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Flash droughts in Japan

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Flash droughts are short-term rapidly evolving droughts with a characteristic of soil moisture deficits. This study studied the assessed the spatial-temporal variability of flash droughts from 1976 to 2012 over Japan. Two types of flash droughts (heat wave and precipitation deficit) were studied based on SiBUC outputs. The results show that P deficit flash droughts are more common than heat wave flash droughts. They can occur over Japan, but they are most prevalent in the Kyushu Island and central part of Honshu Island. August is a P deficit flash drought-prone month. Heat wave flash droughts are most likely to occur in the Kyushu Island and Okinawa. July is a heat wave flash drought-prone month. Heat wave flash droughts have significantly increased in frequency in most regions of the southern Japan. P deficit flash droughts have significantly decreased in frequency in some regions of the northern Japan.

Keywords: Flash drought definition, Soil moisture, Spatial-temporal variability

1. Introduction

Although Japan has abundant precipitation and more than 2000 reservoirs, it is necessary to concern short-term rapidly evolving droughts, named as flash droughts in this study. Because these droughts would cause considerable damage and they are difficult to be predicted in time by changes of precipitation and discharge. These are high-related with the decrease of soil moisture which has few monitor stations. There are two types of flash droughts: heat wave flash droughts (HWFD) and precipitation deficit flash droughts (PDFD). The objectives of this study are to give a quantified definition of flash droughts and evaluate the changes in flash droughts under climate change.

2. Data and Methods

AmeDAS data from 1976 to 2012 were interpolated into each mesh of 20 km horizontal resolution to drive SiBUC model. 5-day mean (pentad) was used to capture the short duration of both types of flash droughts from April to October. There are 1554 pentads for each mesh. The percentage of pentads under flash drought for each mesh, termed as frequency of occurrence (FOC), was applied to estimate the variability of flash drought over Japan.

3. Results

3.1 Flash drought definition

Flash drought was represented by 4 variables, precipitation (P), air temperature (T), soil moisture (SM) and evapotranspiration (ET). HWFD was defined as T anomaly > 1 SD, ET anomaly > 0 and SM percentile (SM%) < 40. For HWFD, P was not one of crucial requirements for heat wave flash droughts. PDFD was defined as T anomaly > 0, ET anomaly < 0, P percentile (P %) < 40 and SM % < 40.

3.2 Spatial variability of flash droughts

The ensemble average FOC for HWFD and PDFD across Japan is shown in Figure 1 (a) and (b). HWFDs did not occur frequently. FOC was less than 3% in most regions. The maximum FOC reached about 4-5% concentrating on the central part of Honshu Island, north part of Kyushu Island and Okinawa region. In general, Kyushu Island and Okinawa region had more heat wave flash droughts than other islands in Japan. The number of HWFD reached a maximum in July. FOC of PDFDs was much greater with a maximum to

7%. The maximum FOC was mainly located at the central part of Honshu Island and some areas of Shikoku and Kyushu Islands. There was a pronounced lower FOC in Hokkaido Island compared with Kyushu Island. The number of PDFD reached a maximum in August, which was about 2 times larger than a minimum in April. It was because evapotranspiration on August is large due to high temperature. Soil moisture is sensitivity to the changes in precipitation. Also vegetation is different due to agriculture. Rice growing at second stage in July and August. In addition, flash droughts did not persist. About 75-85% of HWFD and PDFD persisted for one pentad.

3.3 Annual trends in flash drought

The Mann Kendall test was applied to the annual number of pentads under flash drought and related variables for each grid cell. There were downward trends in parts of central and northern Japan in HWFD and PDFD. The area of downward trend in PDFD was larger than heat wave flash droughts. Whereas, there were upward trends in parts of southern Japan in both types of flash droughts. The area of upward trend in HWFD was larger than PDFD. Figure 2 indicates the number of pentads under flash droughts per year averaged over Japan from 1976 to 2012. Both HWFD and PDFD had maximum events in 1994 and a minimum from 1992 to 1993. Overall, HWFD trended to increase while PDFD trended to decrease in the study period.

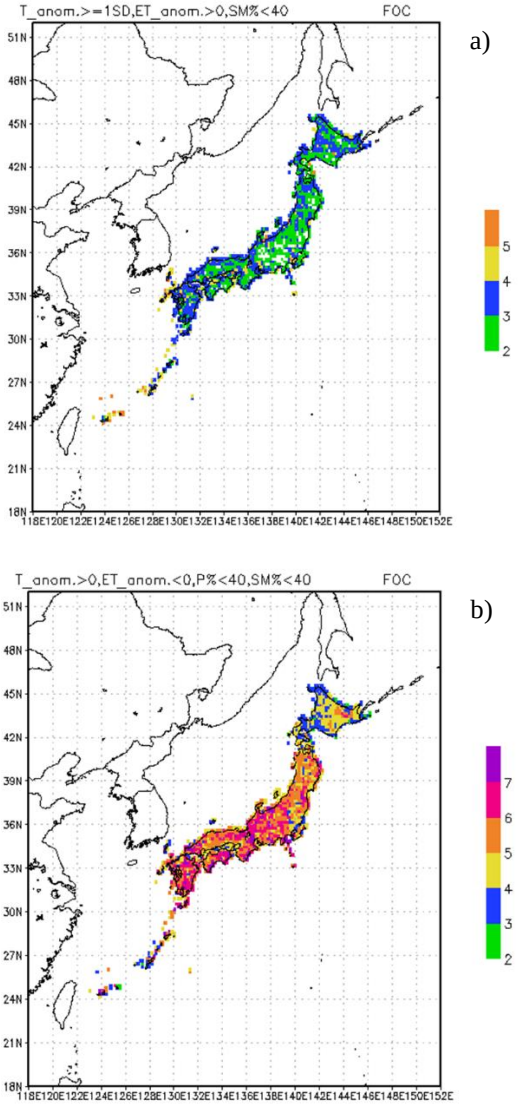

Figure 1 Spatial variability of flash droughts over Japan, a) is heat wave flash droughts and b) is precipitation deficit flash droughts.

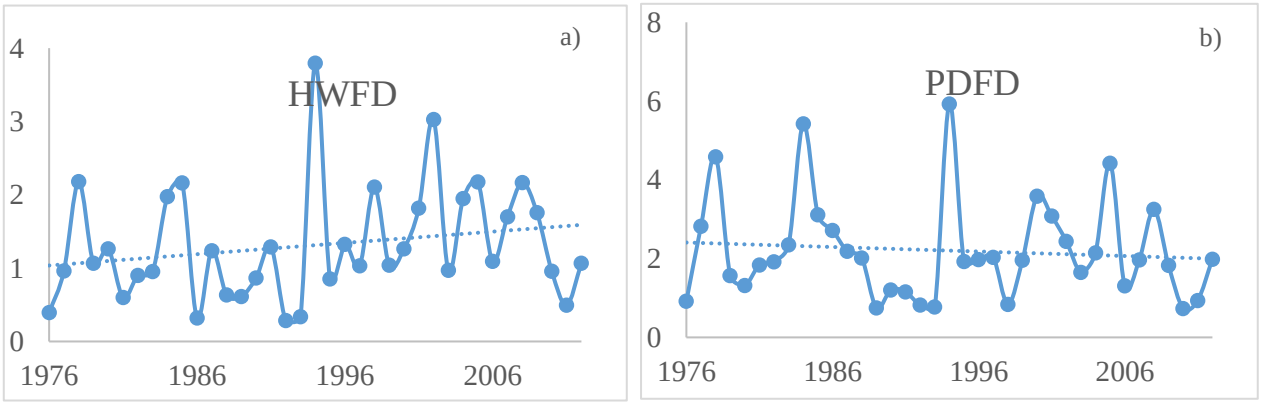

Figure 2 Number of pentads under flash droughts per year averaged over Japan from 1976 to 2012, a) heat wave flash droughts and b) is precipitation deficit flash droughts.