Applied automatic offset detection using Hector

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PROBLEM STATEMENT

The presence of offsets in GNSS coordinate time series is one of the largest source of errors for the correct estimation of the secular motions of permanent stations. Many of the offsets are easily correlated with actual events such as antenna/receiver replacements, which are noted down in the log files, or large earthquakes. However, this still leaves around 30% of the offsets found in the time series unaccounted for (Gazeaux et al., 2013) and with the ever-increasing amount of GNSS stations, their detection by visual inspection is becoming time consuming. This is particularly true for projects like EPOS (European Plate Observing System), https://www.epos-ip.org, where the analysis of thousands of daily time-series will be required on a regular basis. In such cases an automatic offset detection algorithm will be a valuable tool to reduce the workload.

METHOD

A simple automatic offset detection method is to check for each observed day if adding an offset to the time series increases the likelihood function or not. Such an approach was used successfully by Ostini (2012). Two remaining problems that need further improvements are:

1) Stopping criteria. As Figure 1 shows, adding more and more offsets always increases the likelihood function because the fit with the observations continues to increase. The reason is that we did not use a priori information about the number of offsets.
2) Inclusion of temporal correlation in the analysis to compute realistic likelihood values. So far this aspect has been ignored because the computation time become too long.

Both points have been addressed in this study by deriving a more general form of the Bayesian Information Criterion (BICe) and using the approach of Bos et al. (2013) to create a maximum likelihood estimator which has computations times that allow analysis of hundreds of stations in a few days.

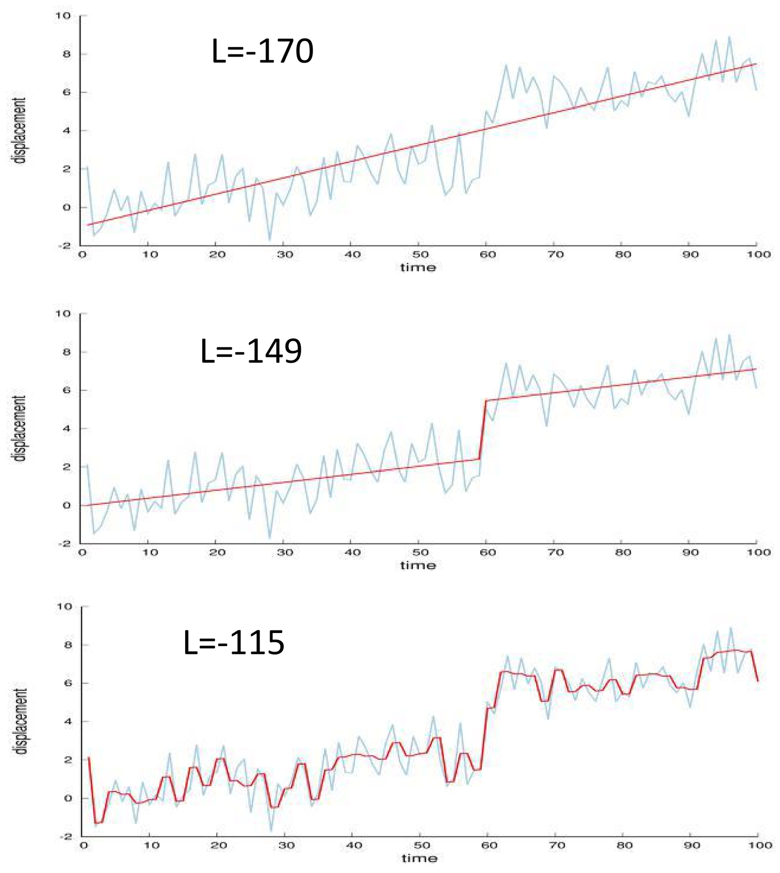
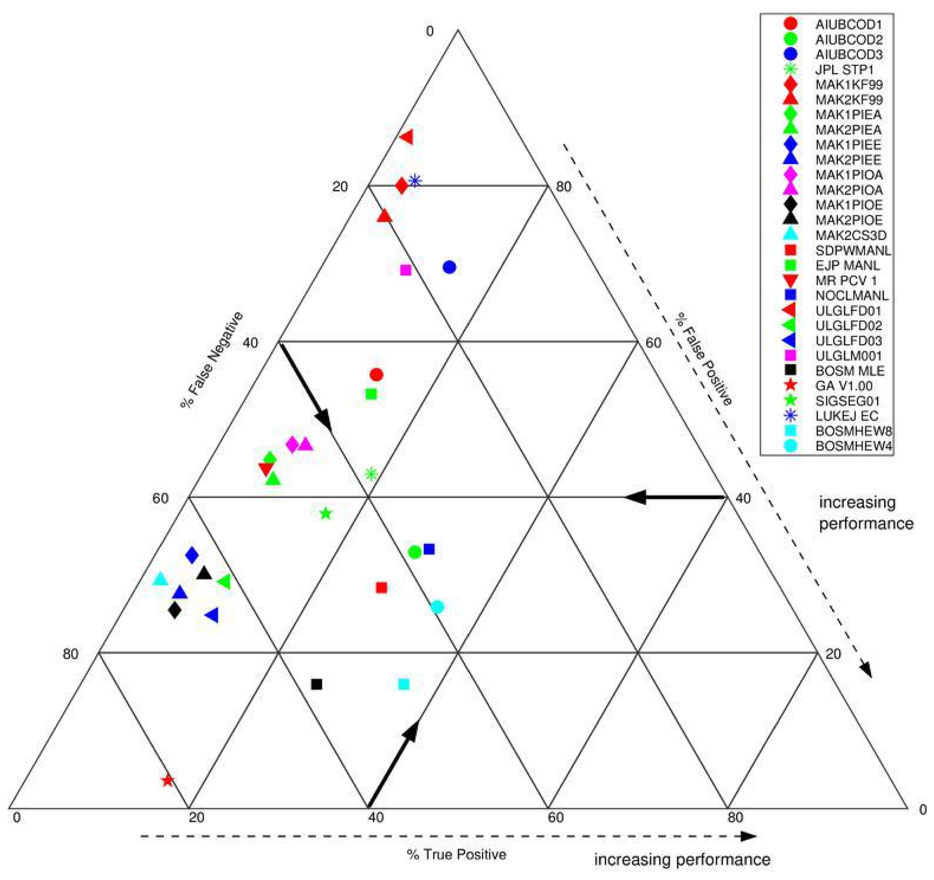


Figure 1. Example of how the log-likelihood L continues to increase for increasing number of offsets. When does one stop adding offsets? In this research we use our extended BIC (BICe) with a priori information about the size and number of the offsets, and the Fisher Information matrix (Kashyap, 1982).

DOGEx

Gazeaux et al. (2013) investigated the accuracy of manual and automatic offset detection using a synthetic data set. We also applied our new algorithm to the same test data and the results are shown in Figure 2 as BOSMLEW4 and BOSMLEW8. It depicts the percentage of times it found an offset (True Positive), how many times it missed an offset (False Negative) and how many times it claimed to have found an offset which in reality was not there (False Positive). There are 2 solutions (W4 and W8) because using a weight factor the user can balance the performance between maximizing the TP percentage or minimizing the FP percentage (Bos and Fernandes, *in preparation*).



Both BOSMLEW4 and BOSMLEW8 show the best TP percentages; perform above the average on the FP percentages; and have an average performance for FN.

Figure 2. Comparison of our algorithm with other methods using the DOGEx data set.

RESULTS OF ANALYSES OF REAL DATA

Offsets in real GNSS time series for 81 IGS stations, shown in Figure 3, were detected manually and using the new automatic detection algorithm. Afterwards they were analysed using Hector (http://segal.ubi.pt/hector/).

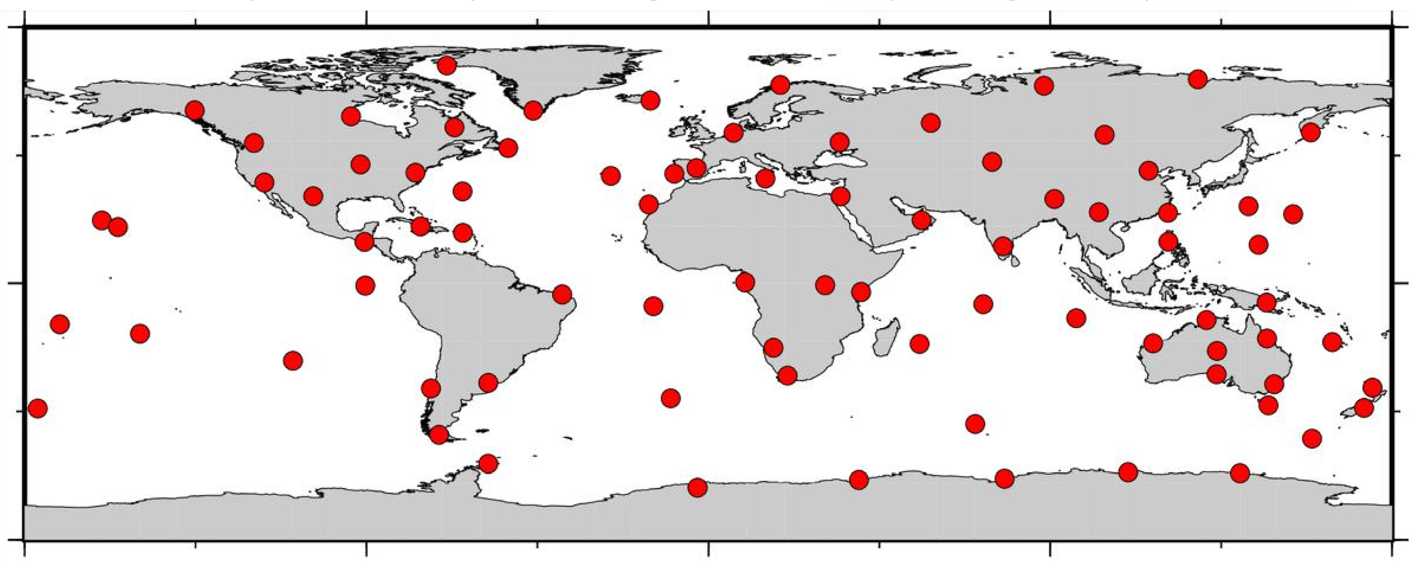


Figure 3. The IGS stations that were analysed.

The time series, together with the estimated breaks, for 4 stations are shown in Figure 4. They show that the automatic algorithm is able to detect most of the identified offsets, even surpassing the manual method in some cases.

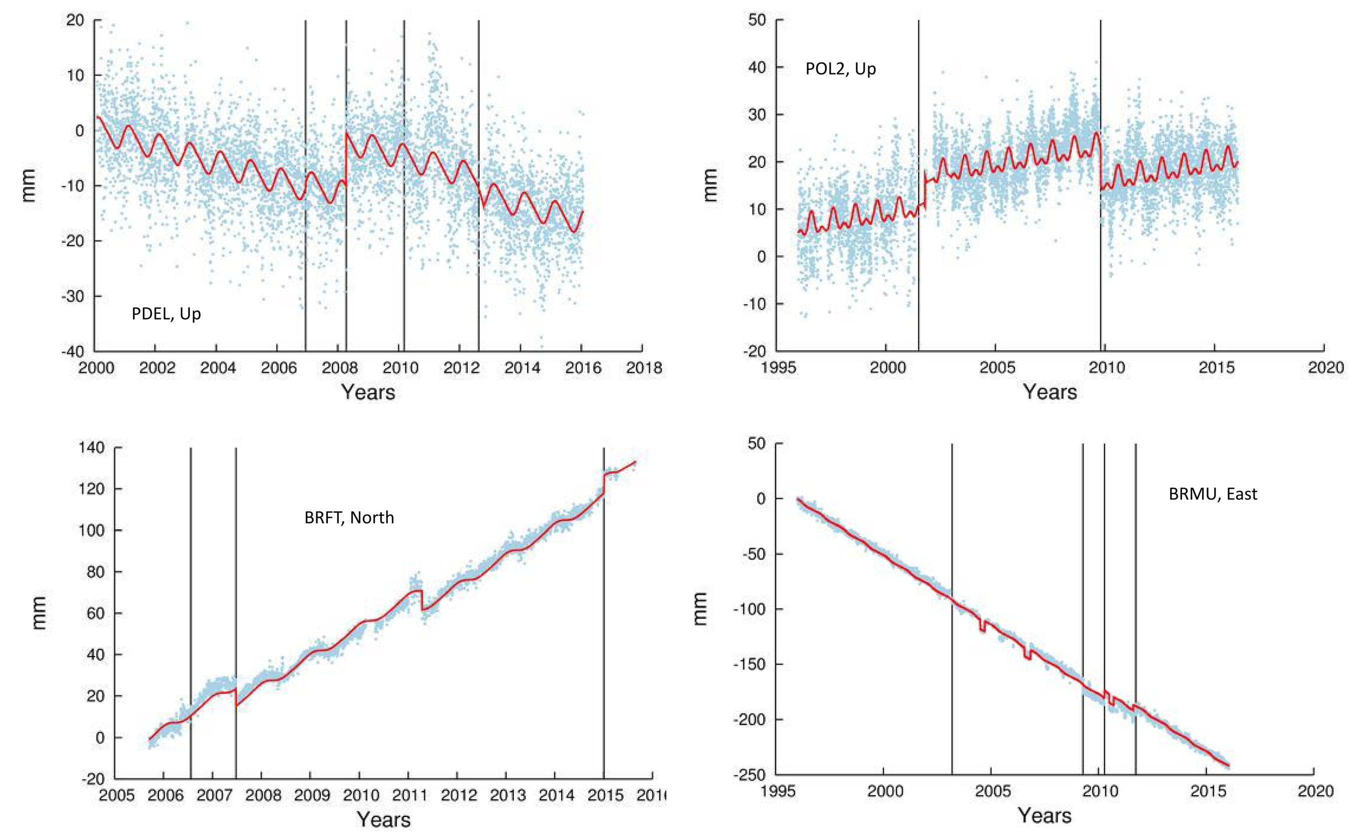


Figure 4. Example of IGS time series where the offsets have been detected automatically. The red line is the fitted model. The black lines note the location of the manually detected offsets.

Figure 5 shows the horizontal differences in estimated velocities between manual and (our) automatic detection. Although converging, we still observe differences of the order of 0.5 mm/yr, which is in accordance with the conclusions of Gazeaux et al. (2013), who states that offset detection is the dominant error in velocity estimation.

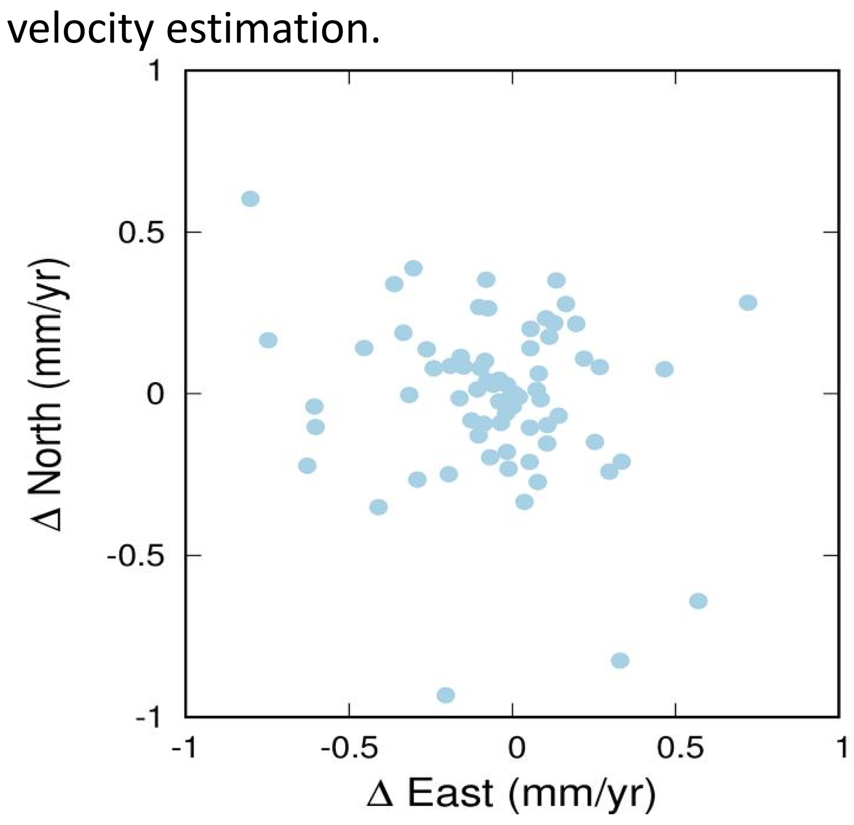


Figure 5. Scatter of estimated horizontal velocity estimated from the 81 time series with offsets detected manually and using the new algorithm.

CONCLUSIONS

1) Including correlated noise in the BIC values leads to better stopping criteria and better detection of offsets in general.
2) The DOGEx results provided independent check that the algorithm has better TP performance than other algorithms.
3) Comparison of the result of manual and automatic offset detection in 81 IGS time series showed horizontal velocity agreement of normally better than 0.5 mm/yr.
4) This algorithm will be used at UBI in the scope of EPOS to assist remaining detecting offsets in the time series which are not already known to exists by looking at the metadata. Any found offset found will be investigated to find its cause before it is officially accepted as an EPOS offset.

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