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Global climate teleconnection with rainfall erosivity in South Korea

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ABSTRACT

Rainfall Erosivity Index (REI) defined as the product of rainfall kinetic energy and rainfall intensity is a well-known hydrologic indicator of the potential risk of soil erosion. Global and regional scale climatic teleconnections with REI variability over South Korea are examined. We calculate leading patterns of observed monthly REIs using the Empirical Orthogonal Teleconnection (EOT) and Function (EOF) decomposition techniques. Also we used monthly statistical analyses using cross-correlation and lag regression for the leading modes and global atmospheric circulation measurement in the Pacific and Indian Ocean. As a result, the northern inland mode is applicable during summer season and the southern coastal mode applies to fall-winter season. The temporal evolution of REI exhibits mostly increasing and depends on interdecadal oscillation patterns. The leading EOT modes explain more variance in REI than the EOF modes during warm and cold seasons. The findings from this study illustrate that the tropical ENSO forcing has the coherent association with fall and winter REI patterns, and the Indian Ocean dipole is identified as a driver for REI variability in November. The monsoon circulations over western North Pacific also exhibit significant negative correlation with the December modes. The September leading modes also show a positive correlation with the tropical cyclone activity. Leading patterns in September and November have predictability up to five month lead time from the tropical Pacific Sea Surface Temperatures (SSTs). In addition, predictability from the Pacific SSTs for above normal extreme value of REI is greater than that for below normal value in winter. In conclusion, South Korea experiences climatic teleconnection between the large scale climate indices and mid-latitude hydrologic variables.

1. Introduction

South Korea experiences spatial and temporal variability of climatic and hydrologic variables to a large degree. This spatiotemporal variability is in association with fluctuations of various global-regional scale climate indices (CIs), such as the El Niño–Southern Oscillation, Indian Ocean dipole, western North Pacific monsoon, and tropical cyclone activity. Classically, a climate index is defined as a diagnostic quantity used to characterize the state and change in the climate system with average state of the atmosphere over a long period, i.e., months and years, and to describe an aspect of a geophysical system such as a circulation pattern. These large scale climate indicators have been one of the most widely studied topics due to the fact that the extreme phases of the climatic impacts are usually related to major hydrologic extremes of floods and droughts in many regions all over the globe. In the global and regional scale studies, significant relationships have been reported between the large scale CIs and hydrologic parameters such as precipitation, streamflow, and rainfall erosivity in the tropics and extratropics.

The effects of the El Niño–Southern Oscillation (ENSO) on hydroclimatic variability on a global and regional scale are previously documented. Since the first investigation of Walker (1923) on the influence of the Southern Oscillation (SO) on rainfall fluctuations by Indian monsoon, recently many global scale studies focused on the evolution of ENSO cycle indicated noticeable climatic links between hydroclimatic parameters and the tropical ocean-atmospheric thermal forcing throughout the world. Bradley et al. (1987), Kiladis and Diaz (1989), and Ropelewski and Halpert (1989) pointed out notable ENSO-related signals with the identification of spatial structures and temporal cycles showing a statistically significant correlations between the tropical ENSO phenomena and precipitation variability throughout the various parts of the world. In addition, the regional scale works for low and middle latitude relating the remote ENSO cycle to hydroclimatic variations by Douglas and Englehart (1981), Shukla and Paolino (1983), Kahya and Dracup (1994), Rasmusson and Wallace (1983), Redmond and Koch (1991) and Price et al. (1998), revealed statistically significant correlation between regional precipitation and ENSO forcing. For midlatitude regions, the importance of the ENSO-streamflow

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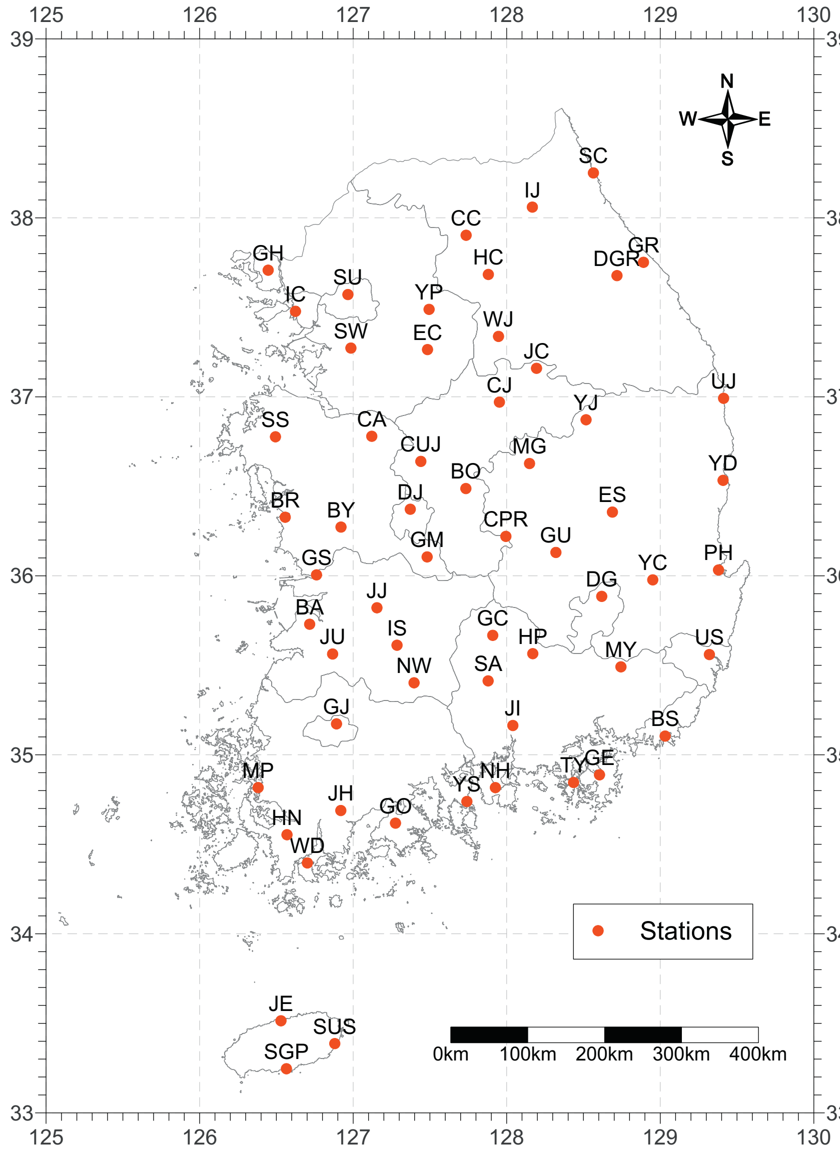

Fig. 1. Stations used for the REI indices.

relationships is emphasized in several studies. Cayan and Peterson (1989), Redmond and Koch (1991), Cayan and Webb (1992), and Diaz and Kiladis (1993) investigated the influence of North Pacific atmospheric circulation on streamflow in the western United States, and Kahya and Dracup (1994) diagnosed the impacts of ENSO on U.S. streamflow patterns from the perspective of extratropical teleconnections triggered by tropical sea surface temperature (SST) variation. In Asian regions, Chandimala and Zubair (2007) investigated the predictability of seasonal streamflow for the Kelani river basin in Sri Lanka associated with ENSO and SST anomalies using a correlation analysis and a principal component analysis.

Meanwhile, Indian Ocean dipole (IOD) has been considered as one of the key CIs of hydroclimatic variability in the Indian and Pacific rim countries. Some studies for IOD pointed out the distinct behavior of the IOD-related precipitation anomalies. Since Saji et al. (1999) reported a dipole mode of the Indian Ocean influencing on precipitation fluctuations, Ashok et al. (2001, 2003) revealed that notable climatic relationship exist between the IOD time series and the Indian monsoon precipitation variability as well as examined the remote response of Australian precipitation anomalies in winter to the IOD through an atmospheric general circulation model (AGCM). The monsoon and tropical cyclone activity could also be considered as a CI for hydroclimatic variability in the Indian and Pacific rim countries. Wang et al. (2008) performed a comparative analysis on pros and cons of 25 existing East Asian monsoon indicators from a viewpoint of interannual variabilities of precipitation and circulation, suggested a new index extracted by principal component analysis, and then stressed the important role of the mei-yu precipitation in quantifying the intensity of the East Asian monsoon activity.

Rainfall erosivity calculated by product of rainfall kinetic energy and rainfall intensity can be used a feasible hydrologic indicator of the potential risk of soil erosion due to climate change. Degradation of soil by water has been an important issue related agricultural productivity, forest and ecological conservation, and environmental problems in the world. The amount of rainfall has been used one of explainable parameters to predict the extent of degradation of soil, however, there have been limitations in explaining the reason why the strength of rainfall energy in two storms could be different if the amounts of rainfall are equal. Rainfall erosivity, which is known as input parameter of empirical models such as USLE or RUSLE for predicting long-term annual mean soil loss for arable land, is a numerical value which represents the erosion potential of soil erosion by water (Wischmeier and Smith, 1978; Renard et al., 1997). The result of soil loss using USLE model depends on the value of rainfall erosivity since the rainfall erosivity factor is