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Century-long variability and trends in daily precipitation characteristics at three Finnish stations

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Abstract

Long-term variations and trends in a wide range of statistics for daily precipitation characteristics in terms of intensity, frequency and duration in Finland were analysed using precipitation records during 1908−2008 from 3 meteorological stations in the south (Kaisaniemi), centre (Kajaani) and north (Sodankylä). Although precipitation days in northern part were more frequent than in central and southern parts, daily precipitation intensity in the south was generally higher than those in the centre and north of the country. Annual sum of very light precipitation (0 mm < daily precipitation ≤ long-term 50th percentile of daily precipitation more than 0 mm) significantly ($p < 0.05$) decreased over time, with the highest rate in northern Finland. These decreasing trends might be the result of significant increases in frequency of days with very light precipitation at all the stations, with the highest and lowest rates in northern and southern Finland, respectively. Ratio of annual total precipitation to number of precipitation days also declined in Finland over 1908−2008, with a decreasing north to south gradient. However, annual duration indices of daily precipitation revealed no statistically significant trends at any station. Daily precipitation characteristics showed significant relationships with various well-known atmospheric circulation patterns (ACPs). In particular, the East Atlantic/West Russia (EA/WR) pattern in summer was the most influential ACP negatively associated with different daily precipitation intensity, frequency and duration indices at all three stations studied.

Keywords: Daily precipitation characteristics; Trend analysis; Intensity; Frequency; Duration; Extremes; Atmospheric circulation patterns; Finland

1. Introduction

Precipitation plays a key role in the planning and management of sustainable water resources, particularly as the fundamental design parameter for dam safety and flood risk analyses. Most previous studies of trends in precipitation on global, regional and local scale have focused on changes in mean values (Groisman and Easterling, 1994; Karl et al., 1996; Dai et al., 1997) and extreme values (e.g. Easterling et al., 2000a; Khon et al., 2007; Trenberth et al., 2007; Halmstad et al., 2012). However, future climate change would influence all characteristics of precipitation in terms of intensity, frequency and duration (Lehner et al., 2006; Radinović and Ćurić, 2009). Hence, a comprehensive analysis of these characteristics can improve our understanding of variations and changes in precipitation patterns.

In probably the most complete analysis of trend detection in global daily precipitation extremes conducted to date, Alexander et al. (2006) reported increases in heavy precipitation indices. Other studies show that heavy precipitation has

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significantly increased over the U.S., eastern Australia and northern Europe (Karl et al., 1996; Suppiah and Hennessy, 1998; Groisman et al., 1999; Rana and Moradkhani, 2015), and could compensate for changes in light precipitation events over many regions, including Europe (Hennessy et al., 1997; Kharin and Zwiers, 2000; Voss et al., 2002). Similarly, more detailed studies during recent years confirm rising tendencies for heavy precipitation over certain regions of Europe (Klein Tank and Können, 2003; Zolina et al., 2009; Łupikasza et al., 2011; Chen et al., 2015). Groisman et al. (1999) concluded that the number of wet days (daily precipitation > 1 mm) slightly increased over Norway (northern Europe), Australia and the U.S. during the 20th century, while it remained unchanged in Canada, China, Mexico, Alaska, Poland and the former Soviet Union. Klein Tank and Können (2003) reported no clear trend in the frequency of wet days in Europe during the second half of the 20th century, but Philandras et al. (2011) showed a significant decrease over the eastern Mediterranean. However, Klein Tank and Können (2003) reported that the frequency of heavy and very heavy precipitation days (daily precipitation greater than 10 mm and 20 mm, respectively) significantly increased in Europe during the period 1946–1999. In addition, changes in the continuous duration of precipitation cause changes in dry or wet spells, which form the intra-seasonal structure of European hydroclimatic conditions (Klein Tank and Können, 2003).

Within Europe, the Alps, the southern Iberian Peninsula, southern Greece and the eastern Adriatic seaboard are projected to experience the largest increase in future drought duration, with earlier onset over the 21st century (Beniston et al., 2007). Otherwise, Schmidli and Frei (2005) concluded that wet spells over the Swiss Alps have become longer during the 20th century. A similar tendency over Europe was found by Zolina et al. (2010) for the period 1950–2008. Besides, Zolina et al. (2013) reported significant growth in wet spell duration over northern Europe and central European Russia for the period 1950–2009. These changes in precipitation characteristics may affect health (e.g. by changing water quality), agriculture (e.g. crop failure due to drought), forestry (e.g. increased water stress in trees), infrastructure and buildings (e.g. by floods and landslides) and ecosystems (e.g. soil erosion) locally and globally. Hence, adaption and mitigation measures are required to achieve proper planning and management of water resources.

Using interpolated monthly time series (1911–2011) at 32 meteorological stations covering the whole country, the most up-to-date analyses of precipitation changes in Finland (Irannezhad et al., 2014a) reported a significant increasing trend of (0.92 ± 0.50) mm per year ($p < 0.05$) in annual mean precipitation nationwide during the period 1911–2011. Finland also experienced severe precipitation periods and alternating dry periods during some months of the year in that period (Irannezhad et al., 2015a). Previous studies on heavy precipitation in Finland have found increasing trends in magnitude for cold months of the year, while no clear trends have been observed for summer months (Haylock and Goodess, 2004; Moberg et al., 2006; Kilpeläinen et al., 2008). In a study evaluating gridded precipitation data for the period 1908–2008 obtained from the Finnish Meteorological Institute, Ylhäisi et al. (2010) reported a growing trend ($p < 0.05$) for seasonal (May–September) precipitation in the north-east of Finland, but no clear trend over south-western parts. They also concluded that precipitation in June had significantly ($p < 0.05$) increased in south-west Finland, resulting in a reduction in early summer drought. Moreover, extremely wet conditions have been seen in recent monthly and daily precipitation records in Finland, although the summer seasons in 2002, 2003 and 2006 were exceptionally dry (Ylhäisi et al., 2010). Increases in chemical leaching (Knapp et al., 2008; Escudero et al., 2012), soil erosion (Marttila and Kløve, 2010) and flooding events (Groisman et al., 2001; Milly et al., 2002) are typical consequences resulting from extreme precipitation events, while severe water availability problems can arise following decreases in surface and groundwater levels caused by prolonged drought (Okkonen and Kløve, 2010). For example, the drought in Finland during 2002–2003 resulted in major economic losses due to decreases in hydropower generation and also affected water supply to households (Silander and Järvinen, 2004).

To explore regional manifestation of global climate change in Finland, this study used a comprehensive set of statistics for analysis of daily precipitation characteristics in terms of intensity, frequency and duration at 3 meteorological stations in northern, central and southern Finland with 101 years of data. Specific objectives were to: 1) summarise statistical analyses of daily precipitation characteristics; 2) identify historical trends in the inter-annual variability of daily precipitation intensity, frequency and duration; and 3) investigate possible relationships between inter-annual variations in daily precipitation characteristics in Finland and well-known atmospheric circulation patterns (ACPs, e.g. the North Atlantic Oscillation).

2. Materials and methods

2.1. Study area and data description

Finland is a long country in the north–south direction (~1320 km) and is located in the Fenno-scandinavian region of northern Europe. The climate in Finland is mainly influenced by geographic settings such as the Baltic Sea, the Atlantic Ocean, the Scandinavian mountain range, latitudinal gradient and continental Eurasia (Käyhkö, 2004). According to the Köppen–Geiger climate classification system, Finland can be characterised as a temperate or cold climate zone (Peel et al., 2007), where precipitation average is moderate in all seasons (Castro et al., 2007). Hence, Finland has no dry season, moderate summers in southern coastal areas and short summers in most other parts (Peel et al., 2007). Annual precipitation in Finland naturally decreases from south to north (Pirinen et al., 2012). Mean annual precipitation on a national scale during 1911–2011 was 601 mm and mean annual precipitation in summer, when heavy to extreme levels of daily