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INNOVATIVE TREND ANALYSIS METHODOLOGY IN LOGARITHMIC AXIS

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ABSTRACT: Future uncertainties of climate change cause people to worry, and therefore, in order to reduce the associated risks, scientific research methodologies are improved continuously. For instance, temperature raises as a result of carbon content increase cause variations in hydro-meteorological data including evaporation, drought, precipitation, runoff, and flood. Along these lines, the most commonly used trend analysis methods are linear regression analysis, Mann-Kendall, sequential Mann-Kendall, Spearman's Rho, and recently a new method referred to as innovative trend analysis (ITA), which does not require initial assumptions, normality, and independence in a data structure. The ITA method presents a great visual ability for trend identification in graphical forms in addition to qualitative and quantitative interpretations. In the original form of the ITA approach, scatter points are presented in the arithmetic scale, where changes of scatter points in small values may not be clearly distinguishable like big values for wide data ranges. In this study, the ITA method is used on arithmetic and logarithmic scales to calculate such differences in two sub-series. The suggested logarithmic scale methodology is referred to as proportional Şen innovative trend analysis (ITA_P). This method is used to determine percent trends for the annual, autumn, winter, spring and summer season rains in England. ITA_P is successful in determining trends in minimum values compared to the classical ITA.

Key Words: *Innovative trend analysis, hydro-meteorological data, proportional innovative trend analysis, climate change.*

Logaritmik Ölçekte Yenilikçi Yönelim Çözümleme Yöntemi

ÖZ: Gelecekle ilgili belirsizlikler insanoğlunu endişelendirmekte ve olası riskleri azaltmak için bilimsel araştırma yöntemleri sürekli geliştirilmektedir. Örneğin karbon salınımının artışıyla birlikte artan sıcaklıklar buharlaşma, yağış gibi iklim olaylarının değişimini artırarak akışlar üzerinde kuraklık ve taşkınlara neden olabilmektedir. Bu olaylar üzerindeki eğilimi belirlemek üzere Mann-Kendall, sıralı Mann-Kendall, Spearman rho ve son zamanlarda ortaya atılan Şen'in yenilikçi yönelim çözümleme (Şen_ITA) yöntemleri literatürde sıklıkla kullanılmaktadır. Bu yöntemlerden Şen_ITA yöntemi normallik ve bağımsız seri gibi başlangıç kabulleri gerektirmemektedir. Ayrıca niteliksel ve nicel yorumlamaları yanında grafiksel olarak görsel kabiliyeti yüksek bir yöntemdir. Şen_ITA yöntemi esasen aritmetik ölçekte kullanılır ve bu durum değişim katsayısı yüksek bir seri üzerinde minimum değerler üzerindeki eğilimin maksimum değerlerin yanında gözden kaçabilmesine neden olabilmektedir. Bu çalışmada, Şen_ITA yöntemi aritmetik ve logaritmik ölçekte kıyaslanmıştır. Önerilen yaklaşım, oransal Şen yenilikçi yönelim çözümleme yöntemi olarak adlandırılmıştır (ITA_P). Bu yaklaşım İngiltere'nin mevsimsel ve yıllık yağışları üzerindeki oransal eğilimleri belirlemek için kullanılmıştır. ITA_P yaklaşımının klasik Şen_ITA yöntemine göre bir seri üzerinde minimum değerlerdeki eğilimleri belirlemede daha başarılı olduğu belirlenmiştir.

Anahtar Kelimeler: *Yenilikçi yönelim çözümlemesi, hidro-meteorolojik veri, oransal yenilikçi yönelim çözümlemesi, iklim değişikliği.*

1. INTRODUCTION

Climate change impacts hydro-meteorological events by incorporating an increasing trend component in temperature records and increasing or decreasing trends in precipitation, evaporation, flood and drought occurrences. The carbon level in the atmosphere affects the temperature, which impacts precipitation and evaporation, and they trigger floods and droughts according to the circumstances.

Mann-Kendall (MK), the sequential MK and Sen's slope estimator are well-known trend calculation methods and they are widely used in the literature (Büyükyıldız and Berktay, 2004; Kendall, 1975; Lin *et al.*, 2008; Mann, 1945; Shahid, 2011; Vinet and Zhedanov, 2010). Recently, Şen innovative trend analysis (ITA) method is launched to determine the trend in a given time series (Şen 2012, 2014, 2017) and it has been used by many researchers. For instance, Elouissi *et al.* (2016) used ITA to investigate trends in monthly precipitation records from 28 meteorology stations in Algerian Macta watershed. Öztopal and Şen (2017) classified precipitation values as low, medium and high in the ITA graph and then determined trends in the precipitation values in different climate regions of Turkey. Some researchers compared the ITA and MK methods. For instance, Nourani *et al.* (2018) investigated trends in rainfall, streamflow, humidity and temperature records in Urmia lake basin, Iran and they stated that ITA indicated a good agreement with the MK method. Dabanlı *et al.* (2016) used MK and ITA methods to determine trends in hydro-meteorological variables such as relative humidity, temperature, runoff and precipitation at 8 stations in Ergene drainage basin, Turkey. They stated that MK does not give significant monotonic trends for the drainage basin while ITA provides verbal partial trend information (low, medium and high) in most of the stations.

Although the ITA method is based on a comparison of two half series, it is possible to work with more than two parts to detect even sudden shifts in a given time series. Deng *et al.* (2017) studied precipitation variability on Weizhou Island, the northern part of the South China Sea by using MK and ITA methods, where they divided the main record into three parts and found a non-homogenous temporal trend distribution. Sonali and Nagesh Kumar (2013) examined trends in Indian maximum and minimum temperatures with different data lengths using ITA and other well-known trend methods. Mohorji *et al.* (2017) applied the ITA to global monthly temperature values, first as two half series and then for various periods (10-year, 20-year, 30-year, 40-year, and 50-year). It was found that the increasing temperature at the global scale is about 0.75 °C. Güçlü (2018b, a) used ITA in half time series for possible determination of trend shifts by considering "increasing-increasing", "decreasing-increasing", "increasing-decreasing" and "decreasing-decreasing" cases.

ITA has a strong graphical visual ability to identify and interpret the trend possibility in a given time series. In the classical trend calculations, serial independence, homoscedasticity, and normal probability distribution assumptions must be satisfied. Şen_ITA method does not require these assumptions, and it is based on the comparison of the two ascendingly ordered halves from the original time series (Şen, 2017). In this method, the trend changes are documented quantitatively, where larger deviations may occur in the maximum values compared to the minimum values with respect to 1:1 (45º) no trend line. It is possible for the same trend in quantity to provide different percent changes in cases of daily or monthly records. The percent approach helps to expose trends on the minimum values.

The aim of this study is to adapt trends similar to the ITA method based on the logarithmic scale, which is referred to as proportional Şen innovative trend analysis (ITA_P). It is observed that similar trends in percent are at equal distance to 1: 1 (45º) no trend line for all series in logarithmic scale. In this way, small quantities and big proportions in the minimum values are easily observed by the ITA_P approach, which leads to better interpretations regardless of the data size.

2. MATERIAL AND METHOD

The Şen innovative trend analysis (ITA) is based on two sub-series comparison from a given parent hydro-meteorological time series. Each sub-series is sorted in ascending order and the first sub-series values are plotted on horizontal (X) against the second sub-series on vertical (Y) axis leading to the scatter diagram graph as in Figure 1, where 1:1 (45°) line represents no trend straight-line. If the scatter points are above (under) the 1:1 line with approximately parallel positions then there is an increasing (decreasing) trend in the records, and this is referred to as a monotonic trend (Figure 1a). If the entire scatter points are not completely above, under or parallel to the 1:1 line then this is referred to as a non-monotonic trend and then the horizontal axis in the graph is divided into ranges such as low, medium, high, etc. (Figure 1b).

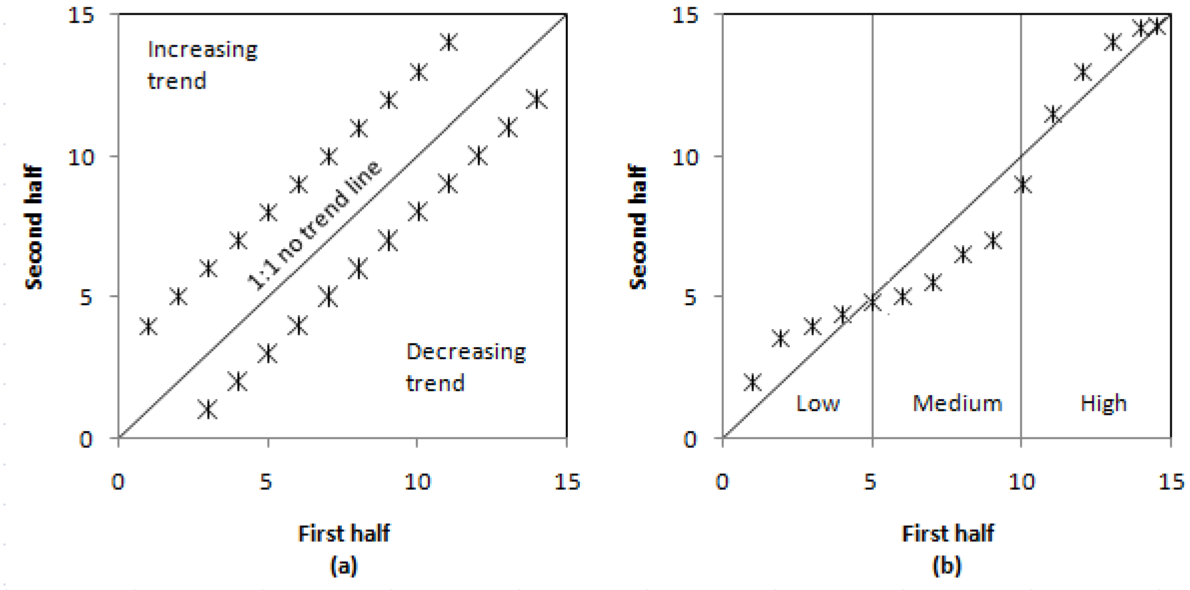


Figure 1. A graphical representation of the ITA method a) monotonic trend b) non-monotonic trend (Alashan, 2018).

The basic equation for a trend in quantity related to the ITA method is given by Şen (2017) in the following expression.

$$s = \frac{2(\bar{y} - \bar{x})}{n} \quad (1)$$

Here, s, $\bar{y}$, $\bar{x}$ and n are trend slope, arithmetic averages of the second and first sub-series and number of data, respectively. Positive (negative) slope values represent increasing (decreasing) trends, while there is no trend for zero slope value. Sometimes, although slope values are marginally bigger (smaller) than zero and in which case there is not any significant positive (negative) trend. For testing the trend significance, a 5% trend line is selected as the critical trend line. By selecting the critical trend value in percent, the critical trend line is determined without the need for assumptions such as normality and independence. Many critical trend lines such as 2%, 5%, 10%, and 20% are used in the ITA method in the literature (Ahmad *et al.*, 2018; Cui *et al.*, 2017; Kambezidis, 2018; Nisansala *et al.*, 2019; Wu *et al.*, 2017).

The difference at the i-th scatter point (a trend indicator) is defined as $y_i - x_i$, where $1 < i < n/2$ (Wu and Qian, 2017). In the literature, the average trend indicator is divided into the mean of the first half series and the trend in percent ($\frac{1}{n}\sum_{i=1}^{n}\frac{y_i - x_i}{\bar{x}}$) is obtained. Figure 2 indicates the result of the ITA after the logarithmic transformation application on both axes (arithmetic and logarithmic) leading to the proportional Şen innovative trend analysis (ITA_P).

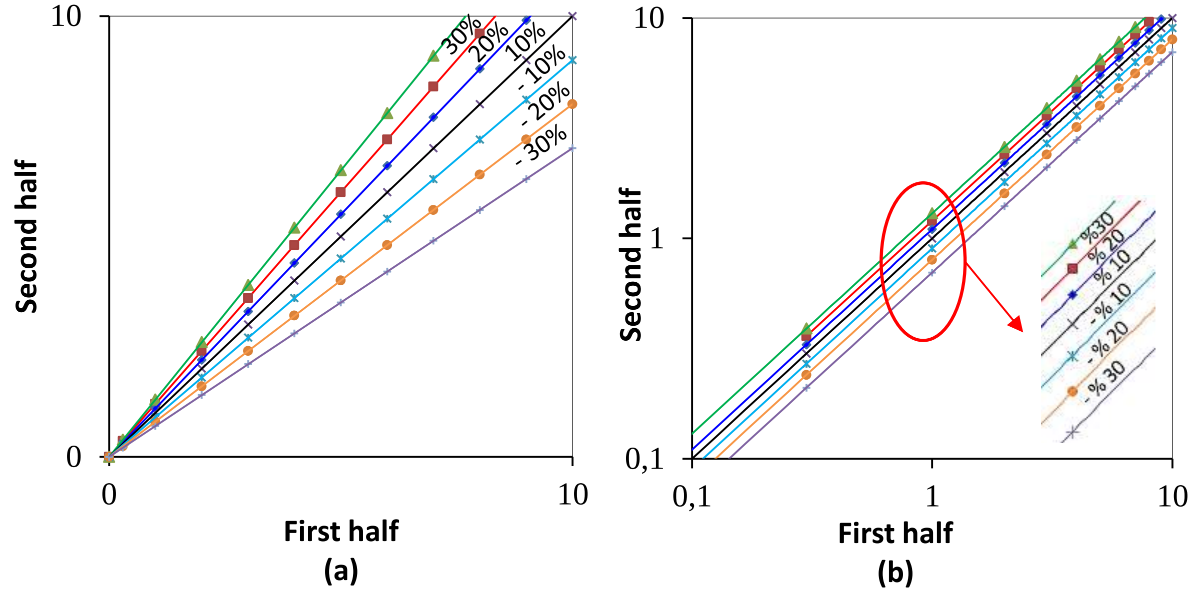


Figure 2. Graphical representations of proportional innovative trend analysis a) arithmetic axis b) logarithmic axis.

To avoid dependence on the mean of the first half series in trend calculations, the ratios of yi/xi lead to dimensionless changes (pi), according to the following expression.

$$p_i = \frac{y_i}{x_i} \qquad \Rightarrow \qquad p = \left(\sqrt[n]{\prod_{i=1}^{n}\left(\frac{y_i}{x_i}\right)}\right) \tag{2}$$

The geometric mean change (p) is calculated for dimensionless values and α parameter is calculated by Eq. (3), which helps to determine a possible trend.

$$\alpha = \mathrm{p} - 1 \tag{3}$$

If $\bar{x} = \bar{y}$ then p=1 (scatter points fall over the 1:1 line) and $\alpha = 0$ implies that there is no trend in the data. However, increasing (decreasing) trend exists in the case of p>1 and $\bar{x} < \bar{y}$ ($p < 1$ *and* $\bar{x} > \bar{y}$). This last sentence implies also that if $\alpha > 0$ ($\alpha < 0$) an increasing (decreasing) trend appears. Application of the logarithmic transformation to Eq.2 yields Eq.4, which implies a set of parallel straight-lines to the 1:1 no trend line according to different trend slopes (α) (Fig. 2b).

$$\log(p) = \frac{1}{n}\left(\log\left(\frac{y_1}{x_1}\right) + \log\left(\frac{y_2}{x_2}\right) + \cdots + \log\left(\frac{y_n}{x_n}\right)\right)$$

$$\log(p) = \frac{1}{n}(\log(y_1) - \log(x_1) + \log(y_2) - \log(x_2) + \cdots + \log(y_n) - \log(x_n)) \tag{4}$$

3. APPLICATION AND STUDY AREA

The application of the ITA_P method is presented for monthly rain values from England. The country is approximately between 49.93⁰ N to 55.8⁰ N latitudes and 5.72⁰ W to 1.77⁰ E longitudes. Some of the important cities are selected as the study areas to observe the climate change impact on the country (Figure 3). The country has a maritime climate with frequent rain events. Annual mean rain values range from 600 mm to 3,000 mm. The eastern and western parts of the country are drier and warmer than the southern and northern parts. The western part has higher elevations that prevent the humid air entrance from the Atlantic Ocean to the east. In addition, the high topography allows for cooling in the western parts and gives rise to intensive rain occurrences. Summer and spring seasons have relatively higher rain values than the autumn and winter seasons in the eastern parts, but in the western part, autumn and summer seasons have higher rain values compared to winter and spring seasons.

Figure 3. Map of locations of the selected rain stations in the study area, England.

Statistical information about the rain stations is given in Table 1 with the minimum, average, maximum, and standard deviation. The rain database is provided by the Met Office which is the national meteorological service of the UK (https://www.metoffice.gov.uk /research/climate/maps-and-data /historic-station-data). The homogeneity of the database is checked by the Run homogeneity test proposed by Swed and Eisenhart (1943). The data of all stations used in the study provides a homogeneity condition of at least a 90% significance level. Newton Rigg station has the maximum altitude and the highest monthly rain values, while Lowestoft and Eastbourne stations are with the minimum rain. Shawbury and Camborne stations have minimum and maximum standard deviations, respectively.

Table 1. Statistical and geographic characteristics of the rain observation stations in the study area.

Station name	Coordinates		Altitude (m)	Observed Years	Data Numbers	Monthly Rain (mm)			
	Latitude	Longitude				Minimum	Mean	Maximum	Standard Deviation
Camborne	50.22	-5.33	87	1981-2018	456	4.40	89.23	242.20	51.73
Chivenor	51.09	-4.15	6	1981-2018	456	1.10	76.80	233.00	40.90
Eastbourne	50.76	0.29	7	1981-2018	456	0.2	65.92	261.10	44.06
Heathrow	51.48	-0.45	25	1981-2018	456	0.3	50.42	174.80	29.91
Lowestoft	52.48	1.73	18	1981-2018	456	0.2	51.47	157.40	29.30
Newton Rigg	54.67	-2.79	169	1981-2018	456	5.3	79.88	329.40	46.81
Shawbury	52.79	-2.66	72	1981-2018	456	2.30	55.54	146.40	27.76
Sheffield	53.38	-1.49	131	1981-2018	456	4.60	68.86	285.60	40.09
Sutton Bonington	52.83	-1.25	48	1981-2018	456	2.40	51.40	161.60	27.91
Whitby	54.48	-0.62	41	1981-2018	456	2.70	51.87	189.00	30.28

The ITA and ITA_P methods are applied to the monthly rain records leading to graphs in Figure 4. It is obvious from these graphs that there are visual discrepancies between ITA and ITA_P methods. Although they have the same trends in quantity, the maximum (minimum) values have smaller (bigger) trends than the minimum (maximum) values. This leads to different visual trend evaluations between ITA and ITA_P scales. Camborne monthly rain records have no visually important trends according to the ITA (Figure 4), but there is an increasing trend in the minimum values according to the ITA_P method. According to ITA, there are increasing trends in Chivenor, Newton Rigg, Shawbury and Sheffield monthly maximum rain values, but the increasing trends in the ITA_P approach are seen at minimum values. Eastbourne, Lowestoft and Sutton Bonington monthly rain records have increasing trends in the ITA concerning the maximum values, but according to the ITA_P approach, there are decreasing trends in the minimum values. At Heathrow, no visual significant trend is seen according to ITA_P but there are increasing trends in the maximum values according to the ITA. There exists a continuously increasing trend on the ITA_P graph in maximum Whitby monthly rain values, and there is a monotonic increasing trend in the ITA graph in the maximum rain values.

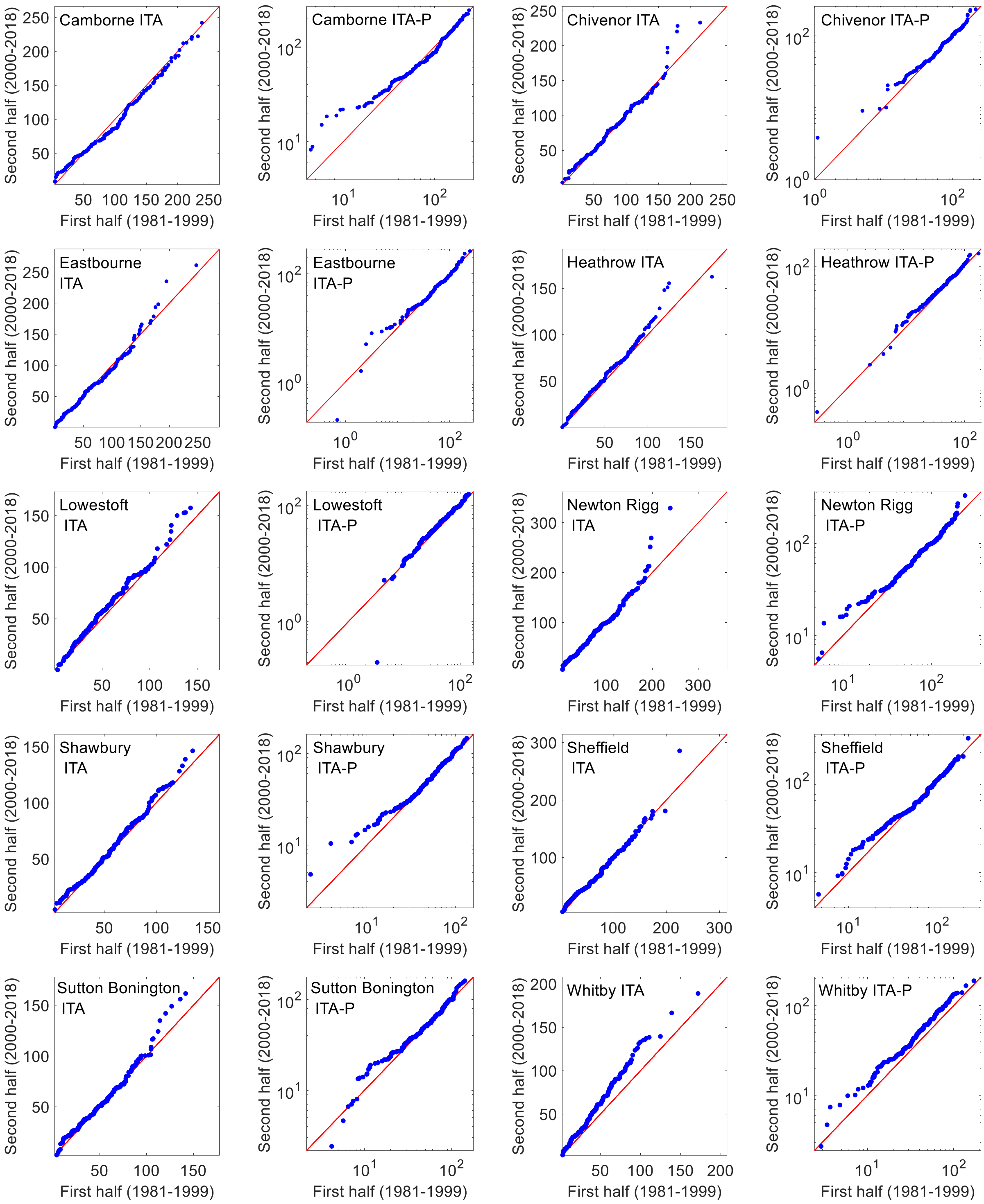


Figure4. Trend graphics for the monthly rain records in ITA and ITA_P scales

Monthly, annual and autumn, winter, spring and summer rain records are treated for trend identifications by means of ITA_P and ITA templates using Eqs. (1) - (4). The parameters in Table 2 are given only for the annual rain records. Trends in the ITA_P template are plotted only for the annual rain records in Figure 5. The green (dashed) lines represent the maximum and minimum changes in the ITA_P template for annual rain records and the black (straight) line is for no trend (1:1) line, the red (bold) line is for a trend in percent according to ITA_P method. Whitby has the largest increasing trend both in ITA and ITA_P methods. The annual rain records in Camborne have a slightly decreasing trend in ITA and the trend slope does not exceed the 5% risk level (Table 2). There is almost no trend in the ITA_P approach on Chivenor, Eastbourne, and Sheffield annual rain records (Figure 5). Newton Rigg, Shawbury and Sutton Bonington have small increasing trends in ITA_P. Heathrow, Lowestoft and Whitby station records have important increasing trends in the ITA_P template for annual rain records and the trend slope values exceed the 5%, 10% and 20% risk level.

Table 2. Trend results and statistical parameters for ITA and ITA_P methods in annual rain values.

Station Name	Data length (n)	Mean		Trend slope	Trend in percent (ITA)	Trend in percent (ITA_P)	Critical Level	Type of trend
		First half	Second half ()					
Camborne	38	90.84	87.61	-0.170	-3.5%	-3.8%	5%	No trend
Chivenor	38	75.88	77.72	0.097	2.4%	1.5%	5%	No trend
Eastbourne	38	66.22	65.61	-0.032	-0.9%	-1.8%	5%	No trend
Heathrow	38	48.31	52.54	0.223	8.8%	8.3%	5%	Increasing
Lowestoft	38	49.00	53.95	0.261	10.1%	10.4%	10%	Increasing
Newton Rigg	38	78.29	81.47	0.168	4.1%	3.5%	5%	No trend
Shawbury	38	54.37	56.71	0.123	4.3%	3.6%	5%	No trend
Sheffield	38	68.75	68.96	0.011	0.3%	-0.8%	5%	No trend
Sutton Bonington	38	50.39	52.40	0.106	4.0%	3.5%	5%	No trend
Whitby	38	45.81	57.92	0.638	26.4%	26.5%	20%	Increasing

Table 3 presents trend both in ITA and ITA_P templates for annual, autumn, winter, spring and summer seasons. Trends slope in quantity changes from -0.170 mm/year (Camborne) to 0.638 mm/year (Whitby) for annual; from -0.376 mm/year (Eastbourne) to 0.875 mm/year (Whitby) for autumn; from -0.468 mm/year (Camborne) to 0.687 mm/year (Newton Rigg) for winter; from -0.495 mm/year (Newton Rigg) to 0.245 mm/year (Whitby) for spring and from 0.079 mm/year (Eastbourne) to 0.807 (Newton Rigg) mm/year for summer rain values.

Trends in ITA_P change from -3.85% per duration (Camborne) to 26.50% (Whitby) for annual rain values; from -12.49% (Eastbourne) to 33.21% (Whitby) for autumn; from -8.19% (Camborne) to 28.90% (Newton Rigg) for winter; from -12.08% (Newton Rigg) to 12.41% (Whitby) for spring and from 10.42% (Eastbourne) to 30.95% (Whitby) for summer rain values.

After the comparison between ITA and ITA_P methods according to trends in percent, Sheffield (Whitby) seems to have the highest decreasing (increasing) trend in percent for winter rain values in the ITA, while Camborne (Whitby) has the highest decreasing (increasing) trend according to ITA_P.

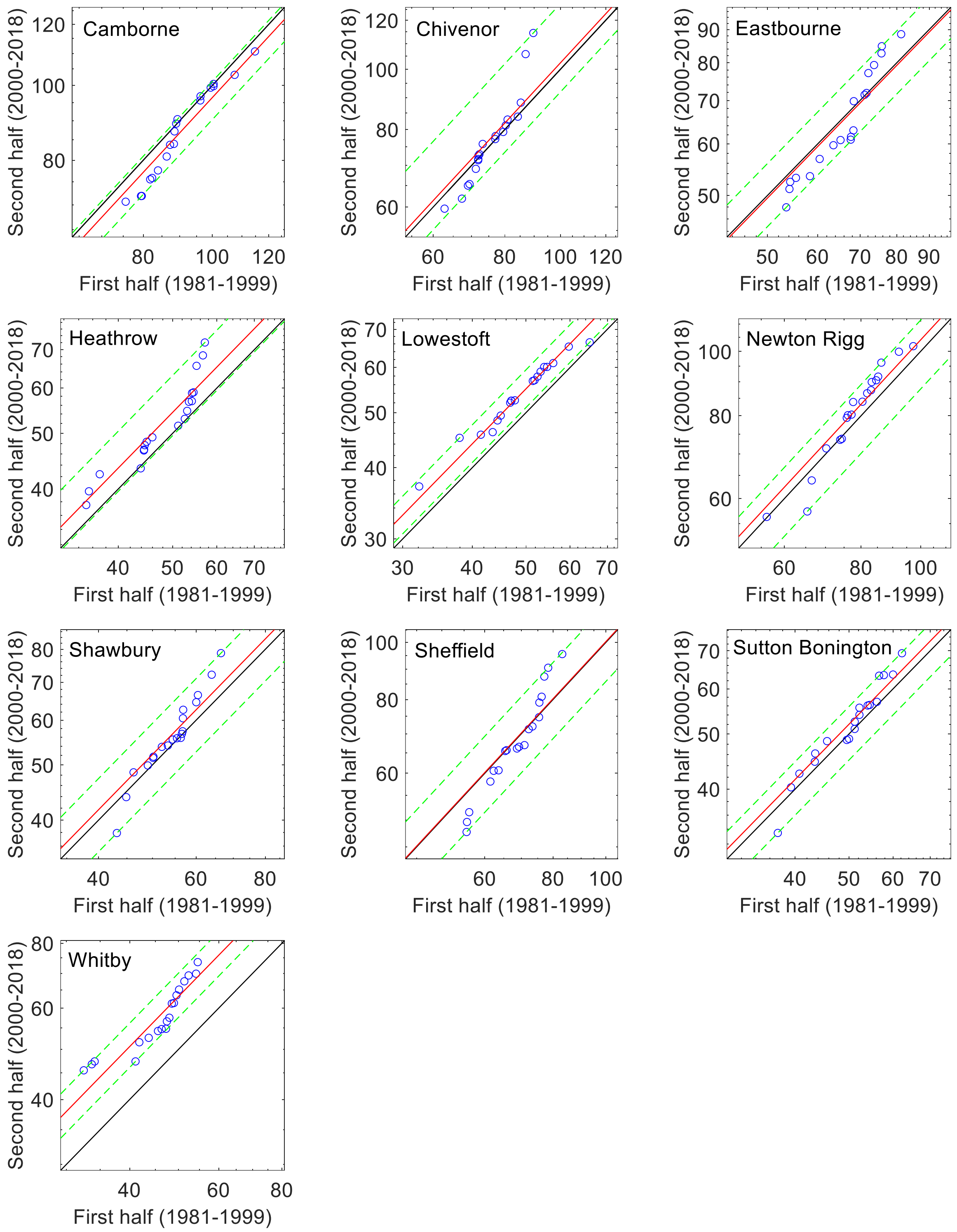


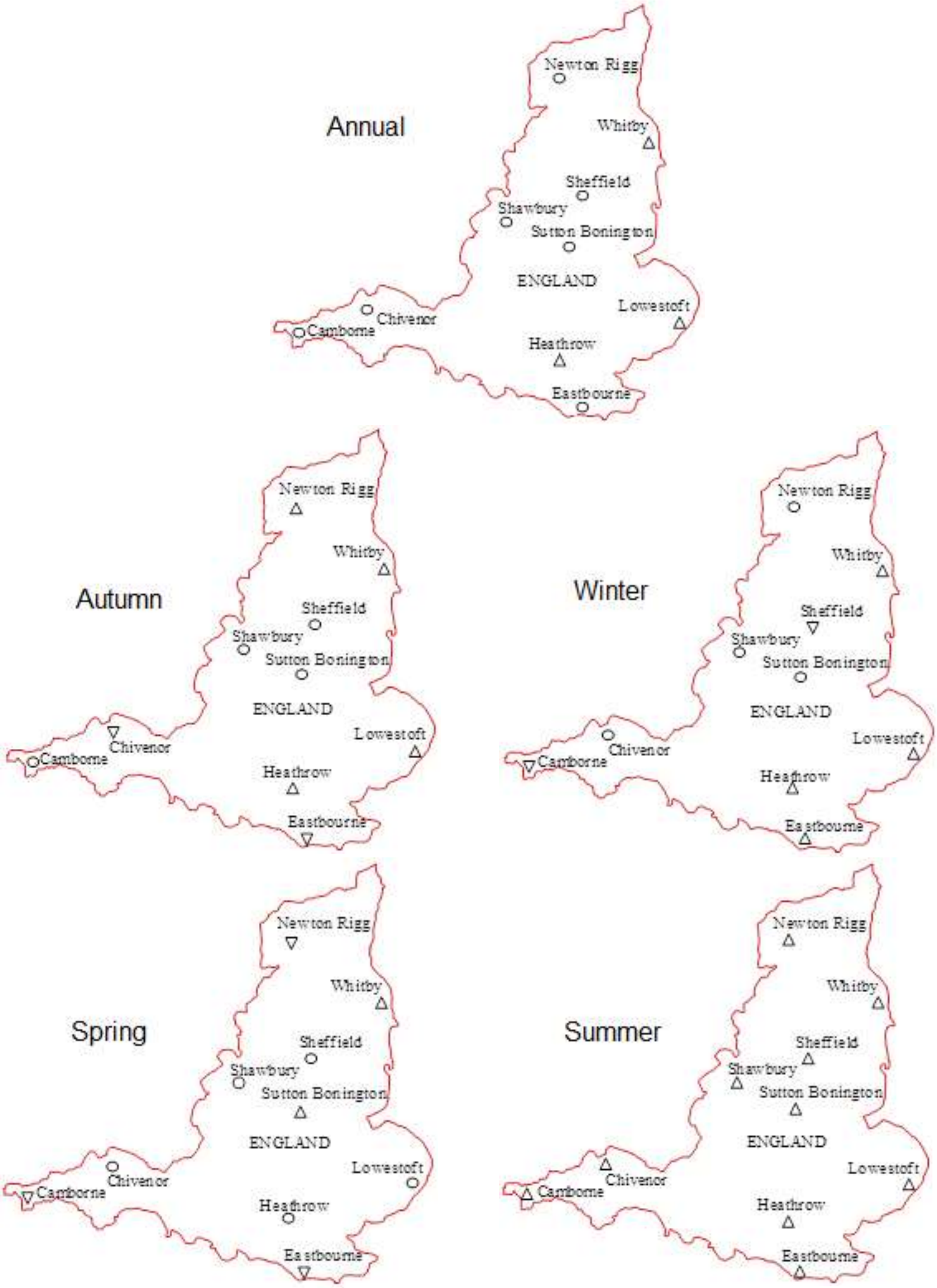
Figure5. Graphical representations of the trends in the ITA_P template for annual rain records in selected stations in England.

Table3. Trend results in quantity and percent in rain values by ITA and ITA_P methods.

	Station name	Camborne	Chivenor	Eastbourne	Heathrow	Lowestoft	Newton Rigg	Shawbury	Sheffield	Sutton Bonington	Whitby
Monthly	s (mm/year)	-0.0141	0.0080	-0.0027	0.0186	0.0217	0.0140	0.0103	0.0009	0.0089	0.0531
	CL (±)	5.0%	5.0%	5.0%	5.0%	10.0%	5.0%	5.0%	5.0%	5.0%	20.0%
	ITA (%)	-3.55%	2.42%	-0.92%	8.77%	10.11%	4.07%	4.31%	0.32%	4.01%	26.44%
	Decision ITA	No trend	No trend	No trend	Increasing	Increasing	No trend	No trend	No trend	No trend	Increasing
	ITA_P (%)	1.97%	5.10%	1.29%	11.69%	9.34%	6.17%	6.97%	3.73%	6.11%	27.49%
	Decision ITA_P	No trend	Increasing	No trend	Increasing	Increasing	Increasing	Increasing	No trend	Increasing	Increasing
Annual	s (mm/year)	-0.170	0.097	-0.032	0.223	0.261	0.168	0.123	0.011	0.106	0.638
	CL (±)	5.0%	5.0%	5.0%	5.0%	10.0%	5.0%	5.0%	5.0%	5.0%	20.0%
	ITA (%)	-3.55%	2.42%	-0.92%	8.77%	10.11%	4.07%	4.31%	0.32%	4.01%	26.44%
	Decision ITA	No trend	No trend	No trend	Increasing	Increasing	No trend	No trend	No trend	No trend	Increasing
	ITA_P (%)	-3.85%	1.48%	-1.81%	8.34%	10.38%	3.49%	3.57%	-0.79%	3.51%	26.50%
	Decision ITA_P	No trend	No trend	No trend	Increasing	Increasing	No trend	No trend	No trend	No trend	Increasing
Autumn	s (mm/year)	-0.193	-0.153	-0.376	0.206	0.331	0.227	0.067	0.033	-0.096	0.875
	CL (±)	5.0%	5.0%	5.0%	5.0%	10.0%	5.0%	5.0%	5.0%	5.0%	20.0%
	ITA (%)	-3.44%	-3.07%	-8.05%	7.06%	11.42%	4.68%	2.10%	0.86%	-3.35%	33.86%
	Decision ITA	No trend	No trend	Decreasing	Increasing	Increasing	No trend	No trend	No trend	No trend	Increasing
	ITA_P (%)	-4.91%	-5.60%	-12.94%	10.10%	13.73%	5.30%	0.82%	-1.07%	-3.48%	33.21%
	Decision ITA_P	No trend	Decreasing	Decreasing	Increasing	Increasing	Increasing	No trend	No trend	No trend	Increasing
Winter	s (mm/year)	-0.468	0.047	0.383	0.363	0.291	0.132	-0.053	-0.388	-0.126	0.687
	CL (±)	5.0%	5.0%	5.0%	10.0%	10.0%	5.0%	5.0%	5.0%	5.0%	20.0%
	ITA (%)	-7.48%	1.02%	9.69%	14.18%	11.69%	2.65%	-1.83%	-9.08%	-4.77%	27.65%
	Decision ITA	Decreasing	No trend	Increasing	Increasing	Increasing	No trend	No trend	Decreasing	No trend	Increasing
	ITA_P (%)	-8.19%	2.87%	12.58%	16.96%	15.02%	2.10%	-0.38%	-8.02%	-3.36%	28.90%
	Decision ITA_P	Decreasing	No trend	Increasing	Increasing	Increasing	No trend	No trend	Decreasing	No trend	Increasing
Spring	s (mm/year)	-0.411	-0.027	-0.214	0.041	0.079	-0.495	-0.015	-0.157	0.071	0.245
	CL (±)	5.0%	5.0%	5.0%	5.0%	5.0%	10.0%	5.0%	5.0%	5.0%	10.0%
	ITA (%)	-10.42%	-0.88%	-7.82%	1.77%	3.44%	-14.51%	-0.57%	-4.76%	2.99%	11.54%
	Decision ITA	Decreasing	No trend	Decreasing	No trend	No trend	Decreasing	No trend	No trend	No trend	Increasing
	ITA_P (%)	-8.29%	0.75%	-7.94%	2.34%	-0.93%	-12.08%	-1.13%	-4.06%	5.15%	12.41%
	Decision ITA_P	Decreasing	No trend	Decreasing	No trend	No trend	Decreasing	No trend	No trend	Increasing	Increasing
Summer	s (mm/year)	0.393	0.519	0.079	0.282	0.342	0.807	0.494	0.558	0.576	0.743
	CL (±)	10.0%	10.0%	5.0%	10.0%	10.0%	20.0%	10.0%	10.0%	20.0%	20.0%
	ITA (%)	11.89%	15.42%	3.04%	11.89%	12.99%	24.99%	18.21%	18.00%	21.23%	30.33%
	Decision ITA	Increasing	Increasing	No trend	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing
	ITA_P (%)	15.80%	16.21%	10.42%	16.54%	14.43%	25.94%	23.04%	19.13%	28.16%	30.95%
	Decision ITA_P	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing

Figure 6 shows the regional distribution of trends in the study area. Camborne city has decreasing trends for winter and spring rain values and has an increasing trend for the summer season. Chivenor has a decreasing trend for winter rain values and an increasing trend for summer rain values.

(a)



Δ *Increasing trend* ∇ *Decreasing trend* o *No trend*

Figure6. ITA and ITA_P trend test results for all season's rain records in the England map

Eastbourne has increasing trends for the winter and summer seasons and has decreasing trends for autumn and spring seasons. There are increasing trends for annual, autumn, winter and summer rain values in Heathrow. Lowestoft has increasing trends for all seasons excluding spring season and there is no trend for the spring season. Sutton Bonington has increasing trends for all seasons excluding spring and there is no trend for the spring season. There is an increasing trend for the summer season in Shawbury. Sheffield has a decreasing trend for winter rain values and an increasing trend for the summer season. Whitby has increasing trends for all seasons. Newton Rigg has increasing trends for autumn and winter seasons but a decreasing trend for the spring season.

4. RESULTS AND DISCUSSIONS

The ITA method has great visual ability. Although it determines trends in quality and quantity but may give rise to overlook the trends in minimum values in wide-range axes graphs. Alternatively, the proportional Şen Innovative Trend Method (ITA_P) is suggested in this paper for more refined trend identifications in logarithmic scales. Zero and negative values cannot be represented by a logarithmic scale. Hydro-meteorological records (wind, rain, flow, flood, and drought, etc.) excluding temperature values as Celsius are not measured by negative values. If temperatures values are converted from Celsius (°) to Fahrenheit (F), they can be used on a logarithmic scale by the ITA_P method. In engineering studies, very small values can be accepted approximately zero with certain error (5% or 10%) and these values can be plotted on a logarithmic scale. Also, changes are determined as a rate (second-half value/first half value) in ITA_P and these proportions are positive even though measurement values are negative. The applications of the ITA and ITA_P methodologies are performed for monthly, annual, autumn, winter, spring and summer seasons rains records in England. While many researchers (Fowler and Kilsby, 2003; Osborn and Hulme, 2002) have reported decreasing trends in summer rains in the UK, there is an upward trend for summer rains in all regions of England. In relation to this situation, de Leeuw *et al.* (2016) states that the trend reversed in summer rainfall after 2007. Also, Whitby has a serious upward trend in all seasons. Annual rains give increasing trends for only 3 stations, and no trends are seen at other stations. In other seasons except for summer, the increasing and decreasing trends are seen together over England.

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