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Comparing trends in hydrometeorological average and extreme data sets around the world at different time scales

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ABSTRACT

Study region: The Present work shows trend analysis results for temperature and precipitation around the world and for river discharges in the Americas, Australia and some European countries for a common time period with free access hydrometeorological information.
Study focus: Hydrometeorological data sets for discharge, precipitation and temperature around the world were analysed for statistically significant trends both in average and extreme value data sets between 1970 and 2010. The data was analysed with the Mann–Kenndall trend test at annual, monthly and daily resolutions, to compare the results on a global scale and between the different time resolutions.
New hydrological insights for the region: Results indicate that trends can be found for all variables and on all latitudes, with an increase of global temperature in the analysed time period. Fewer trends were observed in extreme value data. Trends in discharge data were predominantly negative, and precipitation trends were not very common. In some cases, an opposing pattern was observed in the northern and southern hemisphere. The highest number of trends was found at the annual and least on the daily resolution, nevertheless, trend patterns for discharges remained similar at different time scales. Some of the factors that might influence these results are discussed.

1. Introduction and background

Climate change and extreme weather conditions have been a topic of interest for scientists and institutions around the world aiming to explore causes and possible adaptation strategies for this problem. Changes in the global climate cause changes in the hydrological cycle, which thus will impact on ecosystems and the human society (Abghari et al., 2012; Morin, 2011). Many scientific works have explored the existence of trends in hydrometeorological time series, especially for temperature and precipitation data.

Previous investigations on the topic generally indicate positive trends for temperature on all continents, both in the northern (Nicholson et al., 2013; Del Río et al., 2011; Wang et al., 2011; Xu et al., 2010) and southern hemisphere (Aguilar et al., 2005; Falvey & Garreaud, 2009; Stern et al., 2011). Minimum temperatures have been found to increase stronger than maximum temperatures (Hu et al., 2012; Sonali & Nagesh Kumar, 2012; Xu et al., 2010). Furthermore it was found that the change in temperature patterns has had substantial influence on a big number of other hydrometeorological variables, including precipitation and streamflow (Hayhoe et al., 2007; Xu et al., 2010). Fewer trends were observed in precipitation

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series, which were principally positive (Barros et al., 2000; Vargas et al., 2002; Xu et al., 2010), while in some cases hardly any statistically significant trends could be found (Abghari et al., 2012; Mass et al., 2011). Precipitation trends in South America prove to be divided into stations with a negative trend west of the Andes and a positive one east of them (Minetti & Vargas, 2009; Vargas et al., 2002). Wagner et al. (2011) describe an increase of arctic river discharge in the 20th century, as do Genta et al. (1998) for select South American rivers. Abghari et al. (2012) found principally negative discharge trends in Iranian rivers and a study of tropical South America found negative trends in the Andean rivers and positive ones in the Amazon basin (Marengo et al., 1998). Dai et al. (2009) found that 30% of the discharge series of the largest rivers worldwide show significant trends, most of which were negative. Most studies indicate that human activities are a major cause of trends in discharge series, although this was proven only in some of them (Wang et al., 2009; Woo et al., 2008).

Easterling et al. (2000) show a worldwide increase of extreme events for temperature and precipitation over the 20th century. Goswami et al. (2006) and Wang and Zhou (2005) show an increase of extreme rainfall events in India and China, as well as Haylock et al. (2006) and Manton et al. (2001) do for Australia and the pacific region. Bell et al. (2004) show the same for the North American continent and Hu et al. (2012) found a decreasing trend for heavy precipitation, especially in the winter months, in the Yang Tse basin. Studies from Europe indicate an intensification of short-term heavy precipitation patterns (Costa & Soares, 2009; De Toffol et al., 2009). Min et al. (2011) found that for two thirds of all precipitation stations in the northern hemisphere, extreme events have intensified. Bordi et al. (2009) studied linear and non-linear trends in draught and wetness series in Europe, finding trends until the end of the 20th century that are reversed in the first decade of the 21st century and conclude that nonlinear trends are a better tool to describe these developments. A study of streamflow data in the Mekong basin (Delgado et al., 2010) concluded that there is an increased likelihood of floods in the area, although all studied series show negative trends in the time series. Nyeko-Ogiramoi et al. (2013) found that trends were showing an increase of extreme events in temperature, discharge and especially precipitation series in the Lake Victoria basin. Kundzewicz and Robson (2004) find that the number of large floods in Europe increased significantly from 1985 to 2009, and Hirsch and Ryberg (2012) investigate the relationship between flood magnitudes and global CO_2 levels in the US without finding strong indications of it.

Various works focussing on the topic of trend detection in hydrological time series concluded that trends could be found in studies around the world, and that change detection is a challenging research need (Kundzewicz, 2004). Furthermore it was found that usually trends in extreme value series cannot be proven as reliably as in mean series or are not significant (Lindström & Bergström, 2004; Xiong & Guo, 2004).

Although numerous investigations exist, most of them take into account annual or monthly statistics like mean or maxima in a small geographic region. The main objective of the present study was to investigate trends at different time scales on a global scale and compare between results of the northern and southern hemisphere. Therefore, trend analysis was conducted on an annual, monthly and daily level and both trends in average and extreme value datasets were analysed. Another objective was to try to find out if any differences can be found in the number of trends at the different time resolutions that could explain results in a clearer way. Therefore, trend analysis was conducted on an annual, monthly and daily level and both trends in time and extreme value series were analysed.

2. Materials and methods

2.1. Data used in this investigation

In this investigation, only freely available data on a daily resolution was used from various different data sources on the internet. The observed variables were discharge, precipitation and temperature, where for the latter daily maximum and minimum values were analysed. The period under investigation was the 41 years from 1970 to 2010. The intention was to use data from around the world and cover the whole globe the best way possible, which was possible for temperature and precipitation time series, but proved to be difficult for discharge data due to the lack of a global source with data available in the given time period and sufficient data completeness, as described below.

Temperature and precipitation data was almost exclusively retrieved from the daily database at the Global Historical Climatology Network (GHCN-D), discharge data was downloaded from national meteorological or hydrological agencies that offered data on a daily basis. Since one of the key criteria for this study was to compare the trends on different time scales, only data available on a daily level was used and other sources that offer data on a monthly level were not taken into account, although they could have increased the geographical coverage significantly. Another aspect that had to be considered was the difference of data quality in different regions of the world, which has already played an important role in previous studies (Haylock et al., 2006; Manton et al., 2001). For this reason, only time series with a maximum of 20% missing data were used, which was the reason for a lower number of stations available in regions like Africa and some parts of South America and Asia, especially Brazilian temperature stations. The list of all stations used in this investigation as well as the different data sources can be viewed in the electronic annex.

The stations used for analysis were chosen randomly among all the available stations. Out of all the stations that met the criteria of at least 80% completeness during the time period from 1970 to 2010, stations were selected, counting on a geographically uniform distribution. In regions with scarce data availability, the majority of stations was chosen, avoiding stations within 100 km of each other. In regions with higher availability of information, a percentage of at least 5% should be used where possible, depending on the number of stations per area, adjusting the distance between stations on this number