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TREND ASSESSMENT BY THE MANN-KENDALL TEST AND THE INNOVATIVE TREND ANALYSIS METHOD (NORTH-WEST ALGERIA)

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ABSTRACT

In this article, a trend study, in two watersheds Coastal-Oran and Macta (North-West of Algeria), is carried out using monthly and seasonal rainfall during the period 1975–2015 at 38 stations. Mann-Kendall (MK) and Innovative Trend Analysis (ITA) methods are applied comparatively. The aim of this study is to verify if the trend detection ability is the same in both methods. Monthly rainfall analysis by the MK test shows that 82% of the stations have no significant trends. In contrast, the ITA method detects positive (negative) trends in 56% (33%) of stations in the low rainfall component, 53% (40%) in the average and 41% (58%) in the high rainfall. On a seasonal scale, the MK test still not aware of trends in 75% of the studied stations, while the ITA shows that 63% (31%) of stations with increasing (decreasing) trends. Studying the rainfall trend, using the ITA and Mann-Kendall methods, in the same area can help to understand past variations and therefore extrapolate the results to other areas with the same climate. This is a crucial step in managing climate-related issues. In addition, the ITA detects hidden sub-trends in the low, medium and high components that the MK test does not, which shows the superiority of the ITA method over MK method.

Keywords: Hidden trend; ITA; Mann-Kendall; North-West Algeria; Rainfall.

1 INTRODUCTION

Climate change is a reality that has effects all over the world. Different climatologists have reported that climate change can cause variation in temperature and precipitations [1]. The climate change impacts have already been noticed with different intensities around the world [2,3] concerning atmosphere temperature [4,5], rainfall regimes [6,7], water availability, and the intensification of climate extremes [8,9]. Algeria is one of the semi-arid countries and is affected to a higher degree by phenomena of climate change.

Rainfall is one of the variables commonly used to characterize climate variability. The rainfall time series studies help to highlight the trend of the climatic parameters and the fluctuations in rainfall, which are essential to explain the climate change phenomenon in the world [10,11].

In Algeria, numerous studies were carried out over a period of seven decades (1936–2009) with detection of a decrease in rainfall since the 1970s, and especially, the decade (1980–1990) [12]. The regions with observable trends are located mainly in the North-West of Algeria: The Macta watershed [7,13] and Tafna [14,15].

In the Northwest Algeria region mean variability in total and extreme rainfall since the 1970s [6–9,16] was identified which was also the case of groundwater quality [17].

Over the past decades, many methods were developed [18] and used to assess the trend possibilities in precipitation records [19,20] to highlight the temporal and spatial evolution of the rainfall regime.

The MK method is a non-parametric test [21] and is widely applied to quantify the significance of trend [22,23]. [24] proposed a new technique called Innovative Trend Analysis (ITA), which is easy to use. In addition, it has the advantage of graphically evaluation of the possible trend components in the low, medium and high values [24,25]. [21] examined trends by the ITA and MK methods in the South Island of New Zealand. The results show that for some regions no trend is detected by the MK test, on the contrary trends are obtained through the application of the ITA. The latter provided details on trends in low, medium and high values of annual and seasonal precipitation data. In addition, [26] analyzed the trends of liquid flows in the Yangtze River of China by the MK and ITA tests during the period 1980 to 2015. They highlighted the advantage of the ITA, which detects sub-trends in the temporal flows series. In the same perspective, ITA detected 138 significant trends of which 89 time series did not show significant trends using the linear regression method and the MK test [27]. ITA is considered the best trend detection method, because it performs better compared to MK, Modified MK, and Trend Free Pre-whitening MK tests [28].

This present work aims to determine the monthly and seasonal trends in rainfall in the two watersheds, namely Côtier-Oranais and Macta, in the North-West of Algeria by using records of 41 years (1975–2015). The novelty of this study is the comparison between the MK test and the ITA method, which to our knowledge has not been studied in the region.

2 STUDY AREA AND DATA

The study area is located in the North-West of Algeria between latitudes 34.31°N and 36.01°N and longitudes –1.43° and 0.57°. This area has two watersheds Côtier-Oranais et Macta (Fig. 1).

The Macta watershed has a drainage area of 14,380 km^2. In the North, it is bounded by Beni-Chougranne, Tessala moutains and the Mohamadia plain. In the South, it is limited by the Saida mountains and those of Daya (1356 m) to the Southwest by the Tlemcen mountains [29,30]. This basin is drained by two main rivers Oued Mekerra and Oued El-Hammam. The Macta basin is characterized by a relatively cold and rainy winter and a hot and dry summer [31,17]. Annual precipitation decreases from North to South and varies on average from 500 mm to 300 mm [6,30]. Years with higher precipitation rates occur three to four times more often than the year specified as dry ones. [32].

The Côtier-Oran watershed covers an area of approximately 5,831 km^2, which is limited to the North by the Mediterranean Sea and to the South by the Macta basin. The topography is less rugged and represented mainly by the plain of Oran, where the altitude does not exceed 100 m. The average annual rainfall is between 300 and 400 mm. The spatial variability, from one year to another and from one station to another is quite moderate (from 10% to 36%) [29].

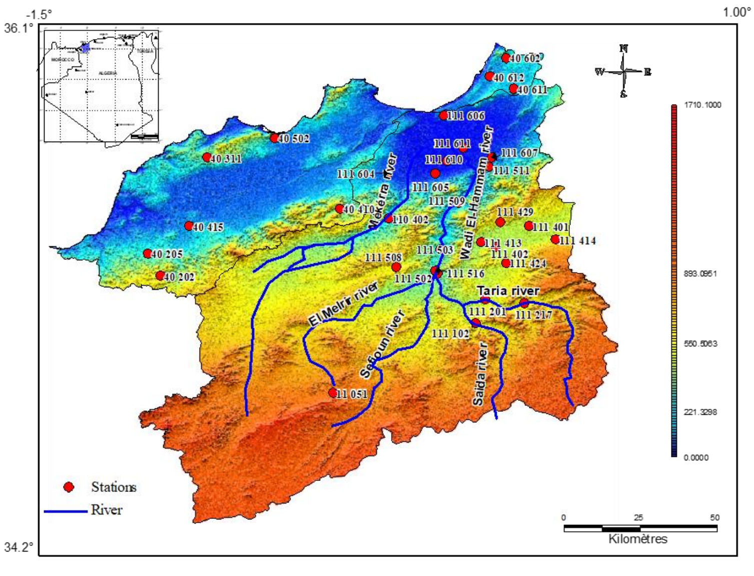

Figure 1. *Study area*

Monthly rainfall data are gained from the National Agency of Hydraulic Resources (NAHR) at 55 rainfall stations. Stations with more than 10% gaps are excluded [6,9]. The filling of the gaps is achieved by Hydrolab [33] using principal component analysis (PCA). Finally, 38 stations are selected for the period of 41 years (1975–2015) (Table 1).

Table 1. *Selected rainfall stations*

N°	Code	Station Name	Longitude	Latitude	Z
01	110203	EL HACAIBA	-0.7556	34.7020	950
02	110304	SARNO Bge	-0.5741	35.1804	425
03	110305	SIDI BEL ABBES	-0.6586	35.1915	485
04	110314	AIN TRID	-0.6757	35.2858	530
05	110402	CHEURFAS BGE	-0.2516	35.4044	230
06	110501	MERINE	-0.4518	34.7813	970
07	111102	MEFTAH SIDI BOUBEKEUR	0.0560	35.0310	530
08	111112	HAMMAM RABI	0.1863	34.9319	710
09	111204	AIN TIFRIT	0.4019	34.9178	970
10	111401	MAOUSSA	0.2482	35.3783	494
11	111402	FROHA	0.1300	35.3032	467
12	111405	MATEMORE	0.2150	35.3298	482
13	111413	TIZI	0.0761	35.3201	453
14	111418	NESMOTH MF	0.3818	35.2516	930
15	111424	GHRIS	0.1665	35.2463	498
16	111429	MASCARA	0.1464	35.3929	600
17	111502	SAHOUET OUIZERT	-0.0795	35.2078	361
18	111503	BOU HANIFIA BGE	-0.0698	35.2920	306
19	111508	SFISSEF	-0.2260	35.2318	545
20	111509	HACINE	-0.0045	35.4599	145
21	111511	MOHAMMADIA GRHA	0.1042	35.5904	50
22	111516	TROIS RIVIERES	-0.0859	35.2185	315
23	111604	OGGAZ	-0.2554	35.5649	73
24	111605	BOU HENNI	-0.0865	35.5653	26
25	111606	FORNAKA	-0.0568	35.7744	78
26	111607	SAMOURIA	0.1153	35.6222	48
27	111611	FERME BLANCHE (S. ABDELMOUMEN)	0.0131	35.6574	20
28	111612	BLED TAOURIA	0.2307	35.8357	118
29	111616	MARAIS DE SIRAT	0.1764	35.7507	30
30	40202	AGHLAL	-1.0662	35.2018	488
31	40205	AIN TEMOUCHENT	-1.1106	35.2807	231
32	40301	BOUSFER	0.8095	35.7018	50
33	40311	BOUTLELISN	-0.8994	35.6238	100
34	40415	H. BOUHADJAR	-0.9644	35.3791	150
35	40502	ORANPEP	-0.6571	35.6940	104
36	40602	KHEIREDDINE	0.1674	35.9804	218
37	40611	DCULTIVEES	0.1964	35.8683	102
38	40612	MOSTAGANEM	0.1108	35.9125	105

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3 METHODOLOGY

The main idea of the trend analysis is to identify whether the observed data of a hydro-meteorological time series show a particular trend. Different parametric and non-parametric methods are used by several researchers to detect possible trends. Parametric methods are considered more effective, but they have many restrictive assumptions such as data normality. On the other hand, non-parametric methods are often used for their simplicity. Mann-Kendall (MK) test [18,34] and Innovative Trend Analysis (ITA) are among the non-parametric tests best appreciated by researchers [35–38].

3.1 Mann-Kendall (MK) trend detection test

The MK method is a statistical test for evaluating time series trend. It assesses whether X (observed values) over time tend to increase or decrease [39]. It is most commonly used to identify trends in hydrology, due to its insensitivity to outliers and freeness from the normality probability distribution function (PDF) condition [40] The rank-based MK test is used to determine whether the correlation between the study variable and time is significant or not. Let (x_1, ..., x_n) be a sample of independent values relating to a random variable X whose stationarity should be evaluated. [18] proposed a monotonic trend test, which is based on τ (tau), a rank correlation coefficient defined by [41]. The Kendall test tries to reject the null hypothesis (H_0: no monotonic trend) and accept the alternative hypothesis (H_1: presence of a monotonic trend).

The test begins by calculating the number of concordant pairs (P = number of (x, y) where y increases as x increases) and discordant (M = number of (x, y) where y decreases as x increases). Kendall's statistics (S) is the difference between P and M (Eq. 1 and 2).

$$S = \sum_{k=1}^{n-1} . \sum_{j=k+1}^{n} sgn\left(Y_j - Y_k\right) \tag{1}$$

where Y_j and Y_k are the sequential values of the data and n is the sample size.
The sgn denotes the sign function, which takes the values 1, 0 or -1 as shown below:

$$\mathrm{sgn}(\mathrm{Xj} - \mathrm{Xk}) \begin{Bmatrix} \mathrm{if}\left(\mathrm{Y_j} - \mathrm{Y_k}\right) < 0;\ then - 1 \\ \mathrm{if}\left(\mathrm{Y_j} - \mathrm{Y_k}\right) = 0;\ \mathrm{then} \quad 0 \\ \mathrm{if}\left(\mathrm{Y_j} - \mathrm{Y_k}\right) > 0;\ then \quad 1 \end{Bmatrix} \tag{2}$$

Note that we have C_n^2 possible comparisons (Eq. 3).

$$\mathrm{C_n^2} = \frac{\mathrm{n}\,!}{2\,!(\mathrm{n}-2)\,!} = \frac{\mathrm{n}(\mathrm{n}-1)}{2} \tag{3}$$

If all of the y's increase as the X's increase, the value of S will be equal to n (n-1)/ 2, and so the τ will be equal to +1. The opposite situation will give a τ equal to -1. The Kendall correlation coefficient (τ) is calculated using Equation 4:

$$\tau = \frac{S}{C_n^2} \tag{4}$$

To test the significance of τ, for $n \leq 10$, Kendall quantiles table offers critical values or critical probabilities. When n is greater than 10, an approximation of the test statistic to the normal distribution is possible. The standard error is calculated as:

$$S_\tau = \frac{1}{3}\sqrt{\frac{2n+5}{C_n^2}} \tag{5}$$

The τ normalization is done according to Equation 6:

$$Z = \frac{\tau}{S_\tau} = 3\tau\sqrt{\frac{C_n^2}{2n+5}} \quad \textit{(6)}$$

The null hypothesis rejected at the significance level α if | Z | >Z_c, where Z_c is the value of the standard normal distribution according to the type of test (one or two tailed test).

3.2 ITA method

The ITA concept was initially suggested by Şen [24] for the identification of partial trend components in low, medium and high values [42,43]. The basic principle is simple, just divide the data series into two equal parts and then draw a scatter plot where the ordered values of the first (second) part are on the x-axis (y-axis). A 1:1 (45°) line divides the plot area into two equal triangles. The upper (lower) triangle represents an upward (downward) trend (Fig. 2). The slope of the trend (S) is calculated as follows:

$$S = \frac{2(m1-m2)}{n} \quad \textit{(7)}$$

where n is the sample size, m1 and m2 are the means of the two parts.

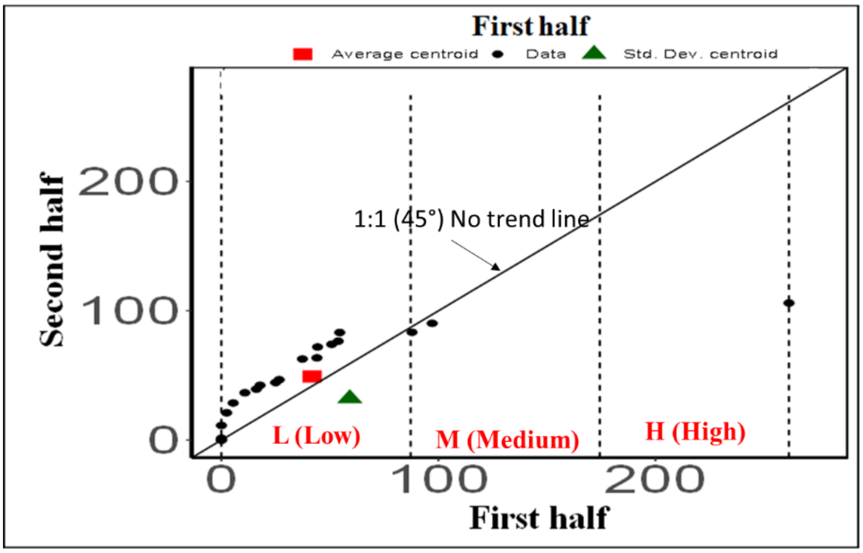

Figure 2. *Innovative Tendance Analyse (ITA) template*

4 RESULTS AND DISCUSSION

All calculations were performed within the R environment [44].

4.1 MK Test results

For MK method Z normal statistical value calculation is achieved for seasonal and monthly precipitation records. A two tailed test at 5% significance level is performed and all the Z superior (inferior) values have critical limit of 1.64 (-1.64), which are considered for increasing (decreasing) trends.

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4.1.1 Monthly trends

The MK test application on the monthly rainfall of the Côtier-Oranais and Macta watersheds (Table 2) shows that the majority (375 "82%") of the months indicate a dominance of a non-trend for most stations except November, where the station with an increasing trend (21 "55%") exceeds other frequencies. Similar results are mentioned by several authors [20].

Table 2. *Monthly trend frequencies (MK method)*

	Trend		
	+	**-**	**0**
January	9	0	29
February	2	1	35
March	0	4	34
April	1	2	35
May	0	3	35
June	1	5	32
July	1	6	31
August	5	2	31
September	14	0	24
October	3	0	35
November	21	0	17
December	1	0	37
Total	58	23	375

(+): Significant Increasing trend. (-): Significant Decreasing trend. (0): No Significant trend.

The pattern results are presented in Table 2, and they are transferrable into a histogram form (Fig. 3). This figure shows that the months of January, September and November have significant increasing trends, 9 (24%), 14 (37%) and 21 (55%), respectively.

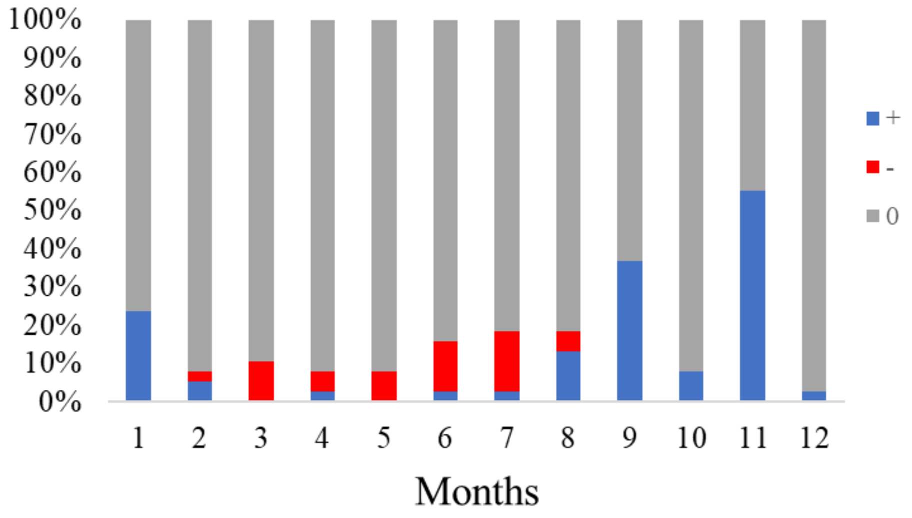

Figure 3. *Monthly frequency percent (MK method). Côtier-Oranais and Macta wtersheds; +: Significant increasing trend. -: Significant decreasing trend. 0: No trend*

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4.1.2 Seasonal trends

The aforementioned results are obtained for seasonal rainfall detection. A non-significant trend prevails over the majority (114 "75%") of the stations (Table 3).

Table 3. *Seasonal trend frequencies (MK method)*

	Trend		
	+	**-**	**0**
Winter	2	3	33
Spring	0	2	36
Summer	16	0	22
Autumn	15	0	23
Total	33	5	114

Figure 4 reflects summer and autumn season trends identifying relatively high increasing tendencies 42% and 39%, respectively.

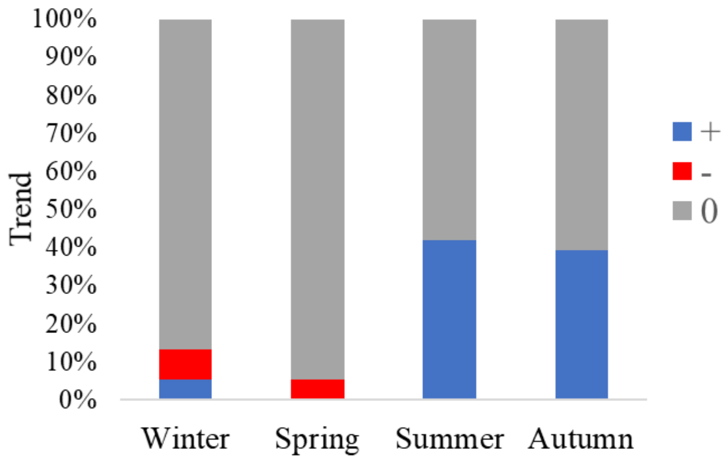

Figure 4. *Seasonal frequency percent (MK method).*
+: Significant increasing trend. -: Significant decreasing trend. 0: No trend

4.2 ITA test results

In order to compare the results between the MK test and the ITA method the same data and scales are used.

4.2.1 Monthly trends

The results of ITA method applications to assess monthly rainfall data are shown in the following figures, namely Figures A1 to A12 in the Appendix 1. Results are summarized by Table 4.

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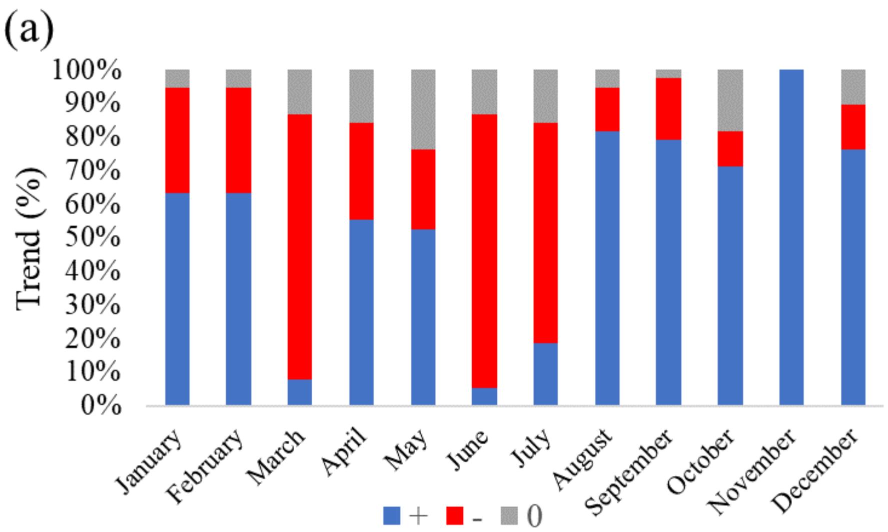
Table 4. *Monthly trend frequencies (ITA method)*

	Trend								
	Low			Medium			High		
	+	-	0	+	-	0	+	-	0
January	24	12	2	33	3	2	23	14	1
February	24	12	2	12	24	2	5	32	1
March	3	30	5	5	32	1	1	37	0
April	21	11	6	30	8	0	35	3	0
May	20	9	9	13	22	3	11	26	1
June	2	31	5	3	30	5	8	29	1
July	7	25	6	6	27	5	10	28	0
August	31	5	2	30	5	3	32	6	0
September	30	7	1	31	6	1	21	17	0
October	27	4	7	20	15	3	8	30	0
November	38	0	0	32	1	5	23	13	2
December	29	5	4	26	9	3	9	29	0
Total	256	151	49	241	182	33	186	264	6

Figure 5 presents the monthly trend percentages for the three components as low, medium and high. The increasing trend in the low rainfall component (Fig. 5a), prevails over the majority of months except March, June and July, which show decreasing tendencies in 30 "79%", 31 "82%" and 25 "66%" stations, respectively. The total of frequencies implies that the increasing (decreasing) trends are 256 "56%" (151 "33%") (see Table 4).

As for the medium component (Fig. 5b), an increase in the negative trend frequencies appears in the months of February (24 "63%"), March (32 "84%") and May (22 "58%"). One can note that the number of stations with an increasing (decreasing) trend shows decreased (increased) trends as 241 "53%" (182 "40%").

The high component in Fig. 5c, has reverse situation, where it is clear that the decreasing trend is reigning except for the months of January (37%), April (8%), August (16%) and November (34%). Thus, the frequency of decreasing trends shows considerable increasing tendency (264 "58%").



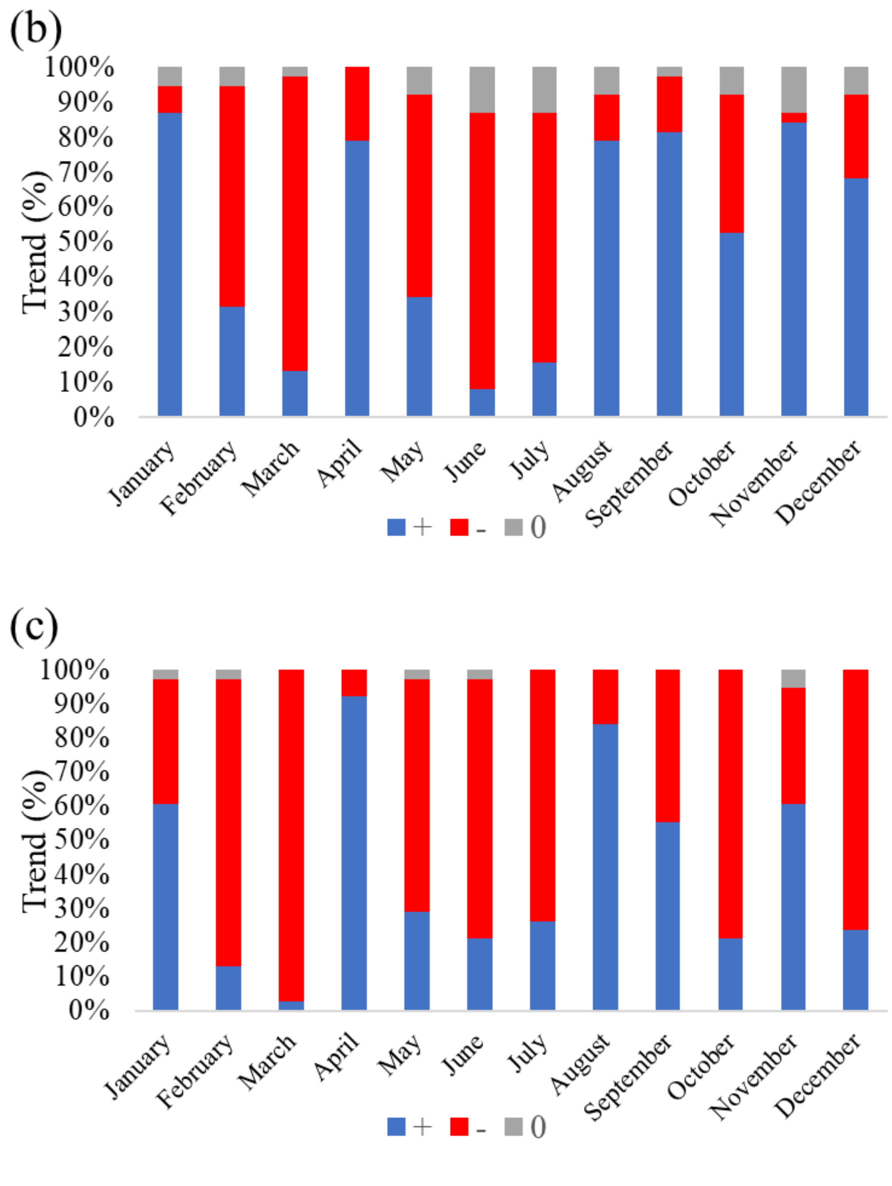


Figure 5. *Monthly frequency percents (ITA method). (a) Low. (b) Medium. (c) High*

The two methods' comparison as in Table 5 indicates that ITA has hidden increasing (decreasing) trends in the low (high) component, which show the ability of the ITA method to detect partial trends, which is not possible by the MK. The same findings are mentioned by [45] in India, [46] in Turkey, [47] in southern Italy, [37] in China and [27] in China. Furthermore, by using MK test, [48] determined inconsistency concerning rainfall trend definite patterns.

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***Table 5.** Monthly trend comparison by MK et ITA methods*

	MK			**ITA**								
				Low			**Medium**			**High**		
	+	**-**	**0**	**+**	**-**	**0**	**+**	**-**	**0**	**+**	**-**	**0**
January	24%	0%	76%	63%	32%	5%	87%	8%	5%	61%	37%	3%
February	5%	3%	92%	63%	32%	5%	32%	63%	5%	13%	84%	3%
March	0%	11%	89%	8%	79%	13%	13%	84%	3%	3%	97%	0%
April	3%	5%	92%	55%	29%	16%	79%	21%	0%	92%	8%	0%
May	0%	8%	92%	53%	24%	24%	34%	58%	8%	29%	68%	3%
June	3%	13%	84%	5%	82%	13%	8%	79%	13%	21%	76%	3%
July	3%	16%	82%	18%	66%	16%	16%	71%	13%	26%	74%	0%
August	13%	5%	82%	82%	13%	5%	79%	13%	8%	84%	16%	0%
September	37%	0%	63%	79%	18%	3%	82%	16%	3%	55%	45%	0%
October	8%	0%	92%	71%	11%	18%	53%	39%	8%	21%	79%	0%
November	55%	0%	45%	100%	0%	0%	84%	3%	13%	61%	34%	5%
December	3%	0%	97%	76%	13%	11%	68%	24%	8%	24%	76%	0%

The neutral trends detected by the MK method are partially split between positive and negative trends by the ITA method in Table 6. For January, the ITA uncovered 46% (25%) of the positive (negative) trends. Regarding other months, it is obvious that February shows 31% (57%), March 8% (76%), April 73% (14%), May 39% (42%), June 9% (66%), July 18% (54%), August 68% (9%), September 35% (26%), October 40% (43%), November 26% (12%) and December 54% (38%).

***Table 6.** Monthly demasked trends by ITA method*

	MK			**ITA**			**Demasked trends**	
	+	-	**0**	+	-	**0**	+	-
January	24%	0%	76%	70%	24%	6%	46%	25%
February	5%	3%	92%	37%	59%	4%	31%	57%
March	0%	11%	89%	5%	89%	5%	8%	76%
April	3%	5%	92%	61%	31%	9%	73%	14%
May	0%	8%	92%	31%	55%	14%	39%	42%
June	3%	13%	84%	8%	83%	9%	9%	66%
July	3%	16%	82%	18%	80%	3%	18%	54%
August	13%	5%	82%	78%	15%	7%	68%	9%
September	37%	0%	63%	69%	27%	4%	35%	26%
October	8%	0%	92%	41%	43%	16%	40%	43%
November	55%	0%	45%	80%	13%	7%	26%	12%
December	3%	0%	97%	54%	39%	6%	54%	38%

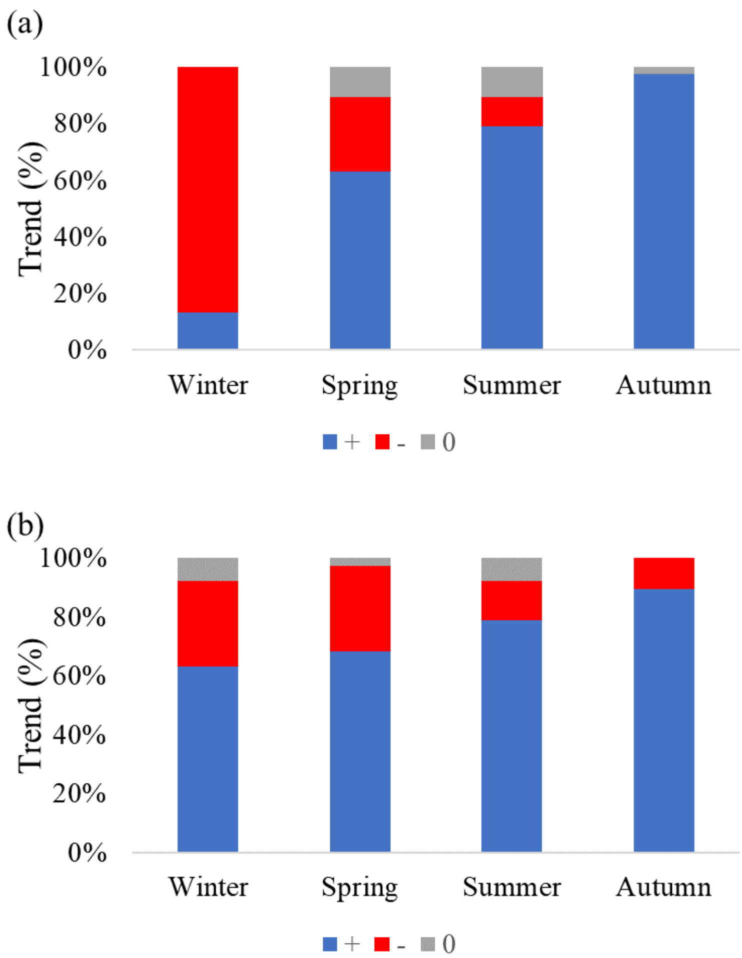
4.2.2 Seasonal trends

Figures A13 to A16 in the Appendix 1 show the ITA application results on the monthly rainfall for 38 stations. Table 7 represents the seasonal trend frequencies for the low, medium and high components.

Table 7. *Seasonal trend frequencies (ITA method)*

	Trend								
	Low			Medium			High		
	+	-	0	+	-	0	+	-	0
Winter	5	33	0	24	11	3	8	28	2
Spring	24	10	4	26	11	1	19	18	1
Summer	30	4	4	30	5	3	23	13	2
Autumn	37	0	1	34	4	0	18	19	1
Total	96	47	9	114	31	7	68	78	6

Reflecting Table 7 values, Figure 6 shows seasonal trend percentages for the aforementioned three components. For the low component (Fig. 6a), the increasing trend dominates the seasons of autumn (37 "97%"), summer (30 "79%") and spring (24 "63%"). On the other hand, in winter the rainy season is marked by a decrease (33 "87%"). From a global point of view, the increasing trends of this component are dominant with a frequency of 96 (63%) followed by the decreasing trend (47 "31%"). In the medium component (Fig. 6b), the winter season (24 "63%") joins the other seasons with a dominance of a positive trend with a total frequency of 114 (75%). The shift from the medium component to the high component is accompanied by a slight reversal tendency towards the decreasing trend of the seasons of autumn (50%), spring (47%) and summer (34%). This reversals more productive information for the winter (28 "74%"), cumulating a total of 78 (51%). On the other hand, the MK test, for the same season, detected only 3 stations (8%). The same is observed for the other seasons, where the MK test failed to detect any trends.



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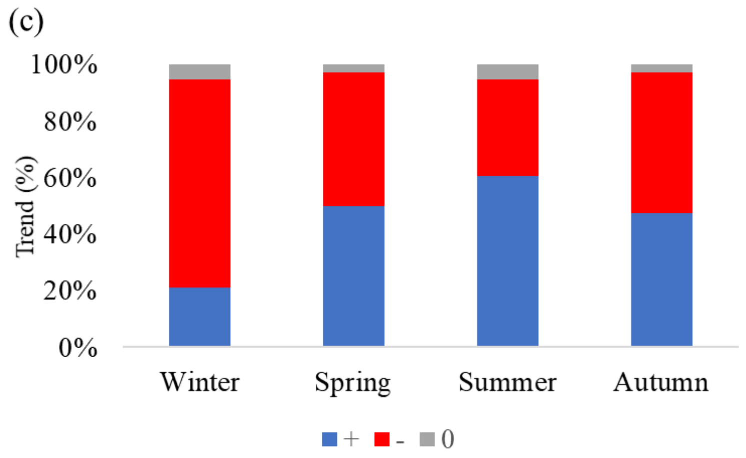

Figure 6. *Seasonal frequency percents (ITA method). (a) Low. (b) Medium. (c) High*

The comparison of the results by the two methods (Table 8) makes obvious that several trends are not detected by the MK test, while they are identifiable by the ITA. Dividing the rainfall into three components revealed increasing trends in the low and medium categories and decreasing tendency in the high component. [38] used three methods (MK, Linear Regression and ITA) to study seasonal rainfall trends in Shaanxi Province, China. They mentioned that the ITA provides many benefits, such as graphical visualization and sub-trends observations. The study of spatial and temporal variations in precipitation in the Umiam and Umtru watersheds in Meghalaya, India by [49] used a series from 1901 to 2018 and on a seasonal timescale; the ITA is more sensitive to hidden variations than the MK test. The same remarks are mentioned by [28].

Table 8. *Seasonal trend comparison by Mk et ITA methods*

	MK			ITA								
	Low	Medium	High	Low			Medium			High		
	+	-	0	+	-	0	+	-	0	+	-	0
Winter	5%	8%	87%	13%	87%	0%	63%	29%	8%	21%	74%	5%
Spring	0%	5%	95%	63%	26%	11%	68%	29%	3%	50%	47%	3%
Summer	42%	0%	58%	79%	11%	11%	79%	13%	8%	61%	34%	5%
Autumn	39%	0%	61%	97%	0%	3%	89%	11%	0%	47%	50%	3%
Total	22%	3%	75%	63%	31%	6%	75%	20%	5%	45%	51%	4%

Table 9 shows hidden seasonal trends detected by ITA. For winter, the 87% of neutral trends are revealed by the ITA as 27% (55%) of positive (negative) trends. Thus, for spring 61% (29%), summer 31% (19%), and fall 39% (20%).

Table 9. *Seasonal demasked trends by ITA method*

	MK			ITA			Demasked trends	
	+	-	0	+	-	0	+	-
Winter	5%	8%	87%	32%	63%	4%	27%	55%
Spring	0%	5%	95%	61%	34%	5%	61%	29%
Summer	42%	0%	58%	73%	19%	8%	31%	19%
Autumn	39%	0%	61%	78%	20%	2%	39%	20%

The study of monthly and seasonal precipitation series indicates that the ITA method is preferable to the MK method, because it is able to detect hidden sub-trends in the time series. The same findings are confirmed by [28] who stated that ITA is the best trend detection method, because ITA performs better compared to MK, Modified MK, and Trend Free Pre-whitening MK tests in the Asir region of Saudi Arabia for the period 1970–2017.

Another advantage of the ITA is the ability to observe hidden sub-trends in the three components, namely, low, medium and high, through the graphical representation.

5 CONCLUSION

In this article, the MK and ITA methods are used to detect monthly and seasonal rainfall trends in the two basins Côtier-Oran and Macta, Northwest, Algeria.

The conclusions are as follows:

The application of the MK test on the monthly rainfall shows that 82% of the stations shows a dominance of a non-trend. In contrast, the ITA method detects increasing (decreasing) trends in 54% (34%) of stations in the low rainfall component, 51% (42%); in the medium component and 34% (64%) in the high rainfall component. The comparison between the two methods shows that the ITA revealed 46% (24%) of the positive (negative) trends for the month of January, 32% (56%) for February, 5% (79%) for March, 58% (25%) for April, 31% (47%) for May, 5% (70%) for June, 15% (64%) for July, 65% (10%) for August, 32% (27%) for September, 33% (43%) for October, 25% (13%) for November and 52% (39%) for December.

On a seasonal scale, the same scenario prevails for the MK test, where 75% of the stations do not show significant trends. On the other hand, the use of ITA approach shows that 60% (29%) of stations show an increasing (decreasing) trend. Therefore, 23% (57%) of positive (negative) trends are revealed for winter, 56% (28%) for spring, 30% (19%) for summer and 39% (18%) for autumn.

By these results, the ITA method is able to detect hidden trends that the MK test cannot do and it show the ability of the method to detect partial trends that the MK test is not able to provide for. In addition, trends of low, medium and high rainfall rates can be detected. Nevertheless, the interpretation of the results of the ITA results is only visual which may result in some inconsistences of interpretation. As such, a further improvement of this method is necessary. The results obtained provide for specification of the right adaptation strategies to confront extreme event occurrence.

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REFERENCES

[1] AMIN, A., W. NASIM, M. MUBEEN, D.H. KAZMI, L. ZHAOHUI, A. WAHID, S.R. SULTANA, J. GIBBS & S. FAHAD. Comparison of future and base precipitation anomalies by SimCLIM statistical projection through ensemble approach in Pakistan. *Atmospheric Research*. 2017, vol. 194, pp. 214–225. ISSN 0169-8095. DOI: 10.1016/j.atmosres.2017.05.002

[2] SOTO-MONTES-DE-OCA, G. & M. ALFIE-COHEN. Impact of climate change in Mexican peri-urban areas with risk of drought. *Journal of Arid Environments*. 2019, vol. 162, pp. 74–88. ISSN 0140-1963. DOI: 10.1016/j.jaridenv.2018.10.006

[3] LE, J.A., H.M. EL-ASKARY, M. ALLALI, E. SAYED, H. SWELIEM, T.C. PIECHOTA & D.C. STRUPPA. Characterizing el Niño-southern oscillation effects on the Blue Nile yield and the Nile River

basin precipitation using empirical mode decomposition. *Earth Systems and Environment*. 2020. vol. 4(4), pp. 699–711. ISSN 2509-9426. DOI: 10.1007/s41748-020-00192-4

[4] ALMAZROUI, M., F. SAEED, S. SAEED, M.N. ISLAM, M. ISMAIL, N.A. BROWNE KLUTSE & M.H. SIDDIQUI. Projected change in temperature and precipitation over Africa from CMIP6. *Earth Systems and Environment*. 2020, vol. 4(3), pp. 455–475. ISSN 2509-9426. DOI: 10.1007/s41748-020-00161-x

[5] CHOURGHAL, N., J.P. LHOMME, F. HUARD & A. AIDAOUI. Climate change in Algeria and its impact on durum wheat. *Regional Environmental Change*. 2016, vol. 16(6), pp. 1623–1634. ISSN 1436-3798. DOI: 10.1007/s10113-015-0889-8

[6] ELOUISSI, A., Z. ŞEN & M. HABI. Algerian rainfall innovative trend analysis and its implications to Macta watershed. *Arabian Journal of Geosciences*. 2016, vol. 9(4), pp. 1–12. ISSN 1866-7511. DOI: 10.1007/s12517-016-2325-x

[7] ELOUISSI, A., M. HABI, B. BENARICHA & S.A. BOUALEM. Climate change impact on rainfall spatio-temporal variability (Macta watershed case, Algeria). *Arabian Journal of Geosciences*. 2017, vol. 10(22), pp. 1–14. ISSN 1866-7511. DOI: 10.1007/s12517-017-3264-x

[8] BENZATER, B. *Evolution des précipitations dans le contexte des changements climatiques au Nord-Ouest Algérien*. Mascara, 2021. Doctoral thesis. Université Mustapha Stambouli – Mascara.

[9] BENZATER, B., A. ELOUISSI, B. BENARICHA & M. HABI. Spatio-temporal trends in daily maximum rainfall in northwestern Algeria (Macta watershed case, Algeria). *Arabian Journal of Geosciences*. 2019, vol. 12(11), pp. 1–18. ISSN 1866-7511. DOI: 10.1007/s12517-019-4488-8

[10] CHEN, J., F.P. BRISSETTE, X.J. ZHANG, H. CHEN, S. GUO & Y. ZHAO. Bias correcting climate model multi-member ensembles to assess climate change impacts on hydrology. *Climatic Change*. 2019, vol. 153(3), pp. 361–377. ISSN 0165-0009. DOI: 10.1007/s10584-019-02393-x

[11] CHARGUI, S., A. JABERI, C. CUDENNEC, F. LACHAAL, R. CALVEZ & M. SLIMANI. Statistical detection and no-detection of rainfall change trends and breaks in semiarid Tunisia—50+ years over the Merguellil agro-hydro-climatic reference basin. *Arabian Journal of Geosciences*. 2018, vol. 11(21), pp. 1–14. ISSN 1866-7511. DOI: 10.1007/s12517-018-4001-9

[12] BALAH, B. & H. AMARCHI. Variabilité des séries pluviométriques du bassin versant de la Seybous du Nord Est-Algérien [Variability of rainfall series of Seybouse watershed of North-East of Algeria]. *Synthèse: Revue des Sciences et de la Technologie*. 2016, vol. 32, pp. 86–97. ISSN 1111-4924. Available at: https://dpubma.univ-annaba.dz/?p=5693

[13] BENZATER, B., A. ELOUISSI, S. FELLAH & A. HACHEMAOUI. Spatio-temporal analysis of trends in annual maximum rainfall in the North-West of Algeria: Comparative analysis of recent and old non-parametric methods. *Water and Environment Journal*. 2023, pp. 1–18. ISSN 1747-6593. DOI: 10.1111/wej.12905

[14] BOUKLIKHA, A., M. HABI, A. ELOUISSI & S. HAMOUDI. Annual, seasonal and monthly rainfall trend analysis in the Tafna watershed, Algeria. *Applied Water Science*. 2021, vol. 11(4), pp. 1–21. ISSN 2190-5487. DOI: 10.1007/s13201-021-01404-6

[15] BOUKLIKHA, A., M. HABI, A. ELOUISSI, B. BENZATER & S. HAMOUDI. The innovative trend analysis applied to annual and seasonal rainfall in the Tafna Watershed (Algeria). *Revista Brasileira de Meteorologia*. 2020, vol. 35(4), pp. 631–647. ISSN 0102-7786. DOI: 10.1590/0102-77863540068

[16] HADDAD, A. & B. REMINI. Extreme rainfall-runoff events modeling by HEC-HMS model for Koudiet Rosfa watershed, Algeria. *GeoScience Engineering*. 2021, vol. 67(4), pp. 144–155. ISSN 1802-5420. DOI: 10.35180/gse-2021-0060

[17] HAMLAT, A. & A. GUIDOUM. Assessment of groundwater quality in a semiarid region of Northwestern Algeria using water quality index (WQI). *Applied Water Science*. 2018, vol. 8(8), pp. 1–13. ISSN 2190-5487. DOI: 10.1007/s13201-018-0863-y

[18] MANN, H.B. Nonparametric test against trend. *Econometrica*. 1945, vol. 13(3), pp. 245–259. DOI: 10.2307/1907187

[19] BELALA, F., A. HIRCHE, S.D. MULLER, M. TOURKI, M. SALAMANI, M. GRANDI, T.A. HAMOUDA & M BOUGHANI. Rainfall patterns of Algerian steppes and the impacts on natural vegetation in the 20th century. *Journal of Arid Land*. 2018, vol. 10(4), pp. 561–573. ISSN 1674-6767. DOI: 10.1007/s40333-018-0095-x

[20] YAGHMAEI, H., S.H. SADEGHI, H. MORADI & M. GHOLAMALIFARD. Effect of Dam operation on monthly and annual trends of flow discharge in the Qom Rood Watershed, Iran. *Journal of Hydrology*. 2018, vol. 557, pp. 254–264. ISSN 0022-1694. DOI: 10.1016/j.jhydrol.2017.12.039

[21] CALOIERO, T., R. COSCARELLI & E. FERRARI. Application of the innovative trend analysis method for the trend analysis of rainfall anomalies in southern Italy. *Water Resources Management*. 2018, vol. 32(15), pp. 4971–4983. ISSN 0920-4741. DOI: /10.1007/s11269-018-2117-z

[22] SAYEMUZZAMAN, M. & M.K. JHA. Seasonal and annual precipitation time series trend analysis in North Carolina, United States. *Atmospheric Research*. 2014, vol. 137, pp. 183–194. ISSN 0169-8095. DOI: 10.1016/j.atmosres.2013.10.012

[23] ABRO, M.I., E. ELAHI, R. CHAND, D. ZHU, J. MUHAMMAD, M.R. DAUDPOTO, A.M. SOOMRO & M.A. KHASKHELI. Estimation of a trend of meteorological and hydrological drought over Qinhuai River Basin. *Theoretical and Applied Climatology*. 2022, vol. 147(3), pp. 1065–1078. ISSN 0177-798X. DOI: 10.1007/s00704-021-03870-z

[24] ŞEN, Z. Innovative trend analysis methodology. *Journal of Hydrologic Engineering*. 2012, vol. 17(9), pp. 1042–1046. ISSN 1084-0699. DOI: 10.1061/(ASCE)HE.1943-5584.0000556

[25] SERINALDI, F., F. CHEBANA & C.G. KILSBY. Dissecting innovative trend analysis. *Stochastic Environmental Research and Risk Assessment*. 2020, vol. 34(5), pp. 733–754. ISSN 1436-3240. DOI: 10.1007/s00477-020-01797-x

[26] ALI, R., A. KURIQI, S. ABUBAKER & O. KISI. Long-term trends and seasonality detection of the observed flow in Yangtze River using Mann-Kendall and Sen's innovative trend method. *Water*. 2019, vol. 11(9), art. no. 1855. ISSN 2073-4441. DOI: 10.3390/w11091855

[27] ZHOU, Z., L. WANG, A. LIN, M. ZHANG & Z NIU. Innovative trend analysis of solar radiation in China during 1962–2015. *Renewable energy*. 2018, vol. 119, pp. 675–689. ISSN 0960-1481. DOI: 10.1016/j.renene.2017.12.052

[28] MALIK, A., A. KUMAR, P. GUHATHAKURTA & O. KISI. Spatial-temporal trend analysis of seasonal and annual rainfall (1966–2015) using innovative trend analysis method with significance test. *Arabian Journal of Geosciences.* 2019, vol. 12(10), pp. 1–23. ISSN 1866-7511. DOI: 10.1007/s12517-019-4454-5

[29] MEDDI, H., M. MEDDI & A. ASSANI. Study of drought in seven Algerian plains. *Arabian Journal for Science and Engineering*. 2014, vol. 39(1), pp. 339–359. ISSN 2193-567X. DOI: 10.1007/s13369-013-0827-3

[30] MEDDI, M., A. ASSANI & H. MEDDI. Temporal variability of annual rainfall in the Macta and Tafna catchments, Northwestern Algeria. *Water Resources Management*. 2010, vol. 24(14), pp. 3817–3833. ISSN 0920-4741. DOI: 10.1007/s11269-010-9635-7

[31] GLIZ, M. & B. REMINI. Bedload Estimation: Case of Wadi El-Hammam in the North-West of Algeria. *GeoScience Engineering*. 2022, vol. 68(2), pp. 213–220. ISSN 1802-5420. DOI: 10.35180/gse-2022-0083

[32] MEDDI, M. & A. TALIA. Runoff evolution in Macta basin (Northwest of Algeria). *Arabian Journal of Geosciences.* 2013, vol. 6(1), pp. 35–41. ISSN 1866-7511. DOI: 10.1007/s12517-011-0318-3

[33] LABORDE, J.P. & N. MOUHOUS. *Hydrolab* [software]. University of Nice Sophia Antipolis and National Centre for Scientific Research, 2010. Available at: https://hydrologie.org/MOD/Hydrolab/hydrolab.htm

[34] KENDALL, M.G. *Rank Correlation Methods*. 4th ed. London: Charles Griffin, 1975. ISBN 9780852641996.

[35] NORTON, P.A., D.G. DRISCOLL & J.M. CARTER. Climate, streamflow, and lake-level trends in the Great Lakes Basin of the United States and Canada, water years 1960–2015: Scientific Investigations Report 2019–5003. *US Geological Survey*. 2019. ISSN 2328-0328. DOI: 10.3133/sir20195003

[36] YILMAZ, B. Analysis of hydrological drought trends in the GAP region (southeastern Turkey) by Mann-Kendall test and innovative Şen method. *Applied Ecology and Environmental Research*. 2019, vol. 17(2), pp. 3325–3342. ISSN 1589-1623. DOI: 10.15666/aeer/1702_33253342

[37] LI, J., W. WU, X. YE, H. JIANG, R. GAN, H. WU, J. HE & Y. JIANG. Innovative trend analysis of main agriculture natural hazards in China during 1989–2014. *Natural Hazards*. 2019, vol. 95(3), pp. 677–720. ISSN 0921-030X. DOI: 10.1007/s11069-018-3514-6

[38] WU, H. & H. QIAN. Innovative trend analysis of annual and seasonal rainfall and extreme values in Shaanxi, China, since the1950s. *International Journal of Climatology.* 2017, vol. 37(5), pp. 2582–2592. ISSN 0899-8418. DOI: 10.1002/joc.4866

[39] OUATIKI, H., A. BOUDHAR, A. OUHINOU, A. ARIOUA, M. HSSAISOUNE, H. BOUAMRI & T. BENABDELOUAHAB. Trend analysis of rainfall and drought over the Oum Er-Rbia River Basin in Morocco during 1970–2010. *Arabian Journal of Geosciences*. 2019, vol. 12(4), pp. 1–11. ISSN 1866-7511. DOI: 10.1007/s12517-019-4300-9

[40] AHMAD, I., F. ZHANG, M. TAYYAB, M.N. ANJUM, M. ZAMAN, J. LIU, H.U. FARID & Q. SADDIQUE. Spatiotemporal analysis of precipitation variability in annual, seasonal and extreme values over upper Indus River basin. *Atmospheric Research.* 2018, vol. 213, pp. 346–360. ISSN 0169-8095. DOI: 10.1016/j.atmosres.2018.06.019

[41] KENDALL, M.G. A new measure of rank correlation. *Biometrika*. 1938, vol. 30(1–2), pp. 81–93. ISSN 1464-3510. DOI: 10.1093/biomet/30.1-2.81

[42] SAPLIOĞLU, K & Y.S. GÜÇLÜ. Combination of Wilcoxon test and scatter diagram for trend analysis of hydrological data. *Journal of Hydrology*. 2022, vol. 612, pp. 128–132. ISSN 0022-1694. DOI: 10.1016/j.jhydrol.2022.128132

[43] BENZATER, B., A. ELOUISSI, I. DABANLI, S. HARKAT & A. HAMIMED. New approach to detect trends in extreme rain categories by the ITA method in northwest Algeria. *Hydrological Sciences Journal*. 2021, vol. 66(16), pp. 2298–2311. ISSN 0262-6667. DOI: 10.1080/02626667.2021.1990931

[44] R CORE TEAM. *R Foundation* [software]. Vienna: 2020. Available at: http://www.r-project.org/index.html

[45] PZ, S. & J. KV. Comparative study of innovative trend analysis technique with Mann-Kendall tests for extreme rainfall. *Arabian Journal of Geosciences*. 2021, vol. 14(7), pp. 1–15. ISSN 1866-7511. DOI: 10.1007/s12517-021-06906-w

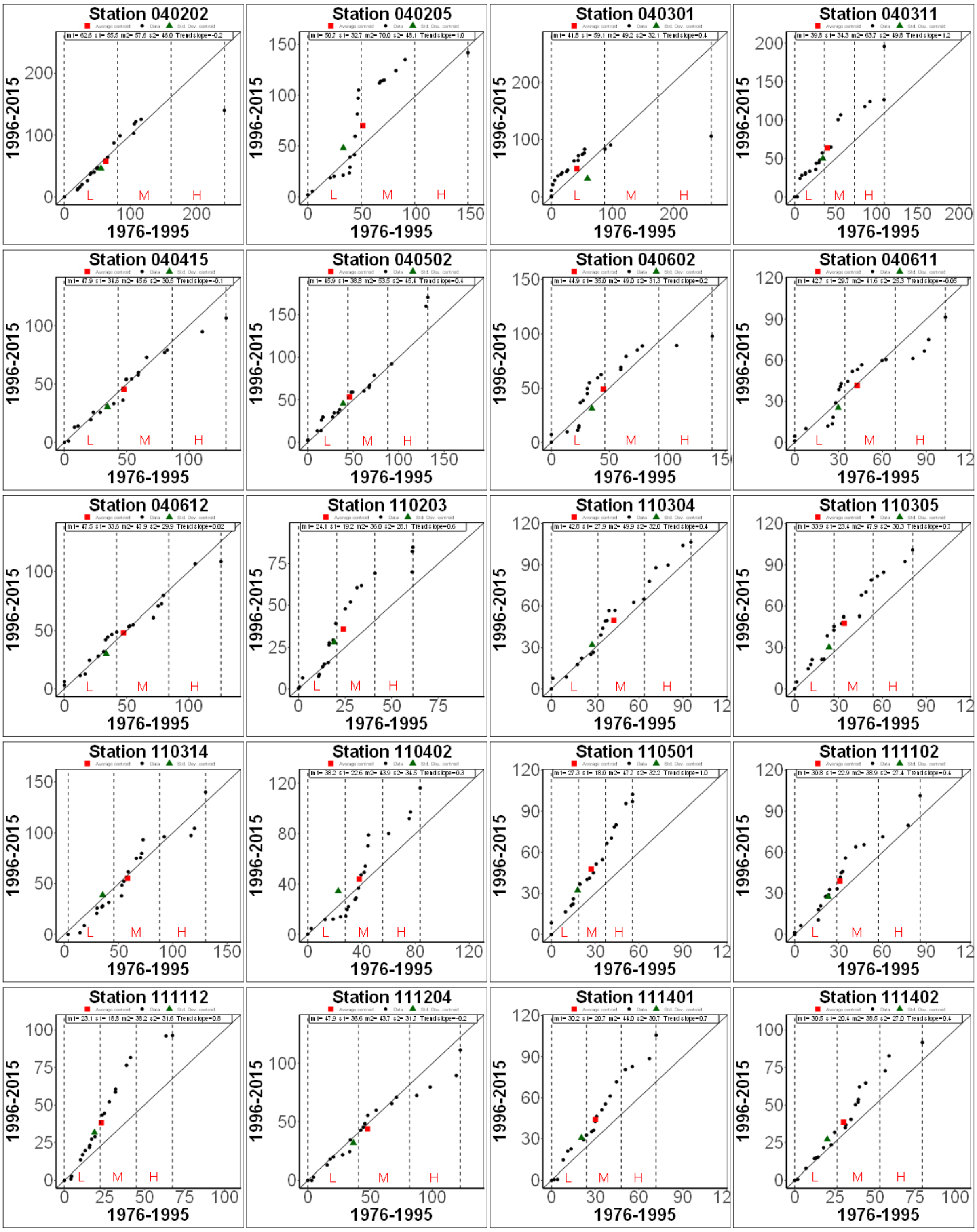
[46] GÜÇLÜ, Y.S. Comments on “Comparison of Mann–Kendall and innovative trend method for water quality parameters of the Kizilirmak River, Turkey (Kisi and Ay, 2014)” and “An innovative method for trend analysis of monthly pan evaporations (Kisi, 2015)”. *Journal of Hydrology*. 2016, vol. 538, pp. 878–882. ISSN 0022-1694. DOI: 10.1016/j.jhydrol.2016.04.064

[47] CALOIERO, T. Evaluation of rainfall trends in the South Island of New Zealand through the innovative trend analysis (ITA). *Theoretical and Applied Climatology*. 2020, vol. 139(1), pp. 493–504. ISSN 0177-798X. DOI: 10.1007/s00704-019-02988-5

[48] KHATTAK, M.S., M.S. BABEL & M. SHARIF. Hydro-meteorological trends in the upper Indus River basin in Pakistan. *Climate research*. 2011, vol. 46(2), pp. 103–119. ISSN 0936-577X. DOI: 10.3354/cr00957

[49] MARAK, J.D.K., A.K. SARMA & R.K. BHATTACHARJYA. Innovative trend analysis of spatial and temporal rainfall variations in Umiam and Umtru watersheds in Meghalaya, India. *Theoretical and Applied Climatology*. 2020, vol. 142(3), pp. 1397–1412. ISSN 0177-798X. DOI: 10.1007/s00704-020-03383-1

APPENDIX



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DOI 10.35180/gse-2023-0099

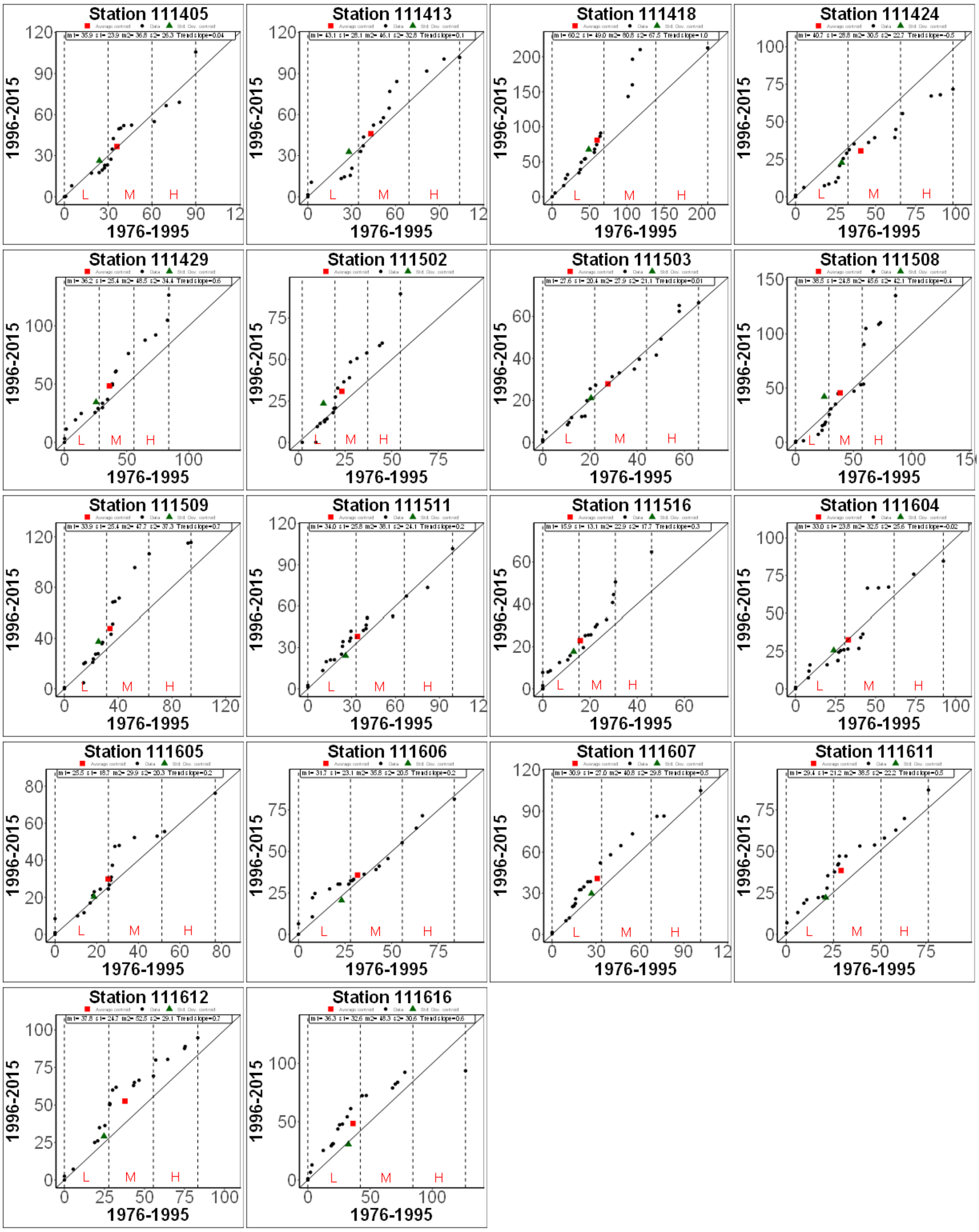
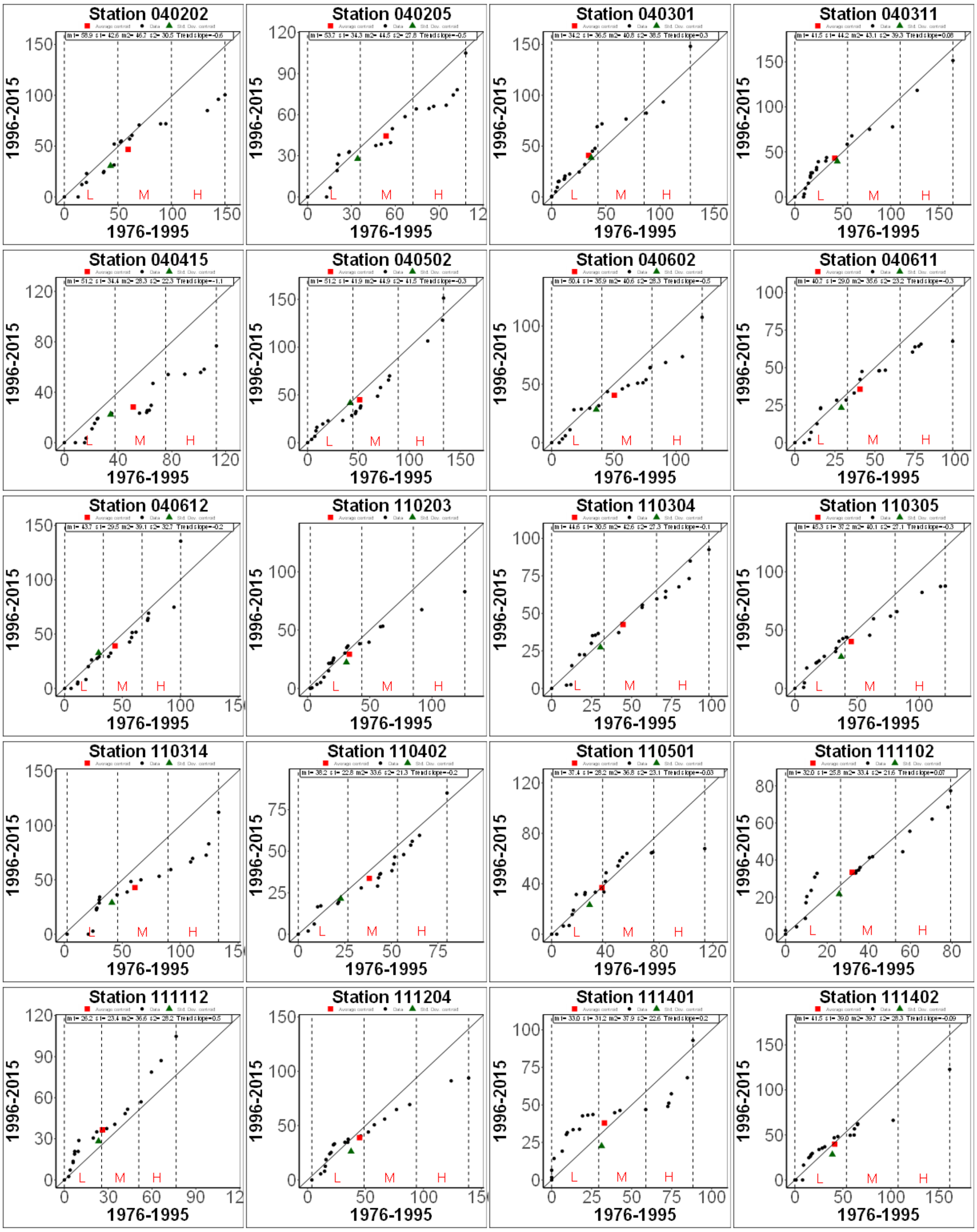


Figure A1. *January Innovative Trend Analysis (ITA) results*



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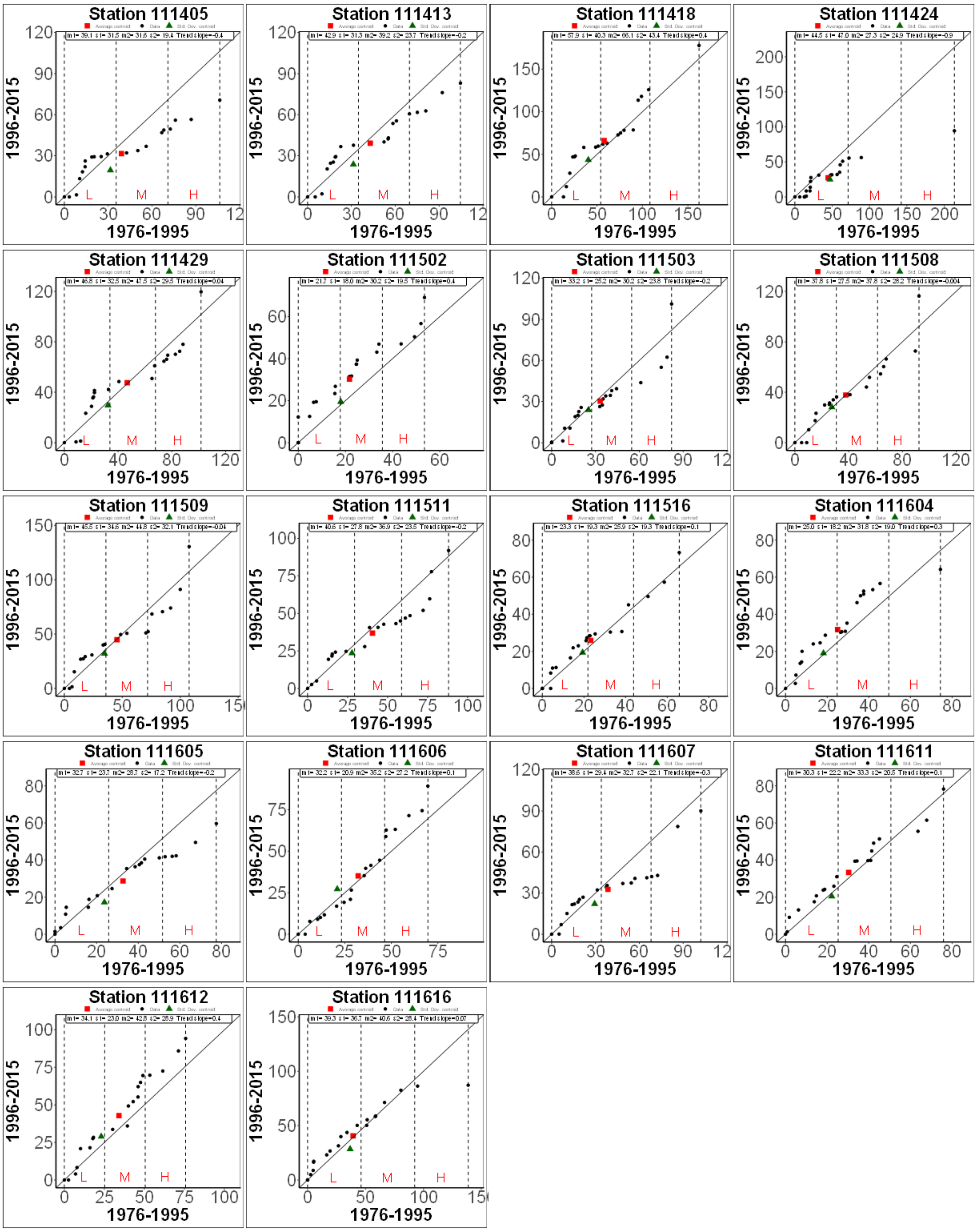

Figure A2. *February Innovative Trend Analysis (ITA) results*

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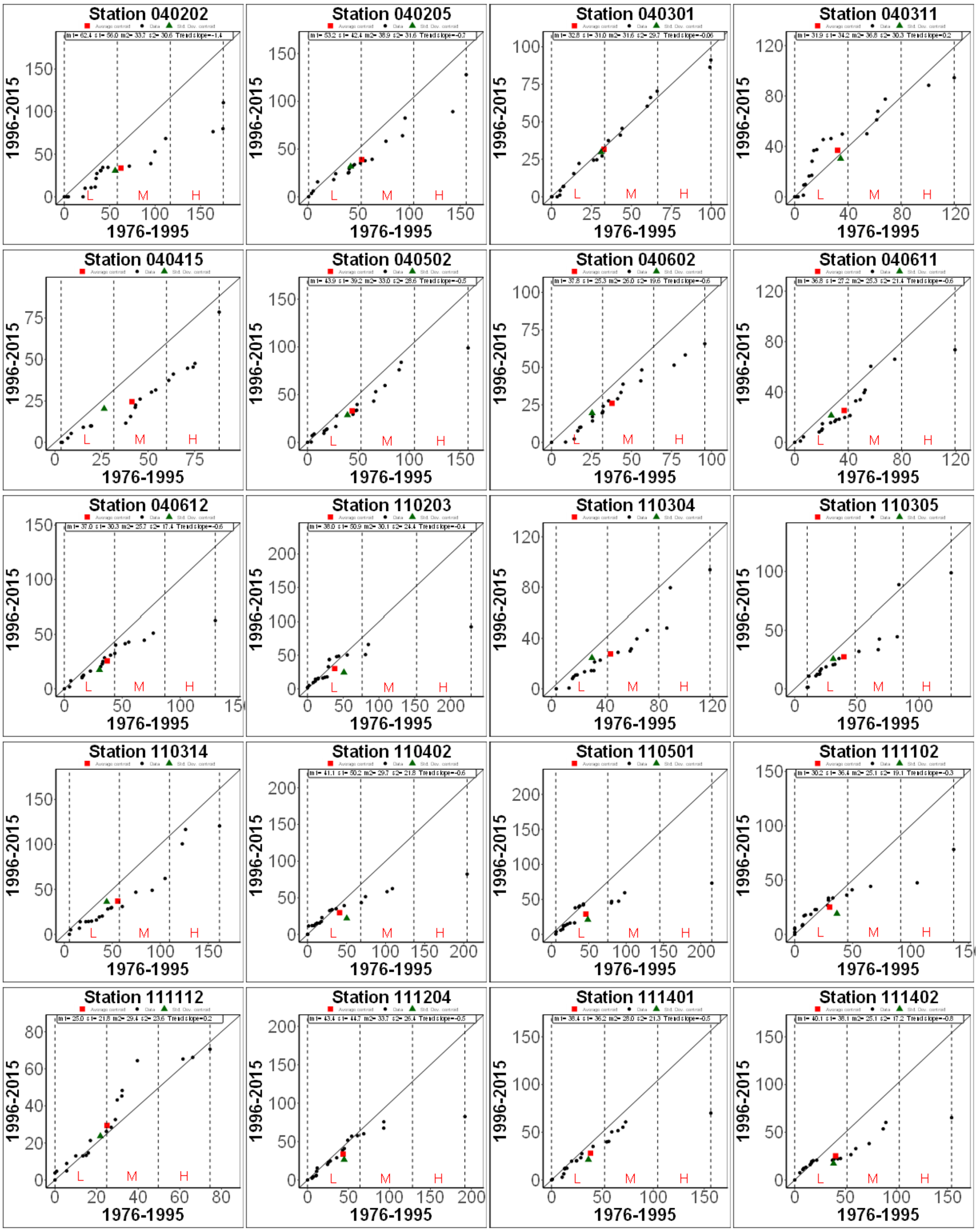

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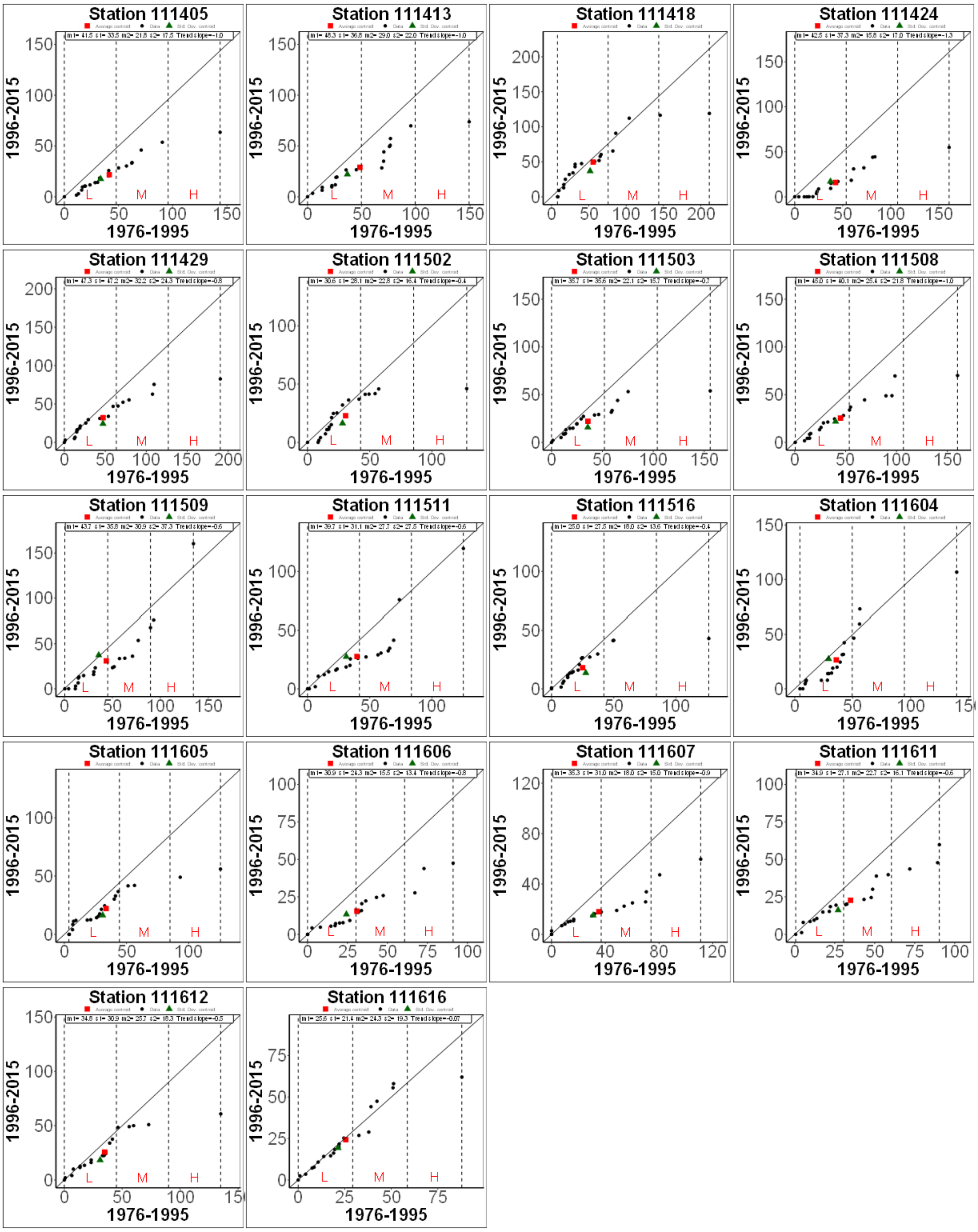

Figure A3. *March Innovative Trend Analysis (ITA) results*

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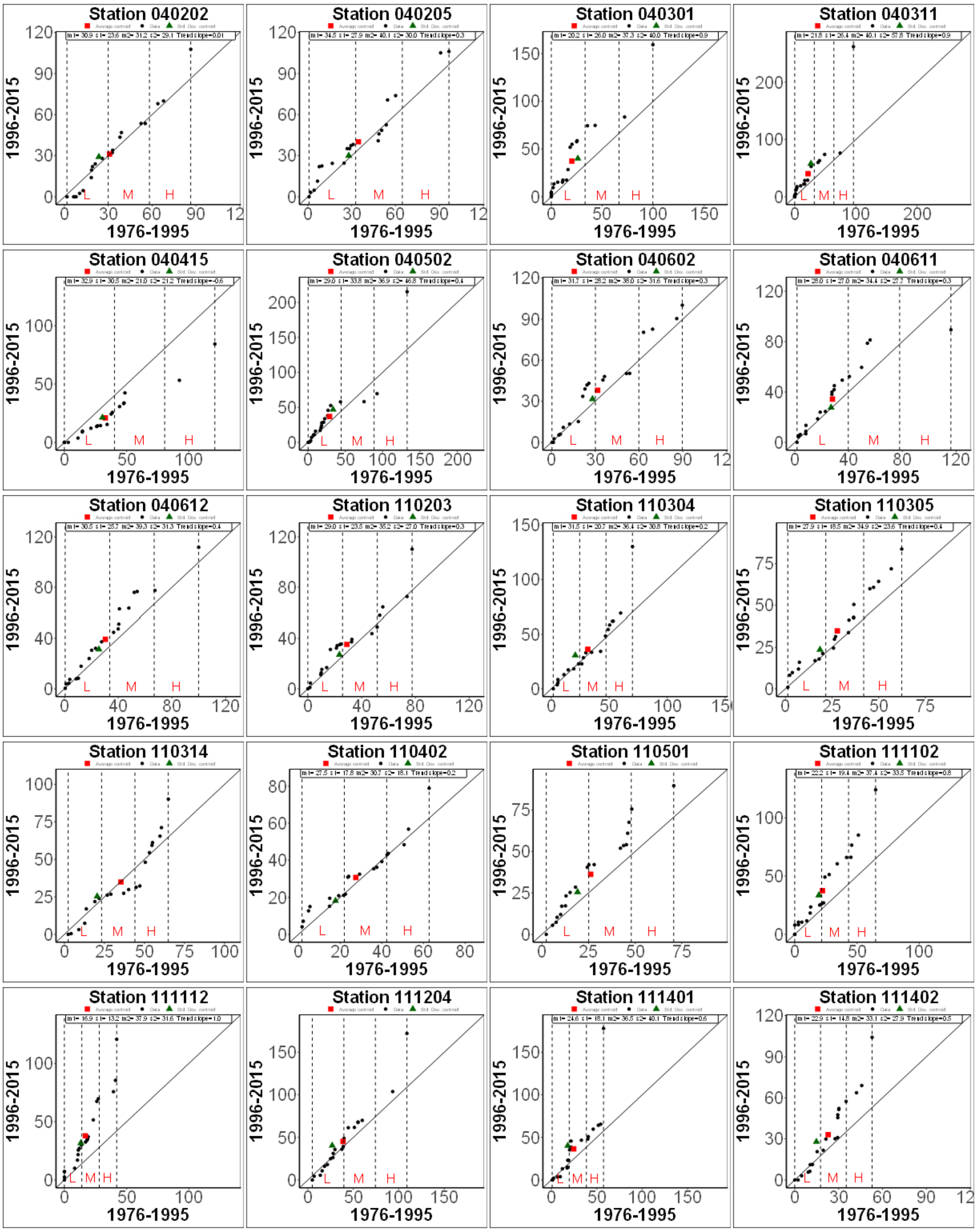

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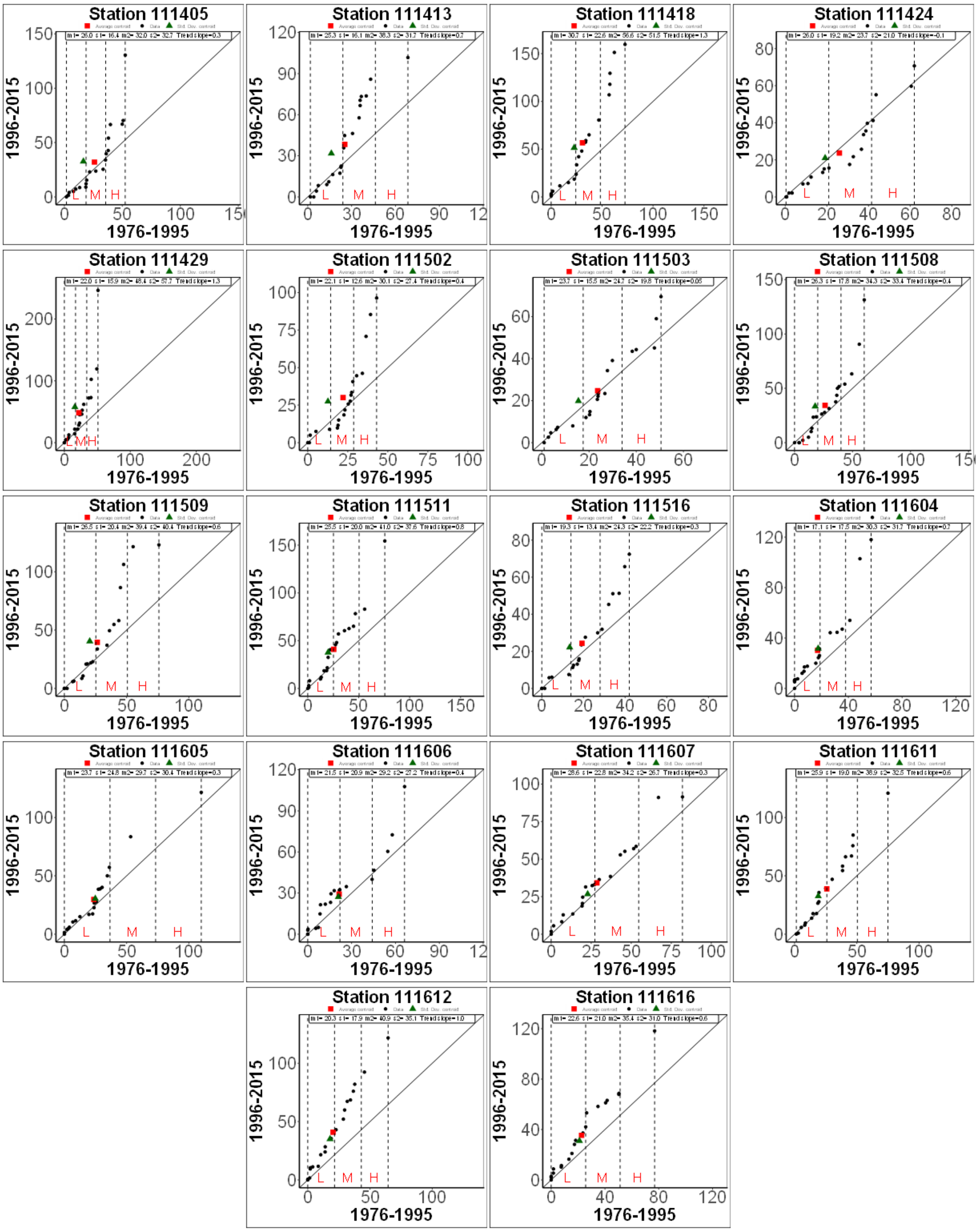

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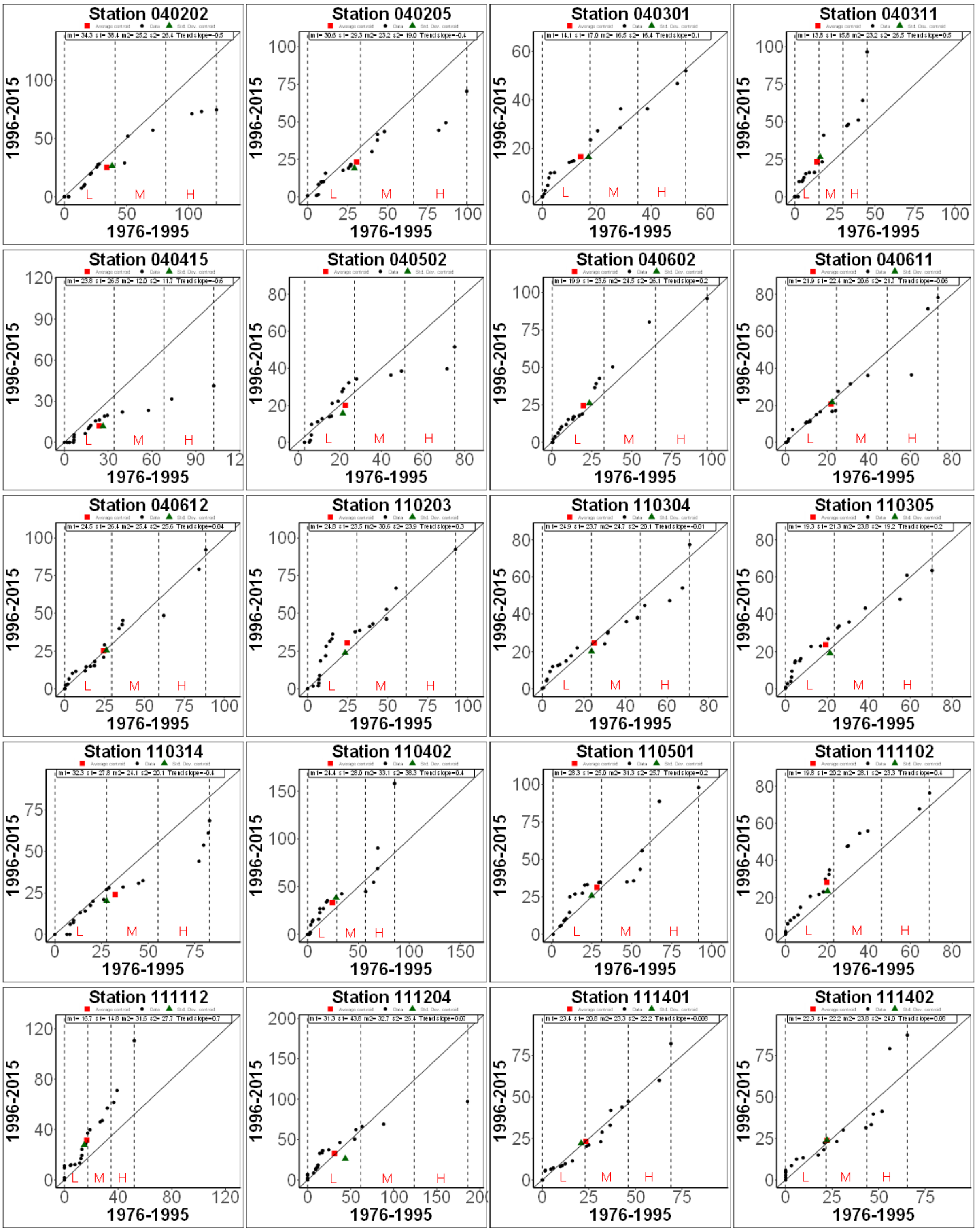

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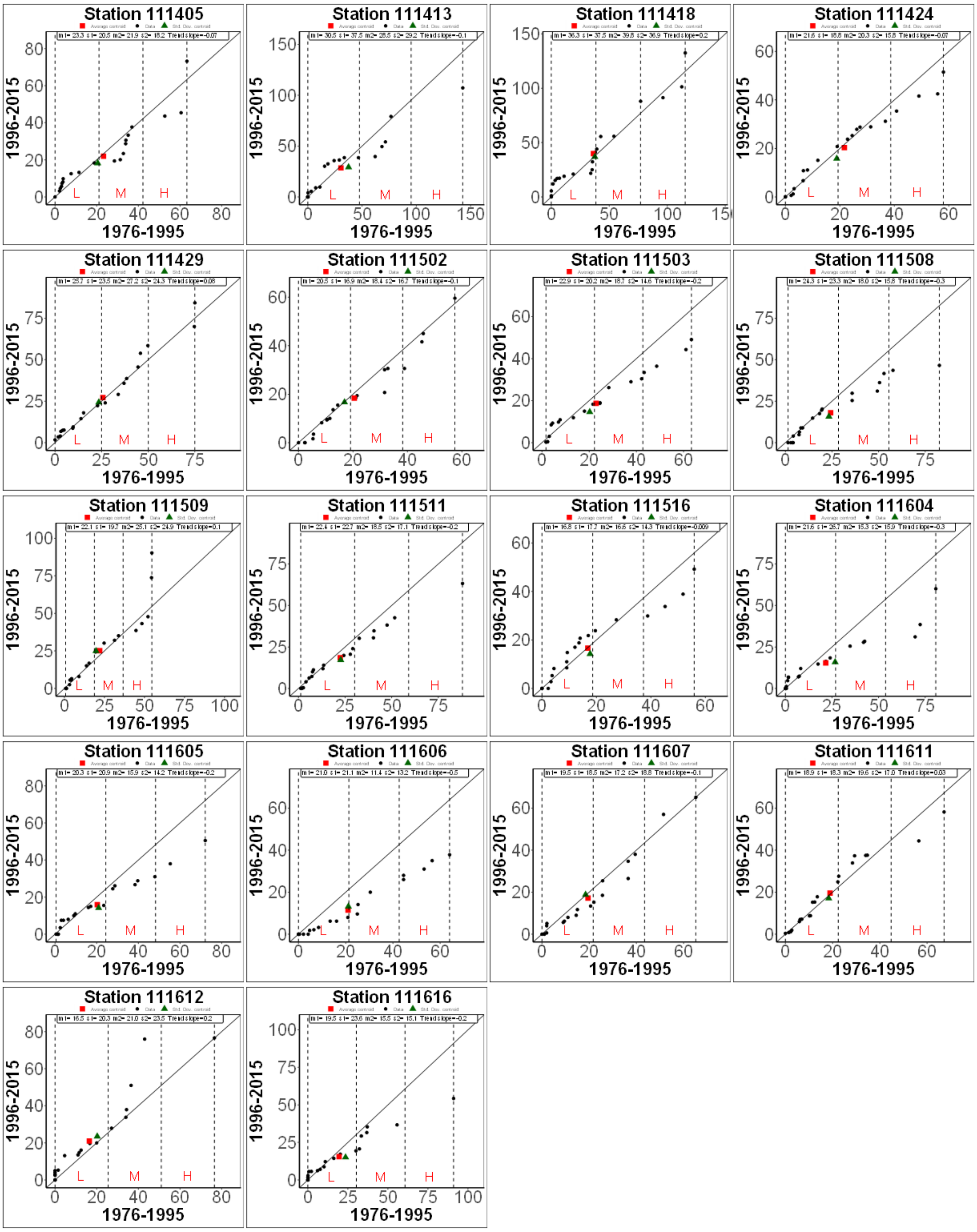

Figure A5. *May Innovative Trend Analysis (ITA) results*

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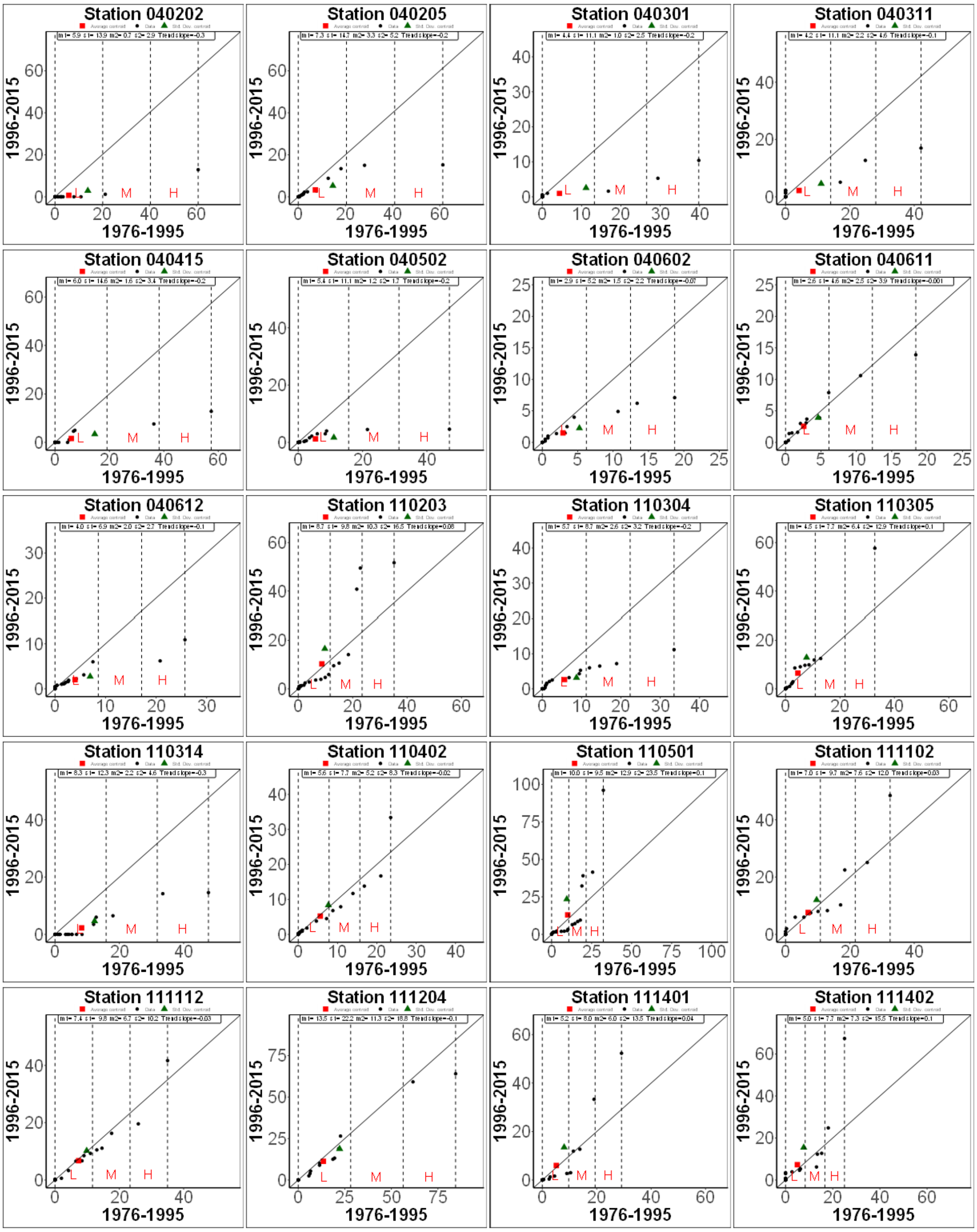
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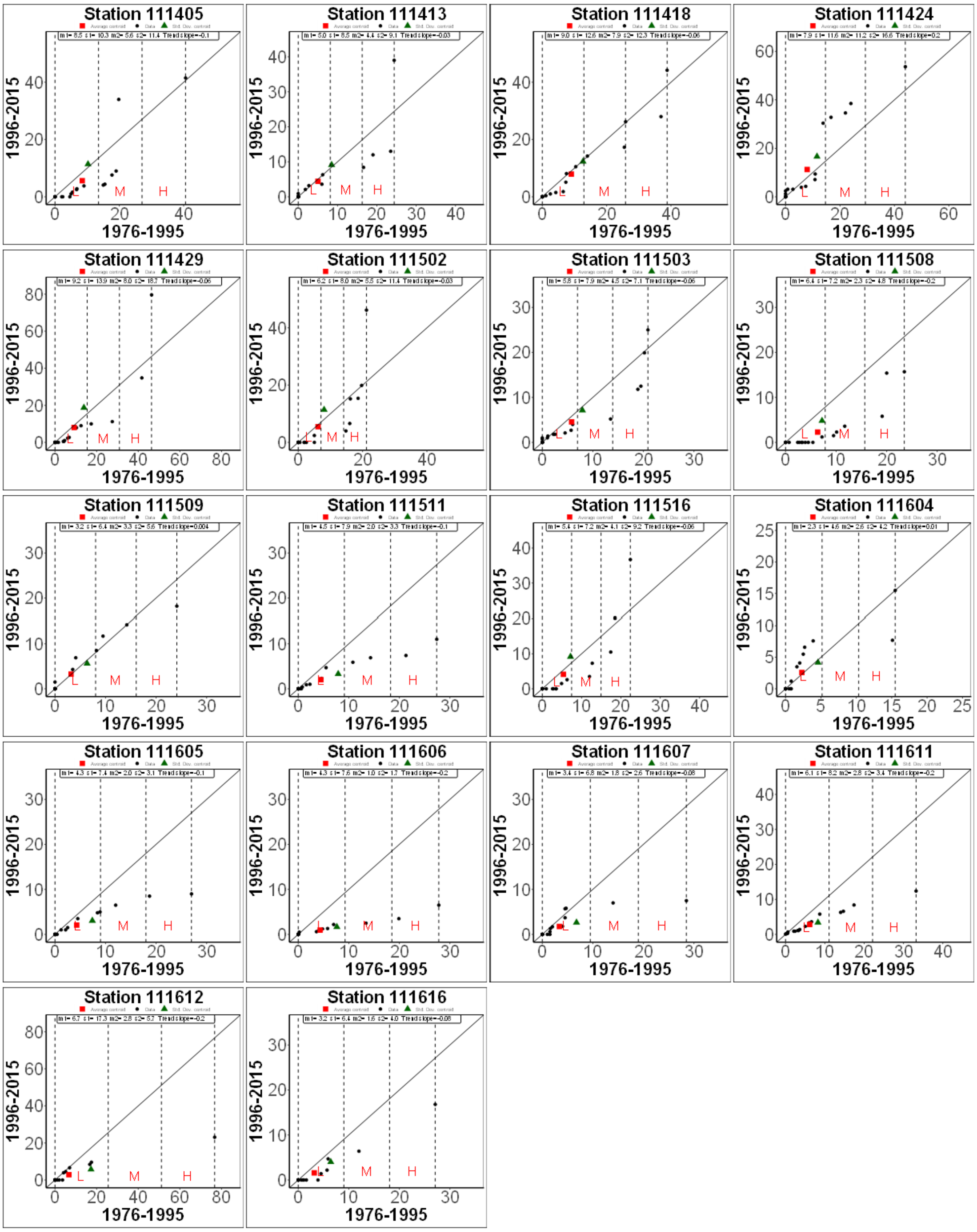

Figure A6. *June Innovative Trend Analysis (ITA) results*

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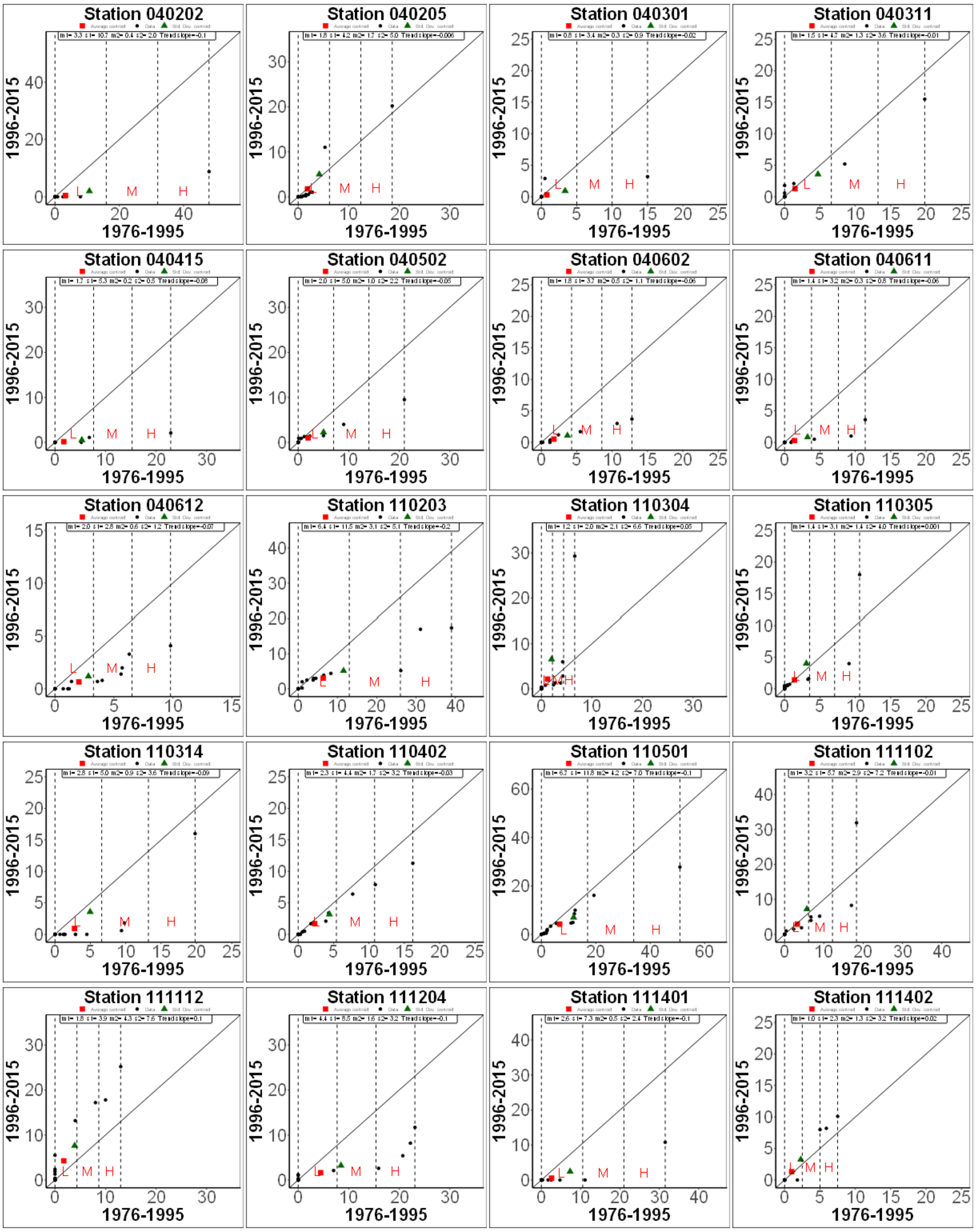
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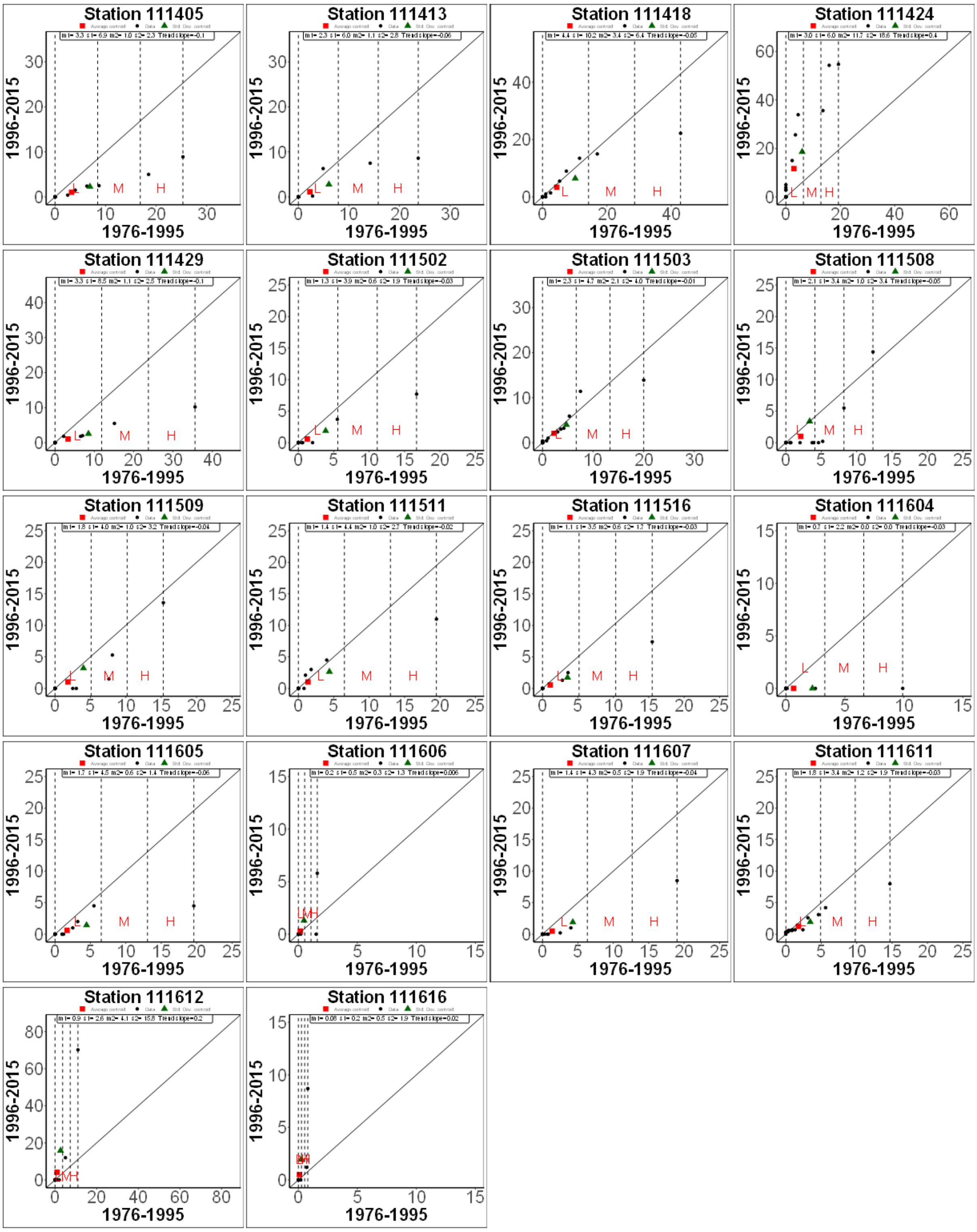

Figure A7. *July Innovative Trend Analysis (ITA) results*

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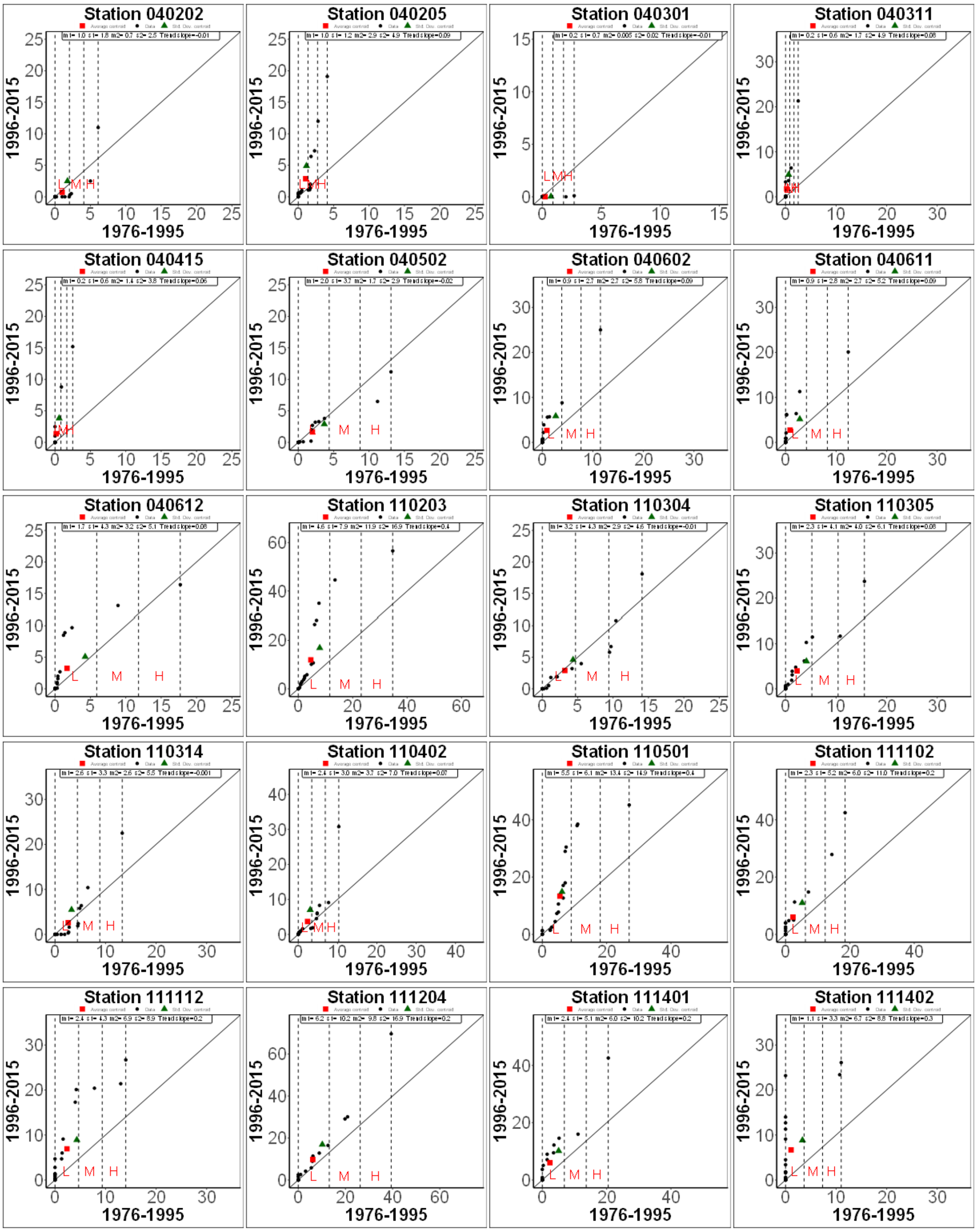
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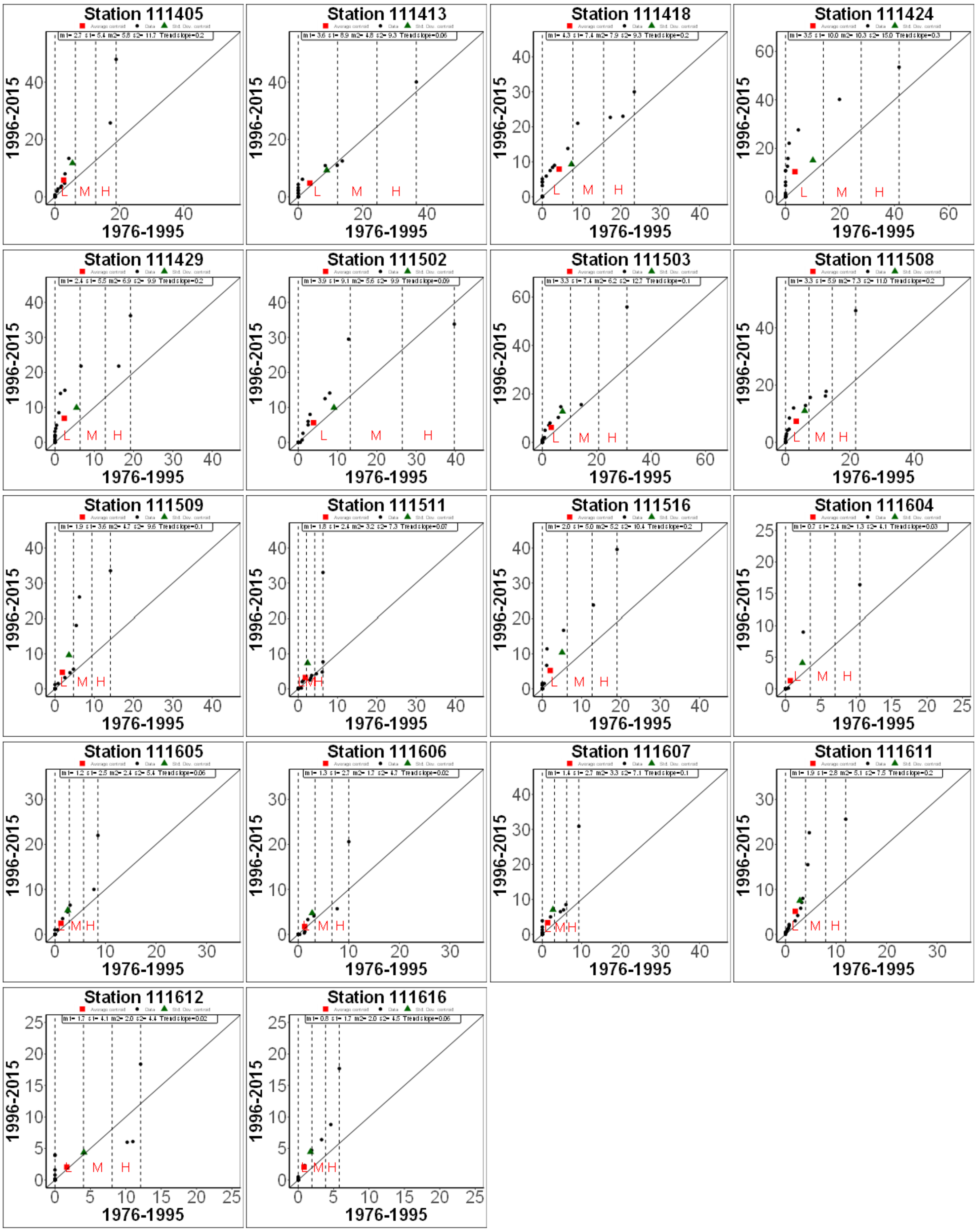
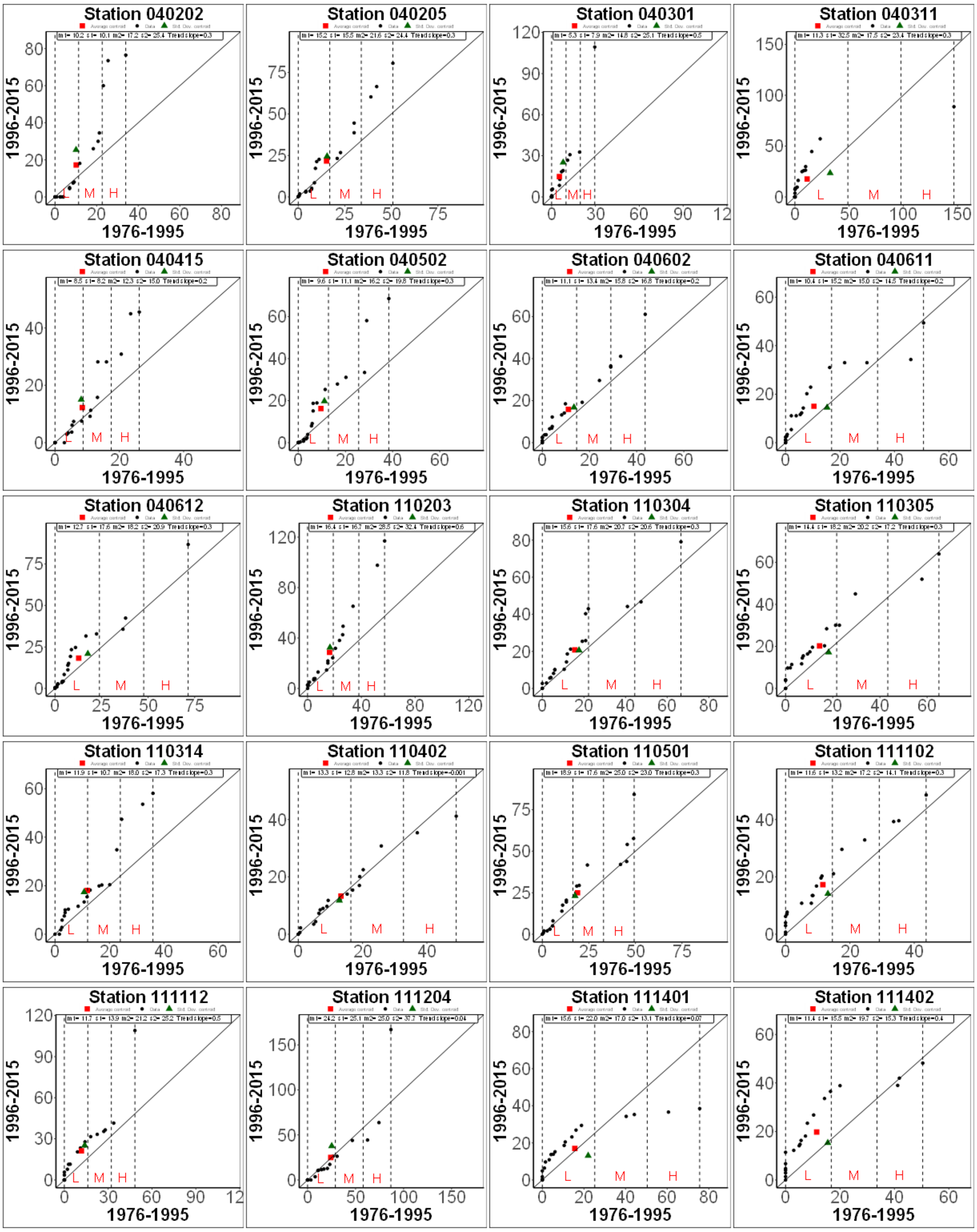


Figure A8. *August Innovative Trend Analysis (ITA) results*



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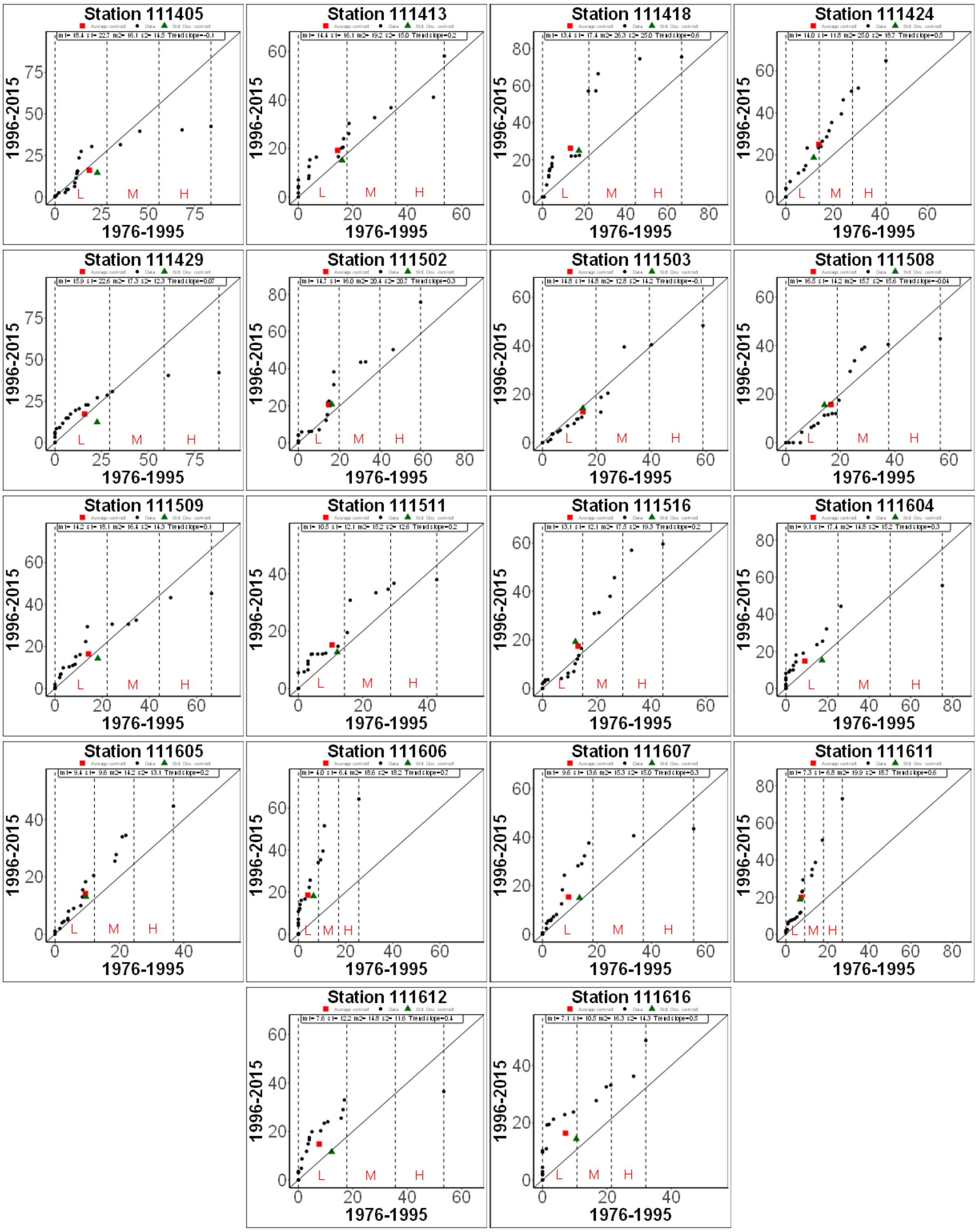

Figure A9. *September Innovative Trend Analysis (ITA) results*

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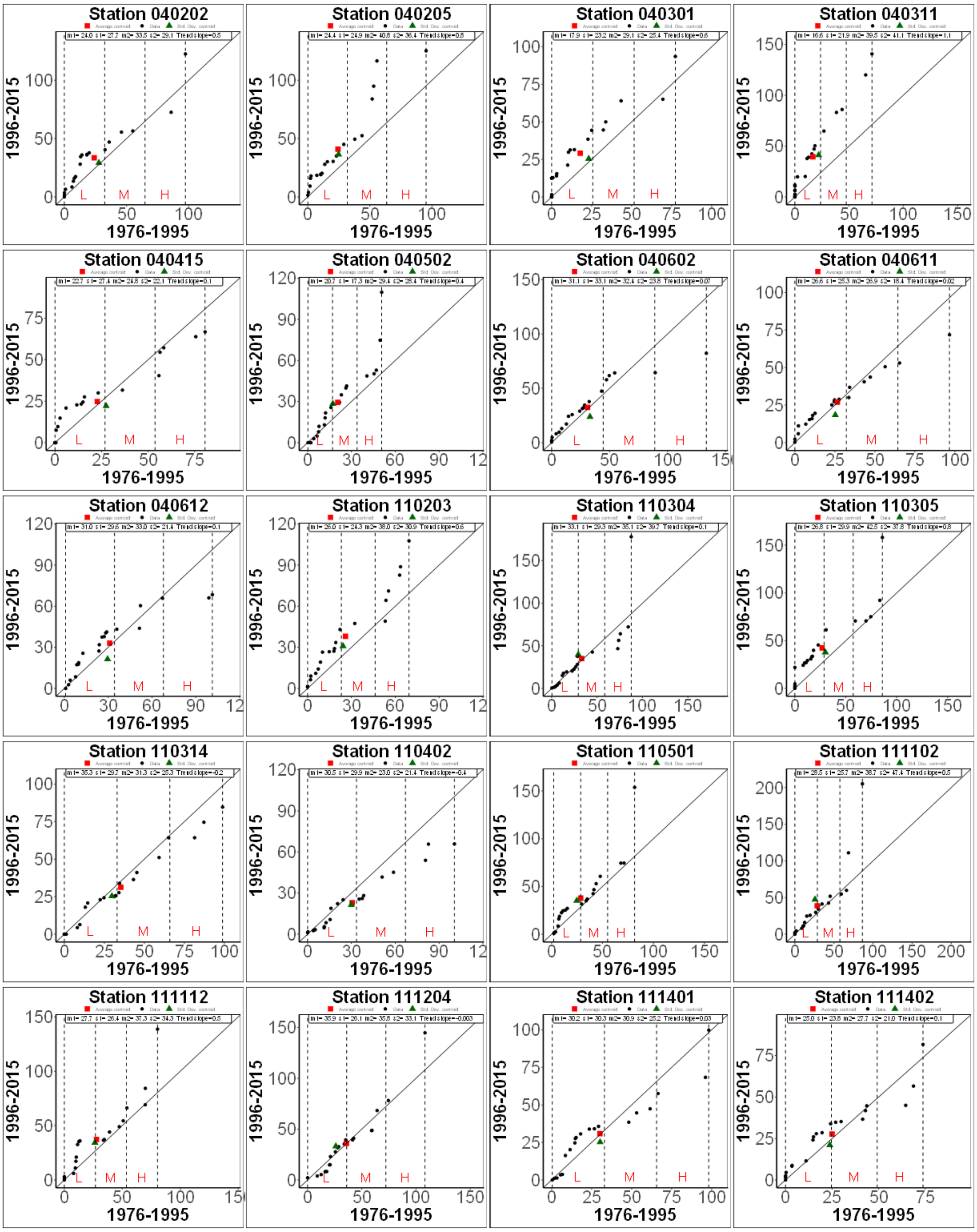

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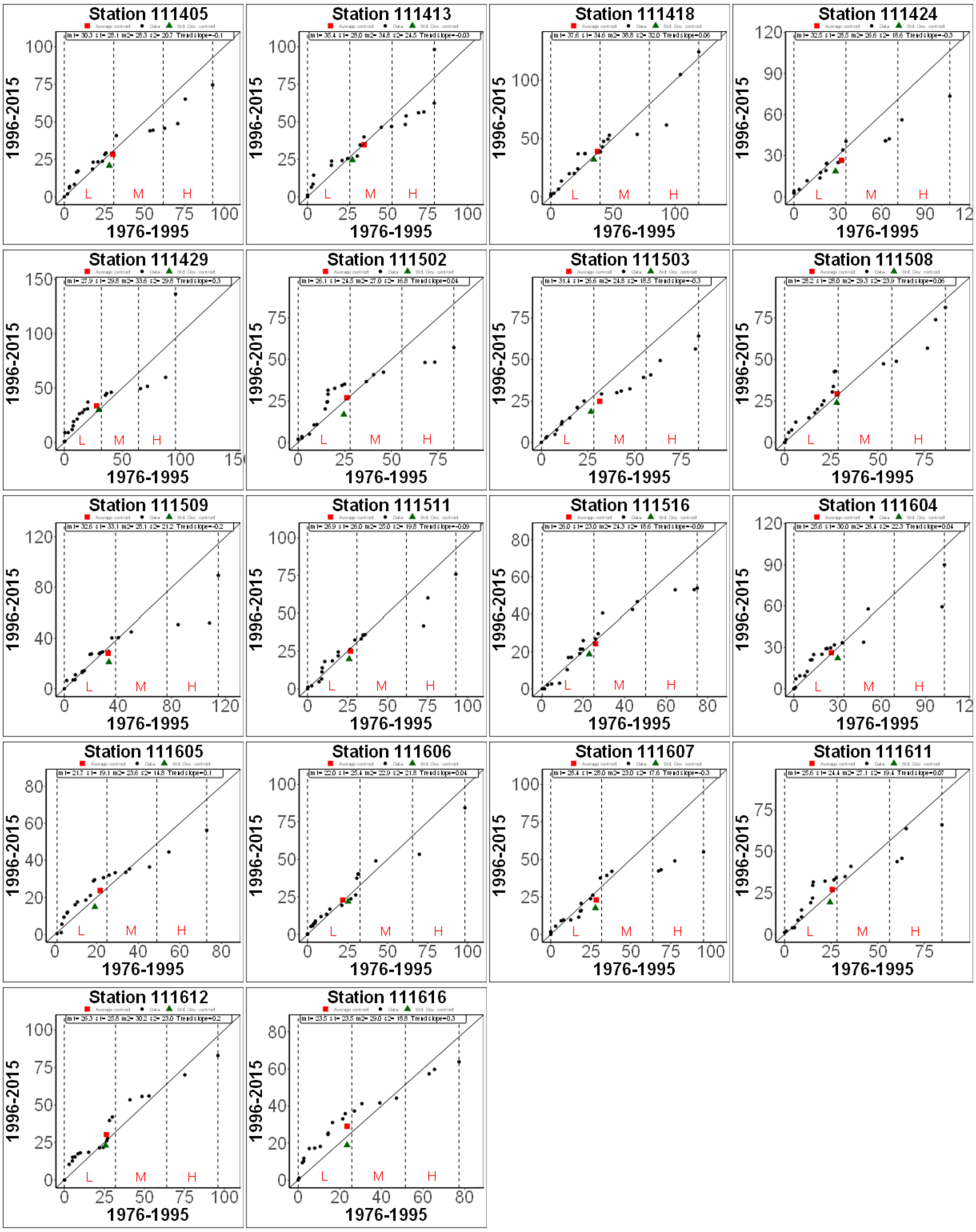
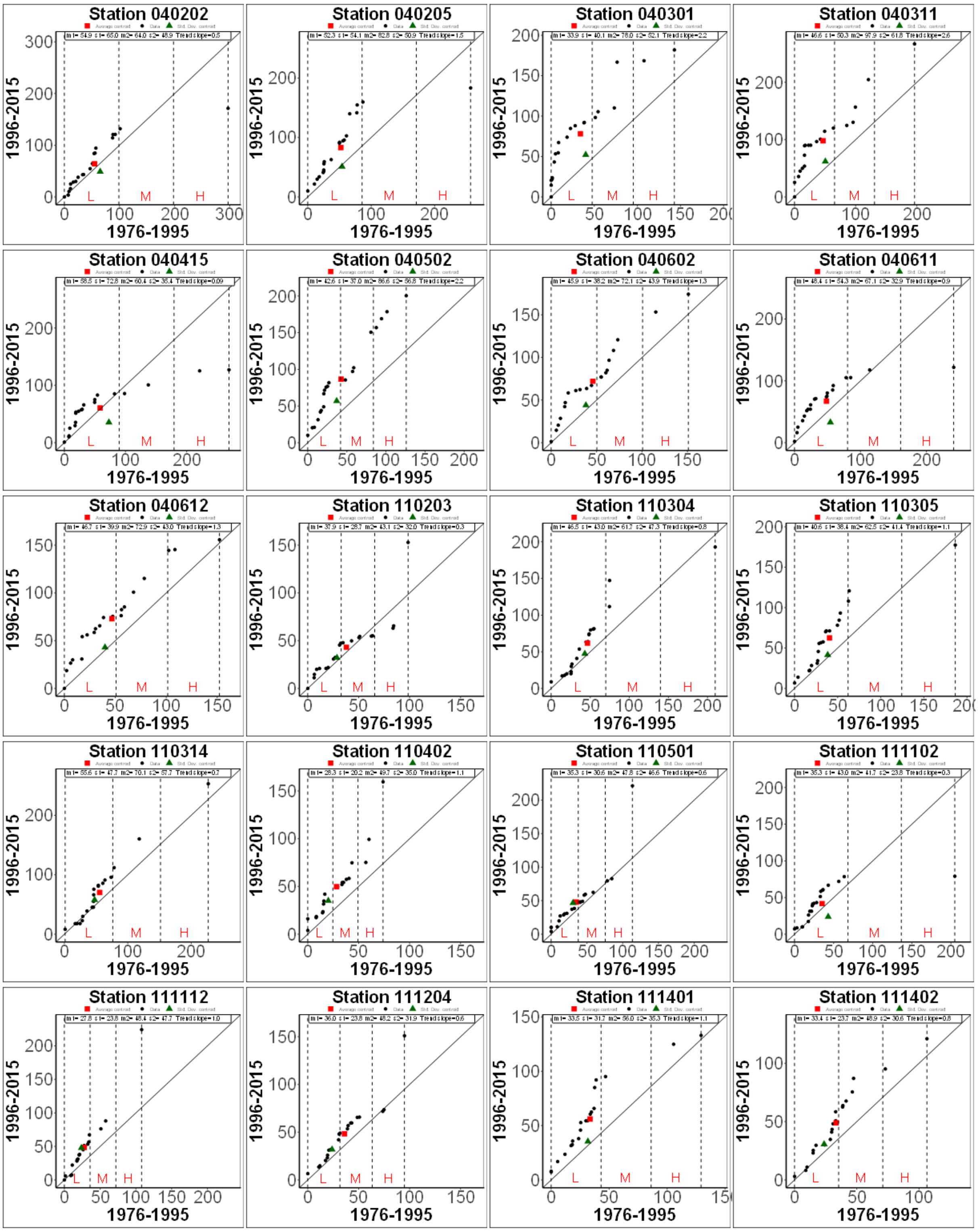


Figure A10. *October Innovative Trend Analysis (ITA) results*



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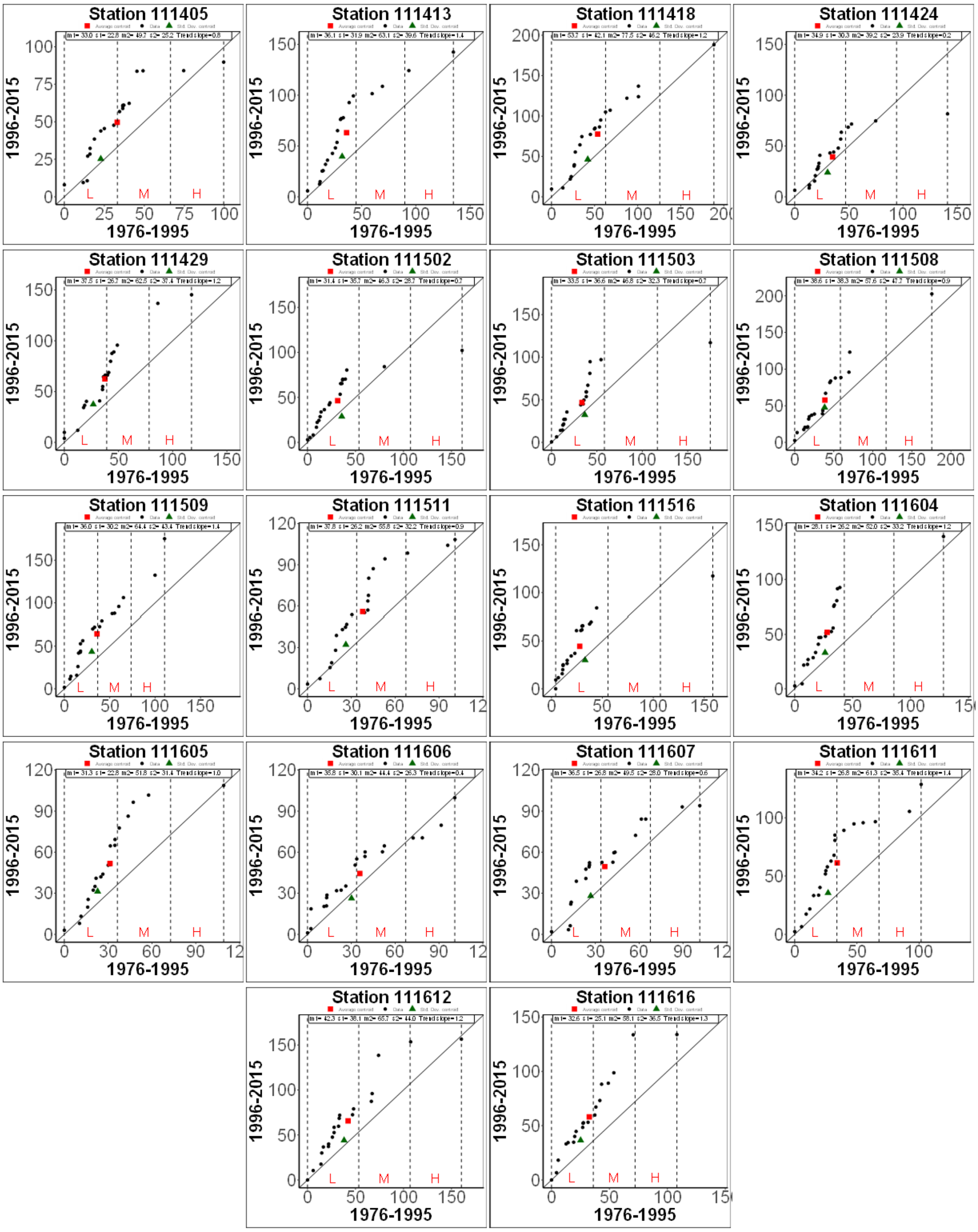
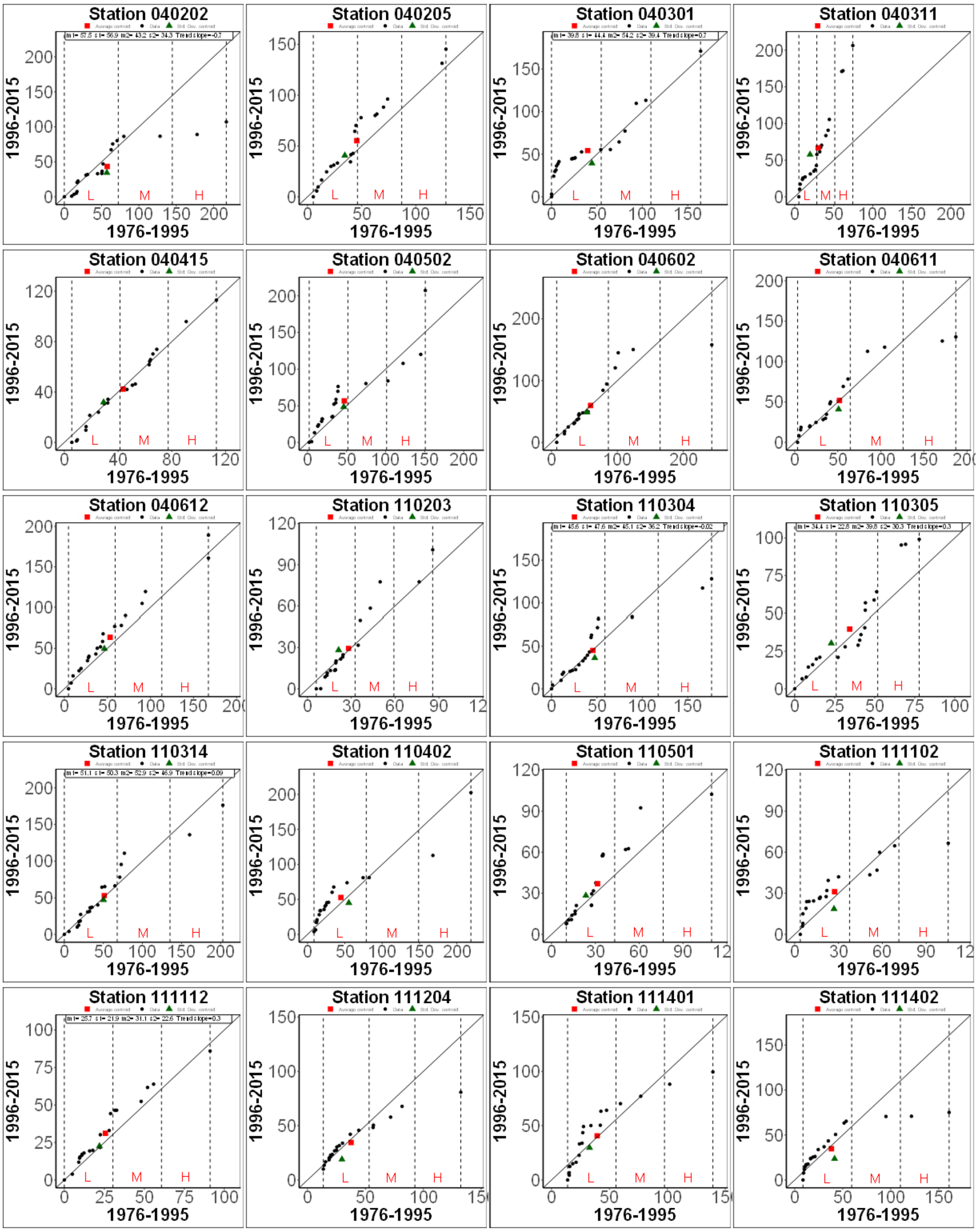


Figure A11. *November Innovative Trend Analysis (ITA) results*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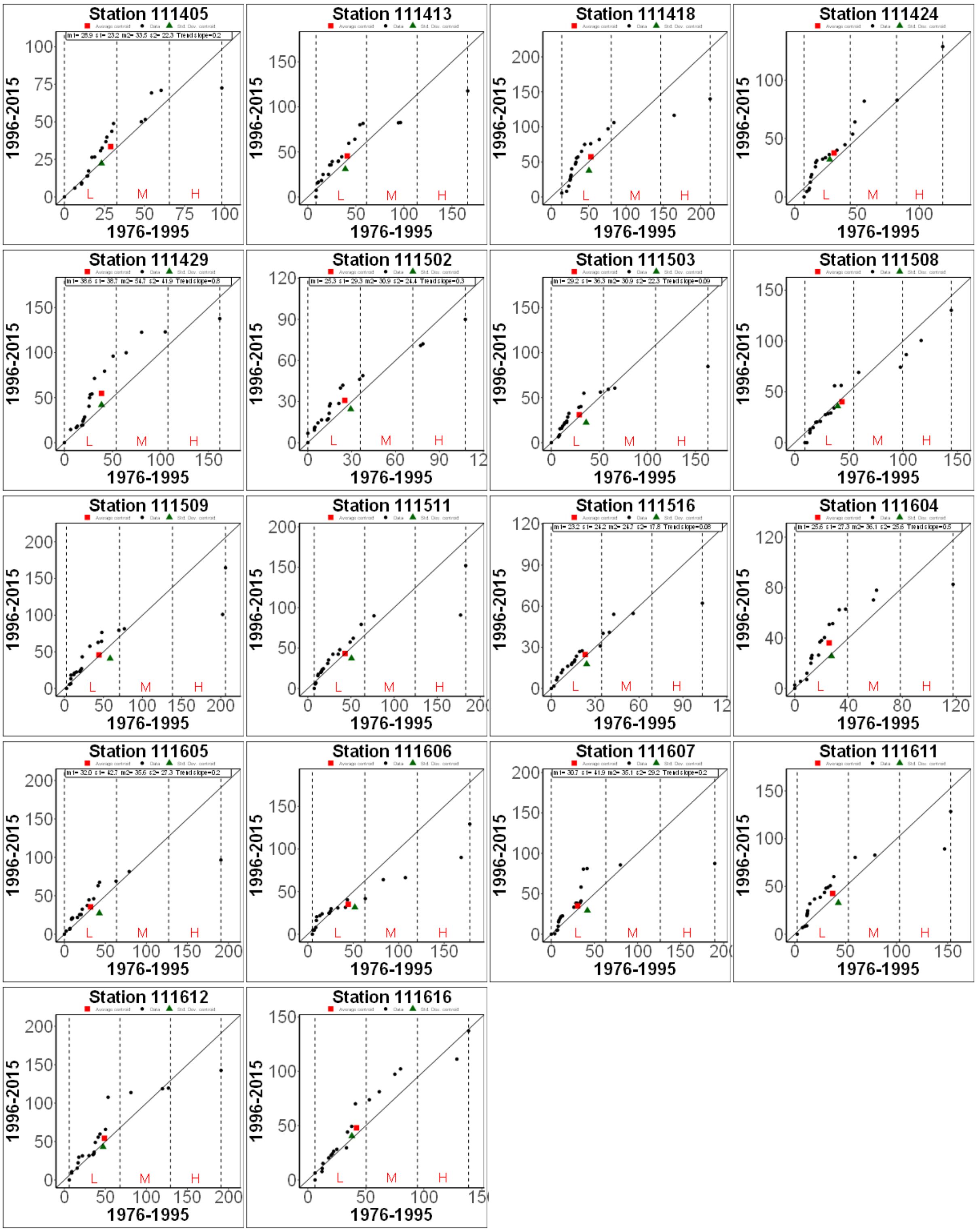

Figure A12. *December Innovative Trend Analysis (ITA) results*

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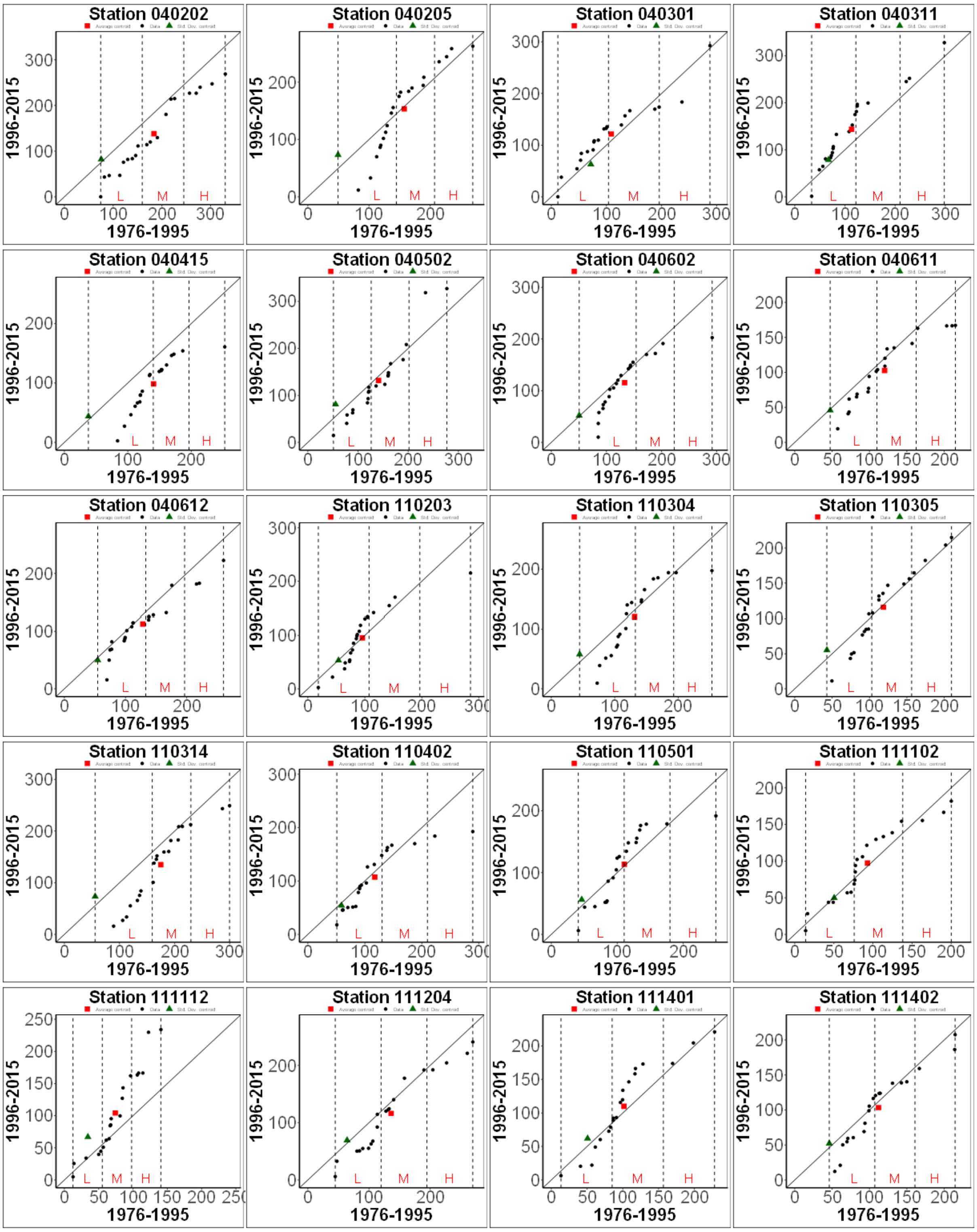
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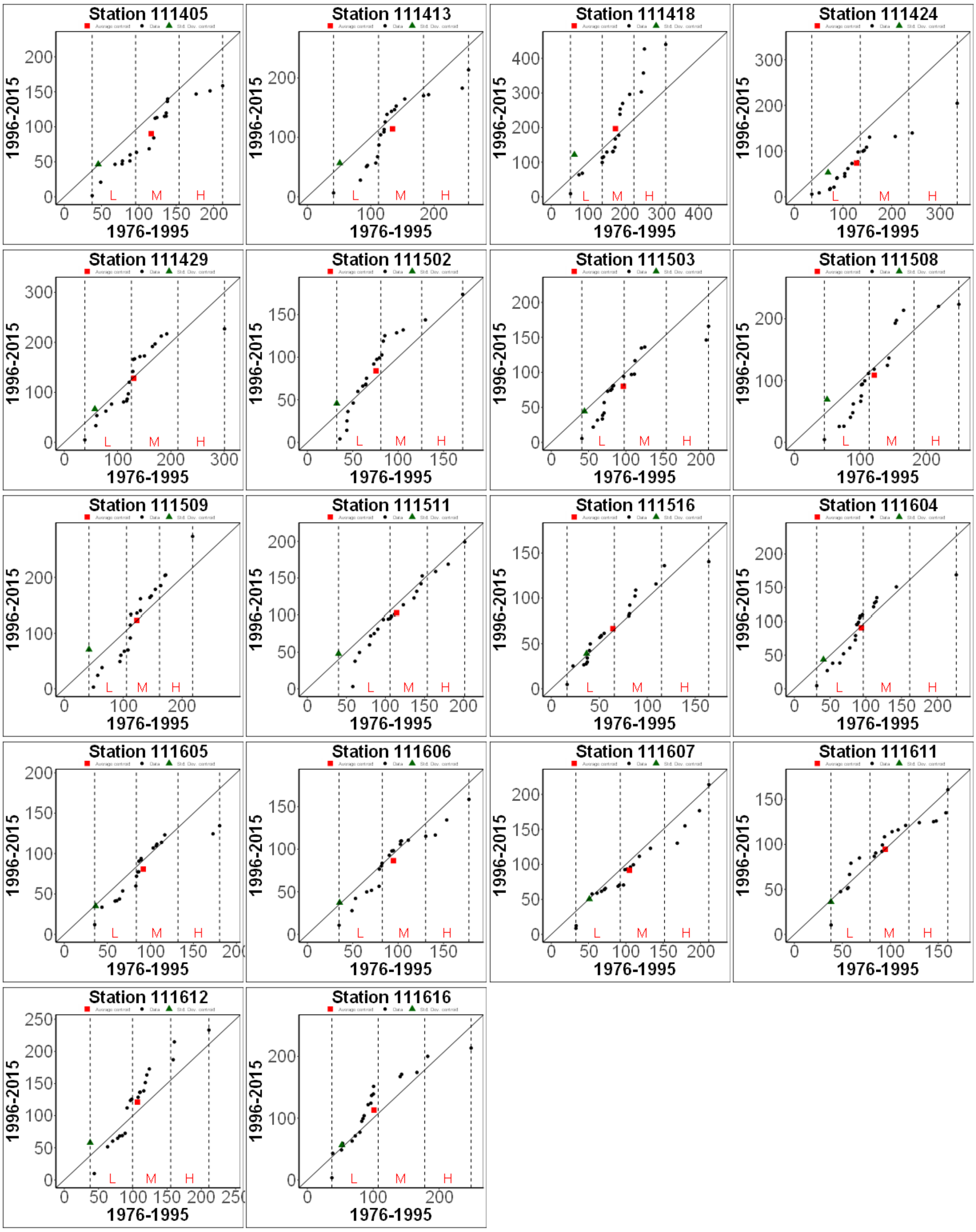

Figure A13. *Winter Innovative Trend Analysis (ITA) results*

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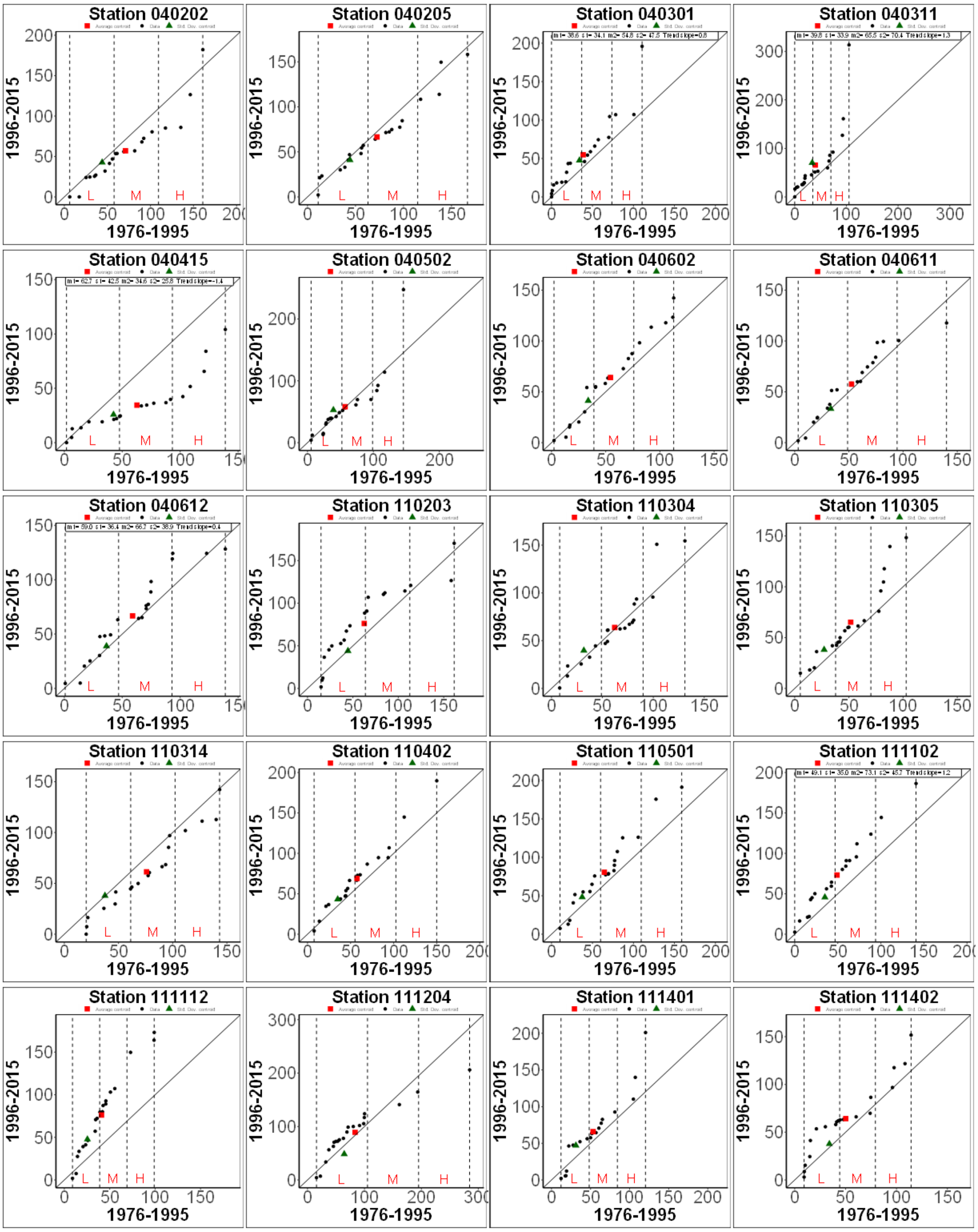

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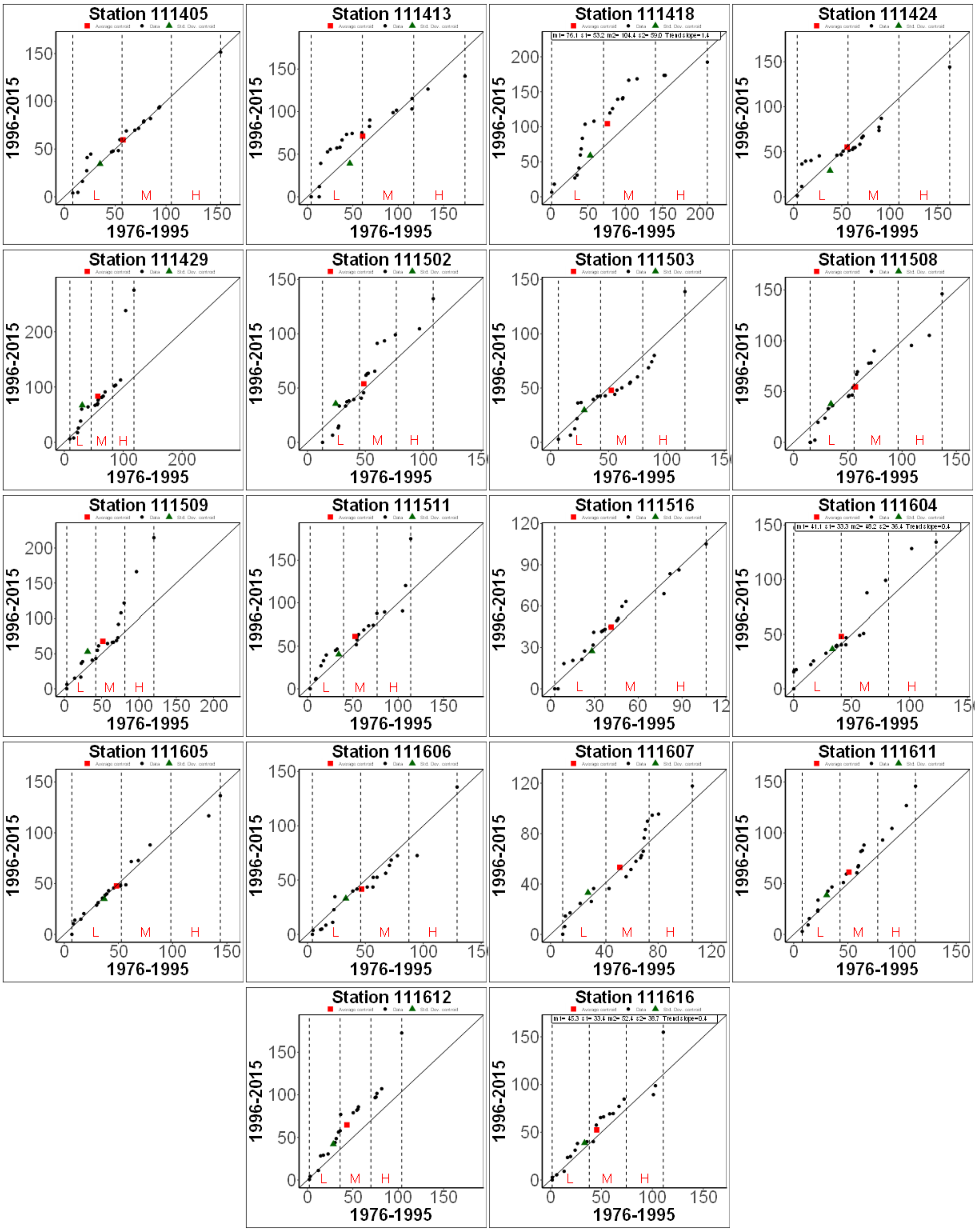
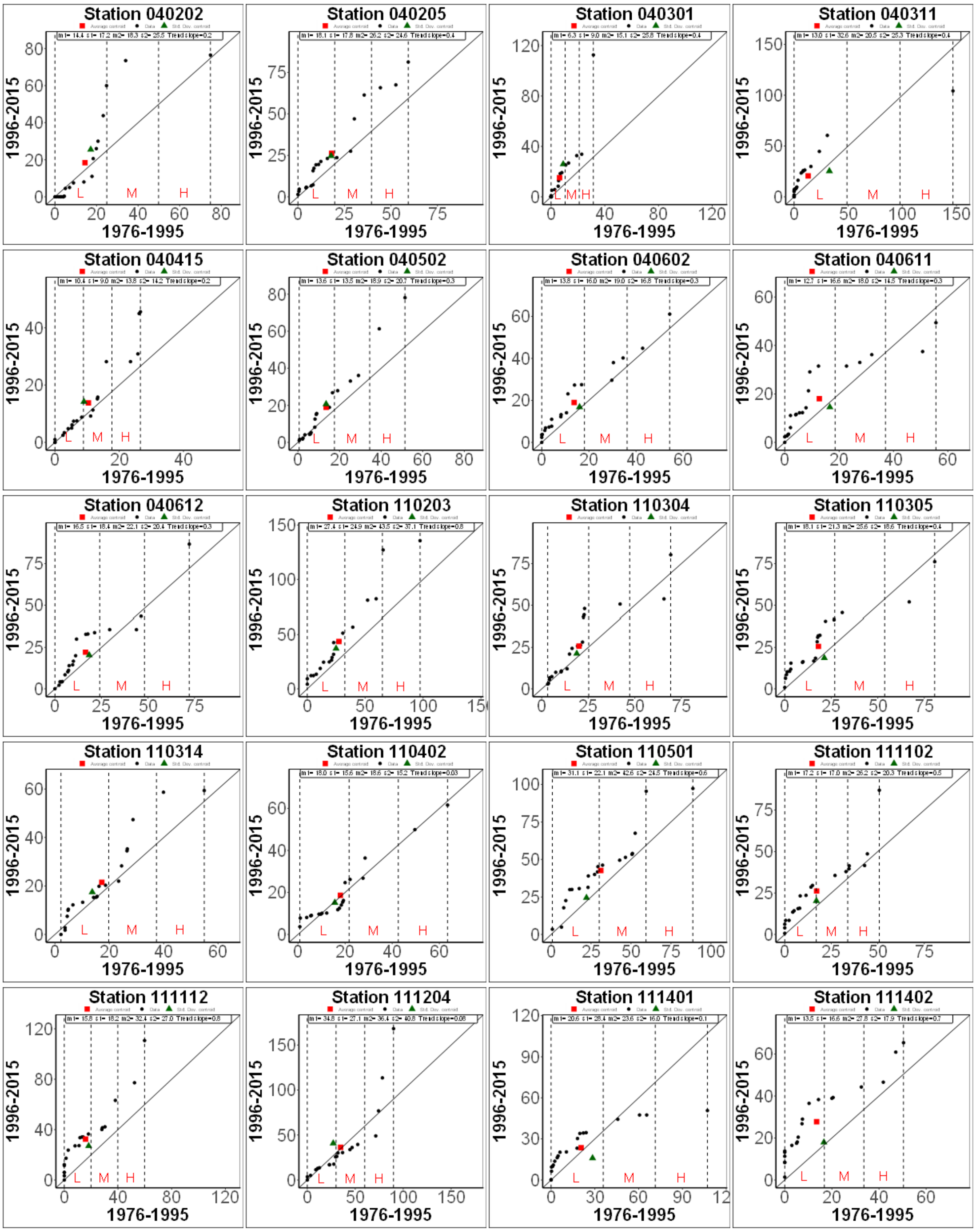


Figure A14. *Spring Innovative Trend Analysis (ITA) results*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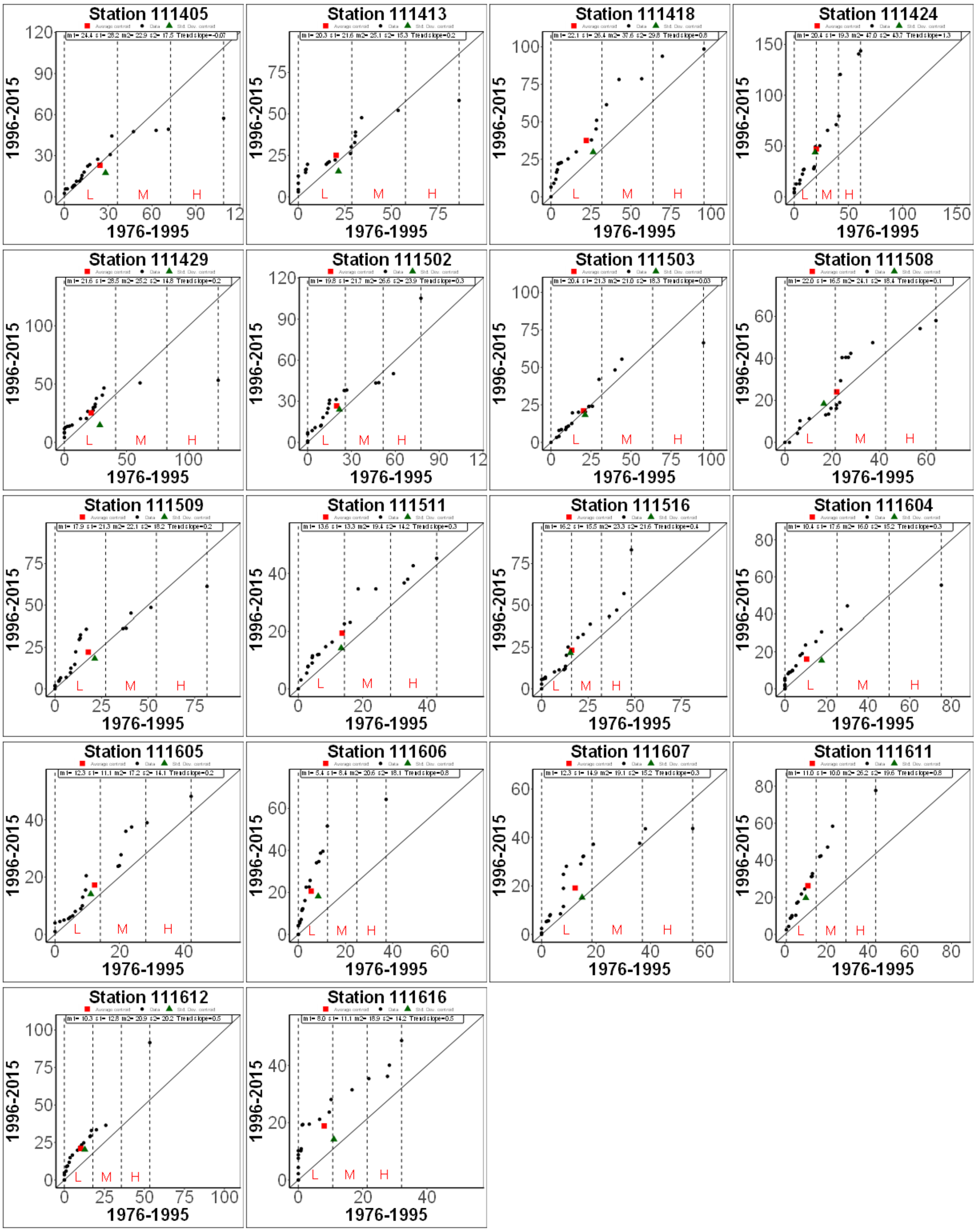
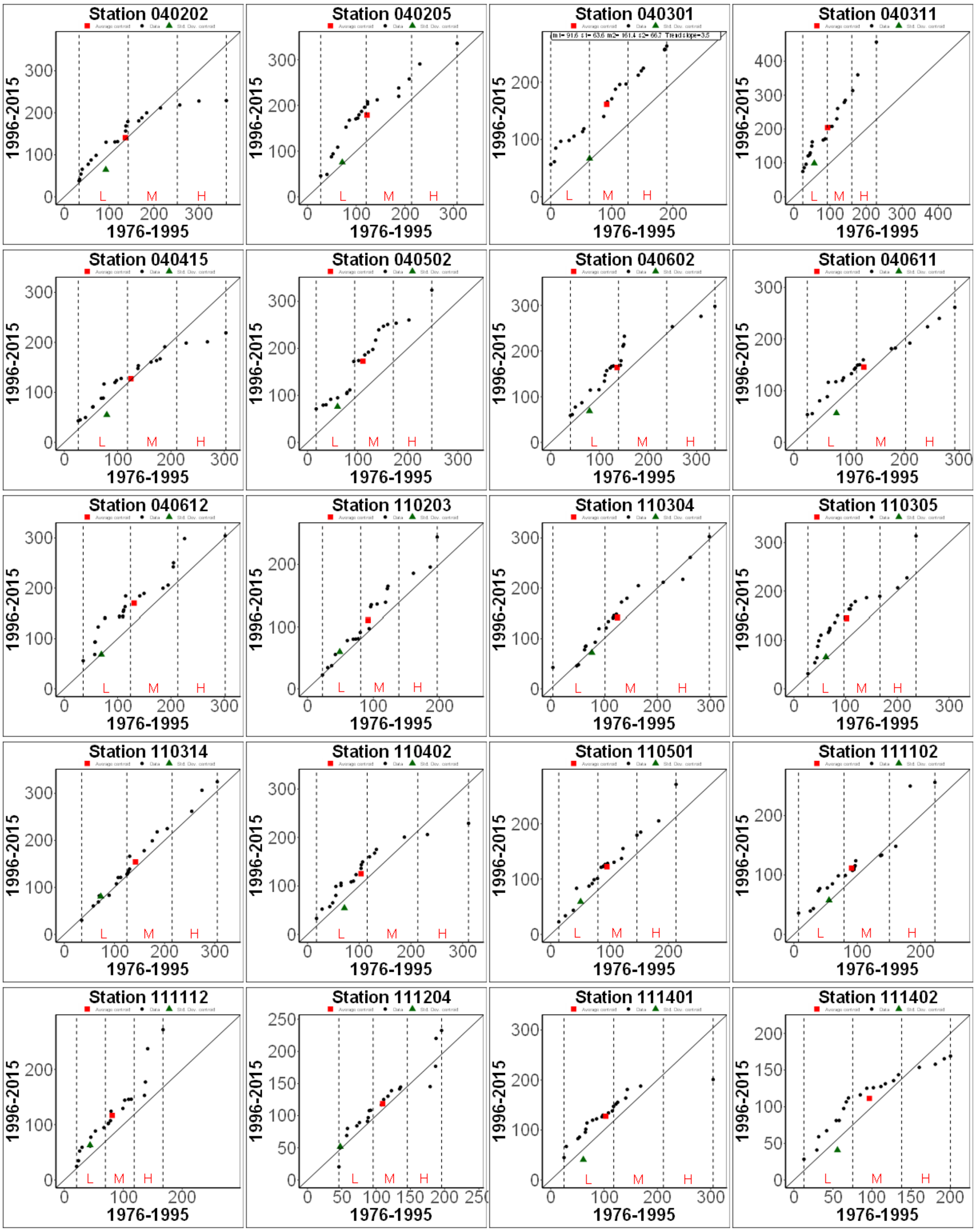


Figure A15. *Summer Innovative Trend Analysis (ITA) results*



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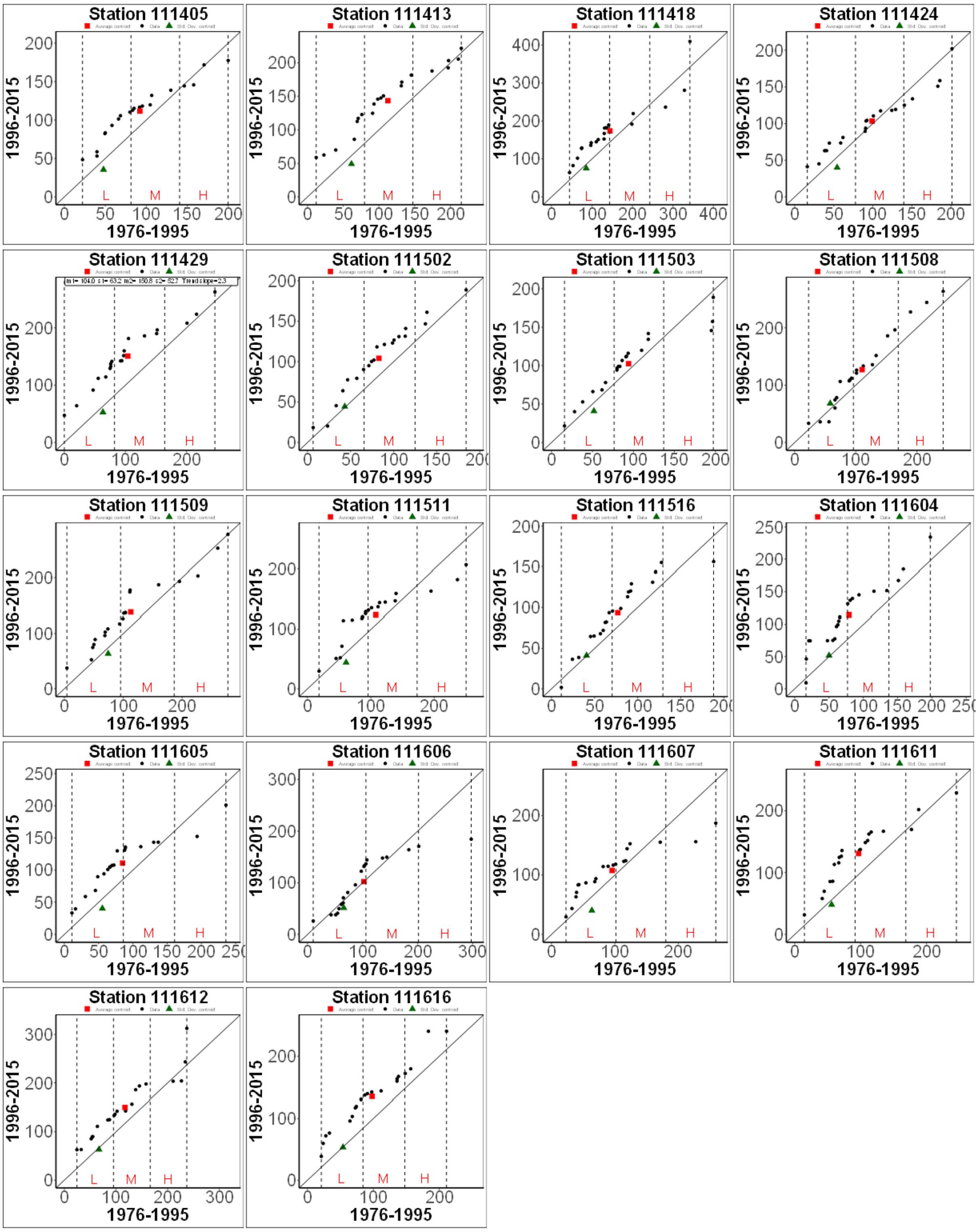

Figure A16. *Autumn Innovative Trend Analysis (ITA) results*

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