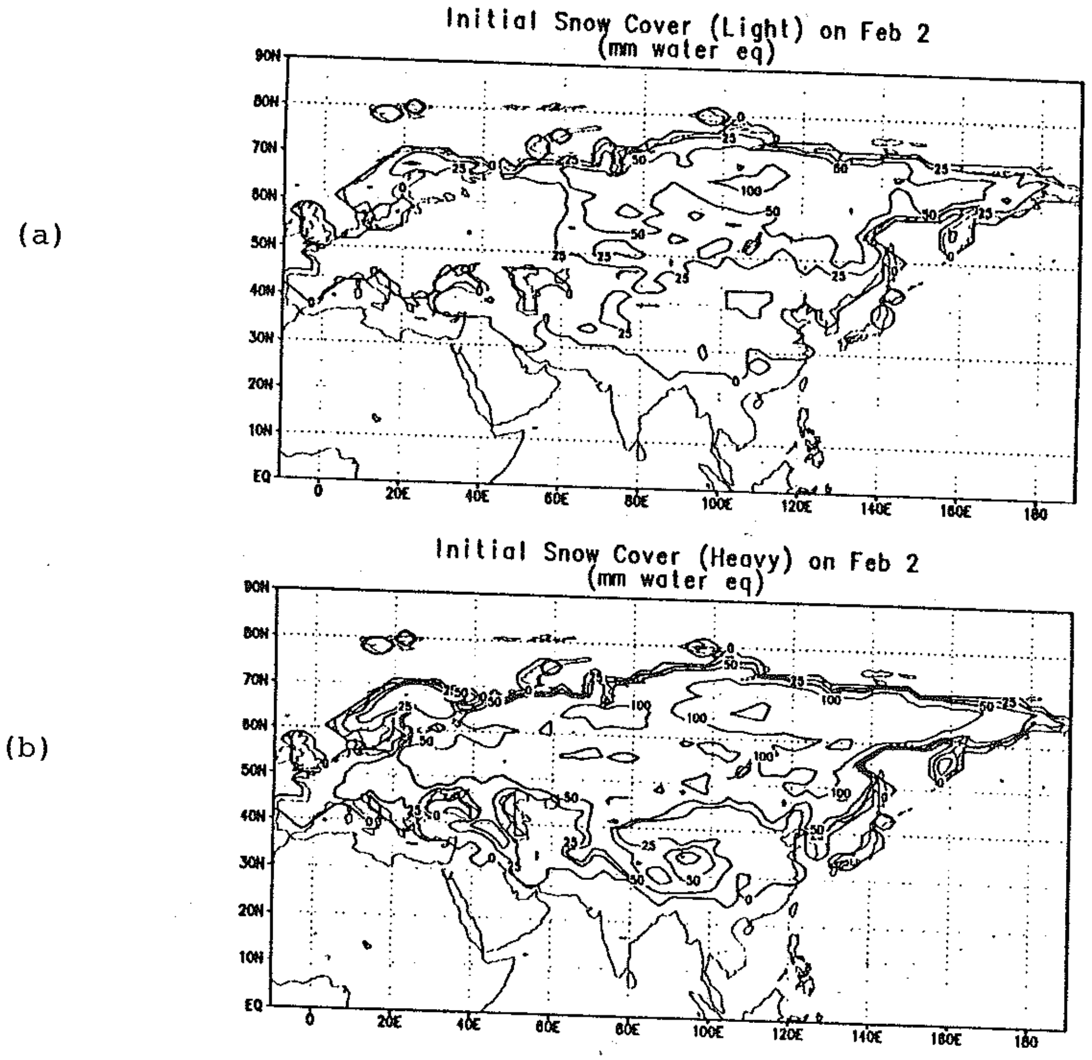


Figure 1. Initial light and heavy snow cover (water equivalent over Eurasia)

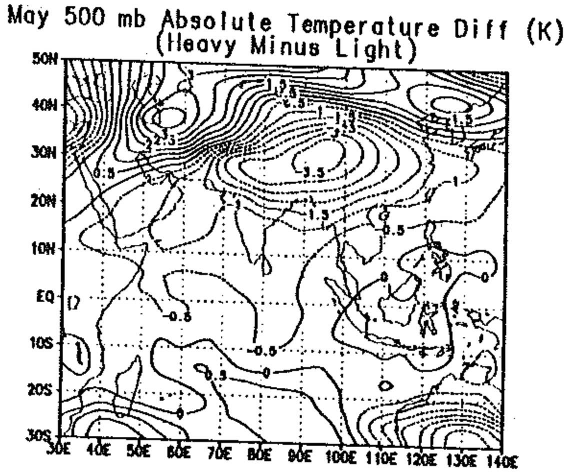
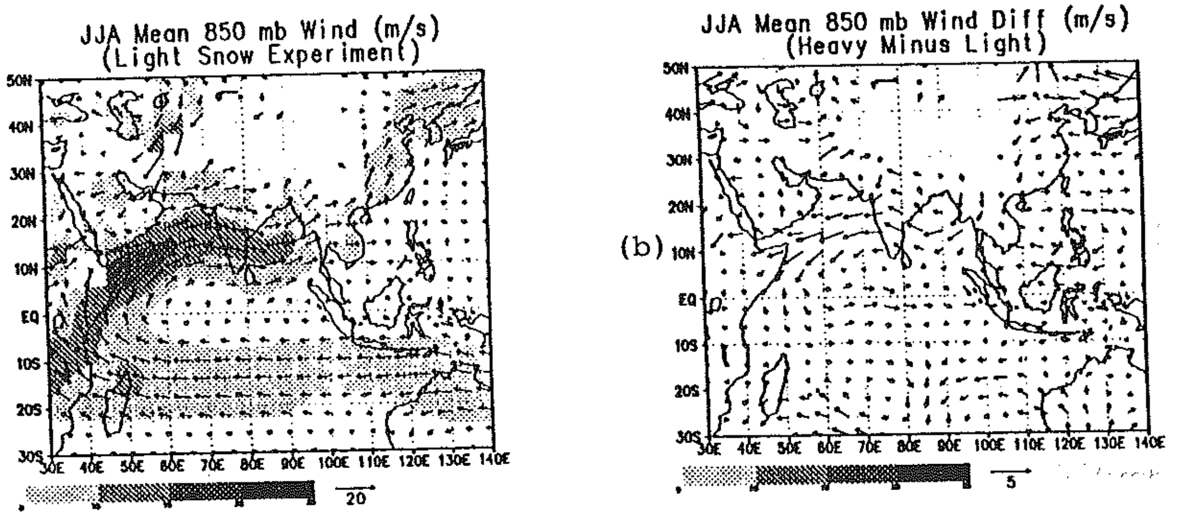


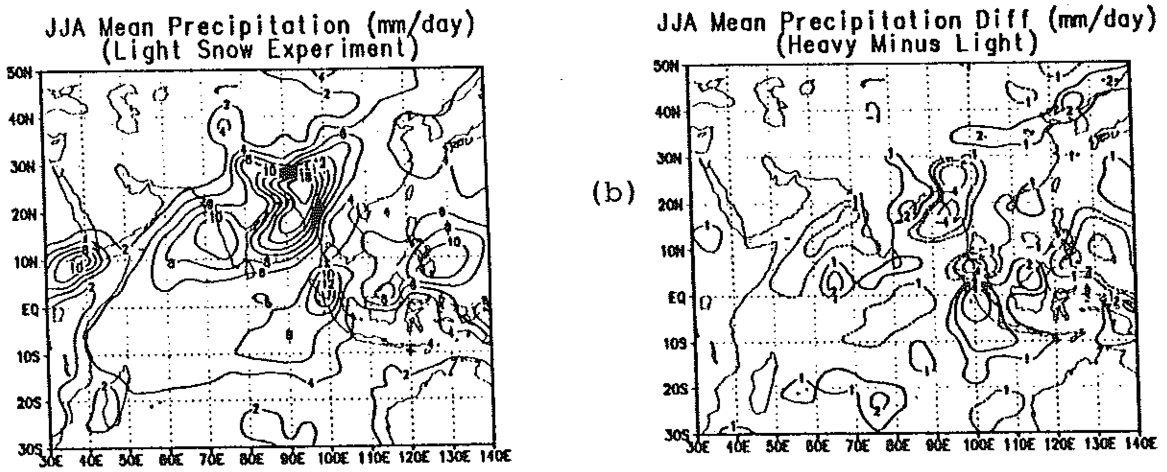
Figure 2. May temperature difference between heavy and



(a) JJA Mean 850 mb Wind (m/s) (Light Snow Experiment)

(b) JJA Mean 850 mb Wind Diff (m/s) (Heavy Minus Light)

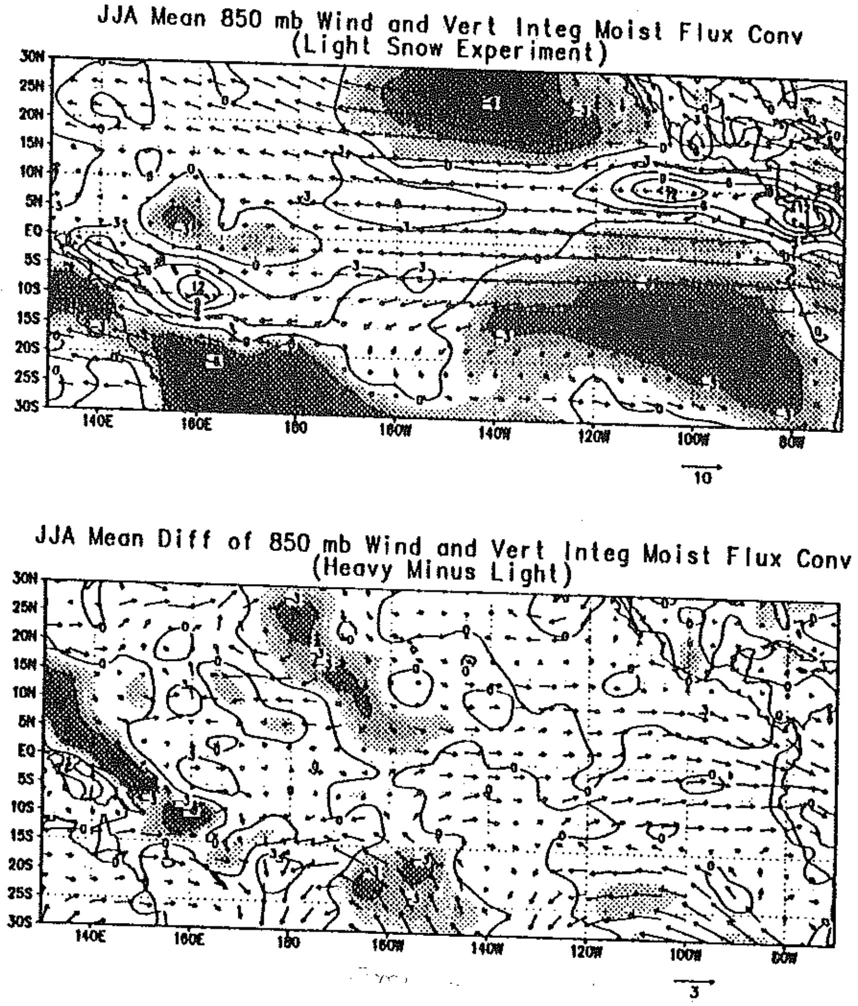
Figure 3. (a) JJA 850 mb wind for light snow cover experiment
(b) Difference in JJA 850 mb wind in heavy and light snow cover experiments



(a) JJA Mean Precipitation (mm/day) (Light Snow Experiment)

(b) JJA Mean Precipitation Diff (mm/day) (Heavy Minus Light)

Figure 4. (a) JJA mean precipitation (mm/day) for light snow cover experiment
(b) Difference in JJA mean precipitation (mm/day) in heavy and light snow cover experiments



(a) JJA Mean 850 mb Wind and Vert Integ Moist Flux Conv (Light Snow Experiment)

(b) JJA Mean Diff of 850 mb Wind and Vert Integ Moist Flux Conv (Heavy Minus Light)

Figure 5. (a) JJA mean vertically integrated moisture flux convergence and mean 850 mb wind field. Dark shaded areas indicate moisture divergence
(b) Difference in JJA mean vertically integrated moisture flux convergence and 850 mb wind field in heavy and light snow cover experiments