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INTERACTION BETWEEN THE SNOW COVER OVER EURASIAN CONTINENT AND THE NORTHERN HEMISPHERE SURFACE AIR TEMPERATURE

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ABSTRACT

Hemispheric interactions between the large-scale snow cover extent over the Eurasian continent and surface air temperature in the northern hemisphere (NHT) were statistically investigated for the 21 years from 1966 through 1987. Snow cover extent data derived by NOAA/NESDIS in Central Asia region was chosen to represent the Eurasian snow cover.

Seasonal dependencies are found in the interaction between snow cover and NHT. That is, snow cover of October is significantly correlated with the NHT, but that of mid-winter showed only marginal correlations. On the other hand, snow cover of spring is significantly correlated to the NHT of concurrent and subsequent winter to summer suggesting the possible links between snow cover and NHT with intervening of Indian summer monsoon and the atmosphere/ocean system.

1. INTRODUCTION

Large scale snow cover are known to have significant influences on interannual variation of atmospheric circulation through two major effects: albedo-effect and hydrological effect through soil moisture supplied by snowmelt. Blanford (1884) pointed out that Himalayan snow is inversely related to the succeeding Indian summer monsoon rainfall (ISM). Using satellite derived snow cover extent data edited by National Oceanic and Atmospheric Administration/National Environmental Satellite, Data and Information Service (NOAA/NESDIS), Hahn and Shukla (1976) reexamined their result. With the atmospheric general circulation model (GCM), Yeh et al.(1984) first noticed the interseasonal hydrological effect of snow cover to the atmosphere as well as its in-situ albedo effect. Removal of the mid-March snow cover increased the surface temperature at high latitude for subsequent 3-4 month, and also reduced the soil moisture over next two seasons. Barnett (1988) and Yasunari et al.(1991) have further investigated the hydrological effect of snow cover by GCM, and showed the substantial effect of excessive snow mass over Eurasia to the northern spring and summer climate.

Morinaga and Yasunari (1987) pointed out that the maximum snow cover extent of Central Asia is correlated with the precedent atmospheric pattern which is similar to the teleconnection pattern of Eurasian Pattern (EU, Wallace and Gutzler, 1981) in the precedent December. On the other hand, Yasunari (1991) showed that teleconnection pattern of EU and Pacific North America (PNA, Wallace and Gutzler,1981) are closely correlated to NHT during winter.

The above studies strongly suggest that the large scale snow cover may also be interactive with large scale temperature field, such as NHT. The present study is aimed to investigate the hemispheric interaction between Eurasian Snow cover and NHT.

2. DATA AND METHOD OF ANALYSIS

NOAA/NESDIS snow cover extent (SC) data, originally digitized to 89 x 89 grid points by NOAA has been rearranged to the grid points of 5^{o} lon. x 5^{o} lat. grids for this study. Central Asia is selected as Eurasian snow cover as shown in Fig. 1 for the following reasons (Morinaga and Yasunari, 1992): 1)it represents the variation of the whole Eurasian continent. 2)it is most closely related to ISM.

The northern hemisphere land-based surface air temperature anomalies (NHT) (Jones et al.(1986) and Jones (1988)) for 1966-87 was used as the hemispheric-mean temperature data (monthly mean).

To detect the two-way interactions between SC and the NHT, the lag correlations of SC were computed from preceding January for 3 years. Lag correlations between SC of October through April and NHT of precedent and subsequent months were computed.

For comparison with NHT, surface air temperature over Eurasia (EUT) was also computed. The region for the EUT is from 45-120^{o}E, north of 30^{o}N (Shaded area in Fig. 1). This region was selected referring to the area of the maximum linear trend in NHT over the 1967-87 period(Fig. 1, Jones, (1988)). The region for EUT does not correspond to the whole Eurasian continent but nearly corresponds to the region at the large increasing temperature trend over the continent. The region with decreasing temperature trend was excluded.

3. RELATIONSHIPS BETWEEN SNOW COVER AND SURFACE AIR TEMPERATURE OVER THE NORTHERN HEMISPHERE

Fig. 2 (a)-(g) show the lag correlation between SC in October through April and NHT and EUT. NHT shows smoother change of correlations than EUT with SC, probably due large spatial averaging.

Fig. 2(a) shows that both NHT and EUT show significant relation with October SC in precedent and concurrent months. EUT in the following January shows negative correlation with October SC. This corresponds to the result of Foster et al.(1984), noting that winter temperature in Eurasia is lag-correlated with precedent autumn snow cover and not correlated with concurrent winter snow

Fig. 1 Linear trends in northern hemisphere land-based annual mean surface air temperature over the 1967-86 period. Units: C per decade. Dark areas show cooling. (Jones, 1988). (Central Asia region is indicated with hatch and shaded area corresponds to the EUT region)

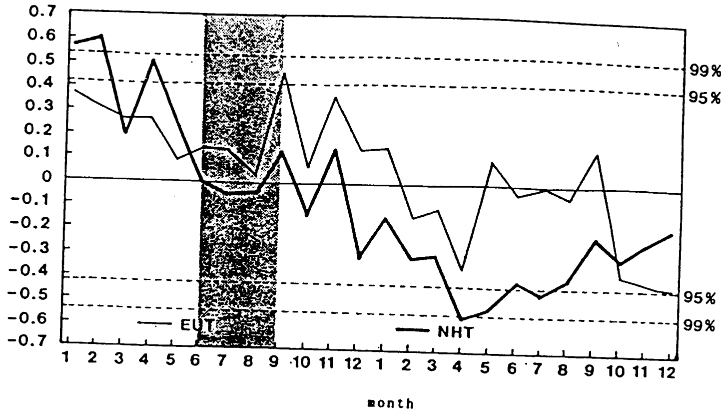

Fig. 3 Lag correlation between Indian summer monsoon and NHT and EUT

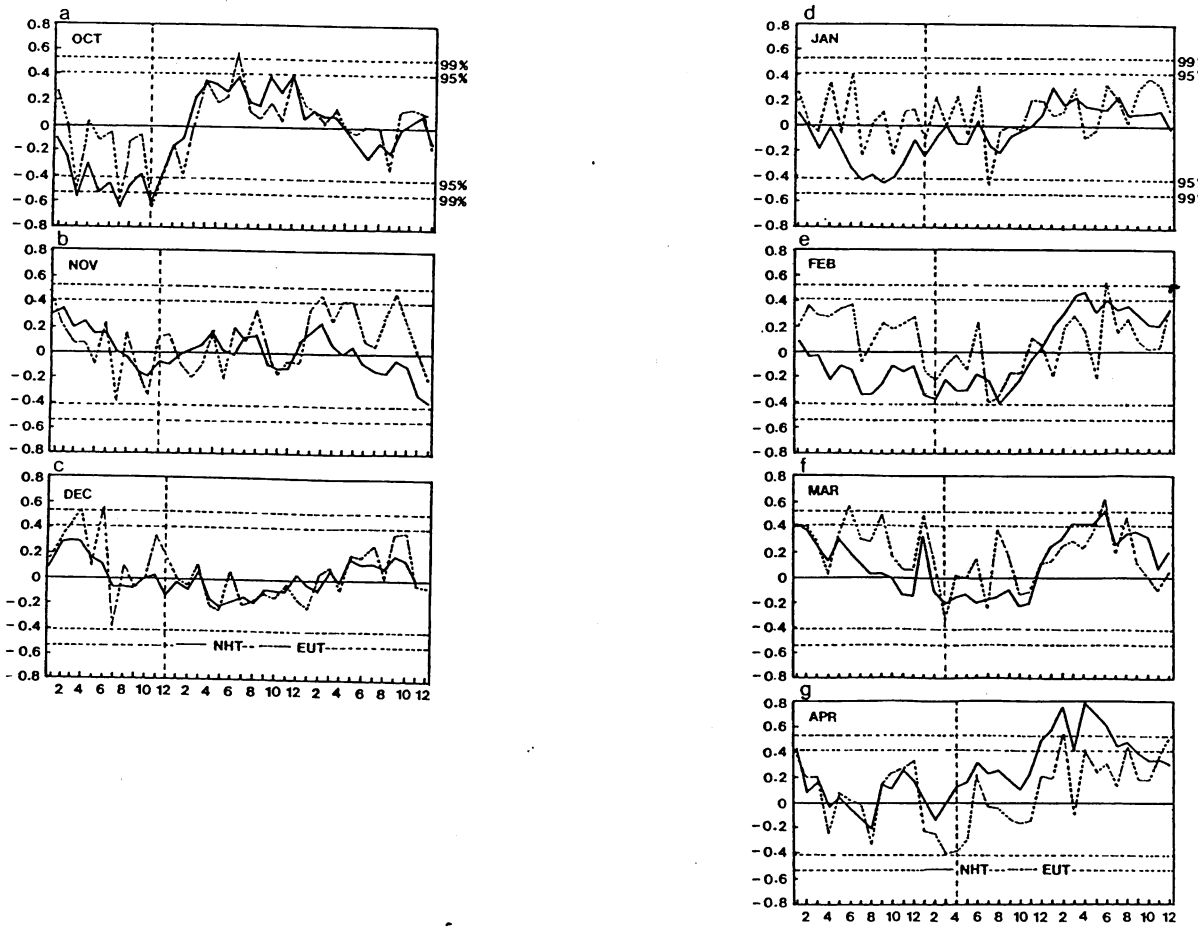

Fig. 2 Lag correlation between snow cover and NHT and EUT
(a) October snow (b) November snow
(c) December snow (d) January snow
(e) February snow (f) March snow
(g) April snow

cover.

Fig. 2(b) and (c) show that SC in November and December are not correlated with NHT. Fig. 2(d) shows that though marginally significant, SC in January is associated with preceding summer to autumn NHT. Fig. 2(e) shows that time sequence of correlations of NHT and EUT are different especially in precedent months with SC in February compared with SC in other months. Fig. 2(f) shows that SC in March is positively correlated to EUT of precedent month, and negatively correlated with concurrent EUT.

Fig. 2(g) indicates that SC in April is strongly correlated to NHT of subsequent winter to summer. It is very interesting that the lag correlation is much more significant compared to the concurrent correlations.

Though marginally, concurrent correlation is significant between SC and EUT with March and April SC. This result is consistent with that of Ropelewski (1991), which notes the spring SC in EU is concurrently

These results have shown that the relation between temperature change (for example, the hemispheric warming or cooling) and SC differs from month to month, and for season to season. October SC would be most sensitive to changes of both NHT and EUT especially in precedent spring to autumn. March and April SC would be sensitive to the concurrent EUT change. On the other hand, temperature of winter to summer is most sensitive to the SC of precedent April. These results suggest that it is NHT or EUT f autumn and spring and not winter that SC is directly related to.

4. EFFECT OF SPRING SNOW COVER TO THE INTERANNUAL VARIATION OF NORTHERN HEMISPHERE MEAN SURFACE AIR TEMPERATURE

In the previous section, close relation between April SC and subsequent winter to summer NHT was found. As April SC is closely related to the subsequent ISM (Morinaga and Yasunari, 1992), ISM and NHT, and ISM and EUT were analyzed to examine more about inter-relations among these parameters.

Fig. 3 shows the lag correlation between ISM and NHT and EUT. ISM is positively correlated to the precedent winter to spring NHT and then the correlation become non-significant during the concurrent summer to autumn. Then from the subsequent winter, the correlations become negative and they are significant from spring to summer. This may suggest that the following relations are significant: the high (low) NHT in winter is followed by strong (weak) ISM, and strong ISM is followed by low (high) NHT in the subsequent spring to summer. This seems to be similar to Fig. 2(g) showing that small (large) SC April is followed by high (low) NHT in the subsequent spring to summer.

These results may suggest that the lag correlation between NHT and April SC may be induced by the intervening of summer monsoon circulation.

5. YEAR TO YEAR VARIATION OF SNOW COVER WITH POSSIBLE LINKAGE OF INDIAN SUMMER MONSOON RAINFALL, NHT AND EUT

Though correlations do not always mean that the two are actually relating or interacting, by considering the previous studies, some speculations among the factors could be made from the above evidences:

Yasunari (1990) reported that ISM is positively correlated with sea water temperature (SWT) in the western Pacific and negatively with that in the eastern Pacific in subsequent winter. Also, Yasunari and Seki (1991) noted the April SC in west Siberia and the oceanic mixed layer temperature of the tropical western Pacific in the subsequent January. Pan and Oort (1983) showed that the anomalies of NHT tend to follow anomalies in the sea surface temperature of the equatorial eastern Pacific at a lag of +6 months.

Smaller than normal spring SC tends to be followed by stronger IMS which induces strong convection over southeast Asia and western Pacific from autumn to winter, and reinforced east-west circulation causes the accumulation of warm water over western Pacific region and SST over eastern Pacific become colder by upwellings (Yasunari, 1990). The lower than normal SST over eastern equatorial Pacific where the anomalous surface exchange of water vapor occur is followed by lower NHT (Pan and Oort, 1983). Thus the lower anomaly of NHT from winter to summer are apt to appear and this connection including tropical ocean may explain the lag correlation found with April SC vs NHT and IMS vs NHT.

The aforementioned discussions strongly suggest that further works should be carried out with snow amount as well as SC especially for understanding of hydrological effect of snow. For this purpose, in addition to the verification of satellite data sets from observational data, and estimates of water equivalent of snow, deduced from temperature and precipitation data (Motoyama, 1990) may be useful. This method will also enable us to study the association between the SC and climate for longer time period even up to the end of 19 th century.

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REFERENCES

Barnett, T.P., Dumenil, L., Schlese, U. and Roeckner, E.(1989): The effect of Eurasian snow cover on regional and global climate variations. J.Atmos.Sci., 46, 661-685.

Blanford, H.F.(1884): On the connection of the Himalayan snowfall with dry winds and seasons of drought in India. Proc.Roy Soc.London, 37, 3-32.

Foster, J.L., Owe, M. and Rango,A. (1983): Snow cover and temperature relationship in North America and Eurasia. J.Climate Appl.Meteor., 22,460-469.

Hahn, D.G. and Shukla, J.(1976): An apparent relationship between Eurasian snow cover and Indian Monsoon rainfall. J.Atmos.Sci., 33, 246-262.

Jones, P.D., Raper, S.C.B.,Bradley, R.S.,Daiz, H.F.,Kelly, P.M. and Wigley T.M.L.(1986):Northern Hemisphere surface air temperature variations: 1851-1984. J.Climate Appl.Meteor., 25, 161-179.

Jones, P.D., (1988): Hemispheric surface air temperature variations: recent trends and an update to 1987. J.Climate, 1, 654-660.

Morinaga, Y. and Yasunari, T.(1987): Interactions between the snow cover and the atmospheric circulations in the Northern Hemisphere. In: Large scale effects of seasonal snow cover. IAHS Publ. no.166, 73-78.

Morinaga, Y. and Yasunari, T.(1992): Interactions between snow cover extent and 500 hPA height field in the northern hemisphere using the NOAA/NESDIS snow cover data. (to be submitted to J. Met. Soc. Japan).

Motoyama, H.(1990): Simulation of seasonal snow cover based on air temperature and precipitation. J. Appl. Met., 29, 1104-1110.

Pan, Y.H. and Oort, A.H.(1983): Global climate variations connected with sea surface temperature anomalies in the eastern equatorial Pacific Ocean for the 1958-73 period. Mon.Wea.Rev., 111, 1244-1258.

Ropelewski, C.F.(1991): Real-time climate monitoring of global snow cover. Palaeogeogr. Palaeoclimatol. Palaeoecol.(Global Planet. Change Sect.), 90, 225-229.

Wallace, J.M. and Gutzler, D.S.(1981): Teleconnections in geopotential height field during the Northern Hemisphere winter. Mon.Wea.Rev, 109, 784-812.

Walsh, J.E. and Ross, B.(1988): Sensitivity of 30-day dynamical forecasts to continental snow cover. J. Climate, 1, 739-754.

Yasunari, T. (1990): Impact of Indian monsoon on the coupled atmosphere/ocean system in the tropical Pacific. Meteor.Atmos.Phys., 44, 29-41.

Yasunari, T. and Seki, Y. (1991): Role of Asian monsoon on the global climate system with the ENSO time-scale. (Submitted to J. Meteor. Soc. Japan.)

Yeh T.C., Wetherald, R.T. and Manabe, S.(1983): A model study of the short-term climatic and hydrologic effects of sudden snow-cover removal. Mon.Wea.Rev., 111, 1013-1024.