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Interactions between the snow cover and the atmospheric circulations in the Northern Hemisphere

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ABSTRACT Hemispheric interactions between large-scale snow cover over the two continents (Eurasia and North America) and the atmospheric circulation in the Northern Hemisphere have been investigated for the period from November 1966 to December 1982. Lag correlations were computed between snow cover extent of central Asia and eastern North America and the 500 mb geopotential height field in the Northern Hemisphere, using of NOAA/NESDIS Satellite Snow Cover data and 500 mb geopotential height data. The snow cover - atmospheric interactions are more hemispheric in central Asia than in eastern North America with the lags of more than a month. In eastern North America, concurrent correlation is prominent. Strong lag correlations are detected between February snow cover in central Asia and the geopotential height anomalies in December, which is specified as the Eurasian pattern by Wallace & Gutzler (1981). February snow cover, in turn, has a considerable lingering effect on the atmosphere in April.

Interactions entre la couverture de neige et les circulations atmosphériques de l'hémisphère nord

RÉSUMÉ De novembre 1966 à décembre 1982, on a étudié l'interaction hémisphérique de la couverture de neige à grande échelle des deux continents (Eurasie et Amérique du Nord) et de la circulation atmosphérique de l'hémisphère nord. On a calculé les corrélations de décalage entre l'étendue de la couverture de neige de l'Asie centrale et de l'est de l'Amérique du Nord et le champs de hauteur géopotentielle à 500 mb de l'hémisphère nord, à partir des données de la couverture de neige établies par le satellite NOAA/NESDIS et des données de hauteur géopotentielle à 500 mb. Les interactions de la couverture de neige et de l'atmosphère sont plus hémisphériques dans l'Asie centrale que dans l'est de l'Amérique du Nord, avec les décalages de plus d'un mois. Dans l'est de l'Amérique du Nord, la corrélation convergente prédomine. On décèle de fortes corrélations de décalage entre la couverture de neige de février en Asie centrale et les anomalies de hauteur géopotentielle de décembre, appelées configuration eurasienne par Wallace et Gutzler (1981). A son tour, la couverture de neige de février exerce un grand et persistant effet sur l'atmosphère en avril.

INTRODUCTION

Recently, satellite derived data are giving us a lot of information about the Northern Hemisphere snow cover and much evidence of interactions between atmosphere and snow cover is being reported. For the North American continent, there are a number of studies on these interactions which contribute to the improvement of the forecast techniques (Dewey, 1977; Walsh *et al.*, 1982 & Namias, 1985). For the Eurasian continent, although the research in this region is much less compared with the North American continent, a few important studies have been made on the influence of snow cover upon the monsoon climate (e.g. Hahn & Shukla, 1976). From this evidence, it is not hard to imagine the existence of hemispheric interactions between snow cover and the atmosphere as Kukla & Gavin (1981) pointed out. As the time scale of snow cover variations is expected to be considerably longer than that of the atmosphere, it may play an important role on the modulation of the seasonal and interannual variation of climate. Some model studies have revealed the existence of hemispheric interactions between snow cover and the atmosphere. For example, using the NCAR General Circulation Model, Williams (1975) demonstrated that a larger snow cover in summer may weaken the Northern Hemisphere summer monsoon. Yeh *et al.* (1983) have shown that a large scale removal of snow cover in middle and high latitudes in spring has a significant effect on the atmosphere. That is, the thermal and dynamic structure of the atmosphere is affected through the decrease of soil moisture by snowmelt.

However, studies of hemispheric interaction based on observational data have up to now rarely been done. The purpose of this study is to investigate hemispheric interactions between snow cover and the atmosphere in the Northern Hemisphere from satellite derived data. Synoptic correlations between the NOAA/NESDIS snow cover area and 500 mb geopotential height were calculated. To evaluate the persistence of the influence of snow cover on the atmosphere (or reverse), lag correlations were computed.

DATA AND METHODS

Data

NOAA/NESDIS Northern Hemisphere Snow and Ice Charts were used for snow cover data. The period of the data is from November 1966 to December 1982. Monthly mean data for November through April were used. The quality of the data is not the same all through the period. More accuracy is expected in the more recent charts. For the parameter of atmospheric circulation, geopotential height of the 500 mb level was chosen to investigate the hemispheric interactions between snow cover and atmosphere. Monthly mean JMA 500 mb geopotential height of Northern Hemisphere grid point data was used for the same period.

Method

To determine the interactions between snow cover and the atmosphere a synoptic correlation analysis was made. Correlation coefficients between snow-cover area in a selected region and 500 mb height in the Northern Hemisphere were calculated for 16 years based upon monthly data. To clarify the intensity and direction of the influences, lag correlations were also computed.

Central Asia and eastern North America were selected as the key regions for the calculation referring to the geographical partitioning made by principal component analysis. Central Asia was chosen since Hahn & Shukla (1976) have pointed out that this region has a close relationship with monsoon climate. The correlation coefficient between the snow cover variation of central Asia and that of the Eurasian continent is 0.84. Eastern North America was chosen because the impact of winter snow cover is greater in the eastern half compared to the western half of the United States (Walsh & Jasperson, 1985). The correlation coefficient between the snow cover variation of eastern North America and that of the North American continent is 0.88.

RESULTS

Derived results from the synoptic correlations between snow cover and 500 mb geopotential height are as follows: hemispheric interactions are detected between the snow cover anomalies both over central Asia and eastern North America and the atmospheric circulation patterns in the Northern Hemisphere. However, characteristics of the interactions are different between the two regions.

Snow cover over central Asia

Snow cover - atmosphere interaction is hemispheric and strong correlations are found between snow cover and the atmosphere over the North American continent as well as over the Eurasian continent. Lag correlation is prominent and the direction of the influences varies with seasons; atmosphere to snow in winter and snow to atmosphere in spring. This feature is especially prominent for the snow cover in February. Fig. 1 shows the correlation between the snow cover of central Asia in February and the atmosphere in December. The EU-pattern of Wallace & Gutzler (1981) is greatly responsible for the large extent of snow cover in central Asia. The PNA-pattern is also detected. Fig. 2 shows the correlation between snow cover in February and the atmosphere in April. A lag effect of winter snow cover on the spring atmosphere seems to be apparent in April, where negative anomalies are produced on the downstream side of central Asia, i.e. over the Far East. A PNA-pattern (positive) is also detected.

Snow cover over eastern North America

Compared to the snow cover in central Asia, snow cover - atmosphere interaction is less hemispheric in extent for eastern North America. However, a strong correlation is found in the atmosphere over the North American continent. Concurrent correlation is dominant rather than lag correlation. A slight effect of the atmosphere on snow cover is detected with a lag of one month and a lag effect of snow on the atmosphere is not apparent.

CONCLUDING REMARKS

Hemispheric interactions between the snow cover and the atmospheric circulations in the Northern Hemisphere have been investigated. Central Asia and eastern North America were chosen as the study area of snow cover. Results show that the snow - atmosphere interactions are more hemispheric for snow cover in central Asia than in eastern North America. This may be because of the larger snow cover extent observed over the Eurasian continent. Lag correlations were prominent in central Asia while concurrent correlations were prominent in the eastern North America. These results agree with the results of Foster *et al.* (1983), that the winter temperature is correlated with winter snow cover over the North American continent while autumn snow cover is correlated with winter temperature over the Eurasian continent.

Especially for February snow cover in central Asia, hemispheric interactions were apparent with lags of two months. Extensive snow cover in February is strongly influenced by the EU-pattern in December. Furthermore, extensive snow cover in February has lingering effects on the atmosphere in such a way as to produce negative heights over the Far East in April. Also, extensive snow cover in February seems to be highly correlated with the negative PNA-pattern in December and the positive PNA pattern in April. In the present analysis, it was not possible to clarify the actual physical process of the interaction. To deduce this aspect, analysis of precipitation, hydrological process of surface and vertical structure of the geopotential or temperature field may be required for further studies.

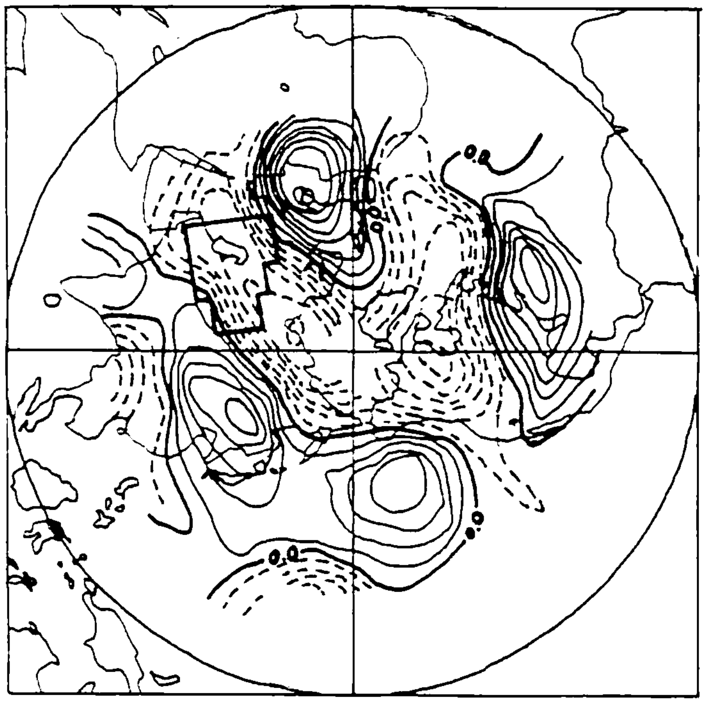

FIG. 1 Lag correlation between snow cover over central Asia in February and the 500 mb geopotential height over the Northern Hemisphere in December. Contour intervals are 0.1. Solid lines indicate the positive correlations and dashed lines indicate the negative correlations

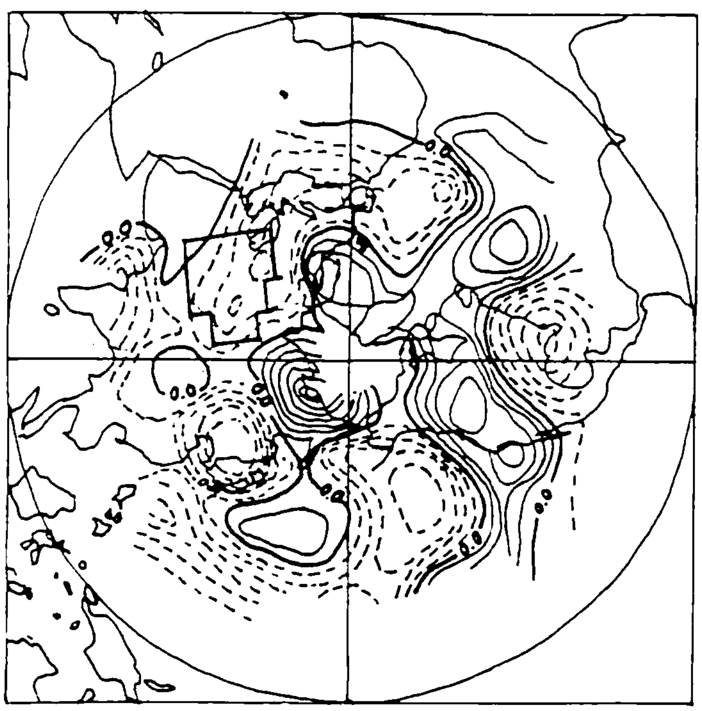

FIG. 2 As in Fig. 1 except for the geopotential height in April

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