A Change of Large-scale Circulations in the Indian Ocean and Asia Since 1976/77 and Its Impact on the Rising Surface Temperature in Siberia

Han-Cheol Lim¹*, Jong-Ghap Jhun², Won-Tae Kwon¹, and Byung-Kwon Moon³

¹Climate Research Laboratory, Meteorological Research Institute, Korea Meteorological Administration, Seoul 156-720, Korea
²School of Earth and Environmental Sciences, Seoul National University Seoul 151-742, Korea
³Institute of fusion science, Chonbuk National University, Jeonbuk 561-756, Korea

Abstract: This study examines the changes of an interdecadal circulation over the Asian continent to find cause of the surface warming in Siberia from 1958 to 2004. According to our study, there is a coherency between a long-term change of sea surface temperature in the Indian Ocean and the rapid increase of air temperature in Siberia since 1976/1977. In this study, we suggest that mean wind field changes induced by the positive sea surface temperature anomalies of the Indian Ocean since 1976/1977 are caused of interdecadal variations in a large-scale circulation over the Asian continent. It also indicates that the interdecadal circulation over the Asian continent is accompanied with warm southerly winds near surface, which have significantly contributed to the increase of surface temperature in Siberia. These southerly winds have been one of the most dominant interdecadal variations over the Asian continent since 1976/1977. In addition, we investigated the long-term trend mode of 850 hPa geopotential height data over the Asian continent from the Empirical Orthogonal Function (EOF) analysis for 1958-2004. In result, we found that there was an anomalously high pressure pattern over the Asian continent, it is called ‘the Asian High mode’. It is thus suggested that the Asian High mode is another response of interdecadal changes of large-scale circulations over the Asian continent.

Keywords: interdecadal variation, global warming, Asian High mode

Introduction

A lot of global warming signals by greenhouse gas effects have been detected in various fields including the ocean, atmosphere, ecosystem and agriculture, etc.. Among many types of phenomena, the rising surface temperature in Siberia is also one of the most sensitive signals of global warming, which is mentioned in New Scientist, science magazine in August 2005. It is commonly known that the sudden melting of the largest frozen peat bog in Siberia as well as the reduction of snow cover over the Asian continent is due to global warming by greenhouse gases effects. However it is not clear why a degree of climate responses to global warming impacts is locally different.

Some previous studies introduced relationships between a carbon dioxide emission and global warming. Crowley (2000) provided the evidence that cause of the global warming is not due to natural variability (solar activities, volcanism, albedo, aerosols, etc.) but to a carbon dioxide emission by anthropogenic activities. Manabe et al. (1990) showed temporally consistent warm signals in both sea surface temperature in the tropics and surface air temperature in the high-latitudes of the northern hemisphere from a doubling experiment of atmospheric carbon dioxide in the coupled ocean-atmosphere model. Furthermore, Barnett (2001) and Barnett et al. (2005) claimed that anthropogenic forces have affected ocean warming trend over the past 45 years. However, they were not able to account for the processes by which the anthropogenic heat penetrated from the atmosphere to the ocean.

Some authors presented evidence of a significant climate shift since the mid-to-late 1970s, and agrees that mean states shift has influenced the El Niño-Southern Oscillation (ENSO) dynamics in tropics as
A cause of the rising surface temperature in Siberia

well as the midlatitude monsoon system (Trenberth, 1990; Wang, 1995; Zang et al., 1997; Krishnamurthy and Goswami, 2000). The Sea Surface Temperature (SST) in the tropical Indian Ocean also experienced a warming shift in 1976/1977 (Clark et al., 2000, 2003). Lau and Weng (1999) showed the characteristics of interdecadal variations in global SST anomaly, which can represent a positive SST anomaly pattern in tropical Indian Ocean. Furthermore, Krishnamurthy and Goswami (2000) investigated interdecadal and interannual time-scale circulations in the latitude-height cross-section averaged over 70-120°E, and they discussed relationships between meridional circulation in Indian Ocean and the Indian summer monsoon rainfall. As such, an interdecadal meridional circulation strengthened the Hadley cell in the Indian Ocean. A strong Hadley circulation then induced the weak Indian summer monsoon rainfall. As such, an interdecadal meridional circulation strengthened the Hadley cell in the Indian Ocean. A strong Hadley circulation then induced the weak Indian summer monsoon rainfall. Lorenz and DeWeaver (2007) found that the poleward shift of the upper level zonal winds in IPCC models, as a global warming is ongoing. Overland et al. (2002) investigated the warming pattern of the lower troposphere from eastern Siberia to northern Canada during spring in the 1990s. They attempted to explain the cause of the temperature increase in this western Arctic as a horizontal heat advection induced by a mean wind shift from anomalous northeasterly flow in the 1980s to anomalous southwesterly flow in the 1990s.

The rising surface temperature in Siberia actually has been influenced by a various causes which include: atmospheric dynamics, chemistry (greenhouse gases effects), surface albedo by both snow melting, etc.. However, the surface temperature in Siberia has remarkably increased since 1976/1977, and the locally non-homogeneous surface warming cannot be perfectly described by chemical reaction or radiation change. The purpose of this study is to reinspect the warming trend of surface temperature in Siberia with an emphasis on large-scale atmospheric dynamics. Firstly, we will show the interdecadal variations of meridional circulations in the Asia-Indian Ocean cross-section, and its impact on the Siberian warming trend in resent are examined in this paper. In chapter 2, we showed long-term warming trends in both the Indian Ocean sea surface temperature and surface air temperature over the Asian continent. These authors suggested that there has been a temporal coherency between long-term warming signals of remote two regions in 1976/1977. Interdecadal variations of meridional circulation in midlatitudes of Asian continent were described in chapter 3, using an eddy fluxes dynamics of large-scale mean flows. In addition, a long-term trend mode in 850 hPa geopotential height of northern hemisphere is also suggested in chapter 4. The last part of this paper contained a brief and some discussion about relationships between the Indian Ocean and Siberia warming. The monthly National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCEP-NCAR) reanalysis dataset and the Climate Research Unit (CRU) analysis of the monthly dataset for 1958–2004 were used to analyze the characteristics of interdecadal variations over the Asian continent. In the Ocean, the monthly Extended Reconstructed Sea Surface Temperature (ERSST version 2) data in a 2° by 2° grid resolution was also used (Smith and Reynolds, 2004).

Coherency of Warming Trends in Both Siberia and Indian Ocean

The most serious long-term changes in the Asian continent and Indian Ocean are the increase of Sea Surface Temperature anomalies in the tropical Indian Ocean and the rising surface temperature in Siberia. It is still controversial whether there is a climate regime shift in the whole depths of ocean or to wherever oceans in the mid/late 1970s, but it is surely that Sea Surface Temperature anomalies in the tropical Indian Ocean have increased as well as its influenced to the Indian Monsoon rainfall change since 1976/1977 (Clark et al., 2003). Meanwhile, the most distinguished long-term change over the Asian continent is the surface warming of the Siberian region in recent. The NewScientist, a science magazine, also reported that