Changes in the intensity of daily precipitation over the UK

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1. Introduction

Global warming induced by anthropogenic emissions of greenhouse gases is likely to impact upon the hydrological cycle at all scales from the global to the local. Changes in the intensity of precipitation events will have important implications for water resources and flood risk/control, soil degradation and agriculture. Under increased greenhouse gas concentrations, some global climate models (GCMs) exhibit enhanced mid-latitude precipitation intensity and shortened return periods of extreme events (Hennessy *et al.*, 1997; Fowler and Hennessy, 1995; McGuffie *et al.*, 1999), driven in some cases by a shift from large-scale (frontal and orographic) to convective mechanisms (Gregory and Mitchell, 1995). **But what do these climate change projections mean for the UK, and has the character of UK precipitation already begun to change?** In sections 2 and 3 we show that the intensity of UK rainfall has changed over recent decades (Osborn *et al.,* 2000), while in section 4 we show projections of future changes, based on results from a high-resolution regional climate model (Jones and Reid, 2000).

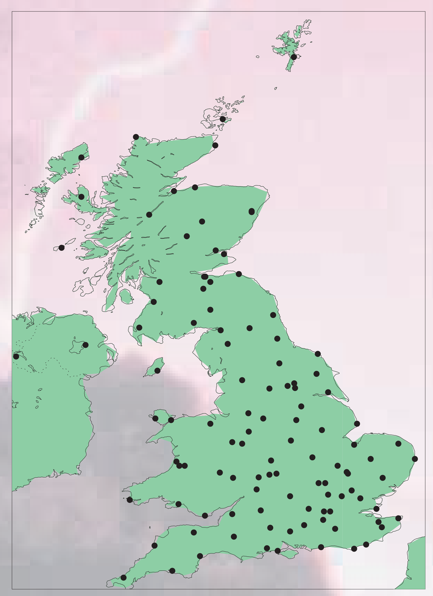

Figure 1: Location of 110 stations with daily precipitation records from 1961-1995.

2. Data and method

The primary data base is a set of 110 stations records (**Figure 1**) with daily precipitation observations for a 35-year period (1961-1995). We classify every wet day (non-zero rainfall) in each record into 10 categories (from 1 to 10, representing lightest to heaviest daily totals). The categories are defined separately for each station, and separately for each of the 12 months. They are defined so that, over the 1961-1995 period, daily totals in each of the 10 categories accumulate to provide 10% of the total rainfall. Thus, we call these categories "*amount quantiles*". Whilst each amount quantile contributes 10% of the total rainfall when averaged over the entire 1961-1995 period, the contributions show interesting year-to-year variability, and trends in certain locations and seasons.

3. What trends have occurred over recent decades?

At each station, and for each season, trends in the contribution of events in each category to total seasonal rainfall were computed over the 1961-1995 period. The set of trends (110 stations, 10 categories) was subjected to Principal Component Analysis (PCA) to identify the dominant trend structures and patterns for each season (**Figure 2**).

For winter, the leading trend structure (**Figure 2a**) shows a shift from the lightest six quantiles to the heaviest four quantiles - particularly to the top quantile. This component, therefore, represents an increasing contribution of heavy precipitation events. The pattern of loadings identifies those stations that exhibit a signal similar to this in winter: those with large red dots do, those with small dots do not, and those with large blue dots show the opposite type of change. The majority of stations exhibit, to some extent, this shift from light and medium to heavy events in winter, especially over Scotland and central and eastern Britain.

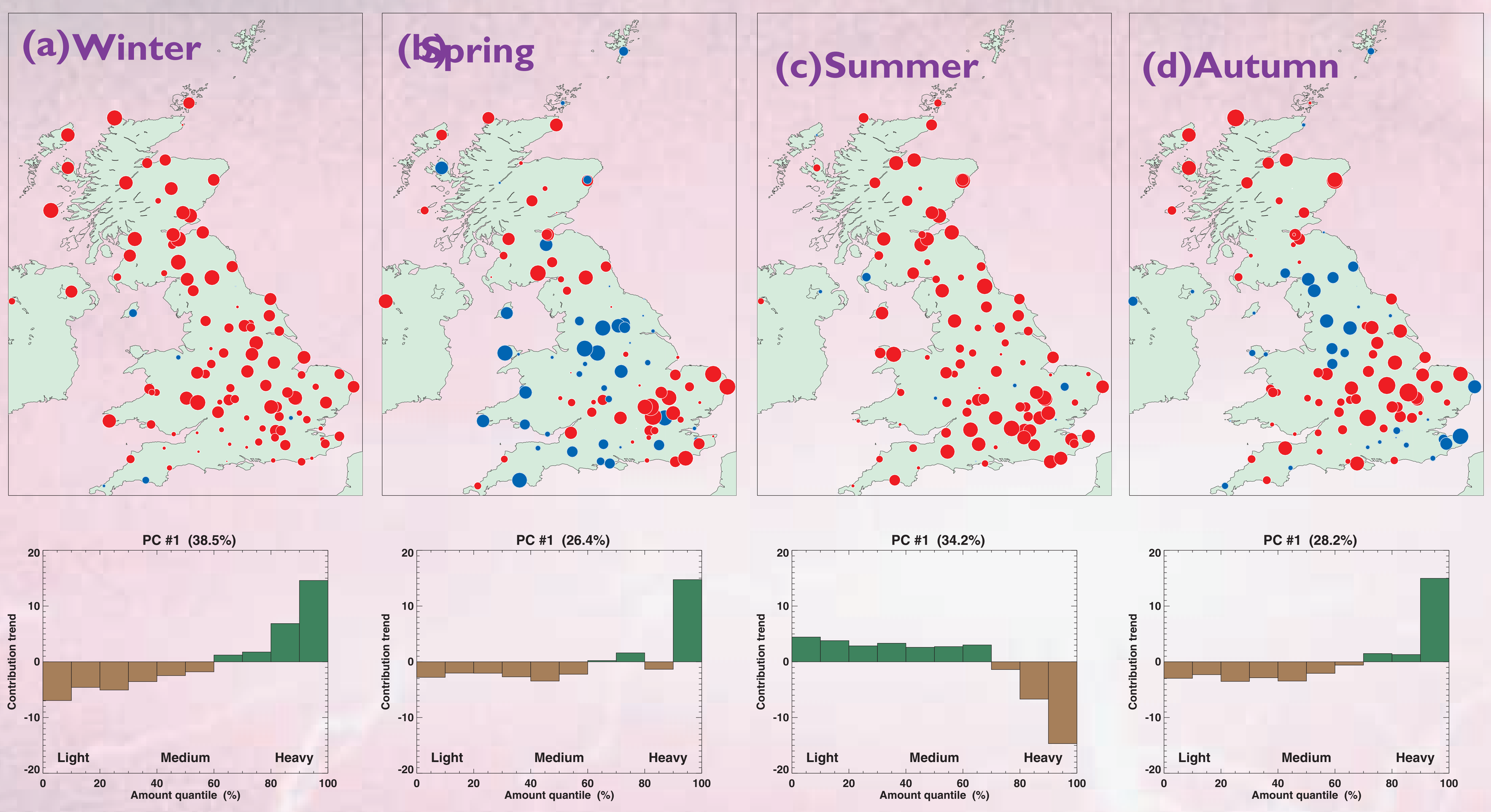

Figure 2: The dominant trend structures and associated patterns in the contribution that events in each of the ten "amount quantile" categories make to (a) winter; (b) spring; (c) summer; and (d) autumn precipitation. These trend structures are identified using principal component analysis. Larger dots indicate stronger loading; positive loading is shown in red, negative in blue. Strong positive loading indicates that the signal of changing contributions shown by the brown/green bars is a good description of the changes at those stations.

In spring and autumn (**Figure 2b** and **2d**) the leading trend structures also show a shift in contributions between light/medium intensity categoriesis and heavy intensity categories, but the associated patterns are not uniform, with some regions showing a shift towards more contribution from heavy events, and some regions showing the reverse.

In summer (**Figure 2c**), a more uniform picture emerges. There is a shift in the contributions away from the heaviest events to the light and moderate events at most stations. This pattern is strongest in south-central and northern England and central and eastern Scotland.

When all station analyses are combined to produce a UK-average picture, the leading trend structures shown in Figure 2 dominate the results. Over 1961-1995, we find downward trends during winter in the contribution of categories 1-6 (light to medium), and upward trends for categories 7-10 (medium to heavy). For summer, almost the reverse has occurred. Many more of the trends are statistically significant than would be expected by chance. The other seasons show only weak trends at the UK-average scale, due to the opposite regional changes that have occurred (**Figure 2b** and **2d**).

These 35-year trends have been placed in a longer term context by comparing them with data sets that have less spatial coverage/detail but extend over a longer period (**Figure 3**). In winter, the trends since 1961 are well-reproduced by a data set than goes back to 1931 and have reached unprecedented levels during the 1990s (**Figure 3a**). In summer, the longer data set also exhibits the recent trends, but suggests that it was the 1960s that were anomalous (in having a higher than normal contribution from heavy summer rainfall events) and that the recent trends have been a return to more normal conditions (**Figure 3b**).

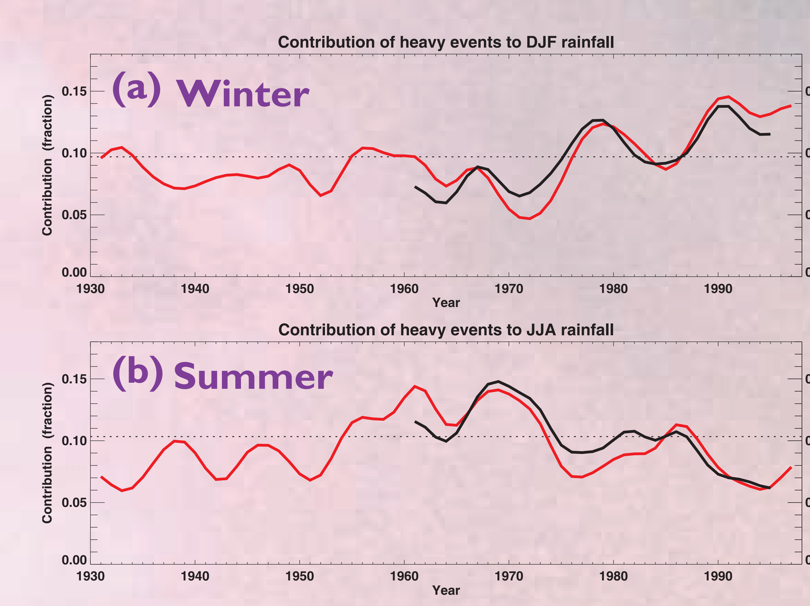

Figure 3: The changing contribution through time made by daily events in the heaviest categories to total (a) winter; and (b) summer rainfall. Data are averaged across all UK records and have been decadally-smoothed. Black curves (1961-1995) are based on the 110 stations (Figures 1 and 2), while the red curves (1931-1997) are based on nine regional time series records (better temporal coverage, but less spatial detail).

4. What changes are predicted for the future?

The observed trend towards more intense winter rainfall over the UK is in general agreement with climate change simulations made by global climate models under conditions of increased greenhouse gases. Global models do not give regional detail, however, so here we present some results from a high-resolution regional climate model simulation (Noguer *et al.*, 1998). Jones and Reid (2000) have used various measures of precipitation intensity and extremes to quantify the simulated changes in UK precipitation. For the 1961-1990 period of the simulation, the magnitude of events with return periods of 5 years, 10 years and 20 years have been computed at each location using the generalised extreme value distribution. One would expect to get approximately 6, 3 and 1.5 daily precipitation totals of this magnitude or greater in a 30-year period. **Figure 4** shows how many times these thresholds are exceeded during a later period of the simulation, when greenhouse gas concentrations were double what they were during 1961-1990. The details of the pattern are probably uncertain, but the key result is that the changes are all positive – i.e., **an increase in the occurrence of extreme precipitation in the future.** Even more critical, perhaps, is that the increases are relatively greater for the more extreme events.

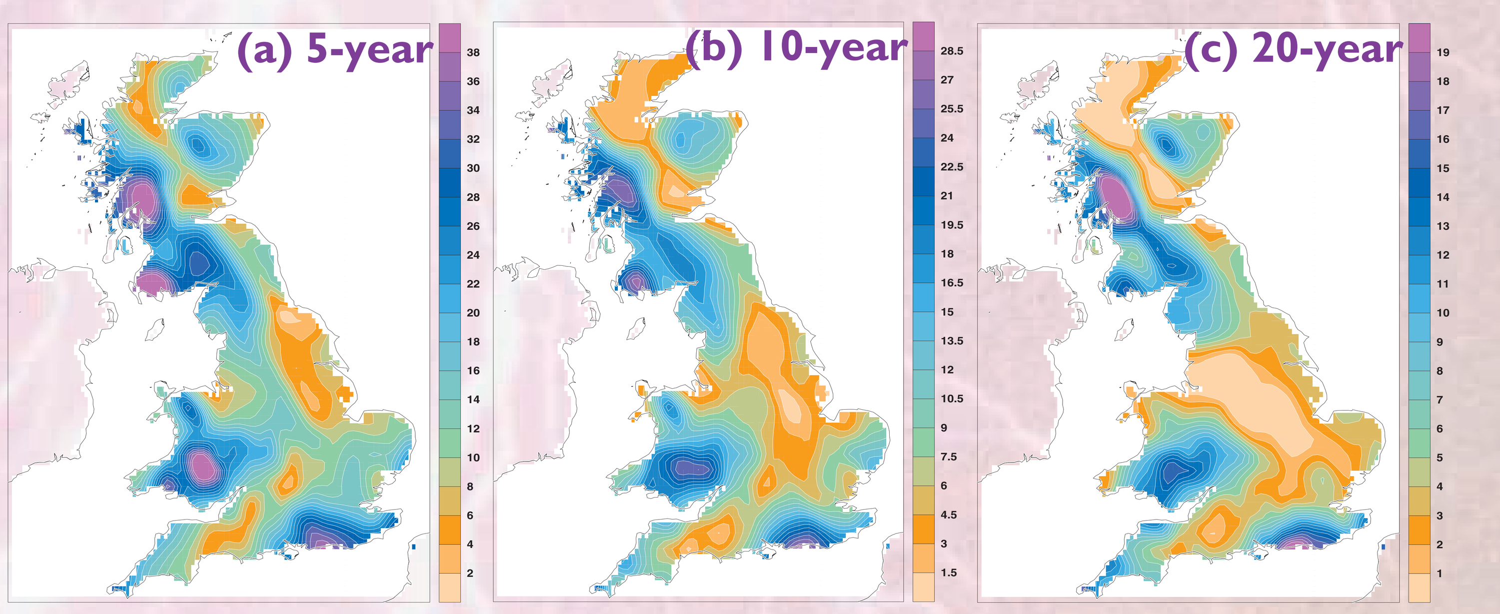

Figure 4: Increase in the number of events (days during a 30-year period) under doubled greenhouse gas concentrations for which the precipitation amount is greater than the 1961-1990 (a) 5-year; (b) 10-year; and (c) 20-year return period events.

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