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# Supplementary Material

## Re-examining the assumption of dominant regional wind and fire spread directions

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# Appendix A – supplementary materials

The following appendix includes supplementary materials for the paper. Fig. A.1. and Fig. A.2. present similar analyses to Fig. 4 and Fig. 5 with only one condition (wind speed or RH, respectively) defining fire weather. Fig. A.4. and Fig. A.5. are similarly equivalent to Fig. 7 and Fig. 8. Fig. A.3. presents wind roses as in Fig. 6, but limits the observations to values that can be considered as fire weather. Fig A.6. present an analysis similar to Fig. 9, but with a 0.1° resolution.

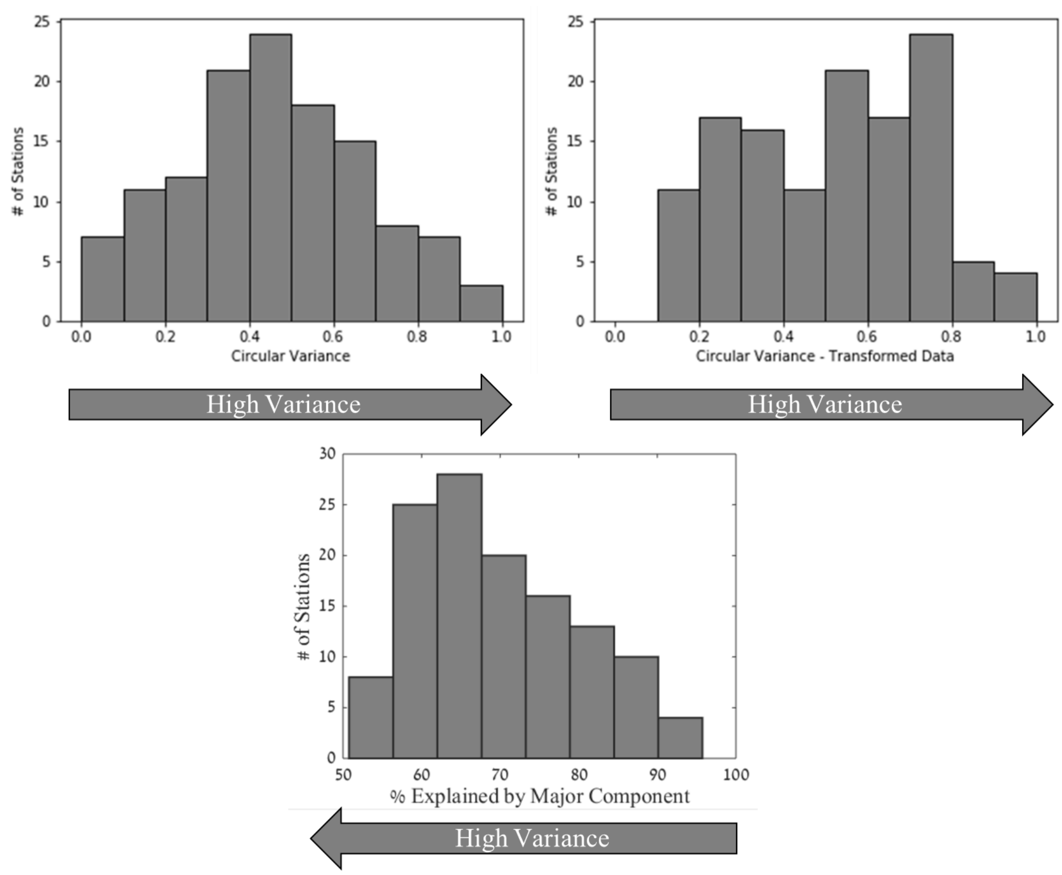


**Fig. A.1.** Circular variance and PCA of wind directions at Israel's meteorological stations during fire weather – high wind speed.

Fig. A.1. caption: Similar to Fig. 4, but the data include only observations with wind speeds higher than 6 m/s. Stations with fewer than 100 observations were discarded, leaving a total of 126 stations.

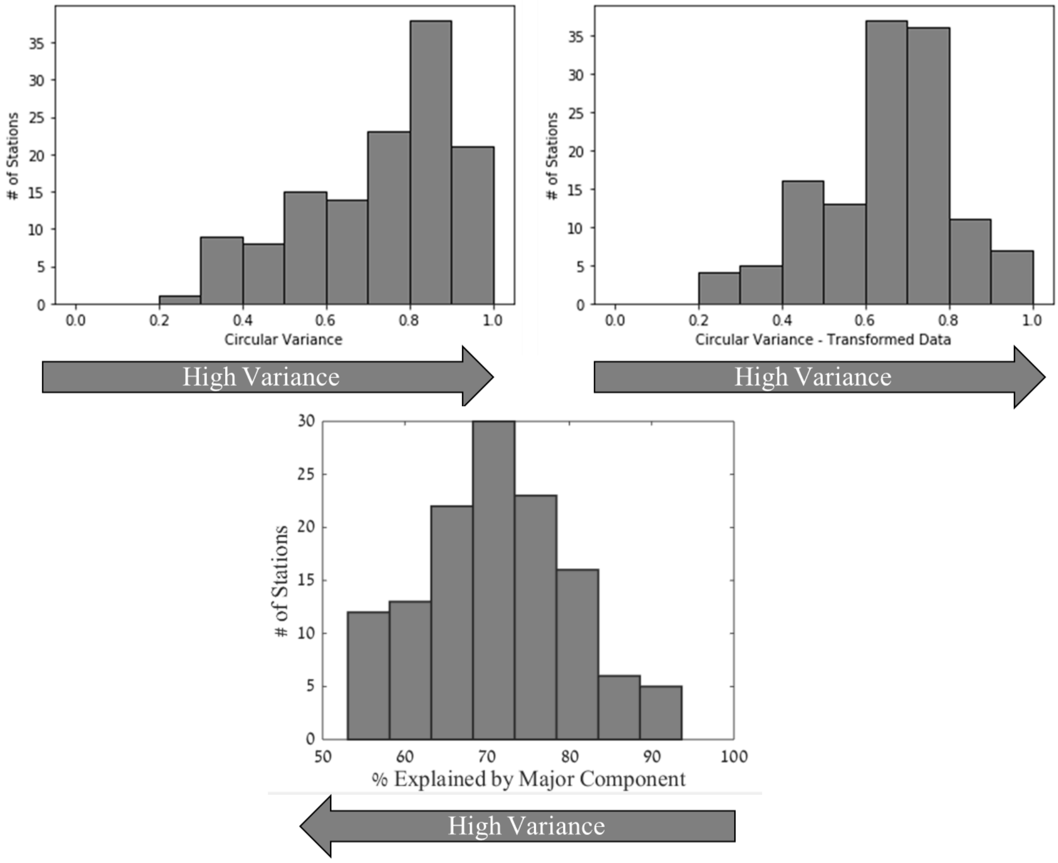


**Fig. A.2**. Circular variance and PCA of wind directions at Israel's meteorological stations during fire weather – low RH.

Fig. A.2. caption: Similar to Fig. 4, but the data include only observations with an RH lower than 30%. Stations with fewer than 100 observations were discarded, leaving a total of 129 stations.

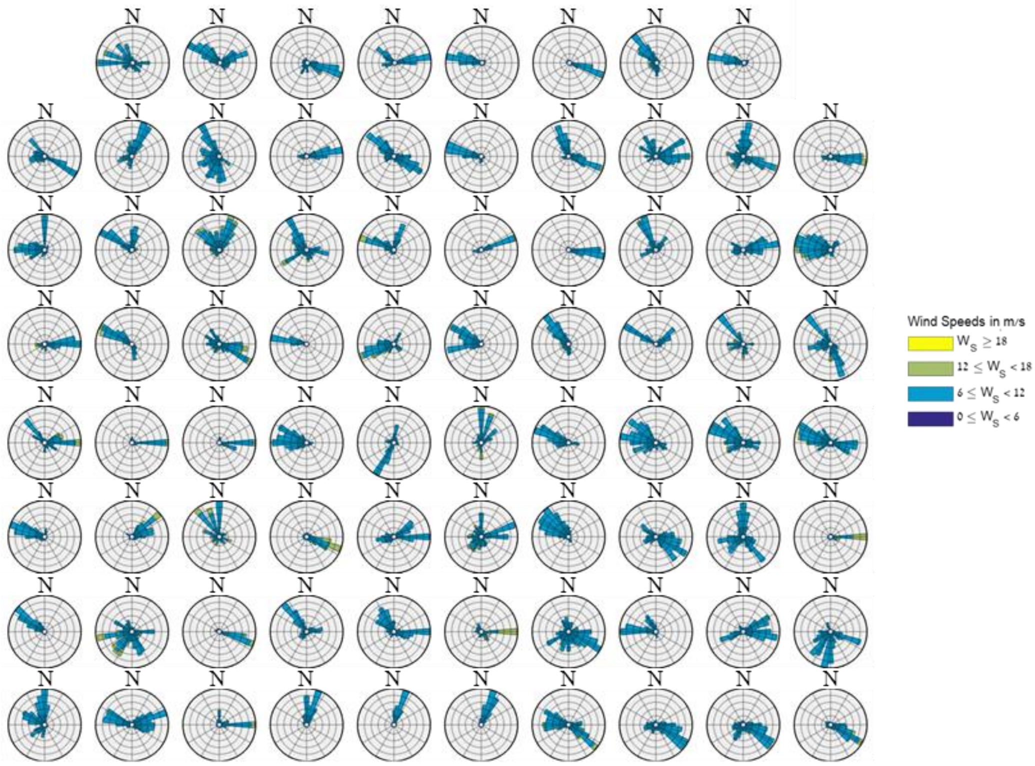


**Fig. A.3**. Wind roses during fire weather for Israel's meteorological stations – low RH and high wind speed.

Fig. A.3. caption: Wind roses for Israel's meteorological stations. The data include only observations in which the RH is lower than 30% and the wind speed is higher than 6 m/s. Stations with fewer than 100 observations were discarded, leaving a total of 81 stations.

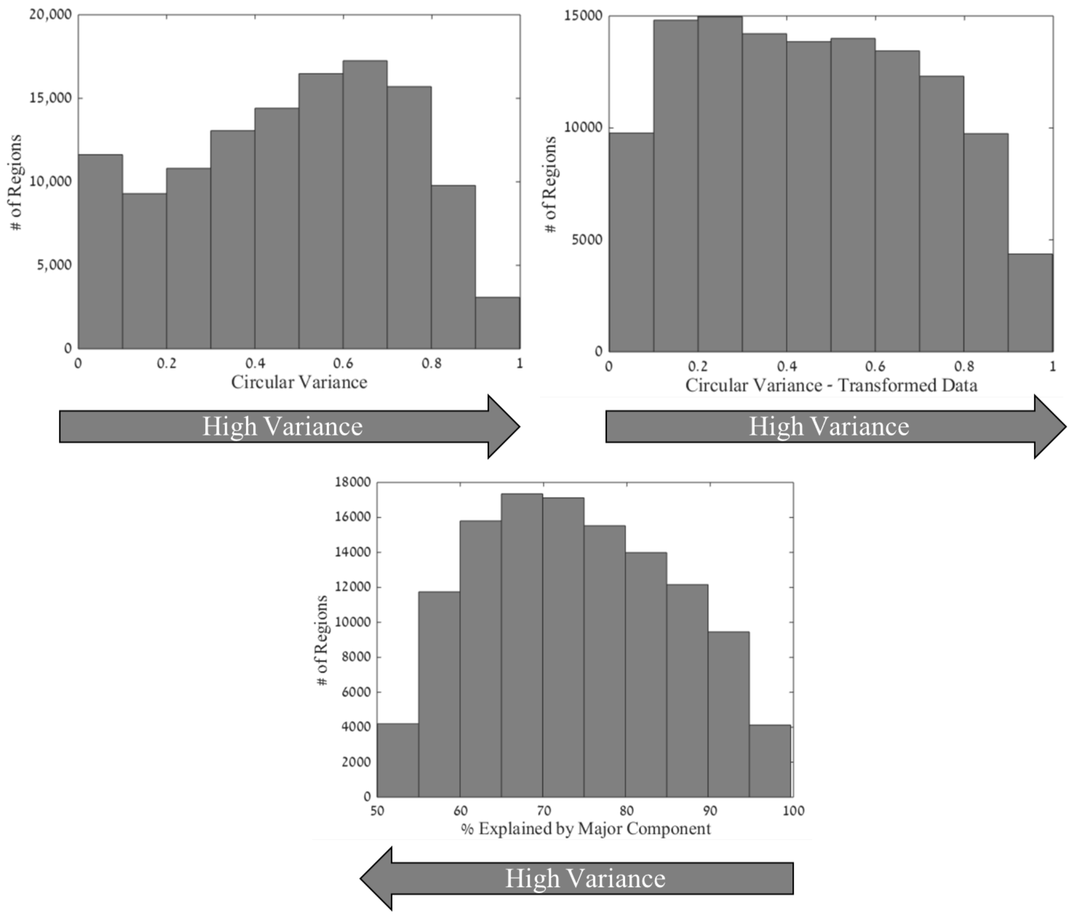


**Fig. A.4**. Circular variance and PCA of wind directions for all regions during fire weather – high wind speed.

Fig. A.4. caption: Similar to Fig. 7, but the data include only observations with wind speeds higher than 6 m/s. Regions with fewer than 100 observations were discarded, leaving a total of 121,476 regions.

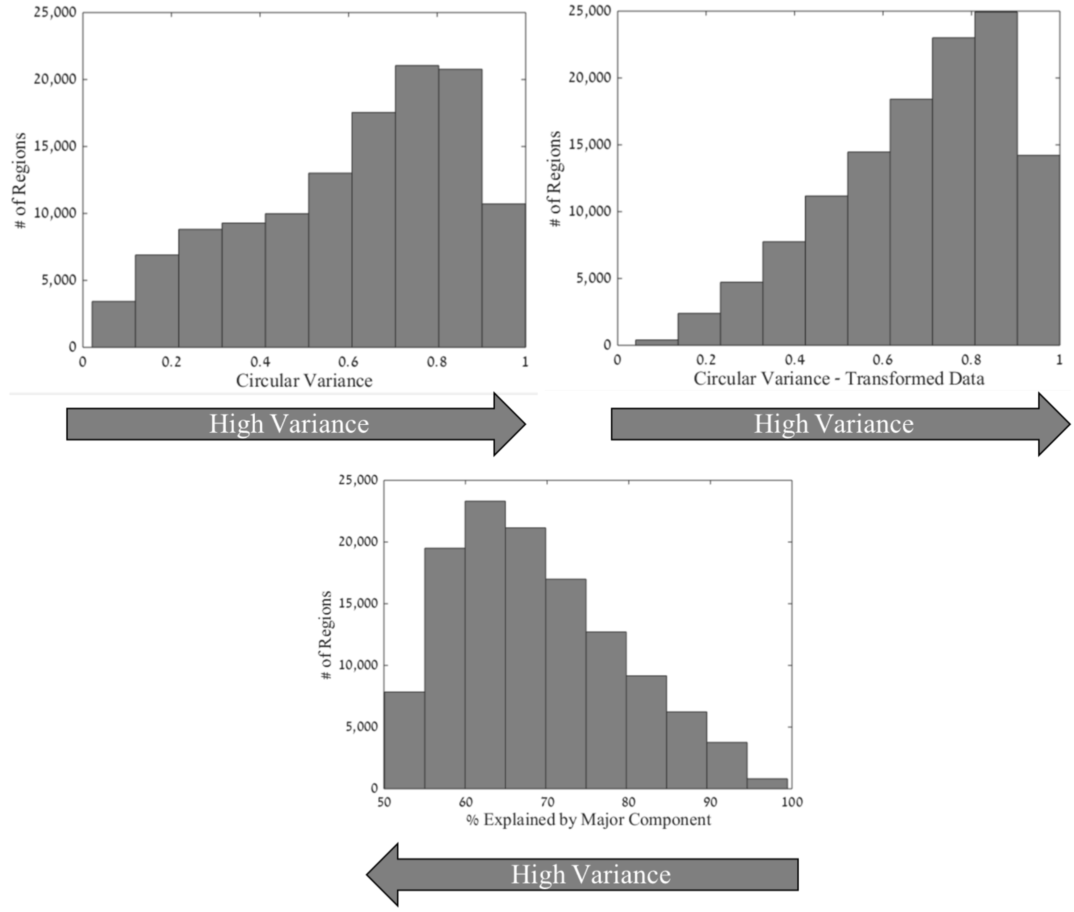


**Fig. A.5**. Circular variance and PCA of wind directions for all regions during fire weather – low RH.

Fig. A.5. caption: Similar to Fig. 7, but the data include only observations with an RH lower than 30%. Regions with fewer than 100 observations were discarded, leaving a total of 121,476 regions.

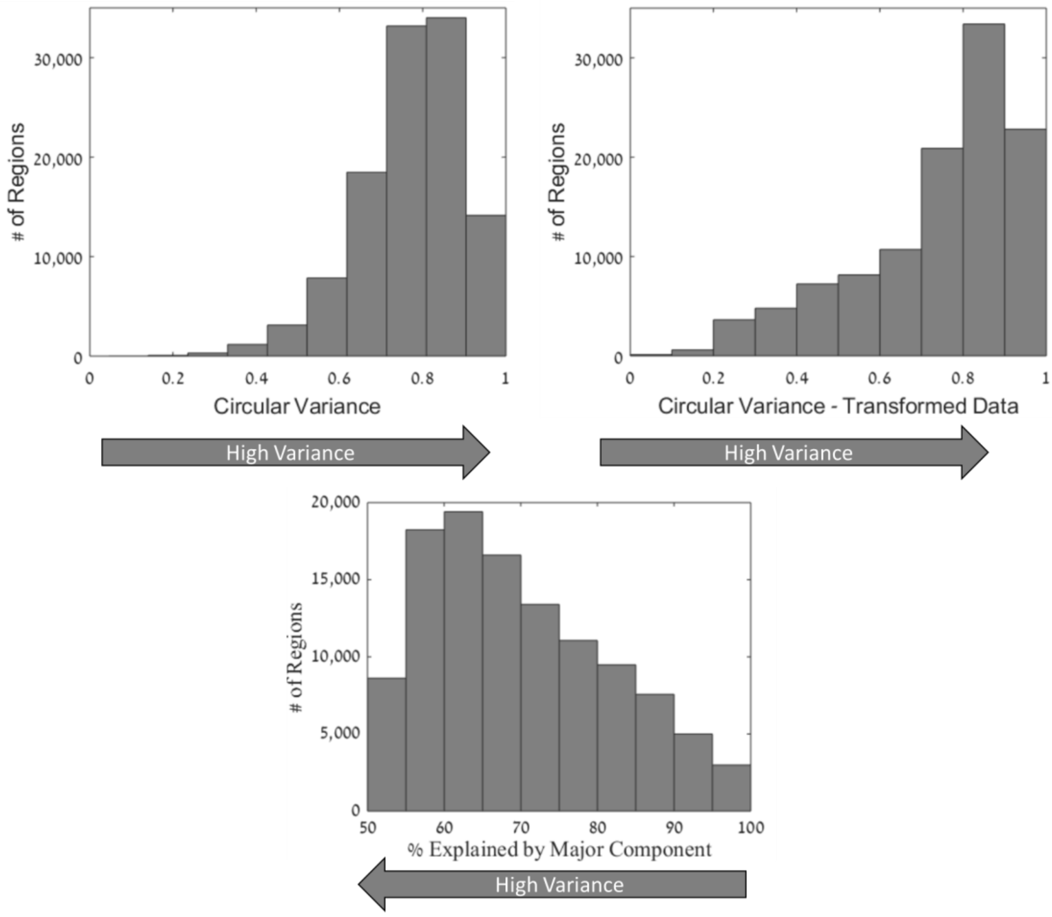


**Fig. A.6**. Circular variance and PCA of fire spread directions in 0.1°×0.1° regions.

Fig. A.6. caption: Similar to Fig. 9, but with 0.1°×0.1° regions. A total of 112,373 regions with 10 large wildfires or more are included in the data.

## Appendix B – comparison of PCA and circular variance analyses

Figures B.1.-B.3. present a comparison between the PCA and circular variance analyses. Fig. B.1 compares wind directions for Israel's meteorological stations, whereas Fig. B.2. and Fig. B.3. compare fire spread directions for regions worldwide. In all three figures, the left subplot compares the circular variance of the original data, and the right subplot compares the circular data of the transformed (doubled) data. As expected, the percentage of variance explained by the major PCA component is strongly (and negatively) correlated with the circular variance of the transformed data, which accounts for data concentrated around an axis in both directions. The percentage explained by the major PCA component is weakly correlated to the circular variance of the original (untransformed) data, as this circular variance is not meant to identify directions that are concentrated around an axis in both directions.

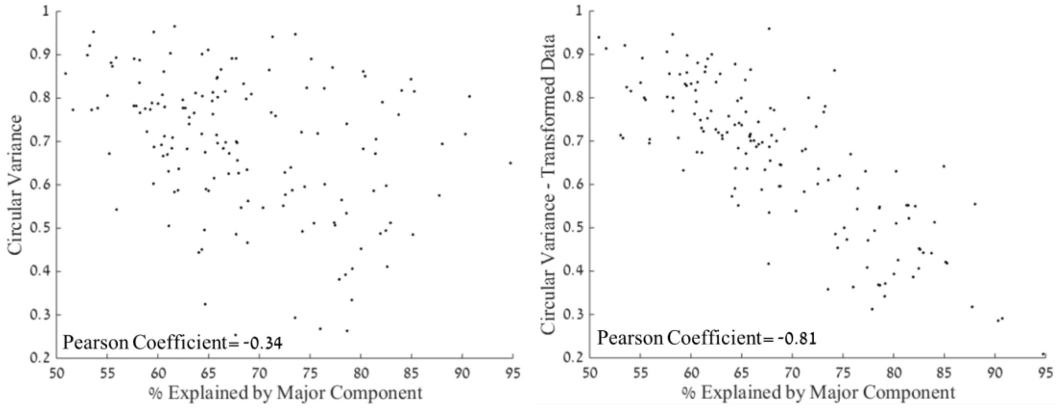


**Fig. B.1**. Comparison of PCA and circular variance for wind direction.

Fig. B.1. caption: A comparison of the circular variance and the variance explained by the major PCA component. The left subplot compares the circular variance of the original data, and the right subplot compares the circular data of the transformed (doubled) data. The Pearson coefficient is large and negative (-0.81) in the transformed data, which accounts for the concentration of data around an axis in both directions. The data include all meteorological stations in Israel.

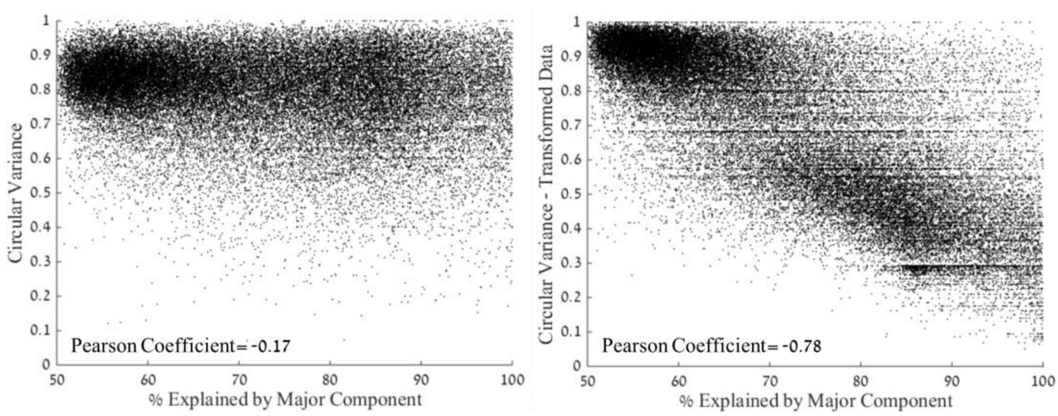

**Fig. B.2**. Comparison of PCA and circular variance for fire spread directions in 0.5°×0.5° regions.

Fig. B.2. caption: A comparison of the circular variance and the variance explained by the major PCA component. The left subplot compares the circular variance of the original data, and the right subplot compares the circular data of the transformed (doubled) data. The Pearson coefficient is large and negative (-0.78) in the transformed data, which accounts for the concentration of data around an axis in both directions. A total of 46,335 regions with 10 large wildfires or more are included in the data.

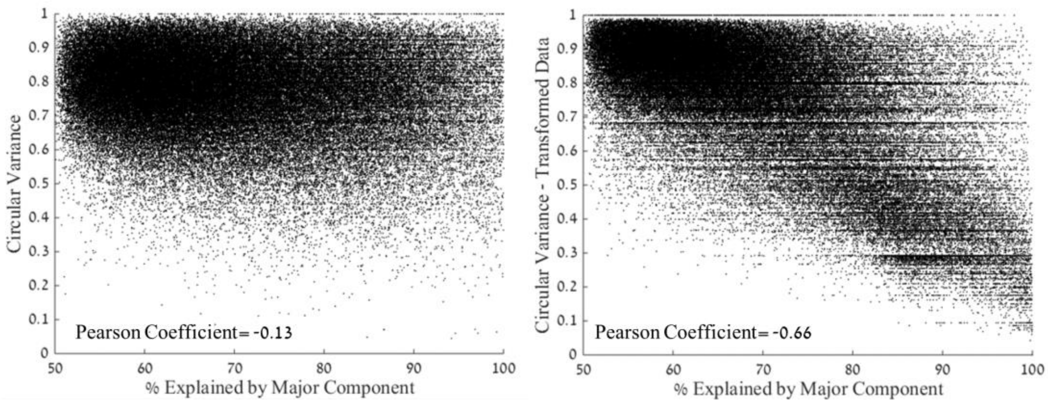


**Fig. B.3**. Comparison of PCA and circular variance for fire spread directions in 0.1°×0.1° regions.

Fig. B.3. caption: A comparison of the circular variance and the variance explained by the major PCA component. The left subplot compares the circular variance of the original data, and the right subplot compares the circular data of the transformed (doubled) data. The Pearson coefficient is large and negative (-0.78) in the transformed data, which accounts for the concentration of data around an axis in both directions. A total of 112,373 regions with 10 large wildfires or more are included in the data.

## Appendix C – robustness tests

*Anomaly detection*

Anomaly detection is the process of removing outliers who differ significantly from the rest of the data (e.g., Zhang et al. 2020). By definition, anomalies occur rarely in the data and differ significantly from normal instances. One of the most common ways of detecting anomalies is by measuring the median absolute deviation (MAD). The MAD value of a sample is defined in the following manner:

$$MAD = median(X_i - X_{median})$$

Leys et al. (2013) discuss the advantages of using MAD. One of its main advantages compared to the standard deviation and the mean is that unlike the latter two, MAD is not significantly influenced by outliers, an attribute that makes it a more robust tool of outlier identification.

As a robustness test, we repeat all the analyses in the paper after removing outliers whose value was outside the station's median plus or minus two times the MAD value of the station. In this way we are able to examine whether the results of the paper are robust and are not affected by a small number of irregular observations. Tables C.1-C.3 are equivalent to tables 1-3 but exclude observations (winds or fires) that were recognized as anomalies. The results are slightly different, but the main conclusions of the study remain valid.

**Table C.1.** Summary of wind direction analysis results for Israel's meteorological stations.

| Data | Number of Stations | Circular Variance | Circular Variance of Transformed Data | % Explained by Major PCA Component | Mean von Mises Kappa Parameter | Mean von Mises Kappa Parameter of Transformed Data |
|---|---|---|---|---|---|---|
| | | Mean (Median) | Mean (Median) | Mean (Median) | Mean (Median) | Mean (Median) |
| All Observations | 148 | 0.71 (0.72) | 0.66 (0.67) | 67% (67%) | 0.66 (0.57) | 0.78 (0.69) |
| Wind Speed >6 m/s | 126 | 0.43 (0.48) | 0.41 (0.36) | 71% (69%) | 2.31 (1.21) | 1.83 (1.67) |
| RH <30% | 129 | 0.76 (0.79) | 0.67 (0.68) | 68% (67%) | 0.54 (0.44) | 0.75 (0.67) |
| Wind Speed >6 m/s and RH <30% | 81 | 0.62 (0.62) | 0.52 (0.50) | 74% (77%) | 0.99 (0.81) | 1.17 (1.15) |

Table C.1. caption: Robustness test for Table 1 – a summary of circular variances and PCA results for wind directions at Israel's meteorological stations. Observations whose value was outside the station's median plus or minus two times the MAD value of the station.

**Table C.2.** Summary of wind direction analysis results for regions around the globe.

| Data | Number of Regions | Circular Variance | Circular Variance of Transformed Data | % Explained by Major PCA Component | Mean von Mises Kappa Parameter | Mean von Mises Kappa Parameter of Transformed Data |
|---|---|---|---|---|---|---|
| | | Mean (Median) | Mean (Median) | Mean (Median) | Mean (Median) | Mean (Median) |
| All Observations | 121,476 | 0.71 (0.75) | 0.72 (0.76) | 67% (66%) | 0.71 (0.52) | 0.62 (0.50) |
| Wind Speed >regional 90th percentile | 121,476 | 0.53 (0.56) | 0.49 (0.51) | 73% (72%) | 2.58 (0.97) | 2.05 (1.14) |
| RH <regional 10th percentile | 121,476 | 0.59 (0.64) | 0.69 (0.74) | 67% (65%) | 1.31 (0.76) | 0.75 (0.54) |
| Wind Speed >90th regional percentile and RH <regional 10th percentile | 103,880 | 0.35 (0.30) | 0.40 (0.36) | 77% (78%) | 6.65 (2.01) | 3.24 (1.67) |

Table C.2. caption: Robustness test for Table 2 – a summary of circular variances and PCA results for wind directions in all regions around the globe. Observations whose value was outside the station's median plus or minus two times the MAD value of the station.

**Table C.3.** Summary of the circular variance of fire spread directions.

| Data | Number of Regions | Circular Variance | Circular Variance of Transformed Data | % Explained by Major PCA Component | Mean von Mises Kappa Parameter | Mean von Mises Kappa Parameter of Transformed Data |
|---|---|---|---|---|---|---|
| | | **Mean (Median)** | **Mean (Median)** | **Mean (Median)** | **Mean (Median)** | **Mean (Median)** |
| $0.5° \ by \ 0.5°$ | 46,335 | 0.78 (0.80) | 0.69 (0.74) | 67% (65%) | 0.41 (0.36) | 0.67 (0.44) |
| $0.1° \ by \ 0.1°$ | 112,373 | 0.75 (0.77) | 0.73 (0.79) | 66% (63%) | 0.45 (0.41) | 0.54 (0.37) |

Table C.3. caption: Robustness test for Table 3 – a summary of circular variances and PCA results for fire spread directions in regions around the globe. Observations whose value was outside the station's median plus or minus two times the MAD value of the station.

*Fire spread directions – robustness tests*

We now present several robustness tests for the analysis of fire spread directions. We perform 10 robustness tests as follows: First, we repeat the analysis with only the small (<median), medium ($25^{th}$ to $75^{th}$ percentiles), or large (>median) fires in each region. Next, we repeat the analysis after excluding regions with a small number of fires. In the original analysis we included regions with 10 fires or more; we present the results for regions with 50 or 100 fires or more. We repeated these analyses for the 0.1° and 0.5° resolution grids.

Table C.4. summarizes the results of the robustness tests. Our conclusion holds in all of the tests. Excluding regions with a small number of fires even strengthens the results, and the median circular variance even exceeds 0.9 in one of the tests.

**Table C.4.** Summary of the circular variance of fire spread directions.

| Data | Resolution | Number of Regions | Circular Variance | Circular Variance of Transformed Data | % Explained by Major PCA Component |
|---|---|---|---|---|---|
| | | | **Mean (Median)** | **Mean (Median)** | **Mean (Median)** |
| Original analysis (all) | 0.1º | 112,373 | 0.77 (0.79) | 0.74 (0.80) | 70% (68%) |
| Only small fires (<median) | 0.1º | 112,373 | 0.71 (0.74) | 0.69 (0.75) | 68% (65%) |
| Only medium fires ($25^{th}$ $to$ $75^{th}$ $percentiles$) | 0.1º | 112,373 | 0.71 (0.74) | 0.69 (0.75) | 68% (65%) |
| Only large fires (>median) | 0.1º | 112,373 | 0.71 (0.74) | 0.68 (0.75) | 72% (70%) |
| Only regions with >50 fires | 0.1º | 31,898 | 0.81 (0.82) | 0.85 (0.87) | 63% (62%) |
| Only regions with >100 fires | 0.1º | 2,757 | 0.82 (0.82) | 0.87 (0.89) | 60% (59%) |
| Original analysis (all) | 0.5 º | 46,335 | 0.80 (0.82) | 0.70 (0.75) | 72% (70%) |
| Only small fires (<median) | 0.5 º | 46,335 | 0.75 (0.78) | 0.67 (0.72) | 68% (66%) |
| Only medium fires ($25^{th}$ $to$ $75^{th}$ $percentiles$) | 0.5 º | 46,335 | 0.75 (0.78) | 0.66 (0.71) | 68% (66%) |
| Only large fires (>median) | 0.5 º | 46,335 | 0.76 (0.79) | 0.65 (0.69) | 73% (72%) |
| Only regions with >50 fires | 0.5 º | 22,098 | 0.84 (0. 84) | 0.81 (0.89) | 65% (61%) |
| Only regions with >100 fires | 0.5 º | 14,936 | 0.84 (0.84) | 0.87 (0.91) | 61% (58%) |

Table C.4. caption: Robustness tests for Table 3 – a summary of circular variances and PCA results for fire spread directions in regions around the globe. We repeat the analysis with only the small (<median), medium (25^th to 75^th percentiles), or large (>median) fires in each region. In addition, we repeat the analysis when limiting the observations to regions with 50 or 100 fires or more, instead of 10 in the original analysis.