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Effects of large aftershocks on spatial aftershock forecasts during the 2017-2019 western Iran sequence

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Introduction

Large earthquakes almost always trigger additional earthquakes, so-called aftershocks, which make up an aftershock sequence that can take months to years. Based on many examples showing a clear correlation between static Coulomb Failure Stress (ΔCFS) changes and the spatial aftershock distribution, the static stress transfer hypothesis is perhaps the most widely accepted and used criterion to explain aftershock triggering and their spatial pattern. Recently, some studies using Recivor Operating Characteristic (ROC) analysis have questioned the ability of ΔCFS values in forecasting aftershock locations and showed that other stress metrics can outperform ΔCFS (Sharma et al. 2020). However, several other studies suggest that smaller but more frequent earthquakes can locally play an equally or even more important role in redistributing stress and should be considered in aftershock forecasting (Asayesh et al. 2020). In this study, by using the ROC and MCC-F1 test metrics, we analysed the Kermanshah (west Iran) 2017-2019 sequence using the some stress scalars and distance based model but additionally accounting for the effect of significant aftershocks.

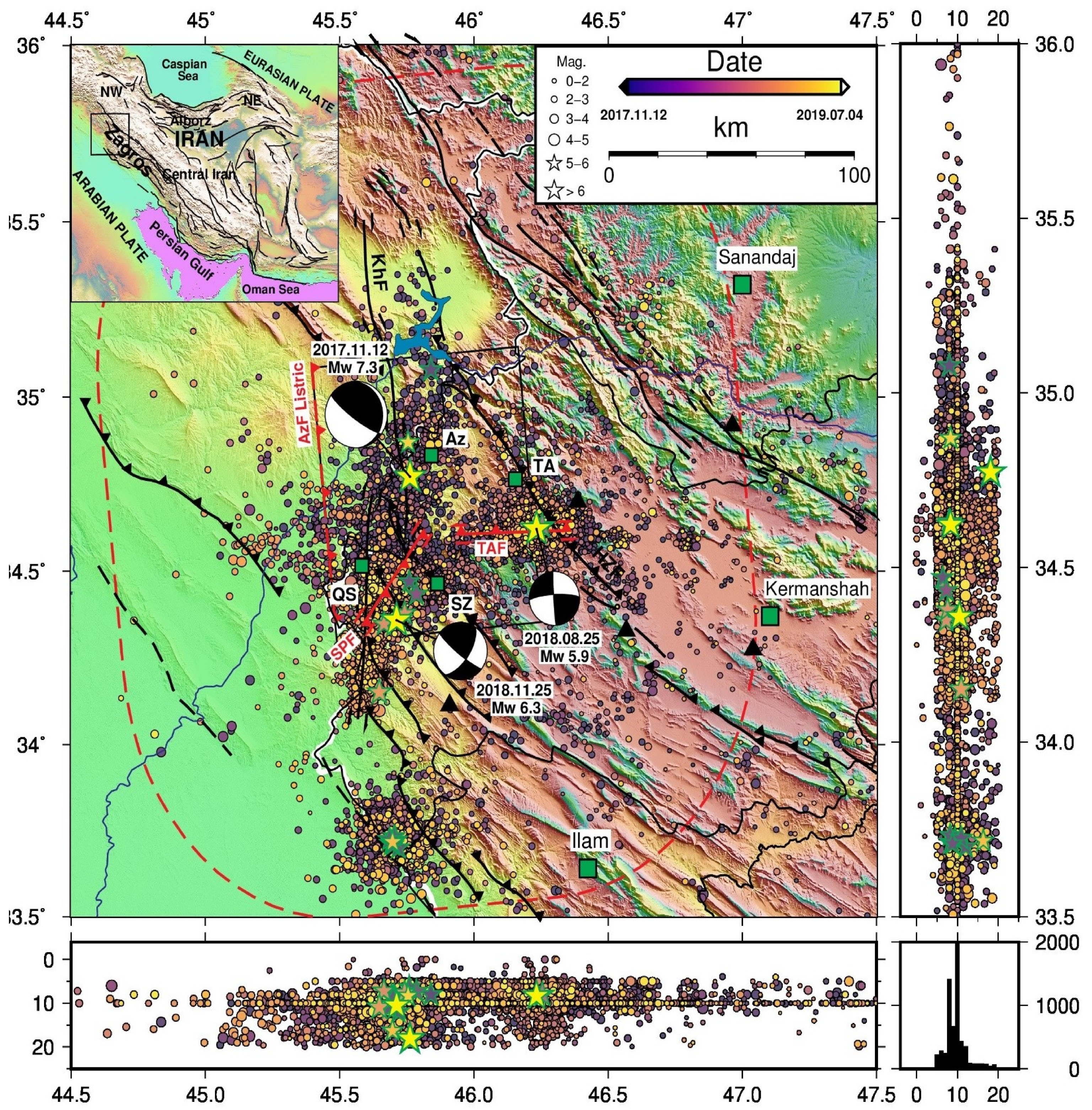

Figure 1. Main tectonic features of the Iranian plateau and the Kermanshah area, west of Iran. Epicentral and depth distribution of the mainshocks (Azgeleh, Tazehabab, and Sarpol-e Zahab earthquakes) (big yellow stars) and their following seismicity (circles and green stars) from Iranian Seismological Center (IRSC).

Data

- Kermanshah sequence: 12/11/2017 – 04/07/2019 (600 days)
- 7800 events from Iranian Seismological Center (IRSC) catalog
- horizontal distance < 75 km with depth: 0 – 20 km and magnitude: 1 – 7.3

Stress metrics and distance model

1. ΔCFS on master fault orientation (MAS)
2. ΔCFS on optimally oriented planes (OOP)
3. ΔCFS assuming fault variability (VM)
4. Maximum Shear (MS)
5. Von-Mises stress (VMS)
6. Distance-slip probabilistic model (R)

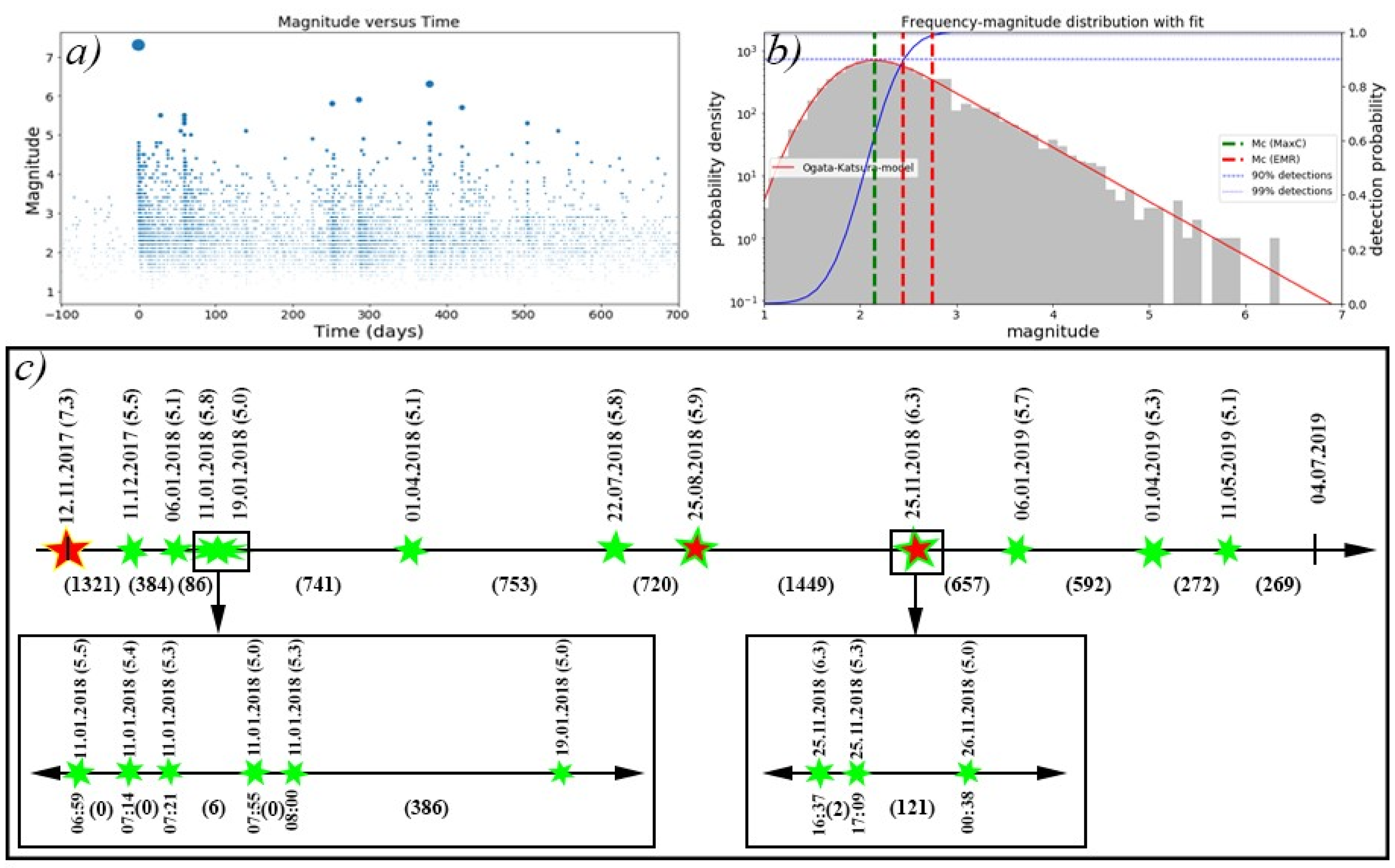

Figure 2. a) Magnitude versus time plot of events occurred during the 2017-2019 Kermanshah sequence. b) Noncumulative frequency-magnitude distribution and estimated completeness magnitude (Mc). c) Time series of the mainshock and largest aftershocks (Mw ≥ 5).

Results

Receiver independent stress scalars, MS and VMS, outperform CFS dependent metrics. Distance-slip based model is found to be the best choice for forecasting aftershocks.

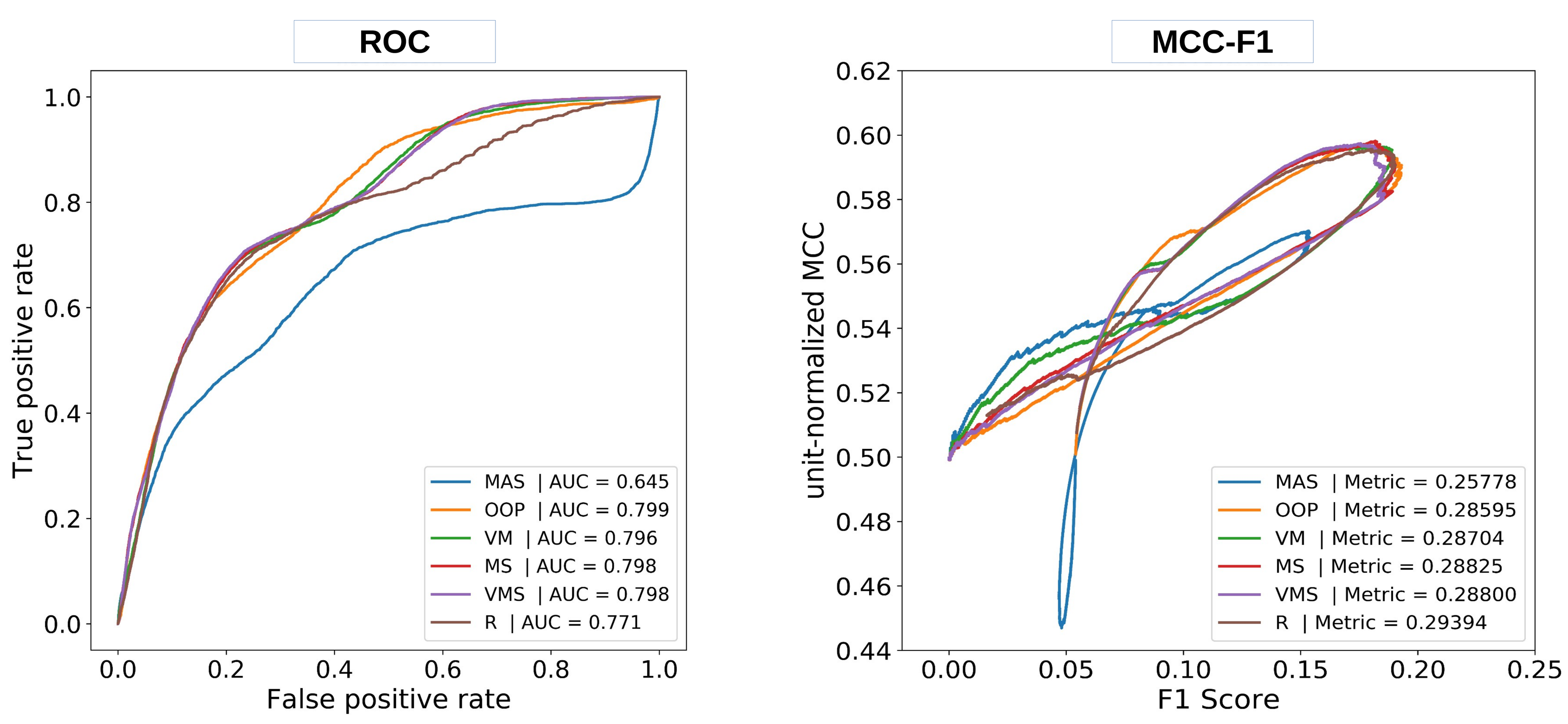

Figure 3. ROC (left) and MCC-F_1 (right) results using only the mainshock source information.

Results

Considering stress information due to large aftershocks improves the VM, MS, VMS, and R results.

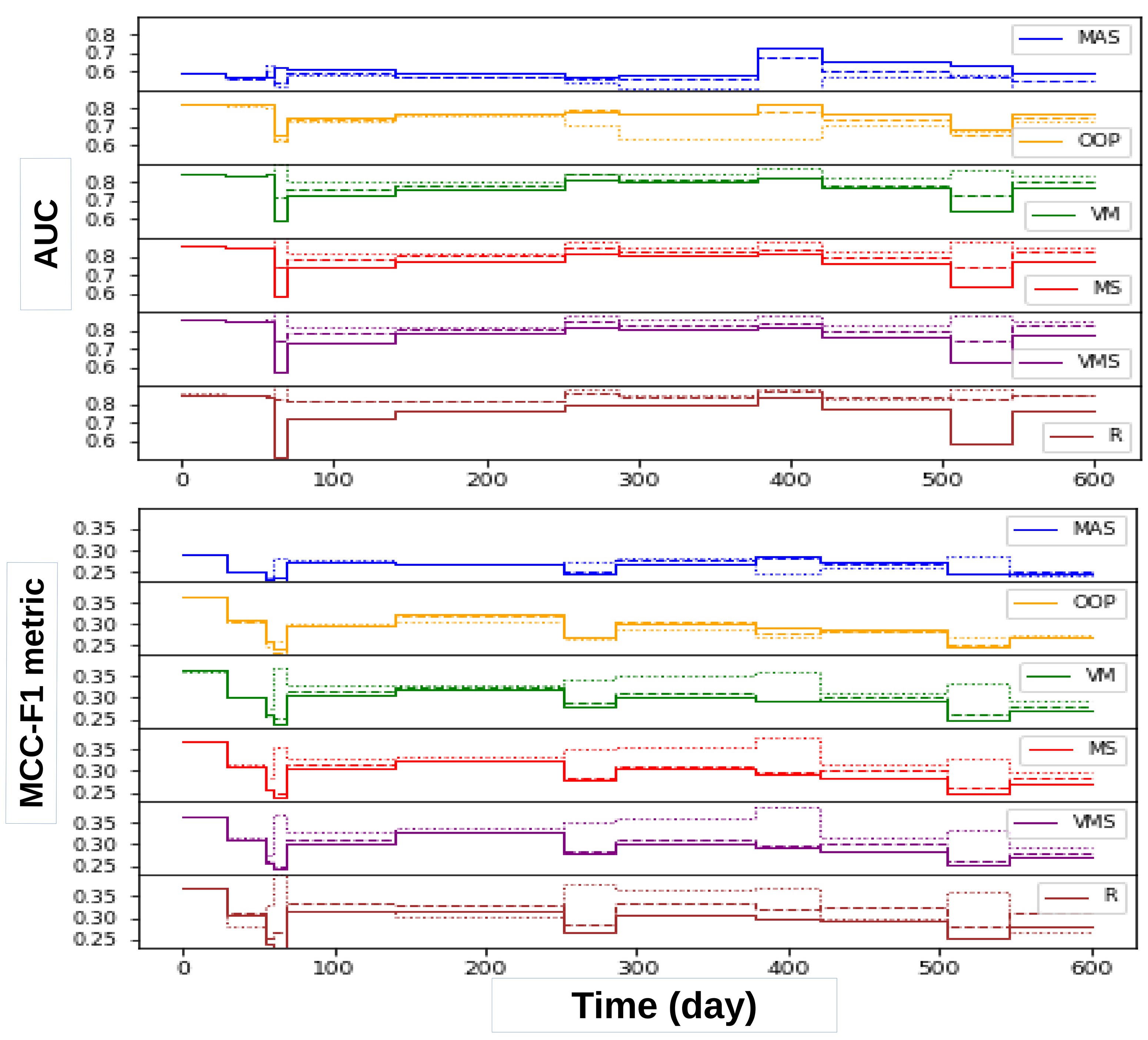

Figure 4. ROC (up) and MCC-F_1 (down) results using source information from mainshock (solid), superimposed stress from large aftershocks source information (dashed), and weighted superimposed stress from large aftershocks source information (dotted).

Conclusion

1. MCC-F1 is better than ROC as it can take account for imbalanced data i.e., earthquake catalog.
2. Superimposing stress due to large aftershocks improves the performance of stress and distance based models.
3. In case of superimposing large aftershocks information, distance-based model outperforms stress scalars.

References

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