

A Nonparametric Approach to Early Warning Signs using COVID-19 data from South Africa

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Abstract

Rapid and often unexpected punctuated shifts have characterized the spread of the COVID-19 pandemic. The ability to identify and predict outbreaks during epidemics and pandemic events is crucial to developing and implementing effective mitigation measures by the public health sector. In this study we examine early-warning signals based on two approaches, the metric based approach and the model -based approach. The metric-based approach analyses the early-warning signals using the standard deviation, skewness, kurtosis, autocorrelation at lag-1, the BDS test and the conditional heteroskedasticity. The model-based model used is the nonparametric Diff-Diffusion-Jump (DDJ) model for early warning signals of COVID-19 incidence in South Africa. The spread of COVID-19 in South Africa is divided into five waves. Analysis of critical transitions is performed for each wave. From the generic early warning signals, the standard deviation is the most effective across all waves. An increase in the standard deviation towards the critical points is shown with a positive Kendall tau value on all waves. The BDS test gives strong evidence of nonlinearity in all the five waves. Conditional heteroskedasticity confirmed the periods of critical transitions that were captured by the generic early warning signals, that is, around day 140 and day 165 of wave 1, between day 110 and 120 of the second wave, from day 120 onwards for wave two. The results from the DDJ model are also consistent of the results from the metric-based early warning signals. A sensitivity analysis for the robustness of the fitted model is based on the standard deviation and it shows positive and increasing Kendall τ estimates across all rolling windows. Results from these different approaches are consistent. Hence this study recommends the use of various approaches to determine whether there is a robust signal of an imminent transition in a time series. Thereby, reducing chances of false alarm. This study provides insights for pandemics that have a similar characteristics as COVID-19 and informs policy making and implementation.

Keywords: Early-warning signals, Generic early warning signals, Drift-Diffusion-jump model, COVID-19.

Supplementary material

This supplementary material contains the additional graphs of the paper titled "A Nonparametric Approach to Early Warning Signs using COVID-19 data from South Africa"

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Appendix A1:

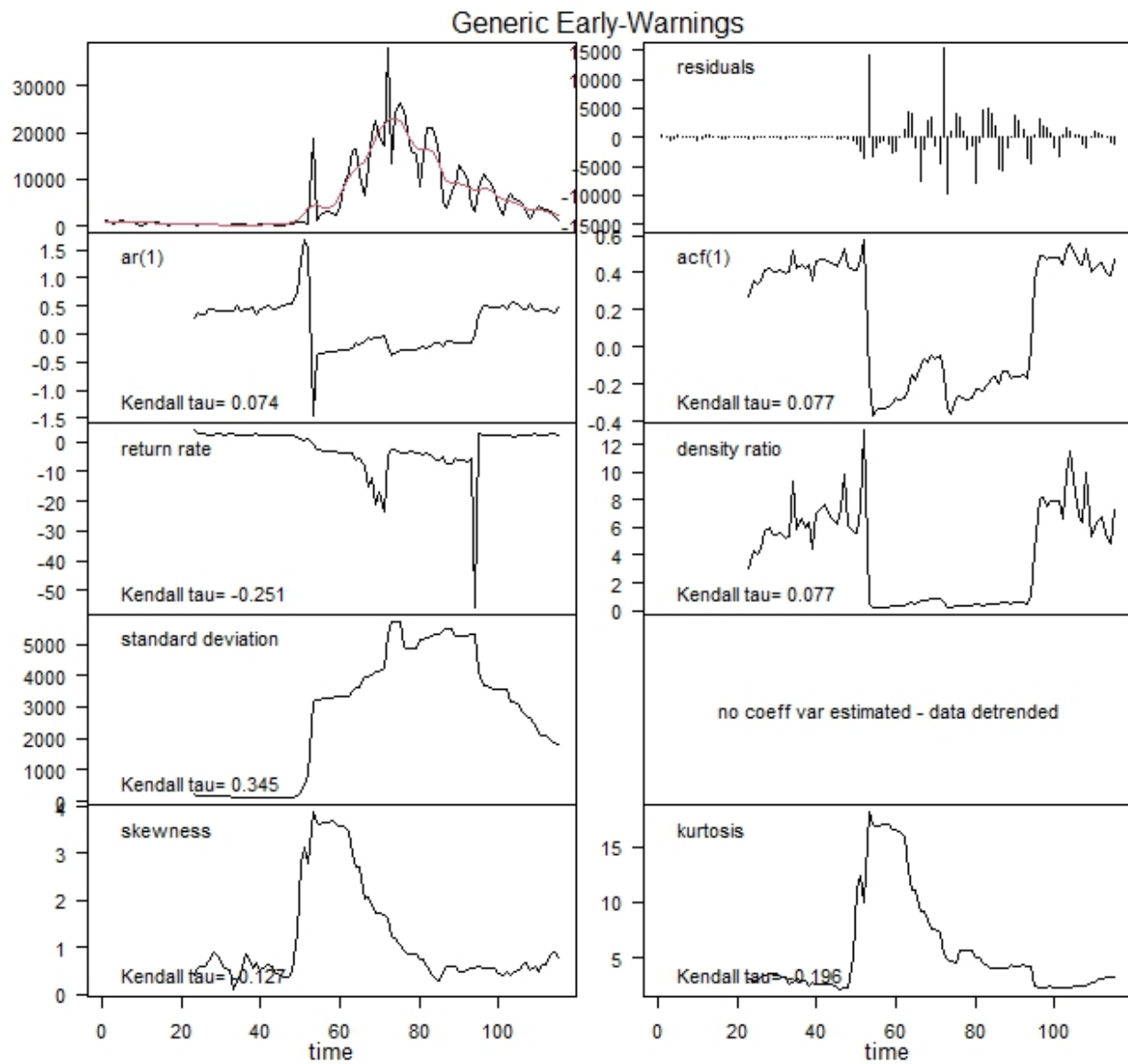


Figure 1: Generic early warning signals for wave 4: the Gaussian detrending, window size =20, bandwidth=5.

Appendix A2:

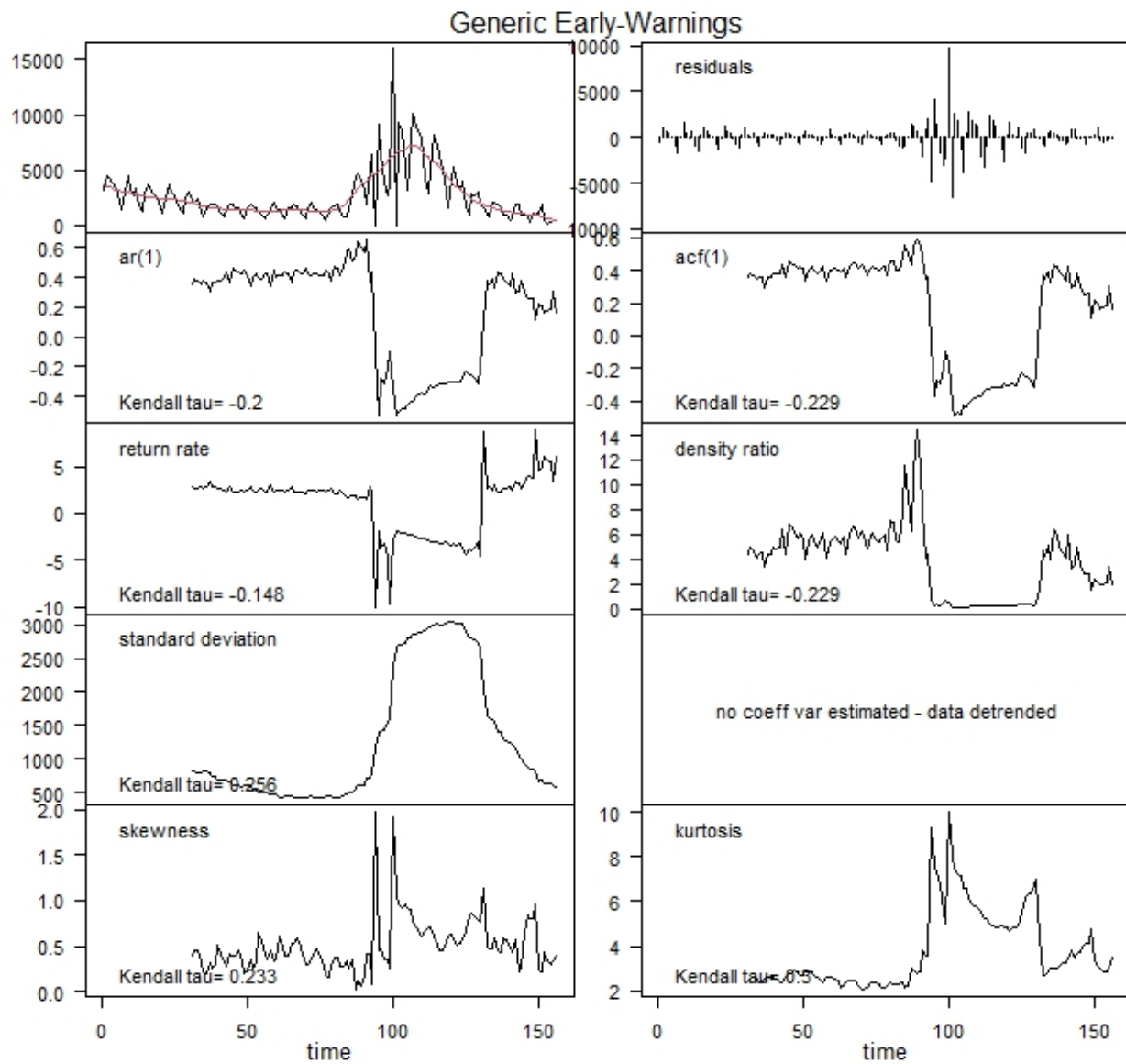


Figure 2: Generic early warning signals for wave 5: the Gaussian detrending, window size =20, bandwidth=5.

BDS_test Diagnostics

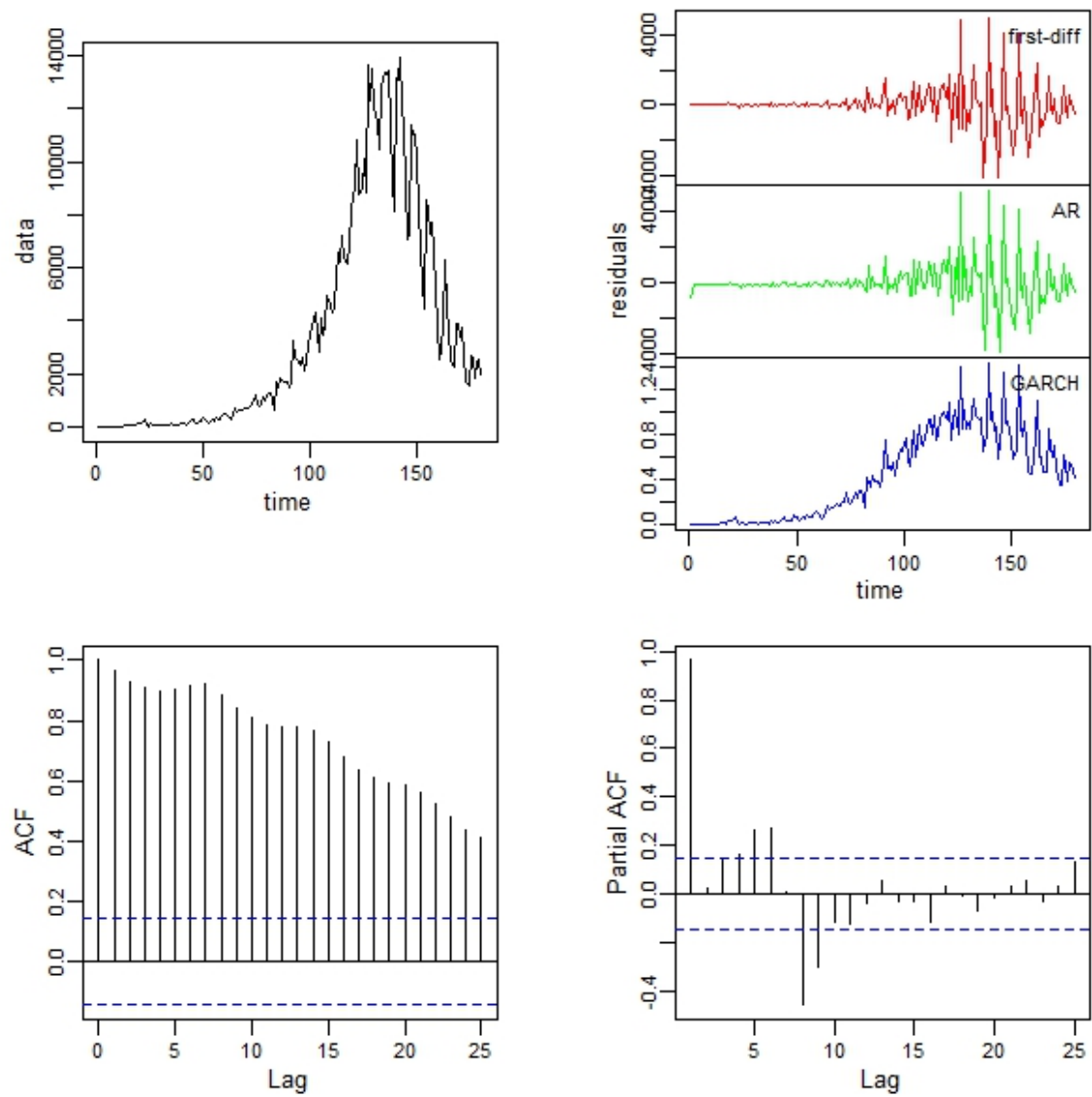


Figure 3: First difference, AR(1) and GARCH(0,1) for wave 1.

BDS_test Diagnostics

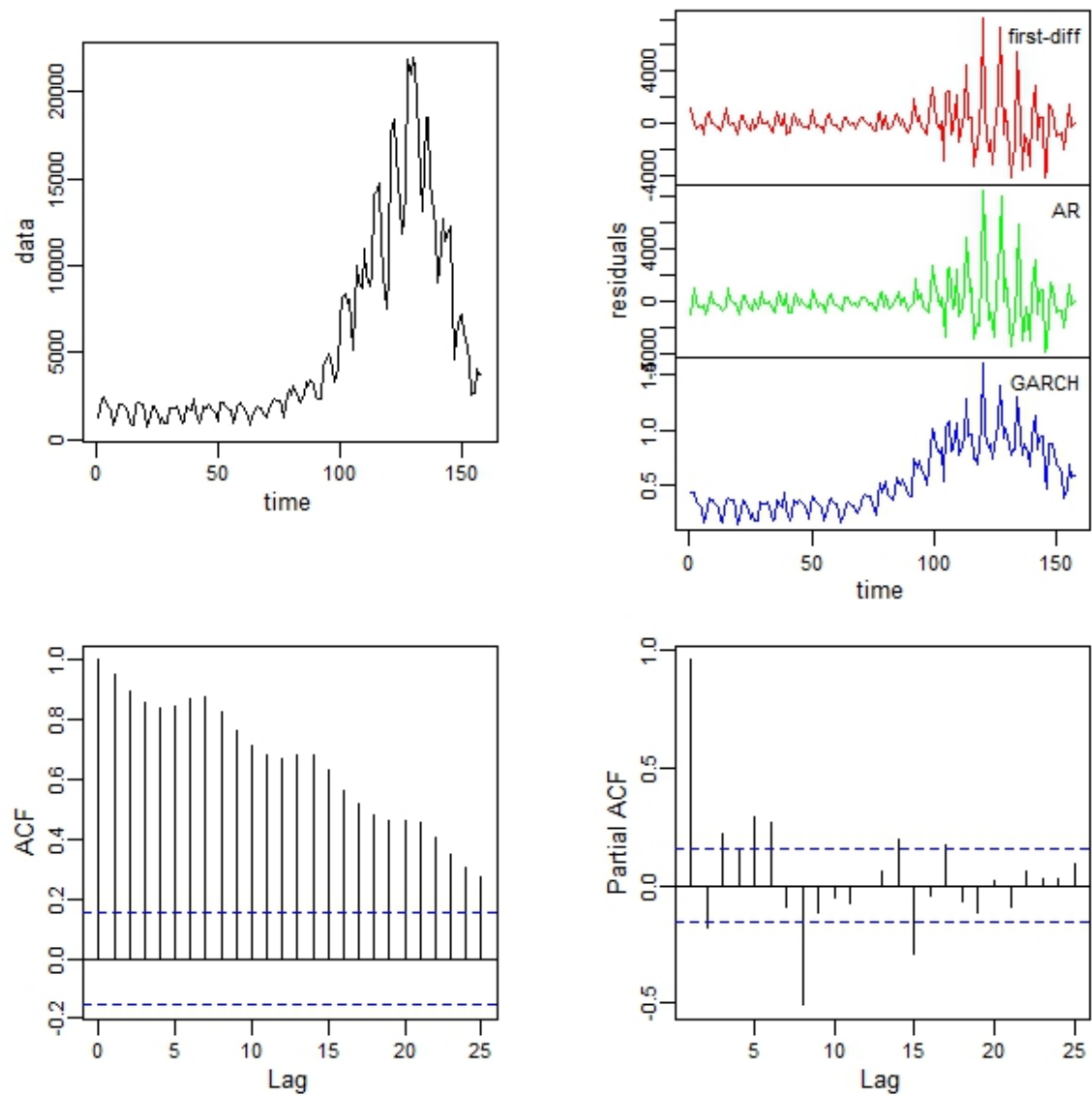


Figure 4: First difference, AR(1) and GARCH(0,1) for wave 2.

BDS_test Diagnostics

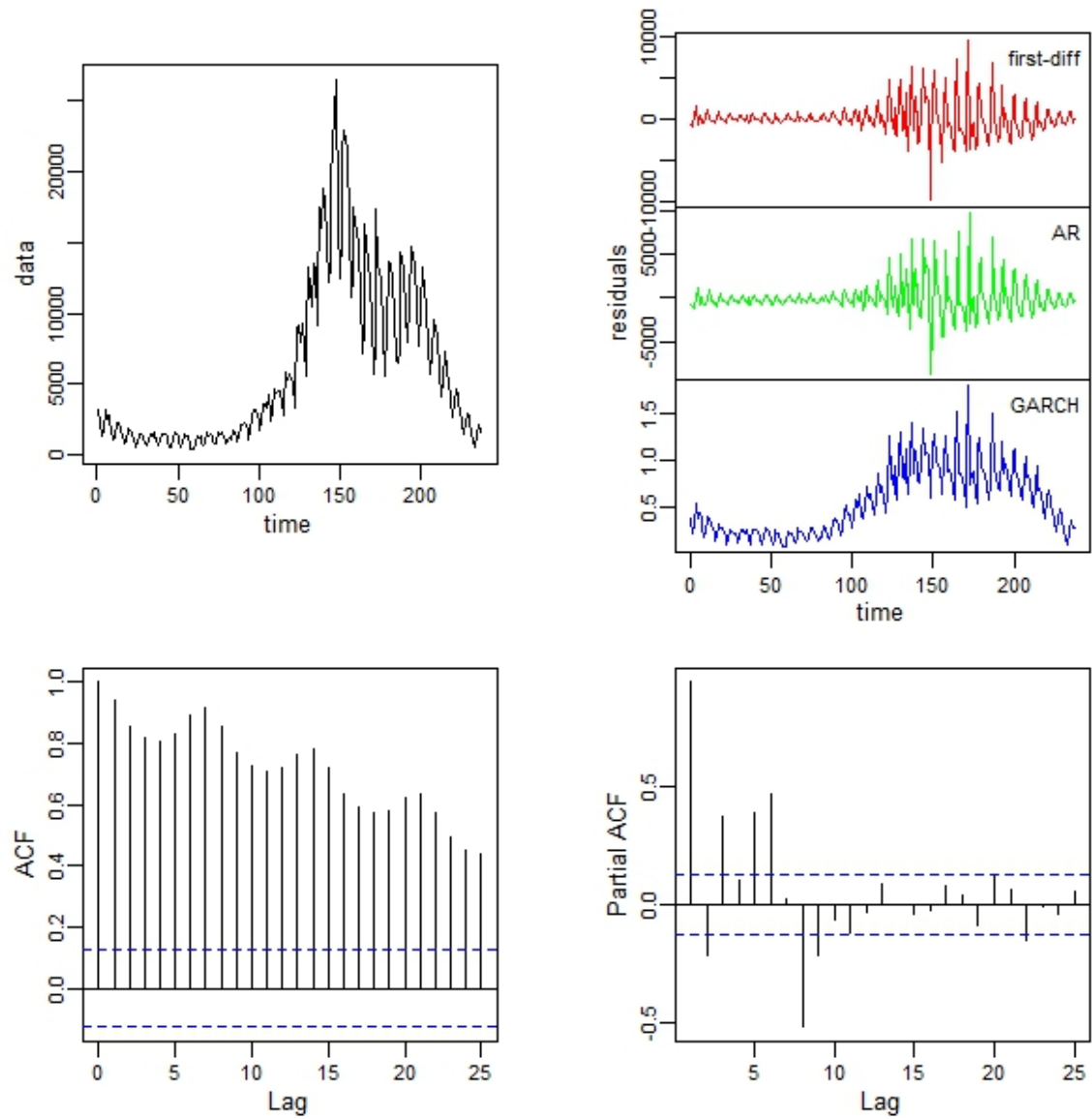


Figure 5: First difference, AR(1) and GARCH(0,1) for wave 3.

BDS_test Diagnostics

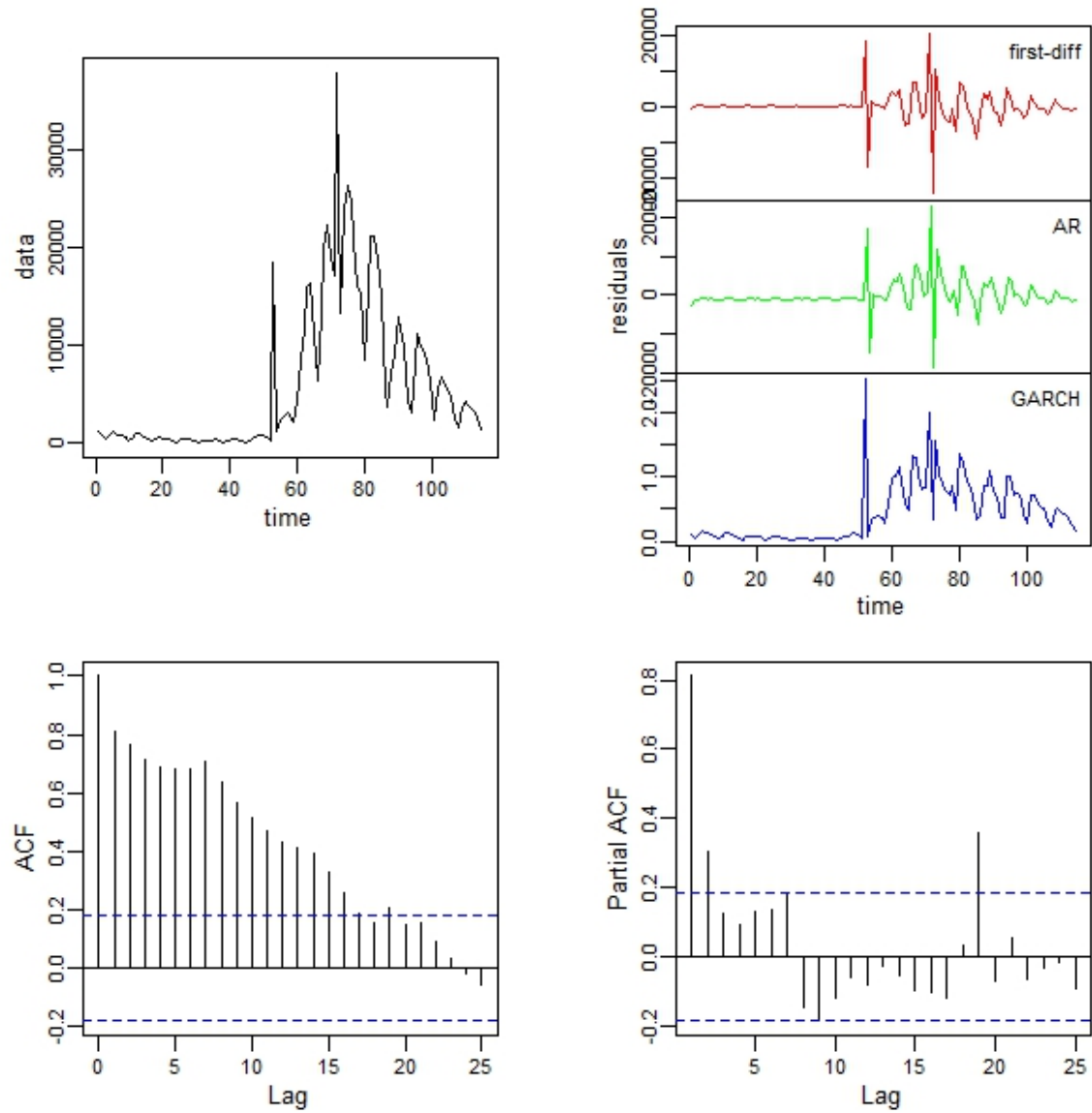


Figure 6: First difference, AR(1) and GARCH(0,1) for wave 4.

BDS_test Diagnostics

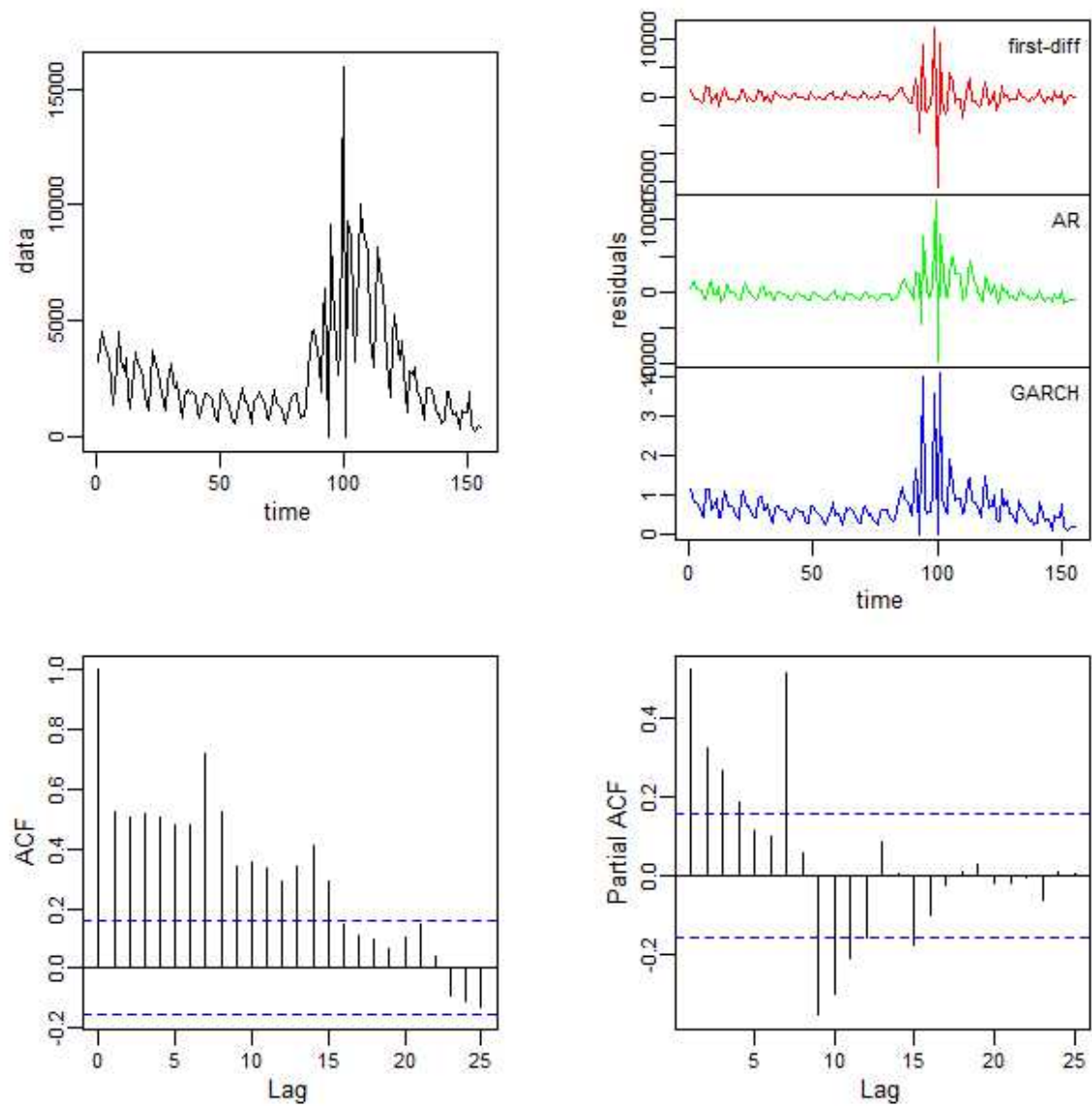


Figure 7: First difference, AR(1) and GARCH(0,1) for wave 5.

DDJ Nonparametric versus time

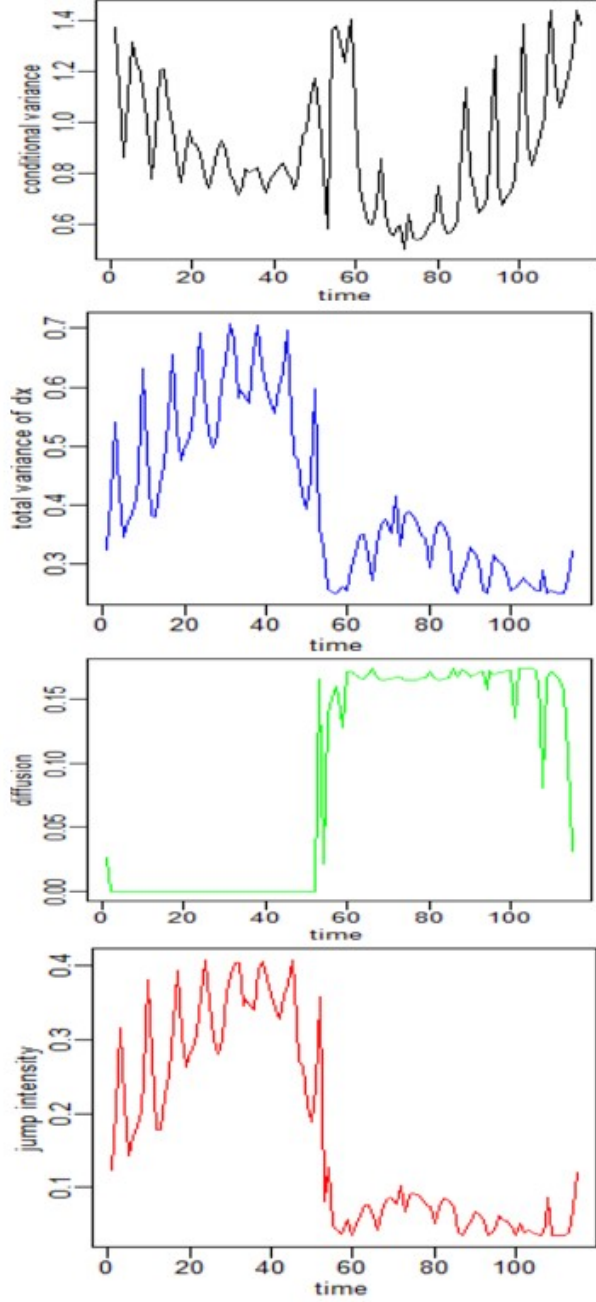
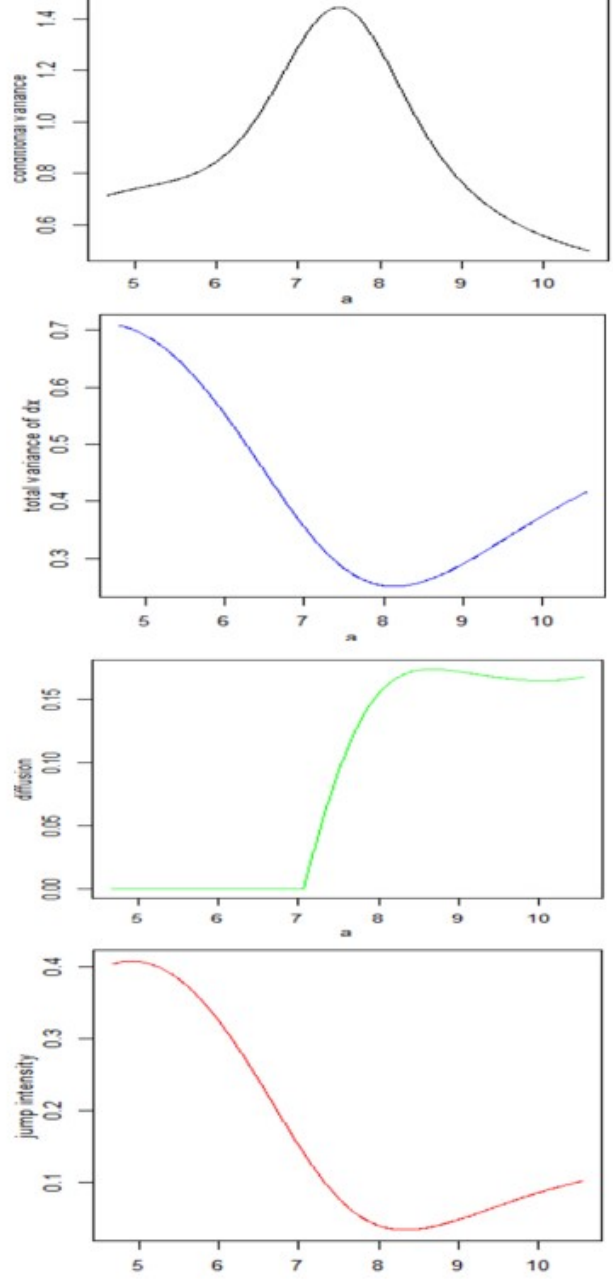
DDJ Nonparametric versus a 

Figure 8: Nonparametric drift-diffusion-jump metrics in the flickering dataset. (A, E) Conditional variance versus time and daily COVID-19 cases, respectively. (B, F) Total variance versus time and daily COVID-19 cases respectively. (C, G) Diffusion versus time a for wave4.

DDJ Nonparametric versus time

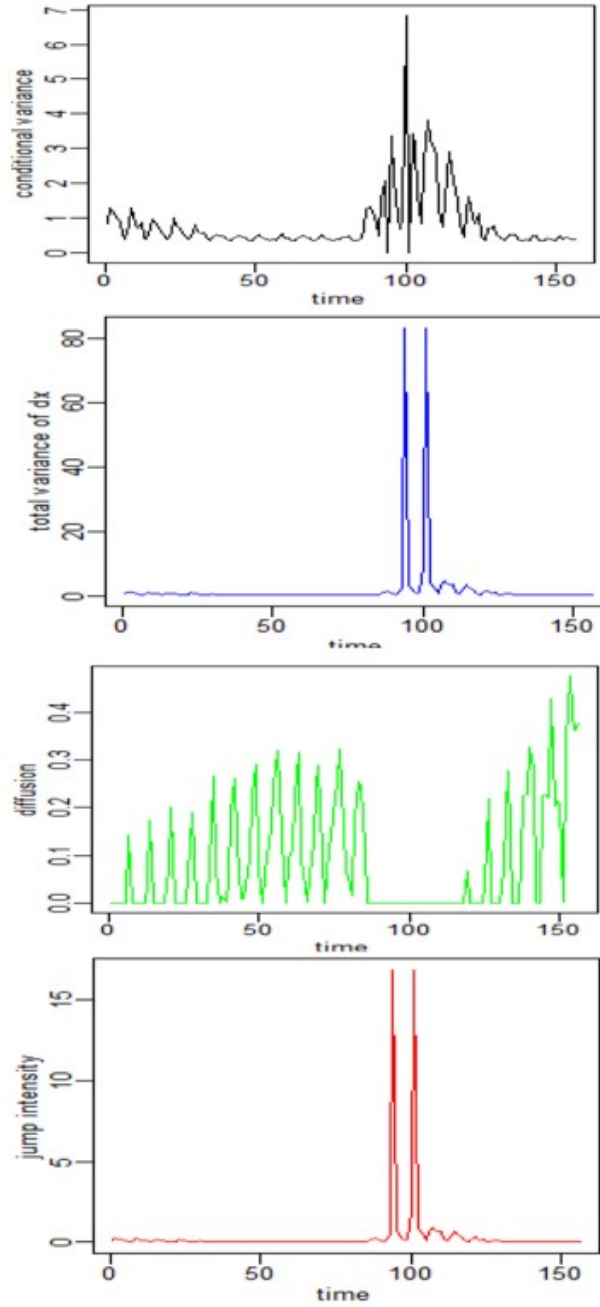
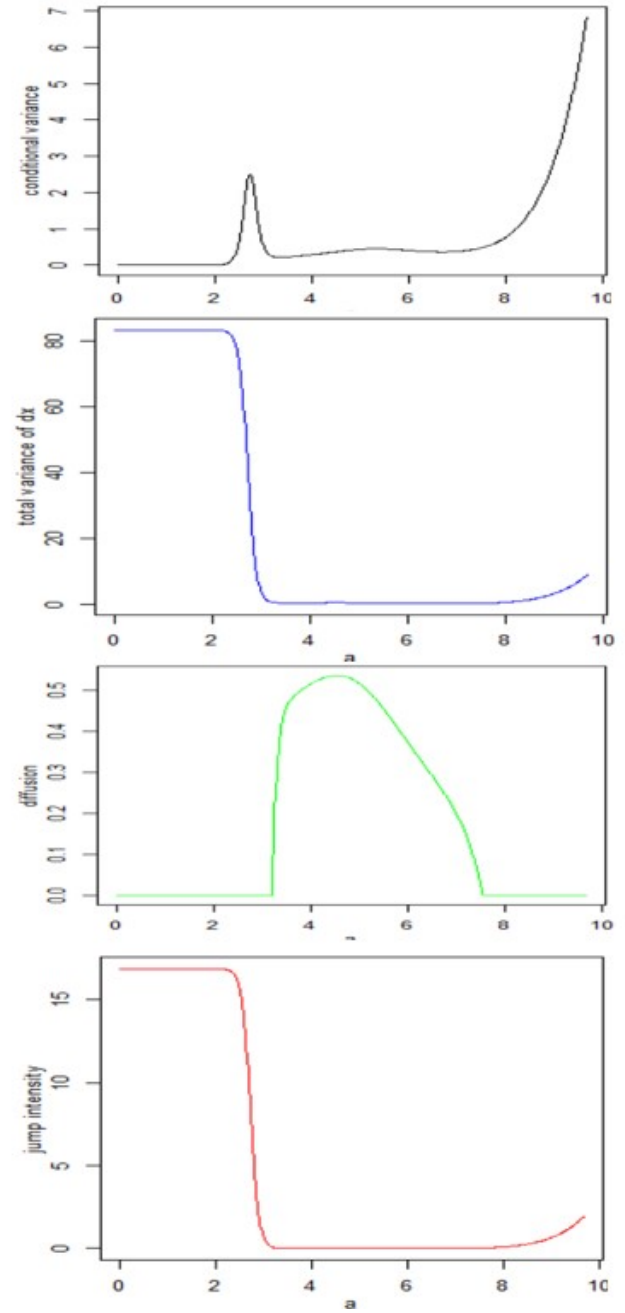
DDJ Nonparametric versus a 

Figure 9: Nonparametric drift-diffusion-jump metrics in the flickering dataset. (A, E) Conditional variance versus time and daily COVID-19 cases, respectively. (B, F) Total variance versus time and daily COVID-19 cases respectively. (C, G) Diffusion versus time a for wave5.

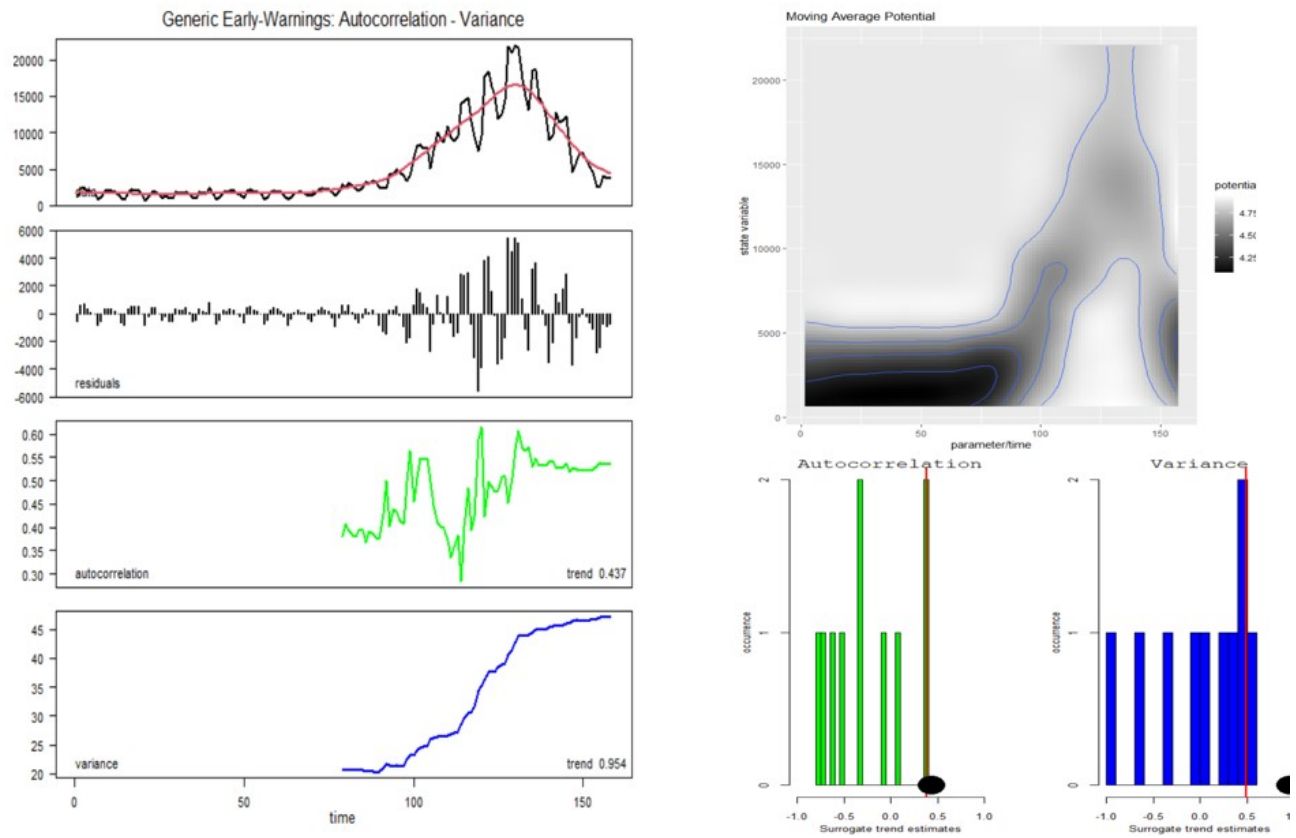


Figure 10: plots for the quick detection analysis of Generic early warning Signals. The first plot contains wave 2 series, the detrending/filtering applied and the residuals, autocorrelation and variance.

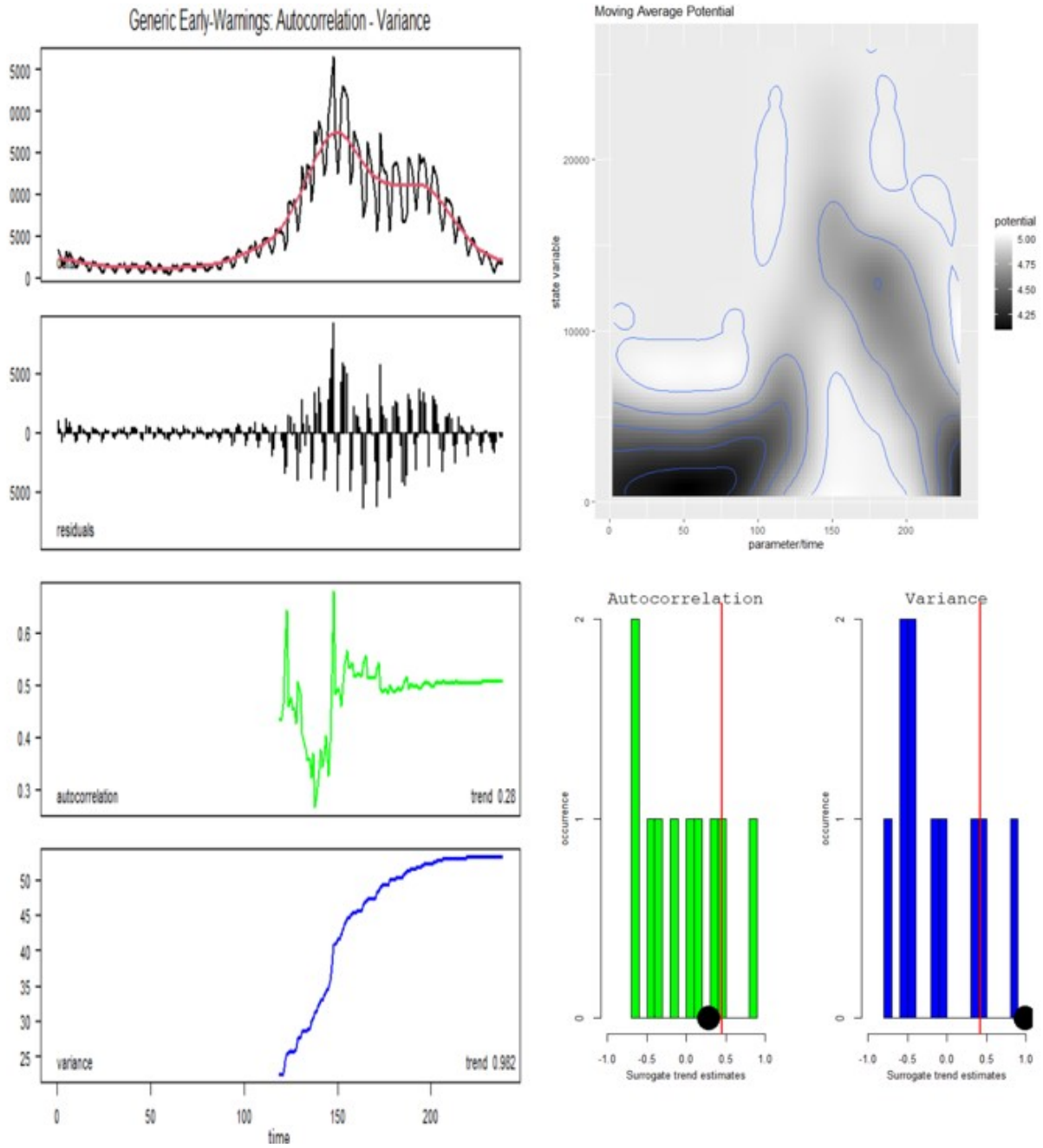


Figure 11: plots for the quick detection analysis of Generic early warning Signals. The first plot contains wave 3 series, the detrending/filtering applied and the residuals, autocorrelation and variance.

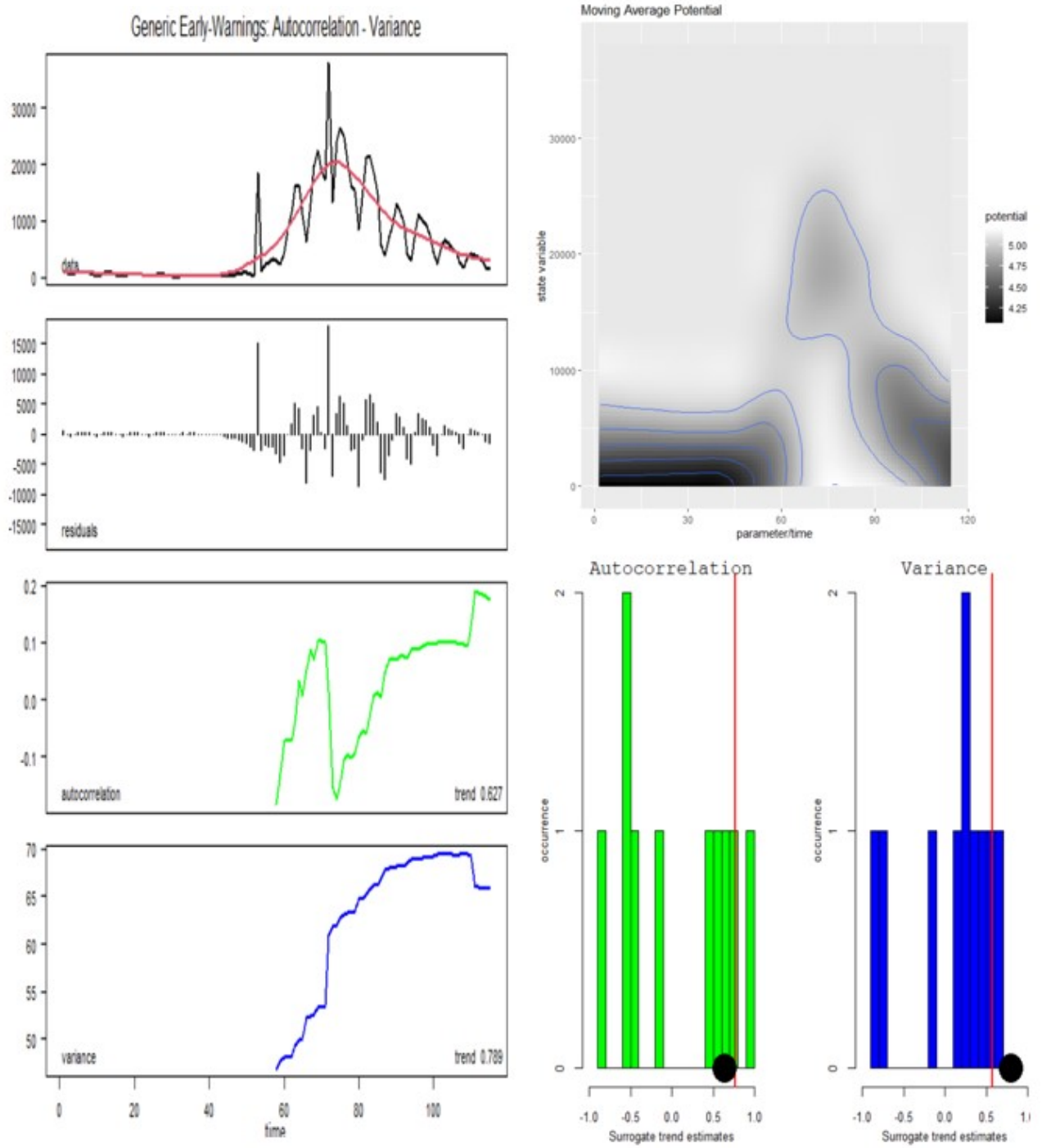


Figure 12: plots for the quick detection analysis of Generic early warning Signals. The first plot contains wave 4 series, the detrending/filtering applied and the residuals, autocorrelation and variance.

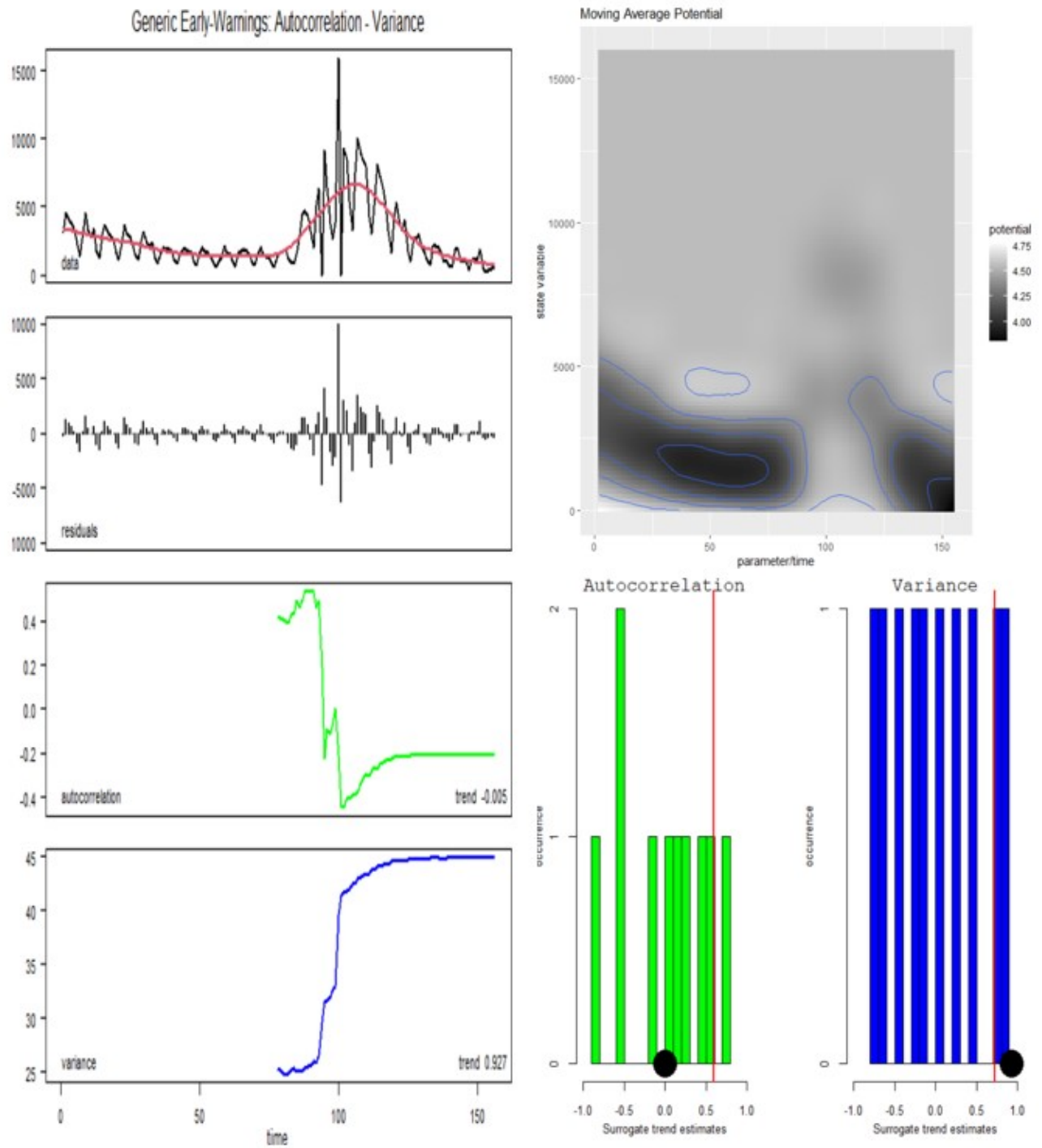


Figure 13: plots for the quick detection analysis of Generic early warning Signals. The first plot contains wave 5 series, the detrending/filtering applied and the residuals, autocorrelation and variance.

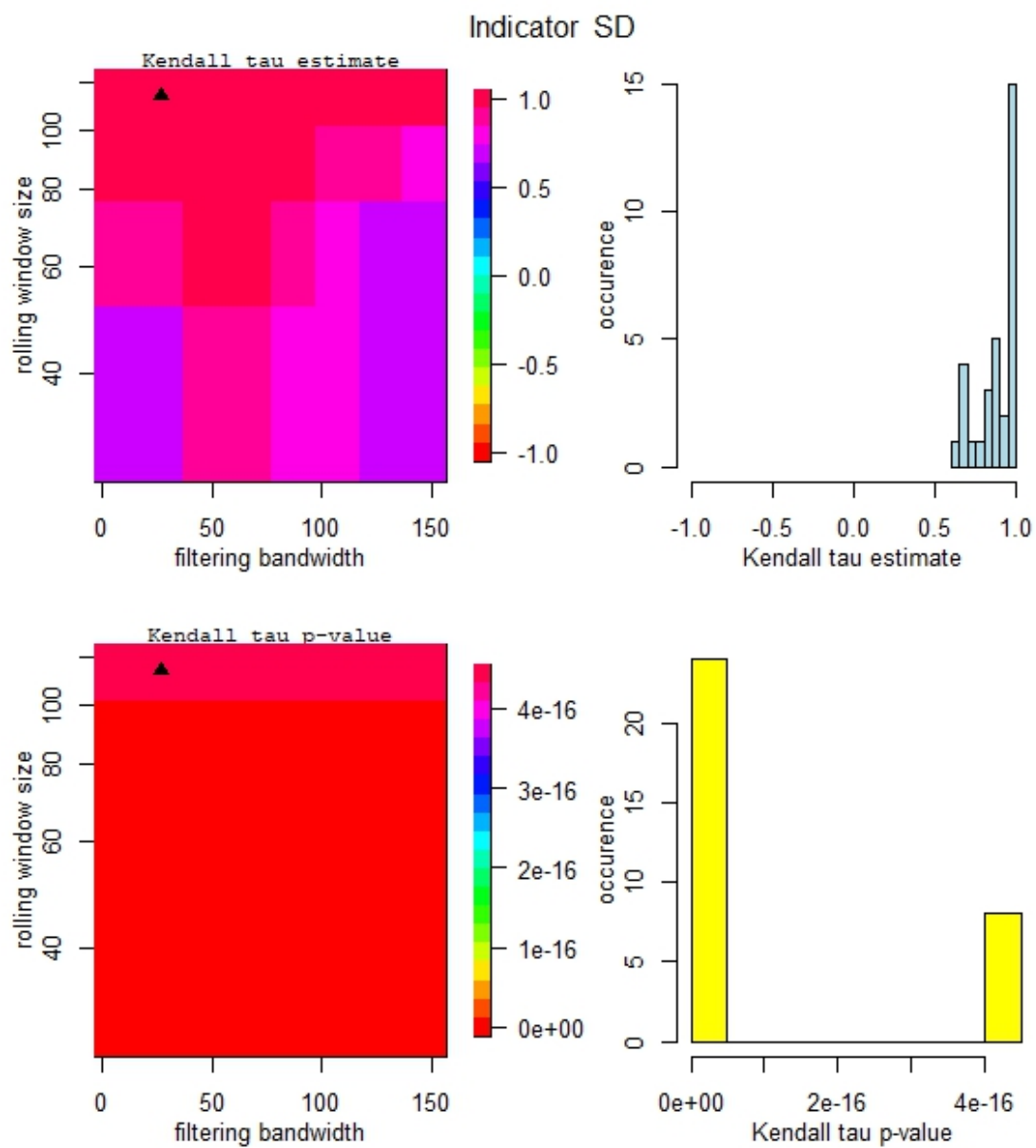


Figure 14: Sensitivity analysis for wave 2.

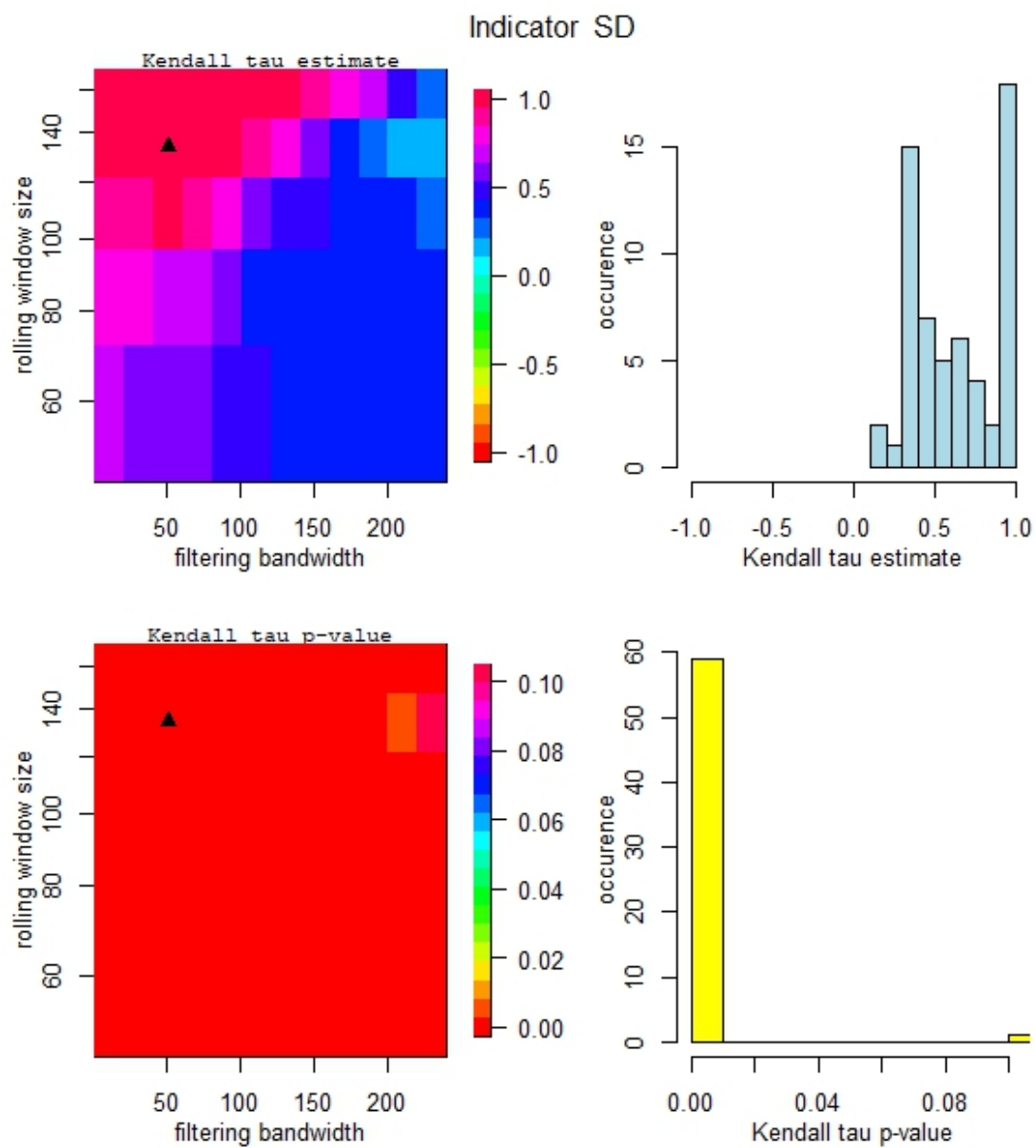


Figure 15: Sensitivity analysis for wave 3.

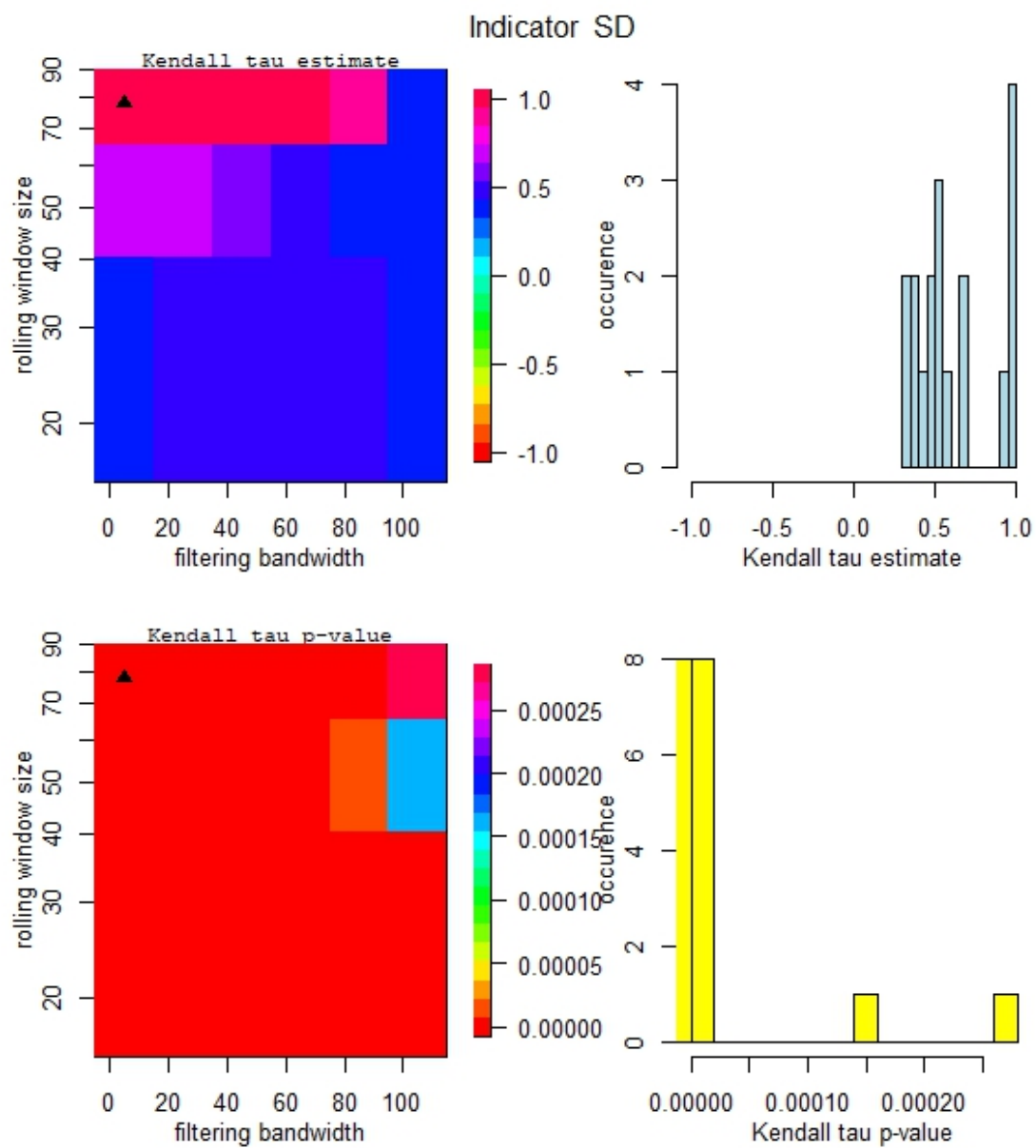


Figure 16: Sensitivity analysis for wave 4.

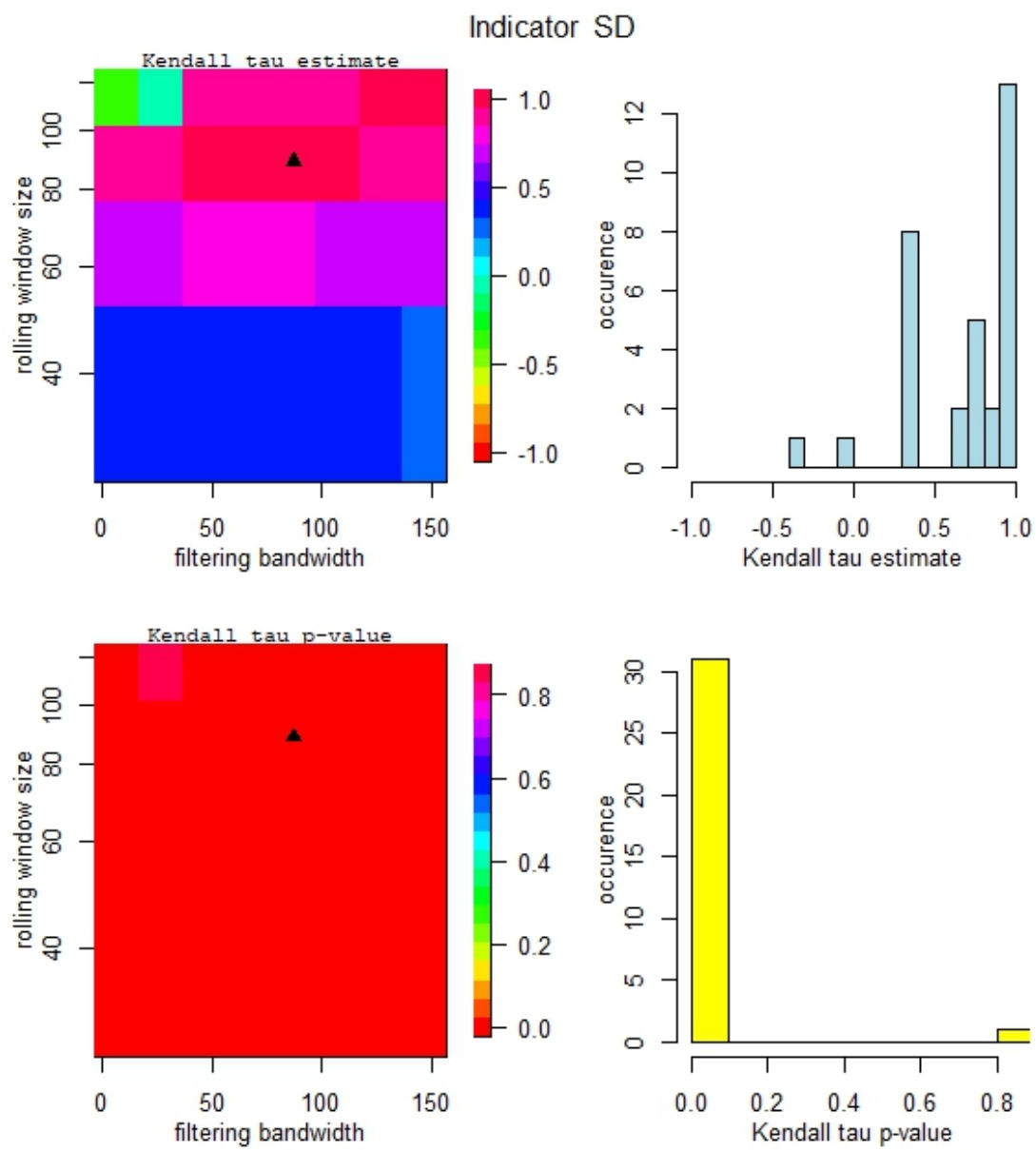


Figure 17: Sensitivity analysis for wave 5.