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# SOME COMMENTS ON THE RECENT STUDIES OF INTERANNUAL FLUCTUATIONS OF NORTHERN HEMISPHERE SNOW AND ICE COVER AND CLIMATE

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***Abstract:*** There are no clear relations between hemispheric temperature records and Northern Hemisphere snow and ice cover as a result of examinations for several related papers. However, many regional analyses and theoretical studies suggest the possible climatic roles of snow covered areas.

If we exclude urbanization effects on observational temperature records, we can expect an enhanced tropospheric temperature gradient between lower latitudes and northern higher latitudes in the 1980s due to increased Northern Hemisphere snow cover trends during the late 1970s.

## 1. Introduction

There are many indices to diagnose the global climatic trends such as surface air temperature, sea-surface temperature, upper atmosphere temperature and hemispheric snow and ice cover (KUKLA *et al.*, 1977); however, their observational criteria, representativenesses, and climatic meaning are not always established internationally. For example, several different results have been published for recent measured global surface air temperatures (ANGELL and KORSHOVER, 1983; ELLSAESSER *et al.*, 1986; YAMAMOTO and HOSHIAI, 1980; HANSEN and LEBEDEFF, 1987). Some similar methodological differences are seen in the analyses of Northern Hemisphere snow cover data (MATSON and WIESNET, 1981; ELLSAESSER *et al.*, 1986) and several analyses have been given for their snow cover data set (ROPELEWSKI, 1986; SCIALDONE and ROBOCK, 1987; ROBINSON and KUKLA, 1988).

Although there are many undisolved problems concerning the above-mentioned climatic indices, the global extent of snow and ice and their albedo are major control factors for world climate progress due to their high reflectivity and large thermal inertia. The climatic response to Northern Hemisphere snow and ice cover should be an important object of climate research despite the many nonlinear relations between snow and climate.

In this paper, several comments for recent global surface air temperature and other climatic indices are presented and important climatic phenomena which may result from decadal changes of global snow and ice cover are discussed.

## 2. Northern Hemisphere Snow Cover and Climate

The first satellite-derived Northern Hemisphere Weekly Snow and Ice Cover

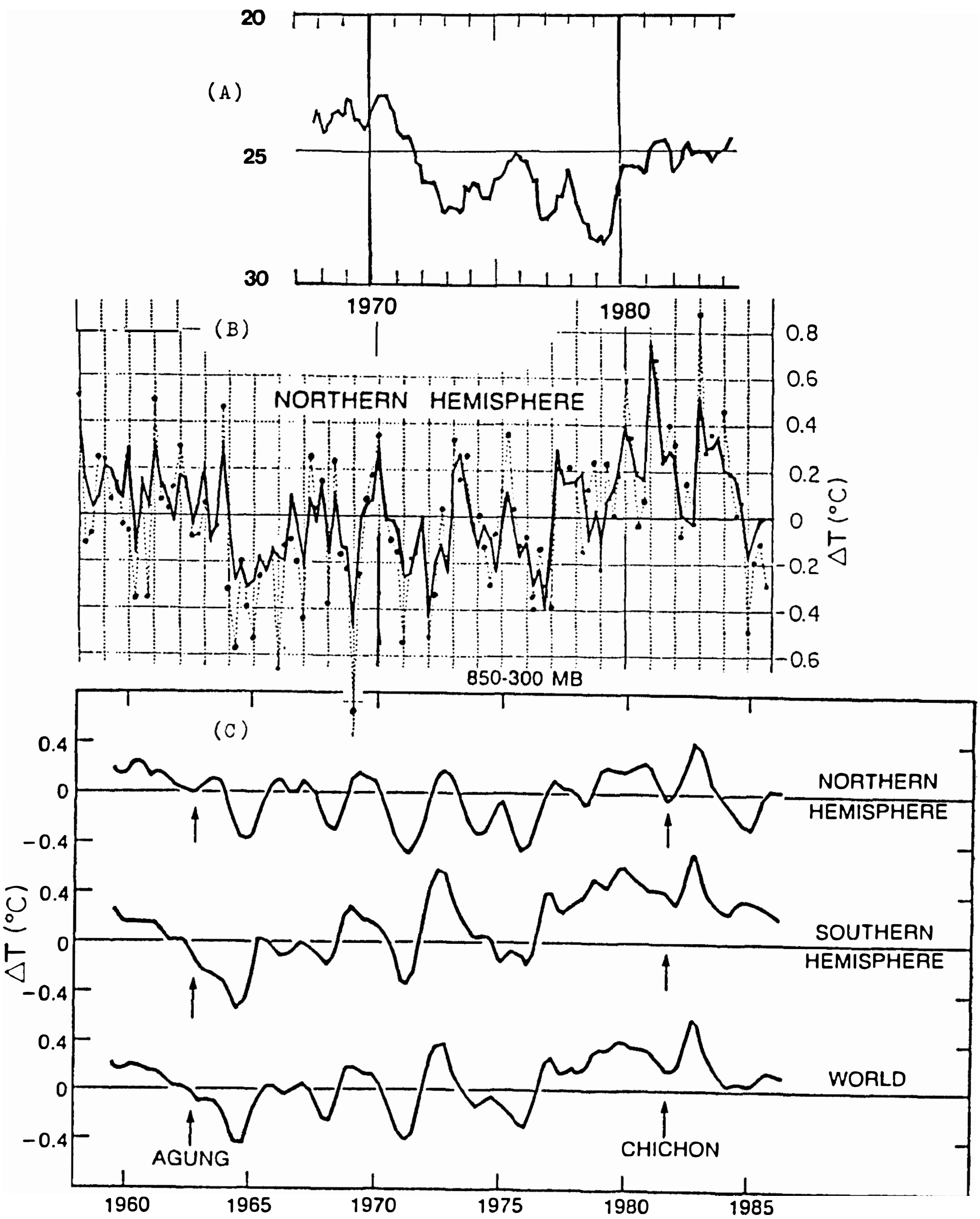


*Fig. 1. Northern Hemisphere snow-covered area and measured global temperature trends. A: Northern Hemisphere snow-covered area ($\times 10^6$ km$^2$), 1967–1984, smoothed by 12-month running means. Source: BARRY, 1985 (from MATSON's unpublished data). B: Northern Hemisphere seasonal surface air temperature. Source: HANSEN and LEBEDEFF, 1987 (with extended result provided by ANGELL and KORSHOVER, 1983, dotted). C: Temperature variations in troposphere 850- to 300-mb layers, 1960–1986. Source: ANGELL (1988).*

Chart was produced by NESS (National Environmental Satellite Service) NOAA, USA in November 1966 (MATSON and WIESNET, 1981). Since then, work on the NOAA/NESS (present NOAA/NESDIS) Northern Hemisphere snow cover data base has progressed during more than 20 years.

KUKLA and KUKLA (1974) demonstrated the importance of snow cover impact on global climate based on the reflection loss index from 1967 to 1973. Thereafter many researchers have studied the relation between climate and satellite-based snow covered area. Although there are several differences with snow-covered areas as shown in the paper of ELLSAESSER *et al.* (1986), we can find a general increasing trend toward the late 1970s.

In Fig. 1, curve A (M. MATSON's unpublished data from BARRY, 1985) indicates a rather large increasing trend during the recent 18 years. The snow cover area during lower level years is about $23\times10^6$ km$^2$ although some incomplete data are included as mentioned by BARRY (1985). It increased to about $28\times10^6$ km$^2$ in 1979. Curve B (from HANSEN and LEBEDEFF, 1987) shows the recent trend of Northern Hemisphere temperature. There is no definite trend of snow cover impact.

Several papers suggest a relation between snow cover and temperature and circulation anomalies. NAMIAS (1985), for example, stressed the positive feedback that occurs when extensive snow cover becomes established over portions of the North American continent. According to his explanation we can speculate on atmospheric forcing due to increasing temperature contrast between colder regions and warmer low latitude regions, which enhances the east coast baroclinicity and intensifies cyclonic activity. Such atmospheric circulation changes bring about large climatic anomalies in specified regions, but global temperature anomalies are weak by reason of which positive and negative regional temperature anomalies are seen globally in the same seasons.

## 3. Global Temperature Trends and Urbanization Effects

Many papers have reported on extreme rising and large interannual fluctuations of world temperatures in the 1980s. Curve B in Fig. 1 is from HANSEN and LEBEDEFF (1987). We suspect that these temperature trends are not real or representative on whole global surface. One misleading factor is the urbanization effect. FENG and PETZOLD (1988) report the temperature effect of urbanization in Metoropolitan Washington, D.C. Their analyses indicated that the absolute heat island magnitudes have increased at the rate of 0.020 and 0.019°C/yr at Washington National Airport and Silver Spring, respectively, from 1945 to 1979.

The heat island magnitude of Tokyo based on a similar estimation scheme but for CLINO (Climatic Normals) data is also 0.02°C/yr from 1921–1950 average to 1951–1980 average. The heat island magnitude is $T_{u-r}=T_{(\mathrm{Tokyo})}-T_{(\mathrm{Choshi})}$, where $T_{(\mathrm{Tokyo})}$ is the trend in an urban area, Tokyo Regional Meteorological Observatory, and $T_{(\mathrm{Choshi})}$ is the trend at a rural city station, Choshi Local Meteorological Observatory, which is about 100 km east of Tokyo (Table 1).

In recent years, many worldwide weather stations have been affected by rapid urbanization. The urbanization warming of 0.001–0.002°C/yr or 0.1–0.2°C in the

*Table 1. Estimation of heat island magnitude (°C/yr) for Tokyo.*

| | CLINO, 1921–1950 (A) | CLINO, 1951–1980 (B) | (B)−(A) |
|---|---|---|---|
| Tokyo (35°41′N, 139°46′E, 5.3 m a.s.l.) | 14.3 | 15.3 | 1.0 |
| Choshi (35°44′N, 140°52′E, 20.1 m a.s.l.) | 14.8 | 15.2 | 0.4 |

$T_{u-r} = T_{(Tokyo)} - T_{(Choshi)} = 1.0/30 - 0.4/30 = 0.02.$

past century estimated by HANSEN and LEBEDEFF (1987, 1988) is an underestimate because of the above-mentioned urban heat island effect.

Upper air temperature is a good global temperature indicator which is not affected by urbanization. The general trend of variation pattern of curve C (from ANGELL, 1988) is similar to the trend of curve B, but the range and increasing trend of curve C is smaller except for southern latitude warming. And global temperature patterns reflect the effect of large volcanic eruptions such as Agung and El Chichon, as pointed out by ANGELL (1988).

A recent important trend is a tropospheric temperature rise in the tropics. HENSE *et al.* (1988) found that the average temperature of the tropical troposphere (200–850 mb layer) has steadily increased, between 1965 and 1984, by about 0.8°C in the whole equatorial belt. Warmer tropical air and possible colder polar air resulting from more snow-covered area implies an increasing temperature gradient in the mid-latitude troposphere, and then a strong circulation regime, which means many stormy days or unusual weather in the northern temperate and polar regions.

## 4. Other Climatic Indices

### *4.1. Sea level change*

The pattern of global sea level change is characterized by a coherent rise of sea level in all regions except Alaska, Scandinavia (both areas of notorious crustal uplift), and Southeast Asia where sea level appears to be falling; however, detection of low-frequency signals of warming will be difficult although there is a linear increase trend of 23 cm/century (BARNETT, 1984b). Then we cannot find the influence of the present trend of the Northern Hemisphere snow-covered area based on BARNETT's view.

### *4.2. Sea surface temperature*

Near-global and northern hemispheric estimations of temperature change of the ocean surface indicate secular rising trends from the 1910s to 1960s and recent falling stationary trends in the 1970s (PALTRIDGE and WOODRUFF, 1981). And significant differences are found between surface air temperature trends and sea-surface temperature trends (BARNETT, 1984a). However, it is possible to speculate on the thermal impact of large snow cover and sea ice area on the ocean area, although present sea-surface temperature data are scanty in high latitudes.

### *4.3. Atmospheric general circulation*

Average number of days per year with westerly winds over the British Isles by

LAMB's method (LAMB, 1972) for the years 1861 to 1976 decreasing in the recent 1970s (LAMB and MOERTH, 1978). The number of westerly days is one of the indices of atmospheric general circulation. LAMB and MOERTH (1978) obtained correlation coefficients of −0.64 between the Icelandic sea ice extent and global temperatures, and −0.54 between the Icelandic sea ice extent and the frequency of westerly winds over the British Isles. According to their explanation, decrease of westerly days means more stormy days in the British Isles.

A note by CARTER and DRAPER (1988) reports the recent rough weather in the North Sea. They have obtained a trend of 0.034 m/yr in the mean significant wave height, which indicates an increase in the 50-year return value of about 0.2 m/yr, from 12 m in 1960 to 18 m in 1990 were the trend to continue. Such a stormy weather increase suggests a tropospheric temperature gradient in the North Sea region which resulted from possible increase of snow-covered area during the 1970s. And we can speculate on the influence of snow and ice cover on the atmospheric general circulation and surface air temperatures in several specified regions.

## 5. Interpretation of Northern Hemisphere Snow Cover Trends

Satellite-observed and mapped snow and ice cover anomalies do not tend to occur simultaneously in all sectors of northern high latitudes. We cannot find a clear relationship between snow and ice cover and surface air temperature over the Northern Hemisphere, as shown in Fig. 1. But many observational implications suggest several relations which form complex climate systems.

Theoretical and numerical considerations also stress the climatic roles of global snow and ice cover. For example, one of the climate models which includes the climatic effect of snow and ice cover shows that the annual temperature change at the surface is −2.1°C with ice-albedo feedback; without ice-albedo feedback the corresponding value is −1.4°C (JUNG and BACH, 1987).

During the past 20 years, large interannual variations and an increase of snow-covered area in the Northern Hemisphere around 1979 are noticeable phenomena. If such snow cover trends are reliable, we should expect large climatic anomalies over several specified or more many regions in the Northern Hemisphere during the 1980s because of an increase of tropospheric temperature gradient between lower latitude air and higher latitude air due to large thermal inertia of snow and ice cover during late 1970s. Additional causes of greater temperature gradient are the tropical tropospheric warming reported by HENSE *et al.* (1988); we can expect weaker global warming than the result (0.5–0.7°C in the past century) of HANSEN and LEBEDEFF (1987), and or no recent warming in several northern high latitude regions, after appropriate exclusion of the urbanization effect.

If there is an increasing thermal gradient in the lower troposphere of the Northern Hemisphere, extraordinary enhanced atmospheric circulations or stormy weather events such as the great North Sea storm in October, 1987 (*e.g.*, BURT and MANSFIELD, 1988) should be researched with reference to global scale anomalies of snow covered area and tropospheric thermal regime.

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