Analyzing a relation between Eurasian snow cover and Indian Monsoon rainfall using a large ensemble data set

Gavin MADAKUMBURA¹, Satoshi WATANABE², Masahiro TANOUE² and Yukiko HIRABAYASHI²
¹Department of Civil Engineering, The University of Tokyo
²Institute of Engineering Innovation, The University of Tokyo

1. Introduction

Indian Monsoon Rainfall (IMR) is directly and indirectly impacting on a large number of people in various socioeconomic aspects such as agriculture, drinking water and energy. Therefore, prediction of the variation and understanding the mechanism of the phenomenon is significantly important and beneficial. Identification of attributing climate factors of Indian monsoon rainfall is extremely important to achieve this target. The inverse relationship between winter Eurasian snow cover and the subsequent IMR is a famous hypothesis which has been studied for over century in order to facilitate better prediction capabilities for the Asian monsoon rainfall. This study was conducted to investigate the above inverse relationship which affirms in Bamzai and Shukla (1999) (hereafter called as B&S99), and to extend the results for a longer time periods using extensive observational data. The present study further analyses the relation of IMR and winter Eurasian snow cover using a 100 ensemble of historical climate experiment, named 'database for Policy Decision making for Future climate change' (d4PDF). The study especially focuses the Western Eurasian winter snow cover (WESN) where a high correlation resides according to previous studies.

2. Data and Methodology

Northern Hemisphere NSIDC EASE-Grid 2.0 (National Snow and Ice Data Center Northern Hemisphere Equal-Area Scalable Earth grid) Weekly Snow Cover and Sea Ice Extent, Version 4 data (Brodzik and Armstrong, 2013) and daily gridded rainfall data set of Indian Meteorological Department– IMD4 (Sridhar et al., 2014) for the period 1973 to 2011 was used for the analysis of the observations. Past experiment of the d4PDF was used to analyze the historical relation between IMR and WESN as well. The 100-member ensemble runs of d4PDF used were produced using a version 3.2H of the Atmospheric General Circulation Model (AGCM) developed by Meteorological Research Institute, Japan (MRI-AGCM3.2H; Mizuta et al., 2012) at 60 km resolution (obtained from DIAS server: http://dias-dss.tkl.iis.u-tokyo.ac.jp/).

Following B&S99, seasonal snow cover for boreal winter from December to March was obtained for the areas in western Eurasia (10W–30E, 40–60N), all of Eurasia (0–190E, 20–90N), southern Eurasia (0–190E, 20–50N), and the Himalayas (60–105E, 30–45N), and the anomaly from the average for 1973-1994 was calculated. Area weighted average of Indian monsoon rainfall (IMR) was calculated for the June-September over whole India and the anomaly from the average for 1973-1994 was calculated. Finally, correlation coefficients of WESN and IMR were calculated for normalized anomalies obtained from anomalies dividing by standard deviations for 1973-1994. For the d4PDF, in addition to the analysis of all ensembles, ensembles with highest or lowest 10% IMR samples among all data (totally 1200 samples, as 20% of 100 ensembles of 60-year simulation) were also analyzed.

Fig. 1. Normalized WESN and IMR anomalies
3. Results and discussion

The calculated correlation coefficients of the observed data for the same period of B&S99 (1973-1994) agreed with the B&S99 at all four regions except for the Himalayas. B&S98 discusses the unexpected positive correlation coefficient (+0.20) obtained in their study for the Himalayas. We used a newly available data (NSIDC EASE-Grid 2.0 and IMD4) and negative correlation coefficient (-0.35) was obtained (not shown here).

Most strongly correlated WESN (-0.63 in B&S98 and -0.66 in this study for 1973-1994) was further considered for the analysis. Firstly, we calculated the correlation coefficient for an extending period of B&S98. Fig 1 shows time series of anomalies of observed data and correlation coefficients between IMR and WESN. The correlation coefficients calculated for the periods 1973 - 1994, 1995 – 2011 and 1973-2011 were -0.66, +0.03 and -0.39 respectively, indicating that the negative correlation between IMR and WESN is not seen in the recently observed data.

We, therefore, analyzed a 100 ensemble data set of d4PDF to investigate the distribution of correlation coefficient between IMR and WESN and to obtain the probability of the strong negative correlation seen in the observation for the period 1973-1994. Fig. 2 shows a histogram of correlation coefficient of all 100 ensembles. Correlation coefficient between IMR and WESN varies between -0.3 and 0.2 and no specific correlation is seen in Fig. 2, which support our findings of a low correlation between IMR and WESN in recent records. Fig.3 shows the same figure of Fig.2 but for samples with 10% largest or smallest IMR. It is clear that when we focus on samples of too wet or too dry year only, negative correlation between IMR and WESN is still dominant.

4. Conclusions

The famous negative correlation indicated in previous studies for IMR and WESN was not seen well in recent records. According to Fig. 2, d4PDF ensemble experiments show a less dominant correlation between IMR and WESN. When we focus on 10% largest or smallest IMR years, however, the inverse WESC-IMR relationship can be slightly obtained (Fig. 3). In order to investigate the further mechanism of the inverse WESC-IMR relationship and potential reason for the change in WESC and IMR including anthropogenic or other influences, an extensive analysis of the observations and numerical experimental results must be conducted.

Acknowledgments

This paper was financially supported by the Funding Program for the Global Environmental Research Fund (S-14) by the Ministry of the Environment, Japan and the SOUSEI program of the Ministry of Education, Culture, Sports, Science and Technology, Japan. We are also grateful to the Indian Meteorological Department for providing the rainfall data.

References


Keywords:

d4PDF, Eurasian snow cover, Indian monsoon rainfall